ЛМНС в 2007 году. Основные научные результаты.

Отчет заведующего лабораторией

Nucleon spin structure. Status of experiments

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

u,d,s→SU(3) f

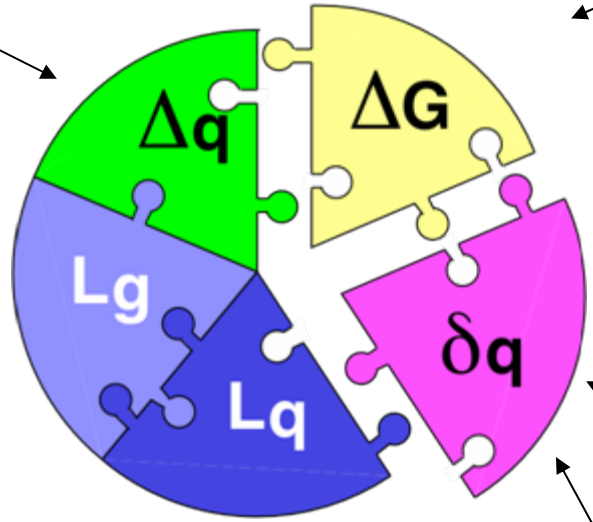
- ✓ *SLAC 10-48 GeV* $\vec{e}\vec{p}, \vec{e}\vec{d}$ — *ΔΣ inclusive, BSR,JSR*
- ✓ *Spin physics at RHIC 100+100 GeV* $\vec{p}\,\vec{p}$ — *ΔG, transverse spin*
- ✓ *COMPASS (EMC,SMC) 160 (100-200) GeV* $\vec{\mu}^{+}\vec{d}$ — *ΔΣ, ΔG ,transverse spin*
- ✓ *HERMES 27.3 GeV* $\vec{e}\,\vec{p}, \vec{e}\,\vec{d}$ — *ΔΣ, ΔG, quark helicity distributions, L_q, transverse spin*

summary: HERMES view at the nucleon spin structure

$$\Delta\Sigma = 0.330 \pm 0.025$$

$$(\Delta s + \Delta\bar{s}) = -0.085 \pm 0.008$$

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



helicity distributions

$\Delta u(x), \Delta d(x), \Delta s(x),$

$\Delta\bar{u}(x), \Delta\bar{d}(x)$

transversity DF and Collins FF

???

Sivers DF

$$J_u + J_d / 2.9 = 0.42 \pm 0.25$$

transverse Λ-polarization

VM production

summary: HERMES view at the nucleon spin structure

$$\Delta\Sigma = 0.330 \pm 0.025$$

$$(\Delta s + \Delta\bar{s}) = -0.085 \pm 0.008$$

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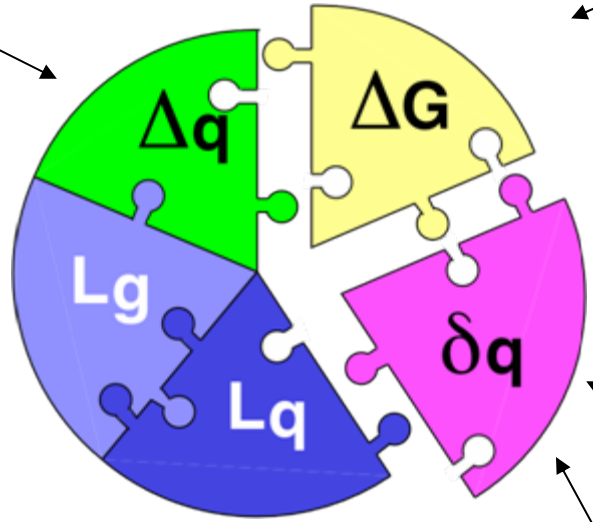


helicity distributions

$\Delta u(x), \Delta d(x), \Delta s(x),$

$\Delta\bar{u}(x), \Delta\bar{d}(x)$

transversity DF and Collins FF

Sivers DF

???

$$J_u + J_d / 2.9 = 0.42 \pm 0.25$$

VM production

transverse Λ-polarization

Contribution from small $X<X_{min}=0.023$??

Deuteron integral saturates

$$\Gamma_d = \frac{1}{36}(4\Delta\Sigma + a_8)$$

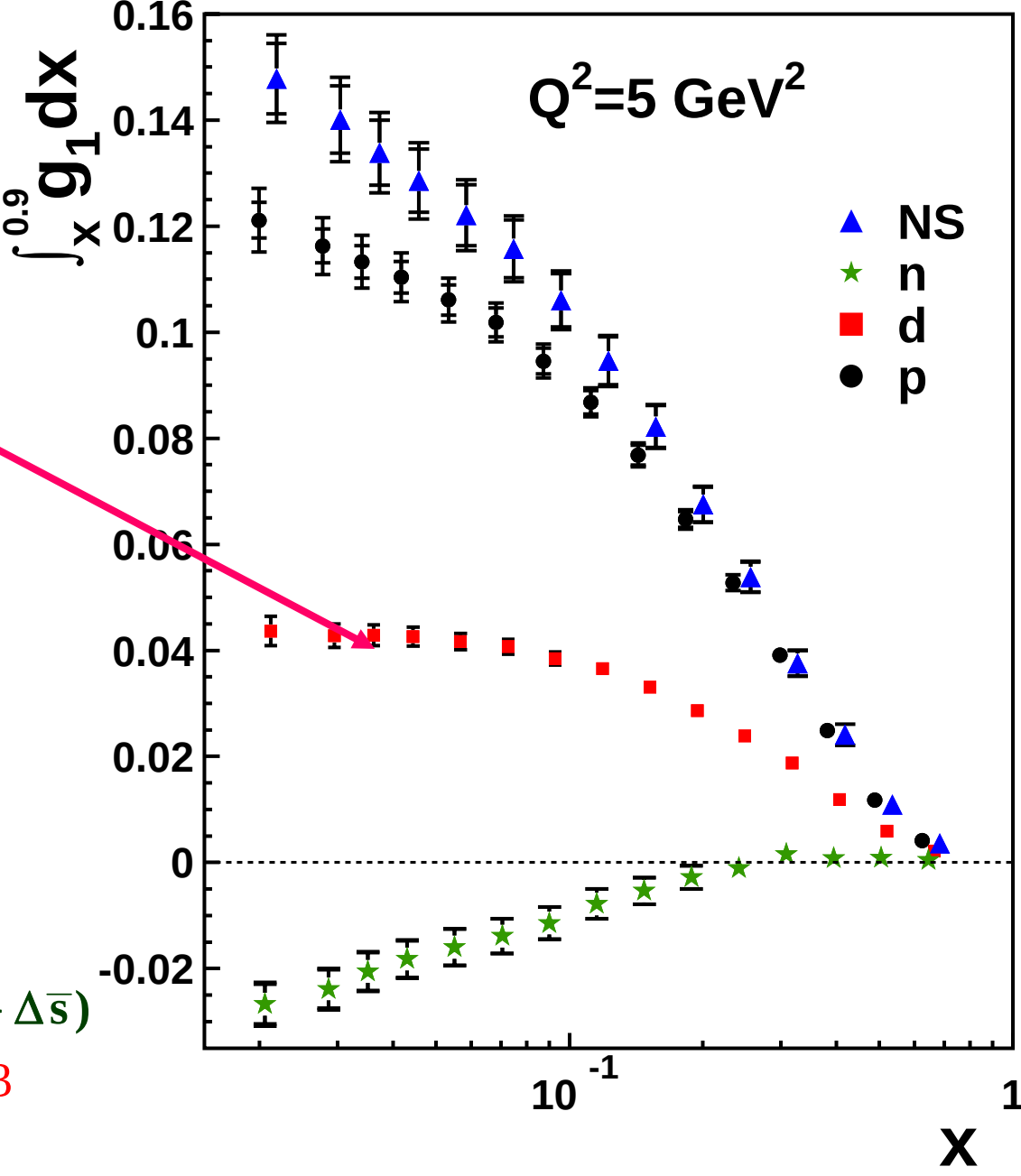
$$\Gamma_{p,n} = \Gamma_d \pm \frac{1}{12} a_3$$

saturates

$$\Delta\Sigma = (\Delta u + \Delta\bar{u}) + (\Delta d + \Delta\bar{d}) + (\Delta s + \Delta\bar{s})$$

$$a_3 = F + D = g_A/g_V = 1.269 \pm 0.003$$

$$a_8 = 3F - D = 0.586 \pm 0.031$$



Polarization of quarks in nucleon

quarks

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

total contribution ΔΣ

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

strange sea content ΔS

$$(\Delta s + \Delta\bar{s}) = -0.085 \pm 0.008(\text{exp}) \pm 0.013(\text{theo})$$

valence quark content Δu, Δd

$$(\Delta u + \Delta\bar{u}) = 0.842 \pm 0.008(\text{exp}) \pm 0.004(\text{theo})$$

$$(\Delta d + \Delta\bar{d}) = -0.427 \pm 0.008(\text{exp}) \pm 0.004(\text{theo})$$

quark helicity distributions.

