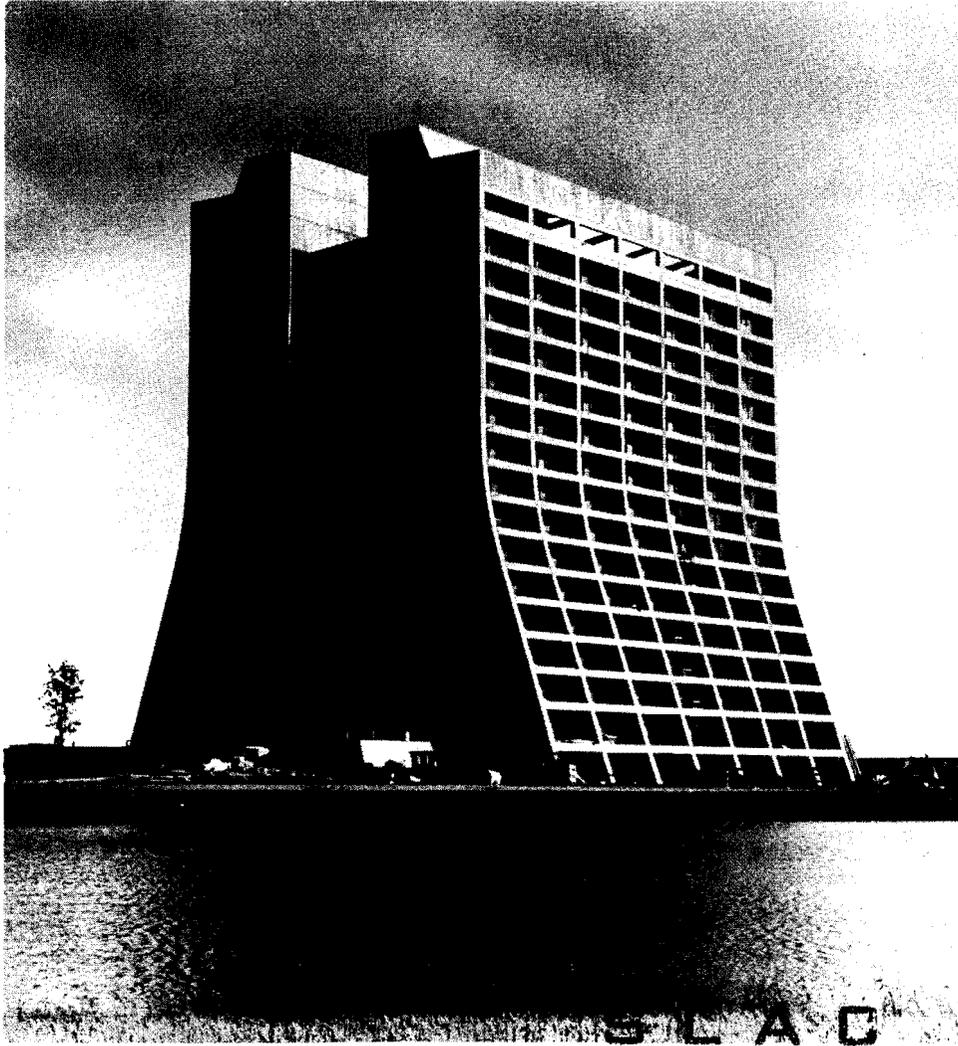


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NALREP

MONTHLY REPORT OF THE NATIONAL ACCELERATOR LABORATORY
NOVEMBER 1973



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THE COVER: View of the Central Laboratory from the Pine Street entrance to the site. Reflecting pond in the foreground is not connected to the industrial water system on site, but provides a haven for migrating birds. (Photograph by T. Fielding, NAL)

THE PRODUCTION OF HIGH TRANSVERSE MOMENTA HADRONS
IN PROTON-NUCLEON COLLISIONS

Reported by H. J. Frisch

A group of experimenters from Princeton University and the Enrico Fermi Institute of the University of Chicago are studying single particles emerging from violent collisions of a high-energy proton with another nucleon (proton or neutron). In particular we are observing secondary particles emerging with large momenta transverse to the beam direction. Such collisions involve a sudden change in the momentum of the incoming proton and, by simple arguments using the uncertainty principle, should come from regions inside the nucleon that are much smaller than the nucleon itself. We are thus using the high energies available at NAL to probe inside the proton and neutron in ways complementary to deep inelastic electron and neutrino scattering.

