Longitudinal and Transverse Λ^0 Polarization in Deep Inelastic Lepton Nucleon Scattering at HERMES

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Motivation

- Λ^0 : unique tool for polarization measurement, due to self-analyzing decay
- Spin Structure of Λ^0–Hyperons

$$\Lambda^0 = (uds)$$

Naive Quark Parton Model (NQPM) :

ud: Spin and Isospin 0

$=>$ s: carries Λ^0–Spin

But: NQPM fails for Proton

$\longrightarrow$ for Λ^0 ?

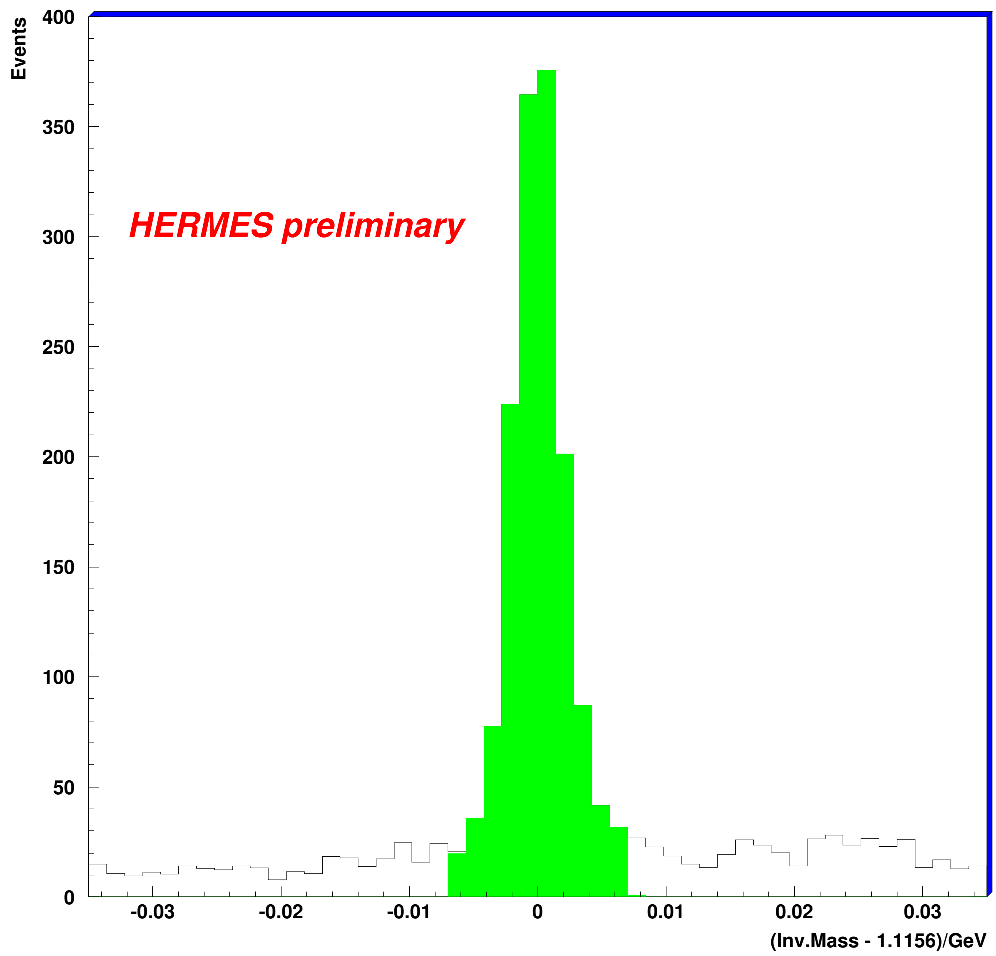
- Spin Transfer in Polarized Lepton–Nucleon Scattering
- Λ^0 from pp collisions: transverse polarization
  $\longrightarrow$ Λ^0 from DIS ?

Λ^0 Reconstruction

Λ^0 : lightest Baryon with Strangeness
=> only weak decay channels

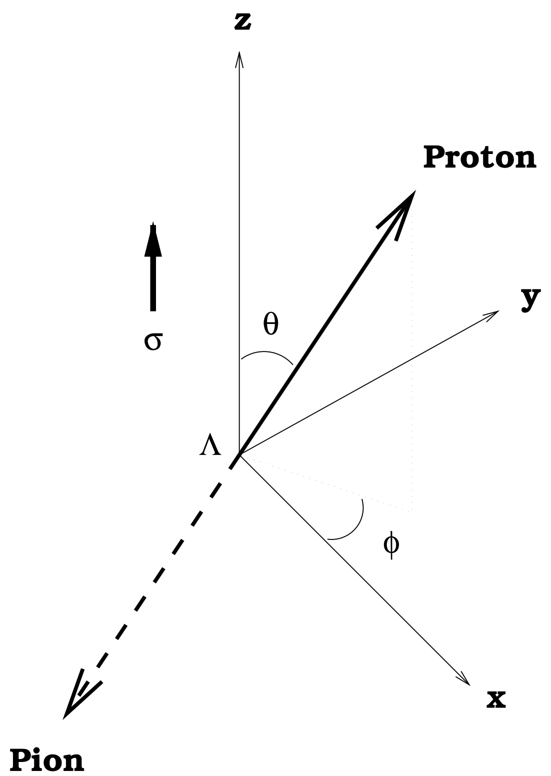
$\Lambda^0 -> \pi^- p$ (63.9 %)
$\Lambda^0 -> \pi^0 n$ (35.8 %)

Mass spectrum for Λ^0 at hermes 96/97



Λ^0 Polarization Measurement

Parity Violating Decay



$$dN_{\text{proton}} \propto (1 + \alpha P \cos\Theta) d\Omega$$

Θ : Angle between proton momentum and Λ^0 polarization direction in Λ^0 CMS

α : (0.642 ± 0.013): asymmetry parameter,

P : Λ^0 Polarization.

