99-177

ОБЪЕДИНЕННЫЙ
ИНСТИТУТ
ЯДЕРНЫХ
ИССЛЕДОВАНИЙ

Дубна

E1-99-177

A MEASUREMENT OF THE TRANSVERSE POLARIZATION OF Λ-HYPERONS PRODUCED IN *nC*-REACTIONS IN THE **EXCHARM** EXPERIMENT

Submitted to «European Physical Journal C»

1999

A.N.Aleev, V.P.Balandin, E.A.Dvalishvili, A.N.Gaponenko, A.V.Gusev, P.Z.Hristov, Z.M.Ivanchenko, I.M.Ivanchenko, M.N.Kapishin, N.N.Karpenko, V.D.Kekelidze, T.V.Khristova, Z.I.Kojenkova, I.G.Kosarev, Yu.A.Kretov, A.S.Kurilin, N.A.Kuz'min, A.L.Lyubimov, D.T.Madigojin, A.S.Mestvirishvili, N.A.Molokanova, A.N.Morozov, Yu.K.Potrebenikov, A.G.Skripnichuk, L.A.Slepets, V.N.Spaskov, G.T.Tatishvili, A.L.Tkatchev*, I.P.Yudin, A.I.Zinchenko
Joint Institute for Nuclear Research, Dubna, Russia

A.P.Bugorski
Institute of High Energy Physics, Protvino, Russia

A.A.Loktionov
High Energy Physics Institute, Academy of Sciences, Almaty, Kazakhstan

T.Ponta, T.Preda
Institute of Atomic Physics, Section of High Energy Physics, Bucharest, Romania

I.M.Geshkov
Institute for Nuclear Research and Atomic Energy, Sofia, Bulgaria

L.N.Abesalashvili, N.S.Amaglobeli, B.G.Chiladze, R.A.Kvatadze, M.V.Kopadze, N.L.Lomidze, G.I.Nikobadze, T.G.Pitskelauri
High Energy Physics Institute, Tbilisi State University, Tbilisi, Georgia

T.S.Grigalashvili
Institute of Physics, Georgian Academy of Sciences, Tbilisi, Georgia

I.F.Emel'janchik, A.V.Raspereza, S.V.Sushkov
Institute of Nuclear Problems of Belarus State University, Minsk, Belarus

*E-mail: tkachea@sunse.jinr.ru

1 Introduction

It has been observed, more than 15 years ago (see e.g.,[1]) that Λ^0's produced inclusively by unpolarized protons have significant polarization. The polarization has been investigated over a wide range of reaction energies and at various Λ^0 production angles. The absolute value of the polarization has been found to grow approximately linearly with Λ^0 transverse momentum p_t in the region of $p_t < 1$ GeV/c. Some theoretical models attempt to describe experimental data on polarization [6–8] but the polarization mechanism is still not well understood.

Most of the experiments have been carried out in proton beams. Up to now, only one experiment has been performed in neutron beam [9] which indicated rather higher polarization of Λ^0's than ones in the proton beam at different energies. In this paper new results of Λ^0 polarization measured in nC reaction are presented. The experiment is performed at the Serpukhov accelerator with the EXCHARM spectrometer located in the neutral channel 5N.

2 Experimental Setup and Data Taking

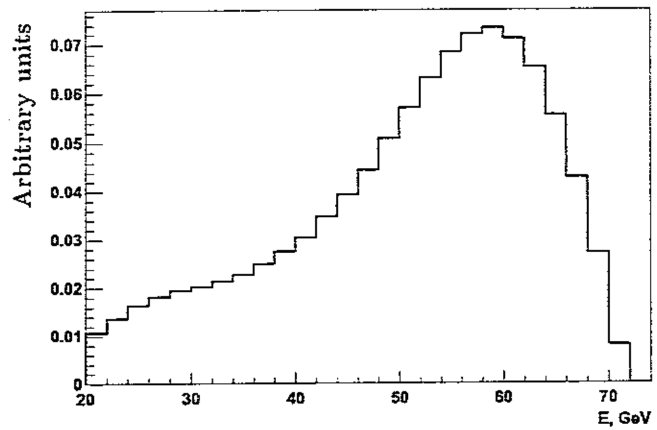

Fig. 1. Neutron beam energy spectrum.

