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BEVATRON OPERATION AND DEVELOPMENT.

XXXIII

February through April 1962

Berkeley, California

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ABSTRACT

Experimental work consisted of one new run started and completed this quarter, and the completion of one of the three continuing runs. The new experiment was the study of β decay of Σ hyperons by using a hydrogen Cerenkov counter with a 660-MeV/c K^- beam. The continuing run completed was the study of K^--p scattering (0.33 to 1.4 BeV/c), by using a spark chamber. The two continuing runs were K^- interactions in hydrogen (1.2 to 1.92 BeV/c) and $\pi^{\pm}$ differential scattering; both used the 72-inch hydrogen bubble chamber.

Of the scheduled operating time, the beam was on for 69.4% of the time, 2.3% of the time was used for experimental setup, and equipment outage took 29.3% of the time.

There were two scheduled and two impromptu shutdowns. During one of the scheduled shutdowns the external-beam extraction magnets were installed in the east and south tangent tanks. The other scheduled shutdown was to readjust the Bevatron magnet elevation to correct for foundation subsidence.

In the new linac development program the ion source was run at 480 kV with a beam current of 100 mA. The linac tank was partially deplated to provide a clean copper surface, and welds and holes were plated with copper. The rf losses were thereby reduced 20%.

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I. OPERATION

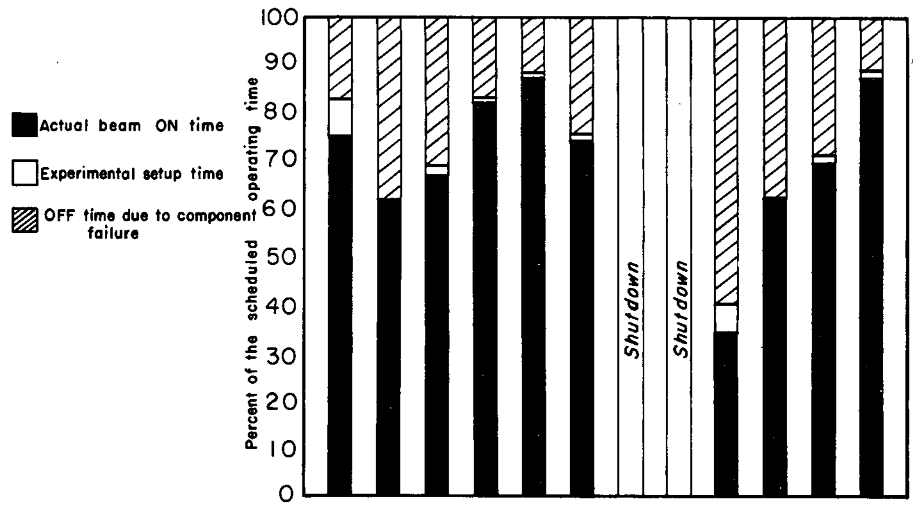
The Bevatron operation record is presented in Fig. 1 and Tables I and II.

During this period there were four shutdowns: two scheduled and two impromptu. The first scheduled shutdown was for two days, February 27 and 28, to raise the inner part of the magnet Quadrant III to correct for the beam orbit misalignment due to magnet subsidence. (This is covered in more detail in Sec. VI of this report.) The second scheduled shutdown was for three weeks, starting March 14 and ending April 4. The major reason for the shutdown was to install the plunging magnets for the external beam.

The first of the unscheduled shutdowns was caused by a power failure when lightning struck the main power line to the Laboratory and destroyed a transformer. Limited power was restored in about an hour and a half. Power for magnet operation was not restored until the following evening, February 16.

The second nonscheduled shutdown was the loss of the Bevatron vacuum, caused by the operating characteristics of an air-operated vacuum gate valve. This particular valve provided isolation between a secondary beam channel and the Bevatron vacuum system. A spectrometer in the secondary beam channel was down to air for inspection so the valve was closed. The air line to the valve had been damaged so it was removed for repair. When the air was reapplied to the valve, the valve opened, letting the Bevatron down to air through the spectrometer. This property of opening when the air is applied to the gate valve without the electrical control being energized is characteristic of many of these valves if the manufacturer has used a low-cost solenoid control valve. All valves of this type that are used in critical places should be checked for this operating characteristic.*

*George W. Edwards, Bevatron Vacuum System: General Operating Characteristics of Temescal Air-Operated Vacuum Valves, Lawrence Radiation Laboratory Engineering Note 7303-03-M21, April 1962 (unpublished).



