Fermi National Accelerator Laboratory

FERMILAB-Conf-85/65
2085.000

HYPERON POLARIZATION - AN UNRESOLVED PROBLEM*

Joseph Lach

April 1985

*Presented at the XXth Recontres de Moriond, March 10-16, 1985, Moriond, France.

Operated by Universities Research Association Inc. under contract with the United States Department of Energy

HYPERON POLARIZATION - AN UNRESOLVED PROBLEM

Joseph Lach
Fermilab

Abstract

The fact that hyperons produced in high energy collisions have polarizations as large as 20% was not predicted by theory. These polarizations have allowed high precision measurements of most hyperon magnetic moments and a recent confirmation of the Cabibbo theory involving semileptonic hyperon decays. However a satisfactory quantitive explanation of hyperon polarization is still lacking. The question of whether the Ω^- is produced with significant polarization is crucial to the measurement of its magnetic moment. Present data are inconclusive as to whether the Ω^- is produced polarized. Phenomenological models and data on antihyperon production may not be useful guides in predicting the Ω^- polarization.

HYPERON POLARIZATION - AN UNRESOLVED PROBLEM

The fact that hyperons produced in high energy proton interactions have substantial polarizations is not well understood. However this has not kept hyperon polarization from being exploited to make important fundamental measurements. The magnetic moments of the Λ, Ξ^0, Ξ^-, Σ^-, and Σ^+ hyperons have been measured with precisions of 1-6% using the classical spin rotation technique. These results have provided important insights into the validity of the constituent quark model. A recent measurement[1] of the correlation of the electron momentum with the hyperon spin direction in the hyperon beta decay, $\Sigma^- \to n e^- \bar{\nu}$, provided a precision test of the Cabibbo hypothesis.

My intent is to stimulate thought about the polarization mechanism itself. The first observation[2] at Fermilab that *polarized* hyperons were produced by the interactions of high energy protons on a target was unexpected and, although a large effect, elicited relatively little theoretical excitement. It was seen as a "soft phenomena" and thus not amenable to perturbative QCD calculations. Hyperon decay lengths are typically meters at Fermilab energies so that inclusive polarization measurements are straight forward. The hyperons' parity violating weak decays gives us their polarization direction by the angular distribution of their decay products.

The salient features of produced hyperon polarization can be succinctly stated[3].

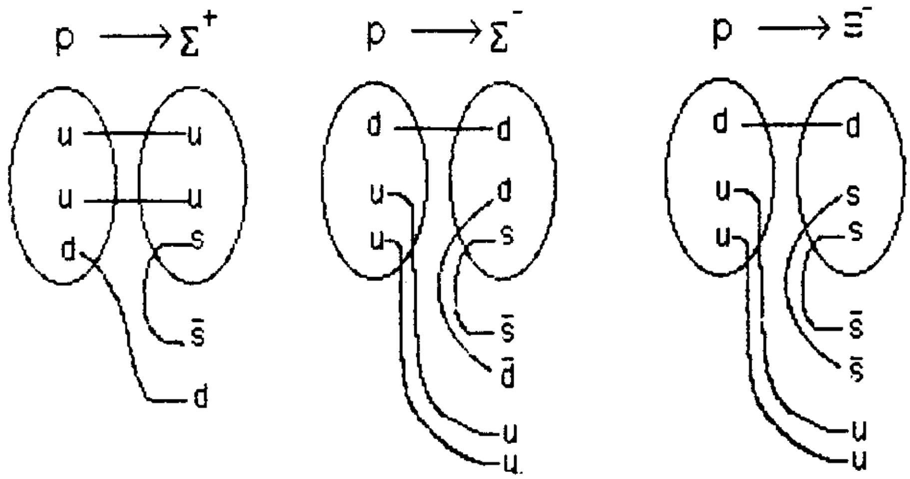
1. Polarization is a general feature of hyperon production at Fermilab energies. It's magnitude rises from 0→20% as p_t goes from 0→1.0 GeV/c for Λ, Σ^-, Σ^+, and Ξ^0. For Ξ^- the polarization is less.
2. The antihyperons, $\bar{\Lambda}$, $\bar{\Xi}^0$ are not polarized.
3. Some hyperons (Σ^+, Σ^-) are polarized in the positive direction; some in the negative (Λ, Ξ^0, Ξ^-). The positive direction is defined by the cross product of the incident proton and the produced hyperon momentum vectors.

Recent measurements of Σ^- inclusive polarization[1,4,5], along with previous measurements[6,7,8] of Σ^+ and Ξ^-, allow us to make some tests of proposed polarization mechanisms. We note (next page) that the quark diagrams for their production are different.

