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HEPAP - projections FY71 - FY76
High Energy Physics Program Informal long-range

1969 Dec

HIGH ENERGY PHYSICS PROGRAM

Informal Long-range Projections

FY 1971 - FY 1976

December 1969

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ARGONNE NATIONAL LABORATORY

November 26, 1969

Dr. Paul W. McDaniel, Director
Division of Research
U. S. Atomic Energy Commission
Washington, D. C. 20545

Dear Paul:

The enclosures are our November 26, 1969, drafts of the five-year long-range projections (FY 1971 - FY 1976) for the Argonne National Laboratory High Energy Physics Program. They represent substantially what we will present in our formal submission in mid-January 1970. We, of course, reserve the right to introduce corrections to the figures shown in this document as we subsequently compare or merge this information with our other activities.

The budgets and objectives contained in this document have been planned from the point of view of maximizing or optimizing the yield on the national investment in plant, equipment, and personnel at the ZGS. It is our position that when the levels requested are in fact authorized, the research productivity (the reason and justification for the ZGS) of the Argonne National Laboratory High Energy Physics Program will increase percentagewise at a significantly and increasingly higher rate to the percent of dollars added. The reason for this is that 100% of fixed operating costs of existing plant take priority of available dollars over opportunities for investment in research and development. Thus, approximately $2 million of new, fixed operating costs ($1. 5 million for the 12-ft Bubble Chamber; $. 5 million for new experimental areas) force trade off of dollars from frontier research and development to the coverage of fixed cost commitments. (For clarity and objectivity, it should be recognized that even though these facilities are classified under the general USAEC heading of Research Costs, the effect to R & D programs is that of rigid fixed costs.) We believe this constriction is inherently wrong and inconsistent with national objectives for any new publicly-owned laboratory. This is especially significant with regard to major investments in advanced concept R & D machines, such as the ZGS and its facilities, wherein opportunities for maximization, optimization, and frontier penetration (cracking the walls of ignorance) decrease with the passing of time.

Sincerely,

Bob Duffield

Robert B. Duffield
Laboratory Director

RBD:gd

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ARGONNE NATIONAL LABORATORY

BUDGET ASSUMPTIONS

05 PROGRAM

ANL HIGH ENERGY PHYSICS

FY 1972 - FY 1976

November 24, 1969

"DRAFT"

Substantially correct but may require correction to minor details.

	SCIENTIFIC MAN YEARS						
	FY 1971						
	President's Budget	Current ANL Plan	FY 1972	FY 1973	FY 1974	FY 1975	FY 19[cut off]
05-01 High Energy Physics	~210	234.3	251.3	259.2	262.2	265.2	265.2

	SCIENTIFIC MAN YEARS						
	FY 1971						
	President's Budget	Current ANL Plan	FY 1972	FY 1973	FY 1974	FY 1975	FY 197
05-01 High Energy Physics							
05-01-05 Zero Gradient Synchrotron							
05-01-05-01 Research	~ 117	121.4	128.4	132.3	135.3	138.3	138.3
05-01-05-02 Design and Development of Devices	~ 57	72.9	80.9	84.9	84.9	84.9	84.9
05-01-05-03 ZGS Operations	~ 36	40.0	42.0	42.0	42.0	42.0	42.0
TOTAL	~ 210	234.3	251.3	259.2	262.2	265.2	265.2

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SCHEDULE B

U.S. ATOMIC ENERGY COMMISSION
Argonne National Laboratory
Budget Assumptions - Operating Expenses
for Physical Research Program
for FY 1972 - FY 1976

	BUDGET PROJECTIONS (in thousands)						
	FY 1971						
	President's Budget	ANL Current Estimate	FY 1972	FY 1973	FY 1974	FY 1975	FY 197
Summary of Estimates by Category							
Operating Costs:							
05-01 High Energy Physics	18,200	20,755	22,554	23,091[1]	23,286[1]	23,486[1]	23,673

[1] 1973 through 1976 amounts do not include price level adjustments.

OPERATING COST ASSUMPTIONS BY CATEGORY

HIGH ENERGY PHYSICS 05-01

	BUDGET PROJECTIONS (in thousands)						
	FY 1971						
	President's Budget	ANL Current Estimate	FY 1972	FY 1973	FY 1974	FY 1975	FY 19[illegible]
05-01 High Energy Physics							
05-01-05 Zero Gradient Synchrotron							
05-01-05-01 Research	~ 9,800	10,719	11,293	11,416	11,523	11,630	11,722
05-01-05-02 Design and Development of Devices	~ 3,900	5,298	5,929	6,318	6,366	6,414	6,464
05-01-05-03 ZGS Operations	~ 4,500	4,738	5,332	5,357	5,397	5,442	5,487
TOTAL	~18,200	20,755	22,554	23,091 (1)	23,286 (1)	23,486 (1)	23,673

(1) 1973 through 1976 amounts do not include price level adjustments.

SCHEDULE B (OPERATING)

HIGH ENERGY PHYSICS - BUDGET ASSUMPTIONS

Major new activities in the ANL High Energy Physics Program in FY 1971 and FY 1972 will be centered around utilization of the 12-ft Hydrogen Bubble Chamber and bringing the new extension to the first external proton beam experimental area into use. These activities are essential parts of our long-range plan to continue to provide at ANL the facilities necessary to carry out a highly competitive and economical program of elementary particle research. Such facilities have allowed us to serve the needs of a continually increasing number of user groups from throughout the United States. In addition, the accuracy of our statement in recent years that the growth and development of the National Accelerator Laboratory would increase the need for diverse facilities at the ZGS is now becoming increasingly evident. Proposals for use of the ZGS by NAL experimental groups were received and acted on this past year; the first approved experiment by an NAL group is scheduled to run at the ZGS during FY 1971. As the number of experimental high energy physicists at NAL continues to grow, and as more experimental apparatus for the NAL groups enters the testing stage, the need for use of the ZGS facilities for such purposes will increase manyfold.

The past year has seen a significant increase in the experimental facilities at the ZGS Complex. The 12-ft Hydrogen Bubble Chamber was successfully tested in October; the first neutrino experiment is scheduled to begin running with this chamber early in CY 1970. The second external proton beam experimental area has been brought into operation. Currently, there are several counter/spark chamber experiments operating simultaneously in this area on a regular schedule. Additional beam lines and experiment stations have been installed in the other experimental areas. During recent months, as many as eight counter/spark chamber experiments, a bubble chamber experiment, and a test beam have been operated simultaneously for extended periods; it has become routine to operate six to seven experiments simultaneously.

Notable success was also achieved in the area of automatic processing of bubble chamber film. The POLLY-II device was put into service early in CY 1969 and by midyear was automatically scanning and measuring film. Currently the device processes events (scan and measure) at a rate of some 80 events per hour, with a precision and reliability exceeding those of non-automated machines.

The continued intense interest of the entire high energy physics community in the elementary particle research program and facilities at the ZGS and the clear need for a strong ZGS physics program complementary to the activities at the National Accelerator Laboratory make it essential that the present facilities be adapted to serve the largest possible number of user groups.

Research

The operating budgets proposed for FY 1972 and subsequent years are considered to be minimal levels for the efficient exploitation of the ZGS. Utmost significance is attached to the use of the 12-ft Bubble Chamber for physics purposes, scheduled to commence in early CY 1970. With this completely unique detector becoming operational, it will be essential to utilize it fully and effectively. A whole class of important new experiments will become possible by making available neon for hydrogen-neon mixture fillings.

The total ANL high energy physics experimental program has been increased by more than a factor of two in the past two years. This has been accomplished within severe financial restrictions, primarily as the result of four identifiable efforts:

1. The efficiency of operations in the experimental area has been subjected to continual scrutiny and automation, particularly for hydrogen targets, power supplies, beam lines, and in the installation of experiments.
2. The increased operational efficiency even in multipulsing modes of both the 30-in. Bubble Chamber and the 40-in. Bubble Chamber has made possible a reduction in the size of the operating crews.
3. Operation of these two bubble chambers has been cut back: the two chambers have been operated only alternately for the past year, resulting in reduced power and film costs.

4. The effort devoted to the design and development of devices has been compromised significantly. The resulting reduction in the personnel who have the responsibility to develop detectors, devices, and systems that will contribute to more efficient utilization of experimental facilities can only be viewed as an extreme sacrifice; it was essential, however, to maintain the funds for operation of the research program at a level sufficient to support the many topical physics experiments which are the heart of the ZGS program.

It is vital to restore adequate support for those productive on-going programs which have been curtailed. The ANL estimate of the operating budget for FY 1971 provides for the following improvements to the experimental facilities:

1. Beam lines, experiment stations, and experiments will be installed and brought into operation in the new extension of the first proton beam experimental area. This area will ultimately provide beams and experimental stations for five experiments operating simultaneously.
2. The scheduled operation of the 30-in. Bubble Chamber will be increased from 50% to 75%.
3. The scheduled operation of the 40-in. Bubble Chamber will be increased from 50% to 100%.
4. An adequate quantity of neon will be purchased for the 12-ft Bubble Chamber.

The increase in the number of experiments that will be carried out at the ZGS in FY 1971 and FY 1972 as a result of the operation of the 12-ft Bubble Chamber and the new experimental area will be reflected in an increase in the number of ZGS users spending time at the Laboratory. Approximately half of the increase in effort from the FY 1970 level to the FY 1972 level comes from this source. Most of the remainder represents our need to bring our resident PhD manpower level up to a point nearer that of other high energy physics laboratories. The PhD research staff must be of sufficient size to provide the on-site scientific support for planning, beam design, development of new instrumentation, acting as a focus for the research activity of the university user program, as well as for carrying out an active research program at the ZGS.

Schedule B - Operating

The operating budget for FY 1972 assumes a continuation of the program as outlined above for FY 1971 with (1) a small increase in effort toward operations of facilities and, (2) an increase in scheduled operation of the 30-in. Bubble Chamber from 75% to 100%.

Design and Development of Devices

To meet current and medium range requirements of the high energy physics program at the ZGS, continual increases in the beam intensity and the extraction efficiency will be needed over the next several years. These requirements are accentuated by the addition of the three new experimental facilities. The second external proton beam area began operation with two beam lines in FY 1969; it is now operating with three, one of which is a low momentum separated beam. The 12-ft Hydrogen Bubble Chamber will soon be operational and a heavy program of neutrino research is planned for this facility. Several additional beam lines from a thick target station in the extension to the first external proton beam area will be installed late in CY 1970. In order to meet these needs, continued strong emphasis will be placed on the development of efficient resonant extraction from the ZGS to both external proton beam experimental areas simultaneously and on the booster injector development program. Effort on these programs, which will be stressed in FY 1971, will nearly level off in FY 1972 and gradually be diverted to other development activities in later years. The latter include understanding of beam dynamics with the higher intensities anticipated for the ZGS.

Although recent budgetary restrictions have limited the number of projects, our development programs have yielded important advances in the technologies of accelerators, magnets, detector systems, film analysis, and computer utilization. These advances are important not only for the ZGS program, but for the progress of the whole field of experimental particle physics. We plan to continue development programs in several of these important areas: in particular, fast-cycling bubble chambers and streamer chambers, on-line wire chamber and composite systems, superconducting magnets for use with detection devices, and data reduction systems. We will be devoting major effort to these areas during FY 1971 and FY 1972.

Schedule B - Operating

Budget restrictions have necessitated a cancellation of our efforts relating to superconducting magnet development for accelerators. The loss of the financial capability to carry on these studies is felt most acutely. We believe superconductivity holds the key to the accelerator technology of the future. Therefore, we propose to reinstate this activity in FY 1972 and have included effort, materials and services, and equipment in the budget proposal for that year. By FY 1973 we anticipate beginning small models of superconducting accelerators into which beam can actually be injected. This may be a storage ring of 50 MeV, or possibly 500 MeV, and would establish the feasibility of achieving adequate precision of fields for such applications. For instance, it is recognized that a dc superconducting storage ring at 12.5 GeV could give an overall gain in utility of the ZGS for counter and spark chamber experiments. This gain is derived from a factor of two in repetition rate of the ZGS (two-second cycle without flattop to inject into the storage ring) and a factor of five in usage duty cycle of the protons which would be ejected continuously from the storage ring.

Other ideas on optimization of characteristics for very high energy accelerators will be studied, since boundary conditions or ideas seem to continually evolve. For instance, it is very clear as a result of many developments (not the least of which may be negative ion injection into a small rapid-cycling synchrotron) that one can achieve very high intensity at very high energy. This fact implies very long flattops at full energy and, therefore, favors superconducting magnets rather than cryogenic Al magnets, and decreases the importance of ac losses in superconductors since the rate of rise and repetition rate of the synchrotron can now be relatively slow. We propose to resume the study of very high energy accelerators in FY 1972, possibly leading to a concrete design proposal by FY 1974 or FY 1975.

ZGS Operations

The level of effort required for ZGS operations and maintenance has been stabilized. The cost increases shown represent for the most part the power costs required to achieve full utilization of the ZGS Complex in FY 1972 and beyond. Major procurements include only those now scheduled.

Schedule B - Operating

In summary, the proposed budget levels for FY 1971 and FY 1972 would avoid further major curtailment of the present program, provide some restoration, allow full utilization of the 12-ft Bubble Chamber, and generally permit the continuation of the high research productivity which characterizes the ANL high energy physics program.

U. S. ATOMIC ENERGY COMMISSION
Argonne National Laboratory
Budget Assumptions
Capital Equipment Not Related to Construction
for Physical Research Program
for FY 1972-FY 1976

	BUDGET PROJECTIONS (In thousands)						
	FY 1971						
Summary of Estimates by Category		ANL Current Estimate	FY 1972	FY 1973	FY 1974	FY 1975	FY 1976
35-05-01 High Energy Physics	$ 1,950	$ 5,065	$ 5,220	$ 5,982	$ 5,205	$ 5,250	$ 5,450

Schedule C - ANL
Physical Res.

High Energy Physics - The FY 1971 through FY 1976 equipment requirements for this program are as follows:

	FY 1971						
ZGS Complex	President's Budget	ANL Requirements	FY 1972	FY 1973	FY 1974	FY 1975	FY 1976
Research							
Beam Transport Components		$ 1,600	$ 1,680	$ 1,880	$ 2,000	$ 2,200	$ 2,200
Remote Station Computer Equipment				50	50	50	50
Equipment for Experiments		500	500	500	500	500	500
Advanced Detector Systems		220	350	250	250	250	250
Radiation Shielding		600	700	500	400	300	300
SHELF Components		100	100	100	100	100	100
Superconducting Magnet System for Large Spectrometer				875			
Other Experimental Equipment		300	300	300	330	350	450
Total Research	~ $ 1,200	$ 3,320	$ 3,630	$ 4,455	$ 3,630	$ 3,750	$ 3,850
Design and Development of Devices							
Polarized Proton Target Development		85	50	50	50	50	50
Superconducting Magnet & Cryogenic Equipment		50	50	50	50	50	50
12-ft Bubble Chamber Development (includes hydrogen target vessel)		440	425	342	350	350	350
Film Scanning, Measuring, and On-Line Data Analysis		365	300	300	300	300	300
Other Design & Development Equipment		615	395	415	455	380	480
Total Design & Development of Devices	~ $ 600	$ 1,555	$ 1,220	$ 1,157	$ 1,205	$ 1,130	$ 1,230
Operations							
Instrument Calibration and Test Equipment		$ 90	$ 120	$ 120	$ 120	$ 120	$ 120
ZGS Retirement Unit Replacements			100	100	100	100	100
Other Operating Equipment		100	150	150	150	150	150
Total Operations	~ $ 150	$ 190	$ 370	$ 370	$ 370	$ 370	$ 370
Total High Energy Physics Equipment	~ $ 1,950	$ 5,065	$ 5,220	$ 5,982	$ 5,205	$ 5,250	$ 5,450

DRAFT 11/26/69

SCHEDULE C (EQUIPMENT)

Research

The further development of the experimental areas associated with the extracted proton beams will continue to increase the number of experiments running simultaneously. To enable the new extension to get into operation on schedule, procurement is necessary of long lead-time items; e.g., magnets, separators, and power supplies. Funds requested in FY 1971 are essential for this task. The need will extend beyond this year if the beam facilities in these areas are to be fully developed; and, in subsequent years, replacement of obsolescent beam transport components will be necessary. The need for increased amounts of shielding is continual, resulting both from the expansion of the experimental facilities and from the increasing beam intensity of the ZGS.

There is a continuing need for equipment within the Laboratory's own research program. Funds requested will provide for replacements and improvements associated with such items as high-speed electronic apparatus, scintillation counter systems, Cerenkov counters, gas handling systems, and electronics for interfacing various signals to data collection systems.

An intensive program of development work is continuing, aimed at determining the physics utility and the technical feasibility of a major composite detector system. This device would have a fast cycling bubble chamber or streamer chamber as the primary detector operating inside a large superconducting magnet and followed by a downstream system of wire chambers and counters. The need for such devices is clear as strong interaction physics begins to focus on rather detailed questions about complicated reactions. We believe that the large magnet such a detector will need should be superconducting, now that the 12-ft Bubble Chamber magnet has demonstrated the feasibility and economy of such devices.

There are related needs associated with the user oriented program SHELF (Standardized High Energy Laboratory Facilities). The overall objective of SHELF is to expedite completion of scheduled experiments by having available a pool of modern electronic circuits and other relatively standard devices to aid in instrumenting experiments and beams at the ZGS. The availability of SHELF equipment to replace instruments which malfunction during an experimental run is one of many factors contributing directly to a productive experimental program. A significant economy and conservation of funds has been realized as a result of the SHELF program.

Design and Development of Devices

The FY 1971 and FY 1972 figures include equipment funds for the design and fabrication of a hydrogen target vessel to be utilized inside the 12-ft Bubble Chamber. The availability of such a device together with the planned neon-hydrogen mixtures for the 12-ft Bubble Chamber would represent a very potent enhancement to the national program in strong interaction research.

In addition to the two new projects mentioned above there are several on-going programs with continuing equipment needs. The on-line computer facilities will require continuous upgrading; nearly all wire chamber and most counter experiments are now dependent on these facilities. The film data analysis facilities such as POLLY will need further hardware to increase their versatility (e.g., in handling new film formats) and their overall productivity. Funds will be needed for equipment to modify the existing bubble chambers (for example, to fully utilize their multipulsing capabilities) to keep abreast of the special equipment needs of the users and to provide for more efficient and reliable operation. The superconducting magnet development program will be carried on with a high priority; the availability of superconducting beam transport magnets for ZGS beams will result in a large saving in future operating costs and, in addition, such magnets will have reduced physical size and greater magnetic field capabilities.

Equipment funds will be needed for the superconducting accelerator study program which is to be resumed in FY 1972. Refrigeration equipment will be needed primarily.

ZGS Operations

Continuous expenditure will be required to upgrade the current diagnostics equipment in the ring and in the external proton beams. A number of equipment items in the various ZGS component systems are gradually reaching the end of their useful life. These will be replaced as part of the maintenance program to prevent unnecessary downtime for the ZGS. Toward this end an amount is labelled, beginning in FY 1972, for ZGS retirement unit replacement.

U. S. ATOMIC ENERGY COMMISSION

Argonne National Laboratory

Budget Assumptions - Construction Projects
for Physical Research Program
for FY 1972-FY 1976

	1971 President's Budget	1971 ANL Needs	BUDGET PROJECTIONS (in millions) FY 1972	FY 1973	FY 1974	FY 1975	FY 1976
1. Accelerator Additions and Improvements - ZGS	$ .9	$ 1.65	$ 2.4	$ 3.0	$ 3.0	$ 3.0	$ 3.0
2. Direct Pulsing from Power Line				1.55			
3. Polarized Proton Source			1.0				
4. ZGS Hot Shop					1.3		
Total Construction	$ .9	$ 1.65	$ 3.4	$ 4.55	$ 4.3	$ 3.0	$ 3.0

SCHEDULE D (CONSTRUCTION PROJECTS)

	BUDGET PROJECTIONS (in thousands)					
	FY 1971	FY 1972	FY 1973	FY 1974	FY 1975	FY 1976
1. Accelerator Improvements, ZGS (sub-total)	$1,150	$1,550	$2,250	$2,050	$2,500	$3,000
Injector Improvements (Booster)	500	850	750	950	500	
Accelerator Improvements Total	$1,650	$2,400	$3,000	$3,000	$3,000	$3,000

The availability of accelerator addition and improvement funds has been a very significant factor in the successful development of the ZGS and its experimental program. Although these funds amount to only a small fraction of the total capital investment in the accelerator, they make possible a large increase in the capability of the accelerator to produce physics results. This increase is far out of proportion to the cost. A continuation of these funds is required if the accelerator is to meet the demands of the expanding experimental program represented by the extension of the first external proton beam experimental area, the operation of the second external proton beam experimental area, and the 12-ft Hydrogen Bubble Chamber.

The injector improvements will add each year to the intensity capability of the ZGS. During FY 1970 and FY 1971, we expect the booster development program to demonstrate the feasibility of injection to high intensity in a small, rapid-cycling booster. The Cornell 2.2 GeV electron synchrotron has recently been shipped to Argonne to assist in this program, which is already under way. The requested funds for injector improvements for FY 1971 would provide a 500-MeV beam transport and ZGS injection system to inject eight pulses into the ZGS to increase the ZGS circulating intensity to 10^{13} protons per ZGS pulse. In FY 1972 the ZGS rf system would be replaced and additional shielding added in the booster to permit 2×10^{13} protons in the ZGS. In FY 1973 modifications to the 50-MeV linac, to the booster rf and extraction systems, and to the ZGS injection system would permit 30-cycle-per-second operation of the injection system and a resultant increase of the ZGS intensity to 4×10^{13} protons per pulse. In FY 1974 the replacement of the dc magnets (BM-100's) and short straight section boxes will further add to the capability of the ZGS.

It is intended to build two new main coils each year beginning in FY 1971. The coils would contain improved radiation resistant materials in their insulation system. While this improvement program is shown to add two coils each year, it is possible that it would be stopped after one or two years if no failures due to radiation damage of the main coils in the ZGS had occurred up to that time.

Several developments within the past year with the computer control system of the ZGS have changed the needs for this program. The addition of floating-point hardware has speeded up computations with programs needing floating-point arithmetic by a factor of 20. The addition of a high capacity disc memory has permitted significantly more background jobs, and an increase in the memory of the CDC 924A has made possible an expansion of the foreground job capability. These developments have removed the threat of the saturation of the system for possibly up to three years. However, by FY 1973 it seems likely that the system will be limited by the computational speed of the computer during a ZGS pulse. Therefore, funds for the addition of a then modern high speed main frame have been included in the FY 1973 total with the addition of peripherals planned in the succeeding years to increase its utility.

A new system to power the ZGS to 9 GeV directly from the line as a backup for the ring magnet power supply is planned in FY 1972 and improvements to the extraction system, particularly resonant extraction, are projected for several years. In FY 1973 a third extraction system is planned for the L-3 straight section; there would then be no internal targets remaining in the ZGS.

In addition to these items, continual improvements to the damper systems will be required as the intensity of the ZGS is increased.

Funds are requested for power and cooling system additions for the experimental areas. The expanded program also requires that systems be installed for improved power distribution, flammable gas handling, and radiation protection. Minor improvements are needed for beam line monitoring and control.

2. Direct Pulsing from Power Line, ZGS

BUDGET PROJECTIONS (in thousands)					
FY 1971	FY 1972	FY 1973	FY 1974	FY 1975	FY 1976
		$ 1,550			

The completion of this project would provide the ability to operate the ZGS at full energy (12.5 GeV) in the event of failure in the motor-generator set of the ring magnet power supply (RMPS). Because of the problems common to all accelerators with their pulsed RMPS systems, this possibility is an ever present concern. Although time lost to the physics program and the cost of repairing such equipment on a creash basis is substantial, generators are too expensive to carry as a spare item. Being able to switch immediately to pulsing from the utility power line through the equipment requested for this project would eliminate this problem.

The equipment requested for this project will supplement the request for funds under Accelerator Improvements, ZGS, FY 1972, to provide equipment for pulsing from the power line at reduced energy. This request for FY 1973 provides for additional compatible equipment which would make it possible to pulse at full energy from the power line. The two projects together total $1,850,000.

3. Polarized Proton Source, ZGS

BUDGET PROJECTIONS (in thousands)					
FY 1971	FY 1972	FY 1973	FY 1974	FY 1975	FY 1976
	$ 1,000				

A system consisting of a polarized proton source, HV column, and power supply would be used in conjunction with the linac to produce a 50-MeV polarized proton beam. In addition, a number of fast tune-changing elements would be installed in the ZGS ring to be used during the acceleration cycle of the polarized protons to prevent depolarization from occurring. Preliminary studies show that a weak-focusing machine such as the ZGS is capable of accelerating polarized protons with a reasonable efficienty. Such a unique facility would have important consequences for the U.S. high energy physics program since it is necessary to use both polarized beams and polarized targets to fully determine the effects of spin in many elementary particle interactions. In particular, the increasingly precise measurements on the nucleon-nucleon interaction during the last few years show that the effects of spin must be determined in order to advance our understanding of this very fundamental interaction.

	BUDGET PROJECTIONS (in thousands)					
	FY 1971	FY 1972	FY 1973	FY 1974	FY 1975	FY 1976
4. ZGS Hot Shop				$ 1,300		

4. <u>ZGS Hot Shop</u>

The increasing beam intensity and the increasing number of experiments being performed at the ZGS plus continued buildup of long-lived radioactivity in the ZGS components will result in a need to be able to repair important items of equipment which are too radioactive for normal handling. The equipment involved ranges from targets and intricate targeting mechanisms to large portions of the ZGS, such as the extraction magnets, diagnostic equipment, slits, electrodes, beam transport components in the ring and in the proton areas, etc. All of this equipment possesses a high level of induced activity. While the buildup of long-lived activity has been slower than initially anticipated, it will continue to increase and special handling will eventually be required. To handle this hot equipment, adequate facilities must be available in the immediate vicinity of the ZGS. These facilities should include some remote handling equipment, plus suitable machine shop facilities for intricate as well as large work.

BROOKHAVEN NATIONAL LABORATORY
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DIRECTOR'S OFFICE

November 24, 1969

Dr. Paul W. McDaniel, Director
Division of Research
U. S. Atomic Energy Commission
Washington, D. C. 20545

Dear Paul:

The enclosed six copies of a draft of our Six-Year Forecast for High Energy are forwarded as you requested in your letter to Maurice of October 30. We have marked it as a draft inasmuch as our Trustees have not had an opportunity to review it.

Sincerely,

Rodney L. Cool

Rodney L. Cool
Associate Director

Encs.

cc: M. Goldhaber
E. L. Van Horn

DRAFT

05-01 High Energy Physics:

The AGS Conversion program will greatly increase the AGS capabilities as an accelerator and expand its facilities for High Energy Physics research. This forecast includes the personnel and financial requirements necessary for a reasonable level of utilization of these improved facilities. The forecast also includes the support necessary to provide the auxiliary devices needed for the current and future experimental program. Provision is included in FY 1972 for funds to increase the energy of the AGS facility to about 100 GeV by the use of new cryogenic magnet systems. This facility would not only increase the capability of the AGS in a new range, but also would provide a test of new synchrotron concepts which can be expected to lead toward a proposal for funds to design a 2000 GeV accelerator in FY 1975.

At the present time personnel levels are far below the requirements to properly operate and maintain the AGS and adequately support the present research program. An analysis of the growing research potential of the AGS, coupled with the experimental commitments, shows that the present operating staff must be increased by approximately 130 by early FY 1972. This increase represents a minimum requirement for efficient post-Conversion operation of the AGS and enables the Department to meet the demands of the experimental research programs.

In FY 1971, as the Conversion project 200 MeV linac achieves a pre-operational status, an increase in operating personnel levels will be required working towards the linac completion by mid-FY 1971. In FY 1972, the remaining aspects of the Conversion project, including all phases of the conversion of the existing AGS, are expected to be

05-01 High Energy Physics (cont'd.):

completed. The appropriate personnel, now working on the Conversion project, will be re-assigned to the AGS Operations and to research, design and development projects necessary for accelerator improvements and modifications to service the experimental requirements and for general support of the research programs.

The High Energy Physics Research Program at the AGS continues to increase in numbers of experiments as well as in complexity. More experiments are using higher momenta particles and parallel and multiple operation of experiments is being employed. The experimental proposals for use of the accelerator facility in mid-FY 1970 exceeds the number which can now be supported by a factor of at least three. In order for the research facilities of the AGS to keep pace with the experimental requirements in the next six years, new experimental areas will be activated, beam transport equipment acquired and utilities and service facilities will be augmented. All the changes will lead to a final experimental area setup as outlined in "A Proposal for Increasing the Intensity of the AGS." Advancement of this program requires the acquisition of support facilities in the next six years during which time the AGS experimental program will continuously increase its productivity.

Beginning in FY 1970, the initial changes to the AGS resulting from the Conversion project will affect the AGS operation and maintenance program. This effect will increase through FY 1971 and FY 1972. The research facilities will be greatly expanded and, for a reasonable level of exploitation, greater operational and maintenance support will be needed.

05-01 High Energy Physics (cont'd.):

In FY 1970 an improved AGS duty cycle with greater flexibility of programming magnet cycle and flat top will soon be available. An enlarged experimental area will be activated. In FY 1972, increased beam intensity will permit a larger and more complex research program. By FY 1972, the Slow External Beam should be operating at high capacity with several simultaneous experiments. By FY 1972, the Bubble Chamber program will be moved into the North Experimental Area where an improved fast external beam will be provided to service a multiple chamber operation.

The Advanced Accelerator Development Division is concentrating its efforts in three major areas. First, this Division has been providing an R&D effort in support of the Conversion project and will complete this effort. Second, it will continue to expand R&D involved with devices exploiting the application of superconductors and cryogenically-cooled aluminum conductors. Third, the Division will continue studies of high energy accelerator designs with emphasis on producing a proposal for increasing the energy range of the AGS accelerator facility with a cold magnet system into the 100 GeV range and produce a conceptual design for the eventual construction of a 2000 GeV proton synchrotron.

Accelerator research and development in progress now, or in the immediate future, determines the scope of future particle physics research. The present effort at the AGS is now severely limited by the financial and personnel levels. It is essential that the scale of the effort be increased substantially during the period FY 1970 to FY 1973.

Requested manpower increases in the operational budget for the Physics Department are minimal. Overall it amounts to a 20 percent increase for the entire period. Approximately one half of this increase is needed in the next few

05-01 High Energy Physics (cont'd.):

years in order to strengthen the OLDF staff, the 7-foot test facility crew, and personnel to turn one of the current spectrometer systems into a facility for use by all AGS users, prior to the completion of the large Double Spectrometer Facility project (FY 1973). Other increases are to strengthen the theory group, the Design and Engineering group, and programming efforts.

The counter-spark chamber groups are currently very much involved in programs using spectrometer systems for precision analysis of secondary particles from an interaction or decay. Plans for the future involve further experiments in this direction, including a very large Double Spectrometer System described in this forecast. These experiments are more nearly programs and thus involve a long period of preparation, data taking and subsequent analysis. Manpower levels in all groups have not increased, even though complexities of experiments and equipment have done so. Modest increases are needed as soon as possible. A future experiment to study hyperon resonances would involve the construction of a wire chamber spectrometer with a superconducting very high field magnet. It should not be forgotten that experiments with wire-chamber spectrometer systems collect an immense amount of data, resulting in a large data analysis problem. Increasing use of the Central Scientific Computer Facility by the counter groups is foreseen.

During the forecast period, major changes are foreseen for the bubble chamber facilities located at the AGS consistent with and necessary for exploitation of the research potentialities of the improved AGS. These are:

1) A new bubble chamber area, the North Area, will be constructed as part of the AGS Improvement Program. The proton

05-01 High Energy Physics (cont'd.):

beam, extracted from the H-10 straight section, will eventually provide secondary beams to all operating bubble chambers at the AGS. This area will begin operation following the last long AGS Conversion shutdown in calendar year 1971. 2) The 80-inch Bubble Chamber will be moved to this new area. A special committee of users, appointed by J. Sandweiss (Yale), Chairman of HEDG (High Energy Discussion Group), has recommended this move. The HEAC (High Energy Advisory Committee) has endorsed it fully. It combines aspects of both economy and physics. Economy is achieved because a very long, expensive, mass separated, high energy particle beam will be able to service two chambers. Proximity of chambers will, in addition, reduce operating costs. Physics is served because during those period when a very large chamber (see next point) is operating for neutrino experiments, the excellent high energy beam can be used in the 80-inch chamber. The move would be started at the time the AGS shuts down in calendar year 1971. Every effort would be made to have it in operation, with a high energy beam within nine months. 3) The 7-foot test facility has recently (November, 1969) produced excellent tracks of cosmic ray particles and further tests continue. After a test run during 1970 at its present location in the Southwest area using the neutrino beam, it will be turned off and moved to the H-10 area. During the move, the chamber will be expanded in volume to approximately 30,000 liters to provide a chamber of a size adequate for full scale neutrino experiments and strong interaction physics, using the greatly improved AGS. The move and expansion will take about a year. It should be completed some time during calendar year 1972. The expansion of the 7-foot test facility will be financed from the capital budget, while the

05-01 High Energy Physics (cont'd.):

move from the Southwest area to the H-10 area will be funded by the operating budget. It is anticipated that few additional personnel will be needed to effect the expansion and the move, since a large fraction of the costs will be contracts outside the Laboratory. A neutrino beam in the H-10 area will be an important ingredient for the program of this large chamber. The high energy separated beam, mentioned previously, will of course be able to send particles into this chamber. 4) Current plans call for ending 31-inch chamber operations during FY 1971. The 30-inch chamber and beam will be left intact at its present location until approximately FY 1973. Eventually it is planned to build a suitable low energy beam for the 30-inch or the 31-inch chamber in the H-10 area.

The equipment presently in the 31-inch beam as well as the equipment in the two beams feeding the 80-inch chamber will be moved to the H-10 area and will be used to construct the high energy separated beam for the 80-inch and the expanded 7-foot chamber.

During the seven months of operation in FY 1970, approximately 4×10^6 bubble chamber pictures are expected. On the assumption that three chambers will be operational eventually in the H-10 area, the yearly rate could potentially increase to more than 10^7 pictures. Multipulsing, i.e., two or more photographs taken by a chamber during a single AGS beam pulse will be a factor in this increase.

Development of satisfactory track sensitive targets (TST) for the larger chambers is an exciting prospect. Many physicists are excited about the potentialities of this technique. [A target of hydrogen or deuterium is placed in a

05-01 High Energy Physics (cont'd.):

cryogenic bubble chamber. The fluid surrounding it would be neon or neon-hydrogen mixtures. On expanding the chamber, both the target and its surrounding fluid are made track sensitive. Interactions are produced in the target and the denser surrounding fluid will convert γ rays to electron-positron pairs, thereby helping identify reactions having π^o's or other particles ultimately decaying into γ rays.] The expanded 7-foot chamber would be expecially useful with TST. At present Brookhaven has five or six proposals to use a TST in the 80-inch chamber. Interest is mounting.

For increasing utilization of the AGS and an expanding experimental program, a high level of capital equipment acquisition will be needed during the next six years. New devices and increased quantities of existing types will be required to service the particle beams in an efficient fashion. In addition, the more sophisticated research projects associated with the AGS make similar demands on capital equipment. The Slow External Beam requires additional transport magnets, power supplies and associated equipment for full exploitation. At the completion of the Conversion project the experimental potential of the AGS will have doubled and the experimental floor area, covered and out-of-doors, will have doubled. To equip these areas fully with adequate beam transport arrays will require that capital equipment funds be maintained at a high level. Another contributing factor to the need for capital equipment funds is obsolescence of equipment and the termination of useful life of equipment which has already been in service for many years. These factors will assume more importance during the next six years.

The capital equipment forecasts shown are based on projected experimental programs. The Accelerator Department

05-01 High Energy Physics (cont'd.):

Experimental Planning and Support Division has developed typical beam arrays and then projected the dates when these beams will be placed in operation. The funding in the forecast has taken into account the lead time necessary for procurement of components such as magnets, power supplies, separators and other equipment.

During FY 1969 a substantial upgrading of the On-Line Data Facility (OLDF) was undertaken. Demands for using this real time computer facility have been steadily growing as experimenters from universities have recognized the power of the on-line computer techniques first developed by the Brookhaven experimental groups. Currently, the overwhelming majority of counter experiments are connected to the OLDF. The OLDF has a PDP-6 and a PDP-10 sharing 96,000 words of magnetic core memory. Considerable input-output peripheral equipment is available: magnetic tapes, card readers, fast printers, teletypes and visual displays. In addition a PDP-9 system is being brought into operation. This PDP-9 will be connected to the Central Scientific Computing Facility (CDC-6600) by a system developed in the Applied Mathematics Department, and designated Brooknet.

