Λ^0 Polarization at HERMES

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Outline:

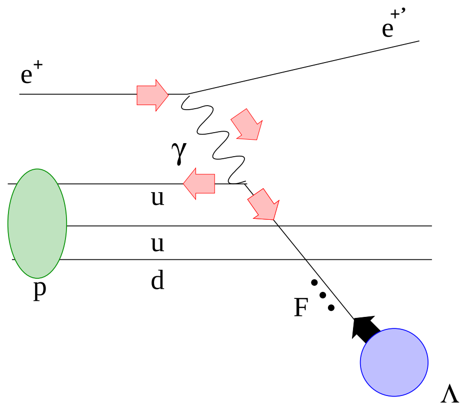
- Longitudinal Spin Transfer in Polarized DIS
  - Motivation for Spin Transfer measurement
  - Λ Production in Polarized DIS at HERMES
  - Spin Transfer Models
  - Longitudinal Spin Transfer Results
- Transverse Polarization in Unpolarized Photoproduction
- Conclusions

Motivation

Measurements of spin transfer in polarized Λ production in DIS using polarized lepton beam and unpolarized target are now possible. These measurements are very interesting:

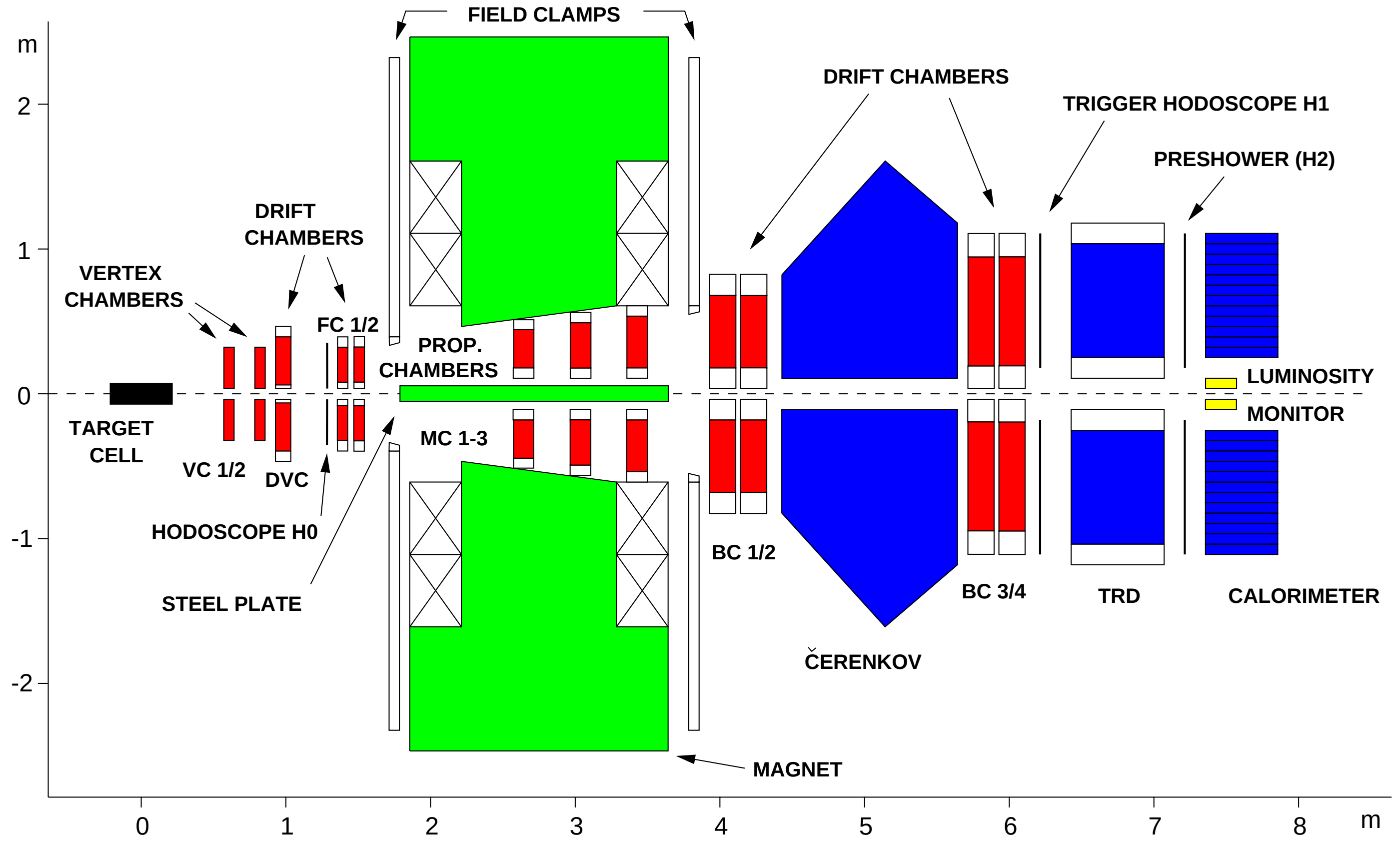
- Independent method to study the spin structure of baryons.
  Complementary to DIS from polarized nucleons.
  Related via SU(3) flavor symmetry.
- Test models of polarized fragmentation.
  Concept of quark helicity conservation.
  SU(3) symmetry for fragmentation functions.
  Complementary to $e^+e^- \to Z^0 \to \Lambda X$

