

PVDIS with SoLID: PVDIS and Hadronic Physics

Dave Gaskell

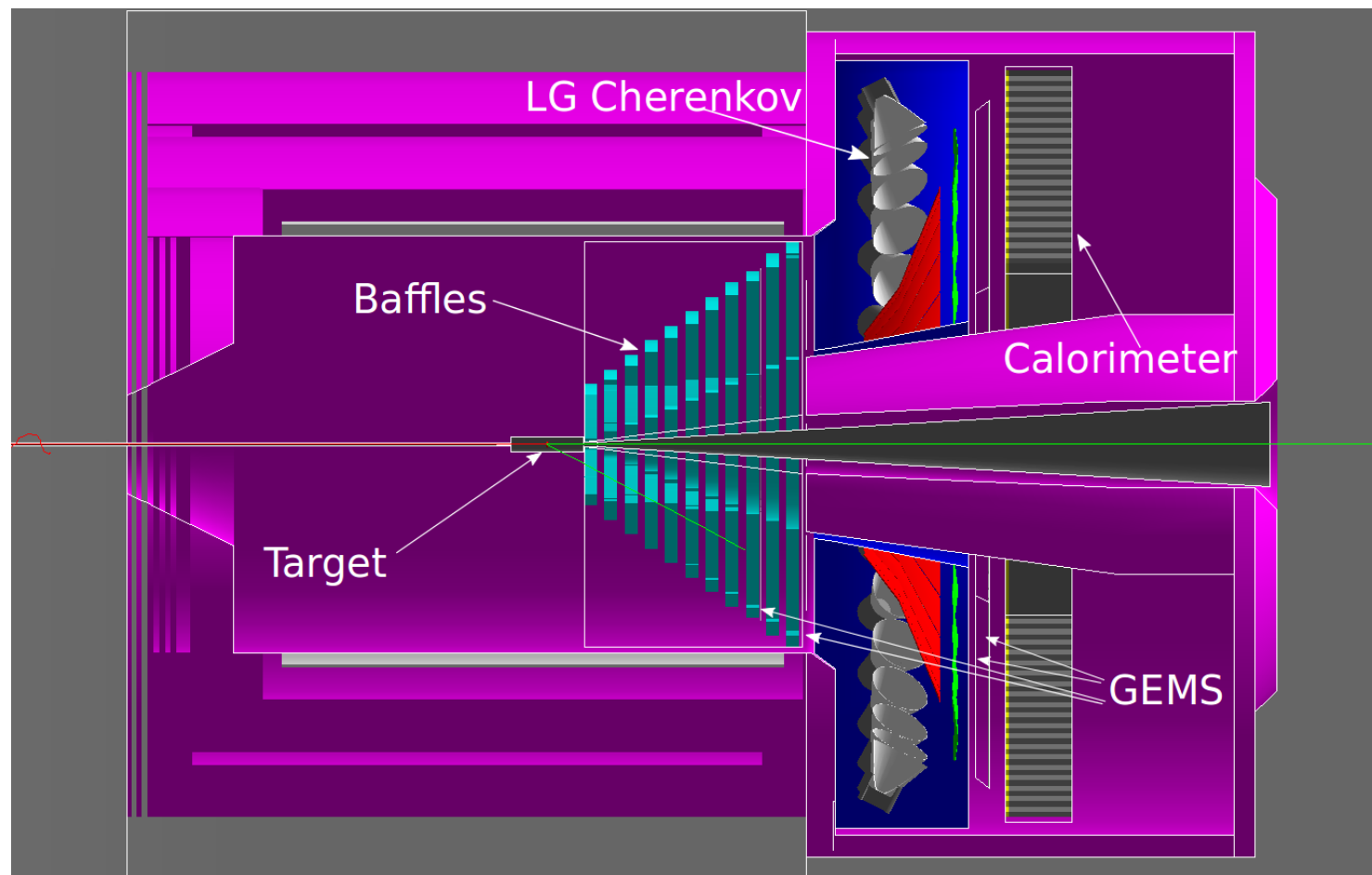
Workshop on the Physics Program with High Luminosity Facilities
October 5-9, 2026

1. PVDIS with SoLID
2. d/u
3. EMC effect
4. Two-photon Exchange
5. Impact of “SoLID-Lite” configuration

PVDIS with SoLID

PVDIS in SoLID setup:

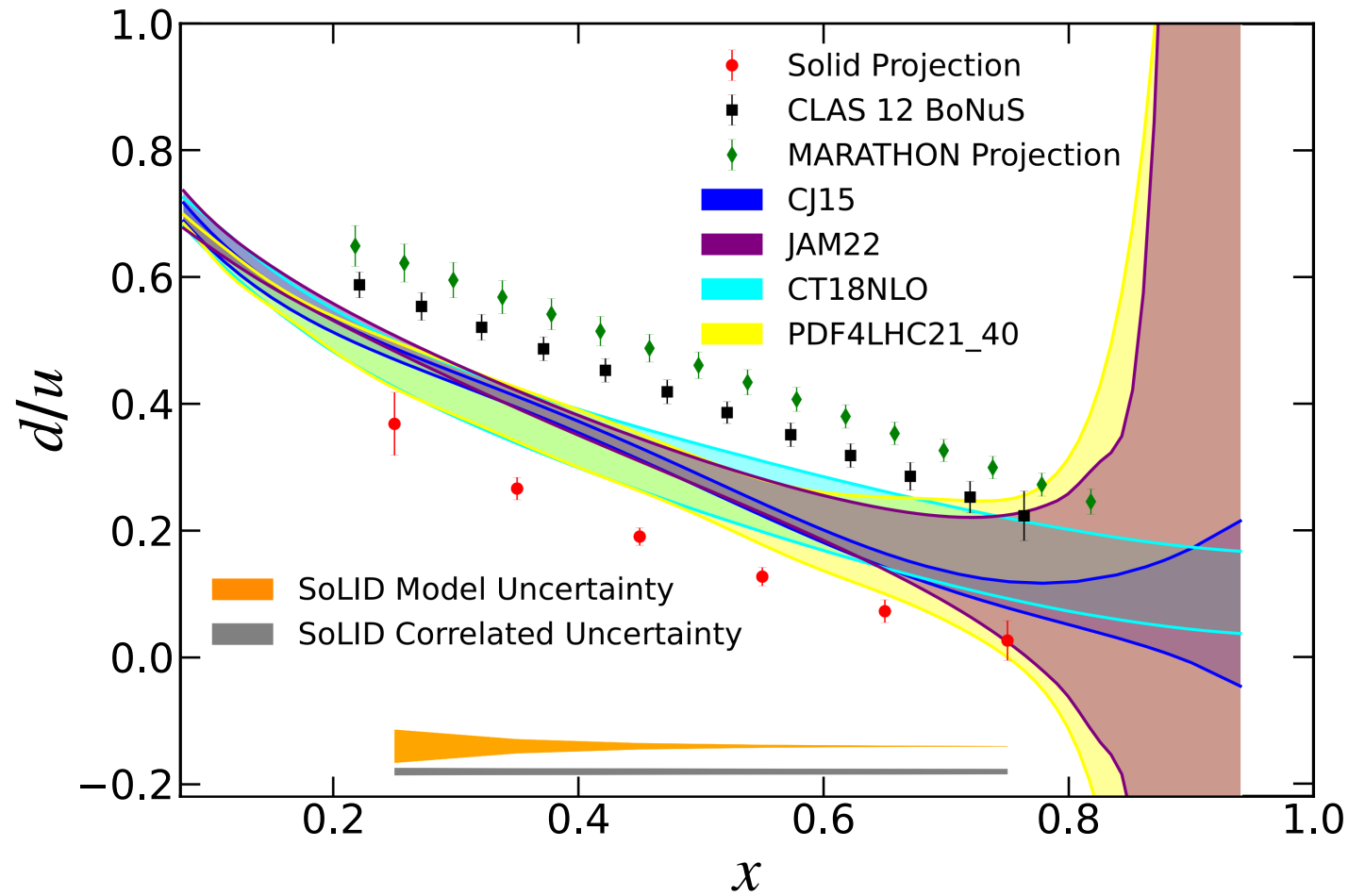
- tracking (GEMs)
- excellent PID (Calorimeter and LG Cherenkov)
- Baffles to reduce backgrounds
- Highest luminosity possible (thick targets, high currents)



