Longitudinal spin structure studies with CLAS

Alexandre Deur

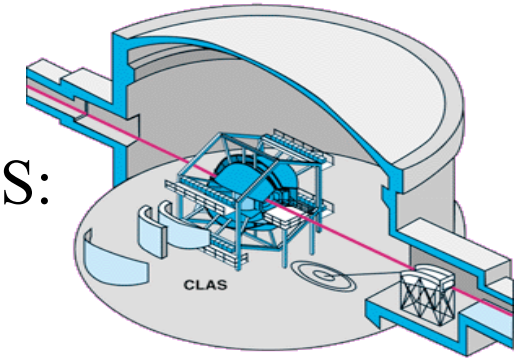
08/19/2011

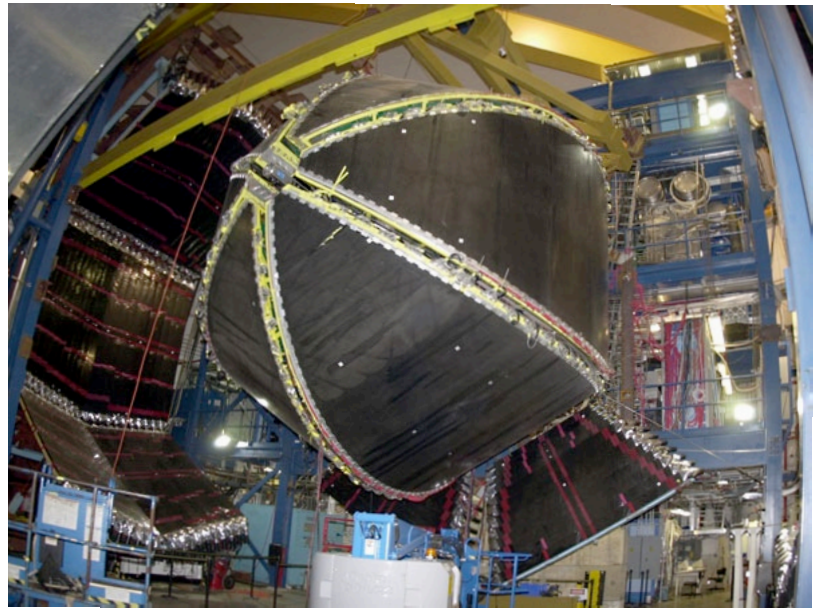
Jefferson Lab

CLAS

Physics of nucleon spin structure already presented (J. Qui, X. Zheng)

Hall B and CLAS:





NH_3 & ND_3 targets (//)
Large acceptance coverage

⇒ •Longitudinal spin structure of proton & neutron;
•Large kinematics coverage (DIS, resonance region, large-x);
•Ideal for low current targets;
•Complementary with high-precision, small-acceptance spectrometers;
•(Exclusive reactions, transversity, DVCS...).

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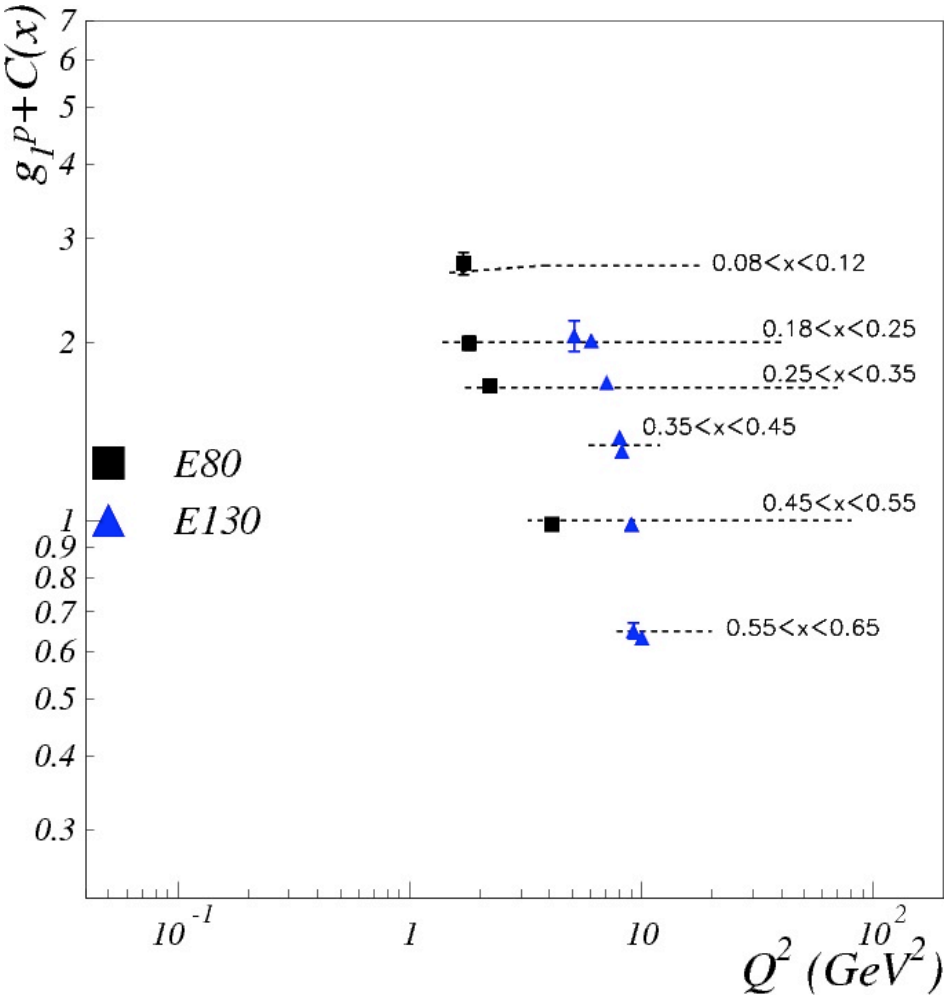
Brief history

SLAC E80: 0.2<x<0.3
E130: 0.18<x<0.7
} 1976, 1980

⇒nucleon spin = Σ (quark spins)



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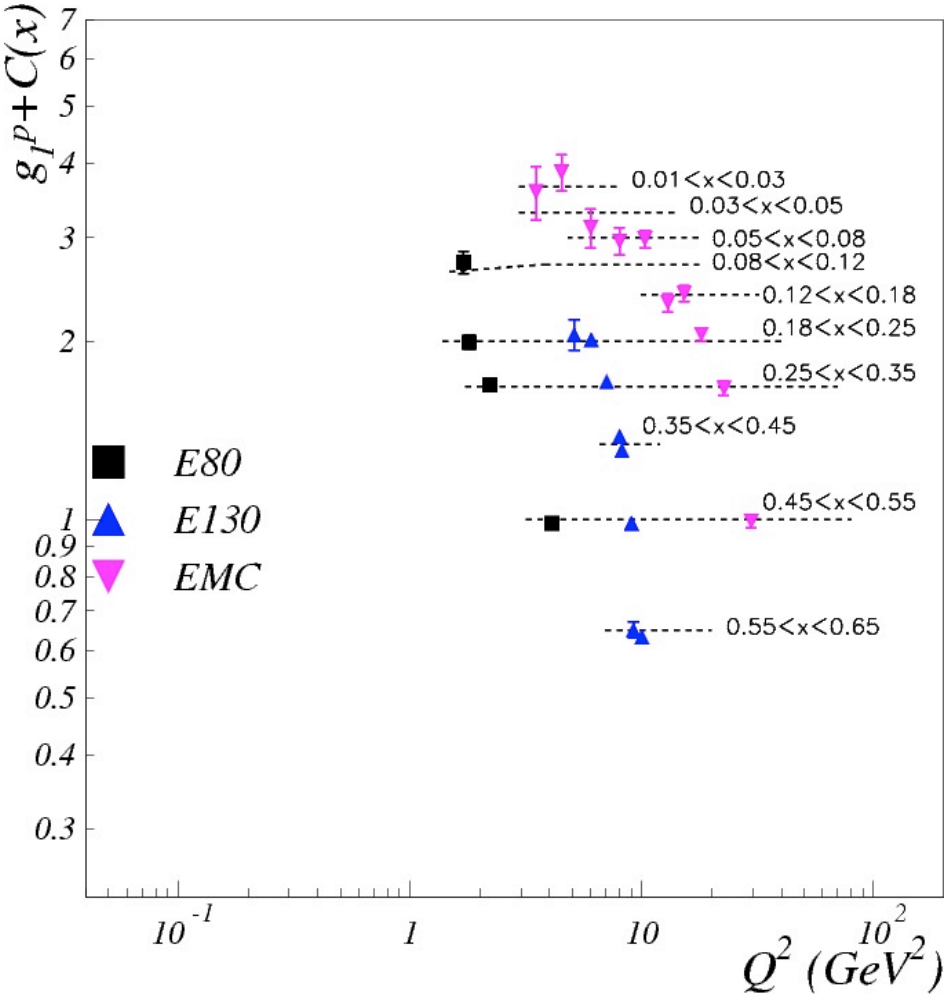
CERN EMC: 0.010<x<0.7 1988

⇒nucleon spin = Σ (quark spins)

"**Spin crisis**": quark spins contribute ~0 to nucleon spin



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Brief history

SLAC E80: 0.2<x<0.3
E130: 0.18<x<0.7
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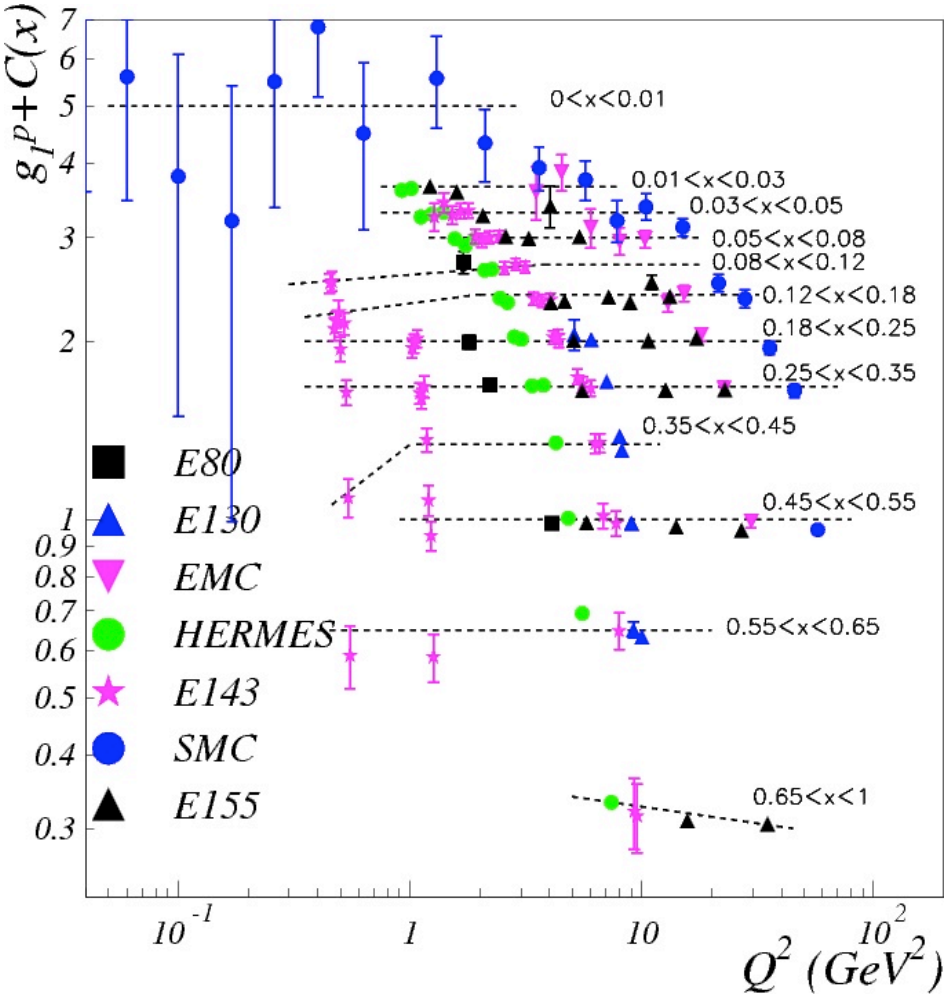
CERN EMC: 0.010<x<0.7 1988

