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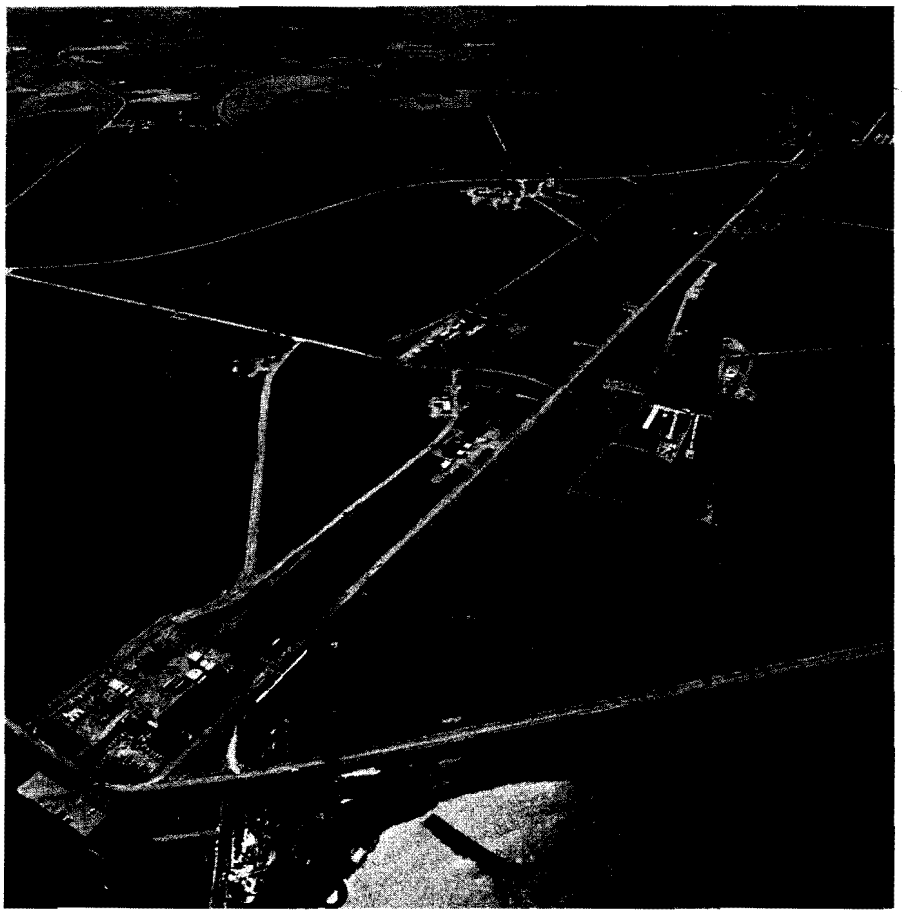
NATIONAL ACCELERATOR LABORATORY REPORT

August 1973



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THE COVER: Aerial view of NAL looking south across the external experimental areas toward the Central Laboratory Building and the accelerator structures. The Neutrino Area containing the 15-ft bubble chamber is in the lower left corner; the Meson Detector Building (right) and the Proton Area (left) are in the center of the photograph. (Photograph by T. Frelo, NAL, April 1973)

THE 1973 SUMMER STUDY - A PRELIMINARY REPORT

For four weeks this summer, from July 9 until August 3, more than sixty physicists came together at the Chateaux Conference Center in Aspen, Colorado, to participate in the 1973 Summer Study. While their families relaxed and enjoyed the mountains, they focused their attention on major new research projects which might be developed at the National Accelerator Laboratory. They also discussed the Energy Doubler, some short-term improvements for existing experimental areas, and the possibilities for physics research with present and future facilities. The major thrust of the study, however, was directed toward future projects which would take a number of years to complete, and might require new funding.

