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PROPOSAL FOR AN EMULSION EXPERIMENT

SEPARATION OF Ξ^- PARTICLES BY MEANS OF A PULSED MAGNETIC FIELD

by

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The aim of the experiment is to separate Ξ^- particles from the background by means of a pulsed 200 KGauss magnetic field and to study Ξ^- capture events in emulsions.

The experimental arrangement is shown in Fig. 1a of the Appendix. A K^- beam enters the magnetic coil through a hole of 1.1 cm diameter (between the two Helmholtz-coils) and hits a target of heavy material. The reaction products have to pass a gap of 1.3 cm before reaching the emulsion; they are bent by the the 200 KGauss field according to their momenta and electric charge. A one-side collimator in front of the coil protects the emulsions against direct K interactions of the beam fringe.

The scanning procedure is described in the Appendix. The gap length of 1.3 cm provides "partial separation". The number of p tracks to be discarded is estimated at 20/1 Ξ^-. There will be additionally some Σ^-, Σ^+, K^+.

Coils. Two magnetic coils are ready for the experiment. They have been tested. These coils are of the type which has been constructed in the CERN emulsion group where they have been used for several exposures; they can stand about 300 pulses each at 200 KGauss.

Beam requirements. We do not know yet, which beam to use; we will report on this question at the first session of the Emulsion Committee in 1965.

Requirements: Separated K^- beam, momentum between 1.4 and 2.0 GeV/c. The intensity should be as high as possible, at least several thousand K^-/pulse; the beam should be collimated to about 1 cm^2. Solid angle and momentum bite could be large. Good separation is desirable; a π^- contamination of x per cent would increase the scanning effort roughly by x per cent.

Emulsions. 1200µ Ilford K5 emulsions will be used. We intend to load the emulsions with lithium in order to increase the probability of finding double hyperfragments.

Rate of Ξ^- captures. 1 Ξ^- coming to rest in the scanning region per 8×10^5 incident K^- on the target is expected. Since the two coils are supposed to give 6×10^3 pulses, one should get about 7 stopping Ξ^- for 1000 K^-/pulse. The scanning rate is estimated at 1 Ξ^-/2 scanner days.

Machine time required. 3 shifts in 9 (pulse rate every 12 or 15 sec) for the run + additional shifts (low intensity) for the beam.

Manpower: 4 physicists, 6 scanners.

APPENDIX

The "Hyperon Beam"

The measurement of the curvature of particle tracks in emulsions is too complicated for scanning purposes even when pulsed high magnetic fields are applied. An easy separation of one kind of particles from the background is possible when the particles produced on a target pass through a strong magnetic field before reaching the emulsion; the particles can be identified by incident angle measurements and grain counting over one field of view in the microscope, provided the target dimensions are small compared to the distance between the target and the emulsion. If, however, one wants to separate hyperons produced by a K^--beam, the target has to be large in order to give reasonable intensities, and the distance has to be small for the short-lived hyperons, at least for the low-momentum particles.

We shall show how complete or partial separation from the background of $\pi^\pm$, K^-, p is possible for negatively charged hyperons. Two procedures will be described. The first one uses a grain density cut-off for small grain densities and separates low-momentum hyperons which can stop in the emulsion (capture events). The second procedure uses a momentum cut-off for small momenta and separates high-momentum hyperons (decays, interactions in flight).

We shall include in the considerations also the possibilities of detecting Ω^- capture events or decays and of using magnetic fields of 400 KGauss. The beams from external targets to be constructed at CERN in the next two years will provide much higher particle fluxes; it should be possible then to get similar or better production rates for Ω^- as one gets now for Ξ^-. The short burst (2 μsec) of these beams will allow the use of single-turn coils which can produce fields much higher than 200 KGauss.

1. Separation of low-momentum hyperons

The geometry is shown in Fig. 1a. Target and emulsion are parallel to each other and to the beam; they are separated by an air gap.