In this six year forecast period, additions to the OLDF will clearly be needed. These additions will include: 1) additional core memory, 2) disc file, 3) small computers, such as PDP-15, etc., 4) displays, 5) magnetic tapes, and 6) additional connections to Brooknet. Approximately $200,000 annually will be needed for this purpose.

The SDS-920 computer (purchased in 1964) now in use by the NIG, has 12 scanning measuring machines connected on line to it and it is at the limit of its capacity. It is rapidly becoming obsolete. A new computer is proposed for

05-01 High Energy Physics (Cont'd.):

FY 1973, at a cost of about $300,000. Some new data analysis equipment will be needed by this group in order to analyze pictures from the new generation of large chambers (7-foot at BNL, 12-foot at ANL, etc.).

In FY 1970 the Data Terminal Network (DTN), (the BCG data analysis system using a Σ 7 computer) has become fully operational with connection to the CDC-6600 Central Scientific Computing Facility. 12 scan/digitizer table terminals and 12 general purpose terminals, some with TV type displays, are connected to the DTN. Clear evidence is available as to the success of the system in improving the efficiency of data processing and analysis. Further improvements will be made in the next two years. However by FY 1974 a new and faster computer to replace the Σ7 is proposed ($500,000) to allow updating and improvements in the sophistication of data analysis procedures.

Capital items will also include additions or replacements of certain other data processing equipment including scanning and measuring machines. For example, it is proposed to replace the two HPD instruments connected to the 7094 by one improved version to be connected directly to the Central Scientific Computer Facility (CDC-6600), (estimated cost $282,000). Savings in the operational budget would result from retiring the 7094. The improved machine would initially be capable of measuring 10^6 events/year, but this number could be increased with a modest additional investment provided a larger computer, such as a CDC-7600 were available at Brookhaven.

Development will be continued on new types of beam handling equipment including improved versions of rf beam separators, beam gathering devices and cryogenic targets. There will be an increased program of development of

05-01 High Energy Physics (Cont'd):

cryogenic or superconducting magnets capable of very high flux densities. Tests on small models of these types of magnets, constructed at BNL, have yielded promising results. The development of rf superconducting separators is now sufficiently advanced to foresee their application in beam transport systems within a few years.

In keeping with the Laboratory's activities in the cryogenic device field, a design will be developed during FY 1971 for a "100 GeV" cryogenic magnet accelerator in order to prepare a proposal for start of construction in FY 1972.

In addition to upgrading the energy of the Accelerator Department facility with the "100 GeV" accelerator, the next major construction project to be undertaken by the Laboratory should be a synchrotron with an energy of about 2000 GeV. This machine would use the AGS as an injector and would include the necessary intermediate equipment to match the AGS to the 2000 GeV synchrotron. This machine would employ ring magnets with conductors operating at cryogenic temperatures. It is planned to develop a design for the 2000 GeV accelerator during FY 1975 and submit a proposal for start of construction in FY 1976.

In FY 1973 a Double Spectrometer Facility is proposed as an extension of the current systems being used at the AGS. This large scale system is envisaged as a flexible device complete with its own data handling computer system which will be available for use by all users of the AGS. In many respects it would function in a manner similar to, but not exactly like, a bubble chamber facility. Its estimated cost would be $4,500,000. Such a facility would

05-01 High Energy Physics (Cont'd):

demand operating and maintenance personnel. They have been included in the manpower estimates. A proposal for an AGS Service Building Addition will also be submitted for FY 1973. This addition would combine engineering space with laboratories and work areas necessary to support the varied development programs carried on at the AGS complex.

In FY 1974, a modest addition to the Physics Building is proposed ($2,200,000). This arises from three needs: 1) Currently the entire Design and Engineering Group (37 permanent and 7 temporary) associated with the Physics Department is housed outside of the Physics building. 2) Demands for space by university users has continued to increase and more space is being made available to them for their needs. 3) This forecast reflects an estimated 20 percent increase in Physics Department personnel.

ASSOCIATED UNIVERSITIES, INC.
BROOKHAVEN NATIONAL LABORATORY

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YEAR-END EMPLOYMENT AND MAN/YEAR
PROJECTIONS FY 1971 - 1976

	FY 1971		FY 1972		FY 1973		FY 1974		FY 1975		FY 1976	
	Y/E	M/Y	Y/E	M/Y	Y/E	M/Y	Y/E	M/Y	Y/E	M/Y	Y/E	M/Y
High Energy Physics												
Operating	840	784	920	880	970	941	1,000	985	1,050	1,025	1,100	1,075
Cap. Equip. & Construction	119	158	135	94	185	160	185	185	187	187	171	143

NOTE: Figures for Operating are direct manpower effort only. Supporting Technical Services are shown separately. Thus, they cannot be related to the budget submission. This format is consistent with all previous Long Range Forecasts submitted.

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BROOKHAVEN NATIONAL LABORATORY

YEAR-END EMPLOYMENT PROJECTIONS
FY 1971 - 1976

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	FY 1971			FY 1972			FY 1973			FY 1974			FY 1975			FY 1976		
	Sci	Prof	Other	Sci	Prof	Other	Sci	Prof	Other	Sci	Prof	Other	Sci	Prof	Other	Sci	Prof	Other
High Energy Physics																		
Operating	148	116	576	157	130	633	164	142	664	169	147	684	172	152	726	176	162	762
Cap. Equip. & Constr.	13	31	75	15	36	84	18	46	121	18	46	121	25	57	105	27	51	93

NOTE:
Scientist - Ph. D or equivalent
Professional - B.S. or equivalent
Other - Technical, administrative & service.

SCHEDULE B

U. S. ATOMIC ENERGY COMMISSION

BUDGET ASSUMPTIONS

OPERATING EXPENSES

for (HIGH ENERGY PORTION) PHYSICAL RESEARCH PROGRAM

for FY 1971 - FY 1976

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Associated Universities, Inc.
Brookhaven National Laboratory
Laboratory

Category/Activity		BUDGET PROJECTION (In Thousands) FY 1971	FY 1972	FY 1973	FY 1974	FY 1975	FY 1976
05-01	High Energy Physics	$ 25,370	$ 30,120	$ 33,385	$ 36,570	$ 39,760	$ 43,505

U. S. ATOMIC ENERGY COMMISSION

SCHEDULE C

BUDGET ASSUMPTIONS

CAPITAL EQUIPMENT NOT RELATED TO CONSTRUCTION

DRAFT

for (HIGH ENERGY PORTION) PHYSICAL RESEARCH PROGRAM
for FY 1971 - FY 1976

Associated Universities, Inc.
Brookhaven National Laboratory
Laboratory

		BUDGET PROJECTION (In Thousands)					
		FY 1971	FY 1972	FY 1973	FY 1974	FY 1975	FY 1976
35-05-01	High Energy Physics	$ 5,300	$ 5,500	$ 5,400	$ 5,300	$ 5,300	$ 6,000

SCHEDULE D

U. S. ATOMIC ENERGY COMMISSION

BUDGET ASSUMPTIONS

CONSTRUCTION PROJECTS

for (HIGH ENERGY PORTION) PHYSICAL RESEARCH PROGRAM
for FY 1971 - FY 1976

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Associated Universities, Inc.
Brookhaven National Laboratory
Laboratory

Project Title	BUDGET PROJECTION (In Thousands) FY 1971	FY 1972	FY 1973	FY 1974	FY 1975	FY 1976
ARAM (High Energy portion ONLY)	$ 1,850	$ 1,500	$ 1,200	$ 1,300	$ 1,400	$ 1,400
Conversion II/Cryogenic Accelerator ("100 GeV")		30,000				
2000 GeV Accelerator (Construction Planning & Design)					4,000	10,000
AGS Service Building Addition			4,500			
Double V Magnetic Spectrometer Facility			4,500			
Physics Building Addition				2,200		
Neutral Particle Detector System						4,500
High Energy Total	$ 1,850	$ 31,500	$ 10,200	$ 3,500	$ 5,400	$ 15,900

ASSOCIATED UNIVERSITIES, INC.
BROOKHAVEN NATIONAL LABORATORY

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PROJECTED OPERATING REQUIREMENTS FY 1971 - FY 1976

(In Thousands of Dollars)

	FY 1970	FY 1971	FY 1972	FY 1973	FY 1974	FY 1975	FY 1976
Adv. Accel. Design & Devel.	$ 1,300	$ 1,630	$ 2,575	$ 3,680	$ 4,340	$ 4,845	$ 5,220
AGS	10,320	12,235	14,820	16,345	17,650	19,400	21,840
Accelerator Department	11,620	13,865	17,395	20,025	21,990	24,245	27,060
Physics Department	9,680	11,505	12,725	13,360	14,580	15,515	16,445
High Energy - Total	$ 21,300	$ 25,370	$ 30,120	$ 33,385	$ 36,570	$ 39,760	$ 43,505

ASSOCIATED UNIVERSITIES, INC.
BROOKHAVEN NATIONAL LABORATORY

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PROJECTED CAPITAL EQUIPMENT DEPARTMENTAL OBLIGATIONS FY 1971 - FY 1976

(In Thousands of Dollars)

	FY 1970	FY 1971	FY 1972	FY 1973	FY 1974	FY 1975	FY 1976
Accelerator Department	$ 1,250	$ 3,000	$ 3,000	$ 2,500	$ 2,500	$ 2,500	$ 3,000
Physics Department	1,250	2,300	2,500	2,900	2,800	2,800	3,000
High Energy - Total	$ 2,500	$ 5,300	$ 5,500	$ 5,400	$ 5,300	$ 5,300	$ 6,000

PROJECTED YEAR-END PERSONNEL LEVELS

HIGH ENERGY PHYSICS

	FY 1970				FY 1971				FY 1972				FY 1973			
	Sci	Pro	Oth	Tot	Sci	Pro	Oth	Tot	Sci	Pro	Oth	Tot	Sci	Pro	Oth	Tot
Operating																
Adv. Accel. Des. & Devel.	24	4	4	32	27	5	9	41	29	11	30	70	32	11	38	81
AGS	29	54	275	358	40	77	332	449	44	83	363	490	45	90	369	504
Accelerator Department	53	58	279	390	67	82	341	490	73	94	393	560	77	101	407	585
Operating	11	18	117	146	13	21	121	155	15	23	126	164	16	27	141	184
Research	66	13	114	193	68	13	114	195	69	13	114	196	71	14	116	201
Physics Department	77	31	231	339	81	34	235	350	84	36	240	360	87	41	257	385
Operating Total	130	89	510	729	148	116	576	840	157	130	633	920	164	142	664	970
Capital Equip. & Construction																
AGS Conversion I	13	36	111	160	5	12	49	66	0	0	0	0	0	0	0	0
Conversion II/Cryo.Acce (CP&D,Const)	0	0	0	0	3	8	9	20	9	25	66	100	12	35	103	150
2000 GeV Accelerator (CP&D,Const)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Accelerator Dept.	3	5	5	13	3	5	5	13	4	5	6	15	4	5	6	15
Physics Department	2	6	12	20	2	6	12	20	2	6	12	20	2	6	12	20
Capital Equipment - Total	5	11	17	33	5	11	17	33	6	11	18	35	6	11	18	35
Cap. Equip. & Construct.-Total	18	47	128	193	13	31	75	119	15	36	84	135	18	46	121	185

	FY 1974				FY 1975				FY 1976			
	Sci	Pro	Oth	Tot	Sci	Pro	Oth	Tot	Sci	Pro	Oth	Tot
Operating												
Adv. Accel. Des. & Devel.	34	13	42	89	36	13	43	92	37	13	44	94
AGS	46	91	379	516	46	95	417	558	48	104	448	600
Accelerator Department	80	104	421	605	82	108	460	650	85	117	492	694
Operating	17	27	145	189	17	27	145	189	17	27	147	191
Research	72	16	118	206	73	17	121	211	74	18	123	215
Physics Department	89	43	263	395	90	44	266	400	91	45	270	406
Operating Total	169	147	684	1,000	172	152	726	1,050	176	162	762	1,100
Capital Equip. & Construction												
AGS Conversion I	0	0	0	0	0	0	0	0	0	0	0	0
Conversion II/Cryo.Acce (CP&D,Const)	12	35	100	147	7	16	50	73	0	0	0	0
2000 GeV Accelerator (CP&D,Const)	0	0	0	0	12	30	33	75	20	40	67	127
Accelerator Dept.	4	5	6	15	4	5	6	15	5	5	10	20
Physics Department	2	6	15	23	2	6	16	24	2	6	16	24
Capital Equipment - Total	6	11	21	38	6	11	22	39	7	11	26	44
Cap. Equip. & Construct.-Total	18	46	121	185	25	57	105	187	27	51	93	171

DRAFT

November 21, 196[illegible]

MASSACHUSETTS INSTITUTE OF TECHNOLOGY · HARVARD UNIVERSITY

CAMBRIDGE ELECTRON ACCELERATOR

HARVARD UNIVERSITY
42 OXFORD STREET
CAMBRIDGE, MASS. 02138

November 20, 1969

Dr. Paul W. McDaniel, Director
Division of Research
U. S. Atomic Energy Commission
Washington, D.C. 20545

Dear Dr. McDaniel:

In accordance with your request of October 30, 1969, I am enclosing an early submission of the five-year long-range projections (FY 1971-1976) for the Cambridge Electron Accelerator.

I trust this is satisfactory.

Sincerely,

C. W. Wooldredge, Jr.

C. W. Wooldredge, Jr.
Administrative Assistant
to the Director

CW/bm

cc/w enc.:

Sheldon Meyers
Philip Thompson

9-4990 A

Cambridge Electron Accelerator
Contract AT (30-1)-2076 and Contract AT (30-1)-3025
Cost Projection
(In Thousand Dollars)

ACCELERATOR	FY 1971	FY 1972	FY 1973	FY 1974	FY 1975	FY 1976
Operations	$4,724	$5,000	$5,350	$5,670	$6,050	$6,400
Equipment	1,569(1)	1,930(4)	1,700(6)	1,200	1,300	1,400
A. I. P.	982(2)	1,200(5)	1,000	1,000	1,100	1,200
G. P. P.	178.8(3)	100	110	120	130	140
TOTAL	$7,453.8	$8,230	$8,160	$7,990	$8,580	$9,140

(1) Includes $215,000 for Magnetic Detector Equipment ($70,000 above President's Submittal for FY'71) along with $200,000 for Equipment for digital control of Spectrometer Systems.

(2) Inside By-Pass $582,000; Improve Ring Vacuum $100,000; Improve DC Power System $200,000; Improve Linear Accelerator $75,000; Improve Radiation Monitoring $25,000.

(3) Second Story to Linac Bldg. $128,000; Renovation and Modification to Laboratory Facilities $50,000.

(4) Includes $800,000 Equipment funds for Additional Colliding Beam and Experimental Facilities and $280,000 for updating Equipment interfacing CEA and Harvard Computing Center

(5) Includes $300,000 to improve entire RF system to operate at 500 KW average.

(6) Includes large Solid Angle Spark Chamber (inside magnet) for Tagged Photon Beam ($700,000).

11/19/69

MASSACHUSETTS INSTITUTE OF TECHNOLOGY · HARVARD UNIVERSITY

CAMBRIDGE ELECTRON ACCELERATOR

HARVARD UNIVERSITY
42 OXFORD STREET
CAMBRIDGE, MASS. 02138

December 1, 1969

Dr. R. Frichen
Division of Research
U. S. Atomic Energy Commission
Washington, D. C. 20545

Dear Dr. Frichen:

We have recently sent you the five-year long-range projections (FY 1971-1976) for the Cambridge Electron Accelerator. In discussing this on the phone with you on November 24, I understand that you would like information on any new projects which were not included in our May 1969 budget submission. These projects are listed below.

FY 71 Equipment

Equipment for Digital Control of Spectrometer Systems - $200,000

The present CEA computers will not control the bypass or the Beam 7 spectrometer, run an experiment and a debug of another experiment. We have studied several approaches to the problem and have reached the conclusion that the best solution commensurate with CEA's long-range plans is the purchase of a small digital computer with suitable peripheral hardware. Estimates from a number of vendors indicate such a system will cost approximately $200,000.

FY 72 Equipment

Equipment for Interfacing CEA and Harvard Computing Center - $280,000

The present SDS-92 computers used to connect experiments online to the Harvard Computing Center were purchased in 1965. This equipment has been declared obsolete by the manufacturer, and it is expected that within a few years maintenance service will no longer be available. We propose to replace these SDS-92 computers with the latest model equivalents at an estimated cost of $280,000.

Dr. R. Frichen December 1, 1969

FY 72 - AIP

Improvement of Rf System to Operate at 500 kW Average - $300,000

The FY 71 budget submission included a Schedule 44 for the improvement of the rf system to attain 250 kW average power with subsequent increase in FY 72 to 500 kW average. This Schedule 44 in the amount of $1,632,000 was entitled "Rf Power Increase to 250 kW (stage 1) and 500 kW (stage 2)" and will not be resubmitted. Recent difficulties with the present rf amplifier make it imperative that CEA revise its rf system immediately, and plans are underway for such a revision. Changeover to a new rf amplifier will automatically increase rf amplifier capabilities to 500 kW average power, but will leave the rest of the rf system with only 250 kW average power capability. This project includes improvement of the rf cavities, cavity voltage and cooling water system to allow for overall operation at 500 kW average.

If you would like any additional information, please let us know.

Sincerely,

C W Wooldredge Jr

C. W. Wooldredge, Jr.
Administrative Assistant
to the Director

CW/bm

UNIVERSITY OF CALIFORNIA

LAWRENCE RADIATION LABORATORY
BERKELEY, CALIFORNIA 94720

DC 69-1200
2 December 1969

Dr. P. W. McDaniel, Director
Division of Research
U. S. Atomic Energy Commission
Washington, D. C. 20545

Dear Dr. McDaniel:

In response to your letter of October 30, 1969, making a special request for early informal submission of LRL's Five-Year Projections for the High Energy Physics Program, we transmitted a lengthy teletype the evening of 1 December 1969.

In the interest of time, we enclose three (3) copies of the information as it was transmitted by teletype. These rough drafts may be of assistance in your discussions. The formal Projections, in the prescribed format, will be included with our regular Five-Year Plan at the normal time.

Sincerely yours,

Edwin M. McMillan

EMM:nh

Encl.

cc: SAN w/Encl.

Informal

1 Dec 1969

LRL Berkeley, High Energy Physics Five-Year Program Projection

INTRODUCTION

The Lawrence Radiation Laboratory's five-year plan in High Energy Physics provides for a program that will assure its continuance as a national center for particle physics and accelerator research. From its beginning to the present time, the Laboratory's complementary activities in high energy physics research and high energy accelerator development have constituted the largest source of its scientific strength. During this five-year projection period, the Laboratory plans to enhance and revitalize these essential features of its role as a national center in these fields. There are three major elements of this plan.

(1) The Laboratory research program in particle physics will continue to explore the basic properties of elementary particles.

(2) A continuing program of development for the Bevatron facility is planned.

(3) A new proton facility in the energy range of 50 to 100 GeV, based on new technology, is proposed for the LRL site; termination of Bevatron operation, beyond the period covered by this projection, will be coordinated with the operation of the new accelerator.

1. Research in Particle Physics

The experimental high energy program, which is centered primarily at the Bevatron, covers nearly every facet of elementary particle physics. It includes work in both the strong interaction field, with systematic studies of production and decay properties of resonant states, and in the area of weak interactions, including studies of rare decay modes. There continue to be occasional esoteric experiments which defy classification. Because many groups both within and outside the Laboratory are ~~very~~ eager to get time on the Bevatron, we foresee no slackening of this effort in the next five years.

A portion of the present and projected experimental activity by physicists at LRL is independent of the Bevatron. The most significant of such activities to date have been at SLAC, based on the 82-inch

0 5 5 4 3

bubble chamber and on the portability of such LRL apparatus as polarized targets and specialized counter and spark chamber arrays. Members of the LRL staff are contributing to the design of experimental facilities at NAL, and are developing a capability for doing experiments at other accelerators. They have also been active in the recent revival of interest in the elementary particle aspects of cosmic rays.

The Laboratory's theoretical group benefits from stimulation by a vigorous experimental particle physics program, access to good computer facilities, and the ability to attract excellent visiting workers, which have contributed to a continuously productive program. The leading role played by this group in the development and application of S-matrix theory is an example. A strong emphasis on phenomenology has not inhibited imaginative innovations such as the bootstrap hypothesis and work on Regge poles.

A major part of the overall experimental program involves the development of new and improved instrumentation and its employment at the Bevatron and at other accelerators. These developments include new particle detectors, spectrometers, beams of novel design, and techniques in both on- and off-line data analysis. The Laboratory possesses in these areas an unusually high degree of competence and technical strength which will contribute toward continuing its significant contributions to high energy physics. A more detailed discussion of the particle physics research program is given in Section I below.

2. The Bevatron Facility

The program at the Bevatron, which involves a large number of experimentalists and theorists, is central to the Laboratory's activity in high energy physics. The importance of research in the Bevatron energy range accounts for the large overlap in the character of the programs at the Bevatron and at higher energy accelerators. The Bevatron is competitive in the production of plus or minus pi, plus K, and zero K beams in the few GeV range; it has, in addition, some special advantages in the production and utilization of beams for low energy and stopping K's.

In order to respond to the needs of a growing number of active users, primarily from outside the Laboratory, and to keep pace with the rapidly developing complexities of the experimental program, the performance and capability of the Bevatron must continue to be improved, as described in Section II below. The scheduling of these improvements will proceed in a manner consistent with progress toward the proposed new accelerator and with the essential demands of the experimental research program.

3. New Accelerator Technology and the Proposed New Accelerator.

In order to retain the vitality and unique strengths of the Laboratory in the future and to continue serving those who depend heavily upon its research facilities, a new accelerator is planned for the LRL site. This facility, in the energy range of 50 to 100 GeV, will be an important tool in both particle physics and accelerator research. By employing in its design and operation important new accelerator technology, it will point the way to future accelerators in the TeV range. The program at LRL is pursued along two related courses. In one, the study of pulsed superconducting magnets has led to an apparently feasible way of building an accelerator. Both experimentally and theoretically, it appears that a superconducting synchrotron with a cycle time in the few second range is feasible. The other course of development involves the use of collective effects in the acceleration of protons and positive ions. Such accelerators potentially have important and exciting applications not only in physics but also in nuclear chemistry, biology, and medicine. The LRL study is now concentrating on the use of isolated relativistic electron rings as carriers to accelerate protons. Rings have already been formed, compressed, and loaded with ions, and acceleration may be demonstrated within a few months. Assuming that an electron ring accelerator is shown to be feasible, it is expected that superconductivity, too, will play an important role in the production of static magnetic fields associated with the accelerator itself, and in a magnet ring involving some combination of stretching and storage. Construction authorization in FY 1973 ~~xxxxxxxxxxxx~~ will be requested. A description of work on the new technologies and their application to the proposed accelerator is contained in Section III; additional details are given in the accompanying five-year construction projection (Schedule D).

While it is not possible to provide sound cost estimates at this time on a new technology accelerator, it is recognized that cost becomes an overriding parameter as accelerators become larger and that the possibility of eventually reaching very high energies with accelerators depends upon achieving low unit costs The first intermediate energy new technology accelerator may or may not itself represent a cost reduction over conventional accelerators, but it must represent a potential cost reduction for future large accelerators.

I. Research in Particle Physics

In summarizing the projection of experimental and theoretical research activities at LRL in high energy physics through FY 1976, emphasis is given to general trends which are foreseeable with reasonable probability, recognizing the lessons of past experience which show that some of the most significant experimental and theoretical results, and new research techniques, develop rather quickly in unexpected ways. Workers at this Laboratory have repeatedly been successful in contributing to such discoveries and in anticipating the innovative instrumental developments required to exploit them.

The activities here projected at LRL are integral parts of our long range plan to maintain and enhance the role of LRL as a center of excellence for both high energy physics research and high energy accelerator development and utilization.

We anticipate continued vigorous use of the Bevatron, whose capabilities are to be further improved as indicated in Section II, for several years. When the Bevatron is supplanted by a "new technology" accelerator (see Section III), experimental activity will shift to it. We shall be prepared for this transition to higher energy by substantial experience gained through activity by various LRL experimental groups at NAL, at SLAC, at BNL, in cosmic ray work, and at other accelerators, supplementing the further evolution of technique and expertise which will occur in work at the Bevatron during this period.

Among the specific areas of investigation in which various groups at the Laboratory are interested in working for the next few years are: studies of production and decay properties of meson and baryon states using existing bubble chamber techniques; studies of rare states and of states involving several neutral particles, to be done with triggerable devices such as spark and streamer chambers; a program on photoproduction using the polarized photon beam at SLAC; studies of electromagnetic and leptonic decays of

hyperons, in which work with the 25-inch bubble chamber is to be supplemented by spark chambers to obtain a very large increase in statistics; continued study of K-mesic and Sigma-mesic x-rays at the Bevatron, photoproduction of pions and kaons from polarized protons and studies of multiparticle final states produced by hadrons incident on polarized protons, using polarized targets at SLAC and at the Bevatron; measurements of recoil neutron polarization in pion-proton reactions, using a new spin-refrigerator type of polarized target; and high energy cosmic ray studies aimed at resolving controversial evidence regarding high transverse momenta in extensive air showers at energies above 10^5 GeV, thought to have a bearing on design considerations for storage rings at NAL. Film from the 25-inch chamber and from chambers at other laboratories will continue to be used by LRL groups from time to time. It is too early to project specific experiments at NAL to be proposed by Berkeley physicists, but such proposals, particularly with the planned neutrino facility, will be forthcoming in the future. Plans to do high energy neutrino physics (E sub nu greater than 15 GeV) at NAL are under way. As can be seen, a portion of present and projected experimental activity by physicists at LRL is independent of the Bevatron. These activities complement the increasing use of the Bevatron by visiting groups.

The maintenance and improvement of existing instruments and facilities for high energy physics research at LRL and the development of new ones, which we project here, are coordinated with our attack on the physics goals described above and with the longer range plan for a future accelerators. They include: (1) further development of the general area of spark, streamer, and proportional chamber technique, including not only improvement in capability of these chambers but also exploration, already started, of totally new chamber concepts based on use of liquids and semiconducting materials as sensitive media; (2) development and use of new types of polarized targets; (3) active planning and development of equipment to handle film for future giant bubble chambers, continuation and improvement of existing systems, and completion and use of the development program on automatic scanning and measurement of events in bubble chamber film (DAPR); (4) further evolution of the necessary trend toward increased use of "small" computers as integral parts of sophisticated detection arrays and their direct interconnection to "large" computers for reduction of data required to guide the progress of experiments; (5) ~~continued~~ utilization of the 25-inch hydrogen bubble chamber as long as strong user demand continues; (6) further basic research and development of semiconductor detectors which have already made possible new and interesting work in mesic x-rays; (7) further development, and probable use in cosmic rays and at NAL, of a very high resolution magnetic spectrometer system utilizing a very high field superconducting magnet and track locating systems of high precision. These topics are discussed in greater detail below.

1. Spark, Proportional, and other Chambers

The direction and style of fundamental research are often strongly dependent upon developments in techniques and principles of observation, measurement, and analysis. Historically, the impact of such devices as the cloud chamber, the electronic particle detectors, and the bubble chamber are evident in the areas of exploration made accessible by them and in the nature of the research enterprise to which they gave rise.

In the past few years and at present, we are witnessing the growth of another technique that markedly extends the discrimination and versatility with which the reactions among elementary particles can be observed and measured. This is the development of the various forms of the spark chamber and its adaptations to direct readout of particle trajectory data in forms immediately accessible to computer treatment and analysis. The coordinate information, giving particle trajectories and event locations, is accessible through various techniques, such as magnetostrictive or electrostrictive effects in "wands" communicating with fine grid wires constituting a chamber plane, by sonic signals generated by sparks, or by Vidicon optical recording of the spark patterns. All these methods can deliver their information directly to magnetic tape for analysis programs. The complete elimination of photography and visual scanning operations contributes to economy and speed.

At this Laboratory, as was the case with early optical chambers, the perfection and application of these direct readout systems, particularly the sonic, the magnetostrictive, the electrostrictive and the Vidicon, have been pioneered. Widespread examples of successful use of these techniques are evidenced throughout the centers of research in high energy physics. The diversity of selective sensitivity and form achievable in such devices is striking; their combination with arrays of scintillation counters and Cerenkov counters to pre-select the kinds of events desired for precise measurement allows the experimenter a degree of discrimination not accessible to the bubble chamber.

It is noteworthy that recent Berkeley developments indicate a likely application of the magnetostrictive spark plane technique to medical and industrial radiography.

Multiwire proportional chambers will play an increasingly important role in many high energy physics experiments. Further developments are needed to improve their space, time, and energy resolution. Much work still needs to be done in designing, constructing, and utilizing efficient fast logic systems to work in conjunction with them. We plan to expand our present development program to further improve the performance of these chambers and their associated electronic circuits; the ideas involved will also be extended in some new directions, such as reliable D.C. spark operation and multidimensional readout systems. In addition a number of standard chambers will be constructed for use in actual physics experiments. We will begin by using four such proportional chambers to study the profiles and phase space characteristics of secondary beams at the Bevatron. Hodoscope systems capable of making fast decisions will be built for use in polarized target experiments. Other systems involving several thousand wires are under active consideration, e.g., for spectrometer applications. Their implementation will be based on the experience gained with some of the simpler systems outlined above.

There exists an unfulfilled need for a device that would surpass in positional accuracy the performance of present day gas-filled spark chambers and wire chambers. This device should have a time resolution equal to or better than the wire chambers and a positional accuracy better by an order of magnitude in order to fulfill the needs of momentum measurement in experiments in cosmic ray physics and with future higher energy accelerators. Present day thin-gap wire chambers have spatial accuracies which are at best 0.2 mm for particles incident at 90 degrees to the plane of the chamber and time resolution of approximately 0.3 microsecond. These resolutions are ~~inherently~~ due to the inherent characteristics of the ionization and avalanche developments in gases, which require that the gap be at least 5 mm wide for satisfactory performance.

Progress is continuing in the development of a device using ionization multiplication in liquid argon; it is hoped that this technique will give an order of magnitude improvement in location accuracy. Another approach is to use an amorphous semiconductor of the glassy or micro-crystalline types which are being developed. These materials have rectifying or switching properties and could be expected to work as the dielectric for a solid chamber. Various materials of this nature will be tested, together with a readout which would be electrical in nature, perhaps even of the magnetostrictive type which has proven so successful so far. Initial work with cadmium sulphide is proceeding in cooperation with the electrical engineering department at UC Berkeley.

As another example of a specialized chamber facility, a streamer chamber system for the Bevatron is being designed jointly by the LRL staff and a group from UCLA.

2. Polarized Targets

Several improvements in the LRL polarized proton target capability are foreseen in the next few years. The advantages already achieved in the change to a butanol target can be enhanced by going to lower temperature or higher magnetic field, or both, so that higher target polarization values can be obtained. The higher polarization will significantly improve the accuracy of the experimental results. To analyze fully most scattering amplitudes it is necessary to build a target that can be polarized in the scattering plane, rather than normal to it as in most present targets. A Helmholtz-coil geometry would be used, presumably with superconducting coils. It will make possible interesting and important experiments at Bevatron energies and also at higher energies, including the proposed future LRL accelerator. Other significant extensions of present experiments can be in studies of pion and kaon photoproduction from polarized protons at SLAC, and in the study of multiparticle final states produced by hadrons incident on polarized protons.

There is need for a polarized target in a geometry allowing a clear view at all angles up to at least 135° in the Laboratory. This equipment precludes the use of the existing types of rf-pumped targets requiring magnetic fields in the 20 Kg. region. Such a polarized target is envisioned as utilizing the spin refrigeration technique. It has obvious applications in experiments involving counter and spark chamber systems, and there exists also a proposal for installation of such a target in the 25-inch bubble chamber. This target uses yttrium ethyl sulfate (YES) crystals, as do most spin refrigerators. Heavy element background is prominent here, as usual in all polarized targets. The chief advantage of the proposed device is that the polarized target itself, and its cryostat, may be withdrawn from its polarizing magnet and moved into the pion beam quite free of the bulky magnet structure, while immersed only in a keeping field of about 1 kG. The e-folding time there for spin relaxation is about 30 minutes, even under 10% field inhomogeneities. The polarization vector remains parallel to the keeping field, so that reversals of the polarization are relatively simple.

Polarization requires about a minute. YES is 5.3 percent by weight polarizable hydrogen and values of P approximately 0.5 are foreseen. Solid state physicists in the Berkeley Department of Physics are currently bringing this improved version of spin refrigerator into operation. Data should soon be available in the degree of polarization to be expected, and LRL will be collaborating on efforts to assay the merits of this most attractive technique for use in high energy physics. A target of reasonable volume, with freedom from bulky magnets and rf pumping, capable of equalling the performance of LMN targets, seems to make the YES spin refrigerator well worth investigating. A dummy target will soon be inserted into a currently operating experimental setup for a few hours to check the dominant heavy element background from YES. If this background is tractable and polarizations of 50% or more appear attainable, the construction of such a target will be undertaken.

3. Bubble Chamber Data Reduction

LRL has played a pioneering role in developing and using data processing systems. A natural evolution of LRL's activity in the area of bubble chamber film analysis involves continually incorporating into the system more advanced hardware and software systems. As a result of these improvements, the LRL processing systems can analyze more events per unit time, but, ~~even~~ more importantly, they can analyze more complicated events than can be handled on smaller systems and can analyze these events at less cost, ~~than on smaller systems~~.

The extension and continued improvement of LRL's data handling systems is ~~are~~ logical for two reasons: (a) physicists will continue to be interested in ever higher energies; (b) the technical competence of LRL's engineers and support groups in the conception, design, construction, and operation of such equipment provides prototype systems for use in other laboratories not having development programs.

The data reduction systems at LRL must be modified to handle the film format of the large bubble chambers and the severe optical distortions resulting from their fish-eye optics. Modified scanning and measuring equipment and software will be required.

Current on-line systems will be expanded to allow for computer-aided scanning. Rough digitizing and real-time reconstruction will enable a scanner to make judgments on directions and associated origins that would not otherwise be possible. Such on-line systems will also be useful for work with "mixed" chambers where a hydrogen target is incorporated inside a neon-filled chamber.

4. Computers

The computation capabilities required to match a balanced physics experimental program have been accurately projected over the past four years. Currently the dual CDC 6600 system is fully utilized. In the immediate future another addition to the Berkeley computer complex will be required. It is planned that a large computer system, equivalent to the CDC 7600, will be procured. Despite the severe budget constraints of recent years, the Laboratory's requirements for computation have continued to increase. A machine such as the CDC 7600, working at 3 to 4 times the speed of a CDC 6600 for the Laboratory's mix of problems, will provide more economical operation and more throughput. The analysis of much more complicated experiments in the future will take more time on the computer to obtain meaningful results. Even now, typical experiments may contain a few hundred thousand events, with computing requirements on each event more than ten times that of experiments ten years ago.

The proposed computer is required not only for the LRL high energy physics program but also for those in medium and low energy physics, nuclear chemistry, biology and medicine, inorganic materials research, and chemical biodynamics. For example, over the past several years, data have been collected by members of the Donner Laboratory staff concerning results of treatment of leukemia and acromegaly patients. These data have now been digitized, and an interactive program has been written which allows members of the Donner staff to test various hypotheses concerning the efficacy of treatments. The result of this activity has been a marked increase in the computational requirements of the Donner Laboratory.

In addition to work related to the Bevatron experimental program and other research in high energy experimental physics, the Laboratory's central computational facility serves workers at the 184-inch cyclotron, the 88-inch cyclotron and the HILAC. Theorists, both in physics and in nuclear chemistry and other research divisions of the Laboratory, also have increasing requirements for computation. They are undertaking the analysis of more complicated theoretical models utilizing more sophisticated numerical techniques. Accelerator designers in both the physics and nuclear chemistry divisions are depending increasingly on the use of high speed computers in their work. Comprehensive, occasionally interactive, programs have been written to assist in the varied accelerator design work currently going on at LRL.

There are large numbers of other computer users in the Laboratory whose work has benefitted from the design and use of more elaborate and precise procedures; these scientists are dependent upon a large computer for many kinds of calculations, including those for control and for evaluation of experiments. An efficient large computer with fast turn-around is essential to their work.

