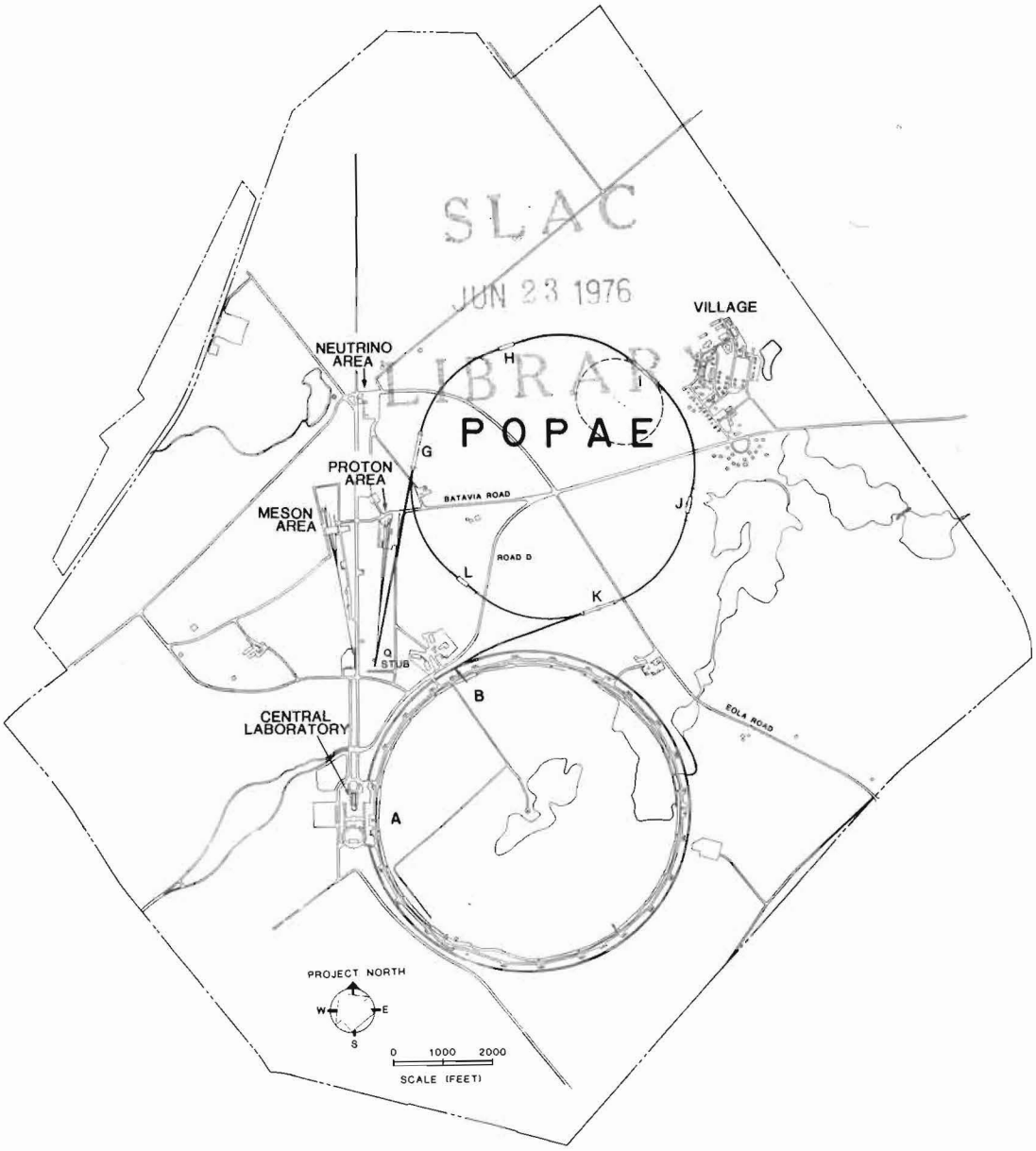
NALREP



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Monthly Report of the Fermi National Accelerator Laboratory

June 1976

Fermi National Accelerator Laboratory

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THE COVER: Location of POPAE on the Fermilab site (see page 8 for further details).

