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BEVATRON OPERATION AND DEVELOPMENT XXVII
August, September, October 1960

Walter D. Hartsough and Glen R. Lambertson

March 2, 1961

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BEVATRON OPERATION AND DEVELOPMENT XXVII*

Contents

Abstract 5
Operation 7
Research 12
Experimental Facilities 12
Shutdowns 22
Magnet Power Supply 22
Acknowledgments 24

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ABSTRACT

Bevatron operation averaged 77 % of the scheduled operating time this quarter. The machine was off 21 % of the scheduled operating time due to equipment failure and 2 % at the request of the user. The physics-research program again was devoted to study of K^- and π^- meson interactions in hydrogen and deuterium.

Seven chemistry bombardments were made in the internal proton beam.

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OPERATION

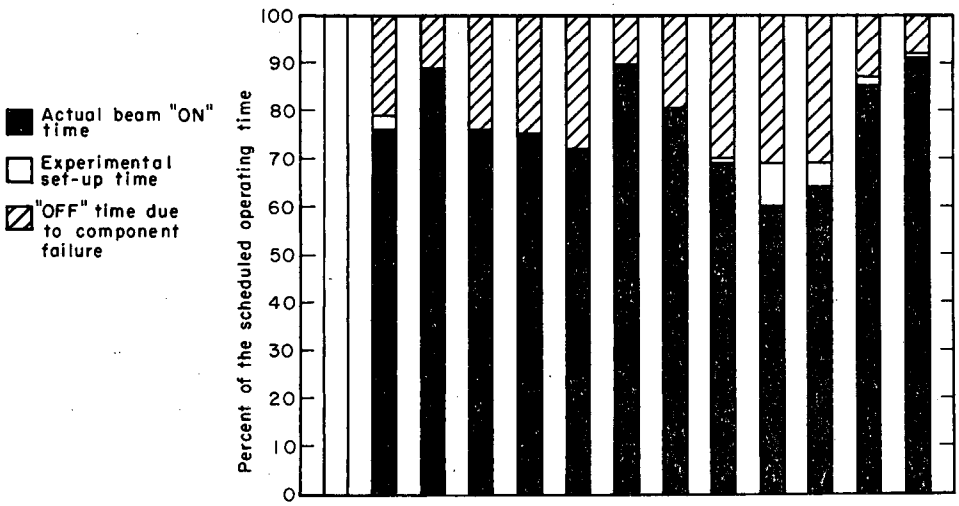
Bevatron Operation is summarized in Fig. 1 and Tables I and II.

Rapid-Beam-Ejector Operation with Two Targets

The closed-orbit distortion produced by the rapid-beam-ejector magnet has been used to deliver the circulating beam to two targets during a single pulse of the RBE. The beam is shared by the targets in adjustable and reproducible proportions.

Figure 2 shows the arrangement of targets that allows beam sharing. The RBE magnet produces an increasing displacement of the equilibrium orbit of the form shown. As the displacement grows, the envelope of the betatron oscillations first encounters target A located about 90 deg from the RBE magnet;—in Fig. 2 the situation is shown at this moment of encounter. Particles with the largest betatron oscillations are taken by target A until the orbit displacement becomes large enough to deliver the beam to target B. The amount of beam received by each target is governed by its radial position relative to the equilibrium orbit. Sharing in all proportions was found possible in an experiment in which the radius of target A was adjusted, B remaining fixed. No detailed observation of beam-pulse length was made, but both were approximately the normal 200-μsec beam. If one or both targets are of small cross section, some sharing will occur, of course, merely because of the probability that the rapidly advancing beam will not strike the target for a number of turns after it is within the range of the betatron oscillations. This was not a large effect with the target used.

Two targets are now used simultaneously for two bubble-chamber experiments. Target A receives about 15 % of the beam for a pion experiment and B takes the remainder for a separated K^--meson beam. Target A was experimentally located at a radius where, without further motion, the fraction of beam deliverable to it could be varied from 10 % to 20 % by changing the radius of the equilibrium orbit at the start of the RBE pulse.



Week of	7/31	8/7	8/14	8/21	8/28	9/4	9/11	9/18	9/25	10/2	10/9	10/16	10/23
Crew hours	168	168	168	168	168	144	168	168	169	168	168	168	168
Turn on & maintenance time (hr)	0	8	9	6	9	6	9	10	9	9	9	9	9
Scheduled operating time (hr)	0	120	152	162	154	138	159	147	160	104	159	159	159
Scheduled Bevatron test time (hr)	0	0	7	0	5	0	0	0	0	0	0	0	0
Scheduled shutdown time (hr)	168	40	0	0	0	0	0	11	0	55	0	0	0
Holiday (hr)	0	0	0	0	0	24	0	0	0	0	0	0	0

MU-23573

Fig. 1. Bevatron operating schedule, August, September, October 1960.

