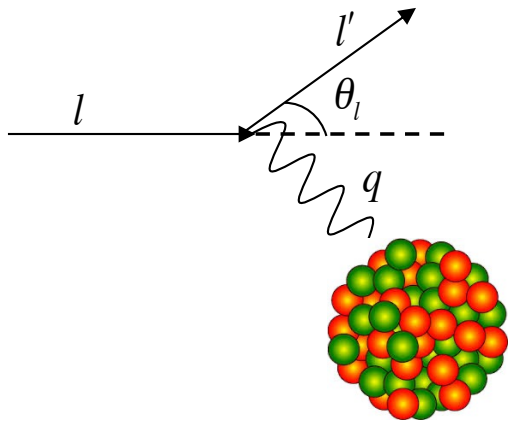


Anti-Shadowing Exploration Opportunities with CEBAF at 22GeV

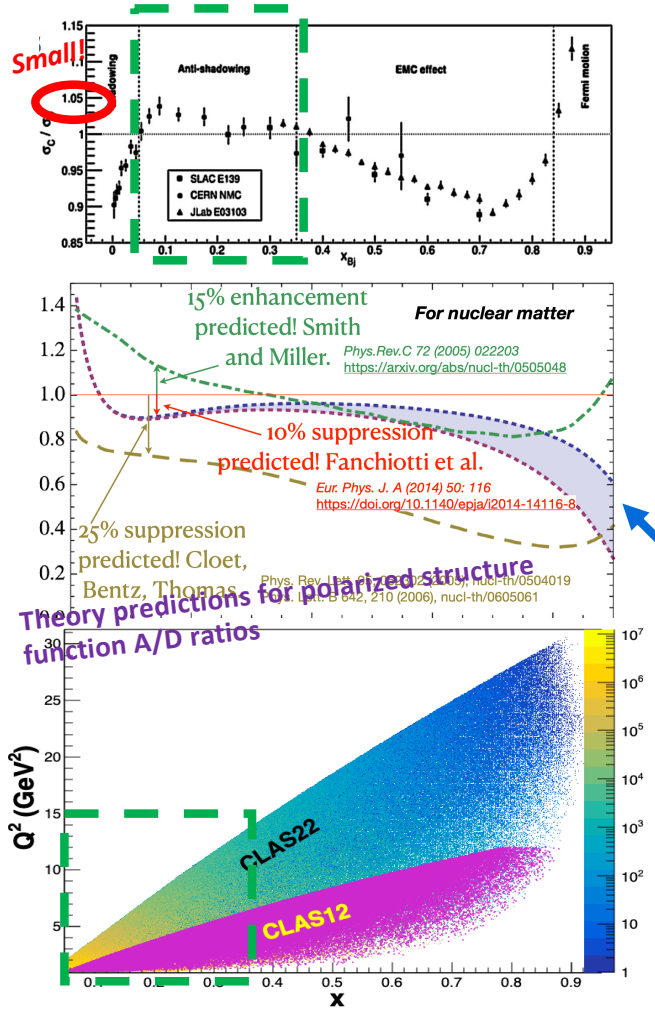
N. Kalantarians (Virginia Union Univ.)

JLab-INFN: 12 Dec 2024

*Work supported by NSF Award 2310076

Jefferson Lab

Anti-shadowing: solving a multi-decade puzzle



With a 22 GeV e- beam JLab can access the anti-shadowing region (x~0.1-0.3) at moderate Q^2

- Region extremely interesting, near-equally dominated by valence quarks, sea-quarks, and gluons → many many models!!

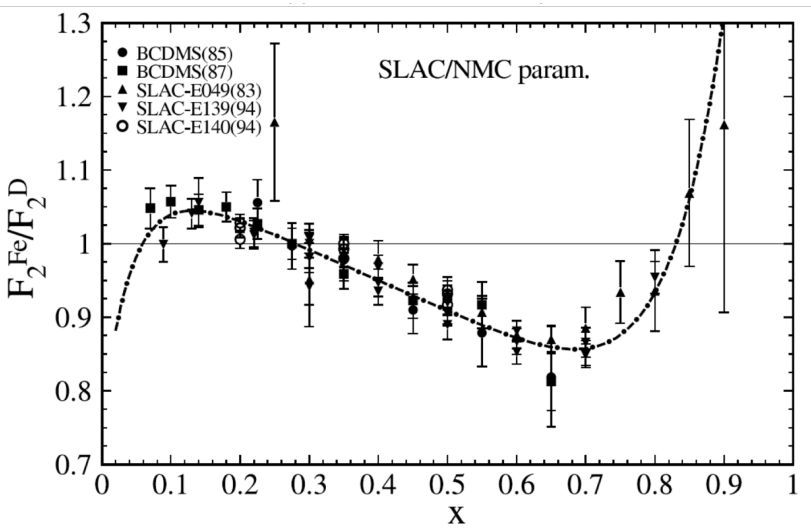
- Anti-Shadowing is the *least studied* nuclear structure function effect experimentally – ***small effect requiring precision and high luminosity***
  - **flavor dependence essentially uncharted**
  - **spin dependence essentially uncharted (~50% differences in predictions)**
  - **no tagged measurements**
  - **no L/T separations**

A rigorous testing ground between shadowing, EMC regimes – models and theory must describe **ALL**

2

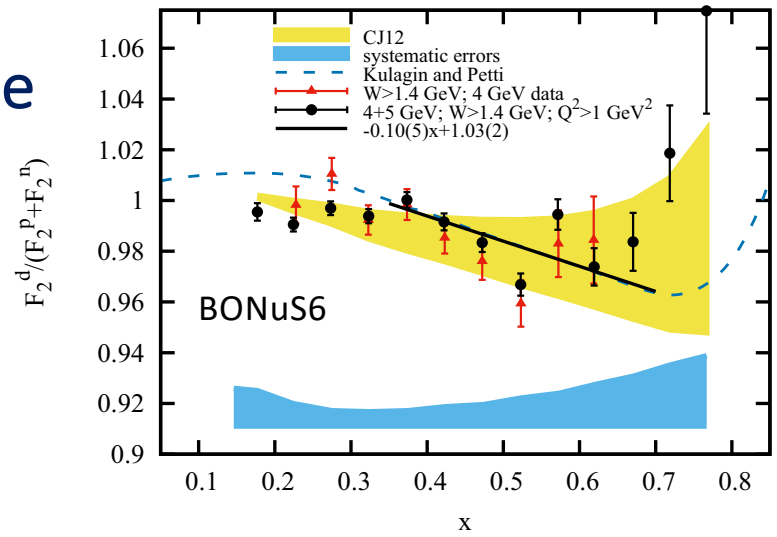
EMC Effect and Nuclear Dependence

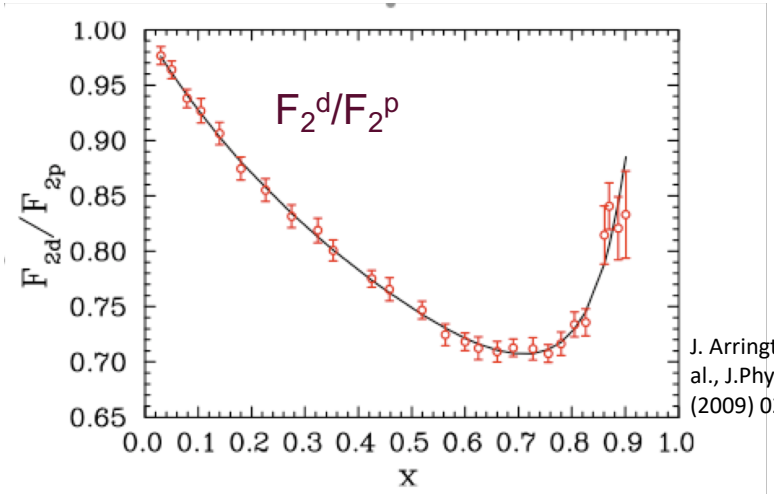
Representative EMC Ratio



- *Seen numerous times.*
- Deuteron also has a nuclear dependence

Phys. Rev. C **92** 015211 (2015)



