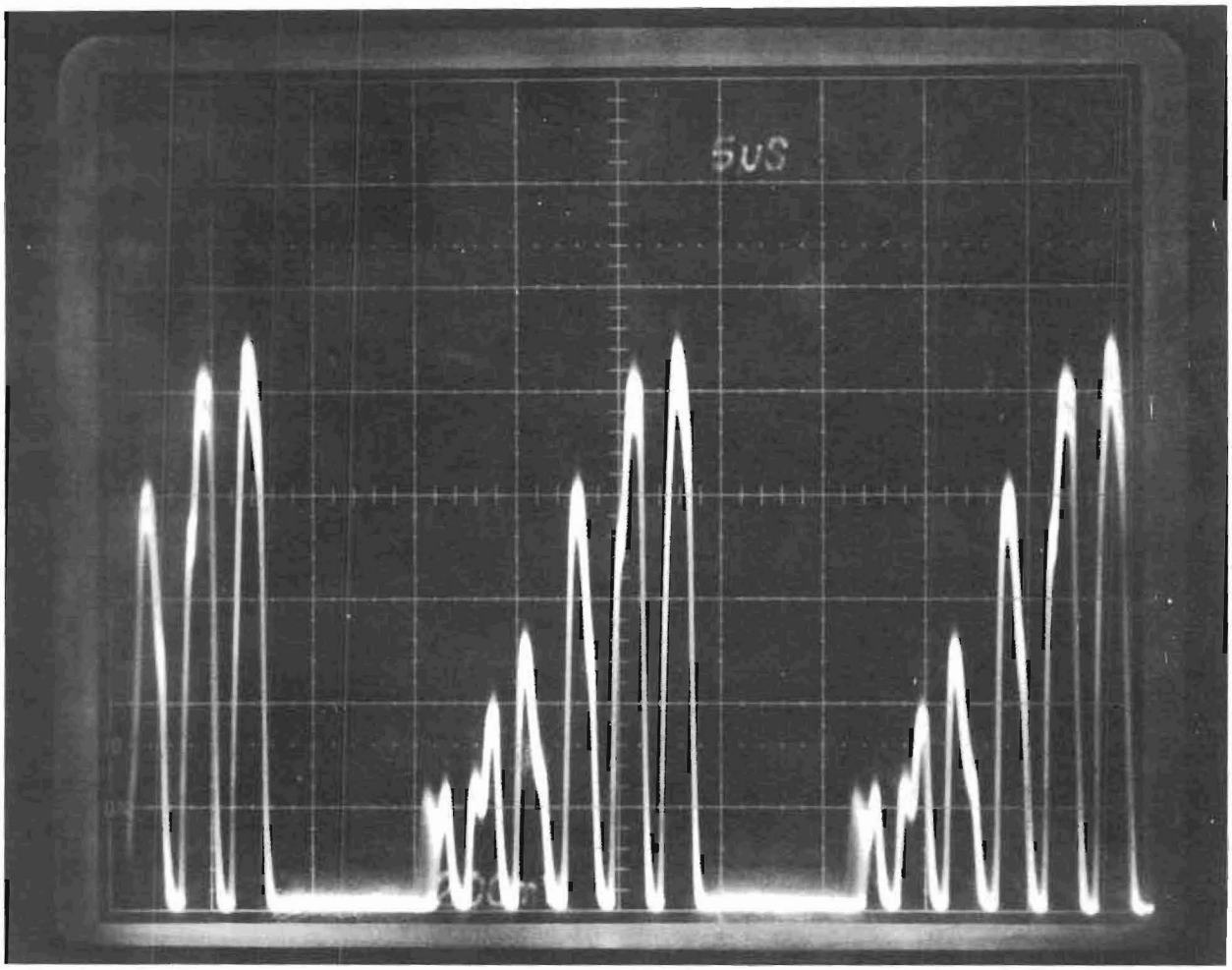
national accelerator laboratory

NAL-79
0090.01

MONTHLY REPORT OF ACTIVITIES

October 31, 1972



SIX BOOSTER PULSES ACCELERATED TO 200 GeV

Operated by Universities Research Association Inc. Under Contract with the United States Atomic Energy Commission

THE COVER: See first paragraph of text.