For $p \to \Sigma^+$ the final state hyperon retains two quarks from the projectile. For the other two cases only one quark is common. Figures 1-3 indicate that $P_{\Sigma^-} \approx P_{\Sigma^+} \approx -1/2\, P_{\Xi^-}$.

A model proposed by DeGrand and Miettinen[9] attempts to explain the polarizations as arising from Thomas precession of the quarks in the recombination process. Although it predicts the correct signs for the polarizations, it predicts $P_{\Sigma^-} = 1/2\, P_{\Sigma^+}$ and $P_{\Xi^-} = -P_{\Sigma^+}$ which is contradicted by the data shown in Figures 1-3.

The Lund group[10] using a string model give the correct signs of the polarizations; however, the quantitative predictiveness of the model has not been demonstrated.



Data on inclusive hyperon polarization is becoming more abundant. In particular the new data on Σ^- polarization should allow a sharper confrontation with the phenomenological models typified by the above. Unfortunately, one still seems far from a real theory of the polarization mechanism.

The Ω^- is the last long lived ($\approx 10^{-10}$ s) hyperon whose magnetic moment has not been measured to high precision. A measurement[11] was attempted in Fermilab E620 which yielded $\mu_{\Omega^-} = -2.1 \pm 1.0$ Nm and a polarization of 0.12 ± 0.08. The large uncertainty on the polarization measurement allows that the Ω^- be produced with zero polarization or as large as that of the Σ^+. If the Ω^- is produced with no polarization, then we cannot measure its magnetic moment by the technique that has yielded such beautiful results with the other hyperons.

If produced by a proton beam, the quarks which make up the Ω^- (and $\overline{\Omega}^+$) must all come from the sea. Is it then like the antihyperons and produced unpolarized? Perhaps not. Figure 4 shows the production ratio of antiparticle to particle as a function of strangeness from the CERN hyperon experiment[12]. One sees that for the Ω, this ratio is about ≈ 0.3 which means that at a given x and p_t there are more than three time more Ω^- than $\overline{\Omega}^+$. Inclusively produced hyperons could be the decay products of higher mass baryon resonances which might explain why the Ω^- is more copiously produced than the $\overline{\Omega}^+$. If this were the case none of the above phenomenological models (which do not consider resonance production) or the zero polarization of the antihyperons will give us any basis for predicting the polarization of the Ω^-.

References

1. Hsueh, S. Y. et al., Fermilab Pub-85/21-E, To be published in Phys. Rev. Lett.
2. Bunce, G. et al., Phys. Rev. Lett. 36 (1976) 1113.
3. Heller, K., Review talk at the 1984 Spin Conference.
4. Wah, Y. W., To be submitted to Phys. Rev Lett.
5. Deck, L. et al., Phys. Rev. D28 (1983) 1.
6. Ankenbrandt, C. et al., Phys. Rev. Lett. 51 (1983) 863.
7. Wilkinson, C. et al., Phys. Rev. Lett. 46 (1981) 803.
8. Rameika, R. A., Rutgers University Thesis, December 1981.
9. DeGrand, T. and Miettinen, H., Phys. Rev. D24 (1981) 2419 and erratum in Phys. Rev. D31 (1985) 661.
10. Andersson, B. et al., Lund Preprint LU TP 82-13, November 1982.
11. Luk, Kam-Biu, Rutgers University Thesis, February 1983.
12. Bourquin, M. and Repellin, J. P., Phys. Reports, 114 (1984) 100.

