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UNIVERSITY OF CALIFORNIA

Radiation Laboratory

BEVATRON OPERATION AND DEVELOPMENT. XV

August, September, October 1957

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ABSTRACT

The interactions and decay of K mesons were studied by use of a 10-inch liquid hydrogen bubble chamber and a 30-inch propane bubble chamber. A counter experiment was done to detect asymmetries in K-μ-e decay. The study of π^0 modes of heavy-meson and hyperon decay continued, using counters. An experiment was done to detect antineutrons in coincidence with He^3 production.

Twenty-three target bombardments in the internal proton beam were made for the Chemistry group.

A pulsed air-core magnet to generate short secondary-particle beam pulses was installed in the south straight section.

External proton beam studies were continued, using an energy-loss target and a pulsed magnetic beam deflector.

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EXPERIMENTAL FACILITIES

Quadrant-Mounted Targets

The quadrant-mounted targets that were available during the latter half of this period are listed in Table I.

Installation for Rapid Beam Ejection (Pulsed Air-Core Magnet for Producing Short Secondary-Particle Beam Pulses)

An air-core magnet was installed in the south straight section for the purpose of producing short secondary-particle beam pulses of adjustable magnitude by rapidly deflecting the circulating high-energy proton beam bunch onto a target. The magnet is capable of being pulsed to a strength of 1000 gauss with a time of 50 microseconds for 100% rise. The field is required to be down to one-half maximum in 50 microseconds and to decay without oscillating. The length of the coil is 96 inches.

The magnet consists of two turns of 2-inch-diameter copper tubing, one turn above and one below the plane of the circulating proton beam. As shown in Fig. 1 and represented in a simplified drawing in Fig. 2, this magnet is supported from the "internal beam-deflection magnet."[1] The radial position of the rapid beam ejector is adjusted by manual operation of the sliding drive shaft that positions the internal beam-deflection magnet. Figure 3 shows the relative positions of the two magnets in retracted and deflection positions.

The electrical feed to the rapid beam ejector is brought through a special coaxial vacuum feedthrough to a flexible coaxial line in the vacuum tank which permits adjustment of the radial position of the magnet.

Test and operation of this new unit await the completion of the power supply.

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[1] Walter Hartsough, Bevatron Operation and Development. X, UCRL-3519, Nov. 1956.

