Spin transfer to lambda and anti lambda hyperons at HERMES

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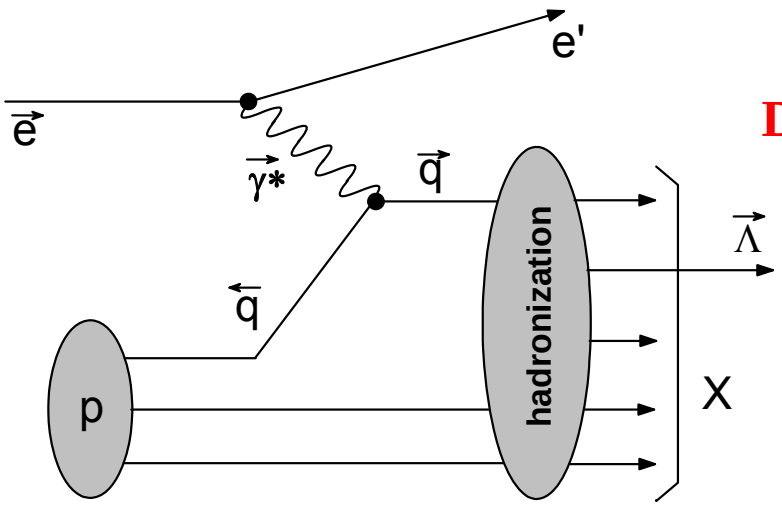
Spin transfer to Λ or $\bar{\Lambda}$ in DIS

$$D^{\Lambda}_{LL'} = \frac{P^{\Lambda}_{L'}}{P_B D(y)} = \frac{P^{\Lambda}_{L'}}{P_{\gamma^*}}$$



$$D^{\Lambda}_{LL}(x,z,Q^2) = \sum_f D^{f\to\Lambda}_{LL}(z,Q^2)\,\omega_p^{f\to\Lambda}(x,z,Q^2)$$

Purity

$$D^{f\to\Lambda}_{LL} = \frac{F^{\Lambda\uparrow}_{f\uparrow} - F^{\Lambda\downarrow}_{f\uparrow}}{F^{\Lambda\uparrow}_{f\uparrow} + F^{\Lambda\downarrow}_{f\uparrow}} = \frac{\Delta F^{\Lambda}_f}{F^{\Lambda}_f}$$

Spin dependent FF

Link to Lambda hyperon spin structure

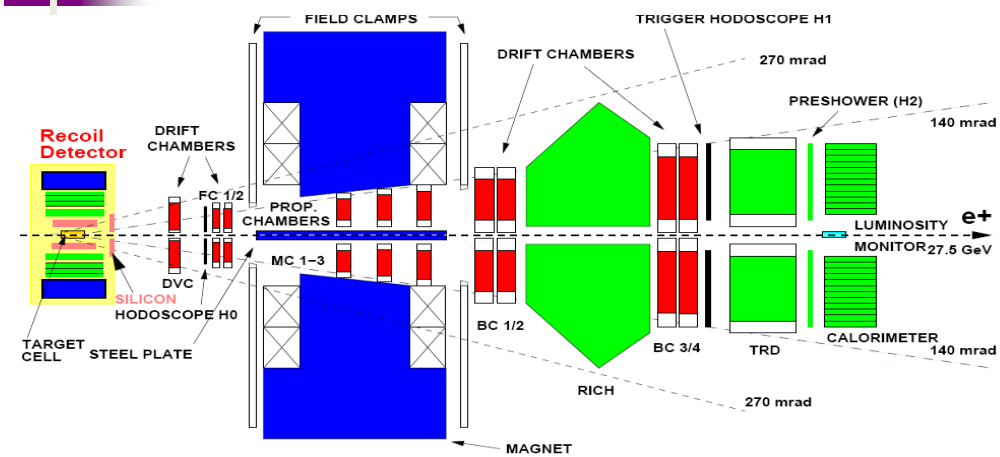
DIS variables

$$Q^2 = -(k-k')^2 \quad \nu = E - E' \quad y = \frac{\nu}{E}$$

$$x = \frac{Q^2}{2M\nu} \qquad z = \frac{E_\Lambda}{\nu} \qquad x_F = \frac{p_\parallel}{p_{\parallel,\max}}$$

DIS regime $Q^2 > 0.8\ \mathrm{GeV}^2$

Polarized Λs in HERMES experiment



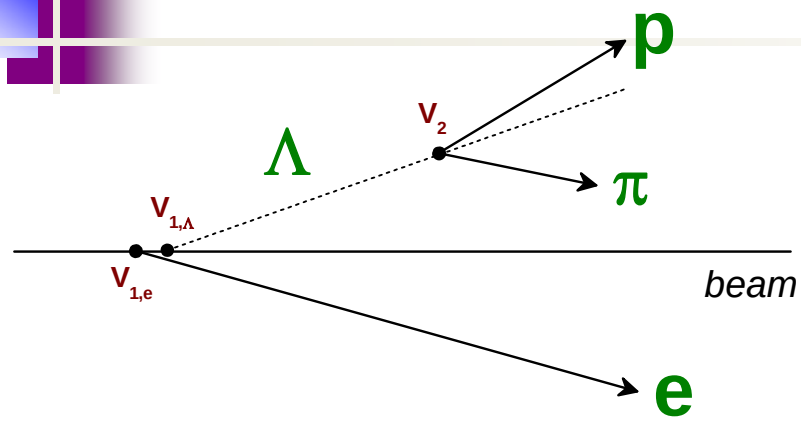
$$\Lambda \rightarrow \mathbf{p} + \pi^-$$

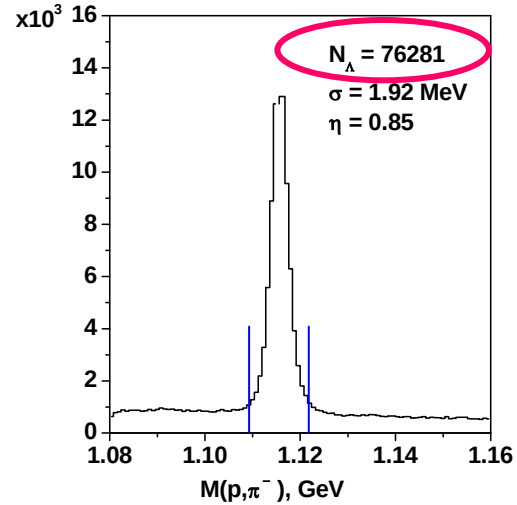
$$\overline{\Lambda} \rightarrow \overline{\mathbf{p}} + \pi^+$$

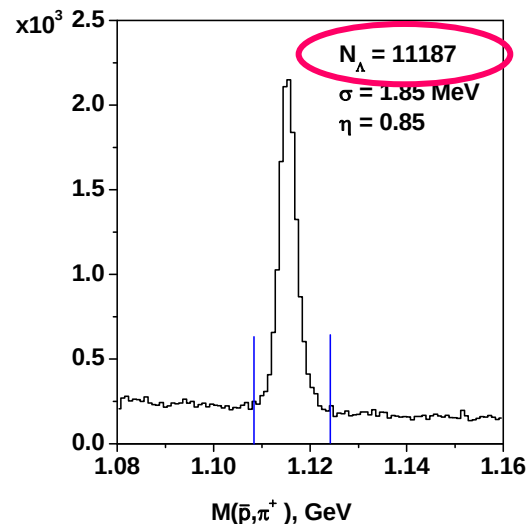
- ✓ ***Forward spectrometer →limited acceptance for Λ ($\bar{\Lambda}$) hyperon detection***
- ✓ ***Longitudinally polarized e^+ or e^- 27.5 GeV beam with P_B=40-50% . Beam polarization reversed on a month basis such that final date sample is practically helicity balanced***

$$[\![P_B]\!] = \frac{\int P(t)L(t)dt}{\int L(t)dt} = 0$$

Λ and $\bar{\Lambda}$ events selection







h^+h^- pair background suppression

Leading π rejection using

threshold Cherenkov det. (1996-1997)

or RICH (1998-2007)

