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BEVATRON OPERATION AND DEVELOPMENT. 62

April through June 1969

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April through June 1969

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August 27, 1969

ABSTRACT

During the period covered by this report, the Bevatron provided beam for 86.8% of the scheduled operating time. During this period, 2.8×10^{18} protons were accelerated. We achieved a maximum beam intensity of 5.2×10^{12} protons per pulse. Three primary experiments were completed and three new primary experiments were set up.

The piston rod of a hydraulic cylinder used in plunging the extraction magnets for the EPB system failed.

Vertical beam blowup that occurs on flattop when the rf voltage is turned off was correlated to a space-charge phenomenon.

I. MACHINE OPERATION AND EXPERIMENTAL PROGRAM

The Bevatron operation record is shown in Fig. 1. The beam was "on" for 86.8% of the scheduled operating time. It was "off" 10.7% of the scheduled operating time because of equipment failure and 2.5% of the time for experimental setup, tuning, and routine checks. During this quarter the Bevatron accelerated 2.8×10^{18} protons. The maximum intensity beam accelerated this quarter was 5.2×10^{12} protons per pulse.

The Bevatron provided beam to fourteen primary and three secondary experiments during the period covered by this report. The Bevatron operated for 121 12-hour periods for high energy physics, and integrated 407 12-hour periods of data-taking and 121 12-hour periods of experimental tuneup for a total of 528 periods for primary experiments. An additional 42 12-hour periods of operation were integrated by the three secondary experiments for a total of 570 12-hour periods for high energy physics.

During this quarter three primary exper-

*Preceding Quarterly Reports: UCRL-19232, UCRL-18890

ments were completed. Experiment #93, done by the Palevsky group from Brookhaven National Laboratory, was completed on June 9, 1969. This experiment, a study of p-d scattering, was done at the third focus of Channel II in the external proton beam (EPB) facility. Experiment #94, by the Jones group from the University of Michigan, was completed on June 26, 1969. It was a study of neutron cross sections, carried out in a neutral beam from an internal target near the north straight section. Experimental #106, by the University of Arizona (Jenkins group), was completed on June 2, 1969. This study of K-nucleon cross sections was done at the second focus of EPB Channel I.

Three new experiments were set up this quarter, and in one of them (Experiment #107) data taking was started by the end of June. The other two, Experiments #82 and #95, are partially set up, and preliminary beam-channel tuning and equipment checks have been done.

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

As reported in the preceding quarterly report,[1] the Brookhaven National Laboratory group, Experiment #93, needed an rf-off spill and lower-energy beam than the rest of the experiments. We had therefore set them up on our new "back-porch" pulsing mode. When we originally started back-porch operation, a number of pieces of equipment had to be modified for back porch tracking. All the EPB transport magnets had to be reprogrammed to track down with the decreasing magnetic field of the Bevatron. Several of the magnet power supplies had to be modified to drive the magnet currents down so that tracking could be maintained. During this quarter, the Brookhaven group required a primary proton beam energy of 1 GeV. When we tried to go down to this energy level on the back porch, the rf final amplifier circuit for the Bevatron failed to track. We could track down to about 2.5 to 2.0 GeV, but then lost beam control.

The Brookhaven group needed only a few periods at this energy, level so it was decided to operate only for them on a low-energy flattop. Later in the quarter they needed some additional low-energy periods. This time we operated them on a mezzanine. In this mode of operation, we turned the Bevatron rf voltage back on after the Brookhaven beam spill and recaptured and bunched part of the remaining beam. This resulted in a beam loss of about 50%, so we were unable to provide beam to any other counter experiments. We operated with Brookhaven on the mezzanine at variable energies from 1 to 3 GeV, and accelerated some beam to 5 GeV and provided two beam spills to the hydrogen bubble chamber on a 300-msec flattop.

In the last few years, the operating complexity of the Bevatron has increased considerably. Operating simultaneously for a num-

ber of experimenters has placed great demands upon the operations crew at the Bevatron. The new multiple-energy pulsing mode we have been trying the last few months has placed even greater demands on their skill. In particular, the tracking program for the current in the EPB transport magnets has caused some difficulties for operation at two different energies on the same Bevatron pulse. The tracking program for the EPB magnets controls the rate of change of current in each of seven zones (Fig. 2). As a result, any tracking adjustments in an early zone affects the tracking for that magnet in all subsequent zones. This obviously causes problems for experimenters operating on a later zone as well as for the operations crew. A new method of selecting references to eliminate this "series" effect has been chosen. Converting this new procedure to a working computer program is, however, not simple. It is under study and we hope the solution will be available within the next year.

