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Enhanced 200 GeV/c K^+ Beam Using Beryllium Filter

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Abstract:

Using beryllium as a selective hadron filter, the kaon fraction of a positively-charged 200 GeV/c secondary beam has been increased from 3% to ∽ 15% without an appreciable effect on tagging efficiency.

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Introduction

The kaon fraction of high energy unseparated beams is generally quite low. The M1 beam at Fermilab, for example, when operated at 200 GeV/c, for 400 GeV/c primary protons, provides at its nominal 3.6 mrad production angle 2.5% K^+, 14.0% π^+ and 83.5% p at about 400 meters downstream of the primary target. The corresponding negative secondary beam contains 3.5% K^-, 95.7% π^- and 0.8% $\bar{p}$.[1] Our experiment to measure radiative widths of the strange mesons[2] required incident-kaon fluxes of $\gtrsim 10^5$ per pulse. Precision requirements necessitated the use of drift chambers for detecting the charged particles. Consequently, because the charged-particle trajectories in the final state were often located in the beam region, this limited the maximum acceptable beam flux to $\sim 10^6$ particle/second. We therefore elected to use a beryllium filter to enhance the kaon fraction of the beam. Because the difference in the proton-kaon absorption cross section is much larger than the difference in the pion-kaon cross sections, and because the K^+/π^+ ratio is larger than the K^-/π^- production ratio, and, finally, because the absolute flux of K^+ mesons is much greater than the corresponding flux of K^-, we chose a positively charged beam for attaining an improved kaon beam fraction. This paper reports the results of using up to 2.2 meters of beryllium absorber in a positively-charged 200 GeV/c secondary beam to enhance the K^+ fraction of that beam.

Beam, Absorber and Cerenkov Systems

The M1 beam at Fermilab originates in interactions of 400 GeV/c primary protons in a 38 cm long (1.25 collision lengths) beryllium target. During our experiment, the production angle for the M1 line was varied from 3.6 mrad to 1.9 mrad, with most of the data obtained at angles <2.5 mrad. The M1 beam is a standard three stage beam[3]. The first stage provides dispersion for momentum selection. The second stage recombines the momentum. The third stage provides a 50 meter long parallel region for species tagging by differential Cerenkov counters. Ray traces of selected beam particles along with a schematic of the beam line are shown in Fig. 1.

The beryllium absorber consisted of four metal blocks, 10 cm x 10 cm in cross section, ranging in length from 15 cm to 125 cm. Any combination of the four could be inserted remotely into the beam, providing a maximum absorber length of 221 cm. The beryllium was placed at the intermediate momentum-dispersed focus to minimize the effect of multiple scattering in the absorber. For a monochromatic beam, the divergence at this focus was ±0.4 mrad in the bending plane and ±0.8 mrad in the vertical plane. Multiple scattering of the beam through two meters of beryllium contributes only 0.2 mr at 200 GeV/c. The effect of multiple scattering was noticeable in the response of the downstream Cerenkov counters, requiring slight retuning of the beam for changes in the length of absorber.

The principal Cerenkov counter used to tag the beam species was a 30 meter long, hellium-filled, differential counter that used a Cerenkov angle of 7.5 mradians.[4] The counter had a ring of six phototubes used for coincidence and another ring of six tubes for veto. At 200 GeV/c it was found that adequate separation of the pion and kaon peaks could be achieved by combining signals from adjacent phototubes (logic OR), and then requiring either a 2-fold or 3-fold coincidence of the three available signals. The veto ring was not used. A pressure curve from this counter is shown as Fig. 2, with both the 2-fold (2/3) and 3-fold (3/3) coincidence plotted. The beam tune involved a compromise between sensitivity to scattering in the beryllium absorber and the need for very good parallelism for Cerenkov tagging. Consequently, the Cerenkov counters were somewhat inefficient, even with the two-fold coincidence requirement. The counter efficiency was ∽97% for a two-fold coincidence, nearly independent of absorber thickness. Requiring a three-fold coincidence dropped the efficiency to 90% without absorber, and to approximately 80% with the maximum 2.2 meters of beryllium. As can be seen from Fig. 2, the pion contamination under the kaon peak was less than 1% of the kaons, even with the two-fold requirement. This was felt to be entirely adequate for the experiment. Far better separation, provided by the three-fold requirement, was used to check results obtained using the two-fold data.