Existing Data from e$^+$ e$^-$ at LEP

Measurement Λ^0 polarization produced at Z^0 pole:

ALEPH (1) and OPAL (2): P$_{\Lambda^0} \approx -0.3$ for $z > 0.3$

But:
contribution of different flavors are not distinguishable

Data consistent with 3 scenarios (3):

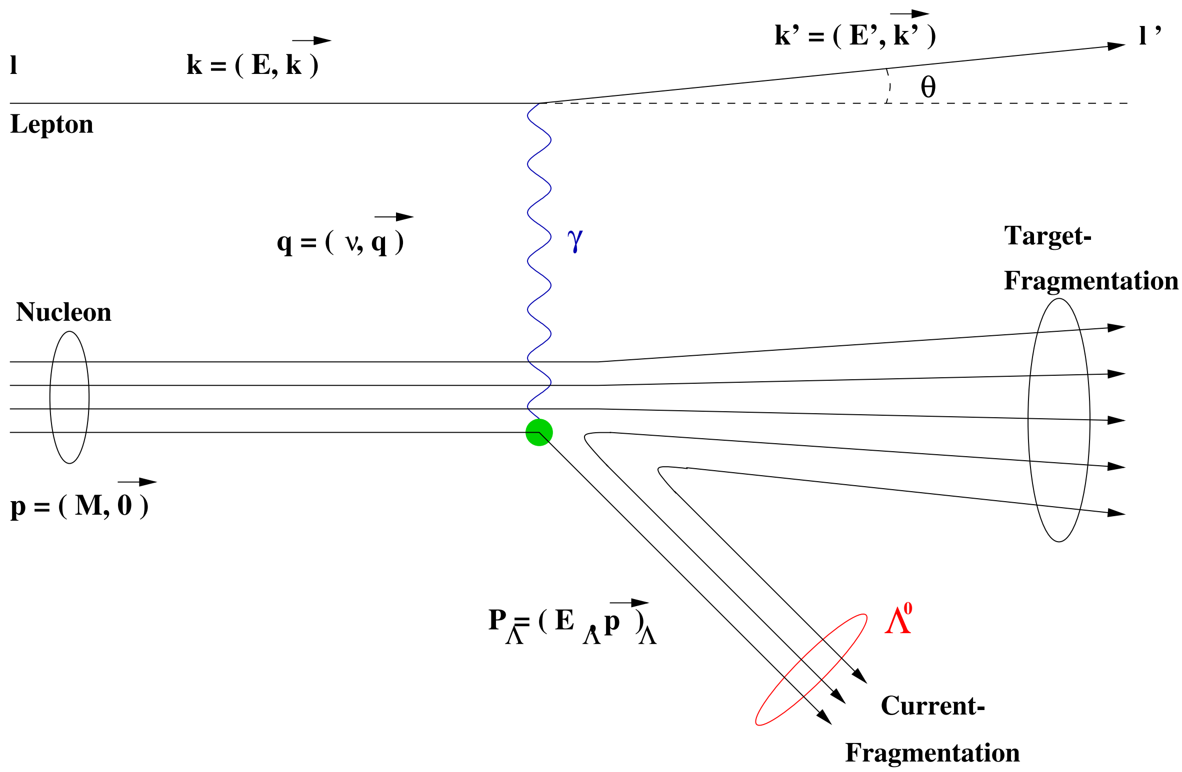
(1) NQPM
$\Delta u_\Lambda = \Delta d_\Lambda = 0; \Delta s_\Lambda = 1$

(2) SU(3) flavor–symmetric model (BJ Model) (4, 5)
$\Delta u_\Lambda = \Delta d_\Lambda \approx -0.2; \Delta s_\Lambda \approx 0.6$

(3) all 3 light flavors contribute equally
$\Delta u_\Lambda = \Delta d_\Lambda = \Delta s_\Lambda$

And model from Boros et al.(6): ΔD_u^Λ and $\Delta D_d^\Lambda > 0$ at high rapidities

