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Abstract

The $\Sigma^+$ magnetic moment has been measured and found to be 2.1 ± 1.0 nuclear magnetons by observing the precession of polarized sigmas in a magnetic field of 18.7 kG. The value is in agreement with SU(3) predictions.

An exposure of $1.3 \times 10^6$ pictures in the Berkeley 25-inch hydrogen bubble chamber yielded 39 000 polarized $\Sigma^+$ in which the entire reaction sequence of $K^-p \to \Sigma^+\pi^-$, $\Sigma^+ \to p\pi^0$ was observed and analyzed. The incident momenta of the $K^-$ beam ranged from 300 to 450 MeV/c.

The sigmas produced in this region are well polarized from interference between a resonant $D_{3/2}$ amplitude, $Y_0^*(1520)$, and a dominant S-wave background. The polarizations determined directly from a partial sample of these events were reported previously.[1] The mean magnitude of polarization for the events used in this determination was 0.44. The value used for the decay asymmetry parameter $\alpha$ was -0.986.[1]

In order to avoid contamination from other reactions only those events satisfying the following criteria were accepted:

(i) Event initially identified by the scanner as $\Sigma^+ \to p\pi^0$.

(ii) Confidence level for the overall fit greater than .01.

(iii) $\Sigma$ length > 1 mm.

(iv) $\Sigma$ decay occurred in flight.

(v) If the decay proton came to rest in the chamber the track length was required to be > 0.6 cm, otherwise it was required to be > 5 cm.

At a certain production angle there is a kinematical ambiguity between the above reaction and $K^-p$ elastic scattering followed by small-angle proton scattering with an invisible recoil. This ambiguity can be eliminated by inspection of the ionization of the negative track. All events with a $\Sigma$ lifetime greater than seven mean lives were reexamined along with those from four to seven mean lives that fell in the kinematically ambiguous region. A small number of false events were thereby eliminated.

All the above conditions reduced our sample to 29 333 events with a mean $\Sigma$ length of 1.01 cm. The lifetime distribution of the weighted events is in agreement with the accepted mean life of $0.81 \times 10^{-10}$ sec.

In the 18.7-kG magnetic field of the bubble chamber the precession of the polarization about the field direction has a value of $0.83\ \mu_\Sigma \sin\theta$ degrees per mean life, where $\mu_\Sigma$ is the $\Sigma$ magnetic moment measured in nuclear magnetons $(e\hbar/2m_pc)$ and $\theta$ is the angle of inclination of the $\Sigma$ polarization to the magnetic field. The mean precession angle for all events is found to be 1.46 deg. In order to study possible systematic biases associated with the measurement of this angle we have investigated the average of the residuals found in the kinematical fitting of each event, and found them to be small compared with the measurement uncertainties. Since the average measurement uncertainty of the decay angle of the proton with respect to the polarization is 1.15 deg, we conclude that systematic biases are small compared with 1.15 deg and are therefore small compared with the average precession angle.

In the $\Sigma$ rest frame the polarization three-vector $\underset{\sim}{S}$ precesses according to the relation

$$\frac{d\underset{\sim}{S}}{d\tau} = \frac{\mu_\Sigma e}{m_p c} \underset{\sim}{S} \times \underset{\sim}{H} . \tag{1}$$

In the laboratory system the expression for the polarization four-vector becomes[2]

$$\frac{dS_\lambda}{d\tau} = -\frac{\mu_\Sigma e}{m_p c}[F_{\lambda\sigma} - \frac{1}{m_\Sigma^2 c^2} p_\lambda p^\gamma F_{\gamma\sigma}]S^\sigma - \frac{1}{m_\Sigma^2 c^2} p_\lambda S_\sigma \frac{dp^\sigma}{d\tau} . \tag{2}$$

For each event and for some assumed value of $\mu_\Sigma$, the precession of the polarization four-vector in the lab was integrated for a time interval corresponding to the decay time of the event; the precessed four-vector was then transformed into the $\Sigma$ rest frame at decay. A likelihood function was constructed from the $\Sigma$ decay distribution $(1 + \alpha \underset{\sim}{S}(\mu_\Sigma)\cdot \hat{q})$, where $\hat{q}$ is the decay proton direction in the $\Sigma$ rest frame at decay. The value of $\mu_\Sigma$ was varied, giving a likelihood function with a maximum at $\mu_\Sigma = 2.1 \pm 1.0$ nuclear magnetons.

We have performed the following checks to confirm within the limits of our statistics that the precession observed is real:

1. The magnetic field was assumed, for the purpose of precession, to be perpendicular to the actual field, i.e., both along the beam and perpendicular to the beam. In both cases the measured "magnetic moment" was consistent with zero.

