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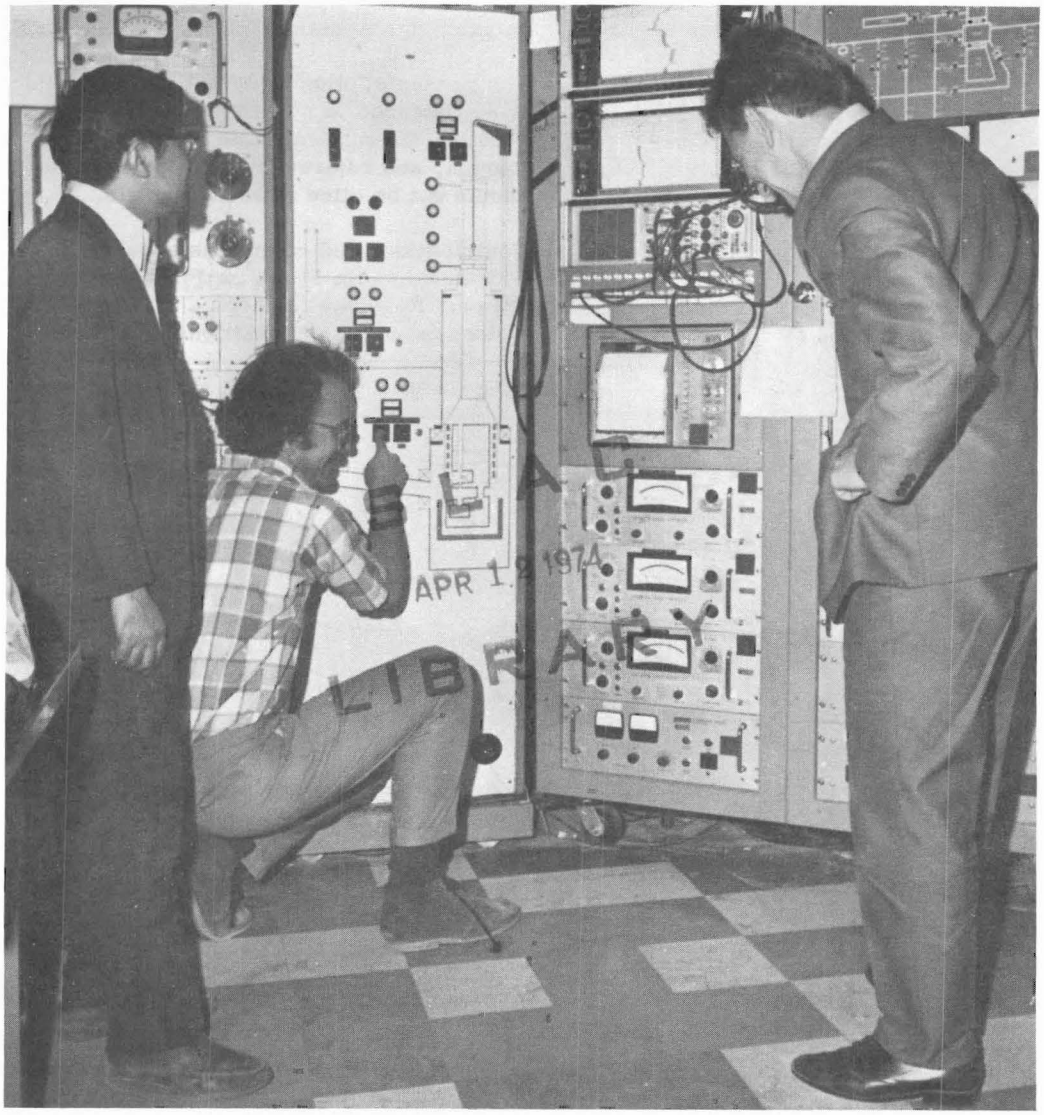

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THE COVER: Working at the controls of the hydrogen jet target in the Internal Target Area service building are three members of the initial proton-proton scattering experiment, (L to R) R. Yamada, S. Olsen, and Y. Pilipenko.

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THE INTERNAL TARGET AREA

". . . The machine should be designed as a device separate from the experimental areas . . . a concept of internal targeting is a bad philosophy . . ." This statement is attributable to G. Cocconi (Round-Table Discussion, UCRL Report No. 16830, 1966), and was fully supported by D. D. Jovanovic according to that same report. What, then, is the reason for such an about-face on the part of one of Cocconi's "followers"? This article is intended as an explanation of such a change of heart. At the same time, it describes the NAL Internal Target Area, located in the C-0 straight section of the main ring.

Heretofore, by "internal target" one has meant a substantial piece of matter placed inside the accelerator beam vacuum pipe which, when struck by the circulating beam, serves as a source of proton interactions. Even under the most restrained experimental use (an unlikely situation), allowing, for example, no more than 10% of accelerated beam to be dissipated on such a target, the surrounding area of the accelerator tunnel, magnets, and vacuum chamber would become so radioactive as to prevent access to the tunnel or work on nearby components. At NAL the effort to reduce extraction losses (currently about 3%) would be ludicrously foiled by dumping 10% of the beam at some other place. It is clear that such operation of the accelerator would indeed follow "a bad philosophy."

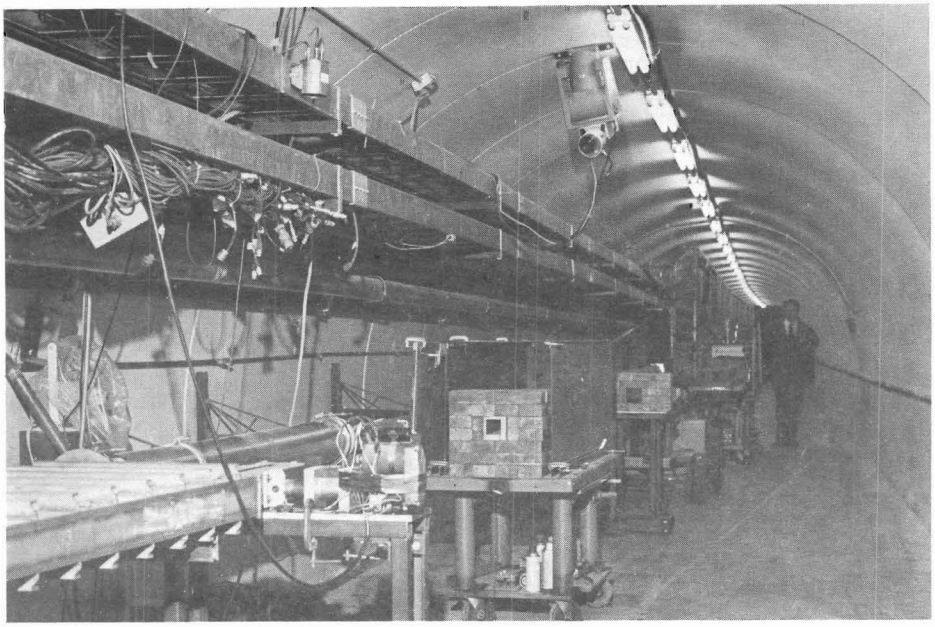
What, then, is the NAL Internal Target Area, and what makes it tolerable, and perhaps, even unique, in comparison with the "good philosophy" external experimental areas?

