Title
A VARIABLE MOMENTUM SEPARATED K+ BEAM AT THE BEVATRON

Authors
Bell, Robert B.
Bland, Roger W.
Bowler, Michael G.
et al.

Publication Date
1964-06-25

UCRL-11527

University of California

Ernest O. Lawrence Radiation Laboratory

A VARIABLE MOMENTUM SEPARATED $K^{\pm}$ BEAM AT THE BEVATRON

Berkeley, California

Rept. sub. for the International
Conference on High Energy
Physics, Dubna, U. S. S. R.
Aug. 5-15, 1964.

Rept. also sub. for pub. in the
Proceedings.

UCRL-11527

UNIVERSITY OF CALIFORNIA

Lawrence Radiation Laboratory
Berkeley, California

AEC Contract No. W-7405-eng-48

A VARIABLE MOMENTUM SEPARATED $K^{\pm}$ BEAM AT THE BEVATRON

Robert B. Bell, Roger W. Bland, Michael G. Bowler, John L. Brown, Robert P. Ely, Sun Y. Fung, Gerson Goldhaber, Allan A. Hirata, John A. Kadyk, James Louie, C. Thornton Murphy, Jack S. Sahouria, Victor H. Seeger, Wesley M. Smart, and George H. Trilling

July 7, 1964

Abstract of paper to be presented at the 1964 International Conference on High Energy Physics, Dubna, U.S.S.R., August 5-15, 1964

A VARIABLE MOMENTUM SEPARATED $K^{\pm}$ BEAM AT THE BEVATRON*

Robert B. Bell, Roger W. Bland, Michael G. Bowler, John L. Brown, Robert P. Ely, Sun Y. Fung, Gerson Goldhaber, Allan A. Hirata, John A. Kadyk, James Louie, Jack S. Sahouria, Victor H. Seeger, Wesley M. Smart and George H. Trilling

Lawrence Radiation Laboratory
University of California
Berkeley, California

and

C. Thornton Murphy

Department of Physics
University of Wisconsin
Madison, Wisconsin

(Presented by Sulamith Goldhaber)

July 7, 1964

ABSTRACT

A two-stage, separated $K^{\pm}$ beam has been built and successfully operated at the Bevatron using a target in the new external proton beam as the source of secondary particles. Some features of the beam include relatively large solid angle, short length and wide operating range of beam momenta (approximately 800-1600 MeV/c). Details of the design and operation of the beam will be presented as well as measured particle flux values appropriate to zero-degree production.

* Work sponsored by the U.S. Atomic Energy Commission.

(To be Presented at the 1964 International Conference on High Energy Physics, Dubna, U.S.S.R., August 5 through 15, 1964).

UCRL-11527

A VARIABLE MOMENTUM SEPARATED $K^{\pm}$ BEAM AT THE BEVATRON

Robert B. Bell, Roger W. Bland, Michael G. Bowler, John L. Brown, Robert P. Ely, Sun Y. Fung, Gerson Goldhaber, Allan A. Hirata, John A. Kadyk, James Louie, Jack S. Sahouria, Victor H. Seeger, Wesley M. Smart, and George H. Trilling

Lawrence Radiation Laboratory and Department of Physics
University of California, Berkeley, California

and

C. Thornton Murphy

Department of Physics, University of Wisconsin, Madison, Wisconsin

(Presented by Sulamith Goldhaber)

July 7, 1964

I. INTRODUCTION

As one part of a general Bevatron improvement program, an extracted proton beam of high intensity became available in 1963.[1] The separated K^+, K^- beam described here, which went into operation early in 1964, incorporates a number of unique features made possible by the external proton beam. It has been successfully used to provide $K^{\pm}$ particles of various momenta (K^+ 850-1600 MeV/c, K^- 800-1150 MeV/c) in experiments involving the new Lawrence Radiation Laboratory' 25-inch hydrogen bubble chamber. This paper describes some of the details of the beam design and gives measured fluxes of various secondary particles.

II. BEAM DESIGN

A. General Features

The beam layout is shown in Fig. 1. Since the target is external to the accelerator, the secondary beam optics are independent of the magnetic field of the Bevatron. This allows the selection of positive or negative particles, within a wide range of momenta, produced at 0° by protons of any convenient energy. Other advantages of having a target external to the Bevatron include the feasibility of a large solid angle and a short distance from target to detector made possible by the placement of the initial beam components close to the target.