The experiment, Particle Search #100, is set up in the Proton East Area. The experimental apparatus is shown in Fig. 1: the external proton beam is focused on a target of either tungsten, beryllium, or titanium. The spectrometer, consisting of a quadrupole doublet and two main ring bending magnets, collects particles that emerge from the target at an angle to the beam direction of 77 mrad, corresponding to an angle of 90° in the proton-nucleon center-of-mass system. The secondaries are detected by scintillation counters in the spectrometer line. Data are then recorded and written on magnetic tape by a PDP-9 computer. An 86-ft long gas Cerenkov counter is used to identify the particles as pions, kaons, or protons.

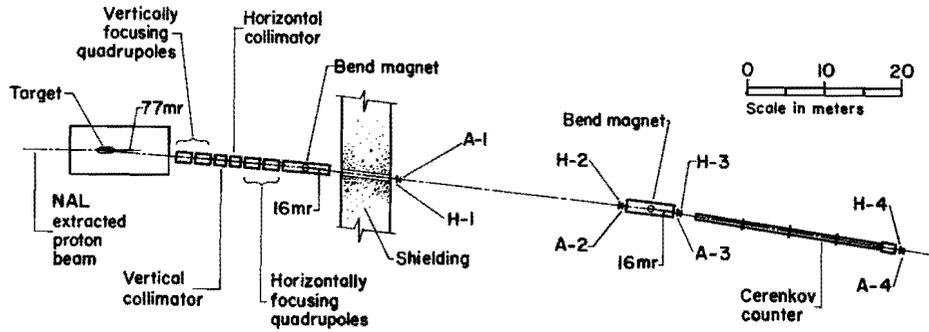


Fig. 1. Diagram of the experimental apparatus for Particle Search #100, set up in NAL's Proton East Area.

We have had two runs during July and August and have taken data at both 200 and 300 GeV. Typical beam intensities on the target were on the order of a few times 10^{11} protons per pulse.

The invariant cross section for the production of positive pions from the tungsten target as a function of the momentum transverse to the beam direction (p_{\perp}) is shown in Fig. 2. The data show an interesting effect: at small p_{\perp} the data at beam energies of 200 and 300 GeV agree well, but at larger p_{\perp} the cross section depends strongly upon energy. One explanation of this effect is that there is a new process governing the cross section in the large p_{\perp} region. It has been suggested, for example, that this process is an interchange of fundamental constituents (e.g., quarks) of the incoming proton and the target nucleon (Blankenbecler, R., Brodsky, S. J., and Gunion, J. F., Phys. Letters 42B, p. 461, 1972).

The measured ratios of protons, antiprotons, and kaons to the pions at 200 GeV are shown in Fig. 3. Again, there are some striking features. The ratios rise steeply with increasing p_{\perp} at small p_{\perp} and then either level out or turn over. In fact, at 200 GeV there are more protons than pions at p_{\perp} above 3 GeV. This observation may also reflect on the quantum numbers and properties of the nucleon constituents.

We feel that these runs at 200 and 300 GeV have been quite successful. Still to be done are measurements at 400 GeV, searches for heavy particles and direct muon production, and measurement of particle production with hydrogen and deuterium targets instead of our nuclear targets.*

*Those engaged in this work include J. Cronin, H. Frisch, and M. Shochet from Chicago and J. Boymond, P. Piroué, and R. Sumner from Princeton.

