HERMES and OLYMPUS experiments

STUDY OF NUCLEON (HADRON) STRUCTURE USING ELECTRON BEAMS AT DESY

HERMES data taking period 1995-2007 , data analysis
OLYMPUS data taking 2012, data analysis

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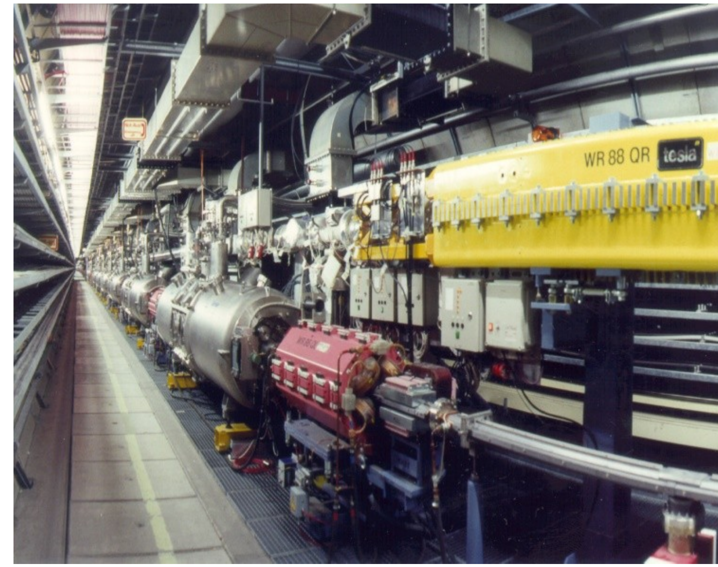
Main motivation: “spin crisis”

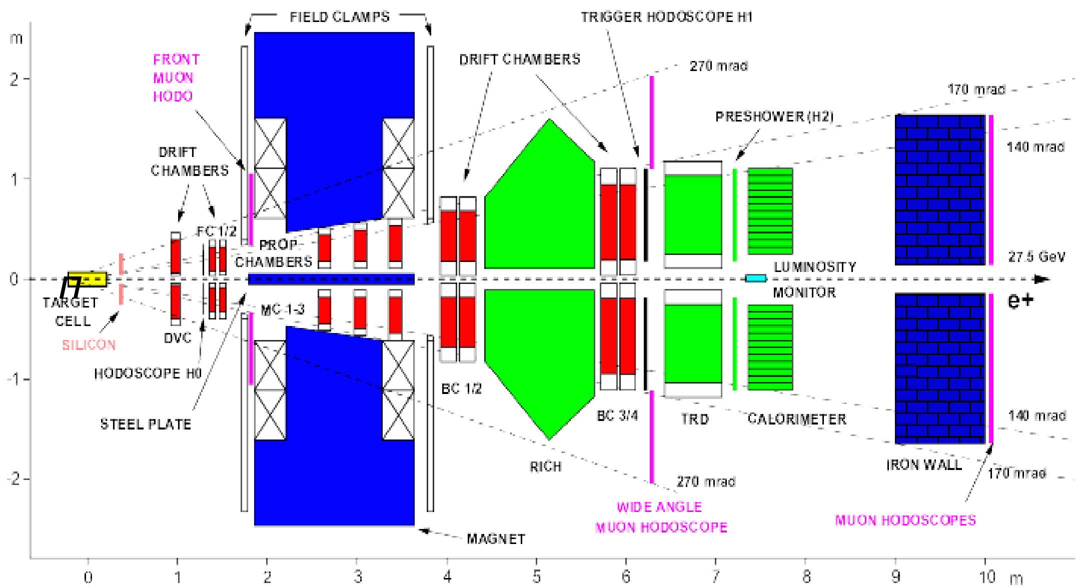
П

HERA RING

P_{beam} ~ 50%



Впервые реализована идея само-поляризации пучка электронов в магнитном поле ускорителя:



HERMES most important contributions to nucleon spin structure

- **Quark spin from DIS inclusive $\Delta\Sigma = 0.33 \pm 002_{exp} \pm 0.03_{model}$**
- **Quark spin from DIS semi-inclusive $\Delta\Sigma = 0.36 \pm 003_{exp} \pm 0.02_{model}$**
- **Gluon polarization estimation $\Delta g/g = 0.05 \pm 003_{stat} \pm 0.01_{syst}$**
- **First measurements of Sivers DF and Collins FF**
- Detailed study of GPDs *not yet*
- Λ-hyperon polarization *fully*
- Spin-dependent exclusive vector meson production *published*

Current analysis. Electroproduction of vector mesons

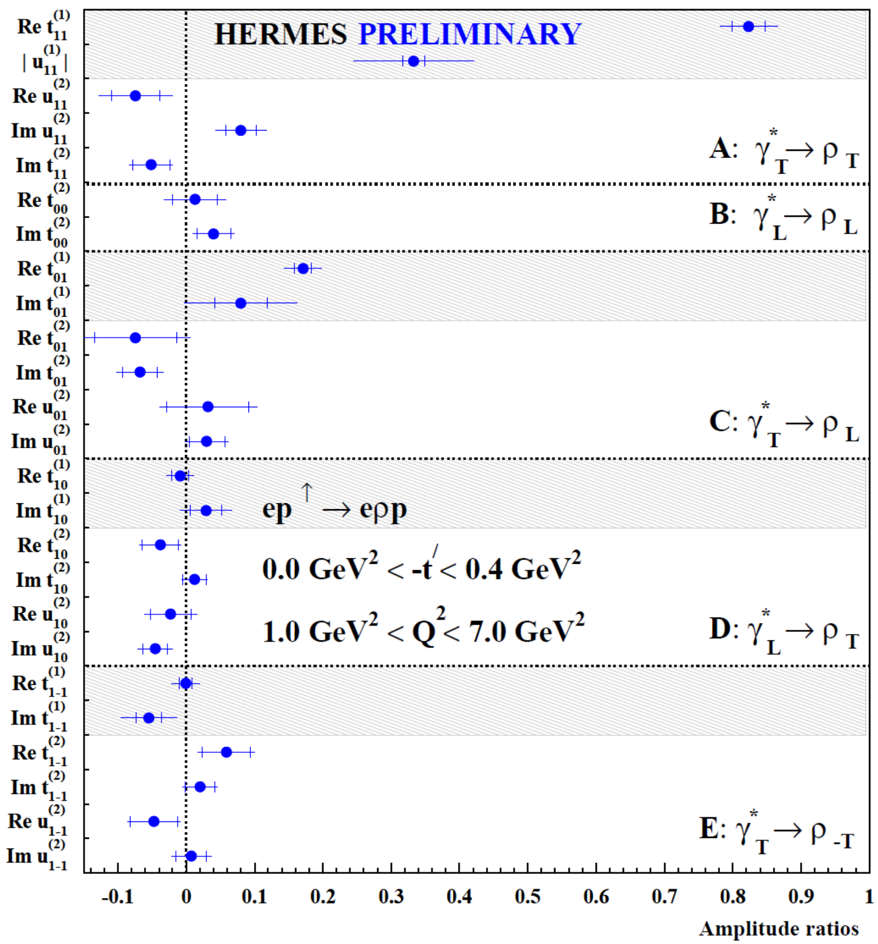
Сергей М.

$$\vec{\gamma}^{*} + \vec{\mathbf{N}} \rightarrow \vec{\mathbf{V}}(\rho, \varphi, \omega) + \mathbf{N}'$$

$$\{3 \times 3\}_{\gamma} \times \{2 \times 2\}_{\mathbf{N}} \Rightarrow \{3 \times 3\}_{\mathbf{V}} \times \{2 \times 2\}_{\mathbf{N}'}$$

V-meson SDM

измеряется



Spin transfer from polarized beam to Λ in DIS

$D_{LL'} = 0.11 \pm 0.10_{stat} \pm 0.03_{syst}$ 8200 Λ *PRD 2006*

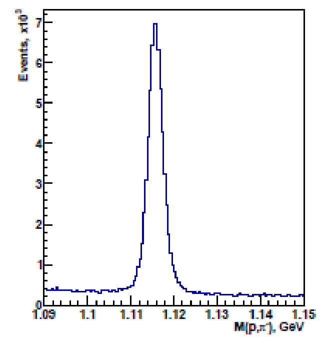
$D_{LZ} = 0.06 \pm 0.03_{stat} \pm 0.02_{syst}$ 61320 Λ

