2/11/3/78

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Status Report

MASTER

LAMPF

Proposal Status and Summaries

University of California

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LAMPF

Proposal Status and Summaries

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LAMPF PROPOSAL STATUS

STATUS OF PROPOSALS AS OF 7/8/76

BEAM HOURS WERE NOT AVAILABLE IN 1974.

PROJ.	PHASE	STATUS	CONDITIONS	CHANNEL	SPOKESMAN	PAC-HRS
1	1	DEFER	NEXT-PAC	LEP	TROWER	0.0
2	1	COMPLETE		LEP	JAKOBSON	150.0
3	1	COMPLETE	PARASITE-Q	LEP	KINSEY	443.0
4	1	COMPLETE	#15	MS	IGO	100.0
5	1	COMPLETE		MS	CHRISTEN	200.0
6	1	APPROVED		MS	SUTTER	200.0
7	1	COMPLETE	WITH-12	SHC	SHERA	63.0
8	1	APPROVED		SHC	JUDICK	480.0
9	1	NEED TO REAR		LEP	B. J.	0.0
10	1	APPROV/COMB	#233	MS	SPENCER	100.0
11	F-5	APPROVED	101/69/ISS	SHC	FOUEN	0.0
12	1	APPROVED		SHC	POWERS	120.0
13	1	APPROVED		EPICS	SETH	200.0
14	1	COMPLETE		EPICS	THIESSEN	250.0
15	2	APPROV/COMB	#4	MS	IGO	200.0
16	1	APPROVED		MS	TAVAKA	200.0
17	1	WITHDRAWN		EPICS	MORRISON	230.0
18	1	COMPLETE		EPICS	ZEIDMAN	0.0
19	2	COMPLETE		EPICS	ZEIDMAN	250.0
20	1	WITHDRAWN		BIOHED	LIEBER	75.0
21	1	REJECTED			EROLLEY	0.0
22	1	WITHDRAWN		EPICS	GEHRELL	150.0
23	1	APPROVED		EPICS	MARTON	250.0
24	1	RESUBMIT	FEAS-STUDY	NEUTRINO-A	LAYDE	0.0
25	1	COMPLETE		LEP	BURMAN	200.0
26	3	103E-HEARD		LEP	VEESER	100.0
27	1	COMPLETE		EPB	WILLARD	300.0
28	2	APPROVED		EPB		200.0
29	1	COMPLETE	AYY-DETERM	LEP	TAVIN	150.0
30	2	APPROV/COMB	#54	LEP	PREEDOM	0.0
31	1	REJECTED		LEP	CIETRE	800.0
		APPROVED			NEUTRINO-A	

STATUS OF PROPOSALS AS OF 78/06/23.
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BEAM HOURS WERE NOT AVAILABLE IN 1974.

PROP. NO.	PHASE	STATUS	CONDITIONS	CHANNEL	SPOKESMAN	PAC-HRS
32	1	APPROVED		P3	MC FARLANE W.K.	300.0
	2	NEED TO HEAR		P3	MACEK R.J.	0.0
33	1	APPRV/COMB	N/335	EPB	BEVINGTON P.R.	450.0
					MUTCHLER G.S.	0.0
34	1	COMPLETE		P3	MINEHART R.C.	220.0
35	1	COMPLETE		LEP	ZIOCK K.O.H.	112.0
36	1	INACTIVE		P3	GUGELOT P.C.	0.0
37	1	COMPLETE		S4C	HUGHES V.W.	300.0
	2	COMPLETE		S4C	CRANE T.	550.0
38	1	WITHDRAWN		NEUTRINO-A	REINES F.	0.0
39	1	APPRV/COMB	COMB/W 342	EPICS	MACEK R.J.	175.0
					THIESSEN H.A.	0.0
40	1	WITHDRAWN			FRANKEL S.	0.0
41	1	WITHDRAWN		EPICS	BOWEN T.	0.0
42	1	COMPLETE		EPB	COLE R.K.	380.0
43	1	WITHDRAWN		EPICS	SWENSON L.W.	250.0
44	1	COMPLETE		BIOMED	CARLSON D.E.	30.0
45	1	RESUBMIT		BSA-RAD	DUDZIAK D.J.	0.0
	2	APPROVED		BSA-RAD	GREEN W.V.	0.0
				ISORAD	GIORGI A.L.	0.0
46	1	WITHDRAWN		EPICS	PETERSON R.J.	300.0
47	1	WITHDRAWN		EPICS	PETERSON R.J.	100.0
48	1	WITHDRAWN		EPICS	PETERSON R.J.	0.0
49	1	COMPLETE		HRS	PETERSON R.J.	150.0
50	1	COMPLETE		LEP	CROWE K.M.	300.0
	2	COMPLETE		LEP	ROME P.	224.0
51	1	APPROVED		S4C	MALANIFY J.J.	100.0
52	1	WITHDRAWN	ACCEL-DEV	EPB	BRYANT H.C.	0.0
53	1	WITHDRAWN	FEAS-STUDY	NEUTRINO-A	DAVIS RAYMOND	0.0
54	1	COMPLETE	WITH-29	LEP	PREEDOM B.M.	112.0
	2	APPRV/COMB	N/29	LEP		165.0
55	1	WITHDRAWN		A3-NEUTRON	SHIVELY F.T.	0.0
					HADDUCK R.P.	0.0
56	1	COMPLETE		A3-NEUTRON	NORTHCLEFF L.C.	400.0
	2	COMPLETE		A3-NEUTRON	SIMMONS J.E.	500.0
57	1	WITHDRAWN			RICHMAN C.	0.0
					GROCE D.E.	0.0
58	1	APPRV/COMB	WITH 120	P3	NEFKENS B.M.K.	150.0
					SADLER M.E.	0.0
59	1	WITHDRAWN		HRS	MACEK R.J.	250.0
60	1	COMPLETE		S4C	KNIGHT J.D.	200.0
	2	COMPLETE		S4C	SCHILLACI M.E.	340.0
61	1	WITHDRAWN		EPICS	NAGLE D.E.	200.0
62	1	NEED TO HEAR		P3	LIND V.G.	0.0
63	1	REJECTED			GRAM P.A.H.	0.0
64	1	WITHDRAWN			SEAGRAVE J.D.	0.0
65	1	APPROVED		A3-NEUTRON	SIMMONS J.E.	250.0
66	1	APPROVED	FEAS STUDY	A3-NEUTRON	SIMMONS J.E.	300.0

STATUS OF PROPOSALS AS OF 78/06/23.
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BEAM HOURS WERE NOT AVAILABLE IN 1974.

PROP. NO.	PHASE	STATUS	CONDITIONS	CHANNEL	SPOKESMAN	PAC-HRS
57	1	COMPLETE		P3	DROPSKY B.J.	100.0
				LEP		0.0
	2	COMPLETE		P3		32.0
				LEP		11.0
58	1	NEEDTOHEAR		P3	HUGHES V.W.	0.0
59	F-5	APPROVED	11/101/155	SMC	LU D.C.	0.0
70	1	WITHDRAWN			FETKOVICH J.C.	0.0
71	1	REJECTED			KNOWLES H.B.	0.0
72	1	REJECTED			HOFFMAN M.M.	0.0
73	1	WITHDRAWN		HRS	COLE R.K.	100.0
74	1	APPROVED		EPICS	PEREZ-MENDO V.	350.0
					STETZ A.W.	0.0
75	1	IN ERROR				0.0
75	1	NEEDTOHEAR		SMC	CHANG C.Y.	0.0
77	1	WITHDRAWN		EPICS	THIESSEN H.A.	120.0
78	1	WITHDRAWN		BIOMED	PHILLIPS G.C.	50.0
				LEP		50.0
79	1	COMPLETE	EXP-AR-DEV	LEP	PHILLIPS G.C.	50.0
				P3		50.0
80	1	COMPLETE		P3	PHILLIPS G.C.	300.0
	2	COMPLETE		P3		320.0
81	1	COMPLETE		EPB	PHILLIPS G.C.	200.0
	2	COMPLETE		EPB		420.0
82	1	COMPLETE		P3	PHILLIPS G.C.	400.0
83	1	INACTIVE		BIOMED	PHILLIPS G.C.	100.0
84	1	COMPLETE	FOR PION	BIOMED	PHILLIPS G.C.	50.0
85	1	APPROVED		SMC	WELSH R.E.	75.0
85	1	COMPLETE		TTA	POSKANZER A.M.	300.0
	2	COMPLETE		TTA		0.0
	3	COMPLETE		TTA		1500.0
87	1	APPROVED		EPICS	MCCARTHY J.S.	300.0
88	1	REJECTED			SHIVELY F.T.	0.0
89	1	APPROVED		EPICS	BARNES P.D.	300.0
90	1	COMPLETE		P3	SHERMAN R.H.	300.0
	2	COMPLETE		P3	SHIVELY F.T.	400.0
					GLODIS P.F.	0.0
					SPENCER J.E.	0.0
					WADLINGER A.	0.0
					VEFKENS B.M.C.	0.0
91	1	NEEDTOHEAR		P3	HADDOK R.P.	0.0
92	1	WITHDRAWN		EPB	MAGLIC B.C.	0.0
93	1	WITHDRAWN		P3	PLENDL H.S.	150.0
					GREENFIELD M.B.	0.0
94	1	NEEDTOHEAR	PARASITE-Q		LEE Y-K	0.0
95	1	REPLACED	BY 139			0.0
95	1	COMPLETE		LEP	NAGLE D.E.	150.0
	2	COMPLETE		LEP		300.0

STATUS OF PROPOSALS AS OF 7B/06/23.
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BEAM HOURS WERE NOT AVAILABLE IN 1974.

PROP. NO.	PHASE	STATUS	CONDITIONS	CHANNEL	SPOKESMAN	PAC-HRS
97	1	COMPLETE		S4C	WU C.S.	32.0
	2	DEFER		S4C		0.0
98	1	REPLACED	BY 139		SPENCER J.E.	0.0
99	1	COMPLETE		P3	REBKA G.A.	250.0
	2	COMPLETE		P3	GRAM P.A.M.	275.0
100	1	COMPLETE		S4C	HUTSON R.L.	100.0
	2	COMPLETE		S4C		170.0
101	F-5	COMPLETE	11/69/155	S4C	JOEHM F.	0.0
					LU D.C.	0.0
102	1	COMPLETE		P3	MARKOWITZ S.S.	30.0
				LEP		0.0
103	1	COMPLETE		P3	HUDIS J.	50.0
	2	APPROVED		A3-NUCCHEM		10.0
				P3		70.0
104	1	COMPLETE	54-P+6HPI	P3	PATE B.D.	5.0
				A3-NUCCHEM		5.0
	2	COMPLETE		A3-NUCCHEM		10.0
				P3		10.0
105	1	COMPLETE		A3-NUCCHEM	BUNKER M.E.	50.0
				SWY-LABS		0.0
	2	APPROVED		A3-NUCCHEM		75.0
106	1	COMPLETE		A3-NUCCHEM	O'BRIEN H.A.	20.0
	2	APPROVED		A3-NUCCHEM		20.0
107	1	REPLACED	BY 134		RYAN V.A.	0.0
108	1	WITHDRAWN			PLENDL H.S.	0.0
109	1	WITHDRAWN		HRS	FLYNN E.R.	250.0
110	1	NEED TO HEAR		P3	SIMON W.G.	50.0
111	1	COMPLETE		BSA-RAD	HILL J.C.	150.0
	2	APPROVED		BSA-RAD		150.0
112	1	WITHDRAWN			PETERSON R.J.	0.0
113	1	RESUBMIT		ISORAD	MICHEL D.J.	0.0
114	1	TO BE HEARD			KNAPP E.A.	0.0
115	1	WITHDRAWN		S4C	WOLFSBERG K.	70.0
116	1	WITHDRAWN			COOK B.C.	0.0
117	1	APPROVED		HRS	IGO G.J.	120.0
118	1	COMPLETE		A3-NUCCHEM	PORILE N.T.	5.0
				P3		20.0
				SWY-LABS		0.0
	2	COMPLETE		P3		50.0
	2			A3-NUCCHEM		0.0
119	1	COMPLETE		P3	KAUFMAN S.B.	67.0
	2	APPROVED		P3		32.0
				A3-NUCCHEM		0.0
120	1	APPRV/COMB	WITH SB	P3	NEFKENS B.M.K.	150.0
					SADLER M.E.	0.0

STATUS OF PROPOSALS AS OF 78/06/23.
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BEAM HOURS WERE NOT AVAILABLE IN 1974.

PROP. NO.	PHASE	STATUS	CONDITIONS	CHANNEL	SPOKESMAN	PAC-HRS
121	1	COMPLETE		LEP	SEGEL R.E.	120.0
				P3		0.0
	2	COMPLETE		P3		52.0
				LEP		112.0
122	1	COMPLETE		LEP	KUNSELMAN A.R.	50.0
	2	DEFER		LEP		0.0
123	1	COMPLETE		A3-NUCCEM	KAROL P.J.	1.0
				P3		50.0
	2	APPROVED		A3-NUCCEM		2.0
				P3		80.0
124	1	COMPLETE	BY ROSEN	A3-NEUTRON	DIETERLE B.D.	24.0
	2	COMPLETE		EPB	MC FARLANE W.K.	200.0
	2	COMPLETE		A3-NEUTRON		0.0
125	1	COMPLETE		A3-NEUTRON	DIETERLE B.D.	200.0
125	1	REJECTED			BRYANT H.C.	0.0
127	1	REJECTED			REICH C.W.	0.0
128	1	COMPLETE	ACCEL-DEV	EPB	HAYWARD T.D.	0.0
129	1	COMPLETE		A3-NEUTRON	WOLFE D.M.	400.0
130	1	COMPLETE		EPICS	THIESSEN H.A.	0.0
	2	COMPLETE		EPICS		0.0
131	1	COMPLETE		LEP	PREEDOM B.M.	123.0
	2	RESUBMIT		LEP		224.0
132	1	NEED TO HEAR	WITH 160	P3	HWANG C.F.	250.0
133	1	COMPLETE		EPICS	SEMMELI D.S.	150.0
134	1	REPLACED	BY 147		RYAN V.A.	0.0
135	1	REJECTED			MADEY R.	0.0
135	1	INACTIVE		EPICS	BURLESON G.R.	0.0
137	1	APPROVED		EPB	VAGLE D.E.	0.0
					MISCHKEI R.E.	0.0
					FRAUENFELD H.	0.0
138	1	APPROVED		HRS	MCDANIELS D.K.	150.0
					SWENSON L.W.	0.0
139	1	COMPLETE	TUNE-UP	HRS	SPENCER J.E.	250.0
					TANAKA N.	0.0
140	1	COMPLETE	WITH 180	LEP	BARNES P.D.	50.0
	2	COMPLETE		LEP		112.0
	3	APPROVED		LEP		350.0
141	1	WITHDRAWN			HARGROVE C.K.	0.0
142	1	COMPLETE		SAC	HUIZENGA J.R.	100.0
	2	APPROVED		SAC		400.0
143	1	COMPLETE		BIONED	KLIGERMAN M.M.	0.0
	2	COMPLETE		BIONED	KNAPP E.A.	0.0
	3	COMPLETE		BIONED		0.0
144	1	COMPLETE		LEP	HIGHLAND V.L.	224.0
	2	APPROVED		P3	MACEK R.J.	335.0
145	1	WITHDRAWN		EPICS	TAMAS G.	0.0
					LAGET J.-M.	0.0
145	1	WITHDRAWN		EPICS	PETERSON R.J.	0.0

STATUS OF PROPOSALS AS OF 7/8/05/23.

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BEAM HOURS WERE NOT AVAILABLE IN 1974.

PROP. NO.	PHASE	STATUS	CONDITIONS	CHANNEL	SPOKESMAN		PAC-HRS
147	1	APPROVED		BSA-RAD	PERRY	D.G.	200.0
					BARR	D.W.	0.0
148	1	COMPLETE		NEUTRINO-A	REINES	F.	0.0
	2	COMPLETE	NULL	NEUTRINO-A	CHEN	H.H.	0.0
149	1	NEED TO HEAR	PARASITE	SMC	CHEN	J.R.	0.0
					SWENSON	L.W.	0.0
150	1	COMPLETE		A3-VUCCHEM	TURKEVICH	A.	100.0
	2	COMPLETE		A3-VUCCHEM			50.0
151	1	APPROVED		BIOMED	KNOWLES	H.B.	10.0
152	1	WITHDRAWN		SMC	DIXIT	M.S.	150.0
153	1	COMPLETE		EPB	EISENSTEIN	R.A.	50.0
				P3			50.0
154	1	APPROVED		P3	MINEHART	R.C.	150.0
					MCCARTHY	J.S.	0.0
155	F-5	APPROVED	11/59/101	SMC	LU	D.C.	0.0
	1	APPROVED		SMC			300.0
156	1	COMPLETE	PARASITE	EPICS	SWENSON	L.W.	0.0
157	1	APPROVED		BSA-RAD	SEITZ	M.G.	25.0
158	1	APPROVED	PARASITE	HRS	IGO	G.J.	0.0
159	1	COMPLETE	PARASITE	EPB	EISENSTEIN	R.A.	0.0
160	1	WITHDRAWN	WITH 132	EPB	HWANG	C.F.	100.0
	2	DEFER		EPB			0.0
161	1	APPROVED	WITH 157	BSA-RAD	HAINES	E.L.	150.0
162	1	COMPLETE		LEP	YAVIN	A.I.	50.0
					ALSTER	J.	0.0
163	1	COMPLETE		SMC	PERKINS	R.B.	100.0
					SHERA	E.B.	0.0
164	1	COMPLETE		LEP	FISHER	T.R.	90.0
					MARSHAK	H.	0.0
165	1	COMPLETE		SMC	HUGHES	V.W.	50.0
166	1	COMPLETE		SMC	POWERS	R.J.	120.0
167	1	COMPLETE	FEAS/PARA	BIOMED	ZIOCK	K.O.H.	0.0
168	1	WITHDRAWN	2-SREL	BIOMED	ZIOCK	K.O.H.	0.0
169	1	COMPLETE		A3-VUCCHEM	ORTH	C.J.	0.0
					SATTIZAHN	J.E.	0.0
170	1	COMPLETE		LEP	ALSTER	J.	50.0
171	1	APPROVED		BIOMED	BENTON	E.V.	14.0
172	1	INACTIVE		SMC	SWALLOW	E.	0.0
173	1	APPROVED		SMC	BOEHM	F.	300.0
					VOGEL	P.	0.0
174	1	COMPLETE		BSA-RAD	ROWLAND	F.S.	200.0
	2	APPROVED		BSA-RAD	MILLER	G.E.	90.0
				ISORAD			0.0
175	1	COMPLETE		SMC	HUGHES	V.W.	0.0
176	1	COMPLETE		EPB	ANDERSON	B.D.	200.0
	2	COMPLETE		EPB			200.0
177	1	APPROVED		HRS	IGO	G.J.	0.0
					BAUER	T.S.	0.0

STATUS OF PROPOSALS AS OF 7/8/06/23.
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BEAM HOURS WERE NOT AVAILABLE IN 1974.

PROP. NO.	PHASE	STATUS	CONDITIONS	CHANNEL	SPOKESMAN	PAC-HRS
178	1	APPROVED	IN PRIN.	HRS	SPENCER J.E.	150.0
					HINTZ N.M.	0.0
179	1	COMPLETE	DETEC/DEV	LINE-B	BOWMAN J.D.	0.0
180	1	COMPLETE		LEP	EISENSTEIN R.A.	50.0
	2	COMPLETE		LEP		280.0
181	1	APPROVED		LEP	ALSTER J.	112.0
					BOWMAN J.D.	0.0
182	1	REJECTED		LEP	PETERSON R.J.	0.0
183	1	APPROVED	IN PRINCIP	HRS	HINTZ N.M.	0.0
					SPENCER J.E.	0.0
184	1	COMPLETE		ISORAD	O'BRIEN H.A.	0.0
				LINE-X-35		0.0
185	1	INACTIVE		A3-NEUTRON	SIMMONS J.E.	0.0
186	1	WITHDRAWN		EPB	PETERSON R.J.	0.0
187	1	APPROVED	PARASITE	BIOMED	REIDY J.J.	0.0
188	1	APPROVED		BIOMED	CARLSON D.E.	50.0
189	1	COMPLETE		A3-NEUTRON	VANDYCKE O.R.	295.0
190	1	APPROVED	PARASITE	LEP	ZIOCK K.O.H.	0.0
191	1	COMPLETE		LEP	HALPERN I.	112.0
	2	COMPLETE		LEP		165.0
	3	APPROVED	BY ROSEN	LEP		200.0
192	1	COMPLETE	ACCEL-DEV.	EPB	HAYWARD T.D.	45.0
193	1	COMPLETE		A3-NEUTRON	DIETERLE B.D.	250.0
					MC FARLANE W.K.	0.0
194	1	APPROVED		EPB	BEVINGTON P.R.	0.0
195	1	COMPLETE		BIOMED	LEON M.	0.0
	2	COMPLETE		P3	REIDY J.J.	100.0
				BIOMED		0.0
	3	APPROVED		P3		168.0
196	1	APPROVED		BIOMED	DANIEL H.	0.0
					REIDY J.J.	0.0
197	1	COMPLETE		EPB	HUNGERFORD E.V.	225.0
198	1	COMPLETE		BIOMED	POWERS G.E.	0.0
199	1	WITHDRAWN			BARRETT R.J.	0.0
200	1	COMPLETE	ACCEL DEV	EPB	BRYANT H.C.	0.0
201	1	COMPLETE		P3	MINEHART R.C.	250.0
202	1	APPROVED		HRS	IGO G.J.	0.0
203	1	REJECTED			PHILLIPS G.C.	0.0
204	1	APPROVED		HRS	IGO G.J.	100.0
205	1	COMPLETE	LIT PART	A3-NEUTRON	KENEFFICK R.A.	50.0
					RILEY P.J.	0.0
206	1	COMPLETE		SMC	HUGHES V.W.	250.0
					EGAN P.O.	0.0
207	1	COMPLETE		BIOMED	BRADBURY J.N.	0.0
					ALLRED J.C.	0.0
208	1	WITHDRAWN		A3-NEUTRON	NORTHCLIFF L.C.	200.0
209	1	COMPLETE		BIOMED	BRADBURY J.N.	0.0
				LEP	ALLRED J.C.	0.0

STATUS OF PROPOSALS AS OF 78/05/23.
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PROPOS. NO.	PHASE	STATUS	CONDITIONS	CHANNEL	SPOKESMAN	PAC-HRS
210	1	COMPLETE		ISORAD	O'BRIEN H.A.	0.0
211	1	COMPLETE		ISORAD	GREEN W.V.	0.0
212	1	APPROVED		BIOMED	MEWISSEN D.J.	15.0
213	1	APPROVED		SMC	SHERA E.B.	32.0
					STEFFEN R.M.	0.0
214	1	COMPLETE	N/195	P3	HARGROVE C.K.	50.0
					LEON M.	0.0
215	1	APPROVED		BIOMED	PEREZ-MENDO V.	104.0
					BRADBURY J.N.	0.0
216	1	REJECTED			WADLINGER A.	0.0
217	1	APPROVED		BIOMED	PACIOTTI M.A.	32.0
218	1	APPROVED		BIOMED	KATZ R.	15.0
219	1	COMPLETE		EPB	JEVINGTON P.R.	225.0
220	1	REJECTED			HOFFMANN G.W.	0.0
					MOORE C.F.	0.0
221	1	COMPLETE		P3	HOFFMANN C.M.	500.0
222	1	COMPLETE		P3	MISCHKE R.E.	500.0
223	F-5	APPROVED	PARASITE	HRS	HOFFMANN G.W.	0.0
224	1	WITHDRAWN		EPICS	ENSSLIN N.	0.0
					MADLAND D.G.	0.0
					MORRIS C.L.	0.0
225	1	APPROVED		NEUTRINO-A	CHEN H.H.	0.0
					REINES F.	0.0
226	1	REJECTED			BURLESON G.R.	0.0
227	1	APPROVED	PARASITE	HRS	RILEY P.J.	0.0
					SPENCER J.E.	0.0
228	1	WITHDRAWN				0.0
229	1	APPROVED		EPICS	BRAITHWAIT W.J.	200.0
					MOORE C.F.	0.0
230	1	WITHDRAWN			BRAITHWAIT W.J.	0.0
					MOORE C.F.	0.0
					THIESSEN H.A.	0.0
231	1	WITHDRAWN		EPICS	BRAITHWAIT W.J.	0.0
					MOORE C.F.	0.0
232	1	APPROVED		EPICS	MADLAND D.G.	250.0
					MORRIS C.L.	0.0
233	1	APPRV/COMB	N/10	HRS	SETH K.K.	100.0
					SPENCER J.E.	0.0
234	1	COMPLETE		LSP	JENKINS D.A.	0.0
235	1	COMPLETE		BIOMED	GILLETTE E.L.	21.0
236	1	APPROVED		BIOMED	RAJU M.R.	230.0
237	1	RESUBMIT		BSA-RAD	HOLLAND J.R.	0.0
					GREEN W.V.	0.0
238	1	REPLACED	BY 290		MADEY R.	0.0
239	1	COMPLETE		BIOMED	FRIEDLAND S.S.	23.0
	2	COMPLETE		BIOMED	MAUSNER L.F.	0.0
240	1	COMPLETE	J	SMC	SHERA E.B.	240.0
					WOHLFAHRT H.D.	0.0

BEAM HOURS WERE NOT AVAILABLE IN 1974.

PAC-HRS	NO.	PHASE	STATUS	CONDITIONS	CHANNEL	SPOKESMAN	PAC-HRS
0.0	241	COMPLETE	EP8	HOFFMAN	HOFFMAN	C.M.	0.0
0.0	242	APPROVED	APPROVED	HOFFMAN	HOFFMAN	R.E.	0.0
54.0	243	APPROVED	APPROVED	HOFFMAN	HOFFMAN	P.	54.0
140.0	244	APPROVED	APPROVED	HOFFMAN	HOFFMAN	N.T.	140.0
0.0	245	APPROVED	APPROVED	HOFFMAN	HOFFMAN	A.B.	0.0
450.0	246	COMPLETE	COMPLETE	HOFFMAN	HOFFMAN	J.	450.0
0.0	247	COMPLETE	COMPLETE	HOFFMAN	HOFFMAN	H.A.	0.0
450.0	248	COMPLETE	COMPLETE	HOFFMAN	HOFFMAN	R.A.	450.0
72.0	249	COMPLETE	COMPLETE	HOFFMAN	HOFFMAN	C.J.	72.0
0.0	250	COMPLETE	COMPLETE	HOFFMAN	HOFFMAN	P3	0.0
0.0	251	COMPLETE	COMPLETE	HOFFMAN	HOFFMAN	LEP	0.0
480.0	252	COMPLETE	COMPLETE	HOFFMAN	HOFFMAN	P3	480.0
0.0	253	COMPLETE	COMPLETE	HOFFMAN	HOFFMAN	J.	0.0
0.0	254	COMPLETE	COMPLETE	HOFFMAN	HOFFMAN	J.S.	0.0
0.0	255	COMPLETE	COMPLETE	HOFFMAN	HOFFMAN	P.C.	0.0
0.0	256	COMPLETE	COMPLETE	HOFFMAN	HOFFMAN	C.A.	0.0
200.0	257	COMPLETE	COMPLETE	HOFFMAN	HOFFMAN	J.J.	200.0
0.0	258	COMPLETE	COMPLETE	HOFFMAN	HOFFMAN	J.J.	0.0
0.0	259	COMPLETE	COMPLETE	HOFFMAN	HOFFMAN	J.J.	0.0
0.0	260	COMPLETE	COMPLETE	HOFFMAN	HOFFMAN	J.J.	0.0
0.0	261	COMPLETE	COMPLETE	HOFFMAN	HOFFMAN	J.J.	0.0
0.0	262	COMPLETE	COMPLETE	HOFFMAN	HOFFMAN	J.J.	0.0
0.0	263	COMPLETE	COMPLETE	HOFFMAN	HOFFMAN	J.J.	0.0
0.0	264	COMPLETE	COMPLETE	HOFFMAN	HOFFMAN	J.J.	0.0
0.0	265	COMPLETE	COMPLETE	HOFFMAN	HOFFMAN	J.J.	0.0
0.0	266	COMPLETE	COMPLETE	HOFFMAN	HOFFMAN	J.J.	0.0
0.0	267	COMPLETE	COMPLETE	HOFFMAN	HOFFMAN	J.J.	0.0
0.0	268	COMPLETE	COMPLETE	HOFFMAN	HOFFMAN	J.J.	0.0
0.0	269	COMPLETE	COMPLETE	HOFFMAN	HOFFMAN	J.J.	0.0
30.0	270	COMPLETE	COMPLETE	HOFFMAN	HOFFMAN	J.J.	30.0
512.0	271	COMPLETE	COMPLETE	HOFFMAN	HOFFMAN	J.J.	512.0
900.0	272	COMPLETE	COMPLETE	HOFFMAN	HOFFMAN	J.J.	900.0

STATUS OF PROPOSALS AS OF 78/06/23.
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BEAM HOURS WERE NOT AVAILABLE IN 1974.

PROP. NO.	PHASE	STATUS	CONDITIONS	CHANNEL	SPOKESMAN	PAC-HRS
272	1	APPROVED		BIOMED	DICELO J.F.	144.0
273	1	APPROVED		BIOMED	RICHMAN C.	535.0
274	1	APPROVED		BIOMED	YUHAS J.	700.0
275	1	APPROVED		BIOMED	KLIGERMAN M.M.	1500.0
276	1	COMPLETE		SMC	YAMAZAKI T.	50.0
	2	COMPLETE		SMC		200.0
	3	APPROVED		SMC		254.0
277	1	COMPLETE	PARASITE	SMC	ALLRED J.C.	80.0
278	1	COMPLETE		EPB	HOFFMANN G.W.	24.0
					MOORE C.F.	0.0
279	1	COMPLETE	FEAS STUDY	AB-NEUTRON	DIETERLE B.D.	72.0
				EPB	MC FARLANE W.K.	0.0
	2	NEED TO HEAR		AB-NEUTRON		0.0
280	1	WITHDRAWN		HRS	NEFKENS B.M.K.	0.0
281	1	DEFER		SMC	HUANG C.Y.	0.0
					ROSENBLUM S.S.	0.0
282	1	COMPLETE		AB-NUCCHEM	CONNERT H.J.	20.0
	2	COMPLETE		AB-NUCCHEM		0.0
	3			AB-NUCCHEM		0.0
283	1	COMPLETE		SMC	CRANE K.S.	100.0
				P3	SHARMA T.C.	0.0
	2	TO BE HEARD		SMC		0.0
284	1	APPROVED		LEP	COOPER M.D.	224.0
					HEFFNER R.H.	0.0
285	1	COMPLETE		BIOMED	MAUSNER L.F.	0.0
286	1	COMPLETE		P3	HANSON K.M.	320.0
287	1	REJECTED		P3	LIND V.G.	0.0
288	1	APPROVED		SMC	NAJMAN R.A.	150.0
289	1	APPROVED		HRS	WHITTEN C.A.	100.0
290	1	RESUBMIT		BSA-RAD	MADEY R.	0.0
					GREEN W.V.	0.0
					VEESER L.R.	0.0
291	1	WITHDRAWN		EPICS	SWENSON L.W.	300.0
					MOORE C.F.	0.0
292	1	COMPLETE		SMC	HUIZENGA J.R.	150.0
	2	APPROVED		SMC		120.0
293	1	COMPLETE		LEP	SEGEL R.E.	112.0
294	1	APPROVED		AB-NUCCHEM	KAROL P.J.	50.0
295	1	APPROVED		LEP	BOWMAN J.D.	300.0
					MOINSTER M.A.	0.0
296	1	APPROVED		EPB	BAER H.W.	0.0
					BOWMAN J.D.	0.0
297	1	COMPLETE	WITH 266	SMC	BROWN J.A.	109.0
	2	APPROVED		SMC		210.0
298	1	COMPLETE		NUCL	SELOVE W.	0.0
299	1	COMPLETE		LEP	ZIOCK K.O.L.	224.0
	2	APPROVED		LEP		0.0

BELOW HOURS WERE NOT AVAILABLE IN 1974.

PROJ. NO.	PHASE	STATUS	CONDITIONS	CHANNEL	SPOKESMAN	PAC-HRS
300		COMPLETE		BLOWED	DANIEL	0.0
301		APPROVED	AS-VUCHEW	ADAMAGE-1	WILSON	0.0
302		APPROVED		PIP	GREEN	0.0
303		COMPLETE		LEP	JACKSON	0.0
304		COMPLETE	SCI-MERIT	BLOWED	LEON	200.0
305		APPROVED	FEAS STUDY	SYC	DENISON	100.0
306		REJECTED		MRS	HUANG	0.0
307		APPROVED		MRS	IGO	0.0
308		APPROVED		TA	WILITEN	0.0
309		APPROVED		P3	REKA	400.0
310		APPROVED		EPICS	BRATHAMIT	200.0
311		COMPLETE		MRS	HOFFMANN	500.0
312		APPROVED		MRS	HUTSON	100.0
313		APPROVED		SYC	HUANG	0.0
314		REJECTED		SYC	HOME	0.0
315		APPROVED		LEP	WARTON	350.0
316		APPROVED		LEP	SETH	350.0
317		APPROVED	COMB/W 368	EPICS	PETERSON	0.0
318		WILCHMAN		LEP	AMANN	0.0
319		COMPLETE		P3	SHERMAN	0.0
320		APPROVED		P3	CHURCH	50.0
321		WILCHMAN		EPH	COLE	0.0
322		APPROVED		LEP	BEERLAND	350.0
323		COMPLETE		EPH	ARYAT	110.0
324		COMPLETE		LEP	HALPERN	50.0
325		COMPLETE	PARASITE	EPICS	HANSON	0.0
326		APPROVED	PARASITE	BSA-RAD	HARVEY	0.0
327		APPROVED		PIP	WILSON	0.0
328		COMPLETE		SYC	COOPER	1020.0

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BEAM HOURS WERE NOT AVAILABLE IN 1974.

PROP. NO.	PHASE	STATUS	CONDITIONS	CHANNEL	SPOKESMAN	PAC-HRS
329	1	WITHDRAWN	FEAS STUDY	SMC	THOMPSON P.A.	150.0
					FRANKELI S.	0.0
					HUGHES V.W.	0.0
330	1	APPROVED	CONDITIONAL	SMC	HUTSON R.L.	90.0
					YATES-WILL M.A.	0.0
331	1	APPROVED		SMC	ORTH C.J.	94.0
332	1	WITHDRAWN		EPICS	SETH K.K.	0.0
333	1	APPROVED		LEP	GOTOW K.	360.0
334	1	APPROVED	IN PART	SMC	SHERA E.B.	115.0
					MUHLFART H.D.	0.0
335	1	APPROVED		SMC	SHERA E.B.	210.0
					YAMAZAKI Y.	0.0
336	1	APPRV/COMB	4/33	EPB	MUTCHLER G.S.	0.0
					BEVINGTON P.R.	0.0
337	1	APPROVED		P3	REBKA G.A.	600.0
					GRAM P.A.M.	0.0
338	1	WITHDRAWN		EPICS	SKAITHWAIT W.J.	0.0
339	1	APPROVED		EPB	RYANT H.C.	504.0
					GRAM P.A.M.	0.0
340	1	WITHDRAWN		EPICS	FISHER T.R.	0.0
					MARSHAKI H.	0.0
341	1	COMPLETE		EPB	PHILLIPS G.C.	170.0
342	1	APPRV/COMB	COMB/W 39	EPICS	MCCARTHY J.S.	175.0
					KALLNE J.	0.0
343	1	REJECTED		HRS	SETH K.K.	0.0
344	1	APPROVED		SMC	HUGHES V.W.	400.0
345	1	APPROVED		HRS	FRANKELI S.	0.0
346	1	COMPLETE		HRS	FRANKELI S.	150.0
347	1	APPROVED		HRS	HINTZ N.M.	150.0
348	1	APPROVED		LEP	CROWE K.M.	500.0
349	1	APPROVED		P3	PORILE N.T.	173.0
350	1	APPROVED		LEP	SEGEL R.E.	144.0
					SCHIFFER J.P.	0.0
351	1	REJECTED		HRS	IGO G.J.	0.0
352	1	APPRV/COMB	W/355	HRS	WHITTEV C.A.	100.0
353	1	REJECTED		HRS	SETH K.K.	0.0
354	1	APPROVED		HRS	BLANPIED G.S.	100.0
355	1	APPRV/COMB	W/352	HRS	HOFFMANN G.W.	100.0
356	1	APPROVED	CONDITIONAL	HRS	GLASHAUSS C.	0.0
					BAKER F.T.	0.0
					SCOTT A.	0.0
357	1	APPROVED		SMC	KNIGHT J.D.	120.0
358	1	APPROVED		P3	MINEHART R.C.	450.0
359	1	REJECTED		HRS	BAUER T.S.	0.0
360	1	APPROVED		A3-NEUTRON	RILEY P.J.	165.0
					SIMMONS J.E.	0.0
361	1	REJECTED		HRS	ADAMS G.S.	0.0

BEAM HOURS WERE NOT AVAILABLE IN 1974.

PAC-4RS	SPOKESMAN	CHANNEL	CONDITIONS	STATUS	PHASE	NO.	
0.0	T.S.	FAUER	CONDITIONA	APPROVED	1	362	
0.0	A.	WRIEAT		APPROVED	1	363	
550.0	M.E.	SADLER		APPROVED	1	364	
0.0	B.M.K.	NEFKENS		APPROVED	1	365	
300.0	P.O.	EGAN		APPROVED	1	366	
0.0	A.B.	DEVISOV		REJECTED	1	367	
0.0	V.W.	HUGHES		REJECTED	1	368	
0.0	N.M.	HINTZ		APPROVED	1	369	
400.0	B.W.	WAVES	AF-NEUTRON	REJECTED	1	370	
0.0	G.S.	WITCHLER		REJECTED	1	371	
0.0	H.	MANN		REJECTED	1	372	
0.0	K.K.	SETH		REJECTED	1	373	
300.0	C.F.	MOORE	EPICS	APPROVED	1	374	
200.0	D.	DEHNHARD	EPICS	APPROVED	1	375	
0.0	J.G.	CRAMER	LEP	APPROVED	1	376	
0.0	M.D.	COOPER		APPROVED	1	377	
95.0	R.L.	HUTSON		APPROVED	1	378	
0.0	R.D.	EDGE		APPROVED	1	379	
0.0	J.J.	REIDY		APPROVED	1	380	
163.0	M.	LEON		APPROVED	1	381	
0.0	M.E.	SCHILLACI		APPROVED	1	382	
144.0	M.E.	SCHILLACI		APPROVED	1	383	
24.0	G.	PAULETTA		APPROVED	1	384	
0.0	J.J.	REIDY		APPROVED	1	385	
24.0	A.	HARVEY	SSA-KAD	REJECTED	1	386	
0.0	S.S.	ROSENBLUM		REJECTED	1	387	
90.0	T.L.	PHILLIPS		REJECTED	1	388	
0.0	L.S.	GOLDSTEIN		REJECTED	1	389	
0.0	A.	HARVEY		REJECTED	1	390	
0.0	R.H.	HEFFNER		REJECTED	1	391	
0.0	A.	HARVEY		REJECTED	1	392	
0.0	W.J.	KOSLER		REJECTED	1	393	
0.0	A.	FIORY		REJECTED	1	394	
0.0	A.	HARVEY		REJECTED	1	395	
0.0	A.	HARVEY		REJECTED	1	396	
0.0	A.	HARVEY		REJECTED	1	397	
0.0	A.	HARVEY		REJECTED	1	398	
0.0	A.	HARVEY		REJECTED	1	399	
0.0	A.	HARVEY		REJECTED	1	400	
0.0	A.	HARVEY		REJECTED	1	401	
0.0	A.	HARVEY		REJECTED	1	402	
0.0	A.	HARVEY		REJECTED	1	403	
0.0	A.	HARVEY		REJECTED	1	404	
0.0	A.	HARVEY		REJECTED	1	405	
0.0	A.	HARVEY		REJECTED	1	406	
0.0	A.	HARVEY		REJECTED	1	407	
0.0	A.	HARVEY		REJECTED	1	408	
0.0	A.	HARVEY		REJECTED	1	409	
0.0	A.	HARVEY		REJECTED	1	410	
0.0	A.	HARVEY		REJECTED	1	411	
0.0	A.	HARVEY		REJECTED	1	412	
0.0	A.	HARVEY		REJECTED	1	413	
0.0	A.	HARVEY		REJECTED	1	414	
0.0	A.	HARVEY		REJECTED	1	415	
0.0	A.	HARVEY		REJECTED	1	416	
0.0	A.	HARVEY		REJECTED	1	417	
0.0	A.	HARVEY		REJECTED	1	418	
0.0	A.	HARVEY		REJECTED	1	419	
0.0	A.	HARVEY		REJECTED	1	420	
0.0	A.	HARVEY		REJECTED	1	421	
0.0	A.	HARVEY		REJECTED	1	422	
0.0	A.	HARVEY		REJECTED	1	423	
0.0	A.	HARVEY		REJECTED	1	424	
0.0	A.	HARVEY		REJECTED	1	425	
0.0	A.	HARVEY		REJECTED	1	426	
0.0	A.	HARVEY		REJECTED	1	427	
0.0	A.	HARVEY		REJECTED	1	428	
0.0	A.	HARVEY		REJECTED	1	429	
0.0	A.	HARVEY		REJECTED	1	430	
0.0	A.	HARVEY		REJECTED	1	431	
0.0	A.	HARVEY		REJECTED	1	432	
0.0	A.	HARVEY		REJECTED	1	433	
0.0	A.	HARVEY		REJECTED	1	434	
0.0	A.	HARVEY		REJECTED	1	435	
0.0	A.	HARVEY		REJECTED	1	436	
0.0	A.	HARVEY		REJECTED	1	437	
0.0	A.	HARVEY		REJECTED	1	438	
0.0	A.	HARVEY		REJECTED	1	439	
0.0	A.	HARVEY		REJECTED	1	440	
0.0	A.	HARVEY		REJECTED	1	441	
0.0	A.	HARVEY		REJECTED	1	442	
0.0	A.	HARVEY		REJECTED	1	443	
0.0	A.	HARVEY		REJECTED	1	444	
0.0	A.	HARVEY		REJECTED	1	445	
0.0	A.	HARVEY		REJECTED	1	446	
0.0	A.	HARVEY		REJECTED	1	447	
0.0	A.	HARVEY		REJECTED	1	448	
0.0	A.	HARVEY		REJECTED	1	449	
0.0	A.	HARVEY		REJECTED	1	450	
0.0	A.	HARVEY		REJECTED	1	451	
0.0	A.	HARVEY		REJECTED	1	452	
0.0	A.	HARVEY		REJECTED	1	453	
0.0	A.	HARVEY		REJECTED	1	454	
0.0	A.	HARVEY		REJECTED	1	455	
0.0	A.	HARVEY		REJECTED	1	456	
0.0	A.	HARVEY		REJECTED	1	457	
0.0	A.	HARVEY		REJECTED	1	458	
0.0	A.	HARVEY		REJECTED	1	459	
0.0	A.	HARVEY		REJECTED	1	460	
0.0	A.	HARVEY		REJECTED	1	461	
0.0	A.	HARVEY		REJECTED	1	462	
0.0	A.	HARVEY		REJECTED	1	463	
0.0	A.	HARVEY		REJECTED	1	464	
0.0	A.	HARVEY		REJECTED	1	465	
0.0	A.	HARVEY		REJECTED	1	466	
0.0	A.	HARVEY		REJECTED	1	467	
0.0	A.	HARVEY		REJECTED	1	468	
0.0	A.	HARVEY		REJECTED	1	469	
0.0	A.	HARVEY		REJECTED	1	470	
0.0	A.	HARVEY		REJECTED	1	471	
0.0	A.	HARVEY		REJECTED	1	472	
0.0	A.	HARVEY		REJECTED	1	473	
0.0	A.	HARVEY		REJECTED	1	474	
0.0	A.	HARVEY		REJECTED	1	475	
0.0	A.	HARVEY		REJECTED	1	476	
0.0	A.	HARVEY		REJECTED	1	477	
0.0	A.	HARVEY		REJECTED	1	478	
0.0	A.	HARVEY		REJECTED	1	479	
0.0	A.	HARVEY		REJECTED	1	480	
0.0	A.	HARVEY		REJECTED	1	481	
0.0	A.	HARVEY		REJECTED	1	482	
0.0	A.	HARVEY		REJECTED	1	483	
0.0	A.	HARVEY		REJECTED	1	484	
0.0	A.	HARVEY		REJECTED	1	485	
0.0	A.	HARVEY		REJECTED	1	486	
0.0	A.	HARVEY		REJECTED	1	487	
0.0	A.	HARVEY		REJECTED	1	488	
0.0	A.	HARVEY		REJECTED	1	489	
0.0	A.	HARVEY		REJECTED	1	490	
0.0	A.	HARVEY		REJECTED	1	491	
0.0	A.	HARVEY		REJECTED	1	492	
0.0	A.	HARVEY		REJECTED	1	493	
0.0	A.	HARVEY		REJECTED	1	494	
0.0	A.	HARVEY		REJECTED	1	495	
0.0	A.	HARVEY		REJECTED	1	496	
0.0	A.	HARVEY		REJECTED	1	497	
0.0	A.	HARVEY		REJECTED	1	498	
0.0	A.	HARVEY		REJECTED	1	499	
0.0	A.	HARVEY		REJECTED	1	500	

STATUS OF PROPOSALS AS OF 78/05/23.
PAGE 14

BEAM HOURS WERE NOT AVAILABLE IN 1974.

PROPOS. NO.	PHASE	STATUS	CONDITIONS	CHANNEL	SPOKESMAN	PAC-HRS
395	1	TO BE HEARD		HRS	BAUER T.S.	0.0
					HOISTAD B.C.	0.0
					VANN H.	0.0
396	1	TO BE HEARD		P3	REIDY J.J.	0.0
397	1	TO BE HEARD		HRS	IGO G.J.	0.0
					THIESSEN H.A.	0.0
398	1	TO BE HEARD		HRS	PAULETTA G.	0.0
399	1	TO BE HEARD		HRS	BERTRAND F.E.	0.0
400	1	TO BE HEARD		SMC	DUONG-VAN M.	0.0
					HOFFMAN C.M.	0.0
401	1	TO BE HEARD		LEP	BOWMAN J.D.	0.0
					COOPER M.D.	0.0
402	1	TO BE HEARD		AB-NEUTRON	GLASS G.	0.0
					SIMMONS J.E.	0.0
403	1	TO BE HEARD		AB-NEUTRON	BONNER B.E.	0.0
404	1	TO BE HEARD		P3	HAMM M.E.	0.0
					SWENSON L.W.	0.0
405	1	TO BE HEARD		HRS	HOISTAD B.C.	0.0
					BAUER T.S.	0.0
					SETH K.K.	0.0
406	1	TO BE HEARD		BSA-RAD	HARVEY A.	0.0
407	1	TO BE HEARD		AB-NUCCEM	SOMMER, JR. W.F.	0.0
408	1	TO BE HEARD		SMC	HEFFNER R.N.	0.0
					LEON M.	0.0
409	1	TO BE HEARD		P3	LIND V.G.	0.0
					GREENFIELD M.B.	0.0
410	1	TO BE HEARD		PIP	COST J.R.	0.0
411	1	TO BE HEARD		HRS	HINTZ N.M.	0.0
					MOSS J.M.	0.0
412	1	TO BE HEARD		LEP	BAER H.W.	0.0
					BOWMAN J.D.	0.0
					OVERVA F.H.	0.0
413	1	TO BE HEARD		EPICS	SETH K.K.	0.0
					VANN H.	0.0
414	1	TO BE HEARD		SMC	HUTSON R.L.	0.0
					REIDY J.J.	0.0
415	1	TO BE HEARD		LEP	ORTH C.J.	0.0
416	1	TO BE HEARD		P3	DROPSKY B.J.	0.0
417	1	TO BE HEARD		SMC	HUIZENGA J.R.	0.0
418	1	TO BE HEARD		P3	LIND V.G.	0.0
419	S1	TO BE HEARD		EPICS	BRAITHWAIT W.J.	0.0
					MOORE C.F.	0.0
					MORRIS C.L.	0.0
420	1	TO BE HEARD		P3	GRUHN C.R.	0.0
					FLYNN E.R.	0.0
421	1	TO BE HEARD		SMC	SOJDER P.A.	0.0
					FRANKEL S.	0.0
					HUGHES V.W.	0.0

STATUS OF PROPOSALS AS OF 78/06/23.
 PAGE 15

TEAM HOURS WERE NOT AVAILABLE IN 1974.

PROP. NO.	PHASE	STATUS	CONDITIONS	CHANNEL	SPOKESMAN	PAC-HRS
422	1	TOBE-HEARD			LU	D.C. 0.0
801	F-5	APPROVED		SMC	30EHM	F. 240.0
					LU	D.C. 0.0

LAMPF PROPOSAL STATUS AND SUMMARIES

Compiled by

Lois Rayburn and Beverly Talley

ABSTRACT

This report contains the status and summaries of the proposed experiments for the Los Alamos Meson Physics Facility. Updates will be added periodically as new proposals are received.

Exp. 1

RARE DECAY MODES OF THE NEUTRAL PION

Virginia Polytechnic Institute and State University

W.P. Trower, Spokesman

J.R. Ficenec, T. Lagerlund

University of Birmingham, England

J.D. Davies

Rutherford Laboratories, England

R. Zia

Los Alamos Scientific Laboratory (LASL)

E.A. Knapp

We propose to study the structure of the pion by measuring the parameters of the rare decay modes of the neutral pion and the electronic products of radiative capture produced by a beam of stopping negative pions in a liquid-hydrogen target. We shall also be able to test symmetry violations in electromagnetic interaction.

The device which we will construct for the experiment, a multiparticle proportional wire chamber magnetic spectrometer, and its attendant software, will be readily adaptable for a large class of other experiments for which LAMPF is ideally suited. After the system is proven on this initial study of the neutral pion, it is hoped other groups will use our device which will require only modification for experiments of their choosing.

Exp. 2

TOTAL PION CROSS SECTIONS

University of Montana

M.J. Jakobson, Spokesman

R.H. Jeppesen

New Mexico State University

G.R. Burleson

Temple University

K.F. Johnson

LASL

D.C. Hagerman, R.P. Redwine, M.D. Cooper

University of Basel, Switzerland

H.O. Meyer

University of Washington

I. Halpern, R. Marrs, L. Knutson

Stanford University

J. Calarco

A measurement of total pion cross sections is to be undertaken for a number of nuclei. It is proposed that these measurements be made with positive and negative pions from the Low-Energy Pion channel (~25 to 30 MeV). Magnetic analysis will be used for some of the measurements and conventional attenuation methods for others. Accuracies of better than 1% are sought. Information should be obtained on pion-nucleus coupling constants, optical model parameters, and neutron densities in nuclei. The work is to be done by experimenters from the University of Montana, the University of Washington, and the Los Alamos Scientific Laboratory.

Exp. 3

**PROPOSAL FOR THE STUDY OF MUON CAPTURE
 γ RAYS AT THE STOPPED MUON CHANNEL OF LAMPF**

University of Texas, Austin

B.B. Kinsey, Spokesman

This proposal concerns the study of both prompt and delayed capture γ rays produced by targets at the Stopped Muon channel of LAMPF. In the following, current knowledge of the nuclear processes that follow, muon capture is reviewed. Apart from the acquisition of new and more detailed data, this proposal suggests studies (1) into discrepancies in γ -ray intensities as measured in different laboratories with different methods; (2) of the anomalous behavior of the yield of the (μ, n) reaction in doubled closed-shell nuclei, like ^{208}Pb ; and (3) of the energy emitted in the γ -ray cascade. The measurements would be made with Ge(Li) detectors of the best quality, suitably shielded by Compton suppressor scintillators of the latest design, and with Moxon-Rae detectors used according to Maier-Leibnitz' principle.

Exp. 4

**LARGE-ANGLE ELASTIC SCATTERING OF PROTONS FROM HELIUM AND THE
QUASI-ELASTIC KNOCKOUT OF ALPHA PARTICLES BY 800-MeV PROTONS**

Virginia Polytechnic Institute and State University

W.P. Trower, Spokesman

J. C. Fong, C. A. Whitten, R. J. Ridge, J. Soupac

LASL

G. W. Hoffmann

The differential elastic scattering of 800-MeV protons on helium will be measured in the angular region between about $\theta_{c.m.} = 60$ and 155° with good statistical accuracy.* Measurements at angles larger than $\theta_{c.m.} \leq 150^\circ$ will be done with reduced statistical accuracy because the beam must be reduced by a factor of 1000 to make small-angle measurements. For $\theta_{lab,\alpha} \leq 60^\circ$, the recoil alpha particle will be energetic enough to be detectable. A $1\text{-}\mu\text{A}$ beam of protons will be used. A liquid-helium target flask and reservoir in use at Berkeley will be available for this experiment. We will prefer to use a liquid-helium target under design at P-8 if it is completed in time. The beam level ($1\text{ }\mu\text{A}$) is set by the heat dissipation in the target and the capacity of the refrigerator.

Quasi-elastic knockout of alpha particles from 4n nuclei and ^{208}Pb and ^{238}U will be measured in the same angular range. The only previous measurements in this energy range were observations at one angle (5.4°) in collision between 665-MeV protons and light nuclei (Komarov *et al.*, 1970).

Theoretical questions of interest are

1. The comparison of elastic-scattering results with a two-coupled channel formalism (E. Lambert and H. Feshbach, 1972), Attachment 7.
2. The extraction of the "effective number" of alpha particles in 4n nuclei and a comparison with predictions on the basis of alpha particle-like nuclear-matter calculations using the elastic-scattering data on helium and the quasi-elastic scattering data on 4n nuclei.
3. Understanding of the nuclear surface of heavy nuclei subject to alpha decay.

*Smaller scattering angle measurements will be covered in Proposal 15, "Elastic Scattering and Total Cross-Section Measurements of Protons on Hydrogen, Deuterium, and Helium."

Exp. 5

INELASTIC SCATTERING OF 800-MEV PROTONS FROM NUCLEI TO STUDY QUASI-FREE MODES

Brookhaven National Laboratory

R.E. Chrien and H. Palevsky, Spokesmen

R.J. Sutter, T. Kozlowski

University of California, Los Angeles

G.J. Igo

Vassar College

R.L. Stearns

LASL

N. Tanaka

The motion of individual nucleons in the nuclear potential can be studied by examining the spectrum of inelastically scattered protons with the aid of the LAMPF High-Resolution Spectrometer. Earlier experiments have shown that such data exhibit a broad peak (quasi-elastic peak) centered near the momentum of the calculated free proton-proton kinematics, and broadened by the nucleon Fermi motion. We propose to make an accurate — 1% statistical accuracy — measurement of the shape and intensity of this peak as a function of scattering angle. In principal, from these data we can determine (1) the nucleon pair correlation function, which is related to the area under the peak; (2) the presence of deuteron-like clusters in the nucleus, inferred from the presence of structure at the momentum corresponding to free proton-deuteron scattering; and (3) the excitation of collective nuclear modes or giant resonances, inferred from angle-independent structure in the quasi-elastic peak. The experiment will be performed in a series of targets — ^6Li , ^{12}C , ^{16}O , ^{40}Ca , ^{90}Zr , and ^{208}Pb .

Exp. 6

STUDY OF n-p AND p-p CORRELATIONS IN NUCLEI

Brookhaven National Laboratory

R.J. Sutter, Spokesman

H. Palevsky, R.E. Chrien, T. Kozlowski

University of California, Los Angeles

G.J. Igo, Spokesman

J.G. Fong, C.A. Whitten, R.J. Ridge, J. Geaga

Vassar College

R.L. Stearns

LASL

N. Tanaka

A characteristic of the interactions of high-energy protons with nuclei is the production of high-momentum deuterons. The angular distribution of these deuterons is sharply peaked in the forward direction and the momentum spectra exhibit well-defined structure which may be interpreted in terms of distinct interaction processes between the incident proton and the constituents of the nucleus. These processes involve very high ($\sim \text{GeV}/c$) momentum transfers and, hence, are sensitive to the presence of such momentum components in the nuclear structure. Of particular interest is deuteron production through the quasi-free backscattering channel, since it provides a direct measure of the properties of highly correlated nucleon-nucleon pairs in nuclear matter. We propose the following sequence of measurements.

- 1) Survey of the forward high-momentum deuteron production cross section $d^2\sigma/d\Omega dP$ from $3\text{-}21^\circ$ (LAB angle) for a series of nine nuclear targets.
- 2) Measurement of the elastic p-d cross section $d\sigma/d\Omega$ from $150\text{-}177^\circ$ (LAB angle).
- 3) Search for events due to the direct pickup reaction:
$$P + {}^{12}\text{C} \rightarrow d + {}^{11}\text{C}.$$
- 4) Search for two-pronged proton events (di-protons) arising from the reaction complementary to quasi-free production of deuterons.

Exp. 7

NUCLEAR STRUCTURE PHYSICS USING STOPPED MUONS

LASL

B.S. Shera, Spokesman

Y. Yamazaki, M.V. Hoehn

Florida State University

R.K. Sheline

Purdue University

R.M. Steffen

Oregon State University

K.S. Krane

It is proposed to establish an experimental program of muonic x rays and capture studies at LAMPF. The initial goals will include developing apparatus to permit the study of muonic x rays via germanium (lithium) detectors from targets available only in very small quantities, as well as from larger targets. The experimental program, as seen from this point in time, will begin with

measurements which bear on the charge distribution in nuclear ground states, isomer shift studies to gain information on the charge distribution in low-lying excited states of nuclei, and studies (at the upper end of the periodic table) of prompt neutron emission, fission, and decay of residual muonic nuclei excited by radiationless transitions of the muonic atom. Our emphasis will be on systematic studies of sequences of nuclei known from other work to exhibit interesting variations in nuclear parameters. We intend to compare results of such studies with results obtained using standard nuclear techniques and with applicable theoretical models.

Exp. 8

**PRECISION MEASUREMENT OF SOFT X RAYS FROM
MUONIC AND PIONIC ATOMS**

New York University

B. Budick and S. Derman, Spokesmen
A.M. Rushton

No summary available.

Exp. 9

ELASTIC AND INELASTIC PION SCATTERING FROM CALCIUM ISOTOPES

University of Virginia

J. S. McCarthy, Spokesman
R. C. Minehart, J. Davis

LASL

C. L. Morris, Spokesman
H. A. Thiessen, G. Hoffmann

New Mexico State University

G. R. Burleson, G. Blanpied

University of Texas, Austin

K. Boyer, C. F. Moore, W. Braithwaite, B. Cottingham, L. E. Smith

Florida A&M University

C. Goulding

Elastic- and inelastic-scattering cross sections of pions from ^{40}Ca , ^{44}Ca , and ^{48}Ca will be measured using the EPICS system. Two approaches can be taken in analyzing the data. In the first approach, the data can be used to test pion-scattering models with the assumption that the nuclear wave functions are known. In the second approach, the data can be used to extract nuclear ground state and excited state wave functions, with the assumption that the pion-scattering model is correct or that the results are insensitive to inaccuracies in the scattering model.

We intend to use both approaches. For analysis of ^{40}Ca elastic data, the proton distributions are well known, and shell-model and Hartree-Fock wave functions are particularly reliable. Hence, ^{40}Ca data will be used to test pion-scattering models. In addition, data from the three calcium isotopes will be used to obtain neutron distributions for ^{44}Ca and ^{48}Ca . This should give particularly reliable results because differences between π^+ and π^- scattering and differences between calcium isotopes will be used to reduce inaccuracies due to the scattering model. Inelastic data will also be analyzed to extract neutron distributions and will be used to test particle-hole and collective models of excited states.

SEARCH FOR (p, π) REACTIONS WITH HRS**LASL***J.E. Spencer, Spokesman*

R.J. Macek, W. Shlaer, N. Tanaka, H.A. Thiessen

Argonne National Laboratory

B.J. Zeidman

We propose to look for (p, π) reactions using the HRS. We will modify the particle identification system to trigger on pions and look for reactions in which the residual nucleus is in the ground state or first few excited states. This experiment is in the nature of a feasibility study which may lead to a longer program of experiments of this type.

For the first experiment, we propose to measure angular distributions of (p, π^+) reactions on ^{12}C , ^{24}Mg , ^{88}Sr , and ^{208}Pb . In addition, we shall try to set an upper limit for the (p, π^-) reactions on ^{13}C and ^{53}Cr . We would like to have approximately two-thirds of our running time at 800 MeV and the remainder of our running time at ~ 230 MeV, in order to directly compare our data with that of the (π ,p) reaction that will be done by Macek *et al.*

Exp. 11

HIGH-RESOLUTION STUDIES OF MUONIC X RAYS
AND PROMPT NUCLEAR GAMMA RAYS**California Institute of Technology***Felix H. Boehm, Spokesman*

E. Seltzer, P. Vogel

1. Resolution of the Hyperfine Magnetic Doublets in the Nuclear Transitions

a. $2^+ - 0^+$ transitions in deformed and transitional even-even nuclei $148 < A < 190$, $226 < A$. The typical energy is about 100 keV; the expected splitting of the $F = 5/2$ and $3/2$ states (nucleus in the 2^+ state and muon in the $1s_{1/2}$ state) is about 0.5 keV. Precise measurements of such magnetic hfs (not done so far) would give information regarding the role of the Bohr-Weisskopf effect on the collective nuclear magnetic moments and would allow us to derive reliable isomer shifts for the 2^+ states and, thus, the nuclear parameter $\delta(r^k)$.

b. *Transitions from both rotational and intrinsic excited states in odd-A nuclei.* The expected splitting is generally somewhat larger than for even-even nuclei. Until now, the hfs was resolved only in a very few cases and shows large deviations from the point-nucleus value. Measurements of ΔE will, again, provide information on the distribution of the nuclear magnetization and isomer shift. In some cases, measured branching ratios combined with data obtained from "usual" nuclear spectroscopy make it possible to study the nuclear magnetic polarization.

2. Muonic X Rays Involving Transitions from Higher ($n \geq 4$) Shells.

a. *For atoms with $Z < 50$, the $M, N \dots$ transitions have energies $E < 200$ keV.* The finite nuclear size effects are already relatively small and may be calculated with high accuracy. On

the other hand, the vacuum polarization effects (long-range effects) are ~ 5 keV with higher order effects of $\sim 3\%$, i.e., at the limits of present day's accuracies. With improved resolution, the higher order vacuum polarization corrections may be measured. The large number of muonic transitions available in the energy region of 100-200 keV makes it possible to provide many consistency checks while accounting for $n \geq 8$. Resolution of the quadrupole hfs for 3d or 4f states in the case of odd-A nuclei would give direct information on the ground-state quadrupole moments.

Exp. 12

MUONIC X RAYS AND NUCLEAR CHARGE DISTRIBUTIONS

California Institute of Technology

R.J. Powers, Spokesman

F. Boehm, P. Vogel

College of William & Mary

R.E. Welsh

University of Wyoming

A.R. Kunselman

Virginia Polytechnic Institute and State University

D. A. Jenkins

In our proposal to the Los Alamos Meson Physics Facility dated March 15, 1971, we proposed to carry out a feasibility study of performing muonic x-ray experiments using solid-state detectors. As our first experiment, we proposed to search for the 3s and 4s muonic levels in ^{208}Pb . Since it is likely that we can do part of the feasibility study during the muon channel beam studies, we would like to propose an additional set of targets to be run during the time allocated to us. We propose to measure the isotope shifts of muonic mercury, using separated isotopes of $^{198}, ^{199}, ^{200}, ^{201}, ^{202}, ^{204}\text{Hg}$. This element has never been well studied because of the large number of stable isotopes and the difficulty of obtaining appreciable amounts of each target. We have only 2.5 g of each of these targets, but with the increased intensity of the muon beam at LAMPF, we should have no trouble in collecting sufficient data in two days.

We propose to run four targets at a time and to use ^{208}Pb muonic x rays as an additional target to provide absolute energy calibrations. We plan to measure both K and L isotope shifts, as well as the isomer shifts of the nuclear transitions. The isotope shifts will be part of a larger program which will study the variation of the nuclear charge distribution as a function of neutron number using the data from muonic x-ray experiments at LAMPF and the electronic x-ray measurements at the California Institute of Technology using the bent-crystal spectrometer. This particular series of isotopes is interesting in that it is a long series of isotopes in the region of the periodic table close to the doubly magic nucleus ^{208}Pb . Hence, the weak-coupling model of the nucleus of the de Shalit should allow interpretation of these data in terms of microscopic nuclear models. The isomer-shifted nuclear transitions should yield information concerning the charge distribution of the excited nuclear states, whereas the magnetic hfs should reveal some of the structure of nuclear magnetization.

If we can stop 10 000 μ/s in each target and if we assume a detection efficiency of 10^{-4} for the K transitions, we would have 1 K x ray per second, or about 10^4 counts in 3 h. Assuming 8-keV resolution at 5.5 MeV, we should be able to measure the K isotope shift, which should be about 4 keV/neutron with a precision of 2%.

Exp. 13

STUDY OF π^+ -INDUCED DOUBLE-CHARGE-EXCHANGE REACTIONS

Northwestern University

K.K. Seth, Spokesman

H. Nann, S. Kaletka, S. Iversen, A. Obst

LASL

H.A. Thiessen, C.L. Morris

Using the π^+ dispersed (and separated) beam of the EPICS channel, it is proposed to study the double-charge-exchange (DCX) reactions

$$A(Z,N) + \pi^+ \rightarrow B(Z + 2, N - 2) + \pi^- .$$

The emerging π^- 's will be analyzed in the EPICS spectrometer. The complete trajectory of negative particles through the spectrometer will be determined (actually overdetermined) by having two spark chambers before entry into the spectrometer and two at the exit of the spectrometer. Electrons will be discriminated more effectively by having an additional Cerenkov counter beyond the last spark chamber. An energy resolution of ~ 200 keV (FWHM) and a differential cross-section accuracy of ~ 15 to 20% is desired.

The experiment is divided into two parts. In Phase I (for which beam time is being requested), targets of natural beryllium (100% ^9Be) and iron (91.7% ^{56}Fe) will be used. Since both the $T = 3/2$ state in ^9C and $T = 2$ state in ^{56}Ni are well known, the emphasis in our experiment will be on establishing the two-body nature of the DCX reaction and its energy and angle dependence. In Phase II (for which beam time is not being requested at this stage), targets will be ^{16}O (in the form of ice) and ^{93}Nb , and the attempt will be to study the possibility of using oxide targets and to see if large neutron excess does indeed enhance DCX cross sections in heavy nuclei.

$$^9\text{Be}(\pi^+, \pi^-)^9\text{C} .$$

The reaction will be studied at 100, 150, and 200 MeV at three angles (20° , 30° , and 35°).

$$^{56}\text{Fe}(\pi^+, \pi^-)^{56}\text{Ni} .$$

The reaction will be studied at 200 MeV at three angles (25° , 30° , and 35°).

Exp. 14

π^+ AND π^- ELASTIC AND INELASTIC SCATTERING FROM ^{16}O

LASL

H.A. Thiessen, Spokesman

D.E. Nagle, D.M. Lee

Carnegie-Mellon University

P.D. Barnes, R.A. Eisenstein

University of Virginia

S.E. Sobottka, J.S. McCarthy

Oregon State University

I.W. Swenson

We propose to measure angular distributions of π^+ and π^- scattering from ^{16}O at three energies. We want to provide very good quality data for testing optical models and Glauber models of pion-nucleus elastic scattering.

Pion scattering from oxygen has already been measured, although no data are yet in the literature. We expect, however, that our data will be of very high quality by comparison with present data. In particular, we expect that two novel features of our experiment will make it significantly better than those existing or proposed elsewhere. First, we will measure for π^+ and π^- scattering at each angle, whereas present data exist only for π^- . Second, we will be able to measure smaller cross sections; hence, we will be able to study details of the cross sections at larger momentum transfer than is available in present data.

We chose ^{16}O for the following reasons. First, it is a light, spherical nucleus for which good nuclear wave functions exist. Second, it is light enough that it is possible to do multiple scattering and Glauber calculations to all orders. Third, the target is easily prepared and solution of 6 MeV is adequate, so that we can use a thick target for measuring small cross sections.

We chose three very different energies, rather than a more closely spaced spectrum because we feel that the analysis of present data does not make as much use of the details of the energy variation of the cross section as it does of the angular distribution. We picked three energies — below resonance (100 MeV), on resonance (180 MeV), and above resonance (300 MeV) — at which the pion-nucleon interaction is very different so that theories of the pion-nucleus interaction will be forced to work over a wide range in the basic pion-nucleon interaction. We save considerable running time by avoiding the intermediate energies. Should it be desirable to fill in these energies, it will be possible to run them at a later date. The only expense will be running time, since we expect that EPICS will be a permanent facility.

Inelastic scattering is a lower priority part of this proposal. We will get a survey of the cross section over a 50- to 100-MeV range. We will limit the data rate—by scaling down the inelastic events we accept, if necessary—so that there is no interference with accumulating the elastic data at maximum rate. We expect to look particularly carefully for inelastic scattering at small angles where it is usually small, and at large angles where inelastic scattering may be larger than elastic scattering. We also expect that we will see the spectrum of quasi-free scattering in some of our data. We feel that a broad survey of inelastic scattering will be more important than concentrating on any particular phenomenon. Finer details will be studied later.

