Charge Symmetry Violation at an Electron Ion Collider

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Parity Violating DIS

Sensitive to different effective charge couplings in PDFs...

$$A_{\mathrm{PV}} \sim \frac{\left| \gamma^* \quad Z^0 \right|^*}{\left| \gamma^* \right|^2} \sim \text{several \% for EIC}$$

$$\approx -\frac{G_F Q^2}{4\sqrt{2}\pi\alpha}\left[a_1(x) + \frac{1-(1-y)^2}{1+(1-y)^2}a_3(x)\right], y = 1 - \frac{E'}{E}$$

$$a_1(x) = 2\frac{\sum C_{1q} e_q (q+\bar{q})}{\sum e_q^2 (q+\bar{q})}, a_3(x) = 2\frac{\sum C_{2q} e_q (q-\bar{q})}{\sum e_q^2 (q+\bar{q})}$$

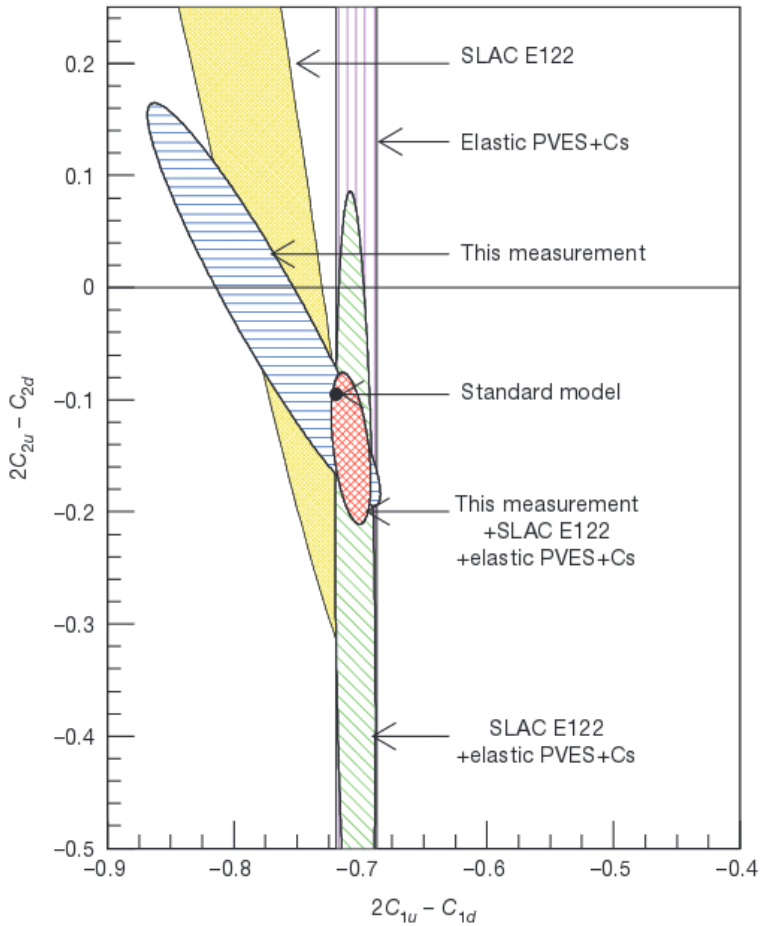
New Effective Weak Couplings

$$C_{1u} = -\frac{1}{2} + \frac{4}{3}\sin^2\theta_W = -0.19 \quad C_{2u} = -\frac{1}{2} + 2\sin^2\theta_W = -0.03$$
$$C_{1d} = \frac{1}{2} - \frac{2}{3}\sin^2\theta_W = 0.34 \quad C_{2d} = \frac{1}{2} - 2\sin^2\theta_W = 0.03$$

Parity Violating DIS - 6 GeV JLab

- Deuterium powerful, since $q(x)$ cancel for large x

$$a_1^D(x) \approx 2\frac{C_{1u}e_u[u(x)+d(x)] + C_{1d}e_d[u(x)+d(x)]}{e_u^2[u(x)+d(x)] + e_d^2[u(x)+d(x)]}$$

