HIGH ENERGY PHYSICS RESEARCH REPORT

UNIVERSITY of PENNSYLVANIA

DEPARTMENT OF PHYSICS

PHILADELPHIA, PENNSYLVANIA 19104

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CONTRACT AT(11-1)-3071

Renewal
PROGRESS REPORT
PROPOSAL FOR RESEARCH PROJECT

High Energy Physica Research

For Fiscal Year 1976

APRIL 1, 1975

MASTER

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UNIVERSITY OF PENNSYLVANIA
Philadelphia, Pa. 19174

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Introduction

The format for this proposal differs considerably from that used in previous years. The changes made are intended to make the Particle Physics Program at the University of Pennsylvania more comprehensible and to sharpen the distinction among the various elements of that program.

The major change is a much more detailed cost breakdown among specific research activities. This breakdown, for experimental activities, is primarily on the basis of individual experiments. In theory, it is on the basis of primary scientific directions. Recent progress, future plans, and expected scientific manpower and funding projections are presented for each sub-activity. Although publications are shown for each sub-activity, they are also collected, for convenience, into a specific section devoted to publication activity.

The funding projections within each sub-activity have been prepared as a comparative guide to present and future activity, and should not be used for detailed accounting purposes. The three month FY 1976 transition budget has been omitted, in the sub-activity projections, to permit easier comparisons among FY 1975, FY 1976, and FY 1977. The contractor's revised estimate is included only for those sub-activities in which tentative allocations from the FY 1976 congressional budget are clearly inadequate to carry out the scientific program. Since those allocations have been made to localize the programmatic effects of the FY 1976 congressional budget to a few specific areas, most sub-activities will contain only figures for the FY 1975 budget, the FY 1976 congressional budget, and the FY 1977 budget request. Finally, the indirect costs for the total program have not been allocated among the specific sub-activities.

The budgets presented include no provision for general inflation in either FY 1976 or FY 1977. Extremely modest (five percent each year) salary increases have been assumed, and mandated changes in personnel benefits and indirect costs have been included. The Special Direct University Subvention (SDUS) to this program is also included - the actual funding received in FY 1975, and estimated amounts for FY 1976 and FY 1977.

UNIVERSITY of PENNSYLVANIA

PHILADELPHIA 19174

Renewal

The College

DEPARTMENT OF PHYSICS

PROPOSAL FOR RESEARCH PROJECT

Submitted to: United States Energy Research and Development Administration

Title of Proposal: High Energy Physics Research - Contract AT(11-1)-3071

Principal Investigator: Position: Professor of Physics
Alfred K. Mann

School: The Faculty of Arts
and Sciences

Department: Physics

FUNDS REQUESTED

	<u>FY 1975</u>	<u>FY 1976</u>	<u>FY 1977</u>
Operating:	\$1,250,000	\$2,050,000	\$1,679,000
Equipment:	145,000	195,000	250,000

Corporate Name of University: The Trustees of the University of Pennsylvania
(a Pennsylvania non-profit corporation)

Contracting Office: Office of Research Administration
Reagan Scurlock, Director
3451 Walnut Street, Philadelphia, Pa. 19174

Date: April 1, 1975

Vartan Gregorian
Dean of the Faculty of
Arts and Sciences

Approved:

Walter D. Wales
Chairman, Physics Department

REAGAN A. SCURLOCK
DIRECTOR
RESEARCH ADMINISTRATION

Martin Meyerson
President
University of Pennsylvania

U. S. ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION - SCHEDULE 21a

ANALYSIS OF OPERATING COSTS BY PROGRAM AND CONTRACTOR
(IN THOUSANDS)

<u>CHICAGO OPERATIONS OFFICE</u>		<u>PHYSICAL RESEARCH</u>		<u>CONTRACT NO. AT(11-1)-3071</u>		
Field Office		Program		UNIVERSITY OF PENNSYLVANIA		
				Contractor		
		FY 1976 *			FY 1977	
Activity Number and Title	FY 1975	Congres- sional Budget	Contractor's Revised Estimate	Field Office Estimate	Contractor's Request	Field Office Request
	(1)	(2)	(3)	(4)	(5)	(6)
NT-01-06-01						
High Energy Physics Research	1,250	1,760	2,050		1,679	

* This represents 15 months: 12 months normal plus 3 months transition (July 1, 1975 to September 30, 1976).

The Presidential Budget for the 3 transition months matches the salary requirement for July, August, September operation without the addition of any personnel. It provides no funds for normal research activities estimated to require \$90,000. Total transition budget requested : \$480,000.

There is no provision for inflation factors in this budget. Costs are estimated at 1.0 x FY'75 except for salaries which reflect 1.05 x for each fiscal year subsequent to FY'75.

U. S. ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION - SCHEDULE 21a

ANALYSIS OF OPERATING COSTS BY PROGRAM AND CONTRACTOR
(DETAILS OF OPERATING COSTS)
(Thousands of Dollars)

	FY 1975	FY 1976 12 Months Presidential Budget	FY 1976 Requested Increase	FY 1976 3 Transition Months Presidential Budget *	FY 1976 3 Transition Months Requested Programmatic Increase	FY 1977
Direct Salaries; Scientific, Technical and Others	492 43 MY	598 48 MY	37 3 MY	200 -	10	691 52 MY
Personnel Benefits	84	134	8	45 -	2	158
Indirect Expenses	370	424	42	105 27	10	505
Travel (Domestic and Foreign)	79	72	13	- 18	3	79
Materials and Services	131	81	52	- 19	13	134
Computer Usage Costs, Rentals, and Maintenance	34	37	-	- 10	-	37
Accelerator and Related Expenses	60 1,250	64 1,410	8 160	- 16 350 90*	2 40	75 1,679
<u>SDUS</u> Salaries	97 (6MY)	55 (3MY)		8		23 (2MY)
Benefits	13	13		2		5
Total	110	68		10		28
Materials and Services	1	2		-		2
Virtual Overhead	50	32		5		14
Effective University Support	161	102		15		44
Total Effective Operating Budget	1,411	1,512		365		1,723
Total Man Years	49MY	51MY	54MY			54MY

* Amount by which Presidential Budget was deficient for normal operations.

U. S. ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION - SCHEDULE 189

JUSTIFICATION FOR OPERATING COSTS AND
EQUIPMENT OBLIGATIONSNumber:
42-3071-001APRIL 1, 1975
DateCHICAGO OPERATIONS OFFICE
Field OfficePHYSICAL RESEARCH
Program

1. Budget Activity Number: NT-01-06-01		2. Project Title: Elementary Particle and Nuclear Research	
3. Method of Reporting: Annually		4. (a) Person in Charge: Prof. A. K. Mann (b) Principal Investigator: Prof. A. K. Mann	
5. Contractor: Type: 3 University of Pennsylvania		6. Working Location: NAL, BNL, SLAC, ZGS, LAMPF, S. Dakota (Mine), Barberton, Ohio (Mine), Mt. Blanc (Tunnel), Univ. of Pennsylvania	
7. Task Number: NA	8. Reactor Concept: NA	9. Materials: NA	
10. Contract Number: AT(11-1)-3071	11. Project Term: Continuing Effort	12. Contractor's Pro- ject Number: NA	
13. Man-Years		FY 1975	FY 1976 ⁽¹⁾
			FY 1977
(a) Scientific		30	35
(b) Other Technical		5	9
(c) Administrative or Supporting		8	8
(1) Total		43	52
(1) 12 Month Basis			
14. Funding:		FY 1975	FY 1976 ⁽²⁾
			FY 1977
		(In Thousands of Dollars)	
(a) Direct Salaries		492	691
(b) Materials, Services		304	325
(c) Indirect Expenses		370	505
(d) Personnel Benefit Expenses		84	158
Total		1,250	1,679
Obligations for Capital Equipment not related to Construction		145	250
(2) 15 Month Funding			

U. S. ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION - SCHEDULE 189

JUSTIFICATION FOR OPERATING COSTS AND EQUIPMENT OBLIGATIONS

Number:
42-3071-001

APRIL 1, 1975
Date

CHICAGO OPERATIONS OFFICE
Field Office

PHYSICAL RESEARCH
Program

Supporting Detail for Items 13 and 14:

Item 13: Many of the scientific personnel engaged in activities connected with research on this contract also obtain funds from the university. The total number of man-years thus supported is:

FY 1975, 5 MY; FY 1976*, 6 MY; FY 1977, 6 MY
(See appendix A-2 for further elaboration)

Item 14:	<u>FY 1975</u>	<u>FY 1976</u> (12 Months)	<u>FY 1976</u> (3 Transition Months)	<u>FY 1977</u>
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(In thousands of dollars)

Direct Salaries

Scientific	\$369	\$458	\$151	\$506
Technical	54	107	36	113
Other	69	70	23	72
	<u>492</u>	<u>635</u>	<u>210</u>	<u>691</u>

Material and Services

Major Materials	0	0	0	0
Major Services	0	0	0	0
Computer Services ¹	34	37	10	37
Mis. Supplies, Services and Expenses ²	270	290	71	288
	<u>304</u>	<u>327</u>	<u>81</u>	<u>325</u>

Subcontracts	0	0	0	0
Indirect Costs ³	370	466	142	505
Personnel Benefits				
Expenses ⁴	84	142	47	158

TOTAL⁵	<u>\$1,250</u>	<u>\$1,570</u>	<u>\$480</u>	<u>\$1,679</u>
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*12 Month Basis

U. S. ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
JUSTIFICATION FOR OPERATING COSTS AND
EQUIPMENT OBLIGATIONS

Number:
42-3071-001

APRIL 1, 1975
Date

CHICAGO OPERATIONS OFFICE
Field Office

PHYSICAL RESEARCH
Program

Supporting Detail for Items 13 and 14 (Continued)

NOTE: 1. Maintenance Services for IBM 360/65

2. This item includes telephone, repairs and maintenance, publication charges, printing and periodicals, travel, equipment rental and accelerator expenses, and miscellaneous supplies.

3. Indirect Charges:

<u>FY 1975</u>	<u>FY 1976</u>	<u>FY 1977</u>
44.5% of Net Total	45.5% of Net Total	45.5% of Net Total
Direct Costs (25.6	Direct Costs (25.6	Direct Costs (25.6
NTDC off-campus)	NTDC off-campus)	NTDC off-campus)

4. Employee Benefit Rates (% of salary and wages):

	<u>FY 1975</u>	<u>FY 1976</u>	<u>FY 1977</u>
A1	12.2	17.7	17.2
A2	20.5	24.6	24.0
A3	15	23.4	22.6
A4	15	23.4	22.6

A1 Administration and Staff
A2 Faculty and Graduate Students
A3 Technicians, Secretarial
A4 Part-time Technical and Secretarial

5. See Appendix A-1

U. S. ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

JUSTIFICATION FOR OPERATING COSTS AND
EQUIPMENT OBLIGATIONSNumber:
42-3071-001APRIL 1, 1975
DateCHICAGO OPERATIONS OFFICE
Field OfficePHYSICAL RESEARCH
ProgramNon-Requirement of Environmental Assessment

Since activity under this contract does not:

- 1) use substantial quantities of non-renewable resources;
- 2) release quantities of air or water pollutants;
- 3) include the potential for new sources of pollution to arise as the result of these studies;
- 4) result in the production of long-term pollution or waste handling problems;
- 5) result in a waste handling or pollution problem due to the ultimate removal or decommissioning of its activity

it is concluded that no Environmental Assessment is required.

Relationship to Other Projects

The scientific activities of this project will be carried on at the University of Pennsylvania laboratories and at NAL, LRL, ZGS, BNL, SLAC, LAMPF, Homestake Mine, Barberton Mine, Mt. Blanc Tunnel, ISR.

ADDENDUM TO SCHEDULE 189

FOREIGN TRAVEL

FY 1976

UNIVERSITY OF PENNSYLVANIA

Contractor

AT(11-1)-3071

Contract Number

PHYSICAL RESEARCH

Program

Number of Travelers	Purpose of Travel	Dates of Travel	Destination	FY 1976 Cost Estimate
1	Attend Symposium on Highly Exited States in Nuclei	Sept. 23-26, 1975	Julich, Germany	1,000
1	Research in collaboration with Barcat, Shahem	Jan. - June 1975	Jerusalem, Israel	1,000
2	International Conference on High Energy Physics	July 1976	Soviet Union	3,000
1	Attend 14th International Cosmic Ray Conference	Aug. 14-30, 1975	Munich, Germany	1,080
1	Work at Mt. Blanc $\bar{\nu}_e$ burst detection station	Oct. 15-22, 1975	Mt. Blanc and Turin, Italy	1,000
1	Work at Mt. Blanc $\bar{\nu}_e$ burst detection station	Dec. 15-30, 1975	Mt. Blanc and Turin, Italy	1,000
1	Work at Mt. Blanc $\bar{\nu}_e$ burst detection station	March 8-22, 1976	Mt. Blanc and Turin, Italy	1,000
1	Work at Mt. Blanc $\bar{\nu}_e$ burst detection station	June 1-15, 1976	Mt. Blanc and Turin, Italy	1,000

Scope and Summary

The research carried out by physicists at the University of Pennsylvania under this contract is part of a global effort to understand the nature of the fundamental particles and of the interactions - strong, weak, and electromagnetic - between them. A major part of the investigations is concerned with the experimental determination of the properties of the fundamental particles and their interactions with matter, and with a search for new phenomena and new particles. The selection of new experiments is determined by the desire to test theoretical assumptions and predictions or by curiosity about gaps in existing knowledge. The experiments are inter-university and international in character, the sites ranging from the Stanford Linear Accelerator in California to the Mont Blanc Tunnel in Europe.

The efforts of the experimental physicists are not distributed uniformly among the areas of particle physics, nor is this distribution static with time. During the decade from the early 1960's to the early 1970's most of the experiments were performed at the Brookhaven National Laboratory or the Princeton-Pennsylvania Accelerator. The experiments focussed on the weak interactions, primarily through study of the decays of K-mesons, and on strong interactions, through particle searches and production studies. The extensive use of visual techniques - bubble chambers and optical spark chambers - led to a major investment of resources in film scanning and measuring equipment.

The decay studies have now been successfully completed, and the availability of new accelerators and new techniques has permitted a shift of resources into somewhat different areas. The advent of high intensity neutrino beams now allows direct investigation of the weak interaction. Such investigations are likely to be unusually productive during the next few years. Strong interaction techniques, once dominated by bubble chambers, have become increasingly oriented to electronic detectors, particularly at the newer accelerators.

The center of gravity of the efforts at Pennsylvania has swung from the east coast to Fermilab, and major efforts are being mounted on both coasts. The techniques used are increasingly intricate, leading to extensive long-term programs which exploit the capital investment. The use of visual techniques has nearly vanished, and the resources once devoted to their support have been swung to building and maintaining the electronic detectors.

In addition, a major program has been begun to study neutrinos from the cosmos. This effort both seeks to understand the nature of the universe and of the least particle in it, the neutrino.

The theoretical effects at Pennsylvania has always been spread over many complementary areas. The theoretical program attempts to extrapolate mathematical techniques into the realm of elementary particle-, nuclear-, and astrophysics and to develop new techniques in the study of fundamental interactions. The elementary particle theory is concerned with field theories, gauge models of weak and electromagnetic interactions, quantum electrodynamics, resonance models, and very high energy inelastic phenomena. The nuclear physics research is concerned with the collective motions in nuclei, pairing and ground state correlations, vibrational and rotational modes, and properties of giant resonances. The astrophysics theory is concerned with neutrinos from dense and collapsing stars, pulsars, neutron stars, and problems in general relativity.

Summary

The program has been remarkably productive in FY 1975. Probably the most exciting event has been the discovery of dimuon events, which may indicate production of a new type of elementary particle, by the neutrino experiment at Fermilab. The work on inclusive scattering at Brookhaven has been successfully completed. Tests of the detector system for the hadron jet experiment at Fermilab are now underway, a major neutrino experiment at Brookhaven is nearly ready to begin taking data, and the MPS system at Brookhaven is about to recover some of the past investment. A second U. S. detection system has been set up to look at cosmic neutrinos.

FY 1976 looks, in most ways, extremely promising. The neutrino experiment at Fermilab is being expanded, and will continue to study dimuon production as well as other important aspects of both neutral and charge current induced weak interactions. The Brookhaven neutrino experiment will take its first real data, and begin to fill in some of the gaps in our knowledge at lower neutrino energies. The inclusive scattering experiment, successfully moved to Fermilab, will complete its program at the higher energies there. The hadron-jet experiment, having been successfully tested, should begin to accumulate useful data.