The Summer Study grew out of discussions held at the Laboratory last winter by the Long Range Planning Committee, which advises NAL on new projects. The Committee proposed six possible projects, and physicists were invited to indicate their relative interest in them. From their responses, four general areas were selected for study:

1. Experimental areas
2. Spectrometer facility
3. Proton-proton storage rings
4. Electron-proton storage rings.

The study was organized by D. Edwards, with assistance from P. Duffield and S. Burton. Participants were divided into subgroups on the basis of their own expressed interest in examining one or more of the general topics.

The reports of the study groups are being written now, and will be presented to the Long Range Planning Committee for further consideration later this fall. The suggestions of that Committee will then go to NAL Director R. R. Wilson and the Board of Trustees of Universities Research Association, Inc.; a decision to seek funding for one or more of the projects may then be made. A volume of proceedings, including the papers contributed to the study and the summaries and recommendations prepared by the group leaders, will also be published. What follows here is a brief summary of the major conclusions from each of the study groups.

Experimental Areas

A. K. Mann led the discussions about the experimental areas, assisted by B. Cox. Both the possibilities for developing new areas and major improvements which might be desirable in the existing areas were considered.

Much interest was expressed in the need for a fourth external experimental area. Such an area could be similar to a higher energy version of the present Meson Area, with a variety of secondary beams. High intensity pion beams, neutral beams, a diffracted proton beam, and certain specialized beams were suggested. These beams would originate from targets along an existing stub in the proton beam, and would be directed into the so-called Quark Area. Targets in the proton line could be exploited to provide four or more secondary beams, at momenta up to 1000 GeV, into a very large detector area several thousand feet downstream. This detector area might share facilities projected for future development of the Proton Area.

Extensive discussions were carried on about the use of the Proton Area as a source of secondary beams. For example, the beam dump region at the end of P-West might prove suitable for high intensity secondary beams with energies up to 500 GeV/c. Thus, the existing Proton Area facility would in time be used primarily as a location for targets for general purpose and specialized secondary beams into a detector area. This detector area might be shared with the beams suggested for the Quark Area. A large spectrometer array might also be housed there.

Discussions about the Neutrino Area were related to the modifications which might be made if the accelerator were able to operate at 1000 GeV as a result of implementation of the Energy Doubler. The group suggested that the pipe for decay of pions and kaons be lengthened in order to improve the neutrino flux. The necessary shield at the end of the decay pipe would then have to be made considerably denser by using either solid or magnetized iron. In particular, 900 meters of decay space might be available if the entire shield could be condensed into 500 meters.

The Meson Area was thoroughly discussed, and the study group recommended that it continue to be used for ≤ 300 GeV physics research. Many experiments have been approved for the Meson Area already, and the best course of action would appear to be to maintain stable, steady operation until they are completed. The consensus of the group was that 300-GeV protons should continue to be provided to the area by a "front porch" when the accelerator is operated at higher energies.

With regard to the Internal Target Area, there was some feeling that the potential of that area is not being completely exploited. With a small modification it would be possible to build a room just outside the beam tunnel, in which recoil detectors and magnets could be located without interfering with access to the accelerator components. A more extensive modification would be the construction of a beam by-pass on the main ring in conjunction with a storage ring facility. Such a by-pass would be the most suitable location for the development of an expanded internal target area.

Spectrometer Facility

R. Diebold led the discussion of a possible spectrometer facility, assisted by L. Voyvodic. The major emphasis was on a large magnetic spectrometer centered around a detector array suitable for hadron experiments. Surrounding a hydrogen target would be detectors of large angular acceptance, to identify the charged and neutral particles produced in the interactions being studied. There would be good energy resolution of the particles produced, involving identification of the charged particles by Cerenkov counters. The entire spectrometer should be able to operate with high-event rates in beams of 10^6 to 10^7 particles per pulse.