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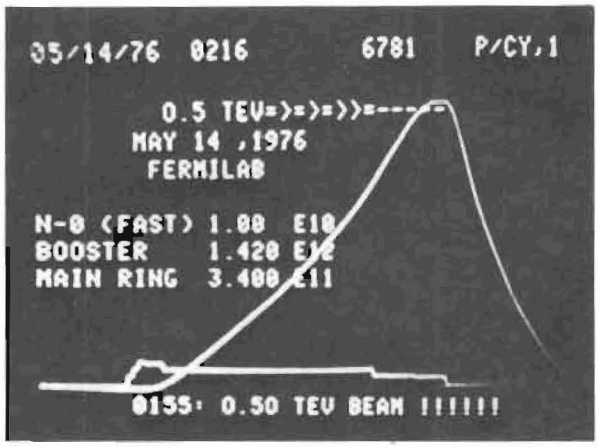
SPECIAL ANNOUNCEMENT

At 1:15 a.m. on Friday, May 14, a proton energy of 500 GeV (0.5 TeV) was achieved. This new milestone is the fruition of many months of effort. This energy was mentioned as a goal on the first page of the Laboratory's original Design Report in January, 1968.

It is especially gratifying to all that the accelerator operated at 500 GeV (0.5 TeV) for 6 hours without interruption for data-taking by Experiments 172 and 321.



POPAE DESIGN COLLABORATION

Reported by Robert Diebold, Argonne National Laboratory

The POPAE design project has been the focus of considerable activity the past few months at Fermilab and Argonne. The design work has been carried out by the two laboratories in collaboration. At this time, the design has been summarized in the form of a proposal for a proton-proton colliding-beam facility capable of 1000-GeV on 1000-GeV collisions at a luminosity of $4 \times 10^{33} cm^{-2} sec^{-1}$. The heart of the design is two proton storage rings located in a common tunnel and crossing one another at six points where the protons in one ring collide with those in the other ring.

The construction of this colliding-beam facility at Fermilab takes advantage of the substantial national investment in the facilities of the Laboratory. The present accelerator is itself a uniquely suitable device for filling storage rings with high-energy protons, and in a few years it is planned that the Energy Saver/Doubler (ES/D) will increase the available proton energy to approximately 1000 GeV. The research capabilities of the Laboratory can be extended in a natural and complementary way by the construction of POPAE.

High-energy storage rings are also being considered at other laboratories. Brookhaven National Laboratory has proposed a 200-GeV on 200-GeV proton-proton colliding-beam facility, ISABELLE, which would accelerate the protons from 30-GeV injection energy. CERN is studying the possibilities of 400-GeV on 400-GeV storage rings, which, like POPAE, would receive protons from an accelerator at the desired energy. As was discussed in the

April issue of NALREP, several smaller colliding-beam projects are also being considered at Fermilab. These projects might provide new knowledge that could be used to improve the design of larger rings. They would also no doubt whet our appetite for the higher energies and luminosities of POPAE, in much the same role that SPEAR has played for PEP.

The history of colliding beams at Fermilab goes back to 1968 when the Laboratory staff carried out a colliding-beam design exercise. In 1973 various possibilities for colliding beams at Fermilab were considered at a lively and productive summer study. Out of this study grew the recommendation that a system of pp and ep colliding beams be pursued, leading to the acronym POPAE or Protons On Protons And Electrons. Although other Laboratory needs were pressing, the work initiated at the summer study was continued by a small group at Fermilab through 1974 and into 1975.

In the fall of 1975, Robert Sachs of Argonne suggested that Argonne and Fermilab collaborate in a joint design study for POPAE. This proposal was welcomed by Robert Wilson for Fermilab, and since that time a collaborative effort has been actively developing a conceptual design for the project, leading to the submission of a report to ERDA. Although the proposal does not include the hardware for electron-proton collisions, the later addition of an electron storage ring could be made with a minimum of disruption and cost.

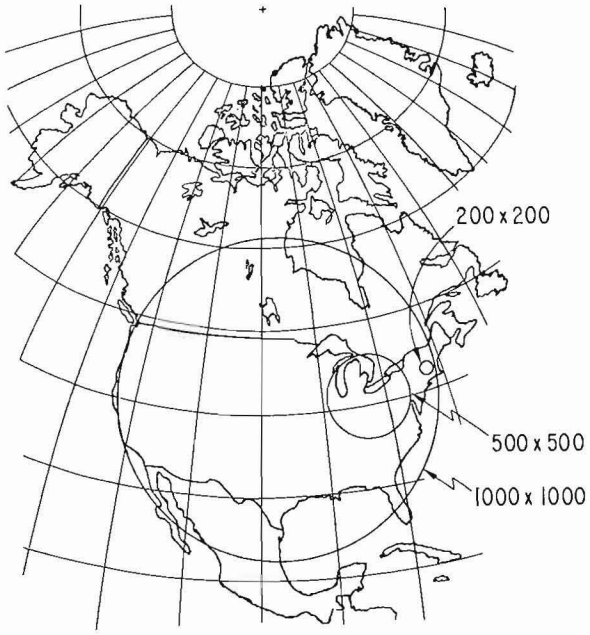
Reasons for Colliding Beams

The great advantage of colliding beams is of course the very large energy available to produce massive particles or to excite new types of interactions and forces. At fixed-target accelerators, beams interact with

