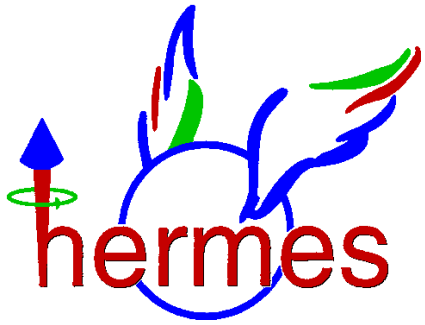
Spin transfer coefficient $D_{LL'}$ to Λ hyperon in Semi-Inclusive DIS at HERMES

D. Veretennikov

On behalf of the HERMES collaboration



SPIN 2010, Jülich

Outline

- *Definition of $D_{LL'}^{\Lambda}$*
- *Motivation*
- *HERMES description*
- *Events selection*
- *Extraction formalism*
- *Results*
- *Compare with models*
- *Summary*

Definition of $D_{LL'}^{\Lambda}$ in DIS

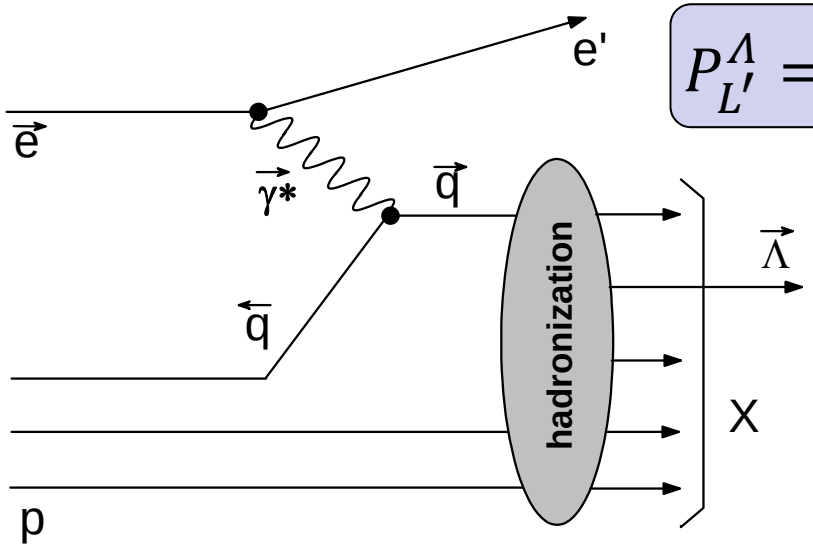
Λ is "self-analyzing" particle due to its parity violation $\Lambda \to p\pi^-$ decay

Angular distribution of protons *(in Λ rest frame)*

$$\frac{dN}{d\Omega_p} = \frac{dN_0}{d\Omega_p}\left(1 + \alpha\, P_{L'}^{\Lambda} \cos\theta_{pL'}\right)$$

- Unpolarized distribution
- decay constant, 0.642
- angle between proton momentum and Λ spin in Λ rest frame

$$\vec{\gamma}^* + p \to \vec{\Lambda} + X$$
$$\hookrightarrow p\pi^-$$



$$P_{L'}^{\Lambda} = P_L^{\gamma^*} \cdot D_{LL'}^{\Lambda} \qquad P_L^{\gamma^*} = P_B D(y) = P_L^q$$

- **Primary quantization axis L: $\vec{P}_{\gamma^*}$ is assumed to be along $\vec{p}_{\gamma^*}$**
- **L' direction of Λ polarization can not be determined from general principles $\Rightarrow$ 3dimensional analysis**

