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November, December 1956, January 1957

Walter D. Hartsough

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ABSTRACT

Studies of π-meson and K-meson interactions were continued with counters, emulsions, and the 10-inch liquid hydrogen bubble chamber. Six emulsion exposures were made for external groups to a π-meson beam, three to K-meson beams, two to a neutral-particle beam, and three to the internal proton beam. An H-D reaction, catalyzed by μ mesons, was observed in the 10-inch liquid hydrogen bubble chamber. Absorption cross-section measurements for antiprotons were continued, using counters. Nineteen target bombardments were made for the chemistry group.

A technique of producing two or more secondary-particle beam pulses per acceleration cycle, using different targets, has been successfully tried and used.

Bevatron operation was suspended temporarily on January 31 pending the results of an investigation of the failure of several of the magnet-coil-box corner retainers.

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INJECTOR

Because of a continued high incidence of failure of resistors in the ion-gun-column voltage divider, the resistor-divider method of obtaining a uniform voltage gradient on the column has been abandoned in favor of electrically connecting the column gradient rings to appropriate points in the 480-kv Cockcroft-Walton power supply. At the present time, temporary connections have been made. If this method proves satisfactory, aluminum tubing and suitable fastenings will be fabricated and installed.

EXPERIMENTAL FACILITIES

Quadrant-Mounted Targets

Table I lists the quadrant-mounted targets that were available during the latter half of this period.

SUMMARY OF BEVATRON VACUUM-TANK PUMPDOWNS

Figure 1 shows five pumpdown curves for the Bevatron vacuum tank. With the exception of curves B and F, each curve represents the average of several pumpdown curves grouped according to the manner in which the tank was opened to air (normal or dry air), and the length of time the tank was open to air.

MULTIPLE SECONDARY-PARTICLE BEAM PRODUCTION

Several methods of secondary-particle beam production have been described previously.[1, 2, 3, 4] In each case the beams were produced by allowing all the primary-beam particles to strike one target during or at the end of each acceleration cycle. Multiple experiments were accomplished

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[1] Harry G. Heard, Extended-Orbit Control for Production of Short Beam Pulses, Bevatron Report 204, December 6, 1956.

[2] Harry G. Heard, Slow and Fast Structure of Secondary-Particle Beams of the Bevatron, UCRL-3428, July 5, 1956.

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

[4] Walter D. Hartsough, Bevatron Operation and Development. IX, UCRL-3444, June 1956.

Table I

Quadrant-mounted targets
December 7, 1956 to End of Quarter

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 x b x c (in.)
II	1° 59'	599-1/16	599-11/16	Graphite	9-23/32 x 1/2 x 1
II	3° 02'	598-15/16	599-9/16	Polyethylene	9-23/32 x 1/2 x 1
II	5° 03'	600-11/16	601-3/16	Beryllium	6 x 1/2 x 1
II	13° 09'	601-1/16	601-1/4	Uranium	1 x 1/2 x 3/4
II	13° 57'	601-9/16 max (adjustable)	601-3/4 max (adjustable)	Beryllium	4 x 1 x 11/16
II	16° 19'	605-1/16 to inner-radius edge (outer-radius target)	-------	Copper	7/8 x 1 x 3/4
II	19° 58'	601-1/8	601-5/16	Polyethylene	1 x 1/2 x 1
III	35° 19'	597-1/16	597-1/4	Graphite	3 x 3/4 x 4
III	69° 56'	599-1/8	599-1/2	Aluminum	4 x 1/2 x 1/2
III	73° 00'	598-3/32	598-7/16	Aluminum	4 x 1/2 x 1
III	79° 45'	598-15/16	599-7/16	Lead	4 x 1/2 x 1/4