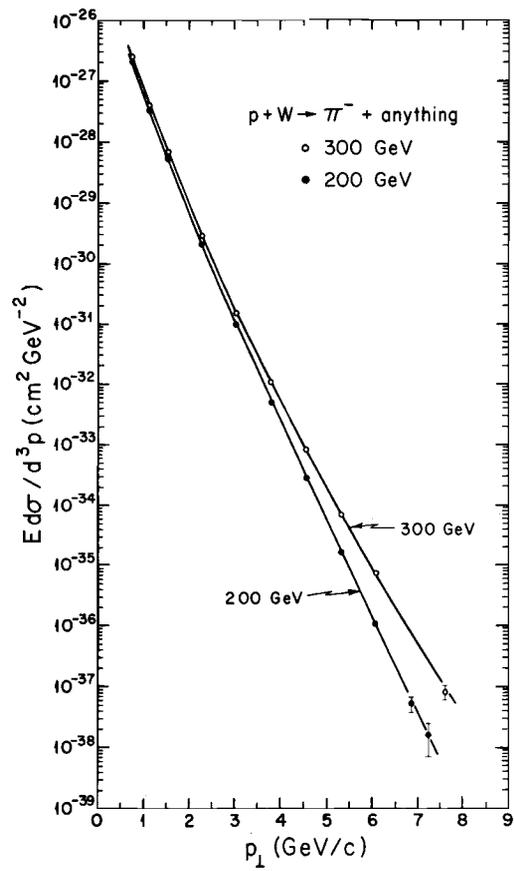


Fig. 2. Transverse momentum distribution of π mesons produced at $\sim 90^\circ$ c.m. in proton-tungsten collisions at incident-proton energies of 200 and 300 GeV.

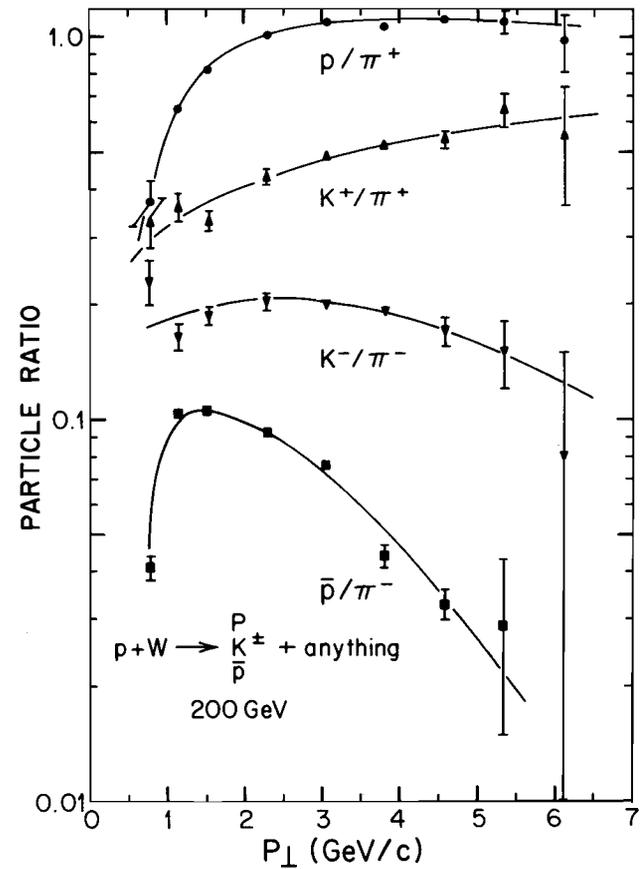


Fig. 3. Measured ratios of protons, antiprotons, and kaons to pions at 200 GeV.

NOTES AND ANNOUNCEMENTS

WORKSHOP ON SPECIAL BEAMS TO THE 15-FT CHAMBER PLANNED . . .

A workshop will be held at the Laboratory in February to explore the possibilities of special beams for the 15-ft bubble chamber. The Program Advisory Committee has urged NAL to consider hadron physics proposals for the large chamber and, in particular, to consider any special hardware requirements presented by such experiments. They have further suggested that duplication of the research capabilities of the 30-in. chamber be avoided. There have been a number of proposals requiring special hadron and neutral beams for use with the 15-ft chamber. These are beyond what can be accommodated by the untagged high energy hadron beam presently available.

The main thrust of the workshop will be to explore the technical possibilities and suggestions for special beams and associated detection equipment. The general capabilities of the 15-ft chamber for research use, including the availability of special liquids, track-sensitive targets, film formats, and the like. Spokesmen for groups having proposals for hadron bombardments in the 15-ft chamber will be invited to say a few words about their physics interests and the use of the chamber. Others interested in submitting proposals for the 15-ft chamber are invited to do so, since it is expected that the Program Advisory Committee will begin to turn attention to this type of physics at their next meeting in March 1974.

The workshop will begin with a summary of the status and characteristics of the 15-ft chamber. This will be followed by a brief discussion of the performance and plans for the present unseparated charged particle beam to

the chamber. The possibilities for new beams, particularly those suitable for the proposed experiments, will then be discussed.

The purpose of the workshop is to define as clearly as possible the general directions in which the bubble chamber hadron program might go, and to delineate what needs to be done to construct the facilities that are needed.

