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Ernest O. Lawrence Radiation Laboratory

BEVATRON OPERATION AND DEVELOPMENT. 44

October through December 1964

Berkeley, California

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ABSTRACT

The Bevatron provided beam for physics research 85% of the scheduled operating time. The only shutdowns this quarter were during the normal weekly maintenance periods and the Thanksgiving and Christmas-New Year holiday periods. Most of the Bevatron study periods were devoted to injection and alignment studies of the injection system. A new beam-spilling device using feedback from the beam-induction-electrode sytem to control the rf voltage was put into operation. One experiment continued through this quarter and four new experiments were started this quarter.

I. OPERATION

The Bevatron operation record for this quarter is shown in Fig. 1. The beam was on for 85% of the scheduled operating time. The beam was off 7% of the time because of component failure, and 8% of the time for setup and routine checks.

A summary of the Bevatron schedule and operating record for 1964 is shown in Table I.

II. SHUTDOWN

The 3-week shutdown reported in the last quarterly report was completed the first week of this quarter. The only additional shutdowns were scheduled in conjunction with the Thanksgiving and Christmas-New Year holidays. They did not involve any machine maintenance or modifications. Over the Thanksgiving holiday, the Bevatron was shut down on Thursday, November 26, at 8:00 a.m. and started operation again Monday, November 30, at 4 p.m., after the normal 8-hour maintenance day. In December the Bevatron was shut down on Thursday the 24th at 8 a.m. and resumed operation on Monday, January 4, 1965, at 4 p.m. after the normal 8-hour maintenance day.

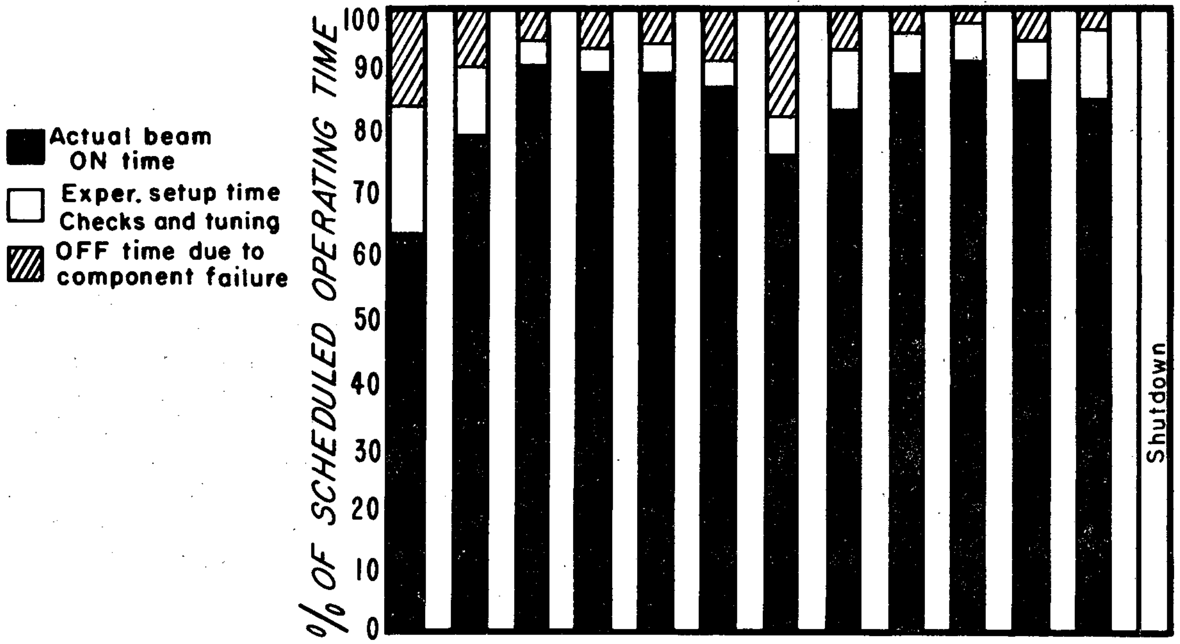
III. BEVATRON DEVELOPMENT AND STUDIES

Most of the Bevatron study periods were devoted to injection and alignment studies of the injection system. Some time was devoted to external proton-beam steering and targetry problems. The final form of the electronic beam spiller was installed and placed in operation. This is reported in detail below.