Motivation

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

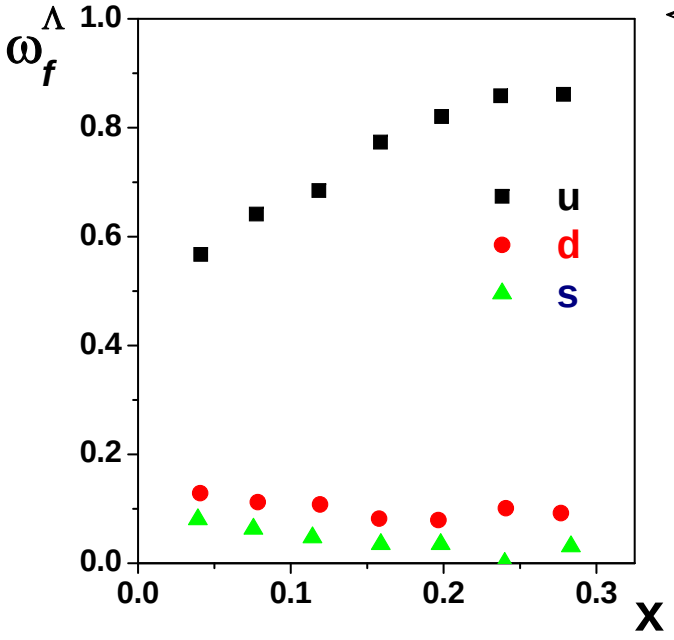
purity

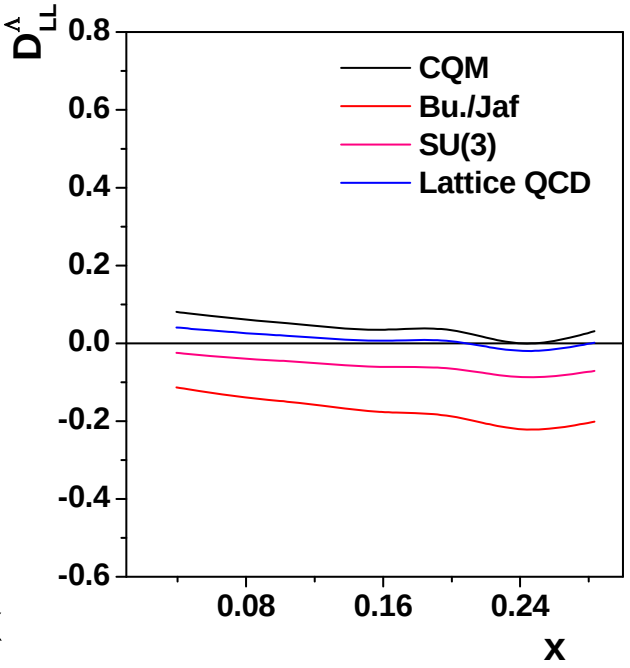
partial spin-transfer

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

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

All models predict negative or small positive value





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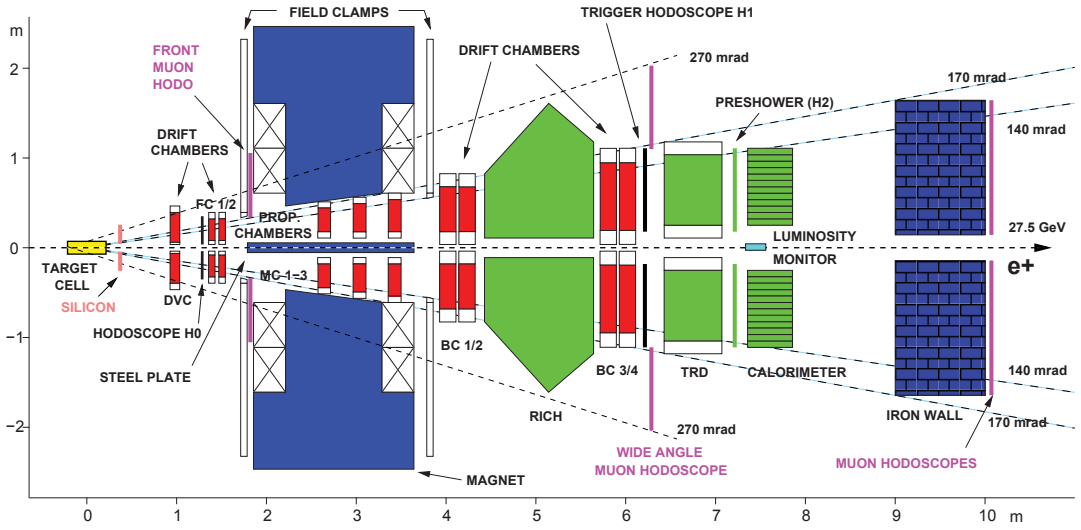
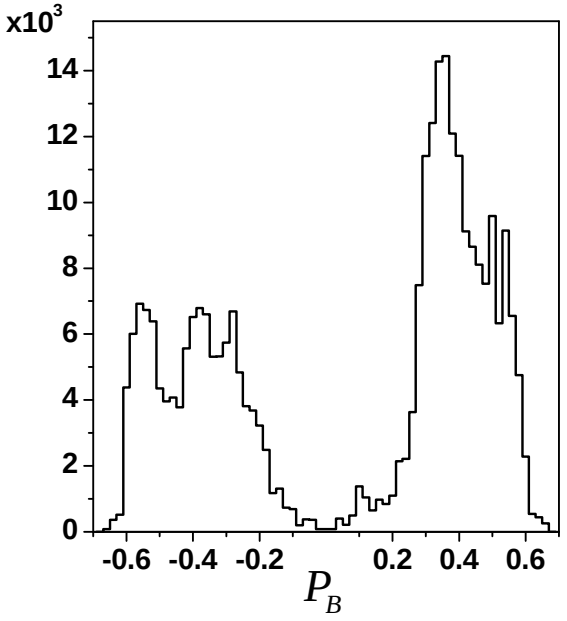
HERMES experiment



HERMES is forward spectrometer

$$1\ \text{GeV} \leq p^{\Lambda} \leq 16\ \text{GeV}$$



- ✓ ***Long. polarized <u>lepton</u> (e^-/e^+) beam E_e = 27.5 GeV***
- ✓ ***Beam spin flipped every few month***
- ✓ ***Long. / trans. polarized gas targets H, D, flipped every 90 sec, $[\![P_{targ}]\!] \approx 0$***
- ✓ ***Unpolarized targets H, D, He, N, Ne, Kr, Xe***

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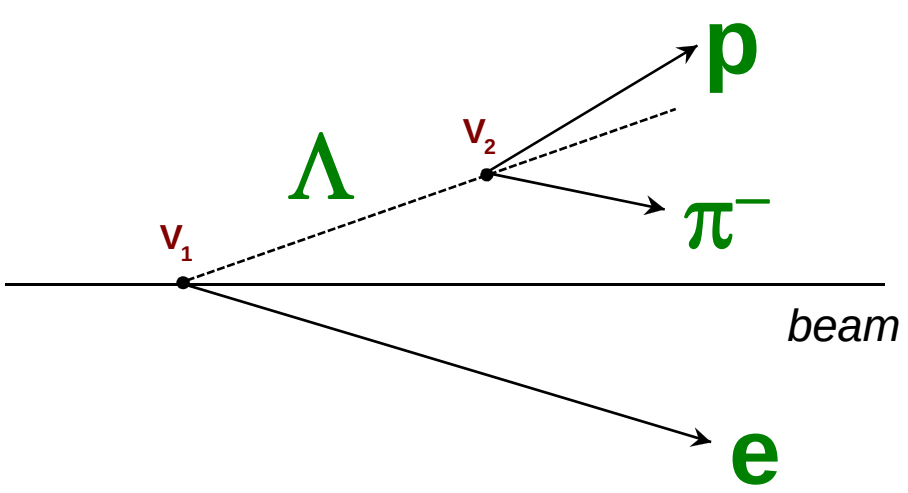
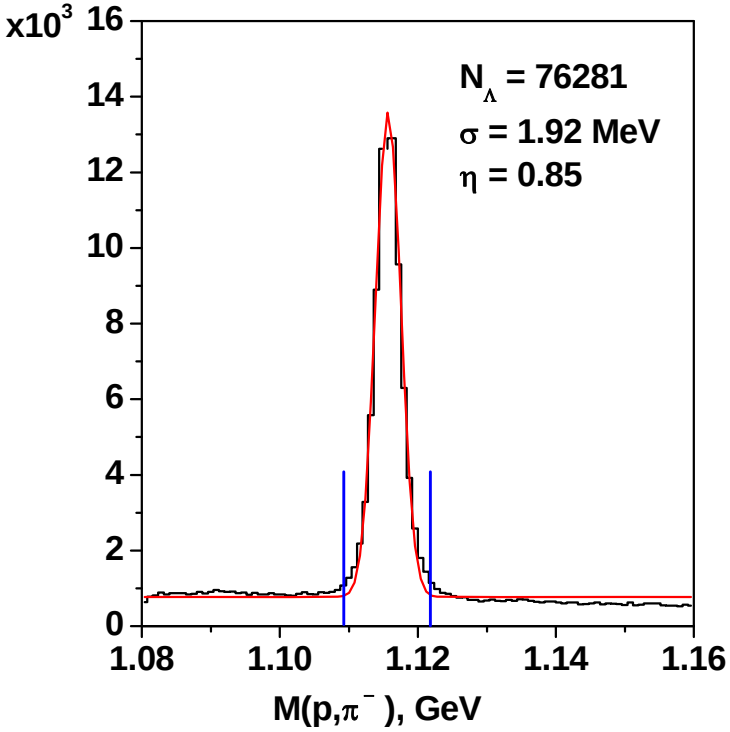
Λ events selection





