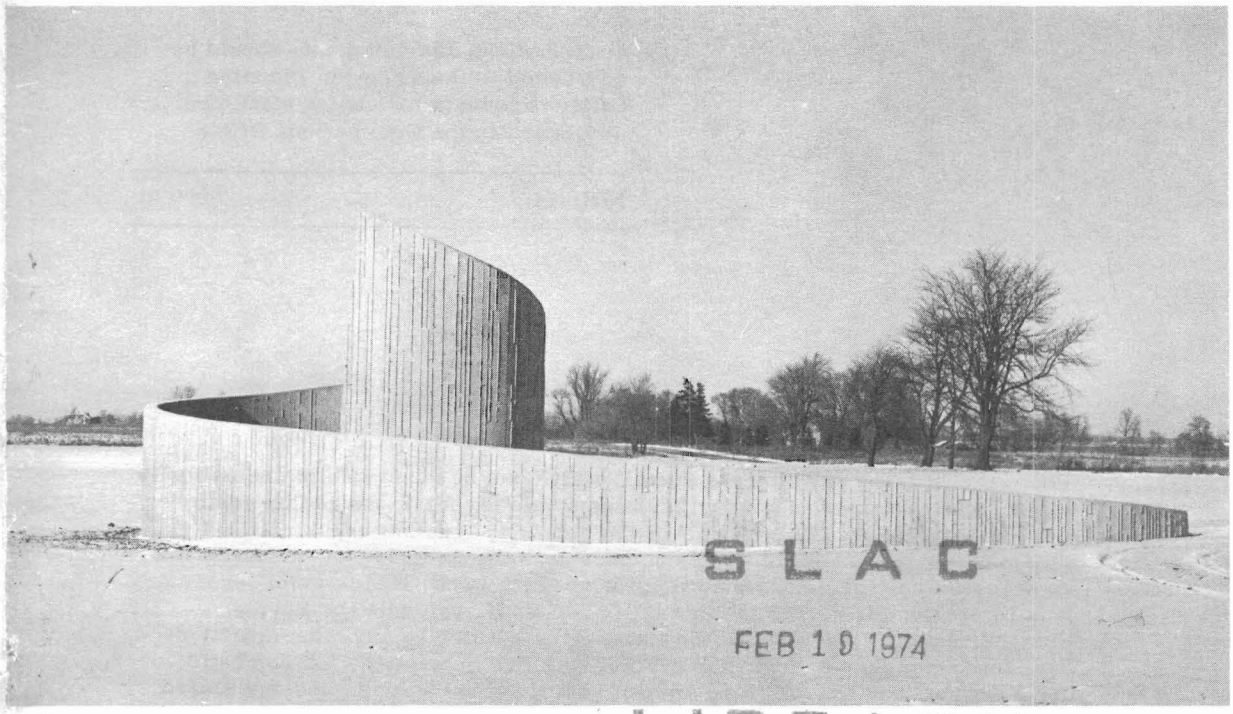
# NALREP



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MONTHLY REPORT OF THE NATIONAL ACCELERATOR LABORATORY

**National Accelerator Laboratory**

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THE COVER: The Archimedes Spiral, which can be described mathematically as the locus of a point moving with uniform velocity along the radius vector while the radius vector moves about the pole with constant angular velocity. This particular version, a textured concrete wall, provides an enclosure and an accessway to the pumping station for Casey's Pond, NAL's main reservoir. It is located on the northwest side of Wilson Road, opposite the Bubble Chamber Area. Nearly all of the Laboratory's water supply--for industrial use, for cooling the accelerator system, for fire protection, for domestic consumption, and for a limited amount of irrigation--is collected and stored on site in four man-made reservoirs and many cooling ponds. The total storage capacity is approximately 140 million gallons.

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# A SEARCH FOR FRACTIONALLY CHARGED QUARKS

Reported by T. Yamanouchi

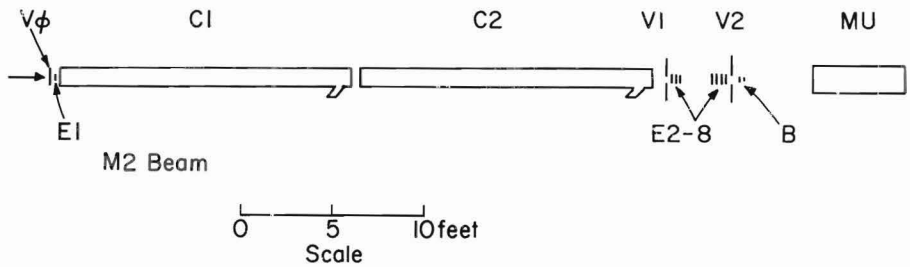
The remarkable success of SU(3) symmetry in particle physics has led to the conjecture that hadrons might consist of bound states of fundamental triplets. In particular, Gell-Mann and Zweig pointed out that a simple explanation of the regularities in the hadron mass spectrum can be achieved by assuming the existence of three particles of fractional charge (1/3 e or 2/3 e) and fractional baryon number. These particles are usually called quarks. A great variety of observations concerning strong, electromagnetic, and weak interactions can be understood if quarks are the basic building blocks of hadrons. Although there have been many searches for quarks, in the cosmic-ray flux, in secondary-particle beams from accelerators, and as stable constituents of terrestrial matter, none of these experiments has given positive results. This fact can be interpreted in several ways: for example, that quarks cannot exist as individual particles, but, like phonons in a crystal, are no more than mathematical entities that can have meaning only inside the hadrons; or that the conservation of some quantum number prohibits their existence in free space; or that they are massive, and therefore difficult to produce, i.e., they have a small production cross section. It is also possible that the basic building blocks of hadrons are unitary triplets of integer charge, as suggested by Han and Nambu. In any case, one of the most important tasks for high-energy physicists is to extend the search for quarks into the region of higher masses and smaller production

cross sections. The NAL accelerator is best suited for this purpose since the energy available for quark production is substantially higher than that at any other existing accelerator except the CERN Intersecting Storage Ring (ISR). At NAL, the beam flux (or luminosity) is many orders of magnitude greater than that of cosmic rays or the ISR.