To begin with, the Internal Target Area at NAL is not a source of secondary beams, but rather a direct proton-proton interaction chamber much like a colliding beam intersection region. At present beam intensities of 5×10^{12} protons per pulse, the fraction of the beam lost is of the order of 10^9 to 10^{10} protons per pulse. At this level, the 55-m long C-0 straight section is relatively "cool," having residual radioactivity levels of 1 to 5 mrem per hour. The low losses and resulting small radioactivity result from the use of special and unique targets.

The C-0 area had its origins in the technique of using hydrogen gas in the form of a supersonic jet which is squirted through the circulating proton beam during its acceleration. This technique was first demonstrably employed by a USSR group working at the 70-GeV accelerator at the Institute for High Energy Research at Serpukhov, USSR. Later, this group formed a collaboration with a U.S. group (Rochester, Rockefeller, NAL), and essentially founded the C-0 area. During the waiting period, while the target was assembled and tested outside the accelerator tunnel, the Rochester group (out of frustration, perhaps) developed a thin-foil rotating target. The rotating target has evolved into a wheel on which 2- to 5-μ thick graphite or polystyrene fibers are mounted.

Before describing in detail the technique and apparatus which make these targets operate, let me enumerate salient features of the Internal Target Area which, from the viewpoint of a high energy physicist, make it particularly attractive.

1. Thin targets (or a jet stream of gas) can be unobtrusively placed in the circulating beam from the moment of injection, thus making the



The Internal Target Area, located at the C-0 straight section of the main-ring tunnel. Beam travels from left to right through the pipe, visible in center of photograph. A series of lead collimators and a gamma detector (far right) for Photon Search # 63 are shown.

whole spectrum of energies from 8 to 400 GeV accessible. With the same apparatus one may study phenomena taking place in proton-proton interactions over an energy span of nearly two orders of magnitude.

2. The interaction region is nearly a point source. The beam, which has a cross section of 2 to 5 mm, interacts with the gas jet of 12-mm extension. The interaction region is even smaller if the rotating target is used.

3. The target densities are so small that the particles recoiling from the interaction with an energy of a few tens of KeV can be detected without

interacting or scattering in the mass of a solid or liquid target. One can extend the good vacuum up to the thin window of a wire-chamber detector, thus substantially reducing multiple scattering limitations to momentum resolution.

4. Momentum resolution of the incident beam, in this case the circulating accelerated beam, is 10^{-4} or better.

5. With gas jet densities of $p \approx 10^{-7}$ g/cm^3 (which can be easily achieved at the 1 atm input hydrogen pressure), the 50,000 per sec multiple traversals of a circulating beam of 10^{12} protons yield 10^8 interactions per sec. This is equivalent to 10^9 protons incident on a 2-ft long hydrogen target in an external beam line.

6. The vicinity of the interaction region is much more free of beam halo than are the external proton beams. Experimentally, the actual "room background" in the main-ring tunnel has been found to be about 10^6 counts per sec in a 100-cm^2 counter placed 1 m away from the vacuum pipe.

The gas jet target was designed to produce a burst of dense hydrogen gas into the circulating beam once or twice each accelerator cycle. The principle on which it operates is simple: at a given time, valve V1 opens and lets through a measured volume of hydrogen (about 50 cm^3) under pressure of 15 to 60 psi, confined initially between the valves V1 and V2. Without being absorbed on a cup surface, this jet pulse would raise the pressure of the whole accelerator volume (50 m^3) to the intolerable level of 2×10^{-3} Torr (mm Hg). By employing cryopumping and precooling the hydrogen, most of the hydrogen in the pulse freezes in the cup enclosure.

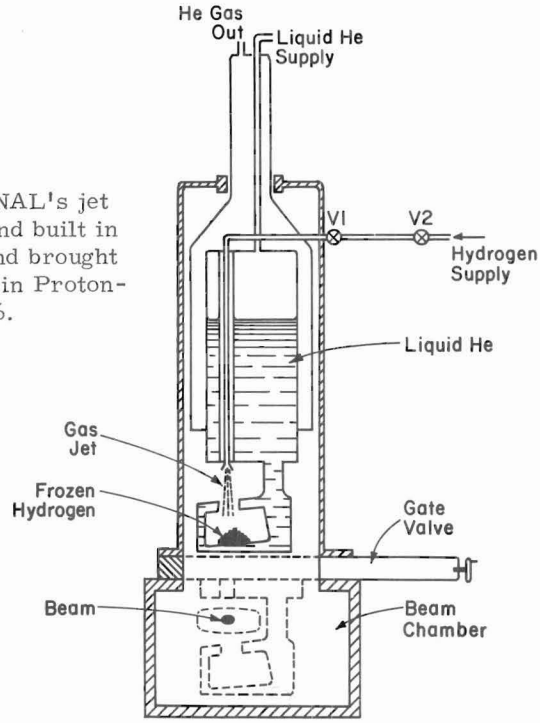


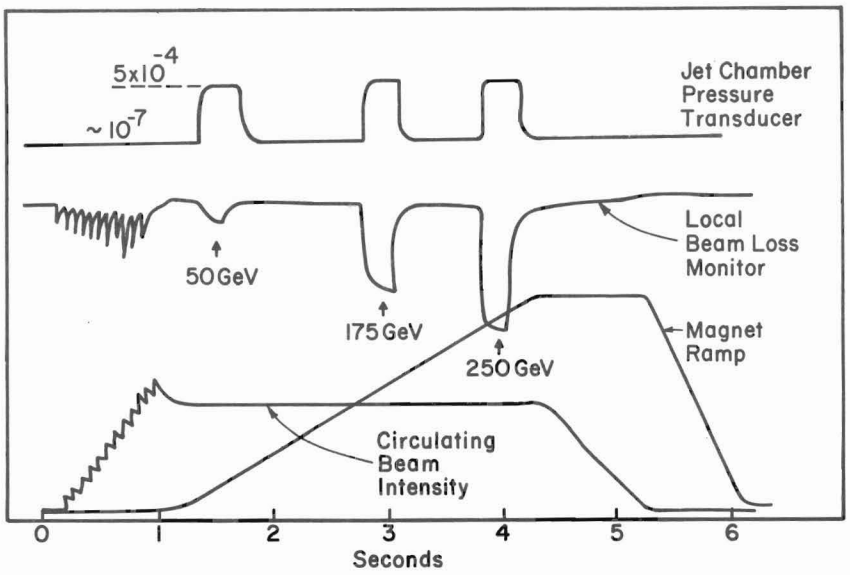
Diagram of NAL's jet target, designed and built in the Soviet Union and brought to Batavia for use in Proton-Proton Elastic # 36.

Additional diffusion and ion pumps restore the vacuum of the accelerator in this section to $\sim 10^{-6}$ to 10^{-7} Torr between cycles.

After 4 to 6 hours of operation the cup is filled with solid hydrogen, and the accelerated beam is interrupted for a few pulses to withdraw the whole target assembly into an upper chamber. After closing the isolation valve, the cup is heated, allowing the hydrogen to sublimate. This procedure lasts from 30 to 60 min, after which the target is ready for use again. Although

the duration of the jet pulse can be up to 3 sec, the more normal use is two to three pulses, each of 100-msec duration, during an accelerator cycle. Under such conditions, the liquid helium consumption for cryopumping the cup is 30 liters per hr. This rate of helium consumption can barely be maintained, since the liquification rate of the local helium refrigerator is ≈ 30 liters per hr.

