DIS 2009
Spin Physics Working Group
Experimental Summary

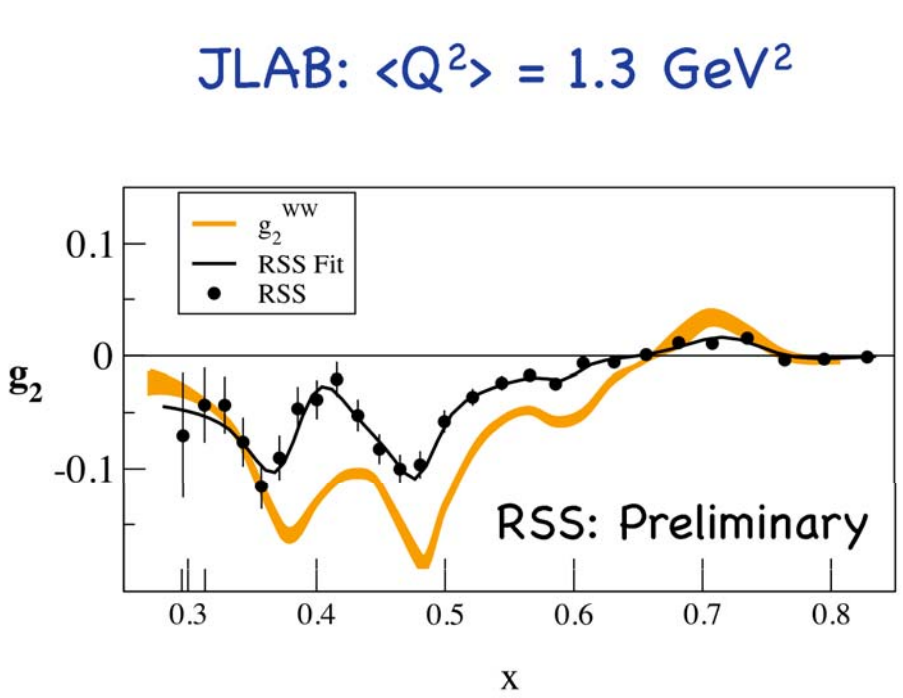
Carl Gagliardi and Gunar Schnell
Experimental co-conveners

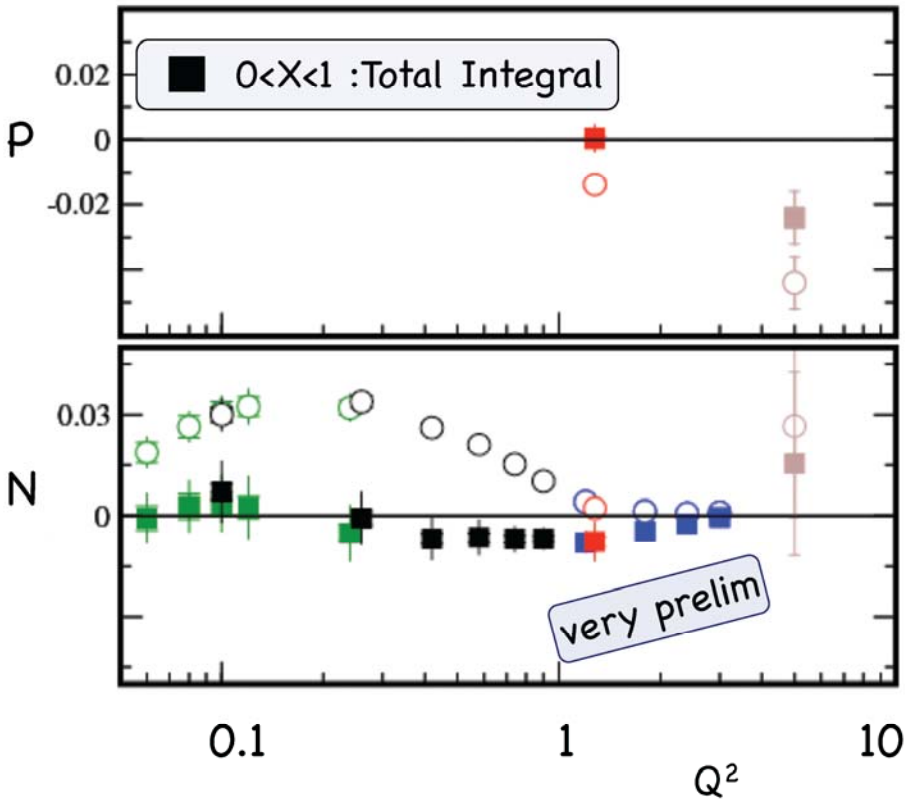
Outline

- Longitudinal spin phenomena (8 talks)
- Transverse spin phenomena (11 talks)
- Generalized parton distributions (9 talks)

Longitudinal spin phenomena

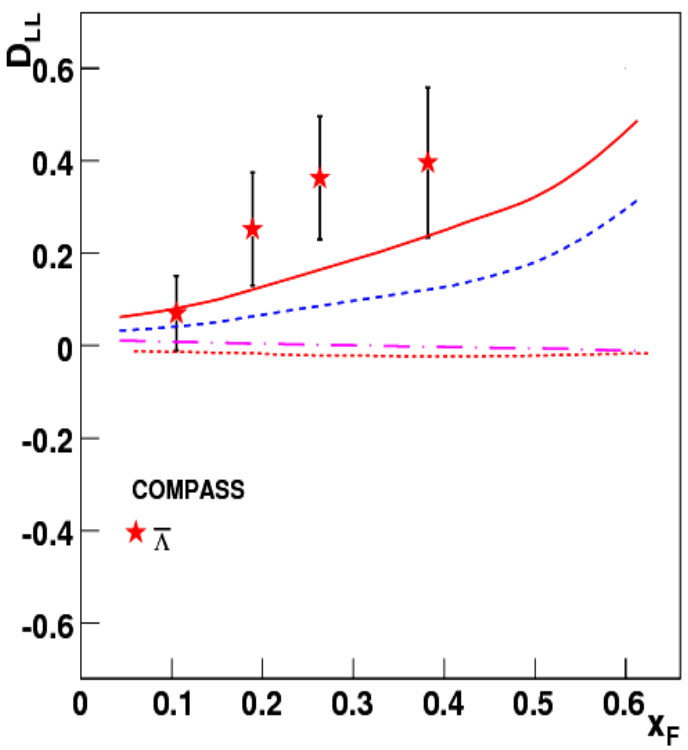
g_2^p and g_2^n in the resonance region

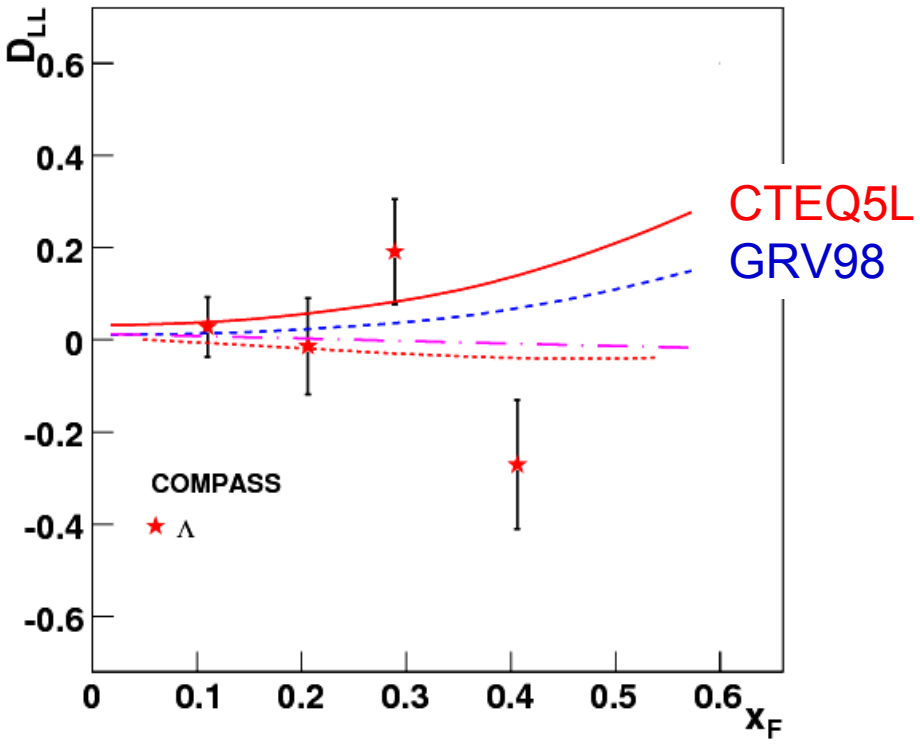




- **Karl Silfer** described new measurements of g_2^p and g_2^n in the resonance region by the **RSS**, **E01-012**, and **SaGDH** experiments at JLab
- "Doubles the Q^2 coverage" for g_2^p (now have 1.3 and 5 GeV^2)
- Provides new tests of the Burkhardt-Cottingham sum rule

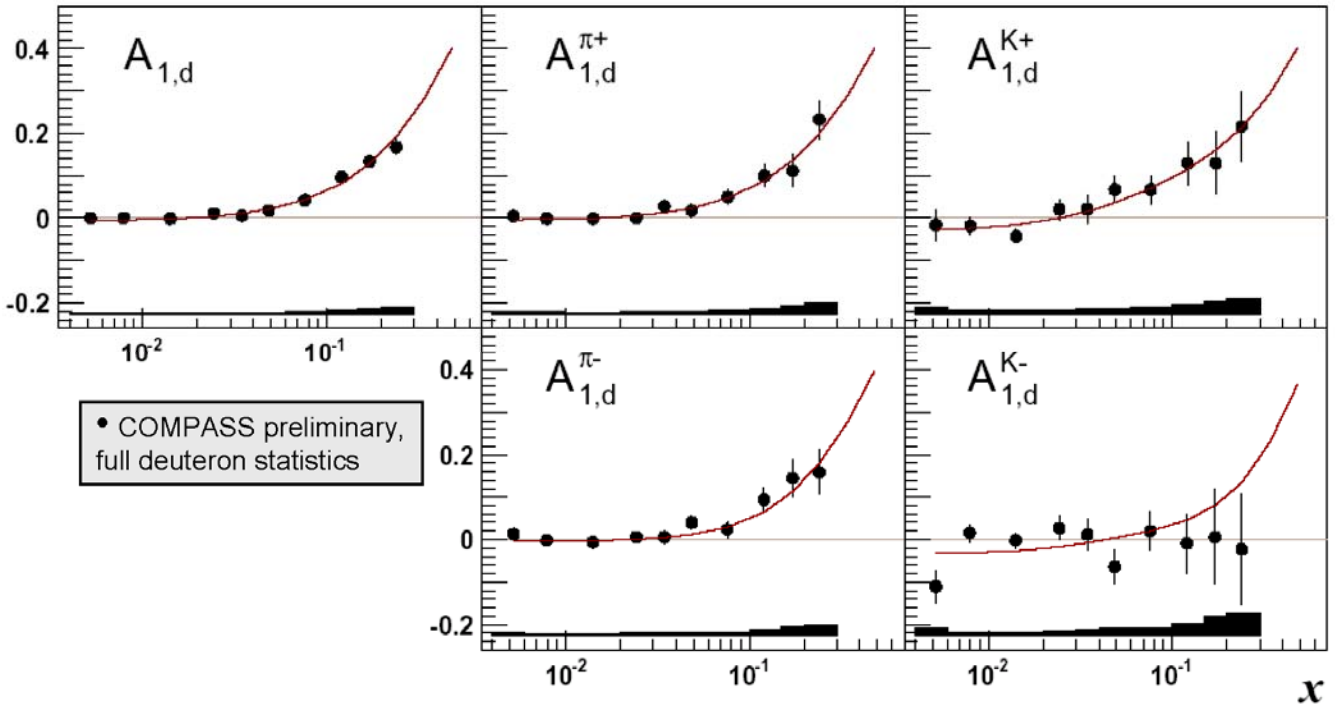
Strange quark density





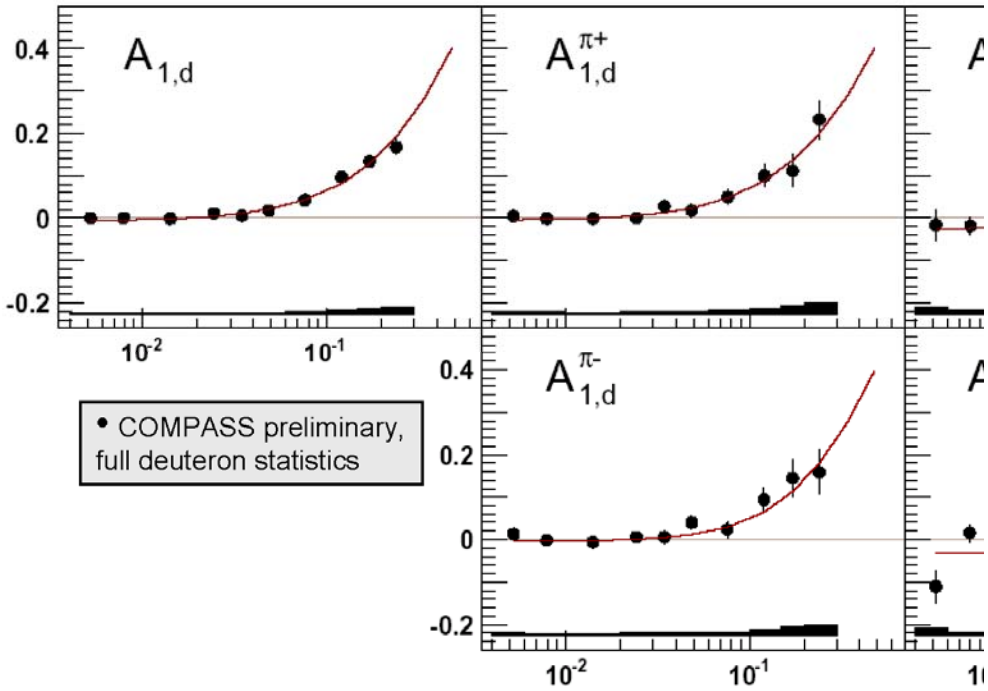
- **M.G. Sapozhnikov** reported measurements of longitudinal polarization transfer in Lambda and anti-Lambda production by COMPASS
- Polarization transfer from the muon to the Lambda is substantial
- Found no sensitivity to the target polarization
- Results are sensitive to the strange (anti-)quark density

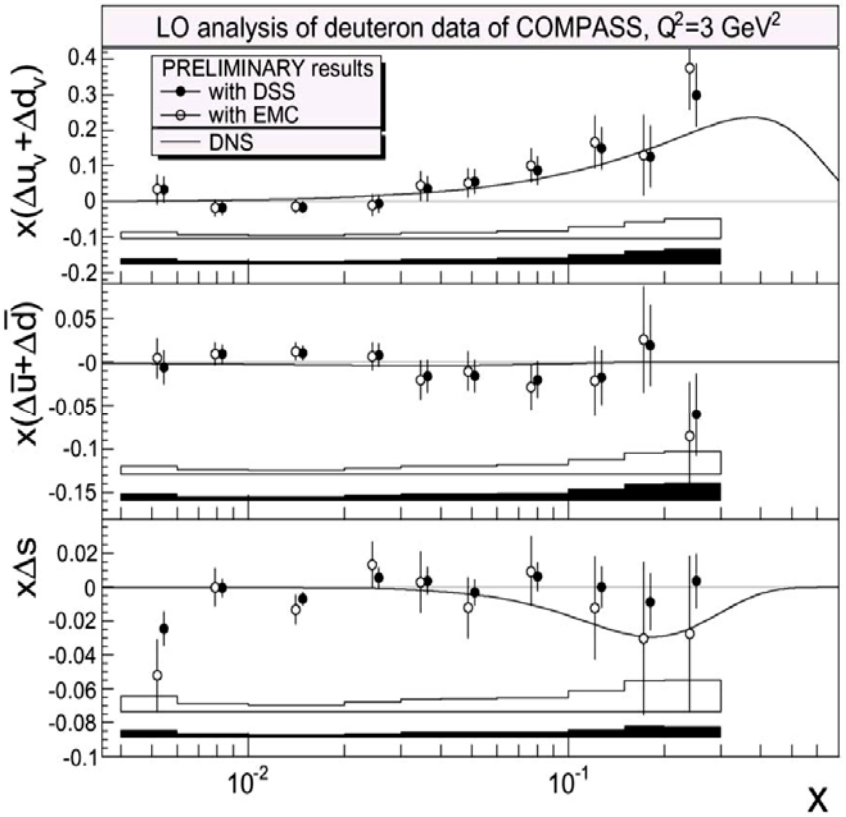
Strange quark polarization



- **Helena Santos** reported COMPASS DIS and SIDIS results for Δs, based on the full (2002-06) deuteron data set
- SIDIS results are in good agreement with HERMES.
- SIDIS also agrees well with predictions from DSSV (except possibly for K^-)
- Results are compatible with $\Delta s = 0$
- Conclude:
  - Δs (inclusive DIS) = –0.045 ± 0.005 ± 0.010
  - Δs (SIDIS) = –0.01 ± 0.01 ± 0.01

