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BEVATRON OPERATION AND DEVELOPMENT. XXVI

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BEVATRON OPERATION AND DEVELOPMENT. XXVI  
May, June, July 1960  
Walter D. Hartsough  
September, 1960

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Walter D. Hartsough

Lawrence Radiation Laboratory  
University of California  
Berkeley, California

September 20, 1960

ABSTRACT

Bevatron operation averaged 88% of the scheduled operating time this quarter. The experimental program was devoted for the most part to continued studies of K- and  $\pi$ - meson interactions, using propane, hydrogen, deuterium, and xenon bubble chambers, and  $\pi^-$ -p interactions, using counting techniques.

Seventeen chemistry bombardments were made in the internal proton beam.

## BEVATRON OPERATION AND DEVELOPMENT. XXVI

May, June, July 1960

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### OPERATION

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

### RESEARCH

The experimental program undertaken during the calendar year 1959 is summarized in Tables III and IV. Table V lists the experiments conducted during the period January through April 1960 and Table VI the experiments for this quarter. Beam or running time is listed in two ways: the number of 12-hour periods that an experiment was conducted, during which both the experimental apparatus and the Bevatron were in operation for a major portion of the period; and the total number of hours that an experiment was in actual operation. Experiments are listed as primary experiments or secondary experiments. Primary experiments are scheduled experiments and are controlling in the sense of determining many of the operating conditions of the Bevatron. This is particularly true in the realm of secondary-particle beam production. Secondary experiments, on the other hand, whether scheduled or not, generally do not dictate the operation conditions of the Bevatron.

### SHUTDOWNS

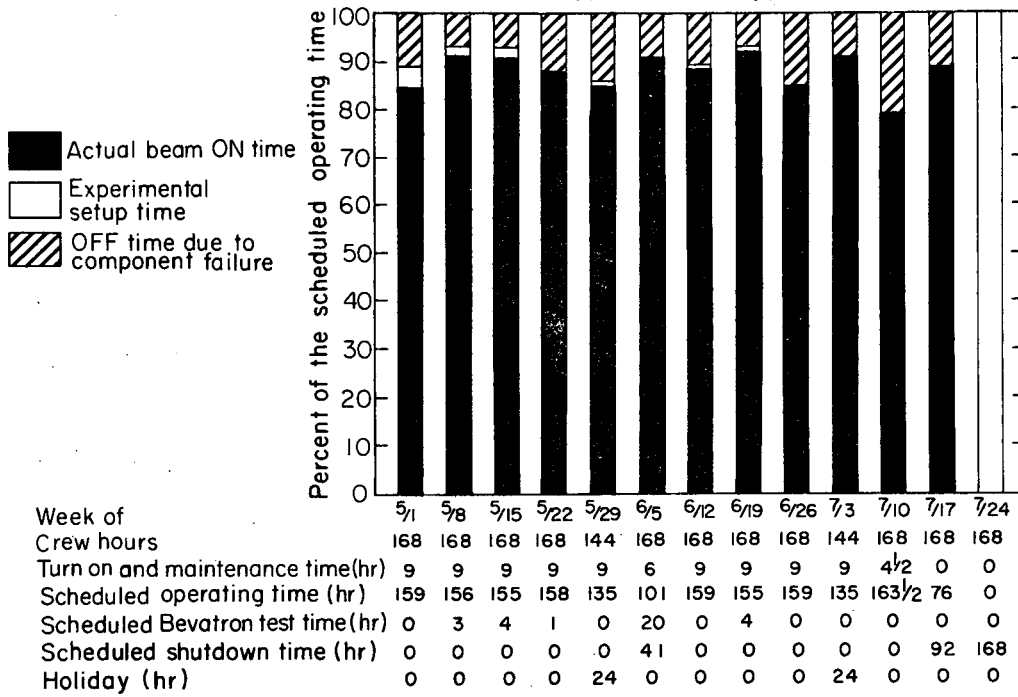
One unscheduled shutdown occurred this quarter. On May 28, a mechanical failure of the rapid-beam-ejector support structure necessitated letting the machine to air. This resulted in a 7-hour beam interruption. Two scheduled shutdowns, June 7 through 9, and July 20 through the end of the quarter, were for experimental setup and target changes and for maintenance. During the latter shutdown (still in progress at the end of the quarter) a vacuum extension for coupling secondary-particle beams into transport systems was attached to the Bevatron vacuum tank at the Quadrant III 89 deg experimental area. A remotely operated flip-target assembly, movable in azimuth, was installed at the entrance of Quadrant III. Operation and life tests of this apparatus will be made during the next quarter.