Beryllium-Absorber Data and Fits

All of the data were obtained parasitically during the running of the principal experiment. Consequently, the information pertaining to fractions of beam species, absolute fluxes for various production angles, and lengths of absorber, was not always recorded. However, enough points were taken to determine the effective absorption cross section for each of the beam species. The data points were fitted to the form:

$$N_i = N_i^o \exp\{-\ell_{Be}/L_i^{abs}\} \qquad (1)$$

where N_i^o is the flux of the i^{th} species without beryllium filter, ℓ_{Be} is the length of beryllium absorber, and L_i^{abs} is the effective absorption length for the i^{th} species in beryllium, that is:

$$L_i^{abs} = A^{Be}/(\sigma_i N_A \rho^{Be}) \qquad (2)$$

where A^{Be} is the atomic weight of beryllium, N_A is Avagadro's number, ρ^{Be} is the density of beryllium, and σ_i is the effective absorption cross section for the i^{th} species. The results of the fit are given in Table I, along with earlier data for absorption cross sections from Ref. 5. Our effective absorption cross sections are 30-40% larger than the measurements of Ref. 5, which specifically excluded elastic and coherent processes. Because of the tight momentum and angular acceptance of the downstream portion of the beam line, our effective absorption cross sections correspond essentially to total cross sections, excluding only the very small-angle elastic scattering contribution. As a measure of how close this effective absorption cross section is to the total cross section, the measured neutron-beryllium total cross section is 272 mb, only 9 mb more than our effective cross section for proton-beryllium collisions.

The beam fractions for each of the species for a 3.6 ±0.45 mrad (p_T = 720 ± 90 MeV/c) production angle, as a function of absorber length, corrected for decay downstream of the primary target, are shown in Fig. 3. The smooth curves are the results of our fit to all the data. Figure 4 displays the beam fractions, as a function of p_T, with no Beryllium and with 221 cm of Beryllium.

Conclusion

We have found that it is feasible to use beryllium in a high energy secondary particle beam to selectively filter and enhance the kaon fraction in the beam. The degree of enhancement that can be obtained depends on the beam flux prior to filtering and on the beam intensity required at the experiment. Placing the filter at an intermediate focus, in our case a momentum dispersed focus, which has reasonably large inherent beam divergence, minimizes adverse effects on beam quality and tagging efficiency.

Using 221 cm of beryllium filter we routinely obtained a 14% K^+ fraction in a beam whose total flux was 5×10^5 particles per second at the experimental target. The kaon tagging efficiency was maintained at $\gtrsim 97\%$, and less than 1% of the tagged kaons were due to misidentified pions. Finally, the K^+/π^+ fraction in the beam was enhanced by about a factor of two as a result of the selective filtering.[7]

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References

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2. D. Berg et al., Phys. Rev. Lett. 44, 706 (1980).

3. S. Ecklund, Fermilab Report TM-743.2833 (1977).

4. See the appendix in Ref. 3.

5. A.S. Carroll et al., Phys. Lett. 80B, 319 (1979).

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7. For previous tests of this kind of filtration scheme see H. Rubin and T. Ludlam, PHS Consortium Newsnote No. 40, Yale-ITT Report (1975).

Table I

Effective hadron-beryllium absorption cross sections at 200 GeV/c

	Cross Section (mb)		
	K^+	π^+	P
Effective Cross Section	157 ± 10	181 ± 8	263 ± 5
Absorption Cross Section[(a)]	122 ± 4	139 ± 4	184 ± 6

[(a)] Ref. 5.

