Measurement of the Λ polarization in NOMAD

ν_μ NOMAD ν_τ

Neutrino Oscillation MAgnetic Detector

$$\nu_\mu N \to \mu^- \Lambda X$$

The NOMAD collaboration

XIX International Conference

on Neutrino Physics & Astrophysics

16-21 June 2000, Sudbury, Ontario, Canada

What can be learnt by measuring Λ polarization ?

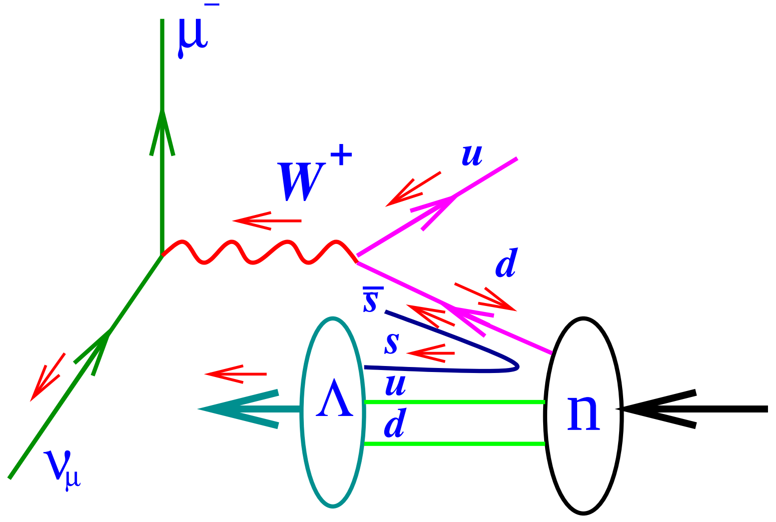
2 physics goals related to spin physics in

2 different regions of Feynman-x ($x_F = 2p^*_L/W$)

Target fragmentation region $x_F < 0$

Ellis et al. (*Z.Phys.* **C69** (1996) 467)

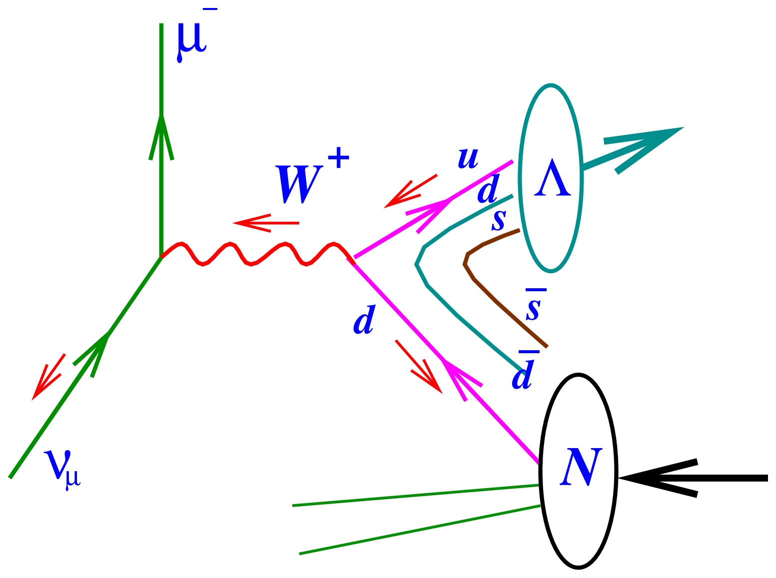
$\Rightarrow$ polarized $s\bar{s}$ pairs in nucleon