One rather specific plan proposed during the course of the study would consist of three spectrometer magnets and numerous detectors extending over 200 ft. It would be capable of taking incident beams up to 400 GeV/c at high intensities. First there would be a vertex magnet with a 2-m gap, 2-m width, and 3-1/2-m length. Downstream from this would be two other magnets with similar apertures, but altogether 8 meters in length. At the vertex would be

a pencil-shaped hydrogen target surrounded by cylindrical and planar multiple-wire proportional chambers. Downstream might be drift chambers interleaved with Cerenkov counters and lead glass detectors. The overall acceptance could be close to 4π rad with successively narrowing acceptance in the forward direction for the higher energy particles. Typical event rates might be 500 per burst, leading to an event-per-microbarn sensitivity. Other interchangeable options for the vertex detector might be a streamer chamber or rapid cycling bubble chamber.

Proton-Proton Storage Rings

Wonyong Lee led the discussions of potential storage rings at NAL, assisted by E. Malamud. The group felt that 1000-GeV protons colliding with 1000-GeV protons would be an appropriate goal. The two storage rings constructed of superconducting elements might be fed by the improved accelerator which would result from the Energy Doubler.

As an intermediate step, the group suggested that a 30- to 50-GeV storage ring be constructed of superconducting elements to collide with a 400 or 500-GeV beam inside the present main-ring accelerator. This developmental project would provide hard-core cost estimates for the larger storage ring project.

Reports from the CERN Intersecting Storage Ring indicate that a number of interesting physics questions could be answered utilizing very high energy proton storage rings. For example, a test for a new energy scale looking at small distances and the production of new particles could be studied. At 2000 GeV in the center of mass the average multiplicity is expected to be 26; clearly, a great many things will be happening in that energy region.

In the case of the larger rings, the group suggested a radius of 1.3 km and a luminosity of approximately 10^{34} cm^{-2} sec^{-1}. By examining some specific examples, they concluded that experiments could be done in straight sections as short as 200 meters. There might be as many as eight such intersecting locations around the ring.

Electron-Proton Storage Rings

The group which studied electron-proton storage rings was led by K. Strauch, assisted by E. Hubbard. The group assumed that a superconducting proton storage ring of 1000 GeV would exist at the Laboratory, and considered the construction of an electron storage ring built of conventional magnets to collide with the high-energy protons. The electron energy proposed was 20 GeV, which would result in a luminosity of 10^{32} $cm^{-2}sec^{-1}$. A storage ring of this energy would radiate 7 MW of power at 350 mA, which would set the upper limit to the energy of the electrons. Inelastic electron scattering experiments which could be done at the much higher energies possible with such a facility would provide an important test of the scaling phenomena related to the internal structure of the proton, and weak interaction experiments should reveal entirely new phenomena.

Various options for the rings were considered. Some called for three- and four-ring "circuses." In the three-ring circus, electrons would be injected into an electron storage ring of 1.3-km radius, where they would interact with 1000-GeV protons. The four-ring circus would consist of two rings operating in one enclosure and two in another; one set for electron-proton collisions and the other for proton-proton collisions. There might be as

many as eight points of intersection with the main ring, each with a crossing angle of 2 mrad. Both groups studying storage rings recommended that proton-proton and electron-proton facilities be integrated, and that preliminary design efforts be initiated at NAL with this goal in mind.

The participants suggested that the Laboratory consider the installation of a lower energy electron accelerator to collide with the existing main ring before embarking upon any more extensive electron-proton project. For example, if the Cambridge Electron Accelerator were brought to the NAL site, it could be used as an electron "target" for a preliminary study of collisions. Although operating at a much lower luminosity, it would allow study of the effect of bunched electron beams on protons, and also of accelerator operating parameters which might be affected by the interaction and collision processes. The electron target might be constructed in an existing straight section or, perhaps even better, in a by-pass in the main-ring tunnel.

These, then, are some of the highlights of the 1973 Summer Study. The projects under consideration at Aspen will be subjected to more review and examination in the months to come.

