MAGNETIC MOMENTS OF CHARGED HYPERONS

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ABSTRACT

Measurements of the magnetic moments of the Ξ^-, Σ^+ and Σ^- baryons are presented. The values found are $\mu_{\Xi^-} = -.69 \pm .04$, $\mu_{\Sigma^+} = 2.31 \pm .027$ and $\mu_{\Sigma^-} = -.89 \pm .14$, in units μ_N. The Ξ^- and Σ^- results are final, while the Σ^+ value is based on a preliminary analysis of about 22% of the data sample.

EXPERIMENTAL PROCEDURE

Figure 1 is a plan view of the spectrometer for the Ξ^- magnetic moment measurement.[1] It was modified somewhat for the Σ^+ and Σ^- runs. Four hundred GeV protons with momentum $\vec{k}_i$ were steered onto a 1/2 interaction length Be target 7 mm in diameter, either coming up from below the average beam height (positive production angles) or coming down from above (negative production angles). Data were taken at ± 7.5 mrad and ± 5 mrad. The xyz axes at production were chosen such that $\hat{z}$ was parallel to the hyperon momentum $\vec{k}_f$, $\hat{y}$ was vertical, and $\hat{x}$ was along the production plane normal $\hat{n} = \vec{k}_i \times \vec{k}_f / |\vec{k}_i \times \vec{k}_f|$ for positive production angles.

The magnet M2 defined the charged hyperon beam by a 10 mrad deflection in the xz plane. The Be target, a 4 mm dia hole in a W collimator at 3 m, and a 1 cm dia hole in a W collimator at the magnet exit at 5.3 m defined the orbits. The coordinate system rotated in the xz plane with the charged hyperon momentum vector. Charged particles downstream of M2 were detected by a scintillation counter S_1, MWPC's C_1 and C_2, and drift Chambers D_1, D_2, and D_3. The charged particle daughters from hyperon decay were detected in MWPC's C_3-C_8, with the measured bend in the xz plane in M_3 used to determine their momenta. The geometry constrained the hyperon spin to lie in the xz plane to within $\sim$ 1/2 mrad. The spin precessed in

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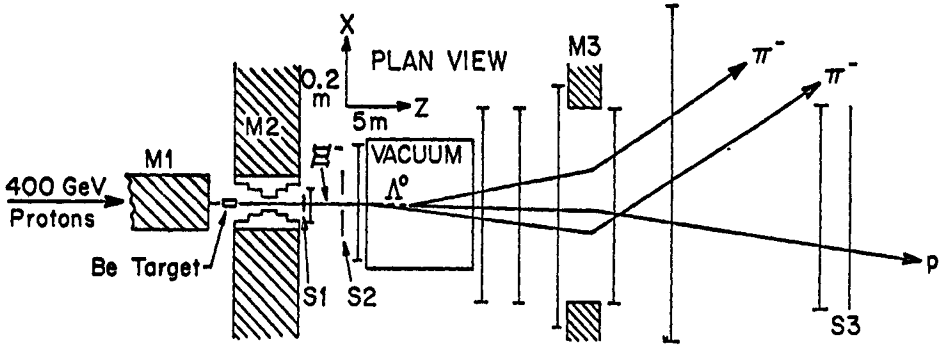

Figure 1. Experimental arrangement for the Ξ^- magnetic moment. M's are bending magnets. The 10 mrad bend in M2, where the spin was precessed in the plane of the drawing, is not shown. The drift chambers D_1-D_3 mentioned in the text were placed between S_1 and S_2. The MWPC's are shown as window frames, and go in increasing order from the left C_1 through C_8..

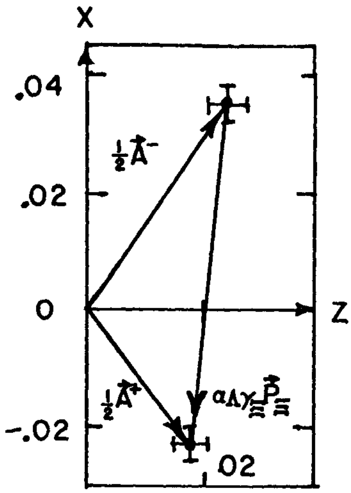

Figure 2. Ξ^- polarization: vector asymmetries obtained from daughter Λ decay in the xz plane for positive and negative production angles. The difference vector is proportional to $\vec{P}_\Xi$.