Polarized Deep-Inelastic Scattering

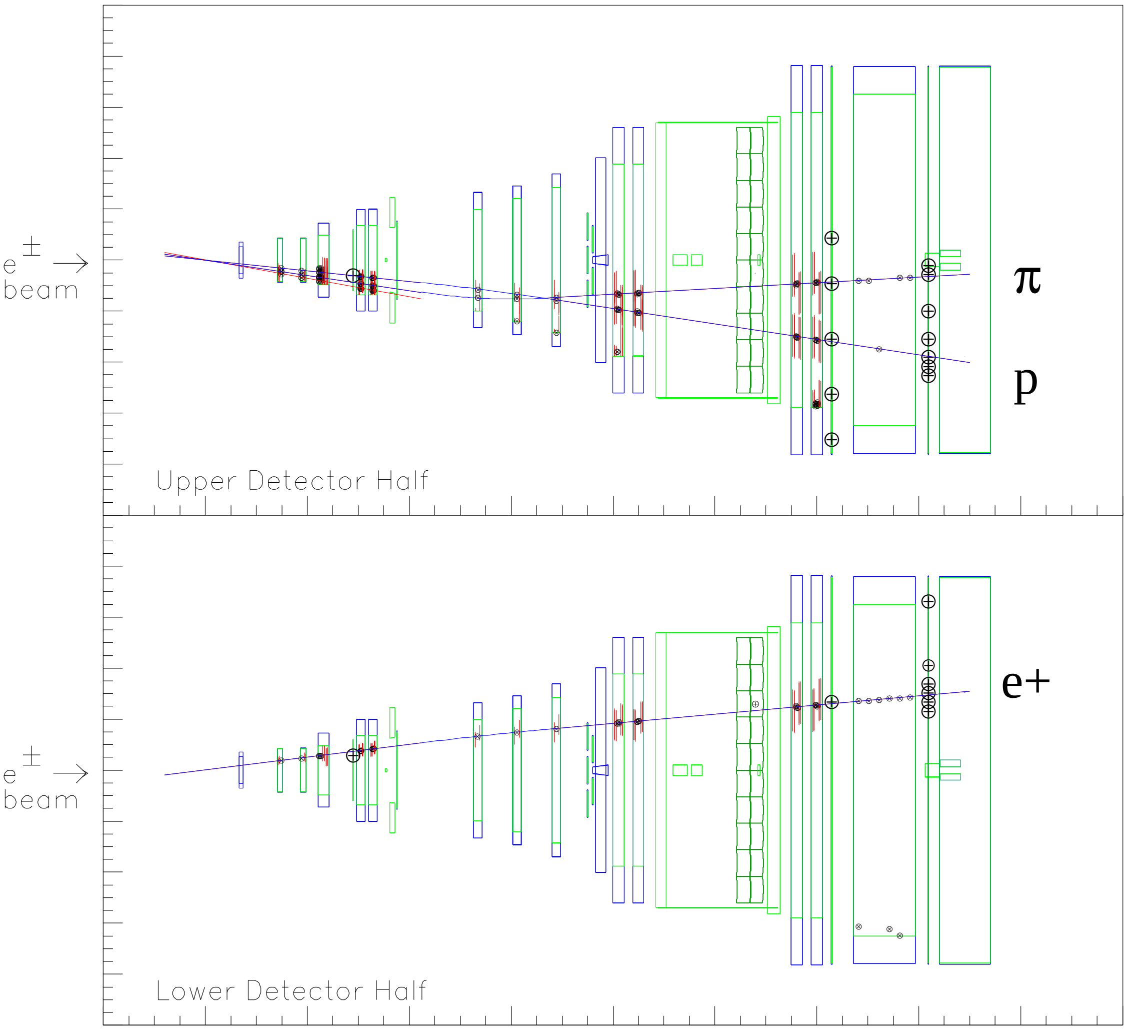


$$
\begin{aligned}
Q^2 &= 4EE' \sin^2\left(\frac{\theta}{2}\right) \\
\nu &= E - E' \\
W^2 &= 2M\nu + M^2 - Q^2 \\
x_{Bj} &= \frac{Q^2}{2M\nu} \\
y &= \frac{\nu}{E} = \frac{p \cdot q}{p \cdot k} \\
z &= \frac{E_h}{\nu} \\
x_F &= \frac{p^*_{\parallel}}{\left| p^*_{\parallel\, max} \right|} \approx \frac{2p^*_{\parallel}}{W}
\end{aligned}
$$

