Spin transfer coefficient $K_{LL'}$ in Λ photoproduction at HERMES

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On behalf of the HERMES collaboration

DIS08, London

Λ decay and spin transfer coefficient

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

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

$$\frac{d\sigma}{d\Omega_p} = \frac{d\sigma_0}{d\Omega_p}(1+\alpha P_\Lambda \cos\theta_{pL'})$$

Unpolarized cross-section

decay constant, 0.642 (Λ), -0.642 ($\bar{\Lambda}$)

angle between proton momentum in the Λ rest frame and the Λ spin

$$P_\Lambda^{L'} = S_{LL'} P_L$$

L* *is primary axis along target or beam polarization

L'* *is secondary axis along Λ momentum

Spin transfer coefficient $S_{LL'}$

- $K_{LL'}$ $\to$ **from longitudinally polarized target**
- $K_{NN'}$ $\to$ **from transversely polarized target**
- $D_{LL'}$ $\to$ **from longitudinally polarized beam**
- $D_{NN'}$ $\to$ **from transversely polarized beam**

Study of Λ polarization at HERMES

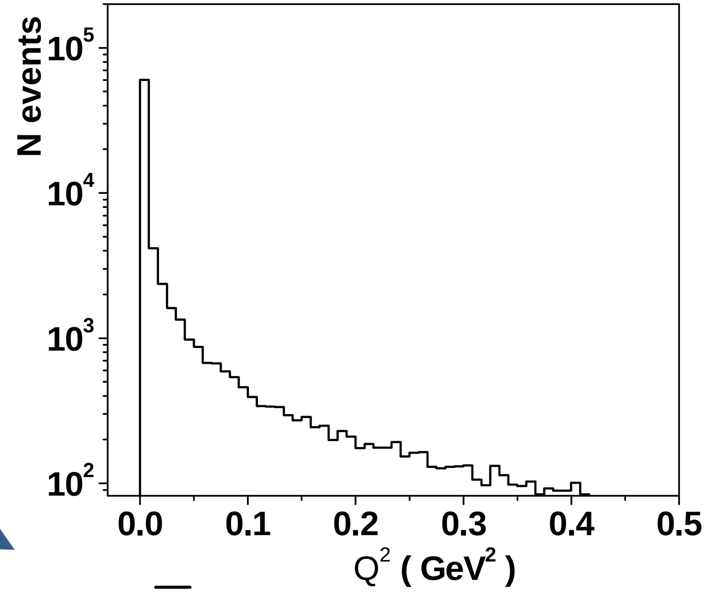
- **DIS**, **e + p → e' + Λ + X**
  - ***$D_{LL'}$*** **→ spin transfer from <u>longitudinally</u> polarized e^+/e^- beam in semi-inclusive reaction** */ Published P.R. D 64 (2001), P.R. D 74 (2006) /*
- **Quasi-real photoproduction**, **e + p → Λ + X**
  ↳ ***e' + γ* ($Q^2 \sim 0$ GeV^2)***
  - ***$K_{LL'}$*** **→ spin transfer from <u>longitudinally</u> polarized target**
  - ***$D_{LL'}$*** **→ spin transfer from <u>longitudinally</u> polarized e^+/e^- beam**
  - ***$K_{NN'}$*** **→ spin transfer from <u>transversely</u> polarized target**
  - ***Pn*** **→ transverse (spontaneous) Λ polarization** */ Publish P.R. D 76 (2007) /*

Λ photoproduction mechanism in PYTHIA

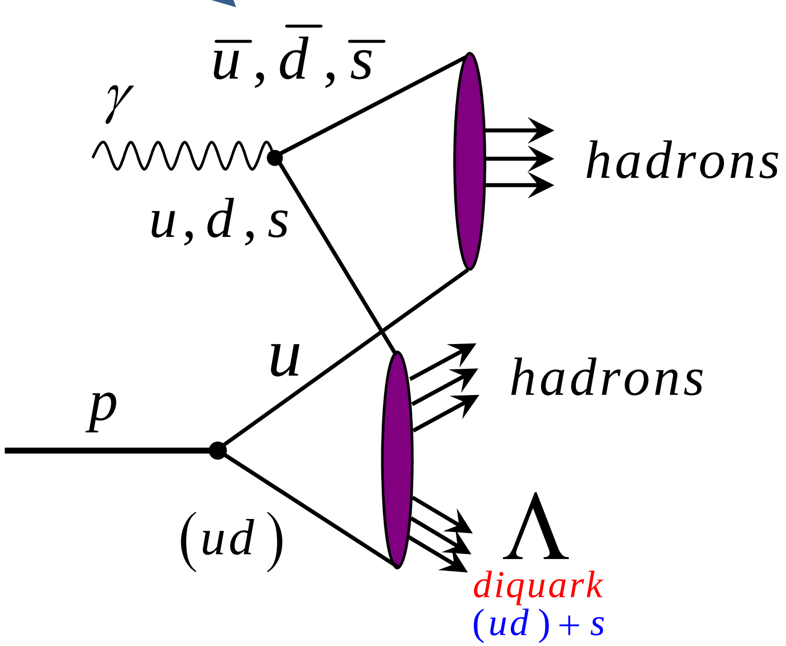
Most of events are within photoproduction peak