The optical properties of the beam are given in Table I and a description of the beam components in Table II. Horizontal and vertical ray diagrams appropriate to the beam operation at or below 1200 MeV/c are shown in Fig. 2 (Mode I). For higher momenta the polarities of quadrupoles Q2, Q3 are reversed in order to decrease the image size at the first slit, at the cost of some intensity. Ray diagrams for this mode of operation (Mode II) are shown in Fig. 3. The difference in the two modes of operation reflects the fact that, of the two mutually contradictory requirements of large solid angle and good separation, the former dominates at low momentum and the latter at high momentum.

The collimation is done as far upstream as possible, this being accomplished primarily by the uranium collimator between M1 and M2. No vertical or horizontal collimation of rational beam particles is done after Slit 1, i.e., the phase space over the entire momentum bandwidth is determined by the main uranium collimator and lead collimators in quadrupoles Q3 and Q5.

B. Beam Optics

1. Horizontal Plane

The horizontal acceptance angle is primarily limited by the aperture of Q1, which is centered only 43 inches from the target. The momentum bandpass is defined by the horizontal focus at Slit 1, where the gap width of five inches corresponds to a 2% momentum interval. The large magnification and small angular divergence at Slit 1 permits some chromatic compensation by maintaining the correlation between transverse horizontal position and momentum from the first focus to M3.

In the second stage the last doublet converges the beam so that its horizontal width matches the bubble chamber entrance aperture. A beam steering magnet M4 is provided for centering the beam on the chamber entrance window irrespective of the momentum.

2. Vertical Plane

The beam is parallel in both spectrometers in order to maximize separation. Because of chromatic aberration in the vertical plane and dispersion in the horizontal plane, the locus of vertical foci at Slit 1 is a line inclined at 20° to the beam direction. The jaws of the first mass slit follow this line. Magnet M3 has a sextupole field component so that the variation of vertical focal length across the horizontal aperture compensates the chromatic aberration due to the first and second stages of the beam, resulting in a locus of vertical images at Slit 2 normal to the beam axis. Slit 2 lies perpendicular to the beam direction which is necessary for good vertical imaging since there is no horizontal focus at this point.

C. Shielding

The shielding is shown in Fig. 1. The external beam is stopped at the Bevatron shielding wall by a removable steel plug four feet long. Additional shielding is placed in the region about this plug and the blockhouse enclosing the chamber is provided with a concrete roof four feet thick. With this shielding, no serious amount of background is observed in the bubble chamber with external beam levels as high as 2×10^{11} per pulse.

III. BEAM MONITORING

A. Target Monitors

Four devices are used to determine the position, profile, and intensity of the external proton beam (EPB) striking the copper target. First, a calibrated secondaryemission foil chamber monitors the absolute flux of protons in the EPB ahead of the target, independently of the condition of focus at the target. Secondly, a remotely-controlled sheet of plastic scintillator can be moved into the EPB just downstream of the target, and viewed via a mirror system by a television camera. The size and shape of the observed scintillation spot is used to optimize the EPB focus. Since the target is slightly smaller, its shadow is readily visible within this spot when the beam is properly centered. Thirdly, a small scintillation counter on each side just ahead of the target is used to monitor the horizontal position of the EPB. These two scintillators, 1/4" x 1/4" transverse to the beam, and 1/16" thick are glued to very thin metal light pipes. The signals are integrated and displayed between Bevatron bursts on an oscilloscope as two square pulses whose heights correspond to the relative EPB intensities at each of the two counters. The integrated signals are reset to zero just before the next beam pulse. Finally, a single Cerenkov counter is situated about three feet from the target and at approximately 90^{o} to the EPB direction. This counter, which monitors the amount of beam hitting the target, consists of a two-inch diameter lucite disc mounted on an aluminum light pipe, and fitted with an accurate calibration light to check the gain of the photomultiplier. The signal is integrated, and read by an electrometer. This monitor, which has been used to normalize all tuning curves, has a wide linear range of signal response, corresponding to a wide flux range, while not suffering from statistical uncertainty even at low fluxes.