Distance between V_1 and V_2 vertices > 5 cm

Extraction of $D_{LL'}$

$$\frac{dN}{d\Omega_p} = \frac{dN_0}{d\Omega_p}(1+\alpha\vec{P}^{\Lambda}\cdot\hat{\vec{k}}_p) = \frac{dN_0}{d\Omega_p}(1+\alpha_\Lambda P_B \sum_{i=x,y,z} D^{\Lambda}_{Li}\cos\theta_i)$$

$$\alpha_{\Lambda\to p+\pi^-} = 0.642 \pm 0.013 \qquad \alpha_{\bar{\Lambda}\to \bar{p}+\pi^+} = -0.642 \pm 0.013$$

For beam helicity balance case $[\![P_B]\!] = 0$

MC simulation of spectrometer acceptance is not needed, acceptance correction does not affect measured asymmetries. D_{Li} components are extracted using experimental data sample only !!

$$\sum_{k=x,y,z} D_{Lk} A_{ik} = \frac{1}{\alpha}\frac{B_i}{[\![P_B^2]\!]} \quad i = x,y,z$$

$$A_{ik} = \frac{1}{N^{\Lambda}}\sum_{\nu=1}^{N^{\Lambda}}\left(D^2(y)\cos\theta_i\cos\theta_k\right)_\nu$$

$$B_i = \frac{1}{N^{\Lambda}}\sum_{\nu=1}^{N^{\Lambda}}\left(P_B D(y)\cos\theta_i\right)_\nu$$

$$[\![P_B^2]\!] = \frac{\int P^2(t)L(t)dt}{\int L(t)dt}$$

average over experimental data sample

Coordinate systems in Λ rest frame

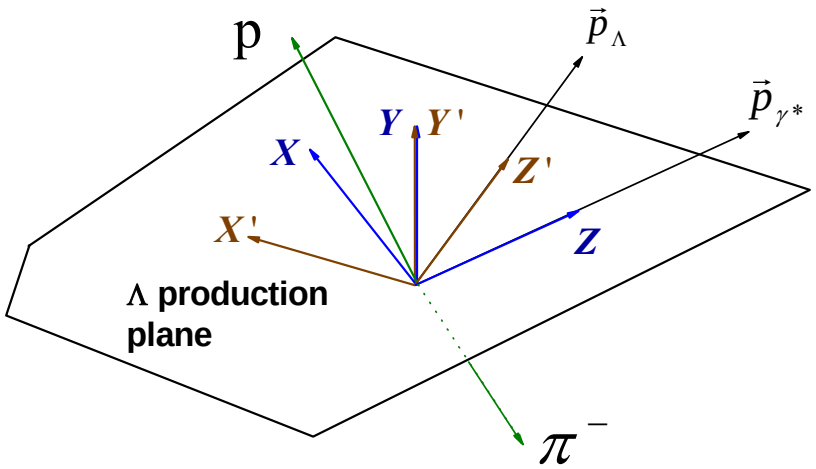
All 3 components of spin transfer D_{Li}^{Λ} ***are extracted from the data in*** **Λ hyperon rest frame** ***using two coordinate system:***

X,Y,Z with Z along virtual photon momentum

X',Y',Z' with Z' along Λ momentum (in lab frame)

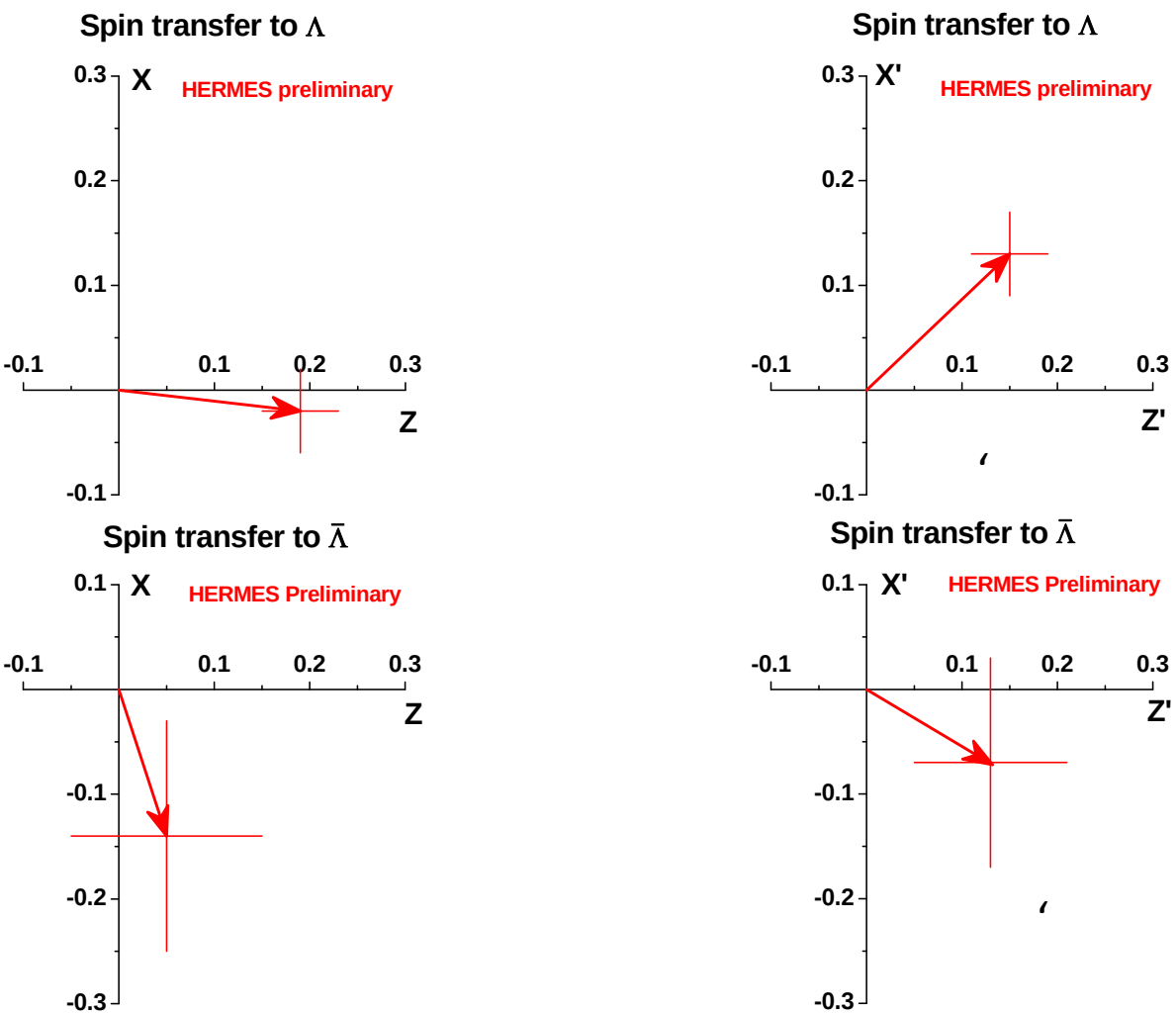
Z and Z' are used to be ***Longitudinal*** spin transfer axes