The first two magnets in the EPB extraction system are plunged 28 inches in about 0.75 second. The first magnet in the system, M1, weighs 2600 pounds. This magnet has an additional 2-in. plunge to provide energy tracking in the Bevatron. This additional 2-in. stroke is provided by a 5-in. diameter hydraulic cylinder mounted between the main plunge hydraulic actuator and the magnet-positioning jack screw. On April 3, 1969, the piston rod of the 5-in. hydraulic cylinder broke in fatigue, after experiencing about 4×10^7 reversing tension and compression cycles over a span of more than 5 years[2] (Fig. 3). The magnet plunge was stopped by emergency crash pads, and no other damage occurred. About 6 hours of down time were necessary to make emergency repairs to the system. The 5-in.-diam hydraulic cylinder was removed and a spacer spool was installed. The 2-in. stroke has never been used in an energy-tracking mode, but has occasionally been used to provide an additional 2-in. radial position adjustment during extraction studies.

II. SHUTDOWN

The Bevatron was shut down from April 7 to April 14, 1969, as an economy move in the present tight fiscal budget. During this period, routine quarterly maintenance was done on the main motor-generator sets. There was a short vacuum shutdown on the Bevatron to replace scintillators on the M1 and M2 magnets and to check the M1 magnet system inside the vacuum tank after the failure in the plunging system reported above. Routine maintenance was carried out on the rest of the Bevatron and associated equipment.

Channel I of the EPB system remained shut down an additional week because of setup work in the backstop region.

III. BEVATRON DEVELOPMENT AND STUDIES

Bevatron studies continued this quarter in four general categories.

1. Resonant extraction studies continued, with some effort being devoted to changes in the closed orbit in the Bevatron. These shifts were accomplished by shunting part of the current in the third quadrant of the Bevatron magnet. Shifts of "tune" in the region of the resonance and better control of the resonance were achieved by pulsing currents up to several hundred amperes through some of the pole-face windings in the Bevatron. These currents cause changes in the field index n of the Bevatron and resultant changes in the ν value of the betatron oscillations.

One observed phenomenon that gives trouble in resonant extraction as well as in normal energy-loss extraction is the vertical blowup of the beam when the rf is turned off and the beam allowed to coast on flattop. This effect was studied in detail this quarter. The blowup is a space-charge effect. The mechanism is still under investigation.

The remaining areas of Bevatron study this quarter were:

2. High beam studies and injection phenomena.
3. Main motor-generator flattop control.
4. Computer control.

IV. BEVATRON MOTOR GENERATOR

The magnet pulsing record is shown in Table II.

References

1. Kenneth C. Crebbin, Don M. Evans, and Robert Frias, Bevatron Operation and Development. 61, UCRL-19232, August 1969.
2. Gerd U. Behrsing, Mechanical Engineering Note Serial M4164, Bevatron Proton Beam Extraction, Plunging Mechanism, Piston Rod of 2-Inch Tracking Cylinder, May 26, 1969 (Internal Report).