The HERMES Spectrometer



$$\vec{e^+} + N \rightarrow \vec{\Lambda^0} + X$$
$$\searrow p\pi^-$$



- Top & Bottom
- DIS e^+ Detected

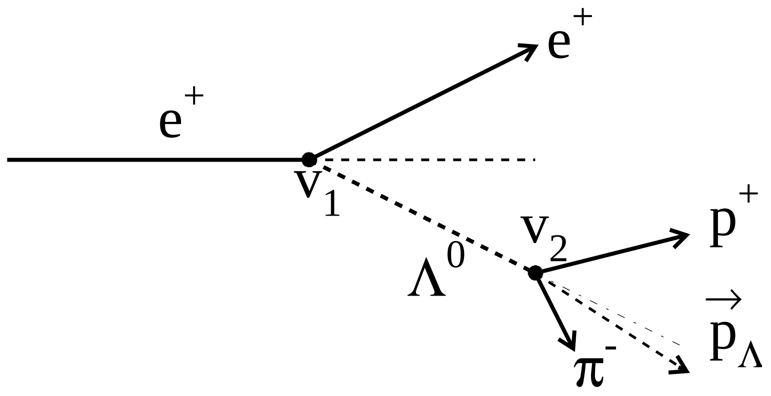
Cuts

1. Data Sample
   - 1996 and 1997 unpolarized target data
   - Beam Polarization: $35\% < P_B < 65\%$
2. Positron
   - PID and Target Geometry
   - DIS Cuts