Week of		2/4	2/11	2/18	2/25	3/4	3/11	3/18	3/25	4/1	4/8	4/15	4/22
Crew hours		168	144	168	168	168	168	168	168	168	168	168	168
Turn-on & maintenance time	(h)	9	5	5	7	5	0	0	0	42	5	5	5
Scheduled operating time	(h)	150	130	154	117	148	78	0	0	36	157	157	163
Scheduled Bevatron test time	(h)	9	9	9	4	15	2	0	0	0	6	6	0
Scheduled shutdown time	(h)	0	0	0	40	0	88	168	168	70	0	0	0
Holiday	(h)	0	24	0	0	0	0	0	0	0	0	0	0

MU-29508

Fig. 1. Bevatron operating schedule, February through April 1962.

Table I. Beam record.

Week of (1962)	Number of 8-hour shifts	Total integrated beam 10^{15} protons
Feb. 4 - 10	21	5.5
Feb. 11 - 17	18	4.2
Feb. 18 - 24	21	5.9
Feb. 25 - Mar. 3	15	7.0
Mar. 4 - 10	21	8.2
Mar. 11 - 17	10	2.7
Mar. 18 - 24	Shutdown	
Mar. 25 - 31	Shutdown	
April 1 - 7	—	—
April 8 - 14	15	0.3
April 15 - 21	17	2.9
April 22 - 28	21	7.5

Maximum beam amplitude at full energy = 2.2×10^{11} protons per pulse
Maximum injected beam = 625 μA
Average beam per 8-hour shift = 2.8×10^{14} protons

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

Month (1962)	Injector	Magnet power supply	rf accelerating system	Other
February	11	57	5	27
March	57	22	11	10
April	28	13	5	54

II. SHUTDOWN

A. March 14 to April 4

The major job on this shutdown was the installation of the plunging magnets for the external beam. These were mounted in the south and east tangent tanks. The hydraulic driving units were still under test so only the magnets, shafts, and seals were installed at this time. The magnets were used for testing for external beam by manually moving the magnets into position and tuning up the Bevatron at reduced beam by using half the Bevatron aperture.

External rework of platform, plumbing, and electrical utilities continued at the north tangent tank area in preparation for the new rf equipment to be installed during the long summer and fall shutdown.

Because of the method of machining and assembling the Bevatron magnet, a survey on the top of the magnet gives a fairly accurate picture of the elevation of the pole tips and magnet aperture. A survey on the bottom of the magnet does not give a good measurement of the gap elevation. When the new shielding is in place after the long shutdown, it will be difficult to survey on the top of the magnet.

Survey points were machined on the bottom of the magnet. Simultaneous surveys were then made on the top and bottom to give a correction curve for future surveys which will be made on the bottom only.

The long thin window (0.020-in. thick by 4-in. high) on the outside of the west tangent tank was replaced with an aluminum plate. At the west outside middle, an 8-in.-diameter port was provided with a 0.030-in.-thick aluminum window for secondary beams at 90 deg to the west inside middle plunging probe.

III. IMPROVEMENT PROGRAM PROGRESS

A. External Beam

W. A. Wenzel

The internal magnets have been completed, tested, measured, and installed in the Bevatron. With the help of shimming, the following results were obtained from the magnetic field measurements.

1. M_1: field flat to ± 1% over the entire aperture; field flat to ±0.1% over 67% of the aperture.

2. M_2: field flat to ± 0.2% over the entire aperture; field flat to 0.1% over 98% of the aperture.

3. Q_1: gradient flat to about ± 1%.

4. Q_2: gradient flat to about ± 1%.

Design of M_3 is completed and construction has begun. The design of Q_3 is now well under way. The design for the thin window on the west outside platform is nearly completed. This window, through which the external beam will emerge from the Bevatron, is intended to improve accessibility to the west tangent tank for experiments using secondary beams. It also provides a low-density exit hole from which the external beam can emerge with a minimum of background.