d/u at Large x

Major focus of JLab 12 GeV program is 1D nucleon structure

- d/u ratio at large x of particular interest
- Extractions from inclusive electron scattering from H and D complicated by nuclear effects at large x
- 3 proposed measurements to address this
 - 2 have already run and have final (near final) results

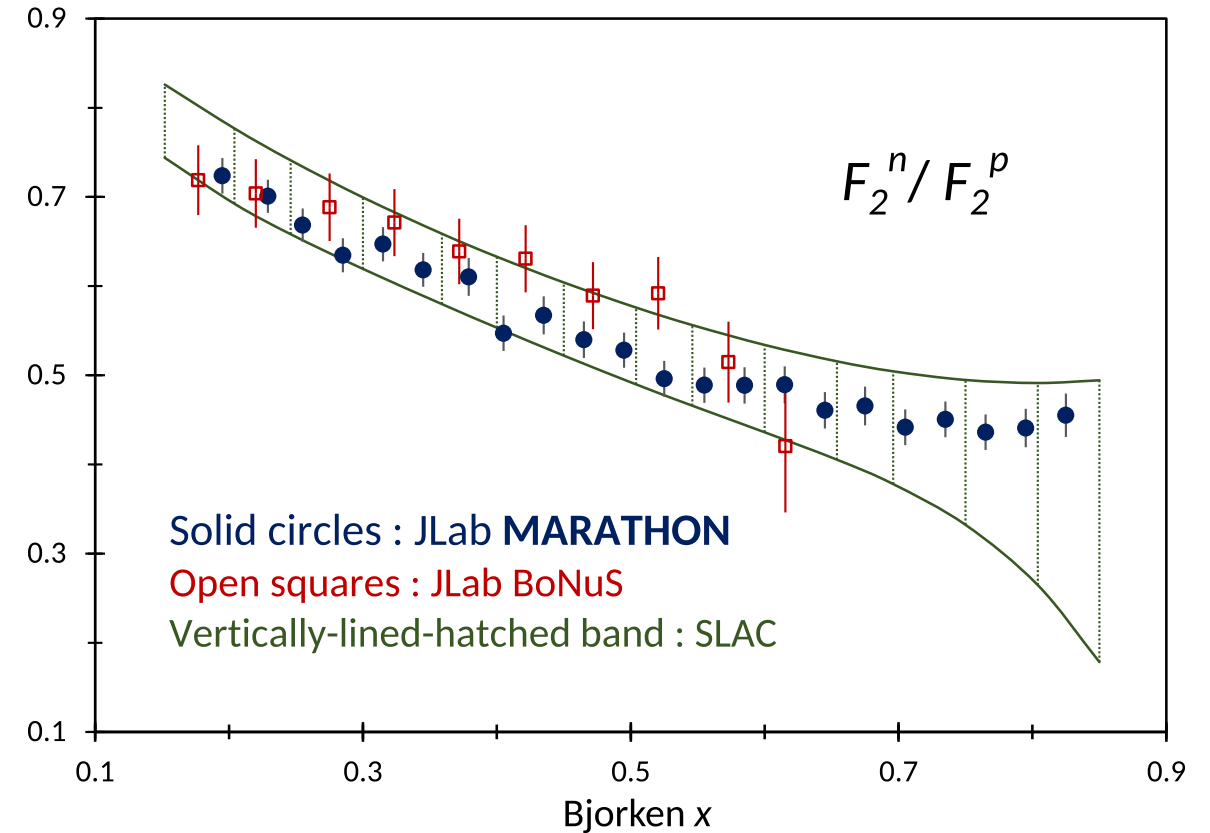


d/u at Large x - MARATHON

n/p structure function ratio extracted from ratio of ^3He (2p+1n) and ^3H (1p+2n) cross sections

$$\frac{F_2^n}{F_2^p} = \frac{2R_{ht} - F_2^h / F_2^t}{2F_2^h / F_2^t - R_{ht}}$$