     $W^2 > 4.0$ GeV^2

     $Q^2 > 1.0$ GeV^2

     $y < 0.85$

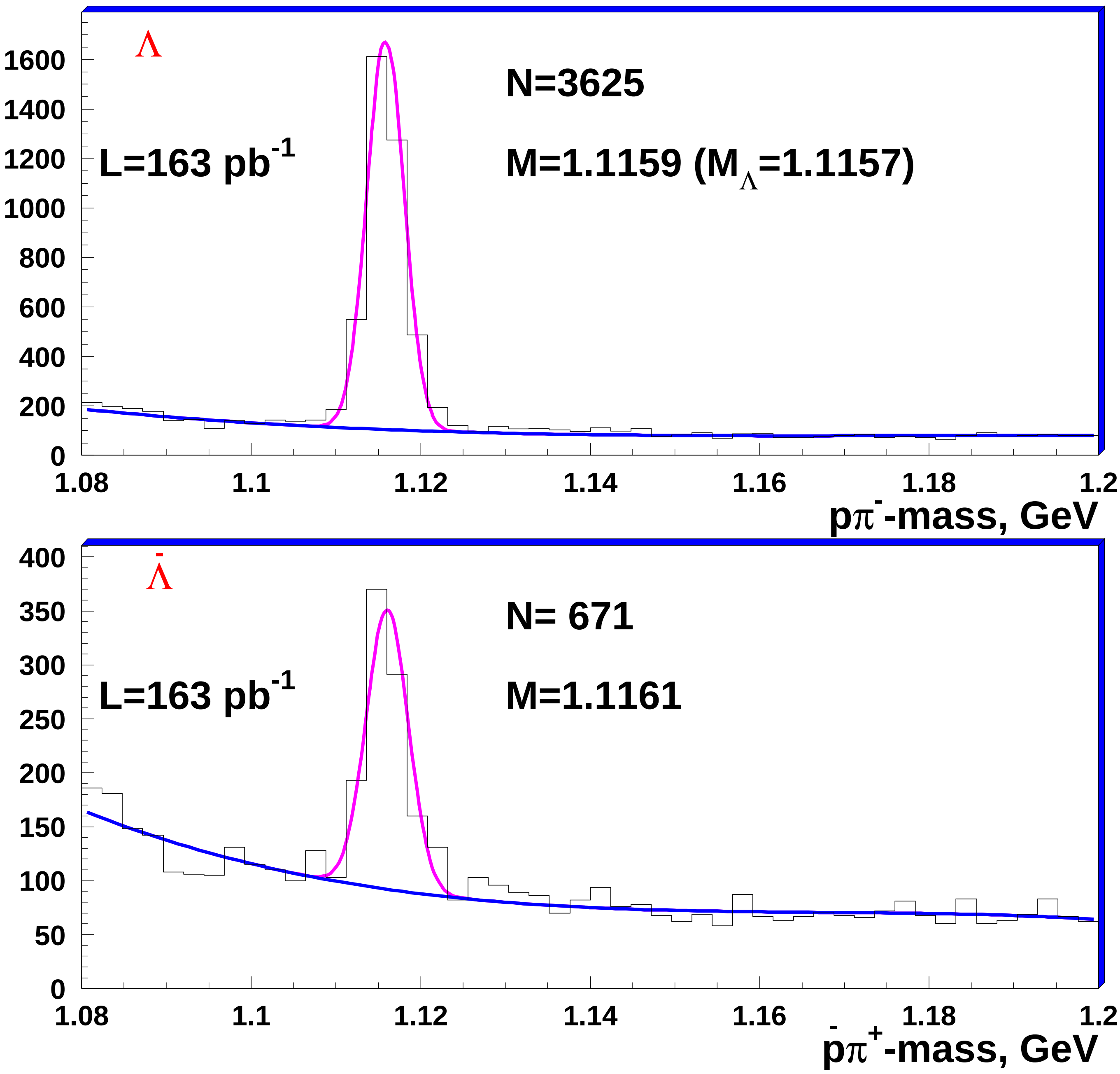


3. Λ Kinematics
   - 3σ Mass Peak: $1.109 < M_{p\pi} < 1.123$ GeV
   - Current fragmentation: $x_F > 0$
   - Decay length of Λ: $|d_2 - d_1| > 10$ cm

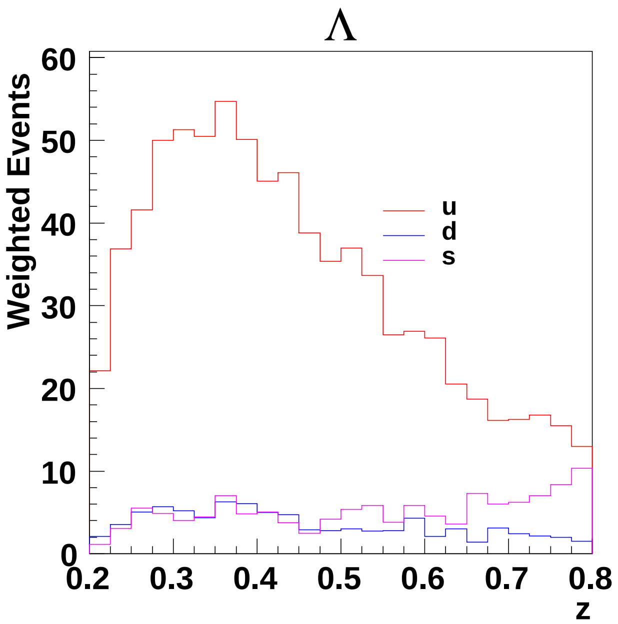
     ($c\tau_\Lambda = 7.89$ cm, $c\tau_{K_s} = 2.68$ cm)
   - Collinearity: $\frac{\vec{p_\Lambda}\cdot(\vec{d_2}-\vec{d_1})}{|\vec{p_\Lambda}||\vec{d_2}-\vec{d_1}|} > 0.998$

HERMES Λ

$$\Lambda(u,d,s) \longrightarrow p\pi^{-} \text{or } \bar{\Lambda}(\bar{u},\bar{d},\bar{s}) \longrightarrow \bar{p}\pi^{+}$$



Polarization and Spin Transfer



At HERMES energies Λ production is dominated by u-quark fragmentation, so for a polarized beam and unpolarized target:

$$
\begin{aligned}
P_\Lambda &\approx P_B\, D(y)\, \frac{\Delta D_u^\Lambda(z, Q^2)}{D_u^\Lambda(z, Q^2)} \\
&\approx P_B\, D(y)\, D_{LL'}^\Lambda
\end{aligned}
$$

- $D_{LL'}^\Lambda$: spin transfer to the Λ
- $D(y) = \frac{1-(1-y)^2}{1+(1-y)^2}$ is the γ depolarization factor

Measurement of Polarization and Spin Transfer

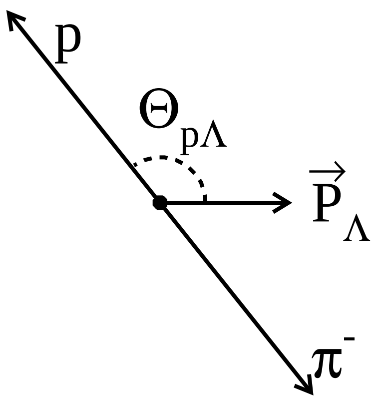
The Λ decay violates parity, so the longitudinal polarization of the Λ is determined from the angular distribution of the decay

