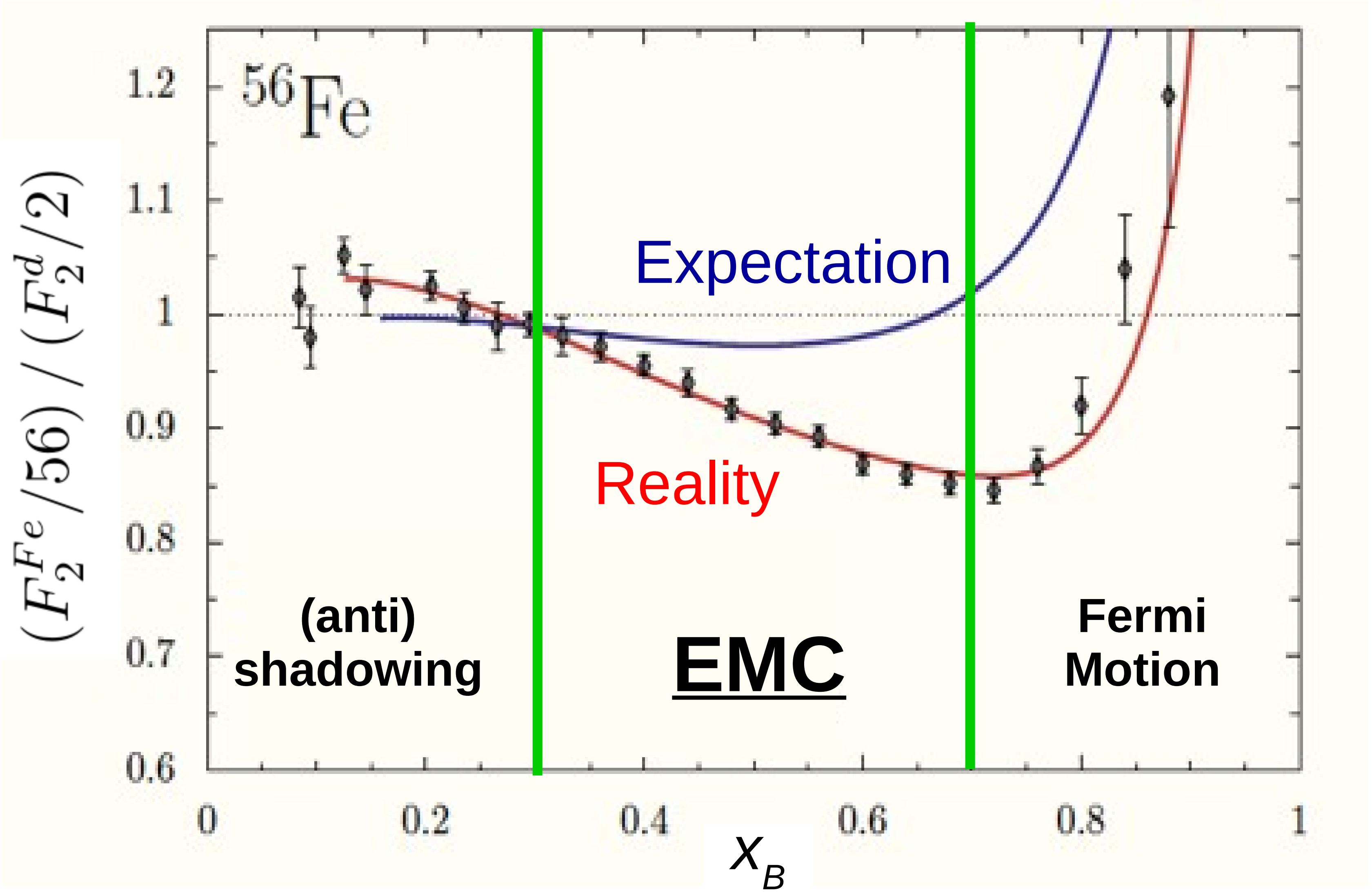
New 6 GeV CLAS Results

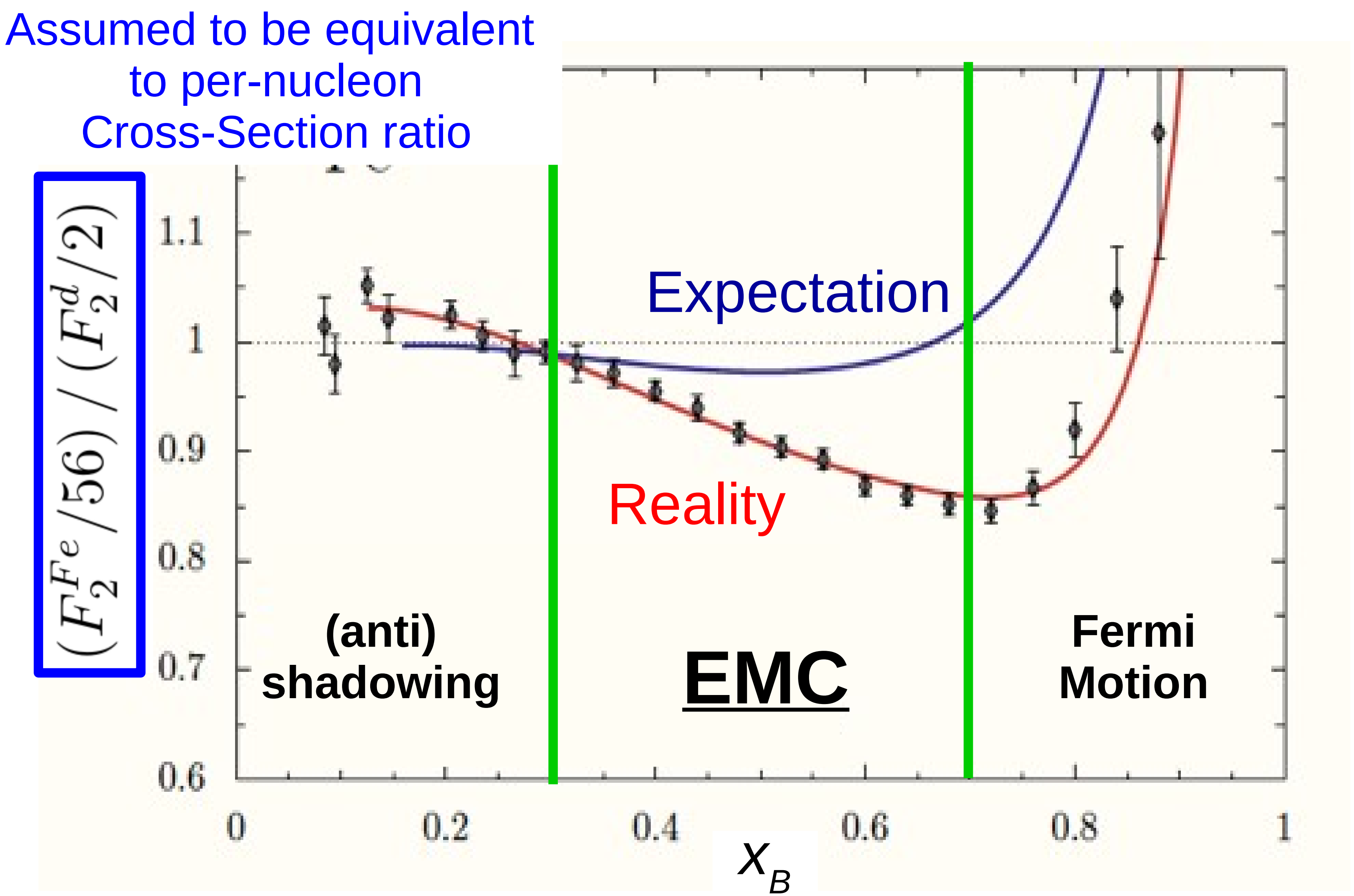