targets at rest in the laboratory. As the beam energy increases, more and more of the beam energy is used just to conserve forward momentum in the laboratory. The useful amount of energy W available to cause interactions (the c.m. energy) increases only as the square root of the laboratory energy E, $W \approx (1.876\ E)^{\frac{1}{2}}$, where both W and E are in units of GeV. A factor of 10 increase in E requires a factor of 100 increase in the laboratory energy. For colliding beams, the situation is much more favorable: $W = 2E$, where E is the laboratory energy of each of the protons in a head-on collision.

At present, the world's only proton-proton colliding-beam facility is at CERN, the Intersecting Storage Rings (ISR). This facility gave an enormous increase in useful energy over that previously available at CERN, up to an energy equivalent to that of a 2000-GeV fixed-target accelerator. But this energy has since been approached by Fermilab, which is now running routinely at 400 GeV, has actually operated for physics experiments at 500 GeV, and should achieve 1000 GeV with the ES/D.

For further energy increases, however, colliding beams quickly outstrip the useful energy of fixed-target accelerators, even those that might conceivably be built as part of a world collaboration. This is illustrated in the drawing on the next page which shows the size of fixed-target accelerators required to match the useful energy of colliding beams of various energies. To match the 1000-GeV on 1000-GeV POPAE energy, a fixed-target accelerator with ES/D-strength magnets would very nearly encircle the contiguous 48 states and would have to run at more than 2,000,000 GeV.



Size of fixed-target accelerators required to achieve the same center-of-mass energy as proton-proton storage rings of the energies indicated (GeV).

Physics at 1000 GeV on 1000 GeV

The factor of 30 in energy over ISR offered by POPAE, combined with its high luminosity, would extend the observable mass range by more than a factor of 30. New kinds of particles and interactions might appear. The most important discovery coming from POPAE might be something completely unexpected.

One of the new particles expected to be found with colliding beams is the W meson, the intermediate vector boson. Even if its mass and cross sections differ considerably from the present predictions, we should be able to examine the properties of this particle in detail. If it is not found at POPAE, a major change in our present understanding of the weak force will be required.

A way of estimating cross sections for W-boson production is provided by the Drell-Yan mechanism. According to this model, a quark from one proton combines with an antiquark from the other proton to produce a massive photon or intermediate vector boson.

Similar predictions for neutral intermediate boson (Z^o) cross sections are about three times smaller, a production rate of several per minute at a mass of 600 GeV, or a few tens of Z^o's per day at 1200 GeV.

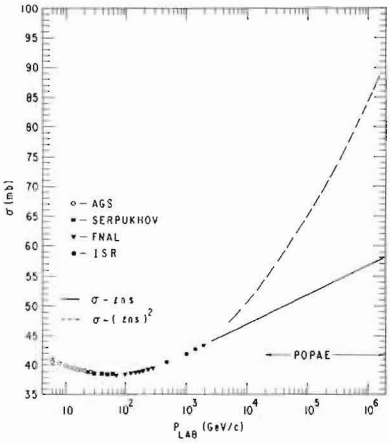
Heavy-lepton pairs are also of interest. The materialization of these "heavy γ rays" into massive lepton pairs will give information on proton structure down to very small distances. In addition to e^+e^- and $\mu^+\mu^-$ decays, such states could also decay to new heavy leptons L^+L^-.

The cross sections for weak interactions become large enough to be studied with final states containing e_ν, μ_ν, or L_ν. At 1000 GeV on 1000 GeV, the cross section for each of these states is estimated to be on the order of $10^{-34}cm^2$, with roughly 10% of them having a lepton-neutrino mass of 500 GeV or more and a production rate of about 2 per minute.

In addition to W mesons and heavy leptons, other new types of particles may be found. Magnetic monopoles and quarks have long been predicted, and the discovery of either one of these would have a large impact on science, and possibly on technology as well.