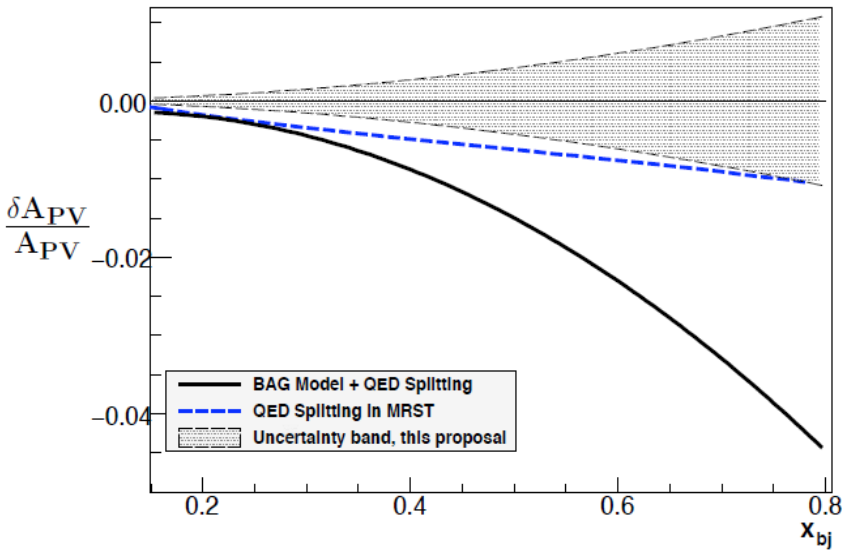


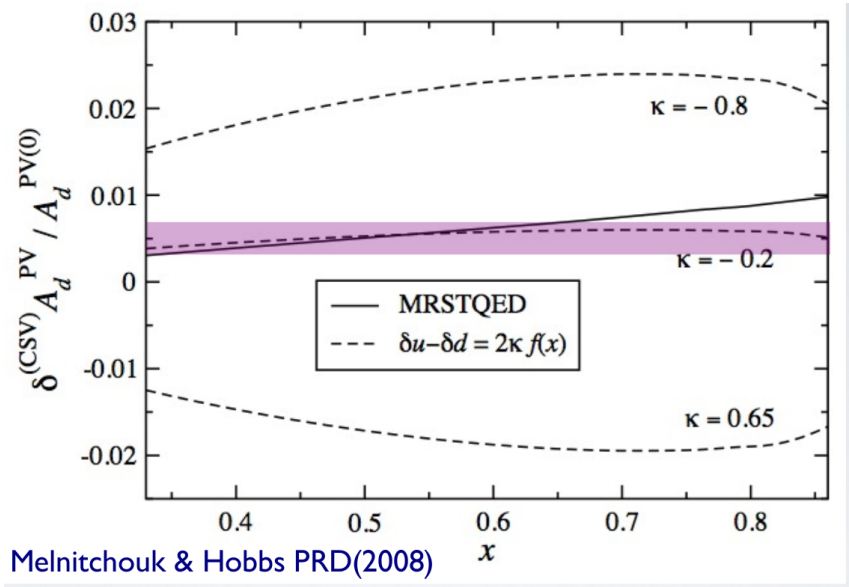
- LD_2 data taken in 2010 at $Q^2 \sim 1{,}2\ \mathrm{GeV}^2$ at $\sim 4\%$ level
- Corresponds to new physics in $\sim 5-6$ TeV range at 95% CL

Jefferson Lab PVDIS Collaboration,
Nature 506, 67-70 (2014)

Charge Symmetry Violation - $u \leftrightarrow d$?

$$a_1^D(x) \approx 2\frac{C_{1u}e_u[u(x)+d(x)] + C_{1d}e_d[u(x)+d(x)]}{e_u^2[u(x)+d(x)] + e_d^2[u(x)+d(x)]}$$





Melnitchouk & Hobbs PRD(2008)

- Differences in distributions would be present in deviation in x dependence from constant
- Lattice in agreement with MRST fits and 1 σ of NuTeV

Shanahan, Phys. Rev. D 87, 094515 (2013)

EIC Calculations - Yuxiang Zhao, SBU

Luminosity and polarization table (e-p collisions)

e-p collisions	10x100, 10x250, 15x100, 15x250
Run time luminosity	10^{34} /cm^2/s
Detector efficiency	70%
Beam efficiency	70%
Beam time for running	2.5 years 5 months per year = 12.5 months
luminosity after all efficiencies	40 fb^{-1} per month
Integrated luminosity	**500 fb^{-1}**
Proton (electron) beam polarization	70% (80%)
Uncertainty of proton (electron) beam polarization	5% (2%)

