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LAWRENCE RADIATION LABORATORY
UNIVERSITY of CALIFORNIA BERKELEY

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ABSTRACT

The beam was on for 78.3% of the scheduled operating time and the Bevatron accelerated 1.9×10^{18} protons. Three primary experiments completed data taking this quarter.

The final target areas in the new dual-channel external proton beam facility were brought into operation. Operation of the new facility and the beam-switching modes are discussed.

During a shutdown in May, measurements were made of the magnetic field of the Bevatron. Data were collected by use of a PDP-8 computer and associated hardware.

The speed change of the main motor generators during pulsing was again reduced to minimize damage to the generator poles from cyclic loading. This reduced the flattop length from the original 1000 msec to 500 msec. A new mode of flattop pulsing is under study to reduce the large generator speed change during flattop and to allow us to run long flattops without cyclic damage to the generator poles.

Table I. Summary of Bevatron experimental research program, April through June 1968.

					Beam time					
		Dates			This quarter (April–June)		Start of run through June 1968			
Groups	Run	Start	End	Experiment	12-hour periods	Hours	12-hour periods	Hours	Pulse schedule	Primary or secondary experiment
Internal Groups										
Lofgren (Wenzel)	67	6/7/67	6/10/68	Ke_2 branching ratio 0.5-GeV/c separated K^+ beam	43	366	155	1646	1:1	P
Powell–Birge (Kalmus)	72	2/21/68	In progress	π^+p interactions	24	273	70	785	1:1	P
Powell–Birge (Ely–Kalmus)	73	6/8/68	In progress	K^-p and K^-d reactions	20	214	20	214	1:1	P
Group A (Rosenfeld) SLAC (Leith)	74	5/3/68	In progress	π^-p inelastic channels	8	101	8	101	1:1	P
Trilling–Goldhaber (Kadyk)	76	4/1/68	In progress	Λp scattering	1/2	5	1/2	5	1:1	P
Group A (Abolins–Smith) U.C.–Davis (Pellett)	83	6/14/68	In progress	$pp \rightarrow d + x$	4	48	4	48	1:1	P
Moyer–Helmholz (Kenney) Group A (Pripstein)	86	8/14/67	In progress	Branching ratios for the neutral and charged decay modes of the η	30	353	42	481	1:1	P
Miller (Miller)	95 (P-32)	5/31/68	In progress	$K^0\mu 3$ charge-asymmetry tests for future Exp. 95	1/2	23	1/2	23	1:1	S
Nuclear Chemistry (Hyde, Poskanzer)	104	9/21/66	In progress	Production of light fragments from P-nucleon collisions	23	263	101	1254	1:1	P
External Groups										
U. of Washington (Davis)	54	7/21/66	5/3/68	Ξ^0 decay parameters	49	528	136	1575	1:1	P
U. of Washington (Williams)	70	5/3/68	In progress	Σ^+ magnetic moment	21	203	21	203	1:1	P
U.C.–San Diego (Piccioni)	71A	3/15/68	In progress	K regeneration amplitudes 1–1.5-GeV/c separated $K^{\pm}$ beam	18	203	25	277	1:1	P
U.C.–San Diego (Masek)	79	3/27/68	In progress	$K_2^0(e_3)$ charge asymmetry	18	231	20	259	1:1	P
Calif. Inst. of Technology (Tollestrup)	80	8/11/67	5/4/68	Leptonic decay, $K \rightarrow \pi^{\pm}, e^{+}, \nu$ Determination of $\Delta S/\Delta Q$ in 2- to 3-GeV/c π^- beam	36	390	197	2285	1:1	P

