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PARTICLE PHYSICS
Annual Technical Report

B.M.K. Nefkens

October, 1991

Work Performed Under Contract No. FG03-88ER40420

For
U.S. Department of Energy

By
UCLA Particle Physics Research Group

October 1991

Technical Report

This budget supports the continuing and new research in basic particle and nuclear physics of the UCLA Particle Physics Research Group presently operating under grant #DE-FG03-88-ER40420. It covers the following research:

Program I: Rare and Forbidden Decays of η and μ to Test the Standard Model

I-1: "Rare and Forbidden Decays of Light Mesons." A comprehensive program for testing the Quark Model, the Standard Model, and Chiral Symmetry. Investigations include: measurement of $\eta \rightarrow \mu^+\mu^-$, search for $\eta \rightarrow \pi^+\pi^-$, $\eta \rightarrow e^+e^-$, and $\eta \rightarrow e\mu$. Saturne Exp. #198, B. Nefkens and B. Mayer, spokesmen. The first experiment lasted four weeks and was run in the late winter of 1990. The data are being analyzed. Thesis research by R. S. Kessler.

Our major new efforts are in the design and creation of a large acceptance η decay spectrometer. We are concentrating on ETAS, a small superconducting split solenoid system which has high acceptance, up to 65% for two-body decays, combined with high resolution and adaptation to SPES II. This is intended for a survey of many rare, forbidden, and ordinary decays such as $\eta \rightarrow \pi^0\mu\mu$ (test of C-invariance), $\eta \rightarrow \pi e\nu$ (search for second class weak current), $\eta \rightarrow e^+e^-$ (search for evidence for leptoquarks), $\eta \rightarrow \pi^+\pi^-\gamma$ (test of axial anomaly), $\eta \rightarrow \pi^+\pi^-\pi^0$ (test of chiral symmetry), and $\eta \rightarrow \mu^+\mu^-\gamma$ (determination of η -form factor).

I-2: "Search for the Rare Decay $\mu^+ \rightarrow e^+\gamma$ (The MEGA Experiment)." LAMPF proposal #969, M. Cooper, spokesman. Approved with A⁺ priority for 4000 hours. This is a multi-year multi-million dollar project by 10 institutions to test lepton family conservation to the unprecedented level of 10^{-13} . Our prime responsibility currently is the development of the surface μ^+ beam of $3 \times 10^7 \mu^+/\text{sec}$. Several test runs in the muon channel have been made and we have developed special beam diagnostic apparatus for this.

Program II Tests of Charge Symmetry and Isospin Invariance

II-1: "The Superratio and the Simple Ratios of π^+ and π^- Elastic Scattering on ^3H and ^3He in the Δ Resonance Region to Test Charge Symmetry." LAMPF Exp. #546, B. Nefkens, spokesman. 250 hours have been used for taking data employing a 30,000 Ci tritium target. In this experiment we introduced the idea of the superratio. This resulted in the discovery of a new type of charge symmetry violation which is the inequality in the wavefunctions of the tri-nucleon system. The final article on elastic scattering has been published in Phys. Rev C, and this aspect is completed; still to be written up are the results on inelastic scattering which are interesting.

MASTER

"Angle and Energy Dependence of the Superratio of π^+ and π^- Elastic Scattering on ^3H and ^3He , Further Evidence for Charge-Symmetry Violation." LAMPF Exp. #905, B. Nefkens, spokesman. 300 hours have been used for data taking using a 180,000 Ci tritium target. The final results on elastic scattering have been published in Phys. Rev C. We are working on the inelastic part.

" π^+ and π^- Scattering on Tritium and ^3He in the Region of the NSF-dip." LAMPF proposal #1032, B. Nefkens, B. Berman, W. Briscoe, co-spokesmen. The experiment ran for 280 hours. The data is being analyzed, preliminary results are available.

"Pion Scattering from ^3H and ^3He near 180° in the Region of the $\Delta(1232)$ Resonance." LAMPF proposal #1064, W. Briscoe, B. Berman, and B. Nefkens, co-spokesmen. Data taking took 480 hours. The analysis is in progress.