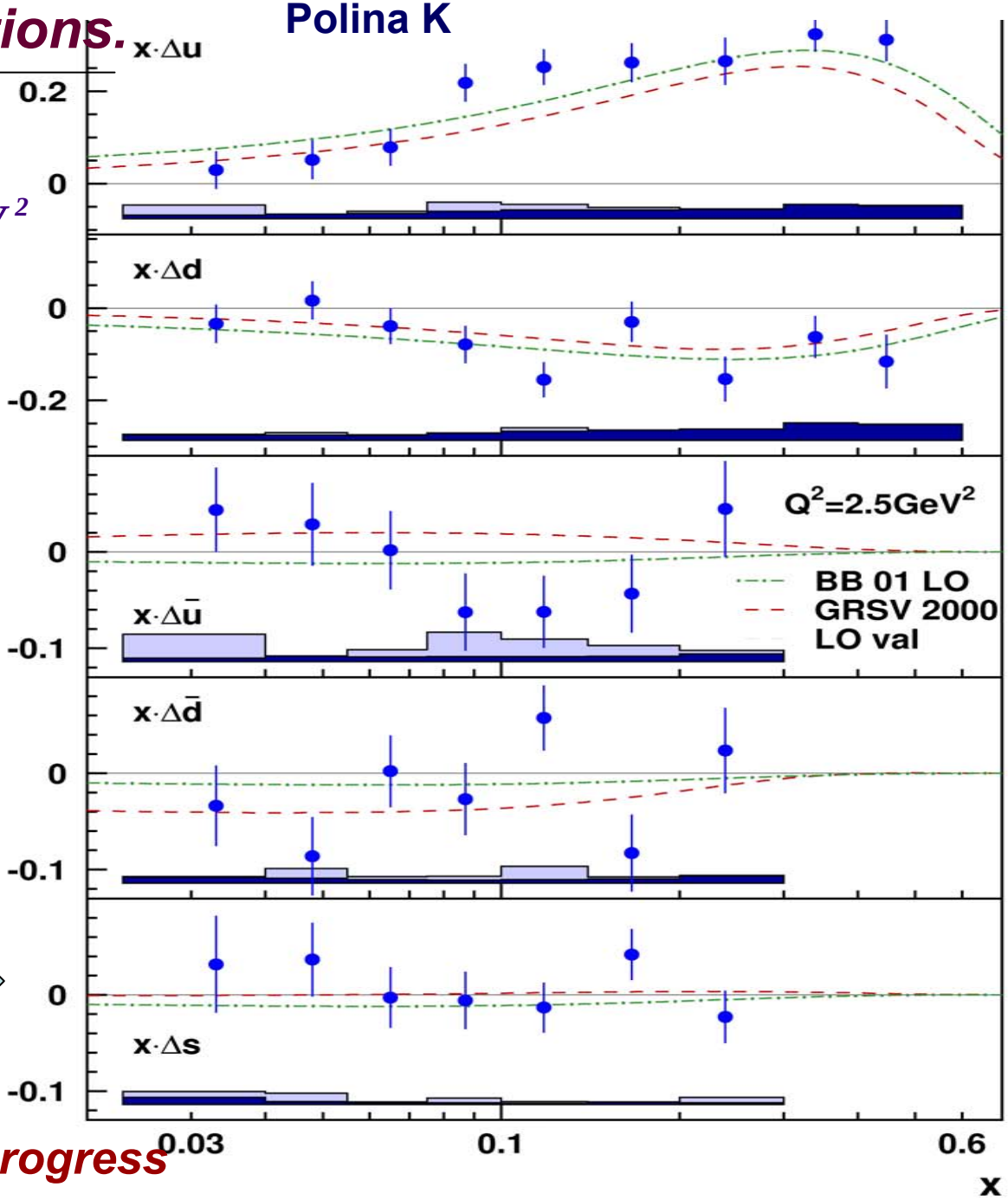
Polina K

evaluated $at\ Q_0^2 = 2.5 GeV^2$

theory: *QCD fit to inclusive DIS, SU(3), BJSR required.*

Agreement looks fine

Δs compatible with zero



NLO +all corrections→ in progress

Vector Meson (VM) production at HERMES

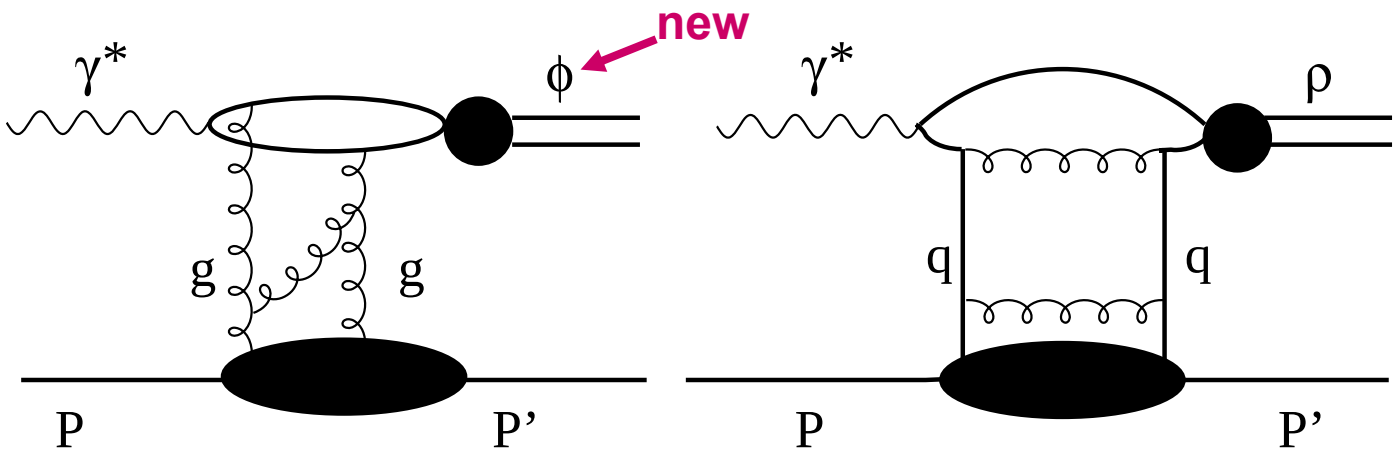
Sergey M

Exclusive VM production provides access to GPDs:

both unpolarized $H, \tilde{H}$ *and polarized* $E, \tilde{E}$

HERMES obtained first POLARIZED data for Φ-meson production

⟶ *gluon exchange*



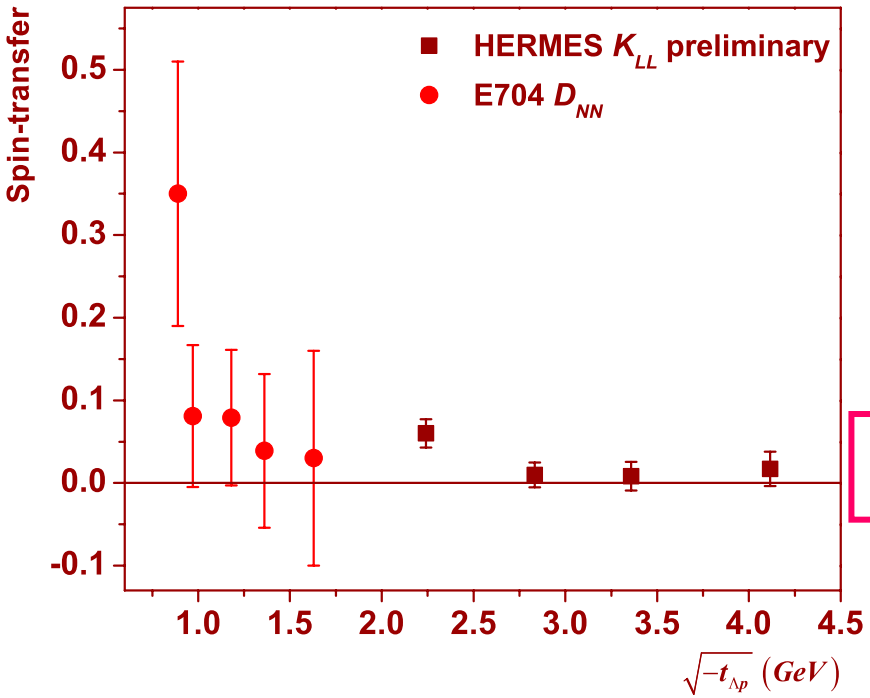
Experimental information (polarized beam&target) sufficient to go from SDME analysis to direct reconstruction of spin-dependent amplitudes⟶ in progress

Lambda polarization observables

Phys Rev. D 2007 Yuri N+Denis V

First solid observation in lepto/photoproduction !!

approved by collaboration



$$N(\Lambda) = 259 \cdot 10^3$$

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

$$N(\bar{\Lambda}) = 51 \cdot 10^3$$

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

$$\varsigma \simeq \frac{E_\Lambda}{E_{beam}}$$

Polarization of Ξ hyperons
Spin transfers KNN, KLL, DLL
A-dependence of P_Λ is under study

} *In progress*

Modification NN-amplitude in nuclear medium

Oleg M

New polarization parameter Cnn in p→2p on ^{4}He

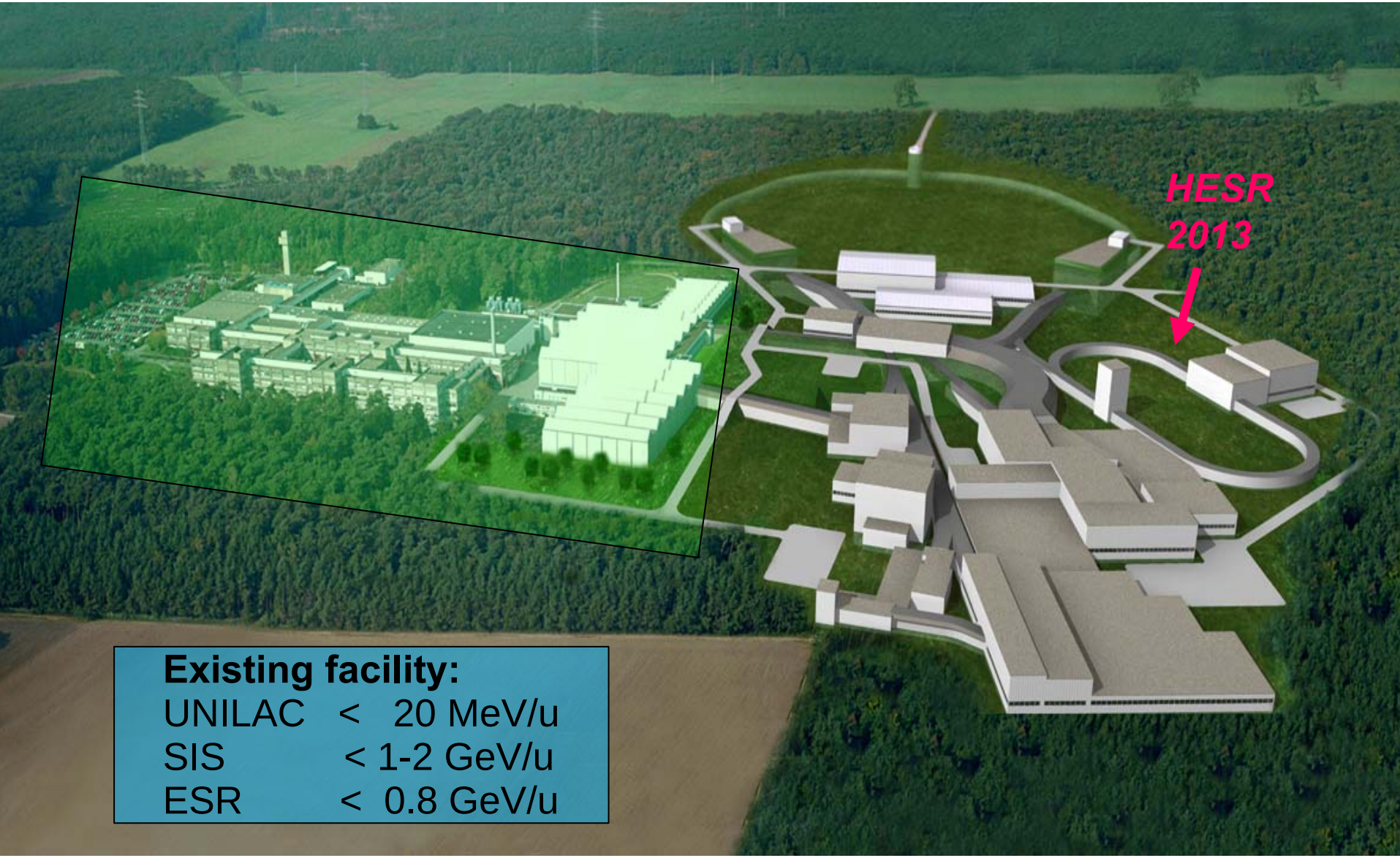
This year:

- *tests of new readout*
- *new hydrogen/ helium target*
- *reference measurements on H*

Next year:

- *Collect statistics on 4He*

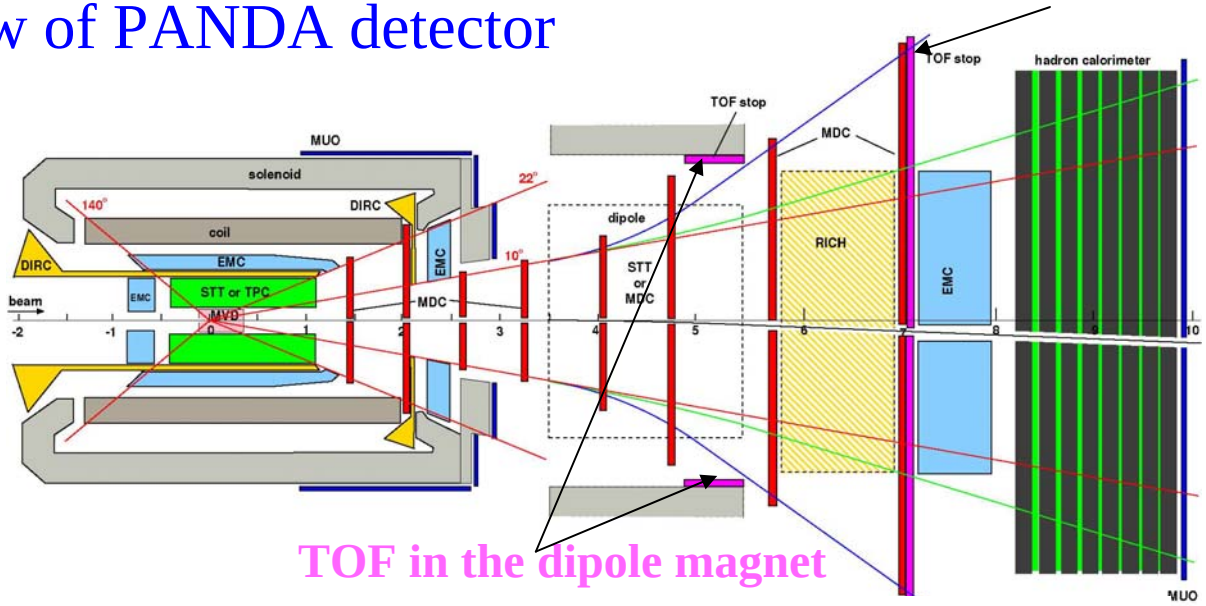
Existing and Future Facility of GSI



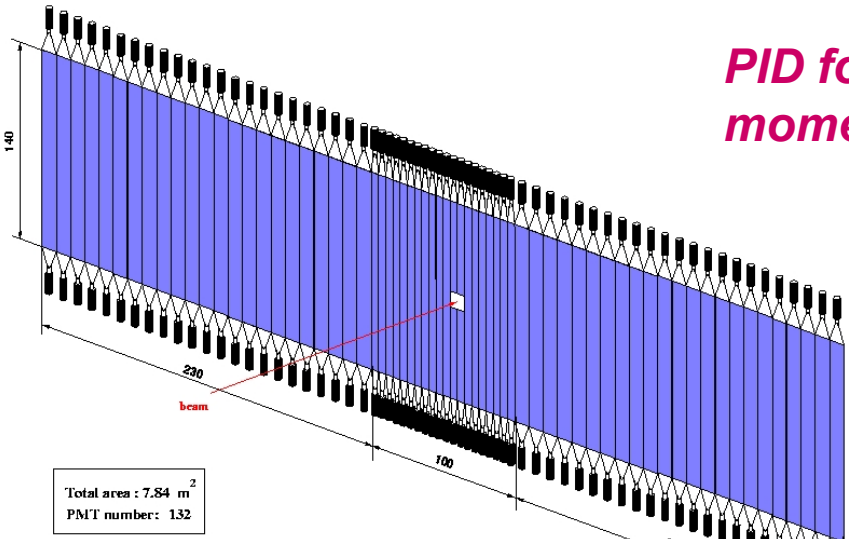
Existing facility:

UNILAC	<	20 MeV/u
SIS	<	1-2 GeV/u
ESR	<	0.8 GeV/u

Top view of PANDA detector



TOF wall



PID for hadrons with momenta < 4 gev/c
50-70 ps

Final request 989 KEU

Mile stones for TOF wall 2008-2012

- ***Design, MC simulations and test of the prototype module***
- ***Procurement of scintillation materials and PM's for mass production***
- ***Design and fabrication of mechanical structure***
- ***Mass-production of all TOF modules***
- ***Assembly and tests of the TOF equipment in place***
- ***Alignment of the TOF wall***
- ***Incorporation of TOF in PANDA DAQ system***

В этом году

2008

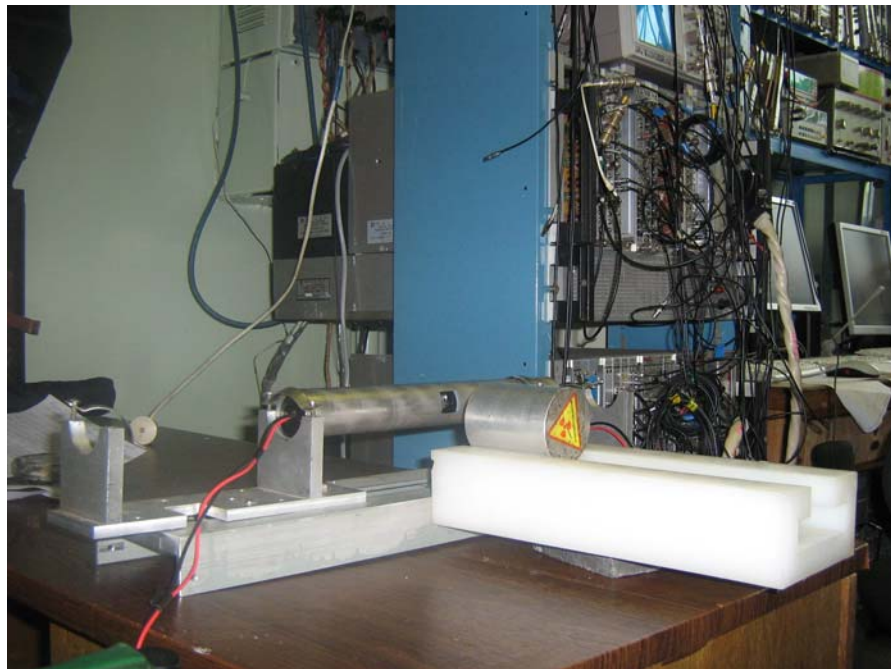
- *MC light propogation*

- *Минимальный вариант тест станции с использованием Hamamatsu R2083, R4998,*
*BC-408 1400mm*100mm*15mm,*
BC-408 1400mm 50mm*15mm,*
*BC-408 1000mm*100mm*15mm*

- *Тест с имеющейся электроникой*

- *Прототип CFD*

Комплектация тест станции и разработка прототипа



Publications&Talks

С.Белостоцкий “Recent results from HERMES” overview talk
12th Workshop on High Energy Spin Physics (DSPIN-07)
Sep 3 - 7, 2007 ..... Dubna, Russia
Д.Веретенников “Lambda and Lambdabar polarization and spin transfer in photoproduction at HERMES”
12th Workshop on High Energy Spin Physics (DSPIN-07)
Sep 3 - 7, 2007 ..... Dubna, Russia
С. Манаенков “Exclusive diffractive electroproduction of rho and phi mesons at HERMES”
7th European Research Conference on Electromagnetic interactions with nucleons and nuclei.
12-15 September, Milos Greece
Ю.Нарышкин “Measurement of transverse Lambda polarization in quasi-real photoproduction at HERMES”
15th International Workshop on Deep Inelastic Scattering and Related Subjects
April 16-20, 2007, Munich, Germany
П.Кравченко “Measurement of the spin structure functions and latest results on quark helicity distributions from Deep-Inelastic Scattering at HERMES”
11th International Conference on Meson-Nucleon Physics and the Structure of Nucleon, MENU2007. September 10-14,2007, Juelich,Germany

Финансы 2007

- $p \rightarrow 2p$ 500 т. руб. ОФН РАН
- PANDA 500 т. руб. ОФН РАН
- PANDA help 15 KEU KFI Juelich
- Визиты DESY 35 KEU МИН. НАУКИ
- Визиты DESY 90 KEU DESY

Состав лаборатории

С. Белостоцкий	зав. проф.	д. ф.-м. н.	
Г . Амальский	н. с.		
Д. Веретенников	м .н. с.		2009
В. Вихров	с. н. с.	к. ф.-м. н.	
З. Гадицкая	ст. лаб.		
А. Жданов	с. н. с.	к. ф.-м. н.	
А. Изотов	с. н. с.	к. ф.-м. н.	
А. Киселев	н. с.		2008-2009
П .Кравченко	м .н. с.		2008-2009
С. Манаенков	с. н. с.	к. ф.-м. н.	+
О. Миклухо	с. н. с.	к. ф.-м. н.	+
Ю.Нарышкин	с. н. с.	к. ф.-м. н.	+
Л. Обрант	инж. прогр. 2 кат.		
А .Прокофьев	с. н. с.	к. ф.-м. н.	
В . Федулов	слес. 6р.		


С Новым
Годом !!!

PNPI in HERMES analysis

П. Кравченко	*Δq(x) helicity distributions final analysis;*
Ю. Нарышкин	*Hyperon production at HERMES, transverse hyperon polarization;*
Д.Веретенников	*KLL DLL in Λ-photoproduction*
С. Манаенков	*polarized vector ρ, φ meson production ;*
С.Белостоцкий	*Sivers function from photoproduction (A_{UT} for pion and kaon)*
А. Киселев	*Data production (alignment, HRC)*

HERMES COMPASS $\Delta\Sigma$ festival !!!

HERMES

at $Q_0^2 = 5\text{GeV}^2$ $x_{min} = 0.023$

$$\Delta\Sigma = 0.330 \pm 0.025(\text{exp.}) \pm 0.033(\text{theo.})$$

$$(\Delta s + \Delta\bar{s}) = -0.085 \pm 0.008(\text{exp}) \pm 0.013(\text{theo.})$$

COMPASS

at $Q_0^2 = 3\text{GeV}^2$ $x_{min} = 0.004$

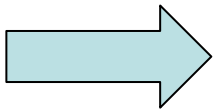
$$\Delta\Sigma = 0.33 \pm 0.01(\text{stat}) \pm 0.02(\text{syst})$$

$$(\Delta s + \Delta\bar{s}) = -0.08 \pm 0.01(\text{stat}) \pm 0.02(\text{syst})$$

Evaluation/summary on ΔΣ

	CQM	Jaffe SR	HERMES experiment
$a_0 = \Delta\Sigma$	1	$a_8 = 0.59$	0.33 ± 0.02
$\Delta u + \Delta\bar{u}$	$\frac{4}{3}$	$(a_8 + a_3)/2 = 0.93$	0.84 ± 0.01
$\Delta d + \Delta\bar{d}$	$-\frac{1}{3}$	$(a_8 - a_3)/2 = -0.34$	-0.43 ± 0.01
$\Delta s + \Delta\bar{s}$	0	0	-0.09 ± 0.01

How sensitive to SU(3)??