We have conducted such an experiment using the M2 beam in the Meson Area. The primary proton beam, 200 and 300 GeV, was focused on a 12-inch long beryllium target. Secondaries produced at 1 mrad were transmitted through the M2 beam line and brought to the second focus at the detection apparatus approximately 1360 feet from the production target. The principal detector was a set of eight scintillation counters which provided ionization loss information on particles transmitted by the beam channel. (Quarks of charge 1/3 e and 2/3 e are expected to exhibit ionization losses 1/9 and 4/9 those of singly charged particles.) Two threshold Cerenkov counters provided information on particle mass. A muon identifier, a steel-liquid scintillator sandwich, was located at the back of the entire apparatus.

During the running period with 200-GeV incident protons, the "super-momentum" method was used. This method makes use of the fact that quarks with momentum p behave in a beam channel as if they were ordinarily charged particles of momentum 3p or 3/2p. In a major portion of the running the beam momentum was set to 270 GeV/c, thus accepting quarks with charge 1/3 e and of momentum 90 GeV/c. This particular momentum was chosen because it was the maximum of the four-body phase-space for the reaction:

$$N + N \rightarrow N + N + q + \bar{q}.$$




Experimental apparatus for Quark #75. E1-8 are ionization loss counters; C1 and C2 are gas threshold Cerenkov counters; MU is a muon identifier; Vϕ, V1, and V2 are veto counters; B is a pair of scintillation counters for beam definition.

Since no particle with momentum greater than 200 GeV/c is produced in 200-GeV proton-nuclear collisions, the beam channel would provide sufficient bending to prevent the transmission of ordinary particles along the beam line. It was expected, however, that some muons which penetrated the shielding and strayed into the beam line after the last bend could reach the detectors. In a run with $10^{17}$ protons on the production target we observed 59 such events. The energy losses in the eight ionization loss counters for these events were clearly those of singly charged particles, and the pulses in the muon identifier indicate that all of these were indeed muons.

Although the super-momentum method provided a clean, efficient way of searching for charge 1/3 quarks, it was not the optimum way of searching for charge 2/3 quarks. A more significant search for the latter was made by raising the primary proton energy to 300 GeV and lowering the secondary beam momentum to 207 GeV/c. Again, this particular momentum value was

chosen on the basis of phase-space considerations. In this mode of running, since there was a large flux of ordinary particles in the beam, an on-line preselection for quark candidates was made by requiring that at least three of the ionization loss counters show quark-like signals. When this condition was met, the event was recorded on magnetic tape. From the off-line analysis of some 14,000 events so obtained, it was concluded that no candidates for fractionally charged quarks had been observed.

In addition to the pair production just discussed, there is another possible mechanism for quark production, i.e.:

$$N + N \rightarrow N + q(2/3) + q(2/3) + q(-1/3).$$

In this case, the optimum beam momentum would be lower than that for the pair production, since more energy is required to produce three quarks than two. It is also possible that the choice of optimum momentum based on the phase-space consideration may be incorrect. This is quite possible for low-mass quarks, but unlikely for high-mass quarks, since the phase-space requirement would dominate for the latter. In order to cover all possibilities, we also took data at several other beam conditions. None yielded positive results. The upper limits (90 per cent confidence level) of the quark production cross section obtained at various conditions are summarized in the table on the facing page.

In order to derive the upper limits for the total cross section for quark production we must assume some plausible production model. The total cross-section limits obtained by assuming (a) four-body phase space for pair production (isotropic center-of-mass angular distribution), and

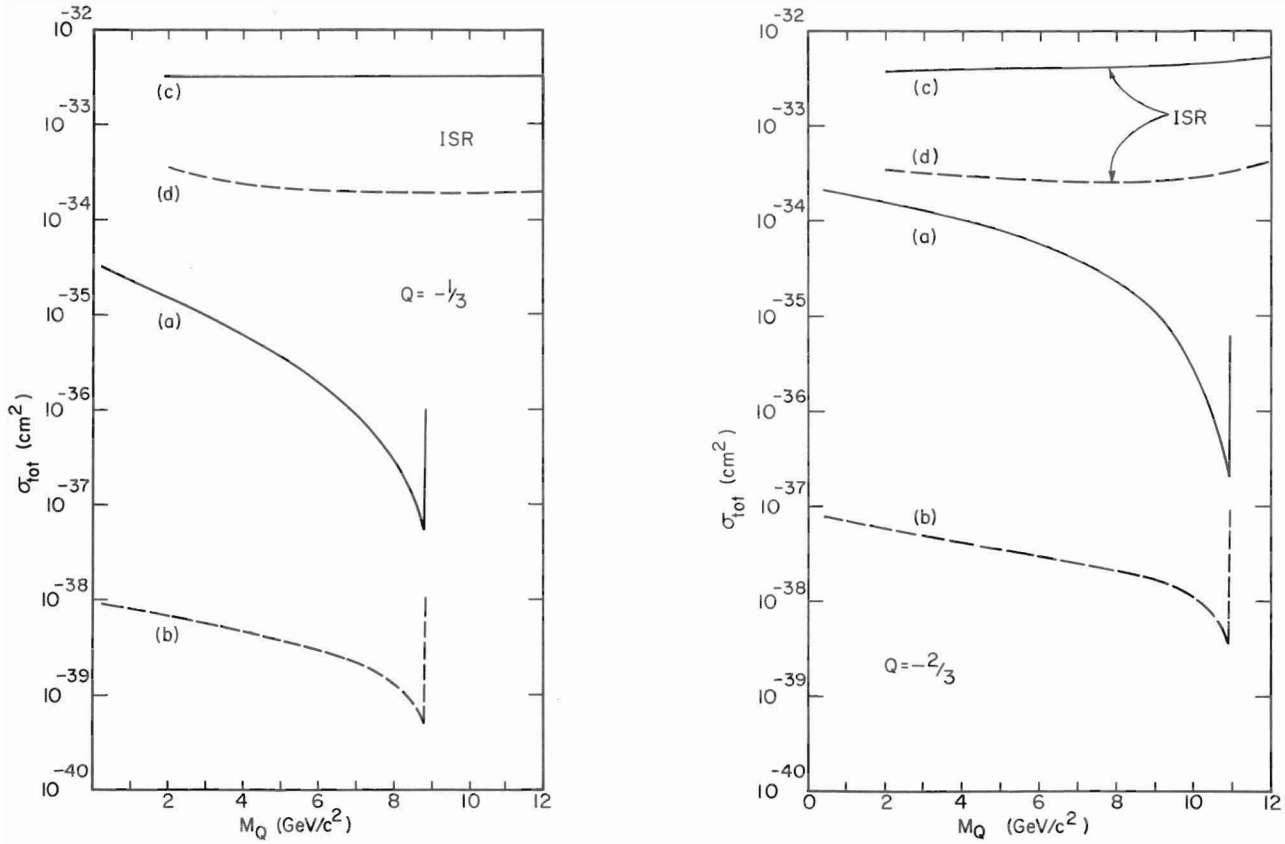
Upper Limits for Quark Production (90% Confidence Level)

