Title
BEVATRON OPERATION AND DEVELOPMENT. VIII

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Publication Date
1956-03-01

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Contract No. W-7405-eng-48

BEVATRON OPERATION AND DEVELOPMENT. VIII
November, December 1955, January 1956

Walter Hartsough

March 1, 1956

Printed for the U. S. Atomic Energy Commission

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Contents

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ABSTRACT

The nuclear absorption of antiprotons in copper, beryllium, and lead glass was measured during this quarter. The annihilation of antiprotons was investigated, and two groups made emulsion exposures in the focused antiproton beams. Total cross-section measurements for π^+ mesons continued; $\theta^0{}_2$ interactions were investigated, using a cloud chamber; and π^--meson scattering was done with a 10-inch liquid-hydrogen bubble chamber. The detection and lifetime measurements of τ^+, $K^+{}_{\mu 2}$ mesons, and $K^+{}_{\pi 2}$ mesons were done. A study of the γ-ray products of hyperons and K mesons continued. Emulsion exposures were made to a focused and momentum-analyzed K^--meson beam. Three groups outside the Laboratory made emulsion exposures to protons, π^- mesons, and K^- mesons.

A new experimental area at the northwest quadrant was added to the Bevatron experimental facilities.

The source of a fluctuation in rf start frequency and initial slope was found and eliminated.

On January 6, 1956 a failure occurred in the east generator, which resulted in a five-week shutdown.

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INJECTOR

Injector-component improvement and injector alignment[1] were again actively continued programs during this quarter. Additional mu-metal shielding for the ion-gun beam was provided in the ion-source focus and accelerating electrodes; at the ground end of the column, mu-metal shielding was provided through the column-support structure and pump manifold. Permanent magnets were also used near the ion source to steer the beam. A new support structure for the bunching cavity and the 20° bending magnet was installed (Fig. 1). This structure mounts from the linear accelerator and allows the above components to remain aligned with the linear accelerator while the ion-gun location is adjusted.

The injector performance is summarized in Table I.

Ion-Source Development

Two new designs of ion sources were tested on the Bevatron injector. The first was a redesign of the conventional low-voltage PIG-type[2, 3] source by the substitution of a high-voltage arc chamber with tantalum cathodes. The arc-starting voltage was 2000 volts; the arc-running voltage was 1000 volts. At low gas pressure the arc current was about 0.5 amp; the proton

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[1] Walter Hartsough, Bevatron Operation and Development. VII, UCRL-3236, Dec. 1955.

[2] James D. Gow and John S. Foster, Jr., A High-Intensity Pulsed Ion Source, UCRL-1698, March 14, 1952.

[3] F. M. Penning, Physica 4, 71 (1937).

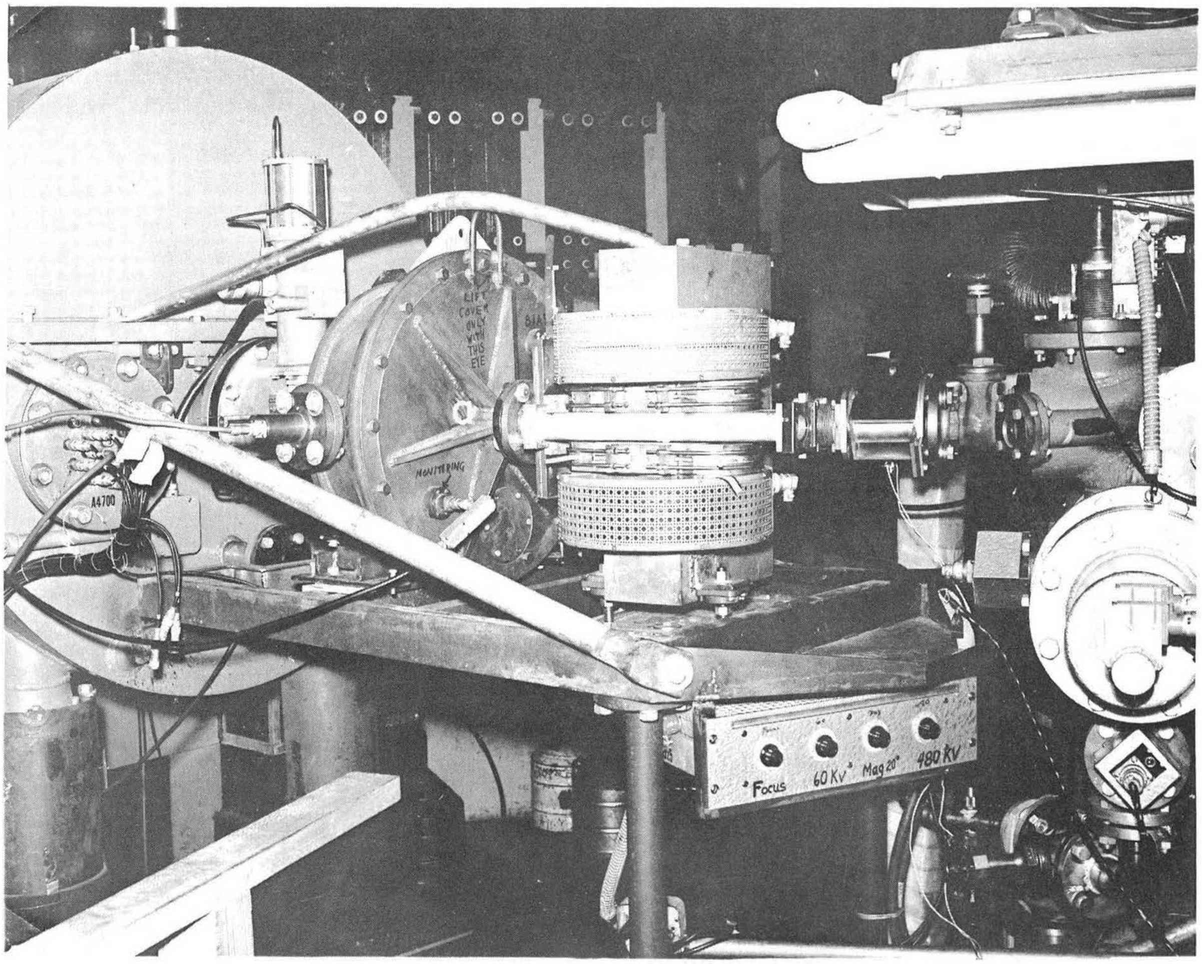

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Fig. 1. New support structure for the 20° bending magnet and bunching cavity: a, bunching cavity; b, 20° bending magnet.

Table I

Injector performance

Week of	Ion gun total beam (ma)	Proton beam at exit of Bevatron inflector (μa)	Transmission efficiency (%)
10-31-55	7.3	214	2.9
11-7-55	5.8	200	3.4
11-14-55	6.3	193	3.1
11-21-55	7.0	190	2.7
11-28-55	10	211	2.1
12-5-55	7.2	177	2.5
12-12-55	7.5	212	2.8
12-19-55	7.7	227	2.9
12-26-55	---	---	---
1-2-56	8.5	140	1.6
1-9-56	---	---	---
1-16-56	---	---	---
1-23-56	5.5	295	5.4

yield was 1 ma (85% of total output beam). At high gas pressure the arc current was about 1 amp. A proton yield of 2 ma and a total output beam of 4 ma were obtained. The above values are to be compared with a total current of 8 to 10 ma at 50% efficiency for protons from the conventional PIG-type source.

The second source was an occluded gas source[4] with axial extraction. One of the difficulties encountered during test of this source was the inability to obtain a focused beam at high accelerating voltage.

Further development is in progress, as neither design has as yet led to a successful source.

Linear-Accelerator Oscillator Tubes

Recently, Eitel-McCullough, Inc., began producing on a production basis a modified model of the 3W10, 000 A3 tube. This tube is used in the three linear-acclerator radiofrequency oscillators.[5] The new tube model, Type X-612, has a platinized tungsten grid structure instead of the low-emission coating type grid structure used in the 3W10, 000 A3 tube.