Exp. 15

ELASTIC SCATTERING AND TOTAL CROSS-SECTION MEASUREMENTS OF PROTON ON HYDROGEN, DEUTERIUM, AND HELIUM

LASL

N. Tanaka, Spokesman

Brookhaven National Laboratory

R.E. Chrien, T. Kozlowski, H. Palevsky, R.J. Sutter

University of Minnesota

N.M. Hintz, M. Oothoudt

University of California, Los Angeles

G.J. Igo, Spokesman

J.C. Fong, R.J. Ridge, C.A. Whitten

The differential cross section and the polarization in elastic scattering of protons from hydrogen, deuterium, and helium will be measured at 800 MeV. If lower energies become available or if a method can be worked out to degrade the beam, additional measurements would be proposed at 725, 650, and 572 MeV. The latter would overlap the recent differential cross-section and polarization measurements by Aebeicher *et al.* at the CERN proton synchrotron. The range of laboratory angles is 1-15° and spans the region of dominant Coulomb scattering to nuclear scattering. By using the special capabilities of the HRS (angular and energy resolution) in conjunction with liquid hydrogen, deuterium, and helium targets, it will be possible to clearly separate the signal for p-p scattering from that from the carbon contaminant in the window.

Exp. 16

DETERMINATION OF THE MASS OF THE MUON NEUTRINO

Northwestern University

S.L. Meyer, Spokesman

Although it has been known for some eight years that electron-neutrinos and muon-neutrinos are different, the nature of that difference and the question of "muon-electron-universality" have remained a puzzle. The present "working hypothesis" is that both neutrinos are massless but the experimental situation shows a striking disparity; the electron-neutrino mass is known to be less than 60 eV, but the mass of the muon-neutrino is known only to be less than ~1.6 to 2.0 MeV (depending on the confidence level quoted). The measurement of the mass of the muon-neutrino would thus appear to be an open question while its importance is clear.

The difficulty with the muon-neutrino mass measurement is that it has been attempted with two-body decays, of the form $A \rightarrow B + \nu_\mu$. If the neutrino mass were identically zero, the momentum of the recoil would be

$$p_B^0 = (m_A^2 - m_B^2)/2m_A .$$

The procedure has been to measure the momentum of B to discern the deviation from the zero-mass value:

$$p_B \approx p_B^0(1 - Km_\mu^2) ,$$

where

$$K = (m_B^2 + m_A^2)/(m_A^2 - m_B^2)^2 .$$

A two-body reaction, therefore, is sensitive only to the square of the mass of the neutrino. We propose to measure the muon-neutrino mass by using a three-body reaction:

$$\mu^- + {}^6\text{Li} \rightarrow \text{T} + \text{T} + \nu_\mu .$$

In the region of maximum triton energies, this has the virtue that the triton endpoint energy is linear in the mass of the neutrino. This reaction has the additional virtue of having two tritons in the final state whose energies are in a range readily accessible to identification and measurement by totally depleted detectors of a type available "off-the-shelf." In addition, we propose to measure the space angles of the tritons with multiwire proportional chambers run in a mode so as to reject lightly ionizing particles. This results in a constrained kinematical situation in which

the muon-neutrino mass may be determined from the measured quantities on an individual event basis:

$$m_{\eta}^2 = [m_{\mu} + m_{e_{Li}} - 2m_T]^2 - 2[m_{\mu} + m_{e_{Li}} - m_T] (T_1 + T_2) + 2 T_1 T_2 - 2 P_1 P_2 \cos \theta_{12} ,$$

where θ_{12} is the angle between the two tritons and

$$p_1 p_2 \approx 2 m_T \sqrt{T_1 T_2} .$$

Exp. 17

INELASTIC PION SCATTERING FROM LIGHT NUCLEI ${}^6\text{Li}$, ${}^{10}\text{B}$, AND ${}^{14}\text{N}$

University of Birmingham, England

G.C. Morrison, Spokesman

Northwestern University

K.K. Seth, Spokesman

P.M. Lang, S. Iversen, A. Obst

Argonne National Laboratory

B.J. Zeidman, Spokesman

H.E. Jackson

Florida State University

H.S. Plendl

The experiment consists of measuring elastic and inelastic scattering of both π^+ and π^- mesons from ${}^6\text{Li}$, ${}^{10}\text{B}$, and ${}^{14}\text{N}$ at an energy near the 3,3 resonance (~ 200 MeV). Angular distributions will be measured over the full angular range for a number of low-lying states. Inasmuch as the level spacing in these targets is large, fairly thick targets will be used, and, hence, the resolution width will be ~ 250 - 350 keV. Particular emphasis will be placed upon measurements of the low-lying $T = 0$ and $T = 1$ levels in the target nuclei. If it proves feasible, an attempt will be made to measure the $(\pi^\pm, \pi^0)$ single-charge-exchange cross section at several forward angles. In addition, there will also be an attempt at some measurement of nuclear deexcitation γ rays by use of Ge(Li) detectors, in order to get some estimate of the $(\pi^\pm, \pi^0)$ cross section to excited states. The π^0 and γ -ray measurements are purely peripheral and will be performed in parallel to the primary measurement.

Upon completion of the experiment, radiochemical analysis of the targets will be attempted to see if the total cross sections for (π^-, π^0) reactions leading to ${}^{10}\text{Be}$ and ${}^{14}\text{C}$ can be measured.

These measurements constitute a first-stage study of π interactions in light nuclei. With future experiments, we hope to provide a comprehensive examination of the π scattering by all 1p-shell nuclei.

SURVEY OF π SCATTERING BY COMPLEX NUCLEI

Argonne National Laboratory

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S.E. Sobottka, J.S. McCarthy

We propose to study the interaction of pions with heavy nuclei through the elastic-scattering process. Such an investigation is likely to be fruitful from several points of view. It will provide information on the average pion-nucleus interaction and its description in terms of the optical model, it will yield the pion-nucleus distorted-wave functions needed in the analysis of other reactions induced by pions, and it is likely to answer some important questions regarding gross anomalies in nuclear-matter radii.

The experiment will consist of measuring the forward-angle ($\sim 5-90^\circ$) elastic scattering of both π^+ and π^- by a number of representative nuclei at energies of $\sim 140, 180$, and 230 MeV, i.e., below, at, and above the $3,3$ resonance. The targets to be studied, ^{28}Si , ^{48}Ca , ^{60}Ni , ^{90}Zr , ^{120}Sn , and ^{208}Pb , allow a survey of the periodic table to be performed with nuclei that all have high first excited states, thereby reducing the demand upon the experimental system. Inelastic scattering of pions will be measured only insofar as these measurements do not detract from efficiency in acquiring the primary data. Statistical accuracy in the elastic-scattering measurements will exceed 4% at all angles less than 60° ; at larger angles the running time will be adjusted to provide better than 10% statistics for $d\sigma/d\Omega \approx 10^{-29} \text{cm}^2/\text{sr}$.

DEVELOPMENT OF A GENERATION-II IMAGE INTENSIFIER-VIDICON TELEVISION SYSTEM FOR MESON-TISSUE INTERACTION VISUALIZATION

LASL

A.J. Lieber, Spokesman

G. Berzins, M. Sanders, R.L. Hutson, A.S. Lundy, M. Trump

It is the objective of this experiment to develop and test a means of imaging meson interactions with tissue which is superior to conventional camera techniques and which ultimately will be used *in situ* radiation treatment at the LAMPF Biomed facility. This imaging system will incorporate an advanced intensifier-vidicon television system which has been developed for weapons testing and is unparalleled in resolution and gating capability. When coupled to a floor and parallel bore collimator, the system should provide spatial resolution at least an order of

magnitude better than that of existing systems, and should have the capability of being gated against tissue scattering as well as being an aid in maximizing image-response parameters. Although initial tests will use pions, it may prove of interest to also investigate muon interactions.

Exp. 20

PROPOSAL TO DO NEUTRINO EXPERIMENT AT SIN

University of Bern, Switzerland

A.A. Hahn, Spokesman

It is proposed to carry out a neutrino physics program, which allows study with the same apparatus of the following:

1. lepton conservation law,
2. inverse β decay on various target nuclei, and
3. neutrino-electron scattering.

The detector is made out of modules, each containing one "massless" multiwire counter, one "massless" optical spark chamber, and one target. One module has dimensions of 200 by 200 by 10 cm. Thirty modules arranged in one row and fanned out for photography will be used. Four- to five-fold coincidences between successive multiwire counters trigger the spark chambers. The multiwire counters are also used to measure ionization. The counting rates of good events will be of the order of 1-10 events per day at LAMPF. Angle and range of the particles can be determined. Additional information comes from multiple scattering. The target will be C, CH₂, H₂O, D₂O, Al, Cl₂C, etc. The detector will be placed at 90° to the beam dump and behind ~8 m of iron shielding. A massive blockhouse around the detector is required against cosmic background. A quantitative study on the cosmic background, which is induced by energetic neutrons with a scaled-down setup, is under way. These measurements will allow us to determine the dimensions of the blockhouse. A cosmic μ -meson veto counter with a veto factor of 10⁻⁴-10⁻⁵, possibly a liquid scintillator surrounding the apparatus, will be a necessity. Our model apparatus also will be exposed to 35-MeV electrons of a betatron at Berne, in order to get experience. An on-line computer is used for data acquisition and detector control.

Exp. 21

MEASUREMENT OF SMALL-ANGLE PROTON-PROTON SCATTERING AND PROTON-DEUTERON SCATTERING AT SMALL ANGLES AND AT 180°

LASL

J.E. Brolley, Spokesman

P.A.M. Gram

University of California, Irvine

P.E. Condon, P. Cowell, M.A. Mandelkern, L. Price, J. Schultz, J. Donahue, J. Dorfan

We plan to measure forward proton-proton scattering to an absolute accuracy of about 1 to 2% in the angular range (c.m.) 10° — ~1°. The NPL proton beam will be directed into a supersonic jet of pure hydrogen. The jet exists *in vacuo*, whence there are no windows to generate background radiations or suffer radiation damage. Target densities of 10¹⁷ molecules/cm³ or greater will be used. Recoil protons, associated with forward scattering, will be detected in multiwire proportional counters (MWPC) and will determine the energy and laboratory angle of the recoil proton, hence redundantly measuring the scattering cross section. Absolute normalization of the experiment will be done by measuring the scattering of molecular electrons by protons. The ratio of real to imaginary parts of the forward-scattering amplitude, α , will be measured to an accuracy of ± 0.01 to 0.02. β , the spin-dependent part, will be determined to ± 0.05 to 0.01.

In phase 2 of this work, we will study small-angle proton-deuteron scattering with the same techniques. The precision of these experiments will be comparable to the proton experiments.

Exp. 22

PION CHANNELING

Argonne National Laboratory

D.S. Gemmell, Spokesman

R.E. Holland, J.P. Schiffer, (Argonne National Laboratory/UCHI), B.J. Zeidman

It is proposed to study the channeling of low-energy positive and negative pions in various monocrystalline target materials. The experiments would make use of the EPICS channel, where one can take advantage of both the good resolution available in pion energy and the small angular divergence of the pion beam. Since the channeling of negative particles heavier than electrons has not yet been explored, the proposed investigations may well lead to a number of unexpected and interesting phenomena and applications.

Exp. 23

A SURVEY OF PION-NUCLEUS ELASTIC AND INELASTIC SCATTERING AT 180 MeV

Carnegie-Mellon University

W.R. Wharton, Spokesman

P.D. Barnes, R.A. Eisenstein, J.D. Sherman, S.A. Dytman, M. Doss

University of Virginia

S.E. Sobottka, J.S. McCarthy

LASL

D.M. Lee, H. A. Thiessen, D.E. Nagle, J.F. Amann, C.L. Morris

New Mexico State University

G.R. Burleson

The original goals and motivation for the experiment remain unchanged and can be re-read in the original proposal. The scope of the experiment has been reduced from five targets and five energies down to two targets and one energy, ^{40}Ca and ^{118}Sn , π^+ and π^- elastic and inelastic scattering at 180 MeV. The reason for the reduction is primarily the anticipation of data from SUSI and other experiments on EPICS. It is intended that the other data be combined with the data from this experiment to constitute a survey of pion-nucleus scattering on a broad range of light-, medium-, and large-mass nuclei. It is intended to exhibit the pronounced features of the elastic and inelastic differential cross sections as a test of various reaction theory descriptions of the pion-nucleus scattering process. Our experiment emphasizes full angular distributions measured at a single bombarding energy. Comparison of π^+ and π^- cross sections will first allow us to obtain more accurately the strong interaction amplitude from the Coulomb amplitude; second, it will allow us to study more accurately the isospin dependence of the π -nucleus interaction; and third, it will allow us to obtain information on proton vs neutron features of the nuclear wave functions.

Exp. 24

SEARCH FOR PULSED EXTRATERRESTRIAL NEUTRINO SOURCES

University of Pennsylvania

K. Lande, Spokesman

G. Bozoki, W. Frati, C.K. Lee

University of Texas, Dallas

E. Fenyves

We started a search for antineutrino pulses of extraterrestrial origin, possibly originating in gravitationally collapsing stars. The search will be carried out with large-volume water Cerenkov counters located deep underground in two widely separated locations. In particular, we intend to operate H₂O Cerenkov counters of total volume 10 m³ in the Homestake Gold Mine Cl³⁷ Neutrino Laboratory in Lead, South Dakota, and a similar detector in the laboratory area of the Mt. Blanc Tunnel. Both of these laboratories are a depth of 4400 hg/cm². We also intend to search for correlations between neutrino pulses and gravitational waves.

Exp. 25

PION DOUBLE-CHARGE-EXCHANGE REACTIONS

LASL

R.L. Burman, Spokesman

M.P. Baker, J.E. Spencer, R.H. Heffner, M.D. Cooper, D.M. Lee

Argonne National Laboratory

B.J. Zeidman, S.E. Vigdor

University of South Carolina

B.M. Freedom

University of Lausanne

J.-P. Perroud

The pion double-charge-exchange (DCE) reaction, $A(\pi^+, \pi^-)B$, has been studied experimentally and theoretically since 1963. However, neither analog-state nor ground-state transitions have yet been seen experimentally. This proposal describes a search for DCE reactions utilizing the intense LAMPF π^+ beams at pion energies of 30 to 100 MeV.

We propose to measure isobaric analog transitions in ⁵¹V, and possibly ⁴⁸Ca, ⁵⁰Ti, and ⁵⁴Cr, and to look for proton-rich nuclei such as ¹²O and ²⁴Si. Measurements of the reaction cross sections will be made at 0° by using the Low-Energy Pion channel as both a pion channel and an energy-loss spectrometer. Analog states and nuclear ground states could be located to ~50 keV.

Exp. 26

NEUTRON TIME-OF-FLIGHT EXPERIMENT AT BEAM STOP

LASL

L.R. Veaser, Spokesman

A. Hemmendinger, E.R. Shunk, R. Fluharty, G.R. Lawrence

The objectives of this experiment are

1. to obtain a high-resolution, time-of-flight spectrum resulting from 800-MeV proton bombardment of "thick" copper, lead, and uranium targets.
2. to measure the neutron-induced fission density in a ^{238}U sphere as a function of incident neutron energies. The neutron production target would be one of those listed in Item 1., above.
3. to investigate the characteristics of this spectrometer for neutron cross-section measurements for neutron energies below 20 MeV.
4. to investigate the characteristics of this neutron source for static and resonance neutron radiography.

The experiments listed above are related directly to the design of the Weapons Neutron Research (WNR) facility.

NOTE: This summary includes the experiments that could be done at the beam-stop area; however, Item 1., above, is the initial experiment for which this proposal is written.

Exp. 27

p-p SPIN CORRELATION EXPERIMENTS

Case Western Reserve University

H.B. Willard, Spokesman

P.R. Bevington, H.W. Baer, M.W. McNaughton, F.H. Cverna, E. Winkleman

University of Southern California

R.K. Cole, C.N. Waddell

LASL

C.F. Hwang, J.H. Jett, A.J. Lieber, R. Stevens, E.P. Chamberlin, J.E. Simmons, J.G. Boissevain

University of Indiana

H. Willmes

University of California, Davis

N. King

The goal of these experiments is to measure the spin-correlation parameter $A_{yy}(\theta)$ for the elastic scattering of protons by protons at an incident beam energy of 725 MeV. Spin correlations will be determined by measuring the differential cross sections for the scattering of polarized protons (produced by scattering from a liquid-hydrogen target) by a polarized $\text{C}_4\text{H}_9\text{OH}$ target (both polarizations in the range of 60%).

Initially, the correlation of spins perpendicular to the planes of scattering [parameter $A_{yy}(\theta)$] will be studied over the laboratory angular range from 10 to 40°. The running time requested should be sufficient to determine the A_{yy} parameters at 725 MeV (scattered beam energy), with an overall precision of better than ± 0.05 . As preliminary (Stage I and II) experiments, we plan to measure differential cross sections and polarizations for p-p scattering at 800-MeV incident beam energy at angles from 15 to 20°, where the polarization is a maximum (greater than 50%).

The proposed program constitutes a long-range effort to study the proton-proton interaction in more detail and higher precision than is now available. It will complement measurements of the neutron-proton interaction which are to be carried out concurrently by other groups at LAMPF.

STUDIES OF THE (π^+, π^0) REACTION**Tel Aviv University**

A.I. Yavin, Spokesman

J. Alster, D. Ashery, Y. Shamaï, M. A. Moinester (LASL/Tel Aviv University)

LASL

R.L. Burman

University of Virginia

J.M. Eisenberg

A series of experiments for the study of the (π^+, π^0) reaction on nuclei is proposed. The motivation of this study is twofold: it bears on the problem of pion-nucleus intervention and the construction of a suitable optical model for such interactions, and it may ultimately be used for the extraction of information on the nuclear structure of isobaric analog resonances and the neutron distribution in nuclei. The basic new experimental idea is to investigate the charge-exchange reaction $A(\pi^+, \pi^0)B^*$, where B^* is the isobaric analog of A , via the new, but already established, technique of observing the proton decay of B^* instead of observing the gamma decay of the π^0 . Calculations based on plane waves or on soft pion theorems, as well as coupled channels calculations, all predict ~ 2 mb for the $^{91}\text{Zr}(\pi^+, \pi^0)^{91}\text{Nb}^*$ cross section at $E \simeq 25$ MeV, then dropping off at higher energies.

We propose to use the Low-Energy Pion channel and investigate carefully first the cross section for the reaction $A(\pi^+, \pi^0)B^*$ on ^{91}Zr , ^{95}Mo , ^{105}Pd , and ^{115}Sn . Since all the analog states here are proton unstable, but neutron stable, we will observe the monoenergetic protons ($\tilde{p}$) from the sequential $(\pi^+, \pi^0 \tilde{p})$ reaction

$$A_Z + \pi^+ \rightarrow {}^A(Z+1)^* + \pi^0 ;$$

$${}^A(Z+1)^* \rightarrow {}^{A-1}(Z-1) + \tilde{p} ,$$

and note that for the stated cases, $\sigma(\pi^+, \pi^0 \tilde{p}) = \sigma(\pi^+, \pi^0)$. Excitation curves will be measured from threshold to the region of the 3:3 resonance. Other targets, whose analog states are both neutron and proton unstable, will also be investigated. Elastic $\pi^\pm$ scattering should also be measured on all targets in order to obtain optical parameters and to check the results of the charge-exchange experiments. Simultaneous measurements of the two γ rays from the π^0 decay, in coincidence, will yield information on the ratio of cross section to the analog state to the total (π^+, π^0) cross section. With some modification, the equipment and technique can be used for more exotic studies, such as $(\pi^+, \pi^- \tilde{p})$ and $(\pi^\pm, \pi^\pm p)$. Parasitic experiments to study the (π^+, π^0) reactions on light elements with radiochemical techniques are also contemplated.

ELASTIC SCATTERING OF π^+ AND π^- AT 10-30 MeV

University of South Carolina

B. M. Freedom, Spokesman

C. W. Darden, R. D. Edge, T. Marks, D. Malbrough

Virginia Polytechnic Institute and State University

M. Blecher, D. A. Jenkins, K. Gotow, W.-C. Lam

Oak Ridge National Laboratory

C. A. Ludemann, F. E. Bertrand, E. E. Gross

LASL

R. P. Redwine, R. L. Burman, M. A. Moinester (LASL/Tel Aviv University)

We propose measurements of π^+ and π^- elastic differential scattering cross sections from complex nuclei at pion energies of 10, 20, and 30 MeV. The experiment aims at an accuracy of 2 to 3% per angular point over an angular range of 20° to 140° with 10 to 15 points.

The primary objective is a precise determination of the parameters in the Kisslinger model optical potential. The parameter values with accuracies sought in this experiment will allow us to study

- 1) consistency of their values with those determined through pionic x-ray experiments,
- 2) detailed features of the isospin dependence of the potential,
- 3) short-range pair correlation within nuclei, manifested in the form of the effective field modification, and
- 4) the problem of saturation of 1s pionic atom level-widths through direct determination of scattering lengths.

We utilize compact range telescopes consisting of stacked thin proportional counters to measure ranges of scattered pions.

Accelerator time (in Low-Energy Pion channel with $\pm 0.5\%$ momentum resolution) is requested for measurements of π^+ and π^- on ^{11}B , ^{12}C , and ^{16}O at 20 MeV as the first set of measurements.

Exp. 30

MEASUREMENTS OF THE NEUTRON ENERGY SPECTRUM FROM THE REACTION $p + d \rightarrow n + \text{ANYTHING AT } 0^\circ$

University of New Mexico

B. D. Dieterle, Spokesman

We propose to measure the neutron energy spectrum from the reaction $p + d \rightarrow n + \text{anything}$ at neutron angles of 0 and 30° . In addition to being a probe of the deuteron structure and a study of the three-nucleon problem, this experiment will provide a neutron beam study for experiments to be performed later in Area B at LAMPF. An earlier experiment by Larsen indicates the 0° neutron spectrum is less than 12-MeV wide at 710 MeV, due to a virtual bound p-p final state. The proposed experiment will measure the neutron energy spectrum over the neutron energy range of 200-800 MeV, with special emphasis placed on the narrow-width high-energy peak. The experiment is divided into three parts.

PHASE I — Neutron time-of-flight energy determination from 200-800 MeV with resolution of ± 15 MeV or better.

PHASE II — Calibration of the neutron counter to obtain absolute normalization for the cross sections.

PHASE III — Determination of the high-energy peak width to ± 3 MeV or better.

Exp. 31

A NEUTRINO EXPERIMENT TO TEST MUON CONSERVATION

Yale University

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V. W. Hughes, S. Willis

Saclay

J. Duclos

LASL

R. L. Burman, D. Cochran, J. S. Frank, R. P. Redwine

Swiss Institute of Nuclear Studies

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National Research Council of Canada

C. K. Hargrove

We propose a neutrino experiment to determine whether "muon conservation" is an additive or a multiplicative law. We search for exotic muon decay,

$$\mu^+ \rightarrow e^+ \bar{\nu}_e \nu_\mu,$$

which is allowed by the multiplicative law but prohibited by the additive one. In order to distinguish this process from the usual muon decay ($\mu^+ \rightarrow e^+ \nu_e \bar{\nu}_\mu$), we detect the electron-anti-neutrino from the exotic decay, using the inverse-beta reaction,

$$\bar{\nu}_e p \rightarrow n e^+,$$

on free protons in water. Our neutrino detector is a 6-m³ water Cerenkov counter. The nonfocus-

ing total absorption counter has an energy resolution of 10% at 40 MeV, the typical positron energy.

We use the LAMPF proton beam stop as an intense source of positive muons decaying at rest. Six meters of heavy neutron shielding separate our detector from the beam stop.

The experiment can be run in a parasitic mode, with all upstream targets operating. With one-third of the full proton beam arriving at the beam stop, we expect a rate of 60 events/day if the multiplicative law holds.

Exp. 32

PRECISION MEASUREMENT OF THE PROCESSES $\pi^\pm \rightarrow \pi^0 + e^\pm + \nu$

Temple University

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LASL

R. J. Macek, Spokesman

M. A. Paciotti, R. D. Werbeck, W. V. Hassenzahl, J. Pratt

This experiment is intended to produce a precise (1%) measurement of the rare decay rates $\pi^\pm \rightarrow \pi^0 + e^\pm + \nu$. Such measurements will check to a new degree the Conserved Vector Current (CVC) hypothesis, which is a fundamental part of the present theory of weak interactions. The theory makes a precise prediction for the branching ratio, $(1.035 \pm 0.005) \times 10^{-8}$, where the uncertainties are due mainly to radiative corrections and errors in measured masses and coupling constants. The present world average for this branching ratio is $(1.02 \pm 0.07) \times 10^{-8}$. This result is dominated by one experiment whose result was $(1.0 \pm_{10}^{08}) \times 10^{-8}$.

A decay-in-flight technique is proposed in order to utilize the intense beams at LAMPF as a means of increasing statistical precision. Such a method also avoids numerous systematic errors associated with stopped pion methods. Decay in flight is the only practical method to measure the π^- decay. Both signs of charge are to be used as a check on systematic errors; the one that presents the fewest problems will be pushed to the 1% level of accuracy.

Exp. 33

SEARCH FOR ASYMMETRY IN π^- PRODUCTION BY PROTON-PROTON COLLISION

LASL

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Case Western Reserve University

P. R. Bevington, Spokesman

M. W. McNaughton, E. Winkelman, H. B. Willard, F. H. Cverna

University of Houston

J. C. Allred, B. W. Mayes, L. S. Pinsky, T. M. Williams

Rice University

G. S. Mutchler, Spokesman

J. M. Clement, I. M. Duck

University of Idaho

H. Willmes

We propose here to search for possible asymmetry in π^+ production by proton-proton collisions, using a polarized proton beam. Although π^+ production experiments have been carried out for quite an extensive period in the past, there have never been measurements made to study the spin dependence of these reactions. With the facilities now envisaged for the external proton beam in NPL, study on π^+ production by a polarized proton beam on a liquid-hydrogen target is readily accessible. This is particularly true in view of the p-p Spin Correlation Experiments (H. B. Willard, Spokesman) now proposed. In fact, if one replaced his polarized proton target by an ordinary liquid-hydrogen target and changed the range of the momentum spectrometer, the p-p C_{nn} experiment can be converted directly to the π^+ -production experiment.

If we assume a 10% production asymmetry in π^+ production, the currently planned precision of this proposal should be able to measure this magnitude of asymmetry adequately. Theoretical studies are now under way to make predictions on the asymmetry expected from different models of production mechanism. We anticipate that the experimental determination of the asymmetry in π^+ production, if it does exist, would shed light on the applicability of the various models in question.

Exp. 34

ELASTIC SCATTERING OF π^- ON DEUTERONS

University of Virginia

R.C. Minehart, Spokesman

K.O.H. Ziock, J.S. McCarthy, R. Cole, A. Wadlinger

LASL

D.M. Lee, P.A.M. Gram

We are proposing to measure the cross section for elastic scattering of charged pions from the deuteron. This fundamental interaction is not particularly well measured nor is it yet completely understood theoretically. The major experimental problem is to guarantee that the deuteron remains intact after the interaction. The procedure to be followed here is to detect both the scattered pion and the recoil deuteron with techniques that will identify the particles according to their charge and mass.

In this experiment, we will measure the cross section for positive pions with energies ranging from 40 to 400 MeV. The P^3 beam will provide adequate energy resolution and will have the additional advantages of supplying pions over a large energy range. The high intensity of this beam will allow the use of a gas target so that low-energy deuterons can get out of the target into the detectors. The target will consist of gaseous deuterium contained in a thin-walled container to minimize the deuteron energy loss. It should be possible to detect and identify the recoiling deuterons down to energies as low as 10 MeV.

As a check on charge independence, we will also measure the cross section for negative pions at some selected energies.

Exp. 35

CLUSTER EFFECTS IN NUCLEAR PION CAPTURE

University of Virginia

K.O.H. Ziock, Spokesman

J. Comiso, H.-J. Ziock, J.P. Ziock

Cross sections will be measured for the production of charged particles emitted following the in-flight absorption of positive and negative pions. The energy and angular distribution of charged particle pairs will be measured following the in-flight absorption of positive pions in ${}^7\text{Li}$, ${}^{11}\text{B}$, ${}^{12}\text{C}$, ${}^{14}\text{N}$, ${}^{16}\text{O}$, and ${}^{27}\text{Al}$. As a basis for the dosimetry of stopping negative pions, the charged particles emitted following their capture from the rest will be measured in ${}^{12}\text{C}$, ${}^{14}\text{N}$, ${}^{16}\text{O}$, and Ca.

Exp. 36

RADIATIVE PION SCATTERING FROM HYDROGEN

University of Virginia

P.C. Gugelot, Spokesman

Radiative scattering of pions from hydrogen provides information on the contributions of off-energy shell matrix elements in analogy to proton-proton bremsstrahlung experiments. In the pion bremsstrahlung, however, one is able to produce bremsstrahlung photons of 50 to 60 MeV with cross sections that are of the order of $10^{-33} \text{ cm}^2/\text{MeV sr}^2$. The results of these experiments can be used in the interpretation of other interactions. For instance, it may be used to find pion-nucleon form factors in pion production of nucleons on nucleons.

The experiment will be carried out initially with 150-MeV positive pions on hydrogen, making use of the P^3 beam. In this case, there are no competing reactions, and the background is only due to elastically scattered pions in the hydrogen and background due to pion interaction in the Mylar liquid-hydrogen container. We propose to carry out the experiment in a box magnet which contains the hydrogen target, the proportional wire chambers which detect the pion and measure its momentum, and the Cerenkov or scintillation counters which detect the photon, or, preferentially, wire chamber shower detectors.

A future development for negative pions and pions of either sign at higher energy will require the detection of the scattered proton.

Exp. 37

**ULTRAHIGH-PRECISION MEASUREMENTS OF MUONIUM
GROUND-STATE ENERGY LEVELS: HYPERFINE STRUCTURE INTERVAL
AND MUON MAGNETIC MOMENT**

Yale University

V.W. Hughes, Spokesman

D.C. Lu, J. Wesley, T. Crane

LASL

P.A. Thompson

University of Heidelberg

G. zu Putlitz

Ultrahigh-precision measurements of muonium ground-state energy levels in a magnetic field are proposed to determine the hyperfine structure interval $\Delta\nu$ and the muon magnetic moment μ_μ . The general method will be that of magnetic resonance spectroscopy as applied to muonium, which our Yale group originated and has studied intensively. Our emphasis will be on ultrahigh-precision measurements which will be possible with the extremely high intensity and otherwise favorable characteristics of the stopped positive muon at LAMPF. Measurements are proposed at strong and weak magnetic fields, using precision strong and weak field magnets, and with argon and krypton gases at several pressures near 1 to 2 atm.

Our experiment is designed to obtain $\Delta\nu$ with a precision of 0.2 ppm, and μ_μ (relative to the proton magnetic moment) with a precision of 1 ppm. These accuracies would represent about a factor of 10 improvement compared to present knowledge. The results will be important as sensitive tests of the validity of muon electrodynamics, and as precise measurements of the muon magnetic moment and mass. Also, the results will give a value for the fine structure constant α accurate to 0.5 ppm, which is a factor of 3 smaller than the present uncertainty in α .

Exp. 38

**NEUTRINO PHYSICS PROGRAM:
ELASTIC-SCATTERING TEST OF MULTIPLICATIVE LAW,
INVERSE β DECAY**

University of California, Irvine*F. Reines, Spokesman*

H.H. Chen, W.R. Kropp, J.F. Lathrop, H.W. Sobel

Case Western Reserve University

M.F. Crouch

The series of experiments here proposed is designed to utilize the unique characteristics of LAMPF as a neutrino source to answer several key questions relating to the weak interaction. Among these questions are a test of the applicability of V-A theory to the elastic scattering of ν_e on e^- , a test of the multiplicative vs additive law of lepton conservation in μ^+ decay, a measurement of the ν_e flux, and a crude measurement of the ν_e spectrum.

Two classes of detectors, a large pot of scintillator and a more sophisticated slab array of scintillator spark chamber plus water (D_2O) target, are considered in some detail so as to illuminate our reasoning in developing the preferred hybrid slab approach. The essential features of the slab array are total energy, rate of energy loss, and sensitivity to delayed coincidences plus directional determination. In addition, the use of deuterated target inserts enable a determination of the ν_e flux via the well-known inverse beta-decay process $\nu_e + D \rightarrow p + p + e^-$.

The experimental design takes into account backgrounds due to cosmic rays and the machine, and includes shielding and anticoincidence detectors. Typical signal rates are $\sim 1/\text{day}$ for detectors with a mass of several tons. These rates make the program here proposed one of 3- to 4-years duration, with costs (excluding the bulk-shielding experimental area) ranging from \$650 000 to \$900 000.

Appendix Summary

A scale model of the proposed plastic-scintillator spark-chamber sandwich system, designed for neutrino-electron elastic scattering, is under construction. It is intended for the study of backgrounds associated with the elastic-scattering experiment.

Exp. 39

SEARCH FOR (π ,p) REACTIONS WITH EPICS

LASL

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We propose to look for (π ,p) reactions using the EPICS facility. We will trigger on protons whose momentum indicates that they come from reactions in which the residual nucleons are in the ground state or first few excited states. Our main goal is to uncover the general features of these reactions, and, in that sense, our experiment is also a feasibility study that may lead to a longer program of similar experiments from which one can extract detailed nuclear structure information.

To be specific, we propose to measure angular distributions of (π^+ ,p) reactions on ^{12}C , ^{13}C , ^{26}Mg , ^{53}Cr , ^{88}Sr , and ^{208}Pb . In addition, we will try to at least set an upper limit on the cross section for (π^- ,p) reactions on one or two of the above nuclei.

The (π ,p) experiments proposed here are complementary to the (p, π) experiments proposed for the HRS. The kinematical regions for the two are different and, for a given target nucleus, they lead to different residual nuclei. Since their backgrounds and systematics are different, the two experiments serve as useful cross-checks on one another for those target nuclei and incident energies where they are related by detailed balance.

PRECISION TEST OF TIME-REVERSAL INVARIANCE IN THE RADIATIVE DECAY OF POLARIZED MUONS

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Although for almost a decade it has been known that CP is violated at the 2×10^{-3} level, no measurements of T violation have been carried out with this accuracy, the leptonic weak current having only been tested to the accuracy of 10^{-2} . Yet CPT conservation requires a T violation at the 2×10^{-3} level.

Sharp and Primakoff have proposed that the source of CP violation comes about from modifications of the leptonic current, $j_{e\nu} = \bar{\psi}_e \gamma_\mu (1 + \alpha \gamma_5) \psi_\nu$, where α is complex ($\alpha = 1 + i\delta$). A value of $\delta \cong 10^{-3}$ and the assumption of a universal weak interaction allow the possible observance of neutrinoless double beta decay and the CP violation in $K_L \rightarrow 2\pi$ to have a common explanation. Independent of this detailed theory, a precision test of T violation in the weak interaction is needed.

It is our belief that the study of T violation in the radiative muon decay by an experimental investigation of the distribution $W = 1 + \bar{a} \hat{\sigma}_\mu \cdot \hat{p}_e \times \hat{p}_\gamma$ will provide the most sensitive test of T violation.

Radiative muon decay of polarized muons has never been studied experimentally and would be an ideal experiment for the LAMPF muon facility.

Using electron and gamma detectors in a ring surrounding the polarized muon axis, we hope to measure $\bar{a}$ to an accuracy of $\cong 5 \times 10^{-4}$.

SEARCH FOR MUONIUM TO ANTIMUONIUM CONVERSION

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This is a preliminary proposal to carry on a search for muonium to antimuonium conversion along the lines which we have initiated at the LRL 184-in. cyclotron. This approach involves two novel elements: (1) an improved low-momentum muon beam from pion decays at rest in the proton beam target and (2) production of muonium in a collision-free vacuum region by thermal diffusion and evaporation from a high-temperature foil. Initial tests at LRL on this type of muon beam indicate that it meets design expectations. Data on the diffusion and evaporation of muonium from hot foils will be obtained at LRL during the next few months. Each of these developments, by itself, offers the possibility of improving the sensitivity of detecting the $M \rightarrow \bar{M}$ rate by a factor of 10 to 10^3 relative to using the LAMPF Stopped Muon beam and looking for $M \rightarrow \bar{M}$ conversion in argon gas.

It is proposed to tune the LAMPF Low-Energy Pion beam to 30 MeV/c or less to obtain a muon beam. This beam would be refocused onto a high-temperature thin foil where many of the muons will stop, diffuse to the surface, and evaporate into the surrounding vacuum. A nearby foil of appropriate Z will detect stopping $\bar{M}$ atoms by mu-mesic x rays. Coincident positron annihilation

gamma rays would also be required in the event signature. If α is the number of muons diffusing out of the foil relative to the number which would stop in $1\text{ }\mu\text{m}$ of tungsten, ϵ is the $\overline{M}$ event detection efficiency, and C_m/C_ν is the ratio of the interaction mediating $M \rightarrow \overline{M}$ relative to the usual weak interaction, then $23\alpha\epsilon(C_m/C_\nu)^2\overline{M}$ events would be observed per minute.

Exp. 42

BREAKUP OF FEW-NUCLEON SYSTEMS AND NUCLEI

University of Southern California

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We propose to do these experiments using the external proton beam line in Area B. This beam has very good energy resolution ($\Delta E \simeq 2\text{ MeV}$) and excellent spatial properties of very small size and angular divergence. We will provide a small scattering chamber which will contain the targets, provide connections to our heavy particle detector chamber, and have an exit window to the proton spectrometer.

The quite dissimilar detectors will be used; the protons will be detected with a magnetic spectrometer, and the coincident heavy particle (d,t, or α) will be detected with an intrinsic germanium telescope. The detector telescope used to detect α particles will differ slightly from that used to detect deuterons and tritons, although they both will be constructed from 1-cm-thick intrinsic germanium diodes that are in use in our 8-cm-thick proton telescope. This detector telescope is presently operational and is discussed in Appendix A. The α -particle detector will consist of a solid angle determining ΔE solid-state diode, two 1-cm-thick intrinsic germanium diodes, and a final veto detector to reject longer range particles. The energy resolution of this detector telescope is $\sim 100\text{-}200\text{ keV}$, and therefore it provides a negligible contribution to the overall energy resolution.

The ${}^6\text{Li}(p,\text{pd}){}^4\text{He}$ and the ${}^7\text{Li}(p,\text{pt}){}^4\text{He}$ experiments can tolerate a poorer overall energy resolution than the corresponding $(p,p\alpha)$ experiments, since more than 20 MeV is needed to break up the ${}^4\text{He}$ nucleus. The range of these particles is much greater than the range of the α particles requiring a thicker detector. However, because of the reduced energy resolution requirements and because only a limited energy range of these particles must be measured, we can utilize stopping material to reduce the energy of the correlated particles so that they stop in $\sim 4\text{ cm}$ of germanium.

The proton detector will be a conventional magnetic spectrometer. The magnet and power supply will be obtained from the LAMPF magnet pool. We will instrument it with wire proportional counters and scintillation detectors. With available magnets and presently developed proportional counters, we expect to obtain an energy resolution of about 1 to 2 MeV for coincident protons. If we assume a 2-MeV energy spread for the incident proton beam, we should obtain an overall energy resolution of about 3 MeV for the $(p,p\alpha)$ study and about 5 MeV for the (p,pd) and (p,pt) experiment.

The electronics required will be standard modular commercially available units. We will supply the preamplifiers and power supplies needed for the germanium detectors. We also expect to provide some amplifiers, ADCs, and TAC and logic units.

We plan to do these experiments in two stages. The $(p,p\alpha)$ measurement on both ${}^6\text{Li}$ and ${}^7\text{Li}$ will be obtained first. The heavy particle detector will be changed and the ${}^6\text{Li}(p,pd){}^4\text{He}$ and the ${}^7\text{Li}(p,pt){}^4\text{He}$ measurements made. Overall systems checks will be made with $\text{H}(p,2p)$, $\text{D}(p,pd)$, and ${}^4\text{He}(p,p\alpha)$ coincidence measurements.

Exp. 43

ELASTIC AND INELASTIC SCATTERING OF PIONS FROM NUCLEI IN THE LEAD REGION

Oregon State University

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University of Oregon

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W. J. Braithwaite

A comprehensive study of elastic and inelastic scattering of pions from nuclei in the lead region is to be carried out with the EPICS system over an energy range spanning the (3,3) resonance.

Phase I: In the first phase of the study, it is proposed to measure the elastic-scattering angular distributions (plus inelastic for strongly excited states) for both π^+ and π^- beams from ${}^{206}\text{Pb}$ and ${}^{208}\text{Pb}$ at two energies near resonance. Since the π^- nuclear interaction is dominated by the 3/2 isospin state with a strong p-wave character, these measurements may be expected to be particularly sensitive to the relative neutron-proton distribution in these nuclei of large neutron excesses. By making experimental measurements of the positions of the minima in the differential cross sections to an accuracy of 0.1 to 0.3°, comparison with computed optical model cross sections should be sensitive to ~ 0.1 F in the assumed neutron distribution. A systematic study is to be made with both π^+ and π^- on more than one isotope to reduce systematic Coulomb effects and model dependence of the computed cross sections.

Phase II: A detailed study of inelastic scattering of pions from nuclei in the lead region offers the possibility of studying many of the important features of a closed-shell nuclear spectrum. These are the single particle (hole) states of 2p, 2h (pairing vibrations) and 1p, 1h states (surface vibrational states), and those generated by coupling them among themselves (particle-phonon-coupled states and two-phonon states). Complete inelastic-scattering measurements complemented with calculations using real nuclear wave functions provide a critical test of our understanding of pion nuclear scattering and assumptions currently being made. If the mechanism can be well represented theoretically, inelastic scattering will become a very useful nuclear structure probe of states not strongly excited by conventional means.

Exp. 44

RADIOBIOLOGY OF NEGATIVE-PI MESONS, A PRELIMINARY STUDY

University of Texas, Dallas

D. E. Carlson, Spokesman

F. J. Bonte, J. E. Dowdey

Experiments outlined in this proposal are designed to provide pretherapeutic radiobiologic information on essential aspects of stem cell inactivation by negative-pion beams. Using an *in vitro* radiation procedure, spleen cell suspension will then be cultured *in vivo* according to two established assay procedures currently being used by the principal investigator, viz., hematopoietic colony formation and secondary antibody formation.

From the proposed experiments, stem cell inactivation as a function of depth will be determined, RBE values for both plateau and star regions will be determined, OER values will be determined, and also differential dose-rate-dependent cell inactivation will be investigated.

Results from these experiments will provide a portion of the essential information that must be obtained before clinical trials for treating human neoplasms by pion beams are begun.

Exp. 45

RADIATION-DAMAGE STUDIES — HIGH-TEMPERATURE REACTOR MATERIALS AND TYPE II SUPERCONDUCTORS

LASL

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E. G. Zukas

One of the key technological problems to be overcome prior to constructing a prototype fusion reactor (D-T or D-D) is that of high-temperature radiation damage. The same problem is a major technological hurdle to achieving economical fast fission reactors. This proposal presents a program of fundamental material science experiments which will lead to a better understanding of the interaction between high-temperature creep and intense neutron irradiation. The LAMPF provides a unique neutron source of high intensity at energies above the (n, α) effective threshold in niobium, molybdenum, and vanadium, for example.

Preliminary calculations show that fluxes in material samples near the beam dump will be $\approx 2 \times 10^{12}$ n/cm²-s averaged over a year of operation, accounting for downtime, duty cycle, beam degradation, etc. This is adequate to produce helium in niobium at a rate of ≈ 0.3 ppm (atom)/yr, which is well above the concentrations needed to produce measurable changes in material properties. Helium production, neutron irradiation, and creep will each contribute to the total material damage. High-temperature irradiation leads to material swelling as follows. Displaced atoms and vacancies are generated in equal numbers. Some, but not all, of the displaced atoms return to normal lattice sites by refilling the vacant sites. This process causes no damage. A small fraction of the displaced atoms attach themselves to dislocations via climb, which leaves a small number of excess vacancies. These excess vacancies form vacancy clusters and eventually pores, which are typically 25 to 400 Å in diameter. The pore density ranges from 10^{14} to 10^{16} per cm³. This process causes high-temperature radiation-damage swelling. Helium, being a noble gas and therefore inert, is quite insoluble in metals. It collects in the pores under high pressure and changes their size and spacing.

The material constraints or swelling in a reactor will generate stresses, as will design loads and magnetic-field changes. Sustained stresses at high temperatures cause time-dependent deformation or creep. Microstructural changes that accompany creep include grain boundary pore formation, cracking, migration and sliding, and large increases in dislocation density within the grains. All of the structural changes are expected to modify radiation swelling. Most significant might prove to be the increased dislocation density, which can amount to a 10 000 times increase. The excess vacancy production, and therefore the swelling rates, would be increased.

It is impossible to predict damage rates from theory, but it is feasible to explain those rates, and to even modify them, in a thorough experimental program. Such a program must include electron transmission and light microscopy, and test sequences of (a) creep damage followed by radiation damage, (b) radiation damage followed by creep damage, and (c) simultaneous creep and radiation damage.

Neutron irradiation changes superconducting transition properties through its effect on defects. Earlier work by others has shown that both the critical current and critical field characteristics are modified by radiation damage. We intend, through a thorough study, to establish the influence of irradiation on superconducting properties.

This program would begin to evaluate radiation damage as it is likely to occur in a fusion reactor.

Exp. 46

ELASTIC PION-DEUTERON SCATTERING

University of Colorado

R. J. Peterson, Spokesman

J. J. Kraushaar, R. A. Ristinen, R. L. Boudrie

The elastic scattering of $\pi^\pm$ from the deuteron is proposed to be studied over an angular range of 15 to 150°, at approximately eight beam energies from 50-300 MeV, using the EPICS system. A target of CD₂ would be used, with scattering from carbon and CH₂ to be studied at some angles for background subtraction and normalization, respectively. Only moderate energy resolution is required, so a thick target is allowed. Approximately 300 h of beam time are requested to complete this experiment.

Exp. 47

ELASTIC AND INELASTIC PION SCATTERING FROM ⁸⁹Y

University of Colorado

R. J. Peterson, Spokesman

J. J. Kraushaar, R. A. Ristinen, R. L. Boudrie, N. DiGiacomo, G. Smith

We propose to study the elastic and inelastic scattering of positive pions from ⁸⁹Y. A metallic foil of naturally monoisotopic yttrium will be the target. Pion energies of 120, 150, and 180 MeV will be used, and scattering angles of 15 to 100° will be studied. The level structure of ⁸⁹Y is such that an energy resolution of 100 keV (FWHM) will allow the clean separation of a set of low-lying levels with known shell-model configuration and known collective enhancement. The most interesting transition is that from the 1/2⁻ ground state to the 9/2⁺ state at 0.906 MeV. This is

one of the purest shell-model excitations known, and the experiment is designed to provide reliable data for this weak transition. We estimate that 240 h of beam time will be required to complete this experiment.

Exp. 48

ELASTIC AND INELASTIC PION SCATTERING FROM THE NICKEL ISOTOPES

University of Colorado

R. J. Peterson, Spokesman

J. J. Kraushaar, B. W. Ridley, R. A. Ristinen, R. L. Boudrie

We propose to study the elastic and collective inelastic scattering of positive pions from ^{58}Ni , ^{60}Ni , and ^{62}Ni at beam energies of 120, 150, and 180 MeV. Thick targets and short runs will allow at least 1000 counts for the lowest 2^+ and 3^- transitions to be obtained over an angular range of $15\text{-}150^\circ$ in 75 h per energy. Targets of all three isotopes will be bombarded simultaneously to allow the extraction of accurate relative elastic cross sections. A total of 285 h of beam time is requested.

Exp. 49

**ELASTIC AND INELASTIC PROTON SCATTERING FROM THE
NICKEL ISOTOPES AND FROM ^{89}Y**

University of Colorado

R. J. Peterson, Spokesman

J. J. Kraushaar, B. W. Ridley, R. A. Ristinen, R. L. Boudrie

We propose to use the HRS facility to study the elastic and inelastic scattering of 800-MeV protons from ^{58}Ni , ^{60}Ni , ^{62}Ni , and from ^{89}Y . The elastic scattering over a wide angular range allows the optical model parameters to be extracted reliably, and the energy-dependence studies of optical model parameters could be extended. This dependence seems to be sensitive to fundamental questions of nuclear structure. The inelastic scattering to collective states (as found in the nickel isotopic sequence) is generated by the derivative of the optical potential, and such scattering is especially sensitive to the nuclear surface. The scattering from ^{89}Y will involve a more complex interplay of collective and single-particle concepts. The results of these proton-scattering experiments will complement the results of pion-scattering studies on the same targets by this group.

RADIATIVE PION CAPTURE IN LIGHT NUCLEI***University of California, Lawrence Berkeley Laboratory****K. M. Crowe and P. Rowe, Spokesmen**J. Bistirlich****Case Western Reserve University****H. W. Baer****University of Zürich****P. Truöel****LASL****R. H. Sherman, F. T. Shively (LASL/LBL)*

We propose to measure the γ -ray energy spectrum from pion capture in tritium and other light elements. This work is a logical extension of work in progress at LRL, Berkeley. The motivation and objectives of these measurements and the details of technique are discussed briefly in the proposal. Since our apparatus is essentially operational, the only new feature is the tritium target, which we propose would be similar to, or, in fact, be the existing LASL1 mole target. Preliminary discussions are under way with regard to a collaboration between NP-Division — Cryogenics and LRL on the use of the target.

TECHNIQUES FOR MATERIALS IDENTIFICATION AND ANALYSIS***LASL****J. J. Malanify, Spokesman**R. H. Augustson, L. V. West, D. A. Close, E. R. Martin, T. D. Riley****University of Kansas****J. P. Davidson*

It is proposed that a quantitative analytical technique for measuring elemental and isotopic constituents in certain kinds of fissionable materials utilizing the characteristic x rays emitted following muon capture be explored at the Los Alamos Meson Physics Facility. The need for such a technique is discussed against a background of the work presently being done in the Nuclear Safeguards area and the realization that there are problems currently developing which will require nondestructive isotopic and elemental analysis for all fissionable species, plutonium, in particular. Examples are presented of application areas in which such a technique can either compete favorably with an existing method or fill a void in present technology. The penetrability of the incoming muon and the outgoing x rays, count rates, and examples of x-ray spectra are discussed for the uranium and plutonium isotopes. A description of the experiment is given with reference to the evolutionary phases necessary to go from the carefully measured x-ray lines (energy, line shape, and intensity) to the determination of grams of fissionable material in a sample and its isotopic composition. Of particular significance will be the effects of background and chemical bonding on the accuracies obtainable. Developments allowing utilization of the full μ^- beam intensities available at LAMPF, as well as scanning of bulk samples, are important phases of the experiment. The new incisive nondestructive assay techniques foreseen, using LAMPF's unique capabilities, promise important applications to major national goals in the areas of environmental quality, waste management, and fissionable materials controls.

Exp. 52

SOLITARY MICROPULSES BY PHOTODETACHMENT OF THE H⁻ BEAM

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Single beam pulses can be provided to beam Area B for time-of-flight work by means of photo-detachment of an electron from H⁻ in selected micropulses. This operation could provide an occasional burst of hydrogen atoms which would be undeflected by a subsequent bending magnet.

Exp. 53

OBSERVATION OF THE ELECTRON NEUTRINO AT LAMPF

Brookhaven National Laboratory

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Purdue University

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Northwestern University

S. L. Meyer

We propose to measure the cross section of the reaction $\nu_e + {}^{37}\text{Cl} \rightarrow {}^{37}\text{Ar} + e^-$, using the neutrinos from μ^+ decay in the LAMPF beam stop. A radiochemical technique will be employed identical to that used in the Brookhaven solar neutrino experiment. An experimental arrangement is suggested that will use a minimum space and optimize the available flux of neutrinos. The measurement would constitute an overall test of the validity of the theoretically calculated neutrino capture cross sections and radiochemical procedures used in the solar neutrino experiment.

Backgrounds from cosmic rays and fast neutrons from the accelerator are estimated and compared to the expected ${}^{37}\text{Ar}$ production rate from neutrinos. We propose measuring these backgrounds in the completed LAMPF neutrino facility as soon as a 200- μA beam is available. These background measurements will test whether a full-scale experiment capable of measuring the neutrino capture cross section to 15% accuracy is feasible.

Exp. 54

ELASTIC SCATTERING OF MESONS IN THE ENERGY RANGE 20-60 MeV

University of South Carolina

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LASL

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Virginia Polytechnic Institute and State University

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It is proposed to measure the elastic scattering of π^+ mesons from a large range of separated isotopes using detector telescopes of plastic scintillators in a multicounter array. These experiments will be carried out for pion energies over the range of 20-60 MeV at the Los Alamos Meson Physics Facility. The systematic behavior of the pion-nucleus optical parameters will be obtained. These parameters can then be used to test various forms for the pion-nucleon interaction and to calculate the necessary distorted wave functions needed in the analysis of pion-induced nuclear reactions.

Exp. 55

**INVERSE PHOTODISINTEGRATION OF THE DEUTERON TEST
OF THE TIME-REVERSAL INVARIANCE OF
ELECTROMAGNETIC INTERACTIONS OF HADRONS**

LASL

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R. P. Haddock, Spokesman

Measurements of angular distributions of the reaction $\gamma + d \rightarrow n + p$, when compared with distributions of the inverse reaction $n + p \rightarrow d + \gamma$, have shown some deviations from the equalities implied by the principle of reciprocity. The discrepancies occur for photon energies corresponding to $\Delta(1236)$ formation in the intermediate state; it is expected that if time-reversal invariance of the electromagnetic interactions of hadrons is not valid, the effects would be manifest for reactions with intermediate states, including a nucleon excited to a state off the mass shell.

The neutron energy for the inverse reaction $n + p \rightarrow d + \gamma$ corresponding to the virtual excitation of the $\Delta(1236)$ is $T_n \sim 600$ MeV. We propose to detect the inverse photodisintegration for three to five neutron energy settings centered about 600 MeV, to measure the angular distributions to better than 1%. Comparison of the total cross sections is also of interest and will be determined to high accuracy. The nearly monoenergetic zero-degree neutron beam planned for the Nucleon Physics Laboratory is ideal for production of clean beams over the range of energies, 400 to 800 MeV, required. Deuterons produced from a thin liquid-hydrogen target bombarded by neutrons will be measured in a magnetic spectrometer with time-of-flight identification. The reaction will be overdetermined by measurement of the photon properties in a spark chamber-Cerenkov counter array. Thus elimination of the background of competing reactions, and of

events from the small tail of low-energy neutrons, will lead to exceptionally precise determination of the shape of the angular distribution.

Exp. 56

STUDY OF NEUTRON SPECTRUM FROM PROTON BOMBARDMENT OF DEUTERIUM IN THE 300-600-MeV REGION

Texas A&M University

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LASL

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R. E. Bonner

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P. J. Riley

Production of a reasonably monoenergetic high-energy neutron beam is a prerequisite for the detailed investigation of the n-p interaction. The most commonly used reactions are proton bombardment of deuterium or beryllium. The little information currently available on the neutron spectra from these reactions is of limited accuracy, and it is proposed to make more precise and more detailed measurements. Aside from their practical usefulness, such measurements will be valuable in determining the reliability of theoretical calculations of deuteron breakup. The proposed experiment would be the initial experiment in a long-range program to make a definitive determination of the n-p interaction in the LAMPF energy region. It is closely related to another important experiment, the accurate measurement of n-p charge-exchange cross section, which would be performed concurrently using essentially the same apparatus.

Exp. 57

PRETHERAPEUTIC BIOMEDICAL INVESTIGATIONS OF PI-MESONS

LASL

C. Richman, Spokesman

JRB Associates

D. E. Groce, Spokesman

In order to initiate, at the earliest possible date, clinical therapeutic trials of negative-pi mesons, it is necessary to first conduct an extensive program of dosimetry and cellular and whole animal radiobiology. Such a program was started a number of years ago at the 184-in. cyclotron at Berkeley; it will continue at the Nevis Cyclotron until LAMPF is available in early 1973. At that time, all programmatic effort will shift to LASL. It is the purpose of this document to outline the requirements of a tentative biomedical program to be performed on one or more of the

physics pion beam lines at LAMPF. Such a program would continue until such time as the Biomedical facility would be available. It is not the intent of this document to say who or what organizations within or outside of LASL will do this work but to establish the overall requirements of the biomedical program as presently envisioned. Detailed proposals from specific individuals will be submitted later to the Program Committee. The LAMPF Biomedical Steering Committee is attempting to determine and coordinate a unified approach to solving each of the specific problems.

The low-energy pion physics channel will be ideally suited in intensity and field size for a number of biomedical experiments that must be performed before therapeutic trials. Among the types of experiments are

- a. equipment development,
- b. physical measurements,
- c. dosimetry,
- d. cellular radiobiology, and
- e. whole animal radiation biology and pathology.

Specific details and basic requirements for each of these areas will be presented in this document as far as they are presently known.

Exp. 58

MEASUREMENT OF $\pi^- p \rightarrow \gamma n$

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R. P. Haddock, K. C. Leung, P. Glodis

Catholic University

D. I. Sober

LASL

C. F. Hwang

Our program of counter experiments to measure the reaction $\pi^- p \rightarrow \gamma n$ consists of three parts:

- 1) differential cross section using an unpolarized hydrogen target,
- 2) differential cross section using a polarized hydrogen target, and
- 3) differential cross section using an unpolarized target and determining the polarization of the final-state neutron.

The momentum of the incoming π^- beam extends over the full range available at LAMPF. Priority exists for the momentum region around 350 MeV/c for investigation of the P_{33} (1236) resonance and around 550 MeV/c for the Roper resonance.

The most exciting part, the one we like to do first, is part two that involves a polarized proton target. There exist no data of this kind, and even rough results will enable us to determine the multipole amplitudes in radiative pion capture, which is necessary for the quantitative evaluation of the tests on T-reversal invariance and the existence of an isotensor component of the electromagnetic current.

The optimum choice of angles and energy depends somewhat on the analysis of part one, which is presently under way at UCLA. Our plans call for $\Theta_{\pi\gamma} \sim 90^\circ$ and $P(\pi^-) \sim 350$ MeV/c. We need a π^- beam of about $1 \times 10^7 \pi^-/\text{s}$, $\Delta p/p = \pm 1\%$, spot size of 1 by 2 in., and divergence of ± 5 mrad.

The detection apparatus consists of 36 neutron counters with time-of-flight information and a bank of lead-glass Cerenkov counters to measure the angle of emission of the photon. We already have most of the hardware, computer programs, and a small on-line computer.

Exp. 59

HIGH-RESOLUTION STUDY OF THE BOSON MASS REGION, 0 to 490 MeV, USING THE HRS

LASL

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We propose to use the HRS as a missing mass spectrometer to study the boson mass range, 0-490 MeV, in the reactions

$$p + d \rightarrow {}^3\text{He} + (\text{MM})^0 \quad I = 0,1$$

and

$$p + d \rightarrow {}^3\text{H} + (\text{MM})^+ \quad I = 1$$

The HRS detection system will be augmented to trigger on the ${}^3\text{He}$ or ${}^3\text{H}$ recoils. In the mass region around 300 MeV, a mass resolution of 3-6 MeV is possible. The cross section, $d\sigma/d\Omega dM^2$, will be measured over most of the phase space accessible to these reactions at a proton energy of 800 MeV.

Of particular interest is the region above the 2π threshold where $\pi\pi$ interactions can be influential. With the good resolution and full coverage proposed in the experiment, we should be able to shed more light on the controversial ABC anomaly observed in the first reaction. In addition, we can confirm or deny structure reported at 450 MeV and search for fine structure at a new level of resolution and sensitivity in both reactions.

Further measurements at a lower proton energy of about 600 MeV would provide an additional invariance test of observed structure in the ABC region.

Exp. 60

CHEMICAL EFFECTS IN THE CAPTURE OF NEGATIVE MESONS IN MATTER

LASL

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L. B. Asprey, C. J. Orth, L. F. Mausner

Princeton University

R. A. Naumann

Münich Technical University and University of Munich

K. Springer, H. Daniel

Washington State University

H. B. Knowles

This experiment is intended to study the influence of chemical composition, structure, and state parameters on the phenomena accompanying capture of negative muons and pions in matter. The goals are twofold: to investigate the fundamental nature of the phenomena themselves, and to find and develop means by which they can be exploited as tools for elucidation of chemical information.

The first and principal line of experimentation will consist of measurements of muonic x-ray spectra from a variety of carefully selected target materials. High-resolution Ge(Li) and Si(Li) detector systems will be used, and primary emphasis will be on precise determination of transition intensities (rather than energies), with the aim of obtaining quantitative correlations between x-ray intensity patterns and chemical parameters of elements and compounds. The targets will include both inorganic and organic materials, and also substances of biochemical interest. Provision will be made for adjustment of temperature, pressure (of gases), crystal orientation, etc., through appropriate ranges. In some cases, e.g., where lattice site "trapping" may be possible, muon decay periods will be observed. In cases where meson capture by hydrogen is important or where the effects may depend on meson mass, parallel experiments will be conducted with pions.

Exp. 61

**π^+ and π^- FORWARD ELASTIC SCATTERING
FROM OXYGEN AND CARBON**

LASL

D. E. Nagle, Spokesman

D. M. Lee, H. A. Thiessen, J. Potter

Carnegie-Mellon University

P. D. Barnes, R. A. Eisenstein

Northwestern University

K. K. Seth, P. M. Lang, S. Iverson, A. Obst

University of Virginia

S. E. Sobottka

We propose to measure π^+ and π^- elastic scattering in ^{16}O , ^{12}C , ^{18}O , and ^{13}C , from 5 to 20° at three energies, namely, 100, 180, and 300 MeV, with good angular and energy resolution, using the EPICS spectrometer facility.

Most elastic-scattering experiments have not included the forward angles, because of experimental difficulties, and because of some complications in the interpretation.

In this angular range, nuclear and Coulomb effects both contribute substantially to the scattering amplitude, and the angular dependence of the cross section shows strong Coulomb interference effects. The object of the experiment is to measure the cross sections well enough so that interference effects can be studied in detail.

After analysis of the results, the following information should be obtained.

1) Investigation and illumination of the validity of various models of the scattering (optical models, eikonal models, etc.) for forward scattering. When a model seems to be valid, information about nucleon distributions may be gleaned. At 300 MeV, the eikonal (Glauber) description of the forward scattering and the optical model may be about equally valid; at 100 MeV, the optical models may be better.

2) Deduction of the real and imaginary parts of the nuclear forward-scattering amplitude, comparison of the imaginary part with the total cross-section data via the optical theorem, application of the forward dispersion relation to the real part, and extraction of the pion-nucleus coupling constant.

3) Comparison with the results of a phase-shift analysis of the full angular distribution. We expect to find $\delta_l(\pi^+) = \delta_l(\pi^-)$ on ^{16}O and ^{12}C ; any deviations will most likely tell us more about the analysis than about charge symmetry of nuclear forces.

4) Study of the Coulomb effects and the meaning of separating nuclear and Coulomb effects, which at present is done in a model-dependent way.

The energies match those of the full angular distribution experiment (Thiessen *et al.*) since it is important to be able to use both sets of data.

Basically, the experiment will use the EPICS channel and spectrometer, but with the spectrometer moved back to allow the more forward angles to be observed without hindrance from the direct beam and with some reorientation of the scattering chamber.

Exp. 62

**STUDIES OF GAMMA-RAY SPECTRA FROM REACTIONS INDUCED
BY PIONS AND PROTONS AT LAMPF**

Utah State University

V. G. Lind, *Spokesman*

J. E. Chatelain, R. E. McAdams, O. H. Otteson

Texas A&M University

R. B. Clark

LASL

P.A.M. Gram, W. V. Hassenzahl

Iowa State University

J. E. Balin, A. J. Bureau, B. C. Cook, R. C. Morrison

Florida State University

H. S. Plendl

College of William & Mary

H. O. Funsten, W. J. Kossler

Florida A&M University

M. Greenfield

Virginia State College

C. Stronach

George Mason University

J. Lieb

Experiments are proposed in which a photon is detected in coincidence with an inelastically scattered pion. We propose to study singles spectra of gamma rays from the target of ^{12}C , as well as the coincidence spectra and the angular correlations between the gamma rays and the scattered pions. The goal of the proposed research is to investigate the basic properties of the pion-nucleus interaction.

Exp. 63

MUON-PROTON SCATTERING

LASL

P.A.M. Gram, *Spokesman*

Experiments in muon physics are designed to determine whether the muon is different from the electron in any way other than having a larger mass. This experiment has as its primary goal the search for an anomaly in muon-proton elastic scattering that would lead to information on a muon form factor or on theories for the muon mass. It is expected that the experiment will contribute to electromagnetic scattering theory and to improvements in our knowledge of the proton form factors.

Intense muon beams will bombard a liquid-hydrogen target. Scattered muons will be detected by a Cerenkov counter and scintillator systems, with trajectories determined by wire chamber planes. Using a beam hodoscope, conditions for the necessary resolution in momentum and angle can be achievable without difficulty. Counting rates will be achieved that are at least an order of magnitude better than previous experiments, and an angular region will be explained where experiments have not yet been done.

NEUTRON TOTAL CROSS SECTIONS OF HYDROGEN AND DEUTERIUM

LASL*J. D. Seagrave, Spokesman**J. C. Hopkins, J. E. Simmons, B. E. Bonner***Texas A&M University***L. C. Northcliffe***University of Texas, Austin***I. L. Morgan*

It is proposed to measure the neutron total cross sections for hydrogen and deuterium as a function of energy, using continuous spectrum sources, supplemented by fixed-energy measurements between 400 and 800 MeV. Previous values in the energy range between 200 and 1000 MeV are quite unsatisfactory, and the n-H cross section is even less well determined than the n-D cross section. These cross sections are of fundamental importance, and, moreover, their difference is a measure of the otherwise inaccessible n-n cross section. Corrections for the "shadowing" effect of the proton on the deuteron depend also on the n-H cross section and a parameter representing the mean separation of the nucleons in the deuteron. This parameter is known from measurements above 1 GeV and will also be derivable from proposed concurrent measurements of total cross sections of *pions* of both signs on hydrogen and deuterium at the Low-Energy Pion channel. Related measurements of *proton* total cross sections for hydrogen and deuterium are proposed at the HRS. The n-n difference between n-D and n-H cross sections is expected to show a maximum in the vicinity of 600 to 700 MeV, and an early delineation of this effect will be a secondary goal of the experiment. The accuracy of "white" spectrum measurements is limited by the accuracy with which the neutron energies may be determined, and possible systematic errors will be given close attention, but calibration of the energy scale by measurements at fixed energies available during the course of the measurements will be possible. The microstructure of the incident beam can also be used to reduce spectral ambiguities and effect a basic improvement in this technique. Since measurements of n-H and n-D cross sections will be made under matched conditions with identical cryogenic liquid samples, the n-n differences will be relatively insensitive to the problem of energy determination. If uncontrollable systematic errors become apparent, the effort will be shifted to measurement with the monoenergetic source to cover the energy range. Beam current and running time requirements are relatively low and the instrumentation relatively simple. The proposed experiment represents both a direct application of the neutron source and detector technology necessary for other measurements at NPL, and promises results significant for progress in both the two- and few-nucleon problems soon after the initial operation of LAMPF.

**NEUTRON-PROTON POLARIZATION MEASUREMENTS
USING A POLARIZED TARGET:
PHASE I, THE N-P POLARIZATION OBSERVABLE $P(\theta)$**

LASL*J. E. Simmons, Spokesman*

B. E. Bonner

Texas A&M University

L. C. Northcliffe

It is proposed to measure the n-p polarization observable $P(\theta)$ with unpolarized neutron beams at $E_n = 600$ and 800 MeV. These measurements will provide new or much improved data relating to the noncentral nature of the isoscalar nucleon-nucleon force. A polarized proton target will be employed in which the target polarization is measured by methods independent of nuclear scattering. The polarized protons will be contained in a large butanol sample in a polarized target that will result from a joint MP- and P-Division collaboration. In order to minimize the background of quasi-elastic events, the detector system will require a coincidence between the scattered proton, of known momentum, and the scattered neutron, of known scattering angle. One of the 18D36 magnets from the LAMPF pool will be required for the proton detector system. Counting rates of 0.8 s^{-1} are such as to permit a precision of $\Delta P = \pm 0.01$ in ~ 21 h of data time. This series of measurements will precede the more difficult spin-correlation experiment, to be proposed in Phase II, of this effort.

(Note added May 6, 1971 — *Time Reversal*. In a recent issue of Phys. Rev. Lett. (Vol. 25, p. 1000, April 19, 1971), Bryan has published his calculations on the polarization/symmetry comparison in n-p scattering (P-A), which is a measure of time-reversal noninvariance in the strong interaction. He finds very large effects of the order 0.25 at 600 MeV at back angles. The proposed Phase I measurement is the asymmetry part of (P-A). The other half of (P-A) should now be seriously considered. It is measurement of outgoing proton spin polarization in n-p scattering.

**NEUTRON-PROTON POLARIZATION MEASUREMENTS
WITH A POLARIZED TARGET: PHASE II, THE N-P SPIN CORRELATION
OBSERVABLE, $C_{NN}(\theta)$**

LASL*J. E. Simmons, Spokesman*

C. F. Hwang, J. D. Seagrave

Texas A&M University

L. C. Northcliffe

University of Texas, Austin

I. L. Morgan

University of Oregon

D. K. McDaniels

It is proposed to measure the n-p spin correlation observable, $C_{NN}(\theta)$, using a polarized neutron beam at $E_n \approx 600$ MeV. These measurements will be the first of their kind in the

medium- or high-energy range, and they will relate directly to the ratio of singlet to triplet scattering and the noncentral character of the N-N force. This experiment will be very similar in concept to the proposal for $P(\theta)$, denoted as Phase I, to which explicit reference is made. A polarized neutron beam will be employed from the $D(p,n)2p$ process at 25° ; neutron polarization of about 0.35 is expected at a neutron energy of 600 MeV, when the incident energy is 800 MeV. These data will provide new input to determination of the elastic-scattering amplitude, and serve to reduce present ambiguities.

