Summary of the Spin Physics working group

Experimental part

Sergey Yaschenko
DESY Zeuthen

On behalf of the Spin Physics working group conveners

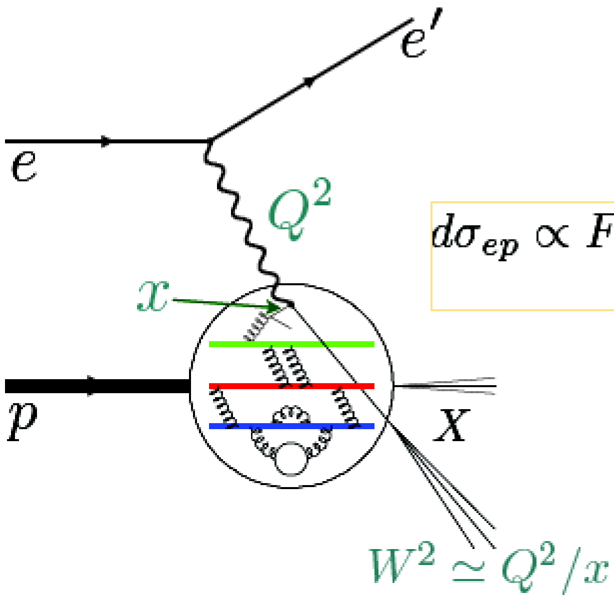
Outline

- Parton helicity distributions
- Transverse momentum dependent parton distributions (TMDs)
- Generalized parton distributions (GPDs)

Parton helicity distributions

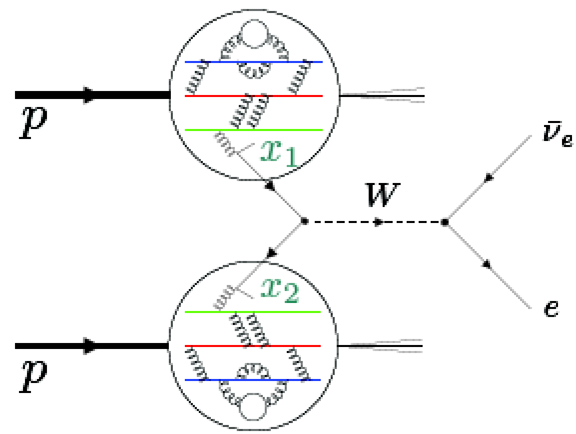
- COMPASS: Marcin Stolarski, *New COMPASS Results on Polarized Parton Distributions inside Nucleon*
- COMPASS: Christian Höppner, *Cross section for quasi-real photoproduction of charged hadrons with high* p_T *in μ-d scattering*
- HERMES: Polina Kravchenko, *Longitudinal semi-inclusive double-spin asymmetries at HERMES*
- PHENIX: Young Jin Kim, *W Physics in Polarized Proton-Proton Collisions at PHENIX*
- PHENIX: Scott Wolin, *Recent Results of Double Helicity Asymmetries at PHENIX*
- STAR: Bernd Surrow, *Recent STAR results on jet and W production of the high-energy polarized p+p program at RHIC at BNL*
- BELLE: Martin Leitgab, *Measurement of Hadron Fragmentation Functions (FFs) at Belle*

Quark flavor structure



$$d\sigma_{ep} \propto F_2 = \sum_q x e_q^2 f_q(x)$$

Universality



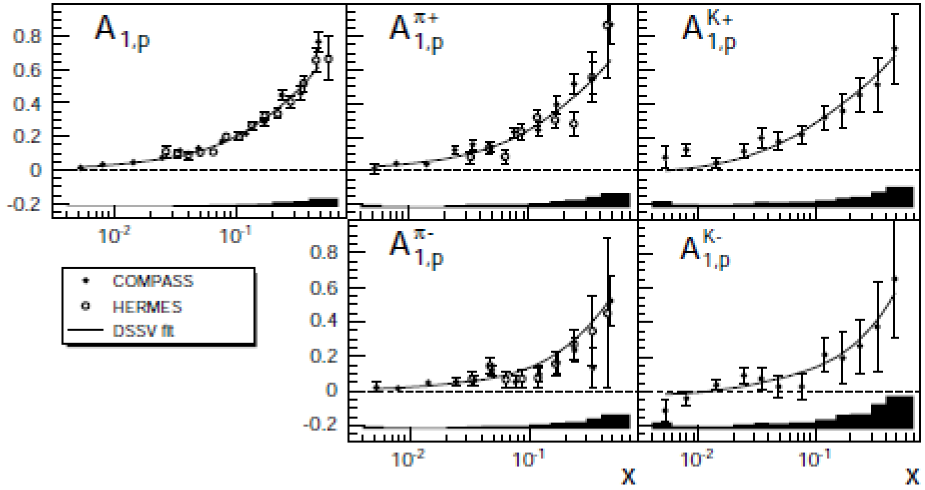
$$d\sigma_{pp} \propto f_1 \otimes f_2 \otimes \sigma_h \otimes D_f^h$$

Factorization

- courtesy of Bernd Surrow -

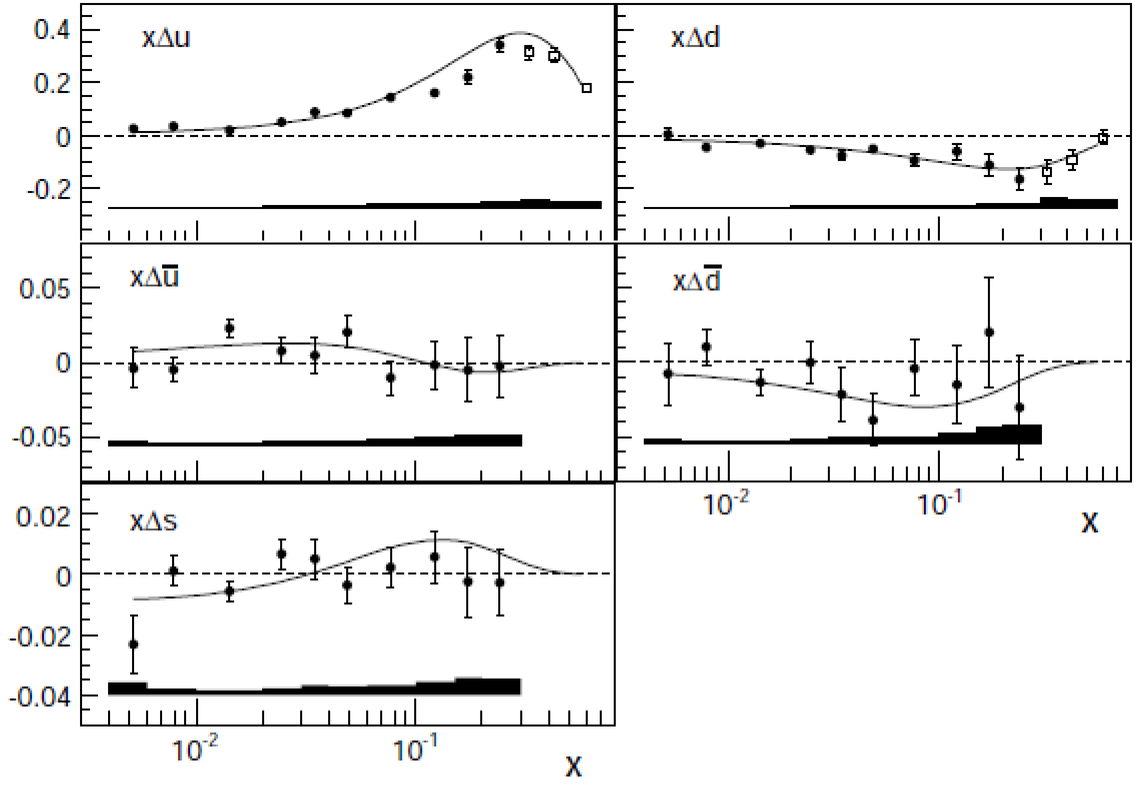
Semi-Inclusive Asymmetries

- semi-inclusive asymmetries were measured on both p and d targets
- for the first time Kaon asymmetries were measured on p target
- in the LO approximation $A_1^h(x,Q^2,z) = \frac{\sum_q e_q^2 \Delta q(x,Q^2) D_q^h(z,Q^2)}{\sum_q e_q^2 q(x,Q^2)}$
- D_q^h are fragmentation Functions (FF) of quark q into hadron h
- with 10 asymmetries ($A_{1p,d}^{incl}, A_{1p,d}^{\pi\pm}, A_{1p,d}^{K\pm}$) and 5 unknown parameters ($\Delta u, \Delta d, \Delta \bar{u}, \Delta \bar{d}, \Delta s$) a flavor separation is possible



LO Flavour Separation

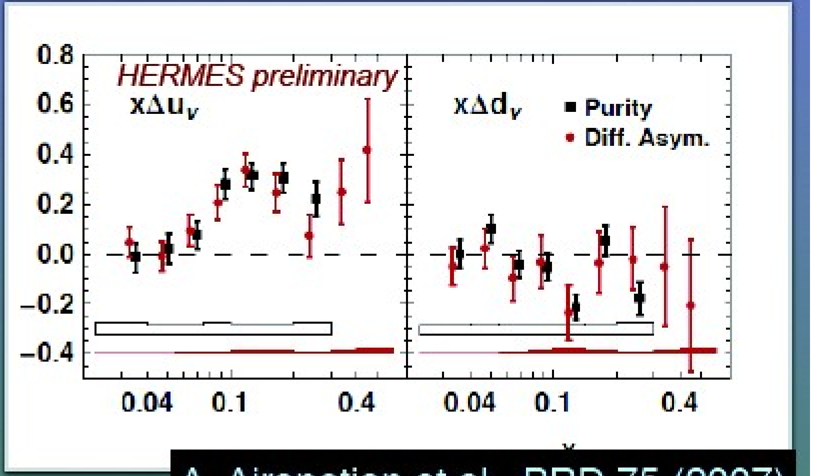
- results are published in PLB 693 (2010) 227
- curves are DSSV NLO parametrization Phys. Rev. Lett. 101 (2008) 072001; Phys. Rev. D80 (2009) 034030.
- good agreement between COMPASS data and DSSV parametrization



Valence helicity distributions

Separation of quark contributions into valence and sea quark contributions

- LO parton model
- Charge conjugation
- No MC usage
- The contribution of fragmentation functions drop out



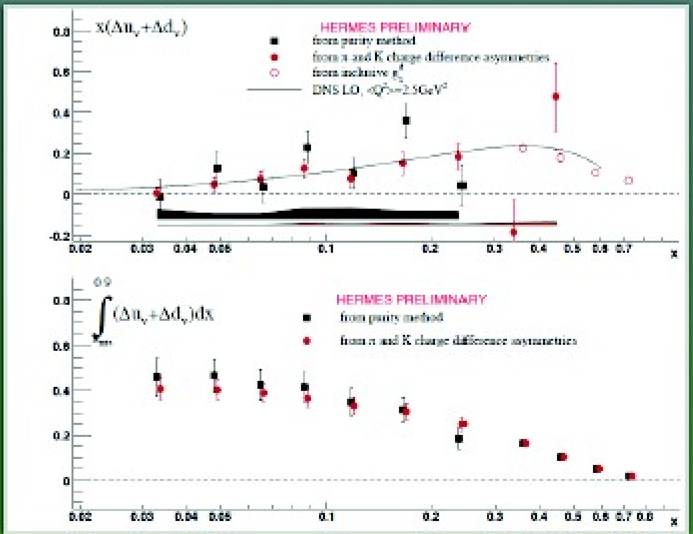
A. Airapetian et al., PRD 75 (2007)

Proton target:

$$A_{1p}^{h^+-h^-} = \frac{4\Delta u_v - \Delta d_v}{4u_v - d_v}$$

Deuteron target:

$$A_{1d}^{h^+-h^-} = \frac{\Delta u_v + \Delta d_v}{u_v + d_v}$$



Cos ϕ moments of A_{LL}

The possible contributions to the DIS cross section in the semi-inclusive measurement

$$\sigma^h = \sigma^h_{UU} + \lambda_l \sigma^h_{LU} + S_L \sigma^h_{UL} + \lambda_l S_L \sigma^h_{LL} + S_T \sigma^h_{UT} + \lambda_l S_T \sigma^h_{LT}$$

two structure functions appear

$$S_L \lambda_l \left[\sqrt{1-\epsilon^2} F_{LL} + \sqrt{2\epsilon(1-\epsilon)} cos(\phi) F_{LL}^{cos\phi} \right.$$

ϕ angle is the azimuthal angle of the hadron plane around the virtual-photon direction

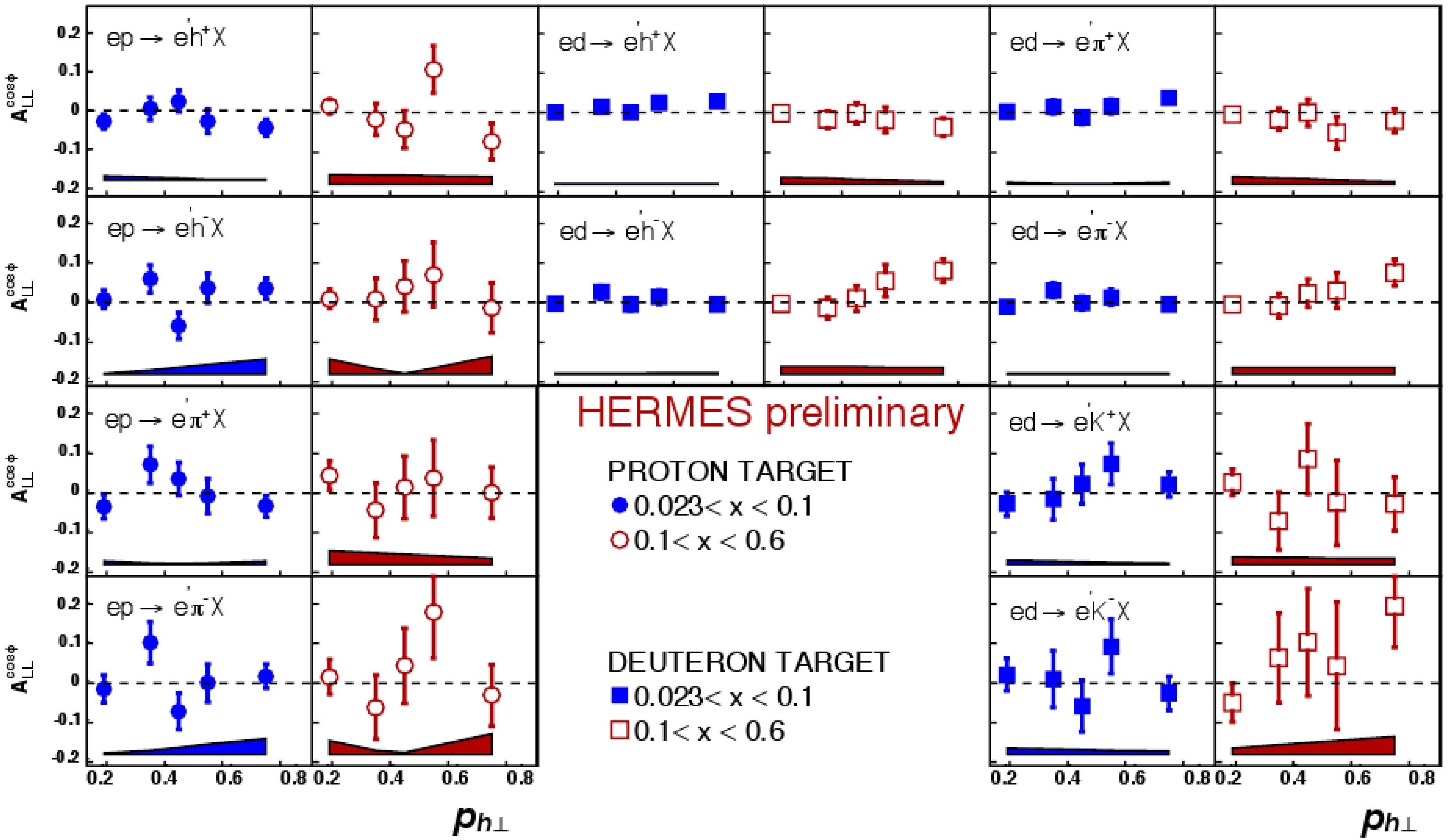
$$F_{LL}^{\cos\phi_h} \sim \frac{2M}{Q} C \left[-\frac{\hat{h} \cdot p_T}{M} x g_L^{\perp} D_1 \right]$$

Unintegrated helicity distributions $\Delta q(x, k_\perp)$

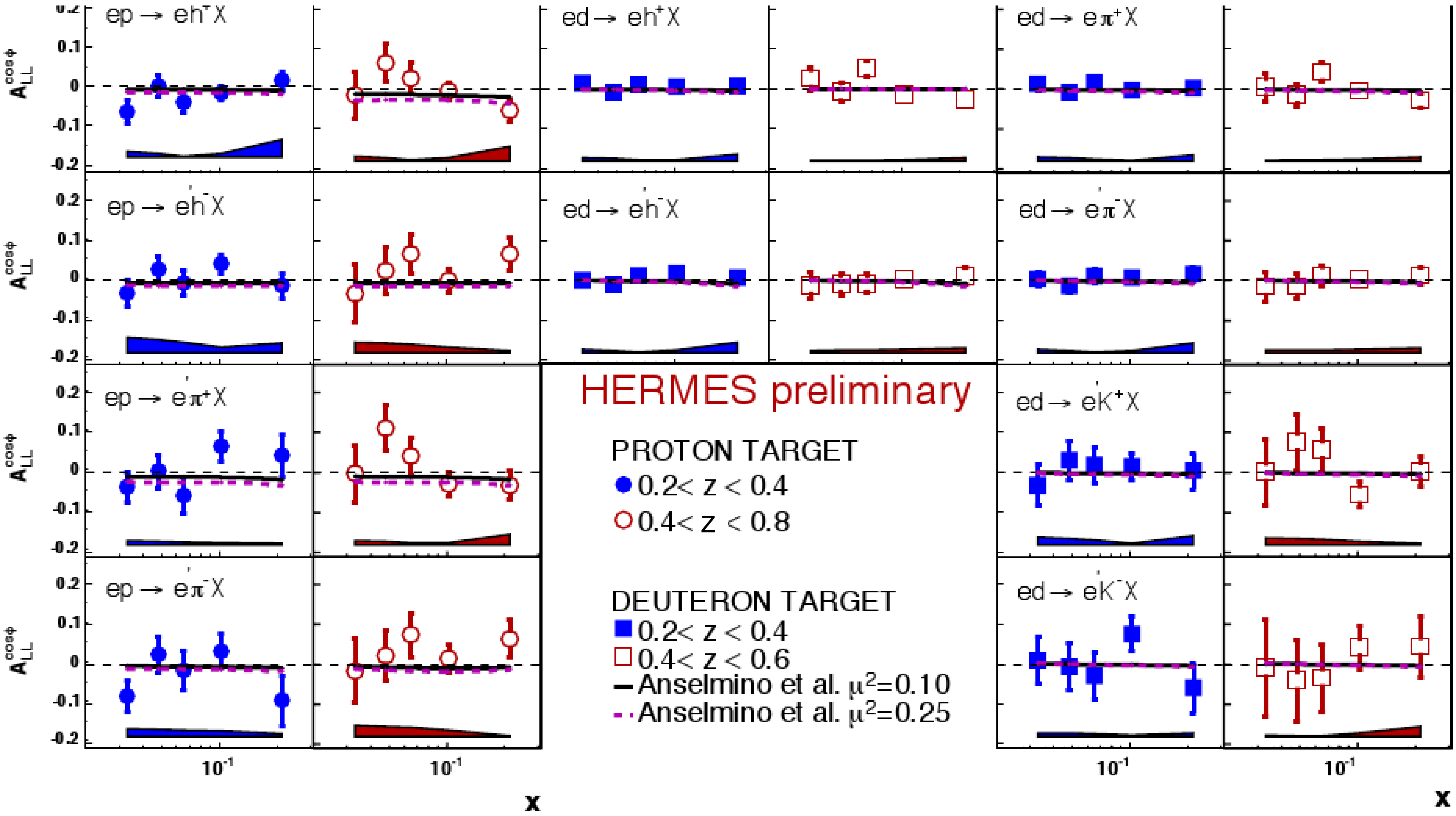
To access

$$A^h_{LL} = \frac{1}{\lambda_l S_L} \frac{d\sigma_h^{\overset{\rightarrow}{\Leftarrow}}(\phi) - d\sigma_h^{\overset{\rightarrow}{\Rightarrow}}(\phi)}{d\sigma_h^{\overset{\rightarrow}{\Leftarrow}}(\phi) + d\sigma_h^{\overset{\rightarrow}{\Rightarrow}}(\phi)} = A^h_{LL}(x, y, z, p_{h\perp}) + cos\phi A_{LL}^{cos\phi}(x, y, z, p_{h\perp})$$