On-Line Data Collection Facilities

The use of data collection facilities on-line to small computers has greatly increased the data output of many experiments. It is anticipated that in the next two years an increasing number of these small data-collecting computers will be run on-line to one of the Laboratory's major, general-purpose computing systems. This mode of operation will again increase the amount of data which can be produced by a given experiment. The largest number of applications will be in physics, but other divisions will also utilize such facilities. For example, the Laboratory of Chemical Biodynamics is currently implementing a centralized data-collection system under which several experiments may be run simultaneously on-line to an SDS Sigma 2 Computer. Much of the data collected from these experiments will ultimately be analyzed on one of the Laboratory's large-scale, general-purpose computers. Similarly, a DEC PDP-9 computer used in nuclear chemistry to control fission experiments will soon be running on-line with one of the Laboratory's 6600 computers.

Digital Readout Spark Chambers

The increasing use of digital readout spark chambers will impose heavy new requirements on the Laboratory's computing capability. These chambers, which pulse very rapidly, allow the traditional scanning and measuring steps of an experiment to be by-passed. This results in a very significant increase in the amount of data to be analyzed

Large Bubble Chambers

New techniques in the large bubble chamber area, fish-eye optics, for example, will place additional heavy demands on the central computing facility as film from these chambers becomes available in the years ahead.

The result of operating at capacity is to increase turn-around time for computer jobs significantly. Long turn-around times have extremely adverse effects on the productivity of scientific and other technical personnel

~~4. Computers (continued)~~

There is an increasing need for additional small and medium size computers which will speed up data acquisition and allow faster feedback to the experimenters during the progress of an experiment. As LRL has done much in pioneering the use of such computers, technical competence has been developed among its personnel in interfacing and maintaining this equipment in accordance with the needs of the experimenters. Additional effort in this area will be required during the next six years.

Studies and development will continue, aimed toward the operation of a comprehensive, expandable system connecting several on-line experiments to a large computer. Such a system will be needed in the future for data processing connected with the use of major on-line experimental data detection facility in this Laboratory.

5. Hydrogen Bubble Chamber Program

The 25-Inch Bubble Chamber is currently operating at a rate of approximately 3-4 million pictures per year. In a 23.5-Kg field, using a resonant expansion system, it is normally run in the double-pulse mode and is capable of triple-pulsing so that is could produce even more pictures per year. Beams of $K^{\pm}$ from 800 MeV/c to greater than 2 GeV/c momentum and $\pi^{\pm}$ beams up to 3 GeV/c are available with high purity and usually take but a small fraction of the Bevatron circulating beam for most energies. The $K^{\pm}$ momentum range between 1 and 1.6 GeV/c, rich in the formation of Y^*, is not covered at any other hydrogen bubble chamber installation in the country. Further there is installed in the chamber a movable platinum target which, when not needed, is retracted in a few minutes so as to be completely invisible. Upstream of the chamber a beam destroyer magnet is used to predetermine the number of beam tracks per picture so that the data collection is optimized. Provision has also been made for a pencil beam which can be stepped across the chamber in uniform intervals. In addition, the high quality of pictures and reliability of operation make the 25-Inch Bubble chamber a very attractive and useful tool with which to do much high energy physics at the Bevatron.

plus or minus K

plus or minus pi

The 25" chamber has been able to schedule very large blocks of pictures which have enabled physicists to make detailed study of particular reactions at many closely spaced momentum points. Much more data need to be gathered to understand the energy region being investigated, including: (a) identification and understanding of Y^* resonances, (b) associated production experiments, (c) understanding of "Cool" bumps in K^+ reactions, and (d) Λp and Λn interactions. A test is in preparation for a (planned) polarized target to be installed inside the chamber, and which will exist as a general facility if it proves to be successful. It is of interest to point out that there is more bubble chamber data on pion elastic scattering than counter or spark chamber data in this region, and for inelastic reactions, the bubble chamber excels.

lambda Λ

Depending on the demand for a chamber of this size, after the end of FY 1971 we will consider shutting down the 25-inch bubble chamber to allocate resources to other Berkeley high energy program requirements of higher priority.

In conjunction with the construction of a "new technology" accelerator at Berkeley, there is interest in building a high field (approximately 70 KG), highly accurate bubble chamber of the order of approximately two meters in size, to do strong interaction physics at high energies.

6. Semiconductor Detectors

This Laboratory has led in the development of lithium-drifted germanium semiconductor detectors. For the past two years an extensive program of crystal growing and material evaluation has been carried out to determine the relationship between crystal growing conditions and the performance of lithium-drifted detectors made from the crystals. The end objective of the program is to achieve gamma-ray energy resolutions limited by the fundamental statistical limitations of charge production in the detector material, not by crystal imperfections. Already these detectors are capable of the highest known resolving power for gamma and X-ray detection. In addition to the importance of these detectors in other areas of research, studies of new kinds of atoms through their X-ray spectra have been made possible by their employment. Experiments on K^--mesic X-rays will continue at the Bevatron in the next few years. The X-ray spectra of many more elements and pure isotopes will be measured, with special emphasis on the isotopes of the rare earths such as Samarium. Rare earth isotopes are expected to give information on the shapes of the nuclei (nuclear deformation). Projected improvement in the intensity of the Bevatron low momentum K-beam by a factor 40 should make sigma$^-$-hyperonic atoms about as observable as are kaonic atoms with the present beam.

K minus

minus

After considering a number of possible detector materials to improve gamma-ray detection efficiency, we have recently started work on thallium selenide. The high atomic number of thallium selenide suggests that a given thickness would be about 100 times more efficient for photoelectric absorption of gamma-rays than the same thickness of germanium. Improved detectors may reveal the doublet structure of sigma$^-$-hyperonic X-ray lines and thus lead to a measurement of the sigma$^-$ magnetic moment.

minus

minus

7. Very High Resolution Spectrometer

7. Very High Resolution Spectrometer

The development of a very high resolution magnetic spectrometer system is proceeding at LRL. This system will utilize a very high field superconducting magnet together with track locating systems of high precision. At first, these will consist of large plates of nuclear emulsion sandwiched between conventional spark chambers. It is hoped that chambers utilizing liquid or other condensed sensitive media may lead to a more flexible and efficient method of track location. Such an instrument could be a valuable tool for cosmic ray studies, both at ground-based sites and, in the future, in balloons or orbiting satellite laboratories; in addition, it could be very valuable research device at high energy accelerators .

II. THE BEVATRON FACILITY

Although other accelerators with energies higher than that of the Bevatron have now been in operation for a number of years, the Bevatron continues to provide to a large and increasing number of institutions facilities for high energy physics research of great interest and importance. For example, several of the detailed studies of inelastic reaction cross sections and angular distributions now being conducted by bubble chamber groups at LRL, to determine resonance parameters of low lying Y^* and N^* states, have also been proposed at CERN but are moving ahead slowly there because of higher priorities assigned to other experiments. As another example, half of all the counter and spark chamber experiments approved for the AGS at BNL as of July 1969 were in beams of momenta and intensities easily provided at the Bevatron. The importance of high energy research in the Bevatron energy range accounts for the large overlap in the character of the programs at the Bevatron and the higher energy accelerators. The Bevatron is competitive in the production of plus or minus pi, plus K, and zero K beams in the few BeV range; it has, in addition, some special advantages in the production and utilization of beams for low energy and stopping kaons.

As has been noted repeatedly in surveys of the nation's high energy physics program, there is and will continue to be a serious shortage of time for experiments in beams generated by high energy protons. The Bevatron can provide such beams with exemplary versatility, multiplicity, reliability, and efficiency. At present, more than half of the Bevatron research program is carried out by visiting groups, predominantly from the western United States, but with continuing activity from other parts of the country. It is well suited to meet the needs of the growing number of active users in the country's high energy community.

During its lifetime the Bevatron must continue to be improved in performance and capability to keep pace with the rapidly changing complexities and special requirements of experiments. These improvements will be planned and executed in a manner consistent not only with the programmatic requirements of experimental research projects but also with the development and construction of its successor. If the development of the "new technology" accelerator proceeds rapidly, the longer range Bevatron improvement schedule will be adjusted appropriately. In this way a smooth and orderly transition can be achieved without damaging the productivity and efficiency of the large number of research groups involved.

Those improvement activities requiring Accelerator Improvement Project or line-item construction funds are separately described in Schedule D of this five-year projection. The following is a general summary of proposed Bevatron operations and improvements.

1. <u>RF System Improvement</u>

A new RF system which provides high frequency bunching of the accelerated beam is being considered. Such a system, which provides ordered structure to the beam, will substantially increase the selectivity of data-taking for spark chambers and counter experiments. A related but separate project provides control of the magnet flattop and provides magnet ripple reduction in order to better control beam spills and reduce slow ripple structure.

2. Increased Intensity

Several projects are underway or are under study to increase the intensity of the machine from the present limit of 5.2×10^{12} protons per pulse to greater than 10^{13} protons per pulse. Included are plans to improve the Bevatron vacuum; plans to neutralize beam instabilities during the acceleration cycle which appear both after injection and at high-energy; and a plan to replace the present 20 MeV Linac Injector with the 50 MeV Linac that will be discarded at BNL in 1972. Computer control, which has already been successfully applied to control and programming of the pulse modes of the Bevatron magnet power supply and to the forty programmed magnets in the multiple channel external proton beam system, will be systematically extended to the control, monitoring and diagnostics of other parts of the Bevatron. Resonant extraction work will continue with the expectation of being able to extract up to 80 percent of the circulating proton beam.

3. Operational Versatility

Versatility in experimental operations will continue to receive high priority. Closed-loop computer control of beams is a promising future development. Other improvements to the experimental facility will include: The application of superconducting magnet technology to the construction of new secondary-particle beam lines; the design and construction of very specialized beams; the installation of an on-line computer facility associated with the Bevatron; and the construction and installation of a major on-line experimental data collection facility at the Bevatron.

4. Stopping K Beams

In accord with these plans is the development of special secondary beams that are particularly well matched to the Bevatron energy. An example is a short beam to provide stopping K mesons. Preliminary estimates indicate that a factor of seven in intensity may be gained by shortening the beam and thus diminishing the loss due to decay in flight, and a factor of six by increasing the solid angle subtended. The number of stopped K's should thus increase by a factor of over 40, giving about 1.5×10^5 plus K^+ and 1.5×10^4 minus K (K^-) stopping per pulse of 10^{12} protons. This is an order of magnitude greater than present day stopping K beams at any accelerator. This beam development will require a new design of beam magnets and electrostatic separators. (We are considering the possibility of using superconducting magnets in this development.) A short beam of this type is well suited to the Bevatron; such a beam would be less attractive at high energy accelerators where shielding requirements are much greater, making the construction of useful short beams more difficult. Many interesting experiments in such a beam can be envisaged. A series of experiments on K-mesic atoms should give information on nuclear shapes and on the surface of the

nucleus. Furthermore, minus Sigma mesic atoms will become about as observable as present minus K mesic atoms, and one might even see their doublets, revealing the magnetic moment of the minus sigma. Rare modes of decay of the K, e.g., plus K goes to plus pi plus nu bar plus nu will become observable, or upper limits on their branching ratios will be improved. A beam of this quality and intensity will match the capabilities of present day detectors and thus will be fully competitive with beams that may be obtained from other machines.

5. Improved K and pi Beams

Improvements are planned for separated K beams in the 1 to 2 GeV/c region and high intensity pion beams in the 1 to 4 GeV/c region. Through careful design, pion beams can be obtained with intensities of 10^8 pions

-15-

or more per 10^{12} protons. The need for these is indicated by the continuing requirements for secondary beams of high quality and high intensity. In some of the beam designs to be studied, superconducting elements may be utilized to achieve maximum solid angles with minimum length.

During this five-year forecast period, it is planned to continue to operate the Bevatron on a seven-day, around-the-clock schedule. Maintenance will be done during short regularly scheduled shutdowns. Longer shutdowns will be scheduled for major overhaul and for modifications.

III NEW ACCELERATOR TECHNOLOGY AND THE PROPOSED NEW ACCELERATOR

A new technology accelerator, with proton energy in the range 50-100 GeV, is planned for the LRL site. The accelerator is to be based on new technologies showing substantial promise of leading the way to a scientifically, technically, and economically attractive accelerator in the TeV range. Because such a machine should not be constructed without the assurance and experience to be gained from construction and operation of a similar machine at a lower but significant energy, the proposed accelerator will provide an essential step toward higher energies. The energy range will be scientifically exciting for many years. Judging from the strong continuing program at the Bevatron, which reflects the strength of scientific activity at LRL and in the growing user community, a vigorous and diversified program can readily be anticipated. It is practical to locate and operate the new accelerator to utilize much of the existing Bevatron facility, with its buildings, utility distribution systems, heavy floors and shielding, experimental areas, etc., and possibly to employ the Bevatron magnet as a spectrometer. The plan is consistent with LRL's scientific and engineering capabilities, and with the Laboratory's established role as a center for high energy physics.

The program of research and development associated with the new technology accelerator at LRL is carried on by an experienced staff who, in close relationship with the research program in particle physics, have maintained a highly productive role in ~~the fields of~~ accelerator research and technology.

The present program at LRL is pursued along two ~~parallel but~~ related courses. On the one hand the study of pulsed superconducting magnets has ~~let~~ led to an apparently feasible way of building an accelerator. ~~The~~ Our study ~~at LRL~~ of large systems of superconducting elements, initially undertaken in connection with the LRL (and later NAL) 200 GeV Design Study, is in many respects directly applicable to the new accelerator study. Also relevant is the operating experience obtained from the use of superconducting magnets in the LRL experimental research program. This has been sufficiently encouraging that the design is now underway for large systems of magnets to be used in secondary beams at the Bevatron. The fundamental studies underlying the LRL program on pulsed superconducting magnets have included stability and degradation effects and extensive measurements on a.c. losses. The results are in essential agreement with recent theory. As a result of these tests it now appears, both experimentally and theoretically, that a pulsed superconducting synchrotron with a cycle time in the few second range is ~~reasonable~~ feasible.

The other course involves the use of collective effects in the acceleration of protons or ions with a large rate of energy gain per foot. Such accelerators are exciting because of potentially important applications not only in high energy physics, but also in nuclear chemistry, biology, and medicine. The LRL study is now concentrating on the use of isolated relativistic electron rings to accelerate protons. An experimental and theoretical program to explore and develop the technology of collective-effect accelerators will continue as a high-level activity during the 5-year period. The Livermore Astron injector is being used as an intense source of electrons in the present experiments, which have successfully demonstrated the ability to form and compress intense rings of electrons and to load them with ions. The program now emphasizes extraction of the loaded rings from the magnetic containment region.

Much experimental investigation is required to develop fully the many ~~significant~~ new concepts for accelerating protons to very high energies. These include a variety of configurations for the compressor, the device in which the rings are formed and compressed ~~in all dimensions~~ to generate high holding fields for the trapped ions. Also, there are a number of possible ways of extracting the rings from the compressor and accelerating them axially along a solenoid. Geometries in which an inner cantilevered solenoid lies within the ring must be explored. In order to establish the electron-ring concept as a useful means to attain very high energies, it is necessary to investigate electric acceleration of the ring. Functionally and economically, a combining of the electron-ring technology with that of superconductivity is very attractive, and one approach under study involves the concept of a static magnetic field compressor into which electrons are injected at high energy to form a ring that is compressed in dimensions without transverse acceleration of the electrons. In the application to very high energy machines, the use of superconducting technology in the form of a static or slow-cycling stacking ring, fed by an electron-ring accelerator, could result in a vastly different concept for future accelerators.

A cornerstone of this development program is the establishment at Berkeley of an experimental test facility to provide an intense source of relativistic electrons. Construction of an electron injector, for currents in the region of hundreds of amperes and an energy of approximately 4 MeV, is expected to be completed during FY 1970. Until that time the experiments on expansion acceleration will continue to be carried out on a time-sharing basis using the Astron injector at Livermore.

It is expected that within the next six to nine months most of the significant unanswered technical questions in both superconducting synchrotron and electron ring acceleration will be resolved. It is anticipated that a construction proposal for the new accelerator will be submitted in June, 1971 for authorization in FY 1973. To accomplish this, authorization of CP &D funds will be requested for FY 1971 to perform detailed cost estimates for the accelerator. At this time a number of possibilities exist; these will be appreciably narrowed as the results of certain key experiments become available. A pulsed superconducting ring with a conventional injector is one concept that is closest to realistic engineering and cost estimation at this time. At the other end of the spectrum is the concept of a full-energy electron-ring-accelerator that could alternately feed experiments requiring short pulses or a static field stretching-ring. In between is the possibility of providing high injection energy from an electron ring device into a pulsed superconducting ring.

In parallel with the effort on the new accelerator, improvements will be needed on the relativistic electron source which serves as the injector for these studies. This will result in an improved high intensity electron gun by FY 1972. If the concept of a static field compressor appears attractive, the energy would be increased from 4.0 MeV to perhaps 15 MeV, by the simple addition of more stages of acceleration, which can be installed with only periodic interruption of the experimental program. A new "Advanced Technology Research and Development" building, for space and support facilities pertinent to this program is proposed for FY 1972.

During the latter years of this period of projection the basic theoretical and fundamental experimental studies of methods of particle acceleration will be continuously pursued, along with the development of the new technology accelerator. It is important to sustain this effort if the maximum benefits of these applications are to be made available for accelerator use in high energy physics and in other fields. There are three noteworthy lines of possible future development. First, a full energy ERA by itself could become a useful physics tool with interesting novel properties to be followed by a superconducting stacking ring, and finally by the addition of a second ring to form an intersecting storage-ring pair. Second, the use of superconducting magnets to provide linear guide-fields for the electron-ring is an extremely attractive concept, which is expected to lead to significant economies. Third, the idea of constructing an accelerator in the 50-100 GeV energy range based on novel technology usually has been thought of as a precurser to an accelerator in the TeV range. This is certainly the major goal, but there are also several other areas of technological importance. For example, pursuit of the ERA applications is likely to have early impact in the fields of nuclear chemistry and biology and medicine. Other possible applications to the rejuvenation of existing proton facilities have yet to be explored. In short, implementation of a new accelerator technology may supply the needed stepping stone to the single new super high energy facility, and in the process may also have a profound effect over a broad frontier at lower levels of energy.

SCHEDULE B

Program 05-01 High Energy Physics
OPERATIONS (in K$)

	FY 1971 LRL Request	FY 1971 Presid. Budget	FY 1972	FY 1973	FY 1974	FY 1975	FY 1976
RESEARCH	15,850	16,300	18,500	20,200	21,400	22,000	22,400
ADVANCE ACCEL DESIGN	2,300	1,550	2,800	3,300	3,600	3,900	4,200
PRE-OPERATING 50-100 GeV Accel	0	0	0	500	1,000	1,700	3,000
TOTAL 05-01	18,150	17,850	21,300	24,000	26,000	27,600	29,600
Direct Man Years of Effort	675	670	752	803	825	829	839

SCHEDULE C

LRL Berkeley

Capital Equipment not related to Construction for Category 35-05-01, High Energy Physics

~~35-05-01~~	FY-1971 LRL Revised Request	FY-1972	FY-1973	FY-1974	FY-1975	FY-1976
Research Equipment	2,150	2,450	2800	3,000	3,000	3,000
Computers	8,760			11,000		
Adv. Accel. Technology	500	500	400	200	200	100
Equip. for Pre-Oper New Technology Accel	-0-	-0-	100	400	700	900
TOTAL	11,410	2,950	3,300 ~~780~~	14,600	3,900	4,000

The equipment levels for LRL's high energy physics program are to provide the necessary equipment to conduct the planned expanded experimental program described in Schedule B. As indicated, the Laboratory plans to fully utilize the Bevatron facility over the next few years.

In FY 1971 we have asked for 11,410 K$ of which 8,760K$ is for a large computer system, and $2,650 for the research program. This level of equipment funding is to regain a level of equipment support which is badly needed for the ongoing Bevatron research program and to provide support for the ERA development program.

It is anticipated that, as a result of vigorous negotiations, the large computer system can be obtained in FY 1971 for the amount requested ($8,760,000). It now appears likely that one more generation of conventionally organized machines will be built by both CDC and IBM and that these machines will provide a factor of four or five in performance over the CDC 7600 and IBM 360/195. An additional sum of $11,000,000 is requested in FY 1974 for the procurement of an advanced computer. However, it is possible that in FY 1974 the Laboratory might wish to procure an array processing machine in lieu of a conventionally orgainzed computer.

Purchase of small and medium-size computers is planned for Fiscal Years 1972, 1973, 1975 and 1976. Equipment funds needed for these computers are estimated at between 300 K$ and 500 K$ in each of these fiscal years. They are to be used with ongoing accelerator facilities and research programs.

Bending magnets, beam transport magnets, associated power supplies, and separators will be required for the secondary particle beams from the Bevatron target areas. Experimental setups require special magnets including large-aperture ones for housing spark chambers. Also power supplies and detecting equipment are required, often of special design and great complexity. With the increasing number of experiments by groups from other universities, the demand on LRL for electronic counting and monitoring equipment will continue to increase during this period. Medium size computers will be increasingly required as integral parts of experiments and in part are to be interfaced to connect into the larger computer systems.

~~Also,~~ Equipment funds will be required for upgrading and extending the energy of the electron injector used to conduct ERA experiments. The specific modification and improvement will be determined by the progress of the experimental program.

Data reduction equipment will be required for new film formats to be utilized at new large bubble chambers at other laboratories which will be producing film during this period. The new film formats associated with these chambers, and their severe optical distortions, will require radically changed scanning and measuring equipment. In conjunction with constructing a new technology accelerator at Berkeley, there is interest in building a high field ($\simeq$70KG), highly accurate bubble chamber of the order of $\simeq$ 2 meters in diameter, to do strong interaction physics at high energies.

In the last year there has been considerable progress in further advancing the technology of superconducting magnets and their application to accelerators, to beam transport, analyzing and backstop magnets and to special purpose magnets for specific physics experiments. Continuing activity in these fields with correspondingly rapid progress can be confidently projected for the next few years. It is foreseen that the development and implementation of this technology will be intimately connected with the evolution of ~~reasearch~~ research and development on many possible embodiments of hardware for forming, transporting, and accelerating electron rings in the ERA program, and also on engineering and economic considerations of future ERA accelerators of various possible types. Research and development activities on the inter-related topics of superconducting magnets and electron ring accelerators will require substantial amounts of new capital equipment funds each year in this period.

Also, superconducting magnets will be fabricated to meet research needs which are not possible with conventional magnets for reasons of space limitation, high field strength requirements, cost or power limitation. Examples of these applications include backstop magnets for Bevatron beams, large volume spark chamber magnets, and magnets for special purposes, such as operating polarized targets, inducing neutron spin flip, or capturing particles for magnetic moment measurements, which require highly precise and specific field shapes and high field strengths. An example of beam transport elements that require superconducting coils are the following that are under construction for Bevatron use: a focussing doublet in which each quadrupole has an 8" warm bore, approximately a 3' length, and a gradient of 6 kG in^{-1}; a bending magnet with a 10" warm bore, approximately 3' length, and a dipole field of 40 kG. A series of magnet and material tests have shown that pulsed superconducting magnets, as might be used in a superconducting synchrotron, are now technically practical. An inital series of pulsed magnets ~~are~~ is required to demonstrate that these elements have sufficient field precision, reliability, ruggedness and economy for accelerator applications. A development program of this type is contemplated, and capital equipment related to this development will be required as the development proceeds.

SCHEDULE D

LRL Berkeley

CONSTRUCTION (in K$)

	FY 1971	FY 1972	fy 1973	FY 1974	FY 1975	FY 1976
Accelerator Improvements, Bevatron	900	2,200	2,200	2,500	2,500	2,500
New Technology Accel, 50-100 GeV	1,000(CP&D)		59,500			
Bevatron Injection System		1,600				
Adv. Accel. Tech R & D Bldg		3,500				
EPB Facility Extension			3,000			
6 GeV Stretching Ring				3,000		
Physics Bldg Addition 50C					2,500	

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Accelerator Improvement Program

Schedule D
FY 1972-1976

The Bevatron will continue to support a vigorous experimental program in high-energy physics during the next five years. Consistent with the overall plans of maintaining a highly productive research and accelerator center it is necessary to keep pace with the user requirements in the rapidly changing complexity of current experiments; therefore it is planned to continue to improve the Bevatron's performance and capability.

Plans are underway to increase the Bevatron intensity to meet the demands of the present and future experimental program. The program will utilize the AGS 50 MeV linac which will be discarded by BNL in 1972. (This project for the transfer of the Linac is a construction item for FY 1972). The 50 MeV injector will raise the injection space charge limit at the Bevatron as well as reduce the initial gas scattering. Main magnet improvements consistent with this program will be made by installing additional pole face windings. At the present time the maximum current allowed in the existing windings is inadequate. Recent tests indicate that an additional increase in beam intensity can be made by improving the Bevatron vacuum. A study of an improved pumping system is underway. These improvements together will result in a factor of five increase in intensity.

Recent developments in the program for improving the EPB extraction efficiency indicate a factor os two increase in extraction efficiency with resonant extraction. Full operational utilization of this system requires improvements in the main magnet ripple reduction system as well as higher pole face winding currents.

The overall program described in the above paragraphs represents a potential order of magnitude increase in the external beam intensity together with a structure-free beam spill having the typical duration of one to two seconds.

During the past year the Bevatron has provided, when required, over 1.5×10^{12} protons per pulse on a single target station in the EPB. With minor shielding improvement more than 2×10^{12} can be utilized at any target station. As there are four target stations in the EPB, the Bevatron has the capability of utilizing 10^{13} protons/pulse in the EPB alone. With resonant extraction the main Bevatron shielding is adequate to handle these intensity levels.

Other improvements under study are an RF system to provide high frequency bunching when required. These RF system improvements will be designed to allow also for the acceleration of deuterons.

In concert with the operational improvements in new secondary beams mentioned in Schedule B there will be improvements to the experimental facilities for increased power and cooling capacity and a more flexible utility distribution system. The application of superconducting magnet technology will be utilized on some new beams when maximum solid angle and minimum length are required. Finally the rapid development of wire spark chamber systems and the anticipated developments in proportional chamber systems for experiments will require a data link from the Bevatron to the LRL central computer center in the near future.

Schedule D

FY 1972

1.6 million $
Bevatron Injection System - ~~$~~ #1.6 M

An improved injection system will provide a significant increase in the intensity of the circulating beam. The need for higher intensity arises from the growing multiplicity of simultaneously operating secondary beam channels and from the developing sophistication of experimentation. With the proposed improvements the Bevatron will retain unique capabilities in its energy range for the production of high intensity and high quality beams.

With the new resonant extraction system, about 80 per cent of the circulating beam will be extracted. Therefore, a larger circulating beam can be accommodated internally without imposing serious radiation problems.

The planned improvements include a higher energy linac, an improved and higher intensity ion source, and a modified inflector. Some modifications to facilitate the acceleration of deuterons will also be made. A particularly attractive way of increasing the injection energy is by replacement of the present 20 MeV linac with the BNL 50 MeV linac, which will not be needed at Brookhaven after completion of the current AGS improvement program.

With higher injection energy the space charge limit of the Bevatron will be raised and the effects of gas scattering will be reduced. With all the improvements, a gain of a factor of five in beam intensity is anticipated.

FY 1972

Advanced Technology R & D Building, 3.5 million $

The proposed building will provide development space and area in which to carry out the necessary research and development work in this field. Scope of the activities of the Group ~~xhxxk~~ will require such space as:

1. Study and development of the applications of superconductivity to particle accelerators and high energy beam lines.
2. Acceleration of electron rings by various electric field configurations, which is fundamental to the achievement of high energies.
3. Development of magnetic expansion acceleration of electron rings.
4. Studies of static field compressors, which will probably include the use of superconducting elements.

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Schedule D

FY 1973 Construction Authorization

High Energy Physics New Technology Accelerator, 50-100 GeV: ~~59.5~~ 60.5 Million $

This project is for the construction of a high energy accelerator incorporating new accelerator technology currently being developed at LRL. The accelerator will be in the energy range of 50-100 GeV. The $60.5 million number shown is an approximation and depends upon the technology and energy level selected. A preliminary cost estimate for the various alternatives will be made during the next four months.

The proposed accelerator will involve the application of new technology and would provide a source of protons for elementary particle research for experimenters at a range of energies expected to be rich in phenomenology as yet not adequately explored.

Two new technologies applicable to high energy accelerators are under active study at this Laboratory. One is the use of superconducting magnets to provide guide and focussing fields for high energy protons. They could be employed at constant field to form stacking, stretching or storage rings of small diameter; or they could be pulsed to accelerate protons, with considerable advantages. The second approach being pursued is development of the electron ring accelerator in which the ring provides a vehicle for accelerating protons, or other ions, with a large rate of energy gain per foot. The technique for forming rings of suitable properties and loading them with ions has now been established by the success of the Compressor II experiment (refer to Operations Section of the five-year Forecast), but the essential experiments to demonstrate the feasibility of acceleration will not be conducted until mid FY 1970.

In both technologies there remain several unanswered technical questions which have important economic considerations. Progress is very rapidly being made in developing both technologies. and it is expected that within the next six to nine months most of the significant answers will be known. It is anticipated that a construction rpoposal will be submitted in June, 1971 for authorization in FY 1973. To accomplish this authorization of CP&D funds will be requested for FY 1971 to perform detail cost estimates in order to attain a high degree of reliability for the cost of the accelerator.

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Accelerator 50-100 GeV (continued)

At this time a number of possibilities exist, and the field will be appreciably narrowed as the results of certain key experiments become available in the next six to nine months. A pulsed superconducting ring with a conventional injector is one concept that is closest to realistic engineering and cost estimation at this time. At the other end of the spectrum is the concept of a full-energy electron-ring-accelerator that could alternately feed experiments requiring short pulses or a static-field stretching-ring. In between is the possibility of providing high injection energy from an electron ring device into a pulsed superconducting ring.

There are three noteworthy possibilities. First, if the concept of a full energy ERA proves feasible, it could first become a useful physics tool by itself with interesting, novel properties; it would then lead to the addition of a superconducting stacking ring, and finally to the addition of a second ring to form an intersecting storage-ring pair. Second, the use of superconducting magnets to provide a linear guide-field for the electron-ring is an extremely attractive concept; it is expected to lead to significant economies. Third, the idea of constructing an accelerator in the 50-100 GeV energy range based on novel technology usually has been thought of as a precursor to an accelerator in the TeV range. This is certainly the major goal, but there are also several more immediate areas of technological impact. For example, pursuit of the ERA applications is chronologically more likely to have its first impact in the fields of nuclear chemistry, biology, and medicine, rather than in ultra-high energy physics. A number of U.S. universities are interested in medium energy physics if a combination superconducting storage ring can be incorporated. Possible applications to the rejuvenation of existing high energy proton facilities have yet to be explored. In short, implementation of a new accelerator technology may supply the needed stepping stone to the single new super high energy facility but, in the process, may have a profound effect over a broader frontier at lower levels of energy.

Schedule D

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FY 1973

Bevatron External Proton Beam Extension - $3 million

The Bevatron external proton beam facility, which now includes four separate target stations, has provided the Bevatron with a considerable increase in experimental capability and flexibility. The growing need to accommodate simultaneously operating experiments is accomplished by heavily shielded target stations at each of which several secondary beams can emerge from a common target. The need to extend the present capability of the EPB System is apparent in the increasing experimental demands on the facility; this comes largely from the growing number of outside groups who now account for more than half of the program. Extension of the experimental area is needed both to provide a greater variety of secondary beams and to relieve the present system from the crowding which has accompanied the development of the more sophisticated beams and large detectors of the spark chamber-spectrometer type. Typical experiments now require more floor space for beam tests in advance of actual operation. The planned extension includes additional target stations with the associated shielding and utilities.

FY 1974

6 GeV Superconducting Stretcher Ring - ~~$~~3 million $

This superconducting magnet system will be a valuable asset to the Bevatron experimental facility and at the same time will serve as a pilot application of new accelerator technology. The ring will be interposed between the accelerator and the external proton beam transport system to provide experimenters with dc beam. Especially with the availability of higher intensity, this will lead to an improvement in operating effectiveness of much more than an order of magnitude for many experiments. For all counter and spark chamber experiments, a significant improvement will occur, not only because a structure-free beam will be available, but also because the accelerator will be able to pulse more frequently to provide a higher average beam intensity.

FY 1975

Physics Building Addition 50C - 2.3 million $

The increase in physics research effort and the necessary support functions during the period of this projection will make it necessary to add another wing to Physics Building 50. The addition is foreseen as being approximately 40,000 square feet of laboratories and offices for scientific and support activities and personnel.

End

NATIONAL ACCELERATOR LABORATORY
P.O. BOX 500
BATAVIA, ILLINOIS 60510
TELEPHONE 312 231-6600
DIRECTORS OFFICE

November 26, 1969

Dr. Paul W. McDaniel
Director, Division of Research
United States Atomic Energy Commission
Washington, D. C.

Dear Dr. McDaniel:

Enclosed are the budget estimates for FY 1972 through 1976 that you requested in your letter of October 30, 1969.

In sending them to you I want to emphasize the inherent inaccuracy of such long-range projections when applied to the kind of fundamental research involved here. Depending on the particular discoveries that are made, upon technological invention, and upon actual availability of funds, the whole scale of the research could change upward or downward by a large factor. The figures enclosed represent the estimates that our physicists have made for a reasonable program of research in terms of the present scope of our facility and on the assumption that the procedures and techniques will be similar to those in use at other similar laboratories now.

Mr. Ramsey has not yet seen these numbers, but I am forwarding them to him now for his review. I would like to reserve the right to change them if he should feel that this should be done. More information will be available when we reexamine the magnitude and details of the experimental plans next spring. I understand, however, that you need this preliminary information for the upcoming HEPAP meetings.

The $20,000,000 item that we included for the large bubble chamber in FY 1971 has been postponed. We still intend to submit a proposal for such a chamber in the future. In the meantime, you will notice that we now intend to build a smaller chamber out of equipment funds so that the initial series of neutrino experiments can begin soon after the accelerator begins operating. We are also assuming that in the somewhat longer range future, an amount of about $10,000,000 will be required annually

9 5 70

for some combination of Accelerator Improvements and General Plant Projects. We do not feel that a prediction for authorization for storage rings should be made at this time although we may wish to include such a request before FY 1976 in future assumptions.

Sincerely yours,

Robert Rathbun Wilson

Enclosures - 3
cc: N. F. Ramsey

November 26, 1969

PROJECTED OPERATING PROGRAM

Fiscal Year 1972 through 1976

The Accelerator Facility is assumed to begin operating in FY 73 with 21 shift per week operation scheduled for FY 74 and 75. The major areas of activity are listed below.

1. Accelerator Operation

This activity includes the operation of the 200 BeV Accelerator. Linac operation and the training of the operations group begins in FY 71. Booster operation begins early in FY 72, and 200 BeV operation late in FY 72.

	Man-Years*			Cost
Fiscal Year	S	T	A	(Thousands of Dollars)
1972	20	90	10	2,000
1973	30	145	30	3,000
1974	40	180	40	4,000
1975	40	180	40	4,000
1976	40	180	40	4,000

*S - Scientific (includes direct-program engineers)
T - Technical
A - Administrative

2. Accelerator Development

This activity includes development and operational improvement of the 200 BeV Accelerator. It will include control-computer software development, beam-sensor development, ion-source development, and experimental work on accelerator performance. It will also include accelerator-theory work on improvement of performance, storage rings, and new accelerator concepts. This work is now going on and will continue.

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Fiscal Year	Man-Years S	Man-Years T	Man-Years A	Cost (Thousands of Dollars)
1972	10	20	10	1,000
1973	30	65	30	3,000
1974	50	110	50	3,500
1975	50	110	50	3,500
1976	50	110	50	3,500

3. Experimental-Area Operations and Support

This activity covers the installation, operation, and maintenance of beam transport, experimental equipment, and shielding.

Fiscal Year	Man-Years S	Man-Years T	Man-Years A	Cost (Thousands of Dollars)
1972	10	64	10	1,000
1973	40	208	40	5,500
1974	40	375	40	9,500
1975	40	330	40	8,500
1976	40	330	40	8,500

4. Experimental Area Equipment Development

This activity includes research and development on secondary-beam transport and general purpose detection equipment for experimental use at the 200 BeV Accelerator. This work began in FY 69 and will continue.

Fiscal Year	Man-Years S	Man-Years T	Man-Years A	Cost (Thousands of Dollars)
1972	70	105	70	7,000
1973	80	120	80	8,000
1974	110	165	110	11,000
1975	110	165	110	11,000
1976	110	165	110	11,000

5. Physics Research

This activity covers the physics-research program of the resident staff as well as the administrative and technical assistance needed at NAL for the physics research of visiting users. In FY 71 and 72 the NAL research program will consist of physics experiments at other laboratories.