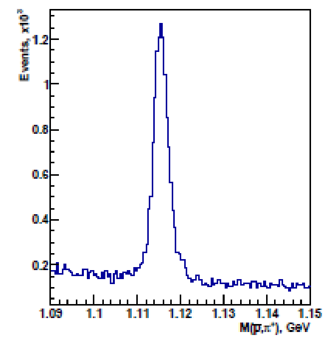
$D_{LX} = -0.02 \pm 0.04_{stat} \pm 0.03_{syst}$

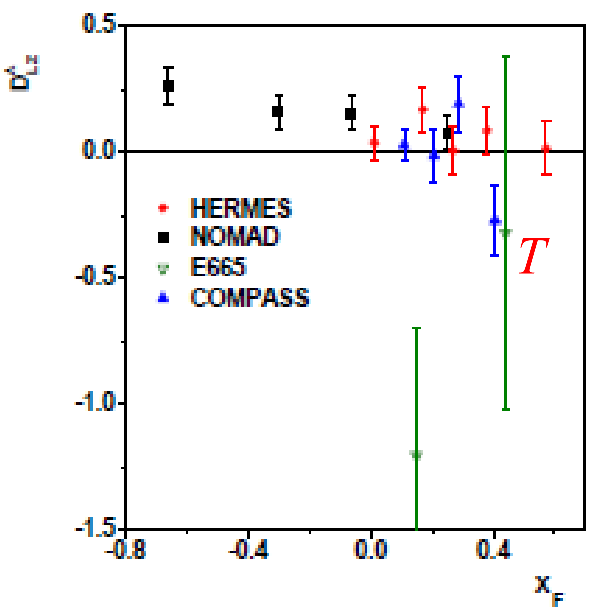
$\bar{\Lambda}$

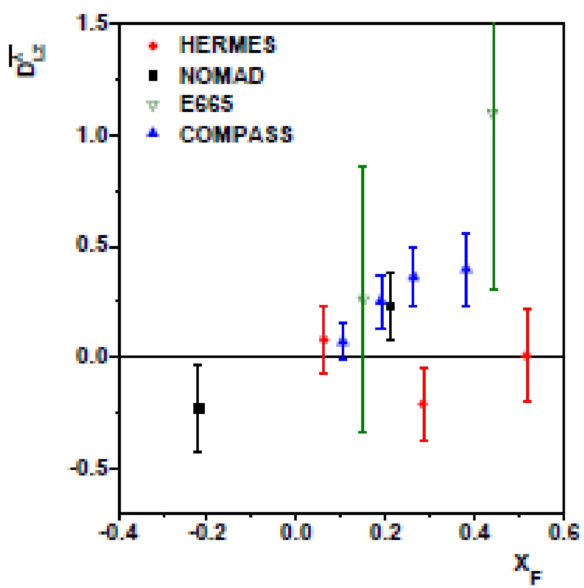
$D_{LZ} = -0.04 \pm 0.07_{stat} \pm 0.02_{syst}$ 8700