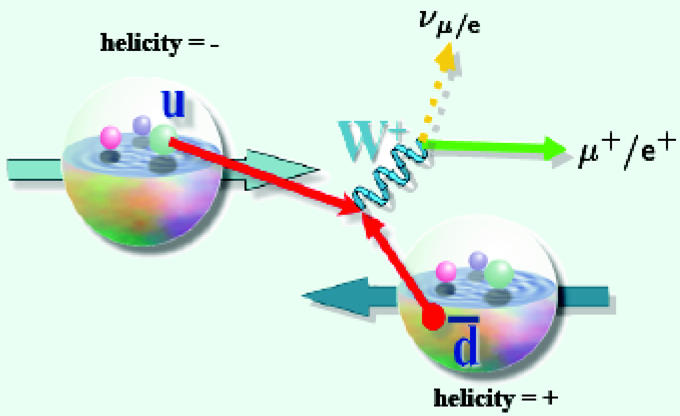
Cos ϕ moments of A_{LL} - HERMES: Polina Kravchenko -



Cos ϕ moments of A_{LL} - HERMES: Polina Kravchenko -



Parity violating W production - PHENIX: Young Jin Kim -



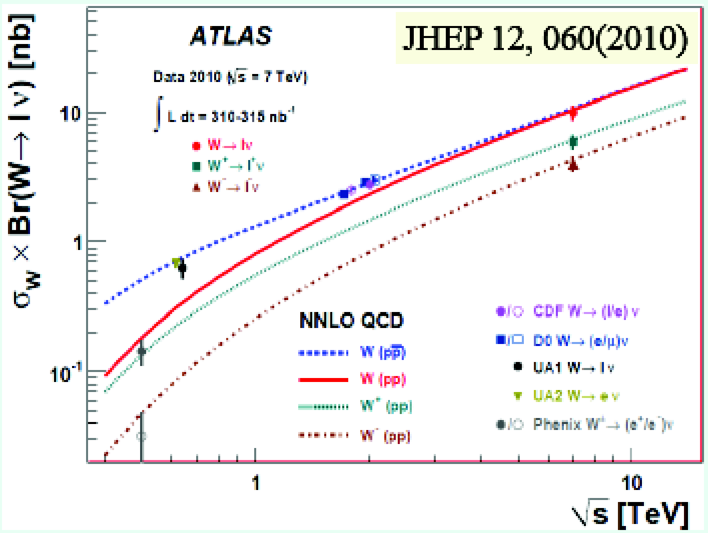
Single spin asymmetry for W^+

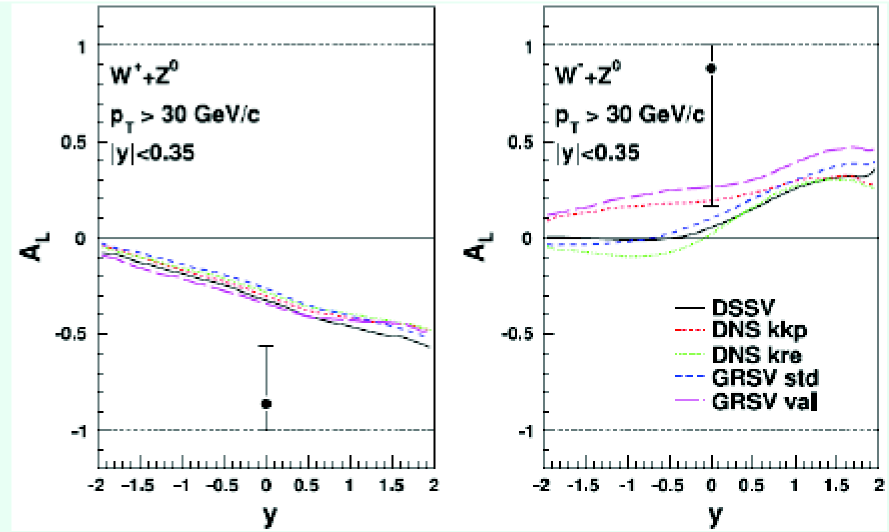
$$A_L^{W^+} = \frac{-\Delta u(x_a)\bar{d}(x_b) + \Delta\bar{d}(x_a)u(x_b)}{u(x_a)\bar{d}(x_b) + \bar{d}(x_a)u(x_b)}$$

$$x_a \gg x_b : A_L^{W^+} \approx \frac{-\Delta u}{u}(y^W \gg 0)$$

$$x_b \gg x_a : A_L^{W^+} \approx \frac{-\Delta\bar{d}}{\bar{d}}(y^W \ll 0)$$

- *W* boson production in $p + p$ collisions
  - ➡Parity violation of the weak interaction and u- & d-quark polarizations in proton
    - control over helicity states of colliding partons
  - ➡Large scale (~ m_W) and independent of knowledge of fragmentation
    - clean interpretation of the results in hard scattering QCD framework
- Asymmetry measurement of *W* boson production is ideal method
  - ➡Forward/backward muons
    - flavor separation
  - ➡High luminosity and longitudinally polarized $p + p$ collisions at 500 GeV (Experimental goal to achieve: integrated $\mathscr{L}$ = 300 pb^{-1}, polarization = 60%)
  - ➡Experimental issues of $W \rightarrow$ lepton
    - need good control of backgrounds at high P_T
      - incorrectly reconstructed high P_T, cosmic rays, beam background





PHENIX Collaboration: Phys. Rev. Lett. 106, 062001(2011)

$$\sigma(pp \to W^+X) \times \mathrm{BR}(W^+ \to e^+\nu_e) = 144.1 \pm 21.2(\mathrm{stat})^{+3.4}_{-10.3}(\mathrm{syst}) \pm 21.6(\mathrm{norm})\ \mathrm{pb}$$

$$\sigma(pp \to W^-X) \times \mathrm{BR}(W^- \to e^-\bar{\nu}_e) = 31.7 \pm 12.1(\mathrm{stat})^{+10.1}_{-8.2}(\mathrm{syst}) \pm 4.8(\mathrm{norm})\ \mathrm{pb}$$

- First measurement of $W^{\pm}$ cross section in $p + p$ collisions
  - -Good agreement between PHENIX and ATLAS data and NNLO pQCD calculations
- At 8.6 pb^{-1} with average polarization 0.39±0.04, we get

$$A_L^{e^+} = -0.86^{+0.30}_{-0.14}$$
$$A_L^{e^-} = 0.88^{+0.12}_{-0.71}$$

-Asymmetry is corrected for dilution by QCD backgrounds

A_L results from STAR

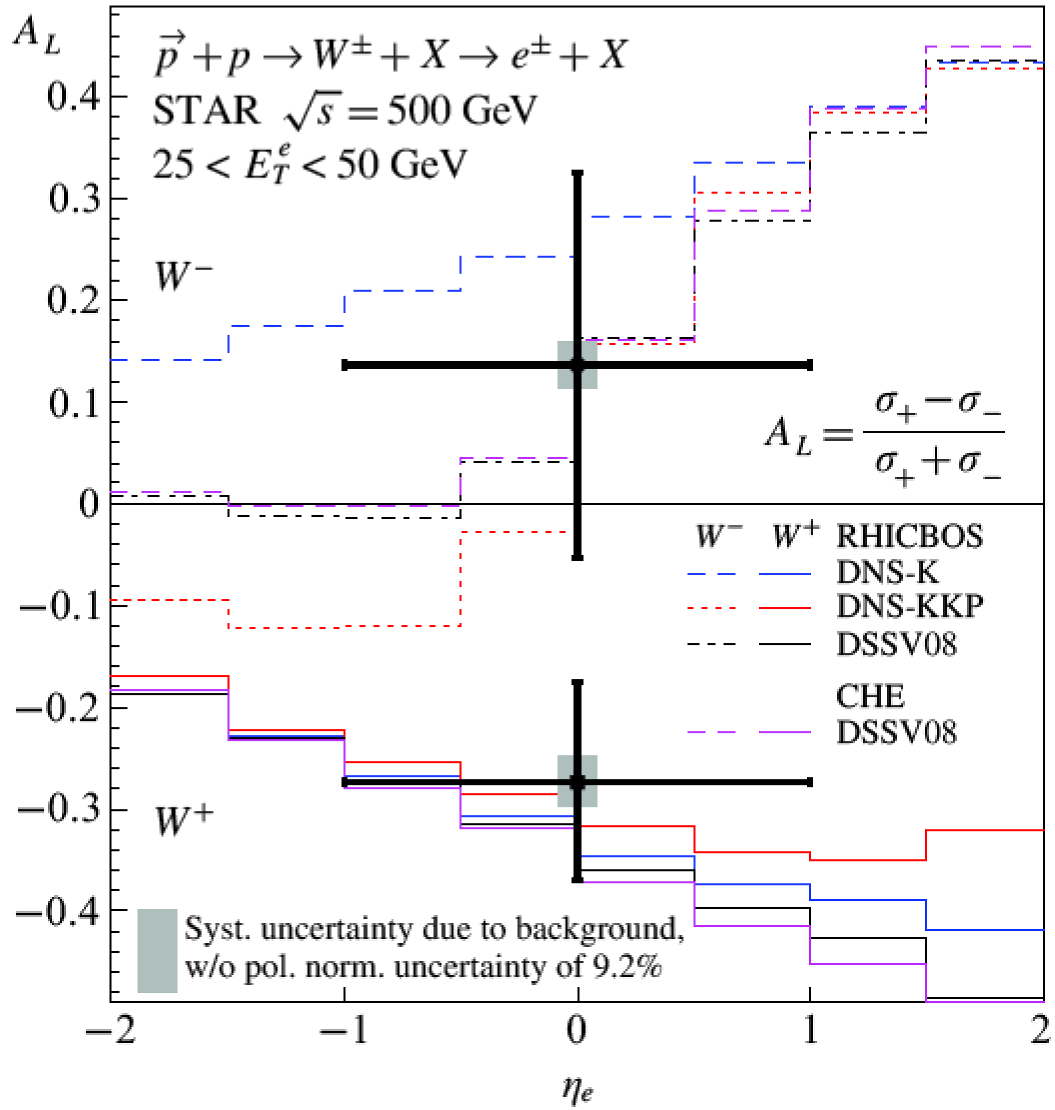
- First STAR A_L result

$$A_L^{W^-} = 0.14 \pm 0.19\ (\text{stat.}) \pm 0.02\ (\text{syst.}) \pm 0.01\ (\text{norm.})$$

$$A_L^{W^+} = -0.27 \pm 0.10\ (\text{stat.}) \pm 0.02\ (\text{syst.}) \pm 0.03\ (\text{norm.})$$

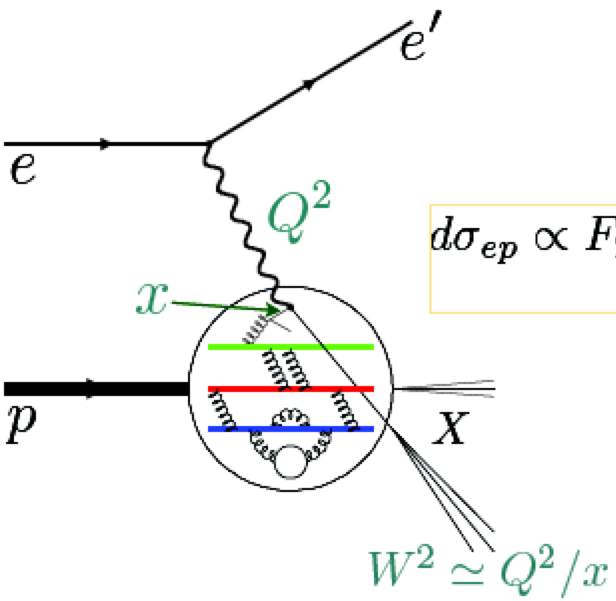
- $A_L(W^+)$ negative with a significance of ~3σ
- $A_L(W^-)$ central value positive
- Measured asymmetries are in agreement with theory evaluations using polarized pdf's (DSSV) constrained by polarized DIS data

⇒ Universality of helicity distr. functions!



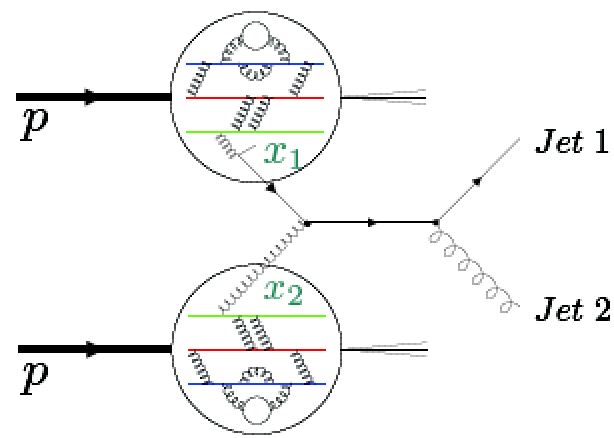
STAR Collaboration, PRL 106, 062002 (2011)

Gluon polarization



$$d\sigma_{ep} \propto F_2 = \sum_q x e_q^2 f_q(x)$$

Universality



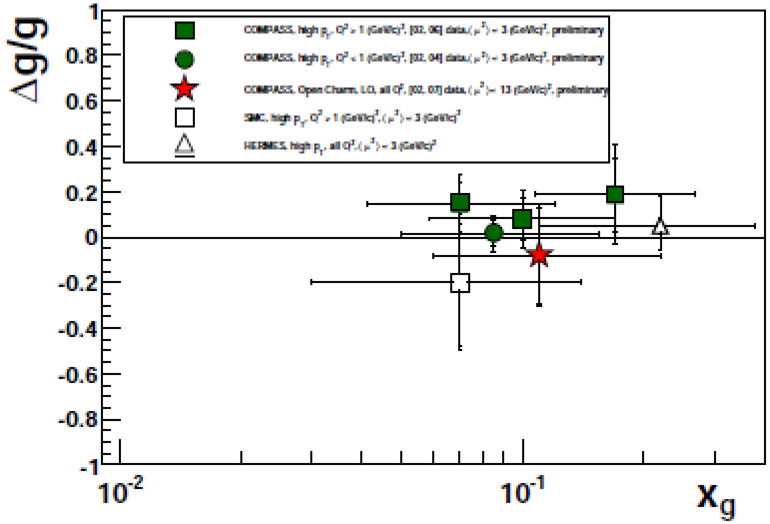
$$d\sigma_{pp} \propto f_1 \otimes f_2 \otimes \sigma_h \otimes D_f^h$$

Factorization

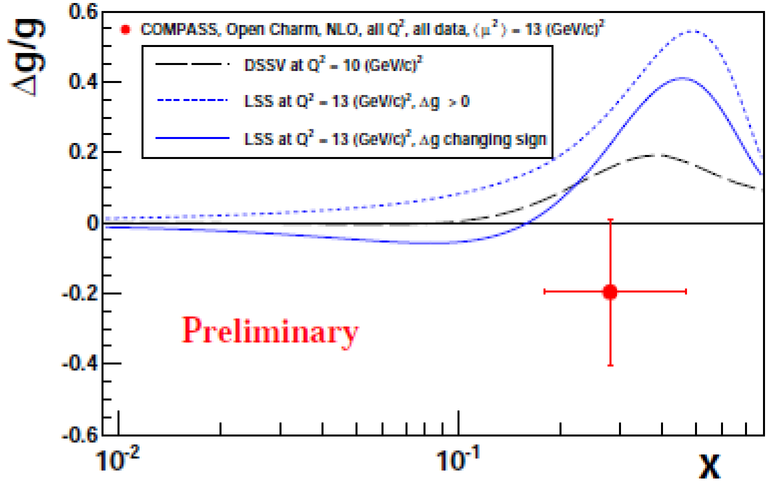
- courtesy of Bernd Surrow -

Summary of $\Delta G/G$ from COMPASS

LO



NLO

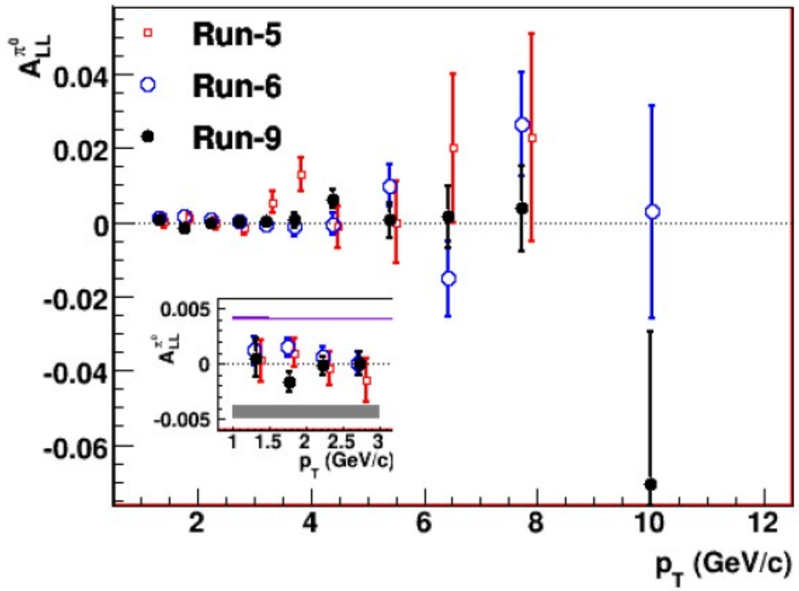


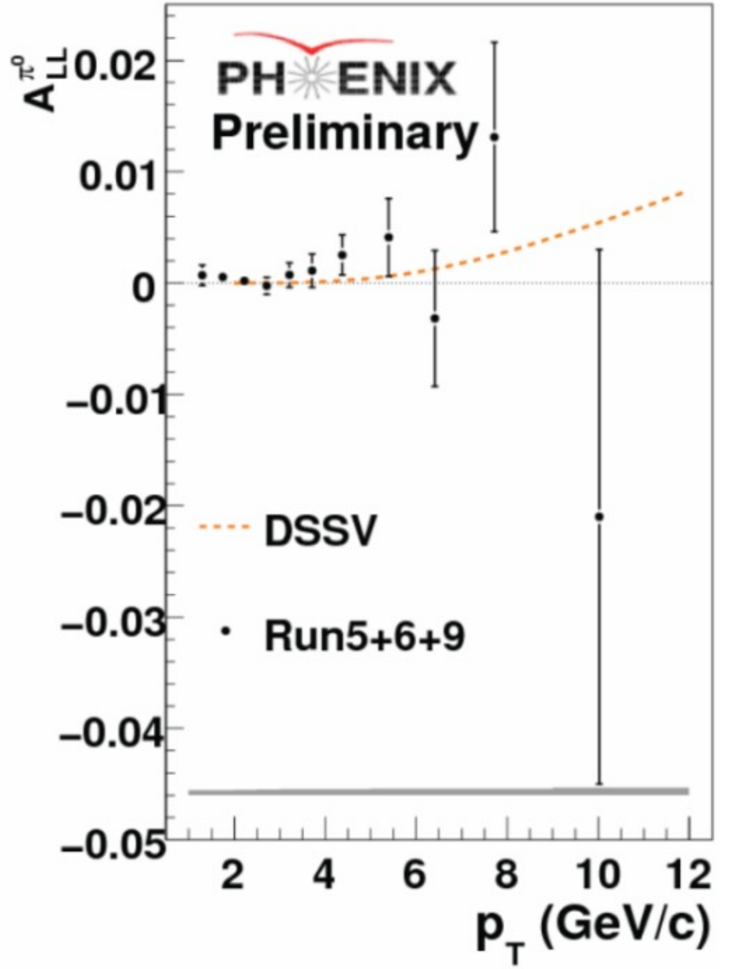
- all results agree with each other
- the ΔG is small, but the data are not precise enough to determine its sign

A_{LL}: π^0 Mid-rapidity $|\eta|<0.35$ - PHENIX: Scott Wolin -

Dataset	$\langle P_B \rangle$ (%)	$\langle P_Y \rangle$ (%)	$L_{analyzed}$ (pb^{-1})	FOM (P^4L)
Run5	50	49	2.5	0.15
Run6	56	57	6.5	0.66
Run9	**57**	**57**	**14**	**1.5**

- FOM increasing every year
- Combined asymmetries consistent with DSSV, and also with 0 to $O(10^{-3})$