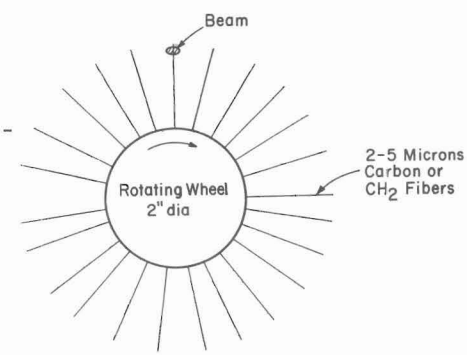
The whole operation is relatively trouble-free, thanks to very skillful operating crews. In the past year and a half the jet has accumulated more than 2000 hr of operating time. When deuterium gas is used in the jet target the closed-loop gas is used so that no deuterium is wasted.



Typical hydrogen jet target operation during one acceleration cycle (6-sec duration).

The thin rotating fiber targets are essentially wheels 5-cm in diameter, with some 60 to 100 fibers protruding 2 cm from the rim. The wheel is driven by the motor, operating in vacuum at 3600 rpm, moving the fibers through the beam at the rate of 2 cm per msec. In such a fashion, one obtains a duty factor of about 50%, i.e., a fiber intersects the beam approximately 50% of the time. The interaction rate of the proton on the fibers is 10 to 50 times larger than it is on the jet pulse, i.e., 10^9 to 5×10^9 interactions per sec. A combination of carbon and polyethylene (CH_2) targets can be used allowing for simulated hydrogen data by CH_2 - C subtraction. The depletion of hydrogen from polyethylene fibers is substantial: typically CH_2 fibers are burned up in about 48 hr. However, by popping the target out of the beam for part of the acceleration cycle, and by more gentle immersion into the beam, one can both control the beam intensity and the lifetime of the fibers.

At present, in addition to the jet target, there are three rotating target mechanisms installed in the Internal Target Area. There is, however, considerable interference between experiments taking data simultaneously--the background of upstream targets interferes with the detectors of downstream users. Although in practice only one experimental group uses one target at a time, by judicious gating



The rotating fiber target.

and adjustments of popping and jet squirting times, three groups were operating simultaneously for a period in December 1973.

This article would be incomplete without some mention of several serious limitations and drawbacks in the utilization of the Internal Target Area.

1. Absolute monitoring of the interaction rate or luminosity is difficult. One method used so far has been to monitor the elastic cross section at very low recoil momentum by a pair of solid-state detectors and then, via the optical theorem and measured total cross sections, calculate the absolute luminosity. Another method, still being studied, is to monitor the light output from the ionized hydrogen in the jet. Presumably, the only correction then would be the relativistic rise in the energy loss, which is calculable. We hope that the absolute monitoring problem will be solved as experience accumulates.

2. The maximum allowable interaction rate should not exceed 10^{10} interactions per pulse. This implies that infrequent processes having cross sections lower than nanobarns ($\sim 10^{-33}$ cm^2) are barely accessible, since they will result in counting rates of few events per hour.

3. Access times to experimental equipment inside the main-ring tunnel is very limited, because the entire accelerator must be turned off. Premiums are to be awarded for reliable equipment which can be remotely controlled. The set-up times for new experimental apparatus are short and far apart, of the order of one week every several months.

4. Minimum interference with accelerator operations is mandatory. The use of magnets having fringe fields of more than 1 G at the beam pipe is essentially proscribed, and interference with the nominal beam pipe of 5 × 10 cm is ruled out.

5. Finally, the space limitation in the C-0 straight section is severe. Tunnel width is only 12 ft, and clearance must be allowed for passage of service carts and the magnet-moving vehicle. Any experimenter wanting to occupy the tunnel "freeway" is strongly discouraged from doing so, and must be prepared to move his apparatus out of the way on 30-min notice, day or night.

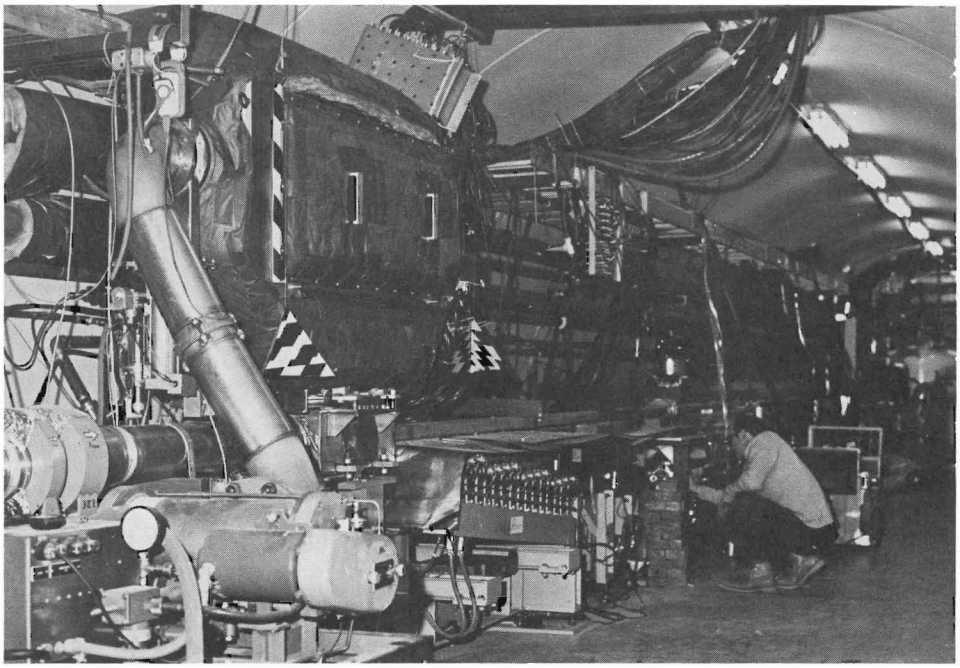
Some of these limitations may be alleviated by the enlargement of the area which has been suggested. This enlargement, very limited in purpose, would be a room attached to the main-ring enclosure by a 6- × 6-ft opening in the outside tunnel wall. Such a room--actually a pit--might house a modest recoil-arm spectrometer with limited momentum analyzing capability up to 10 GeV/c. This addition, predicated upon many other factors in addition to the obvious cost limitations, can only be contemplated if its construction does not impede accelerator operation for any longer than normal shutdown periods.

This article would be incomplete without the mention of both the experimenters and the crew who operate the Internal Target Area. Primary credit goes to E. Malamud, who initiated the area and collaborated with the Soviet group in Proton-Proton Elastic #36 (see page 13). The physicists from Dubna who nursed the hydrogen jet through its teething period were Y. Pilipenko, V. Bartenev, and B. Morosov. Equal credit goes to the Internal Target

operating crew, under the leadership of J. Klen, who showed that a limited access area was viable operationally, and who fathomed the intricate technique of operating the jet.