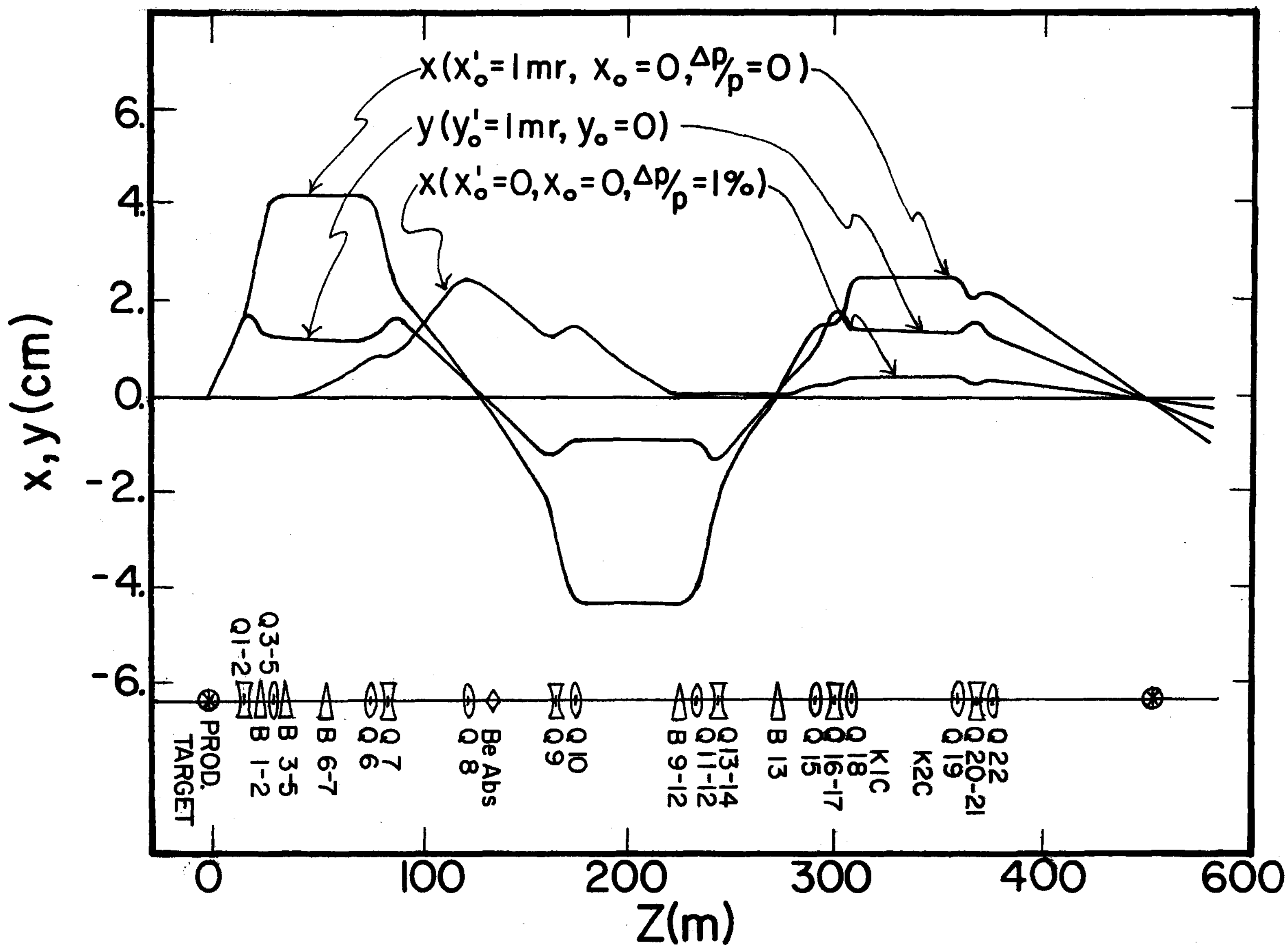

Figure 1: Fermilab secondary particle beam M1, schematic and ray traces of selected particles.

