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INTRINSIC POLARIZED STRANGENESS AND Λ^0 POLARIZATION IN DEEP-INELASTIC PRODUCTION* **

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We propose a model for the longitudinal polarization of Λ^0 baryons produced in deep-inelastic lepton scattering at any x_{F}, based on static SU(6) quark-diquark wave functions and polarized intrinsic strangeness in the nucleon associated with individual valence quarks. Free parameters of the model are fixed by fitting the NOMAD data on the longitudinal polarization of Λ^0 hyperons in neutrino interactions. Our model correctly reproduces the observed dependences of Λ^0 polarization on the kinematic variables. Within the context of our model, the NOMAD data imply that the intrinsic strangeness associated with a valence quark has anticorrelated polarization. We also compare our model predictions with results from the HERMES and E665 experiments using charged leptons. Predictions of our model for the COMPASS experiment are also presented.

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1. Introduction

Measurements of the longitudinal polarization of Λ^0 hyperons in lepton nucleon deep inelastic scattering (DIS) processes provide access to the polarization of intrinsic strangeness of the nucleon [2] and to the polarized quark spin transfer function [3]: $C_q^{\Lambda}(z) \equiv \Delta D_q^{\Lambda}(z)/D_q^{\Lambda}(z)$, where $D_q^{\Lambda}(z)$ and $\Delta D_q^{\Lambda}(z)$ are unpolarized and polarized fragmentation functions for the quark q to yield a Λ hyperon with the fraction z of the quark energy. Several experimental measurements of Λ^0 polarization have been made in neutrino and anti-neutrino DIS. Longitudinal polarization of Λ^0 hyperons was first observed in bubble chamber (anti) neutrino experiments [4–6]. The NOMAD Collaboration has recently published new and interesting results on Λ^0 and

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** This article is a short version of a more detailed paper [1].

$\bar{\Lambda}^0$ polarization with much larger statistics [7]. There are also recent results on longitudinal polarization of Λ^0 hyperons from polarized charged lepton nucleon DIS processes from the E665 [8] and HERMES [9] experiments. A key assumption, adopted widely in theoretical analyzes of these data, is that the struck quark fragmentation can be disentangled from the nucleon remnant fragmentation by imposing a cut: $x_{\rm F} > 0$. As we show in Sec. 2.3 this assumption fails at moderate beam energies [4–10]. A method of calculation of the longitudinal polarization of Λ^0 hyperons is presented in Sec. 2, and our model predictions are compared to the available data in Sec. 3.

2. Calculational method

There are different mechanisms whereby strange hadrons can be produced in DIS processes. They can be produced by fragmentation of the struck quark or the nucleon remnant diquark, or in color string fragmentation. We assume that strange hadrons can be polarized only in the (di)quark fragmentation. Λ^0 hyperons can be produced *promptly* or as a decay product of heavier strange baryons (Σ^0, Ξ, $\Sigma^\star$). Therefore, to predict the polarization of Λ^0 hyperons in a given kinematic domain one needs to know the relative yields of Λ^0 's produced in different channels and their polarization. We take into account all these effects explicitly tracing the Λ^0 origin predicted by the fragmentation model adopted (Sec. 2.3) and assigning the polarization predicted by the polarized intrinsic strangeness model (Sec. 2.1) in the diquark fragmentation and by SU(6) and Burhardt–Jaffe [3] models for the quark fragmentation (Sec. 2.2). We take into account a difference in observed yields of heavier strange hyperons [11].

2.1. Polarized intrinsic strangeness model

The main idea of the polarized intrinsic strangeness model applied to semi-inclusive DIS is that the polarization of s quarks and $\bar{s}$ antiquarks in the hidden strangeness component of the nucleon wave function should be (anti)correlated with that of the struck quark. This correlation is described by the spin correlation coefficients C_{sq}: $P_s = C_{sq}P_q$, where P_q and P_s are the polarizations of the initial struck (anti)quark and remnant s quark. In principle, C_{sq} can be different for the valence and sea quarks. We leave $C_{sq_{\rm val}}$ and $C_{sq_{\rm sea}}$ as free parameters, that are fixed in a fit to the NOMAD data [7].

2.2. Polarization of strange hadrons in (di)quark fragmentation

We define the quantization axis along the three-momentum vector of the exchanged boson. To calculate the polarization of Λ^0 hyperons produced in the diquark fragmentation we assume the combination of a non-relativistic

SU(6) quark-diquark wave function and the polarized intrinsic strangeness model described above. The polarization of Λ^0 hyperons produced in the quark fragmentation via a strange baryon (Y) is calculated as: $P^q_{\Lambda^0}(Y) = -C_q^{\Lambda^0}(Y)P_q$, where $C_q^{\Lambda^0}(Y)$ is the corresponding spin transfer coefficient, P_q is the struck quark polarization which depends on the process. We use SU(6) and BJ models to compute $C_q^{\Lambda^0}(Y)$.