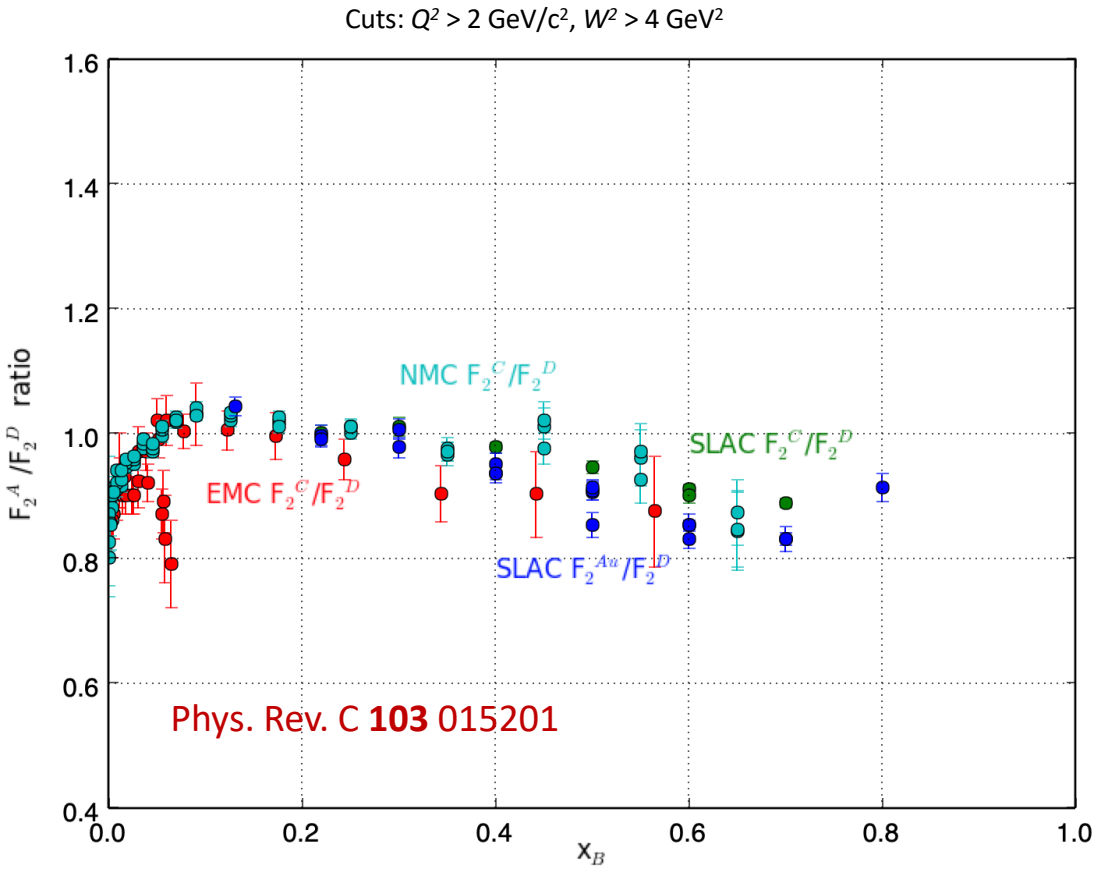


J. Arrington et al., J.Phys. G36 (2009) 025005

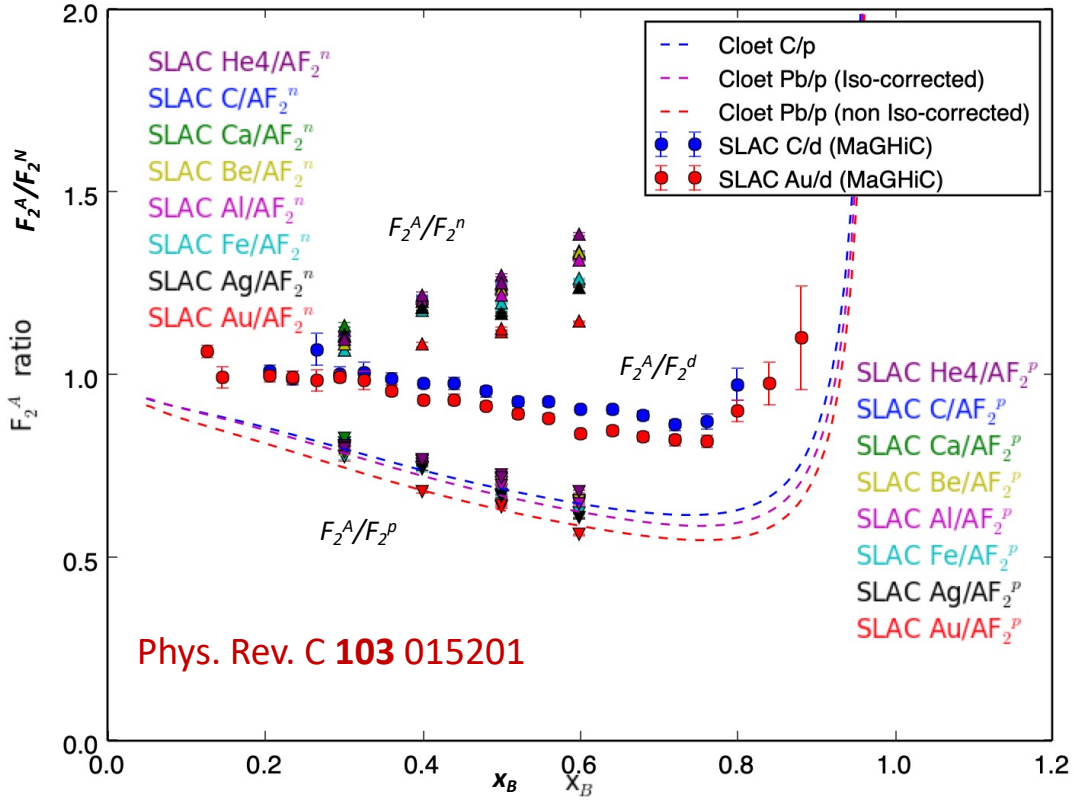
EMC data-mining effort

- SLAC (E139) published cross-sections – Phys. Rev. D **49** 4348 (1994).
- Used R1990* parameterization (assumes no nuclear dependence of R) to obtain F_2^A.

** L. Whitlow, et al., Phys.Lett.B 282 (1992)*

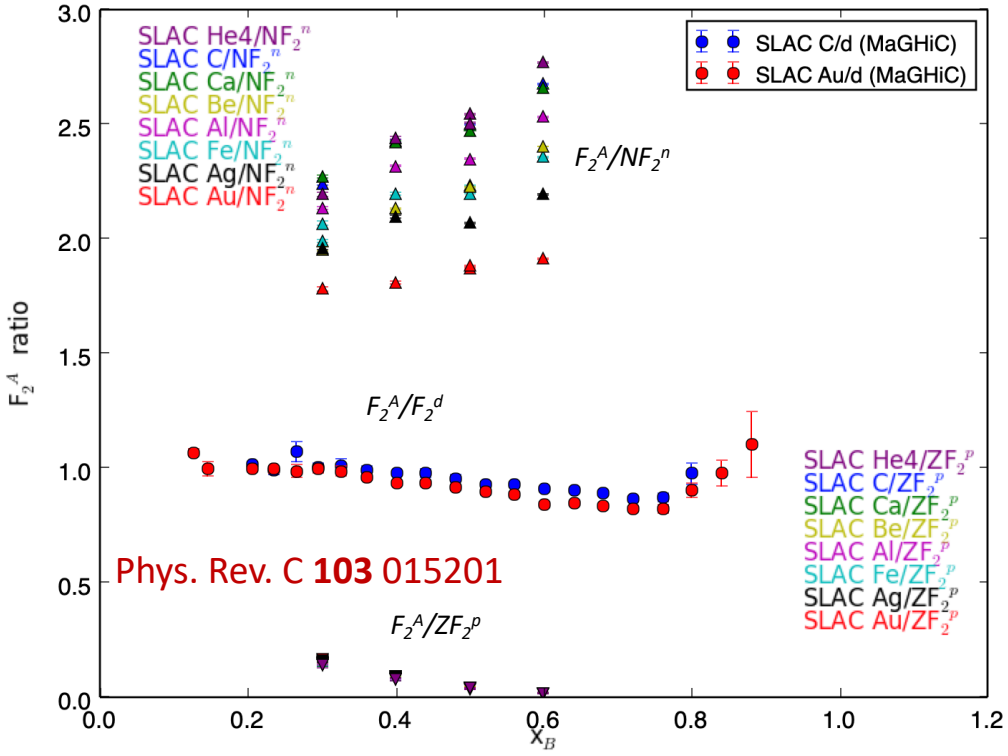


F_2^A/F_2^N ratios per nucleon



- We don't apply iso-scalar corrections for this analysis.
- Theory curves from I. Cloet.
- F_2^p from NMC parameterization. Checked with CJ15 fit.
- F_2^A/F_2^p seem to agree with theory.
- F_2^A/F_2^n seem to have broader spread between nuclei.
- Expect some spread with nuclear asymmetry.
- "MaGHiC" Intl. Journ. Mod. Phys. E **23** 8 (2014).

Comparing F_2^A per free neutron, proton.