The Figs. 2a,b show in two examples how the separation is achieved. It is assumed that particles producing tracks of grain density g^* = 4.5 originate at the edge of the target. The corresponding momenta are: $p(\pi)$ = 55, $p(K)$ = 190, $p(p)$ = 350, $p(\Sigma)$ = 450, $p(\Xi)$ = 500, $p(\Omega)$ = 640 MeV/c. For particles originating inside the target or for particles of higher grain densities the separation will be better.

Fig. 2a demonstrates "partial separation". The magnetic field is assumed to be 200 KGauss, the gap width 1.6 cm. All negatively charged hyperons of g^* = 4.5 enter the emulsion in a narrow angular interval; the incident angle varies very slowly with the emission angle θ; the kinematical limits for θ lie between 20° and 40°, depending on the momentum of the K^--beam. $\pi^\pm$, K^- particles of $g^* \geq 4.5$ cannot enter the emulsion in the angular interval for negative hyperons; protons can enter only if they are emitted at large emission angles out of a small angular interval; for emission angles smaller than 40° the protons cannot enter the emulsion at all. It is evident that the effect of the magnetic field is to concentrate negatively charged particles out of wide intervals of emission angles into small intervals of incident angles; the opposite is true for positively charged particles. The relatively small number of protons which enter in the interval for hyperons can be excluded by track following over some length and determining the sign of the electric charge.

Fig. 2b demonstrates "complete separation". The magnetic field is assumed to be 400 KGauss, the gap width 2 cm, the grain density again 4.5. $\pi^\pm$ cannot reach the emulsion, while K^- can enter only in backward direction including K^- starting at θ = 0°. Protons can enter at very flat incident angles for emission angles $\theta > 60°$ (the kinematical limit for θ is 90° in the high energy limit). The negative hyperons enter in an interval completely free from $\pi^\pm$, K^-, p; they are even separated from one another. Taking into account also hyperons originating inside the target and of higher grain densities, the regions for Σ^-, Ξ^-, Ω^- will partially overlap.

The variable parameters in this procedure are the grain density cut-off, the gap width and the momentum of the K^--beam. The cut-off and the gap width are both a compromise between a good separation and a high hyperon intensity. A lower limit for the grain density cut-off is given by the maximum possible ranges of the desired particles which one wants to stop in the emulsion.

Only a small fraction of the hyperons produced in the target will come to rest in the emulsion:

a) Only the low-momentum tail of the spectrum is used; reduction factor about 0.1 - 0.2.

b) A fraction 0.2 of the full solid angle can be used, taking into account the "concentration effect" of the magnetic field: a part of the particles starting into other directions are bent into the direction of the emulsions.

c) Most of the hyperons will decay before coming to rest. Only a fraction 2 - 15% will be captured at the end of their ranges.

The present beam conditions at CERN (intensities, burst length) can give good numbers for Σ^- captures. For Ξ^- captures the present conditions are just above the threshold where the experiment becomes feasible. From beams with higher K^- intensities (order 10^5/pulse) one could get large samples of Ξ^- capture events. For Ω^- the necessary beam intensities would be greater by a factor 100 than those for Ξ^-, assuming a production cross-section of 2μb. Since the background would be very high, "complete separation" would be necessary. This would require fields higher than 200 KGauss unless is turned out that the lifetime of the Ω^- is relatively long ($\gtrsim 2.5 \times 10^{-10}$ sec.).

2. Separation of high-momentum hyperons

The geometry is shown in Fig. 1b. The emulsions are placed in the space between the two Helmholtz-coils.

Example for the scanning procedure: the two trajectories drawn in Fig. 1b correspond to two 700 MeV/c momentum particles of opposite electric charge in a magnetic field of 200 KGauss. If we take the angular interval between the incident angles of these particles as scanning region, then we have a momentum cut-off for momenta $\lesssim$ 700 MeV/c (the limits are slightly smeared out according to the finite target size.).

To this momentum cut-off correspond the following grain density cut-offs: $g^{*}(\pi,K) = 1$, $g^{*}(p) \leq 1.8$, $g^{*}(\Sigma) \leq 2.3$, $g^{*}(\Xi) \leq 2.6$, $g^{*}(\Omega) \leq 4.2$. This means π and K produce minimum tracks, p, Σ, Ξ produce grey tracks or minimum tracks (p and Σ^-, Ξ^- enter from opposite sides), Ω produce black tracks or grey tracks. The high grain density of the Ω is a consequence of the high mass of this particle. This procedure makes much better use of the momentum spectrum than the low-momentum separation; but the useful solid angle and the "effective" target length are smaller.