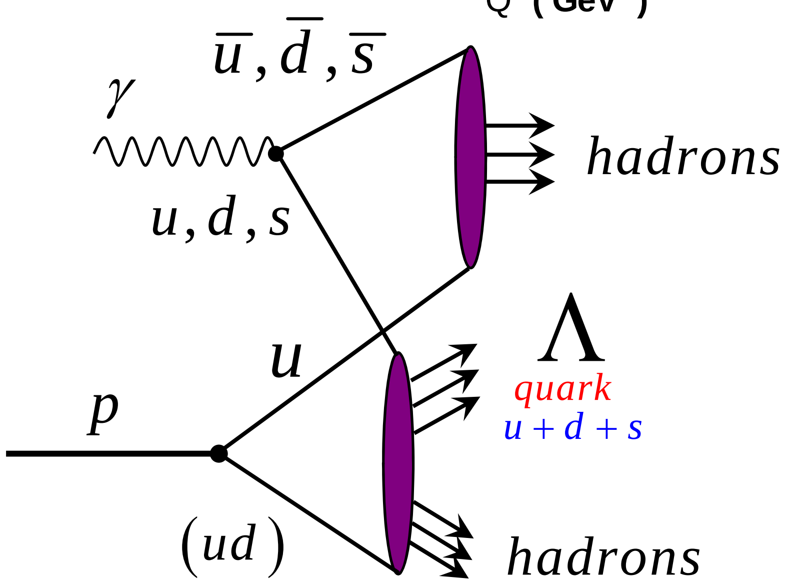
(for ~80% events $Q^2 < 0.05$ GeV^2, $\nu \approx 15$ GeV)