Strange quark polarization





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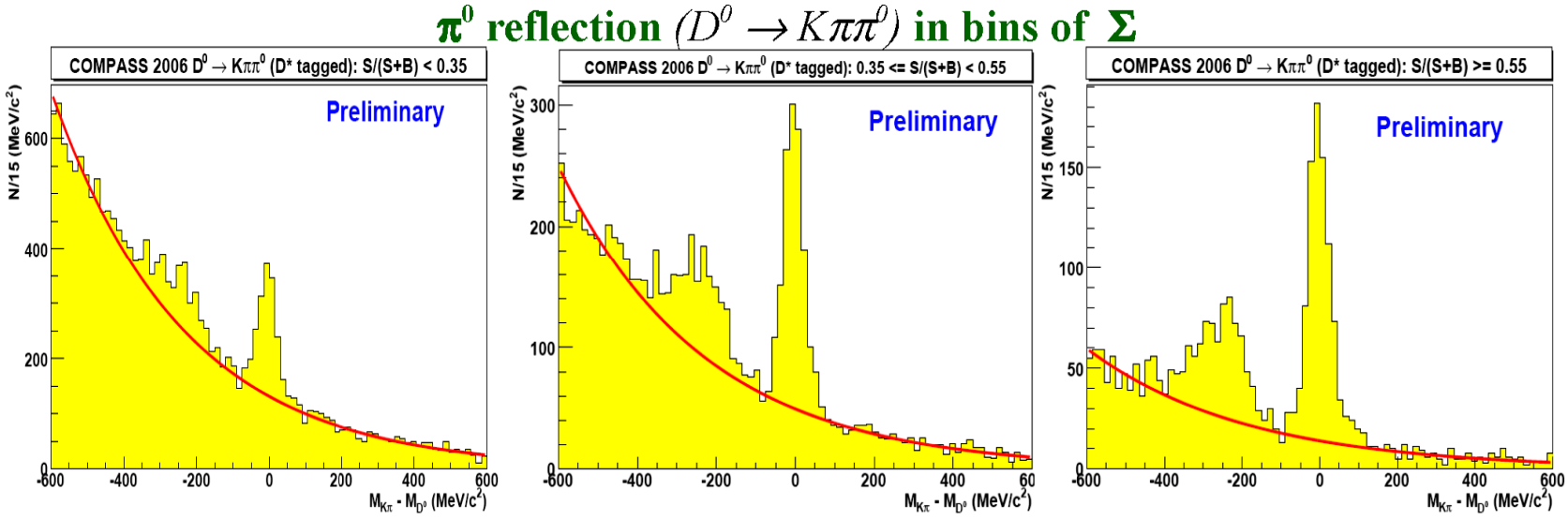
$\Delta G/G$ from photon-gluon fusion



- **Celso Franco** reported the latest (2002-06) COMPASS results on gluon polarization in the proton from open charm measurements
- Calculate asymmetries weighted by the S/(S+B) probability
- Have recently included events from $D^0 \to K\pi\pi^0$
- Find:
  - $\Delta G/G = -0.49 \pm 0.27 \pm 0.11$ @ $\langle x_g \rangle = 0.11$ and $\langle \mu^2 \rangle = 13$ GeV^2
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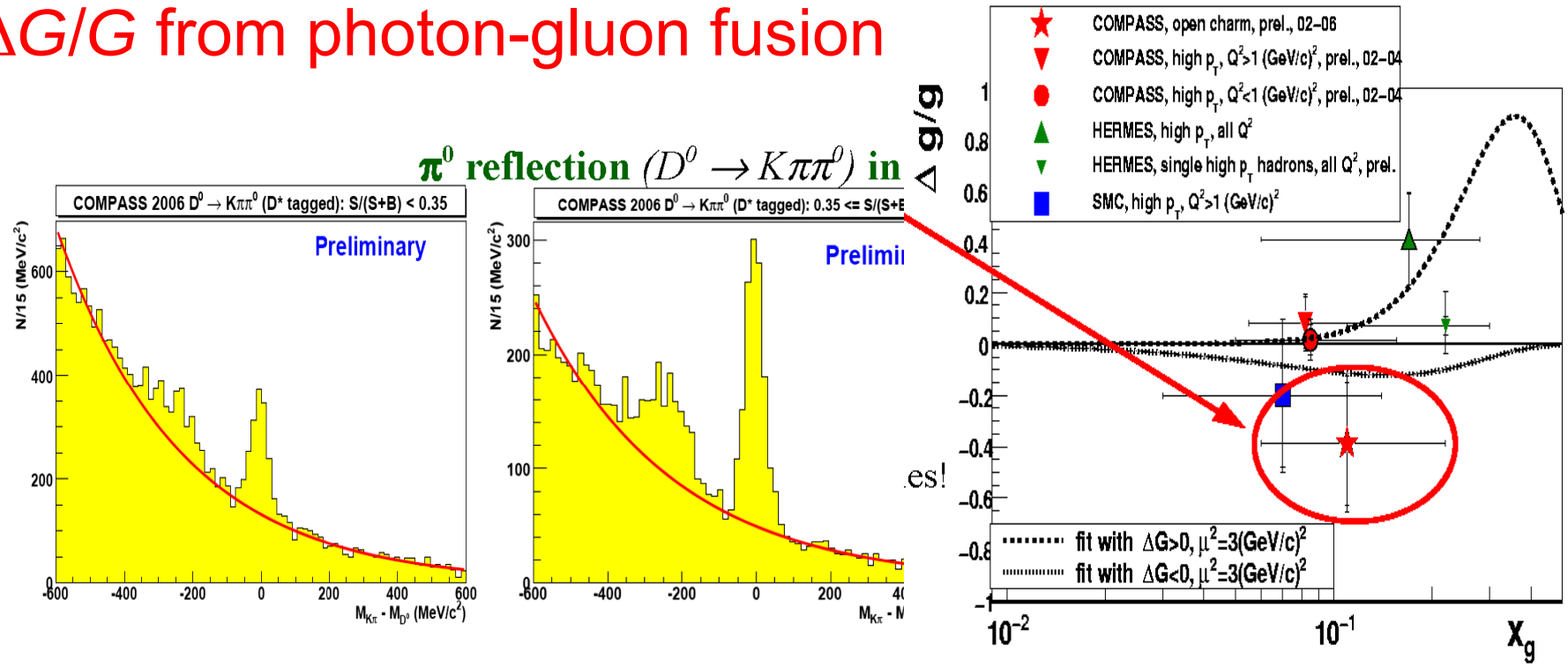

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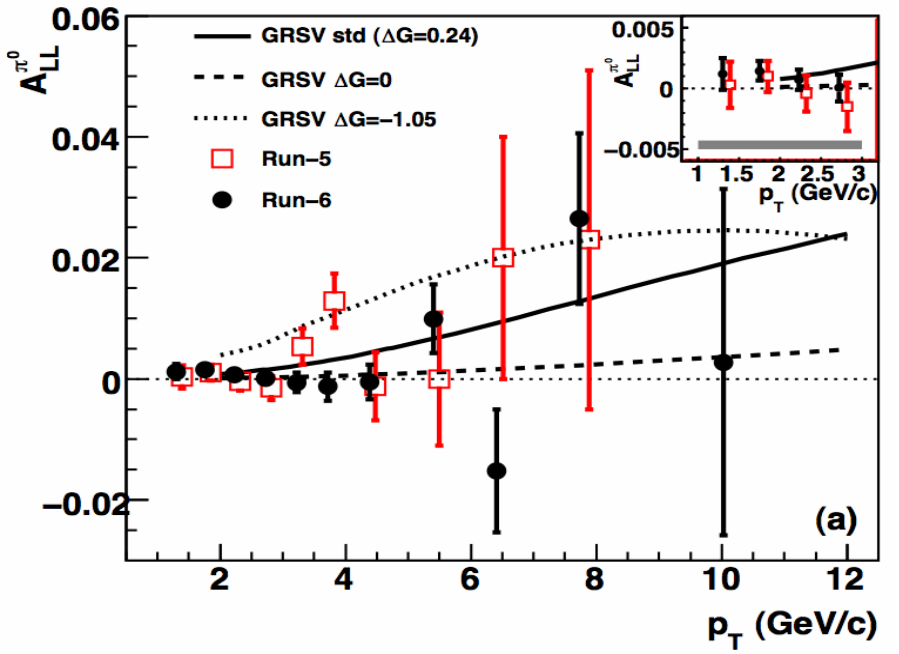
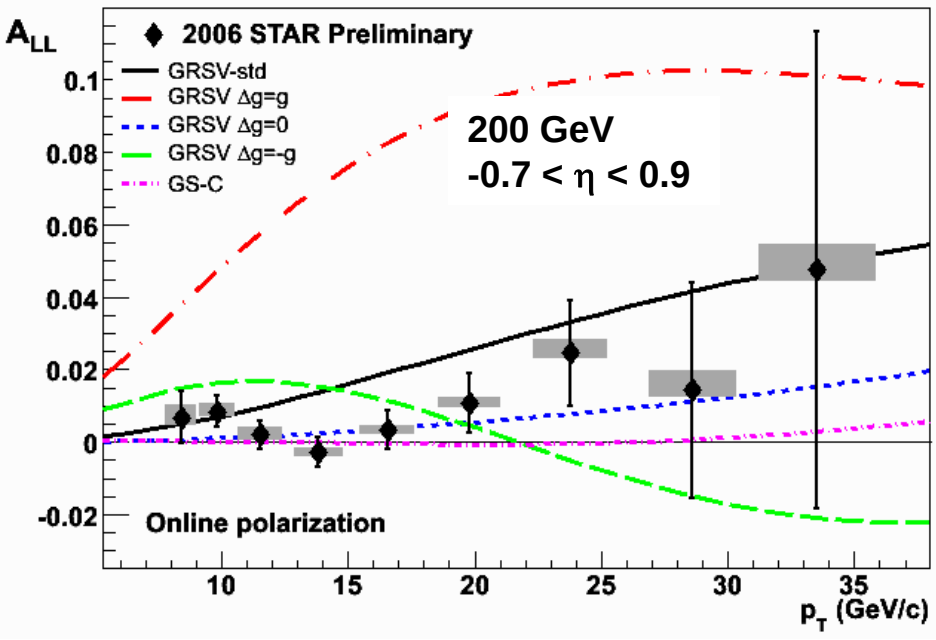
ΔG from polarized pp collisions at RHIC

PHENIX



STAR



- **Swadhin Taneja** (PHENIX, inclusive π^0) and **Bernd Surrow** (STAR, inclusive jets) reported the latest results on gluon polarization from A_{LL} measurements in pp collisions at RHIC
- Find the gluon polarization for $0.02 < x < 0.3$ is small

ΔG from polarized pp collisions at RHIC

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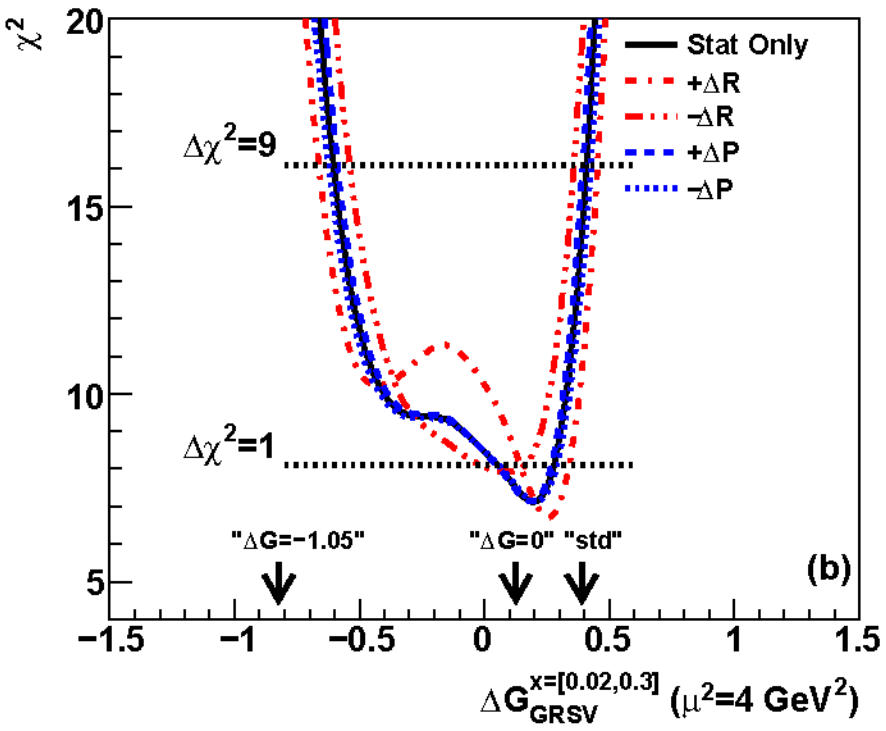

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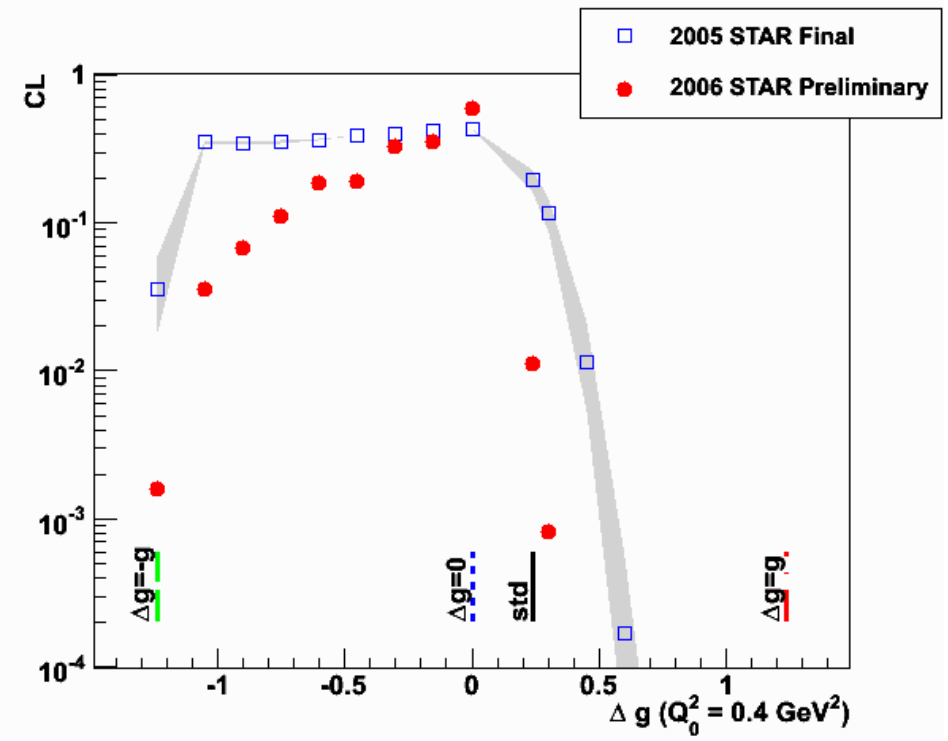