II. SHUTDOWN

There was a scheduled shutdown of the Bevatron from May 5 through May 20. During most of this time the Bevatron vacuum system was at air pressure. Measurements of the Bevatron magnetic field and inspection of the motor generator sets were the major jobs of the shutdown. The first group of measurements was a sector-to-sector field check in Quadrant III and part of Quadrant II. The purpose was to look for a change in the Bevatron gap magnetic field that could account for a measured perturbation of the closed orbit. (The closed-orbit measurements were associated with the studies of resonant extraction.) The second group of magnetic field measurements was a detailed field plot of the Bevatron field at the exit of Quadrant III. The measurements were taken in the Bevatron aperture and extended out through the fringe field along the path of secondary-particle beams from Quadrant III targets. These measurements were taken to make possible more accurate calculations of the trajectories of secondary-particle beam from internal targets in the Bevatron. They were made by the Laboratory Magnet Measurements Group in collaboration with the Bevatron Computer Group, who set up the PDP-8 computer and its associated hardware for the project. This was the first major trial of the computer and remote hardware coupled together. A remote terminal consisting of data-acquisition gear and a teletypewriter located at the north straight section area operated continuously for two weeks, during which time all the Bevatron magnetic measurements were made. At no time during this interval was it necessary to get to the computer itself.

Another job that was done during the vacuum shutdown was the determination of the current-carrying capabilities of the pole-face windings. These windings, which run azimuthally around the Bevatron, are spaced at 3-in. intervals across the upper and lower pole faces of the Bevatron magnet. They are used to correct the field gradient near injection. The resonant-extraction studies indicate the need to pulse some of the windings to about 100 A during the extraction period. The windings as installed are rated at 20 A dc limit. The actual cooling efficiency was unknown. Current was run through the windings and hot spots were located and measured. The measurements indicated that, considering the duty cycle for the flattop length and the pulse rate at which we had been operating, we can pulse the windings to 100 A.

The main motor generator sets were given the normal 3-month check of bearings and journals.

The remainder of the shutdown work was devoted to routine inspection and maintenance of the Bevatron and associated equipment and installation of new EPB equipment and experiments.

There was an unscheduled shutdown at 4:39 a.m. on June 4 as the result of a total power outage. Three P. G. and E. high-voltage towers feeding the Oakland area had been dynamited. Partial power was restored at 5:47 a.m., complete power at 6:16 a.m. The Bevatron was able to accelerate beam by 11:00 a.m., and was ready to run beam for experimenters by 12:30 p.m. The experimenters, however, took longer to recover; they were ready for beam about 7:00 p.m.

III. BEVATRON DEVELOPMENT AND STUDIES

The major effort on Bevatron development this quarter was devoted to the new flattop magnet pulsing modes, as described in the preceding quarterly report. There are no new details to report at present.

Resonant-extraction tests continued this quarter. The remainder of the Bevatron development time was spent testing new components of the dual-channel EPB system, and checking on EPB extraction efficiency and compatibility of various experiments.

IV. BEVATRON MOTOR GENERATOR

Cracks in Pole Laminations

During the shutdown the generators were carefully examined, and additional cracks were found in the pole laminations. The crack that was detected[1] in the first lamination in the dovetail section of pole #6 on the west generator was actually the first of ten. Holes were drilled to provide stress relief. It was necessary to drill several inspection holes as well as crack-stopper holes to insure that each of the cracks (which had progressed through ten laminations) had been terminated. Figure 2 shows the resultant honeycomb of pole #6.

Further Speed Reduction

Following the shutdown it was decided to reduce the cyclic speed range of the Bevatron generators to less than 75 rpm for any pulsing mode. This was a reduction from the 100 rpm limit that had been in effect since the new poles were installed last year. The most significant effect of this on the physics program was a reduction of the flattop period in the 6000- and 7000-A ranges. At 6400 A, an 825-msec flattop which was allowable with the 100-rpm range was now reduced to 500 msec. A new mode of flattop pulsing is under study. It is expected to substantually reduce cyclic loads on the generator and to restore flattop lengths to 1 second or more (see below).

Testing New Pulsing Modes

Tests are now in progress with different connections of the rectifier cubicles in order to develop a new method of flattopping the magnet pulse. Synchronization of motor generators has become necessary because of this reconnection. It has not yet been determined whether synchronization can be provided with existing equipment or whether it will be necessary to install a synchronizing transformer of 3 MVA capacity. If synchronization can be accomplished with existing circuitry, a new pulsing technique that will significantly reduce the generator speed range during flattop pulsing will be in operation soon.