Those who participated in the study were:

Name	Institution
G. Ascoli	University of Illinois
W. F. Baker	National Accelerator Laboratory
C. Baltay	Columbia University
D. Berley	Brookhaven National Laboratory
G. Buschhorn	DESY
D. Cline	University of Wisconsin
T. L. Collins	National Accelerator Laboratory
B. Cox	National Accelerator Laboratory
J. Cronin	University of Chicago
T. Devlin	Rutgers University

Name	Institution
R. Diebold	Argonne National Laboratory
D. Drickey	University of California, L. A.
R. M. Edelstein	Carnegie-Mellon University
D. Edwards	National Accelerator Laboratory
H. Edwards	National Accelerator Laboratory
A. R. Erwin	University of Wisconsin
E. Fowler	Purdue University
D. Frisch	Massachusetts Institute of Technology
E. von Goeler	Northeastern University
L. Gutay	Purdue University
L. Hand	Cornell University
E. L. Hubbard	National Accelerator Laboratory
D. Jovanovic	National Accelerator Laboratory
T. Kirk	University of Illinois
U. E. Kruse	University of Illinois
A. Kuznetsov	Serpukhov Laboratory
Martin Lee	Stanford Linear Accelerator Center
Wonyong Lee	Columbia University
W. W. Lee	National Accelerator Laboratory
E. Malamud	National Accelerator Laboratory
A. K. Mann	University of Pennsylvania
A. Michelini	CERN
F. Mills	National Accelerator Laboratory
L. Mo	University of Chicago
C. T. Murphy	Carnegie-Mellon University
U. Nauenberg	University of Colorado
V. Nikitin	Serpukhov Laboratory
T. O'Halloran	University of Illinois
L. S. Osborne	Massachusetts Institute of Technology
J. Peoples	National Accelerator Laboratory
J. Pine	California Institute of Technology
I. A. Pless	Massachusetts Institute of Technology
K. Pretzl	DESY
P. Reardon	National Accelerator Laboratory
J. Rees	Stanford Linear Accelerator Center
B. P. Roe	University of Michigan
R. Rubinstein	Brookhaven National Laboratory
J. Sanford	National Accelerator Laboratory
W. Selove	University of Pennsylvania
M. L. Stevenson	Lawrence Berkeley Laboratory
K. Strauch	Harvard University
M. Strovink	Princeton University
L. C. Teng	National Accelerator Laboratory
M. Tigner	Cornell University
T. Toohig	National Accelerator Laboratory
F. Turkot	Brookhaven National Laboratory
L. Voyvodic	National Accelerator Laboratory

Name	Institution
J. K. Walker	National Accelerator Laboratory
W. D. Walker	Duke University
A. Wehmann	National Accelerator Laboratory
E. J. N. Wilson	CERN
R. Wilson	Harvard University
R. R. Wilson	National Accelerator Laboratory
H. Winick	Stanford University

Another milestone--Director R. R. Wilson conducting the first Director's Meeting held in the new NAL Auditorium on August 8, 1973. Director's Meetings, on the first Wednesday of each month at 9:30 a.m., are open to visitors as well as to NAL staff members. (Photograph by T. Fielding, NAL)

THE LONG RANGE PLANNING COMMITTEE

The Long Range Planning Committee was established by NAL Director R. R. Wilson to advise him on the future development of the Laboratory facilities. The Committee will review the summaries and recommendations of the participants in the 1973 Summer Study this fall. Their recommendations as to merit and relative priority will go to Mr. Wilson and to the Board of Trustees of URA. The projects deemed most appropriate will then become part of the Laboratory's long range development plans, and will be included in funding requests to the U. S. Atomic Energy Commission.

The present members of the Long Range Planning Committee are:

Name	Institution
D. H. Frisch, Chairman	Massachusetts Institute of Technology
S. L. Adler	Institute for Advanced Study
B. C. Barish	California Institute of Technology
H. Courant	University of Minnesota
L. Durand III	University of Wisconsin
E. Fowler	Purdue University
R. S. Livingston	Oak Ridge National Laboratory
A. Pevsner	Johns Hopkins University
C. Rubbia	Harvard University
M. Sands	University of California, Santa Cruz
K. Symon	University of Wisconsin
G. H. Trilling	University of California, Berkeley
D. H. White	Cornell University
F. Zachariasen	California Institute of Technology
R. Zdanis	Johns Hopkins University

HADRON PHYSICS IN THE 15-FT CRYOGENIC BUBBLE CHAMBER

For several years we have postponed consideration of proposals for the study of strong interaction in the 15-ft bubble chamber. Preliminary work using a bare bubble chamber has been done in the 30-in. chamber. The potential of that chamber has now been augmented by the addition of a downstream system of wide-gap and proportional spark chambers. The first

major test of this hybrid spectrometer system for physics will soon be started.

