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ABSTRACT

A considerable number of major improvements have been made in experimental facilities this quarter. These include four targets, three air locks, a deep well, and several thin windows for beam extraction in the target area. Simultaneous operation of up to five experiments has been achieved with a relay-controlled automatic operations selector. A beam-amplitude regulating device has been used to set the beam level on any pulse to within a few percent. The range of this equipment is 1000:1.

Experimentation on the accelerator this quarter included measurements of start frequency and frequency-tracking jitter, beam-versus-radial-aperture measurements, empirical study of gas scattering effects, and preliminary testing of an automatic beam-controlled frequency-tracking system.

High-energy physics experiments have been performed by ten groups within this laboratory. These groups are using counter techniques for the elastic proton-proton scattering, K-particle half-life determination, and π^--meson cross-section measurements. A high-pressure hydrogen diffusion chamber is being used to study multiple production of π^- mesons. A strong-focusing pair spectrometer has been used to produce beams of K particles. Emulsion exposures have been made to determine the masses and mean lifetimes of K mesons. The interactions and modes of decay of $K^\pm$ mesons at rest, as well as in flight, have been studied in emulsions.

Ten groups from other institutions have also made use of the Bevatron facilities.

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INJECTOR

The peak output of the injection system this quarter was achieved early in March immediately following a short shutdown period. Approximately 300 μamp of analyzed protons (∼9.8 Mev) were obtained at the exit of the inflector. This performance is compared with previously quoted figures.[1]

Table I

Comparative Performance Data, Bevatron Injection System

	Ion Gun Output	Linear Accelerator		Inflector	
	Total Ion Current (μamp)	Entrance Protons (μamp)	Exit Protons (μamp)	Entrance Protons (μamp)	Exit Protons (μamp)
UCRL-2822 Peak Beam	6,000	3,100	210	190	160
Peak Beam	10,000	6,000	430	400	300
Typical Beam	6,000 to 8,500	2,000 to 4,800	260 to 120	240 to 100	165 to 60

Table I shows that the real increase in injected beam is directly proportional to the increase in total ion current. The present cold-cathode ion source does not operate reliably at high output currents, and, in fact, this peak performance was obtained for only a few hours. Improved reliability of the ion source has been achieved by frequent change of sources when their focal properties begin to deteriorate and by jig alignment of the source electrodes. Sources are now changed on the average of about once a month. The reliable life of a source is a function of the peak ion current, which accounts for the difference between the peak and typical beams.

A series of experiments was carried out with a new source,[2] which presented a virtual instead of a real focus to the ion-gun column. The effort did not lead to a successful design.

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[1] Edward J. Lofgren and Harry G. Heard, Bevatron Operation and Development. III, University of California Radiation Laboratory Report No. UCRL-2822, February 8, 1955

[2] Troy E. Stone, Experiments on Improving the Efficiency of the Bevatron Ion Source (Thesis), University of California Radiation Laboratory Report No. UCRL-3010, May 19, 1955.

EXPERIMENTAL FACILITIES

The experimental facilities in the target area (west straight section tank) are diagramed in Fig. 1. In the curved section of the vacuum tank there are five targets. Four of these are "flip-up" devices (Fig. 2) actuated by a coil rotating in the Bevatron magnetic field. The flip-up target mechanisms have gone through several revisions; the latest are capable of raising a target of 150 grams into the beam in less than 300 milliseconds. Vibration is entirely damped out by eddy-current braking. The length of the target in the beam direction is limited to 1-1/8 inches to avoid encroachment on the useful aperture. A thin window is provided in the corner of the curved tank for use with these targets. The shielding wall has provision for making collimation apertures by moving small blocks in a slot 2 feet high, extending the length of the target area.

Beams of π^- of 2 to 4.5 Bev/c momentum are produced by using the targets at 13^o or 14^o and placing a steel collimator and an analyzing magnet outside the window. At the outer end of the shielding-wall aperture and at the highest energy the beam is about 10 π^- per 10^{10} protons on the target. These beams have been used for π^- interaction studies with cloud chambers, for π^--p cross-section measurements with counters, and for exposures of nuclear emulsions. Neutron beamsat small angles from the forward direction are also obtainable from these targets and at zero forward angle from the 20^o target.

There are three air locks on the inside of the straight section, and one on the top. The latter, which is not shown on the diagram, is a re-entrant lock 24 inches by 30 inches. It is mounted on the upstream end of the tank. Its wall on the downstream side is of 0.091-inch 52S0 aluminum.

A 12- by-18-inch air lock has been installed for use with heavy targets on the center of the inner straight section tank. A rail is provided inside the vacuum tank so that heavy targets can be plunged into the beam. In one case a 30-kg stack of emulsions was exposed to the beam through this lock. It has also been used to plunge heavy beam clippers in studies of beam dynamics.

A 46-inch-deep well was added to the north end of the top of the west straight section. This well extends to within 7 inches of the median plane and is sufficiently large to permit the insertion of small magnets and shielding for counter experiments or emulsion exposures which must be located near the target. The center line of this well is above the west inside north plunging mechanism. This well has a 0.091-inch 52S0 aluminum thin window along the entire west side and a 6-inch-diameter and 1/2-inch-thick lucite window in the bottom.

A solid copper clipper, which is 12 inches in the radial direction, 8 inches high, and 2 inches thick in the beam direction, has been provided in the east straight section. This clipper is driven into the aperture by an air cylinder. It can cover all radial positions from 581 inches to 600 inches in a period of less than 1/2 second. A 1/8-inch by 3/16-inch lucite lip is provided on the leading edge of the clipper to damp betatron oscillations. While this facility is ordinarily used at the east entrance of the southeast quadrant, it has also been used at times in the west end of the south straight section. Preliminary tests indicate that it is useful in preventing multiple