SMC, E142, E143, E154,E155, HERMES

Σ quark spin contribution ~30%



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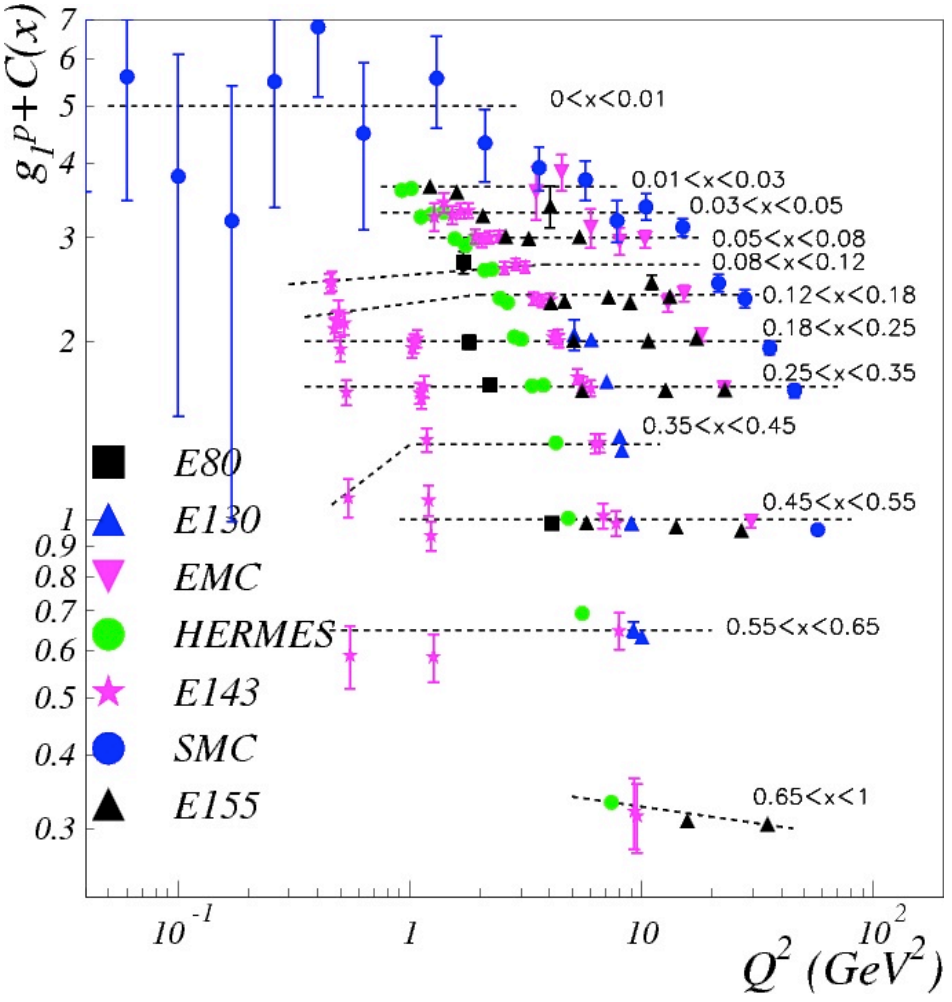
Brief history

Data mostly in perturbative regime of QCD and at low-x

Remains to be done:

nucleon spin = (quark spins+gluon spins + quark OAM+ gluon OAM)

- Gluon spin (COMPASS, RHIC)
- Orbital angular momentum (COMPASS, DESY, HERMES, **JLab**)
- Transversity (HERMES, **JLab**, RHIC)
- Spin structure in non-perturbative region (**JLab**)
- Large-x precision measurements (**JLab**)



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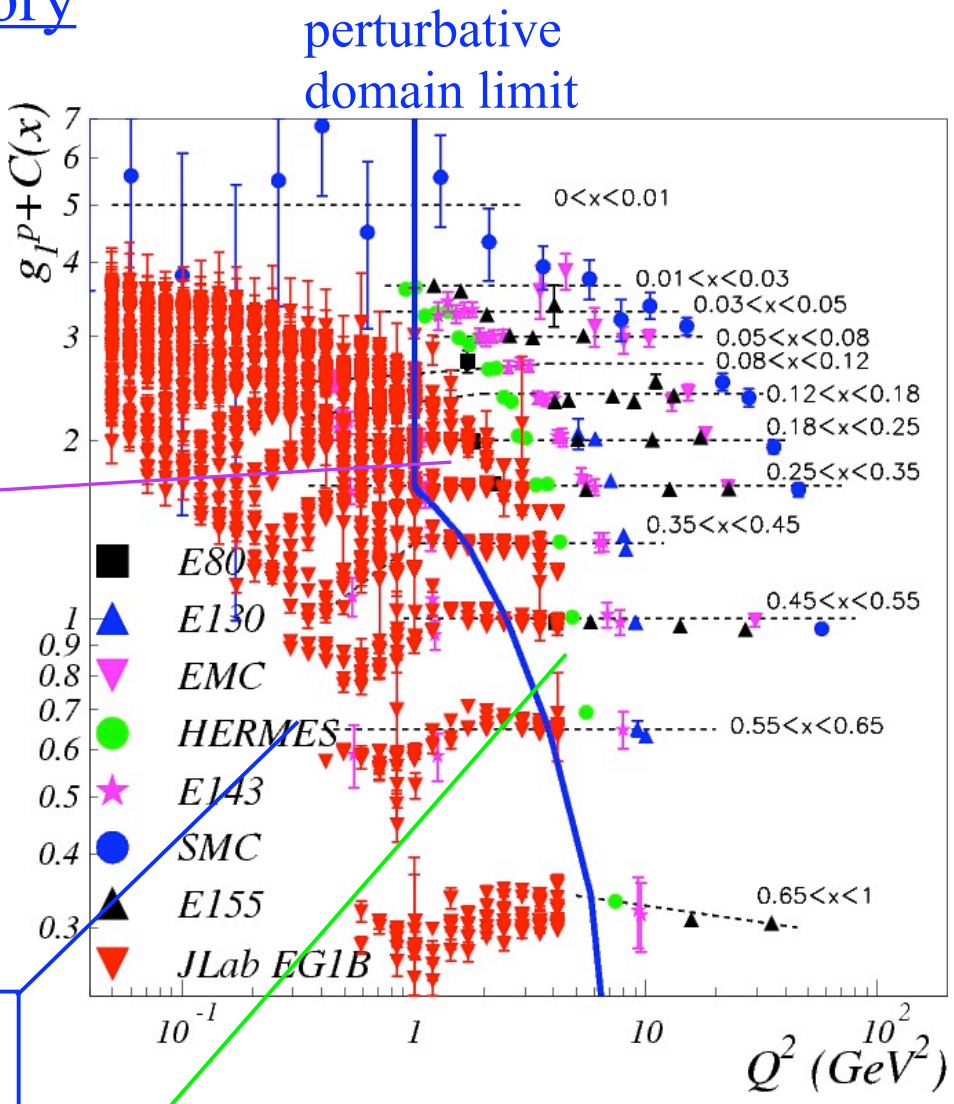

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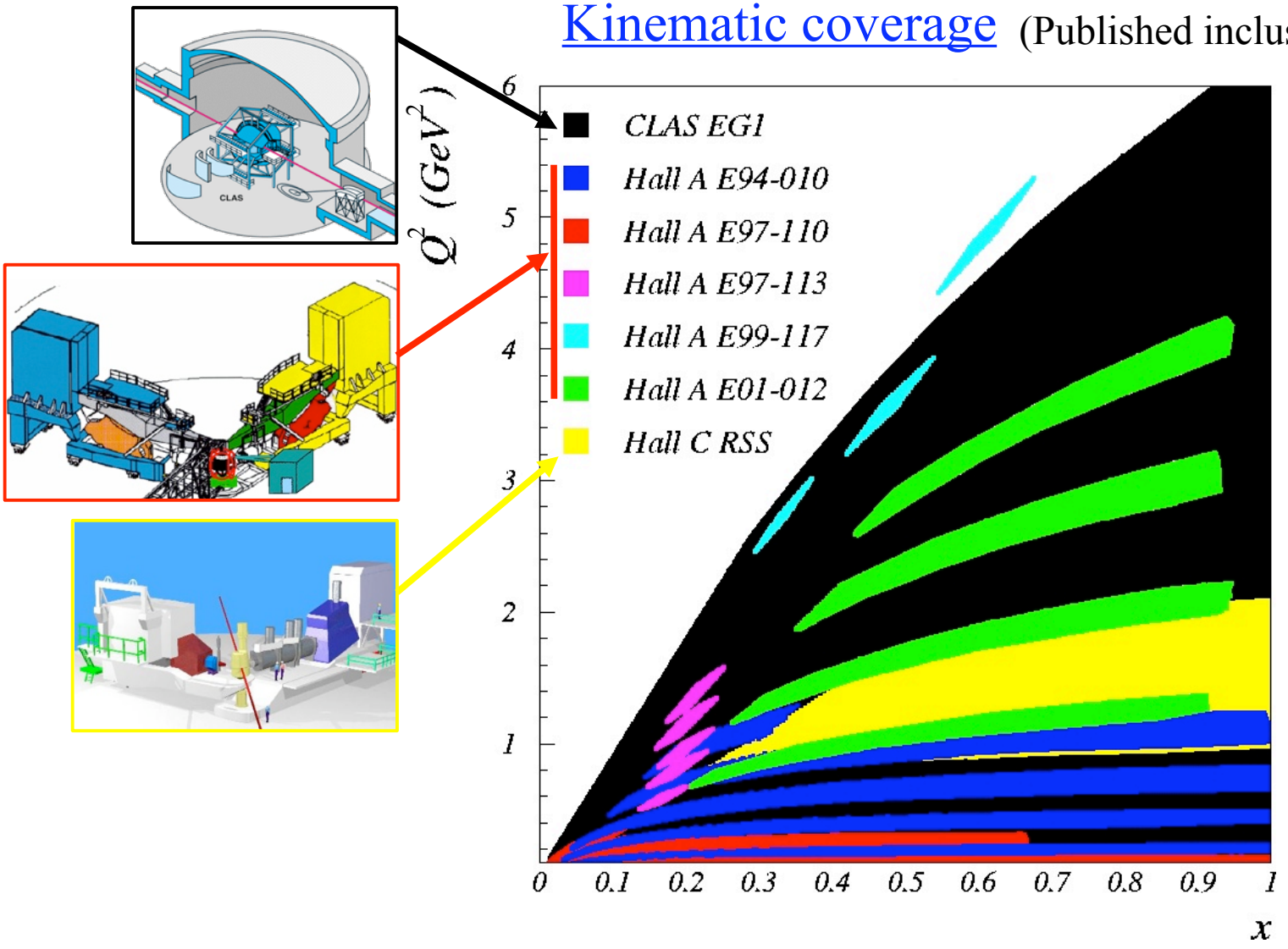
Kinematic coverage (Published inclusive data)