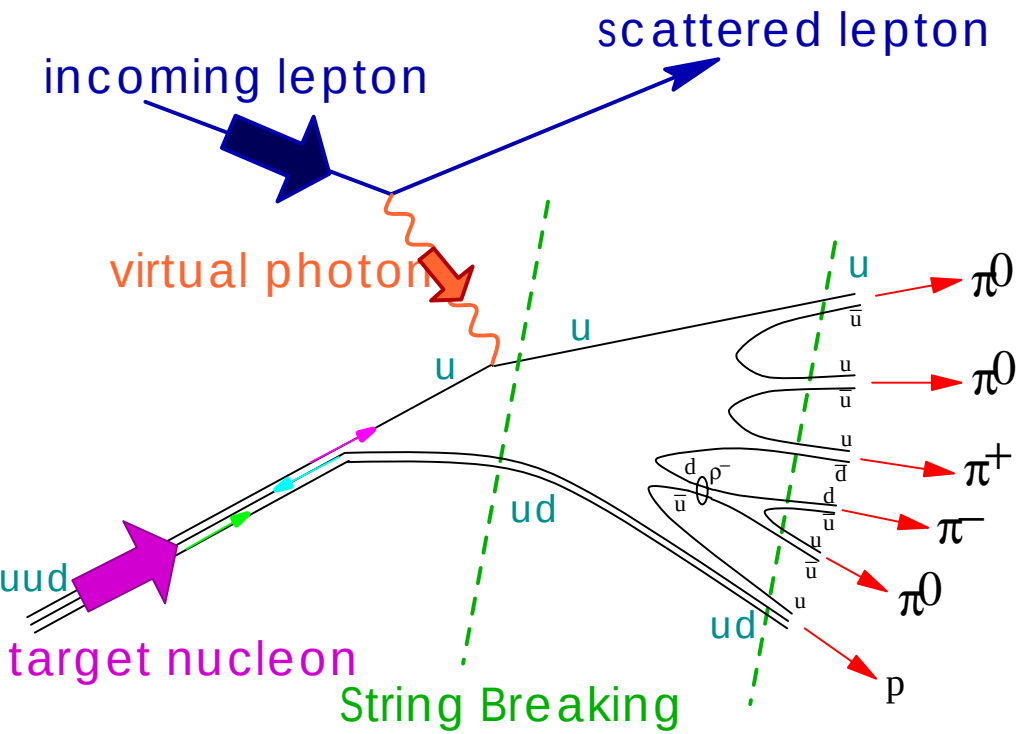
D.De Florian et al Phys.Rev.D 2005

Recent fit Inclusive +semi-inclusive data without SU(3) gives $0.284 < \Delta\Sigma < 0.311$

Quark helicity distributions from semi-inclusive DIS

$$\vec{e} + \vec{p},\vec{d} \Rightarrow e' + h + X \quad at\ Q^2 > 1GeV$$

semi-inclusive case



FF q to hadron

$$A_1^h = \frac{\sum_q e_q^2 \Delta q(x,Q^2) D_q^h(Q^2,z)}{\sum_{q'} e_{q'}^2 q(x,Q^2) D_{q'}^h(Q^2,z)}$$

new variable

$$z = \frac{E^h}{\nu}$$ hadron fractional energy

Quark polarizations, first moments and ΔΣ

Quark polarization

Polarized PDF

$$\frac{q(x,\mu)\Uparrow\uparrow - q(x,\mu)\Uparrow\downarrow}{q(x,\mu)\Uparrow\uparrow + q(x,\mu)\Uparrow\downarrow} = \frac{\Delta q(x,\mu)}{q(x,\mu)} \qquad \mu^2 = Q^2$$

Unpolarized PDF

Contribution to proton (hadron) spin from a given quark flavor is given by first moments of Δq(x)

$$\Delta q = \int_{x=0}^{x=1} dx \cdot q(x) \cdot \frac{\Delta q(x)}{q(x)} \equiv \int_{x=0}^{x=1} dx\, \Delta q(x)$$

Full quark contribution to proton (hadron) spin

$$S_z = \frac{1}{2} = \frac{1}{2}\Delta\Sigma \quad \text{or}$$

$$\Delta\Sigma = \sum_q \Delta q = (\Delta u + \Delta\bar{u}) + (\Delta d + \Delta\bar{d}) + (\Delta s + \Delta\bar{s}) = 1$$

$\Delta\Sigma$ from inclusive DIS

Phys. Rev. D 2007

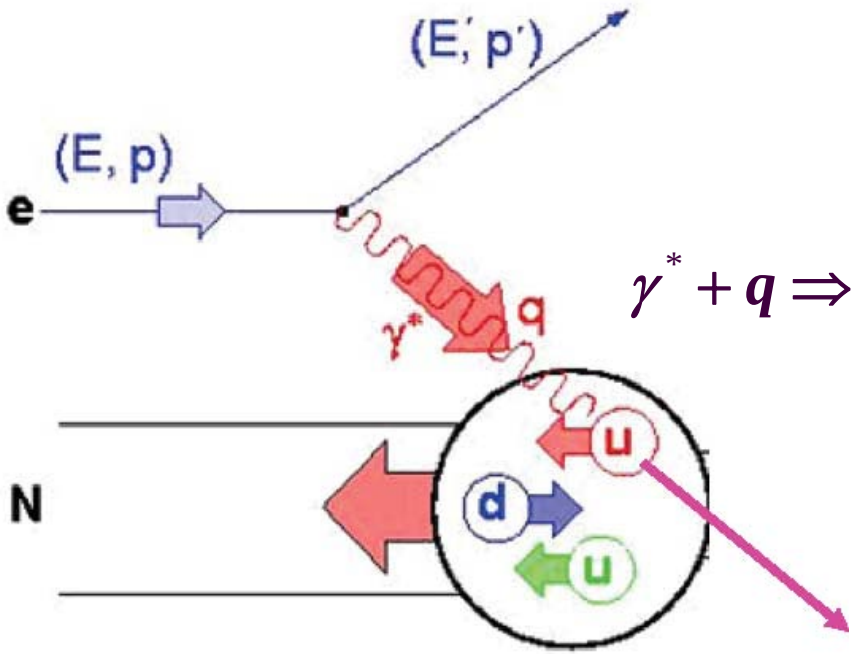
Only scattered electron (muon) detected

$$\vec{e} + \vec{p}, \vec{d} \Rightarrow e' + X \quad at\ Q^2 > 1 GeV$$

LO

Measured in DIS are structure functions

$$\begin{cases} g_1(x,Q^2) = \frac{1}{2}\sum_{q.\bar{q}} e_q^2 \Delta q(x,Q^2) \\ F_1(x,Q^2) = \frac{1}{2}\sum_{q.\bar{q}} e_q^2 q(x,Q^2) \end{cases}$$



$$\gamma^* + q \Rightarrow q^{current}$$

DIS kinematics in Lab frame

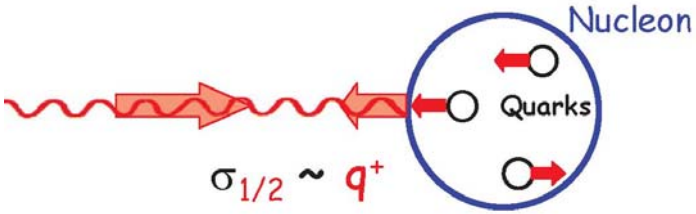
$$\nu = E - E' \quad \vec{q} = \vec{p}' - \vec{p}$$

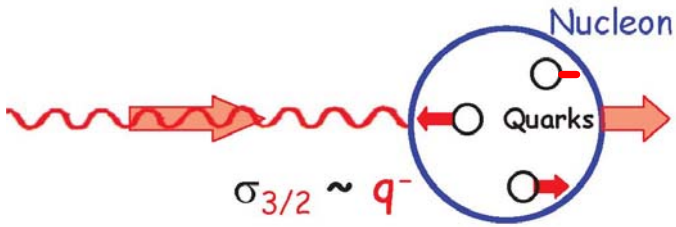
$$Q^2 = -q^2$$

$$x = \frac{Q^2}{2M\nu}$$

$$\nu \to \infty \quad x \to 0$$

Double-spin asymmetry





$$\sigma_{1/2} \sim q \Uparrow\uparrow$$

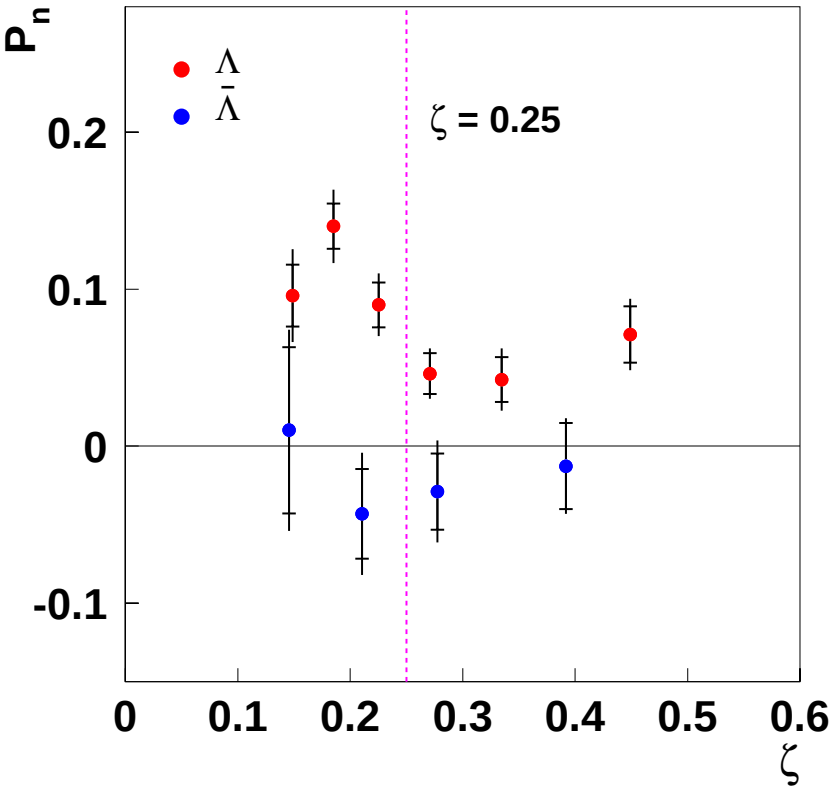
$$\sigma_{3/2} \sim q \Uparrow\downarrow$$

$$(\gamma^{*}\,\textit{nucleon})\,\textit{asymmetry} \quad A_1(x) = \frac{\sigma_{1/2} - \sigma_{3/2}}{\sigma_{1/2} + \sigma_{3/2}} \approx \frac{g_1(x)}{F_1(x)}$$