While the weak and electromagnetic interactions presently appear to be the most exciting areas for exploration in our search for new phenomena, strong-interaction processes promise a new richness of their own. The increase with energy of the proton-proton total cross section σ_T (total

probability of a collision) in the ISR range was a remarkable surprise. We do not yet understand what the rise means. It could be a threshold effect associated with the production of very heavy particles, in which case POPAE investigations may result in the discovery of these particles and yield a new constant value of σ_T. On the other hand, several theories suggest that the rise is a truly asymptotic effect. Present extrapolations suggest, as shown in the graph at the right, values of σ_T ranging from 50 to 90 mb at 1000 GeV on 1000 GeV, up to twice that measured at present Fermilab energies.



Total cross-section data and two possible phenomenological extrapolations.

Storage-Ring Design

The location on the Fermilab site proposed for POPAE is shown on the cover. The two rings will be housed in a common tunnel of circumference 5.5 km (slightly smaller than the 6.3 km of the Main Ring). This tunnel will be located in an area bounded by the Main Ring, the Proton Laboratory, and the Village, a region rather level and free of obstructions. This position results in nearly straight injection lines to the storage rings. These lines will consist mainly of buried vacuum pipe with quadrupole doublets every 150 m for focusing; they will be relatively inexpensive both to build and to operate. One of these lines will originate at the "Q stub" of the Proton Area and the other from a new extraction point at the B-0 straight section. The

future electron ring is shown dashed on the cover near the Village. It has a size to yield an ep luminosity of $10^{32} cm^{-2} sec^{-1}$ at an electron energy of 10 GeV [$(s)^{\frac{1}{2}}$ = 200 GeV], with 5 MW of synchrotron radiation. The luminosity at 20 GeV would be $4 \times 10^{30} cm^{-2} sec^{-1}$, still a respectable number.

Each storage ring will have six 720-m long curved sections, separated by 200-m long straight sections where the beams are focused and cross one another. Each 720-m long sextant is composed of 12 lattice cells, each having eight 6-m long bending magnets with a field of 60 kG at 1000 GeV. The focusing in the two end cells of each sextant is slightly modified to make the dispersion zero in the straight sections. This allows the beams to be focused down to small spots at the intersection points, independent of the momentum spread. One bending magnet also is omitted from the end cells of the inner ring to achieve in a natural way the horizontal crossing of the beams at 11 mrad.

Injection into the storage rings will be handled in a manner similar to that used at the ISR, making use of rf stacking in momentum space. To obtain maximum brightness and thus the highest interaction rates, injection will be accomplished with less than maximum intensity from the ES/D. To fill one ring to the design value of 5 A will take 6×10^{14} protons, 66 accelerator pulses at 10^{13} per pulse. The time to do this will range from a few minutes at low energies to about one hour at 1000 GeV. Each ring can store high beam currents at energies between 100 GeV and 1000 GeV, and unequal energy operation is possible. There is no firm low-energy limit and although

the attainable luminosity falls with decreasing energy, some experiments should be possible even below 100 GeV.

Some typical operating parameters are shown in the table below.

Typical Performance Parameters.

Type of Insertion	Injection Crossing	High β_v^*	Low β_v^*			High Luminosity
			Large Angle		Small Angle	
Energy (GeV)	1000	1000	100	1000	1000	1000
Luminosity $10^{33}\,cm^{-2}sec^{-1}$	0.041	0.029	0.12	0.26	2.8	4.5
Tune shift (10^{-3})	3	4	2	0.4	5	4
Crossing angle (mrad)	11	11	11	11	1	1
Free space (m)	±28	±45	±45	±45	±10	±10
$\ell_{interaction}$ (m)	0.2	0.1	0.2	0.1	0.9	0.4
β_v^* (m)	~100	200	2.5	2.5	2.5	1
β_h^* (m)	~80	12.4	13.5	13.5	13.5	3
β_{max} (m)	550	680	810	810	810	1080

The luminosity $\mathcal{L}$ is second in importance only to the energy. It is defined such that the number of events N produced with cross section σ in time t is $N = \mathcal{L}\sigma t$. For operational ease, the rings will be tuned initially with fairly gentle focusing in the interaction regions. Later, stronger focusing will permit the luminosity to be increased to the design value of $4 \times 10^{33}\,cm^{-2}sec^{-1}$ and perhaps beyond. This is two or three orders of magnitude higher than the values obtained at the ISR. This increase in luminosity is possible even with a lower proton current thanks to the high energy; the beams are smaller in size and a smaller crossing angle can be

used without the beam-beam tune shift becoming important. The high luminosity should help considerably in experiments looking for rare processes. For example, at this luminosity a process with cross section $10^{-38}\,cm^2$ will yield a few events per day. There appears to be no hard limit on the stored proton current, and it may eventually be possible to store more than the design current of 5 A, possibly giving $\mathcal{L} \gtrsim 10^{34}\,cm^{-2}\,sec^{-1}$.