Semi–Inclusive Deep Inelastic Scattering



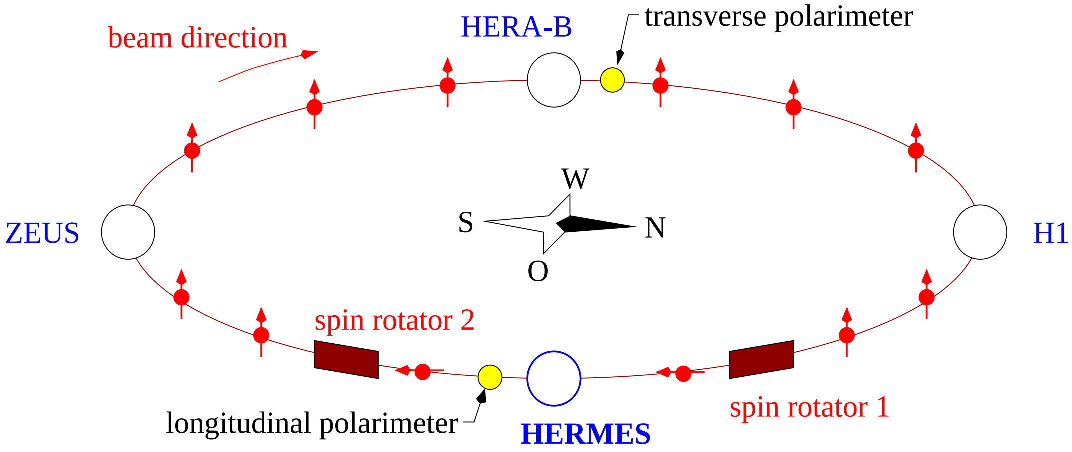
$$x = \frac{-q^2}{2M\nu}$$

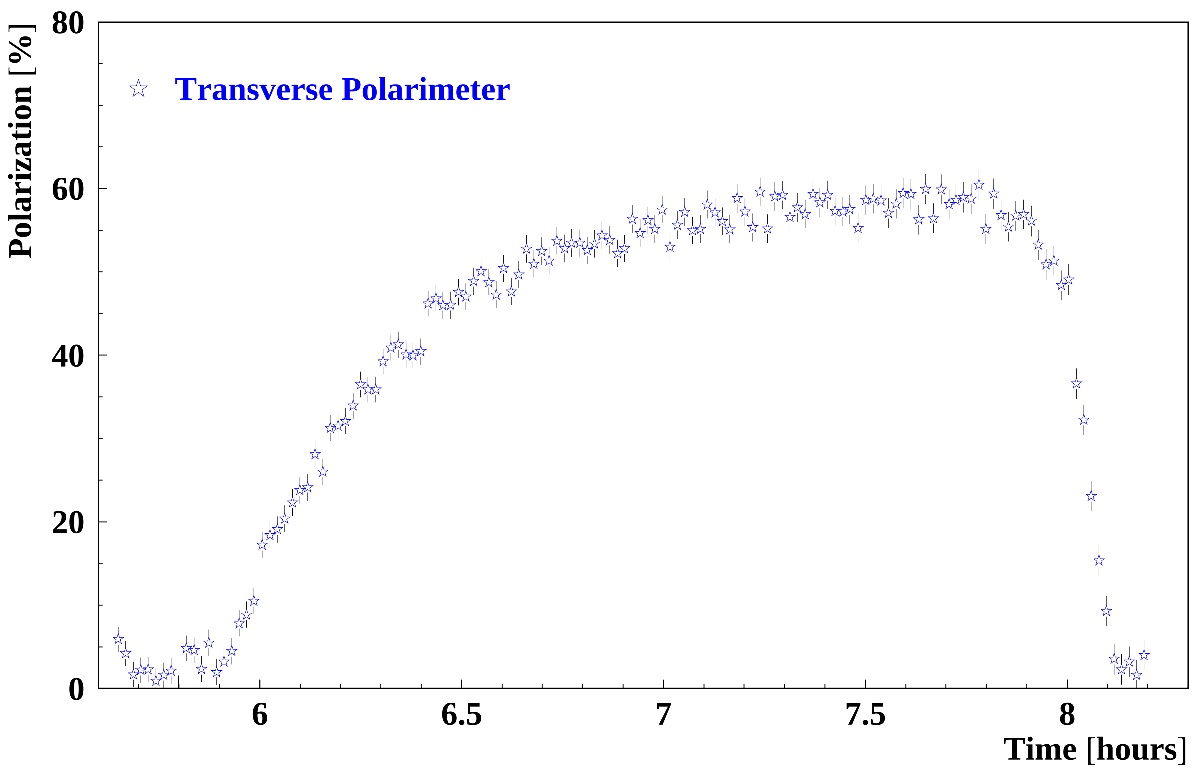
$$y = \frac{\nu}{E}$$

$$z = \frac{E_\Lambda}{\nu}$$

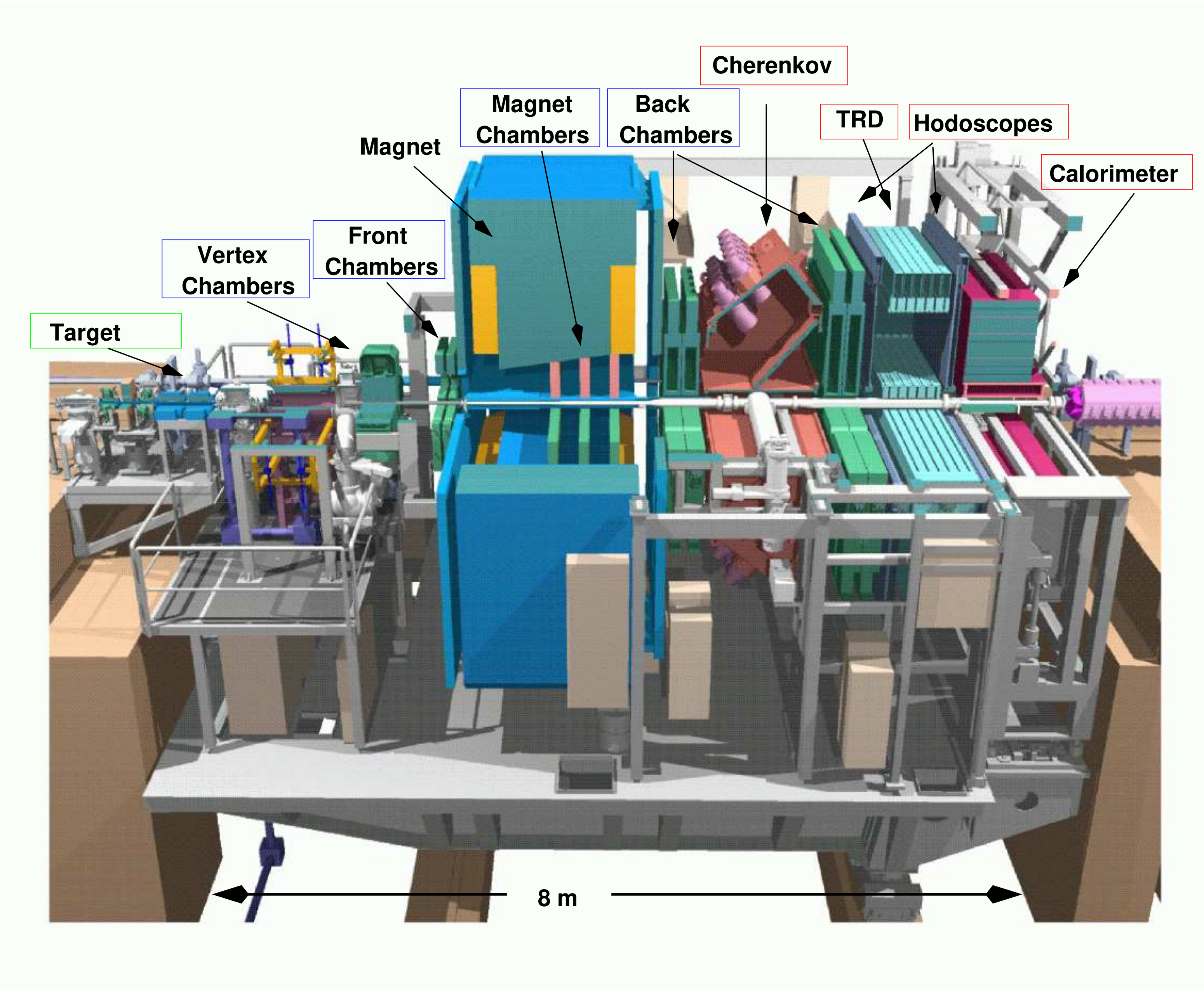
interaction with u quark dominates

The Polarized HERA-Lepton Beam

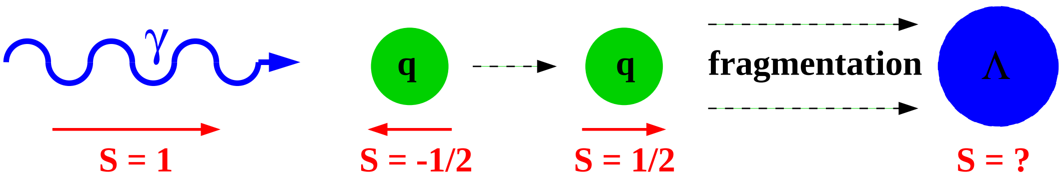




The hermes –Detector



Longitudinal Λ^0 Polarization for Unpolarized Targets



$$
\begin{aligned}
P_\Lambda &= P_\gamma \cdot Q^{\mathrm{LL}'}_{\mathrm{Beam}} \\
&= P_{\mathrm{Beam}} D(y) \cdot Q^{\mathrm{LL}'}_{\mathrm{Beam}}
\end{aligned}
$$

where

$$
Q^{\mathrm{LL}'}_{\mathrm{Beam}} = \frac{\sum_{\mathrm{q}} \left[e_{\mathrm{q}}^2 q(x) \Delta D_{\mathrm{q}}^{\Lambda}(z) \right]}{\sum_{\mathrm{q}} \left[e_{\mathrm{q}}^2 q(x) D_{\mathrm{q}}^{\Lambda}(z) \right]} \approx \frac{\Delta D_{\mathrm{u}}^{\Lambda}(z)}{D_{\mathrm{u}}^{\Lambda}(z)}
$$

and

$$
\begin{aligned}
q(x) &= \text{quark distribution in nucleon} \\
D(y) &= \text{photon–depolarization factor} \\
D_{\mathrm{q}}^{\Lambda}(z) &= \text{unpolarized fragmentation function} \\
\Delta D_{\mathrm{q}}^{\Lambda}(z) &= \text{polarized fragmentation function}
\end{aligned}
$$