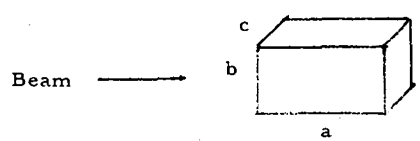
Table I

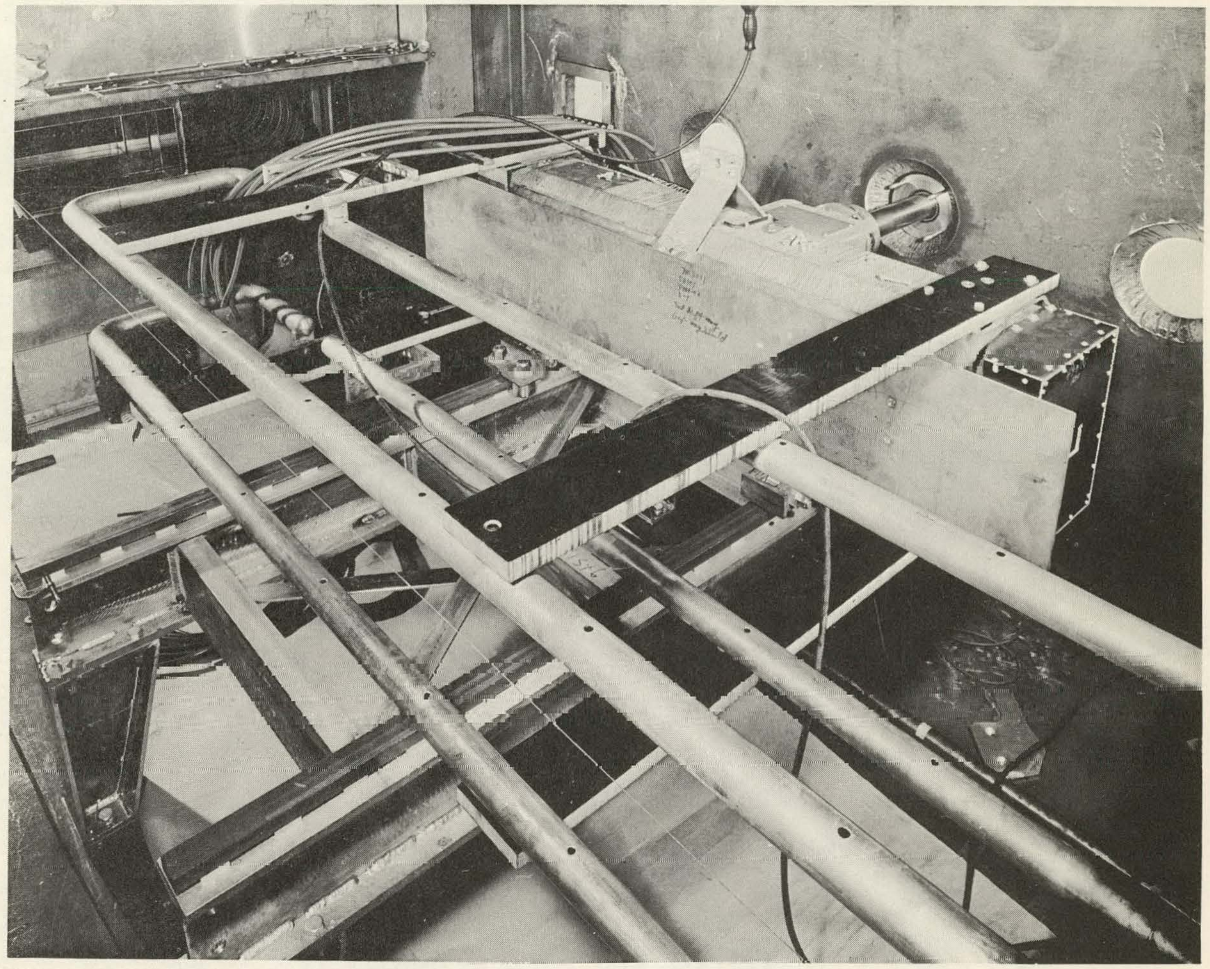
Quadrant-Mounted Targets

September 22, 1957 to October 30, 1957

Quadrant	Azimuthal location (Ref: West straight section)	Radial Location: Outer-radius edge of target (in.)	Radial Location: Outer-radius edge of lip (in.)	Target material	Target size[a] a × b × c (in.)
II	$2^\circ 16'$	601-13/16	602-1/16	copper	$1 \times \frac{1}{2} \times \frac{1}{2}$
II	$4^\circ 32'$	599-9/16	599-13/16	beryllium	$6\frac{1}{2} \times 3/4 \times \frac{1}{2}$
II	$8^\circ 06'$	611-1/8 to center of target (outer-radius target)	- - - -	uranium	
II	$11^\circ 00'$	604-13/16 to inner-radius edge (outer-radius target)	- - - -	polyethylene	$3 \times 1/4 \times 1\text{-}3/4$
II	$11^\circ 00'$	604-13/16 to inner-radius edge (outer-radius target)	- - - -	carbon	$3 \times 1/4 \times 1\text{-}3/4$
II	$13^\circ 57'$	601-9/16 max (adjustable)	601-3/4 max (adjustable)	beryllium	$4 \times 1 \times 11/16$
II	$16^\circ 19'$	605-1/16 to inner-radius edge (outer-radius target)	- - - -	copper	$7/8 \times 1 \times 3/4$
II	$19^\circ 58'$	601-1/8	601-5/16	polyethylene	$1 \times \frac{1}{2} \times 1$
III	$1^\circ 45'$	605-1/8 to inner-radius edge of foil (outer-radius target)	- - - -	.005-inch Al foil	$.005 \times 9\frac{1}{2} \times 10$
III	$35^\circ 32'$	$600\frac{1}{2}$	600-3/4	graphite	$3\text{-}5/16 \times 1 \times 4$
III	$71^\circ 42'$	599-5/8	600	aluminum	$4 \times \frac{1}{2} \times \frac{1}{2}$
III	$72^\circ 43'$	599-3/4	600-1/8	copper	$3\frac{1}{2} \times \frac{1}{2} \times \frac{1}{2}$
III	$79^\circ 06'$	596-5/16 to center of target	- - - -	polyethylene	1/8 dia × 1 high

[a] Dimensions are given thus:





ZN-1892

Fig. 1. Rapid beam ejector and internal beam-deflection magnet in the south straight section.

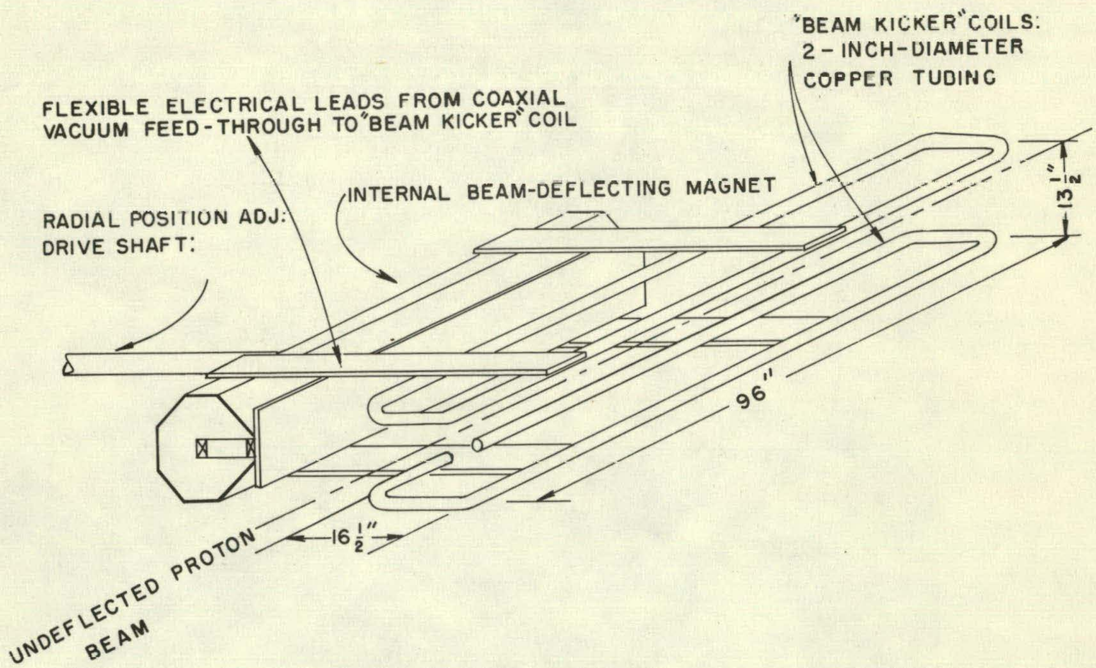


Fig. 2. Rapid beam ejector in deflecting position. This simplified drawing shows the manner in which the rapid beam ejector coils are supported from the internal beam-deflection magnet. Radial position is adjusted by manual operation of the drive shaft attached to the internal beam-deflection magnet.