X and X' ***transverse*** spin transfer axes



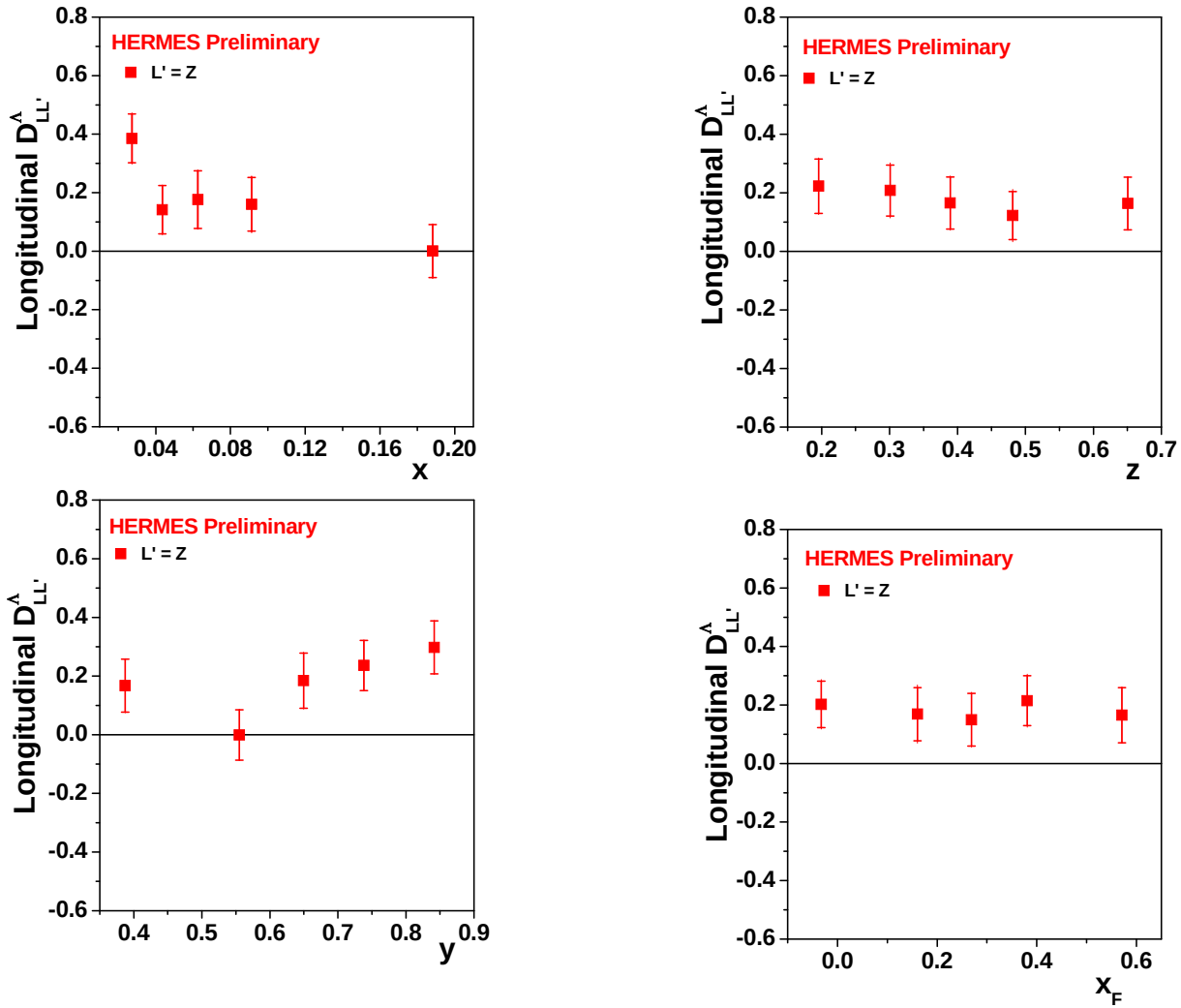
Y and Y' components of spin transfer are compatible with zero due to parity conservation requirement

Integrated over kinematics

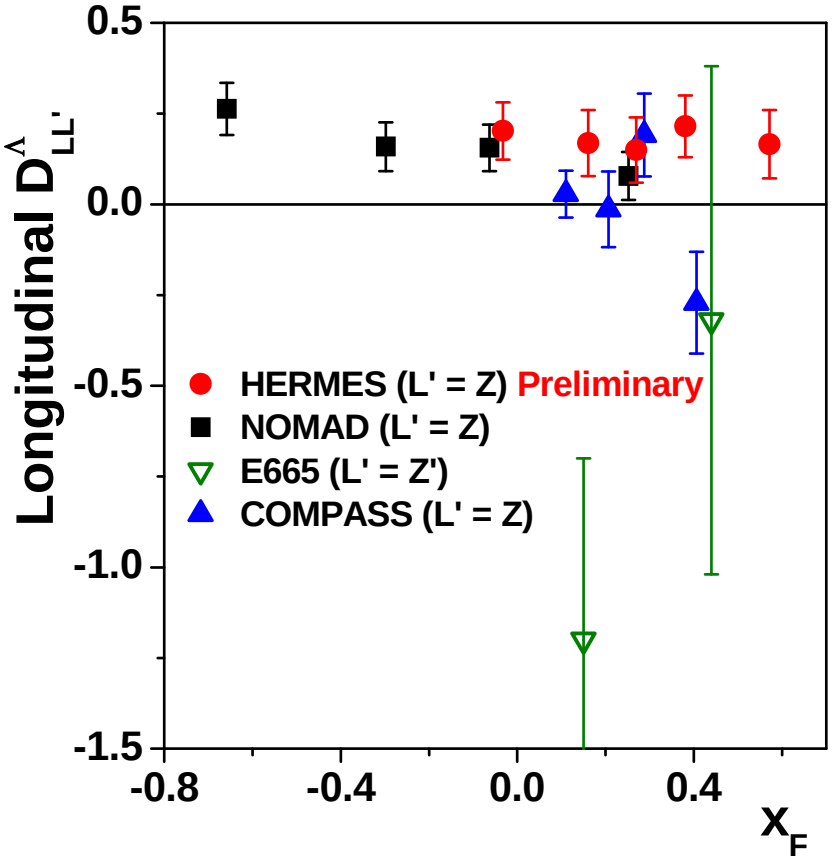


Londitudinal spin transfer, Z axis along virtual photon momentum ⇨ $D_{LL}^{\Lambda} = 0.19 \pm 0.04_{stat} \pm 0.01_{syst}$

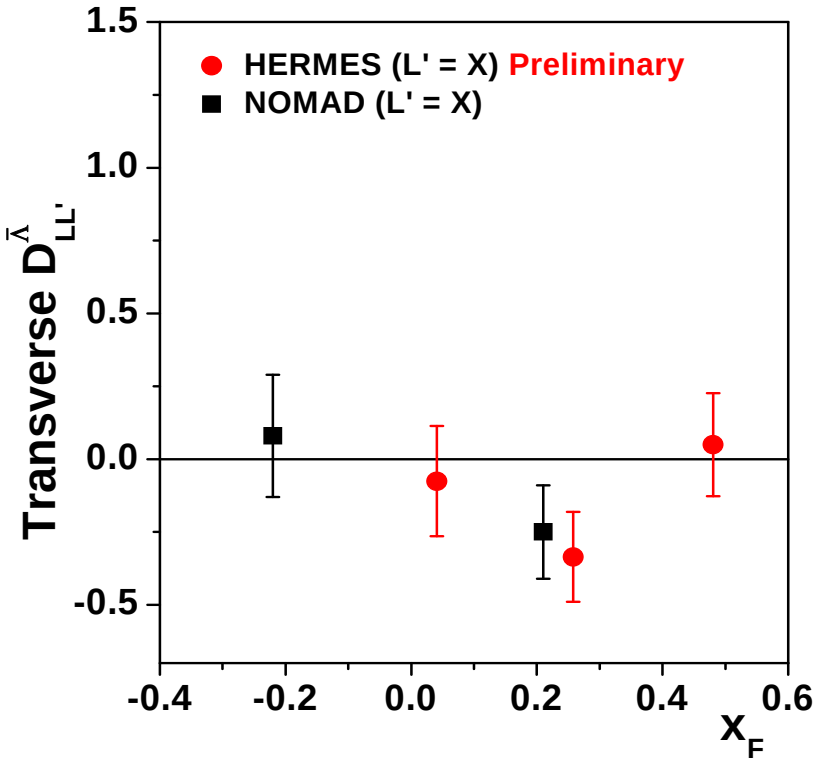
Dependences on kinematic variables for spin transfer to Λ hyperon