2.3. Fragmentation model

To describe Λ^0 production and polarization in the full x_{F} interval, we use the LUND string fragmentation model, as incorporated into the `JETSET7.4` program [12]. We use the `LEPTO6.5.1` [13] Monte Carlo event generator to simulate charged-lepton and (anti)neutrino DIS processes. We introduce two rank counters: R_{qq} and R_q which correspond to the particle rank from the diquark and quark ends of the string, correspondingly. A hadron with $R_{qq} = 1$ or $R_q = 1$ would contain the diquark or the quark from one of the ends of the string. However, one should perhaps not rely too heavily on the tagging specified in the LUND model. Therefore, we consider the following two variant fragmentation models:

Model A: The hyperon contains the stuck quark (the remnant diquark) only if $R_q = 1$ ($R_{qq} = 1$).

Model B: The hyperon contains the stuck quark (the remnant diquark) if $R_q \geq 1$ and $R_{qq} \neq 1$ ($R_{qq} \geq 1$ and $R_q \neq 1$).

Clearly, Model B weakens the Lund tagging criterion by averaging over the string, whilst retaining information on the end of the string where the hadron originated.

In the framework of `JETSET`, it is possible to trace the particles' parentage. We use this information to check the origins of the strange hyperons produced in different kinematic domains, especially at various x_{F}. According to the `LEPTO` and `JETSET` event generators, the x_{F} distribution of the diquark to Λ^0 fragmentation is weighted towards large negative x_{F}. *However, its tail in the $x_{\mathrm{F}} > 0$ region overwhelms the quark to Λ^0 x_{F} distribution at these beam energies.* In Fig. 1, we show the x_{F} distributions of Λ^0 hyperons produced in diquark and quark fragmentation, as well as the final x_{F} distributions. These distributions are shown for ν_μ CC DIS at the NOMAD mean neutrino energy $E_\nu = 43.8$ GeV, and for μ^+ DIS at the COMPASS muon beam energy $E_\mu = 160$ GeV. The relatively small fraction of the Λ^0 hyperons produced by quark fragmentation in the region $x_{\mathrm{F}} > 0$ is related to the relatively small centre-of-mass energies — about 3.6 GeV for HERMES, about 4.5 GeV for NOMAD, about 8.7 GeV for COMPASS, and about 15 GeV for the E665 experiment — which correspond to low W.

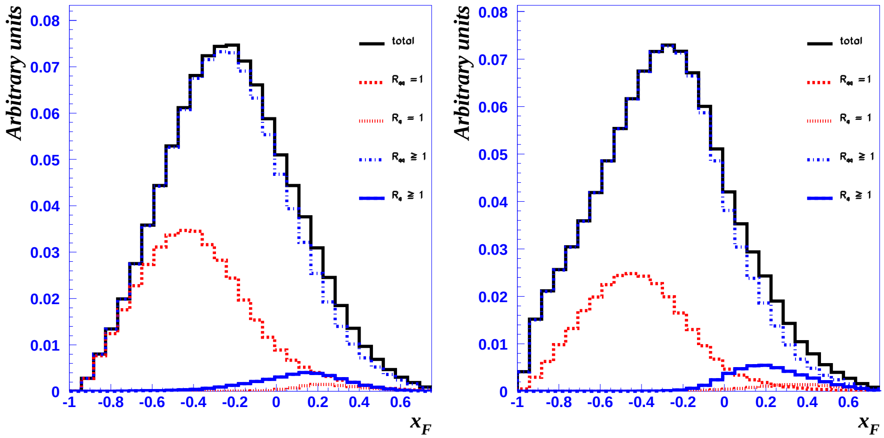

Fig. 1. Predictions for the $x_{\rm F}$ distributions of all Λ^0 hyperons (solid line), of those originating from diquark fragmentation and of those originating from quark fragmentation, for the two model variants A and B, as explained in the legend on the plots. The left panel is for ν_μ CC DIS with $E_\nu = 43.8$ GeV, and the right panel for μ^+ DIS with $E_\mu = 160$ GeV.

We vary the two correlation coefficients $C_{sq_{\rm val}}$ and $C_{sq_{\rm sea}}$ in fitting Models A and B to the following 4 NOMAD points:

(1) νp: $P_x^\Lambda = -0.26 \pm 0.05(\text{stat})$,
(2) νn: $P_x^\Lambda = -0.09 \pm 0.04(\text{stat})$,
(3) $W^2 < 15$ GeV^2: $P_x^\Lambda(W^2 < 15) = -0.34 \pm 0.06(\text{stat})$,
(4) $W^2 > 15$ GeV^2: $P_x^\Lambda(W^2 > 15) = -0.06 \pm 0.04(\text{stat})$.

We find from these fits similar values for both the SU(6) and BJ models: $C_{sq_{\rm val}} = -0.35 \pm 0.05$, $C_{sq_{\rm sea}} = -0.95 \pm 0.05$ (model A) and $C_{sq_{\rm val}} = -0.25 \pm 0.05$, $C_{sq_{\rm sea}} = 0.15 \pm 0.05$ (model B).

