Эксперимент HERMES
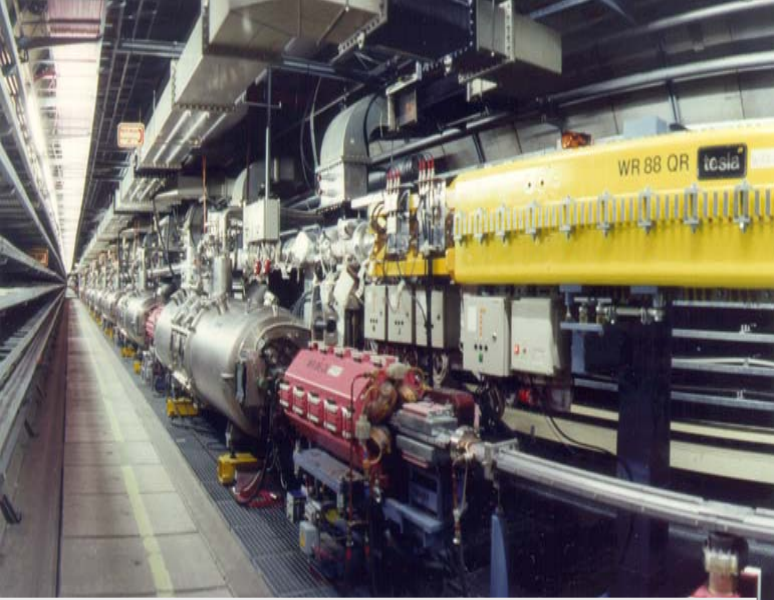
Поляризованные позитроны (электроны) 27.6 ГэВ поляризованные H или D мишени, неполяризованные ядерные мишени
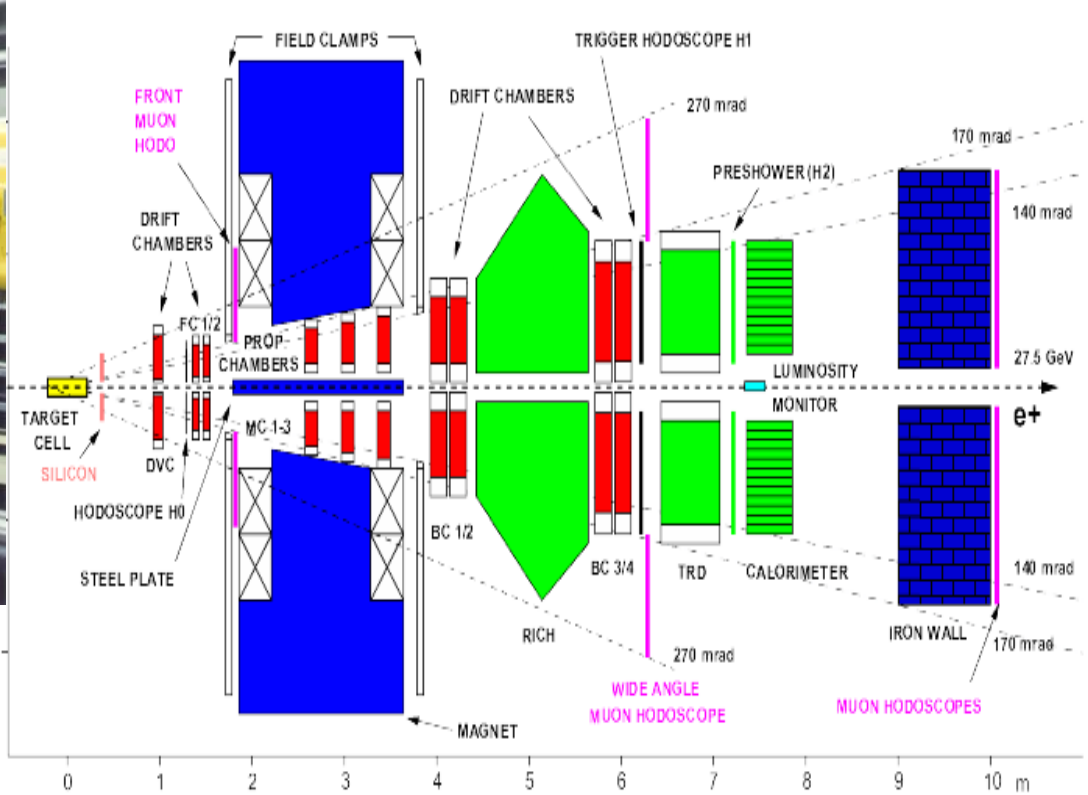
С.Белостоцкий
Д.Веретенников
В.Вихров
Г.Гаврилов
О.Гребенюк
А.Жгун
А.Изотов
А.Киселев
П.Кравченко
А.Крившич
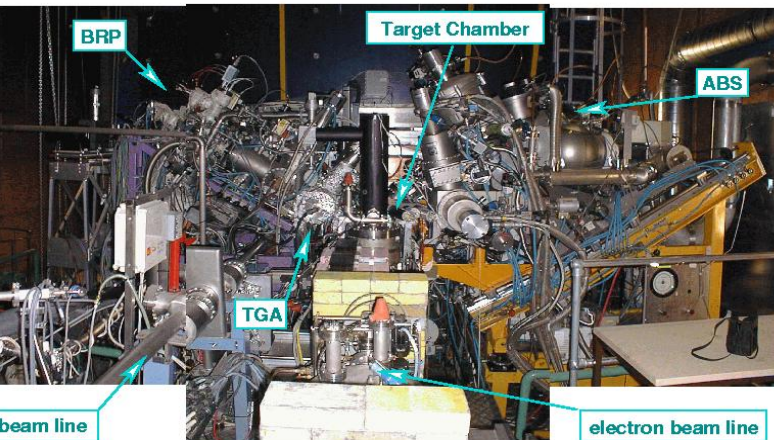С.Манаенков
О.Миклухо
Ю.Нарышкин
Ю.Санжиев

+

Отд.трек.дет.
Лаб.крио.тех.
КБ
Инст.Ефремова

Polarized lepton beam of
The HERA ring $\langle P_b \rangle$ ~ 54%

Polarized gas target $\langle P_t \rangle$ ~ 85(-84)%

Hermes spectrometer
Resolution:
 $\Delta p/p$~1%, $\Delta\Theta$<1 mrad
PID: 98% lepton identification with <1% hadron contamination
Excellent separation of π, K and p with RICH

Вклад ПИЯФ в эксперимент

Hardware:

- **Магнит спектрометра** (раразработка концепции, организация производства, частично инвестирование, магнитные измерения карты поля);
- **Пропорцианальные камеры** (11тыс.каналов) в зазоре магнита;
- Инвестирование (частично) системы считывания PCOS-4;
- Автоматизированная **система охлаждения** для frontend PCOS-4 и TRD;
- **Система охлаждения** для силикон-стрип детектора Lambda Wheels;

Software

- Разработка программ кодирования события **HERMES Decoding;**
- Разработка программы улучшенного трекинга **HERMES TC;**
- Производство файлов данных **HERMES HRC /DST** files;
- Программа выстройки элементов детектора по трекам, и пр.
- Разработка программ **SLOW CONTROL;**

DATA TAKING

- Поддержание **MCs, TRD**;
- Поддержание силикон.-стрип дет. **LW**;
- Поддержание **DAQ**;
- Газообеспечение ;
- Поддержание **Slow Control**;
- Обработка **сырых данных**;
- Работа в качестве **период координатора**;

DATA ANALYSIS

$\vec{e} + \vec{p}\ (\vec{d}) \Rightarrow e' + X$ Inclusive DIS   with $Q^2 \geq 1 \text{GeV}$

$\vec{e} + \vec{p}\ (\vec{d}) \Rightarrow e' + h + X$ Semi-Inclusive DIS   with $Q^2 \geq 1 \text{GeV}$

$\vec{e} + \vec{p}\ (\vec{d}) \Rightarrow h + X\ (\text{e.g.} h = \vec{\Lambda}\ )$ $quasi - real$ photoproduction

                                 with $Q^2 \approx 0$

$\vec{e} + p(\vec{p}, \vec{d}) \Rightarrow e' + h, \gamma + p, n\ (\text{e.g.} h = \rho, \varphi, \pi...)$ exlusive reactions

$e + A \Rightarrow e' + \gamma, \pi, K, \Lambda, ... + X$ unpolarized interaction with nucleus

                                       targets

$A = H, D, {}^3He, {}^4He, N, Ne, Kr$ and Xe

Longitudinal beam polarization PB=0.5

Longitudinal and transverse target polarization PT=0.8-0.9

Unpolarized nucleus targets

$180 \cdot 10^6$

DIS positrons (electrons)

more than $3.5 \cdot 10^3$ pb^{-1}

of Integrated Lumi

Вклад ПИЯФ в HERMES анализ

Исследование вклада кварков и глюонов в спин нуклона;
Полина Кравченко →Δq from SIDIS and DIS,
kinematic distributions

Поляризационные параметры в рождении векторных мезонов;
Сергей Манаенков →ρ,φ,ω SDME, direct amplitude reconstruction

Параметры передачи спина и поляризация в рождении Λ;
Денис Веретенников , Юрий Нарышкин, Станислав Белостоцкий
→ DLL, KLL, Pn-tranasverse Lambda and Lbar

Ядерные эффекты в рождении гиперонов;
Юрий Нарышкин, Станислав Белостоцкий
→ Study of nuclear medium effects on transverse Λ hyperon polarization

Обработка сырых данных. Модернизация кода восстановления треков.
Александр Киселев→new Hermes Track Reconstruction Code HTC

Поляризация кварков в нуклоне
(спиновый кризис ??)

$$\Delta\Sigma = 0.12 \pm 0.09 \pm 0.14 \neq 1 \ !!?$$

$$S_z = \frac{1}{2} = \frac{1}{2}\Delta\Sigma + \Delta G + L_q + L_g$$

Inclusive polarized DIS

$$\Delta\Sigma = 0.33 \pm 0.02(\text{exp}) \pm 0.03(\text{theo})$$

quarks

Gluons high PT

$$\frac{\Delta g}{g} = 0.078 \pm 0.034 \pm 0.011$$

$$\text{at} \quad \langle x \rangle = 0.204$$

Semi nclusive polarized DIS

$$evaluated \ at \quad 0.021 < x < 0.6$$

$$\Delta\Sigma = 0.359 \pm 0.026(\text{exp}) \pm 0.018(\text{theo})$$

$$(\alpha_S = 0.29 \pm 0.01 \quad Q_0^2 = 2.5\,\text{GeV}^2 \ )$$

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quarks   **Gluons high PT**

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$$(\alpha_S = 0.29 \pm 0.01 \quad Q_0^2 = 2.5\,\text{GeV}^2 \ )$$

Conclusion. Quark and gluon contributions account for 50% of nucleon spin. Is the rest due to orbital motion of nucleon constituents ?

