ABOUT Λ^0 POLARIZATION PROBLEM

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ABSTRACT
It is very well known that Λ^0 hyperons are produced with significant polarization in *pp* reactions, where both the beam proton and the target proton are initially unpolarized. Despite the theoretical efforts to understand this phenomenon, the puzzle remains. In order to shed some light on this phenomenon, we report and discuss, from a phenomenological point of view, the present status of Λ^0 polarization problem.

1. INTRODUCTION

An ample experimental evidences on polarization of Λ^0's produced in *pp* collisions at high energies, have been collected over more than 20 years[1-15]; where both the beam proton and the target proton are initially unpolarized; these evidences show that spin particle plays a very important role in particle production mechanism; and despite some theoretical studies[16-21], the ultimate explanation of polarization remains obscure. Normally, transverse polarization is defined as: $\wp = \langle \hat{\sigma} \cdot P_{beam} \times P_{\Lambda} \rangle$; where $\hat{\sigma}$ is the spin of Λ^0; P_{beam} is the momentum of the beam and P_{Λ} is the momentum of the Λ^0. These two vectors define the Λ^0 creation plane and also the quantization axis –the normal to the creation plane-. It was useful to speak about inclusive reactions (reactions where only Λ^0 is collected and studied) and exclusive reactions (where besides Λ^0 the rest of the reaction is collected and analized); Λ^0 polarization has been studied as a function of the scaling parameter x_F and P_T (these quantities are the fraction of incident proton momentum carried by Λ^0 in the initial direction of the bean proton, in the c.m. system, and the transverse momentum with respect to the incoming beam proton direction, in that order). Another variable, that can be used to characterize Λ^0 polarization is the Λ^0 energy in the c.m. system and the complementary diffracted mass (M_X) (this means the mass of all final state particles, excepting the diffracted proton, or the mass of a subset of final state particles; for instance, in the reaction $pp \rightarrow p\Lambda^0 K^+\pi^+\pi^-$, the diffracted mass, means the mass of the system $\Lambda^0 K^+\pi^+\pi^-$ or the mass of the system $\Lambda^0 K^+$).

2. EXPERIMENTAL FACTS ABOUT Λ^0 POLARIZATION

According to all reported data, Λ^0 polarization is consistent with zero at $P_T = 0$ and linearly decreases roughly to ~ -0.25 at $P_T = 1.2$ GeV[1-14], see Figure 1. These are evidences that the slope of the straight line fit increases as x_F increases, and for P_T above 1.2 GeV and up to 3.5 GeV, the slope of the straight line fit is zero[22]. Λ^0 polarization depends on x_F the same way it depends on P_T, see Figure 2; and we can anticipate that, if we observe the polarization as a function of x_F, the slope of the straight line would increase as P_T increases. Because P_T and x_F are correlated throught the energy and the mass Λ^0, there must be a Λ^0 polarization dependence on Λ^0 energy very similar to that on P_T or x_F. These facts have not been observed yet. From those mentioned figures, it is interesting to note that polarization is independent of the beam energy; studies of polarization with beam energy between 6 and 2000 GeV have been done[1-10]. It is a common believe that Λ^0 polarization is independent of the target nature; even though that this supposition could be plausible, there are no data enough to support this statement , because all the information about polarization is in the beam fragmentation region ($x_F > 0$) when protons do not constitute the target. Some dependence of Λ^0 polarization on the complementary diffracted mass has been observed, that dependence is alike to the dependence observed on P_T or x_F[14,15]. But none dependence has been observed of Λ^0 polarization on relative momenta of Λ^0 and other reaction particles, for example the proton, the one that does not come from Λ^0, and K^+[14,15].

3. Λ^0 POLARIZATION MODELS

Since Λ^0 polarization was discovered in 1976[1,2], some theoretical models have been proposed in order to understand this phenomenon. In spite of such efforts the underlying polarization process remains unknown. Although these models describe somewhat qualitative the trends of Λ^0 polarization data, there is no a satisfactory explanation. The old models are based on partial information about Λ^0 polarization; for instance, most of them consider that Λ^0 polarization depends only on P_T, others include a weak dependence on x_F. A strong x_F – dependence was not suspected until recently it was discovered[14,15]. In the following lines, we expose and discuss briefly the main proposed ideas to describe Λ^0 polarization data and confront their consequences with observed facts.