Table I. Beam record

Week of (1960)	Number of 8-hour shifts	Total integrated beam (10^{15} protons)
July 31 - August 6	——— Shutdown	———
August 7 - 13	17	0.6[a]
August 14 - 20	21	2.8[a]
August 21 - 27	17	5.2
August 28 - Sept. 3	19	7.4
Sept. 4 - 10	18	7.1
Sept. 11 - 17	21	12.0
Sept. 18 - 24	19	10.5
Sept. 25 - Oct. 1	19	8.4
Oct. 2 - 8	12	2.8[a]
Oct. 9 - 15	20	5.7
Oct. 16 - 22	21	7.2
Oct. 23 - 29	21	9.6

Maximum beam amplitude at full energy = 2.7×10^{11} protons per pulse

Maximum injected beam = 625 μa

Average beam per 8-hour shift = 3.5×10^{14} protons

[a]Beam amplitude limited by gas scattering (poor vacuum following the shutdown).

Table II. Analysis of the total lost beam time due to component failure (%)

Month (1960)	Injector	Magnet power supply	rf Accelerating system	Other
August	13	32	33	22
September	19	29	24	28
October	16	15	55	14

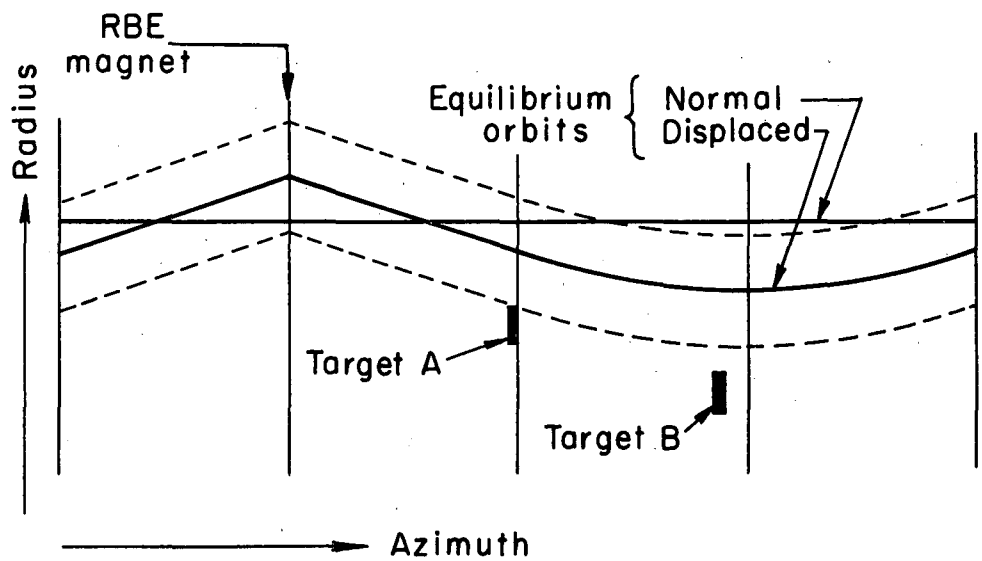


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Fig. 2. Position of beam at first encounter with target A. (Envelope of betatron oscillation is shown dashed.)

RESEARCH

Table III summarizes the Bevatron experimental research program for the period January through July 1960. Table IV lists the experiments conducted this quarter.

EXPERIMENTAL FACILITIES

Quadrant III 89-Degree Experimental Area — Vacuum Coupling of Beam-Transport Systems

The secondary-particle beam exit at the Quadrant III 89-deg experimental area was modified to permit vacuum coupling of beam-transport systems to the Bevatron tank. Negative-particle beams, 0.5 Bev/c to 6.0 Bev/c, may now be brought out of the Bevatron along unobstructed beam paths. Figure 3 is a schematic presentation of this area. Shown are typical beam paths originating at targets in Quadrant III. The particles are deflected by the Bevatron field along curved paths through an aperture 4-1/2 in. high by 55-7/8 in. wide in the Bevatron tank. The four-sector window stanchion previously installed at this location was used and remained unchanged.[1]

Movable supports were required within the vacuum-tank extension to carry the vacuum loading on the top and bottom of the enclosure. The extension tank terminates in a flanged aperture to which suitable attachments may be made (air locks, vacuum-gate valves, beam-transport systems, etc.).

Figures 4 and 5 picture the beam slot in the Bevatron tank and the vacuum-tank extension during this modification period.