Поляризация кварков в нуклоне.
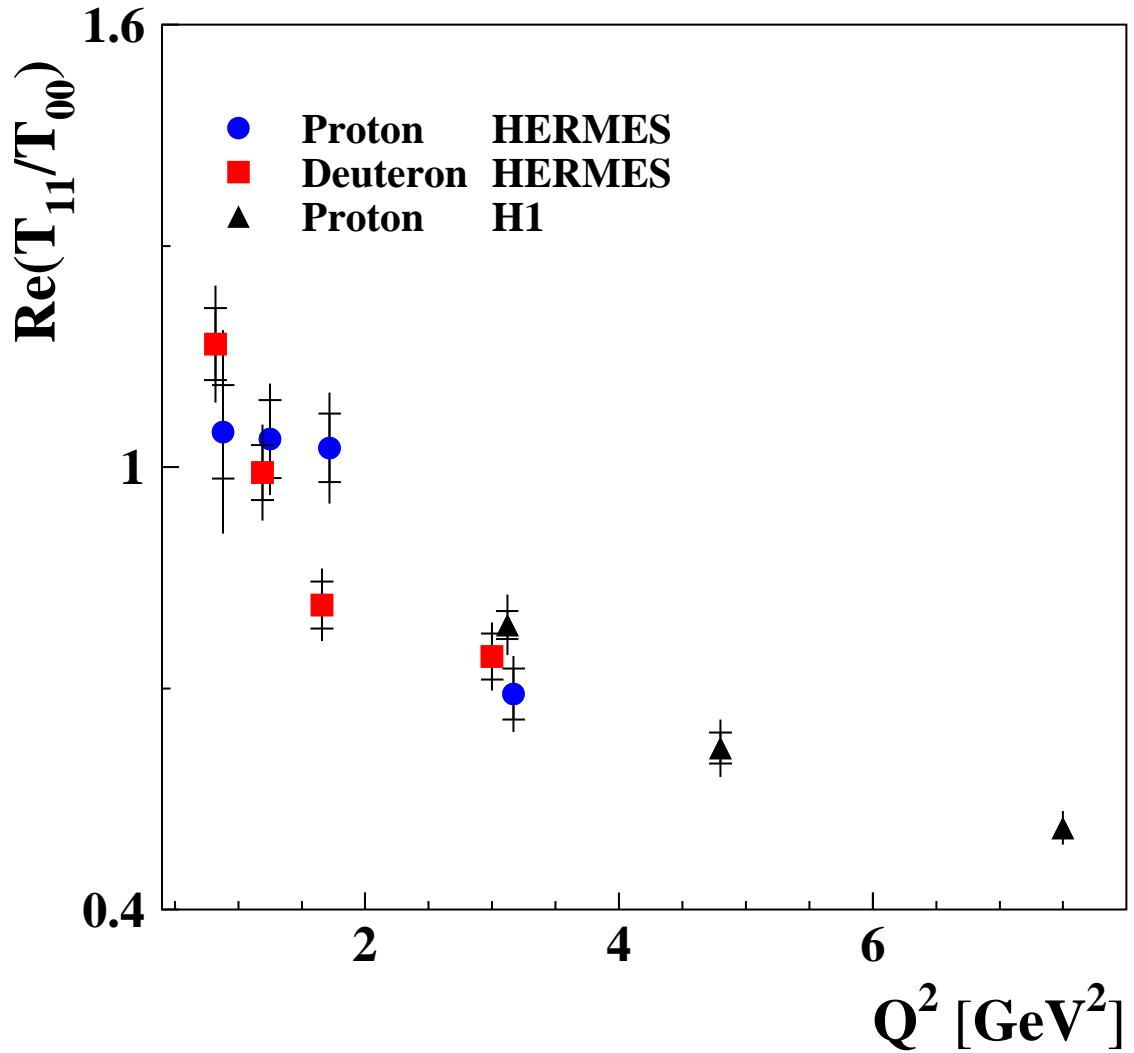## Окончательные результаты

Полина Кравченко PhD- 2010

✓*Control of factorization theorem;*

✓*Control of P_T dependence*

✓*Taking into account Cahn effect ;*
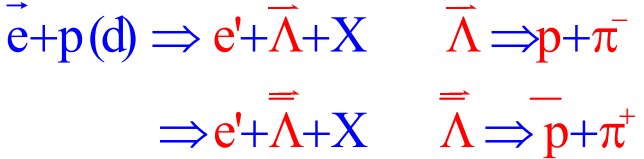
✓*NLO corrections. Small Q^2*

✓*3d unfolding*

- ● HERMES published data
- ■ 3D Extraction method, $Q^2 > 1 GeV^2$
- ○ 3D Extraction method, $Q^2 < 1 GeV^2$
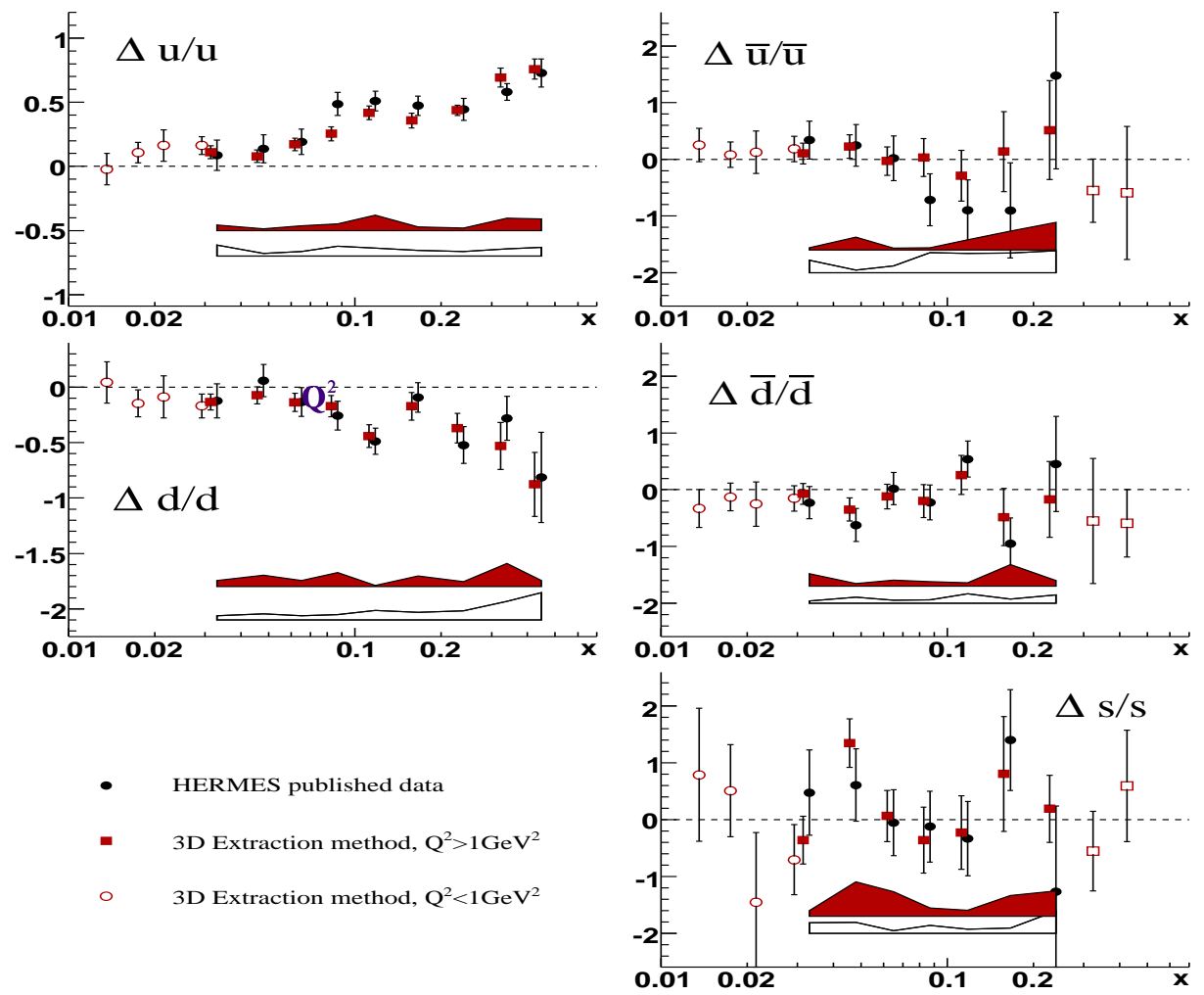
$$\vec{e} + \vec{p} \left(\vec{d}\right) = e' + \vec{\rho} + X$$

Нарушение SCHC Signal from T_{01}

γ helicity 1

to ρ helicity 0

Semi Inclusive DIS
at $Q^2 > 0.8$ GeV^2

$$\vec{e}+p(d) \Rightarrow e'+\vec{\Lambda}+X \qquad \vec{\Lambda} \Rightarrow p+\pi^-$$