Background suppression

- **leading π rejection (in HERMES kinematics proton is always leading) :**
  - ***Threshold Cherenkov det. 1996-1997***
  - ***Ring imaging Cherenkov 1998-2007***
- **h^+h^- pair background rejection :**
  - ***Vertex separation $d(V_1,V_2) > 5$ cm***

$$\vec{P}_{L'}^{\Lambda} = \frac{\vec{P}_{L'}^{\Lambda+bkg} - (1-\eta)\,\vec{P}_{L'}^{bkg}}{\eta}$$

$$\eta = \frac{N_\Lambda}{N_\Lambda + N_{bgr}}$$

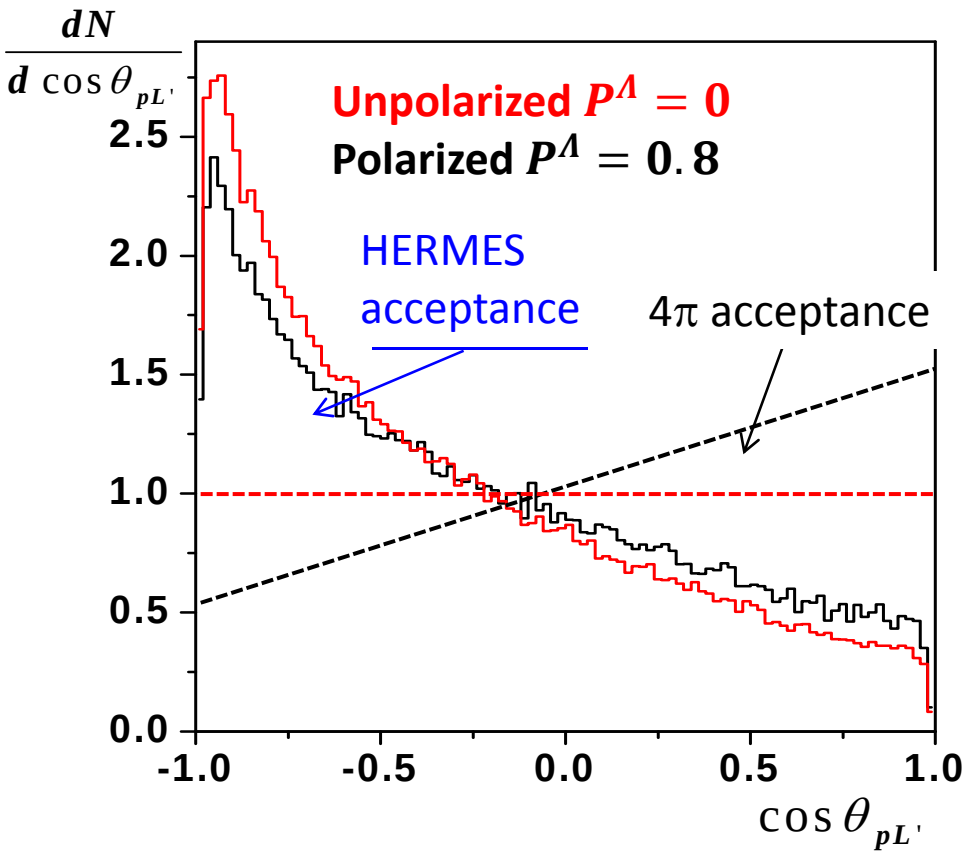
Formalism extraction of $D_{LL'}^{\Lambda}$

- Angular distribution of decay protons

$$\frac{dN}{d\Omega_p} = \frac{dN_0}{d\Omega_p}\left(1 + \alpha\, P_{L'}^{\Lambda} \cos\theta_{pL'}\right)$$

Unknown, need MC simulation of acceptance

Main source of systematic uncertainty !



Formalism extraction of $D^{\Lambda}_{LL'}$

- **Helicity balanced data sample** $[\![P_B]\!] = \frac{1}{L}\int P_B\, dL = 0$
- **Moment method in simple 1Dim case**

$$\langle P_B \cos\theta_{pL'}\rangle = \frac{[\![P_B]\!]\langle\cos\theta_{pL'}\rangle_0 + \alpha D_{LL'}[\![P_B^2]\!]\langle\cos^2\theta_{pL'}\rangle_0}{1 + \alpha D_{LL'}[\![P_B]\!]\langle\cos\theta_{pL'}\rangle_0} \overset{[\![P_B]\!]=0}{=} \alpha D_{LL'}[\![P_B^2]\!]\langle\cos^2\theta_{pL'}\rangle_0$$

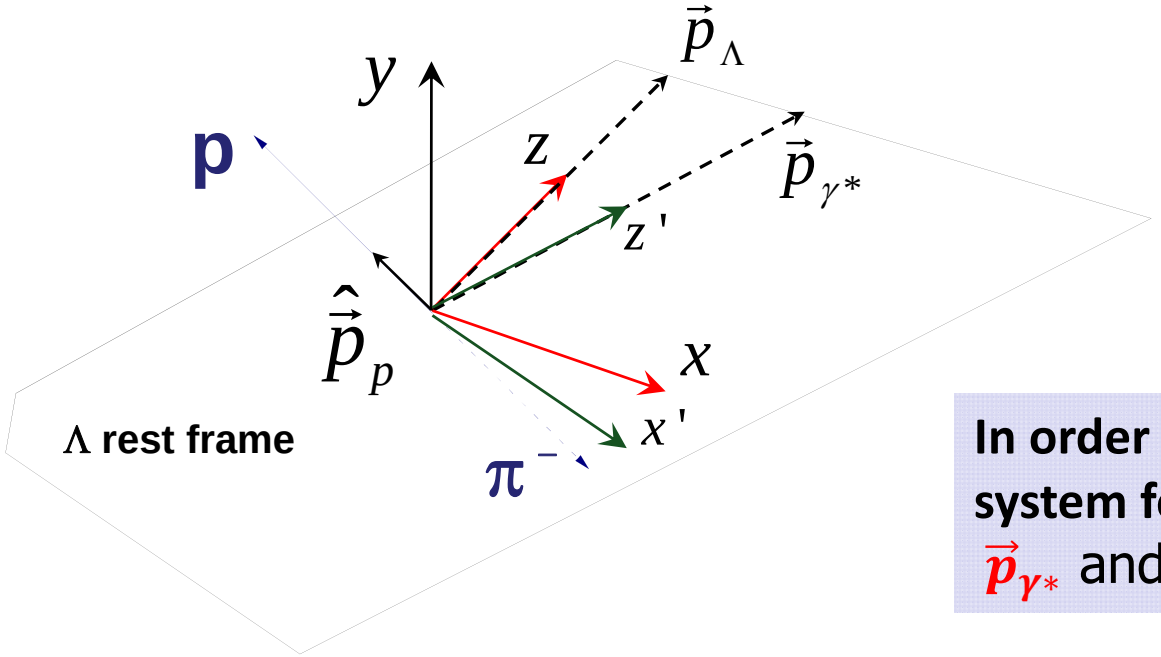
$$\langle\cos^2\theta_{pL'}\rangle = \frac{\langle\cos^2\theta_{pL'}\rangle_0 + \alpha D_{LL'}[\![P_B]\!]\langle\cos^3\theta_{pL'}\rangle_0}{1 + \alpha D_{LL'}[\![P_B]\!]\langle\cos\theta_{pL'}\rangle_0} \overset{[\![P_B]\!]=0}{=} \langle\cos^2\theta_{pL'}\rangle_0$$

$$D^{\Lambda}_{LL'} = \frac{1}{\alpha\,[\![P_B^2]\!]} \cdot \frac{\langle P_B \cos\theta_{pL'}\rangle}{\langle \cos^2\theta_{pL'}\rangle}$$