Transverse Λ polarization

Phys Rev. D 2007 Yuri N+Denis V

First solid obsevation in lepto/photoproduction !!



$$N(\Lambda) = 259 \cdot 10^3$$

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

$$N(\bar{\Lambda}) = 51 \cdot 10^3$$

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

$$\varsigma \simeq \frac{E_{\Lambda}}{E_{beam}}$$

- Polarization of Ξ hyperons
- Spin transfers KNN, KLL, DLL
- A-dependence of P_{Λ} is under study

} In progress

Scintillators and accessories: *Available in April*

BC-408 1400mm*100mm*15mm, edges DTF - one plate - 800 USD
BC-408 1400mm* 50mm*15mm, edges DTF - one plate - 656 USD
BC-408 1000mm*100mm*15mm, edges DTF - one plate - 572 USD

BC-600 optical cement, 250 ml - one ~ 100 USD
BC-630 Silicon Optical Grease, 60 ml, - one ~ 100 USD
----

total ~2228 USD
(~1790Euro)

The prices for the Scintillators are from the BICRON offer
The prices for the accessories - by estimation

PMT with (divider, housing...) *Available*

Hamamatsu H6533 (1") - 4 PMT 4*1848=7392 Euro
Hamamatsu H2431-50 (2") - 2 PMT 2*2278=4556 Euro

PMT total 11948 Euro

Cost estimation

- Materials:	Bicron BC408 scintillator bar 140*10*1.5 cm^3		~ 670 €
	Bicron BC408 scintillator bar 140*5*1.5 cm^3		~ 550 €
	Bicron BC408 scintillator bar 100*10*1.5 cm^3		~ 480 €
	optical cement, etc.		~ 150 €
- PMT:	Hamamatsu R2083, diameter -2”, 2 pmt		~ 7400 €
	Hamamatsu R4998, diameter -1”, 4 pmt		~ 4560 €
- Electronics:	TDC, Phillips 7186, CAMAC,	1 module	~ 4000 €
	ADC, Phillips 7166, CAMAC,	1 module	~ 4000 €
	NIM to CAMAC, Phillips 433,	5 module	~ 1000 €
	Preamplifier, ORTEG 9306,	2 module	~ 2000 €
	CDF, ORTEG 935,NIM,	1 module	~ 3000 €
	TAC, ORTEG 567, NIM,	2 module	~ 6000 €
	Quard 8k ADC AD 4BA, CAMAC,	1module	~ 3000 €
- Oscilloscope:	Tektronics TDS5104B, 1GHz		~15000 €
- Total:			~ 52160 €

To summarize, TOF

needs for identification of forward going charged particles detected by FS with momenta below 4-5 GeV/c. TOF resolution ~50 ps.

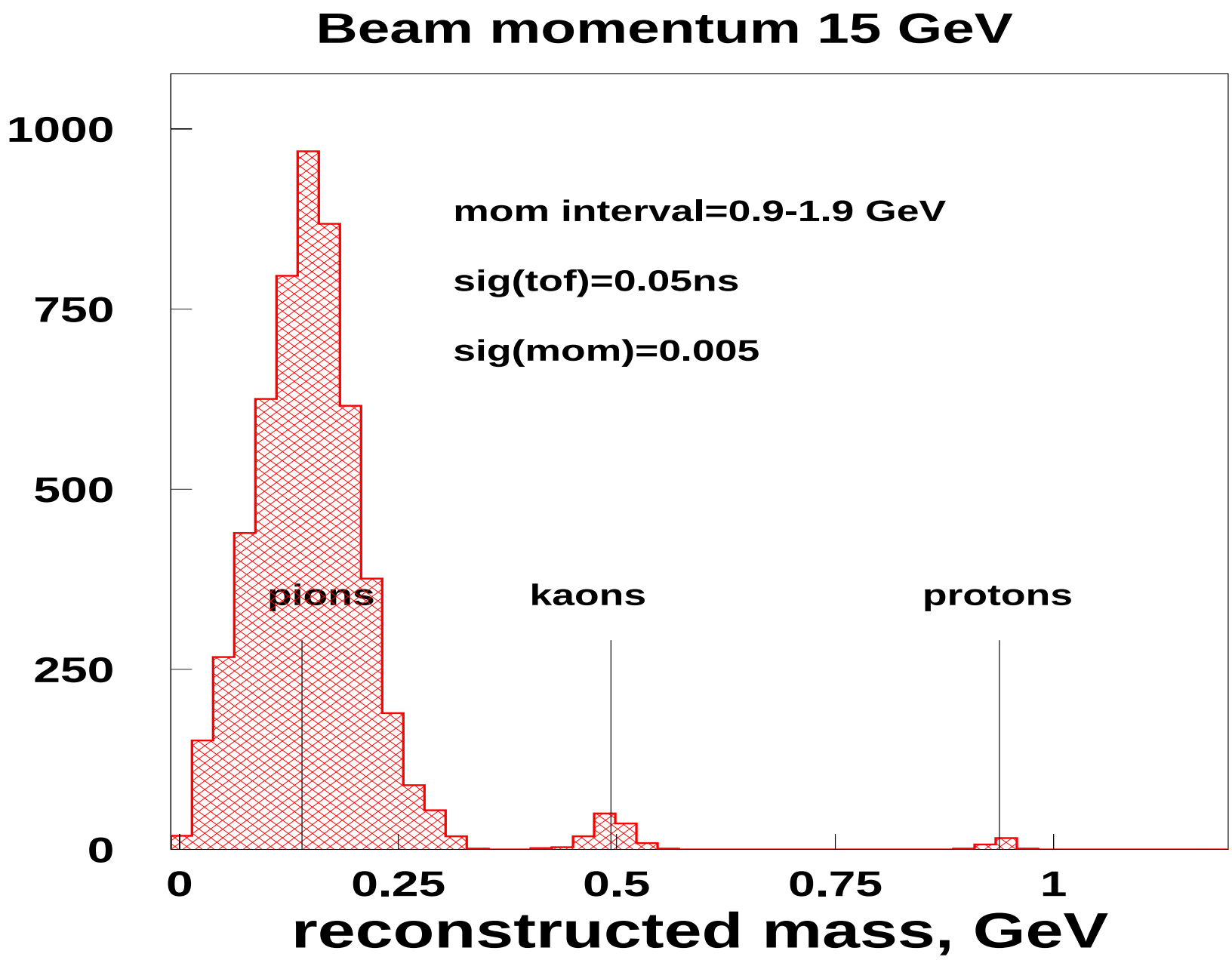
consist of

- scintillation wall (1.4*5.6 m^2, 66 strips, 132 PMT)
- side-TOF, inside the dipole magnet -two (1*1 m^2, 5 strips 10 PMT)

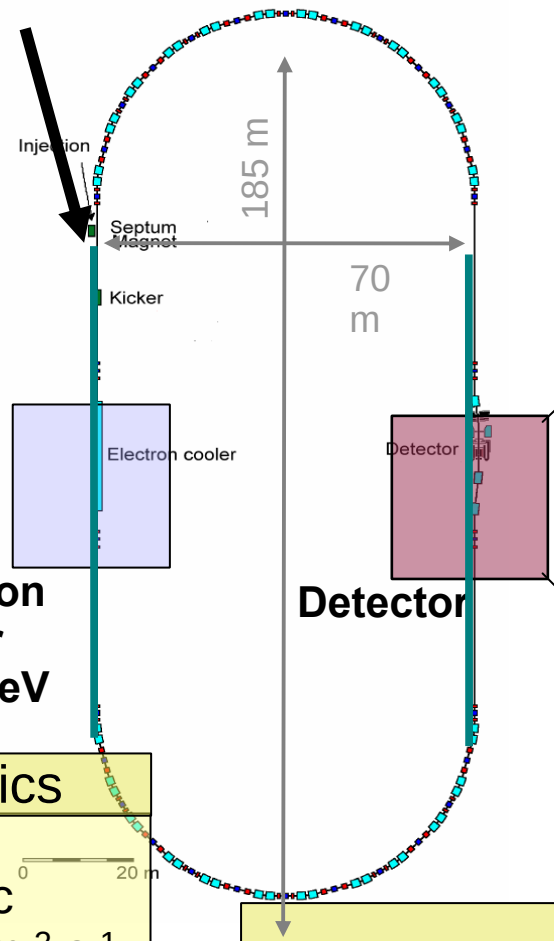
Cost estimation ***(not final)***

- materials (scintillators, light-guides, optical cement..)	– 43000 €
- PMT (PMT, housings, dividers, μ-metal shielding,…)	– 170000 €
- electronics (TDC, CFD, VME crates, …..)	– 120000 €
- HV power supply, cabling	– 60000 €
- Support structure	– 20000 €
- Test stand	– 35000 €
total	– 448000 €

Final request 989 KEU


Beam momentum 15 GeV
1000
750
500
250
0
mom interval=0.9-1.9 GeV
sig(tof)=0.05ns
sig(mom)=0.005
pions
kaons
protons
0
0.25
0.5
0.75
1
reconstructed mass, GeV

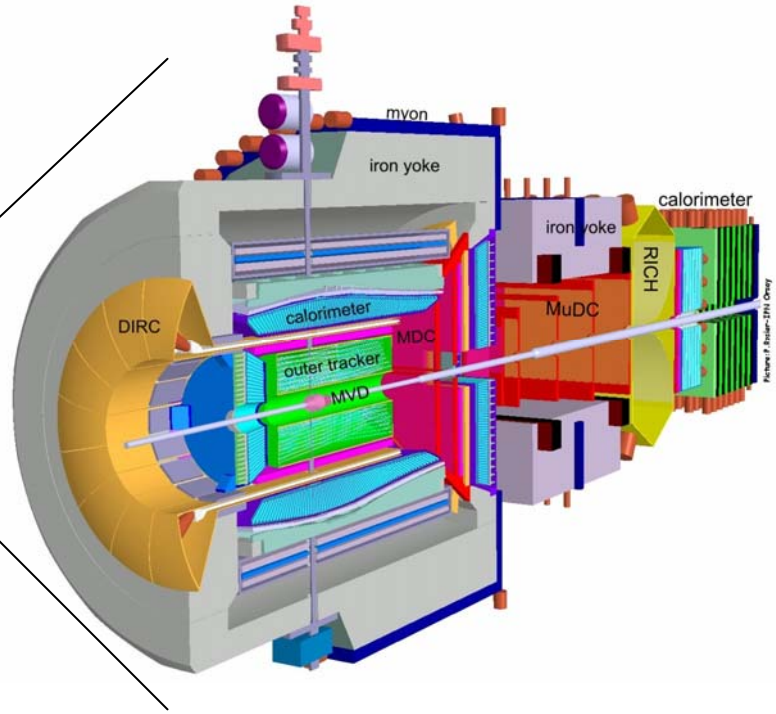
High Energy Storage Ring



HESR

Electron cooler E<8 GeV

Detector



Characteristics

P_{max} = 15 GeV/c
L_{max} = $2 \cdot 10^{32}$ cm^{-2} s^{-1}
Ø < 100 μm
δp/p < 10^{-5}
internal target