At the time of this writing there were four experimental teams doing experiments in the Internal Target Area.

Proton-Proton Inelastic #221, for which solid-state detectors are used to study $p + p \rightarrow p + x$ at small momentum transfers. The group have mastered a way of using CH_2 rotating targets for this investigation. Equally



Experimental apparatus for Proton-Proton Inelastic #221 and Particle Search #184 in the tunnel. Solid-state detectors for #221 are in box in upper foreground. The single-arm spectrometer for #184, not visible in photograph, is just below the beam pipe.

clever is their ability to handle enormous data rates and preprocess the events before going to the magnetic tape. They hope to accumulate a billion potential events on their data tapes.

Photon Search # 63, the study of $p + p \rightarrow \gamma$ + anything. The use of a lead-glass detector inside the tunnel with a modest amount of shielding is the accomplishment of this group. Rather forward angles down to 30 to 40 mrad are being explored. This group uses both rotating carbon filaments and the hydrogen jet as a target (see September 1973 NALREP for details).

Particle Search # 184, a search for muons or other penetrating particles at large transverse momenta. This group uses a modest, but very compact single-arm spectrometer (6-m length) with proportional chambers. They have successfully managed to shield their stray magnet field to negligible values in the vicinity of the accelerator vacuum pipe. They use a filament-rotating target as their source under investigation.

Proton-Deuteron # 186, the study of p + d elastic scattering. This group, another Soviet-American collaboration, is continuing in the tradition of the already successful p + p elastic scattering experiment (# 36) already completed.

Physicists from all of these groups, as well as those from past and future experimental groups, provide constant stimulation and input toward solving the problems of better targets, more efficient monitoring, and the developing of other technologies for use in this small, but viable experimental area.

I would like to add one, perhaps subjective comment. The limitation in space in the Internal Target Area calls for small, ingeneous, and clever

solutions. The size of the experiments so limited may bring about the onset of small, "table-top" or cyclotron-type experiments. This will allow small groups with a lot of perserverance, patience, and ingenuity to mount useful experiments at the energies available at the NAL accelerator.

Reported by D. Jovanovic

SMALL ANGLE PROTON-PROTON SCATTERING

The traditional technique for measuring the scattering of elementary particles dates back to the original approach of Lord Rutherford and is based on the detection of the angle of deflection of the incident particle. In the late 1960's, Nikitin and his collaborators from the Joint Institute for Nuclear Research in Dubna, USSR, demonstrated that for scattering at very small momentum transfer it is advantageous to measure the recoil particle instead. Indeed, the kinetic energy, T_r, of the recoil of mass, m_r, is a direct measure of the four-momentum transfer $q^2 = 2m_r T_r$. The recoil angle depends very weakly on the incident energy

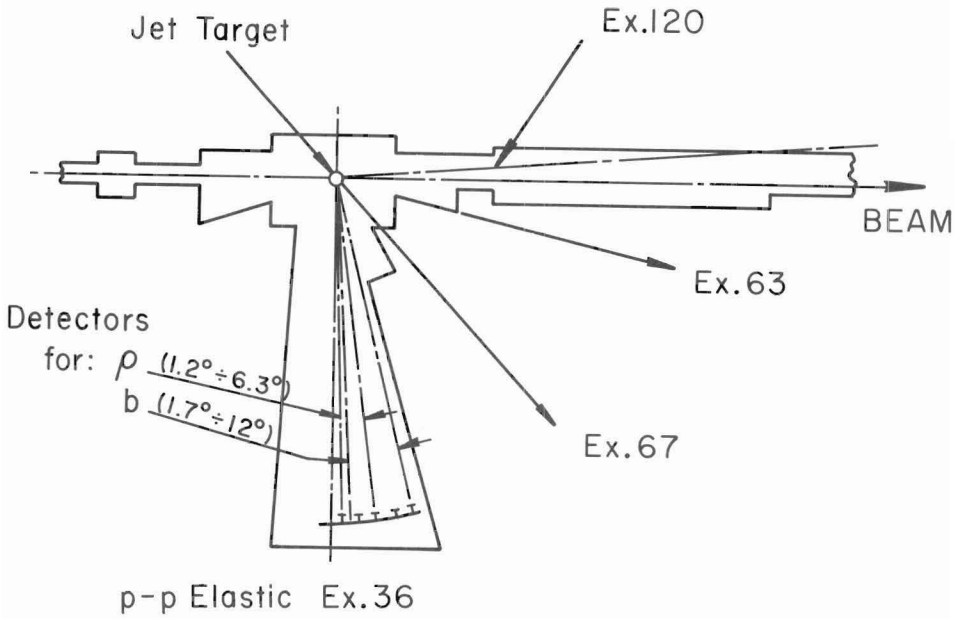
$$\sin^2 \phi = \frac{|t|}{4m_r^2 + |t|} \frac{(E+m_r)^2}{E^2 - m_p^2},$$

where ϕ is the angle measured from 90°.

In an experiment at Serpukhov, the Dubna group used solid state detectors to measure the energy and angle of the recoils from a supersonic jet of hydrogen, which served as the target. The jet is placed in the path of the circulating beam; because (2×10^{-7} g/cm^3), recoils with energies as low as 0.2 MeV can be detected. The use of the high intensity internal beam and the multiple transversals through the target compensate for the very small density of the target. Furthermore, since the energy of the beam varies during the acceleration period, it is possible to study the scattering as a continuous function of the energy.

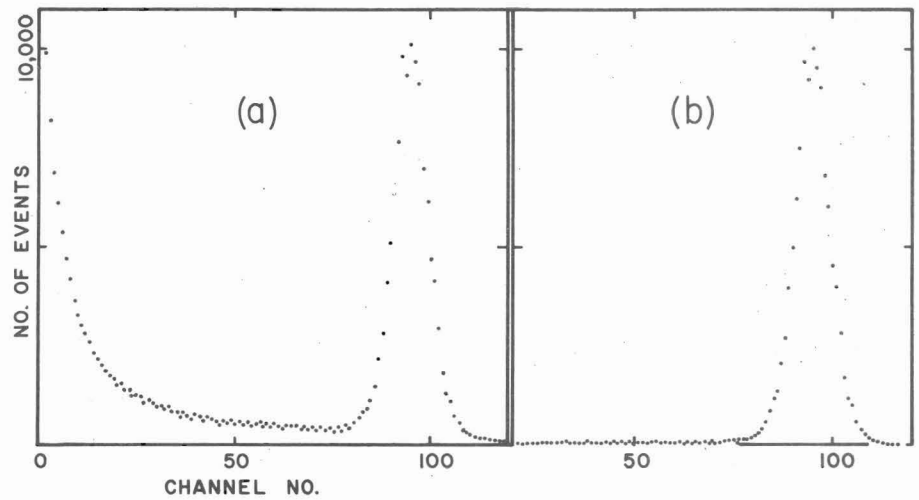
Proton-Proton Elastic #36, a measurement of small-angle scattering using this technique, was performed at NAL by a joint team of Soviet and American physicists. The members of the group were V. Bartenev, A. Kuznetsov, B. Morosov, V. Nikitin, Y. Pilipenko, V. Popov, and L. Zolin from The State Committee for Utilization of Atomic Energy of the USSR in Moscow; R. Carrigan, Jr., E. Malamud, and R. Yamada of NAL; R. Cool and K. Goulianos of The Rockefeller University in New York, N. Y., and I.-H. Chiang, A. Melissinos, D. Gross, and S. Olsen of the University of Rochester in Rochester, N. Y. The experiment was one of the first to be done at NAL; using a polyethylene foil target, data were obtained in March 1972, soon after protons were accelerated to 200 GeV in the main ring. This experiment was also an example of Soviet American collaboration in high-energy physics research, which is continuing with several new experiments. Not only was this collaboration essential to the success of the experiment, but also it provided the opportunity for close friendships and wide ranging exchanges of ideas among all participants.