Neutrons were produced on a 3 millimeters in diameter and 3 centimeters long inner beryllium target by 70 GeV primary protons. The target is followed by a set of collimators located at $\approx 0^0$ angle with respect to the incident protons. Neutral channel 5N of ≈ 110 m long includes the set of collimators and 20 cm lead filter for γ rejection. Charged particles

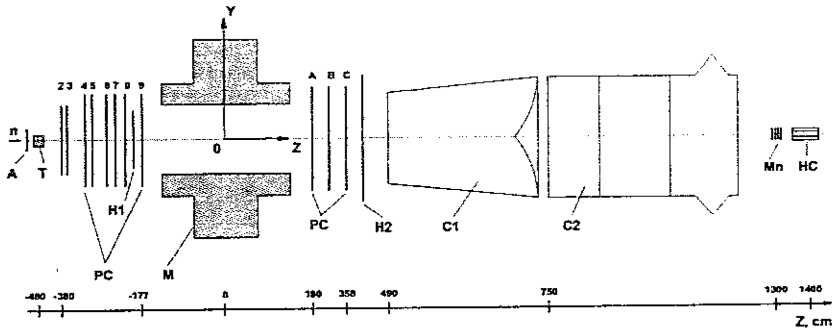

Fig. 2. Setup of EXCHARM spectrometer (schematic).

were swept out by the accelerator magnets and special sweeping magnet $SP-129$ installed at the exit of the final collimator. The neutron beam energy spectrum has a maximum at ≈ 58 GeV and a width of ≈ 12 GeV (Fig.1).

The Layout of the EXCHARM setup is presented in Fig. 2. The detector is described in the right coordinate system with the OZ axis directed along the beam (n). The center of coordinate system coincides with the center of analyzing magnet M. The magnet aperture is 274×49 cm^2 with the maximum field of ≈ 0.79 T. Magnetic field was directed vertically along the 0Y axis. The polarity of magnetic field was alternated every 5-6 hours during data taking. The neutron beam was interacting with the 1.3 g/cm^2 (1.5 cm) long carbon target T located in front of the spectrometer. Produced particles were detected by 11 proportional chambers (PC) with 0.2 cm wire spacing (25 coordinate planes in total). PC's dimensions are up to 100×60 cm^2 (before the magnet) and 200×100 cm^2 (after the magnet). Two scintillator hodoscopes $H1$ and $H2$ consist of 15 and 60 counters respectively. Two Čerenkov counters $C1$ and $C2$ filled with air and freon, respectively, are intended to distinguish protons, K and π-mesons. In present analysis $C1$ and $C2$ were not used. The setup geometry is symmetric with respect to the horizontal plane X0Z.

The trigger was designed as a coincidence logic of signals from $H1$, $H2$, three hodoscopes of the PC planes and charge anti-counter A as a veto. Trigger condition required at least four charged particles passed through the spectrometer.

More detailed description of the apparatus can be found elsewhere [10].

3 Event selection

The presented results are based on the analysis of 1.72×10^8 nC interactions recorded under mentioned conditions.

Λ^0's have been selected by their decay

$$\Lambda^0 \to p\pi^- \quad (1)$$

which corresponds to the so-called "V^0" topology. V^0 is a pair of reconstructed tracks of positive and negative particles. These tracks have to meet within 0.4 cm (closest distance of approach - CDA) which corresponds to 3 fold of experimental resolution on this parameter. To reduce the background caused by interactions in the target and chamber media it was required that Z coordinate of Λ^0 decay vertex occupy a region from 5 cm downstream the target to the first PC. Λ^0 production point (event vertex) was reconstructed as a point of CDA of all particles detected in the event. A cut was applied on the event vertex quality: distance between the CDA point and each track used for the vertex reconstruction should not exceed 3-σ where $\sigma\approx 0.1$cm is the experimental resolution on this parameter. The event vertex should be not further than 3 cm from the target T nominal position which corresponds to the target thickness taking into account our event vertex resolution.