While we have been able to project our previous investment in these exciting experiments within the limits of the tentative FY 1976, these limitations may force us to sacrifice other parts of the program in which less investment has been made. Some of these experiments are potentially very important, and their loss has very grave implications for the future of the program. The $e^+e^- \rightarrow \mu + \mu^-$ experiment at SPEAR II, which has been allocated twenty-five weeks of beam time, cannot proceed unless major additional operation and equipment funds are secured. The Italian collaboration on the Mt. Blanc neutrino stations may have to be abandoned, and work on a major large volume detection cannot begin. Perhaps worst of all, initial work on new experiment, on which the program will depend critically in the late 1970's must be severely limited.

The limitations imposed by the congressional budget for the three-month period between the end of FY 1976 and the beginning of FY 1977 will cause even more serious problems. We have assumed modest salary increases (five percent) and no increase of staff before July 1, 1976. With these assumptions we find that the entire sum allocated would be used for salaries and personnel benefits. We would thus face a choice of either reducing staff by about one-quarter, or having no activity whatever. Either of these choices, or any linear combination we have been able to develop, would prove extremely detrimental to the program.

The program in FY 1977 is not yet as clear, but will be dominated by continued exploitation of past investments on major programs. The neutrino experiments, at both Fermilab and Brookhaven, will be very active, as will the hadron jet experiment at Fermilab. The SPEAR experiment, if built in FY 1976, should be acquiring very exciting data. Finally, some new experiments, probably at Fermilab, will begin to contend with these more established programs.

II. Operations - Experiment

A. Neutrino Studies at Fermilab

This program, which began with Fermilab Experiment 1A, consists of a series of experiments to study the interactions of high energy neutrinos and antineutrinos with matter. The program is a collaboration between physicists here and physicists from Harvard University, the University of Wisconsin, and Fermilab.

Technical Progress in FY 1975

The program reached its first climax when it participated in the discovery of neutrino- and antineutrino-induced events without final state muons. This work was reported in several publications in FY 1975. The program is approaching a new climax with the probable discovery of new particle production by high energy neutrinos and antineutrinos. Indications of this new phenomena were first manifest in anomalies in the observed scaling-variable distributions for neutrinos and antineutrinos. Recently, corresponding anomalies in the invariant mass distributions of the recoiling hadron systems have been observed and, most important, events with two (and only two) final state muons have been detected. The latter events cannot be accounted for as neutrino-induced single muon events followed by the decay into a muon of a pion or kaon. A tentative conclusion concerning the origin of these events points to the production of new hadrons in the charge-current channel of neutrino (and antineutrino) interactions. These hadrons carry a new quantum number not conserved by the interaction responsible for their decay, either leptonically or semileptonically, into a muon and a neutrino. This work, and work on coordinated aspects of those experiments, has been reported in the publications listed below.

Expected Results in FY 1976

It is necessary to explore further the entire phenomenon of muonless events to determine the Lorentz covariants, i.e., space-time structure, of the effective neutral currents giving rise to the muonless events. It is also important to search intensively for new particle production in the neutral current channel. Furthermore, the effective violation

of scale invariance and charge symmetry invariance, and the diuon events, that have been observed recently - all of which strongly suggest new particle production by neutrinos and antineutrinos - must be studied until definitive conclusions are obtained. These possibilities indicate that research with high energy neutrinos, if expanded and carried out with increased vigor and determination, will yield intellectual dividends of the highest order.

An extension of Experiment 1A as Experiment 310 has been approved by Fermilab, which has begun and nearly completed an addition of equal area to the present experimental area of E-1A. This building will be occupied by an improved, more massive, more flexible detector, for which the funding is now being negotiated with Fermilab. The new apparatus will incorporate a large (24 ft. diameter) toroidal iron magnet in addition to the present 12 ft. diameter magnet, and new components of the ionization calorimeter. These latter will increase the mass of the target-detector to about 300 metric tons, and provide discrimination between the electromagnetic and hadronic components - as well as the muonic component - of the final states of neutrino-nucleon interactions. The new apparatus will make possible an intensive search for the process $\nu_{\mu} + e^{-} \rightarrow \nu_{\mu} + e^{-}$, and initial studies of electron neutrino (ν_e) interactions with nucleons at very high energy. It will also incorporate drift chambers to allow all-electronic data acquisition.

The design of all parts of the new apparatus is complete. The new magnet should be installed in the new building by May 1975, to be followed by the new components of the target-detector in successive phases. One such component is now under test. The entire new apparatus should be ready for data-taking by the fall of 1975.

Expected Results in FY 1977

The Fermilab Neutrino Program is a very long-range program and should continue to be extremely productive for several more years. Most effort in FY 1977 will be spent exploiting the modifications and improvements which will be installed in FY 1976.

Publications

- (i) Observation of Muonless Neutrino-Induced Inelastic Interactions, (A. Benvenuti, D. C. Cheng, D. Cline, W. T. Ford, R. Imlay, T. Y. Ling, A. K. Mann, F. Messing, R. L. Piccioni, J. Pilcher, D. D. Reeder, C. Rubbia, R. Stefanski, and L. Sulak), Phys. Rev. Lett. 32, 800 (1974).
- (ii) Further Observation of Muonless Neutrino-Induced Inelastic Interactions, (B. Aubert, A. Benvenuti, D. Cline, W. T. Ford, R. Imlay, T. Y. Ling, A. K. Mann, F. Messing, R. L. Piccioni, J. Pilcher, D. D. Reeder, C. Rubbia, R. Stefanski, and L. Sulak), Phys. Rev. Lett. 32, 1454 (1974).
- (iii) Measurement of Rates for Muonless Deep Inelastic Neutrino and Antineutrino Interactions, (B. Aubert, A. Benvenuti, D. Cline, W. T. Ford, R. Imlay, T. Y. Ling, A. K. Mann, F. Messing, J. Pilcher, D. D. Reeder, C. Rubbia, R. Stefanski, and L. Sulak), Phys. Rev. Lett. 32, 1457 (1974).
- (iv) Dr. Messing's thesis entitled, "A Search for Weak Neutral Currents in Semileptonic Interactions" also followed from this work. He has accepted a position as Research Associate in Physics at the Laboratory of Nuclear Studies of Cornell University.
- (v) Scaling-Variable Distributions in High Energy Inelastic Neutrino Interactions, (B. Aubert, A. Benvenuti, D. Cline, W. T. Ford, R. Imlay, T. Y. Ling, A. K. Mann, F. Messing, J. Pilcher, D. D. Reeder, C. Rubbia, R. Stefanski, and L. Sulak), Phys. Rev. Lett. 33, 984 (1974).
- (vi) Observation of New Particle Production by High Energy Neutrinos and Antineutrinos, (A. Benvenuti, D. Cline, W. T. Ford, R. Imlay, T. Y. Ling, A. K. Mann, F. Messing, R. Orr, D. D. Reeder, C. Rubbia, R. Stefanski, L. Sulak, and P. Wanderer), Phys. Rev. Lett. 34, 419 (1975).
- (vii) Invariant Mass Distributions from High Energy Inelastic Neutrino and Antineutrino Interactions, (A. Benvenuti, D. Cline, W. T. Ford, R. Imlay, T. Y. Ling, A. K. Mann, F. Messing, D. D. Reeder, C. Rubbia, R. Stefanski, and L. Sulak), Phys. Rev. Lett. 34, (1975).

In addition to the two main thrusts of the neutrino program discussed above, various coordinated aspects of those experiments have been described in the following publications:

- (viii) Flux Independent Search for New Particle Production in High Energy Neutrino and Antineutrino Collisions, (A. Benvenuti, D. Cline, W. T. Ford, R. Imlay, T. Y. Ling, A. K. Mann, F. Messing, D. D. Reeder, C. Rubbia, R. Stefanski and L. Sulak), Phys. Rev. Lett. (to be published)

- (ix) A New Measurement of High Energy Neutrino and Antineutrino Total Cross Sections, (B. Aubert, A. Benvenuti, D. Cline, W. T. Ford, R. Imay, T. Y. Ling, A. K. Mann, F. Messing, J. Pilcher, D. D. Reeder, C. Rubbia, R. Stefanski and L. Sulak), Proc. of the XVII International Conference on High Energy Physics, London (1974).
- (x) A Liquid-Scintillator Total Absorption Hadron Calorimeter for the Study of Neutrino Interactions, (A. Benvenuti, D. Cline, W. T. Ford, R. Imay, T. Y. Ling, A. K. Mann, F. Messing, J. Pilcher, D. D. Reeder, C. Rubbia, R. Stefanski, and L. Sulak), submitted to Nuclear Instruments and Methods.
- (xi) A Large Area Magnetic Spectrometer for the Study of High Energy Neutrino Interactions, (A. Benvenuti, D. Cline, W. T. Ford, R. Imay, T. Y. Ling, A. K. Mann, F. Messing, J. Pilcher, D. D. Reeder, C. Rubbia, R. Stefanski and L. Sulak), submitted to Nuclear Instruments and Methods.

The following published articles also resulted directly from the neutrino experiments at Fermilab:

- (xii) Force, Weak and Electromagnetic, (A. K. Mann), article for the 1975 McGraw-Hill Yearbook of Science and Technology.
- (xiii) The Detection of Neutral Weak Currents, (D. Cline, A. K. Mann, and C. Rubbia), Scientific American 231, 108 (1974).
- (xiv) Probing the Weak Force with Neutrinos, (D. Cline, A. K. Mann, and C. Rubbia), Physics Today, March 1974.

Direct Scientific Personnel* (Man Months)

	<u>FY 1975</u>	<u>FY 1976</u>	<u>FY 1977</u>
<u>A. K. Mann, Prof.</u>	1(3)	1(3)	1(3)
W. T. Ford, Asst. Prof.	3(4.5)	1.5(0)	-
T. Y. Ling, Res. Asst. Prof.	-	12	12
T. Y. Ling, Res. Investigator	12	-	-
Research Investigator	-	12	12
F. Messing, Graduate Student	8	-	-
Graduate Student	-	12	12

* Figures in parenthesis indicate additional research support provided, in the form of faculty salaries, by the University of Pennsylvania.

<u>Direct Cost Estimates</u>	<u>FY 1975</u>	<u>FY 1976</u> Congressional Budget	<u>FY 1977</u> Contractor's Request
Direct Salaries	55,000	71,500	73,000
Personnel Benefits	9,500	16,000	16,000
Travel	10,000	10,000	10,000
Materials and Services	12,000	12,000	12,000
Accelerator and Related Expenses	<u>21,000</u>	<u>15,000</u>	<u>15,000</u>
	\$108,000	\$124,500	\$126,000

Comments on Cost Estimates:

The major increase in salary costs from FY 1975 to FY 1976 results from a shift of University-supported personnel (W. T. Ford) to the experiment at SPEAR. The reductions in other areas may be optimistic. The limited funding in FY 1976 will have little direct impact on this experiment, since it has been given highest priority within the program, in recognition of its obvious scientific merit and our own previous investment.

B. Hadron Jet Studies

This program centers on Fermilab Experiment 246, which has been approved to run in a high-intensity pion beam. The experiment, which is a collaboration with Fermilab and the University of Wisconsin, aims at studying particle structure by examining the effects of differences between the pion and proton components at large p_T , where the parton model predicts larger average momentum for the pion component.

Technical Progress in FY 1975

Following work with a 10-ton test calorimeter tested in FY 1974, a modular calorimeter detector for NAL-246 was designed. First tests of a prototype unit were successfully completed in March 1974. This design provides a stackable system of calorimeter modules, with essentially no voids as seen on the entrance plane. Production of full-size modules started in April. Fifteen ton modules are being built with about 10 tons completed by Dec. 31, 1974 and the remainder by about March 1, 1975. A special 30-ton transporter system has been built for very rapid measurements with the calorimeter system.

Tests were carried out at BNL with several modules. First results show edge effects quite small, as predicted. The modules include 3 types each, of 2 segment sizes, designed to give optimum performance for various energies, and with the important ability to distinguish purely electromagnetic entering particles (π^0 , e^+) from others. Development of extensive collection of hardware and software for Expt. 246, and construction of initial quantities of components (amplifiers, fan-outs, fan-ins, etc.) has proceeded in parallel.

Fairly extensive tests with a system of about 15 tons are now being performed. These tests are expected to show very effective performance.

Expected Progress in FY 1976

The present schedule for the approved full-scale Experiment 246 (80 to 100 tons) is delayed because of construction fund tie-up at NAL. Because of this delay an intermediate experiment using an existing beam, to use a two-arm detector with 2 to 3 times the present 15 tons, is being prepared. Such

an intermediate set-up, while only about half the full system intended for E-246, would still permit initial study of two of the major objectives of this experiment: (1) the intensity of jets, and thus the possible elucidation of the primary mechanisms in high p_T events, and (2) the search for a 2 quark/3 quark difference in pion/proton internal structure.

Expected Progress in FY 1977

Final construction of the full-scale apparatus of E-246 should be completed. Modifications indicated by earlier experience will be incorporated. The use of this flexible calorimeter system should yield productive physics results for several years.

Direct Scientific Personnel* (Man Months)

	<u>FY 1975</u>	<u>FY 1976</u>	<u>FY 1977</u>
<u>W. Selove, Prof.</u>	2(4)	2(4)	2(4)
T. Kondo, Res. Asst. Prof.	-	12	12
T. Kondo, Res. Investigator	12	-	-
L. Kroger, Res. Inv.	7	-	-
Res. Investigator	-	8	12
W. Kononenko, Res. Spec.	12	12	12
B. Yost, Res. Spec.	12	6	6
D. Peebles, Graduate Student	12	-	-
Graduate Student	-	12	12

*Figures in parenthesis indicate additional research support provided, in the form of faculty salaries, by the University of Pennsylvania.

<u>Direct Cost Estimates</u>	<u>FY 1975</u>	<u>FY 1976</u>	<u>FY 1977</u>
Direct Salaries	57,800	57,600	64,500
Personnel Benefits	9,700	12,900	14,500
Travel	10,000	10,000	10,000
Materials and Services	36,500	20,000	20,000
Accelerator and Related Expenses	<u>5,000</u>	<u>15,000</u>	<u>15,000</u>
	\$119,000	\$115,500	\$124,000

Comments on Cost Estimates:

The figures quoted should provide adequate support for this component of the program. Because of its very high priority, it will not be impacted by limitations in the FY 1976 budget.

C. Neutrino Studies at Brookhaven

The Neutrino Program at Brookhaven is being initiated with AGS Experiment 613: Measurement of the Elastic Scattering of Neutrinos by Protons and other Neutral Current Processes at Moderate Neutrino Energies. This experiment is a collaboration with Harvard University and the University of Wisconsin.

Technical Progress in FY 1975

In the past year, extensive in situ tests of the backgrounds in this experiment were conducted. The tests indicated that a very favorable elastic scattering signal-to-noise ratio can be expected using the final design of the apparatus for this experiment. During this period, construction of the apparatus went forward, and some preliminary neutrino data were taken.

The experimental arrangement, which is soon to be completed, consists of an ionization calorimeter of about 30 metric tons mass, subdivided into about 300 separate elements, each of dimensions $7\frac{1}{2}'' \times 7\frac{1}{2}'' \times 108''$. These allow discrimination of muonless events from events with muons, and further discrimination within the family of muonless events. In addition, there are four drift chambers (each of four planes) interspersed with calorimeter segments in one-half the calorimeter; the remainder of the calorimeter is arranged as compactly as possible. Finally a very large air core magnet, with attendant drift chambers, is at the downstream end of the ionization calorimeter to measure the momentum of the outgoing muons from the charged current (muon) events. The entire apparatus is housed in a blockhouse of shielding blocks of area about 18 ft. x 25 ft. and height about 20 ft. with appropriate heating, electrical capacity and crane capacity. This laboratory was constructed for this experiment by BNL.

Expected Results in FY 1976

Several weeks of intensive running on neutrinos are anticipated in the spring of 1975, and an equivalent amount of experimental time in the fall of 1975. If the cross section for elastic ν_{μ} -p scattering is 10% as large as the cross section for quasielastic scattering ($\nu_{\mu} + n \rightarrow \mu^{-} + p$), roughly 1 elastic scattering event per hour of beam time should be observed. The

measured kinetic energy T of the recoiling proton is related to the squared momentum transfer of the event q^2 by $q^2 = 2mT$, where m is the nucleon mass. Hence a run of a few hundred hours will lead to a measurement of $\sigma(\nu_\mu + p \rightarrow \nu_\mu + p)$ with an accuracy of about $\pm 20\%$, and also a measurement of $d\sigma/dq^2$ as a function of q^2 , from which a first attempt may be made to extract the nature of that scattering process. The experiment will need to be repeated with antineutrinos for the same reason. Subsequently, it will be directed at the measurement of other neutral and charged weak current channels.