Longitudinal Spintransfer for Unpolarized Targets

$Q^{\mathrm{LL}'}_{\mathrm{Beam}}$ from the forward–backward asymmetry in the angular distributions :

$$Q^{\mathrm{LL}'}_{\mathrm{Beam}} = \frac{1}{\alpha < P^2_{\mathrm{Beam}} >} \cdot \frac{\sum_{\mathrm{i}=1}^{N_\Lambda} P_{\mathrm{Beam,i}} \cos\theta_{\mathrm{P,i}}}{\sum_{\mathrm{i}=1}^{N_\Lambda} D(y_{\mathrm{i}}) \cos^2\theta_{\mathrm{P,i}}}$$

with

$< P^2_{\mathrm{Beam}} >$: luminosity–weighted average square of the beam polarization

spin quantization axis parallel to direction of motion of Λ^0

hermes Result

$$Q^{\mathrm{LL}'}_{\mathrm{Beam}} \quad = \quad 0.11 \pm 0.17(\mathrm{stat}) \pm 0.03(\mathrm{sys})[7]$$

But : Dilution due to Λ^0s from weak processes

Estimated : $\approx$ 20% of Λ^0 come from:

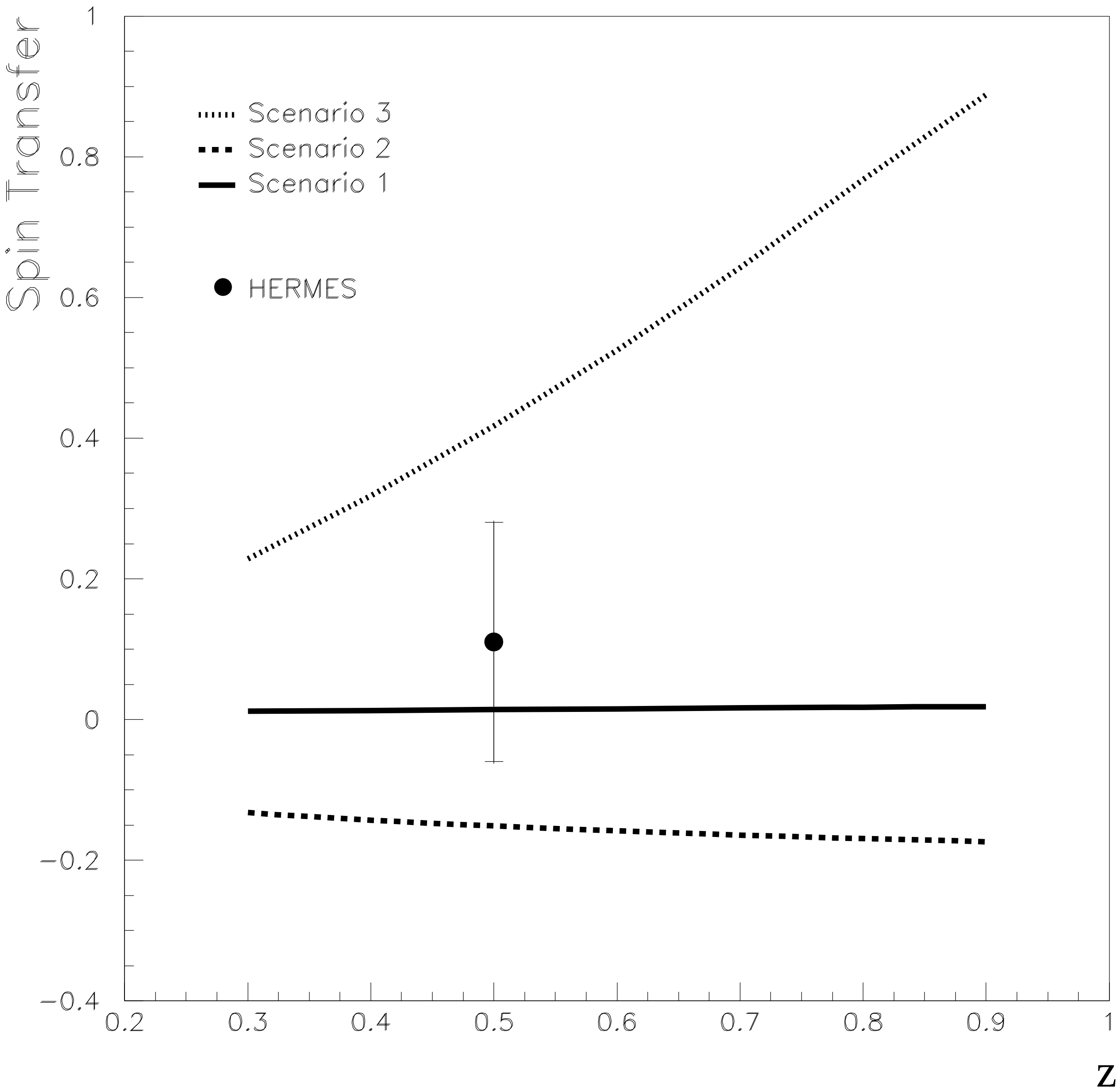
$$\Sigma^0 => \Lambda^0 + \gamma$$

Model dependent contribution (8):

NPQM:	≈ -0.04
BJ:	≈ -0.02

(other weak contributions below 2%)

All strong decays (from $\Sigma(1385)$ etc.) by definition included in ΔD_q^Λ !



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Longitudinal Λ^0 Polarization for Polarized Targets

$$P_\Lambda = \frac{P_{\mathrm{Tar}} \cdot Q^{\mathrm{LL}'}_{\mathrm{Tar}} + P_{\mathrm{Beam}} D(y) \cdot Q^{\mathrm{LL}'}_{\mathrm{Beam}}}{1 + P_{\mathrm{Tar}} P_{\mathrm{Beam}} D(y) \cdot Q^{\mathrm{LL}'}_{\mathrm{BeamTar}}} \tag{1}$$

$$Q^{\mathrm{LL}'}_{\mathrm{Beam}} = \frac{\sum_{\mathrm{q}} \left[e_{\mathrm{q}}^2 q(x) \Delta D_{\mathrm{q}}^{\mathrm{h}}(z) \right]}{\sum_{\mathrm{q}} \left[e_{\mathrm{q}}^2 q(x) D_{\mathrm{q}}^{\mathrm{h}}(z) \right]} \approx \frac{\Delta D_{\mathrm{u}}^{\Lambda}(z)}{D_{\mathrm{u}}^{\Lambda}(z)}$$