We cannot yet evaluate the effectiveness of the 15-ft chamber for studying hadron interactions. In part, this will hinge upon the turbulence of the liquid and the quality of the photography. Within the next few months we should have information regarding the resolution of this new device. The responsibility for getting this information rests with the NAL physicists who have been involved in the planning and construction of the chamber. They have received approval for an engineering run consisting of 50,000 pictures with hadrons of known momentum incident on the chamber.

While we are awaiting this new information, we are also planning to hold a workshop in which various possibilities for special beams to the 15-ft chamber will be discussed and developed. Many hadron bombardments will require a tagging system associated with the beam to the chamber. Others may need a special transport system or special detectors in the beam line. If you are interested in participating in this workshop, please advise us of your interest by writing to J. Sanford in the Program Planning Office at NAL. At the same time, if you are interested in proposing a hadron bombardment in the 15-ft bubble chamber and have not yet done so, I suggest that you submit your proposal to us in the near future. E. L. Goldwasser

NAL'S COMMITTEES

The Laboratory has several standing committees whose members consider technical matters of interest to visiting experimenters. These committees are composed primarily of NAL staff members, but on most there is some outside representation.

Safety Committee: To organize and set down safety procedures for the Laboratory. H. Allen (Chairman), M. Awschalom, F. Cole, T. Collins, R. Dorner, H. Hinterberger, Q. Kerns, W. Riches, J. Sanford, and D. Young.

Cryogenic Safety Subcommittee: To focus attention on cryogenic safety problems, to help the Laboratory establish reasonable and safe guidelines for cryogenic activities, and to discipline control of the implementation of sound procedures. H. Allen (Chairman), D. Chelton (U. S. National Bureau of Standards), M. Morgan, R. Niemann, M. Otavka, B. Strauss, D. Theriot, L. Voyvodic, A. Wehmann, and V. Zernoski.

Computer Advisory Committee: To give advice on the development of Laboratory computer facilities. J. K. Walker (Chairman), W. F. Baker, T. Collins, J. Lach, L. Leipuner (Brookhaven National Laboratory), J. Peoples, P. Piroué (Princeton University), L. Voyvodic, and R. Yamamoto.

Controls Committee: To recommend broad priorities to be followed in the design, development, construction, and commissioning of control systems throughout the Laboratory. T. Collins (Chairman), R. Daniels (Secretary), W. F. Baker, D. Jovanovic, P. Livdahl, R. Lundy, R. Orr, and J. Peoples.

PREP (Physics Research Equipment Pool): To advise on the acquisition, testing, cataloging, and repair of commercial electronics equipment, such as oscilloscopes, power supplies, and logic circuit for general laboratory use; also to provide standardized and general-purpose experimental equipment. Q. Kerns (Chairman), W. F. Baker, H. Edwards, P. Franzini (Columbia University), F. Hornstra, P. Limon, J. Rosen (Northwestern University), and R. Shafer.

Cafeteria Committee: To monitor the quality and presentation of food at the Laboratory. L. Teng (Chairman), J. Campbell, R. Carrigan, T. Kirk (University of Illinois), and T. Nash.

Colloquium Committee: To plan the programs for the weekly physics colloquia, held Wednesday afternoons at 4 p.m. J. Peoples (Chairman), M. Einhorn, and T. Nash.

Auditorium Committee: To consider policy and programming for the auditorium. A. Roberts (Chairman), D. R. Getz, M. Einhorn, M. Hann, M. Paul, J. Roberts, J. Satti, and I. Walker.