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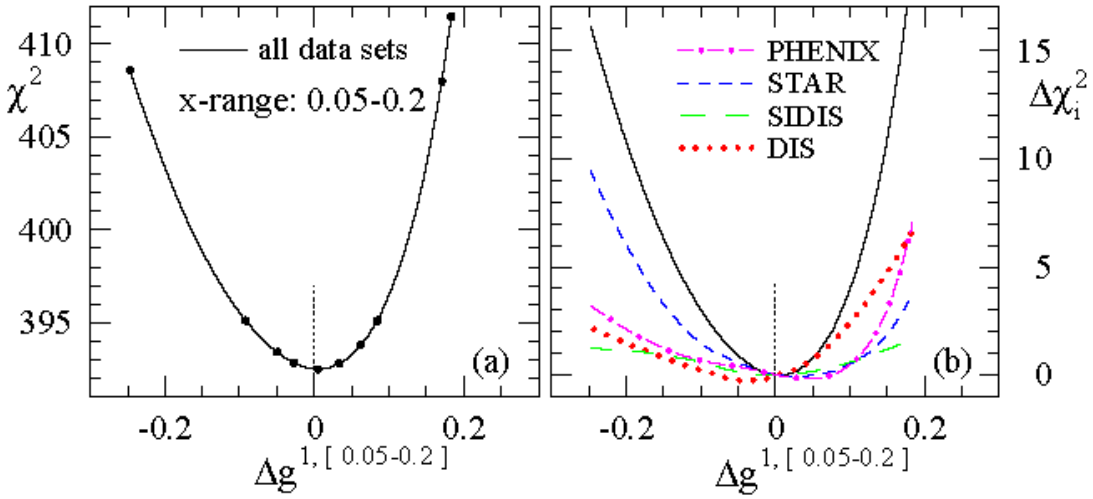
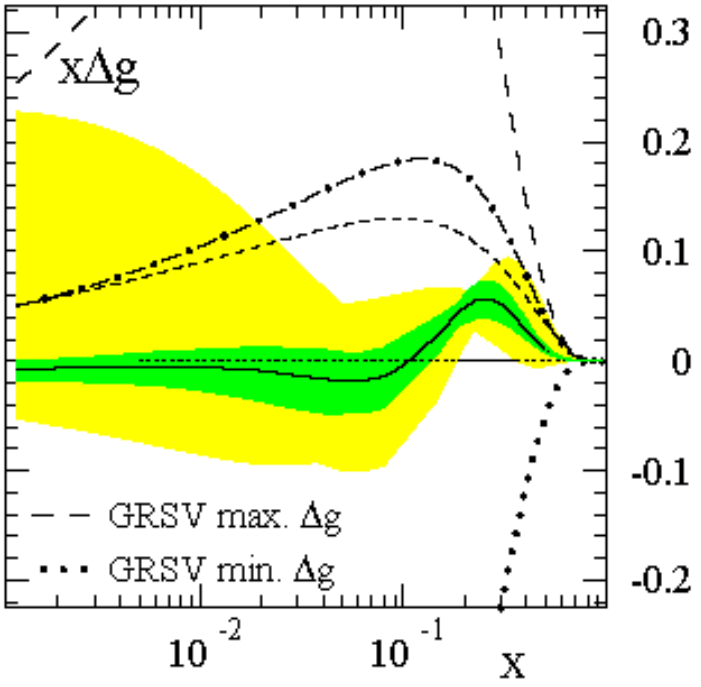
DSSV – first global analysis with RHIC *pp* data

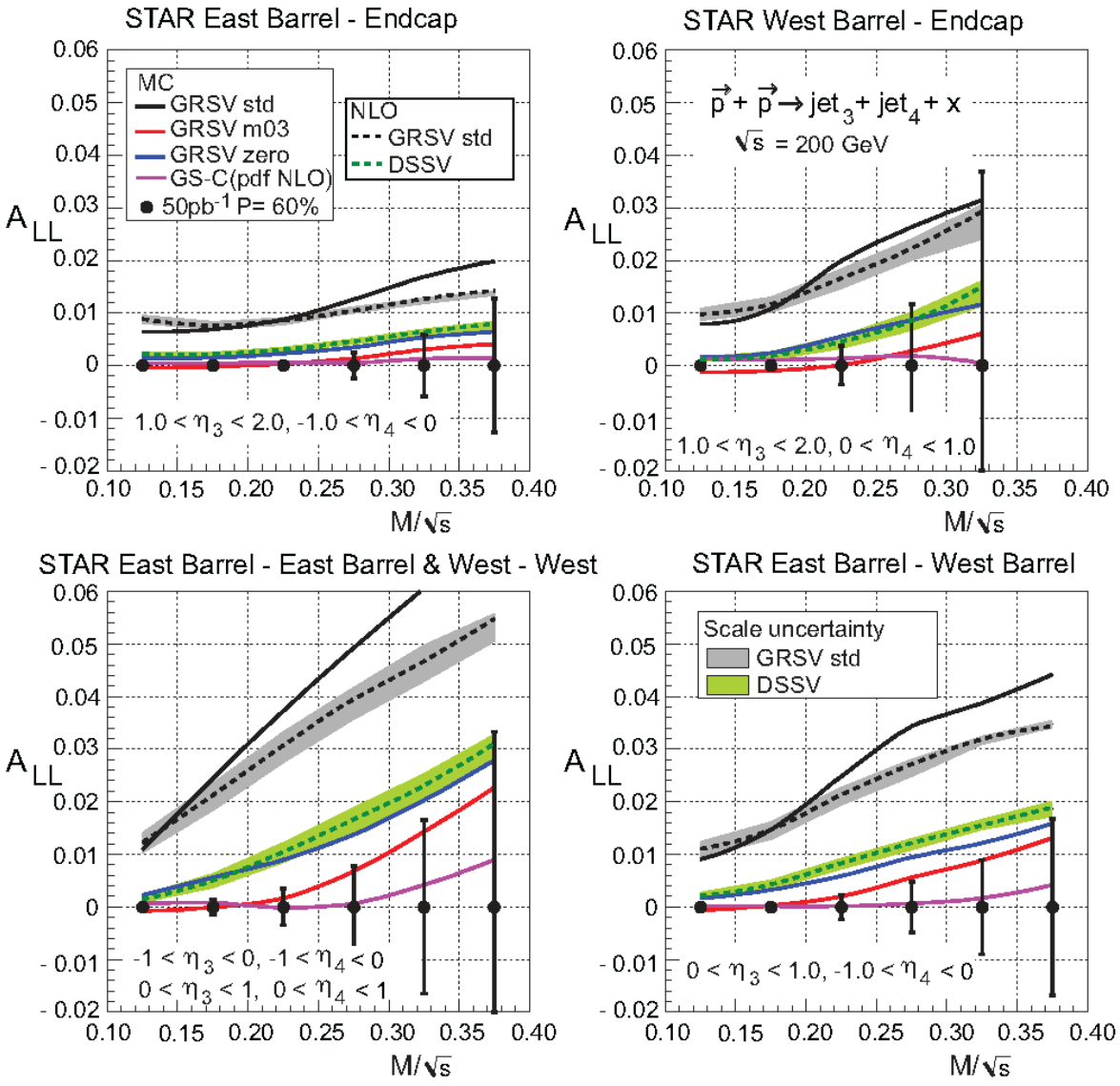
de Florian et al., PRL 101, 072001





- The first global NLO analysis to include **inclusive DIS, semi-inclusive DIS, and RHIC pp data** on an equal footing
- RHIC data (PHENIX neutral pions, STAR jets) play a significant role in constraining the gluon polarization
- Finds a node in the gluon distribution near $x \sim 0.1$

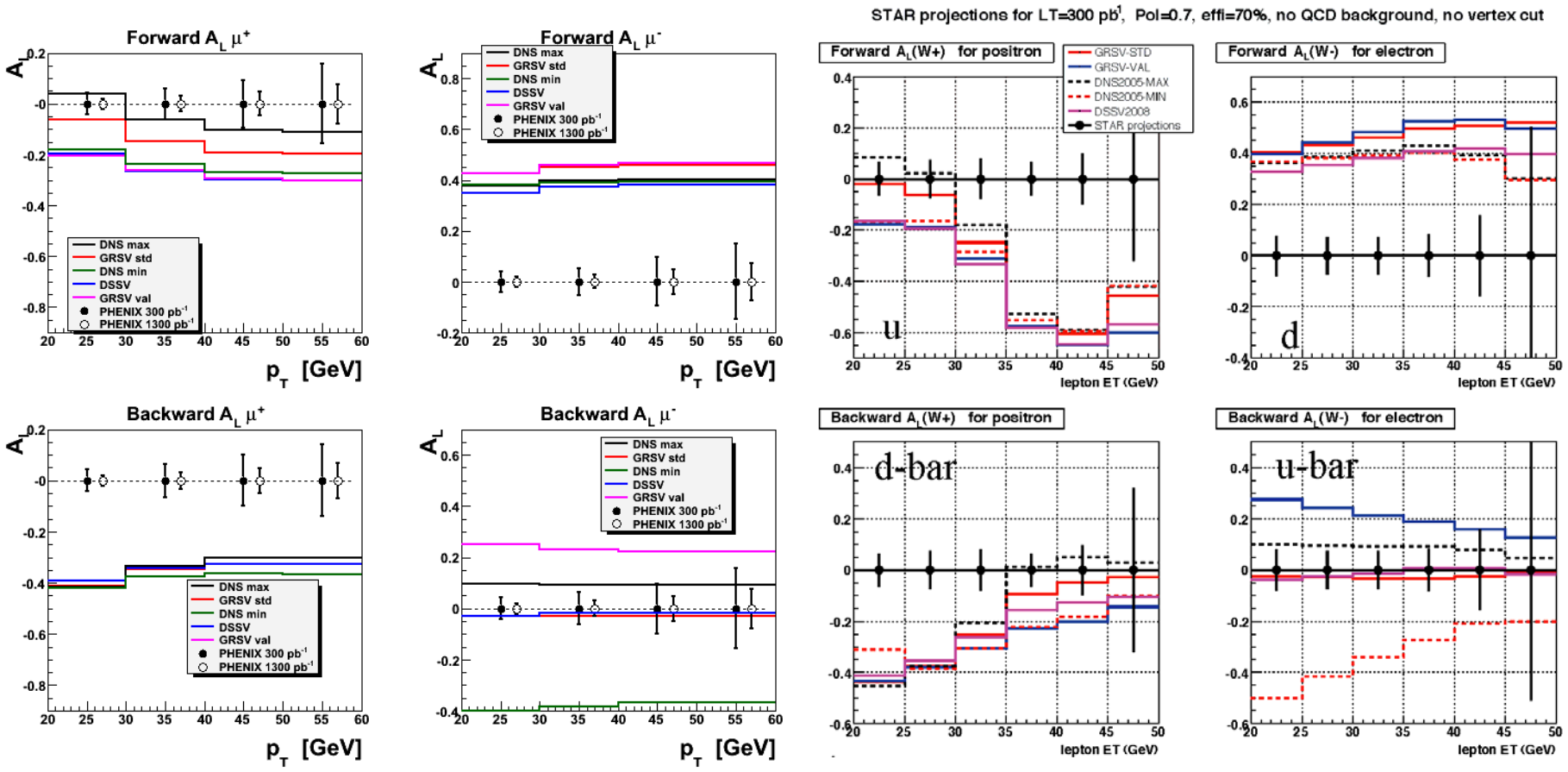
Next step at RHIC: correlation measurements



$$x_1, x_2 = \frac{M}{\sqrt{s}} e^{\pm y}$$

- Direct measure of the momentum-dependence of $\Delta g(x)$
- Measurements at $\sqrt{s}$ = 500 GeV will extend the reach to lower x

And the step after that: *W* asymmetries



- **Todd Kempel** (PHENIX) and **Jan Balewski** (STAR) described plans to measure A_L for *W* production at RHIC to separate the quark and antiquark polarizations
- Will also provide a dramatic extension of Q^2 compared to polarized DIS and SIDIS

Transverse spin phenomena

Many different transverse distributions available

		quark		
		U	L	T
nucleon	U			
	L			
	T			

Many different transverse distributions available

		quark		
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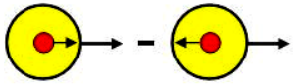
	L		g_1 	
	T			

Many different transverse distributions available

		quark		
		U	**L**	**T**
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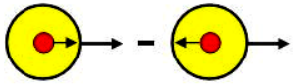
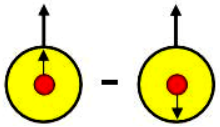
	L		g_1 	
	T			h_1 

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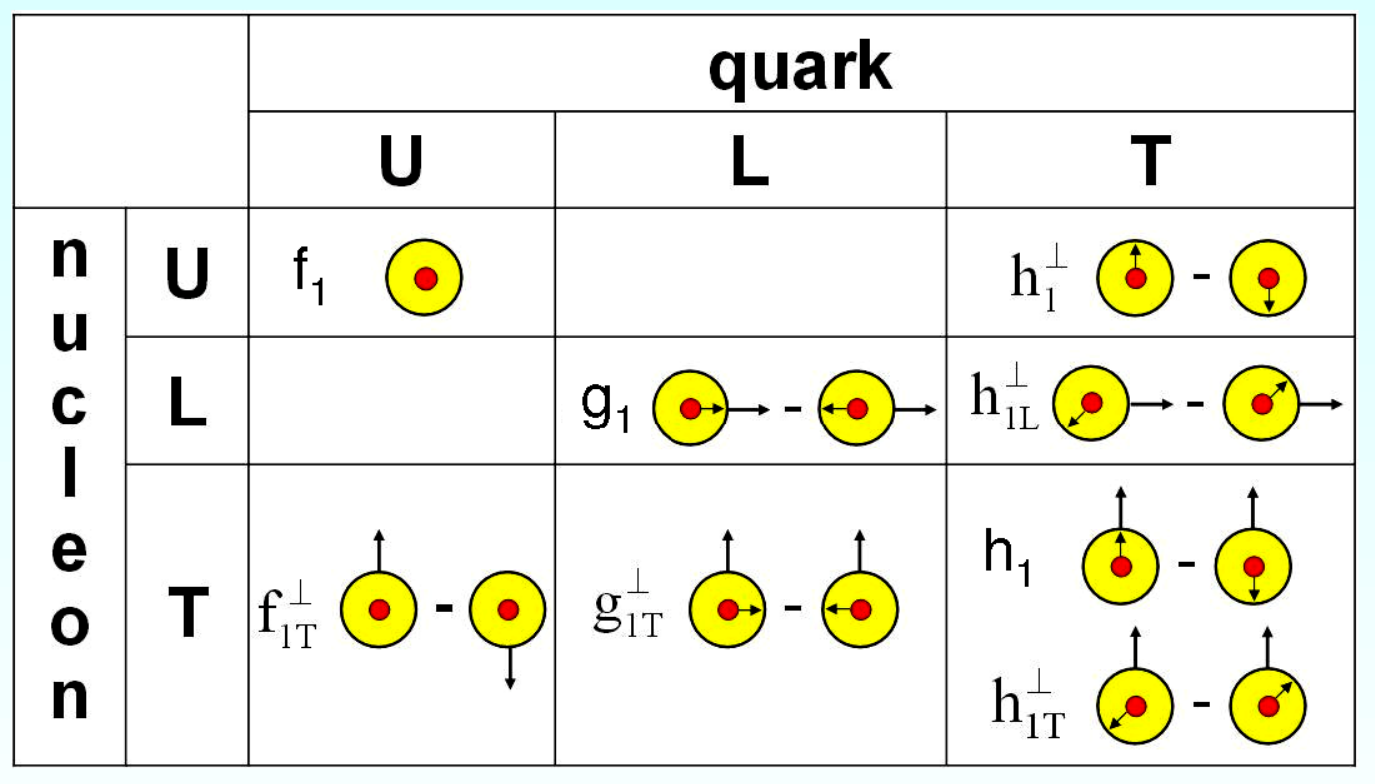