Although all six intersection regions can be used for elementary-particle experiments, we expect that one of the two injection/dump straight sections will be reserved for accelerator-physics equipment and experiments, including a luminosity-measuring device. The other injection/dump region will be limited to experiments requiring "low" luminosity ($4 \times 10^{31}\,cm^{-2}\,sec^{-1}$--still more than the present maximum at the ISR). The remaining four intersections might each have two or three experiments each, as at the ISR.

Magnets

There are several clear advantages to using superconducting magnets for high-energy storage rings. The most obvious is the power saving, which amounts to hundreds of megawatts. Another is the length of the expensive underground tunnel, which can be reduced by a factor of two or three because of the higher fields obtainable. This saves not only real estate and tunnel costs, but also improves the quality of the machine by reducing the sensitivity to various instabilities. Fortunately, superconducting technology has been moving ahead in the past few years to the point where one can confidently predict its successful application to high-energy storage rings. A

design field of 60 kG at 1000 GeV has been chosen. This field is somewhat higher than the 40 to 45 kG of present accelerator projects, all of which were started several years ago. With the steady improvements in technology, 60-kG superconducting dc dipoles now seem quite feasible, and this field is a worthy goal for the next step in dipole technology. For POPAE, this high field will result in both cost savings and a better behaved machine compared with lower-field designs.

Magnets using NbTi superconductor at 60 kG have somewhat different design characteristics than those for 40 to 45 kG magnets. Considerably more superconductor must be properly arranged around the bore, and, at the same time, adequate support must be supplied for the increased forces. At these high fields, flat rectangular-block coils become attractive, especially since the dc character of POPAE operation allows generous use of metal in the support structure.

The block-coil design is being studied in detail, and winding and testing of model coils has begun. In FY 77, prototype magnets will be constructed to refine the design and provide more reliable cost estimates. Although the block coil design appears promising at present, when the time comes to start production fabrication of the magnets, the most cost-effective magnet design with adequate field quality will be used.

Since protons are stored at a fixed energy, and the high-current beam is not accelerated, several of the design criteria commonly imposed on pulsed magnets can be relaxed. Rectangular monolithic wire or cable can be utilized instead of braid, thus saving the expense of braiding as well as

improving the packing fraction of the coil. A thick metal bore tube can be employed for mechanical rigidity, without concern for the eddy currents that degrade the field quality of a pulsed magnet. A dc magnet has less stringent requirements on the insulation between superconducting elements and does not require field corrections that depend on the rate at which the magnet is ramped.

Vacuum

The vacuum will be primarily a cold-bore system, with warm bore only in the straight sections. This is a natural choice for superconducting magnets and takes advantage of the extremely high pumping speeds available at liquid helium temperatures. With high-vacuum preparation of materials, a vacuum of about 10^{-11} Torr will be obtained in the warm-bore sections, while better than 10^{-13} Torr is expected from the cold-bore regions. With the high pumping speed of a cold-bore system and the relatively low beam current, it should not be difficult to avoid the pressure bump problem seen at the ISR.

Although a cold-bore system is somewhat less flexible than warm bore, it is very attractive due to simplifications of construction, low heat leak, very low residual gas density, and large reduction in the number of conventional vacuum pumps required. Such considerations have led to its adoption in the ES/D and in the Lawrence Berkeley Laboratory ESCAR project.

Cost Estimate and Schedule

The total construction cost of the system, including engineering, contingency, etc., is estimated to be $245 M in 1976 dollars. With inflation this becomes $295 M. If the project were authorized for FY 78, with a vigorous magnet-development program in the meantime to allow production fabrication of magnets to begin in 1979, high energy physics experiments could start exploring the new frontier in 1982.

A cost estimate was also made for a 500 GeV on 500 GeV storage-ring system. That system was assumed to be built in the same tunnel as the one that accommodates the 1000 GeV on 1000 GeV set of rings described above. The energy capability is reduced by reducing the magnetic-field intensity from 60 kG to 30 kG. The cost of the 500 GeV on 500 GeV system is estimated to be $145 M in 1976 dollars.