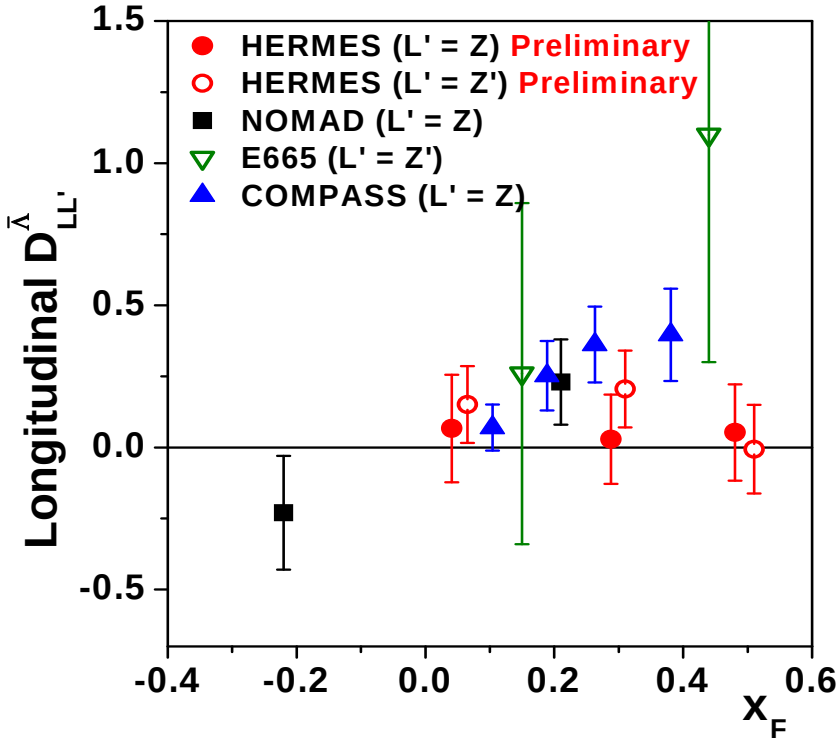


Longitudinal spin transfer world data for Λ



Longitudinal and transverse spin transfer world data for $\bar{\Lambda}$





SUMMARY

- Spin transfer to Λ hyperon produced in DIS is found to be

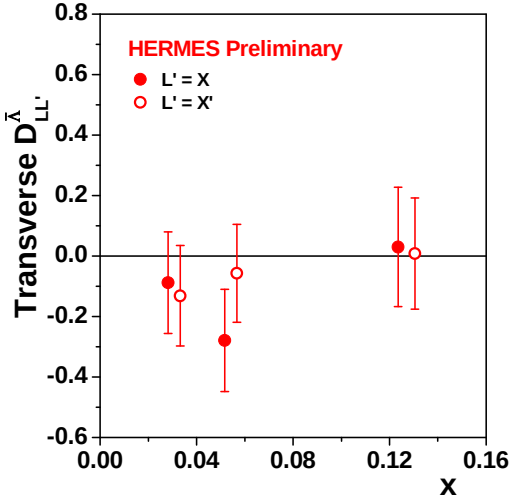
$$D_{LL'}^{\Lambda} = 0.19 \pm 0.04_{stat} \pm 0.01_{syst}$$

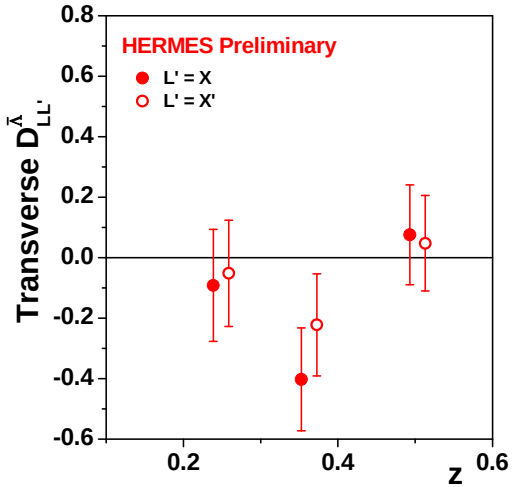
- 3-d analysis shows that spin is transversed along the virtual photon momentum (XZ coordinate system), i.e. ***L=L'***. Transverse component in this coordinate system is compatible with zero.

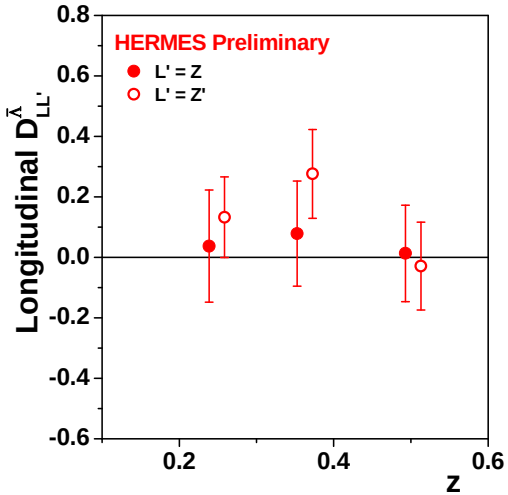
- Both longitudinal and transverse components of spin transfer to $\bar{\Lambda}$ hyperon is compatible with zero in the two coordinate system (XZ and X'Z') within statistical uncertainty ± 0.2.

