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NATIONAL ACCELERATOR LABORATORY REPORT

July 1973

This report is the first of a new series intended to provide a means of communication between the NAL Laboratory Staff and experimenters and guests who use the Laboratory. It is hoped that it will be of value to others interested in the Laboratory. NALREP will include descriptions of experiments in progress, timely articles concerning technical features of the Laboratory, photographs or sketches of significant devices or events, administrative information such as new appointments and committees formed at the Laboratory, and other matters of general interest. An attempt will be made to improve communication between us at NAL and present and future experimenters who make use of the research facilities. It is hoped that this will make the planning for experiments go more smoothly and provide the general technical information necessary to make the research opportunities as realistic as possible. Suggestions of material for future issues and contributions to NALREP may be made through:

NALREP Editor
National Accelerator Laboratory
P. O. Box 500
Batavia, Illinois 60510.

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Muon Beam Improvements in the Neutrino Area

Since mid-May there have been a number of activities in the Neutrino Area that are of significant interest to the muon and neutrino experimenters. The Neutrino Area, like the Meson Area, has a target box in which targeting and focusing systems may be located. The initial focusing system, called the "prototype dichromatic load," used for previous muon and neutrino running was removed in March and rebuilt. This was done in order to accept a larger flux of pions and kaons and to resolve more sharply the sign of the charge of the particles produced from the target. The target load consists of focusing and energy selecting magnetic elements that direct the 300-GeV proton beam onto a target. Downstream from the target are quadrupoles and dipoles that gather the secondary flux of particles including pions and kaons with a selected polarity. By means of steel blocks the unused primary proton beam is absorbed on the train load while the secondary beam at momenta up to 200 GeV/c is transported into the decay pipe. The train load itself rests on narrow-gauge railroad flatcars which are driven into the target box. All elements on the load are operated from an external service building. The 1300-ft long, 36-in. diameter evacuated decay pipe provides space for the pions and kaons to decay into neutrinos and muons. At the end of the decay pipe, some of the muons are chaneled into the muon beam and conveyed through magnetic elements to experiments in the Muon Laboratory. In order to improve the flux of muons, changes have been made recently to the muon beam elements. Before describing these changes, it may be useful to remind the reader of the objectives of the original beam and how it has developed.

The initial muon beam was designed to make use of the muons that are a byproduct of the forming of the neutrino beam. The beam uses the muons that arise from the decay of the pions and kaons and selects the muons that come through a 2-in. × 4-in. hole at the end of the decay pipe. Unfortunately in the original design, the elements that produced a favorable neutrino beam produced am image of muons at the end of the decay pipe oriented in an inappropriate manner to be easily accepted by the muon channel and only a small fraction of the muons were able to get into the beam line.

The design energy of the initial beam was a maximum of 300 GeV with an energy spread of ±5%. If a simple quadrupole doublet focusing system in the target box had been used the design flux would have been about 5×10^6 μ/pulse into a 4-in. × 4-in. spot at the Muon Laboratory for 5×10^{13} p/pulse on the target; that is a μ/p ratio of 10^{-7}. The simple quadrupole focused front end was not used, and instead the prototype dichromatic load was substituted to attempt to provide compatible neutrino running, incorporating a narrow-band focusing system suitable for Neutrino Experiment #21.

The muon beam that was installed picked up a portion of the muons in an underground enclosure (Enclosure 100) at the end of the decay pipe and transported it through the other enclosures (101, 102, 103, and 104) to the Muon Laboratory. The muon beam elements consisted primarily of dipole magnets with a pair of quadrupoles at Enclosure 101 to cancel the multiple scattering in a hadron absorber at Enclosure 100 and to focus the beam into Enclosure 102. A 40-ft CH_2 hadron absorber (filter) at Enclosure 102 was installed to provide further attenuation of the hadrons in the beam. A second

pair of quadrupoles in Enclosure 103 cancelled the multiple scattering from the filter. The Muon Laboratory, which is the experimental station fed by the muon beam, is located half way along the Neutrino Area shielding berm. The detector building now contains Muon Experiments #'s 26 and 98. After passing through the Muon Laboratory, the residual muon beam plows into the earth shielding berm downstream of the Muon Laboratory.