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Abstract: This report summarizes the activities of the National Accelerator Laboratory in October, 1972.

Cover

Up to six booster pulses have been injected into the main ring and accelerated to 200 GeV. In a project led by E. Hubbard and B. Peters the number of pulses is now limited only by the overheating of blocking capacitors in the booster rf systems. These capacitors are being replaced by the new ceramic models as they are delivered. Intensities of up to 5×10^{11} protons per pulse have been achieved and main-ring multipulse injection has been regularly used for high-energy physics.

Operating Record

	Hours	Per Cent
Beam Delivered for High-Energy Physics	311	42
Accelerator Studies	168	23
Start-Up	33	5
Accelerator Failure	148	20
Accelerator Off (all other causes)	18	2
Scheduled Shutdown	66	9
	744	100

Internal Target Area

The hydrogen jet operated reliably throughout the month with approximately 53 hours of beam interaction. During the month a new helium-recovery tank was installed and operated. This system recovers 75% of the helium used for the jet operation.

Experiments

pp-Elastic Scattering #36. Approximately 1.8×10^6 elastic-scattering events from the hydrogen jet target have been obtained at 14 energies between 36 and 190 GeV in the t range 0.003-0.16 $(\mathrm{GeV/c})^2$. The analysis of some of these data shows an improvement in the determination of the average radius of the proton, i.e., the error in the slope parameter, b, is now ±0.2, or one half that obtained in the CH_2 foil experiment this summer. Preliminary values of Re A/ImA are also coming out of the data, but the Coulomb-interference part of the experiment will probably be repeated later with better detectors.

303-GeV/c Bubble Chamber #37A. All tracks with laboratory momentum < 1.4 GeV/c have been measured. With this criterion it is possible to distinguish pions from protons in an unambiguous manner if one neglects the small contamination from kaons. In the $(p\pi^+)$ effective mass plot substantial $\Delta^{++}(1238)$ production is observed in the inclusive reaction $pp \rightarrow \Delta^{++}$ + anything. The measured cross section is > 4 mb (after putting in a factor of 2 for c.m. symmetry). This is to be compared with ~7 mb for the same reaction at 6.6 GeV/c.

Photon Search #63. Gamma rays are being detected at 100 millirads from both the gas jet and the rotating target. The following characteristics of the system have now been determined.

1. The target in/out effect is $\gtrsim 100/1$.
2. The gamma-ray converter in/out effect is $\gtrsim 20/1$.
3. Scattering from the edges of collimators into our detection system is less than 2% of direct gamma rays.
4. Singles rates in our detectors are such that we can run with less than 3% random coincidences at 10^{11} protons and the foil target. Singles rates are lower for fiber targets and the gas jet.

5. Muons are used to provide a clean and continuous calibration of all counters in the detection system.

6. The output pulse of the lead glass counter has been checked to be linear up to at least 60 GeV equivalent gamma-ray energy.

7. Preliminary data has been taken with the gas jet target in the range $0.1 \leq p_{\perp}(\mathrm{GeV/c}) \leq 1.5$.

8. Preliminary data has been taken with the rotating target in the range $0.1 \lesssim p\ (\mathrm{GeV/c}) \lesssim 3$.

9. Further checks on systematic errors are being made on the data and in particular on our monitoring system.

10. Measurements of gamma rays from the hydrogen gas jet indicate a source distribution which is somewhat more diffuse than expected. Further detailed measurements on this effect will be required.

pp-Inelastic Scattering #67. This experiment has used the two jet target periods (9/30 to 10/2 and 10/14 to 10/15) to collect data on $pp \rightarrow pX$ away from the Jacobian peak. The physics objective is to obtain information on this reaction in a limited region of phase space where a simple triple Regge model has been used successfully to fit ISR and sub-NAL energies. These fits rely mainly on the M_x^2 dependence of the invariant cross section and cannot distinguish between the triple pomeron (PPP) and pomeron-pomeron-meson (PPf) couplings. By studying the s dependence of the cross section one can differentiate between these two terms.