2. The data were divided into four intervals of $\cos\theta$, and the magnetic moment was calculated for each interval separately. Figure 1a shows that they agree with each other.

3. The magnetic moment was also determined for various lifetime intervals and the results, which again are consistent, are shown in Fig. 1b.

Our value is in agreement with previous measurements;[3-6] combining all measurements gives a world average $\mu_\Sigma = 2.6 \pm 0.5$. Neglecting mass differences, SU(3) leads to the prediction $\mu_\Sigma = \mu_p = 2.79$ (Ref. 7), whereas a correction for mass differences suggests (Ref. 8) $\mu_\Sigma = \frac{m_p}{m_\Sigma} \mu_p = 2.20$.

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## Footnotes and References

*This work was done under auspices of the U. S. Atomic Energy Commission.

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$$\frac{dp^\lambda}{d\tau} = \frac{e}{m_\Sigma c} p^\sigma F_\sigma^\lambda + \frac{p^\lambda}{|\underset{\sim}{p}|} \frac{d|\underset{\sim}{p}|}{d\tau} \quad \text{for } \lambda = 1, 2, 3,$$

$$\frac{dp^4}{d\tau} = \frac{e}{m_\Sigma c} p^\sigma F^4_\sigma + \frac{|\underset{\sim}{p}|}{p^4} \frac{d|\underset{\sim}{p}|}{d\tau} .$$

Here the first terms arise from the Lorentz force and the second terms from the momentum loss due to ionization.


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## Figure Legend

Fig. 1. Magnetic moment of the $\Sigma^+$ in nuclear magnetons as determined from different data samples: (a) for various intervals of $\cos\theta$, where $\theta$ is the angle of inclination of the $\Sigma$ polarization with respect to the magnetic field, (b) for various intervals of $\Sigma$ lifetime.

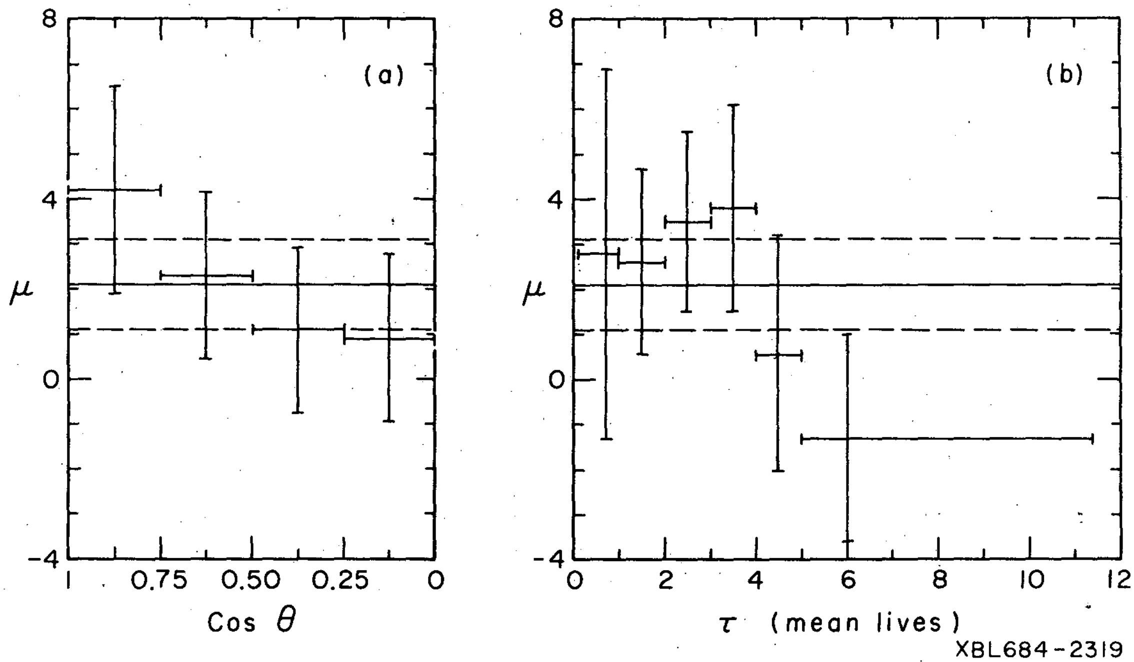
8
(a)
4
μ
0
-4
1
0.75
0.50
0.25
0
Cos θ
8
(b)
4
μ
0
-4
0
2
4
6
8
10
12
τ (mean lives)
XBL684-2319

Fig. 1