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This paper reports preliminary results from Fermilab experiment E-497 on the magnetic moments of the Σ^+ and Σ^-. The experiment was designed to measure the fluxes and polarizations of the hyperons. It is possible to measure the magnetic moment by measuring the spin precession of a polarized hyperon beam. Results for the fluxes and polarizations are reported separately at this conference[1,2].

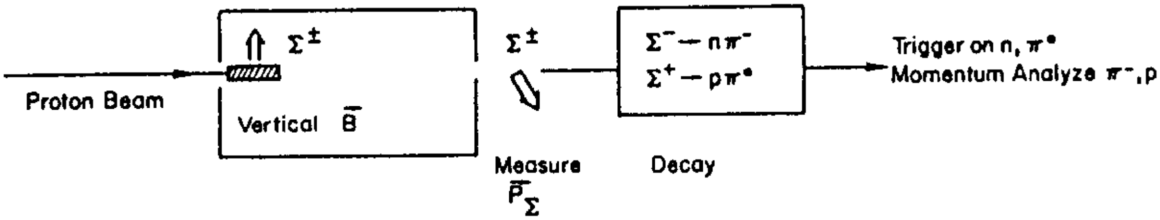

Figure 1. Idea of the Σ magnetic moment experiment.

The idea of the experiment is shown in figure 1. A 400 GeV/c proton beam was incident on a copper target at an angle with respect to the horizontal plane. This angle can be varied between -7 mr and 7 mr. The target is placed at the upstream end of a 7 m long magnet with a field integral of 15 T-m for the Σ^+ data, and 18 and 21 T-m for the Σ^- data. The direction of the polarization of the Σ is parallel (or anti-parallel) to the normal to the production plane and thus lies in the horizontal plane and is initially perpendicular to its momentum. The vertical magnetic field precesses the polarization about the vertical axis. The precession angle θ_p is given by:

$$\theta_p = \frac{(g-2)}{2} \gamma\theta_B \qquad (1)$$

where g is the Lande g factor, $\gamma = E/m$ for the hyperon and θ_B is the bend angle in the magnet. The precession angle θ_p is found by measuring the direction of the polarization of the Σ by analyzing its parity violating weak decay[3]. The decay angular distribution is given by:

$$\frac{dw}{d\Omega} = \frac{1}{4\pi} (1 + \alpha \underline{P} \cdot \underline{\hat{n}}) \qquad (2)$$

where $\underline{P}$ is the polarization vector and $\underline{\hat{n}}$ is a unit vector in the direction of the decay baryon momentum. The value of the constants α are: $\alpha_{\Sigma^+} = -.978 \pm .016$ and $\alpha_{\Sigma^-} = -.069 \pm .008$. The small value of α_{Σ^-} makes an analysis of the Σ^- polarization very difficult, but this difficulty is partially offset by the ease with which Σ^- data can be collected in this experiment (50,000 events per hour). The bend angle θ_B is known from the magnet geometry and γ is known from the magnetic field measurements initially and ultimately from a magnet calibration using the known masses of the hyperons. Thus g can be calculated from (1). Once g is known, the magnetic moment μ_Σ can be calculated:

$$\mu_\Sigma = \frac{Q_\Sigma m_p}{Q_p m_\Sigma} \frac{g}{2} \mu_N \qquad (3)$$

where $Q_p(Q_\Sigma)$ and $m_p(m_\Sigma)$ charge and mass of the proton (hyperon) and $\mu_N = e\hbar/2m_pc$ is the nuclear magneton.

The experimental apparatus is shown in figure 2.

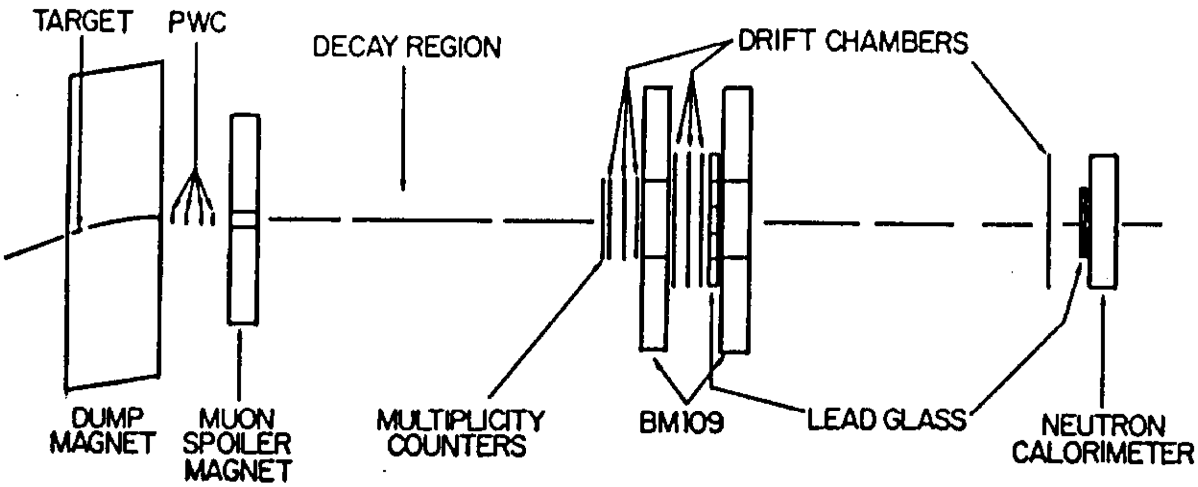

Figure 2. Experimental Apparatus.