Assumes knowledge of the relative EMC effects in ^3He and ^3H

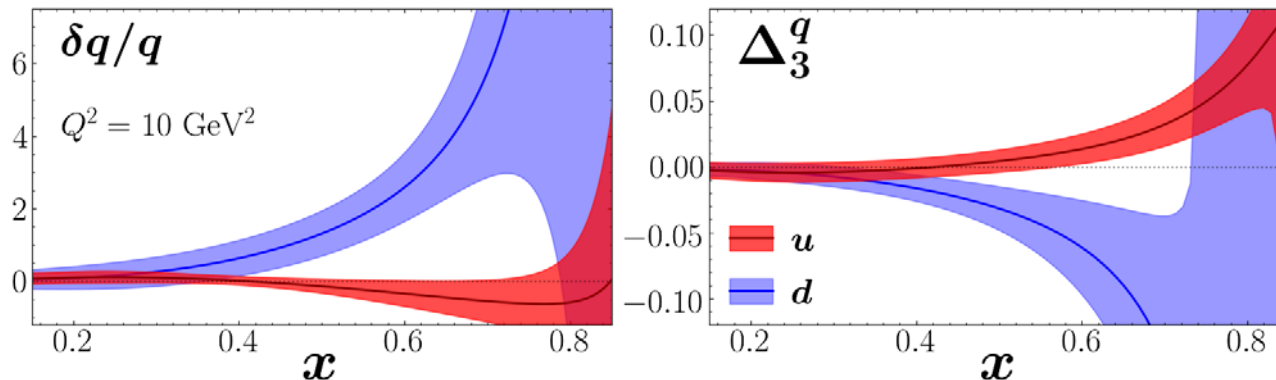
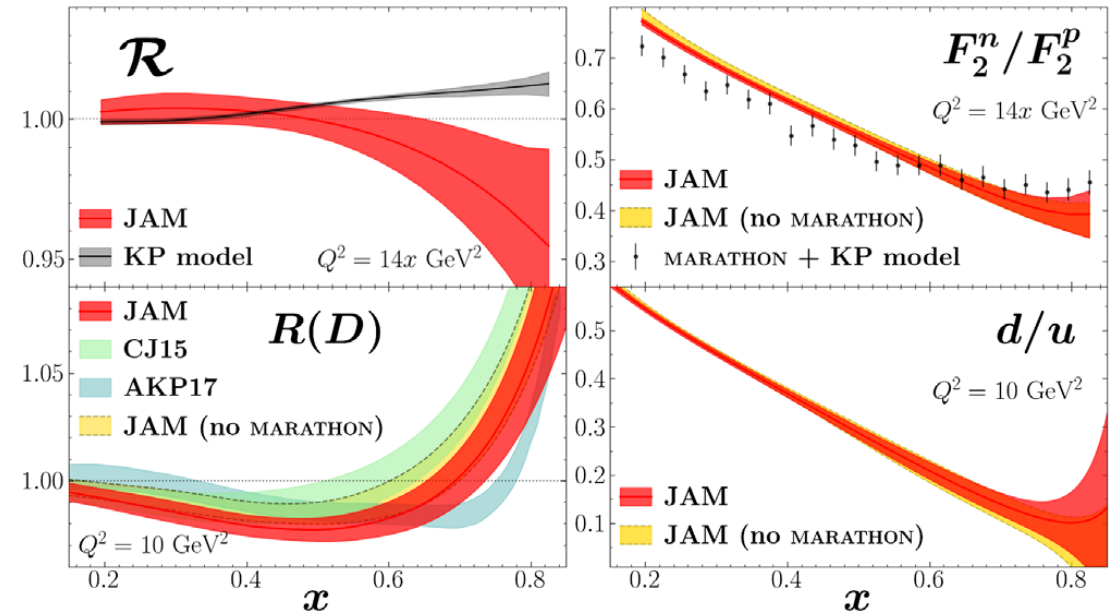


D. Abrams et al, PRL 128, 132003 (2022)

d/u at Large x – MARATHON + Global Fits

Global fits suggest MARATHON data might provide more information about the existence of a possible isovector EMC Effect than d/u

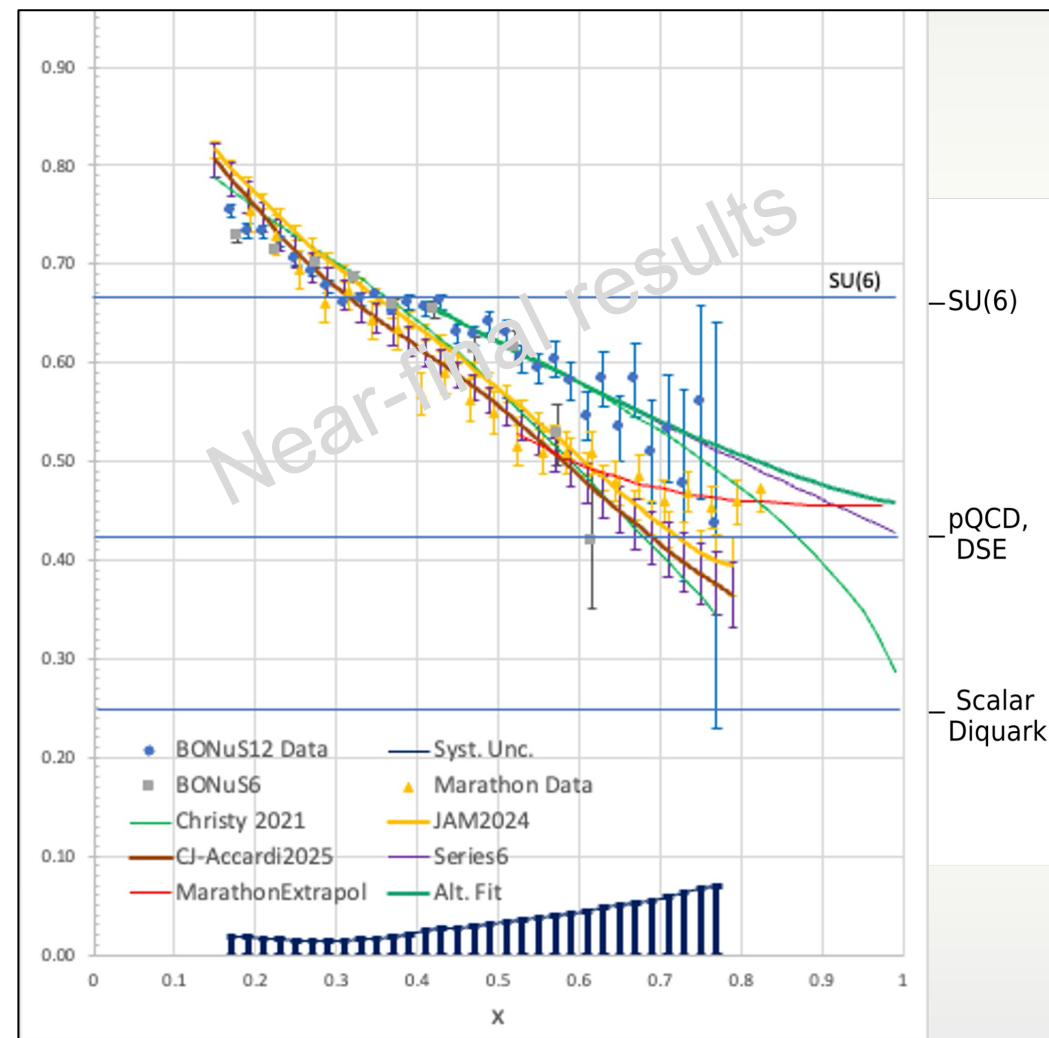
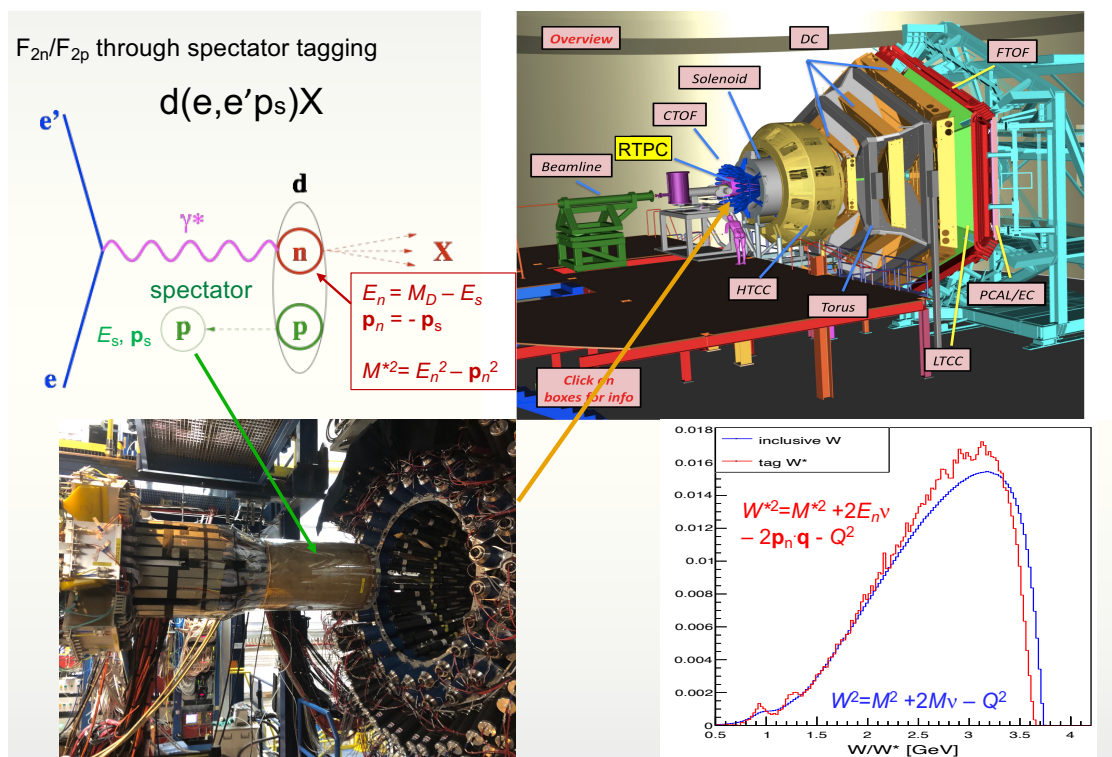
→ C. Cocuzza *et al* (JAM Collaboration), *PRL* 127, 242001 (2021)