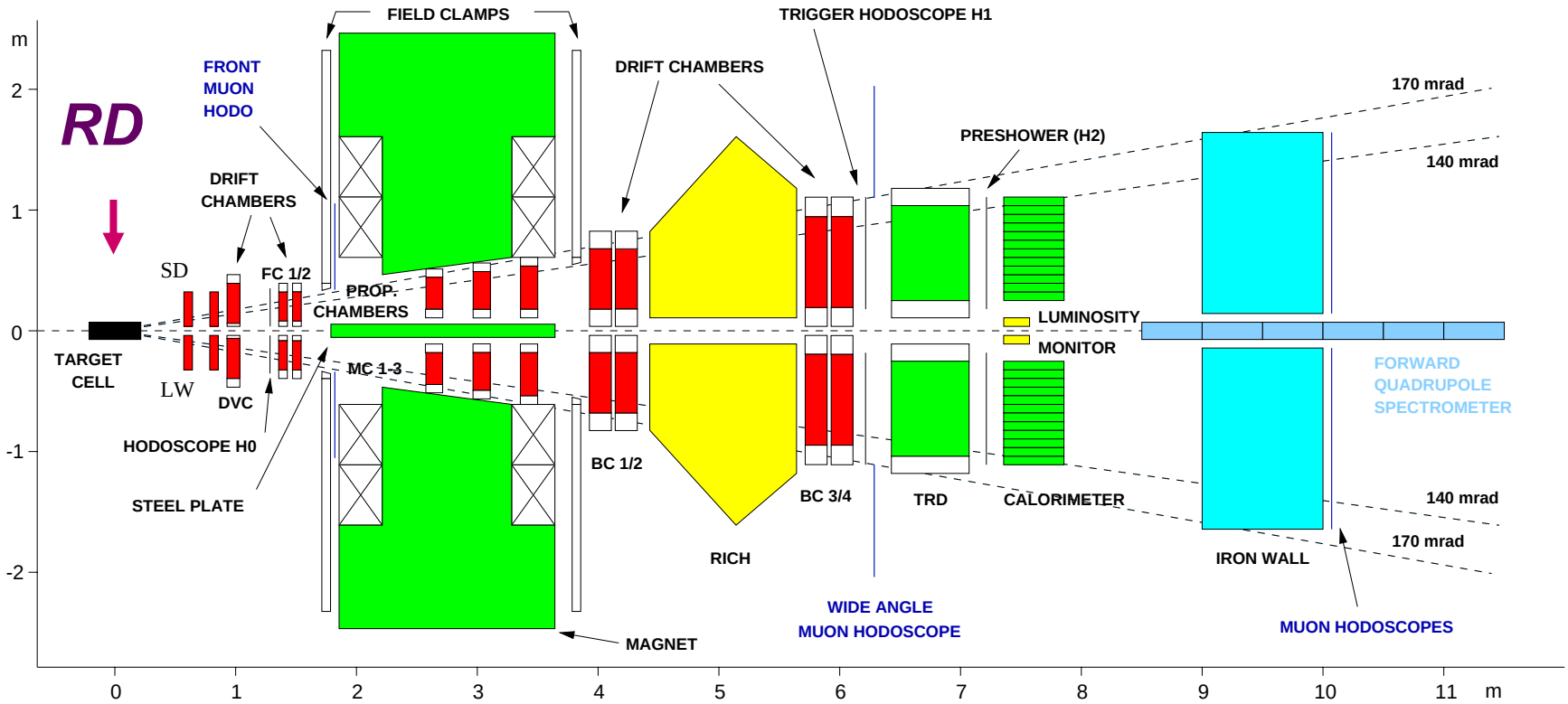
electron cooling

High resol. Mode: L = 10^{31} cm^{-2} s^{-1} δp/p < 10^{-5}
High lum. Mode: L = $2 \cdot 10^{32}$ cm^{-2} s^{-1} δp/p < 10^{-4}

Hermes spectrometer

E_e=27.5 GeV , polarized P_b≈50% (longitudinal)

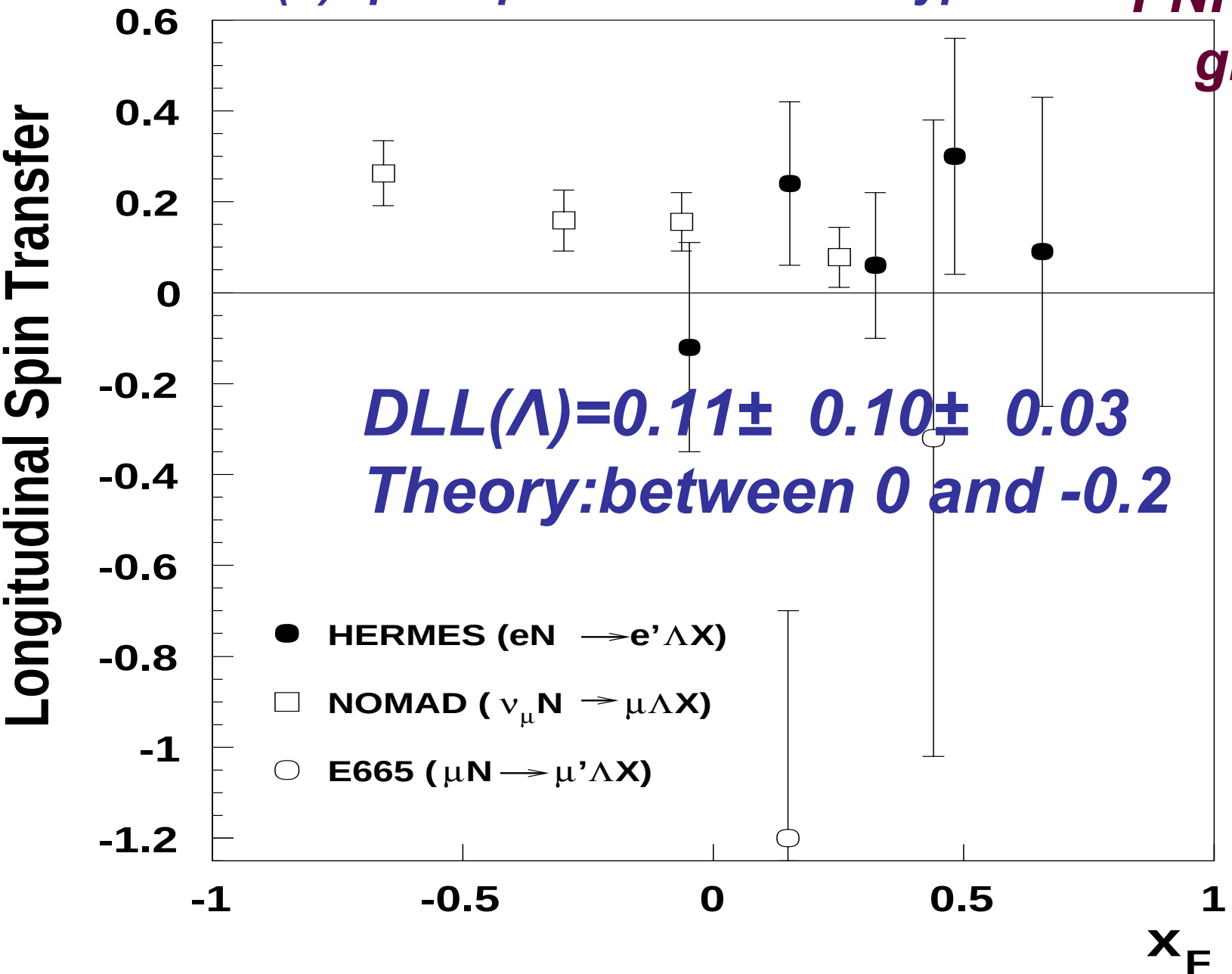
Polarized H2,D2 gas target,P_t~90%, longitudinal and transverse, unpolarized A target



Spin-transfer in DIS, published in PRD 2006

u (d)-quark polarization in Λ hyperon

PNPI/China groups



DLL(Λ)=0.11± 0.10± 0.03

Theory:between 0 and -0.2

Summary of HERMES data-taking with polarized targets

1994 HERMES test RUN

1995-2000 HERMES RUN I

Beam pol. =51%

Lumi H,D pol.=259 pb-1

Lumi unpol. = 593 pb-1

(H,D, ^{3}He, ^{4}He, ^{14}N, ^{20}Ne and ^{84}Kr)

Longitudinal polarization

year	type	target polar. %
1995	^{3}He	46
1996	H	76
1997	H	85
1998	D	86
1999	D	83
2000	D	84.5

2001-2002 HERA lumi upgrade

2002-2007 HERMES RUN II

Beam pol. =36%

Lumi H pol.=161 pb-1

Lumi unpol. ~ 530 pb-1

Transverse polarization

years	type	polar.%
2002-2005	H	78

2006-2007 unpol. (RD)

