Lambda Physics at HERMES

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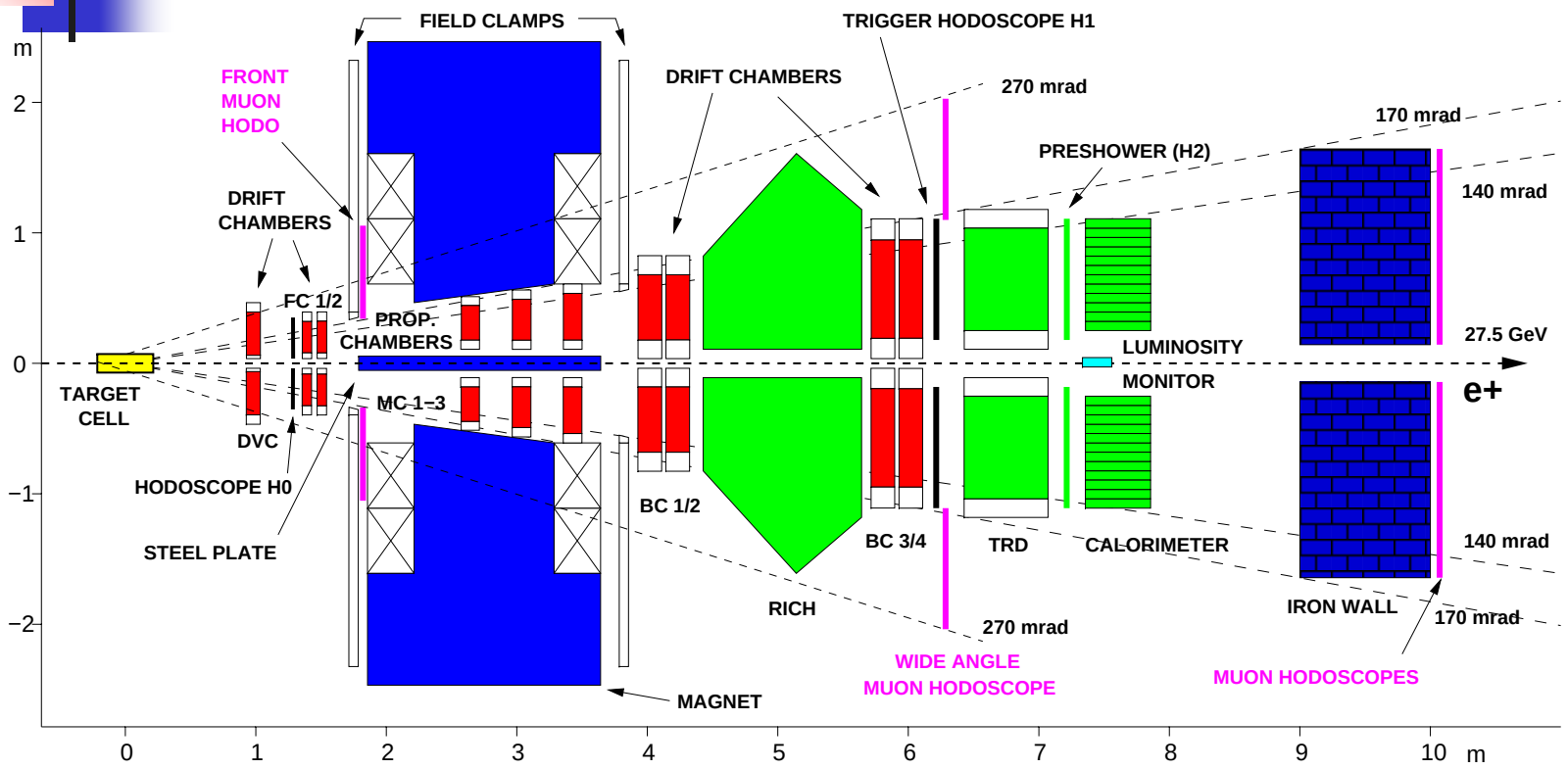
On behalf of the HERMES collaboration

XIII. WORKSHOP ON HIGH ENERGY SPIN PHYSICS DSPIN-09
Dubna, Russia, September 1 - 5, 2009

Outline

- *HERMES experiment*
- *Spin transfer $D_{LL'}$ from the longitudinally polarized beam to Λ hyperon*
- *Spin transfer $K_{LL'}$ from the longitudinally polarized target to Λ hyperon*
- *Transverse (spontaneous) Λ polarization*
- *Conclusion and Outlook*

HERMES experiment



- *polarized positron (and electron) beam E_e = 27.5 GeV,*
- *average beam polarization P_b=51% (Run I) and P_b=36% (Run II)*
- *beam helicity is reversed about monthly*
- *polarized and unpolarized internal gas targets: H, D, He, Ne, N, Kr, Xe*
- *GOOD lepton and hadron PID*
- *up/down symmetric*