Traveling Flip Target

Bevatron targetry, for the most part, is located in the curved sections of the machine. Therefore, advantage may be taken of the Bevatron magnetic field for momentum selection of secondary particles. A disadvantage of these gap-mounted targets is that they generally must remain in fixed locations during an experiment—they are inaccessible when the machine is at vacuum. Target locations must be chosen carefully. Some of the determining factors are: available space, the position of suitable beam-exit ports, and a suitable compromise of secondary-particle production angle and momentum.

The desirability of a remotely operated movable target has been recognized for some time. Recently a mechanism has been designed and built which will allow azimuthal motion of a dual Mark VIII target assembly.[2] This unit is now installed in the Bevatron and is undergoing final operational tests. Figure 6 pictures a dual Mark VIII target assembly and transport mechanism during test prior to installation in the Bevatron. The transport mechanism (drive motor, position-readout device, track, and electrical-bus system) is again shown in Fig. 7.

Table III. Summary of Bevatron experimental research program, January — July 1960

Group	Start of experiment	End of experiment	Experiment	Beam time (12-hour Periods)	Beam time (hours)	Pulse schedule	Primary or secondary experiment
INTERNAL GROUPS							
Lofgren	10/29/59	1/31/60	K^+-meson interactions in hydrogen and deuterium (220 to 875 Mev/c).	36	403	1:2	P
Barkas	1/19/60	1/23/60	Emulsion exposure (2-Bev/c μ^-).	—	—	1:2	S
Barkas	1/22/60	1/22/60	Emulsion exposure (3.5-Bev/c π^-).	—	—	1:2	P
Powell	1/26/60	1/31/60	π^+-p scattering (730-Mev/c).	7	69	1:2	P
Powell	2/13/60	5/20/60	K-meson interactions and θ_1-θ_2 mass difference (700-Mev/c K^+).	73	500 319	1:1 1:2	P
Lofgren	2/13/60	3/15/60	K^--p and K^--n scattering (1.5-Bev/c).	39	443	1:1	P
Segrè	3/18/60	4/19/60	π-π scattering (1.5-Bev/c).	43	469	1:1	P
Alvarez	4/22/60	in progress	$\pi^\pm$ interactions in hydrogen and deuterium (0.9 to 1.6-Bev/c).	132	875 388	1:1 1:2	P
Lofgren	5/12/60	in progress	Test of an argon spark chamber in a π-meson beam.	9	84 22	1:1 1:2	S
Glaser	5/23/60	6/7/60	Measure θ_1^0 branching ratio, using Xe bubble chamber (700-Mev/c K^+).	25	117 139	1:1 1:2	P
Moyer	6/9/60	7/20/60	π^- - p elastic scattering and differential cross sections (550-to 925-Mev/c).	75	746	1:1	P
Seaborg	Chemistry target bombardments (21) in the internal proton beam.						

Table III (continued)

Institution and Experimenter	Start of experiment	End of experiment	Experiment	Beam time (12-hour periods)	Beam time (hours)	Pulse schedule	Primary or secondary experiment
EXTERNAL GROUPS							
Princeton U. Fitch	12/2/59	1/6/60	Study $\theta_1 - \theta_2$ mass difference	8	69	1:1	P
U. Washington Masek	1/8/60	2/3/60	μ-meson scattering in lead and carbon (3.5-Bev/c π^-).	46	515	1:1	P
Tufts U. Schneps	1/22/60	1/22/60	Emulsion exposure (3.5-Bev/c π^-).	—	—	1:2	P
U. Tennessee King	1/22/60	1/22/60	Emulsion exposure (3.5-Bev/c π^-).	—	—	1:2	P
U. Wisconsin Fry	1/22/60	1/22/60	Emulsion exposure (3.5-Bev/c π^-).	—	—	1:2	P
Tata Inst., India Biswas	1/22/60	1/22/60	Emulsion exposure (3.5-Bev/c π^-).	—	—	1:2	P
U. Washington	1/22/60	1/22/60	Emulsion exposure (3.5-Bev/c π^-).	—	—	1:2	P
U. Michigan Perl	4/1/60	in progress	π^--p scattering (1.5-Bev/c).	38	330 64	1:1 1:2	S
U. Washington	6/2/60	6/22/60	Study π^- in emulsions in high magnetic field (0.7-to 1.5-Bev/c).	10	119	1:1	S
U. Michigan Vander Velde	6/29/60	6/29/60	Study energy loss of π mesons in a silicon solid-state ionization chamber.		No record kept		S
Princeton U. Cronin	7/6/60	7/20/60	Spark-chamber tests in a π-meson beam.		No record kept		S

Table IV. Bevatron experimental research program; August, September, October 1960

Group	Start of experiment	End of experiment	Experiment	Beam Time (12-hour periods)	Beam Time (hours)	Pulse schedule	Primary or secondary experiment
INTERNAL GROUPS							
Alvarez	4/22/60	in progress	$\pi^{\pm}$ interactions in hydrogen and deuterium using the 72" hydrogen bubble chamber (0.9-1.6 Bev/c).	93 5	995 48	1:1 1:2	P
Lofgren	5/12/60	in progress	Test of an argon spark chamber in a π-meson beam.	—	54	1:1	S
Alvarez	8/9/60	in progress	Study K^- interactions in hydrogen using the 15" hydrogen bubble chamber (740 Mev/c).	76 34	811 330	1:1 1:2	P
Thornton	9/8/60	in progress	K^- total cross sections at 500 Mev/c to 1 Bev/c.	20	210	1:1	P
Seaborg	Chemistry target bombardments (7) in the internal proton beam.						