| Proton Energy (GeV) | Secondary Momentum (GeV/c) | $d^2\sigma/dpd\Omega$ $q = 1/3$ ($cm^2$/sr GeV/c) | LS $q = 2/3$ ($cm^2$/sr GeV/c) |
|---|---|---|---|
| 200 | 270 | $5.6\times10^{-36}$ | $2.8\times10^{-36}$ |
| | 207 | $5.6\times10^{-35}$ | $2.8\times10^{-35}$ |
| | 150 | $8.0\times10^{-35}$ | $4.0\times10^{-35}$ |
| 300 | 270 | $5.1\times10^{-34}$ | $2.5\times10^{-34}$ |
| | 207 | $1.0\times10^{-34}$ | $5.0\times10^{-35}$ |
| | 150[a] | $4.8\times10^{-33}$ | $2.4\times10^{-33}$ |

[a]Positive polarity. All others are negative.

(b) four-body phase space constrained by a multiplicative factor of $\exp[-p_t/0.16(\mathrm{GeV/c})]$, where $p_t$ is the transverse momentum, are shown in the figures on the following page. We present these as extreme cases. For comparison, similar limits from the CERN ISR experiment are also shown.

The experiment was performed by T. Nash, D. Nease, J. Sculli, and T. Yamanouchi with the help of J. Upton of the NAL Physics Department. T. White participated in the design of the experiment.



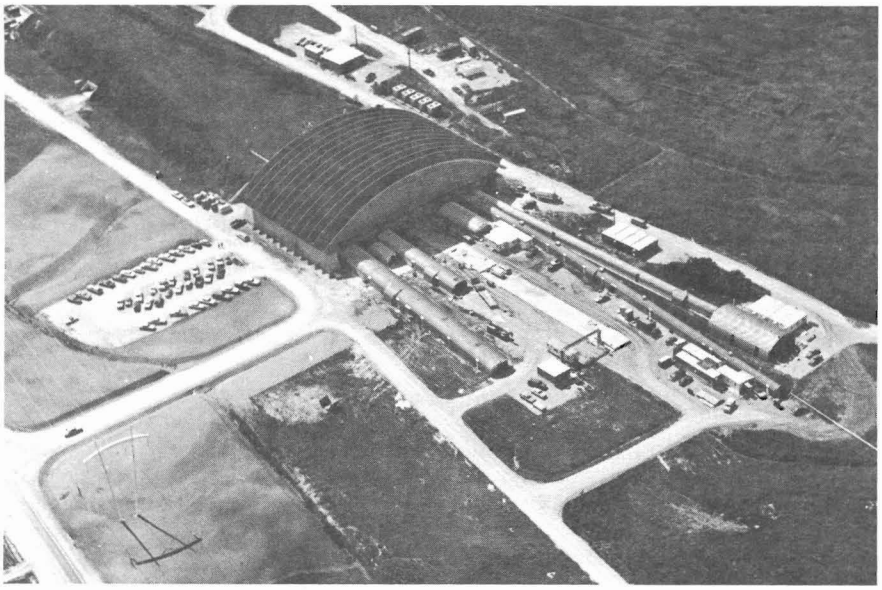

Cross-section limits (90% confidence level) for q = 1/3 and q = 2/3 as a function of quark mass for (a) four-body phase space and (b) four-body phase space constrained by a multiplication factor of $\exp[-p_t/0.16(\mathrm{GeV}/c)]$. Similar limits obtained from the CERN ISR experiments are shown in (c) and (d).

# THE MESON AREA: STATUS REPORT

Reported by R. A. Lundy

During 1973 the Meson Area came into nearly full operation, with the completion of all of the beam lines except M5, and the installation of approximately ten experiments. As originally conceived, the Meson Area was to accept a 200 GeV proton beam, and with it to produce six secondary beams. Four of these were to be charged particle beams and two were to be neutral particle beams. One of the charged particle beams--M5, an 80-GeV/c beam--was deferred early in the planning stage and has since been revived as a minimal 50 GeV/c test beam. The other three charged particle beams, M1 (a high intensity, medium resolution beam), M2 (a diffracted proton beam), and M6 (a medium intensity, high resolution beam), had been designed with protons of only 200-GeV/c incident on the target in the Meson Area in mind. One of the first major tasks was to investigate the possibility of raising the momentum range of these beams to match the 300 GeV/c incident protons which have become the standard operating mode for the accelerator.

Fortunately, the M2 beam had a momentum capability of approximately 260 GeV/c, which had been intended for use in Quark #75. By adding more magnets and power supplies, it was possible to raise the capability of this beam to slightly over 300 GeV/c. The M1 beam line was also redesigned to operate at a maximum momentum of 280 GeV/c, and the necessary components installed late in 1973. To increase its usefulness, a switching magnet was added which provides a branch beam and allows for more than one experiment to be set up at one time. The branches cannot be used



Aerial view looking west over the Meson Area, taken in September 1973. It shows the earth shielding over the secondary beam lines and the research areas. Far to the left, the protons for the accelerator produce secondary beams of particles. These beams fan out into the Detector Building, where the experiments are installed. The forward detector apparatus for the experiments extends beyond the building in the corrugated roofed extensions to the right. Beam lines are numbered M1 through M6, with M1 in the foreground, and the west branch of M6 at the back. (Photograph by T. Frelo, NAL)

simultaneously; however, beam can be switched from one to the other in approximately an hour's time. A similar magnet was installed in the M6 beam line but the momentum capability (180 GeV/c) of that line was not increased. The two neutral beams, M3 (predominantly a neutron beam) and M4 (a beam in which the larger production angle is expected to favor $K^0$ production relative to neutrons) were capable of functioning with 300-GeV protons on target with no changes.