$\Rightarrow$ negative Λ polarization

Current fragmentation region $x_F > 0$

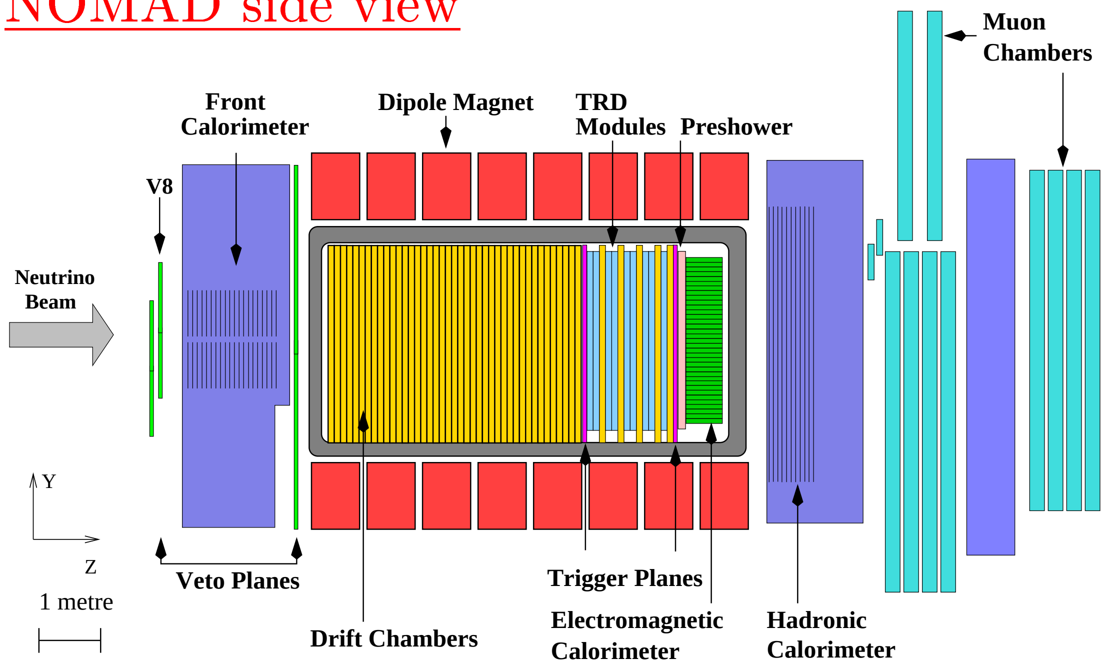
$\Rightarrow$ spin transfer mechanism



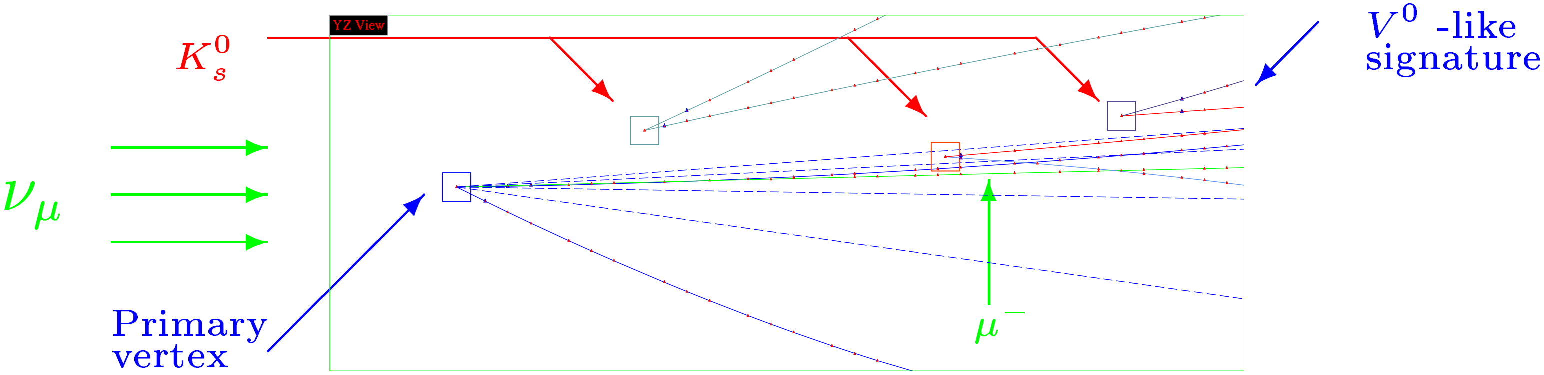
Leading process: $u \to \Lambda \Rightarrow C_u^\Lambda$

V^0 reconstruction in NOMAD

NOMAD side view



- Drift chambers used as a target (2.7 tons) and for momentum measurement (3.5% resolution)
- Magnetic field: 0.4 T
- TRD and Preshower for electron identification
- ECAL and HCAL for energy measurement
- Muon chambers for muon identification

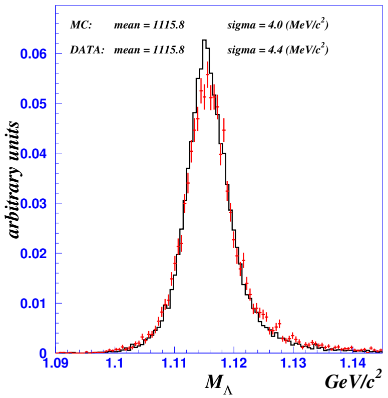


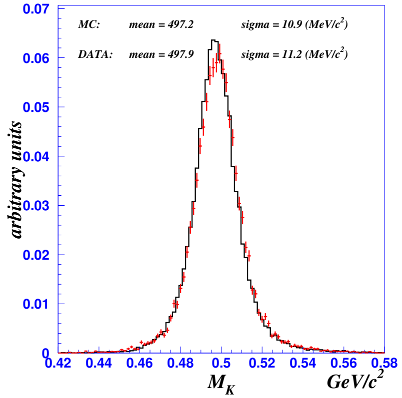
Λ, $\overline{\Lambda}$, K_s^0 identification in ν_μ CC events

Identification

1. Selection of ν_μ CC events
2. Preliminary cuts for V^0 selection
3. Kinematic constrained fit for final V^0 identification

Mass resolution: Λ, K_s^0

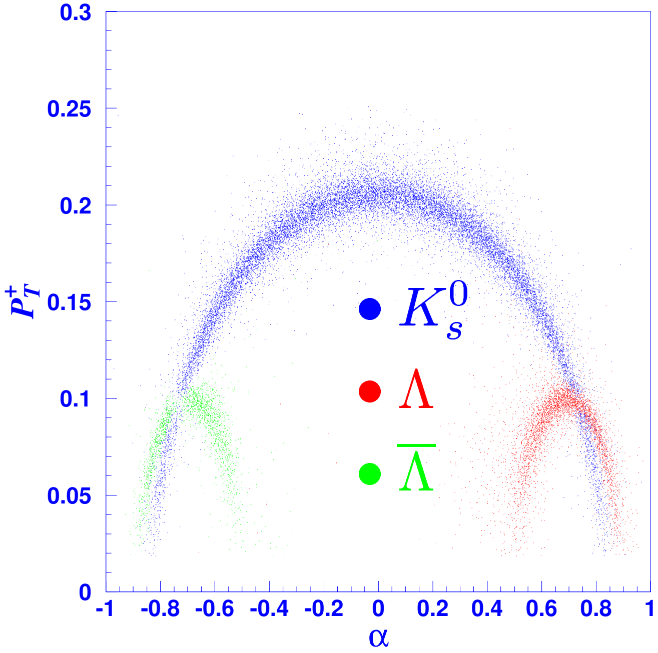




M_Λ: mean = 1115.8, sigma = 4.4 (MeV)