Beam

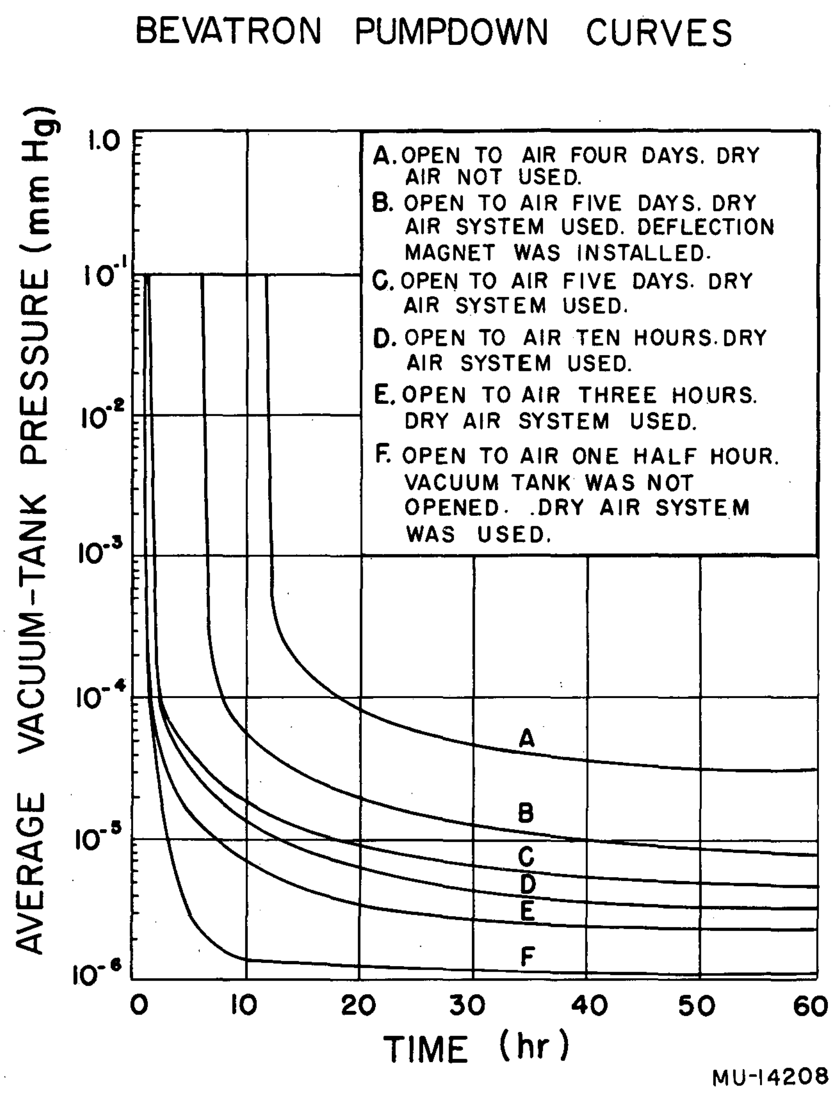

Fig. 1. The finishing pumps were opened to the vacuum tank, when the tank pressure was 1 - 2 x 10^{-1} mm Hg.

because two or more experimental groups shared the same secondary-particle beam or because they received consecutive beam pulses in a programmed sequence.

Recently, a method of multiple targeting and of perturbing the rate of change of rf has been used successfully to permit two or more experiments to use the same beam pulse if the experiments could be done at different energies. The method consists of erecting the targets in the order of desired beam energy, expanding or contracting the beam orbit just enough to cause some of the beam to strike the target, and returning the remaining beam to its unperturbed position. The beam particles in the bunch remain phase-synchronous as long as the frequence perturbation is slow in comparison with the period of a phase oscillation. Beam pulses 2 to 4 milliseconds wide have been produced by this method. The minimum energy spacing between pulses is limited by the time it takes to erect and lower the targets.

The lower trace in Fig. 2 pictures two secondary-particle beam pulses produced as described above: a 5.3-Bev beam pulse of 2-millisecond half width for a bubble chamber experiment, and a 150-millisecond-wide pulse (5.7 to 6.5 Bev) for a counter experiment. The upper trace shows the signal from the beam-induction electrode.