During 1973 a number of experiments were set up in the Meson Detector Building and the extensions north of it. The goal has been to provide as many compatible installations as possible to provide for maximum flexibility in scheduling, and to give each group a first look at experimental possibilities. The major experiments installed in the M1 beam line are Total Cross Section #104 and Elastic Scattering #7. Quark #75 has been completed, and Pion Charge Exchange #111 and Missing Mass #51A are installed in the M2 beam line, along with parts of Beam Dump #108 and Neutral Hyperon #8. Neutron Cross Section #4 shares the use of the M3 beam with Neutron Dissociation #27A, while equipment is tested parasitically for Neutron Backward Scattering #12. Quark #72 has been completed in the M4 beam line, and $K^0$ Regeneration #82 is now installed there. In the M6 beam line, the first major installation was the single-arm spectrometer currently being used for Elastic Scattering #96. Elastic Scattering #69A will soon be installed in the M6 west branch beam line, along with some portions of Multiparticle #110.

In addition to upgrading the beam lines to match the higher accelerator momentum, we have continued to improve the target load, to enable it to handle beam intensities of several times $10^{13}$ protons per pulse. The latest and, we hope, final version of the target load was installed during December 1973 and January 1974. Basically, it consists of a large evacuated box embedded in heavy shielding, containing four 20-ft long railroad cars. Protons are brought into the target load through steel collimators, which serve to define the target angle and the angular spread of the proton beam. It is important that these two angles be controlled, to help guard against accidentally transmitting a very high intensity proton beam into the experimental area. Following these collimators is a movable shuttle which supports eight water-cooled targets of varying lengths and diameters. Made of either beryllium or tantalum, each target is equipped with a thermocouple to monitor the effectiveness of the cooling. The shuttle permits both horizontal and vertical positioning of the targets. Downstream of the targets is a water-cooled aluminum "spoiler." It is designed to intercept the proton beam which has passed through the targets, and allow it to develop into a hadron shower spread out geometrically to reduce the specific energy deposit which could conceivably melt components of the target train. The spoiler is remotely controlled so that it can be positioned for optimum "spoiling," yet not appear as a secondary target during operation. Downstream of the spoiler is the first of three steel collimators which define apertures for the six secondary beam lines. This collimator contains a water-cooled aluminum core which absorbs the bulk of the power carried in

by the proton beam. In addition to these collimators and targets, a number of diagnostic devices which provide information about the proton beam position and size are mounted on the train load.

Late in December, during the 400-GeV operating period, the Meson Area was shut down so that changes in the target load and other installation work in the beam lines and experimental setups could be carried out. On December 26, a fire was accidentally started by a construction worker in the west branch extension of the M6 beam line. It spread rapidly along the extension to the north wall of the Detector Building, damaging both. Fortunately, no one was injured, and the experiments installed in the Detector Building and in the other beam line extensions suffered no major damage beyond deposits of soot and smoke. An extensive cleanup effort was immediately started, and it is hoped that the experimental program in the Meson Area, which had been scheduled to recommence on January 10, will in fact begin in mid February.

## LONG-RANGE PLANS FOR THE NATIONAL ACCELERATOR LABORATORY

The results of the 1973 Summer Study, summarized in the August 1973 issue of NALREP, were presented to the Long Range Advisory Committee last fall. Group Leaders who participated in the study made presentations concerning the major areas examined during the Summer Study. Following the presentation of the different programs, the Chairman of the Long Range Advisory Committee, Professor David Frisch of the Massachusetts Institute of Technology, convened the group in executive session and recommendations were formulated. These were forwarded to the Laboratory and have provided material for discussion and consideration concerning NAL's longer range plans. The Director has described several of the objectives which now represent the plans for the next few years. The highlights of the plans are the following:

The Laboratory's planning for the long-range future will center around the design of "POPAE" (proton on proton and electron) storage rings. The three rings will be about the same diameter as the present accelerator. The proton rings will accommodate energies up to 1000 GeV. The electron ring will probably operate somewhere between 20 and 30 GeV. All rings are envisoned to be in a single tunnel, and the eventual goal will be to produce proton-proton collisions or proton-electron collisions, hopefully with only minor modifications of the installed facilities. In order to achieve a better understanding of this project, it is our intention to start a serious design study as soon as possible, with a goal of producing designs and reports this year.

We shall not undertake the construction of a "super Omega" type detector in the near future. In fact, we shall resist suggestions that we build a single, enormous, all-purpose detector. We shall, however, be receptive to proposals for specific experiments exploring multiparticle final states and, if appropriate, we shall undertake the construction of individual components (e.g., a large vertex magnet) which might eventually constitute parts of a "super-Omega" program--the parts comprising the whole.

We are giving no further consideration to the construction of a still larger hydrogen bubble chamber in the near future. There was no significant user interest expressed in such a facility, and it seems appropriate to examine the effectiveness of the 15-ft chamber before contemplating the construction of a larger detector of this kind.

We shall not view the possible construction of a totally new experimental area in terms that would suggest it to be a long-range future project. Rather, we shall continue our upgrading of the experimental facilities and beams in a manner which will give experimenters access to the highest energies and highest intensities that the accelerator can produce.

In addition to these projects, the Laboratory is pursuing the possibility of the Energy Doubler, a superconducting ring of magnets placed in the main-ring tunnel that might serve to increase the energy of the beam to double its ultimate energy, possibly to 1000 GeV, and which might effect considerable economy in the electrical bill. An exploratory effort has shown the feasibility of building small magnets that appear to be of adequate quality and reproducibility. The cost of the components would appear to be within the financial capabilities of the Laboratory. On the basis of these modest studies, the development will now be pursued more vigorously to the next stage, which envisions the construction of several 20-ft long magnets which are to be installed and tested in the 200-ft long tunnel in the NAL Village which was used as a prototype of the main ring. A project report is nearly completed on the feasibility of the construction and installation of the Energy Doubler. If the idea continues to look good, the effort toward realizing the Doubler will be expanded in the near future.