Meson Area

Two operating periods were scheduled in October, the 12th to the 13th and the 26th and 27th. During the first period R. Lundy, A. Wehmann, and their colleagues succeeded in focusing protons on the target but the experimenters in the M3 and M4 lines observed only minute fluxes of particles. This effect was subsequently traced to an alignment problem with the train which was corrected.

The second run enjoyed beam for only a few hours. The particle yields measured in the M2, M3, and M4 lines were much higher than before but still less than expected. Again alignment problems are the most likely explanation.

Neutrino Area

Under the direction of R. Huson, G. Mulholland, and J. Purcell (ANL), the superconducting magnet for the 15-ft bubble chamber was cooled down, filled from the liquid-helium storage dewar, operated to full field (30 kG) on October 10 and the liquid helium returned to storage. All functions of the helium liquifier, cooldown exchanger, low and high pressure storage, transfer-line system, and magnet were successfully exercised.

Proton Area

During a 24-hour run this month, much was accomplished in determining and tuning the proton-beam trajectory in the switchyard.

Quadrupole tuning showed a reasonable agreement with calculations but consistently indicated a large effective emittance at H Enclosure and at the Proton Lab (0.2π-0.6π mm-mrad). J. Peoples and A. Read report this large emittance was a fundamental problem making steering cleanly through H Enclosure very difficult. It is felt that this was due both to the large number of flags in the beam and thick Al windows in the line in the Transfer Hall. The total material amounting to about 3/4 in. of Al has been removed for the next run and flags will be remotely removable. Preliminary indications from the October run were that equipment has been located close to the actual beam trajectory.

Other Experiments

The energy dependence of the backward peak in $\pi^+ p$ scattering was measured in an experiment carried out by an NAL group at ANL's ZGS. This group, which included W. Baker, D. Eartly, K. Pretzl, S. Pruss, and A. Wehmann, worked in collaboration with physicists from Argonne and the University of Notre Dame.

A double focusing spectrometer was designed for this experiment. It separated the forward-going recoil protons from beam particles and forward-scattered mesons. Because of the high resolution of the spectrometer, only counters were required as detectors. This new technique permitted data to be taken at high rates compared to previous experiments. It was thus possible to run with beam intensities as high as three million particles per burst. The energy dependence was measured from 2 to 6 GeV/c in 100 MeV/c steps with good statistical accuracy.

The data show considerable structure which is interpreted as due to doubly-charged, S-channel Δ resonances. In addition to previously known resonances at 2800 and 2850 MeV the experiment established the existence of a resonance of mass approximately 3230 MeV. This resonance was predicted by theory as the next expected on the Δ_δ trajectory. Its spin is predicted to be 19/2 and it has positive parity.

A deep dip in the energy distribution was observed at an incident momentum of 2.1 GeV/c. Fits to this data made by K. Pretzl show that this cannot be explained simply as a gap between the 1950 and the 2400-MeV resonances which lie on the Δ_δ trajectory. It can only be explained as due to a resonance with negative parity and of mass approximately 2160 MeV. This

therefore is the first experimental proof of the existence of a new Δ trajectory with negative parity.

One purpose of this experiment was to test the feasibility of using a strong focusing spectrometer for hadron scattering studies at NAL. This technique is particularly well-suited to NAL energies where the backward scattering cross sections are expected to be very low and the high beam intensity capabilities are required. Some members of the group which performed this experiment that discovered two new resonances plan to propose a continuation at NAL.

Accelerator

The linac operated at design intensity (67.5 mA) for significant periods during October, including one 24-hour continuous stretch. Little or no prime time was devoted to linac studies or tuning to improve beam, but C. Curtis and C. Owen conducted a series of emittance measurements on a parasitic basis. The transverse emittances were measured to be approximately 3.4 mrad-cm, compared with a design value of π mrad-cm. The relative momentum spread without a debuncher was measured to be 2.8×10^{-3} (after an estimated correction for transverse emittance), compared with the design value of 2.7×10^{-3} (also without debuncher).