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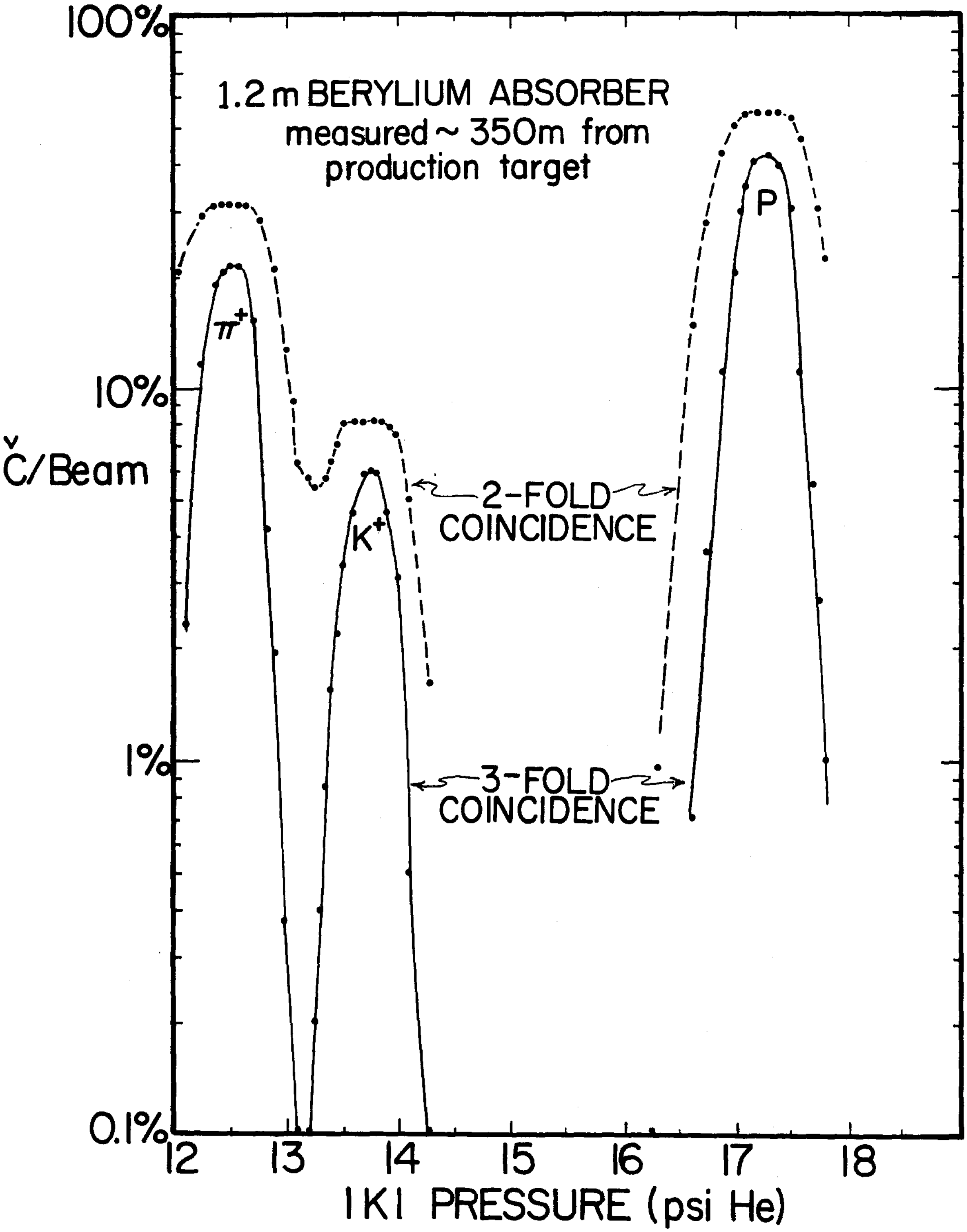

Figure 2: Pressure curves of the 30m differential Cerenkov counter. The curves are explained in the text.

