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BEVATRON OPERATIONS AND DEVELOPMENT. 45

January through March 1965

Berkeley, California

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[*] Preceding quarterly reports: UCRL-16203, UCRL-11935.

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ABSTRACT

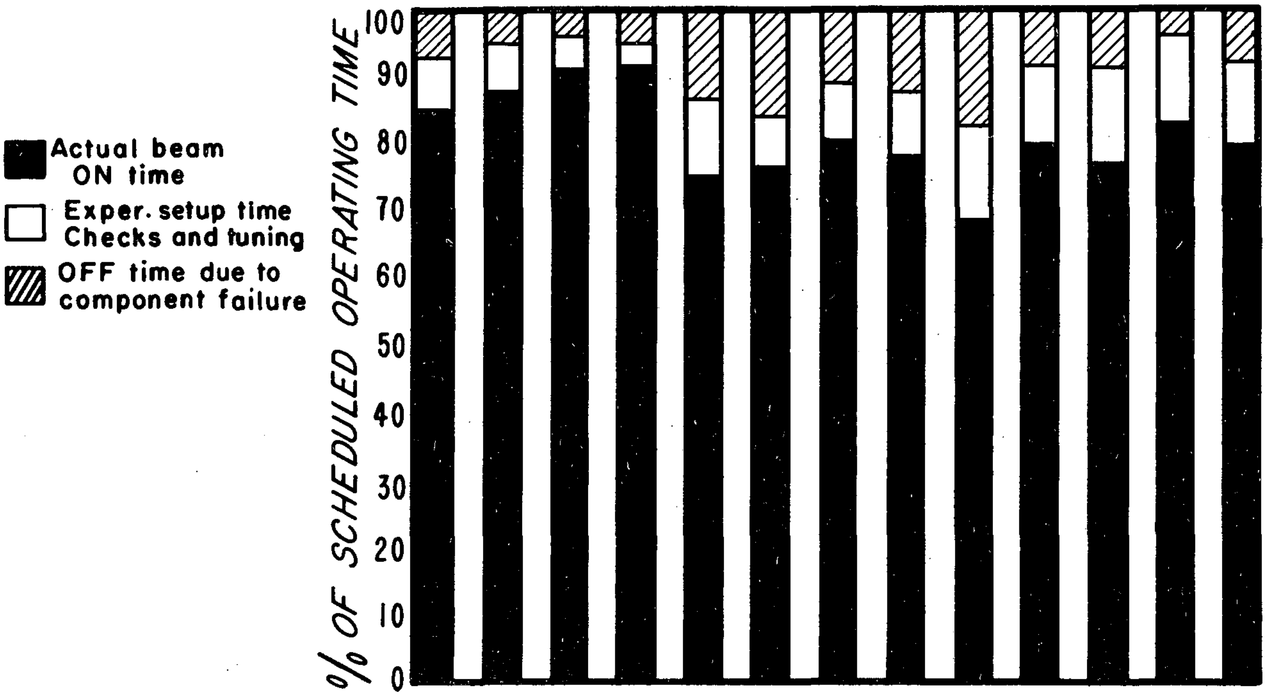
The Bevatron provided beam for physics research for 81% of the scheduled operating time. We achieved a much more stable operation than formerly by using (1) a modified inflector-tuning procedure and (2) an inner radius cup with which beam injected into the Bevatron was measured. A major shutdown this quarter allowed inspection of bearings and journals on the main motor generator sets. Four primary experiments ended this quarter and one new primary experiment started.

I. OPERATION

The Bevatron operation record is shown in Fig. 1. The beam was on for 81% of the scheduled operating time. The beam was off for 9.5% of the time because of equipment failure and 9.5% of the time for experimental setup, tuning, and routine checks.