Λ event topology, detection and kinematical variables

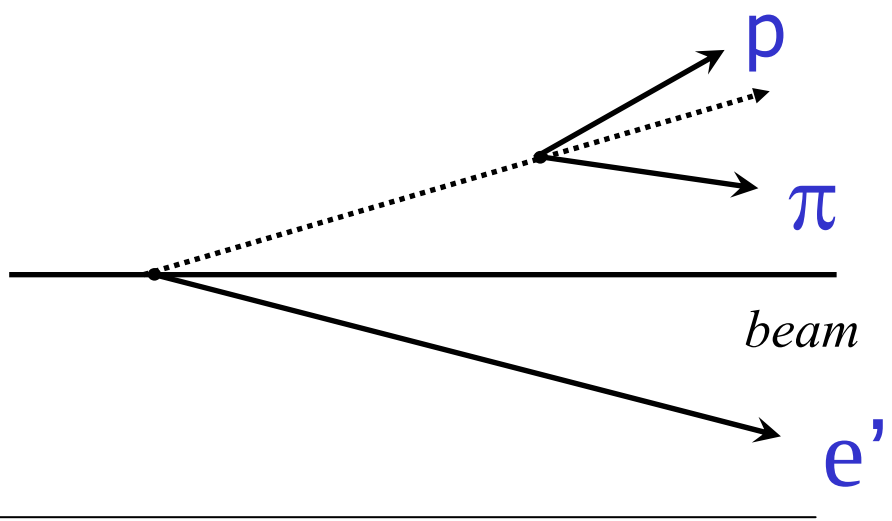
Under study

$e + p(d,A) \rightarrow e' + \Lambda(\bar{\Lambda}) + X$ *semi-inclusive DIS*

$e + p(d,A) \rightarrow \Lambda(\bar{\Lambda}) + X$ *inclusive* $\Lambda(\bar{\Lambda})$

$$\Lambda \rightarrow p + \pi^-$$

$$\bar{\Lambda} \rightarrow \bar{p} + \pi^+$$



always detected by HERMES spectrometer

detected ➡ *DIS regime:*

$Q^2 > 0.8\ GeV^2 \quad x, y, z, x_F$

not detected ➡ *Quasi-real photoproduction regime:*

$Q^2 < 0.05\ GeV^2$, *for 80% of events*

$$x = \frac{Q^2}{2M\nu},\ y = \frac{\nu}{E_e} = \frac{E_e - E_{e'}}{E_e},\ z = \frac{E_\Lambda}{\nu},\ x_F = \frac{\tilde{p}_{\|}^{\Lambda}}{\tilde{p}_{\max}^{\Lambda}}$$

SIDIS variables (lab. frame)

$$t_{\Lambda p}^2 = -(p_\Lambda - p_N)^2,\ \zeta = \frac{E_\Lambda + p_{\Lambda z}}{E_e + p_e},\ p_{\Lambda T}$$

Λ polarization measurement

Λ^0 polarization is "self analyzing" due to its parity violation decay:

$$\Lambda^0 \rightarrow p + \pi^-$$

$$\frac{dN}{d\Omega_p} = \frac{dN_0}{d\Omega_p}(1 + \alpha P^{\Lambda}_{L'} \cos\theta_{pL'})$$

$\alpha = 0.642$ **for** Λ $(\alpha = -0.642$ **for** $\bar{\Lambda})$

$L' \rightarrow \Lambda$ *spin direction*

Longitudinal spin transfer from beam/target

$$P^{\Lambda}_{L'} = P^{\gamma^*}_{L} \cdot D^{\Lambda}_{LL'} \qquad P^{\Lambda}_{L'} = P_{L,t} \cdot K^{\Lambda}_{LL'}$$

$$P^{\gamma^*}_{L} = P_b D(y)$$

Maximum likelihood method

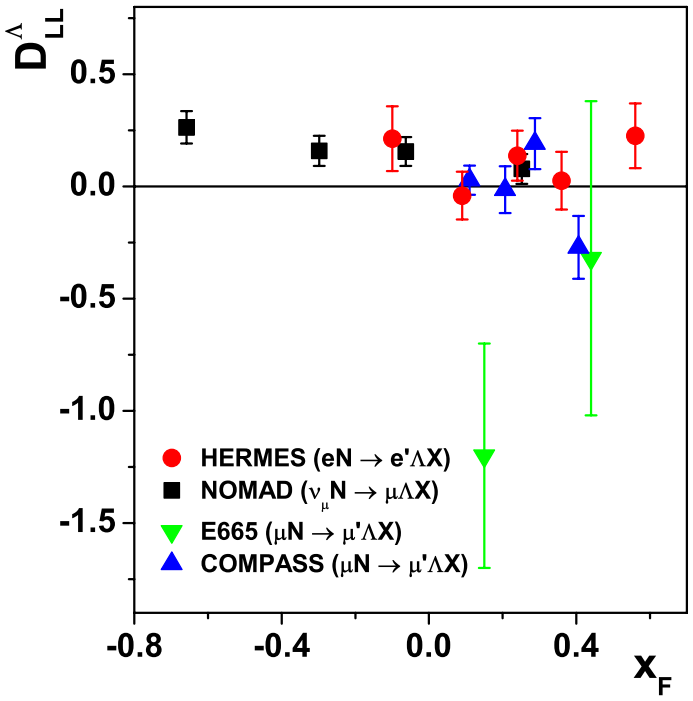
Helicity balanced data sample ⇒

$$D_{LL'} = \frac{\sum_{i=1}^{N} P_{b,i} D(y_i) \cos\theta^i_{pL'}}{\alpha \| P_b^2 \| \sum_{i=1}^{N} D^2(y_i) \cos^2\theta^i_{pL'}}$$

$$K^{\Lambda}_{LL'} = \frac{\sum_{i=1}^{N} P_{t,i} \cos\theta^i_{pL'}}{\alpha \| P_t^2 \| \sum_{i=1}^{N} \cos^2\theta^i_{pL'}}$$