$$\Delta_3^q \equiv \frac{q_{p/{}^3\text{H}} - q_{p/{}^3\text{He}}}{q_{p/{}^3\text{H}} + q_{p/{}^3\text{He}}},$$

d/u Ratio at Large x – BONuS12

BONuS collaboration uses spectator tagging
 → Detect recoil protons from deuteron target to tag
 “barely offshell” neutrons
 → Reduces uncertainties due to nuclear effects



d/u Ratio at Large x from PVDIS

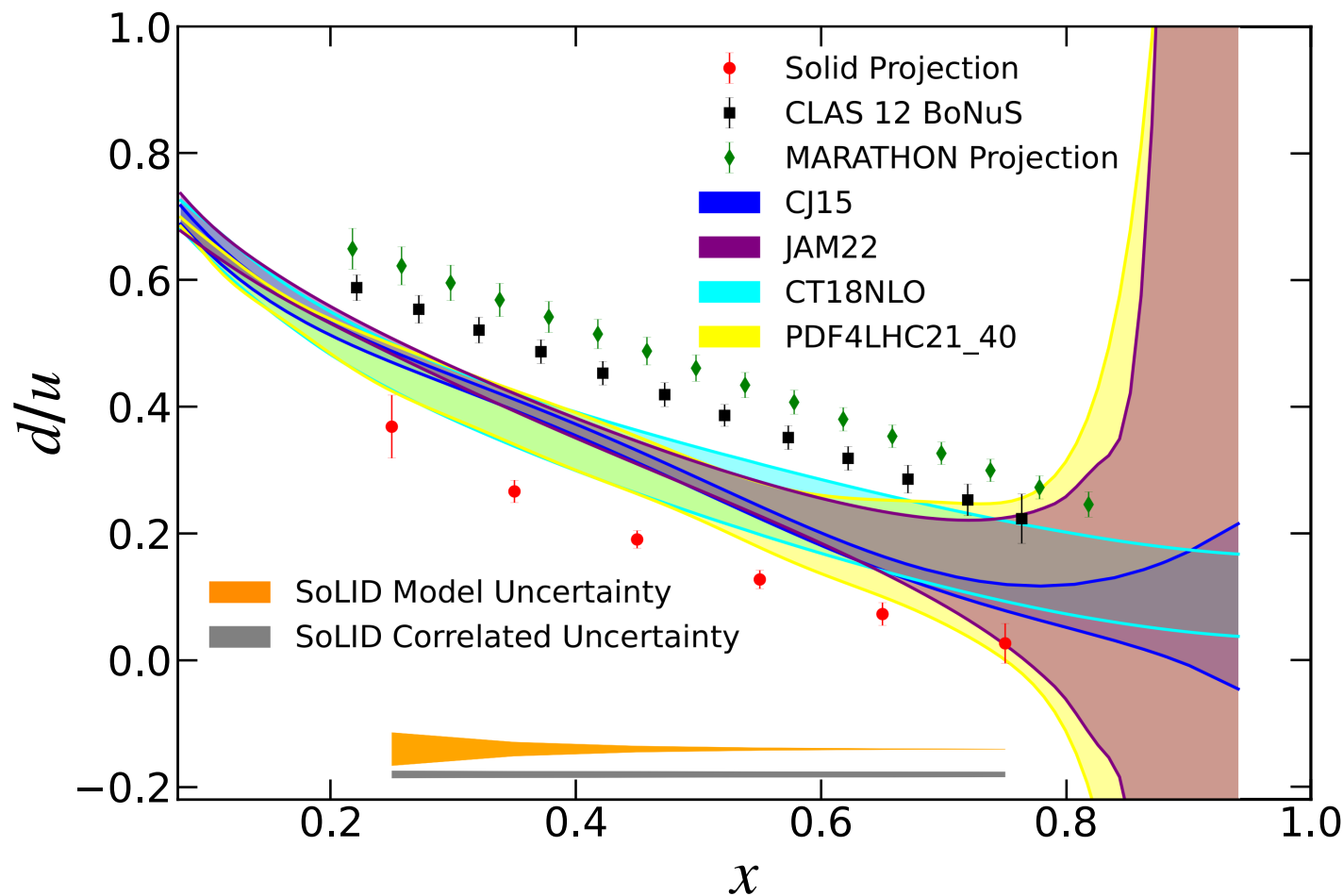
PVDIS with proton target provides alternate approach with reduced (or maybe just different) model dependent uncertainties

