AN EXPERIMENTAL PROGRAM IN
MEDIUM ENERGY PHYSICS

Progress Report
for Period February 16, 1976 - November 15, 1976

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ABSTRACT

This report covers the nine month period, February 15-November 15, 1976.

During this period we have, in the main part, continued our activities towards the completion of the EPICS and HRS spectrometers at LAMPF. The entire HRS facility has been successfully completed and test-data is now being taken.

The EPICS channel has been completed and the tune-up of the channel has been successfully done. The EPICS spectrometer assembly is still continuing. Data taking on one experiment in collaboration with CEN de Saclay was completed.

Ph.D. was awarded to one student during this period.

PROGRESS REPORT

EPICS PROGRAM [Iversen, Obst, Seth]

Since the last progress report, the EPICS channel and spectrometer project has made major progress. The channel was mounted in March '76 and the first pion tune-up experiment (Part I of Expt. #130) was done in March-April. This experiment, intended to test to what extent the channel design specifications have been met, was a complete success. The measured phase space fluxes, and beam composition are listed in Table 1. Also listed are the design specifications. It is obvious that all design specifications have been successfully met, and we do have a quite pure, well defined pion beam from EPICS.

We have completed our very exhaustive Monte-Carlo studies on the feasibility of a DISC Cerenkov counter for the focal plane of the EPICS spectrometer, and concluded that it is possible to obtain a 10:1 rejection of muons, with 98% pion efficiency, for the full acceptance of the spectrometer. An abstract relating to these conclusions is appended. We have recently moved into the engineering design phase of this device and hope to have the prototype unit ready by July '77. The detailed report on this project is appended.

HRS PROGRAM [Lang, Seth]

We have completed the taut-wire, magnet alignment monitoring system for the HRS beam line system. It has been installed and tested on HRS. We have also started work on the HRS focal-plane Cerenkov detectors for our (p, π^-) experiment. The parts for the Lucite Cerenkov detectors have all been designed and fabricated and will be assembled and tested soon. The propane Cerenkov counter is still in the design stage.

COLLABORATIVE PROGRAM AT SACLAY [Seth and Saclay Collaboration]

Data taking was completed for the experiment entitled "Radiative Capture of Low Energy π^- on Hydrogen" in the energy range 20 MeV to 100 MeV. Some preliminary analysis has been done but there are no final results yet.

TABLE II. EPICS CHANNEL PERFORMANCE

P (MeV/c)	T_{π} (MeV)	π Count Rate		Percentage Beam Composition			
		Measured ($10^7 \pi/\text{sec}$)	Predicted (in $10^7 \pi/\text{sec}$)	$\pi^{\pm}$	$\mu^{\pm}$	$e^{\pm}$	p
128	50	1.1 ± 0.15	0.9 ± 0.1	60 ± 2	29 ± 5	4 ± 2.5	0.8 ± 0.4
153	67.5	2.2 ± 0.3	2.1 ± 0.2	63 ± 2	19 ± 2	3.5 ± 2.0	0.7 ± 0.4
255	151	14 ± 2	14 ± 1	76 ± 3			2.2 ± 0.2
310	200	20 ± 3	24 ± 2	77 ± 3			3.8 ± 1.0
369	255	23 ± 3	32 ± 3	74 ± 4			6.0 ± 1.6
406	290	18 ± 3	27 ± 3	$21 \pm 1^*$			$74 \pm 12^*$
				π^-			
153	67.5	0.66 ± 0.10	0.58 ± 0.05	56 ± 2	17 ± 3	15 ± 2.5	
255	151	2.8 ± 0.4	3.2 ± 0.2	69 ± 2			
310	200	4.1 ± 0.6	3.6 ± 0.3	82 ± 3			
369	255	3.9 ± 0.6	3.5 ± 0.3	81 ± 3			
406	290	3.4 ± 0.5	2.8 ± 0.3	83 ± 3			

Beam Profile: Vertical extent (90% beam) x vertical divergence = 21.6 cm x 105 mrad, design: 20 cm x 100 mrad

Horizontal extent (90% beam) x horizontal divergence = 5.8 cm x 13 mrad, design: 7 cm x 10 mrad

* Without particle separator functioning properly.

The design of the Differential Range Measuring Spectrometer for the experiment "Low Energy $\pi^\pm$ Scattering from Deuterium" was completed. The spectrometer was successfully tested and appears to work equally well for π^+ and π^- as illustrated in Fig. 1. Data taking for the experiment has been begun.

SUPPORTING PROGRAMS [Saha, Seth]

The series of studies of (p,t) reactions on odd-A, even-A pairs of nuclei in the s-d and f-p shells has been completed. Mr. Saha submitted the thesis entitled "A Study of Weak Coupling Relations Between States of Odd and Even Nuclei by Means of (p,t) Reactions" for his Ph.D. degree. The abstract of the thesis is appended. Several journal articles based on the thesis are in preparation.