From a theoretical point of view, we can see that in terms of constituent quarks, when a proton fragments into a Λ^0, which has P_T different from zero, an u valence quark is replaced by a strange quark s coming from the decay of a gluon[7] –or from the quark sea[16-21]; for simplicity, the ud system is supposed to be in zero spin state, consequently the Λ^0 spin and its polarization come from the spin and polarization of s. The difference between the proposed models is the source of s polarization. For the first case, in Heller **et al** model[7], it is the s which gives Λ^0 both its transverse momentum and spin. If the gluon is polarized, so is the $s\bar{s}$ pair and this polarization is correlated with the transverse momentum direction of Λ^0. In other hand, to produce a $\bar{\Lambda}^0$, $\bar{u}$ and $\bar{d}$ quarks must be created.This model considers that $\bar{s}$ is created unpolarized when s is polarized, to fit the partial experimental evidences –apparently $\bar{\Lambda}^0$ is no polarized, on the light of partial information[7,22-24]-. For the second case, there are some models: in the fragmentation model of Anderson **et al**[18], the confined linear color field is stretched and the strange quark needed to obtain the final Λ^0 with transverse momentum different from zero is produced by an $s\bar{s}$ pair whose orbital angular momentum is balanced by the sum of $\bar{s}$ spin and s spin; a negative polarization is obtained, which value decreases as P_T increases. In the recombination model of DeGrand **et al**[16], the polarization comes from the Thomas precession effect; to minimize the associated energy with this effect –the dot product of the s spin with the Thomas precession angular frequency- the spin direction must be opposite to the Thomas precession angular frequency; one expects a negative Λ^0 polatizarion in inclusive pp production; this model predicts a zero polarization for $\bar{\Lambda}^0$ at the same x_F and P_T where Λ^0 polarization is non-zero. In the model of Troshin and Tyurin[20] Λ^0 polarization is generated during the diffractive production of Λ^0 particles, the description of such process is given on the basis of the solution of a dynamical equation written in the direct channel of the reaction and on simple ideas about the quark structure of the particles; for instance, there is a non-zero probability of hadron states containing not only valence quarks but also $q\bar{q}$; in this way diffraction dissociation is regarded as the results of the decay of an excited hadron state containing an additional $q\bar{q}$; in particular, the model considers that the system uud is not polarized and $s\bar{s}$ is polarized (the spin projection of this pair into the normal of the production plane is 1); as a result of the scattering, the spin directions of the quarks s and $\bar{s}$ can be either preserved or simultaneously reversed; for small P_T, this model gives $\wp(P_T) \cong -\frac{1}{8}\left(\frac{P_T}{2m_s}\right)^2\left(1-\frac{1}{\kappa^2}\right)$ for Λ^0 polarization distributions; where κ is the ratio of the spin-flip amplitude to non-spin-flip amplitude (a constant greater that 1), m_s is the mass of the strange quark, P_T transverse momentum of Λ^0; for $\kappa = \sqrt{3/2}$, and $x_F > 0.6$ a comparison is presented in Figure 3.

4. CONCLUSIONS

All models so far created obtain the correct sign for Λ^0 polarization and a Λ^0 polarization distribution which does not fit the data well. All models are written to obtain $\bar{\Lambda}^0$ polarization consistent with zero, this fact seems to contradict recent results. All models consider Λ^0 polarization independent, or weakly dependent, of x_F. We have not a convincing explanation for Λ^0 polarization in *pp* reactions and a honest calculation of Λ^0 polarization distribution.

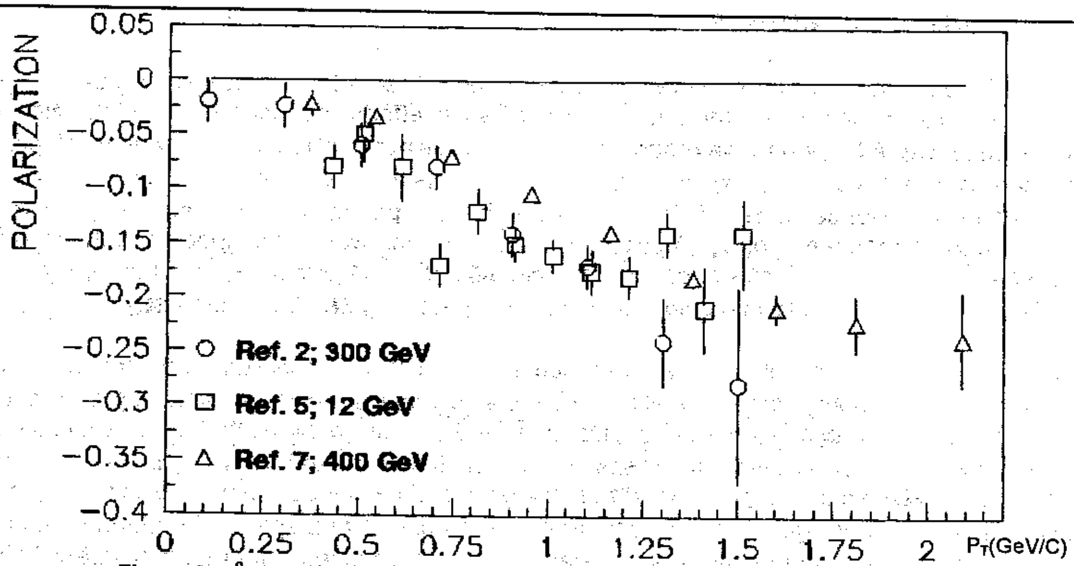

Figure 1: Λ^0 polarization as a function of P_T; its beam energy independence is shown.