A. Linac and Inflector-System Alignment

Robert W. Allison, Jr., and Emery Zajec

The alignment of the inflector and linac was checked with the south scintillator.[1] We discovered that IQ1 and IQ2 (injector quadrupoles) had settled after the shielding wall was replaced at the end of September 1964; these magnets were releveled. We also found that changing the rf level in the linac tank and the drift-tube currents produced 1-in. vertical deflections in the beam at the south scintillator. These deflections were minimized to about 1/2 in. by careful adjustment of the elevations of the ends of the linac tank. Because this movement affects the inflection-system tuning, design studies were started on adding steering magnets and beam-position indicators to the linac exit section.



Week of	10/4	10/11	10/18	10/25	11/1	11/8	11/15	11/22	11/29	12/6	12/13	12/20	12/27
Crew hours	168	168	168	169	168	168	168	104	136	168	168	104	0
Turnon & maintenance time (h)	9	10	10	10	10	10	10	10	12	10	10	10	0
Scheduled operating time (h)	127	150	147	149	152	150	143	90	124	150	147	86	0
Scheduled Bevatron test time (h)	0	8	4	10	6	8	15	4	0	8	11	8	0
Scheduled shutdown time (h)	32	0	7	0	0	0	0	16[a]	32[a]	0	0	16[a]	120[a]
Holiday (h)	0	0	0	0	0	0	0	48	0	0	0	48	48

[a] No crews scheduled

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Fig. 1. Bevatron operation schedule, October through December, 1964.

Table I. Summary of the Bevatron schedule and operating record for 1964.

	Twelve-Hour Periods
Scheduled operation	573.25
Shutdown and maintenance	83
Weekends "Off"	39.75
Holidays and enforced vacation	25
Warmup periods following shutdowns, weekends, and holidays	9
TOTAL number of periods per year	730
	% of scheduled operation hours
"ON" time	85
"OFF" time due to failure of the Bevatron	8
"OFF" time due to experimental setup, routine checks, and tuning	7

B. Electronic Beam Spiller

Fred H. G. Lothrop

(For a complete description of the Electronic Beam Spiller see Ref. 2.)

Experiments by Crebbin on methods of extracting particles slowly from the circulating bunch of protons in the Bevatron have led to the design and fabrication of the Electronic Beam Spiller. (Spilling is the jargon used to describe the action of protons' being lost from synchronism.) Crebbin showed that suitable amplitude modulation of the accelerating voltage led to a stable extraction of protons over a period of several hundred milliseconds. The thought of a closed-loop feedback system around the proton beam and the accelerating system to provide a spill linear with time immediately presented itself. The Electronic Beam Spiller is the successful result of that thought.

The basic feedback loop is shown in Fig. 2. A voltage derived from the beam-induction electrode signal is compared to a reference ramp voltage, and the error signal is applied to the amplitude modulator of the rf accelerating system. This error signal causes the amplitude of the accelerating voltage to decrease to where the circulating protons start to lose synchronism and are lost from the main beam bunch. The average value of the accelerating voltage is maintained by the closed loop at the point where protons are lost at a rate determined by the slope of the reference ramp voltage.

The intensity of the proton beam is not constant during the acceleration cycle, or from experiment to experiment. In order to make this device insensitive to fluctuations in beam intensity, the reference voltage is derived from the induction electrode signal just before the spill of protons is started.

Figure 3 is a block diagram of the Electronic Beam Spiller. The detector converts the high-frequency induction electrode signal to a slowly varying dc voltage proportional to proton-beam intensity. This proportional voltage is fed to the sample-and-hold circuit that provides a steady dc voltage to the reference ramp generator. The proportional voltage is also fed to the summing junction and to one input of the comparator. The other input of the comparator comes either from the output of the sample-and-hold circuit or from a fixed dc supply voltage. The comparator sends a triggering pulse to the electronic switch to turn off the spiller after the requisite number of protons have left the bunch. If one comparator input is the voltage from the sample-and-hold circuit, the spiller will spill a certain percentage of the total circulating beam. If that comparator input is switched to the dc supply voltage, the spiller will spill to a fixed level of remaining beam. A trigger derived from the Bevatron magnet-timing signals turns on the spiller.