## SOME RECENT ACTIVITIES OF THE USERS EXECUTIVE COMMITTEE

Reported by W. D. Walker, Chairman

The Users Executive Committee meets once every couple of months. We find out how the accelerator is operating and what organizational changes have been made in the Laboratory staff, as well as other housekeeping matters. In addition, we usually meet for an hour or so with the Director. The result is a fairly steady dialogue between the Committee, as representatives of the Users, and the administration of the Laboratory.

We recently polled Users who have or have had active experiments at NAL to find out their needs for services and facilities at the Laboratory. The results of this poll, which were not terribly surprising, have resulted in a report to Dr. Wilson. In many instances, these needs had been anticipated by the Laboratory. The need for additional housing was the most popular complaint. More on-site housing is being renovated now and should be available in a few months. This work was held up for many months by governmental red tape. The need for off- and on-site transportation was stressed by others as the second most popular complaint. It is hoped that the availability of lower cost rental cars (based on-site) will help alleviate this problem.

The Committee has proposed to the administration that a Users Office be established in the Central Laboratory. This office should be headed by a person of considerable authority, who would have cognizance over all the User Services. The office might handle housing, transportation (car rentals), communication, and typing, for example.

We also discussed at our last meeting possible plans for a faculty-type club at NAL. The most interesting item discussed was the Laboratory's success in constructing prototype superconducting magnets for a possible energy doubler.

## "PROCEDURES FOR EXPERIMENTERS" FOR 1974

A new edition of the Procedures for Experimenters booklet has just been issued by the Program Planning Office. As part of the Laboratory's continuing program of improving communications with experimenters, the booklet is intended to reflect changing policies and practices at NAL. No one should have any qualms about discarding the 1973 version--it was printed on genuine "100% recycled waste" with just that in mind.

The 1974 edition differs considerably from earlier versions. The administrative organization of the Laboratory is detailed in the first chapter, along with a listing of some of the department and group leaders with whom experimenters will need to work. Safety information, including radiation safety requirements, is covered in another chapter, as well as in two appendices. General area information, business arrangements, descriptions of the assistance obtainable from service and support groups at the Laboratory, and the methods followed in planning the experimental program are all discussed in later chapters. The new NAL policy on publications and the purposes of the NAL Physics Department, as well as an appendix containing information for foreign visitors have been added. The booklet ends with a subject index.

Copies of Procedures for Experimenters 1974 have been mailed to the spokesmen for all approved experiments. New experimenters will receive copies in the Visitors Center, when registering on site for the first time. All other experimenters are encouraged to pick up copies of the booklet from either the Program Planning Office or the Visitors Center.

## NOTES AND ANNOUNCEMENTS

### WORKSHOP ON SPECIAL BEAMS TO BE HELD . . .

The technical possibilities and suggestions for special hadron beams to the 15-ft bubble chamber, and the associated detection equipment, will be explored in a Workshop to be held at the Laboratory on Friday, February 15. A panel, including H. Foelsche, Chairman; A. Erwin; J. Lannutti; L. Voyvodic; and R. Yamamoto; will meet separately after the Workshop to formulate recommendations for the consideration of the NAL Program Advisory Committee. Spokesmen for experiments proposed which would require such beams have been invited to participate; all others interested are welcome to attend. The Workshop will be held in the Curia, NAL Village, starting at 9:00 a.m.

### PLEASE NOTE . . .

The dates for the March meeting of the NAL Program Advisory Committee have been changed--the Committee will meet on Thursday and Friday, March 14 and 15. Experimenters are invited to submit their proposals for use of the 30-in. bubble chamber filled with deuterium, and to send any other appropriate proposal revisions to the Director's Office by early February.

# EXPERIMENTAL PROGRAM SITUATION REPORT

The experimental program situation at NAL is summarized below. The experiments are listed separated by experimental area under categories that best describe their circumstance as of January 1, 1974. The experimental area names are abbreviated as follows: Internal Target Area (ITA), Meson Area (MA), Neutrino Area (NA), Proton Area (PA). Publications are available or talks have been given about the experiments marked *.

Total Number of Approved Experiments - 108

| | | Spokesman | Extent of Run to Date | Date Completed |
|---|---|---|---|---|
| A. | EXPERIMENTS THAT HAVE COMPLETED DATA TAKING (36): | | | |
| ITA | *Proton-Proton Scattering #36A | Cool | 700 hours | June 24, 1973 |
| | *Proton-Proton Missing Mass #67A | Sannes | 600 hours | Aug. 8, 1973 |
| | *Photon Search #120 | Cline | 1,200 hours | May 29, 1973 |
| | *Proton-Nucleon Inclusive #188 | Sannes | 1,050 hours | May 9, 1973 |
| MA | *Quark #72 | Leipuner | 500 hours | June 11, 1973 |
| | *Quark #75 | Yamanouchi | 900 hours | Sept. 8, 1973 |
| | Super-Heavy Elements #147 | Debeauvais | 3 exposures | Aug. 29, 1973 |
| | *Emulsion exposures to protons @ 200 GeV for experiments 90, 103, 105, 114, 116, 117A, 156 171, 183 | | 45 Stacks | Sept. 20, 1972 |
| NA | *Proton-Proton Inelastic #14A | Franzini | 140 hours | June 21, 1973 |
| | *30-Inch p-p @ 300 #37A | Malamud | 51,000 pix | June 1, 1973 |
| | 30-Inch $\pi^-$-p @ 100 #125 | Morrison | 54,000 pix | Aug. 28, 1973 |
| | *30-Inch $\pi^-$-p @ 200 #137 | Huson | 48,000 pix | March 10, 1973 |
| | *30-Inch p-p @ 200 #141A | Fields | 67,000 pix | Nov. 27, 1972 |
| | *Massive Particle Search #199 | Frankel | 2 targets exposed | Aug. 22, 1973 |
| | Beam Dump #211 | Goebel | 2 hours | Nov. 14, 1973 |
| | *30-Inch p-p @ 100 #252 | Ferbel | 33,000 pix | Dec. 6, 1972 |
| | Emulsion exposures to muons @ 150 GeV for experiments 205A, 255 | | 3 stacks | Oct. 16, 1973 |
| | Emulsion exposures to protons @ 300 GeV for experiments 181, 195, 232, 233, 237, 242, 244, 250, 275 | | 29 stacks | Oct. 20, 1973 |
| PA | *Particle Search #187 | Lederman | 200 hours | Nov. 6, 1973 |
| B. | EXPERIMENTS THAT ARE IN PROGRESS (21): | | | |
| ITA | *Photon Search #63A | Walker | 2,200 hours | |
| | Particle Search #184 | Mann | 250 hours | |
| | Proton-Deuteron Scattering #186 | Melissinos | 100 hours | |
| | Proton-Proton Inelastic #221 | Franzini | 150 hours | |
| MA | Neutron Cross Section #4 | Longo | 1,350 hours | |
| | Elastic Scattering #7 | Meyer | 400 hours | |
| | Neutron Dissociation #27A | Rosen | 400 hours | |
| | *Nuclear Chemistry #81A | Weisfield | 52 bombardments | |
| | Elastic Scattering #96 | Ritson | 650 hours | |
| | Pion Charge Exchange #111 | Tollestrup | 700 hours | |