A cost study has been started for the coil support and leg yoke modifications associated with bringing the beam clear of the Bevatron.

The longer-range problem of transporting the beam across the building to a "backstop" near building 59 is under study. Given the approximate path and dimensions of the beam, a cost study will be made to determine the optimum specifications for the bending and focusing magnets used in the transport system. It is intended that this system be achromatic so that the requirements on magnet regulation can be relaxed, and so that two possible experimental areas – one near the Bevatron and the other at the backstop – may be operated as independently as possible.

B. Bevatron Acceleration System

F. H. G. Lothrop

Initial successes with the model III master oscillator for the Bevatron led to its installation in its permanent location in the main control room. Tracking of the accerleration frequency with magnetic field is now accomplished by saturating a magnetic core with a current proportional to integrated B-dot instead of saturating with a portion of the main magnet current. Operation of the machine has not suffered any losses from the shift to integrated B-dot in the short time the system has been in service, even though more electronics are involved.

The relocation of the master oscillator and its associated temperature regulator in the main control room completed a requirement initiated by the major improvement program that all electronics be as accessible as possible. The master oscillator's present location provides ease of maintenance and facility of programming of frequency modulation of the oscillator. Spurious signals and random noise, which had been problems for years, have been eliminated.

Tests were made of a prototype function generator with a trapezoidal output waveform. These tests were to determine the suitability of such a waveform for guiding the proton beam during a Bevatron pulse. Suitability was proven, and several units will be built for the remodeled Bevatron.

C. Bevatron Linac II

R. M. Johnson

During this period the temporary installation of the ion source and the linear accelerator tank was completed. The installation in building 64 is for the purpose of testing the operation of the linac before installing it on the Bevatron. The ion source was successfully operated at 480 kV with beam currents of 100 mA. The oscillator pulse lines and power supplies were installed and tested. The specific achievements are as follows:

1. Ion Source

The ion source was first operated in January. An energy calibration measurement was made by the $Li^7(p, \alpha) Be^8$ reaction. The optical properties of the beam were measured with scan boxes. Later on, the new four-jaw aperature was installed and the optical properties again measured with greater ease and precision. These emittance (beam optics) measurements told us that we have approximately a beam of 45 mrad-mm and a cross-section of 0.150 in. at the first half drift tube. These values are for a 50-mA measured current. An improvement in ion-gun filament life was made by making a change in power supply hook-up that allowed the filament current to be reduced by 20%. The geometry of the exit cone was modified so as to reduce sparking in the ion source.

2. Linac Tank

The low rf Q values that were measured on the linac tank were improved by

a. deplating the entire inside copper surface with phosphoric acid, leaving a clean bright copper surface;

b. plating the 1309 pump-out holes (3/4-in. diameter) with copper; and

c. copper-plating some of the copper welds and fillets that showed poor surfaces.

The rf losses were thereby reduced 20%.

The linac tank was first installed off-center from the ion source, then the drift tubes were installed and optically aligned very accurately. The drift-tube alignment was done with the tank water temperature regulated to ± 1/4°C. The precision of the position of the drift tubes in the tank was ± 0.005 in. vertically and horizontally, and ± 0.010 in. longitudinally.

The tank was then moved into position in front of the ion source. The ion source was connected, the oscillators installed, and the tank pumped down to a vacuum. A concrete block-house shield will be installed at the exit of the linac to protect personnel from the neutrons that will be made from 19.2-MeV protons striking the carbon targets.

IV. RESEARCH

The experimental program for this quarter is shown in Table III. During much of the Chamberlain run on β decay of hyperons, using a hydrogen Cerenkov Counter, the Bevatron was operated with magnet flat top from I_{30} to I_{30} + 300 msec. More complete details of this mode of operation will be given in the next Bevatron quarterly report.