$$a_1^p(x) = \frac{12C_{1u}u(x) - 6C_{1d}d(x)}{4u(x) + d(x)}$$

No nuclear effects!

→ Higher twist relevant, but can get information from the LD2 measurements

Larger reach in x would be nice, but provides constraint on PDF fits at large x, and tests systematics of other techniques



The EMC Effect – Modification of Nuclear Structure Functions

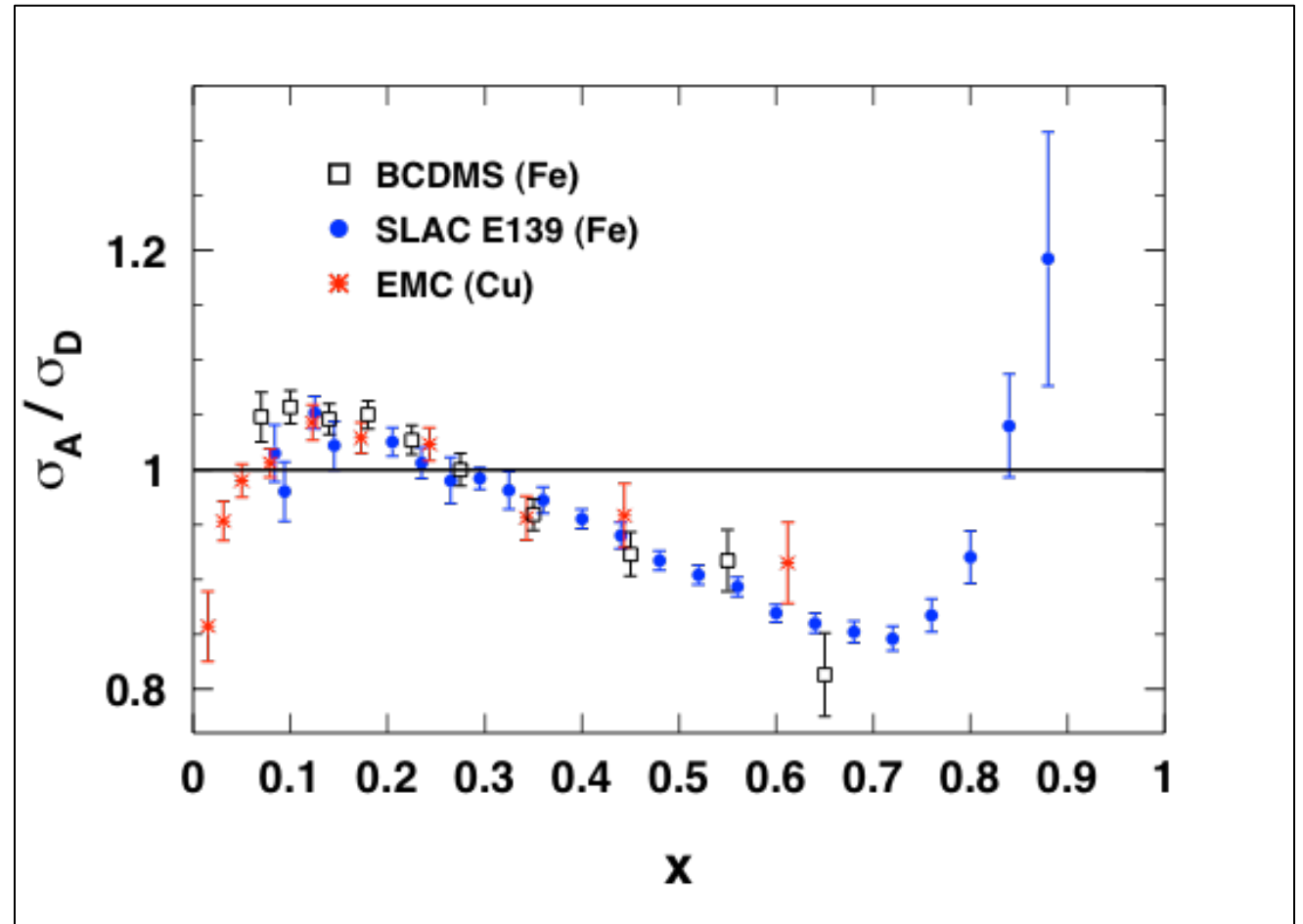
Observation of the EMC Effect more than 40 years ago

→ Inelastic structure function modified in nuclei

→ Relevance of quark degrees of freedom in the nucleus

Measured for large body of nuclei – many questions remain:

1. What is the origin of the EMC Effect?
2. Are polarized quark structure functions also modified?
3. Are all quark flavors modified in the same way?



Flavor Dependence of the EMC Effect from PVDIS

$$A_{PV} \approx -\frac{G_F Q^2}{4\sqrt{2}\pi\alpha} \left[a_1(x) + \frac{1 - (1-y)^2}{1 + (1-y)^2} a_3(x) \right] \quad \leftarrow \text{Suppressed by small values of } C_2, y\text{-factor}$$

$$a_1(x) = 2 \frac{\sum C_{1q} e_q (q + \bar{q})}{\sum e_q^2 (q + \bar{q})} \quad C_{1u} = -0.19, C_{1d} = 0.34$$

Expanding about $u_A = d_A$ limit, neglecting sea quarks:

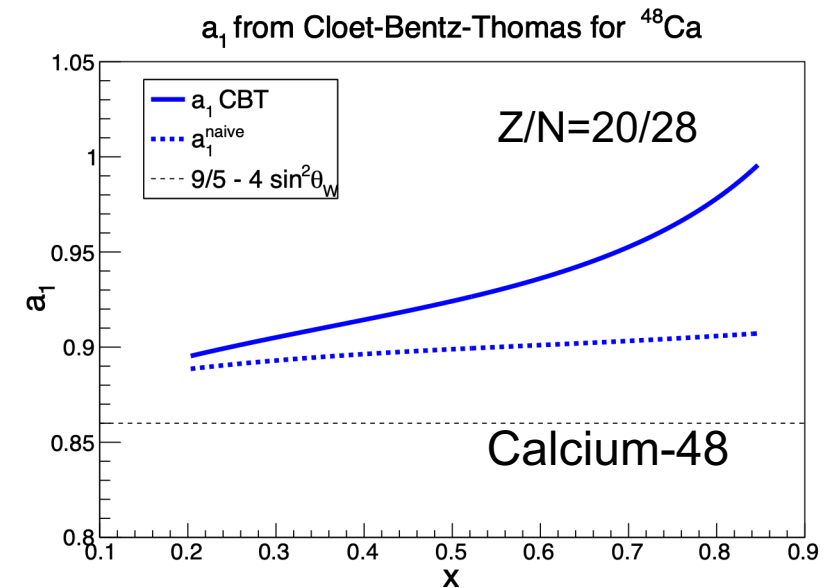
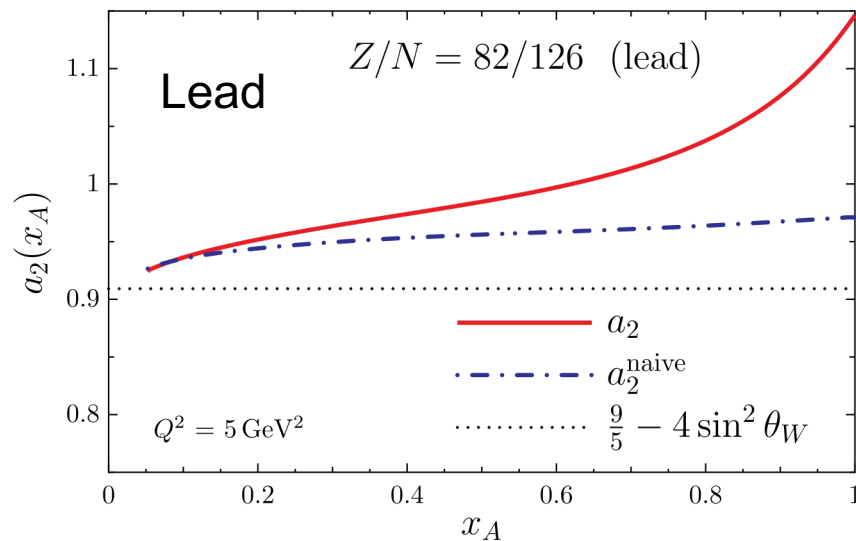
$$a_1(x) \approx \frac{9}{5} - 4 \sin^2 \theta_W - \frac{12}{25} \frac{u_A^+ - d_A^+}{u_A^+ + d_A^+} \quad q^\pm = q(x) \pm \bar{q}(x)$$

PVDIS directly sensitive to difference in up and down quark distributions in nuclei

Flavor Dependence of the EMC Effect from PVDIS

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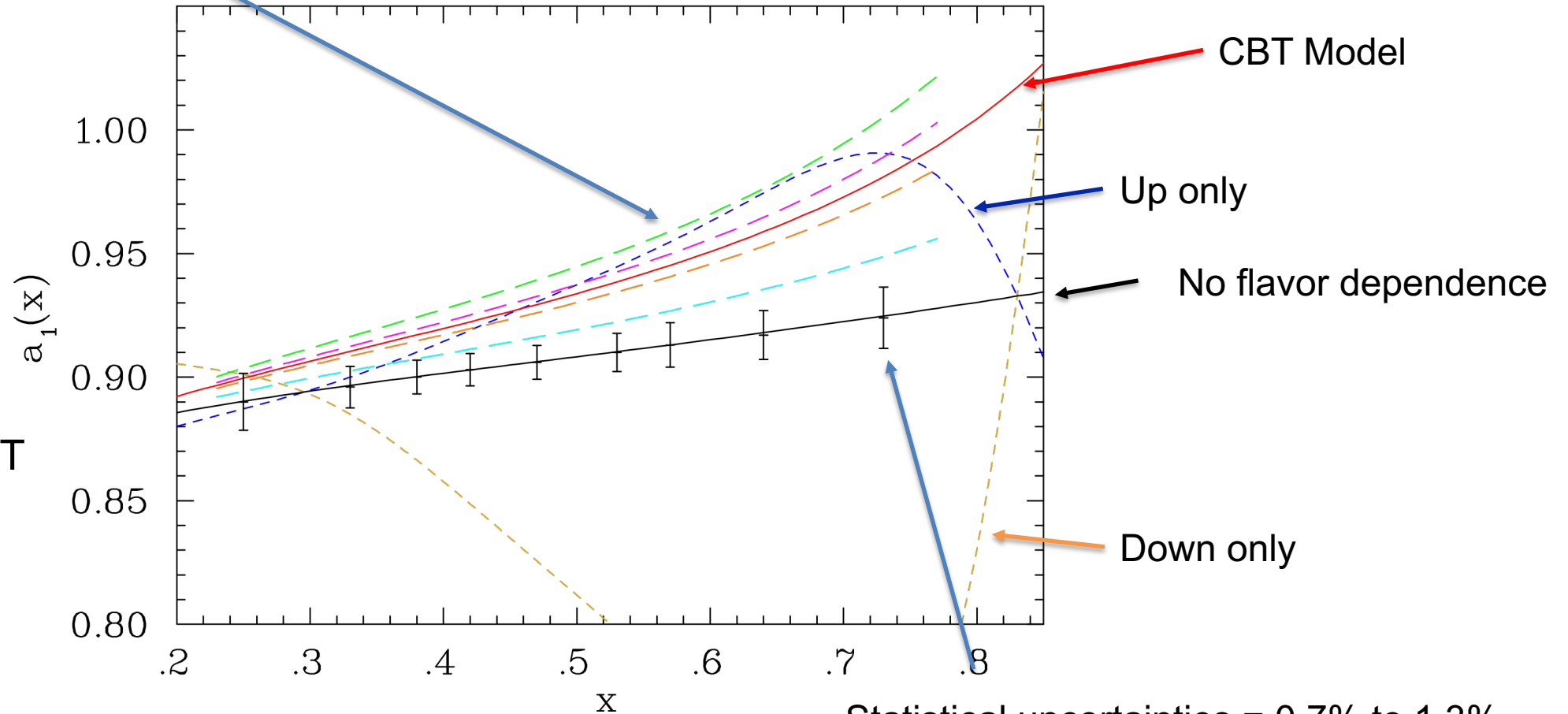