$D_{LX} = 0.04 \pm 0.10_{stat} \pm 0.03_{syst}$

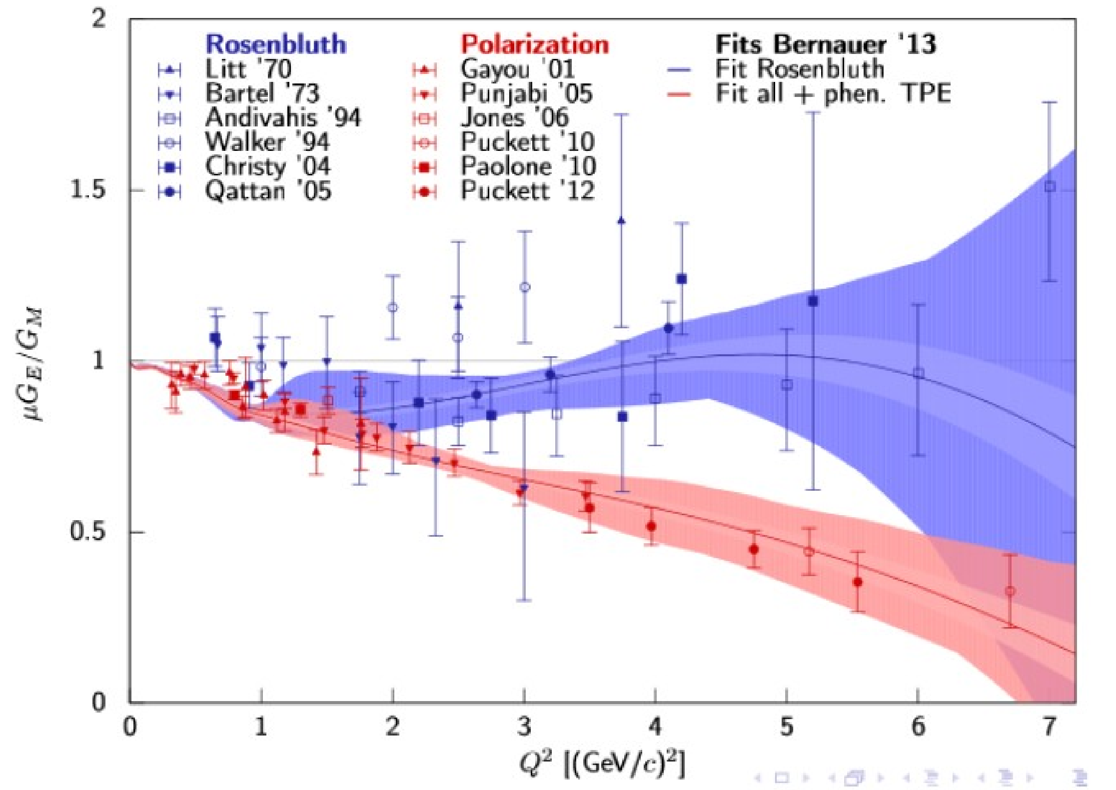


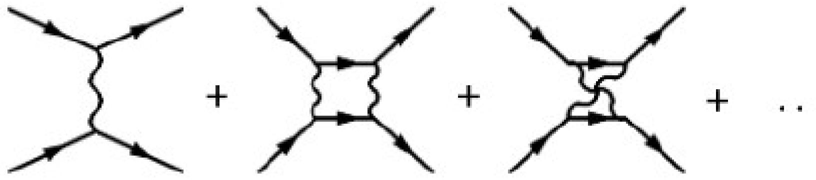




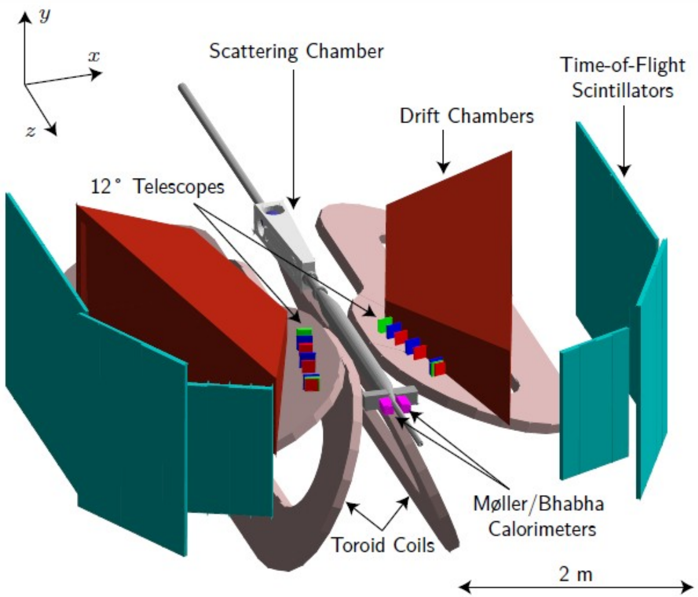


OLYMPUS. Proton form factor puzzle and TPE

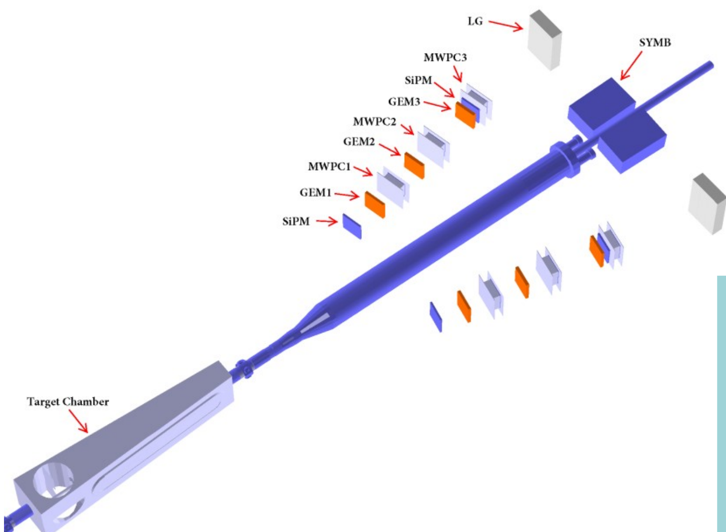




$$\frac{e^+ p}{e^- p} = 1 + \color{red}{TPE} + ..$$



as conceived



PNPI
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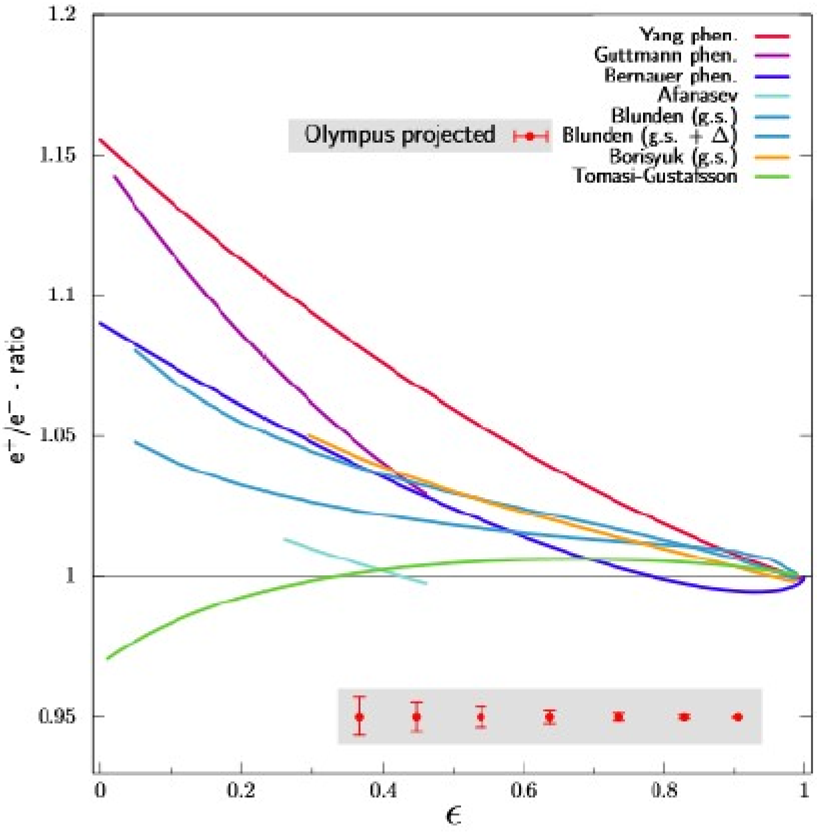
(0.16