Such that photon is quasi-real

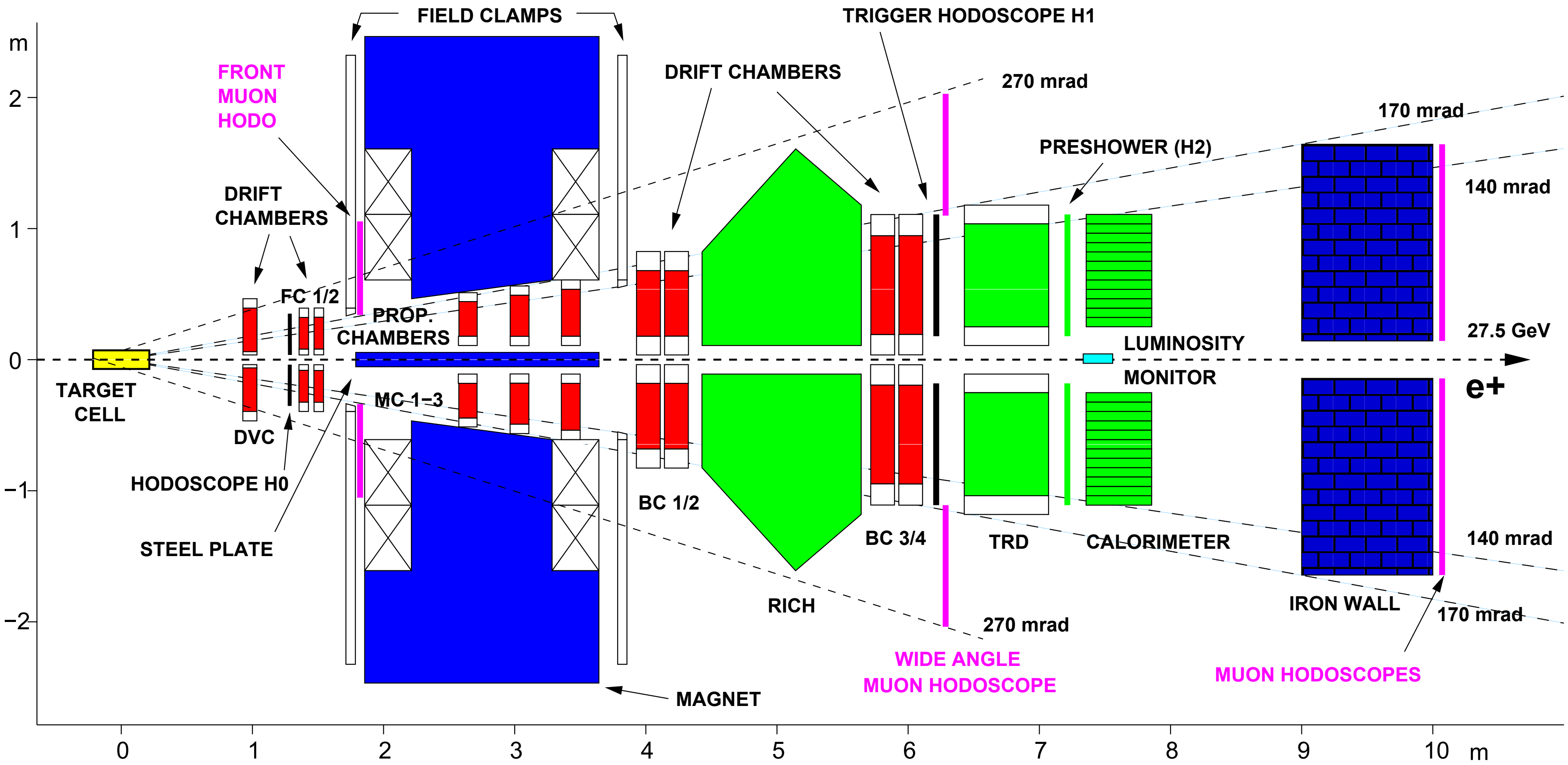


According to PYTHIA Λ is produced due to diquark fragmentation or due to quark fragmentation



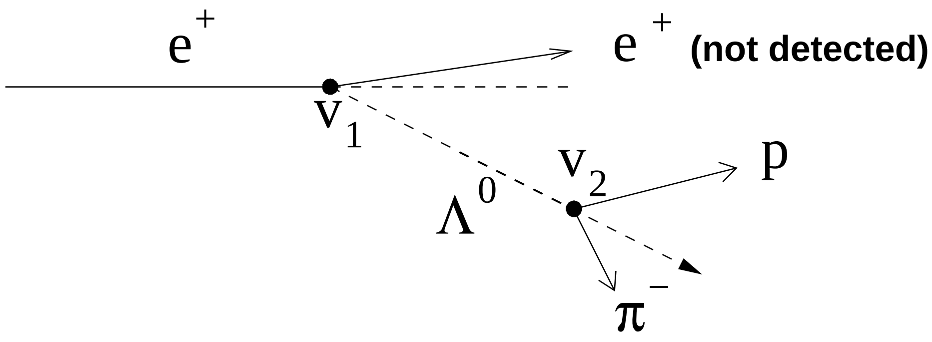


HERMES experiment

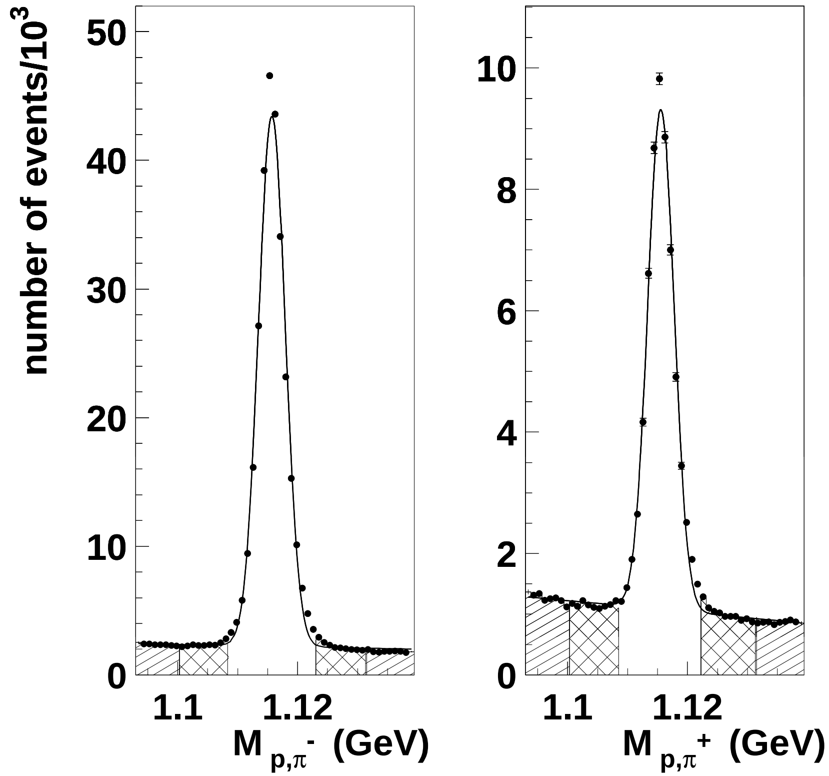


- ✓ *Polarized lepton (e^-/e^+) beam $E_e = 27.5$ GeV , monthly spin flip → ($D_{LL'}$)*
- ✓ *Long. / trans. polarized gas targets (H, D) , spin flip every 90 s → ($K_{LL'}$, $K_{NN'}$)*
- ✓ *Detector is up / down symmetric → (P_n)*