3. Results

In Figs. 2, 3, 4 we show our model predictions compared to the available data from the NOMAD [7], HERMES [9] and E665 [8] experiments. One can conclude that our model quite well describes all the available experimental data. The NOMAD Collaboration has measured separately the polarization of Λ^0 hyperons produced off proton and neutron targets. We observe good agreement, within the statistical errors, between the model B description and the NOMAD data, whilst model A, although reproduces quite well the polarization of Λ^0 hyperons produced from an isoscalar target, fails to describe target nucleon effects. We provide many possibilities for further checks of our approach for future data (for details, see [1]).

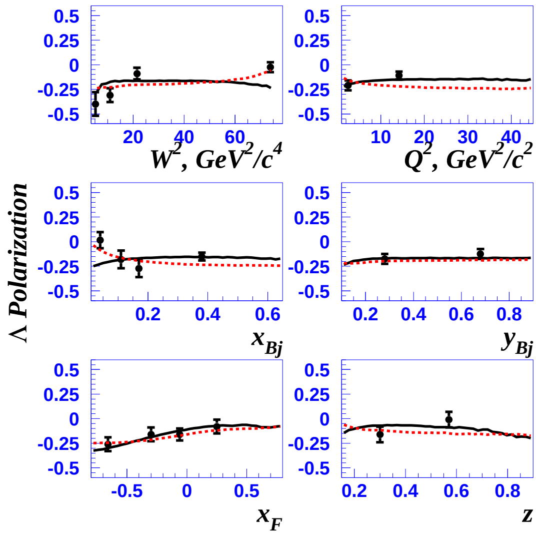

Fig. 2. The predictions of model A — solid line and model B — dashed line, for the polarization of Λ hyperons produced in ν_μ charged-current DIS interactions off nuclei as functions of W^2, Q^2, $x_{\rm Bj}$, $y_{\rm Bj}$, $x_{\rm F}$ and z (at $x_{\rm F} > 0$). The points with error bars are from [7].

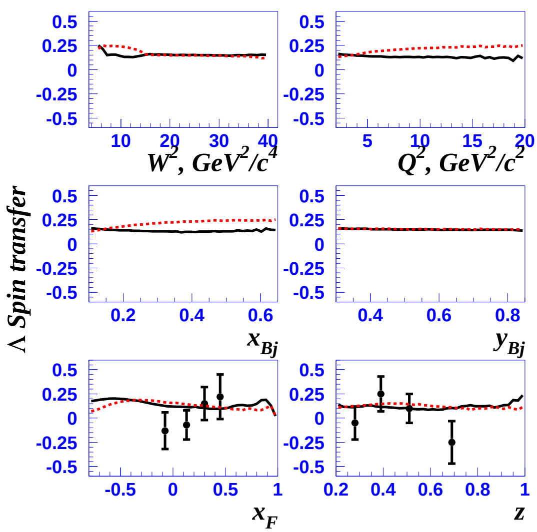

Fig. 3. The predictions of model A — solid line, model B — dashed line, for the spin transfer to Λ hyperons produced in e^+ DIS interactions off nuclei as functions of W^2, Q^2, $x_{\rm Bj}$, $y_{\rm Bj}$, $x_{\rm F}$ and z (at $x_{\rm F} > 0$). We assume $E_e = 27.5$ GeV, and the points with error bars are from [9].

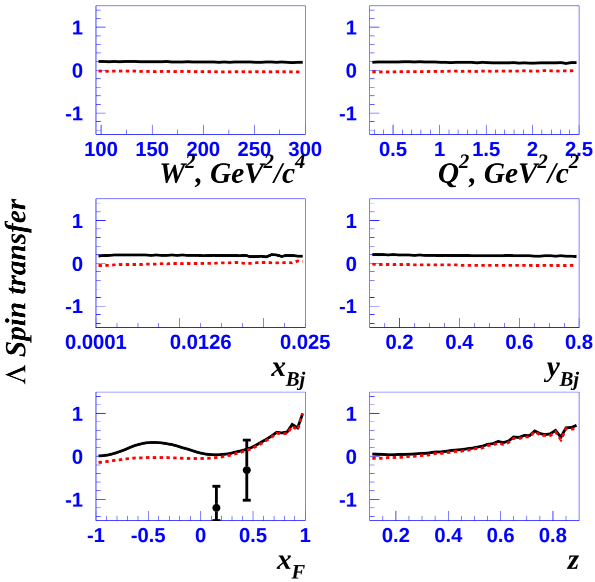

Fig. 4. The predictions of model A — solid line, model B — dashed line, for the spin transfer to Λ hyperons produced in μ^+ DIS interactions off nuclei as functions of W^2, Q^2, x_{Bj}, y_{Bj}, x_{F} and z (at $x_{\mathrm{F}} > 0$). Here we assume $E_\mu = 470$ GeV, as appropriate for E665 [8].

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