### MAGNET POWER SUPPLY

The magnet Pulse record appears in Table VII.

### BEVATRON OPERATING SCHEDULE

May, June and July, 1960



MU - 22109

Fig. 1. Bevatron operating schedule, May, June, July 1960



Table I

Beam Record		
Week of (1960)	Number of 8-hour shifts	Total integrated beam <sup>a</sup> (10 <sup>15</sup> protons)
May 1 - 7	20	6.3
May 8 - 14	20	7.3
May 15 - 21	19	4.9
May 22 - 28	20	4.8
May 29 - June 4	18	3.0
June 5 - 11	12	2.8
June 12 - 18	21	4.4
June 19 - 25	21	8.0
June 26 - July 2	21	10.2
July 3 - 9	18	7.8
July 10 - 16	21	8.0
July 17 - 23	10	2.9
July 24 - 30	—	SHUTDOWN

Maximum injected beam = 675 microamperes

Maximum beam amplitude at full energy =  $2.3 \times 10^{11}$  protons per pulse

Average beam per 8-hour shift =  $3.2 \times 10^{14}$  p<sup>+</sup>

<sup>a</sup>Beam level was reduced at the request of the experimental group during a portion of this quarter.

Table II

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Analysis of the total lost beam time due to component failure (percent)

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Month (1960)	Injector	Magnet power supply	rf accelerating system	other
May	36	29	10	25
June	20	18	17	45
July	10	54	9	27

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Table III

Bevatron experimental research program for the year 1959.				Summary of primary (controlling) experiments		
Group and	Institution	Experiment	Date (Start and end of experiment)	Beam Time		Pulse schedule
				12-hour periods	Hours	
Lofgren	LRL, Berkeley	External proton beam studies	12/31/58 to 1/7/59	2	17	1:1
Goldhaber	LRL, Berkeley	$K^-$ emulsion exposures, 430 Mev/c and 1.1 Bev/c	1/3/59 to 1/10/59	4	32	1:1
Ekspong	Univ. of Uppsala	$K^-$ emulsion exposures, 430 Mev/c	1/7/59 to 1/10/59	2	27	1:1
Alvarez	LRL; Berkeley	$K^-$ interactions in hydrogen, 1.1 Bev/c (continuation of experiment in progress)	1/7/59 to 1/24/59	9	92	1:1
Prowse	Bristol Univ.	$K^-$ emulsion exposures, 1.1 Bev/c	1/7/59 to 1/10/59	4	42	1:1
Keefe	Univ. Dublin	$K^-$ emulsion exposure, 1.1 Bev/c	1/7/59 to 1/10/59			1:1
	Delhi Univ.	$K^-$ emulsion exposure, 1.1 Bev/c	1/10/59 to 1/12/59	1	9	1:1
Bhowmik	Bristol Univ.	$K^-$ emulsion exposure, 430 Mev/c	1/10/59 to 1/12/59	3	28	1:1
Wilkinson	Oxford Univ.	$K^-$ emulsion exposure, 430 Mev/c	1/12/59 to 1/15/59	4	42	1:1
Fry	Univ. Wisconsin	$K^-$ emulsion exposure, 1.1 Bev/c	1/14/59 to 1/22/59	2	20	1:1
Powell	LRL, Berkeley	$\pi^-$ -p scattering; 500, 600, 800 Mev/c	1/15/59 to 1/20/59	6	54	1:1
Lofgren	LRL, Berkeley	K-mesic x-ray studies, 430-Mev/c $K^-$	1/16/59 to 1/18/59	-	5	1:1
Barkas	LRL, Berkeley	$K^-$ emulsion exposure, 430 Mev/c and 1.1 Bev/c	1/18/59 to 1/19/59	4	32	1:1
Prowse	Bristol Univ.	$K^-$ emulsion exposure, 430 Mev/c	1/20/59 to 1/22/59	-	5	1:1
Crussard	Univ. Paris	$K^-$ emulsion exposure, 430 Mev/c	1/22/59 to 1/22/59	1	9	1:1

Table III (continued)

