K2 Beam : Note 1

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Discussion of the Low Momentum $K^{\pm}$ Beam "K_2"

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The programme of the CERN HBC in 1962 is oriented toward low energy K meson physics. One of the main experiments, determination of the $\Sigma^0 - \Lambda^0$ parity, requires 5 K^- to stop in a HBC, per picture. It is therefore essential to produce an intense low momentum K^- beam.

I. K^- Flux at Target

There are no measurements of K^- flux for the conditions which would be correct for a stopping K beam. The Table I shows the most relevant measurements. For the purpose of optimizing the beam, it has been assumed that

$$K^- \text{ flux at } 15^\circ = 3 \times 10^{-3}/\text{proton - GeV/c - steradian} \times \frac{P_K}{1 \text{ GeV/c}}$$

(the momenta of interest are $0.6 < P_K < 1$ GeV/c). Since the beams we have been able to design do not show a large excess of flux over that required, it seems essential to have a measurement of this flux. Kinematic considerations, and the results of bubble chamber studies of high energy interactions, seem to indicate that the flux does not change rapidly with production angle, for angles smaller tha 20°.

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II. Optimum Transport Momentum

The fraction of K^- accepted by the beam which stop in the bubble chamber is

$$F_S = e^{-\frac{L}{\lambda}} D \ F_T$$

where the factors take into account loss due to decay, loss due to interactions and multiple scattering in the degrader, and the variation of flux at target with K momentum. Factor D is taken from experiment: Alvarez Physics Note #252. Figure 1 shows the actual numbers of stopping K^- for two beam lengths, for beam acceptance of 10 MeV/c millisteradians, per 10" protons on the target. It will be seen that the optimum momentum in ~ 850 MeV/c, but little flux is lost by choosing a momentum of ~ 700 MeV/c, which increases the separation by ~ 50%.

III. Required Acceptance and Separation Factor

We desire 5 stopped K^- per pulse. The target efficiency for the fast pulse should be $\gtrsim$ 70%. We note that in the beams which we are considering it is possible to reduce the momentum spread by means of a wedge absorber at the momentum defining slit, so that all the K^- may be made to stop in the bubble chamber. We also fix the initial momentum at 700 MeV/c. Then the required acceptance may be given as a function of beam length (Fig. 2). If the π^- flux at target is taken as 10^{-1}/p - GeV/c - Steradian, the number of π^- accepted in the beam per stopping K^- ($\simeq$ required separation factor) may also be calculated, and is shown on Figure 2.

IV. Beam Optics

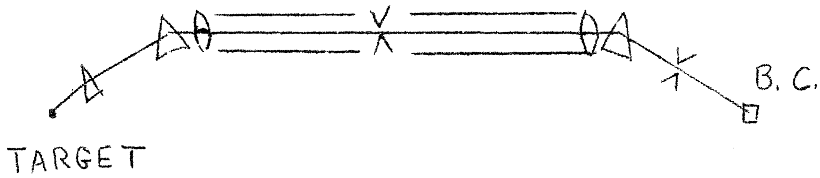
The required separation factors shown in Figure 2 suggest that a two stage separator would be desirable. With the 3 m separators, one can obtain a beam length of ~ 18 - 24 m for different designs. It became clear to us that it was impossible to attain the required acceptance for lengths of the right order, while maintaining a production angle of 15°, without a special magnet. Figure 3 shows one type of beam we have considered, incorporating a special bending magnet, M1, which may be placed near the target, allowing the first quadrupole to be brought closer to the target.

The design of this magnet, which decreases the beam length somewhat and increases the solid angle substantially, has been undertaken by G. Petrucci. It is found that a beam of this type has an acceptance approximately equal to that required to give 5 K^-/10" p, but further consideration is necessary to determine the exact momentum band which may be transmitted without broadening the vertical image too much. This, in turn, depends on the electric field which can be maintained in the separators. The present calculations have assumed E = 40 KV/cm over 10 cm, allowing $\frac{\Delta p}{p} \sim \pm 1\%$. In beams with the highest flux, a field lens is necessary at the first mass slit, as shown in Figure 3.

The beam, which utilizes the vertical focusing of the bending magnets, is "parallel" in the vertical plane in the separators.

To obtain an increased safety factor in K^- flux, it is necessary to consider shorter beams. Two approaches seem possible:

a) A beam with the absolute minimum number of elements, converging and diverging in the separators, such as is shown schematically below:



Such a beam could be ~ 18 m long. It would have sufficient separation only if a rather high electric field (~ 50 - 60 KV/cm) could be attained.

b) We intend to investigate also the possibility of a rather short one stage separator. In this case, the increased flux available might allow sufficiently precise optics to obtain the required separation.