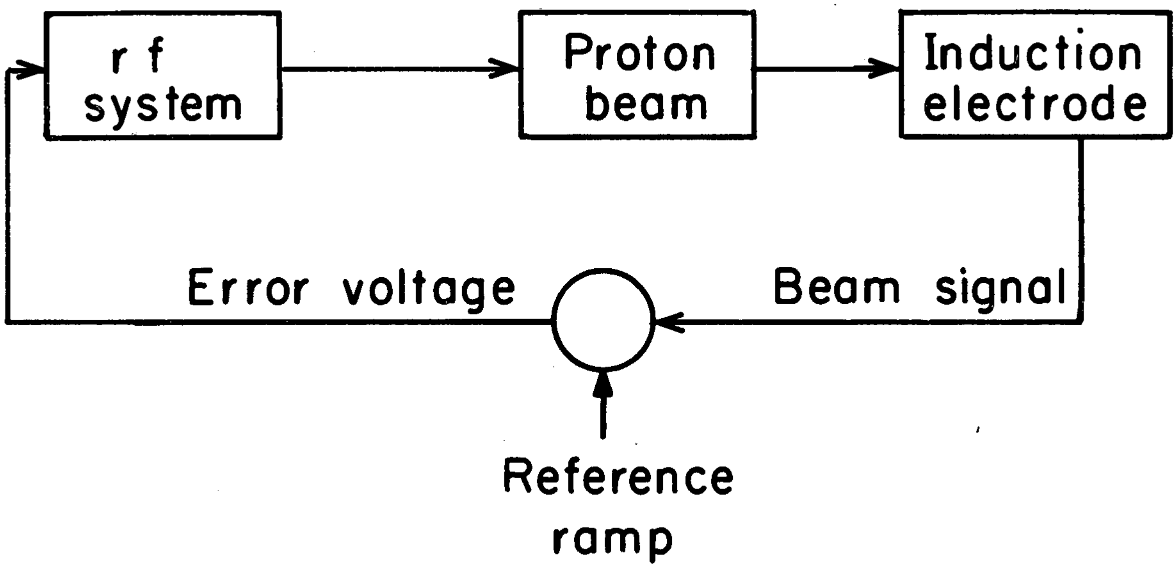

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Fig. 2. Feedback loop for electronic beam spiller.

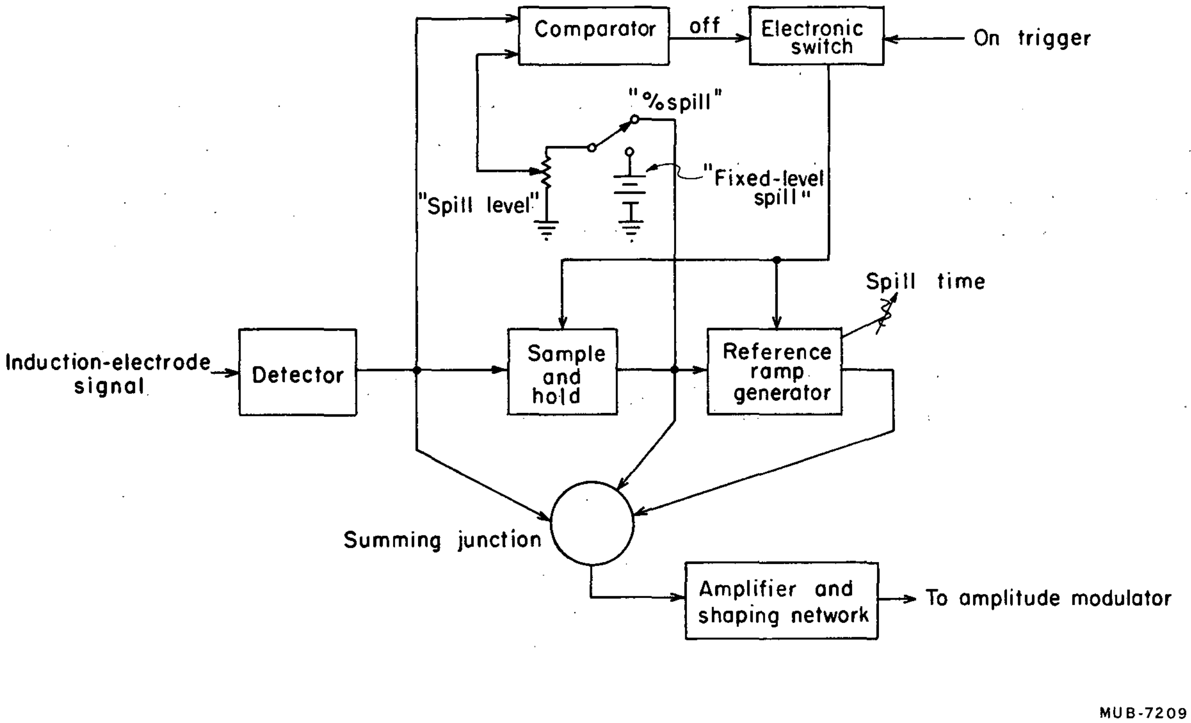

Fig. 3. Block diagram of electronic beam spiller.