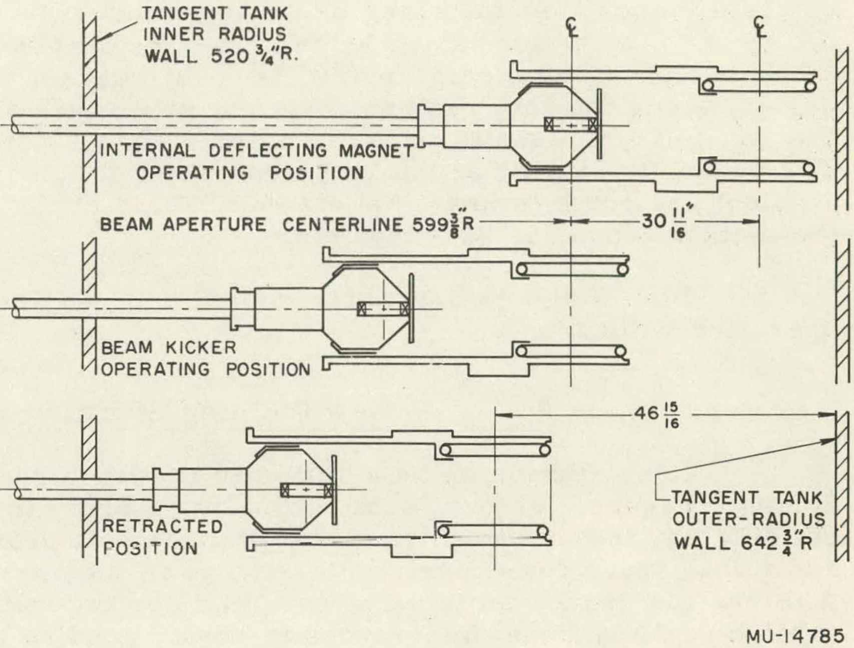


Fig. 3. Rapid beam ejector and internal beam-deflecting magnet in their respective operating positions and in the retracted position.

New Auxiliary Bending Magnets

Bending magnets of two new designs have been added to the number of auxiliary magnets already available for physics experiments at the Bevatron. Within the next two months, two completed units of each new type will be ready for service. One of the new magnets ("C" type construction) is pictured in Fig. 4. The pole tip is 12.5 by 23.5 inches; the normal gap is 6 inches. At the rated operating temperature, 40° C above ambient, the power dissipation is 150 kilowatts. The magnetic field at the center of the pole tip, in the median plane, is 17 kilogauss; the line-integral flux density along the long dimension of the pole tip is 4.6×10^5 gauss-inches. The second type, shown in Figs. 5 and 6, has a pole tip 18 by 36 inches. The power dissipated at the rated operating temperature, 40° C above ambient, is 300 kilowatts; the magnetic field at the center of the pole tip, in the median plane, is 20 kilogauss.

Both magnets are water cooled and run conservatively at the rated operating values.

New Building Addition

Construction on an addition to the Bevatron building began last Spring. Figure 7 shows, schematically, a plan view of both the existing building and the new facility. The addition will provide much-needed additional space for experimental setups in the various external beam area. A thirty-ton crane, suitable power, and cooling water facilities will be available. Additional generators to power bending and focusing magnets will be housed within the new addition in a room adjacent to the present generator room.

The building is scheduled to be ready for occupancy in March 1958.

EXTERNAL PROTON BEAM STUDIES

(Warren Chupp)

Experimental studies designed to provide information necessary to produce a high-intensity external beam of protons from the Bevatron have been carried out. As previously described,[1, 2] the deflection scheme is of the Wright-Piccioni type,[3, 4] consisting of (a) an energy-loss target of graphite whose purpose is to decrease the proton energy sufficiently on a