As reported in the preceding quarterly report,[1] the erratic operation of the injected beam caused by the shorted turn in inflector magnet IM3 was cured when IM3 was replaced. However, a certain amount of variation in beam intensity continued to plague us. The accelerated beam intensity, 2.5×10^{12} ppp (protons per pulse), would drop and could be brought back only by increasing the injected beam from the normal level of from 4 to 5 ma to the higher level of 7 to 8 ma. When these drops occurred, a great deal of retuning of both the Bevatron and the injector system (ion source through the inflector system) resulted. When this retuning was done it usually resulted in loss of beam for the experimenters during retuning. The retuning also produced disagreement among the operating group as to whether the problem was in the Bevatron tracking system or the injector system. The most pressing problem seemed to be a method of isolating the efficiency of the two systems (injection and Bevatron). This would settle the disagreement, and then if we could further find the actual cause we could improve the overall efficiency of the beam to the experimenter. An inner radius cup was used to measure the coasting beam at injection. This cup signal seemed to provide a suitable means of separating injector tuning from Bevatron tuning. General machine operation has been much more stable since we started using the inner radius cup and modified our tuneup procedure. A description of the system follows.

The south cup, which was installed on the inner radius of the Bevatron last September,[1] seemed to provide a possible means of isolating the injector tuning from the Bevatron tuning. By making this cup the innermost radial obstruction, all the beam that clears the inflector on successive turns around the Bevatron and spirals in should be collected on the cup. This then should give us a reliable measure of the tuning of the inflector system (IM1, IM2, IM3, and electrostatic inflector). Other than magnetic-field changes and injection timing, the cup reading should be independent of the Bevatron tuning. A peak reading on the inner radius cup should indicate both optimum tuning of the inflector system and best emittance of the beam. For a specific reading on the inner radius cup, we should be able to accelerate a specific amount of beam if the Bevatron is tuned correctly. The only thing that will change the amount of pickup and acceleration of beam in the Bevatron for a specific value on the inner radius cup is a change in the energy spread of the linac beam. This energy spread should be measured at the base of the energy-spread curve rather than at the width at half maximum. If the energy spread of the injector should increase, some of the circulating particles will have larger amplitudes of phase oscillation. As we are limited by radial aperture at injection, with up to full-aperture betatron oscillations, any increase in amplitude of phase oscillations will wipe out more of the beam. If the energy spread is made narrower, more beam is picked up and accelerated. To establish the inner radius cup as a reliable tool, these above effects were checked by varying the injection-system parameters and observing the results. In addition, measurements were made over a period of many weeks any time the injection efficiency changed to establish statistics on the results.



Week of	1/3	1/10	1/17	1/24	1/31	2/7	2/14	2/21	2/28	3/7	3/14	3/21	3/28
Crew hours	136	168	168	168	168	168	168	144	168	168	168	168	168
Turnon & maintenance time (h)	15	10	10	10	6	10	10	10	10	10	10	10	10
Scheduled operating time (h)	117	152	151	150	89	152	152	119	152	152	150	150	148
Scheduled Bevatron test time (h)	4	6	7	8	5	6	6	15	6	6	8	8	0
Scheduled shutdown time (h)	32[a]	0	0	0	68	0	0	0	0	0	0	0	10
Holiday (h)	0	0	0	0	0	0	0	24	0	0	0	0	0

[a] No crews scheduled

MUB-7097

Fig. 1. Summary of Bevatron operation for January through March, 1965.

I now briefly describe our inflector system and the cups in the Bevatron used for these tests and measurements. The achromatic inflector system consists of three electromagnets (IM1, IM2, IM3) and a final electrostatic inflector. The beam out of the electrostatic inflector can be read on a Faraday cup EOS (east outside south). An injected beam of 1 ma as read on this cup is used as a standard for tuning. The cup "reads" all of the injector pulses (3 to 5) except the one injected into the Bevatron during injection. For Checking injected beam, the cup is held in front of the inflector during the normally injected pulse. This particular pulse is the one that is set at 1 ma for tuneup and is measured on an oscilloscope.

The south cup is a block of aluminum 8 in. high, and 1 in. thick in the beam direction and 2 in. thick radially. The radial position is remotely adjustable over a range of 10 in. This is sufficient travel to allow it to move from out of the aperture to a position where it is the inner radial obstruction. The cup is connected to a capacitor and the voltage is read with an integrating digital voltmeter. No calibration is used (only the arbitrary voltmeter reading).