Table IV (continued)

Institution and Experimenter	Start of experiment	End of experiment	Experiment	Beam time (12-hour periods)	Beam time (hours)	Pulse schedule	Primary or secondary experiment
EXTERNAL GROUPS							
U. Michigan Jones, Perl	4/1/60	8/10/60	π^--p elastic differential scattering cross section (1.5, 2.0, 2.5 Bev/c).	6	64	1:2	S
	8/10/60	9/4/60	Same	38 30	437 318	1:1 1:2	P
U. Michigan Vander Velde	6/29/60	8/26/60	Study energy loss of π mesons in a silicon solid state ionization chamber.	5	67	1:1	S
Univ. Ohio Randall	8/19/60	8/19/60	Emulsion exposure (2.5-Bev/c π^-).	—	1	1:1	P
Northwestern U.	9/6/60	9/13/60	Emulsion exposure (740-Mev/c K^-).	5 9	60 56	1:1 1:2	S
Duke Univ. Block	9/12/60	10/3/60	Test of a helium bubble chamber (1-Bev/c π^-).	15 2	169 19	1:1 1:2	S
Univ. Chicago	9/20/60	9/23/60	Emulsion exposure (740-Mev/c K^-).	5	54	1:1	S
U. Washington Kim	9/21/60	9/21/60	Emulsion exposure (2-Bev/c π^-; background measurement).	—	1	1:1	S
U. Wisconsin Fry, Good		in progress	This experiment is the same as the Alvarez 72" bubble-chamber experiment. Running time is included in the Alvarez-group totals.				