Systematic error determination: false polarization is studied using h^+h^- pairs and K_s data sample
It must be $D_{LL}(h^+h^-) \Rightarrow 0, \quad D_{LL}(K_s) \Rightarrow 0$

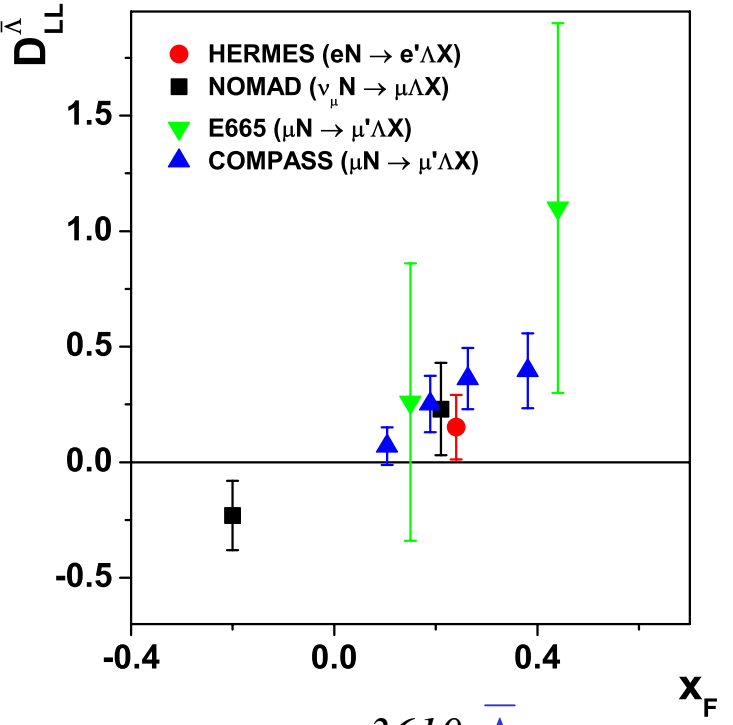
HERMES and world results: $D_{LL'}(x_F)$



26714 Λ's

$D_{LL'} = 0.102 \pm 0.056_{stat.} \pm 0.03_{syst.}$

(1996-2005)



3610 $\bar{\Lambda}$

$D_{LL'} = 0.152 \pm 0.139_{stat.} \pm 0.03_{syst.}$

(1996-2005)

A. Airapetian et al., Phys.Rev.D74:072004,2006. (7300 Λ's)

Spin transfer $K_{LL'}$ from longitudinally polarized target to Λ hyperon

$$\gamma + \vec{p}(\vec{n}) \rightarrow \vec{\Lambda} + X \quad \text{at} \langle E_\gamma \rangle = 15,6 \text{ GeV}$$

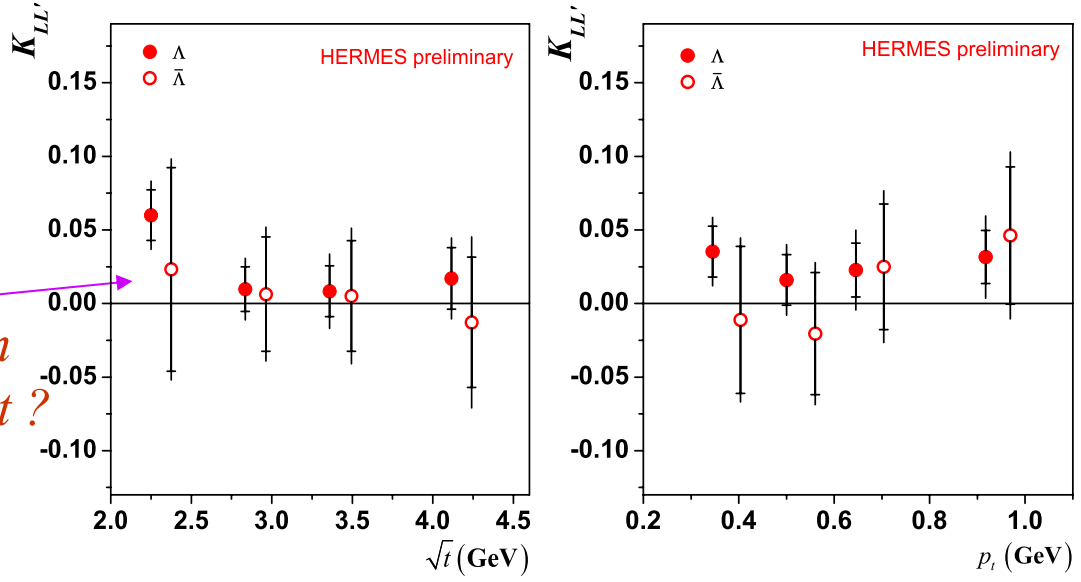
(lepton is not detected)

for 80% of events $Q^2 < 0.05\ GeV^2$

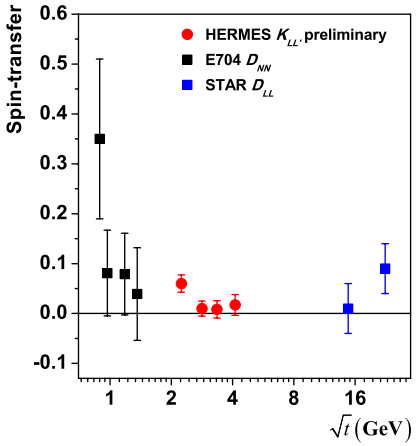
$K_{LL'} = 0.024 \pm 0.008_{stat.} \pm 0.003_{syst.}$ *for* Λ

$K_{LL'} = 0.002 \pm 0.019_{stat.} \pm 0.003_{syst.}$ *for* $\bar{\Lambda}$

di-quark polarization in the target ?