Other committees have been established at NAL to determine criteria for electrical and mechanical standards, to advise on electrical power distribution, to consider traffic safety on site, and to provide for site and property protection, among other things. A complete list of NAL committees is available for study in the Director's Office; all the chairmen welcome suggestions, and will be happy to assist with problems falling within their sphere of influence.

ACCELERATOR PERFORMANCE - JULY 1973

The accelerator facility ran poorly in July. During the first half of the month operations were hampered by problems with component reliability. Following a shutdown period for maintenance and development, an unusually long time was required to get the accelerator operating with relative stability at 300 GeV. Performance during the latter part of the month was much improved; this continued on into August.

The overall accelerator utilization summary for July is as follows:

I. Summary of Accelerator Operations

A. Hours for physics research

Accelerator physics research	79
High energy physics research	249
Subtotal:	328

B. Hours for nonphysics use

Accelerator setup and tuning to experimental areas	72
Programmed interruption	15
Unscheduled interruption	329
Subtotal:	416

C. Unmanned hours 0

Total: 744

II. Summaries of Experimental Use

A. Integrated number of hours in external beams:

For approved experiments	1,177
Other (for beam tuning and studies)	188
Total:	1,365

B. Total hours charged to approved experiments 1,439

C. Total bubble chamber pictures for approved experiments 27,000

D. Total number of experiments to which time or pictures were charged 10

The above tabulations do not include six approved experiments which ran parasitically for a total of 835 hours.

Looking northeast into the ground floor Atrium of the Central Laboratory Building. This view was taken from the third-floor cross-over where the library will be located. (Photograph by T. Fielding, NAL)

MANUSCRIPTS SUBMITTED FOR PUBLICATION
DURING JULY AND AUGUST 1973

Experimental Physics

F. T. Dao et al. NAL-Pub-73/37-EXP	Study of Charged Multiplicity Distributions in High Energy Particle Collisions (Submitted to Phys. Letters)
F. T. Dao and J. Whitmore NAL-Pub-73/47-EXP	Study of Neutral-Charged Particle Correlations in High-Energy Collisions (Submitted to Phys. Letters)
R. A. Carrigan, Jr., et al. NAL-Pub-73/51-EXP (Experiment 76)	Search for Magnetic Monopole Production by 300-GeV Protons (Submitted to Phys. Rev.)
R. A. Carrigan, Jr., et al. NAL-Pub-73/54-EXP (Experiment 36)	Measurement of the Slope of the Diffractive Peak for Elastic p-p Scattering from 8 to 400 GeV (Submitted to Phys. Rev. Letters)
D. Bogert et al. NAL-Pub-73/57-EXP (Experiment 137)	$\pi^- p$ Interactions at 205 GeV/c: Cross Sections and Charged Particle Multiplicity (Submitted to Phys. Rev. Letters)
ANL-Iowa State-Univ. of Maryland-NAL-Michigan State (Experiment 2B)	Inclusive Spectra of Secondaries from 200 GeV/c Proton-Proton Interactions Detected in the NAL 30-In. Bubble Chamber-Wide Gap Spark Chamber Hybrid System (Submitted to the APS Division of Particles and Fields Meeting, Berkeley, Calif., August 13-17, 1973)
W. D. Shephard et al. (Experiment 2B)	Magnetic Field of the 30-In. Hydrogen Bubble Chamber at NAL: Report on Results of Fringe-Field Measurements and Central-Field Measurements (Notre Dame Report 73-9, May 1973)
ANL-Iowa State-Univ. of Maryland-NAL-Michigan State (Experiment 2B)	Track Reconstruction in the NAL 30-In. Bubble Chamber-Wide Gap Spark Chamber Hybrid System (Submitted to the APS Division of Particles and Fields Meeting, Berkeley, Calif., August 13-17, 1973)
ANL-Iowa State-Univ. of Maryland-NAL-Michigan State (Experiment 2B)	The NAL 30-In. Bubble Chamber-Wide Gap Spark Chamber Hybrid System (Submitted to the APS Division of Particles and Fields Meeting, Berkeley, Calif., August 13-17, 1973)