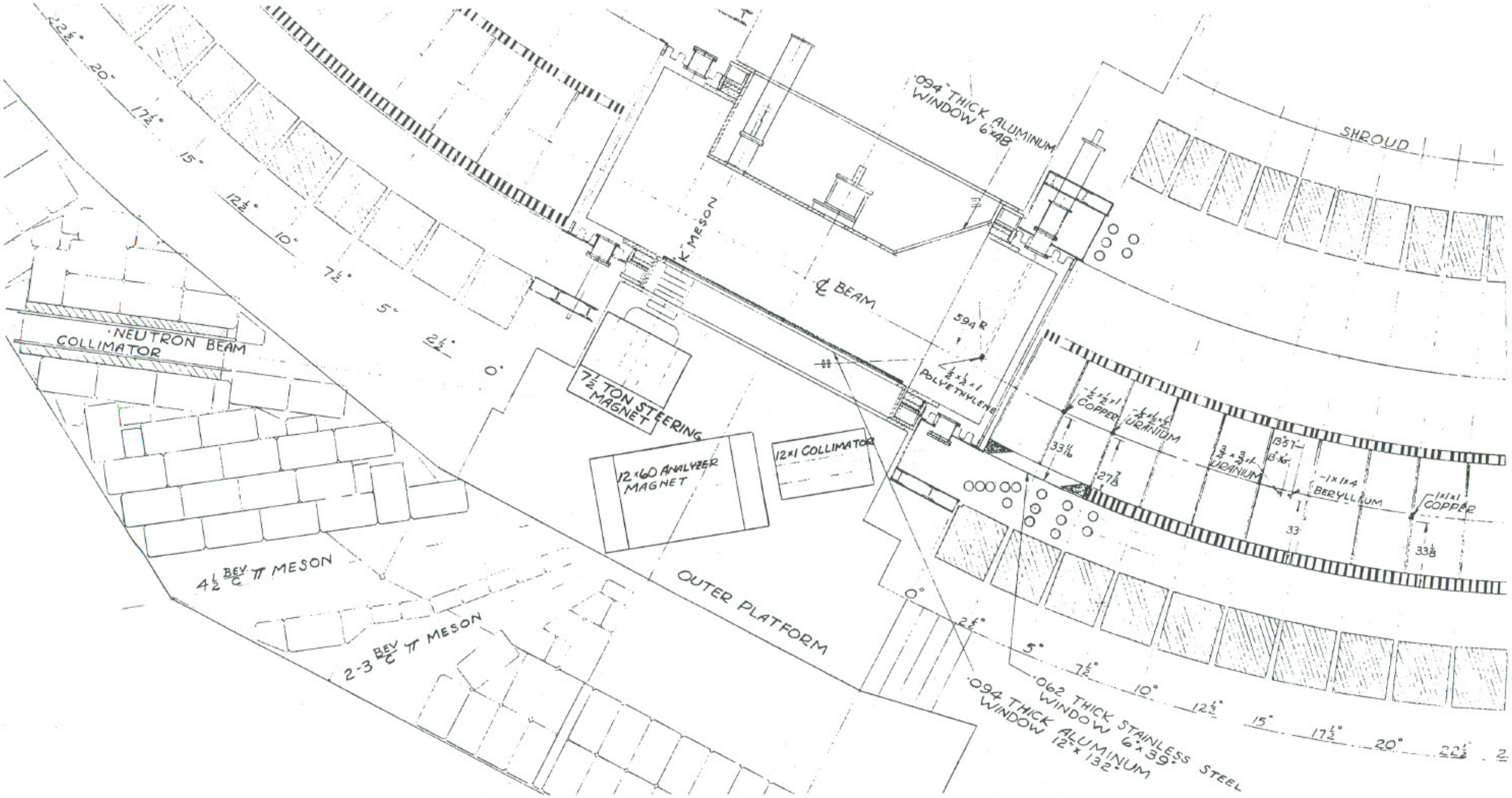

Fig. 1. Cross section of the target area (west straight section) showing the major experimental facilities.

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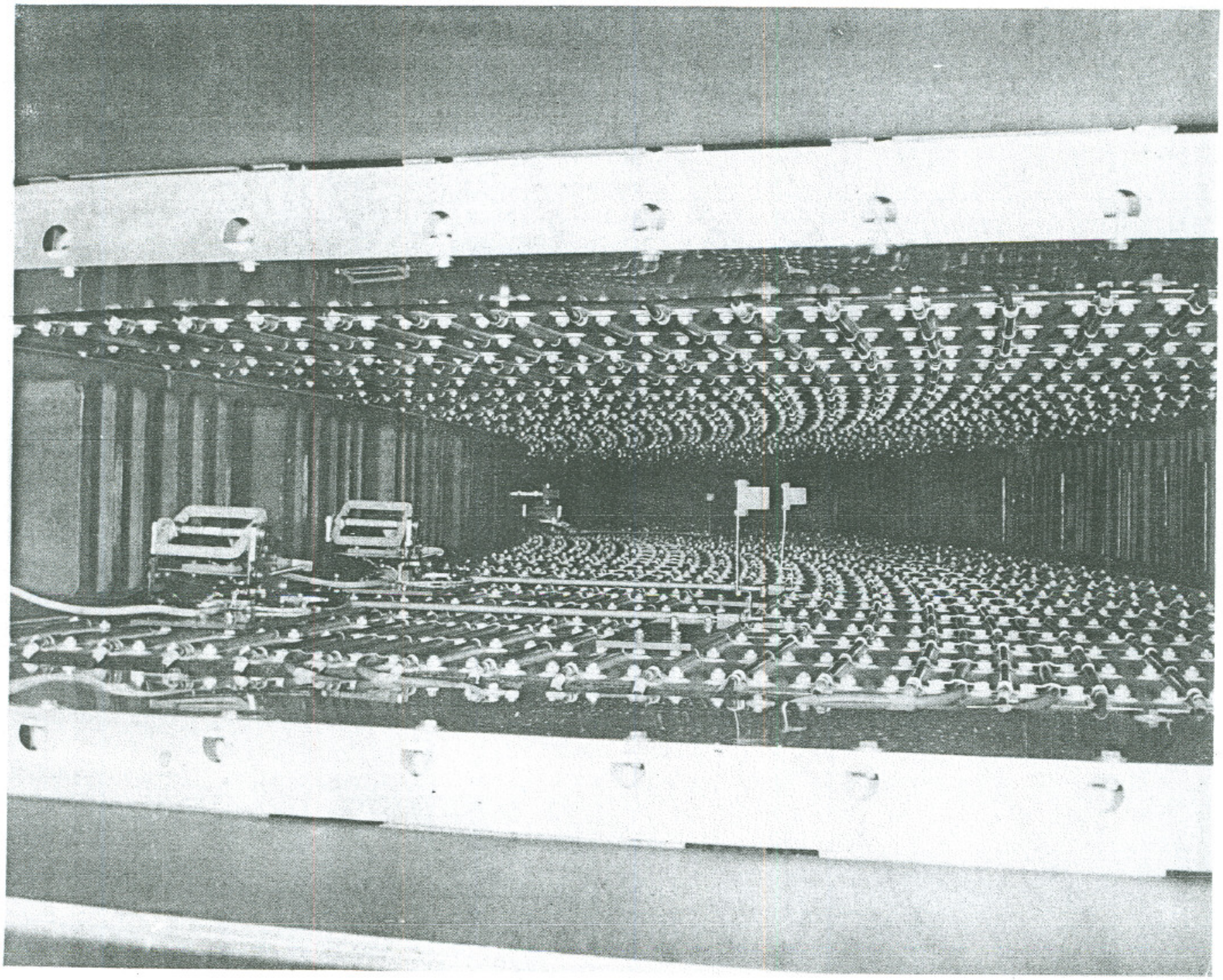