CONTRACT PERSONNEL

1. Principal Investigator, Kamal K. Seth

June 15, 1976- September 15, 1976 100%

Feb. 16-Present (except 6/15-9/15) 5%

2. Research Associates

Andrew W. Obst (February 16-Present) 100%

A. Saha (November 1, 1976-Present) 100%

3. Research Assistants

a. Steven G. Iversen

b. Phillip M. Lang

c. A. Saha (February 16-October 31, 1976)

PUBLICATIONS

Removed (abstract)

- †1. "Study of Core Excited States by (p,t) Reaction", Kamal K. Seth, Proceedings International Conference on Physics of Tandems, Trieste 1976 (to be published).
- *2. "Study of Fine Structure in the Deeply Bound Hole States", Kamal K. Seth (with Berrier-Ronsin et.al.) Submitted to Phys. Rev. Letters.
- †3. "EPICS Pion Channel Performance", Iversen, Obst and Seth (with the EPICS collaboration), submitted as LASL report. *Removed (abstract)*
4. "The Cascade Gamma Decay of ^{12}C ", A. W. Obst (with W. J. Braithwaite) *Il* Nuovo Cimento Lett.
5. "Measurement of the Radiative Branching Ratio for the 7.65 MeV State in ^{12}C using Cascade γ -Decays", A. W. Obst (with W. J. Braithwaite), Phys. Rev. C13 (1976)2033.
6. "Mutual Excitation Near the Coulomb Barrier in $^{12}\text{C} + ^{12}\text{C} \rightarrow ^{12}\text{C}^* + ^{12}\text{C}^*$ Reactions", A. W. Obst (with W. J. Braithwaite) Phys. Rev. C.(in press).
- *7. "Scintillators and Photomultipliers", A. W. Obst (with J. Källne and H. A. Thiessen) - LASL Report LA-6356-MS (July 1976). *Removed*
- *8. "One and Two-Step Processes in Single Nucleon Pickup", A. W. Obst (with J. Källne), Phys. Rev. C (in press).
- *9. "Photomultiplier Tube Base for High Pulse Anode Currents", A. W. Obst (with R. A. Hiebert and H. A. Thiessen), submitted to Nuclear Instruments and Methods.

* Reprint or preprint appended.

† Abstract appended.

Multichannel DISC Cerenkov Counter for EPICS Spectrometer

Progress Report - November 15, 1976

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I. DESIGN

The Monte-Carlo ray tracing design of a multichannel DISC Cerenkov counter for identifying pions in the large phase space of the EPICS pion spectrometer (Fig. 1) is essentially complete. A schematic top view of the optics is shown to scale in Fig. 2. These include a liquid radiator with 1/8" thick quartz exit window, two water prisms with 3/8" or 1/2" thick quartz windows, two spherically concave 1/4" thick plate glass mirrors (front surface aluminized) and two arrays of quartz-faced photomultipliers with aluminized aluminum light collectors.

Since the Cerenkov light separation of the pion-muon groups is as small as 25 mrad at 300 MeV pion energy, it is necessary to bin the particle trajectories both horizontally and vertically. This is accomplished by tagging the particles passing through the Cerenkov radiator with wire chambers positioned both before and after the radiator, which also reduces the effects of multiple scattering by a factor of 2. Due to the large beam divergence in the vertical or dispersion plane, and also because of the large momentum acceptance in that plane, it is practical to set up an array of photomultiplier light collectors (to be correlated to the particle trajectory bins) only in the horizontal plane, preferably on each side of the focal plane with a coincidence requirement.

An 80-bin array of light collectors is shown in Fig. 3, corresponding to 6 vertical x 6 horizontal particle angle bins. The shaded region represents the light collectors used in an "OR" coincidence for the particle trajectory $\Delta\theta = (+50, 0)$ mrad, $\Delta\phi = (-15, 0)$ mrad. These 15 signals would then be taken in an "AND" coincidence with those from the other side of the focal plane. The offset of each row is due to the different particle momenta corresponding to the different vertical angular bins. Multiple scattering and chromatic aberration limit the advantage of a larger number of light bins, and a total of 160 is already a barely manageable number. A more economical arrangement of 30 light collectors per side (3 vertical x 4 horizontal particle bins) is shown in Fig. 4, and the ability of these two arrangements to reject muons is summarized in Fig. 5. Utilization of

1/2 of the focal plane reduces the muon contamination to about 2/3. As can be seen in Fig. 5, the pion-muon separation at 300 MeV is about 10:1, at 250 MeV about 20:1, and rapidly improves thereafter with decreasing energy.

Over the useful energy range of 50 to 300 MeV it is necessary to use a total of 5 different radiator liquids, due to the variation of the Cerenkov light cone angle with particle velocity. The index of refraction of only the highest energy liquid (actually the most critical situation) is reasonably well known over the wavelength region of interest (2000 to 5000 Angstroms). For the lower energy liquids, the known index of refraction at 5000 Å was used along with an estimated extrapolation down to 2000 Å. Precise measurements of all the necessary indices are currently in progress at the National Bureau of Standards, each measurement requiring about 2 weeks.

II. FABRICATION AND COST ESTIMATES

A sketch of the entire counter is presented in Fig. 6. A discussion of each component follows, ending with a cost summary.