The magnet pulsing record is shown in Table II.

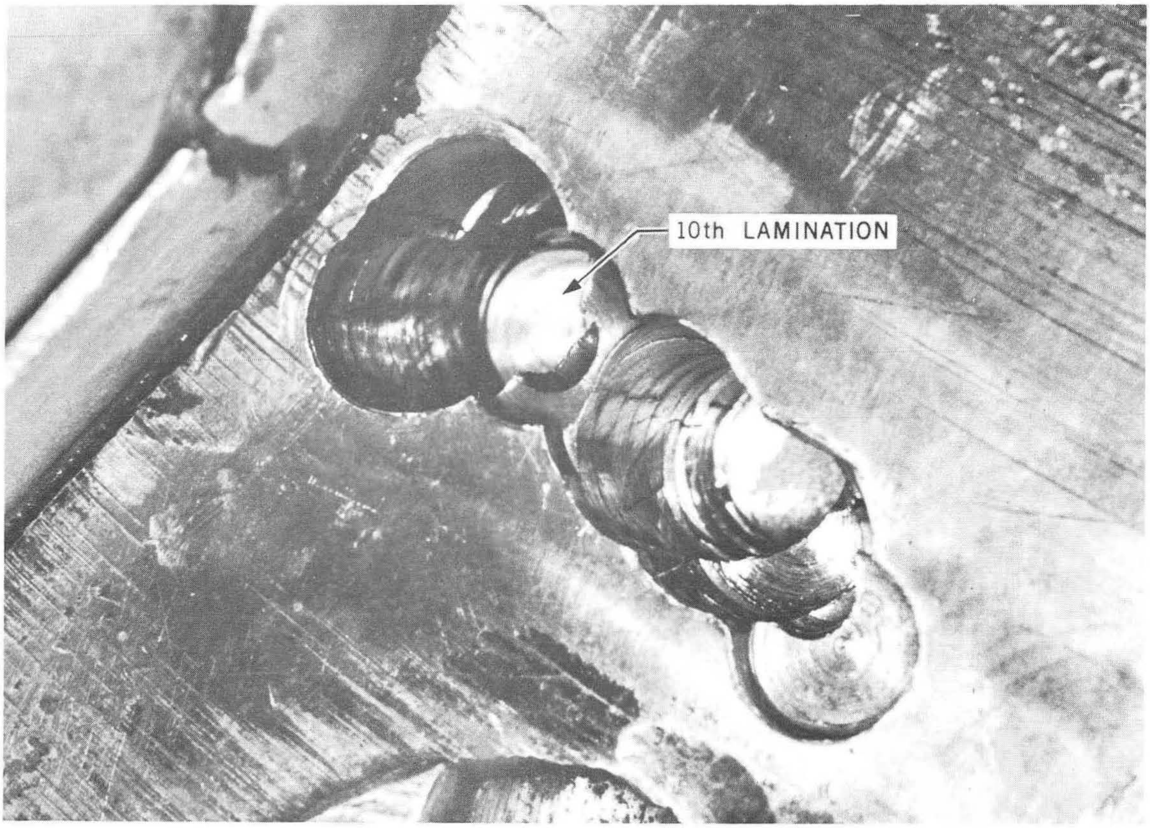

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Fig. 2. Crack-stopping drill holes in laminations of pole number 6.

Table II. Bevatron motor generator set monthly fault report.