Statistical uncertainty

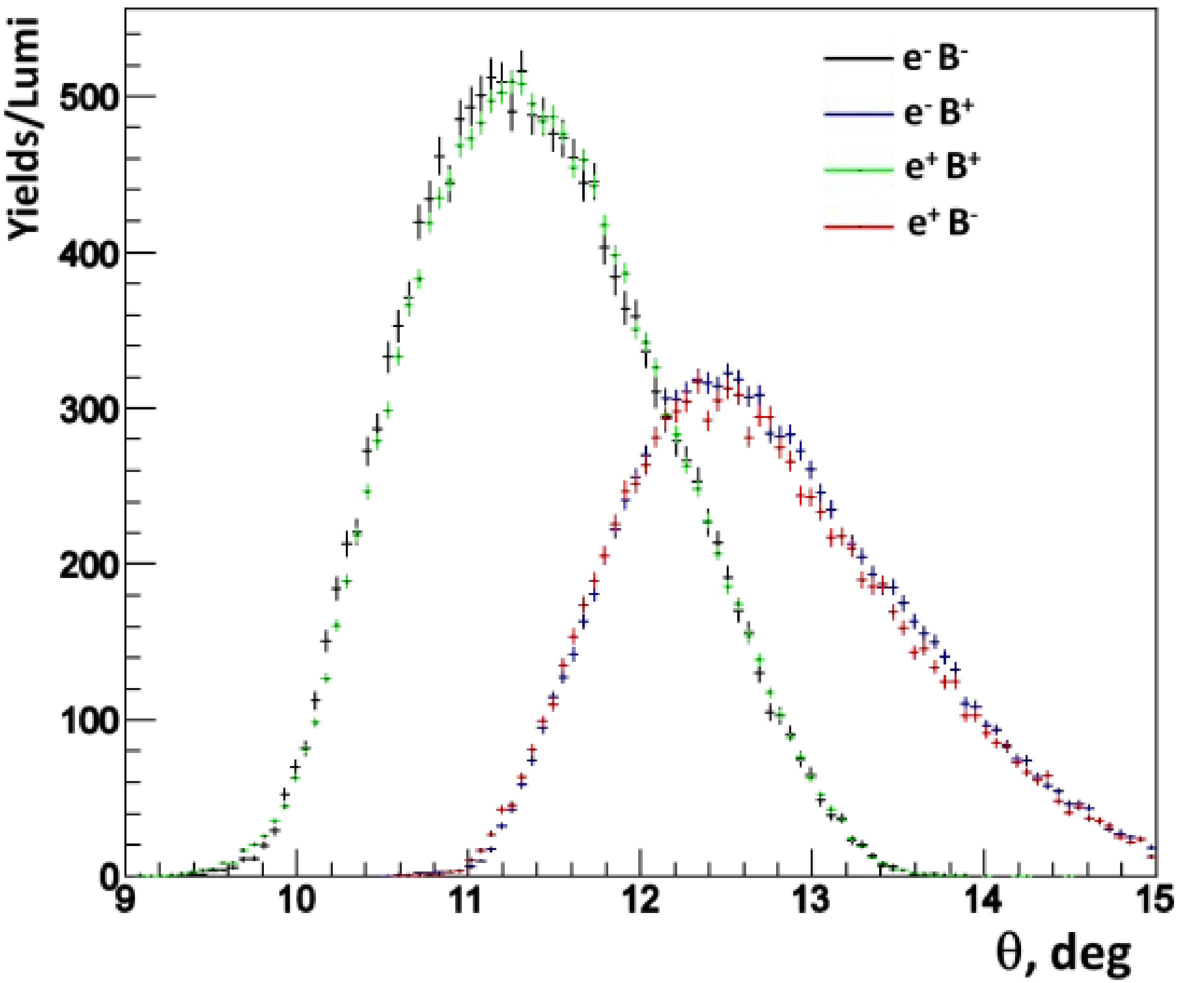
as realized

A



Data analysis. Double ratio, control measurement, large Q^2 …

1



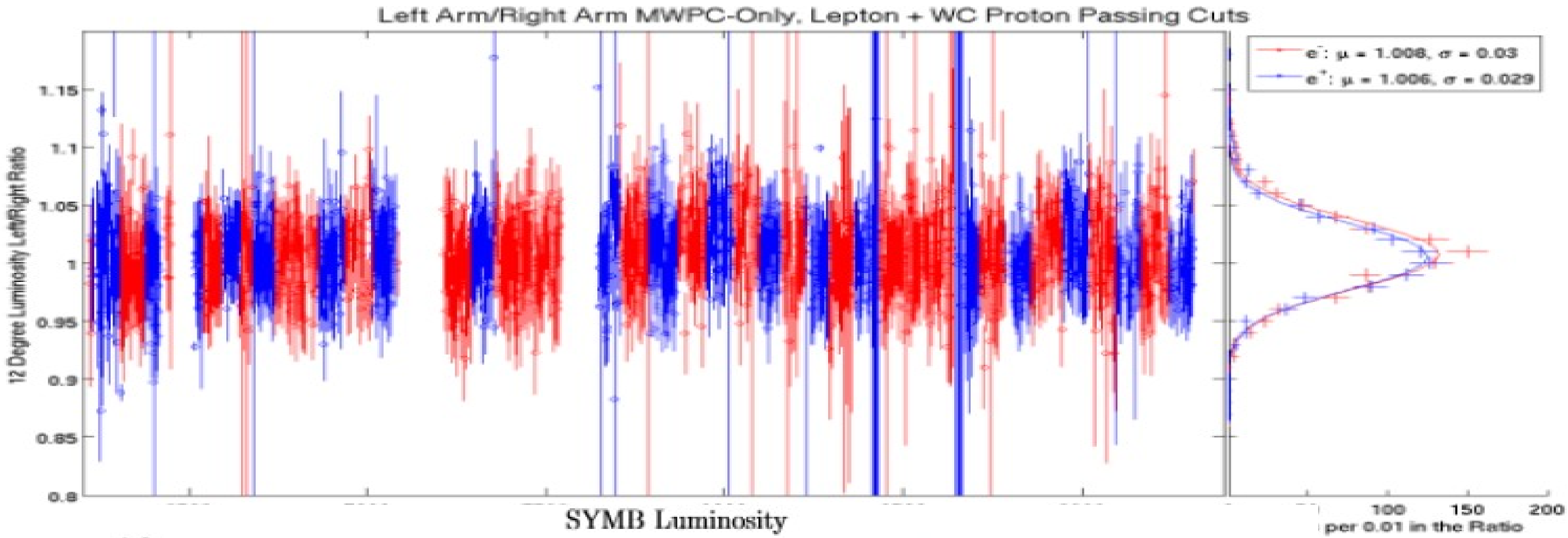
At large Q^2

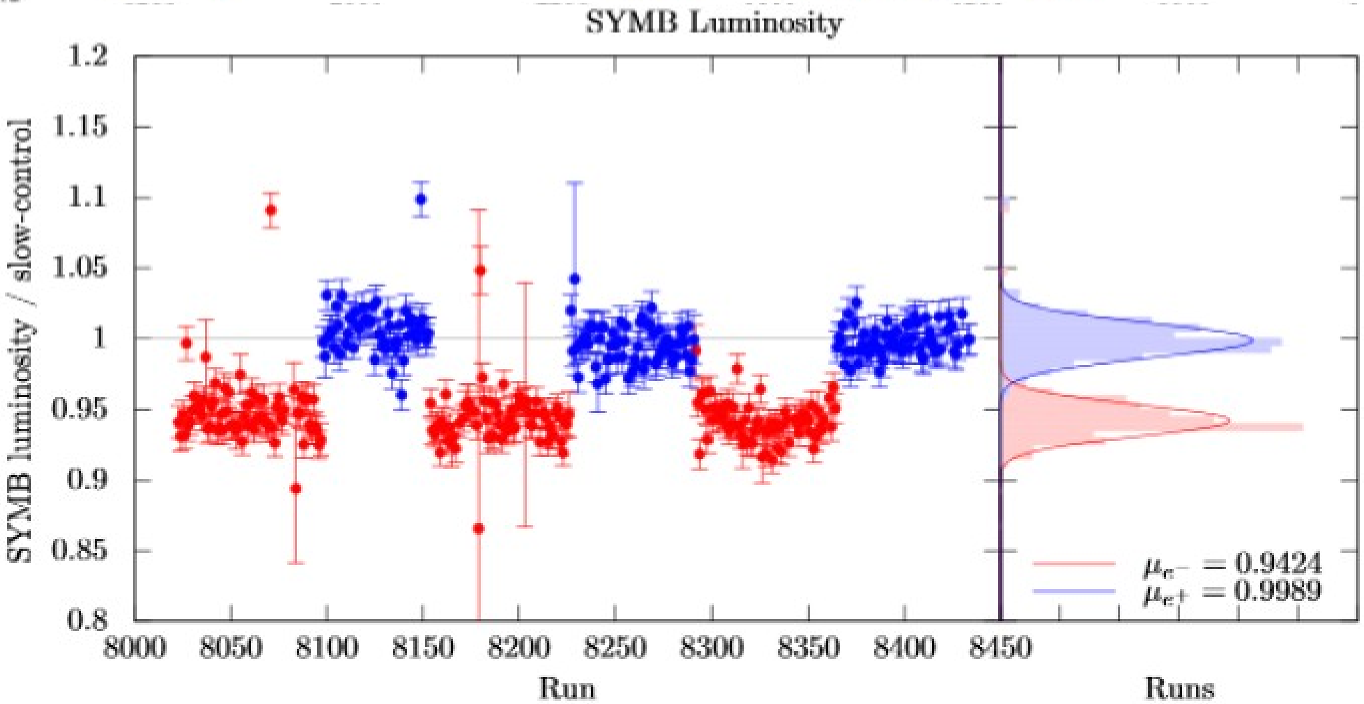
statistics is not sufficient for double ratio

→

intensive MC study of acceptance , efficiency…. tracking etc.

-


Left Arm/Right Arm MWPC-Only, Lepton + WC Proton Passing Cuts
12 Degree Luminosity Left/Right Ratio
e⁻: μ = 1.008, σ = 0.03
e⁺: μ = 1.006, σ = 0.029
per 0.01 in the Ratio


SYMB Luminosity
SYMB luminosity / slow-control
Run
Runs
$\mu_{e^-} = 0.9424$
$\mu_{e^+} = 0.9989$

The progress includes

- the analysis of 80% of the Olympus dataset;
- the achievement of good agreement between the luminosity measurement of the 12^{o} MWPC and the slow control luminosity;
- a further improvement of the calibration and the description of the TOF and tracking chambers;
- the achievement of reasonably good agreement for the MC–data comparison.

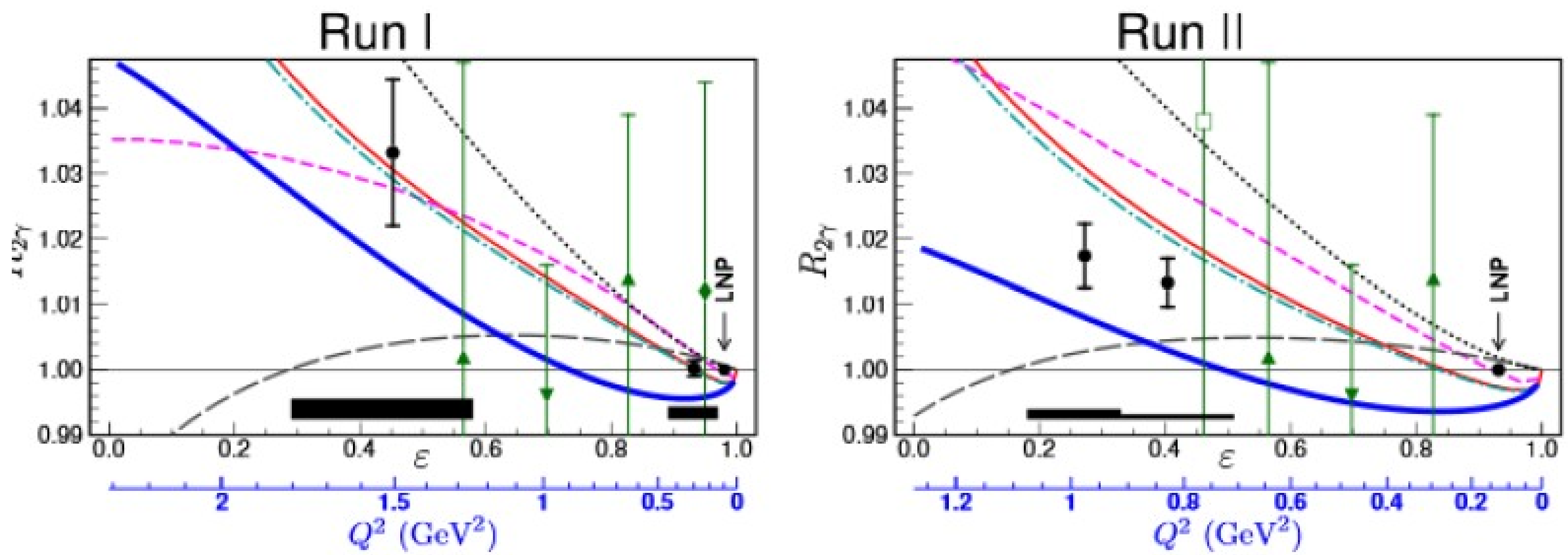
The PRC has still some remaining concerns:

- There is still no understanding why the symmetric Moeller/Bhabha detector does not provide the best luminosity measurement in the experiment. The PRC feels it is extremely important to clarify the reason for this mismatch.
- There is unfortunately not yet a detailed idea what type of systematic precision can be achieved at the end.