EMC (1988) experiment and spin crisis

DIS of polarized muons on polarized target

$$\Delta\Sigma = 0.12 \pm 0.09 \pm 0.14 \neq 1 \text{ !!!}$$

Jaffe sum rule based on SU(3) f.s. and assumption Δs=0

Hyperon ß-decay

$$\Delta\Sigma = 3F - D = 0.586 \pm 0.031 \approx 0.6$$

to date sum rule

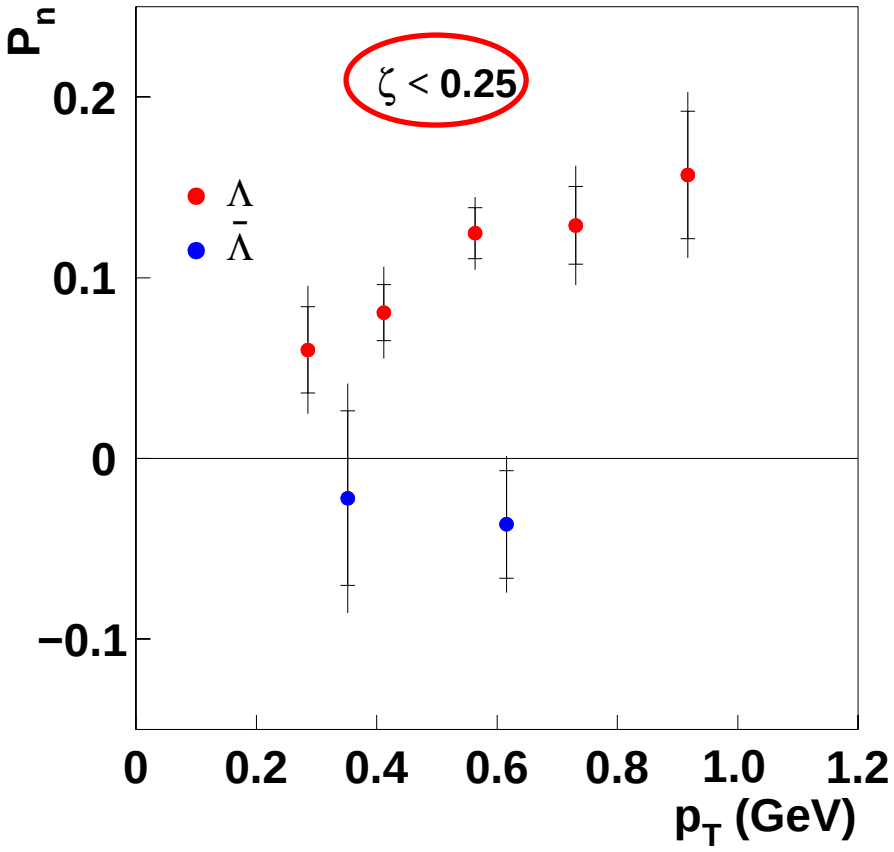
$$S_z = \frac{1}{2} = \frac{1}{2}\Delta\Sigma + \Delta G + L_q + L_g \quad (\text{slow function of } \mu)$$

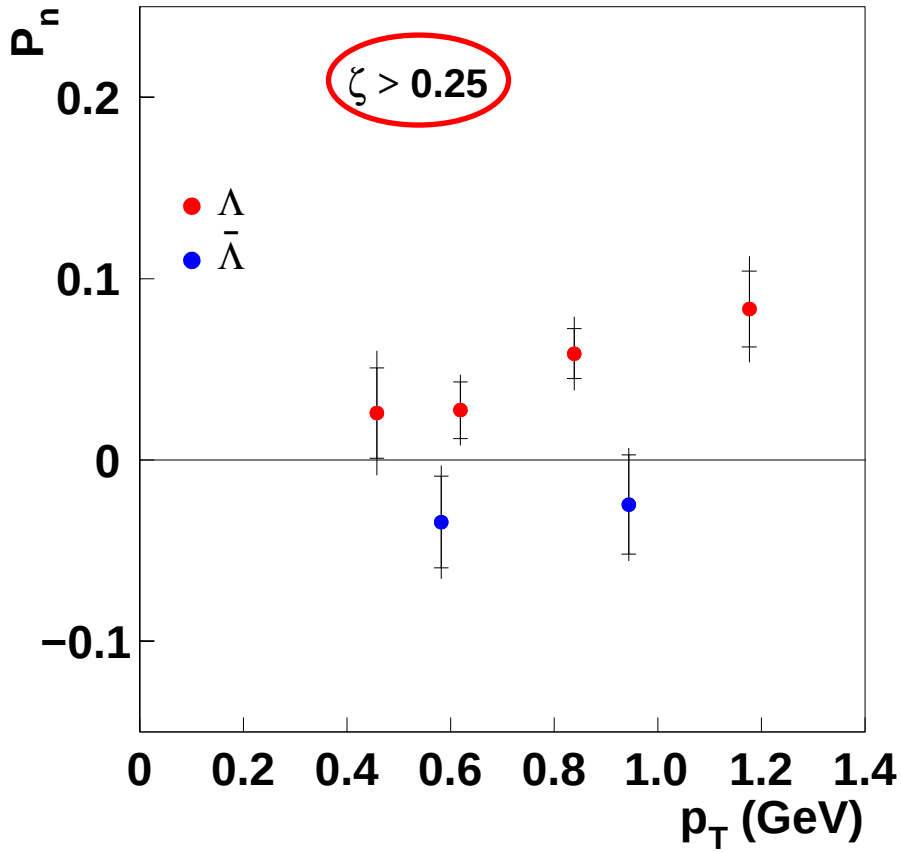
quarks gluons orbital motion

Transverse Λ polarization, P_T dependence

Phys Rev. D 2007 (accepted)

First solid observation in lepto/photoproduction !!

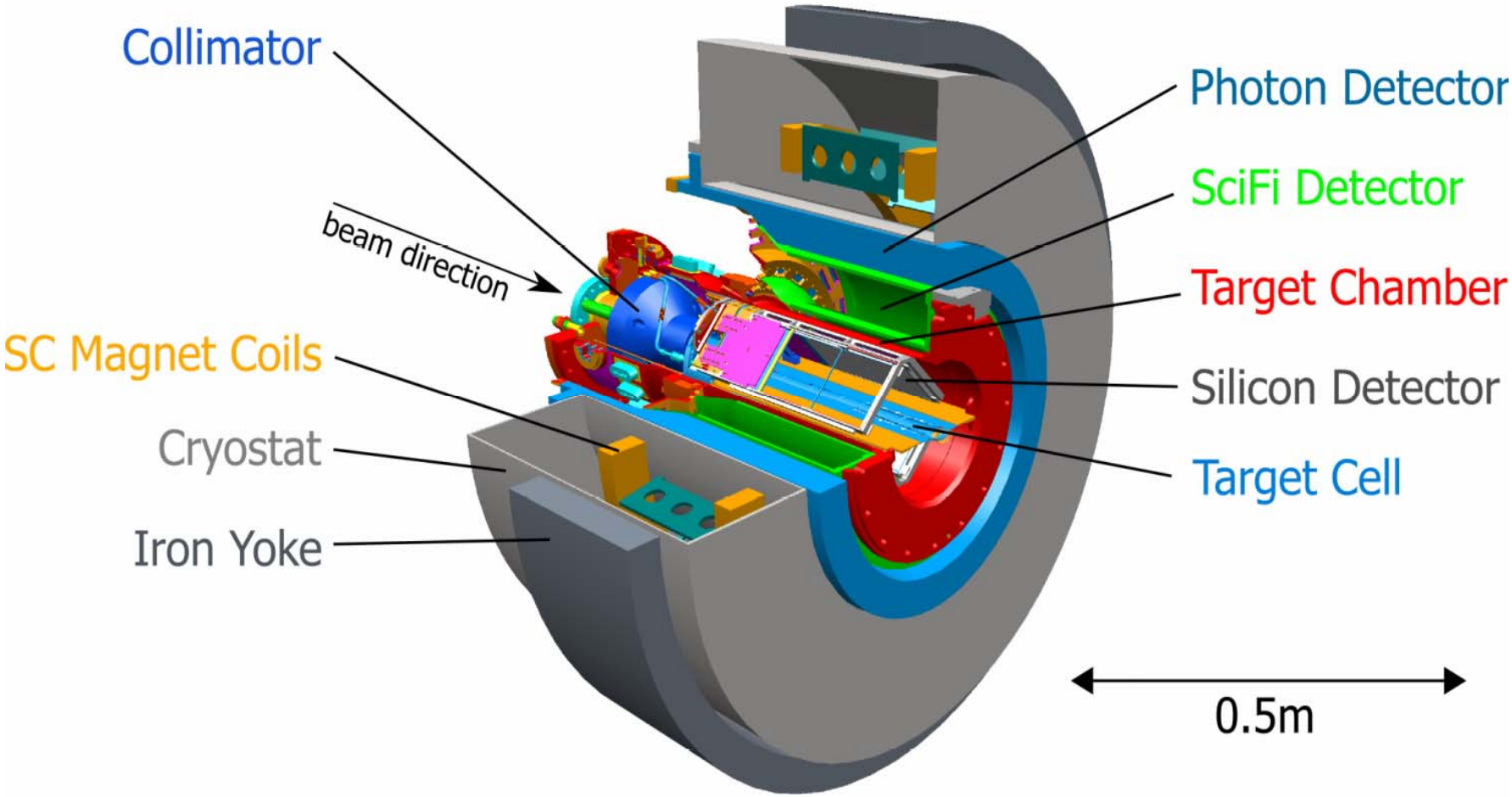




Transverse Λ polarization is larger at low Λ momenta

→ *indication of diquark fragmentation mechanism DM model*

The HERMES Recoil Detector



transverse Λ polarization

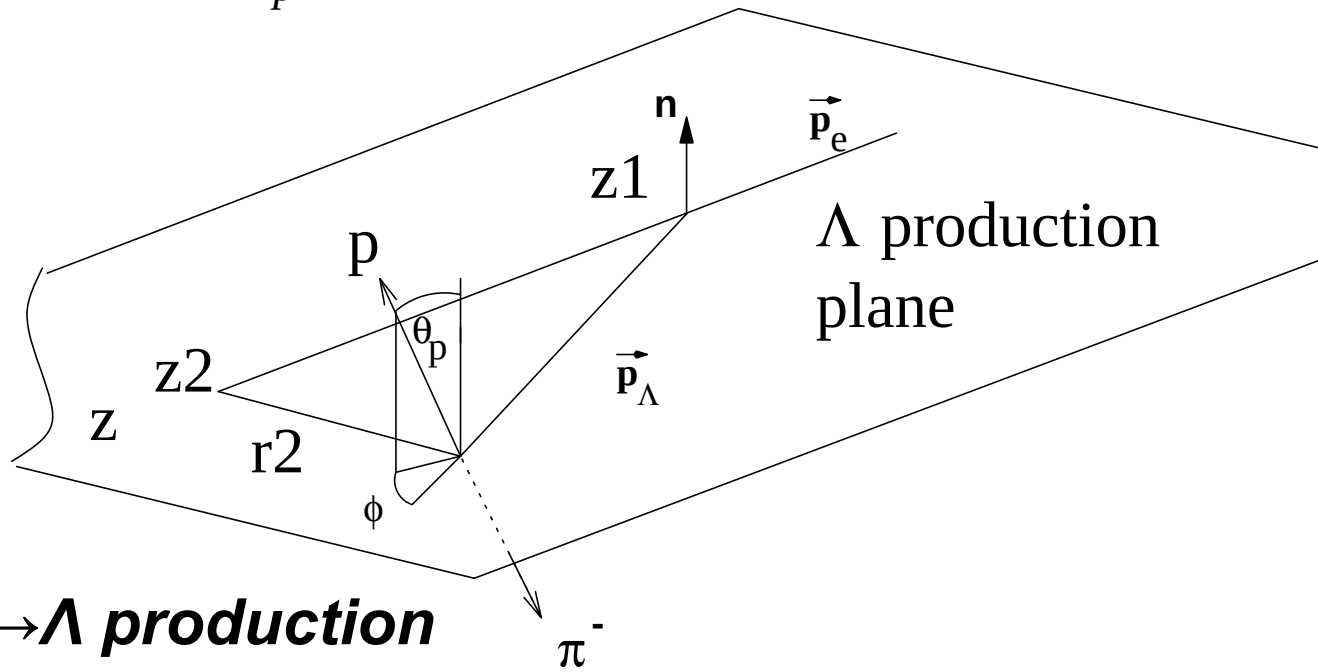
$$\overrightarrow{P_\Lambda} = P_\Lambda \cdot \vec{n}, \quad \vec{n} = \frac{\vec{p}_e \times \vec{p}_\Lambda}{\left|\vec{p}_e \times \vec{p}_\Lambda\right|}$$