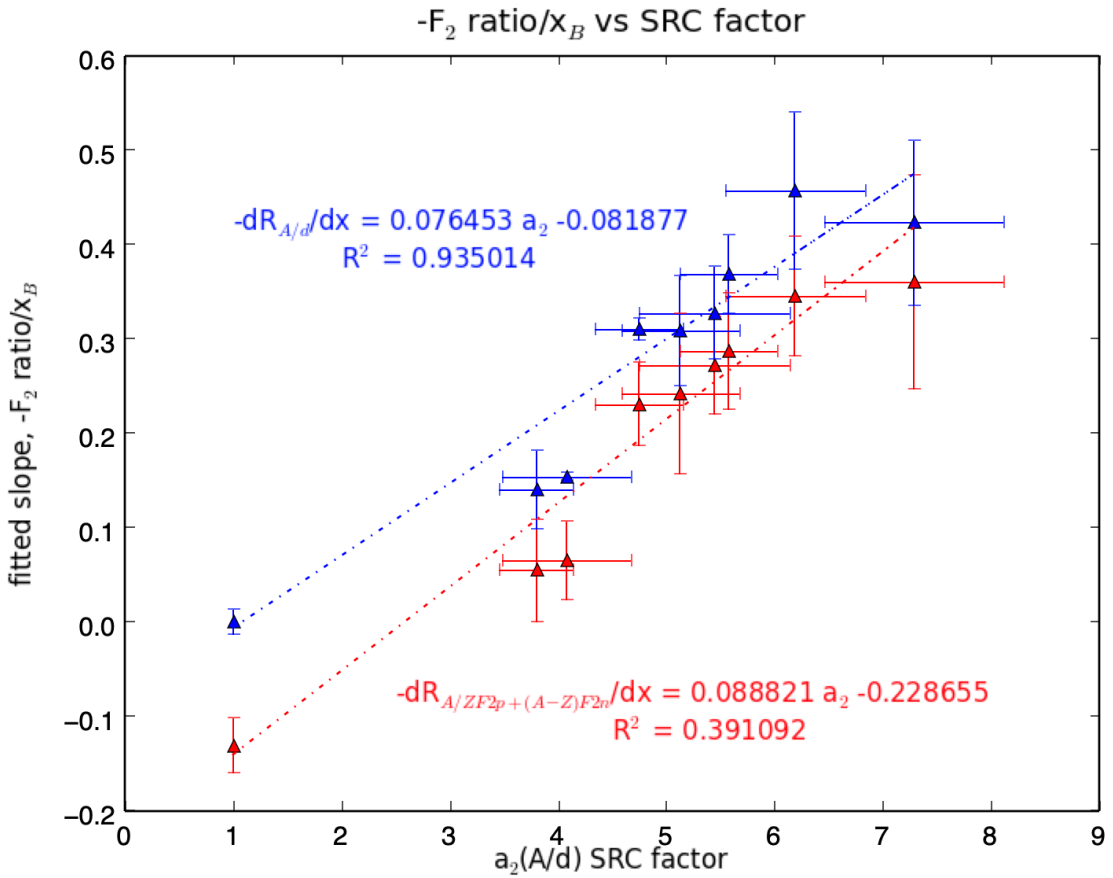
- Typically observed nucleon spread.
- Starts below 1; approximately 10%.
- Large spread in A/n compared to A/p
- Expect some spread with nuclear asymmetry.
- "MaGHiC" Intl. Journ. Mod. Phys. E **23** 8 (2014).

$N = A - Z$

Comparison of $F_2^A/F_2^{n,p}$ to SRC factor a_2 (A/d)

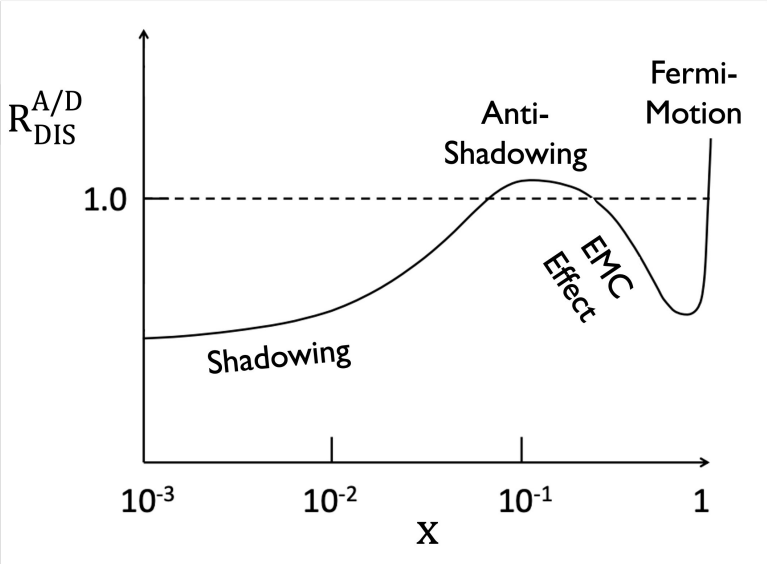
- a_2(A/d) scaling factor: PRL **106** 052301 (2011). Blue points are for A/d; Red points are for A/n+p.
- Slope of near -0.08 (with deuteron point set to 0) consistent with previous studies.
- Difference in these 2 sets seems to come from nuclear effects from deuteron.
- R^2 orth. distance regression (goodness of fit).

a_2 probability nucleon belongs to a pair (represented as ratio for A/d)

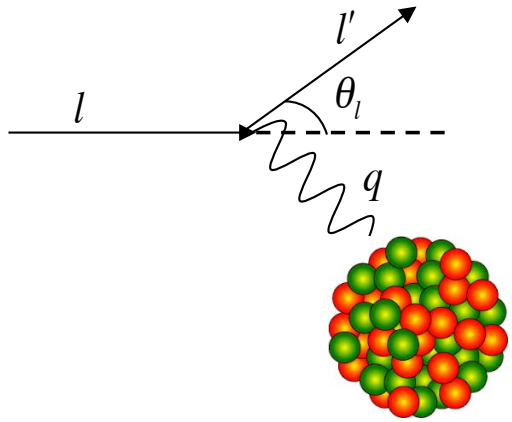


Summary: *JLab at ~22 GeV is an anti-shadowing regime machine**

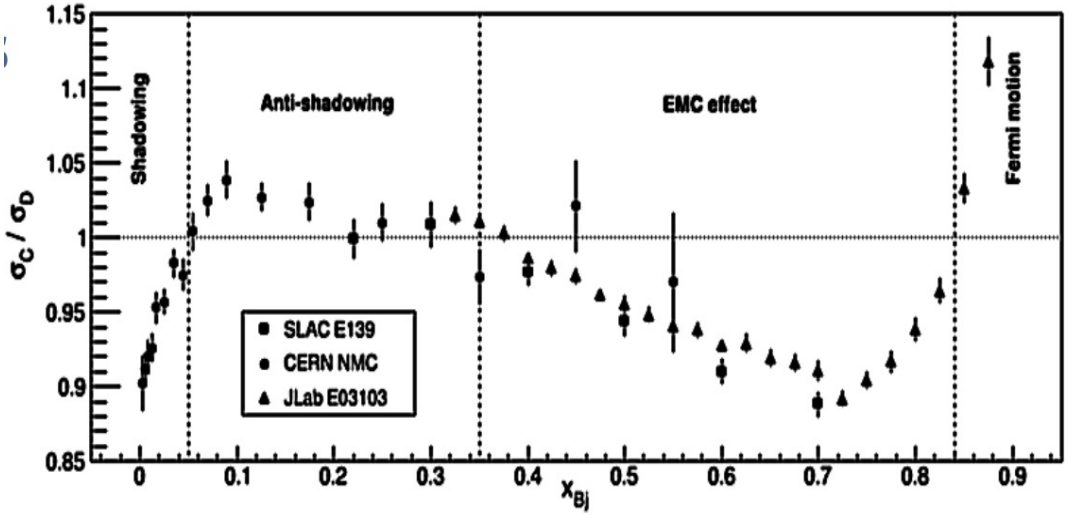
- e-A (x, Q^2) "transition" range accessible for the first time in decades
- High precision required: perfect for JLab beam, spectrometers, ability to change targets quickly,…
- Polarized beam and target mapping across A, N, Z
- Nuclear tagging, mirror nuclei,.. – ALL POSSIBLE at JLab



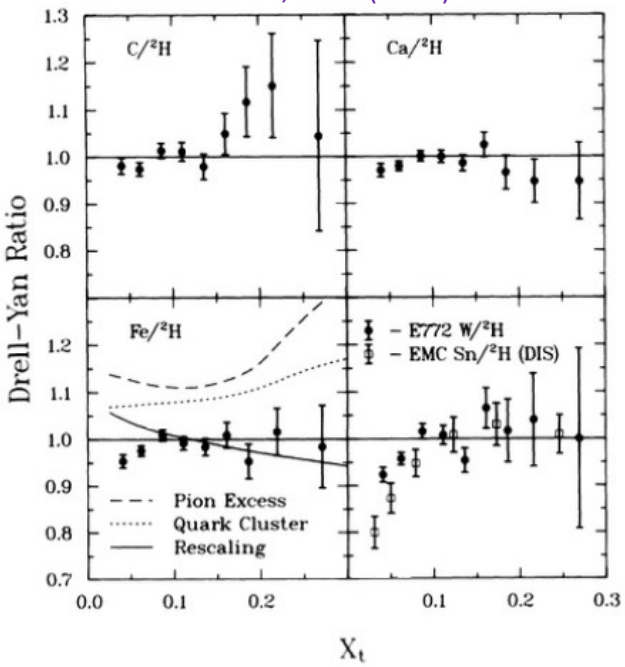
Backup Slides



EMC and Anti-shadowing



PRL 64, 2479 (1990)



- Hard probe with x in the anti-shadowing region is sensitive to the inter-nucleon distance in a nucleus. *J. Qiu, 2023 Workshop*
- A hard probe at small-x can interact with multiple nucleons (partons from multiple nucleons) at the same impact parameter coherently
- No anti-shadowing seen in sea quarks (DY, E772): strong flavor dependence? Calculations needed!

Effect Reproduced many times

PLB **123** (1983) 275.

