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BEVATRON OPERATION AND DEVELOPMENT. 65
January through March 1970

Kenneth C. Crebbin and Robert Frias

January 12, 1971

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BEVATRON OPERATION AND DEVELOPMENT. 65

January through March 1970

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ABSTRACT

The Bevatron resumed operation January 6, 1970 after a six-week shutdown. A new septum beam split was installed in the F1 Channel I region. Details of the operation and backstop region of the new beam are discussed.

The Bevatron operated for high energy physics 82.6% of the scheduled operating time and accelerated 2.9×10^{18} protons during the first quarter of 1970. Nine new experiments were started.

Pulse-to-pulse stability of the main magnet motor-generator sets is discussed.

I. MACHINE OPERATION AND SHUTDOWNS

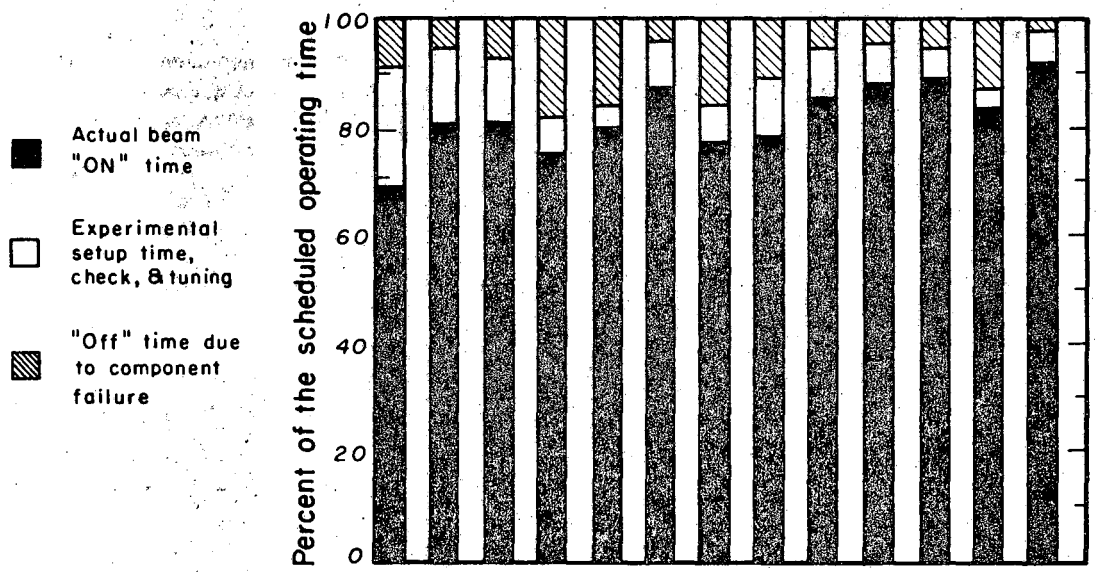
The Bevatron resumed operation on January 6, 1970, following a scheduled shutdown that started on November 27, 1969. The jobs done during this shutdown were described in the preceding quarterly report.[1] Because of continuing work in the new septum split of External Proton Beam I, initial Bevatron operation following the shutdowns was for internal beam experiments only. On January 14, 1970, work had progressed far enough to allow operation of Channel II of the External Proton Beam (EPB) facility. By January 20, we were able to start limited operation of EPB Channel I. In March the new septum-beam split was completely checked out and the septum backstop area became operational. Experiments No. 96 and No. 116 were the first to begin use of secondary beam channels originating at this new facility. We returned to essentially full operation in March and ran an average of 3.5 experiments. The Bevatron operations record is shown in Fig. 1.

Experiment No. 84 was completed on January 26, 1970. This experiment, a study of $\pi^- p \rightarrow \pi^0\pi^0 n$, was done in a 2.4-GeV/c π^- beam from an internal target near the exit of Quadrant III of the Bevatron.

Two short experiments, No. 133 and No. 134, were started and completed in February 1970 using the experimental setup used in Experiment No. 84. Experiment No. 133 was a study of $d\sigma/d\Omega(\pi^- p \rightarrow \pi^0 n)$; Experiment No. 134 was a study of $\pi^- p \rightarrow \eta' + n$.

The 25-in. hydrogen bubble chamber went to a three-pulse-per-Bevatron-pulse mode of operation in March. The typical operation mode was: A short beam spill (300 μsec) just after the start of flattop; a second short beam spill 300 msec later; the third short beam spill just before the end of flattop. The flattop length varied between 1 sec and 1.3 sec,

*Preceding Quarterly Reports: UCRL-19399, UCRL-19399.