"Measurement of the Superratio in the Backward Hemisphere at $T_\pi = 180$ MeV." LAMPF Experiment #1155, K. Dhuga spokesman. The running is completed and the analysis is in progress, preliminary data are available.

II-2: "Comparison of $\pi^- d \rightarrow nn$ and $\pi^+ d \rightarrow pp$ Differential Cross Sections to Test Charge Symmetry in the Δ Region." TRIUMF Exp. #270, B. Nefkens, spokesman. 250 hours were used for data taking at 4 incident pion energies. The analysis is substantially done, and preliminary results have been submitted for publication.

II-3: "Charge Symmetry, Quarks, and Light Flavor Symmetry." This is a lengthy survey article which appeared recently in Physics Reports. This work was done in collaboration with G. Miller and I. Šlaus. Another paper has been accepted by "Comments in Nuclear/Particle Physics." Further work on a unified approach, based on the quark model and QCD, to charge symmetry, isospin invariance, and G-parity is continuing at a modest level.

II-4: "Testing Charge Symmetry in the Ratios $R_1 \equiv [d^2\sigma(\pi^+ d \rightarrow pp\eta)]/[d^2\sigma(\pi^- d \rightarrow nn\eta)]$ and $R_2 \equiv [d^2\sigma(\pi^+ d \rightarrow pp\pi^0)]/[d^2\sigma(\pi^- d \rightarrow nn\pi^0)]$." Exploratory investigations have begun for a novel test of charge symmetry in nuclear/particle physics that focusses on the rarely seen $\pi^0 - \eta$ mixing by a comparison of the doubly differential cross sections for $\pi^+ + d \rightarrow p + p + \eta$ with $\pi^- + d \rightarrow n + n + \eta$ near threshold as well as $\pi^+ + d \rightarrow p + p + \pi^0$ with $\pi^- + d \rightarrow n + n + \eta$ near the opening of the η threshold. Research is contemplated for the AGS, with possible extensions to PILAC.

Program III Studies of Baryon Resonances: πN Scattering, Inverse Pion Photoproduction, Eta-Meson Photoproduction, and the Production of the Eta Meson in $\pi^- p \rightarrow \eta n$

III-1: "Measurement of the Spin Rotation Parameters A and R in $\pi^+ p$ and $\pi^- p$ Elastic Scattering from 427 to 657 MeV/c." LAMPF Exp. #806, B. Nefkens principal spokesman, D. Barlow, W. Briscoe, M. Sadler, spokesmen. This A approved experiment has run for 1700 hours. The apparatus includes a longitudinal, frozen-spin target and a spectrometer-polarimeter combination for precessing the spin of the recoil proton. The

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data analysis is about finished, a Phys. Rev. Lett. has appeared, the full paper is in progress. Thesis research by I. Supek at Ruder Boskovic Institute.

III-2: "Measurement of the Left-Right Asymmetry in $\pi^-p \uparrow \rightarrow \gamma n$ and $\pi^-p \uparrow \rightarrow \pi^0 n$ in the Region of the $\Delta(1232)$ and Roper Resonances and a Determination of $d\sigma/d\Omega(\gamma n \leftarrow \pi^-p)$." LAMPF Exp. #804, B. Nefkens, spokesman. The experiment ran for 1200 hours, the data taking and analysis are finished. Thesis research by G.J. Kim. Five papers in Phys. Rev., Phys. Rev. Lett., and Physics Letters on this have appeared. This program is now completed.

III-3: "Photoproduction of Eta-Mesons." New research on the $S_{11}(1535)$ and other resonances via their photoproduction and decay through the $N\eta$ channel. Research performed at ELSA in Bonn. The data taking on the reaction $\gamma + p \rightarrow \eta + p$ near threshold using the Jacobian Spike technique is done and the results are being analyzed at UCLA. Thesis research by J.W. Price. Some exploratory results on $\gamma + d \rightarrow \eta + d$ have been obtained, these data are being analyzed at Bonn as the thesis project by W. Beulertz. Extension of this, including η' and the ω production at CEBAF, is being considered.