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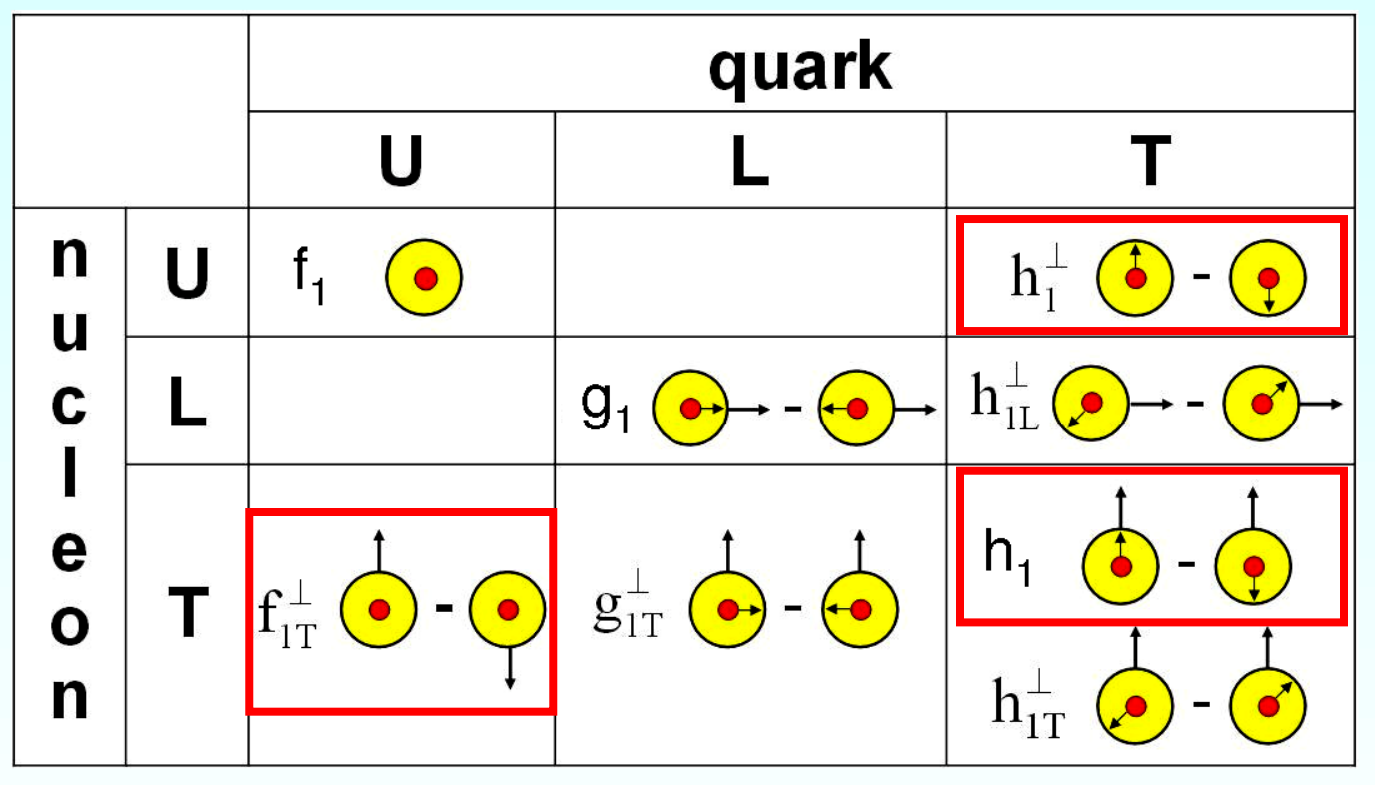
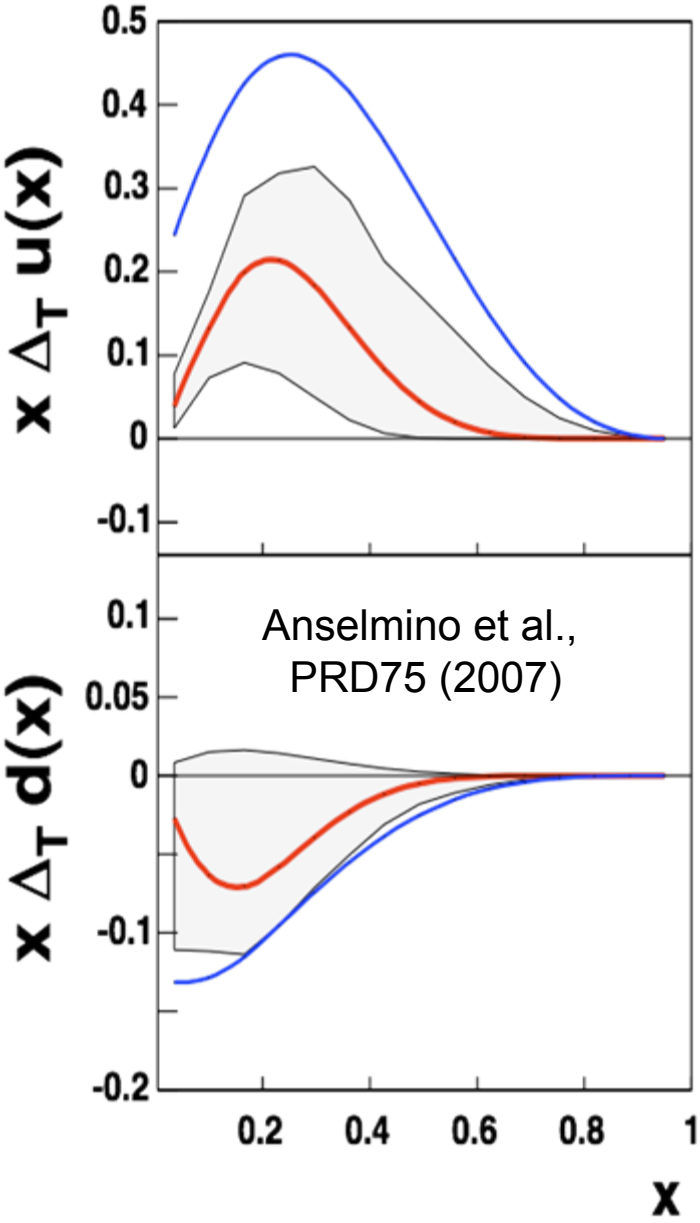


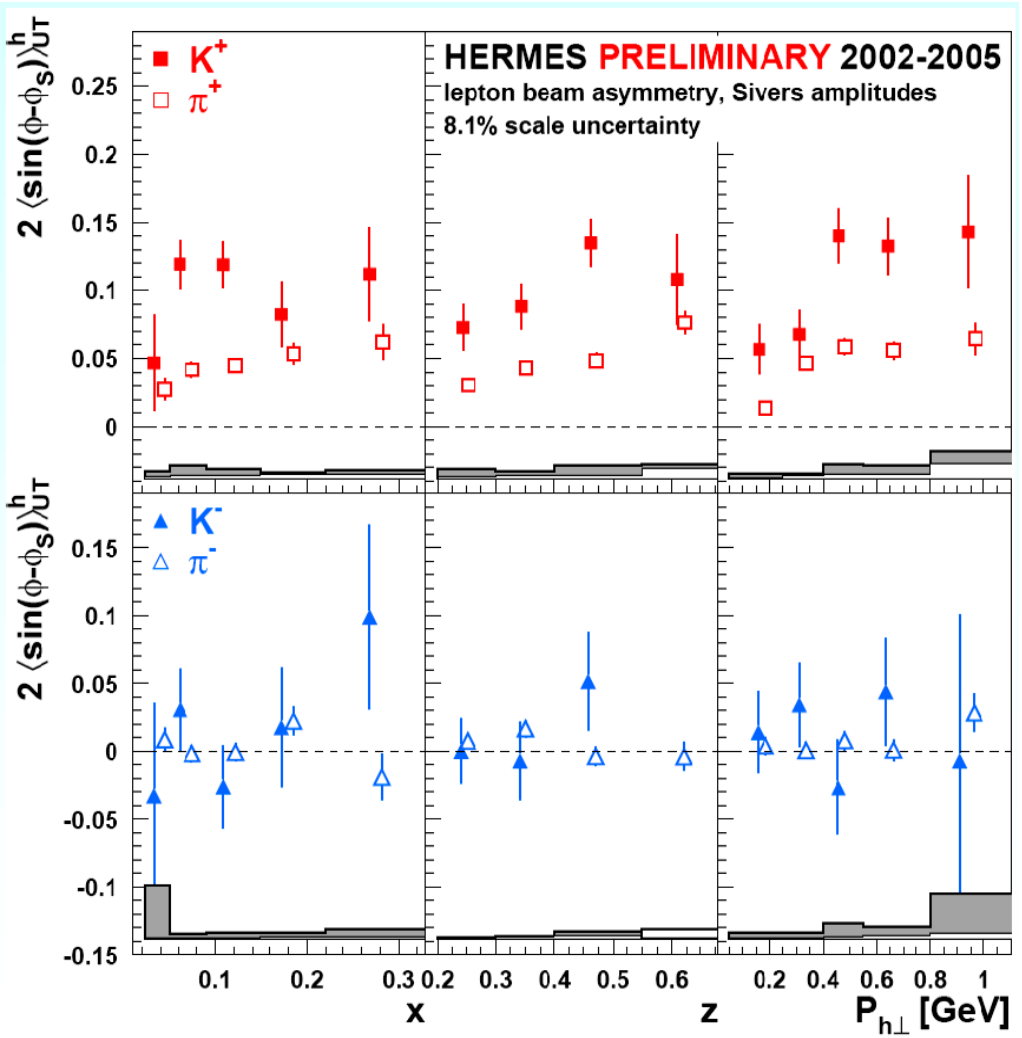
- Several experiments presented results involving the **Sivers function**, **transversity**, and/or the **Boer-Mulders effect**
- In addition, **Patrizia Rossi** discussed the expected sensitivity of experiments with CLAS that are underway or planned for the 12 GeV JLab upgrade

First extraction of transversity



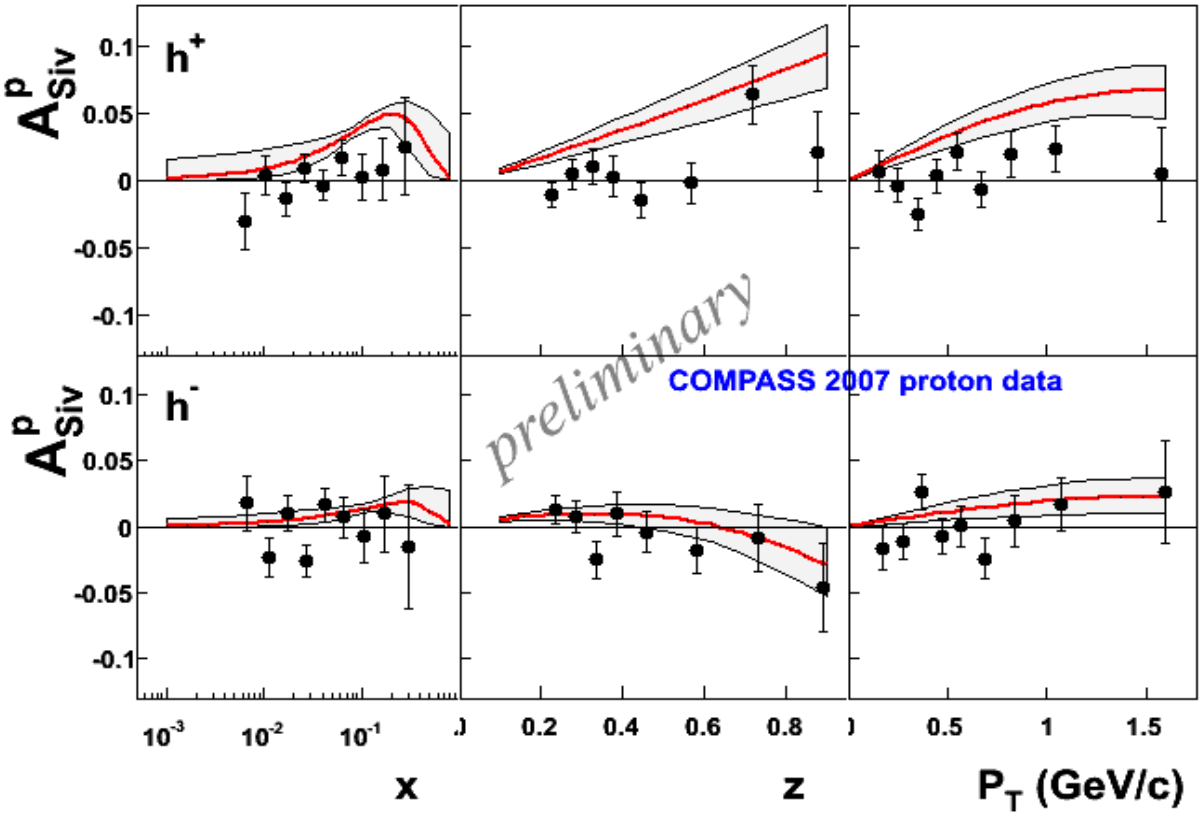
- The recent **first extraction of transversity** came from a global analysis that combined measurements of the Collins effect by HERMES and COMPASS with measurements of the Collins fragmentation function by BELLE

Sivers function measurements on hydrogen



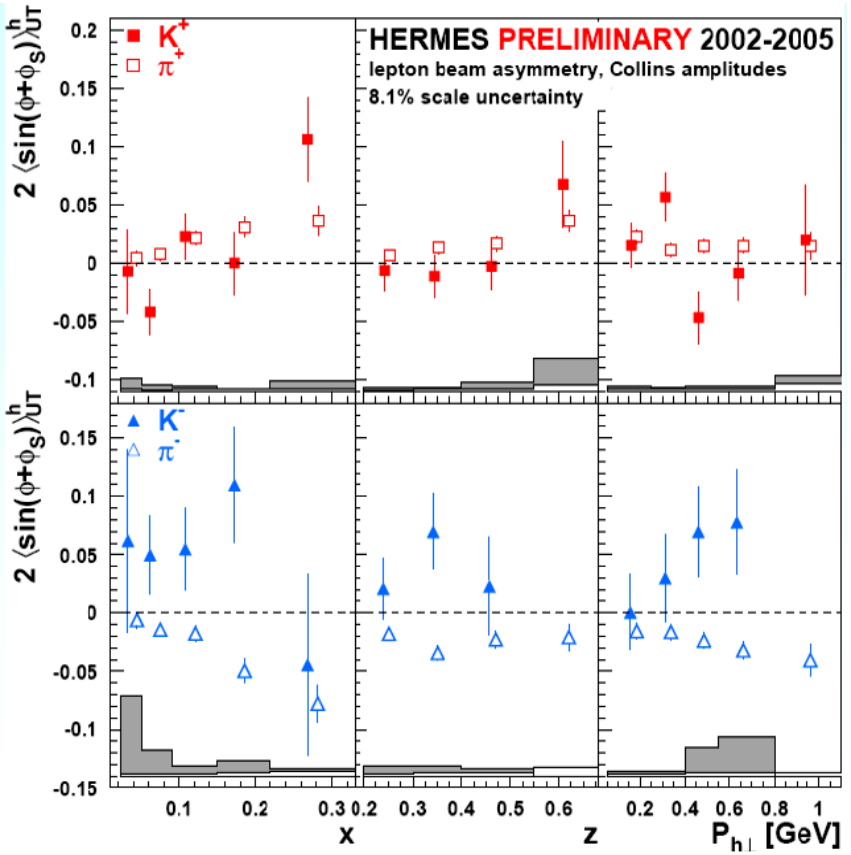
- **Luciano Pappalardo** presented HERMES measurements of the Sivers function for identified pions and kaons
- Large K^+ amplitude suggests the Sivers function may be sizable for sea quarks