Week of		1/4	1/11	1/18	1/25	2/1	2/8	2/15	2/22	3/1	3/8	3/15	3/22	3/29
Crew hours		128	168	168	168	168	168	168	144	168	168	168	144	168
Turn on & maintenance time	(h)	16	10	10	10	10	9	9.5	10.5	10	10	10	14.5	10
Scheduled operating time	(h)	96	158	158	158	158	159	158.5	133.5	158	158	158	129.5	158
Scheduled Bevatron test time	(h)	18	14	18	14	14	14	14	14	14	14	14	22.5	18
Scheduled shutdown time	(h)	16	0	0	0	0	0	0	0	0	0	0	0	0
Holiday	(h)	0	0	0	0	0	0	0	24	0	0	0	24	0

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Fig. 1. Bevatron operating schedule.

depending on operating conditions. Long beam spills for counter experiments were provided in the intervals between the beam spills for the bubble chamber. One bubble chamber experiment (No. 126) was completed on March 26, 1970. This experiment was a study of K^+p inelastic channels.

During this quarter we had five continuing primary experiments and nine new primary experiments set up or in the process of being set up. We had three continuing secondary experiments and two new setups. All together, 20 experiments were operated or being set up this quarter. Four primary and one secondary experiment were completed this quarter. We accelerated 2.9×10^{18} protons and operated for high energy physics 82.6% of the scheduled operating time. The total integrated experimental hours divided by the number of hours of Bevatron operation for high energy physics gives a multiplicity of 2.5 for this quarter.

A summary of the experimental program for this quarter is shown in Table I.

On January 31, 1970, a Bevatron Experimenters' Meeting was held. A total of 91 persons attended, 60 from LRL and 31 from outside institutions. Two reports were given on high energy physics subjects. Bevatron scheduling and current experimental programs were discussed. Reports were given on current Bevatron operation and proposed future improvements. Two papers were given on advanced accelerator design studies.

II. NEW EXPERIMENTS

There were nine new experiments started this quarter. Three were counter experiments done by groups already set up and tuning, and three were done in the 25-in. hydrogen bubble chamber facility. The remaining three were major installations in the EPB facility. Two of these experiments were set up in the new septum channel backstop area.

The first experiment set up at the new septum backstop was Experiment No. 116 to be done by C. Wiegand of the Segrè-Chamberlain group from LRL. Results of an experiment done by this group in 1968 at the Bevatron indicated that the nuclear surfaces are rich in neutrons. Negative kaons appeared to be absorbed at nuclear radii greater than the radii of conventional nuclear dimensions. More accurate measurements of nuclear sizes can be achieved by studying the finer details in the spectrum of elements whose characteristic x-ray lines are strongly absorbed. A number of rare isotopes are available for target material, so that isotope effects will be an important part of the measurements. New solid-state detectors are available with better resolution than in the previous experiment.

In addition, attempts will be made to observe coupling between nuclear energy levels and the levels of kaonic orbits. The group hopes to be able to extend the observation of hyperonic atoms to the heavy elements. This experiment is set up in Beam No. 28, which is described in the next section.

The second experiment, set up at the new septum backstop, was Experiment No. 96, being done by the University of Washington group (V. Cook).

Recent measurements of total cross section for K-nucleon interactions indicate the possibility of the existence of baryon resonances with strangeness +1. The peaks in the total cross section occur at incident momenta of 1.25, 1.8, and 2.6 GeV/c for the I = 1 state and at 1.15 GeV/c for the I = 0 state. Bubble chamber studies of K^-p total cross section at 1.25 GeV/c show no evidence of resonant behavior.

In π^--meson scattering experiments, the presence of π^--nucleon resonances introduces considerable structure into the 180-deg elastic

Table I. Summary of Bevatron Experimental Research Program, January through March 1970