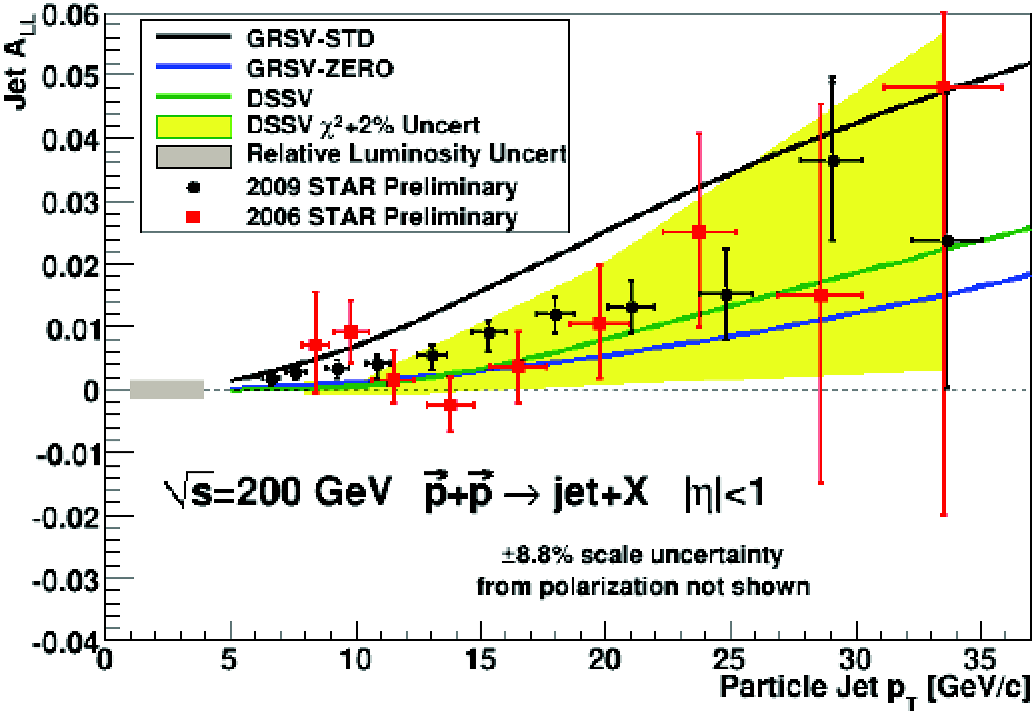


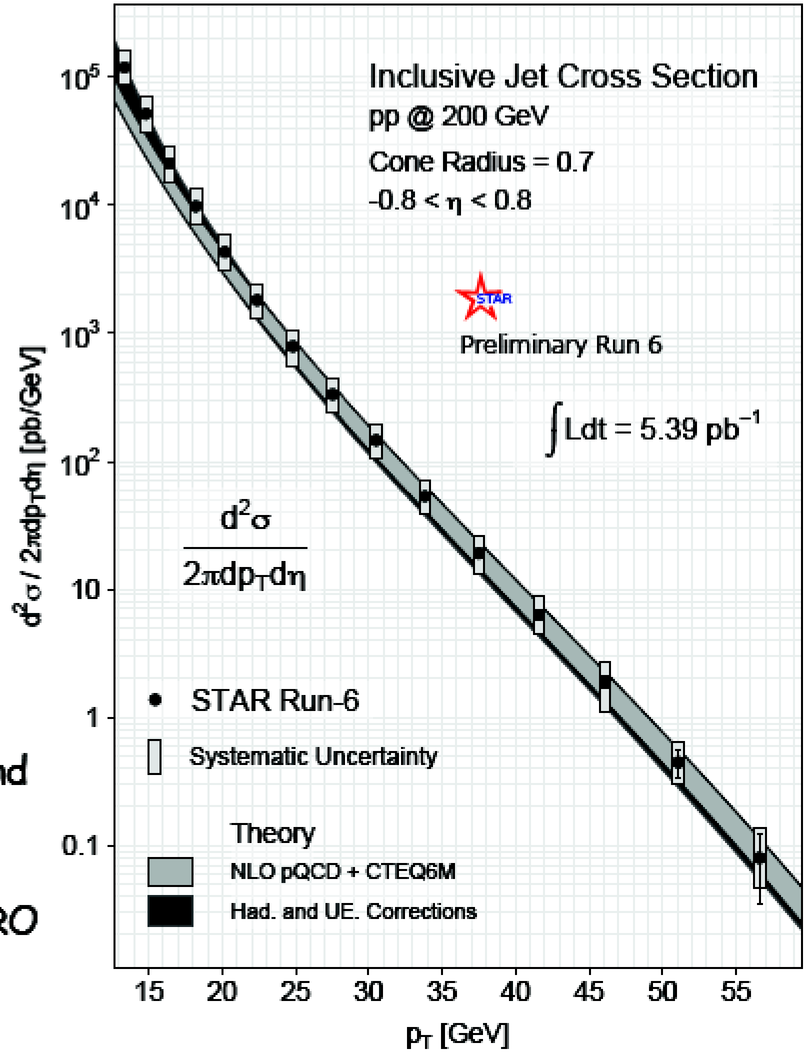


Gluon polarization

- STAR: Bernd Surrow -

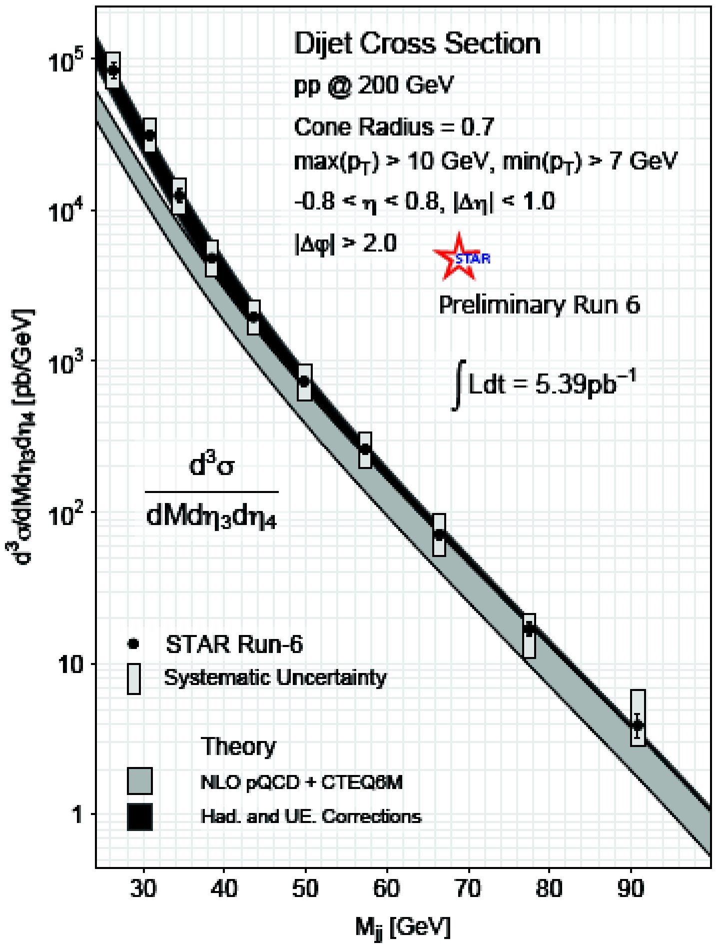
- STAR: Mid-rapidity Inclusive Jet A_{LL} measurement





- Data are well described by NLO pQCD plus hadronization and underlying event corrections
- Run 6 A_{LL} measurement between GRSV-STD and GRSV-ZERO
- Run 9 A_{LL} measurement between GRSV-STD and DSSV

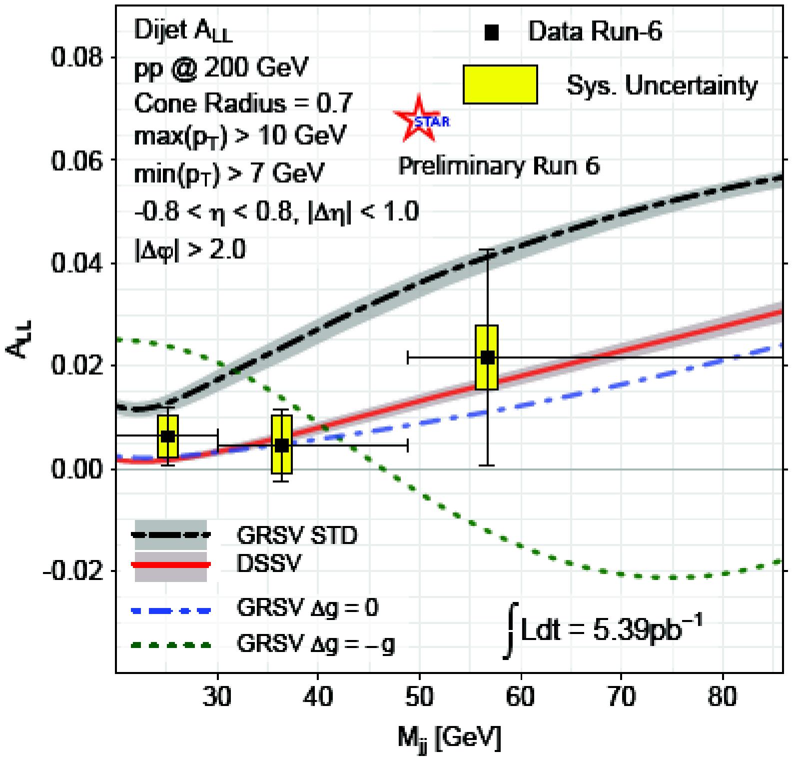
First STAR Di-Jet A_{LL} measurement



- Data are well described by NLO pQCD plus hadronization and underlying event corrections

$$M = \sqrt{x_1 x_2 s}$$

$$\eta_3 + \eta_4 = \ln\frac{x_1}{x_2}$$

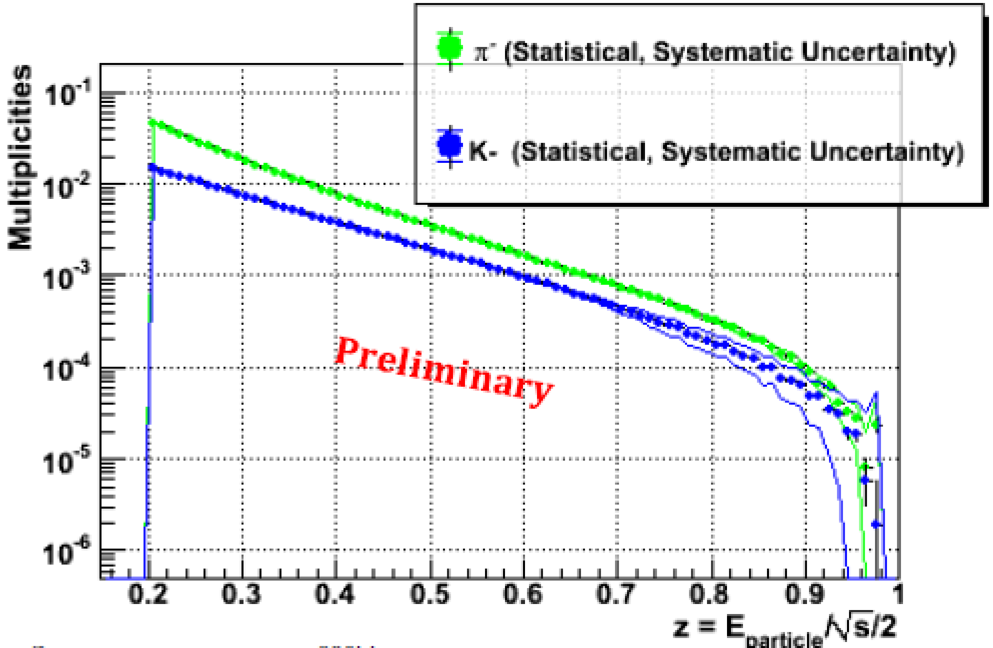


- First Di-Jet A_{LL} measurement in agreement with Δg constrained by previous inclusive jet result, i.e. small gluon polarization preferred!

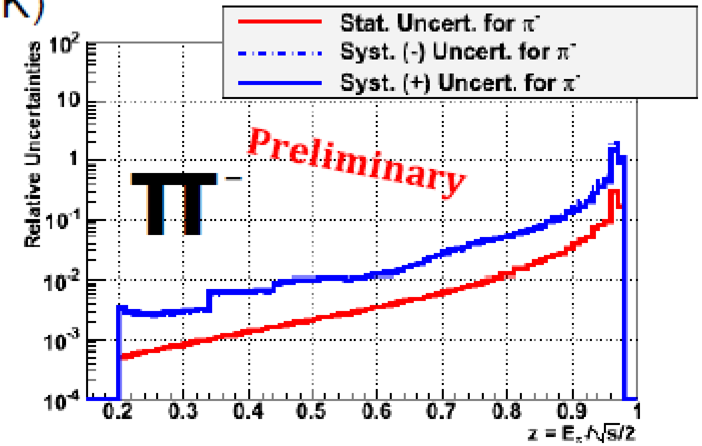
Pion and kaon multiplicities - BELLE: Martin Leitgab -

4) Preliminary Results

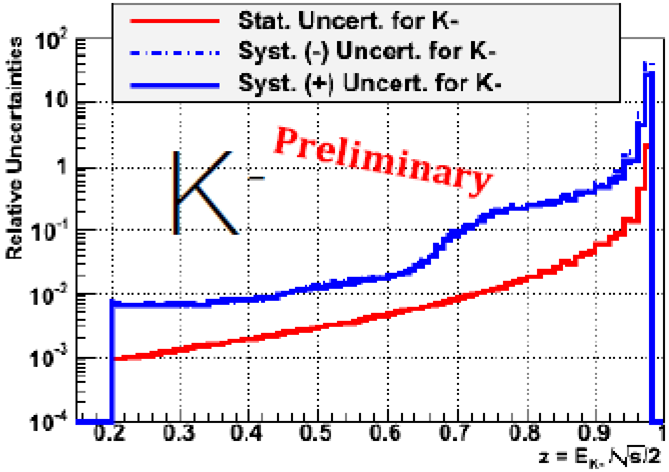
- Binning in z: width = 0.01; yields normalized to hadronic cross section
- Systematic uncertainties: z ~0.6: 1% (2%) for π (K);
  z ~0.9: 14% (50%) for π (K)



Belle experimental data, ~220M events



Additional normalization uncertainty of 1.4% not shown.



Improvement of precision: cf. slide 10.

Transverse momentum dependent parton distributions (TMDs)

- BELLE: Martin Leitgab, *Measurement of Hadron Fragmentation Functions (FFs) at Belle*
- COMPASS: Christoph Adolph, *1-Hadron transverse target spin asymmetries at COMPASS*
- COMPASS: Christopher Braun, *COMPASS results on transverse spin asymmetries in two-hadron production in SIDIS*
- HERMES: Francesca Giordano, *Flavor dependent azimuthal cosine modulations in SIDIS unpolarized cross section*
- JLAB: Vincent Sulkosky, *Single and Double Spin Asymmetry Measurements in Semi-Inclusive DIS on Polarized* ^{3}*He*
- PHENIX: Yousef I. Makdisi, *PHENIX Transverse Spin Physics*

Leading-Twist TMD PDFs

Nucleon Polarization		Quark polarization: Unpolarized (U)	Quark polarization: Longitudinally Polarized (L)	Quark polarization: Transversely Polarized (T)
	U	f_1 =		$h_1^{\perp}$ = − Boer-Mulders
	L		g_1 = − Helicity	$h_{1L}^{\perp}$ = − Worm Gear (Kotzinian-Mulders)
	T	$f_{1T}^{\perp}$ = − Sivers	g_{1T} = − Worm Gear	h_1 = − Transversity $h_{1T}^{\perp}$ = − Pretzelosity

Nucleon Spin

Quark Spin

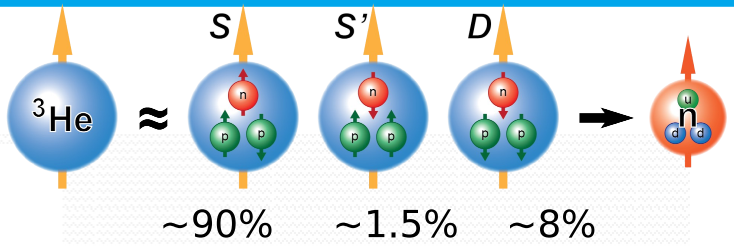
: Survive trans. Momentum integration

Jefferson Lab

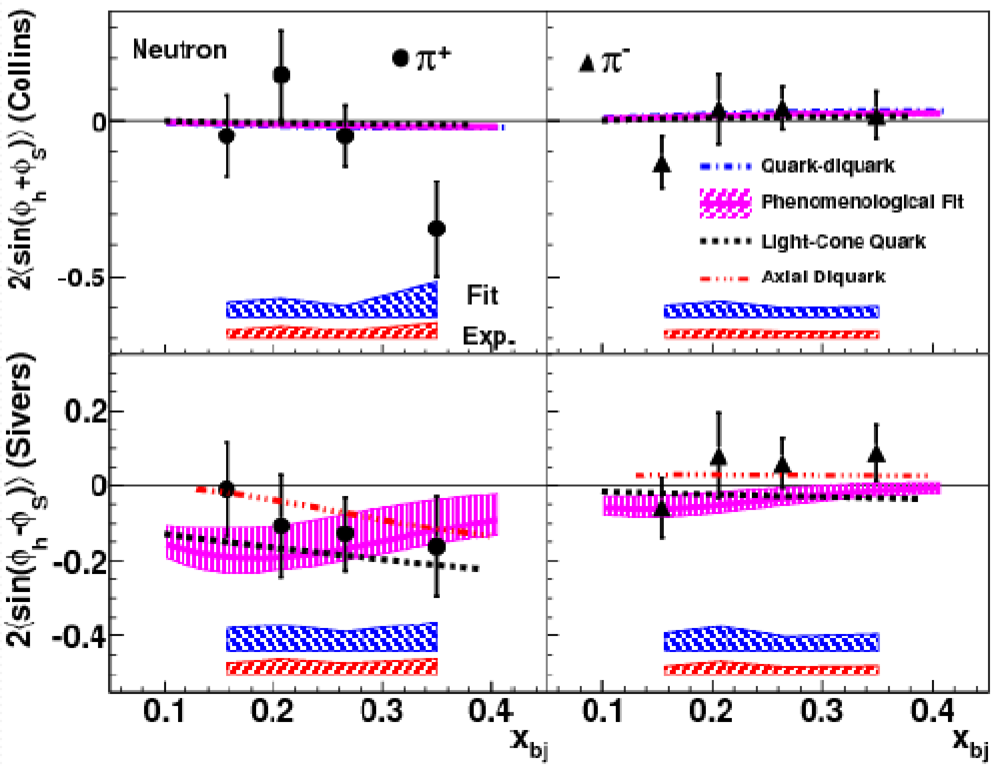
- Courtesy of Vincent Sulkosky -

Collins and Sivers asymmetries on neutron

- JLAB: Vincent Sulkosky -



Phys. Rev. Lett. 107 (2011) 072003



Collins

asymmetries are not large, except at x=0.34

Sivers

agree with global fit, and light-cone quark model.
Consistent with HERMES/COMPASS
$\pi^+ \ (u\bar{d})$ favors negative

Independent demonstration of negative d-quark Sivers function.