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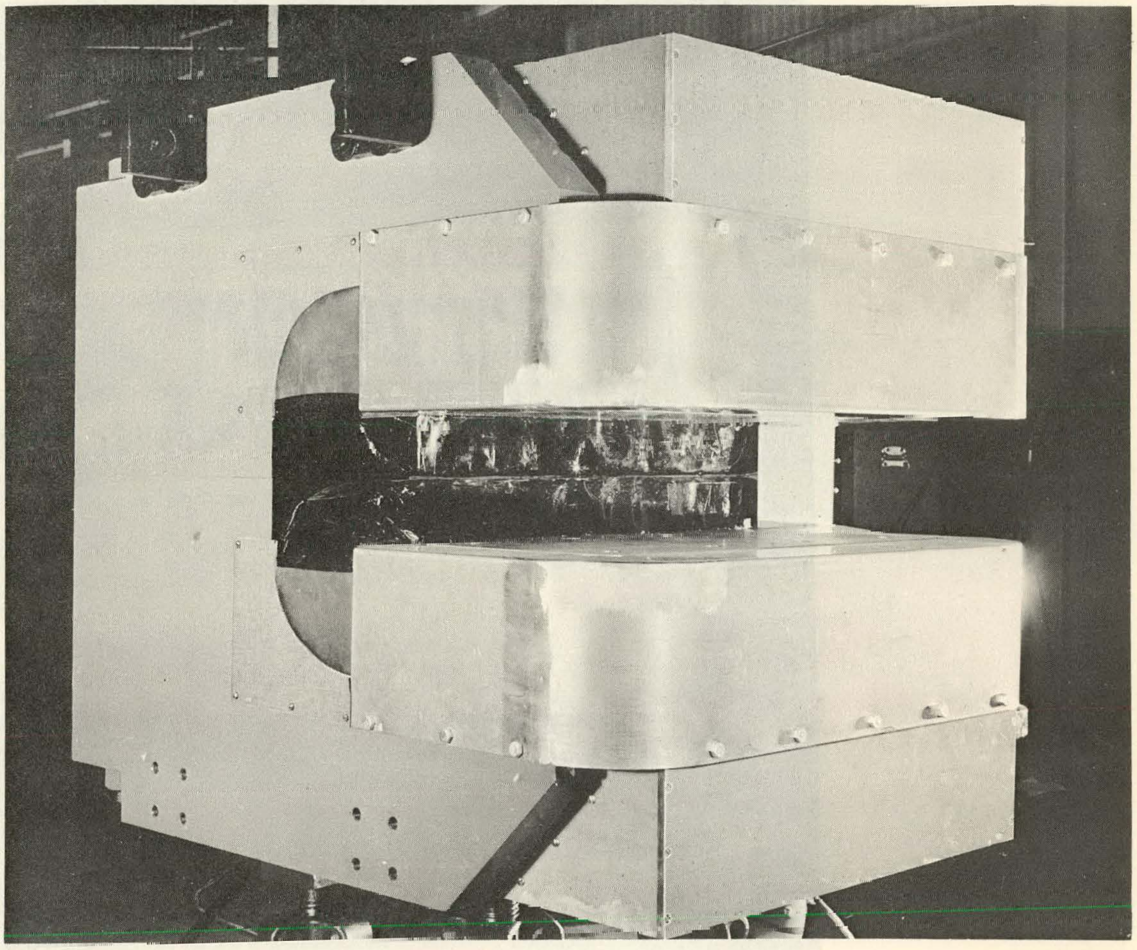
[2]Bruce Cork, Warren Chupp, and Edward J. Lofgren, Bevatron Operation and Development. IV, University of California Radiation Laboratory Report No. UCRL-2954, April 1955.

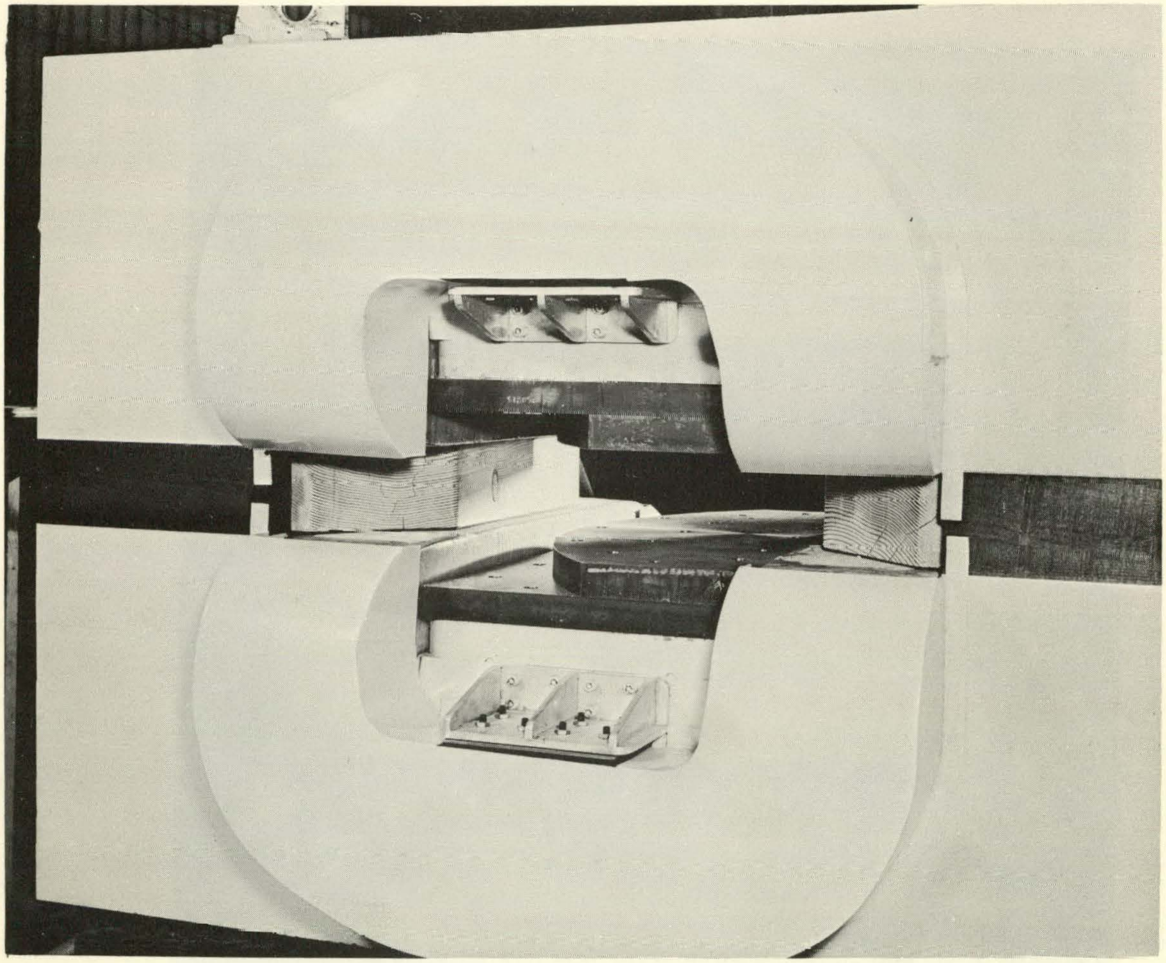
[3]Byron T. Wright, Magnetic Deflector for the Bevatron, Rev. Sci. Instr. 25, No. 5, pgs. 429-431 (1954).