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Fig. 2. View into Bevatron aperture from inside west straight section, showing two flip-up targets.

target traversals in some cases.

The plunging meson target was reactivated after repairs during the shutdown from April 26 to 30. This target, located at 13° 57', supplements the 13° 16' flip-up target and has greater flexibility. A 1-inch by 1 inch by 4 inch beryllium target was mounted so that the 4-inch dimension was along the beam direction. The radial position of this target can be varied externally, and π^--meson beams of 2 to 4.5 Bev/c momentum and neutral-particle beams can be obtained from this target via the thin window.

A new guarded induction electrode was installed in the east straight section. This electrode is of the box type and its capacitance is 354 μμf to its surroundings. As soon as noise and rf pickup problems are solved, this induction electrode will be used as a standard for beam intensity monitoring. A new integrator unit is being designed to be used in conjunction with this electrode to give more accurate measurements of total beam charge.

A strong-focusing spectrometer has been used to obtain a relatively high flux of K mesons from the Bevatron with a good signal-to-noise ratio.[3] The spectrometer consists of a strong-focusing magnetic quadrupole lens followed by a momentum-analyzing magnet. The arrangement is shown in Figs. 1 and 3. The focusing magnets used thus far have a 2-inch aperture and a maximum gradient of 4000 gauss per inch. The analyzing magnet and the focusing magnets may be adjusted for K energies as high as 240 Mev. The flight distance from the target to the exit of the analyzing magnet is 2.7 meters. The only target used very extensively has been copper. The flux obtained for copper target 1 inch in the beam direction and 3/8 inch high is about 1 K per cm^2 per 10^{10} protons at a K energy of 114 Mev and about 0.4 $\text{K/cm}^2/10^{10}$ protons at 170 Mev. The K^- flux in the energy regions 70 to 114 Mev is about 1/100 the K^+ flux. This arrangement has had very extensive use with nuclear emulsions as the detector. The problems associated with counter detection of K particles are being worked on.

An additional 540-kw dc generator has been installed; there are now three of them available for powering magnets.

CONTROLS AND MONITORING

In most counter experiments and in cloud-chamber studies of nuclear events it is desirable to have a constant quantity of charge delivered to the target each beam pulse. Variations in the quantity of injected beam, as well as in the injection parameters, can introduce large fluctuations in the beam intensity at the target. Although careful regulation of supply voltages, accurate timing of the injected beam, and stabilization of the ion-source arc current will minimize these changes, the resulting beam pulses exhibit a normal amplitude distribution of finite width. Without regulation the Bevatron beam amplitude at 6.2 Bev in a specific test fluctuated from 6×10^9 to 10^{10} protons per beam pulse, with a gaussian amplitude distribution centered approximately

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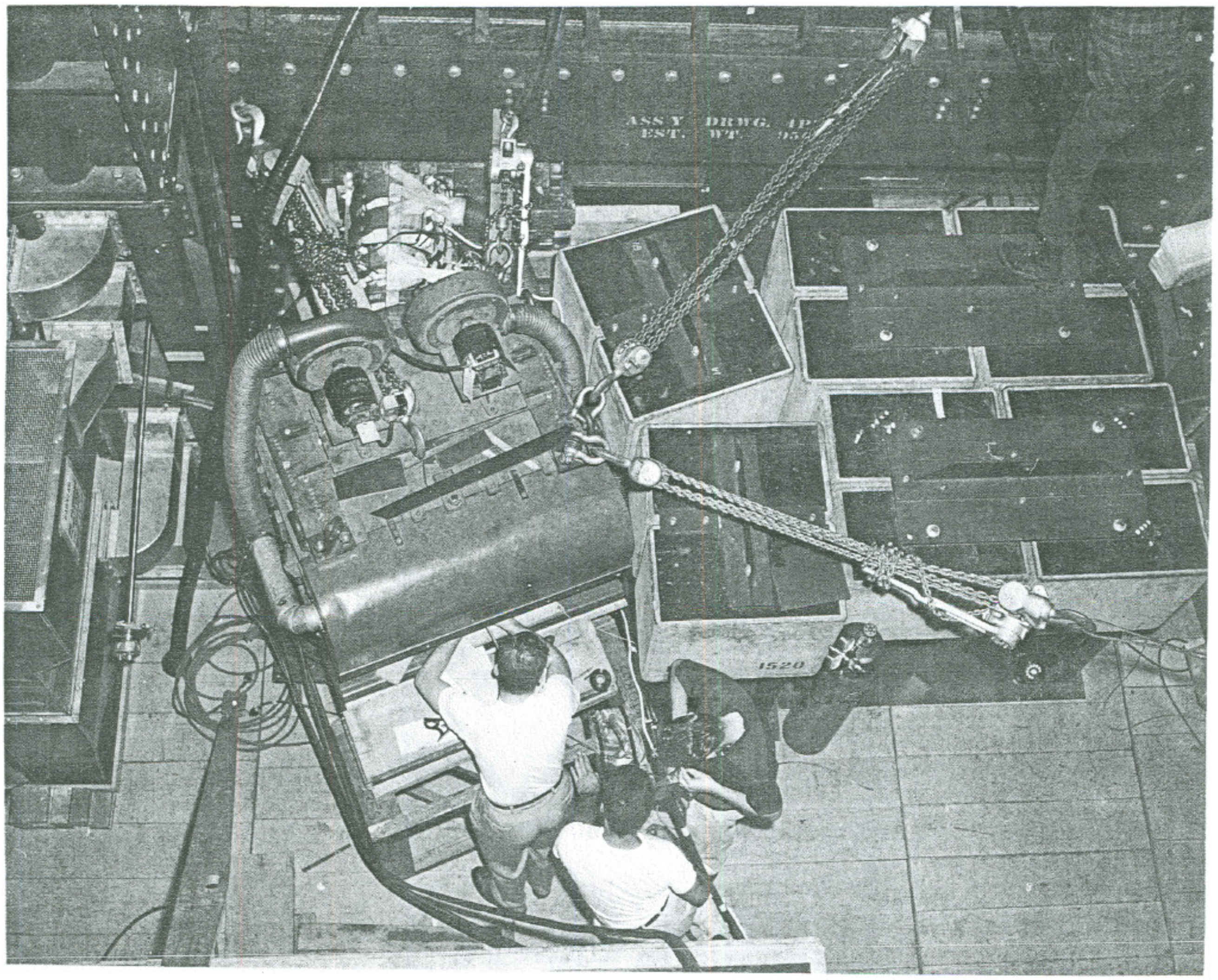
[3] Robert W. Birge, Roy P. Haddock, Leroy T. Kerth, James R. Peterson, Jack Sandweiss, Donald H. Stork, and Marian N. Whitehead, Positive Heavy Mesons Produced at the Bevatron, University of California Radiation Laboratory Report No. UCRL-3031, June 6, 1955.