Exp. 67

DEVELOPMENT OF PION BEAM-MONITORING TECHNIQUES

LASL

B. J. Dropesky, Spokesman

G. W. Butler, C. J. Orth, R. A. Williams

Argonne National Laboratory

S. B. Kaufman

Brookhaven National Laboratory

G. Friedlande

The objective of this experiment is to establish accurate pion beam flux monitoring techniques over the full energy range of positive and negative pion beams available at LAMPF. Initially, the absolute cross sections for the $^{12}\text{C}(\pi^\pm, \pi^\pm n)^{11}\text{C}$ reactions will be determined at pion fluxes of $\approx 10^6/\text{s}$, and the number of incident pions will be measured directly with a scintillation-counter telescope. The resultant ^{11}C activity, induced in plastic scintillator targets, will be measured either by internal scintillation counting or by positron-annihilation radiation counting.

Efforts will also be made to measure, in the same manner, the absolute cross sections for some other potentially useful pion monitor reactions, such as $^{27}\text{Al} \xrightarrow{\pi^\pm} ^{18}\text{F}$ and $^{27}\text{Al} \xrightarrow{\pi^\pm} ^{24}\text{Na}$, at a few pion energies. At the higher pion intensities (10^7 - 10^9 π/s), the cross sections for these monitor reactions and others will be measured relative to the $^{12}\text{C} \xrightarrow{\pi^\pm} ^{11}\text{C}$ reaction over the full energy range of the pion channels. The measurements of these excitation functions will establish accurate and convenient beam-monitoring techniques that are of extreme and fundamental importance to the entire nuclear chemistry pion research program at LAMPF.

PRECISE MEASUREMENT OF THE MUON G-2 VALUE

Yale University

V. W. Hughes, Spokesman

P. Nemethy, J. Wesley

LASL

W. Lysenko, W. V. Hassenzahl, P. A. Thompson

University of Karlsruhe

H. Brechna

A measurement of the muon g-2 value to a precision of 10-20 ppm is proposed. The method is a variant of the method used at CERN, and involves a small muon storage ring consisting of a superconducting, weak-focusing magnet. The ring will also contain an electrostatic quadrupole field. Due to the electric field, the g-2 frequency ω_a will be independent of position in the ring, and focusing will be provided principally by the magnetic field. The high intensity of the P^3 pion beam at LAMPF and the short width of the micropulses are of great value for a precision measurement.

A determination of g-2, or a , to 10-20 ppm would represent an improvement by about a factor of 15 compared to the present experimental accuracy of 300 ppm. A precise value of a will provide a most sensitive test of quantum electrodynamics, of the behavior of the muon as a heavy electron, and of the influence of virtual hadrons on the properties of a lepton.

Exp. 69

PRECISION MEASUREMENTS OF MUONIC X RAYS IN LOW-Z ATOMS:
VACUUM POLARIZATION AND NUCLEAR SIZES**Yale University**

D. C. Lu, Spokesman

R. D. Ehrlich, V. W. Hughes

Columbia University

M. Y. Chen, C. S. Wu

High-accuracy measurements of muonic x rays in the low-Z region ($Z < 18$) will be carried out with a crystal diffraction spectrometer to achieve the following goals.

a) High-Precision Test of Muon Vacuum Polarization: A 0.3% or better test of the quantum-electrodynamical treatment of vacuum polarization for a μ atom can be achieved by resolving the fine structure components of 3d-2p transitions in low-Z muonic atoms, and measuring the transition energies to 1-eV accuracy. To reveal any residual nuclear effects and instrumental effects, measurements will be made in a number of atoms: μ - ^{27}Al , μ - ^{28}Si , μ - ^{31}P , μ - ^{32}S , μ - ^{35}Cl , and μ - ^{37}Cl .

b) High-Accuracy Study of Nuclear Charge Radius: The rms nuclear charge radii in ^{10}B , ^{11}B , ^{12}C , and ^{14}N can be deduced to an accuracy of $\sim 0.1\%$ by measuring the 2p-1s transition energies to an accuracy of 1-2 eV.

Exp. 70

**A SENSITIVE TEST OF CPT AND PRECISION MEASUREMENTS
OF ELEMENTARY PARTICLE MASSES**

Carnegie-Mellon University

J. C. Fethovich, Spokesman

Gary Keyes

Argonne National Laboratory

L. G. Hyman

By stopping $\pi^\pm$ in helium gas and measuring the decay muon energy in a Ge(Li) detector, we will be able to determine the $\pi^\pm$ mass difference to a precision of about 2 ppm, as a sensitive test of CPT conservation. This is to be compared to the most sensitive existing test (e^+e^- mass difference), which is at the level of 200 ppm, and to the best π^+, π^- mass difference determination, which has a precision of 500 ppm. The same apparatus will be used to make an improved measurement of the pion mass and to significantly reduce the upper limit on the mass of the muon neutrino. Finally, the apparatus will be used to study the mechanism of cascade (deexcitation) of π^- mesonic helium atoms.

Exp. 71

FRAGMENTATION OF LIGHT NUCLEI BY LOW-ENERGY PIONS

Washington State University

H. B. Knowles, Spokesman

G. E. Tripard

Central Washington State College

B. F. Gore, E. S. Murphy, W. C. Sperry

University of Idaho

P. A. Deutchman

The purpose of this investigation is to obtain better quantitative information about the modes of fragmentation of selected light nuclei ($4 < A < 40$) when exposed to beams of π^+ and π^- mesons of between 20- and 100-MeV kinetic energy. Interest is taken in the excitation functions and differential cross sections of the various modes and their relation to the several theories that are applicable. The energies and states of excitation of recoiling heavy nuclear fragments will be sought by using, respectively, solid-state particle detectors and gamma-ray detectors. Detection of single counts exclusively is envisaged in the first phase of the experiment, with extension to coincidence counting planned only after the species and spectra of the individual particles are well understood. The procedures employed are essentially those of experimental nuclear structure physics, applied to a new type of projectile.

Exp. 72

A STUDY OF THE DI-NEUTRON AND TRI-NEUTRON AS INTERMEDIATE STATES OF DOUBLE CHARGE EXCHANGE ON ^3He

LASL

M. M. Hoffman, Spokesman

L. J. Brown, W. M. Sanders, G. J. Berzins, A. J. Lieber

A double-charge-exchange experiment ($^3\text{He} + \pi^- \rightarrow \pi^+ + 3n$) is proposed as a means of searching for possible multineutron states. In some respects it is similar to other work reported in literature. The unique feature of the proposed experiment is the use of a high-pressure gas-filled ^3He cell that simultaneously serves as the target and neutron detection chamber. A π^+ coincidence counter will be used to identify signals arising from neutrons produced in the double-charge-exchange process, and thus discriminate against background events. The energy resolution of the ^3He cell is sufficient to distinguish among pulses due to the three types of neutron capture reactions

$$^3\text{He} + n \rightarrow p + t + 0.762 \text{ MeV} ,$$

$$^3\text{He} + ^2n \rightarrow n + ^4\text{He} + 4.1 \text{ MeV, and}$$

$$^3\text{He} + ^3n \rightarrow t + t + 9.25 \text{ MeV} .$$

If no evidence for multineutron states is found, the upper limits for formation of such states can be determined to be $\approx 0.1 \mu\text{b}$.

Exp. 73

(p,2p) EXPERIMENTS USING LAMINATED SOLID-STATE DETECTORS

University of Southern California

R. K. Cole, Spokesman

C. N. Waddell

University of California, Santa Barbara

R. M. Eisberg, D. Ingham, M. Makino

LASL

N. Jarmie

The purpose of these experiments is to study (p,2p) reactions in the energy range 800 to 500 MeV, using solid-state detector telescopes. At 800 MeV, a 200-MeV telescope will be used in conjunction with the HRS facility to measure, with ~ 200 - to 300-keV energy resolution, the binding energies and widths of proton single-particle states in nuclei throughout the periodic table. This technique allows one to measure the entire binding energy spectrum from $Q = 0$ to 200 MeV at the same time. When lower energy beams become available at LAMPF, we will measure angular correlations in (p,2p) reactions using two solid-state detector telescopes. These experiments depend upon a technique developed by us for rejection of events in which a proton undergoes a nuclear reaction or scatters in the detector telescope. This technique is described in the proposal.

A program for the development of thin dead-layer intrinsic germanium detectors for use in the telescopes was initiated last year, and the results that have been obtained show that such detectors are well within present technical capabilities. Prototype detectors with completely acceptable characteristics have been fabricated and tested, and are described in the proposal.

Details of the electronics and calculations of the expected yields are also presented in the proposal.

Exp. 74

STUDY OF PION-INDUCED DOUBLE-CHARGE-EXCHANGE REACTIONS ON LOW-Z ELEMENTS

Lawrence Berkeley Laboratory

V. Perez-Mendez, Spokesman

J. B. Carroll, D. Ortendahl

Oregon State University

A. Stetz, Spokesman

L.W. Swenson

LASL

H. A. Thiessen

Using the dispersed pion beam, we propose to study the double-charge-exchange (DCX) reactions

and

with ^3He , ^4He , and ^3H targets. The emerging pion will be analyzed in the EPICS spectrometer with the help of spark chambers and a Cerenkov counter. An energy resolution of 1 MeV (FWHM) and counting statistics of approximately 10% per 5-MeV energy bin are desired. Primary emphasis will be on establishing the existence and studying the properties of the three-nucleon enhancement. This problem will be approached by measuring the energy and angular dependence, as well as neutron correlations in the DCX reactions. The reactions will be studied at 100, 200, and 300 MeV and at three angles (10, 20, and 40°).

Exp. 75 - ENTERED IN ERROR

Exp. 76

SEARCH FOR MUONIUM-ANTIMUONIUM TRANSITION

University of Maryland

C. Y. Chang, Spokesman

G. B. Yodh

College of William & Mary

M. Eckhause, C. S. Hsieh, J. R. Kane, R. T. Siegel

Since evidence for the emission of free muonium ($M \equiv \mu^+ e^-$) from the surface of thin gold foils has been obtained from our recent M precession experiment, we propose to expose our detector to the LAMPF high-intensity positive muon beam and search for the possible $M \leftrightarrow \bar{M}$ conversion *in vacuo*. Detection of transition such as $M \leftrightarrow \bar{M}$ with high precision would be of substantial theoretical interest in the study of interactions involving leptons.

The apparatus consists of a set of thin gold foils hanging in a long cylindrical vacuum chamber, as well as scintillation counters and multiwire proportional chambers. When the foils are exposed to a low-energy positive muon beam prior to every μ^+ stopping in any foil, we expect that there is a certain chance for the μ^+ being associated with an e^- and spend some time together as a free M *in vacuo*. If $M \leftrightarrow \bar{M}$ conversion should occur in that period of time, the existence of $\bar{M}$ can be identified through the detection of high energy e^- from its μ^- decay. On the other hand, by counting the number of positrons observed in a 90° direction from the incident muon beam, we can determine the flux of muonium.

Exp. 77

π^+ ELASTIC AND INELASTIC SCATTERING FROM CARBON, MAGNESIUM, STRONTIUM, AND LEAD ISOTOPES AT 100 MeV

LASL

H. A. Thiessen, Spokesman

R. J. Macek, D. E. Nagle, J. E. Spencer, D. M. Lee

University of Virginia

S. E. Sobottka, M. D. Thomason

This experiment is a companion to experiments proposed for the (π, p) , (p, π) , and (p, p) reactions using the same series of isotopes. We will survey the elastic and inelastic scattering in order to determine optical model parameters which will be used in a coupled channel analysis of all four reactions. The targets have been chosen to span the periodic table, to allow separated isotope targets, and to include targets which have large enough level spacing that many excited states can be resolved with the EPICS system.

PROTON BEAM MONITOR

Rice University

G. C. Phillips, Spokesman

G. S. Mutchler

University of Houston

E. V. Hungerford, J. C. Allred, B. W. Mayes, L. Y. Lee

We propose to use a grid of 2-mil tungsten and molybdenum wires inside the beam tube to map and monitor the primary proton beam as it exits from each production target. Three types of measurements will be carried out concurrently: a) optical scanning by remote TV of the light emitted by the incandescent wires (2000 to 3000 K), b) electron current from the wires resulting both from thermionic emission and from secondary electrons (delta rays) ejected from the wires by passage of the protons through the wires, and c) temperature measurements by means of thermocouples formed by spot-welding wolfram and molybdenum wires.

Calculations indicate that the intensity of light emitted, the electron currents produced, and the thermoelectric emfs are all measurable by simple electronic means.

Calibration of the wires and grids will be carried out with steady 12-MeV proton beams in the Bonner Laboratory in Houston and with 600-MeV pulsed proton beams at the Space Radiation Effects Laboratory in Newport News.

In order to have this development phase in with the LAMPF schedule, an early decision on this proposal is imperative.

CALIBRATION OF THE PION BEAM TRANSPORT SYSTEMS AND A PION BEAM MONITOR

Rice University

G. C. Phillips, Spokesman

G. S. Mutchler

University of Houston

E. V. Hungerford, J. C. Allred, L. Y. Lee, B. W. Mayes

It is proposed that the pion beam transport and optics be investigated with the use of multi-wire proportional counters (MWPC) that have been developed by this group. In addition, we propose a pion beam monitor. The pion beam monitor will allow the continuous determination of the pion beam flux at a scattering target without interrupting the pion beam.

The spatial distribution of the intensity of the pion beam on any plane can be measured to 0.13 cm., and simultaneously the slope of the rays may be determined so as to construct a phase-space plot of the pion beam at critical positions in the beam transport system. In addition, we will be able to verify ray-tracing programs on a particle-by-particle basis to determine the operating characteristics of the pion channels. It is proposed that the P³, Low-Energy, and EPICS channels be checked in this way for various beam conditions.

We propose a pion flux monitor that will also give pion momentum, momentum resolution, and spatial distribution of the beam without interrupting the pion beam itself. This monitor consists of an arrangement of MWPCs so that the decay muons are detected from the pion decay in

flight at a range of angles with respect to the pion beam. This technique has already been proven in previous experiments by the group.

It should be emphasized that pion beam monitoring and the investigation of the beam transport system have been made possible by MWPCs. Our experience in the technology and techniques in using these detectors has been developed over several years. We have experience with applications of these detectors and techniques for similar problems at other laboratories. The strength of this proposal lies in the ability of our group to provide, as soon as desired, a unique service to the staff at LAMPF and future users of this machine.

Exp. 80

**FORWARD ELASTIC SCATTERING OF π^+ AND π^-
 ^{12}C , ^{13}C , ^{18}O , ^{40}Ca , AND ^{208}Pb**

Rice University

G. C. Phillips, Spokesman

G. S. Mutchler, T. M. Williams, J. Hudomalj, J. Clement

Kent State University

T. R. Witten

University of Houston

J. C. Allred, E. V. Hungerford, L. Y. Lee, B. W. Mayes, M. Warneke

The output phase space of the P³-East channel will be measured using two X-Y multiwire proportional counters in the beam. These measurements will be compared to the predictions of TRANSPORT to verify that the magnet parameters determined in the original tuneup are still valid. Time of flight over a 10-m flight path, and Cerenkov counters, will be used to measure the beam composition as a function of momentum and phase space.

Exp. 81

**STUDY OF NEUTRON-PROTON AND PROTON-PROTON
COINCIDENCE SPECTRA FROM
 $p + d \rightarrow n + p + p$ REACTION**

Rice University

G. C. Phillips, Spokesman

R. D. Felder, G. S. Mutchler, T. M. Williams, J. Hudomalj, J. Clement

Kent State University

T. R. Witten

University of Houston

J. C. Allred, E. V. Hungerford, L. Y. Lee, B. W. Mayes, M. Warneke

Measurement of neutron-proton and proton-proton coincidence spectra from the proton-induced deuteron breakup will yield valuable information on the mechanism of nuclear reactions with three particles in the final state. Both final-state interaction (FSI) and quasi-free scattering (QFS) processes will be studied. At bombarding energies of several hundred MeV, the contributions of FSI and QFS processes are expected to be well separated. The study of p-n QFS by proton-neutron coincidence detection and with neutron detection at $\theta = 0^\circ$ will be valuable in determining the feasibility of attaining a high-resolution neutron beam. The study of n-p and p-p FSI at higher relative energies will give complementary information to the elastic-scattering data. In order to fully understand the reaction mechanisms in the reactions with three particles in the final state, several other proton-induced three-body breakup reactions will be studied in later phases of the program.

Exp. 82

**INVESTIGATION OF PION-INDUCED REACTIONS ON LIGHT ELEMENTS
WITH THREE PARTICLES IN THE FINAL STATE**

Rice University

G. C. Phillips, Spokesman

V. Valkovic, G.S. Mutchler, J.M. Clement, R.D. Felder, W.H. Dragoset, W. Van Witsch, J. Hoftiezer, D. Judd, G. Pepin

University of Houston

J.C. Allred, B.W. Mayes, L.Y. Lee, E.V. Hungerford, L.S. Pinsky, T.M. Williams, J. Lo, A.D. Hancock

Nuclear reactions induced by pions in very light nuclei ($A \leq 7$) resulting in three particles in the final state will be studied by coincidence detection of at least two final-state particles using multiwire proportional counters (MWPC). Both pion-induced breakup of light elements with π production and without π production will be studied. The experimental study of these reactions will give information on the reaction mechanism of nuclear reactions with three particles in the final state. In particular, the quasi-free scattering (QFS) and final-state interactions (FSI) will be studied in detail. Quasi-free scattering processes will allow the determination of the pionic structure of the nucleon and cluster structure of light nuclei.

Interference and rescattering effects will be studied in detail. It has been shown that the singularities of the triangle, or rescattering diagram, cannot produce peaks in the *total* transition rate. However, rescattering bands should be observable on the *differential* Dalitz plot. The effect is expected to be very small, but observable.

The Rice Univ./Univ. of Houston group has significant experience in the study of reactions with three particles in the final state at lower bombarding energies. Special apparatus that has been developed will allow new ways of studying a series of reactions in order to investigate reaction mechanisms.

Exp. 83

**INVESTIGATION OF MULTIWIRE PROPORTIONAL COUNTERS
FOR TREATMENT VOLUME VISUALIZATION**

Rice University

G. C. Phillips, Spokesman

G. S. Mutchler

University of Houston

J. C. Allred, E. V. Hungerford, L. Y. Lee, B. W. Mayes

Columbia Scientific Industries

M. C. Taylor

Before negative pions can be employed effectively in radiotherapy, the technological problems associated with delivering this potent radiation with accurate spatial localization must be solved. These problems are basically: 1) monitoring the π^- stopping region, 2) tailoring the pion beam to a prescribed treatment volume, and 3) determining the beam parameters required to give a prescribed dose.

The object of this experiment is to investigate the feasibility of using multiwire proportional counters for solving the above-mentioned problems. The studies will be conducted with existing devices, which have been proven through previous experiments by the Rice Univ./Univ. of Houston medium-energy physics group.

The *multiwire proportional counter* has certain advantages in comparison with multiwire spark counters (MWSC) and Anger cameras. The resolution of the MWPC is comparable to that of the MWSC (both of the order of 1 mm) and is an order of magnitude better than the Anger camera. Counting-rate capability, which is computer limited for the MWPC, can exceed 10^5 per second. This is comparable to Anger camera rates and far greater than MWSC rates. Thus, the MWPC combines the best features of the other two counters and should be superior for detecting certain types of radiation.

Exp. 84

QUALITY OF MESON RADIATION FIELDS

Rice University

G. C. Phillips, Spokesman

G. S. Mutchler

University of Houston

J. C. Allred, E. V. Hungerford, L. Y. Lee, B. W. Mayes

Columbia Scientific Industries

M. C. Taylor

Washington University

G. Oliver

The prospects of employing pions for therapeutic purposes and muons for diagnostic purposes demand detailed studies of the interactions of these radiation fields with tissue. In order to contribute to a better understanding of these processes and the corresponding deposition of energy, we propose the following studies.

a) Measure the rate of energy deposition from $\pi^\pm$ and $\mu^\pm$ meson beams inside a tissue-equivalent phantom as a function of depth for selected energies from 30 to 150 MeV.

b) Using microdosimetry techniques, determine the gross and specific radiation quality spectrum for each of the above beams in the plateau, stopping, and tail regions of the respective ionization paths.

c) For a scattered beam of $\pi^\pm$ and $\mu^\pm$ mesons, determine the radiation quality and derive appropriate personnel protection guidelines.

Previous experience by G. D. Oliver of M. D. Anderson Hospital and others with LET measurements for neutrons has led to the development of a microdosimeter system which should be ideally suited for meson LET studies.

Exp. 85

GAMMA-NEUTRINO CORRELATION AFTER NEGATIVE-MUON CAPTURE

College of William & Mary

R. E. Welsh, Spokesman

M. Eckhause, J. R. Kane, G. H. Miller, R. T. Siegel

Angular correlation between the emitted neutrino and a nuclear gamma ray following muon capture will be studied. A high-intensity muon beam and a high-resolution GeLi detector will be employed. Preliminary experiments at the Space Radiation Effects Laboratory have shown such experiments to be feasible. The experiment should yield results sensitive to weak interactions coupling constants and, in particular, to the pseudoscalar coupling constant.

Exp. 86

COUNTER EXPERIMENTS IN THE THIN TARGET AREA

Lawrence Berkeley Laboratory

A. M. Poskanzer, Spokesman

Texas A&M University

J. B. Natowitz

Oak Ridge National Laboratory

F. Plastl

LASL

G. W. Butler, D. G. Perry

Brookhaven National Laboratory

L.P. Remsberg

The experiments involve the use of semiconductor detectors with particle identification by dE/dx and time-of-flight techniques to study the products of the interaction of 800-MeV protons with nuclei. The purpose of the experiments is to study the mechanisms of the interaction of high-energy protons with nuclei and the deexcitation of highly excited nuclei. That is, to study spallation, evaporation, and fission, and to learn what other processes may be important in these reactions. To this end, the measurement of the energy spectra, angular distributions, and production cross sections of a large number of products will provide detailed information about these complex reactions.

Two configurations are visualized for the experiment. The first consists of a thin ΔE detector 3 m from the target followed by an E detector 30 cm farther away. From each detector, one would obtain energy signals and also timing signals accurate to 0.25 ns. From the $\Delta E, E$ information alone, one would obtain the nuclear charge of the fragments, and from the timing signals one would obtain the mass in a way to be described. The second configuration replaces the ΔE detector by a thin foil, from which the secondary electrons are collected with a lens for a timing signal only. In this configuration, one loses the nuclear-charge information, but one is able to measure the energy spectra down to very low energies.

In either case, one would use the time-of-flight information between the two detectors to calculate during which rf micropulse the fragment left the target. The rf micropulses occur once every 5 ns and are only 0.25-ns wide. Thus, the flight time over the 300-cm distance would be known to an accuracy of about 0.3 ns. This ratio of distance-to-time resolution is a factor of 10

better than in previous experiments. Adjacent masses should be resolved at all energies for all masses. Thus, by taking advantage of the unique time structure of the LAMPF beam, it is possible to obtain fantastic mass resolution without having any detectors close to the beam.

Exp. 87

π^+ AND π^- SCATTERING FROM ^3He AND ^4He

University of Virginia

J. S. McCarthy, Spokesman

R. C. Minehart, A. Wadlinger

LASL

H. A. Thiessen

Elastic and inelastic cross sections of pion scattered from ^3He and ^4He will be measured at three different energies. This experiment will contribute to an increased understanding of the nuclear structure of these relatively simple 3- and 4-body systems. Using suitable scattering models, information concerning the nuclear distributions of these isotopes will be obtained. Many of the difficulties involved in the theoretical models for the scattering process can be eliminated by measurements using positive and negative pions.

It is anticipated that these results, together with improvements in the theory, will provide another source of information to complement that available from electron and proton scattering from the helium isotopes. Questions that arose from the latter experiments concerning modification of the nucleon-nucleon potential within the nucleus and the effects of dynamic, short-range correlations are still unanswered. The use of pions as the interacting particle may help resolve some of these important uncertainties involved in all basic nuclear models.

Exp. 88

DECAY RATE OF CHARGED PIONS BY THE ELECTRONIC MODE:

$$\pi \rightarrow e + \nu$$

Lawrence Berkeley Laboratory

F. T. Shively, Spokesman

The concept of universality has been basic to the development of an understanding of the weak interactions. Among the most fundamental tests of the concept are those to determine if the (ν_μ, μ) and (ν_e, e) parts of the total Lepton current enter in a symmetric way. The most accurate evidence for μ -e universality is extracted by measurement of the branching ratio $\pi \rightarrow e + \nu_e / \pi \rightarrow \mu + \nu_\mu$. At the same time, the A part of (V,A) theory is tested. We propose to measure this ratio to an accuracy of better than one-half percent.

The branching ratio is of the order 10^{-4} . The pion beams of LAMPF make feasible a measurement in flight of this π_{e2} mode. The ratio is accurately determined by detection of a well-defined portion of both the $\pi_{\mu2}$ spectrum and the π_{e2} spectrum. High angular and momentum resolution, necessary to eliminate electrons from the π - μ -e decay chain, is obtained by a magnetic spectrometer arrangement equipped with multiwire proportional chambers. Particle identification is accomplished by a final Cerenkov or range detector.

**DETAILED STUDY OF THE RESONANCE BEHAVIOR OF THE
TOTAL ELASTIC CROSS SECTION IN PION-NUCLEUS SCATTERING**

Carnegie-Mellon University

P. D. Barnes, Spokesman

R. A. Eisenstein

Lawrence Berkeley Laboratory

A. C. Thompson

The thrust of the proposed experiment is an attempt to determine some properties of the broad maximum that appears in the π -nucleus elastic scattering between pion laboratory energies of about 130 to 200 MeV. This maximum is believed to be a manifestation of the (3,3) resonance which appears in π -nucleon scattering. In the case of π^- - ^{12}C scattering, the maximum is observed to be shifted downward in energy and broadened, compared to the π^+ -p (3,3) resonance. Several theories predict such a shift and broadening; they differ on the magnitude of the effect and, in particular, on the dependence of the shift on atomic mass A . To better understand the role of the (3,3) resonance in nuclear systems, and to elucidate a comparison of various theories, we propose to measure the total elastic cross section for π^+ scattering on several light nuclei: ^4He , ^6Li , ^9Be , ^{10}B , ^{12}C , ^{16}O , and ^{24}Mg . We should like to investigate one heavy nucleus, e.g., ^{208}Pb , if time permits. We restrict ourselves to elastic scattering to avoid the complications presented by other reaction channels available and thus leave the system in a well-defined final state. For each nucleus, measurements at 16 pion energies would be made on the EPICS facility, allowing an accurate determination of the position and width of the maximum. The differential cross sections will be measured at forward angles and integrated to obtain the total elastic cross section.

Exp. 90

A TEST OF THE REVERSAL INVARIANCE IN SINGLE-PION PHOTOPRODUCTION THROUGH A STUDY OF RECIPROCITY IN THE REACTIONS $\pi^-^3\text{He} \rightleftharpoons \gamma\text{T}$ AND $\pi^+\text{T} \rightleftharpoons ^3\text{He}\gamma$

LASL

R. H. Sherman and J. E. Spencer, Spokesmen

D. L. Roder, J. Pratt

Lawrence Berkeley Laboratory

F. T. Shively, Spokesman

University of Virginia

A. Wadlinger, Spokesman

J. S. McCarthy, R. C. Minehart

University of California, Los Angeles

B.M.K. Nefkens, Spokesman

P. Glodis, I. Kostoulas, H. Brandle, Z. David, H. Nakata, O. R. Sander, R. P. Haddock

The objectives of this program are to provide 1) at least half of the precision data necessary to test reciprocity in the electromagnetic interaction of hadrons through precision measurements of the reactions $\pi^-^3\text{He} \rightleftharpoons \text{T}\gamma$ and $\pi^+\text{T} \rightleftharpoons ^3\text{He}\gamma$ and, more generally, to provide 2) precision data on photo-pion production in the few-nucleon system over the region of the first pion-nucleon resonance.

This program must be carried out at LAMPF because 1) the final-state nucleus must be identified; 2) at the angles where the nucleus has sufficient energy to get out of a liquid target, the cross section is expected to be vanishingly small; and 3) at angles where the cross section is expected to be relatively large, a gas target must be used. The latter problem is also helped by the small spot size anticipated for LAMPF beams.

The experiment consists of allowing a variable-energy well-focused pion beam to enter a variable-density liquid or gas target of ^3He or tritium and then detecting and identifying the final-state nucleus in coincidence with a single monoenergetic high-energy photon. The program is to be carried out over the $\Delta(1236)$ resonance for c-o-m angles between 15 and 135°.

Exp. 91

PROTON POLARIZATION IN RADIATIVE π -PROTON SCATTERING AT 300 MeV

University of California, Los Angeles

R. P. Haddock, Spokesman

B.M.K. Nefkens

We propose to study the reaction $\pi p \rightarrow \pi p \gamma$ at 300-MeV pion lab energy in detail. The world total is less than 200 events at present. We expect to measure the magnetic moment of $\Delta(1236)$, the density matrix elements of $\Delta(1236)$ in the reaction $\pi p \rightarrow \Delta\gamma$, the coupling constant $\gamma \rightarrow 3\pi$, or $\gamma\text{-p-}\pi$, and also check the soft pion and partial conservation of axial current (PCAC) predictions for this reaction.

The study of the recoil nucleon's polarization can only be accomplished with a very intense pion beam because of the requested scattering in the analyzing system.

We plan to use a liquid-hydrogen target, with lead-glass Cerenkov counters for the detection of photons, a wire chamber and carbon array to analyze the proton polarization, and a bending magnet to measure the outgoing pions.

SEARCH FOR STRUCTURES IN π - π MASS-SPECTRUM NEAR THRESHOLD**Rutgers University**

B. C. Maglic, Spokesman

J. Alspector, K. Cohen, W. C. Harrison, F. Sannes, M. Liberman, D. Vanharling, B. Weber

A simple magnetless missing-mass experiment consisting of a point-target and a hodoscope is proposed to investigate the isovector (pure $I_{\pi\pi} = 1$) and the isoscalar (pure $I_{\pi\pi} = 0$) π - π mass spectrum for $140 \leq m_{\pi\pi} \leq 460$ MeV with an average resolution of ± 2.5 MeV and statistics of 10^8 events per day. We plan to measure *simultaneously* the missing-mass spectra of ^3He and the triton from the reactions

and

The mass-bite per setting will be ~ 100 MeV.

The difference between the two spectra, automatically normalized to the number of ^3He and T counts, can be displayed on our multichannel analyzer in real time, thus yielding the pure $I = 0$ spectrum, resonant and nonresonant. This technique makes a comparison of reactions (1) and (2) insensitive to systematic errors.

We will first use a liquid-deuterium target 0.05 cm in diameter (Option 1). If an effect (fine structure) is found, a deuterium gas jet target will be used to eliminate target wall effects and improve the resolution.

Helium-3 will be separated from tritons by time of flight (trigger), pulse height, and range.

By running at two incident energies, $T_1 = 600$ and 800 MeV, we will be able to check directly if any observed effect is invariant to changes in t and u . For each incident energy, the mass spectrum will be measured by running at constant t (constant p_s) with variable angle. The recoil momentum, p_s , will be chosen to correspond to the Jacobian Peak where $\partial M / \partial p_s = 0$, so that the mass resolution will be independent of Δp_s .

Because no magnets or computing facilities are needed for this experiment, it can be done as soon as the beam is available. In addition, the simplicity of our apparatus and data-reduction system will permit a high data rate, and we will be able to obtain 0.5% statistics for each 2-MeV mass bin for $140 < m < 420$ MeV in ~ 2 days at one momentum transfer setting.

We have developed and tested in actual experiments all the techniques contained in this proposal; (i) magnetless spectrometer (Enclosure 2); (ii) separation of ^3He in conditions of heavy background (Enclosure 3); and (iii) direct data retrieval without an on-line computer (Enclosures 1, 2, and 3).

Exp. 93

MECHANISM OF $(\pi, \pi N)$ REACTIONS ON COMPLEX NUCLEI

Florida State University

H. S. Plendl, *Spokesman*

Florida A&M University

M. Greenfield, *Spokesman*

C. Goulding

Utah State University

V. G. Lind

LASL

P.A.M. Gram

Oregon State University

L. W. Swenson, T. C. Sharma

University of Oregon

P. Varghese

We propose to determine the detailed kinematical relationships in $(\pi^\pm, \pi^\pm n)$ and $(\pi^\pm, \pi^\pm p)$ reactions on ^{12}C and ^{16}O at incident pion energies near and above the $(3/2, 3/2)$ pion-nucleon resonance. The interpretation of such measurements is expected to reveal the nature of the mechanism by which $(\pi, \pi N)$ reactions proceed. In particular, we expect to learn why all values so far observed for the cross section ratios,

$$\sigma(\pi^-, \pi^- n) / \sigma(\pi^+, \pi^+ n) ,$$

$$\sigma(\pi^+, \pi^+ p) / \sigma(\pi^-, \pi^- p) , \quad \text{and}$$

$$\sigma(\pi^-, \pi^- n) / \sigma(\pi^-, \pi^- p) ,$$

near the $(3/2, 3/2)$ resonance are in gross disagreement with the predictions based on a quasi-free scattering mechanism.

Exp. 94

DIFFUSION OF MUONS IN SOLIDS AND EXPERIMENTS WITH SLOW MUONS

Johns Hopkins University

Y-K. Lee, *Spokesman*

L. Madansky

LASL

P. W. Keaton

It is highly desirable to obtain a slow positive-muon beam in the range of electron volts to kiloelectron volts, but simple decelerating devices would eliminate most of the muons in the initial flux. The present proposal describes a scheme by which positive muons are first moderated to the few million-electron-volt range and then allowed to thermalize and diffuse in a special diffuser. Such muons are extracted and reaccelerated to the desired energy in the range mentioned. Our immediate choice of diffuser material is a single crystal of silicon, for which proton channeling properties are already known. The slow muons from the diffuser are momentum selected by a

spectrometer in order to eliminate the background. The detection of the slow muons is accomplished by stopping the muons in a thin carbon foil, and by detecting the decay positrons by a telescope counter. The counters will be gated by a time-of-flight arrangement with a time-zero derived from a wobble on the reacceleration potential.

The slow muons can be used to study the hyperfine interaction of the muonium where muonium is created in a dilute gas target in a small volume. With this arrangement, the present limitation on muonium physics due to the pressure shift and the difficulty of obtaining homogeneous magnetic field over a large area can be avoided. With the thermalized muon beam, the study of metastable states in muonium will become possible. The charge transfer collision cross section with muons is also planned.

Exp. 95

THIS EXPERIMENT WAS REPLACED BY EXP. 139.

Exp. 96

SCATTERING OF 20-40 MeV $\pi^\pm$ BY HYDROGEN AND DEUTERIUM

LASL

D. E. Nagle, Spokesman

J. S. Frank, K. Klare, R. E. Mischke, D. C. Moir, A. A. Browman, J. S. Sarracino

We propose to measure π^+ and π^- elastic scattering at a range of energies between 20 and 50 MeV, using the good resolution beams of the Low-Energy Pion channel, a hydrogen-deuterium target, and proportional wire chamber detectors.

As is well known, the S-wave phase shifts δ have a momentum (k) dependence which is basically

$$\delta = a k + c k^3 + \dots ,$$

where a is the scattering length. The reaction $\pi^+p \rightarrow \pi^+p$ at low energy depends upon the isospin 3/2 scattering length a_3 , and the reaction $\pi^-p \rightarrow \pi^-p$ determines the linear combination $(a_3 + 2a_1)$, where a_1 is the isospin 1/2 scattering length. This experiment will primarily measure a_1 , a_3 , and the P-wave phase shift α_{33} . The smaller P waves also contribute and are of considerable interest; we intend to measure them also. The π -D scattering length yields directly $a^+ \equiv a_1 + 2a_3$.

The scattering lengths a_1 and a_3 are of current theoretical interest. A result of current algebra in the soft pion limit is that $a^+ \approx 0$. The present *fitted* values cluster near zero. However, the present accuracy is such that even the sign is uncertain. The sign is of physical significance; it is related to the number of zeros in the real part of the scattering amplitude and the below-threshold behavior of the amplitude. The individual lengths a_1 and a_3 , we believe, are known to about 10%. Our objective would be to reduce the errors in a_1 and a_3 to 1 or 2% and to use predominantly low-energy information. Furthermore, we would obtain the small P-wave scattering lengths. The superior beam of LAMPF and modern detectors make feasible an improved measurement of these important quantities.

Exp. 97

UPDATE: July 11, 1978

**MUON CAPTURE IN GASEOUS HYDROGEN AND DEUTERIUM —
MEASUREMENT OF SINGLET AND TRIPLET RATES IN HYDROGEN**

Columbia University

C. S. Wu and G. Dugan, Spokesmen

Yale University

V. W. Hughes, D. C. Lu, and P. O. Egan, Spokesmen

The objective of the experiment is to obtain the first direct measurement of the muon-capture rate from the triplet state, Λ_T , of muonic hydrogen (μ^-p), and to improve substantially the accuracy in the determination of the muon-capture rate from the singlet, Λ_S , of (μ^-p). In addition, corresponding measurements are proposed for muonic deuterium (μ^-d).

The measurements will be made in gaseous hydrogen (and deuterium) at pressures of about 10 and 0.5 atm. The experimental approach will be similar to that of recent CERN experiments of Zavattini *et al.* The high stopping rate of the LAMPF muon beam is required for this experiment.

Exp. 98

THIS EXPERIMENT WAS REPLACED BY EXP. 139.

Exp. 99

**MEASUREMENT OF THE CROSS SECTION FOR
 $\pi^- + p \rightarrow \pi^- + \pi^+ + n$ WITH A MAGNETIC SPECTROMETER**

University of Wyoming

G. A. Rebka, Spokesman

T. R. King

Colorado College

C. Bordner

LASL

P.A.M. Gram, Spokesman

W. V. Hassenzahl, E. A. Knapp, R. J. Macek, M. A. Paciotti,

Lawrence Berkeley Laboratory

F. T. Shively

University of Virginia

P. C. Gugelot

Massachusetts Institute of Technology

M. E. Lomon

We propose to measure the cross section for the production process

$$\pi^- + p \rightarrow \pi^+ + \pi^- + n$$

in the energy region near threshold by detecting only the outgoing π^+ . The experiment is designed to achieve 5% accuracy in the total cross section and lesser precision in the doubly differential cross section,

$$d^2\sigma/dp_{\pi^+} d\Omega_{\pi^+} ,$$

for seven incident pion energies in the range from 200 to 350 MeV.

We will use the measurements to extract the soft pion contribution to the total cross section, employing the analysis scheme described by Lomon. We intend to place narrow limits on ξ , the parameter that distinguishes between diverse forms of soft pion theory, and, assuming the theory to be valid, to measure a_0 , the isoscalar π - π scattering length, to within 6%. The differential cross sections will be useful in untangling the influence of hard pion effects.

A focusing magnetic spectrometer will be used to detect the outgoing π^+ . In this way, there is no material except the target itself in the way of the outgoing low-energy pion until it strikes a detector. Its sign, momentum, and angle are defined by optical properties of the magnet. Identification of background particles (protons), arising from the dominating elastic scattering, is easily done by dE/dx once their momentum is defined.

By scanning the range of laboratory production angles between 20 and 150° and the laboratory momentum range between 45 and 260 MeV, we sample 63% of the center-of-mass phase space at 200-MeV incident energy, 78% at 225 MeV, and more than 83% thereafter.

Exp. 100

TISSUE CHEMICAL ANALYSIS WITH MU-MESIC X RAYS

LASL

R. L. Hutson, Spokesman

A. S. Lundy

University of Munich

K. Springer

University of Mississippi

J. J. Reidy

Measurements will be made of mu-mesic x-ray spectra arising as a result of the capture of stopped negative muons in mammalian tissue.

Beef bone and selected soft-tissue organs will be used.

Comparison will be made between the yield of x rays from various elements in the tissue and the amount of those elements as determined by chemical analysis of the tissue.

This comparison will indicate the precision and accuracy with which the concentration of selected elements can be determined by use of mu-mesic x rays.

The results will provide information on which medical researchers can base subsequent studies of the potentialities of mu-mesic x rays in their specialties, and will lay the groundwork for a more extensive program of study.

Exp. 101

**FEASIBILITY STUDIES: MEASUREMENTS OF MUONIC X RAYS
AND NUCLEAR GAMMA RAYS WITH
CRYSTAL DIFFRACTION SPECTROMETERS AT LAMPF**

California Institute of Technology

F. Boehm, Spokesman

P. Vogel, R. J. Powers, J.-L. Vuillieumi, A. A. Hahn

Yale University

D. C. Lu, Spokesman

P. Egan, D. Casperson

Columbia University

M. Y. Chen, C. S. Wu

The feasibility of using crystal diffraction spectrometers to carry out high-precision, high-resolution studies of muonic x rays and nuclear gamma rays at LAMPF will be explored. Stopped muon fluxes will be optimized and monitored, and the ambient and target-related backgrounds in the solid-state detectors minimized by proper shielding. Finally, the spectrometers will be operated under realistic conditions to check ultimate signal-to-noise ratio, stability of operation, and any unforeseen problems.

Exp. 102

**EXCITATION FUNCTIONS AND ANGULAR DISTRIBUTION RECOIL STUDIES
OF SIMPLE PION-INDUCED NUCLEAR REACTIONS**

University of California, Berkeley

S. S. Markowitz, *Spokesman*

N. P. Jacob

It is proposed within this report to study the mechanisms of simple pion-induced nuclear reactions in order to use pions as probes for nuclear structure study. The main techniques required entail (1) measurement of cross sections for simple pion reactions, i.e., ($\pi, \pi N$), for constructing excitation functions and examination of existing resonances, and (2) utilizing a simple but powerful recoil catcher setup for the purpose of measuring angular distributions of recoiling product nuclei from simple pion reactions. Knowledge of simple two- and three-body-collision kinematics will permit certain inferences about pion-reaction mechanisms to be made on the basis of these angular distributions.

Exp. 103

**SPALLATION YIELD DISTRIBUTIONS FROM PION INTERACTIONS
WITH COMPLEX NUCLEI**

Brookhaven National Laboratory

J. Hudis, *Spokesman*

LASL

A. E. Norris, C. J. Orth, B. J. Dropesky, R. A. Williams

Carnegie-Mellon University

A. A. Caretto, J. Clark

Brookhaven National Laboratory

P. E. Houstain

We propose to measure the radioactive spallation products formed by the interaction of 100-400-MeV $\pi^\pm$ incident on cobalt, niobium, and tantalum targets. In addition, we propose to measure the yields of a few radioactive double-charge-exchange reaction products at incident pion energies of 75 and 200 MeV. The absolute values and energy dependence of these yields and the ratio of yields between π^+ and π^- irradiations will supply necessary information to help develop and test a reaction model which includes intranuclear pion-nucleon reactions. The major question we wish to answer is: How and to what extent can the pion-nucleon isobar model, developed to describe free pion-nucleon interactions, be included in calculations of intranuclear cascades to describe adequately both simple and complex nuclear reactions?

One interest in the double-charge-exchange (DCE) reaction, especially at energies below the isobar threshold, comes from the fact that the mechanism must involve at least two nucleons and thus should provide information on nucleon correlation. Since the yield of the DCE reaction is expected to be very low, the radiochemical technique which integrates the yield over a time comparable to the half-life of the product is probably the most sensitive method available. In addition, we measure that part of the cross section in which the residual nucleons have less than ~ 8 MeV of excitation.

Exp. 104

PROPOSAL FOR LAMPF EXPERIMENT: STUDIES OF THE PROTON- AND PION-INDUCED FISSION OF MEDIUM-MASS NUCLIDES

Simon Fraser University

B. D. Pate, Spokesman

F. M. Kiely, D. Dautet

The fission will be studied of target nuclides ranging in mass from copper to gold, induced by protons and pions. Fission fragments will be measured by means of solid-state track detectors; fragment ranges, fragment intensities, and angular distributions will be measured.

Measurement of total fission cross sections and, hence, fissilities will permit comparison with predicted fissilities calculated from liquid drop model fission barriers and nuclear temperature values for nuclei in the saddle-point configuration. In particular, the search will be pressed for the predicted increase in fissility of nuclei lighter than silver, corresponding to reduced fission barriers.

An attempt will be pursued to extract mass-distribution and kinetic-energy data from measured fragment ranges in various detector materials, previously calibrated with ions of known mass and energy. Such data will be compared with theoretical predictions; of particular interest is the prediction that for nuclei lighter than some limit (near silver), the width of the mass distribution becomes infinite.

Angular-distribution data will be analyzed to extract moment of inertia information. Fission induced by protons and π^+ and π^- mesons will be compared with that induced by other projectiles.

Exp. 105

NUCLEAR SPECTROSCOPY STUDIES OF PROTON-INDUCED SPALLATION PRODUCTS

LASL

M. E. Bunker, Spokesman

W. R. Daniels, B. J. Drolesky, D. C. Hoffman, J. W. Starnner, G. Giesler, S. V. Jackson

Aerojet Nuclear Co.

J. D. Baker, R. C. Greenwood, R. L. Heath, R. G. Helmer, L. D. McIsaac, C. W. Reich, R. J. Gehrke

We propose to study the radioactive decay of short-lived nuclides rather far from β -stability, produced via high-energy proton-induced spallation and fission reactions. The irradiations will be made in LAMPF Area B and thus will not consume primary beam time. We expect this program to extend over many years. In our initial experiments, we plan to concentrate on the study of neutron-deficient nuclei in the region $Z = 55$ to $Z = 83$, using high-resolution solid-state detectors. Sources will be prepared by fast radiochemical techniques. When isotopes having similar half-lives are encountered, an off-line isotope separator may be used to isolate specific nuclides.

The principal objectives of our experiments will be (1) to determine nuclear masses, via total decay-energy measurements, (2) to discover new nuclides and new isomers, and (3) to extend the systematics of nuclear-level structure and of β - and γ -transition probabilities as far as possible into the neutron-deficient region. We will seek new evidence for nuclear deformations in the $Z = 55$ to 59 region and will attempt to trace out more fully the boundary between the spherical and

deformed regions. Specific experiments are planned to learn more about the residual neutron-proton interaction.

These measurements should lead to improvements in the semi-empirical mass formula and in our knowledge of the effective nuclear Hamiltonian.

Exp. 106

**PROTON-INDUCED SPALLATION REACTIONS RELATED TO THE
ISOTOPE-PRODUCTION PROGRAM AT LAMPF**

LASL

H. A. O'Brien, Spokesman

J. W. Barnes, M. E. Schillaci, A. E. Ogard, P. M. Grant

University of New Mexico

M. Kahn

In support of the Isotope Development Program at LAMPF, we are requesting 2 h/week of beam time in the Low-Intensity Proton Station in Area B during the first year of operation at LAMPF. The availability of this facility will allow us the opportunity to perform the necessary research and development for this program in the following areas: a) spallation cross-section measurements, b) radiation-damage studies, and c) chemical-process development.

Exp. 107 — REPLACED BY EXP. 134.

Exp. 108 — WITHDRAWN.

Exp. 109

**THE STUDY OF THE MICROSCOPIC STRUCTURE OF COLLECTIVE
MODES BY MEDIUM-ENERGY PROTONS**

LASL

E. R. Flynn, Spokesman

N. Tanaka, J. E. Spencer, N. Stein, D. G. Madland

Niels Bohr Institute

O. Hansen

University of Minnesota

N. M. Hintz, D. Dehnhard, G. Kyle

Argonne National Laboratory

B. J. Zeidman

University of California, Los Angeles

G. J. Igo

Lawrence Berkeley Laboratory

D. Hendrie

In order to study the complete wave functions of collective nuclear states, it is necessary to have both a sensitive probe of the details of this wave function and a knowledge of the interactions producing the collectivity. Medium-energy protons provide a unique tool for satisfying both of these goals. The proton energy will be sufficient to penetrate deeply into the nucleus and measure the shape and magnitude of the microscopic form factors in a region previously unexplored. Additionally, the energy will be sufficient to excite high-lying collective states, the existence of which so far has been inferred only from their influence on the low-lying states. Thus, the (p,p') process at ≈ 800 MeV offers the unique possibility of studying the complete family of collective excitation (surface and volume, isoscalar and isovector) at the same time. Recent calculations have indicated greatly increased cross sections expected for these high-lying states for medium-energy protons as opposed to energies from conventional nuclear-spectroscopy accelerators. In addition, by studying chains of isotopes near closed shells, it will be possible to investigate the blocking effects of shell closures on the intensities and positions of these collective states. Ideal targets for this study will be $^{206,207,208}\text{Pb}$, $^{116,118,124}\text{Sn}$, $^{90,92,94}\text{Zr}$, and $^{40,42,48}\text{Ca}$. The principal goals will be to examine the microscopic form factors of the low-lying states excited through inelastic scattering, to measure excitation energies, strengths, and the dependence upon shell closures of high-lying collective modes, and to measure the elastic scattering to obtain parameters for theoretical interpretation of the inelastic data.

Exp. 110

BELOW-THRESHOLD KAON PRODUCTION RATES WITH THE P^3 PION BEAM

University of Wyoming

W. G. Simon, Spokesman

L. Schick, A. R. Kunselman, G. A. Rebka

We propose to measure the production rate of kaons by the P^3 pion beam. Measurements will be taken at a few different pion momenta, and the momentum spectrum of the emerging kaons will be observed. Nuclear emulsions will be used for detecting the kaons after they are magnetically analyzed. The reaction studies are $\pi^+ + \text{nucleus} \rightarrow \text{nucleus} + \Lambda + K^+$, where the lambda may or may not be captured to form a hypernucleus. The measurement of these reaction rates is considered to be very important because, if the rates are favorable, one may use this reaction to observe excited states of hypernuclei. The importance of experimentally observing the excited-state energies of hypernuclei has been emphasized by Dalitz and others. Up to now, experimental methods used to study hypernuclei yielded information on the energy level of the ground state only. Better values for the binding energy of the Λ particle in heavy nuclei may also be obtained. The experiment requires a bending magnet to do approximate momentum analysis of the emerging kaons. The absolute kinematic maximum for the kaons is about 400 MeV/c. A 6- by 12-m magnet with a 15-cm gap capable of going to 15 kg would cover all cases of interest. However, either by limiting the cases considered to those in which the kaon momentum is smaller, or by using a degrader foil in front of the bending magnet, we could obtain useful information with a magnet limited to lower maximum momentum.

Exp. 111

SEARCH FOR NEW NEUTRON-RICH NUCLIDES PRODUCED BY FAST NEUTRONS

Iowa State University

J. C. Hill, Spokesman

LASL

B. J. Dropesky

University of Oklahoma

R. F. Petry

Baylor University

K. H. Wang

Texas A&M University

D. G. Shirk

The main beam stop at the Los Alamos Meson Physics Facility (LAMPF) provides a unique high-intensity source of neutrons with energies above 20 MeV. The long-range objective of this work is to study the properties of new neutron-rich nuclides produced in the regions $A > 170$ and $A < 75$. Effective cross sections for the reactions $(n,2pn)$, $(n,2p)$, and $(n,3pn)$ were measured radiochemically to $A = 142$, using beam stop neutrons at typical currents of $5 \mu\text{A}$ of 800-MeV protons on the stop. The $(n,2pn)$ and $(n,2p)$ reactions have typical effective cross sections of 1 mb and $100 \mu\text{b}$, respectively. The effective cross sections for the $(n,3pn)$ reactions were about $100 \mu\text{b}$ at low A but decreased rapidly with increasing A . All three reactions are potentially useful in searches for new neutron-rich nuclides in appropriate regions of the periodic table. Searches for the new neutron-rich nuclides ^{202}Pt and ^{84}Si have been inconclusive due to the low neutron fluxes now available. For the first time, γ rays from ^{200}Pt , produced in the $^{204}\text{Hg}(n,2p3n)^{200}\text{Pt}$ reaction, have been observed, and a study of the $^{200}\text{Pt} \rightarrow ^{200}\text{Au} \rightarrow ^{200}\text{Hg}$ decay chain is under way.

Exp. 112

**DETERMINATION OF THE MASS OF ^{64}Ge BY THE
DOUBLE-CHARGE-EXCHANGE REACTION**

University of Colorado

R. J. Peterson, Spokesman

We request 120 h of EPICS running time with 250-MeV positive pions to instigate the double-charge-exchange reaction on ^{64}Zn leading to ^{64}Ge . Knowledge of the mass of this $T = 0$ nucleus is valuable for nuclidic mass relations, systematics of clustering phenomena, and some problems in explosive nucleosynthesis in certain astrophysical conditions.

RADIATION DAMAGE AND HELIUM EMBRITTLEMENT IN ELEVATED-TEMPERATURE REACTOR STRUCTURAL ALLOYS

Navy Research Laboratory

D. J. Michel, Spokesman

H. H. Smith, J. A. Sprague

A significant problem area for advanced, high-temperature reactors is that of helium embrittlement. This phenomenon arises from the high-energy neutron production of helium gas by (n, α) reactions, with the gas bubbles moving either by thermal transport or by dislocations into the grain boundaries where they can grow and provide an easy path for fracture with the application of stresses. This manifestation of a loss in material ductility can be realized with small concentrations of helium on the order of ~ 0.1 ppm. Such concentrations can be produced many times over during the operational lifetimes of both fast breeder and fusion reactors; hence, it is a problem that must be dealt with in order to provide the means for design solutions for safe future reactor systems.

This research problem is being studied by the Naval Research Laboratory by cyclotron-injection of helium into thin-sheet fatigue specimens. The specimens are implanted with varying amounts of helium, from 0.1 to 100 ppm, while the specimens are at an elevated temperature and also under cyclic loading. A range of materials of both fundamental and applied interest are being used; these include 304 and 316 stainless steels, plus pure iron, nickel, molybdenum, vanadium, and niobium, plus alloys of these metals. The properties of the 0.127-cm-thick specimens being measured include crack initiation and crack growth. While these properties have important applications to structures in operating reactors, they provide significant fundamental information about the influence of the helium upon the fracture behavior of the metal. Posttest observations include light microscopy for observation of surface effects and depth of cracking, as well as for determination of gross intergranular cracking. Transmission-electron microscopy will be used for more detailed study of dislocation-bubble-grain boundary interactions.

The cyclotron-injection studies at NRL provide a means for rapidly screening many materials and many combinations of material-temperature-strain-helium concentration conditions. At best, however, the effects are limited to surfaces because the cyclotron cannot inject helium to great depths; it should, nevertheless, be recognized that fatigue is a surface-dependent property, so that good advantage is taken of the principal weakness of the cyclotron-injection technique. Reactor-irradiated alloys will be uniformly loaded with helium gas, however, and will also suffer displacement damage. Thus, correlations must be established between surface-layer results from cyclotron irradiations and through-thickness helium concentrations plus displacement damage from reactor irradiations. Such through-thickness helium production can be attained using the beam-dump facilities of the LAMPF coupled with the tritium-helium decay technique pioneered by the Los Alamos Scientific Laboratory; the correlation is greatly enhanced by the displacement-type damage produced by the high-energy neutrons.

The NRL experiment proposed for the LAMPF beam-dump area would be for a series of controlled temperature furnaces capable of flexing fatigue specimens during neutron bombardment; the capability for simultaneous introduction of tritium for decay to additional helium is also desired. The general experimental scheme is similar to that already proposed by D. J. Dziak, W. V. Green, and A. L. Giorgi of LASL entitled "Radiation-Damage Studies — High-Temperature Reactor Materials and Type II Superconductors." The extensive background material developed in that proposal is mentioned because of the similarity of objectives.

DETERMINATION OF ELECTROMAGNETIC FORM FACTORS USING THE REACTION $\pi^- + p \rightarrow e^+ + e^- + n$

LASL

E. A. Knapp, Spokesman

J. A. Helland, M. A. Paciotti

University of Utah

J. Ball

We propose an experiment to study the interaction $\pi^- p \rightarrow n e^+ e^-$, measuring the differential cross section $d^2\sigma/dt dk^2$ at various values of s . By extrapolating the function $p(t) = (t - m_\pi^2)^2 d^2\sigma/dt dk^2$ (at fixed values of s and k^2) to the pion pole at $t = m_\pi^2$, we expect to obtain the value of the pion electromagnetic form factor $F_\pi(k^2)$ as a function of k^2 , the square of the total energy of the e^+e^- system (i.e., the square of the mass of the virtual photon that decays into e^+e^-).

The experimental method consists of sending a high-flux beam of pions through a liquid-hydrogen (LH) target, and collecting events in which an electron passes through a magnetic spectrometer and Cerenkov counter to the left of the LH target, in coincidence with a positron passing through identical equipment to the right. Each spectrometer will consist of several planes of multiwire proportional counters before and after a magnetic field. The momenta of the electron and positron will be measured with the spectrometers, and from this each event can be reconstructed.

Exp. 115

RADIOCHEMICAL STUDY OF STOPPED NEGATIVE-MUON-INDUCED FISSION

LASL

K. Wolfsberg, Spokesman

G. P. Ford, A. E. Norris, B. R. Erdal

New Mexico State University

A. E. Richardson

This proposal encompasses the first radiochemical studies of muon-induced fission. We propose to measure, for stopped μ^- -induced fission of ^{238}U ,

- 1) the number of fissions that occur per stopped muon,
- 2) fission product peak-to-valley ratio,
- 3) fission product yield curve, and
- 4) fractional chain yields of gaseous fission products.

In addition, it will be necessary to make muon range measurements in the energy degrader and in uranium.

Although some data about muon-induced fission are available from emulsion studies and counter experiments, the present work will yield higher mass resolution and additional information which will permit comparisons of muon-induced fission with more thoroughly studied fission processes. We expect these comparisons to elucidate the energy deposited by muons in ^{238}U for reactions that result in fission.

Exp. 116

THE QUASI-DEUTERON PHOTOEFFECT IN ^{12}C AT 130 MeV

Iowa State University

B. C. Cook, Spokesman

An experiment to measure the $^{12}\text{C}(\gamma, \text{pn})^{10}\text{B}$ cross section using monoenergetic 130-MeV photons is proposed. The proton energy distribution is measured in a liquid scintillation detector and the neutron energy distribution is measured by the time-of-flight method. A comparison will be made between the results of this experiment and the known properties of the $^{12}\text{C}(\pi^-, 2\text{n})^{10}\text{B}$ reaction. The kinematic similarities between 130-MeV photons and stopping π^- are stressed, as well as dynamical differences between the two probes. While both processes explore n-p correlations in the nucleus, the photon-induced reaction emphasizes volume effects, whereas π reactions emphasize surface phenomena.

The 130-MeV photons are obtained by radiative capture of π^- in liquid hydrogen. The Low-Energy Pion channel will be used. One week of running time is requested.

Exp. 117

HIGH-RESOLUTION STUDY OF THE NEUTRON PICKUP REACTIONS

University of California, Los Angeles

G. J. Igo, Spokesman

C. A. Whitten, G. W. Hoffmann, T. S. Bauer, J. C. Fong, G. Adams, G. Pauletta, J. Soukup, R. J. Ridge

We propose to use the HRS to make a survey of selected light-, intermediate-, and heavy-target angular distributions to determine the magnitude of the cross sections and asymmetries. Using the survey measurements as input, we will determine absolute values of the spectroscopic factors using the relativistic version of DWUCK developed by Dale Kunz. We will compare these values and the relative values for each target nucleus with those obtained at 50 MeV. We will determine whether high spin $\ell^\pm 1/2$ states can be differentiated by the asymmetry produced by using polarized protons. We will obtain data on the fine structure of deeply bound holes in the s-d shell.

Exp. 118

FRAGMENT EMISSION FROM PION INTERACTIONS WITH COMPLEX NUCLEI

Purdue University

N. T. Porile, Spokesman

LASL

B. J. Dropesky, R. A. Williams

We propose to measure the cross sections for the formation of ^{24}Na in reactions induced by 100-400-MeV $\pi^\pm$ in copper, silver, gold, and uranium. If the cross sections turn out to be sufficiently

large, thick-target recoil experiments will also be performed. Sodium-24 is a typical fragmentation product in proton-induced reactions, and a comparison of the absolute cross sections and excitation functions for this product from pion- and proton-induced reactions will provide information on the possible role of pion scattering and absorption in fragmentation.

Exp. 119

CROSS SECTIONS OF SIMPLE NUCLEAR REACTIONS INDUCED BY PI-MESONS

Argonne National Laboratory

S. B. Kaufman, Spokesman

E. P. Steinberg

LASL

G. W. Butler, D. G. Perry

This is a proposal to measure the cross sections for certain simple nuclear reactions of pi-mesons, with special emphasis on the determination of the ratio σ^+/σ^- , that is, the cross-section ratio for the same nuclear reaction induced by π^+ and π^- mesons. The reactions to be studied are of the types

$$Z^A (\pi^\pm, \pi^\pm n) Z^{A-1} \quad (1)$$

and

$$Z^A (\pi^\pm, \pi^\pm p) Z^{A-1} , \quad (2)$$

and the cross sections are to be measured by the radiochemical method, namely by measurement of the radioactive product nucleus. These reactions are analogous to the (p,pn) and (p,2p) reactions induced by protons, which have been extensively studied. The advantage provided by pions is the resonance structure in the pion-nucleon scattering cross sections, which can be used as a probe of reaction mechanisms. In the vicinity of the (3,3) resonance (180-MeV pion kinetic energy), the cross-section ratio for pion-proton scattering, $\sigma(\pi^+p)/\sigma(\pi^-p)$, is 3.0. With increasing energy, it decreases, becoming equal to 1.0 at 410 MeV and 0.35 at 600 MeV. If the principal mechanism for reactions (1) and (2) is a quasi-free scattering of the incident pion by a single nucleon, the ratio σ^+/σ^- should show the same behavior as the corresponding free-particle ratio. On the other hand, if the principal mechanism is one of excitation of the entire nucleus followed by a particle evaporation, the free-particle effects will be washed out. If the target is a $Z = N$ nucleus, the latter mechanism would result in equal cross sections for π^+ and π^- mesons. It is, therefore, proposed to measure cross-section ratios for the simple reactions (1) and (2) for a selected group of target nuclei at several energies, in order to probe the reaction mechanisms.

Exp. 120

MEASUREMENT OF THE POLARIZATION ASYMMETRY AND THE DIFFERENTIAL CROSS SECTION OF PION-NUCLEON CHARGE EXCHANGE FROM 160 TO 500 MeV

Catholic University

D. I. Sober, Spokesman

University of California, Los Angeles

B.M.K. Nefkens, Spokesman

K. C. Leung

LASL

C. F. Hwang

We propose to measure the polarization asymmetry and the differential cross section of pion-proton charge exchange,

$$\pi^- + p \rightarrow \pi^0 + n ,$$

for incident pion momenta between 250 and 625 MeV/c (total center-of-mass energy $\tilde{E}$ between 1210 and 1450 MeV). We will cover the complete angular range, including 0° and 180° . Both neutron-photon and two-photon coincidence techniques will be used, with some redundancy to assure correct relative normalization. The apparatus developed for these experiments will also be used for differential cross-section and polarization measurements on radiative pion capture

$$\pi^- + p \rightarrow \gamma + n .$$

The objectives of our efforts are

1. to obtain an improved parameterization of the π -N interaction,
2. to test the breakdown of isospin invariance due to the electromagnetic interaction,
3. to test the Aued-Bareyre-Sondererger phase degeneracy at 180° ,

$$\sigma^0 = 1/2 | \sqrt{\sigma^+} - \sqrt{\sigma^-} |^2 ,$$

4. to determine the mass difference of the members of the $P_{33}(1236)$ quartet. This will test SU(3) and quark-model predictions, and
5. to test fixed-t dispersion relations and model calculations via the measurement at 0° .

Exp. 121

INTERACTION OF STOPPED NEGATIVE PIONS WITH COMPLEX NUCLEI

Argonne National Laboratory

R. E. Segel (ANL/Northwestern University), Spokesman

L. Meyer-Schützmeister, J. P. Schiffer (ANL/University of Chicago), H. E. Jackson, S.

B. Kaufman, D. G. Kovar, S. E. Vigdor, T. P. Wangler

LASL

R. L. Burman

The study of prompt gamma rays provides perhaps the only technique to date in which a large fraction of the channels responsible for the interaction of pions with complex nuclei can be identified. Important clues to reaction mechanisms have been found in our first run which need to be explored further before they are properly understood. We propose a program of measurements which should constitute the next stage of exploration with this technique; some particle measurements to complement these data are also proposed. In particular, the surprising lack of charge and energy dependence found in our first run needs to be explored further.

Exp. 122

PIONIC-ATOM X RAYS AND NUCLEAR DISTRIBUTIONS

University of Wyoming

A. R. Kunselman, *Spokesman*

T. R. King

California Institute of Technology

R. J. Powers, F. Boehm, P. Vogel, A. Zehnder, A. A. Hahn

Virginia Polytechnic Institute and State University

P. Roberson

LASL

J. J. Jarmer

Experimental time for Proposal No. 122 was delayed until we were set up in Area A and had tested our equipment in the SMC. We are now prepared to conduct a largely exploratory part of the experiment in the LEP channel. We plan to determine the rates for Ge(Li) and bent-crystal experiments, as well as obtain some useful data on pionic-atom strong interaction effects.

The targets we plan to use exhibit a large change in mean square charge radius at $A = 149$. Presumably, the change in matter distribution should be equally as large. We plan to use the measured charge distribution as known from muonic-atom measurements to infer the change in neutron distributions.

According to the LAMPF Users Handbook, the 50-MeV pion beam (128 MeV/c) with $\Delta p/p = \pm 2.8\%$ should yield $6 \times 10^6 \pi^-/s$ for 10 μA of protons on the target in Area A. This allows for a factor of 4 less than the values in the table because π^+ rather than π^- are tabulated and a factor of 2 less because of wrong cross-section numbers tabulated. The beam should have a spot size of about 4 cm by 8 cm, and we plan to run two 4-cm by 4-cm targets next to each other. We should be able to stop between 30% and 40% of the beam in targets 2.5 g/cm² (about 50 g of material for each of the targets).

• The expected x-ray line width for $z = 60$ is about 10 keV, and the difference between the isotopes of $A = 150$ and 146 is about 1.2 keV. We will want the centroid positions measured to about 0.1 keV, so we will need about 1600 counts in each of the 4-3 x-ray transition lines. The transition is at about 650 keV with an x-ray yield of about 30%. A Ge(Li) detector of about 5-cm² area, 10 cm away from the center of the target, with a detector efficiency of about 10^{-2} at 650 keV, should allow the experiment to be done in six shifts of beam time. We have allowed an adequate margin of time for tuning up and testing as well as for collecting data.

NUCLEAR STRUCTURE EFFECTS IN PION-INDUCED NUCLEAR REACTIONS

Carnegie-Mellon UniversityP. J. Karol, *Spokesman*

A. A. Caretto, M. Yester

LASL

M. A. Yates-Williams, R. A. Williams, B. R. Erdal

Reed College

L. B. Church

The objective of these proposed experiments is to determine the cross sections of two classes of nuclear reactions induced with π^+ and π^- mesons, both on and off the $3/2-3/2$ resonance, on a series of targets designed to elucidate the effect of different aspects of nuclear structure on production yields. The two classes of reactions to be studied are (i) simple pion-induced reactions and (ii) pion-induced "deep" spallation.

(i) Pion-Induced Simple Nuclear Reactions

The cross sections to be measured are for reactions analogous to (p,pn), (p,2p), and (p,n) reactions, namely,

$$Z^A(\pi^\pm, \pi^\pm n)Z^{A-1} \quad , \quad (1^\pm)$$

$$Z^A(\pi^\pm, \pi^\pm p)Z-1^{1-1} \quad , \quad \text{and} \quad (2^\pm)$$

$$Z^A(\pi^\pm, \pi^0)Z \pm 1^1 \quad . \quad (3^\pm)$$

Cross-section measurements for reactions $(1^\pm)$ and $(2^\pm)$ on a series of target isotopes and isotones would be expected to probe the quasi-free scattering nature of the reaction mechanism, helping to clarify the apparent discrepancy between theory and existing experimental results.

Anticipating that reactions $(1^\pm)$ and $(2^\pm)$ take place in the peripheral-spatial region of the nucleus, the changing neutron-to-proton density ratio in this "skin" region for the various targets selected should effect the reaction probabilities in a manner analogous to what has been observed for (p,pn) and (p,2p) reactions. Because of the large pion-nucleon interaction cross section at the resonance, one anticipates that these and the $(3^\pm)$ reactions would be even more sensitive to skin structure than the equivalent proton-induced reactions, thereby hopefully providing information regarding the existence and extent of the neutron halo.

Several isomer-yield ratios are implicitly accessible in these investigations and would be expected to provide insight regarding population of particular "hole" states in the residual nuclei.

(ii) "Deep" Spallation Reactions

Of considerable importance to understanding the nature of complex high-energy nuclear reactions are the isobaric production cross sections of one or more mass chains. Targets chosen for these studies will be the same as in part (i). Thus, the detailed effects of systematically changing Z, N, and A should become evident. In particular, a given isobaric yield distribution is to be determined for each target nuclide in order to establish the effect of target structure on production probabilities. This information is of fundamental importance in constructing the yield surface from spallation reactions and must be carefully determined in order to make meaningful comparisons between proton and pion interactions with complex nuclei.

Exp. 124

**MEASUREMENT OF THE NEUTRON ENERGY SPECTRUM
IN $p + p \rightarrow n + \pi^+ p$**

University of New Mexico

B. D. Dieterle, Spokesman

*H. C. Bryant, C. P. Leavitt, D. M. Wolfe, T. Rupp, R. Carlini, J. Donahue, W. Thomas,
C. Gregory*

Temple University

W. K. McFarlane, Spokesman

V. L. Highland, L. B. Auerbach, K. F. Johnson, H. Balshem, J. Valentine

LASL

R. F. Bentley, J. Pratt

We propose to make high statistics measurements of the neutron double differential cross section ($d\sigma/d\Omega_n$) dE_n (θ_n , E_n) for the reaction $p + p \rightarrow n + \pi^+ + p$. We will use 400-800-MeV incident protons and measure the neutron energy spectrum at lab angles $0^\circ < \theta_n < 20^\circ$. About 10^6 events are expected, whereas previous experiments have about 10^3 events. Neutron time-of-flight technique will be used with a pulsed beam. This beam will be either the proposed Neutron Energy Spectrometer or the existing H^- beam with micropulse selection.