B. Slit 1 Monitor

For monitoring the position of the beam at Slit 1, a triad of solid-state counters is used.[2] The triad counters consist of three wafers of lithium-drifted silicon[3] having dimensions: 1.3" transverse to the beam by 0.5" in the beam direction by .06" high. The three wafers are mounted one above the other with their planes parallel, and have a center-to-center spacing of .08". The signals from these counters are integrated and displayed as three square pulses on an oscilloscope in a manner similar to the display of the two EPB position counters. The triad is used by positioning it ahead of and just above Slit 1, centering it in the image of rejected particles. Since the image width is comparable with the spacing between triad counters, the profile and position of the image is directly indicated, and any vertical shift of the beam particles from their desired position is immediately observed.

C. Slit 2 Monitors

In order to monitor the total number of particles entering the chamber for each beam pulse, two scintillation counters are used in coincidence as a telescope. One is inserted into the middle of the slit along the focal line, the other is placed immediately behind the slit. A close correlation is found between the counts on this monitor and the number of tracks in the bubble chamber pictures. A separation curve obtained with this telescope is shown in Fig. 4. The counter inside Slit 2 is comparable in height with the vertical image size in Mode I operation, and much larger than the image in Mode II operation. In order to observe clearly the true image profile, a solid-state counter with dimensions 1.3 inches by 0.04 inches high by 0.5 inches thick has also been used at Slit 2. A separation curve taken with this counter is shown in Fig. 5.

IV. PARTICLE FLUXES AND CONTAMINATION

Secondary particle fluxes were obtained from an analysis of tuning curves taken at the second slit. The results are presented in Fig. 6. As estimated from bubble chamber photographs, the pion contamination at the chamber varies from less than 1% at 860 MeV/c to about 20% at 1600 MeV/c.

REFERENCES

1. W. A. Wenzel, Lawrence Radiation Laboratory Report UCRL-10868, July 1963. We are indebted to W. A. Wenzel and T. Elioff for considerable help with optimization of the EPB operation.
2. A triad monitor was first used by Eberhard, Good and Ticho, Rev. Sci. Instr. 31, 1054 (1960).
3. F. S. Goulding, Nucleonics 22, 54 (1964). We are indebted to R. Lothrop and H. Smith for making the counters.

FIGURE CAPTIONS

Fig. 1. Plan view of the layout of the beam components and shielding on the Bevatron floor.

Fig. 2. Ray diagrams in the horizontal and vertical plane for Mode I operation of the beam.

Fig. 3. Ray diagrams in the horizontal and vertical plane for Mode II operation of the beam.

Fig. 4. Separation curve at 1200 MeV/c beam momentum taken with the scintillation telescope at the second slit (Mode I). Counts per monitor volt are plotted against the magnet current in the second spectrometer.

Fig. 5. Separation curve at 1600 MeV/c beam momentum taken with the solid state counter at the second slit (Mode II). Counts per monitor volt are plotted against the magnet current in the second spectrometer.