In the linear-accelerator oscillator application, these tubes are used as pulsed power oscillators. Because the duty cycle is low, grid emission is not a problem; however, high plate current and long tube life are highly desirable tube attributes. There has been evidence that the low-emission coating on the grids of the 3W10, 000 A3 migrates to the filament structure and lowers the emission of the filament. The resultant increase in filament power necessary to maintain the desired cathode emission shortens the tube life. For this reason, the X-612 may prove to be a more satisfactory tube for this application than the 3W10, 000 A3. (The average 3W10, 000 A3 tube life during 1955 was about 2000 hours).

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[4] Richard B. Crawford, James D. Gow, Wing G. Pon, and Lawrence Ruby. An Occluded Gas Ion Source, UCRL-3103, August 1955.

[5] Alvarez, Bradner, Franck, Gordon, Gow, Marshall, Oppenheimer, Panofsky, Richman, and Woodyard. "Berkeley Proton Linear Accelerator," Rev. Sci. Instr. 26, No. 2, 111-133 (1955).

Minor modifications to the oscillator circuit are necessary, as the μ of the X-612 is slightly different from the μ of the 3W10,000 A3. These modifications are now in progress.

EXPERIMENTAL FACILITIES

Arrangement of the West Experimental Area

Figure 2 shows the arrangement of the west experimental area during the first part of this quarter. A second negative-particle spectrograph was constructed and was operated independently of the original negative-particle time-of-flight equipment.

Figure 3 shows the arrangement of the west experimental area during the latter part of this quarter.

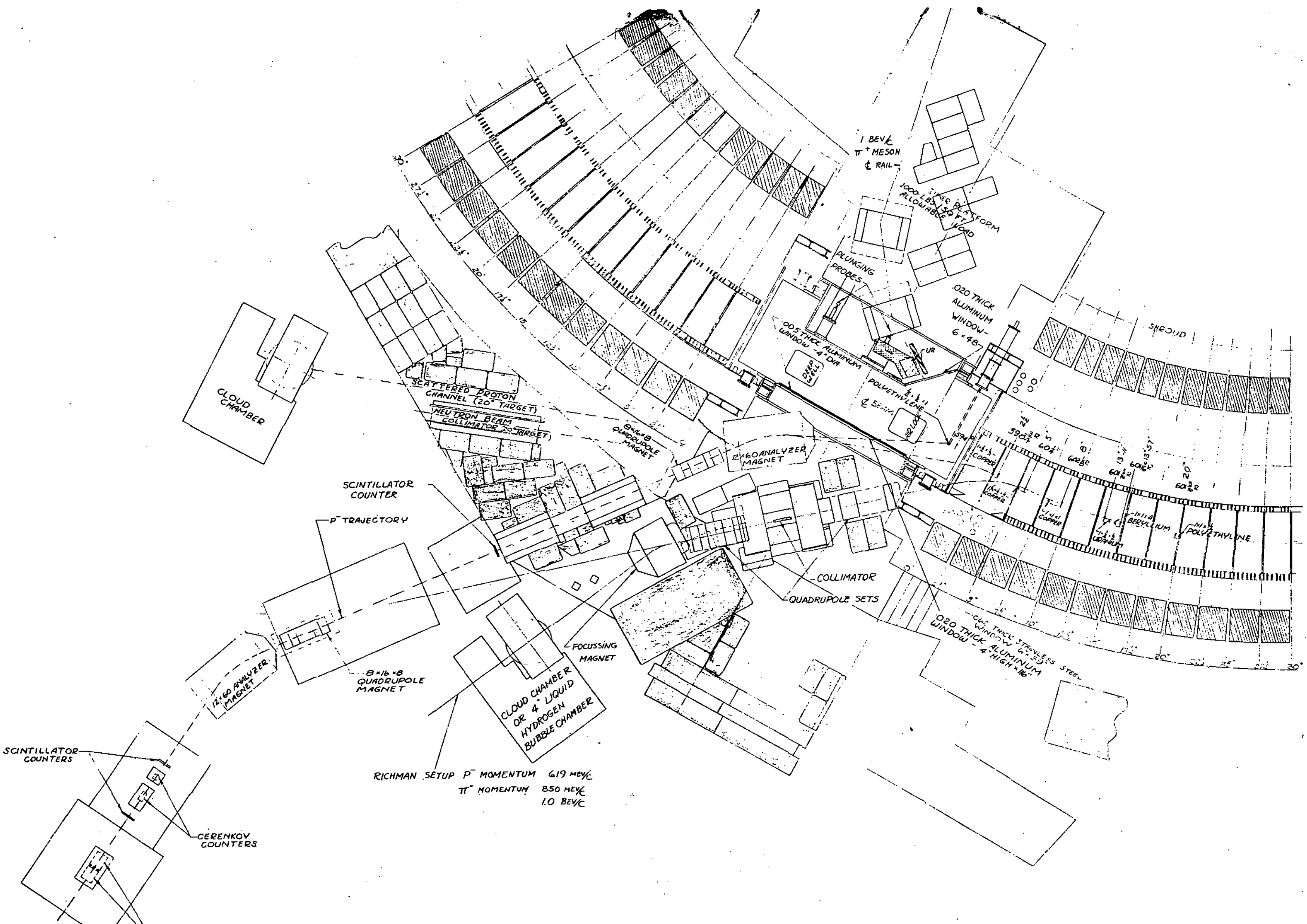
New K-Meson-Beam Experimental Area

A new experimental area for the investigation of K-mesons was constructed in the northwest quadrant (Quadrant III). Figure 4 shows the plan layout of the area; Fig. 5 pictures the platform and shielding facilities, which were designed to accommodate a flexible experimental program.

The outer magnet yoke slab was reconstructed to form a beam channel 3-15/16 inches wide through the magnet. The 1/16-inch-thick stainless steel Bevatron vacuum-tank wall is the one obstruction in the path of the deflected beam. A copper target 0.5 inch high by 1 inch wide by 3.5 inches in the beam direction is actuated by a flip-coil mechanism (Fig. 6) which moves the target into position in less than 100 msec. The momentum selection of the magnet and beam channel for K^- mesons that leave the target at 6° to the direction of the incident proton beam has been computed to be 430 ± 20 Mev/c.

Strain-Gauge Evaluation of Loads at the Proposed North Target Area

During the engineering design of a three-sector window-frame stanchion for the north target area, it became necessary to evaluate more precisely the existing loads on the outer-radius stanchions. This support frame would provide an opening 6 inches high by 72 inches long for the



ZN-1471

Fig. 2. West experimental area during first half of this quarter (top view)