Exp. 125

**ELASTIC NEUTRON-PROTON BACK-ANGLE DIFFERENTIAL
CROSS-SECTION MEASUREMENTS 300-800 MeV**

University of New Mexico

B. D. Dieterle, Spokesman

H. C. Bryant, C. P. Leavitt, D. M. Wolfe, S. Cohen, C. Cassapakis

Texas A&M University

J. C. Hiebert, L. C. Northcliffe

LASL

B. E. Bonner, J. D. Seagrave, J. E. Simmons

We propose to measure the np elastic differential cross section over a range of angles $\theta \simeq 90$ - 180° , and a range of energies 300-800 MeV. The experiment can be normalized absolutely to $\pm 5\%$. We will use the magnetic spectrometer system we used in Exp. 56. Geometrical modifications to obtain greater solid angle will be made. We estimate that 200 hours of beam time will be needed if we are scheduled immediately after Exp. 56.

Exp. 126

A MEASUREMENT OF THE ELECTRON AFFINITY OF H^0

University of New Mexico

H. C. Bryant, Spokesman

The availability of a high-quality, relativistic H^- beam at LAMPF makes possible a measurement of the electron affinity of H^0 to a much higher precision than previous measurements. A gas laser beam will intersect the H^- beam, producing detached electrons with the same phase space as the H^- beam. These 430-keV electrons will be bent out of the primary beam and focused upon a LiSi detector. The center-of-mass energy in the $H^0 + e$ system is determined via the Doppler shift from the lab photon energy and the angle between the two beams. Since the form of the cross section near threshold is known, the cross section as a function of the center-of-mass energy just above threshold enables us to determine the electron affinity to a precision of about ± 0.002 eV. The principal energy uncertainty arises from the 0.4% uncertainty in the primary beam.

Exp. 127

NUCLEAR SPECTROSCOPY OF NUCLIDES OF THE LINE OF BETA STABILITY

Aerojet Nuclear Co.

C. W. Reich, Spokesman

We propose to study the radioactive decay of nuclides rather far from β -stability, produced via high-energy proton-induced spallation and fission reactions. The irradiations will be made in LAMPF Area B and thus will not consume primary beam time. We expect this program to extend over many years. In our initial experiments, we plan to concentrate on the study of neutron-deficient nuclei of the rare-earth elements, using high-resolution solid-state detectors. Sources will be prepared by fast radiochemical techniques. When isotopes having similar half-lives are encountered, an off-line isotope separator may be used to isolate specific nuclides. Those isotopes with sufficiently long half-lives ($T_{1/2} > \text{a few days}$) will be brought back to our laboratory for detailed study, including high-resolution electron spectroscopy utilizing our air-cored $\pi\sqrt{2}$ electron spectrometer.

The principal objectives of our experiments will be 1) to determine nuclear mass differences via total decay-energy measurements, 2) to discover new nuclides and new isomers, and 3) to extend the systematics of nuclear level structure and of β - and γ -transition probabilities as far as possible into the neutron-deficient region. We will attempt to trace out more fully the boundary between the spherical and deformed regions. Specific experiments are planned to learn more about the transition from deformed to spherical equilibrium shape and rotation-particle coupling near the edge of the region of deformed nuclei.

These measurements should lead to improvements in the semiempirical mass formula and in our knowledge of the effective nuclear Hamiltonian.

Exp. 128

WNR STORAGE RING STRIPPER EXPERIMENT

LASL

T. D. Hayward, Spokesman

R. F. Bentley, J. A. Farrell, J. C. Hopkins, G. P. Lawrence, A. J. Lieber, D. J. Liska, J. E. Spencer

It is planned to test and demonstrate the feasibility of various stripping schemes for injection of negative hydrogen ions into the WNR storage ring. The stripping cross sections σ_{-10} , σ_{-11} , and σ_{01} will be accurately measured at 800 MeV for various stripping materials (both solid and gas), using the negative hydrogen line in Area B (Line EP). Noncoherent photodetachment and magnetic bump stripping will be investigated for the H^- to H^0 transition. Later, it is planned to make supplemental multiple-scattering measurements for thicknesses of these strippers equivalent to many thousand traversals by the circulating beam. In order to carry out this program, a test stand will be constructed in which various stripper prototypes can be mounted and evaluated. These measurements are crucial to the WNR storage ring program.

Exp. 129

PION PRODUCTION IN NEUTRON-PROTON COLLISIONS

University of New Mexico

D. M. Wolfe, Spokesman

H. C. Bryant, B. D. Dieterle, C. P. Leavitt, C. Cassapakis, S. Cohen

Texas A&M University

L. C. Northcliffe, J. C. Hiebert

LASL

J. E. Simmons, J. D. Seagrave, B. E. Bonner

We propose to measure the double differential cross sections $(d\sigma/d\Omega dE_{\pi^-})$, $(d\sigma/d\Omega dE_p)$, and $(d\sigma/d\Omega dE_{\pi^+})$ from the reaction $n + p \rightarrow nn\pi^+$ or $pp\pi^-$. The angular range will be 0 to 120° in the lab. We will use the single-arm spectrometer used in Exp. 56 and in the elastic differential cross-section measurements. We estimate 500 h of beam time will be needed if we are scheduled immediately after the np differential cross-section measurement.

Exp. 130

EPICS TUNEUP PROPOSAL: PION CARBON SCATTERING

LASL

H. A. Thiessen, Spokesman

D. M. Lee, J. F. Amann, J. Potter

University of Virginia

M. D. Thomason, S. E. Sobottka

Carnegie-Mellon University

R. A. Eisenstein, P. D. Barnes

Oregon State University

L. W. Swenson

New Mexico State University

G. R. Burleson

Institut de Physique, Switzerland

J. P. Egger

We propose to debug and tune the EPICS system on a simple target. We believe that the best results will be obtained if we measure useful, publishable information. We will measure the following quantities.

1. Complete angular distributions of π^+ and π^- elastic scattering on ^{12}C and ^{13}C at two angles,
2. Restricted angular distributions at three additional energies,
3. Quasi-free scattering measurement of π^+ from ^{12}C at one energy and five angles, and
4. Pion-proton scattering measurement using a CH_2 target at a sufficient number of energies and angles to allow normalization of our results to existing pion-nucleon data.

In addition, we will make background surveys relevant to the first few approved EPICS experiments, study the effects of using "strip" targets, study the day-to-day variation of results, and attempt to measure and optimize the system resolution.

Exp. 131

A STUDY OF THE $\pi^+ + d \rightarrow p + p$ REACTION AT PION ENERGIES 10-60 MeV

University of South Carolina

B. M. Freedom, Spokesman

D. Malbrough, C. W. Darden, R. D. Edge

Oak Ridge National Laboratory

E. E. Gross, C. A. Ludemann, M.J.M. Saltmarsh, K. Gabathuler, T. Marks, R. E. Bertrand

Virginia Polytechnic Institute and State University

M. Blecher, K. Gotow, D. A. Jenkins, P. Bertin, W.-C. Lam

LASL

R. L. Burman, R. P. Redwine

Tel Aviv University

J. Alster

University of Lausanne

J.-P. Perroud

It is proposed to study the $\pi^+ + d \rightarrow p + p$ reaction at pion energies of 10, 20, 40, and 60 MeV. Angular distributions of the protons with respect to the incident pion direction will be measured as a function of energy, using an array of eight scintillation-detector telescopes. The results of this study will provide information on the mechanism of pion absorption processes and, by detailed balance, on pion production processes.

In addition to the basic physics that can be investigated using this reaction, a very important pragmatic benefit can be realized. Since the two protons resulting from this reaction have sizeable energies, this reaction provides a unique signature for a π^+ via the strong force and, thus, can be used as a low-mass, in-beam monitor for positive pion beams. A proposed monitor based on this effect will be studied.

Exp. 132

MEASUREMENTS OF "P," "R," AND "A" PARAMETERS IN $\pi^\pm$ -p ELASTIC SCATTERING

LASL

C. F. Hwang, Spokesman

L. E. Agnew, G. A. Keyworth, P. A. Thompson

Virginia Polytechnic Institute and State University

R. A. Arndt, L. D. Roper

State University of New York, Geneseo

J. R. Chen

Measurements of P, R, and A parameters in $\pi^\pm$ -p elastic scattering are proposed to establish for the first time complete data sets at each energy of the experiment. From these data we will determine directly the π -N scattering amplitudes f and g . Single-energy phase-shift analyses at each energy of the experiment will be done by the group at Virginia Polytechnic Institute and State University (Arndt and Roper) at various stages of the experiment, with preliminary data to serve as checks on the experiment. Finally, single-energy and energy-dependent analyses will be done, utilizing the final results and the π -N data set.

The experiment will study the scattering of 410, 491, and 533-MeV pions off longitudinally polarized protons, with subsequent analysis of the momentum and polarization of the recoil protons in a magnetic spectrometer and a carbon-analyzing polarimeter. The angular range covered will be 85 - 160° for π^- , and 105 - 160° for π^+ (cms). The energies selected are ones where the cross sections have already been measured and the design intensities of the P^3 channel are adequate. Due to lack of intensity, absolute $d\sigma/d\Omega$ measurements have been done, but not the basically easier ratio measurements involved in determining the spin parameters. This proposed experiment is the first step towards the complete determination of the scattering amplitudes in the energy range which LAMPF makes accessible.

These proposed R and A measurements will be the first data on the $\text{Re}(f^*g)$ and $|f|^2 - |g|^2$ in this energy region. We will simultaneously measure P to get $\text{Im}(f^*g)$ and, with $d\sigma/d\Omega = |f|^2 + |g|^2$ from existing data, will determine directly the scattering amplitudes f and g . In addition to allowing a detailed comparison with the predictions of the various phase-shift analyses, the determination of f and g is of fundamental importance to any theory of strong interactions.

Exp. 133

PRELIMINARY PION-CHANNELING EXPERIMENTS

Argonne National Laboratory

D. S. Gemmell, Spokesman

R. E. Holland, J. P. Schiffer (ANL/University of Chicago), T. P. Wangler, J. N. Worthington, B. J. Zeidman, A. J. Ratkowski, W. Pietsch, H. W. Jackson, J. Kulaga

LASL

H. A. Thiessen

It is proposed to make some measurements on pion (both π^+ and π^-) channeling that do not require a pion spectrometer. These measurements would be suitable for scheduling on the EPICS channel during the period when the pion beam preparation system is operational but before the EPICS spectrometer is installed. Two types of measurement are presently envisaged. First, the stopping power for pions in a silicon crystal would be measured as a function of the orientation of the crystal with respect to the pion beam. Second, and beam intensity permitting, the production of characteristic x rays from various target crystals would be measured also as a function of crystal orientation with respect to the pion beam.

Exp. 134

**STUDY OF THE ENERGY DISTRIBUTION OF NEUTRONS FROM
LAMPF BEAM STOP AND OF THE FEASIBILITY OF USING
THIS SPECTRUM FOR ACTIVATION ANALYSIS**

University of Wyoming

V. A. Ryan, Spokesman

The main LAMPF beam stop is expected to be an abundant source of energetic neutrons, produced in a broad spectrum range and accessible without significant interference with accelerator operation. Using sets of activation monitor foils exposed in pneumatic transfer carriers ("rabbits") positioned at selected locations in the carrier tube at the side of the beam stop, we propose to characterize the neutron spectra at these locations. It is remarked that this work of characterization will probably prove valuable to other people working at the beam stop, including other users of the rabbit and users of the energetic neutron station. The latter include those making radiation-damage studies. Their neutron spectrum is essentially the same as ours.

We propose to investigate the feasibility of activation analysis using the radiation from the Area A beam stop for bombardments. We submit that this is a unique resource for which little demand has been made for other uses. Seven elements — beryllium, carbon, fluorine, phosphorous, titanium, nickel, and lead — are not usually done by neutron-activation analysis, and also are difficult to do by wet chemistry or spectroscopy. At the same time, these are important elements for which nondestructive determination is often needed.

LAMPF is a unique location at which neutrons suitable for such analysis are readily available. Other neutron sources produce fewer neutrons of the required energies, and are excessively costly. The LAMPF neutrons are so far sought by only two or three users requiring a small amount of time, but are available in quantity and quality suitable for this proposal almost all the time the accelerator is running.

Exp. 135

NEUTRONS IN NEGATIVE-PION RADIOTHERAPY

Kent State University

R. Madey, Spokesman

The objective of the proposed research is to generate data needed to determine the biological damage caused by neutrons in π^- meson irradiation of a cancerous tumor. Specifically, it is proposed to measure the number and energy distribution of neutrons resulting from π^- meson capture in oxygen, carbon, and nitrogen, and in tissue-equivalent materials. Measurements will be made by a time-of-flight technique over the energy region from 1 to 150 MeV, with a resolution varying from about 5 to 15%. A comparison will be made between these measurements and the predictions of the Monte Carlo intranuclear-cascade calculations to determine the degree of validity of the calculation. In addition, data will be generated to resolve discrepancies currently existing among the previous measurements of Anderson *et al.* (1964), Venuti *et al.* (1964), and Hattersly *et al.* (1965).

Exp. 136

LARGE-ANGLE PION-NUCLEUS SCATTERING

New Mexico State University

G. P. Burleson, Spokesman

R. W. Dressel, S. L. Verbeck

Temple University

K. F. Johnson

Institut de Physique, Switzerland

J. P. Egger

LASL

H. A. Thiessen

We propose to begin a study of the scattering of pions from nuclei at large angles with the use of the EPICS system. Very little is known about large-angle scattering, since the data are virtually nonexistent, and we feel that measurements of this type will aid greatly in improving our understanding of the pion-nucleus interaction.

The EPICS system, as currently designed, will reach a maximum angle of about 145° . We propose to make a modification of the system that will allow for coverage over the remainder of the angular regions, out to 180° , with an overlap of about 10° at both ends of the range as a check (135° - 190°). This modification is being planned so that it can be fairly easily inserted and removed whenever particularly large-angle data would be desired. We are requesting time to debug and tune the modified system, as well as to obtain useful data. In particular, we propose to gather data on π^+ and π^- elastic and quasi-elastic scattering from ^{12}C at energies between 75 and 300 MeV.

Exp. 137

**SEARCH FOR PARITY-VIOLATING CONTRIBUTION TO
SCATTERING OF HADRONS**

LASL

D. E. Nagle and R. E. Mischke, Spokesmen

C. F. Hwang, R. J. Macek, J. Potter, R. Stevens, E. P. Chamberlin, J. D. Bowman, C.

M. Hoffman, J. L. McKibben

University of Illinois

H. Frauenfelder, Spokesman

D. Alde, V. Yuan

We propose to search for a helicity dependence of the total and differential cross sections in p-p, p-d, and p-nucleus scattering, with proton energies between 200 and 800 MeV. A measurement of the magnitude and energy dependence of the parity-violating effect will very likely allow definite conclusions about the form of the weak-interaction contribution to the hadronic force.

Previous experiments, mainly measurements of the circular polarization of gamma rays in favorable nuclear transitions, have shown conclusively that such a contribution exists. However, the magnitude of the observed parity-violating component disagrees with present calculations. Investigations on simpler systems, as proposed here, are needed to disentangle nuclear and weak-interaction effects.

Our experiment will use a longitudinally polarized proton beam at LAMPF, incident on a hydrogen or nuclear target. We will look for a current from our detectors (to allow very high data rates) which has a component correlated with the frequency of reversing the proton spin. The precision required is estimated to be 1 part in 10^6 .

Exp. 138

**INELASTIC PROTON SCATTERING AND EXCITATION OF STATES OF
INTERMEDIATE COLLECTIVITY IN OPEN-SHELL NUCLEI**

University of Oregon

D. K. McDaniels, Spokesman

P. Varghese

Oregon State University

L. W. Swenson, Spokesman

A. Stetz, K. S. Krane, T. C. Sharma

LASL

M. Othoudt, J. E. Spencer, G. W. Hoffmann

University of Texas, Austin

G. S. Blanpied, R. Liljestrand

The inelastic scattering of medium-energy protons will be studied for even-mass open-shell nuclei spanning the range from zinc to tellurium. This mass region is chosen for investigation because of our belief that open-shell nuclei may be as useful as target nuclei (or in some cases, complementary) for nuclear-physics experiments as the conventional closed-shell nuclei like ^{16}O , ^{40}Ca , and ^{208}Pb . This proposal centers on the search for special bound and unbound states which may have a degree of collectivity intermediate between true collective states, such as the 2^+ quadrupole and 3^- octupole states, and the single-particle background. In order to excite these

possible modes of motion, a high-energy, high-current proton beam will be indispensable. Also, the high resolution of the HRS facility will be needed. The possibility of finding these modes of excitation is of particular interest since they should be quite sensitive to the details of the microscopic calculations. The elastic scattering and inelastic scattering from collective states will also be measured to assist in the analysis of the inelastic proton data.

Exp. 139

PRELIMINARY PROTON-SCATTERING SURVEY WITH HRS

LASL

J. E. Spencer and N. Tanaka, Spokesmen

We propose using the High-Resolution Spectrometer (HRS) facility to study proton elastic scattering from an assortment of target nuclei. Our primary objective will be to establish the systematics existing at LAMPF energies. The results should, therefore, provide an orientation for future experiments. Since we expect to interweave these experiments with the general tuneup and checkout of the HRS facility, we propose using targets of CH_2 , CD_2 , $^{12,13}\text{C}$, $^{90,91,92}\text{Zr}$, and $^{208,207,206}\text{Pb}$. While not exhaustive, this set covers the full range of stable nuclei required, both to establish the operating capabilities of the system and to provide an adequate preliminary survey. The proposed measurements are

- 1) total cross sections,
- 2) restricted forward angular distributions,
- 3) complete angular distributions on at least one isotope, and
- 4) extended energy spectra at a few angles.

Exp. 140

**STUDY OF THE ($\pi^\pm$,d) REACTION WITH AN
INTRINSIC GERMANIUM DETECTOR**

Carnegie-Mellon University

P. D. Barnes, Spokesman

R. A. Eisenstein, S. A. Dytman, K.G.R. Doss, J. N. Craig, W. R. Wharton

LASL

J. F. Amann

We propose to search for the emission of complex charged particles in pion-nucleus absorption reactions leading to a two-body final state. Of special interest are the (π^+ ,d) and (π^- ,d) reactions. The experiment will use a 6-cm-deep intrinsic germanium detection system with good energy resolution. It will be sensitive to t, ^3He , and ^4He production, as well as to d production. Initially, it is proposed to bombard targets of widely different mass with both π^+ and π^- projectiles of 100 MeV. Measurements of angular distributions for specific final states should give detailed information about the absorption mechanism and the particle correlations in the nuclear surface. If the recently proposed theoretical models for the absorption process are correct, the (π^+ ,d) cross section could be significantly larger than the (π^+ ,p) reaction cross section. This experiment is a direct test of models of complex charge particle production.

Exp. 141

SEARCH FOR A LIGHT SCALAR BOSON

National Research Council of Canada

C. K. Hargrove, Spokesman

Weinberg, in a theory that unites the weak and electromagnetic interactions, was led to introduce a scalar boson (ϕ) of unknown mass. In a muonic-atom experiment, we have found a discrepancy between our measurements and theory. Jackiw and Weinberg have pointed out that this discrepancy could be removed by invoking a scalar boson of mass about 20 MeV. Sundaresan and Watson, in a careful comparison of muonic-atom theory with experiment, conclude that the discrepancy is best removed with a mass 8 MeV, but that any value between 0 and 22 MeV would be acceptable. (It could not, however, be 0.)

It is our proposal to look directly for ϕ s produced in π decay. The properties of this boson have been calculated by Resnick, Sundaresan, and Watson, using its coupling to the leptons as provided by Weinberg's theory. Assuming a mass 8 MeV, they predict the lifetime for decay to e^+e^- to be 10^{-9} s. The estimated branching ratio $(\pi \rightarrow \mu\nu\phi)/(\pi \rightarrow \mu\nu)$ is about 10^{-9} .

We are proposing an experiment in which we would use the LAMPF stopped π^+ beam to produce ϕ s in the reaction $\pi \rightarrow \mu\nu\phi$. We would then detect the e^+e^- pairs from ϕ decay in a detector such as a streamer chamber, which would be separated from the pion stopper by a suitable amount of shielding. This shielding is necessary to eliminate the high γ -ray background from the bremsstrahlung of μ decay electrons, the decay of π^0 s produced by $\pi^+n \rightarrow \pi^0p$, nuclear γ rays, etc. The chamber will be triggered by a scintillation hodoscope designed on the basis of the kinematics of the ϕ decay.

We require two running periods. The first would be for a background study for which we will use an existing streamer chamber with dimensions 100 by 64 by 20 cm. This will take

about one week of beam time at the highest available intensity, even before LAMPF is at full intensity.

If the background can be made adequately low, we will then wish to run at full stopped pion intensity, $\sim 3 \times 10^9 \pi/s$. At this time, we believe that the final experimental arrangement should closely resemble that used for the background tests. However, we would determine the final form of the apparatus only after assessing the results of these tests.

Exp. 142

NEGATIVE-MUON-INDUCED FISSION IN THE ACTINIDE ELEMENTS

University of Rochester

J. R. Huizenga, Spokesman

M. W. Johnson, W.-U. Schröder

LASL

W. K. Hensley, D. G. Perry

Lawrence Livermore Laboratory

J. C. Browne, S. D. Bloom

It is proposed to utilize the negative-muon beam facilities at LAMPF to institute a study of muon capture and of radiationless atomic muon transitions in the actinide elements. Initial work would probably include studies of fission induced by capture and by nonradiative transitions in order to determine both the relative yields of fission fragments from these two processes and the half-life for muon capture from the 1s atomic orbital. It is also hoped that additional measurements of the yields of the different muonic x rays per mu-stop would provide information on the yields of the different radiationless transitions exciting the nucleus above the fission threshold. This would permit the determination of the partial fission width following a radiationless transition. The systematics of all these quantities (prompt-to-delayed fission yield, capture half-life, and postradiationless-transition fission branching ratio) will be studied as functions of both the neutron and proton number of the system. Where possible, they will be related to theoretical expectations or to the results of fission studies using more conventional nuclear techniques. Eventually, these investigations may also be extended to include the study of neutrons or protons emitted following the stopping of a muon in the target.

Exp. 143

STUDY OF THE RADIOBIOLOGICAL PROPERTIES OF NEGATIVE PIONS

LASL

M. M. Kligerman and E. A. Knapp, Spokesmen

L. L. Deaven, J. A. Helland, R. L. Hutson, A. S. Lundy, M. A. Paciotti, D. F. Peterson,
M. R. Raju, C. Richman, R. A. Walters

University of New Mexico

J. E. Barnes

University of Mississippi

J. J. Reidy

Tulane University

R. M. Wilenzick

We propose to study the radiobiological properties of negative pions by using the π^- beam at the LEP channel. This program will allow us to get a start on some of the relevant problems prior to the completion of the Biomedical channel. Some of the results, which can be obtained relatively quickly, will be the basis for dose prescription in future biological experiments requiring higher intensities. The proposed program can be carried out with relatively low dose rates, although part of it will be repeated when dose rates of the order of 20 to 100 rads/min are available.

Early RBE measurements are crucial for subsequent preclinical and clinical radiobiology experiments. This work will lead to the more efficient use of the Biomedical channel and will permit us to proceed with other biological experiments before accurate physical dosimetry data are available.

In order to facilitate starting this program at the earliest possible date, we propose to set up this experiment at the same time as Exp. 96, which would be located in its preferred position. This experiment would be placed $\sim 3\frac{1}{2}$ m downstream, with a doublet quadrupole in between to refocus the pion beam. We do not intend to run simultaneously with Exp. 96.

Exp. 144

SEARCH FOR THE C-VIOLATING DECAY $\pi^0 \rightarrow 3\gamma$

Temple University

V. L. Highland, *Spokesman*

L. B. Auerbach, W. K. McFarlane, K. F. Johnson

LASL

R. J. Macek, *Spokesman*

J. Pratt, R. D. Werbeck

This experiment is intended to measure an upper limit for the decay rate of $\pi^0 \rightarrow 3\gamma$. Such a decay is forbidden by charge conjugation invariance, but the principle has not been thoroughly checked for electromagnetic decays of strongly interacting particles. The π^0 decay represents a particularly clean test of the principle.

Present experimental knowledge allows a C-violating amplitude of 0.5 relative to the C-conserving amplitude. This experiment intends to push the limit on the rate down another factor of 100.

Exp. 145

RESEARCH FOR NONQUASI-FREE PROCESSES IN THE 'He(π , π p) REACTIONS

Saclay

G. Tamas and J.-M. Laget, *Spokesmen*

P. E. Argan, G. Audit, N. De Botton, J. L. Faure, J. Martin, C. Schuhl

LASL

H. A. Thiessen, C. L. Morris

University of Virginia

J. S. McCarthy

TRIUMF

J. Källne

University of Oregon

D. K. McDaniels, P. Varghese

Oregon State University

L. W. Swenson

We propose a coincidence experiment to study the quasi-free scattering of pions from ${}^4\text{He}$. The EPICS spectrometer will be used to detect the pion, and a sodium-iodide crystal will be used to measure the energy of the proton. The data obtained in this experiment will complement the information obtained at the Saclay Linac in the reaction

$$\gamma + {}^4\text{He} \rightarrow \text{p} + \pi^- + \text{npp}.$$

It is possible that the results will bear on the question of the binding of an N^* in the nucleus.

Exp. 146**INELASTIC PION SCATTERING TO GIANT MULTIPOLE STATES****University of Colorado***R. J. Peterson, Spokesman*

J. J. Kraushaar, R. A. Ristinen, R. L. Boudrie, G. Smith, N. DiGiacomo

We propose to study the inelastic scattering of pions from the giant multipole states of ${}^{40}\text{Ca}$, ${}^{90}\text{Zr}$, and ${}^{208}\text{Pb}$. The EPICS system will be used with a pion energy of 150 MeV, and spectra will be taken at scattering angles between 20 and 60°. All three nuclei will be studied simultaneously with three moderately thick targets in order to increase counting rates. The purpose of the experiment is to identify E0, E1, E2, or other giant multipole excitations, and to determine the ability of pion scattering to uncover new information about their nature. We estimate that 180 h of beam time on EPICS will be required to complete this experiment.

Exp. 147**DETERMINATION OF THE ENERGY DISTRIBUTION OF NEUTRONS
FROM THE LAMPF BEAM STOP****LASL***D. G. Perry and D. W. Barr, Spokesmen*

G. W. Butler

University of Wyoming

V. A. Ryan, R. J. Jiacoletti

Argonne National Laboratory

M. J. Fluss

This is a proposal to determine the spectrum of energetic (1- to 50-MeV) neutrons emerging at different angles from the Area A proton beam stop at LAMPF by foil activation techniques. Targets with different neutron energy thresholds and experimentally determined excitation

functions will be irradiated in the pneumatic transport system at the beam stop. The activated foils will undergo chemical and/or isotopic separations as necessary, and then the radioactive nuclides of interest will be quantitatively determined with high-resolution gamma-ray detectors in the Nuclear Chemistry Laboratory. After obtaining a sufficient number of these integral responses, a differential neutron spectrum will be unfolded by using the computer program SPECTRA.

In preparation for this experiment, we have carried out extensive Monte Carlo calculations for the production and transport of neutrons of all energies out of the beam stop and into the adjacent pneumatic transport system where the foils will be irradiated. This theoretical neutron distribution will be used as a trial input to the SPECTRA program, which uses an iterative method to converge on a final differential neutron spectrum.

The series of experiments outlined in this proposal are designed to allow accurate determination of the energetic component of the beam stop neutron spectrum. The techniques developed will be of use to other programs interested in using the energetic neutrons from the beam stop, e.g., the radiation-damage studies for the controlled thermonuclear research program.

Exp. 148

NEUTRINO-ELECTRON ELASTIC SCATTERING AT LAMPF (A FEASIBILITY STUDY)

University of California, Irvine

F. Reines and H. H. Chen, Spokesmen

A. A. Hruschka, J. F. Lathrop, E. Prasierb, H. W. Sobel

A detector system consisting of plastic scintillators and spark chambers in a sandwich array is under construction. It is designed for the study of backgrounds associated with neutrino-electron elastic-scattering experiments at LAMPF, and will supply background information for other neutrino experiments as well.

Exp. 149

TEST OF LEPTON NONCONSERVATION AND ASSIGNMENT SCHEMES

IN 1. $\mu^- + (Z,A) \rightarrow (Z-2,A) + e^+$ AND

2. $\mu^- + (Z,A) \rightarrow (Z,A) + e^-$

State University of New York, Geneseo

J. R. Chen, Spokesman

Oregon State University

L. W. Swenson, Spokesman

J. J. Amato, S. A. Richert, D. M. Stupin

LASL

P. A. Thompson

An experiment is proposed to test lepton number assignment schemes and lepton nonconservation by looking for the occurrence of the following reactions.

$$\mu^- + (Z,A) \rightarrow (Z-2,A) + e^+ \quad (1)$$

and

$$\mu^- + (Z,A) \rightarrow (Z,A) + e^- . \quad (2)$$

These processes are identifiable by the unique energy of the emitted $e^\pm$. The experiment is designed to measure the branching ratios of these processes down to the 10^{-10} level, which will extend our knowledge two orders of magnitude deeper into the muon-electron puzzle.

The apparatus consists essentially of a pool magnet, four wire planes, and a Cerenkov dE/dx detector.

Exp. 150

SEARCH FOR POLYNEUTRON SYSTEMS

University of Chicago

A. Turkevich, Spokesman

J. Warren, J. LaRosa, J. R. Cadievx, T. E. Economou

A search is proposed for particle-bound polynutron systems formed by 800-MeV protons interacting with various nuclei. Emphasis in the first experiments will be on the possibility of 6n formed by (p;xp,yn) reactions in light targets such as ${}^{11}\text{B}$ or ${}^{12}\text{C}$. Radioactive detectors, such as ${}^{212}\text{Pb}$ produced from ${}^{208}\text{Pb}$, ${}^{212}\text{Bi}$ produced from ${}^{209}\text{Bi}$, or possibly, ${}^{17}\text{N}$ produced from ${}^{14}\text{N}$, will be used. A production probability of greater than 10^{-9} per nuclear reaction with ${}^{11}\text{B}$ should be detectable.

Exp. 151

**DETERMINATION OF HEAVY CHARGED PARTICLES FROM
STOPPED AND MOVING NEGATIVE PIONS IN WATER BY
SOLID DIELECTRIC TRACK RECORDERS**

Washington State University

H. B. Knowles, Spokesman

S. C. Luckstead, G. E. Tripard, F. H. Ruddy

Central Washington State University

W. C. Sperry

Oak Ridge National Laboratory

T. W. Armstrong

Ochsner Clinic

R. M. Wilenzick

Tulane University

J. M. Collier

University of Indiana

P. A. Deutchman, H. Willmes

Batelle Northwestern Laboratory

B. F. Gore

Radiation & Dosimetry, Inc., Richland, Washington

R. Gold

University of Mississippi

J. J. Reidy

Because of the interest in preliminary data obtained from passive track detectors in and near the pion peak in a water phantom using various collimators and also the uncollimated beam, it is desired to perform a more thorough series of experiments, particularly with *solid dielectric* (plastic) *track recorders* in order to determine heavy ion species and spectra emitted from pion stars in carbon, oxygen, and nitrogen. These experiments require about 4 shifts (32 h) of exposure at high intensity (100 μA). Preceding these, however, and working together with those members of the consortium who have concentrated on measurement of the fast neutron fluences by *fast fission track detectors*, several shorter exposures at low intensity (10 μA) are needed to resolve questions about fragment multiplicity from pion stars in different elements and to

remove an ambiguity in the measurement of fast neutron fluences by this method compared with measurements by other techniques.

Continuation of the plastic track detector work has obtained recommendation for support by NIH.

Exp. 152

**HIGH-PRECISION MUONIC X-RAY MEASUREMENTS USING
INTRINSIC GERMANIUM DETECTORS**

Carleton University, Ontario, Canada

M. S. Dixit, Spokesman

A. L. Carter, E. P. Hincks, D. Kessler

LASL

E. B. Shera

University of Chicago

H. L. Anderson

National Research Council of Canada

R.J. McKee, C. K. Hargrove, H. Mes

We propose to make high-precision measurements of muonic x rays below 500 keV using ultrapure germanium detectors. At present, there are established discrepancies between the experimental and theoretical energies for muonic transitions with small nuclear effects. We will extend these measurements to a larger set with improved accuracy. The experiment will include a large range of targets from chlorine ($Z = 17$) to uranium ($Z = 92$). Measurements of lines from different elements over the wide energy range will be used to check the internal consistency of the corrections applied to the Dirac energies, as well as the manner of handling experimental problems of line shape, background, and energy calibration of the detector. For the transitions chosen, the largest corrections to the Dirac energies are quantum electrodynamical in origin. At 150 keV, measurement accuracies of about 5 eV are possible, whereas at 450 keV, accuracies of about 8 eV should be attainable. These measurements should, therefore, be useful in looking for possible differences in electron-nuclear and muon-nuclear interactions and testing the unified theories of weak and electromagnetic interaction.

Exp. 153

**INVESTIGATION OF NUCLEAR GAMMA RAYS RESULTING FROM
IN-FLIGHT PION AND PROTON REACTIONS**

Carnegie-Mellon University

R. A. Eisenstein, Spokesman

J. Penkrot, S. A. Dytman, P. D. Barnes

Lawrence Berkeley Laboratory

A. C. Thompson

LASL

J. F. Amann

We propose to study the low-energy gamma rays produced when π^+ and π^- mesons interact in flight with complex nuclei to determine to what extent the multiple $2n2p$ emission observed in

stopped π^- and K^- work is observable with in-flight reactions. Rather than survey a large number of targets, we propose to concentrate on three neighboring nuclei and to use three bombarding energies. The variation in target will show binding energy and pairing effects, while the variation in bombarding energy will indicate the role of the 3-3 resonance in the production process. We further propose to look at the gamma-ray spectrum produced in proton bombardment to ascertain whether the pion plays a special role in these reactions.

Exp. 154

ELASTIC SCATTERING OF π^- AND π^+ FROM THE HELIUM ISOTOPES

University of Virginia

R. C. Minehart and J. S. McCarthy, Spokesmen

Elastic cross sections of pions scattered from ^3He and ^4He will be measured at incident pion energies of 250-500 MeV. This experiment will contribute to an increased understanding of the various reaction mechanisms used to describe this interaction. With a more consistent theory, the goal will be to extract nuclear-structure information for the relatively simple three- and four-body systems. In order to assure an elastic-scattering event for ^3He , it will be necessary to detect in coincidence the scattered pion and recoil ^3He nucleus; this will not be necessary for ^4He because of its large breakup energy.

It is anticipated that these results, together with improvements in the theory, will provide another source of information to complement that available from electron and proton scattering from the helium isotopes. Questions that arose from the latter experiments concerning modification of the nucleon-nucleon potential within the nucleus and the effects of dynamic, short-range correlations are still unanswered. The use of pions as the interacting particle can help resolve some of these uncertainties if the information gained in this and similar experiments can clarify and strengthen the theoretical description of the scattering process.

This experiment will be undertaken with the same personnel and equipment to be used in experimental Proposal No. 34, "Elastic Scattering of $\pi^\pm$ on Deuterons." The experience gained in this early experiment will be of significant advantage in the successful completion of this new proposal. The data on ^3He and ^4He represent a natural extension of the work on deuterium. The information gained from this experimental sequence will detail the systematics of pion scattering from very light nuclei, particularly since the data will be taken under similar conditions and analyzed with uniform assumptions. This experiment is intended to complement the proposed scattering experiment on the helium isotopes using the EPICS facility (Proposal No. 87). The energy will in general be higher except that duplication of some of the experimental data will be used as a consistency check on the results. This latter will be necessary since the two experiments are dependent upon different methods.

Exp. 155

HIGH-PRECISION MEASUREMENTS OF PIONIC MASS WITH CRYSTAL DIFFRACTION SPECTROMETER

Yale University

D. C. Lu, Spokesman

L. A. Schaller (University of Frieberg), V. W. Hughes, R. D. Ehrlich

Lawrence Berkeley Laboratory

K. M. Crowe

Columbia University

C. S. Wu, M. Y. Chen

California Institute of Technology

P. Vogel, R. J. Powers, F. Boehm

The pion mass m_π will be determined to an accuracy of about 15 parts per million, which will represent an improvement by a factor of 4 over our current knowledge. Measurements will be made with a crystal diffraction spectrometer of pionic x rays in low-Z atoms, in particular, of the 4f-3d transitions in π - ^{11}Na , π - ^{12}Mg , π - ^{13}Al , and π - ^{14}Si . The high-energy resolution (about 10 eV at 30 keV) and the inherent stability of a crystal diffraction spectrometer make such a high-precision measurement possible with a high-intensity pion beam. For relatively low-Z atoms, theoretical uncertainties, such as orbital electron screening and nuclear-structure effects, are sufficiently small so that m_π can be determined from the measured pionic x-ray energies to the desired accuracy.

Exp. 156

SURVEY OF QUASI-ELASTIC PION SCATTERING

Oregon State University

L. W. Swenson, *Spokesman*

T. C. Sharma, S. A. Richert, D. M. Stupin

Florida State University

H. S. Plendl

University of Oregon

P. Varghese, D. K. McDaniels

Florida A&M University

M. Greenfield

University of Virginia

S. E. Sobottka

LASL

H. A. Thiessen

A single-counter quasi-elastic-scattering survey is proposed for the EPICS beam line. Scattered pions will be detected from (π, π') , $(\pi, \pi'N)$, $(\pi, \pi'd)$, and $(\pi, \pi'\alpha)$ reactions for incident pion momenta of 415 MeV/c ($T_\pi = 300$ MeV) and 160 MeV/c ($T_\pi = 75$ MeV). Where kinematically allowed, the p's, d's, and α 's will also be detected from these reactions (but not in coincidence with the pions).

The anomalous $\pi^+:\pi^-$ ratio for $(\pi, \pi'n)$ reactions, the pion wavefunction in nuclear matter, effects due to a neutron halo, and $(\pi, \pi'd)$ and $(\pi, \pi'\alpha)$ reactions will be studied. Giant resonances and strongly excited states from (π, π') reactions will be noted.

This proposal is preliminary to experiments in which two particles will be detected in coincidence with two detectors at EPICS.

Exp. 157

MICRODISTRIBUTION OF THORIUM IN GEOLOGIC SAMPLES

Argonne National Laboratory

M. G. Seitz, Spokesman

The purpose of the experiment is to map the microscopic distribution of thorium in geologic samples. This is to be done by inducing fission of thorium and uranium with high-energy neutrons. The resulting fission fragments produce radiation-damage tracks in a solid detector such as quartz, and are made visible by chemical etching. The detector then serves as a map of the fissionable material in the sample. Using an auxiliary experiment in which the uranium is mapped by thermal neutron bombardment, the contribution of tracks from uranium can be subtracted from the map produced by high-energy neutrons to give the distribution of thorium in the samples. The technique will be used in two studies of geologic importance — one concerning the thorium distribution in ultramafic rocks, the other concerning the partitioning of thorium and uranium in meteorites.

Exp. 158

SEARCH FOR (p,K) REACTIONS

University of California, Los Angeles

G. J. Igo, Spokesman

A. Liberman, H. Spinka

Lawrence Berkeley Laboratory

J. B. Carroll, V. Perez-Mendez

Carleton University, Ontario, Canada

M. S. Dixit

LASL

B. C. Hoistad, J. E. Spencer

We propose to look for (p,K) reactions. We will use a wire proportional-magnetic spectrometer utilizing an existing UCLA spectrometer, which is to be placed at the point past the target position of the HRS just after the point where the beam has passed through a 4-in. quadrupole singlet on its way to the beam dump. Thus, we will be able to parasite, especially during the debug period and during the periods when most experiments proposed so far for HRS are being performed, without interference. Our targets will be thin enough so that they will not appreciably affect the beam size when the beam reaches the dump tunnel.

We will look for reactions which produce hypernuclei left in discrete states. This experiment is in the nature of a feasibility study which may lead to a longer program of experiments of this type.

For the first experiment, we propose to measure spectra of the (p,K⁺) reactions on ⁶Li, ¹²C, and ⁶⁰Ni.

Exp. 159

**CHARGED-PARTICLE EMISSION IN PROTON-INDUCED REACTIONS AS A
FEASIBILITY STUDY IN THE USE OF INTRINSIC GERMANIUM DETECTORS
WITH THE PRIMARY LAMPF BEAM**

Carnegie-Mellon University

R. A. Eisenstein, Spokesman

S. A. Dytmar, J. Penkrot, P. D. Barnes

LASL

J. F. Amann

Lawrence Berkeley Laboratory

A. C. Thompson

The feasibility of using intrinsic germanium crystals as particle detectors for proton-induced reactions using the primary LAMPF beam will be studied. The cross sections for production of deuterons, tritons, ^3He , ^4He , and possibly for subthreshold kaon production will be measured. Background neutron and gamma-ray fluxes will be investigated.

Exp. 160

MEASUREMENT OF "D," "R," AND "A" PARAMETERS IN p-p ELASTIC SCATTERING

LASL

L. E. Agnew, Spokesman

G. A. Keyworth, P. W. Keaton, M. P. Baker, D. M. Lee, C. F. Hwang

Texas A&M University

R. A. Bryan

State University of New York, Geneseo

J. R. Chen

Virginia Polytechnic Institute and State University

L. D. Roper, R. A. Arndt

Fermi Laboratory

P. A. Thompson

Lawrence Berkeley Laboratory

F. T. Shively

Measurements of "D," "R," and "A" parameters (the Wolfenstein parameters) in p-p elastic scattering are proposed. This proposal is very similar to LAMPF Exp. 132, planned for the pion-nucleon system, and identical equipment will be used. Single-energy phase-shift analyses at each energy of the experiment will be done by the group at VPI (Arndt and Roper) at various stages of the experiment, with preliminary data to serve as checks on the experiment. Finally, single-energy and energy-dependent analyses will be done, utilizing the final results and the N-N data set.

The experiment will first study the scattering of 800-, 650-, and 500-MeV protons off longitudinally polarized protons, with subsequent analysis of the momentum and polarization of the recoil protons in a magnetic spectrometer and a carbon analyzing polarimeter. The angular range covered will be 15-40° in the laboratory, corresponding to 30-80° and 100-150° in the center-of-mass system. We will measure two separate combinations of "R" and "A," from which "R" and "A" will be determined to a relative error of 5-10%. The measurement of "D" will call for a transversely polarized proton target, and the angular range covered in this configuration will be 15-80° lab, corresponding to 30-160° cms. The energies selected are ones where the differential cross sections and polarizations have already been measured. At energies near 650 MeV, some less precise measurements of the Wolfenstein parameters are also available.

This proposed experiment is a part of the effort towards the complete determination of the scattering amplitudes in p-p elastic scattering in the LAMPF energy range. It will allow a detailed comparison with the predictions of the presently existing phase-shift solutions. It may shed light on the detailed mechanism of inelastic processes and the existence of the di-baryon resonance D*. Moreover, the information obtained here will enable one to understand the fundamental nucleon-nucleon interaction, which is essential to the understanding of medium-energy nuclear physics — a primary objective of LAMPF.

Exp. 161

THE MICRODISTRIBUTION OF THORIUM IN METEORITES

Jet Propulsion Laboratory

E. L. Haines, Spokesman

California Institute of Technology

D. S. Burnett, J. Weiss, D. S. Woolum

Martin-Marietta Corp., Denver, Colorado

J. Baum

This proposal requests permission to perform irradiations of meteorite samples with high-energy neutrons produced in the beam stop area of the Meson Factory. The purpose of the irradiations is to determine *in situ* the concentration of thorium in individual mineral grains in the meteorite sample. The samples will have been previously exposed to thermal neutrons in order to determine the uranium contents of the same grains; consequently, it will be possible to calculate thorium/uranium ratios for the individual grains. This is the quantity of prime scientific interest. The basic technique is to irradiate a polished section of the meteorite that is covered with a sheet of mica. The mica records fission fragment tracks from the induced fission of the thorium and uranium. Standard glasses of known uranium and thorium content are also irradiated in order to determine absolute concentrations and the relative thorium and uranium fission cross sections that are necessary to separate the contributions of thorium and uranium in the high-energy bombardment.

Exp. 162

STUDIES OF THE (π^+, π^0) REACTION ON LIGHT ELEMENTS

Tel Aviv University, Israel

J. Alster and A. I. Yavin, Spokesmen

Y. Shamai, S. Cochavi, D. Ashery

LASL

M. A. Moinester (Tel Aviv University), C. M. Drake, E. D. Arthur

We propose to study the single-pion charge-exchange reaction on light elements in the energy region 50-300 MeV. The process of the (π^+, π^0) reaction on nuclei is currently not well understood. Plane wave impulse calculations for (π^+, π^0) analog-state transitions have been performed for light nuclei and give an excitation curve with a *maximum* near the energy of the (3,3) resonance. Distorted wave calculations have also been carried out for these transitions employing the Kisslinger nonlocal optical potential, and predict a *minimum* in the excitation function in the region of the (3,3) resonance. The data that exist are scarce and cannot be explained by any calculation.

We propose to use the Low-Energy Pion channel and to investigate the excitation functions for the reactions (π^+, π^0) on ^{13}C (analog transition only), ^7Li (analog + excited analog transition), ^{14}N (single nonanalog transition), and ^{10}B (two nonanalog transitions). The activities of the residual nuclei will be measured with Ge(Li) and NaI(Tl) detectors. For the short-lived activities (^{10}C and ^{14}O), we will use the pendulum method to measure the activity in a shielded region in the target room, but far from the beam line. For the 10.0-min ^{13}N activity, the measurement will be carried out in a shielded area outside the target room. The 53 days ^7Be activity will be measured in our laboratory at Tel Aviv, where the background counting rate in the energy region of interest is ~ 50 counts per (day)-(keV). All the data can be collected in 24-h running time with good

statistics. The experimental results will then be compared with the various available calculations.

Exp. 163

INVESTIGATION OF CHANGES IN CHARGE DISTRIBUTIONS FOR NUCLEI NEAR $Z = 28$ BY ELECTRON SCATTERING AND MUONIC X RAYS

LASL

E. B. Shera and R. B. Perkins, Spokesmen

G. Rinker, H. D. Wohlfahrt

Oregon State University

K. S. Krane

Massachusetts Institute of Technology

J. Negele

Florida State University

R. K. Sheline, L. Wagner

Purdue University

R. M. Steffen

Institut für Kernphysik der KFA Jülich

P. Kleinheinz

Energy Research & Development Administration

E. T. Ritter

University of Mainz, Germany

G. K. Fricke

Elastic electron scattering cross sections up to the second minimum have been measured with the electron-scattering equipment of the Mainz 300-MeV linac for the isotopes $^{54,56,58}\text{Fe}$, ^{59}Co , $^{58,60,62,64}\text{Ni}$, $^{63,65}\text{Cu}$, and $^{64,66,68,70}\text{Zn}$.

The main objective of these measurements has been to investigate relative changes of the charge distributions as a result of adding protons and/or neutrons near the $1f_{7/2}$ and $2p_{3/2}$ shell.

In order to obtain all possible information about the charge distributions of these nuclei, we also would like to measure the x-ray spectra of these μ -atoms. It would then be possible

- 1) to make an improved model-independent analysis of the nuclear charge distribution,
- 2) to compare with experimental results the available restricted H.F.B. calculations in the $1f, 2p$ shell with ^{40}Ca as core, and
- 3) to compare the results of these two methods, which yield information on polarization of nuclei, radiation corrections, vacuum polarization, and Lambshift.

Exp. 164

**PION TOTAL CROSS-SECTION MEASUREMENTS WITH AN
ORIENTED ^{165}Ho TARGET**

Lockheed Research Laboratory, Palo Alto, California

T. R. Fisher, Spokesman

National Bureau of Standards

H. Marshak, Spokesman

University of Basel, Switzerland

H. O. Meyer

University of Washington

I. Halpern, R. Marrs

LASL

M. D. Cooper, R. P. Redwine, D. C. Hagerman

Stanford University

J. Calarco

Temple University

K. F. Johnson

University of Montana

M. J. Jakobson, R. H. Jeppesen

New Mexico State University

G. R. Burleson

In order to obtain information on the relative neutron and proton deformations in a strongly deformed nucleus, we propose to measure π^- and π^+ total cross sections for an aligned target of ^{165}Ho . The measurements will be carried out at 25-MeV energy intervals from 100 to 300 MeV using the Low-Energy Pion channel. A nuclear alignment $B_2/B_2(\text{max}) = -0.45$ will be obtained by cooling a single crystal of holmium metal to a temperature below 0.1 K. The unaligned total cross section will be measured in the same geometry with the target temperature of 4 K, so that the difference in aligned and unaligned cross sections or "deformation effect" can be accurately obtained. The aim is to measure the deformation effect to an accuracy of a few percent for both π^- and π^+ beams. At this level of accuracy, differences of the order of 10% in the neutron and proton deformations β_n and β_p should be readily discernible.

Exp. 165

MUONIUM FORMATION IN HELIUM AND OTHER RARE GASSES

Yale University

V. W. Hughes, Spokesman

R. Stambaugh, P. A. Souder, D. C. Lu, S. Dhawan, T. Crane, D. Casperson

University of Heidelberg

G. zu Putlitz

Fermi Laboratory

P. A. Thompson

Swiss Institute for Nuclear Studies

H. Kaspar

We propose to search for the formation of muonium (μ^+e^-) in helium and other rare gasses, or, more generally, to investigate the behavior of positive muons stopped in helium and other rare

gases. By classical methods of studying the precession of the muon magnetic moment, we will search for free muon precession and for muonium Larmor precession.

For helium, it is important to understand the behavior of positive muons in the gas, including the question of whether muonium is formed, in order to interpret recent experimental results on the behavior of positive muons in liquid helium. The behavior of positive muons stopping in helium gas is basically the atomic and molecular problem of what are the final equilibrium states of a positive muon stopped in helium, and is determined by the collision cross sections for the various atomic processes. It is interesting to study positive muons stopped in other rare gases as well, because very different behaviors for muonium formation are expected for the different rare gases.

Exp. 166

MUONIC X RAYS AND NUCLEAR CHARGE DISTRIBUTIONS ELECTRIC QUADRUPOLE MOMENTS OF $_{67}\text{Ho}^{165}$ AND $_{73}\text{Ta}^{181}$

California Institute of Technology

R. J. Powers, Spokesman

F. Boehm, P. Vogel

University of Wyoming

A. R. Kunselman

In light of the fact that it is expected that LAMPF will be operating at between 1- and 3- μA proton current during the first six months of 1974, we would like to propose the following experiment which can be performed at relatively low intensities. This proposal has the merits that it should produce some good physics, and also it will allow us some experience with the muon channel beam before the high-intensity beams arrive.

Exp. 167

HEAVY FRAGMENT FORMATION FOLLOWING π^- ABSORPTION IN ^{12}C

University of Virginia

K.O.H. Ziock, Spokesman

J. Comiso, R. C. Minehart

In two separate experiments, we will measure

1. the branching ratios for the emission of heavy fragments ($A \geq 3$), emitted following π^- capture in ^{12}C , as a function of energy. This experiment is designed to provide information to the biomedical users of the channel.
2. the branching ratios or the formation of particle unstable states of ^4H , as formed in the reactions

and

Exp. 168

FORMATION OF ${}^4\text{H}$ FOLLOWING π^- ABSORPTION IN ${}^6\text{Li}$ AND ${}^7\text{Li}$

University of Virginia

K.O.H. Ziock, Spokesman

R. C. Minehart, J. Comiso

In two separate experiments, we will measure

1. the branching ratios for the emission of heavy fragments ($A \geq 3$), emitted following π^- capture in ${}^{12}\text{C}$, as a function of energy. This experiment is designed to provide information to the biomedical users of the channel.
2. the branching ratios or the formation of particle unstable states of ${}^4\text{H}$, as formed in the reactions

and

Exp. 169

REQUEST FOR PROTON IRRADIATIONS AT LAMPF FOR PROJECT JUMper

LASL

C. J. Orth and J. E. Sattizahn, Spokesmen

We have been requested to provide uranium-tracer radioactivity for use in the Los Alamos Scientific Laboratory's project JUMper. In order to meet this request, we propose to produce 10- to 1000- μCi amounts of 21-d ${}^{230}\text{U}$ and 4.2-d ${}^{231}\text{U}$ per irradiation from 300- to 800-MeV proton-induced spallation of ${}^{237}\text{Np}$; the optimum energy is between 400 and 600 MeV.

We are requesting the first irradiation as soon as possible to work out the chemical separation procedures, to measure the production cross sections, and to confirm the integrity of the target assembly. Assuming the project proceeds successfully, we anticipate a need for one or two irradiations per month of 1- to 4-h duration at a beam intensity of 10 to 30 μA . We prefer the use of the Line A-direct, switchyard irradiation facility because of the small beam spot.

The target material, 200-mg ${}^{237}\text{NpO}_2$, is a potentially dangerous substance, and, according to LA-4400, the maximum permissible body dose is 96 μg of ${}^{237}\text{NpO}_2$. Neptunium-237 is an α -emitting bone seeker similar to ${}^{239}\text{Pu}$; however, it has ≈ 100 -fold lower specific activity than ${}^{239}\text{Pu}$ due to its longer 2.14×10^6 -y half-life. The 200-mg targets will emit 4.7×10^6 alphas per second. The target assembly, which is described in the following paragraph, will degrade a 500-MeV proton beam by 1.6 MeV, resulting in the dissipation of ≈ 16 W at 10 μA . This should cause no difficulty because the melting point of NpO_2 is $\approx 2000^\circ\text{C}$ and the target assembly will be mounted on a water-cooled heat sink.

The targets are constructed by placing the NpO_2 in a 2-cm-diam capsule consisting of an overlapping lid and base of 0.005-in.-thick copper sealed with soft solder. This capsule is then placed into a slightly larger copper lid and base, and this outer container is also sealed with soft solder. This double-sealed copper container will be seated in a depression in the aluminum target holder and then covered with a 0.005-cm aluminum foil securely clamped to the holder.

Disassembly and processing of the targets will be done at TA-48.

Exp. 170

STUDY OF THE REACTION $^{13}\text{C}(\pi^+, \pi^0)^{13}\text{N}$ (GROUND STATE)

Tel Aviv University, Israel

J. Alster, Spokesman

A. I. Yavin, Y. Shamai, D. Ashery

LASL

C. M. Drake, E. D. Arthur, M. Zaider, M. A. Moinester (Tel Aviv University)

We propose to study the single-pion charge-exchange reaction $^{13}\text{C}(\pi^+, \pi^0)^{13}\text{N}$ (ground state) by measuring the 10-min β^+ activity of ^{13}N . The measurements will be done at $E_{\pi^+} = 100, 130$, and 180 MeV.

We will use the Low-Energy Pion channel. Because of the short bombardment times involved, we propose to do this experiment on a *standby basis*.

During the low-intensity operation of the accelerator, we will calibrate our monitoring system, whereas the ^{13}C bombardments will be done at higher intensity [$\sim (2-5) \times 10^6$ pions/s at $E_{\pi^+} = 100$ to 200 MeV].

All the equipment is built and tested in actual running conditions.

Exp. 171

**STUDY OF NEGATIVE-PION BEAMS BY
PLASTIC NUCLEAR TRACK DETECTORS**

University of San Francisco

E. V. Benton, Spokesman

M. R. Cruty, R. P. Henke

LASL

M. R. Raju

A series of biomedically oriented experiments designed to measure and evaluate the high-LET (linear-energy transfer) portion of the negative-pion beams by means of plastic nuclear track detectors is proposed. The main objectives are given here.

a. *Dosimetric studies.* These basic studies involve the measurement of the LET, charge, and range spectra of high-LET, $Z > 1$ fragments produced by negative-pion interactions in special plastic detectors placed within a suitable phantom; the detectors are designed to simulate the stopping power of tissue (tissue equivalence). Additionally, the variation of these spectra within the phantom, together with the variation of the high-LET dose as a function of total dose within the phantom, will be investigated. The necessary measurements and data-reduction techniques have already been developed and used in our previous proton and heavy ion experiments with plastic detectors.

b. *Beam diagnostics.* The use of plastic detectors to accurately determine the three-dimensional location and shape of the stopping pion beam in phantoms will be investigated. Our experience in heavy ion beam dosimetry at LBL will serve to provide guidelines for development of a pion beam diagnostic technique.

c. *Pion radiography.* The possibility of using pions for radiography will be investigated, using both photographic film and stacks of plastic detectors. The main objectives here will be the determination of the depth and lateral resolution of the image.

A main objective of this study is to make an intercalibration and comparison of the high-LET beam characteristics at LAMPF and Stanford. A similar study by us, designed to evaluate heavy ion beams at the LBL Bevatron-Bevalac, is already in progress.

Exp. 172

A PROPOSAL TO MEASURE THE HELICITY OF μ DECAY ELECTRONS

University of Chicago

E. Swallow, Spokesman

The only experimentally observed process in which the weak interaction can be studied uncomplicated by strong interaction effects is the decay of the muon. Precise determination of the μ decay parameters is thus of fundamental significance, particularly at a time when there is heated theoretical activity directed toward formulating a unified theory of weak and electromagnetic interactions. Likewise, it is important to establish a firm empirical base for the common assumption that the structure of the weak leptonic current is "well known," so that it can then be used with confidence to probe the structure of the hadrons. The program of research proposed here has as its objective a substantial improvement of our knowledge of the μ decay parameters.

Exp. 173

PHYSICS OF THE PION AND THE PIONIC ATOM

California Institute of Technology

P. Vogel and F. Boehm, Spokesmen

H. E. Henrikson, A. A. Hahn, J.-L. Vuillieumier, R. J. Powers, K. C. Wang, J. Miller

University of Wyoming

A. R. Kunselman

Fermi Laboratory

P. A. Thompson

LASL

J. Thomas

We propose to measure pionic x rays from few-nucleon systems in the 2- to 10-keV region with a new, efficient silicon-crystal diffraction spectrometer. We anticipate using the focused pion beam of the SMC-East Leg. From the results, parameters pertaining to the fundamental pion-nucleon interaction will be obtained.

Studies of pionic x rays from simple few-nucleon systems allow us to determine the pion-nucleon interaction parameters. By comparing transition energies from pionic ${}^1\text{H}$, ${}^2\text{H}$ and ${}^3\text{He}$, ${}^4\text{He}$, the role of the different isospin parts in the interaction (as described by an optical model) can be elucidated.

An experimental method extending the use of a reflection-type diffraction crystal spectrometer down into the keV region is now being developed at Caltech. Moderate resolutions of 1% and good efficiencies of 10^{-5} are anticipated by using the 111 planes from a large silicon monocrystal. A study of the energies, and in some cases the widths, of the 2p-1s transitions in ${}^1\text{H}$, ${}^2\text{H}$, ${}^3\text{He}$, and ${}^4\text{He}$ is proposed, and an accuracy of one part in 10^4 is aimed for.

The proposed experiment will be ready for staging in the fall of 1977. As the data rate will be slow (a few counts per minute), a large block of beam time will be requested.

Exp. 174

**INVESTIGATION OF THE CHEMICAL REACTIONS OF ATOMIC ^{18}F AS A MEANS
FOR DIRECT SYNTHESIS OF ^{18}F -LABELED COMPOUNDS**

University of California, Irvine

G. E. Miller and F. S. Rowland, *Spokesmen*

W. G. Smith

LASL

P. M. Grant

We wish to investigate the potentialities of fast neutrons produced at the LAMPF main beam stop for direct synthesis of ^{18}F -labeled compounds. Our studies of ^{18}F atom chemistry at the microcurie level, using 14-MeV neutrons at a flux of approximately $5 \times 10^9 \text{ n-cm}^{-2}\text{-s}^{-1}$, have shown that in gaseous samples containing excess SF_6 , most of the ^{18}F atoms resulting from the $^{19}\text{F}(\text{n},2\text{n})^{18}\text{F}$ reaction react directly with substrate molecules present in small amounts. In several such systems, more than 50% of the ^{18}F atoms are subsequently found incorporated into one specific carrier-free molecule. Our long-range interest in LAMPF irradiations involves the possibility that proper control of such experiments at the multi-mCi level may result in useful organic radio pharmaceuticals.

In the initial phase, we propose to repeat experiments with systems already well studied at the University of California, Irvine, using similar flux levels and doses as available at LAMPF, to provide details on any effects introduced by the different irradiation conditions. We then intend to work up steadily to higher levels of radioactivity, with continual assessment of any problems introduced with the higher neutron fluxes. None of the ^{18}F -labeled products formed in these initial experiments have any known use as radiopharmaceuticals; however, these experiments should reveal the nature and magnitude of the interaction of any radiation chemistry with the ^{18}F chemistry in the system. This information is essential in assessing the potentialities of LAMPF neutrons for direct synthesis of useful quantities of ^{18}F -labelled compounds.

Detailed planning and scheduling will depend heavily on the availability of information regarding neutron energy and intensity distributions from other experimenters.

Exp. 175

SEARCH FOR THE FORMATION OF MUONIC HELIUM ($\alpha\mu^-e^-$)

Yale University

V. W. Hughes, *Spokesman*

R. Stambaugh, P. A. Souder, D. C. Lu, S. Dhawan, T. Crane, D. Casperson

University of Heidelberg

G. zu Putlitz

Fermi Laboratory

P. A. Thompson

Swiss Institute for Nuclear Studies

H. Kaspar

In an experiment at LAMPF, we have measured the depolarization of negative muons in helium gas and have searched for formation of the muonic helium atom, $\alpha\mu^-e^-$. The Stopped Muon channel provided a flux of 90-MeV/c longitudinally polarized negative muons. Our gas target was an aluminum pressure vessel lined with tin and tantalum, and fitted with internal

scintillation counters. It was filled either with 50 atm of ultranigh-purity helium gas or with the helium together with 0.1% xenon.

The "nucleus" $(\alpha\mu^-)^+$ of the muonic helium atom is formed when μ^- is captured by a helium atom and cascades to the ground state of $(\alpha\mu^-)^+$, with both helium electrons being ejected by Auger processes. The $(\alpha\mu^-)^+$ cannot capture an electron to form muonic helium in a collision with a helium atom from energetic considerations, but a xenon atom can serve as an electron donor to form $\alpha\mu^-e^-$.

The method of detection of the $(\alpha\mu^-)^+$ and of the $\alpha\mu^-e^-$ is to observe the characteristic Larmor precession frequency of 13.6 kHz/G and 1.40 MHz/G, respectively, in a transverse magnetic field. The decay positrons are counted as a function of time after the muons stop in the gas target. The data are fit to the equation

$$N(t) = N_0 \left\{ e^{-t/\tau} [1 + A \cos(\omega t + \phi)] + B \right\},$$

in which A is the precession amplitude and ω is the precession frequency.

We observe that the "free" muon precession amplitude in the run searching for $(\alpha\mu^-)^+$ is low, and indeed much lower than the precession amplitude observed for μ^- in carbon and many other materials, indicating, therefore, some other depolarizing mechanism than spin-orbit interaction in the $\alpha\mu^-$ atom. The observed amplitude of the characteristic precession frequency for $\alpha\mu^-e^-$ is consistent with no formation of the muonic helium atom.

Exp. 176

P-NUCLEUS TOTAL AND TOTAL REACTION CROSS-SECTION MEASUREMENTS

Kent State University

B. D. Anderson, Spokesman

LASL

R. J. Barrett, N. Jarmie

Case Western Reserve University

P. R. Bevington, H. B. Willard, H. W. Baer, F. W. Cverna, M. W. McNaughton

University of California, Davis

N. King

The purpose of these measurements is to determine the total and total reaction cross sections for proton scattering by various nuclei at incident energies of 400-800 MeV. These measurements would provide constraints to any theoretical description of nucleon-nucleus scattering. Additionally, they will be intended to provide as direct a measurement as possible of the change in the nuclear-matter radii of different isotopes of an element. The experiment would supplement other experiments to be performed at LAMPF with the HRG or EPICS facilities.

Measurements would be performed in a transmission geometry with multiple-wire proportional counters. Recent developments in experimental technique would be adapted so that the measurements could be performed precisely and quickly on many nuclei with a minimum of beam time required. The entire experimental arrangement would be simple and flexible to readily allow consideration of new targets or energies if theoretical interest should so suggest.

Exp. 177

**QUASI-ELASTIC KNOCKOUT OF ALPHA PARTICLES BY
MEDIUM-ENERGY PROTONS**

University of California, Los Angeles

G. J. Igo and T. S. Bauer, Spokesmen

C. A. Whitten, J. C. Fong, G. Pauletta, J. Soukup

LASL

G. W. Hoffmann

Quasi-elastic knockout of α particles will be measured in the laboratory angular range 35 to 72°. This corresponds to protons in the elastic case from 25 to 85° in the laboratory.

The experiment will attempt to verify the quasi-elastic mechanism at 800 MeV. This will be done by using HRS to look at protons in the range from 25 to 85°, in coincidence with α particles detected in a semiconductor telescope of resolution of 1 to 2 MeV.

In light "4N" nuclei, by virtue of the impulse approximation, we will measure the "effective number" of α particles. We will examine neighboring nuclei of near "4N" types. In heavy nuclei, we will study surface clustering.

Exp. 178

PROTON-SCATTERING SURVEY ON s-d SHELL NUCLEI

LASL

J. E. Spencer, Spokesman

J. Pratt, M. Oothoudt, C. L. Morris, G. W. Hoffmann, T. Kozlowski, D. G. Madland

Northwestern University

H. Nann

University of Minnesota

N. M. Hintz, Spokesman

G. Kyle, D. Dehnard

The purpose of this experiment is to study, in the deformed part of the s-d shell, the

1. nuclear shapes (β_2 , β_4 , β_6 . . . deformations) and, correspondingly, nuclear-reaction mechanisms,
2. differences between matter and spin distributions (proton scattering) and charge and magnetization distributions (comparison with electron scattering),
3. low-excitation collective rotational vibration modes — microscopic structure, and
4. giant resonance behavior, including possible splitting due to nonspherical shape (Nuclear Zeeman effect).

The basic outline of the experiment is presented in the main body of the proposal. Additional justification for the experiment and related information from other experiments is presented here.

Exp. 179

**DIFFERENTIAL PRODUCTION CROSS SECTIONS OF MULTIPLY-CHARGED
FRAGMENTS IN PROTON- AND PION-INDUCED SPALLATION
OF LIGHT NUCLEI**

LASL

J. D. Bowman, Spokesman

J. N. Bradbury, J. F. Dicello, R. E. Mischke, R. H. Heffner, M. Zaider

Washington State University

H. B. Knowles, S. C. Luckstead, G. E. Tripard

The proposed experiment is the measurement of production cross sections of multiply-charged fragments resulting from proton- and pion-induced spallation of light nuclei. Nuclei in the range $Z = 3$ to 14 will be exposed to beams of stopping π^- , energetic π^- and π^+ (20-300 MeV), and energetic protons (100-800 MeV). The yield as a function of mass, charge, energy, and angle of the emitted fragments will be determined. Fragments with specific energies greater than ~ 2 MeV/nucleon will be detected, using a conventional δE -E solid-state counter telescope. A thin δE detector with good time resolution (< 0.5 ns) is to be developed in order to employ a δE -E time-of-flight technique for determining the characteristics of fragments with lower specific energies. These data are important for understanding the spallation mechanism, and also have direct application to certain radiobiological, radiation-protection, and astrophysical problems.

Exp. 180

ELASTIC AND INELASTIC π^+ -NUCLEUS SCATTERING AT 25, 50, AND 75 MeV

Carnegie-Mellon University

R. A. Eisenstein, Spokesman

P. D. Barnes, S. A. Dytman, K.G.R. Doss, J. N. Craig, W. R. Wharton

LASL

J. F. Amann

We propose to study elastic and inelastic pion (π^+) scattering on two targets as a measurement that will greatly restrict the ambiguity existing in pion-nucleus optical potentials, as well as test pion inelastic-scattering predictions. The reactions $^{24}\text{Mg}(\pi^+, \pi^+)^{24}\text{Mg}^*(2^+)$ and $^{58}\text{Ni}(\pi^+, \pi^+)^{58}\text{Ni}^*(2^+)$ will be investigated at 25, 50, and 75 MeV on the LEP channel. The outgoing pions will be detected with an intrinsic germanium spectrometer. Cross-section predictions have been made for typical optical potentials, and the b_0 and b_1 tested. We find that the greatest sensitivity will be to $\text{Re } b_1$, with somewhat less sensitivity to $\text{Im } b_0$ and $\text{Im } b_1$. The calculations for the inelastic cross section use a standard (phenomenological) inelastic form factor expressed in terms of the deformation parameter, β_2 , which has been measured for these nuclei at low energy. Our measurement of elastic and inelastic cross sections will provide a stringent constraint on the parameters b_0 , b_1 , and β_2 used in this model.

Exp. 181

MEASUREMENTS OF THE $\pi^-p \rightarrow \pi^0n$ ANGULAR DISTRIBUTION AT LOW ENERGIES AND CALIBRATION OF THE π^0 SPECTROMETER

Tel Aviv University

J. Alster, Spokesman

M. A. Moinester, S. Gilad

LASL

J. D. Bowman, Spokesman

R. H. Heffner, M. B. Johnson, C. M. Hoffman, M. D. Cooper, J. Potter

Case Western Reserve University

H. W. Baer, P. R. Bevington, F. H. Cverna

Progress on this experiment includes detailed Monte Carlo studies of the behavior and resolutions of the devices that have enabled us to settle on design parameters. In addition, we propose to measure a specific process, $\pi^-p \rightarrow \pi^0n$, at low energies. This process will be measured both to calibrate the spectrometer and to provide significant input to the low-energy πN phase-shift analysis.