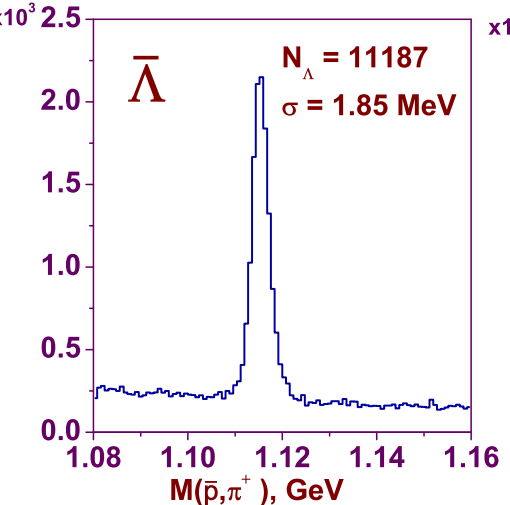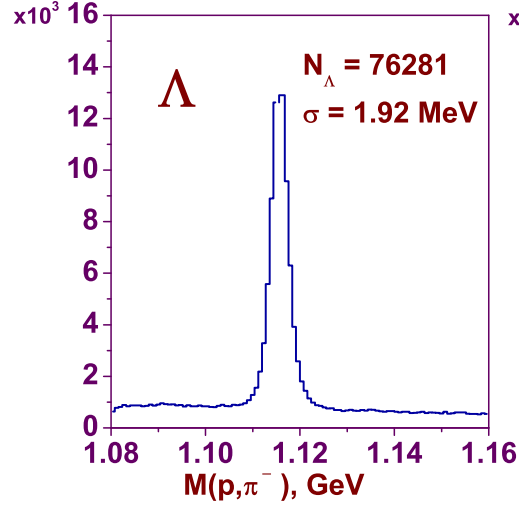$$\Rightarrow e'+\vec{\bar{\Lambda}}+X \qquad \vec{\bar{\Lambda}} \Rightarrow \bar{p}+\pi^+$$

$$\vec{P}_\Lambda = \vec{D}_\Lambda P_{quark} \qquad P_{quark} = D(y)P_B$$

For the first time 3-d analysis

e'

$\vec{e}$

$\vec{\gamma^*}$

$\vec{q}$

$\vec{\Lambda}$

$\overleftarrow{q}$

hadronization

X

p

HTC ⟹

Λ $N_\Lambda = 76281$ $\sigma = 1.92$ MeV   M(p,π⁻), GeV

$\bar{\Lambda}$ $N_\Lambda = 11187$ $\sigma = 1.85$ MeV   M(p̄,π⁺), GeV

K_s $N_{Ks} = 99034$ $\sigma = 5.44$ MeV   M(π⁺,π⁻), GeV

10
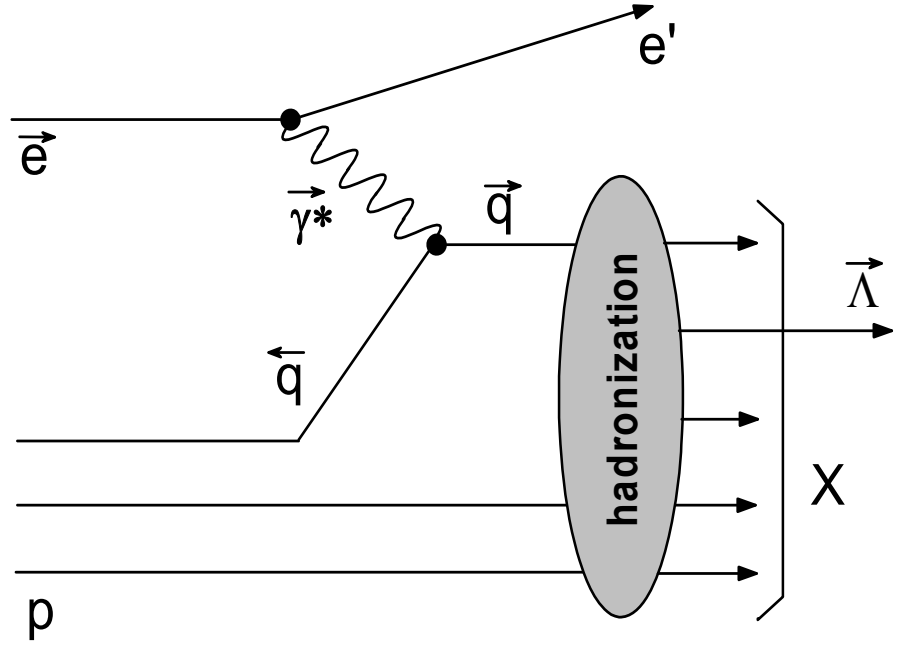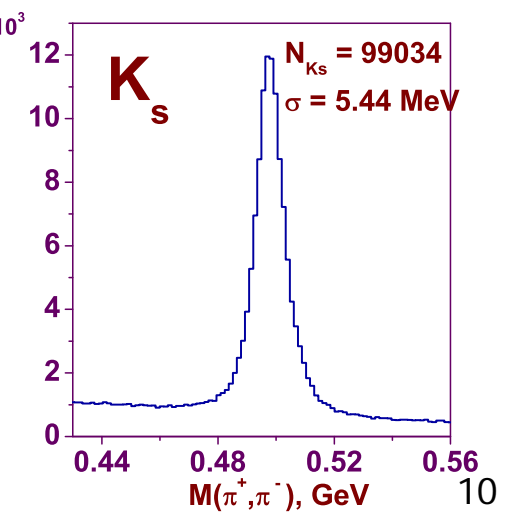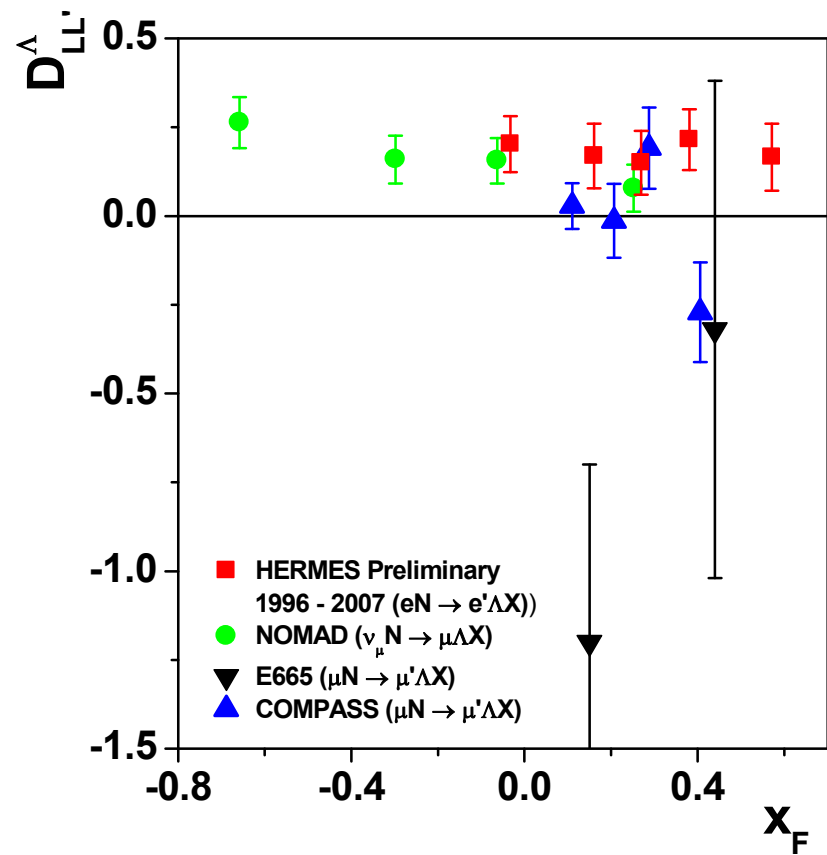
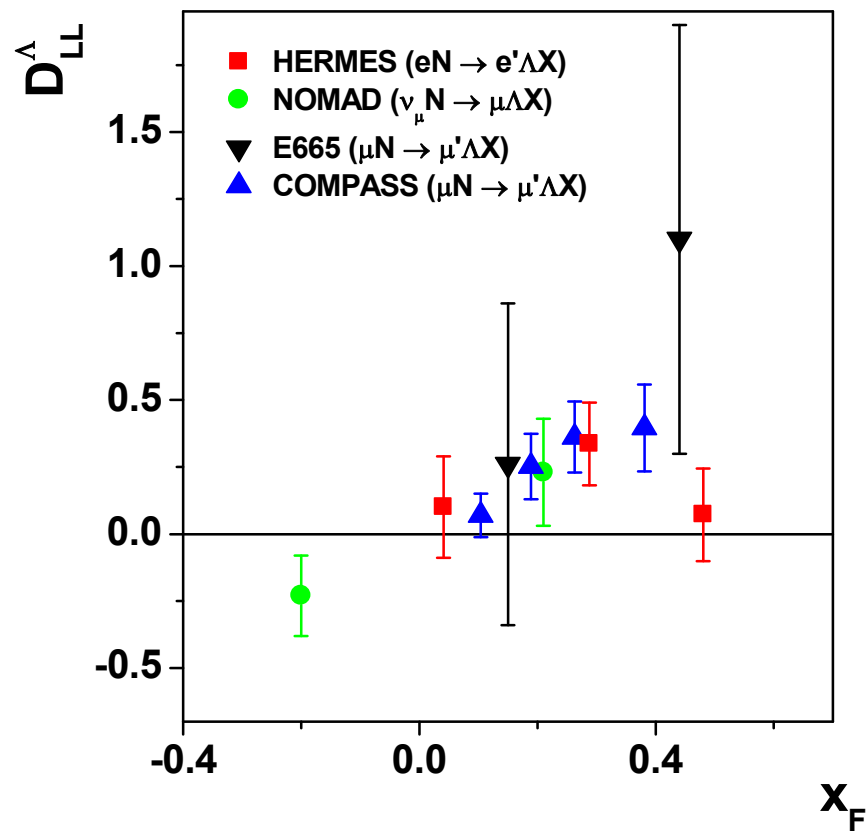# Compilation of world data on longitudinal spin transfer

Various Λ-spin structure tests

Constituent quark model (CQM)

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

Lattice QCD

$\Delta u = \Delta d = -0.02 \pm 0.04, \qquad \Delta s = 0.68 \pm 0.04$

SU(3) flavor symmetry

$\Delta u = \Delta d = -0.09 \pm 0.06, \quad \Delta s = 0.47 \pm 0.07$

Burkard/Jaffe

$\Delta u = \Delta d = -0.23 \pm 0.06, \quad \Delta s = 0.58 \pm 0.07$

$\Sigma(1193) \to \Lambda\gamma, \ \Sigma(1385), \Xi \to \Lambda\pi$

are to be taken into account !!