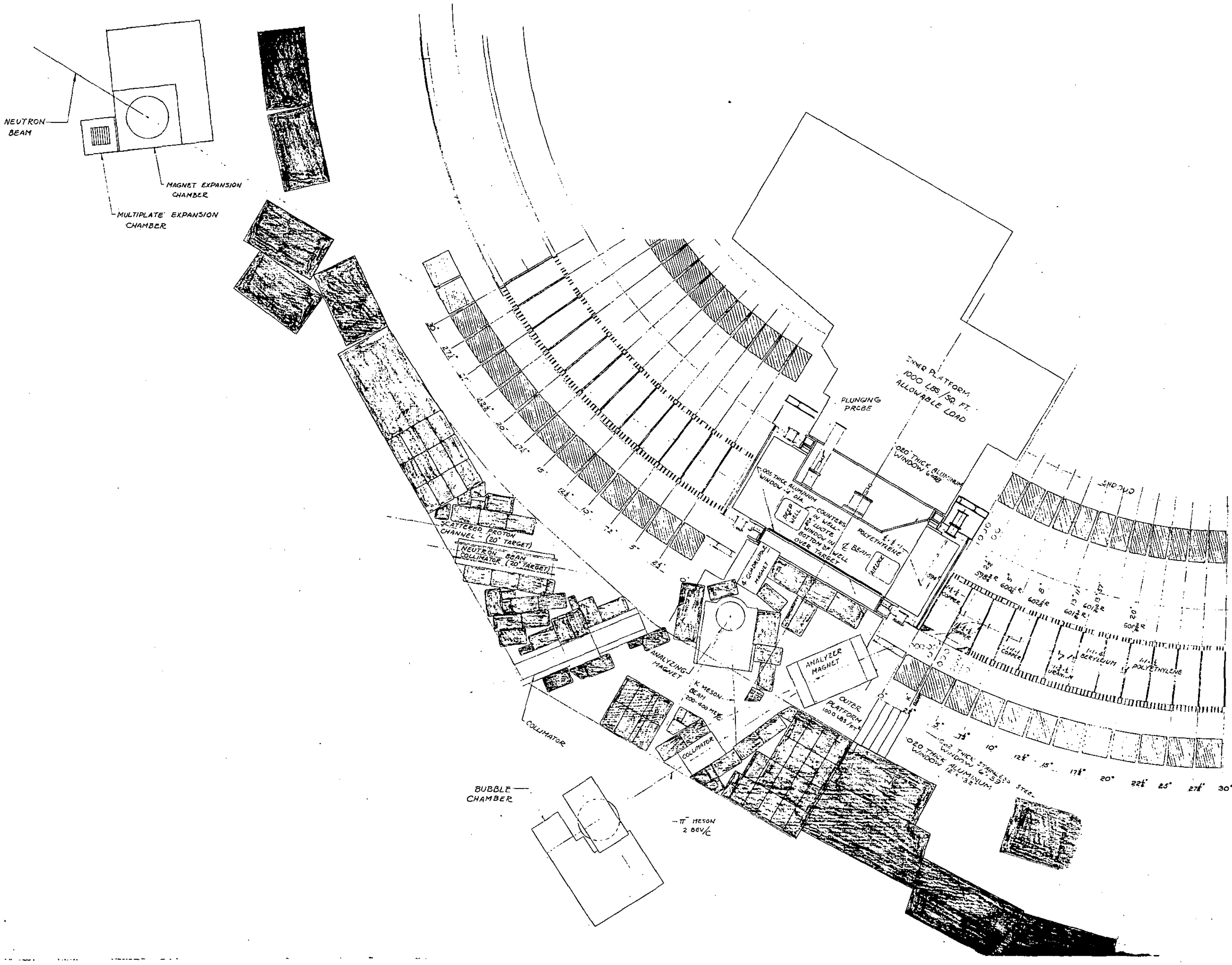


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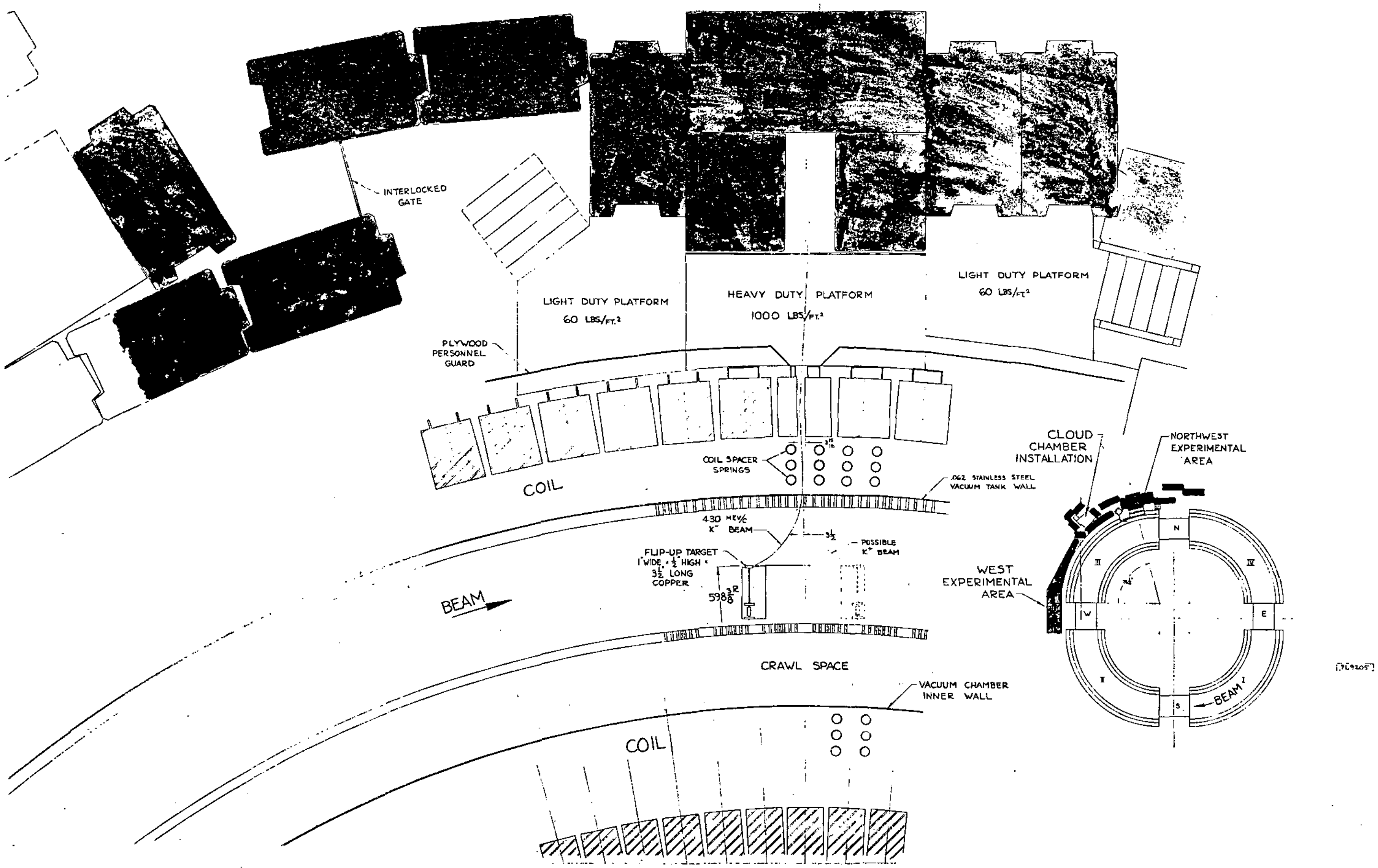
Fig. 3. West experimental area during the latter part of this quarter (top view)