No MC simulation of acceptance needed

- **Slightly more complicated iteration procedure used in case of unbalanced** P_B
- **3 projection *of* $D^{\Lambda}_{LL'}$ calculated**
- **3Dim extraction formalism verified with help of MC**

Definition of coordinate system



$$\vec{\gamma}^* + p \to \vec{\Lambda} + X$$

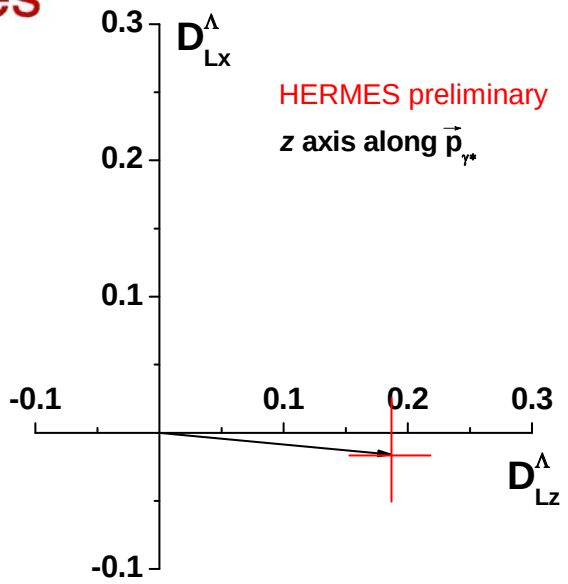
In order to build coordinate system for Λ at rest two vectors: $\vec{p}_{\gamma^*}$ and $\vec{p}_\Lambda$ are used

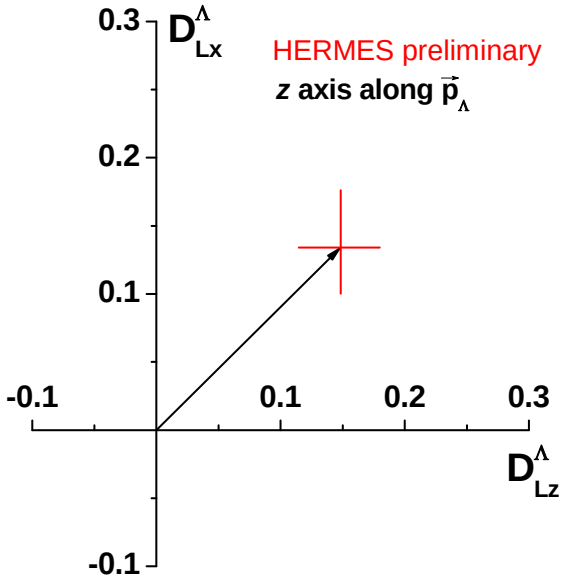
2 variants of system

$$\vec{k}_z = \hat{\vec{p}}_\Lambda, \quad \vec{k}_y = \hat{\vec{p}}_\Lambda \times \hat{\vec{p}}_{\gamma^*}, \quad \vec{k}_x = \vec{k}_y \times \vec{k}_z$$

$$\vec{k}_z = \hat{\vec{p}}_{\gamma^*}, \quad \vec{k}_y = \hat{\vec{p}}_\Lambda \times \hat{\vec{p}}_{\gamma^*}, \quad \vec{k}_x = \vec{k}_y \times \vec{k}_z$$

Integrated over kinematics result





$D_{Lx} = -0.016 \pm 0.042_{stat} \pm 0.017_{syst}$

$D_{Lz} = 0.186 \pm 0.040_{stat} \pm 0.012_{syst}$

$D_{Lx} = 0.133 \pm 0.039_{stat} \pm 0.015_{syst}$

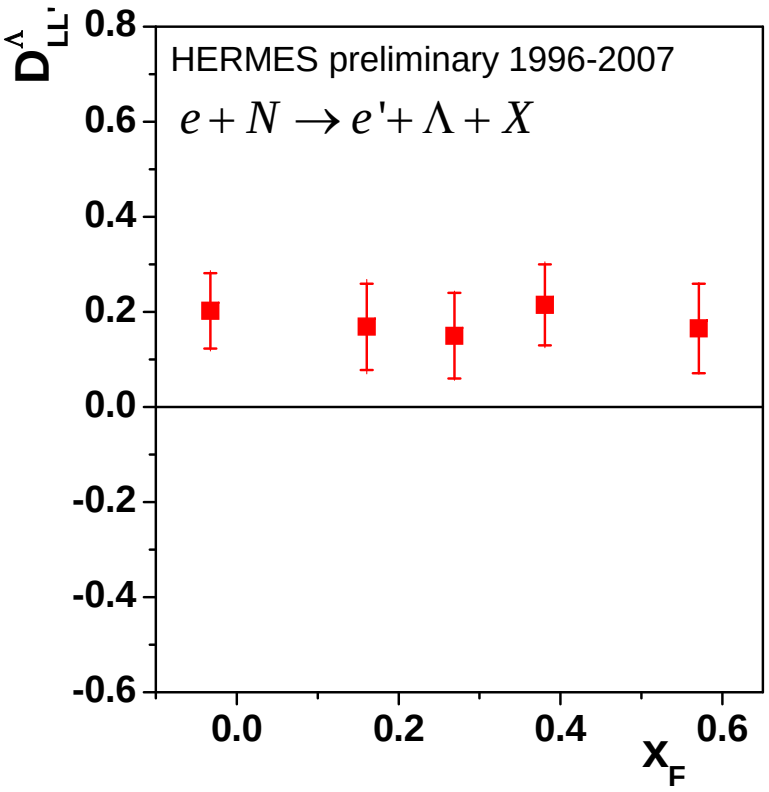
$D_{Lz} = 0.147 \pm 0.038_{stat} \pm 0.015_{syst}$