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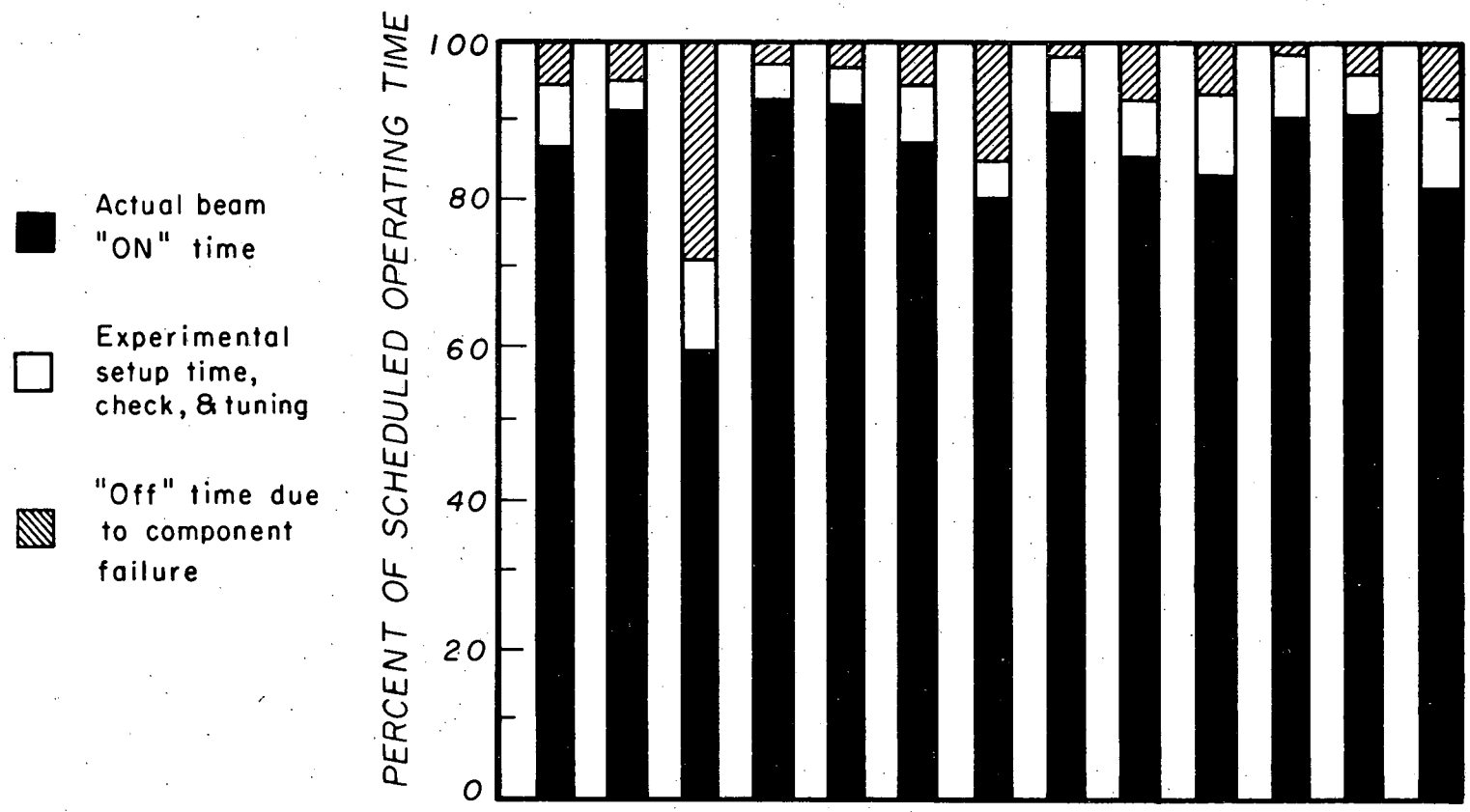
Table I. Summary of Bevatron Experimental Research Program April through June 1969.

Groups	Experiment location	Run	Dates: Start	Dates: End	Experiment	Beam Time: This quarter April - June: 12-Hour periods	Beam Time: This quarter April - June: Hours	Beam Time: Start of run through June 1969: 12-Hour periods	Beam Time: Start of run through June 1969: Hours	Pulse Schedule	Primary or secondary experiment
Internal Group											
Powell-Birge (Kalmus)	EPB 25-in. BC	72	2/21/68	In progress	π^+p Interactions	25	258	151	1599	1:1	P
Powell-Birge (Ely-Kalmus)	EPB 25-in. BC	73	6/8/68	In progress	K^-p and K^-d reactions	26	268	113	1167	1:1	P
Trilling-Goldhaber (Kadyk)	EPB 25-in. BC	76	10/30/68	In progress	Λp Scattering	7	70	41	375	1:1	P
Lofgren (Wenzel)	EPB X1F3	82	5/21/69	In progress	$K_L^0 \rightarrow \mu^+e^-$, e^+e^-, $\mu^\mp e^\pm$, branching ratios	5	69	5	69	1:1	P
Powell-Birge (Gidal)	EPB 25-in. BC	87	11/26/68	In progress	π^+p Interactions	20	197	52	542	1:1	P
Miller	EPB XIIF3	95	5/25/69	In progress	$K^0\mu3$ charge asymmetry	14	169	14	169	1:1	P
Nuclear Chem. Hyde-Poskanzer	EPB X1F2	104	9/21/66	In progress	Production of light fragments from p-N collisions	8	88	255	2911	1:1	P
Segrè-Chamberlain (Stiening) U. Chicago (Hildebrand)	EPB X1F2	107	6/14/69	In progress	Study of $K^+ \rightarrow \pi^+\nu\bar{\nu}$	16	177	16	177	1:1	P
Miller	Internal west area straight section	P-32 (95)	5/31/68	In progress	$K^0\mu3$ charge asymmetry tests for projected Exp. #95	11	131	26	341	1:1	S
Lofgren	Internal west area straight section	P-33	10/11/68	In progress	Preliminary counter checks for projected Exp. #82	22	367	32	393	1:1	S
External Group											
U. Hawaii (Cence) LRL-Moyer-Helmholz (Perez-Mendez)	EPB X1F3	60	1/14/69	In progress	Ke_4 decays	79	826	98	1083	1:1	P
UCLA (Nefkens) LRL (Crowe)	Internal west area straight section	88	12/5/68	In progress	$\pi^-p \rightarrow n\gamma$ Differential cross sections	104	1114	157	1682	1:1	P
BNL (Palevsky)	EPB X2F3	93	2/4/69	6/9/69	p-d Elastic and inelastic scattering	79	821	110	1188	1:1	P
U. Michigan (Jones)	Internal north area straight section	94	7/23/68	6/16/69	Neutron cross sections for p, d, and various metal targets	53	588	192	2182	1:1	P
U. Arizona (Jenkins)	EPB X1F2	106	1/16/69	6/2/69	$K^\pm$-Nucleon cross sections	61	626	152	1574	1:1	P
UCLA (Schlein) CIT (Gomez) NAL (Malamud)	EPB 25-in. BC	112	2/16/69	In progress	Study of $K\pi$ system	24	248	25	261	1:1	P
Space Science Laboratory (Smith)	Internal west area straight section	P-30	10/1/68	In progress	Counter tests for balloon experiment	9	113	22	256	1:1	S