In addition to the achievement of multipulse injection into the main ring, E. Hubbard and R. Peters have had some success in attaining multiturn injection into the booster. Two turns have been injected and captured but there has been little success with third and fourth-turn injection (design criterion is four-turn acceleration). Detailed studies are in progress to understand the problems.

In the main accelerator, even the single-pulse intensity is improving. There have been significant periods when we have operated at 0.6 to 0.8×10^{11} protons per pulse with very good stability. With the best tuning conditions, approximately 30% of the beam is lost at injection. The lifetime of the coasting beam is approximately 2 seconds.

Twelve main-ring quadrupoles were realigned by rotation about the beam axis. S. Mori reports that this reduced the coupling between radial and vertical oscillations to a small fraction of its former value. It did not appear to increase the coasting-beam lifetime.

The vertical-orbit distortion was increased by this rotation and quadrupoles were realigned vertically to reduce this. The vertical-orbit distortion is now back to its former value of ±1/4 in.

Four bending magnets and one quadrupole shorted and were replaced in October. All were old magnets from early in the production sequence. L. Sauer notes that no magnet of the present unit construction (integrally impregnated) variety has ever shorted.

Almost all of the power-supply module problems now being encountered are caused by water leaks. No thyristors have had to be replaced this month. R. Cassel and R. Trendler succeeded in increasing the rate of rise of the main-ring field from 68 to 100 GeV/sec (compared with the design rate of 125 GeV/sec). No problems were encountered in operation. The system has operated up to 115 GeV/sec.

At least once a month temperature and humidity readings are taken in the main-ring tunnel. Two complete sets were taken by P. Gavin with the following results.

	Temperature (°F)				Relative Humidity (%)			
Date	High	Low	Average	Outside	High	Low	Average	Outside
10/2	86	79	83	77	50	38	44	45
10/24	86	70	82	46	40	29	33	79

For comparison, the following were recorded on June 28 of this year:

Temperature (°F)				Relative Humidity (%)			
High	Low	Average	Outside	High	Low	Average	Outside
85	73	77	73	50	32	43	61

It appears that the tunnel is settling down to steady conditions with only small variations with season.

Fig. 1. "Topping out" of Meson Building.

Fig. 2. View to the southwest from the 15th floor of the Central Laboratory Building.

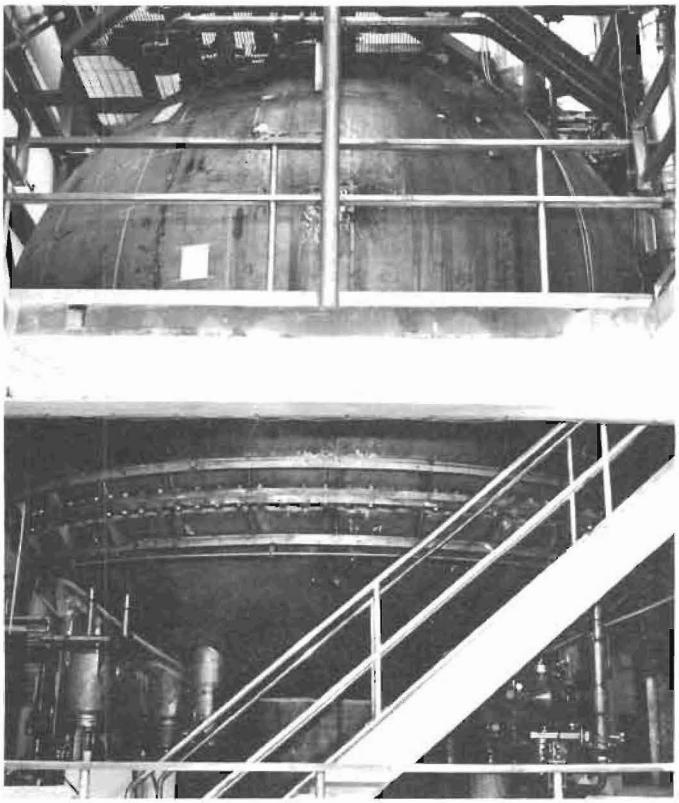

Fig. 3. Fifteen-foot bubble chamber in place.