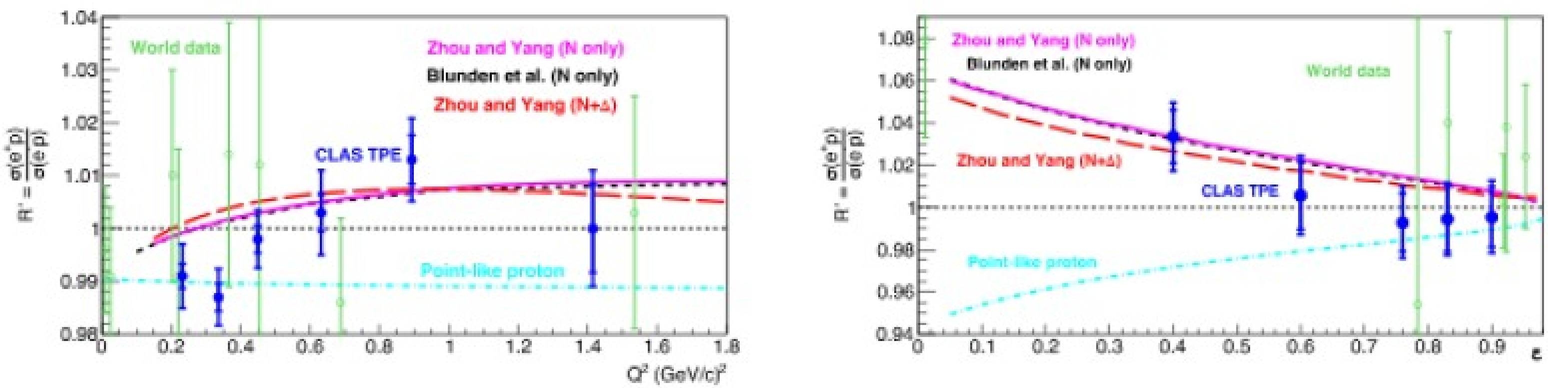
The PRC awaits with eagerness the first results.

BACKUP SLIDES

V

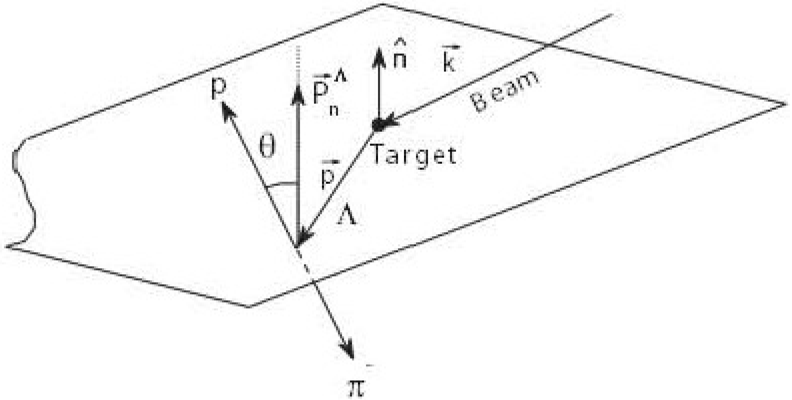

Run I
Run II
$R_{2\gamma}$
LNP
ε
Q^2 (GeV^2)

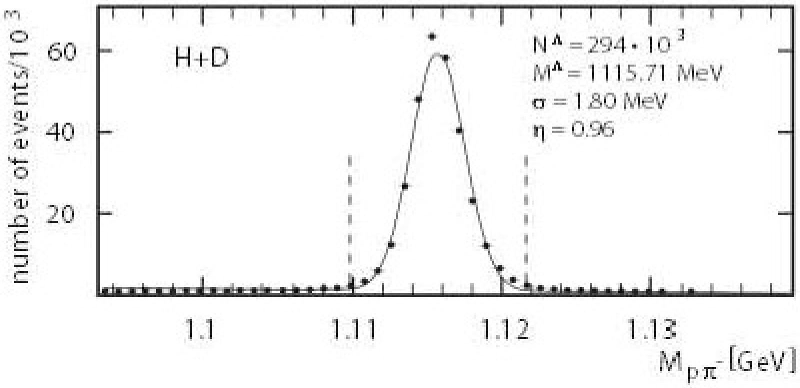
C

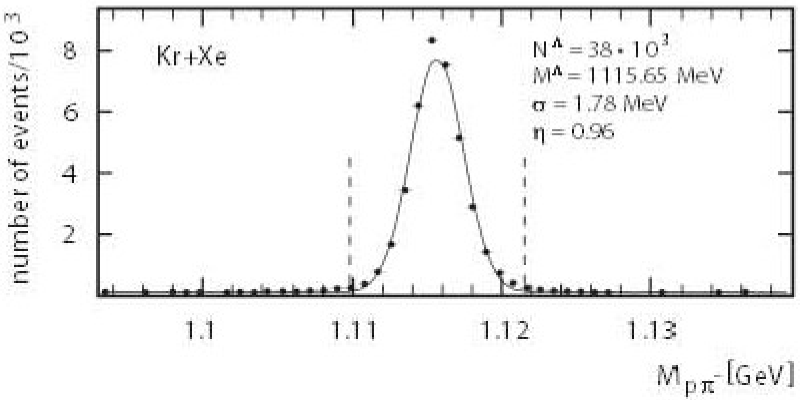

World data
Zhou and Yang (N only)
Blunden et al. (N only)
Zhou and Yang (N+Δ)
CLAS TPE
Point-like proton
R' = σ(e⁺p)/σ(e⁻p)
Q² (GeV/c)²
ε

$\tilde{\gamma} + A \to \Lambda(\bar{\Lambda}) + X$ at $Q^2 \approx 0$ quasireal photoproduction

$\Lambda \to p\pi^-$ $\bar{\Lambda} \to \bar{p}\pi^+$ weak decay $\frac{dN}{d\Omega_p} \sim 1 + \alpha P_\Lambda \cos\theta_p$







$$\widetilde{\frac{dN}{d\Omega_p}} \sim (1 + \alpha P_\Lambda \cos\theta_p) \otimes \text{acceptance function}$$

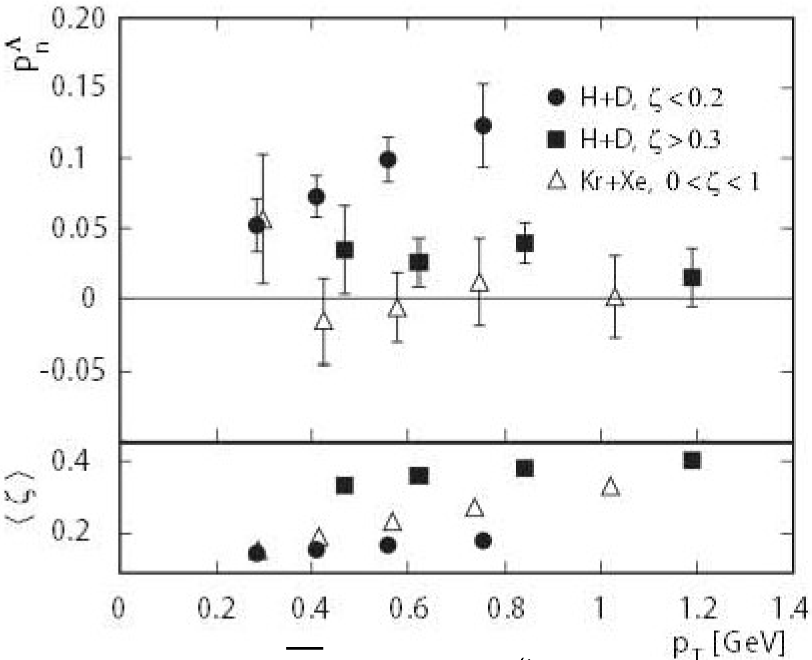
moment method $\Leftrightarrow$

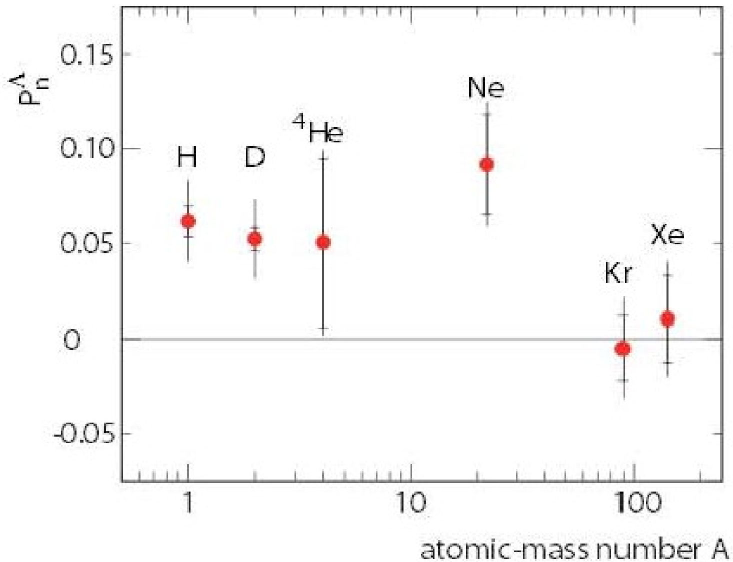
up/down detector mirror symmetry $\Rightarrow$

$$P_\Lambda = \frac{\langle \cos\theta_p \rangle}{\alpha \langle \cos\theta_p^2 \rangle}$$

$\alpha_\Lambda = 0.62$ $\alpha_{\bar{\Lambda}} = -0.62$

Ю.Н. С.Б. K.R.