Sivers function measurements on hydrogen



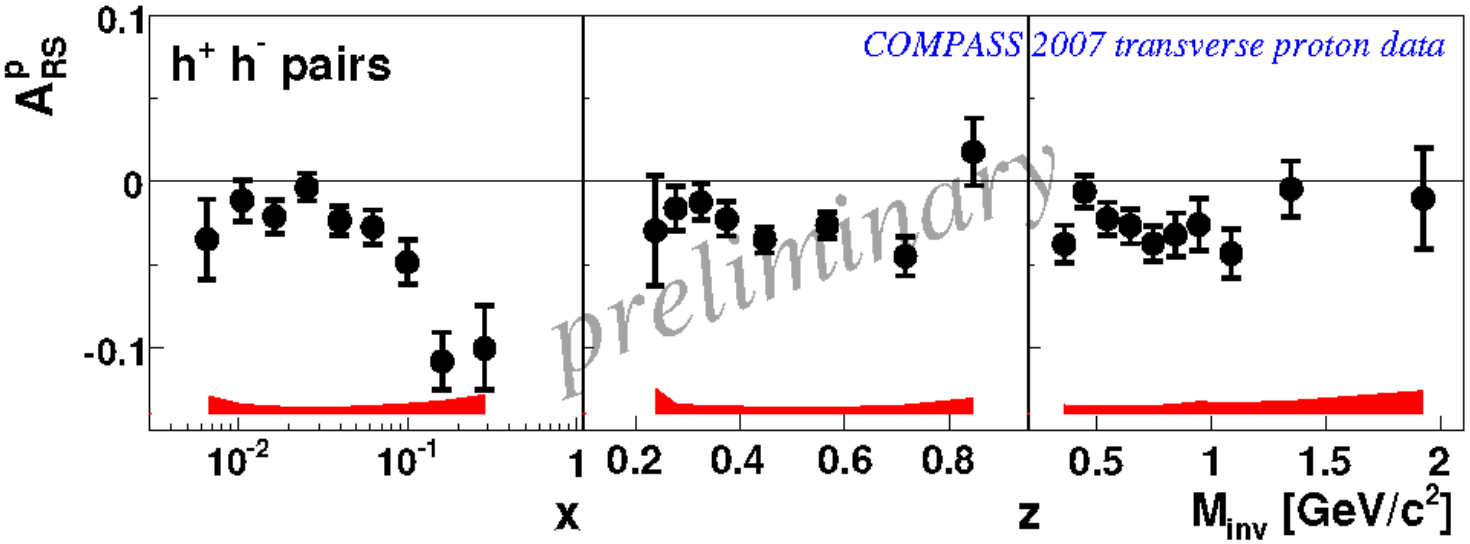
- **Andrea Bressan** presented Sivers function measurements from COMPASS, compared to the most recent predictions from Anselmino et al.
- The predictions tend to overshoot the h^+ asymmetries

Transversity measurement on hydrogen



- **Luciano Pappalardo** presented Collins effect results for identified pions and kaons
- π^+ and π^- have significant asymmetries of opposite signs. K^- has a sizable, positive asymmetry
- Also presented di-hadron asymmetries that are sensitive to transversity via the interference fragmentation function

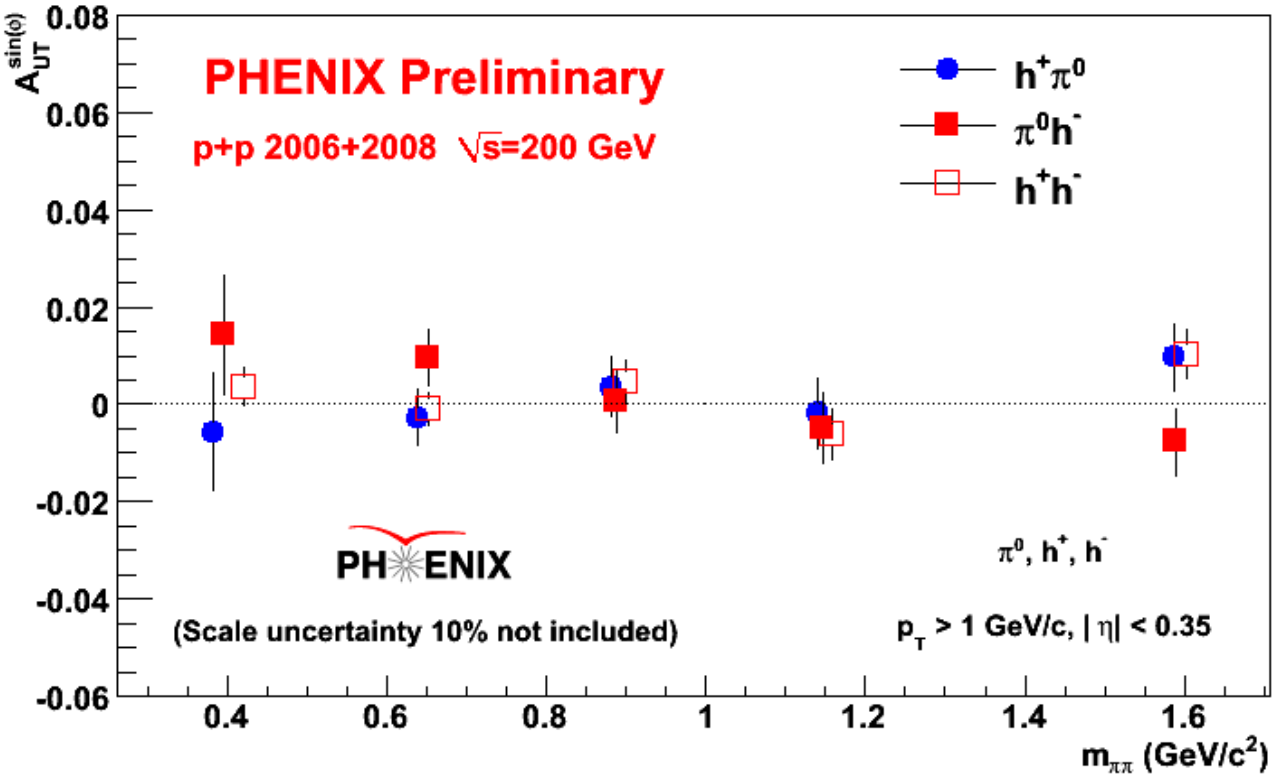
Transversity measurement on hydrogen



- **Heiner Wollny** presented 2007 COMPASS results for h^+h^- pair asymmetries that are sensitive to transversity through the interference fragmentation function
- Results similar to, but somewhat larger in magnitude than, HERMES
- No sign change is seen when crossing the rho mass

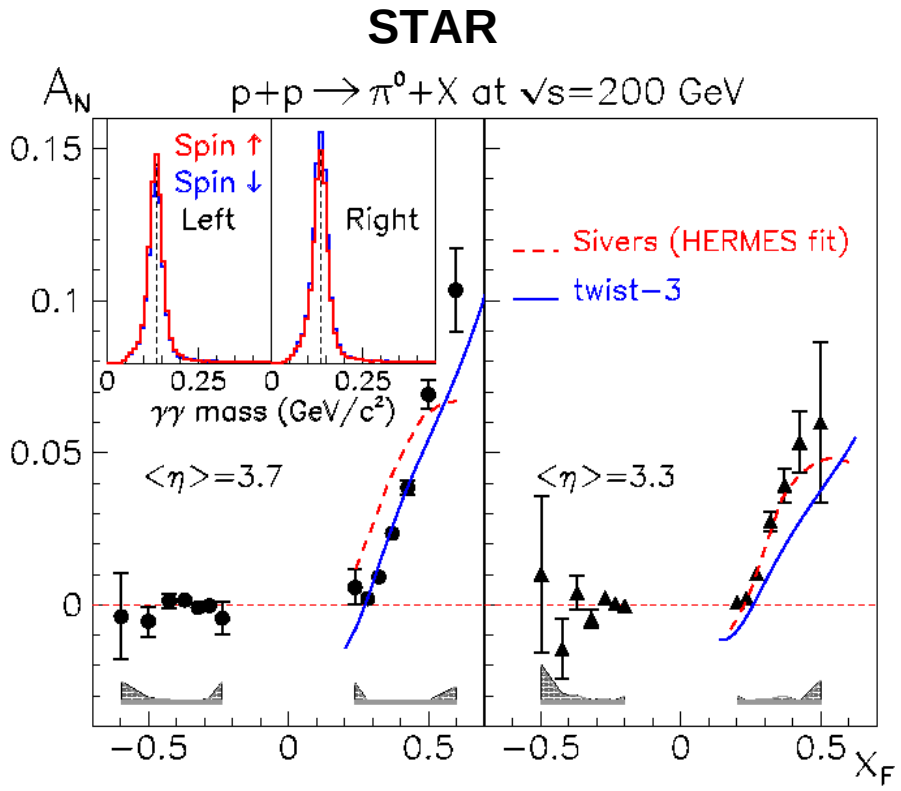
- **Andrea Bressan** presented 2007 COMPASS single-hadron results for Collins asymmetries on hydrogen with increased statistics compared to the previous preliminary results

Interference fragmentation function in *pp* collisions



- **John Koster** presented 2006-08 PHENIX results for the mid-rapidity di-hadron interference fragmentation function in 200 GeV *pp* collisions at RHIC
- Results appear consistent with zero with current statistics
- Will provide access to transversity once the interference fragmentation function is measured in e^+e^- collisions at BELLE

Forward transverse spin asymmetries at RHIC



- **Steve Heppelmann** (STAR) and **J.H. Lee** (BRAHMS) presented measurements of large transverse single-spin asymmetries for forward rapidity inclusive hadron production at RHIC
- May involve a combination of Sivers and Collins effects

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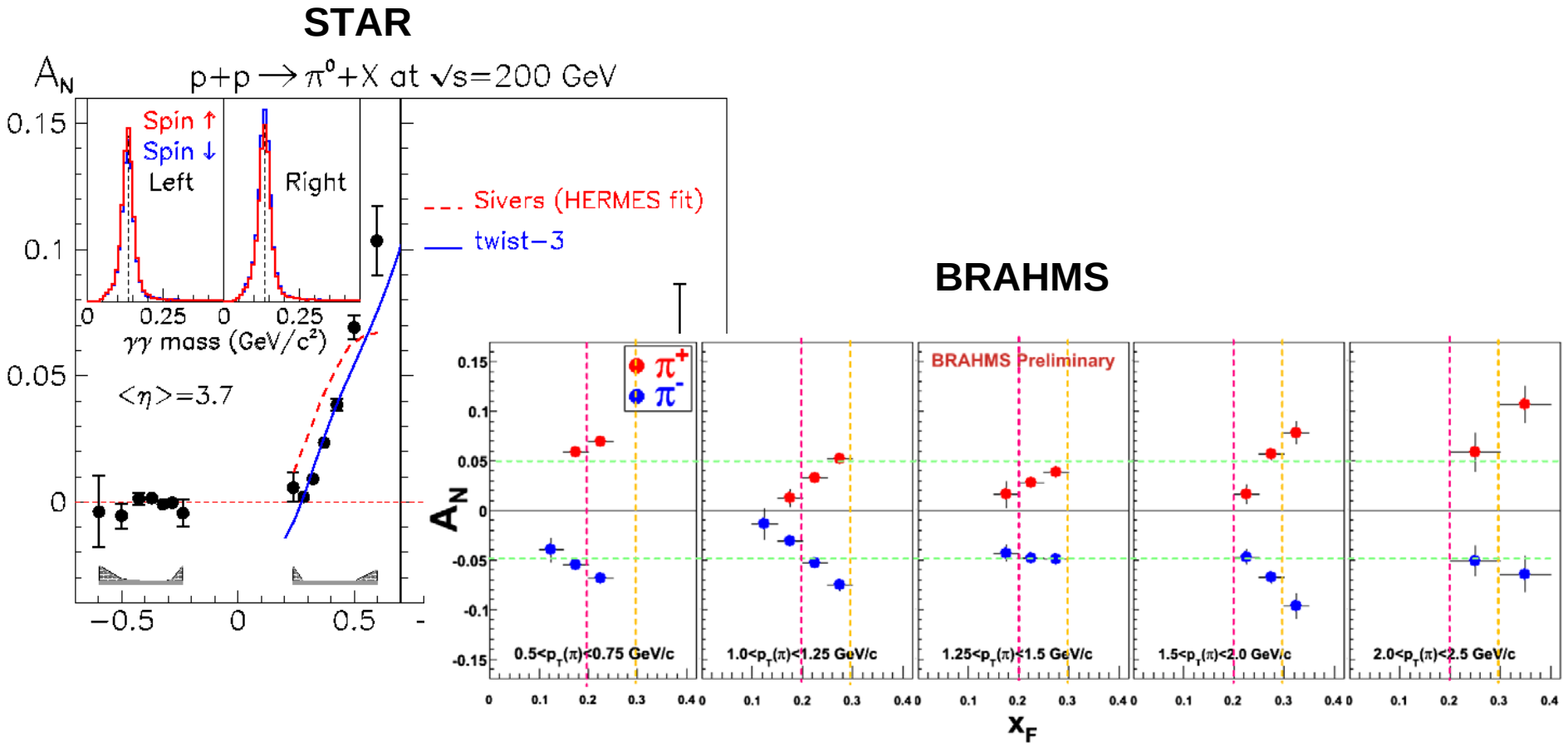

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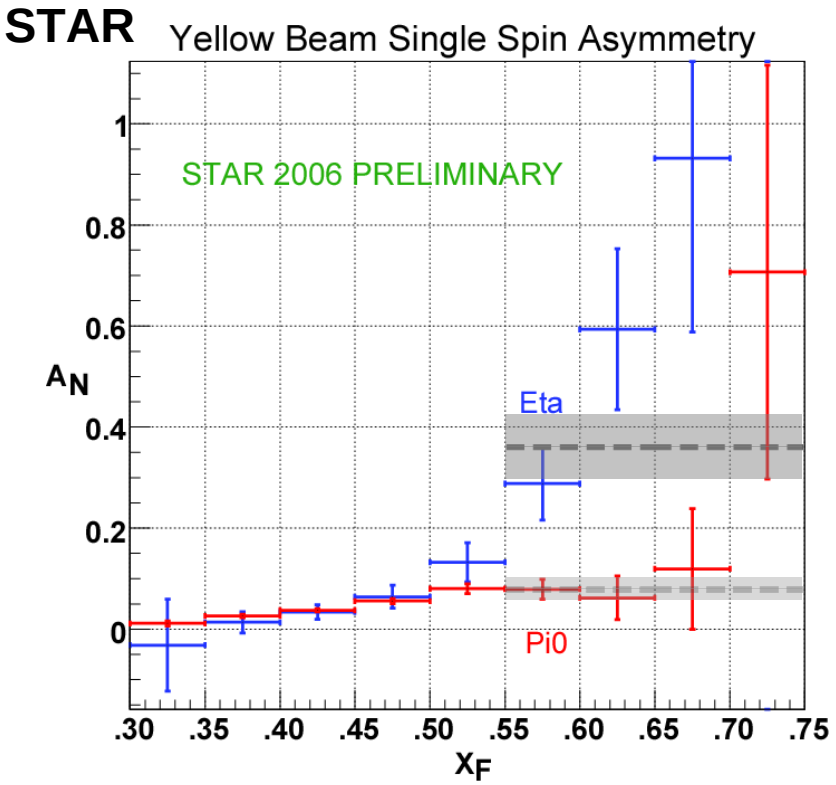
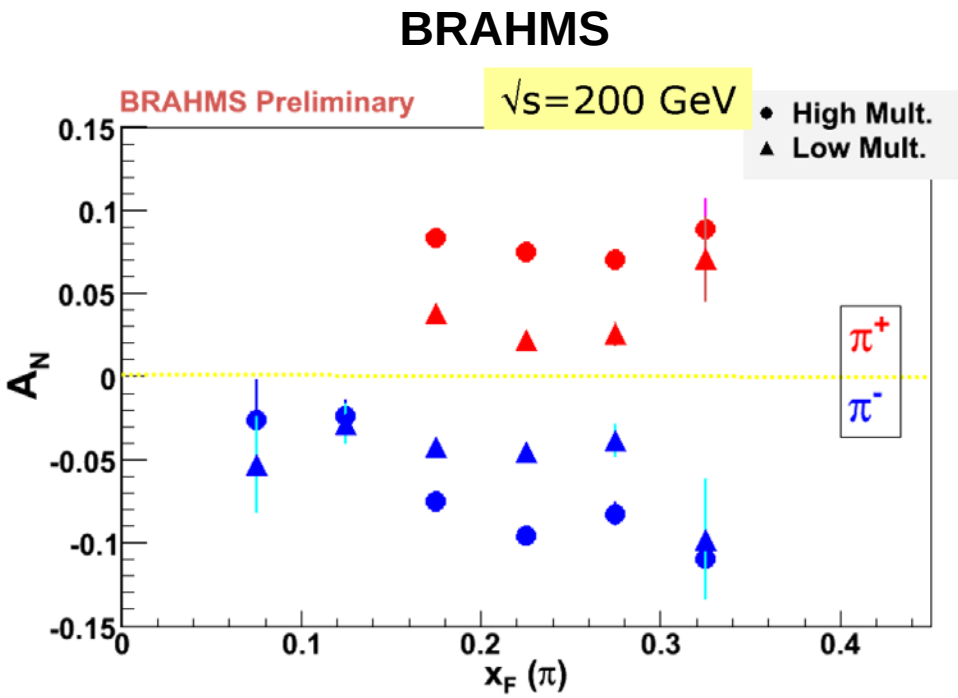
Surprises in the forward direction at RHIC