FAILURE OF THE MAGNET-COIL-SHROUD CORNER RETAINERS

On January 31, an investigation of the source of a loud metallic noise during magnet pulsing disclosed several loose and, in some cases, missing mild-steel retainer assemblies at the corners of the air shrouds surrounding the magnet windings. These retainers, because of the force exerted on them during magnet pulsing, had sheared the rivets that secured them to the masonite shrouding; the inner half of each retainer assembly had fallen into the magnet coil space, the outer half against the vacuum-tank skin. Figure 3 shows schematically a cross-sectional view of the Bevatron in the region of the outer-radius coil.

Because of the possibility of serious damage to the coil windings and the vacuum-tank skin if magnet pulsing were continued, Bevatron operations have been suspended pending a determination of the extent of the failure and an engineering survey of the feasibility of redesign and installation of air-shroud retainers using nonmetallic materials. If, as it appears now, it is necessary to replace all the shroud retainers, the time required is estimated to be about three months.

MAGNET POWER SUPPLY

During this period, three ignitrons failed and were replaced. The magnet-pulsing record appears in Table II.

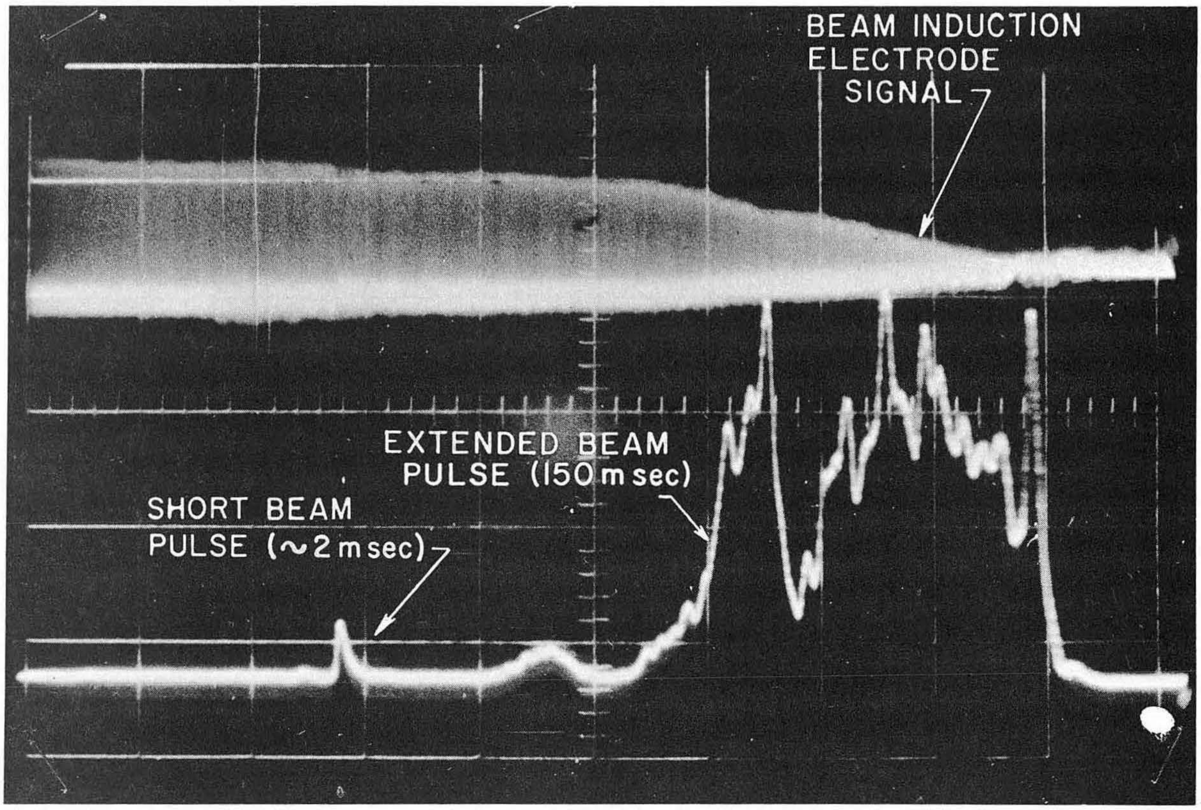

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Fig. 2. The short beam pulse was produced by causing some of the primary proton beam to strike a target at the Northwest Target Area. The remaining beam was spilled slowly on a target at the West Experimental Area.

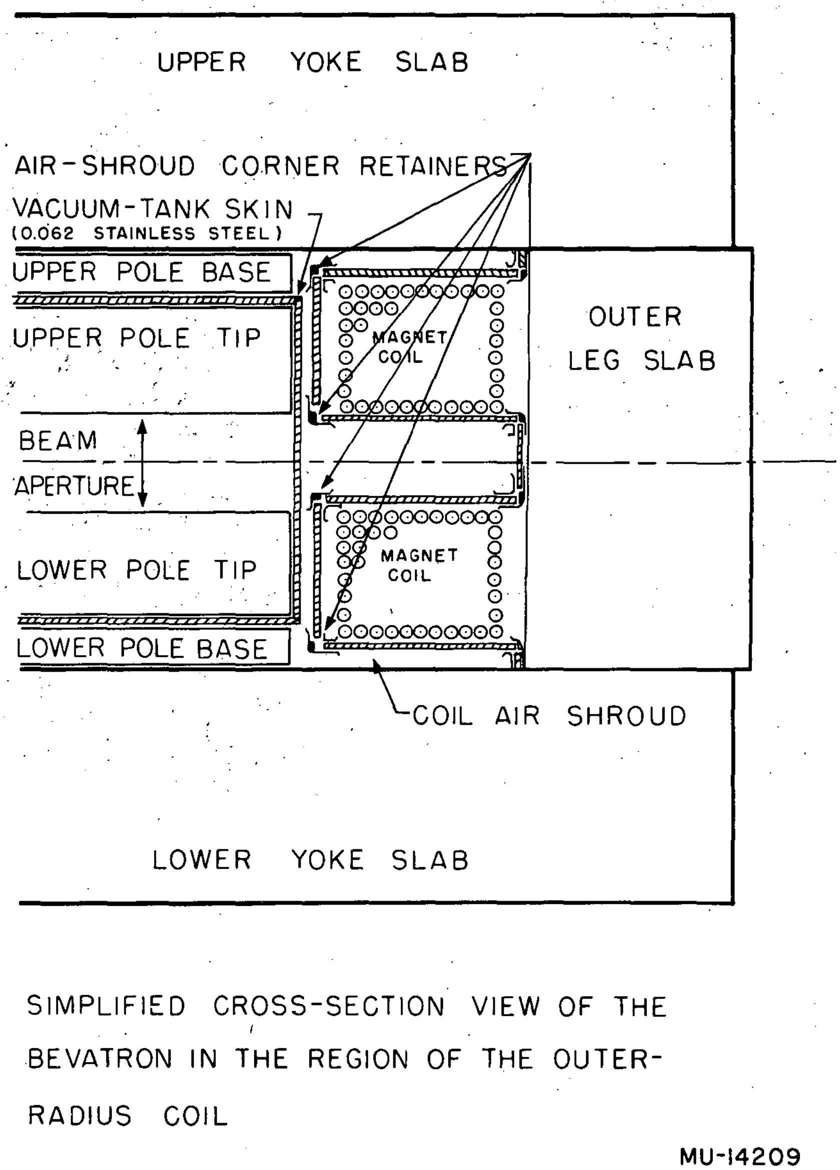

Fig. 3. Simplified cross-section view of the Bevatron in the region of the outer-radius coil.