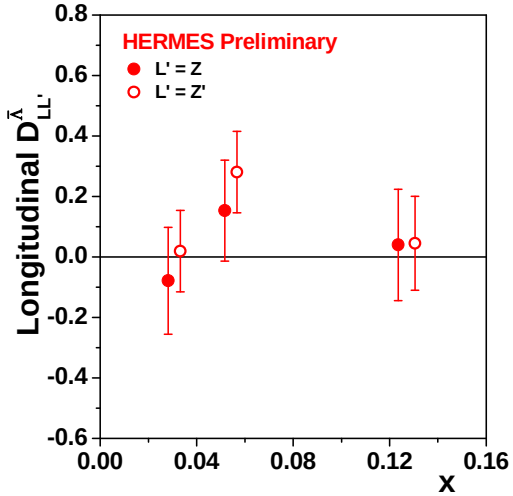
BACKUP SLIDES

Dependences on kinematic variables, spin transfer for $\bar{\Lambda}$

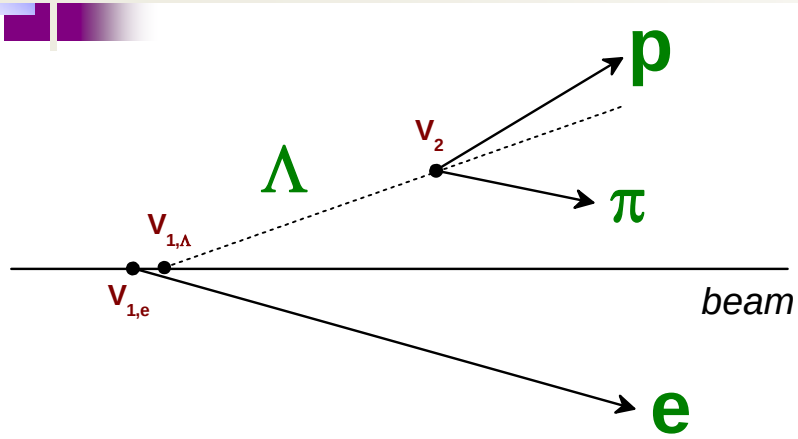


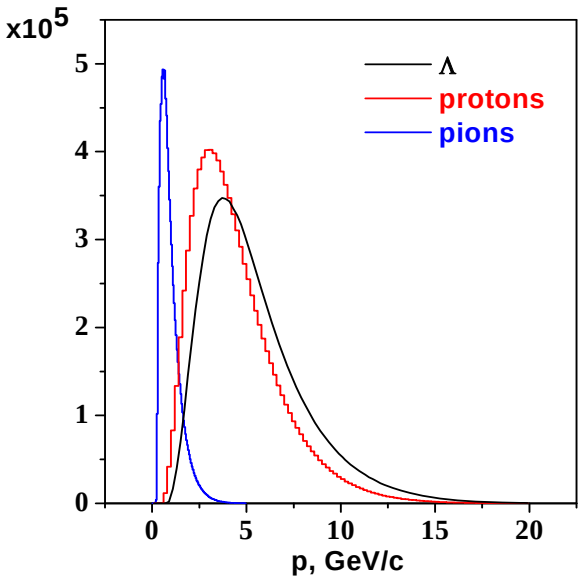






Λ and $\bar{\Lambda}$ events selection





h+h- pair background suppression

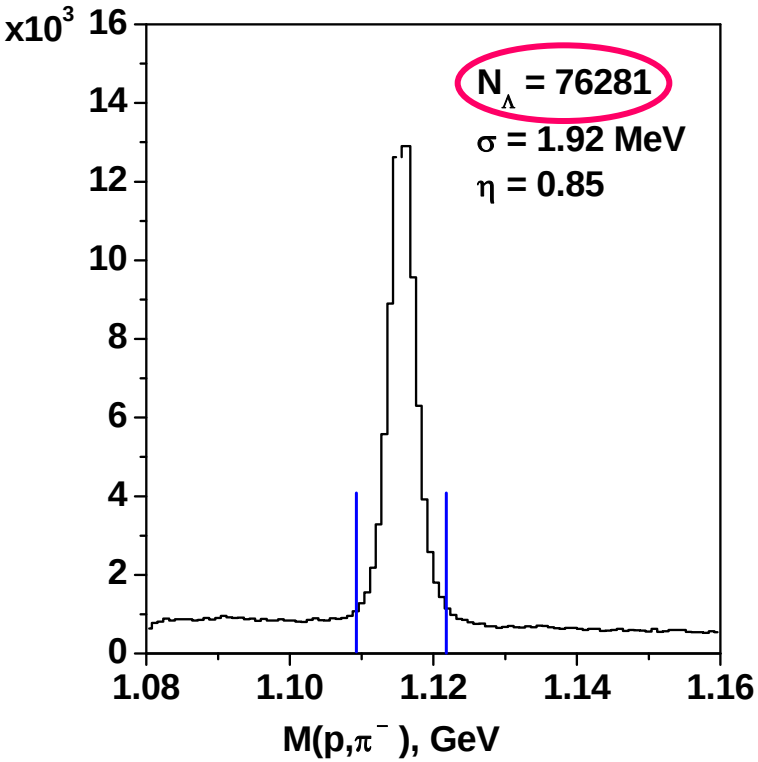
Leading π rejection using

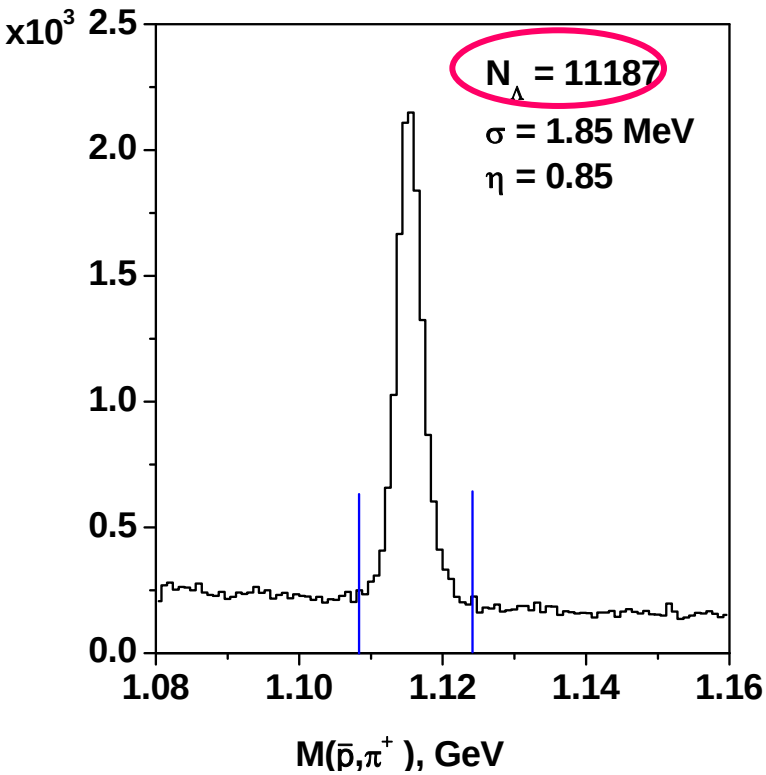
threshold Cherenkov det. (1996-1997)

or RICH (1998-2007)

Distance between V_1 and V_2 vertices > 5 cm

Final data sample





Spin transfer is corrected for bgr contamination $1-\eta = \frac{N_\Lambda^{bgr}}{N_\Lambda + N_\Lambda^{bgr}}$

Extraction of $D_{LL'}$

- Angular distribution of decay protons in Λ rest frame

$$\frac{dN}{d\Omega_p} = \frac{dN_0}{d\Omega_p}\left(1 + \alpha P_{Beam}\, \vec{D}^{\Lambda}_{LL'} \bullet \hat{\vec{k}}_p\right)$$

$$\alpha = 0.642 \pm 0.013$$

$$\frac{dN_0}{d\Omega_p} = \text{const} \quad \text{for } 4\pi \text{ acceptance}$$