Conceptually, there are two modes of extracting beam with the Electronic Beam Spiller—constant spill rate, or constant spill time. The latter mode was chosen because a major constraint on Bevatron experiments is that protons should be delivered during a specified period of time. Any desired fraction of the beam, including all of it, will be spilled by the Electronic Beam Spiller during the interval of time selected by the operator.

As installed at the operations console of the Bevatron, the Electronic Beam Spiller provides four independently adjustable sequential beam spills. Each spill is adjustable for length and amount of beam spilled. The spiller will reliably spill amounts ranging from 1% to 99% of the total beam; the latter percentage is the most difficult to control. One-hundred-percent spills are routine, and are the normal situation.

IV. EXPERIMENTAL PROGRAM

The Alvarez group experiments, in which K^- and π^- interactions in hydrogen and deuterium were studied in the 72-in. bubble chamber, were continued through this quarter. Four new experimental groups started experiments this quarter.

The Segrè-Chamberlain group started an experiment to determine the relative parity of the Σ hyperon and the K meson by means of the re-raction $\pi^{\pm} + p \rightarrow \sigma^{\pm} + K^{+}$ in which the target protons are polarized. This group used the internal beam of the Bevatron in a flattop mode of operation and spills of the order of 500 to 800 milliseconds long.

The three other new experiments were set up in the external proton beam (EPB), one at each of the three EPB focus points. The Crowe group (EPB F_1) studied the decay spectra of the K^+ meson. The Lofgren group (EPB F_2) studied p-p scattering by means of a parallel beam of protons through the target; this change from nonparallel beam was sufficient to distort the image at F_3 if there was also a target at F_1 (Crowe). Because of this distortion only two of these three experiments could be run simultaneously. The third experiment (EPB F_3) was conducted by the Stanford-Michigan group, who studied neutron-proton elastic scattering: diffraction peaks, large angle, and charge exchange.

A summary of the experimental research program for this quarter is shown in Table II. Table III is a summary of the experimental research program for 1964.

V. MAGNET POWER SUPPLY

The magnet pulsing record is shown in Table IV.

Table II. Summary of Bevatron experimental research program, October through December 1964

Group	Start of experiment	End of experiment	Experiment	Beam Time: This quarter, 12-hour periods	Beam Time: This quarter, Hours	Beam Time: Start of run through Dec. 1964, 12-hour periods	Beam Time: Start of run through Dec. 1964, Hours	Pulse schedule	Primary or secondary experiment
Internal groups									
Alvarez (No. 16)[a]	3-23-63	In progress	Study of π^- interactions in the 72 in. bubble chamber with hydrogen,	20	197	195	2042	1:1	P
			deuterium	0	0	3	41	1:1	S
Alvarez (No. 17)	4-26-63	In progress	Study of K^- interactions in the 72 in. bubble chamber with hydrogen,	78	1017	359	4062	1:1	P
			deuterium	4	38	4	38	1:1	S
Segrè-Chamberlain (No. 13)	10-5-64	In progress	K-Σ relative partity experiment	7	70	7	70	1:1	S
	10-5-64	In progress	Same	53	562	53	562	1:1	P
Crowe (No. 22)	10-27-64	In progress	K^+ decay spectra	12	126	12	126	1:1	S
	12-11-64	In progress	Same	1/2	7	1/2	7	1:1	P
Lofgren (No. 20A)	12-13-64	In progress	p-p Scattering	4	56	4	56	1:1	S
External groups									
Stanford-Michigan (No. 3) (Perl-Longo)	5-6-64	In progress	n-p Scattering	11	106	15	146	1:1	S
	10-13-64	In progress	Same	62	669	62	669	1:1	P

[a]Numbers in parentheses are experiment numbers.

Table III. Summary of Bevatron experimental research program for 1964.