III-4: "Measurement of the Eta-Threshold Cusp in $\pi^-p \rightarrow \pi^0 n$ and of the Cross Section and Asymmetry in $\pi^-p \rightarrow \eta n$." There is a dire need for good data in the region around the $P_{11}(1440)$ which is just outside the reach of LAMPF. A collaboration has been formed with the Leningrad Nuclear Physics Institute (LNPI) and M. Sadler of Abilene Christian University. A three week test run was made at LNPI at Gatchina to calibrate the π^- beams and to test the apparatus using the reaction $\pi^-p \rightarrow \eta n$ near threshold. We employed for this six of the UCLA high resolution neutron counters that have been shipped to Gatchina for the purpose. 500 hours of beam time have been approved for next year.

III-5: "Pion-Nucleon Partial Wave Analysis," and " πN Newsletter." The first is theoretical work in support of the above research. The second is a survey and appraisal of the field.

Program IV: Exploratory Investigations in Support of the New Programs under Consideration

IV-1: "Feasibility Study of Tagged Eta Meson Production in $p + {}^3H \rightarrow {}^4He + \eta$." LAMPF proposal #1135, C. Pillai, D. Barlow, and C. Mishra, spokesmen. An exploratory investigation of a novel way to produce tagged eta mesons at LAMPF. We propose to use the MRS or HRS near 0° to detect the 4He 's and our 180,000 curies gaseous tritium target used in Program II. A test run has been approved and awaits installation of the tritium safety systems. We have measured the 4He background rate for production on the titanium of a solid tritium target. A paper on this has been submitted to Phys. Rev. C.

IV-2: "Coherent η Production near Threshold by Protons on ${}^6\text{Li}$." Saturne Prop. #206, B. Nefkens spokesman. A test run was made last year, another is planned when the ${}^6\text{Li}$ beam at Saturne becomes available.

IV-3: "An Alternative η Production Reaction, $\pi^+ + d \rightarrow p + p + \eta$." Measurements of the doubly differential cross section from threshold to $p_\pi = 800$ MeV are being considered using the AGS.

IV-4: "Particle Physics with PILAC." Physics options with clean, intense, monochromatic π^+ and π^- beams at $p_\pi = 0.7$ to 1.3 GeV/c.

IV-5: "Quark Physics at a Phi-Meson Factory." Discussion of quark physics options discussed at the UCLA ϕ Factory Workshops.

The partition of the budget among the four programs for the next year is as follows:

Program I:	45%
Program II:	20%
Program III:	25%
Program IV:	10%

Alternatively, the budget can be divided into:

Analyzing data already acquired:	30%
Construction and testing of equipment and experiment preparation	40%
Running of experiments:	30%

We do not anticipate to have an unexpended balance at the end of the budget period.

BUDGET: DOE - Year 2 Revised Budget
PRINCIPAL INVESTIGATOR: Professor B. M. Nefkens

2.1.92/
1.31.93

SALARIES:

B. M. Nefkens, Professor of Physics Principal Investigator 100% time, 2 Summer months Anticipated to Step VIII 7.92:	\$21,304 \$10,652
B. Tippens Assistant Research Physicist II 50% time, 12 months Current salary base: Anticipated 7.92:	\$22,279 \$3,608 \$3,789
M. J. Wang Staff Research Associate III 50% time, 12 months Current salary base: Anticipated 7.92:	\$18,427 \$2,984 \$3,133
M. Clajus Staff Research Associate III 50% time, 12 months Current salary base: Anticipated 7.92:	\$18,427 \$2,984 \$3,133
J. Price Graduate Student Researcher III 50% time, 9 academic mos.:100% time, 3 Summer mos. Current salary base: Anticipated 7.92:	\$19,778 \$2,552 \$2,680
R. Kessler Graduate Student Researcher III 40% time, 9 academic mos.:50% time, 3 Summer mos. Current salary base: Anticipated 7.92:	\$13,411 \$2,552 \$2,680
D. White Graduate Student Researcher II 25% time, 9 academic mos.:50% time, 3 Summer mos. Current salary base: Anticipated 7.92:	\$10,363 \$2,674 \$2,808
H. Teplitz Graduate Student Researcher I 25% time, 9 academic mos.:50% time, 3 Summer mos. Current salary base: Anticipated 7.92:	\$8,646 \$2,343 \$2,231
P. Polin Secretary III 75% time, 12 months Current salary base: Anticipated 7.92:	\$22,885 \$2,471 \$2,594
TOTAL SALARIES	\$155,520