ZN-1375

Fig. 3. Strong-focusing spectrometer set up on west platform for exposure of emulsions to K beam.

at 8×10^9 protons per pulse. Less than 20% of the beam pulses varied by more than 20% from the central value. However, a much more constant beam has been attained by the technique described below.

Theoretical as well as experimental studies at this laboratory[1] have shown that the nonlinear phase oscillations of particles in a beam bunch are very sensitive to small random fluctuations in the frequency of the accelerating voltage, particularly when the frequency spectrum of the fluctuations overlaps that of the normal phase oscillations. It is usually desirable to keep these frequency fluctuations below 0.01%. This characteristic of phase oscillations can be utilized to:

(a) Produce extended beam pulses. This will reduce the counting rate requirements on beam-monitoring equipment.

(b) Produce multiple-energy beam pulses during a given acceleration cycle. A controlled portion of the accelerating beam can be caused to fall upon targets at the desired energy, thereby permitting the performance of several simultaneous experiments.

(c) Regulate and set the amplitude of the final beam to within a few percent.

To effect (a) and (b) a noise source is switched on to modulate the frequency of the rf voltage during particle acceleration. With slightly more involved electronics (c) can be achieved. This requires a means, such as an electromagnetic induction electrode, of monitoring the amplitude of the beam during acceleration. The amplitude of this latter signal is compared with an arbitrarily set reference level in voltage comparator circuit. Noise is programed into the rf system to cause particle loss until the beam level reaches the reference value. A trigger generated by the voltage comparator circuit shuts off the noise. The regulated beam pulse then accelerates to full energy. This method of beam-level adjustment and regulation produces beam pulses of less than the maximum intensity, but the advantages of a constant beam amplitude are often more desirable.

The amplitude range over which a constant beam may be obtained is limited by the normal fluctuation in beam amplitude without regulation and the smallest beam level that can be distinguished from thermal noise.

The accuracy with which the beam amplitude can be controlled depends upon the normal amplitude of the phase oscillations in that they affect the envelope of the induction electrode signal, the reproducibility and long-time drift of the beam-tracking equipment, and the speed, accuracy, and stability of the voltage comparator. Regulation to within a few percent has been achieved.

Automatic Operations Selector

A relay-controlled automatic operations selector was installed this quarter to permit the simultaneous performance of a number of different experiments. This unit has three channels, which are selected in a preferential order as determined by the number of magnet pulses. It automatically performs the functions of selecting the target and clipper and the beam energy, as well as triggers and gates. In addition, it can be used in conjunction with the beam regulator to provide a choice of beam amplitude over a range greater than 1000:1. When used with the final amplifier plate-voltage-control circuitry, it can be programed to cause the beam to spill onto the target in a controlled manner for periods in excess of one second. While as many as five simultaneous and different experiments have been performed at one time with the aid of this device, equipment limitation or background effects usually limit the number to two.

Beam Integrator

A beam integrator was placed in operation this quarter. This device operates from the induction electrode signal and uses a tuned circuit to select that portion of energy spectrum of interest. This preliminary model has been used to measure integrated beams for emulsion exposures and chemistry bombardments. It is believed to be accurate to better than 20%. An improved and more accurate model is under design and should be available by the next quarter.

VACUUM

A day-to-day comparison of accelerated beam, straight section pressure, and injected beam has resulted in the empirical relation plotted in Fig. 4. This graph enables one to predict the maximum beam, within a factor of two, from the vacuum and the injector performance.

The losses encountered from 100 Mev to 6.2 Bev reduce the beam by not more than a factor of three. On the basis of these data one can compute an expected maximum beam level consistent with the minimum base pressure in the Bevatron and the maximum performance of the injection system. For an average base pressure of 2×10^{-6} mm Hg and a peak injected beam of 300 μamp it should be possible to accelerate about

$$(1/3)\ (5 \times 10^{8})\ (300) \cong 5 \times 10^{10} \text{ protons/pulse at 6.2 Bev.}$$

This intensity has not been reached, presumably because the low pressure and peak injector amplitude have not been reached simultaneously. Peak beams at full energy this quarter have been of the order of 0.5 to 1.5×10^{10} protons per pulse.