The jet target was designed and constructed in the Soviet Union and installed in the C-0 straight section of the Main Accelerator during the summer of 1972. It is now operated with hydrogen or deuterium gas as part of the Internal Target Area. The rotating foil targets were designed and built by T. Haelan of Rochester. The detection apparatus consisted of a set of eight solid-state detectors, approximately 100 mm^2 in area, placed 2.5 m from the interaction region. The apparatus was in vacuum, as shown in the diagram on the following page.



Schematic layout of the apparatus in the C-0 straight section of the NAL main ring during the running of Proton-Proton Elastic #36. Other experimental groups using the gas jet target are indicated.

A typical pulse-height (i.e., recoil energy) spectrum is shown on page 16. The width of the elastic peak is due to the finite angular resolution of the system, which is due to the ±5-mm width of the jet. The elastic counts of the detectors yield the differential cross section $d\sigma/dt$. A typical cross section in the range $0.01 < t < 0.16$ is shown on page 18 (left). It provides information on the slope of the diffraction peak. If one wishes to examine the region in which the electromagnetic (Coulomb) and nuclear amplitudes interfere, the detectors are placed closer to 90° and a cross section such as that shown on page 18 (right) is obtained. Since the phase of the Coulomb amplitude is known--being essentially real except for a small, calculable phase shift--it is possible to determine from these data the phase of the



Typical pulse-height spectrum from a 2-mm thick solid-state detector at 50-GeV incident energy; the proton energy is approximately 10 MeV. (a) Original spectrum. (b) Spectrum after correction for "room" background.

nuclear amplitude. Furthermore, since the Coulomb cross section is known in absolute magnitude, one can attempt to normalize the data and obtain the total cross section through the optical theorem:

$$\sigma_T(s) = \sqrt{\frac{d\sigma}{dt}(s, t=0)}\ \frac{4\sqrt{\pi}}{(1+\rho^2/2)}.$$

The great advantage of this experimental technique lies in the ability to measure the small-angle cross section as a function of energy, since most of the biases and systematic effects are independent of the energy. The diffractive scattering of protons can be represented by $d\sigma/dt = Ae^{-b/t/}$, and the slope of the diffraction peak (b) as a function of $\ln s$ is shown in the upper diagram on page 20. The energy dependence of b can be parametrized as $b = b_o + 2\alpha' \ln(s/s_o)$ which is the prediction of Regge theory for a simple Pomeron trajectory of slope α', and fits the data for $s > 100\ (\mathrm{GeV})^2$. One finds that:

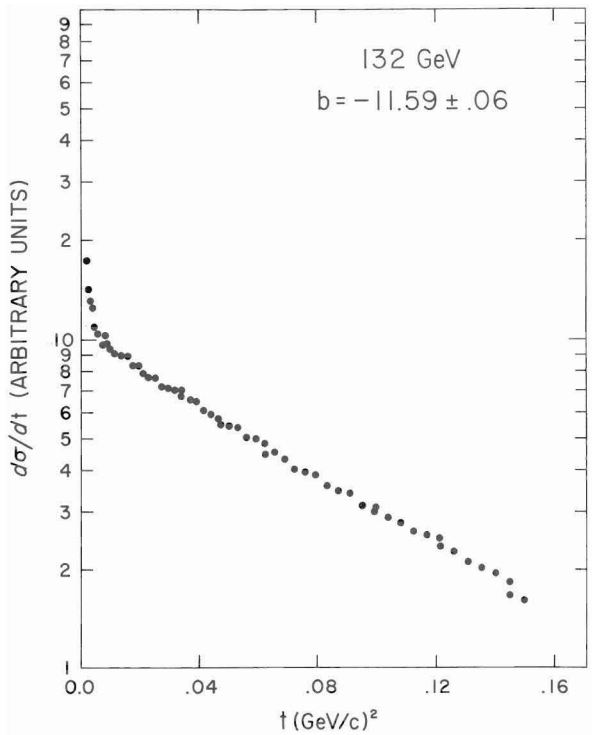
$$b_o = 8.23 \pm 0.27 \text{ and } \alpha' = 0.28 \pm 0.03\ (\mathrm{GeV}/c)^{-2}$$

with s_o equal to $1\ (\mathrm{GeV})^2$. On the other hand, it is possible to fit the data equally well, and over a wider range of values of s with several other more complex models.

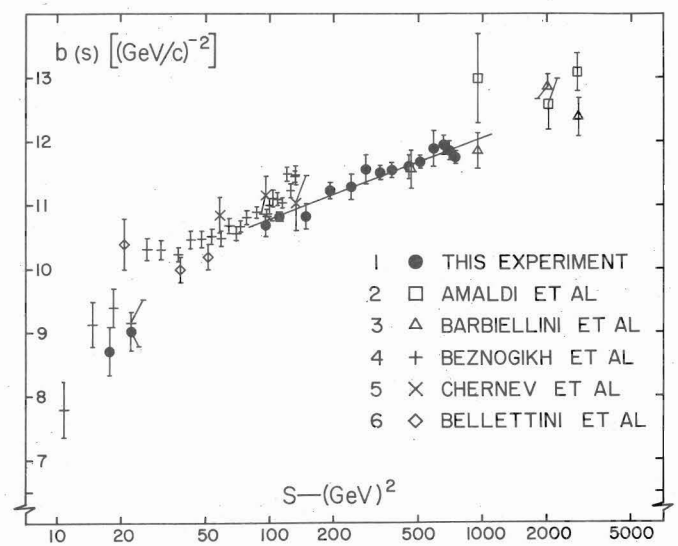
A simple interpretation of b comes from an optical (diffraction) model in which an interaction radius (R) yields a differential cross section:

$$d\sigma/dt = Ae^{-\frac{R^2}{3}|t|}.$$

Thus, our results indicate that the interaction radius increases with energy. Furthermore, in the optical model, the opacity of the proton can be obtained



The differential cross section $d\sigma/dt$ in arbitrary units in the interval $0.005 < t < 0.15$ for p-p elastic scattering at an incident energy of 132 GeV.