[4]O. Piccioni, D. Clark, R. Cool, G. Friedlander, D. Kassner, Bull. Am. Phys. Soc. 29, No. 8, pg. 27 (December 28, 1954).



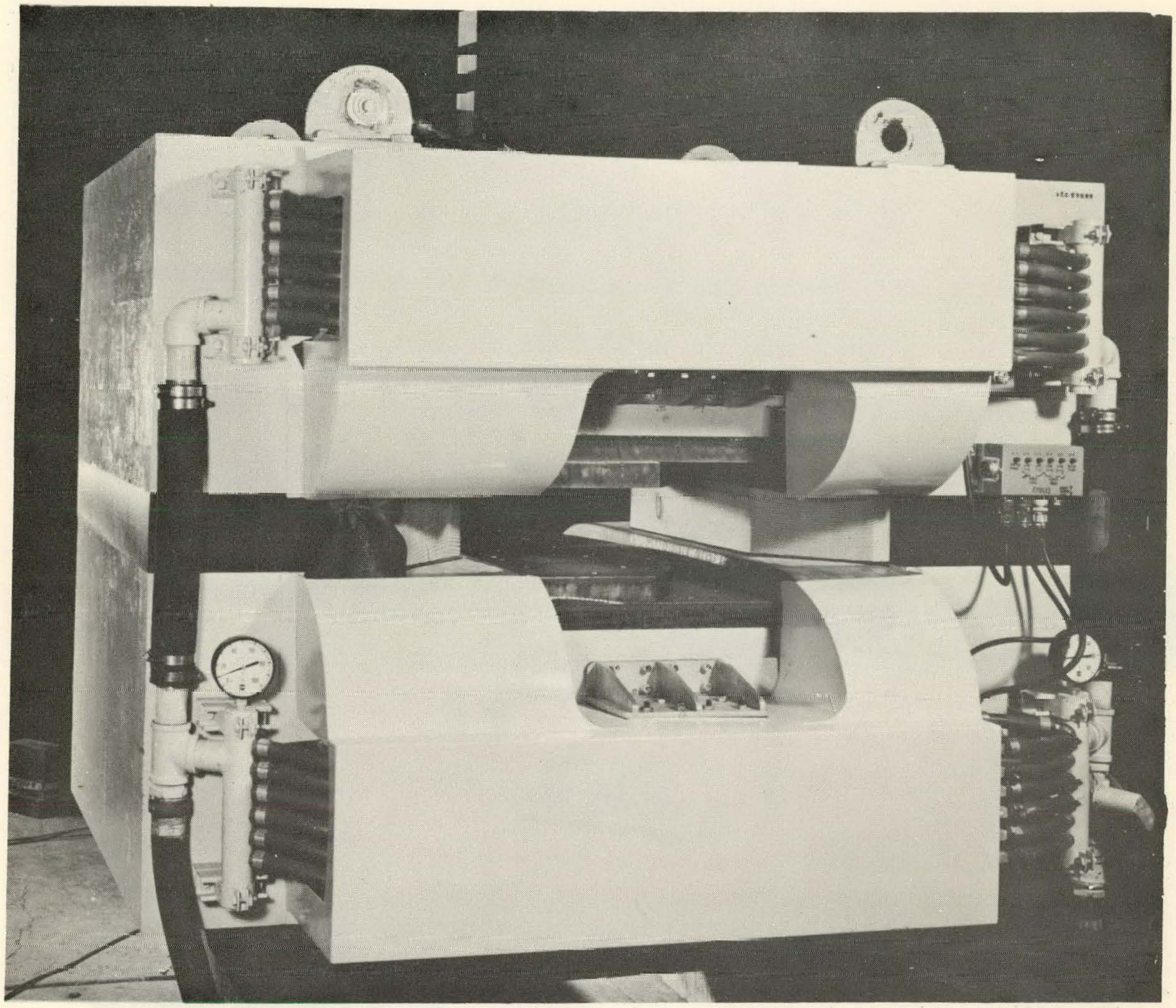
ZN-1893

Fig. 4. New 12.5-by-23.5-inch bending magnet.



