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Hyperon Polarization : Theory and Experiments

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Abstract

We give a brief review of the experimental situation concerning hyperon polarization. We mention also the current models developed to understand the experimental results and make some coments on some theoretical aspects contained in the Thomas precession model.

Key-words: Hyperon polarization; Models; Thomas precession.

INTRODUCTION

The first observation of polarization in inclusively produced hyperons at high energy was made in 1976 when G. Bounce et al (1) found that Λ_0 produced in the reaction $p + Be \rightarrow \Lambda_0 + X$ are polarized with polarization about 20%.

From thereon, a great amount of experiments have measured polarization in inclusively produced hyperons.

The first measure of polarization in anti-hyperons was made in 1978, when K. Heller et al (2) found that $\overline{\Lambda}_0$ was not polarized.

Until 1990 it was commonly accepted that anti-hyperons were not polarized, but in this year, the first observation of a sizeable polarization in $\overline{\Xi}^+$ was made (3). In 1993 some polarization was measured in $\overline{\Sigma}^+$ (4).

From the theoretical point of view, the polarization phenomenon is not well understood. There are several models trying to explain hyperon polarization, but none of them can explain the full characteristics of experimental data.

THE EXPERIMENTAL DATA

The usual sign convention is that for the fixed target reaction $a + b \rightarrow c + X$ the polarization vector of c is given by

$$P_c = P \frac{\overrightarrow{p}_a \times \overrightarrow{p}_c}{\left| \overrightarrow{p}_a \times \overrightarrow{p}_c \right|}$$

where P is the polarization and $\overrightarrow{p}_a$ and $\overrightarrow{p}_c$ are the momenta of particles a and c.

The polarization in inclusively produced hyperon has the following characteristics:

- Some hyperons show positive polarization (Σ^+, Σ^-) while other exhibit negative polarization (Λ_0, Ξ^0, Ξ^-). Ω^- seems to have zero polarization. Similar behavior is found in anti-hyperons: $\overline{\Lambda}_0$ and $\overline{\Xi}^0$ are not polarized while $\overline{\Xi}^+$ and $\overline{\Sigma}^-$ are positively polarized.
- Polarization increases with the transverse momentum of the outgoing hyperon and with x_F.
- It does not show remarkable dependence on the nature of the target b and energy of incident hadron a.
- Polarization depends strongly on the type of hyperon or anti-hyperon produced (see the first point).

THEORETICAL MODELS

We give here a very brief review of theoretical models on polarization.

SU(6) model

This is the simplest model possible. In it, hadrons collision are described in function of elementary interaction between the constituent quarks. In a reaction like $p+p \to \Lambda_0+X$ a ud diquark in a singlet spin-isospin state coming from the incident proton combines with a s quark produced by gluon bremsstrahlung (2). The s quark is produced polarized. Polarization of other hyperons may be calculated relative to Λ_0 polarization. The $\overline{\Lambda}_0$ is not polarized because $\overline{u}$ and $\overline{d}$ quarks must be produced incoherently to combine with a $\overline{s}$. In consequence, anti-hyperons are not polarized in this model.

Lund model

A color dipole field is produced between the diquark of the incoming particle and the central collision region. A pair $s\overline{s}$ is produced in this region with equal but opposite transverse momenta. Since the s and $\overline{s}$ have mass, they must be produced at certain distance one from another in order to conserve momentum and energy, thus the string has angular momentum that must be compensated by the spin of s and $\overline{s}$. Then the s quark, and hence the Λ_0, is polarized (5). Predictions of the model agree qualitatively with experimental data.

S-quark scattering model

In this model, the s quark originated in the sea of the incident proton or produced during the collision in the subprocess $g \to s\overline{s}$ acquires transverse momentum by multiple scattering on quark-gluon matter. Since the s quark is massive, it becomes polarized. Polarization appears in the second order of a perturbative calculation. The s quark must be relatively slow, otherwise polarization is negligible (6).

Models like triple-Regge

This type of models use triple-Regge mechanism to describe hadron fragmentation. Since the outgoing hyperon may be produced directly or via virtual baryon decay, polarization is obtained due to interference between several diagrams (7).

Thomas-precession model

In 1981 a simple rule was proposed to describe hyperon polarization (8):

Sea partons (slow) recombine preferentially with spin down
Leading partons (fast) recombine preferentially with spin up.

Hyperon polarization is calculated with this rule and $SU(6)$. The dynamical origin of the rule is explained by the fact that slow sea partons must be accelerated in passing from the initial hadron to the outgoing hyperon and, since they carry transverse momentum (which is assumed not to change in the recombination process), then the velocity of sea quarks is not parallel to the accelerating force and this causes Thomas precession. For sea quarks, $\overrightarrow{\omega}_T$ points out and up the scattering plane then recombination is enhanced when sea quarks recombine with spin down. The same argument shows that leading partons are decelerated in recombination process then they preferentially recombine with spin up.

This model can produce a change of sign in polarization at small x_F (of the order of 0.2 or less) due to the fact that, in this case, there are more sea quarks decelerated than accelerated in the recombination process.

CONCLUSIONS

A careful comparison of polarization models with recombination models can help clarifying which is the physical mechanism involved in hyperon polarization, in particular in the case of Thomas precession model, where can help to decide on the validity of the model.

Moreover, since none of these models can describe anti-hyperon polarization, more efforts in that direction are necessary.

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