The slope of the diffraction peak, $b(s)$ for $|t| \leq 0.12\ (\mathrm{GeV}/c)^2$, as a function of the square of the c.m. energy. The solid line is a fit of $b(s) = b_0 + 2\alpha' \ln(s/s_0)$ only to our data points for $s \gtrsim 100\ \mathrm{GeV}^2$.

from the ratio of the elastic cross section to the total cross section. For a black sphere this ratio is 0.5, while experimentally it is observed that $\sigma_{el}/\sigma_T \simeq 0.175$. Since the nuclear amplitude is almost purely imaginary, it holds that:

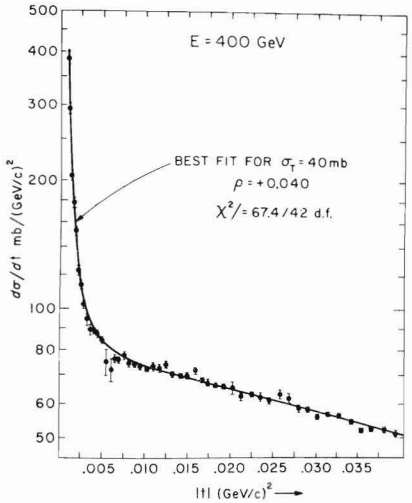
$$\sigma_{el} = \int_{t=0}^{\infty} Ae^{-bt}\, dt = \frac{\sigma_T^2}{16\pi}\,\frac{1}{b}$$

leading to:

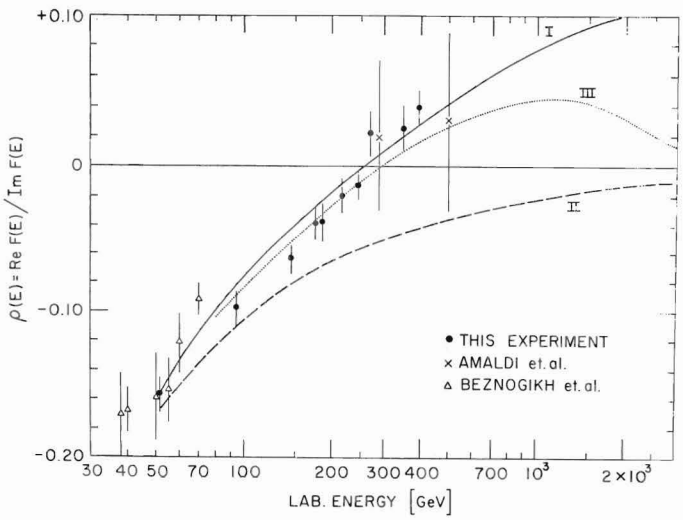
$$\sigma_{el}/\sigma_T = \frac{1}{16\pi}\,\frac{\sigma_T}{b}\,.$$

Such relations are examples of the interrelation between σ_T and b which result in various bounds which can be proven rigorously from local field theory. Thus far, none of these bounds is violated by the data.

The ratio ρ of the real part to the imaginary part of the nuclear amplitude is plotted as a function of the energy in the lower diagram on page 20. Given analyticity, causality, and the validity of the Pomeranchuk theorem, it is possible to obtain the ratio from a knowledge of the pp and $\bar{p}p$ total cross sections through a dispersion relation. If, on the other hand, $\sigma_T(pp)$ rises as $(\ln s)^2$, then ρ must cross the $\rho = 0$ axis and tend to zero from above as shown by curve I. Curve III is calculated on the assumption that σ_T rises as $(\ln s)^2$ up to E = 2000 GeV and then remains constant at a value of $\sigma_T = 44.2$ mb. While the data are not sufficiently accurate to distinguish between the assumptions used for curves II and III, they clearly rule out a constant total cross section. Conversely, if the ISR data on rising total cross sections are



The measured differential cross section $d\sigma/dt$ for p-p small-angle scattering at 400 GeV. The solid curve is the best fit to the data which are normalized on the basis of the optical point assuming a total cross section $\sigma_T(pp)$ = 40.0 mb.

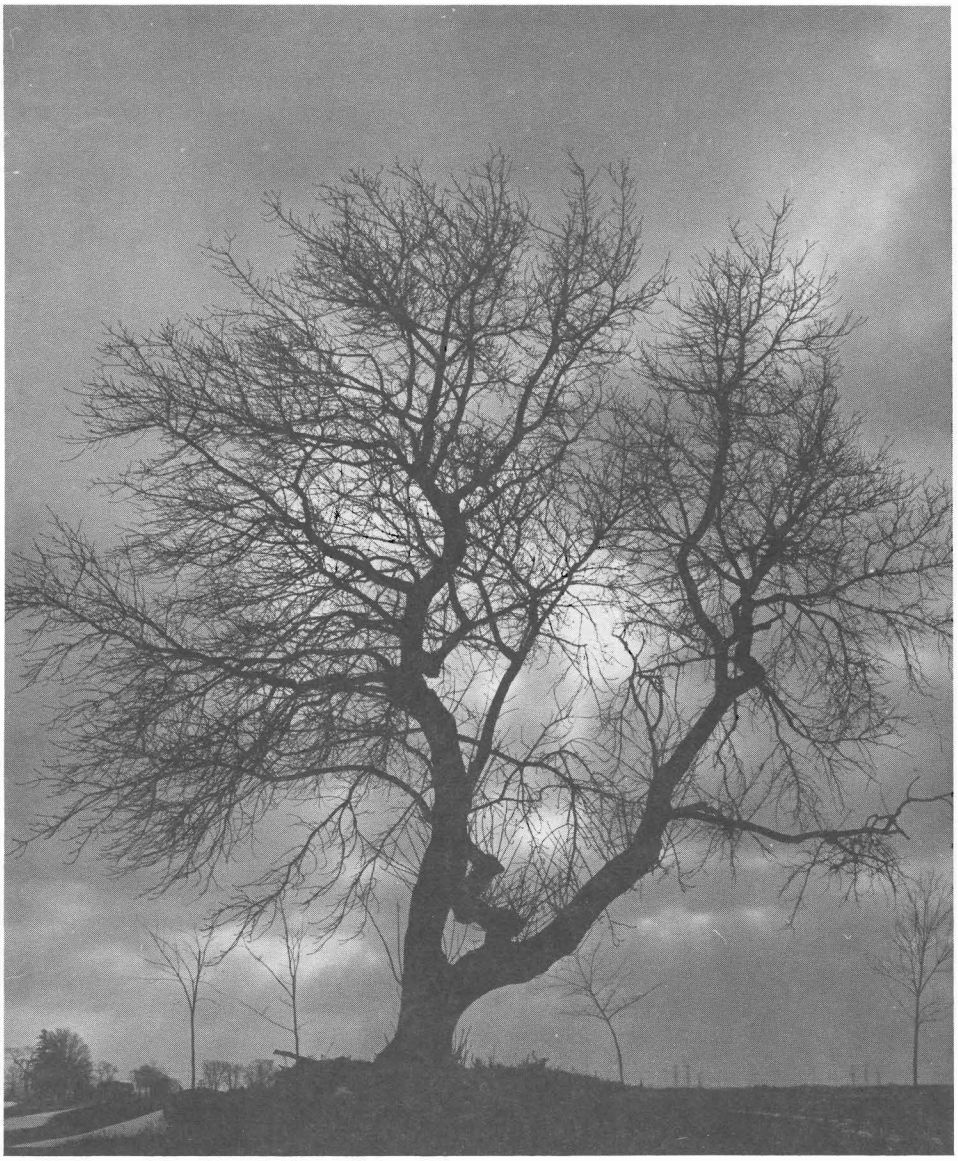


The ratio ρ of the real to the imaginary part of the forward p-p nuclear amplitude as a function of energy. The curves are dispersion relation calculations assuming: (I) $\sigma_T(pp)$ and $\sigma_T(\bar{p}p)$ increases as 0.49 $\ln^2(s/122)$ to E_∞; (II) $\sigma_T(pp)$ is constant for E > 120 GeV at 38 mb; (III) $\sigma_T(pp)$ becomes constant above 2000 GeV at 44.2 mb. In each case it is assumed that $\sigma_T(\bar{p}p)$ approaches $\sigma_T(pp)$ as $E^{-0.602}$

accepted, then our data are a further confirmation of the validity of local field theory up to energies of 400 GeV/c.