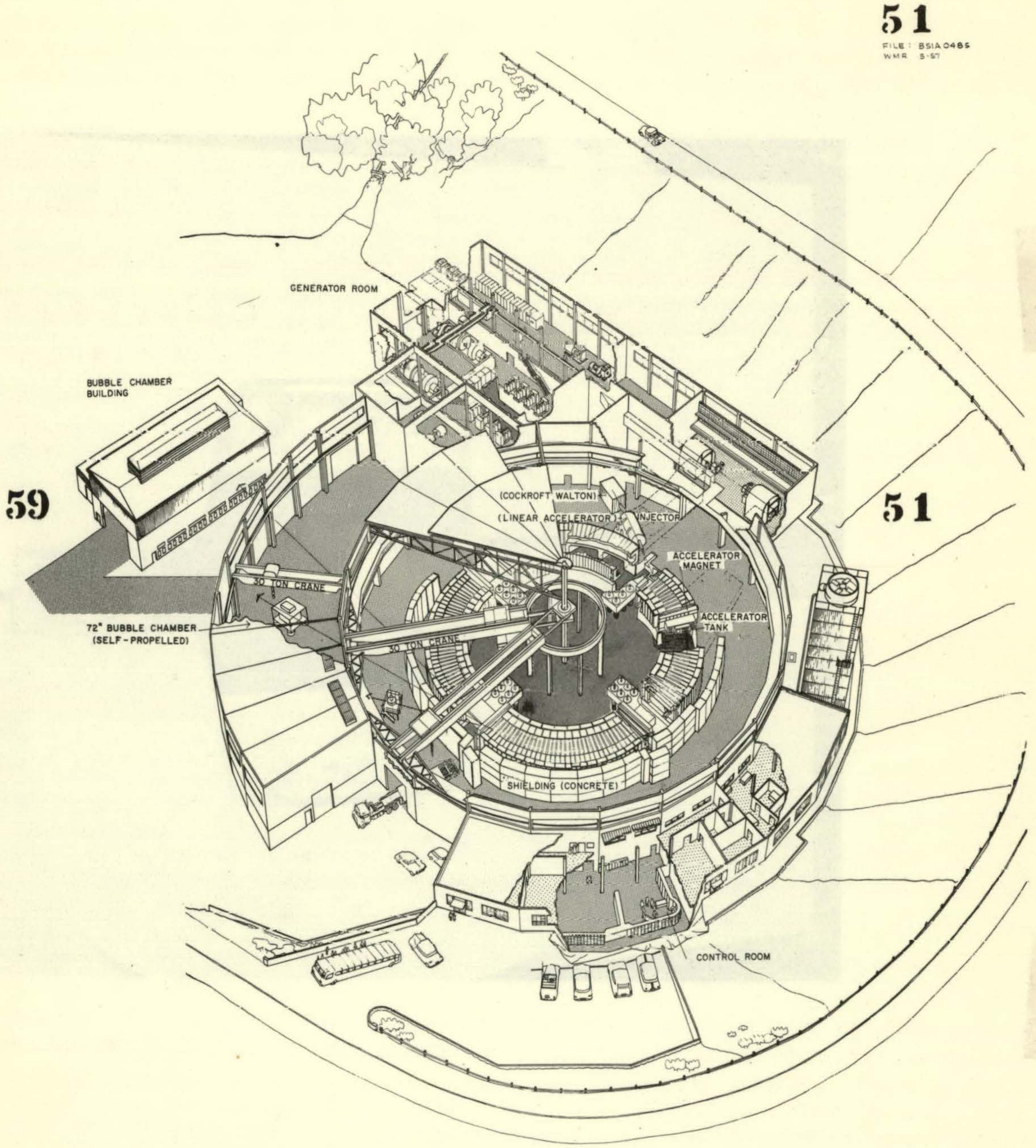
ZN-1895

Fig. 5. New 18-by-36-inch bending magnet.



ZN-1928

Fig. 6. New 18-by-36-inch bending magnet (view of end with water manifold and electrical connection).



MUB-146

Fig. 7. Bevatron building with new addition. The new bubble chamber building is also shown.

single traversal to move the orbit approximately 6 inches inside the circulating undeflected proton beam, and (b) an internal deflection magnet located near the first radial focus of protons that have penetrated the energy-loss target. The magnet is designed to apply to the protons a deflection sufficient to permit them to cross the guiding field in the accelerating aperture and emerge at some point on the outer periphery of the vacuum chamber.

The particular studies carried out at this time were designed to yield information on the deflection properties of the internal magnet and to study the deflected-beam shape and intensity at various possible points of emergence from the vacuum chamber.

The graphite energy-loss target was located 35 degrees into Quadrant III at a radius of 600-3/4 inches. The thickness was 17.89 g/cm^2. The internal deflecting magnet was located in the south straight section (between Quadrants I and II). The radial position of the magnet was adjusted so that the magnet gap was centered on the deflected-beam peak. This peak was located by use of a threefold coincidence telescope viewing a movable copper target -- 1 inch in the radial direction, 4 inches high, and 2 inches thick -- which was located near the end of the deflecting magnet and was moved radially to survey the radial distribution of the displaced beam. The signal from the beam-induction electrode used as a monitor and the peak of the displaced beam was found to be at a radius of 591.5 inches. The deflecting-magnet aperture was thus centered at this radius. The 6-inch width of the deflecting-magnet aperture included the radial width of the beam plus about 2 inches of clearance on either side. The height of the magnet gap is 2 inches, and, as indicated above, the target was 4 inches high. Magnet-in and magnet-out comparisons indicate that approximately one-half of the diplaced beam gets through the magnet. Part of the loss may occur because the deflecting magnet may not be at the position of vertical focus.

For observing the deflected beam, a second and similar counter telescope was used at the exit of the next quadrant to view a copper target, 1 by 1 by $\frac{1}{2}$ inch high, which could be moved in the radial direction. The deflecting-magnet field was adjusted to bring the deflected beam peak to a radial position of 616 inches, which is well outside the circulating beam and approximately 10 inches inside the vacuum chamber. The deflected beam was determined to be 6 inches wide at half maximum.

Attempts were made to deflect the beam out through the vacuum-tank wall. The arrangement of the quadrant end frames, internal stanchions, and other structural members made it difficult to find a place where the emergent beam could clear these obstructions. It is therefore difficult, at this time, to make any meaningful statements on the shape and direction of the deflected beam. The vertical height of the beam, however, was measured as 1 inch. The beam apparently can be steered to emerge at the exit end of the quadrant and at an angle of about 6 degrees to the wall of the straight section. It is estimated that essentially all the deflected beam arrives at the west straight section, but an accurate estimate of the deflection efficiency will require further refinements in the detection technique.