The following tests were performed. The injected beam at the inflector cup (EOS) was set at 1-ma peak (600-μsec width). The inflector magnets were adjusted to give a peak reading (0.700 V) on the inner-radius cup (with rf off). The inner-radius cup was retracted from the aperture and the rf turned on. Bevatron tuning was peaked to give us about 5×10^{11} ppp accelerated; this is our normal beam accelerated for 1 ma injected. A number of tests were made with varying injection-system parameters. In all cases for which we had about 0.700 V on the inner radius cup we would accelerate 5×10^{11} ppp independently of what current was read on the EOS cup. Slight variations in beam energy from the linac had no effect on the beam pickup. Total energy spread of the injected beam had no effect on the inner radius cup reading but did affect the beam picked up and accelerated, as we expected.

Our inflector tune-up procedure was modified as a result of these tests. It is now done as follows. The beam is centered at the entrance to each of the inflector magnets, IM1, IM2, and IM3. With the beam level into the EOS cup set at 1 ma, the reading on the inner radius cup is peaked up to about 0.700 V by adjusting IM2, the electrostatic inflector, and injection time only. During machine operation the currents in IM1 and IM3 are held at posted values which have remained essentially constant over many months of machine operation. Only the electrostatic inflector voltage and IM2 current are varied. After the beam is peaked on the inner radius cup, the cup is retracted and the beam is accelerated in the Bevatron. Beam intensity at peak field should be about 5×10^{11} ppp. After this level is reached, the injected beam current is increased to our desired operating level (normally 2.5×10^{12} ppp). This requires about 4 to 5 ma injected beam.

About five months of operation with the inner radius cup used for tune-up and checking, we have almost eliminated our pickup efficiency problem. We believe that our major problem in varying pickup efficiency came from slow tuning changes in IM1, IM2, and IM3 that resulted in more critical orbits. These orbits could be just as efficient when correctly set but were more subject to beam loss by aperture clipping, if the currents varied slightly, than orbits properly centered in IM1 and IM3.

II. SHUTDOWN

A 67.5-hour scheduled shutdown the first week in February allowed inspection of the bearings and journals on the main motor-generator sets. This inspection is routinely done after 1.3×10^6 magnet pulses, or about every 3 months. The bearings were checked for tarnishing and scraping, and the shaft journals given ultrasonic and "magnaflux" inspection.

On February 2 we shut down the vacuum system for 8 hours and 27 minutes to replace the shaft seals on the external proton beam plunging magnets. Some additional work was done on the travel target system during this vacuum shutdown. The rest of the shutdown work was routine maintenance of the electrical and mechanical equipment.

The 72-in. hydrogen bubble-chamber experimental setup of the Alvarez group, and the Michigan-Stanford experimental setup were removed during this shutdown. Setup was started on a new Trilling-Goldhaber experiment at the third focus of the EPB.

On March 29 we briefly shut down the vacuum system again, during our normal weekly maintenance period, to install a vacuum gate valve at the Quadrant III 75° beam port. This will allow a vacuum-coupled beam-transport system to be used by the Alvarez group to test a septum separator.

III. BEVATRON DEVELOPMENT AND STUDIES

Most of the study periods this quarter were devoted to the injector parameters and pickup efficiency as discussed in Sec. I. Some time was also devoted to studying beam spills and structure, particularly in the EPB. These beam-structure studies were also involved in the testing of magnet ripple-reduction equipment that is still in the development stage.

IV. EXPERIMENTAL PROGRAM

The Lofgren group's p-p scattering experiment and the Crowe group's K^+ decay-spectra experiment continued through this quarter. The Michigan-Stanford group's n-p scattering experiment, the Alvarez group's two experiments on K^- and π^- interactions in hydrogen, and the Segrè-Chamberlain group's experiment on K-Σ relative parity ended this quarter.

A new primary experiment by the Trilling-Goldhaber group was set up at the third focus in the external proton beam; this group is studying the decays and strong interactions with K_2^0 mesons in the 25-in. hydrogen bubble chamber. There was a 32-hour emulsion exposure to K^- mesons at 2.1 BeV/c for the University of Washington. They used the Alvarez group's K^- beam from the internal Quadrant III, 22° target, with beam exit at the 29° area port.