$$Q^{\mathrm{LL}'}_{\mathrm{Tar}} = \frac{\sum_{\mathrm{q}} \left[e_{\mathrm{q}}^2 \Delta q(x) \Delta D_{\mathrm{q}}^{\mathrm{h}}(z) \right]}{\sum_{\mathrm{q}} \left[e_{\mathrm{q}}^2 q(x) D_{\mathrm{q}}^{\mathrm{h}}(z) \right]} \approx \frac{\Delta u(x)}{u(x)} \cdot \frac{\Delta D_{\mathrm{u}}^{\Lambda}(z)}{D_{\mathrm{u}}^{\Lambda}(z)}$$

$$Q^{\mathrm{LL}'}_{\mathrm{BeamTar}} = \frac{\sum_{\mathrm{q}} \left[e_{\mathrm{q}}^2 \Delta q(x) D_{\mathrm{q}}^{\mathrm{h}}(z) \right]}{\sum_{\mathrm{q}} \left[e_{\mathrm{q}}^2 q(x) D_{\mathrm{q}}^{\mathrm{h}}(z) \right]} \approx \frac{\Delta u(x)}{u(x)}$$

But : Poor Statistics : 550 Λ^0

Inclusive Λ^0 Events

Same analysis with events without DIS positron in the detector.

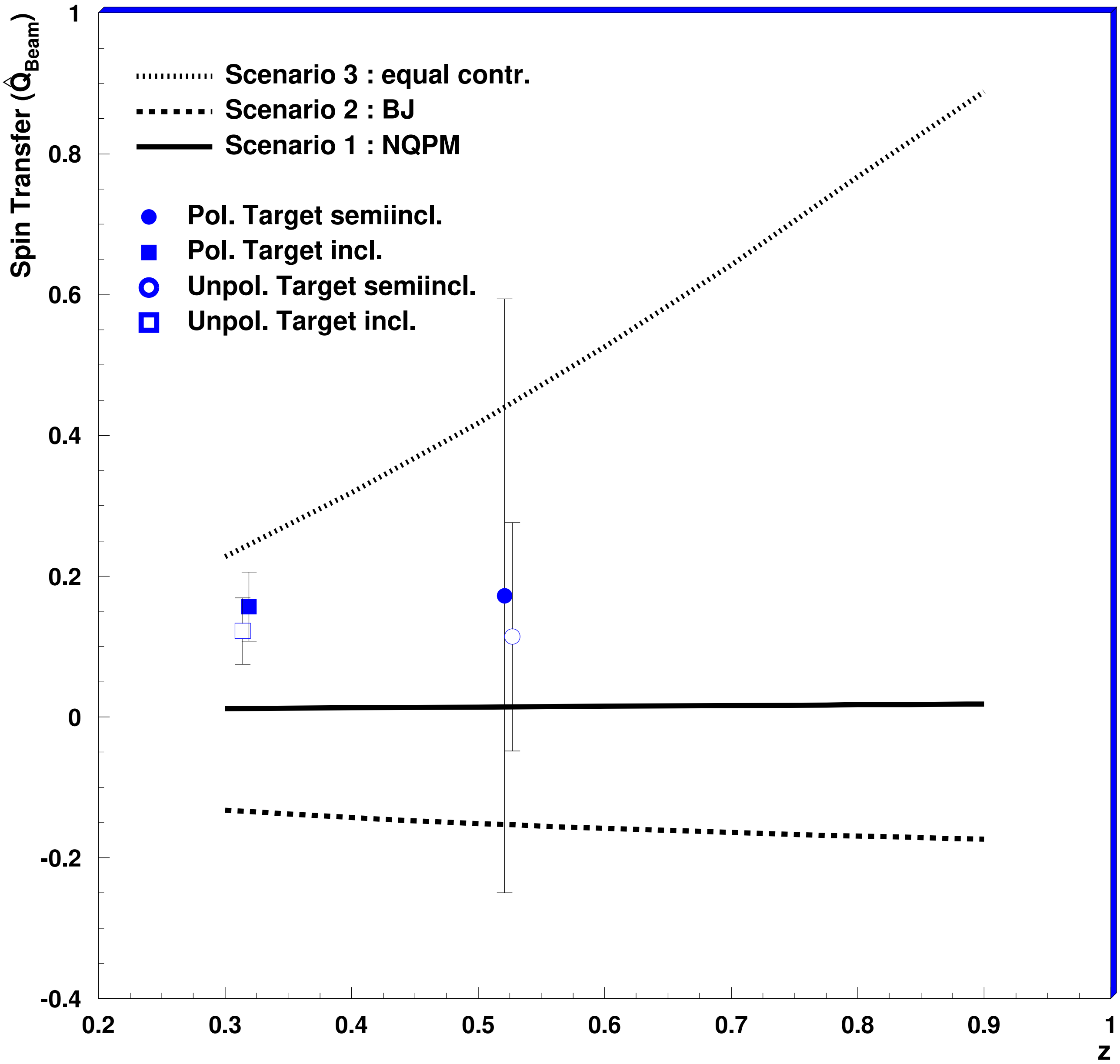
Advantage:

Yield much higher:	factor 10 for unpol. target
	factor 40 for pol. target

Disadvantage:

Need MonteCarlo for event kinematics

All Results (9)