Tests were made to determine the effect of the internal magnet on the magnitude and beam-tracking characteristics of the circulating beam. With the magnet fully excited at injection, no effect on the accelerated beam was observed, hence there is no problem due to the stray field of the deflecting magnet. The magnet "in position" reduces the accelerating aperture by a factor of two. The best beam obtained with the magnet at the deflecting position and fully excited was approximately 30% of that obtained at full aperture; however, the vacuum tank had been recently evacuated and part of the loss may have been due to gas scattering. Previously, a survival of 46% had been obtained under better vacuum conditions.

At present, an orbit-tracing program is being carried out. The object is to verify the experimental results obtained to date and - once this is achieved - to predict the behavior of the deflection system with more confidence.

MAGNET-PULSING RECORD

The magnet pulsing record appears in Table II.

OPERATION

Since June, when Bevatron operation was resumed following the extended shutdown this spring, the Bevatron has been operated at reduced magnet voltage (14 kv at Tap 5 instead of 16 kv at Tap 3) in an effort to improve the reliability and performance of the motor generator sets and their associated ignitrons. At the time the decision was made to run at reduced voltage, there was little operating information of a comparable nature with which to predict the performance of the machine at the lower voltage. It was believed, however, that the magnetic-field correction circuits and radio-frequency tracking equipment could be completely compensated for the reduced rate of rise of magnet current and that the beam acceptance and survival, therefore, should be essentially unchanged.

During the preceding quarter, it was not possible to separate the effects of operation at reduced magnet voltage from possible lingering effects of the shutdown. The period must be considered a recovery period.

This quarter, however, the operation must be considered as typical and normal for the present mode of operation. The generator and ignitron performance and the Bevatron beam record should not now be influenced by temporary conditions attributable to a recovery period. The magnet-pulsing record (see preceding section) shows an improvement both in the total pulses per month and in the number of pulses per fault. However, since the shutdown, the number of rectification faults (arc-backs) has increased in relation to the number of inversion faults. It has not been

Table II

IGNITRON FAULT RATE

MONTH	5 - 6 pulses per minute						7 - 9 pulses per minute						10 - 17 pulses per minute					
	1500-6000 amps			6100-9000 amps			1500-6000 amps			6100-9000 amps			1500-6000 amps			6100-9000 amps		
	PULSES	FAULTS	P/F	PULSES	FAULTS	P/F	PULSES	FAULTS	P/F	PULSES	FAULTS	P/F	PULSES	FAULTS	P/F	PULSES	FAULTS	P/F
1957																		
June	1144		1144	12799	23	550	1744	1	1744	36648	80	458	17929	9	1992			
July	72		72	5012	11	456	1372	2	686	48854	70	6979	33027	35	945	106896	124	878
August	2711	5	542	7463	14	533	536	1	536	81217	89	912	20918	5	4183	89439	53	1686
September	959	2	479	5674	10	567	1053	3	351	22926	40	573	11644	18	647	98469	97	1015
October				1335	5	267	1124			129138	114	3133	14070	4	3515	22967	25	918

TOTALS

MONTH	Number of Pulses	Number of faults: Arc-Backs	Number of faults: Arc-Through	P/F
1957				
June	70, 264	6	117	562
July	195, 233	29	247	707
August	202, 284	29	138	1211
Sept.	140, 725	47	123	828
Oct.	168, 634	80	68	1139

determined whether this change in fault pattern is due to Tap 5 operation or due to circuit changes introduced during and since the shutdown. The beam output also has increased considerably during this quarter, although it has not approached the performance record established prior to the spring shutdown. Again, it is not known whether the failure to obtain the maximum beam levels is due to some misadjustment or inherent unknown factor associated with low-voltage magnet pulsing or due to one or more unknown causes created during or since the spring shutdown.

The maximum recorded beam amplitude, at high energy, was 9×10^{10} protons per pulse; the maximum injected beam was 300 microamperes. As was true previously with Tap 3 operation, the average value of beam at any particular time was about 50% of the peak value.

Tap 3 operation will probably be resumed within the next month or so in order to obtain a more realistic appraisal of Tap 3 versus Tap 5 performance.

Figure 8 summarizes the operation of the Bevatron during this quarter.