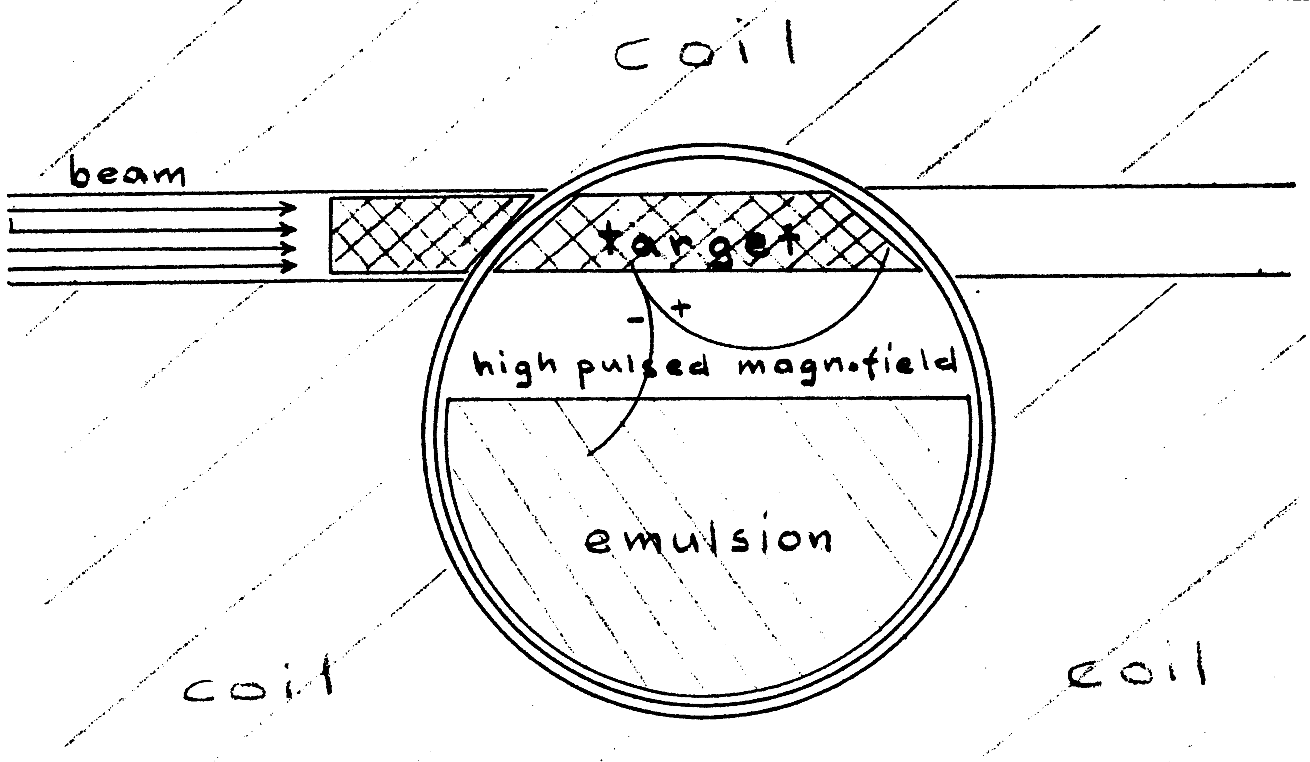
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Fig. 1a