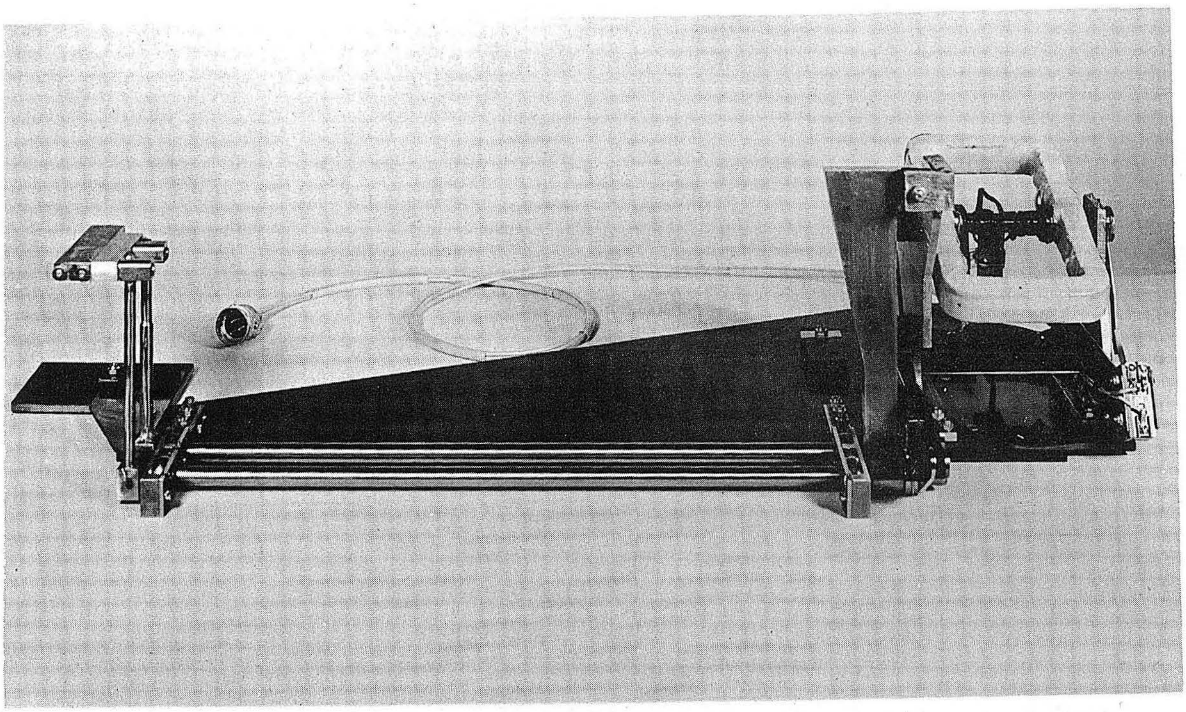


ZN-1475

Fig. 4. Northwest experimental area (top view)

ZN-1494

Fig. 5. New northwest experimental area. The K^--meson beam is deflected through a channel in the Bevatron magnet yoke at the right of the picture. The beam is focused by a quadrupole set before it is collimated in the concrete shielding wall at the left of the picture.



ZN-1497

Fig. 6. Flip-up target (capable of raising a 450-g target in 100 msec).

extraction of 1.5 to 6-Bev negative-particle beams. Only the 0.062-inch-thick stainless steel vacuum-tank wall would be in the path of these particles. Such a frame would replace four existing outer-radius stanchions which now carry the dead-weight load of the pole base and pole tip, the yoke-clamping load, the vacuum load, and the pole-tip magnetic load. These loads on the basis of the most pessimistic assumptions, could have a maximum value of 350, 000 lbs per sector (about 150, 000 lbs per stanchion), although in actuality the loads may be only one-third to one-half of that value. The magnetic load due to the attraction between pole tips, in particular, is an undetermined quantity and may be less than the estimated value. Preliminary study indicates that a structure capable of supporting the estimated maximum total possible loads would be nearly impossible to supply within the space limitations without further modification to the magnet structure so as to transfer part of the load from the window frame. In addition, magnetic-field perturbation, due to eddy currents induced in a massive support, might seriously affect the beam at injection. It has therefore become necessary to measure the actual value of the loads on the outer-radius stanchions so that an accurate evaluation of the structural requirements may be made.

A strain-gauge load-measurement cell has been installed to resolve the load uncertainties on the outer-radius stanchions.

The first measurements will be taken with the subject pole tip flush with the adjacent pole tips. Further measurements will then be taken with as much as 0.050 inch vertical difference between the subject pole tip and its neighbors. This decrease in gap is tolerable from the standpoint of magnetic field disturbance, but a greatly different magnetic load on the stanchions could result. Evaluation of this load variation will define the permissible deflection in the proposed window frame.

The proposed north experimental area also requires major changes to the coil-box outer supports at the exit of Quadrant III in order to provide an unobstructed beam path outside the thin window. Again, not knowing the loads hampers the design of an alternate structure. Strain gauges are being used to measure these loads.

MONITORING

Magnet-Current Marker Pulses

Two sets of twenty-nine marker pulses each (numbered 3, 4 . . . 29, 30, 33) are generated at discrete values of magnet current by stepped peaking transformers. The set of voltage pulses associated with the east peaking transformers are mixed and are used to monitor the circulating proton beam amplitude vs energy by a simultaneous display of a beam-induced signal and the mixed current markers. These mixed markers are also useful for the adjustment and monitoring of target timing and of the manner in which the proton beam is spilled on the target. Individual marker pulses are used as oscilloscope and equipment triggers. The set of marker pulses associated with the west peaking transformers have, in the past, been used primarily as a facility for the physics research groups. These pulses were gated through the operations selector and were used as reference markers and as triggers for experimental equipment. A jitter in time between the two sets of markers has been a source of undesirable fluctuation in counting-equipment permissive gate time and in the expansion times of the cloud chambers and bubble chambers.

In order to synchronize the timing of experimental and operational functions, current markers from the operational set are now available in the counting room.

Isolation for the Bevatron operational information is provided by isolation amplifiers (thyratrons). Coaxial switching circuits are also available in the counting room for programming the marker pulses according to the Bevatron Automatic Operations Selector.[6]

The second current-marker set is now on stand-by and is available for immediate substitution.

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[6] Harry H. Heard, Bevatron Operation and Development. V, UCRL-3033, Aug. 1955.

MAGNET POWER SUPPLY

Two ignitrons were replaced during this quarter. The first was removed from service because of a loose anode stem. The second was the source of many arc-backs and inversion arc-throughs. The anode seal would not hold the plate voltage. Both tubes were on the west machine.

The magnet-pulsing record is shown in Table II.

Magnet Generator Failure

On January 6, 1956 an electrical short occurred in the Bevatron east generator. The short was discovered during a routine high-voltage check of the magnet and generators prior to pulsing. Subsequent inspection disclosed that one of the stator windings had become loose and had come in contact with the generator rotor (Fig. 7). Several strands of wire had been stripped from this winding. There was some evidence of turn-to-turn arcing in the damaged winding.

The stators of both the east and the west generator were pulled from the rotors, and an overhaul of the generators was begun. Several displaced stator-winding blocking wedges were found in each machine. The coil wedges in the west machine showed some scoring. Both machines were cleaned; the stator-winding wedges were removed and new wedges installed.

During the shutdown, the shaft bearings were rolled out and inspected. Raised spots were noted in the babbit metal on the bottom sections of five bearings. Figure 8 shows the bottom half of the No. 2 bearing (between the generator and flywheel) on the east machine. This bearing is subject to higher stress and temperature than the other bearings. In the opinion of the Westinghouse engineers, the raised areas were due to hydrogen bubbles that form between the steel casting and the babbit metal. At normal bearing-operating temperatures, occluded hydrogen in the steel casting is released and becomes trapped under the babbit. Escapement holes were drilled at the raised areas to relieve the gas pressure, and the bearings were resurfaced.

At the end of this quarter the reassembly of the generators was still in progress.