Blue band: model (fitting) uncertainties
Red band: other systematic uncertainties

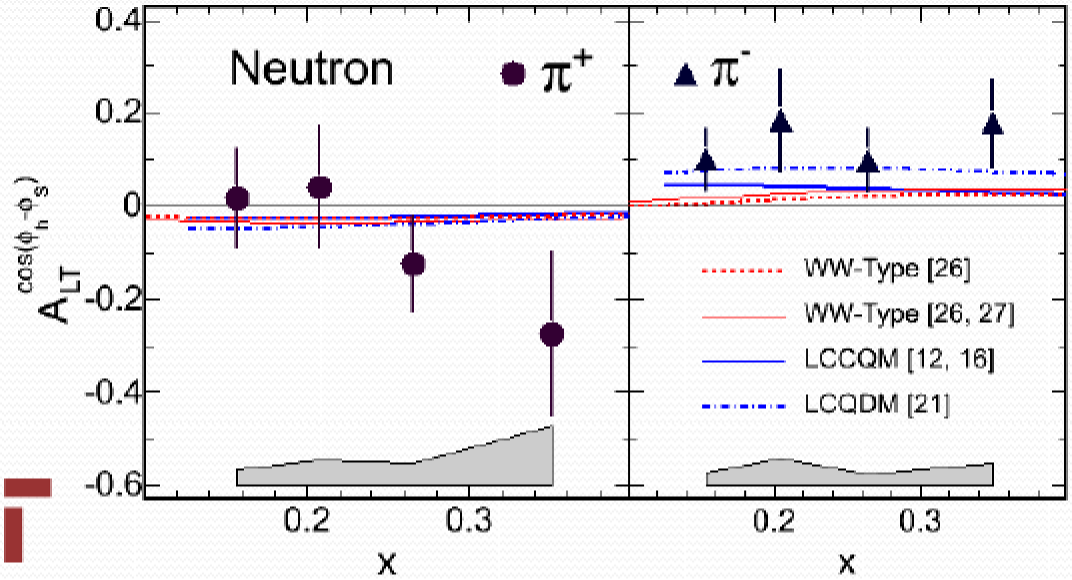
Radiative correction: bin migration + uncer. of asy.
Spin-dependent FSI estimated <1% (Glauber rescattering + no correction)   Diffractive rho: 3-10%

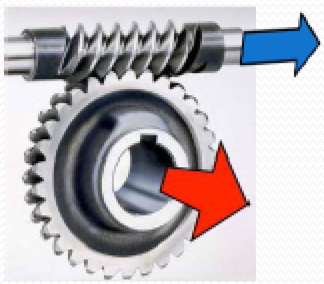
A_{LT} on neutron

- JLAB: Vincent Sulkosky -

- $A_{LT}^{^3He} = P_n \frac{\sigma_n}{\sigma_{^3He}} A_{LT}^n + P_p \frac{2\sigma_p}{\sigma_{^3He}} A_{LT}^p$ $\begin{cases} P_n = 0.86^{+0.036}_{-0.02} \\ P_p = -0.028^{+0.009}_{-0.004} \end{cases}$
  - Corrected for proton dilution, f_p
  - Predicted proton asymmetry contribution < 1.5% (π^+), 0.6% (π^-)
- $A_{LT}^n \propto g_{1T}^q \otimes D_{1q}^\pi$, sensitive to *d* quark
  - Dominated by L=0 (S) and L=1 (P) interference
- Consist w/ model in signs, suggest larger asymmetry

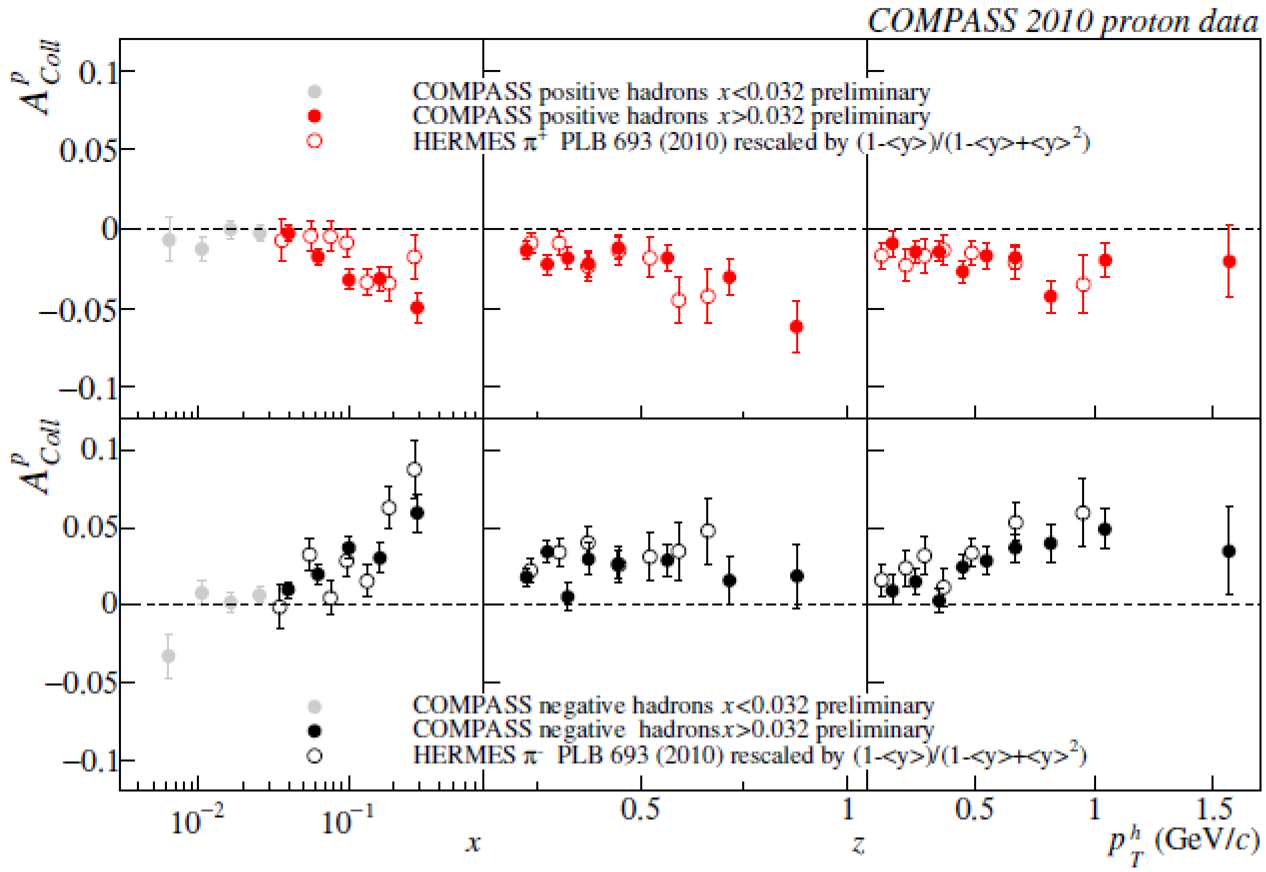
Phys. Rev. Lett. 108 (2012) 052001





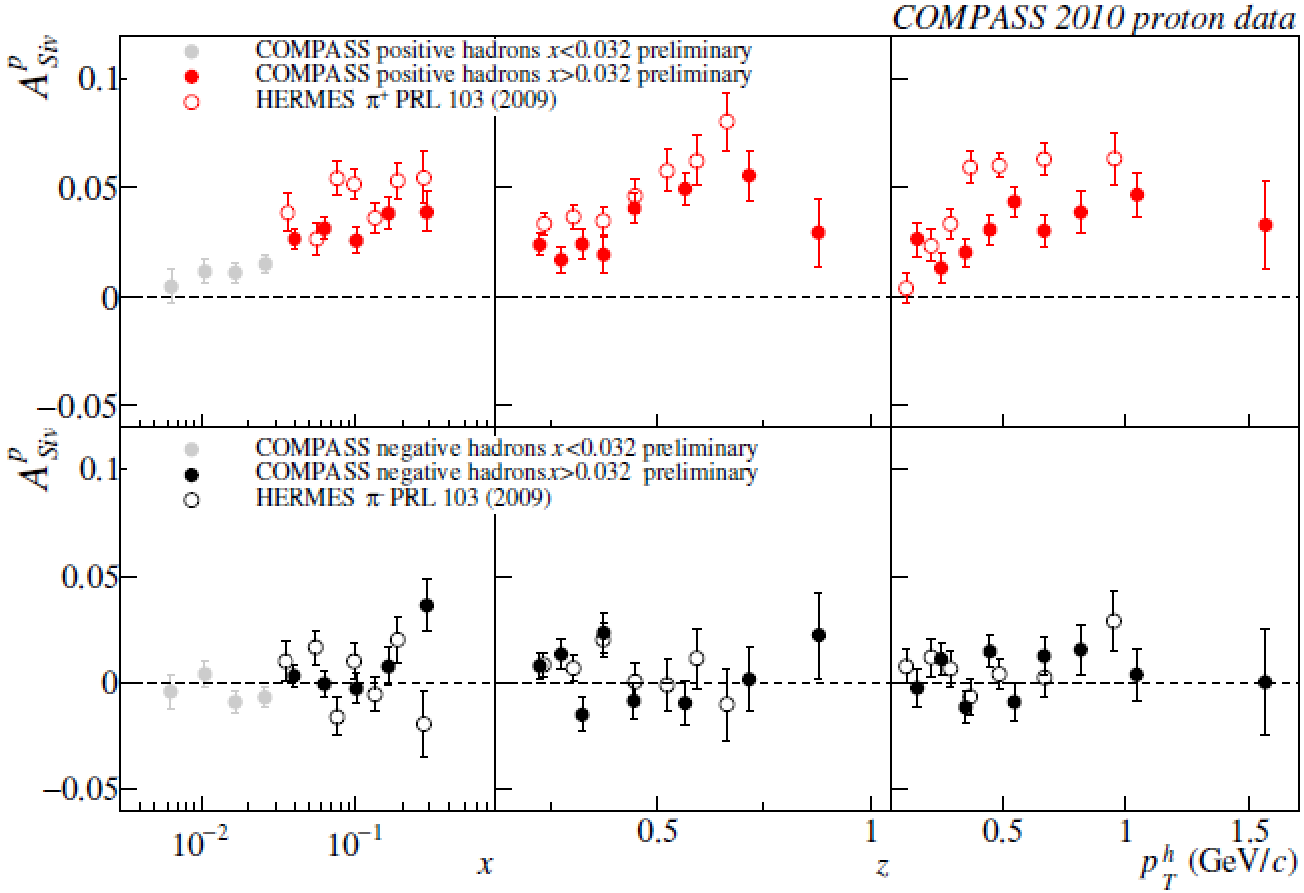
Jefferson Lab

The Collins modulation Comparison to HERMES data for x > 0.032



nice agreement between COMPASS and HERMES

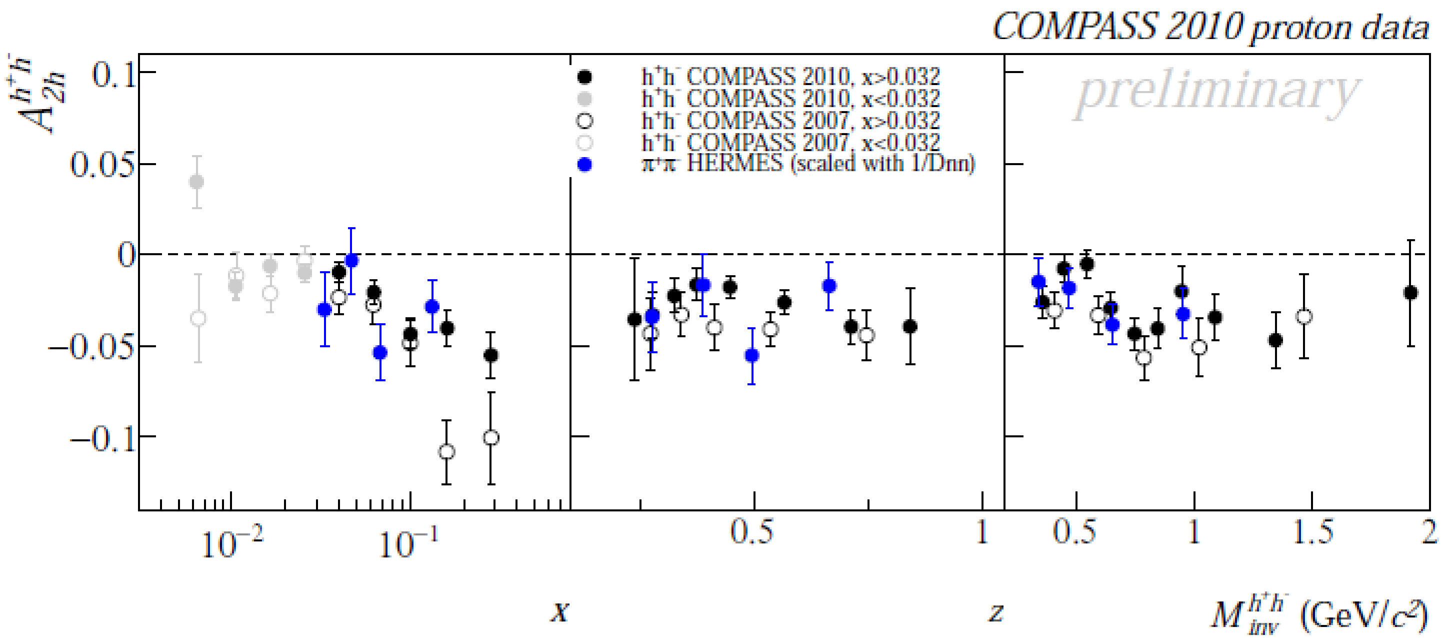
The Sivers modulation
Comparison to Hermes data
for x > 0.032



difference between COMPASS and HERMES results, but same trend

Two-hadron asymmetries - COMPASS: Christopher Braun -

Comparison with results from HERMES

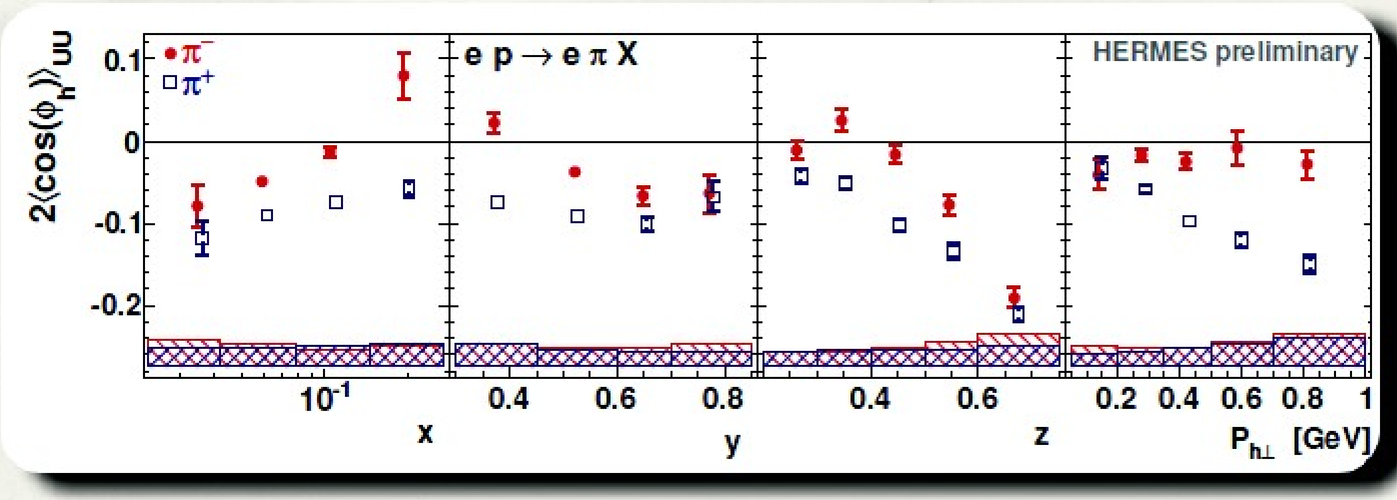


Airapetian *et. al.*, JHEP, **06** (2008) 017 scaled with $\frac{1}{D_{nn}}$

↪ Good agreement with HERMES data within the error bars

Cos ϕ, cos 2ϕ modulations

- HERMES: Francesca Giordano -



$\cos\phi_h$

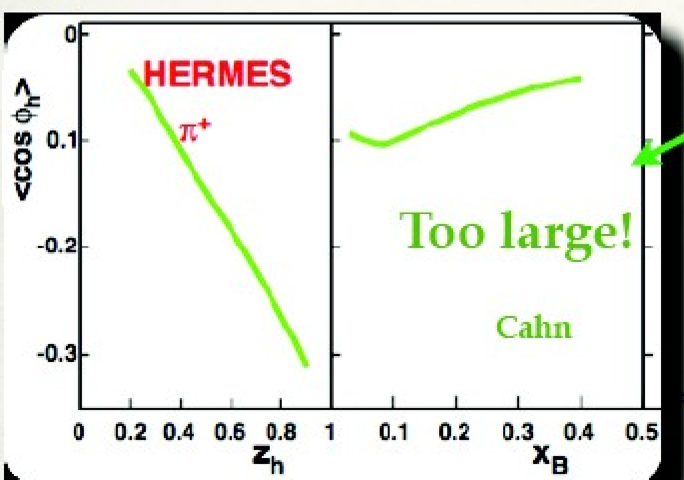
pions

Boer-Mulders

$$\propto \frac{2M}{Q} C[-h_1^\perp H_1^\perp - f_1 D_1 + ...]$$

Cahn

M. Anselmino et al.,
Phys. Rev. D71:074006, 2005
Eur. Phys. J. A31:373, 2007

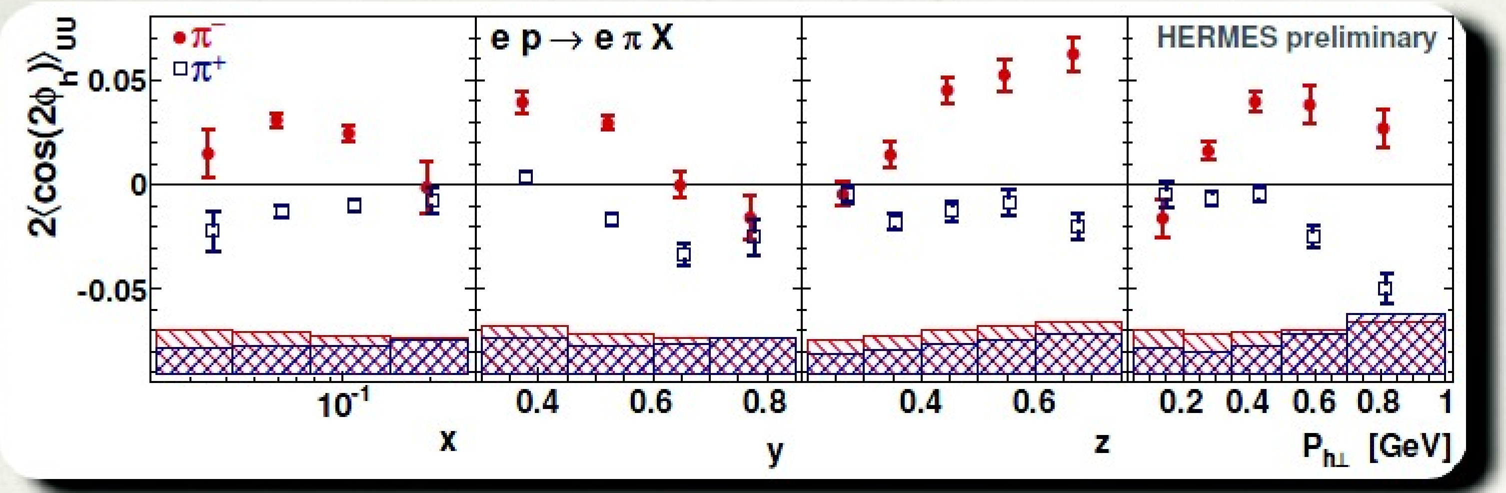


Cahn expected flavor blind

different π^+/π^- amplitudes
⇨ Boer-Mulders effect

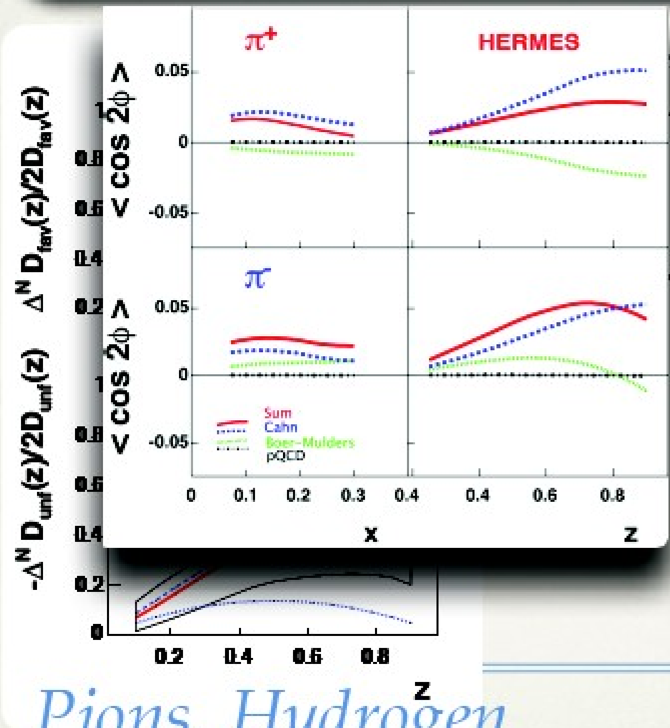
Cos ϕ, cos 2ϕ modulations

- HERMES: Francesca Giordano -



$\cos 2\phi_h$

pions



Pions, Hydrogen

r-Mulders

$$h_1^\perp H_1^\perp + \frac{\kappa_T^2}{Q^2} f_1 D_1 + \ldots]$$

Cahn

$$\pi^- \approx -H_1^{\perp, u\rightarrow\pi^+}$$

BELLE

Gamberg, Goldstein
Phys. Rev. D77:094016, 2008

Zhang et al
Phys. Rev. D78:034035, 2008

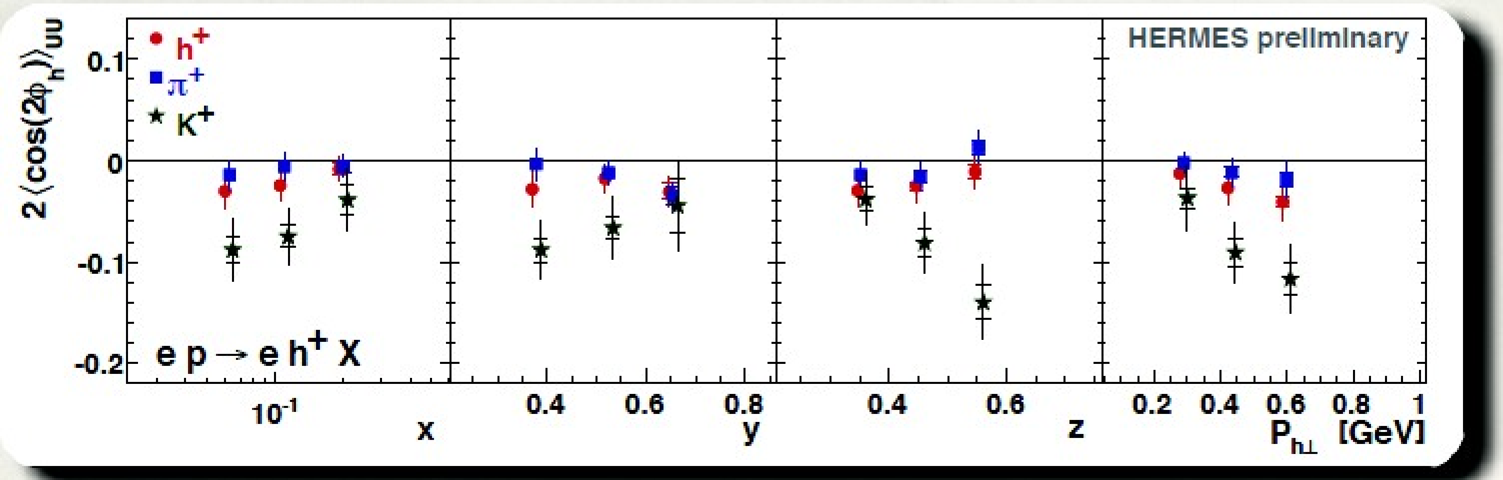
Barone et al
Phys. Rev. D78:045022, 2008

Cahn expected flavor blind

different π^+/π^- amplitudes
⇨ Boer-Mulders effect

Cos 2ϕ modulations: kaons

- HERMES: Francesca Giordano -



$\cos 2\phi_h$

kaons

No model available!