Historical Perspective

In this bicentennial year it is appropriate that we end on an historical note. The westward development of this country was spurred on in large measure by the frontiersman's curiosity as to what lay over the horizon. In this tradition, POPAE will provide us a giant step beyond the horizon of our present frontier. What we will find can only be imagined. With so much energy available, one might dream of a land rich with new and wonderful phenomena. Theorists have long predicted W's, quarks, and monopoles, but nature has previously shown herself to be more inventive than man. Westward, Ho!

RESEARCH ACTIVITIES DURING MAY 1976

Reported by Halsey Allen

A long-term goal of the Fermilab accelerator facility was realized at 1:55 a.m. on Friday morning, May 14, when the first pulses of beam were accelerated to 500 GeV (0.5 TeV). This achievement was the culmination of a period of accelerator studies that began on the previous Tuesday. The beam was coaxed from 450 to 480 and then 492 GeV over the succeeding two nights of high-energy testing. After a day of accelerator maintenance and a change in the main-ring tune on Thursday, studies were resumed in the evening which led to the long-sought milestone. Key to the success of the endeavor was steady operation, particularly on Thursday and Friday, of the "Capacitor Tree" condenser bank used to sustain the line voltage during the high peak-power pulse required to produce the 500-GeV magnet ramp. Once achieved, 500-GeV operation continued smoothly at $1\text{-}2\times10^{12}$ ppp for six of the following seven hours with fast-spilled beam extracted to the Neutrino Area for about 70% of this time. The stable operation, coupled with good performance of the 15-ft bubble chamber, made it possible to obtain over 700 pictures in the heavy neon-hydrogen mixture using a neutrino-antineutrino beam produced by the 0.5-TeV incident-proton antineutrino beam. In addition, p-p Inelastic #321 at the Internal Target Area collected scattering data with their hydrogen gas jet during nearly all of the 0.5 TeV running time. Samples of both sets of data obtained in the short 500-GeV run were available at the opening of the Annual Users Meeting later that same morning. The results of these studies were a highlight of the May operation.

Insofar as running for the scheduled May high-energy physics research program is concerned, four different modes of accelerator operation were employed. When the neutrino and antineutrino programs were operational, using the focusing horn and 15-ft bubble chamber, both slow and fast spills were delivered from a 400-GeV one-second flattop. When the horn failed and was being repaired during the first week in May, slow spill only from a 1.25-second flattop was sent to the Meson and Proton Areas. On May 24 and 25 there were some five shifts of running with a 100-millisecond flattop, a 7 to 9 second cycle period and a high-intensity fast extracted beam to the Neutrino Area only, to expedite the antineutrino run by Experiment #172. This run was cut slightly short of a 50,000 picture goal by combined accelerator and 15-ft chamber cooling-loop failures. For the final five days of the month, including the long Memorial Day weekend, 300-GeV operation was established with slow spill only and a 2-second flattop to provide beam to the Meson and Proton Areas.

Reliability of operations for the overall high-energy physics program during May was 68%, with over 455 hours of beam time available. The major interruption was once again caused by the failure of a main-ring feeder cable, which cost some six shifts of downtime. Plans are currently being drawn up to upgrade many splices and lengths of cable in the system that are known to have been severely weakened. Other assorted failures scattered throughout the month reduced the overall performance to an "average" level.

The research program in the Neutrino Area received highest priority during the periods that it was in operation during May. The total running

time for this work amounted to only about two weeks. The 15-ft run of ν/H_2 & Ne #53A ended on May 3 as the result of a horn-train failure, having received a total of 64,421 pictures, some of which were taken with a bare target. The trainload was then repaired and modified to permit operation with Horn #2 only; this was followed by a nine day 48,539 picture run by 15-ft $\bar{\nu}/H_2$ & Ne #172. Particle Search #247 continued to express their emulsions in the neutrino beam, in conjunction with the running for Experiment #53A and a portion of Experiment #172, and completed their experiment on May 18. Meanwhile, Muon #319 and Muon #398 used hadrons in the N1 beamline, from low-intensity spill on the horn target, or a bare target, to do some equipment testing prior to runs planned for this summer. During the second weekend in May, negative pion beams at 25 and 50 GeV/c were also directed into the 15-ft chamber, using the N5 bypass line, for some calibration tests. The Neutrino Area was shut down on May 26 for cool down and to begin preparations for installation of the quadrupole triplet trainload.