RADIOFREQUENCY SYSTEM

Self-tracking experiments

Some preliminary experiments were conducted this quarter on an automatic tracking system. The technique used differs from the usual automatic tracking schemes in the method of utilizing the error signal. In this experiment the oscillator tracking information was derived in the normal manner from the half-magnet current shunt signal. Initial tracking of the beam was obtained by appropriate adjustment of the capacity in shunt with the saturable reactor in the master oscillator. As soon as the radial component

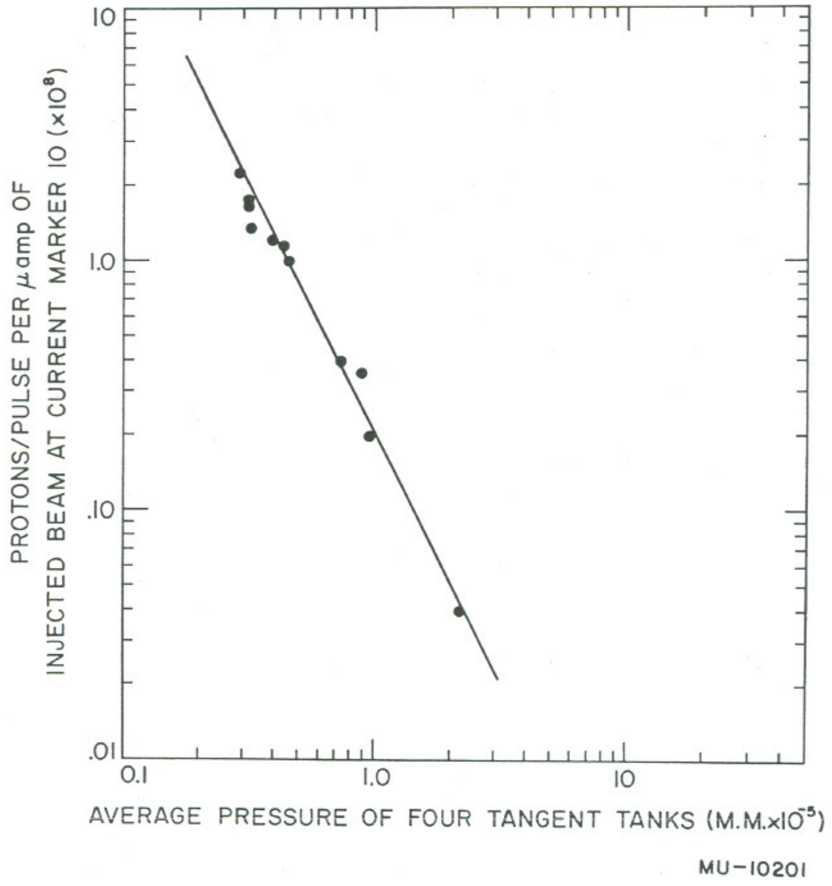


Fig. 4. Protons/pulse per μ amp of injected beam at 100 Mev as a function of average pressure of four tangent tanks.

of normal phase oscillations had decayed to a negligible value, an error signal was gated into the shaper reactor control circuits to phase-modulate the master oscillator. This error signal was derived from the difference between the induced voltages on a symmetrically located pair of induction electrodes in the south tangent tank. When the beam amplitude was sufficiently reproducible, this closed-loop regulating system allowed acceleration to 6.2 Bev without the 30-point curve corrector.

The amount of beam retained at 4.0 Bev (2×10^{10} protons/pulse) was roughly comparable with that obtained by the best tuning, using the curve corrector.

The two major disadvantages of the present system are
(a) a limited control of average beam position at high energy,
(b) that the loop gain is not independent of beam intensity.

The first effect results in an average beam position in the center of the aperture. In most experiments it is desirable to track the beam on the outer radius at the edge of the good field region ($n > 0.53$) to allow targets to reach the terminal positions as late as possible in the acceleration cycle. Also, as the magnet reaches peak fields, the center of the good field regions shifts to the outer radius. If the radial position of the beam is not tracked accordingly, beam will be lost on the $n = 0.75$ resonance value. As an indication of the importance of this effect, compare the beam loss that occurs from 4 to 6.7 Bev with and without automatic tracking, as shown in the table below.

Table II

Effect of automatic tracking on beam loss

Beam tracking	Radial position of beam at high energy	Beam magnitude at 4.0 Bev (protons/pulse)	Beam magnitude at 6.0 Bev (protons/pulse)
30-point curve corrector	Outer edge of field $\sim$606 inches	2×10^{10}	$\sim 2 \times 10^{10}$
Automatic tracking	Center of aperture $\sim$600 inches	2×10^{10}	$3 - 5 \times 10^{8}$

If the loop gain is not independent of the beam amplitude, two undesirable effects result. First, and most important, the beam tracking will stop at any point in the accelerating cycle where the beam amplitude drops below a threshold value. Second, the automatic tracking scheme will not be usable at low beam levels.

Both of these defects can be corrected with additional electronic circuitry. Beam-positioning control can be obtained with two radially offset pairs of induction electrodes. Control of the mixing of these two pieces of information will permit arbitrary beam location. Mixing a sum and a difference signal from the induction electrodes results in an amplitude-dependent term, which can be used in conjunction with an automatic gain-control system to permit operation at any desired beam level above the minimum set by the over-all noise level of the accelerating system.

Fluctuations in Start Frequency and Initial Slope

Measurements were made this quarter of the fluctuations in the initial rf accelerating conditions as determined by the frequency and rate of change of frequency with respect to magnet current. The fluctuations in these variables from their correct values must be minimized if a reproducible beam amplitude is to be obtained for a fixed quantity of injected charge.

Combined fluctuations in these starting conditions were measured indirectly by a statistical study of the time interval between the rf turn-on trigger and the first frequency marker that follows injection. The resultant histogram depicting the frequency of occurrence of a given delay time versus that delay time is shown in Fig. 5. These data correspond to 377 consecutive magnet pulses at a peak current of 4500 amp. The asymmetry in the delay curve indicates that in addition to the fluctuations, which produce an almost gaussian curve, there appears to be a slight tendency for the start frequency to be low. If the width of this curve at half amplitude is considered as a measure of the fluctuation, the jitter in rf turn-on frequency and initial slope corresponds to a time jitter of not more than ± 3 microseconds.

