MEASUREMENT OF Λ^0 AND $\bar{\Lambda}^0$ POLARIZATION IN ν_μ CC INTERACTIONS IN NOMAD*

Dmitry V. Naumov

For the NOMAD Collaboration

Joint Institute for Nuclear Research, Dubna, Russia

(Received June 5, 2002)

The Λ^0 and $\bar{\Lambda}^0$ polarizations in ν_μ charged current interactions have been measured in the NOMAD experiment. The event sample (8087 reconstructed Λ^0's and 649 $\bar{\Lambda}^0$'s) is more than an order of magnitude larger than that of previous bubble chamber experiments, while the quality of event reconstruction is comparable. For the Λ^0 hyperons we observe negative polarization along the W-boson direction which is enhanced in the target fragmentation region: $P_x(x_{\rm F} < 0) = -0.21 \pm 0.04({\rm stat}) \pm 0.02({\rm syst})$. In the current fragmentation region we find $P_x(x_{\rm F} > 0) = -0.09 \pm 0.06({\rm stat}) \pm 0.03({\rm syst})$. A significant transverse polarization (in the direction orthogonal to the Λ^0 production plane) has been observed for the first time in a neutrino experiment: $P_y = -0.22 \pm 0.03({\rm stat}) \pm 0.01({\rm syst})$. The dependence of the absolute value of P_y on the Λ^0 transverse momentum with respect to the hadronic jet direction is in qualitative agreement with the results from unpolarized hadron-hadron experiments. The polarization vector of $\bar{\Lambda}^0$ hyperons measured for the first time in neutrino interactions is found to be consistent with zero.

PACS numbers: 13.88.+e, 13.15.+g

1. Introduction

It is very interesting to measure both longitudinal and transverse Λ^0 and $\bar{\Lambda}^0$ polarizations in νN deep inelastic process due to different physical mechanisms related to them. When I was presenting first time the NOMAD results on Λ^0 polarization measurement at SPIN2000 Symposium (Osaka, Japan) [1] I followed the common belief that a cut on $x_{\rm F}$ can separate target remnant from the struck quark fragmentation regions. This assumption leads to a possibility to observe the effect of the polarized intrinsic

* Presented at the X International Workshop on Deep Inelastic Scattering (DIS2002) Cracow, Poland, 30 April–4 May, 2002.

strangeness at $x_{\rm F} < 0$ (target fragmentation region) and to measure the spin transfer coefficient $C_q^{\Lambda^0}$ in quark to Λ^0 fragmentation at $x_{\rm F} > 0$. However, recently it was found that beam energies of all experiments involved in Λ^0 polarization measurements are too low to disentagle quark fragmentation region from the target remnant [2] and all the experiments deal mainly with left over diquark fragmentation. Therefore, the interpretation of the data at $x_{\rm F} > 0$ should be changed.

The transverse polarization of Λ^0 hyperons has been observed for a long time in unpolarized hadron–hadron experiments [3], and was never observed in (anti)neutrino nucleon DIS experiments [4]. This surprising feature challenges experimental and theoretical efforts in this field. It is interesting to note that the transverse polarization of $\bar{\Lambda}^0$ hyperons measured in hadron experiments is consistent with zero.

Let me skip here the details of the reconstruction and identification procedures of Λ^0 and $\bar{\Lambda}^0$ hyperons and redirect the interested reader to the original literature [5, 6]. As a result we obtained 8087 (649) reconstructed and identified Λ^0 ($\bar{\Lambda}^0$) hyperons with about 4% (10%) background contamination in our data samples. These samples are used for the polarization analyzes reported below. The Λ^0 ($\bar{\Lambda}^0$) polarization is measured through the *asymmetry* in the angular distribution of the protons (pions, π^+) in the parity violating decay process $\Lambda^0 \to p\pi^-$ ($\bar{\Lambda}^0 \to \bar{p}\pi^+$). In the Λ^0 ($\bar{\Lambda}^0$) rest frame the decay protons (pions, π^+) are distributed as: $\frac{1}{N}\frac{dN}{d\Omega} = \frac{1}{4\pi}(1 + \alpha_\Lambda \boldsymbol{P} \cdot \boldsymbol{k})$, where $\boldsymbol{P}$ is the Λ^0 ($\bar{\Lambda}^0$) polarization vector, $\alpha_\Lambda = 0.642 \pm 0.013$ [7] is the decay asymmetry parameter and $\boldsymbol{k}$ is the unit vector along the decay positively charged track (proton for $\Lambda^0 \to p\pi^-$ and pion for $\bar{\Lambda}^0 \to \bar{p}\pi^+$) direction. We define the quantization axes as follows:

- $\boldsymbol{n}_x = \boldsymbol{e}_W$, where $\boldsymbol{e}_W$ is the reconstructed W-boson direction;
- $\boldsymbol{n}_y = \boldsymbol{e}_W \times \boldsymbol{e}_{\rm T}/|\boldsymbol{e}_W \times \boldsymbol{e}_{\rm T}|$ axis is orthogonal to the Λ^0 ($\bar{\Lambda}^0$) production plane;
- $\boldsymbol{n}_z = \boldsymbol{n}_x \times \boldsymbol{n}_y$.