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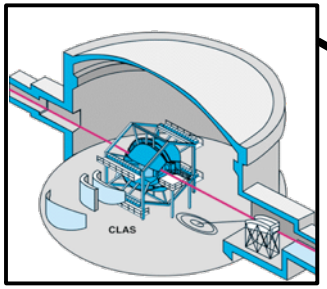
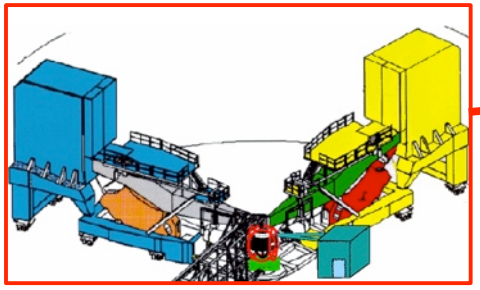
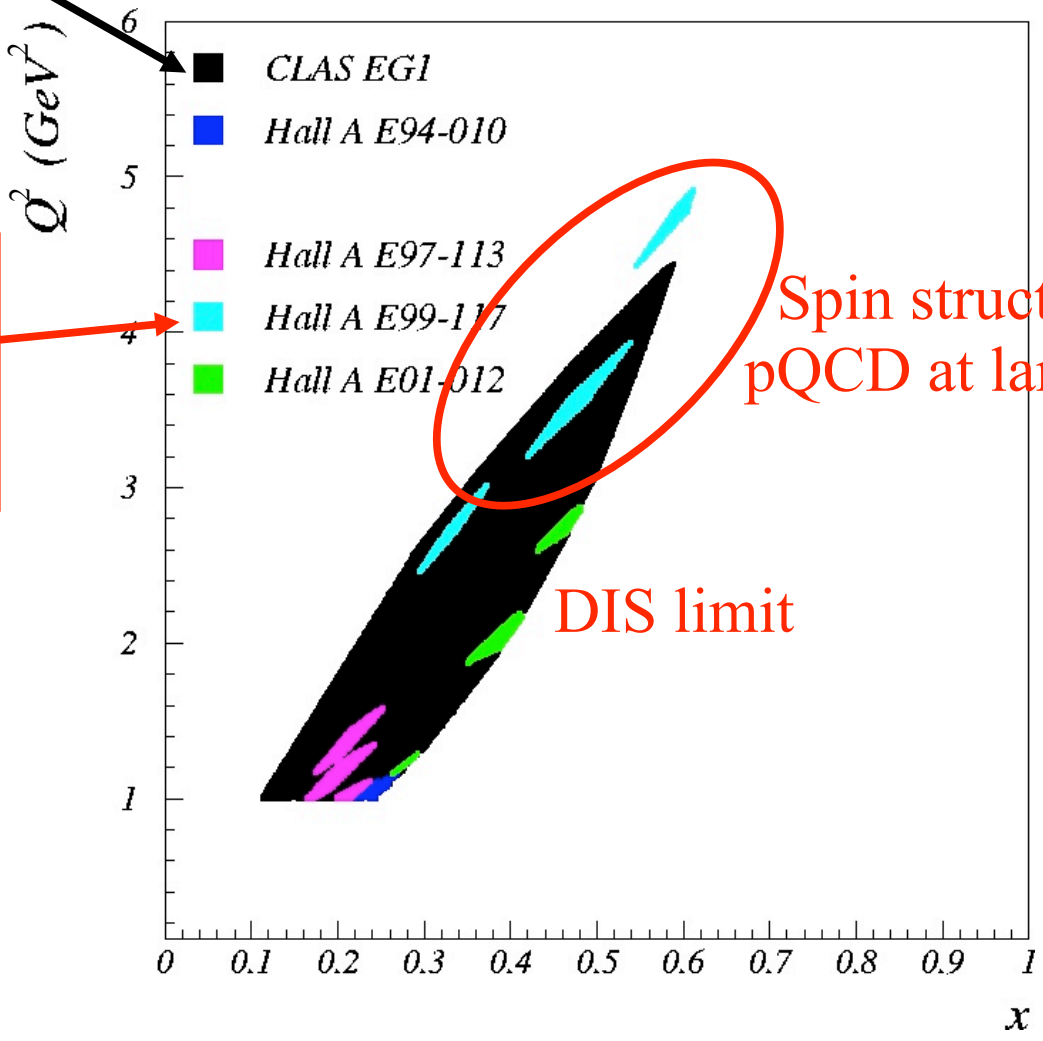
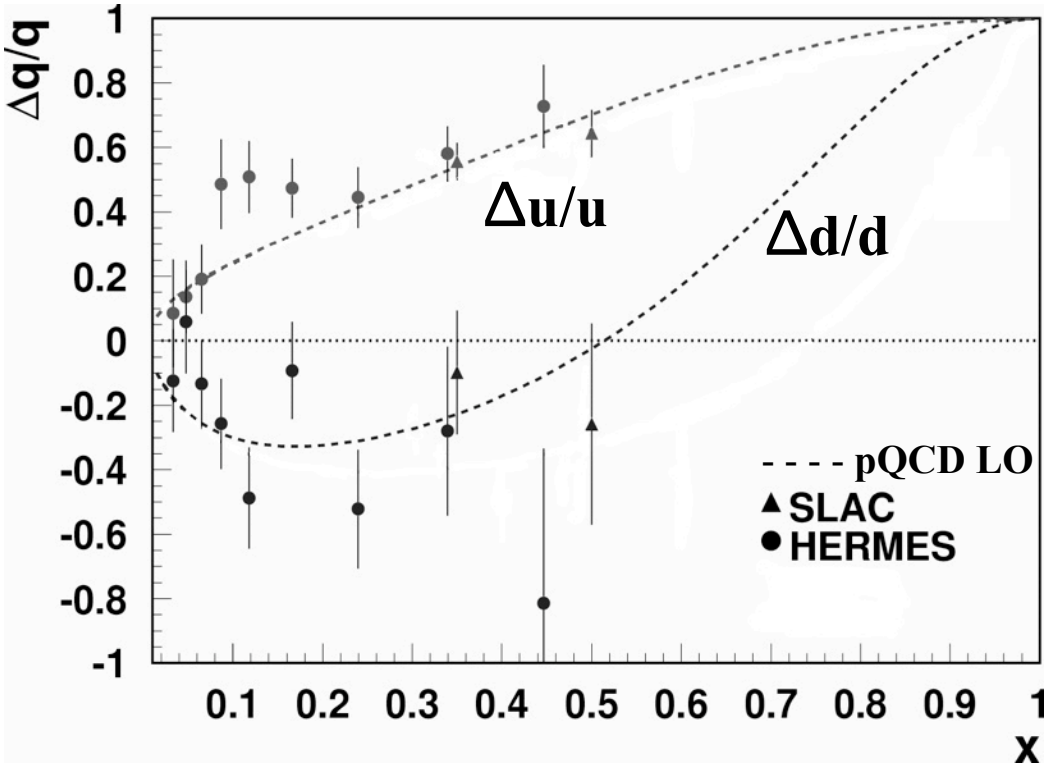
Kinematic coverage (perturbative domain)







From g_1 and F_1 at large x and Q^2 quark polarizations $\Delta q/q$ can be extracted



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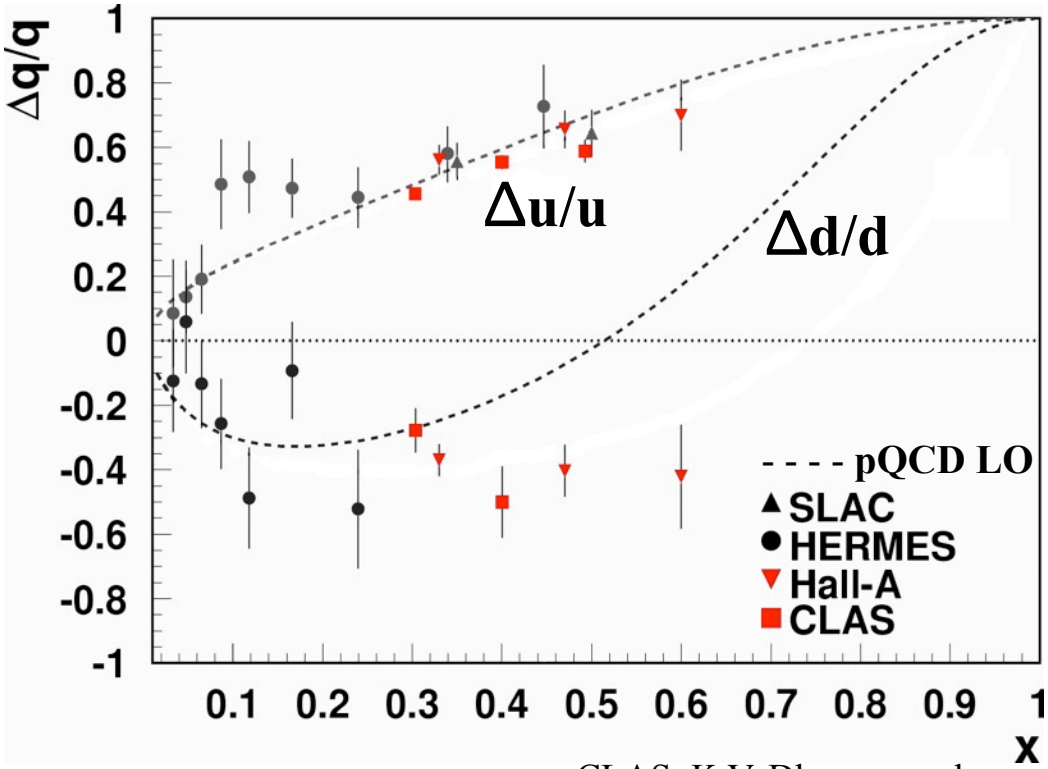

CLAS: K.V. Dharmawardane, *et al.* Phys. Lett. B 641, 11 (2006)
Hall A: X-C Zheng *et al.* Phys. Rev. C 70, 065207 (2004)

Δu/u follows expectation

Δd/d disagrees with pQCD calculations without quark orbital momentum

⇒Role of quark orbital angular momentum ?

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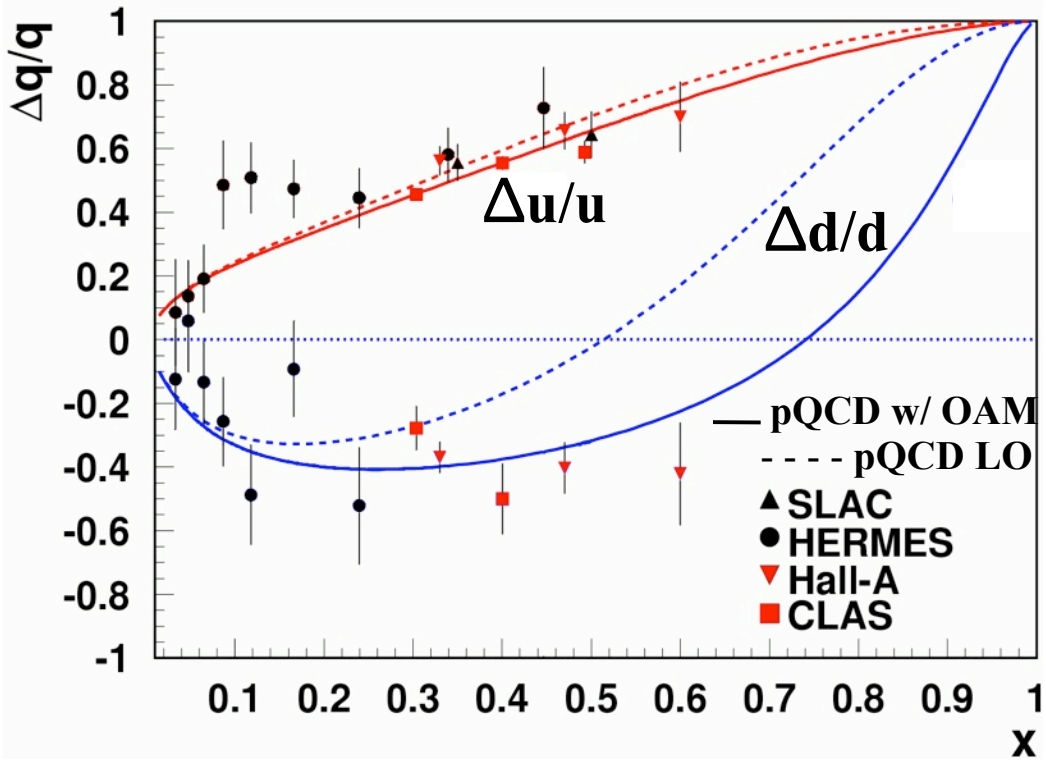
From g_1 and F_1 at large x and Q^2 quark polarizations $\Delta q/q$ can be extracted



Including quark orbital angular momentum in pQCD calculation solves discrepancy

⇒Evidence of the role of the (experimentally elusive) quark OAM

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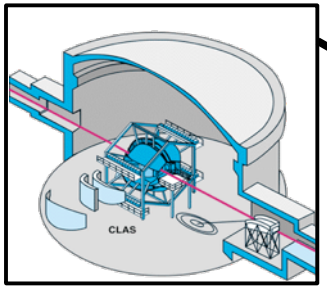
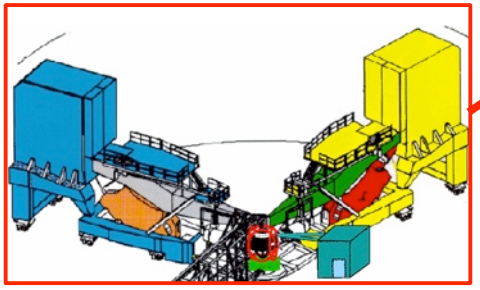
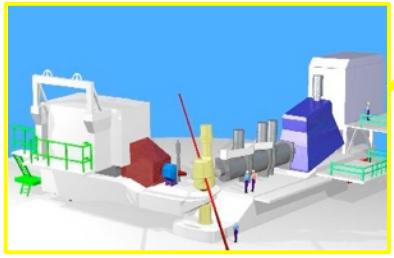
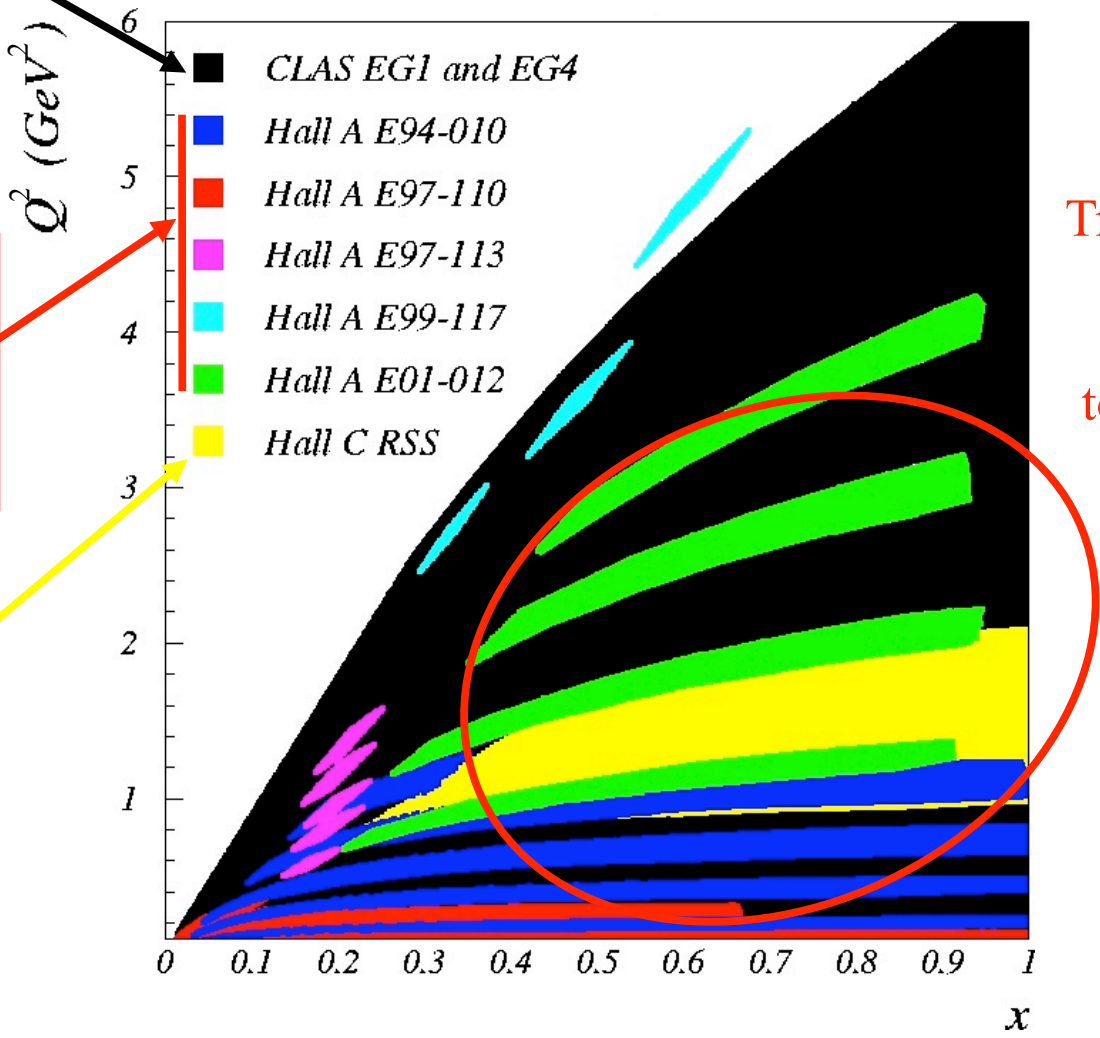
Kinematic coverage