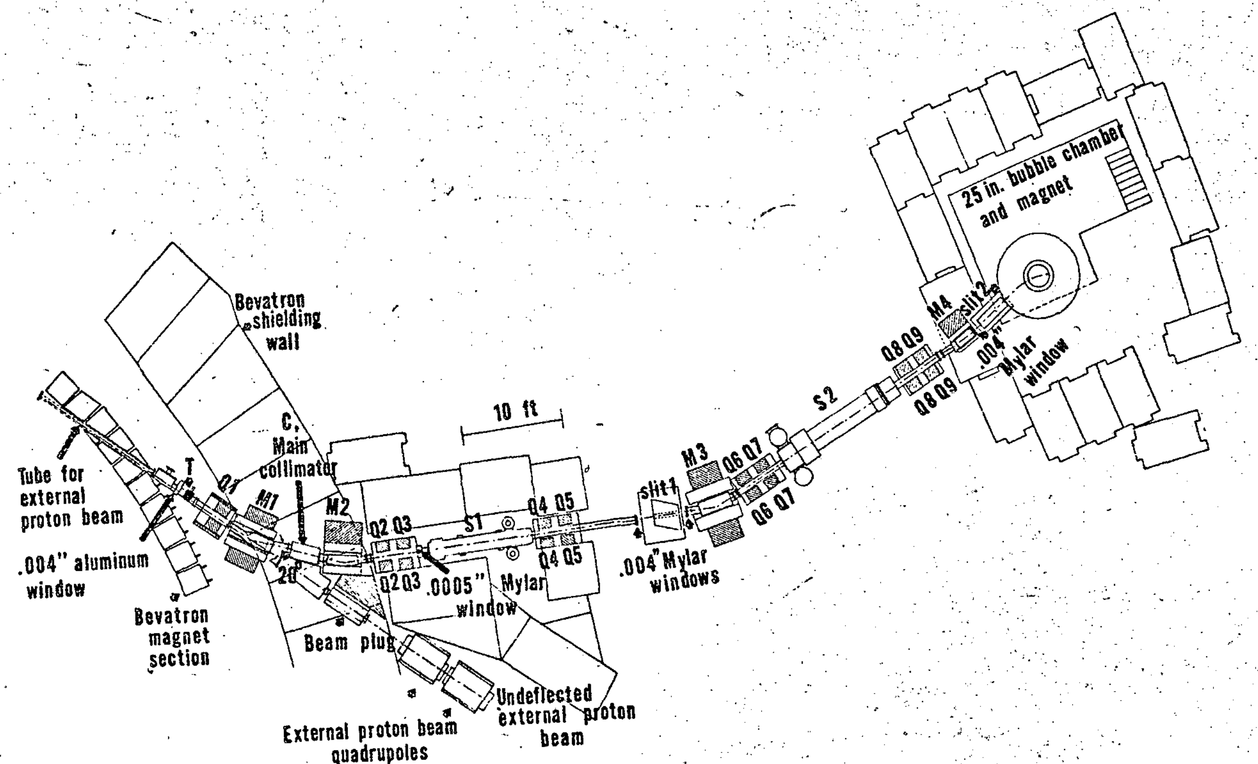
Fig. 6. Secondary particle fluxes produced at 0° by 6 BeV protons, as a function of momentum. The ordinate represents the number of particles per 10^{11} protons in the EPB channel, per 1% total momentum interval, per millisteradian. It should be noted that only about 60% of the protons in the EPB channel are intercepted by the target.

Table I. Optical characteristics of the beam

	Mode I	Mode II
Momentum (MeV/c)	800-1200	1200-1600
Solid Angle (msr)	.89	.36
Length (target to chamber, inches)	1115	1115
Horizontal Acceptance Angle (mrad.)	130	96
Vertical Acceptance Angle (mrad.)	6.8	3.8
Total Momentum Bite	2%	1.5%
Vertical Magnification, First Stage	0.59	0.33
Horizontal Magnification, First Stage	8.66	8.80
Vertical Magnification, Second Stage	1.0	1.0
Vertical Image Size at Slit 2 (inches)	0.09	0.06
K-π Separation at Slit 1 (inches)	0.25 (1200 MeV/c)	0.11 (1600 MeV/c)
K-π Separation at Slit 2 (inches)	0.28 (1200 MeV/c)	0.12 (1600 MeV/c)