2. Results and discussion

Table I displays the results for the polarization of Λ^0 hyperons in our sample as a function of $x_{\rm F}$. We observe negative longitudinal ("P_x") and transverse ("P_y") polarizations of Λ^0's which are enhanced in the target fragmentation region. Note that transverse polarization has never been observed before in (anti)neutrino nucleon DIS experiments. The polarization vector of $\bar{\Lambda}^0$ hyperons measured at different cuts on $x_{\rm F}$ and $x_{\rm Bj}$ is shown in Table II. One can conclude that this vector is consistent with zero within the statistical errors. In what follows we present further results for Λ^0 hyperons.

TABLE I

Dependence of the Λ^0 polarization on $x_{\rm F}$ in ν_μ CC events (statistical errors only).

Selection	Entries	$\langle x_{\rm F}\rangle$	Λ^0 Polarization		
			P_x	P_y	P_z
full sample	8087	-0.18	-0.15 ± 0.03	-0.22 ± 0.03	-0.04 ± 0.03
$x_{\rm F} < 0$	5608	-0.36	-0.21 ± 0.04	-0.26 ± 0.04	-0.08 ± 0.04
$x_{\rm F} > 0$	2479	0.21	-0.09 ± 0.06	-0.10 ± 0.06	0.02 ± 0.06

TABLE II

$\bar{\Lambda}$ polarization in ν_μ CC events (the error is statistical).

Selection	Entries	$\bar{\Lambda}$ Polarization		
		P_x	P_y	P_z
full sample	649	-0.07 ± 0.12	0.09 ± 0.13	0.10 ± 0.13
$x_{\rm F} < 0$	248	0.23 ± 0.20	0.04 ± 0.20	-0.08 ± 0.21
$x_{\rm F} > 0$	401	-0.23 ± 0.15	0.10 ± 0.17	0.25 ± 0.16
$x_{\rm Bj} < 0.2$	331	-0.12 ± 0.17	0.08 ± 0.18	0.01 ± 0.17
$x_{\rm Bj} > 0.2$	318	-0.03 ± 0.17	0.10 ± 0.18	0.20 ± 0.19

The dependence of the longitudinal polarization of Λ^0 on W^2 at $x_{\rm F} < 0$ is shown in Fig. 1. Large negative P_x is observed at small W^2, while at larger W^2 the longitudinal polarization vanishes. We have performed a study of the dependence of the transverse polarization on the Λ^0 transverse momentum with respect to the jet direction ($p_{\rm T}$) in $x_{\rm F} < 0$ region and found it to be in qualitative agreement (both sign and shape) with that found in unpolarized

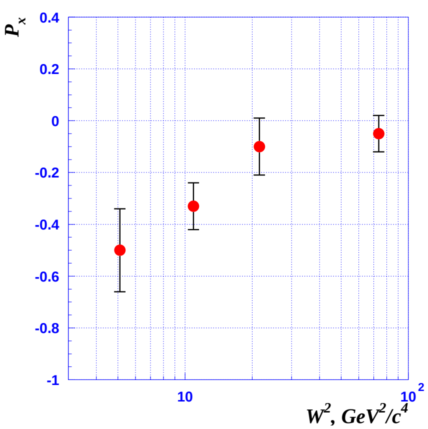

Fig. 1. Longitudinal polarization of Λ^0 as a function of W^2 for $x_{\rm F} < 0$.

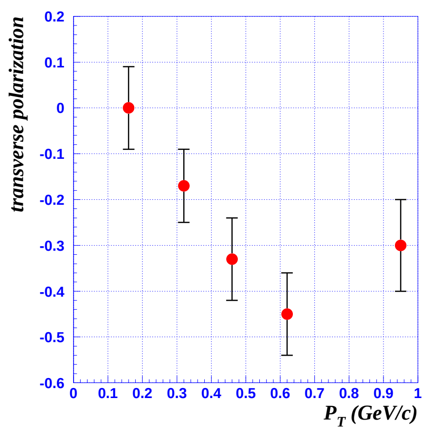

Fig. 2. Transverse polarization of Λ^0 as a function of $P_{\rm T}$ for $x_{\rm F} < 0$.

hadron-hadron collisions [3]. Also, we observed no dependence of P_y on W^2. These features make possible to conclude that the origin of the transverse polarization is in the fragmentation process.

Imposing a cut on the sum of charges of the all outgoing tracks from the primary vertex ($Q_{\rm tot}$) of the event we can study Λ^0 polarization on different target nucleons. We select $\nu_\mu p$ ($\nu_\mu n$)-like events requiring $Q_{\rm tot} \geq 1$ ($Q_{\rm tot} \leq 0$) with purity of the selection 76% (85%). The results are summarized in Table III. There is a strong dependence of the polarization vector on the type of the target nucleon.