Transition from short scales (pQCD) to large scales

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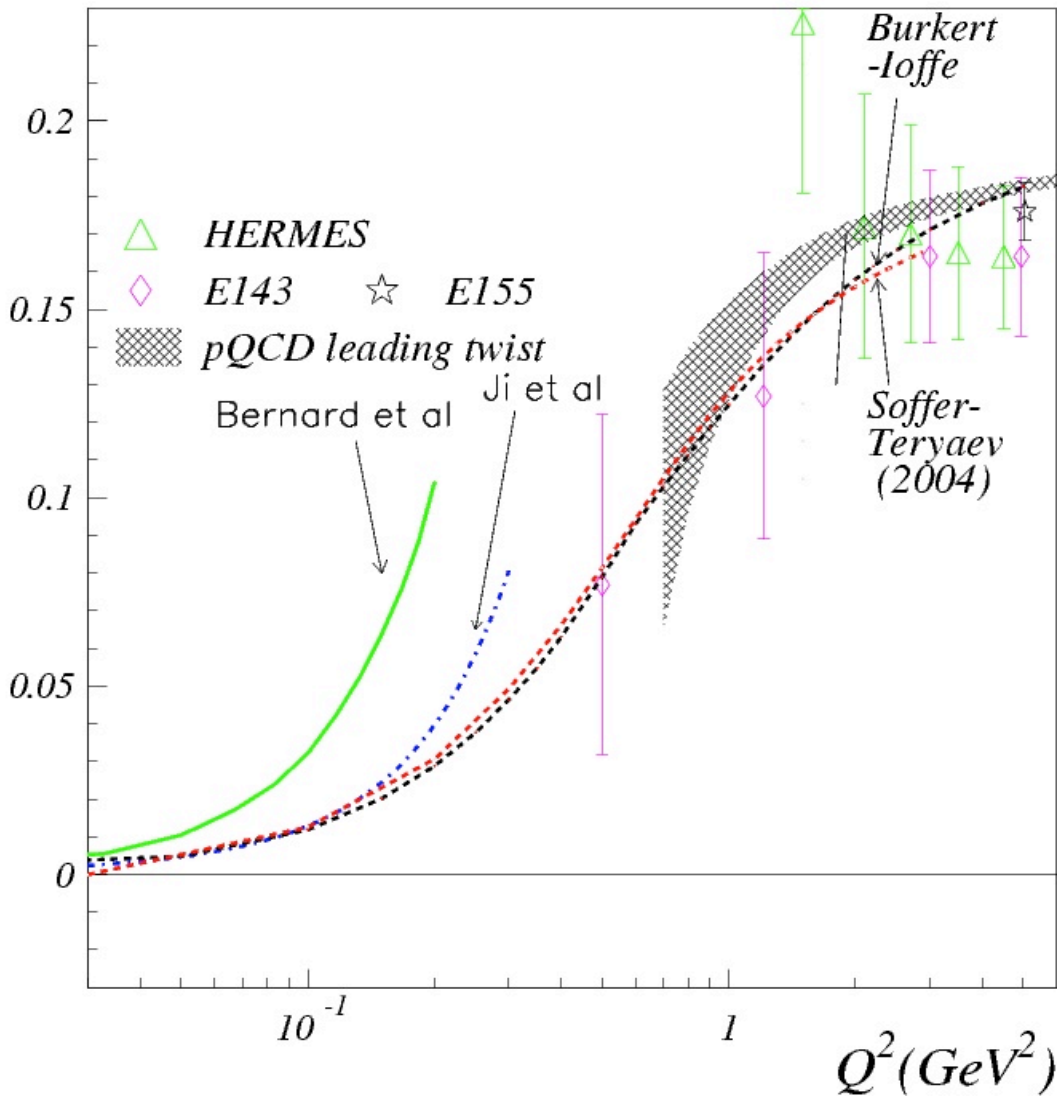
Transition from short to large scales: results on $\int g_1^p - g_1^n \, dx$



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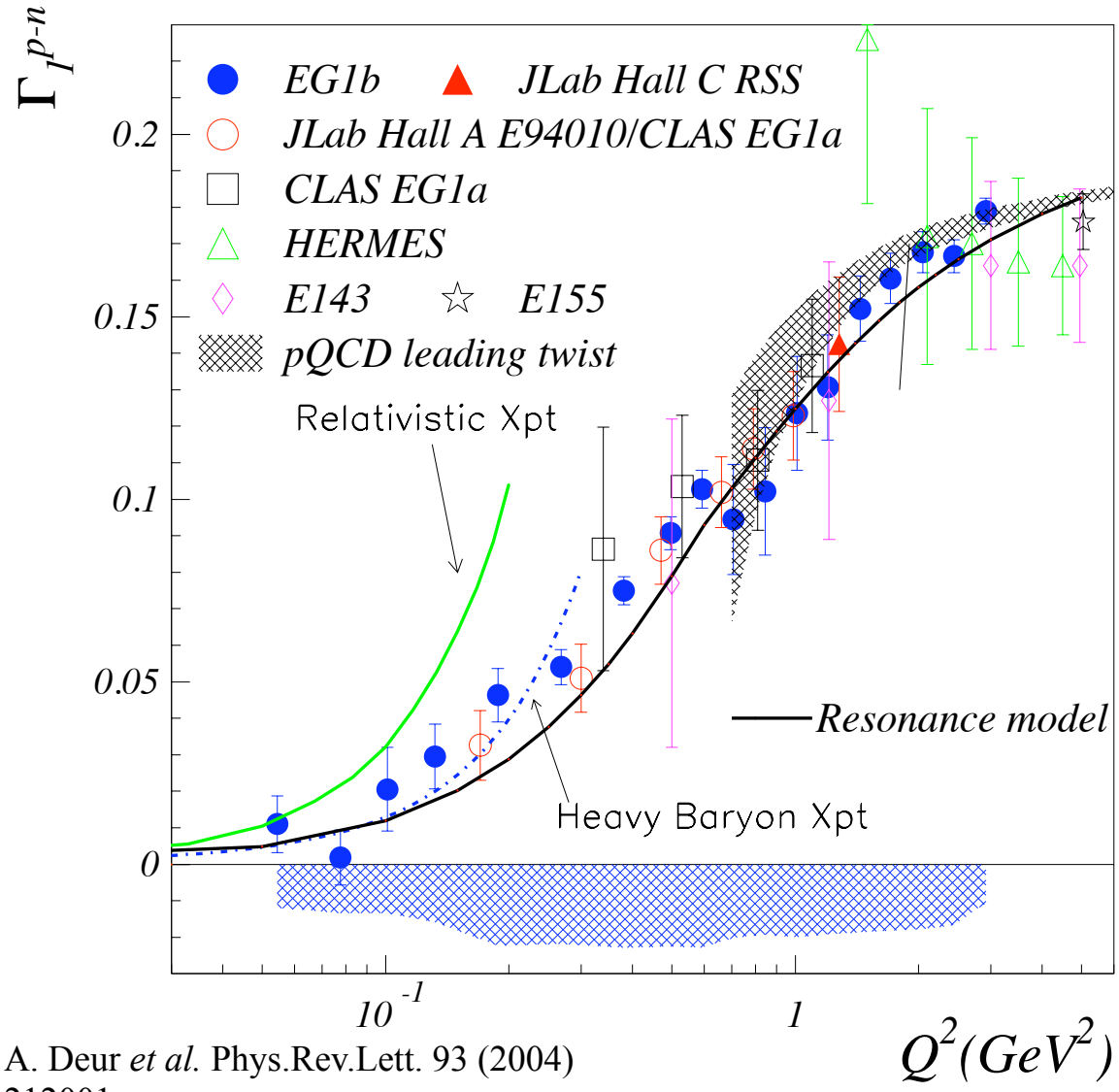

A. Deur *et al.* Phys.Rev.Lett. 93 (2004) 212001

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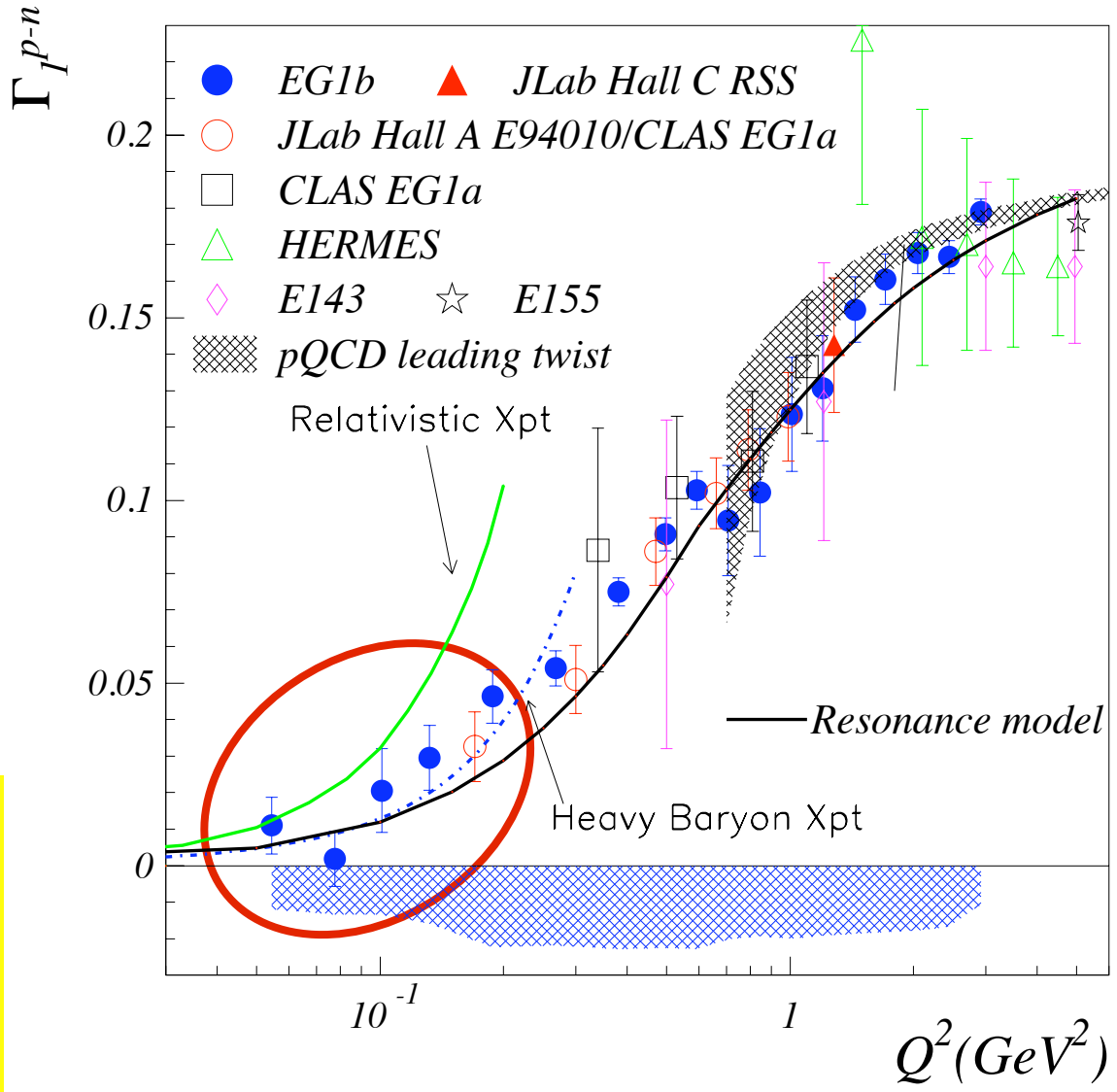
- Low Q^2: extraction of χpt series coefficients;