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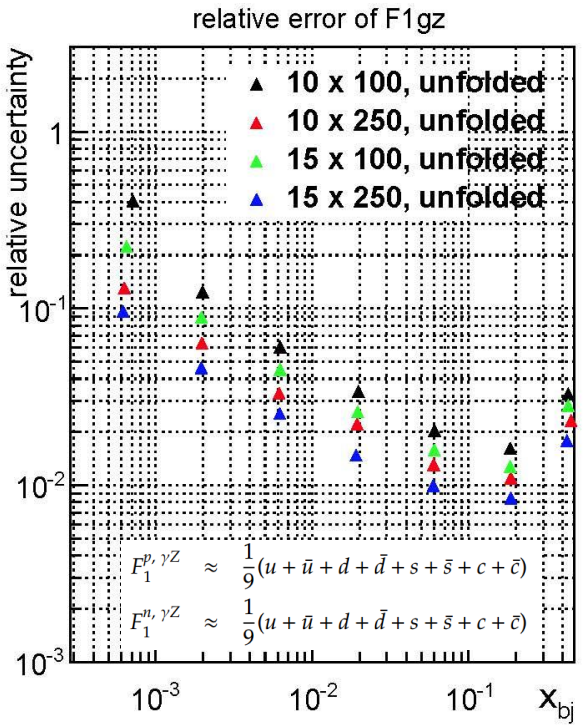
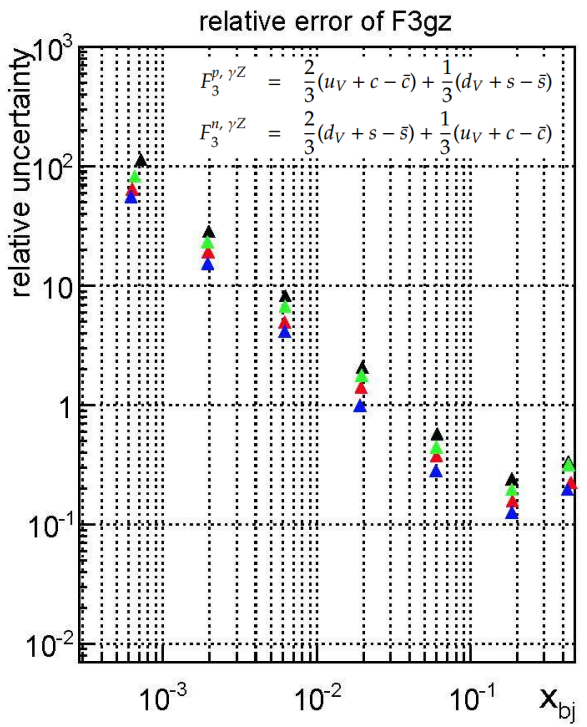
- 500 fb^1 gives...

Unpol. SFs projections after unfolding





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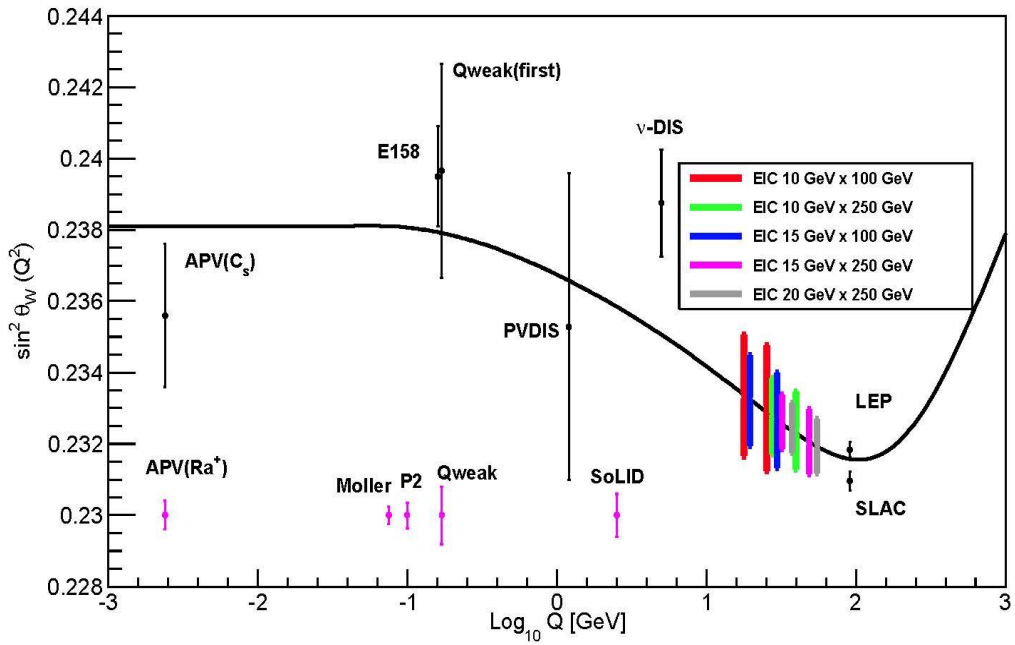
- Few percent (wide bins) at moderate x