Expected Results in FY 1977

The early results from Brookhaven Neutrino Program are expected to point to other directions for which the neutrino detector may be exploited. This program should continue to be productive for at least the next several years.

Direct Scientific Personnel* (Man Months)

	<u>FY 1975</u>	<u>FY 1976</u>	<u>FY 1977</u>
<u>H.H. Williams, Asst. Prof.</u>	5.5(2)	7.5(2)	7.5(2)
A.K. Mann, Prof.	1(1)	1(1)	1(1)
A. Entenberg, Res. Investigator	12	12	12

*Figures in parentheses indicate additional research support provided, in the form of faculty salaries, by the University of Pennsylvania.

<u>Direct Cost Estimates</u>	<u>FY 1975</u>	<u>FY 1976</u>	<u>FY 1977</u>
Direct Salaries	24,400	29,000	30,600
Personnel Benefits	4,100	6,500	6,900
Travel	6,000	6,000	6,000
Materials and Services	16,000	17,000	12,000
Accelerator and Related Expenses	<u>16,000</u>	<u>15,000</u>	<u>15,000</u>
	\$66,500	\$73,500	\$67,500

Comments on Cost Estimates:

It is estimated that the costs of this experiment will remain approximately constant during the three years in question. It will not be significantly impaired by shortages in funding in FY 1976.

D. Inclusive Scattering

Technical Progress in FY 1975

AGS Experiment 635 (single particle production in the projectile fragmentation region) was completed. The analysis of this experiment and of AGS Experiment 555 (single particle production in the target fragmentation region) has been started at the University of Pennsylvania on the IBM 360/65. The reconstruction and particle identification programs have been operating on-line on a sampling basis during the running periods and require essentially no development. Data processing will consist of production runs on the data tapes to reconstruct events and write summary tapes, Monte Carlo calculations of the spectrometer acceptance, calculation of absolute cross sections, and analysis of the physics content of the data.

Fermilab Experiment 324, which extends AGS 555 to higher energy was approved in the summer of 1974. The experimental apparatus will be moved from BNL to FNAL during spring 1975.

Expected Results in FY 1976

Fermilab Experiment 324 should be completed during FY '76. Although the physics and equipment of this experiment are essentially identical to AGS 555, the following three problems require new investment of resources:

1. The duty cycle in the Meson Lab at FNAL is approximately four times lower than at the AGS. Since AGS 555 was sometimes limited by the rate at which data could be acquired by our PDP-9 computer, the data rate must be increased. To do this some of the decision-making regarding acceptable events will be converted from our PDP-9 to dedicated hardware, thereby reducing the number of times the PDP-9 is interrupted. Further a Fermilab PDP-11 will be used as a large data buffer so that the experiment is not limited by the rate at which we write tape.
2. Since this experiment measures 36 cross sections as a function of three kinematic variables, a high level of on-line monitoring diagnostics, and analysis is essential. During the AGS experiments this was provided by the OLDF PDP-10. Since no

comparable facility exists at Fermilab the most essential of these tasks must be taken over by the PDP-11. This will require a substantial investment in software. A research associate, Dr. R. Patton, from Yale University, has been added to help achieve this.

3. Because running time at Fermilab is so valuable, the equipment must have high reliability. To this end the proportional chambers (but not the electronics) are being rebuilt, and every quantity that affects the operation of the experiment will be monitored.

The analysis of our AGS data should proceed smoothly during FY 1976. The data from the Fermilab experiment can be added to the AGS data with relatively little additional programming effort. Thus results from the Fermilab experiment should come rapidly and be directly combined with those from AGS 555. All the data should be processed during FY 1976 and final publications in FY 1976 and FY 1977.

Expected Results in FY 1977

The program on inclusive scattering should be effectively complete by the beginning of FY 1977. The final phases of the analysis will be completed, and resources will be shifted from this program to other programs within the overall particle physics effort at the University of Pennsylvania.

Publication

- (i) The Approach to Scaling in Single Particle Inclusive Hadron Scattering from 4 to 24 GeV/c, (E. Beier, H. Brody, G. Featherston, D. Kreinick, K. Raychaudhuri, R. Thern, H. Takeda, R. Van Berg and H. Weisberg) (to be published).

Direct Scientific Personnel* (Man Months)

	<u>FY 1975</u>	<u>FY 1976</u>	<u>FY 1977</u>
<u>E. Beier, Assoc. Prof.</u>	2(3)	5(3)	1(1.5)
<u>H. Brody, Prof.</u>	3(3)	2(2)	1(1)
<u>H. Weisberg, Asst. Prof.</u>	5(1)	6(1)	-
R. Patton, Res. Investigator	4	10	6
R. Thern, Res. Investigator	8	10	6
R. Van Berg, Res. Spec.	8	10	4
G. Featherston, Graduate Student	12	4	-
K. Raychaudhuri, Graduate Student	8	12	-
H. Takeda, Graduate Student	6	-	-

*Figures in parenthesis indicate additional research support provided, in the form of faculty salaries, by the University of Pennsylvania.

<u>Direct Cost Estimates</u>	<u>FY 1975</u>	<u>FY 1976</u>	<u>FY 1977</u>
Direct Salaries	52,100	66,000	26,500
Personnel Benefits	8,900	15,000	6,000
Travel	8,000	10,000	1,000
Materials and Services	25,000	14,000	2,000
Accelerator and Related Expenses	<u>6,000</u>	<u>10,000</u>	<u>-</u>
	\$100,000	\$115,000	\$35,500

Comments on Cost Estimates:

Since this program is of great merit and nearly completed, it will be given adequate priority, even with limited funding in FY 1976, to be completed expeditiously.

E. Electron-Positron Interactions at SPEAR

The program at SPEAR began with SLAC SP-7; Measurement of Beam Polarization in e^+e^- Storage Rings Utilizing Elastic Scattering within a Single Bunch. It has evolved into a series of increasingly penetrating experiments, in collaboration with the University of Wisconsin and Stanford University, at SPEAR I and SPEAR II facility.

Technical Progress in FY 1975

The effort to observe polarization of a single circulating beam in SPEAR at an energy of 2.4 GeV by means of the spin dependent part of the cross section for elastic scattering of particles within a given bunch has been successful. Furthermore, preliminary evidence on the existence of polarization with two circulating beams also suggests the presence of polarization. This work will soon be extended to higher energies and to include other methods.

A collaboration between Stanford and Pennsylvania has resulted in work on the newly-discovered vector mesons, ψ and ψ' . Publications from both experiments are listed below.

In collaboration with Stanford and Wisconsin, the total hadronic cross section for the process $e^+ + e^- \rightarrow \text{hadrons}$ at a center of mass energy of 5.2 GeV has been measured, and a lower limit on the mass of heavy leptons produced in the reaction $e^+ + e^- \rightarrow L^+ + L^-$ has been determined. These results are under final study now.

Expected Results in FY 1976

First, it is planned to continue the spin-dependent Möller outscattering experiments with two circulating beams in the storage ring at an energy of more than 4 GeV. The characteristic polarization time will then be a few minutes, after which the beams should be highly polarized. During these runs simultaneous observation of azimuthal angle asymmetries in the final states of the reactions $e^+ + e^- \rightarrow \mu^+ + \mu^-$ and $e^+ + e^- \rightarrow \gamma + \gamma$ will be attempted by making use of existing, available detectors of those processes. The reaction $e^+ + e^- \rightarrow e^+ + e^-$, which should show a negligibly small azimuthal asymmetry, can be used as a control for the experiment. The simultaneous observation of both of these manifestations of beam polarization would provide

unambiguous evidence of the value of that effect in the study of e^+e^- scattering at high energies.

Second, an additional, independent monitor, with very rapid response, of beam polarization will be sought. This method may be in the Compton backscattering of blue laser light of one of the circulating beams in SPEAR, which will exhibit an up-down asymmetry if the beam is polarized. This experiment has been designed, proposed and accepted as an addendum to SP-7. The necessary apparatus is being accumulated and constructed for use at SPEAR during early FY 1976.

Third, a second addendum to SP-7 involves an experimental program to search for neutral weak current effects in the purely leptonic process $e^+ + e^- \rightarrow \mu^+ + \mu^-$ at very high center of mass energies. This was the original intent of SP-7. An experiment utilizing an iron magnetic detector of essentially 4π solid angle acceptance to detect the two muon final state has been approved by the SPEAR Program Advisory Committee for 25 weeks of beam time. The magnet, which is a series of thin toroids of different diameters arranged to form a compact sphere, fits tightly about the storage ring beam pipe, and allows for the insertion of spark or drift chambers to identify the tracks of the outgoing muons at several points along their trajectories. The basic design of the magnet is complete; detailed design will occupy the next few months, with construction to begin early in FY 76. This program must require more personnel and funds in the coming year than it has received previously if it is to reach successful fruition.

Expected Results in FY 1977

Construction, testing, and preliminary running of the apparatus described above should occupy most of FY 1976. FY 1977 will be devoted to final running, analysis, and interpretation of the results.

Publications

- (i) Measurements of $e^+e^- \rightarrow e^+e^-$, $e^+e^- \rightarrow \mu^+\mu^-$ and $e^+e^- \rightarrow \gamma\gamma$ at Center of Mass Energies Close to 3105 MeV, (R.L. Ford, B.L. Beron, E. Hilger, R.H. Fstadter, R.L. Howell, E.B. Hughes, A.D. Liberman, T.W. Martin, L.H. O'Neill, J.W. Simpson and L.K. Resvanis), submitted to Phys. Rev. Lett.
- (ii) Measurement of the Radiative Electron Polarization in a 2.4 GeV Storage Ring, (U. Camerini, D. Cline, J. Learned, A.K. Mann, and L.K. Resvanis), submitted to Phys. Rev. Lett.

Direct Scientific Personnel* (Man Months)

	<u>FY 1975</u>	<u>FY 1976</u>	<u>FY 1977</u>
<u>W.T. Ford, Asst. Prof.</u>	0	6.0(2)	7.5(2)
A.K. Mann, Prof.	1(1)	1(1)	1(1)
L. Resvanis, Res. Asst. Prof.	12	12	12

*Figures in parenthesis indicate additional research support provided, in the form of faculty salaries, by the University of Pennsylvania.

<u>Direct Cost Estimates</u>	<u>FY 1975</u>	<u>FY 1976</u>		<u>FY 1977</u>
		Congressional Budget	Contractors Revised Estimate	
Direct Salaries	22,200	20,000	32,300	32,700
Personnel Benefits	3,800	4,500	7,200	7,300
Travel	4,000	4,000	8,000	8,000
Accelerator and Related Expenses	4,000	4,000	12,000	12,000
Materials and Services	<u>7,500</u>	<u>4,500</u>	<u>29,500</u>	<u>30,000</u>
	\$41,500	\$37,000	\$89,000	\$90,000

Comments on Cost Estimates:

Although this experiment has great scientific merit, the other obligations faced, of also great merit, will prevent us, within the levels permitted by the FY 1976 Congressional Budget, to properly mount this experiment. At present, an additional \$52,000 will be required to continue the experiment expeditiously. In addition, considerable additional equipment funding is required. (See Sections II and VII)

F. Multiparticle Systems (BNL)

Significant effort has been expended on experiments with the Multiparticle Spectrometer (MPS) and with its predecessor, ARGO. The latter was the first detection system with the ability to study multiparticle final states at high p_T with comprehensive detection and momentum measurement of most of the charged particles in the final state (along with substantial particle identification capability). In addition to providing important physics results, this system provided a great deal of important practical information on the capabilities and problems of such a multiparticle magnetic detection system, very valuable for use in further experiment plans on high p_T phenomena.

Technical Results in FY 1975

Two MPS experiments, No. 557 on resonance searches, and No. 654, which is a search for charmed states, are underway. Activity by the University of Pennsylvania group has been limited by funding shortages.

Expected Progress in FY 1976 and FY 1977

The preliminary experiments with the MPS indicate that this will be a very productive tool for research. The Penn group will maintain a very active participation in the experiments listed above.

Publications

- (i) Design and Performance of the Multiparticle Argo Spectrometer System, (E.W. Anderson...L. Von Lindern...T.S. Clifford...W.P. Trower...A.R. Eerwin...W. Selove...et.al.), Nuclear Instruments and Methods 122, 587 (1974).
- (ii) Properties of Hadronic Finite States in Highly Inelastic pp Collisions at 28.5 GeV/c, (W. Schreiner, T. Clifford,...W. Selove, et.al.), Bull. APS 19, 66 (1974).

Direct Scientific Personnel* (Man Months)

	<u>FY 1975</u>	<u>FY 1976</u>	<u>FY 1977</u>
<u>W. Selove, Prof.</u>	1(1)	1(1)	1(1)
Asst. Prof.	-	-	7.5(2)
Research Investigator	-	8	-
S. Ciarochi, Res. Specialist	7	-	-
B. Yost, Res. Specialist	-	6	6

*Figures in parenthesis indicate additional research support provided, in the form of faculty salaries, by the University of Pennsylvania.

<u>Direct Cost Estimates</u>	<u>FY 1975</u>	<u>FY 1976</u>	<u>FY 1977</u>
Direct Salaries	13,700	13,800	16,300
Personnel Benefits	2,300	3,200	3,700
Travel	2,000	2,000	4,000
Accelerator and Related Expenses	5,000	3,000	8,000
Material and Services	<u>11,000</u>	<u>7,000</u>	<u>12,000</u>
	\$34,000	\$29,000	\$44,000

Comments on Cost Estimates:

The estimates above support limited by productive activity during FY 1976. Additional academic staff, anticipated in FY 1977, will permit expanded activity in this area.

G. Direct Electron Production

Technical Progress in FY 1975

During the summer of 1974 it was determined that the existing single particle spectrometer could be adapted to the study of direct electron production in hadron-hadron collisions. Because of the commitments to the university and to the recently completed AGS experiments, the resources to undertake this experiment without outside help were not available. A collaboration was formed with Professors Good, Grannis and King at SUNY-Stony Brook, and the experiment was approved (AGS 650) to run beginning October 1974.

Data taking on $pp \rightarrow e$ at 24 GeV/c was completed in December 1974, and a preliminary analysis is well under way. If a large signal ($\frac{e}{\pi} = 1.0 \times 10^{-4}$) is observed, the effect cannot be due to the decays of known vector mesons (ρ , ω , ϕ) since inclusive production of those particles has been measured at 24 GeV/c. More generally, the experiment provides an important contribution to understanding the energy dependence and possible existence of a threshold for the anomalously large direct production of leptons which has been observed at FNAL, the ISR, and Serpukov energies.

The collaboration with Stony Brook has been congenial, with both groups making important contributions. A preliminary result should be available soon, and a final result should be published early in FY '76.

Publication

Evidence for Direct Positron Production in Proton-Proton Collisions at 24 GeV/c (E. Beier, R. Thern, H. Weisberg, R. Van Berg, K. Raychaudhuri, H. Takeda, M. L. Good, P. Grannis, J. Kirz, K. Johnson) (to be published).

Direct Scientific Personnel* (Man Months)

	<u>FY 1975</u>	<u>FY 1976</u>	<u>FY 1977</u>
<u>E. Beier, Assoc. Prof.</u>	1(1.5)	1(1)	-
<u>H. Weisberg, Asst. Prof.</u>	2.5(1.0)	1.5(1)	-
R. Patton, Res. Investigator	2	2	-
R. Thern, Res. Investigator	4	2	-
R. Van Berg, Res. Spec.	4	2	-
K. Raychaudhuri, Graduate Student	4	-	-
H. Takeda, Graduate Student	6	12	-

*Figures in Parenthesis indicate additional research support provided, in the form of faculty salaries, by the University of Pennsylvania.

<u>Direct Cost Estimates</u>	<u>FY 1975</u>	<u>FY 1976</u>	<u>FY 1977</u>
Direct Salaries	20,500	17,500	
Personnel Benefits	3,500	4,000	
Travel	4,000	500	
Accelerator and Related Expenses	3,000		
Material and Services	<u>5,500</u>	<u>1,000</u>	<u> </u>
	\$36,500	\$23,000	-

H. Astrophysics

The establishment of a network of stations to search for $\bar{\nu}_e$ bursts of extraterrestrial origin, begun in the summer of 1972, is approaching completion. The detection station in the Homestake Gold Mine, Lead, South Dakota utilizing 14m^3 of detector volume began taking data in August 1973. A second station, with 28m^3 of detector volume in the PPG Limestone Mine, Barberton, Ohio became operational in June, 1974. The timing of triggers at these two stations, which are 2000 km apart, is presently correlated to within 1 msec. A description of the status and operating characteristics of this system was presented at the VII Texas Symposium on Relativistic Astrophysics and is being published in the Annals of the New York Academy of Science as part of the Proceedings of that Symposium.