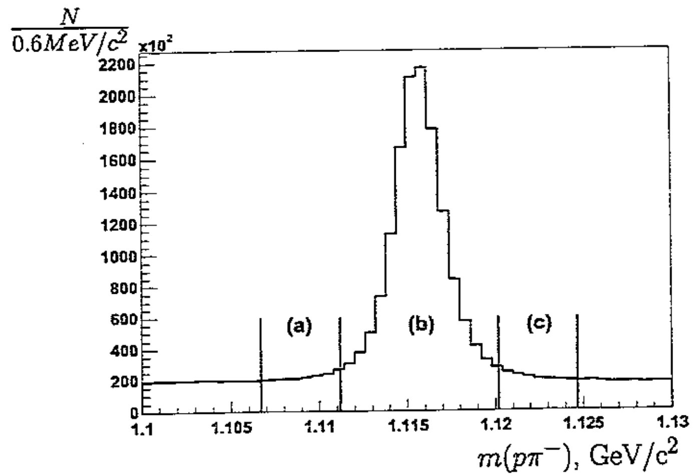

Fig. 3. Effective mass spectrum of $p\pi^-$. Events in region (b) are selected as Λ^0 while events in regions (a) and (c) are treated as the background.

The $p\pi^-$ effective mass, $m(p\pi^-)$, spectrum for selected V^0's is shown in Fig. 3. Events have been identified as (1) decays if the $m(p\pi^-)$ was within $3\sigma_m$ of the Λ^0 nominal mass ($\sigma_m \approx 1.5$ MeV is the experimental resolution on the $m(p\pi^-)$). The integrated number of Λ^0 decays in the signal is $\approx 1.1\times10^6$ and signal to background ratio is ≈ 3.3. These values were estimated by the approximation of the spectrum by a sum of the Gaussian function for the signal and constant value for the background. Background distributions for all subsequent analysis were estimated using sidebands (marked as (a) and (c) in Fig.3) of the signal mass region and subtracted.

4 Polarization measurement

According to the parity conservation in strong interactions, any non-vanishing polarization must be transverse to the production plane defined as $\mathbf{n_{prod}} = \mathbf{k_n} \times \mathbf{k_\Lambda}$, where $\mathbf{k_n}$ and $\mathbf{k_\Lambda}$ are the direction vectors of the neutron beam and Λ^0, respectively. The vector $\mathbf{k_n}$ was reconstructed as a vector pointing from the inner target center to the reconstructed event vertex. The Λ^0 polarization ($\mathcal{P}$) is determined by the angular distribution of the decay proton in the Λ^0 rest frame,

$$\frac{dN}{d\cos\theta} = A(\cos\theta)(1 + \alpha\mathcal{P}\cdot\cos\theta) \qquad (2)$$

where $\cos\theta = \mathbf{n_{prod}} \cdot \mathbf{k_p}$, ($\mathbf{k_p}$ is the direction vector of the decay proton), $\alpha = 0.642$ is the Λ^0 -decay asymmetry parameter [11], and $A(\cos\theta)$ is the acceptance which depends on $\cos\theta$ and a set of kinematic variables. The experimental distribution of (2) is shown in Fig.4 and indicates rather significant influence of acceptance distortions.

To measure the Λ^0 polarization so-called bias canceling technique was applied, similar to one used in [12,13]. The applied method exploits the symmetry of the setup with respect to the horizontal Z0X plane (the magnetic field is directed vertically). Two distributions (2) were plotted separately for each of the azimuthal sectors of Λ production direction: upstream ("Up") and downstream ("Down") the Z0X plane which are related with the $\mathcal{P}$ in the following way:

$$U(\cos\theta) \equiv \frac{dN_U}{d\cos\theta} = A_U(\cos\theta)(1 + \alpha\mathcal{P}\cdot\cos\theta)$$

$$D(\cos\theta) \equiv \frac{dN_D}{d\cos\theta} = A_D(\cos\theta)(1 + \alpha\mathcal{P}\cdot\cos\theta)$$

where N_U and N_D are the numbers of Λ^0 produced in "Up" and "Down" sectors, respectively. In $U(\cos\theta)$ and $D(\cos\theta)$ estimation the background