Simple Parton Counting Expects One

MANY Explanations

SLAC E139

Phys. Rev. D **49** (1994) 4348.

Precise large-x data

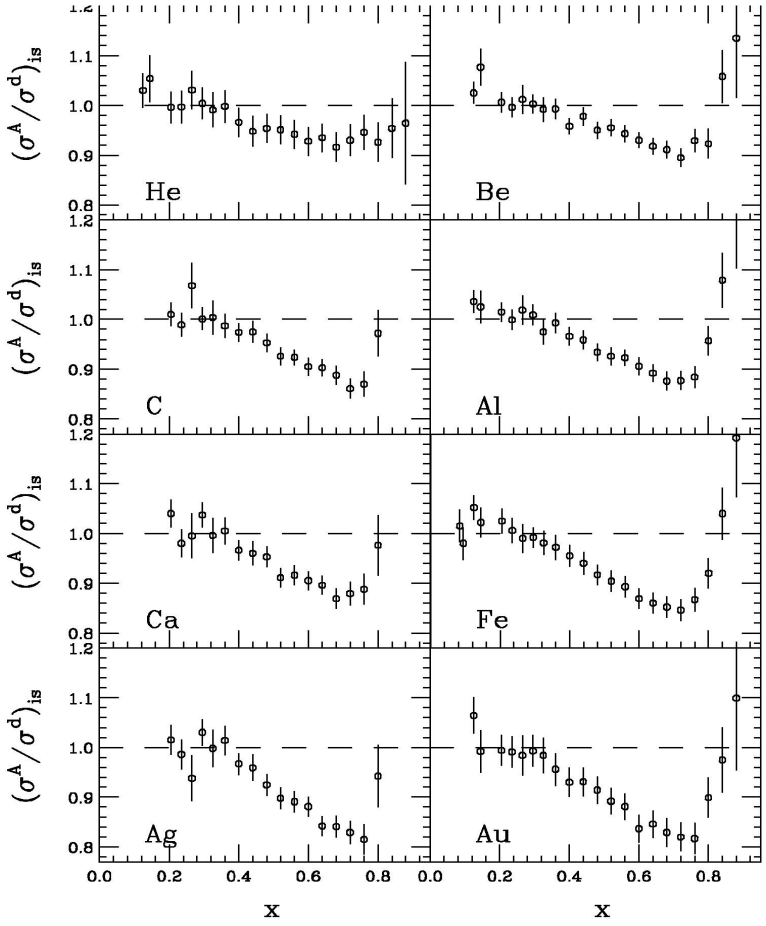
Nuclei from A=4 to 197

Conclusions from SLAC data

Nearly Q^2-independent

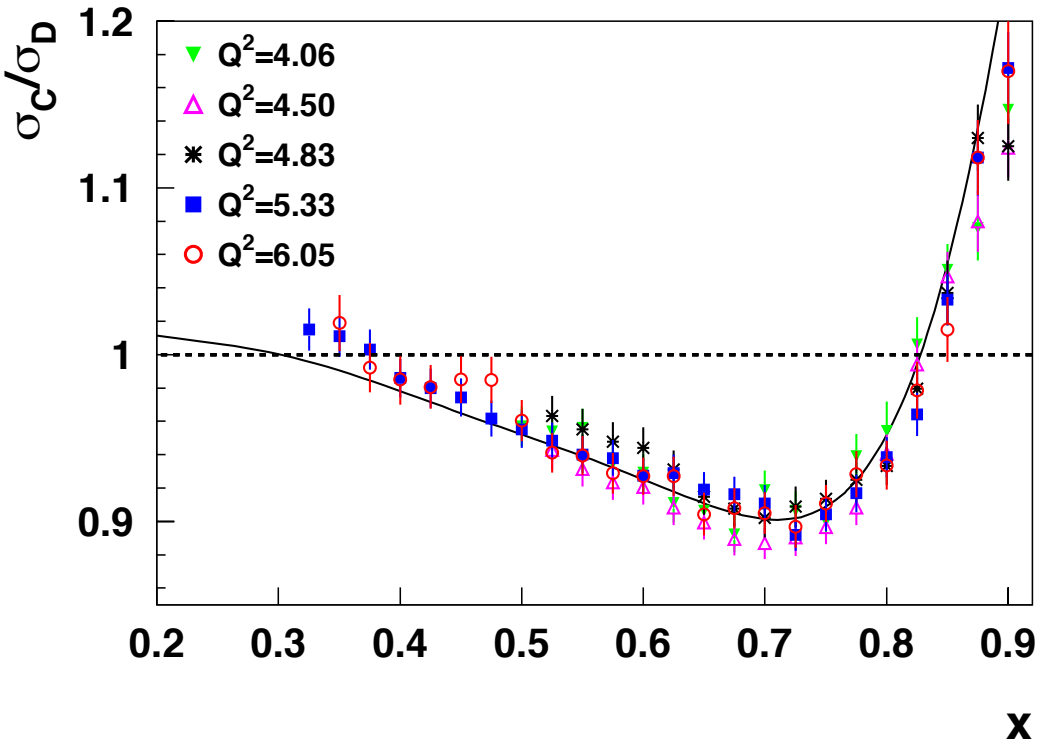
Universal x-dependence (shape)

Some A dependence

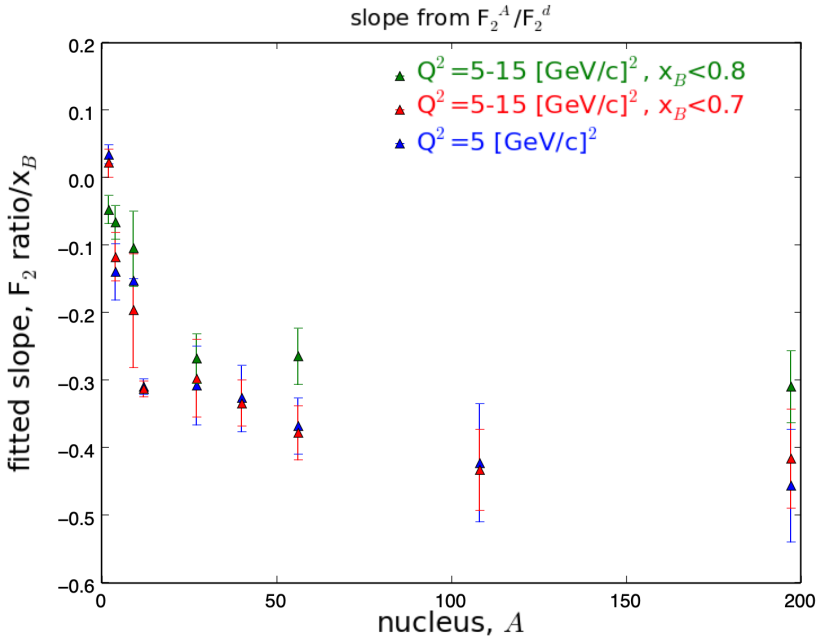


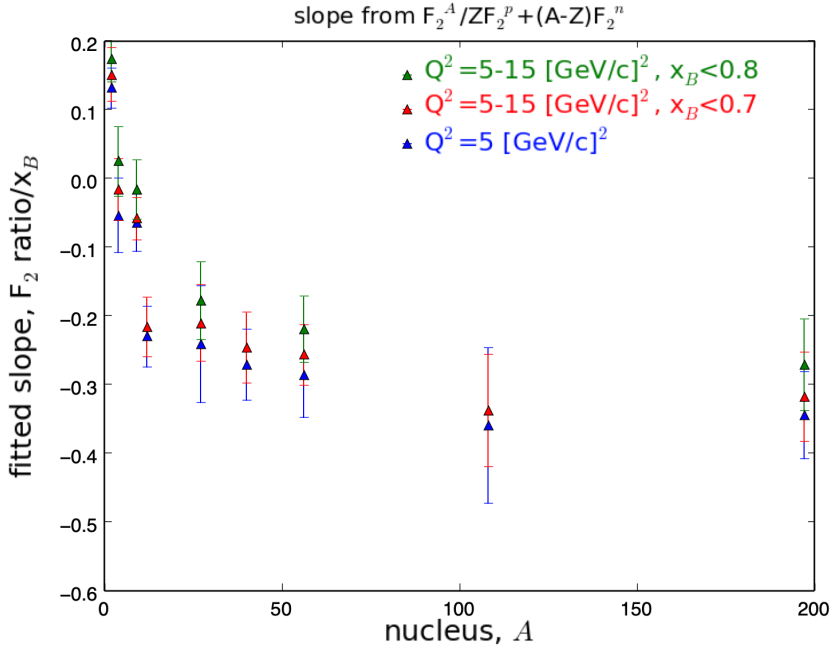
JLab EMC Data

Phys, Rev. Lett. **103** (2009) 202301.