Technical Progress in FY 1975

A third ν_e burst detection station is being assembled in the vehicular tunnel under Mt. Blanc, on the French-Italian border, by the University of Turin. This station, with 16m^3 of detector, should soon be added to the network. Preparations are also being made to correlate signals with those to be detected by the 100m^3 detector soon to be put into operation by G. T. Zatsepin in the U.S.S.R.

On January 4, 1974, before the two station system was in operation, a most unusual event was observed at Homestake. It consisted of four groups of pulses. Each group was $\sim 1 \mu$ sec. wide and the groups were separated by ~ 1 msec. No explanation for the event could be found within the framework of cosmic ray secondaries or local radioactivity. Also, the nature of the data and the behavior of the system before and after the event spoke against an internal electronic origin. Since the system seems immune to mining activities, no explanation for it could be found there. In the year that has passed since it occurred no other events like it have been observed, so that it appears to be quite rare.

The detectors in Barberton and Homestake are measuring the remnant cosmic ray muon flux, its angular distribution and stopping probability at depths of 2160 m.w.e. and 4400 m.w.e. respectively. This data is being reported in an article to be published in Acta Physica Austria.

Expected Results in FY 1976

1) $\bar{\nu}_e$ Burst Search

The present two station $\bar{\nu}_e$ burst detection system will continue to operate in FY 76. The main effort with respect to this system will be to maintain a high operating efficiency, modify or replace those elements of the system that prove troublesome and continue high precision time correlations between the clocks at the two sites.

In order to provide reliable time correlation between the present systems and prepare for some intercontinental time transfers between these systems and those to be put into operation in the Soviet Union and Italy, a portable Rubidium clock, the least expensive transportable instrument available for such time transfers, should be acquired.

From the mass distribution of stars in our galaxy, a maximum rate of ~ 1 collapse per year for our galaxy is predicted. From these limits it is clear that a system restricted to seeing only one galaxy, as are the present detectors, will have a low signal rate. In order to extend the range of the system into the intergalactic range and so achieve a more reasonable anticipated signal rate, it is necessary to increase the volume of the detectors by two or more orders of magnitude. It is now possible to design a relatively inexpensive $2 \times 10^3 \text{ m}^3$ detector. Assuming a source of 10^{53} ergs emitted in $\bar{\nu}_e$ and $\langle E_{\bar{\nu}_e} \rangle = 50 \text{ MeV}$, such a detector would have a range of 2×10^6 light years.

This detector would be constructed by flooding a gallery in the PPG Limestone Mine, Barberton, Ohio, and floating an array of rafts with photomultiplier tubes on the pool. The gallery available is 125 ft. long, 35 ft. wide and 28 ft. high. A plastic liner would be inserted into the water to separate the inner active clean water from the outer layer of passive water shielding. The inner volume would be divided into 10 ft. x 10 ft. cells by white plastic curtains with each cell viewed by four photomultipliers. The system would be shielded from background from the surrounding rock by the 2 ft. thick passive water shield and each cell, in addition to being an active $\bar{\nu}_e$ detector, would serve as an anticoincidence element for its adjacent cells. Continuous calibration of the system would be provided by horizontal muons, such as those produced by cosmic ray neutrino interactions, traversing the detector.

This detector would be by far the largest cosmic and stellar neutrino detector in the world. At present there are two operating detectors with volumes 28m^3 in Barberton and 14m^3 in the Homestake Gold Mine, Lead, South Dakota. The University of Turin in collaboration with the University of Pennsylvania is assembling a 16m^3 detector under Mt. Blanc. G. T. Zatsepin of the Lebedev Institute in the Soviet Union is now bringing into operation a 100m^3 detector.

At Homestake the water shield surrounding the Brookhaven Solar Neutrino Detector would be used for a second very large $\bar{\nu}_e$ burst detector. The chamber in which the Solar Detector is housed has a volume of 2000m^3 , of which about 400m^3 is occupied by the Solar Detector. About 1000m^3 of the water shield could conveniently be used for the $\bar{\nu}_e$ burst search.

In addition to providing intergalactic range for the search for $\bar{\nu}_e$ bursts these very large detector arrays can also be used for several other experiments. One, which would run concurrently with $\bar{\nu}_e$ burst search, would be the observation of interactions of ν_μ and ν_e from the decays of cosmic ray mesons in the atmosphere. The enormous dimensions of this detector will make it possible to distinguish between electron and muon secondaries from the neutrino interactions, measure secondary energy up to 10 GeV and determine the direction of the incident neutrino.

2) Solar Neutrino Problem

The first attempt to search for evidence of nuclear fusion in the Sun, the Brookhaven Cl^{37} Solar Neutrino Experiment, has produced a most startling result, an upper limit on solar ν_e flux from B^8 decay on order of magnitude below that predicted by the standard solar model. The possible sources for this discrepancy may lie in: 1) the solar model and its prediction for the B^8 production rate, 2) the properties of the neutrino as regards its passage through the Sun, its behavior between Sun and Earth and its detectability on Earth or 3) some unknown aspects of energy generation in the Sun.

A collaboration with R. Davis and colleagues at Brookhaven National Laboratory is being set up to directly look for the ν_e emitted by the main energy generating fusion reaction in the Sun, $p + p \rightarrow D + e^+ + \nu_e$. Since these ν_e range from 0 - 0.42 MeV in energy, the most promising detection approach is radio chemical using Ga^{71} , where $\nu_e + \text{Ga}^{71} \rightarrow \text{Ge}^{71} + e^-$.

The resulting Ge^{71} has a half-life of 11.4 days before it decays back by electron capture to Ga^{71} .

Several of the steps necessary for the execution of this experiment has been established. One standard approach to the separation of Ge from Ga is by solvent extraction. This has been successfully done in a small scale test. Several different approaches will be tested to find the most efficient and economical method for carrying out this separation. The extracted Ge would be converted in GeR_4 , a gas which functions very well in a proportional counter, and the Ge decays would be counted in a similar fashion to the A^{37} decays.

In order to achieve a detectable Ge decay counting rate from the $6 \times 10^{10} \nu_e/\text{cm}^2 \text{ sec.}$ that presumably arrive at the Earth from hydrogen fusion in the Sun 15-20 tons of Ga are needed. Fortunately, the widespread commercial use of light emitting diodes has resulted in a large scale increase in Ga production so that the required amount of material is now readily available. Although Ga is quite expensive, it would be possible to acquire it on the basis of repurchase at the conclusion of the experiment so that only rental charges would be incurred.

A pilot plant feasibility study of the experiment and establishment of the procedures appropriate to a full scale experiment will be carried out during the next year.

Expected Results in FY 1977

The expanded neutrino burst network will continue to take data through FY 1977. The characteristics of the detectors will make them ideal devices with which to observe the FNAL neutrino beam at large distances from Batavia, Illinois. The observation of neutrinos and the measurement of ν_μ and ν_e composition at such long distances from their source would provide limits on neutrino lifetime and constitute a search for neutrino oscillations. If one assumes that neutrino mixing is governed by the same interaction as is the $K_1 - K_2$ mass difference and one uses the present limits on lepton conservation derived from double β decay, a 2-200 km path length is indicated for Fermilab neutrino mixing. Since the ν beam flight path would be through the Earth, any small angle scattering interactions with $\sigma \geq 10^{-34} \text{ cm}^2$ would give a measurable dis-

persion in neutrino arrival time. In addition to further exploration of neutrino and weak interaction characteristics these measurements would also be of considerable interest either in understanding or in limiting the options appropriate to the Solar Neutrino Puzzle. Finally, such a program would provide precise Earth distance measurements and time variations of them that would be of geophysical interest in observing Earth body tides, continental drift and seismic effects. The pilot studies for the solar neutrino detectors will, if successful, lead to the fabrication and operation of the large Ga-based detector.

Publications

- (i) Possible Antineutrino Pulse of Extraterrestrial Origin, (G. Bozoki, W. Frati, E. Fenyves, K. Lande, C. K. Lee, and O. Saavedra), Nature 251, 485 (1974).
- (ii) Status of the Search for $\bar{\nu}_e$ Signals of Extraterrestrial Origin, (K. Lande et. al.) to be published in Annals of the New York Academy of Sciences.
- (iii) Angular Distributions and Stopping Probabilities of Muons, (K. Lande, et. al.) to be published in Acta Physica Austria.

Direct Scientific Personnel* (Man Months)

	<u>FY 1975</u>	<u>FY 1976</u>	<u>FY 1977</u>
<u>K. Lande, Prof.</u>	3(4)	3(4)	3(4)
W. Frati, Res. Spec.	6	6	6
Research Investigator		12	12
J. Supplee, Graduate Student	3	12	12

* Figures in parenthesis indicate additional research support provided, in the form of faculty salaries, by the University of Pennsylvania.

<u>Direct Cost Estimates</u>	<u>FY 1975</u>	<u>FY 1976</u>		<u>FY 1977</u>
		Congressional Budget	Contractors Revised Estimate	
Direct Salaries	22,200	22,900	35,000	37,500
Personnel Benefits	3,800	5,100	8,000	8,500
Travel	8,000	10,000	15,000	15,000
Materials and Services	<u>17,000</u>	<u>12,000</u>	<u>25,000</u>	<u>25,000</u>
	\$51,000	\$50,000	\$83,000	\$86,000

Comments on Cost Estimates:

Although this program is very exciting and potentially extremely productive, the limited funding we have assigned it in FY 1976 would preclude most of the projected expansion of the system. Unless additional funding in the amount of about \$30,000 is made available, the large detector program will not begin, and the Mt. Blanc collaboration may have to be abandoned.

I. Particle Search

A series of searches for massive long-lived particles has been made at Fermilab and IAMPF during the past few years. These experiments are now complete, and will receive little emphasis in FY 1976 or later.

Technical Progress in FY 1975

The work of IAMPF, in collaboration with physicists from IAMPF, measured cross-sections for backward production of protons, deuterons and tritons by 600 MeV and 800 MeV protons. No abnormal nuclear states were discovered, but the data are being examined to study the nuclear physics aspects.

Publications

- (i) Search for Massive Long-Lived Particles Produced by 400 GeV Protons, (S. Frankel, W. Frati, L. Resvanis, W. Yang and F. Nezzrick), Phys. Rev., D9, 1932 (1974).
- (ii) Search for Abnormal Nuclear States (in preparation).

Direct Scientific Personnel* (Man Months)

	<u>FY 1975</u>	<u>FY 1976</u>	<u>FY 1977</u>
<u>S. Frankel, Prof.</u>	3(5)**	-	-
<u>W. Frati, Res. Inv.</u>	6	-	-

*Figures in parenthesis indicate additional research support provided, in the form of faculty salaries, by the University of Pennsylvania.

**On sabbatical leave at CERN

<u>Direct Cost Estimates</u>	<u>FY 1975</u>	<u>FY 1976</u> Cong.B	<u>FY 1977</u> Contractor's Req.
Direct Salaries	17,500	-	-
Personnel Benefits	3,000	-	-
Travel	12,000	-	-
Materials and Services	<u>8,000</u>	<u>2,000</u>	<u>-</u>
	\$40,500	\$2,000	-

J. Incipient Programs

The long-range future of the entire program depends critically on new ideas and experiment only now being formulated. While much of the program for FY 1976 and FY 1977 can be predicted by a relatively simple extrapolation of present programs, a significant part of it will be new, and will replace other programs which will phase out in the next few years. Prof. S. Frankel, who is now on leave at CERN, and Prof. E. Beier, who will spend next year on leave at Fermilab, are both actively considering new experiments which deal with possible consequences with charmed particles. This is expected to lead to proposals, probably to Fermilab, for implementation in FY 1977. In addition, it is also obvious that the extrapolation of continuing programs as far ahead as FY 1977 may prove in some instances to have been incorrect.

The tables below are very rough estimates, and should be used only as an indicator of possible directions rather than a reliable guide to future activity.

Direct Scientific Personnel* (Man Months)

	<u>FY 1975</u>	<u>FY 1976</u>	<u>FY 1977</u>
<u>E. Beier, Assoc. Prof.</u>	(1)	1 (1)**	2 (3)
H. Brody, Prof.	-	1 (1)	2 (2)
S. Frankel, Prof.	1 (3)**	3 (5)	3 (5)
W. Wales, Prof.	-	1 (0)	2 (1)
W. Frati, Research Specialist	-	6	6
R. Thern, Research Specialist	-	-	6
R. Patton, Research Investigator	-	-	6
Research Investigator	-	12	12
R. Van Berg, Res. Specialist	-	-	8
Graduate Student	-	-	12

*Figures in parenthesis indicate additional research support provided, in the form of faculty salaries, by the University of Pennsylvania

**On sabbatical leave

<u>Direct Cost Estimates</u>	<u>FY 1975</u>	<u>FY 1976</u> Congressional Budget	<u>FY 1976</u> Contractor's Revised Estimate	<u>FY 1977</u> Contractor's Request
Direct Salaries	4,300	29,000	41,300	91,000
Personnel Benefits	700	6,500	9,200	20,000
Travel	2,000	6,000	11,000	15,000
Accel. & Related Expenses		2,000	2,000	10,000
Material and Services	<u>2,000</u>	<u>6,500</u>	<u>19,500</u>	<u>40,000</u>
	\$9,000	\$50,000	\$83,000	\$176,000

Comments on Cost Estimates

The funding limitations force an unpleasant choice between present and future experiments. Additional funds in FY 1976 are necessary if the program is not to falter several years in the future.

K. Terminating Programs

There are a number of experimental programs on which major experimental activity has ceased, but on which there is residual analysis or publication activity. These programs now occupy a small fraction of the resources we have available. The costs listed are for the total activity.

1. Missing Mass Investigations (Brody, Wales)

A series of experiments were performed at PPA (Brody, Wales) and at the ZGS (Brody) to study neutral bosons produced in the reaction $p + d \rightarrow \text{He}^3 + X^0$. The PPA work is now complete and published, while some final analysis work is still underway on the Argonne work.

Study of the Reaction $p + d \rightarrow \text{He}^3 + X^0$, (Brody, Groves, Van Berg, Wales, Maglich, Noren, Oostens, Silverman and Cvijanovich).
Phys. Rev. D, 1917 (1974)

2. Search for Lepton Production in High Energy Proton-Nucleus Collisions (Mann)

This experiment, Fermilab No. 184, performed in collaboration with Chicago, Harvard, and Wisconsin, has successfully performed the searches for which it was intended, namely to look for prompt single lepton production in the region of transverse momentum from about 1 to 4 GeV/c, and over incident proton energy from about 50 to 400 GeV. The data-taking stage of the experiment was completed in the fall of 1974, and the apparatus has been removed from its location in the Fermilab synchrotron. Data analysis is almost complete.

This experiment will be completed with the publication of the final reports on prompt muon production in the near future. No further effort in this direction is planned at Pennsylvania, but this research will be continued in a new experiment - - an outgrowth of E-184 - - to be carried out by Professor Pilcher at Chicago.

The Observation of Prompt Muons from Nucleon-Nucleon Interactions and a New Limit on the Production Cross Section for Massive Leptons, (D. Bintinger, J. Curry, J. Pilcher, D. Cheng, C. Rubbia, L. Sulak, W. Ford, A. K. Mann, A. Benvenuti, D. Cline, R. Imley, and P. Wanderer). Proc. of the XVII International Conference on High Energy Physics, London (1974)

A Limit on the Production Cross Section for Massive Leptons, (D. Binstinger, J. Curry, J. Pilcher, A. Zylberstajn, D. Cheng, C. Rubbia, L. Sulak, W. Ford, A. K. Mann, A. Benvenuti, D. Cline, R. Inlay, and P. Wanderer), submitted to Phys. Rev. Lett.

3. K-Meson Decays (Beier, Frankel, Mann)

The analysis of kaon decay experiments performed at Brookhaven (K_{e4} ; Beier, Mann) and at PPA ($K_{\pi 3}$, $\pi_{\mu 3}$, K_{e3} ; Frankel) is now nearly complete. All activity on this work should be finished by early in FY 1976.

Experimental Measurement of the Form Factors of the Decay $K_L^0 \rightarrow \pi^\pm e^\mp \nu$, (R. Blumenthal, S. Frankel, J. Nagy, L. Resvanis, O. Van Dyck, R. Werbeck, R. Winston and V. Highland), Phys. Rev. Lett 34, 164 (1975)

Experimental Study of Decay $K^\pm \rightarrow \pi + \pi^\mp e^\pm \nu$, (E. Beier) Preprint in preparation.