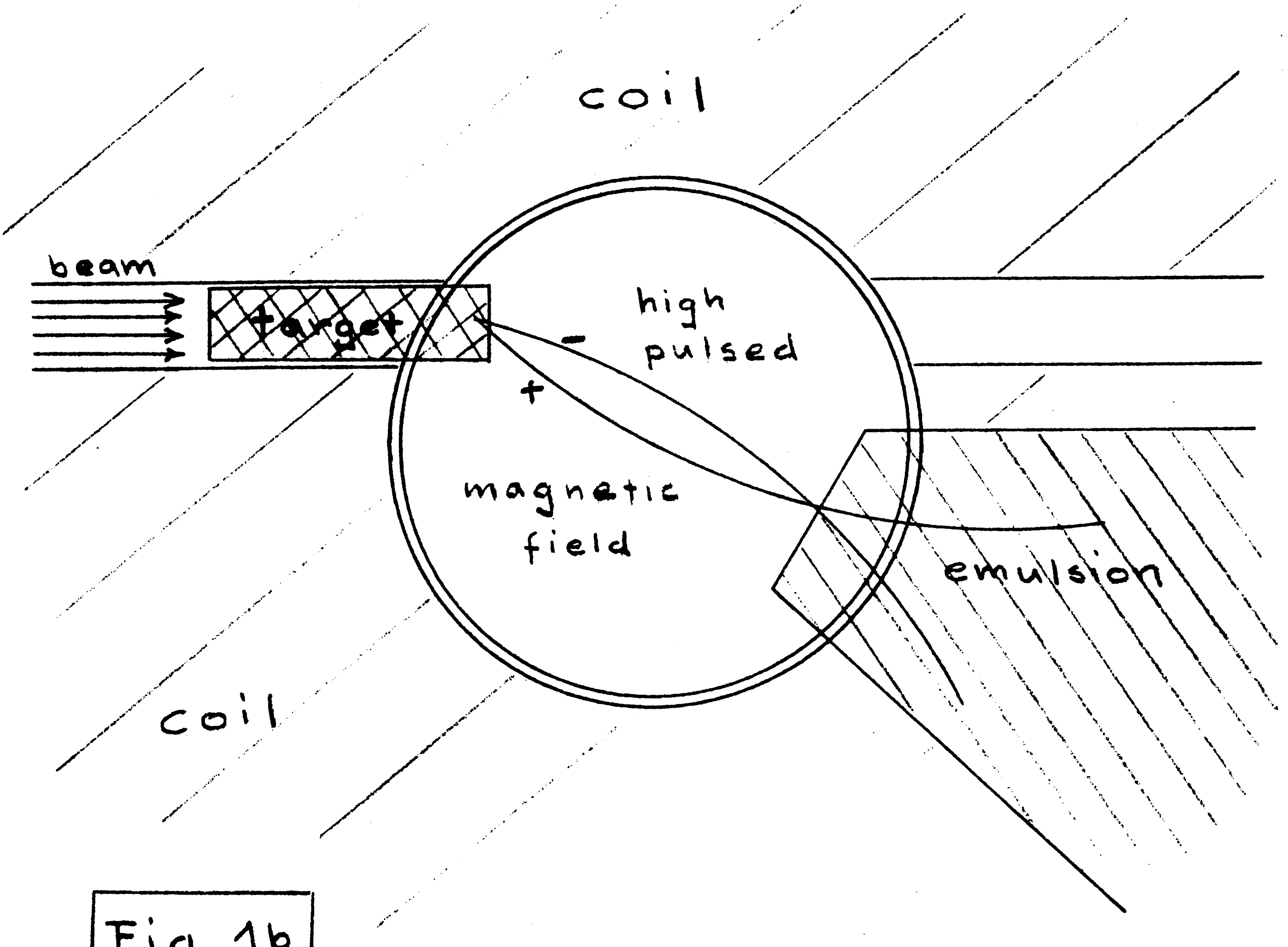
coil
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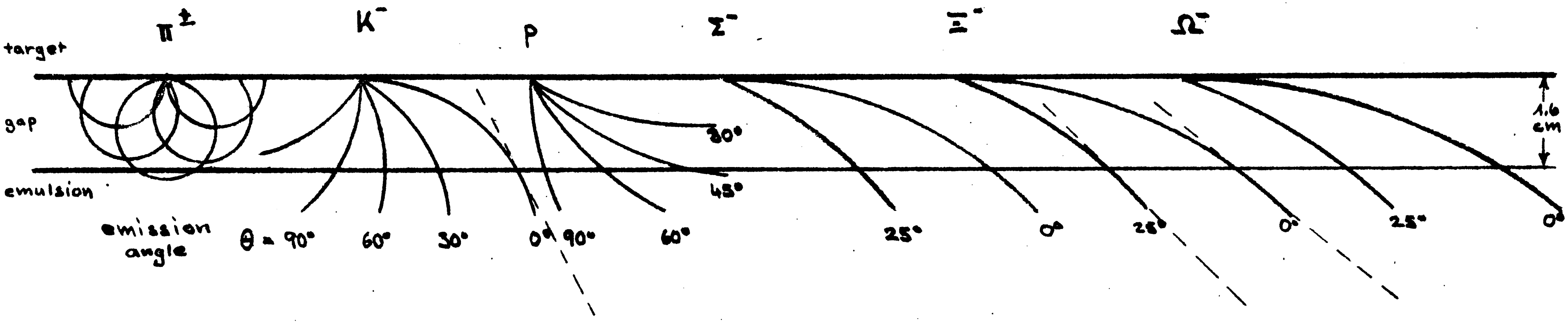
Fig. 1b