G. Krafczyk et al. (Experiment 21)	An Exploratory Study of High Energy Neutrino Interactions (Submitted to Phys. Rev. Letters)
D. C. Carey et al. (Experiment 63)	Large Transverse Momentum Production of Gamma Rays at NAL (Submitted to the International Conference on New Results from Experiments on High Energy Particle Collisions, Vanderbilt University, Nashville, Tennessee, March 26-28, 1973)
D. C. Carey et al. (Experiment 63)	Production of Large Transverse Momentum Gamma Rays in pp Collisions from 50 to 400 GeV (Submitted to the 2nd Aix-en-Provence International Conference on Elementary Particles, France, Sept. 6-12, 1973)
Rutgers University Upsala College (Experiment 67)	Measurement of N^* Production in $p + p \rightarrow p + N^*$ Between 9 and 300 GeV/c (Submitted to the APS Division of Particles and Fields Meeting, Berkeley, Calif., August 13-17, 1973)
A. Van Ginneken et al. (Experiment 116)	Study of Nuclear Interactions of 200-GeV Protons in Emulsion (Submitted to the V International Conference on High-Energy Physics and Nuclear Structure, Upsala, Sweden, June 18-22, 1973)
P. Slattery (Experiment 138-I)	Proton-Proton Collisions at 102 GeV/c (Submitted to the International Conference on New Results from Experiments on High Energy Particle Collisions, Vanderbilt University, Nashville, Tennessee, March 26-28, 1973)
K. Abe et al. (Experiment 188)	Measurement of $p + p \rightarrow p + X$ Between 50 and 400 GeV (Submitted to the APS Division of Particles and Fields Meeting, Berkeley, Calif., August 13-17, 1973)
D. C. Carey	Future Developments in Charged Particle Beam Optics (Submitted to the 3rd Colloquium on Advanced Computing Methods in Theoretical Physics, Marseilles, France, June 25-29, 1973)

M. Atac et al.	$\lvert g_A/g_V \rvert$ In the Decay $\Sigma^- \to ne^- \bar{\nu}$ (Submitted to the 2nd Aix-en-Provence International Conference on Elementary Particles, France, Sept. 6-12, 1973)
M. Atac et al.	The Design and Operation of the Yale-NAL-BNL Hyperon Beam (Submitted to Nucl. Instr. and Methods)

Theoretical Physics

H. J. Lipkin and E. A. Paschos NAL-Pub-73/29-THY	A New Approach to Relations Between Deep Inelastic Structure Functions (Submitted to Phys. Rev. - Comments and Addenda)
A. I. Sanda NAL-Pub-73/36-THY	A Field Theory Formulation of the Parton Model (Submitted to Phys. Rev.)
S. D. Ellis and M. B. Kislinger NAL-Pub-73/40-THY	Implications of Parton Model Concepts for Large Transverse Momentum Production of Hadrons (Submitted to Phys. Rev.)
C. S. Lam NAL-Pub-73/42-THY	Completely Unitary Multiparticle Models (Submitted to Phys. Rev.)
H. J. Lipkin NAL-Pub-73/43-THY	SU(3) Symmetry in Electron-Positron Annihilation (Submitted to Phys. Rev. Letters)
B. Kayser et al. NAL-Pub-73/44-THY	Tests of Higher Symmetries (Submitted to Phys. Rev.)
D. Horn and M. Moshe NAL-Pub-73/46-THY	Patterns of Diffractive Production (Submitted to Nucl. Phys.)
D. J. Gross and F. Wilczek NAL-Pub-73/49-THY	Asymptotically Free Gauge Theories - I (Submitted to Phys. Rev.)
D. Horn NAL-Pub-73/50-THY	Inclusive Decay Amplitudes (Submitted to Phys. Rev.)