4. Inclusive Pion Production by Nuclei (Wales)

A study of pions produced by energetic nitrogen nuclei striking a variety of targets was performed at the PPA in the spring of 1972 with physicists from the Princeton Particle Accelerator. The analysis of the experiment is now complete, and a final paper has been accepted for publication by the Physical Review.

Measurement of Charged-Pion Production by 7.28 GeV Nitrogen Ions, (W. Schimmerling, K. G. Vosburgh, K. Koepke, and W. D. Wales), Phys. Rev. Lett 33, 1170 (1974).

5. Bubble Chamber Experiments (Selove)

The Bubble Chamber program is now completely finished at Pennsylvania, but a few papers from final analysis of a few experiments still continue:

$\pi^- \pi^+$ Cross Section Determined by Extrapolation Methods, (P. Jacques, W. Selove, et.al.), Bull. APS 19 566 (1974)

Search for Evidence of a $\Delta(1236)$ - $\Delta(1236)$ Component of the Deuteron, (C. Horne, S. Hagopian, V. Hagopian, ...J. R. Bensinger, et.al.) Phys. Rev. Lett. 33, 380 (1974)

<u>Direct Cost Estimates</u>	<u>FY 1975</u>	<u>FY 1976</u> Congressional Budget	<u>FY 1977</u>
Direct Salaries	1,700	800	-
Personnel Benefits	300	200	-
Travel	2,000	1,000	-
Materials and Services	<u>2,000</u>	<u>1,000</u>	<u>-</u>
	\$6,000	\$3,000	-

III. Operations - Theory

Although the division of the experimental effort into specific experimental programs is quite logical and perhaps even informative, a similar division of the theoretical effort is more difficult and may be somewhat misleading. The total effort in nuclear and particle theory in the Physics Department includes five senior faculty, two junior faculty, six research investigators (post-doctoral appointments) and seven graduate students. Since two of the five senior faculty, three of the six research associates, and three of the seven students are funded through a contract with the National Science Foundation, much of the total effort here is not included in this report. The nominal division of effort, into high energy theory, medium and low energy theory, and astrophysics, ignores the very vital and productive interactions among the persons involved.

A. Particle Theory

Work in theoretical high energy physics at the University of Pennsylvania goes on in several different areas, often because one or another individual will shift his interests. Of particular note is the blend of fundamental theory and phenomenology with emphasis smoothly shifting from one to another. This will become clearer as the work of some of the individuals in the group is described. The research atmosphere in high energy physics at the University of Pennsylvania also benefits greatly from the presence of Ralph Amado and Henry Primakoff, specializing respectively in strong and weak interactions. Although they are supported by a separate contract with the National Science Foundation, their work complements and supports the work of the ERDA-supported theorists.

Technical Progress in FY 1975

Paul Langacker, a research associate, is well known for his work on chiral symmetry. About six months ago he did interesting work in attempting to phenomenologically fit rising hadron collision cross sections. Now he is engaged in studying the asymptotic behavior of Green's functions for theories with bound states. John Ng, another research associate, has worked in the areas of conformal symmetry and Reggeon calculus recently, but presently is attempting to fit the recent experimental data on dimuon production in inelastic neutrino scattering.

This particular effort, in collaboration with Emanuel Derman*, another research associate, and Lay Nam Chang, an assistant professor, hypothesizes that the energetic neutrino converts, by a weak interaction, into a heavy neutral lepton, which subsequently decays into two muons and a neutrino. The opposing view is that the neutrino converts into a single muon, but that among the final hadron states lies one, perhaps with charm, which rapidly decays semi-leptonically.

Lay Nam Chang has been working for the past five years on the dual resonance model of strong interactions, going back to an early collaboration with Nambu at the University of Chicago. He is one of the internationally acknowledged leaders in this field and the author, with F. Mansouri of Yale, of the relativistic string model, presently the most popular approach to dual resonance models. He foresees continued work in this area with collaborators during the next few years.

Gino Segré has been working recently in several different areas of high energy physics; his latest interest is in a model of weak interactions which is renormalizable, reproduces the known low energy phenomenology, but for which the fundamental interaction is mediated by scalar rather than vector mesons. Experimentally it is distinguishable from gauge models by as of yet inconclusive experiments such as elastic ν_{μ} -electron scattering.

The bulk of Abraham Klein's work is described later in this report; his recent efforts lie in the direction of trying to construct field theoretical models of quark containment.

Expected Results in FY 1976 and FY 1977

In such a rapidly changing field, it is hard to prophesy what the group will be working on two or three years from now; they have all benefited from the freedom to pursue whatever problems seemed interesting to them at the time and hope to use the same approach to maintain their high productivity.

Publications

- (1) Investigations in Two Dimensional Vector Meson Field Theories, (G. Segré and W. Weisberger), Phys. Rev. D, 1767 (1974).

*supported by NSF

- (ii) Low Energy Theorem for Radiative Corrections to Pion Nucleon Scattering Lengths, (G. Segré), Phys. Rev. D, 2934, (1974).
- (iii) Scalar Models of Weak Interactions, (G. Segré) Phys. Rev. Lett. 33, 1244, (1974).
- (iv) The Conductive String: A Model for Hadrons, (L. N. Chang, C. E. Carlsen, F. Mansouri, J. Willemsen) Phys. Rev. D, (1974).
- (v) Models of Particles with Internal Structure, (L. N. Chang and F. Mansouri) Proceedings of Johns Hopkins Workshop on Current Problems, (1974).
- (vi) Dual Strings, (L. N. Chang), Proceedings of XVII Conference on High Energy Physics, London, (1974).
- (vii) Supersymmetric String Model and Supergauge Constraints in Dual Resonance Models, (L. N. Chang, K. Macrae and F. Mansouri) Preprint.

Direct Scientific Personnel* (Man Months)

	<u>FY 1975</u>	<u>FY 1976</u>	<u>FY 1977</u>
<u>G. Segré, Prof.</u>	3(4.5)	3(9)**	3(4.5)
Lay Nam Chang, Ass't. Prof.	3(4.5)	3(4.5)	3(4.5)
P. Langacker, Res. Inv.	12	-	-
P. Langacker, Ass't. Prof.	-	3(4.5)	3(4.5)
J. Ng, Res. Inv.	10	12	
Res. Inv.	-	12	12
Res. Inv.	-	-	12
D. Wilkinson, Grad. Student	12	-	
Grad. Student	-	12	12

*Figures in parenthesis indicate additional research support provided, in the form of faculty salaries, by the University of Pennsylvania.

**On leave at CERN

<u>Direct Cost Estimates</u>	<u>FY 1975</u>	<u>FY 1976</u> Congressional Budget	<u>FY 1977</u> Contractor's Request
Direct Salaries	35,500	47,000	49,000
Personnel Benefits	6,000	10,500	11,000
Travel	3,000	3,000	3,000
Material and Services	<u>4,000</u>	<u>5,000</u>	<u>5,000</u>
	\$ 48,500	\$ 65,500	\$ 68,000

B. Low and Intermediate Energy

The total effort in this rather ill-defined area spans the range from nuclear structure to quark confinement. In addition to the personnel listed below, Professors Ralph Amado and Henry Primakoff, whose research is supported by the National Science Foundation, are also pursuing vigorous programs in this area.

Technical Progress in FY 1975

1. Nuclear Structure

The theory of non-linear nuclear vibrations previously developed has been applied to single -closed - shell nuclei. The numerical program is working and results should be available shortly. This work will constitute the thesis of P. K. Chattopadhyay. The success of this first effort opens up a large research area to this new method.

2. Nuclear Forces and the Isobar Model

The problem of deriving the two-nucleon interaction from quantum field theory is being studied once more. Various methods of deriving covariant Schrodinger equations from field theory have been reviewed and codified. A form of the equation has now been derived in which the interaction kernel is an expansion in terms of the number of mesons exchanged, but there is no expansion of virtual meson effects. The isobar model has been derived as a special case of this equation, which is more general, however, and will allow corrections to this model to be calculated. Preliminary calculations indicate that the contributions of nucleon isobar intermediate states to the two-nucleon potential are badly underestimated by the conventional approximations. A paper describing the theoretical development and the preliminary numerical investigation is in preparation. The collaborator on this work is T.S.H. Lee of Bartol Research Foundation.

3. Models of Quark Confinement

An investigation of models of quark confinement has been undertaken. Two different ideas concerning this problem are being studied: (1) Confinement in a theory with gauge vector mesons and broken symmetry. Here there are two possibilities, confinement by generalized electric fields or by generalized magnetic fields. For the latter an analogy exists with the

properties of type II superconductors. (11) Bag models in which confinement is effected by a scalar field which modulates the mass of the quark (small when confined, large or even infinite mass when free). Publishable results have been obtained only for the latter so far. Methodological advances have been made in the treatment of field theories of the type involved which have led to an understanding of some shortcomings of previous work in this area and to at least a temporary pessimism concerning a class of bag models. More work is, however, warranted and will be pursued. A first paper has been completed and submitted.

4. Matrix Mechanics as a Computational Tool

This investigation is an outgrowth of the work in nuclear structure. It was realized that certain methods developed over the years to deal with problems in collective motion (algebraic and algebraic-variational methods) were in reality specialized applications of a general approach to the solution of problems in quantum theory using the method of matrix mechanics and that this represents a useful and sometimes preferable alternative to methods based on the Schrödinger equation. So far, successful work has been carried out on low-lying bound states. We plan also to exploit an approach to the semi-classical limit as an alternative to the WKB approximation.

5. Pion-Nucleus Interactions

In recent years exotic experimental probes, e.g. pions, muons, etc., have become very useful probes in obtaining nuclear structure information. The availability of good quality data from the meson factories will generate much more interest in coupling high energy and nuclear physics.

In the last year a more or less complete shell model theory of radiative pion capture has been developed. It is cast in a simple and concise form so that it can be used with directly or in a computer. The giant magnetic (GMR), the giant electric dipole (GDR) and quadrupole (GQR) resonances have been studied in the case of ^{16}O , ^6Li , ^{14}N , ^{10}B and ^{209}Bi . The results are in good agreement with experiment. Calculations involving the (π^-, γ) cross section are being continued in intermediate (Sr, Zr, etc.) and heavy (Pb etc.) nuclei.

In order to extract useful information from the (π^-, γ) reaction a good understanding of the shape of the background is required. This

results primarily from γ -ray followed by simultaneous particle emission, e. g. $(\pi^-, n\gamma)$. The shape of the background had hitherto been treated phenomenologically in the context of the pole model. A method has been developed whereby the background is treated microscopically in the context of direct reaction theory in the distorted wave impulse approximation using realistic pion and nuclear wave functions. Good agreement with experiment is achieved regarding the shape of the background in the case of ^{14}N and ^{16}O . However, there remains the problem of overall normalization.

6. Giant Dipole Resonance

The understanding of the properties of the giant dipole resonance (GDR) [shape, width, location] is one of the most interesting problems in nuclear physics. We attempted to explain these properties microscopically using shell model wave functions, realistic nuclear-nucleon interactions and utilizing the isospin quantum number. A generalized schematic model, appropriate for non closed-shell nuclei, was proposed on a way of understanding the fragmentation of the GDR.

Expected Results in FY 1976

Of the work described for 1975 items (1) and (2) and (4) are definite programs with guaranteed results if the personnel to carry out the work is available. Category (3) is highly speculative. It may develop greatly or it may collapse. Prof. A. Klein will be on sabbatical leave at M.I.T. during much of FY 1976 and part of FY 1977. There he hopes personally to pursue programs (2) and (3). At Pennsylvania, there will be at least one and possibly two graduate students to study and develop (1) and (4).

In the very recent past the study of pions following absorption of high energy γ -rays, i.e. (γ, π) reaction, has developed into a useful tool for obtaining nuclear structure information. The formalism described in section 5 above is now being modified to accommodate this reaction. Realistic pion wave functions are obtained using the recent pion nucleus optical potential of the Pittsburgh group. The importance of double β -decay in the theory of weak interactions, in particular lepton violation, has been emphasized. The calculation of the nuclear matrix elements in the double β -decay of the experimentally interesting nuclei $^{82}\text{Se} \rightarrow ^{82}\text{Kr}$, $^{76}\text{Ge} \rightarrow ^{76}\text{Se}$, $^{128}\text{Te} \rightarrow ^{128}\text{Xe}$ and $^{130}\text{Te} \rightarrow ^{130}\text{Xe}$ is now in progress and will continue in FY 1976.

Since the experiments performed in the meson factories are beginning to provide a rich supply of pion-nucleus inelastic data, it is of great theoretical interest to examine the intermediate energy pion-nucleus inelastic scattering. The point of view adopted is a direct reaction mechanism in the framework of the standard distorted wave impulse approximation. The pion distorted waves are obtained from optical potentials based on the basic pion-nucleon collision matrix and the nuclear wave functions are obtained from the standard shell model theory.

Expected Results in FY 1977

While some of the directions in FY 1977 are now distinct, much of the work will depend on the results of work in FY 1975 and FY 1976. This is particularly true of much of the speculative work discussed early in this section. The intermediate energy program outlined above will be expanded and collaboration with various experimental groups (Berkeley, M.I.T.) will be encouraged. The number of people likely to use our computer code, which links intermediate energy and nuclear physics, is expected to increase. This program will be expanded further to cover more complex nuclei which are of experimental interest.

The effects of exchange currents in electromagnetic and weak processes in nuclei will be examined. The highly hindered Gamow-Teller transition $^{14}\text{C}(0^+) \rightarrow ^{14}\text{N}(1^+)$ with $\log ft = 9.0$ will be the first to be investigated. Because of the above mentioned hindrance exchange current effects are expected to be crucial. These investigations will be linked to the radiative pion absorption on ^{14}N and may shed some more light in PCAC theory.

Publications

- (i) Simple Estimate of Deformations in the Aligned Coupling Scheme, (A. Klein and C. Dasso), Phys. Rev. C9, 414 (1974).
- (ii) The Coriolis Anti-Pairing Transition in a Simplified Shell Model with the Symmetry of $R(5) \times R(5)$, (A. Klein and C. Dasso), Nucl. Phys. A222, 445 (1974).
- (iii) Boson-Like Expansion Without Bosons: Application to Several Exactly Soluble Models with Collective Features, (A. Klein, P. K. Chattopadhyay and F. Krejs), Nucl. Phys. A229, 509 (1974).
- (iv) Lie Algebras, Exactly Soluble Shell Models and Theories of Collective Motion, (A. Klein), Revista Mexicana de Fisica 23, 59 (1974).

- (v) On Contributions to the Pion-Nucleus Optical Potential Non-Linear in Nuclear Density: The Ericson-Ericson Lorentz-Lorenz Correction, (A. Klein and J. Rafelski), Phys. Letts. 49B, 318 (1974).
- (vi) Remarks Concerning a Model Field Theory Suggested by Quantum Electrodynamics in a Strong Electric Field, (A. Klein and L. Fulcher), Annals of Physics 84, 335, (1974).
- (vii) Possible Measurement of the Vacuum Polarization in Heavy-Ion Scattering, (A. Klein and J. Rafelski), Phys. Rev. C9, 1756 (1974).
- (viii) What We Can Learn About Quantum Electrodynamics from Heavy Ion Collisions, (A. Klein and J. Rafelski), Proceedings of the Nashville Conference on Heavy Ion Reaction, North Holland Publishing Co., 397 (1974).
- (ix) Instabilities of Matter in Strong External Fields and at High Densities, (A. Klein and J. Rafelski), Fundamental Theories in Physics, Plenum Press, 153, New York (1974).
- (x) QED of Spin 1/2 and 0 Particles in External Fields of Arbitrary Strength, (A. Klein and J. Rafelski), In press in an AIP Conference Proceeding.
- (xi) Derivation of Relativistic Three-Dimensional Formalisms from the Bethe-Salpeter Equation, (A. Klein and T.S.H. Lee), Phys. Rev. D10, 4308, (1974).
- (xii) Inclusion of Pauli Principle Constraints in Equations of Motion Methods for the Nuclear Many-Body Problem, (A. Klein and P. K. Chattopadhyay), Phys. Rev. C11, 610 (1975).
- (xiii) Bose Condensation in Super-Critical External Fields, (A. Klein and J. Rafelski), Phys. Rev. D11, 300 (1975).
- (xiv) The Structure Transition Probabilities and π^- Capture Rates of the A=6 Nuclei, (J. D. Vergados), Nucl. Phys. A220, 259 (1974).
- (xv) Radiative Pion Capture in ^{209}Bi and the GQR, (J. D. Vergados et. al.), Phys. Rev. C11, 1140 (1974).
- (xvi) Realistic Calculations of the $(\pi^-, n\gamma)$ Reaction, (J. D. Vergados and T.S. Lee), Phys. Letts. 53B, 125 (1974).
- (xvii) The Fragmentation of the Giant Dipole Resonance in the Schematic Model, (J. D. Vergados), Phys. Letts. 53B, 151 (1974).
- (xviii) The $T = T_z + 2$ GDR and Dipole States of the A=6 and A=14 Nuclei, (J. D. Vergados), Nucl. Phys. A205, 170 (1974).
- (xix) Excitation of Giant Magnetic Resonance and the Spin-Isospin Dipole States in Radiative π -Capture on ^{14}N and ^{10}B , (J. D. Vergados, et. al.), to be published in Physical Review.
- (xx) Shell Model Theory of Radiative Pion Capture, (J. D. Vergados), submitted for publication in Nuclear Physics.