1968	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	Arc-backs (AB)	Arc-through (AT)	P/F	Ignitrons replaced
	Pulses	Faults		P/F	Pulses	Faults		P/F	Pulses	Faults		P/F	Pulses	Faults		P/F	Pulses	Faults		P/F	Pulses	Faults		P/F					
		AB	AT			AB	AT			AB	AT			AB	AT			AB	AT			AB	AT						
Jan.	–	–	–	–	200	–	–	–	4 956	–	–	–	9 182	1	1	4 591	414 210	9	27	11 506	4 289	1	2	1 430	432 837	11	30	10 557	0
Feb.	–	–	–	–	1 625	–	–	–	–	–	–	–	25 816	2	8	2 582	195 627	6	9	13 042	55 162	2	10	4 596	278 230	10	27	7 520	1
March	1 834	0	–	–	–	–	–	–	687	–	–	–	15 065	1	7	1 883	293 760	46	7	5 543	88 108	14	13	3 263	399 454	61	27	4 539	2
April	1 689	–	–	∞	180	–	–	∞	203	–	–	∞	960	1	1	480	198 047	9	11	9 902	183 230	10	36	3 983	384 309	20	48	5 652	2
May	1 594	–	–	∞	308	–	–	∞	–	–	–	–	976	–	–	–	95 108	3	6	10 568	106 720	13	27	2 668	204 706	16	33	4 178	1
June	873	1	1	436	175	–	–	∞	410	–	–	∞	–	–	–	–	303 899	16	29	6 753	114 209	10	27	3 087	419 566	27	57	4 995	1
July																													
Aug.																													
Sept.																													
Oct.																													
Nov.																													
Dec.																													

V. DUAL-CHANNEL EXTERNAL PROTON BEAM FACILITY

Construction was started on the new dual-channel EPB system in July 1966, and its progress has been reported in previous Bevatron Quarterly reports.[2] During this quarter the final target area X2F3 went into operation. The operating features and flexibility of the new facility are as follows.

A plan view of the Bevatron experimental areas is shown in Fig. 3. The secondary beam channels and experiments are shown as they were set up in June 1968. The extraction system is basically the same as described previously.[4,5] However, some modifications have been made in order to carry out resonant extraction studies. The quadrupole just downstream from the first septum extraction magnet has been removed in order to accommodate a new septum magnet, M1, which includes a perturbation magnet for resonant-extraction studies. This change was made in the spring of 1967. The present system still has the energy-loss target in the south straight section. The energy-loss target is a beryllium target 0.5 in. high, 1 in. radially and 0.75 in. azimuthally. The first septum magnet M1 is located three quarters of a turn (1/2 betatron wave length) after the energy-loss target. The beam is deflected radially inward by this magnet. A quarter turn later the beam enters a quadrupole, Q_2, and deflecting magnet, M2. M2 deflects the beam radially outward. The beam leaves the Bevatron vacuum system another quarter turn later in the west straight section. It goes through a deflecting magnet, XM3, a quadrupole doublet, XQ3AB, and a vertical deflecting magnet, XM3V, and enters a beam pipe cut through the leg slabs of the main ring magnet. The beam finally clears the Bevatron just upstream from the first (external) focus F1. The first focus area and magnets XM3 and XQ3AB are shown on Fig. 3.

At the F1 area the beam can be switched into EPB channel I or EPB channel II. If all the beam is to go down channel I, magnet XM4 is used to deflect the beam down that channel; magnet XM5 is turned off. If all the beam is to go down channel II, magnet XM4 is turned off and magnet X2M5 is turned on. These are pulsed magnets tracking the magnetic field of the Bevatron. If the beam is to be time-shared in channel I and channel II, then both magnets XM4 and X2M5 are turned on. The beam is then switched between channel I and channel II by a fast-rise-time pulsed magnet, XMK, just upstream from F1. When magnet XMK is on, the beam is displaced 2 in. toward the Bevatron at F1. The beam then goes through magnets XM4 and X2M5 and down channel II. With XMK off, the beam goes through XM4 and down channel I. The beam trajectories for the two cases are shown in Fig. 4.

The XMK magnet is capable of being switched on three times during a Bevatron pulse or held on for a full second. The rise and fall time of the XMK pulse is 10 msec. It has a minimum pulse length of 30 msec.