Transverse Polarization for Inclusive Λ^0s

In proton-proton collisions:
Λ^0 polarized perpendicular to production plane

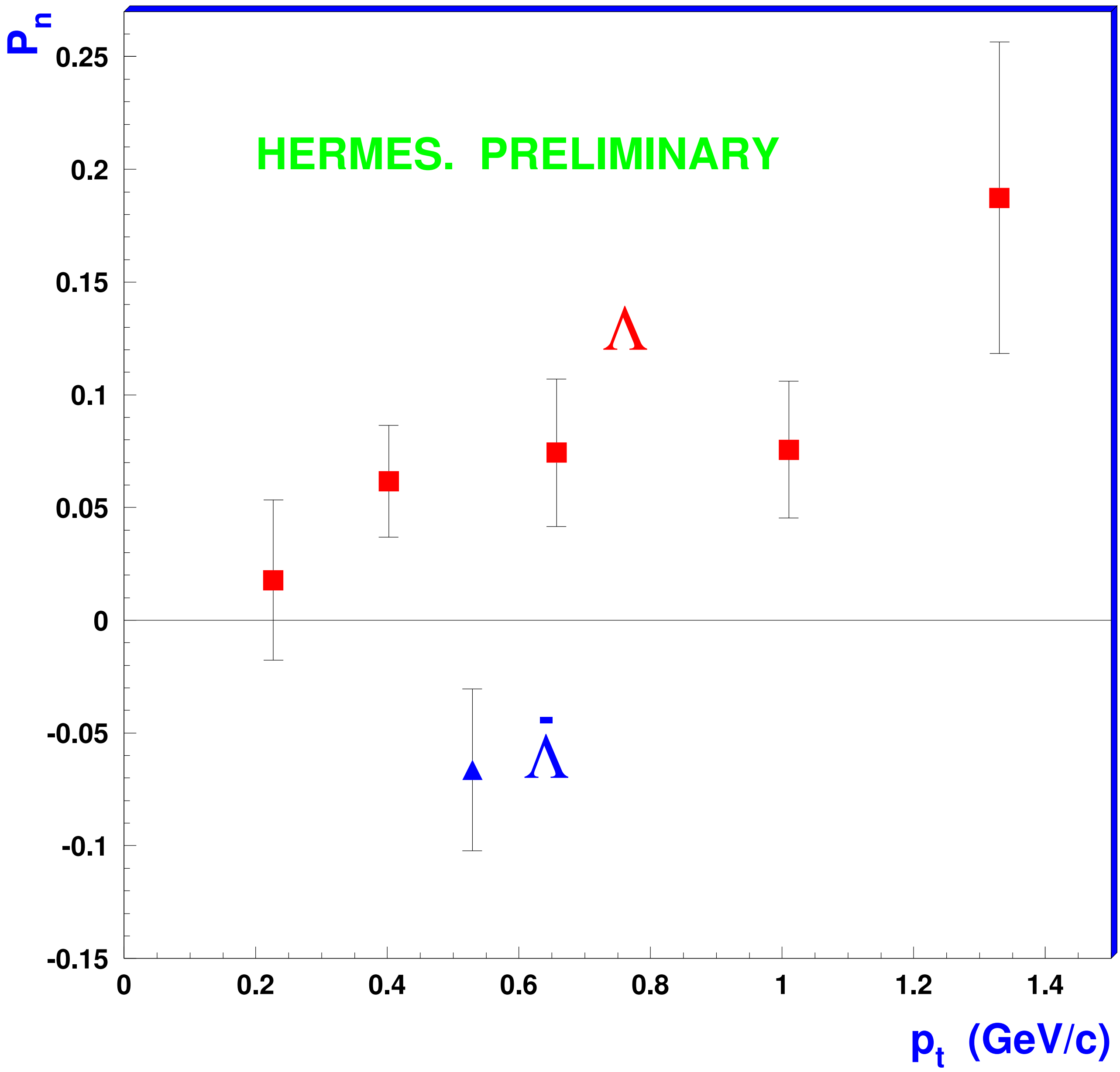
Photoproduction :
CERN (10) and SLAC (11) measurements
within large errors compatible with zero

Quasi-photoproduction at HERMES ($Q^2 < 0.08$ GeV^2)
(12):

$$\alpha P_\Lambda = \frac{\frac{1}{N_\Lambda^\mathrm{T}} \sum_{\mathrm{i}=1}^{N_\Lambda^\mathrm{T}} \cos\theta_{\mathrm{P,i}}^\mathrm{T} + \frac{1}{N_\Lambda^\mathrm{B}} \sum_{\mathrm{i}=1}^{N_\Lambda^\mathrm{B}} \cos\theta_{\mathrm{P,i}}^\mathrm{B}}{\frac{2}{N_\Lambda} \sum_{\mathrm{i}=1}^{N_\Lambda} \cos^2\theta_{\mathrm{P,i}}}$$

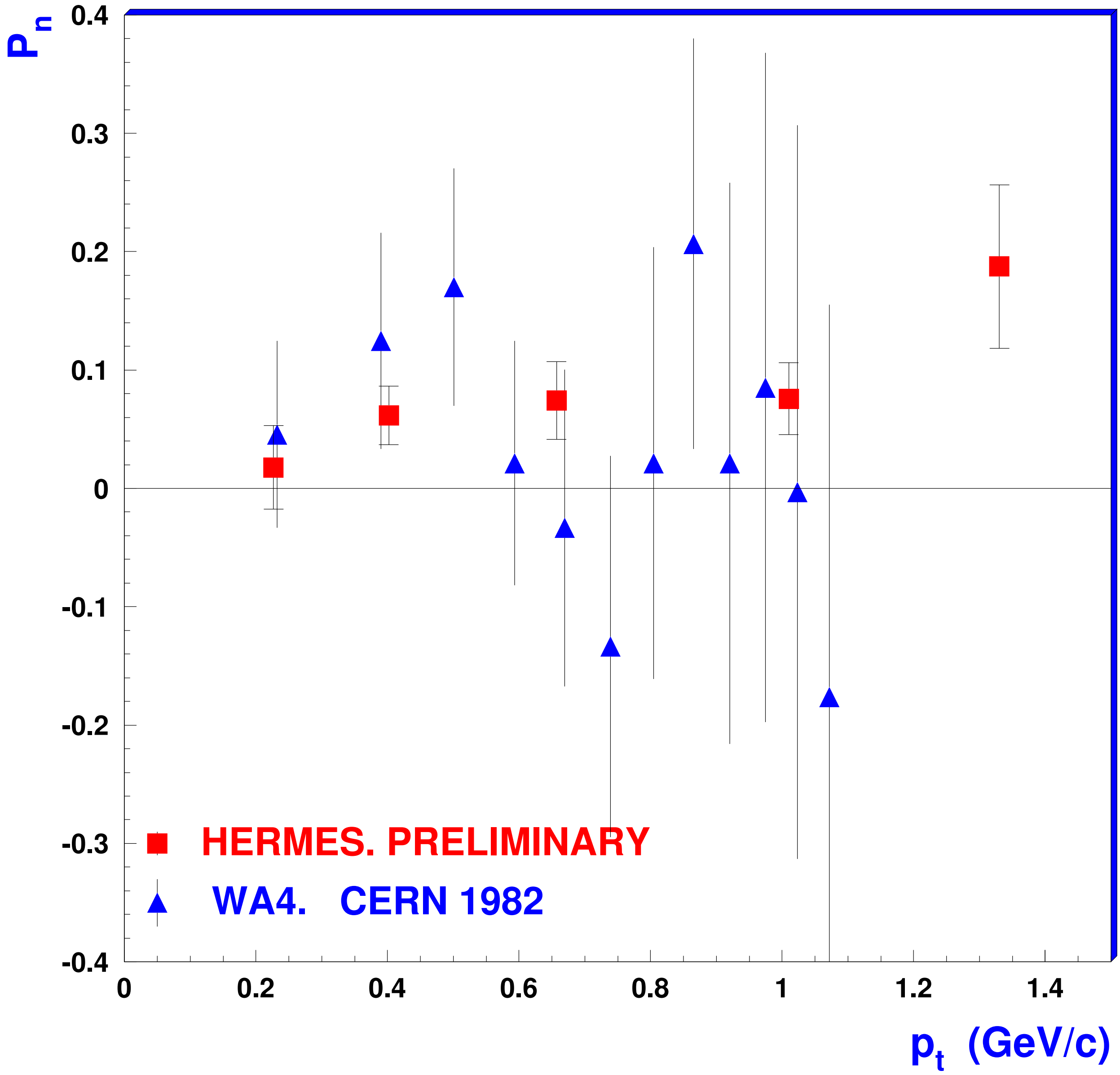
with N_Λ^T and N_Λ^B being the numbers of Λ^0s in the top and bottom half of the detector and $N_\Lambda = N_\Lambda^\mathrm{T} + N_\Lambda^\mathrm{B}$