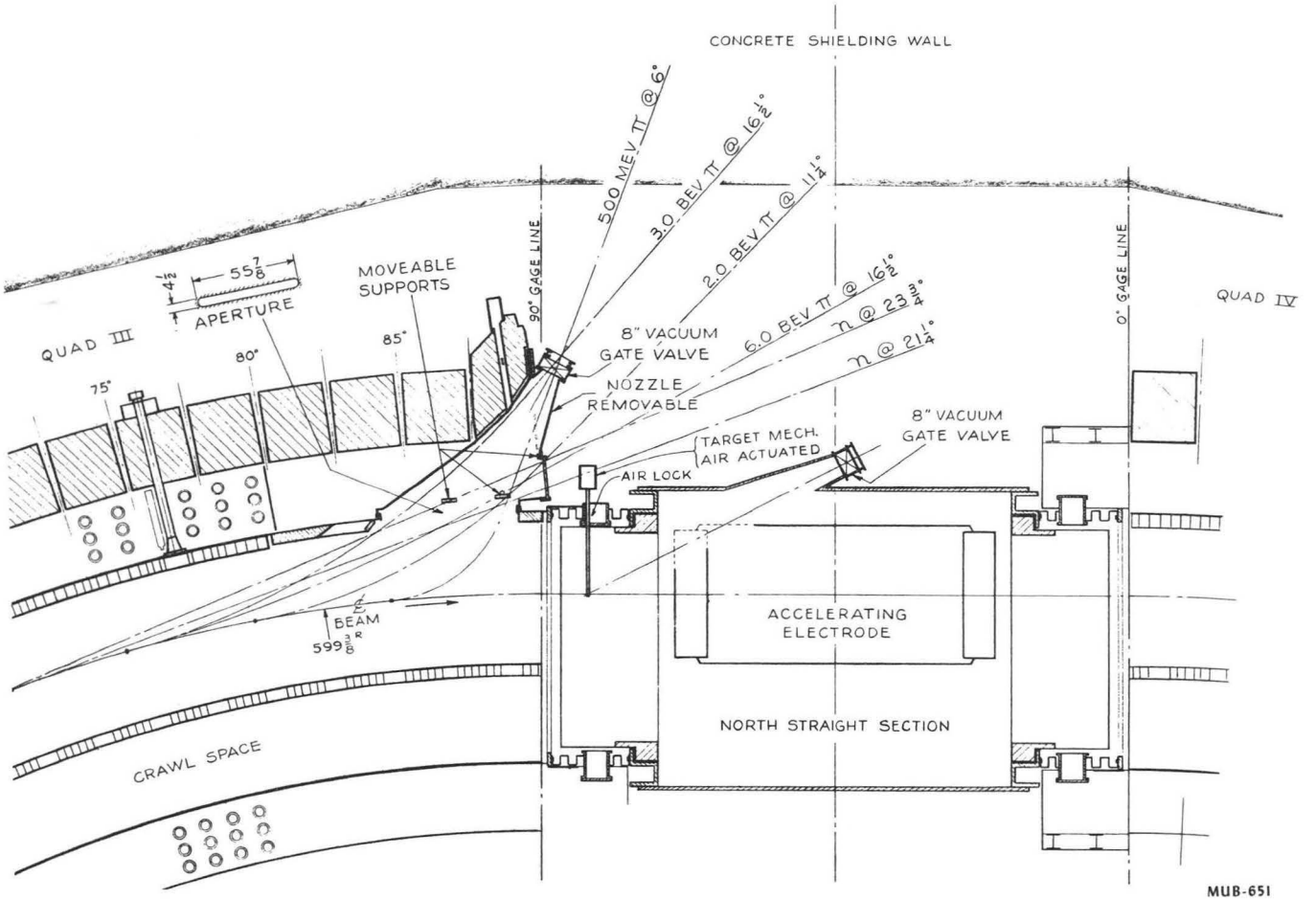

Fig. 3. Quadrant III 89-degree experimental area.

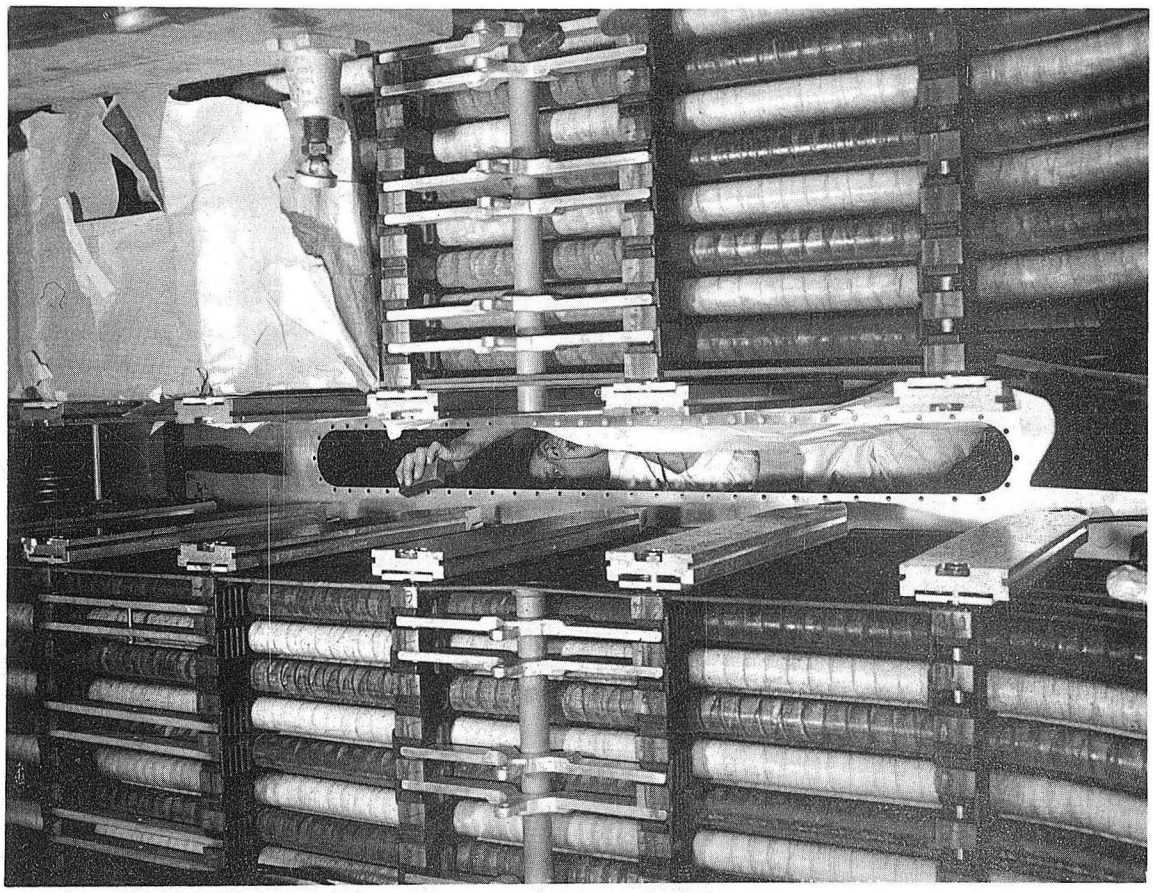

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Fig. 4. Quadrant III 89-degree experimental area. Finished slot in the vacuum-tank skin prior to installation of the vacuum-tank extension.