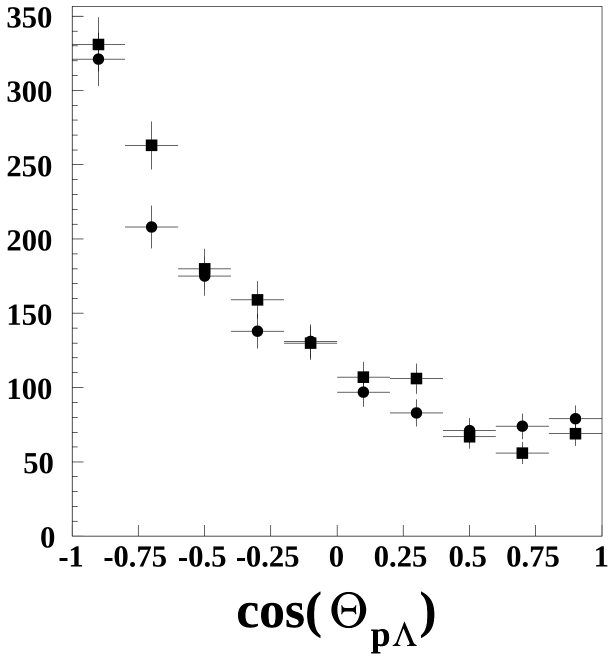
$$I(\theta) = 1 + \alpha P_\Lambda \cos\Theta_{p\Lambda}$$

with decay asymmetry parameter:

$\alpha = 0.642 \pm 0.013$ for the Λ

The angle $\Theta_{p\Lambda}$ can be defined in the Λ rest frame as:





where the quantization axis $\hat{P}_\Lambda$ transforms as a spin vector.

Λ Spin-Transfer Models

Bigi, Gustafson and Häkkinen (BGH)[1] *modified Naive Quark Model (NQM):*

- s-quark contributes 100% to Λ polarization (NQM).
- Remainder comes from decays of heavier particles

Burkardt and Jaffe (BJ)[2]*:*

- Polarized quark distributions obtained from flavor SU(3), using hyperon β decay and DIS g_1 data.

Polarized quark distributions of Λ^0:

	NQM	SU(3)
Δu_Λ	0	$\frac{1}{3}(\Delta\Sigma - D) =$ -0.20
Δd_Λ	0	$\frac{1}{3}(\Delta\Sigma - D) =$ -0.20
Δs_Λ	1	$\frac{1}{3}(\Delta\Sigma + 2D) = +$0.60

Spin transfer is proportional to quark polarization in the Λ
Additional contributions come from decay of heavier particles.
MC estimates for HERMES:

Decay Channel	Yield	Resulting P_Λ
$\Sigma(1385) \to \Lambda\pi$	29%	$P_{\Sigma(1385)}$
$\Sigma^0 \to \Lambda\gamma$	18%	-$\frac{1}{3}P_{\Sigma^0}$
Ξ and others	2%	0.9P_Ξ

[1] NC 41A 1977 and PL B303 1993
[2] PRL70 1993

Some Comments about e^+e^- Annihilation

$$e^+e^- \to Z^0 \to q\bar{q}$$

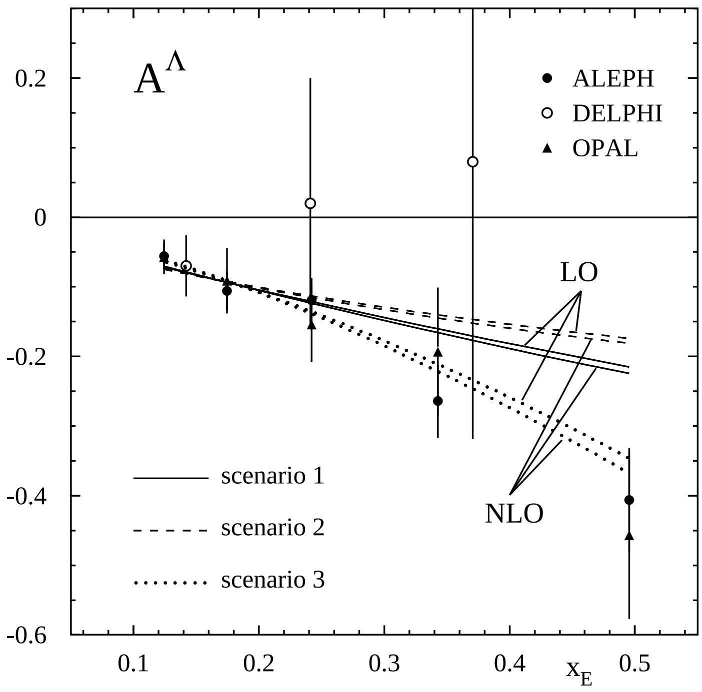
Quarks are naturally polarized by parity violating decay