Exp. 182

SHORT-LIVED RADIOACTIVITIES FROM PION BOMBARDMENT

University of Colorado

R. J. Peterson, Spokesman

J. J. Kraushaar

LASL

N. Ensslin

Indiana University

M. E. Rickey

A fast rabbit system is proposed for the study of the short-lived radioactivities induced by pion beams on the LEP line. The system is complete, and currently in use on other projects. A number of interesting decay schemes may be studied, yielding information on the reaction mechanism and the half-lives of interesting nuclei. This latter information may be used to infer the nuclear masses. The most interesting reaction would be $(\pi^-, {}^3\text{He})$, which has the effect of picking up three protons. Targets of ${}^{19}\text{F}$, ${}^{23}\text{Na}$, and ${}^{27}\text{Al}$ are ideal for observing this reaction.

Exp. 183

PROTON-SCATTERING SURVEY ON HEAVY DEFORMED NUCLEI

University of Minnesota

N. M. Hintz, Spokesman

D. Dehnhard, G. Kyle

LASL

J. E. Spencer, Spokesman

N. Tanaka, J. Pratt, D. G. Madland, M. Ootoudt, T. Kozlowski, C. L. Morris, G. W. Hoffmann

The purpose of this experiment is to study, in the heavy deformed and shape transition nuclei, the

1. nuclear shapes (β_2 , β_4 , β_6 . . . deformations) and, correspondingly, nuclear-reaction mechanisms,
2. differences between matter and spin distributions (proton scattering) and charge and magnetization distributions (comparison with electron scattering),
3. low-excitation collective rotational and vibration modes — microscopic structure, and
4. splitting of "giant resonances" due to nonspherical nuclear shape (Nuclear Zeeman effect).

The basic outline of the experiment is presented in the main body of the proposal. Additional justification for the experiment and related information from other experiments is presented.

Exp. 184

PRODUCTION OF ${}^{82}\text{Sr}$

LASL

H. A. O'Brien, Spokesman

A. E. Ogard, J. E. Sattizahn

This experiment was used to produce ${}^{82}\text{Sr}$, which was the first radioisotope produced at LAMPF and shipped to an outside medical research team.

Exp. 185

DEUTERON PRODUCTION IN $np \rightarrow d\pi\pi$

LASL

J. E. Simmons, Spokesman

B. E. Bonner

University of Birmingham, England

C. D. Blyth, J. D. Davies, J. S. McKee, L. Riddiford

The object of this proposal is to investigate the deuteron production process observed in the $np \rightarrow d\pi\pi$ reaction. It is proposed to

- a. measure the complete double differential cross section for deuterons from the reaction with an incident neutron energy $T_n = 800$ MeV,
- b. hence, obtain a value for the total cross section (σ_T) at $T_n = 800$ MeV, and
- c. obtain an approximate value for σ_T at $T_n = 700$ MeV.

The liquid-hydrogen target and the proportional wire-chamber magnetic-spectrometer system, constructed in Area B for Exps. 56 and 125, will be used to produce the deuterons and define their trajectories. Because background problems will be considerable, further particle identification is provided by improving the existing dE/dx time-of-flight systems, and by including a large area Cerenkov counter of high uniform detection efficiency. A cylindrical scintillator wrapped round the hydrogen target will flag the $\pi^+\pi^-$ channel and, hence, allow a simultaneous determination of the $T = 0$ and $T = 1$ contributions to be obtained.

If the present proposal is accepted and this experiment follows that proposed in Exp. 129, it is estimated that 120 h of machine time at 1974 beam levels will provide 5×10^4 events from the $np \rightarrow d\pi\pi$ reaction at $T_n = 800$ MeV and a few $\times 10^2$ events at $T_n = 700$ MeV. These measurements will be the first with good statistics below 1 GeV, and are made possible by the quality of the neutron beam available at LASL. The measurements will help to distinguish between the various theories of the particular enhancements seen in this reaction at higher energies and, in parallel, few-nucleon reactions.

Exp. 186

MEASUREMENT OF (p,π^+) AND (p,π^-) REACTION CROSS SECTIONS ON COMPLEX NUCLEI

University of Colorado

R. J. Peterson, Spokesman

R. E. Anderson, J. J. Kraushaar

LASL

N. Ensslin

Indiana University

M. E. Rickey

It is proposed to measure the (p,π^-) , and in one case the (p,π^+) , reaction cross sections on several light nuclei as a function of bombarding energy from 300 to 800 MeV. The cross sections will be determined by measuring the amount of induced radioactivity using Ge(Li) gamma-ray counters and a fast rabbit system for transporting the target a short distance from the bombardment area to a nearby low-background counting area. Particular emphasis will be placed on comparing the $^{19}\text{F}(p,\pi^+)^{20}\text{F}$ to the $^{19}\text{F}(p,\pi^-)^{20}\text{Na}$ reaction.

Exp. 187

**NUCLEAR GAMMA RAYS PRODUCED BY NEGATIVE PIONS STOPPING IN
CARBON, NITROGEN, OXYGEN, AND TISSUE**

University of Mississippi

J. J. Reidy, Spokesman

LASL

J. N. Bradbury, J. F. Dicello, R. L. Hutson, M. Leon, A. S. Lundy

University of M $\ddot{u}$ nich

H. Daniel, K. Springer

Washington State University

H. B. Knowles

Prompt gamma rays and pionic x rays arising from stopped negative pions will be measured in various targets by conventional techniques. The stopped pions will be obtained from the Biomed channel as a parasitic experiment. "Signature" gamma rays from pion capture on compounds of carbon, nitrogen, and oxygen of known composition will be determined and, subsequently, used to determine pion-capture fractions in tissue samples and one or more "tissue-equivalent" materials. The results have both basic nuclear-structure significance and value to the pion therapy program; in addition, when combined with muon-capture measurements, some inferences on the similarity between pion and muon capture may be drawn.

Exp. 188

NEGATIVE-PION EFFECTS ON IMMUNOCOMPETENT CELLS

University of Texas, Dallas

D. E. Carlson, Spokesman

A study is proposed to quantitate the effects of negative pions on cells involved in both cellular and humoral immune responses.

Experiments will assay primed and unprimed T cells, as well as primed and unprimed B cells. With a hapten-carrier system, T-cell function will be assayed by means of carrier recognition, and B-cell function will be followed by enumeration of cells that synthesize antibody against the hapten.

For the cellular immune response, the action of negative pions in inactivation of cells capable of mediating cytotoxicity against transplanted plasmacytomas will be studied. Immune spleen cells will be taken from immunized donors and transferred, together with viable myeloma cells, to a second recipient. Pion inactivation will be quantitated on the basis of diminished ability of irradiated immune cells to abrogate outgrowth of the transferred myeloma.

Pions from both peak and plateau will be used to generate dose-survival curves for each class of immunocompetent cells. These results will be compared with survival curves generated by conventional ^{60}Co gamma rays. Data from this study will provide valuable RBE comparisons for the action of pions on immunocytes at the tumor site, as well as for estimating pion effects in intervening tissue included in the radiation field.

Exp. 189

**SEARCH FOR CONDENSED NUCLEAR STATES AND STUDY OF
HIGH- q^2 LOW- ν NUCLEAR INTERACTIONS**

LASL

O. B. van Dyck, Spokesman

R. D. Werbeck

University of Pennsylvania

S. Frankel, W. Frati, W. Yang

Temple University

V. L. Highland

High-energy protons do not scatter backward elastically from nuclei with any appreciable probability at high-momentum transfer (q^2) and with low-energy transfer (ν). They would, however, form condensed nuclear states that possessed very high nucleon binding energies.

High-energy protons passing through a bending magnet, striking a target, and bouncing back elastically would pass backwards through the magnet (now serving as a momentum analyzer) and fan out into a simple counter telescope with the dE/dx and time-of-flight capability.

Even if condensed states were not present in ordinary matter, the low- ν high- q^2 scattering region studied in this experiment is virtually unexplored.

Sensitivities for condensed nuclei would be $\sim 10^{-15}$ condensed nuclei/nucleus for unprocessed targets using a 20-mb σ estimate.

The study consists of measurements of $\sigma_p(q^2)$, extrapolated to $\nu = 0$. As a byproduct, $\sigma_a(q^2)$ and $\sigma_t(q^2)$ are obtained.

Exp. 190

A PRECISION MEASUREMENT OF THE $\pi^- - \pi \pi^0$ MASS DIFFERENCE

University of Virginia

K.O.H. Ziock, Spokesman

J. Comiso, R. C. Minehart

We propose to measure the mass difference between the negative and the neutral pion with an accuracy of ± 500 eV by precisely measuring the energy of the neutron in the reaction

$$\pi^- + p \rightarrow \pi^0 + n ,$$

making use of the unique microstructure of the Low-Energy Pion channel beam.

Exp. 191

π^- -NUCLEUS INELASTIC SCATTERING TO GIANT RESONANCES

University of Washington

I. Halpern, Spokesman

D. Chiang

Carnegie-Mellon University

P. D. Barnes, R. A. Eisenstein, J. D. Sherman, K.G.R. Doss, J. N. Craig, W. R. Whar-
ton

LASL

M. D. Cooper, J. F. Amann

University of Wisconsin

L. Knutson

The aim of the proposed feasibility study is to see whether an available two-component intrinsic germanium telescope can be used to study nuclear excitations induced by inelastically scattered pions which lose energies up to about 30 MeV. The detector in question has been developed by the Carnegie-Mellon group and can distinguish positive pions from other particles and measure their energy in the range from about 35 to 50 MeV. We propose to use incident pions of energy somewhat greater than 50 MeV, on a zirconium or lead target, to examine the pion-energy spectrum in the interval of excitation energies from 5 to 15 MeV.

The main current interest in such spectra arises from structures several MeV wide that have been observed in similar spectra with other projectiles. These structures have been associated with multipole excitations; i.e., it appears that the nuclear levels of given spin and parity to which transitions from the ground state go strongly are characteristically bunched rather than broadly dispersed in energy.

The spins and parities (and hence their multipolarities) of the observed structures may be unraveled by measurement of angular distributions. Because of their low mass (compared with other strongly interacting projectiles), pions may have some advantages over other projectiles in producing identifiable multipole excitations.

The proposed run will be largely devoted to counter tests to establish that the observed particles are really inelastic pions rather than (1) an energy-degraded component of the pion beam that elastically scatters in the target, (2) elastic pions that have a nuclear interaction in the detector, (3) muons or electrons, or (4) other forms of background.

Exp. 192

MEASUREMENT OF THE EMITTANCE GROWTH IN H⁻ STRIPPING

LASL

T. D. Hayward, Spokesman

E. A. Knapp, G. P. Lawrence, R. F. Bentley

The purpose of this experiment is to measure the small-angle scattering that results from the stripping of an 800-MeV H⁻ beam in a thin material stripper.

This will be done by preparing a supercollimated H⁻ beam and then passing it through a suitable stripping target. The angular divergence of the beam will be determined by the beam image recorded on a photographic plate located 50-m downstream from the stripping target.

Exp. 193

**MEASUREMENT OF SMALL-ANGLE NEUTRON ELASTIC
SCATTERING FROM PROTONS**

University of New Mexico

B. D. Dieterle, Spokesman

J. Donahue, C. P. Leavitt, D. M. Wolfe, T. Rupp, R. Carlini, W. Thomas, J. Valentine,
C. Gregory

Temple University

W. K. McFarlane, Spokesman

L. B. Auerbach, V. L. Highland, K. F. Johnson, H. Balshem

LASL

R. F. Bentley, J. Pratt

We propose to measure the neutron-proton differential cross section at neutron lab angles from 2.5 to 2.7°, covering the C.M.S. angular range of about 5 to 65°. Angular resolution will be $\gtrsim 0.3^\circ$. Accuracies expected are $\pm 1\%$ statistical and $\pm 3\%$ absolute. Energies desired are 500, 650, and 800 MeV, in order to complement other data at larger angles.

Elastically scattered neutrons will be distinguished from inelastically scattered neutrons using a neutron time-of-flight detector. For this experiment, it has the advantage that no intermediate calibration need be made to correct for inelastic effects. The well-defined neutron beam ($\delta E \lesssim 10$ MeV) and the beam-chopping capability made time-of-flight measurement possible.

The experiment is proposed for the existing 0° neutron beam line in Area B. The total running time requested is 220 h at an average H⁻ beam of 2 μ .

Exp. 194

P-P, D, R, AND A MEASUREMENT

Case Western Reserve University

P. R. Bevington, Spokesman

H. W. Baer, F. H. Cverna, H. B. Willard, M. W. McNaughton, E. Winkelman

Virginia Polytechnic Institute and State University

L. D. Roper, R. A. Arndt

Texas A&M University

R. A. Bryan

State University of New York, Geneseo

J. R. Chen

LASL

R. R. Stevens, Jr., E. P. Chamberlin

Fermi Laboratory

P. A. Thompson

University of Idaho

H. Willmes

University of California, Davis

N. King

The goal of these experiments is to measure the Wolfenstein "triple-scattering" parameters for the elastic scattering of protons by protons at incident energies of 400-800 MeV. These parameters include the depolarization $D(\theta)$ and $A(\theta)$.

Measurements will be performed with an incident polarized beam of protons from the polarized ion source and analysis of the final polarization through scattering by protons. Identification of purely elastic scattering will be made by detection with MWPCs of forward- and conjugate-scattered protons from the first analyzer, momentum analysis of the conjugate-scattered protons from the first scattering, and dE/dx and time-of-flight analysis with scintillation detectors.

Initially, the depolarization $D(\theta)$, with spins perpendicular to the planes of scattering, will be studied over the laboratory angle range from 10 to 70° (approximately 25 to 145° in the center of mass). Later measurements of the rotation parameters over the same angular range will require only slight modifications to the detection equipment. The running time needed will depend on the availability of incident polarized proton beams at energies below 800 MeV.

The proposed program constitutes part of a long-range effort to study the proton-proton interaction in more detail and higher precision than is now available. It will complement measurements of the polarization-transfer parameters $D_t(\theta)$, $R_t(\theta)$, and $A_t(\theta)$ of Exp. 160, measurements of the differential cross section $\sigma(\theta)$, polarization $P(\theta)$, and spin-correlation parameters $A_{yy}(\theta)$, etc., of Exp. 27, as well as measurements of the neutron-proton and pion-nucleon interaction that are to be carried out concurrently by other groups at LAMPF.

Exp. 195

NUCLEAR RESONANCE EFFECT IN PIONIC ATOMS

LASL

M. Leon, Spokesman

J. N. Bradbury

University of Mississippi

J. J. Reidy, Spokesman

The experiment consists of comparing the pionic x-ray intensities from an "interesting" isotope with those from a reference isotope of the same element. An "interesting" isotope is one for which a significant attenuation of one or more mesic atom x-ray lines, because of the nuclear resonance effect, is predicted. Observations of pionic x rays from ^{110}Cd and ^{111}Cd yielded attenuations which are in good agreement with theoretical predictions. It is proposed that the experiment be extended to include several other physically interesting isotopes. In particular, observation of

pionic x-rays from ruthenium and palladium can provide a check on theoretical predictions of the sign change in the pion-nucleus p-wave interaction.

Exp. 196

A VISUALIZATION EXPERIMENT WITH CHARGED PARTICLES

Technische Universität München

D. H. Daniel, Spokesman

University of Mississippi

J. J. Reidy, Spokesman

LASL

J. A. Helland, R. Hutson, E. A. Knapp

A visualization experiment with particular respect to radiotherapy with negative pions is proposed. The underlying basic concept is to trace charged particles with wire chambers. Two different methods are proposed: tracing the outgoing high-energy electrons ejected by high-energy gamma rays after radiative capture of negative pions in coincidence or not in coincidence with the incoming pion (method 1), and tracing the outgoing positron from mu decay in delayed coincidence with the incoming positive pion (method 2). In method 1, a resolution of the order of 1 mm can be expected for a treatment volume at a depth of 10 cm under muscle when Compton effect in a low-Z converter is used. Method 2 will yield a resolution of 7 mm. Both methods are three dimensional. The experiment can be done almost entirely with existing equipment at the Biomed channel. The rate of recorded events will be about $10^2/s$. Five data-taking shifts, plus two (maybe parasitic) check shifts, are requested for a thorough test of the two proposed methods on a phantom. Because much information on beam and scattering in water will be obtained, this work can very well be regarded as part of channel development.

Exp. 197

INVESTIGATION REACTION $p + d \rightarrow {}^3\text{He} + \pi^0$ AT LAMPF ENERGIES

University of Houston

E. V. Hungerford, Spokesman

J. C. Allred, B. W. Mayes, L. S. Pinsky, J. Lo, S. Bart, K. Koester, T. M. Williams

Rice University

G. C. Phillips, G. S. Mutchler, J. Hudomalj, J. Hoftiezer, W. H. Dragoset, R. D. Felder, J. M. Clement

Differential cross sections for the reaction $p + d \rightarrow {}^3\text{He} + \pi^0$ will be measured for incident proton energies of 500, 600, 700, and 800 MeV. The reactions will be investigated using the EPB facility with a magnetic spectrometer and detecting the ${}^3\text{He}$ for pion center-of-mass angles between 10 and 60°. Absolute values of the cross section will be measured to ~5%.

The experiment tests the various models of (p,π) reactions as a function of momentum transfer. In particular, it will obtain detailed angular distributions at several energies, from 800 MeV, where the model calculations should work best, down to 500 MeV, where the models completely fail at back angles.

Exp. 198

EFFECTS OF PIONS ON DNA OF NONDIVIDING CELL SYSTEMS

Colorado State University

G. E. Powers, Spokesman

University of Colorado

P. Keng

Summary unavailable.

Exp. 199

PION PRODUCTION IN PROTON-PROTON SCATTERING

LASL

R. J. Barrett, Spokesman

N. Jarmie

University of Idaho

A. N. Anderson, H. Willmes

Kent State University

B. D. Anderson

Case Western Reserve University

H. W. Baer, P. R. Bevington, F. H. Cverna, D. J. Ernst, R. M. Thaler, H. B. Willard

We propose to study the pion production reactions

1. $p + p \rightarrow p + n + \pi^+$,
2. $p + p \rightarrow p + p + \pi^0$, and
3. $p + p \rightarrow d + \pi^+$,

with measurements of the doubly differential cross section $d^2\sigma/d\Omega dT(\pi^+)$ at $T_p = 800$ MeV, with an unpolarized beam and a liquid-helium target. Pions from reaction 3, above, will be identified by the two-body kinematics. The remaining π^+ yield will determine the differential and integrated cross-sections for reaction 1 to an accuracy of $\pm 5\%$. A concurrent measurement of the inelastic proton spectra $d^2\sigma/d\Omega dT(p)$ will be made in order to obtain the integrated cross section for reaction 2 with an absolute accuracy of $\pm 10\%$. Approximate corrections should suffice to compensate for multiple pion-producing reactions, which have cross sections more than an order of magnitude lower.

The experiment will be performed on the LAMPF external proton beam with a magnetic spectrometer for momentum analysis, multiwire proportional counters (MWPC) for position resolution, plastic scintillators for time-of-flight analysis, and Cerenkov detectors for particle identifications.

The data from this survey of pion production from proton-proton collisions are needed for theoretical studies of the pion-nucleon interaction, pion-nucleus scattering, and proton-proton phenomenological phase-shift analysis.

Exp. 200

**STUDY OF THE PHOTODETACHMENT SPECTRUM OF H^-
IN THE VICINITY OF 11 eV**

University of New Mexico

H. C. Bryant, Spokesman

J. Donahue, B. D. Dieterle, C. P. Leavitt, H. Sharifian, H. Tootoonchi, D. M. Wolfe

LASL

R. F. Bentley, P.A.M. Gram, T. D. Hayward, G. P. Lawrence

ILC, Sunnyvale, California

P. Lovoi

The unique relativistic H^- beam at LAMPF makes possible photodetachment studies at reasonable counting rates at energies in the H^- system center-of-mass in the vacuum ultraviolet. Since no adequate photon beams in this region have been available heretofore, a theoretically predicted shape resonance in the H^0 -e system at around $n = 2$ (11 eV) has so far not been observed. With rather simple apparatus, this resonance should be observable at LAMPF.

In addition to allowing us to study the shape resonance itself, which is of intrinsic scientific interest, our technique could serve as a way of determining the absolute energy of the H^- beam.

Exp. 201

THE $\pi^+d \rightarrow 2p$ REACTION AT 100-500 MeV

University of Virginia

R. C. Minehart, Spokesman

H.-J. Ziock, J. S. McCarthy, J. Boswell

LASL

A. Wadlinger

Using simple scintillation counters for time of flight and helical wire proportional chambers for spatial resolution, we plan to detect both protons from the $\pi^+ + d \rightarrow 2p$ interaction in a liquid-deuterium target. Angles will be chosen to cover the range $0 < \cos \theta_{cm} < 0.95$, at momenta from 200-650 MeV/c in 50-MeV/c steps. We plan to achieve a statistical accuracy of 1.5%, and an absolute accuracy of $\sim 3\%$. We are asking for a total beam time of 250 h.

Exp. 202

THE (p,t) REACTION ON SPHERICAL NUCLEI

University of California, Los Angeles

G. J. Igo, Spokesman

C. A. Whitten, G. Mardirossi, J. C. Fong, G. Pauletta, J. Soukup, G. S. Adams, T. S. Bauer

LASL

G. W. Hoffmann

The (p,t), along with the inverse reaction, has been the most used tool to investigate the pairing vibrational mode. The importance of pairing vibrations in nuclei was emphasized by A. Bohr and B. Mottelson about six years ago. Since then, many investigations have found interesting

and clear-cut examples of the pairing vibrational mode in nuclear states, particularly in spherical nuclei. (We restrict our attention in the discussion below to spherical nuclei because of the nature of the proposed experimental work.) Clearly, all investigations to date have been at bombarding energies below 50 MeV because of the restricted availability of high-resolution, high-intensity beams and high-resolution spectrometers at facilities above 50 MeV. It is, therefore, intriguing to ask questions about what would be expected to occur at the bombarding energy available at HRS. Four questions immediately come to mind.

1. Can evidence be found for the persistence of two-nucleon correlations in inner shells? Experiments at low-bombarding energies (defined as below 50 MeV) have identified pairing vibrations in which the valence nucleons participate.

2. Is the pairing-vibrational mode excited as strongly compared to other modes, i.e., 1p-1h collective excitations (p,p'), as it is at low-bombarding energies?

3. Will the expectation that *high angular-momentum* pairing-vibrational modes be preferentially excited be borne out by the experimental data?

4. Can we learn about high-momentum components in the wave function of pairing-vibrational states?

We choose as our goals in this proposal the four questions posed above. We choose as our targets the spherical nuclei in the lead, tin, and calcium regions of the table of isotopes, because these have provided the clearest-cut examples of pairing-vibrational modes in low-energy nuclear physics.

There is no question that this experiment is better done at HRS than at Saclay because the cross section is expected to be small and, therefore, the high-beam intensity at HRS is an important factor.

Exp. 203

MEASUREMENT OF THE REAL PART OF THE FORWARD-SCATTERING AMPLITUDE IN π^+p ELASTIC SCATTERING NEAR THE P_{33} RESONANCE

Rice University

G. C. Phillips, *Spokesman*

G. S. Mutchler, N. D. Gabitzsch, J. Hudomalj-Gabitzsch

Kent State University

T. R. Witten

University of Houston

J. C. Allred, B. W. Mayes, E. V. Hungerford, L. Y. Lee

University of California, Los Angeles

B.M.K. Nefkens

LASL

O. R. Sander

We propose to measure the differential cross section for π^+p elastic scattering in forward direction in the momentum interval 240-360 MeV/c, which covers the peak of the $P_{33}(1232)$ πN resonance. The range of angles to be investigated is from 5.5-22.5°, spanning the region of dominant Coulomb to dominant nuclear scattering. From the interference between the Coulomb and the nuclear amplitudes, one can determine the magnitude and sign of the real part of the nuclear-scattering amplitude.

The objectives of the experiment are

- a) to test forward-dispersion calculations for πN scattering at low energies,
- b) to provide data for accurate πN phase-shift analysis,

c) to investigate the t dependence of the nuclear-scattering amplitude in the small t region, and

d) to investigate the mass splitting $\epsilon \equiv m(p_{33}^{++}) - m(p_{33}^0)$.

No measurement of forward π^+p scattering exists below 620 MeV/c. Foley *et al.* have made measurements between 8 and 24 GeV/c to test dispersion relations and Reggs Pole models at high energy. Very recently, four measurements between 0.62 and 2.0 GeV/c have been reported by Baillon *et al.* The authors report reasonable agreement with dispersion relations.

Exp. 204

EXCITATION AND ASYMMETRY MEASUREMENT OF $T \approx 1$, HIGH-SPIN, NONNORMAL-PARITY "PARTICLE-HOLE" STATE BY (p,p') SCATTERING IN THE INTERMEDIATE-ENERGY RANGE

University of California, Los Angeles

G. J. Igo, *Spokesman*

C. A. Whitten, T. S. Bauer, J. C. Fong, G. Pauletta, J. Soukup, G. S. Adams, G. Mar-
dirossian

LASL

G. W. Hoffmann

Inelastic scattering (and asymmetry measurements when polarized beam becomes available) of protons from light, closed-shell nuclei will be measured in the laboratory angular range 5 to 90°. We will measure both (p,p') and (e,e') (proposal to the Bates Linear Accelerator Facility) on these targets, seeking to identify the excitation of $T = 1$, high-spin, nonnormal-parity particle-hole states. The (p,p') and (e,e') reactions with high-beam current and good resolution can provide experimental data to tie down both the (p,p') reaction mechanism and the relevant nuclear structure. Specific examples of exotic states that are expected to be observable at large-momentum transfers are a 6^- , $T = 1(1_{7/2})(1d_{5/2})^{-1}$ state in $^{28}\text{Si}(p,p')^{28}\text{Si}^*$ and a 4^- , $T = 1(1d_{5/2})(1p_{3/2})^{-1}$ state in $^{16}\text{O}(p,p')^{16}\text{O}^*$. Form factor minima associated with wave function radial nodes may also be observable.

Exp. 205

(n,p) CHARGE-EXCHANGE AND NEUTRON-INDUCED QUASI-FREE SCATTERING ON LIGHT NUCLEI

Texas A&M University

R. A. Kenefick, *Spokesman*

G. Glass, M. Jain, L. C. Northcliffe

University of Wyoming

C. W. Bjork

University of Texas, Austin

P. J. Riley, *Spokesman*

LASL

B. E. Bonner, J. E. Simmons, N. Stein

We propose to carry out, for the first time at LAMPF energies, angular distribution measurements of the elastic and inelastic charge-exchange (n,p) reaction, and of quasi-free (quasi-elastic) (n,np) , (n,nd) , and (n,nt) scattering. Eight-hundred-MeV neutrons from the $D(p,n)2p$ reaction

at 0° will be used; the initial targets will be ${}^6\text{Li}$, ${}^9\text{Be}$, ${}^{12,13}\text{C}$, and ${}^{27}\text{Al}$. In addition, we propose to carry out (p,n) measurements at 0° from the ${}^6\text{Li}$ and ${}^{13}\text{C}$ targets; (n,p) measurements on the remaining three targets have already been carried out at LAMPF.

The charge-exchange (n,p) and (p,n) measurements are of broad interest in several areas of nuclear physics, and will be compared with each other, with such measurements as (p,p') where possible, and with theoretical calculations. Quasi-free proton and deuteron scattering at forward angles will be compared with free n-p and n-d elastic-scattering measurements previously measured by this group at 800 MeV. For the light nuclei, particularly lithium and beryllium, measurement and comparison of the knockout deuteron and triton yields should be an excellent test of cluster probabilities in these nuclei.

Exp. 206

SEARCH FOR THE 2S METASTABLE STATE OF MUONIC HYDROGEN

Yale University

V. W. Hughes and P. D. Egan, Spokesmen

D. Casperson, D. C. Lu, P. A. Souder, R. Stambaugh, H. Orth, J. Vetter (Univ. Heidelberg/Yale Univ.), H. W. Reist, F. G. Mariam, S. Dhawan

Columbia University

H. W. Wu

University of Heidelberg

G. zu Putlitz, Spokesman

Fermi Laboratory

P. A. Thompson

We propose an experiment at LAMPF to search for the metastable 2S state of muonic hydrogen (μ^-p). Because of the many atomic and molecular processes involved in the life history of a muon stopped in hydrogen, it is not possible realistically to predict the fraction of μ^-p formed in the 2S state. Theoretical calculations show that if the kinetic energy of the μ^-p atom is less than the 0.3-eV threshold for the inelastic collision $2S \rightarrow 2P$, the 2S state will have a mean life of about $0.4 \mu\text{s}$ in H_2 at 1 atm, which is determined by collisional Stark quenching. Metastable μ^-p atoms with kinetic energies greater than 0.3 eV will be quenched by collisions about 10^3 times more rapidly. The existence and lifetime of the 2S state can be measured by observing the time distribution of delayed $2P \rightarrow 2S$ 1.9-keV γ rays.

Since the fraction of μ^-p atoms in the 2S state with K.E. < 0.3 eV is unknown, it is difficult to estimate counting rates. The experiment is designed so that the lifetime of the 2S state can be determined to 10% if as few as 0.05% of the μ^- stopped in H_2 form the $\mu^-p(2S)$ state with kinetic energy < 0.3 eV.

The formation and stability of metastable 2S μ^-p would be a valuable test of muon electrodynamics, particularly of electron vacuum polarization, and would provide valuable information on the structure of the proton through the effect of proton structure on the fine structure and hyperfine structure.

Exp. 207

**MEASUREMENT OF NEUTRON SPECTRUM AND INTENSITY RESULTING
FROM π^- CAPTURE IN WATER PHANTOM AND HUMAN TISSUE**

University of Houston

J. C. Allred, Spokesman

C. D. Goodman, E. V. Hungerford, H. R. Kidder, L. Y. Lee, B. W. Mayes, W. Z. Os-
borne, L. S. Pinsky

Rice University

G. C. Phillips, G. W. Pfeufer, G. S. Mutchler

LASL

J. N. Bradbury, Spokesman

L. Rosen, E. A. Knapp

This is a parasitic experiment; there is no summary available.

Exp. 208

**MEASUREMENT OF $\sigma(\theta)$ FOR n-p ELASTIC SCATTERING
AT FORWARD ANGLES**

Texas A&M University

L. C. Northcliffe, Spokesman

G. Glass, J. C. Hiebert, M. Jain, R. A. Kenefick, P. J. Riley

Absolute measurements of the differential cross section for n-p elastic scattering of $\sim 2\%$ accuracy in the angular range $2^\circ \leq \theta_{\text{lab}} \leq 50^\circ$ (i.e., $5^\circ \leq \theta_{\text{cm}} \leq 111^\circ$) at incident neutron energies of 500, 650, and 800 MeV are proposed. The experiment will use the monoenergetic neutron beam in Area B, a liquid-hydrogen target, and a multiwire proportional chamber spectrometer as a proton recoil detector. In the first phase of the experiment, the spectrometer will be used in conjunction with a radiator as a neutron detector to measure $\sigma(\theta)$ at very small angles ($2-6^\circ$) by a ratio method. In the second phase, the spectrometer will be used as the proton detector in a determination of the efficiency of a neutron detector by the associated particle method. The calibrated neutron detector will be used to measure $\sigma(\theta)$ in the angular region $6^\circ \leq \theta_{\text{lab}} < 50^\circ$ at 500 and 600 MeV, and the region $22^\circ \leq \theta_{\text{lab}} \leq 50^\circ$ at 800 MeV.

Exp. 209

PION INTERACTIONS IN NUCLEAR EMULSIONS

LASL

J. N. Bradbury, Spokesman

L. Rosen, E. A. Knapp

University of Houston

J. C. Allred, Spokesman

C. D. Goodman, E. V. Hungerford, H. R. Kidder, L. Y. Lee, B. W. Mayes, W. Z. Os-
borne, L. S. Pinsky

Rice University

G. C. Phillips, G. W. Pfeufer, G. S. Mutchler

This is a parasitic experiment; no summary available.

Exp. 210

**ISOTOPE PRODUCTION FACILITY IRRADIATION VANADIUM,
MOLYBDENUM, AND LANTHANUM TARGETS**

LASL

H. A. O'Brien, Spokesman

P. M. Grant, A. E. Ogard

The objectives of this experiment are (1) to test equipment and procedures pursuant to target irradiations in the Isotope Production Facility; (2) to measure induced-radiation levels as a function of time and compare the results with values calculated from Barbier tables; (3) to provide moderately active targets for testing recovery procedures; and (4) to provide sufficient amounts of aluminum, silicon, scandium, titanium, strontium, yttrium, iodine, and xenon activities for further research and to initiate cooperative studies with extramural investigators.

Exp. 211

NEUTRON IRRADIATION OF COPPER SINGLE CRYSTALS

LASL

W. V. Green, Spokesman

D. M. Parkin, M. L. Simmons, E. G. Zukas

Argonne National Laboratory

T. H. Blewett, B. S. Brown

The proposed experiment will be the bombardment of copper single crystals in the neutron-irradiation cavity with the spallation neutrons emitted by the interaction of the 800-MeV protons with the copper beam stop. From the increase in the yield stress as a function of temperature and integrated beam current, the neutron flux can be determined in relationship to fission neutrons. A comparison of this value with the flux determined by neutron activation will enable estimates to be made of effectiveness of high-energy spallation neutrons. Experimental copper single crystals with known yield stress will be bombarded at the beam stop. The yield stress will then be measured after bombardment at various temperatures to determine the tested neutron-damage function.

Exp. 212

**COMPARATIVE EFFECTIVENESS OF NEGATIVE PIONS vs ^{252}Cf
IN A TUMOR-ANIMAL SYSTEM**

University of Chicago

D. J. Mewissen, Spokesman

L. Lanzl, J. H. Rust, M. Furedi, F. Moser, M. Rozenfeld, R. Oswald

The proposed research is aimed at assessing the *cell viability* and the size of the *anoxic cell component*, in a transplanted mouse tumor, following external irradiation of negative pions vs the application of ^{252}Cf for neutron irradiation using an *animal-model system*, duplicating, to some extent, a clinical situation. The research plan is both dosimetric and radiobiologic, involving comparative application of pions vs ^{252}Cf on an established

transplantable fibrosarcoma in C57 black mice. The relative biological effectiveness (RBE) and the ratio of oxygenated and anoxic cells in tumor tissue will be determined, *in vivo*, following pion irradiation modalities by the T.D. 50 method, i.e., a dilution-titration method using, as an endpoint, the mean effective number of tumor cells that will produce 50% of takes after inoculation to various sites in an isogenic receptor.

For ^{252}Cf , three experimental methods of in-phantom dosimetry are being used: a) ionization chambers filled with tissue-equivalent gas, b) liquid dielectric ionization chambers, and c) fission track etching techniques. These methods are complementary in making dose determinations for interstitial and intracavitary neutron sources sufficiently accurate for radiobiology and radiotherapy applications.

For pion dosimetry, we propose to use two in-phantom experimental techniques: a) ionization chambers filled with tissue-equivalent gas, and b) star-track etching techniques. In addition, LASL in-house dosimetric determinations and techniques will need to be employed.

Exp. 213

MUON-TRANSFER STUDY

LASL

E. B. Shera, Spokesman

G. Rinker, R. B. Perkins

Purdue University

R. M. Steffen, Spokesman

Oregon State University

K. S. Krane

This experiment will investigate the probability of the transfer of muons stopped in liquid hydrogen to suspended powder target (e.g., platinum and gold particles in liquid H_2).

Exp. 214

PIONIC X-RAY ABSOLUTE YIELDS AS A FUNCTION OF Z

National Research Council, Ottawa, Canada

C. K. Hargrove, Spokesman

LASL

M. Leon, Spokesman

J. N. Bradbury, R. L. Hutson, M. E. Schillaci

University of Mississippi

J. J. Reidy

The capture of negative mesons into atoms is a poorly understood phenomenon, but is important both from the point of view of pure physics (for understanding the intensities observed in a great variety of mesonic x-ray experiments) and for the various applications proposed for muonic x rays. Recently, Wiegand and Godfrey have discovered striking variations, as functions of Z, of the absolute K^- x-ray yields in elemental targets. These variations must be due to the atomic capture and deexcitation processes, and, indeed, are clearly correlated with position in the periodic table. We propose to measure the *pionic* absolute x-ray yields, in order to explore the similarities to and differences from the kaonic data and the correlations with other mesonic x-ray results and atomic properties, and thus, hopefully, shed some light on the underlying mechanisms.

Exp. 215

VISUALIZATION OF STOPPING PION DISTRIBUTION

University of California, Berkeley

V. Perez-Mendez, Spokesman

D. Ortendahl

LASL

J. N. Bradbury, Spokesman

E. A. Knapp, J. A. Helland

An important aspect of pion radiotherapy is the ability to visualize the spatial distribution of stopping pions. The proposed experiment will evaluate the suitability of using selected γ rays resulting from the pion-capture process for routine on-line monitoring of the stopping distribution. The equipment to be used consists of multiwire proportional chambers with electromagnetic delay line readouts, honeycomb structures to convert the γ rays into charged particles, and, in some cases, lead collimators. This equipment has been successfully used in a variety of imaging applications in nuclear medicine.

Exp. 216

DECAY RATES FOR $\pi^\pm \rightarrow e^\pm + \nu$

LASL

A. Wadlinger, Spokesman

University of Virginia

J. S. McCarthy, R. C. Minehart

We propose to measure the absolute decay rates for both $\pi^+ \rightarrow e^+ \nu$ and $\pi^- \rightarrow e^- \bar{\nu}$ ($\pi^\pm_{e2}$) to 0.8% by observing the electron from pion decays in flight. (Note that for negative-pion decays, this is the only available technique.) These measurements will then be combined with the known value of the pion lifetime to determine the branching ratio $\Gamma_{\pi_{e2}} / \Gamma_{\pi_{\mu2}}$. Our measurement of the π^-_{e2} decay rate, when compared with π^+_{e2} , will provide a test of CP to 0.7%. The LEP beam will be used to obtain 250-MeV/c pions. The π_{e2} electron detector set at 30° to the beam will consist of two scintillation counters to define the decay volume, followed by a magnetic spectrometer consisting of the PPA 30D40 with four helical wire proportional chambers to be used for trajectory measurements. The spectrometer is necessary to distinguish between π_{e2} decay electrons and electrons from muon decays.

Exp. 217

π^- PRODUCTION CROSS SECTIONS

LASL

M. A. Paciotti, Spokesman

J. N. Bradbury, J. A. Helland, E. A. Knapp

Negative-pion production cross sections will be measured for several proton energies, several pion energies, and several target materials, utilizing the Biomed channel at LAMPF. These data are needed for assessing the effect of variable energy on the performance of the LAMPF Biomed channel and for determining the optimum energy of a medical proton linac.

Exp. 218

PION DOSIMETRY WITH NUCLEAR EMULSIONS AND ALANINE

University of Nebraska

R. Katz, Spokesman

LASL

H. I. Amols, J. N. Bradbury, J. F. Dicello

Two types of passive dosimeters are to be exposed to negative-pion beam: alanine and nuclear emulsion. Alanine dosimeters need to be evaluated for use in the postal intercomparison of high-LET dosimetry. Special nuclear emulsions may react to the star dose in approximately the same manner as biological cells, and thus provide a passive method for measuring effective dose absorbed.

Exp. 219

DOUBLE PION PRODUCTION IN PROTON-PROTON SCATTERING

Case Western Reserve University

P. R. Bevington, Spokesman

H. W. Baer, F. H. Cverna, D. J. Ernst, R. M. Thaler, H. B. Willard, M. W. McNaughton

Kent State University

B. D. Anderson

LASL

R. J. Barrett, N. Jarmie

University of California, Davis

N. King

We propose to measure the double differential cross sections $d^2\sigma/d\Omega dp(\pi^-)$ for π^- production in the double pion production reaction $p + p \rightarrow p + p + \pi^+ + \pi^-$ at $T_p = 800$ MeV for pion energies from 15 MeV to the maximum available (220 MeV) at angles as far forward as 10° (lab). The experiment will be mounted on the LAMPF External Proton beam (EPB) with a liquid-hydrogen target, a magnetic spectrometer for momentum analysis, and multiwire-proportional-counter (MWPC) chambers for position resolution. Suppression of background will be accomplished with a time-of-flight telescope and a gas Cerenkov detector.

The experiment seeks to resolve what appears to be a significant discrepancy between recent measurements of Cochran *et al.*, who obtained $\sigma = 0.03 \pm 0.01$ mb at 730 MeV, and the earlier results of Bugg *et al.* and Barnes *et al.*, who obtained $\sigma = 0.016 \pm 0.02$ mb at 970 MeV. Resolution of this discrepancy is important to check the correctness of two-pion production models and, in particular, the validity of the isobar model near threshold.

Exp. 220

**GAMMA-RAY SPECTROSCOPY OF ISOMERIC STATES INDUCED
BY PI-NUCLEUS REACTIONS**

LASL

G. W. Hoffmann, Spokesman

R. J. Macek

University of Texas, Austin

C. F. Moore, Spokesman

J. Bolger, W. J. Braithwaite, C. Chiu, W. R. Coker, R. P. Liljestrand, J. McIntyre

New Mexico State University

G. S. Blanpied

University of California, Los Angeles

C. A. Whitten

A fast pneumatic rabbit, used in conjunction with high-resolution gamma-ray detectors, will allow isomeric gamma transitions to be used to study $\pi^\pm$ -induced reactions in a variety of nuclei. The University of Texas PDP-15 computer, with 32k core and two 256k disks, will be moved to LAMPF and used to sequence the rabbit system and store spectra in the appropriate time bins. The PDP-15-controlled rabbit system has been used extensively at Texas in studies with the EN tandem accelerator over the past several years and is a proven system. The actual rabbit itself is being reconstructed to allow larger targets as required by the P^3 channel.

Previous prompt gamma-ray experiments have shown that pion-nuclear reactions hold many surprises. These include, for example, unexpected cross-section ratios for single-nucleon-removal processes, unexpectedly high cross sections for double-charge-exchange reactions, and unexpectedly high cross sections for single and multiple alpha-particle removal. Since isomeric states are somewhat selectively populated (in the sense that they are not fed significantly by the continuum, e.g., the giant dipole resonance), it is felt that their study will provide a significant tool for understanding the pion-nucleus reaction mechanism. We are specifically interested in studying a class of pion-induced reactions which can strongly be argued to be direct single-step. In this way, detailed and reliable comparisons between the data and theory can be made. Beam time for the specific reactions, $^{90}\text{Zr}(\pi^\pm, \pi^\pm p\gamma)^{89}\text{Y}(0.91)$ and $^{89}\text{Y}(\pi^\pm, \pi^\pm \gamma)^{89}\text{Y}(0.91)$, is requested. If the experiment is successful, beam time will be requested for other interesting pion-induced single-step reaction studies.

Exp. 221

**PRECISION MEASUREMENT OF THE DECAY RATE FOR THE
DALITZ DECAY MODE OF THE π^0 MESON**

LASL

C. M. Hoffman, Spokesman

J. S. Frank, R. E. Mischke, R. D. Werbeck, D. C. Moir

Arizona State University

M. Schardt

Fermi Laboratory

P. A. Thompson

Several recent experiments measuring the x-ray spectra emitted by muonic atoms have obtained results that are in disagreement with the theoretical predictions based on quantum electrodynamics. The proposed explanations for this discrepancy are the possible existence of a weakly coupled light-scalar boson and the possible existence of nonperturbative vacuum polarization modification. A nonperturbative decrease in the vacuum polarization spectral function reduces the vertex for the coupling of a time-like photon to an electron-positron pair. We propose to measure the π^0 Dalitz decay ($\pi^0 \rightarrow e^+e^-\gamma$) branching ratio to an accuracy of 1% in order to test this hypothesis.

The π^0 s are produced by charge exchange, $\pi^-p \rightarrow \pi^0n$, at $T_\pi = 190$ MeV, from a thin polyethylene target. The electron pair is analyzed in a magnetic spectrometer, and the photon is detected with a shower detector.

Exp. 222

MEASUREMENT OF THE DECAY RATE FOR $\pi^0 \rightarrow e^+e^-$

LASL

R. E. Mischke, Spokesman

J. S. Frank, C. M. Hoffman, R. D. Werbeck, D. C. Moir

Arizona State University

M. Schardt

Fermi Laboratory

P. A. Thompson

We propose to measure the decay rate for the rare decay mode, $\pi^0 \rightarrow e^+e^-$. The branching ratio for this mode has a unitarity lower bound of $\Gamma(\pi^0 \rightarrow e^+e^-)/\Gamma(\pi^0 \rightarrow \gamma\gamma) = 4.7 \times 10^{-8}$. We expect to observe 100 events, and will detect more if the branching ratio is greater than the unitarity limit.

The π^0 s are produced by the charge-exchange reaction, $\pi^-p \rightarrow \pi^0n$, at $T_\pi = 190$ MeV, and the electron pair is detected in a magnetic spectrometer. The experiment is designed to optimally separate true $\pi^0 \rightarrow e^+e^-$ events from backgrounds. The most serious background appears to be the kinematically indistinguishable process $\pi^-p \rightarrow n e^+e^-$ with $M_{e^+e^-} \cong M_{\pi^0}$. A subtractable background 1.5 times the signal at the unitarity limit is expected.

Exp. 223

STUDIES OF THE $(p, n\bar{p})$ CHARGE-EXCHANGE REACTION

LASL

G. W. Hoffmann, Spokesman

J. E. Spencer

New Mexico State University

G. S. Blanpied

University of Texas, Austin

C. F. Moore, M. Bartlett, C. Harvey

University of California, Los Angeles

C. A. Whitten

Decay protons from ground isobaric analog states populated via the (p, n) charge-exchange reaction at proton-bombarding energies between 200-800 MeV will be studied in an attempt to better understand the charge-exchange reaction.

A detector-telescope will be mounted inside the HRS scattering chamber, and the measurements will be made parasitically during the HRS tuneup (Exp. 139). Targets of $^{207,208}\text{Pb}$ and $^{90,91}\text{Zr}$ will be used.

Exp. 224

INELASTIC PION SCATTERING FROM ^{148}Sm AND ^{152}Sm

LASL

N. Ensslin, D. G. Madland, and C. L. Morris, Spokesmen
H. A. Thiessen

We propose to study the inelastic scattering of pions from ^{148}Sm and ^{152}Sm . The EPICS beam line will be used with a pion energy of 200 MeV, and spectra will be taken at scattering angles between 20 and 70°. Samarium-148 is a spherical nuclei, whereas ^{152}Sm shows a low-lying spectrum common to strongly deformed nuclei. The purpose of this experiment is to measure the transition strengths to low-lying vibrational and rotational states of ^{148}Sm and ^{152}Sm . If the deformation parameters extracted from the transition strengths agree with those obtained using conventional nuclear probes, this will imply that the reaction mechanism used is satisfactory for nuclear spectroscopy work. By studying both π^+ and π^- spectra, it should be possible to determine the ratio of the neutron and proton deformation parameters to an accuracy of about 5%. We estimate that 240 h of beam time on EPICS will be required to complete this experiment.

Exp. 225

A STUDY OF NEUTRINO-ELECTRON ELASTIC SCATTERING

University of California, Irvine

H. H. Chen and F. Reines, Spokesmen
J. F. Lathrop, R. D. Newman, H. W. Sobel, W. R. Kropp

We are proposing to study the elastic scattering of neutrinos on electrons with a sandwich detector system consisting of alternating layers of thick plastic scintillator slabs and thin foil spark chamber modules. We have studied both cosmic ray and accelerator-associated backgrounds for elastic scattering in a smaller version of this sandwich detector, and have concluded that these backgrounds can be kept at sufficiently low levels with the use of inert shielding and a cosmic-ray anticoincidence. Typical signal rates are $\sim 2/\text{day}^{-1}$ for elastic scattering in our proposed 10-ton sandwich detector system, with 1/3-mA protons at the beam stop. With this rate, two years of data-taking would be required in order to collect ~ 600 elastic-scattering events at the V-A level. This number of events would allow a measurement not only of the total cross section for elastic scattering, but also information with respect to the differential cross section. Subsidiary results of this experiment would be (1) a sensitive test of the multiplicative lepton number conservation law in μ^+ decay, (2) a measurement of the inverse beta cross section in ^{12}C , and (3) a search for anomalous neutrino effects.

Exp. 226

**COMPARISON OF π^+, π^- ELASTIC SCATTERING FROM TWO
SELF-CONJUGATE NUCLEI**

New Mexico State University

G. R. Burleson, Spokesman

LASL

W. V. Hassenzal, P.A.M. Gram

University of Wyoming

T. R. King, A. T. Dyer, G. A. Rebka

We propose to make measurements of differential cross sections for the elastic scattering of π^+ and π^- on two self-conjugate, zero-spin, zero-isotopic spin nuclei, ^{12}C and ^{40}Ca , at two energies, 100 and 150 MeV. The 180° double-focusing spectrometer system built for Proposal No. 99, now in the P^3 beam, will be used, and special care will be taken to minimize the systematic errors between the π^+ and π^- runs. The sums and differences of the π^+ and π^- cross sections will be used in an attempt to extract, in a model-independent way, the nuclear amplitude by utilizing its interference with the known Coulomb amplitude. These measurements could begin soon after the great shutdown; we believe it is desirable to test the usefulness of such an approach before experiments begin with the EPICS system.

Exp. 227

(p,n) REACTION STUDIES ON LIGHT NUCLEI

University of Texas, Austin

P. J. Riley, Spokesman

LASL

J. E. Spencer, Spokesman

M. P. Baker, C. F. Hwang, J. Pratt, J. D. Bowman, R. E. Mischke

Using the HRS in conjunction with a thin position-sensitive, solid-state detector, we propose to measure the coherent (p,n) charge-exchange cross sections on targets of ^7Li , ^{10}B , ^{12}C , and ^{13}C . These cross sections would be measured relative to the simultaneously measured (p,p) and (p,p') reactions whose cross sections will have been measured previously on the HRS. The position-sensitive detector will be positioned at laboratory angles between about 70° and 90° , for all energies, and will be used to detect the heavy recoil nuclei. In the case of the $^7\text{Li} + \text{p}$ reaction, the elastic and inelastic protons would be detected with the HRS in coincidence with the ^7Li ions. The signature of the $^7\text{Li}(p,n)^7\text{Be}$ reaction would be the detection of the ^7Be in the position-sensitive detector without detection of a charged particle in the HRS; thus, the (p,p) and (p,n) reactions can be cleanly separated and measured. The resolution of the (p,n) reaction will be limited by the target thickness and the resolution obtainable in the detection of the heavy recoil ion. For a target thickness giving a reasonable count rate ($\sim 10 \mu\text{g}/\text{cm}^2$), a resolution sufficient to resolve the first excited state of ^7Be on the order of 200 keV is calculated.

Exp. 228

**REAL AND IMAGINARY PARTS OF THE FORWARD-SCATTERING AMPLITUDE
IN $\pi^\pm$ NUCLEUS SCATTERING FROM 20 TO 60 MeV**

LASL

H. A. Thiessen, Spokesman

C. L. Morris, N. Ensslin

University of Texas, Austin

J. Bolger, K. G. Boyer, W. J. Braithwaite, A. Obst, C. F. Moore

University of Virginia

M. D. Thomason, D. Slater

New Mexico State University

G. R. Burleson, W. Harvey

TRIUMF

J. Källne

This experiment will measure total cross sections for π^+ and π^- scattering on nuclear targets. The small-range portion of the angular distribution of elastic scattering will be measured simultaneously. By using Coulomb-nuclear interference and the optical theorem, it will be possible to measure separately the real and imaginary parts of the forward-scattering amplitude. This experiment will be performed at five energies (20, 30, 40, 50, and 60 MeV), using five targets (^6Li , ^{12}C , ^{13}C , ^{28}Si , and ^{40}Ca).

This experiment is compatible with and complements the development of the EPICS pion channel. It will serve as an incentive and check that the operation of the channel is satisfactory. The experimental techniques which must be developed are very similar to those required for use with the EPICS spectrometer. The bulk of the apparatus to be used is identical with the apparatus being developed for the EPICS channel tuneup. During the expected period of running, the EPICS channel will be debugged while the EPICS spectrometer will be under construction. Only one previously approved experiment (No. 133, Gemmel, Spokesman, 50 h) can be performed during this period.

Exp. 229

**π^+ vs π^- INELASTIC EXCITATION OF LOW-LYING
COLLECTIVE STATES IN $N \approx 28$ NUCLEI**

University of Texas, Austin

W. J. Braithwaite and C. F. Moore, Spokesmen

J. Bolger, K. G. Boyer

LASL

H. A. Thiessen, G. W. Hoffmann, C. L. Morris

Inelastic excitation of collective states by positive and negative pions is proposed for several nuclei, at a bombarding energy of 180 MeV. In each case, a difference yield is expected, due to a difference in the expected participation of valence protons from that of valence neutrons.

We propose to study the best known and best understood collective states (i.e., the lowest 2^+ and 3^- states) in even-even nuclei. Five neutron-magic isotopes were chosen, with $N = 28$: ^{48}Ca , ^{50}Ti , ^{51}V , ^{52}Cr , and ^{54}Fe .

Closure in the $f_{7/2}$ subshell blocks valence-neutron promotion to the $f_{7/2}$ from the lower s-d shell orbitals, and, thus, inhibits neutron participation in forming negative-parity states. Further, a

valence neutron, from the large population in the $f_{7/2}$ subshell, may be promoted easily to higher negative-parity orbitals within the f-p shell, contributing to neutron participation in forming positive-parity states. In contrast, an unfilled or partially filled $f_{7/2}$ proton subshell favors proton participation in forming positive-parity states. Thus, we expect a preferential yield for π^- inelastic scattering to the 2^+ states, and preferential yield for π^+ inelastic scattering to the 3^- states, with this selectivity decreasing as A increases.

Exp. 230

**ENERGY DEPENDENCE OF THE $\pi^\pm$ CARBON TOTAL
CROSS SECTION FROM 20 TO 300 MeV**

University of Texas, Austin

W. J. Braithwaite and C. F. Moore, Spokesmen

J. Bolger, K. G. Boyer

LASL

H. A. Thiessen, Spokesman

C. L. Morris, N. Ensslin

TRIUMF

J. Källne

New Mexico State University

W. Harvey, G. R. Burleson

Northwestern University

A. W. Obst

University of Virginia

M. D. Thomason, D. Slater

Temple University

K. F. Johnson

This experiment will measure the excitation function for the pion-carbon total cross section from 20 to 300 MeV. New information will be provided by this experiment in two ways: first, an excitation function with fine steps will be taken and used to search for fine structure in the pion-nucleus interaction; and second, the excitation function will cover the region 20-70 MeV, where the Coulomb field of the nucleus will create substantial differences in the π^+ and π^- cross sections and little or no data presently exists.

This experiment is compatible with and complements the development of the EPICS pion channel. It will serve as an incentive and check that the operation of the channel is satisfactory. The experimental technique that must be developed is very similar to that which will be used with the EPICS spectrometer. During the expected period of running, the EPICS spectrometer will be under construction, and only one previously approved experiment (No. 133, Gemmel) can be performed.

Exp. 231

SELECTIVITY IN π^+ vs π^- INELASTIC EXCITATION OF ODD-A NUCLEI

University of Texas, Austin

W. J. Braithwaite and C. F. Moore, Spokesmen

J. Bolger, K. G. Boyer

LASL

H. A. Thiessen, G. W. Hoffmann

Oregon State University

L. W. Swenson

Pion-nucleon elastic scattering on the (3,3) resonance favors π^+ -p and π^- -n over π^+ -n and π^- -p. Thus, from the shell-model point of view, one might reasonably hope that a comparison of π^+ inelastic scattering with π^- inelastic scattering on complex nuclei would permit an extraction of the valence proton from the valence neutron activity in the description of nuclear excited states.

At least two effects may complicate any such analysis. (1) Collective effects are known to play an important role in all inelastic-scattering measurements. Since collective excitations involve both protons and neutrons coherently, we expect that their contribution to inelastic excitation will lessen the amount of selectivity with incident pion species. (2) For nuclear excitations involving nonself-conjugate cores, some selectivity with incident pion species may arise due to core-coupling effects.

We propose to measure inelastic scattering of positive and negative pions from odd-A nuclei near shell closure. In an initial sampling of the periodic chart, we propose to compare inelastic excitation in the lead region, using isotopes of ^{207}Pb , ^{208}Pb , and ^{209}Bi . In the odd-A nuclei, we will be exciting two different types of well-known states: (1) states formed by promotion of a valence neutron or a valence proton, built on a doubly magic core, and (2) states formed by coupling a spectator neutron or a spectator proton to an excited core.

In a comparison between inelastic-scattering yields, we expect to see π^+ preferentially exciting proton states and π^- preferentially exciting neutron states of type (1). In contrast, we do not expect to see any more selectivity in the inelastic pion scattering to spectator-nucleon $\otimes$ excited-core states of type (2) than measured in the inelastic excitation of the appropriate states in the doubly magic (core) nuclei, where this selectivity arises as a consequence of the nonself-conjugate character of the core.

Exp. 232

INELASTIC PION SCATTERING BY ^{24}Mg AND ^{25}Mg

LASL

D. G. Madland, C. L. Morris, and N. Ensslin, Spokesmen
H. A. Thiessen

We propose to study the inelastic scattering of positive and negative pions from the low-lying collective states of ^{24}Mg and ^{25}Mg , at a pion energy of 200 MeV. We will extract both the neutron and proton components of the transition strengths to these states and, by doing so, provide new formation on their structure. We estimate that 240 h of beam time on EPICS will be required to complete this experiment.

Exp. 233

SEARCH FOR 5 CONFIGURATIONS IN NUCLEI

Northwestern University

K. K. Seth, Spokesman
S. G. Iversen, A. W. Obst, H. Nann

LASL

J. E. Spencer, Spokesman
J. Pratt, R. L. Burman, N. Tanaka, M. Oothoudt, T. Kozłowski, G. W. Hoffmann, B. C. Hoistad, D. M. Lee

University of Minnesota

G. Kyle

We propose measuring the absolute differential cross sections for the (p, π^-) reaction on targets of ^{28}Mg and ^{30}Si . The reaction mechanism is generally believed to be more complicated

than for the (p, π^+) reaction, but has the interesting feature that the only possible first-order process by which it can occur is via δ^{++} transfer. Recent calculations by Miller and Kisslinger indicate that there are circumstances where this process will be favored over the usual second-order processes. Except for this possibility and certain related questions, we believe that the (p, π^-) reaction is generally less interesting than the (p, π^+) . As a result, we propose doing a careful but limited study of the reaction to test certain predictions of the current theory.

Exp. 234

**A STUDY OF THE INELASTIC PION-SCATTERING REACTION
AT PION ENERGIES 10-100 MeV**

Virginia Polytechnic Institute and State University

D. A. Jenkins, Spokesman

M. Blecher, K. Gotow, F. Milder, R. Roberson

Oak Ridge National Laboratory

F. E. Bertrand, E. E. Gross, C. A. Ludemann, T. P. Cleary

University of South Carolina

C. W. Darden, B. M. Freedom, T. Marks, D. Malbrough, R. D. Edge

LASL

R. L. Burman, M. A. Moinester (LASL/Tel Aviv University), R. P. Redwine

We propose to study inelastic pion scattering in the energy range from 10 to 100 MeV with the Low-Energy Pion channel. Excitations of nuclear states will be studied over a wide energy range for many nuclei in order to investigate the pion-nucleus reaction mechanism and nuclear structure. The principal purposes of the experiment are to study the form of the optical potential and to look for excitations induced by pions in both the low-lying excitation region and the high-lying continuum. The experiment will use a magnetic spectrometer which is being constructed for pion elastic-scattering experiments at the Low-Energy Pion channel.

Exp. 235

RADIATION REPAIR OF NORMAL MAMMALIAN TISSUES

Colorado State University

E. L. Gillette, Spokesman

J. W. Watters

LASL

L. W. Holland

The purpose of this investigation is to evaluate the response of capillary endothelial cells to negative-pi mesons. A model has been developed at Colorado State University, using the eyes of beagle dogs to examine effects of beta and x radiation on capillary endothelium at the limbus. This *in vivo* experimental system can be used to estimate the RBE of high-LET radiation for endothelial cells. This has important clinical implications because effects on capillaries may determine the response of dependent tissues late after a course of radiation therapy. Additional stress to irradiated tissues may cause injury to fine vasculature, leading to degeneration and necrosis. It is difficult to study radiation dose response and repair capability of nonproliferating or slowly proliferating mammalian tissues. However, knowledge about radiation repair by normal tissues becomes critical when considering use of radiation-therapy techniques that may alter this capability.

During the past two years, single- and split-dose techniques have been used to establish dose-effect curves and to quantitatively evaluate repair capability of endothelial cells. The proposed study at LAMPF will be only of single doses, initially, to determine the dose response of endothelium to negative-pi mesons. This will be followed by a split-dose assay to determine effects on repair capability.

Exp. 236

BIOLOGICAL EFFECTS OF NEGATIVE PIONS

LASL

R. M. Raju, Spokesman

J. H. Jett, E. Bain, L. L. Deaven, R. A. Walters, R. A. Tobey, L. M. Holland, H. I. Amols, J. F. Dicello, R. A. Cox, S. Carpenter, J. B. Robertson

The biological effects of negative pions at the plateau and at the peak for at least two different widths (4 and 8 cm) will be measured using (1) cells in culture (T₁, V79); (2) early and late effects on mouse foot; (3) tumor regression of KHT sarcoma; and (4) tumor cell survival (exposure *in vivo* and assay *in vitro*). A limited number of fractionation experiments will also be carried out. In addition, stage sensitivity variations as a function of cell cycle will be studied, using CHO cells at the plateau and peak for the nearly monoenergetic negative-pion beam.

A proposal was submitted to the National Cancer Institute on "The Pretherapeutic Potential of Heavy Charged Particles," and it was recommended for funding. Some of these proposed studies at LAMPF comprise part of the experiments proposed to the NCI. Most of the proposed experiments in this proposal to LAMPF are complementary to the ongoing pretherapeutic radiobiology program at LAMPF.

Exp. 237

RADIATION-DAMAGE STUDIES ON STRUCTURAL MATERIALS FOR ADVANCED REACTORS

Westinghouse Research Laboratory

J. R. Holland, Spokesman

W. J. Choyke, L. R. Fleischer, J. A. Spitznagel

LASL

W. R. Green, Spokesman

Radiation & Dosimetry, Inc., Richland, Washington

R. Gold

In the development of fusion reactors, perhaps the most important questions which must be answered after scientific feasibility has been demonstrated will be those associated with radiation damage to structural materials. The structural materials of a D-T fueled fusion device, particularly those in the first wall, will be required to perform in a sustained radiation environment more severe than any heretofore encountered. As many as 20-30% of the neutrons passing through the first wall will have energies greater than 10 MeV. Hence, in addition to the already formidable void-swelling and radiation-hardening problems, we have to consider the effects of concurrent high neutron-energy (n,p), (n, α), etc., reactions. At a 1-MW/m² neutron wall loading, approximately 250 appm helium would be produced in a 316 stainless steel wall; for a niobium first wall, this value would be about 30 appm/yr.

The whole question of the behavior of helium in metals and its probable influence on mechanical and physical properties is only now beginning to be addressed. Limited observations to date, in the 10-40 appm helium range, indicate the most probable effects may be in the area of drastic loss of elevated temperature ductility due to accumulation of helium bubbles along grain boundaries. While it may be possible to extrapolate volume swelling results from microspecimens such as TEM foils to macrospecimens such as fuel cladding, mechanical property evaluations do not lend themselves to such ultraminiaturization; we must measure bulk effects on bulk specimens. Although other high-energy neutron facilities are available, and are, in fact, currently being used by the present investigators, only the LAMPF radiation-damage facility offers a sufficient neutron flux ($\approx 2 \times 10^{12}$ n/cm²-s averaged over a year's time) in a volume adequate for mechanical specimens.

The test program we propose to conduct at LAMPF will consist of neutron irradiations of large, mechanical property size specimens of CTR candidate materials (niobium, vanadium, tantalum, and molybdenum) at elevated temperatures in vacuum or inert atmospheres. After irradiation, these specimens will be mechanically tested and the defect microstructures characterized. The defect structures will be correlated with results of 14-MeV neutron irradiations at the LLL RTNS facility and with the results of ion simulation work performed at the Westinghouse-University of Pittsburgh HEIBS facility. Subsequent LAMPF experiments will combine *in situ* irradiation with mechanical testing, using techniques modeled after that developed by Dr. Green for use in the LAMPF radiation facility.

Exp. 238

FEASIBILITY STUDY FOR THE MEASUREMENT OF NEUTRON SPECTRUM FROM THE MAIN BEAM STOP AT LAMPF WITH A SELF-CONTAINED TWO-PARAMETER SPECTROMETER

Kent State University

R. Madey, Spokesman

This experiment was replaced by Experiment No. 290.

Exp. 239

STUDY OF ¹¹C AND ¹³N PRODUCTION BY π^- IRRADIATION OF C, N, O, AND TISSUE FOR RADIOTHERAPY MONITORING

Tel Aviv University

S. S. Friedland, Spokesman

A. Cochavi, M. A. Moinester (LASL/Tel Aviv)

Argonne National Laboratory

L. F. Mausner, Spokesman

LASL

J. D. Knight

We propose to study the production of ¹¹C and ¹³N by stopping π^- in samples of oxygen, carbon, nitrogen, and various tissues. The purposes of this research are (1) to study the feasibility of using the β^+ activity of tissue as an *in vivo* dose monitor; (2) to provide data to compare with calculations predicting the direct and secondary yields of ¹¹C and ¹³N per stopped pion in the

beam path; (3) to investigate the secondary production of ^{11}C and ^{13}N (mainly from neutrons) outside the beam path; and (4) to investigate the usefulness of the elemental radioactivity data for tissue analysis. We will measure activities in entrance, stopping, downstream, and surrounding regions.

Exp. 240

ISOTOPE AND ISOTONE SHIFTS IN THE $1f_{7/2}$ SHELL

LASL

B. Shera and H. D. Wohlfahrt, Spokesmen

G. Rinker, Y. Yamazaki, M. V. Hoehn (LASL/Florida State University)

University of Mainz, Germany

G. K. Fricke

Oregon State University

K. S. Krane

Princeton University

R. Sherr

Purdue University

R. M. Steffen

It is proposed to determine the charge radii of a series of nuclei in the $1f_{7/2}$ shell by measurement of the muonic x-ray spectra. These new data will extend the region studied in Exp. 163 and should be helpful in understanding the systematic features of the isotope/isotone shifts observed in that experiment.

Exp. 241

PROPOSAL TO SEARCH FOR DIRECT LEPTON PRODUCTION AT LAMPF

LASL

C. M. Hoffman and R. E. Mischke, Spokesmen

A. A. Browman, J. S. Frank, H. H. Howard, D. C. Moir, J. P. Morgan, D. E. Nagle, R. D. Werbeck

Temple University

L. B. Auerbach, V. L. Highland, W. K. McFarlane

Several experimental groups have reported evidence for direct production of leptons in hadron-nucleus collisions at high energies. These results aroused considerable interest since the production mechanism is not understood. We propose to search for the production of electrons or positrons in p-p collisions at LAMPF energies. The design sensitivity of the experiment is 10^{-34} cm²/sr, which is an order of magnitude less than would be expected from an optimistic extrapolation of the high-energy results.

The apparatus consists of an LH₂ target, Cerenkov counters (gas threshold and lead-glass) for electron identification, and a magnet plus hodoscope counters for rough momentum and charge analysis.

Exp. 242

**SURVIVAL OF SYNCHRONIZED CULTURED HUMAN-KIDNEY T-1 CELLS
EXPOSED TO STOPPING PIONS AND X RAYS AT
VARIOUS TIMES AFTER MITOSIS**

Pennsylvania State University

P. Todd, Spokesman

No summary available.

Exp. 243

**RECOIL STUDIES OF DEEP SPALLATION AND FRAGMENTATION PRODUCTS
FROM THE INTERACTION OF 800-MeV PROTONS WITH HEAVY ELEMENTS**

Purdue University

N. T. Porile, Spokesman

S. Biswas, D. Fortney, S. Pandian

We propose to measure the recoil properties and cross sections for the formation of a number of deep spallation and fragmentation products in the interaction of 800-MeV protons with heavy elements. These experiments will be performed in conjunction with similar studies at higher energies and are designed to provide data at the lower end of the energy range of interest. The experiments involve (1) thick-target recoil and cross-section measurements, (2) angular distribution studies, and (3) differential range measurements at specific angles

Exp. 244

**SYSTEMS DEVELOPMENT FOR EFFICIENT UTILIZATION OF HIGH-PURITY
GERMANIUM MOSAIC DETECTORS FOR TUMOR LOCALIZATION**

Vanderbilt University

A. B. Brill, M.D., Spokesman

J. A. Patton

Lawrence Berkeley Laboratory

R. H. Pehl

University of Mississippi

J. J. Reidy

LASL

D. H. Janney

A nine-element high-purity germanium array has been fabricated at Berkeley (LBL) for use in tumor localization studies at Vanderbilt University. High-resolution images (surface projections and depth distributions) will be available from such systems which should assist in tumor diagnosis and treatment planning. The development of interfaces and programs for data acquisition and image reconstruction is now beginning. As soon as these are complete, tests with patients and animals will be carried out to evaluate the potential benefits to be derived from these systems. On the basis of this experience, a decision should be made at LAMPF concerning mapping of the beam stopping region and tumor localization with analogous systems.