Many other combinations of sharing between channels are possible, depending on the needs of the experimenters at the time. Following are two typical operating modes. Mode 1: XMK is on for 30 msec, a short rapid beam ejector pulse (RBE) is put down channel II for the bubble chamber, and XMK goes off. A long spill (800 msec) is put down channel I. XMK is turned back on for 30 msec, and a second RBE pulse is put down channel II. Mode 2: XMK is on

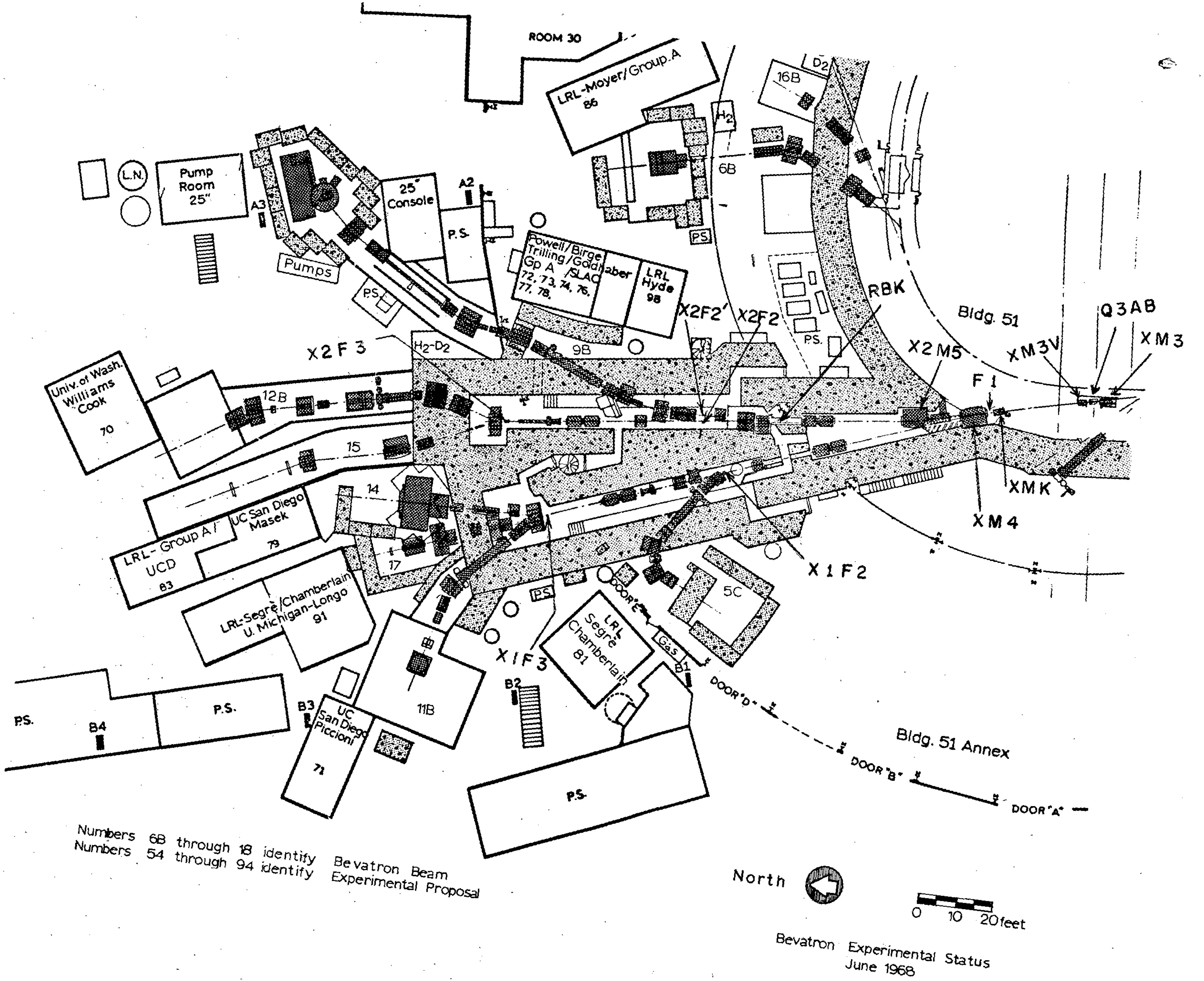

Fig. 3. Plan view of dual-channel external proton beam facility.