$\Lambda(\bar{\Lambda})$ event reconstruction



Data sample for longitudinally polarized target (1996 - 2000)



Background suppression cuts for

- **leading π rejection (in HERMES acceptance proton is always leading) :**
  - *Threshold Cherenkov det. 1996-1997*
  - *Ring imaging Cherenkov 1999-2000*
- **h^+h^- pair background rejection :**
  - *Vertex separation $d(V_1,V_2) > 15$ cm*

$$N_\Lambda \cong 126\cdot 10^3,\ \ N_{\bar{\Lambda}} \cong 25\cdot 10^3$$

Formalism extraction of $K_{LL'}$

$$\frac{d\sigma}{d\Omega_p} = \frac{d\sigma_0}{d\Omega_p}(1+\alpha K_{LL'} P_T \cos\theta_{pL'})$$

- **Helicity balanced data sample** $[\![P_T]\!] = \frac{1}{L}\int P_T \, dL = 0$ $\quad P_T \rightarrow$ target polarization, $L \rightarrow$ luminosity

- **Moment method**

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

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

$$K_{LL'}^{\Lambda} = \frac{1}{\alpha[\![P_T^2]\!]}\cdot\frac{\langle P_T\cos\theta_{pL'}\rangle}{\langle\cos^2\theta_{pL'}\rangle} = \frac{1}{\alpha[\![P_T^2]\!]}\cdot\frac{\sum_{i=1}^{N_\Lambda} P_{T,i}\cdot\cos\theta_{pL'}^{i}}{\sum_{i=1}^{N_\Lambda}\cos^2\theta_{pL'}^{i}}$$

No MC simulation needed

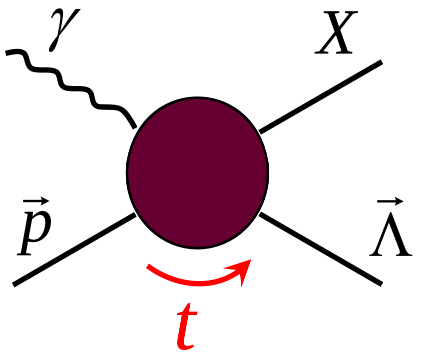
- **Background subtraction**

$$K_{LL'\ \Lambda+bgr}^{\Lambda} = \eta K_{LL'}^{\Lambda} + (1-\eta)K_{LL'\ bgr}^{\Lambda} \qquad \eta = N_\Lambda \big/ \left(N_\Lambda + N_{bgr}\right)$$

Photoproduction kinematics

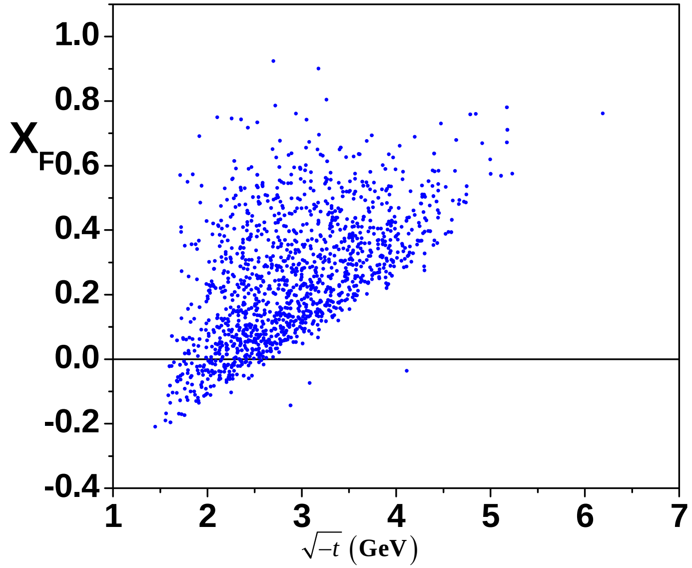
$x_F = p_z / p_{\max}$ ***in** $(\gamma^* p)$ **rest frame*** $\mapsto$ ***not measured***