BUDGET: DOE - Year 2 Revised Budget	2.1.92/
PRINCIPAL INVESTIGATOR: Professor B. M. Nefkens	1.31.93

BENEFITS:

Academic Summer: 10%	\$2,130
Postdoctoral: 28/29% (actual - Tippens)	\$6,257
Staff Res. Assoc.: 25/26%	\$9,244
Student: 4.7/1.82% (Summer)	\$1,884
Staff: 19/20% (actual - Polin)	\$4,367

TOTAL BENEFITS	\$23,882
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TOTAL SALARIES AND BENEFITS	\$179,402
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SUPPLIES & EXPENSE:

Telephone/copying/mailling	\$3,000	\$16,800
Computer hardware maintenance	\$6,200	
Computer software maintenance	\$700	
Mag tapes & computer supplies	\$1,500	
Office/lab supplies	\$2,400	
Shipping of equipment to France, Germany and U.S.S.R.	\$3,000	

PUBLICATION:

@ \$72 x 20 pgs.	\$1,440	\$3,440
@ \$42 x 40 pgs	\$1,600	
Illustrator @ \$8.00/hr. x 50 hrs.	\$400	

TRAVEL:

DOMESTIC -

(4) LAMPF trips: Airfare - \$200 x 4 = \$800	\$2,000
Lodging/meals \$200 x 4 = \$1,200	
Scientific meetings	\$1,000
TRIUMF, Canada - Airfare: @ \$400	\$1,000
Per diem @ \$40/day x 15 days = \$600	
BNL: Airfare - \$500, Lodging/meals - \$500	\$1,000

TOTAL DOMESTIC TRAVEL	\$5,000
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FOREIGN - by Principal Investigator:

(3) Saclay, France trips for experiments	\$7,500
Airfare - @ \$900 x 3 = \$2,700	
Per diem - @ \$80x60 total days = \$4,800	

(2) Bonn, Germany trips for experiments	\$4,200
Ground transportation - @ \$900 x 2 = \$1,800	
Ground travel from Saclay	
Per diem - @ \$80x30 total days = \$2,400	

(1) Academy of Science, LNPI Gatschina, St. Petersburg, Soviet Union	\$1,900
Airfare - \$1,500	
Per diem - \$20x20 days = \$400	

(1) Dubna, Moscow	\$780
Airfare - \$500	
Per diem - \$40 x 7 days = \$280	

BUDGET: DOE - Year 2 Revised Budget
PRINCIPAL INVESTIGATOR: Professor B. M. Nefkens

2.1.92/
1.31.93

FOREIGN - by Postdoctorates/Graduate Students:

(3) Saclay trips by M. Clajus	\$6,700
Airfare - @ \$900 x 3 = \$2,700	
Per diem for 5 total mons. @ \$800/mo. = \$4,000	
(1) Saclay trip by D. White	\$3,900
Airfare - \$900	
Per diem for 3 mons. @ \$1,000/mo. = \$3,000	
(1) Bonn trip by J. Wang	\$2,400
Airfare - \$900	
Per diem for 1.5 mons. @ \$1,000/mo. = \$1,500	
(1) Saclay trip by B. Tippens	\$1,900
Airfare - \$900	
Per diem for 1.mon. @ \$1,000/mo. = \$1,000	
(1) Bonn trip by J. Price	\$1,700
Airfare - \$900	
Per diem for 1.33 mons. @ \$600/mo. = \$800	

TOTAL FOREIGN TRIP \$30,980

TOTAL DIRECT COST \$235,622

(4) GSRs' Fee Remissions @ \$650/yr. \$2,600
NOT subject to overhead

TOTAL INDIRECT COST @ 27% \$63,618

SUB-TOTAL \$301,840

EQUIPMENT: \$11,500

(6) Electronic modules @ \$1,000	\$6,000
Terminal	\$2,500
General computer system hardware updates	\$3,000