In the Proton Area, three experiments ran during the month, one in each of the main beams. Di-Lepton #288 had completed the di-muon data taking phase of their work in Proton-Center by May 24, when several days were taken to rerig the apparatus and set up for di-electron and di-hadron running. Startup and momentum calibration in this configuration was well underway by June 1. In Proton-East, Particle Search #325 collected high-p_T data with 400-GeV and later 300-GeV beam incident on their solid targets. Photon Search #95A also collected data throughout the month using their two-arm spectrometer set up in Proton-West.

Five experiments were running and collecting data during May in the secondary beams of the Meson Area, which was also in standby for the short period of exclusive fast-spill operation. In the east branch of M1, Polarized Scattering #61 completed beamline tuneup, check-out of their apparatus, and debugging of the polarized target early in the month and then took data with the incident beam tuned for both plus and minus 100 GeV/c. Particle Search #357, running in M2, added to their data on various two-body final states produced using the diffracted-proton beam; much of this was with a modified targeting scheme to suppress backgrounds for short-lived particles. Particle Search #366 continued to amass data on high-mass di-hadron production, using the M3 neutron beam while in the other neutral beam, M4, K^o Regeneration #425 completed the data-taking phase of their experiment. The M6E beamline was utilized throughout the period by Inclusive Scattering #118A using the Single Arm Spectrometer. All except the latter experiment benefited greatly from the increase in duty factor that resulted during the period of accelerator running at 300 GeV with the 2-second flattop.

At the Internal Target Area, three user groups have continued to use the circulating proton beam. p-N Scattering #198A and p-p Polarization #313 are both using the superconducting magnet spectrometer arm to collect data, alternating as the prime user on successive weeks. Some preliminary data have been taken by both groups but progress has been slowed by a series of difficulties with the helium liquifier. The rotating target has been utilized on several occasions for equipment testing and debugging purposes. Meanwhile, p-p Inelastic #321 has continued to collect data at various beam

energies using their 3-mil warm gas jet. They have continued to work on reducing their backgrounds with considerable success and now routinely pulse the jet three times per accelerator cycle, typically at 50, 200, and 400 GeV. In addition, testing and debugging of equipment was a continuing effort on the part of the p-N Scattering #381 users.

FACILITY UTILIZATION SUMMARY -- MAY 1976

I. Summary of Accelerator Operations

		Hours	
A. Accelerator use for physics research			
Accelerator physics research		47.9	
High energy physics research		455.4	
Research during other use		(44.4)	
	Subtotal		503.3
B. Other activities			
Accelerator setup and tuning to experimental areas		3.0	
Scheduled interruption		24.4	
Unscheduled interruption		213.3	
	Subtotal		240.7
C. Unmanned time			
	Total		744.0

II. Summaries of High Energy Physics Research Use

	# of Expts.	Hours	Results
A. Counter experiments	14	3794.5	
B. Bubble-chamber experiments	2	210.5	55,617 pictures
C. Emulsion experiments	-	-	
D. Special target experiments	-	-	
E. Test experiments	-	-	
F. Engineering studies and tests	3	18.6	4024 pictures; 2 targets
G. Other beam use		27.3	Beamline tuning
	19	4050.9	2 experiments completed

III. Number of Protons Accelerated and Delivered ($\times 10^{18}$)

A. Beam accelerated in Main Ring	@ 400 GeV	1.485*		
	@ 300 GeV	0.651		
				2.136
B. Beam delivered to experimental areas				
Meson Area	@ 400 GeV	0.315		
	@ 300 GeV	0.322		
			0.637	
Neutrino Area				
Slow Spill	@ 400 GeV	0.034		
Fast Spill	@ 400 GeV	0.639		
			0.673	
Proton Area	@ 400 GeV	0.208		
	@ 300 GeV	0.193		
			0.401	
Total				1.711

*Includes 2.2×10^{15} protons accelerated during 450-, 480-, and 500-GeV studies, 5/11-5/14.

IV. Beam Utilization By Experiment

	Hours	Results
A. Meson Area		
Polarized Scattering #61	319.2	Data
Inclusive Scattering #118A	376.3	Data
Particle Search #357	393.2	Data
Particle Search #366	406.3	Data
K^0 Regeneration #425	209.3	Data; completed
B. Neutrino Area		
15' ν/H_2 & Ne #53A	55.6	7,078 pictures
15' $\bar{\nu}/H_2$ & Ne #172	154.9	48,539 pictures
Particle Search #247	40.6	Data; completed
Muon #319	68.6	Tests
Muon #398	156.2	Tests
C. Proton Area		
Photon Search #95A	359.3	Calibration and data
Di-Lepton #288	320.8	Data
Particle Search #325	394.0	Data
D. Internal Target Area		
p-N Scattering #198A	259.3	Tests and data
p-p Polarization #313	267.9	Tests and data
p-p Inelastic #321	223.5	Data
Total	4005.0	

MANUSCRIPTS AND NOTES PREPARED DURING MAY AND JUNE 1976

Copies of preprints with Fermilab publication numbers can be obtained from the Publications Office or Theoretical Physics Department, 3rd floor east, Central Laboratory. Copies of some articles listed are on the reference shelf in the Fermilab Library.