Low Q^2 fit:

$$\Gamma_1^{p-n} = \frac{\kappa_n^2 - \kappa_p^2}{8M^2} Q^2 + aQ^4 + bQ^6$$

$a=0.80\pm0.07\pm0.23$, $b=-1.13\pm0.16\pm0.39$

$a^{\chi pT,Ji}=0.74$, $a^{\chi pT,B.}=2.4$

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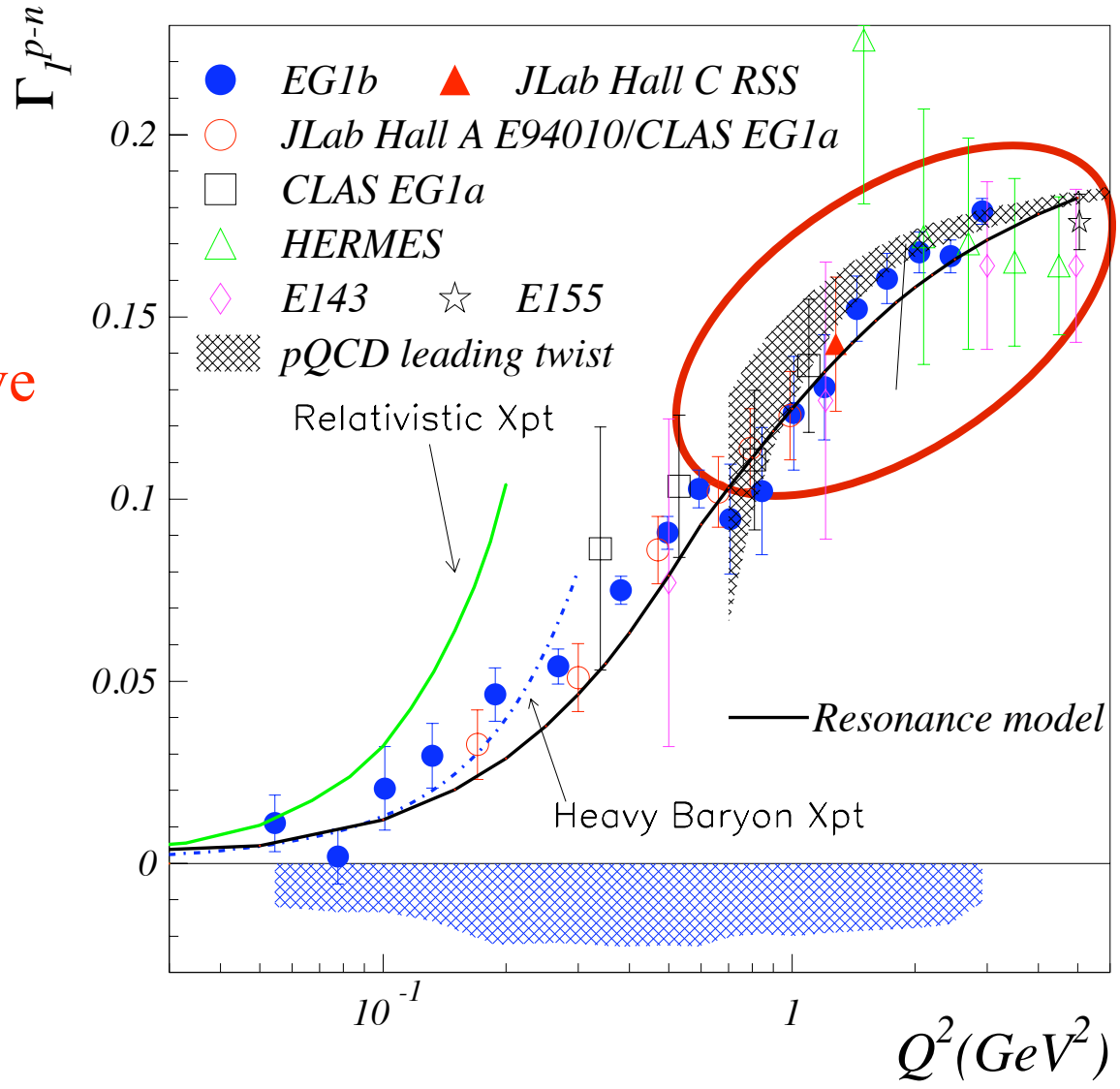
•High Q^2: extraction of power series coefficients (Higher twists);

pQCD without non-perturbative corrections: good description (surprising)



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- High Q^2: extraction of power series coefficients (Higher twists);

Higher Twists: Non-perturbative power corrections:

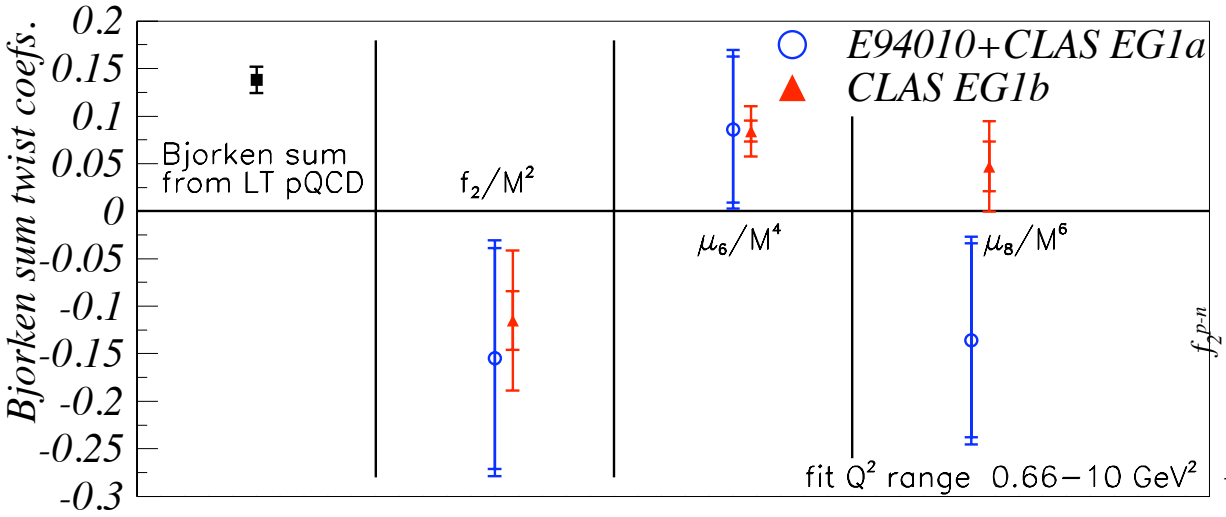
$$\int g_1 dx = \sum_{\substack{\text{twist} \\ =2,4...}} \frac{\mu_{\text{twist}}}{Q^{\text{twist-2}}}$$

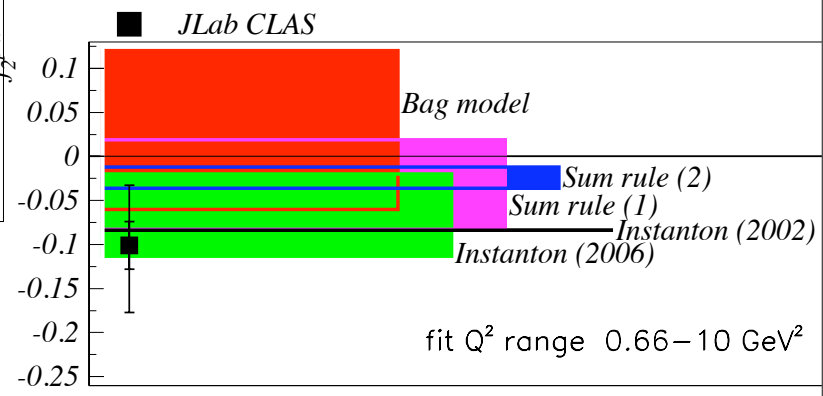
Ex. Bjorken sum: $$\int g_1^{p-n} dx = \underbrace{\frac{1}{6} g_a \left(1 + \frac{\alpha_s(\ln(Q^2))}{\pi} + ...\right)}_{\text{Leading twist (twist 2)}} + \underbrace{\frac{\mu_4}{Q^2} + \frac{\mu_6}{Q^4} + ...}_{\text{Higher twists}}$$

$$\frac{\mu_4}{Q^2} = \frac{M^2}{9}(a_2 + 4d_2 + 2f_2)$$

- a_2: Leading twist (known from high energy data)
- d_2: Twist 3 (known from high energy data+JLab at large x)
- f_2: Twist 4

Results from $\int g_1^{p-n} dx$:





f_2 large (similar to leading twist at Q^2 =1 GeV^2) in accordance to intuition.

μ_6/M^4 similar size as f_2 but opposite sign (true also for HT from $\int g_1^p dx$ and $\int g_1^n dx$).

Overall, higher twist contribution small at Q^2 =1 GeV^2.

Relevant to hadron-parton duality

Jefferson Lab

Accurate mapping from low to high Q^2.

- Models and data agree.
- Not so clear agreement with χpT at low Q^2.
- pQCD without non-perturbative corrections: good description (At first, surprising. HT analysis explains it as a cancelation between twist terms)

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- Not so clear agreement with χpT at low Q^2.
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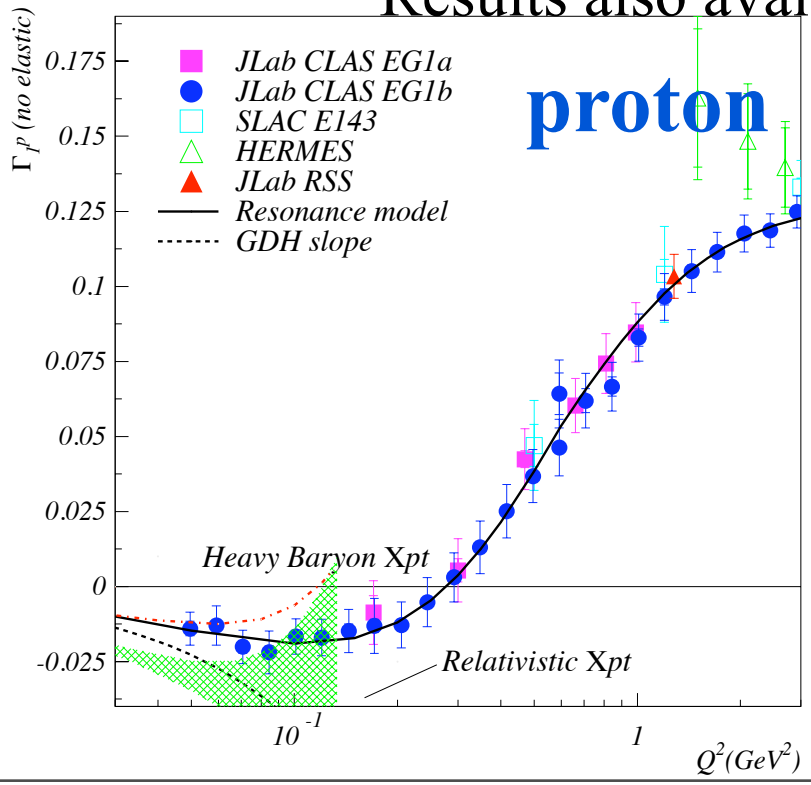
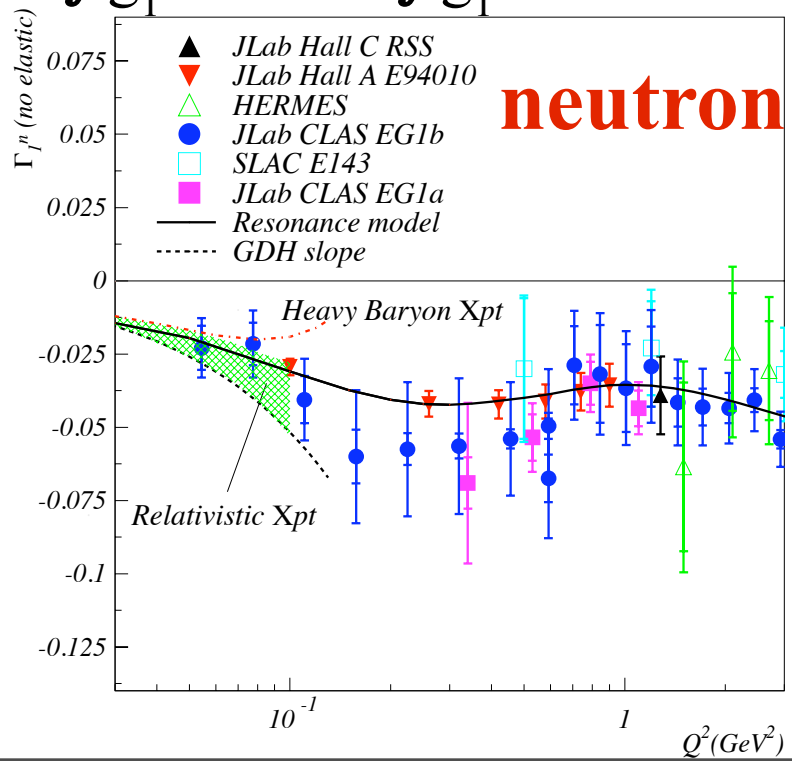
Results also available on $\int g_1^p\,dx$ and $\int g_1^n\,dx$