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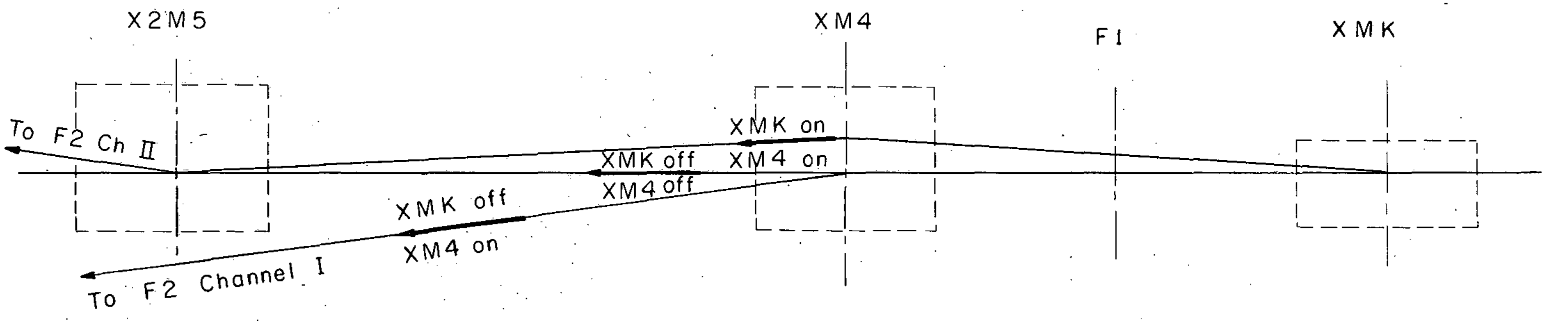

Fig. 4. Beam switching between EPB channel I and channel II.

for about 500 msec, an RBE pulse is put down channel II, followed by a 400-msec-long spill, and XMK goes off. A 400-msec spill is put down channel I. XMK is turned back on and a second RBE pulse is put down channel II. A diagram of these two modes is shown in Fig. 5.

The beam going down channel I can be simultaneously shared by targets at EPBI F2 and EPBI F3. Two or three experiments can be set up in secondary beams from the target EPBI F3. Whether or not all these experiments can take data simultaneously depends on the momentum and charge of the secondary particle desired and beam intensity compatibility. If not all experiments can take data simultaneously some can usually do tuning and equipment checks while the others take data.

A number of experiments have been scheduled for the next year using the 25-inch hydrogen bubble chamber in the present secondary beam from EPBI F2. It was desirable that the target for the 25-inch bubble chamber secondary beam not be in the proton beam during the long spill to the third focus. As we have been more successful with fast switch magnets for putting beam on targets than in trying to develop fast plunge or flip targets (10 msec), a rapid beam deflection magnet (called RBK) was installed upstream from the XII F2 area to deflect the primary proton beam onto the bubble chamber target. This target location, designated XII F2', is shown in Fig. 6.

The current pulse through RBK is a sine wave with a flattened top. This pulse takes 6 msec (the bubble chamber beam pulse is 250 msec wide). The energy is recycled through the magnet to the capacitor bank, to save on power supply costs. The pulse and recycle occurs in about 12 msec.

The long spill goes through the RBK magnet without deflection. The beam is focused again at the EPBII F3 area, where the secondary beam channels are operated in the same manner of compatibility with each other as described above for EPBI F3.

In the present setup, we have eight experiments in the two EPB channels. We can usually operate compatibly with six of the presently set up experiments.

The beam spot size at F2 and F3 in both channels is about 0.06 in. vertically by 0.15 in. horizontally.

To insure independence of operation and setup activities in each channel, the beam may be stopped by beam plugs just downstream from magnet XM4 for either or both channels. People can work in channel I while beam is operating in channel II if the beam plug is in for channel I, and vice versa.