Subsequent to the original design and prior to the completion of the construction of the beam enclosures, a substitution of quadrupoles was made in Enclosure 103. Six 12-in. diameter quadrupoles borrowed from the Cambridge Electron Accelerator replaced the two main-ring quadrupoles planned for that enclosure. This change was based on a calculated 5-fold increase in the flux of muons and an 8-fold improvement in the quality of the beam by reducing the halo of particles around the core of the muon beam. One effect of these changes was a reduction in focusing capability from 300 GeV to 200 GeV and an increase in required electrical power from 125 kW to 825 kW for 200-GeV muons.

When the entire system was energized and tuned up for the highest muon flux, the measured μ/p ratio with this configuration and the prototype target load was:

$$\frac{\mu}{p} \approx 5 \times 10^{-9}.$$

With the intensity available from the accelerator, this ratio produced an unsatisfactorily low flux of muons, and additional beam improvements were initiated.

A recent change in the beam is the substitution of 4-in. aperture dipole magnets in Enclosure 104 in place of the 2-in. aperture main-ring magnets. The calculated gain from this opening up of the aperture is a 30% increase in intensity and a further factor of two reduction in the halo. The maximum beam energy is now reduced to 150 GeV with an eventual upper limit of 200 GeV when an additional power supply is added and when pulsed current is used to energize the dipole magnets.

Using the recently modified and improved narrow-band target load as designed by R. Stefanski, L. Teng, T. Yamanouchi, and others, the measured μ/p ratio has increased by a factor of five:

$$\frac{\mu}{p} \approx 2.5 \times 10^{-8}.$$

To achieve the goal of 10^6 $\mu/10^{13}$ p in the absence of a high-acceptance quadrupole target load, a basic change in design has been initiated in the so-called Mark II beam. The beam port at the end of the decay pipe will be opened up to 4 in. with a substitute of 4-in. aperture dipoles magnets for 2-in. and the addition of 5-in. aperture quadrupoles. The function of the quadrupoles will be to capture more muon flux. The result of these improvements should give an additional factor of two improvement in intensity at the Muon Laboratory giving an intensity of 10^5 muons/pulse.

Since the objective remains to have a beam with at least 10^6 muons/pulse, new studies are being initiated for a Mark III beam design. This beam would continue to use the improved narrow-band target load in the target box but would incorporate larger aperture quadrupoles and higher field dipoles

in the muon beam itself to increase both the flux and the maximum energy of the beam. The objective will be to provide a 300-GeV muon beam and a flux of 10^6 muons/pulse at 150 GeV/c. The Energy Doubler Group of the Accelerator Division is studying the application of superconducting magnet elements for this beam-improvement project. For example, a prototype superconducting dipole magnet with an aperture of 4 in. × 6 in. and a length of 10 ft is under construction. It is hoped that it will be feasible to design and install superconducting elements within the existing enclosures. Designs are currently being worked on in the Neutrino Section under the leadership of T. Yamanouchi and P. Limon and interested experimenters are invited to participate. Many experimenters (B. Barish, F. Sculli, L. Hand, L. Verhey, etc.) have contributed numerous ideas to this design work. More extensive ideas concerning future improvements to the muon beam, including changes to the front end of the beam in the vicinity of the target load is a subject being discussed at the 1973 Aspen Summer Study. New ideas of focusing systems located adjacent to the existing neutrino beam are being developed and will be considered in the future.