Fiscal Year	Man-Years S	Man-Years T	Man-Years A	Cost (Thousands of Dollars)
1972	55	85	55	5,500
1973	90	120	90	8,500
1974	120	180	120	12,000
1975	125	250	125	14,000
1976	125	250	125	14,000

national accelerator laboratory

November 26, 1969

ESTIMATED OBLIGATIONS FOR EQUIPMENT

Fiscal Year 1971 through 1976
(Millions of Dollars)

		1971	1972	1973	1974	1975	1976
I.	Beam Transport	4.0	4.0	3.0	3.0	4.5	3.0
II.	Spectrometer Magnets	4.0	4.0	3.0	.5	2.5	2.0
III.	Shielding	1.5	3.0	1.5	1.0	1.5	1.5
IV.	Experimental Equipment	.5	1.5	1.5	1.0	1.5	1.5
V.	Film Analysis	.5	1.0	1.0	.5		1.0
VI.	Computers						
	Large		5.0	8.0	7.0		
	Medium	1.5	1.5				1.0
	Small			1.0			
VII.	Neutrino Beam	4.0					
VIII.	R.F. Beam		1.0	3.0	1.0		
IX.	Hybrid Spectrometer	2.0	3.0	5.0	3.0		
X.	Bubble Chamber	3.0	2.0				
	Total	21	26	27	17	10	10
	Accumulated Total	25	51	78	95	105	115

9.5[illegible]70

I. Beam Transport Magnets

Each \$2M spent on beam transport magnets will buy approximately 30 dipoles, 15 quadrupoles, their power supplies and associated equipment. The dipoles are 6" by 2" by 120" and use 184 K watts each. The quadrupoles are 2" by 72" and use 52 Kw each.

II. Spectrometer Magnets

Approximately 20 spectrometer magnets are planned in a variety of sizes. A possible magnet is one 72" wide by 36" high by 48" long. It will cost \$500,000 and use 400 K watts.

III. Shielding

Standard concrete block and steel shielding will be needed.

IV. Experimental Equipment

The experimental equipment will require large amounts of fast electronic equipment, scintillation counters, spark chambers, spark chamber readout systems and Cerenkov counters.

V. Film Analysis

The film analysis system consists of a number of measuring, analyzing and scanning machines plus a \$300,000 computer to be purchased in FY 1971, which is included in item V and not in VI.

VI. Computers

The central computing facility is envisaged as 3 CDC 6600 systems at about \$5M apiece. It might consist of 2 CDC 7600 systems at about \$7.5M apiece. Three SDS Sigma 7 systems at \$1M apiece are included. Only one small computer, an SDS Sigma 2 at \$0.2M, is indicated since it is expected to buy it in FY 1970.

VII. Neutrino Beam

The principal expense presently understood is \$3M for a large superconducting magnet to sweep secondary muons out of the beam.

VIII. Superconducting R. F. Beam

This beam requires about 20 dipole and 25 quadrupole magnets of a conventional type for about \$2M plus superconducting R. F. cavities of a sort not yet in existence for about another \$2M.

IX. Hybrid Spectrometer

This is an example of a possible large system and includes 2 large superconducting magnets at \$2.5M apiece, a 30" H_2 bubble chamber, at 30" streamer chamber and a superconducting magnet for these chambers.

X. Bubble Chambers

The initial bubble chamber is envisioned to be one containing approximately 25,000 liters of liquid hydrogen or deuterium.

The obligations for FY 1975 and FY 1976 are projected equipment costs for additional target stations not yet authorized.

Nearly 40% for contingency and escalation have been added to the costs in the table. The costs in the notes do not include this 40%.

November 26, 1969

ESTIMATED COMMITMENTS

Fiscal Year 1972 through 1976

Fiscal Year	Amount (in thousands)	Item
1972	$ 2,000	Accelerator Improvements and General Plant Projects
1973	3,000	Accelerator Improvements and General Plant Projects
1974	5,000	Accelerator Improvements and General Plant Projects
	20,000	Twenty-Five Foot Bubble Chamber
1975	10,000	Accelerator Improvements and General Plant Projects
1976	10,000	Accelerator Improvements and General Plant Projects

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Kp

STANFORD UNIVERSITY

STANFORD LINEAR ACCELERATOR CENTER

Mail Address
SLAC, P. O. Box 4349
Stanford, California 94305

December 1, 1969

Dr. Paul W. McDaniel
Director, Division of Research
U. S. Atomic Energy Commission
Washington, D. C. 20545

Dear Paul:

Thank you for your letter of October 30, 1969, which invites us to submit a preliminary 5-year long-range projection. We are particularly pleased to participate in this phase of the planning in order to give HEPAP the opportunity to review our projections.

There are four aspects of the program included in the projection to which I would like to call your attention:

1. The informal planning guidance provided to us relative to the preparation of the President's Budget for FY1971 suggests that the total effort of the laboratory will be less than was accomplished in FY1969 or FY1970. While we understand the severe pressures upon the totality of federal resources, the lack of growth is disappointing in view of stated long-range objectives of the Joint Committee on Atomic Energy to more fully exploit the unique opportunities available at SLAC. Growth toward fuller utilization of the SLAC facility, however, is included beginning in FY1972.

2. We have identified for FY1970 initiation the fabrication and installation of a single ring colliding beam device to be located in the northern part of End Station A. This very desirable extension of the SLAC experimental program has been identified by HEPAP as having extremely high priority. We estimate that a total of \$3.2 million in equipment funds would be required for this projection in the FY1970-71 period. Considering the overriding importance which we attach to this project SLAC would be willing to absorb a substantial part of this additional cost. Nevertheless, in order for us to contemplate the installation of this device a very substantial fraction of this amount would have to be added to SLAC's normal funding levels during these FY1970-71 periods.

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3. The permanent computer building has been identified as an FY1972 line item construction project. As you will recall, the trustees of Stanford University permitted the use of temporary structures during the construction phase of the project with the stipulation that they be removed or replaced at the earliest possible date. We first proposed a permanent computer building for FY1968 authorization. In accordance with the stipulation of the trustees we assign the highest priority to this project of any line item construction project included in our projection.

4. Several references are made in the attached projection to the superconducting accelerator conversion. As we mentioned to you previously a feasibility study on this projection has been carried out for some time which includes several design alternatives. I am including a copy of this feasibility study as it now stands including the documentation relating to budgets. The study is being continued and supplementary material will be issued when available to the loose-leaf format of the attached document. As stated in the introduction to the study, this document is in no way to be considered as a proposal but is submitted at this time in the framework of our long-range projections only.

Again let me thank you for inviting our participation in this new mechanism of the Commission's long-range planning.

With best personal regards,

Pief

W. K. H. Panofsky
Director

Attachments:
1. Long-Range Plan
2. Feasibility Study for a Two-Mile Superconducting Accelerator

cc: Mr. Howard Hooper, PAAO

Dr. William A. Wallenmeyer

STANFORD LINEAR ACCELERATOR CENTER

PROGRAM GOALS AND OBJECTIVES

PHYSICAL RESEARCH PROGRAM
FY1971 THROUGH FY1976

<u>Goals:</u> The Stanford Linear Accelerator Center is a national facility where experiments in high energy physics may be performed by qualified scientists from all laboratories. The goal of the Center is to conduct an effective research program in elementary particle physics.

<u>Objectives:</u> During the five year period covered by this projection SLAC hopes to reverse the present trend and achieve a significant growth in its experimental, theoretical and applied physics research programs.

1. It is proposed to increase operating shifts of the accelerator from the FY1970-FY1971 level of 560 to 685 in FY1972, 845 in FY1973 and 936 thereafter.

2. Production of bubble chamber photographs is proposed to increase to a level of about twelve million by FY1974. This level of production would be consistent with any effort to concentrate bubble chamber photograph taking at SLAC and BNL.

3. A continuing program to exploit new and interesting aspects of particle physics is planned. This will include extensive use of spectrometer facilities for elastic and inelastic electron scattering, electrodynamics and photoproduction. The use of optical spark chambers and wire chambers will be extended and continue to be highly productive through the period of this projection. A small rapid cycling bubble chamber will be put into use in FY1971 as a visible target for spark chamber counter combination. The development and use of special secondary beams unique to SLAC will be furthered in this period. New specialized bubble chamber techniques will be developed such as triggered light operations, the use of neon-hydrogen combinations and others.

4. Design and fabrication of a single ring colliding beam device was initiated in FY1970. This device will become operational in mid-FY1972 at an energy range of up to 2 GeV. Following a year of experimental exploitation, an upgrading program is proposed which will add a second ring to the device and increase the energy to about 3 GeV.

A large solid angle detector for the colliding beam device is identified for initiation in FY1974.

5. A large wire spark chamber system will be installed in the pion beam and be available in FY1973 for the investigation of a large multi-use program of meson spectroscopy in the 8 to 16 GeV range.

6. Expansion of the data analysis capability is projected. Despite expansion of the central computer, saturation is projected by FY1973, a follow-on computer is therefore included for FY1973 obligation and FY1974 delivery. The acquisition of two PDP-10 class computers is projected. The first of these will serve as a buffer between on-line data acquisition and the central computer. The second will serve in conjunction with the large wire spark chamber system. Gradual improvement of conventional, automated and semi-automated data reduction equipment aimed at improving both speed and reliability is projected.

7. It is planned by FY1973 to equip the 40" bubble chamber with a 70 Kg cryogenic magnet. This conversion not only represents a large forward step in bubble chamber technology, but for a relatively low investment permits an immediate improvement in the accuracy and energy range of the chamber.

8. The energy of the SLAC accelerator will be increased to about 25 GeV by the end of FY1973. This will be accomplished by replacing the present complement of vendor supplied klystron tubes with a higher power (30 MW) tube as the existing tubes fail.

9. A concentrated effort in the design feasibility of the superconducting conversion of the SLAC linac is proposed with engineering and design funds requested for FY1972 and FY1973. Assuming the successful conclusion of the feasibility studies, construction authorization for the superconducting conversion of SLAC is identified for FY1974.

STANFORD LINEAR ACCELERATOR CENTER

BUDGET ASSUMPTIONS

OPERATING EXPENSES

PHYSICAL RESEARCH PROGRAM
FY1971 THROUGH FY1976

	Dollars in Millions					
	Estimated	Long Range Projection				
	FY1971	FY1972	FY1973	FY1974	FY1975	FY1976
Current Program Level	$24.7	$24.7	$24.7	$24.7	$24.7	$24.7
Special Items and Proposed Changes:						
Increased Accelerator Shifts and Beam Switchyard-Target Area Operation	--	1.3	2.9	3.8	3.9	4.0
Increased Bubble Chamber Photos	--	.6	.7	1.2	1.2	1.2
Colliding Beam Device Operation	--	.4	.8	.9	1.0	2.2
Proposed Level of Superconducting Accelerator Development	.4	.5	.5	.4	.3	--
Improved Support to Research Groups		.3	.7	1.0	1.3	1.4
Increase Data Analysis and Computer Operation	--	.3	.5	.8	1.5	1.7
Klystron Upgrading Program	.2	.2	.1	--	--	--
Increased Plant Maintenance	--	.2	.2	.3	.3	.4
Experimental Group H	--	.1	.2	.3	.4	.4
Experimental Group I	--	--	--	.1	.3	.4
Subtotal Projected Program	25.3	28.6	31.3	33.5	34.9	36.4
Escalation @ 5% per year	NA	1.4	3.1	5.0	7.0	9.1
Subtotal Program with Escalation	25.3	30.0	34.4	38.5	41.9	45.5
Decrease Permitted by FY1974 Auth. of Superconducting Conv. of SLAC w/escalation	--	--	--	.7	1.9	3.4
Grand Total	$25.3	$30.0	$34.4	$37.8	$40.0	$42.1

STANFORD LINEAR ACCELERATOR CENTER

BUDGET ASSUMPTIONS

ASSUMPTIONS USED IN PREPARING COST PROJECTION FOR PROPOSED PROGRAM

	Estimated	Long Range Projection				
	FY1971	FY1972	FY1973	FY1974	FY1975	FY1976
1. Operations						
a. Proposed Accelerator Shifts per Year	560	685	845	936	936	936
2. Other Factors						
a. Bubble Chamber Photos Taken	5M	8M	9M	12M	12M	12M
b. Manned Computer Shifts	15	18	21	21	21	21
c. Manned Computer Shifts Follow-on Computer				10	15	18
3. SLAC Experimental Groups and PHD Research Physicists						
a. Number of SLAC Research Groups	7	8	8	9	9	9
b. Number of Experimental Physicists	50	53	55	58	60	62
c. Number of Theoretical Physicists	16	18	19	20	21	23

The FY1971 SLAC Budget Request was for $29.6 million and was consistent with our understanding of internal AEC planning as reflected in the Five Year Plan. The requested level of support would have permitted fuller exploitation of the accelerator and existing research equipment. The current projections are based upon planning guidance informally received relative to the preparation of the President's Budget. While the long standing objective expressed by HEPAP and the JCAE of achieving full operation of the Center will be delayed by the enormous pressure on federal resources, the projections include attaining full operation of the accelerator in FY1974. Cost estimates for accelerator operating costs are based upon the assumption that favorable experience with accelerator components like klystron and thyratron tubes will continue. The projections for Target Area operation recognize only increased activity due to denser accelerator scheduling. It is assumed that increased cost factors brought about by increasing beam paths and complexity can be accommodated by reductions made possible by improved efficiencies resulting from the continuing improvement (AI) program; for example, the present two control rooms will be computerized and unified, requiring manning of the DAB (Data Assembly Building) only.

The program initiated in FY1969 to gradually increase the energy of the accelerator to about 25 GeV should be complete by FY1973. Under this program the present complement of vendor supplied 20 MW tubes are replaced by 30 MW tubes as they fail.

The level of bubble chamber picture output is planned to be increased from the present level of about five million to twelve million by FY1974. Approximately nine million of the photographs would be made available to outside users of SLAC for analysis at their home institutions.

It is planned to begin the fabrication and installation of a single ring colliding beam device in FY1970. This device will come into operation midway through FY1972. Following experimental exploitation of the device for about one year, an improvement program is proposed. This program will add a second ring and increase the maximum energy of the device. In parallel with the upgrading program, a large solid angle detector will be installed and placed in service in FY1974. The research program carried out with the device will be accomplished by a combination of outside user participation and diversion of SLAC research interest. The operation of the device, however, is identified starting with modest support in FY1972 increasing to a $2.2 million level in FY1976 when the improved device, as well as the detector, become operational.

Commensurate with the proposed increase in accelerator operation and bubble chamber picture production, some improvement in the level of support for SLAC research groups is planned. This includes improvement not only for the experimental groups but allows provision for the applied physics groups to pursue more vigorously such fields as high field cryogenic magnets and bubble chamber developments. The estimates for the support of the SLAC experimental groups is consistent with SLAC Scientific Policy Committee guideline of about 50% utilization of the accelerator beam by SLAC experimentors.

It is planned in FY1972 to restore the level of data analysis to FY1969 levels. Thereafter, some modest improvement in data analysis, particularly system programming support, and full operation of large computer is planned. The significant increase in projected cost in FY1975 is associated with maintenance service for the follow-on computer system.

An allowance is made to increase plant maintenance in recognition of decreased effort in this area experienced in FY1970 and FY1971 and in recognition of the gradual aging of the laboratory facilities.

An increase in the number of SLAC experimental groups is proposed with one group each planned for FY1972 and FY1974.

STANFORD LINEAR ACCELERATOR CENTER

BUDGET ASSUMPTIONS

CAPITAL EQUIPMENT NOT RELATED TO CONSTRUCTION

PHYSICAL RESEARCH PROGRAM
FY1971 THROUGH FY1976

	Dollars in Millions					
	Estimated	Projected				
	FY1971	FY1972	FY1973	FY1974	FY1975	FY1976
Large Computer Additions	$ .1	$ .5	$ .5	$ .5	$ .5	$ .5
Follow-on Computer			12.0			
Follow-on Computer Additions					.5	1.0
PDP-10 Class Computers (2)		.6		.6		
Subtotal Computer	.1	1.1	12.5	1.1	1.0	1.5
Colliding Beam Program	2.2	2.1	1.0	3.6	2.1	--
All Other High Energy Physics	1.4	4.0	3.3	2.6	3.1	2.4
Subtotal Non-Computer	3.6	6.1	4.3	6.2	5.2	2.4
Escalation @ 5%/year	NA	.3	.4	.9	1.0	.6
Subtotal Escalated Non-Computer	3.6	6.4	4.7	7.1	6.2	3.0
Total Capital Equipment	$ 3.7	$ 7.5	$17.2	$ 8.2	$ 7.2	$ 4.5

1. During the period of this projection it is planned to purchase $.5 million in additions for the IBM 360/91 system annually. Despite the planned level of system expansion, it is projected that the system will be saturated by FY1973 and for that reason a follow-on computer system is included for FY1973 obligation and FY1974 delivery. Additions are planned for the follow-on systems at a level of $.5 million for FY1975 and $1.0 million for FY1976.

A more immediate increase in the computational facilities at SLAC will be effected with the acquisitions of PDP-10 class computers in FY1972 and FY1974. The first of these will be a data acquisition computer, interfacing with the 360/91 system. The second one will be utilized in conjunction with a large wire spark chamber.

2. It is planned to install a colliding beam device in the area north of End Station A. The initial installation will be a single ring configuration capable of up to 2 GeV per beam. In order to undertake this program, the laboratory plans on $1.4 million being added to the normal equipment level for FY1970 and FY1971. The estimated cost of the device is $5.3 million with completion planned for mid-FY1972. After about one year of experimental exploitation it is planned to begin an improvement program. This program will extend over 2½ years (FY1973 - $1.0 million, FY1974 - $1.8 million, FY1975 - $1.4 million) and will progressively add a second ring to the device and increase rf power such that beams of 3 GeV can be accepted.

3. A large solid angle magnetic detector, perhaps using superconducting techniques, is proposed for the colliding beam device. The estimated cost of this detector is $2.5 million; $1.8 million is included in the FY1974 projection and $.7 million in the FY1975 projection.

4. Continued addition to elements of beam transport systems, targets and shielding will be needed as additional beam paths are developed and higher energies are achieved with the accelerator. Allowances of $.3 million in FY1972, $.4 million in FY1973, $.5 million in FY1974 and FY1975 and $.6 million FY1976 are included in the projection. Consistent with the advice of the SLAC Scientific Policy Committee to increase the level of beam transport elements to levels more comparable with other major laboratories, $.5 million is added to the base projection for both FY1972 and FY1973 for this purpose.

5. The conversion of the SLAC 40" bubble chamber to a cryogenic coil of about 70 Kg is planned to begin late in FY1971, $.1 million, and to extend through FY1972, $1.5 million, and FY1972, $.5 million. This conversion will enable the SLAC chamber to increase its energy acceptance from 6 to 10 GeV to the higher energies possible at SLAC and to provide very high accuracy for the study of particle resonances.

6. It has been concluded that use of a large spark chamber system in SLAC's pion beam will provide a superior facility for strong interaction physics. Such a facility will be developed in cooperation with other universities and will be operated as a facility available for general scheduling under advice of the Program Advisory Committee. This system will be installed in the central beam in conjunction with the wire spark chamber magnet which is presently in design and will be used for the precise quantitative investigations in broad areas of meson spectroscopy in the 8 to 16 GeV range. Cost estimates for the components of the spark chamber system are about $.8 million. It is planned to commit $.2 million in FY1971 and the balance in FY1972.

7. A large aperture, large angular acceptance threshold Cerenkov counter has been proposed for complementary use with the large spark chamber system. This device will permit the separation of pions from kaons at SLAC energies. The projection for FY1973 includes $.6 million for this detector.

8. Improvement to the complement of major experimental devices is projected with $.2 million in FY1972 and $.3 million thereafter. Examples of the improvements contemplated include increased instrumentation and experimental capability of the spectrometers, revised pole tips on one or more of the research magnets and the installation of a cryogenic coil on the 82" bubble chamber. An allowance of $.7 million and $1.0 million is provided for the latter purpose in FY1974 and FY1975 respectively.

9. Provision is included in the projections for equipment associated with the general SLAC experimental and applied physics programs. Also included is an estimate for indirect costs associated with the labor required for the fabrication of equipment items.

STANFORD LINEAR ACCELERATOR CENTER

BUDGET ASSUMPTIONS

CONSTRUCTION PROJECTS

PHYSICAL RESEARCH PROGRAM
FY1971 THROUGH FY1976

	Dollars in Millions					
Project	FY1971	FY1972	FY1973	FY1974	FY1975	FY1976
1. Accelerator Improvements	$ .7	$ .9	$ 1.1	$ 1.3	$ 1.5	$ 1.7
2. General Plant Projects	.5	.8	.7	.8	.9	1.0
3. Computer Building		4.0				
4. Superconducting Accel. Design and Engineering		2.0	2.0			
5. Superconducting Accel. Conv.				62.9-84.9*		
6. Large Track Chamber					16.0	
7. Engineering and Support Building						3.4
8. 100 GeV Spectrometer						15.0
	$ 1.2	$ 7.7	$ 3.8	$65.0-87.0	$18.4	$21.1

*Range of preliminary cost estimates stated in calendar 1969 dollars.

1. Accelerator Improvements: The projected levels of Accelerator Improvement funding during the period of the projection are designed to provide resources for modifications to the accelerator-switchyard-target area complex at SLAC, necessary for the continued improvement of the Center's operating effectiveness and efficiency. This will include both a reduction in lost beam time, through the upgrading of existing hardware, the expansion of existing systems, and an increase in the flexibility of experimental preparation, set-up and execution. A significant portion of the annual AIP allotments will continue to be devoted to the improvement of control systems and the ultimate consolidation of the control rooms into the Data Assembly Building.

2. General Plant Projects: The investment in conventional facilities at SLAC is in excess of $47 million. The projected levels of General Plant funding are necessary both to maintain adequately this investment and to accommodate the continuous changes to the physical makeup of the site necessitated by the evolving SLAC Research Program.

The projection for FY1972 includes the provision of an on-site warehouse of approximately 15,000 gross square feet. The building cost of the warehouse is about $120,000; the total cost is about $185,000. The building will be designed so as to be expandable if future needs require it. It will, in the long run, be less expensive to acquire on-site warehouse space than to continue leasing such space off site.

3. Computer Building: At present both the SLAC Computer Facility and the related Automatic Data Reduction Group are housed in temporary facilities. Although the Board of Trustees of Stanford University maintains a stringent policy which precludes the erection of sub-standard or temporary buildings, the utilization of these facilities was allowed during the construction phase of the project, with the understanding that SLAC would replace these buildings with more permanent accommodations at the earliest possible date.

In accordance with this stipulation SLAC first proposed a permanent computer building for FY1968 authorization. The building which is now proposed for FY1972 authorization contains approximately 50,000 net square feet. This building will accommodate both the present IBM 360/91 system and the follow-on system which is identified elsewhere in these projects (Schedule C) for FY1974 delivery. The building will also house the Automatic Data Analysis Group near the central computer, an operational necessity given this group's development of devices which will measure experimental data on film automatically.

The scope of the building included in this projection is unchanged from that included in the FY1971 Budget Request. The cost estimate, however, has been escalated 8% in recognition of the one year slip in schedule.

4. & 5. Superconducting Accelerator Design & Engineering: After using the SLAC accelerator for a number of years with energies up to 25 GeV, major change in the accelerator may be desired. Recent developments at Stanford have indicated that a superconducting accelerator would combine the advantages of the SLAC accelerator (beam quality and intensity) with the better duty cycle of other type machines. The energy (100 GeV) would be five times the energy of the present SLAC accelerator.

It is felt that by FY1972 it will be possible on the basis of work done at Stanford, SLAC and other centers, to initiate an extended two year construction planning and design study. It is anticipated that by FY1974 the actual conversion of the SLAC accelerator to superconducting operation will be feasible. Stated in calendar 1969 dollars, the preliminary cost estimate, including contingencies, for the conversion is $62.9 million to $84.9 million depending upon which of four design alternatives proves to be technically feasible. If one assumes escalation at 5% per year the estimate then becomes $77.3 to $104.6 million.

6. Large Track Chamber: It is anticipated that SLAC will propose for FY1975 the construction of a large track chamber, probably a hydrogen bubble chamber of 4 meter diameter. Such a chamber would be a very good match to the 100 GeV accelerator, especially for unique experiments with very high energy polarized photons, as well as with more classical experiments in secondary beams, pions, kaons, and anti-protons.

7. Engineering and Support Building: A building of approximately 75,000 square feet will be required to house physicists and support personnel due to the projected increase in research activities. The building is expected to contain laboratory space; it is identified for FY1976 authorization. While not well scoped at this time, an estimate based upon recent experience and escalated 5% per year is included.

8. 100 GeV Spectrometer: A high energy spectrometer is a necessity for continuing the elastic and inelastic electron and muon scattering that has already been such a source of fundamental information at present SLAC energies. It could also be used in two-body photoproduction at very high energies as well as in coincidence with the already existing spectrometers.

MANPOWER PROJECTIONS

	FY1971	FY1972	FY1973	FY1974	FY1975	FY1976
I. MANYEARS						
A. Operations:						
Scientific	295	300	310	315	320	325
Other	560	630	700	730	760	795
Total	855	930	1,010	1,045	1,080	1,120
B. Equipment:						
Scientific	25	25	20	25	20	10
Other	80	80	90	100	100	40
Total	105	105	110	125	120	50
C. Construction:						
Scientific	10	40	45	45	55	60
Other	20	45	45	225	395	425
Total	30	85	90	270	450	485
D. Indirect	305	305	310	310	315	315
E. Subtotal	1,295	1,425	1,520	1,750	1,965	1,970
F. Reduction to Operating Program made possible by FY1974 authorization of Superconducting Accelerator	—	—	—	(50)	(100)	(150)
G. Total Manyears	1,295	1,425	1,520	1,700	1,865	1,820
II. HEADCOUNT						
A. Full Time	1,230	1,405	1,495	1,545	1,640	1,655
B. Temporary and Part-time	130	135	140	145	150	155
C. Total	1,360	1,540	1,635	1,690*	1,790*	1,810*

*SLAC personnel only; figures exclude subcontract and/or temporary personnel associated with the Superconducting Accelerator Conversion.

Ames Laboratory USAEC

IOWA STATE UNIVERSITY

Ames, Iowa 50010

November 20, 1969

Dr. Paul W. McDaniel
Director, Division of Research
U.S. Atomic Energy Commission
Washington, D.C. 20545

Dear Dr. McDaniel:

Transmitted herewith is a five-year long-range projection (FY 1971-1976) for the High Energy Physics Program as requested in your letter of October 30, 1969.

You will notice that this projection reflects a contemplated increase in the High Energy Physics Program in preparation for a substantial participation in the National Accelerator Laboratory facility. We have also included a list of papers published and in preparation for the period January, 1969, to November, 1969, as part of the report.

Very truly yours,

Robert S. Hansen

Robert S. Hansen
Director

Enc.

cc: Chicago Operations Office w/enc.
Dr. D. J. Zaffarano w/o enc.
Dr. W. J. Kernan w/o enc.

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SUBJECT

PROGRAM 05 - NARRATIVE JUSTIFICATION OF SCHEDULE B

NAME W. J. Kernan

DATE 11-14-69

High Energy Physics:

Bubble Chamber Group. The program of experimental studies of multi-pion production in meson-nucleon, nucleon-nucleon, and antinucleon-nucleon interactions is continuing. The partial funding of a multiple-view POLLY system by the A.E.C. in FY 69 and additional funding with University money has allowed construction of this system to begin. This construction is proceeding on schedule. Preliminary discussions with the University of Colorado and the University of Minnesota have been held about our servicing some of their measuring needs on a contract basis. It appears that such an arrangement may be worked out. To fully implement this arrangement will require some additional personnel.

To make effective use of the capability of the POLLY system will require some expansion of the physics staff. Over the next three years we would plan on adding one additional faculty member and three research associates to this group. Additional equipment needs of this group will be less than \$50,000 per year except in 1972, when an expansion of our ASI 6050 computer will be necessary (\$85,000) and in 1974 when a new computer system will be requested (\$235,000).

Counter Group. A counter hodoscope experiment to study the charge zero meson spectrum has been approved for running at the Argonne ZGS. The experiment will detect neutron angles and time of flight near zero degrees laboratory production angle and will determine the missing mass recoiling against the neutron with a typical accuracy of ±12 MeV. An experiment to determine the backward scattering cross section in $\pi^+ d$ interactions as a function of energy has been proposed to LRL for possible running at the Bevatron. This experiment is in collaboration with a group from St. Louis University.

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This group needs additional postdoctoral associates and technicians. We would plan to add two postdoctoral associates and two technicians over the next three years. Additional graduate students will also be added.

A computer for use with scintillation counter arrays and/or wire spark chambers is on order. Additional peripheral equipment (magnetic tape unit) at a cost of $25,000 will be needed in FY 1971. Construction of spark chambers and scintillation counter hodoscopes with interfacing to the counter is estimated to cost $40,000 per experiment.

General Comments on Future Experimental Program. Both the bubble chamber and counter groups expect to participate in the experimental program at the National Accelerator Laboratory, using the 200-GeV accelerator, at the earliest possible date. Part of the projected future personnel needs are associated with these plans. For example, the counter group would like to devote one person at least half time to trying to plan experiments for NAL and to develop familiarity with the planned experimental areas, schedules, and services at the installation. The bubble chamber group, in addition to devoting some effort to the planning of experiments, must also devote time to the necessary hardware and software changes on the POLLY system to accommodate film from the bubble chambers that will be operating at NAL. This is necessary not only to service our own research program but also for the programs with the University of Colorado and the University of Minnesota if they are to be able both to use our measuring system and to do experiments at NAL.

Theoretical Group. The theoretical group has been very active and productive and has interacted extensively with the experimentalists. Their greatest need is for one additional staff member in phenomenology and some postdoctoral associates in the same area.

It is hoped to add a total of three people in phenomenologically oriented work over the next five years.

General Comments on the Experimental and Theoretical Programs. There has been no budget growth in this area in three years. These years have corresponded to a period when we hoped to become a well established competitive (with other appropriate sized universities) center of research in high energy physics. We felt, and still feel, that significant growth in this area is necessary to provide the Physics Division of the Ames Laboratory with a balanced research program. Conscious of the need to continue the momentum of this program we have made sacrifices in other areas to promote the necessary growth. Basically all of the growth in University money available to the Physics Department has been absorbed in increasing the effort in High Energy Physics. For example, the entire counter group program was begun and has grown during this period of no additional AEC money. This was accomplished despite rising costs in the other areas of high energy physics research. We have reached the limit of our ability to support this area of research at the expense of our other commitments. Either the funding in this area must grow or a contraction of our effort in high energy physics must begin. The size of all the groups in this area is so small that it is difficult to see how they can effectively survive a contraction of effort.

SUBJECT

PROGRAM 05 - NARRATIVE JUSTIFICATION OF SCHEDULE B

NAME W. J. Kernan

DATE 11-14-69

Schedule B

Operating Expenses for High Energy Physics
under Program 05 for Fiscal Years 1971-1976
Budget Projections (in Thousands)

FY 1971	FY 1972	FY 1973	FY 1974	FY 1975	FY 1976
$600	$750	$900	$1000	$1100	$1150

Schedule C

Capital Equipment not related to construction
for High Energy Physics under Program 05 for FY 1971-76
Budget Projections (in Thousands)

FY 1971	FY 1972	FY 1973	FY 1974	FY 1975	FY 1976
$125	$195	$125	$400	$200	$125

Appendix: Papers Published, Submitted for Publication, or IS Reports from January 1969 to November 1969

Bubble Chamber Group:

1. "Investigation of the Final States $K^-\pi^-\pi^+\pi^o p$ and $K^-\pi^-\pi^+\pi^+ n$ Produced in K^-p Interactions at 4.6 and 5.0 GeV/c," R. E. Juhala et al., accepted by the Phys. Rev. (in press).
2. "$\bar{p}$-p Annihilations to K and π Mesons at 2.7 GeV/c," L. S. Schroeder et al., Phys. Rev. (in press), Dec. 25 issue, 1969.
3. "Spin Analysis of $p\pi^+\pi^-$ Enhancements in the $pp\pi^+\pi^-$ Final State Produced in pp Interactions at 22 GeV/c," J. I. Rhode et al., accepted by the Phys. Rev.
4. "Interpretation of the $p\pi^+\pi^-$ and $\bar{p}\pi^+\pi^-$ Mass Spectra in the Reaction $\bar{p}p \rightarrow \bar{p}p\pi^+\pi^-$ at 2.7 and 2.9 GeV/c," W. J. Kernan et al., accepted by the Phys. Rev.
5. "Two and Three Pion Production Without Annihilation in Antiproton-Proton Interactions at 2.4 and 2.9 GeV/c," R. A. Jespersen, W. J. Kernan, and R. A. Leacock, submitted to the Phys. Rev. 11/6/69. (A preliminary paper on this was presented at the Lund Conference but will not be listed here since the final version has been submitted to the Phys. Rev.)

In addition two papers were submitted to (and presented at) the Lund Conference.

6. "Hyperon-Antihyperon Production in $\bar{p}p$ Interactions at 2.4 and 2.9 GeV/c," T. L. Schalk, L. S. Schroeder, and W. J. Kernan.
7. "Antiproton-Proton Annihilations at 2.4 and 2.9 GeV/c," R. P. Radlinski and W. J. Kernan.

APPENDIX (continued)

Counter Group:

1. "$\pi^- p$ Elastic Scattering at 2.51, 2.76, and 3.01 GeV/c near $t \simeq -3$ $(\mathrm{GeV/c})^2$," M. Fellinger et al., Phys. Rev. Letters 23, 600 (1969).
2. "Elastic Scattering of Negative Pions from Deuterium at 2.01, 3.77, and 5.53 GeV/c," M. Fellinger et al., Phys. Rev. Letters 22, 1265 (1969).

Theory Group:

1. "Uniform Treatment of Pion Electro- and Photo-Production in Regge Theory," K. E. Lassila and T. Ebata, Phys. Rev. 183, 1425 (1969).
2. "Pomeranchuk Pole Exchange Contribution to Forward Photon Processes," T. Ebata and K. E. Lassila, Nuovo Cimento Letters 2, 284 (1969).
3. "K-Parity for Systems with SU(3) and Charge Conjugation Summetry," A. C. Dotson and R. H. Good, Nuovo Cimento 61A, 706 (1969).
4. "Gauge Invariance and Regge-Pole Theory in Compton Scattering," T. Ebata and K. E. Lassila, Phys. Rev., accepted for publication.
5. "V-Particle Decay in the Lee Model," C. L. Hammer and T. A. Weber, J. Math. Phys. (in press), Nov. 1969.
6. "Covariantly Defined Matrices," T. J. Nelson and R. H. Good, accepted by J. Math. Phys.
7. "On Production Dependence of the $A_2(1300)$ Mass Distribution," T. P. Coleman, R. C. Stafford, and K. E. Lassila, submitted to Phys. Rev. Letters.
8. "Pion-Deuteron Elastic Scattering and Bakamjian-Thomas Transformation Theory," D. E. Johnson and R. A. Leacock, submitted to Nuovo Cimento, Nov. 1969.
9. "A Method of Quantization for Relativistic Fields," C. L. Hammer and R. H. Tucker, submitted to J. Math. Phys.

SUBJECT

PROGRAM 05 - NARRATIVE JUSTIFICATION OF SCHEDULE B

NAME

DATE

Appendix (continued)

In addition three papers were published in special proceedings or as IS Reports:

10. "Mass Structure of the A_2 Meson," P. V. Ruuskanen and K. E. Lassila, Proceedings of the 1968 Finnish Summer School in Theoretical Physics, Liperi, Finland (Gordon and Breach, Inc., 1969).

11. "Two Particle Quantum Electrodynamics," C. L. Hammer and D. S. Moroi, IS Report 2085, May 1969.

12. "Wave Packet Solutions of the Time Dependent Schroedinger Equation," T. A. Weber and C. L. Hammer, IS Report 1795, October 1969.

UNIVERSITY OF CALIFORNIA, SAN DIEGO

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DEPARTMENT OF PHYSICS
REVELLE COLLEGE

POST OFFICE BOX 109
LA JOLLA, CALIFORNIA 92037

2 December 1969

Dr. Paul W. McDaniel, Director
Division of Research
United States Atomic Energy Commission
Washington, D. C. 20545

Dear Dr. McDaniel:

Enclosed is the five-year long-range projection for Contract No. AT(11-1) GEN 10, PA 10, Task C, that was requested in your letter of October 30, 1969.

We are sorry for the delay in sending this information and sincerely hope that it will not prove to be an inconvenience to you.

Sincerely yours,

George E. Masek

George E. Masek
Professor of Physics

GEM:mb

Encls.