Table II

Ignitron Fault Rate*

	5 to 7 pulses per minute						7 to 10 pulses per minute						10 to 17 pulses per minute						TOTAL			
	1500 to 6000 amps			6000 to 8000 amps			1500 to 6000 amps			6000 to 8000 amps			1500 to 6000 amps			6000 to 8000 amps						
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	MONTH	NO PULSES	NO FAULTS	P/F
1956																			1956			
Jan	------	--	---	------	--	---	------	--	---	6718	7	960	11148	1	11148	3433	1	3433	Jan	21, 299	9	2,366.6
Feb	177	--	---	7468	15	497.6	2922	4	730	38146	95	401	23624	3	7874	6735	15	449	Feb	79, 072	132	599.0
Mar	678	6	113	3208	7	458.2	207	1	207	43782	71	616	30358	9	3373	119065	162	735	Mar	197, 298	256	770.7
Apr	13193	1	13193	26778	43	622	35831	3	11943	31209	57	547	16297	6	2716	16024	17	942	Apr	139, 332	127	1,097.1
May	165	--	----	3054	1	3054	2062	1	2062	59288	115	515	35595	6	5932	72777	92	790	May	172, 876	215	804.1
June	120	--	----	285	--	----	3198	0	-----	123197	187	657	17759	16	1109	3070	3	1023	June	147, 629	206	716.6
July	-----	--	----	-----	--	----	-----	-	-----	90655	131	684	14036	2	7018	90375	83	1088	July	195, 066	216	903.1
Aug	-----	--	----	-----	--	----	-----	-	-----	7755	7	1107	10938	1	-----	190009	208	913.5	Aug	208, 702	216	966.2
Sept.	-----	--	----	-----	--	----	1677	-	-----	12447	10	1245	6278	1	----	95784	71	1346	Sept	116, 186	82	1,417
Oct	-----	--	----	-----	--	----	-----	-	-----	59320	4	14830	-----	-	-----	144463	111	1301.5	Oct	203, 783	115	1,772
Nov	-----	--	----	-----	--	----	174	-	-----	11496	12	958	82523	4	20630	147582	102	1446.8	Nov	241, 775	118	2,049
Dec	467	--	----	2560	2	1280	355	-	-----	39394	15	26263	7987	4	1997	36367	44	825.3	Dec	87, 130	65	1,340
1957																			1957			
Jan	1456	--	----	5882	15	392	2680	-	-----	29639	32	926	29157	2	14578	117745	113	1042	Jan	186, 559	162	1,153

*Refer to previous Quarterly Reports for information on 1954 and 1955 Fault Rates.

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BEVATRON SHUTDOWNS

Two scheduled shutdowns and four unscheduled shutdowns occurred during this period. The first scheduled shutdown, December 3 through December 7, was for routine maintenance, repair, and installation of new equipment on the Bevatron and the magnet power supply. The second, December 22 through January 1, was for the Christmas and New Year Holiday. The first unscheduled shutdown, on November 14, was for the removal of a damaged target probe. The tank was up to air less than one-half hour. On December 21, the machine was shut down for inspection and repair of several gap-mounted targets. The 7° target was removed; the 1° 59', the 69°, and the 73° target mechanisms were repaired. Mechanical failure of gap-mounted targets again was the cause of a shutdown on January 10. The 1° 59' target mechanism was replaced; the 3° 02' target assembly was removed. On January 31, operations were suspended because of a loud metallic noise, during magnet pulsing, in the region of the outer-radius coil windings in Quadrant II. (See previous section.)

OPERATION AND RESEARCH

Figure 4 summarizes the Bevatron operation during this quarter. Not included in the listing of normal crew time and operating hours is a 7-hour shift, 1 A.M. - 8 A.M. one day per week, for motor generator equipment development and testing, and for limited work on the radiofrequency accelerating system.

Figure 5 shows the peak and average values of beam-survival efficiency. The maximum recorded beam amplitude at full energy was 1.2×10^{11} protons per pulse.