Table II. Bevatron Motor Generator Set Monthly Fault Report.

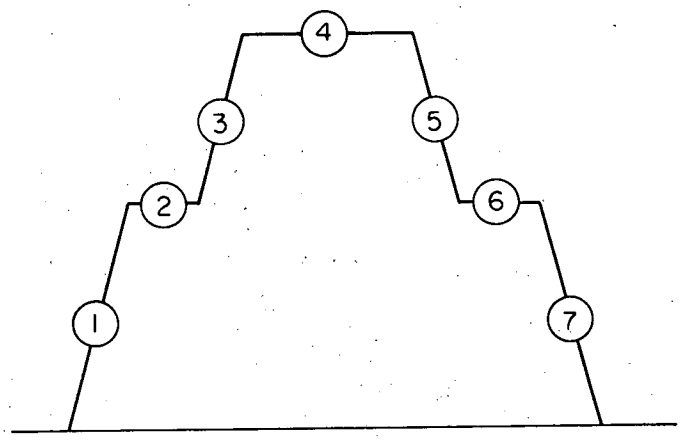
1969	4 to 6 pulses/min								7 to 8.7 pulses/min								9.3 to 17 pulses/min								Total				
	1.5 to 6.9 kA				7.0 to 9 kA				1.5 to 6.9 kA				7.0 to 9 kA				1.5 to 6.9 kA				7.0 to 9 kA								
	Pulses	Faults AB	Faults AT	P/F	Pulses	Faults AB	Faults AT	P/F	Pulses	Faults AB	Faults AT	P/F	Pulses	Faults AB	Faults AT	P/F	Pulses	Faults AB	Faults AT	P/F	Pulses	Faults AB	Faults AT	P/F	Pulses	Arc-backs (AB)	Arc-through (AT)	P/F	Ignitrons replaced
Jan.	3979	-	1	3979	-	-	-	-	3307	-	-	-	-	-	-	-	241713	7	15	10987	5144	3	5	643	254786	10	21	8219	1
Feb.	661	-	-	-	-	-	-	-	1740	-	-	-	21868	2	1	7289	280881	5	8	20063	18290	2	1	18290	323440	9	10	17023	1
March	-	-	-	-	-	-	-	-	120914	-	-	30228	4212	8	1	4212	247406	1	5	24741	1738	1	2	579	374270	10	8	20793	0
April	1022	-	-	-	-	-	-	-	1625	2	-	812	7288	1	-	7288	276881	7	4	25171	1220	2	1	407	288036	12	5	16943	0
May	316	-	-	316	-	-	-	-	9263	1	1	4632	7928	2	-	3964	344117	2	2	86029	7544	1	5	1257	369168	6	9	24611	1
June	-	-	1	-	-	-	-	-	5927	-	-	-	10989	-	1	10989	373406	7	5	31117	1793	-	2	897	392115	7	8	26141	0
July																													
Aug.																													
Sept.																													
Oct.																													
Nov.																													
Dec.																													



Week of		3/30	4/6	4/13	4/20	4/27	5/4	5/11	5/18	5/25	6/1	6/8	6/14	6/22
Crew hours		144	168	168	168	167	168	168	168	144	168	168	168	168
Turn on & maintenance time	(h)	10	0	2	10	10	10	10	10	14	10	10	10	10
Scheduled operating time	(h)	134	32	126	158	157	158	158	158	130	158	158	158	158
Scheduled Bevatron test time	(h)	16	0	18	18	14	16	14	17	14	16	16	16	18
Scheduled shutdown time	(h)	0	136	40	0	0	0	0	0	0	0	0	0	0
Holiday		24	0	0	0	0	0	0	0	24	0	0	0	0

XBL699-3731

Figure 1. Bevatron operating schedule.



Zones of EPB magnet current control.

XBL699-3732

Figure 2. General magnet pulsing mode showing seven control zones.

XBB 694-2304

Figure 3. Fatigue failure of piston rod from EPB plunged magnet M1. Piston provided 2-in. energy tracking stroke.

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