Summer Meeting of the Program Advisory Committee

The Program Advisory Committee met in Aspen, Colorado, the first week in July and considered the content of the entire experimental program, including the approved and proposed experiments. The present members of the Program Advisory Committee are

Name	Institution	Term Expiration
V. L. Fitch, Chr.	Princeton University	1974
M. Gell-Mann	California Institute of Technology	1974
B. L. Roe	University of Michigan	1974
N. P. Samios	Brookhaven National Laboratory	1974
J. W. Cronin	Enrico Fermi Institute	1975
J. D. Jackson	Lawrence Berkeley Laboratory	1975
M. J. Tannenbaum	Rockefeller University	1975
S. Wojcicki	Stanford University	1975
B. Barish	California Institute of Technology	1976
R. Diebold	Argonne National Laboratory	1976
T. O'Halloran	University of Illinois	1976
S. Treiman	Princeton University	1976

The work to be done in each experimental area and beam line was reviewed and the overall duration of the experiments was examined. The priorities among experiments in a given beam line were reexamined and all discussions of new proposals were carried on in the context of the already approved program. The following table shows the status of proposals before the meeting of the Program Committee and the status following the meeting.

Overall Summary of the
Status of Proposals/Experiments

	Before PAC '73	After
Number of Proposals Approved	64	75
Number Not Yet Considered	48	10
Number for Which Action is Deferred	35	43
Number of Experiments Completed	16	16
Number of Proposals Rejected	23	42
Number Inactive/Withdrawn	47	47
Total	233	233

After letters have been written to spokesmen for experiments the recommendations of the Program Advisory Committee will be made known. A Program Reference Book describing, in a brief way, the status of all

proposals and approved experiments will be available for examination in the NAL Library in August.

In addition to specific advice, the Program Committee gave some overall consideration to the direction in which the Laboratory is moving. For example, they have advised NAL to acquire deuterium gas suitable for filling both the 30-in. chamber and the 15-ft chamber. It is hoped that by working out a cooperative arrangement with Argonne and Brookhaven it will be possible to stockpile a large enough reserve of deuterium for these purposes. The Program Advisory Committee urged the Laboratory to look into the possibility of creating more secondary beams, particularly at higher energies. It was felt that the backlogs of experiments in the M1 and M6 beams in the Meson Laboratory are too long for an optimal experimental program. The Committee also urged the Laboratory to pursue major muon beam improvements and postponed making a decision on experiments needing an electron beam, pending an examination of the performance of the improved muon beam.

Following is a list of the proposals that have been received at NAL during May and June, 1973:

Experiment Number	Title	Submitted By
205	Phenomenological Study of Muon-Nucleon Collision at Energy More Than 100 GeV in Emulsion	O. Kusumoto
206	Development of a Transition Radiation Detector for Discriminating Between Pions and Kaons at NAL Energies	V. Z. Peterson
207	Proposal to Study pp Interactions at 500 GeV in the 30-In. Bubble Chamber at NAL	R. J. Engelmann

Experiment Number	Title	Submitted By
208	A Proposal to Study Proton-Proton Interactions at the Energy of 300 GeV or Higher in the NAL Bubble Chamber	M. A. Markov
209	A Study of 300 GeV/c pd Interactions in the 30-In. Bubble Chamber	R. A. Dzierba
210	Inclusive Production of $\pi^{\pm}$ in the Backward Direction from Complex Nuclear Targets	K. J. Cohen
211	Proposal for Radiation Measurements Around a Proton Beam Dump at 300 GeV	K. Goebel
212	Measurement of Backward 2-Body and Quasi-2-Body Reactions Induced on Unpolarized and Polarized Protons by $\pi^{\pm}$, $K^{\pm}$, p Ranging from 20 to 100 GeV/c	M. David
213	Proposal to Study High-Energy $\pi^{+}K^{+}$ and K^{-} Interactions in the NAL 15-Ft Hydrogen Bubble Chamber	J. G. Rushbrooke
214	Proposal to Study High Energy Negative Hyperon Interactions with the NAL 15-Ft Bubble Chamber	J. G. Rushbrooke
215	Study of 400 GeV $\pi^{-}p$ Interactions in the Bare 30-In. Bubble Chamber	G. Goldhaber
216	A Measurement of the Pion Form Factor by Direct Pion-Electron Scattering	D. J. Dirckey
217	A Comparison of 100 GeV and 200 GeV $\pi^{\pm}p$ Interactions	R. L. Lander
218	Pion-Deuteron Interactions at 200 GeV/c	P. M. Yager
219	Detailed Study of Nucleon Dissociation and Particle Exchange Reactions	P. Oddone
220	Experimental Proposal for NAL 30-In. Bubble Chamber $\bar{p}p$ and $K^{-}p$ Interactions at 100 GeV/c	T. Kitagaki