In order to interpret these data in terms of direct variations in start frequency and slope, it is necessary to separate out the true fluctuations in the observed data from those which accrue from the measuring and indicating apparatus. Finally, the time delay must be converted into the relevant frequency and slope variations. Consider first the fluctuations in the frequency-versus-time curve. These arise naturally from fluctuations in the current-versus-time curve from which the frequency-tracking information is obtained. Figure 6 shows a histogram of a typical set of data obtained when the time between the first two current markers is measured. If we use the half amplitude of the gaussian-shaped curve as a measure of the fluctuation, we observe that the raw data indicate that the time for the current to rise from 110.1 amp (Marker 3) to 139.0 amp (Marker 4) is 10,798 ± 6 microseconds. Two errors are included in this measurement. First, there is an error that is due to the chronometer used in making the time measurement. This instrument was a one-megacycle crystal-controlled clock, which has an inherent jitter of ±1 microsecond. Second, there is an error in the measurement of the instantaneous current that results from fluctuations in the peaking-coil bias current. A chopper-stabilized regulator that is referenced from a standard cell is used to set the bias current. The static regulation of this supply is good to 1 part in 10^5. While the dynamic regulation of this unit has not been measured (because of the relatively great instrumental difficulties), the relative stability of this unit has been compared with another similar unit. The relative regulation of the two units sampling the same time-varying current agreed to better than 1 part in 10^4. If this figure is used as an upper limit, the time fluctuation introduced by the peaking-coil bias-current regulator becomes

$$\Delta t_{\text{regulator}} = \left(\frac{\Delta I/I}{dI/dt}\right) I = \frac{(10^{-4})}{(28.9) \;/\; (1.08 \times 10^{-2})} (110.1) \cong 4 \text{ microseconds.}$$

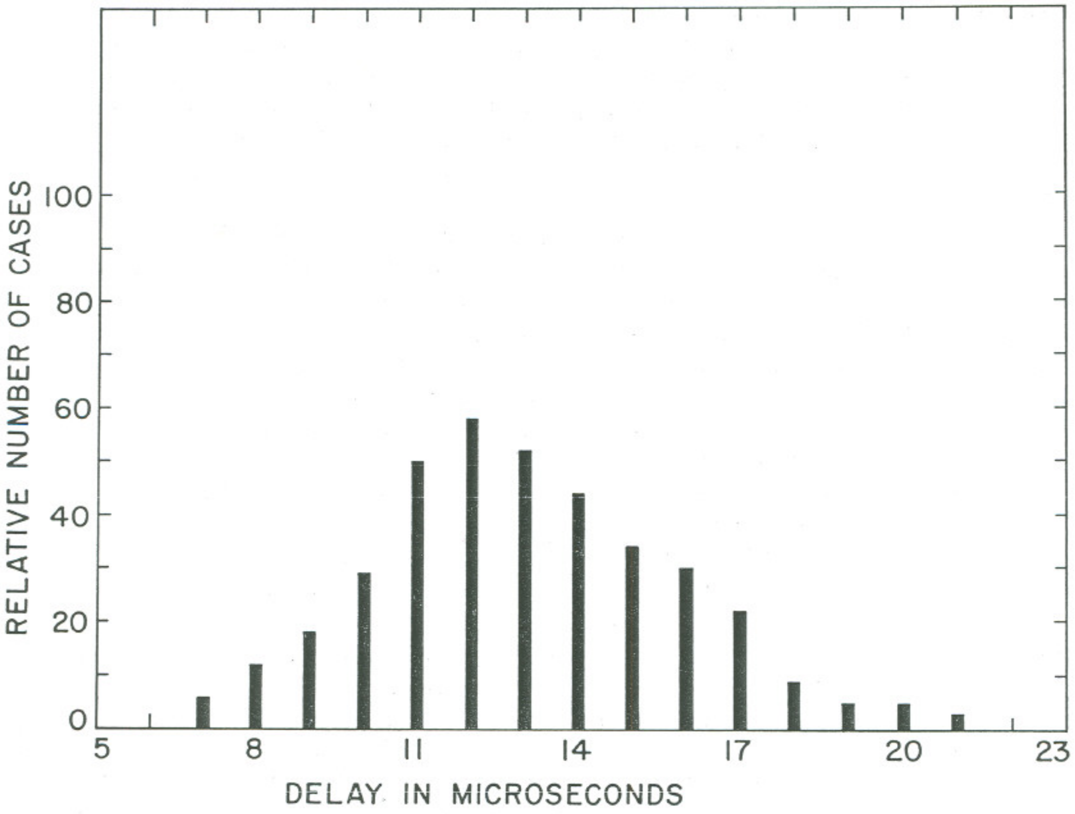


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Fig. 5. Jitter in start frequency, determined by difference between time of rf turn-on signal and 1st frequency pip. Total of 377 consecutive pulses. Pulse rate 14 per minute. Magnet pulsing to 4500 amps.