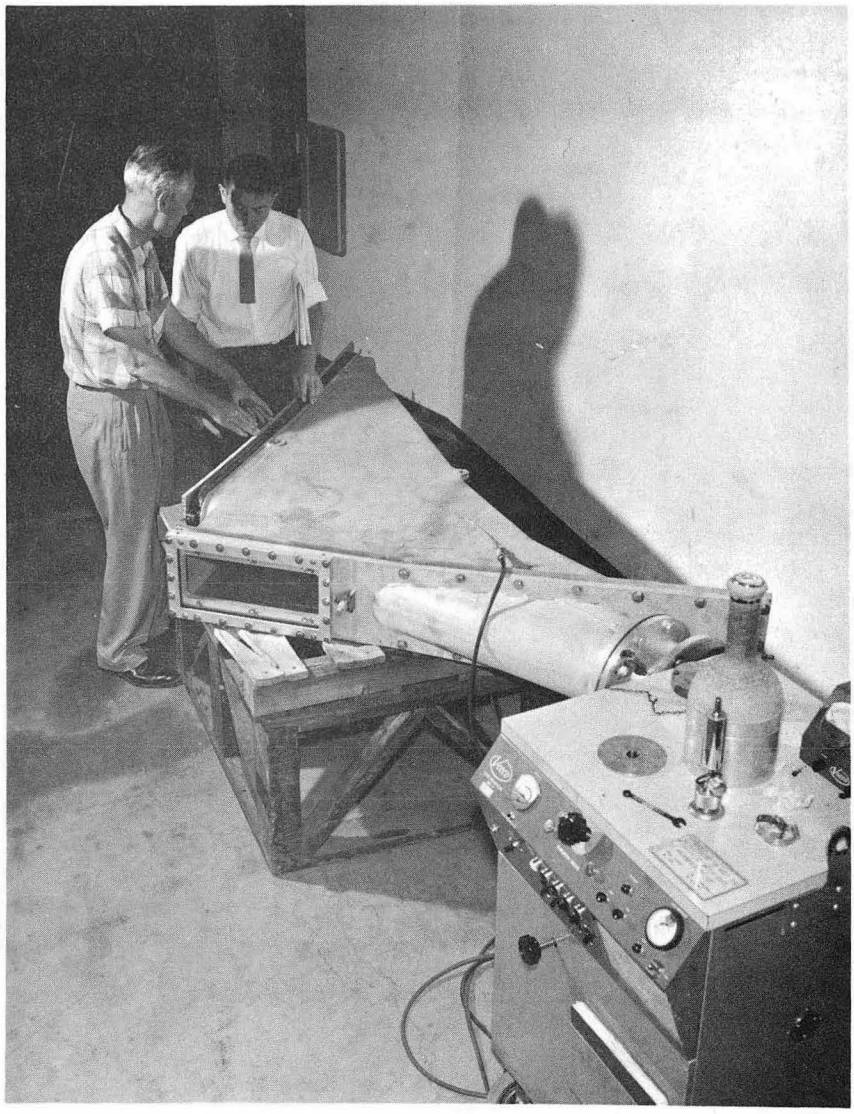

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Fig. 5. Quadrant III 89-degree experimental area. Vacuum-tank extension during vacuum test prior to installation.