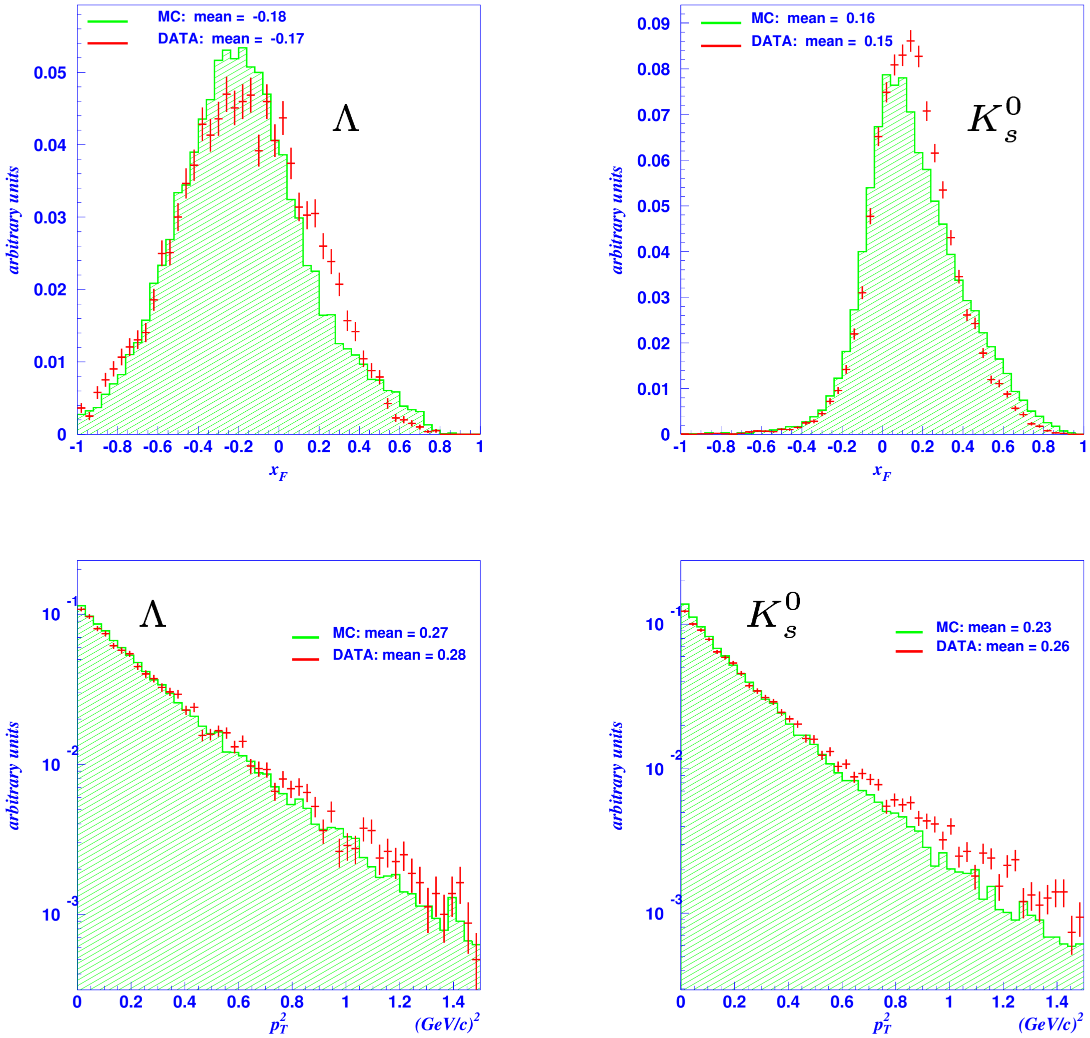
$M_{K_s^0}$: mean = 497.9, sigma = 11.2 (MeV)

Final samples: Armenteros' plot



V^0	Data	Purity (%)	Efficiency (%)
Λ	8087	95.9 ± 0.1	16.4 ± 0.1
$\overline{\Lambda}$	649	89.7 ± 0.7	18.6 ± 0.5
K_s^0	15074	97.2 ± 0.1	22.1 ± 0.1

Relevant kinematic variables



Feynman-x of V^0

transverse momentum squared of V^0 with respect to the hadronic jet

Polarization measurement

1) Λ polarization

The parity violating decay: $\Lambda \rightarrow p\,\pi^-$

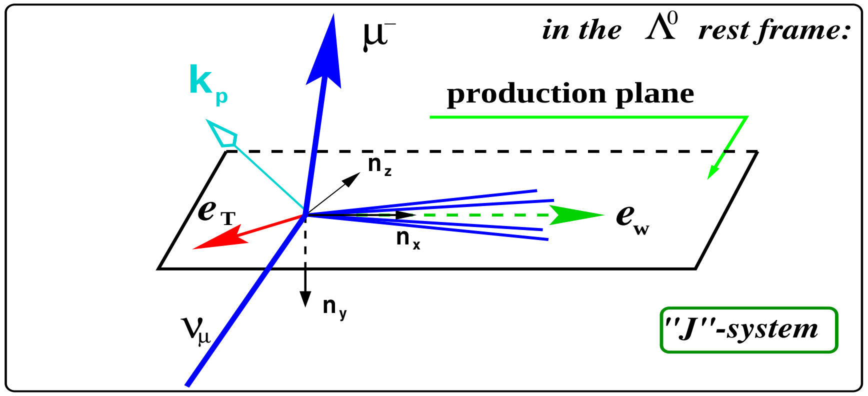
$$\Rightarrow \quad \frac{1}{N}\frac{dN}{d\Omega} = \frac{1}{4\pi}(1 + \alpha\, \vec{P}\cdot\vec{k}_p) \qquad \alpha = 0.642$$