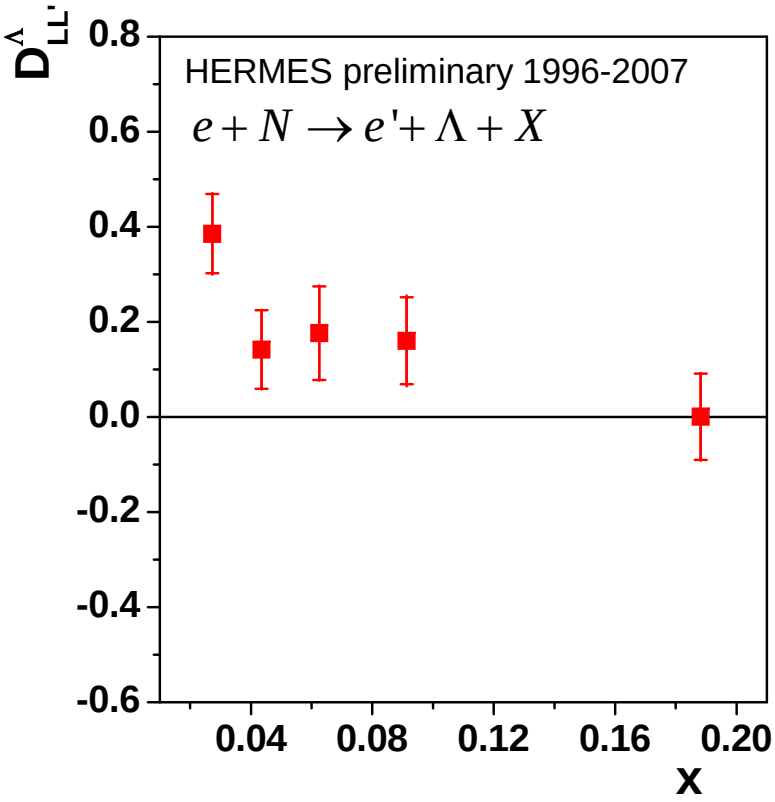
$D_{Ly} = 0.037 \pm 0.037$

Due to parity conservation and time reversal invariance *y* - component must be zero

Spin transfer is practically along γ* ! → so L' chosen along $\vec{p}_{\gamma*}$

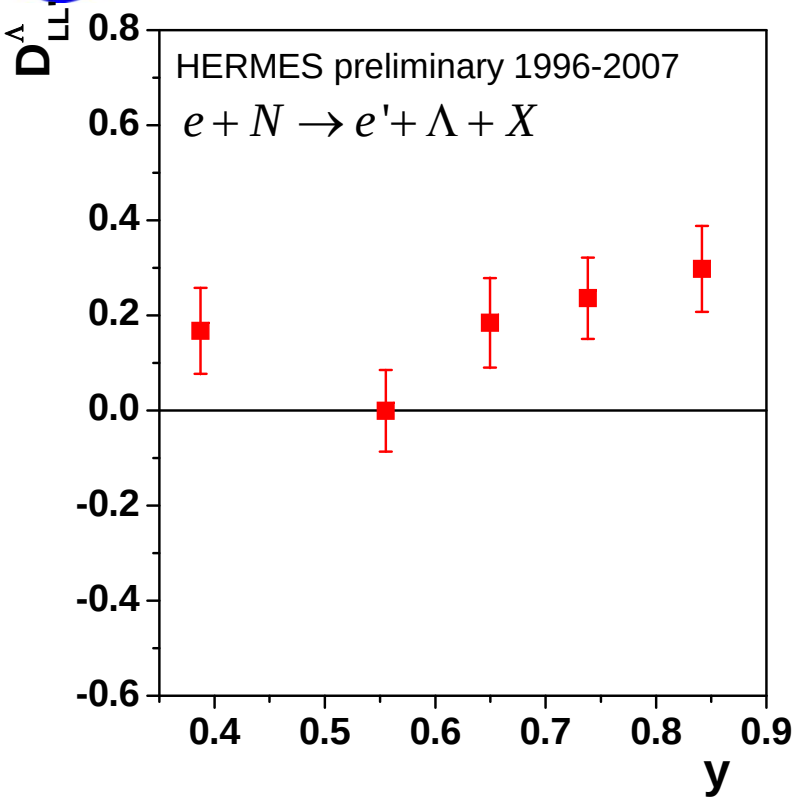
Dependences on kinematic variables

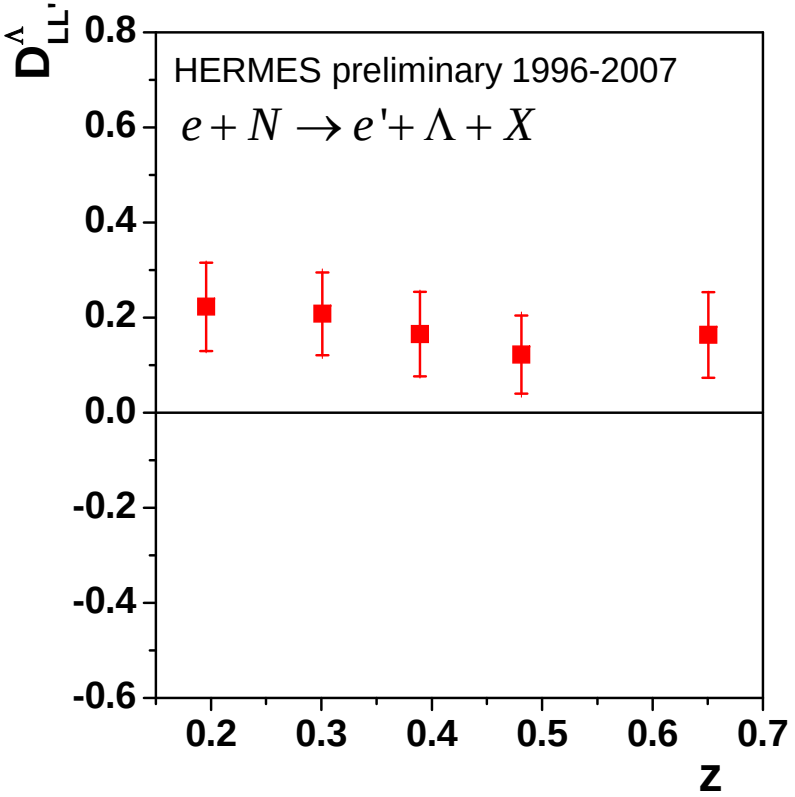




- ✓ $D^{\Lambda}_{LL'}$ ***increasing*** ***at small*** x
- ✓ ***Flat*** x_F ***dependence***

Dependences on kinematic variables





- ✓ *z dependence are flat, $z \cong x_F$ at $z \to 1$*
- ✓ *y dependence are not strong unless flat*
- ✓ *$D_{LL'}^{\Lambda}$ must not depend on y if single scattering model of DIS is valid*