f	P_f
d	-93.5%
u	-66.4%
s	-93.5%

$D^h_{u,d}$ is saturated by non-strange hadrons h

$$P_\Lambda \sim \frac{\Delta D_s^\Lambda}{D_s^\Lambda}$$

e^+e^- Polarization Measurements



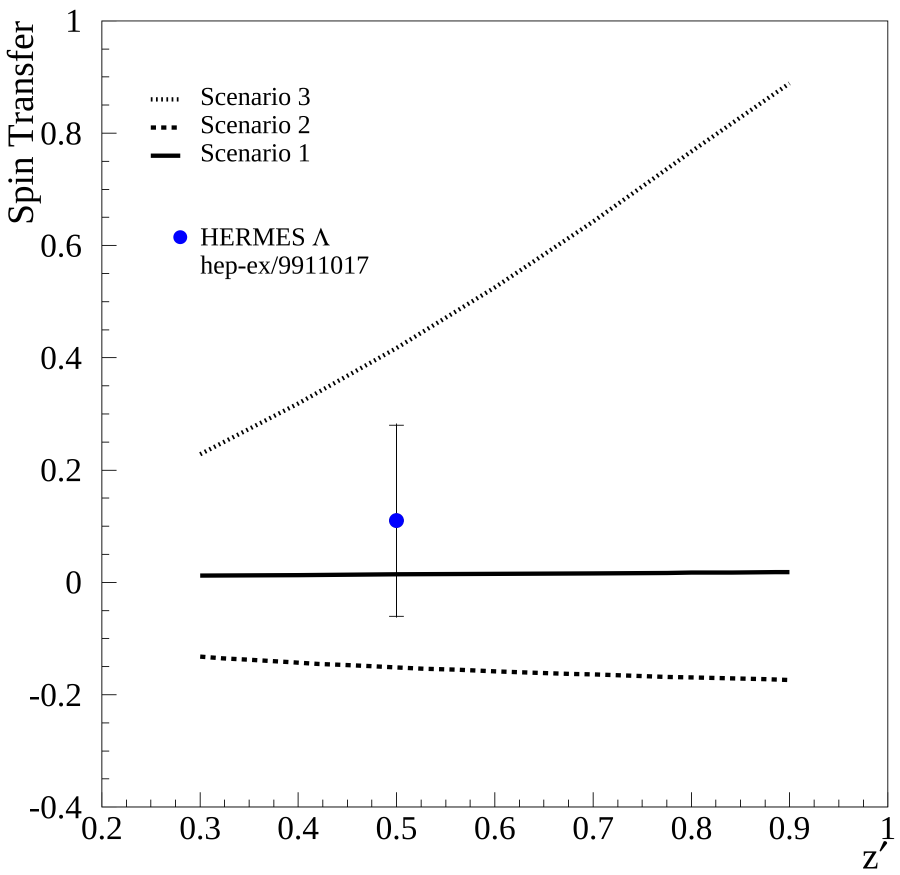
$$x_E = 2E_\Lambda/\sqrt{s}$$

- Data
  - Large polarizations observed
  - Good agreement of ALEPH and OPAL data (most significant)
- Calculations (deFlorian, Stratmann, Vogelsang)
  - NLO effects small
  - Model neglects heavy and unfavored quarks and gluon.
  - Comparison does not exclude any scenario.

HERMES Spin-transfer Result

$$D^{\Lambda}_{LL'} = 0.11 \pm 0.17 \pm 0.03$$

Consistent with zero or no quark spin transfer to Λ



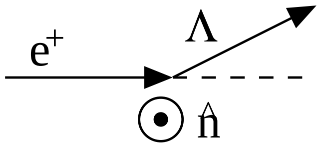
- $z' = E_\Lambda / E_N (1 - x)$
- curves: leading order from de Florian et al.[3]

[3] PR D57 1998

Transverse Λ, $\bar{\Lambda}$ Polarization

In hadron-hadron collisions Λ polarization has been extensively studied. If neither beam nor target are polarized, the only allowed direction of transverse polarization is normal to the $\Lambda/\bar{\Lambda}$ production plane. These Λ's are usually strongly polarized in the transverse direction:

$$\hat{n} = \frac{\vec{p}_{beam} \times \vec{p}_{\Lambda}}{|\vec{p}_{beam} \times \vec{p}_{\Lambda}|}$$



and have not been extensively studied in DIS.

HERMES has studied inclusive:

$$e^+ + N \to \Lambda/\bar{\Lambda} + X$$

- no scattered e^+ detected $\to$ low Q^2

Measurement takes into account the up/down symmetry of HERMES and that the first moment of the polarization in $\cos\Theta_{np}$ should be zero for unpolarized Λ.