Fig. 2a "Partial separation" ($\pi^{\pm}, K^{-}, p$ for $\theta < 60°$) $g^{*} = 4.5$ $H = 200$ KGauss



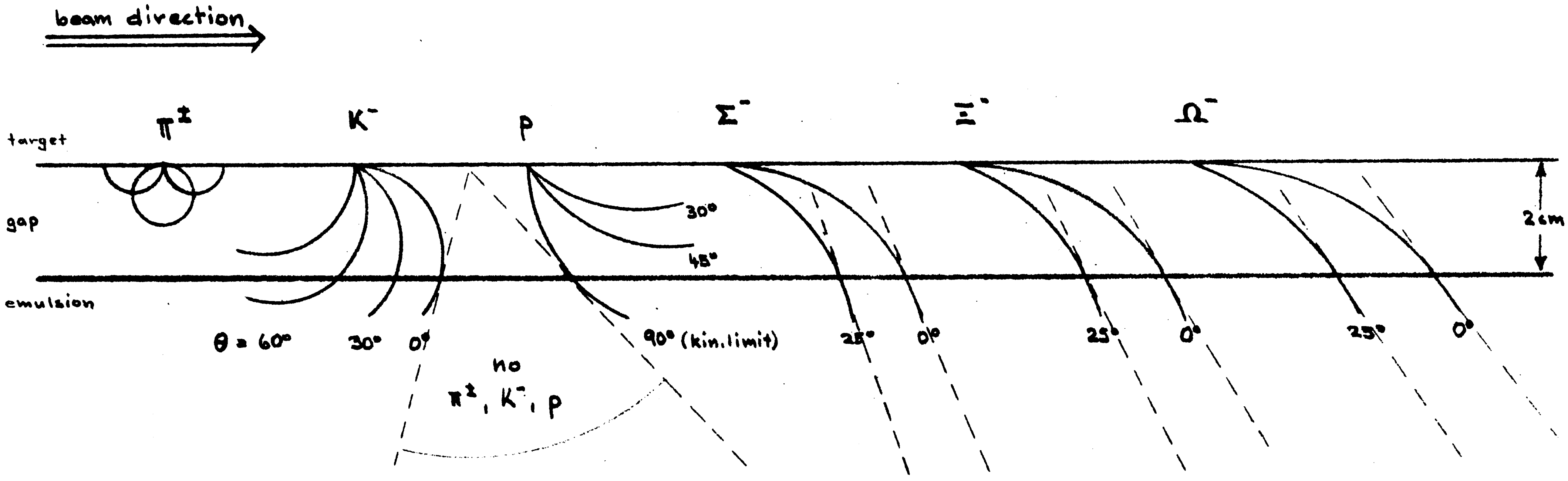


Fig. 2b "Complete separation" ($\pi^{\pm}, K^{-}, p$) $g^{*} = 4.5$ $H = 400$ KGauss