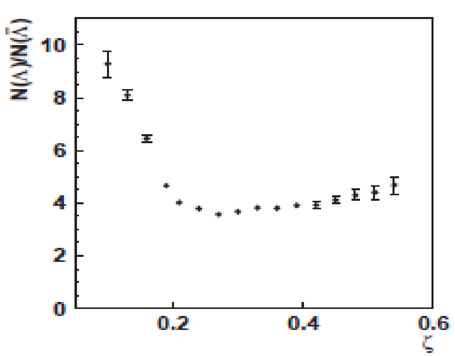




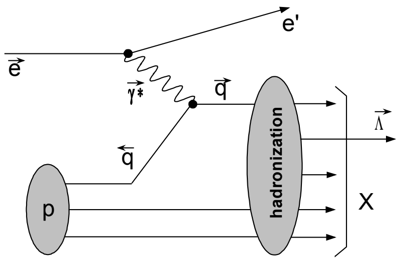
$P_\Lambda\,(H + D) = 0.056 \pm 0.005_{stat} \pm 0.02_{sys}$

$P_{\bar{\Lambda}} = 0.025 \pm 0.015_{stat} \pm 0.018_{sys}$

$\Lambda\ /\ \bar{\Lambda}$ ratio of ξ



- ❑P_Λ positive like in K^- Σ^- beam Λ production
- ❑Polarization $P_{\bar{\Lambda}} \approx 0$
- ❑Target and current fragmentation regimes
- ❑P_Λ drops down for heavy nucleus targets



$\vec{e} + p \rightarrow e' + \vec{\Lambda} + X \quad P_{\Lambda} \sim D^{\Lambda}_{LL'} \times P_{beam}$

Λ spin structure

Naïve CQM

$\Delta\Sigma = 1 \qquad \Delta u = \Delta d = \mathbf{0} \qquad \Delta s = \mathbf{1}$

$SU(3)_f$ S.B. using HERMES $\Delta\Sigma = 0.32$

$\Delta u = \Delta d = -0.16 \quad \Delta s = 0.64$

L

$$D^{\Lambda}_{LL}(x,z) = \sum_{f=u,d,s,\ldots} D^{\Lambda}_{LL,f}(z)\,\omega^{\Lambda}_{f}(x,z)$$

$$D^{\Lambda}_{LL,f}(z) = \frac{\Delta F^{\Lambda}_{f}}{F^{\Lambda}_{f}}$$ access to spin-fragmentaton f-n

partial spin transfer

$D^{\Lambda}_{LL,f}$ is strongly related to Λ spin structure

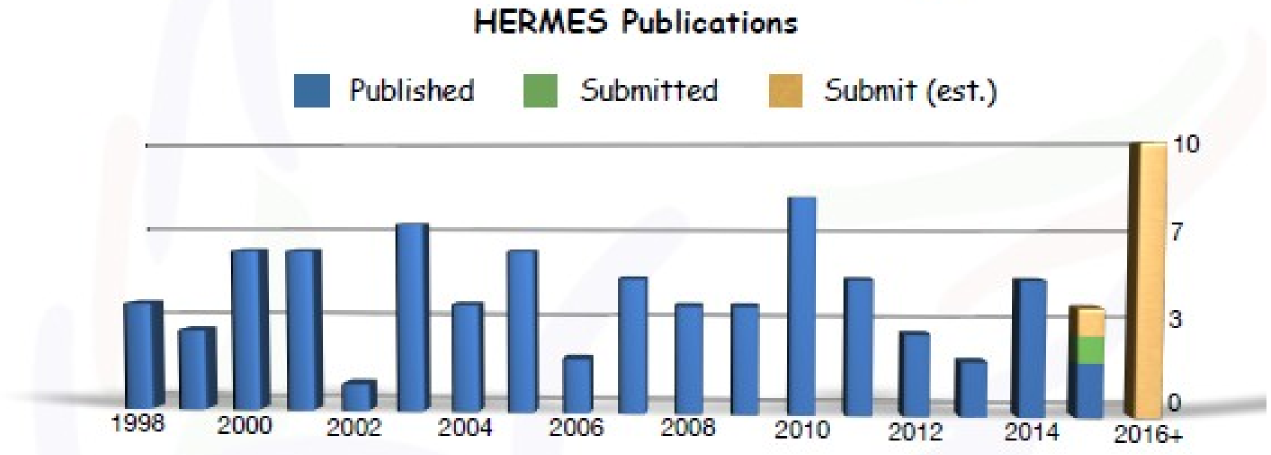
i.e, $D^{\Lambda}_{LL,f}$ is a measure of poorly known u,d-quark polarization in Λ

$$\frac{\Delta F^{\Lambda}_{u}}{F^{\Lambda}_{u}} \sim \Delta_u \qquad \frac{\Delta F^{\Lambda}_{s}}{F^{\Lambda}_{s}} \sim \Delta_s$$

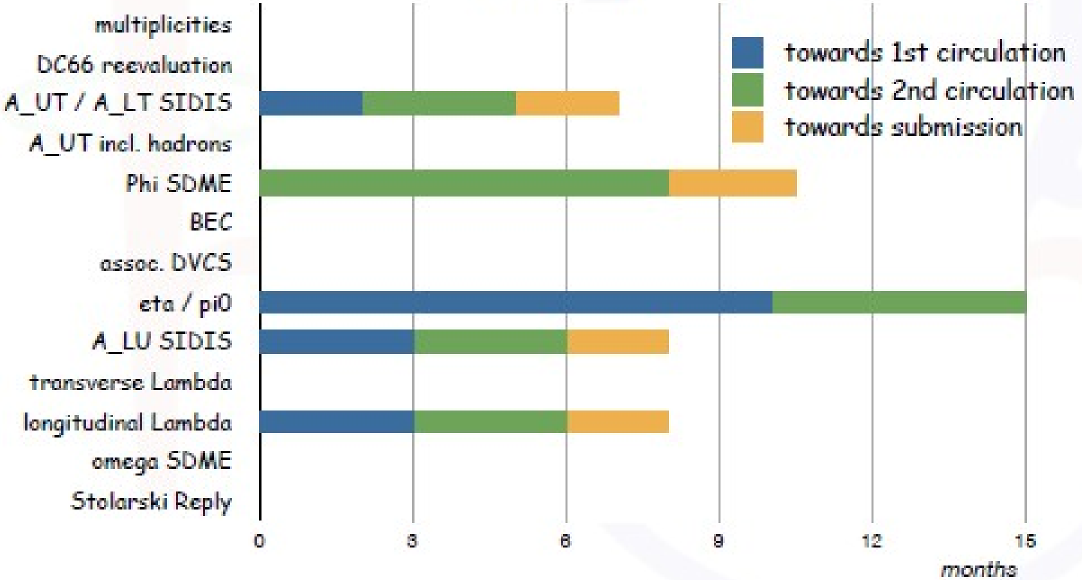
Expectation

$$D^{\Lambda}_{LL} \approx D^{\Lambda}_{LL,u} \leq 0$$

Publication statistics (Nov 2015)