9 5208

G. Masek

FIVE-YEAR BUDGET FORECAST

Contract No. AT(11-1) GEN 10, PA 10, Task C

Fiscal Year	Direct Salaries	Materials and Supplies	Travel	Indirect Expense	Total
1971	144	184	25	77	430
1972	164	175	20	91	450
1973					500
1974					525
1975					525

BASIS OF FIVE-YEAR PROJECTION

We base our projections for the 1st year (Fiscal '70) on a program that is partially established (Cosmic Ray Muon Experiment) and upon experiments which are in advance stages of planning and are expected to be running during Fiscal '71.(Sigma Leptonic and Heavy Lepton Experiments). The Fiscal '71 is outlined in some detail in the following table. Subsequent years are based not on specific projects, but upon our experience as to the general level needed to cary on an effective program in high energy physics. The increases in these subsequent years are based on: (a) A general 7% per year increase in salaries and doing experiments. (b) The addition of one more post-doctoral appointment and one more academic appointment and appropriate increases in non-professional staff. (c) The expectation that we will be participating more and more in programs at SLAC and NAL, where it is anticipated that the costs of experiments will be greater (see enclosure on NAL estimates - last page).

Task C - Masek

Activity	Location of Experiment	Start Date	Data Analysis Completion Date	Costs for Fiscal 1971 (exclusive of salaries) in thousands.				
				Instrumentation	Operation	Travel	Analysis	Total
Zenith Angle Dependence of Cosmic Ray Muons.	UCSD	Sept.'68	Sept. '70	4	15		10	29
Sigma Leptonic Decays and Associated Experiments.	LRL Bevatron	July '70	Sept. '71	40	40	15	15	110
Heavy Lepton Experiment	SLAC	Dec. '70	Sept. '71	25	25	10		60
Miscellaneous Instrumentation Research and Equipment.				10				10

Total 209

As can be seen, we expect to have completed the analysis on our $\pi\pi$, K_{e3} charge asymmetry, and velocity of light experiments by Fiscal '71 and, therefore, they have not been included. We expect to continue running on the cosmic ray telescope through all of Fiscal '71 and probably into Fiscal '72. The budget restrictions imposed for this year (Fiscal '70) have caused us to postpone the start of any new experiments until late in Fiscal '70 or early Fiscal '71 -- thus the Sigma experiment now appears as the major item in Fiscal '71. We are also carrying out tests on the feasibility of looking for heavy leptons at SLAC and so have included this near the end of Fiscal '71. The salaries are based on our present level with the following additions:

1 - Assistant Research Physicist I	one-half year	$ 6,000
1 - Senior Electronics Technician or engineer (electronics)	full time	8,972
2 - Research Assistant I		7,188
2 - Laboratory Helper		8,616
		$30,776

	6/70	6/71	6/72	6/73	
			NAL turn on		
Experimental Plans:					
Staff for proposal.	→				
Proposal preparation and initial design for instrumentation.	→	→			
Instrumentation and soft ware.		→	→		
Experiment.			test	run →	

	FY 71 #	FY 71 Cost*†	FY 72 #	FY 72 Cost*†	FY 73 #	FY 73 Cost*†	Totals #	3 Years' Cost
Manpower:								
Physicist [one during proposal preparation and one before run].	1	14.0	1	14.0			2	28.0
Engineer [one electronic for computer interface and one mechanical].	1	16.0	1	16.0			2	32.0
Technicians including Lab assistants.	1	10.0	2	20.0	3	20.0	6	50.0
Students.	2	12.0	2	12.0	1	6.0	5	30.0
		52.0		62.0		26.0		140.0
Instrumentation:								
Data system expansion (Not including computer)		10.0		15.0				25.0
Detector (for heavy leptons)								
- forward angle 50-Bev muon spectrometer (with wire chambers).		5.0		50.0				55.0
- target spark chamber (assume target built by NAL).				10.0				10.0
- counter system.				10.0		10.0		20.0
		15.0		85.0		10.0		110.0
On-site Expenses and Travel: ?				5.0		50.0		55.0
		67.0		152.0		86.0		305.0

*Includes overhead and benefits. †These are taken to be excess costs over our present level and directed towards experiment at NAL.

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DEPARTMENT OF PHYSICS
REVELLE COLLEGE

POST OFFICE BOX 109
LA JOLLA, CALIFORNIA 92037

December 2, 1969

Director Paul W. McDaniel
Division of Research
Atomic Energy Commission
Washington, D. C. 20545

Dear Dr. McDaniel:

I hope this enclosed tenative five-year plan still arrives in time for the HEPAP meeting.

To be noticed that it includes plans for the National Accelerator Laboratory. However, it is difficult to foresee at this moment what part of the experimental expenses will actually be assumed by NAL. In the worst case, our expenses might possibly be quite a bit higher than those indicated here if we are to be allowed to work at Batavia. As an average, this is my best estimate.

I understand from your letter that the details that led me to this figures should not be submitted as they are subject to change more than the totals themselves.

I hope this report will be of some use.

Sincerely yours,

Oreste Piccioni

Oreste Piccioni

OP:mt

Encl. 1

9 5144

AEC AT(11-1) GEN 10 PROJECT 10
TASK A

PROJECTION OF MANPOWER AND EXPENSE
for the Fiscal Years 1971 to 1976

	1971	1972	1973	1974	1975	1976
MANPOWER						
Professors	2	2	2	2	2	2
Post Doctorals	10	10	10	10	10	10
Graduate Students	4	5	5	5	5	5
Engineers	1	1	2	2	2	2
Technicians	2	3	3	3	3	3
Laboratory Assistants	4	4	5	5	5	5
Scanners	8	8	9	9	9	9
Secretary	1	1	1	1	1	1
Total Manpower (Man-years)	32	34	37	37	37	37
EXPENSE (in thousands)						
Salaries	246.8	287.8	348.4	365.8	383.8	402.9
Indirect Costs	137.2	160.2	189.1	198.4	208.1	218.5
Travel & Shipping	60.0	70.0	80.0	85.0	90.0	90.0
Materials & Supplies	170.0	250.0*	210.0	230.0	250.0	275.0
Total Expense	614.0	768.0	827.5	879.2	931.9	986.4

*This figure may be underestimated. It reflects the expectation of preparing experiments for NAL. It is not known the extent to which NAL will cooperate financially.

9 5 44

CALIFORNIA INSTITUTE OF TECHNOLOGY

CHARLES C. LAURITSEN LABORATORY OF HIGH ENERGY PHYSICS
PASADENA, CALIFORNIA 91109

December 2, 1969

Dr. Paul W. McDaniel, Director
Division of Research
U.S. Atomic Energy Commission
Washington, D.C. 20545

Dear Paul:

This letter is in reply to your request for an informal submission of five-year long-range projections for the High Energy Physics Program at Caltech. These projections are similar to those presented last year, although they are slightly higher in FY 1973 and beyond because of anticipated increased costs of performing experiments at the 200-BeV accelerator. The projections are:

FY 1971	$1,500,000	FY 1974	$1,950,000
FY 1972	1,600,000	FY 1975	2,100,000
FY 1973	1,800,000	FY 1976	2,250,000

These cost projections are based on the following assumptions regarding our research program:

(1) The theoretical program is expected to continue growing during this period. The theory group is very active and productive and has been stimulated by the move to adequate facilities in our new building. We intend to maintain our strength in this area in which we have been outstanding.

(2) The user group activities involving counter and spark chamber techniques will continue at a high level. We anticipate that this group will participate actively in the experimental program at NAL and that this will require a modest increase in funds after FY 1972.

(3) The development of our user group activities in the area of data analysis, which has begun during the time that the synchrotron program is being terminated, will continue during FY 1971 and FY 1972. This data analysis program is well-started but it has been held back by lack of funds until the final shut-down of the synchrotron.

With best regards,

Sincerely yours,

Robert Walker 9 5A83

Robert L. Walker

RLW:jc

cc: W. A. Wallenmeyer
San Francisco Operations Office
R. F. Bacher

Columbia University in the City of New York | *New York, N. Y. 10027*

DEPARTMENT OF PHYSICS 538 West 120th Street

November 19, 1969

Dr. Paul W. McDaniel, Director
Division of Research
U. S. Atomic Energy Commission
Washington, D. C. 20545

Dear Dr. McDaniel:

The budget forecast for the years 1971-1976 in theoretical physics research is as follows:

FY 1971	FY 1972	FY 1973	FY 1974	FY 1975	FY 1976
293,000	346,000	424,000	487,000	559,000	600,000

The considerable rise in the amounts requested, increasing progressively until FY 1975, is dictated by Columbia University's plan to add three new senior faculty members to our permanent staff by that time. With the enlarged senior staff we will have need of more research associates. Due to budget limitations we have been forced, in the last couple of years, to cut the number of research associates from six to three. By FY 1975 we hope the number will rise to eight. The number of graduate students in theoretical physics will also increase. This year, in order to meet the stringencies of our budget, we have (with difficulty) succeeded in having all but one of our graduate students supported by University Fellowships during the academic year. However we have saturated the possibilities of University support, and additional graduate students will require contract support, as has been our custom in the past. We estimate that we will have six more graduate students. Finally, there is an item for two visiting scientists. In the past we have found extended visits by distinguished theoretical physicists very rewarding and indeed sometimes essential to our research program, and we hope to be able to afford such visits in the future.

Our figures represent the cost of this larger staff, plus a "cost of living" rise, and an allowance for a proportional increase in other services.

Sincerely,

Robert Serber

Robert Serber
Principal Investigator
AT (30-1)-1932, Task 2

RS:it

cc New York Operations Office

0 4086

Columbia University
DEPARTMENT OF PHYSICS

NEVIS LABORATORIES
P.O. Box 137
Irvington, N.Y. 10533
914 LY 1-8100

November 26, 1969
Nevis 9413

Dr. Paul W. McDaniel, Director
Division of Research
U.S. Atomic Energy Commission
Washington, D.C. 20545

Dear Dr. McDaniel:

Re: AT(30-1)1932 Task I

Here are our projections for FY 1971-1976 for the experimental physics part of the high energy research program at Columbia.

High Energy Experimental Physics Program (in thousands of dollars) (Note: Theoretical Physics costs for AT(30-1)1932 Task II are not included).

FY	Research*	Special Additional Costs	
1971	1850	210	Intersection Storage Ring Study of Dileptons**
1972	2035	100	
1973	2240	300 600	Spectrometer System at NAL***
1974	2460		
1975	2710	500	Upgrading of instrumentation for NAL full scope activities (transition to 400 GeV, full intensity, etc.)
1976	2980		

* A yearly increase of 10% is assumed for inflation, complexity factor, and minimal growth.

** Expected as Task III of AT(30-1)1932.

*** Amounts for equipment to be used at NAL could be reduced to the extent that NAL funds might be available for this purpose.

November 26, 1969

In addition to the above we expect for FY 1971-1972 a line item construction project of $1,900,000 for the new research building requested in several previous budget proposals.

Sincerely,

Marcel Bardon

Marcel Bardon
Deputy Director

MB:b
cc: Mr. George Macpherson
New York Operations Office

HARVARD UNIVERSITY

DEPARTMENT OF PHYSICS

CYCLOTRON LABORATORY
CAMBRIDGE 38, MASSACHUSETTS

November 28, 1969

Dr. Paul McDaniel
Director of Research
Atomic Energy Commission
Washington, D.C. 20545

Dear Paul,

This is a reply to your letter of October 30, 1969 requesting a five-year forecast for funding under the contract of Harvard University with the Atomic Energy Commission for research in high energy physics. Although you asked for this informal projection in the same format we send the information to the New York Operations Office, we have in fact, in the past only sent them the figures and not words. I understand that for the use to which you wish to put the projection, the words are more important than the figures and accordingly, I will present them to you.

Some of this was communicated to you by Professor Pipkin -- at that time Chairman of the High Energy Physics Committee -- on July 19, 1969 in response to a request for our plans for experiments at NAL.

In this five-year period, we expect some of the methods of doing high energy physics to remain similar and others to be changing. We are expecting to continue and expand work in connection with the Cambridge Electron Accelerator. The three lines of work in which we are engaged are a large coincidence electroproduction program, a production of vector bosons with tagged gamma ray beam, and colliding beam experiments. In the first of these, it should be noted that electroproduction experiments whereby the scattered electron is detected in coincidence with outgoing particles are possible only at accelerators with good duty cycle, such as synchrotrons, and are not yet possible at the pulsed electron accelerators. They are very difficult experiments and need a lot of running time. However, we believe they will be very fruitful of good physics results. We expect to be continuing with them all through this period of time. The second of these, the boson photoproduction with the tagged gamma ray beam, is just beginning and looks as if it is a very fruitful source of experimentation and is something we wish to continue. Thirdly, we are preparing, in conjunction with the CEA staff members, a detector for on line colliding beam experiments. This is, of course, very exciting, and we hope that these will begin some time in approximately 12 months and will continue for an appreciable period of time. It may be appropriate also for these on line colliding beam experiments to be replaced by spark chamber experiments of the optical type with or without a magnetic field. We expect to be involved with these also, particularly in the use of the automatic spark chamber measuring apparatus SPASM. At the present moment, this research constitutes a little more than 60% of our budget and the rate of progress is limited by the limited finances. All of these experiments are using wire spark chamber detectors now, all of fairly similar design and in fact, in order to save money, time, and effort, we have made some standardization on the type of detector. We expect these will need increasing amounts of computer time, as we will note below.

As to experiments done elsewhere, at other accelerators, we have been carrying out an extensive program at Brookhaven National Laboratory on the alternating gradiant synchrotron. We have been working on inelastic scattering of mu mesons and expect to continue this in an experiment scheduled next year simultaneous with an elastic scattering experiment of mu mesons on protons. This will be done in collaboration with physicists from Columbia, Rochester, and NAL. We also have a proposal to measure the scattering of pi mesons by electrons, an experiment which we think has great merit and can successfully be accomplished. We expect to continue this type of experiment and to push for extension into the National Accelerator Laboratory. We are particularly concerned with any experiments on electromagnetic physics in which our expertise will be of use. We have participated in summer studies at NAL and expect to be presenting proposals in collaboration for experiments for the mu beams and electron and gamma ray beams. In addition, we are shortly presenting to NAL a proposal that we, at Harvard, prepare polarized target facilities. Since this last will be a facility, we anticipate they will be funded through NAL and are not included here.

We expect in a few months the first of 10^6 bubble chamber pictures on KP interactions which will be measured during FY 71 and 72 using our computer measuring system SPASM.

All of this work is severely pinched for lack of funds and we accordingly will be requesting an increase for next year on this account alone.

We expect to have increased tenure faculty in the field of high energy physics at Harvard by adding to our number Dr. Carlo Rubbia, who is in my view, probably the best high energy physicist in Europe at the present moment. At the time of Professor Pipkin's letter of July 19, we had not heard from Dr. Rubbia, so that his plans were not included in that letter. He expects to engage in research in high energy physics using American accelerators. During the fiscal year 1971, he expects to be doing an experiment either at the CEA or at the AGS, and will be bringing some apparatus over from CERN for doing this. For the following fiscal year (1972) he will be collecting together a group from Harvard to work on the intersecting storage rings (ISR) at CERN on an experiment in collaboration with CERN staff. This experiment has already been approved as one of the first experiments to work. It is an experiment on elastic p-p scattering. It will therefore be a joint Harvard-CERN collaboration and we will want some part of the funding, particularly of the American personnel, with which by this time Rubbia will be counted, to come out of the Harvard AEC contract. Following this, we expect that Dr. Rubbia will be working at other American accelerators and his interest at the present moment looks towards spark chamber experiments with neutrino beams at NAL. Dr. Rubbia has already shown himself to be a master in the usage of spark chambers in high energy physics experiments : he has performed a succession of magnificent experiments using a K_2^o beam at CERN and we anticipate that this mastery of technology will be enviable also at his experiments at NAL.

Harvard Cern ISR

Thus for fiscal year 1971, we are requesting a modest increase in our budget in order to take account of the additional work that we expect Carlo Rubbia will be doing while with us. Towards fiscal year 1972, the increase has to be more substantial because by this time, not only will Professor Rubbia be fully involved with us, but in addition, we expect that large sums will be needed for our spending on preparation for the experiments at NAL. These were already intimated to you in the letter from Professor Pipkin in July.

For fiscal years 1971 to 1973, also, we anticipate a large equipment expense for computer facilities. If this expense is not begun by fiscal year 1971, we will be overloaded in our existing facilities, which are approaching saturation even now. This expense, we hope, will be a part of a joint proposal involving other AEC users in the Cambridge area, Chemistry from Harvard University and users in Tufts University, Brandeis University, and possibly some other government users. This is under discussion at the present time, and we expect that it will be presented before the end of 1969. What we put here is an estimate of our share of this, or in case a joint proposal is not possible, what would approximately be necessary for buying a computer to perform these functions by itself. If it is not possible, of course, to begin this in fiscal year 1971, it will be even more necessary in the year 1972.

It is probably in fiscal year 1973 that we will be presenting to the AEC jointly with Tufts and Brandeis Universities a proposal for expansion of computer measuring of pictures. In a separate letter to Dr. Wallenmeyer I have outlined our present commitments in this area. I am estimating the whole expense of this at this moment here for this budget. I will note here that already a spark chamber experiment at Tufts University is being measured on our measuring device SPASM, which was built on our AEC contract, and we have made an informal arrangement with Tufts and Brandeis Universities so that they will collaborate with us in some of the software development or using the SPASM bubble chamber film. At the moment we are doing all the hardware and the funding and we assume that for the bigger proposal, the funding will come from the Harvard contract. The modified SPASM will be useful for both the spark chamber and bubble chamber film.

It is always hard to put requests into the "reasonable" dollar amounts. Ten years ago we would be making large requests with strong expectation of seeing them granted. However, too large a request now seems unrealistic.

Accordingly I present here a <u>lower</u> figure than we feel could be justified and granted in a more favorable fiscal climate. This is the minimun figure below which the research program must be emasculated. They are thus lower than our projections last year.

Please note also a slightly slower rate of additional spending for NAL than anticipated in the letter of July 19, 1969.

Yours sincerely,

Dick.

Richard Wilson
Chairman, High Energy
Physics Committee
Harvard University

RW:spc

Harvard University

Department of Physics
Contract AT(30-1) 2752
Informal Cost Projection in Thousands of Dollars

November 28, 1969

Fiscal Year	1971	1972	1973	1974	1975	1976
Programs As Existing	1800	1900	2100	2200	2300	2400
Extra For New Programs	150	50	250	300	300	350
Work on ISR	50	200	50	-----	----	------
Extra For NAL	50	300	400	400	450	500
Total Operations	2050	2450	2800	2900	3050	3250
			Equipment			
Existing Program	200	200	150	150	150	150
NAL	0	100	180	180	200	200
Computer*	300	300	300	-----	-----	-----
New Picture Measuring Facilities**	-----	-----	300**	------	------	------
Total Equipment	500	600	930	330	350	350

* Our Share
** To Be Used Jointly by Tufts and Brandeis Universities

UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN
DEPARTMENT OF PHYSICS
URBANA, ILLINOIS 61801

November 24, 1969

Dr. Paul W. McDaniel, Director
Division of Research
U. S. Atomic Energy Commission
Washington, D. C. 20545

Dear Dr. McDaniel:

Re: Contract AT(11-1)-1195

This is in response to your letter of October 30, 1969 to Professors Robert D. Sard and A. Wattenberg requesting an informal early submission of the long-range projections (FY1971-1976) for the High Energy Physics Program.

Our projections have been modified by the reduced level of the present FY-70 operating budget and our plans to modernize our equipment as soon as possible. The amounts presented below are preliminary statements of what would be involved in continuing our program in experimental elementary particle physics at present accelerators and preparing for experiments at NAL. The amounts do not constitute any major perturbations or departures from continuation of existing operating programs.

FY71	$1,950,000
FY72	2,000,000
FY73	2,250,000
FY74	2,400,000
FY75	2,500,000
FY76	2,550,000

During FY-71 we hope to acquire a computer for operating the DOLLY bubble chamber measuring and data analysis system. If we do not acquire the computer prior to FY-72 then an additional (approximately) $700,000 should be included during FY-72 under equipment obligations.

It is our interpretation that construction projects funded from the plant and capital equipment appropriation are not applicable.

Sincerely,

R D Kenworthy

R. D. Kenworthy

RDK:js
cc: R. Sard
A. Wattenberg
Chicago Operations Office

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
LABORATORY FOR NUCLEAR SCIENCE
CAMBRIDGE, MASSACHUSETTS 02139

December 3, 1969

Dr. William A. Wallenmeyer
Assistant Director for High Energy
Physics Program
Division of Research
U. S. Atomic Energy Commission
Washington, D. C. 20545

Dear Dr. Wallenmeyer:

This letter is to confirm LNS research cost estimates for FY71 through FY76 that were telephoned to your office earlier this week in response to Dr. McDaniel's request of October 30, 1969.

Our estimates for total Operations and Equipment costs, exclusive of any allowance for equipment costs that might be incurred in connection with NAL research performed by LNS staff, is as follows:

	FY71	FY72	FY73	FY74	FY75	FY76	
Operations	3,850	4,700	4,900	5,300	5,500	5,700	(thousands)
Equipment	1,203	670	1,090	1,200	610	600	(thousands)

The figures given reflect base personnel levels similar to those that have been held to by the Laboratory during the past year. Estimated materials, services and travel costs are those we regard to be minimally required for the effective continuation of existing and planned programs, including importantly, among others, the photoproduction and colliding beam work at CEA by Drs. Deutsch, Frisch, Luckey and Osborne. The operating costs show also for FY72 and thereafter expenses for the program of Professor Ting that will have until then been borne jointly by MIT non-government funds and by the DESY accelerator program. The higher-than-average equipment expenditures for FY71, FY73 and FY74, additionally, are due mainly to our proposed plans for augmentation of our computer facility (FY71), for a data analysis facility for CEA magnetic analyzer experiments (FY73) and for a proposed new generation computer for PEPR (FY74).

In respect to expected operations at NAL, we submitted in our letter to you of July 31, 1969 our appraisal at that time of the potential dollar impact of LNS activity, without regard for the specific channel (i.e. LNS or NAL or both) through which those funds might be administered. We regard those estimates as highly tentative and, without question, as considerably higher than would likely be expended directly by LNS. We are at present making a serious effort to review this question and will submit our estimate, hopefully before the end of December, along with our customary, more detailed breakdown of the five-year forecast.

Sincerely yours,

Peter Demos

Peter T. Demos
Director

PTD/jp

THE UNIVERSITY OF MICHIGAN
ANN ARBOR

THE HARRISON M. RANDALL LABORATORY
OF PHYSICS

TEL. NO. 313-764-4437

November 17, 1969

Paul W. McDaniel, Director
Division of Research
U. S. Atomic Energy Commission
Washington, D. C. 20545

Dear Mr. McDaniel:

This letter is in response to your request for a five year projection for the Theoretical High Energy Physics program at the University of Michigan. The current program involves five faculty members whose research is supported by the AEC at just under $100K per year.

We plan to submit to the University, to the AEC High Energy Division, and to other agencies, a proposal for FY71 for an Institute of Theoretical Physics which will bring together theorists and applied mathematicians around the campus. High Energy will form a substantial portion of this Institute. With a new appointment and addition of the other high energy theorists now on campus, the scientific manpower will rise to 10 in FY71. The budget proposal will be for about $200K per year. The estimates for ensuing years are given in the table:

FY	Scientific Manpower HE Theory	Secretarial & Technical Staff	AEC Support in Thousands $
71	10	1	200
72	10	2	220
73	11	2	240
74	11	2	240
75	12	2	260

We do not contemplate any requests for equipment or construction.

Yours truly,

Marc Ross

Marc Ross
Professor
of Physics

cc: H. R. Crane
H. Houk

THE UNIVERSITY OF MICHIGAN
ANN ARBOR

THE HARRISON M. RANDALL LABORATORY
OF PHYSICS

TEL. NO. 313-764-4437

November 26, 1969

Dr. Paul W. McDaniel, Director
Division of Research
U. S. Atomic Energy Commission
Washington, D. C. 20545

Dear Dr. McDaniel:

This letter is in reply to a request you made for an estimate of the funding required by the Michigan Bubble Chamber Group over the next five years. During this period I estimate our annual operating costs should rise from the present $330,000 to approximately $405,000. The average annual operating costs over the next five years should be about $380,000. In addition, I estimate total equipment purchases of about $300,000 for this five year period.

The following table shows how the increases in operating costs should be spent.

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Dr. Paul W. McDaniel, Director
November 26, 1969

	FY69 Level (Full-time Equivalent)	Additions Requested	Additional Cost (Thousands of Dollars)
Scanning and Measuring Help	12	---	---
Other Non-Professional Help	4	---	---
Professional Help	1	+ 1	23
Research Associates	1	+ 2	34
Graduate Students	8	+ 2	14
Faculty	4	+ 1	4

The equipment purchases will be for automatic measuring equipment and additional computing facilities.

Yours truly,

Daniel Sinclair /sdm

Daniel Sinclair

DS/sdm

cc: B. K. Leverette, Jr.

9 5[illegible]81

THE UNIVERSITY OF MICHIGAN
ANN ARBOR

THE HARRISON M. RANDALL LABORATORY
OF PHYSICS

TEL. NO. 313-764-4437

November 20, 1969

Paul McDaniel, Director
Division of Research
Atomic Energy Commission
Washington, D. C. 40550

Dear Dr. McDaniel:

During the five year period from 1971-1976 the 200 GeV accelerator will come into operation. To use this accelerator properly we anticipate having around a 30% increase in staff size mostly at the post-doctoral level. A comparable increase in equipment complexity is expected. Thus including inflationary effects we will need a 50% increase over our present operating budget to utilize the 200 GeV accelerator efficiently.

At some time during this period it is very likely that we will want to build a relatively large spectrometer system which will require capital equipment money of about $250,000. We have worked out some ideas for such a spectrometer. What is indefinite at present is what parts of such devices should be built by N.A.L. as generally available facilities and what parts should be supplied by users. I would hope that some general overall decision was reached on the policy to be followed within the next 6 months since detailed plans must begin to be made soon.

In a similar vein we will need a computer to use with on line experiments at N.A.L. The cost of such an installation will be $300,000 to $400,000. While N.A.L. will have some on line computers an overall policy on types and utilization is still not formulated. There could be need for capital equipment money for such a machine.

I hope that this information is not so vague as to be useless but some policy decisions have not been made at N.A.L. yet.

Sincerely,

D. I. Meyer

Donald I. Meyer

DIM:aa

THE UNIVERSITY OF MICHIGAN
ANN ARBOR

THE HARRISON M. RANDALL LABORATORY
OF PHYSICS

TEL. NO. 313-764-4437

December 2, 1969

Paul W.McDaniel, Director
Division of Research
U. S. Atomic Energy Commission
Washington, D. C. 20545

Dear Dr. McDaniel:

I am writing this letter in response to your request for a five year projection on our high energy physics counter program at Michigan.

During the period 1971-1976 we expect to continue our studies of very high energy proton proton interactins, at Argonne, at the CERN intersecting storage rings, and at the 200 GeV accelerator at Batavia. We expect to continue to do simple counter experiments so that we do not anticipate any need for a large increase in our support which is presently about $95,000. We propose the following increases mainly to counter the unfortunate inflation which seems to exist:

FY	SCIENTIFIC STAFF	SECRETARIAL	AEC SUPPORT
71	5	1	$ 100,000
72	5	1	105,000
73	5	1	110,000
74	5	1	115,000
75	5	1	120,000

We do not anticipate any requests for major equipment or construction.

Sincerely yours,

Alan Krisch

A. D. Krisch
Professor of Physics

ADK:aa

0 5148

UNIVERSITY of PENNSYLVANIA

PHILADELPHIA 19104

The College

DEPARTMENT OF PHYSICS

November 21, 1969

Dr. Paul W. McDaniel, Director
Division of Research
Atomic Energy Commission
Washington, D. C. 20545

Dear Dr. McDaniel:

I am pleased to answer your letter of October 30, 1969 that asks for an advance in formal submission of our five-year long-range projections (FY1971 - FY1976) for the High Energy Physics Program. These are furnished you via enclosure and while they are, of course, only tentative it is my estimate that the formal submission which we expect to be making next January will contain the same data.

Should you need further information please let me know.

Sincerely,

Sherman Frankel

Sherman Frankel
Principal Investigator

SF:mm
Encl. (as above)
cc: Mr. J. D. Hart, Princeton Br., AEC(NYO)

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UNIVERSITY of PENNSYLVANIA

PHILADELPHIA 19104

The C[redacted]

DEPARTMENT [redacted]

ADVANCE ESTIMATE

[redacted]ROGRAM ASSUMPTIONS AND FORECASTS FOR FY1971-1976

AEC CONTRACT NO. AT(30-1)-2171

Ac[redacted]	1971	1972	1973	1974	1975	1976
Operations [redacted]-01)	1,850	2,060	2,200	2,300	2,400	2,500
Equipment [redacted]						
Non-comp[redacted]	250	250	300	300	350	350
Computer [redacted]	100	100	125	150	1,200	150
Constructi[redacted]. No. 69-2						
Particle [redacted]aboratory	2,500					

Explanator[redacted]

a. The su[redacted]or FY1975 anticipates replacement of the 360/65 computer at obsole[redacted]e.

SF:mm
11-21-69

PRINCETON UNIVERSITY
PALMER PHYSICAL LABORATORY

Department of Physics

Palmer Physical Laboratory
Post Office Box 708
Princeton, New Jersey 08540

November 24, 1969

U.S. Atomic Energy Commission
Division of Research
Washington, D.C. 20545

Atten: Dr. Paul W. McDaniel, Director

Subject: Informal Five Year Forecast, High Energy Physics Research Contract AT(30-1)-2137

Dear Sir:

Pursuant to your request, we are submitting our long-range projection for Fiscal Years 1971 - 1976.

Yours very truly,

T. Wunderlich

T. Wunderlich
Technical Business Manager
High Energy Physics Research

TW:ec
Enclosure

cc: J. D. Hart, Princeton Branch, A.E.C.
G. T. Reynolds
R. A. Rossi
D. T. Wilkinson

FIVE YEAR PLAN

High Energy Physics Research

(Figures in Thousands of Dollars)

	FY 1969 Carry Forward	FY 1970 Oblig.	FY 1970 Cost	FY 1971 Oblig.	FY 1971 Cost	FY 1972 Oblig.	FY 1972 Cost	FY 1973 Oblig.	FY 1973 Cost	FY 1974 Oblig.	FY 1974 Cost	FY 1975 Oblig.	FY 1975 Cost	FY 1976 Oblig.	FY 1976 Cost	Cost After FY 1976
Operations	-	1,600	1,600	1,700	1,700	2,000	2,000	2,100	2,100	2,200	2,200	2,300	2,300	2,400	2,400	-
Equipment	261	100	180	150	200	300	200	200	175	200	200	150	200	150	200	156
TOTAL	261	1,700	1,780	1,850	1,900	2,300	2,200	2,300	2,275	2,400	2,400	2,450	2,500	2,550	2,600	156

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THE UNIVERSITY OF ROCHESTER
DEPARTMENT OF PHYSICS AND ASTRONOMY
ROCHESTER, NEW YORK 14627

PARTICLE PHYSICS LABORATORY

November 24, 1969

Dr. Paul W. McDaniel
Director, Division of Research
United States Atomic Energy Commission
Washington, D. C. 20545

Dear Dr. McDaniel:

In reply to your letter of October 30, please find attached the long-range five-year projections for the High Energy Physics Research Program at the University of Rochester.

These projections are based on our present effort in theoretical and experimental research, as well as the needs and potential for growth of these groups. The high energy theory group under the leadership of Professors Marshak and Okubo projects a modest increase in staff and graduate students in order to maintain its high level of productivity. The experimental group has been engaged in experiments at BNL, Argonne and SLAC and is actively considering and preparing for early participation in the NAL research effort.

The projections are in line with the excellent recommendations of the HEPAP report of June 1969 and have been adjusted on the basis of our current funding and of the projected AEC recommendations communicated to us by the N.Y. Operations Office on May 7, 1969. On July 8, 1969 in answer to a request by Dr. Wallenmeyer, we submitted estimates for our research participation at NAL; these estimates were based on our needs for a more accelerated increase in support than is presented in the attached long-range plan.

Finally, we have indicated the need for funding of two major facilities:
(a) An automatic film measuring device (PEPR) to serve four Universities in the upper New York state region (Rochester, Syracuse, Albany, Buffalo)
(b) The construction of a magnetic spectrometer facility for use at NAL.

Sincerely yours,

J Bruce French　　Adrian Melissinos

J. B. French　　A. C. Melissinos

ACM/bmm
Encl.
CCs: R.S. Knox
D. McBride

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OPERATING COSTS (In thousands)

	FY70	FY71	FY72	FY73	FY74	FY75	FY76
HIGH ENERGY 05-01-29-01							
Theory							
Scientific Personnel	9*	10	11	11	12	12	12
Graduate Students	6	8	9	10	11	12	12
Costs	242	300	340	380	420	450	480
Particle Physics							
Scientific Personnel	9	10	11	12	13	14	14
Graduate Students	10**	11	12	13	15	17	17
Costs	643	780	910	1020	1130	1250	1320
Total High Energy Costs	885	1080	1250	1400	1550	1700	1800
Major Facilities							
(a) PEPR	-	300	100	-	-	-	-
(b) Magnetic Spectrometer	-	-	100	250	-	-	-
Total Facilities	-	300	200	250	-	-	-

* One of the 9 members of the High Energy Theory Group is presently supported by an NSF Postdoctoral Fellowship which expires in June 1970. Thus, the increase from FY70 to FY71 is in essence for the support of two additional staff members.

** Only 6 of the 10 participating students are supported by the AEC.

THE UNIVERSITY OF WISCONSIN

MADISON 53706

DEPARTMENT OF PHYSICS
475 NORTH CHARTER STREET

November 21, 1969

Dr. Paul W. McDaniel
Director, Division of Research
Atomic Energy Commission
Washington, D. C. 20545

Dear Dr. McDaniel:

The purpose of this letter is to outline the long range projections (FY 1971-76) of the phenomenology program at Wisconsin, as requested in your letter of October 30, 1969.

In the FY 1971 budget proposal of AEC contract AT(11-1)-881, the phenomenology program costs will be included as line items. This action was suggested by Dr. Hildebrand last fall, in discussion of our proposal to the AEC on "Phenomenological Analysis of Fundamental Particle Scattering Data". The phenomenology budget request for FY 1971 will be at the level of the original proposal, $70,000.

Assuming that this fiscal requirement is met in FY 1971, our five year projection in phenomenology for FY 72-76 is as follows:

<u>FY 1972 cost increases</u>

1 visiting staff member (distinguished scientist with phenomenological interests)	$25,000
1 graduate research assistant	6,000
computer costs, estimated, (no computer costs will be included in FY 1971 budget)	15,000
	$46,000

<u>FY 1973 cost increases</u>

1 postdoctoral research associate	$20,000
1 computer programmer (full-time)	15,000
1 graduate research assistant	6,000
	$41,000

<u>FY 1974 cost increases</u>

1 graduate student	$ 6,000
hourly help	4,000
	$10,000

FY 1975 cost increases

none

FY 1976 cost increases

none

The above cost projections include salaries, travel and publication costs, fractional secretarial help, and University overhead. The proposal submitted to the AEC for the "Formation of a Particle Data Bank" as a national facility is independent of the phenomenological research costs projected above.

The phenomenological program at Wisconsin has already made significant contributions to research in strong interaction physics, as indicated in outside letters of evaluation that were recently obtained for the AEC (copies of the letters were sent to Dr. Hildebrand). We hope to maintain this role as a world's center in phenomenological particle research and to interact strongly with the theory and experimental programs at the National Accelerator Laboratory. By FY 1974 we expect that this program will reach a optimal size, so that no further cost increases will be necessary in FY 75 or 76.

Sincerely yours,

Vernon Barger

Vernon Barger

kmp

THE UNIVERSITY OF WISCONSIN

MADISON 53706

DEPARTMENT OF PHYSICS
475 NORTH CHARTER STREET

November 20, 1969

Dr. Paul W. McDaniel
Director, Division of Research
Atomic Energy Commission
Washington, D. C. 20545

Dear Dr. McDaniel:

We are writing in response to your letter of October 30, 1969 concerning the long range program projections for FY 1971-76 for the Theoretical Physics part of AEC contract AT(11-1)-881.

The needs of the Theoretical Physics program at Wisconsin are sufficiently pressing, especially for the next year or two, that we thought it would be desirable to describe the Theory program separately and in more detail than in the past.