2) Reference system (in Λ rest frame)

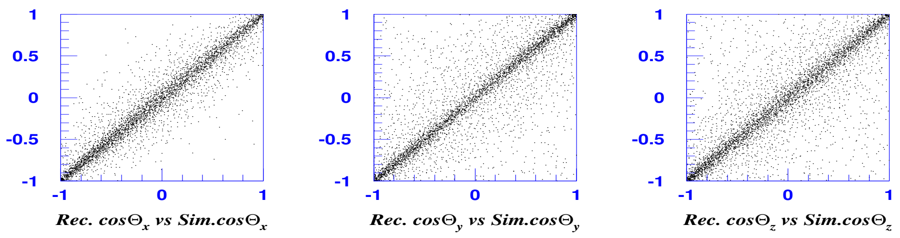
Correlated with expected polarization

(W $\Rightarrow$W-boson, T $\Rightarrow$target nucleon)

$$\left.\begin{array}{l} \bullet\ \vec{n}_x = \vec{e}_W \\ \bullet\ \vec{n}_y = \vec{e}_W \times \vec{e}_T / |\vec{e}_W \times \vec{e}_T| \\ \bullet\ \vec{n}_z = \vec{n}_x \times \vec{n}_y \end{array}\right\} \Rightarrow J\ system$$

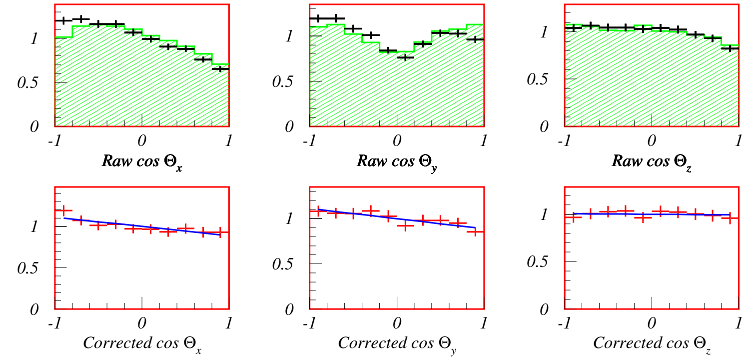


Simulated *versus* reconstructed $\vec{k}_p \cdot \vec{n}_i$:



2 methods for polarization extraction

- correct real data angular distributions for detector acceptance and fit with a straight line: $A_i(1 + \alpha P_i \cos\theta_i)$