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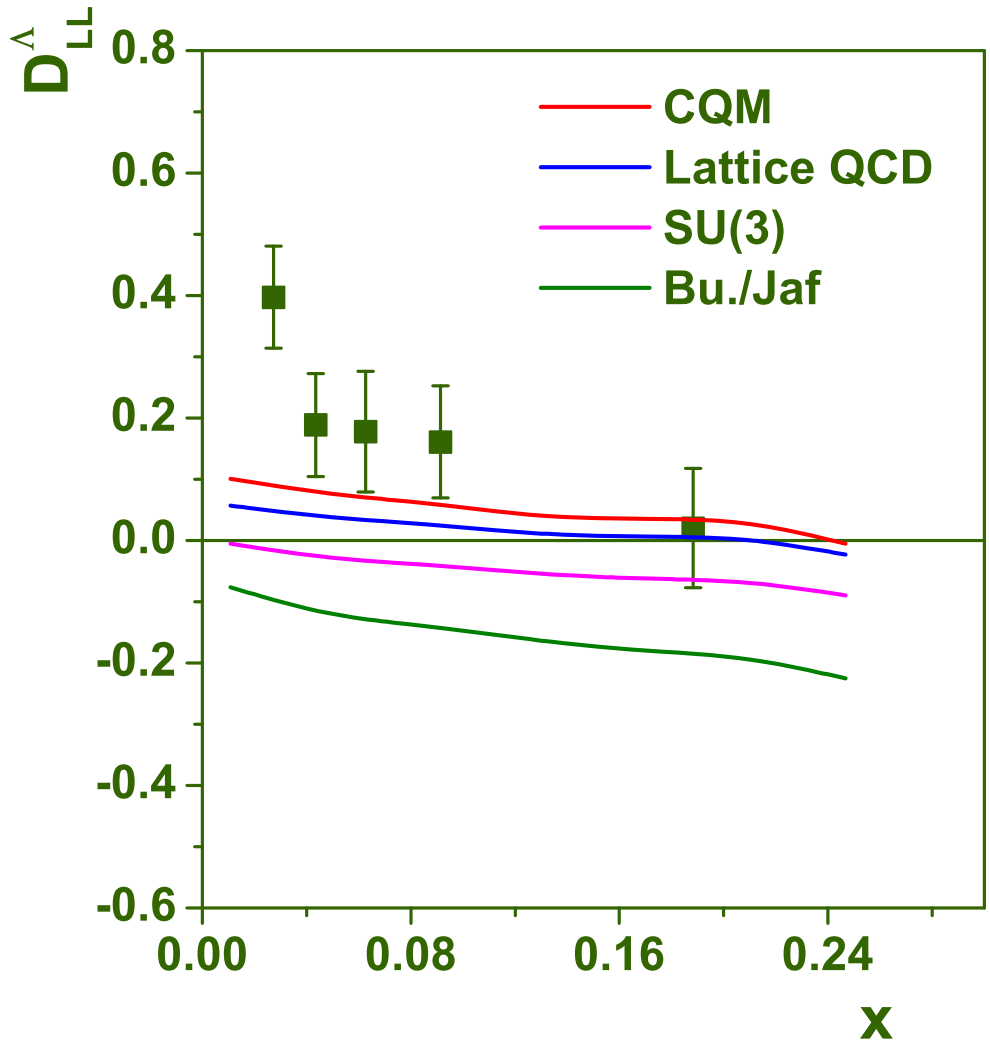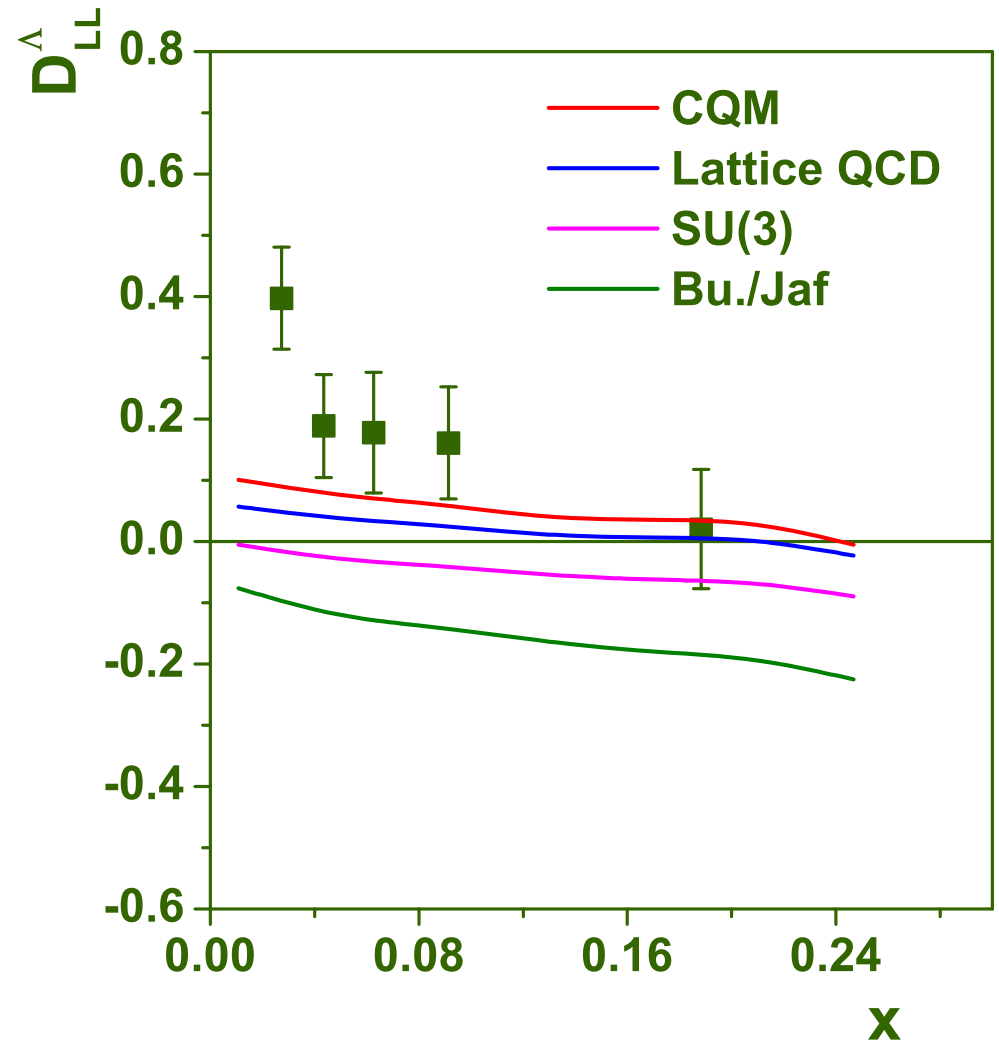
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$\Sigma(1193) \to \Lambda\gamma, \; \Sigma(1385), \Xi \to \Lambda\pi$

are to be taken into account !!

**Conclusion. Contribution of strange quark at small x
and FF(s→Λ) is essentially larger than in LUND MC.**

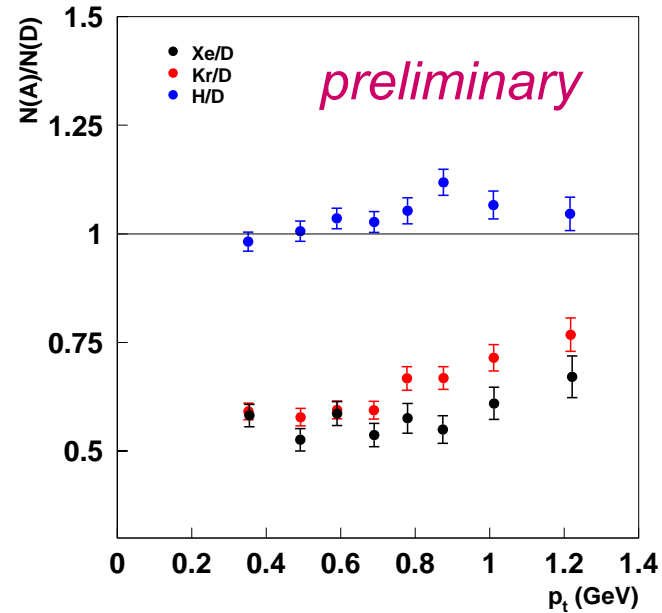# Strong A-dependence of Λ yields and transverse polarization in photoproduction

Ю. Нарышкин

$$\gamma + A \Rightarrow \vec{\Lambda} + X$$

$$A = H, D, {}^{3}He, {}^{4}He, N, Ne, Kr \text{ and } Xe$$
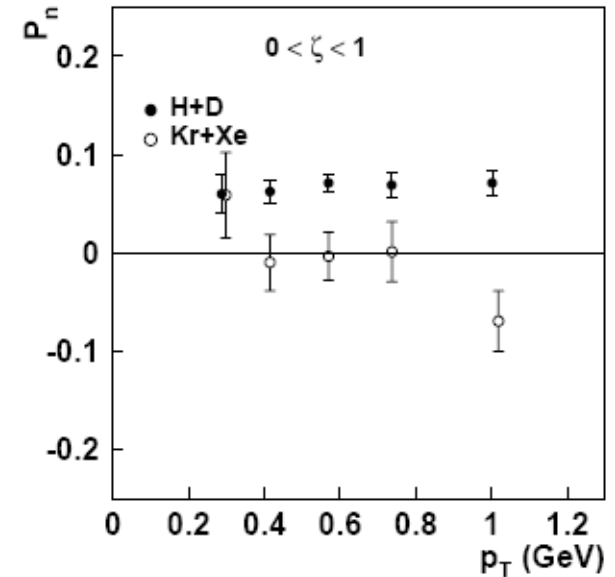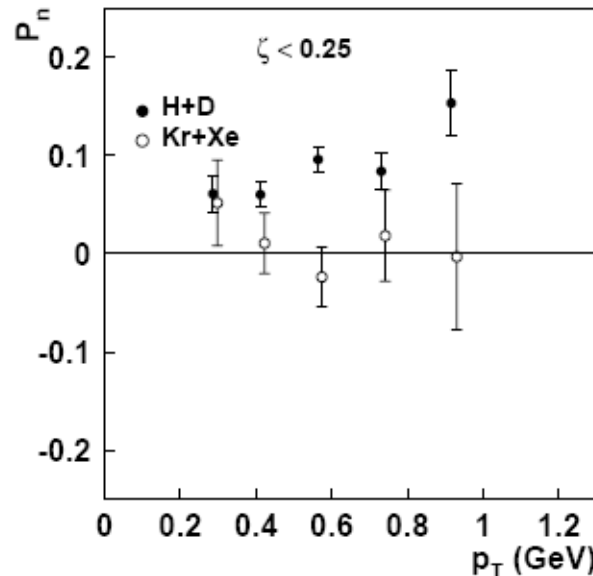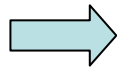
$$R_{\Lambda} = \frac{\left(\dfrac{N_{\Lambda}(A)}{A \cdot Lumi}\right)}{\left(\dfrac{N_{\Lambda}(D)}{2 \cdot Lumi}\right)} = \frac{\sigma_{\Lambda}(\gamma \tilde{n}(A) \rightarrow \Lambda X)}{\sigma_{\Lambda}(\gamma n \rightarrow \Lambda X)}$$