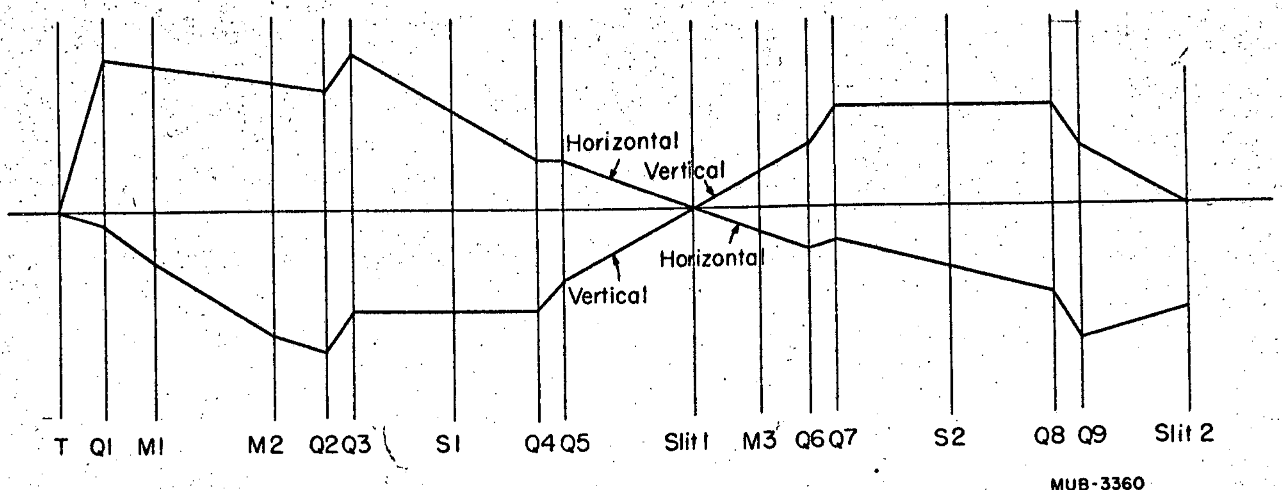
Table II. Beam Components

Symbol Used in Fig. 1.	Description
Q1, Q2...,Q9	8" bore x 16" long quadrupole magnets
M1, M3	18" wide x 36" long bending magnets
M2	16" wide x 36" long bending magnet
M4	13" wide x 24" long bending magnet
S1, S2	Parallel Plate Spectrometers, 2" gap, 9 and 10 feet long respectively, 450 kv
Slit 1	Uranium Mass-Separation Slit, 30" long, .15" gap
Slit 2	Lead Mass-Separation Slit, 40" long, .15" gap
T	Copper Target for EPB, .35" wide x 4" long x .15" high
C	Uranium collimator, 24" long, horizontal aperture variable 0 to 5".



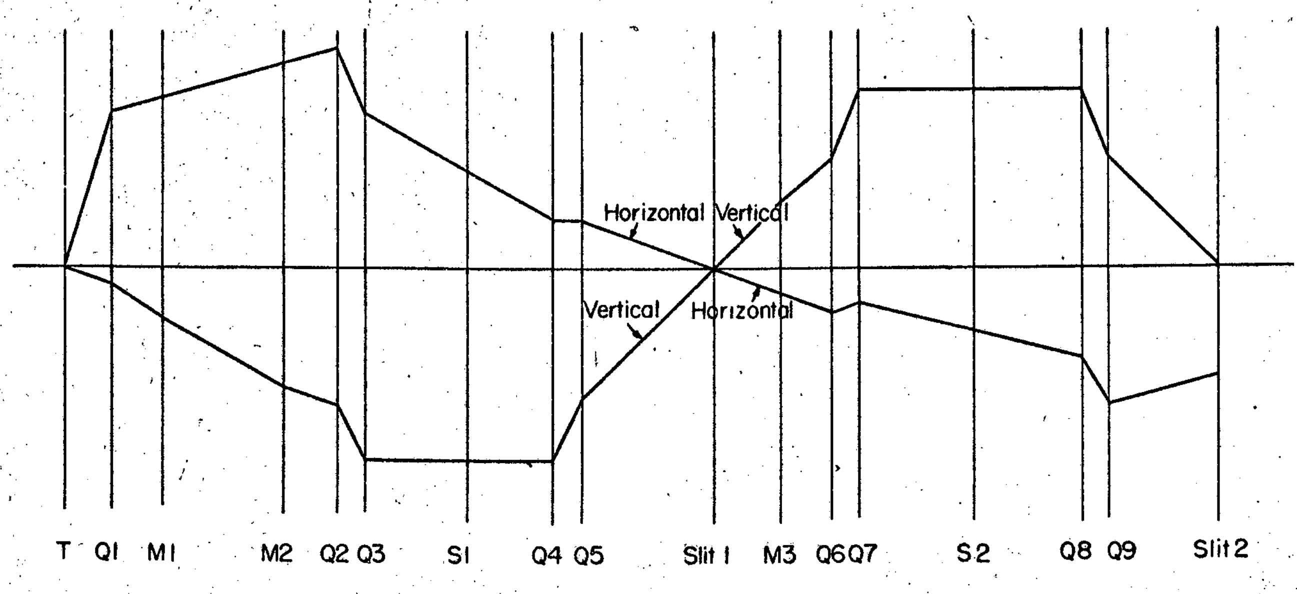
MUB-3362

Fig. 1.