Group and	Institution	Experiment	Date (Start and end of experiment)	Beam time		Pulse schedule
				12 hour Periods	Hours	
Wataghin	Univ. Torino	$K^-$ emulsion exposure 430 Mev/c	1/22/59 to 1/23/59	1	12	1:1
Powell	LRL, Berkeley	$K^-$ interactions in propane, 1.1 Bev/c	1/25/59 to 2/16/59	23	252	1:1
Blau	Univ. Miami	$K^-$ emulsion exposure, 430 Mev/c	1/25/59 to 1/26/59	2	17	1:1
Hill	Univ. Illinois	$K^-$ emulsion exposure, 430 Mev/c	2/1/59 to 2/2/59	2	15	1:1
Levi-Setti	Univ. Chicago	$K^-$ emulsion exposure, 430 Mev/c	2/2/59 to 2/3/59	2	24	1:1
White	LRL, Livermore	$K^-$ emulsion exposure, 430 Mev/c	2/6/59 to 2/12/59	2	23	1:1
Furth	LRL, Livermore	Emulsions in high magnetic field, 430 Mev/c	2/6/59 to 2/13/59	4	48	1:1
Prowse	UCLA	Emulsions in high magnetic field, 430 Mev/c	2/6/59 to 2/13/59			
Stork	UCLA	$K^-$ emulsion exposure, 430 Mev/c	2/12/59 to 2/13/59	1	12	1:1
Wataghin	Univ. Torino	$K^-$ emulsion exposure, 1.1 Bev/c	2/16/59 to 2/17/59	2	18	1:1
Lofgren	LRL, Berkeley	External proton beam studies	2/21/59 to 2/25/59	2	23	1:1
Segré	LRL, Berkeley	$\bar{p}$ production versus angle, 1.0- to 1.8-Bev/c $\bar{p}$	2/21/59 to 4/22/59	39	406	1:1
Lord	Univ. Washington	Emulsion exposure, 5.1-Bev internal $p^+$ beam	3/24/59 to 3/24/59	-	3	1:1
Barkas	LRL, Berkeley	Emulsion exposure, 6.2-Bev internal $p^+$ beam	3/24/59 to 3/24/59	-	2	1:1
Peters	Copenhagen	Emulsion exposure, 6.2- Bev internal $p^+$ beam	3/24/59 to 3/24/59	-	1	1:1

Table III (continued)

Group	and Institution	Experiment	Date (Start and end of experiment)	Beam time		Pulse schedule
				12-hour periods	Hours	
Zorn	Brookhaven	Emulsion exposure, 6.2- Bev internal $p^+$ beam	3/24/59 to 3/24/59	-	1	1:1
Alvarez	LRL, Berkeley	$K^-$ interactions in deuterium, 430 Mev/c	2/25/59 to 4/20/59	30	328	1:1
Powell	LRL, Berkeley	$\theta_2^0$ decays and interactions in propane, 1.4-Bev/c $\pi^-$	4/26/59 to 5/21/59	37	433	1:1
Lofgren	LRL, Berkeley	$\bar{p}$ -p cross sections and hyperon production, 1.4 to 3.0 Bev/c	6/7/59 to 6/28/59	29	318	1:2
Alvarez	LRL, Berkeley	$\bar{p}$ -p interactions in hydrogen, 1.7 Bev/c	6/7/59 to 11/12/59	65	737	1:2 1:3
Moyer	LRL, Berkeley	$\pi^\pm$ -nucleon cross sections, 4 Bev/c	6/14/59 to 7/24/59	10	112	1:2
Helmholz	LRL, Berkeley	$\pi^\pm$ -nucleon cross sections, 0.6 to 1.5 Bev/c	7/8/59 to 8/5/59	4	89	1:2
Fitch	Princeton Univ.	$\theta_1$ - $\theta_2$ mass difference	7/10/59 to 8/5/59	1	21	1:2
Kalbach	Univ. Arizona	Emulsion exposure: 0.9-Bev/c $\pi^-$ ; 1.1 Bev/c $\pi^+$	7/31/59 to 7/31/59	-	4	1:1
Lofgren	LRL, Berkeley	External proton beam studies	8/11/59 to 8/13/59	4	45	1:1
Alvarez	LRL, Berkeley	Septum separator tests	8/12/59 to 8/26/59	6	61	1:2 1:3
	Univ. Durham	Emulsion exposure, 6.2- Bev external $p^+$ beam	8/13/59 to 8/13/59	-	-	1:1
Kalbach	Univ. Arizona	Emulsion exposure, 6.2- Bev external $p^+$ beam	8/14/59 to 8/14/59	-	5	1:1
Zorn	Brookhaven	Emulsion exposure, 6.2-Bev internal $p^+$ beam	8/15/59 to 8/15/59	-	5	1:1
Van Heerden	Univ. Ottawa	Emulsion exposure, 6.2-Bev internal $p^+$ beam	8/15/59 to 8/15/59	-	2	1:1