World data of $\sin^2\Theta_w$ including EIC projections



- 200 days of dedicated run
- Can reach similar precision to SoLID measurement
- Interesting Q^2 region never been measured or planned

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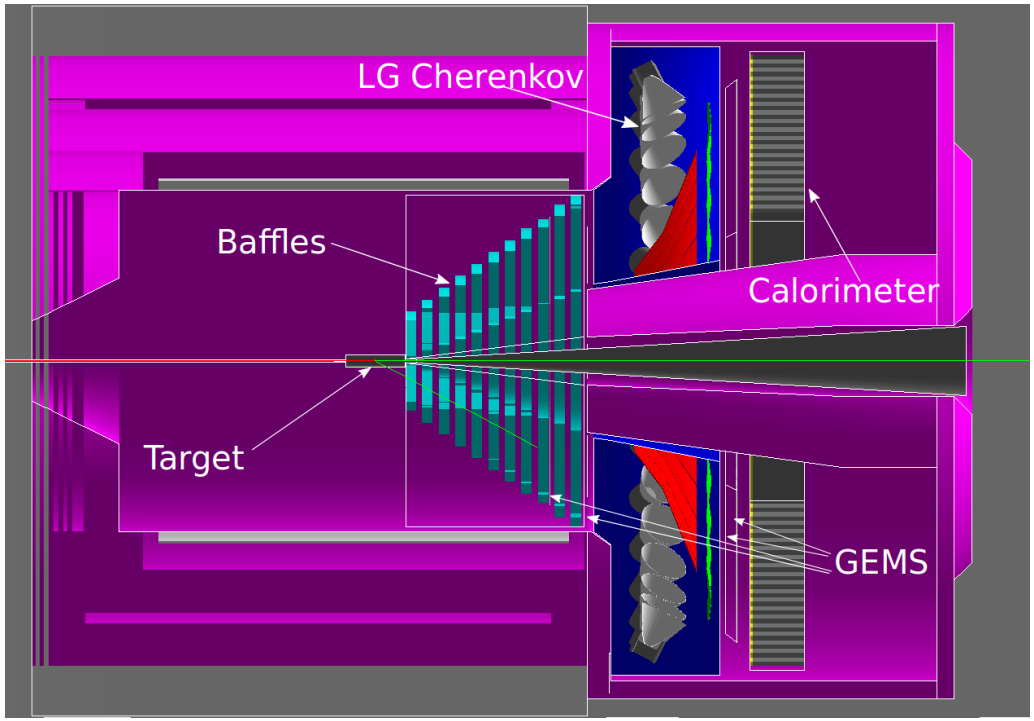
PVDIS Measurements - SoLID Proposed Setup

Solenoidal **L**arge **I**ntensity **D**evice - 12 GeV Hall A at JLab

More than 200 collaborators at over 60 institutions



SoLID provides large acceptance

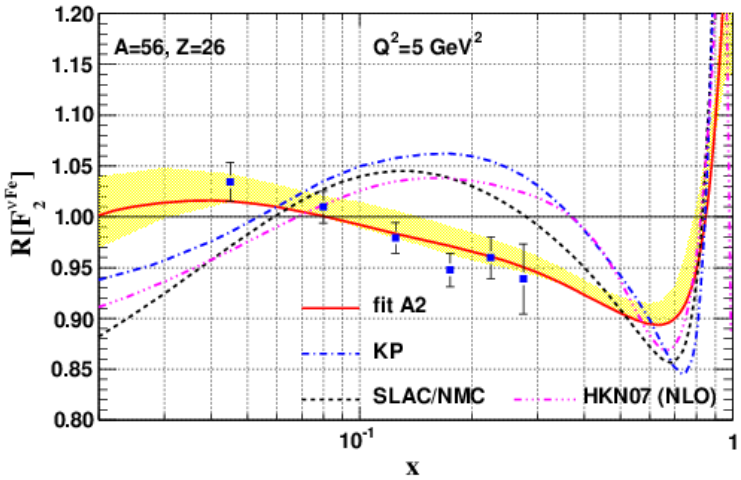
- $2 < p < 8$ GeV
- $2 < Q^2 < 10$ GeV^2
- $0.2 < x_{\mathrm{bj}} < 1$
- Acceptance $\sim 40\%$
- Lumin $\sim 5 \times 10^{38}$ Hz/cm^2