Direct Scientific Personnel*(Man Months)

	<u>FY 1975</u>	<u>FY 1976</u>	<u>FY 1977</u>
<u>A. Klein, Prof.</u>	3(4)	3(9)**	3(4.5)
J. Vergados, Ass't. Prof.	3(4.5)	3(4.5)	3(4.5)
F. Krejs, Res. Inv.	12	12	-
Res. Investigator	-	-	12
C-T Li, Graduate Student	6	12	6
P. Chattopadhyay, Grad. Student	12	12	6
Graduate Student	-	-	12

* Figures in parenthesis indicate additional research support provided, in the form of faculty salaries, by the University of Pennsylvania.

** On sabbatical leave at M.I.T.

<u>Direct Cost Estimates</u>	<u>FY 1975</u>	<u>FY 1976</u>	<u>FY 1977</u>
Direct Salaries	39,000	40,500	40,500
Personnel Benefits	6,500	9,000	9,000
Travel	3,000	3,000	3,000
Material and Supplies	<u>4,500</u>	<u>5,000</u>	<u>5,000</u>
	\$53,000	\$57,500	\$57,500

C. Astrophysics

The Astrophysics theory supported by this contract has evolved directly from particles physics work, and continues to draw heavily on and contribute to understanding of basic particle physics. It is closely allied with the experimental neutrino work discussed above, at accelerators as well as with the burst network. In addition, there are somewhat weaker associations with other astrophysics work in the Physics Department and in the Department of Astronomy.

Technical Progress in FY 1975

1. Bounds on Neutrino Intensity Imposed by the Exclusion Principle and Causality (with M. A. Ruderman, Columbia University)

Two different limits on the anti-neutrino or neutrino luminosity of a source have been derived respectively from the Exclusion Principle and from the strength and form of the weak interactions. Together with causality, the statistics of burst observations, and the maximum total mass in local astronomical objects, this Exclusion Principle limit on luminosity rules out nearby or non-relativistic sources as astrophysical models for recently reported antineutrino bursts. More distant sources with relativistically expanding shells are ruled out by the weak interaction limit.

2. Neutrino Astrophysics

This work is principally concerned with neutrino or antineutrino emission from collapsing or bouncing stars. Up to $10^{15} \text{ gm cm}^{-3}$, a hot neutron fluid behaves like an ideal gas and that the neutron-proton ratio is generally less than that of a cold neutron star. The neutrino diffusion approximation is expected to be valid down to $E_\nu = 8 \text{ Mev}$, but the Fermi statistics and the energy dependence of weak cross-sections lead to important differences between photon- and neutron-emitting stars.

From the energy release in collapse of a degenerate core to neutron star radius and the dynamics of free-fall a period $T \approx 1 \text{ ms}$ and pulse width $\Delta T > 14 \mu\text{s}$ is expected. Two limits are derived on the ν -luminosity; one from Fermi statistics and another from the strength and form of weak interactions. Together with causality, these luminosity limits imply that if ν or $\bar{\nu}$ bursts occur five times a year: (1) They must contain $< 2 \times 10^7$

erg cm⁻² per burst or the maximum energy neutrino detected must have $E_m > 100$ Mev; (2) The source is more than 40 pc away and so contracted relativistically that $\gamma \equiv (1 - v^2/c^2)^{-1/2} \gg 16$; (3) The source must be larger than 8×10^6 cm so that even when Lorentz contracted, the pulse width $\Delta T \gg \mu s$.

A study of the dynamics of rich clusters of galaxies shows that the missing mass cannot be attached to massive superhalos about the galaxies, but must lie in intergalactic objects of lower mass. The cluster missing mass cannot, however, lie in a degenerate superstar of small mass neutrinos.

The work listed below was not directly supported by this contract in FY 1975. However, much of it was initiated with contract support in prior years.

3. Electromagnetic Fields in Curved Spaces: A Constructive Procedure
(J. M. Cohen, L. S. Kegeles)

A new procedure for computing electromagnetic fields in curved space-times reduces the problem to solving one complex linear scalar wave equation. Many space-times of astrophysical importance may be treated in this manner, including black-hole and neutron-star spaces and cosmological models.

4. Analytic Pulsar Models (J. M. Cohen, R. C. Adams, R. J. Adler and C. Sheffield)

An analytic solution to Einstein's field equations has been given. This analytic model of a uniform density slowly rotating neutron star can describe differentially as well as uniformly rotating stars.

5. Rotating Magnetic Neutron Stars in General Relativity (J. M. Cohen and E. T. Toton)

The effect of slow rotation on the dipole magnetic field of neutron stars has been studied. It is shown that the differential rotation of inertial frames produced by the effect of "dragging of inertial frames" induces an additional component of electric field outside the star. This new component, as well as the usual electromagnetic components, vanishes as in the limit of collapse of a star to its Schwarzschild radius. For typical neutron stars, the electric quadrupole moment is about half that obtainable from a flat space analysis.

Expected Results in FY 1976, 1977

A diffusion model treatment of ν emission from collapsing or bouncing stars is in progress that includes effects of thermal gas pressure, changing chemical composition, chemical potential transport and other effects of ν degeneracy. Calculations are being made of the composition of a perfect gas of neutrons, protons, electrons, positrons, photons, neutrinos and antineutrinos in β - and γ -equilibrium both where the matter was transparent and where it was opaque to neutrinos. Numerical hydrodynamic calculations will be made initially for the adiabatic oscillations of a sphere containing hot gas and radiation pressure, and ultimately including radiation loss. Research activities will focus on astrophysical consequences of recent developments in neutrino physics, with particular emphasis on the Pennsylvania experiment work in this area.

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- (i) Cosmological Neutrinos in Neutrinos - 1974, (S. A. Bludman), American Institute of Physics, ed. C. Baltay, New York, (1974).
- (ii) Bounds on Neutrino Burst Intensity Imposed by the Exclusion Principle and Causality, (S. A. Bludman and M. A. Ruderman), Astrophysical Journal, 195, L19 (1975).
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- (iv) Mass and Stability of Rigidly Rotating Relativistic Polytropes, (K. Van Riper), Annals of Physics (1975).
- (v) Electromagnetic Fields in General Relativity: A Constructive Procedure, (J. M. Cohen and L. S. Kegeles), Phys. Lett. 47A, 261, (1974).
- (vi) Electromagnetic Fields in Curved Spaces: A Constructive Procedure, (J. M. Cohen and L. S. Kegeles), Phys. Rev. D10, 1070, (1974).
- (vii) Analytic Pulsar Models, (R. C. Adams, R. J. Adler, J. M. Cohen, and C. Sheffield), Astrophysical Journal, 192, 525 (1974).
- (viii) Rotating Magnetic Neutron Stars in General Relativity, (J. M. Cohen and E. T. Toton), Ann. Phys. 87, 244 (1974).
- (ix) Antineutrino Pulses Expected from a Newly Formed Hot Vibrating Neutron Star, (S. A. Bludman, J. M. Cohen and K. Lande), General Relativity and Gravitation (1975).

- (x) Neutrino Cosmology, (S. A. Bludman), General Relativity and Gravitation (1975).

Scientific Personnel* (Man Months)

	<u>FY 1975</u>	<u>FY 1976</u>	<u>FY 1977</u>
<u>S. Bludman, Prof.</u>	3 (4.5)	3 (7)**	3 (5)
K. Van Riper, G.S.	12	6	-
G.S.			12

*Figures in parenthesis indicate additional research support provided, in the form of faculty salaries, by the University of Pennsylvania.

** On sabbatical leave during Spring, 1976.

<u>Direct Cost Estimate</u>	<u>FY 1975</u>	<u>FY 1976</u>	<u>FY 1977</u>
Direct Salaries	12,500	13,500	16,400
Personnel Benefits	2,000	3,000	3,600
Travel	2,000	2,000	2,000
Materials and Services	<u>2,000</u>	<u>2,000</u>	<u>2,000</u>
	\$18,500	\$20,500	\$24,000

IV. Operations - Support Services

A. Computer

The total research program is supported by an IBM 360/65 computer facility. This facility is used for theoretical calculations, Monte-Carlo simulation, and data analysis. The computing costs (cost per calculation) have been kept low by maintaining only a staff sufficient to provide minimum operation and programming support. In addition, computing services are provided, at cost, to other elements of the University when spare capacity. This sale of service reduces the net cost to this contract.

<u>Direct Cost Estimates</u>	<u>FY 1975</u>	<u>FY 1976</u> Congressional Budget	<u>FY 1977</u> Contractor's Request
Direct Salaries	70,000	77,600	81,700
Personnel Benefits	12,000	17,400	18,300
Materials and Services	(36,000)	(42,000)	(45,000)
Computer Usage Costs, Rentals, and Maintenance	<u>34,000</u>	<u>37,000</u>	<u>37,000</u>
	\$80,000	\$90,000	\$92,000

Comments on Cost Estimates

We hope to add an additional programmer-analyst in FY 1976, which will provide better service to the physicists here. Part of the additional costs would be recovered from other users of this service.

B. Engineering and Technical Support

A pool of mechanical and electronic technicians, supervised by a research specialist (L. Taylor) provides long-term engineering design and short-term technical support for the experimental research groups. The groups' tasks have ranged from design of electronic interfaces to routine maintenance of small computers. During the past year most of the work has been on direct support (fabrication and testing) of the experimental program. It is anticipated that future activities will be similarly directed, with most emphasis on direct support of the highest priority aspects of the experimental program.

<u>Direct Cost Estimates</u>	<u>FY 1975</u>	<u>FY 1976</u>	<u>FY 1977</u>
Direct Salaries	72,300	77,600	81,700
Personnel Benefits	12,200	17,400	18,300
Materials and Services	<u>4,500</u>	<u>5,000</u>	<u>5,000</u>
	\$89,000	\$100,000	\$105,000

C. Administration

The internal administration of the funds provided by the contract is supervised by a senior faculty member (W. Wales), part of whose salary is a direct charge to administration. In addition, one-half salary for a research specialist (L. Taylor) who provides an interface between the contract and the Chicago Operations Office, is a direct charge. In addition, charges for various administrative services provided by the Physics Department, such as purchasing, accounting, vehicle service, etc. are made to this account. Administrative services provided by the Central University Administration are not charged directly, but are supported by overhead funds.

<u>Direct Cost Estimates</u>	<u>FY 1975</u>	<u>FY 1976</u>	<u>FY 1977</u>
Direct Salaries	66,300	69,400	69,400
Personnel Benefits	11,200	15,600	15,600
Travel	3,000	3,000	2,000
Materials and Services	<u>10,000</u>	<u>11,000</u>	<u>11,000</u>
	\$90,500	\$99,000	\$98,000

Equipment Summary

The changing mode of experimental particle physics at the University of Pennsylvania has necessitated major changes in the level and use of equipment funds. A decade ago, our equipment funding was used primarily for off-the-shelf electronic gear, minor parts of actual experimental apparatus, and film-analysis instrumentation. At the present time, we depend much more heavily on the central equipment pools at accelerator laboratories for standard electronic equipment, and our investments in film-analysis equipment are nearly nil. However, the experimental programs now underway require much more major equipment investments in apparatus specific to that program. The large calorimeter systems and massive detection systems are used over a long period of time, but require a much larger specific investment than previous experiments. Although the costs are typically shared by more than one university, the share for each university contract is not consequential.

The major expenditures in FY 1976 are expected to be in support of the neutrino experiments at Fermilab and Brookhaven, the hadron jet experiment at Fermilab, and the muon experiment at SPEAR. The latter, since it is a major new program, is particularly in need of funds, and may not be expeditiously started unless additional funds are available. The table below is a summary, by experiment, and does not include contributions through other universities.

<u>Experiment</u>	<u>FY 1975</u>	<u>FY 1976*</u>		<u>FY 1977</u>
		Congressional Budget	Contractors Revised Estimate	Contractor's Request
A. Neutrino Studies at Fermilab	45,000	30,000	30,000	30,000
B. Hadron Jet Studies	65,000	30,000	30,000	50,000
C. Neutrino Studies at Brookhaven	45,000	30,000	30,000	30,000
D. Inclusive Scattering	20,000	10,000	10,000	-
E. Electron-Positron Inter- actions	5,000	30,000	65,000	70,000
F. Multiparticle Spectrometer	5,000	5,000	5,000	10,000
G. Electron Production	5,000	-	-	-

*Twelve Month Fiscal Year

	<u>FY 1975</u>	<u>FY 1976</u> [*] Congressional Budget	Contractors Revised Estimate	<u>FY 1977</u> Contractor's Request
H. Astrophysics	15,000	10,000	20,000	20,000
I. Incipient Programs	-	-	5,000	35,000
General Equipment	<u>5,000</u>	<u>-</u>	<u>-</u>	<u>5,000</u>
<u>Total</u>	\$ 210,000	\$145,000	\$195,000	\$250,000

SUMMARY OF OBLIGATIONS FOR CAPITAL EQUIPMENT

<u>Identification</u>	<u>Cost</u> (Thousands of Dollars)		<u>Reasons for Acquisition</u>	<u>Economic Data</u>
	FY'76	FY'77		
Lead-Plate Scintillation-Type Calorimeter (Gamma Catcher Type)	30	30	Neutrino experiment 1A at NAL	Only viable way to couple high Z target with total absorption detector
Scintillation-Type Calorimeter - Actively Shielded	30	30	BNL, AGS No. 613	Unique solution for unique problem
Iron Ball Detector (Iron, coils, fabrication)	25	25	SLAC - SPEAR-7 Major purpose of detector is to search for the inter- ference between weak neutral currents and electromagnetic interactions using the reaction $e^+e^- \rightarrow \mu^+\mu^-$. Detector is equally useful for detection of charm particle pair production with one particle decaying semileptoni- cally into a muon and neutrino and hadrons.	Unique
"End Cap" D. C. (18" x 12") Inside Track Detectors 8" x 8" Drift Chambers (1" wire spacing)	12	12		
Inside Scintillators	1	1		
Outside Liquid Scintillator Counters 1' x 8' or 1' x 10' container with 2 PMS, bases, TDC's, scintillator, HVPS, cables, Readout electronics	12	12		
Outside Track Detectors ~8' x 8' Drift Chambers	15	20		
Scintillation-Type Calorimeter-Hodoscope	30	50	Only suitable device for detection and identification of correlated, transverse "jets" with unusually high transverse momentum. NAL E-246	The only calori- meter design suitable for such experiments at NAL.

SUMMARY OF OBLIGATIONS FOR CAPITAL EQUIPMENT (Continued)

<u>Identification</u>	<u>Cost</u> (Thousands of Dollars)		<u>Reasons for Acquisition</u>	<u>Economic Data</u>
	FY'76	FY'77		
Multi-Particle Spectrometer	5	10	Acquisition of this equipment is required for the study of Meson resonance in collaboration with BNL, Brandeis University and University of Massachusetts.	No economic substitute to achieve suitable transverse momentum sensitivity.
General Instrumentation		5	Required to provide technical support to current and planned experiments	No viable substitute
Kennedy 9000/9230C Tape Recorder	5		Barberton/Homestake Needed to establish fiducial sites in multi-site extra-terrestrial neutrino experiment	Least expensive solution to experimental need.
$\pm 6, \pm 12, \pm 24$ volt power supply system with stand by battery - 100 amp.	5	5		
Prototype Gallium Solar ν_e Detector		15		
Rubidium Atomic Clock Hewlett Packard E21-5065A	10			
Proportional Chambers/Electronics	10		NAL 324	Only suitable equipment available
Initial design, construction and set-up	5	35	New and/or incipient programs	Needed to fund efficient start-up of new programs
	<u> </u>	<u> </u>		
TOTAL	195	250		

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Angular Distributions and Stopping Probabilities of Muons, (K. Lande, et. al.), to be published in Acta Physica Austria.