$u - dominance$

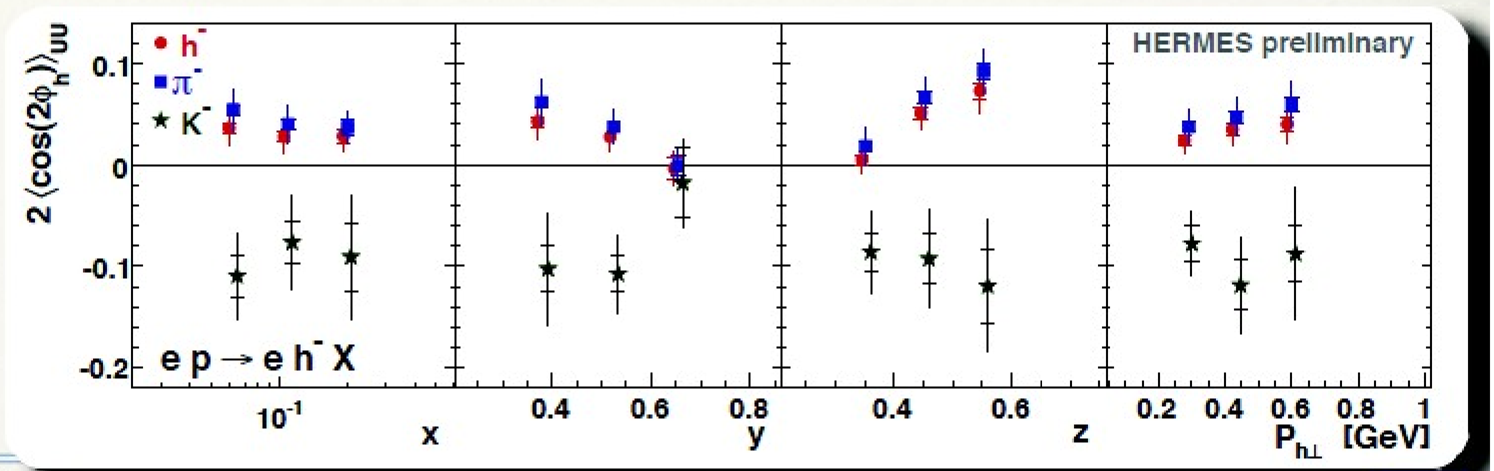
$$H_1^{\perp,u\to K^-} \overset{?}{\approx} H_1^{\perp,u\to K^+}$$

$$\propto C[-h_1^\perp H_1^\perp + \frac{\kappa_T^2}{Q^2} f_1 D_1 + ...]$$

Boer-Mulders

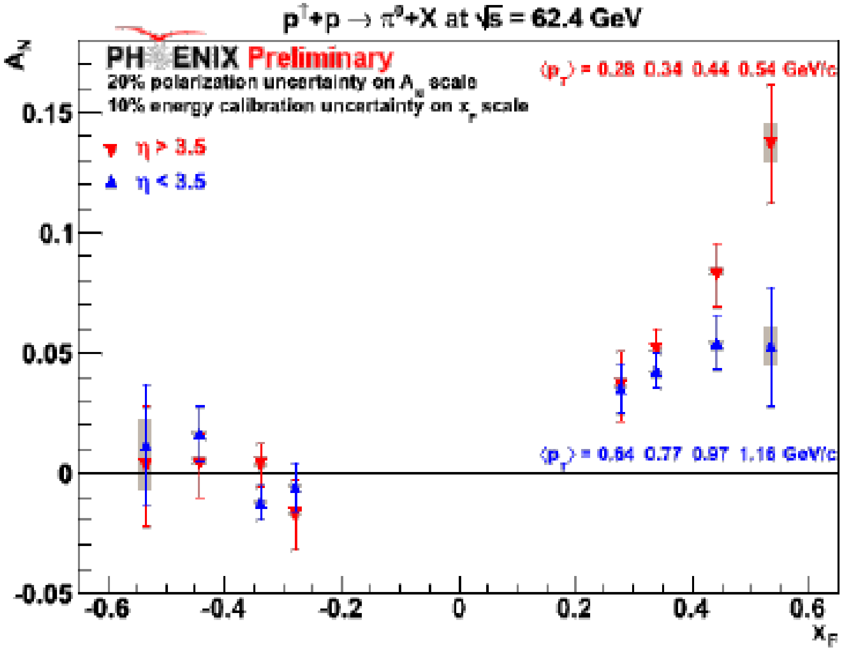
Cahn

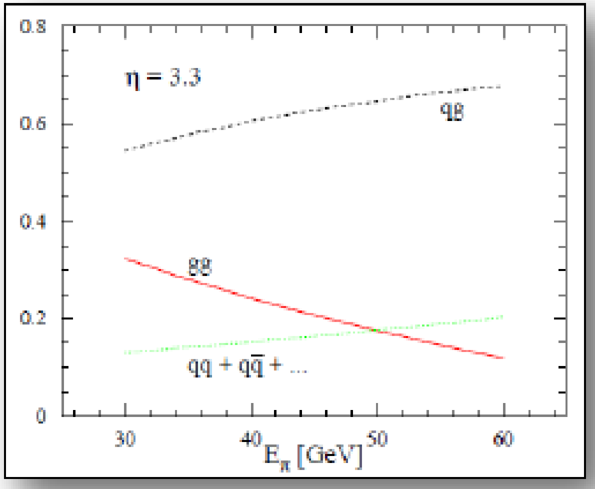
... in progress ...



Kaons, Hydrogen

Asymmetries: forward region π^0 $3.1 < |\eta| < 3.9$





- significant asymmetries similar to $\pi^{+/-}$ (Brahms)
- quark-gluon is the dominant partonic component

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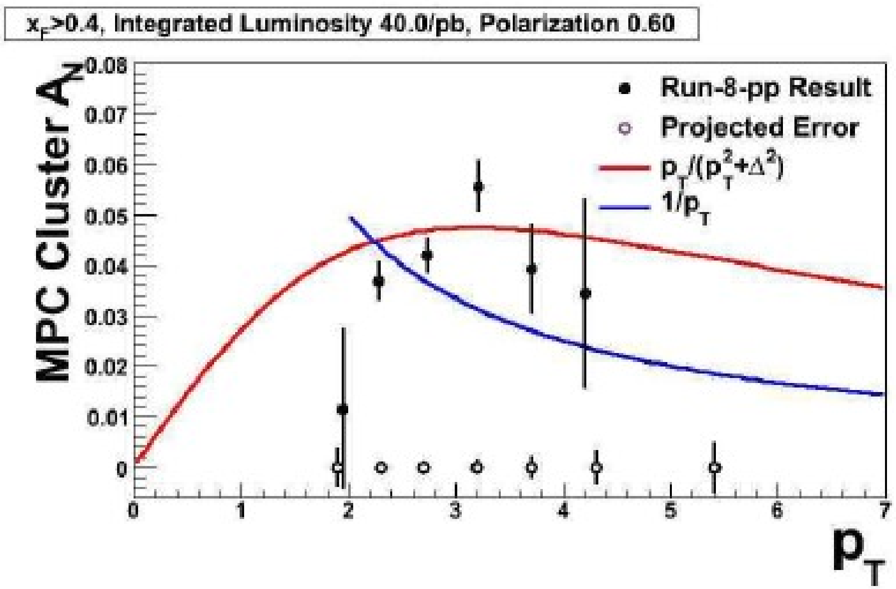
PHENIX Pt dependence



No evidence of 1/pt fall off yet w/ 8 pb-1 so far

Projected statistical errors are indicated from Run 12 &13 with expected 33 pb-1

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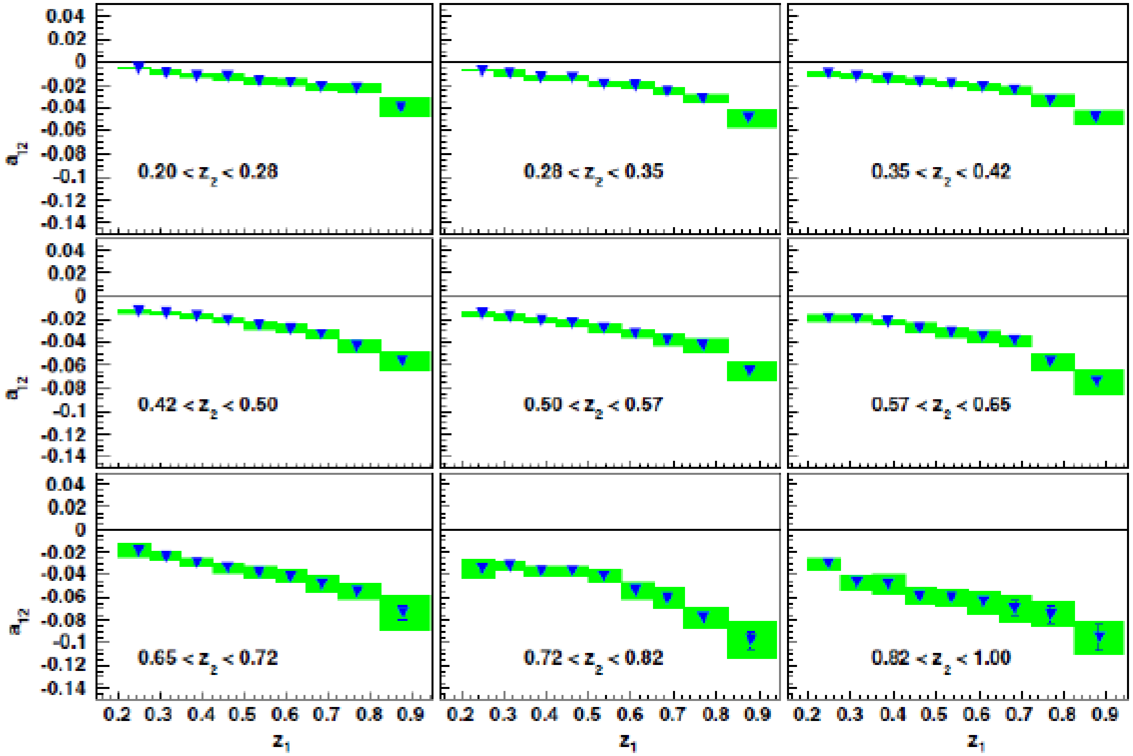
Interference FF at BELLE

- Martin Leitgab -

PRL **107,** 072004 (2011) PHYSICAL REVIEW LETTERS week ending 12 AUGUST 2011



$$z \equiv \frac{E_h^{cms}}{\sqrt{s}/2}$$

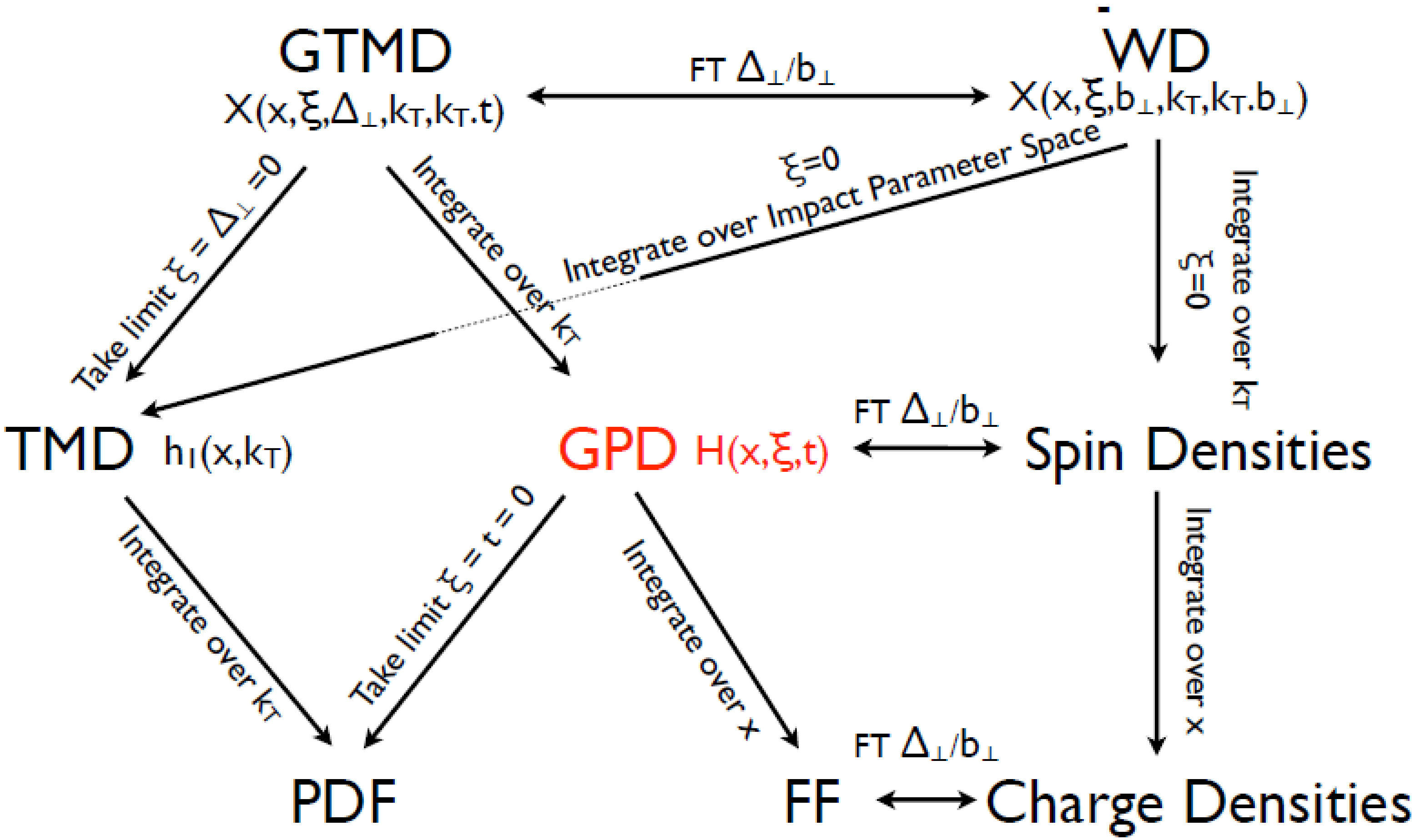
FIG. 3 (color online). a_{12} modulations for the 9×9 z_1, z_2 binning as a function of z_1 for the z_2 bins. The shaded (green) areas correspond to the systematic uncertainties.

$$a_{12} \propto IFF_{h1a,h1b} * IFF_{h2a,h2b}$$

Generalized parton distributions

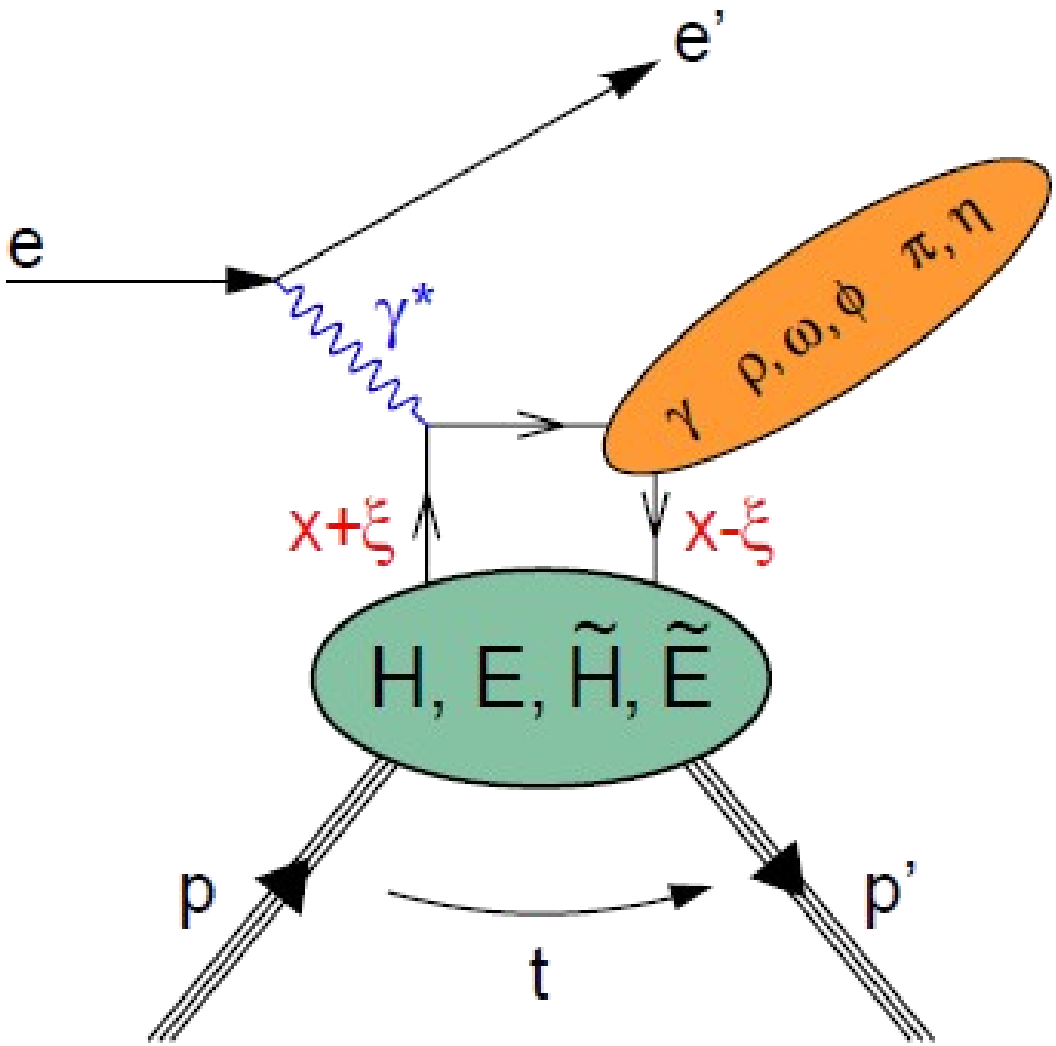
- COMPASS: Heiner Wollny, *Hard Exclusive Meson Production at COMPASS and Future DVCS Measurements at COMPASS-II*
- HERMES: Morgan Murray, *DVCS at HERMES*
- HERMES: Mayya Golembiovskaya, *Hard exclusive φ meson leptoproduction at HERMES*
- JLAB: Daria Sokhan, *Vector Meson Production and DVCS at CLAS and CLAS12*