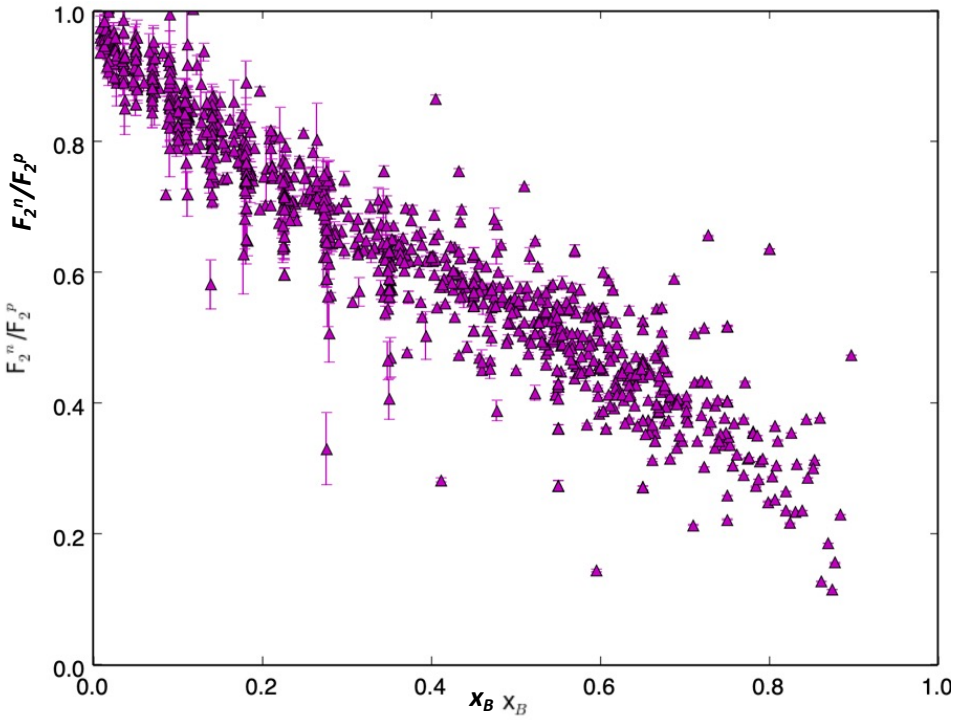
Fitting Slopes of Ratios.

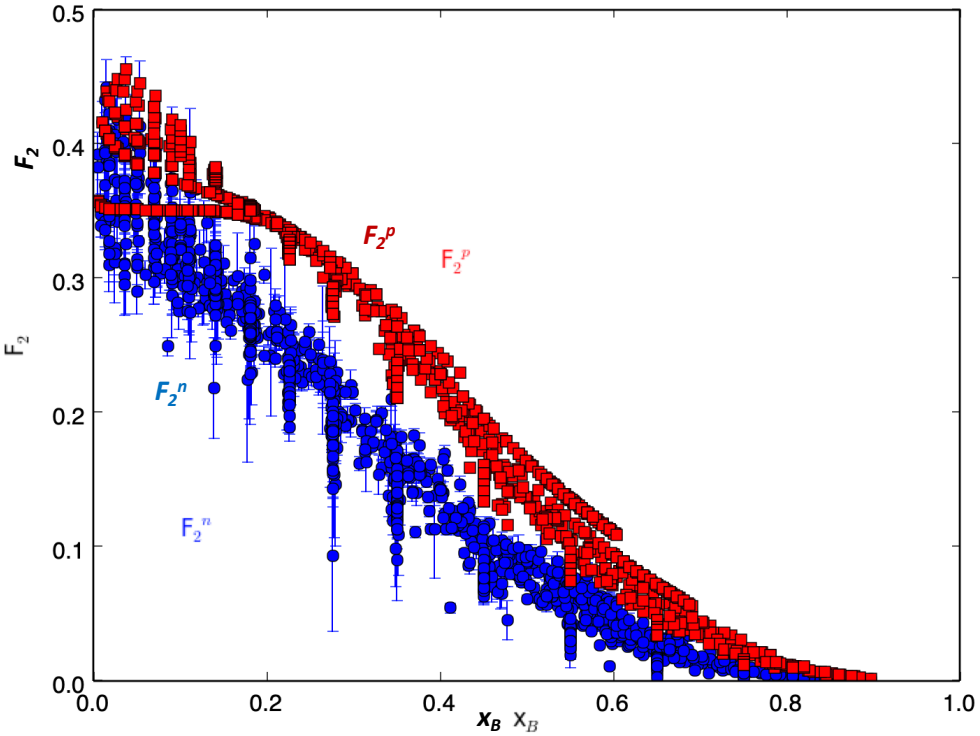




- Fits done in region $0.3 < x < 0.6$, with 0.7 included
- Non-negligible nuclear effects in x 0.6-0.7 for extracting EMC Effect in meaningful way.
- Not trivial to disentangle between x and Q^2.
- Inclusion of higher x and Q^2 generates somewhat shallower slopes from rise in nuclear effects.

Looking at F_2^n/F_2^p via data

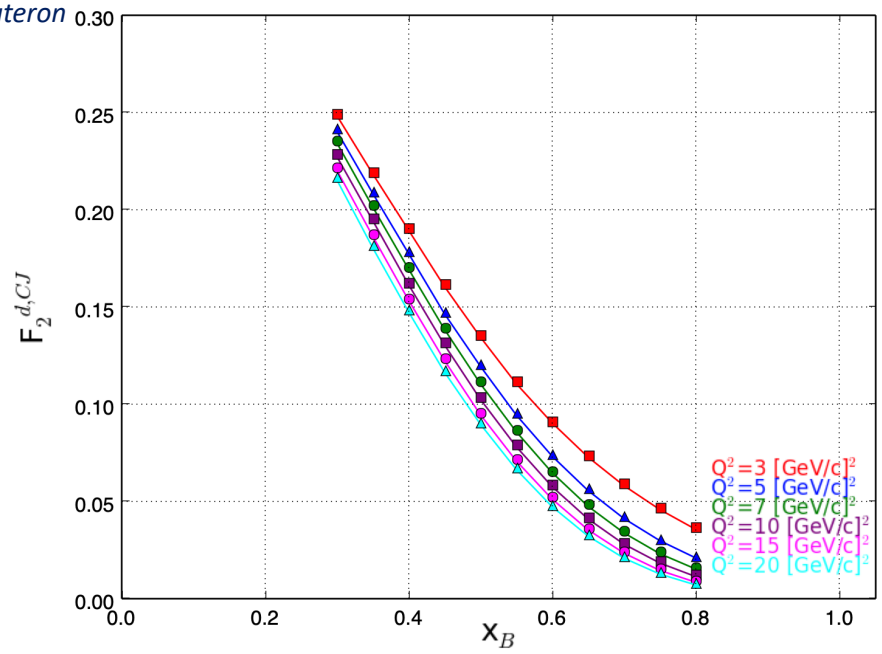




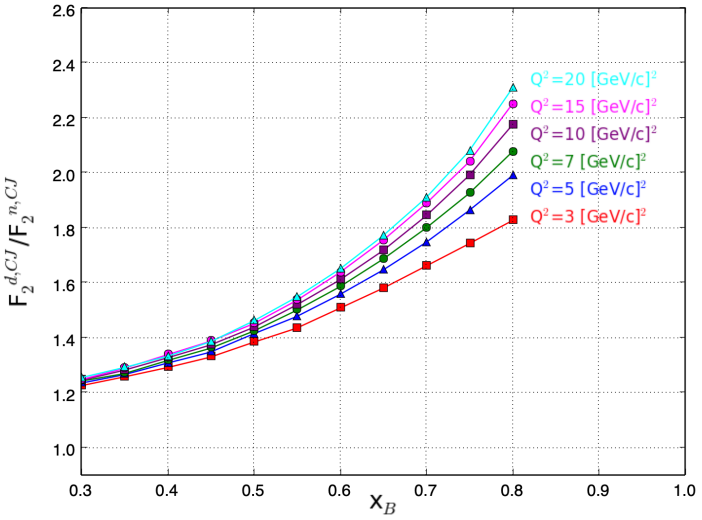
- F_2^n from world data: S. Li's analysis using CJ15 nuclear corrections for deuteron Phys. Rev. D **93** 114017 (2016). Data publication being drafted.
- F_2^p (at same x and Q^2) using SFTM - J. Phys. G **35** 053101 (2008).