During a recent experiment in the 310-Mev/c K^- beam, using the 10-inch liquid hydrogen bubble chamber, the Alvarez Physics Research Group observed a new reaction in which a μ meson comes to rest, catalyzes an H-D reaction, and is rejuvenated by the reaction.[5] A summary of the above work and of the other research activity during this period appear in Table III.

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[5] Alvarez, Bradner, F.S. Crawford, Jr., J.A. Crawford, Falk-Variant, Good, Gow, Rosenfeld, Solmitz, Stevenson, Ticho, and Tripp, Phys. Rev. 105, 1127 (1957).

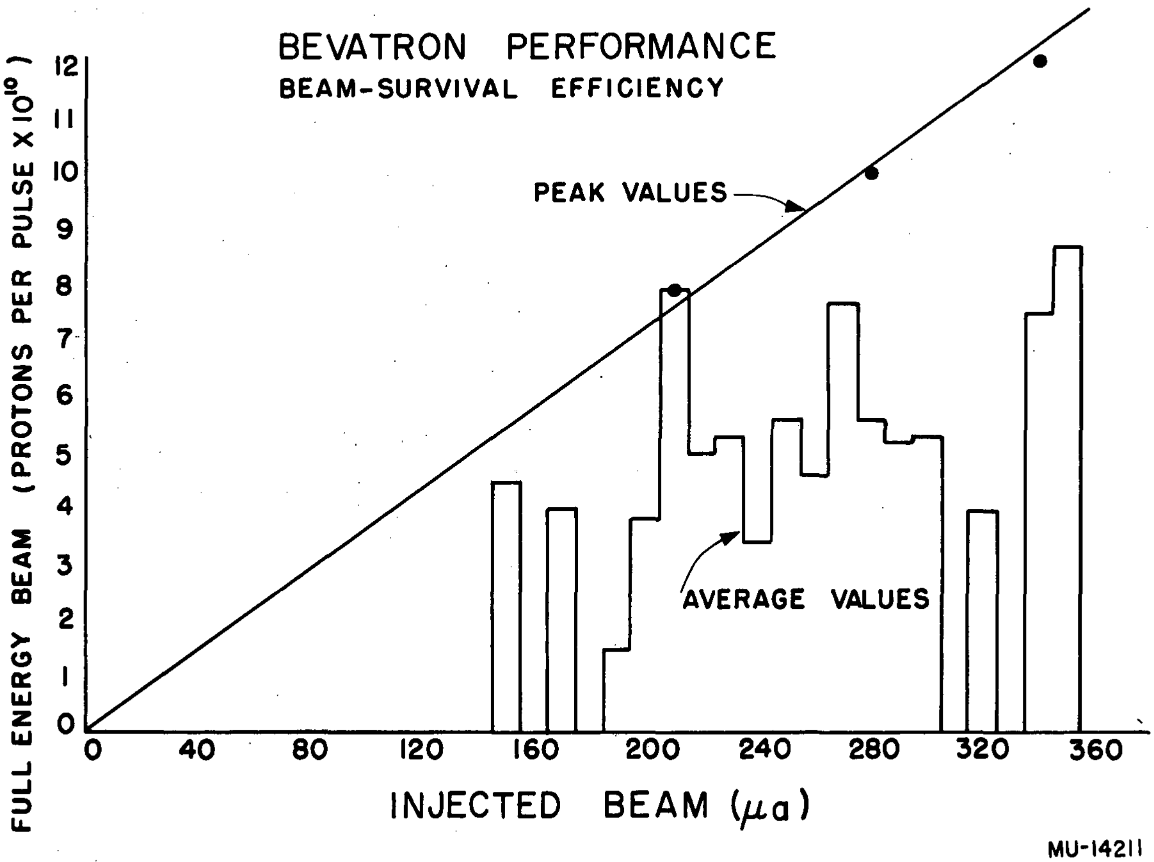
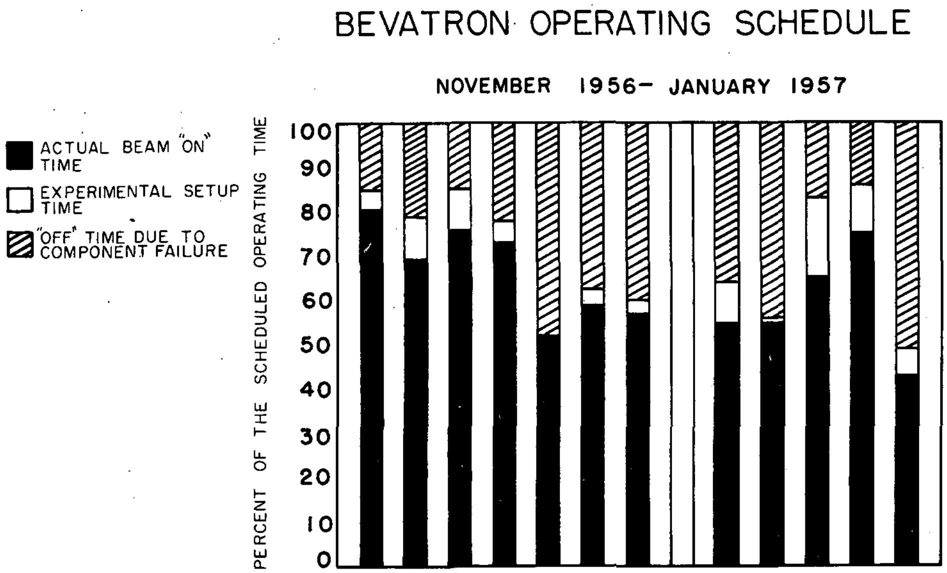