A. Radiator

The radiator consists of 4 separate cells in order to keep the exit window thin for the particles. Since 5 radiators are necessary for the full energy range, a total of 20 14" x 12" x 1/8" plates of Corning 7940 quartz (UV transmitting) are necessary. Up to 8 plates cost \$455 each (including a commercial polish) with price breaks occurring at 20 plates (\$409.50 each) and 22 plates (\$386.75 each). 22 plates would then cost \$8508. The index of refraction measurements cost \$1363 each. The total cost for 5 liquids, including a few absorption measurements, is about \$7000. Both the index and the absorption of the quartz are well known over the present wavelength range.

B. Water Prism

The choice of window thickness of 3/8" (minimum without breaking) vs. 1/2" (slightly more absorbing in the UV) has not yet been decided. The known hydrostatic deflection of each thickness is an existing option in the ray tracing code and along with further stress calculations will determine the choice. The prism frame construction can proceed regardless of this choice. Four 30" x 30" and four 30" x 24" quartz plates are required for the two prisms. Their cost is tabulated as follows:

<u>Size</u>	<u>Cost</u>	<u>Commercial polish</u>
30" x 30" x 3/8"	\$3900	\$290
30" x 30" x 1/2"	\$4688	\$290
30" x 24" x 3/8"	\$3263	\$275
30" x 24" x 1/2"	\$3938	\$275

with a 15% discount only if all 8 pieces (either thickness) are ordered simultaneously. Again the water indices and absorbtion are well known.

C. Mirrors

The 4 mirrors will be made by MP-8 by sagging 3 foot square pieces of ordinary 1/4" thick plate glass ($\sim$ \$50 per sheet) over a machined spherically concave graphite block in a furnace at a temperature of 615°C. The graphite block (\$1080) has already been ordered and the machining will be done at the LASL main shops at a cost of $\sim$ \$600. The aluminizing will be done at the University of Utah at cost ($\sim$ \$50 per mirror).

D. Photomultiplier light collectors

These will have the shape of a modified parabola with the sides trimmed to a rectangular opening. Ray tracing is currently in progress to find the optimum length of funnel. The funnels will be fabricated by machining a solid aluminum block at the LASL main shops, from which secondary epoxy molds will be made at the Argonne plastics shop. There the actual light collectors will be pressed out, lacquered, and aluminized. The cost will be about \$2300 for 40 funnels or \$3200 for 80 funnels (estimates including attrition for instrumenting one side vs. both sides of the focal plane).

E. Photomultipliers

EMI 9813QA 2" photomultipliers represent the best compromise between cost and performance. With a quantum efficiency of 22% at 2000 Å, the first dynode gain is about 25:1, therefore single photon counting is possible and in fact has been observed at EMI. The current price is \$750 per tube with discounts of 5% at 26 tubes and 7% at 51 tubes. A large purchase can be spread out over a year or so without any funds committed to take advantage of the discount. 12 such tubes have already been purchased, of which 2 are from this current fiscal year. For a single array, therefore, 18 more tubes are needed, or 48 more tubes for the dual array. Bases and magnetic shields are \$110 and \$15 each, respectively.

F. Main Frame

The cost of fabricating the main frame, including the prism frames and mirror supports, should be about \$5000. Once all the optics are aligned, only the photomultiplier array as a whole need be moved horizontally as a function of energy. MP-8 will provide all the engineering support, so that only the raw materials cost will enter into the fabrication.

G. Cost Summary

The cost of instrumenting one half vs. the whole 60-bin counter, based on the above figures, is as follows:

	Half-instrumented	Fully-instrumented
Final computer calculations	\$3000	\$3000
Radiator windows	\$8508	\$8508
Refractive index measurements	\$7000	\$7000
3/8" prism windows	\$15456	\$28763
Mirrors	\$1900	\$2100
Light funnels	\$2300	\$3200
Photomultipliers still needed	\$13500 (18)	\$35572 (51)
Bases and shields	\$2500	\$6200
Frame fabrication	\$4000	\$5000
Total	\$58164	\$99343

* Northwestern University, work supported by U.S.E.R.D.A.

** LAMPF, work supported by U.S.E.R.D.A.

FULL EPICS SPECTROMETER FOCAL PLANE AT +1 METER

FIG. 1

80 BIN DESIGN

$$\theta = \begin{pmatrix} +150 \\ \Delta=50 \\ -150 \end{pmatrix}$$

$$\phi = (-45, \Delta=15, +45)$$

FIG. 3

30 BIN DESIGN

$$\theta = \begin{pmatrix} +150 \\ \Delta = 100^\circ \\ -150 \end{pmatrix}$$

$$q = (-50, \Delta = 25, +50)$$

FIG. 4

FULL EPICS SPECTROMETER

FOCAL PLANE

50% π 's, 50% μ 's

99% Efficiency each side of beam

(98% Coincidence Efficiency)

30 bins
per side

80 bins
per side

FIG. 5

E_{π} (MeV)

150

200

250

300

8

6

4

2

0

MULTICHANNEL DISC CERENKOV COUNTER FOR EPICS SPECTROMETER