Groups	Experiment location	Dates Run	Dates Start	Dates End	Experiment	Beam Time: This quarter January-March Hours	Beam Time: Start of run through March 1970 Hours	Pulse Schedule	Primary or secondary experiment
Internal Group									
LRL-Lofgren (Wenzel)	EPB XIF3	82	5/21/69	In progress	$K_L^0 \to \mu^+e^-$, μ^-e^+, $\mu^+\mu^-$, e^+e^- branching ratios	660	1647	1:1	P
LRL Moyer-Helmholz (Kenney) Group A (Pripstein)	Internal north area straight section	84	8/9/69	1/26/70	Study of $\pi^-p \to \pi^0\pi^0$	306	1178	1:1	P
LRL-Miller (Budnitz/Ross)	EPB XIIF3	95	5/25/69	In progress	$K^0\mu_3$ charge asymmetry	371	1152	1:1	P
LRL Segrè-Chamberlain (Wiegand)	EPB XSF3	116	3/12/70	In progress	Study of K^- mesic x rays	58	58	1:1	P
LRL Moyer-Helmholz (Kenney) Group A (Pripstein)	Internal north area straight section	133	2/6/70	2/12/70	A study of $\frac{d\sigma}{d\Omega}$ for $\pi^-p \to \pi^0n$	73	73	1:1	P
LRL Moyer-Helmholz (Kenney) Group A (Pripstein)	Internal north area straight section	134	1/27/70	2/6/70	A study of $\pi^-p \to \eta' + n$	149	149	1:1	P
LRL-Miller (Budnitz-Ross)	Internal west area straight section	P-32	5/31/68	In progress	Counter check for Experiment No. 95	23	435	1:1	S
LRL Health Physics (Smith)	EPB various target areas	P-43	2/18/70	In progress	Activation measurements directed toward calibration of Bevatron beam-intensity measuring-equipment	1/4	1/4	1:1	S
LRL Moyer-Helmholz (Kenney) Group A (Pripstein)	Internal north area straight section	P-44	2/12/70	In progress	Tests for a future proposed experiment using a polarized target	69	69	1:1	S
External Groups									
U. of Hawaii (Cence) U. of Wisconsin (Cline)	EPB XIF3	60	1/14/69	In progress	Ke_4 decays	296	2472	1:1	P
U. of Washington (Cook)	EPB XSF3	96	2/26/70	In progress	K-nucleon backward scattering in 1-1.5 GeV/c K^+ beam	15	15	1:1	P
U. of Wisconsin (Cline) U. of Hawaii (Cence)	EPB XIF3	113	1/14/70	In progress	$K^+ \to \pi^+e^+e^-$	104	104	1:1	P
U. of Chicago (Levi-Setti)	EPB XIIF2 25" BC	115	1/14/70	In progress	Study of $\Lambda(1520) \to \Sigma(1385)$	612	612	2:1	P
UCLA (Schlein) CIT (Barish) NAL (Malamud)	EPB XIIF2 25" BC	126	2/26/70	3/26/70	K^+p inelastic channels	486	486	2:1	P
U. C. Santa Barbara (Caldwell)	EPB XIF3	127	11/24/69	In progress	Interaction of short-lived particles with nucleons	3	6	1:1	P
U. of Massachusetts (Shafer)	EPB XIIF2 25" BC	128	3/26/69	In progress	K^-p reaction on polarized target in bubble chamber. Test with simulated polarized target	40	40	2:1	P

scattering cross sections as a function of incident momentum. This experiment proposes to investigate 180-deg K nucleon scattering to see if it may provide similar evidence of a resonance for the K-nucleon interactions. This experiment is being done in Beam No. 29, which is described in the next section.

The third new major experiment set up this quarter was Experiment No. 127, to be done by the UC-Santa Barbara (Caldwell) group. This experiment is a study of the interaction of short-lived particles with nucleons. Studies of cross sections for particle-nucleon interactions have provided fundamental information about particles. Until recently, no such information has been available for short-lived particles. In this experiment, a π^- beam strikes a target. Some of the π^--nucleon interactions produce short-lived particles which, in turn, interact with the target nucleons. The attenuation rate of π^- in a nucleus is known. The attenuation rate of the short-lived particles is measured for various target materials. From the "A" dependence of the yield, the cross section for short-lived particle-nucleon interactions can be determined. The π^0 cross section will be measured to provide a calibration of the equipment.

III. EPB SEPTUM CHANNEL FACILITY

A. Septum Beam Split

In 1963, the first experiments were run in the external proton beam at the Bevatron. By 1964 the external proton beam line had been extended to provide three target stations in series. We operated in this manner until 1967. During a six months' shutdown, from December 1966 to June 1967, a new channel external proton beam facility was installed. The first target station F1 was eliminated. The proton beam was now switched from one channel to the other channel at the F1 region. Details of this dual-channel EPB facility have been reported previously.[1] By June 1969, the dual-channel EPB facility was in full operation.