The long range plans of the Theory group are closely tied to the development of the National Accelerator Laboratory. As you know, our present theory program places great emphasis on the interaction of theorists with experimentalists. We believe we have the core of a group which will interact strongly with, and contribute to, the NAL program. In the five-year projections outlined below, we have specifically made provisions for two continuing positions for visiting staff, one at a junior level, and one at a more senior level. We intend to use these positions for one-year visitors who will spend part of their time at NAL. This arrangement is in keeping with the spirit of the URA-NAL policy on visiting scientists and the NAL program.

Our projections are based on our feelings about the composition of an ideal theoretical group in high energy physics, given realistic boundary conditions with respect to the University and the AEC, and our expected interaction with the NAL. We would like to emphasize that the financial projections which we have prepared are conservative as judged by our past experience. We should also note that we do not anticipate much growth in the permanent staff beyond the five year period covered in the projections.

There are six faculty members in the present high energy theory group. We hope to add three more permanent staff, one each in FY 1971, FY 1973, and FY 1975. We already have an offer outstanding for FY 1971 to a very strong candidate, Dr. Christopher Michael, at the Assistant Professor level. If he accepts, we will have reached the level we project in the strong interaction area. Since there will be a major effort in the areas of weak and electromagnetic interactions at NAL, we will emphasize these areas in filling the remaining two faculty positions. The visiting positions will first be filled in FY 1972 and FY 1974, at roughly the time the NAL facilities will come into partial and full operation.

We feel that an optimal high energy theory group should have roughly one postdoctoral research associate and two graduate research assistants per faculty member. Our long-term projections for increased AEC contracted support are aimed at reaching this optimum level by FY 1976. We anticipate that University support will continue at least at the level of six researcl assistants.

A breakdown of our projected cost increases over the present contract for FY 1971-76 is given below. Travel and publication costs, fractional secretarial help, and University overhead are included in the salary figures quoted in the projections. No provisions for inflation or increases in salaries beyond the current level are included.

For completeness we include increases for FY 1971. The postdoctoral research associate and graduate research assistant positions listed for 1970-71 restore positions which were eliminated in FY 1970 due to budgetary limitations.

Incremental costs 1970-71

1 permanent faculty member	12,000
2 postdoctoral research associates	40,000
2 graduate research assistants	12,000
	$64,000

We will require an additional $20,000 in FY 1971 just to cover increases in operating costs that have already been evident in FY 1970.

Assuming that the foregoing requirements are met in FY 1971, our five year projection of cost increases for FY 1972-76 is as follows:

Incremental costs FY 1972-76

FY 1972

1 visiting junior staff member	26,000
2 postdoctoral research associates	40,000
2 graduate research assistants	12,000
	$78,000

FY 1973

1 permanent faculty member	12,000
2 postdoctoral research associates	40,000
2 graduate research assistants	12,000
	$64,000

FY 1974

1 visiting senior staff member	40,000
1 postdoctoral research associate	20,000
2 graduate research assistants	12,000
	$72,000

FY 1975

1 permanent faculty member	12,000
2 postdoctoral research associates	40,000
2 graduate research assistants	12,000
	$64,000

FY 1976

1 postdoctoral research associate	20,000
1 graduate research assistant	6,000
	$26,000

Total incremental costs, 1972-76	$304,000

We consider ourselves to be one of the strongest high energy theoretical groups in the country. We have made substantial contributions to the progress of high energy physics, and expect to continue to do so. We intend in the future to work closely with NAL, and to assist in making it a successful national and international facility. In view of our past success, and the importance of University-NAL collaboration in the future, we regard the projected cost increases as well justified.

Sincerely,

Vernon Barger

Vernon Barger

Loyal Durand, III

Loyal Durand, III

bp

THE UNIVERSITY OF WISCONSIN

MADISON 53706

DEPARTMENT OF PHYSICS
475 NORTH CHARTER STREET

November 28, 1969

Dr. Paul W. McDaniel
Director
Division of Research
United States Atomic Energy Commission
Washington, D. C. 20545

Dear Dr. McDaniel:

This letter is in response to your request of 30 October 1969 for a five year projection for our contract (AT(11-1)-881). The letter is a general view of the experimental project for the next five years including as enclosures brief projections by the various groups and a five year budget. The theoretical program is covered in separate letter.

For an overview of the projected research work and concomitant budgetary requirements the following input information was used:

1. During the past three fiscal years the funding level for experimental physics has dropped from $1.52 M to $1.41 M. As a result of this, bubble chamber data production is now only 30% of the 67-68 rate, and the equipment used by the counter spark-chamber group is rapidly becoming obsolete.

2. The National Accelerator Laboratory facility at Batavia, Illinois will provide beams in 1972. The research groups have shown considerable interest in the project, and geographic proximity will lead naturally to active participation in work at the laboratory.

3. A working automatic film measurement device will be essential within the next two years for the group to remain competitive in the analysis of pictures from the large bubble chambers.

4. Development of rapid cycling bubble chambers will require additional cryogenic facilities at Madison.

The enclosed projection was prepared with these factors in mind. Provision has been made for increasing the base level of the budget, purchasing new equipment for use at the National Accelerator Laboratory, adding two visiting appointments at the professorial level for users of the Batavia facility, and completing and operating the SATR automatic film analysis project. In addition over the next 5 years two new appointments at the assistant professor level should be made. More detail about the plans of the various groups can be found in the attached summaries.

Sincerely,

Lee G Pondrom

Lee G. Pondrom

LGP:jw
Encs.

5-Year Plan - Camerini, Cline, Fry, March, Reeder

We foresee three major trends in our research over the period 1970-75:

(1) Bubble chamber experiments with weak and electromagnetic interactions will continue at least until 1973. We are planning a muon exposure in Gargamelle (1971) and an antineutrino exposure at BNL (1972). Our work on the ANL 40" chamber should be completed by the end of 1972.

(2) Conventional strong interaction experiments in bubble chambers will be de-emphasized as a major activity as the currently proposed experiments are completed. Future plans in this area are tied to SATR.

(3) Starting in 1972 or 1973, a major share of our research will be at NAL, and we anticipate that this will be mainly in electronic and hybrid systems rather than conventional bubble chamber physics.

For the immediate future, our only requirement for bubble chamber work is funds to hire additional personnel to bring the analysis system up to capacity. We will continue to gain experience in electronic and hybrid experiments through collaborations (we have had three so far), working toward an independent hardware capacity at NAL in fiscal 1973, as indicated in the budget projections.

We expect a reduction in graduate students of about 50%, the funds freed thereby to go to acquiring a 1/1 ratio of postdoctoral to faculty employees.

5 Year Plan - Pondrom-Prepost

During the next five years the counter group plans to continue experiments using optical and digital spark chambers to study the interactions and decays of elementary particles. In addition to using the accelerators at which we have worked in the past, we are interested in using the new Batavia accelerator when it becomes available in 1972. Through 1970 the group will be principally occupied with two optical spark chamber experiments at the Argonne ZGS. Additional work with digital spark chambers is planned in conjunction with the deuteron beam at the Princeton-Pennsylvania Accelerator. Work at Batavia is still in the very early planning stage. The group should add one more physicist, preferably at the assistant professor level within the next two years. Continuation of present budgetary limitations will soon force the group to perform fewer experiments, because the present equipment will not only become obsolete, but simply wear out, and limited funds will have to be spent on development rather than on operations.

Five Year Plan - Walker-Erwin-Thompson

In addition to relatively routine bubble chamber experiments, the group efforts are concentrated in three directions: 1) rapid cycling bubble chamber development; 2) use of a rapid cycling chamber employing counters and spark chambers in "hybrid" configurations; and 3) development of the SATR automatic film measurement system. These three projects are mutually complementary; automatic data processing will be essential in handling output from rapid cycling hybrid configurations. The rapid cycling chamber now being built is 14" in diameter, and hopefully will operate as high as 50 HZ. A superconducting magnet for the bubble chamber will be needed, and local cryogenic facilities will be expanded for further bubble chamber development. The SATR project will begin measuring film in July, 1970, and will be in complete working order by June, 1971. The effort will change from hardware to software work in order to increase the measurement speed and achieve fully automatic scanning.

1971-1976

Projected Program & Costs

Experimental Physics - Contract AT(11-1)-881

	FY 1970	FY 1971	FY 1972	FY 1973	FY 1974	FY 1975	FY 1976
Previous Year Adjusted		1,480,000	2,180,000	2,260,000	2,550,000	2,700,000	2,830,000
To Fund Shortages in Current Program		300,000	---	---	---	---	---
SATR - Completion of Project ($100.0 K) & Operation ($80.0 K)		100,000	<21,000>	---	---	---	---
Rapid Cycling and Cryogenic Facilities		25,000	25,000	---	---	<50,000>	---
Batavia Program Development & Operation: Initial - $200.0 K; Steady State $100.0 K.		200,000	<105,000>	---	---	---	---
Two New Professorial Staff Members & Support		---	100,000	---	100,000	---	---
Spark Chamber Expansion & Development		---	---	100,000	---	---	---
Relocation of Laboratory & Computing Facilities in New Physics Building		---	---	75,000	<79,000>	---	---
Totals	1,410,000	2,105,000	2,204,000	2,485,000	2,621,000	2,700,000	2,830,000

THE UNIVERSITY OF WISCONSIN

MADISON 53706

DEPARTMENT OF PHYSICS
475 NORTH CHARTER STREET

November 28, 1969

Dr. Paul W. McDaniel
Director
Division of Research
United States Atomic Energy Commission
Washington, D. C. 20545

Dear Dr. McDaniel:

This letter is in response to your request of 30 October 1969 for a five year projection for our contract (AT(11-1)-881). The letter is a general view of the experimental project for the next five years including as enclosures brief projections by the various groups and a five year budget. The theoretical program is covered in separate letter.

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9 5357

Sincerely,

Lee G. Pondrom

Lee G. Pondrom

LGP:jw

THE UNIVERSITY OF WISCONSIN

MADISON 53706

DEPARTMENT OF PHYSICS
475 NORTH CHARTER STREET

November 26, 1969

Dr. Bernard Hildebrand
Chief, Research Branch
U.S. Atomic Energy Commission
Washington, D. C. 20545

Dear Dr. Hildebrand:

We thought you would be interested in receiving a copy of our long-range projection for FY 1971-76.

We are enclosing copies of the Theory section.

Sincerely,

L Durand

Loyal Durand, III

bp

Encl.

Hildebrand

THE UNIVERSITY OF WISCONSIN

MADISON 53706

DEPARTMENT OF PHYSICS
475 NORTH CHARTER STREET

November 20, 1969

Dr. Paul W. McDaniel
Director, Division of Research
Atomic Energy Commission
Washington, D. C. 20545

Dear Dr. McDaniel:

We are writing in response to your letter of October 30, 1969 concerning the long range program projections for FY 1971-76 for the Theoretical Physics part of AEC contract AT(11-1)-881.

The needs of the Theoretical Physics program at Wisconsin are sufficiently pressing, especially for the next year or two, that we thought it would be desirable to describe the Theory program separately and in more detail than in the past.

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There are six faculty members in the present high energy theory group. We hope to add three more permanent staff, one each in FY 1971, FY 1973, and FY 1975. We already have an offer outstanding for FY 1971 to a very strong candidate, Dr. Christopher Michael, at the Assistant Professor level. If he accepts, we will have reached the level we project in the strong interaction area. Since there will be a major effort in the areas of weak and electromagnetic interactions at NAL, we will emphasize these areas in filling the remaining two faculty positions, The visiting positions will first be filled in FY 1972 and FY 1974, at roughly the time the NAL facilities will come into partial and full operation.

We feel that an optimal high energy theory group should have roughly one postdoctoral research associate and two graduate research assistants per faculty member. Our long-term projections for increased AEC contracted support are aimed at reaching this optimum level by FY 1976. We anticipate that University support will continue at least at the level of six researcl assistants.

A breakdown of our projected cost increases over the present contract for FY 1971-76 is given below. Travel and publication costs, fractional secretarial help, and University overhead are included in the salary figures quoted in the projections. No provisions for inflation or increases in salaries beyond the current level are included.

For completeness we include increases for FY 1971. The postdoctoral research associate and graduate research assistant positions listed for 1970-71 restore positions which were eliminated in FY 1970 due to budgetary limitations.

<u>Incremental costs 1970-71</u>

1 permanent faculty member	12,000
2 postdoctoral research associates	40,000
2 graduate research assistants	12,000
	$64,000

We will require an additional $20,000 in FY 1971 just to cover increases in operating costs that have already been evident in FY 1970.

Assuming that the foregoing requirements are met in FY 1971, our five year projection of cost increases for FY 1972-76 is as follows:

Incremental costs FY 1972-76

FY 1972

1 visiting junior staff member	26,000
2 postdoctoral research associates	40,000
2 graduate research assistants	12,000
	$78,000

FY 1973

1 permanent faculty member	12,000
2 postdoctoral research associates	40,000
2 graduate research assistants	12,000
	$64,000

FY 1974

1 visiting senior staff member	40,000
1 postdoctoral research associate	20,000
2 graduate research assistants	12,000
	$72,000

FY 1975

1 permanent faculty member	12,000
2 postdoctoral research associates	40,000
2 graduate research assistants	12,000
	$64,000

FY 1976

1 postdoctoral research associate	20,000
1 graduate research assistant	6,000
	$26,000

Total incremental costs, 1972-76 $304,000

We consider ourselves to be one of the strongest high energy theoretical groups in the country. We have made substantial contributions to the progress of high energy physics, and expect to continue to do so. We intend in the future to work closely with NAL, and to assist in making it a successful national and international facility. In view of our past success, and the importance of University-NAL collaboration in the future, we regard the projected cost increases as well justified.

Sincerely,

Vernon Barger

Vernon Barger

Loyal Durand, III

Loyal Durand, III

bp

Yale University New Haven, Connecticut 06520

Office of the Chairman
Physics Department
217 Prospect Street

November 26, 1969

Mr. Paul W. McDaniel
Director, Division of Research
United States Atomic Energy Commission
Washington, D.C. 20545

Dear Mr. McDaniel:

We have a strong high energy physics program at Yale where six of our sixteen tenure faculty members engage in the experimental aspects of this program and three are concerned with the theoretical parts of the program (although one of these is supported by the NSF). The experimental program has been divided historically into four groups which have acted independently in major activities. In particular we have experimental work directed primarily by Hughes, by Adair, by Taft and Kraybill, and by Willis and Sandweiss, as well as the theoretical work directed by MacDowell and Gursey. All of these men are tenure members of the faculty and they constitute half of the tenure faculty of the department.

The budget has traditionally been divided into three parts administrated somewhat independently. For this fiscal year (1969-70) the budget for Hughes' group is $260,000, for the theory group $80,000, and for the three other groups, AK-S-TW, $680,000, for a total of $1,020,000. We anticipate an incremental funding of $60,000 (half provided by the University) for the Willis-Sandweiss experimental program, bringing the grand total to $1,080,000.

In order to continue programs which are as intellectually relevant as in the past, we will need to add to the normal escalation of 6% per annum further capital funds for satellite computers for data analysis in electronic experiments and added funds for the considerable added expense we forsee as required to explore new techniques and in the expenses required to use the 200 GeV accelerator. We believe we will require funding according to the table below if we are to proceed at the present level of accomplishment without any expansion in the basic size of our operations.

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Mr. P.W. McDaniel November 26, 1969

Fiscal Year	Theory	Hughes	A-K-S-T-W	Capital Equipment
1971	95,000	285,000	900,000	150,000
1972	105,000	320,000	1,130,000	150,000
1973	115,000	360,000	1,250,000	200,000
1974	130,000	410,000	1,460,000	250,000
1975	150,000	470,000	1,670,000	300,000

While it is difficult to look far into the future and predict the most useful activities in detail, we can forsee certain rather definite activities which may help suggest the kind of expenditures which will be required.

1970) The time-reversal experiment at the Argonne National Laboratory should be brought to a conclusion this fiscal year though some computing expense will be requited in fiscal 1971. The K-decay form-factor measurement carried out now at the Argonne, will also require some expenditure in fiscal 1971, but, again, the major work should be accomplished this year. The examination of the scattering of K-mesons from protons at Brookhaven should be nearly completed this fiscal year, though again some analysis will continue into the next fiscal year. The PEPR programs concerning the analysis of sigma decays will be largely finished also.

In FY 71, plans include acquisitions of small computers for on-line experiments and also purchases for improvements and major maintenance for our existing PDP 6. In FY 73 is also planned to acquire an IBM 1401 or equivalent to perform auxiliary operations related to our accelerator work. Other equipment funds are included to provide for readouts and additions to computer system. The AGS hyperon experiment will begin during this year. This is a big show, and while the die is cast for this FY to a large extent, there is some flexibility, and should the BOB kill some existing facility, there would be bequests for the survivors. We would therefore take this opportunity to plead for some relief.

There is also an experiment planned to make measurements on the charge asymmetries in K-meson decays and we believe that it is essential, during this fiscal year, to modify the PEPR system so as to allow the analysis of the larger bubble chambers now beginning operations.

If the hyperon beam lives up to expectation, we would want to retain the setup over the next shutdown. However, we probably will have run the present experiment as much as we want to. We would come back in FY 72 with a new experiment replacing the spark chambers with proportional chambers to take advantage of the available intensity, proposing to do more of the same, or radiative decays, or strong interactions. This will require an infusion of new equipment. I note that the BNL committee seems already to expect something of this sort.

In fiscal year 1973, 74, 75 we hope to be involved in the programs at NAL concerning the surveys of hyperon beams (FY 73) experiments using the neutrino beam (FY 74) and experiments concerning the strong and weak interactions of hyperons, in particular. In all of our contemplation of the problems of such experiments, we are impressed by the necessity of sophisticated -- and expensive -- instrumentation and the necessity of a strong technical back up on the group level. This is also expensive and it is expensive to make viable arrangements for technicians to commute to Chicago and to live there while experiments are being prepared. Our estimates of these expenses for the experiments we are now doing at Chicago (Argonne) have not been adequate: the experiments have cost us more than we have expected.

Sincerely yours,

Robert K Adair

RKA/dm

Robert K. Adair
Chairman

Yale University New Haven, Connecticut 06520

PHYSICS DEPARTMENT
217 Prospect Street

November 29, 1969

Dr. Paul McDaniel
Director, Division of Research
U. S. Atomic Energy Commission
Washington, D. C. 20545

Dear Paul:

Enclosed is an informal five-year projection on Yale/EPI, and related material. Bob Adair suggested that I send this to you directly since he and I had not had a chance to discuss our program before he sent you his letter.

With best regards,

Sincerely,

Vern

Vernon W. Hughes
Donner Professor of Physics

Encl.

VWH:eg

cc: W. A. Wallenmeyer
B. Hildebrand
R. Adair

9 5 3 0 8

11/29/69

Five Year Forecast
High Energy Physics (Yale/EPI) (Prepared by V. W. Hughes)

The research problems that we are either presently doing or planning for the future include the following:

1) Asymmetry in elastic scattering of hadrons from polarized protons at Brookhaven National Laboratory.

a) Elastic scattering of K^+ mesons of momenta from 1.2 to 2.4 BeV/c from polarized protons with measurement of asymmetry and differential cross section.

This experiment is AGS experiment no. 390 and is presently set up at the AGS. The data-taking will be completed during the 1st half of 1970. A paper based on the first phase of this experiment is enclosed. We have submitted this paper to Physical Review Letters and it is entitled:
"Asymmetry and Differential Cross Section for Elastic Scattering of K^+ Mesons by Polarized Protons" by G. A. Rebka, Jr., J. Rothberg, A. Etkin, P. Glodis, J. Greenberg, V. W. Hughes, K. Kondo, D. C. Lu, S. Mori and P. Thompson.

b) Elastic scattering of K^+ and K^- mesons and antiprotons ($\bar{p}$) of momenta from 0.7 to 1.2 BeV/c from polarized protons.

This experiment has been proposed to BNL and would be done in the new low momentum separated beam derived from the slow external proton beam. The physical interest in the K^+ -p and K^- -p scattering is in the questions of the existence of S=+1 baryon states, of the resonant states of the K^- -p system, and in the accurate determination of K^+ -p and K^- -p phase shift parameters. The physical interest in the $\bar{p}$ -p scattering is the studies of the diffractive behaviour of the scattering and of possible resonant states.

c) Other scattering experiments of hadrons on polarized protons using the new intense beams to be available at BNL after the AGS conversion is completed in 1972.

2) High energy muon pair production at Cornell 10 BeV synchrotron.

a) Precision test of limits of QED in the reaction:

$$\gamma + p \rightarrow p + \mu^+ + \mu^-$$

Unlike the best quoted result[1] (for the reaction $\gamma + C \rightarrow C + \mu^+ + \mu^-$) which is based solely on absorption or range measurements, our experiments will utilize a pair spectrometer. Supercondicting quadrupole magnets will be required in the spectrometer. The use of a hydrogen target rather than a carbon target is important in order to avoid uncertainties in the interpretation associated with nuclear structure.

b) Search for heavy leptons of mass greater than the kaon mass ($\gtrsim$ 500 MeV).

This experiment would observe high energy muon pairs and would measure the polarization of the muons. The polarization measurement will allow a distinction between muons arising from the decay of heavy leptons and muons arising from direct electromagnetic muon pair production. The muon background from pion decay must also be considered and will probably be the principal factor limiting the sensitivity of the experiment.

3) Experiments with polarized targets at the National Accelerator Laboratory.

Small angle elastic scattering of p, $\pi^{\pm}$, $K^{\pm}$, and $\bar{p}$ by polarized protons of very high momenta in order to study polarization effects relevant to the validity of asymptotic limit theorems, Regge pole theory and dispersion theory at very high energies. These experiments would be similar to experiments that have been done at CERN[2] and at BNL[3], and we would hope to establish a collaboration with another counter group (We have discussed these experiments with Dr. S. Lindenbaum of BNL and a collaboration might be established with his group.) These experiments have been discussed in an informal proposal submitted to the AEC from the Yale/EPI group on July 11, 1969.

4) Hadronic X-rays

The intensities of the new low momentum K^- and $\bar{p}$ separated beam derived from the slow external proton beam to be available in 1970, and even more the beam to be available after the AGS conversion in 1972, will make possible exciting new experiments with hadronic atom X-rays. We have been considering the following experiments:

a) Determination of magnetic moment of Σ^- [4]

b) Search for K-mesic X-rays from helium.

c) Precision measurement of hadronic X-rays (K^-, $\bar{p}$, Σ^-) for low Z atoms to determine the hadron-nucleus or hadron-nucleon interactions.

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The funds requested for Yale EPI are given in Table I. The allocation of these operating and capital funds to these experiments has been discussed in our form 189 of April, 1969 and in our informal proposal with regard to the NAL experiment of July 11, 1969, for the next two years. There follow Tables I and II indicating further the detailed distribution of funds through FY73. Distribution of funds beyond FY73 is very difficult to make reliably at this time.

Table I: Five Year Forecast

High Energy (Yale/EPI)

	FY71	FY72	FY73	FY74	FY75	FY76
Operating	400K	500K	550K	600K	650K	700K
Capital	100K	150K	150K	100K	100K	100K

Table II: Distribution of Operating Funds

	FY71	FY72	FY73
BNL scattering experiments using polarized proton target	325K	200K	250K
Cornell muon pair experiment	35K	200K	150K
NAL scattering experiment using polarized proton target	40K	100K	100K
BNL hadronic X-ray experiment	0	0	50K
Total	400K	500K	550K

Table III. Distribution of Capital Funds

	FY71	FY72	FY73
BNL scattering experiments using polarized proton target	0	0	30K
Cornell muon pair experiment	60K	60K	0
NAL scattering experiment using polarized proton target	40K	90K	120K
BNL hadronic X-ray experiment	0	0	0
Total	100K	150K	150K

YALE/EPI

Informal Proposal to the US Atomic Energy Commission for Future Experiments with Polarized Proton Targets at the National Accelerator Laboratory.

V. W. Hughes, Donner Professor

G. Rebka, Associate Professor

July 11, 1969

Experiments at National Accelerator Laboratory with Polarized Targets

Many important experiments have been done in high energy physics with polarized targets (principally polarized protons) and there is at present a large amount of activity in this field.[1,2,3,4] It will clearly be of great importance to extend such experiments to the higher energies to be available at the National Accelerator Laboratory. In particular, the study of polarization effects relevant to the validity of asymptotic limit theorems, Regge Pole theory and dispersion theory at very high energies will be important. We are interested specifically first in considering experiments on the small angle elastic scattering of P, $\pi^{\pm}$, $K^{\pm}$, and $\overline{P}$ by polarized protons.

Since such experiments are a very large endeavor, we would hope to establish a collaboration with another counter group for doing these experiments.

Research in FY71 will be devoted firstly to consideration and planning of experiments at high energies with polarized targets and secondly to laboratory studies of polarized targets.

The experiments we are interested in initially are the forward elastic scattering of P, $\pi^{\pm}$, $K^{\pm}$, and $\overline{P}$ from polarized protons. These experiments would be the extension to high energies from 30 BeV to 200 BeV of experiments similar to those done at CERN with polarized targets[5,6] and at BNL[7,8,9] with unpolarized targets. The design of such experiments will be considered.

The polarized proton target we are currently using in our experiment at BNL on the elastic scattering of K^+ mesons by polarized protons is of the LMN type. We propose to study and develop a laboratory prototype hydrocarbon type polarized proton target, since it will be particularly important at the higher energies of NAL. Much of the relevant equipment for this work is now available in our laboratory, so the budget required for this development can be relatively low.

By FY72 we would hope to be actively involved in preparing for a high energy experiment with a polarized proton target and to be designing and constructing the polarized proton target. As mentioned above we would hope to establish a collaboration with another counter group. We have discussed a possible collaboration with Dr. S. Lindenbaum of BNL and we will explore this and other possibilities further.

At the present we do not feel it is possible to project a budget beyond FY72 in any detail. If these experiments do materialize, however, a substantial increase in operating budget will be required.

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Yale/EPI Research at NAL

Budget for FY71 and FY72

	FY 71		FY72
Scientific Faculty			
V. W. Hughes, Professor			
G. A. Rebka, Jr., Associate Professor			
Assistant Professor, 1/2 time academic year	6,000		6,500
" " 2 mo. summer comp.	2,667		2,889
Research Associate, full time	12,000		13,000
Total Scientific Faculty	20,667		23,389
Other Scientific			
Graduate Student (1)	5,350	(2)	10,700
Mechanical Engineer, 1/4 time	5,000		5,250
Electrical Engineer, 1/4 time			4,750
Total Other Scientific	10,350		20,700
Technical			
Machine and electronic shops (1000 hrs. at 6.50/ hr.)	6,500	(1700 hrs.)	11,000
Other			
Administrative and secretarial	1,000		1,500
TOTAL salaries	38,517		56,589
Indirect Expenses			
Overhead at 44.6%	17,179		25,239
14.5% (on $18,000)		(on $19,500)	
Fringe Benefits at 4.5% (on 20,517)	3,533	(on 37,049)	4,495
TOTAL indirect costs	20,712		29,734
Travel	5,000		5,000
Computer time, 8 hrs. at 170/hr.	1,360	(8 hrs.)	1,360
Shop materials, electronics components, other expendables	10,000		10,000
Capital equipment: Modification of electromagnet for hydrocarbon polarized proton target	25,000	Power supply, microwave equipment, electronics and cryogenic equipment	46,500
TOTAL operating costs	41,360		62,860
TOTAL SALARY AND OPERATING BUDGETS	100,589		149,183

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CAPITAL EQUIPMENT, FY72: We estimate the cost of a polarized proton target, including the magnet system, cryogenics, microwaves and electronics at about $250,000. In FY72, we request $150,000.

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Submitted to Phys. Rev. Letters 10/31/69

Asymmetry and Differential Cross Section for Elastic Scattering of K^+ Mesons by Polarized Protons at 1.54 and 1.71 GeV/c.*

G.A. Rebka, Jr., J. Rothberg,† A. Etkin, P. Glodis, J. Greenberg,
V.W. Hughes, K. Kondo,†† D.C. Lu,
S. Mori, and P.A. Thompson
Gibbs Laboratory, Yale University
New Haven, Conn.

Abstract

The asymmetry and differential cross section for elastic scattering of K^+ mesons from polarized protons have been measured at meson momenta of 1.54 and 1.71 GeV/c, and these new data have been included in an energy independent phase shift analysis. The $P_{3/2}$ wave obtained displays some resonance-like character.

* This research was supported in part by the U.S. Atomic Energy Commission.

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†† On leave from University of Tokyo, Tokyo, Japan.

Search for strangeness S=+1 baryon states has drawn attention to the study of the K^+ meson-proton interaction. Measurements of the total cross section with precision,[1] photoproduction of K^- mesons,[2] backward elastic scattering,[3] and elastic scattering below 1.5 GeV/c with subsequent phase-shift analyses[4] of these data initially suggested such resonances might exist; however, measurements of the inelastic cross section and further analysis[5] cast doubt on their existence. Recent investigation of the elastic channel between 0.86 and 1.91 GeV/c using polarized targets[6,7] has indicated a resonance-like behavior for the $P_{3/2}$ partial wave, but has definitely precluded substantial resonance in other partial waves of this channel. We report[8] measurements of the asymmetry and differential cross section for elastic scattering of K^+ mesons from polarized protons for meson momenta of 1.54 and 1.71 GeV/c, and the results of an energy-independent phase-shift analysis which corroborate other recent studies of the elastic channel.

The experimental arrangement is shown in Fig. 1. K^+ mesons with a ±2% momentum interval from the partially separated beam no. 5 at the AGS at Brookhaven National Laboratory were detected by the telescope of scintillation counters S1, S2, S3, and S4. The kaons were further distinguished from residual π^+ mesons in the beam by an ethylene-gas, differential Cerenkov counter CB, and were focused onto a 3 cm. by 2 cm. by 2.5 cm. thick LMN target[9] containing protons with 0.60 polarization. Of the particles accepted by the beam telescope and Cerenkov counter, at most 0.5% could be particles other than K^+ mesons. The ten by ten hodoscope of scintillation counters HB before the Cerenkov counter located beam particles at this plane to 5 mm. Scintillation counter S5 vetoed events with no scattering or with one particle scattered in a very forward direction, while scintillation counters S6 which covered the poles of the polarizing magnet vetoed some inelastic events, quasielastic events, and elastic events outside the angular acceptance of the apparatus.

The scattered K^+ mesons and protons were detected by five banks, each of three wire spark chambers, distributed about the perimeter of the polarizing magnet and by an array of scintillation counters paralleling the planes of the spark chambers. Each spark chamber had a spacial resolution of 1.3 mm. vertically and 0.6 mm. horizontally FWHM. The scintillation counters were organized into seven vertical sectors (RI, RII, RIII, RIV, LI, LII, LIII) each having ten counters. Each individual counter subtended approximately a constant $\Delta\varphi = 3^\circ$ and corresponding counters in the several sectors were arranged to cover the same range of $\Delta\varphi$. Two 15 cm. thick water threshold Cerenkov counters, CS1 and CS2, were also used to distinguish scattered K^+ mesons from protons in the approximately 20° range of angles in the laboratory for which kinematic distinction alone was ambiguous.

A signal formed by pulse logic from S1, S2, S3, S4, $\overline{S5}$ provided the initial trigger for an event which opened the gates of a DC logic system[10] to the scintillation counters of the seven sectors, as well as the hodoscope HB. The logic was formed into two tables, the sector table and the coplanarity table. The sector table was set to require one and only one particle detected on either side of the incident beam, while the coplanarity table was set to require these events to be coplanar within 15°. If these conditions were satisfied, as well as a signal S1, S2, S3, S4, $\overline{S5}$, $\overline{S6}$, CB, then the spark chambers were triggered and their output, the state of the DC logic tables, the state of the DC logic observing HB, and the pulse heights in all Cerenkov counters CB, CS1, and CS2 were entered into a PDP-8 computer, which edited and transferred the data to magnetic tape and the BNL "on line" PDP-6 for analysis.

Two kinematic reconstructions were computed for each event. The first reconstruction assumed a K meson had been elastically scattered to the left. From the coordinates established by the spark chambers, the trajectory of each scattered particle was traced through the field of the polarizing magnet to determine the point of interaction in the target to 6 mm. Using these trajectories and the point of interaction, the horizontal and vertical scattering angles of each scattered particle were established, the scattering angles expected for a recoil proton on the right were computed, and the differences between the actual angles for the particle on the right and these predicted angles, $\Delta\theta_H$ and $\Delta\theta_V$, were determined. The reconstruction was then repeated assuming a K meson had been elastically scattered to the right, and both solutions given equal weight in the analysis to follow.

For identification of the particles and separation of elastic events from background, reconstructed events were combined in each range of $\Delta(\cos\theta_K^{CM}) = 0.1$ to form a density of events as a function of $\Delta\theta_V$ and $\Delta\theta_H$. This density contained a sharp peak at the origin corresponding to correctly identified elastic events and a second broad peak displaced in $\Delta\theta_H$ corresponding to incorrectly identified elastic events. The average density was computed ignoring the region of the misidentification peak, except where the two peaks merged and the kinematic ambiguity was resolved by the water Cerenkov counters CS1 and CS2. Samples of the density are displayed in Fig. 2 for (a) forward, (b) middle, and (c) backward ranges of $\cos\theta_K^{CM}$. The angular width at half maximum of the elastic peak, which resulted primarily from small angle scattering in the target, is seen to be $1/2^\circ$ in the favorable middle range (b), but to broaden to $1\ 1/2^\circ$ in the forward range (a) where the momentum of the recoil proton is small. The increased background observed in the backward (c) region was due primarily to the misidentified forward quasielastic scattering. The background was extrapolated to the origin using the region indicated between the arrows and subtracted, and introduced a systematic error less than ± 0.02 in the asymmetry and $\pm 4\%$ in the differential cross section except for the most backward points.

From the 5500 elastic events gathered at 1.54 GeV/c and 6900, at 1.71 GeV/c, the left-right asymmetries have been determined for each range of $\Delta(\cos\theta_K^{CM}) = 0.1$ covered, and are displayed in Fig. 3(a) and (b). Since the polarization of the target protons, which averaged about 0.60 and was measured to an accuracy of ± 0.03, was reversed at least three times at each momentum, the asymmetries were determined on each side of the apparatus independently without recourse to the acceptance and efficiencies. These two independent measurements were a convenient check on the consistency of the experiment. The errors shown are purely statistical and do not include possible systematic error in subtraction of background or error in polarization of the target.

The differential elastic cross sections displayed in Fig. 3(c) and (d) were determined from the fraction of events which occurred in the central portion of the spark chambers where the acceptance and efficiencies could be well established. Because of uncertainty in these factors and in the subtraction of background, the errors indicated in the figure include a ±7% error in the cross sections, in addition to the statistical error, but do not include a possible 5% error in normalization.

An energy independent phase-shift analysis for the elastic channel of the K^+ meson-proton interaction has been made for 10 incident meson momenta between 0.778 and 2.00 GeV/c. In addition to the new data presented above, all published data on asymmetry and differential cross section in elastic scattering,[6,7,11] total cross sections,[1] inelastic cross sections,[5] and real parts of the forward elastic amplitude were used in the analysis. For each momentum except 0.778 GeV/c, at least one measurement of asymmetry was available. The analysis was restricted to S, P, and D waves below 1.4 GeV/c and S, P, D and F waves above, for these were sufficient to fit the experimental data. Since the rate of angular variation was restricted by the number of partial waves, measurements of the asymmetry and differential cross section at two or three angles were statistically combined for most of the published data to make computations less cumbersome.

Sets of phase-shift parameters yielding minima in χ^2 were found by randomly searching a domain for a set with $\frac{\chi^2}{P} \leq 15$, where P is the number of pieces of data, and then by systematically minimizing χ^2 for such candidates. The domain of parameters for random search at each momentum was established by extrapolating from solutions at the momenta immediately lower; however, if any solutions appeared near the edge of this domain, it was expanded accordingly. This procedure, itself, constituted a loose condition for a smooth variation of parameters with momentum. The domain for the lowest momentum at 0.778 GeV/c was established from the results of Goldhaber et al,[12] to which solutions were required to connect smoothly.

At each momentum 100 sets of phase-shift parameters which yielded $\frac{\chi^2}{P} \leq 2.5$ were obtained.[13] These were found to cluster in a limited region of the Argand diagram for each wave, and formed a density of solutions which appeared to peak. Over-all momentum-dependent solutions were constructed from these by selecting sets which yielded the minimum path[14] in scattering-amplitude space weighted by χ^2. Three such solutions which are distinct have been obtained, and are compared to the present data by the curves in Fig. 3, where the agreement appears satisfactory. They also agree with the other individual items of data which have been used in the analysis, and yield $\chi^2/N<1.5$, where N is the number of degrees of freedom, for the totality of original, uncombined data at each momentum except 1.37 and 1.89 GeV/c for which agreement appears considerably less satisfactory and systematic error in the data might be presumed.