- Parity-violation requires lots of statistics - need high rate
- Want to cover broad kinematic range - need large acceptance
- High impact \$ ~50M project, 2020+ in the future
- Program also includes SIDIS, J/ψ at threshold, TCS, SSA, possible w/ EMC PVDIS, DDVCS, PV polarized PDFs...

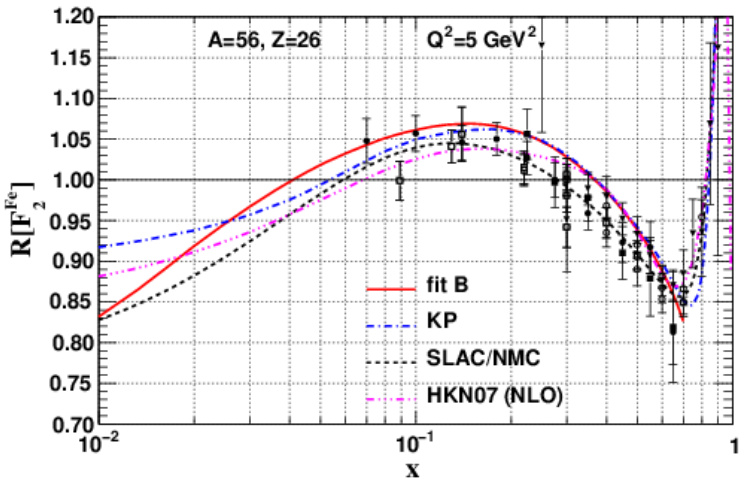
Something else: eA Isovector Dependence? Partitioned Fits

- Existing fits to world data show controversy
- Studies partitioning data between lepton/Drell Yan and ν show significant incompatibilites in nuclear corrections using common PDFs

CC ν



NC l, DY



$R = F_2^A / F_2^N$

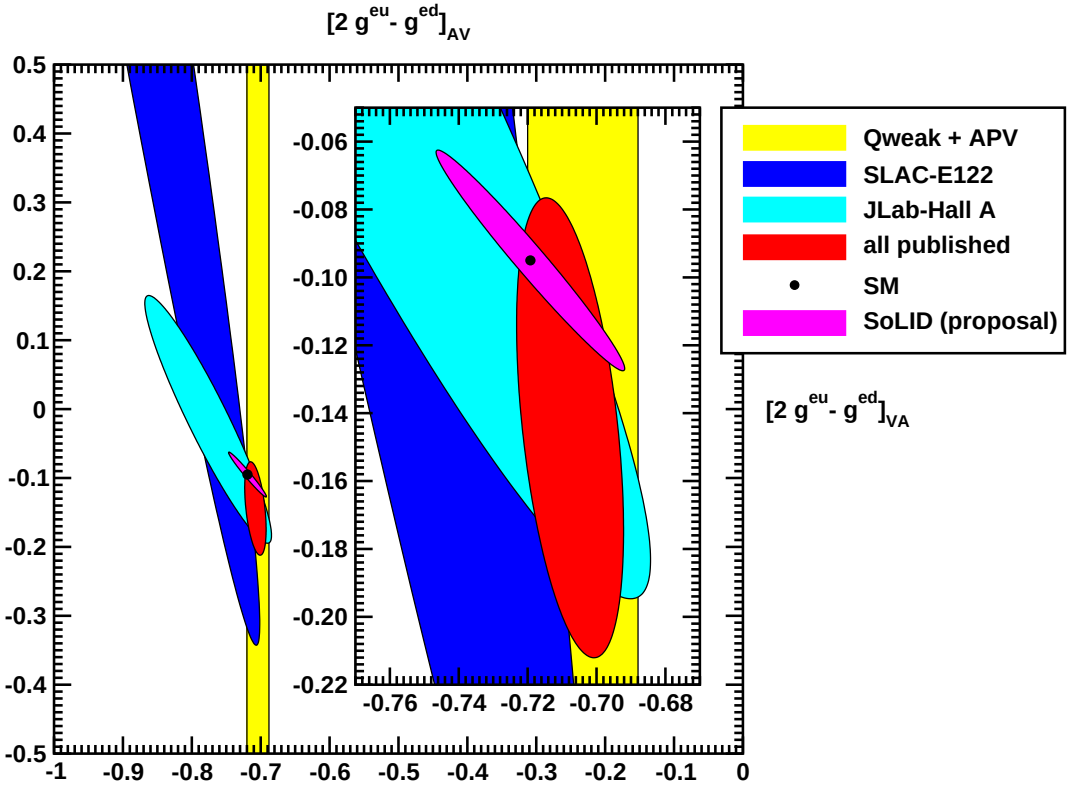
I. Schienbein et *al.* PRD77 054013 (2008); I. Schienbein et *al.* PRD80 094004 (2009)