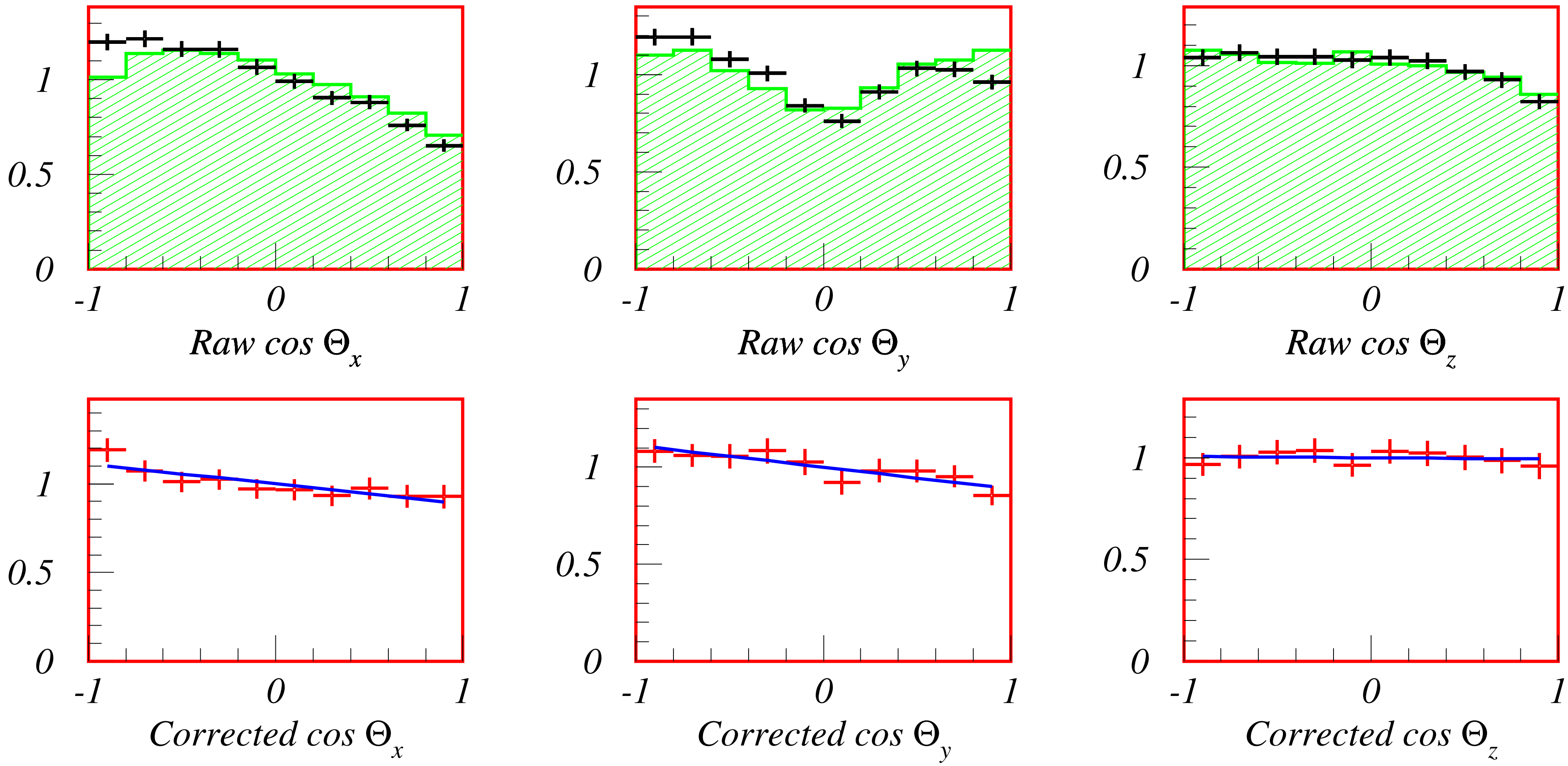
- advanced χ^2 minimization

Systematic errors study

- uncertainty in the incoming neutrino energy determination
- uncertainty in the background predictions
- potential dependence of final results on the selection criteria
- spin precession for a particle traveling through a magnetic field
- smearing of the x_F distribution
- contamination from ν neutral current interactions

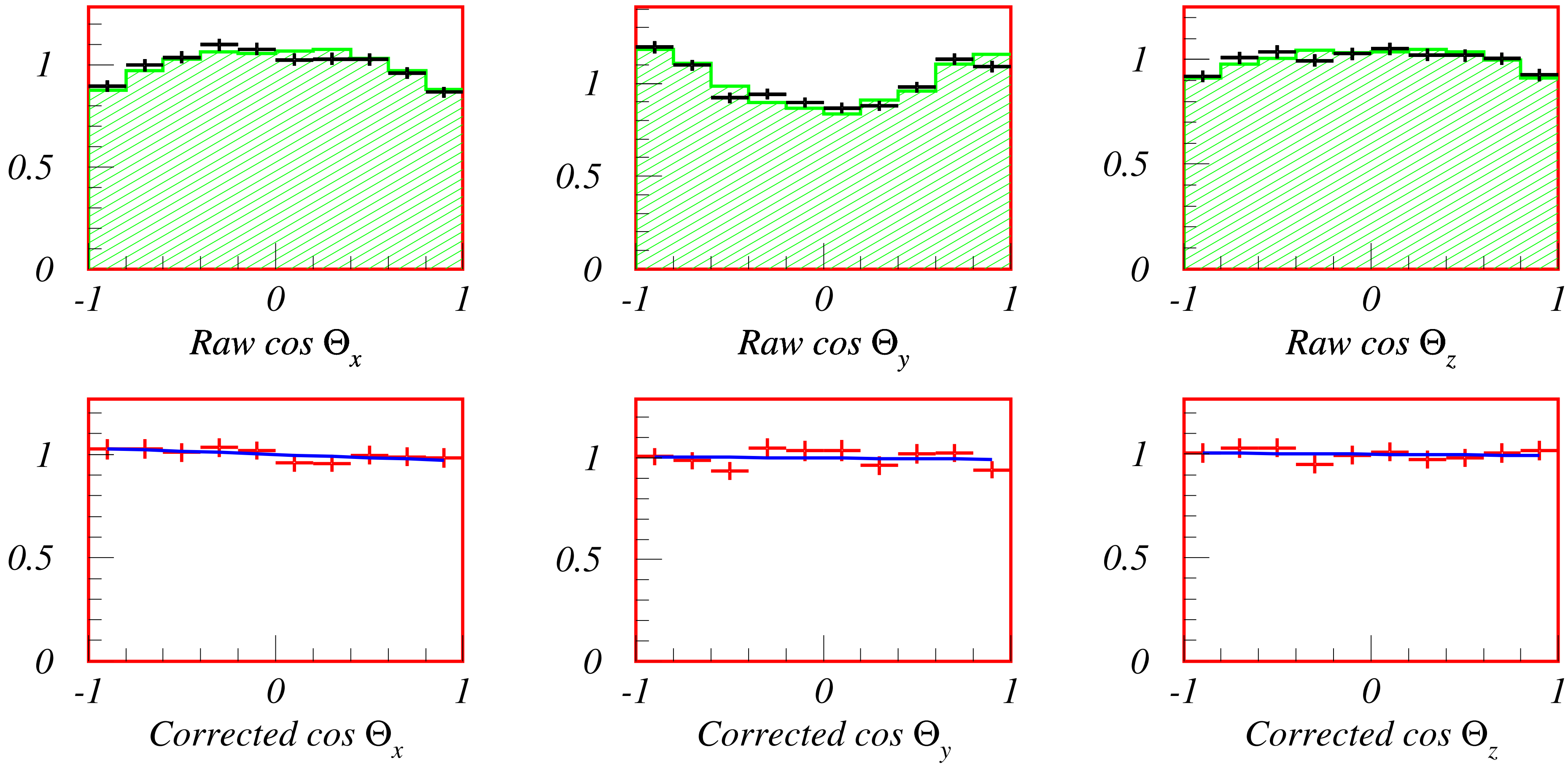
P_i	ν energy reconstruction	V^0 induced background	Variation of cuts	Spin precession	Total
P_x	$3.4 \cdot 10^{-3}$	$3.5 \cdot 10^{-3}$	$1.7 \cdot 10^{-2}$	$1.4 \cdot 10^{-3}$	$1.8 \cdot 10^{-2}$
P_y	$8.5 \cdot 10^{-3}$	$4.9 \cdot 10^{-3}$	$3.8 \cdot 10^{-3}$	$7.2 \cdot 10^{-5}$	$1.1 \cdot 10^{-2}$
P_z	$1.2 \cdot 10^{-2}$	$7.8 \cdot 10^{-3}$	$1.2 \cdot 10^{-2}$	$8.6 \cdot 10^{-4}$	$1.9 \cdot 10^{-2}$