| | | | |
|---|---|---|---|
| NA | *Neutrino #1A | Cline | 500 hours |
| | *30-Inch Hybrid #2B | Smith | 98,000 pix of p-p @ 200 & 300 |
| | *Neutrino #21A | Barish | 900 hours |
| | *Muon #26 | Chen | 750 hours |
| | *Monopole #76 | Carrigan | 3 targets exposed |
| | *30-Inch $\pi^+$-p @ 100 #121A | Lander | 58,000 pix |
| | *30-Inch p-p @ 400 #138 | VanderVelde | 12,200 pix |
| | Long-Lived Particles #239 | Frati | 50 hours |
| PA | Monopole #3 | Eberhard | Exposure of 4 targets in progress |
| | Lepton #70 | Lederman | 700 hours |
| | *Particle Search #100A | Cronin | 550 hours |

C. EXPERIMENTS THAT ARE IN TEST STAGE (5):

| | | | |
|---|---|---|---|
| MA | Missing Mass #51A | von Goeler | 20 hours |
| | Total Cross Section #104 | Cool | 300 hours |
| | Multiplicities #178 | Busza | 50 hours |
| NA | Muon #98 | Wilson | 100 hours |
| | 30-Inch Hybrid #154 | Pless | 9,000 test pix |

D. EXPERIMENTS BEING INSTALLED (8):

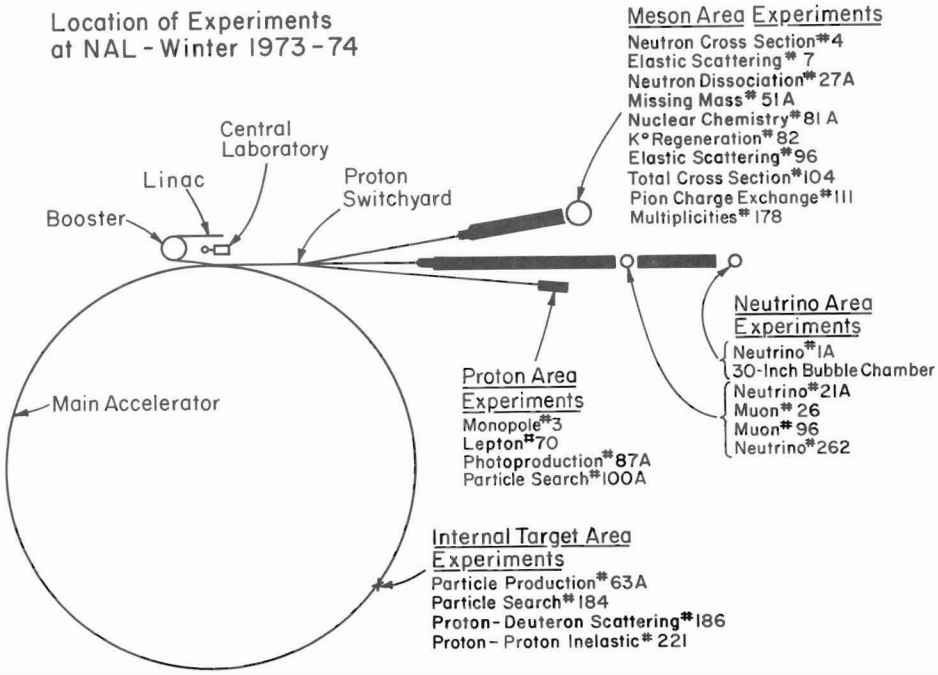
| | | | |
|---|---|---|---|
| MA | Elastic Scattering #69A | Sandweiss | 50 hours |
| | K Zero Regeneration #82 | Telegdi | 150 hours |
| NA | 15-Foot Neutrino/$H_2$ #45A | Nezrick | |
| | 15-Foot EMI Test #155 | Peterson | |
| | 15-Foot Engineering Run #234 | Huson | |
| | Neutrino #262 | Barish | |
| PA | Photoproduction #87A | Lee | 50 hours |
| | Photon Search #95A | Cox | |

E. EXPERIMENTS TO BE SET UP WITHIN A YEAR (16):

| | | |
|---|---|---|
| MA | Neutral Hyperon #8 | Pondrom |
| | Neutron Backward Scattering #12 | Reay |
| | Monopole #22 | Collins |
| | Beam Dump #108 | Awschalom |
| | Multiparticle #110A | Pine |
| | Detector Development #229 | Yuan |
| NA | 15-Foot Anti-Neutrino/$H_2$ #31A | Derrick |
| | Super-Heavy Elements #142 | Stoughton |
| | 30-Inch $\pi^-$-p @ 300 #143A | Kalbfleisch |
| | 30-Inch p-p & Ne @ 300 #161 | Fry |
| | 30-Inch $\pi^-$-p & Ne @100 or 200 #163A | Walker |
| | Emulsion/Protons @ <400 #189 | Ritson |
| | 30-Inch $\pi^+$-p @ 200 #217 | Lander |
| | 30-Inch p-p @ 50 or 60 #228 | Ferbel |
| | Emulsion/Protons @ 400 #251 | Kusumoto |
| PA | Proton-Proton Elastic #177A | Orear |