Fig. 4. Bevatron Operating Schedule.



WEEK OF	11/4	11/11	11/18	11/25	12/2	12/9	12/16	12/23	12/30	1/6	1/13	1/20	1/27
CREW HOURS	119	119	85	119	119	119	102	0	68	119	119	119	119
TURN ON & MAINTENANCE TIME (HRS)	20	20	13	20	2	18½	18	0	14	20	20	20	20
SCHEDULED OPERATING TIME (HRS)	84	99	72	99	15	100½	84	0	54	99	99	99	99
SCHEDULED BEVATRON TEST TIME (HR)	15	0	0	0	0	0	0	0	0	0	0	0	0
SCHEDULED SHUTDOWN TIME (HRS) HOLIDAY	0	0	34	0	102	0	17	{85 *34}	{17 *34}	0	0	0	0

MU-14210

Fig. 5. Bevatron Performance. Beam-Survival efficiency.

Table III

Bevatron Experimental Research Program
November, December 1956, January 1957

Experimenters	Experiments
INTERNAL GROUPS	
Group	
ALVAREZ	
Crawford and Stevenson	K^- meson interactions in hydrogen, using the 10-inch liquid hydrogen bubble chamber with magnetic field (310 Mev/c).
	Investigation of H-D reaction catalyzed by μ mesons.
Crawford and Gow	1.5-Bev/c π-and K^--meson interactions in hydrogen, using the 10-inch liquid hydrogen bubble chamber with magnetic field.
Bradner	Search for magnetic monopoles, using nuclear emulsions.
ALVAREZ, LOFGREN	
G. Goldhaber, S. Goldhaber, and Rosenfeld	Determination of the range distribution of 505-Mev/c K^--meson beam, using emulsions.
BIRGE	
Kerth, Kycia, and Van Rossum	K^+ scattering in hydrogen and complex nuclei with focused 560 Mev/c K^+ mesons using counters.
LOFGREN	
Heard	Bevatron acceptance-time measurements.[6]
Cork, Chupp, Heard, and Wenzel	Internal-beam deflection experiments.
Horwitz and Murray	Detection of x-rays from 200-Mev/c π-mesonic atoms.
	Shielding study for NaI scintillation counter.