for restricted acceptance

$$\frac{dN_0}{d\Omega_p} \quad \text{depends on } \cos\theta_{pL'}$$

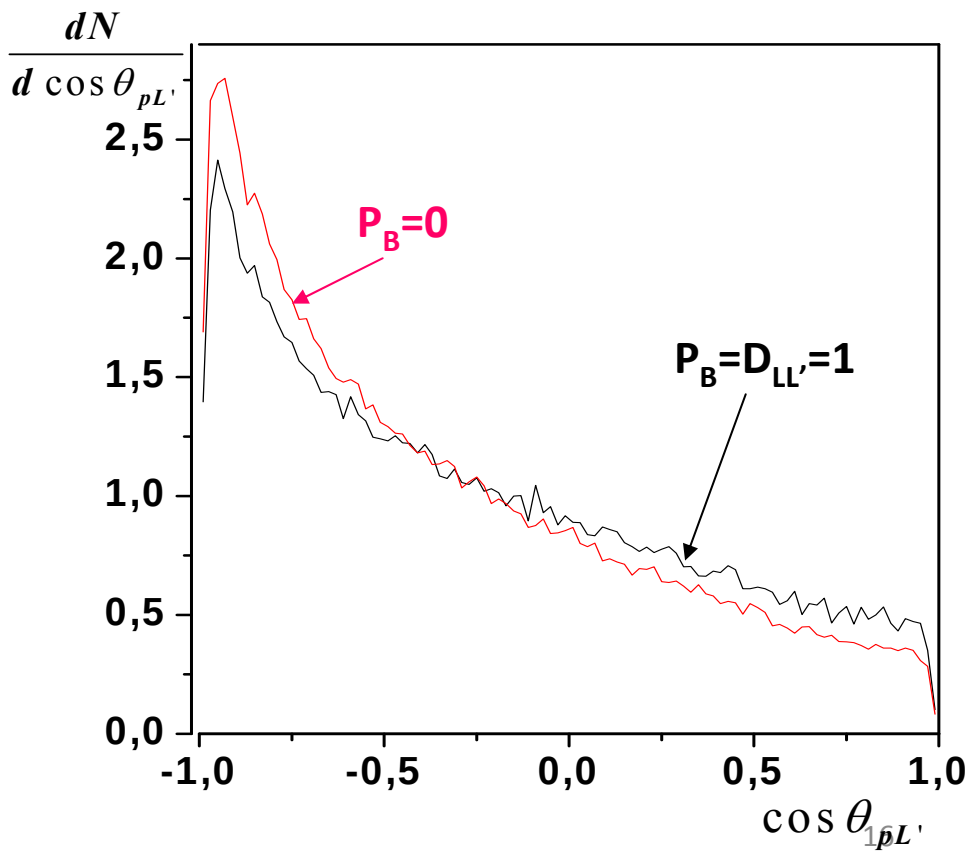
↓

Distorted by spectrometer acceptance

↓

May in principle be calculated using MC

difficulty to avoid false asymmetry induced by MC acceptance simulation



Theoretical models

Λ spin structure

Constituent quark model (CQM) Δu=Δd=0, Δs=1

Burkard/Jaffe Δu=Δd=-0.23±0.06, Δs=0.58±0.07

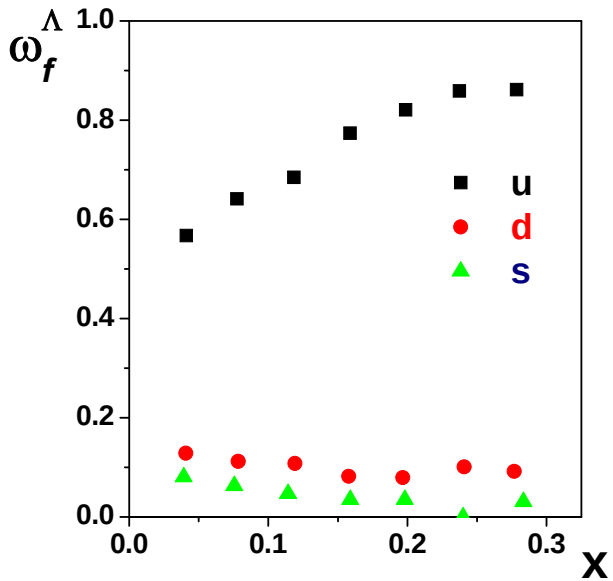
SU(3) flavor symmetry Δu=Δd=-0.09±0.06, Δs=0.47±0.07

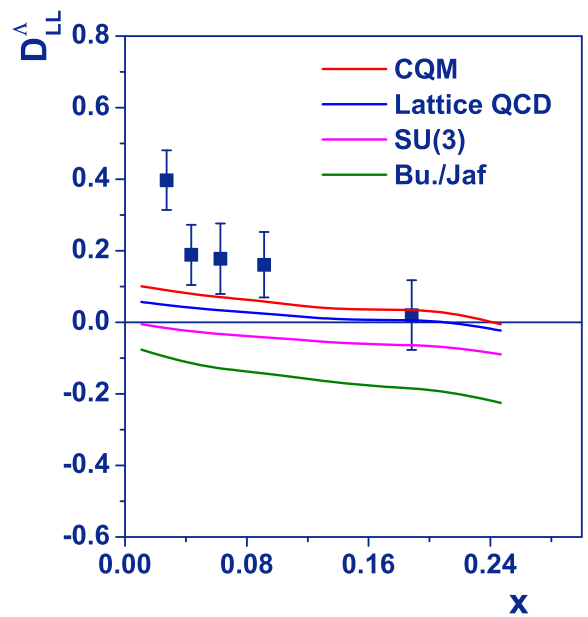
Lattice QCD Δu=Δd=-0.02±0.04, Δs=0.68±0.04

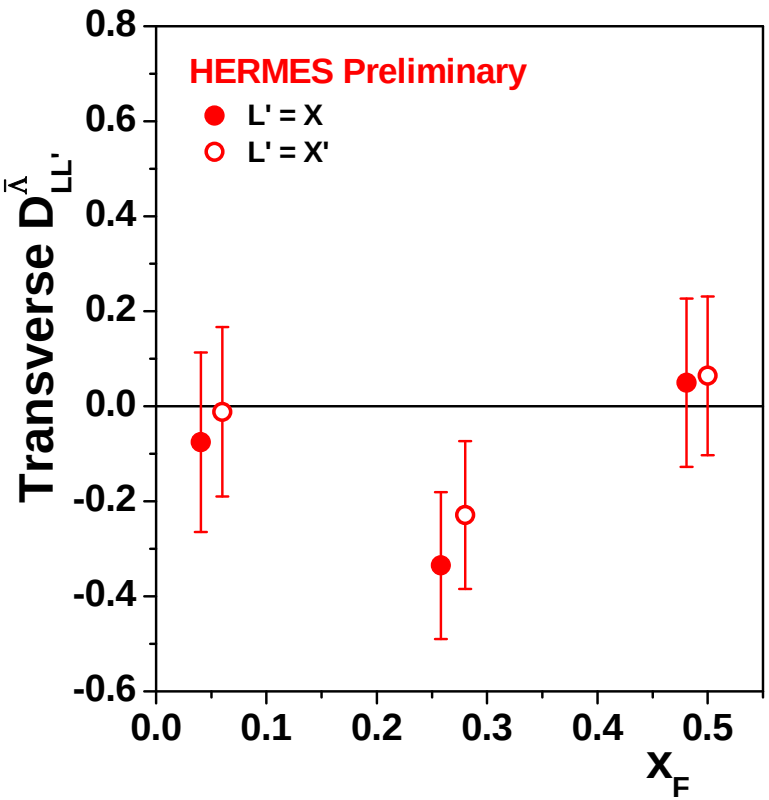
$$D^{\Lambda}_{LL'} = \sum_f D^{\Lambda}_{LL',f}\,\omega^{\Lambda}_f$$