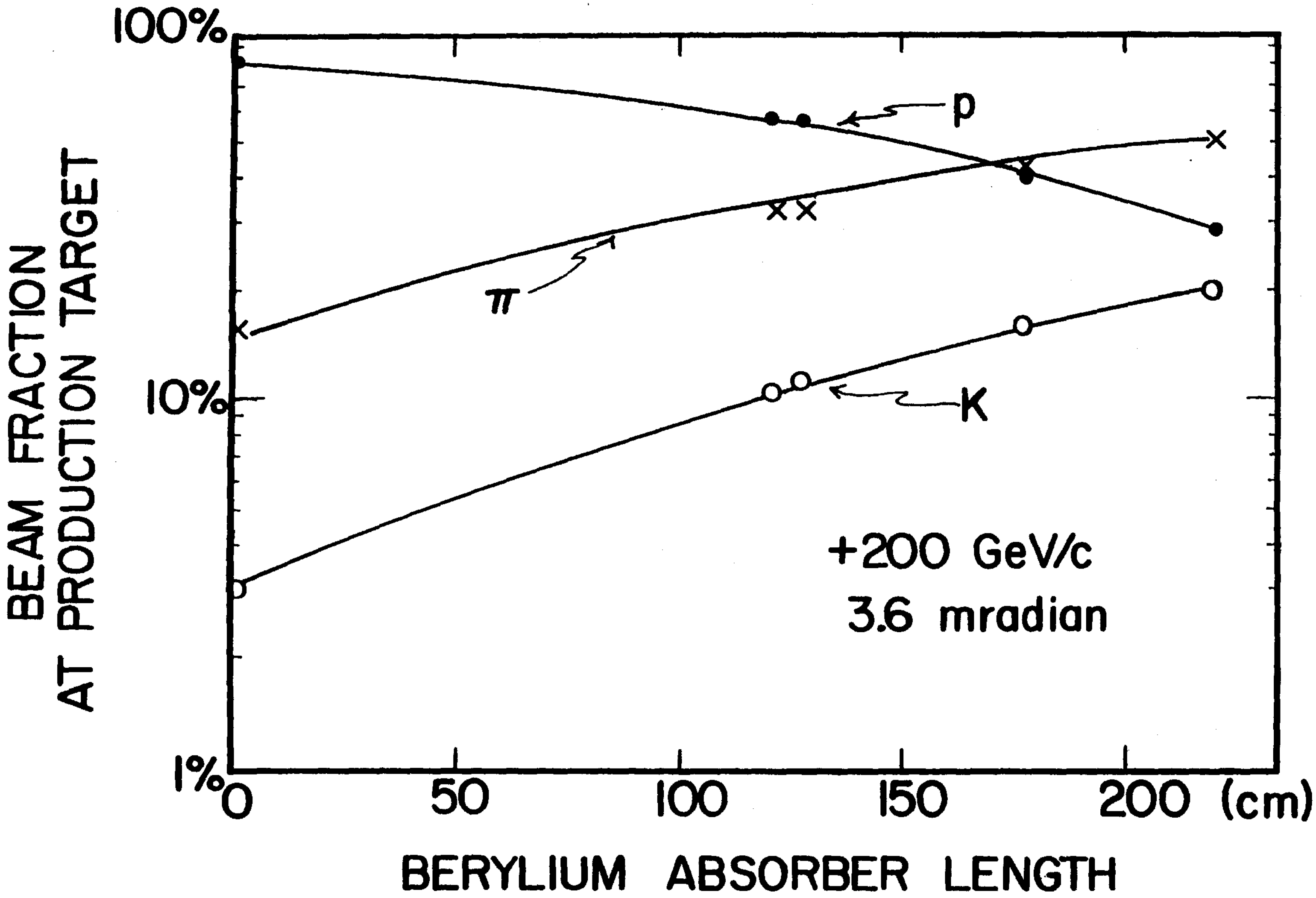

Figure 3: Particle beam fractions as a function of Beryllium absorber length. The curves are the result of the fit discussed in the text.