Runs completed or in progress		12-hour periods of machine time scheduled to run this year	Actual 12-hour periods run prime time	Parasitic periods run	Scheduled periods lost: Due to Bevatron trouble	Scheduled periods lost: Due to experiment trouble	Scheduled periods lost: Due to other causes
Longo-Perl (3)[a,b]		76	62	17	3	8	3
Masek (5) (Univ. Wash.)		24 1:1 3 1:2 113 1:3	28 1:1 3 1:2 83 1:3	110	0 1:1 0 1:2 5 1:3	0 1:1 0 1:2 24 1:3	0 1:1 0 1:2 1 1:3
Segrè-Chamberlain (13)[a]		56	53	80	0	2	1
Alvarez (π) (16)[a]		55	70	0	0	1	0
Alvarez (K) (17)[a]		336	254	4	13	69	0
Powell-Birge (18)		130	114	0	11	3	2
Lofgren (20)		37	34	0	2	1	0
Trilling-Goldhaber (29)		120	102	0	5	8	5
Powell-Birge-Frye		--	--	69	--	--	--
Elioff-Stiening		12	12	4	0	0	0
Lofgren (20A)		--	--	4	--	--	--
Crowe (22)		$\frac{1}{2}$	$\frac{1}{2}$	12	--	--	--
Bevatron development		38	33	0	2	1	2
Schnepps, Kang, Kwak (Tufts University)	Emulsion exposures	2	2	0	0	0	0
Bhowmik (Delhi, India)	Emulsion exposures	4	4	0	2	0	0
Lord, Piserschio (Univ. Wash.)	Emulsion exposures	3	3	0	0	0	0
Barkas	Emulsion exposures	6	6	0	0	0	0
Jain (Univ. NY, Buffalo)	Emulsion exposures	$\frac{1}{2}$	$\frac{1}{2}$	0	0	0	0
Danysz (Univ. Warsaw, Poland)	Emulsion exposures	2	2	0	0	0	0
Raymund (Univ. Chicago)	Emulsion exposures	2	2	0	0	0	0
Lee (Columbia University) p^- production cross sections		--	9	0	0	0	0
Chinowsky Test of p^- in the 25" bubble chamber		$\frac{1}{2}$	$\frac{1}{2}$	0	0	0	0
Piccioni (UCSD, La Jolla) Test for future experiment		$\frac{1}{2}$	$\frac{1}{2}$	0	0	0	0
Mack, Jackson Evaluation of counting equipment		--	--	2	0	0	0

[a]Runs still in progress. [b]Numbers in parentheses are experiment numbers.

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

Month (1964)	4 to 6 pulses per minute						7 to 9 pulses per minute						10 to 17 pulses per minute						Totals					Comments
	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				
	Pulses	Faults[a] 14	26	Pulses	Faults[a] 14	26	Pulses	Faults[a] 14	26	Pulses	Faults[a] 14	26	Pulses	Faults[a] 14	26	Pulses	Faults[a] 14	26	Pulses (P)	Arc-backs	Arc-throughs	Total (F)	P/F	
Jan.										192221	18	27	125392		4	10612	2		328225	20	31	51	6435	
Feb.										179440	24	11	31879		6	133180	10	17	344499	34	34	68	5066	
March	186									352			4961			336999	19	37	342498	19	37	56	6116	
April	779						1210			3021			6776	2	2	396484	18	32	408270	18	34	52	7851	
May													7671			424194	12	8	431865	12	8	20	21593	
June				359			1327		1	35693	2	6	12340			317993	30	32	367712	32	39	71	5179	
July	3096	1	5	422			8481			1750			76289	2	5	310154	28	33	400192	31	43	74	5408	
Aug.	185			384			1076			267643	14	21	16238			98172	5	8	383698	19	29	48	7993	
Sept.							387			76478		5	59959			18552			155376		5	5	31075	
Oct.	1146						385			262156			2865			32324	16	7	298876	33	19	52	5947	
Nov.							43167	11	2	202715	14	26	53635	4					299517	29	28	57	5255	
Dec.													117005	7	7	130833	5	8	301838	12	15	27	11179	

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

VI. RADIATION DETECTION AND CONTROL STUDIES

William L. Everette

A. Experimental Facilities

Except for minor deletions in shielding detail, the general arrangement of secondary and external primary-beam transport systems in operation at the end of the fourth quarter are shown in Fig. 4. Radiation shielding about the external beam channel is shown in greater detail in Figs. 5 and 6. The front section of the Segrè-Chamberlain group's beam-transport equipment was installed during the September shutdown. Construction of the transport system and equipment housing was completed and beam tune-up commenced in October.

B. External Beam

Radiation detection-and-control studies for this period primarily concerned the external-beam operations. A description of the external beam-transport and shielding arrangements, including phase II extension, was given in the third quarterly report, 1964.[1]

Beam tuneup and transport were studied with beam intensities below 5×10^{10} ppp (protons per pulse). At this time, the shield roof and walls (except near the beam backstop) were made of ordinary concrete four and five feet thick, respectively. Two foil-type neutron detectors, $Ag(n,\gamma)$ and G-M, were interlocked with the beam-extraction system in such a way that they would turn off the beam if the trip-level reading were exceeded.