General results : Λ



$P_x = -0.15 \pm 0.03$ $P_y = -0.22 \pm 0.03$ $P_z = -0.04 \pm 0.03$

Control sample : K_s^0



$P_x = -0.04 \pm 0.02$ $P_y = -0.02 \pm 0.02$ $P_z = -0.02 \pm 0.02$

General results

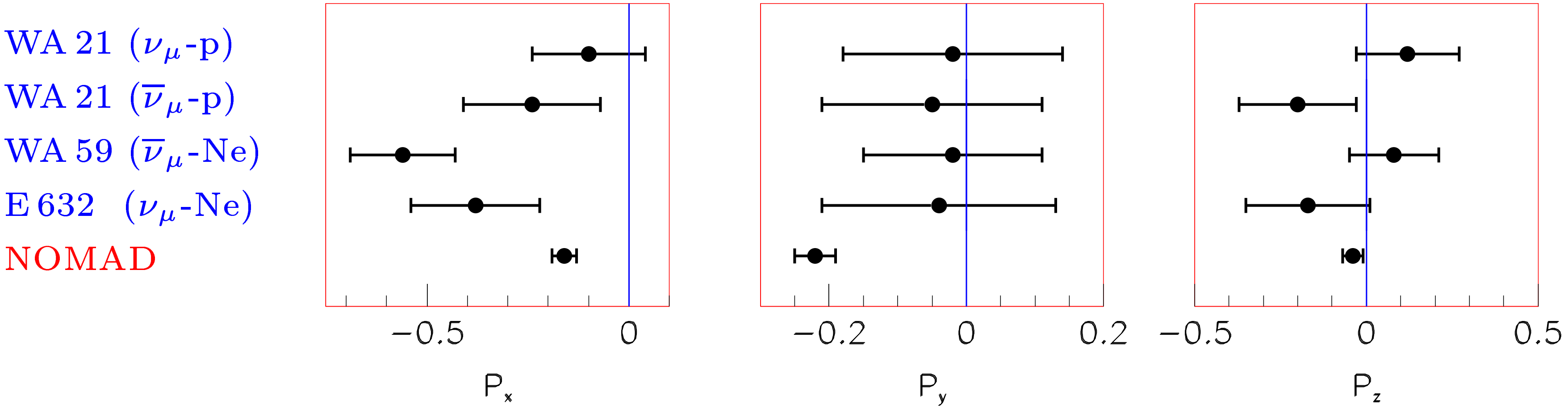
Λ polarization

$$P_x = -0.15 \pm 0.03\ (stat) \pm 0.02\ (syst)$$

$$P_y = -0.22 \pm 0.03\ (stat) \pm 0.01\ (syst)$$

$$P_z = -0.04 \pm 0.03\ (stat) \pm 0.02\ (syst)$$

NOMAD results with respect to previous bubble chamber measurements



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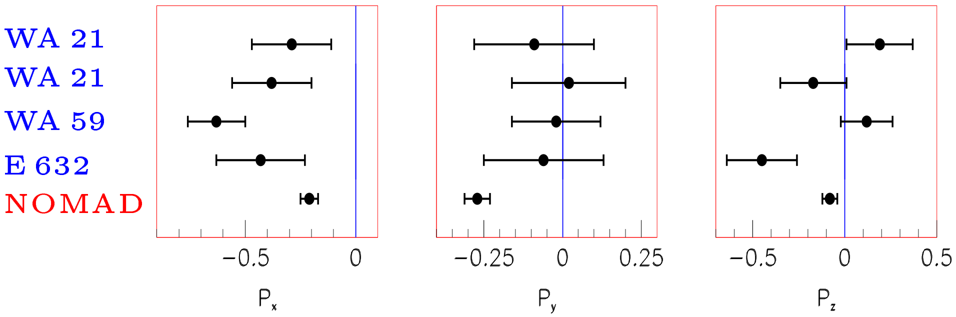
Results: target and current fragmentation region