To assist the Laboratory in this task, a panel has been appointed. The panel will meet following the workshop to formulate recommendations for presentation to the Program Advisory Committee at their next meeting.

More information about the workshop may be obtained from the Program Planning Office, Ext. 3244.

DISCONTINUED . . .

The shuttle bus service along Road A from the Central Laboratory to the Neutrino Area is no longer available. It will be reinstated when there is more demand for it.

NEW MANAGER FOR AEC'S BATAVIA AREA OFFICE . . .

Donald L. Bray has been appointed Area Manager for the Batavia Area Office of the U. S. Atomic Energy Commission at Batavia. In this position, he will administer the contract for the operation of the Laboratory. He succeeds F. C. Mattmueller, who now serves as Deputy Manager, Chicago Operations Office.

Bray has been with the AEC since 1960 when he became a General Engineer in the Engineering Division of the Oak Ridge Operations Office. He holds the B. S. and M. S. degrees from Auburn University in Auburn, Alabama.

NEW CAFETERIA OPENS . . .

Ice cream, cake, and coffee were served to celebrate the opening of the Central Laboratory Cafeteria on Thursday, November 1. Located on the first floor near the Atrium, it is a much more pleasant place to eat than the basement, to which employees and visitors have been repairing for sustenance for the last year and a half. By next February that basement area will be converted into a fully equipped kitchen, over which an NAL chef will preside. A coffee lounge will be open on the mezzanine floor as well.

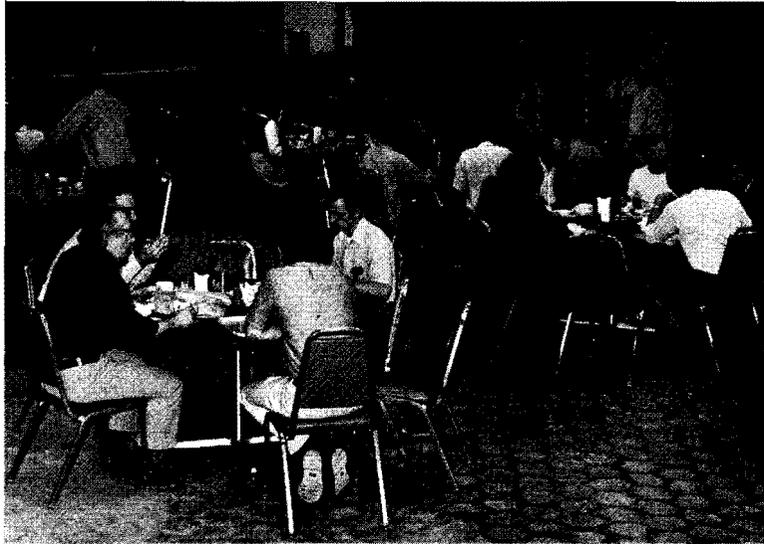
As the focus of the Laboratory gradually shifts to the new building, more services and amenities are being located there. Hours in both cafeterias have been changed. In the Central Laboratory Cafeteria, weekday hours are as follows:

Breakfast	7:30 a. m. to 9:30 a. m.
Lunch	11:30 a. m. to 1:30 p. m.
Dinner	5:00 p. m. to 8:00 p. m.

On weekends, breakfast and lunch are served from 8:00 a. m. to 1:30 p. m. and dinner from 5:00 p. m. to 8:00 p. m.

Service in the Village Cafeteria is limited to lunch, served from 11:30 a. m. to 1:30 p. m. on weekdays only.

For those who get hungry during off-hours, vending machines are located in the Village Cafeteria, on the ground floor of the Central Laboratory, and in the High Bay area of the Cross Gallery.



NAL's new cafeteria, open for limited service in November. Atrium is to the left; serving area is to the right.

FINALLY . . .

The Laboratory has received approval from the AEC to convert a number of the farmhouses in NAL Village--the so-called Sauk Center area--into living quarters for visitors. The initial plans call for the remodeling of five of them; three into two- and three-bedroom apartments with kitchen facilities, and two others into single rooms similar to those in Aspen East. More on-site housing will be provided as the need for it develops.

Generally speaking, visitors should be aware that it is virtually impossible to rent four- and five-bedroom furnished apartments or houses near the Laboratory. If there is a need for such large quarters, they might eventually be provided on site. Anyone interested should contact D. Getz in the Director's Office.