World data



FNAL, E704
pp collisions with transversely polarized beam
Phys. Rev. Lett., 78:4003–4006, 1997.

RICH, STAR
pp collisions with longitudinally polarized beam.
hep-ex/0612035

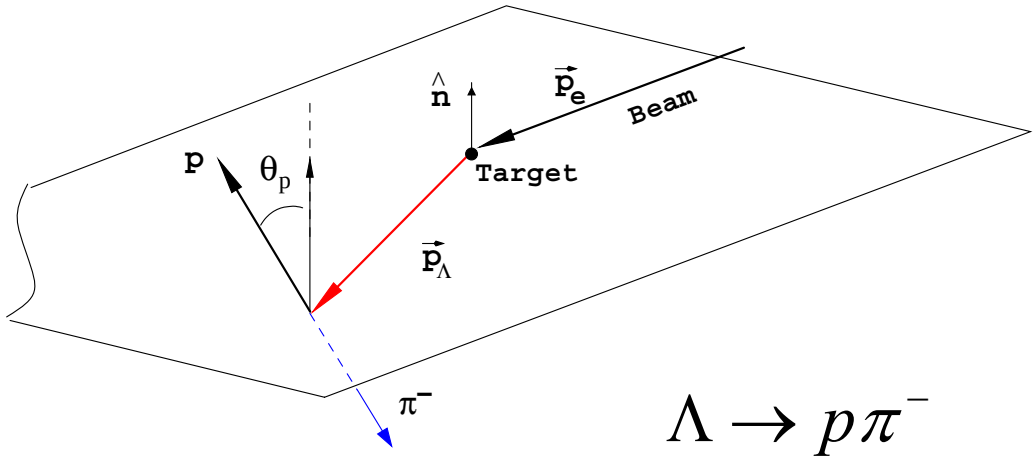
Transverse Λ polarization

Quasi-real photoproduction: $e + N \Rightarrow \Lambda\uparrow + X$ *at 27.6 GeV*

Transverse Λ polarization is directed along $\hat{n}$

(neither beam nor target is polarized)

$$\vec{P}_\Lambda = P_\Lambda \cdot \hat{n}, \quad \hat{n} = \frac{\vec{p}_e \times \vec{p}_\Lambda}{|\vec{p}_e \times \vec{p}_\Lambda|}$$



Formalism of Λ polarization extraction is based on up/down mirror (geometrical) symmetry of the detector :

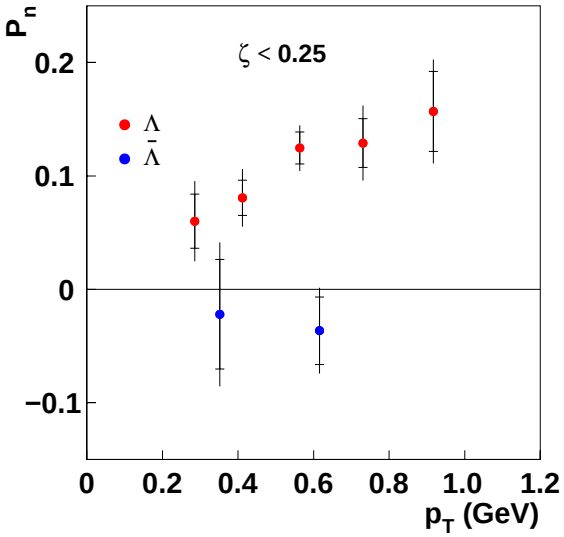
$$< \cos\theta >_0^{up} = - < \cos\theta >_0^{down}$$