Generalized parton distributions (GPDs)



Courtesy of Morgan Murray

DVCS and DVMP



- Different final state – access to different GPDs

DVCS @ HERMES

$$\mathcal{A}_C(\phi) \equiv \frac{\mathrm{d}\sigma^+(\phi) - \mathrm{d}\sigma^-(\phi)}{\mathrm{d}\sigma^+(\phi) + \mathrm{d}\sigma^-(\phi)} \quad \tilde{\propto} \quad \mathrm{Re}(\mathcal{H})$$

$$\mathcal{A}_{\mathrm{LU}}^{\mathrm{I}}(\phi) \equiv \frac{(\mathrm{d}\sigma(\phi)^{+\rightarrow} - \mathrm{d}\sigma(\phi)^{+\leftarrow}) - (\mathrm{d}\sigma(\phi)^{-\rightarrow} - \mathrm{d}\sigma(\phi)^{-\leftarrow})}{(\mathrm{d}\sigma(\phi)^{+\rightarrow} + \mathrm{d}\sigma(\phi)^{+\leftarrow}) + (\mathrm{d}\sigma(\phi)^{-\rightarrow} + \mathrm{d}\sigma(\phi)^{-\leftarrow})} \quad \tilde{\propto} \quad \mathrm{Im}(\mathcal{H})$$

$$\mathcal{A}_{\mathrm{LU}}^{\mathrm{DVCS}}(\phi) \equiv \frac{(\mathrm{d}\sigma(\phi)^{+\rightarrow} + \mathrm{d}\sigma(\phi)^{-\rightarrow}) - (\mathrm{d}\sigma(\phi)^{+\leftarrow} + \mathrm{d}\sigma(\phi)^{-\leftarrow})}{(\mathrm{d}\sigma(\phi)^{+\rightarrow} + \mathrm{d}\sigma(\phi)^{-\rightarrow}) + (\mathrm{d}\sigma(\phi)^{+\leftarrow} + \mathrm{d}\sigma(\phi)^{-\leftarrow})} \quad \tilde{\propto} \quad \mathrm{Im}[\mathcal{H}\mathcal{H}^* + \tilde{\mathcal{H}}\tilde{\mathcal{H}}^*]$$

$$\mathcal{A}_{\mathrm{UT}}^{\mathrm{I}}(\phi, \phi_S) \equiv \frac{d\sigma^+(\phi, \phi_S) - d\sigma^+(\phi, \phi_S + \pi) - d\sigma^-(\phi, \phi_S) + d\sigma^-(\phi, \phi_S + \pi)}{d\sigma^+(\phi, \phi_S) + d\sigma^+(\phi, \phi_S + \pi) + d\sigma^-(\phi, \phi_S) + d\sigma^-(\phi, \phi_S + \pi)} \quad \tilde{\propto} \quad \mathrm{Im}(\mathcal{E})$$

$$\mathcal{A}_{\mathrm{UT}}^{\mathrm{DVCS}}(\phi, \phi_S) \equiv \frac{d\sigma^+(\phi, \phi_S) - d\sigma^+(\phi, \phi_S + \pi) + d\sigma^-(\phi, \phi_S) - d\sigma^-(\phi, \phi_S + \pi)}{d\sigma^+(\phi, \phi_S) + d\sigma^+(\phi, \phi_S + \pi) + d\sigma^-(\phi, \phi_S) + d\sigma^-(\phi, \phi_S + \pi)} \quad \tilde{\propto} \quad \mathrm{Im}(\mathcal{E})$$

$$\mathcal{A}_{\mathrm{LT}}^{\mathrm{BH+DVCS}}(\phi, \phi_S) \equiv \frac{1}{8 d\sigma_{\mathrm{UU}}}\left[(d\overrightarrow{\sigma}^{+\uparrow} - d\overrightarrow{\sigma}^{+\downarrow} - d\overleftarrow{\sigma}^{+\uparrow} + d\overleftarrow{\sigma}^{+\downarrow}) + (d\overrightarrow{\sigma}^{-\uparrow} - d\overrightarrow{\sigma}^{-\downarrow} - d\overleftarrow{\sigma}^{-\uparrow} + d\overleftarrow{\sigma}^{-\downarrow})\right] \quad \tilde{\propto} \quad \mathrm{Re}(\mathcal{H} + \mathcal{E})$$

$$\mathcal{A}_{\mathrm{LT}}^{\mathrm{I}}(\phi, \phi_S) \equiv \frac{1}{8 d\sigma_{\mathrm{UU}}}\left[(d\overrightarrow{\sigma}^{+\uparrow} - d\overrightarrow{\sigma}^{+\downarrow} - d\overleftarrow{\sigma}^{+\uparrow} + d\overleftarrow{\sigma}^{+\downarrow}) - (d\overrightarrow{\sigma}^{-\uparrow} - d\overrightarrow{\sigma}^{-\downarrow} - d\overleftarrow{\sigma}^{-\uparrow} + d\overleftarrow{\sigma}^{-\downarrow})\right] \quad \tilde{\propto} \quad \mathrm{Re}(\mathcal{H})$$

$$\mathcal{A}_{\mathrm{UL}}(\phi) \equiv \frac{[\sigma^{\leftarrow\Rightarrow}(\phi) + \sigma^{\rightarrow\Rightarrow}(\phi)] - [\sigma^{\leftarrow\Leftarrow}(\phi) + \sigma^{\rightarrow\Leftarrow}(\phi)]}{[\sigma^{\leftarrow\Rightarrow}(\phi) + \sigma^{\rightarrow\Rightarrow}(\phi)] + [\sigma^{\leftarrow\Leftarrow}(\phi) + \sigma^{\rightarrow\Leftarrow}(\phi)]} \quad \tilde{\propto} \quad \mathrm{Im}(\tilde{\mathcal{H}})$$

$$\mathcal{A}_{\mathrm{LL}}(\phi) \equiv \frac{[\sigma^{\rightarrow\Rightarrow}(\phi) + \sigma^{\leftarrow\Leftarrow}(\phi)] - [\sigma^{\leftarrow\Rightarrow}(\phi) + \sigma^{\rightarrow\Leftarrow}(\phi)]}{[\sigma^{\rightarrow\Rightarrow}(\phi) + \sigma^{\leftarrow\Leftarrow}(\phi)] + [\sigma^{\leftarrow\Rightarrow}(\phi) + \sigma^{\rightarrow\Leftarrow}(\phi)]} \quad \tilde{\propto} \quad \mathrm{Re}(\tilde{\mathcal{H}})$$

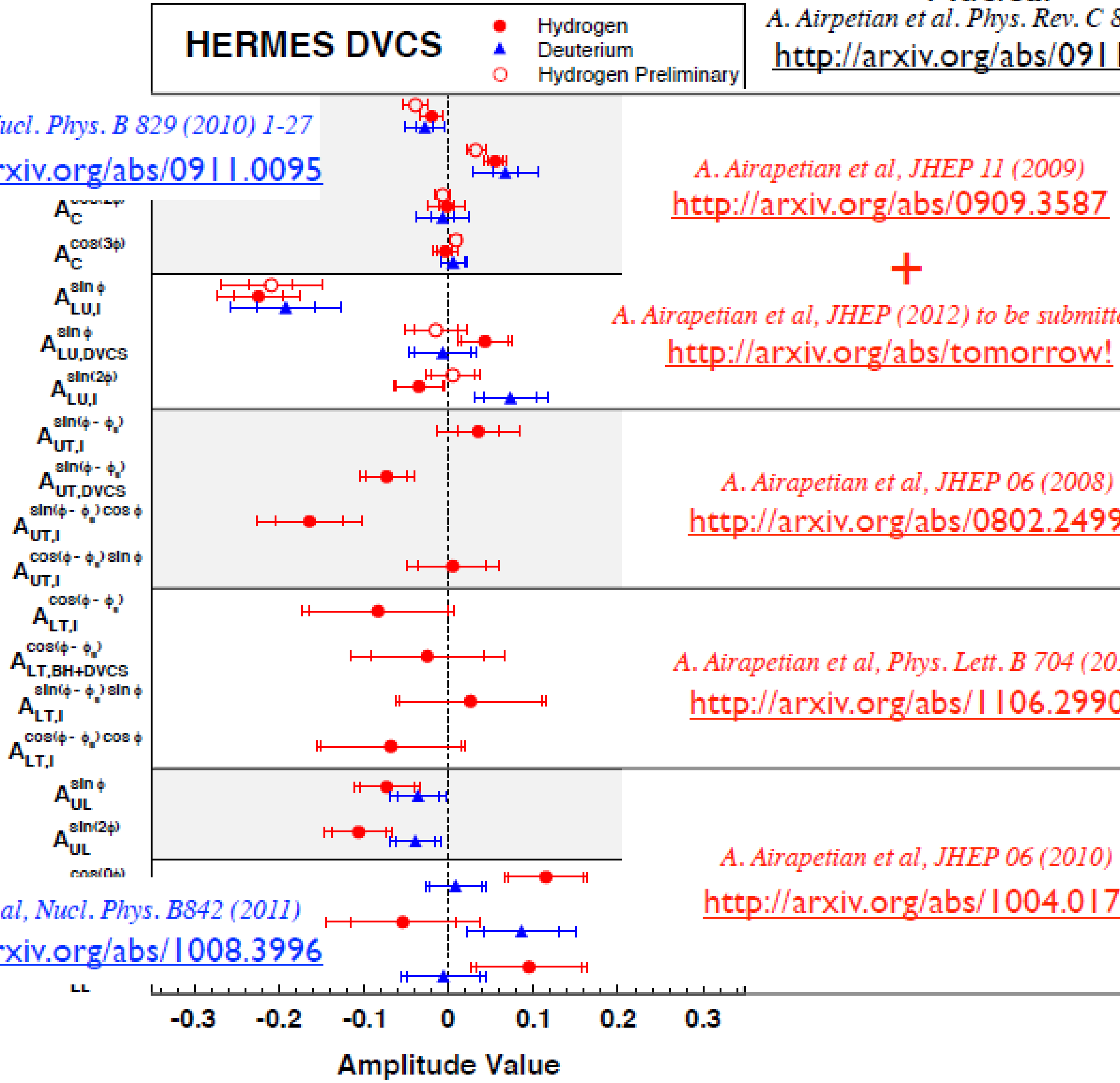
DVCS results at HERMES

- Morgan Murray -

Nuclear
A. Airpetian et al. Phys. Rev. C 81 (2010)
http://arxiv.org/abs/0911.0091

A. Airapetian et al, Nucl. Phys. B 829 (2010) 1-27
http://www.arxiv.org/abs/0911.0095

D V C S @



A. Airapetian et al, JHEP 11 (2009)
http://arxiv.org/abs/0909.3587

+

A. Airapetian et al, JHEP (2012) to be submitted
http://arxiv.org/abs/tomorrow!

A. Airapetian et al, JHEP 06 (2008)
http://arxiv.org/abs/0802.2499

A. Airapetian et al, Phys. Lett. B 704 (2011)
http://arxiv.org/abs/1106.2990

A. Airapetian et al, JHEP 06 (2010)
http://arxiv.org/abs/1004.0177

A. Airapetian et al, Nucl. Phys. B842 (2011)
http://www.arxiv.org/abs/1008.3996

H E R M E S

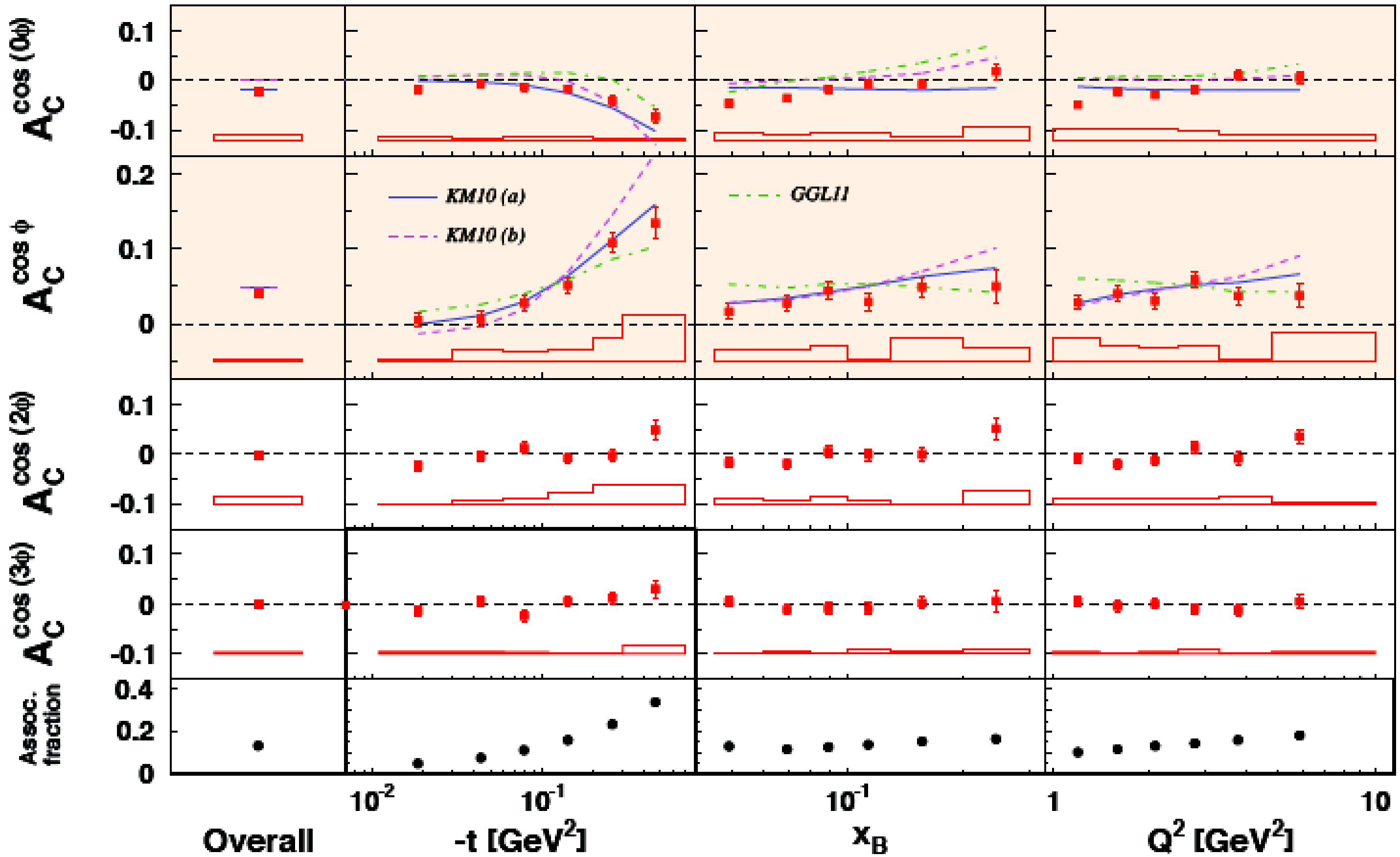
BCA complete data set

- HERMES: Morgan Murray -

arXiv:1203.6287 [hep-ex]

Beam-Charge Asymmetries

A. Airapetian et al, JHEP (2012), (to be submitted) http://arxiv.org/abs/(tomorrow!)



Beam Charge Asymmetries access Re($\mathcal{H}$)

Kumerički and Müller, Nucl. Phys. **B841** (2010) http://arxiv.org/abs/0904.0458

G. Goldstein, J. Hernandez and S. Liuti, Phys. Rev. D84 (2011) http://arxiv.org/abs/1012.3776

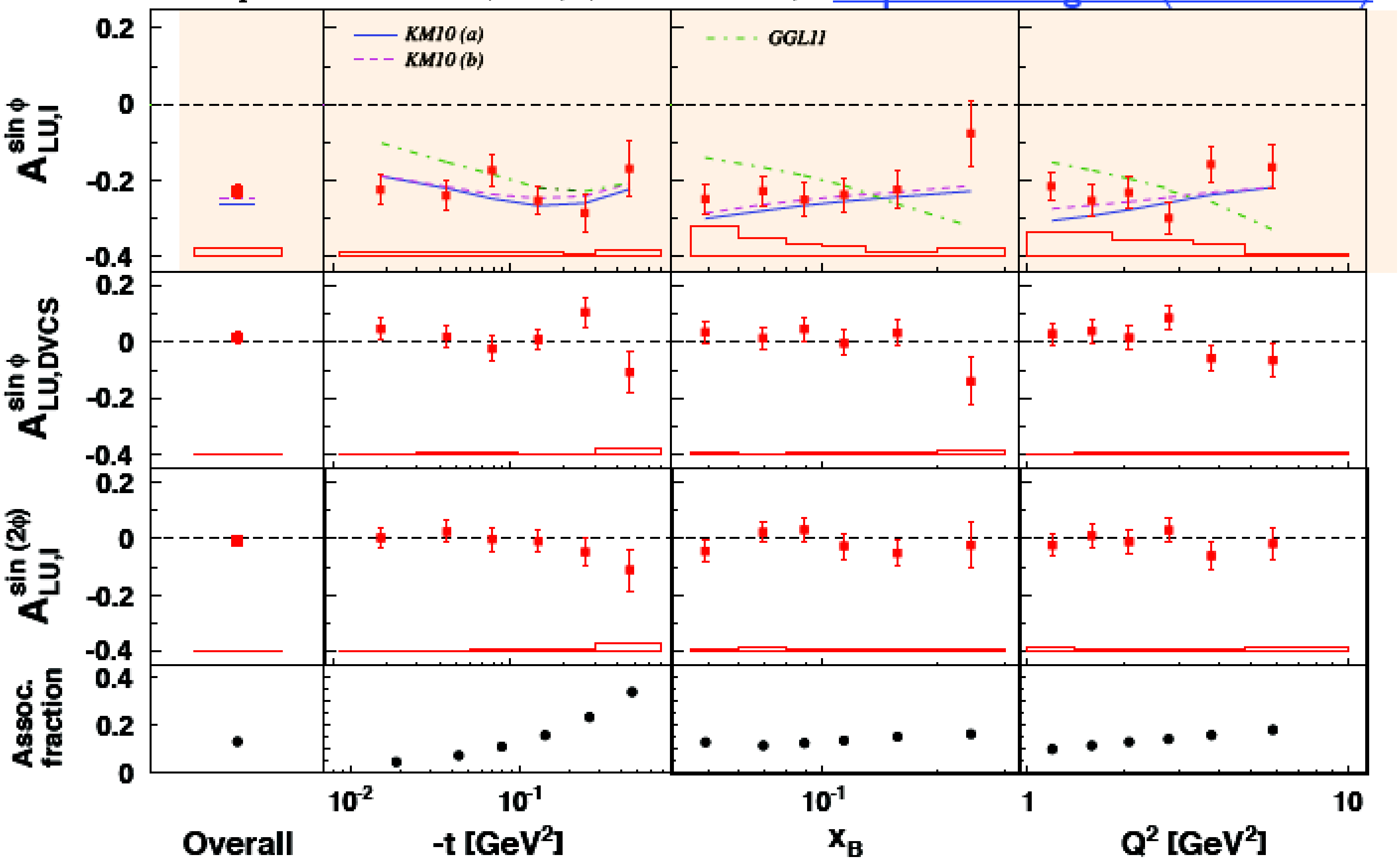
BSA complete data set

- HERMES: Morgan Murray -

arXiv:1203.6287 [hep-ex]

Beam-Spin Asymmetries

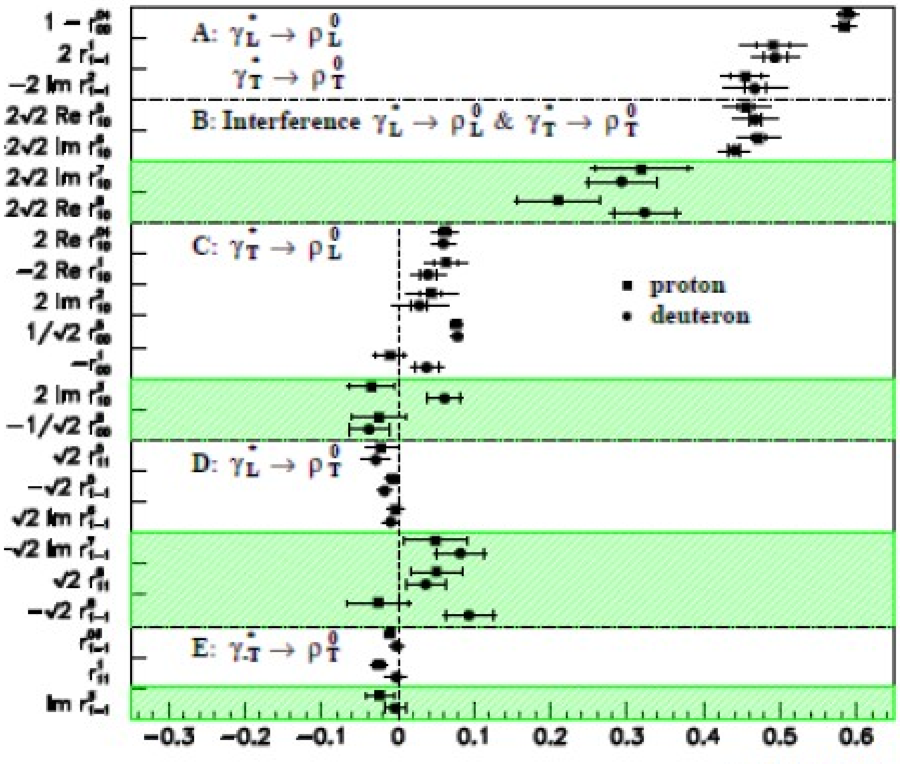
A. Airapetian et al, JHEP (2012), (to be submitted) http://arxiv.org/abs/(tomorrow!)