STUDY OF THE (π^-, n) AND $(\pi, \pi p)$ REACTIONS IN ^3He
AND HEAVIER NUCLEI BY DETECTING RECOILING TRITONS OR DEUTERONS

TRIUMF

J. Källne, Spokesman

LASL

H. A. Thiessen, Spokesman

C. L. Morris, J. F. Amann, B. C. Hoistad

Northwestern University

S. G. Iversen, A. W. Obst

University of Virginia

J. S. McCarthy

University of Texas, Austin

W. J. Braithwaite, J. Bolger, K. G. Boyer, C. F. Moore

New Mexico State University

G. R. Bursleson, S. L. Verbeck

We intend to study the (π^-, n) and $(\pi, \pi p)$ reactions in ^3He , ^4He , and some heavier nuclei by detecting the recoil products. Deuterons will be detected for ^3He and tritons for the other nuclei. The deuterons or tritons will be identified, and their energy and angle will be measured with a detector consisting of three plastic scintillators.

For the ^3He and ^4He targets, the measured spectra contain all the information needed to determine the (π^-, n) and $(\pi, \pi p)$ reactions completely. Spectra recorded at fixed beam energy, covering the angular range $\theta_r = 84\text{--}152^\circ$, will provide momentum distributions in the range $q \approx 390\text{--}750$ MeV/c. By varying the incident energy, we will obtain excitation functions at fixed momentum transfer for the differential (π^-, n) cross section through the interesting 3,3-resonance region, $T_\pi = 50\text{--}300$ MeV. For the highest incident energies, the recoil spectra will contain the cross section of $(\pi, \pi p)$ as well, which directly supplies information on the single-particle momentum distribution of the nuclear wave function. In addition to the nuclear-structure information that we will obtain, this experiment will contribute to the understanding of the π -N interaction in nuclei. Of particular interest, then, is the role of the 3,3-resonance (δ). This might be most influential around $T_\pi = 170$ MeV, which is in the middle of the energy range covered in this experiment.

For nuclei heavier than ^4He , triton emission can be caused by various reactions. It will be possible to recognize those involving only the presumed α core in light nuclei. We intend to search for such quasi-free $^4\text{He} (\pi^-, n)t$ reactions. If observed, they will evidence the α -core structure of light nuclei so we will gain nuclear-structure information. Moreover, we can exploit this type of quasi-free reaction to learn about the influence of the surrounding nucleons mainly on the pion projectile (distortion). Comparison of the excitation functions for the heavier nuclei will thus hopefully elucidate the role of the δ .

Exp. 246

STUDIES OF π^+ SCATTERING AT 50 MeV FROM LIGHT NUCLEI

Carnegie-Mellon University

R. A. Eisenstein, Spokesman

P. D. Barnes, W. R. Wharton, J. N. Craig, J. D. Sherman, K.G.R. Doss, S. A. Dytman

LASL

J. F. Amann, H. A. Thiessen, C. L. Morris

University of Virginia

D. Slater

University of Colorado

R. J. Peterson

New Mexico State University

G. R. Burlson, S. L. Verbeck

We propose further tests of the optical model description of low-energy pion-nucleus scattering. We propose elastic- and inelastic-scattering experiments (using a 50-MeV π^+ beam from the EPICS channel) on the following targets: ${}^6\text{Li}$, ${}^7\text{Li}$, ${}^{12}\text{C}$, ${}^{13}\text{C}$, ${}^{28}\text{Si}$, and ${}^{56}\text{Fe}$. The questions of special interest are (1) Does the sharp disagreement between experiment and theory regarding the elastic angular distribution, observed at ~ 50 MeV and lower on light nuclei, persist for heavier nuclei (e.g., ${}^{28}\text{Si}$ and ${}^{56}\text{Fe}$)? (2) Do discrepancies which exist between theory and experiment in low-energy elastic scattering persist in inelastic scattering? Can one make definite conclusions about the optical model from inelastic-scattering experiments? and (3) Can one directly learn detailed spectroscopic information from elastic and inelastic pion scattering by, for example, comparing an angular distribution from ${}^6\text{Li}$ to one from ${}^7\text{Li}$ or ${}^{12}\text{C}$ to ${}^{13}\text{C}$? Detection of the scattered pions will be accomplished using the CMU intrinsic germanium spectrometer and helical delay line chambers for ray tracing. A total of 740-h running time at primary intensity of $20\ \mu\text{A}$ will be required.

Exp. 247

DISTRIBUTIONS OF PRODUCTS FROM INTERACTIONS OF STOPPED π^- WITH SEVERAL MEDIUM- AND HEAVY-MASS NUCLEI

LASL

C. J. Orth, Spokesman

W. R. Daniels, B. J. Dropesky, R. A. Williams, J. N. Ginocchio

We propose to measure the distributions of γ -emitting products from stopped π^- interactions in copper, tantalum, scandium, and enriched ${}^{130}\text{Te}$ targets using activation techniques. Relative yields will be measured in targets exposed to the highest π^- flux available ($\approx 100\text{-}\mu\text{A}$ protons on production target). In runs at lower π^- intensity, the relative yields will be put on an absolute basis by measuring the atoms of a high-yield product formed per pion stop; stops will be counted with a conventional three-element (123) scintillator telescope.

The experiment is designed to complement our results from Exp. 103, in which we are measuring cross sections for fast pion- and proton-induced spallation of copper and tantalum. As in Exp. 103, the yields from these measurements will be compared with values calculated by means of the VEGAS intranuclear cascade plus DFF evaporation codes. From the amount of excitation energy (product distribution) and angular momentum (isomer ratios) imparted to the target nuclei, we expect to gain information about the average depth of π^- absorption by the nucleus.

We wish to expose scandium and ^{130}Te targets because the former yields measurable (π^-, pxn) products without (π^-, xn) interference while the latter yields measurable (π^-, xn) and (π^-, pxn) products with a large range of x values.

The yields will be determined by γ -ray measurements of residual products with germanium diodes in low-background environments. The scandium and copper targets will be measured directly, while radiochemical separations will be performed on the ^{130}Te and tantalum targets before counting.

Exp. 248

STUDY OF THE $(\pi, \pi\text{N})$, (π, Δ) , (π, B_Δ) , AND (π, N) REACTIONS IN ^3He AND ^6Li BY MEASURING RECOIL SPECTRA

TRIUMF

J. Källne, Spokesman

University of Virginia

J. S. McCarthy and P. C. Gugelot, Spokesmen

L. Orphanos

LASL

P.A.M. Gram, A. Wadlinger, B. C. Hoistad

College of William & Mary

C. F. Perdrisat

We propose an experiment to measure the energy spectra of charged particles from reactions in ^3He , induced by pions of different energies up to the highest available at LAMPF, i.e., an experiment for the P^3 channel. The emitted particles will be detected with a counter telescope of plastic scintillators and wire chambers allowing for particle identification, energy, and position measurements. Besides the (π^-, n) and (π^-, π^0) reactions (whose two-body final state can be uniquely identified), we shall obtain information on the $(\pi, \pi\text{p})$ reaction.

We also note that the energy range $E_\pi = 200\text{--}500$ MeV of the P^3 channel offers favorable kinematical conditions to look for single- and multi-nucleon transfer reactions involving an excited nucleon (Δ) in the exit reaction channel. Indications of reactions such as $\pi^- + ^4\text{He} \rightarrow \Delta^0 + \text{t}$ and $\pi^- + ^4\text{He} \rightarrow \text{p} + \Delta^-$ will therefore be searched for in the recoil spectra.

Exp. 249

THE (p, π^+) REACTION ON ^4He WITH 800-MeV PROTONS

University of California, Los Angeles

C. A. Whitten, Spokesman

G. J. Igo, T. S. Bauer, J. C. Fong, G. Pauletta, J. Soukup

LASL

B. C. Hoistad, G. W. Hoffmann

We propose to study the (p, π^+) reaction on ^4He at 800 MeV. The angular distributions of the pion production leading to the ground state or first excited state of ^5He can be measured confidently in the momentum transfer region 500–1200 MeV/c. No data exist so far in such a large q range for any nucleus or energy. It is also possible to extend the measurement to the kinematic momentum transfer limit 1600 MeV/c, if the cross section levels off at ~ 1 nb/sr for very high q.

The experimental results from ^4He constitute an essential part of the total information required to understand the reaction process in a microscopic way.

The experiment is designed for HRS with its general particle identification system tuned for pions. Good time resolution in the trigger system is required. It might be necessary to install an extra Cerenkov counter. A superfluid helium target designed for Exp. 4 can be used without modifications. All information about the background from the target should be available from Exp. 4.

Exp. 250

**INVESTIGATION OF THE USE OF STOPPED NEGATIVE MUONS
FOR MATERIALS ANALYSIS**

University of Mississippi

J. J. Reidy, Spokesman

LASL

R. L. Hutson, Spokesman

J. N. Bradbury

Techniques will be investigated for performing selected materials analysis, using the muonic x rays resulting from atomic capture of negative muons in the materials. The feasibility of doing quantitative analysis using "standards" for comparison will be investigated, as well as the possibility of interrogating small volumes ($\sim 1 \text{ cm}^3$) of large samples.

Archaeological artifacts, coal, and exotic materials supplied by CMB-6 will be studied in this initial investigation. Relative elements (abundance $\geq 0.05\%$) will be determined. Absolute determinations will be attempted. Limits to the technique will be established as a guide for future work.

Exp. 251

NEUTRON IRRADIATION OF COPPER TENSILE SPECIMENS

Lawrence Livermore Laboratory

J. B. Mitchell, Spokesman

M. W. Guinan, R. A. Vankonynenburg, R. Vandervoort

LASL

D. M. Parkin, Spokesman

W. V. Green

The proposed experiment will be the bombardment of copper samples in the neutron-irradiation cavity with the spallation neutrons emitted by the interaction of the 800-MeV protons with the copper beam stop. From the increase in the yield stress as a function of integrated beam current, a comparative damage effectiveness with fission and D-T fusion neutrons will be obtained. Further comparisons will be made by characterizing the damage structures via transmission electron microscopy.

Exp. 252

**PION CHARGE EXCHANGE AND INELASTIC SCATTERING ON
LITHIUM NUCLEI BY OBSERVING THE GAMMA DECAYS**

University of Colorado

J. J. Kraushaar, Spokesman

R. J. Peterson, R. A. Ristinen

The inelastic scattering of positive pions from ${}^6\text{Li}$ populates only one state that decays by gamma decay. On ${}^7\text{Li}$, the inelastic scattering and the charge-exchange reaction each also pop-

ulate only one gamma-emitting state. Since the spins of the states are 0^+ for ${}^6\text{Li}$ and $1/2^-$ for ${}^7\text{Li}$ or ${}^7\text{Be}$, the angular distribution of the gamma radiation is isotropic in the recoiling frame. We propose to study the gamma-ray yield at one angle to determine the total inelastic cross section to these particular channels as a function of beam energy. The experiment is to be done with the EPICS beam spot, in the time before the spectrometer is in position.

Exp. 253

**NEUTRON IRRADIATION OF METAL SAMPLES FOR USE IN
POSITION ANNIHILATION STUDIES OF DEFECTS**

Brookhaven National Laboratory

A. N. Goland, Spokesman

K. G. Lynn

LASL

D. M. Parkin, Spokesman

W. V. Green

Sandia Laboratories

W. B. Gauster

The proposed experiment will be the bombardment of samples of aluminum, copper, niobium, stainless steel, molybdenum, wolfram, and gold in the neutron-irradiation cavity with the spallation neutrons emitted by the interaction of the 800-MeV protons with the copper beam stop. Following irradiation, the characteristics of positron annihilation in each sample will be measured and compared with preirradiation behavior. From the changes observed, information about the types of defects created by high-energy neutrons will be developed. Experiments performed on samples irradiated at different temperatures will be used to determine how the state of agglomeration of the defects depends upon the irradiation temperature.

Exp. 254

**FEASIBILITY STUDY FOR THE MEASUREMENT OF THE
INELASTIC NEUTRINO-SCATTERING CROSS SECTION IN ${}^{39}\text{K}$**

Smithsonian Institution

E. L. Fireman, Spokesman

Catholic University

H. Uberall

LASL

J. W. Barnes

Inelastic neutrino-scattering cross sections on ${}^{39}\text{K}$ and ${}^{40}\text{Ca}$ producing ${}^{37}\text{Ar}$ are caused by neutral-current interactions. Although neutral-current reactions may have been observed for very high neutrino energies, $>10^9$ eV, no observations have been made for intermediate-energy neutrinos, 60 to 200 MeV, which would be made available at the Los Alamos Meson Physics Facility (LAMPF) neutrino laboratory. A radiochemical technique will be employed identical to that used for solar-neutrino studies. The use of potassium instead of chlorine, which is em-

ployed for solar-neutrino studies, changes the theoretical aspects of the neutrino experiment to a test of neutral-current interactions.

Backgrounds from cosmic rays and neutrons from the accelerator are estimated and compared to the expected ^{37}Ar production rate by neutrinos in two target-detector arrangements. We propose to measure these backgrounds in the LAMPF neutrino facility to check these estimates, with the aim of measuring neutrino inelastic-scattering cross sections.

A 2839-liter tank filled with an aqueous $\text{Ca}(\text{NO}_3)_2$ solution exists at LAMPF. This tank, when filled with an aqueous potassium-acetate solution, would contain 27 kg of ^{39}K . With this amount of ^{39}K , the accelerator neutron background can be determined with the accelerator operating at low beam intensity. The cosmic-ray background under various amounts of shielding could be determined with this tank or with a smaller tank.

Neutrinos of 60- to 200-MeV energies arise from pion decays in flight, and of 90- to 100-MeV energies from muon captures. Their intensity at the ^{39}K detector depends upon the experimental arrangement. Two arrangements, which are practical possibilities, are considered. In one arrangement, a cross section equal to the theoretical estimate would be measurable if the background were sufficiently low. The other arrangement is three times less sensitive.

Exp. 255

MEASUREMENT OF $\sigma(\theta)$ FOR n-p ELASTIC SCATTERING AT 460 MeV

Texas A&M University

L. C. Northcliffe, Spokesman

G. Glass, M. Jain

LASL

J. E. Simmons, B. E. Bonner

Measurements of the differential cross section for n-p elastic scattering at 460 MeV in the angular region $60^\circ < \theta_{\text{cm}} < 180^\circ$, to complement completed measurements at 647 and 800 MeV, are proposed. The apparatus and methods are the same as those used successfully at 647 and 800 MeV, and results of comparable accuracy (~ 0.1 mb/sr relative; $\sim 7\%$ absolute) would be obtained.

Exp. 256

I. p-NUCLEUS ELASTIC SCATTERING AT $q^2 = {}^8\text{Be}$, C, AND THE STUDY OF p-NUCLEUS INTERACTIONS IN Co AND Au UP TO $m^* = q^2/2\nu \cong 20$

University of Pennsylvania

S. Frankel, Spokesman

W. Frati

LASL

O. B. Van Dyck, G. W. Hoffmann, H. A. Thiessen

Brookhaven National Laboratory

T. Kozlowski

University of Minnesota

M. Othoudt

We shall use the HRS to measure $d\sigma/d^3p$ for the production of p, d, and t at 170° , out to momenta that include *elastic* nuclear scattering for beryllium, carbon, and aluminum, and to even higher momenta corresponding to $m^* = q^2/2\nu \cong 20$ for cobalt and gold.

This experiment will extend our earlier measurements above $m^* = 6.5$, greatly improve precision and accuracy, and represent the first observation of nuclear elastic scattering at such high q^2 ($\sim 8 \text{ BeV}^2$) in the region of $A \geq 9$.

In addition, some data will be taken for beryllium and gold at 150° .

Exp. 257

II. INCLUSIVE (180°) PRODUCTION OF NEUTRONS IN HIGH- q^2 p-NUCLEUS COLLISIONS OF HIGH EFFECTIVE MASS

University of Pennsylvania

S. Frankel, Spokesman

W. Frati

LASL

O. B. Van Dyck

University of New Mexico

D. M. Wolfe, B. D. Dieterle, J. Donahue

As a parasite (perhaps on Exp. 256 but possibly on another HRS experiment which works on suitable targets), we will measure $d\sigma/d^3p$ for 170° *neutron* production on a variety of nuclear targets. These data will be the first data on neutron production at high q^2 and high m^* . A 25- to 50- μs front porch of chopped beam will be utilized for time-of-flight experiments. As a parasite on Exp. 256, some p-n coincidence data will be accumulated.

Exp. 258

STUDY OF MECHANISMS FOR EJECTION OF ΔC HIGH-MOMENTUM PARTICLES FROM NUCLEI BY STUDY OF THE COINCIDENCE SPECTRUM IN $p + A \rightarrow (p,d,t) + (p,d,t) + X$

University of Pennsylvania

S. Frankel, Spokesman

W. Frati

LASL

O. B. Van Dyck

This experiment is designed to study the kinematic configurations that dominate the ejection of high-momentum target nucleons from nuclei.

We propose to build a small spectrometer ($\Delta p/p = \pm 1\frac{1}{2}\%$ $d\Omega = 10$ millirad) to be located near 90° on the HRS floor, composed of a pool quadrupole doublet, dipole magnet, and a scintillation telescope. This "backward" arm, detecting the target nucleons ejected with momentum q , will be placed in coincidence with the HRS used as a forward arm.

We propose to measure the HRS spectrum $N(p')$ for several momenta in the backward arm. Quasi-two-body scaling predicts that a peak will be seen in the HRS momentum spectrum of width $\cong$ the mean excitation ϵ of nuclei, as obtained in quasi-free scattering.

Data will also be obtained simultaneously for p,d,t in both arms to help elucidate the mechanisms for d,t ejection at high momenta.

Exp. 259

**HIGH-RESOLUTION RELATIVE MUONIC X-RAY INTENSITY
MEASUREMENTS FROM ELEMENTAL TARGETS IN THE RANGE $Z = 12-52$**

University of Mississippi

J. J. Reidy, Spokesman

LASL

R. L. Hutson, M. E. Schillaci

Weigand and Godfrey have discovered large variations, as a function of Z , of the absolute K^- x-ray yields in elemental targets. These variations are undoubtedly due to atomic capture and deexcitation processes, and are correlated with position in the periodic table. Kunselman *et al.* have pointed out that a similar correlation may be evident in the relative muonic x-ray intensities as well, but data are lacking that would uniquely establish such a correlation. If the interpretation of their data as proposed by Wiegand and Godfrey is correct, then fairly precise statements can be made concerning the expected muonic x-ray intensities.

We propose to perform high-resolution, high-accuracy measurements on the muonic x rays resulting from atomic negative-muon capture in elemental targets. Emphasis will be placed on measuring the relative intensities of the lines in the Lyman and Balmer series up to near the series limit from muonic sulfur, potassium or calcium, manganese titanium, germanium or selenium, and cadmium. These targets are in the regions of the periodic table where striking variations were obtained by Wiegand and Godfrey. These measurements will complement similar work done with kaons and proposed with pions (LAMPF Exp. 214). These data should aid in developing a unique theory for atomic meson capture.

**DETERMINATION OF NEUTRON DENSITY DISTRIBUTIONS
FROM ELASTIC PROTON SCATTERING AT 800 MeV**

LASL

G. W. Hoffmann, Spokesman

University of Texas, Austin

W. R. Coker, Spokesman

G. S. Blanpied, T. A. Griffy, R. Liljestrand

University of California, Los Angeles

G. J. Igo, Spokesman

J. C. Fong, J. Geaga, M. Nasser, R. J. Ridge, H. Spinka, C. A. Whitten

We propose to better determine the neutron density distributions for the isotopes of tin via a study of 800-MeV proton elastic scattering using the High-Resolution Spectrometer (HRS) at LAMPF. Proposal 109 (E. R. Flynn, Spokesman), "The Study of the Microscopic Structure of Collective Modes by Medium-Energy Protons," includes targets of $^{116,118,124}\text{Sn}$ and will provide elastic-scattering data on these tin isotopes. We wish to obtain elastic-scattering data for $^{112,114,115,120,122}\text{Sn}$ with the best possible accuracy in order to provide a complete set of elastic-scattering data on most of the isotopes of tin, and to systematically study elastic scattering for a complete isotopic sequence. Tin isotopes are ideal for such a study since the proton number is magic; coupled-channel effects are not expected to be important, and correlations and spin-dependent effects are expected to average out. Further, tin targets are easy to construct and are not prohibitively expensive.

The short de Broglie wavelength of the incident nucleon results in improved sensitivity to the details of the nuclear mass distribution and, in particular, the difference between the neutron mass radius and the proton mass radius when different isotopes of the same element are studied. Analyses made previously at lower energies suffered from a number of ambiguities which are not present at medium energies. Both phenomenological and microscopic optical model analyses can be made, the latter relying, e.g., on the Kerman-McManus-Thaler prescription connecting the first-order optical potential with the on-shell nucleon-nucleon scattering amplitude. The proton mass distributions are available from charge distributions via electron scattering.

The experiment requires excellent angular resolution ($\pm 0.05^\circ$) but only an energy resolution on the order of 1 MeV. A total running time of 233 h is requested, and the experiment could be scheduled concurrent with the HRS tuneup.

Since further progress in fitting the medium-energy elastic-scattering data and more conclusive results concerning neutron distributions extracted from such analysis require great confidence in the nucleon-nucleon scattering amplitudes, we also propose, as a second phase of the experiment, measurements of the analyzing power for proton elastic scattering on the tin isotopes at 800 MeV. These measurements can be done when the polarized source is operational, and will require 156 h.

Exp. 261

INTERMEDIATE ENERGY (p,d) REACTION MECHANISM STUDIES

Indiana University

M. E. Rickey, Spokesman

University of Colorado

J. R. Shepherd, Spokesman

R. E. Anderson, J. J. Kraushaar

LASL

R. F. Bentley

The (p,d) reaction has long been used in nuclear-structure studies at low (<100 MeV) bombarding energies. Recently, data at higher energies have become available which show effects not seen in the low-energy cases. In particular, the standard zero-range treatments of the reaction process have been shown to be inadequate, primarily because of effects arising from the D-state of the deuteron. In the framework of the DWBA, exact finite-range (EFR) calculations are required to treat these effects properly. Unfortunately, no (p,d) data at bombarding energies between 200 and 500 MeV are presently in existence. Such data are essential to examine in detail the initial conclusions based on the severely limited data mentioned above.

Thus, we propose to measure (p,d) cross sections at $E_p = 300, 400,$ and 500 MeV (the maximum deuteron energy which can be analyzed using the HRS facility is ~ 500 MeV), using targets of ^{12}C , ^{58}Ni , ^{90}Zr , and ^{208}Pb . The first target was selected to provide comparison with 700-MeV data already in existence. The remaining targets were chosen according to criteria which will allow analysis of the data to concentrate on questions of the (p,d) mechanism. The targets lead to well-known, well-separated (>300 -keV separation for low-lying levels) levels representing both $j = \ell + 1/2$ and $j = \ell - 1/2$ components of the 1p, 1f, 2p, and 4p shells. All targets except ^{12}C are also nearly spherical; hence, two-step reaction effects can be expected to be minimized. We also propose to measure proton + ^{90}Zr elastic-scattering data at 500 MeV. These data will serve as a benchmark to be used in generating distortion potentials for the DWBA calculations.

The goal of this study is a sound understanding of the (p,d) reaction mechanism at intermediate energies, which clearly must be achieved prior to use of the reaction in structure studies.

Exp. 262

TEST OF ISOSPIN INVARIANCE IN THE REACTION $np \rightarrow d\pi^0$

LASL

B. E. Bonner, Spokesman

J. E. Simmons

Texas A&M University

G. Glass, M. Jain, L. C. Northcliffe

Case Western Reserve University

M. W. McNaughton

University of Texas, Austin

P. J. Riley

There have been few experiments which have measured the $np \rightarrow d\pi^0$ angular distribution and compared this to that observed in the $pp \rightarrow d\pi^+$ reaction. As pointed out many years ago, charge independence dictates that the differential cross sections in the two reactions must differ

exactly by a factor of 2. In addition, the deuteron angular distribution in $np \rightarrow d\pi^0$ must be symmetric about 90° in the center of mass in order to conserve isospin. An alternative formulation of the latter condition is known as the Barshay-Temmer Test. The reaction $np \rightarrow d\pi^0$ is free from the normal Coulomb effects which complicate the application of this Test and has only 0.1% mass difference effects.

Using our presently existing MWPC spectrometer and the sharp monokinetic neutron beam from $pD \rightarrow n$, we propose to measure the complete angular distribution in $np \rightarrow d\pi^0$ at 800, 647, and 500 MeV, with an accuracy heretofore unobtainable.

Exp. 263

MEASUREMENT OF THE ENERGY AND ANGULAR VARIATION OF THE np CHARGE-EXCHANGE CROSS SECTION

LASL

B. E. Bonner, Spokesman

J. E. Simmons

Texas A&M University

G. Glass, M. Jain, L. C. Northcliffe

Case Western Reserve University

M. W. McNaughton

University of Texas, Austin

P. J. Riley

Many phenomenological approaches to calculation of the np elastic-scattering cross section at medium energy are presently being explored. Unfortunately, the large discrepancies between the recently published data sets mean that the presently existing data cannot provide very stringent tests for any calculation.

Using a continuum neutron beam together with our present MWPC spectrometer, we propose to measure as a function of neutron energy the ratio of the differential cross sections for the two reactions $np \rightarrow pn$ and $np \rightarrow d\pi^0$ over the neutron energy range from 325 to 800 MeV. The resolution of the measurement is limited only by our spectrometer and is typically ≤ 15 MeV for neutrons of 650 MeV. Under the assumption that measurements of the $pp \rightarrow d\pi^+$ cross section scheduled here at LAMPF will determine this quantity accurately, then our measurement will provide an excitation function of the np charge-exchange cross section with very good neutron energy resolution. Alternatively, using a calibrated neutron detector to be developed for Exp. 208, an independent measurement of the neutron spectrum will enable the extraction of both cross sections in an absolute fashion.

Exp. 264

**MEASUREMENT OF THE ENERGY VARIATION OF THE
nD ELASTIC DIFFERENTIAL CROSS SECTION NEAR 180°**

LASL

B. E. Bonner, Spokesman

J. E. Simmons

Texas A&M University

G. Glass, M. Jain, L. C. Northcliffe

Case Western Reserve University

M. W. McNaughton

University of Texas, Austin

P. J. Riley

The failure of the one-nucleon exchange mechanism to fit the backward peaking in the pd elastic-scattering angular distribution has led to postulation of various excited nucleon states (N^* 's, Δ - Δ) residing in the deuteron. Furthermore, the excitation function of the (extrapolated) 180° cross section shows a striking shoulder and change of slope around 600-MeV bombarding energy. Various theories have met with different degrees of success in explaining the observed results.

We have the capability of accurately measuring the elastic-scattering cross section for $n + d$ (which should, of course, be the same as $p + d$) as a function of both incoming energy and angle. Since with neutrons we can measure the cross section at 180° , this will provide the aforementioned excitation function without the necessity of extrapolation (which our preliminary results at 800 MeV show can lead to gross errors). Using a continuum neutron beam produced by 800-MeV protons, we propose to measure the energy variation of the nd elastic cross section for neutron center-of-mass angles from 140 - 180° over the energy range 325-800 MeV. The resolution at any given energy will be ≤ 15 MeV. The region of the shoulder and slope change in the excitation function will be mapped out accurately and in a consistent manner in the proposed experiment.

Exp. 265

**STUDY OF PROMPT NUCLEAR DEEXCITATION GAMMA RAYS
FROM PION INTERACTIONS WITH ${}^6,{}^7\text{Li}$, AND ${}^{12}\text{C}$**

LASL

C. L. Morris, Spokesman

H. A. Thiessen

University of Texas, Austin

W. J. Braithwaite, Spokesman

C. F. Moore, K. G. Boyer, J. Bolger

TRIUMF

J. Källne

University of Colorado

J. J. Kraushaar, R. J. Peterson, R. A. Ristinen

We propose studying prompt deexcitation gamma rays from pion-induced reactions on ${}^6\text{Li}$, ${}^7\text{Li}$, and ${}^{12}\text{C}$ [the states to be studied are ${}^6\text{Li}$ (3.56), ${}^7\text{Be}$ (0.429), and ${}^{12}\text{C}$ (15.11)]. Primary

emphasis will be placed upon extracting total cross sections for states which are preferentially populated through the $(\sigma \cdot L)(T \cdot \tau)$ term in the π -N interaction. Secondly, we will measure the $\sigma_{\pi^+}/\sigma_{\pi^-}$ ratios for neutron knockout from ${}^7\text{Li}$ to ${}^6\text{Li}$ (3.56). The experiment will be performed at a set of pion energies which spans the 3,3 resonance; 100, 150, 200, and 250 MeV.

Since all of these states are not fed from higher states in the residual nucleus, total cross section can be extracted directly from gamma-ray yields. Furthermore, since the pion energy can be varied over the 3,3 resonance, and the strength of the interaction varied, such things as multiple-step contributions and distortion effects can be measured and corrected for, and the strength of the interaction can be extracted in the energy region.

Gamma-ray fluxes will be measured in a set of existing detectors, two 12.7- by 12.7-cm NaI scintillators, and one 40-cm³, at least, Ge(Li) detectors. Since all of the states to be studied are the highest particle stable states in the final nuclei, problems associated with feeding from higher states and with Compton backgrounds from higher states will be minimized. We have chosen to use NaI counters because Doppler broadening of the gamma lines of interest cancels the advantages of the better resolution associated with Ge(Li) detectors, and enhances the importance of higher efficiencies obtainable with NaI detectors in all but the low-energy state in ${}^7\text{Be}$.

Exp. 266

TRAPPING OF POSITIVE MUONS AT DEFECTS IN METALS

Sandia Laboratories

W. B. Gauster, Spokesman

LASL

R. H. Heffner, Spokesman

J. N. Bradbury, R. L. Hutson, M. Leon, D. M. Parkin, M. E. Schillaci

Hochschule der Bundeswehr München

W. Triftshäuser

The purpose of the proposed experiment is to ascertain whether positive muons are captured by defects in metals. The technique is to stop a beam of spin-polarized positive muons in a sample target and to determine the attenuation of muon precession in a transverse magnetic field as a function of sample temperature.

The first experiments, using face-centered cubic metal crystal targets, are intended as a feasibility study. Both annealed crystals and samples with defects produced either by quenching or by particle irradiation will be used. From a comparison of the muon-spin depolarization as a function of temperature (from 100 K to room temperature) for the nondefected samples on the one hand and the ones containing defects on the other, it will be possible to infer whether or not the muons are trapped at defect sites.

If, in fact, as expected from theory, positive muons are trapped by defects in metals, a new experimental tool for the study of radiation damage will become available. The use of muons as probes for defects would complement and extend the study of defects by positron annihilation. If — contrary to expectation — muons are not trapped, the experiments in the form proposed would yield information on the diffusion of muons in metals.

Exp. 267

PREPARATION OF RADIOISOTOPES FOR MEDICINE AND THE PHYSICAL SCIENCES USING LAMPF ISOTOPE PRODUCTION FACILITY

LASL

Dr. A. Thompson, Spokesman

A. B. Denison, P. M. Grant, J. W. Barnes

Funding funds provided by ERDA's Division of Biomedical and Environmental Research, Los Alamos Nuclear Chemistry Group (CNC-11) has effected a complete retrofit of the remote handling equipment in the Isotope Production Facility (ISORAD) such that it now appears possible to insert and remove targets with a minimal interference to the normal LAMPF operation. For this reason and because the operations carried out by CNC-11 personnel in this program are not expected to place appreciable demands upon LAMPF services or materials, this program is judged to be a parasitic experiment.

This experiment will endeavor to utilize the equipment in the Isotope Production Facility to produce a variety of different target materials in the proton beam immediately upstream of the target stack. The primary objective of these irradiations is to make sufficient amounts of different radioisotopes for biomedical studies both at LASL and at distant sites, in accord with the objectives of LASL's Medical Radioisotope Research Program. It is expected that the on-site production of these radioisotopes will have impact on the translocation efforts as well as on the new therapy program.

Since the major emphasis of this experiment is the preparation of radioisotopes for medical diagnosis and limited clinical investigations, we propose, in addition, to produce a small amount of special isotopes for studies in the physical sciences. Already under active consideration are the preparation of ^{26}Al , ^{28}Si , ^{72}Y , ^{208}Pb , and ^{210}Pb .

Most of the radioisotopes prepared in this experiment will be used to satisfy the program requirements of the LASL Medical Radioisotope Research Program. However, some of the radioisotopes developed in this program are expected to have future commercial value. When this new Isotope Production Program will be established at LASL for the routine production and distribution of radioisotopes to commercial firms in accordance with established ERDA procedures, it is our estimate that commercial production will not develop within the next year, and that the program will be self-sustaining thereafter.

Exp. 268

MEASUREMENT OF THE GROUND-STATE HYPERFINE STRUCTURE INTERVAL OF THE MUONIC HELIUM ATOM ($\alpha\mu e$)

Yale University

P. A. Souder and V. W. Hughes, Spokesmen

D. Casperson, T. Crane, P. Egan, D. C. Lu, F. G. Mariam, H. W. Reist

University of Heidelberg

H. Orth (University of Heidelberg/Yale University), G. zu Putlitz

LASL

P. A. Thompson

University of Wyoming

A. B. Denison

Recently, the muonic helium atom has been discovered. We propose to measure its hyperfine-structure interval $\Delta\nu$ to a precision of about 10 ppm by the microwave magnetic resonance method used for muonium. The same equipment and setup will be used as in LAMPF Exp. 37A. This measurement will test the theory of this unique atom and will provide the most precise measurement of the μ^- magnetic moment.

Exp. 269

800-MeV PROTON IRRADIATION OF METAL SAMPLES

LASL

W. V. Green, Spokesman

C. A. Coulter, L. S. Levinson, D. M. Parkin, L. Rosen

The proposed set of experiments will be the irradiation of metals by the 800-MeV proton beam in the switchyard. Postirradiation examinations of the irradiated metals will be used to verify the atomic displacement and transmutation calculations of A. Coulter *et al.* Vacuum fusion inside a calibrated mass spectrograph will be used to determine the total helium produced by spallation in copper disks and other metals and alloys. Microhardness measurements across the irradiated spot on 0.25-mm-thick metal targets will be used to compare radiation hardening produced by high-energy protons to that by neutrons. The increase of microhardness measures the increase of flow stress and work hardening rate. The flow stress and work hardening rate increases are the result of dislocation pinning and the formation of dislocation glide barriers. Any distinctive difference between radiation hardening produced by high-energy protons and by neutrons will indicate differences in the displacement spike structures and their subsequent annealed states. Voids will be produced in two aluminum disks of 0.25-mm thickness. The first will be thinned for electron-transmission microscopy well away from the surface; the second disk will be thinned so that transmission work will be on material between 5000 and 10 000 Å from the surface, as with heavy ion irradiation work. Comparison will disclose whether heavy ion irradiated materials examined in their usual way are representative of bulk irradiation.

Voids are formed in molybdenum when it is irradiated at room temperature and later annealed at about 1000°C. The dose required to observe voids is very low for this two-step process. Molybdenum disks 0.25 mm thick will be irradiated to demonstrate that this also occurs with irradiation by protons.

Exp. 270

THERAPY BEAM DEVELOPMENT — BIOMEDICAL CHANNEL TUNING

LASL

M. Paciotti, Spokesman

J. Bradbury, J. Helland, R. Hutson, E. Knapp

Four static beams to be used for therapy will be developed along with a fan beam to be used for future dynamic treatments. In addition, we propose to arrive at an understanding of the beam shaping section (Q4-Q3) of the channel so that future beam development will be simplified.

Exp. 271

THERAPY BEAM DEVELOPMENT — DOSIMETRY

University of New Mexico

A. Smith, Spokesman

R. Lane, C. Kelsey

LASL

H.I. Amols, J.F. Dicello

Automated three-dimensional dosimetry measurements will be performed for several π^- beams produced at the Biomedical channel to determine their therapeutic usefulness. Promising candidate beams will be characterized in detail. Conventional (ion-chamber, film) and non-conventional (nuclear emulsions, solid-state devices) detectors will be employed. Absolute pion dosimetry will be investigated in several ways.

Exp. 272

THERAPY BEAM DEVELOPMENT — MICRODOSIMETRY

LASL

J.F. Dicello, Spokesman

H.I. Amols, M. Zaider

It is proposed that microdosimetric techniques be continued to investigate the radiation quality of biomedical beams, the change in quality for different tunes, and the change in quality as a function of depth and position for specific tunes. These data are necessary input 1) for choosing appropriate tunes; 2) for designing targets, wedges, collimators, and bolus; 3) for achieving precise and accurate dosimetry; 4) for interpreting change in biological response; and 5) as input data into treatment planning.

The probability of depositing a given energy in a volume equivalent to 1 or 2 μm in unit density material as a function of the energy deposited will be measured. Spherical proportional counters, 2.5-cm in diameter, and constructed from Shonka A150 neutron tissue-equivalent plastic, will be used. Work to develop smaller chambers of various materials will proceed in parallel with the measurements.

Exp. 273

THERAPY BEAM DEVELOPMENT — LET MEASUREMENTS

LASL

C. Richman, Spokesman

Four static beams suitable for therapy will be studied along with a fan beam to be used for future dynamic treatments. The studies utilize solid-state detectors to separate the various particles in the peak and the plateau, and also to determine the LET distributions at various depths in a phantom.

Exp. 274

PION RADIOBIOLOGY

University of New Mexico

J. Yuhas, Spokesman

W. Black, S. Jordan, C. Key, M.M. Kligerman, M. Kornfeld, C. Sternhagen, M. Yurcinic

LASL

L.S. Gomez

The objective of this project is to provide a broad base of information on the expected responses of normal and tumor tissues following exposure to negative pions, so that clinical trials of pion radiotherapy can be designed most effectively. Biological studies will be conducted to determine injury to normal and tumor tissues in the peak pion region, the sparing factor for normal tissues adjacent to the tumor volume and/or in the plateau beam path, optimal fractionation schedules, isoeffect characteristics, and reasons for observed changes in therapeutic effect.

Exp. 275

PION CLINICAL TRIALS

University of New Mexico

M.M. Kligerman, Spokesman

R. Hilgers, T. Powell, J. Sala, C. Sternhagen, G. West

The purpose of this experiment is to conduct (in accordance with the requirements of the U.S. Department of Health, Education, and Welfare, and the University of New Mexico guidelines for research involving human subjects) the necessary studies required to evaluate the efficiency and potential benefit of negative-pi mesons (pions) in treatment of advanced tumors. Some of these studies are

1. Human radiobiology studies to establish the response of critical normal structures surrounding metastatic lesions to low doses of pions and control x radiation,
2. Pilot studies to establish the response of primary tumors and surrounding normal structures to palliative doses of pions and control x radiation, and
3. Phase III studies to establish the response of primary tumors and surrounding normal structures to curative doses of pions and control x radiation.

Exp. 276

PERTURBED CIRCULAR POLARIZATION OF MUONIC X RAYS

University of Tokyo

T. Yamazaki, Spokesman

R. Hayano, K. Nagamine, J. I. Mazato

California Institute of Technology

F. Boehm

LASL

C. Y. Huang

Each state of a muonic atom has a large polarization brought by the original muonic polarization, and, thus, muonic x rays have a large circular polarization that depends on the formation of their initial states. While an extensive program on this subject is being planned at TRIUMF for the future, the present proposal aims at studies of two specific problems: 1) possible depolarization during the muonic cascade (perturbed circular polarization) in metallic palladium (paramagnetic), and 2) measurements of the unperturbed circular polarization for $2p \rightarrow 1s$, $3p \rightarrow 1s$, and $4p \rightarrow 1s$ muonic x rays in one typical nonmagnetic metal (cadmium), which will tell us about the formation and cascade mechanism of muonic atoms. This proposal is motivated by the surprising result of the Tokyo group on the depolarization of the negative muon in paramagnetic nickel and palladium metals, indicating that the initial polarization is completely lost either during the muonic cascade (unexpectedly violent mechanism) or by an extremely fast relaxation at the $1s_{1/2}$ state (associated with an unexpectedly large hyperfine anomaly). To pin down these two mechanisms, it is essential to measure the x-ray circular polarization, but no such experiment has ever been done. The maximum (unperturbed) circular polarization of the $2p_{3/2} \rightarrow 1s_{1/2}$ and $2p_{1/2} \rightarrow 1s_{1/2}$ x rays is +0.05 and -0.33, respectively, which can be detected by means of a conventional transmission-type polarization analyzer (using Compton scattering in polarized iron) in connection with a Ge(Li) detector.

Exp. 277

MUONIC X-RAY ANALYSIS OF CORE SAMPLES FROM OIL-BEARING FORMATIONS

University of Houston

J.C. Allred, Spokesman

LASL

J.N. Bradbury

Petroleum and the formations which contain it are mainly composed of light elements, $Z < 20$. For this reason, muonic x-ray analysis (MXA) appears to be of considerable interest. Of course, many analytical techniques have been employed in the past to study oil-bearing formations. Among them are wet chemistry, x-ray fluorescence, and neutron-activation analysis. MXA would appear to offer some advantages over these other methods, such as homogenization of the sample, rapid analysis, and, in some instances, evaluation of elemental composition which is otherwise done with greater difficulty.

While it may turn out that MXA produces no new results, the general consensus among knowledgeable geologists and geochemists whom I have consulted is that it would be quite worthwhile to have a look at this technique in the study of geological specimens.

Exp. 278

**STUDY OF REACTION MECHANISMS USING INTERNAL
CONVERSION TECHNIQUES**

University of Texas, Austin

C.F. Moore, Spokesman

G.S. Blanpied, J. Bolger, R. Liljestrand, L.E. Smith

LASL

G.W. Hoffmann, Spokesman

Three years ago, we designed and built an in-beam internal conversion spectrometer for use at the Center for Nuclear Studies at the University of Texas at Austin.

We are very interested in using this device as a tool at LAMPF for studying both proton- and pion-induced reactions. The large solid angle (40 msr), excellent energy resolution (4 keV FWHM), and low background provided by this instrument make it ideal for use at LAMPF. The liquid-nitrogen-cooled lithium drifted silicon detector is shielded from the target by almost 1.5 m of lead. The device is relatively small and lightweight. It is quite easy to move about. It has its own current regulated power supply, which requires 240-V three-phase power.

Exp. 279

**MEASUREMENT OF NEUTRON-NEUTRON DIFFERENTIAL
CROSS SECTION AND A TEST OF CHARGE INDEPENDENCE**

University of New Mexico

B.D. Dieterle, Spokesman

H.C. Bryant, J. Donahue, C.P. Leavitt, D.M. Wolfe, T. Rupp, R. Carlini, W. Thomas

Temple University

W.K. McFarlane, Spokesman

L.B. Auerbach, V.L. Highland, K.F. Johnson

LASL

R.F. Bentley, J. Pratt

We propose to perform a measurement of $\sigma_{nn}(\theta)$ with 5% precision for the purpose of testing charge independence. We cover the angular region $30^\circ < \theta \text{ c.m.} < 90^\circ$. The apparatus is almost identical to Exp. 193 [$\sigma_{np}(\theta)$], and, therefore, that proposal is included. We hope eventually to measure $\sigma_{pp}(\theta)$ from the protons bound in deuterium so that a comparison of the two cross sections can be made without the effects of interference being important.

Exp. 280

**MEASUREMENT OF FORWARD-SCATTERING CROSS SECTION IN
p-p AND p-d ELASTIC SCATTERING BETWEEN 500-800 MeV**

University of California, Los Angeles

B.M.K. Nefkens, Spokesman

H. Brandle, N. Matz, W. Plumlee

LASL

O.R. Sander, J. Pratt, J.E. Spencer

We propose to measure the differential cross section for pp and pd elastic scattering for incident energies of 500, 600, 700, and 800 MeV. The range of c.m. angles to be investigated is 0 to 20° (0 to 8° laboratory), and spans the region of dominant Coulomb scattering to that of dominant nuclear scattering. For this study, we propose to use the LAMPF High-Resolution Spectrometer (HRS) and liquid-hydrogen and deuterium targets.

The objectives of the experiment are to provide

- a) accurate data for the phenomenological description of the p-p interaction at 500-600 MeV, using phase-shift analysis, and at 700-800 MeV, using invariant amplitude analysis;
- b) better knowledge of the t dependence of nuclear scattering at small values of t ;
- c) a test of dispersion relations via the measurement of α_p , the ratio of the real part of the nuclear amplitude to the imaginary part of p-p scattering; and
- d) accurate p-d data at small values of t .

This experiment is an ideal tuneup experiment for the HRS, in that it combines good, solid physics with the necessary parameter optimization of the HRS.

Exp. 281

STUDY OF DEFECTS IN SUPERCONDUCTORS USING μ^+

LASL

C.Y. Huang, Spokesman

R.L. Hutson, S.S. Rosenblum, M.E. Schillaci, R.H. Wang

Cleveland State University

C.W. Chu

No summary available.

Exp. 282

**MEASUREMENT OF CROSS SECTIONS FOR PROTON-INDUCED
FORMATION OF SPALLATION PRODUCTS IN COPPER
BY ACTIVATION ANALYSIS**

Kansas State University

H.J. Donnert, Spokesman

LASL

B.J. Dropesky, L.S. Levinson, R.A. Williams

Recent radiation-damage calculations by Coulter *et al.* entail the use of spallation cross sections calculated by the Nucleon-Meson Transport Code on the basis of an intranuclear-cascade subroutine following the model of Bertini *et al.* There is serious question as to the validity of cross sections thus obtained, as well as for cross sections calculated by a different and more sophisticated intranuclear-cascade mode for which some experimental comparisons of spallation cross sections are available. The need for an experimental check and possible verification of calculated spallation cross sections appears to be in order.

Exp. 283

CHARGED-PARTICLE EMISSION FOLLOWING μ^- CAPTURE

Oregon State University

T. C. Sharma and K. S. Krane, Spokesmen

L.W. Swenson

University of Oregon

P. Varghese, D.K. McDaniels

LASL

N. Tanaka, R.R. Silbar, E.B. Shera

Florida A&M University

C. Goulding

An experiment is proposed to measure charged-particle emission following μ^- capture on ^{12}C , ^{24}Mg , ^{28}Si , ^{32}S , and ^{40}Ca targets. The measurements will yield cross sections for charged particles emitted with energies greater than 10 MeV.

The existing data on pion-induced nuclear knockout reactions near the (3,3) resonance point to the resolution of a long-standing puzzle concerning the large deviations from the impulse approximation for ratios of π^- total neutron knockout cross sections, and it appears that charge exchange of the outgoing recoil nucleon can account for the observed ratio. An important feature of the proposed experiment is to test this idea by seeing if there are any "direct charge-exchange protons" coming out of nuclei after μ^- capture.

It is proposed to use the Oregon State University detector system to detect charged particles. This system consists of two wire chambers for position and angle information, two thin scintillators for ΔE information, and a thick scintillator to determine the energy. Particle identification will be established by the E, ΔE PDP-11 computer, and the CAMAC interface of OSU will be used for data acquisition. These detectors and computer were used in Exp. 156 and are on site at LAMPF.

Exp. 284

MEASUREMENT OF THE $^3\text{He}(\pi^-, \pi^0)^3\text{H}$ ANGULAR DISTRIBUTION

LASL

M.D. Cooper, Spokesman

J.D. Bowman, R.H. Heffner, C.M. Hoffman, J. Potter, M. Zaider

Tel Aviv University

J. Alster, S. Gilad, M. A. Moinester (LASL/Tel Aviv)

Case Western Reserve University

H.W. Baer, P.R. Bevington

University of Virginia

J.S. McCarthy

We propose to measure the $^3\text{He}(\pi^-, \pi^0)^3\text{H}$ reaction to the ground state of tritium, using a cryogenic ^3He target and the π^0 spectrometer presently under construction by groups at LASL, Tel Aviv University, and Case Western Reserve University. Differential cross sections at seven angles between 0 and 180° will be measured at seven energies from 30 to 230 MeV. The data are expected to be important for understanding the charge-exchange process in light nuclei. The most important effects which will be elucidated by the data are expected to be spin-flip and nonspin-flip contributions to the amplitude, as well as absorption of the pion waves.

Exp. 285

**MIGRATION OF ^{11}C AND ^{13}N RADIOACTIVITY PRODUCED
IN VIVO BY NEGATIVE PIONS**

LASL

L.F. Mausner, Spokesman

L.S. Gomez, J.D. Knight, H.A. O'Brien, M.A. Moinester (LASL/Tel-Aviv University)

We propose to study the migration of ^{11}C and ^{13}N produced by negative pions in a dog. Information on this migration could influence plans to use radioactive species as pion dosimetry indicators, and might eventually prove useful for various physiological applications. We will irradiate the heart, lung, and muscle (rump), and, subsequently, count at areas remote from the irradiation zones.

Exp. 286

PROTON AXIAL TOMOGRAPHY

LASL

K.M. Hanson, Spokesman

J.N. Bradbury, M.A. Paciotti, E.A. Knapp

The purpose of the proposed experiment is to study the feasibility of using protons to obtain axial tomographs of quality comparable to existing commercial x-ray scanners, and to demonstrate that such proton axial tomographs can be obtained with a substantial reduction in

dose to the specimen. A variety of proton detection schemes will be explored to determine their suitability for medical use.

Exp. 287

STUDIES OF GAMMA ANGULAR-RAY SPECTRA AND PION-GAMMA ANGULAR CORRELATIONS IN SCATTERING OF PIONS AT LAMPF

Utah State University

V.G. Lind, *Spokesman*

O.H. Otteson, R.E. McAdams, W. Denig

Texas A&M University

R.B. Clark

LASL

P.A.M. Gram, W.V. Hassenzahl

Florida State University

H.S. Plendl

Florida A&M University

M. Greenfield

Virginia State College

C. Stronach

We will endeavor to obtain coincidences between the scattered pions and the prompt gamma rays emitted by the target nucleus. If time permits, we will collect data for a crude angular correlation by varying the angle between the gamma-ray detector and the pion detector.

Exp. 288

STUDIES OF μ^- CAPTURE PROBABILITIES FOR SOLID-STATE SOLUTIONS

Princeton University

R.A. Naumann, *Spokesman*

G. Schmidt

LASL

J.D. Knight, C.J. Orth, M.E. Schillaci

Argonne National Laboratory

L. F. Mausner

Muon-capture x-ray spectra will be recorded for five single-phase systems of variable composition containing two or three elements. Relative muon-capture probabilities will be determined from the summed elemental K x-ray intensities observed for alloy and ionic crystal samples.

The objective is to quantitatively test

- (1) the linearity of muon-capture ratio with composition, and
- (2) the invariance of the individual elemental x-ray spectra to composition.

The experiment is intended to enhance knowledge of negative-muon-capture cascade processes in atomic systems. The results relate directly to the use of muons for elemental analysis.

**MEASUREMENT OF THE PHASE OF THE FORWARD
NUCLEON-NUCLEON SPIN-INDEPENDENT ELASTIC-SCATTERING
AMPLITUDE AT 800 MeV**

University of California, Los Angeles

C. Whitten, Spokesman

T.S. Bauer, J.C. Fong, G.J. Igo, R.J. Ridge

LASL

J.E. Spencer, G.W. Hoffmann

This experiment will determine the phases, ϕ_{pp} and ϕ_{pn} , of the forward spin-independent amplitudes for proton-proton and proton-neutron elastic scattering, respectively, by accurate measurements of the p-p and p-d elastic-scattering cross sections at 800 MeV in the region of four momentum, t , where the Coulomb and nuclear amplitudes are of comparable magnitude and Coulomb-nuclear interference effects may be observed. Spin-dependent effects in the forward-scattering amplitudes will also be studied. The forward-angle elastic-scattering cross sections are obtained from measurements in a gas target cell of the energy spectra for the recoil target particles. The p-p and p-d forward-angle elastic-scattering cross sections measured in this experiment will represent a significant improvement over similar data currently available in the incident proton energy range from 500 MeV to 1 GeV. Accurate determinations of ϕ_{pp} and ϕ_{pn} are very important input data for

1. all analyses — in particular, phase-shift analyses — of the nucleon-nucleon elastic-scattering amplitude,
2. all nucleon-nucleus scattering theories — for example, the Glauber theory — that use parameterizations of the forward nucleon-nucleon scattering amplitude, and
3. theoretical checks of dispersion relations.

Exp. 290

**MEASUREMENT OF THE NEUTRON SPECTRUM FROM THE
MAIN BEAM STOP AT LAMPF WITH A SELF-CONTAINED
TWO-PARAMETER SPECTROMETER**

Kent State University

R. Madey, Spokesman

B.D. Anderson, A. Baldwin, R. Cecil, T.R. Witten

LASL

W. V. Green and L. R. Veaser, Spokesmen

It is proposed to measure the neutron spectrum from the main beam stop at LAMPF with the Kent State University two-parameter neutron spectrometer. The measurements would be performed at the exit of an existing 18.5-m-long collimator at an angle of 135° . The primary use of these measurements would be to serve as an on-line monitor of the neutron flux present at the site of an irradiated sample in the radiation-damage facility. Neutron spectra at these two locations will be related with Monte Carlo neutron transport calculations and with comparison to the results obtained from simultaneous foil activation experiments. The two-parameter spectrometer is particularly attractive for monitoring changes in the neutron spectra on line. For a proton beam intensity of $100 \mu\text{A}$, a data-acquisition time of ~ 3 h should be sufficient for on-line monitoring, and ~ 12 h for a publishable spectrum.

Exp. 291

**COMPARISON OF THE QUASI-ELASTIC RATIO $\sigma(\pi^-, \pi^- n)/\sigma(\pi^+, \pi^+ n)$
TO THE RATIO $\sigma(\pi^+, \pi^+ p)/\sigma(\pi^-, \pi^- p)$ IN A COINCIDENCE EXPERIMENT**

Oregon State University

L. W. Swenson, Spokesman

K. S. Krane

University of Texas, Austin

C. F. Moore, Spokesman

New Mexico State University

G. R. Burleson, M. J. Devereux, S. L. Verbeck

Florida A&M University

M. Greenfield, C. Goulding

LASL

G. W. Hoffmann, C. L. Morris, N. Tanaka, H. A. Thiessen

University of Oregon

D. K. McDaniels, P. Varghese

University of Oregon/ Oregon State University

T. C. Sharma

Florida State University

H. S. Plendl

The experiment will measure the ratios $\sigma(\pi^-, \pi^- n)/\sigma(\pi^+, \pi^+ n)$ and $\sigma(\pi^+, \pi^+ p)/\sigma(\pi^-, \pi^- p)$ on the pion-nucleon (3,3) resonance by detecting both the outgoing pion and nucleon in coincidence for targets of carbon, nickel, and lead. The results of Exp. 156 (completed in May 1976) demonstrated that such coincidence measurements are indeed possible with the present pion intensities in the EPICS channel.

The emphasis of the experiment is to determine whether or not charge exchange of the outgoing nucleons with the residual target nucleus is as important as has been suggested by Silbar and collaborators. Based on the impulse approximation and isospin coupling coefficients, both of the ratios are expected to be 9, since the experiment is not sensitive to pion charge exchange. If charge exchange of the outgoing nucleon occurs, deviations from the ratio of 9 are expected, most dramatically for the case of heavy nuclei, where there is a large neutron excess that can charge exchange with the knocked-out protons. This process must leave the residual target nucleus in the analog of the original proton hole state. However, a neutron excess inhibits the residual nucleus charge exchanging with the knocked-out neutrons, since there are no available $T^<$ analog states for the (n,p) charge-exchange reaction to populate (obviously, since T cannot be less than T_2). Therefore, the (p,n) and (n,p) charge-exchange cross section will differ in the case of heavy nuclei, and thus will reflect a difference in the $\pi^\pm$ neutron knockout ratio vs the $\pi^\pm$ proton knockout ratio, that is, if nucleon charge exchange is an important process in the $(\pi, \pi'N)$ reaction.

The outgoing pions, protons, and neutrons will be detected with large, solid-angle position-sensitive systems consisting of wire counters and plastic or liquid scintillators. Thick scintillators, preceded by thin scintillators, will detect and identify the recoil protons and neutrons. The proton energy will be measured with $E, \Delta E$ methods, and the neutron energy and angle will be measured by time-of-flight methods. The proton angle will be measured with wire chambers. Pulse-shape and/or time-of-flight discrimination may be used to separate neutron events from gamma background events in the neutron counters.

Since the Coulomb displacement energy in lead is about 19 MeV, the energy information will be able to distinguish between knockout neutrons or protons from quasi-elastic scattering and those originating from nucleon charge exchange.

This work will, therefore, provide an extremely stringent test of the suggestion by Sternheim and Silbar, and others, that charge exchange is the process responsible for the discrepancy between impulse approximation predictions and experimental measurements for the $(\pi, \pi'N)$ reaction.

The time requested is 50 h for installation and tuneup, and 250 h for data production. More time, if available, could be used to take either complete angular distributions or excitation functions. The experiment is proposed to be run on the EPICS channel during the time the EPICS spectrometer is being readied for use, thus, sometime during the fall or winter of 1976.

Exp. 292

NEUTRON EMISSION FROM MUON-INDUCED REACTIONS ON ACTINIDE ELEMENTS

University of Rochester

J. R. Huizenga, Spokesman

M. W. Johnson, W. U. Schroder

LASL

W. K. Hensley, D. G. Perry

It is proposed to study the time distributions of neutrons emitted in muon-induced reactions on actinide targets at the LAMPF Stopped-Muon channel. The main goal of these experiments is to measure accurately the rate of disappearance of a muon from the 1s state of muonic atoms in the range from muonic ^{232}Th to ^{248}C . The muonic lifetimes deduced from these measurements are needed as a standard for the comparison to fission half-lives, which are studied in current experiments. In addition, the muon-capture rates obtained will be useful to test recently developed

theories on muon capture in complex nuclei and, hopefully, reduce uncertainties of existing experimental data.

It is also proposed to perform exploratory studies on the radiationless excitation mode leading to fission and neutron emission by measuring the spectrum of promptly emitted neutrons. Depending on the details of the excitation mechanism, valuable information on the excitation function of radiationless transitions can be obtained. Such information will further our understanding of prompt muon-induced fission of actinide elements.

Exp. 293

STUDY OF THE DOMINANT REACTION MODES FOR PIONS INTERACTING WITH COMPLEX NUCLEI

Argonne National Laboratory

R. E. Segel, Spokesman

H. E. Jackson, S. L. Tabor, E. Rehm, J. P. Schiffer (ANL/UCHI)

Northwestern University

L. Rutledge

LASL

R. L. Burman, M. A. Yates-Williams

Saclay

J. Julien

A study of the dominant reaction mechanisms for pions interacting with complex nuclei is proposed. The study is an outreach of Exp. 121 (Interaction of Fast Pions with Complex Nuclei). The work will be done in the LEP channel using pions, mainly π^+ , in the 50- to 200-MeV range. Particles will be detected in counter telescopes capable of detecting pions, protons, and deuterons. The particle detectors will subtend rather large solid angles, and the particle energies will be measured by 12.7-cm-thick NaI(Tl) crystals. Both particle-particle and particle-gamma coincidence measurements will be made, with the γ rays detected by a Ge(Li) spectrometer. The targets will be ≈ 2 g/cm² thick.

Exp. 294

HIGH-ENERGY NUCLEAR REACTIONS

Carnegie-Mellon University

P. J. Karol, Spokesman

Spallation of complex nuclei by 800-MeV protons will be examined by determining yields and recoil properties of products from a variety of medium and heavy targets. Isobaric yield curves will be measured by activation techniques with emphasis on precisely defining and extending the curves away from stability where results are expected to be particularly sensitive to details of the cascade-evaporation model. The combination of LAMPF's high-intensity external beam, pneumatic target transfer capabilities, and the anticipated development of very rapid separation procedures should provide for copious new and valuable input to high-energy reaction mechanisms.

STUDY OF THE PION-DEUTERON SINGLE-CHARGE-EXCHANGE REACTION $D(\pi^-, \pi^0)2n$

LASL

J. D. Bowman, Spokesman

M. D. Cooper, W. R. Gibbs, R. H. Heffner, C. M. Hoffman, J. Potter, G. J. Stephenson, M. Zaider

Tel Aviv University/LASL

M.A. Moinester, Spokesman

Tel Aviv University

J. Alster, S. Gilad

Case Western Reserve University

H. W. Baer, P. R. Bevington, M. W. McNaughton, F. H. Cverna

We propose to measure the single-charge-exchange reaction $D(\pi^-, \pi^0)2n$, using a cryogenic D_2 target and the π^0 spectrometer presently under construction by groups from LASL, Tel Aviv University, and Case Western Reserve University. Measurements will be carried out at six incident energies between 30 and 230 MeV at eight angles per energy. The double differential cross section as a function of incident energy will provide a number of tests and constraints on theoretical models. In particular, the reaction should be sensitive to (1) the isospin-flip spin-flip part of the πN scattering amplitude, (2) the influence of the outgoing π^0 on the n - n final state interaction, (3) the off-shell extension of the πN scattering amplitude, (4) the effects of true π absorption, and (5) multiple-scattering effects.

MEASUREMENT OF INCLUSIVE π^0 PRODUCTION ON HYDROGEN ISOTOPES AND SELECTED NUCLEI AT $T_p = 800$ MeV

Case Western Reserve University

H. E. Baer, Spokesman

P. R. Bevington, F. H. Cverna, M. W. McNaughton, H. B. Willard

LASL

J. D. Bowman, Spokesman

M. D. Cooper, R. H. Heffner, C. M. Hoffman, J. Potter, M. Zaider, R. H. Sherman

Tel Aviv University

J. Alster, S. Gilad, M. Moinester (LASL, Tel Aviv University)

We propose to measure differential cross sections for the $pp \rightarrow pp\pi^0$ and $pd \rightarrow {}^3\text{He}\pi^0$ reactions to both bound and unbound states at 800 MeV by detection of the π^0 using the spectrometer presently under construction by the three groups represented on this proposal. A range of scattering angles spanning 0 to 180° will be measured, and absolute cross sections will be determined to $>10\%$. When these data are evaluated and we have assessed the capabilities of the spectrometer in the external proton beam, we propose to extend the study to the $pt \rightarrow {}^4\text{He}\pi^0$ reaction and selected nuclear targets.

These π^0 data will complement the charged-pion production studies which are being undertaken at LAMPF and other medium-energy laboratories. High-quality π^0 energy spectra for the above reactions will be the first data of its kind. It will provide tests of charge independence in the strong interaction at medium energies. The $pp \rightarrow pp\pi^0$ data will guide the development of

production models and the theory of the N-N interaction. The studies on nuclear targets will elucidate the (p,π) reaction mechanisms and nuclear structure aspects of large-momentum transfers.

Exp. 297

**A BICENTENNIAL PROPOSAL TO STUDY THE BEHAVIOR
OF POSITIVE MUONS IN SOLIDS**

LASL

J. A. Brown, Spokesman

R. H. Heffner

Sandia Laboratory

W. B. Gauster

Bell Laboratories

A. T. Fiory

The purpose of these experiments is to study the behavior of positive muons in solids with emphasis on well-characterized metals. Through analogy with the development of positrons as a tool in studying solids, this work will involve the study of the basic physics of positive-muon interactions with a crystal as well as the positive muon's sensitivity as a probe of intrinsic and extrinsic defects.

The primary goal of these experiments will be to study the body-centered cubic (bcc) metals sodium, vanadium, niobium, tantalum, and tungsten, and the hexagonal close-packed (hcp) metals titanium and zirconium. Measurements will be made of the muon spin-relaxation rate as a function of temperature. These results will be used to calculate the mobility of muons in solids and the μ^+ interactions with defects.

The above metals were chosen for study at LAMPF for several reasons.

1. The LAMPF intensity enables the use of "small" samples. This is a significant advantage for preparing well-characterized samples, especially for bcc metals.
2. The bcc metals are more difficult to study than face-centered cubic (fcc) metals using other techniques.
3. The data will form an important basis for possible future studies of hydrogen behavior in metals using positive muons.
4. Positron annihilation experiments present very puzzling results that positive muons may play an important role in solving.

The utilization of positive-muon spin relaxation to study solids is in its early stages of development. Experiments are currently being performed by a number of groups at accelerators throughout the world. It is expected that the results of these experiments may have an impact on the details of the LAMPF experiments in that we intend to use the best currently available experimental techniques focused on the key unanswered questions regarding μ^+ behavior in solids.

Exp. 298

**MEASUREMENT OF LIGHT OUTPUT VS ENERGY
FOR VARIOUS SCINTILLATORS**

University of Pennsylvania

Walter Selove, Spokesman

LASL

D. M. Lee, R. J. Macek

University of Wisconsin

A. Erwin

This experiment will test some new plastic with 50- to 300-MeV/c π s on the test channel.

Exp. 299

AN INVESTIGATION OF THE REACTION (π^+ , π^+ + p)

University of Virginia

K.O.H. Ziock, Spokesman

R. C. Minehart, H. J. Ziock, R. J. Ellis

This will be a study of the reaction ($\pi^\pm, \pi^\pm p$) on a variety of nuclei in a coincidence experiment that will identify the state of the residual nucleus and will measure recoil momentum distributions for various values of the energy of the incoming pion.

Exp. 300

**π^- COULOMB CAPTURE AND π^- TRANSFER IN TISSUE,
TISSUE-EQUIVALENT LIQUID, AND SIMPLE COMPOUNDS**

Technical University of Munich

H. Daniel, Spokesman

LASL

M. Leon, Spokesman

J. N. Bradbury, R. L. Hutson, M. E. Schillaci

California State University

R. Seki

Pionic x-ray spectra will be measured with a germanium detector for tissue, tissue-equivalent liquid, polyethylene (normal and deuterated), water (normal and heavy), potassium iodide, potassium, and iodine. Per-atom Coulomb capture ratios and the effect of hydrogen on the pionic cascades will be determined.

Exp. 301

**IMPAIRMENT OF SUPERCONDUCTING CHARACTERISTICS
BY PROTON IRRADIATION**

LASL

M. T. Wilson, Spokesman

D. M. Parkin, T. A. Kitchens, L. Rosen, W. V. Green

University of California, Davis

B. Matthias

The purpose of this experiment is to compare the characteristics of superconductors irradiated with 800-MeV protons with data published on superconductors that have been neutron irradiated.

Exp. 302

800-MeV PROTON IRRADIATION OF AN ALUMINUM SAMPLE

LASL

W. V. Green, Spokesman

R. D. Brown, L. S. Levinson, D. M. Parkin, L. G. Lindquist, M. T. Wilson

The proposed program will be the irradiation of metals by the LAMPF 800-MeV proton beam. This program is based on the suggestion of Rosen that high-energy proton irradiation might be a useful technique to simulate radiation damage by neutrons. The suggestion was evaluated by theoretical calculations by Coulter *et al.* The scope of the proposal work is to establish the temperature and dose dependencies of swelling for aluminum, and to complete scoping irradiations on nickel and molybdenum. Postirradiation examinations of the irradiated metals will be used to determine the character of radiation effects produced by electron-transmission microscopy. The principal goal during the initial 12 months of operation will be (1) to produce the same degree of damage as that produced in reactors in a year of operation on the basis of displacement calculations at several temperatures in aluminum, and (2) to produce scoping irradiations

in nickel and molybdenum in a thickness equivalent to that of 0.254-mm aluminum. Damage stability will be established by postirradiation annealing.

Exp. 303

**A SURVEY OF PION SINGLE-CHARGE-EXCHANGE SCATTERING
USING BACK-ANGLE GAMMA SPECTROSCOPY**

Argonne National Laboratory

H. E. Jackson, Spokesman

D. Geesaman, R. Holt, R. Laszewski, T. J. Bowles, E. J. Stephenson, R. E. Segel
(ANL/NWU)

Saclay

J. Julien

A survey of single-charge-exchange scattering is proposed, in which the spectra of scattered neutral pions are studied by means of Back-Angle Gamma (BAG) Spectroscopy. The targets will be chosen to permit a study of the gross mass dependence as well as a study of the variation with neutron excess for several elements. Angular distributions and total single-pion-exchange cross sections will be measured as a function of incident pion energy and charge. The measurements will cover the pion energy range of 50-200 MeV.

This series of measurements is presented as an experimental survey of qualitative features of single charge exchange (CEX) for a range of nuclei which should yield valuable insights into the reaction mechanism. The BAG technique is based on the large Doppler shift of decay photons emitted in the backward direction that makes possible measurements with relatively modest NaI spectrometers. While this technique is not capable of the high resolution necessary to resolve individual states, it will permit the observation of scattering involving excitations averaged over intervals of ~ 5 MeV. Thus, one can expect to measure the angular distribution and integrated CEX strength over the bound excitation region or the giant dipole region for a given target. Such data, together with information on the importance of neutron excess, should be useful in determining such questions as the extent to which CEX can be described by a simple optical model, the importance of multiple-step processes, and the extent to which giant multipole resonances are excited in CEX reactions.

Exp. 304

STUDY OF THE AUGER PROCESS IN PIONIC ATOMS

LASL

M. Leon and L. F. Mausner, Spokesmen

J. N. Bradbury, J. D. Knight, M. E. Schillaci

California State University

R. Seki

We plan to measure the intensities of the pionic $10 \rightarrow 9$, $9 \rightarrow 8$ and lower transitions, and electronic $Z - 1$ K x rays for several elements in the region $Z = 60 - 90$. Observation of a "step" as a function of Z in these intensities due to the K absorption edge will test the assumption of fast electron refilling and give information on the Auger rates.

Exp. 305

MUON PROBE STUDIES OF MAGNETIC SYSTEMS

University of Wyoming

A. B. Denison, Spokesman

LASL

R. H. Heffner, Spokesman

R. L. Hutson, M. Leon, M. E. Schillaci, T. A. Kitchens, C. Y. Huang

We propose to study negative-muon spin rotation (μ^-SR) of μ^-0 in several simple anti-ferromagnetic oxides and fluorides, and in ferromagnetic EuO. The experiments will be carried out as a function of temperature, both above and below the Néel or critical temperature. The negative muon provides an excellent probe, such that from measurements of the temperature and external field dependence of the muon precession frequency and of the relaxation rate of the muon polarization, the effects attributed to the exchange interaction at the oxygen site can be illuminated.