Target fragmentation region: $x_F < 0$

$N_\Lambda = 5608 \qquad < x_F >= -0.36$

$$P_x = -0.21 \pm 0.04$$
$$P_y = -0.26 \pm 0.04$$
$$P_z = -0.08 \pm 0.04$$



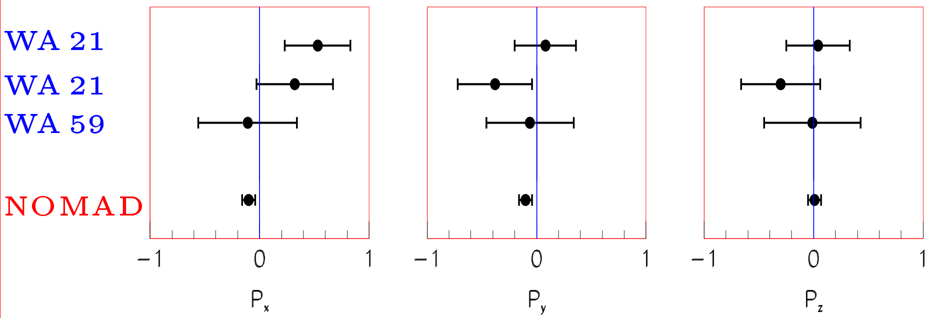
The absolute value of both longitudinal and transverse polarization is enhanced

$\Rightarrow$ results consistent with the model of polarized $s\bar{s}$ pairs in the nucleon

Current fragmentation region: $x_F > 0$

$N_\Lambda = 2479 \quad < x_F >= 0.21$

$$P_x = -0.09 \pm 0.06$$
$$P_y = -0.10 \pm 0.06$$
$$P_z = 0.02 \pm 0.06$$



Longitudinal polarization is related to the spin transfer coefficient C_u^Λ :

$$P_x^\Lambda \approx -\frac{\Delta D_u^\Lambda}{D_u^\Lambda} = -C_u^\Lambda$$

Λ sample $\Rightarrow$ primary and decay products: theoretical interpretation of this result depends strongly on the yields of Σ^0, $\Sigma^\star$ and Ξ

NOMAD
ν_μ ν_τ
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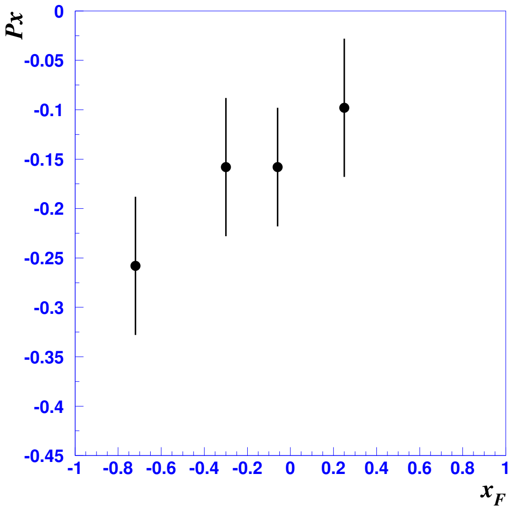
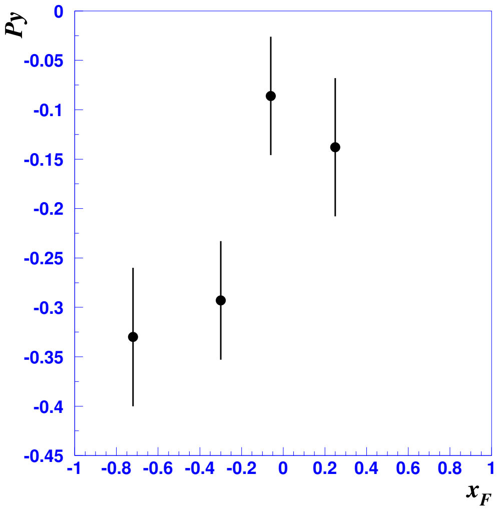
More results

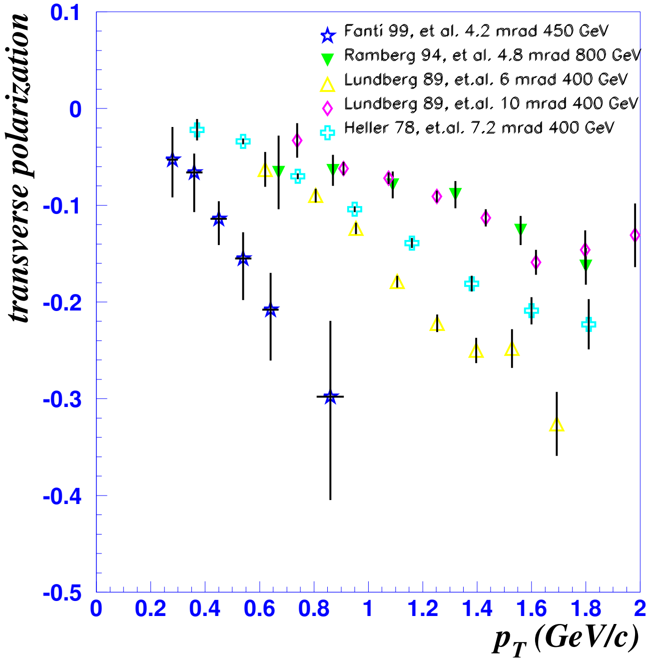




Selection	Entries	Λ Polarization		
		P_x	P_y	P_z
$x_B < 0.2$	3508	-0.15 ± 0.05	-0.17 ± 0.05	-0.11 ± 0.05
$x_B > 0.2$	4579	-0.15 ± 0.04	-0.26 ± 0.04	0.00 ± 0.05
$W^2(\mathrm{GeV}^2) < 15$	2755	-0.34 ± 0.06	-0.25 ± 0.06	-0.08 ± 0.06
$W^2(\mathrm{GeV}^2) > 15$	5332	-0.06 ± 0.04	-0.21 ± 0.04	-0.03 ± 0.04
$Q^2(\mathrm{GeV}^2) < 5$	3429	-0.21 ± 0.05	-0.20 ± 0.05	-0.08 ± 0.05
$Q^2(\mathrm{GeV}^2) > 5$	4658	-0.11 ± 0.04	-0.24 ± 0.04	-0.02 ± 0.04