$$L_{\gamma} \gg R_{A}$$

pure

Λ- absorption

effect

preliminary

In disagreement with hadron-hadron Lambda production

1. **Measurement of azimuthal asymmetries associated with deeply virtual Compton scattering on a longitudinally polarized deuterium target**
   A. Airapetian et al, Nucl. Phys. B842 (2011) 265-298
   Eprint numbers: arXiv:1008.3996 (hep-ex) and DESY-10-136

2. **Leading Order Determination of the Gluon Polarization from high-pT Hadron Electroproduction**
   A. Airapetian et al, JHEP 08 (2010) 130
   Eprint numbers: arXiv:1002.3921(hep-ex) and DESY-10-021

3. **Effects of transversity in deep-inelastic scattering by polarized protons**
   A. Airapetian et al, Phys. Lett. B 693 (2010) 11-16
   Eprint numbers: arXiv:1006.4221 (hep-ex) and DESY-10-87

4. **Exclusive Leptoproduction of Real Photons on a Longitudinally Polarised Hydrogen target**
   A. Airapetian et al, JHEP 06 (2010) 019
   Eprint numbers: arXiv:1004.0177 (hep-ex) and DESY-10-046

5. **Nuclear-mass dependence of beam-helicity and beam-charge azimuthal asymmetries in DVCS**
   A. Airapetian et al, Phys. Rev. C 81 (2010) 035202
   Eprint numbers: arXiv:0911.0091 (hep-ex) and DESY-09-190

6. **Transverse momentum broadening of hadrons produced in semi-inclusive deep-inelastic scattering on nuclei**
   A. Airapetian et al, Phys. Lett. B 684 (2010) 114-118
   Eprint numbers: arXiv:0906.2478 (hep-ex) and DESY-09-082

7. **Measurement of azimuthal asymmetries associated with deeply virtual Compton scattering on an unpolarized deuterium target**
   A. Airapetian et al, Nucl. Phys. B 829 (2010) 1-27
   Eprint numbers: arXiv:0911.0095 (hep-ex) and DESY-09-189

Международные конференции (4-6 докладов от ПИЯФ в год)

2008

Кравченко П. *"Measurement of Flavor Separated Quark Polarizations at HERMES"*
International Conference DIFFRACTION 2008,
La Londe-les-Maures,
France   September 9-14, 2008

Манаенков С. *"Exclusive Electroproduction of $\rho0$ and ϕ Mesons at HERMES"*
International Workshop on Hadron Structure and QCD (HSQCD2008), Gatchina June 30 -July 04

Веретенников Д. "Spin transfer coefficient K_LL in Lambda photoproduction in HERMES"
16-th International Workshop DIS 2008,
London, 7-11 April 2008

Белостоцкий С. *"Polarization in Lambda and Lambdabar production at HERMES.*
"The 18th International Symposium on Spin Physics,
Spin 2008October 6 - 11, 2008 in Charlottesville,
Virginia, USA

Белостоцкий С. *"Lambda physics at HERMES"*
ECT 2008 International Workshop "Strangeness polarization in semi-inclusive
and exclusive Lambda production" Trento, November 2008

2009

Ю.Г.Нарышкин *"A-dependence of the transverse Lambda polarisation"*
European Nuclear Physics Conference (ENPC09)
Mar 16 - 20, 2009 Bochum, Germany

Ю.Г.Нарышкин *"Lambda Physics at HERMES"*
XIII Workshop on High Energy Spin Physics (DSPIN09)
Sep 1 - 5, 2009 Dubna, Russia

П. Кравченко "*Hermes measurements of strange quark helicity distributions*"
Europian Nuclear Physics Conference (EuNPC)
March 16-20, 2009 , Bochum

С.И.Манаенков *"Exclusive Electroproduction of $\rho0$, ϕ, and ω Mesons at HERMES"*
XIII Workshop on High Energy Spin Physics (DSPIN09)
Sep 1 - 5, 2009 Dubna, Russia

2010

С.И.Манаенков *"Direct Extraction of Helicity Amplitude Ratios in Exclusive $\rho0$ Electroproduction".*XVIII International Workshop
on Deep-Inelastic Scattering and Related Subjects (DIS2010),
19-23 April, Florence, Italy

С.И.Манаенков *"DIRECT EXTRACTION OF HELICITY AMPLITUDE RATIOS IN EXCLUSIVE $\rho0$ ELECTROPRODUCTION".*International Workshop "Hadron
Structure and QCD (HSQCD2010)", Gatchina 5-9 July, 2010, Russia

Ю.Г.Нарышкин *"Lambda polarization at HERMES"*
IX International Conference on Hyperons, Charm and Beauty Hadrons
21-26 June 2010, AulaMagna, University of Perugia Perugia, Italy

Ю.Г.Нарышкин *"Measurement of the nuclear-mass dependence of spontaneous (transverse) Λ polarisation in quasi-real photoproduction at HERMES"*
SPIN2010 –19th International Spin Physics Symposium
September 27 –October 2, 2010, Jülich, Germany

Д.О.Веретенников *"SPIN Transfer Coefficient DLL to Lambda Hyperon in SIDIS at HERMES".*
SPIN2010 –19th International Spin Physics Symposium
September 27 –October 2, 2010, Jülich, Germany

Publication in progress

Draft-84   "Ratios of Helicity Amplitudes for Exclusive ρ Electroproduction"   *С.Манаенков*

Draft- 83   "Study of nuclear medium effects on transverse Λ hyperon polarization   *С.Белостоцкий*
In quasi-real photoproduction"

Draft-88   *"Spin Transfer Coefficient DLL to Λ and Λ Hyperons in Semi-Inclusive DIS*   *С.Белостоцкий*

at HERMES experiment

Draft-85   "An Exploration of kinematical dependences of longitudinal double-spin asymmetry
 at HERMES"   *П.Кравченко*

Защищенные диссертации
А. Жгун, Ю.Нарышкин, П.Кравченко

Грядущие диссертации

Д.Веретенников   *2012*

С.Манаенков

Ю.Нарышкин

BACKUP SLIDES

Status and plans of Lambda analysis 2010-2012

I.Recently completed or nearly completed analyses.

<u>A-dependence of Lambda polarization</u>-> draft 83
Status: first circulation.

<u>Longitudinal spin transfer DLL in DIS</u>->draft 88
Status: DLL for Λ released, DLL for Λ analysis
is finished and to be released early in 2011.

II. Analyses in progress.

Longitudinal spin transfer DLL in
photoproduction_ >draft ??
Status:first run of analysis is finished, very preliminary
results obtained.
Draft ?? will include DLL (spin transfer from the beam)
and KLL (spin transfer from longitudinally polarized
target, already released).

A-dependence of Λ, Λ,Ks normalized yield in
photoproduction.
Pt and ζ dependences (Cronin effect ?). Reduced cross
section per nuclear in heavy nuclei.
Status: First very preliminary Pt dependences for Λ
obtained. Jointly with Yerevan group. Tentative.

III.Analyses planned to be performed.

Study of production of S0 (1193),X- (1321), S*+ (1393), S*- (1388) and their anti particles. Study of hyperon polarization. (Preliminary results on hyperon yields detected by HERMES in table 1 below.)