ACCELERATOR UTILIZATION SUMMARY - OCTOBER 1973

Perhaps the most positive achievement during October has been the significant increase in accelerator intensity during regular operation. This was made possible largely because of an improvement in the extraction efficiency, which has been increased from 90% to a standard exceeding 95%. High-intensity operation is now near 5×10^{12} protons per pulse, almost a factor of two better than in September.

Other improvements have come from an increase in the flat-top to 1 sec and, hence, an extension of the time over which a slow spill is available (approximately 0.9 sec). The effective spill is now approximately 0.4 sec (not considering rf structure) due to regular 12-pulse injection into the Main Ring and better methods for regulating the extraction power supply.

Accelerator operation was interrupted during the last week of the month for a maintenance and development period. The return to operations was on schedule.

Some highlights of the physics research in each experimental area are described below.

Internal Target Area: Data taking for Photon Search # 63A on single photon production at various angles continued, while three other experimental groups prepared for later running.

Meson Area: Data taking on neutron total cross sections for Neutron Cross Section # 4 was interrupted to provide time for Neutron Dissociation # 27A. Five other experimental groups are testing and making preparations for data taking.

Neutrino Area: A test run was completed for Muon #98, and a considerable amount of data at 150 GeV were collected by Muon #26. Fluxes have been as high as 250,000 muons per pulse, with the accelerator intensity directed primarily at the neutrino/muon target. Emulsion stacks were exposed to muons and protons for ten experiments, and there were several days of tests of the hadron beam to the 15-ft bubble chamber, as well as tests of the chamber itself. The neutrino horn was installed during the maintenance and development period, following which the system was tested and anti-neutrino data for Neutrino #1A were collected. An electrostatic septum for the splitting station failed during early tests, thus reducing flexibility in providing a beam to the bubble chambers. However, picture taking has been resumed using diffracted protons at 300 GeV.

Proton Area: Additional data were accumulated by Lepton #70 on electron production at 50 mrad by protons. Beam was successfully transported to the Proton West Area for the first time.

The summary of accelerator utilization for October follows:

I. Summary of Accelerator Operations

A. Accelerator hours for physics research

Accelerator physics research	43
High energy physics research	<u>276</u>

Subtotal: 319

B. Nonphysics hours

Accelerator setup and tuning to experimental areas	85
Scheduled interruption	81
Unscheduled interruption	<u>260</u>

Subtotal: 426

C. Unmanned hours

0

Total: 745*

II. Summaries of Experimental Use

A. Integrated number of hours in external beams:

For approved experiments	1385
Other (for beam tuning and studies)	<u>368</u>

Total 1753

B. Total hours charged to approved experiments** 1658

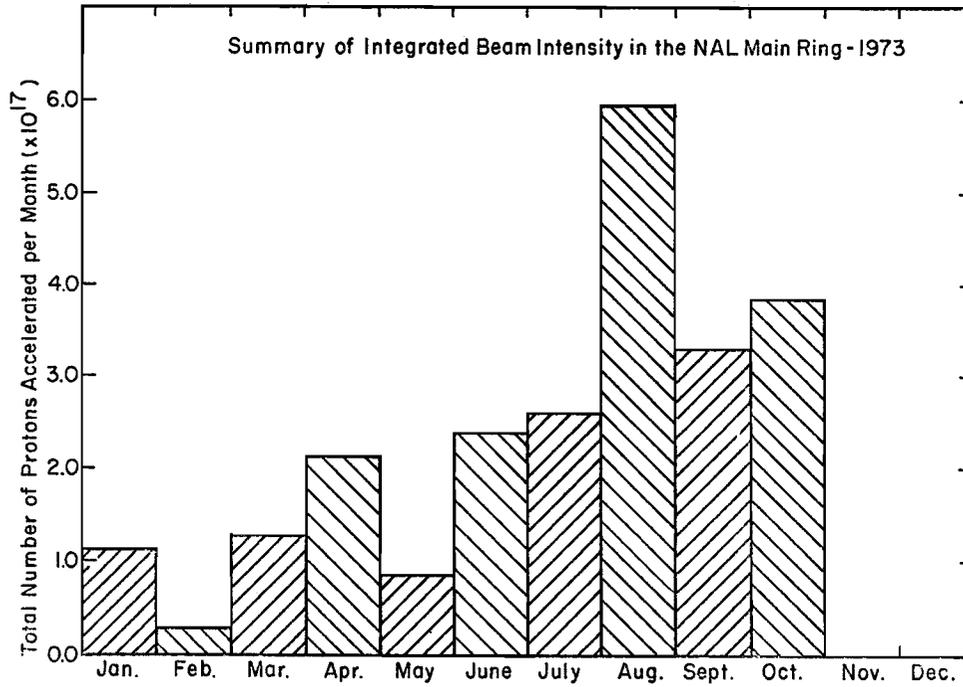
C. Total bubble chamber pictures for approved experiments 0