[6] Harry G. Heard, The Effect of Rate of Rise of Magnetic Field on the Acceptance Time of the Bevatron, UCRL-3682, Feb. 1957.

INTERNAL GROUPS

Group	
Experimenters	Experiment
Chupp, G. Goldhaber, and S. Goldhaber	Emulsion exposures in the focused K^--meson beam (430 Mev/c and 493 Mev/c).
MOYER	
Osher and Parker	π^o modes of heavy-meson and hyperon decay.
	Determine if p+p produces θ^o mesons in associated production.
	Measurement of the lifetime of θ^o mesons.
POWELL	
Lander and Fowler	Angular distribution of regenerated θ_1^o- and θ_2^o-meson decays, using a propane bubble chamber.
SEABORG	
Amiel, Sikkeland, and Winsberg	KI, Al target bombardment (6.2 Bev)
Amiel	KI, Al target bombardment (6.2 Bev)
Barr	Cu, Al foil bombardment (5.7 Bev)
Benioff	$(CF_2)n$, $(CH_2)n$, Al target bombardment (5.7 Bev).
	$(CH_2)n$, Al target bombardment (5.7 Bev).
Caretto	Mylar, Ag foil bombardment (5.7, 6.2 Bev)
	Mylar, U foil bombardment (6.2 Bev)
Currie	Pb, Al, Au foil bombardment (6.2 Bev).
	Al, Fe, polyethylene, Au target bombardment (6.2 Bev).
Nethaway	In, Al foil bombardment (1.0 Bev).
	Rh, Al foil bombardment (3.2, 6.2 Bev).

INTERNAL GROUPS

Group

Experimenters	Experiments
SEGRÈ	
Chamberlain, Steiner, Weigand, and Ypsilantis	Measurement of the absorption cross section for 1.175-Bev/c antiprotons on Pb, U, H_2O, and D_2O.
Chamberlain, and G. Goldhaber	Emulsion exposure in the focused and separated 700-Mev/c antiproton beam.

EXTERNAL GROUPS

Institution

Experimenters	Experiments
ENGLER Rochester University IMAEDA University of Yamanashi, Japan BRISTOL GROUP Bristol, England STEINBERG Northwestern University WATAGHIN Torino, Italy WILKINSON Cambridge University, England	Emulsion exposures in the focused 4.3-Bev/c π-beam.
HOUTERMANS Bern University, Switzerland	Emulsion exposure in the focused 430-Mev/c K^- beam.
TEUCHER University of Oklahoma	Emulsion exposure in the focused 430-Mev/c K^- beam.
PROWSE Bristol, England	Emulsion exposure in the focused 470-Mev/c K^+ beam.
WATAGHIN Torino, Italy	Emulsion exposure to neutral particles at 42° to the forward direction.

EXTERNAL GROUPS

Institution Experimenter	Experiments
LEVI-SETTI, TELEGDI, and SLATER	
Enrico Fermi Institute, Chicago	Emulsion exposure to neutral particles at 42° to the forward direction.
NAKAGAWA	
St. Paul's University, Tokyo	Emulsion exposures to the internal proton beam at 6.2 and 1.04 Bev.
LORD	
University of Washington	Emulsion exposures (2) to the internal 6.2-Bev proton beam.

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 Oson, and Robert Richter as crew chiefs, G. Stanley Boyle, Gary Burg, Duward Cagle, Norris Cash, Frank Correll, Robert Gisser, William Kendall, Ross Nemetz, Frank Ulbrich, and Glenn White as crew members. Special development projects were carried out by Warren Chupp, Bruce Cork, Harry Heard, 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 by Clarence Harris and Marion Jones. Ivan Lutz directed the electronic development group. Lorenzo C. Eggertz was in charge of the electrical maintenance group.

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