The dump magnet is a combined target, proton beam dump and analyzing magnet for the hyperons. A small channel with a 1μsteradian angular acceptance and a 20.5 mr bend defines the hyperon beam. A 20kG field in this magnet yields an approximately 200 GeV/c beam with a full momentum width of $\Delta p/p=\pm 7.5\%$. The 10 proportional wire chamber (PWC) doublet planes measure the beam tracks with an accuracy of 60 μm per plane (provided the particle is not so obnoxious as to decay before the last PWC). The momentum is inferred assuming the particle originated at the center of the target. After a drift space of about 20 m in which nearly all the hyperons decay, the charged secondaries are momentum analyzed by 18 doublet planes of drift chambers with an accuracy of 200 μm per plane. An additional downstream drift chamber improves the accuracy of the measurement of the fast proton from the decay $\Sigma^+\to p\pi$.

The trigger consisted of a beam track plus a neutral particle. The neutral particle was a neutron seen in the neutron calorimeter in the case of the $\Sigma^-\to n\pi^-$ decay and a

γ seen in the lead glass in the case of the decay chain $\Sigma^+ \to p\pi^0$, $\pi^0 \to \gamma\gamma$. The mass resolution (σ) of the apparatus was 7 MeV/c^2 for the Σ^- and 24 MeV/c^2 for the Σ^+, the larger width for the Σ^+ being attributable mostly to the smaller laboratory angles involved for the charged particle in Σ^+ decay.

The analysis of the polarization of the Σ's was made by histograming the direction cosines of the charged decay particle. These were computed from the lab momenta as follows:

$$\cos\theta_t = \frac{P_t}{q} \tag{4}$$

where t stands for either transverse direction (x or y), P_t is the transverse momentum, and q is the center of mass decay momentum. The third direction cosine is:

$$\cos\theta_z = \frac{2(P_z - P_z^{90^\circ})}{(P_z^{max} - P_z^{min})} \tag{5}$$

where P_z is the momentum component parallel to the momentum of the parent hyperon, and $P_z^{90^\circ}$ (P_z^{max}, P_z^{min}) is the z component of the momentum for a decay at cos90° (cos0°, cos180°). We have assumed that the observed angular distributions are given by

$$\frac{dw}{d(\cos\theta_i)} = \frac{1}{2} A(\cos\theta_i)\ (1+\alpha P_i \cos\theta_i) \tag{6}$$

where (6) differs from (2) by projection onto the ith axis and by inclusion of the funtion $A(\cos\theta_i)$, which includes the effects of experimental acceptance and efficiency. The function $A(\cos\theta_i)$ is not well known *a priori*, but it can be measured experimentally. The data for this experiment was taken with symmetric targeting angles: ±2.5 mr, ±5.0 mr, and ±7.5 mr. When the angle of the incoming proton beam is reversed, P_i changes sign. $A(\cos\theta_i)$, however, should remain the same since the apparatus is unchanged. Thus, by dividing the distribution $dw/d\cos\theta_i$ for positive targeting angle by that for negative targeting angle the common factor $A(\cos\theta_i)$ in (6) can be eliminated and one can find P_i.

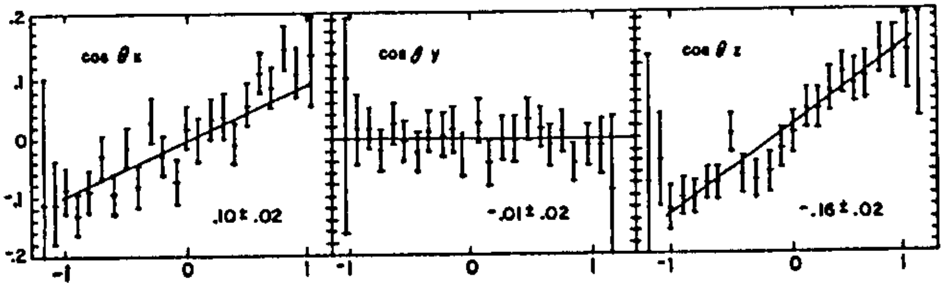

Fig. 3. Σ^+ projected angular distributions for 200 GeV/c Σ^+ produced at 5 mr. The fitted slopes and their statistical errors are shown on each projection.