The behavior of the scattering-amplitudes for the three solutions is similar for momenta below 1.4 GeV/c, where, most strikingly, the $P_{3/2}$ amplitude describes a counter-clockwise half circle in the Argand diagram as displayed by Fig. 4(a). Such behavior could be consistent with a $P_{3/2}$ resonance in the K^+P system. However, above 1.5 GeV/c, behavior of the solutions becomes qualitatively different and, for II and III, becomes rather uneven. As an example of the behavior of the three solutions, Solution I is described in detail by the curves for δ and η in Fig. 4(b) and (c).

The solutions in this analysis are compatible with one obtained by Bland et al.[11] (A_I^-) at 0.78, 0.86, and 0.96 GeV/c; with two obtained by the CERN group[6] (their solutions I and II) below 1.45 GeV/c; and with one obtained by the Argonne group[7] (their solution I). Resolution of the ambiguities which remain in all these analyses of the K^+P elastic channel and, particularly, verification of the tantalizing behavior of the $P_{3/2}$ amplitude must necessarily await more copious data on the asymmetry and differential cross section for elastic scattering of K^+ mesons from polarized protons with meson momenta above 1.5 GeV/c.

We wish particularly to acknowledge the important work of S. Dhawan in the design and construction of the electronics system. We also gratefully acknowledge the contributions of A. Disco, L. Trudell and G. Chihoski in the mechanical construction of the apparatus, of J. Zornig during the data taking, and of R. Patton in computing the real part of the forward elastic amplitude. We are also most indebted to the AGS staff at BNL.

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13. At 1.37 BeV/c and 1.89 BeV/c 100 solutions with $\frac{\chi^2}{P} \leq 4$ were obtained because of apparent systematic errors among differ-

ential cross section data.

14. The paths in the scattering-amplitude space were defined by

$$D = \sum_{m,n} \left| f_m^{(n)} - f_m^{(n+1)} \right|^2 \left[\left(\frac{\chi^2}{P}\right)_{(n)} \left(\frac{\chi^2}{P}\right)_{(n+1)} \right]^Q .$$

$$(Q = 0, 1, 2, 4)$$

Figure Captions

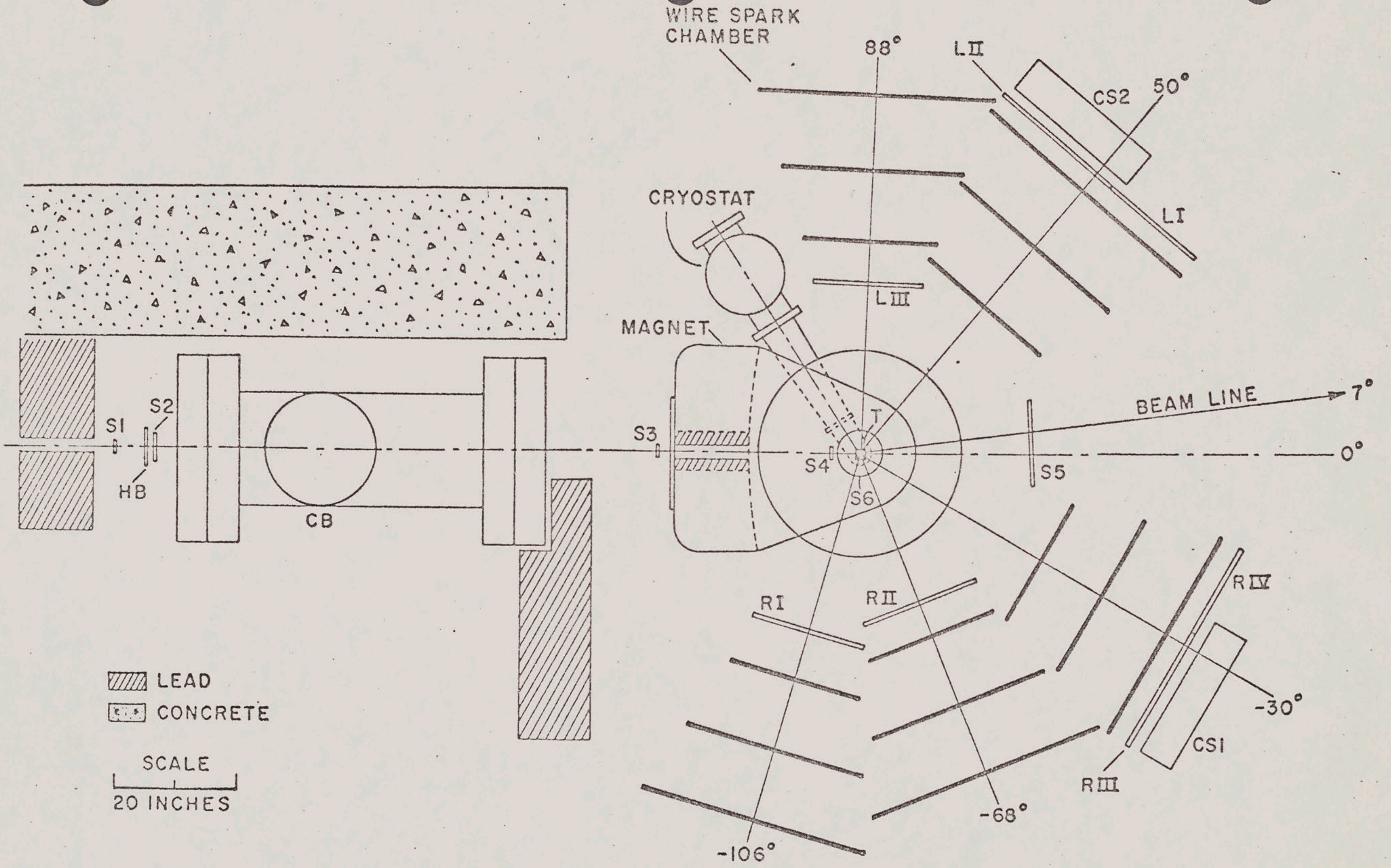
Fig. 1. Experimental arrangement: T, LMN target; S1, S2, S3, S4, S5, and S6, scintillation counters; HB, 10 by 10 scintillation beam hodoscope; CB, differential ethylene gas Cerenkov counter; RI, RII, RIII, RIV, LI, LII, and LIII, scintillation trigger hodoscope, 10 counters per sector; CS1 and CS2, water Cerenkov counters. The cryostat, polarizing magnet and wire spark chambers are indicated.

Fig. 2. Density of events versus deviation from elastic prediction showing the elastic peak and background for both signs of polarization in three ranges of $\cos\theta_K^{CM}$. The arrows indicate the region used to extrapolate background to the origin. The increased width of the peak in (a) resulted from small angle scattering of the low-momentum, recoiling protons, while the increased background in (c) resulted from misidentified quasielastic and inelastic events.

Fig. 3. Asymmetry and differential cross section for elastic scattering of K^+ mesons from polarized protons at meson momenta of 1.54 and 1.71 GeV/c in the laboratory. The errors shown for the asymmetry (a) and (b) are statistical only; however, the errors shown for the differential cross section (c) and (d) are statistical uncertainty plus 7% uncertainty in the estimate of acceptance and efficiency. An additional 5% error is estimated for the scale of the differential cross section. The several curves shown represent the predictions of solutions I,

II, and III of our phase-shift analysis.

Fig. 4. Phase-shift analysis for the K^+P elastic channel. (a) shows Argand diagrams of the $P_{3/2}$ scattering amplitude for our solutions I, II, and III which describe counter clockwise half circles. The complete behavior of solution I is given by the phase-shifts and elasticities in (b) and (c) for the S, P, D, and F elastic amplitudes. Solutions II and III are similar. Points below 0.8 GeV/c are from S. Goldhaber et al, Ref. 12.



WIRE SPARK CHAMBER
88°
LII
CS2
50°
LI
CRYOSTAT
LIII
MAGNET
BEAM LINE
7°
S1
S2
HB
CB
S3
T
S4
S6
S5
0°
RI
RII
RIV
RIII
CS1
-30°
-68°
-106°
LEAD
CONCRETE
SCALE
20 INCHES

Fig. 1

Elastic Peaks for

K^+ Polarized p Scattering at 1.71 GeV/c

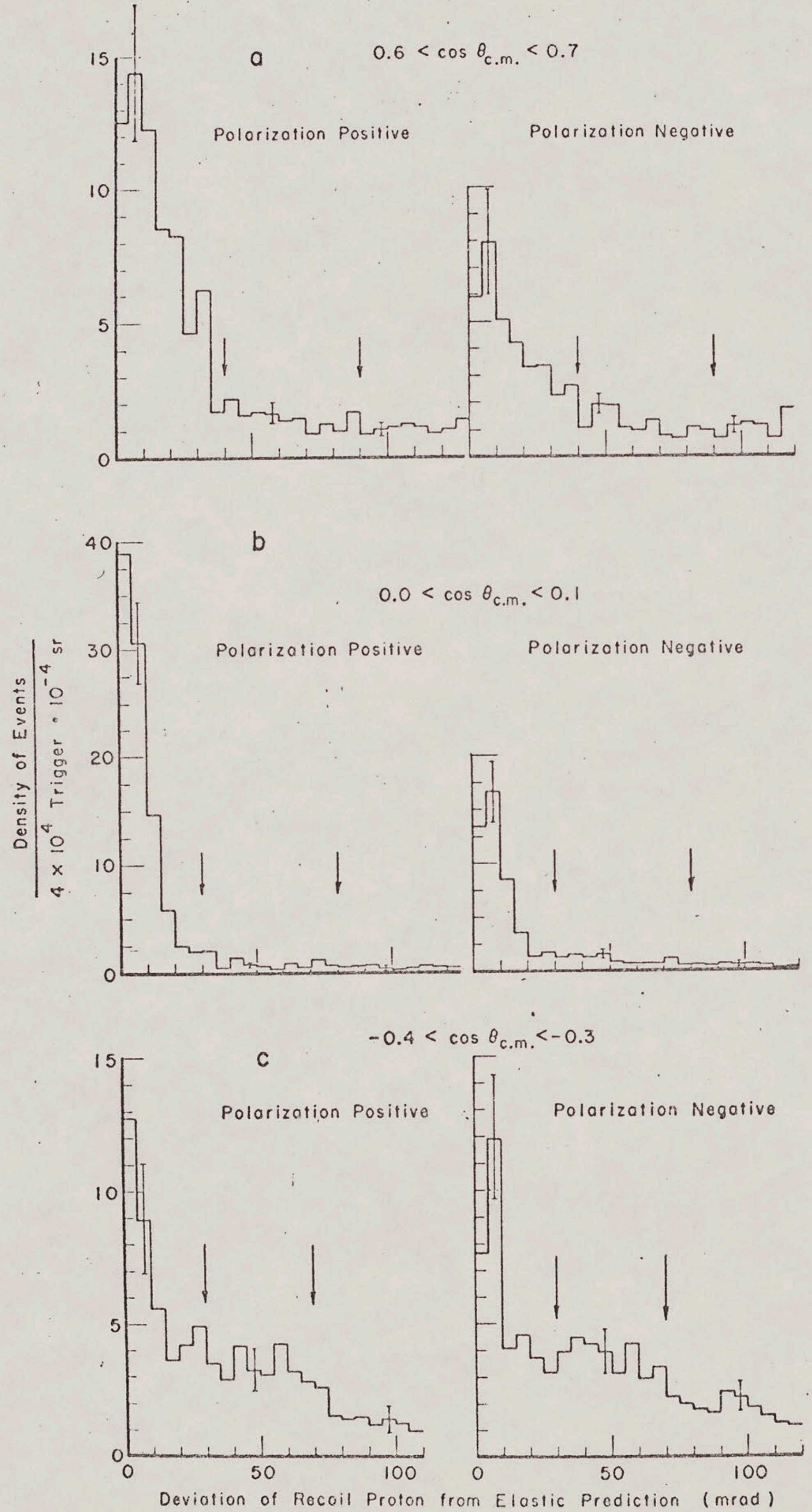
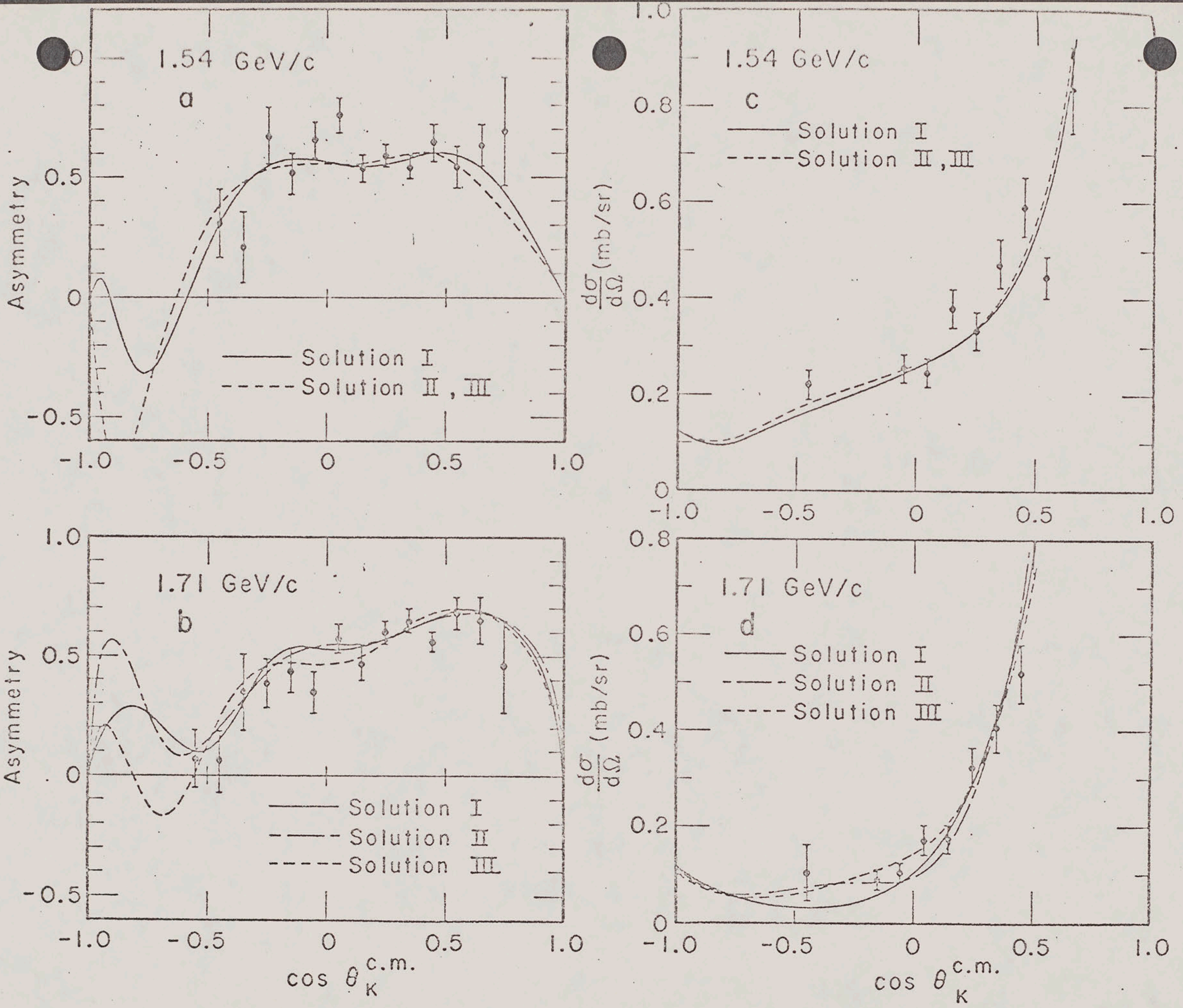
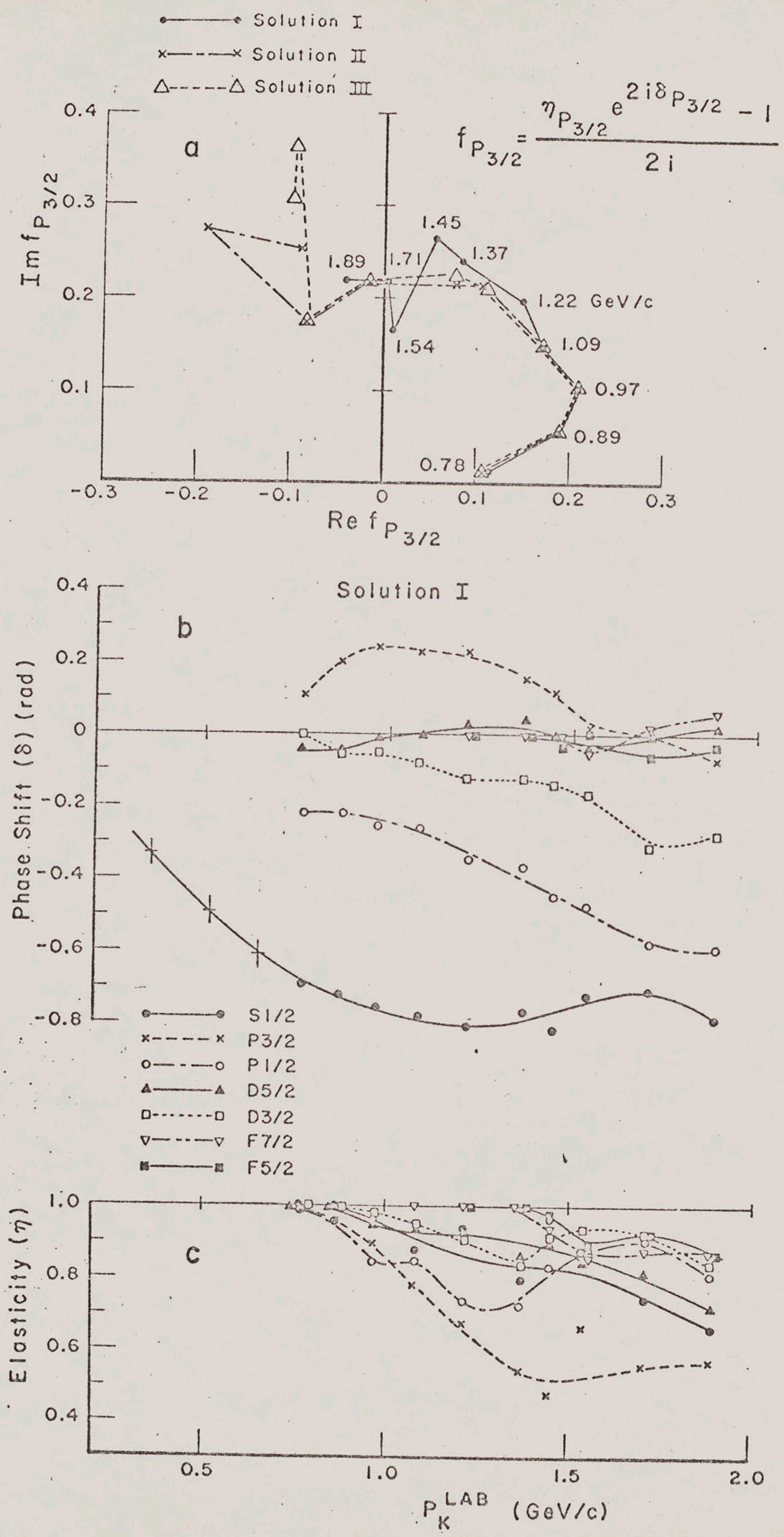


Fig. 2



1.54 GeV/c
a
Solution I
Solution II, III
Asymmetry
1.54 GeV/c
c
Solution I
Solution II, III
$\frac{d\sigma}{d\Omega}$ (mb/sr)
1.71 GeV/c
b
Solution I
Solution II
Solution III
Asymmetry
$\cos\theta_K^{c.m.}$
1.71 GeV/c
d
Solution I
Solution II
Solution III
$\frac{d\sigma}{d\Omega}$ (mb/sr)
$\cos\theta_K^{c.m.}$

Fig. 3



Solution I
Solution II
Solution III
a
$f_{P_{3/2}} = \frac{\eta_{P_{3/2}} e^{2i\delta_{P_{3/2}}} - 1}{2i}$
$\mathrm{Im}\, f_{P_{3/2}}$
$\mathrm{Re}\, f_{P_{3/2}}$
0.4
0.3
0.2
0.1
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
1.45
1.37
1.89
1.71
1.22 GeV/c
1.54
1.09
0.97
0.89
0.78
Solution I
b
Phase Shift (δ) (rad)
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
S1/2
P3/2
P1/2
D5/2
D3/2
F7/2
F5/2
c
Elasticity (η)
1.0
0.8
0.6
0.4
0.5
1.0
1.5
2.0
P_K^{LAB} (GeV/c)

Fig. 4

AGS PROPOSAL

PART I

From: V. W. Hughes and G. A. Rebka (correspondents)
R. Ehrlich, D. C. Lu, S. Mori, P. Thompson,
K. Kondo, M. E. Zeller - Yale University

Subject: Measurement of the polarization asymmetry in elastic scattering of K^+ and K^- mesons from polarized protons with meson momenta between 0.7 BeV/c and 1.2 BeV/c. Search for S = +1 baryon states; K^-p interaction, including resonant states.

Beam: Use of low momentum separated K beam derived from the slow external proton beam.
K momentum range 0.7 BeV/c to 1.2 BeV/c.
425 hours of AGS time.

Detectors: Hodoscope system of scintillation counters.

Scattering Target: Ethylene Glycol Polarized Proton Target

September 30, 1969

1. PURPOSE OF EXPERIMENT AND EXPECTED RESULTS

(A) K^+p Asymmetry and Differential Elastic Scattering Cross Section Measurements

Within the past year, stimulated by the great interest in the question of whether an $S = +1$ baryon state exists, much progress has been made in the understanding of the K^+p interaction. This has been accomplished principally by measurements of the asymmetry (or polarization, P) in the elastic scattering of K^+ mesons by polarized protons, and also by additional measurements of the differential cross section for elastic scattering, $d\sigma/d\Omega$. Based on these new data several new phase shift analyses have been done.

Polarization measurements have been reported as follows:

(1) From CERN[1,2] in the K^+ momentum range from 0.86 GeV/c to 1.45 GeV/c and at 2.48 GeV/c. Their statistical accuracy in the measurement of P for the two kaon momenta studied below 1 GeV/c (865 MeV/c and 971 MeV/c) is between about ±0.15 to ±0.25 over most of the angular range.

(2) From Argonne[3] by an Argonne-University of Maryland group at four points in the range from 1.37 GeV/c to 1.89 GeV/c.

(3) From Brookhaven National Laboratory by our group[4] at K^+ momenta of 1.54 and 1.71 BeV/c. Within the next few months our A.G.S. experiment no. 390 will be completed and will produce additional measurements of P in the K^+ momentum range from 1.2 to 2.4 BeV/c.

The CERN and BNL experiments mentioned above have also provided data on $d\sigma/d\Omega$ at the momenta studied.

All three groups have made phase shift analyses based on essentially all of the data available at the time of their publications on polarization, differential cross section, inelastic cross section, and total cross section. In order to fit the data up to 2 BeV/c, S, P, D, and F partial waves are required. All three solutions are in rough agreement. Our solution and that of the CERN group are based on more of the recent data and agree quite well. Several features of the CERN and Yale solutions can be mentioned. The most interesting one is the behavior of the $P_{3/2}$ partial wave which describes a counter-clockwise half circle in the Argand diagram crossing the imaginary axis at a momentum of about 1.5 BeV/c, thus suggesting the possible existence of a $P_{3/2}$ resonant state. Both the CERN and Yale solutions exhibit somewhat erratic (or discontinuous) variation of the $S_{1/2}$ partial wave with momentum, which suggests some systematic errors in the experimental data. The $P_{1/2}$ and $P_{3/2}$ waves are important above 700 MeV/c, and they become inelastic above about 700 MeV/c. The D waves are small below 1 BeV/c, and the F waves are small below 1.5 BeV/c.

We propose to measure with high accuracy the polarization in K^+p elastic scattering in the range from 0.7 BeV/c to 1.1 BeV/c at 8 K^+ momenta. The new high intensity kaon beam being developed from the slow extracted proton beam will provide at present a unique facility for such a high precision experiment. No polarization data exist for momenta below 0.86 BeV/c and the accuracy of existing data from 0.86 BeV/c to 1.1 BeV/c is rather limited. This new polarization data will provide us with a rather continuous coverage of the momentum range from 0.7 to 2.4 BeV/c, and can be regarded as an extension of our present AGS experiment no. 390 (K^+ momenta from 1.2 to 2.4 BeV/c). We also simultaneously will measure $\frac{d\sigma}{d\Omega}$ to high accuracy.

Accurate data on P and $d\sigma/d\Omega$ over a wide energy range are most important to obtain a unique and accurate phase shift analysis.[5] Hence the data we propose should aid considerably in determining a reliable phase shift analysis. In particular clarification may be provided on the erratic behavior of the $S_{1/2}$ wave and on the transition of the $P_{1/2}$ and $P_{3/2}$ waves from elastic to inelastic. Since the possible resonance-like behavior of the $P_{3/2}$ wave is of the greatest interest and since the $P_{3/2}$ wave is appreciable in the range from 0.7 to 1.1 BeV/c, it is important to determine its behavior as accurately as possible in this range.

A more accurate knowledge of the phase shift parameters characterizing the interaction of the K^+p system will also be useful for the application of finite energy sum rules or super-convergence relations, which relate the low energy parameters of the interaction to the high energy behavior.[6] A more detailed discussion of this application is given in section 1B where it is applied to the K^-p system.

B. K^-p Measurement

The K^-p system in the incident K^- momentum range of 0.7 to 1.2 GeV/c (invariant mass range 1650-1890 MeV) contains a wealth of resonant structure which has been examined only sparsely with respect to polarization phenomena.[7] We show in Table I the present status of the resonances in this region including their "rating" as established by Levi Setti at the recent Lund Conference.[5] We note that the spin assignment of the $\Lambda(1870)$ is still vacillating between $3/2^+$ and $7/2^+$, the $\Lambda(1800)$ requires confirmation, and the $\Sigma(1760)$, while assigned a B rating, needs further investigation. A K^-p elastic scattering polarization measurement will give information which will aid in the resolution of these problems.

In addition to this resonance study, a K^-p polarization measurement will be useful in determining the parametrization of the elastic scattering channel. In the past different approaches have been taken in this parametrization. Specifically, Armeteros et al.[8] have assumed certain waves to be pure background with a scattering amplitude described by a complex number having slow linear variation in incident kaon momentum. These authors then assume that the résonant waves contain no background and can be described completely by the Breit-Wigner form with appropriate masses, widths and elasticities.[9] In contrast to this formalism, Lasinski et al.[10] parametrize each isospin amplitude by a linear combination of diffractive background and resonant contribution. Here the background is a complex function of incident kaon momentum multiplied by an exponentially varying function of momentum transfer. The resonant contribution is again of the Breit-Wigner form. These two formulations both successfully fit the existing differential cross section data[11-12] but have never been tested with polarization measurements.

Work is presently being done on finite energy sum rules (FESR's) which can be used to relate integrals of scattering amplitudes over a finite low-energy region to Regge-Pole parameters as determined by high energy behavior.[13-14] Thus detailed knowledge of the K^-p amplitudes at low energies, even in the presence of resonant structure, can be used to check the Regge-Pole parametrization for higher, non-resonant, energy regions. Such predictions have been made in the K^-p system by Dass and Michael.[15] However, as they noted, their low energy input amplitudes were not a unique representation, as they were derived from total and differential cross section measurements only below 1.1 GeV/c. In short, improved knowledge of low energy amplitudes, via polarization measurements, is necessary before these calculations can be made reliable.

Recent interest in a K^-p polarization measurement has been demonstrated at the Lund Conference in the Rapporteur talk on Strange Baryon Resonances.[5] In this summary of the present status of the $\bar{K}N$ system it was stated that good polarization data in the 0.8 - 1.2 GeV/c region are "urgently needed." Such data will be useful in resolving some of the ambiguities in the numerous partial wave analyses that exist at present.

As in the K^+p case, the anticipated intense kaon beam being constructed at the A.G.S. will provide a facility for making precise measurement of the K^-p system in the above momentum range. Since the data are obviously needed, and since a pure, high flux K^- beam will be available, we propose to measure the "left-right" asymmetry in elastic scattering of K^- mesons from polarized protons. We will also measure the differential cross section in the angular region accessible with our apparatus to an accuracy comparable with previous measurements.

TABLE I

Strange Baryon Resonances Reported at the Lund Conference 1969

	J^P	Width (MeV)	Br. Frac. To Elastic	Rating* 1968	Rating* 1969
$\Lambda(1670)$	$1/2^-$	23	17%	A	A
$\Sigma(1760)$	$1/2^-$	80	13%	B	B
$\Lambda(\sim 1800)$	$1/2^+$	20	20%		C
$\Lambda(1870)$	$3/2^+$	70	21%		C
$\Lambda(1690)$	$3/2^-$	27	22%	A	A
$\Sigma(1660)$	$3/2^-$	30	2.5%	A	A
$\Lambda(1830)$	$5/2^-$	145	8%	B	A
$\Sigma(1765)$	$5/2^-$	112	44%	A	A
$\Lambda(1820)$	$5/2^+$	72	65%	A	A
$\Sigma(1915)$	$5/2^+$	60	10%	C	C
$\Lambda(1860)$	$7/2^+$	49	10%	C	C
$\Sigma(2026)$	$7/2^+$	130	13.5%	A	A
$\Lambda(2100)$	$7/2^-$	145	30.5%	A	A

*The rating system is:

A = well established

B = good evidence but in need of confirmation

C = shaky evidence

F = failed

**The J of the $\Lambda(1860)$ is not yet firmly established.

2. GENERAL DESCRIPTION

Our experimental program is to measure the polarization asymmetry and differential cross section for elastic scattering in the incident kaon momentum range 0.7 to 1.2 GeV/c. For K^+p scattering we shall make measurements at 8 points (0.70, 0.75, 0.80, 0.85, 0.90, 0.95, 1.00, 1.10 GeV/c), while for K^-p we anticipate 11 points evenly distributed throughout the momentum band in 50 MeV/c intervals. The angular resolution will be $\pm 2^o$ which is sufficient to produce an elastic peak 5 times that of the quasielastic and inelastic background and to identify kinematically the K mesons and protons except for an angular region where such identification is ambiguous. The ambiguity in this region is resolved by particle identification with Cerenkov counters. The polarization asymmetry will be measured at all available angles. As discussed below, the angular range will be limited by small angle scattering and energy loss in the target; however a significant experiment can be conducted within the available range, $-0.90 \lesssim \cos\theta \lesssim 0.85$. A total of approximately 2.5×10^5 K events will be collected for each momentum.

Assuming an analysis of those events into 20 angular bins, and a polarization of the target of 0.60, then a typical r.m.s. statistical error in the asymmetry of ± 0.02 is expected for K^+p scattering and an error ranging from ± 0.02 to ± 0.08 for K^-p scattering. These data will be significantly more accurate than existing asymmetry measurements at other kaon momenta; no asymmetry measurements at all have been made over most of the momentum range to be studied.

A measurement of the differential scattering cross section is also provided simultaneously by the data to be obtained. The accuracy in the determination of $d\sigma/d\Omega$ will be better than 5%.

(A) Instrumentation

A schematic diagram of the principal elements of the experimental arrangement is shown in Fig. 1. The separated beam of K^+ or K^- mesons will be derived from the external primary target for the slowly extracted beam.[16] A further separation of the kaons from the residual $\pi^\pm$ mesons, protons, or antiprotons will be performed with a differential liquid Cerenkov counter. The incident beam will be tagged and its divergence angle determined by a scintillation counter hodoscope immediately following the final quadrupole magnet of the beam.

The polarized target will be an ethylene glycol target (1" x 1" x 1") in size.[17] Our present target being used in AGS no. 390 is an LMN type polarized proton target; this target will be converted to an ethylene glycol type target, where the principal change involves operation of the magnet at 25kG rather than 19kG. A proton polarization of 0.6 has been obtained with the ethylene glycol target and the ratio of free protons to bound (nuclear) protons is much more favorable than for the LMN target. The absolute polarization of the target can be measured with an accuracy of about 3%; however the relative size of the polarization in opposite directions can be determined with considerably greater accuracy.

Both of the final state particles are detected by a scintillation counter hodoscope system appropriately placed around the polarized target magnet. This hodoscope system subtends approximately 230° of polar angle and 30° azimuthal angle in the lab. The system involves approximately 200 counters and gives an event by event resolution of 6 msr. This counter technique has been chosen over the spark chamber method used in AGS experiment no. 390 because it can be operated at a higher rate while maintaining a resolution consistent with the uncertainties imposed by multiple scattering and energy loss by the final state particles. We also note that due to the more favorable kinematic conditions of a low incident momentum, the resolution need not be as good as at high energies to separate adequately the quasielastically scattered background from the elastic signal.

(B) Region of Kinematic Ambiguity

As mentioned above, a region of ambiguity exists in the kinematic identification of the scattered particles. The magnitude and location of this ambiguity region for K^+p elastic scattering can be seen in Fig. 2 as computed for mesons with 0.9 BeV/c incident momentum. Similar curves for other momenta vary in detail, but are identical in character. If a particle from an elastic scattering is detected in a left-hand hodoscope at the angle in the laboratory shown on the ordinate, then the particle going to the right will appear at the angle in the laboratory on the abcissa indicated by one of the two central curves depending on whether the left hand particle is a K^+ meson or a proton. Bending of trajectories due to the magnet for the polarized target has been included in these calculations. The bands indicate the consequence of finite angular resolution of the system, including the effects due to size of counters, size of target, and multiple scattering; hence their intersection defines the region where kinematic identification is ambiguous. Fig. 3 gives a plot of the K^+ meson laboratory angle against its center of mass angle, where the crosses indicate the limits of the ambiguous region. Also plotted are the β's for the K^+ meson and proton against the K^+ meson center of mass angle. From these we conclude that appropriate threshold Cerenkov counters can be used to resolve the ambiguity.

For K^-p scattering, the field of the polarized target magnet bends the trajectories of the scattered particles in opposite directions. This effect removes the above mentioned ambiguities. Figure 4 demonstrates the situation for K^-p in a manner equivalent to Figure 2 for K^+p. As can be seen, there is no region of kinematic ambiguity for K^-p.

(C) Angular Acceptance

The low momentum recoil proton for small angles of K meson scattering and the low momentum K meson for large angles of scattering suffer substantial multiple scattering and loss of energy. Using the criterion that the overall r.m.s. uncertainty of angle due to small angle multiple scattering and uncertainty in the trajectory resulting from loss of energy be less than 5^o for events from the entire target, the maximum and minimum values of $\cos\theta_K^{cm}$ between which data may be collected are plotted in Fig. 5 as a function of incident momentum of the K mesons. Evidently a significant experiment can be conducted within these limits.

(D) Time Required

The time required for a measurement has been estimated using the anticipated intensity of the beam which has been designed with a ±2% momentum bite and a ±0.2" horizontal image.[16] However, for our proposed experiment the momentum bite must be reduced to ±1.5% and the horizontal image must be increased to ±0.5" to reduce the divergence of the beam. Hence we have assumed that only 3/4 of the particles in the beam can be used and that the useful intensity will be $3/4 \times 1.5 \times 10^5$ K^+ mesons per burst of 10^{12} protons. Using the data of Cool et al.,[18] we anticipate that the K^-/K^+ ratio in our momentum interval is 1/4. We therefore expect a useable flux of $1/4 \times 3/4 \times 1.5 \times 10^5$ K^- mesons per burst of 10^{12} protons.

For K^+p we have used a typical integrated elastic cross section of 12 mb for this range of momenta and have estimated that 1/7.5 of the elastic events will be accepted by the counters. In the case of K^-p estimates, we have performed calculations using the phenomenology described by Armenteros et al.[6] to obtain some idea of rates, polarizations, and sensitivities to various resonances. We have also used the results of Daum et al.[19] – a measurement of K^-p polarization and differential cross section in the region 1.4 - 2.4 GeV/c – to estimate backgrounds. Based on the above considerations, we present Table II which outlines the details of the measurements and Table III which gives estimated running time.

TABLE II

Experimental Details

	K^+	K^-
Incident beam intensity (Particles/10^{12} protons)	1.1×10^5	2.8×10^4
Detected events/pulse (Assume 10^{12} particles/pulse)	33	9.6
Events/hr (Assume 1500 pulses/hr)	4.9×10^4	1.4×10^4
Hrs/momentum point	6	17
Events/momentum point	2.8×10^5	2.5×10^5
Number of points	8	11
Statistical accuracy/point		
a) Polarization	±0.02	±0.02 - ±0.08
b) Cross section	1%	1.5% - 5%

TABLE III

Time Estimates
(Times in Hours)

	K^+	K^-
1) Collection of data	48	190
2) Set up time/momentum point (4 hr/point)	32	44
3) Reversing polarization (1/2 hr/ reversal)	12 (3 reversals/point)	25 (5 reversals/point)
4) Background measurement	10	25
5) 10% separator breakdown	10	29
Total	112 hr	313 hr

Total hours for K^+p and K^-p experiments: 425 hrs.