An alternative interpretation of the sign of ρ in terms of potential scattering is that the real part of the nuclear amplitude reflects the sign of the real part of the p-p potential. Since the Coulomb force is repulsive, a positive value of ρ indicates that the p-p potential which at very low energies is attractive and then becomes repulsive, changes its sign at $E \sim 280$ GeV and again becomes attractive. Whether this behavior continues to infinite energies or whether the sign of ρ is oscillatory, is an open question.

Reported by A. C. Melissinos



A Box Elder tree silhouetted against a stormy sky. Tree is located near Batavia Road, east of its intersection with Eola Road on the NAL site, a part of the former Anderson Farm. (Photo by T. Fielding, NAL)

THE PROTO-DOUBLER PROJECT

Until very recently, NAL's Energy Doubler project has had as its primary goal the construction of a ring of superconducting magnets able to accelerate protons to 1000 GeV, twice the energy of which the main ring is capable at present (see September 1973 NALREP for details). It now appears that within our original construction appropriation we may not be able to construct the full Energy Doubler and the remaining improvements to the experimental areas. The Energy Doubler project has been carefully reviewed and re-evaluated in light of these considerations. The results of these deliberations are reported in "The Energy Doubler Design Study--A Progress Report," just issued by the Laboratory.

Three different modes of operation of the Energy Doubler can now be anticipated. One is as originally conceived and would raise the ultimate capability of the main ring to 1000 GeV. Another is the "energy saver" mode, in which superconducting magnets would be used to decrease electrical power consumption while providing 300- or 400-GeV beams to the external experimental areas. The third is the "beam stretcher" mode, in which the magnets are kept at constant field strength, filled from the regular accelerator working at as high a rate as possible. The superconducting magnets would serve to store at high intensity and stretch it out over a nearly 100% duty cycle.

The development of cryogenic, superconducting systems, whatever their eventual application, is important in solving some of the nation's energy problems, and the Energy Doubler Design Study contributes to this

development. The preliminary work having to do with the feasibility of constructing appropriate magnets, and the results of some very recent tests on the prototype magnets and the one full-scale 20-ft dipole magnet are described in the report, as is the development of the associated refrigeration system. The next step, the joining of several full-scale magnets into the refrigeration system is now under way, and significant results should be available later this year.

The problems still to be answered are largely ones of standardization, tolerance of manufacture, procurement, quality control, installation, and over-all cost. The present estimate of a complete Energy Doubler is between $20 million and $30 million; the amount of funds still left from the original $250 million for construction is estimated to be about $20 million. Because of the step-wise approach which has been followed in this project, and in view of its potential cost, the Laboratory is now seeking authorization only to proceed to the next step, the construction of a Proto-Doubler.

This Proto-Doubler would consist of nearly 150 superconducting dipole and quadrupole magnets installed in one-sixth of the main ring. Although such a system obviously could not be used for multiple transversals of accelerating protons, it would make possible the testing of the most critical principles and procedures which might be adopted if the entire Doubler were constructed. Just the construction of the Proto-Doubler itself would provide a unique opportunity to develop and test superconducting equipment. This project is estimated to cost approximately $10 million, of which all but about $3 million would be recoverable if it were decided not to build the Energy

Doubler. Magnets, refrigerators, superconducting wire, instrumentation, all could be used in the experimental areas to exploit the available 400-GeV beams.

In transmitting the report to the AEC Division of Physical Research, NAL Director R. Wilson urged them to agree to this authorization for an expenditure of up to $10 million to build the Proto-Doubler, commenting, "It presents to us an unusual opportunity to prepare ourselves to take the next exceedingly important step toward reaching 1000 GeV. It provides for the development of techniques that will find immediate application in reducing the large energy usage at the Laboratory. Finally, as pointed out in the report, it has direct relevance to the general problem of energy conservation."

NOTES AND ANNOUNCEMENTS

DEDICATION. . .

The formal dedication ceremonies for the Laboratory have been scheduled for Saturday, May 11, 1974. At that time, NAL will officially become the Fermi National Accelerator Laboratory. Details of the ceremonies are being formulated.

USERS MEETING PLANNED. . .

The Annual Meeting of the Users Organization will be held this year on Friday, May 17. For those who arrive early, a Social Hour will be held on Thursday afternoon, beginning at 5 p.m.

The emphasis of this year's meeting will be upon the operation of the accelerator and the development of experimental facilities, with reports from the Board of Trustees, the Laboratory staff, and the Users Executive Committee. Hotel reservation forms will be mailed to members of the organization soon; anyone not a member who wishes to attend should write to:

Users Organization Secretary
National Accelerator Laboratory
P. O. Box 700
Batavia, Illinois 60510.

More details about the program for the day will be announced in the April issue of NALREP.

MORE MOVES. . .

The following offices are now located in the Central Laboratory, on the Atrium Floor adjacent to the elevator in the West Wing:

Medical Office	Ext. 3232
Housing Office	Ext. 3560, 3569
Visitors Office	Ext. 3440, 3582
Public Information and Village Crier Office	Ext. 3341, 3351
Travel Office	Ext. 3397
NAL Employee Benefits Office	Ext. 3395
Argonne Credit Union	Ext. 3293 from 8 a.m. to 2 p.m.

Medical offices--formerly in the NAL Village and in a trailer near the Transfer Hall at the main site--are now combined in the Central Laboratory. A physician is available on Tuesday and Thursday afternoons.

Other offices scheduled to be moved to the Central Laboratory during March include the NAL Personnel Offices and the AEC Batavia Area Office to the sixth floor, east wing; and Engineering Services to the fifth floor, east wing. In addition, three groups already in the building will be relocated to their permanent quarters: Neutrino Department will be moved from the second floor, west wing, to the twelth floor, east and west wings; Proton Department will be moved from the third floor, west wing, to the eleventh floor, east and west wings; and DUSAF will be moved from the second floor, east wing, to the fifth floor, west wing. Present plans are to have all personnel in their permanent offices in the building by early summer.

FACILITY UTILIZATION SUMMARY--FEBRUARY 1974

For the first three days of February the high-energy physics research program was continued, with the accelerator operating at 300 GeV. A number of experimental groups took data during this period.

In the Internal Target Area, Photon Search #63A and Proton-Deuteron Scattering #186 each used portions of the available beam time. Lepton #70 took data at 50 mrad in Proton Central, while Particle Search #100A took data in Proton East. In the Neutrino Area, Neutrino #262 used a fast beam spill for tuning, background studies, and preliminary data taking for their neutral current experiment; Long-Lived Particles #239 completed their data taking, and Hybrid #2B, operating in the multiple pulse mode, took 44,512 pictures of π^+-p interactions at 100 GeV.