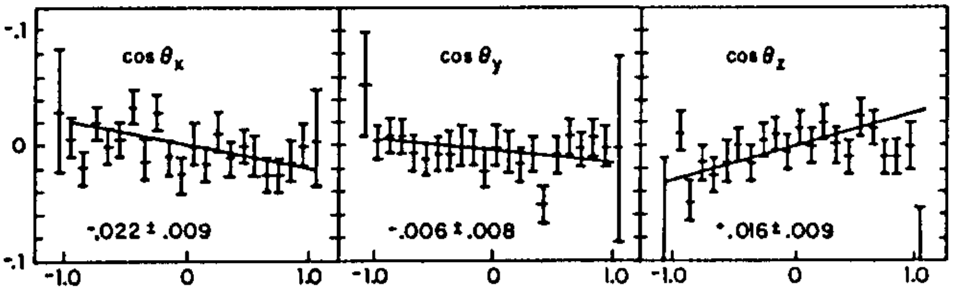

Fig. 4. Σ^- projected angular distributions for 250 GeV/c Σ^- produced at 5 mr. The fitted slopes and their statistical errors are shown on each projection.

Figure 3 shows the result of this procedure for the Σ^+ ±5 mr data (6,000 events). The data are described well by the straight line fits shown, and the polarization is statistically significant. Figure 4 shows a similar plot for the Σ^-. While the straight lines provide adequate fits to the data, the slopes are significant by only 2 standard deviations. it was decided somewhat arbitrarily, to include only data in the region $-0.8<\cos\theta_i<0.8$. While this is of little importance for the Σ^+, a somewhat different slope would be obtained for the Σ^- $\cos\theta_z$ distribution if data with larger $\cos\theta_z$ were included.

An analysis of 40K Σ^+ events from 8 different targeting angles (4 positive and 4 negative) yields consistent results with the magnetic moment:

$$\mu_{\Sigma^+} = 2.368 \pm .014 \pm .04 \text{ nuclear magnetons}$$

where the first error is statistical and the second is systematic. Because the precession angle θ_p is measured modulo 2π and the sign of the initial polarization is unknown, magnetic moments differing by multiples of .677 are equally likely based on data from this experiment, but these other values are not consistent with the previous world average of 2.33 ± 0.3[4]. The systematic error is a crude estimate of the errors in magnetic field calibration and acceptance cancellation. We expect to be able to reduce the systematic error by making a more detailed analysis. R. Handler, et al. have reported the result $\mu_{\Sigma^+} = 2.31 \pm .027$[5] where the error is statistical only.

The analysis of the Σ^- moment is based on 170K events from ±5mr at 250 and 300 GeV/c hyperon momenta. The results from the two momenta are consistent ($\chi^2=1.07$ for 1 d.o.f.) and yield:

$$\mu_{\Sigma^-} = -1.180 \pm .028 \pm ?? \text{ nuclear magnetons}$$

where the error is statistical only. Only 15% of all the

Σ^- data have been analyzed and it will not be possible to give a systematic error on this result until more data has been processed.

Since data are available with two different values of magnetic field integral and since the sign of the initial polarization is measured in this experiment[1], most of the $\pm n\pi$ ambiguities in the measured value of θ_p are unlikely. A second solution, $\mu_{\Sigma^-} = -.206$, has a $\chi^2=2.65$ for 1 d.o.f. compared with $\chi^2=1.07$ for $\mu_{\Sigma^-} = -1.180$. No other solution with $-6.5<\mu_{\Sigma^-}<5.0$ has a $\chi^2<10$. The previous world average for the Σ^- is $-1.4\pm.25$[6] and R. Handler, et. al[5] have reported $-.89\pm.14$ where the error on the last number is statistical only.

The reader is cautioned that we are not yet able to quote a systematic error for the Σ^- magnetic moment. Note also that the statistical error for the Σ^- is deceptively small because the anomolous magnetic moment, which we measure, is small relative to the Dirac moment. We do, however, have some confidence that the systematic error is not too large because of the consistency of the measurements of polarization under different experimental conditions (see ref. 1).

This experiment has reported preliminary results for the Σ^+ and Σ^- magnetic moments. Further calibration and studies of our analysis procedures should allow a reduction of the systematic error on μ_{Σ^+} by a factor of 4 or so. Analysis of the remaining Σ^- data should allow a statistically highly significant result and an opportunity to understand the systematics better. Data are also available which should allow a determination of the Ξ^- magnetic moment.

1. P.S. Cooper, et al., this conference.

2. L.J. Teig, et al., this conference.

3. Note that θ_p can only be measured modulo π. The sign of the initial polarization is not measured, nor is the number of complete (2π) revolutions measured. Another phase of the experiment did measure the initial polarization of the Σ^-.

4. R. Settles, et al., Phys. Rev. D 20 , 2154 (1979).

5. R. Handler, et al., this conference.

6. B.L. Roberts, et al., Phys. Rev. D, 12 , 1232 (1975) and G. Dugan, et al., Nucl. Phys., A254 , 396.