F. OTHER APPROVED EXPERIMENTS (22):

| | | |
|---|---|---|
| MA | Inclusive Scattering #23A | Rothberg |
| | Polarized Scattering #61 | Chamberlain |
| | Diffractive Dissociation #86A | Lubatti |
| | Charged Hyperon #97 | Lach |
| | Form Factor #216 | Drickey |
| | Neutron Elastic Scattering #248 | Longo |
| | Hadron Jets #260 | Pine |
| NA | 15-Foot Neutrino/$H_2$ & Ne #28A | Fry |
| | Detector Development #32 | Hofstadter |
| | Detector Development #34 | Huggett |
| | 15-Foot Neutrino/$H_2$ or Ne #53A | Baltay |
| | 15-Foot Anti-Neutrino/$H_2$ & Ne #172 | Bingham |
| | 15-Foot Anti-Neutrino/$H_2$ & Ne #180 | Nezrick |
| | Tachyon Monopole #202 | Bartlett |
| | Detector Development #206 | Peterson |
| | 30-Inch $p\bar{p}$ @ 500 #207 | Engelmann |
| | 30-Inch $\pi^-p$ @ 400 #215 | Goldhaber |
| PA | Photon Total Cross Section #25A | Caldwell |
| | Muon Search #48 | Adair |
| | Monopole #74 | Fleischer |
| | Long-Lived Particles #115 | Stevenson |
| | Multigamma #192 | Guiragossian |



# FACILITY UTILIZATION SUMMARY - DECEMBER 1973

Operation of the accelerator at 400 GeV dominated activities at the Laboratory during the month of December. The purpose of this effort was to test systems in both the accelerator and the experimental areas. The test was only partially successful, in part because of a lack of reliability of many of the accelerator components and utility systems.

During the first week of December the 300-GeV operation, which had been in progress since late October, came to an end. The Meson Area target train was then removed for repairs and for improvements to make possible its use with higher intensity beams. Improvements were also made in the M1 beam line to enable it to operate up to 280 GeV/c. Many of the accomplishments of the 300-GeV run in the Meson Area have been described in the Status Report on page 9.

A few days were required for maintenance and development work before the start of 400-GeV operation, scheduled for December 13. The 400-GeV beam which was available during the month for high energy physics use came about a week later and was limited to the equivalent of a week. The primary experimental groups taking data during that period included Neutrino #1A, using the single-horn system in the Neutrino Area and Particle Search #100A, using the slow-spill beam to compare data with that taken earlier at 200 and 300 GeV in the Proton Area. Beam tuning was also underway in the Neutrino Area to the 30-in. bubble chamber. Significant data were also collected by three groups working in the Internal Target Area, Proton-Proton Inelastic #221, Proton Deuteron Scattering #186, and

Particle Search #184. The 400-GeV operation continued into the first week of January, after which preparations to return to the 300 GeV operating mode began.

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

| | | |
|---|---|---|
| I. Summary of Accelerator Operations | | |
| A. Accelerator Hours for Physics Research | | |
| Accelerator Physics Research | | 15 |
| High Energy Physics Research | | 186 |
| | Subtotal: | 201 |
| B. Nonphysics Hours | | |
| Accelerator Setup and Tuning to Experimental Areas | | 21 |
| Scheduled Interruption | | 64 |
| Unscheduled Interruption | | 420 |
| | Subtotal | 543 |
| C. Unmanned Hours | | 38* |
| | Total: | 744 |
| II. Summaries of Experimental Use | | |
| A. Integrated Number of Hours in External Beams | | |
| For Approved Experiments | | 972 |
| Other (for beam tuning and studies) | | 61 |
| | Total: | 1033 |
| B. Total Hours Charged to Approved Experiments | | 1078** |
| C. Total Bubble Chamber Pictures for Approved Experiments | | 20,000 |
| D. Total Number of Experiments to which Time or Pictures were Charged | | 19 |

*Christmas standby.

**These tabulations do not include 149 hours of parasitic time run for the above approved experiments, nor do they include 3 additional experiments which ran parasitically for a total 228 hours.

III. Total Number of Protons Accelerated

| | | |
|---|---|---|
| Main Ring | Total: | $30.12 \times 10^{16}$ |
| Experimental Areas | | |
| Meson Area | | $5.14 \times 10^{16}$ |
| Neutrino Area | | $13.06 \times 10^{16}$* |
| Proton Area | | $2.12 \times 10^{16}$ |
| | Total: | $20.32 \times 10^{16}$ |

*This does not include fast spilled beam for bubble-chamber operation.

## MANUSCRIPTS SUBMITTED FOR PUBLICATION DURING NOVEMBER AND DECEMBER 1973

### Experimental Physics

| | |
|---|---|
| R. A. Carrigan, Jr. et al.<br>NAL-Pub-73/73-EXP<br>(Experiment 36) | The Real Part of the Proton-Proton Forward Scattering Amplitude from 50 to 400 GeV (Submitted to Phys. Rev. Letters) |
| G. Giacomelli<br>NAL-Pub-73/74-EXP | Inelastic Reactions at Very High Energies (Lectures at the Canadian Institute of High Energy Physics, McGill University, 1973) |
| A. E. Brenner et al.<br>(Single Arm Spectrometer Facility Group)<br>NAL-73/83-EXP<br>(Experiment 96) | Search for Heavy Mass Particles and Antideuteron Flux Produced by 300 GeV Protons on Beryllium |
| M. Atac and W. E. Taylor<br>NAL-Pub-73/89-EXP-THY | High Resolution Cryogenic Spark Chambers (Submitted to Nucl. Instr. and Methods) |
| J. C. Vander Velde<br>(General Bubble Chamber) | Recent Results from the NAL Bubble Chamber (Presented at the 5th International Conf. on High Energy Collisions, Stony Brook, 1973) |
| J. Lach<br>(General Bubble Chamber) | Multiplicities and Correlations in Particle Production at NAL (Invited Talk at the IV International Symposium on Multi-particle Hadrodynamics, Pavia, Italy, August 31-Sept. 4, 1973) |
| R. Stefanski et al.<br>(Experiment 1A) | Measurements of Neutrino and Antineutrino Cross Sections at High Energies (Submitted to Phys. Rev. Letters) |
| S. Childress et al.<br>(Experiment 14A) | Small Momentum Transfer p-p Inelastic Scattering at 300 GeV/c (Submitted to Phys. Rev. Letters) |
| G. Krafczyk et al.<br>(Experiment 21) | Calibration of a Sampling Total Absorption Detector at 200 GeV (Submitted to Nucl. Instr. and Methods) |
| S. K. Chang and N. Sugarman<br>(Experiment 81) | Interaction of 300-GeV Protons with Uranium (Submitted to Phys. Rev. C, "Communications") |