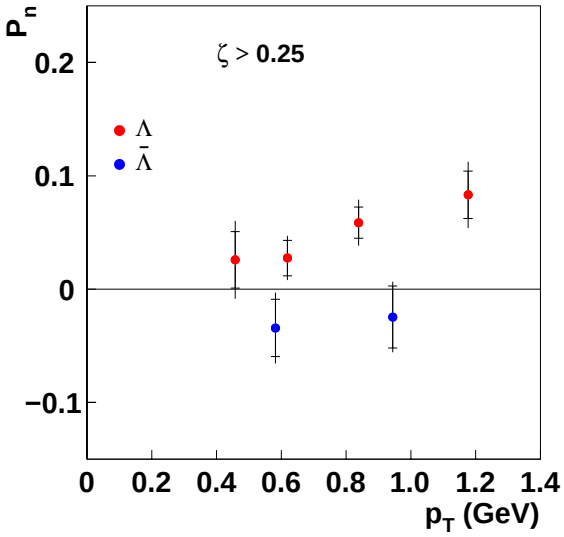
$$\Lambda \rightarrow p\pi^-$$

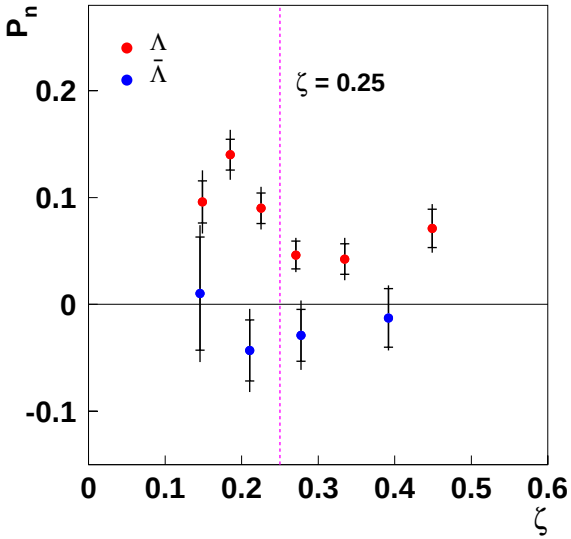
$$P_\Lambda = \frac{<\cos\theta_p>}{\alpha <\cos^2\theta_p>} = \frac{\frac{1}{N_\Lambda}\sum_{i=1}^{N_\Lambda}\cos\theta_p}{\alpha\frac{1}{N_\Lambda}\sum_{i=1}^{N_\Lambda}\cos^2\theta_p}$$

(to a first approx.)

Kinematical dependences of the transverse Λ polarization





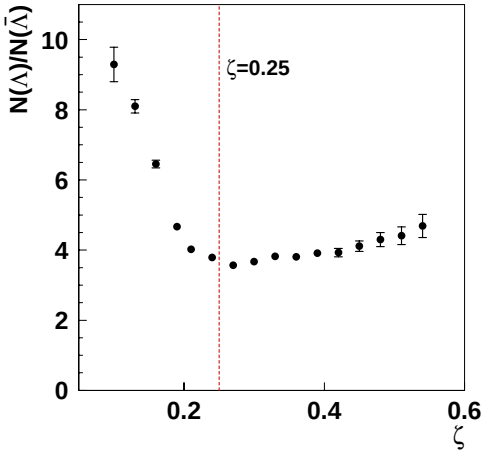


For Λ

$$P_{\Lambda} = 0.078 \pm 0.006_{stat.} \pm 0.012_{syst.}$$

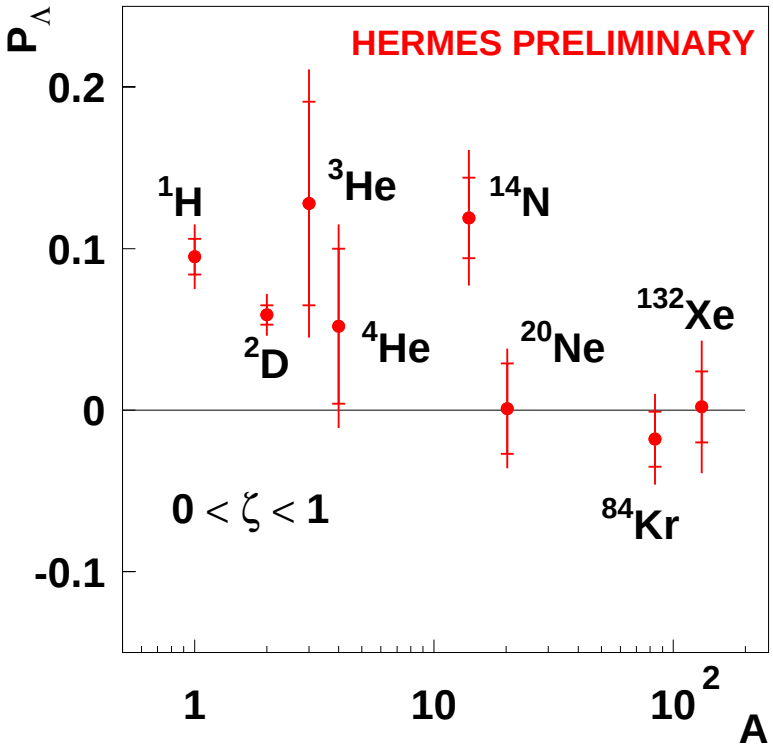
For $\overline{\Lambda}$

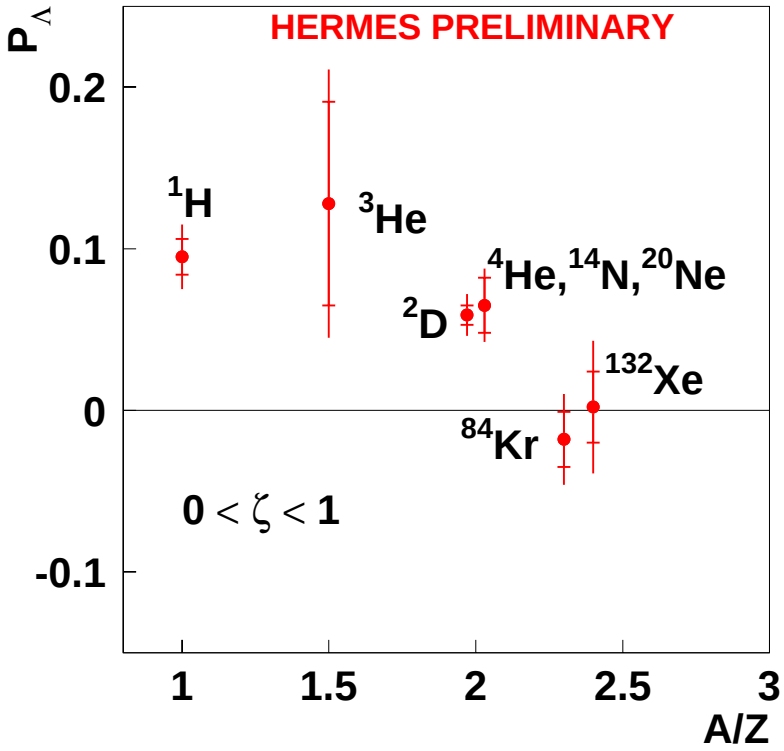
$$P_{\overline{\Lambda}} = -0.025 \pm 0.015_{stat.} \pm 0.018_{syst.}$$