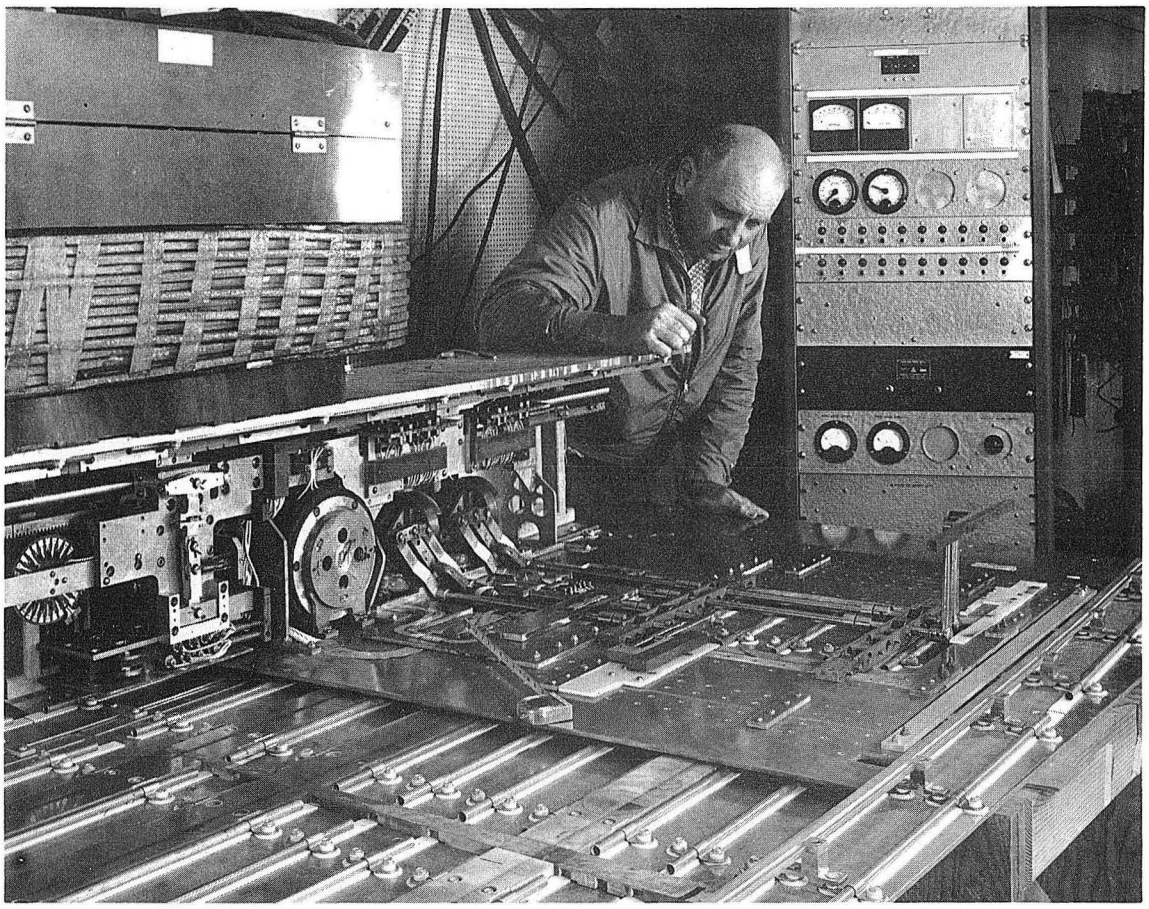

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Fig. 6. Traveling flip-target assembly during test prior to installation in the Bevatron.