SCHEDULE 34

U. S. ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
UNDELIVERED ORDERS FOR OPERATIONS
(FORWARD FINANCING)

Number:
42-3071-001

CHICAGO OPERATIONS OFFICE

University of Pennsylvania

AT(11-1)-3071

	FY 1974	FY 1975	FY 1976 (12 Months)	FY 1976 (+3 Months)	FY 1977
(1)	(2)	(3)	(4)	(5)	(6)
Total Undelivered Orders for Operations at June 30	<u>323,887</u>	<u>343,887</u>	<u>433,000</u>	<u>445,000</u>	<u>462,000</u>
To cover in the succeeding fiscal year:					
1. Estimated costs for the first quarter;	355,379	328,887	413,000	427,000	442,000
2. Estimated commitments at the end of the first quarter	(31,492)	15,000	20,000	18,000	20,000
* Cost per Form 65					

U. S. ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION - SCHEDULE 45

OBLIGATIONS AND COSTS INCURRED FOR
CAPITAL EQUIPMENT NOT RELATED TO CONSTRUCTION

Number:
42-3071-001

APRIL 1, 1975
Date

CHICAGO OPERATIONS OFFICE
Field Office

PHYSICAL RESEARCH
Program

Budget and Reporting Classifications Number and Title	Uncosted Obligations 6/30/74	Obligations Incurred			Costs Incurred			
		FY 1975	Estimated		FY 1975	Estimated		After FY 1977
			FY 1976	FY 1977		FY 1976	FY 1977	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
35-ED-01 Physical Research; High Energy Physics		145,000	195,000	250,000	211,253	190,000	240,000	
Forward	66,253					0	5,000	10,000
Total	66,253	145,000	195,000	250,000	211,253	190,000	245,000	10,000

U. S. ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION - SCHEDULE 45
OBLIGATIONS AND COSTS INCURRED FOR CAPITAL
EQUIPMENT NOT RELATED TO CONSTRUCTION

Number:
42-3071-001

APRIL 1, 1975
Date

CHICAGO OPERATIONS OFFICE
Field Office

PHYSICAL RESEARCH
Program

Justification and Analysis of Commitments:

A. Uncosted obligations carried forward from prior fiscal year:	\$ 66,253.
B. Contractual obligations, current fiscal year to date:	<u>145,000.</u>
C. Total funding available, current fiscal year to date:	\$211,253.
D. Less current fiscal year costs:	
1. Amount recorded in CH books through January 19:	\$66,538.
2. Amounts billed for month(s) just completed not contained in D-1 above.	9,212. <u>75,750.</u>
E. Uncosted Balance	\$135,503.
F. Amount covered by required approvals under contract terms or administrative procedures. (Sub-contracts, purchase orders, work orders, work authorizations, project directives, which have not been taken into costs):	20,697. ¹
G. Amount earmarked for equipment projects after programmatic approval by AEC or a contractor official, as required by contract terms of administrative procedures, prior to final commitment:	-0-
H. Uncosted amount not included in items "F" and "G" above which will be committed by June 30, current year:	<u>114,806²</u>
I. Amount which will remain uncosted and uncommitted at June 30, current year.	<u>\$ 0 .</u>

Justification and Analysis of Commitments (Continued)

NOTE 1. Item F

	<u>Name</u>	<u>Estimated Cost</u>	<u>Scheduled Delivery Date</u>
(1)	Scintillation-Type Calorimeter Actively Shielded	\$ 19,100.	7/75
(2)	Scintillation-Type Calorimeter- Hodoscope	<u>1,597.</u>	6/75
	<u>Total</u>	\$ 20,697.	

NOTE 2. Item H

	<u>Name</u>	<u>Estimated Cost</u>	<u>Scheduled Delivery Date</u>
(1)	Proportional Chambers/ Electronics	\$ 13,100.	5/75
(2)	Scintillation-Type Calorimeter- Hodoscope	40,000.	5/75
(3)	Lead Plate Scintillation-Type Calorimeter (Gamma-Catcher Type)	25,206.	6/75
(4)	Scintillation-Type Calorimeter Actively Shielded	26,500.	6/75
(5)	$\pm 6, \pm 12, \pm 24$ volt power supply system with stand by battery - 100 amp	5,000.	6/75
(6)	Tape Recorder: Synchronous	<u>5,000.</u>	7/75
	<u>Total</u>	\$ 114,806	

U. S. ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION - SCHEDULE 46
ANALYSIS OF OBLIGATIONS FOR CAPITAL
EQUIPMENT NOT RELATED TO CONSTRUCTION

Number:
42-3071-001

APRIL 1, 1975
Date

CHICAGO OPERATIONS OFFICE
Field Office

PHYSICAL RESEARCH
Program

Budget and Reporting Classification Number and Title	FY 1975	FY 1976		FY 1977		
		Congres- sional Budget	Field Office Estimate ¹	Field Office Request		
				Total	Additions	Replacements
(1)	(2)	(3)	(4)	(5)	(6)	
35-ED-01 Physical Research; High Energy Physics	145,000	145,000				

NOTE 1. The FY 1976 estimate (Column 4) exceeds the proposed Presidential budget (Column 3) by \$ 50,000 because of the equipment acquisitions needed to support our research program. These acquisitions are detailed in the following justification schedules for Schedule 46 (46-1 through 46-13).

ERDA Chicago Operations Office		BUDGET ESTIMATES: Justification for Schedule 46, Analysis of Obligations for Capital Equipment Not Related to Construction	
CONTRACTOR: University of Pennsylvania	CONTRACT NUMBER AT(11-1)-3071	BUDGET ACTIVITY NO. 35-ED-01	189 REF. NO. 42-3071-001
1. Identification of Equipment: Lead-Plate Scintillation-Type Calorimeter (Gamma-Catcher Type)			
2. Title of Research Project for Which Required: Elementary Particle and Nuclear Research			
3. Is this research now being supported by ERDA under this contract: <u>Yes</u>		4. Cost (including transportation and installation): FY'76 \$30,000 FY'77 \$30,000	
5. Probable ordering date (commitment of funds): 1st Quarter, FY'76 1st Quarter, FY'77		6. Probable delivery date (cost date): 3rd Quarter, FY'76 3rd Quarter, FY'77	
☒ ☐			
8. Programmatic reasons for acquisition of equipment. Total-absorption particle detector is needed for neutrino experiment 1A at NAL.			
9. For Automatic data processing (ADP) equipment (major equipment item over \$200,000), identify where equipment will be located. N.A.			
10. Economic Data. Only economically viable way to couple high Z target with total absorption detector.			
11. Will there be any additional operating costs associated with the acqui- sition or operation of this equipment? <u>No</u>			
12. Will the purpose of this equipment precipitate program expansion in order to use the item efficiently? <u>No</u>			
13. What is the expected useful life of the item to be acquired? 5 years			
14. No Potential or actual adverse environmental impact.			

ERDA Chicago Operations Office		BUDGET ESTIMATES: Justification for Schedule 46, Analysis of Obligations for Capital Equipment Not Related to Construction	
CONTRACTOR: University of Pennsylvania	CONTRACT NUMBER AT(11-1)-3071	BUDGET ACTIVITY NO. 35-ED-01	189 REF. NO. 42-3071-001
1. Identification of Equipment: Scintillation-Type Calorimeter: Actively Shielded			
2. Title of Research Project for Which Required: Elementary Particle and Nuclear Research			
3. Is this research now being supported by ERDA under this contract: <u>Yes</u>		4. Cost (including transportation and installation): FY'76 \$30,000 FY'77 \$30,000	
5. Probable ordering date (commitment of funds): 1st Quarter, FY'76 1st Quarter, FY'77		6. Probable delivery date (cost date): 3rd Quarter, FY'76 3rd Quarter, FY'77	
☒ ☐			
8. Programmatic reasons for acquisition of equipment. Needed for BNL, AGS No. 613 search for weak neutral currents at the level of the EM form factor of neutrino.			
9. For Automatic data processing (ADP) equipment (major equipment item over \$200,000), identify where equipment will be located. N.A.			
10. Economic Data. Unique solution for unique problem.			
11. Will there be any additional operating costs associated with the acquisi- tion or operation of this equipment? <u>No</u>			
12. Will the purpose of this equipment precipitate program expansion in order to use the item efficiently? <u>No</u>			
13. What is the expected useful life of the item to be acquired? 5 years			
14. No Potential or actual adverse environmental impact.			

ERDA Chicago Operations Office		BUDGET ESTIMATES: Justification for Schedule 46, Analysis of Obligations for Capital Equipment Not Related to Construction	
CONTRACTOR: University of Pennsylvania	CONTRACT NUMBER AT(11-1)-3071	BUDGET ACTIVITY NO. 35-ED-01	189 REF. NO. 42-3071-001
1. Identification of Equipment: Iron Ball Detector (Iron, coils, fabrication)			
2. Title of Research Project for Which Required: Elementary Particle and Nuclear Research			
3. Is this research now being supported by ERDA under this contract: <u>Yes</u>		4. Cost (including transportation and installation): FY'76 \$25,000 FY'77 \$25,000	
5. Probable ordering date (commitment of funds): 1st Quarter, FY'76 1st Quarter, FY'77		6. Probable delivery date (cost date): 3rd Quarter, FY'76 3rd Quarter, FY'77	
☒ ☐			
8. Programmatic reasons for acquisition of equipment. For SLAC-SPEAR-7 Experiment Major purpose of detector is to search for the interference between weak neutral currents and electromagnetic interactions using the reaction $e^+e^- \rightarrow \mu^+\mu^-$. Detector is equally useful for detection of charm particle pair production with one particle decayer semileptonically into a muon and neutrino and hadrons.			
9. For Automatic data processing (ADP) equipment (major equipment item over \$200,000), identify where equipment will be located. N.A.			
10. Economic Data. Unique			
11. Will there be any additional operating costs associated with the acquisi- tion or operation of this equipment? <u>No</u>			
12. Will the purpose of this equipment precipitate program expansion in order to use the item efficiently? <u>No</u>			
13. What is the expected useful life of the item to be acquired? 5 years			
14. No Potential or actual adverse environmental impact.			

ERDA Chicago Operations Office		BUDGET ESTIMATES: Justification for Schedule 46, Analysis of Obligations for Capital Equipment Not Related to Construction	
CONTRACTOR: University of Pennsylvania	CONTRACT NUMBER AT(11-1)-3071	BUDGET ACTIVITY NO. 35-ED-01	189 REF. NO. 42-3071-001
1. Identification of Equipment: Inside Track Detectors, "End Cap" D.C. (18" x 12") (Iron Ball Detector)			
2. Title of Research Project for Which Required: Elementary Particle and Nuclear Research			
3. Is this research now being supported by ERDA under this contract: <u>Yes</u>		4. Cost (including transportation and installation): FY'76 \$12,000 FY'77 \$12,000	
5. Probable ordering date (commitment of funds): 1st Quarter, FY'76 1st Quarter, FY'77		6. Probable delivery date (cost date): 3rd Quarter, FY'76 3rd Quarter, FY'77	
☒ ☐			
8. Programmatic reasons for acquisition of equipment. For SLAC-SPEAR-7 Experiment Major purpose of detector is to search for the interference between weak neutral currents and electromagnetic interactions using the reaction $e^+e^- \rightarrow \mu^+\mu^-$. Detector is equally useful for detection of charm particle pair production with one particle decayer semileptonically into a muon and neutrino and hadrons.			
9. For Automatic data processing (ADP) equipment (major equipment item over \$200,000), identify where equipment will be located. N.A.			
10. Economic Data. Unique			
11. Will there be any additional operating costs associated with the acquisi- tion or operation of this equipment? <u>No</u>			
12. Will the purpose of this equipment precipitate program expansion in order to use the item efficiently? <u>No</u>			
13. What is the expected useful life of the item to be acquired? 5 years			
14. No Potential or actual adverse environmental impact.			

ERDA Chicago Operations Office		BUDGET ESTIMATES: Justification for Schedule 46, Analysis of Obligations for Capital Equipment Not Related to Construction	
CONTRACTOR: University of Pennsylvania	CONTRACT NUMBER AT(11-1)-3071	BUDGET ACTIVITY NO. 35-ED-01	189 REF. NO. 42-3071-001
1. Identification of Equipment: Inside Scintillators for Iron Ball Detector			
2. Title of Research Project for Which Required: Elementary Particle and Nuclear Research			
3. Is this research now being supported by ERDA under this contract: <u>Yes</u>		4. Cost (including transportation and installation): FY'76 \$1,000 FY'77 \$1000	
5. Probable ordering date (commitment of funds): 1st Quarter, FY'76 1st Quarter, FY'77		6. Probable delivery date (cost date): 3rd Quarter, FY'76 3rd Quarter, FY'77	
☒ ☐			
8. Programmatic reasons for acquisition of equipment. For SLAC-SPEAR-7 Experiment Major purpose of detector is to search for the interference between weak neutral currents and electromagnetic interactions using the reaction $e^+e^- \rightarrow \mu^+\mu^-$. Detector is equally useful for detection of charm particle pair production with one particle decaying semileptonically into a muon and neutrino and hadrons.			
9. For Automatic data processing (ADP) equipment (major equipment item over \$200,000), identify where equipment will be located. N.A.			
10. Economic Data. Unique			
11. Will there be any additional operating costs associated with the acquisition or operation of this equipment? <u>No</u>			
12. Will the purpose of this equipment precipitate program expansion in order to use the item efficiently? <u>No</u>			
13. What is the expected useful life of the item to be acquired? 5 years			
14. No Potential or actual adverse environmental impact.			

ERDA Chicago Operations Office		BUDGET ESTIMATES: Justification for Schedule 46, Analysis of Obligations for Capital Equipment Not Related to Construction	
CONTRACTOR: University of Pennsylvania	CONTRACT NUMBER AT(11-1)-3071	BUDGET ACTIVITY NO. 35-ED-01	189 REF. NO. 42-3071-001
1. Identification of Equipment: Outside Liquid Scintillator Counters, 1' x 8' or 1' x 10' container with 2 PMS. bases. TDC's. scintillator. HVPS. cables			
2. Title of Research Project for Which Required: Elementary Particle and Nuclear Research			
3. Is this research now being supported by ERDA under this contract: <u>Yes</u>		4. Cost (including transportation and installation): FY'76 \$12,000 FY'77 \$12,000	
5. Probable ordering date (commitment of funds): 1st Quarter, FY'76 1st Quarter, FY'77		6. Probable delivery date (cost date): 3rd Quarter, FY'77 3rd Quarter, FY'77	
☒ ☐			
8. Programmatic reasons for acquisition of equipment. For SLAC-SPEAR-7 Experiment Major purpose of detector is to search for the interference between weak neutral currents and electromagnetic interactions using the reaction $e^+e^- \rightarrow \mu^+\mu^-$. Detector is equally useful for detection of charm particle pair production with one particle decayer semileptonically into a muon and neutrino and hadrons.			
9. For Automatic data processing (ADP) equipment (major equipment item over \$200,000), identify where equipment will be located. N.A.			
10. Economic Data. Unique			
11. Will there be any additional operating costs associated with the acquisi- tion or operation of this equipment? <u>No</u>			
12. Will the purpose of this equipment precipitate program expansion in order to use the item efficiently? <u>No</u>			
13. What is the expected useful life of the item to be acquired? 5 years			
14. No Potential or actual adverse environmental impact.			

ERDA Chicago Operations Office		BUDGET ESTIMATES: Justification for Schedule 46, Analysis of Obligations for Capital Equipment Not Related to Construction	
CONTRACTOR: University of Pennsylvania		CONTRACT NUMBER AT(11-1)-3071	BUDGET ACTIVITY NO. 35-ED-01
			189 REF. NO. 42-3071-001
1. Identification of Equipment: Outside Track Detectors ~ 8' x 8' Drift Chambers (Iron Ball Detector)			
2. Title of Research Project for Which Required: Elementary Particle and Nuclear Research			
3. Is this research now being supported by ERDA under this contract: <u>Yes</u>		4. Cost (including transportation and installation): FY'76 \$15,000 FY'77 \$20,000	
5. Probable ordering date (commitment of funds): 1st Quarter, FY'76 1st Quarter, FY'77		6. Probable delivery date (cost date): 3rd Quarter, FY'76 3rd Quarter, FY'77	
☒ ☐			
8. Programmatic reasons for acquisition of equipment. For SLAC-SPEAR-7 Experiment Major purpose of detector is to search for the interference between weak neutral currents and electromagnetic interactions using the reaction $e^+e^- \rightarrow \mu^+\mu^-$. Detector is equally useful for detection of charm particle pair production with one particle decaying semileptonically into a muon and neutrino and hadrons.			
9. For Automatic data processing (ADP) equipment (major equipment item over \$200,000), identify where equipment will be located. N.A.			
10. Economic Data. Unique			
11. Will there be any additional operating costs associated with the acquisi- tion or operation of this equipment? <u>No</u>			
12. Will the purpose of this equipment precipitate program expansion in order to use the item efficiently? <u>No</u>			
13. What is the expected useful life of the item to be acquired? 5 years			
14. No Potential or actual adverse environmental impact.			