As the beam intensity was increased to 10^{11} ppp, the more interesting results of fast-neutron-detection surveys were: 300 to 500 n/cm^2-sec occurred on the roof over plastic scintillator targets and thin windows; as high as 1000 n/cm^2-sec occurred on the roof above points where the beam scraped vacuum pipes, flanges, and magnets; and 300 n/cm^2-sec occurred at beam elevation about four feet from and outside of the shielding wall in the vicinity of a target (4 inches of copper). These results gave substance to a previous conviction (based on calculation) that the external beam transport was not adequately shielded. For beam intensities above 10^{11} ppp, more concrete was needed to keep the neutron intensity down near the 20 n/cm^2-sec level specified for the 0.1-rem dose per 40 hours to occupational personnel.

In November the west shielding wall, downstream from target station at the second beam focal plane, was modified to accommodate the Lofgren group's p-p scattering experiment. The new arrangement is shown in Fig. 5. The roof shielding was increased to 6 feet of concrete above the F_2 target. The fast-neutron-detection survey was repeated, with results shown in that figure. Following this survey, additional blocks

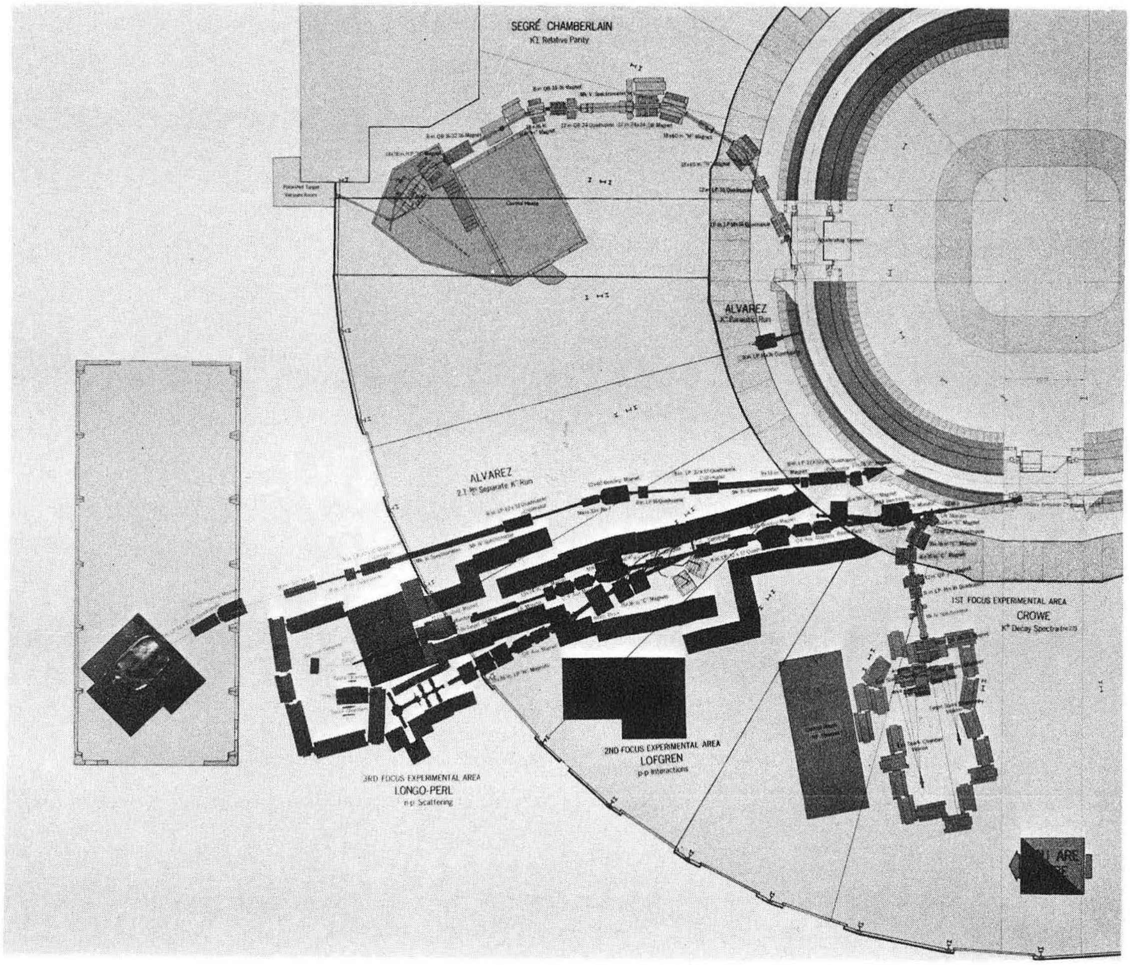

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Fig. 4. Spatial arrangement of experimental equipment and beam-transport systems.