Mode I

Fig. 2.



Mode II

Fig. 3.

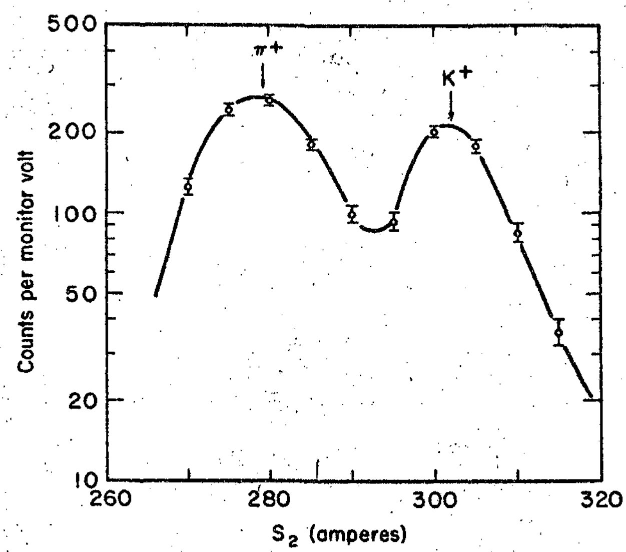
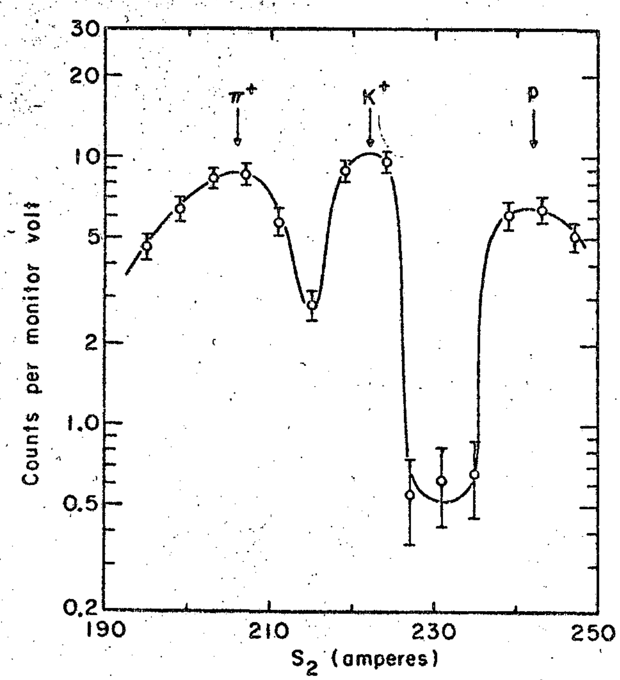
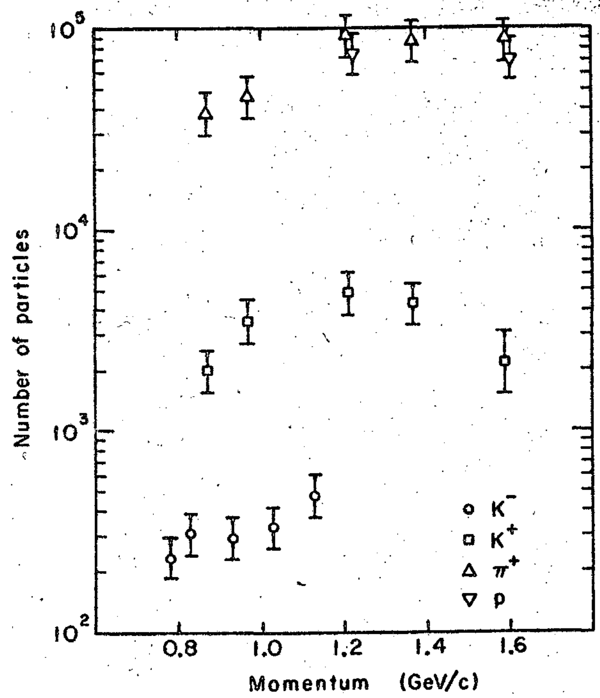


Fig. 4.





MUB-3403

Fig. 5.

Fig. 6.