M2 according to the formula $\phi = 18.3° (g/2-1)\, m_p/m_Y \int Bdl/\beta$, where the field integral is in Tm, and β is the hyperon velocity in units of c. Reversal of the production plane normal reversed the spin direction everywhere in space, enabling a cancellation of instrumental biases.

Ξ^- RESULTS

Ξ^-'s were detected via the decay mode:

$$\Xi^- \rightarrow \Lambda° + \pi^-,\ \Lambda° \rightarrow p + \pi^-.$$

The trigger for this event looked for a single particle at S_1, at least one particle in both the left and right part of C_7 and a stiff positively charged particle in C_8. After kinematic fitting and fiducial cuts we had a sample of 215K such events: 145K taken with a precession field of 6.6 Tm and 70K taken with a precession field of 5.13 Tm.

The polarization $\vec{P}_\Xi$ of the Ξ^- was inferred from examining the asymmetry vector $\vec{A}_p$ of the proton resulting from the decay of the daughter Λ. This vector is defined by the angular distribution in the Λ rest frame of the protons:

$$\frac{dN_p}{d\Omega} = 1 + \vec{A}_p \cdot \hat{p}_p$$

where $\hat{p}_p$ is a unit vector in the proton direction and $\vec{A}_p$ is a function of $\vec{P}_\Xi$. In particular one can show that the difference in $\vec{A}_p$ for positive and negative production angles, integrated over our acceptance is given by:

$$\frac{1}{2}\,[\vec{A}_p(\vec{P}_\Xi) - \vec{A}_p(-\vec{P}_\Xi)] = .975\ \alpha_\Lambda\ \gamma_\Xi\ \vec{P}_\Xi,$$

where α_Λ is the Λ asymmetry parameter and $\gamma_\Xi = +\sqrt{1 - \alpha_\Xi^2}$.

Figure 2 shows $\vec{A}_p$ for positive and negative production angles and the inferred direction of $\vec{P}_\Xi$ for positive production angles after precession through the 6.6 Tm field of M_2. The precession angle Φ depends on whether the initial polarization was in the positive or negative $\hat{x}$ direction and how many additional multiples of 2π it may have precessed in M_2. In order to resolve the sign ambiguity, we took some data with a precession field of 5.13 Tm. The only solution consistent with both sets of data corresponded to the case where the initial polarization was in the negative $\hat{x}$ direction and the precession was through a small clockwise angle (opposite from its bend). When the 6.6 Tm and 5.13 Tm data are combined, the results correspond to $\mu_{\Xi^-} = -.69 \pm .04$, with the quoted error being purely statistical.

Σ^+ EVENTS

Σ^+'s were detected via the decay string $\Sigma^+ \rightarrow p + \pi^\circ$, $\pi^\circ \rightarrow \gamma + \gamma$.[2] To observe this event a lead glass array was added to the basic spectrometer behind C_8 to detect the final state γ's. This array had a hole in it so that the proton would not be detected. The trigger for a Σ^+ event consisted of a charged particle at S_1 and in the lead glass hole plus a neutral in the lead glass.

While the lead glass gives both the position and energy of the γ's, this information was not used in the following results. In this preliminary analysis sample selection was done purely on the charged particle data, where chamber hits were tested against the kinematics of the $\Sigma^+ \rightarrow p$ decay. Events consistent with this pattern were used to determine $\vec{A}_p$ the proton asymmetry in the Σ^+ rest frame.

As in the Ξ^- case the proton asymmetry vector was defined through the proton angular distribution via the equation $\frac{dN_p}{d\Omega} = 1 + \vec{A}_p \cdot \hat{p}_p$. Here since the distribution of a decay product is being observed directly $\frac{1}{2}(A_p(\vec{P}_{\Sigma^+}) - A_p(-\vec{P}_{\Sigma^+})) = \alpha_{\Sigma^+} \vec{P}_{\Sigma^+}$ where α_{Σ^+} is the asymmetry parameter of the Σ^+ decay $= -.97$. Since α_{Σ^+} is negative this difference is in the opposite direction from $\vec{P}_{\Sigma^+}$.