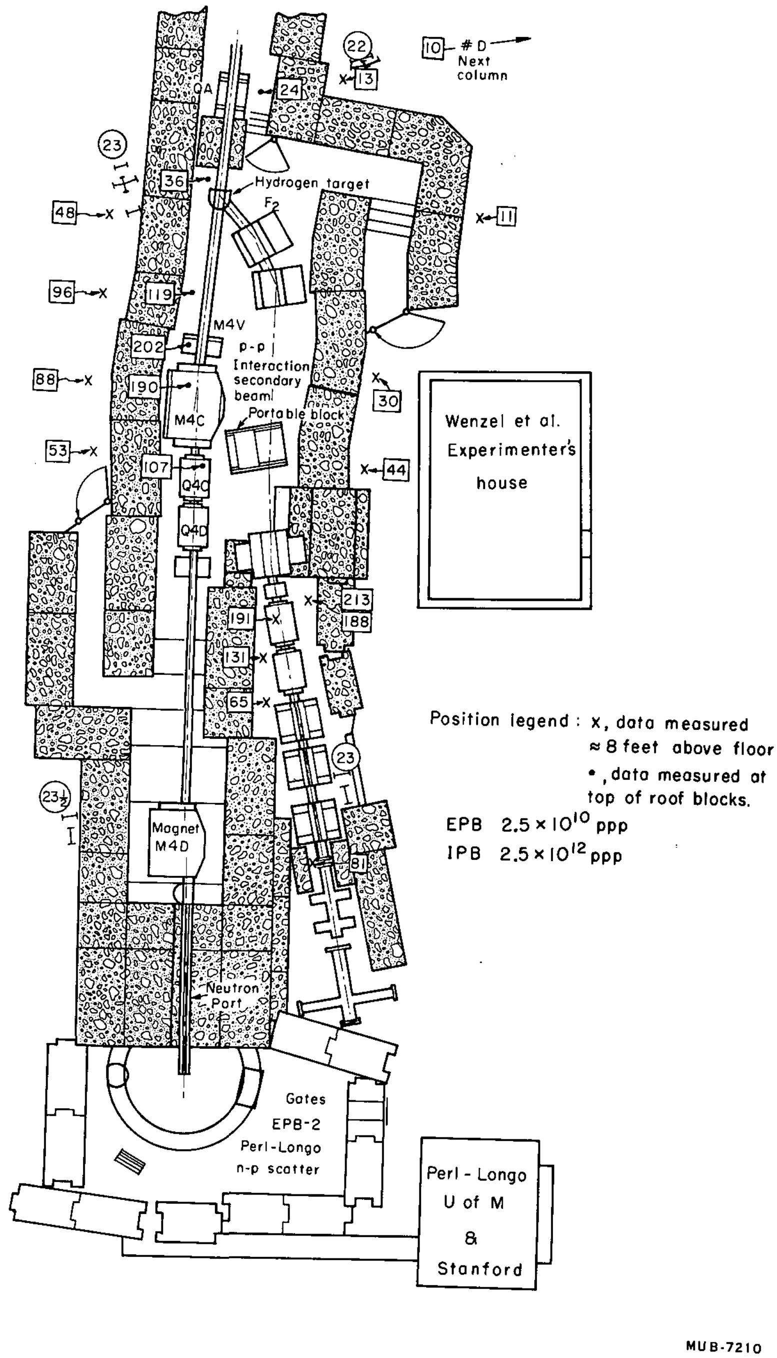

Fig. 5. Phase II external proton beam transport shielding modified to accommodate the Lofgren group p-p scatter work. (Fast neutron flux values are enclosed in squares; the values marked with an x were determined at roughly 8 ft. above floor level, and those marked with o were determined at roof level.) Column numbers are enclosed in circles.