Transverse polarization of inclusive Λ and $\bar{\Lambda}$



Experimental systematic error $\delta P \approx 0.025$

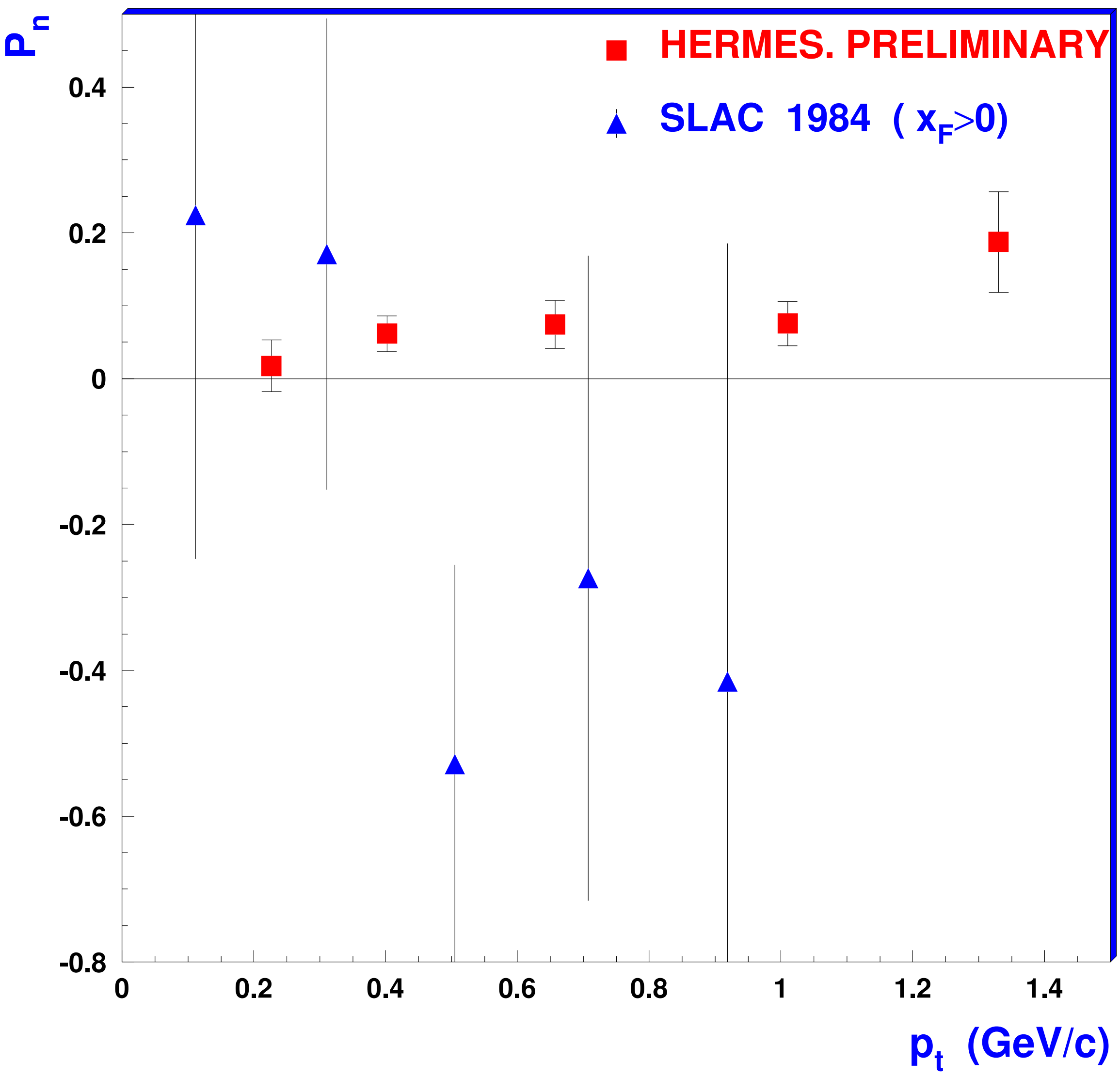
Comparison with CERN data



CERN: $\gamma p \to \Lambda X$, E_γ=25÷70 GeV.

HERMES: $\gamma^* p \to \Lambda X$, $Q^2 \approx 0$, $E^{max}_{\gamma^*}$=26 GeV.

Comparison with SLAC data



SLAC: $\gamma p \rightarrow \Lambda X$, $E_\gamma = 20$ GeV.

HERMES: $\gamma^* p \rightarrow \Lambda X$, $Q^2 \approx 0$, $E_{\gamma^*}^{max}$=26 GeV.

Conclusion

- Hermes is able to measure longitudinal spin transfer in DIS
- Unpolarized (target) data were taken in very short dedicated running 1996 and 97
- Transverse Λ^0 Polarization, increasing with transverse momentum has been measured