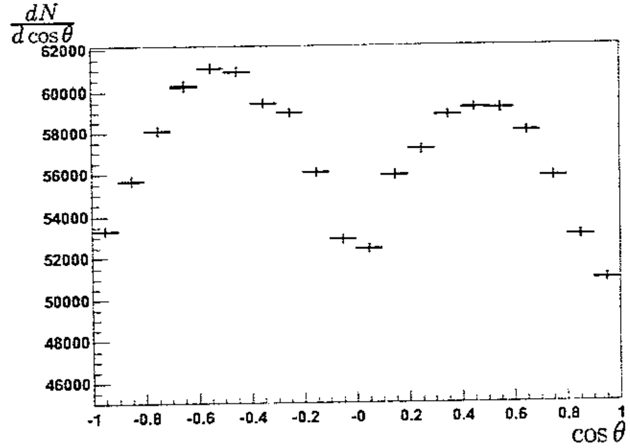

Fig. 4. Experimental angular distribution of Λ^0 decay proton.

events have been subtracted. If the detector upper and lower parts are symmetric versus X0Z plane, then:

$$A_U(\cos\theta) = A_D(-\cos\theta) \qquad (3)$$

for $-1 < \cos\theta < 1$,
and thus a ratio

$$R \equiv \frac{\sqrt{U(\cos\theta)D(\cos\theta)} - \sqrt{U(-\cos\theta)D(-\cos\theta)}}{\sqrt{U(\cos\theta)D(\cos\theta)} + \sqrt{U(-\cos\theta)D(-\cos\theta)}} \qquad (4)$$

defined in the region of $0 < \cos\theta < 1$ is not biased by the acceptances and is related to $\mathcal{P}$ as

$$R = \alpha\mathcal{P}\cdot\cos\theta. \qquad (5)$$

The obtained distribution of R over $\cos\theta$ for all selected Λ^0's is presented in Fig.5 as well as its fit by the expression (5). The obtained Λ^0 polarization is

$$\mathcal{P} = (-4.2 \pm 0.3)\%.$$

The obtained value of $\chi^2/Ndf = 8.8/9$ indicates that the hypothesis (3) is reasonable and the applied procedure can be implemented.

The polarization has been measured as a function of Λ^0 transverse momentum p_t and Feynman variable x_F.

Fig.6 shows the distributions R over $\cos\theta$ and its fit by (5) for the different p_t ranges for all accepted Λ^0's which are characterized by $< x_F > = 0.34^{+0.19}_{-0.23}$. The results of the fit are presented in Table 1. The

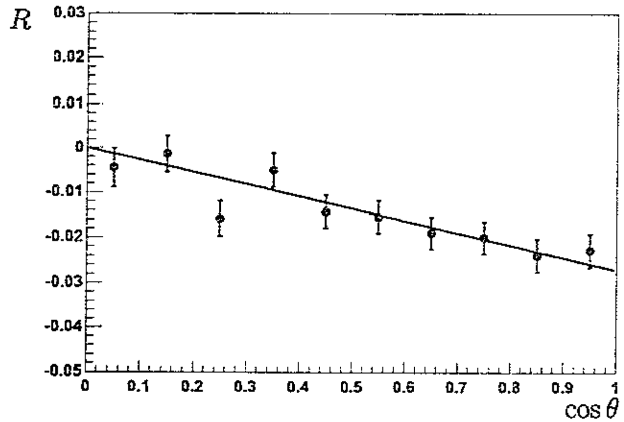

Fig. 5. Distribution of R (4) for all selected Λ^0.

data show a reasonable agreement with the assumption (3) for all intervals of p_t.

Since the initial neutron momentum is not known in each detected event the x_F regions have been determined by a selection of three intervals of Λ^0 longitudinal momentum p_L. A relevant correlation between x_F and p_L was obtained from the Monte-Carlo simulation (Fig.7). Arrows in Fig.7 indicate three chosen p_L intervals which correspond to a particular x_F regions.