$EPB \approx (2 \text{ to } 5) \times 10^{10}$ ppp

$IPB \approx 2.5 \times 10^{12}$ ppp

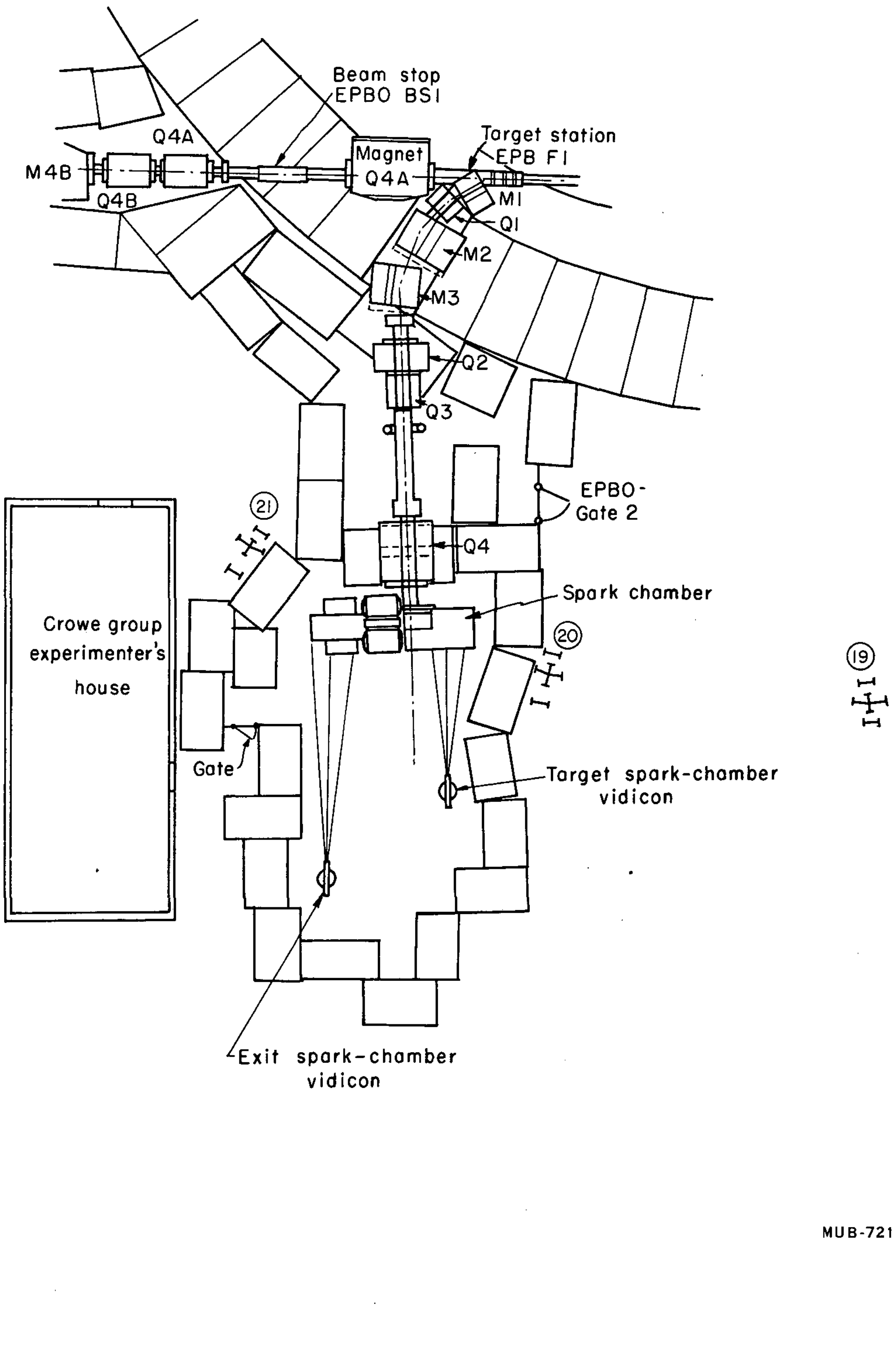

Fig. 6. EPB F_1 target station and beam transport for Crowe group's experiment.

(dashed lines) were placed in the more vulnerable spots. Thus, with the shielding we have at the time, we expect that no man working near the EPB shield channel will receive a combined neutron-and-gamma exposure that exceeds the allowed value of 0.4 rem per 160 hours for beam intensities up to 3×10^{11} ppp. Figure 6 shows the experimental arrangements at the F_1 target station. The secondary beam shielding is arranged in two compartments; a thick shielding wall around the upstream compartment compensates for the weakening of the Bevatron shielding wall resulting from the transport magnet installation near the target. The entrance gate to this cave is interlocked with the EPB 0 (or upstream transport segment) radiation safety chain. The second compartment is a low-level cave designed to shield spark chambers and scintillators from stray particles. The entrance gate to this cave is interlocked with the F_1 target in such a way that the target is moved away from the beam turning off the secondary beam when the gate is opened. Manual reset is required to place the target in the beam again. Neutron intensities in this area outside the upstream cave and Bevatron shield wall are typically 20 to 30 n/cm^2-sec.

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Kenow Lou Cedric Larson Abraham Glicksman	In charge of Mechanical Engineering Group

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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, February 1965.

2. Fred H. G. Lothrop, Electronic Beam Spiller at the Bevatron, UCRL-16219 (in preparation).