Exp. 306

**FORWARD-ANGLE ANALYZING POWER AND BACKWARD-ANGLE
DIFFERENTIAL CROSS-SECTION MEASUREMENTS OF
COLLECTIVE-STATE EXCITATIONS BY INTERMEDIATE-ENERGY PROTONS**

University of California, Los Angeles

G. J. Igo, Spokesman

T. S. Bauer, J. C. Fong, G. Pauletta, J. Soukup, C. A. Whitten

University of Texas, Austin

G. S. Blanpied

LASL

G. W. Hoffmann, H. A. Thiessen

An exciting development in nuclear physics during the past six years has been the observation of a new giant resonance. This resonance is located at an excitation energy of $\approx 63A^{-1/3}$ MeV, and has been identified as an isoscalar giant quadrupole (E2) resonance (GQR). Its observation in many nuclei implies that the GQR represents a general behavior of nuclei and, as such, may lend itself to a generalized description. Some evidence has also been obtained for the existence of isoscalar monopole (E0) and (E3) resonances, and an isovector quadrupole (E2) resonance.

Very little inelastic-scattering data exists above 200 MeV. However, enough high-resolution work has been done at 1.05 GeV with protons and at 1.37 GeV with alpha particles to establish the magnitude of the cross sections for collective excitations at least at forward angles. Collective states in the discrete region and in the collective region will be studied in this experiment. A new probe (polarized protons) will become available at the HRS facility in the next few months. Satchler pointed out as long ago as 1973 that the angular distribution of the analyzing power for polarized proton excitation of the $63A^{-1/3}$ -MeV resonance should be markedly different for an $L = 0$ excitation compared with $L = 2$.

The analyzing power measurements will be done at relatively small-momentum transfer ($\theta \leq 30^\circ$) because of the limiting intensity of polarized protons expected (initially, 2-1/2 to 10 nA, 20 nA after the polarized source and peripherals are completely developed).

In addition to high-resolution polarized proton investigations at relatively low q , an almost virgin territory exists at larger momentum transfers using the higher intensity, unpolarized 800-MeV proton beam. Due to the lack of the combination of a vertical spectrometer and intense beams, the horizontal spectrometer at Saturne, Saclay, has not been used to investigate the q region beyond $q \sim 1(\text{GeV}/c)$. The HRS offers a q range which considerably exceeds this ($\leq 3 \text{ GeV}/c$). It also offers a unique opportunity to search for possible new reaction mechanisms associated with near 180° scattering. The nuclei which will be studied are many of those which have been investigated at lower energies with protons, deuterons, ^3He ions, alpha particles, and electrons.

Exp. 307

POLARIZATION IN p - ^4He ELASTIC SCATTERING AT 800 MeV

University of California, Los Angeles

G. J. Igo and C. A. Whitten, *Spokesmen*

T. S. Bauer, G. Pauletta, J. Soukup, J. C. Fong, R. J. Ridge, G. Adams, G. Mardirossi

LASL

G. E. Hoffmann, J. F. Amann, B. C. Hoistad, E. W. Hoffman, D. M. Lee, C. L. Morris, N. Tanaka

University of Texas, Austin

G. S. Blanpied

Stimulated by the BNL data at 1 GeV obtained in 1967, theoretical investigations have been made using the KMT model, the Glauber model, and phenomenological optical potentials. A measurement in 1974 by Baker *et al.* did not show the deep minimum seen in the BNL data. Measurements at 650 MeV and 50 MeV suggested an interesting variation of the depth of the minimum near and below 1 GeV. In looking closely at the data, the ratio R of the cross section at the section maximum and the minimum is seen to vary systematically and to reach a maximum near 0.65 GeV. Recently, Auger, Gillespie, and Lombard have included spin dependence in the nucleon-nucleon amplitudes in a calculation of the differential cross section and polarization in the range $T_\alpha = 0.6 - 23.1 \text{ GeV}$ with the Glauber model. The theoretical differential cross sections between 0.60 and 1.15 GeV are much improved in the region of the first minimum, compared to those using the spin-independent nucleon-nucleon parameters. However, there is a tendency to predict too large values of R , especially at 1.05 and 1.15 GeV.

Very little data existed, until recently, on polarization in p - ^4He elastic scattering in the intermediate-energy region. A recent measurement at 0.56 GeV (Boschitz) was reported in 1972. The measurement was performed before the polarized proton beam at the ZGS accelerator at ANL became available. An earlier measurement at the LBL 184-in. synchrocyclotron (McManigal, 1965), over a smaller range of q , completed the catalog of available data. Recently, data have become available (Igo, 1976) at laboratory kinetic energies of 0.56, 0.80, 10.3, 1.3, and 1.7 GeV. The statistical accuracy of this data is improved because the intense ZGS beam (10^9 protons/pulse at $2 \text{ GeV}/c$, 70% polarized) was used. These measurements verify the magnitude of the polarization found at the first maximum at about 1.2 fm^{-1} and at the second peak, also positive, which occurs at 4 fm^{-1} . A very interesting behavior is noted in the region just before and at the q value where the minimum is observed in the differential cross section. At 1.03 GeV and above, the polarization is always positive; at 0.80 GeV, the polarization goes to zero in this region; and at 0.56 GeV, the polarization changes sign and is -0.35 at $q = 1.24 \text{ fm}^{-1}$. This behavior is quite different from the polarization measured at lower energies.

Using the HRS facility, we propose to extend the region of four-momentum transfer, $-t$, investigated at 800 MeV, by a factor of 12 over the existing measurement from the ZGS by measuring the polarization of 180° [$-t = 4.3 \text{ (GeV/c)}^2$]. It has been possible to estimate the count rates with reliability because of the existence of differential cross-section measurements at 800 MeV at backward angles (Goldzahl, Saclay, 1975), and using the beam intensities expected from the LAMPF polarized source in a 50-50 shared mode of running with Area B (initially, 2-1/2 to 10 nA, 20 nA after the source and peripheral equipment is completely developed).

Exp. 308

**AN ATTEMPT TO MAKE DIRECT ATOMIC MASS MEASUREMENTS
IN THE THIN TARGET AREA**

Lawrence Berkeley Laboratory

A. M. Poskanzer, *Spokesman*

D. J. Vieira

LASL

G. W. Butler, *Spokesman*

D. G. Perry

Texas A&M University

J. B. Natowitz

Oak Ridge National Laboratory

F. Plasil

Brookhaven National Laboratory

L. P. Remsberg

It is proposed to attempt to make direct atomic mass measurements of nuclei far from beta stability to an accuracy of the order of 100 keV by time-of-flight and energy measurements. The neutron-excess isotopes of the low-Z elements produced as fragments from uranium would be studied. In addition, it is planned to search for new neutron-deficient isotopes produced as spallation residues from a calcium target.

Exp. 309

**π^+ AND π^- DOUBLE-CHARGE-EXCHANGE DISINTEGRATION
OF ^{16}O , ^{40}Ca , AND ^{208}Pb**

University of Wyoming

G. A. Rebka, *Spokesman*

C. W. Bjork

LASL

P.A.M. Gram

Colorado College

C. Bordner

We propose to survey the π^+ and π^- double-charge-exchange reaction to continuum states of considerable excitation energy with the light, medium, and heavy targets of ^{16}O , ^{40}Ca , and ^{208}Pb . We will measure the doubly differential cross section, $d^2\sigma/d\Omega_\pi dp_\pi$, for the emitted pion at inci-

dent pion momenta of 200, 250, 300, and 350 MeV/c. We will make measurements at four laboratory angles between 30 and 140°. At each angle, we will detect the emitted pion at about four different momenta spanning those available to the pion.

The measurements will be made with the Exp. 99 magnetic spectrometer, which was used to make similar measurements for the reaction $\pi^- + p \rightarrow \pi^+ + \pi^- + n$. The spectrometer is ideally suited to detect pions of opposite charge from pions in the incident beam of the LAMPF P³ channel. With its relatively large solid-angle acceptance, 15 msr, and with its momentum acceptance of about 9% ($\Delta p/p$), the spectrometer is suited to probe the small cross sections of pion double charge exchange.

Our measurements of the inclusive double-charge-exchange cross sections should provide a body of data sampling a large range of parameters. Our data should be useful stimulus to extensive calculations of pion double charge exchange in nuclei.

**(π^+, π^-) DOUGLE-CHARGE-EXCHANGE REACTIONS
USING CORE 2n TARGETS**

University of Texas, Austin

W. J. Braithwaite, *Spokesman*

K. G. Boyer, C. F. Moore

LASL

C. L. Morris, *Spokesman*

H. A. Thiessen

University of Colorado

R. L. Boudrie

We are proposing to study the reactions $^{18}\text{O}(\pi^+, \pi^-)^{18}\text{Ne}(\text{g.s.})$ and $^{42}\text{Ca}(\pi^+, \pi^-)^{42}\text{Ti}(\text{g.s.})$ in conjunction with elastic scattering of π^+ and π^- from these two target nuclei in an effort to unravel the reaction mechanism for double charge exchange (DCE) and to gain some understanding of the role of two-particle correlations within complex nuclei.

The targets, ^{18}O and ^{42}Ca , were chosen for the following reasons: (1) both targets are nuclei with two valence neutrons outside a self-conjugate, doubly magic core; (2) the DCE reaction to be studied is a ground-state to ground-state transition, where the two valence neutrons are transmuted into valence protons (also, outside a self-conjugate, doubly magic core); and (3) elastic scattering, used to pin down pion-distortion effects in both incoming and outgoing channels, may be carried out using π^+ and π^- probes on the target nuclei, as final state nuclei in the DCE.

The EPICS channel and spectrometer will be used to measure angular distributions for elastic scattering in 5° steps from 10 to 120° (lab) for both charged pion species, and EPICS will be used to measure the DCE differential cross sections at four angles between 10 and 60° (lab). The elastic-scattering data, used to parameterize the pion distortions in the incident and exit channels, should permit a more thorough analysis of the DCE data.

ELASTIC-SCATTERING SURVEY USING POLARIZED PROTONS

LASL

G. W. Hoffmann, *Spokesman*

D. C. Madland, C. L. Morris, J. Pratt, J. E. Spencer, H. A. Thiessen, O. B. van Dyck

University for California, Los Angeles

G. J. Igo, J. C. Fong, C. A. Whitten, T. W. Bauer, G. Pauletta

University of New Mexico

N. M. Hintz, G. Kyle, M. Oothoudt

University of Texas, Austin

G. S. Blanpied, R. Liljestrand

Brookhaven National Laboratory

T. Kozlowski, H. Palevsky, R. J. Sutter

University of Oregon

D. K. McDaniels, P. Varghese

Oregon State University

L. W. Swenson

Northwestern University

K. K. Seth, H. Nann

We propose to use the High-Resolution spectrometer and the 800-MeV polarized H^- beam to measure the asymmetry in elastic scattering of polarized protons by nuclei which span a broad range of the periodic table.

The objectives are (1) to provide data from which the phenomenological spin-orbit potential may be investigated across the periodic table, (2) to provide data which test theoretical predictions that incorporate spin-dependent nucleon-nucleon scattering amplitudes, and (3) in this way, provide data from which nucleon density distributions can be explored through better application of existing theories.

Exp. 312

MATERIALS ANALYSIS WITH MUONIC X RAYS

LASL

R. L. Hutson, Spokesman

J. N. Bradbury, M. E. Schillaci, M. E. Yates-Williams

University of Houston

J. C. Allred

This experiment is aimed at extending our knowledge of the potential usefulness of muonic x rays for the elemental analysis of bulk material samples. The proposed work will involve two lines of study. In the first, we will measure the detection limits for a range of elements up to $z = 22$, both in aqueous solution and in solid mixtures. In another series of measurements, we will investigate the usefulness of muonic x-ray analysis as applied to several real problems of practical interest.

Exp. 313

INVESTIGATION OF MAGNETISM IN ACTINIDE COMPOUNDS USING μ^+

LASL

C. Y. Huang, Spokesman

S. S. Rosenblum, T. A. Kitchens, J. L. Smith, R. H. Heffner, M. E. Schillaci

Cleveland State University

C. W. Chu

University of Wyoming

A. B. Denison

Recently, positive muons (μ^+) have been used to probe the magnetic behavior of 3d. The technique used is the measurement of the precession frequency as well as the depolarization of the μ^+ in a transverse magnetic field as a function of temperature and applied field. The μ^+ is thought to measure the effective magnetic field acting at the interstitial positions in the lattice. Although the data are far from completely understood for the above cases, the μ^+ work has already provided stringent experimental tests for the theory of the hyperfine interaction in these materials.

To date, no work has been done on the 5f metals using μ^+ . We propose to investigate two well-studied neptunium compounds, $NpAl_2$ and $NpOs_2$. Both of these cubic Laves-phase structures

have been studied extensively, principally by groups at ANL using Mössbauer effect, neutron diffraction, and magnetic measurements. The ANL group has agreed to lend us some of their already well-characterized samples. A comparison of the μ^+ results with all the previous work on these samples will shed some light on the magnetic behavior of these materials as well as the behavior of μ^+ in them. As a test of our experimental procedure, we plan to repeat the measurements of Gurevich *et al.* on gadolinium metal.

Exp. 314

**MEASUREMENT OF TEMPERATURE DEPENDENCE FOR THE
MESON-MOLECULAR-FUSION RATE IN DEUTERIUM**

Kansas State University

S. S. Howe and H. J. Donnert, Spokesmen

LASL

R. L. Hutson

The purpose of this experiment is to determine the formation rate of $d\mu^-d$ molecules as a function of the kinetic energy of the μ^-d atom formed by stopping negative muons in gaseous targets of deuterium.

This determination will be done by observing the neutrons with an approximate energy of 2.5 MeV emitted as one of the products of the fusion of the $d\mu^-d$ molecule. The high-intensity, low-momentum, low-contamination backward decaying μ^- beam at LAMPF is required for this experiment.

Exp. 315

HIGH-RESOLUTION STUDY OF $(\pi^+, 2p)$ REACTION

Carnegie-Mellon University

W. R. Wharton, Spokesman

P. D. Barnes, R. A. Eisenstein, J. N. Craig, J. D. Sherman, K.G.R. Doss, S. A. Dytman

LASL

J. F. Amann

We propose a high-resolution, high-statistical measurement of the (π^+pp) reaction, using the 900-MeV π^+ beam from the LEP channel. We will detect both protons in coincidence using CMU's two stacks of intrinsic germanium crystals and helical delay line chambers for ray tracing. In a single 50-h run, we plan to obtain a spectra of the residual nucleus with 10 000 events and 1-MeV resolution, a distribution of recoil momentum for separate final states or groups of states of residual nucleus, and an angular correlation over a 20° variation in proton opening angle for separate final states. Spectra at three sets of angles will be taken to determine variations in angular distributions for separate final states. The data will also be compared to the recent (π^-, NN) data, with 3-MeV resolution obtained from pionic atomics to see how cross sections to separate final states vary with pion energy. We plan to use two targets; one target will be ^{16}O and the other target will be in the 1d-2s shell (probably ^{28}Si). A total time of 324 h with a primary beam intensity of 100 μA will be required.

By improving both the energy resolution and statistics by more than a factor of 6 over previous (π^+ ,pp) studies, we hope for the first time to apply our rich knowledge of nuclear structure to study of the reaction mechanism of the (π^+ ,pp) reaction and its dependence upon nuclear structure.

Exp. 316

π^- -NUCLEUS ELASTIC SCATTERING BETWEEN 20 AND 50 MeV

Northwestern University

K. K. Seth, Spokesman

S. I. Iversen, A. Obst

New Mexico State University

G. R. Bureson, Spokesman

S. L. Verbeck

LASL

R. P. Redwine

It is proposed to measure π^- elastic scattering from a series of nuclei, ranging from ${}^6\text{Li}$ to ${}^{208}\text{Pb}$, in the energy range 20 to 50 MeV, using a large solid-angle differential range-measuring spectrometer. The results will be compared with π^+ scattering from the same nuclei in the same energy range to shed further light on the problem of low-energy pion elastic scattering, as revealed by recent π^+ experiments done at LAMPF.

Exp. 317

INELASTIC PION SCATTERING TO THE 1^+ STATES OF ${}^{12}\text{C}$

University of Colorado

R. J. Peterson, Spokesman

R. L. Boudrie, J. J. Kraushaar, D. A. Lind, R. A. Ristinen

We propose to study the inelastic scattering of positive pions to the 1^+ states of ${}^{12}\text{C}$ at 12.71 MeV ($T = 0$) and 15.11 ($T = 1$). The structure of these states is well known, and although they are only weakly excited by pions, the experiment is feasible and of great interest. The EPICS system will be used, and beam energies of 50, 150, and 250 MeV are proposed. One-hundred-forty hours of beam are requested.

Exp. 318

**EXCITATION OF SINGLE-PARTICLE STATES IN NUCLEI
BY LOW-ENERGY INELASTIC PION SCATTERING**

Carnegie-Mellon University

J. N. Craig and J. D. Sherman, Spokesmen

P. D. Barnes, R. A. Eisenstein, W. R. Wharton, K.G.R. Doss

LASL

J. F. Amann, Spokesman

The purpose of this experiment will be to investigate single-particle excitations in nuclei by inelastic scattering of 50-MeV π^+ on ^{13}C , ^{17}O , and ^{209}Bi . These targets provide the opportunity to study the promotion of both neutrons and protons between known single-particle shell model states. This proposal will then complete an initial survey of low-energy pion scattering from nuclei. Previous work has established elastic-scattering data, as well as inelastic scattering to collective nuclear states.

Exp. 319

**DETERMINING THE MECHANISM FOR MULTINUCLEON AND
CLUSTER REMOVAL IN 200-MeV π -NUCLEAR INTERACTIONS**

Utah State University

V. G. Lind, Spokesman

E. Hatch, C. H. Otteson, R. E. McAdams, W. Denig

Texas A&M University

R. B. Clark

LASL

P.A.M. Gram, W. V. Hassenzahl

Florida State University

H. S. Plendl

Florida A&M University

M. Greenfield

George Mason University

J. Lieb

Virginia State College

C. Stronach

The purpose of this experiment is to (1) determine which pi-nuclear reactions yielding gamma rays are associated with pion scattering and which with pion absorption, (2) establish the mechanism for various multinucleon removal processes including cluster removal, and (3) observe and measure the cross sections for weak processes such as single and double charge exchange and determine which states are populated by such reactions. The goals are to obtain a pion-gamma-ray coincidence spectrum and a high-statistics single-gamma-ray spectrum.

A COMPARISON OF (π^+ ,xn) AND (π^- ,xn) REACTIONS*Reed College**L. B. Church, Spokesman**Carnegie-Mellon University**A. A. Caretto*

This research will investigate a specific set of reaction cross sections and the differences in excitation energies following π^+ and π^- absorption into nuclei of two different mass regions. The vehicle for both parts of this research is the ($\pi^\pm$,xn) reaction. The cross sections will be studied as a function of "x" to determine the probability of neutron evaporation which is, in part, a function of the excitation energy, E^* , of the excited nuclei. In order to study the mechanism of π absorption and the role which the (3,3) pion-nucleon isobar plays in this absorption, excitation functions will be determined with pion energies between 100 and 400 MeV, which is over the (3,3) free-particle resonance. To be able to cleanly and directly compare the excitation energy resulting from π^+ and π^- capture, the targets will be two isobars differing by Z of 2; in this way, they share common isotopic products as the result of the (π^+ ,xn) and (π^- ,xn) reactions. A comparison of these reactions in the mass region of 75 and 175 will also show the importance of the pion-nucleon isobar formation as a function of the target's N/Z ratio. As a result of these experiments, the conclusions of published calculations using the isobar model can be critically evaluated.

Exp. 321

STUDIES OF NUCLEON CLUSTERING IN LIGHT NUCLEI

*University of Southern California**R. K. Cole, Spokesman**C. N. Waddell**LASL*

L. E. Agnew, M. P. Baker, M. D. Edmiston, C. R. Gruhn, R. B. Hammond, C. F. Hwang, J. J. Jarmer, D. M. Lee, C. J. Maggiore, P. A. Thompson

Interest in nucleon clustering in p-shell nuclei has been renewed lately with studies that indicate clusters such as d,t - ^3He and ^4He exist as more separated entities than the shell model predicts. Examples are the alpha-particle nuclei, where stability is explained by Majorana forces — an important element of the nucleon-nucleon interaction. Indirect evidence of clustering comes from calculations of energy levels, electric quadrupole moments and magnetic moments. For example, Majorana forces explain the differences in excitation energies of the lower states with $T = 1$ in even-even and odd-odd shell nuclei, and at least indicate the existence of more pronounced nucleon clusters than the shell model predicts. More direct evidence is obtained from analyses of high-energy electron scattering which give form factors not consistent with the simple shell model of lithium and beryllium. Fits to the (p,2p) measured angular distribution for these nuclei are improved by assuming clustering. Thus, cluster configurations appear to be a part of the wave function of some light nuclei with sufficient amplitude to influence some of their properties.

Because the relatively large cross sections of two nucleon transfer reactions can be explained also by the intermediate coupling shell model for p-shell nuclei, these experimental results do not

necessarily confirm the existence of subsystems such as the dineutron, diproton, deuteron, or alpha cluster. However, correlation experiments detecting the direct knockout of a cluster at sufficiently high energy so that the impulse approximation can be justified can provide direct evidence of such clusters.

We have recently completed measurements of the (p,pd) reaction for ${}^6\text{Li}$ and ${}^7\text{Li}$ with 800-MeV protons from EPB that indicate comparable deuteron clustering in both of these nuclei. Although ${}^6\text{Li}$ may be considered to be a special case with any one neutron and one proton outside an alpha core, ${}^7\text{Li}$ is more representative of 1p nuclei. We now propose to extend these studies to include the other 1p nuclei, ${}^9\text{Be}$, ${}^{10}\text{B}$, ${}^{11}\text{B}$, and ${}^{12}\text{C}$, encompassing even, even-odd, and odd nuclei of this subshell. Our experimental techniques will allow us to simultaneously obtain (p,pt) events and some (p,p α) information together with our (p,pd) measurements.

Exp. 322

SYSTEMATIC STUDY OF PION-NUCLEUS INELASTIC SCATTERING AT ENERGIES BELOW 100 MeV

Oak Ridge National Laboratory

F. E. Bertrand, Spokesman

T. P. Cleary, E. E. Gross, C. A. Ludemann

Virginia Polytechnic Institute and State University

K. Gotow, Spokesman

M. Blecher, D. A. Jenkins, F. Milder, P. Roberson

University of South Carolina

C. W. Darden, R. D. Edge, B. M. Freedom

LASL

R. L. Burman, R. P. Redwine, J. E. Spencer M. A. Moinester (LASL/Tel Aviv University)

Beam time is requested for a systematic study of pion-nucleus inelastic scattering for incident pion energies below ≈ 100 MeV. Inelastically scattered pions will be detected in the recently completed Bicentennial Spectrometer. Since the spectrometer is a broad-range device, the inelastic spectrum can be studied up to ≈ 25 MeV of excitation for a single magnetic-field setting. This permits the efficient study of low-lying particle states and collective states simultaneously with the study of high-excitation collective states such as giant multipole resonances.

Exp. 323

STARK-EFFECT QUENCHING OF RESONANCES IN THE PHOTODISINTEGRATION OF THE H^- ION

University of New Mexico

H. C. Bryant, Spokesman

J. Donahue, C. P. Leavitt, H. Sharifian, H. Tootoonchi, D. M. Wolfe

LASL

P.A.M. Gram, M. A. Yates-Williams

We propose to extend the study of H^- photodisintegration, using intersecting photon and H^- beams begun in Exp. 200. That experiment successfully demonstrated the existence of a

long-sought "shape" resonance and, in addition, turned up a "Feshbach" resonance that was generally thought to be too narrow to be observed. The addition of a small magnet to our apparatus will enable us to observe the quenching of these structures by Stark-effect broadening. We will also make a study of the energy dependence of the cross section in a region where no finely tunable conventional light source is now available. It is not inconceivable that further interesting structure will turn up.

Exp. 324

**PRECISION MEASUREMENT OF RATIOS OF CERTAIN LIGHT
ELEMENT PION EXCITATION FUNCTIONS**

University of Washington

I. Halpern, Spokesman

K. Aniol, D. Chiang

LASL

E. D. Arthur, M. D. Cooper, D. M. Drake

The study of cross-section ratios admittedly provides only a limited view of the interesting field of pion inelastic scatterings, but it provides that view with unusual precision. We believe that a systematic and careful investigation of these ratios will provide some useful insights and constraints for developing our understanding of inelastic interactions of pions.

Exp. 325

**PION AND MUON MULTIPLE COULOMB-SCATTERING EXPERIMENT
ON THE EPICS BEAM LINE**

LASL

K. M. Hanson, Spokesman

H. A. Thiessen, C. L. Morris, E. A. Smith

Northwestern University

A. Obst, S. I. Iversen,

New Mexico State University

S. L. Verbeck, M. J. Devereux

University of Texas, Austin

W. J. Braithwaite

University of Colorado

R. L. Boudrie

Multiple Coulomb scattering of both charged species of pions and muons will be used to test the Fano correction for low-Z targets. The size of the Fano correction varies approximately as $1/Z$, contributing roughly 10% to the size of the peak width of the multiply scattered beam, which will be measured to $\sim 1\%$.

In a previous effort, the Rice Univ./Univ. of Houston group reported about a 4% discrepancy between their measured widths and their multiple-scattering predictions. However, they did not include targets with $Z < 6$.

In the present study, incident pions, muons, and electrons will be distinguished, and targets of ${}^7\text{Li}$, ${}^9\text{Be}$, and ${}^{12}\text{C}$ will be used at incident pion energies of 67.5 MeV.

Exp. 326

ELECTRICAL COMPONENT RADIATION-EFFECTS STUDY

LASL

Alex Harvey, Spokesman

This study will cover tests of miscellaneous electrical components which are used at LAMPF for their resistance to radiation damage. Examples are:

1. Cables: [mica-insulated, mineral-insulated (m.i.), H-film, silica, and fiber glass], by insulation resistance and dielectric strength.
2. Temperature switches: for insulation resistance, series switch resistance, and deviation of setpoint. Also, mechanical damage to hermetic seals, if any.
3. Seals and insulators: ceramic-to-metal assemblies used in rad-hardened magnets. Post-irradiation examination will be made of insulation resistance and mechanical integrity.
4. Connectors and feedthrough insulators: *in situ* tests of contact and insulation resistance. Intermediate withdrawal-reinsertion cycles for connectors.

Exp. 327

PROTON IRRADIATION PORT (PIP)

LASL

M. T. Wilson, Spokesman

W. V. Green, R. D. Brown, L. O. Lindquist

The objectives of Irradiation No. 1, using the PIP are

1. to demonstrate that specimens can be positioned to within ± 1 mm of the beam center,
 - a. to use harp wires on sample holder to locate beam relative to stringer adjusting mechanisms,
 - b. to ensure that the stringer can be accurately positioned with respect to the experimentally determined beam position,
 - c. to autoradiograph the irradiated specimens to check that they were properly positioned, and also to verify the configuration of the spot,
2. to demonstrate, using 1-mil-diam thermocouples, that desired temperatures are being achieved, and
3. to irradiate 10-mil-thick high-purity aluminum and 3-mil-thick molybdenum specimens for subsequent study.

This irradiation will demonstrate the ability of PIP to do routine proton irradiation studies. The time required is 8 h.

MEASUREMENT OF THE DECAY RATE AND PARITY-VIOLATING ASYMMETRY FOR $\mu^+ \rightarrow e^+ \gamma$

LASL

J. D. Bowman and M. D. Cooper, Spokesmen

M. E. Hamm, C. M. Hoffman, R. E. Mischke, D. E. Nagle, J. S. Sarracino, P. A. Thompson

Stanford University

R. Carrington, R. Eichler, R. Hofstadter, E. B. Hughes, T. McPharline

University of Chicago

H. L. Anderson, W. W. Kinnison, H. W. Matis, S. C. Wright

We propose to search for the decay $\mu^+ \rightarrow e^+ \gamma$. The experiment will be able to measure a branching ratio of greater than 10^{-10} , or set an upper limit of 5×10^{-11} . This is a factor of 200 below the present upper limit, and a factor of 10 below the design goals of either the SIN or TRIUMF experiments. In addition, if the branching ratio is greater than a few times 10^{-10} , we will measure the angular correlation between the e^+ momentum and the μ^+ spin, which will give information on the form of the interaction responsible for the decay.

The apparatus consists of a magnetic spectrometer to measure the e^+ momentum and a position-sensitive NaI detector to measure the photon energy and conversion point.

SENSITIVE SEARCH FOR $\mu^- \rightarrow e$ CONVERSION

Fermi Laboratory

P. A. Thompson, Spokesman

University of Pennsylvania

S. Frankel, Spokesman

Yale University

V. W. Hughes Spokesman

We propose a sensitive search for the rare muon decay mode of $\mu \rightarrow e$ conversion $\mu^- + Z \rightarrow e^- + Z$. Modern unified gauge theories of the weak and electromagnetic interactions predict that this conversion, with its violation of muon number conservation, will occur with a branching ratio relative to muon capture in the range of 10^{-8} to 10^{-10} . By using the Yale solenoid electromagnet as a large-aperture focusing spectrometer together with multiwire proportional chambers and a sodium-iodide crystal detector, we plan to achieve sufficient sensitivity and background rejection to observe $\mu^- + Z \rightarrow e^- + Z$, if its branching ratio is as large as 10^{-10} . This will represent an improvement in sensitivity of more than two orders of magnitude compared to the present limit of 2×10^{-8} .

FUNDAMENTAL MUONIC X-RAY MEASUREMENT OF INTEREST TO MATERIALS ANALYSIS

LASL

R. L. Hutson and M. A. Yates-Williams, Spokesmen

J. D. Knight, L. F. Mausner, M. E. Schillaci

University of Houston

J. C. Allred

The object of this experiment is to measure muonic x-ray intensity patterns and relative muon-capture probabilities for nitrogen, oxygen, and sulfur in a series of compounds chosen to represent several different electron environments for these elements. The choice of these three elements reflects a variety of chemical-analysis problems in materials of practical interest, to which muonic x-ray analysis might be expected to contribute useful information. This study will extend the limited previous studies of compounds containing these same elements, but with different electron environments.

Exp. 331

FAST MUON REACTIONS WITH ^{12}C , ^{48}Ti , AND ^{58}Ni

LASL

C. J. Orth, Spokesman

J. D. Knight, K. Wolfsberg

University of Rochester

M. W. Johnson

We propose to measure muodisintegration cross sections at 80 and 130 MeV/c for the $^{12}\text{C}(\mu^\pm, \mu^\pm n)^{11}\text{C}$, $^{48}\text{Ti}(\mu^\pm, \mu^\pm p)^{47}\text{Sc}$, and $^{58}\text{Ni}(\mu^\pm, \mu^\pm n/p)^{57}\text{Ni}/^{57}\text{Co}$ reactions, using activation techniques.

To our knowledge, very little has been reported on electromagnetic inelastic reactions of muons with nuclei and no one has yet reported cross sections for formation of neutron- and proton-out products. Measurements of these reactions, which are initiated by Coulomb interactions of muons with protons in the nucleus, should provide interesting information on a number of phenomena, including *i*) nucleon charge exchange of the scattered proton with neutrons, *ii*) momentum distribution of the nuclear protons, and *iii*) possible Coulomb distortion effects (differences in trajectories for incoming μ^+ and μ^-). These measurements will also provide a comparison between muon cross sections and already-published electro- and photodisintegration cross sections.

We will expose 5-cm-diam targets to maximum fluxes of backward-decaying muons at the SMC. Secondary-particle and bremsstrahlung effects will be determined by varying the target thickness and exposing targets just to the side of the muon beam. Special care will be taken to determine the level of possible pion contamination in the beam. The intense muon flux will be determined by "small bite" beam profile monitoring with miniature scintillators.

Exp. 332

MASSES OF EXTREMELY NEUTRON-RICH NUCLEI BY (π^- , π^+) REACTIONS

Northwestern University

K. K. Seth, Spokesman

S. I. Iversen, M. O. Kaletka, H. Nann, A. Obst

The newly discovered attribute of pion double-charge-exchange reactions to populate non-analog states with cross sections comparable to those for analog states is exploited for the purpose of measuring masses of neutron-rich nuclei very far from the valley of stability. These nuclei, though predicted to be particle stable, cannot be reached by any other known reaction.

It is proposed to study the (π^- , π^+) reaction at $T_\pi = 240$ MeV at the EPICS facility on a number of stable targets, with maximum available neutron excess, ranging from ^{15}N to ^{124}Sn at one relatively forward angle.

Exp. 333

**$\pi^\pm$ -NUCLEAR ELASTIC SCATTERING AT ENERGIES
BETWEEN 50 TO 100 MeV**

Virginia Polytechnic Institute and State University

Kazuo Gotow, Spokesman

M. Blecher, D. A. Jenkins

Oak Ridge National Laboratory

F. E. Bertrand, E. E. Gross, C. A. Ludemann

University of South Carolina

C. W. Darden, R. D. Edge, B. M. Freedom

LASL

R. L. Burman, R. P. Redwine, J. E. Spencer, M. A. Yates-Williams

We request beam time for study of $\pi^\pm$ elastic nuclear scattering in the energy range of 50 to 100 MeV. The recently completed Bicentennial Magnetic Spectrometer will be used to identify elastically scattered pions.

Motivation of the experiment is identical to that of Exp. 29/54. The proposed experiment will permit us to extend our study of π^+ -nuclear elastic scattering at 20-50 MeV (Exp. 29/54) into the energy range where experimental results may serve as critical tests for validity of the theoretical approaches recently advanced to explain elastic-scattering data with pion energies of 50 MeV or less.

NUCLEAR CHARGE PARAMETERS OF ^{41}Ca AND THE STABLE CADMIUM AND TELLURIUM ISOTOPES

LASL

E. B. Shera and H. D. Wohlfahrt, Spokesmen

M. V. Hoehn (Florida State University), Y. Yamazaki

University of Mainz

G. Fricke

University of British Columbia

R. Hayano

Oregon State University

K. S. Krane

Princeton University

R. Sherr

Purdue University

R. M. Steffen

It is proposed to determine the charge radii of ^{41}Ca and a sequence of stable cadmium and tellurium nuclei by measurement of the muonic x-ray spectra. These new data will extend the region studied in Exps. 163 and 240, and should be helpful in understanding the systematic features of the isotope/isotone shifts observed in those experiments. The new information will be compared with recent or planned optical isotope shift measurements in these nuclei and, hopefully, will be useful in illuminating the discrepancy in ^{43}Ca that exists between muonic and optical results that use high-resolution tunable dye laser techniques. The muonic 2s states will be included in the cadmium and tellurium charge parameter study to investigate the validity of theoretical nuclear polarization corrections in $Z = 50$ mass region.

MONOPOLE AND QUADRUPOLE CHARGE DISTRIBUTIONS IN THE SAMARIUM AND GADOLINIUM ISOTOPES

LASL

E. B. Shera and Y. Yamazaki, Spokesmen

M. V. Hoehn (Florida State University), H. D. Wohlfahrt

Oregon State University

K. S. Krane

Purdue University

R. M. Steffen

Indiana University

J. G. Wills

It is proposed to determine the charge-distribution parameters of a series of samarium and gadolinium nuclei by measurement of the muonic x-ray spectra. These data will extend the results of Exp. 7 and will be helpful in understanding the systematics of nuclear structure in the gadolinium transition region. Recently developed model-independent analysis methods will be used in analyzing the new data. Isomer shifts of low-lying nuclear states will be measured and, in

particular, the isomer shift of the 0^+ beta-band head will be determined in those nuclei in which it is observably excited.

Exp. 336

**STUDY OF THE SPIN DEPENDENCE OF PROTON-PROTON
PION PRODUCTION REACTIONS**

Rice University

G. S. Mutchler, *Spokesman*

I. M. Duck, J. M. Clement

University of Houston

J. C. Allred, B. W. Mayes, L. Pinsky, T. M. Williams

LASL

E. P. Chamberlin, C. F. Hwang, N. S. King, D. M. Lee

Case Western Reserve University

P. R. Bevington, *Spokesman*

M. W. McNaughton, H. B. Willard, E. Winkelman, F. H. Cverna

University of Idaho

H. Wilmes

The spin dependence of the reactions $pp \rightarrow d\pi^+$ and $pp \rightarrow \Delta^{++}n$ will be investigated with a transversely polarized 800-MeV proton beam. Complete kinematical information will be obtained by detecting scattered particles in coincidence in a magnetic spectrometer arm and a time-of-flight arm. The asymmetries for these reactions will be measured to an accuracy $\Delta A \lesssim 0.01$ for pion c.m. angles between 35° and 110° in $pp \rightarrow d\pi^+$, and Δ^{++} c.m. angles between 0° and 115° in $pp \rightarrow \Delta^{++}n$. Such measurements provide valuable information on the relative importance of the various exchange mechanisms involved in pion production.

Exp. 337

**MEASUREMENT OF THE CROSS SECTION FOR
 $\pi^-p \rightarrow \pi^-\pi^+n$ AT 200 AND 229 MeV**

University of Wyoming

Glen A. Rebka, Jr., *Spokesman*

C. W. Bjork, A. R. Kunselman, M. Manley, J. Walter

LASL

P.A.M. Gram, *Spokesman*

Colorado College

C. Bordner

Massachusetts Institute of Technology

E. Lomon

North Carolina State University

R. Carawon

We propose to measure the doubly differential cross sections $d^2\sigma/d\Omega^*dT^*$ for positive pions produced in the reaction $\pi^-p \rightarrow \pi^-\pi^+n$ at incident energies of 200 and 229 MeV, which are very

near threshold, and to deduce from these the total production cross sections. A double-focusing magnetic spectrometer whose "optical" properties define the sign, momentum, and angle of scattering of a charged particle will identify positive pions produced in a liquid-hydrogen target. The target flask, flight path in the spectrometer, and array of detectors will be in a common vacuum to minimize loss of energy and multiple scattering of pions produced with extremely low momenta, and, hence, to maximize the accessible portion of $T^* \cdot \cos \theta^*$ phase space. Accuracies of 5% in the total production cross sections and 10% in the doubly differential cross sections should be achieved by this experiment.

From the two proposed measurements and our previous results between 229 and 356 MeV, we will extract the soft-pion contribution to the total cross section. The new measurements nearer threshold will greatly improve the reliability of extrapolation to threshold and, hence, the validity of comparison to soft-pion theory. We shall accurately determine ξ , the parameter that distinguishes among diverse effective Lagrangians, as well as a_0 and a_2 , the S-wave $\pi\pi$ -scattering lengths for isospin 0 and 2. The doubly differential cross sections will not only facilitate extraction of the soft-pion contribution, but will also yield hitherto unavailable information about the hard-pion contribution.

Exp. 338

MASS MEASUREMENTS OF EXOTIC NEUTRON-RICH NUCLEI USING THE (π^-, π^+) REACTION

University of Texas

W. J. Braithwaite, Spokesman

W. B. Cottingham, C. F. Moore

LASL

C. L. Morris, H. A. Thiessen

We are proposing to measure the masses of four exotic neutron-rich nuclei, $^{16,17,18}\text{C}$ and ^{48}Ar , using the (π^-, π^+) double-charge-exchange reaction on targets of $^{16,17,18}\text{O}$ and ^{48}Ca , respectively.

Carbon-16 is the most neutron-rich carbon isotope whose mass has been measured, and its determination in this experiment will provide an independent energy calibration for the other mass determinations. Further, this measurement is necessary to correct for the small ^{18}O contaminant in the ^{17}O target, used in the determination of the mass of ^{17}C .

Argon-48 is +8 neutrons from stability and +2 neutrons away from the most neutron-rich argon isotope whose mass has been measured. At present, no in-beam mass measurements have been made of nuclei +8 neutrons from stability exploiting two-body kinematics in the description of the final state.

The EPICS spectrometer will be used to measure the energy of positive pions emerging at 10° (lab), and the EPICS channel will be used to provide negative pions for the DCE measurement. Elastic scattering of $\pi^+ + {}^2\text{H}$ at several scattering angles will be used to calibrate the spectrometer, with the channel magnets exactly reversed to provide the positive pions for this calibration.

SURVEY OF PHOTODETACHMENT CROSS SECTION OF H^- FROM THRESHOLD TO 15 eV AND ITS DEPENDENCE UPON ELECTRIC FIELD

University of New Mexico

H. C. Bryant, Spokesman

J. Donahue, H. Sharifian, H. Tootoonchi, D. Clark

LASL

P.A.M. Gram, Spokesman

J. C. Pratt, M. A. Yates-Williams

The work on photodetachment resonances in H^- , completed in Exps. 200 (November 1976) and 323 (March 1977), revealed a much richer structure than had been anticipated. In Exp. 200, we unexpectedly found a resonance of the Feshbach type, as well as the shape resonance we had set out to study. In Exp. 323, we discovered that, contrary to theoretical expectation, the Feshbach resonance showed a marked Stark splitting, *linear* in the field, whereas the shape resonance was extremely resistant to perturbation. These resonances are associated with the $n = 2$ state of neutral hydrogen.

In this proposal, we outline our plans to increase the energy range of our measurements in order to look for resonances associated with the higher states of the hydrogen atom, with and without a barycentric electric Stark field. In addition to the insight its perturbation gives into the wave functions of allowed transitions (1P states), the electric field is expected to make possible transitions to states forbidden in the field-free case. Our ability to apply large barycentric electric fields to H^- is unique to the relativistic beam technique, and opens up a new dimension in H^- spectroscopy.

The experimental arrangement will be similar in concept to that which we have used earlier; counting rates and signal-to-noise ratios will be increased somewhat. The source of higher frequency light will be a "YAG" (neodymium-doped yttrium-aluminum-garnet) laser, directed through two nonlinear crystals ("frequency doublers") to produce 4.68-eV photons ($4 \times$ the YAG energy). The optical bench and scattering chamber assembly will be rebuilt to be a single rigid unit, and additional beam-scanning equipment will be installed. We are, in short, building a Mark II version of the experiment based on our experience and on the revelation of the interesting physics that remain to be done with this technique.

PION SCATTERING FROM ALIGNED ^{165}Ho

Lockheed Research Laboratory

T. R. Fisher, Spokesman

J. A. Becker, B. A. Watson

National Bureau of Standards

H. Marshak, Spokesman

University of Virginia

J. S. McCarthy

As a continuation of the experimental program to study pion scattering from oriented deformed nuclei, we propose to measure the differential cross section for pion scattering from a target of aligned ^{165}Ho over the angular range from 10° to 50° . Operation of the target at a temperature below 0.1 K in a magnetic field of 3 kOe will achieve almost 100% alignment with respect to the Z axis defined by the magnetic-field direction. Two orientations of the Z axis will be investigated, both perpendicular to the incident beam direction and lying either in the scattering plane or perpendicular to it. The measurements will also be performed for both positive and negative pions at two energies, one of which will correspond to the peak of the (3,3) resonance. From a comparison of the aligned target results with results from an unaligned target, information on the multipole moments of the neutron and proton distributions will be derived.

STUDY OF $\text{pd} \rightarrow \text{d}\pi^+\text{n}$ REACTION MECHANISMS

Rice University

G. C. Phillips, Spokesman

G. S. Mutchler, I. M. Duck, J. M. Clement, W. H. Dragoset

University of Houston

J. C. Allred, E. V. Hungerford, B. W. Mayes, L. Pinsky, T. M. Williams

University of Bonn

Wolfram von Witsch

Institute "Ruder Boskovic," Zagreb, Yugoslavia

M. Fúric

The differential cross section for the reaction $\text{pd} \rightarrow \text{d}\pi^+\text{n}$ will be measured in a kinematically complete experiment for neutron spectator momenta ranging from 0 to 1000 MeV/c. The reaction will be investigated using the EPB channel with the deuteron detected in a magnetic spectrometer and the pion in a time-of-flight (TOF) arm. The deuteron angle will be varied from 10° to 50° to sweep out the available spectator momentum range. Absolute values of the cross sections will be measured to $\sim 5\%$.

The purpose of the proposed research is to make a detailed study of the $\text{pd} \rightarrow \text{d}\pi^+\text{n}$ reaction at all momentum transfers in order to test the extension of Glauber theory to inelastic reactions.

STUDY OF THE (π^+, p) REACTION IN ^{12}C *University of Virginia**J. S. McCarthy, Spokesman**P. C. Gugelot**University of British Columbia (TRIUMF)**Jan Källne, Spokesman**LASL**H. A. Thiessen, J. F. Amann, B. C. Hoistad, C. L. Morris, D. M. Lee, R. J. Macek*

We propose to study the $^{12}\text{C}(\pi^+, p)^{11}\text{C}$ reaction in order to learn about pion-nucleon interaction and reaction mechanism effects. The single-particle relationship between some states in ^{12}C and ^{11}C are known from other reactions, so we can use these nuclei to study the (π^+, p) reaction under controlled nuclear-structure conditions. The idea of the proposal is to compare (π^+, p) cross sections for a transition that can proceed by a single-step transfer and one that requires a two-step process for nuclear-structure reasons, the two typical cases being the transitions to the ^{11}C ground state and the $5/2^-$ state at 4.31 MeV. The basic (π^+, p) process is governed by a single-nucleon interaction (pickup model) or multinucleon interaction; the objective of this experiment is to determine which.

HIGH-SPIN STATES IN MEDIUM-ENERGY
PROTON INELASTIC SCATTERING*Northwestern University**K. K. Seth, Spokesman**S. Iversen, M. O. Kaletka, A. Obst, H. Nann*

It is proposed to study inelastic scattering of 400-, 600-, and 800-MeV protons on ^{23}Na , ^{42}Ca , ^{50}Ti , and ^{90}Zr , in order to obtain an understanding of the mechanism of excitation of high-spin states, both of simple particle-hole type and of the collective type.

HIGHER PRECISION MEASUREMENT OF MUON MAGNETIC MOMENT
AND OF MUONIUM HFS INTERVAL*Yale University**V. W. Hughes, Spokesman*

We propose to measure 1) μ_μ/μ_p , the muon-to-proton magnetic moment ratio, to 0.04 ppm; and 2) $\Delta\nu$, the hyperfine structure interval in muonium, to 0.03 ppm, in an extension of the strong field part of our LAMPF Exp. 37. This substantial improvement in precision by a factor of at least 3 compared to present knowledge is made possible by the extremely high μ^+ stopping rate available from the new 30-MeV/c "surface" muon beam. The increased precision in μ_μ/μ_p and in $\Delta\nu$ will be useful to muon electrodynamics.

Exp. 345

**STUDY OF THE STRUCTURE FUNCTION AND THE CONNECTION
BETWEEN ELASTIC AND INELASTIC CROSS SECTION AT LARGE t
IN THE p - ^4He INTERACTION**

University of Pennsylvania

Sherman Frankel, Spokesman

W. Frati, M. Gazzaly

University of California, Los Angeles

G. J. Igo

LASL

G. W. Hoffmann

We propose to measure the structure function $G(k)$ for ^4He in the reaction $p + ^4\text{He} \rightarrow p + X$, to see whether ^4He , a very *light* nucleus, has the *same structure function* as does ^6Li , ^9Be , ^{12}C , . . . ^{181}Ta , as measured in Exp. 256 (LAMPF).

In addition, we propose to measure the dependence of the inelastic cross section at backward angles near the elastic region to see if the turn-up of the elastic cross section at large t in ^4He is mirrored in the inelastic cross section. This is done by studying the reaction in a small angular region at the largest HRS angle where the structure function is stationary.

Exp. 346

**STUDY OF HIGH-MOMENTUM COMPONENTS IN NUCLEI
USING A POLARIZED PROTON BEAM**

University of Pennsylvania

Sherman Frankel, Spokesman

W. Frati, R. Woloshyn, M. Gazzaly

University of California, Los Angeles

G. J. Igo

LASL

G. W. Hoffmann

We propose use of the HRS with 800-MeV polarized protons to probe high-momentum components of nucleons in nuclei.

Measurement of the polarization P at 90, 100, and 120° laboratory angles is used to decide between various reaction mechanisms. The single-scattering quasi-two-body scaling model predicts polarizations ranging from 0.1 to 0.45. By studying P for ^6Li , ^9Be , and ^{181}Ta , the effects of scattering of the incoming proton and outgoing proton within the nucleus can be investigated.

Study of the polarization in the reaction $p + A \rightarrow d, t + X$ is obtained as a byproduct, since p, d, t are separated on line by time-of-flight and dE/dx binning. This serves to study mechanisms for fragment ejection.

Measurements of the forward quasi-elastic-scattering process, where the projectile proton (rather than the ejected proton) is detected with the HRS, will also be carried out to elucidate the low-momentum components studied in that kinematic region.

Exp. 347

SEARCH FOR "ORBIT-FLIP" STATES BY INELASTIC PROTON SCATTERING

University of Minnesota

N. Hintz, Spokesman

D. Dehnhard, G. Kyle

LASL

G. W. Hoffman, H. A. Thiessen, E. R. Flynn, M. Oothoudt

University of Texas

G. Blanpied, R. Liljestrand

We propose to use the High-Resolution Spectrometer to study giant "orbit-flip" states ($\Delta l = 2$) that can be formed by 1p-1h excitation between the two members of a spin-orbit doublet in the single-particle shell model. These J_{max} states should be rather pure, since other configurations which can give rise to the same J are usually at much higher energies (typical spin-orbit splittings are about 4-6 MeV). Because of the simple microscopic structure of these states, they should be useful in establishing the nature of the high-energy nucleon-nucleon interaction inside the nucleus.

Targets of ^{70}Ge , ^{90}Zr , ^{120}Sn , ^{140}Ce (or ^{142}Nd), and ^{208}Pb will be used, and a total time of 150 h is requested.

Exp. 348

**STUDY OF GIANT RESONANCES WITH RADIATIVE PION CAPTURE
ON MEDIUM-Z NUCLEI AT LEP**

Lawrence Berkeley Laboratory

Kenneth M. Crowe, Spokesman

J. Bistirlich, J. Miller, S. S. Rosenblum, W. Zajc, J. Martoff

University of Zürich

P. Truoel, C. Strassner

University of Maryland

S. Wall

We propose to measure the γ -ray energy spectrum in the range 55-150 MeV resulting from pion capture on ^{13}C , ^{19}F , ^{20}Ne , ^{48}Ti , ^{90}Zr , and in-flight capture of π^+ on ^{12}C . The primary interest is nuclear structure of the giant resonances. The motivation and details of technique are discussed briefly in the proposal. Little modification of existing apparatus is required, and although some lead time is required to set up the pair spectrometer, preparations are negligible compared to the previous tritium run. During the run, we also propose studies for detecting neutrons and low-energy gammas in coincidence with the hard gammas of the pair spectrometer.

NUCLEAR REACTIONS OF ^{127}I WITH PIONS

Purdue University

N. T. Porile, Spokesman

S. Pandian

LASL

C. J. Orth

We propose to study the interaction of π^+ and π^- with ^{127}I by means of two separate but related experiments: 1) a measurement of the excitation functions of $(\pi^\pm, \pi^\pm xn)$ reactions ($x = 1-4, 6-8$) between ~ 50 and 350 MeV, by use of activation techniques; and 2) determination of the mass-yield curve for π^+ and π^- at three energies ($\sim 100, 200$, and 300 MeV), by a combination of activation and in-beam techniques.

STUDY OF PION-ABSORPTION MECHANISMS IN NUCLEI

Northwestern University

R. E. Segel, Spokesman

Argonne National Laboratory

J. P. Schiffer, Spokesman

H. E. Jackson, S. J. Sanders, E. J. Stephenson

LASL

R. P. Redwine, M. A. Yates-Williams

A more detailed study is proposed to the $\pi + A \rightarrow p + X$ reaction to follow up on the results of Exp. 293, which raised a number of questions on the pion-absorption process even on as simple a system as ${}^4\text{He}$. It is proposed to obtain more detailed angular distribution on ${}^4\text{He}$ to study the angle dependence of the yield for both the high-energy and low-energy proton groups seen in the spectra and the $\pi^+:\pi^-$ ratios. The data on the low-energy proton group were somewhat obscured by the 50-MeV cutoff in the detector telescope; it is planned to lower this cutoff to ~ 30 MeV. The differences between ${}^4\text{He}$ and ${}^{12}\text{C}$ were quite dramatic at 220 MeV; it is planned to obtain data on ${}^6\text{Li}$ and ${}^9\text{Be}$, as well as ${}^4\text{He}$, ${}^{12}\text{C}$, and one or more heavier targets. In view of the recent observation of backward peaking in the (π^+, π^0) integral yield, some data will also be obtained on the angle dependence of the integral charged-pion yield.

The equipment to be used will be the same as for Exp. 293, with some minor modifications and improvements.

SEARCH FOR DEUTERON ABNORMAL MATTER

University of California, Los Angeles

G. J. Igo, Spokesman

G. Adams, T. Bauer, G. Pauletta, C. Whitten, A. Wriekat

LASL

G. Hoffmann, A. Thiessen

University of Pennsylvania

M. Gazzaly

The missing mass spectrum will be searched between (1.87 ± 0.17) GeV and (1.87 ± 0.37) GeV for ~ 20 MeV (2σ) width structure signaling abnormal deuteron matter $\tilde{d}$ speculated to occur in the reaction $\bar{p} + d \rightarrow p' + \tilde{d}$ ($Q_{\text{est.}} \cong -0.27$ GeV). The full range in four-momentum transfer squared, $-t$, available at 0.8 GeV in a pd collision, will be searched. The HRS spectrometer will be used to detect the outgoing proton, p' .

Exp. 352

DETERMINATION OF NEUTRON MASS DISTRIBUTIONS FROM PROTON MEASUREMENTS [$P(t)$ AND $d\sigma/dt$] IN ISOTOPES ON THE CALCIUM REGION

University of California, Los Angeles

C. A. Whitten, *Spokesman*

G. Adams, T. S. Bauer, G. J. Igo, G. Pauletta, A. Wriekat

University of Texas

R. Liljestrang

New Mexico State University

G. Blanpied

LASL

G. W. Hoffmann, T. Kozlowski, M. Oothoudt, H. A. Thiessen

Extensive measurements of elastic quantities [$d\sigma/dt$ and $P(t)$] and of collective inelastic quantities (asymmetry and $d\sigma/dt$) on nine isotopes in the calcium region will be made at 800 MeV. A fair amount of work on the titanium isotopes and on ^{40}Ca and ^{42}Ca have already been completed during Cycle 17, and subsequently analyzed. We will provide accurate data over a large t range to be used primarily to determine the dependence of the neutron mass distribution on changes in the neutron number (fixed Z) and on changes in the proton number (fixed N) near a closed-shell configuration.

Exp. 353

PROTON ELASTIC AND INELASTIC SCATTERING AT ~ 600 MeV

Northwestern University

K. K. Seth, *Spokesman*

S. G. Iversen, M. O. Kaletka, A. W. Obst, H. Nann

LASL

G. W. Hoffmann

It is proposed to study elastic and inelastic scattering of ~ 600 -MeV protons on ^{12}C , ^{28}Mg , $^{40,42}\text{Ca}$, ^{58}Ni , ^{88}Sr , ^{90}Zr , ^{120}Sn , and ^{208}Pb . The requirement of consistency between results obtained at 600 MeV and those obtained at 800 MeV is expected to provide strong constraints for parameters, and, thus, submit the competing formalisms of scattering theory to a crucial test.

Exp. 354

SCATTERING OF 800-MeV PROTONS FROM ^{12}C AND ^{13}C AT MOMENTUM TRANSFERS GREATER THAN 4 fm^{-1}

New Mexico State University

G. S. Blanpied, *Spokesman*

G. R. Burleson

LASL

G. W. Hoffmann, H. A. Thiessen, T. Kozlowski, M. A. Oothoudt, O. van Dyck

We propose to use the High-Resolution Spectrometer to extend the differential cross sections for 800-MeV proton scattering on targets of ^{12}C and ^{13}C . Angular distributions, which extend to 36°_{lab} (momentum transfer of 4.5 fm^{-1}), have been analyzed, yielding interesting information about these complex nuclei.

The objectives are to extend these data to momentum transfer of 8 fm^{-1} , in order to 1) increase the sensitivity of the elastic data to the details of the matter distributions; 2) study the off-shell behavior of the proton-nucleon scattering amplitudes; 3) extend the data on the collective excitations in ^{12}C and ^{13}C which are sensitive to the derivatives of the matter distributions; and 4) extend the data for the 0^+ , 2^+ , and 4^+ rotational band in ^{12}C , in order to study the two-step process.

A total time of 100 h is requested.

We propose also that the elastic analyzing power measurements for ^{12}C , which stop at 31°_{lab} , be extended past one more diffraction minimum. This should be done with at least 5 nA of polarized beam on target.

A total time of 24 h of polarized beam is requested for this.

Exp. 355

**FURTHER ELASTIC-SCATTERING CROSS SECTION AND ANALYZING POWER
MEASUREMENTS ON ^{208}Pb AND $^{116,124}\text{Sn}$**

LASL

G. W. Hoffmann, Spokesman

J. F. Amann, C. L. Morris, N. Tanaka, M. Othoudt, H. A. Thiessen

New Mexico State University

G. S. Blanpied, R. Liljestrang

University of California, Los Angeles

G. Adams, T. S. Bauer, G. J. Igo, G. Pauletta, C. A. Whitten

University of Minnesota

N. Hintz, G. Kyle

Rutgers University

C. Glashausser

We propose the three experiments listed below in order to answer questions raised in regard to the interpretation of existing LAMPF-HRS data analysis.

1. To use the HRS and transverse polarized beam to extend 800-MeV elastic-scattering analyzing power measurements for $p + ^{208}\text{Pb}$ from 20 to 30° .

2. To use the HRS and unpolarized beam to extend 800-MeV elastic differential cross sections for $p + ^{208}\text{Pb}$ from 30 - 40° .

3. To use the HRS and unpolarized beam to extend 800-MeV elastic differential cross sections for $p + ^{116,124}\text{Sn}$ from 20 - 35° .

Exp. 356

**ANALYZING POWER AND CROSS-SECTION MEASUREMENTS FOR INELASTIC
PROTON EXCITATION OF SIMPLE STATES**

Rutgers University

C. Glashausser, Spokesman

University of Georgia

F. T. Baker and A. Scott, Spokesmen

LASL

G. W. Hoffmann

The High-Resolution Spectrometer will be used to measure the analyzing power (A_y) and the differential cross section (σ) for inelastic excitation of selected states favorable for microscopic analysis. The A_y measurements will highlight the role of the spin-dependent forces in the inelastic scattering, particularly the two-body spin-orbit force. In addition, they serve as an overall index of the accuracy of the theoretical analysis. Successful explanation of both σ and A_y should yield reliable values for the relative strengths of isoscalar and isovector excitations, as well as good numbers for the relative importance of neutron valence and core participation. Suggested targets include ^{90}Zr , ^{92}Zr , ^{18}O , ^{207}Pb , ^{39}K , ^{92}Mo , ^{16}O , ^{208}Pb , and ^{40}Ca .

Exp. 357

MUONIC X-RAY SPECTRA OF GASES: I. DENSITY AND ADMIXTURE EFFECTS

LASL

J. D. Knight, Spokesman

M. Leon, C. J. Orth, M. E. Schillaci

Princeton University

R. A. Naumann

As an incidental result of a previous experiment, we have observed that the muonic x-ray spectrum of atmospheric N_2 differs significantly from that of liquid N_2 , that is, that there is a density effect. The effect is thought to be associated with rate of replenishment of electrons lost by the muonic N atom during its deexcitation cascade.

We propose to measure the muonic x-ray intensity patterns of 1) N_2 , O_2 , and Ar at 1 atm, 10-20 atm, and in the liquid state; 2) SF_6 at 1 atm and in the solid state; and 3) NO and CO at 1-5 atm, and N_2 - O_2 mixtures at 10-20 atm. Results of these measurements should help us to formulate more exact models of the formation and deexcitation of muonic atoms in both gas and condensed phases.

Exp. 358

ELASTIC SCATTERING OF PIONS FROM DEUTERIUM

University of Virginia

R. C. Minehart, Spokesman

J. S. McCarthy

LASL

E. A. Wadlinger

Cross sections for elastic scattering of $\pi^\pm$ on deuterium will be measured with 2-3% accuracy at four momenta from 350-650 MeV/c, and at angles from 20-160° in the lab. Some measurements at selected angles and momenta will also be made for π^- scattering to test charge independence. Both the scattered pion and the recoil deuteron will be measured, using time-of-flight and momentum measurements to separate elastic from inelastic scattering. To detect low-energy deuterons, a gas target will be used along with solid-state detectors, and a NaI scintillator to identify the deuteron with E- Δ E. For higher energy deuterons, a liquid target will be used in conjunction with a magnetic spectrometer to measure the deuteron momentum. The momentum and time of flight will be combined to identify the deuteron by its mass.

Exp. 359

ASYMMETRY MEASUREMENTS OF THE (p, π^+) REACTION ON LIGHT TARGETS AT $T_p = 800$ MeV AND $T_p = 650$ MeV

University of California, Los Angeles

T. S. Bauer, Spokesman

G. S. Adams, G. J. Igo, G. Pauletta, C. A. Whitten, A. Wriekat

We propose to measure the asymmetry in the $(\vec{p}, \pi^+)$ reaction on several light nuclei (CH_2 , ^6Li , ^9Be , and ^{12}C) using polarized beam and HRS. By using thick targets, the counting rates will be adequate with the existing 3-nA polarized beam. The only changes required to the existing HRS facility are the installation of two Lucite Cerenkov counters (with one phototube each) and a minor change in the trigger electronics. Thus, this experiment can be run now without waiting for substantial development work on the HRS facility or on the polarized ion source.

Exp. 360

**THE MEASUREMENT OF THE POLARIZATION TRANSFER COEFFICIENTS D_t
AND A_t AT 800 MeV FOR THE REACTIONS
 $d(\vec{p}, \vec{n})2p$, ${}^6\text{Li}(\vec{p}, \vec{n}){}^6\text{Be}$, AND ${}^9\text{Be}(\vec{p}, \vec{n}){}^9\text{B}$**

LASL*J. E. Simmons, Spokesman**B. E. Bonner***University of Texas, Austin***P. J. Riley, Spokesman**C. L. Hollas, C. R. Newson***Texas A&M University***T. S. Bhatia, G. Glass, J. C. Hiebert, L. C. Northcliffe*

Using the LAMPF polarized proton beam incident on a liquid-deuterium target, we propose to measure the polarization transfer parameters D_t and A_t at 0° for the reaction $d(\vec{p}, \vec{n})2p$. The outgoing neutron polarization will be measured by using a polarimeter consisting of a liquid-hydrogen radiator target and a modified multiwire proportional counter (MWPC) spectrometer in Area B. If D_t and A_t turn out to have low magnitudes, it will be desirable to undertake measurement of R_t at 7° . Similar measurements will be carried out using solid ${}^6\text{Li}$ and ${}^9\text{Be}$ targets. The measurements of D_t and A_t will indicate the value of polarization transfer as a source of a polarized neutron beam at 800 MeV. In addition, the values of D_t and A_t are sensitive to the phase shifts input into impulse approximation calculations, and can thus provide information relating to n-p scattering phase shifts.

Exp. 361

**CROSS-SECTION AND ASYMMETRY MEASUREMENTS FOR THE REACTIONS
 ${}^2\text{H}(\vec{p}, \pi^+){}^3\text{H}$ AND ${}^3\text{He}(\vec{p}, \pi^+){}^4\text{He}$ AT INTERMEDIATE ENERGIES**

University of California, Los Angeles*G. S. Adams, Spokesman**T. S. Bauer, G. J. Igo, G. Pauletta, C. A. Whitten, A. Wriekat***University of Pennsylvania***M. Gazzaly***LASL***G. W. Hoffmann, C. L. Morris***University of Virginia***J. S. McCarthy*

Studies of reaction mechanisms and nuclear structure through the (p, π) reaction are of fundamental interest to nuclear physicists. However, these two facets of the reaction are not well separated; in order to understand the nuclear-structure effects, one should have prior knowledge of the dominant reaction mechanism or mechanisms. Therefore, it is desirable to have a large amount of experimental data on reactions that have well-known wave functions in the initial and final states with which one can test the mechanism. One can further constrain the theories by measuring the asymmetry of the pions in the $(\vec{p}, \pi)$ reaction.

Since the dominant reaction mechanism is likely to change as one varies the incident proton's energy, measurements over a wide range of energies are desirable. Of particular interest is the

region above ~ 500 MeV. At these energies, the $(3/2, 3/2)$ resonance in the pion-nucleon system is less dominant, and projectile and pion distortion is minimal.

We propose to measure the differential cross sections and asymmetries of the pions from the reactions ${}^2\text{H}(\bar{p}, \pi^+){}^3\text{H}$ and ${}^3\text{He}(\bar{p}, \pi^+){}^4\text{He}$ over the angular range 4.5 to 160° (lab). In order to investigate the above-mentioned energy dependence, the measurements will be duplicated at 650 and 800 MeV. Light targets were chosen because their wave functions have been studied in great detail, and because they will produce minimal distortion of the projectile and pion waves. Also, their cross sections are known from previous measurements to be relatively large.

Exp. 362

STUDY OF QUASI-FREE (p,2p) REACTIONS AT 800 MeV WITH USE OF UNPOLARIZED AND POLARIZED BEAM

University of California, Los Angeles

T. S. Bauer and A. Wriekat, Spokesmen

G. Adams, G. J. Igo, G. Pauletta, C. A. Whitten

Brookhaven National Laboratory

R. Chrien, M. May, H. Palevsky, R. Sutter

LASL

G. W. Hoffmann

Vassar College

R. Stearns

We propose to measure the quasi-free (p,2p) reaction on targets ranging from ${}^{12}\text{C}$ to ${}^{208}\text{Pb}$ at 800 MeV with an energy resolution of less than 0.5 MeV. This resolution, achieved by the use of HRS in coincidence with a new spectrometer of the type QQD, will allow us to study individual final states. Furthermore, the low background and the low counting rate will allow us to study the structure of deep-lying shells.

On one target (${}^{12}\text{C}$), we propose to measure asymmetries in the continuum region of deeper lying shells, using a polarized proton beam and a thick target.

Since the new coincidence spectrometer is suitable for other knockout reactions [(p,p α), for example], we intend at a later time to extend the measurements on such reactions. In particular, we plan to pursue the approved UCLA experiment on the (p,p α) reaction (Proposal No. 177).

Exp. 363

MEASUREMENT OF $\pi^\pm + p$ ELASTIC SCATTERING

University of California, Los Angeles

M. E. Sadler and B. M. Nefkens, Spokesmen

F. O. Borcharding, P. F. Glodis, R. P. Haddock, N. Matz, W. Briscoe, C. Setter

When measurements of $\pi^- + p \rightarrow \gamma + n$ and $\pi^- + p \rightarrow \pi^0 + n$ were proposed (Exps. 58 and 120, respectively), it was felt that accurate differential cross-section measurements of pion-

proton elastic scattering at LAMPF energies would be forthcoming. Since this has not been the case, we wish to add these measurements for

$$\pi^{\pm} + p \rightarrow \pi^{\pm} + p$$

for incident laboratory pion energies of 300-580 MeV to our original proposals. The total center-of-mass (c.m.) energy range is 1300-1500 MeV, beginning just above the P_{33} resonance and extending to the P_{11} resonance region. Measurements will be made at laboratory angles corresponding to c.m. scattering angles of $0.8 \geq \cos \tilde{\theta} \geq -0.8$, approximately spaced at intervals of $\cos \tilde{\theta} = 0.2$. A statistical accuracy of 2% and an overall accuracy of 3% will be sought. The objectives of the experiment are

1. to provide more accurate elastic-scattering data to be used with charge exchange and polarization data in order to obtain a better parameterization of the pion-nucleon interaction.
2. to obtain uniform angular coverage of the differential cross sections, a feature especially lacking in present π^-p data.
3. to further investigate the properties of the P_{11} resonance, which are poorly determined by present data.
4. to test the Ayed-Bareyre-Sonderregger phase degeneracy at 180° .

Exp. 364

SEARCH FOR THE EXCITED 2S STATE OF MUONIU

Yale University

P. O. Egan, A. B. Denison, and V. W. Hughes, Spokesmen

J. Vetter, W. Beer, P. Bolton, P. A. Souder, D. C. Lu, F. Mariam

University of Heidelberg

G. zu Putlitz, H. Orth

We propose to search for the $n = 2$ excited state of muonium in vacuum, utilizing the technique of muonium formation at thin foil surfaces to produce the states. The initial stage of the experiment will study this formation mechanism in detail by observing the Larmor precession of the $n = 1$ ground state. The $n = 2$ excited state will be detected by two methods: 1) observation of the "two-frequency" Larmor precession of the muonium polarization, and 2) optical observation of the muonium spectral lines.

The principal ultimate objective of this search, if successful, will be a high-precision measurement of the Lamb shift in $n = 2$ muonium as a test of quantum electrodynamics.

Exp. 365

COMPARISON OF DENSITY DISTRIBUTIONS OF ^{207}Pb , ^{208}Pb , AND ^{209}Bi

University of Minnesota

N. M. Hintz, Spokesman

D. Dehnhard, G. Kyle

LASL

G. W. Hoffmann, H. A. Thiessen

University of Texas, Austin

R. Liljestrand, L. E. Smith

We propose the use of the HRS to make a precision measurement of the ratios of elastic scattering at 800 MeV for the three nuclei, ^{207}Pb , ^{208}Pb , and ^{209}Bi , over the angular range of $3\text{--}40^\circ$ (5 fm^{-1} momentum transfer).