Study of Λ production in the target fragmentation region using RD.
Using coincidences of K+ detected with HERMES spectrometer with Λ in RD. With a hope to detect exclusive Λ K+ reaction.Tentative.
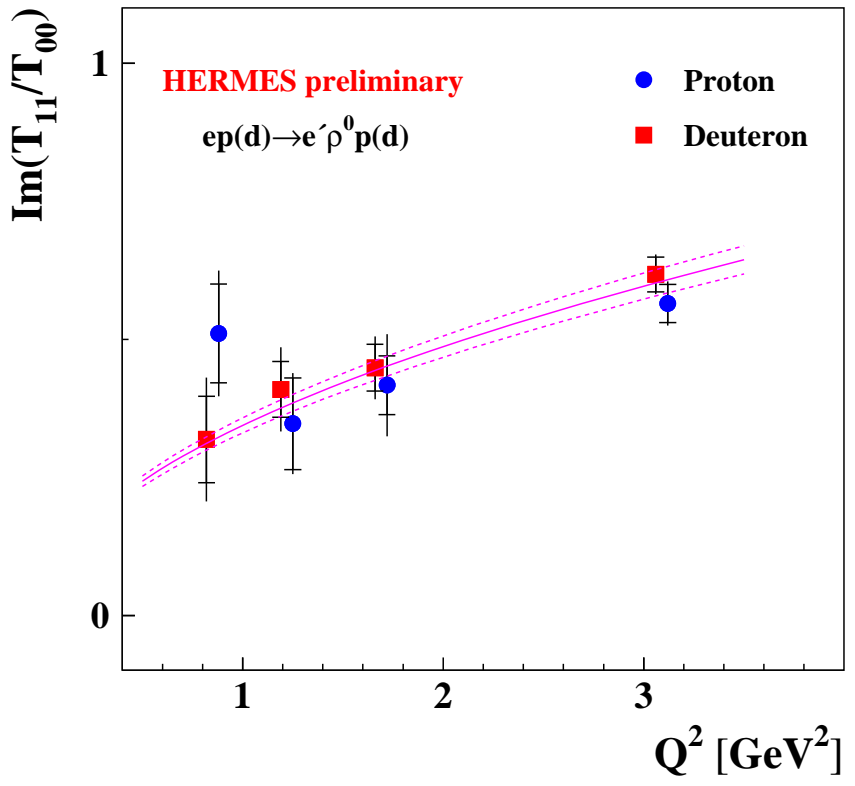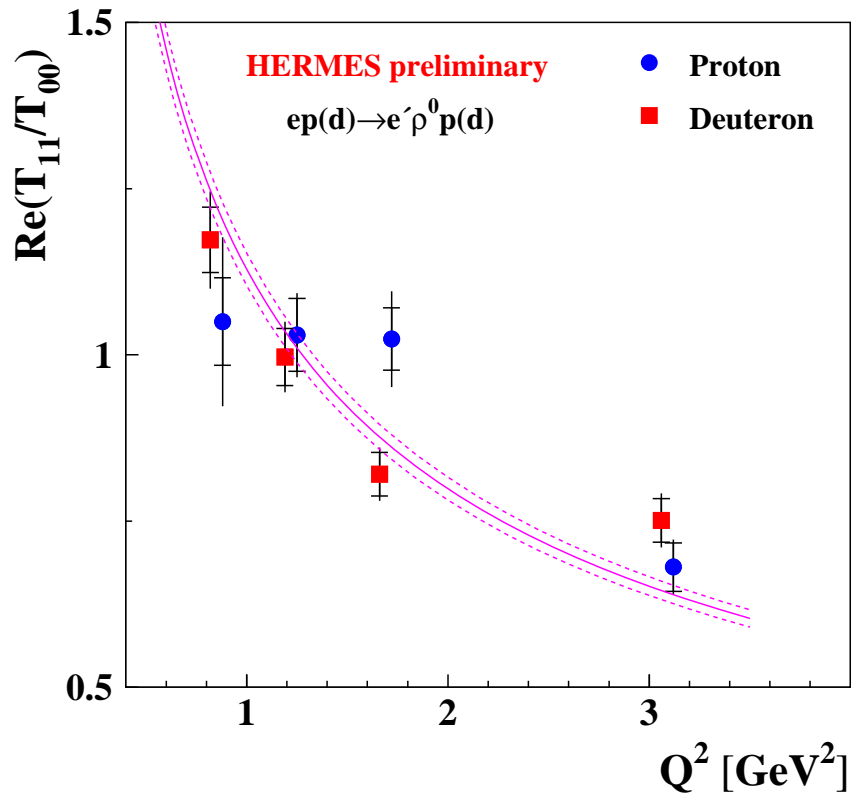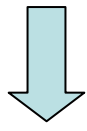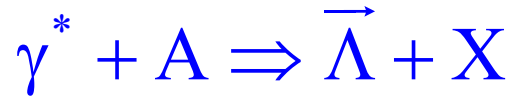
VM production with polarized beam and target

Сергей М
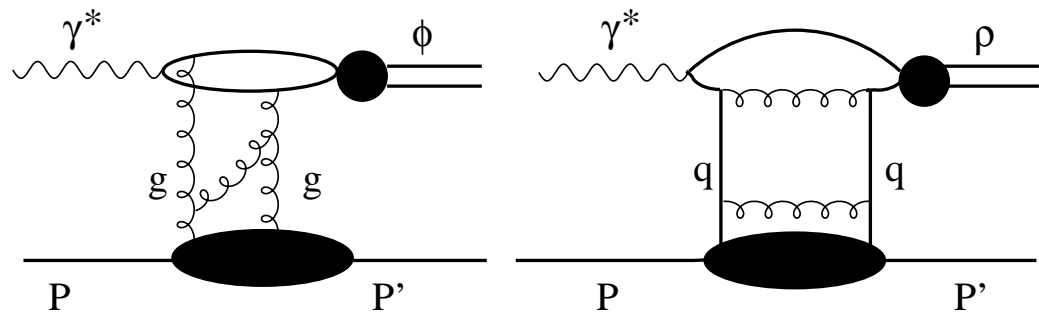
direct reconstruction of ρ0 production amplitudes

Reaction mechanism ??

С.Белостоцкий 22.12.09 сессия ОФВЭ

$$\gamma^* + A \Rightarrow \vec{\Lambda} + X$$

Data 1996-2005 only,
(2006-2007 will double the statistics)

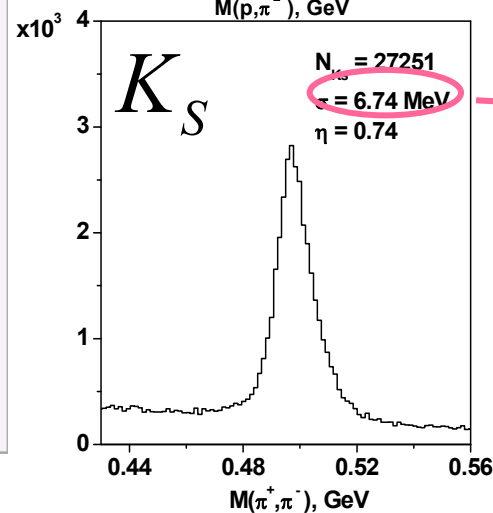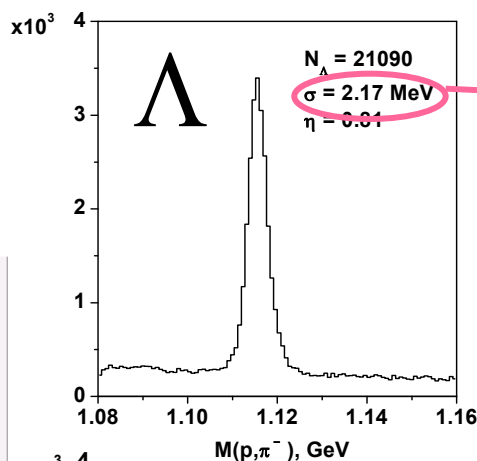*New result* →*unlike hadron*

and heavy ion collisions

strong effect of target on P_Λ

HERMES PRELIMINARY

P_Λ

0.2

0.1

0

-0.1

^{1}H

^{3}He

^{2}D

^{4}He,^{14}N,^{20}Ne

^{84}Kr

^{132}Xe

$0 < \zeta < 1$

1   1.5   2   2.5   3

A/Z

Существенное улучшение пространственного, углового и импульсного разрешения.
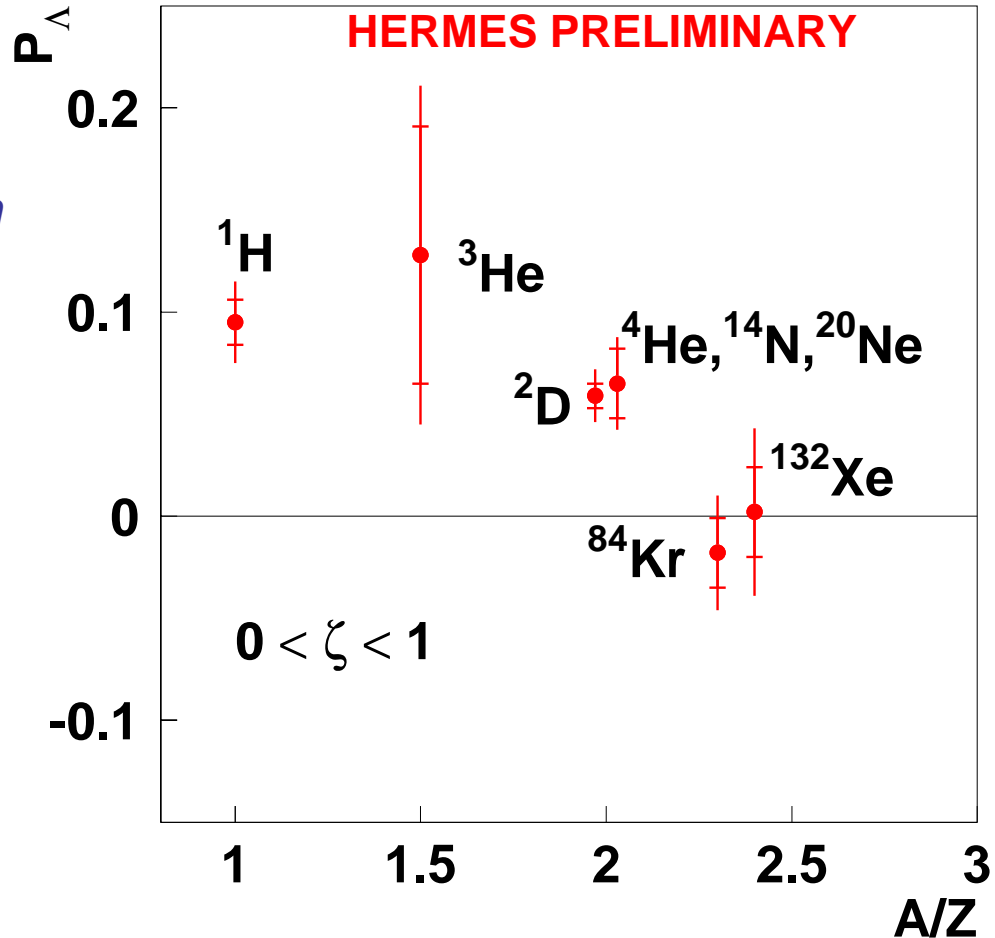
- 3D survey and alignment data
- Material distribution in the detector
- Magnetic field maps

- Beam line offset determination
- accuracy ~100μm
- Beam line slopes determination
- accuracy ~100μrad