D. Total number of experiments to which time, pictures,
or emulsion exposures were charged 27

* Change to Central Standard Time.

** In addition, we exposed 3 emulsion stacks in the muon beam at 150 GeV for 2 experiments and 25 emulsion stacks in a proton beam at 300 GeV for 8 experiments.

These tabulations do not include 106 hours of parasitic time run for the above approved experiments, nor do they include 3 additional experiments which ran parasitically for a total of 373 hours.



A steady improvement in beam intensity is evident from this histogram of the total number of protons accelerated in the Main Ring for each month during 1973. Features which are not indicated on the graph are periods for maintenance and development, and the accelerator operating energy. The peak during August was due to a long period of high-intensity operation, but the data were influenced by the lack of a maintenance and development period and the shorter cycle time during some 200-GeV operation.

PROPOSALS RECEIVED DURING SEPTEMBER AND OCTOBER 1973

<u>Exp. No.</u>	<u>Title</u>	<u>Submitted By</u>
241	Energy Dependence of Backward π^-p Elastic Scattering	R. M. Heinz
242	Study of Secondary Particles Produced by 300-GeV Protons in Emulsion Chambers	K. Niu
243	Study of Secondary Particles Produced by 400-GeV Protons in Emulsion Chambers	K. Niu
244	Interaction of 300-GeV Protons in Nuclear Emulsion	P. L. Jain
245	Interaction of 400-GeV Protons in Nuclear Emulsion	P. L. Jain
246	Search for Difference in Pion/Proton Internal Structure	W. Selove
247	A Proposed Experiment to Search for Heavy Leptons	E. H. S. Burhop
248	Neutron-Proton Diffraction Scattering up to 300 GeV (formerly # 4-II)	M. J. Longo
249	Cracow Emulsion Exposre to 400-GeV Protons	J. Gierula
250	Phenomenological Study of Proton-Nucleus Collision at NAL Energies in Emulsion (300 GeV)	O. Kusumoto
251	Phenomenological Study of Proton-Nucleus Collision at NAL Energies in Emulsion (400 GeV)	O. Kusumoto
252	Study of Multiparticle Production in a 30-In. Bubble Chamber (formerly # 138-I)	T. Ferbel
253	Neutrino-Electron Scattering at NAL	L. W. Mo
254	Proposal to Search for a Second Muon Neutrino	G. Kalbfleisch
255	Exposure of Nuclear Emulsions to a Beam of 150-GeV Muons at the National Accelerator Laboratory	P. L. Jain

256	2nd Generation Electronic Neutrino Detector at NAL	L. Osborne
257	Proposal for the Investigation of Virtual Photoabsorption by Nuclear Matter	L. Mo
258	A Proposal to Measure Particles Produced at High Transverse Momentum by Pions	P. A. Piroue
259	Backward Pion-Nucleon Scattering	R. Heinz/M. David
260	A Proposal to Study High P_T Physics with a Multiparticle Spectrometer	J. Pine
261	Proposal to Test Transition Counters at NAL	C. L. Wang
262	Neutral Current Investigation at NAL	B. C. Barish
263	A Proposal to Study Photoproduction of ϕ Mesons	S. C. C. Ting
264	Exposure of Emulsions to 200-300 GeV π_0^- for New Determination of Mean Life of π_0^-	P. S. Young
265	Exposure of Emulsions to 400-GeV Protons for New Determination of Mean Life of π_0^0	P. S. Young
266	Inclusive Angle and Multiplicity Distributions of Charged Secondaries and of Neutral Pions Produced by Nucleons on Nuclei	L. W. Jones
267	Proposal to Study 100 GeV/c Negative Particle Interactions in the NAL 15-Ft Bubble Chamber	D. R. O. Morrison
268	A Proposal to Study High p_{\perp} Region with a γ -Ray Detector	J. Mellema