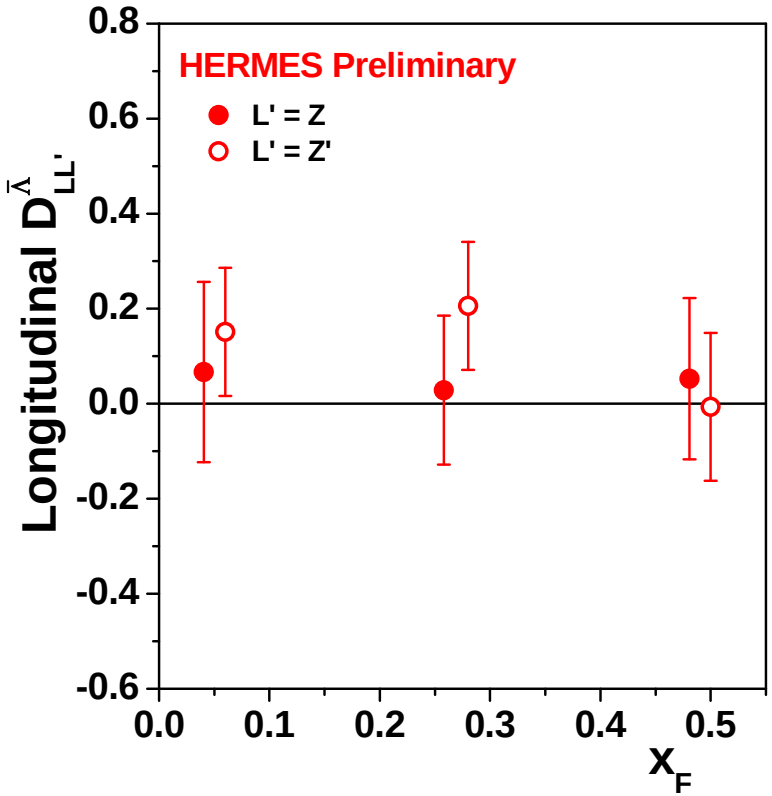
Jaffe $\rightarrow D^{\Lambda}_{LL',f} \simeq \frac{\Delta q^{\Lambda}_f}{q^{\Lambda}_f}$

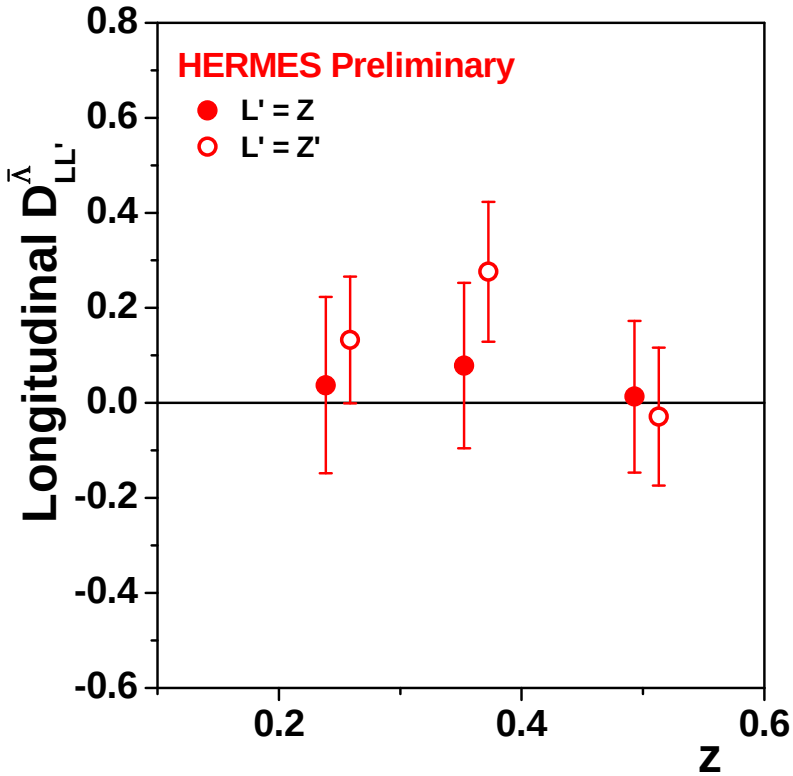
All models predict negative or small positive value