Table III (continued)

Group and	Institution	Experiment	Date (Start and end of experiment)	Beam time		Pulse schedule
				12-hour periods	Hours	
Lofgren	LRL, Berkeley	Asymmetry in decay of $\Sigma^+$ , $\Lambda^0$ ; 1.13-Bev/c $\pi^+$	8/16/59 to 9/14/59	32	484	1:2 2:3
Glaser	LRL, Berkeley	$K^+$ decay modes, 700 Mev/c	9/14/59 to 10/10/59	36	397	1:2 2:3
Peters	Copenhagen	Emulsion exposure, 6.2-Bev internal $p^+$ beam	9/20/59 to 9/26/59	—	4	1:1
Lofgren	LRL, Berkeley	$K^+$ interactions in $H_2$ and $D_2$ , 0.6 to 1.5 Bev/c	10/29/59 to 1/26/60	71	777	1:1
Segré	LRL, Berkeley	$\pi^+ + p \rightarrow \Sigma^+ + K^+$ , 1.03 to 1.33- Bev/c $\pi^+$	10/31/59 to 11/29/59	23	253	1:1
Fitch	Princeton Univ.	$\theta_1$ - $\theta_2$ mass difference	12/2/59 to 1/5/60	20	225	1:1
Van Heerden	Univ. Ottawa	Emulsion exposure, 350- Mev/c $K^+$	12/8/59 to 12/9/59	1	11	1:1
Glaser	NRL, Washington, D. C.	Emulsion exposure, 350- Mev/c $K^+$	12/10/59 to 12/11/59	1	12	1:1
Gottstein	Germany	Emulsion exposure, 350- Mev/c $K^+$	12/12/59 to 12/12/59	1	8	1:1
Taylor	Stephens Inst.	Emulsion exposure, 350- Mev/c $K^+$	12/12/59 to 12/15/59	1	12	1:1
Mulvey	Oxford Univ.	Emulsion exposure, 350- Mev/c $K^+$	12/13/59 to 12/14/59	1	12	1:1
Seaborg	LRL, Berkeley	Chemistry target bombardments (17) in the internal proton beam.				

Table IV

Bevatron experimental research program for the year 1959. Summary of secondary (Parasitic) experiments			
Group	Institution	Experiment	Dates
Helmholz	LRL, Berkeley	Attenuation of 5-Bev neutron in various materials.	1/4/59 to 8/22/59
Sprenkel	Brookhaven	Fe(P,-)Cl <sup>36</sup> cross section for 6.2 Bev p <sup>+</sup> .	Tgts. sent Jan. 59 Tgts. bombarded Nov.- Dec., 1958
Prowse	Bristol Univ.	Emulsion exposure to neutral particles.	1/14/59 to 1/15/59
Prowse	Bristol Univ.	Emulsion exposure to neutral particles.	1/22/59 to 1/22/59
Moyer	LRL, Berkeley	Test of liquid Freon counter.	1/29/59 to 2/10/59
Moyer	LRL, Berkeley	Radiation surveys.	2/12/59 to 4/22/59
Alvarez	LRL, Berkeley	Test of 3-Bev $\pi^-$ beam for 72-inch bubble chamber.	3/14/59 to 4/22/59
Fry	Univ. Wisconsin	Emulsion exposure to neutral particles.	3/27/59 to 3/29 to 59
Nier	Univ. Minnesota	Analysis of targets bombarded by 6.2-Bev p <sup>+</sup> .	Tgts. sent June, 1959 Tgts. bombarded Apr.- May, 1959
Barkas	LRL, Berkeley	Emulsion exposure to external 6.2-Bev p <sup>+</sup> .	8/13/59 to 8/13/59
Alvarez	LRL, Berkeley	Eng. test of 72-inch bubble chamber in $\pi$ beam.	9/9/59 to 9/12/59
Amaldi	Rome, Italy	Emulsions exposed to 1.7-Bev p <sup>-</sup> beam.	10/11/59 to 10/24/59
Ronne	Univ. Uppsala	Emulsions exposed to 1.7-Bev p <sup>-</sup> beam.	10/23/59 to 10/31/59
Mulvey	Oxford Univ.	Emulsions exposure, 700-Mev/c K <sup>+</sup> .	11/25/59 to 11/25/59

