EmC 62/5
16.2.1962

PROPOSAL FOR AN EXPERIMENT TO MEASURE THE MAGNETIC MOMENT OF THE Σ^+ HYPERON

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1. Introduction

The determination of the magnetic moments of the different hyperons is of considerable interest and measurements of the magnetic moment of the Λ^0 hyperon are now in progress[(1)(2)]. The magnetic moments of the charged hyperons are expected to be larger than that of the Λ^0 hyperon. We wish to point out that the conditions presently available at CERN would enable us to measure the magnetic moment of the Σ^+, using essentially the same technique which we are employing to determine the Λ^0 magnetic moment[‡].

These conditions are:

(i) The polarization of the Σ^+ from the reaction

$$\pi^+ + p \rightarrow \Sigma^+ + K^+ \tag{1}$$

is known to approach unity at a π^+ momentum which is below the threshold for 3 particles to be produced in the final state[(3)(4)]. The known asymmetry

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‡ We believe that Cool (Brookhaven) and Peterson (Cal. Tech.) are also considering an experiment to measure the magnetic moment of the Σ^+ hyperon.

in the decay mode

$$\Sigma^+ \rightarrow p + \pi^0 \qquad (2)$$

can be used as an analyser.

(ii) The cross-section for reaction (1) at an incident π^+ momentum of 1.15 GeV/c is 0.26 mb[5][6], which indicates that an adequate yield of Σ^+ particles could be obtained from a target placed in the existing k_1 beam[7].

(iii) CERN coils (type IIIb) are available and have been tested. They can provide a field of 200 Kgauss (pulsed) with a geometry suitable for this experiment.

2. Experimental Method

The arrangement which we propose to use is shown in Fig. 1. A π^+ beam of 1.15 GeV/c momentum (k_1 beam set for π^+ particles) is focussed on to a polythene target. Σ^+ particles produced at angles between 9^o and 18^o (laboratory system) to the beam direction are detected in stacks of nuclear emulsion. These are placed so that they will record Σ^+ decays which occur between 4 and 7 cm from the centre of the polythene target. The path of the Σ^+ particles from their point of production to their point of decay will lie in a transverse magnetic field of 200 Kgauss. The precession, φ_o, of the Σ^+ spin direction in the plane perpendicular to the magnetic field (this plane being nearly the plane of the emulsions - see Fig. 1) is given by:

$$\varphi_o = 4.3 \times 10^5 \mu \frac{Hd}{\beta c} \text{ degrees} \qquad (3)$$

where μ = Σ^+ magnetic moment in Σ magnetons $\left(\frac{e\hbar}{2m_{\Sigma} c}\right)$

H = magnetic field in gauss

d = path length in cm through the field

βc = velocity of the Σ^+ particles.

Taking the mean values of d and β to be 5 cm and 0.54 respectively, we obtain $\varphi_0 = 28^\circ$ for $\mu = 1$ Σ- magneton.

We choose to observe the Σ^+ decay mode $\Sigma^+ \rightarrow p + \pi^0$. The data at present available indicate that there is negligible asymmetry in the decay mode $\Sigma^+ \rightarrow n + \pi^+$ (3)(4).

3. Estimate of the number of events which could be obtained and of the accuracy possible

The polarization is not known of Σ^+ particles produced in a reaction of the type $\pi^+ + n \rightarrow \Sigma^+ + K^0$ which can occur in the carbon of the target. Accordingly, in the calculation below we consider only Σ^+ produced from the effective number of protons in the target. If additional Σ^+ particles from neutrons are not polarized, their effect will be to reduce the observed asymmetry, whilst increasing the number of events found.

The expected number of decays $\Sigma^+ \rightarrow p + \pi^0$ in the emulsions is given by

$$N_{\Sigma^+} = \eta \cdot \sigma \cdot \left(\frac{N}{M}\rho a\right) \cdot \left(\frac{\Omega^*}{4\pi}\right)\left[\frac{1}{2}\left(e^{-\frac{d_1}{\tau\gamma\beta c}} - e^{-\frac{d_2}{\tau\gamma\beta c}}\right)\right] \qquad (4)$$

$\simeq 1.6 \times 10^{-6}$ Σ^+ per incident π^+ meson

where η = effective number of protons per CH_2 ($M = 14$), estimated as $\frac{A^{2/3}}{2} + 2 \simeq 5$

$\left(\frac{N}{M}\rho a\right)$ = number of CH_2 molecules per cm^2 in the target

$\left(\frac{\Omega^*}{4\pi}\right)$ = fraction of solid angle (Centre of Mass system) covered by the emulsion stacks

σ = total production cross-section for the reaction $\pi^+ + p \rightarrow \Sigma^+ + K^+$ (5)

d_1, d_2 = distances from the target centre to the front and back of the emulsion stack respectively

τ = mean life-time of Σ^+ hyperon = 0.83×10^{-10} sec

The precession angle, φ_o, is computed from the number of $\Sigma^+ \rightarrow p + \pi^o$ decays which occur forward (N_F), backward (N_B), right (N_R) and left (N_L), in the rest frame of the Σ^+ particle[1]. Then φ_o is given by

$$\tan \varphi_o = \frac{N_F - N_B}{N_L - N_R} \qquad (5)$$

The statistical uncertainty in φ_o, for a total number of events N is, from (5),

$$\delta \varphi_o \simeq \frac{\pi}{2 \bar{P}\alpha \frac{\pi}{4} \sqrt{N}}$$

If we take $\bar{P}\alpha$ to be at least 0.5 and N = 400 then $\delta \varphi_o \simeq \pm 12^o$, corresponding to an uncertainty in the magnetic moment of the Σ^+, $\delta\mu$, equal to $\pm$ 0.4 Σ- magnetons.