TABLE III

The dependence of the Λ^0 polarization on the type of target nucleon.

Target	Entries	Λ^0 Polarization		
		P_x	P_y	P_z
"proton"	3472	-0.26 ± 0.05	-0.09 ± 0.05	-0.07 ± 0.05
$x_{\rm F} < 0$	2407	-0.29 ± 0.06	-0.10 ± 0.06	-0.09 ± 0.06
$x_{\rm F} > 0$	1065	-0.23 ± 0.09	-0.06 ± 0.09	-0.02 ± 0.10
"neutron"	4615	-0.09 ± 0.04	-0.30 ± 0.04	-0.03 ± 0.05
$x_{\rm F} < 0$	3201	-0.16 ± 0.05	-0.37 ± 0.05	-0.07 ± 0.05
$x_{\rm F} > 0$	1414	0.01 ± 0.08	-0.11 ± 0.08	0.04 ± 0.09

A comparison of our data to theoretical calculations [2] is presented in Fig. 3. The calculations [2] are based on SU(6) plus polarized intrinsic strangeness model for the diquark fragmentation and it uses SU(6) model to take into account spin transfer from quark fragmentation. One can conclude that this model nicely describes the NOMAD data on the longitudinal polarization though it is not as good in describing the target nucleon effects observed by the NOMAD (see Table IV). Still there is no model able to address the transverse polarization measured by the NOMAD Collaboration.

TABLE IV

Dependence of the polarization of Λ hyperons produced in ν_μ CC DIS on the type of target nucleon predicted in [2] compared with the NOMAD data.

P_Λ (%)	Target nucleon		
	isoscalar	proton	neutron
model A	–17.4	–11.4	–20.2
model B	–19.3	–18.1	–19.9
NOMAD	–15.0±3	–26.0±5	–9.0±4

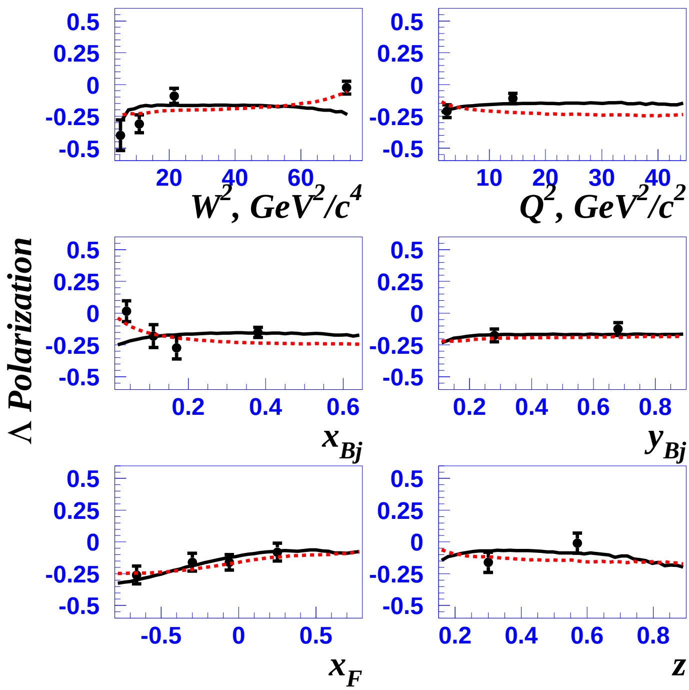

Fig. 3. The predictions of model A — solid line and model B — dashed line, for the polarization of Λ hyperons produced in ν_μ charged-current DIS interactions off nuclei as functions of W^2, Q^2, $x_{\rm Bj}$, $y_{\rm Bj}$, $x_{\rm F}$ and z (at $x_{\rm F} > 0$) [2].

REFERENCES

[1] D.V. Naumov [NOMAD Collaboration], *AIP Conf. Proc.* **570**, 489 (2001).

[2] J. Ellis, A. Kotzinian, D. Naumov, `hep-ph/0204206`.

[3] See review J. Félix, *Mod. Phys. Lett.* **A14**, 827 (1999).

[4] G.T. Jones *et al.*, *Z. Phys.* **C28**, 23 (1985); S. Willocq *et al.*, *Z. Phys.* **C53**, 207 (1992); D. DeProspo *et al.*, *Phys. Rev.* **D50**, 6691 (1994); V. Ammosov *et al.*, *Nucl. Phys.* **B162**, 205 (1980); D. Allasia *et al.*, *Nucl. Phys.* **B224**, 1 (1983).

[5] P. Astier *et al.* [NOMAD Collaboration], *Nucl. Phys.* **B588**, 3 (2000); P. Astier *et al.* [NOMAD Collaboration], *Nucl. Phys.* **B605**, 3 (2001).

[6] D.V. Naumov, Ph.D. Thesis, JINR, Dubna, Russia, (2001), in Russian (available upon request).

[7] Review of Particle Properties, *Eur. Phys. J.* **C15** (2000).