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5. FACILITIES REQUIRED FROM BROOKHAVEN

In addition to the use of the low momentum separated beam from the external primary target for the time indicated and assistance for rigging our apparatus into position, the following major facilities will be required.

Polarized target

1)	60 ampere, 208 volt, 3φ 4 wire Y services	- 1 unit
2)	100 kW power supply for magnet	- 1 unit
3)	50 gallon per minute, 90 psi cooling water	- 1 unit
4)	20 ampere, 208 volt, 3φ, 4 wire Y services	- 1 unit
5)	20 ampere, 110 volt, 1φ services	- 3 units

Counters

1)	trailer with air conditioner	- 1 unit
2)	20 ampere, 110 volt services	- 12 units
3)	tektronix 585 oscilloscope	- 2 units
4)	model 100 frames	- 5 units
5)	NIM bins	- 4 units
6)	Dual discriminators (M101)	- 10 units
7)	Dual discriminators (New type)	- 2 units
8)	And/Or (M102 or 103)	- 6 units
9)	Dual And (M107)	- 4 units
10)	Dual Fan-In (M112)	- 2 units
11)	Dual Fan-Out (M108)	- 1 unit
12)	Dual Nanoamp (M106)	- 4 units
13)	Linear Gate (M116)	- 2 units
14)	D. C. Mixer	- 6 units
15)	100 MHz dual scalers	- 4 units

16) 10 MHz dual scalers - 10 units

17) Delay box - 10 units

18) 3 K volt, 40 ma power supply - 10 units

On Line Data Facility

A PDP-8 computer will be used as a satellite to the PDP-6. We would expect to use about 40,000 memory words in the PDP-6 and about 1 second of processor time per AGS burst. We would expect to have a line printer and oscilloscope readily available as well as 2 IBM magnetic tape drives, two dec-tape units and the use of about 50,000 words on the magnetic disk.

PERSONNEL

Yale Faculty

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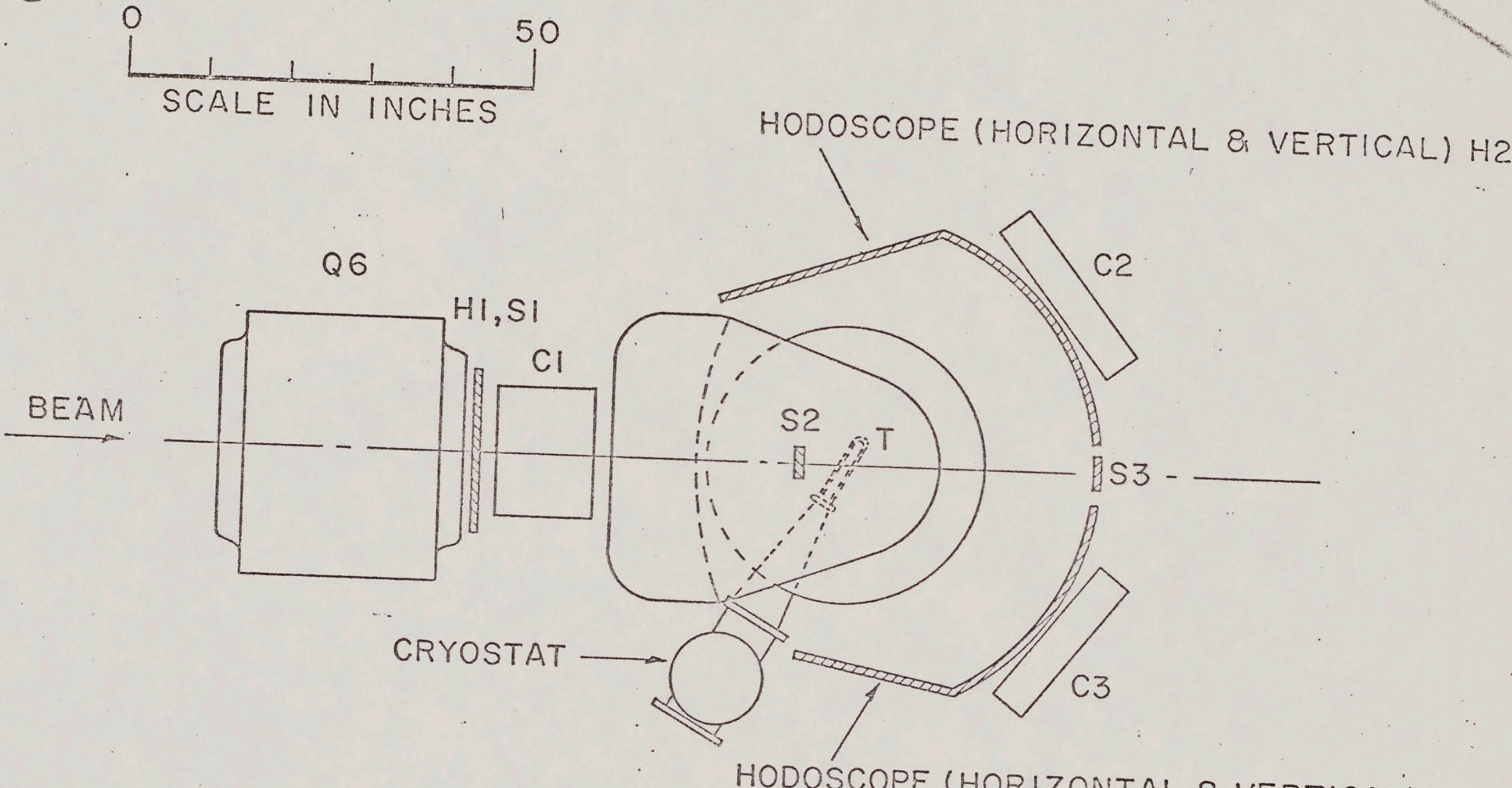
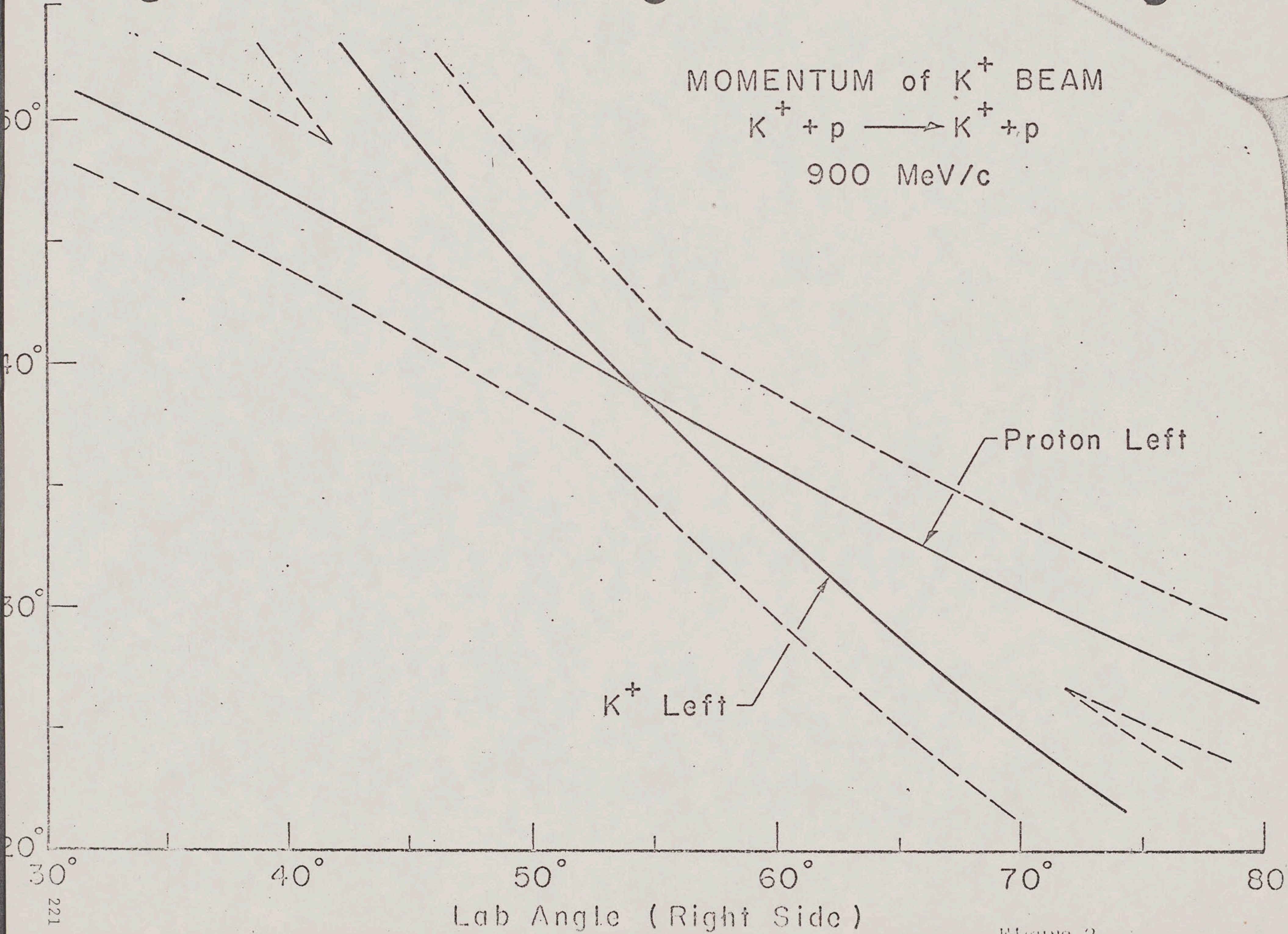


Q6 : LAST QUADRUPOLE MAGNET
H1 : BEAM HODOSCOPE
C1 : DIFFERENTIAL LIQUID CERENKOV COUNTER
S1,S2,S3 : TRIGGER COUNTER
T : POLARIZED PROTON TARGET
H2 : SCATTERED PARTICLE HODOSCOPE
C2,C3 : THRESHOLD LIQUID (OR SOLID) CERENKOV COUNTERS

Figure 1



MOMENTUM of K^+ BEAM
$K^+ + p \longrightarrow K^+ + p$
900 MeV/c
Proton Left
K^+ Left
50°
40°
30°
20°
30°
40°
50°
60°
70°
80
Lab Angle (Right Side)

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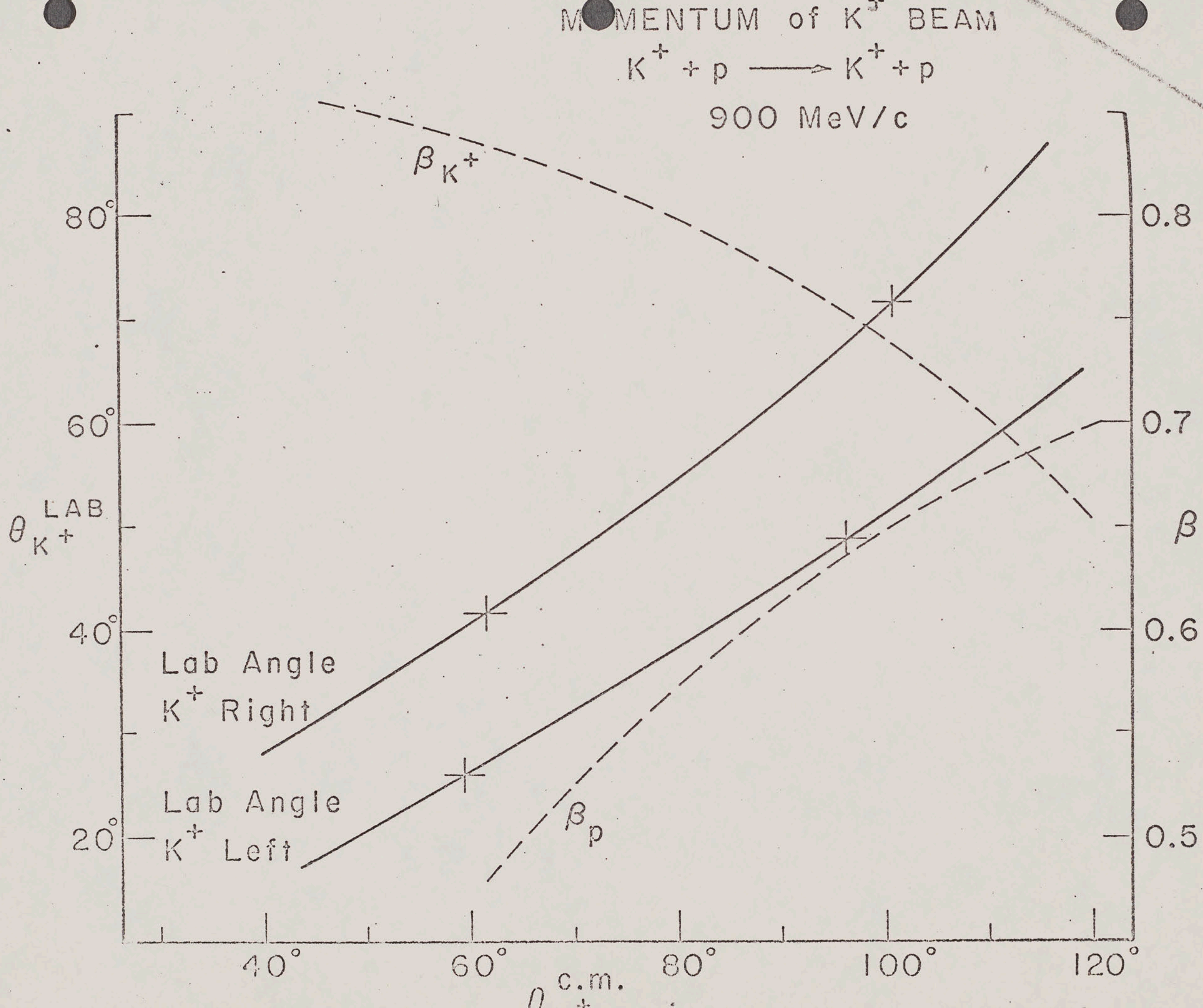
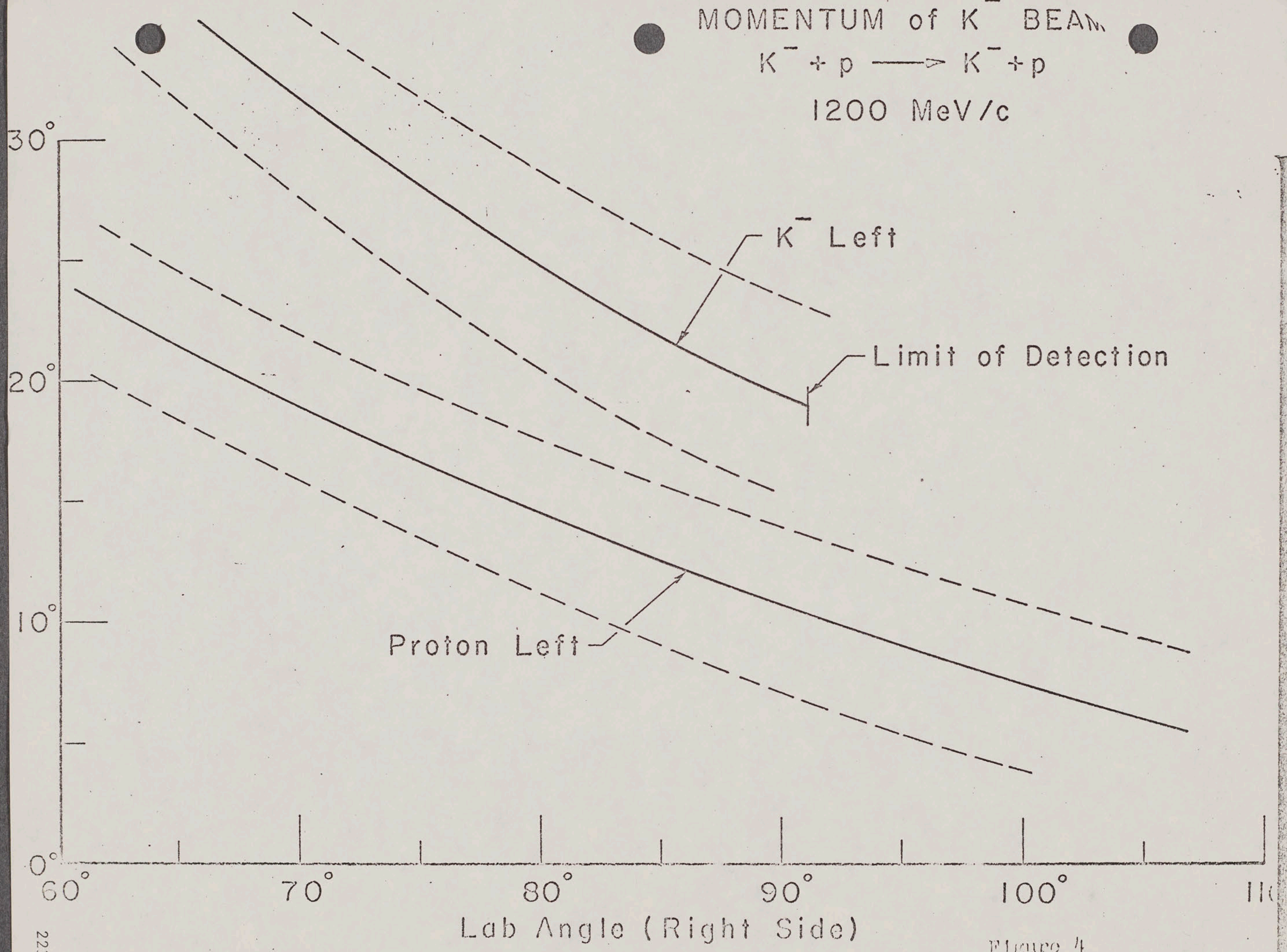
Figure 2



MOMENTUM of K+ BEAM
K+ + p ⟶ K+ + p
900 MeV/c
β_{K^+}
β_p
β
$\theta_{K^+}^{LAB}$
80°
60°
40°
20°
0.8
0.7
0.6
0.5
Lab Angle K+ Right
Lab Angle K+ Left
40°
60°
80°
100°
120°
$\theta_{K^+}^{c.m.}$

Figure 3


MOMENTUM of K⁻ BEAM
$K^- + p \longrightarrow K^- + p$
1200 MeV/c
K⁻ Left
Limit of Detection
Proton Left
30°
20°
10°
0°
60°
70°
80°
90°
100°
110
Lab Angle (Right Side)
Figure 4

ESTIMATED EXPERIMENTAL LIMITS on cos $\theta_K^{c.m.}$ for

$K^+ + p \longrightarrow K^+ + p$

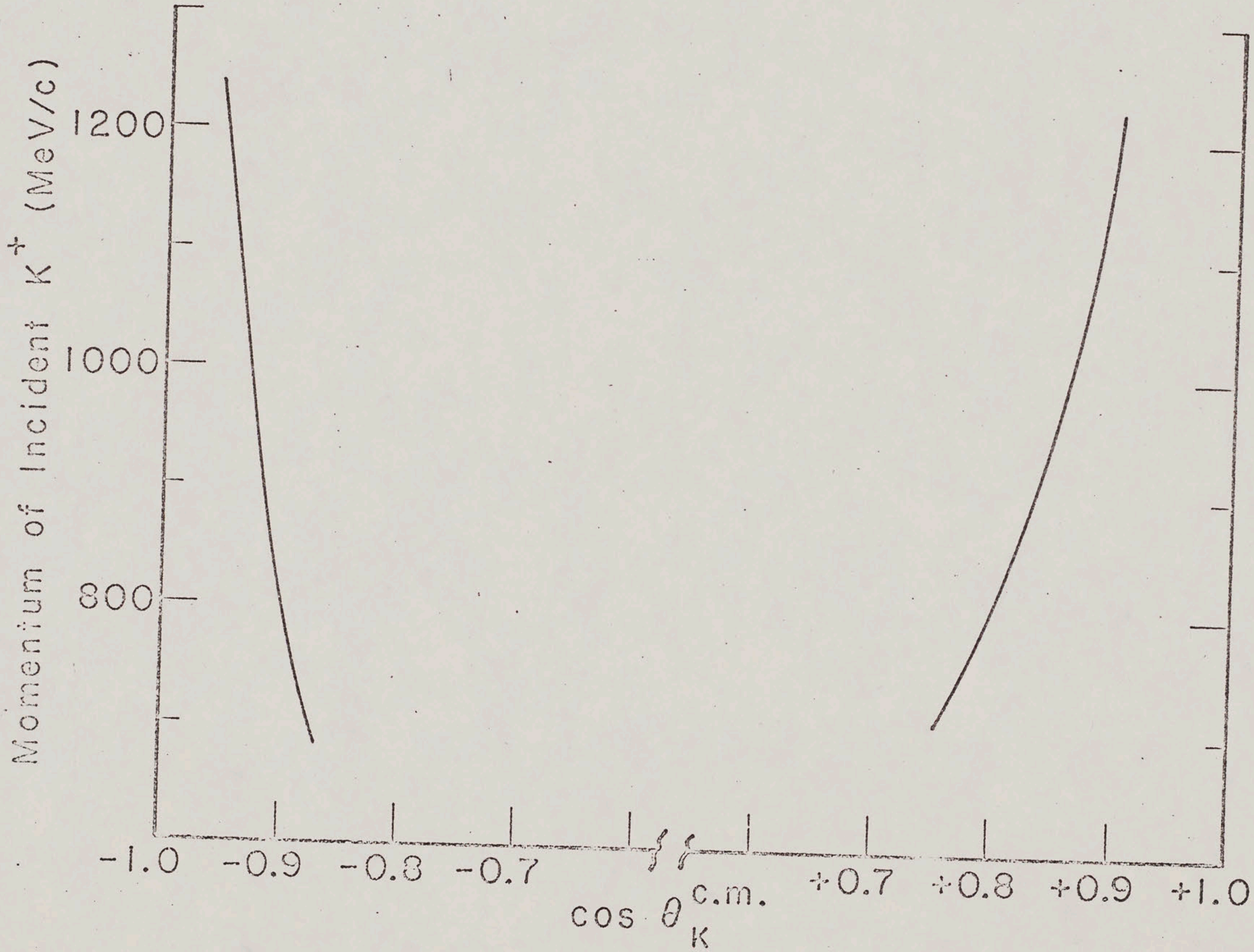


Figure 5

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AGS PROPOSAL

PART II

From: V. W. Hughes and G. A. Rebka (correspondents)
R. Ehrlich, K. Kondo, D. C. Lu, S. Mori
P. Thompson, M. E. Zeller - Yale University

Subject: Measurement of the polarization asymmetry in elastic scattering of antiprotons from polarized protons for incident momenta between 0.7 BeV/c and 0.8 BeV/c. Study of diffractive behavior and possible resonance formation.

Beam: Use of low momentum separated $\bar{p}$ beam derived from the slow external proton beam.
$\bar{p}$ momentum range 0.7 BeV/c to 1.2 BeV/c.
175 hours of AGS time.

Detectors: Hodoscope system of scintillation counters.

Scattering Target: Ethylene Glycol Polarized Proton Target

September 30, 1969

1. Introduction

The $\bar{p}p$ system has intrinsic interest from at least two standpoints. It can provide means for studying the properties of hypothetical high mass bosons, with high mass resolution, whose existence (or non-existence) is important to various particle classification schemes. Secondly, as a consequence of the many available inelastic channels, the elastic $\frac{d\sigma}{d\Omega}$ has a "diffractive" appearance even for very low incident momenta.

A CERN group[1] has analyzed both $\frac{d\sigma}{d\Omega}$ and the polarization asymmetry in the region 1.73 - 2.97 BeV/c in terms of a very simple optical model, with considerable success. A Caltech-BNL-Rochester[2] collaboration has had similar success in describing the backward $\frac{d\sigma}{d\Omega}$ with the same model in the region 0.7 to 2.16 BeV/c, using optical parameters which vary only gradually with energy. Optical models of this sort can provide a standard with which one can contrast models involving resonance formation; e.g., an "unreasonable" energy dependence of the optical parameters will emerge in the presence of significant resonance formation, if indeed an optical model will fit the data at all. Figs. 1 and 2 show typical expectations for $\frac{d\sigma}{d\Omega}$ and polarization on the basis of Ref. 2's model.

2. Experimental goals

The proposed $\bar{p}p$ experiment would, like the $K^{\pm}p$ experiments, use the projected separated beam, derived from the slow extracted beam. The available momentum region would then correspond to 0.7 BeV/c $\leq$ p $\leq$ 1.2 BeV/c. This corresponds to a mass range between 1.99 and 2.15 BeV. Within this range (or near its bounds) lie at least two suspected boson resonances. The first object, observed by Cline et al.,[3] is reflected in clear enhancements in the elastic cross section near 90° and 180°. It occurs at an incident $\bar{p}$ momentum of ~70 MeV/c and has a full width corresponding to ~70 MeV/c. If, as is possible under favorable circumstances, it were to induce a polarization reversal about 90° in the c.m., such behavior would automatically conflict with the simpler optical models.

Another structure, perhaps more well-founded, occurs at ~1.1 BeV/c. It has been recently observed in the reaction $\bar{p}p \to \pi^{+}\pi^{-}$.[4] The quantum numbers favored by the authors of ref. 4 are $IJ^{PG} = 13^{-+}$. It is estimated to have a mass ~2.12 BeV and width ~200 MeV. Its relation to a bump in the I=1 $p\bar{p}$ total cross section, observed by Abrams, et al.[5] is uncertain. The elasticity of the Abrams bump, if J=3, would be ~0.2. While such an inelastic resonance would not radically affect $\frac{d\sigma}{d\Omega}$ elastic (it would enhance the elastic cross section of ~30 mb by only ~0.5 mb), it could appreciably modify the polarization for $\cos\theta \lesssim 0.0$. Since, however, the CERN group has recently measured $\bar{p}p$ polarization between 1.0 and 1.4 BeV/c,[6] we shall restrict our proposal to the lower energy region.

Our program will consist of 3 measurements at ~50 MeV/c (Δm ~ 15 MeV) intervals; i.e., at 700, 750 and 800 MeV/c.

3. Experimental technique

The experimental appartus will be largely indentical to that described in our $K^{\pm}p$ proposal. No region of kinematic ambiguity exists, and separation of elastic from quasielastic and inelastic events should present no problem. Because the $\bar{p}$ rates are expected to be quite modest, we shall also be able to apply a time of flight criterion to both the incident beam and the scattered particles. The former condition, in combination with a threshold Cerenkov counter in veto should eliminate events induced by π's and K's. Time of flight applied to the scattered particles will reduce mesonic annihilation background to a negligible level: even at 0.8 BeV/c, the velocity of the slower scattered particle does not exceed 0.51c.

The principal experimental limitation in available center of mass angles is set by the heavy ionization and multiple scattering experienced by both the recoil proton from small θ, and the $\bar{p}$ at large θ. We expect to obtain useful polarization data in the range $|\cos\theta_{c.m.}| \leq 0.6$ at .700 BeV/c. Data on $\frac{d\sigma}{d\Omega}$ will likely be restricted to a somewhat smaller range.

For deriving estimates of the time required we have set a nominal goal of an absolute polarization error of ± 0.1 at $\cos\theta_{c.m.} = 0.0$, and assuming bins of 0.1 in $\cos\theta$. As a consequence we expect smaller errors elsewhere, since $\frac{d\sigma}{d\Omega}$ is generally at a near minimum at $\sim 90^\circ$.

We assume a typical $\bar{p}$ flux of 5×10^3/pulse and a typical $\frac{d\sigma}{d\Omega}_{90^\circ} \sim 0.1$ mb/ster. With 60% average polarization, and a detection efficiency of ~0.16, the error in polarization is:

$$\delta(P) \sim \frac{2.0}{\sqrt{N_{SC}}} ,$$

where N_{SC}, the number or detected elastic events, $= 7.5\times10^{-2}$ x number of machine pulses. Thus we require 3×10^8 incident $\bar{p}$'s or ~40 hrs. of machine time to attain the specified precision at each momentum. Below, we summarize our machine time requirements.

1)	data collection (3 pts)	120 hrs.
2)	beam adjustment and set up	15 hrs.
3)	polarization reversals	5 hrs.
4)	background study	20 hrs.
5)	10% separator breakdown	~15 hrs.
		175 hrs.

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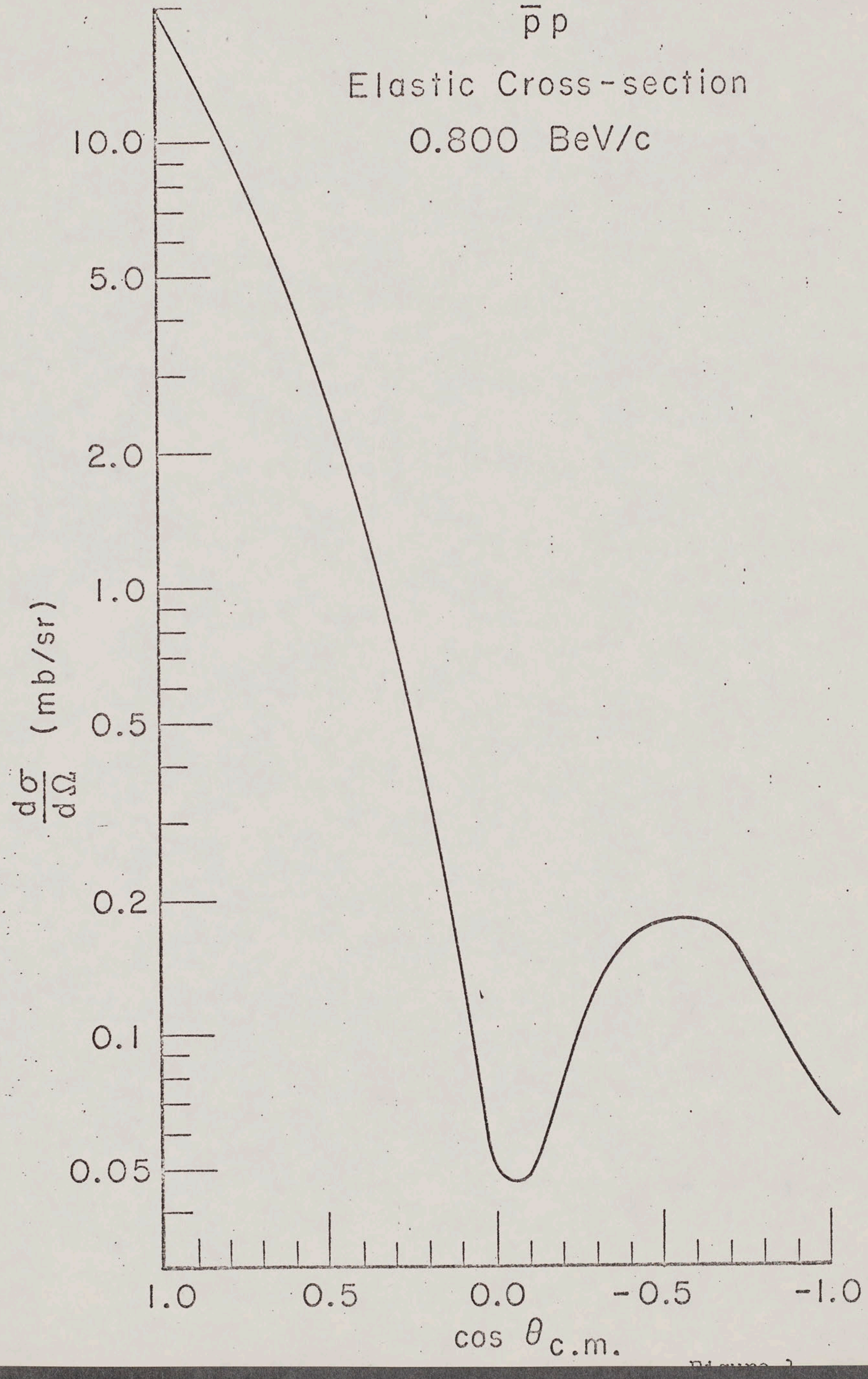
6. Private communication from J.C. Sens to V.W. Hughes.


$\bar{p}p$
Elastic Cross-section
0.800 BeV/c
10.0
5.0
2.0
1.0
0.5
0.2
0.1
0.05
$\frac{d\sigma}{d\Omega}$ (mb/sr)
1.0
0.5
0.0
-0.5
-1.0
$\cos\theta_{c.m.}$

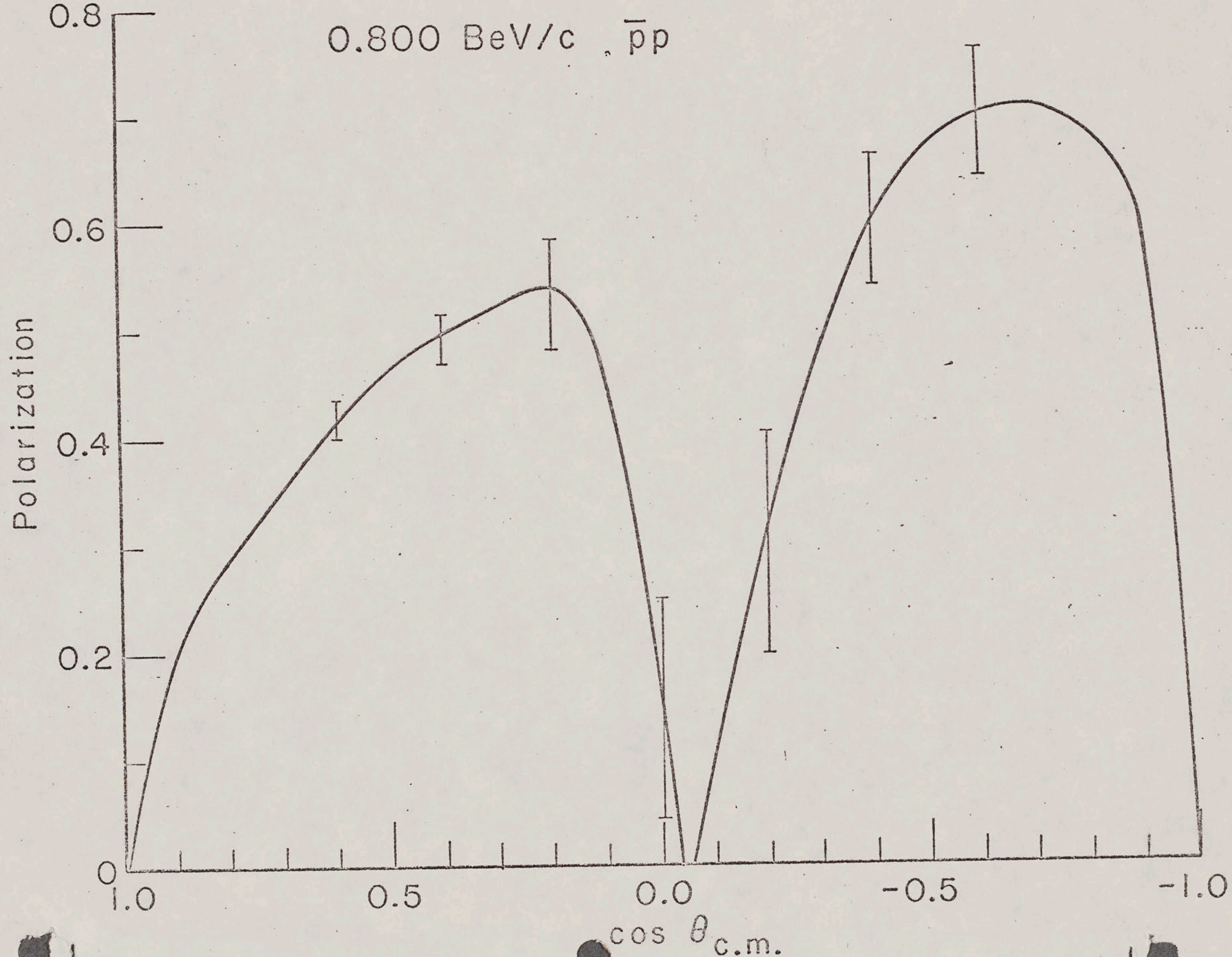

0.800 BeV/c , $\bar{p}p$
Polarization
0.8
0.6
0.4
0.2
0
1.0
0.5
0.0
-0.5
-1.0
cos $\theta_{c.m.}$

Figure 2