The equation for the polarization was determined to be:

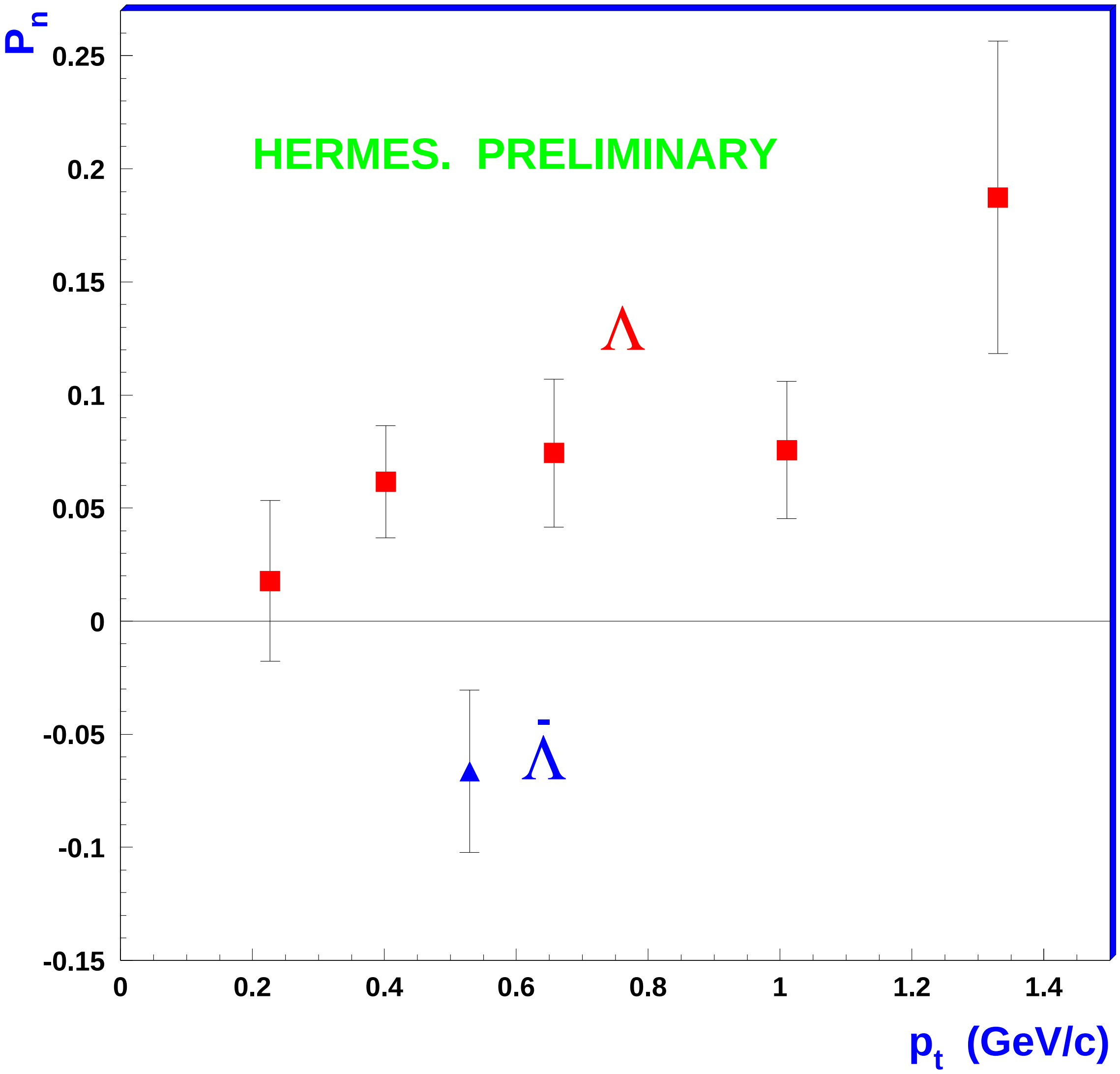
$$P_{n\Lambda} = \frac{\frac{1}{N_\Lambda^{up}} \sum_{i=1}^{N_\Lambda^{up}} \cos\Theta_{np,i} + \frac{1}{N_\Lambda^{down}} \sum_{i=1}^{N_\Lambda^{down}} \cos\Theta_{np,i}}{\frac{2\alpha}{N_\Lambda} \sum_{i=1}^{N_\Lambda} \cos^2\Theta_{np,i}}$$

Where $\cos\Theta_{np}$ is between $\overrightarrow{n}$ and $\overrightarrow{p_p}$ in the Λ CMS.

Cuts were similar to those for the semi-inclusive case, except no lepton cuts, and the Λ production vertex is fit to the beam line.