V. MAGNET POWER SUPPLY

The record of magnet pulsing appears in Table IV.

VI. MAGNET SUBSIDENCE

The new concrete shielding to be installed around the Bevatron requires considerable foundation work. To minimize the loss of operating time, the foundation for the support beams for the inner end of the roof blocks was made by tunneling under the Bevatron. A ring was then tunneled around the inside of the Bevatron foundation and filled with concrete to provide a footing for the roof support beams. As the tunneling proceeded necessary shoring columns were installed to prevent subsidence of the Bevatron.

In December 1961, prior to tunneling under the Bevatron, a Bevatron magnet elevation survey was made as a reference for any future magnet movement.

By January 17, 1962 the tunnel had been brought under the Bevatron and the ring tunnel started. A magnet survey on that date showed a sag of 0.070 in. in the region of the tunnel. The tunneling continued and on January 23 another magnet level survey was made. This showed a sag of 0.085 in. in the region of the tunneling. Surveys on January 30 showed 0.100 in. sag; February 2, 0.105 in. sag; February 6, 0.110 in. sag. February 12 was a holiday and the Bevatron was not operating. A more detailed survey was made over the whole machine to compare the magnet sectors that had been tunneled under with those that had not as yet been reached. This survey showed a sag of 0.150 in. in the tunnel region since the December survey.

On February 13 strain gauge measurements were made on one of the support columns in the tunnel. Only one-half the required loading could be achieved. On February 14 a load-monitoring hydraulic jack confirmed the strain gauge results. On February 15 work stopped on the tunneling operation until proper techniques could be developed for achieving the proper loading on the shoring columns. By February 22 new column-loading techniques had been developed and monitoring was established. The column loads were then checked and adjusted every 24 hours.

Table III. Summary of bevatron experimental research program, February through April 1962.

Group	Start of experiment	End of experiment	Experiment	Beam time (start of run through April 1962) 12-hour periods	hours	Pulse schedule	Primary or secondary experiments
Internal groups							
Alvarez	8-29-61	In progress	K^- interactions in hydrogen, by using the 72-inch hydrogen bubble chamber (1.2 to 1.95 BeV/c).	114 49	1254 589	1:1 1:1	P S
Alvarez	9-1-61	In progress	$\pi^{\pm}$ differential scattering, by using the 72-inch bubble chamber.	(included in above totals)			
Lofgren	1-7-62	2-12-62 (pri.) 3-14-62 (sec.)	K^--p scattering, by using spark chambers (0.33 to 1.4 BeV/c).	36 59 7	408 604 65	1:1 1:1 1:2	P S S
Chamberlain, Lofgren, UCLA	2-17-62	4-15-62	β decay of Σ hyperons, by using a hydrogen Cerenkov counter (660-MeV/c K^-).	16 8 7	178 91 55	1:1 1:1 1:2	P S S
External groups							
Univ. of Wash. Masek	2-13-62	2-22-62	Test of spark-chamber performance in a 200- to 300-kG pulsed magnetic field, by using stray beam from Alvarez experiment target.	4	43	1:1	P
Cal. Tech. Tollestrup	4-7-62	In progress	Study of polarization of μ mesons from $K\mu^3$ and $K\pi^2$ decay, by using spark chambers (500- to 600-MeV/c K^+).	9 10	113 123	1:1 1:1	P S
Univ. of Wash. Masek	4-25-62	In progress	Test of counters for a future experiment.	5	68	1:1	S

Table IV. Bevatron motor-generator set monthly fault report.