Beam Helicity Asymmetries access Im($\mathcal{H}$)

Spin-density matrix elements (SDMEs) for ρ^0
- HERMES Mayya Golembiovskaya -

Unpolarized (white areas) and beam-polarized (green areas) SDMEs



EPJC 62 (2009) 659-694, arXiv:0901.0701

- no statistically significant difference between proton and deuteron

s-channel helicity conservation (conservation the helicity of γ^* in $\gamma^*_L \to \rho^0_L$ and $\gamma^*_T \to \rho^0_T$) – non-zero SDMEs of classes A,B

$r^1_{1-1} = -Im\{r^2_{1-1}\}$,

$Re\{r^5_{10}\} = -\mathrm{Im}\{r^6_{10}\}$,

$Re\{r^8_{10}\} = Im\{r^7_{10}\}$ - fulfilled

- s-channel helicity violation

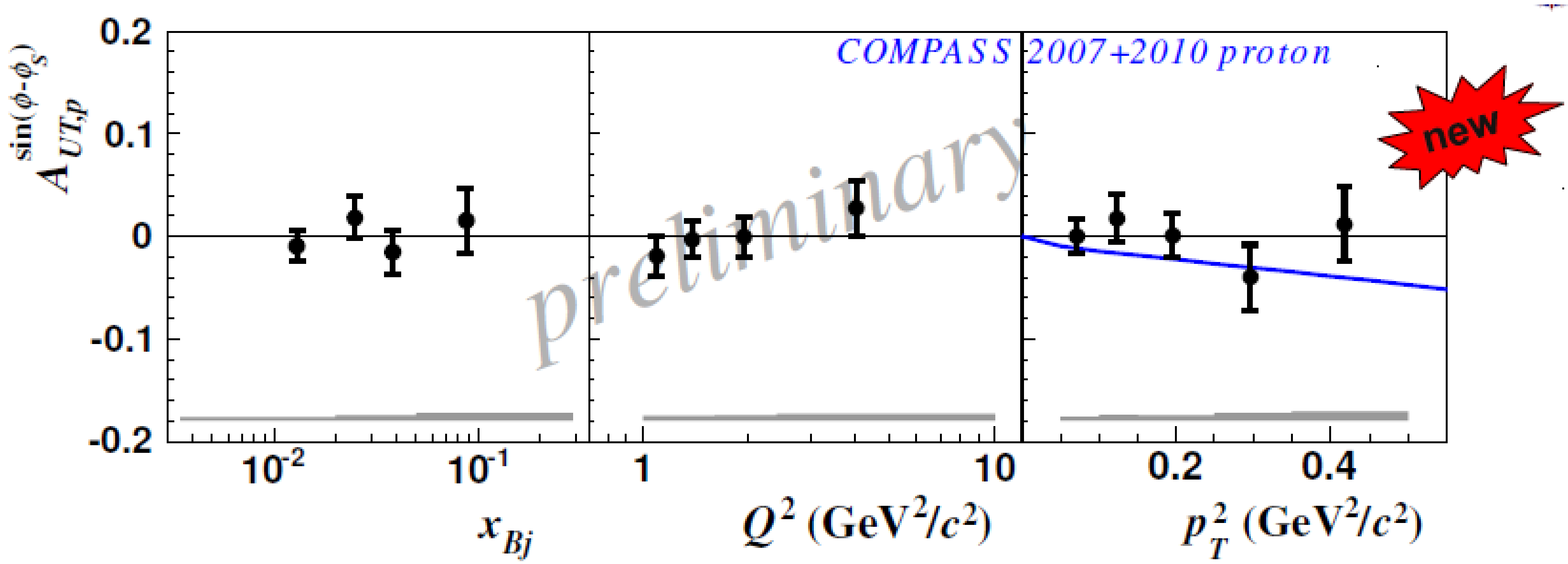
significant $\gamma^*_T \to \rho^0_L$ - non-zero elements of class C, not so significant $\gamma^*_{-T} \to \rho^0_T$ and $\gamma^*_L \to \rho^0_T$ - non-zero elements of classes D,E

Hierarchy of amplitudes at HERMES kinematics for ρ^0:

$|T_{00}|^2 \sim |T_{11}|^2 \gg |T_{01}|^2 > |T_{10}|^2 \sim |T_{-11}|^2$

13

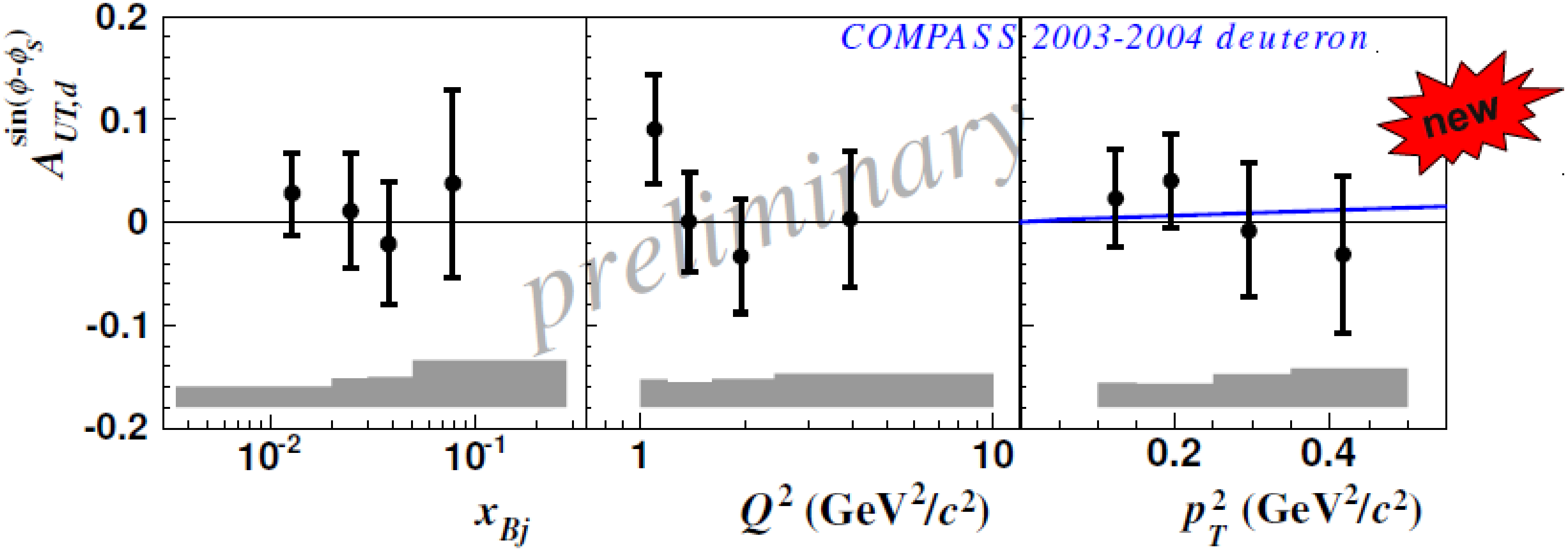
A_{UT} for ρ^0 NH_3 2007-2010 - COMPASS: Heiner Wollny -



- Asymmetries are small, compatible with zero within uncertainties
- In agreement with model: Goloskokov and Kroll, Eur. Phys. J. C 59 4 (2009)

$\rightsquigarrow$ approximate cancellation of E^u and E^d $\left(E_{\rho^0} = \frac{1}{\sqrt{2}}\left(\frac{2}{3}E^u + \frac{1}{3}E^d + \frac{3}{8}E^g\right)\right)$

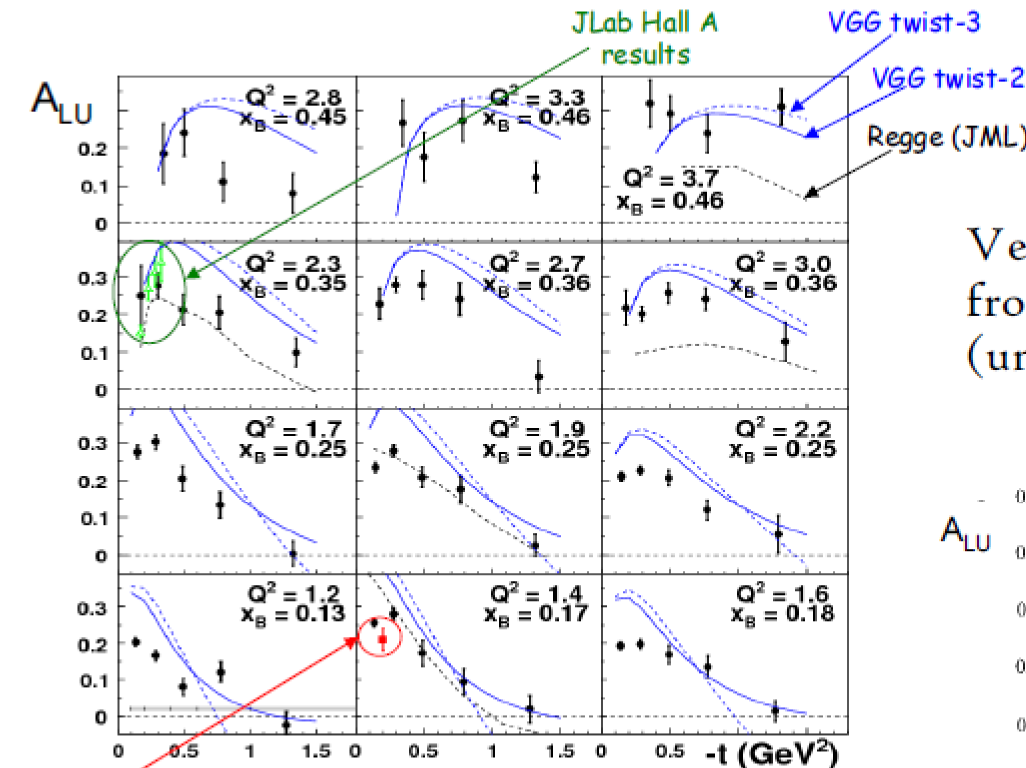
A_{UT} for ρ^0 ^{6}LiD 2003+2004 - COMPASS: Heiner Wollny -



- Asymmetries are small, compatible with zero within uncertainties
- In agreement with model: Goloskokov and Kroll, Eur. Phys. J. C 59 4 (2009)
- Paper will be published soon

DVCS A_{LU} on proton

- JLAB: Daria Sokhan -



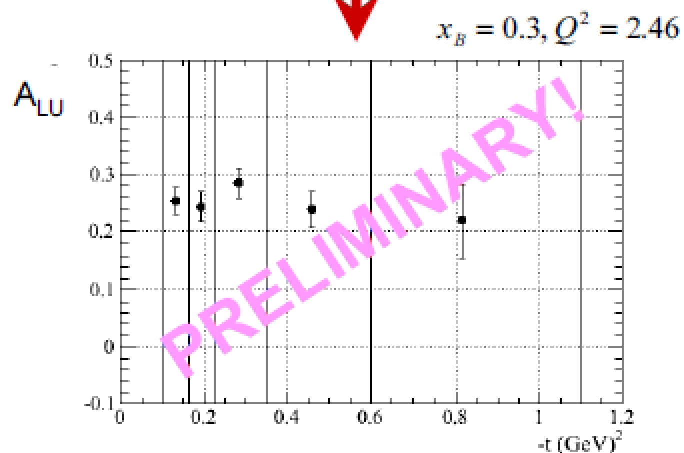
F.X. Girod *et al.* (CLAS Collaboration), Phys. Rev. Lett. 100, 162002 (2008)

VGG model: Vanderhaeghen, Guichon, Guidal

A_{LU} from fit to asymmetry:

$$A = \frac{A_{LU} \sin\varphi}{1 + p_1 \cos\varphi}$$

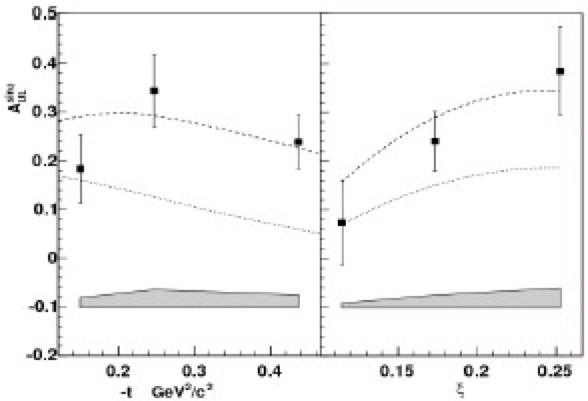
Very preliminary measurement from eg1-dvcs experiment, (uncorrected for π^0 background)

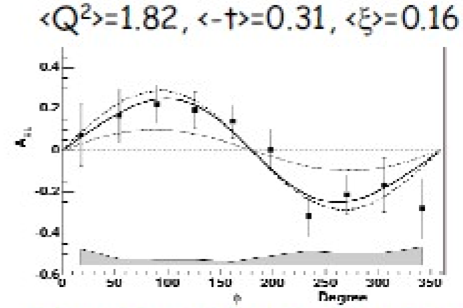


Gary Smith, University of Glasgow

DVCS A_{UL} on proton

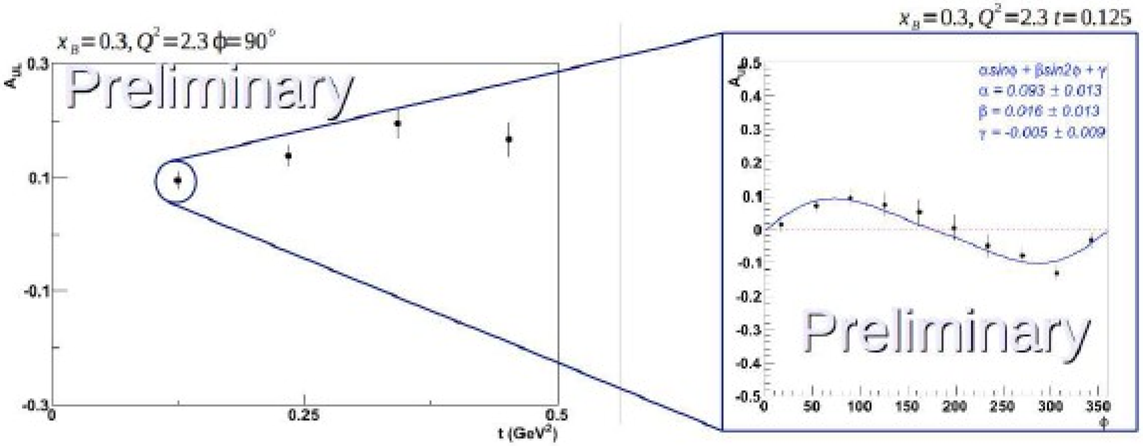
- JLAB: Daria Sokhan -





S. Chen et al. (CLAS Collaboration), Phys. Rev. Lett. 97, 072002 (2006)

Very preliminary measurement from **eg1-dvcs experiment**, (uncorrected for π^0 background):



Erin Seder, University of Connecticut

DVCS A_{LU} on neutron

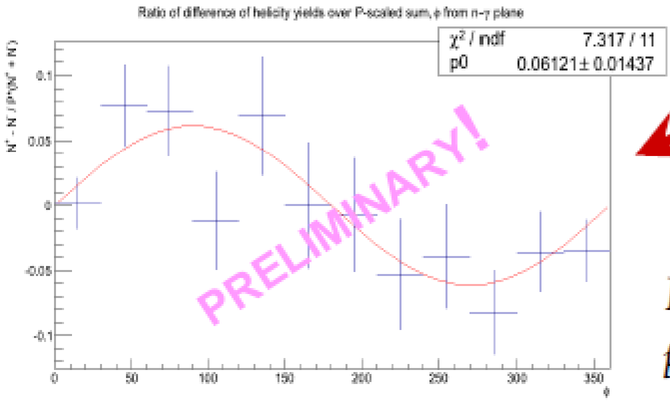
- JLAB: Daria Sokhan -

Beam-spin asymmetry

$$\vec{e} + d \rightarrow e' + n + \gamma + (p_s)$$

One previous measurement from Hall A @ JLab, A_{LU} *~ 0.* Big statistical and systematic uncertainties.

M. Mazouz et al, PRL 99 (2007) 242501



Analysis of A_{LU} from neutron DVCS on eg1-dvcs data underway

Integrated over all kinematics, extremely preliminary, no background subtraction!

Target-spin asymmetry

Never before measured on the neutron! Also under extraction from eg1-dvcs data.