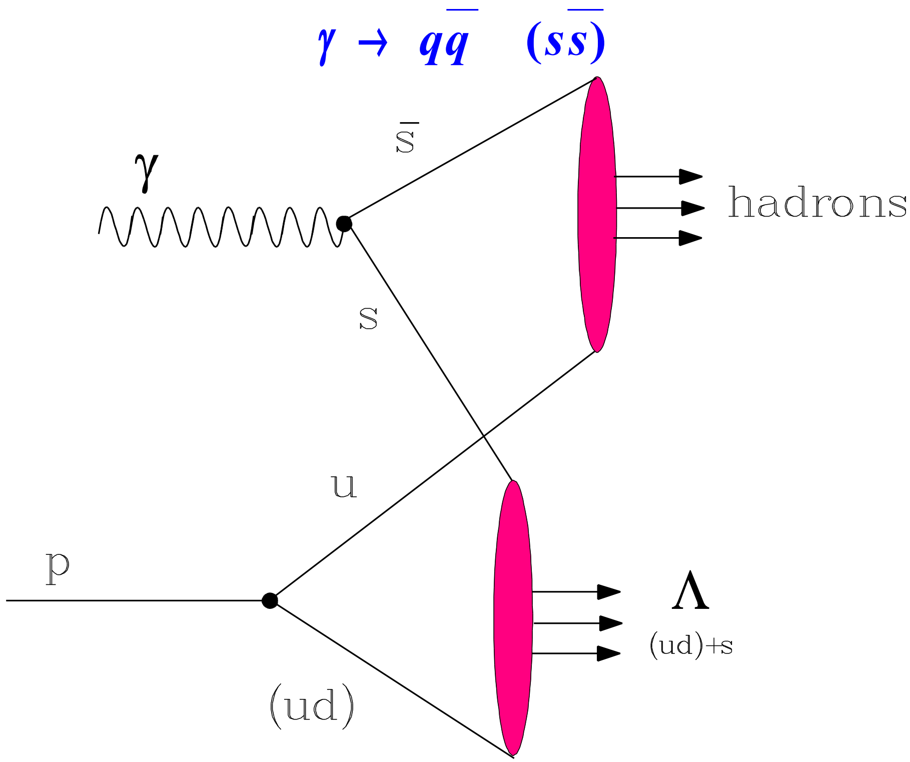


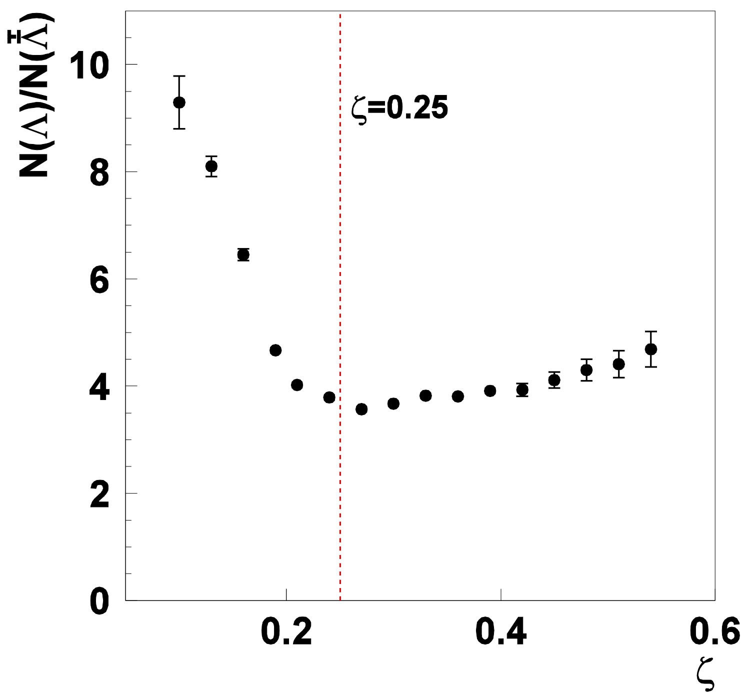
Publication schedule for **priority** analysis (Nov 2015)



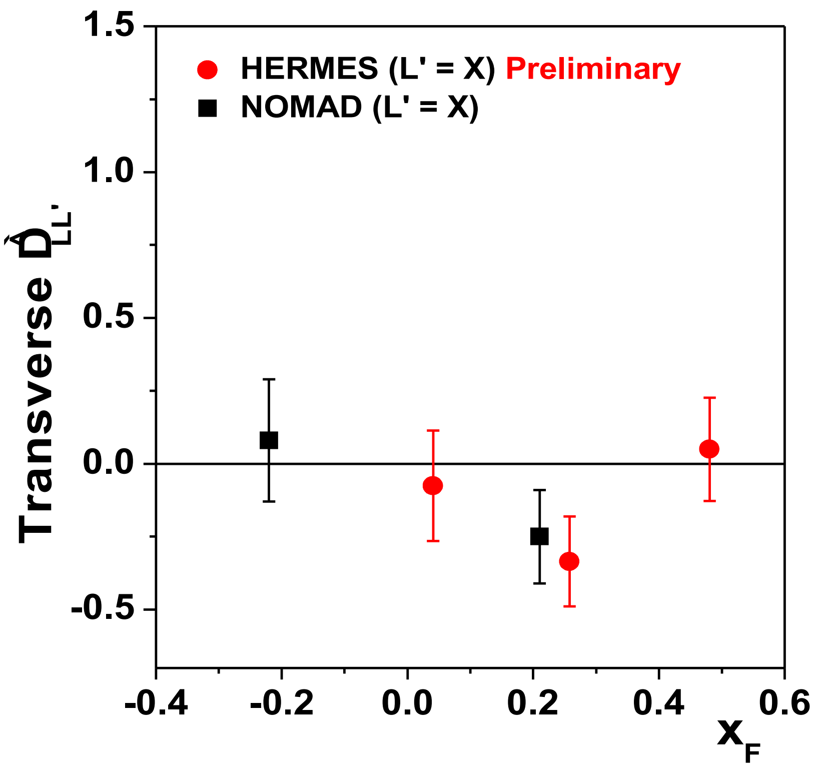
$$\langle E_\gamma \rangle = \langle E_e - E_{e'} \rangle \simeq 15.6\ GeV$$

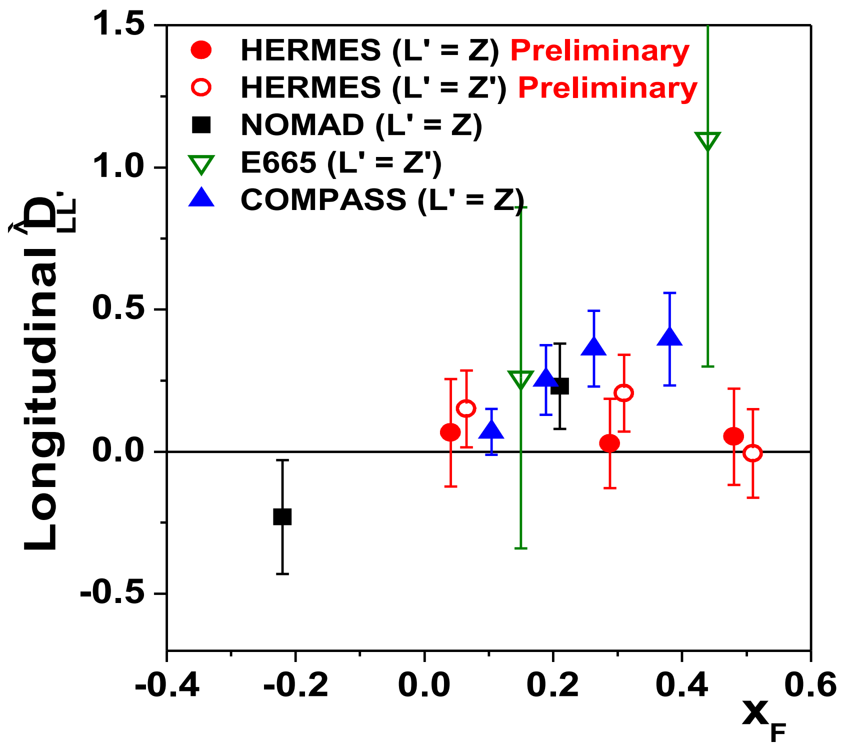
Λ to Λ̄ yield ratio





$$\zeta^{\Lambda} \simeq \frac{E^{\Lambda}}{E_e} < 0.25 \quad \sqrt{t} = 3.31\, GeV$$


1.5
1.0
0.5
0.0
-0.5
Transverse $\hat{D}_{LL'}$
HERMES (L' = X) Preliminary
NOMAD (L' = X)
-0.4
-0.2
0.0
0.2
0.4
0.6
x_F


1.5
1.0
0.5
0.0
-0.5
Longitudinal $\hat{D}_{LL'}$
HERMES (L' = Z) Preliminary
HERMES (L' = Z') Preliminary
NOMAD (L' = Z)
E665 (L' = Z')
COMPASS (L' = Z)
-0.4
-0.2
0.0
0.2
0.4
0.6
x_F