Most of the counter experiments were set up in secondary beams from the two target areas in Channel I (F_2 and F_3). The proton beam passed through a target at the F2 area, and was then refocused and repositioned on a target at the F3 area. Operation in this manner had a number of disadvantages. The beam that passed through the F2 target was degraded. As a result, if part of the beam passed through the F2 target and part of the beam did not, there were two beam spots at slightly different positions when it was refocused at F3. This made intensity sharing difficult between the two target stations, ordinarily accomplished by moving the beam or the target position at F2. Target position changes at F2, to optimize secondary-particle beams in that region, should also require a shift of the beam position at F2, so that transmission of the beam to F3 without some loss was impossible. Slight beam shifts on the F2 target caused beam position shifts at the F3 target. This required readjustment of correcting magnets in the system to restore the beam position on the F3 target.

To eliminate this coupling between the two target areas, we decided to install a septum beam split at the F2 target area and create a new backstop target area. (The target area at EPBI F2 was eliminated.) This change allows greater flexibility in the setup of secondary-beam channels. It provides a better choice of production angles, as well as the possibility of more than one secondary-beam channel from each of the two end-station targets. Figure 2 shows the layout of the entire Bevatron experimental area including the new septum channel.

Operation of the new septum split is as follows. Beam going down Channel I from

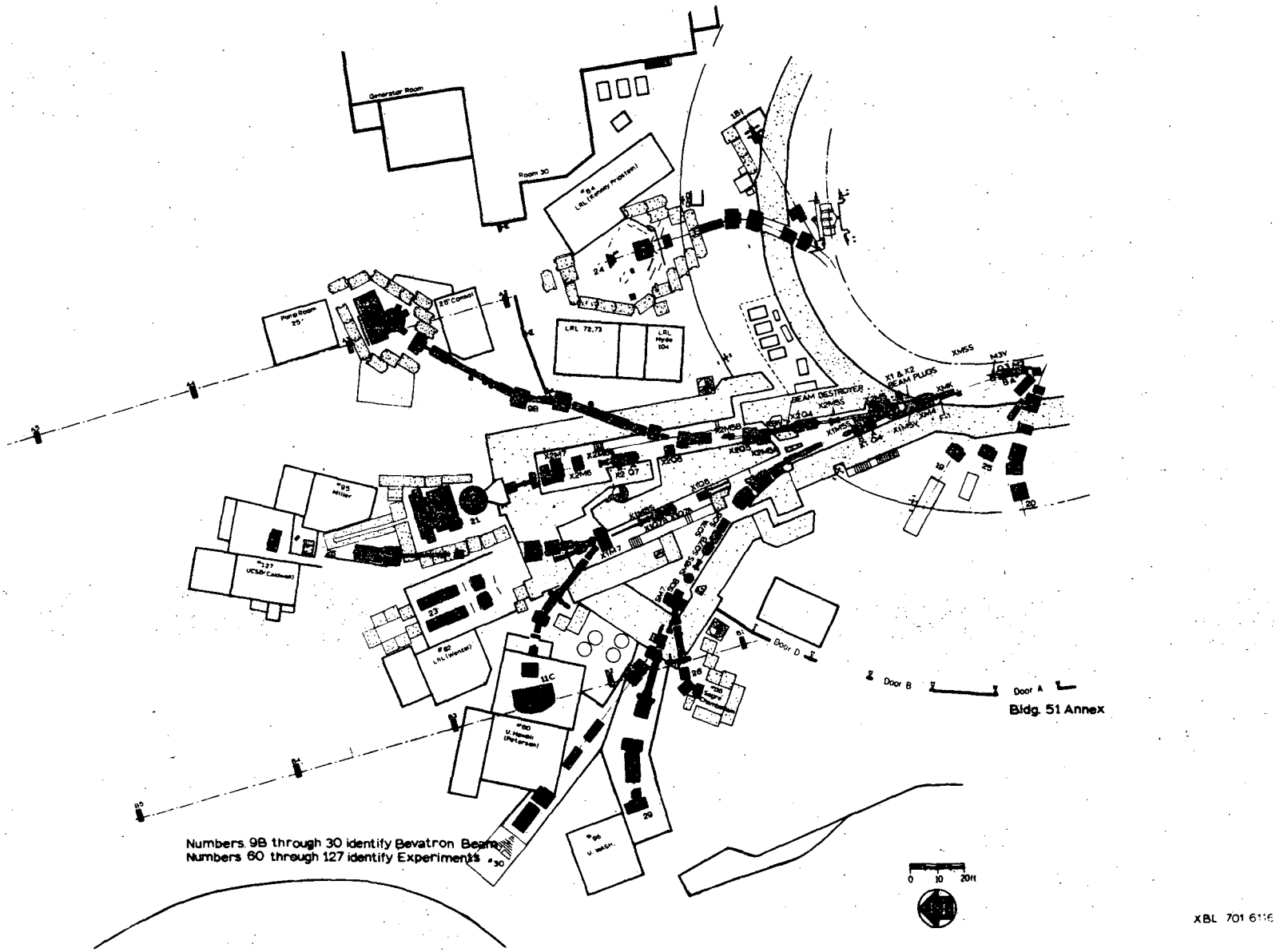

Fig. 2. Bevatron experimental layout.

the focus at F1 was previously refocused by X1 Q4A and B to a spot at F2. In the septum system operation, however, X1 Q4A and B are set to give a vertical focus at the F2 region and a horizontally parallel beam of about 3.5 inches width. This parallel beam then can be displaced sideways, by the use of magnet XMS, across the septum of bending magnet XS M1. This magnet is the first of six bending magnets in the septum channel. By adjusting the current in the XMS magnet, any desired fraction of the beam can be directed down the septum channel, the rest of the beam remaining in Channel I. Thus from zero to full-beam intensity can be placed down either channel. The loss on the septum has been about 10% during normal operation.