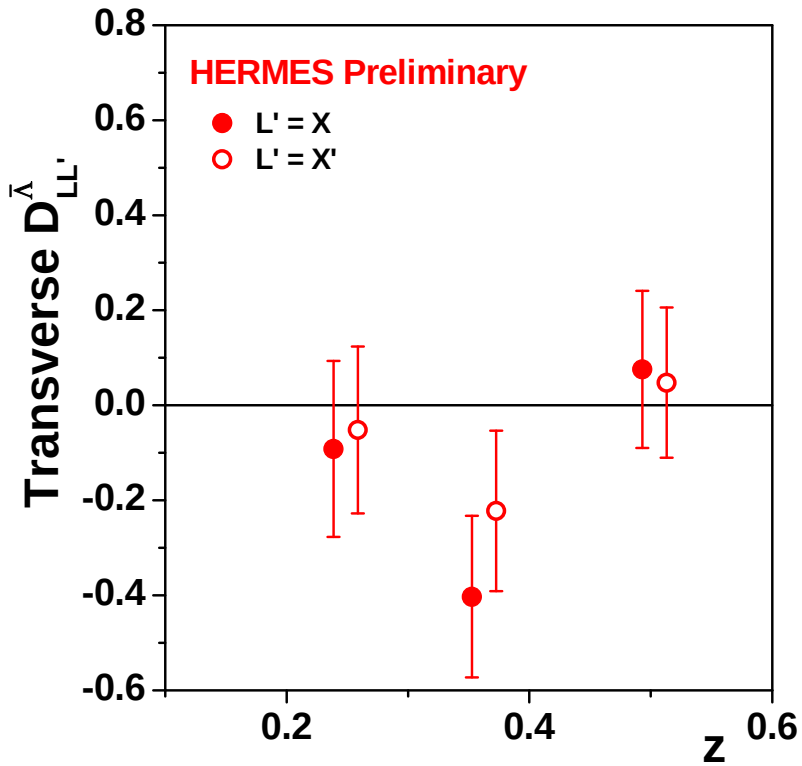


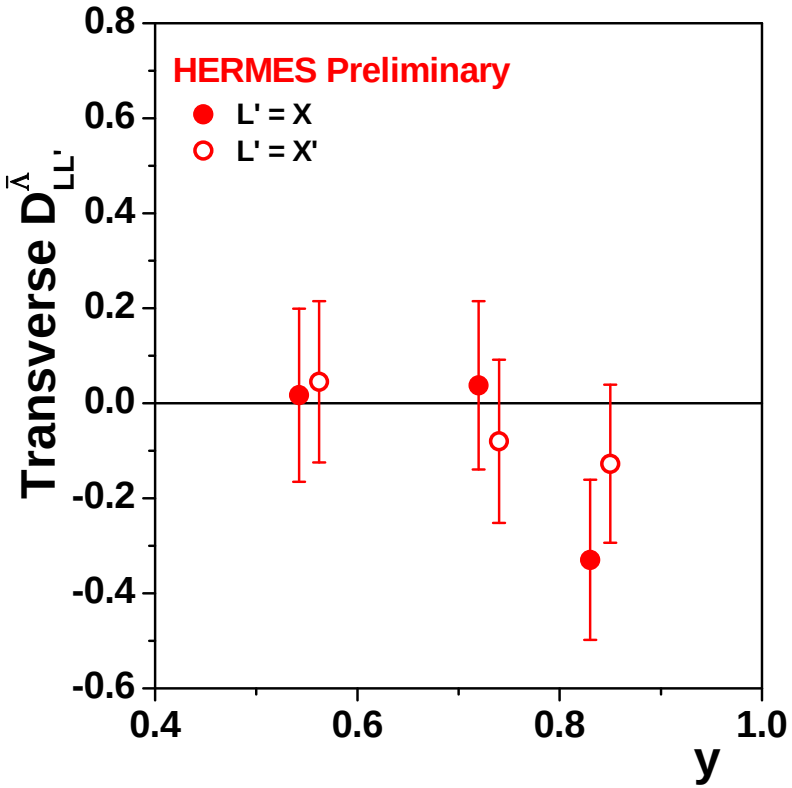


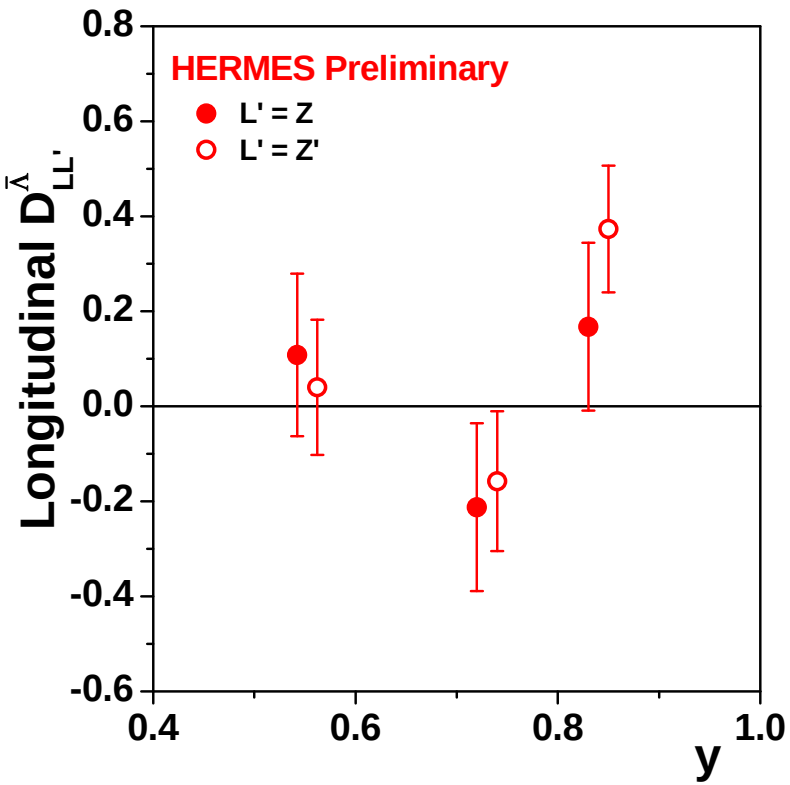

HERMES Preliminary
L' = X
L' = X'
Transverse $D_{LL'}^{\bar{\Lambda}}$
x_F
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
0.0
0.1
0.2
0.3
0.4
0.5


HERMES Preliminary
L' = Z
L' = Z'
Longitudinal $D_{LL'}^{\bar{\Lambda}}$
x_F
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
0.0
0.1
0.2
0.3
0.4
0.5

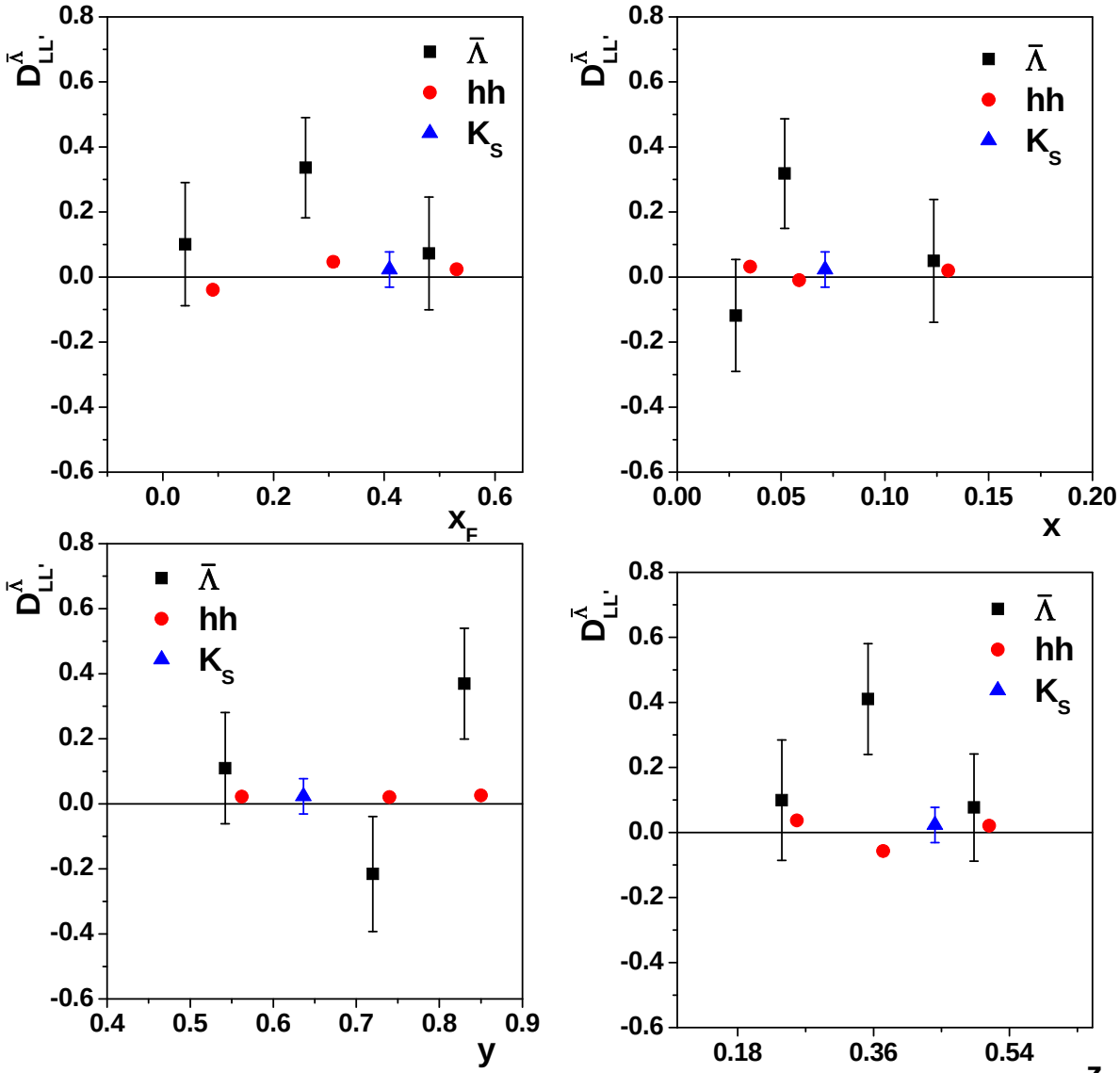

HERMES Preliminary
L' = Z
L' = Z'
Longitudinal $D_{LL'}^{\bar{\Lambda}}$
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
0.2
0.4
0.6
z


HERMES Preliminary
L' = X
L' = X'
Transverse $D_{LL'}^{\bar{\Lambda}}$
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
0.2
0.4
0.6
z


HERMES Preliminary
L' = X
L' = X'
Transverse $D_{LL'}^{\bar{\Lambda}}$
y
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
0.4
0.6
0.8
1.0


HERMES Preliminary
L' = Z
L' = Z'
Longitudinal $D_{LL'}^{\bar{\Lambda}}$
y
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
0.4
0.6
0.8
1.0

Systematic uncertainties using h^+h^- pairs and K_S



$$D^{hh}_{LL'} = 0.021 \pm 0.006$$

$$D^{Ks}_{LL'} = 0.023 \pm 0.054$$

Λ hyperon spin structure

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

- **Constituent quark model (CQM)** $\Delta u = \Delta d = 0,\ \Delta s = 1$
  - *Fails for proton, what about Λ ?*
- **SU(3) flavor symmetry** $\Delta u = \Delta d = -0.09 \pm 0.06,\ \ \Delta s = 0.47 \pm 0.07$
  - *Used SU(3) rotation for proton data*
- **Burkard/Jaffe** $\Delta u = \Delta d = -0.23 \pm 0.06,\ \Delta s = 0.58 \pm 0.07$
  - *Also SU(3) rotation for proton data with $\Delta\bar{s} \equiv 0$ in proton*
- **Lattice QCD** $\Delta u = \Delta d = -0.02 \pm 0.04,\ \Delta s = 0.68 \pm 0.04$
  - *"grid" calculation*