Fitted value of par[2]=Sigma

Momentum, GeV/c

Λ $N_\Lambda = 21090$, $\sigma = 2.17$ MeV, $\eta = 0.81$

Λ $N_\Lambda = 55003$, $\sigma = 1.71$ MeV, $\eta = 0.87$

$M(p,\pi^-)$, GeV

K_S $N_{KS} = 27251$, $\sigma = 6.74$ MeV, $\eta = 0.74$

K_S $N_{KS} = 72373$, $\sigma = 5.07$ MeV, $\eta = 0.82$

$M(\pi^+,\pi^-)$, GeV

С.Белостоцкий 22.12.09 сессия ОФВЭ

Transverse Λ polarization   _Data 1996-2000 (RUN I only)_   _Phys Rev. D 2007_
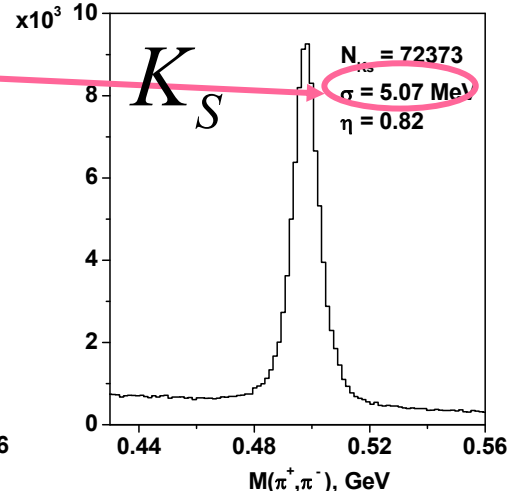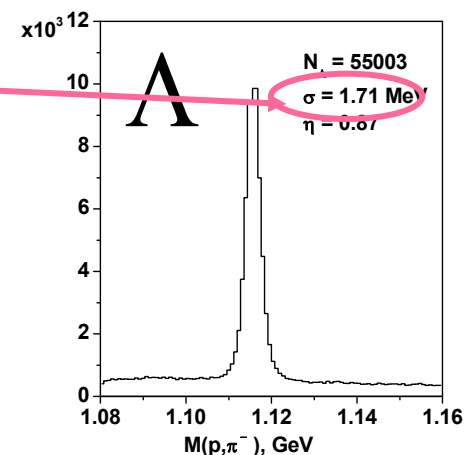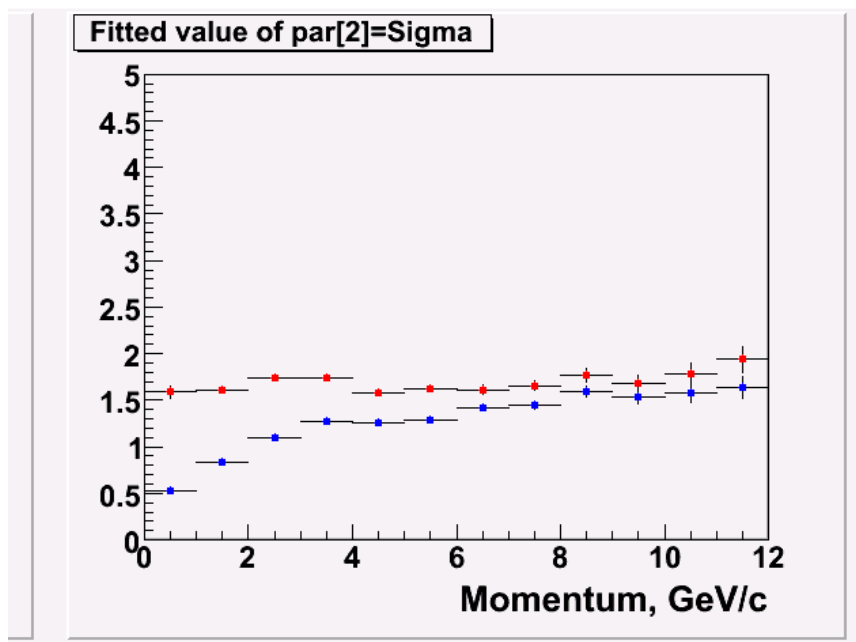
$$e + d(p, A) \rightarrow \Lambda \uparrow + X \ \text{at} \ \langle E_\gamma \rangle = 15.6 \ \text{GeV}$$

$$P_\Lambda = 0.078 \pm 0.006(stat) \pm 0.012(syst)$$

$$P_{\bar{\Lambda}} = -0.025 \pm 0.015(stat) \pm 0.018(syst)$$

inclusively detected
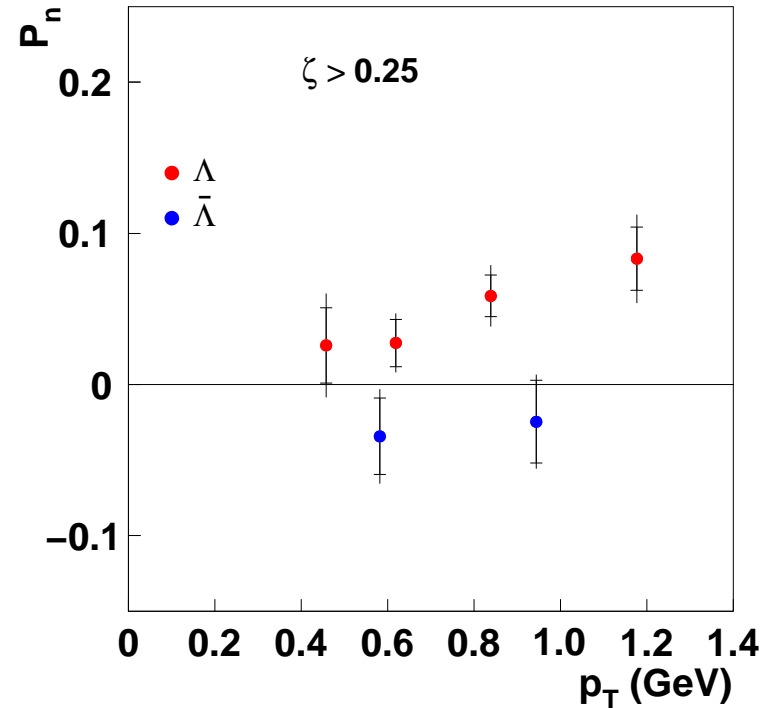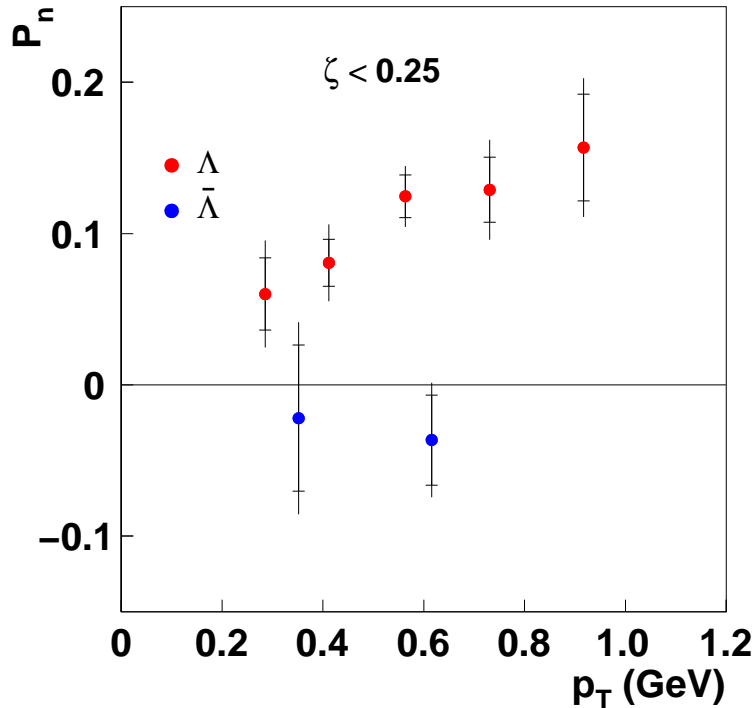
Включение данных _RUN II_ даст фактор 3-5 в числе событий, что особенно важно для Λ.
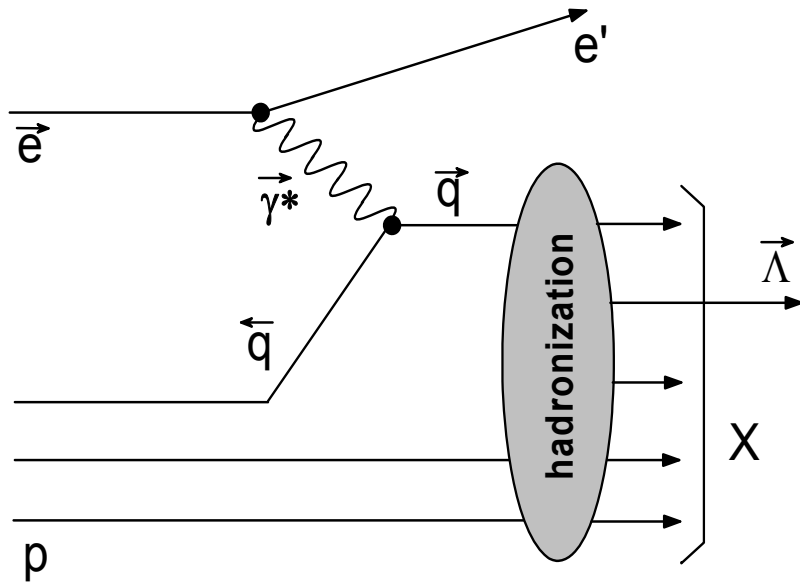
Longitudinal spin transfer DLL'

$$\vec{e} + p,d \Rightarrow e' + \vec{\Lambda} + X$$

$$P_{L'}^{\Lambda} = D_{LL'}^{\Lambda} \cdot P_L^q$$

$$D_{LL'}^{\Lambda} = \sum_q \omega_q \cdot D_{LL'}^{q\Lambda} \approx \sum_q \omega_q \frac{\delta q^{\Lambda}}{q^{\Lambda}}$$
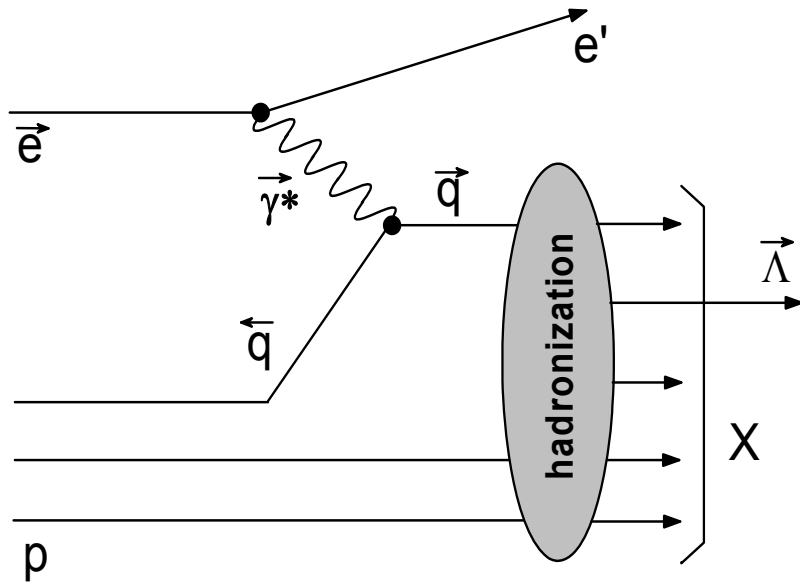
Λ spin structure

$$SU(3)_f \;\rightarrow\; \frac{\delta u}{u} = \frac{\delta d}{d} = -0.16 \quad \frac{\delta s}{s} = 0.64$$

$$Lattice\ calculations \;\rightarrow\; \frac{\delta u}{u} = \frac{\delta d}{d} = -0.02 \pm 0.04 \quad \frac{\delta s}{s} = 0.68 \pm 0.04$$

Longitudinal spin transfer DLL'

$$\vec{e} + p, d \Rightarrow e' + \vec{\Lambda} + X$$

Valid only for current fragmentation !!