Only reconstructed are p_z ***and*** $p_t = \sqrt{p_x^2 + p_y^2}$



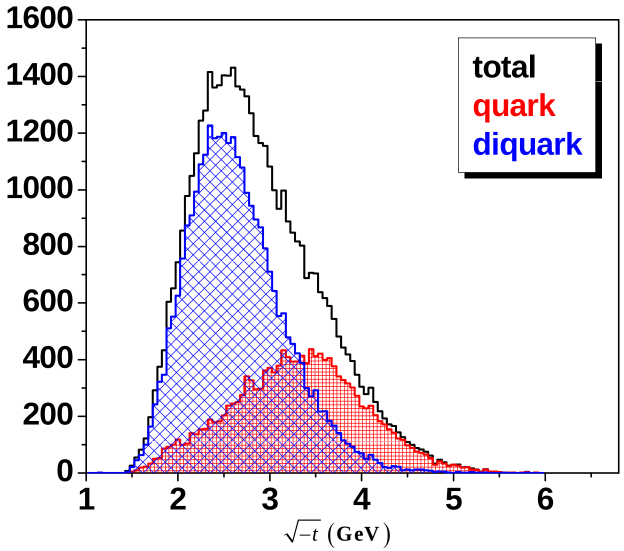
Mandelstam invariant

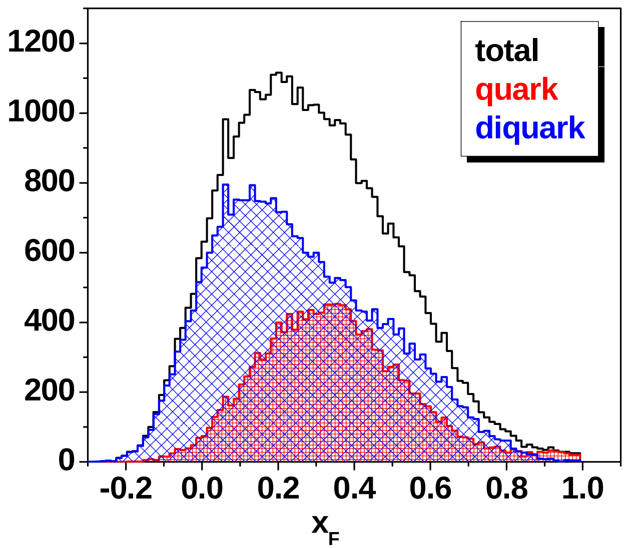
$$t = \left(p_\Lambda - p_p\right)^2$$



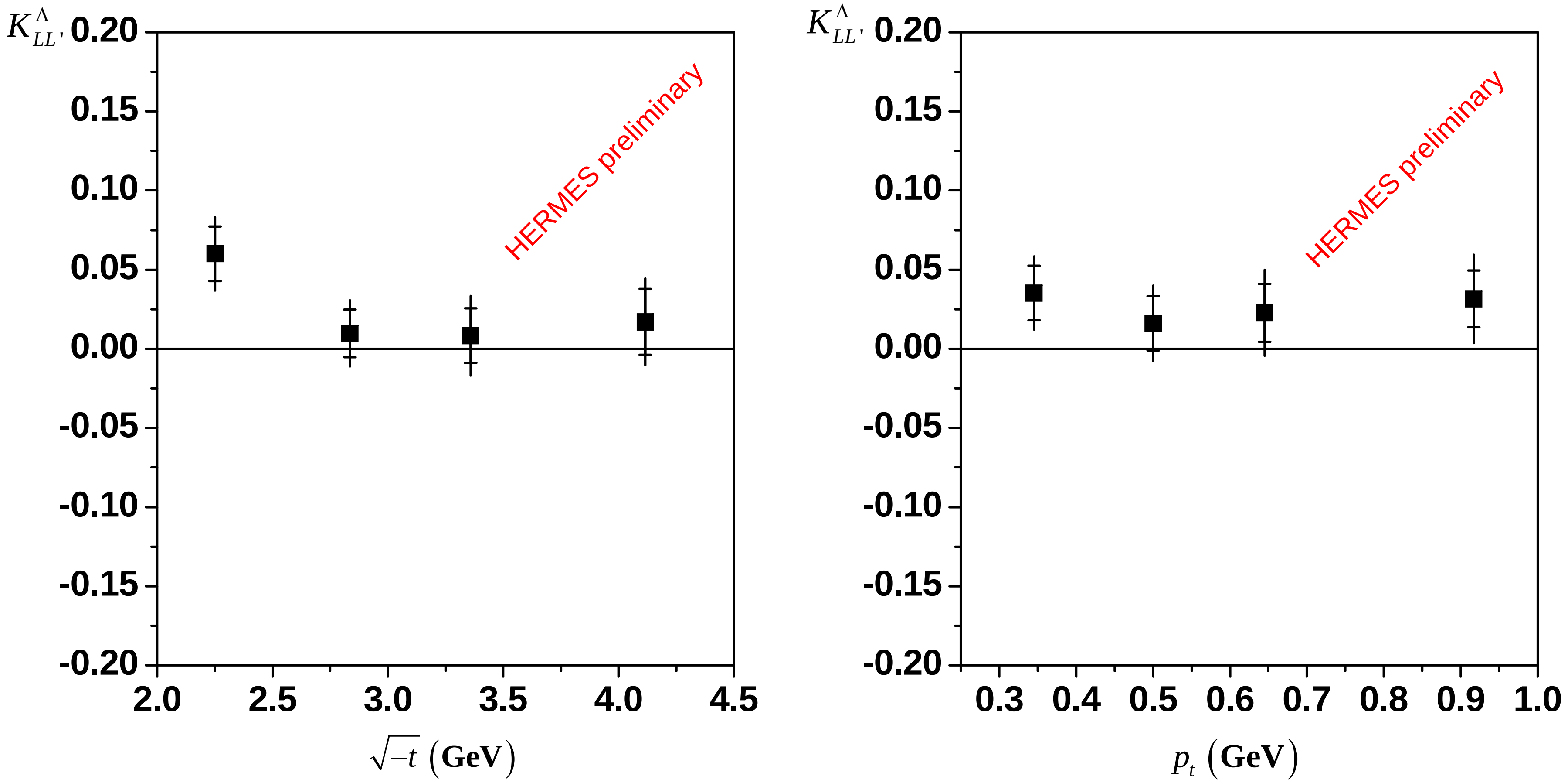
✓ ***Better separate Λ production channels***