A low intensity (1 to 2×10^{11} protons per pulse) slow-spilled beam was sent successfully to the Meson Area for beam transport and target train tuning. This work proceeded so smoothly that one full day was available for tuning of the secondary beams by experimenters. This was the first beam brought into that area since the fire, and all systems worked well.

A period of maintenance and development work followed from February 4 to 16, during which the installation of a new transformer for providing pulsed power to the main ring was completed. This transformer is connected to the 345-kV main supply feeders at the Master Substation and supplies power to the main-ring magnets at 13.8 kV. It is designed to handle the heavy pulsed loads what will occur during 400- to 500-GeV operation. It was put into service under load on February 15; within two days normal ramping of the main-ring magnets at 300 GeV had been achieved.

An additional week was then spent in starting up and tuning the accelerator and external beam lines for 300-GeV operation, after which the high-energy physics program was resumed. In Proton East, Particle Search #100 collected data on direct muon production. In Proton Central, Lepton #70 began checking and tuning their apparatus, which had been repositioned to collect data at 83 mrad. In the Neutrino Area, Neutrino #262 began background studies, after the train had been tuned for positive particles at 120 GeV/c. An effort was then made to establish conditions for compatible operation of the muon beam line for Muon #257. The attempt was not completely successful, indicating a need for additional tests. The train was then retuned for 140 GeV/c and Neutrino #262 began taking data. Neutrino #1A collected data simultaneously. Meanwhile, pictures were taken in the 30-inch bubble chamber to complete an 80,000 picture exposure of π^+-p interactions at 100 GeV/c for Hybrid #2B. The N-3 beam line was then changed to transport 200-GeV negative pions, and additional pictures were taken for Hybrid #2B. Six experimental groups made use of the secondary beams in the Meson Area for beam tuning and equipment checking. These included Total Cross Section #104 in the M-1 West line, Charge Exchange #111 in the M-2 line, Neutron #4 in the M-3 line, Elastic Scattering #96 in the M-6 East line with Multiplicities #178 using an upstream target in the same beam, and K^o-Regeneration #82 in the M-4 beam line.

The summary of facility utilization for the month of February is as follows:

I. Summary of Accelerator Operations

		Hours
A. Accelerator use for physics research		
Accelerator physics research		23
High energy physics research		137
Research during other use		(20)
	Subtotal	160
B. Other activities		
Accelerator setup and tuning to experimental areas		77
Scheduled interruption		327
Unscheduled interruption		108
	Subtotal	512
C. Unmanned time		0
	Total	672

II. Summaries of High Energy Physics Research Use

	# of Expts.	Hours	Results
A. Counter experiments	15	948	948 hr
B. Bubble-chamber experiments	2	69	87,000 pictures
C. Emulsion stacks exposed	-	-	-
D. Specific target bombardments	1	101	1 target
E. Test experiments	-	-	-
F. Engineering studies and tests	-	8	-
G. Other beam use	-	221	221 hr
	18	1347	

III. Number of Protons Accelerated and Delivered

		Protons
A. Beam accelerated in main ring	Total	2.8×10^{17}
B. Beam delivered to experimental areas		
Meson Area		0.2×10^{17}
Neutrino Area*		1.3×10^{17}
Proton Area		0.6×10^{17}
	Total	2.1×10^{17}

*This does not include slow spilled beam for bubble chamber and muon beam operation.

MANUSCRIPTS SUBMITTED FOR PUBLICATION DURING JANUARY AND FEBRUARY 1974

Experimental Physics

W. F. Baker et al. NAL-Pub-74/13-EXP (Experiment 104)	Measurement of $\pi^{\pm}$, $K^{\pm}$, p, and $\bar{p}$ Production by 200 and 300 GeV/c Protons (Submitted to Phys. Rev. Letters)
V. A. Tsarev NAL-Pub-74/17-THY/EXP	Are There Small Scale Oscillations in High-Energy Proton-Proton Scattering? (Submitted to Phys. Rev. Letters)
M. Atac et al. NAL-74/19-THY/EXP	Drift Chamber Development at NAL
M. Atac and W. E. Taylor NAL-Pub-74/22-EXP	The Development of a New Drift Chamber With a New Gas Mixture (Submitted to Nucl. Instr. and Methods)
T. Nash et al. NAL-Pub-74/25-EXP (Experiment 75)	A Search for Fractionally Charged Quarks Produced by 200 and 300 GeV Proton-Nuclear Interactions (Submitted to Phys. Rev. Letters)
H. R. Gustafson et al. (Experiment 4)	A Measurement of the p-p Total Cross Section at 200 and 300 GeV/c (Submitted to Phys. Rev. Letters)
B. C. Brown et al. (Experiment 187)	Heavy Particle Production in 300 GeV/c Proton/Tungsten Collisions
D. F. Bartlett et al. (Experiment 202)	Detecting Near Ultraviolet Radiation in the Presence of Visible Light (Submitted to Rev. Sci. Instr.)
J. Whitmore (General Bubble Chamber Review)	Experimental Results on Strong Interactions in the NAL Hydrogen Bubble Chamber (Submitted to Physics Reports)
S. Ohnuma	Nonlinear Effects and Their Corrections in the NAL Main Ring (Submitted to the U.S.-Japan Seminar on High-Energy Accelerator Science, Tokyo, Nov. 5-9, 1973)
S. Ohnuma	Quarter Integer Resonance by Sextupoles (Submitted to the U.S.-Japan Seminar on High-Energy Accelerator Science, Tokyo, Nov. 5-9, 1973)

L. C. Teng	Proposed NAL Future Projects (Submitted to the U.S.-Japan Seminar on High-Energy Accelerator Science, Tokyo, Nov. 5-9, 1973)
L. C. Teng	Status of the NAL Synchrotron (Submitted to the U.S.-Japan Seminar on High-Energy Accelerator Science, Tokyo, Nov. 5-9, 1973)

Theoretical Physics

S. L. Adler et al. NAL-Pub-73/86-THY	Nuclear Charge Exchange Corrections to Leptonic Pion Production in the (3,3)-Resonance Region (Submitted to Phys. Rev. D)
H. D. I. Abarbanel and J. B. Bronzan NAL-Pub-73/90-THY	Structure of the Vacuum Singularity in Reggeon Field Theory (Submitted to Physics Letters)
H. D. I. Abarbanel and J. B. Bronzan NAL-Pub-73/91-THY	Structure of the Pomeranchuk Singularity in Reggeon Field Theory (Submitted to Phys. Rev. D)
R. W. Brown et al. NAL-Pub-74/14-THY	Possible Effects of Weakly Coupled Neutral Currents in $pp \to \ell^+\ell^- + X$ (Submitted to Nucl. Phys.)
A. R. White NAL-Pub-74/15-THY	Analytic Continuation of the Two Reggeon Cut Discontinuity Formula (Submitted to Phys. Rev.)
A. I. Sanda NAL-Pub-74/16-THY	Parton Model Predictions for Colliding Beam Processes at Present Energies (Submitted to Phys. Rev. Letters)