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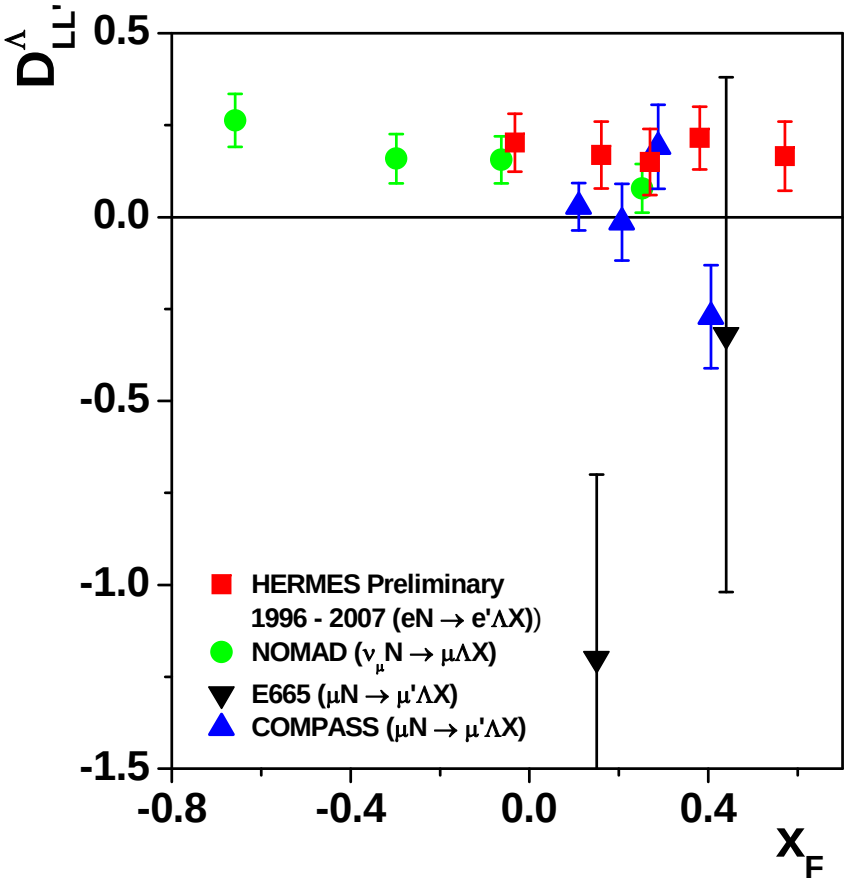
World data



- HERMES – **found experimentally** L' **along** γ^* (3D analysis)
- L' **assumed** along γ^*
  - NOMAD
  - COMPASS
- L' **assumed** along Λ
  - E665

Theoretical model

- **Constituent quark model (CQM)**

$\Delta u=\Delta d=0,\ \Delta s=1$

- **Burkard/Jaffe**

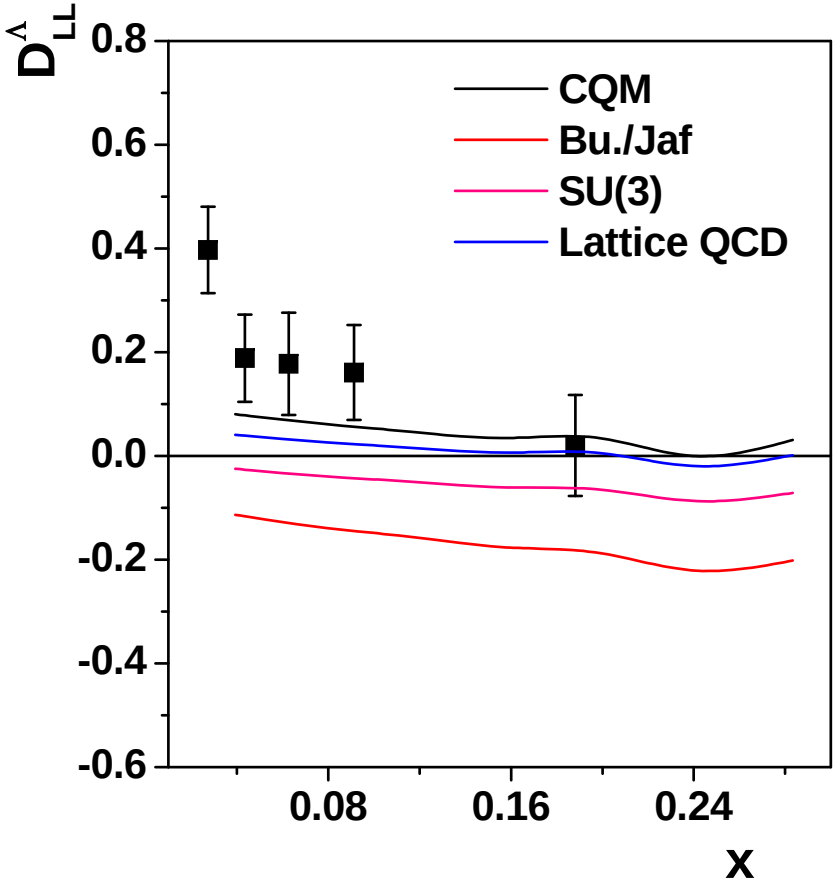
$\Delta u=\Delta d=-0.23\pm0.06,\ \Delta s=0.58\pm0.07$