Beam diagnostic equipment at present consists of scintillators and television monitoring of the beam size and position at the septum magnets XM1 and XM2, at the exit of the Bevatron (west straight section, entrance to XM3), and at each of the focal points and target areas. Secondary-emission monitors at each focal point are used to measure the beam intensity. The radiation shielding for the EPB facility is such as to permit operation with 1×10^{12} protons per pulse down each channel.

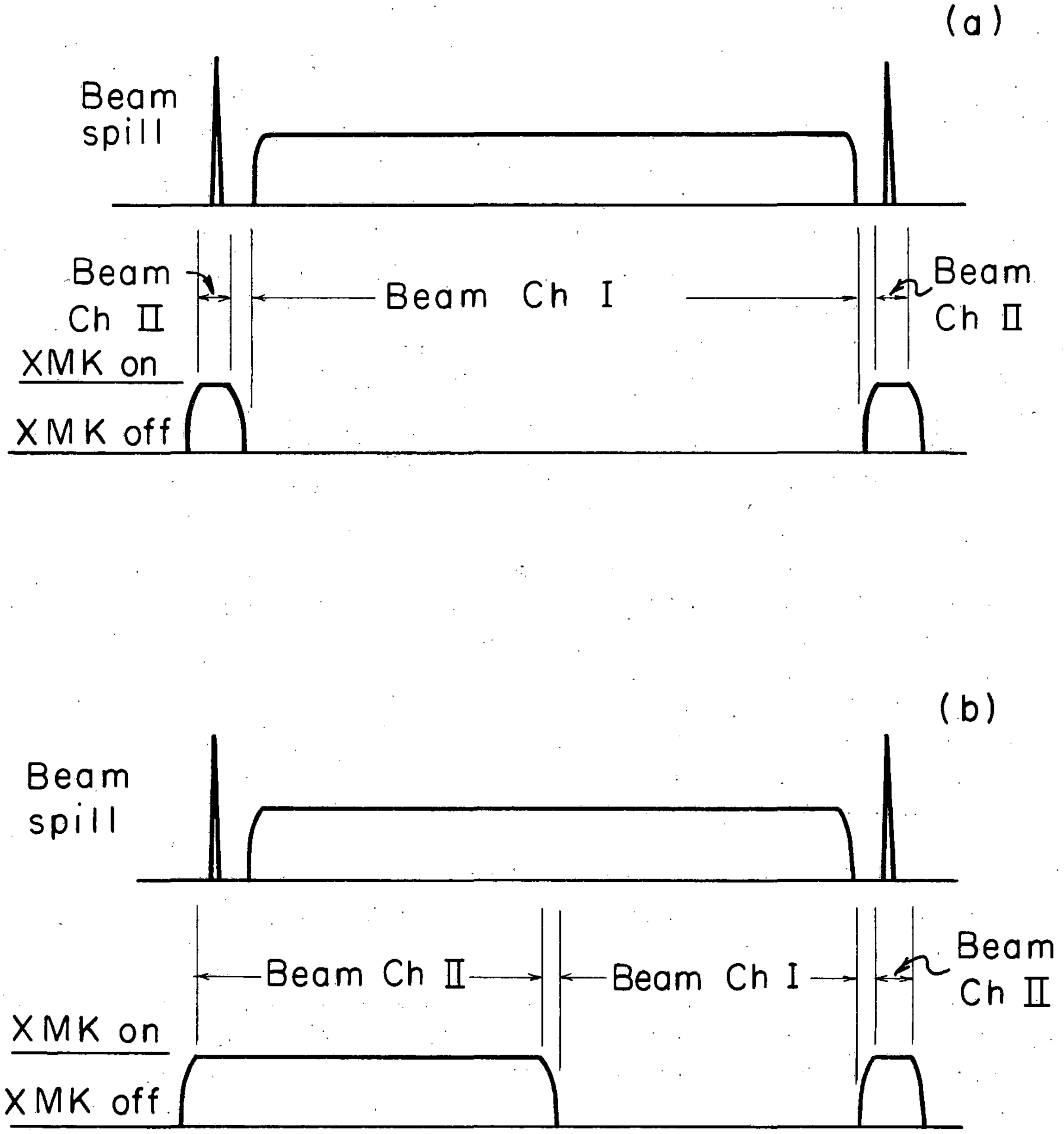

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Fig. 5. Typical modes of beam switching between EPB channel I and channel II by use of XMK rapid switch magnet.