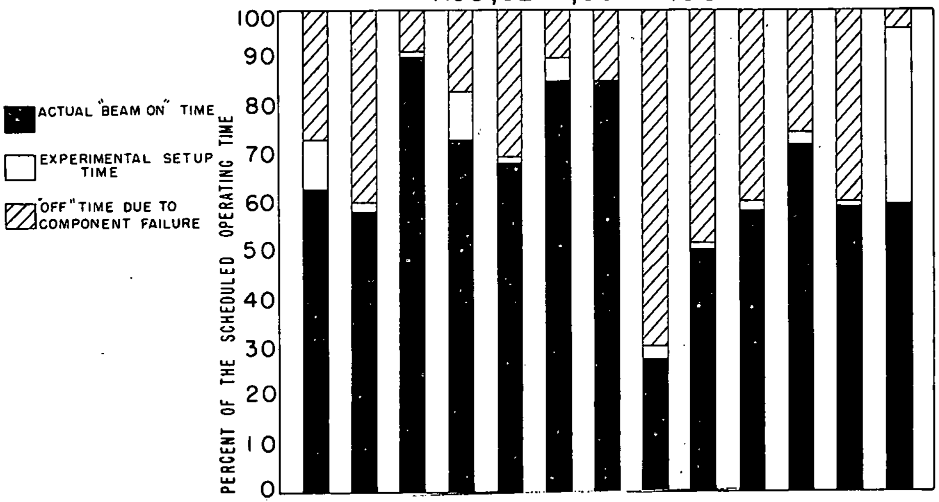
SHUTDOWNS

Five shutdowns occurred during this quarter. Two scheduled shutdowns, September 18 and October 30, were for routine maintenance and modifications, and for installation of new equipment. On August 7, the Bevatron was "at air" for 4 hours for the repair of the Quadrant III 79° flip-target mechanism. On October 4 and again on October 23, failure of the inflector to hold high voltage necessitated work in the vacuum tank. In each case, the vacuum tank was pumped down again the same day. During the shutdown on October 4, two support insulators for the inflector "main" electrode and the two insulators on the "trim" electrode were removed, cleaned, and replaced. On October 23, the inflector trim electrode was removed and reworked. The radii of the entrance and exit edges and corners were increased in order to reduce the field gradient at these points (it was suspected that the corona and sparking that had necessitated the shutdown had occurred at the gap between the main electrode and trim electrode and at the corners at the exit end of the trim electrode. Also, the surface of the trim electrode was ground in an attempt to improve the surface finish. Two insulators were cleaned and replaced on the inflector main electrode.

RESEARCH

The research activity during this quarter is summarized in Table III.

BEVATRON OPERATING SCHEDULE
AUG, SEPT, OCT 1957



WEEK OF	8/4	8/11	8/18	8/25	9/1	9/8	9/15	9/22	9/29	10/6	10/13	10/20	10/27
CREW HOURS	119	119	119	119	102	119	119	119	119	119	119	119	119
TURN-ON & MAINT. TIME (HR)	20	20	20	20	15	20	9	11	20	20	20	20	11
SCHEDULED OPERATING TIME (HR)	99	99	99	99	87	73	42	57	84	65	98	89	57
SCHEDULED BEVATRON TEST TIME (HR)	0	0	0	0	0	26	0	0	15	34	1	10	0
SCHEDULED SHUTDOWN TIME (HR)	0	0	0	0	*17	0	68	51	0	0	0	0	51

* HOLIDAY

MU-14786

Fig. 8. Bevatron Operating Schedule
Aug., Sept., Oct. 1957

Table III

Bevatron Experimental Research Program
August, September, October 1957

INTERNAL GROUPS

Group / Experimenters	Experiments
ALVAREZ	
Gow, Lyman, Ticho	Interactions of negative particles in hydrogen using the 10-inch liquid hydrogen bubble chamber (927 Mev/c, 995 Mev/c, 1.05 Bev/c, 1.12 Bev/c, 1.24 Bev/c). Search for asymmetries in the production and decay of $\pi^- + p \rightarrow \Lambda + K$, $\pi^- + p \rightarrow \Sigma + K$, and $K^- + p \rightarrow \lambda + \pi$, $K^- + p \rightarrow \Sigma + \pi$. Also a search for $K^- + p \rightarrow \Xi^{-,0} + K^{+,0}$.
Bradner	Search for magnetic monopoles using nuclear emulsions (five exposures).
HELMHOLZ-MOYER	
Atkinson, Hess, Peréz-Mendez, Wallace	Total and absorption cross-sections for 5 Bev neutrons in various materials using counters.
LOFGREN	
Chupp, Wenzel	Internal-proton-beam deflection experiment.
Coombes, Cork, Galbraith, Lambertson, Wenzel	Study asymmetries in K-μ-e decay, using counters. (500-Mev/c K^+ mesons)
MOYER	
Brabant, Hess, Hinrichs, Osher, Patterson, Wallace	Detection of antineutrons in coincidence with He_3 production, using counters.
Osher, Parker	π^0 modes of heavy-meson and hyperon decay, using counters.
Patterson, Smith, Wallace	Radiation-shielding study. Study of attenuation of neutrons in concrete an lead.

INTERNAL GROUPS

Group	Experimenters	Experiments
POWELL		
	Barkas group, Birge group, Lofgren group, Powell group	Decay of 900-Mev/c K^+ mesons in a 30-inch propane bubble chamber.
SEABORG		
	Alexander	Al, U foil bombardments (7) (3.0 Bev, 4.1 Bev, 6.2 Bev)
	Altman	Bi foil bombardments (2) (4.1 Bev)
	Benioff	$(COOH)_2$ Al, (CH_2)n target bombardments (2) (5.7 Bev) (CN_5H_3), Al, (CH_2)n target bombardment (5.7 Bev)
	Caretto	Ag, U foil bombardment (6.1 Bev)
SEABORG		
	Ladenbauer	Iodoform in cellulose target bombardments (6) (2.0 Bev, 6.2 Bev)
	Winsberg, Crosby	Au, Al foil bombardments (4) (3.0 Bev, 4.1 Bev, 4.5 Bev, 6.2 Bev)

ACKNOWLEDGMENTS

The Bevatron group leader is Edward J. Lofgren, and under him Harry Heard, with Walter Hartsough assisting, is in charge of operations. The Bevatron operators are Robert Anderson, Wendell Olson, and Robert Richter as crew chiefs; G. Stanley Boyle, Gary Burg, Duward Cagle, Norris Cash, Frank Correll, Robert Gisser, William Kendall, Ross Nemetz, Fred Lothrop, Frank Ulbrich, and Glenn White as crew members. Special development projects were carried out by Bruce Cork, Harry Heard, Glen Lambertson, and Emery Zajec. Harold Vogel was the engineer in charge of the motor generator sets. The mechanical engineering group was headed by William Salsig; the electrical engineering group was headed by Clarence Harris and Marion Jones. Ivan Lutz directed the electronic development group. Lorenzo C. Eggertz was in charge of the electrical maintenance group.

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