- **SU(3) flavor symmetry**

$\Delta u=\Delta d=-0.09\pm0.06,\ \Delta s=0.47\pm0.07$

- **Lattice QCD**

$\Delta u=\Delta d=-0.02\pm0.04,\ \Delta s=0.68\pm0.04$



No Λ from hyperon resonances decay is taken in to account

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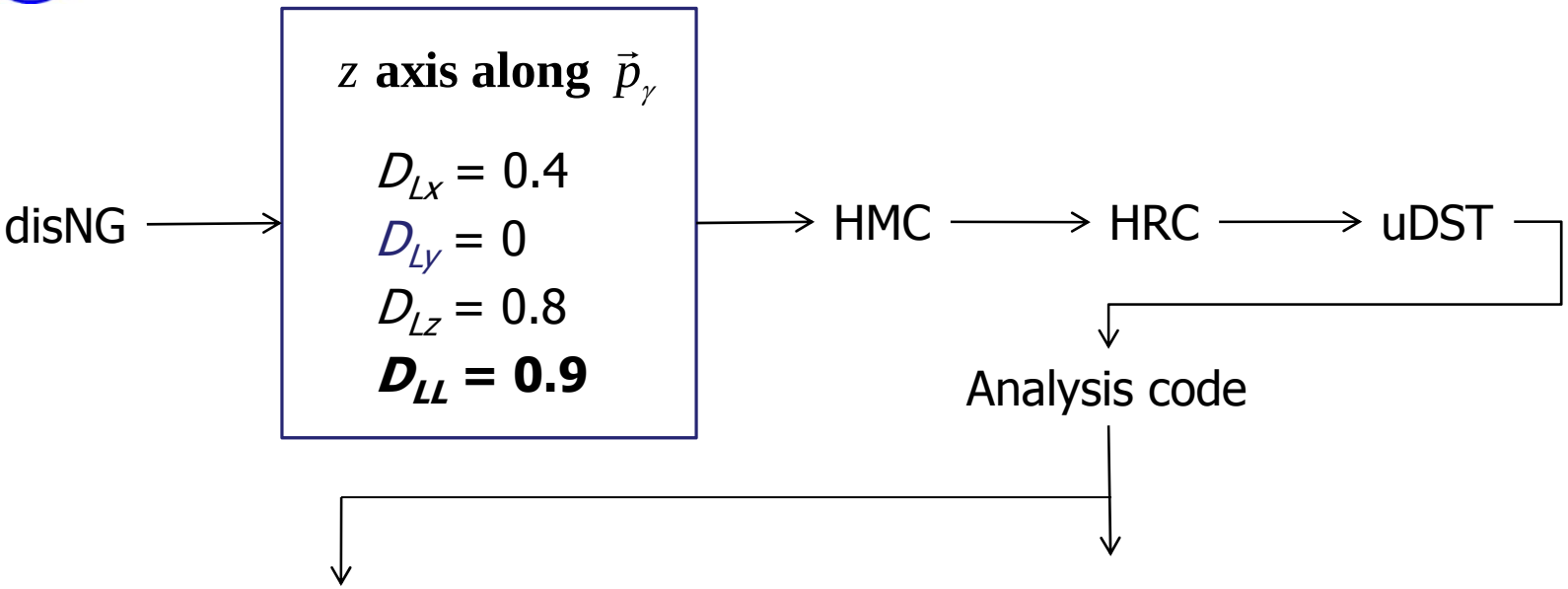
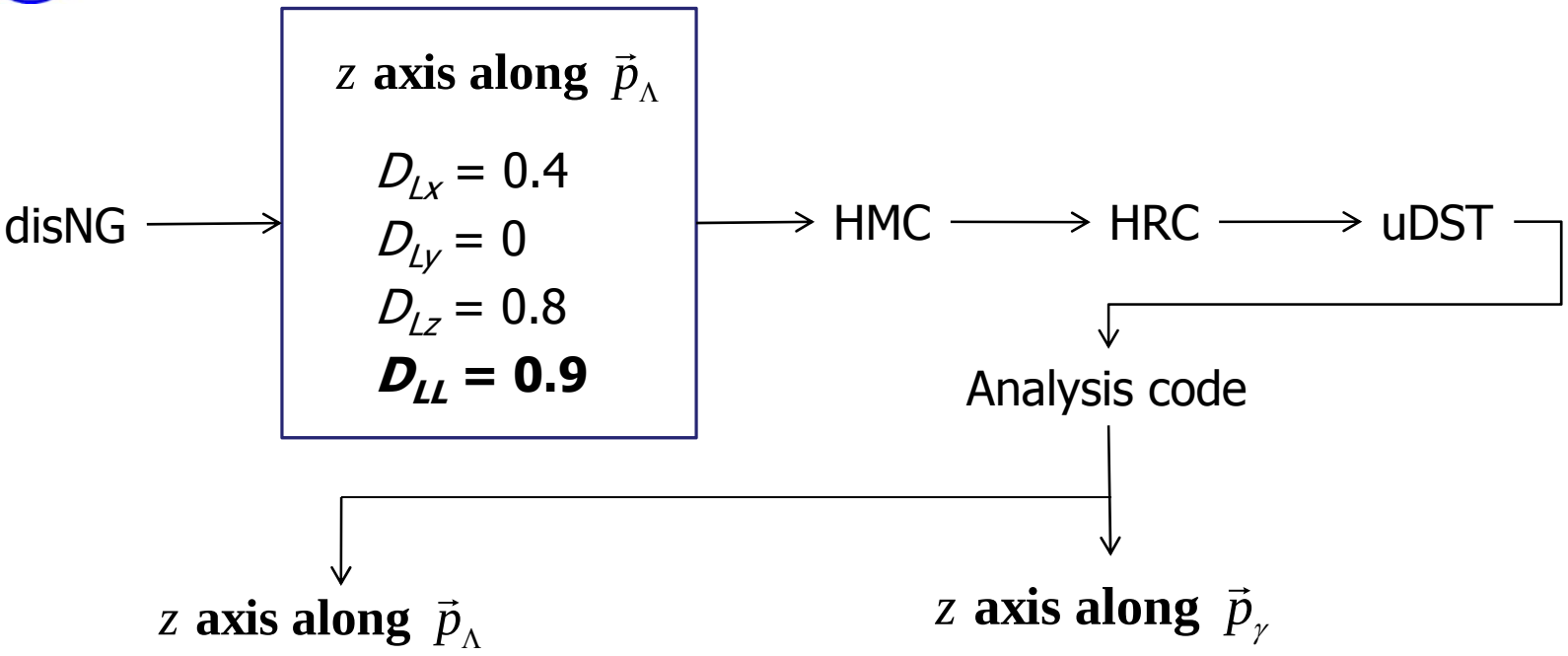
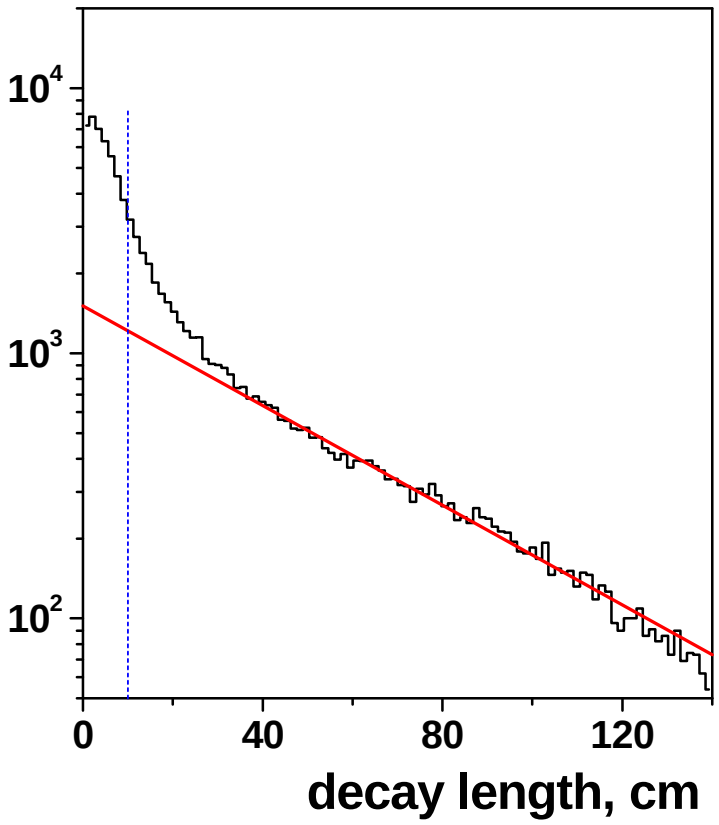
Conclusion