A. Airapetian et al., Phys.Rev.D76:092008,2007

Nuclear effects: A, A/Z-dependence of Λ polarization





Conclusion

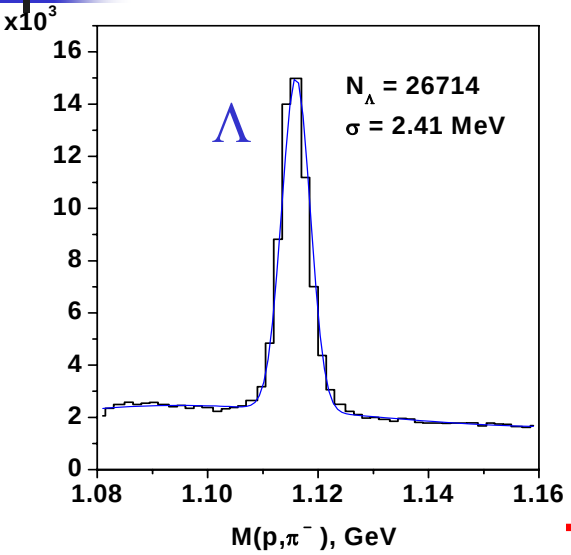
- *Update of longitudinal spin transfer from beam in semi-inclusive DIS ($Q^2 > 0.8$ GeV^2) for Λ* $D_{LL'} = 0.102 \pm 0.056_{stat.} \pm 0.03_{syst.}$
  Measurement of $D_{LL'}$ for $\bar{\Lambda}$ in DIS $D_{LL'} = 0.152 \pm 0.139_{stat.} \pm 0.03_{syst.}$

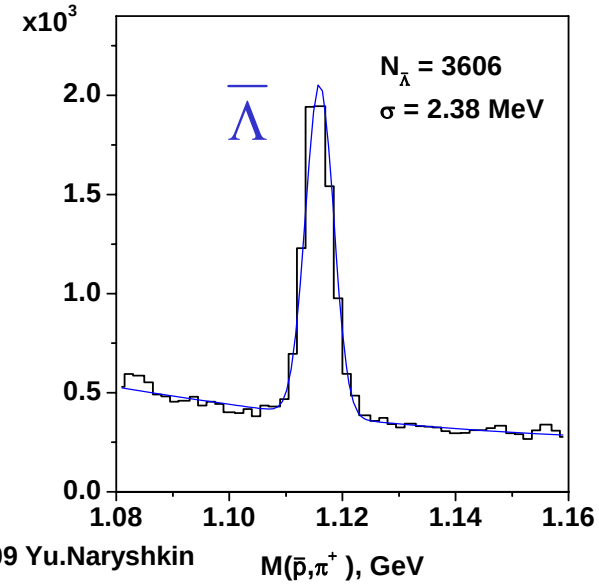
- *First measurement of longitudinal spin transfer from the target in quasi-real photoproduction regime ($Q^2 \sim 0$ GeV^2)*
  for Λ $K_{LL'} = 0.024 \pm 0.008_{stat.} \pm 0.003_{syst.}$ *and*
  for $\bar{\Lambda}$ $K_{LL'} = 0.002 \pm 0.019_{stat.} \pm 0.003_{syst.}$

- *Reliable observation of transverse polarization in quasi-real photoproduction regime ($Q^2 \sim 0$)*
  for Λ $P_n = 0.078 \pm 0.006_{stat.} \pm 0.012_{syst.}$
  and $\bar{\Lambda}$ $P_n = -0.025 \pm 0.015_{stat.} \pm 0.018_{syst.}$
  For Λ in quasi-real photoproduction regime, both $K_{LL'}$ and P_n increase at small ς(or t) showing a possible contribution from di-quark mechanism

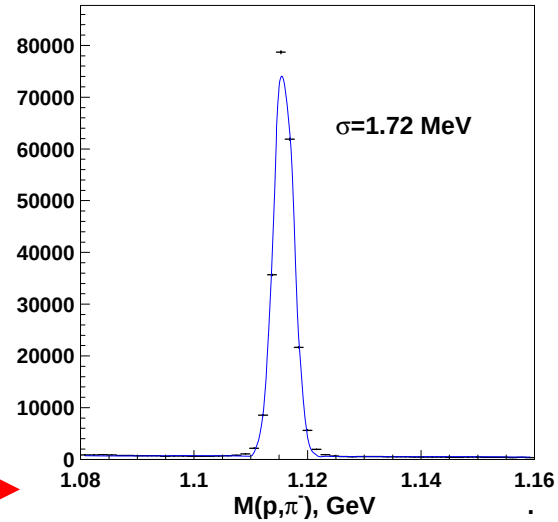
- *There is an indication of A (A/Z) - dependence of Pn. For heavy nuclei P_n is compatible with zero*