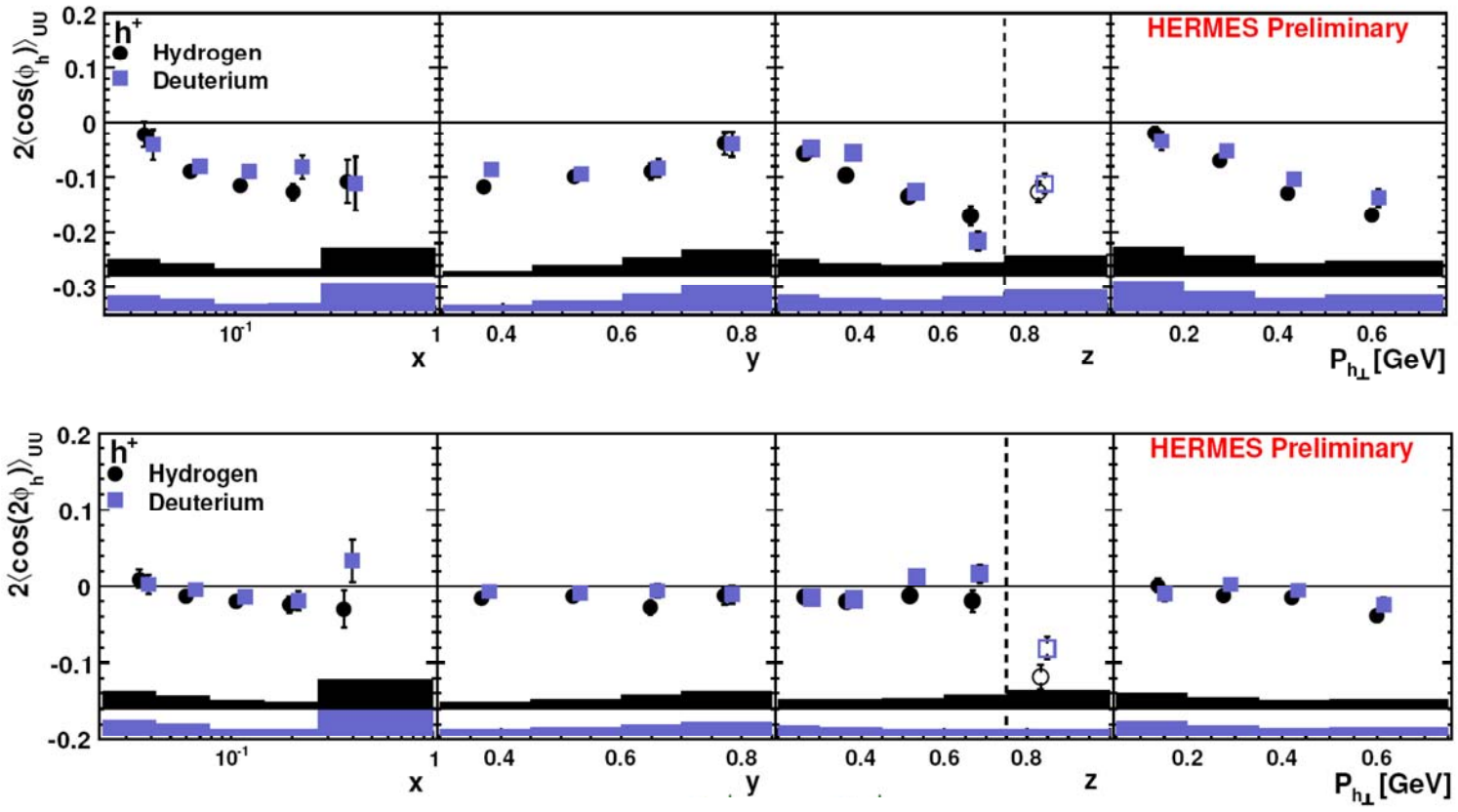




- **STAR** finds η asymmetries are much larger than π^0 asymmetries at large x_F
- STAR also finds that A_N is increasing or constant with p_T to ~3.5 GeV/c

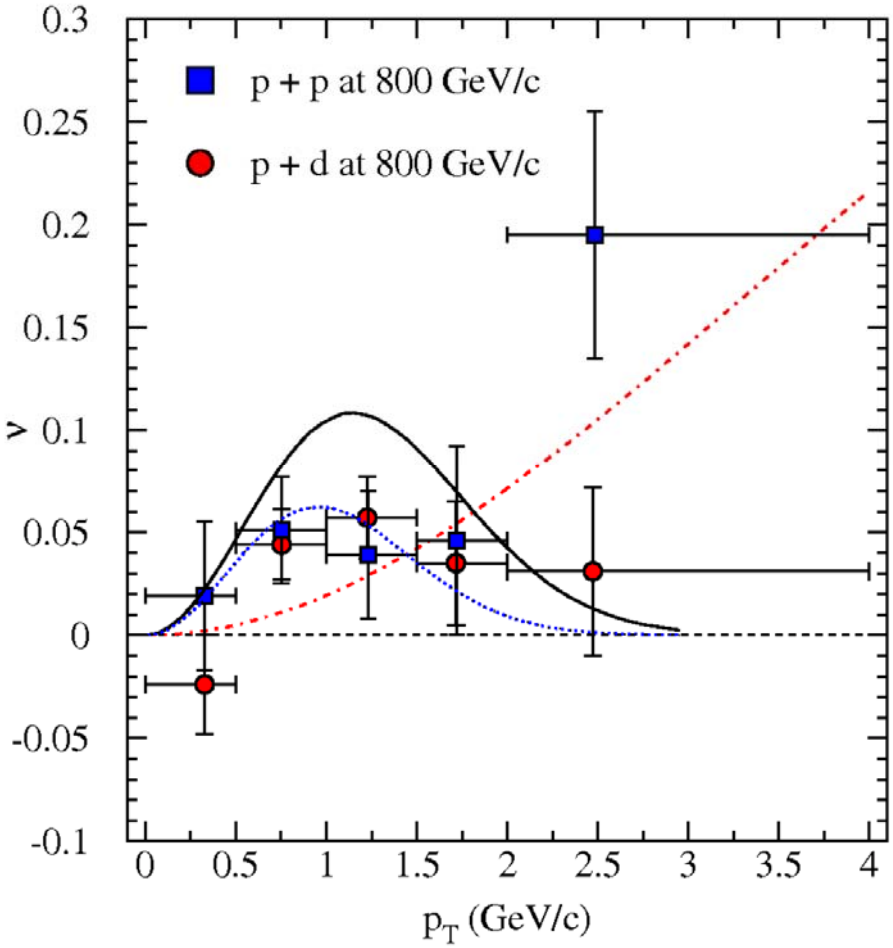
- **BRAHMS** finds that the forward charged pion asymmetries are larger when the mid-rapidity charged multiplicity is higher

Evidence for a non-zero Boer-Mulders function



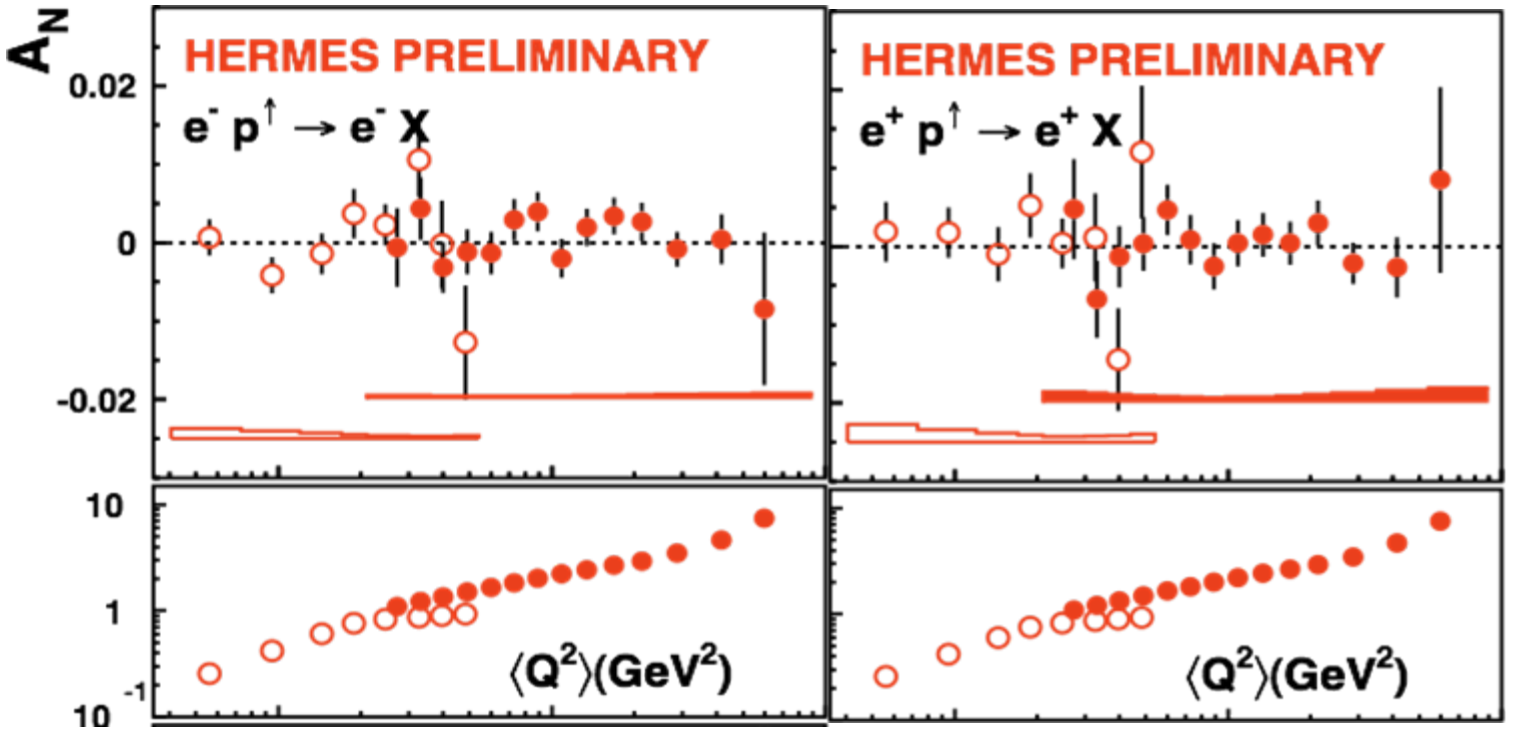
- **Francesca Giordano** presented HERMES measurements of angular distributions in unpolarized SIDIS that are sensitive to the Boer-Mulders effect
- **Andrea Bressan** presented similar results for COMPASS

Boer-Mulders effect in *pp* and *pd* Drell-Yan



- **Paul Reimer** described FNAL E866 measurements of the Drell-Yan angular distribution in *pp* and *pd* collisions at 800 GeV
- The Lam-Tung relation appears to be satisfied, in contrast to π-induced Drell-Yan
- The angular distributions appear to be similar in *pp* and *pd*, in contrast to expectations

Search for two-photon exchange in DIS

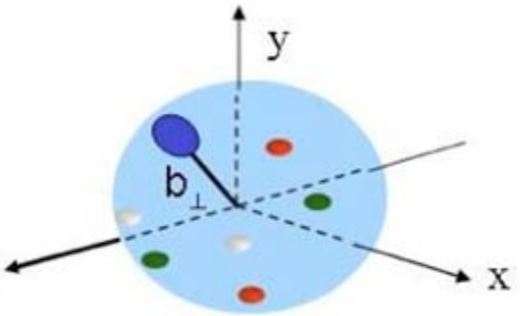


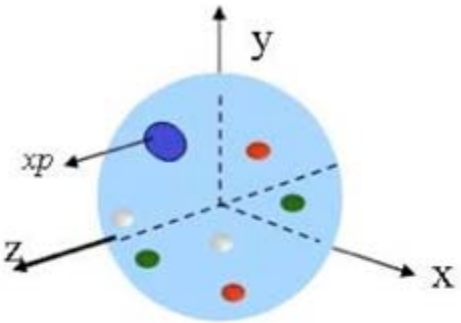
- **Alejandro Lopez Ruiz** reported a HERMES search for evidence of two-photon exchange in inclusive DIS
- Interference between one-photon and two-photon exchange is expected to produce $A_N \sim 10^{-4}$ to 10^{-2}
- See no effect at the ~10^{-3} level

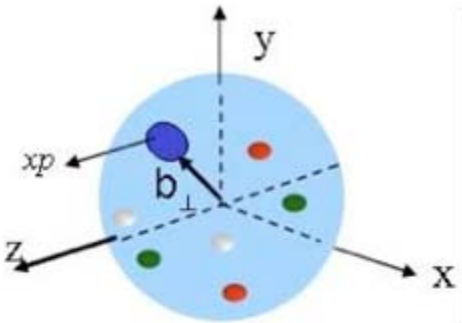
Generalized parton distributions

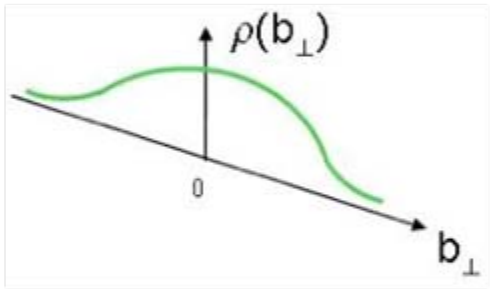
- Many of the GPD results were discussed in joint sessions with the **Diffraction and Vector Mesons WG**.
- Results from **COMPASS** were described in that summary.