BACKUP

PVDIS Physics - Precision

- Deuterium powerful, since $q(x)$ cancel for large x

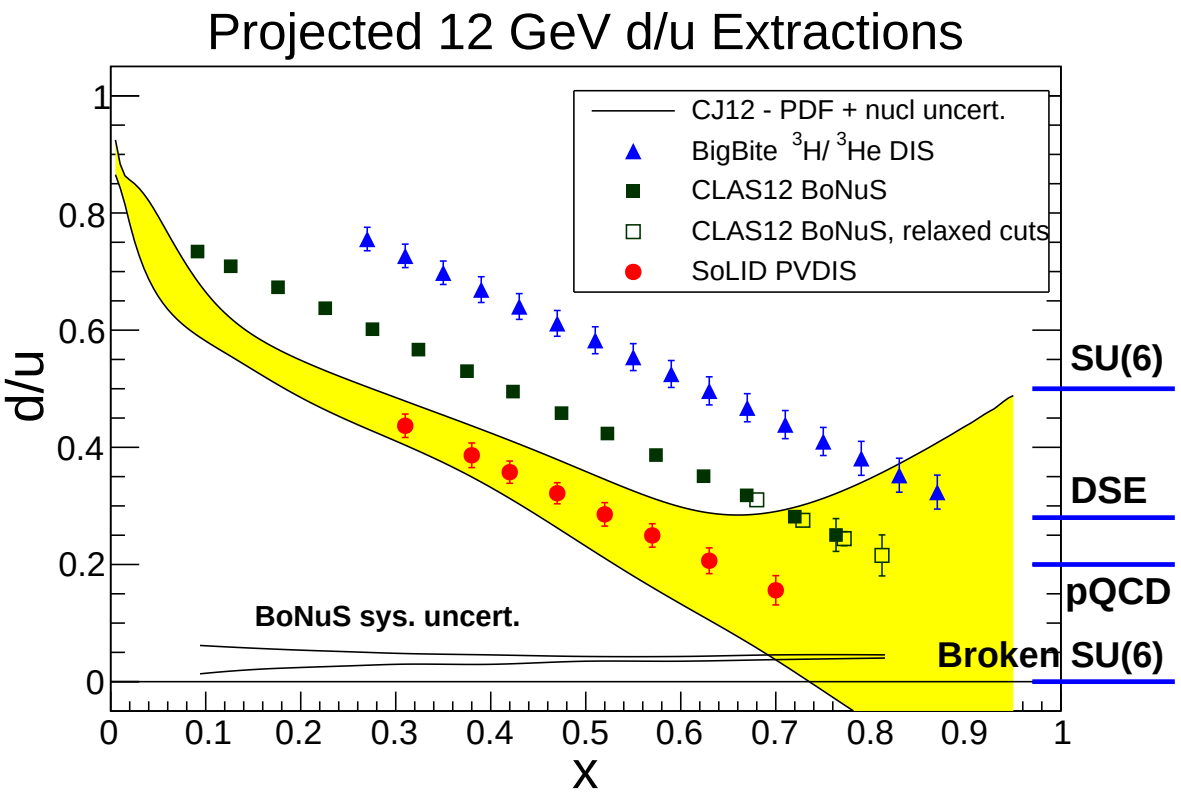
$$a_1^D(x) \approx 2\frac{C_{1u}e_u[u(x)+d(x)] + C_{1d}e_d[u(x)+d(x)]}{e_u^2[u(x)+d(x)] + e_d^2[u(x)+d(x)]}$$