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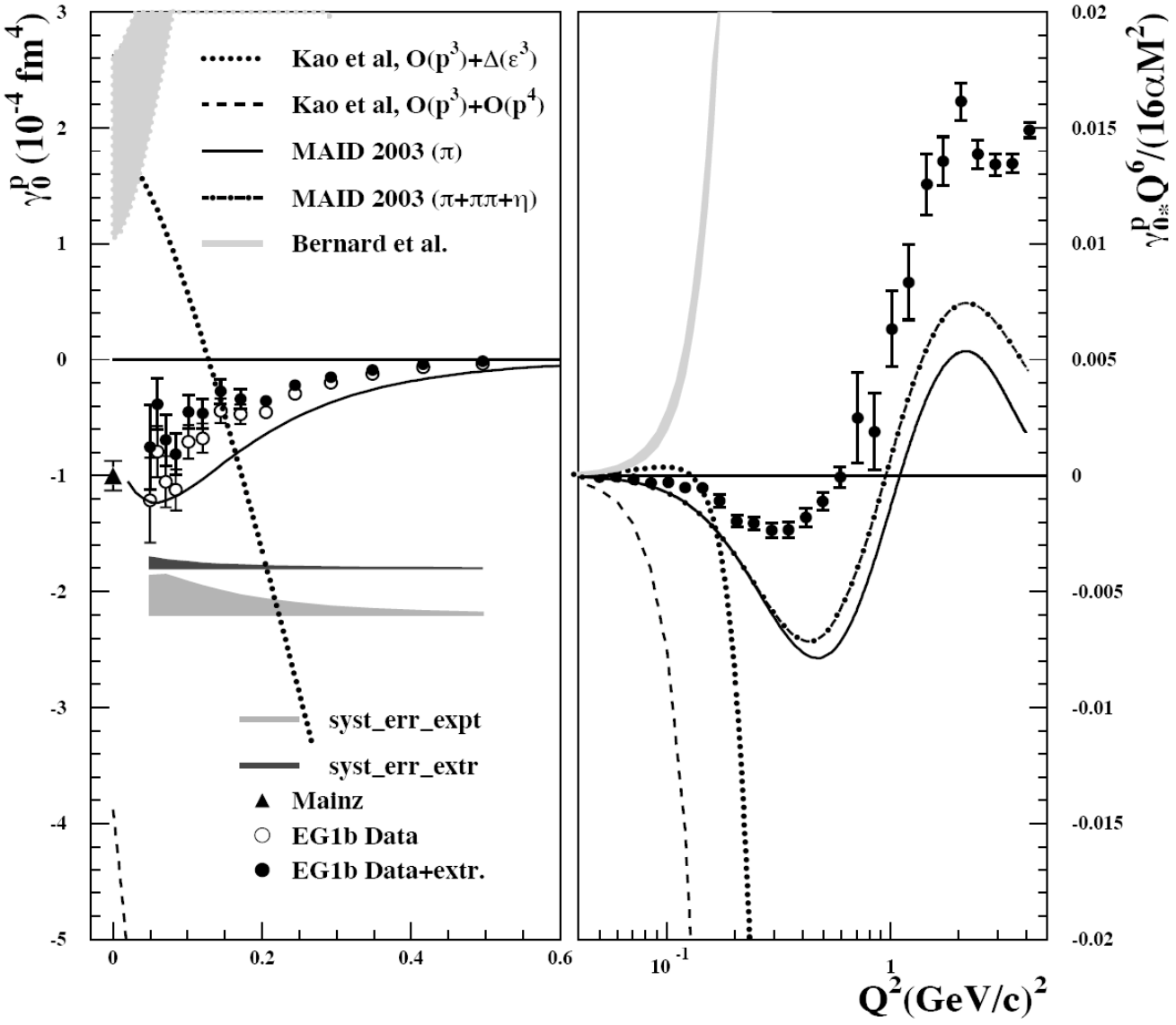
Higher moments from EG1b

Spin Polarizabilities

proton



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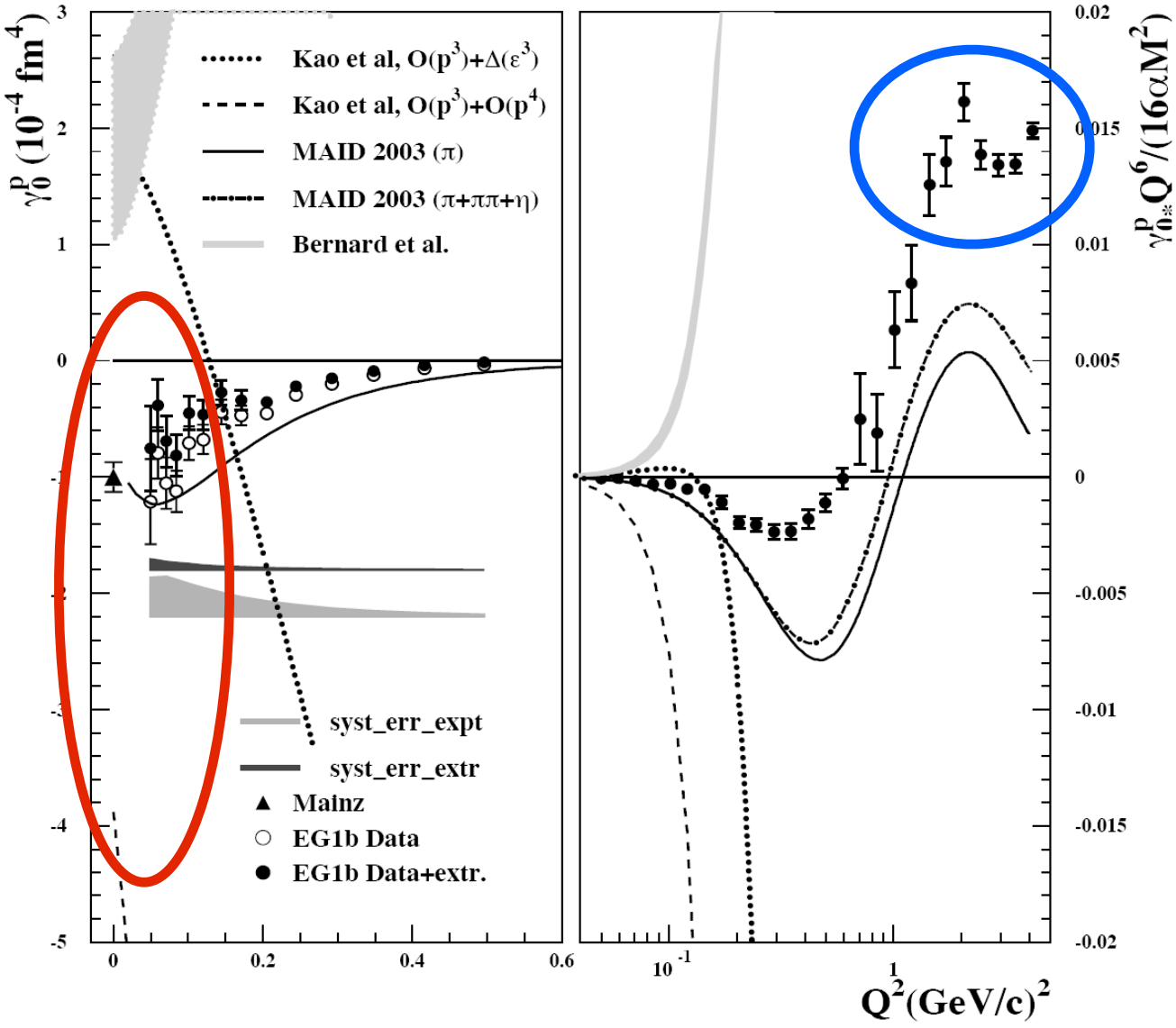
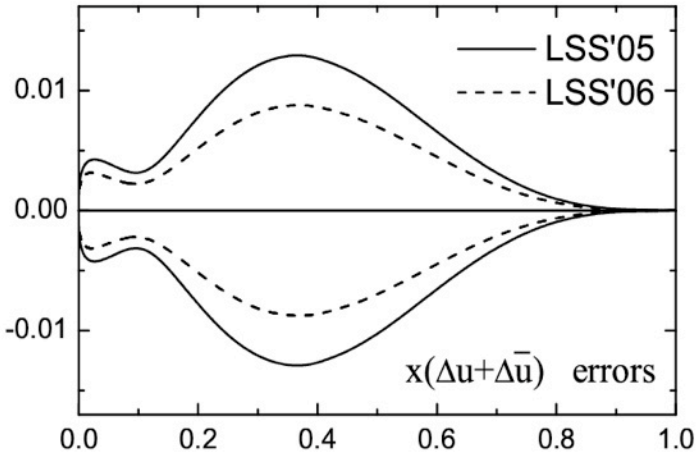
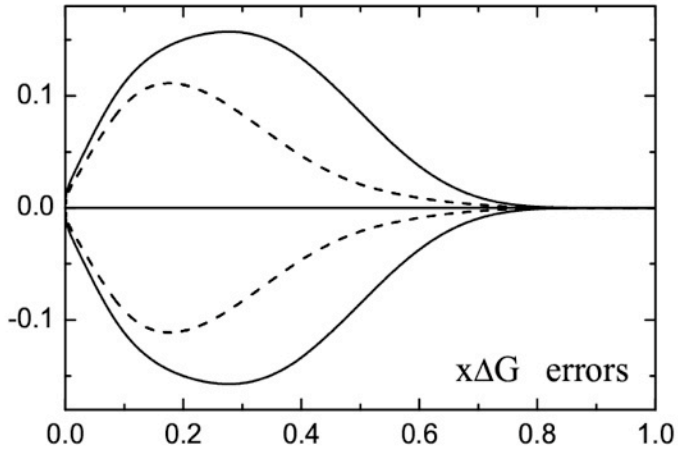
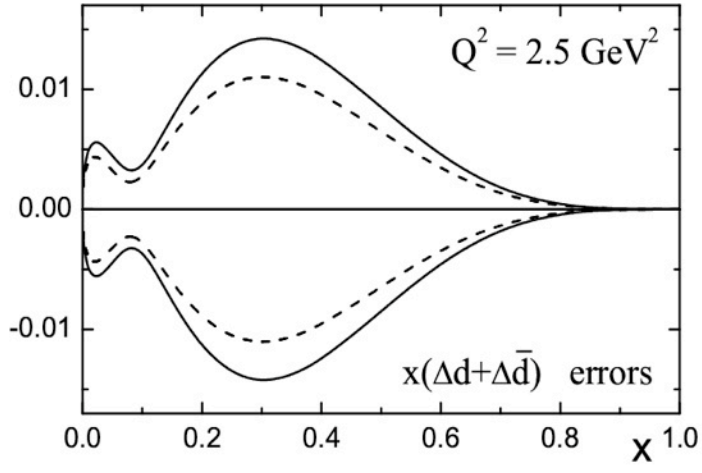
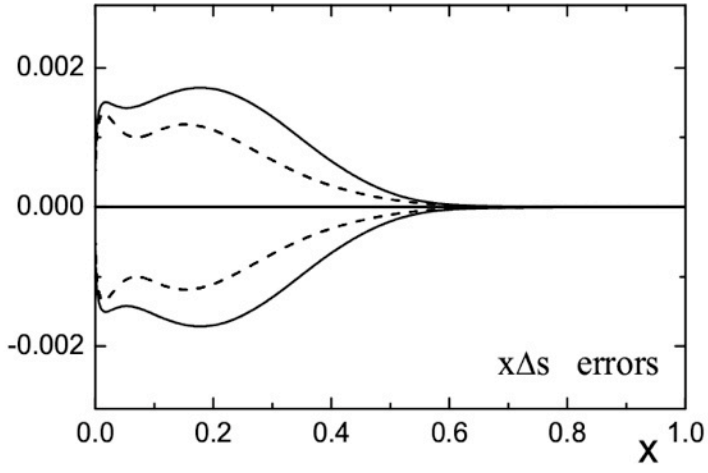


From DGLAP evolutions:









Leader, Sidorov and Stamenov, Phys. Rev. D75:074027 (2007)