- ✘ For Λ: $P_{n\Lambda} = 6.6 \pm 1.1 \pm 2.5\,\%$
- ✘ For $\bar{\Lambda}$: $P_{n\bar{\Lambda}} = -6.6 \pm 3.7 \pm 2.5\,\%$

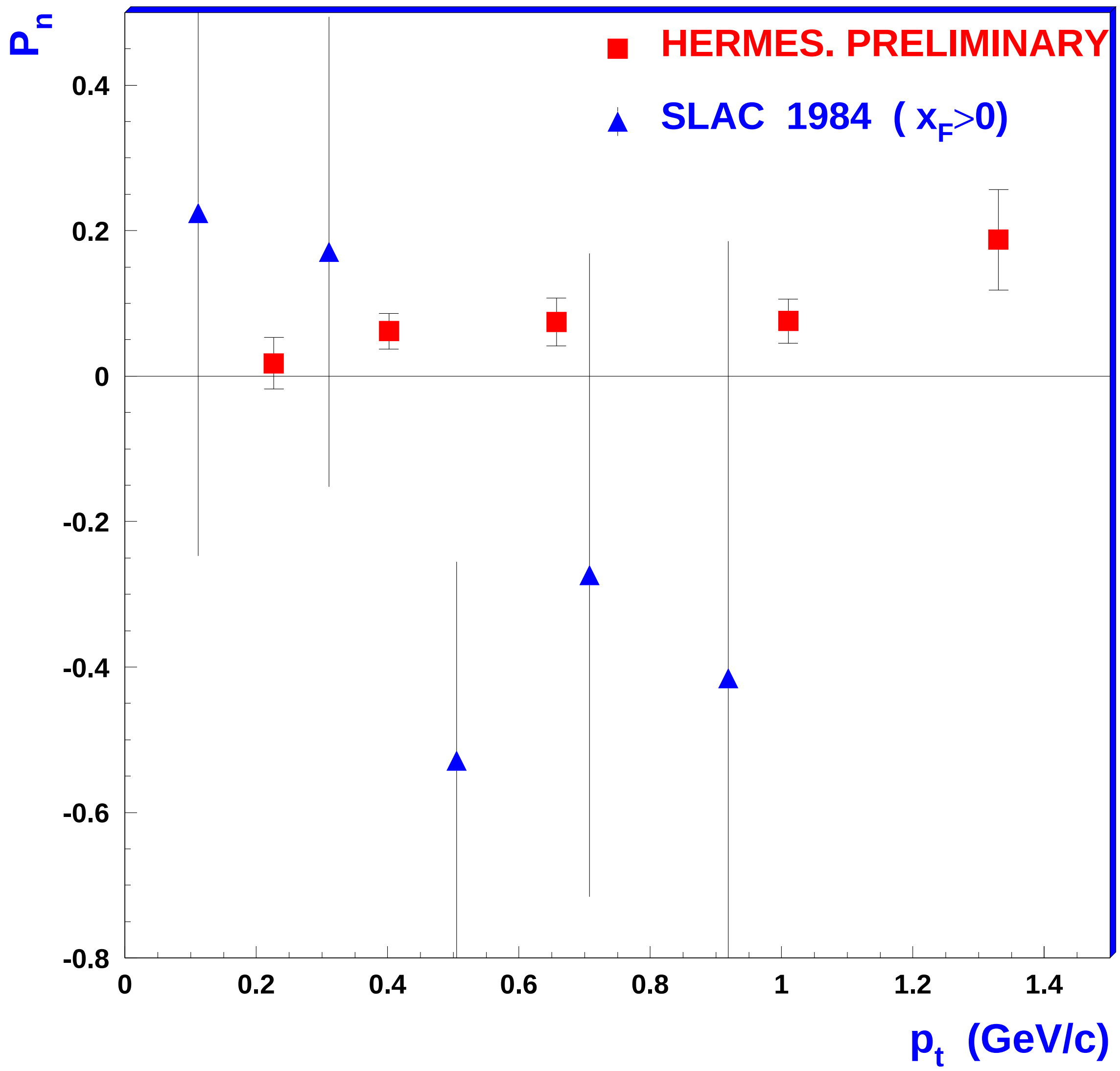
Transverse Polarization at HERMES



Increases with p_t!

Systematic Error ~0.025

Comparison with SLAC



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

Conclusions

- Longitudinal Spin transfer for Λ has been determined and is consistent with zero.
- Current state of data and theory is inconclusive.
- Higher quality data can distinguish competing models.
- First high statistics measurement in photoproduction of the transverse polarization of Λ and $\bar{\Lambda}$ has been determined. For the Λ it increases with p_t.

Future:

- Reduce uncertainty of polarization result
  - Include all 1998-2000 data: polarized and unpolarized target
  - Detector upgrades will enhance acceptance
- Study target fragmentation in DIS

HERMES Projection