The polarization measured in each of three chosen x_F regions and in all p_t intervals are listed in Table 2. Fig. 8 shows $\mathcal{P}$ as a function of p_t separately for each of three x_F regions. Our results reveal nearly linear dependence of polarization versus p_t at fixed x_F. Λ^0 polarization as a function of x_f is also listed in Table 2 and plotted in Fig 9. The

Table 1. Λ^0 polarization as a function of p_t obtained at $< x_F >= 0.34^{+0.19}_{-0.23}$. The χ^2/Ndf column refers to the hypothesis (3)

p_t interval, GeV/c	$< p_t >$, GeV/c	$\mathcal{P}$, %	χ^2/Ndf
$0.10 \div 0.25$	0.20	-1.2 ± 0.7	5.4/9
$0.25 \div 0.40$	0.32	-2.9 ± 0.6	15.0/9
$0.40 \div 0.55$	0.48	-4.0 ± 0.7	6.4/9
$0.55 \div 0.70$	0.61	-5.7 ± 0.8	2.2/9
$0.70 \div 0.85$	0.77	-7.4 ± 1.1	9.2/9
$0.85 \div 1.00$	0.91	-11.3 ± 1.6	7.4/9
$1.00 \div 2.00$	1.18	-11.2 ± 1.7	9.0/9

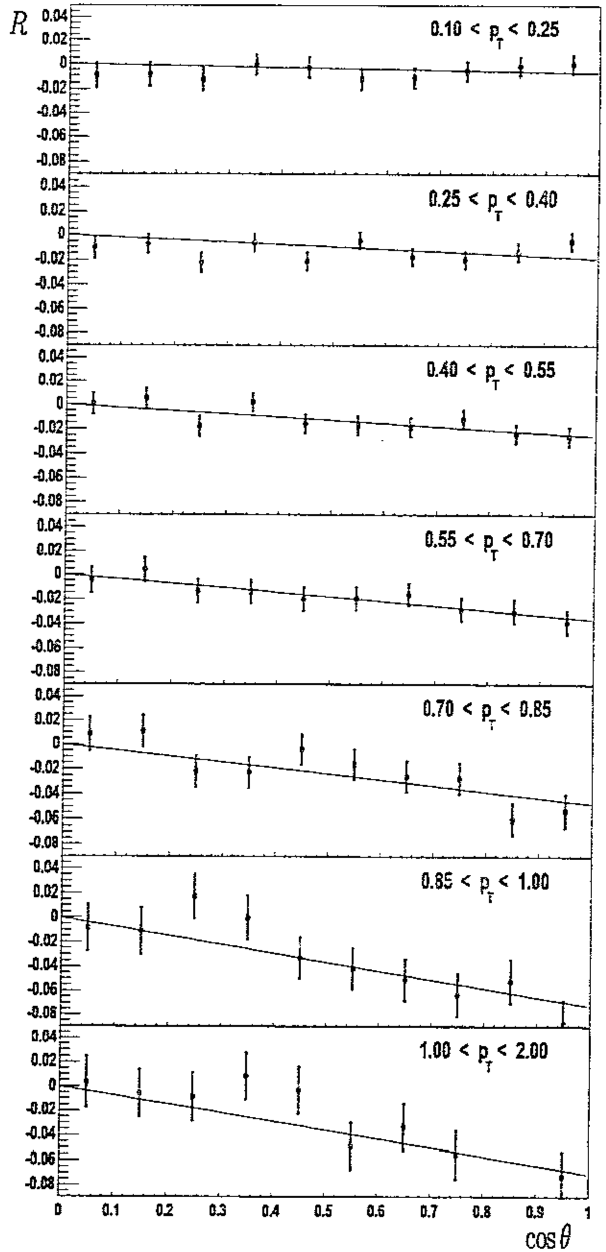

Fig. 6. Distributions of R (4) obtained at seven p_t intervals.

polarization was found to increase roughly linearly with x_F. The errors quoted in Table 2 and in Fig 8 and 9 are statistical only.

Table 2. Λ^0 polarization as a function of p_t for three x_F data sets.