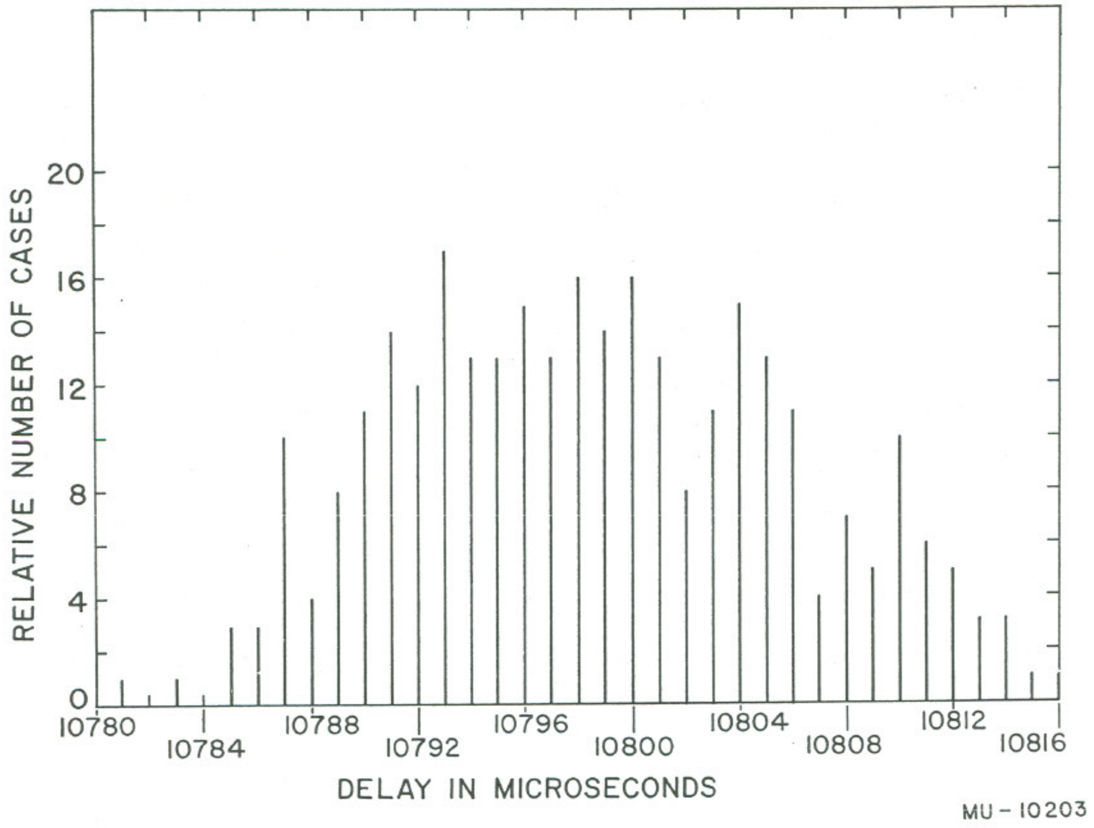

Fig. 6. Time fluctuation in microseconds between marker 3 and marker 4; 300 consecutive pulses, 4500 amps/pulse, 15 pulses/min; I - pip 3 = 110.1 amps, I - pip 4 = 139.0 amps.

If it is assumed that all the fluctuations sum in a root-mean-square sense, the true fluctuation in time associated with slope resolves to

$$\Delta t_{\text{slope}} = \sqrt{\Delta t^2_{\text{total}} - t^2_{\text{regulator}} - t^2_{\text{chronometer}}}$$

$$= \sqrt{(12)^2 - (4)^2 - (2)^2}$$

$$\cong 11 \text{ microseconds (or } \pm 5.5 \text{ microseconds)}$$

This corresponds to an average real fluctuation in slope of 0.1%. The regulation in magnet excitation voltage, which is the major source of this fluctuation, is not better than 0.1%.

A delayed-coincidence circuit technique is used to measure the instantaneous frequency. The coincidence unit which compares the direct and 20-microsecond-delayed sample of the rf has a time resolution of 7 x 10^{-9} second. This corresponds to an angular resolution of approximately 1° at rf turn-on. While the average accuracy with which this circuit measures frequency is dependent upon the rate of change of frequency with time, the time jitter associated with marking a given frequency that is varying in a reproducible manner is negligible in these measurements. Therefore, one may resolve the fluctuation in time, as shown in Fig. 5, by subtracting, in a root-mean-square sense, the jitter associated with the rf turn-on trigger. Now the rf turn-on trigger is generated by a peaking strip that is located in the fringing field of the Bevatron magnet. The accuracy with which the peaking strip senses the correct value of magnetic field for rf turn-on depends upon the regulation of the power supply in its associated bias-coil circuit. This power supply is of the same design as that used in the peaking transformer circuits and should have a dynamic regulation of better than 1 part in 10^4. The time jitter associated with marking the rf turn-on field will then be

$$\Delta t_{\text{regulator}} = \left(\frac{\Delta I/I}{dB/dt}\right) B = \frac{(10^{-4})}{(8.2 \times 10^3)} (330.6) \cong 4 \text{ microseconds.}$$

Therefore, the true fluctuation in time associated with Fig. 5 becomes

$$\Delta t_{\text{total}} = \sqrt{\Delta t^2_{\text{meas}} - \Delta t^2_{\text{regulator}}} = \sqrt{3^2 - 2^2} \cong \pm 2 \text{ microseconds.}$$

It is highly improbable that the slope fluctuates an amount corresponding to 4 microseconds in the relatively short 12-microsecond average delay between rf turn-on and the first frequency marker. Therefore, all of the 4-microsecond time fluctuation will be arbitrarily assigned to variations in start frequency. This corresponds to

$$\frac{\Delta\omega}{\omega} = \frac{d\omega/\omega}{\Delta t/t} = (9.4 \times 10^6) \frac{(4 \times 10^{-6})}{(3.54 \times 10^5)} \cong 10^{-4} \text{ or } 0.01\%,$$

which is negligible.

Magnet Power Supply

There has been an appreciable improvement in ignitron performance. This is especially important at high current and pulse rate where the average fault rate is now about one per hour of operation. This improvement is shown in Table III, where the average monthly fault rate is tabulated for high and low currents and various pulse rates.

The program of finding and remedying the causes of trouble continues. The resistive load across the ignitrons was increased to 6 amp to prevent a high transient voltage at the end of inversion. It has also been noted that there is a notch in the generator voltage, causing a poor grid voltage wave shape which may correlate with inversion faults. This wave shape has been improved with transformers, and it is proposed to couple an auxiliary generator to the shaft and provide a separate source of grid voltage. As operation has gone to the higher pulse rates, the water-temperature regulation has become poorer, and this seems also to correlate with faults. The water system is being investigated with a view to improving this regulation.

BEAM DYNAMICS

Beam Versus Aperture

On April 15 a study was made of the effect of an inner-radius obstruction on the amplitude of the accelerated beam. The experiment modeled the least favorable condition to be expected in the extraction of the circulating proton beam, that is, a fixed magnet in the south tangent tank, which would necessarily reduce the radial aperture by a factor of two. In order to conduct this experiment with the available facilities, it was necessary to compromise to the extent of using an inner-radius Faraday cup in the middle of the east tangent tank as the inner-radius obstruction. With this cup located at the nominal 600-inch point, it was determined that

(a) the range of existing rf equipment was sufficient to track the beam on the outer half of the aperture,

(b) the amplitude of the accelerated beam due to a localized inner-radial obstruction would only be reduced by a factor of two.

This linear dependence between fractional aperture and fractional beam amplitude should not be extrapolated without due care. Other considerations of beam dynamics, such as minimum root-mean-square amplitude of free radial oscillations, precession of betatron oscillations, etc., must be considered.