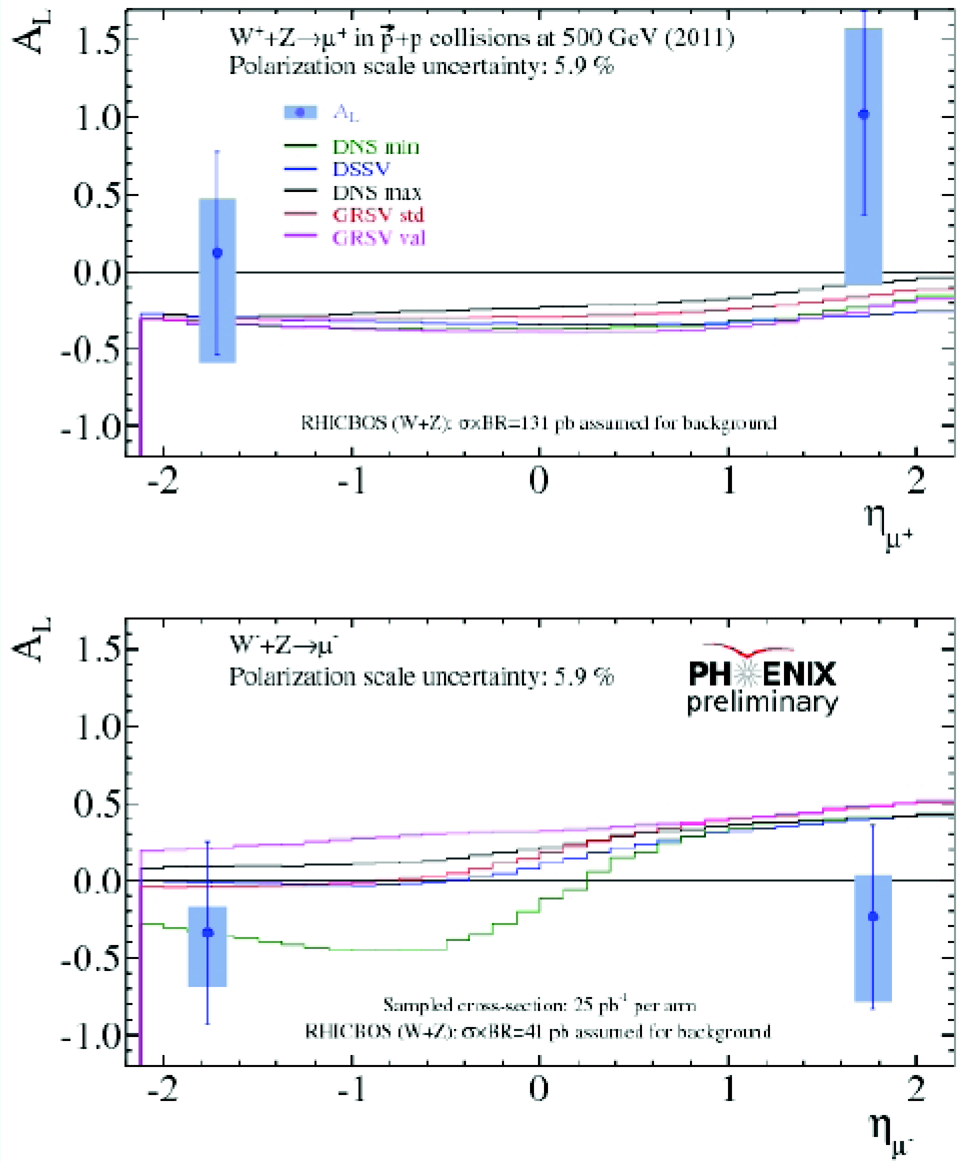
Conclusion

- 16 experimental talks in the Spin Physics working group
- Many talks cover several analysis topics
- Thanks to all speakers!
- Activity in spin physics is ongoing
- Essential input to theoretical development

Backup

$W^{\pm} \to \mu^{\pm}$ Single Spin Asymmetry at Muon Arms

PHENIX

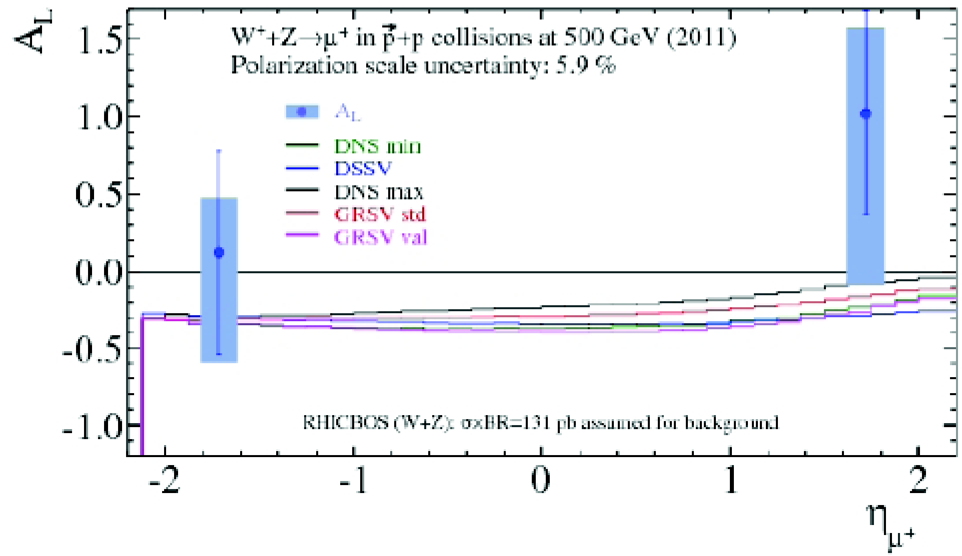


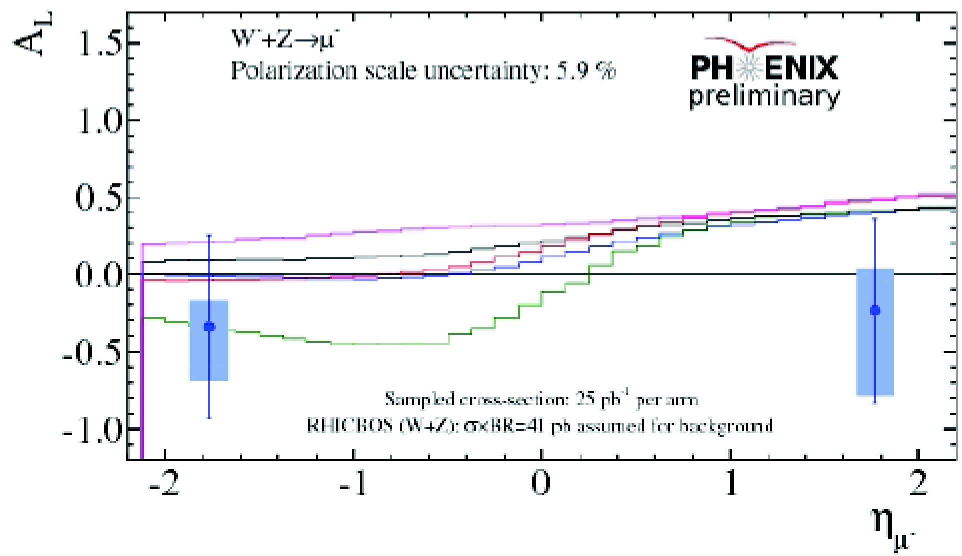
First measured single spin asymmetries at forward $W^{\pm} \to \mu^{\pm}$

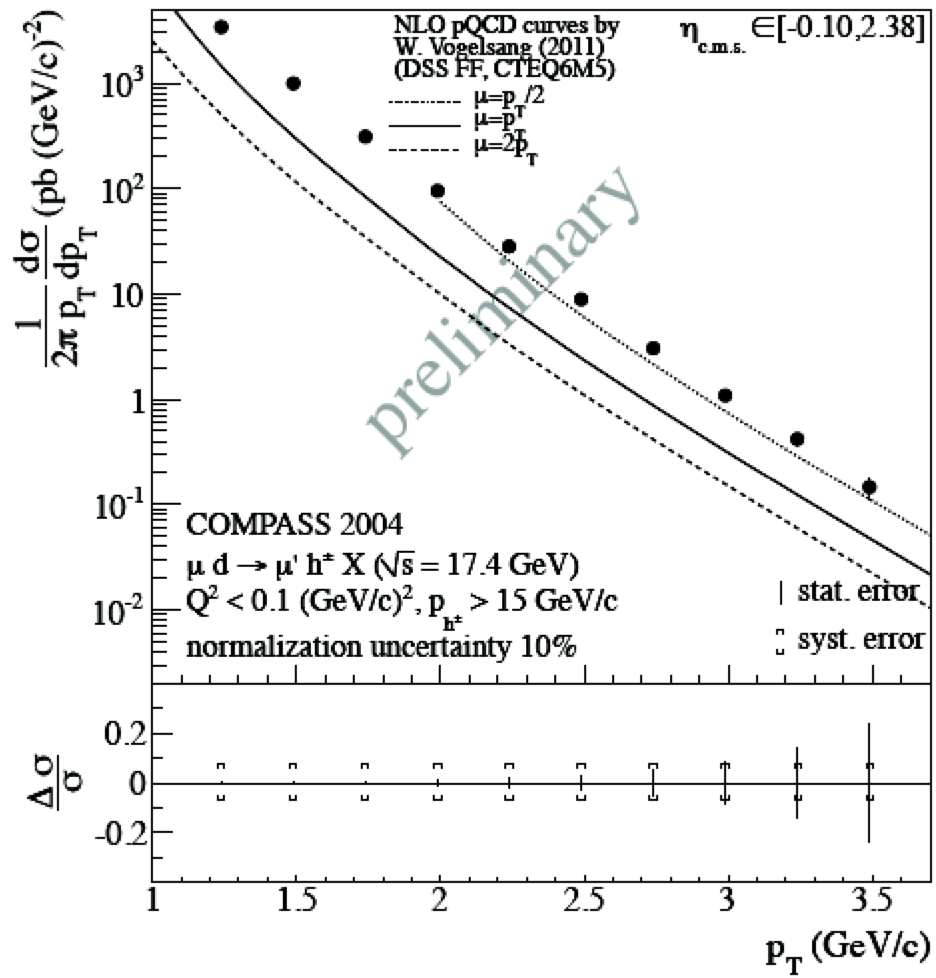
Beam averaged experimental results

In order to reduce statistical & systematic errors, improve detector & trigger performances and plan to collect 500 GeV $p+p$ collision data over 2016 at least

Different lines are expectation from RHICBOS calculation


W⁺+Z→μ⁺ in p⃗+p collisions at 500 GeV (2011)
Polarization scale uncertainty: 5.9 %
A_L
DNS min
DSSV
DNS max
GRSV std
GRSV val
RHICBOS (W+Z): σ×BR=131 pb assumed for background
A_L
1.5
1.0
0.5
0.0
-0.5
-1.0
-2
-1
0
1
2
η_μ+

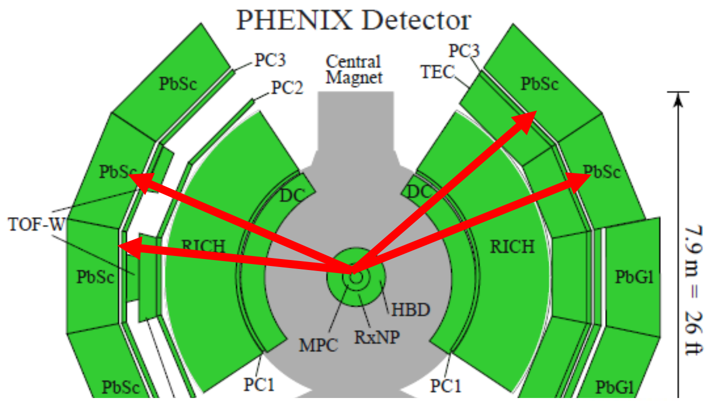

W⁻+Z→μ⁻
Polarization scale uncertainty: 5.9 %
PHENIX
preliminary
Sampled cross-section: 25 pb⁻¹ per arm
RHICBOS (W+Z): σ×BR=41 pb assumed for background
A_L
1.5
1.0
0.5
0.0
-0.5
-1.0
-2
-1
0
1
2
η_μ-

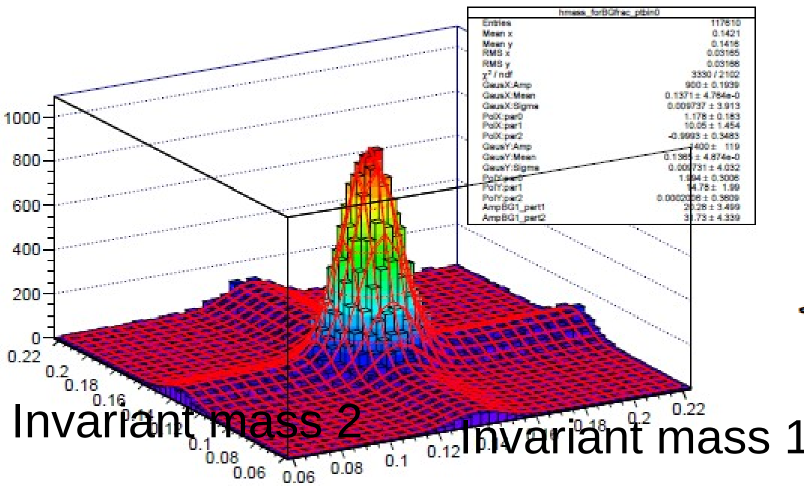


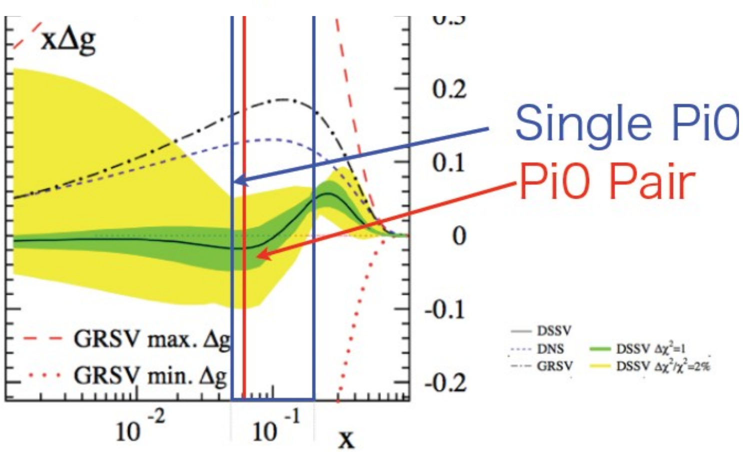
NLO pQCD curves by
W. Vogelsang (2011)
(DSS FF, CTEQ6M5)
μ=p_T/2
μ=p_T
μ=2p_T
η_c.m.s. ∈[-0.10,2.38]
preliminary
COMPASS 2004
μ d → μ' h± X (√s = 17.4 GeV)
Q² < 0.1 (GeV/c)², p_h± > 15 GeV/c
normalization uncertainty 10%
stat. error
syst. error
(1/2π p_T) dσ/dp_T (pb (GeV/c)^-2)
Δσ/σ
p_T (GeV/c)

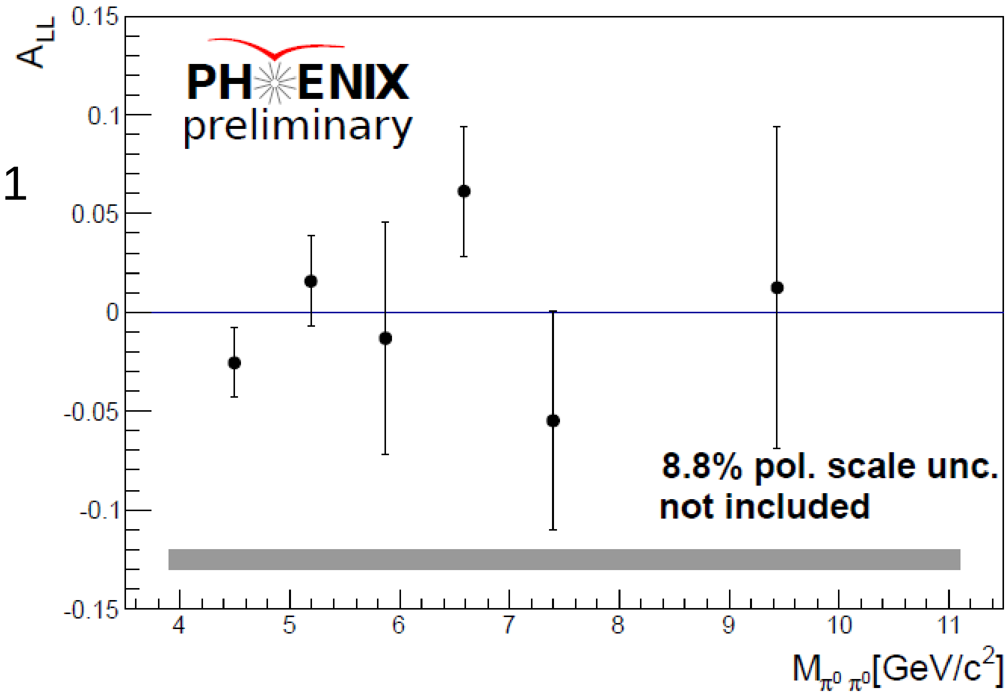
New Result : π^0

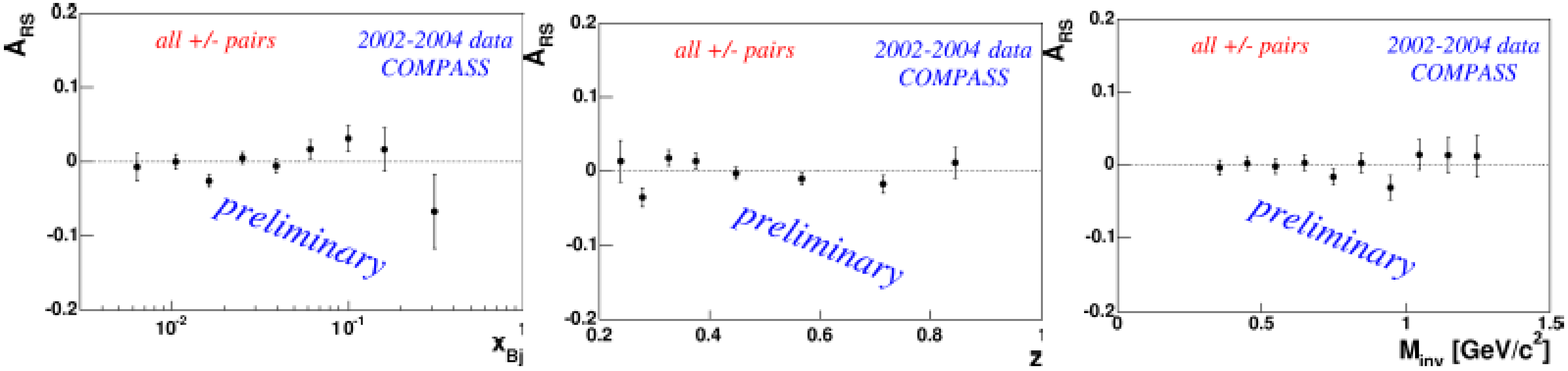
- ✓ **Result < 2 weeks old (Kimiaki Hashimoto)**
- ✓ **Constrains event kinematics further**
  - ✓ **more accurately map out ΔG**
    - ✓ **Sensitivity within the single inclusive range, but more narrow**
  - ✓ **Will be able to provide confirmation of the single hadron result**
- ✓ **Cost=statistics, need more P^4L**



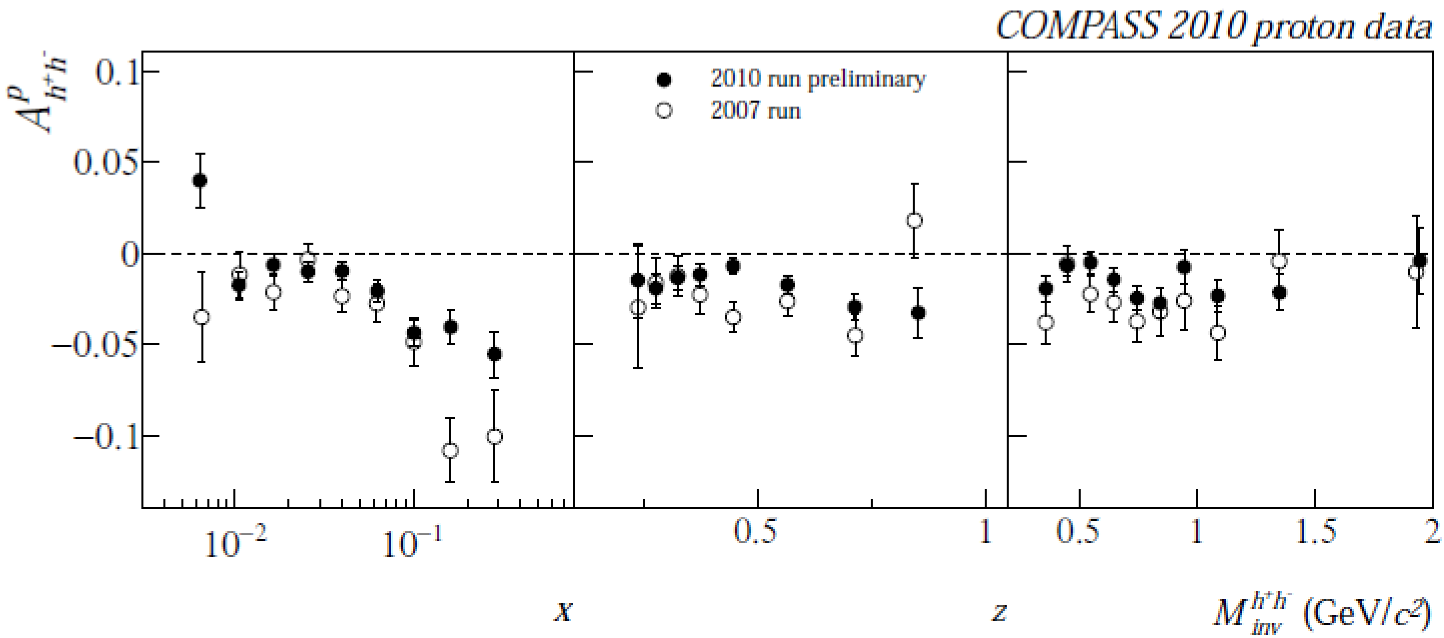








all +/- pairs
2002-2004 data
COMPASS
preliminary
A_{RS}
x_{Bj}
z
M_{inv} [GeV/c^2]



COMPASS 2010 proton data
2010 run preliminary
2007 run
$A^p_{h^+h^-}$
x
z
$M_{inv}^{h^+h^-}$ (GeV/c^2)