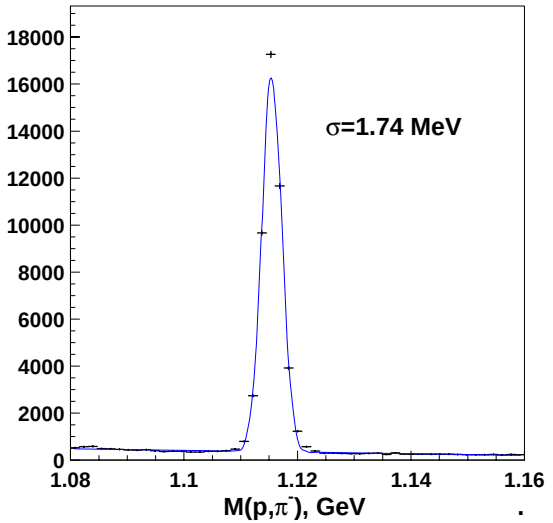
Detection of $\Lambda(\bar{\Lambda})$ by HERMES spectrometer



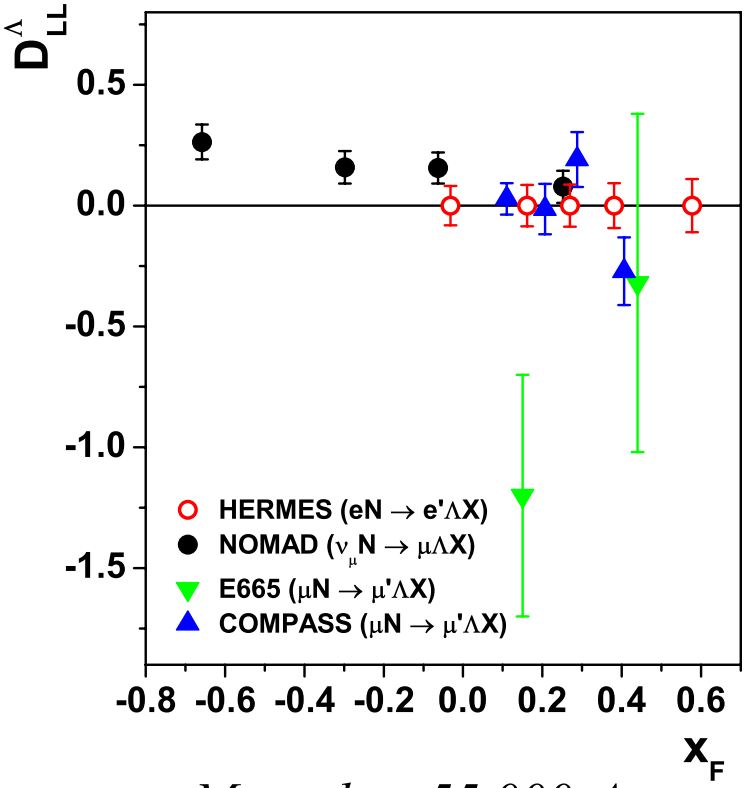


After upgrade of the reconstruction program

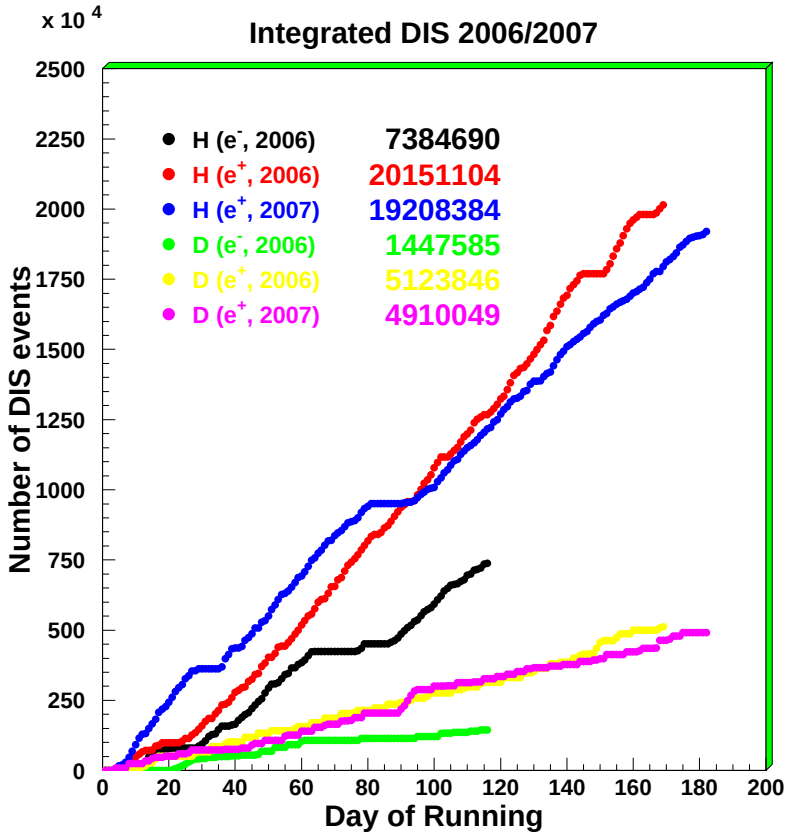




HERMES statistics 2006-2007



More then 55,000 Λs projected (1996-2007)