Looking at $F_2^D/F_2^{n,p}$ via CJ15

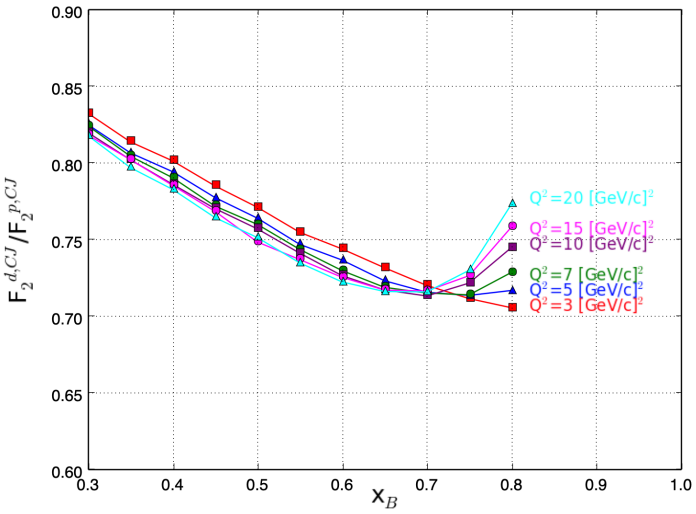
Deuteron



D/n



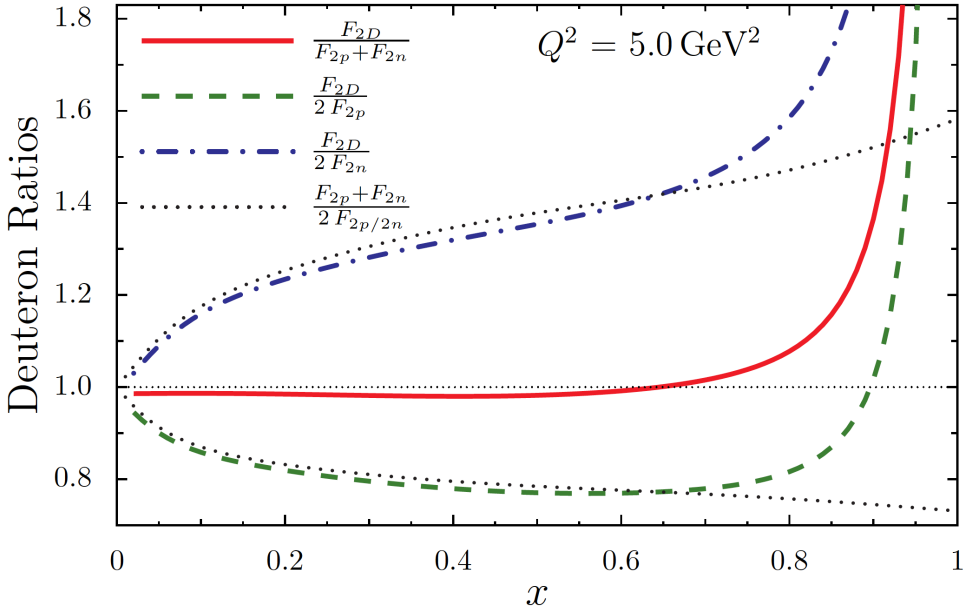
D/p



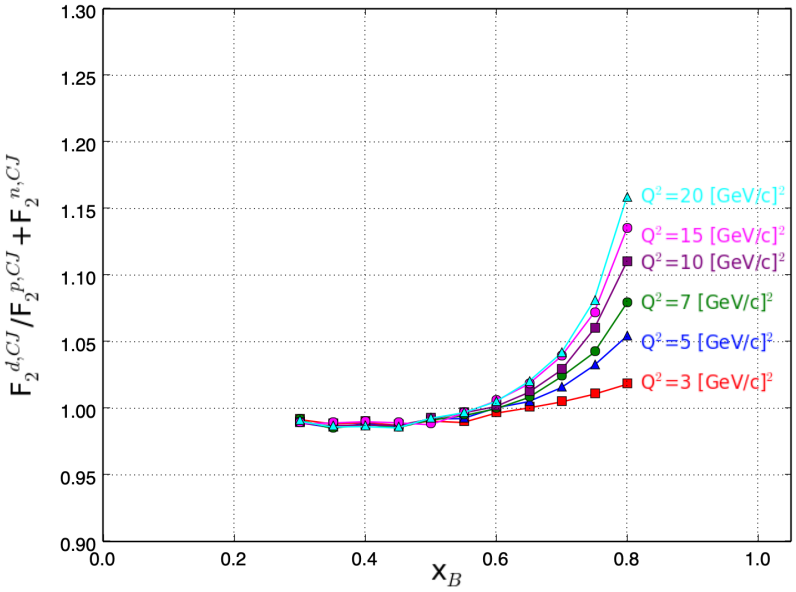
- Neglecting uncertainties on purpose to highlight behavior in the plot.
- There is Q^2 dependence, in particular at large *x*.
- Phys. Rev. D **93** 114017 (2016)

Looking at F_2^D/F_2^{n+p}

Theory-driven

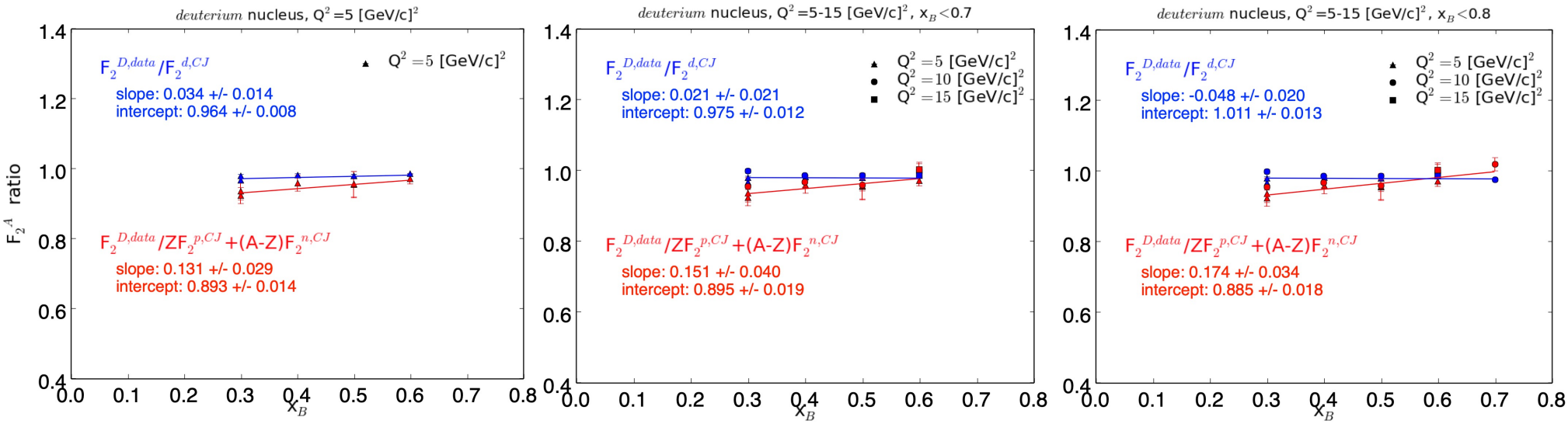


CJ15



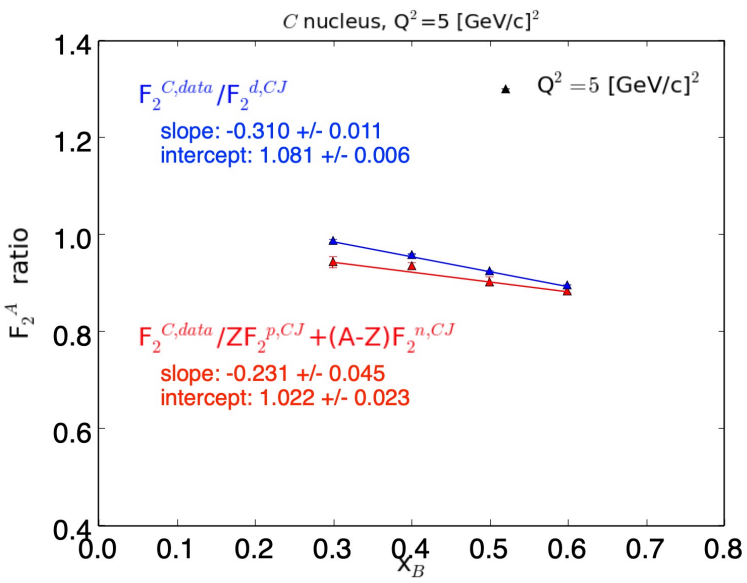
- Theory-driven deuteron to sum of free neutron and proton ratio (in red) dips just below unity in EMC region.
- $F_2^D/2F_2^p$ well below unity with similar shape. $F_2^D/2F_2^n$ well above unity with positive slope.
- Phys. Rev. D **93** 114017 (2016)

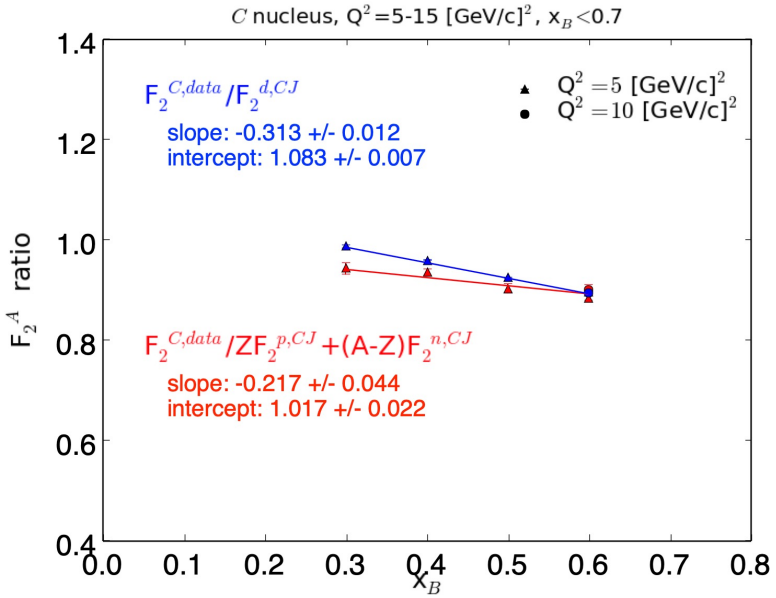
Fitting Slopes of Ratios: Deuteron



- Linear fits to deuterium data, with cuts on Q^2 and x_B.
- Blue points are ratio of E139 data to deuterium from CJ15.
- Red points are ratio of E139 data to sum of free (CJ15) neutron and proton, without nuclear effects.