$< p_t >$, GeV/c	$< x_F >$ $0.16^{+0.09}_{-0.12}$	$< x_F >$ $0.35^{+0.08}_{-0.13}$	$< x_F >$ $0.56^{+0.12}_{-0.17}$
	$\mathcal{P}$, %	$\mathcal{P}$, %	$\mathcal{P}$, %
0.20	-1.2 ± 0.9	-1.8 ± 1.2	$+1.2 \pm 2.7$
0.32	-3.4 ± 0.8	-2.9 ± 1.0	-2.1 ± 2.1
0.48	-1.0 ± 1.0	-6.4 ± 1.0	-6.2 ± 2.1
0.61	-2.0 ± 1.4	-7.5 ± 1.1	-7.8 ± 2.3
0.77	-1.6 ± 2.0	-8.7 ± 1.5	-12.8 ± 2.8
0.91	-0.4 ± 2.9	-12.4 ± 2.1	-20.4 ± 3.6
1.17	-1.4 ± 3.6	-8.9 ± 2.2	-23.5 ± 3.8
all p_t 0.50	-1.9 ± 0.5	-5.7 ± 0.5	-7.9 ± 1.0

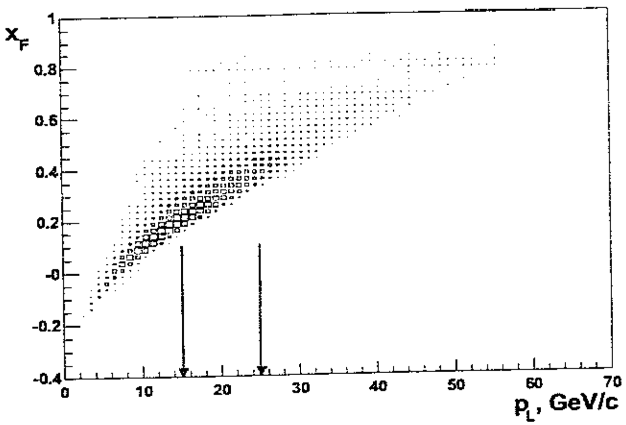

Fig. 7. Correlation between x_F and p_L of Λ^0. Arrows indicate the chosen p_L intervals which correspond to selected x_F regions.

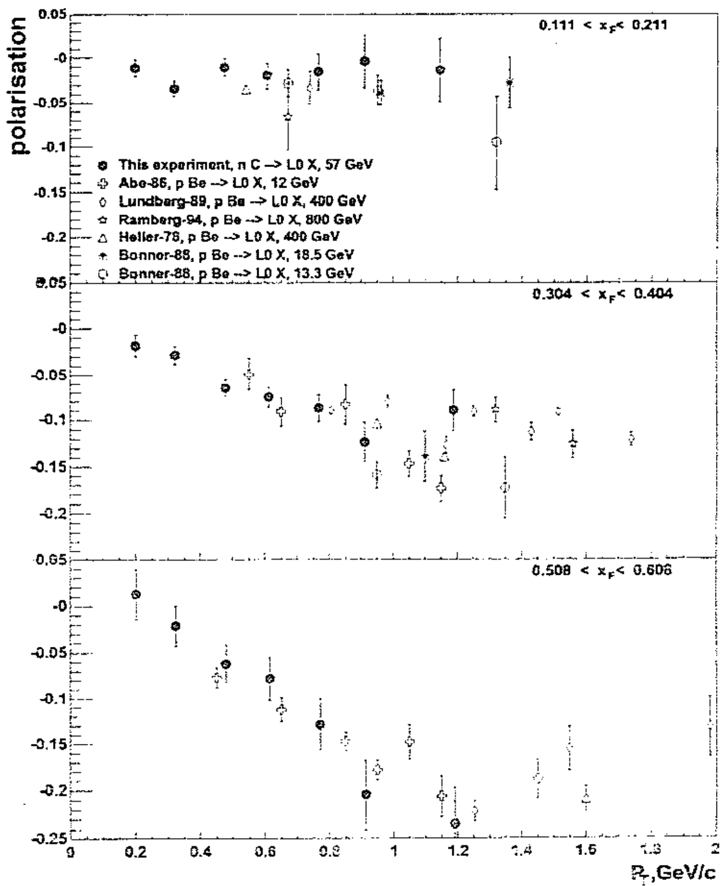

Fig. 8. Inclusive Λ^0 polarization as a function of p_t with x_F restricted to each of three ranges indicated on the plot. The data of present experiment and Refs.[1–5] are shown.