Λ and other hyperon spin structure still poorly established

SU(6) spin-1/2 hyperon octet

$\Delta\Sigma$=0.32 F=0.47 D=0.81

	Δu	Δd	Δs
p(uud)	0.84	-0.43	-0.09
n(udd)	-0.43	0.84	-0.09
Λ(uds)	-0.16	-0.16	0.64
Σ^+(uus)	0.84	-0.09	-0.43
Σ^0(uds)	0.375	0.375	-0.43
Σ^-(dds)	-0.09	0.84	-0.43
Ξ^0(uss)	-0.43	-0.09	0.84
Ξ^-(dss)	-0.09	-0.43	0.84

Λ spin structure

Jaffe assumption (Δs_{proton}=0)

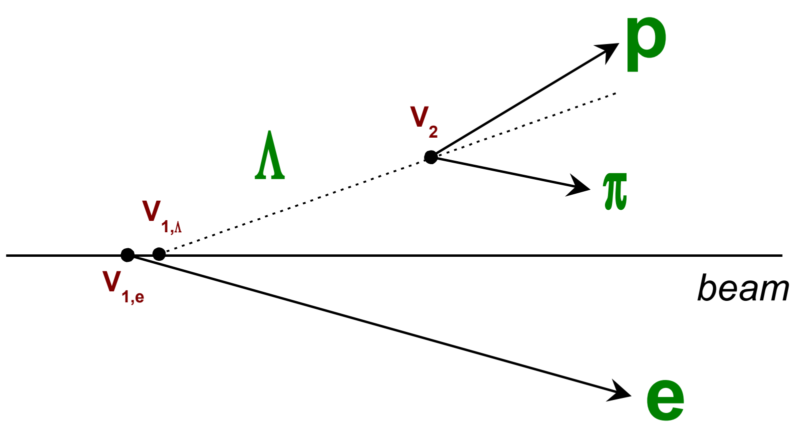
$\Delta\Sigma$=**0.586** Δu=Δd= **-0.073** Δs= **0.732**

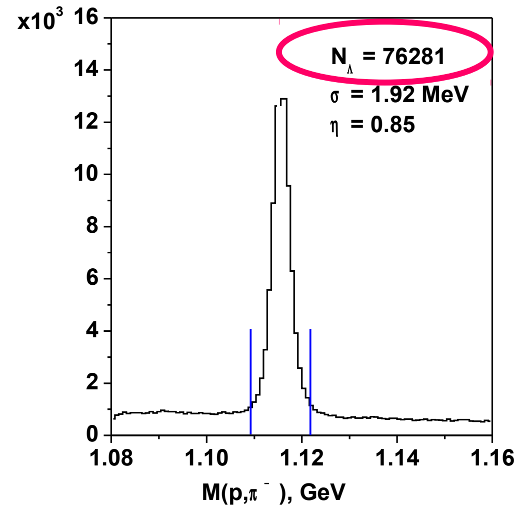
Burkard & Jaffe from EMC result

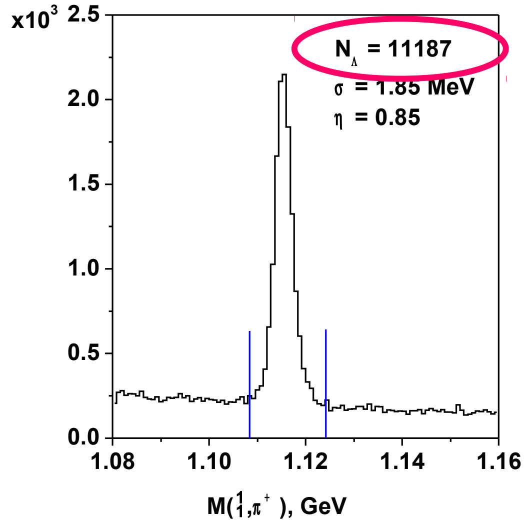
$\Delta\Sigma$=**0.12** Δu=Δd= **-0.23** Δs= **0.58** **(±0.04)**

L

Λ and λ̀ events selection







h⁺h⁻ pair background suppression

leading π or K rejection *using threshold Cherenkov det. (1996-1997) or RICH (1998-2007)*

vertex separation cut: *distance between V_1 and V2 vertices > 5 cm*

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

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

For beam helicity balance case

$$\left[\left[P_B^2\right]\right] = \frac{\int P^2(t)L(t)dt}{\int L(t)dt} = 0$$

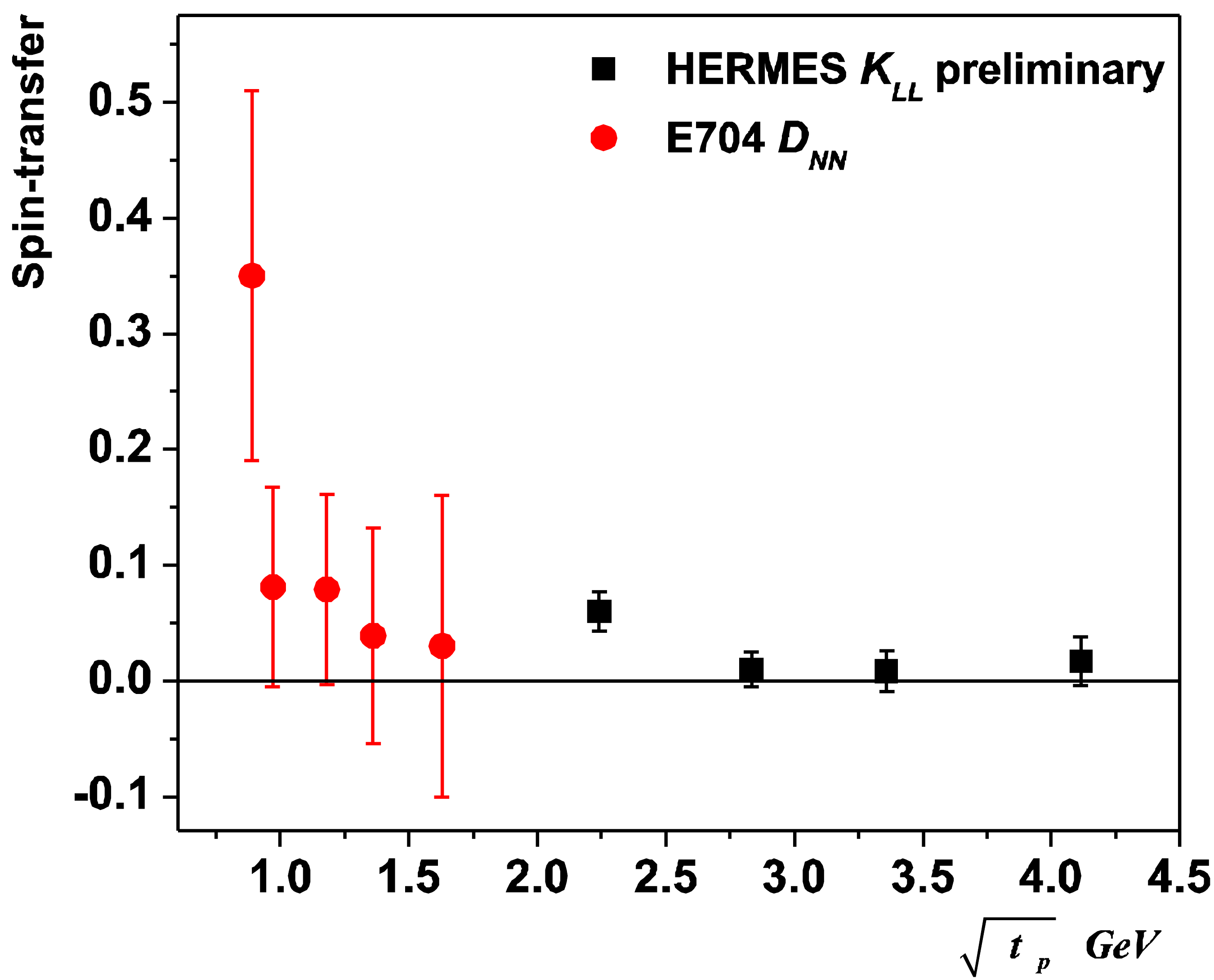
a

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

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

Вклад ПИЯФ в эксперимент

отка концепции, организация производства,



HERMES K_LL preliminary
E704 D_NN
Spin-transfer
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
√t_p GeV