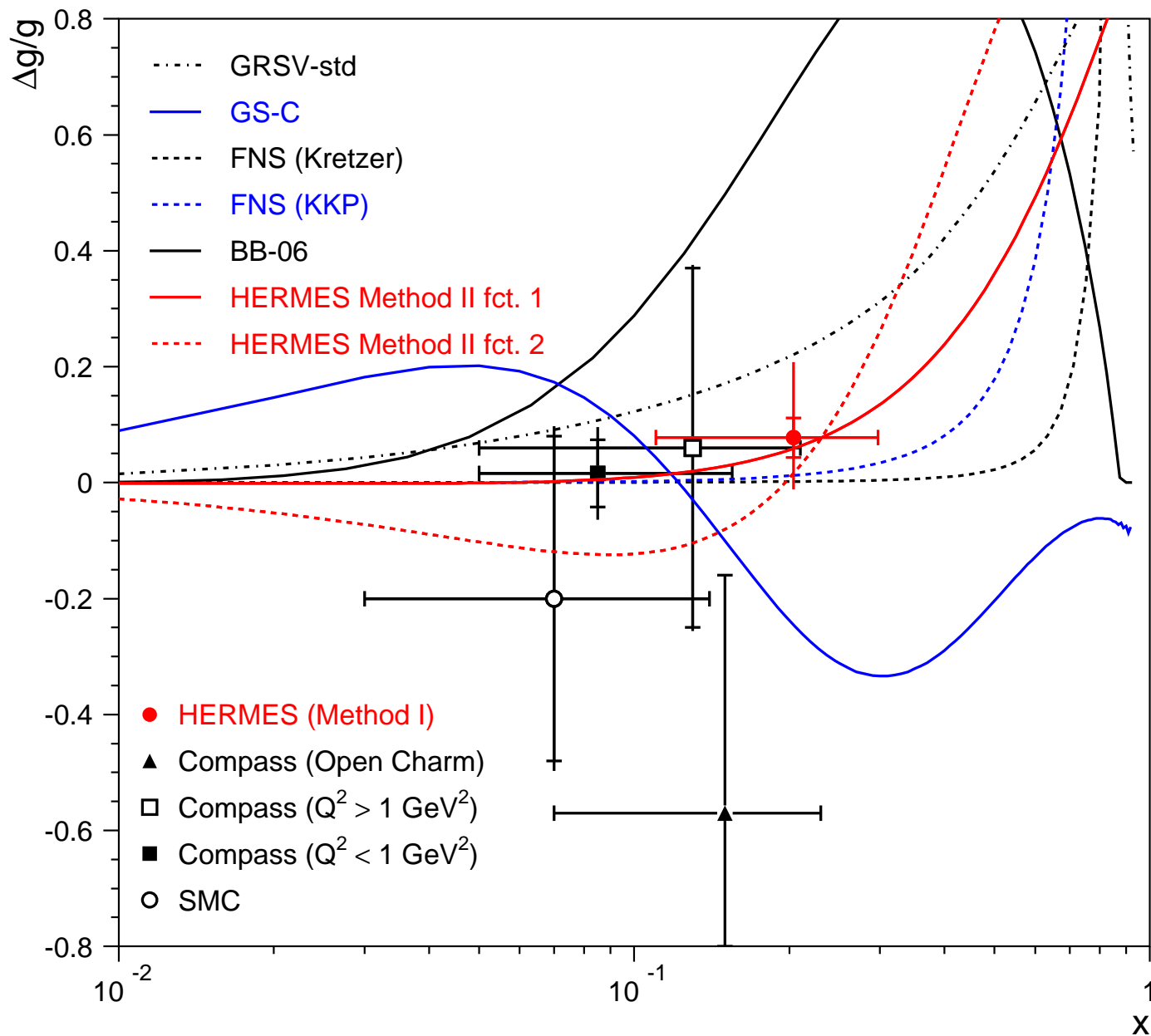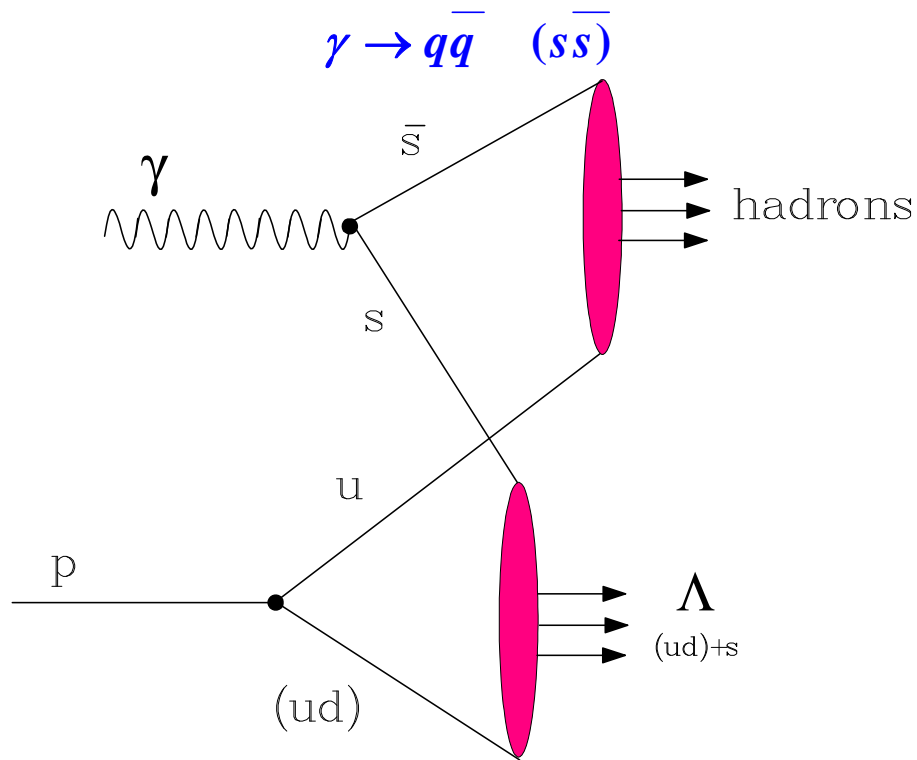$$P_{L'}^{\Lambda} = D_{LL'}^{\Lambda} \cdot P_L^q$$

$$D_{LL'}^{\Lambda} = \sum_q \omega_q \cdot D_{LL'}^{q\Lambda} \approx \sum_q \omega_q \frac{\delta q^{\Lambda}}{q^{\Lambda}}$$

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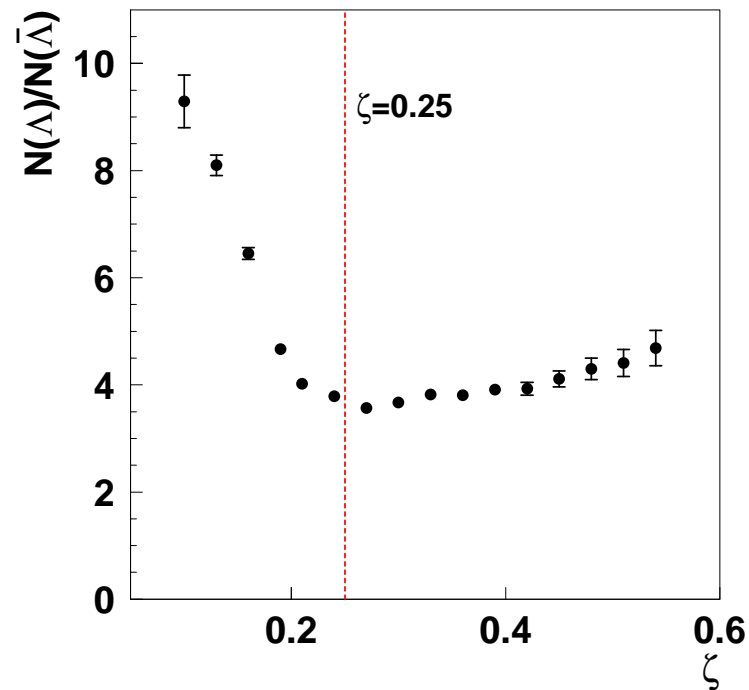
ΔG final result compilation

Legend:
- GRSV-std
- GS-C
- FNS (Kretzer)
- FNS (KKP)
- BB-06
- HERMES Method II fct. 1
- HERMES Method II fct. 2

- ● HERMES (Method I)
- ▲ Compass (Open Charm)
- □ Compass ($Q^2 > 1$ GeV^2)
- ■ Compass ($Q^2 < 1$ GeV^2)
- ○ SMC

Λ photoproduction mechanism by PYTHIA

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

$$\gamma \to q\bar{q} \quad (s\bar{s})$$

Λ to Λ yield ratio

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

target (ud) mechanism