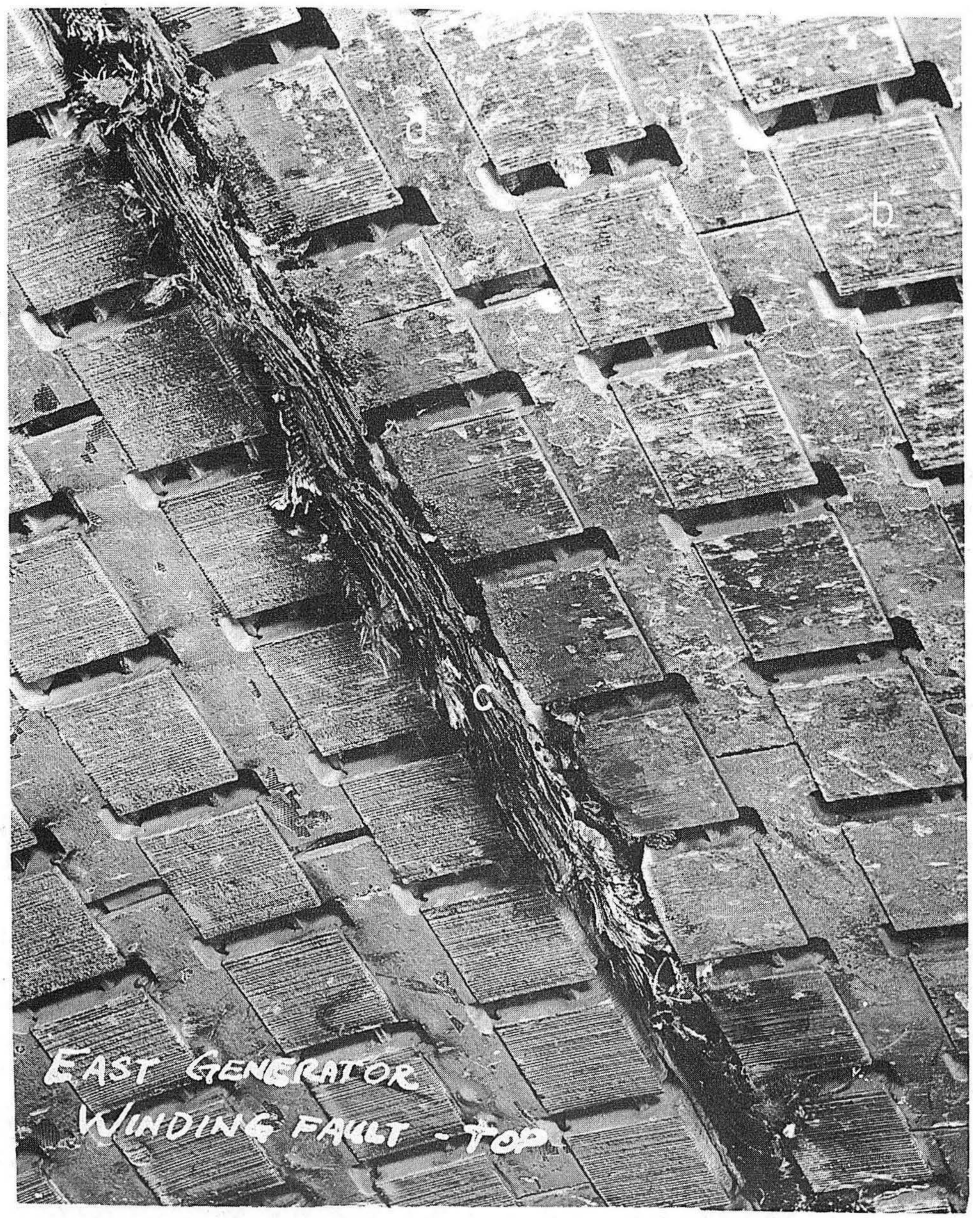

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Fig. 7. Damaged stator winding, east generator: a, stator winding keeper wedges; b, stator; c, damaged stator winding.

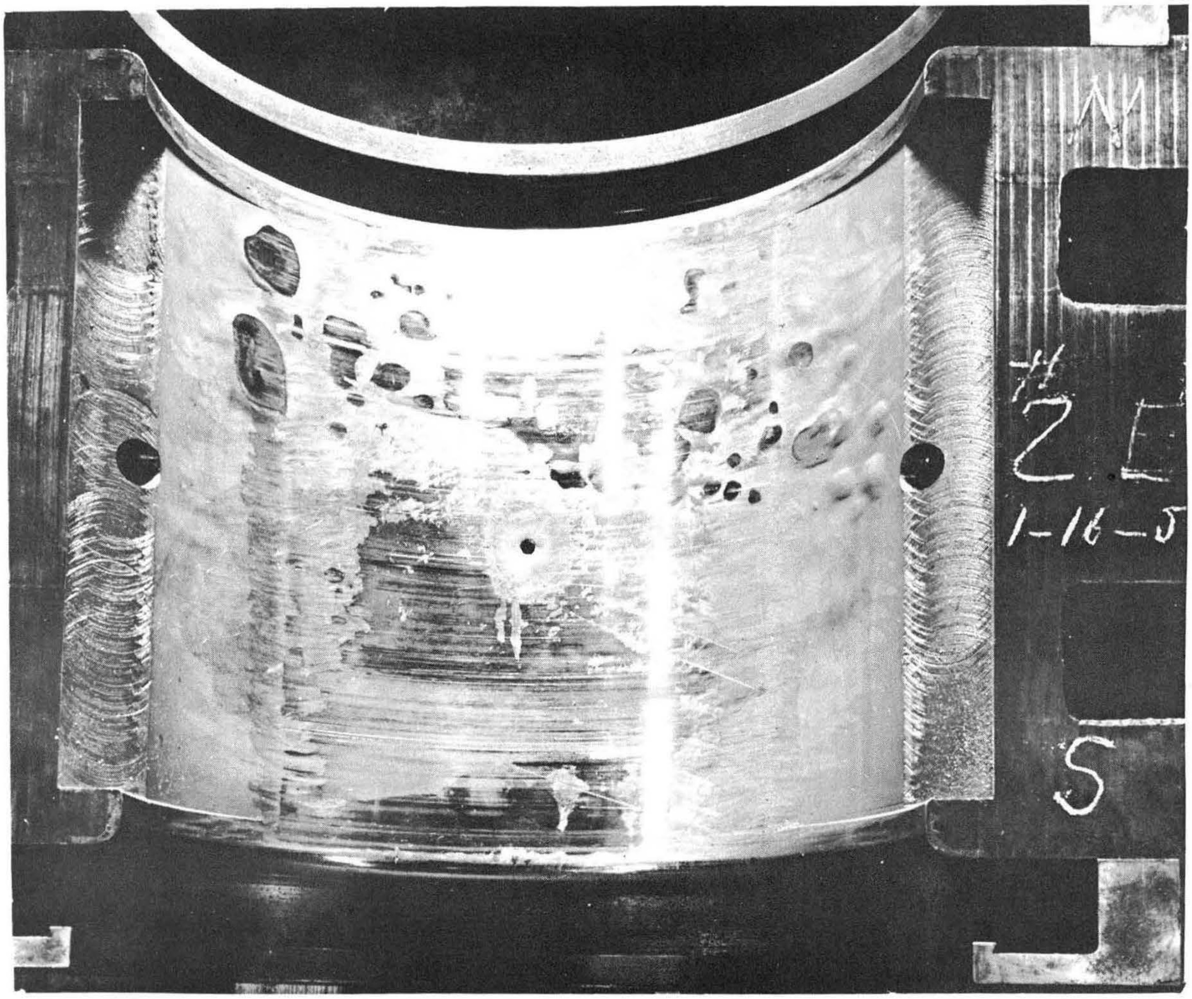

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Fig. 8. Bottom half of bearing between generator and flywheel, east machine.

Table II

Ignitron fault rate																		
	5 to 7 pulses per minute						7 to 10 pulses per minute						10 to 17 pulses per minute					
	1500 to 6000 amp			6000 to 8000 amp			1500 to 6000 amp			6000 to 8000 amp			1500 to 6000 amp			6000 to 8000 amp		
Month	Pulses	Faults	P/F	Pulses	Faults	P/F	Pulses	Faults	P/F	Pulses	Faults	P/F	Pulses	Faults	P/F	Pulses	Faults	P/F
1954																		
Oct	103	0	----	3111	27	115	11200	47	239	16200	114	142	80300	24	3348	2363	35	68
Nov	3434	8	429	5146	42	122	255	0	---	33200	259	128	29100	18	1617	7237	39	186
Dec	310	2	155	35600	122	292	1640	18	91	1529	39	39	19600	12	1630	0	0	0
1955																		
Jan	1757	4	439	42500	193	220	0	0	0	9480	60	158	55400	36	1538	259	3	86
Feb	793	0	----	19600	76	258	431	4	108	19800	97	204	39000	29	1347	9817	44	223
Mar	434	0	----	14900	16	933	456	0	----	37500	64	586	48400	39	1240	16400	51	232
Apr	948	0	----	19600	39	503	425	1	425	16700	38	440	102500	8	12800	9587	18	533
May	0	0	----	14500	34	427	34	0	----	58400	171	341	76400	15	5094	3400	9	379
June	0	0	----	8500	2	4249	0	0	----	9700	9	1075	132800	4	33194	12500	14	896
July	0	0	----	300	1	341	0	0	----	10300	9	1144	137700	25	5510	15800	22	720
Aug	0	0	----	6469	9	719	580	2	290	70832	62	1142	48037	1	48037	18473	10	1847
Sept	86	0	----	0	0	----	0	0	----	33269	44	756	44798	10	4480	341	0	----
Oct	1361	0	----	1289	0	----	0	0	----	54562	88	620	38136	1	38136	29305	56	523
Nov	----	-	----	16	0	----	0	0	----	46656	86	542	37670	2	----	59304	84	706
Dec	----	-	----	0	0	----	0	0	---	11875	18	659	14378	14	1027	91761	113	812
1956																		
Jan	----	-	----	----	----	----	----	----	----	6718	7	960	11148	1	11148	3433	1	3433