Outlook

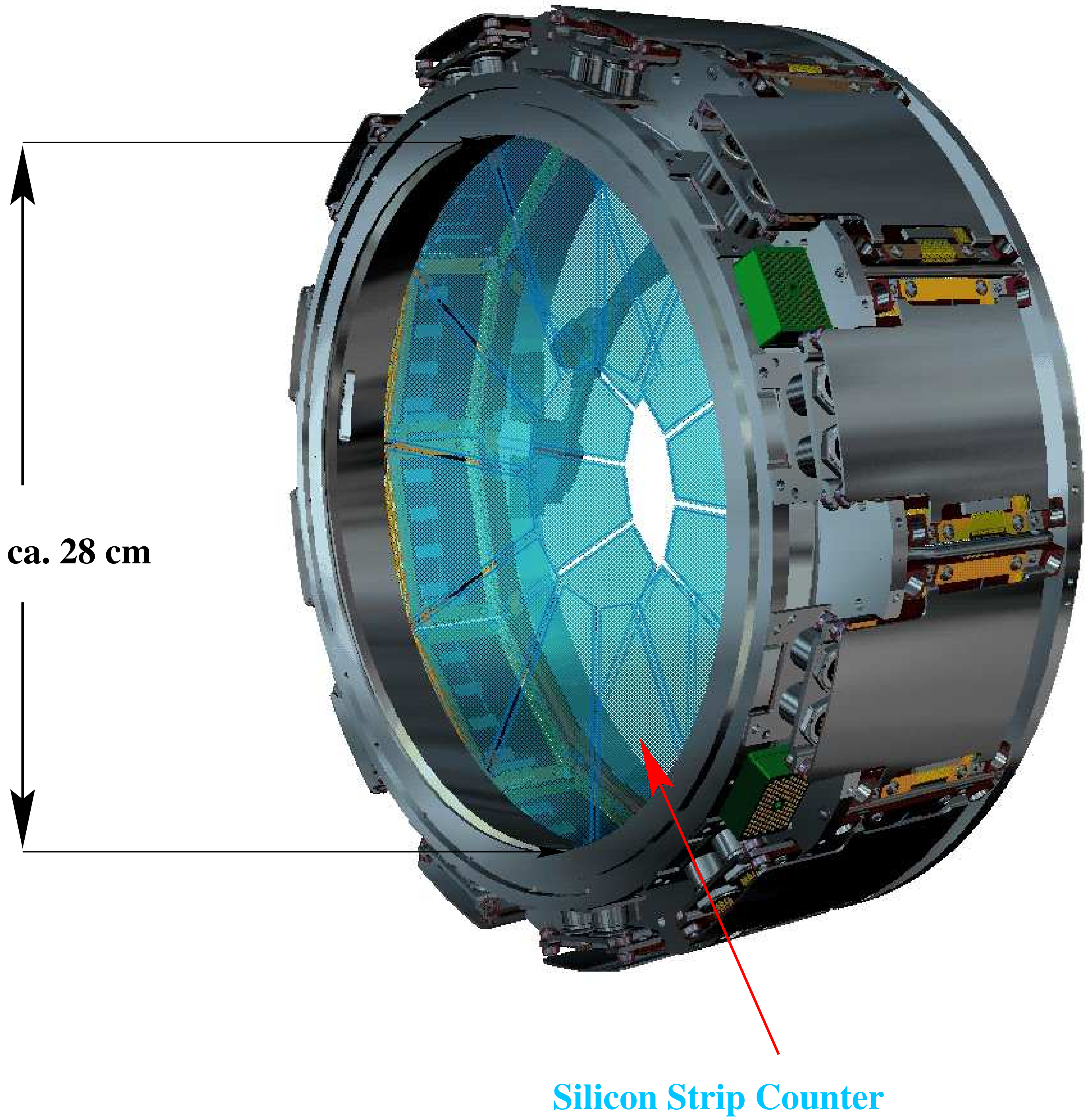
- much more statistics already on tape (1998-2000)
- more detailed studies on transverse Λ^0 Polarization ($\rightarrow$ paper)
- unpol. fragmentaton function D_q^Λ ($\rightarrow$ paper)
- much better PID with RICH
- HERMES upgrade : "Lambda–Wheels " :

  gain of factor 4 in Λ^0's

  flat acceptance function

  target fragmentation reachable

Λ–Wheels



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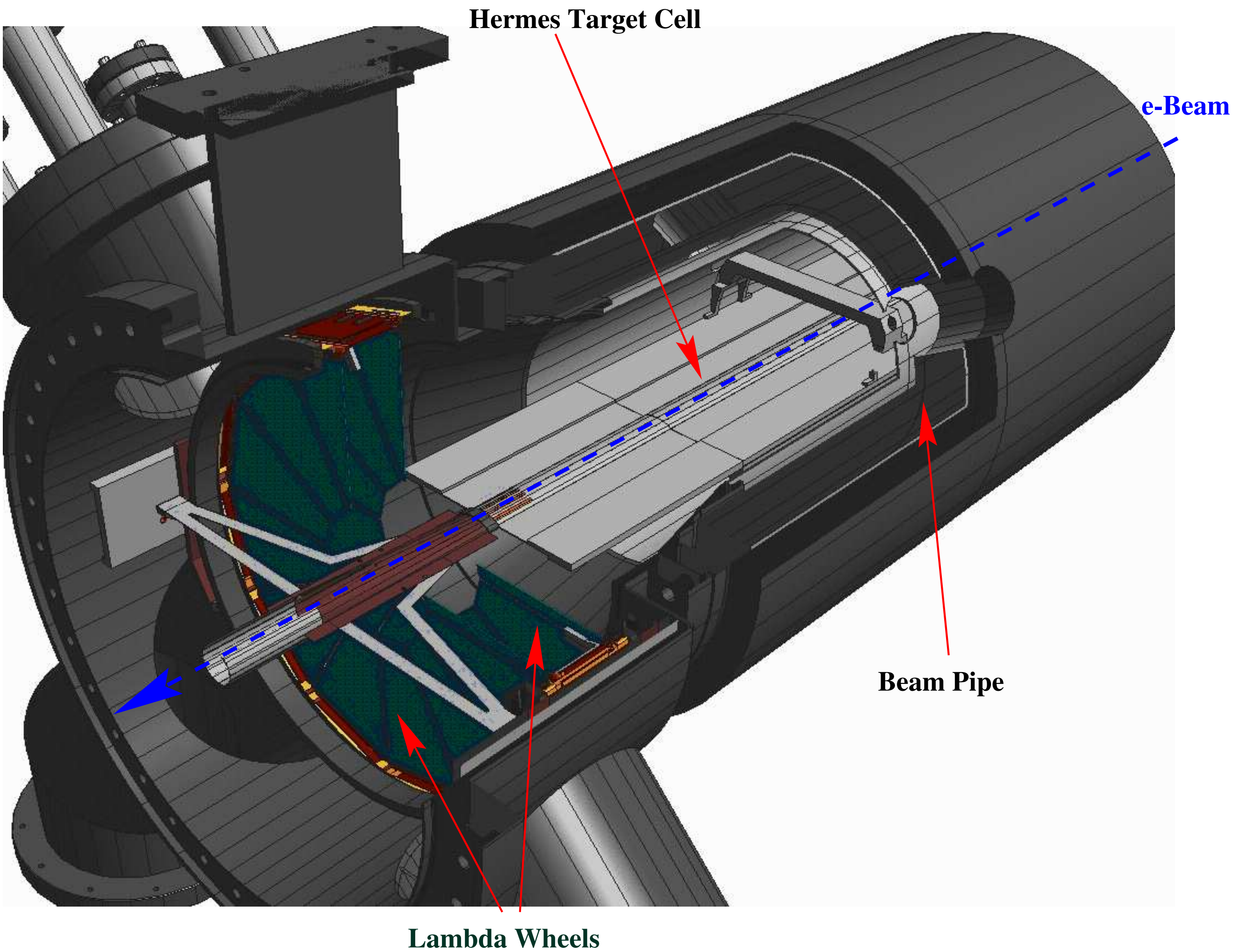
Λ–Wheels



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