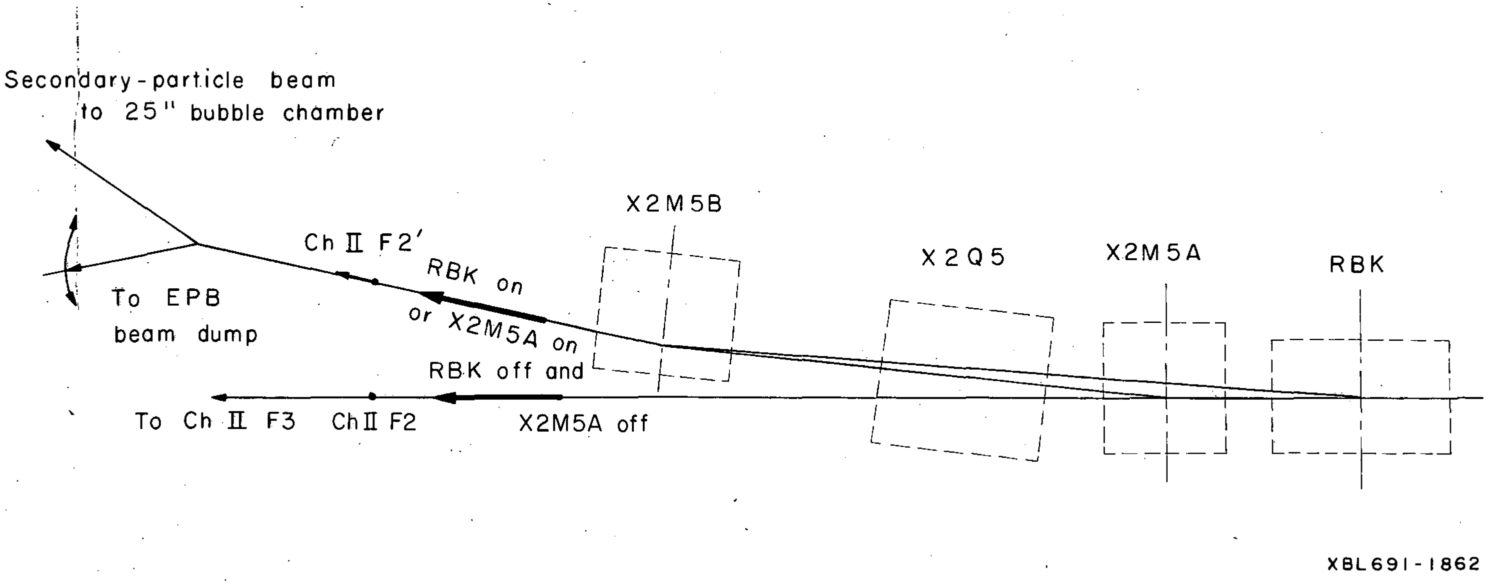

Fig. 6. Beam switching in the channel II second focus area for the 25-inch hydrogen bubble chamber.

The new EPB facility provides considerable improvement over the extreme congestion that existed before[2] in the experimental area. The dual channel and additional target areas provide a great deal more flexibility in setting up a new experiment and bringing it to an operating mode without having to shut down the Bevatron and all the other experiments. The multichannel system increases the demands on the operation group to provide satisfactory beam for more people in a compatible mode of operation. Work on spill techniques, beam monitoring, and magnet controls becomes even more important for good operational efficiency. It is to these areas that the current Bevatron improvement effort is being directed.

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