Cloët, Bentz, and Thomas, PRL 109, 182301 (2012)

Projections - Sensitivity

Scaling models (p>300 MeV, kinetic energy, average density, overlap probability)

8 σ sensitivity to CBT model (neglecting normalization uncertainty)

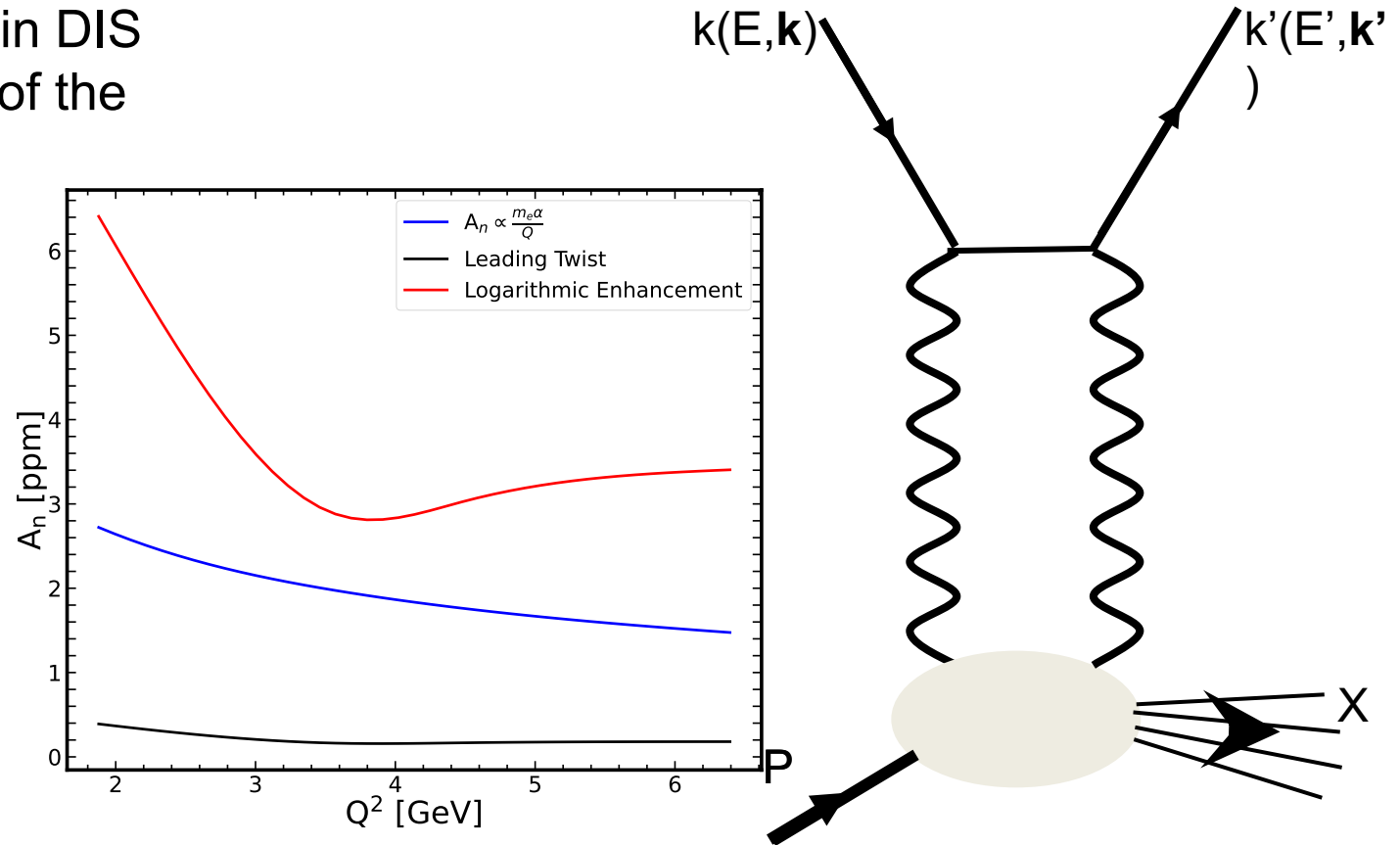


Statistical uncertainties = 0.7% to 1.3%

Beam Normal Single Spin Asymmetry

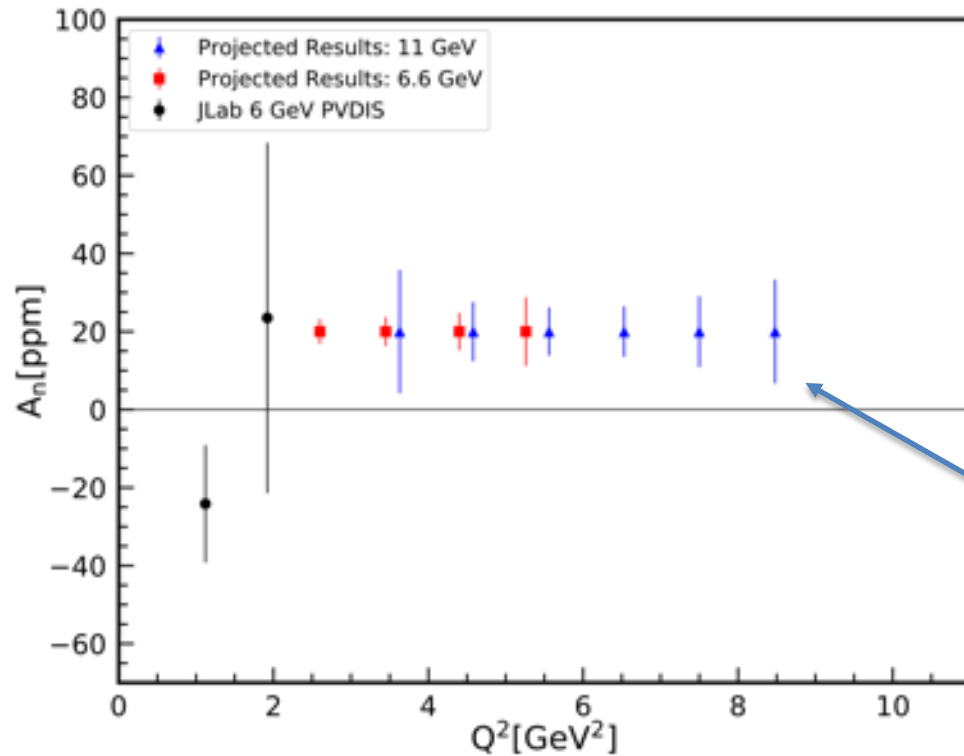
Beam normal single spin asymmetry in DIS provide access to the imaginary part of the two-photon exchange amplitude

Q^2 dependence provides sensitivity to whether both photons couple to same quark, or if dynamics are more complex.