| | |
|---|---|
| J. Babecki et al. (Experiment 90) | Angular Distributions in Proton-Nucleus Collisions at 67 and 200 GeV (Submitted to Phys. Letters B) |
| J. W. Cronin et al. (Experiment 100) | Production of Hadrons with Large Transverse Momentum at 200 and 300 GeV (Submitted to Phys. Rev. Letters) |
| P. L. Jain (Experiment 114) | Interaction of 200 GeV Proton in Nuclear Emulsion (Submitted to the 13th International Cosmic-Ray Conf., Denver, August 17-30, 1973) |
| D. Bogert et al. (Experiment 137) | Diffraction Dissociation in 205 GeV/c $\pi^- p$ Two- and Four-Prong Interactions (LBL-2112 and presented at the APS Division of Particle and Fields Meeting, Berkeley, California, August 13-17, 1973) |
| D. Bogert et al. (Experiment 137) | Pion Diffraction Dissociation in 205 GeV/c $\pi^- p$ Interactions (LBL-2113 and submitted to Phys. Rev. Letters) |
| M. Derrick et al. (Experiment 141) | The Reaction $pp \rightarrow pp\pi^+\pi^-$ at 205 GeV/c (ANL/HEP 7354 and submitted to Phys. Rev.) |
| M. Derrick et al. (Experiment 141) | Diffraction Dissociation in Four-Prong Proton-Proton Interactions at 205 GeV/c (ANL/HEP 7356 and submitted to Phys. Rev. Letters) |
| M. Derrick et al. (Experiment 141) | Updated Charged-Particle Multiplicity Distribution from 205 GeV/c Proton-Proton Interactions (ANL/HEP 7361 and submitted to Phys. Rev. Comments and Addenda) |
| R. Singer et al. (Experiment 141) | Inclusive Two-Particle Rapidity Correlations in 205 GeV/c pp Interactions (ANL/HEP 7368 and submitted to Phys. Rev. Letters) |
| R. Singer et al. (Experiment 141) | Semi-Inclusive Two-Particle Rapidity Correlations in 205 GeV/c pp Interactions (ANL/HEP 7369 and submitted to Phys. Rev. Letters) |

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|---|---|
| L. Voyvodic et al. (Experiment 141) | Evidence for Scaling of Semi-Inclusive Cross Sections Between 13 and 205 GeV/c (Submitted to Phys. Rev. Letters) |
| K. Niu et al. (Experiment 156) | Detailed Analysis of Jet Showers Observed by Emulsion Chambers with Producing Layer (Presented at the 13th International Cosmic-Ray Conf., Denver, August 17-30, 1973) |
| F. Nezrick et al. (Experiment 199) | Search for Massive Long Lived Particles in Aluminum Targets Irradiated by 300 BeV and 400 GeV Protons (Submitted to Phys. Rev.) |
| J. Lee-Franzini (Experiment 221) | p-p Inelastic Scattering at Small Momentum Transfer (Talk given at the 5th International Conf. on High Energy Collisions, Stony Brook, 1973) |
| D. Cohen (Experiment 252) | Study of pp Interactions at 102 and 405 GeV/c (Presented at the IV International Symposium on Multiparticle Hadrodynamics, August 31-Sept. 4, 1973, Pavia, Italy) |
| C. Bromberg et al. (Experiment 252) | Cross Sections and Charged Particle Multiplicities at 102 and 405 GeV (Submitted to Phys. Rev. Letters) |
| D. Cohen (Experiment 252) | Some Remarks Concerning $K_S^0$ and $\Lambda$ Production in High Energy Proton-Proton Collisions |
| J. W. Chapman et al. (Experiment 252) | Production of $\gamma$, $\Lambda^0$, $K_S^0$, and $\overline{\Lambda^0}$ in pp Collisions at 102 GeV/c (Submitted to Phys. Letters) |
| T. Ferbel (Experiment 252) | Particle Multiplicities and Correlations at NAL Energies (Presented at the APS Division of Particle and Fields Meeting, Berkeley, California, August 13-17, 1973) |
| J. W. Chapman et al. (Experiment 252) | Pion Production in pp Collisions at 102 GeV/c (Submitted to Phys. Rev.) |
| B. A. Prichard, Jr. | Mechanisms of Electrical Discharges in High Vacuum at Voltages Up to 400 000 V [J. Appl. Phys. 44, 4548 (1973)] |

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| E. J. Barsotti et al. | Operational Aspects of a Serial CAMAC Control System (Submitted to the IEEE Nuclear Science Symposium, San Francisco, Nov. 14-16, 1973) |
| R. G. Martin | CAMAC Stand-Alone Control System (CAMSAC) (Submitted to the IEEE Nuclear Science Symposium, San Francisco, Nov. 14-16, 1973) |
| A. E. Brenner and R. G. Martin | CAMAC Scanning DVM System (Submitted to the IEEE Nuclear Science Symposium, San Francisco, Nov. 14-16, 1973) |

Theoretical Physics

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| E. A. Paschos NAL-Conf-73/65-THY | High Energy Neutrino Physics (Lectures Delivered at the "Ettore Majorana" Summer School, Erice, Sicily, July 1973) |
| J. B. Bronzan NAL-Pub-73/69-THY | The Reggeon Calculus for $\alpha > 1$ (Submitted to Phys. Rev.) |
| B. W. Lee NAL-Pub-73/71-THY | Renormalization of Gauge Theories - Unbroken and Broken (Submitted to Annals of Physics) |
| A. I. Sanda NAL-Pub-73/75-THY | Massive Quarks and the Quark-Parton Model (Submitted to Phys. Rev.) |
| D. Z. Freedman NAL-Pub-73/76-THY | Coherent Neutrino-Nucleus Scattering as a Probe of the Weak Neutral Current (Submitted to Phys. Rev. Letters) |
| M. B. Einhorn and S. Nussinov NAL-Pub-73/79-THY | Antinucleon Production and Its Relation to the Rise in the Proton-Proton Total Cross Section (Submitted to Phys. Rev.) |