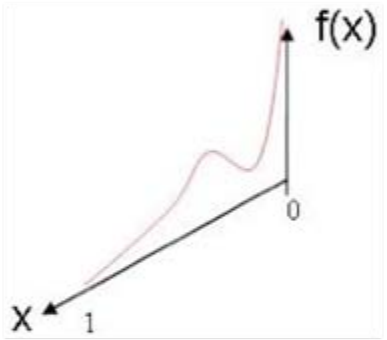
Generalized Parton Distributions

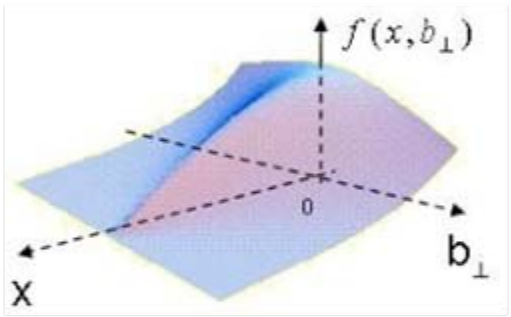












Form factors

Transverse distribution of quarks in space coordinates

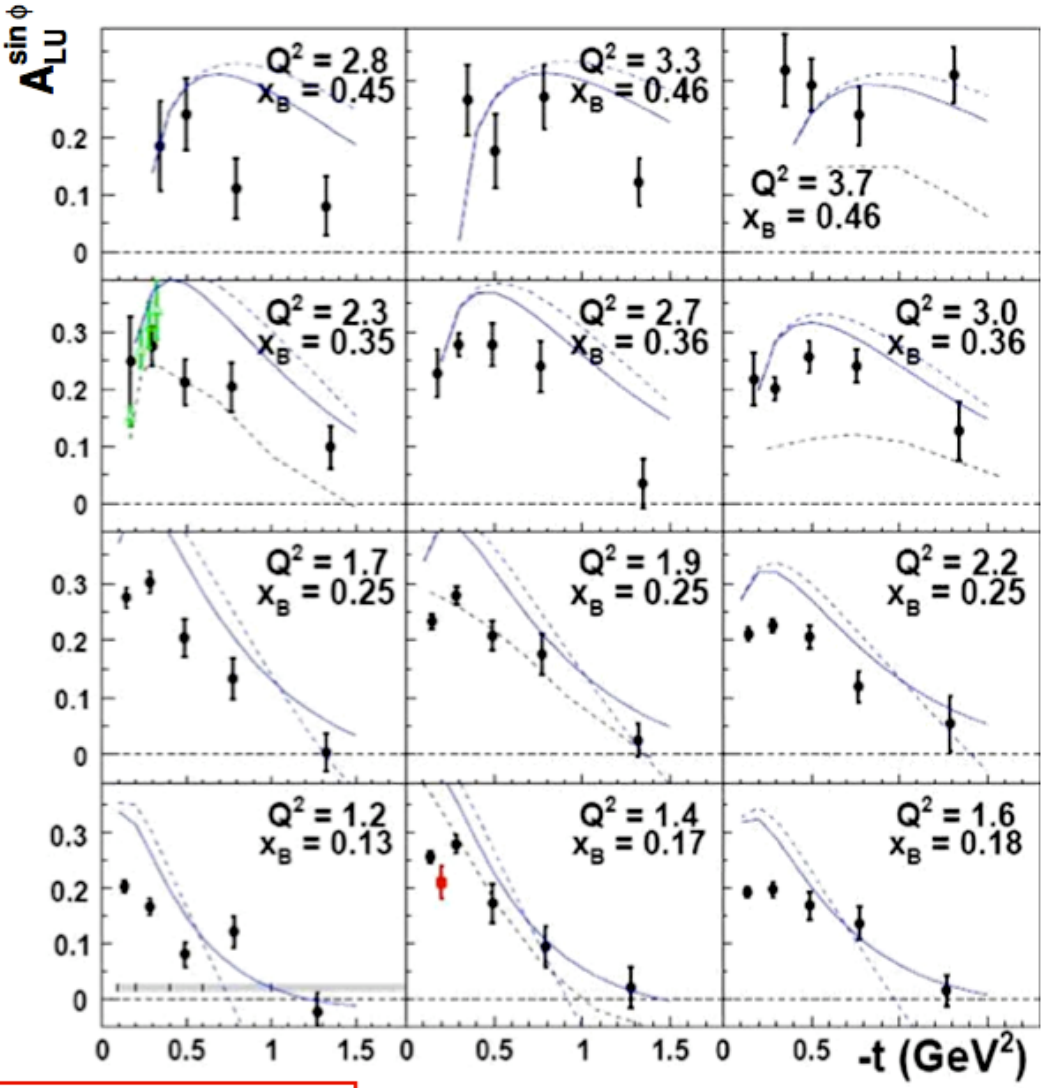
Parton Distribution Functions

Quark longitudinal momentum fraction distribution in the nucleon

GPDs

Correlation between transverse position and longitudinal momentum fraction of quark in the nucleon

DVCS results from CLAS



Hall B e1-dvcs

Hall A

Hall B (4.3 GeV)

VGG (*) twist 2

VGG (**) twist 3

Regge calculation (***)

(*)Guidal, Polyakov, Radyushkin,Vanderhaegen, PRD 72, 054013 (2005)

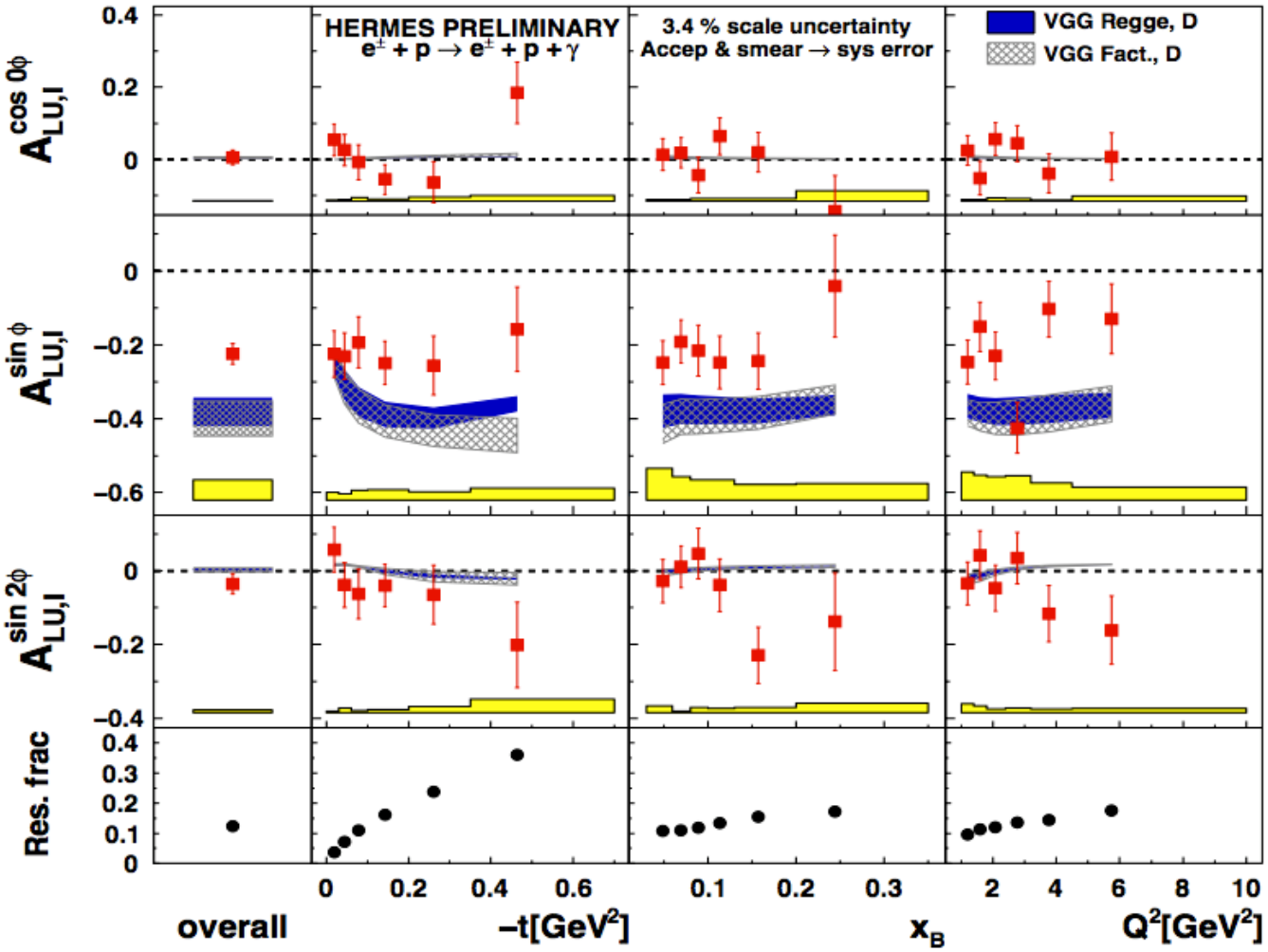
(**)Kivel, Polyakov, Vanderhaegen, PRD 72, 114014 (2005)

(***) Cano and Laget, PL B551 (2003)

F.X. Girod *et al.* (CLAS), PRL 100, 162002 (2008)

B. Moreno - SPIN-6

DVCS results from HERMES



$\propto \Im m[F_1\mathcal{H}]$

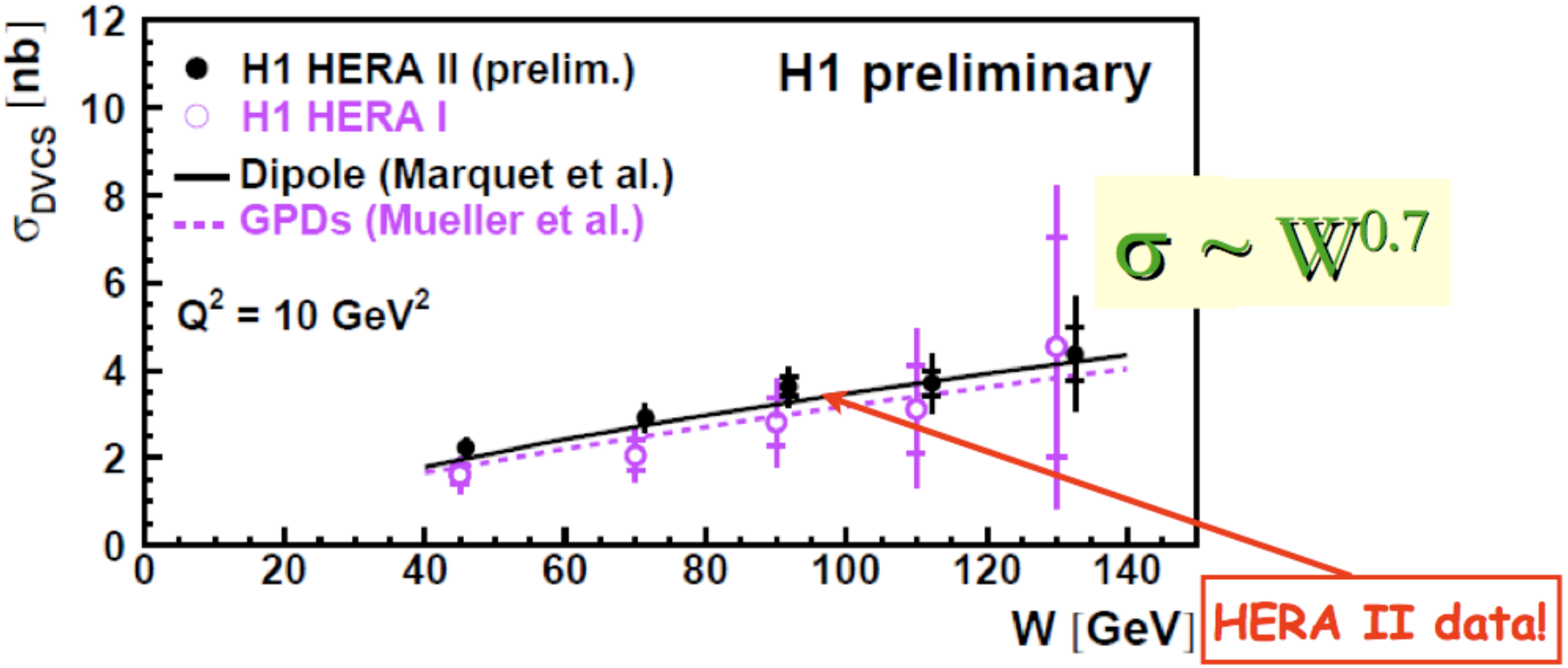
← Higher twist

← Resonance fraction $ep \to e\Delta^+\gamma$

S. Yaschenko - SPIN-9

Additional HERMES results from deuterium were shown by **A. Movsisyan**

DVCS cross section at H1



Unlike at fixed-target experiments, DVCS at H1 not highly suppressed compared to Bethe-Heitler

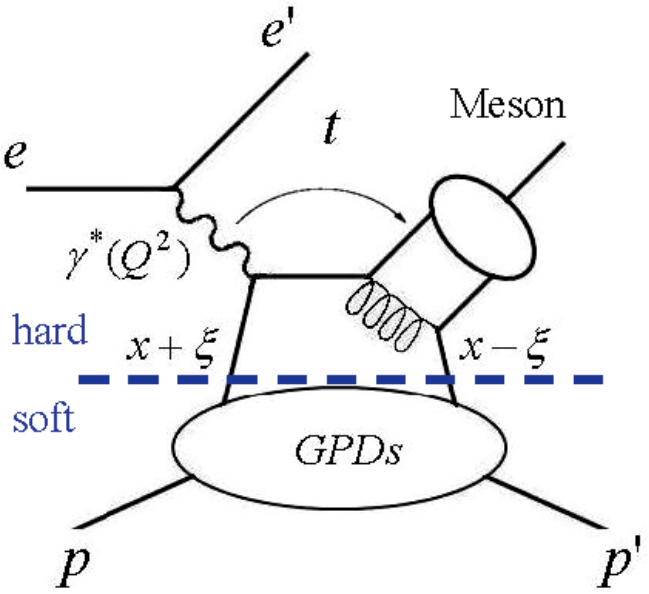
➠ DVCS cross section measurement possible