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

V. MAGNET POWER SUPPLY

The magnet pulsing record is shown in Table II.

Table I. Summary of Bevatron experimental research program, January through March, 1965.

				Beam time					
				This quarter (Jan. -Mar.)		Start of run through March 1965			
Group	Start of experiment	End of experiment	Experiment	12-hour periods	Hours	12-hour periods	Hours	Pulse schedule	Primary or Secondary Experiment
Internal groups									
Alvarez (No. 16)[a]	3-23-63	2-1-65	Study of π^- interactions in hydrogen and deuterium using the 72 inch bubble chamber.	13	141	208	2183	1:1	P
				0	0	3	41	1:1	S
Alvarez (No. 17)	4-26-63	1-25-65	Study of K^- interactions in hydrogen and deuterium using the 72 inch bubble chamber.	28	284	387	4346	1:1	P
				0	0	4	38	1:1	S
Segrè-Chamberlain	10-5-64	3-3-65	K-Σ relative parity	12	143	19	213	1:1	S
	10-13-64	3-3-65	Same	14	149	67	711	1:1	P
Crowe (No. 22)	10-27-64	In progress	K^+ decay spectra	26	298	38	424	1:1	S
	12-11-64	In progress	Same	22 1/2	247	23	254	1:1	P
Lofgren (No. 20A)	12-13-64	In progress	p-p scattering	16	184	20	240	1:1	S
	1-14-65	In progress	Same	75	737	75	737	1:1	P
Mack	1-19-65	2-5-65	Evaluation of counting equip.	1	19	1	19	1:1	S
Alvarez	2-11-65	In progress	Test of a septum separator in a negative-particle beam	3	53	3	53	1:1	S
Trilling-Goldhaber (No. 27)	3-3-65	In progress	Study of decays and strong interactions with K_2^0 mesons using the 25 inch hydrogen bubble chamber.	21	209	21	209	1:1	S
	3-5-65	In progress		13	134	13	134	1:1	P
External groups									
Stanford-Michigan (Perl-Longo)	10-18-64	1-5-65	n-p scattering	2	17	13	123	1:1	S
	10-13-65	1-13-65	Same	10	116	72	785	1:1	P
Univ. Washington (Lord)	1-26-65	1-27-65	Emulsion exposure to 2.1 BeV/c K^- mesons	3	32	3	32	1:1	P

[a] Numbers in parentheses are experiment numbers.

Table II. 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 (1965)	Pulses	Faults[a] 14	Faults[a] 26	Pulses	Faults[a] 14	Faults[a] 26	Pulses	Faults[a] 14	Faults[a] 26	Pulses	Faults[a] 14	Faults[a] 26	Pulses	Faults[a] 14	Faults[a] 26	Pulses	Faults[a] 14	Faults[a] 26	Pulses (P)	Arc-backs	Arc-through	Total (F)	P/F	Comments
Jan.	1,566			1,732						2,397	2		26,909			246,571	19	42	279,175	21	42	63	4431	
Feb.	4,501			1,358						10,422			89,963	4	4	168,801	14	31	275,045	18	35	53	5189	
March							454						246,308	10	10	145,517	22	30	392,279	32	40	72	5448	
April							245			49,942	2	2	160,776	12	28	11,422		2	222,385	14	32	46	4834	
May	2,539						4,039			2,071	1		310,039	16	35	34,413	4	6	353,155	21	41	62	5696	
June																								
July																								
Aug.																								
Sept.																								
Oct.																								
Nov.																								
Dec.																								

[a] 14 indicates an arc-back, 26 indicates an arc-through.

STAFF

Edward J. Lofgren	Bevatron Group Leader
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Wendell Olson	
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Kenow Lou	In charge of Mechanical Engineering Group
Cedric Larson	
Abraham Glicksman	

REFERENCE

1. Robert W. Allison, Jr., Kenneth C. Crebbin, William L. Everette, and Emery Zajec, Bevatron Operation and Development. 43, July through September 1964, UCRL-11935, Feb. 12, 1965.