The following diagnostic equipment is available for tuning the septum channel. A secondary-emission monitor (SEM) measures the beam intensity at F1 and at the septum third focus (F3) target area. Beam position and focus are monitored with closed-circuit television cameras looking at zinc sulfide scintillators. There is a TV scintillator installation at each of the focus points (F1 and F3). The TV cameras at these points are outside the main shielding wall and look through a hole in the concrete shielding wall. There is a set of three scintillators just "upstream" from septum magnets XS M1, 2, and 3. A folded optical system places the images of these scintillators one above the other at an equal distance away. One television camera can then monitor all three scintillators. All of the scintillators can be put in or taken out of the proton beam independently and remotely from the Bevatron main control room.

B. Septum Target Area

Three secondary beams have been designed and are being set up in the new septum beam. In addition, a spallation study is being done in the septum proton beam by the Nuclear Chemistry Department (Hyde et al.). The design characteristics are given in Table II. Beam No. 28 is in operation, Beam No. 29 and No. 30 are being set up.

The Hyde group's Experiment No. 104 was installed just "upstream" from the septum thrid-focus target, between magnets SQ8 and SM6S (Fig. 2). Secondary-particle beams emanating from the end station originated at a target just ahead of dispersing magnet SM7. The target position was adjustable remotely in three directions: (1) vertical, (2) transverse to the proton beam direction, (3) parallel to the proton beam direction. The target size and material can be changed to suit the needs of the experiments being done.

The beam dump is located 6 ft beyond SM7, just north of the beginning of secondary-beam channel No. 30. It is composed of 2 ft of uranium and 80 in. of steel followed by 9 ft of heavy concrete.

To provide flexible operation, beam plugs and interlock systems are provided so that set-up and maintenance work can proceed in Channel I and the septum channel while the beam is on in Channel II, and vice versa. Similar systems are also provided for each of the several secondary beams originating at end stations, so that experimenters may work on their experimental apparatus while other experiments continue to operate.

The EPB shielding is designed to allow operation at 1×10^{12} protons per pulse (ppp) in each channel and at 10 pulses per minute. At present, the normal operation level is between 1.5×10^{12} and 2×10^{12} ppm divided between the three channels. Typical fast neutron flux (30 keV to 100 MeV) on the floor outside the external proton beam shielding varies from 10-40 $n/cm^2/sec$ for the above-mentioned operation.

Table II. Design characteristics of three Bevatron beams.