- Sub - 1% data at $Q^2 \sim 6-7$ GeV^2 range dramatically improves constraints
- New contact interactions $1/\Lambda^2$ contrained into ~ 10 TeV range

Clean Measurement of d/u with PVDIS

- d/u as $x \to 1$ gives information on valence quark dynamics - models give varying predictions on behavior
- Flavor extraction difficult at high x because no free neutrons



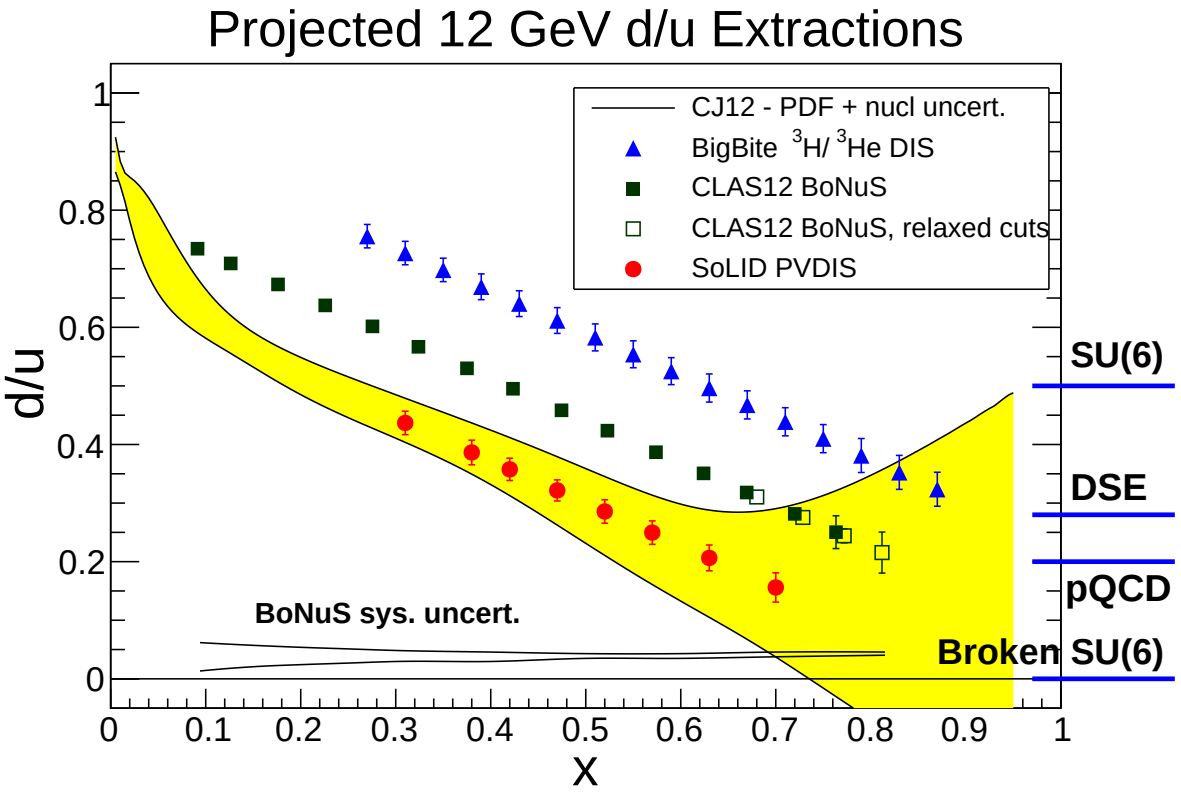
- Three JLab 12 GeV experiments:
  - CLAS12 BoNuS - spectator tagging
  - BigBite - DIS $^3\mathrm{H}/^3\mathrm{He}$ Ratio
  - SoLID - PVDIS *ep*
- The SoLID extraction of d/u is made directly from *ep* DIS: *no nuclear corrections*
- Disagreement would also signal CSV

DSE - Wilson *et al.*, Phys Rev C**89**, 025205 (2012)

Clean Measurement of d/u with PVDIS

For high x on proton target:

$$a_1^p(x) = \left[\frac{12C_{1u}u(x) - 6C_{1d}d(x)}{4u(x) + d(x)}\right] \approx \left[\frac{1 - 0.91d(x)/u(x)}{1 + 0.25d(x)/u(x)}\right]$$



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