V. Equipment Required

For the beam shown in Figure 3, the elements required are:

- 6 (or 7) - 20 cm SC-type quadrupoles
- 2 - 1 m bending magnets
- 2 - 3 m separators
- 1 - special bending magnet
- 1 - target box accommodating special magnet
- 1 - 40 cm vertical bending magnet

Since the magnets must be used to the designed aperture (~ 10 x 18 cm^2) to obtain the required flux, the non-linear aberrations must be investigated carefully, and, if necessary, controlled by shimming.

If the Cresti separators are to be used, one should consider a redesign of the high voltage bushings and, if possible in time, provide them with glass electrodes.

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Table I

Source	Conditions	K^- production angle	K^- momentum	K^- Flux per proton-GeV/c-steradian
BNL	29.5 GeV/c Be	30°	1	$1.1 \pm .2 \times 10^{-3}$
K1 Beam	18 GeV/c Al	15°	1.5	$7 \pm 2 \times 10^{-3}$
K1 Beam	18 GeV/c Al	15°	1.3	$3.5 \pm 1 \times 10^{-3}$
Lundby	18 GeV/c	15°	1.5	$6 \pm 2 \times 10^{-3}$

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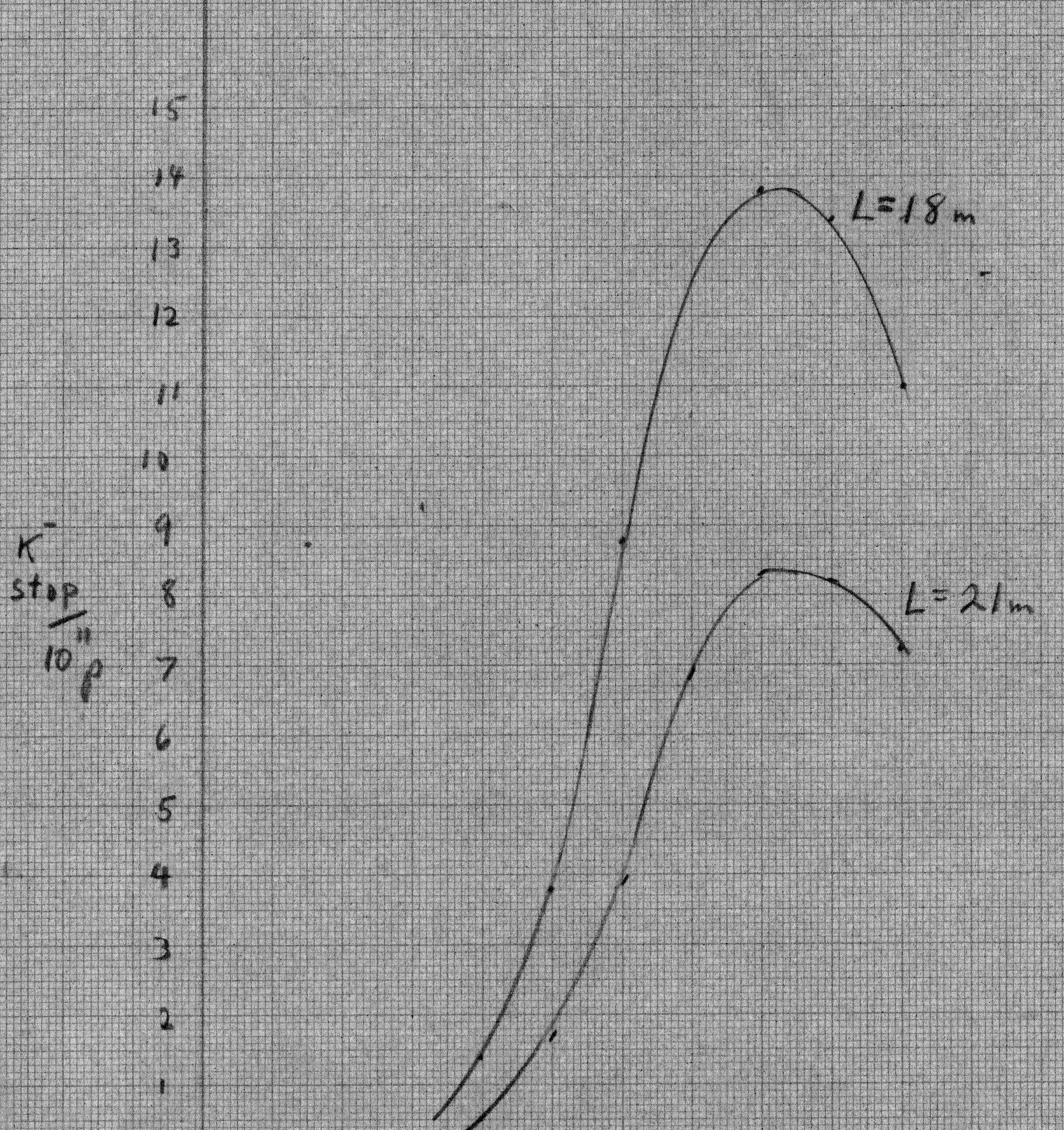
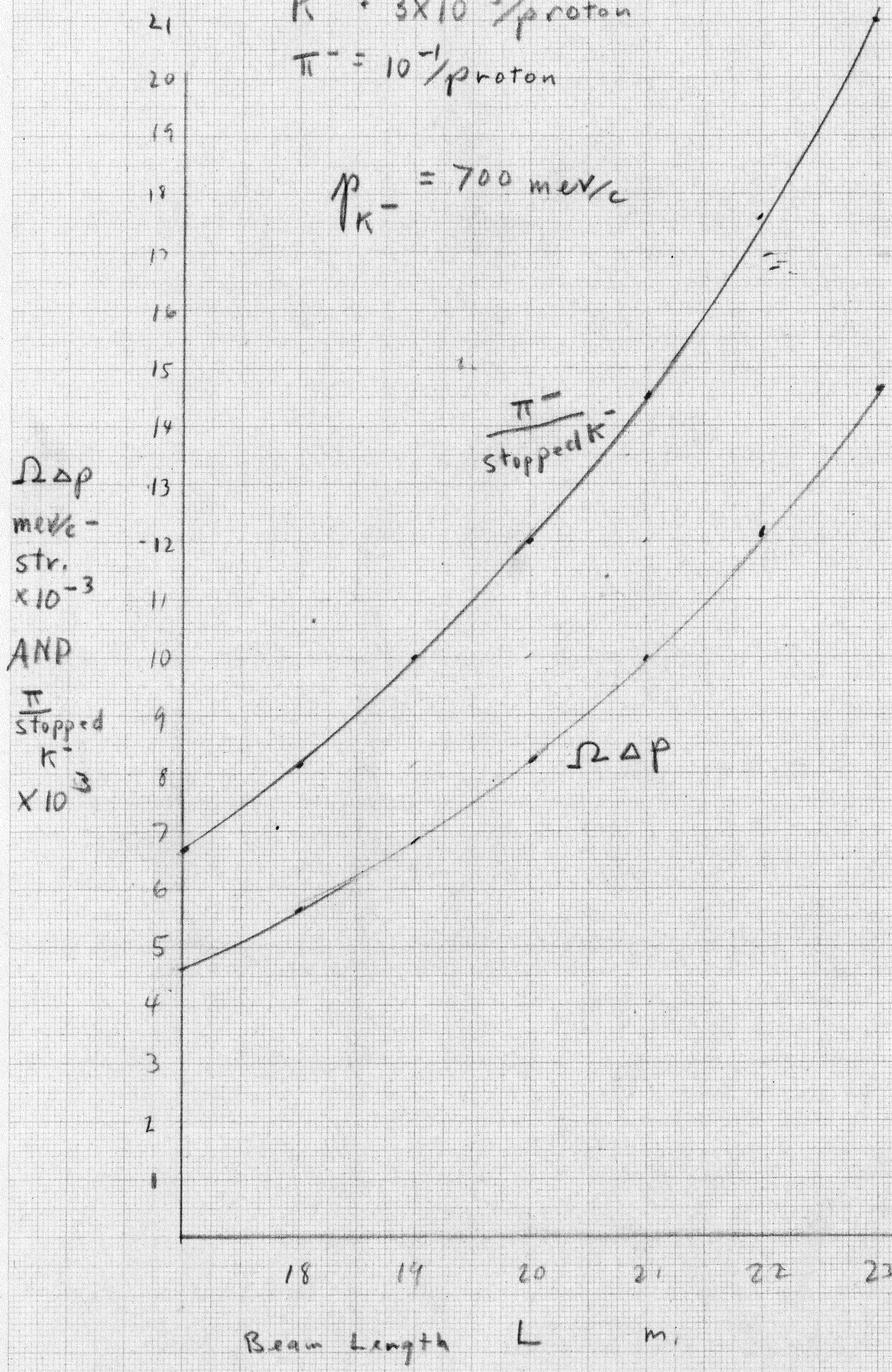
Fig. 1



L=18 m
L=21 m
K⁻ stop / 10¹¹ p
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
p_K

Fig. 2



K⁻ : 3×10⁻³/proton
π⁻ = 10⁻¹/proton
p_K⁻ = 700 mev/c
π⁻ / stopped K⁻
ΩΔp
ΩΔp mev/c - str. ×10⁻³ AND π / stopped K⁻ ×10³
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
18
19
20
21
22
23
Beam Length L m.

NORTH HALL