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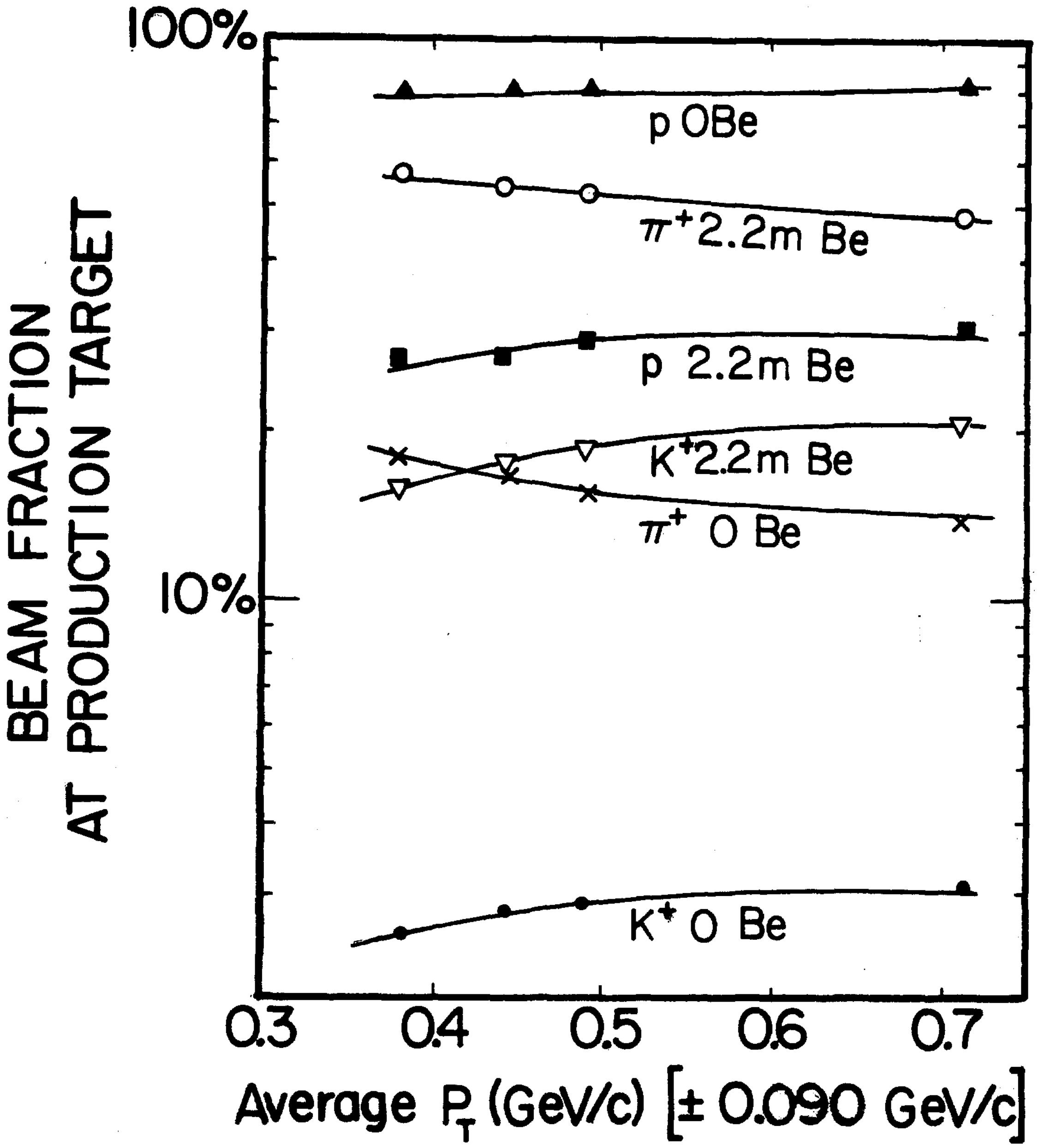

Figure 4: Particle beam fractions as a function of the production transverse momentum for the two cases; no Beryllium and 2.2m of Beryllium absorber. The curves are the result of the fit discussed in the text.