	4 to 6 pulses per minute				7 to 9 pulses per minute				10 to 17 pulses per minute				Totals					
	1500 to 6900 A		7000 to 9000 A		1500 to 6900 A		7000 to 9000 A		1500 to 6900 A		7000 to 9000 A			Faults				
MONTH	Pulses	Faults	Pulses	Faults	Pulses	Faults	Pulses	Faults	Pulses	Faults	Pulses	Faults	Pulses (P)	Arc-backs	Arc-throughs	Total (F)	P/F	Ignitrons replaced
(1961)																		
Jan.	2001	--	1200	--	5099	--	--	--	6671	--	277091	59	292062	24	35	59	4951	--
Feb.	--	--	--	--	--	--	--	--	4431	--	345853	45	350284	9	36	45	7784	--
Mar.	--	--	--	--	--	--	--	--	3941	--	396827	51	400768	10	41	51	7857	--
April	--	--	--	--	--	--	--	--	4364	--	398449	55	402813	20	35	55	7323	--
May	--	--	--	--	--	--	--	--	2752	--	416350	61	419102	16	45	61	6870	--
June	--	--	--	--	--	--	--	--	9781	--	343112	38	352893	7	31	38	9287	--
July	--	--	--	--	--	--	--	--	3891	--	373182	41	377073	11	30	41	9197	--
Aug.	--	--	--	--	--	--	--	--	10235	--	322324	53	332559	15	38	53	6275	--
Sept.	--	--	--	--	--	--	--	--	5010	--	351237	44	356247	7	37	44	8097	--
Oct.	--	--	--	--	--	--	--	--	1308	--	110165	11	11473	11	--	11	1044	--
Nov.	1080	--	--	--	6684	--	--	--	11633	--	235942	45	255339	10	35	45	5675	{ Flywheel shutdown
Dec.	--	--	--	--	838	3	2905	2	2477	--	317347	48	323567	16	37	53	6105	
(1962)																		
Jan.	--	--	--	--	--	--	--	--	4911	--	383584	50	388495	23	27	50	7769	--
Feb.	4254	--	--	--	4452	--	40560	15	5194	1	240330	55	294790	30	41	71	4151	--
Mar.	--	--	--	--	--	--	77234	18	--	--	133160	10	210394	25	3	28	7514	{ shutdown 15-31
April	856	--	--	--	--	--	27304	4	--	--	279795	85	307955	17	72	89	3460	{ shutdown 1-4

On February 27 and 28 the Bevatron was shut down to realign the magnet to restore normal beam operation. The inner edge of the magnet in quadrant III was raised about 0.090 in. This brought the closed particle orbit into closer alignment with the magnet gap centerline. The adjustment did not constitute a magnet releveling but a minimum motion adjustment to return to reasonable operating conditions.

The tunnel work was resumed on February 28. The column loading was checked every 24 hours; no appreciable additional magnet subsidence was noted as the tunneling operation continued around the machine.

When Bevatron operation resumed the rapid beam ejector (RBE) worked much better than ever before. It operated at lower voltage and had excellent control of the beam. Prior to the magnet readjustment the RBE was practically useless even at maximum voltages.

ACKNOWLEDGMENTS

Edward J. Lofgren is the Bevatron Group Leader; William A. Wenzel is the Alternate Group Leader. Walter D. Hartsough, with Glen R. Lambertson and Wendell Olson assisting, is in charge of Bevatron Operation. Members of the Operating Crew are: Robert W. Allison, G. Stanley Boyle, Robert W. Brokloff, Ashton H. Brown, Duward Cagle, Norris D. Cash, Frank W. Correll, Ferdinand Dagenais, John R. Ellisen, Robert Gisser, William Kendall, William Lee, Wayne Logan, David Loucks, Kenneth Morgan, Martin E. Scolnick. The following members of the Operating Group are carrying out support and development projects: Robert Anderson, Perry Arana, Trancuilo Canton, Warren Chupp, Bruce Cork, Kenneth Crebbin, Walter Hartsough, Rudin Johnson, Leroy Kerth, Glen Lambertson, Fred Lothrop, Ross Nemetz, Douglas Pounds, Robert Pratt, Robert Richter, Joseph Smith, William Wenzel, Glenn White, Emergy Zajec, and Theodore Zipf. Engineering Groups were headed by Edward Hartwig, Electrical Engineering; Clarence Harris, Electrical Coordination; Harold Vogel and Gordon Harding, the Motor Generator Group; and William Salsig, Mechanical Engineering. Donald Milberger was in charge of the Electrical Maintenance Group.