Systematic errors will be reduced by comparing the data from pairs of exposures made using opposite magnetic fields. The sense of rotation of the spin direction can be found from the results from an exposure made with zero magnetic field.

Scanning

Tracks in the emulsions with a grain density and direction corresponding to a Σ^+ particle emitted from the target will be followed and examined for evidence of a decay in flight or at rest. Grain density, curvature and angle measurements will determine the decay parameters.

The proton is emitted at angles up to 26^o in the laboratory system. The grain density, g*, of the Σ^+ particles lies in the range $1.5 \lesssim g^* \lesssim 2$; for the decay protons, g* is greater than 1.3, whereas π^+ mesons will have a g* less than unity if they are to have magnetic curvature (i.e. momentum) which permits them to reach the stack with the correct direction.

Proton tracks arising from pion interactions in the target will have to be followed. They will be a few hundred times more numerous than the Σ^+ particles. Proton contamination in the primary beam would give rise to many scattered protons. It is essential, therefore, to use an incident beam of high purity in π^+ mesons.

A preliminary result could be obtained after three months with the effort of approximately 5 scanners. To reach an accuracy of 0.4 Σ- magnetons, in a reasonable time, more scanning power would be required. This could probably be obtained by enlarging the collaboration to include the group at Bristol University.

Conclusions

The exposure should be made in a beam free from proton contamination, and yielding a flux of at least 5×10^4 π^+ per pulse at 1.15 GeV/c, on a target 1 cm in diameter. The present k_1 beam is suitable for this purpose. The experiment requires about 6 shifts (taking 1 pulse in 5) for optimising the beam and about 4 shifts (taking 1 pulse in 3) for the production run.

References

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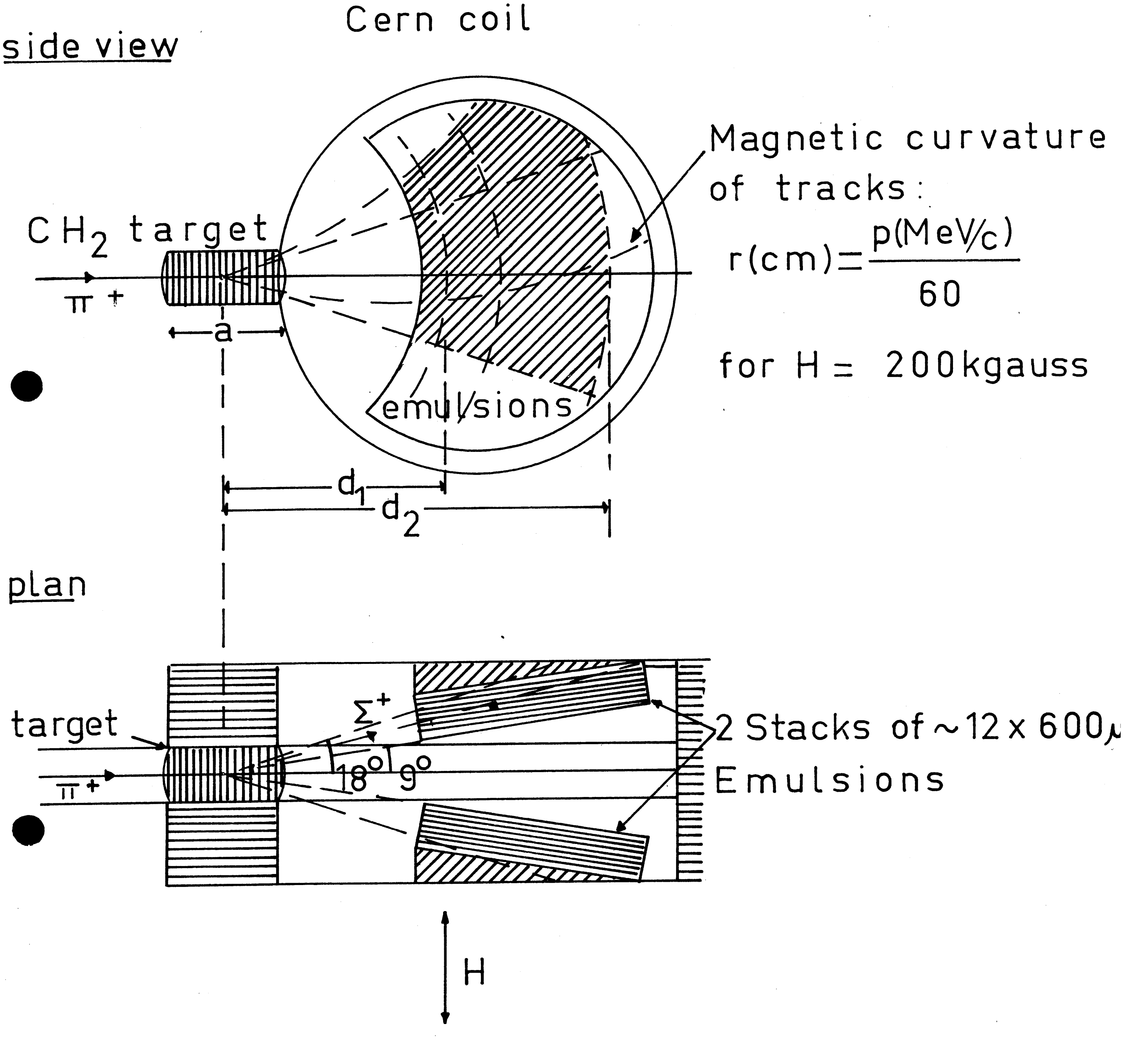
Fig 1



SIS/R/3871