Polarized Λ decay (Λ rest frame)

$$\frac{dN}{d\Omega_p} = \frac{dN_0}{d\Omega_p}(1 + \alpha P_\Lambda \cos\theta_p)$$

$\alpha = 0.642$ for Λ

$\alpha = -0.642$ for $\overline{\Lambda}$



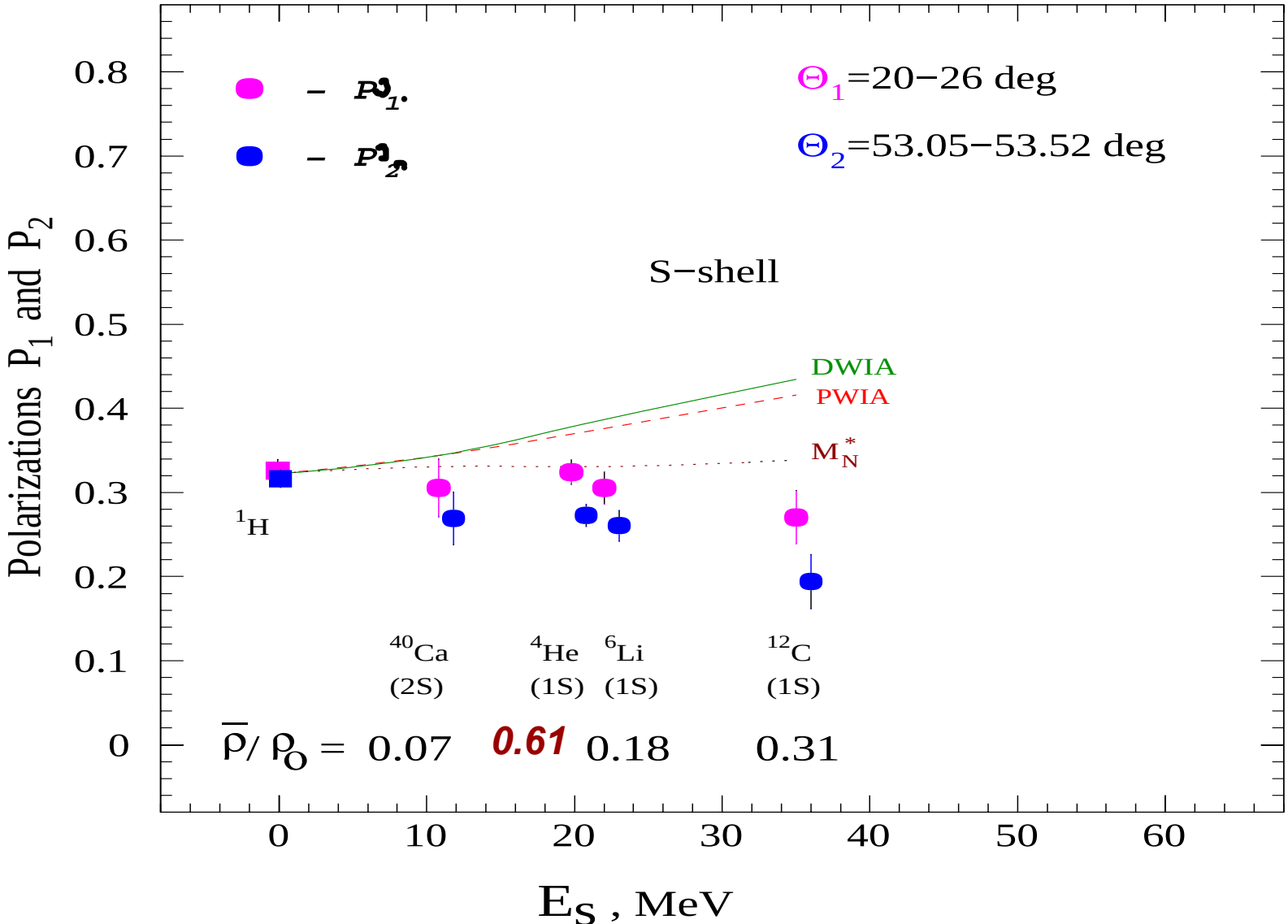
ϕ →**decay plane position**

$\cos\Phi = \vec{n} \cdot \vec{n}_y$ →**Λ production plane position**

Влияние ядерной среды на PN амплитуду

Олег М+Noro

Published in ЯФ 2006

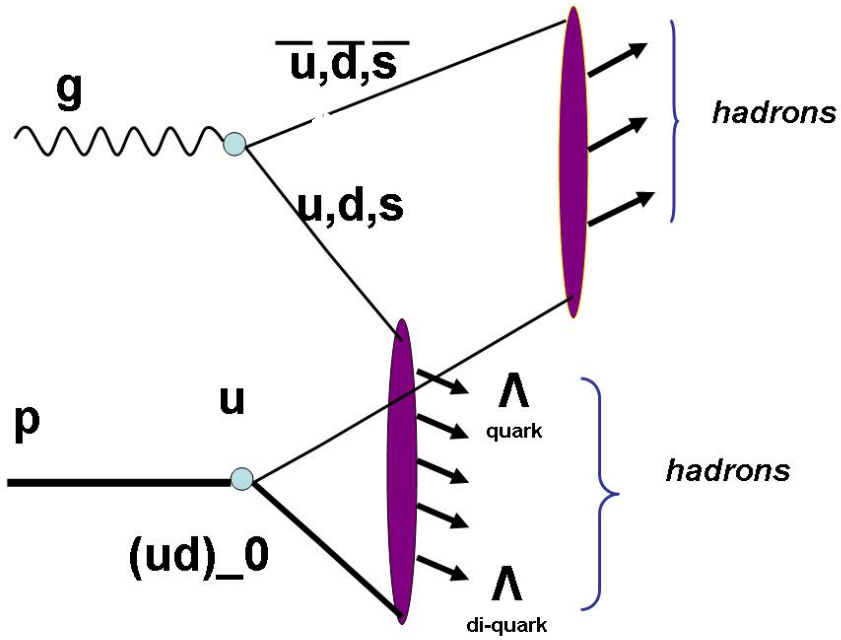


Transverse Λ polarization

$$\gamma(E_\gamma \approx 20\text{GeV}) + \text{P/D} \rightarrow \Lambda\Uparrow + \text{X}$$

Hyperon polarization in hadron collision is well-known phenomenon: 30 years ago in Fermilab P+Be→Λ(↑)+X studied. Then $\bar{K}$+ P →Λ(↑)+X , $\sum$ +P →Λ(↑)+X , etc. But no data in lepto/photoproduction(!)

typical PITHIA mechanism



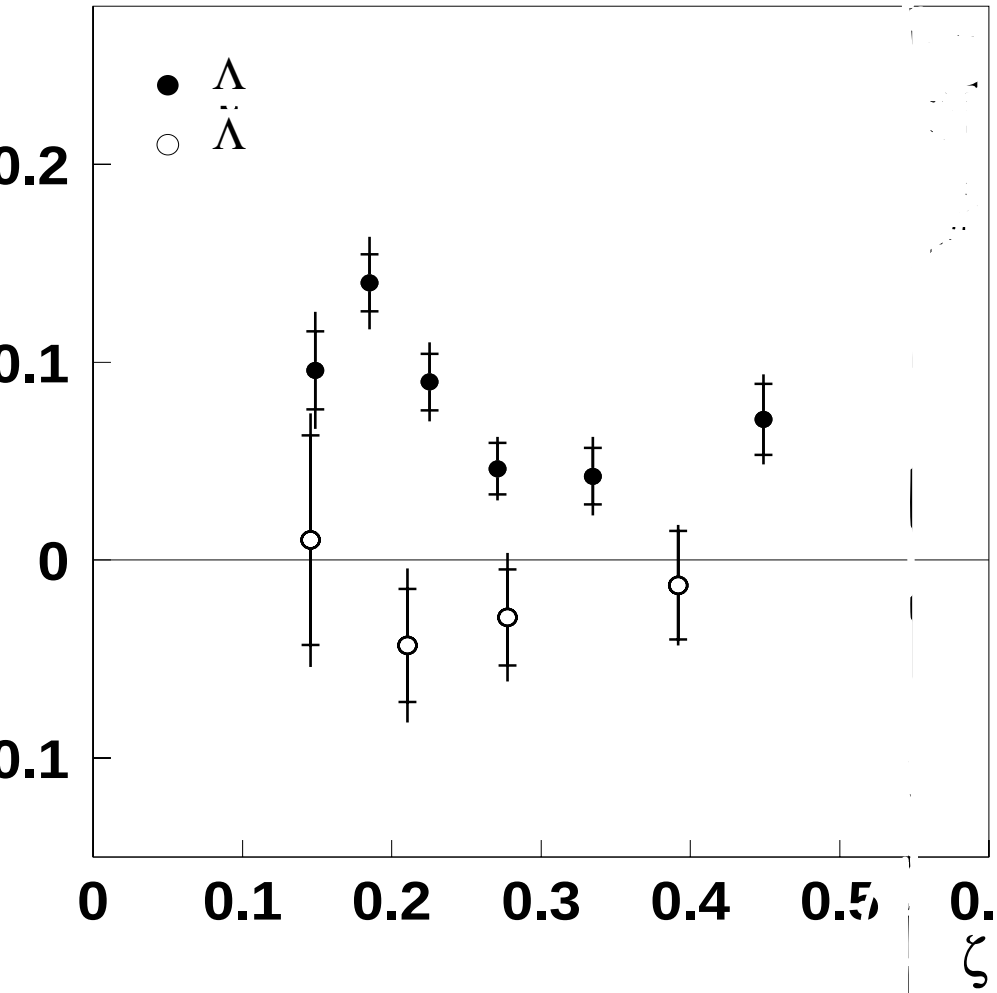
$$\Lambda\Uparrow = (ud)_0 + s\Uparrow \qquad \Lambda\Uparrow = \text{u} + (\text{ds})_{0,1} \qquad \bar{\Lambda}\Uparrow = \bar{\text{u}} + (\bar{\text{d}}\bar{\text{s}})_{0,1}$$

dominates *or* $\Lambda\Uparrow = \text{d} + (\text{us})_{0,1}$ *.....etc.*

Юрий Нарышкин, С.Б. + A.Andrus, Makin

final

polarization



Λ to $\bar{\Lambda}$ yield