	Beam No. 28	Beam No. 29	Beam No. 30
General description	500-MeV/c $K^{\pm}$ separated	2-GeV/c $K^{\pm}$ separated	5-GeV/c $\pi^{\pm}$
Physicists responsible	W. A. Wenzel and Tom Elioff	Victor Cook and Keith Green (U. Wash.)	Tom Elioff
Installation date	January 1970	January 1970	March 1970
Target location	EPB septum channel, F3	EPB septum channel, F3	EPB septum channel, F3
Target material	copper or platinum	copper	copper
Target size (adjustable)	0.1 in. high, 0.2 in. wide, 2 in. long	3/32 in. high, 3/16 in. wide, 5 in. long	3/32 in. high, 3/16 in. wide, 5 in. long
Momentum range	up to 600 MeV/c (positives or negatives)	up to 2 GeV/c (positives or negatives)	up to 5 GeV/c
Momentum width	± 2%	± 3% } or 6.1 msr %	± 4%
Solid angle[a]	20 msr (nominal)	1.3 msr } or 6.1 msr %	1 msr
Production angle	0 deg	0 deg	2 deg
Type of separator	electrostatic Mark V (10 ft long, 4-in. gap)	electrostatic Mark VI (15 ft long, 3-in. gap)	
Separation factor[b]	3.3 at 500 MeV/c (including aberrations)	8 at 1.5 GeV/c (aberrations not included)	
Acceptance	450 mrad horizontal, 50 mrad vertical	≈160 mrad horizontal, ≈ 8 mrad vertical	28 mrad horizontal, 36 mrad vertical
Flux transmitted	expect 50 000 K^+ transmitted or 15 000 K^+ stopping per 10^{12} protons	expect 40 000 K^+ per 5×10^{11} protons (at 1.5 GeV/c)	expect $\approx5\times10^5$ π per 5×10^{11} protons at 4 GeV/c, $\approx2\times10^6$ π per 5×10^{11} protons at 1 to 2 GeV/c
Other information:	1. At final focus (20 in. downstream from final quadrupole) magnification=1.8 horizontally, 5.0 vertically. 2. Length of beam to final focus = 42 ft. 3. Mass slit and momentum slit are immediately downstream from separator; magnification=8 horizontally, 1.8 vertically. 4. Mass slit is not in vacuum system.	1. Final image is expected to be 1.5 in. wide × 0.5 in. high.	1. Total magnification at final focus = 0.9 horizontally, 0.9 vertically. 2. Magnification at first focus= 1.1 horizontally, 1.6 vertically. 3. Dispersion at first focus ≈1.2%/in. 4. Momenta are recombined at final focus.

[a]Solid angle can be increased further (by adjustment of the first quadrupole) at the expense of horizontal magnification and separation (or vice versa).
[b]Distance between $K^{\pm}$ and $\pi^{\pm}$ images divided by image size at mass slit.

IV. MACHINE IMPROVEMENTS

The Bevatron is normally shut down on Monday from 0800 to 1600 hours. Machine startup and study periods are scheduled from 1600 on Monday afternoon until about 1000 Tuesday morning. The remainder of the week is around-the-clock operation for high energy physics.

Bevatron study periods this quarter were devoted to a number of continuing programs. Resonant-extraction studies continued during this period. A detailed status report was given on this project in the preceding quarterly report.[2] Vertical beam blowup, when the rf is turned off, was reported in a previous quarterly report.[3] Studies to determine the cause and methods of controlling beam blowup continued through this quarter. Some work continued on beam pickup and early loss problems.

Two operational problems were worked on during development periods this quarter. Septum channel beam optics and related tuning problems were studied. A triple-pulse mode (three 300-msec beam pulses) was developed for bubble chamber operation. Past operation for the bubble chamber had been with one or two beam pulses per Bevatron cycle.

V. BEVATRON MOTOR GENERATOR

Stability of the 120-MVA Bevatron Power Supply can be measured by recording pulse-to-pulse changes of operating parameters. The use of the EPB Septum Channel and future use of resonant-extraction techniques has reinforced the demand for pulse-to-pulse repeatability.

The computer control and data acquisition system, which now programs the Bevatron guide field, also provides a typed record of instantaneous values of magnet current, magnet field, and motor-generator speed. In addition, the program calculates and displays the error between actual and specified parameters.

This report describes the present pulse-to-pulse stability and illustrates the data acquisition format used to display data.

A. Guide Field Characteristics

Figure 3 shows a typical flattop pulse at the Bevatron. The flattop start current is 5140 A (12 559 G) and increases 200 A during the 1760 msec of flattop.

The rate of rise of magnet current just prior to flattop is 7 A/msec (9 G/msec) therefore, a 1-msec change in the time of entering flattop results in a 7-A jitter.

B. Stability of Operating Parameters

The teletype printout shown in Table III shows instantaneous operating parameters at the following times:

Pulse No. 2	Start of pulse
Pulse No. 8	Start of flattop
Pulse No. 1	End of flattop.