Taken in connection with existing electron-scattering data on the ^{208}Pb - ^{209}Bi elastic-scattering ratio (to $q = 2.8\text{ fm}^{-1}$), we expect to obtain the change in the neutron and proton density distributions when an $h9/2$ proton (^{209}Bi) or a $p1/2$ neutron hole (^{207}Pb) is added to the doubly closed shell ^{208}Pb .

Exp. 366

NONRESONANT PION PRODUCTION IN THE REACTION $np \rightarrow \pi^- pp$

Rice University

G. S. Mutchler, *Spokesman*

G. C. Phillips, I. M. Duck, J. M. Clement, W. H. Dragoset

University of Houston

B. W. Mayes, *Spokesman*

J. C. Allred, E. V. Hungerford, L. Pinsky, T. M. Williams

LASL

B. E. Bonner

Texas A&M University

G. Glass

Institute "Ruder Boskovic," Zagreb, Yugoslavia

Miroslav Fúric

University of Texas, Austin

C. L. Hollas, P. J. Riley

The differential cross section for the reaction $np \rightarrow pp\pi^-$ will be measured in a kinematically complete experiment. The reaction will be investigated using NPL neutron beam at 800, 700, and 600 MeV. The purpose of the proposed research is to determine the resonant and nonresonant amplitudes for pion production from nucleon-nucleon collisions. The data will be taken for a large number of angle pairs spanning the available phase space. This data set and the data set from Exp. 81, $pp \rightarrow pp\pi^0$ and $pp \rightarrow \pi^+pn$, will be used to determine the resonant and nonresonant amplitudes as a function of energy and angle.

Exp. 367

STUDY OF HIGH-SPIN STATES BY THE $(p, {}^3\text{He})$ REACTION

Northwestern University

H. Nann and K. K. Seth, *Spokesmen*

S. G. Iversen, M. O. Kaletka, A. W. Obst

In the case of momentum mismatch between the entrance and exit channels and due to the geometrical coefficients in the structure factor, stretched configuration high-spin states are strongly populated in two-nucleon transfer reactions. It is proposed to study such states via the $(p, {}^3\text{He})$ reaction using the High-Resolution Spectrometer. These high-spin states should be rather pure, since possibilities for mixing with other configurations are minimal.

Targets of ^{47}Ti , ^{59}Co , ^{58}Ni , ^{95}Mo , ^{115}In , ^{116}Sn , ^{208}Pb , and ^{209}Bi will be used. A total time of 424 h is requested.

Exp. 368

INELASTIC PION SCATTERING TO THE 19.2 ± 0.3 MeV STATE IN ^{12}C

University of Texas, Austin

C. F. Moore, Spokesman

W. J. Braithwaite

University of Colorado

R. L. Boudrie, R. J. Peterson

LASL

C. L. Morris, H. A. Thiessen

Northwestern University

A. W. Obst

We propose to study the inelastic scattering of pions to the state(s) in ^{12}C at 19.2 ± 0.3 MeV. This state or close multiplet of states is strongly populated at a pion energy of 164 MeV [on the (3,3) resonance] and at a scattering angle of 70° . Our major interest is to measure the energy dependence of inelastic excitation over the (3,3) pion-nucleon resonance. The EPICS channel spectrometer will be used, and beam energies of 80, 100, 120, 140, 160, 180, 200, 220, 240, 260, and 280 MeV are proposed. Several angles near the maximum in the angular distribution will be measured. One hundred and fifty hours of beam time are requested.

Exp. 369

INELASTIC PION SCATTERING BY ^{17}O , ^{18}O , AND ^{19}F

University of Minnesota

D. Dehnhard, Spokesman

LASL

D. C. Madland, C. L. Morris, H. A. Thiessen

We propose a study of elastic and inelastic scattering of π^+ and π^- by ^{17}O , ^{18}O , and ^{19}F using the EPICS channel with ≈ 200 -MeV pions. Transitions to particularly simple states will be investigated to extract the relative strengths of proton and neutron contributions. Oxygen-17 is an especially unique target because it is the only stable nucleus, besides ^{209}Bi , which consists of a single nucleon outside a doubly magic core. Deviations in the ratio $\sigma(\pi^+)/\sigma(\pi^-)$ from expectations based on nuclear models and the π -nucleon interaction would yield new information on the reaction mechanism for inelastic π scattering and on the relative merit of the numerous spherical and deformed shell-model calculations.

In the case of ^{19}F , we are especially interested in the discrepancy between the experimental inelastic transition strengths to the $5/2^-$ state at 1.35 MeV. Values obtained by electromagnetic excitation are typically a factor of 3 larger than with strongly interacting probes. A summary of the data on this transition has been made.

No resolution problems exist for performing the inelastic-scattering experiment with EPICS for a number of simple states in ^{17}O and ^{18}O ($\Delta E \sim 250$ -350-keV FWHM would be sufficient).

During the measurement on an enriched ^{17}O target, the elastic scattering on ^{16}O would be taken simultaneously so that a partial overlap exists with Proposal No. 14. For the experiment on ^{19}F , a resolution of better than 150-keV FWHM will be needed.

We expect that valuable information can be obtained already from a comparison of a few (π^+, π^-) and (π^-, π^-) spectra taken at the first maxima of the $\Delta L = 2$ and $\Delta L = 1$ transitions. We estimate that after setting up, this can be accomplished in less than 24 h of beam time. Of course, a detailed analysis of the reaction requires angular distributions to be taken, for which we estimate about 240 h of beam time.

SUB-COULOMB π^+ ELASTIC SCATTERING AND (π^+, p) REACTIONS
 ^{208}Pb AT $E_\pi = 7\text{-}12$ MeV

University of Washington

J. G. Cramer, Spokesman

W. G. Lynch

LASL

M. D. Cooper, Spokesman

J. E. Spencer

Carnegie-Mellon University

R. A. Eisenstein

University of Wisconsin

L. D. Knutsen

University of Montana

R. H. Jeppeson

It is proposed to measure the cross sections for π^+ elastic scattering and the (π^+, p) reaction on ^{208}Pb at bombarding energies near and below the Coulomb barrier. There are three principal objectives for these measurements: (1) to measure elastic scattering in a relatively pure Coulomb domain in order to test the lowest order corrections to Coulomb scattering arising from the use of a relativistically invariant wave equation (e.g., the Klein-Gordon equation); (2) at somewhat higher energies and/or larger angles, to observe the effects of the tail of the pion-nucleus potential while using the Coulomb barrier to prevent closer collisions; and (3) as a parasitic measurement, to gain information of (π^+, p) reactions very near the Coulomb barrier for comparison with reaction models and measurements of (p, π^+) reactions. This experiment will provide an introduction to very low-energy pion scattering for future use with other targets. We propose to do 1% accurate relative measurements of two excitation functions at 110 and 130°, at energies between 7 and 12 MeV, one six-point angular distribution at 8 MeV, and partial angular distributions at 7, 10, and 12 MeV. We propose to use the LEP channel and to develop the required low-energy pion beams as a part of the experiment. The outgoing particles will be detected and identified with two-element solid-state detector telescopes backed by NaI scintillators. Estimated running time is on the order of 11 days, if a beam of $3 \times 10^5 \pi^+/\text{s}$ in a 3% momentum interval and a channel angular acceptance of 17 msr at 8 MeV can be developed.

Exp. 370 — ADDENDUM

This addendum to LAMPF Proposal 370, "Sub-Coulomb π^+ Elastic Scattering on ^{208}Pb at $E_\pi = 7$ to 12 MeV," is a response to the request of the Program Advisory Committee for more details on the sensitivity of the measured cross sections in discriminating among various nuclear models. The addendum will address this question within the framework of determining the parameters of an optical potential model of π -nucleus scattering. The form for the potential is one that has recently been applied to both π scattering at 50 MeV and to pionic atoms. The time request will reflect some evolution in thinking as to the best way to get at the nuclear effects, most notably, the use of a ^{90}Zr target. In addition, a short report has been written on the status of development of a low-energy π^+ beam at LEP and on the acquisition of a 1.22-m scattering chamber.

MUONIC X-RAY SPECTRA OF GASES II. CAPTURE PROBABILITIES IN MIXTURES

LASL

R. L. Hutson, Spokesman

J. D. Knight, M. Leon, M. E. Schillaci, M. A. Yates-Williams

University of Mississippi

J. J. Reidy

We propose to measure the relative capture probabilities of negative muons by helium, neon, argon, and krypton atoms in binary mixtures. Group T-12 is undertaking a program of quantum mechanical calculations of the relative capture probabilities in these binary mixtures. Results of the theoretical predictions would be compared with the results of this experiment. Group T-12's eventual goal is to predict the relative strengths of the muonic Lyman and Balmer series lines in simple systems. It is important to know the distribution of muon atomic states at capture if the subsequent cascade calculations are to predict correctly the relative strengths of Lyman and Balmer series lines. The same physical processes that affect capture probabilities also affect the distribution of muon states at capture, so an accurate prediction of capture probability would provide evidence that the processes involved are being described correctly and that cascade calculations could proceed with some assurance.

Relative capture ratios will be measured by stopping muons from the SMC in the gas mixtures and measuring the Lyman series yields from the gases. A muon telescope will be used to monitor stopped muons, and muonic x rays will be detected with a germanium detector.

STOPPING POWER OF $\pi^\pm$ AT ENERGIES BELOW 100 MeV

University of South Carolina

R. D. Edge, Spokesman

C. W. Darden, B. M. Freedom

Virginia Polytechnic Institute and State University

M. Blecher, K. Gotow, D. A. Jenkins

We request beam time to make accurate measurements of the stopping power of pions in the range up to 100 MeV. There are, at present, no measurements available for pion stopping powers, which would be of considerable interest because

1. pions of both positive and negative charge are available, whereas ions traversing matter are normally positive.
2. the mass differences between the electron and the pion, and the pion and the proton, are both large. Hence, really accurate interpolations are not easy to make. It would be a definite advantage to be able to check with experiment.
3. accurate values would help both in determining the thickness of targets used in intermediate-energy physics, and in obtaining dosage for use in radiation therapy.

Some work at low energy has been done by the V.I.P. group on pion ranges, and, currently, the group at TRIUMF is making some preliminary stopping power measurements.

Exp. 373

**A COMPARISON OF RESIDUAL NUCLEI YIELDS FROM π^- ABSORPTION
IN ^{112}Cd (GROUND STATE) AND ^{112}Cd (FIRST EXCITED STATE)**

University of Mississippi

J. J. Reidy, Spokesman

LASL

M. Leon, Spokesman

The large E2 nuclear resonance effect in ^{112}Cd offers us the unique opportunity to observe and differentiate π^- absorption by excited nuclei. We shall be able to compare the γ spectrum following π^- absorption on ^{112}Cd in the nuclear excited state (2^+ , 617 keV) with the γ spectrum following ground-state absorption. This will be done by comparing the γ spectrum in prompt coincidence with the 5-4 pionic x ray with the γ spectrum in coincidence with the 6-5 x ray. Since about 45% of the π^- that land in the (nuclear state, pionic atom state)(0^+ , 5g) state in ^{112}Cd are actually absorbed from the (2^+ , 3d) state and, hence, do not give 5-4 x rays, we can easily separate the 0^+ absorption and 2^+ absorption γ spectra. From these spectra, we shall be able to make some residual nuclei determinations and from this deduce particle-emission probabilities.

Exp. 374

μ^- CAPTURE PROBABILITIES FOR SELECTED SOLID BINARY COMPOUNDS

LASL

M. E. Schillaci, Spokesman

J. D. Knight, C. J. Orth

Princeton University

R. A. Naumann

Motivated by comparison of recent theoretical calculations with experimental data, we propose to study μ^- capture probabilities in selected binary compounds with the following objectives.

1. To systematize capture-ratio data for well-defined chemical series — viz., alkali halides, Group II metal oxides and sulfides, and Group IIIa-Va compounds.

2. To further pursue the possibility of determining ionicities of chemical bonds in simple compounds.

Objective (2) would be the first example of new chemical information obtained by μ^- x-ray analysis. Both objectives are clearly linked to future development of theory in this field.

Exp. 375

**μSR STUDY OF DIFFUSION IN METALS IN THE
PRESENCE OF PARAMAGNETIC IONS**

LASL

M. E. Schillaci, Spokesman

J. A. Brown, R. H. Heffner, M. Leon

Above room temperature, μ^+ depolarization rates are so small that they are often consistent with zero within experimental error. Since the diffusion rate is inversely proportional to the

depolarization rate, a very large uncertainty exists for this quantity. We propose to increase the depolarization rate by implanting paramagnetic ions in dilute concentrations, extrapolating the results to zero concentration. This method is especially attractive for metals with small nuclear magnetic moments which otherwise would show little depolarization. Time sufficient to test the feasibility of this technique is requested for two metals, aluminum and copper, each with four paramagnetic ion concentrations. This initial experiment will be done at room temperature.

Exp. 376

LARGE-ANGLE ELASTIC SCATTERING ON ^{48}Ca BY MEDIUM-ENERGY PROTONS

University of California, Los Angeles

G. Pauletta, Spokesman

G. Adams, T. Bauer, G. J. Igo, C. A. Whitten, A. Wriekat

University of Pennsylvania

M. Gazzaly

LASL/University of Texas, Austin

G. W. Hoffmann

We propose to extend measurements of differential cross sections for elastic scattering and inelastic scattering to low-lying collective vibrational states, on ^{48}Ca , to regions of momentum transfer not yet investigated by Exp. 311 (which used polarized protons). This experiment was stimulated by recent p- ^4He elastic-scattering measurements that revealed interesting new structure ("backward diffraction") at large-momentum transfer. We wish to investigate scattering at large-momentum transfers on a "typical nucleus" to see whether "backward diffraction" is a general feature of proton scattering of these energies and, more generally, to satisfy a growing demand for data of this kind by theorists interested in understanding reaction mechanisms.

We have chosen ^{48}Ca as a target because it is the lightest known rigid spherical nucleus. This is essential in order to reduce the ambiguity of subsequent analyses. All groups currently analyzing intermediate-energy elastic scattering are restricted to models which assume spherical symmetry in the scatters. It is therefore important to match this feature in the experiment if we want to avoid confusing general features with those dependent on particular nuclear shapes.

We propose to optimize target thickness, detector sizes, and local shielding (about target and focal plane detectors) to increase real-to-background ratios. To this same end, we will use only the HRS Faraday cup under design as a primary beam monitor.

Exp. 377

**INVESTIGATION ON THE EFFECT OF GRAIN SIZE IN
MUON CAPTURE IN INHOMOGENEOUS SYSTEMS**

University of Mississippi

J. J. Reidy, Spokesman

LASL

R. L. Hutson, Spokesman

Technical University of Munich

H. Daniel

Daniel has calculated the effect of grain size on per-atom muon capture and has shown that a marked dependence with grain size is expected. In particular, for a mixture of carbon and lead,

he has shown that for small grain sizes ($\sim 10 \mu$) the capture ratio A (carbon/lead) is about 0.25, and this decreases to the Z-law value of 0.073 for large grain sizes (~ 0.1 mm). Since his results bear on the use of muonic x rays in materials analysis as well as other types of basic and applied investigations involving meson capture, it is important that his calculations be tested experimentally. We propose to do this initially by measuring the capture ratios for three different mixtures of carbon and tungsten grains. These ratios will be determined from measurement of the Lyman series from each of the elements.

Exp. 378

A-6 NEUTRON FLUX AND SPECTRUM INVESTIGATION

LASL

A. Harvey, Spokesman

Atomic Energy of Canada, Ltd.

J. S. Fraser

This investigation is intended to explore the possibilities of using self-powered neutron and gamma flux detectors in the Radiation Effects Facility, under the A-6 beam stop at LAMPF. These detectors are physically small, and may give some spectrum information to experimenters, as well as continuous flux density. They are, therefore, worthy of study for monitoring irradiations in the facility, and should be calibrated in conjunction with a foil-package irradiation.

Exp. 379

DEVELOPMENT OF A MUON POLARIMETER USING A STROBOSCOPIC TECHNIQUE

Lawrence Berkeley Laboratory

S. S. Rosenblum, Spokesman

K. M. Crowe, C. J. Martoff, J. P. Miller, W. A. Zajc

LASL

R. H. Heffner

We propose to examine two possible approaches to a stroboscopic detection technique for muon spin-rotation experiments (μ SR). The techniques are both applicable to either positive or negative muons. The relative advantages of stroboscopic techniques are described in the body of this proposal.

The two methods we propose to test are

1. *"Free-running" stroboscope.* This technique was used by Bingham at the 184-in. cyclotron at Lawrence Berkeley Laboratory to measure g/m for μ^+ and μ^- . The method, which relies on a free-running rf oscillator for its time structure, does not require use of beam microstructure for its success. It is, however, limited to instantaneous μ^+ stop rates of $\sim 10^5/s$.

2. *"Fixed-phase" stroboscope.* This technique, described by Schenk, makes use of the beam microstructure. It has the major advantage of being able to handle instantaneous μ^+ stop rates up to $10^6/s$, much higher than those presently attainable at LAMPF. In order to see if this technique will work at LAMPF, we need to do a careful study of how to sharpen the microstructure in the muon beam at SMC as a function of channel tune. The conventional tune has no perceptible microstructure.

Exp. 380

RBE AND OER FOR NORMAL AND TUMOR TISSUES

University of California, San Francisco

T. L. Phillips and L. S. Goldstein, Spokesmen

These experiments will establish the Relative Biological Effectiveness (RBE) and the Oxygen Enhancement Ratio (OER) for pions in biological systems where these parameters are known for other high-LET particles. By using the same geometry (i.e., 14-26-cm penetration with a Bragg peak spread to 4 or 10 cm) as used for accelerated heavy ions, a direct comparison of the theoretical therapeutic advantages of pions, accelerated heavy nuclei, and 14-MeV neutrons can be made.

We will evaluate the biological effects in both normal tissue and a model tumor. The normal tissue assay is the jejunal crypt cell-survival method of Withers and Elkind, the model tumor system is the EMT-6 cell of Rockwell and Kallman, and, for both these assays, the exposure will be to the whole animal and the beam focused in a 3- by 5-cm field on the target of interest. In addition, we will establish the OER for the tumor cells *in vitro*, inducing hypoxia by the metabolic-depletion method of Hall and standard tissue-culture techniques. For this, the beam will be focused to a 2- by 2-cm field.

The ideal beam characteristics for therapeutic applications include, among others, good depth-dose distribution (i.e., a favorable peak-to-plateau ratio) with a broadly spread Bragg peak, penetrations to 26 cm, and efficient killing of hypoxic cells. These, in turn, contribute to a favorable therapeutic ratio where the killing of malignant tissue is maximized and the damage to surrounding normal tissue is minimized. These experiments will evaluate these parameters for pions and thereby contribute to our understanding of the therapeutic potential of this source.

Exp. 381

ALUMINA CERAMIC RADIATION-EFFECTS STUDY

LASL

A. Harvey, Spokesman

Science Research Council, Rutherford Laboratory, England

J. R. J. Bennett

This study will cover the effect of proton beam impingement on alumina, simulating lost beam in the proposed neutron source SNS at Rutherford Labs. The alumina is in the form of a circular cross-section tube, and grazing incidence will simulate beam loss.

Exp. 382

**A μ SR INVESTIGATION OF THE EFFECTS OF IMPURITIES
ON THE TRAPPING AND DIFFUSION OF μ^+
PARTICLES IN BCC METALS**

LASL

R. H. Heffner, Spokesman

D. M. Parkin, J. A. Brown

Bell Laboratory

A. T. Fiory, Spokesman

College of William & Mary

W. J. Kossler, Spokesman

University of Illinois

H. K. Birnbaum

Sandia Laboratories

W. B. Gauster

Brookhaven National Laboratory

K. G. Lynn

Several recent μSR experiments have demonstrated the sensitivity of μ^+ particles to the presence of impurities in bcc metals. Stimulated by these results, this proposal is being submitted in order to carry out a more comprehensive investigation. It appears that two basic and important phenomena may be investigated in detail. (1) Impurities influence the diffusion of muons between the interstitial sites in metals as they introduce random perturbations of the host lattice. (2) The muon can be trapped in the strain fields around certain substitutional and interstitial impurities. Our aim is to learn of the basic processes that govern diffusion and trapping of muons. It is expected that the most valuable information will be acquired by comparing the results obtained for single-crystal samples of exceptional purity with others that have been given a controlled doping.

The direction in which this project will go in detail would depend upon the outcome of the two cases that are proposed for the first experimental run: (1) a study of the effect of a small concentration of interstitial oxygen impurities on the μ^+ depolarization in an otherwise very pure niobium crystal, and (2) depolarization associated with niobium impurities in a tungsten crystal. Other impurity isotopes having nuclear moments will be tried as well. The tungsten experiment will be impurity specific, as only nuclear magnetic impurities are expected to contribute spin depolarization.

Exp. 383

NICKEL IRRADIATION WITH PROTONS AND NEUTRONS**LASL**

A. Harvey, Spokesman

L. S. Levinson

Naval Research Laboratory

J. A. Sprague

Pure (Marz-grade) nickel will be exposed to (a) the neutron flux at the Radiation-Effects Facility at A-6, and (b) the proton beam in the Proton Irradiation Port, target cell A-1. This will enable subsequent electron microscope examination to provide a direct comparison of the damage produced by these two LAMPF irradiations with the previously determined damage produced by EBR-II and by nickel-ion bombardment. The criterion for damage will be swelling, measured by void size and size distribution. Dislocation density will also be determined. This characterization, in a pure material, of the damage mechanisms available at LAMPF will be valuable in the assessment of the usefulness of LAMPF facilities for irradiation studies on technological materials.

**BIOLOGICAL INTERCOMPARISON OF π^- THERAPY BEAMS AT
TRIUMF AND LAMPF USING MOUSE TESTES AS A
BIOLOGICAL TEST SYSTEM**

University of Washington

J. P. Geraci, Spokesman

The large number of patients required to evaluate the efficacy of π^- therapy will require the cooperation of TRIUMF and LAMPF. This will necessitate biological intercomparisons between the two centers. For this purpose, we propose to use decrease in mouse testes weight 28 days after exposure to biologically intercompare π^- therapy beams at TRIUMF and LAMPF. The advantages of using mouse testes for this purpose are discussed in the application. The π^- beams to be intercompared at both facilities are the narrow peak beam and a 7-cm extended Bragg peak beam. The absolute RBE, using x rays as the reference radiation and the relative potency of TRIUMF and LAMPF π^- beams at different positions in Bragg peak, will be determined.

**MEASUREMENT OF THE $\vec{p} + n$ ANALYZING POWER,
 $A_y(\theta)$, FROM $\theta_{c.m.}$, 10-70°**

LASL

G. W. Hoffmann, Spokesman

J. F. Amann, B. E. Bonner, M. W. McNaughton, C. L. Morris, N. Tanaka, and H. A. Thiessen

University of Texas, Austin

M. Barlett, C. Harvey, C. F. Moore, L. E. Smith

New Mexico State University

G. S. Blanpied, G. R. Burleson

The proposed experiment will provide data from which the "free" $\vec{p} + n$ analyzing power $A_y(\theta)$ at an incident proton energy of 800 MeV can be investigated over the center-of-mass angular range 10-70°. Such data, apart from being needed for our basic understanding of the nucleon-nucleon interaction at 800 MeV, provides crucial first-order input for (microscopic) calculations that are being made to analyze a vast amount of $\vec{p} + \text{nucleus}$ elastic and inelastic data already obtained at LAMPF.

Deuterium will be used as the "neutron" target. The forward-going high-energy proton will be detected with the High-Resolution Spectrometer, while the low-energy "recoil" neutron will be detected in coincidence using a neutron detector. Because of the possible strong final-state interaction between the recoil neutron and the spectator proton for the smaller angles ($\theta_{c.m.} < 29^\circ$), it is essential to provide additional data that will help the theory in interpreting the experimental results. This additional data will be provided through measurements of the low-energy proton spectra in coincidence with the outgoing high-energy protons.

TOTAL REACTION CROSS SECTIONS FOR P⁺ NUCLEI AT 800 MeV**LASL***G. W. Hoffmann, Spokesman*

J. F. Amann, C. L. Morris, N. Tanaka, H. A. Thiessen

University of Texas, Austin

M. Barlett, C. Harvey, C. F. Moore, L. E. Smith

New Mexico State University

G. S. Blanpied, G. R. Burleson

The proposed experiment will measure the attenuation cross sections for 800-MeV protons incident upon target nuclei for which elastic differential cross-section data have been obtained in Exp. 311. From these attenuation cross sections, the total reaction cross sections will be determined experimentally (no model or theory dependence) by appropriately subtracting the experimentally known elastic-scattering cross sections.

The total reaction cross section adds an additional constraint in the analysis of p + nucleus-scattering data, and may well serve to severely test the present theoretical formulations of p + nucleus scattering at medium energies. The experiment will be performed in Area C, utilizing the unique features of the High-Resolution Spectrometer. The experiment should unambiguously determine the attenuation cross sections to the level of 1% and the total reaction cross sections to about 10%. When the normalization of the elastic data is improved, so will be the error associated with the extracted total reaction cross section.

Exp. 387

**ENERGY DEPENDENCE OF THE FORWARD ANGLE np
DIFFERENTIAL CROSS SECTION****LASL***B. E. Bonner, Spokesman*

J. E. Simmons

Texas A&M University

T. S. Bhatia, G. Glass, J. C. Hiebert, L. C. Northcliffe

University of Texas, Austin

C. L. Hollas, R. D. Ransome, P. J. Riley

The experimental difficulties associated with neutron production and detection have largely precluded measurements at intermediate energies of the forward-angle np differential cross section. Such measurements, however, are essential to the determination of the nucleon-nucleon amplitudes, which are required for the extraction of the physics from many of the experiments performed at LAMPF and other places. Using an extension of the novel technique developed for LAMPF Exps. 263 and 264, we propose to measure the forward-angle np cross section for neutron energies from 200-800 MeV, and neutron c.m. angles from 5-70°.

LOW-ENERGY PION ELASTIC SCATTERING FROM THE PROTON AND DEUTERON AT 180°

Argonne National Laboratory

R. J. Holt, Spokesman

H. E. Jackson, R. M. Laszewski, J. R. Specht, E. J. Stephenson, B. J. Zeidman

LASL

R. L. Burman, J. S. Frank, J. D. Moses, R. P. Redwine, J. E. Spencer

We propose to observe the energy dependence of the π -P and π -D elastic-scattering cross section at a reaction angle of 180° and throughout the energy region 30-50 MeV. In addition, we propose to study the feasibility of observing the tensor polarization T_{20} of the deuteron recoiling from π -D elastic scattering.

We should exploit the unique features of the Low-Energy Pion channel in order to perform these measurements. The target, in the form of CH₂ or CD₂, will be located in the central position of the channel. The upstream half of the channel will be used to focus pions ($\pm$) onto the target, while the downstream half will be operated as a 0° proton or deuteron spectrometer. With this experimental method, the effects of background should be minimized and the detector system be simplified.

The purpose of studying these reactions is to provide further information concerning the fundamental π -N interaction and the most basic π -nucleus interaction. The importance of observing these reactions at an angle of 180° is manifold: (i) the spin-flip amplitudes vanish at 180° and the theoretical calculations are simplified; (ii) the momentum transfer is largest at 180° and certain effects of form factors become more pronounced; (iii) the π -P cross section at 180° exhibits a great sensitivity to the $T = 1/2$, s-wave amplitude; (iv) elastic scattering of pions from the deuteron at 180° is extremely sensitive to the model of the π -D system; (v) the amount of d-state admixture in the deuteron wave function is sensitive to the tensor polarization at 180°, and (vi) the Coulomb effects are at a minimum at 180°.

Exp. 389

INELASTIC PION SCATTERING FROM LIGHT NUCLEI: ¹⁰B, ¹¹B, ¹⁴N, AND ¹⁵N

Argonne National Laboratory

B. J. Zeidman, Spokesman

D. F. Geesaman, H. E. Jackson, C. Olmer, E. Stephenson

University of Birmingham, England

G. C. Morrison, Spokesman

New Mexico State University

G. S. Blanpied, G. R. Burleson

LASL

C. L. Morris

The experiment consists of measuring complete angular distributions for the elastic and inelastic scattering of both π^+ and π^- from targets of ¹⁰B, ¹¹B, ¹⁴N, and ¹⁵N at energies near, and either above or below, the resonance energy, with the EPICS system. Inasmuch as the level spacing in these nuclei is large, fairly thick targets, consistent with an energy resolution of ~250 keV,

will be used. Particular emphasis will be placed upon studies of the low-lying $T = 0$ and $T = 1$ states in ^{10}B and ^{14}N , and low-lying states of ^{11}B .

The basic objective of this proposal is to obtain information about reaction mechanisms in pion-nucleus interactions under conditions where details of nuclear structure are well understood. The nuclei proposed for study have been investigated extensively in light ion-induced reactions. The energies chosen are near resonance, where the pion-nucleon interaction is particularly strong and dominated by a single phase shift, and somewhat above or below resonance, where the nucleus is more transparent to the probe and other details may be elucidated.

A STUDY OF INCLUSIVE INELASTIC PION SCATTERING NEAR THE $\Delta(3/2,3/2)$ RESONANCE

Argonne National Laboratory

H. E. Jackson, Spokesman

E. P. Colton, D. F. Geesaman, R. J. Holt, R. Laszewski, J. Schiffer, J. Specht, E. Stephenson, B. J. Zeidman

Northwestern University

R. E. Segel

A comprehensive series of measurements of inelastic pion scattering, by nuclei ranging from helium to lead, is proposed. The experiment is part of a continuing program to determine major features of pion-nucleus interactions by examining simple inclusive spectra for various reaction products. Recent results from LAMPF Exp. 303, showing large backward peaking in the inclusive charge-exchange cross sections, suggest that total inelastic scattering will be a major portion of the reaction cross sections, and that the average pion energy loss will be about half the kinetic energy. The measurements would be performed at the high-energy pion channel, P^3 , using a magnetic spectrometer of large momentum acceptance, $\Delta P/P \approx 30\%$, and fair momentum resolution, $\Delta P/P \approx 2\%$, constructed specifically for these studies. A survey of six targets will be made for eight scattering angles between 30° and 140° at incident pion energies in the large 100-300 MeV. The data, in conjunction with results from earlier experiments, will provide estimates of the partition of the pion interaction cross section between scattering and absorption channels. The energy spectrum of the scattered pions should also provide information on the character of the inelastic scattering and the extent to which it is dominated by quasi-free processes. These studies will complement other related pion-scattering measurements at LAMPF since they emphasize observation of the gross properties of the scattered spectra.

Exp. 391

INELASTIC $\pi^\pm$ SCATTERING ON ${}^7\text{Li}$

University of Colorado

R. J. Peterson, Spokesman

R. L. Boudrie, J. J. Kraushaar, R. A. Ristinen

We propose to study $\pi^\pm$ inelastic scattering to the low-lying states of ${}^7\text{Li}$, with 5% statistics at beam energies of 162, 240, and 80 MeV, in this order of importance. Such data are desired to determine the ratio of isovector-to-isoscalar transition rates for a very light collective nucleus. Other experiments, including pion scattering, have measured these relative strengths explicitly for $A = 18, 26$, and 30 , while future scheduled experiments will be able to supply the ratio of strengths for heavier nuclei. This relative isovector strength is valuable in that it is determined by core polarization effects, which we expect to be small for ${}^7\text{Li}$. Three beam energies are desired to separate the target structure effects from the reaction mechanism. The experiment is very standard, and is well matched to the capabilities of EPICS.

**A MEASUREMENT OF THE TRIPLE-SCATTERING PARAMETERS
D, R, A, R', AND A' FOR PROTON-PROTON AND PROTON-NEUTRON
SCATTERING AT 800 MeV**

LASL

H. A. Thiessen, Spokesman

J. F. Amann, B. E. Bonner, E. P. Chamberlin, G. W. Hoffmann, C. L. Morris

Case Western Reserve University

P. R. Bevington, M. W. McNaughton, H. B. Willard

New Mexico State University

G. S. Blanpied, G. R. Burleson

Colorado State University

R. L. Boudrie

We propose to measure five "triple-scattering" parameters, D, R, A, R', and A', for proton-proton and proton-neutron scattering. These data will extend the existing body of pp data to smaller angles and will provide important new information on pn scattering. These new data will make a major impact on our understanding of the nucleon-nucleon interaction at 800 MeV.

The method we propose consists of using a polarized beam (six orientations of the spin direction) incident on unpolarized targets of hydrogen and deuterium. A polarization analyzer, capable of analyzing two components of spin simultaneously, will be placed on the focal plane of HRS. Coincidence counters detecting the recoil protons and neutrons will be used to separate pp and pn scattering in the deuterium target. A method of calibrating both the beam polarization and the analyzing power of our analyzer is proposed, which should allow measurements with statistical precision of ± 0.02 and absolute accuracy of ± 0.05 over most of the angular range of the experiment.

**ANGULAR DISTRIBUTION MEASUREMENTS OF THE PION SINGLE-
CHARGE-EXCHANGE REACTION ON ^{13}C**

Tel Aviv University

J. Alster and M. A. Moinester, Spokesmen

A. Doron

LASL

J. D. Bowman, M. D. Cooper, F. H. Cverna, R. H. Heffner, C. M. Hoffman

Case Western Reserve University

H. W. Baer, P. R. Bevington, E. Winkelman

We propose to measure the $^{13}\text{C}(\pi^+, \pi^0)^{13}\text{N}(\text{g.s.})$ reaction. The π^0 s will be detected using the π^0 spectrometer built for Exp. 181. We will measure the differential cross sections between 0 and 75° , at two energies at and below the (3,3) resonance. These data are important to the understanding of charge-exchange reactions in light nuclei. The contribution of second- (and higher-) order effects, as well as the importance of absorption of the pion waves, are among the subjects expected to be clarified.

APPLICATION OF PROTON-COMPUTED TOMOGRAPHY

LASL*K. M. Hanson, Spokesman*

J. N. Bradbury, R. M. Macek, D. R. Machen, M. A. Paciotti

University of Chicago

J. Curry, V. W. Steward

An experiment is proposed that will compare the imaging capabilities of protons with those of x rays for a variety of pathologic human tissues. Application to industrial radiographic specimens will also be explored. An improved experimental technique will allow high-quality proton-computed tomographic scans to be completed in less than 30 min.

Exp. 395

THE (p, π^+) REACTION ON ^{16}O AND ^{40}Ca **University of California, Los Angeles***T. S. Bauer, Spokesman*

G. S. Adams, G. J. Igo, G. Pauletta, C. A. Whitten

Northwestern University*H. Nann, Spokesman*

K. K. Seth

LASL*B. C. Höistad, Spokesman*

H. A. Thiessen

We propose to measure the (p, π^+) reaction on ^{16}O and ^{40}Ca in the range of momentum $q \geq 3.1 \text{ fm}^{-1}$ at an incident energy $T_p = 800 \text{ MeV}$. The measurements will include two asymmetry points in the $(\bar{p}, \pi^+)$ reaction on ^{16}O . Due to the fact that the reaction will be measured over a much larger range in momentum transfer than before, and due to the additional measurements of the asymmetry, important constraints will be put on theoretical models that purport to describe the (p, π^+) reaction. The chosen target nuclei lead to final nuclei with both good single-particle shell-model states, as well as core-excited $(1p-1h)$ states. In addition, at $T_p = 185 \text{ MeV}$, the angular distributions for the (p, π^+) reaction on these two nuclei leading to the ground states of ^{16}O and ^{40}Ca , respectively, reveal considerable structure at momentum transfer of $q \leq 3.3 \text{ fm}^{-1}$, which can be related to the momentum distribution of the valence neutron or of the nuclear matter. Hence, it is interesting to extend these data to much larger momentum transfers.

Exp. 396

COMPARISON OF MEASURED PIONIC-ATOM CASCADE INTENSITIES
WITH THEORETICAL INTENSITIES OBTAINED
USING PARAMETERS FROM MUONIC-ATOM STUDIES**University of Mississippi***James J. Reidy, Spokesman***Technische Universität München**

F. Joachim Hartman

LASL

R. L. Hutson, J. D. Knight

The relative intensities of a large number of muonic x-ray lines (ranging from 26 to 103 lines) from muonic magnesium, aluminum, iron, indium, holmium, and gold have recently been reported. The use of these line intensities as constraints in a muon cascade calculation has enabled the Munich-SIN group to obtain for each element near-unique muon l distributions for the initial state $n = 20$. The same approach would not be as fruitful in the case of pionic atoms since the number of observable pionic x rays is considerably less than this. However, it is of considerable interest to determine whether the pion l distribution for an equivalent initial n is the same for a given atom as one obtains in the case of muonic atoms.

We propose to investigate this by comparing measured pionic x-ray yields from aluminum, iron, indium, and gold with calculated values. These calculated values will be obtained by using the Munich-SIN cascade code (suitably modified for pions), incorporating the parameters that have been determined from the muonic x-ray studies. If the detailed capture mechanism is the same for pions and muons (as one expects), then the measured and calculated yields should agree. If they do not agree, then further studies will be indicated. This would mean a difference in the details for pion and muon capture and/or problems with the cascade code. Since we think we understand the physics of the capture process and the physics that guided the development of the cascade code, then this latter case (disagreement between the calculations and experiment) would be an exciting development. A comparison like this has never been done and represents a unique method of comparing pion and muon capture.

Exp. 397

A MEASUREMENT OF THE TRIPLE-SCATTERING PARAMETERS R , A , R' , AND A' FOR PROTON-NUCLEUS ELASTIC SCATTERING

LASL

H. A. Thiessen, Spokesman

J. F. Amann, C. L. Morris, G. W. Hoffmann

University of California, Los Angeles

G. J. Igo Spokesman

G. Adams, G. Pauletta, C. A. Whitten

Four "triple-scattering" parameters, R , A , R' , and A' , will be measured for proton-nucleus scattering. Six nuclear targets, which have been thoroughly studied at 800 MeV ($P, d\sigma/d\Omega$, and elastic scattering), will be measured.

The method consists of using a polarized beam, alternating frequently between four orientations of the spin direction on nuclear targets. A polarization analyzer capable of analyzing two components of spin simultaneously will be placed on the focal plane of HRS. Previous experience with carbon analyzers suggests that the absolute uncertainty of the analyzing power can be expected to be of the order of 1-2%. Two new beam polarimeters will be constructed in order to measure the three components of the beam's spin.

Exp. 398

**A SYSTEMATIC STUDY OF ISOTOPIC (ISOTONIC) DEPENDENCE OF THE
NEUTRON-MATTER DISTRIBUTIONS IN THE MASS-40 REGION**

University of California, Los Angeles

G. Pauletta, Spokesman

G. S. Adams, C. A. Whitten, G. J. Igo

LASL

G. W. Hoffmann

We intend to continue the elastic scattering and polarization measurements performed recently in the mass-40 region to larger momentum transfer and additional isotopes. The object of these measurements is to provide a complete and accurate set of data suitable for the study of isotopic dependence of the matter distribution, in the same spirit as has been done, by means of electron scattering and μ x-ray measurements for the charge distribution. Simultaneous measurements under identical conditions for various isotopes, and analysis of the results expressed in terms of cross-section differences, will provide a sensitive test of recent theories, which is free of ambiguities arising from normalization uncertainties.

Exp. 399

**EXCITATION OF GIANT MULTIPOLE RESONANCES BY
200- TO 400-MeV PROTONS**

Oak Ridge National Laboratory

F. E. Bertrand, Spokesman

E. E. Gross, D. J. Horen, G. R. Satchler

LASL

R. L. Burman, E. R. Flynn

Indiana University

W. P. Jones, D. W. Miller

University of Minnesota

N. M. Hintz, G. Kyle

Kernfysich Versneller Instituut

A. van der Woude

Beam time is requested for a study of giant multipole resonance excitation in nuclei by use of inelastic scattering of 200- to 400-MeV protons. The proposed measurements will be made using the HRS facility.

The use of protons in this range provides significant advantages over projectiles now in use and over protons having higher energies. The major objective of this proposal is to observe isoscalar giant resonances having $L \geq 3$. In addition, these measurements will provide important information on the previously observed giant quadrupole and giant monopole resonances.

SEARCH FOR THE RARE DECAY $\mu^+ \rightarrow e^+e^+e^-$ **LASL***Minh Duong-Van and C. M. Hoffman, Spokesmen*

J. D. Bowman, M. D. Cooper, F. H. Cverna, J. S. Frank, H. S. Matis, D. R. Machen, R.

E. Mischke, D. E. Nagle, R. P. Redwine, J. S. Sarracino

Princeton University

G. H. Sanders

Stanford Linear Accelerator Center

S. S. St. Lorant, F. Villa

We propose to search for the decay $\mu^+ \rightarrow e^+e^+e^-$. The experiment will be able to measure a branching ratio of less than 10^{-11} , which is more than two orders of magnitude below the present upper limit.

The apparatus makes use of a specially designed magnet that has a field which varies approximately as $1/r$. This field configuration sweeps negatively charged particles to one end of the magnet and positively charged particles to the other end. This sign-separation magnet reduces the trigger rate by ~ 5 orders of magnitude by requiring a negatively charged particle in coincidence with two positively charged particles. The tracks are detected by a combination of MWPCs and scintillation counters.

STUDY OF THE ISOBARIC ANALOG CHARGE-EXCHANGE REACTION

$$^{15}\text{N}(\pi^+, \pi^0)^{15}\text{O}$$

LASL*J. D. Bowman and M. D. Cooper, Spokesmen*

C. M. Hoffman, F. H. Cverna

Case Western Reserve University

E. Winkler, H. W. Baer

Tel Aviv University, Israel

J. Alster, M. Moinester, A. Doron

We propose to measure angular distributions for the isobaric analog transition $^{15}\text{N}(\pi^+\pi^0)^{15}\text{O}(\text{g.s.})$. The newly developed LAMPF π^0 spectrometer will be used at the Low-Energy Pion channel. The large excitation energy (5.2 MeV) of the first excited state in ^{15}O and the simple shell-model description of the initial and final states make this an ideal case from both the experimental and theoretical point of view. Angular distributions will be taken at 50-, 100-, and 180-MeV π^+ energy. The data will be interpreted in terms of optical models, the fixed-scatterer model, and the Glauber model. The results will be compared with elastic and double-charge-exchange data from ^{16}O and ^{18}O .

Exp. 402

**A MEASUREMENT OF THE POLARIZATION TRANSFER COEFFICIENTS
 $D_t(0^\circ)$ AND $A_t(0^\circ)$ IN THE REACTION $\bar{p} p \rightarrow \bar{n} X$
 AT 800 MeV**

Texas A&M UniversityG. Glass, *Spokesman*

T. S. Bhatia, J. C. Hiebert, L. C. Northcliffe, B. Ver West

LASLJ. E. Simmons, *Spokesman*

B. E. Bonner

University of Texas, Austin

C. L. Hollas, C. R. Newsom, R. D. Ransome, P. J. Riley

The LAMPF polarized proton beam, upon striking a liquid H_2 target, produces neutrons as a result of π^+ production. The neutron polarization, both longitudinal and transverse, will be measured for neutrons at 0° over the neutron momentum spectrum from 550 to 1300 MeV/c. The np analyzing power that is being measured in Exp. 65 will be used to ascertain the resultant neutron polarization in momentum bins, 50-MeV/c wide. A determination of D_t and A_t in this region, where the δ^{++} resonance dominates the final-state configuration, is most desirable in an attempt to sort out the contributions from various mechanisms, primarily one-pion exchange, ρ exchange, and final-state interactions for both the πN and NN systems in the final state.

Exp. 403

**A MEASUREMENT OF THE TRIPLE-SCATTERING PARAMETER D_t
 FOR THE CHARGE-EXCHANGE REGION IN np SCATTERING**

LASLB. E. Bonner, *Spokesman*

W. R. Gibbs, C. L. Morris, J. E. Simmons, H. A. Thiessen

Texas A&M University

T. S. Bhatia, G. Glass, J. C. Hiebert, L. C. Northcliffe

University of Texas, Austin

C. L. Hollas, R. D. Ransome, P. J. Riley

Case Western Reserve University

M. W. McNaughton

The striking double-exponential behavior of the np charge-exchange cross section when plotted as a function of u (the square of invariant four-momentum transfer) has defied explanation in terms of simple one-pion exchange, the mechanism one feels should certainly dominate. A recent theory by Gibbs that allows both s- and p-wave single-pion exchange fits all the np charge-exchange cross sections measured to date. In addition, it makes the definite prediction that $D_t = 1$ at 180° c.m. No measurements exist at any energy of D_t in the very backward charge-exchange region. Constrained phase-shift analyses predict D_t is close to zero at 180° . The experiment proposed here will measure D_t for the charge-exchange region at 800 MeV.

Exp. 404

**A KINEMATICALLY COMPLETE STUDY OF THE $(\pi, \pi'p)$ REACTION ON ^{16}O
ABOVE THE RESONANCE BY DETECTING PIONS AND PROTONS
IN COINCIDENCE**

LASL

M. E. Hamm, Spokesperson

P.A.M. Gram, M. A. Yates-Williams

Florida A&M University

C. A. Goulding, M. A. Greenfield

Oregon State University

L. W. Swenson, Spokesman

K. S. Krane

University of Oregon

D. K. McDaniels

Florida State University

H. S. Plendl

We propose a coincidence measurement of the $(\pi, \pi'p)$ quasi-free scattering reaction on a single nucleus, ^{16}O , at three incident energies above resonance, duplicating one of them with π^- . The detection geometry of the experiment will be programmed specifically to emphasize the effect of individual features of the distorted wave impulse approximation description of the process. The choice of nucleus will allow the knockout of protons from a known shell to form a known residual state to be identified. The aims of this work are to study the impulse approximation description in an energy regime where it should work well and, if possible, to get a first look at the off-shell π -p t-matrix.

The apparatus consists of a magnetic pion detector and a scintillator proton detector that are developments of equipment that has been used successfully (by most of the authors) in several previous experiments, although not together to define coincidences.

Exp. 405

THE (p, π^-) REACTION ON ^{12}C AND ^{13}C

LASL

B. C. Hoistad, Spokesman

H. A. Thiessen

University of California, Los Angeles

T. S. Bauer, Spokesman

G. S. Adams, G. C. Igo, G. Pauletta, C. A. Whitten

Northwestern University

K. K. Seth, Spokesman

H. Nann

We propose to study the $\pi^+:\pi^-$ ratio in the (p, π) reaction on ^{12}C and ^{13}C , with the general aim to obtain important information on the reaction mechanism. We are especially interested to see if the π^- production can be explained by final-state interaction in the pionic stripping model. Such a process should be revealed by a difference in the $\pi^+:\pi^-$ cross-section ratio from ^{12}C and ^{13}C because the isobaric analog transitions are not possible from ^{12}C and are possible from ^{13}C .

Exp. 406

NEUTRON FLUX CHARACTERIZATION AT A-6 RADIATION-EFFECTS FACILITY

LASL

A. Harvey, Spokesman

D. W. Barr, J. Gilmore, N.S.P. King, D. Kneff, P. W. Lisowski, L. R. Veaser

Argonne National Laboratory

T. H. Blewitt

Kansas State University

H. J. Donnert

Atomics International

H. Farrar, J. Fraser

This experiment is an omnibus effort to characterize the neutron flux density and spectrum in the Radiation-Effects Facility below the A-6 beam stop at LAMPF. Two beam-stop configurations are used: 1) the copper stop alone, and 2) the copper stop with a typical complement of isotope production targets upstream. The flux will be explored with a number of detectors:

- foil activation (Barr *et al.*, CNC-11),
- helium accumulation dosimetry (Farrar *et al.*, Atomics International),
- fission foil activation (Donnert, Kansas State),
- fission chamber (Veaser, P-3),
- self-powered detectors (Harvey *et al.*, MP-13),
- damage function measurements (Blewitt, ANL), and
- neutron time of flight in the 135° beam tube (Veaser *et al.*, P-3).

The experiment is parasitic, except for the time-of-flight measurements.

Exp. 407

**THE EFFECT OF DISTRIBUTION VIBRATION ON VOID GROWTH
IN METALS DURING IRRADIATION**

LASL

W. F. Sommer, Jr., Spokesman

W. V. Green, L. S. Levinson

This experiment will be used to study the effect of dislocation vibration on void growth in metals during irradiation. The objectives are to determine whether void growth during irradiation can be reduced by the dislocation vibration produced by cyclic stress, and whether the threshold dose for void growth can be influenced.

Void growth during irradiation occurs because interstitials interact more strongly with dislocations than do vacancies. An analysis of the effect of dislocation vibration on the efficiency of a dislocation line as a sink for point defects predicted that dislocation vibration should suppress void growth. The effect results from the fact that the dislocation will sweep up vacancies, which diffuse less rapidly than interstitials. The proposed experiment is intended to test this theory.

The growth rate of voids in aluminum under simultaneous proton irradiation and cyclic stressing will be compared to that of samples irradiated at the same time but without any stressing. The samples will be placed one behind the other along the proton path so that identical irradiation histories can be achieved. The temperature of the samples will be controlled, known, and uniform. The damage level also will be uniform.

The samples will be irradiated through the threshold dose for void formation before the cyclic stress is initiated. The initial preirradiation state will be a prestrained state of a few hundred stress cycles. Other irradiations will be made in which the cyclic stress is applied from the beginning to determine if there is an effect on the threshold dose.

The evaluations will be done using postirradiation measurements with transmission-electron microscopy (TEM).

Exp. 408

MACROSCOPIC DIFFUSION STUDIES IN METALS

LASL

R. H. Heffner and M. Leon, Spokesmen

J. A. Brown, K. M. Hanson, R. L. Hutson, M. E. Schillaci, B. L. Barthell, R. W. Springer, O. B. van Dyck

Sandia Laboratories

W. B. Gauster

University of Wyoming

A. B. Denison

The subject of muon diffusion in metals is an important one, both as a fundamental test of our understanding of impurities in metals and for its relationship to the problem of hydrogen in metals, a subject of great technological importance. The standard time differential μ SR technique for measuring μ^+ diffusion in metals is severely limited, however, both in the range of materials that can be studied (large nuclear magnetic moments are required) and in the range of diffusion coefficients that can be measured (very rapid diffusion produces no depolarization). The methods we are proposing are not limited in these ways and, thus, if successful, should add greatly to our knowledge of muon diffusion.

Several methods for the measurement of macroscopic diffusion are discussed. Initially, we propose to measure macroscopic diffusion in gold, aluminum, and copper.

Exp. 409

A STUDY OF PION-INDUCED CLUSTER REMOVAL

Utah State University

V. G. Lind, Spokesman

R. E. McAdams, O. H. Otteson

Florida A&M University

M. B. Greenfield, Spokesman

The possible existence of quasi-free pion-cluster scattering from medium-mass nuclei wherein the cluster is knocked out of the nucleus is strongly indicated by a recent π - γ coincidence experiment (Exp. 319). Other experiments also hint at such a possibility. We propose, therefore, to investigate the reality of such a process by detecting cluster fragments in coincidence with scattered pions. The cluster fragments will be detected by using large-area surface-barrier detectors enclosed within an evacuated chamber. The pions will be observed with a particle telescope made of scintillators, as used in Exp. 319.

RADIATION EFFECTS IN AMORPHOUS METALS DUE TO 800-MeV PROTONS

LASL

J. R. Cost, Spokesman

L. S. Levinson, W. F. Sommer

General Purpose

To determine how the newly discovered metallic state of glassy metals is affected by particle radiation. Since there are only four papers published on this topic, it is relatively "hot."

Specific Purposes

- (1) To investigate the current controversy as to whether irradiation swelling occurs in amorphous metals.
- (2) To study the detailed nature of radiation damage in these materials, particularly to determine whether amorphous materials have point defects analogous to those in the crystalline state.

Specimens

- (1) Two alloys, $\text{Fe}_{80}\text{B}_{20}$ and $\text{Fe}_{40}\text{Ni}_{40}\text{B}_{14}\text{P}_6$, in the form of thin strips, roughly 5 by 0.18 by 0.006 cm.
- (2) Five specimens of each alloy (total of 10) are to be irradiated edge-on, resulting, roughly, in a 1.5-cm length of each specimen being available for measurement.

Radiation Procedure

- (1) Radiation with protons (unpolarized and either H^+ or H^-) at 3 to 10 μA in the Nuclear Chemistry Cave of Area B.
- (2) Radiation fluence of 60- μA days (in range from 20 days at 3 μA to 6 days at 10 μA) will give a calculated number of displacements per atom of 0.12.
- (3) Beam size to be the present one at above location (elliptical Gaussian with $\sigma_{\text{horiz}} = 0.75$ cm and $\sigma_{\text{vert}} = 0.25$ cm).
- (4) Cooling will be by flow of gaseous helium over the sample. Calculations indicate an adiabatic temperature rise at the center of the specimens of less than 0.1°C . Simulation experiments using Joule heating equivalents to the proton beam indicate a steady-state temperature increase of less than 15°C in still air.
- (5) Dosimetry will be conventional ^{22}Na analysis of aluminum foils.

Experimental Methods

- (1) To study radiation-induced swelling by measuring immersion density and dimensional changes (using a profilometer).
- (2) To study radiation-induced structural changes with the following.
 - (a) Field-on microscopy (first time for an amorphous metal).
 - (b) Transmission-electron microscopy and electron diffraction (to determine possible regions of crystallization).
- (3) To investigate possible point defect concentrations and annealing by electrical resistivity and stress-induced atomic mobility measurements.
- (4) To determine whether irradiation causes any changes in the mechanical properties of these materials (stress-strain behavior and hardness).

General Comments

(1) Scheduling is requested as soon as possible because of recent high activity of research on amorphous materials.

(2) This experiment is designed so that irradiation can occur simultaneously with Exp. 302 and/or the experiment, "The Effect of Dislocation Vibration on Void Growth in Metals During Irradiation," by W. Green, W. Sommer, and L. Levinson.

Exp. 411

MEASUREMENT OF SPIN-FLIP PROBABILITIES IN PROTON INELASTIC SCATTERING AT 800 MeV AND SEARCH FOR COLLECTIVE SPIN-FLIP MODES, PRELIMINARY SURVEY

University of Minnesota

N. M. Hintz, Spokesman

G. Kyle, D. Dehnhard

Texas A&M University

J. M. Moss, Spokesman

W. D. Cornelius

LASL

G. W. Hoffmann, H. A. Thiessen, E. P. Chamberlin, C. L. Morris

Rutgers University

C. Glashausser

We propose to measure spin-flip probability (SFP) in inelastic scattering from ^{12}C , ^{16}O , and ^{208}Pb targets at 800 MeV, using a polarized incident beam and the HRS focal plane polarimeter as described in a separate proposal. The spin-flip probability is determined mainly by the relative strength of the various spin-dependent terms in the effective nucleon-nucleon interaction and by the nature of the state being excited.

Collective electric modes $[E(\lambda)]$ are expected to show a small SFP (≤ 0.1), whereas the less well-established magnetic excitations $[M(\lambda)]$ should show a large SFP ($\sim 0.5-1$). Thus, the technique can be used to help establish the relative importance of the spin dependence of the effective two-body force (for well-known states) and to search for new magnetic modes in a background of the more strongly excited electric multipoles.

Exp. 412

SEARCH FOR ANALOG STATE TRANSITIONS IN (π^+, π^0) REACTIONS ON ^7Li , ^{27}Al , ^{90}Zr , ^{120}Sn , AND ^{208}Pb AND FOR COLLECTIVE ISOVECTOR STATES IN THE (π^-, π^0) REACTION ON ^{90}Zr

LASL

J. D. Bowman and F. H. Cverna, Spokesmen

N.S.P. King, E. R. Flynn, C. M. Hoffman, M. D. Cooper

Case Western Reserve University

H. W. Baer, Spokesman

E. Winkelman

Tel Aviv University

J. Alster, M. A. Moinester, A. Doron

We propose to search for the isobaric analog state (IAS) transition in (π^+, π^-) reactions on ${}^7\text{Li}$, ${}^{27}\text{Al}$, ${}^{90}\text{Zr}$, ${}^{120}\text{Sn}$, and ${}^{208}\text{Pb}$ at energies $t_\pi = 70$ and 150 MeV. The experiment will be performed with the newly built and tested π^0 spectrometer with an overall resolution in the measurement of 3 MeV (FWHM). Differential cross sections for the IAS transitions have not been measured previously for $A > 3$ nuclei. They represent the most definitive means for measuring the isovector component of the π -nucleus interaction since the cross sections are directly proportional to

$$| \langle \Pi_3 + 1 | \vec{t}_\pi \cdot \vec{T} | \Pi_3 \rangle |^2 .$$

We propose to concentrate our search on the forward angles because calibrations predict the largest cross sections at 0° . For each target and at each energy, we will run at 0° at one additional forward angle, chosen to best determine the width of the first diffraction peak. We selected one nucleus from each region of the periodic table, and two beam energies that will allow us to determine the mass dependence of the isovector interaction and the slope of its energy dependence up to the P_{33} resonance. Except for ${}^7\text{Li}$ and ${}^{27}\text{Al}$, the targets have closed proton and/or neutron shells, thereby making the IAS transition particularly amenable to microscopic analyses.

We propose an exploratory run on the ${}^{90}\text{Zr}(\pi^-, \pi^0){}^{90}\text{Nb}$ reaction. This reaction is particularly well-suited to study isovector collective states in $N > Z$ nuclei, as is discussed in the proposal. Its selection rule $\delta I = -\delta I_3 = 1$ guarantees that only $I_\pm$ components of isovector states built on the target ground state will be populated. A promising possibility is to observe the $I_\pm$ components of the giant dipole resonance. Such states are believed to exist in ${}^{90}\text{Zr}$, although convincing evidence is still lacking. If we could find evidence for their existence, or for other isovector collective states, it would be a nice demonstration of the pion in the role of uncovering new features of nuclear structure, and it would serve as the basis for future studies of (π^-, π^0) charge-exchange reaction.

Exp. 413

MASS MEASUREMENT OF ${}^{26}\text{Ne}$ AND ${}^{48}\text{Ar}$ BY THE (π^-, π^+) REACTION

Northwestern University

K. K. Seth and H. Nann, Spokesmen

S. G. Iversen, M. O. Kaletka

It is proposed to measure the masses of the neutron-rich exotic nuclei ${}^{26}\text{Ne}$ and ${}^{48}\text{Ar}$ via the (π^-, π^+) double-charge-exchange reaction on ${}^{26}\text{Mg}$ and ${}^{48}\text{Ca}$. Both nuclei are predicted to be particle stable by the various mass formulas. The nucleus ${}^{48}\text{Ar}$ is of special interest from the shell-model point of view, since at ${}^{48}\text{Ar}$ the $1f_{7/2}$ neutron shell is filled and the two additional neutrons are most probably in the $2p_{3/2}$ shell. The missing mass will be measured with the EPICS spectrometer.

Exp. 414

BONE CALCIUM ASSAY WITH MUONIC X RAYS: SIGNAL/NOISE AND REPRODUCIBILITY STUDIES

LASL

R. L. Hutson, Spokesman

University of Mississippi

J. J. Reidy, Spokesman

We propose to measure the yields of calcium muonic x rays from simulated bone embedded in tissue-equivalent material. Our purpose is to develop a practical and precise technique for monitoring bone mineral concentration (BMC) changes in patients. We intend to concentrate on two goals.

1. To study ways to optimize signal/noise ratio in such a way as to minimize irradiation time.
2. To study techniques for beam monitoring and x-ray yield normalization that will give long-term reproducibility of results of 2% or less.

The proposed experiment does not address itself to studies of fundamental physical interest, but instead is intended as a preparatory investigation leading to a potential practical application of the LAMPF muon channel.

Exp. 415

TWO-NUCLEON-OUT PRODUCTS FROM STOPPED π^- INTERACTIONS

LASL

C. J. Orth, Spokesman

B. J. Dropesky, G. C. Giesler, J. N. Ginocchio, R. S. Rundberg, R. A. Williams

We propose to measure yields of two-nucleon-out products from stopped π^- interactions in isotopically enriched targets of ^{28}Mg , ^{74}Ge , ^{114}Cd , ^{142}Ce , and ^{174}Yb using activation methods. The ratios of the ground-state yields of the residual product pairs from either two neutrons out or a proton-neutron out will provide a direct experimental determination of the probability for pion absorption on p-n pairs or on p-p pairs. The absolute yields of these product pairs, coupled with the yields of other measurable products, will provide a critical test for a model of stopped π^- interactions which couples a pionic atom cascade code to the VEGAS-DFF intranuclear cascade-evaporation codes.

Exp. 416

STUDY OF FAST PION-INDUCED FISSION OF URANIUM

LASL

B. J. Dropesky, Spokesman

B. P. Bayhurst, C. J. Orth, R. J. Prestwood, R. S. Rundberg, W. Wolfsberg

We propose to carry out a survey-type radiochemical investigation of the fission of ^{238}U induced by fast pions. The objectives will be (a) to determine the influence of the (3,3) pion-nucleon resonance on the total fission cross section and on the competition between fission and spallation, (b) to delineate to some extent the differences between π^+ - and π^- -induced fission, and (c) to learn something about the nature of the energy deposition processes and the role of the linear momentum in pion-induced fission.

Experimentally, we plan to irradiate thin metal uranium foil targets at several π^+ energies from below to above the (3,3) resonance and at a π^+ energy where the intensity is about maximum. Then targets will be radiochemically assayed using, in general, well-developed chemical procedures and standard counting techniques for a selected set of fission products and a few spallation products.

STUDY OF THE NUCLEAR AUGER PROCESS IN HEAVY MUONIC ATOMS

University of Rochester

J. R. Huizenga, Spokesman

M. W. Johnson, W. U. Schroder, W. W. Wilcke, D. Hilscher

LASL

D. G. Perry

We propose to study the energy spectra and emission probabilities of neutrons produced following radiationless deexcitation of muons bound to heavy nuclei (nuclear Auger process). The objective of this work is to gain heretofore unavailable information on the mechanism of nuclear excitation by the radiationless process and on the patterns of nuclear deexcitation from excited states from which both neutron emission and fission are energetically allowed. Additionally, information on the probability of fission induced by radiationless transitions will be gained, expanding the interpretation of experiments performed previously at LAMPF. The spectra will be accumulated using time-of-flight techniques; targets to be studied include ^{209}Bi , ^{232}Th , ^{235}U , ^{238}U , and possibly ^{239}Pu .

PARTICLE γ -RAY COINCIDENCE STUDIES FROM π -NUCLEAR REACTIONS

Utah State University

V. G. Lind, Spokesman

R. E. McAdams, O. H. Otteson

Oregon State University

L. W. Swenson

Florida A&M University

M. A. Greenfield, C. A. Goulding

Florida State University

H. S. Plendl

College of William & Mary

H. O. Funsten

George Mason University

J. B. Lieb

Virginia State College

C. Stronach

Time is requested on the P⁸ channel to carry out particle γ -ray coincidence experiments induced by energetic (100- to 250-MeV) pions. The γ rays will be detected with a Ge(Li) detector, whereas the particles will be detected with three or four scintillator particle telescopes each similar to the type used in the fall of 1977 in Exp. 319. The experiment will consist of three parts, each with both π^+ and π^- beams; namely,

- (1) A study of the angular dependence of the reactions at one energy (190 MeV),
- (2) A study of the dependence of the reactions on beam energy through the (3,3) resonance for one target and setting of the detector system, and

- (3) A study of the target dependence of the reactions at one energy and setting of the detector system.

The experiment will give information on numerous pion-nucleus reaction channels simultaneously. Not only pions will be observed but protons and deuterons as well, each in coincidence with γ rays. Comparison of the data with the accidental spectrum (equivalent to singles) will measure the contribution to each γ -ray line due to absorption, since the singles spectra is made up of both reaction and absorption events. Based on current evidence, it appears the reaction/absorption ratio may change significantly with energy, and this dependence will be explored. The energy spectrum of each particle type will also be obtained. This allows the quasi-elastic scattering peak to be observed for such processes, as well as to provide other clues about this reaction. Since several particle detectors will be set up and operating simultaneously, it may be possible to observe a few multicoincidence reactions.

Exp. 419

EXCITATION OF SINGLE-PARTICLE AND CORE-COUPLED STATES IN ^{207}Pb AND ^{209}Bi

University of Texas, Austin

W. J. Braithwaite and C. F. Moore, Spokesmen

C. Harvey, D. Holtkamp, J. McGill, L. E. Smith

LASL

C. L. Morris, Spokesman

G. W. Hoffmann, H. A. Thiessen

Pion-nucleon elastic scattering on the (3,3) resonance favors $\pi^+ + p$ and $\pi^- + n$ over $\pi^+ + n$ and $\pi^- + p$. Thus, from a shell-model point of view, one might reasonably hope that a comparison of π^+ inelastic scattering with π^- inelastic scattering on complex nuclei would permit an extraction of the valence proton contribution from the valence neutron contribution in the description of nuclear excited states.

Several effects may complicate any such analysis. For example, collective effects are known to play an important role in all inelastic-scattering measurements. Since collective contributions such as core polarization involve both protons and neutrons coherently, we expect that this contribution to inelastic excitation will lessen the amount of selectivity with incident charged-pion species. Also, for nuclear excitations involving nonself-conjugate core, some selectivity with incident pion species may arise due to core-coupling effects.

We propose to measure inelastic scattering of positive and negative pions from odd-A nuclei near shell closure; specifically, we propose to compare inelastic excitations in the lead region using isotopes ^{207}Pb , ^{208}Pb , and ^{209}Bi . In the odd-A nuclei, we will be exciting two different types of well-known states: (1) single-particle states formed by a promotion of a valence neutron or a valence proton, which, in each case, will be built on a doubly-magic core; and (2) weak-coupling states formed when a spectator neutron or a spectator proton is coupled to a collective excitation of the core.

In a comparison between inelastic-scattering yields, we expect to see π^+ preferentially exciting single-particle proton states type (1). In contrast, we do not expect to see any more of the selectivity in the inelastic pion scattering to the weak-coupling states of type (2) that is measured in the inelastic excitation of the appropriate parent states in the doubly magic core nucleus of ^{208}Pb , where this selectivity arises due to the nonself-conjugate character of the core.

DEVELOPMENT OF A HIGH-RESOLUTION LIQUID-ARGON CHARGED-PARTICLE DETECTOR OF MEDIUM-ENERGY PARTICLES

LASL

C. R. Gruhn and E. R. Flynn, Spokesmen

R. DeVries

Lawrence Berkeley Laboratory

D. Hendrie, K. Van Bibber

A low-energy proton beam (~ 200 MeV) having a momentum resolution of 0.2% has been developed on the P^3 channel for the purpose of proton radiography (Exp. 286). The beam spot is 1.6 by 3.0 mm². The beam appears to be ideally suited for this detector test. The five days requested do not have to come continuously but could come as five individual days during the period requested.

The particles enter the detector from the left, passing through two 3-mil-thick Kapton windows, and stop after traversing through ~ 15 cm of liquid argon. The electrons from the track drift in a 4-cm space upwards through a screening grid to a structured anode. The anode is structured to sample the signal along the track. At the end of the chamber, beyond the terminating point of the track, is a window that will allow a phototube to permit viewing the scintillations from the track. This signal will be used as a start signal to measure the drift time to the grid, thus allowing for corrections to be made for screening inefficiencies and differential attenuation due to electron scavenging by oxygen impurities. We are designing the detector so that these corrections are no more than the design goal in the resolution.

Exp. 421

SENSITIVE SEARCH FOR $\mu^- \rightarrow e$ CONVERSION

Yale University

P. A. Souder and V. W. Hughes, Spokesmen

University of Pennsylvania

S. Frankel, Spokesman

We propose a sensitive search for the rare muon decay process

$$\mu^- + Z \rightarrow e^- + Z ,$$

or

$$[\mu^- + Z \rightarrow e + (Z - 2)] .$$

Numerous examples of unified gauge theories of the weak and electromagnetic interactions suggest that this conversion, with its violation of muon number conservation, may occur with a branching ratio relative to ordinary muon capture that is greater than 10^{-12} . The upper limit for this branching ratio has been established experimentally at SIN to be 10^{-10} , and indeed this number provides useful constraints on the above theories. By using a large magnet and a high-resolution drift chamber, we should be able to establish a limit for the branching ratio of 10^{-11} or better. The resolution and background rejection will be good enough to achieve sensitivity at the 10^{-12} level.

Exp. 422

**HIGH-PRECISION MEASUREMENTS OF PIONIC MASS AND PIONIC
X-RAY ENERGIES WITH A BENT-CRYSTAL SPECTROMETER**

Yale University

D. C. Lu, Spokesman

We propose to measure the pionic mass to an accuracy of approximately ± 2 ppm experimentally by measuring the energies of selected pionic x rays (π -P 4f-3d, π -Si 4f-3d, π -Ti 5g-4f) with a bent-crystal spectrometer, using the same approach as we have used in an experiment at the Nevis Synchrocyclotron with encouraging results. Our proposed measurements will include both the main fine structure components and the next prominent components to provide a check of the Klein-Gordon equation.

Exp. 423

EXCITATION OF GIANT RESONANCES BY INELASTIC PION SCATTERING

LASL

C. L. Morris, Spokesman

H. A. Thiessen, J. F. Amann, G. W. Hoffmann

University of Texas, Austin

C. F. Moore, Spokesman

W. J. Braithwaite, W. B. Cottingham

New Mexico State University

G. R. Burleson

University of Colorado

R. L. Boudrie, R. J. Peterson

It is proposed to measure the excitation of giant resonances in pion inelastic scattering. Specifically, it is intended to establish the multiplicity of a resonance already seen in pion inelastic scattering on ^{209}Bi , and to look for its existence in other nuclei in the medium- to heavy-mass range. Angular distributions will be measured for ^{90}Zr , ^{148}Sm , ^{181}Ta , ^{208}Pb , ^{209}Bi , and ^{238}U at three energies, both on and off the (3,3) pion-nucleon resonance.