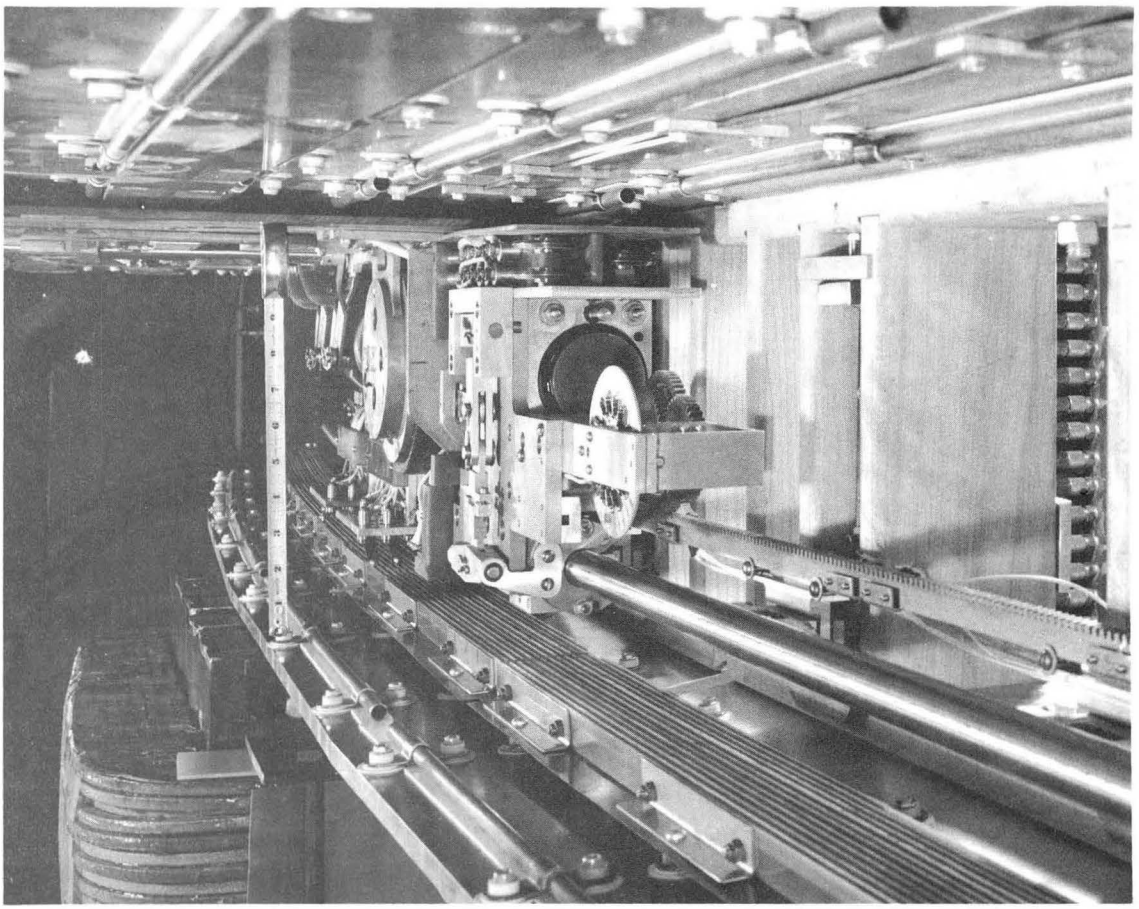

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Fig. 7. Traveling flip target. Transport mechanism shown during test prior to installation in the Bevatron.

Target motion is limited to azimuthal movement at a rate of 1/4 deg per second; the target may be traveled into a straight section for maintenance. Remote-position readout is accurate to 1/50 deg (about 1/5 in.). The radial position of the target is fixed at the time of target assembly.

A Horizontal String Target for Long Beam Spillout

Long-duration beams for counting experiments are normally produced at the Bevatron by introducing a thin "foil" target into the accelerating beam and allowing the particles, upon loss of phase stability, to cascade into the desired target.[3] This "foil" evolved into a set of vertical fibers which are plunged from the outside radius of the aperture. To produce a long, smooth beam requires a careful eclipsing between beam and fibers. Radial-position noise in either beam or plunging mechanism alters the beam-spill pattern.

On the assumption that variation in radial beam position was more probable than vertical variation, a rotating-probe mechanism has been tried which introduces an array of horizontal fibers from below the aperture. With this device, secondary-beam durations of 400 msec are readily achieved. The spillout is roughly Gaussian in shape, free of strong radiofrequency structure, and repeatable. A welcome advantage of the vertically moving probe is the decoupling between radial beam steering and beam spillout. The probe is a simple air-cylinder-operated rotating shaft with a frame carrying 0.001-diam stainless steel wires. It is expected that the reduced scattering in aluminum wires would make them preferable to the steel.

SHUTDOWNS

The scheduled shutdown for maintenance and equipment installation that started July 20 was still in progress at the beginning of this quarter. Operation resumed on August 8. A 25-hour unscheduled shutdown occurred on August 22 and 23, during which time an insulation repair was made on the rapid-beam-ejector coil. A scheduled shutdown, October 4-6, was primarily for experimental-setup change.

MAGNET POWER SUPPLY

The magnet pulse record appears in Table V.

Table V. Bevatron motor-generator set monthly fault report

MONTH 1960	4 to 6 pulses per minute						7 to 9 pulses per minute						10 to 17 pulses per minute						Totals				
	1500 to 6900 amp			7000 to 9000 amp			1500 to 6900 amp			7000 to 9000 amp			1500 to 6900 amp			7000 to 9000 amp			Number of pulses	Number of faults		P/F	Ignitrons replaced
	Pulses	Faults	P/F	Pulses	Faults	P/F	Pulses	Faults	P/F	Pulses	Faults	P/F	Pulses	Faults	P/F	Pulses	Faults	P/F		Arc-backs	Arc-throughs		
January	4809		--	2289	2	1145	510	1	510	701		--	5254	2	2627	368039	68	5412	381602	23	50	5227	--
February	927	1	927	1097		--	--		--	--		--	5519		--	248528	44	5648	256071	5	40	5690	--
March	144		--	1062		--	770		--	735		--	7501		--	387451	87	4453	397612	16	71	4909	4B2
April	400		--	--		--	--		--	--		--	4449		--	324768	40	8119	329617	10	30	8240	--
May	--		--	--		--	--		--	--		--	4683	3	1561	419546	43	9759	424229	12	34	9222	--
June	--		--	--		--	--		--	1168		--	3337		--	410794	63	6520	415299	5	58	6592	--
July	--		--	--		--	1887		--	--		--	1857		--	259094	61	4248	262838	14	47	4309	1B4, 2B4, 2B6, 3B1
Aug.	--		--	--		--	4139		--	--		--	9371		--	311852	69	4519	325362	12	58	4648	--
Sept.	--		--	--		--	--		--	--		--	5157		--	365832	52	7035	370989	13	39	7134	--
Oct.	--		--	--		--	--		--	--		--	24830		--	375822	47	7997	400652	14	33	8525	--

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