The samples were taken over a period of 2.2 min, which represents a span of approximately 20 Bevatron pulses. Each pulse cannot be recorded due to printing rate limits.

The flattop start current and rate of rise during the flattop can be monitored and displayed for each pulse with the following printout:

5142.	198.
5142.	198.
5143.	195.
5143.	201.
5143.	201.
5144.	200.
5143.	199.
5143.	199.
5143.	200.
5144.	201.

The recorded data indicate that pulse-to-pulse changes in the guide field can be held to 3 A. In general, changes of less than 7 A are acceptable.

C. Speed-Range Changes

A change in the motor-generator speed excursion during the Bevatron pulse causes shifts in the flattop start current. The shift

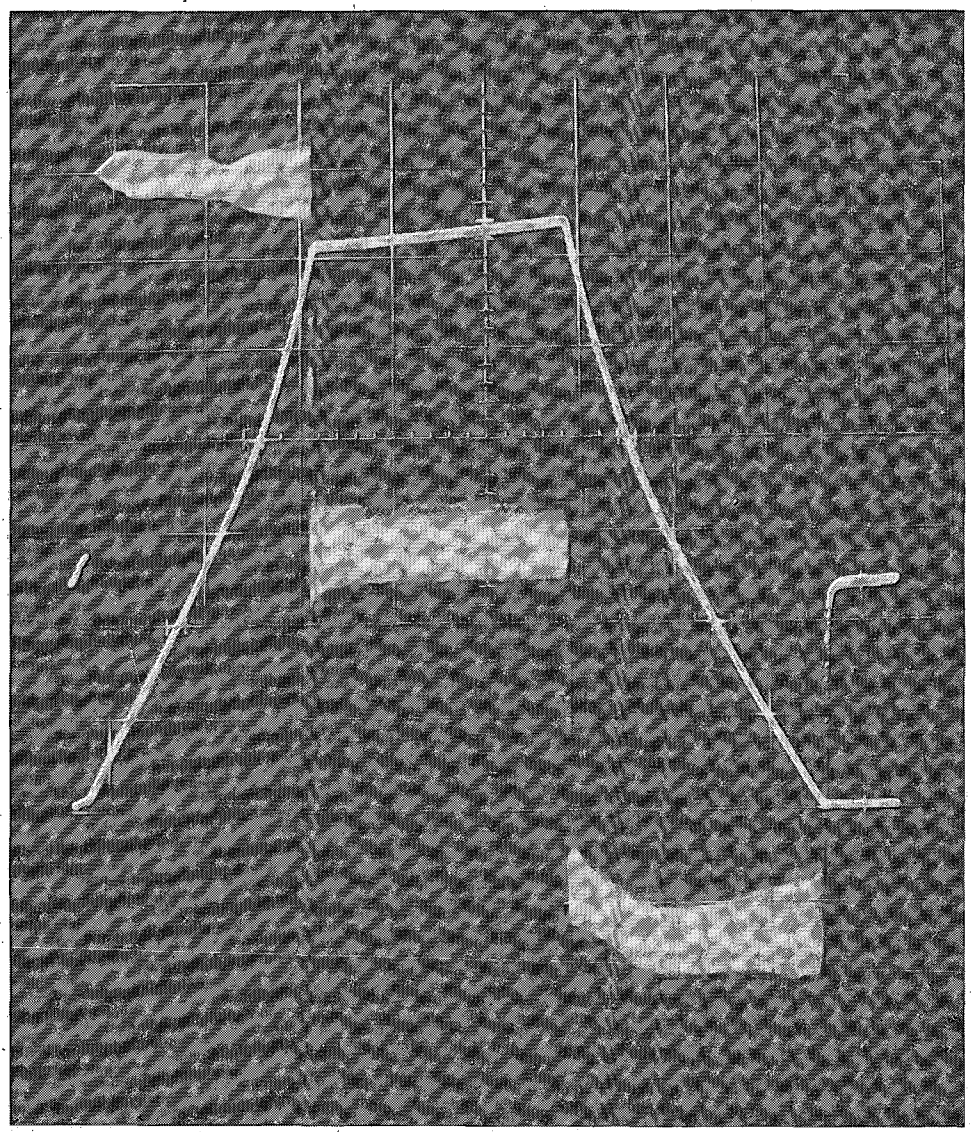

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Fig. 3. Typical Bevatron flattop-pulse.

Table III. Instantaneous operating parameters.