✓ ***Value of t allows for easy comparison with other experiments***





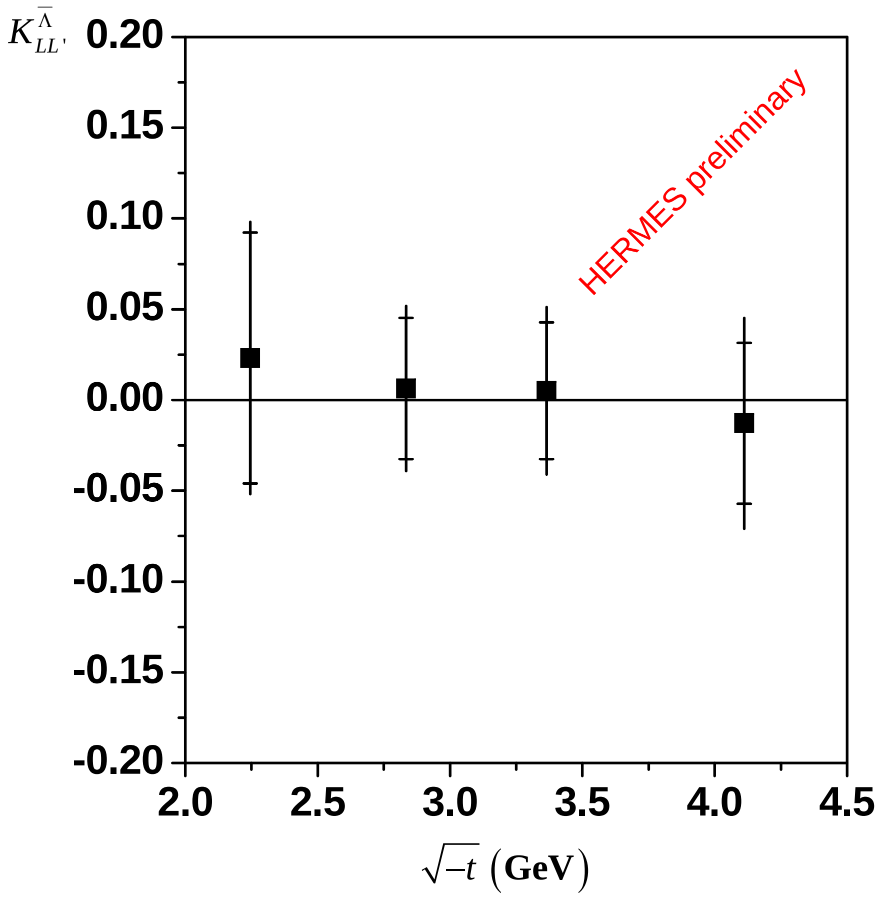
Kinematical dependences of $K_{LL'}$ for Λ