Fitting Slopes of Ratios: Carbon

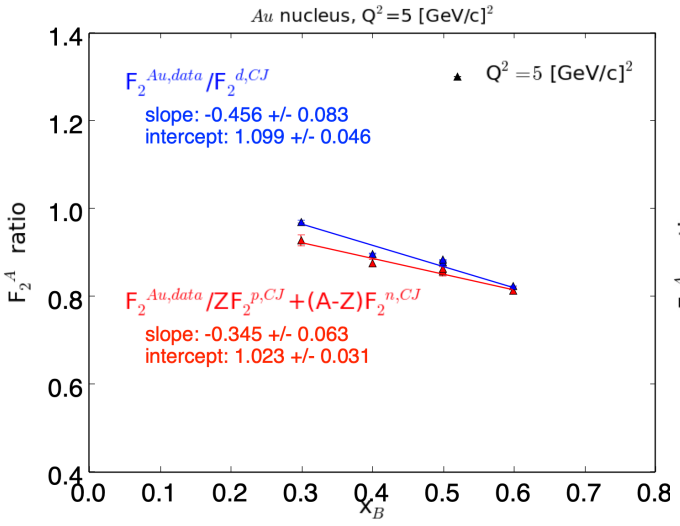


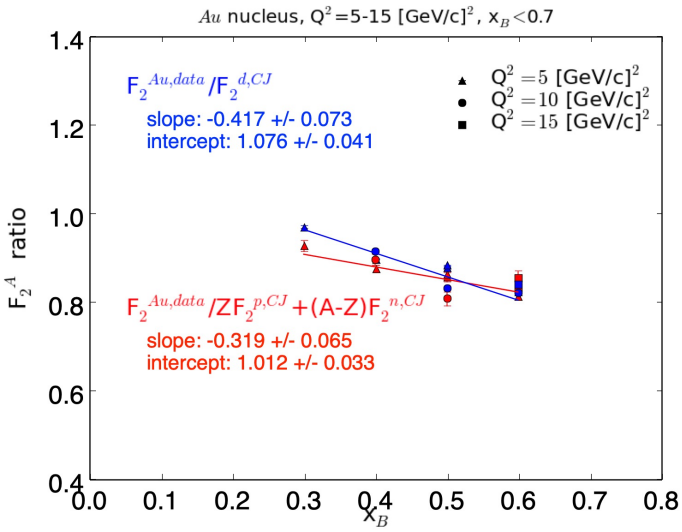


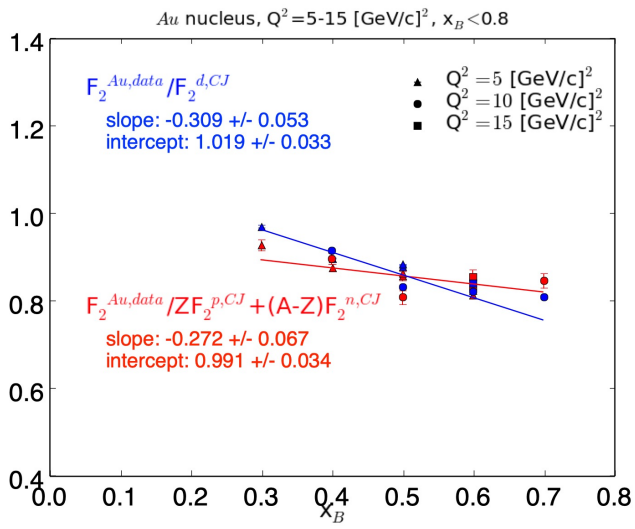
F_2^A/F_2^N

- Linear fits to deuterium data, with cuts on Q^2 and x_B.
- Blue points are ratio of E139 data to deuterium from CJ15.
- Red points are ratio of E139 data to sum of free (CJ15) neutron and proton, without nuclear effects.
- E139 Carbon data didn't go to $x_B > 0.6$.

Fitting Slopes of Ratios: Gold

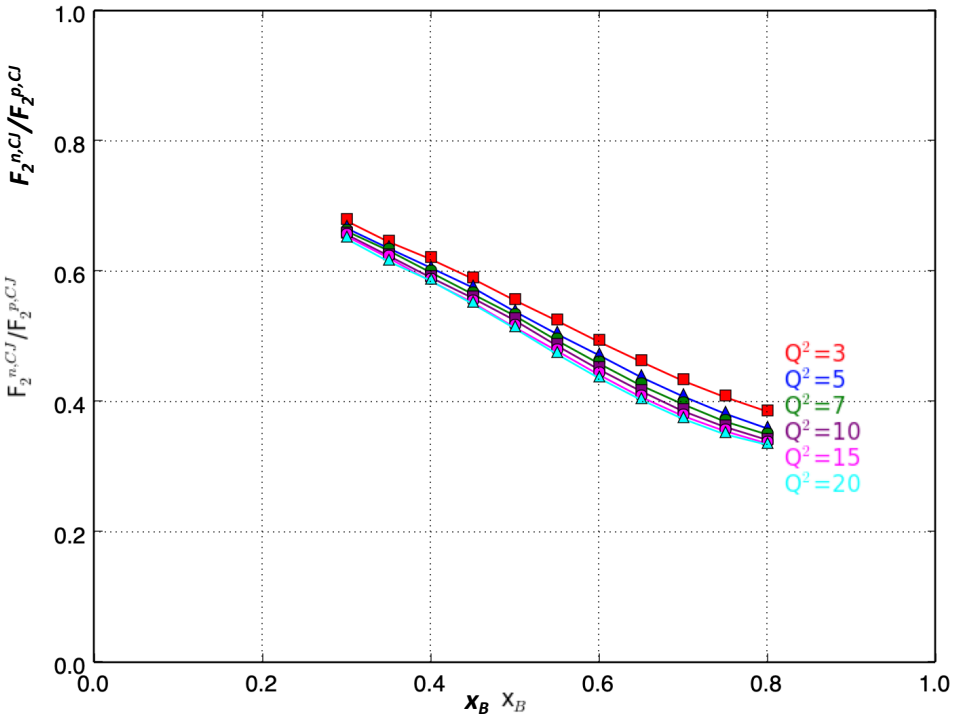


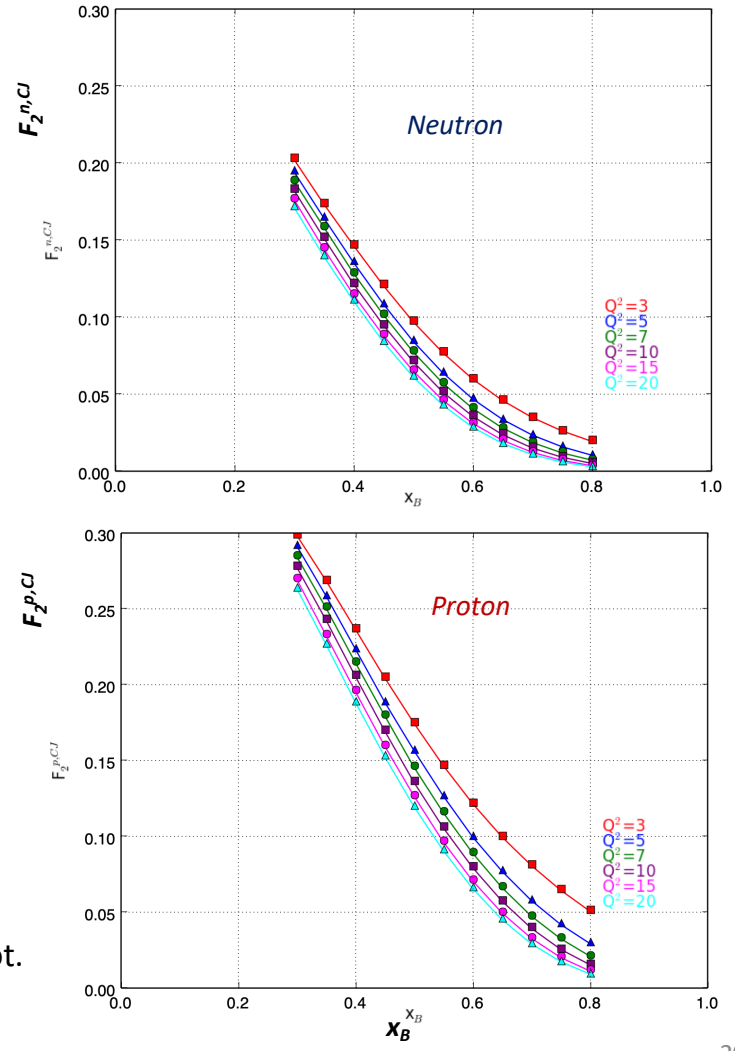




- Linear fits to deuterium data, with cuts on Q^2 and x_B.
- Blue points are ratio of E139 data to deuterium from CJ15.
- Red points are ratio of E139 data to sum of free (CJ15) neutron and proton, without nuclear effects.