ERDA Chicago Operations Office		BUDGET ESTIMATES: Justification for Schedule 46, Analysis of Obligations for Capital Equipment Not Related to Construction	
CONTRACTOR: University of Pennsylvania	CONTRACT NUMBER AT(11-1)-3071	BUDGET ACTIVITY NO. 35-ED-01	189 REF. NO. 42-3071-001
1. Identification of Equipment: Scintillation-Type Calorimeter-Rodoscope			
2. Title of Research Project for Which Required: Elementary Particle and Nuclear Research			
3. Is this research now being supported by ERDA under this contract: <u>Yes</u>		4. Cost (including transportation and installation): FY'76 \$30,000 FY'77 \$50,000	
5. Probable ordering date (commitment of funds): 1st Quarter, FY'76 1st Quarter, FY'77		6. Probable delivery date (cost date): 3rd Quarter, FY'76 3rd Quarter, FY'77	
☒ ☐			
8. Programmatic reasons for acquisition of equipment. The only suitable device for detection and identification of correlated, transverse "jets" with unusually high transverse momentum. Will be used at NAL for experiment No. 246.			
9. For Automatic data processing (ADP) equipment (major equipment item over \$200,000), identify where equipment will be located. N.A.			
10. Economic Data. The only calorimeter design suitable for such experiments at NAL.			
11. Will there be any additional operating costs associated with the acquisi- tion or operation of this equipment? <u>No</u>			
12. Will the purpose of this equipment precipitate program expansion in order to use the item efficiently? <u>No</u>			
13. What is the expected useful life of the item to be acquired? 5 years			
14. No Potential or actual adverse environmental impact.			

ERDA Chicago Operations Office		BUDGET ESTIMATES: Justification for Schedule 46, Analysis of Obligations for Capital Equipment Not Related to Construction	
CONTRACTOR: University of Pennsylvania		CONTRACT NUMBER AT(11-1)-3071	BUDGET ACTIVITY NO. 35-ED-01
		189 REF. NO. 42-3071-001	
1. Identification of Equipment: Multi-particle Spectrometer Detector (MPS)			
2. Title of Research Project for Which Required: Elementary Particle and Nuclear Research			
3. Is this research now being supported by ERDA under this contract: <u>Yes</u>		4. Cost (including transportation and installation): FY'76 \$5,000 FY'77 \$10,000	
5. Probable ordering date (commitment of funds): 1st Quarter, FY'76 1st Quarter, FY'77		6. Probable delivery date (cost date): 3rd Quarter, FY'76 3rd Quarter, FY'77	
☒		☐	
8. Programmatic reasons for acquisition of equipment. Acquisition of this equipment is required for the study of Meson resonance in collaboration with BNL, Brandeis University and University of Massachusetts.			
9. For Automatic data processing (ADP) equipment (major equipment item over \$200,000), identify where equipment will be located. N.A.			
10. Economic Data. No economic substitute to achieve suitable transverse momentum sensitivity.			
11. Will there be any additional operating costs associated with the acquisi- tion or operation of this equipment? <u>No</u>			
12. Will the purpose of this equipment precipitate program expansion in order to use the item efficiently? <u>No</u>			
13. What is the expected useful life of the item to be acquired? 5 years			
14. No Potential or actual adverse environmental impact.			

ERDA Chicago Operations Office		BUDGET ESTIMATES: Justification for Schedule 46, Analysis of Obligations for Capital Equipment Not Related to Construction	
CONTRACTOR: University of Pennsylvania		CONTRACT NUMBER AT(11-1)-3071	BUDGET ACTIVITY NO. 35-ED-01
			189 REF. NO. 42-3071-001
1. Identification of Equipment: Instrumentation (Oscilloscopes, Pulse Generators, Etc.) and Special Electronics			
2. Title of Research Project for Which Required: Elementary Particle and Nuclear Research			
3. Is this research now being supported by ERDA under this contract: <u>Yes</u>		4. Cost (including transportation and installation): FY'77 \$ 5,000	
5. Probable ordering date (commitment of funds): 1st Quarter, FY'77		6. Probable delivery date (cost date): 3rd Quarter, FY'77	
☒ ☐			
8. Programmatic reasons for acquisition of equipment. Acquisition of this equipment is required to provide technical support to current and planned experiments.			
9. For Automatic data processing (ADP) equipment (major equipment item over \$200,000), identify where equipment will be located. N.A.			
10. Economic Data. No viable substitute.			
11. Will there be any additional operating costs associated with the acqui- sition or operation of this equipment? <u>No</u>			
12. Will the purpose of this equipment precipitate program expansion in order to use the item efficiently? <u>No</u>			
13. What is the expected useful life of the item to be acquired? 5 years			
14. No Potential or actual adverse environmental impact.			

ERDA Chicago Operations Office		BUDGET ESTIMATES: Justification for Schedule 46, Analysis of Obligations for Capital Equipment Not Related to Construction	
CONTRACTOR: University of Pennsylvania	CONTRACT NUMBER AT(11-1)-3071	BUDGET ACTIVITY NO. 35-ED-01	189 REF. NO. 42-3071-001
1. Identification of Equipment: Kennedy 9000/9230C Tape Recorder			
2. Title of Research Project for Which Required: Elementary Particle and Nuclear Research			
3. Is this research now being supported by ERDA under this contract: <u>Yes</u>		4. Cost (including transportation and installation): FY'76 \$5,000	
5. Probable ordering date (commitment of funds): 1st Quarter FY'76		6. Probable delivery date (cost date): 3rd Quarter FY'76	
☒ ☐			
8. Programmatic reasons for acquisition of equipment. Needed to establish fiducial sites in multi-site extraterrestrial neutrino experiment.			
9. For Automatic data processing (ADP) equipment (major equipment item over \$200,000), identify where equipment will be located. N.A.			
10. Economic Data. Least expensive solution to experimental need.			
11. Will there be any additional operating costs associated with the acquisi- tion or operation of this equipment? <u>No</u>			
12. Will the purpose of this equipment precipitate program expansion in order to use the item efficiently? <u>No</u>			
13. What is the expected useful life of the item to be acquired? 5 years			
14. No Potential or actual adverse environmental impact.			

ERDA Chicago Operations Office		BUDGET ESTIMATES: Justification for Schedule 46, Analysis of Obligations for Capital Equipment Not Related to Construction	
CONTRACTOR: University of Pennsylvania		CONTRACT NUMBER AT(11-1)-3071	BUDGET ACTIVITY NO. 35-ED-01
			189 REF. NO. 42-3071-001
1. Identification of Equipment: + 6, + 12, + 24 volt power supply system with stand by battery - 100 amp			
2. Title of Research Project for Which Required: Elementary Particle and Nuclear Research			
3. Is this research now being supported by ERDA under this contract: <u>Yes</u>		4. Cost (including transportation and installation): FY'76 \$5,000 FY'77 \$5,000	
5. Probable ordering date (commitment of funds): 1st Quarter, FY '76 1st Quarter, FY '77		6. Probable delivery date (cost date): 3rd Quarter, FY'76 3rd Quarter, FY'77	
☒ ☐			
8. Programmatic reasons for acquisition of equipment. Needed to establish fiducial sites in multi-site extraterrestrial neutrino experiment.			
9. For Automatic data processing (ADP) equipment (major equipment item over \$200,000), identify where equipment will be located. N.A.			
10. Economic Data. Least expensive solution to experimental need.			
11. Will there be any additional operating costs associated with the acqui- sition or operation of this equipment? <u>No</u>			
12. Will the purpose of this equipment precipitate program expansion in order to use the item efficiently? <u>No</u>			
13. What is the expected useful life of the item to be acquired? 5 years			
14. No Potential or actual adverse environmental impact.			

ERDA Chicago Operations Office		BUDGET ESTIMATES: Justification for Schedule 46, Analysis of Obligations for Capital Equipment Not Related to Construction	
CONTRACTOR: University of Pennsylvania		CONTRACT NUMBER AT(11-1)-3071	BUDGET ACTIVITY NO. 35-ED-01
			189 REF. NO. 42-3071-001
1. Identification of Equipment: Prototype Gallium Solar ν_e Detector			
2. Title of Research Project for Which Required: Elementary Particle and Nuclear Research			
3. Is this research now being supported by ERDA under this contract: <u>Yes</u>		4. Cost (including transportation and installation): FY'77 \$ 15,000	
5. Probable ordering date (commitment of funds): 1st Quarter, FY'77		6. Probable delivery date (cost date): 3rd Quarter, FY'77	
☒ ☐			
8. Programmatic reasons for acquisition of equipment. Prototype of detector to be used in search for ν_e from hydrogen fusion in the sun.			
9. For Automatic data processing (ADP) equipment (major equipment item over \$200,000), identify where equipment will be located. N.A.			
10. Economic Data. Least expensive solution to experimental need.			
11. Will there be any additional operating costs associated with the acquisition or operation of this equipment? <u>No</u>			
12. Will the purpose of this equipment precipitate program expansion in order to use the item efficiently? <u>No</u>			
13. What is the expected useful life of the item to be acquired? 5 years			
14. No Potential or actual adverse environmental impact.			

ERDA Chicago Operations Office		BUDGET ESTIMATES: Justification for Schedule 46, Analysis of Obligations for Capital Equipment Not Related to Construction	
CONTRACTOR: University of Pennsylvania	CONTRACT NUMBER AT(11-1)-3071	BUDGET ACTIVITY NO. 35-ED-01	189 REF. NO. 42-3071-001
1. Identification of Equipment: Rubidium Atomic Clock Hewlett Packard E21-5065A			
2. Title of Research Project for Which Required: Elementary Particle and Nuclear Research			
3. Is this research now being supported by ERDA under this contract: <u>Yes</u>		4. Cost (including transportation and installation): FY'76 \$ 10,000	
5. Probable ordering date (commitment of funds): 1st Quarter, FY'76		6. Probable delivery date (cost date): 3rd Quarter, FY'76	
☒ ☐			
8. Programmatic reasons for acquisition of equipment. Needed to establish fiducial sites in multi-site extraterrestrial neutrino experiment.			
9. For Automatic data processing (ADP) equipment (major equipment item over \$200,000), identify where equipment will be located. N.A.			
10. Economic Data. Least expensive solution to experimental need.			
11. Will there be any additional operating costs associated with the acqui- sition or operation of this equipment? <u>No</u>			
12. Will the purpose of this equipment precipitate program expansion in order to use the item efficiently? <u>No</u>			
13. What is the expected useful life of the item to be acquired? 5 years			
14. No Potential or actual adverse environmental impact.			

ERDA Chicago Operations Office		BUDGET ESTIMATES: Justification for Schedule 46, Analysis of Obligations for Capital Equipment Not Related to Construction	
CONTRACTOR: University of Pennsylvania		CONTRACT NUMBER AT(11-1)-3071	BUDGET ACTIVITY NO. 35-ED-01
		189 REF. NO. 42-3071-001	
1. Identification of Equipment: Proportional Chambers/Electronics			
2. Title of Research Project for Which Required: Elementary Particle and Nuclear Research			
3. Is this research now being supported by ERDA under this contract: <u>Yes</u>		4. Cost (including transportation and installation): FY'76 \$10,000	
5. Probable ordering date (commitment of funds): 1st Quarter, FY'76		6. Probable delivery date (cost date): 3rd Quarter, FY'76	
☒ ☐			
8. Programmatic reasons for acquisition of equipment. Required for the detection of single particle inclusive cross sections in hadron-hadron scattering for experiment NAL 324.			
9. For Automatic data processing (ADP) equipment (major equipment item over \$200,000), identify where equipment will be located. N.A.			
10. Economic Data. Only suitable equipment available.			
11. Will there be any additional operating costs associated with the acquisi- tion or operation of this equipment? <u>No</u>			
12. Will the purpose of this equipment precipitate program expansion in order to use the item efficiently? <u>No</u>			
13. What is the expected useful life of the item to be acquired? 5 years			
14. No Potential or actual adverse environmental impact.			

ERDA Chicago Operations Office		BUDGET ESTIMATES: Justification for Schedule 46, Analysis of Obligations for Capital Equipment Not Related to Construction	
CONTRACTOR: University of Pennsylvania		CONTRACT NUMBER AT(11-1)-3071	BUDGET ACTIVITY NO. 35-ED-01
			189 REF. NO. 42-3071-001
1. Identification of Equipment: Initial Design and Construction			
2. Title of Research Project for Which Required: Elementary Particle and Nuclear Research			
3. Is this research now being supported by ERDA under this contract: <u>Yes</u>		4. Cost (including transportation and installation): FY'76 \$ 5,000 FY'77 \$ 35,000	
5. Probable ordering date (commitment of funds): 1st Quarter, FY'76 1st Quarter, FY'77		6. Probable delivery date (cost date): 3rd Quarter, FY'76 3rd Quarter, FY'77	
☒ ☐			
8. Programmatic reasons for acquisition of equipment. New and/or incipient programs			
9. For Automatic data processing (ADP) equipment (major equipment item over \$200,000), identify where equipment will be located. N.A.			
10. Economic Data. Needed to fund efficient start-up of new programs.			
11. Will there be any additional operating costs associated with the acquisi- tion or operation of this equipment? <u>No</u>			
12. Will the purpose of this equipment precipitate program expansion in order to use the item efficiently? <u>No</u>			
13. What is the expected useful life of the item to be acquired? 5 years			
14. No Potential or actual adverse environmental impact.			

APPENDIX A-1

Explanation of Increases in Operating Costs1. Direct Salaries

Wage increases of five percent between FY 1975 and FY 1976 and between FY 1976 and FY 1977 are assumed. This is an extremely conservative assumption, particularly in view of the fact that inflation has recently been over twice this rate.

In addition, some very modest real growth is assumed. Under the President's budget for FY 1976, the actual staff level would not change. However, because a number of research investigators will devote the entire year to contract work, the number of man-years will be slightly higher. The incremental request would permit the addition of three research associates to aid those areas of the program which are presently endangered. The request for FY 1977 does not project any staff increase beyond the level of the incremental request, but assumes major shifts within the program.

2. Personnel Benefits

The personnel benefit rate for FY 1976 and FY 1977 is approximately five and one-half percent higher than in FY 1975. This major increase is partially due to federally-mandated increases in Social Security taxes and to increased costs of unemployment compensation. Both of these are beyond the control of the University.

3. Indirect Expenses

The indirect expense rate will increase by one percent in FY 1976 and FY 1977. The university is working vigorously to improve the efficiency of its indirect costs centers, so there is at least some prospect this rate can be reduced in the future.

4. Materials and Services

We have included no inflation factor in estimating the costs of materials and services. The increment suggested in FY 1976 is barely adequate to maintain the present level of activity. Travel costs and material costs have increased at an extraordinary rate due to inflationary effects in the recent past. If this rate continues unabated, the requested funding will be grossly inadequate for the programmed research.

Summary of University Contributions to Research Program

The University of Pennsylvania, in recognition that the work supported by the contract is a cooperative venture between the university and the Federal Government, contributes to the research program in three different ways. First, the university, over a period of five years, is making a direct financial contribution to ease the impact of the change in indirect charges which occurred on July 1, 1973. This special university direct subvention (SDUS) is itself free of indirect charges, has been extremely helpful in maintaining the momentum of the program. Second, the demands on faculty time for specific university programs are sufficiently moderate to permit them to spend part of their time during the academic year on research. This contribution of faculty time, which is estimated to be equivalent, on the average, to half time for each faculty member, is a major contribution to the program. The table below estimates the contribution from each of these sources for FY 1975, FY 1976, and FY 1977:

	<u>FY 1975</u>	<u>FY 1976</u>	<u>FY 1977</u>
SDUS	111,000	70,000	30,000
Faculty Salaries	151,800	161,300	175,000
Personnel Benefits	31,100	39,700	42,000
Equivalent Indirect Costs	<u>130,800</u>	<u>123,300</u>	<u>112,400</u>
	\$424,700	\$394,300	\$359,400

The third contribution made by the university, probably much more important than either of those mentioned above, is the maintenance of an intellectual and social environment which is both stable and conducive to long range research activity. The lifetime commitment which the university has made to its senior faculty provides a base for their own work and in turn for all other work on this contract.