OPERATING AND RESEARCH PROGRAM

The scheduled operating hours were increased from 65 to 77 hours per week. As indicated in Fig. 7, the machine runs about 65% of that time, with about 50% of the 77 hours effective for physics research. Ten groups in the laboratory are carrying on active, continuing programs. In addition, about 25% of the effective research time has been devoted to emulsion exposures for various groups outside the laboratory.

Table III

Ignitron fault rate

Month	5 to 7 pulses per minute						7 to 10 pulses per minute						10 to 17 pulses per minute					
	1500-6000 amp			6000-8000 amp			1500-6000 amp			6000-8000 amp			1500-6000 amp			6000-8000 amp		
	Pulses	Faults	P/F	Pulses	Faults	P/F	Pulses	Faults	P/F	Pulses	Faults	P/F	Pulses	Faults	P/F	Pulses	Faults	P/F
1954 Oct	103	0	---	3111	27	115	11200	47	239	16200	114	142	80300	24	3348	2363	35	68
Nov	3434	8	429	5146	42	122	255	0	---	33200	259	128	29100	18	1617	7237	39	186
Dec	310	2	155	35600	122	292	1640	18	91	1529	39	39	19600	12	1630	0	0	0
1955 Jan	1757	4	439	42500	193	220	0	0	0	9480	60	158	55400	36	1538	259	3	86
Feb	793	0	---	19600	76	258	431	4	108	19800	97	204	39000	29	1347	9817	44	223
Mar	434	0	---	14900	16	933	456	0	---	37500	64	586	48400	39	1240	16400	51	232
Apr	948	0	---	19600	39	503	425	1	425	16700	38	440	102500	8	12800	9587	18	533

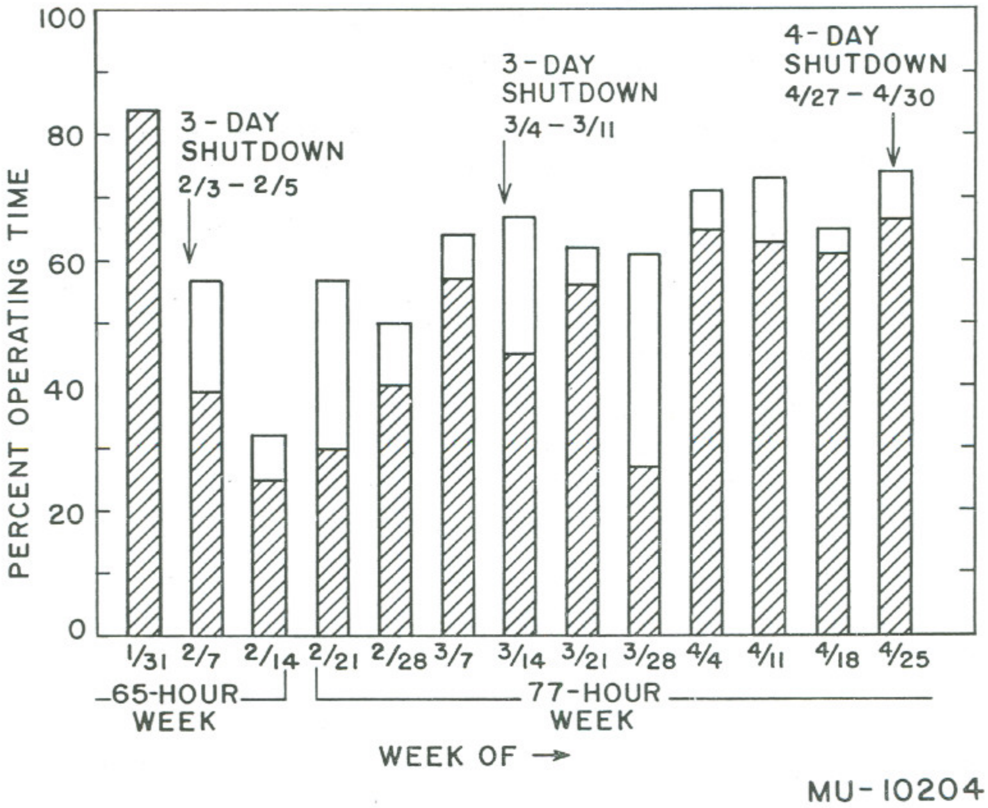

Fig. 7. Bevatron operating time. Height of bar indicates actual operating hours as a fraction of nominal operating week. The shaded portion represents time on physics research.

The major research activities during this period are listed in Table IV.

Table IV

Bevatron Research Program

February, March, April 1955

Radiation Laboratory Group

Alvarez	K- and τ-meson counting, bubble chamber tests.
Barkas	Emulsion exposures, K-particle masses.
Lofgren	P-P scattering using counter telescopes $C^{12}(p, pn)C^{11}$ cross section.
Richman	Strong-focusing spectrometer for K Particles. Production and mass of K particles. K-meson half lives.
Moyer	π^-, p total cross section using counter telescope.
Van Atta	Inelastic cross sections of π^- mesons in cloud chamber with Pb and Al plates. Hyperon production.
Powell	π^-, p interactions in 35-atmosphere hydrogen cloud chamber (4.5 Bev/c).
Segrè	Emulsion exposures to K, π^-, and protons. K ± interactions and half lives.
Chemistry Dept.	Preliminary radiochemical investigations.

Outside Institutions

Univ. of Wisconsin (W.F. Fry)	Emulsions in K beam.
Univ. of Manchester (G.D. Rochester)	Emulsions in π^- beam.
Univ. of Chicago (Arthur Rosenfeld)	Emulsions in π^- beam.
Univ. of Chicago (Marcel Schein)	Emulsions in π^- beam.
Mass. Inst. of Tech. (David M. Ritson)	Emulsions in K beam.
Los Alamos Laboratory (Glenn M. Frye)	Emulsions in K beam.
Ecole Polytechnique (L. LePrince-Ringuet)	Emulsions exposed to protons.
Commissariat a L'Energie Atomique (J. Vilain)	
Univ. of Bristol (C.F. Powell)	Emulsions in external 4.5-Bev π^- beam.
U.C.L.A. (H.K. Ticho)	Emulsion in circulating proton beam. Emulsion in deep well at 90° to target.

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