——— Without JLab data

-------- With CLAS EG1b and Hall A large-x data

⇒ Important impact on ΔG

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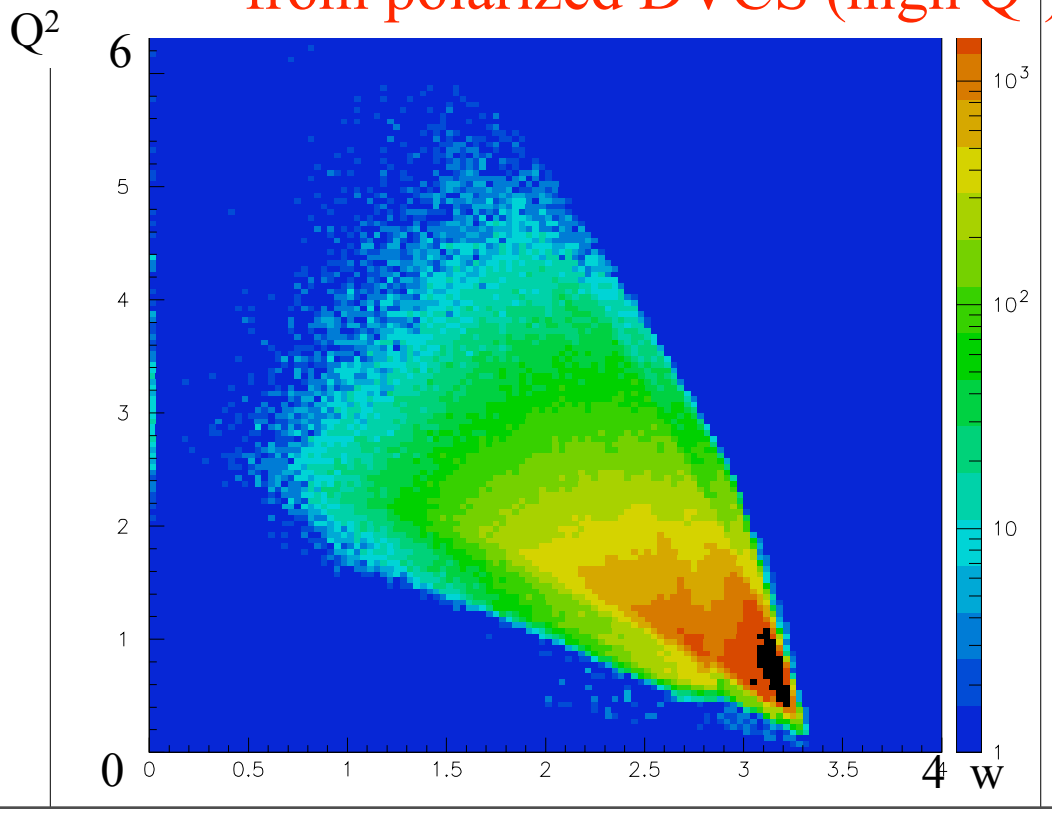
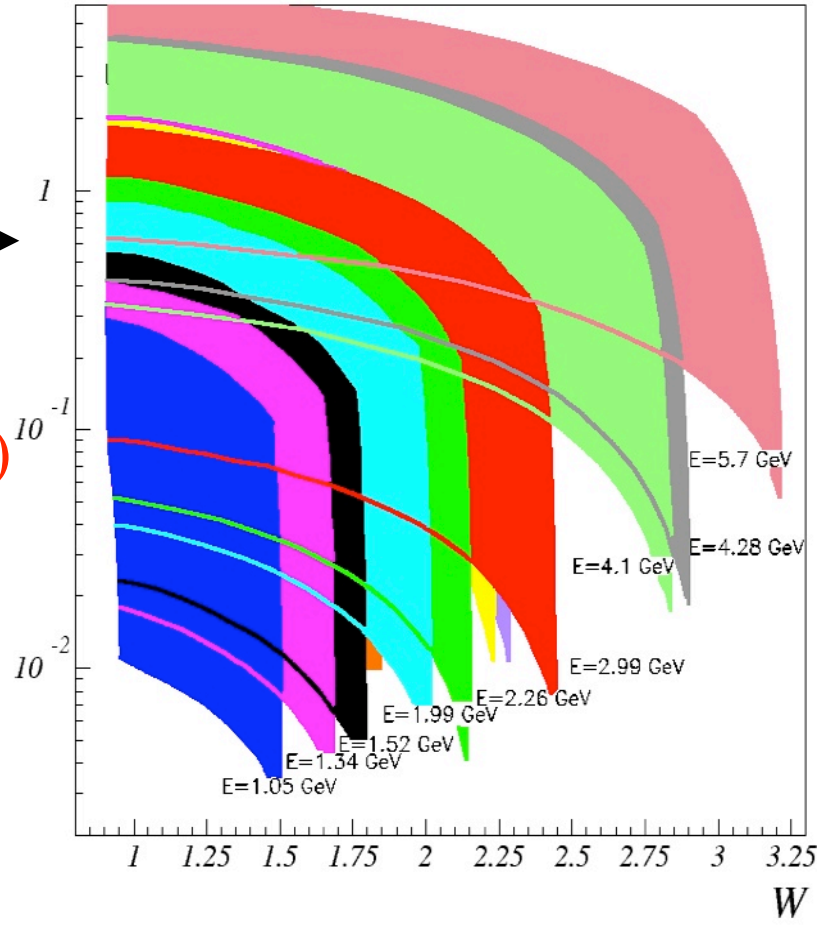
Upcoming results from CLAS

- EG1b: Intermediate Q^2 data.
- EG4: Going to low Q^2: →
- EG1dvcs: Large set of inclusive data from polarized DVCS (high Q^2)





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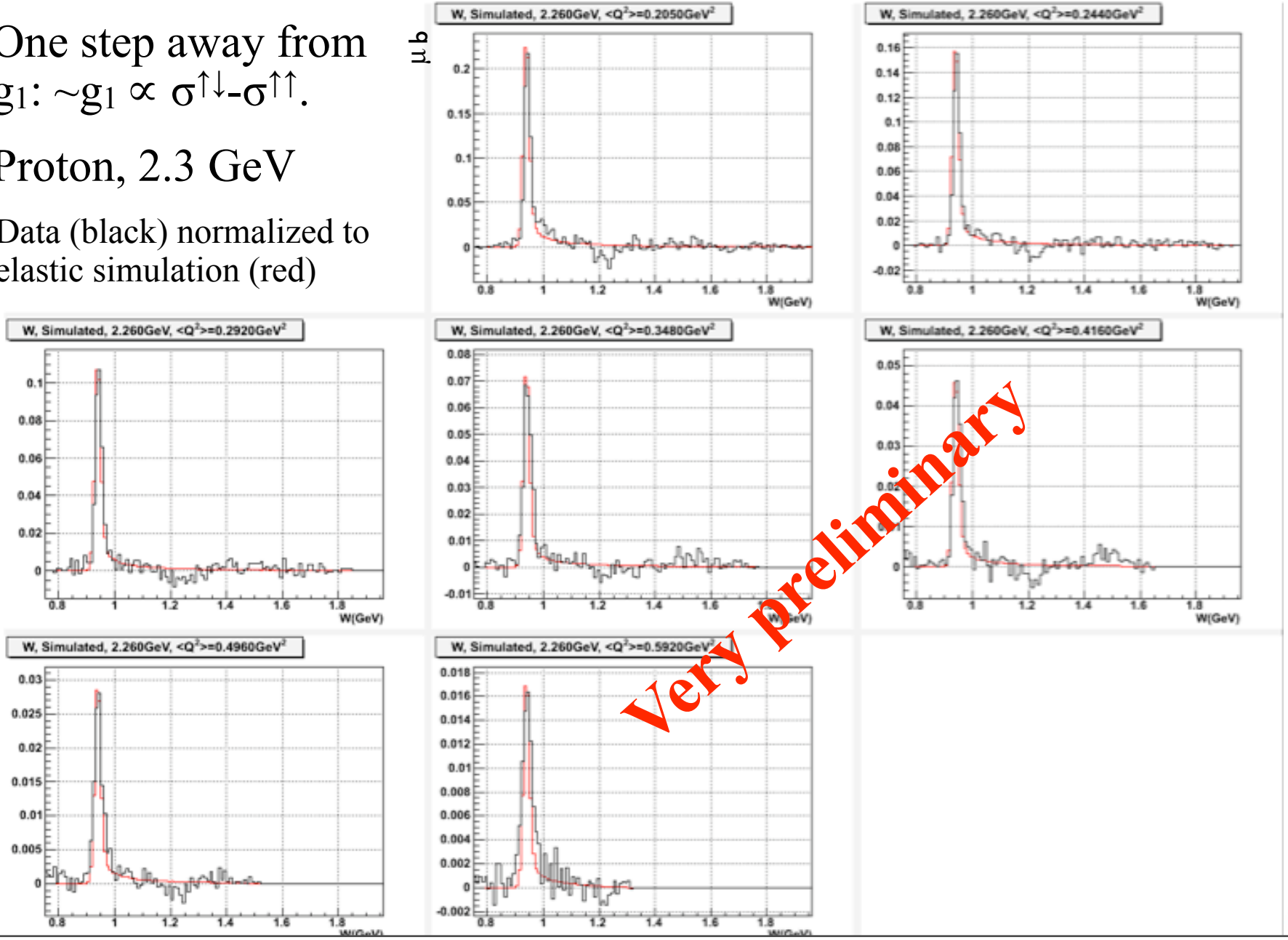
EG4: Preliminary results on difference of polarized cross sections

One step away from g_1: $\sim g_1 \propto \sigma^{\uparrow\downarrow} - \sigma^{\uparrow\uparrow}$.

Proton, 2.3 GeV

Data (black) normalized to elastic simulation (red)



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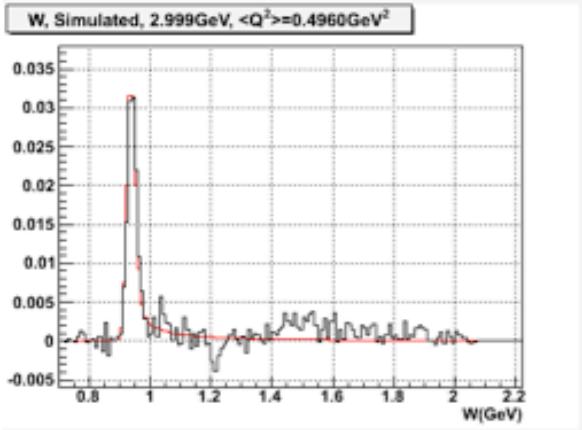
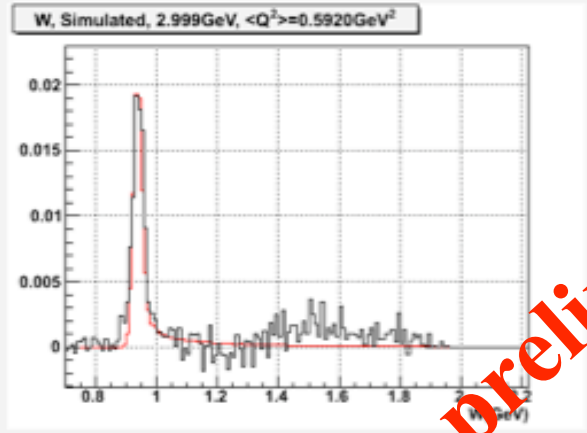
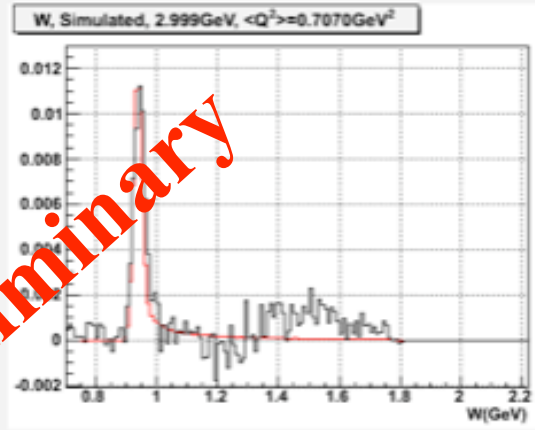
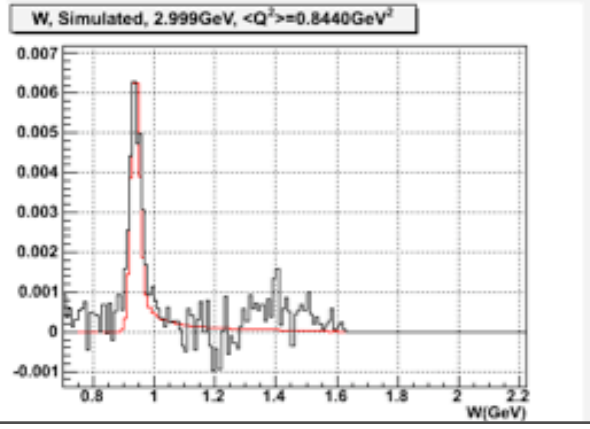
EG4: Preliminary results on difference of polarized cross sections

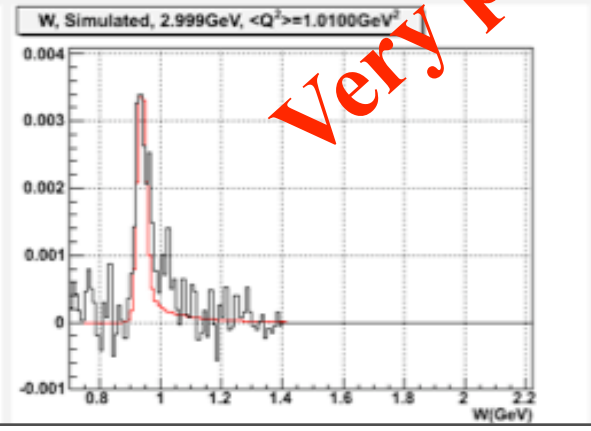
Proton, 3.0 GeV











Very preliminary

- Not full statistics;
- No radiative corrections;
- No detector efficiency;
- Lowest Q^2 data not included (Scat. angle >10° data);
- ND_3 to be analyzed.