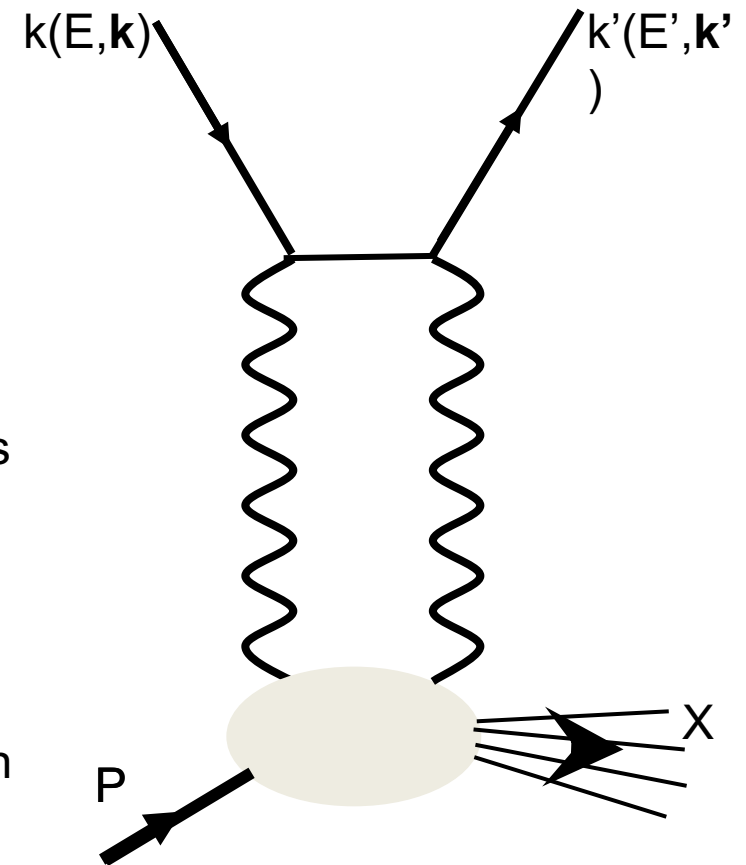


$$A_n = \frac{\alpha_{\text{EM}} m_l |\vec{S}_T| \sin(\varphi_s)}{2Q} \frac{y^2 \sqrt{1-y}}{1-y + \frac{1}{2}y^2} \frac{\sum_q e_q^3 q(x)}{\sum_q e_q^2 q(x)}$$

Beam Normal Single Spin Asymmetry



Projected uncertainties



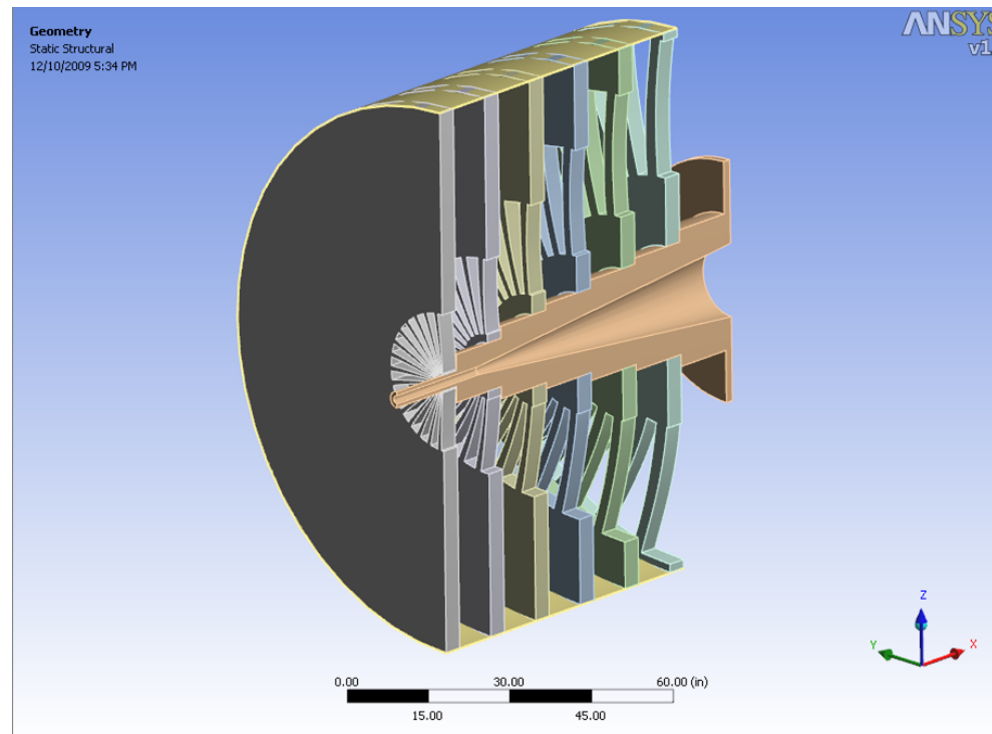
E12-22-004: Measurement of the Beam Normal Single Spin Asymmetry in Deep Inelastic Scattering using the SOLID Detector
Spokespersons M. Nycz*, W. Henry, Y. Tian, W. Xiong, X. Zheng
→ 38 days

SoLID-Lite and PVDIS

What does “SoLID-Lite” look like for PVDIS?

- Calorimeter can be reconfigured to provide about half of nominal PVDIS acceptance
- Still need Cherenkov, GEMs for larger acceptance

What about the baffles? Can they be simplified or optimized for reduced acceptance?



Summary

- Rich and interesting program of hadronic physics measurements accessible with PVDIS in SoLID
 - Not discussed here: higher twist, target mass corrections
- Many of these measurements are dominated by statistical uncertainties
- Still of interest in a SoLID-lite scenario with possibly reduced statistics/acceptance
 - $d/u \rightarrow$ loss of factor of 2 in statistics likely tolerable. Primary strength/interest is in reduced systematics in the interpretation
 - PVEMC $\rightarrow$ loss of statistics not ideal, but discriminating power is large (8σ with planned statistics), so may be ok
 - BNSSA $\rightarrow$ reduced statistics would be more challenging

EXTRA