Looking at F_2^n/F_2^p via CJ15

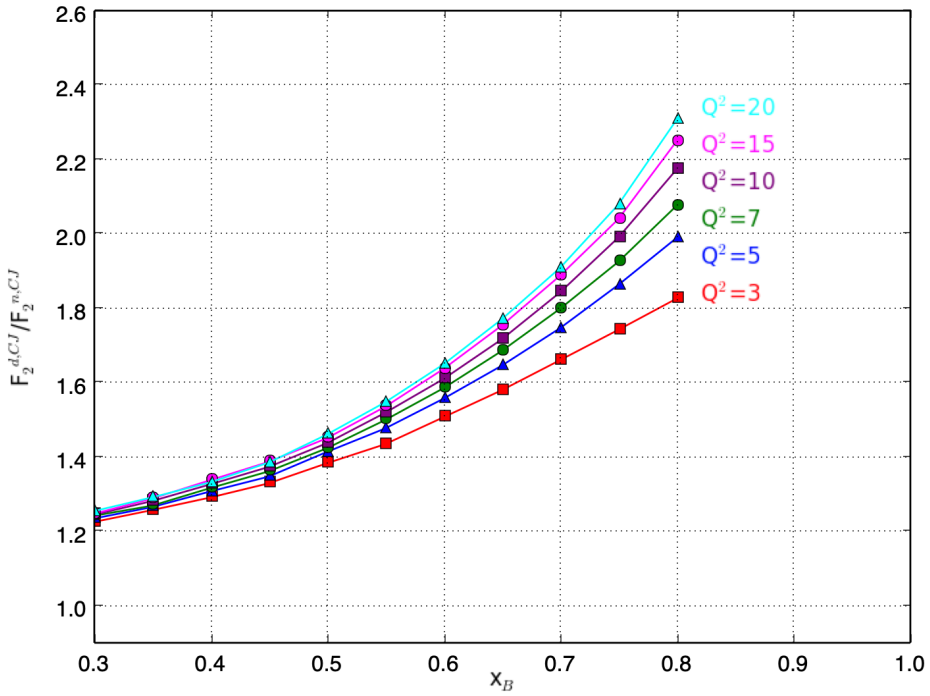




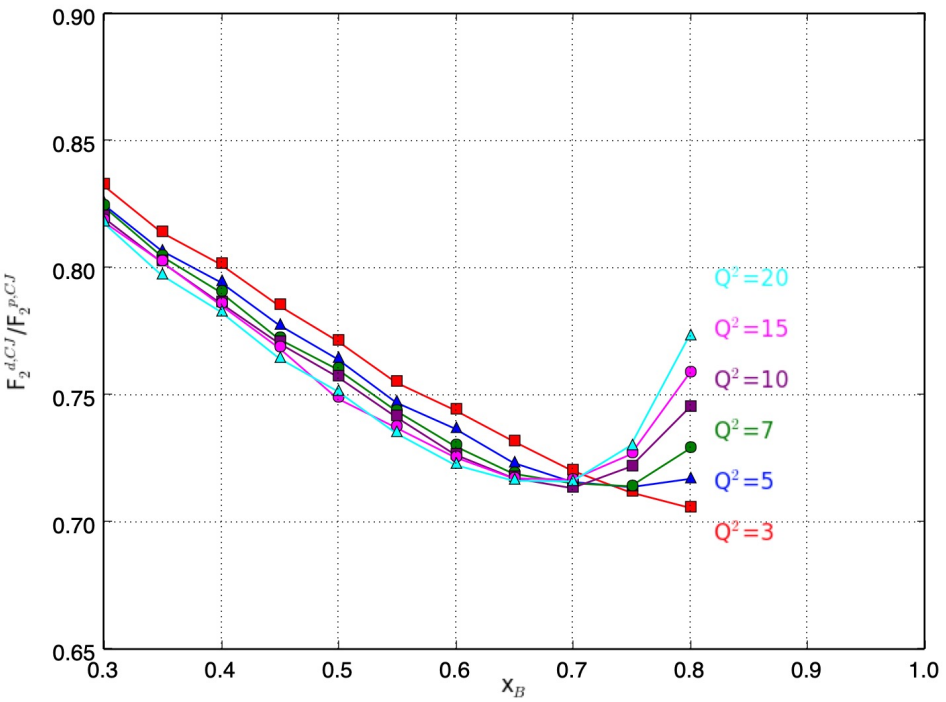
- Neglecting uncertainties on purpose to highlight behavior in the plot.
- There is Q^2 dependence, in particular at large x and low Q.
- Phys. Rev. D **93** 114017 (2016)

Looking at $F_2^d/F_2^{n,p}$ via CJ15

d/n

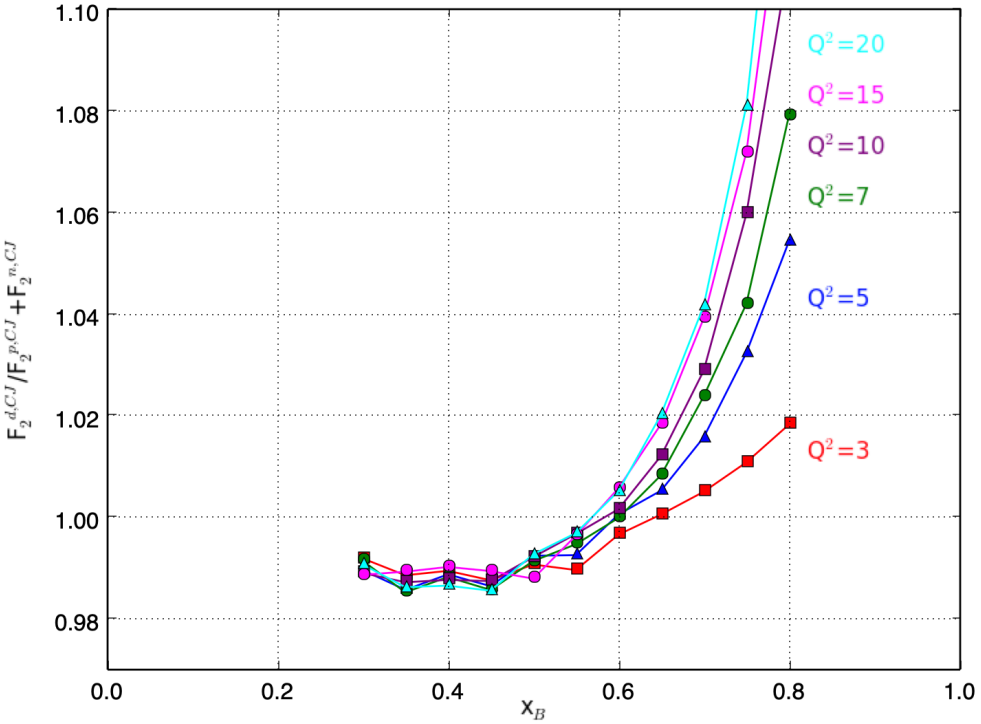


d/p



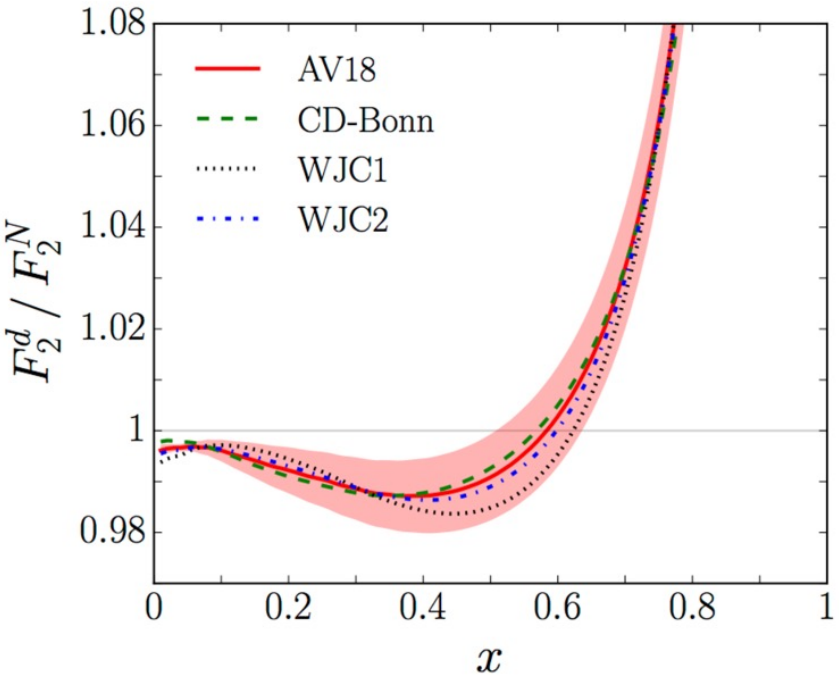
- Phys. Rev. D **93** 114017 (2016)

Looking at F_2^d/F_2^{n+p} via CJ15



- Phys. Rev. D **93** 114017 (2016)

Looking at F_2^d/F_2^N Theory



- Theoretical extraction of F_2^d/F_2^N.
- Some *x* dependence -> ~2% effect in 0.3-0.7 *x* region.
- Phys. Rev. D **93** 114017 (2016)