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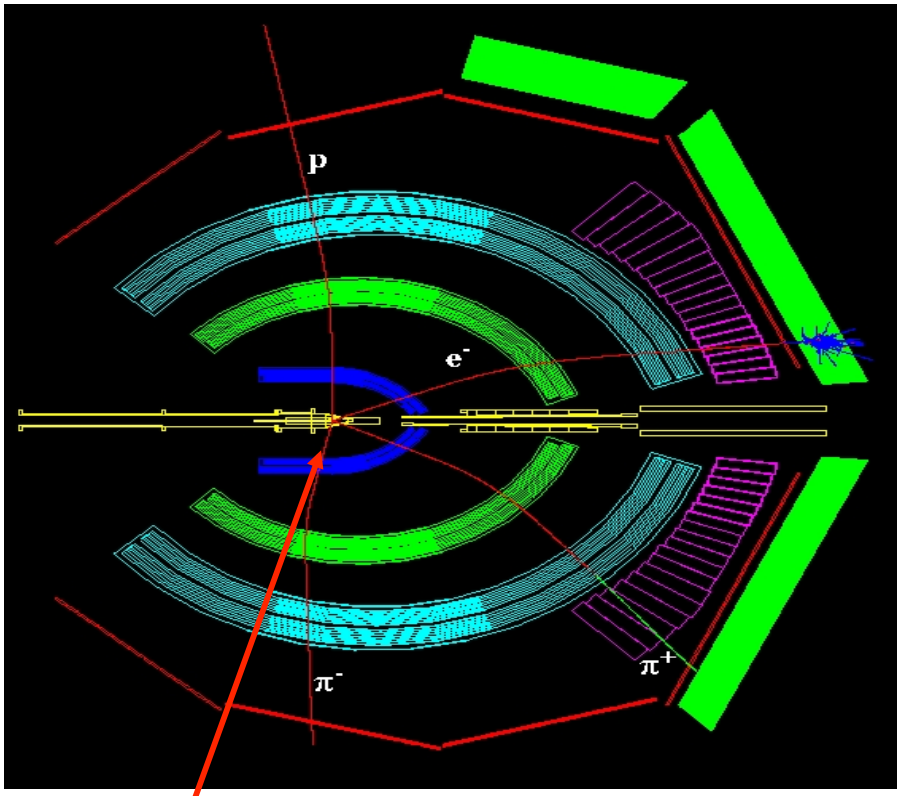
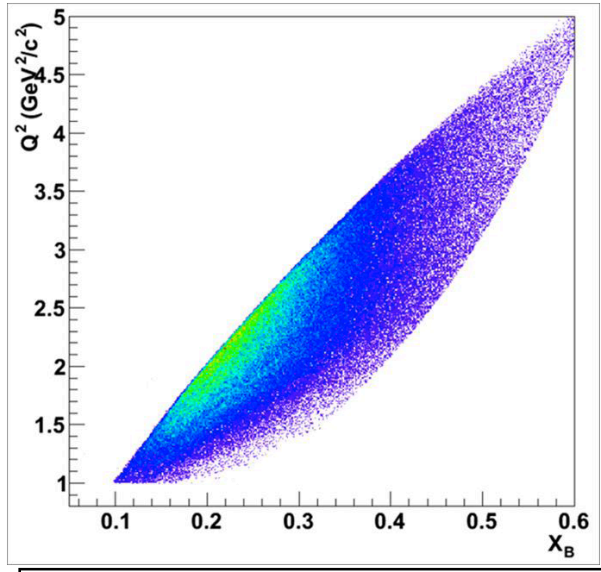
CLAS Experiment EG1-DVCS

Y. Prok

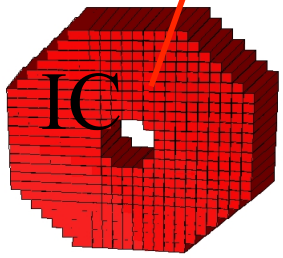




February-September 2009
Beam Energy = 5.7 GeV
Beam polarization: >80
Target polarization: >75%

20x more π^+, π -,

40x more π^0 for g_1/F_1 at 6 GeV



Inner Calorimeter (424 $PbWO_4$ crystals) for the detection of high energy photons at forward lab angles.

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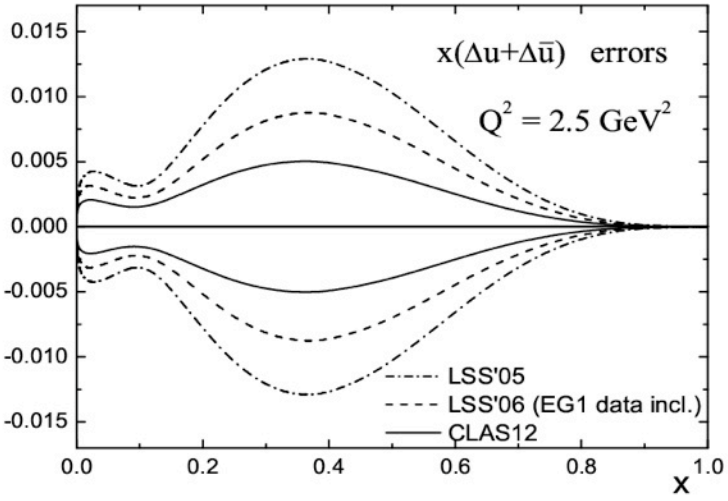
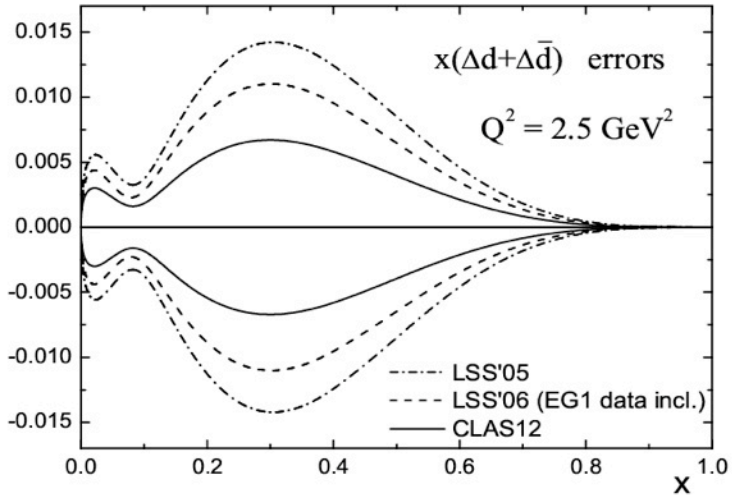
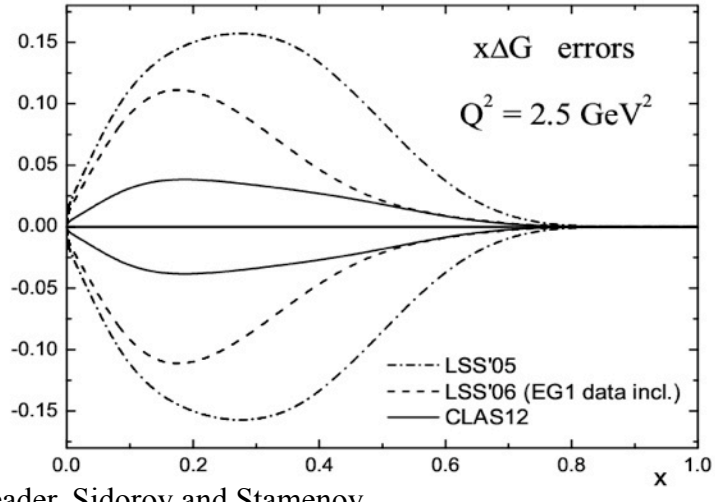
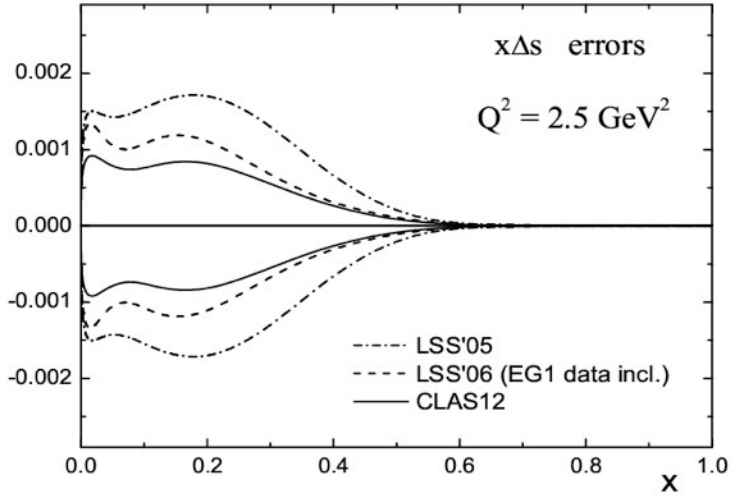
Perspectives with CLAS12









Leader, Sidorov and Stamenov,

Jefferson Lab

A spin-off of spin structure study α_s, the strong coupling constant

(includes large distances, >0.2 fm, i.e. low Q^2).

$$g^p_1 - g^n_1 \, dx = \Gamma_1^{p-n} = \frac{1}{6} g_A \left(1 - \frac{\alpha_s}{\pi} - 3.58\left(\frac{\alpha_s}{\pi}\right)^2 - \ldots\right) + \frac{M^2}{9Q^2}\left[a_2(\alpha_s) + 4d_2(\alpha_s) + 4f_2(\alpha_s)\right] + \ldots$$

Nucleon axial charge (Bjorken limit)

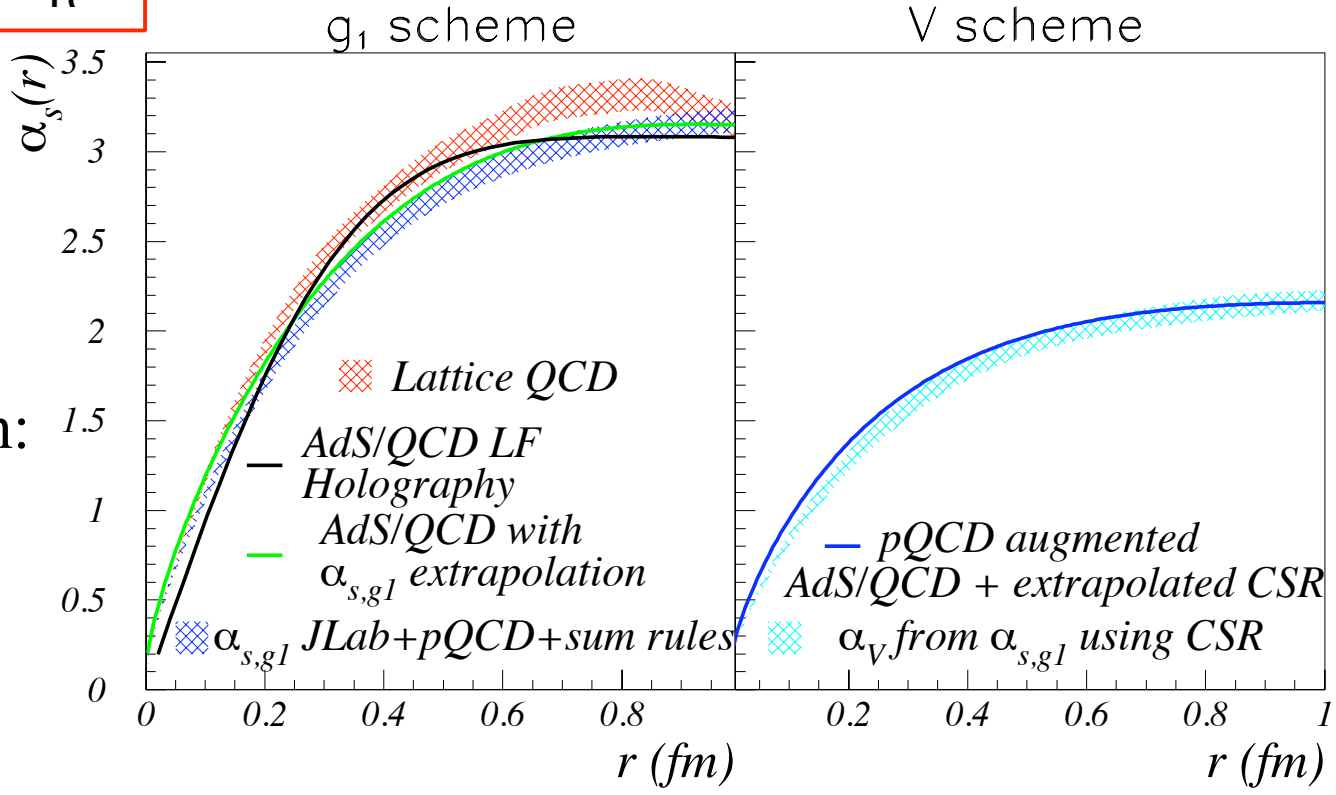
pQCD radiative corrections.

Higher Twists (+rad. corr.)

$$\Rightarrow \boxed{\Gamma_1^{p-n} \triangleq \frac{1}{6} g_A \left(1 - \frac{\alpha_{s,g1}}{\pi}\right)}$$

$\alpha_{s,g1} \triangleq \alpha_s$ extracted from Γ_1^{p-n}

After $Q^2 \rightarrow r$ fourier transform:



Conclusion

- CLAS: major contribution to JLab longitudinal spin structure program:
  - Investigation of transition from small to large scales;
  - pQCD study in region hitherto inaccessible;
  - Long lever arm allows efficient DGLAP extraction (ΔG)
  - low Q^2-high W data.

Missing piece from CLAS: transversally polarized target with electron beam. Polarized HD target in Hall B: may provide a transverse target for electron beam (12 GeV). If not, will use DNP target.

12 GeV will continue the large Q^2 part of this program:

- High-x data
- Convergence of sum rules (minimize low-x issue);
- increase Q^2 range;
- Increase lever arm for DGLAP;
- higher precision extraction of higher twists.

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