Results: transverse polarization

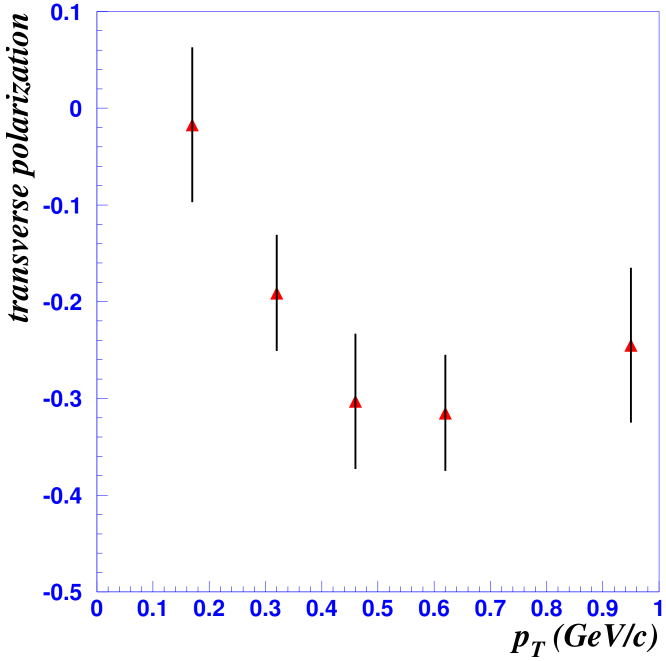
Transverse polarization has been studied in hadron-hadron experiments (plot NA 48):



where p_T is the transverse momentum of the Λ with respect to the beam direction

$\Rightarrow$ absolute value grows linearly with p_T

We have also studied the p_T dependence of the transverse polarization

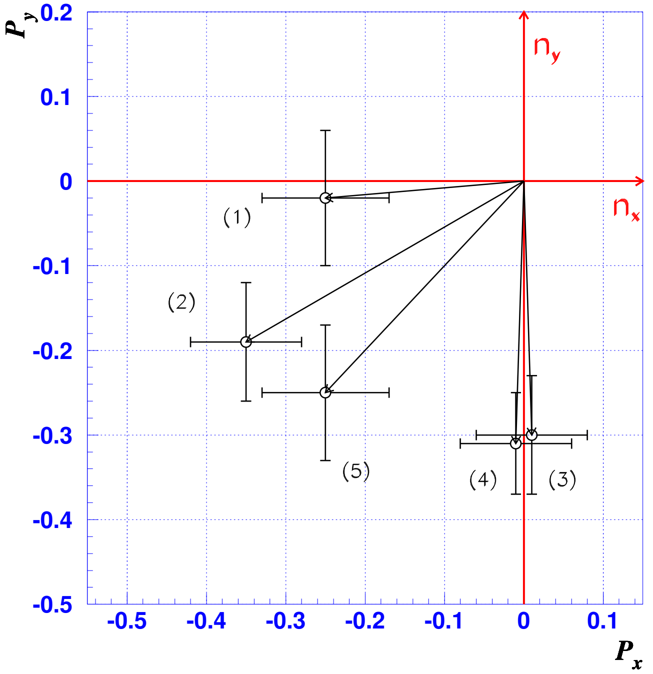


$\Rightarrow$ negative transverse polarization

$\Rightarrow$ similar dependence on p_T where p_T is the transverse momentum of the Λ with respect to the hadronic jet

Results: polarization vector

The behaviour of the Λ polarization vector in the XY plane in different p_T intervals.



Results: target nucleon effects

proton-like events with $Q_{tot} \geq 1$ $\Rightarrow$purity 76%

where Q_{tot} is the sum of charges at the primary vertex

Target	Entries	Λ Polarization		
		P_x	P_y	P_z
"ν p"	3472	-0.26 ± 0.05	-0.09 ± 0.05	-0.07 ± 0.05
$x_F < 0$	2407	-0.29 ± 0.06	-0.10 ± 0.06	-0.09 ± 0.06
$x_F > 0$	1065	-0.23 ± 0.09	-0.06 ± 0.09	-0.02 ± 0.10

The uu quark pair left $\Rightarrow$

A considerable contribution from $\Sigma^{\star +}$ and other resonances

Results: target nucleon effects

neutron-like events with $Q_{tot} \leq 0$ $\Rightarrow$purity 85%

Target	Entries	Λ Polarization		
		P_x	P_y	P_z
"ν n"	4615	-0.09 ± 0.04	-0.30 ± 0.04	-0.03 ± 0.05
$x_F < 0$	3201	-0.16 ± 0.06	-0.37 ± 0.05	-0.07 ± 0.05
$x_F > 0$	1414	0.01 ± 0.08	-0.11 ± 0.08	0.04 ± 0.09

The ud pair left $\Rightarrow$

Probably more directly related to the nucleon strangeness

Conclusion

The general result on the Λ polarization measurement in NOMAD is:

$$P_x = -0.15 \pm 0.03\ (stat) \pm 0.02\ (syst)$$
$$P_y = -0.22 \pm 0.03\ (stat) \pm 0.01\ (syst)$$
$$P_z = -0.04 \pm 0.03\ (stat) \pm 0.02\ (syst)$$

Obtained with 8087 reconstructed and identified Λ's

A detailed paper to be submitted to Nuclear Physics