RADIOFREQUENCY TRACKING EQUIPMENT

Fluctuations in Start Frequency and Initial Slope

The source of an intermittent fluctuation in start frequency and initial slope[7] was carefully investigated during this period. An occasional shift in start frequency of as much as 5 kc (1.4%) made beam tracking very difficult. Complete compensation for a fluctuation of this magnitude was not possible within the range of existing controls and correction equipment.

Primary frequency-tracking information for the rf acceleration system was derived from shunted magnet current. The magnet and magnet voltages were, therefore, possible sources of information and were investigated by observing simultaneously the fluctuations in start frequency and the fluctuations in the following critical parameters: magnet voltage; phase and amplitude of magnet voltage ripple; voltage unbalance between magnet halves; individual magnet-quadrant voltages; $\dot{B}$-winding voltage; jitter between the various magnet-current and magnetic-field-derived marker pulses; self-induced pole-face-winding currents. No observable correlation was found between start frequency jitter and any fluctuation of the above parameters.

The various components associated with the primary frequency generator were checked: the master oscillator; the master-oscillator bias supply; the master-oscillator temperature regulator; the shaper and the shaper reactor; the master-oscillator reactor; the magnet-current shunt; and the slope-control equipment. A process of elimination, by component substitution wherever possible, proved that the source of fluctuation was the coaxial magnet-current shunt (Fig. 9). This component has been removed for repair.

During the latter part of this quarter, while the magnet-current shunt was being repaired, successful operation was obtained by using the $\dot{B}$-integrator reactor as the source of tracking information.

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[7] Harry G. Heard, Bevatron Operation and Development. VI, UCRL-3212, Nov. 1955.

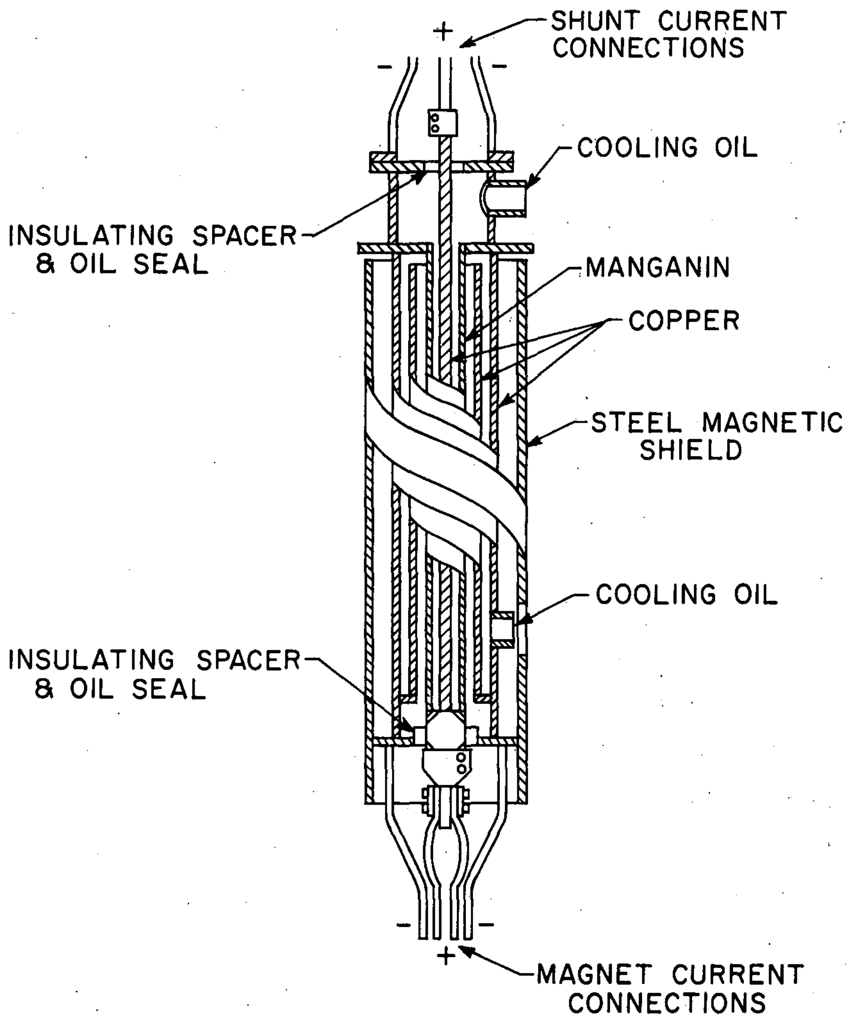

Fig. 9. Cutaway view of the coaxial magnet-current chunt-simplified.

Magnet Current Shunts

The faulty magnet-current shunt was resistance-checked before repair. The manganin resistance Rm, common to the input and output circuit, was $9.77 \pm .02 \times 10^{-4}$ ohms (at 10 amp). This value agreed very well with the previously measured value of $9.75 \pm .02 \times 10^{-4}$ ohms (at 1 amp). The output resistance ($R_o = 1.497 \times 10^{-4}$ ohms + Rm) indicated a poor connection in the low-current circuit. The shunt was disassembled and reworked; a threaded joint was hard-soldered and another joint was tightened. The output resistance now measured 0.38×10^{-4} ohms + Rm.

The spare shunt[8] was also reworked. The manganin resistance values of the two shunts were then measured:

East Shunt	$Rm = 9.987 \times 10^{-4}$ ohms
West Shunt	$Rm = 9.847 \times 10^{-4}$ ohms

The two manganin shunts were then resistance-matched, baked (18 hr in vacuum at 150^{o} C), and trimmed to a common resistance value of 1.0545×10^{-3} ohms. Resistance measurements were made at 10 amp dc and were repeatable to 1 part in 5000. The assembled shunts were then connected in series and pulse-tested at 10,000 amperes. Output currents were identical to within 1 part in 1,000.

The following are the measured resistance characteristics of the repaired shunts:

Shunt mutual resistance R = 1.0545 milliohms

High-current terminals (low-current terminals open)
R = 1.09 milliohms

Low-current terminals (high-current terminals open)
R = 1.12 milliohms

Improvement in Reliability of Radiofrequency Components

Many critical Bevatron electronic circuits make use of 304 TL tubes as switch tubes or as rf amplifiers. Until recently, these tubes have been war surplus stock. Substitution of new 304 TL tubes in the injector

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8 Walter Hartsough, Bevatron Operation and Development. VII, UCRL-3236, Dec. 1955.

arc-pulse supply made a marked improvement in the reliability of that unit. Because of this increase in reliability, new 304 TL tubes were installed in the Bevatron rf driver modulator and in the rf final-amplifier-reactor saturating supply. An increase in reliability of these components has resulted.