15.434	73170.						
PROFILE	10.						
PULSE	FIELD	ERROR	AMPS	DI/DZ	TIME	SPEED	DS/DP
2.	.000	.000				878.	
8.	12.558	-.001	5140.	5140.	1590.	848.	-30.
1.	12.826	.266	5339.	199.	1760.	841.	-36.
15.440	73170.						
PROFILE	10.						
PULSE	FIELD	ERROR	AMPS	DI/DZ	TIME	SPEED	DS/DP
2.	.000	.000				879.	
8.	12.559	-.000	5140.	5140.	1586.	848.	-31.
1.	12.827	.267	5339.	199.	1760.	842.	-37.
15.448	73170.						
PROFILE	10.						
PULSE	FIELD	ERROR	AMPS	DI/DZ	TIME	SPEED	DS/DP
2.	.000	.000				879.	
8.	12.557	-.002	5139.	5139.	1585.	848.	-30.
1.	12.825	.265	5338.	198.	1760.	840.	-38.
15.456	73170.						
PROFILE	10.						
PULSE	FIELD	ERROR	AMPS	DI/DZ	TIME	SPEED	DS/DP
2.	.000	.000				879.	
8.	12.557	-.002	5139.	5139.	1587.	848.	-30.
1.	12.825	.265	5338.	199.	1760.	842.	-37.

is developed because although the magnitude of the guide field can be compared at computer speeds, the rectifier cubicles must be switched into the flattop mode at discrete 3-phase rectifier rates. Therefore, to ensure minimum pulse-to-pulse jitter, the speed range of the two synchronized motor-generator sets should repeat for each pulse.

Load variation and changes in the 12 000-V motor feeder line are major causes of shifts in the speed range. Load changes are a function of magnet temperature, and the 12-kV line can vary as much as 2%. However, continuous operator surveillance and open-loop reference correction reduce the effect of these variations.

Additional monitoring and control techniques are now being developed in order to minimize the effect of inherent instabilities. These efforts include a 256-channel data-acquisition system to monitor both analog and digital reference information, and the refining of control equipment to compensate for the listed variables.

D. Magnet Pulsing Record

The magnet pulsing record is shown in Table IV.

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1. Kenneth C. Crebbin, Robert Frias, and Hermann A. Grunder, Bevatron Operation and Development, 64, UCRL-19720, March 6, 1970.

2. Kenneth C. Crebbin and Robert Frias, Bevatron Operation and Development, 58, UCRL-18482, January 17, 1969.

3. Kenneth C. Crebbin, Bevatron Operation and Development, 62, UCRL-19299, August 27, 1969.

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

Table IV. Bevatron Motor-Generator Set Monthly Fault Report.

1970	4 to 6 pulses/min						7 to 9.3 pulses/min						10 to 17 pulses/min						Total				
	1.5 to 6.9 kA			7.0 to 9 kA			1.5 to 6.9 kA			7.0 to 9 kA			1.5 to 6.9 kA			7.0 to 9 kA							
	Pulses	Faults	P/F	Pulses	Faults	P/F	Pulses	Faults	P/F	Pulses	Faults	P/F	Pulses	Faults	P/F	Pulses	Faults	P/F	Pulses	Arc-backs	Arc-through	P/F	Ignitrons replaced
Jan.	1 557	0	∞	0	0	0	122 321	12	10 193	16 338	1	16 338	175 197	2	87 598	462	0	∞	315 875	6	9	21 058	3A2, 3A5
Feb.	639	0	∞	0	0	0	207 674	8	25 959	0	0	0	126 975	19	6 682	101	0	∞	335 389	18	9	12 421	3A2, 3A6, 1B[2]
Mar.	0	0	0	0	0	0	272 140	8	34 017	1 888	0	∞	79 459	0	∞	0	0	∞	353 487	8	0	44 186	
April																							
May																							
June																							
July																							
Aug.																							
Sept.																							
Oct.																							
Nov.																							
Dec.																							

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Bevatron Operators

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Gary M. Byer	John E. Tommaney
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Kenneth C. Crebbin	Robert Richter
Tom Elioff	Edward W. Stuart
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Don M. Evans	Glenn White
Robert Force	Emery Zajec
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In charge of Electrical Engineering Group

Edward Hartwig	Robert Force

In charge of Electrical Coordination Group

Marion Jones

In charge of Mechanical Engineering

Kenow Lou	Cedric Larson
Abe Glicksman	

In charge of Motor Generator Group

Harold Vogel	Robert Frias

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