Experimental Physics

C. A. Ayre and M. J. Longo Experiment #4	Comparison of High Energy Neutron-Nucleus Total Cross Sections with Theory
S. B. Kaufman et al. Experiment #81A	Nuclear Reactions of ^{197}Au with 11.5- and 300-GeV Protons
R. L. Anderson et al. (Fermilab Single Arm Spectrometer Group) Experiment #96	Elastic Scattering Crossovers from 50 to 175 GeV (FERMILAB-Pub-76/47-EXP; submitted to Phys. Rev. Lett.)
H. L. Anderson et al. Experiment #98	Measurement of Nucleon Structure Function in Muon Scattering at 147 GeV/c (Submitted to Phys. Rev. Lett.)
L. W. Mo Experiment #98	High Energy Muon Scatterings at Fermilab/Serpukhov (Rapporteur's talk presented at the 1975 International Symposium on Lepton and Photon Interactions at High Energies, Stanford University, August 21-27, 1975)
R. Wilson Experiment #98	Scattering of Muons at 150 GeV (Presented at Erice Summer School, 1975)
C. Bromberg et al. Experiment #228	Cross Sections and Charged Particle Multiplicities in π^+p and pp Collisions at 60 GeV/c (Submitted to Phys. Rev.)
G. Donaldson et al. Experiment #268	Inclusive π^0 Production at Large Transverse Momentum from $\pi^\pm p$ and pp Interactions at 100 and 200 GeV/c [Phys. Rev. Lett. 36, 1110 (1976)]
H. R. Gustafson et al. Experiment #330	Search for New Massive Long-Lived Neutral Particles

D. Bintinger et al. Experiment #357	A Search for New Particles in Proton-Nucleus Collisions at 400 GeV/c (Submitted to the Proceedings of the II International Conference on New Results in High Energy Physics, Vanderbilt University, March 1-3, 1976)
M. Binkley et al. Experiment #358	Dimuon Production on Nuclear Targets (FERMILAB (FERMILAB-Pub-76/41-EXP; submitted to Phys. Rev. Lett.)
M. Binkley et al. Experiment #358	Dynamics of Inclusive Dimuon Production (FERMILAB-Pub-76/42-EXP; submitted to Phys. Rev. Lett.)
V. Cook et al. (SOD Collaboration) Experiment #416	Search for New States Which Decay Semi-Leptonically (Presented by H. J. Lubatti at the II International Conference on New Results in High Energy Physics, Vanderbilt University, March 1-3, 1976)

Theoretical Physics

W. A. Bardeen and R. B. Pearson	Local Gauge Invariance and the Bound State Nature of Hadrons (FERMILAB-Pub-76/24-THY; submitted to Phys. Rev.)
C. H. Albright and R. J. Oakes	Meson Masses and Electromagnetic Decays in Six Quark Models (FERMILAB-Pub-76/27-THY; submitted to Phys. Rev.)
M. B. Einhorn et al.	Comment on Hadronic Production of Psions (FERMILAB-Pub-76/29-THY; submitted to Phys. Rev. Comments)
C. Quigg	Postlude - Concluding Remarks at the II International Conference on New Results in High Energy Physics, Vanderbilt University, March 1-3, 1976 (FERMILAB-Conf-76/30-THY)
W. A. Bardeen et al.	Phase Transition in the Nonlinear σ Model in a $2 + \epsilon$ Dimensional Continuum (FERMILAB-Pub-76/33-THY; submitted to Phys. Rev.)

General

J. Whitmore	Multiparticle Production in the Fermilab Bubble Chambers

B. L. Chrisman	Auto-Correlations with Irregular Signals (Submitted to Nucl. Instr. and Methods)

Physics Notes

L. Cohen and M. Awschalom FN-291	The Cancer Therapy Facility at the Fermi National Accelerator Laboratory: A Preliminary Report

DATES TO REMEMBER

June 28 - July 9, 1976	Summer Study on the Use of the Energy Saver/ Doubler.
July 15, 1976	Deadline for receipt of reservations for Fall housing.