Figure 3 shows our Σ^+ results. The only one of the ambiguous solutions consistent with previous measurements of the Σ^+ magnetic moment corresponds to an initial polarization in the + $\hat{x}$ direction and a counter clockwise precession of 183.4° in the 6.6 Tm field. This implies $\mu_{\Sigma^+} = 2.31 \pm .027$.

Σ^- EVENTS

Here we were looking for the decay $\Sigma^- \rightarrow \pi^- + n$. A two absorption length long steel plate scintillator sandwich with a charged particle veto and 10 cm of lead glass in front of it was stationed in the neutral beam downstream of C_8. The signature for a neutron was a series of counts in the scintillation counters with nothing in the veto and pulse height less than a set threshold in the lead glass. A detected neutron plus a particle in S_1 and the negative particle side of C_7 caused a Σ^- trigger.

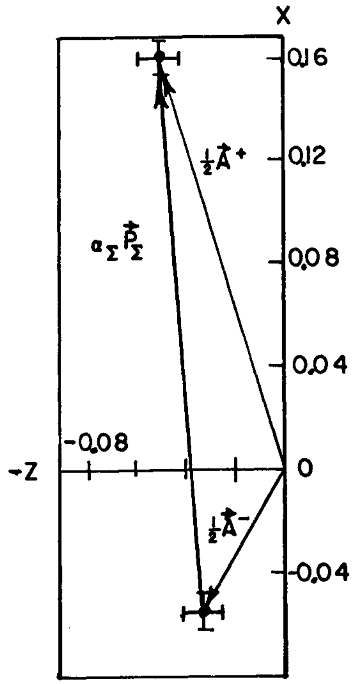

Figure 3. Σ^+ polarization: vector asymmetries in $\Sigma^+ \rightarrow p\pi^\circ$ in the xz plane for positive and negative production angles. The difference vector is proportional to $-\vec{P}_{\Sigma^+}$.

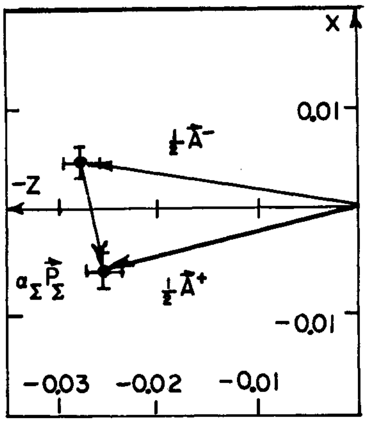

Figure 4. Σ^- polarization: vector asymmetries in $\Sigma^- \rightarrow n\pi^-$ in the xz plane for positive and negative production angles. The difference vector is proportional to $-\vec{P}_{\Sigma^-}$.

As for the Σ^+, the relation between the neutron asymmetry vector $\vec{A}_n(\vec{P}_{\Sigma^-})$ and the Σ polarization $\vec{P}_{\Sigma^-}$ for positive production angles is:

$$\frac{1}{2}\left[\vec{A}_n\ (\vec{P}_{\Sigma^-}) - \vec{A}_n\ (-\vec{P}_{\Sigma^-})\right] = \alpha_{\Sigma^-}\ \vec{P}_{\Sigma^-}$$

with $\alpha_{\Sigma^-} = -.068 \pm .008$. The small value of α_{Σ^-} means that we are looking for a much smaller signal than was observed in the Ξ^- and Σ^+ data.

Figure 4 shows our Σ^- results. As expected the signal is small but is statistically significant. The initial direction of $\vec{P}_{\Sigma^-}$ which leads to the value $\mu_{\Sigma^-} = -.89 \pm .14$ is in the positive $\hat{x}$ direction corresponding to a counter clockwise precession of 11.4° ± 15°.

References

1) The Ξ^- and Σ^- results are presented in two PhD theses: R. Rameika and L. Deck, both Rutgers University Theses (1981).

2) C. Wilkinson, et al Phys Rev Lett 46, 803 (1981).