5 Systematic errors

The major contribution to the possible systematic error of the measured $\mathcal{P}$ is from the detector assymetry and precision of neutron beam geometry definition.

The polarization has been measured for two data sets recorded at the reverse polarities of magnetic field. The observed difference in polariza-

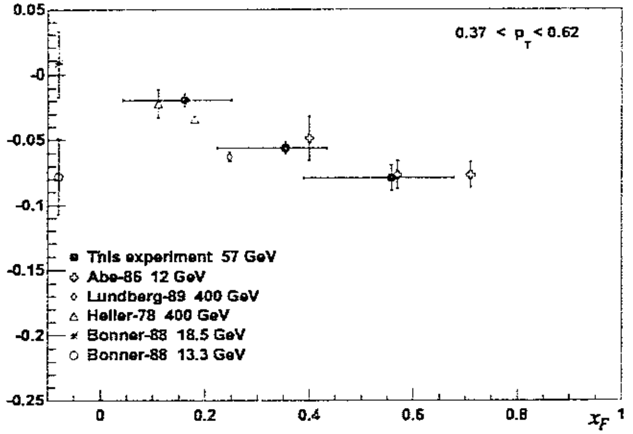

Fig. 9. Inclusive Λ^0 polarization as a function of x_F. Other experiments p_t values are limited to be similar to ours as indicated on the plot.

tion of 0.008 averaged over all p_t intervals indicates the systematic error caused by the setup assymetry.

To estimate systematic errors related with the uncertainty of the neutron beam direction an inner target position has been varied within the known precision. This yields a systematic error equal to 0.002.

An independent check of systematic errors has been done by measuring assymetry in $K_S^0 \to \pi^+\pi^-$ decay. The assymetry measured for 700 000 such decays selected is equal to $+0.003 \pm 0.003$. The related average systematic error on the Λ^0 polarization is $+0.005 \pm 0.005$.

A variation of measured assymetries with the variations of applied cuts has been studied as well. No statistically significant changes in $\mathcal{P}$ have been found.

Thus, the estimated systematic errors are essentially lower than the statistical ones and have not been indicated in the measured $\mathcal{P}$.

6 Conclusions

The Λ^0 polarization has been measured in inclusive production in nC interactions with average beam energy $\approx$ 50 GeV. The kinematic range of detected Λ^0's is $0.1 \lesssim x_F \lesssim 0.6$ and $0.2 \leq p_t \leq 1.2$ GeV/c which extends existing Λ^0 polarization data to the low p_t. Our measurement shows that polarization has nearly linear dependence within all range of p_t: $0 \div \lesssim 1$ GeV/c at fixed x_F. The polarization increases roughly linearly with x_F at fixed p_t. The (x_F,p_t) dependence of the polarization is consistent with the data [1-5] taken in proton beam at different beam energies (see Fig.8 and 9).

The authors are greatly indebted to A.A.Logunov, N.E.Tyurin and A.N.Sissakian for their permanent support of present studies.
The work is supported by the Russian Foundation for Basic Research, project 98-07-90294.

References

1. K. Heller et al. *Phys. Rev. Lett.*, 41:607, 1978.
2. B. Lundberg et al. *Phys. Rev. D*, 40:3557, 1989.
3. B. E. Bonner et al. *Phys. Rev. D*, 38:729, 1988.
4. E. J. Ramberg et al. *Phys. Lett. B*, 338:403, 1994.
5. F. Abe et al. *Phys. Rev. D*, 34:1950, 1983.
6. B. Andersson et al. *Phys. Lett. B*, 85:417, 1979.
7. J. Szwed. *Phys. Lett. B*, 105:403, 1981.
8. T. De Grand und H. Miettinen. *Phys. Rev. D*, 24:2419, 1981.
9. A. Aleev et al. *Yad. Phys.*, 37:6,1479, 1983.
10. A. Aleev et al. *JINR Preprint* P13-98-268B, 1998.
11. Review of Particle Physics. *EPJ*, Vol.3 Num.1-4, 1998.
12. M.I. Adamovich et al. *Z. Phys. A*, 350:379,1995.
13. M.W.McNaughton et al. *Phys. Rev. C*, 23:1128, 1981.

Received by Publishing Department
on June 23, 1999.