L. Schoeffel - SPIN-5

Deeply-virtual meson production

Meson electroproduction

In the **Bjorken limit**



Factorization holds for longitudinally polarized virtual photons

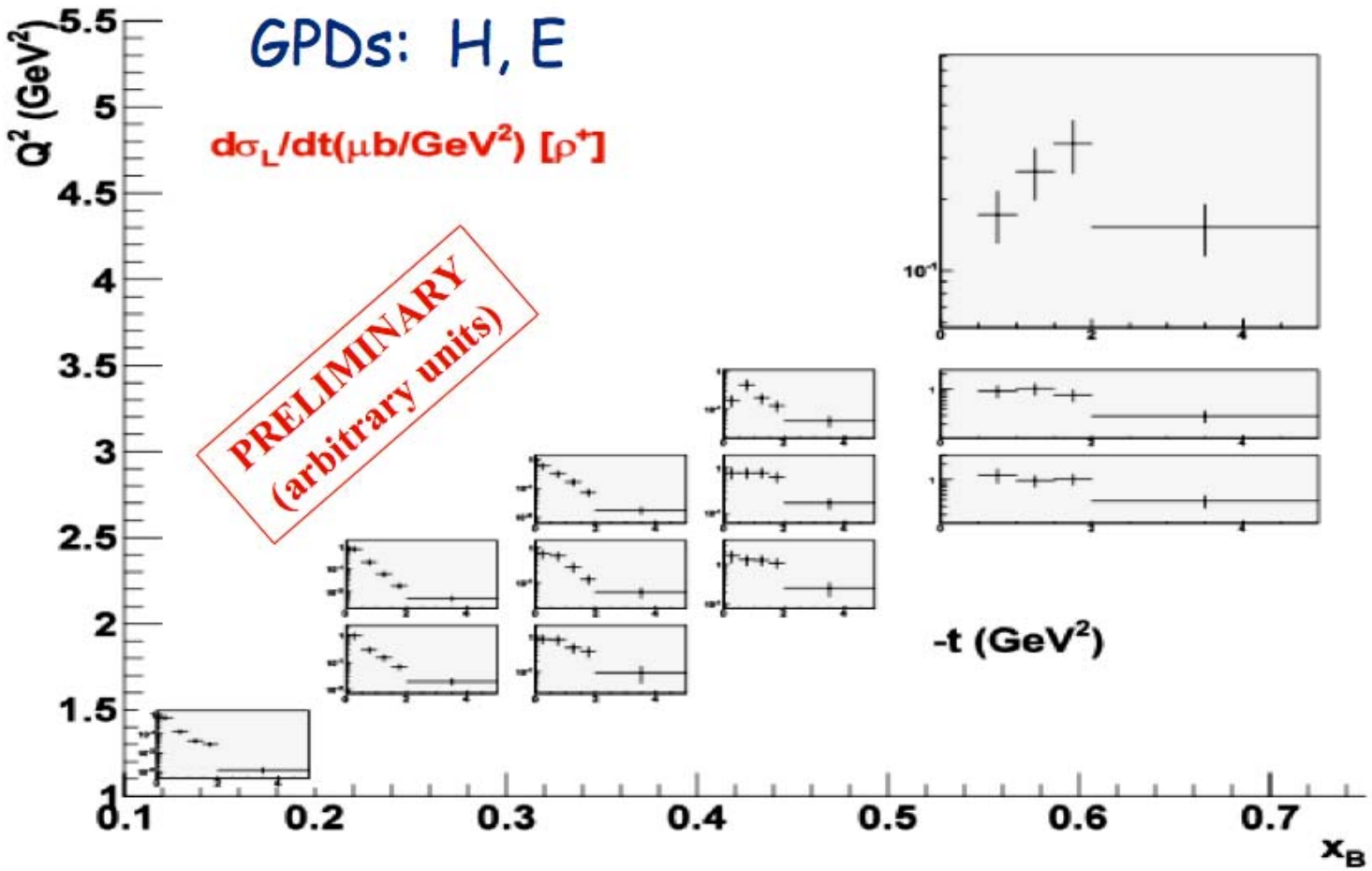
Vector mesons (ρ,ϕ,ω): H E

Pseudo-scalar mesons (π^0,η): $\widetilde{H}$ $\widetilde{E}$

Vector mesons		Pseudoscalar mesons	
ρ^0	2u+d	π^0	2Δu+Δd
ρ^+	u-d	η	2Δu-Δd
ω	2u-d		

Flavour decomposition

Exclusive ρ^+ production at CLAS

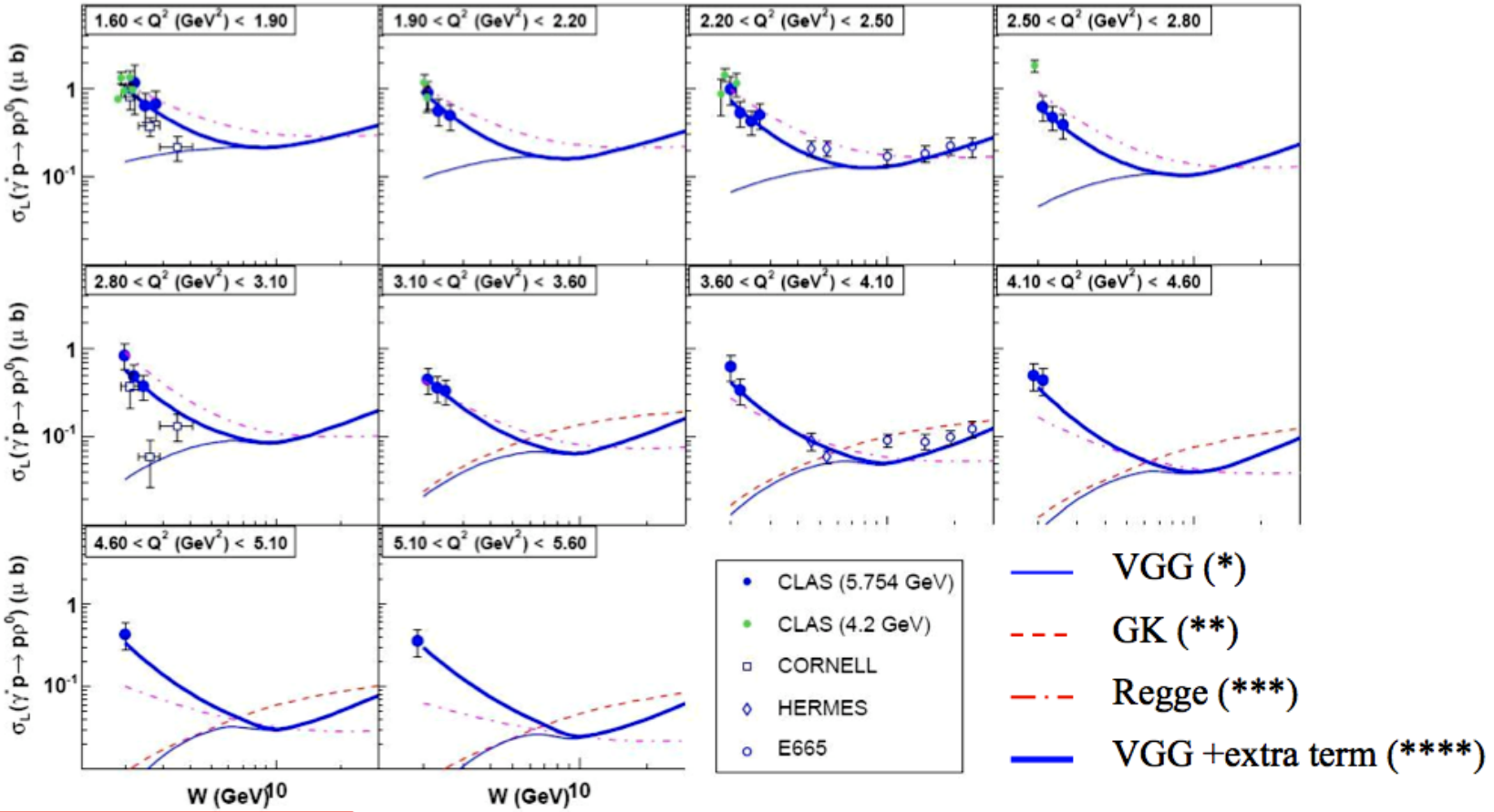


A. Fradi - SPIN-5

Exclusive ρ^0 production at CLAS

Longitudinal cross section

$$\gamma_L^* p \to p\rho_L^0$$

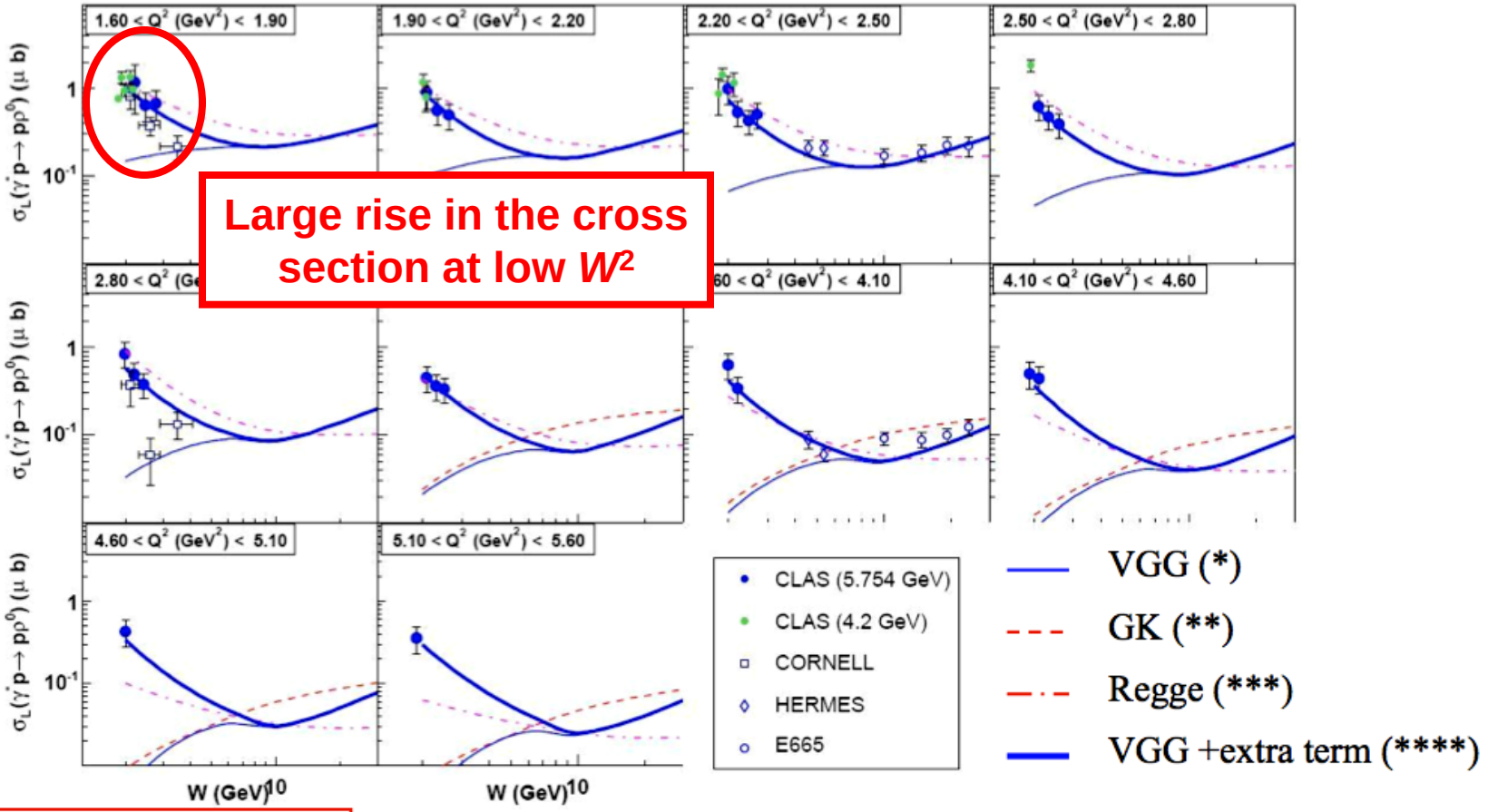


B. Moreno - SPIN-6

Exclusive ρ^0 production at CLAS

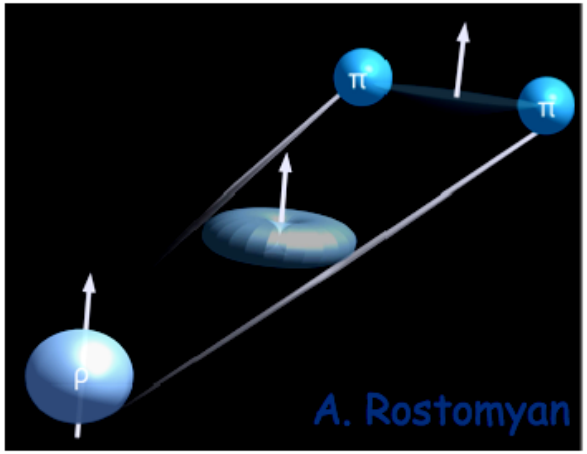
Longitudinal cross section

$$\gamma_L^* p \to p\rho_L^0$$



B. Moreno - SPIN-6

Helicity structure of DVMP



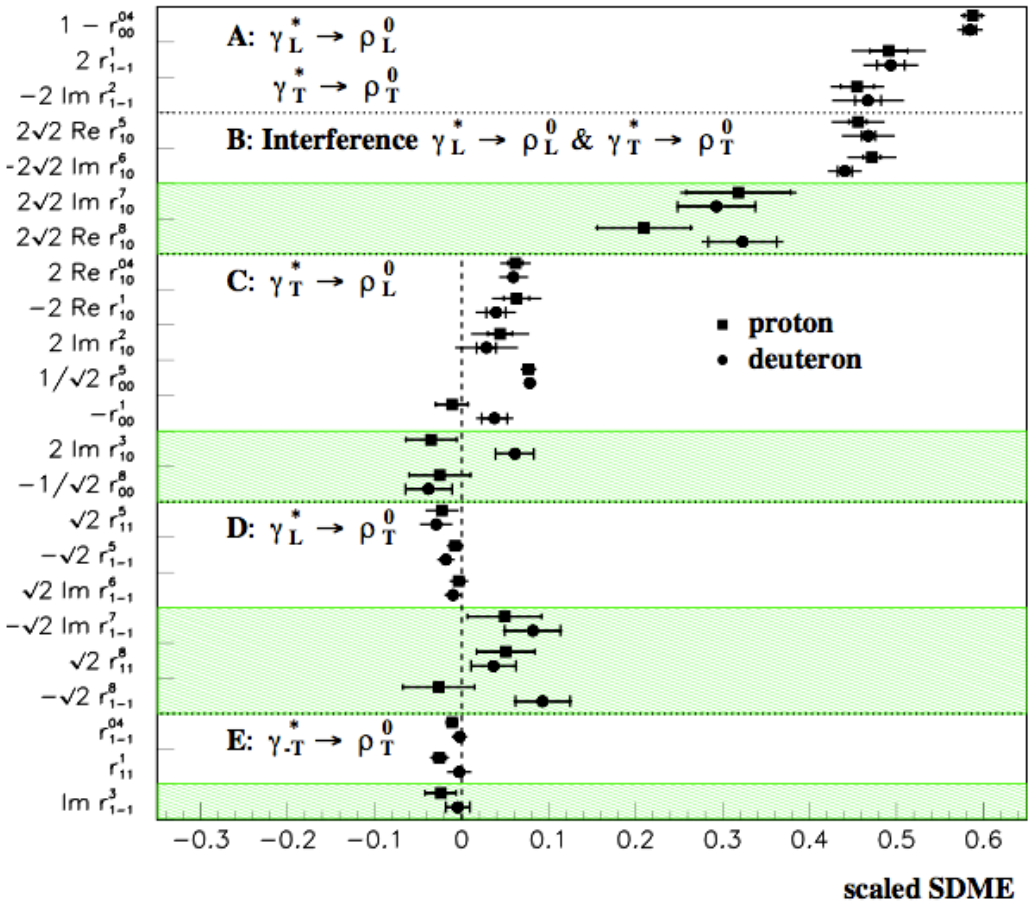
$$\frac{d\sigma}{dx_B\, dQ^2\, dt\, d\phi_s\, d\phi\, d\cos\vartheta\, d\varphi} \sim \frac{d\sigma}{dx_B\, dQ^2\, dt} W(x_B, Q^2, t, \phi_s, \phi, \cos\vartheta, \varphi)$$

$$W = W_{UU} + P_l W_{LU} + S_L W_{UL} + P_l S_L W_{LL} + S_T W_{UT} + P_l S_T W_{LT}$$

angular decay distribution parameterized by Spin-Density Matrix Elements (SDMEs)

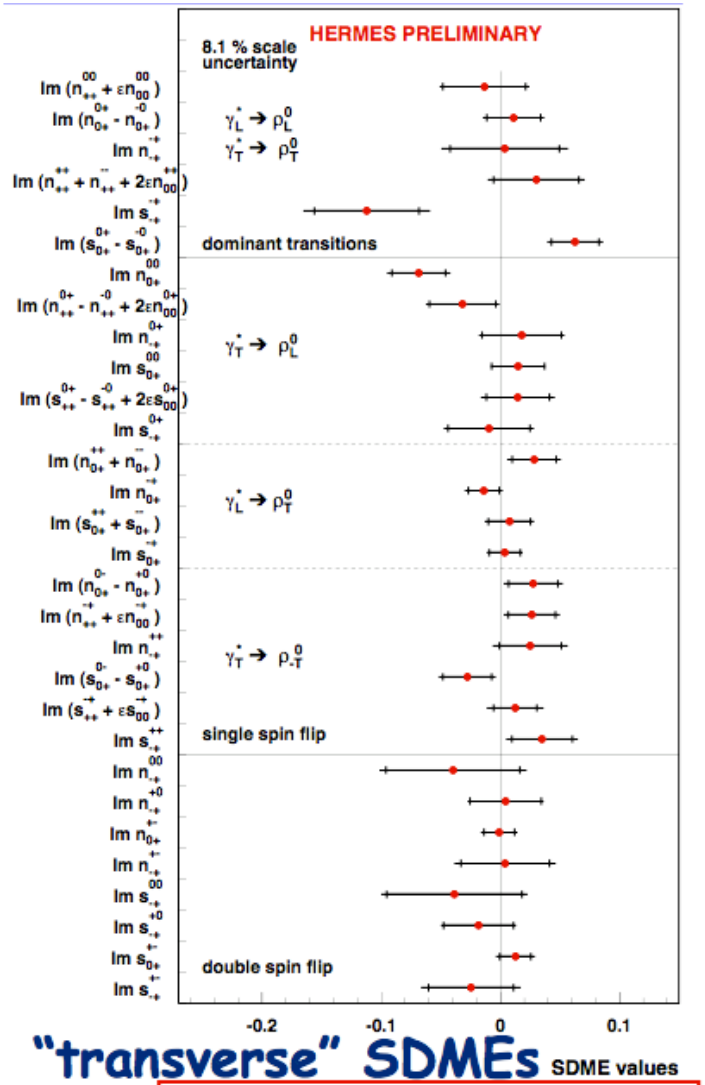
A. Rostomyan - SPIN-5 | W.-D. Nowak - SPIN-6

ρ^0 spin-density matrix elements from HERMES



target-polarization independent SDMEs

W.-D. Nowak - SPIN-6



"transverse" SDMEs

A. Rostomyan - SPIN-5

Conclusion

- It's been more than 20 years since EMC gave us the "**spin crisis**". We've learned a huge amount since then. But we still haven't found the rest of the proton spin.
- **Many important new results** toward this quest were presented during the **Spin Working Group** sessions
- This summary has only been able to highlight a small subset
- Check the talks on the web for additional results
- **THANKS TO ALL THE SPEAKERS !!!**