- All three components of spin transfer $D_{LL'}^{\Lambda}$ have been measured in DIS of charge leptons at HERMES for the first time
- It is shown that $D_{LL'}^{\Lambda}$ is mostly directed along the momentum of virtual photon direction
- Longitudinal spin transfer from beam in DIS ($Q^2 > 0.8$ GeV^2) for Λ $D_{LL'}^{\Lambda} = 0.186 \pm 0.040_{stat} \pm 0.012_{syst}$ while theoretical models predict negative or small positive value
- Kinematical behavior of $D_{LL'}^{\Lambda}$ shows the dependence on x while x_F and z dependencies looks practically flat
- y dependence must be flat (otherwise single scattering model is not valid)

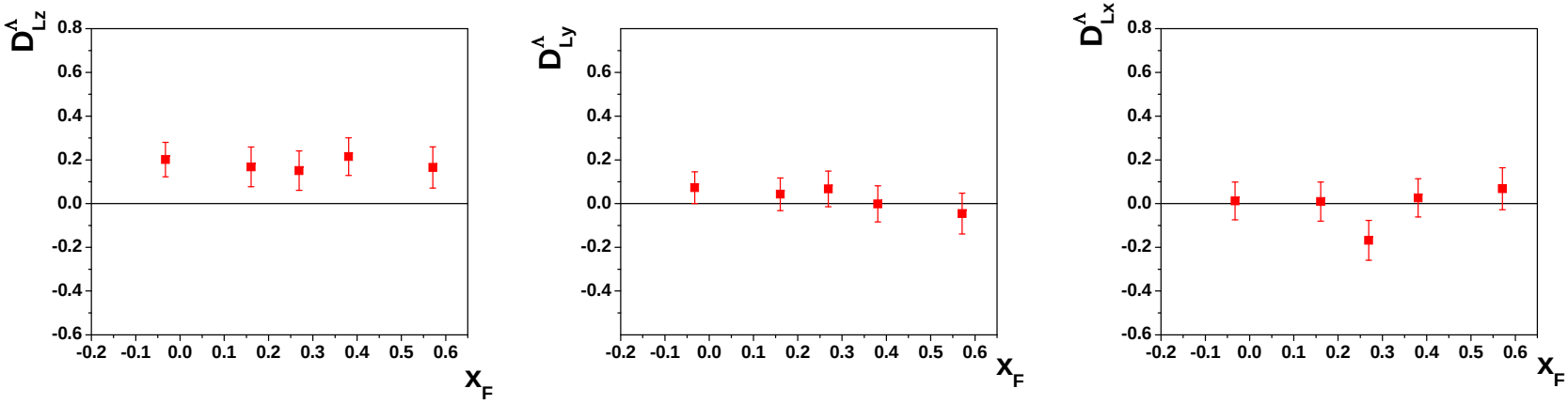

z axis along $\vec{p}_\gamma$
D_{Lx} = 0.4
D_{Ly} = 0
D_{Lz} = 0.8
D_{LL} = 0.9
disNG
HMC
HRC
uDST
Analysis code
z axis along $\vec{p}_\gamma$
D_{Lx} = 0.3879 ± 0.0121
D_{Ly} = 0.0068 ± 0.0106
D_{Lz} = 0.8138 ± 0.0106
D_{LL} = 0.9015 ± 0.0109
z axis along $\vec{p}_\Lambda$
D_{Lx} = 0.6697 ± 0.0107
D_{Ly} = 0.0082 ± 0.0106
D_{Lz} = 0.5161 ± 0.0085
D_{LL} = 0.8455 ± 0.0100


z axis along $\vec{p}_\Lambda$
D_{Lx} = 0.4
D_{Ly} = 0
D_{Lz} = 0.8
D_{LL} = 0.9
disNG
HMC
HRC
uDST
Analysis code
z axis along $\vec{p}_\Lambda$
D_{Lx} = 0.3978 ± 0.0087
D_{Ly} = -0.0024 ± 0.0087
D_{Lz} = 0.7962 ± 0.0072
D_{LL} = 0.8901 ± 0.0075
z axis along $\vec{p}_\gamma$
D_{Lx} = -0.0200 ± 0.0092
D_{Ly} = -0.0032 ± 0.0084
D_{Lz} = 0.8658 ± 0.0081
D_{LL} = 0.8660 ± 0.0081

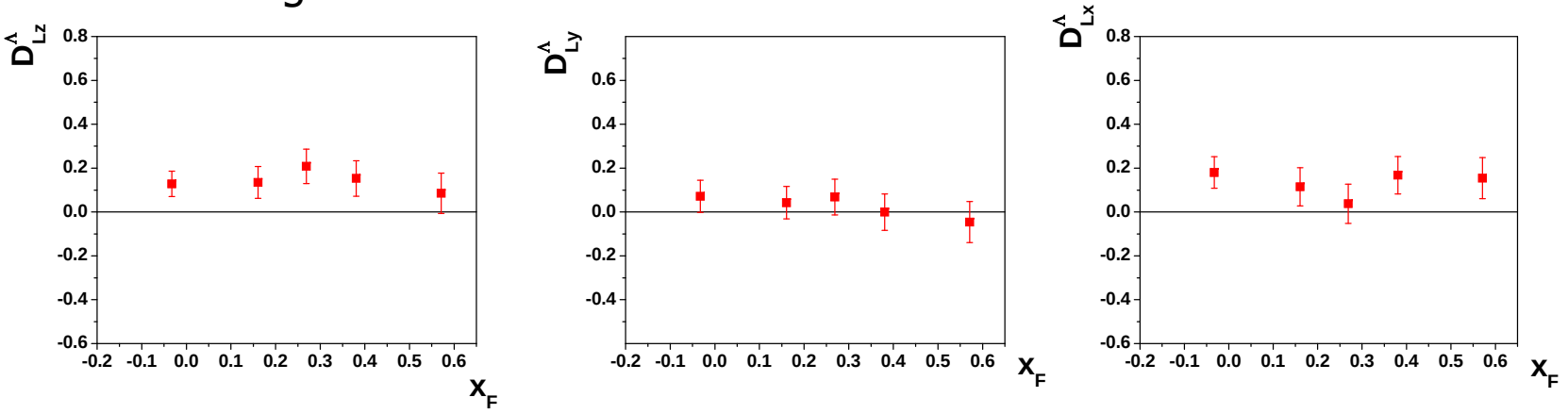

10^4
10^3
10^2
0
40
80
120
decay length, cm

Results in 3D case

z along γ^* momentum



z along Λ momentum trace



Due to parity conservation -> *y* component $D_{Ly} = 0$
partly check the formalism