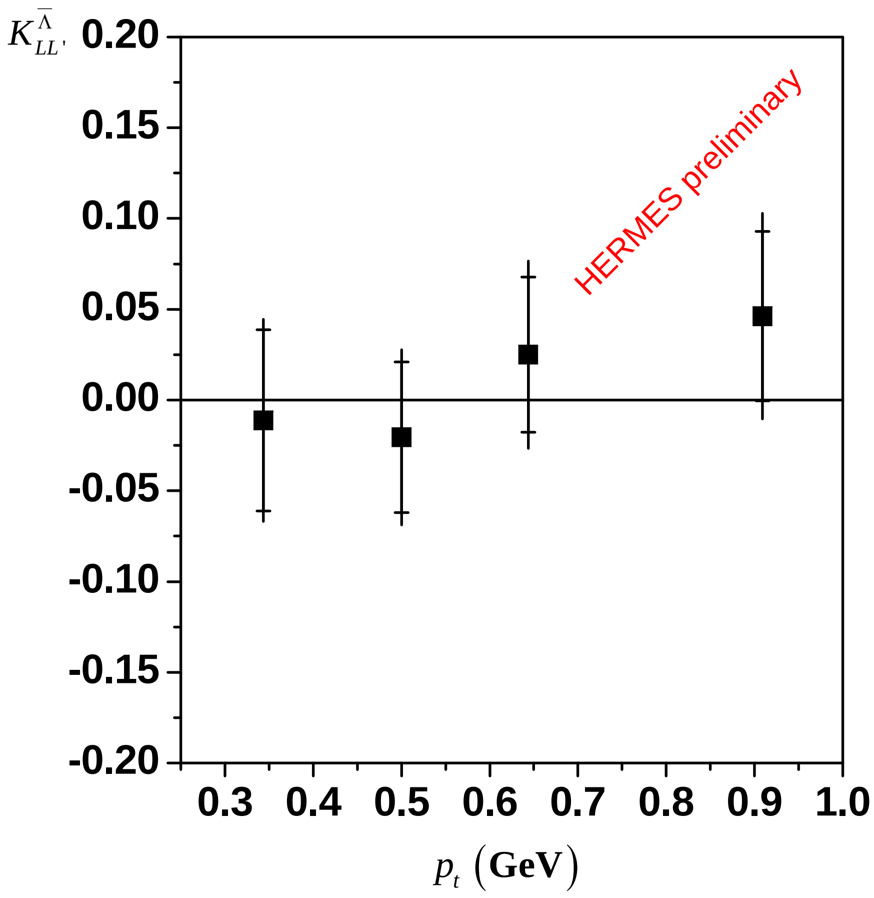


$$K_{LL'}^{\Lambda} = 0.026 \pm 0.009_{stat} \pm 0.005_{syst}$$

- ✓ ***$K_{LL'}$* seems to be *increasing* at small t** *(diquark fragmentation?)*
- ✓ ***$K_{LL'}$* is p_t *independent*** *(0 < p_t < 1.2 GeV)*

Kinematical dependences of $K_{LL'}$ for $\bar{\Lambda}$





$$K_{LL'}^{\bar{\Lambda}} = 0.002 \pm 0.022_{stat} \pm 0.008_{syst}$$

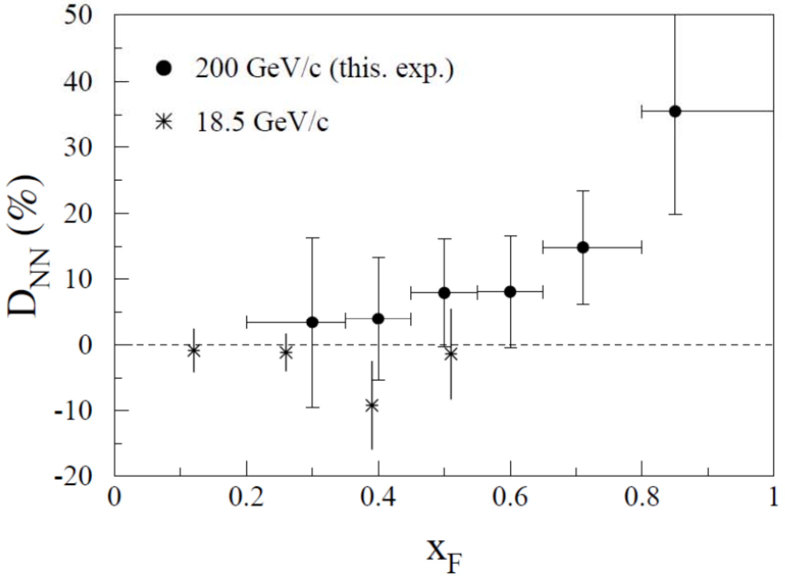
Statistics for $\bar{\Lambda}$ is not enough to see dependences on t or p_t