DEVELOPMENT

Floating Stuffing-Box Vacuum-Seal for Plunging Targets

A new design of vacuum seal for plunged target shafts has been tested and is now in use on the Bevatron. The new design (Fig. 10) employs a fixed bearing and a floating seal assembly. The previously used aluminum-bronze bearings have been replaced by graphited polytetrafluoroethylene bearings. This latter material has a lower coeffiecient of friction, and its use resulted in less wear and damage to either the bearing or the shaft. The seal has operated reliably on the Bevatron for more than 500, 000 strokes (40-inch-long strokes in 200 msec or less). Bevatron tank vacuum was 2×10^{-6} mm Hg.

BEVATRON SHUTDOWNS

The alignment of motor generator set bearings, which was started on October 26, was completed on November 2, and Bevatron operation was resumed. Three shutdowns occurred during the remainder of the quarter. The first, on December 8, was for the repair of the 2.5° flip-coil target assembly. The target had become stuck in the "up" position and had therefore become an obstruction for the injected beam. The second, December 26 to December 31, was a scheduled shutdown for the rebuilding of the outer magnet yoke at the new K-meson experimental area (Fig. 4). The third shutdown, which started on January 9 and is still in progress, is for the purpose of rebuilding the damaged east generator stator.

OPERATING AND RESEARCH PROGRAM

A summary of the operation during this quarter appears in Fig. 11. The scheduled operating time of eighty-one hours per week is reduced by the magnet power-supply warmup time (1/2 hour per day). The vertical

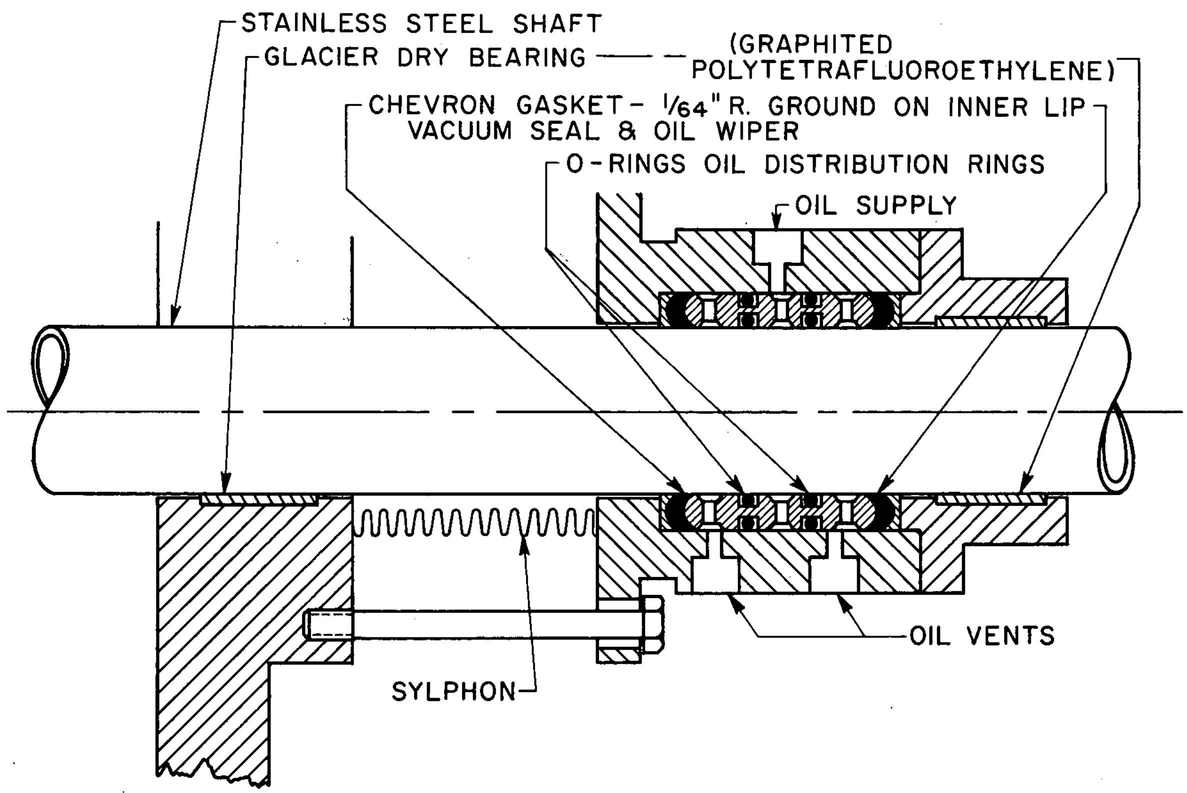

Fig. 10. Floating stuffing-box vacuum seal for plunging targets.

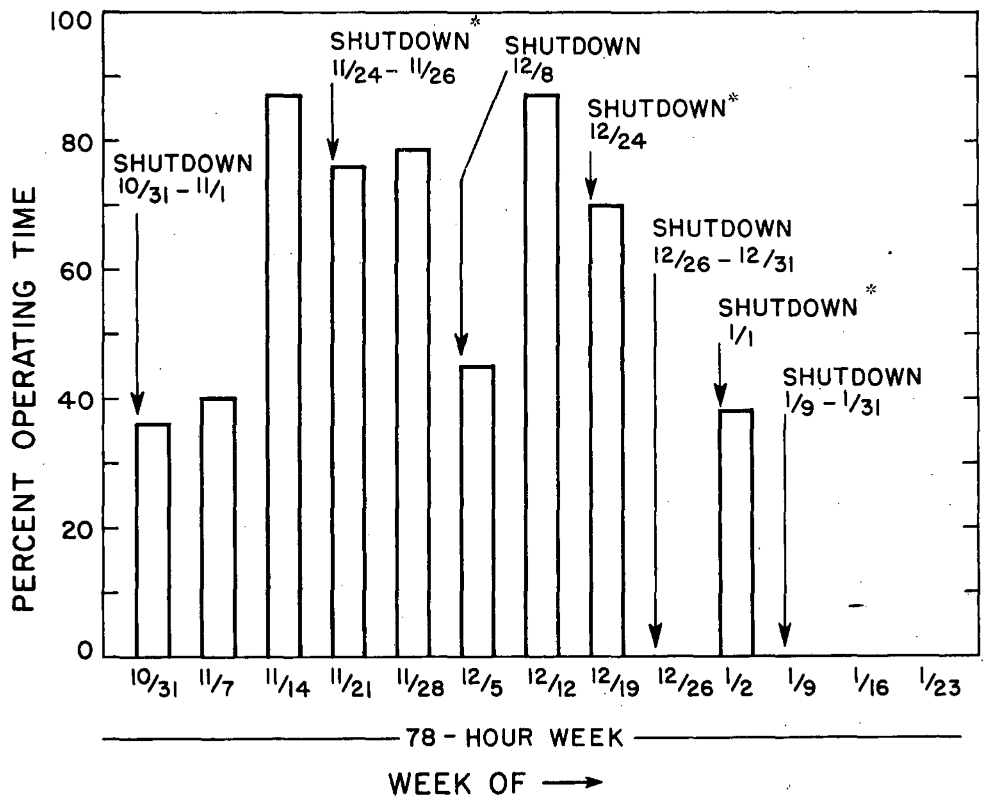

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Fig. 11. Bevatron operating time November 1955 - January 1956. *Holiday.

bars, therefore, represent a percentage of the scheduled effective hours for physics research.

The maximum recorded beam amplitude at 6.2 Bev was 3.5×10^{10} protons per pulse at 11 pulses per minute. The peak and average values of beam-survival efficiency are shown in Fig. 12.

The antiproton research program was continued during November and December. The nuclear absorption of P^- in copper and Be was investigated by the Segrè group. The Moyer-Lofgren group, using P^- signature triggers from the Segrè spectrometer, investigated the annihilation of antiprotons. The P^- absorption cross section in copper, Be, and lead glass was also measured by this group. Emulsion exposures were made by the Segrè-Lofgren group at the first focal point of the Segrè setup, using 700- and 900-Mev/c antiprotons. These emulsions were subsequently divided among the following groups: Amaldi (University of Rome) and the Barkas, Lofgren, Richman, and Segrè groups of this laboratory.