Figure 1

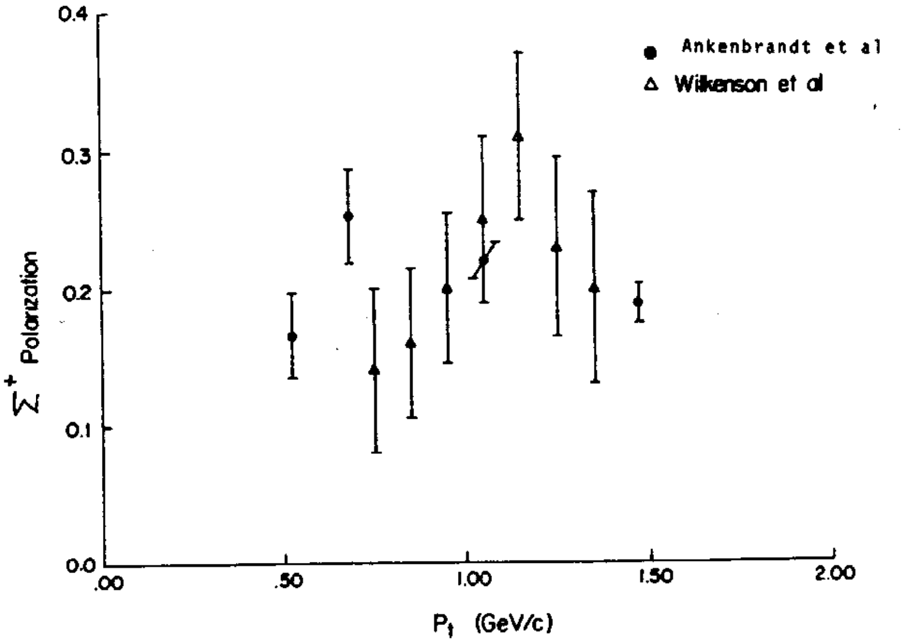


Figure 2

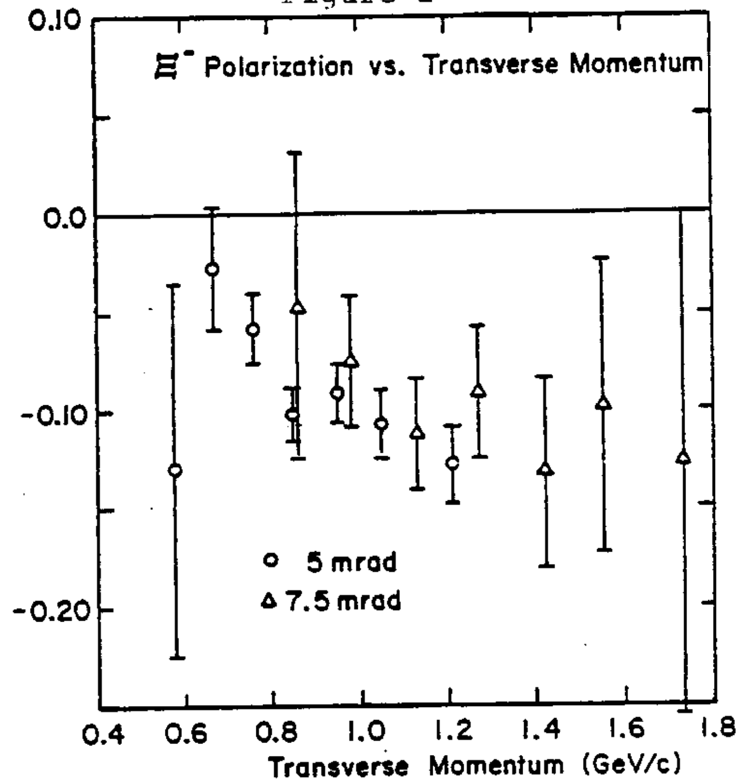


Figure 3

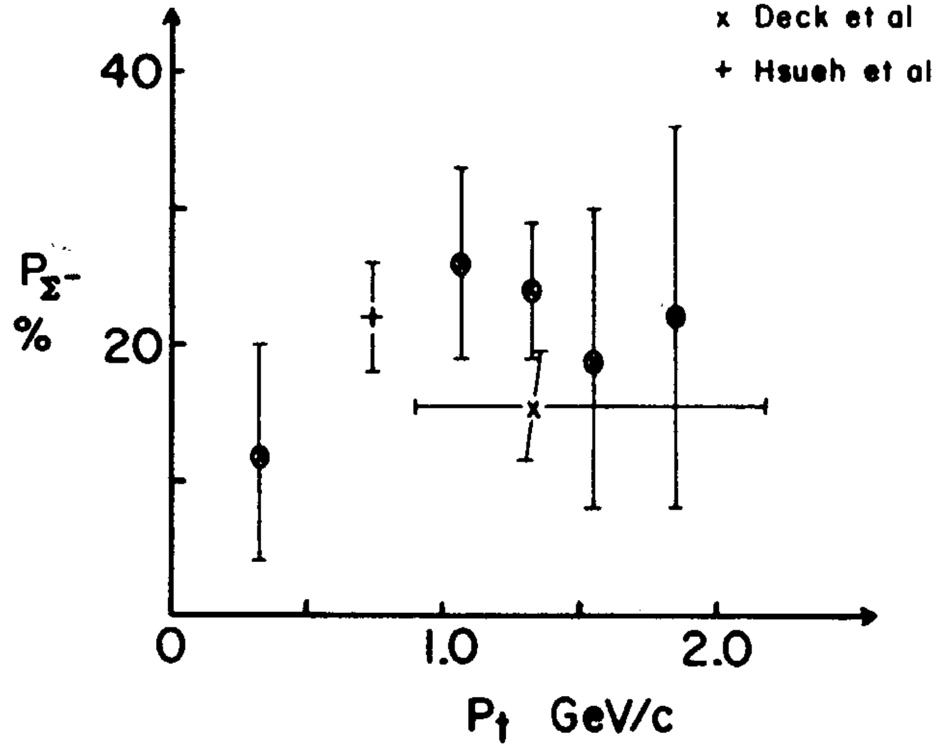


Figure 4