Spin transfer for Λ and $\bar{\Lambda}$, world data

FNAL, E704
pp collisions with transversely polarized beam

$$E_p = 200\,\mathrm{GeV},\ p_t^{\Lambda} \sim 1.0\,\mathrm{GeV/c}$$

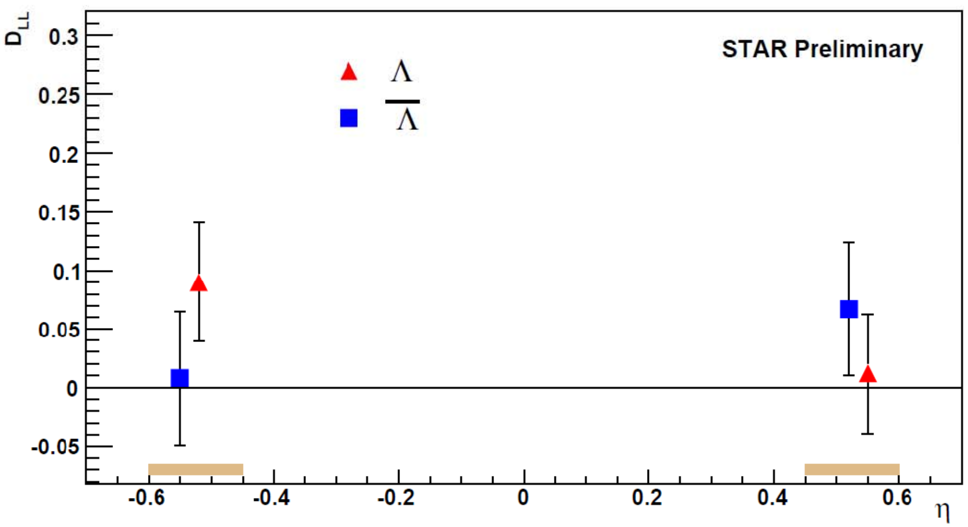
$$\left(E_p, x_F, p_t^{\Lambda}\right) \to t$$



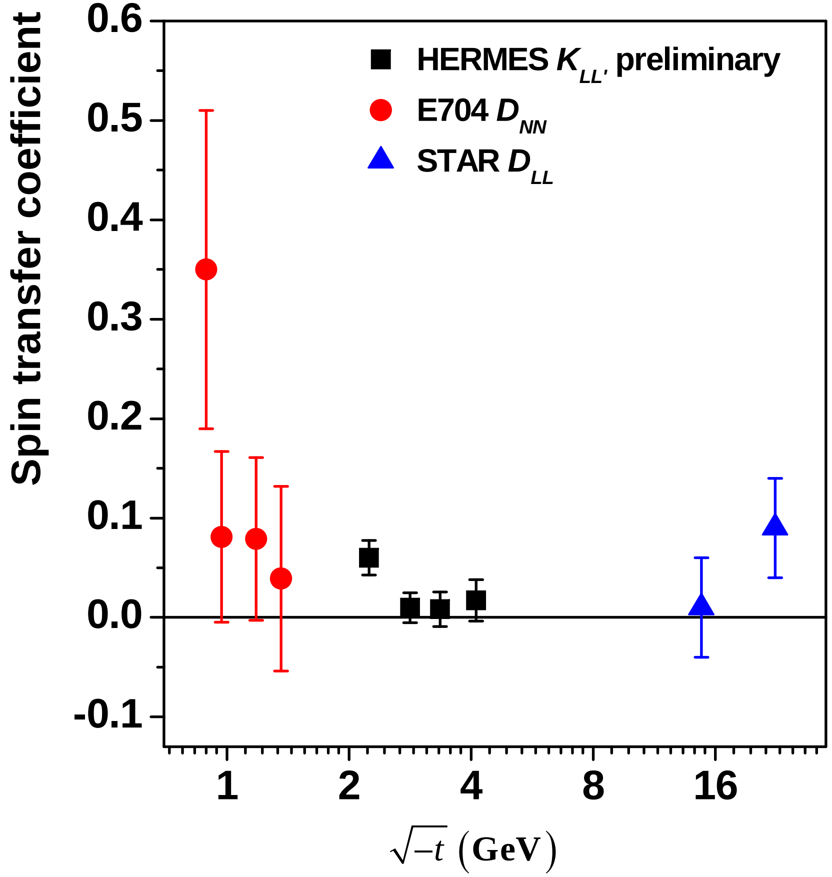
RICH, STAR
pp collisions with longitudinally polarized beam

$$\sqrt{s} \simeq 200\,\mathrm{GeV},\ \eta = \tanh^{-1}\left(p_z/p\right)$$

$$\left(\sqrt{s}, \eta\right) \to t$$



World data compilation for spin transfer



FNAL result confirms a trend to increase spin transfer at small t

Conclusion

- *Longitudinal spin transfer from polarized target to the Λ is measured for the first time in quasi-real photoproduction*

$$K_{LL'} = 0.026 \pm 0.009_{stat} \pm 0.005_{syst}$$

- *Spin transfer is increasing at small t*
- *$K_{LL'}$ is p_t independent*
- *Longitudinal spin transfer to $\bar{\Lambda}$ is compatible with zero for available statistics*

$$K_{LL'} = 0.002 \pm 0.022_{stat} \pm 0.008_{syst}$$