A second focused and analyzed negative-particle beam (Fig. 2) was used by the Richman Group for a P^- emulsion exposure at 619 Mev/c. It was also used by the cloud-chamber and bubble-chamber groups to investigate π^- mesons at 850 Mev/c and 1.09 Mev/c.

Near the end of December, the experimental area was rearranged for a scheduled series of $K^\pm$-meson-beam experiments. These experiments were interrupted by the failure of the motor generator set.

A summary of the research activity appears in Table III.

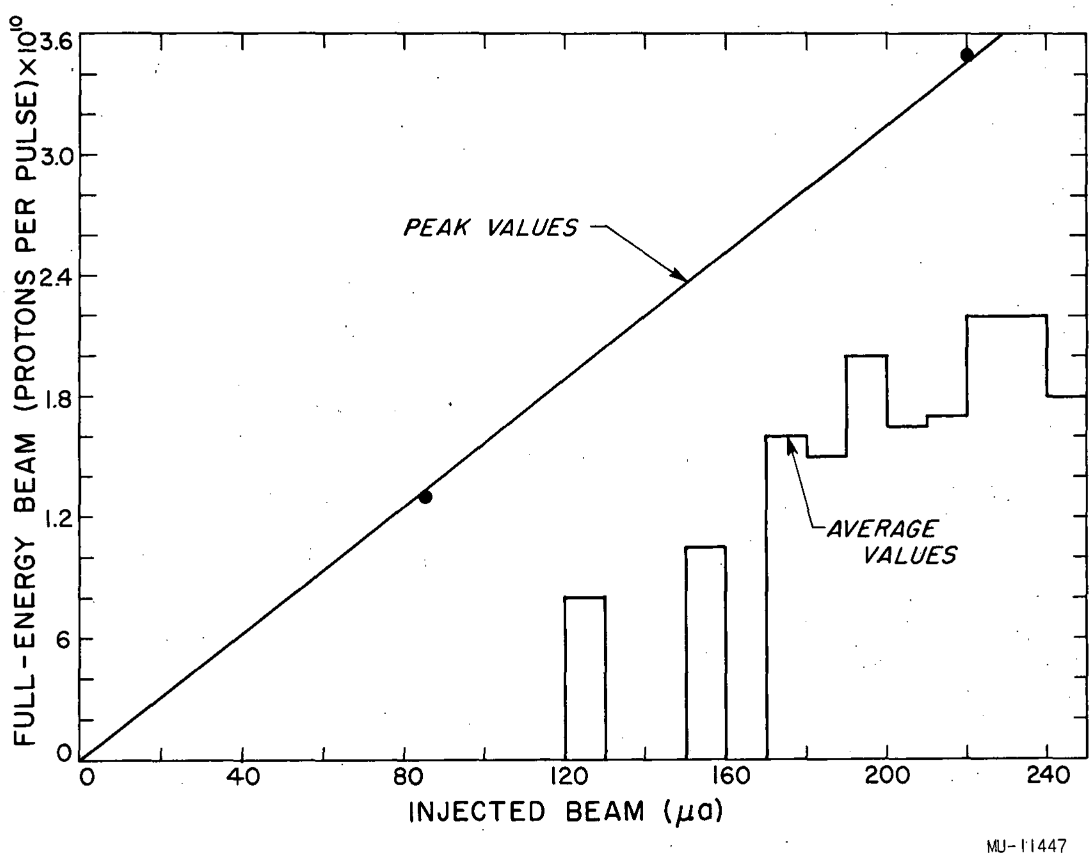

Fig. 12. Bevatron Performance beam survival efficiency.

Table III

Bevatron Experimental Research Program
November, December 1955, January 1956

INTERNAL GROUPS

Group / Experimenters	Experiments
ALVAREZ	
Crawford, Stevenson	π^--scattering experiment using a 4-inch liquid-hydrogen bubble chamber (850 Mev/c).
Crawford, Good, Stevenson, Tripp	τ^+, $K_{\mu 2}^+$, $K_{\pi 2}^+$ detection and lifetime measurement using counters (385 Mev/c).
Gow, Rosenfeld	10-inch bubble-chamber test in the 2-Bev/c negative-particle beam. Investigation of the reaction $\pi^- + P \rightarrow \lambda^0 + \theta^0$.
Bradner	Two internal emulsion exposures. Emulsions placed 4 inches below a target which was bombarded at 6.2 Bev. Search for magnetic monopoles.
MOYER	
Bostick, Wikner	π^+ total cross section using counter (1 Bev/c).
Brabant, Osher	Radiofrequency structure of the proton beam, using a counter telescope.
Osher, Parker	γ-rays and charged particles from the displaced decay of hyperons and K-mesons, using counters.
MOYER-LOFGREN	
Brabant, Cork, Horwitz, Murray, Wallace, Wenzel	Study of the P^--annihilation energy release, using counters. P^- absorption cross section in Cu, Be, and lead glass.
POWELL	
Fowler, Lander	P^- capture in a multiplate expansion cloud chamber with magnetic field (619 Mev/c).

INTERNAL GROUPS

Group / Experimenters	Experiments
Fowler, Piccioni	θ_2^{o} interactions in a multiplate expansion cloud chamber with magnetic field. (1.09 -Bev/c π^- mesons on an aluminum target).
Fowler, Courant	Preliminary investigation of K-meson production by neutrons; K-meson decay and interactions. Two cloud chambers are used as a mass spectrometer (an expansion cloud chamber in magnetic field and an expansion cloud chamber with five 1-cm. - thick lead plates).
RICHMAN	
Kerth, Stork	Emulsion exposures in the focused and analyzed P^- beam (619 Mev/c).
SEGRÈ	
Chamberlain, Steiner, Ypsilantis, Weigand	P^- nuclear absorption in Cu and Be, using counters (1.19 Bev/c).
SEGRÈ-LOFGREN	
Chupp, G. Goldhaber	Emulsion exposures in P^- beam. Three stacks exposed at 700 Mev/c, two stacks exposed at 900 Mev/c.
WINSBERG	
Benioff	Oxalic acid, Cu, Al target bombardment (5.7 Bev). Al, Cu, 5-Aminotetrazole traget bombardment (2.2 Bev).
Grover-Shudde	U, Al, Ta foil bombardment (5.7 Bev).
Shudde	U-foil bombardment (5.7 Bev).
Winsberg	Mn-foil bombardment (6.2 Bev).
LIVERMORE NUCLEAR EMULSION GROUP	
White	K^--meson interactions in emulsions (200 Mev/c and 300 Mev/c).

EXTERNAL GROUPS

Experimenter / Institution	Experiments
ASCOLI HABER-SCHAIM University of Illinois	Two internal emulsion exposures at 6.2 Bev.
HASKIN University of Chicago	Emulsion exposure in the 1-Bev/c π^- beam.
TICHO UCLA	Two emulsion exposures. K^- study outside the neutron window and in the 2.5^o magnet slot.

ACKNOWLEDGMENTS

The Bevatron operating group consists of Robert Anderson, Wendell Olson, and Robert Richter as crew chiefs; Norris Cash, Duward Cagle, Frank Correll, Robert Gisser, William Kendall, Ross Nemetz, Glenn White, and Emery Zajec as crew members. Harold Vogel was the engineer in charge of the motor generator sets. The Bevatron group leader is Edward J. Lofgren, and under him Harry Heard, with Walter Hartsough assisting, is in charge of operations. Special development projects were carried out by Bruce Cork, Harry Heard, and Nahmin Horwitz. The mechanical engineering group was headed by William Salsig; the electrical engineering group was led by Clarence Harris and Marion Jones. Jerome Russell directed the electronic development group.

This work was done under the auspices of the U. S. Atomic Energy Commission.