FABRICATION: \$60,660

Polarimeter Components -	
(5) Scintillation counters @ \$1,000	\$5,000
(3) Stands @ \$1,050	\$3,150
(1) Hodoscope	\$3,600

Fabrication Materials -	
Nuts, bolts, resistors, capacitors, etc.	\$2,000

Fabrication Hours -	
Machine shop: @ \$8.55/hr. x 200 hrs.	\$1,710
Electronic Shop: @ \$8.00/hr. x 100 hrs.	\$800
Fabricating hours: @ \$30/hr. x 1,480 hrs.	\$44,400

TOTAL REQUESTED FROM DOE \$374,000

REVISED BUDGET FOR YEAR 2
 ER F 4620.1 U.S. Department of Energy
 Grant Application Budget Period Summary

OMB Approval
 No. 1910-1400

ORGANIZATION: University of California, Dept. of Physics, 405 Hilgard Ave. L. A. CA 90024			PERIOD COVERING: From: 02.01.92		FOR DOE USE ONLY Proposal No:	
Principal Investigator/Project Director: Professor B. M. Nefkens			To: 01.31.93		Award No: FG03-88ER40420	
A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title; A.6. show number in brackets)			DOE Funded Person-Mos.		Funds Requested By Applicant \$	
			CAL.	ACAD.	SUMR.	
1. Professor B. M. Nefkens					2	\$21,304
2.						
3.						
4.						
5.						
6. (1) TOTAL SENIOR PERSONNEL			0	0	2	\$21,304
B. OTHER PERSONNEL(SHOW NUMBERS IN BRACKETS)						
1. (1) POST DOCTORAL ASSOCIATES			12			\$22,279
2. (2) OTHER PROFESSIONALS(TECHNICIAN, PROGRAMMER, ETC.)			12			\$36,854
3. (4) GRADUATE STUDENTS				12.6	7.5	\$52,198
4. () UNDERGRADUATE STUDENTS						
5. (1) SECRETARIAL-CLERICAL						\$22,885
6. () OTHER Visiting Assistant Research Physicist						
TOTAL SALARIES AND WAGES (A+B)						\$155,520
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)						\$23,882
TOTAL SALARIES WAGES AND FRINGE BENEFITS (A+B+C)						\$179,402
D. PERMANENT EQUIPMENT (LIST ITEM AND \$ AMOUNT FOR EACH ITEM EXCEEDING \$1,000) (6) Electronic modules, (1) terminal and computer hardware updates TOTAL EQUIPMENT & FABRICATION						\$72,160
E. TRAVEL 1. DOMESTIC (INCL.CANADA AND U.S. POSSESSIONS)						\$5,000
2. FOREIGN						\$30,980
F. OTHER DIRECT COSTS						
1. MATERIALS AND SUPPLIES						\$16,800
2. PUBLICATIONS COSTS/PAGE CHARGES						\$3,440
3. CONSULTANT SERVICES						
4. COMPUTER (ADPE) SERVICES						
5. CONTRACTS AND SUBGRANTS						
6. OTHER - GSRs' Fee Remissions @ \$650/ea.						\$2,600
TOTAL OTHER DIRECT COSTS						\$22,840
G. TOTAL DIRECT COSTS (A THROUGH F)						\$310,382
H. TOTAL INDIRECT COSTS(SPECIFY RATE AND BASE) @ 27%						\$63,618
I. TOTAL DIRECT AND INDIRECT COSTS (G & H)						\$374,000
J. APPLICANT'S COST SHARING(IF ANY)						\$0
K. TOTAL AMOUNT OF THIS REQUEST (ITEM I LESS ITEM J)						\$374,000
PI/PD TYPED NAME & SIGNATURE Professor B. M. Nefkens			DATE 10-21-91			
INST. REP. TYPED NAME & SIGNATURE Elisabeth V. Johnson			DATE			

END

**DATE
FILMED**

12/30/91