Table V

Summary of bevatron experimental research program, January through April, 1960							
Group	INTERNAL GROUPS		Experiment	Beam Time		Pulse Schedule	Primary or secondary expt.
	Start of Experiment	End of Experiment		12-hour periods	Hours		
Lofgren	10/29/59	1/31/60	$K^+$ -meson interaction 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 $\mu^-$ beam)	—	—	1:2	S
Barkas	1/22/60	1/22/60	Emulsion exposure (3.5-Bev/c $\pi^-$ beam)	—	—	1:2	P
Powell	1/26/60	1/31/60	$\pi^+$ -p scattering, 730 Mev/c.	7	69	1:2	P
Powell	2/13/60	in progress	K meson interactions and $\theta_1$ - $\theta_2$ mass difference (700-Mev/c $K^+$ beam).	42	465	1:1	P
Lofgren	2/13/60	3/15/60	$K^-$ -p and $K^-$ -n scattering (1.5-Bev/c $K^-$ ).	39	443	1:1	P
Segré	3/18/60	4/19/60	$\pi$ - $\pi$ scattering, 1.5-Bev/c $\pi$ beam.	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).	8	79	1:1	P
Seaborg			Chemistry target bombardments (4) in the internal proton beam.				
EXTERNAL GROUPS							
Institution and Experimenter	Start of Experiment	End of Experiment	Experiment	12-hour periods	Hours	Pulse Schedule	Primary or secondary expt.
Princeton U. Fitch	12/2/59	1/6/60	Study $\theta_1$ - $\theta_2$ mass difference.	8	69	1:1	P
Univ. Washington Masek	1/8/60	2/3/60	$\mu^-$ -meson scattering in lead and carbon (3.5-Bev/c $\pi^-$ beam).	46	515	1:1 1:2	P
Tufts Univ. Schneps	1/22/60	1/22/60	Emulsion exposure in 3.5-Bev/c $\pi^-$ beam.	—	—	1:2	P
U. Tennessee King	1/22/60	1/22/60	Emulsion exposure in 3.5-Bev/c $\pi^-$ beam.	—	—	1:2	P
U. Wisconsin Fry	1/22/60	1/22/60	Emulsion exposure in 3.5-Bev/c $\pi^-$ beam.	—	—	1:2	P
Tata Inst., India Biswas	1/22/60	1/22/60	Emulsion exposure in 3.5-Bev/c $\pi^-$ beam.	—	—	1:2	P
U. Washington	1/22/60	1/22/60	Emulsion exposure in 3.5-Bev/c $\pi^-$ beam.	—	—	1:2	P
U. Michigan Perl	4/1/60	in progress	$\pi$ -p scattering (1.5-Bev/c $\pi^-$ ).	32	330	1:1	S



Table VI

Bevatron experimental research program, May, June, July 1960

Group	INTERNAL GROUPS		Experiment	Beam Time		Pulse Schedule	Primary or Secondary expt.
	Start of Experiment	End of Experiment		12-hour Periods	Hours		
Powell	2/13/60	5/20/60	K-meson interactions and $\theta_1$ - $\theta_2$ mass difference (700-Mev/c $K^+$ ) using the propane bubble chambers.	31	35 319	1:1 1:2	P
Alvarez	4/22/60	in progress	$\pi^\pm$ interactions in hydrogen and deuterium (0.9 to 1.6 Bev/c)	124	796 388	1:1 1:2	P
Lofgren	5/12/60	in progress	Test of an argon spark chamber in a $\pi$ -meson beam.	9	84 22	1:1 1:2	S
Glaser	5/23/60	6/7/60	Measure $\theta_1^0$ 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	$\pi^-$ -p elastic scattering and differential cross sections (550- to 925-Mev/c $\pi^-$ ).	75	746	1:1	P
Seaborg			Chemistry target bombardments (17) in the internal proton beam.				
EXTERNAL GROUPS							
U Michigan Jones, Perl	4/1/60	in progress	$\pi$ -p scattering cross section	6	64	1:2	S
U. Washington	6/2/60	6/22/60	Study $\pi^-$ 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 $\pi$ 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 $\pi$ meson beam.		No record kept		S

Table VII

Bevatron motor generator set monthly fault rate

MONTH	4 to 6 pulses per minute						7 to 9 pulses per minute						10 to 17 pulses per minute						Totals			Ignitrons replaced	
	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
	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		
1960																							
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	4 B 2
April	400												4449			324768	40	8119	329617	10	30	8240	
May													4583	3	1561	419536	43	9759	424229	12	34	9222	
June													3337			410794	63	6520	415299	5	58	6592	
July							1887			1168			1857			259094	61	4248	262838	14	47	4309	1B4 2B4 2B6 3B1

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