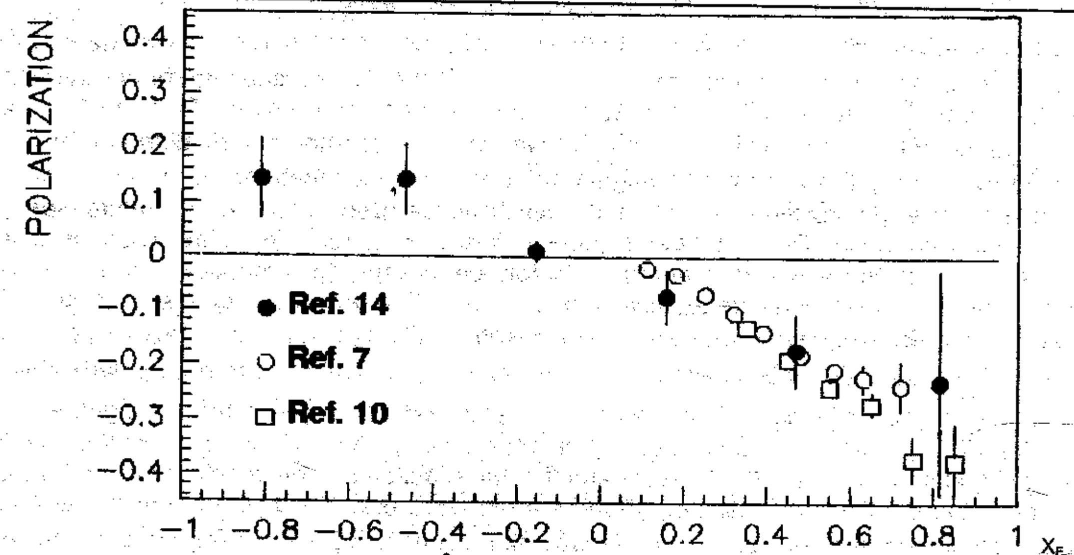

Figure 2: Λ^0 polarization as a function of X_F.

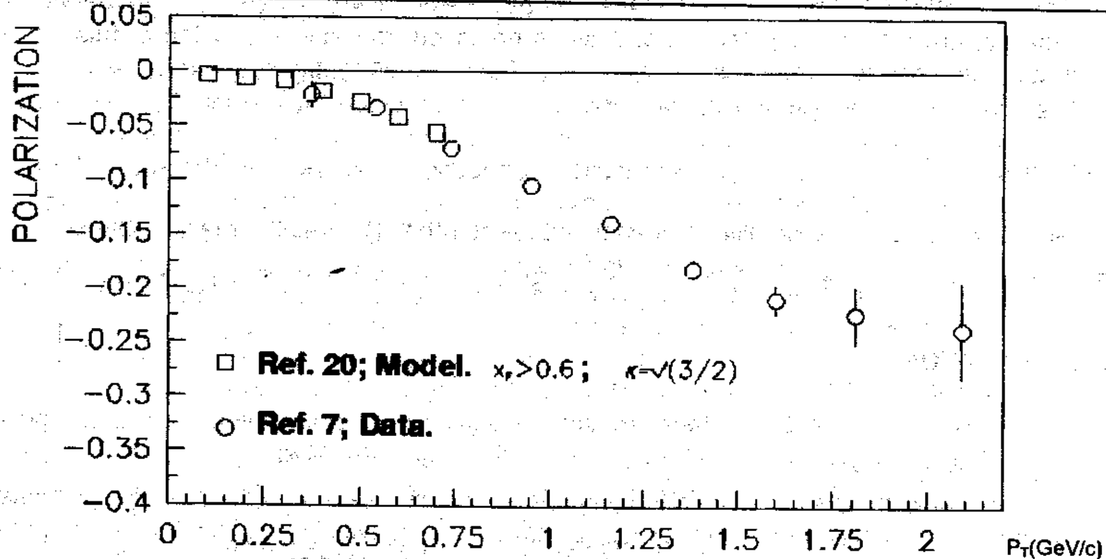

Figure 3: Comparison between Λ^0 polarization data and model is shown.

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