Outlook

- *Analyze data collected in 2006-2007 years to substantially reduce statistical error uncertainties for measured polarization observables.*
- *3d reconstruction of D_{LL} (is Λ polarization vector directed along γ momentum, Λ momentum, … ?).*
- *Spin transfer K_{NN} from transversely polarized target to Λ hyperon in photoproduction.*
- *Spin effects in Σ, Ξ photoproduction.*
- *Λ polarization at $x_F < 0$ (with Recoil detector).*
- *Exclusive Λ production $\gamma^* + p \to \Lambda K^+$ (with Recoil detector).*
- *……*

Backup slides

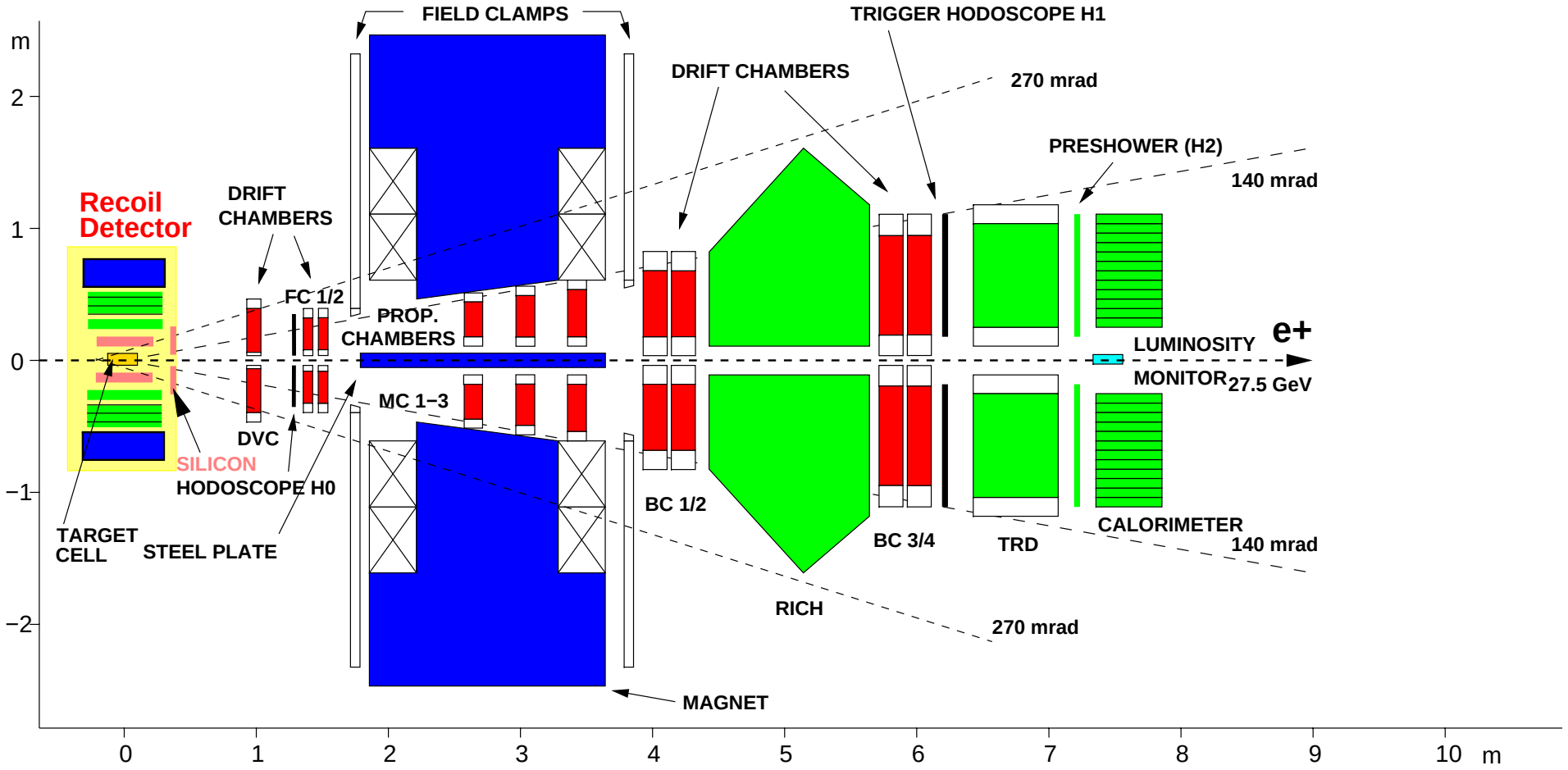
New reconstruction code Hermes Tracking Code

Kalman filter based tracking procedure
(instead of lookup table usage)

Taken into account:

- *Magnetic field in the target region for decaying particles*
- *Multiple scattering on the spectrometer material*

HERMES detector with Recoil Detector



Event selection

- *HERA Run I: polarized and unpolarized targets*
- *HERA Run II: only unpolarized targets, no 2006-07 years data*
- *$-18 < z_1 < 25$ cm*
- *$d_2 < 1.5$ cm*
- *$-18 < z_2 < 130$ cm*
- *$1 < dd_2 < 18$ cm*
- *$p_\pi > 0.4$ GeV*
- *Leading particle is not a pion according to Cherenkov and RICH PID*
- *$z_2 - z_1 > 15$ cm*