Experiment Number	Title	Submitted By
221	p-p Inelastic Scattering in the Diffractive Region	P. Franzini
222	A Proposal to Study Hard Hadron-Hadron Collisions	J. E. Pilcher
223	Proposal to Study High Transverse Momentum Energy Distributions and Correlations Using Total Absorption Calorimetry at NAL	P. Schlein
224	Study of Diffractive Dissociation (Coherent and Incoherent) and Inclusive Parameters of the Interaction of High Energy Pions and Protons on Nuclei Heavier Than Hydrogen	L. W. Jones
225	Excited Muon, Lepton Pair Production, W Production, and Deep Inelastic Muon Scattering in High Energy Muon Interactions	K. W. Chen
226	Coherent K_S Regeneration by Electrons	E. I. Rosenberg
227	Proposal to Investigate Neutrino Interactions in Deuterium Using the NAL 15-Ft Bubble Chamber	R. Engelmann
228	Proposal to Extend the Energy Range of a Study of Multiparticle Production in pp Collisions	T. Ferbel
229	A Proposal for Testing a Transition Radiation Detector at NAL	L. C. L. Yuan
230	A Search for "Schein Events" and Events with a High Multiplicity of γ's	M. J. Longo
231	p-p and p-d Elastic and Inelastic Scattering in the High t-Region in the New Internal Target Laboratory	R. Yamada

Research Topics

This section of the Report will be available for accelerator and particle physics experimenters and theorists to describe their current work. It is hoped that this will make it possible for timely and interesting news about the NAL research program to reach interested readers. Please submit contributions to the NALREP Editor.

Notices and Announcements

In response to numerous requests for on-site public transportation, the Laboratory has initiated a bus service along Road A, the main road to the external experimental areas. The bus runs in a long loop from the Cross Gallery out Road A passing the Meson and Neutrino Areas (with a brief detour to the Proton Area) and back out Road A to the Bubble Chamber Area. It then returns by the same path to the Cross Gallery. The entire cycle is completed in 20 minutes so no one's wait is too long.

We urge you to use this service. It is on a trial basis and will be discontinued if not useful. Please send any comments you have about this service to the Operations Center, c/o Halsey Allen.

Accelerator Facility Performance for June 1973

The physics research program at the Laboratory consists of work done with the accelerator and in the experimental areas. The accelerator facility operated well this month, and a peak intensity of nearly 4×10^{12} protons/pulse at 300 GeV was recorded. For substantial periods of time four experimental areas operated simultaneously. The circulating beam was used in the Internal

Target Area while the slow/fast extracted proton beam was split into three parts and used at the same time in the Meson, Neutrino, and Proton Areas.

The overall accelerator utilization summary for June is as follows:

I. Summary of Accelerator Operation

A. Accelerator Hours for Physics Research

Accelerator Physics Research	89
High Energy Physics Research	285
Subtotal:	374

B. Nonphysics Hours

Accelerator Setup and Tuning to Experimental Areas	18
Programmed Interruption	143
Unscheduled Interruption	185
Subtotal:	346

C. Unmanned Hours	0
Total:	720

II. Summaries of Experimental Use

a. Integrated number of hours in external beams: For approved experiments	732
Other (for beam tuning and studies)	466
Total:	1198
b. Total hours charged to approved experiments	996
c. Total bubble-chamber pictures for approved experiments	7000
d. Total number of experiments to which time or pictures were charged	12

Note: The above tabulations do not include two (2) approved experiments which ran parasitically for a total of 59 hours.