Barak Schmookler

Nature 566, 354-358 (2019)

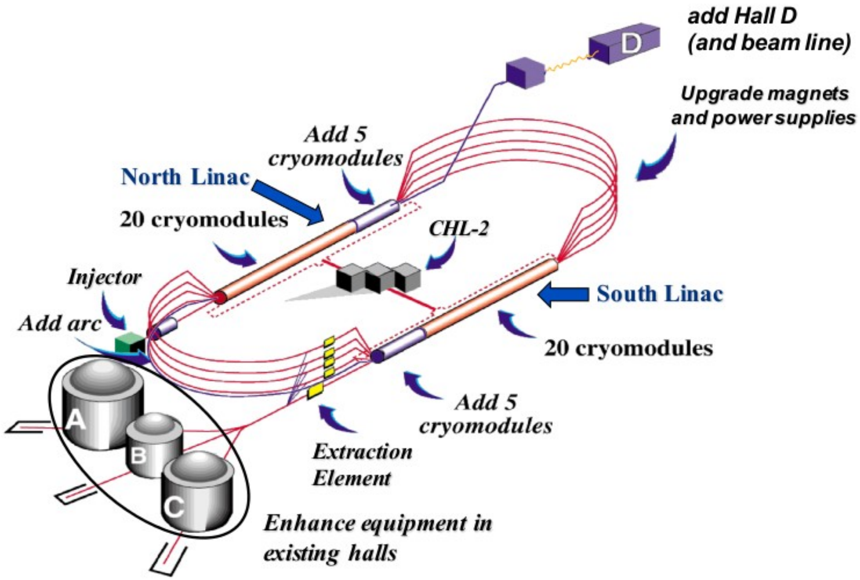
DIS and the EMC Effect



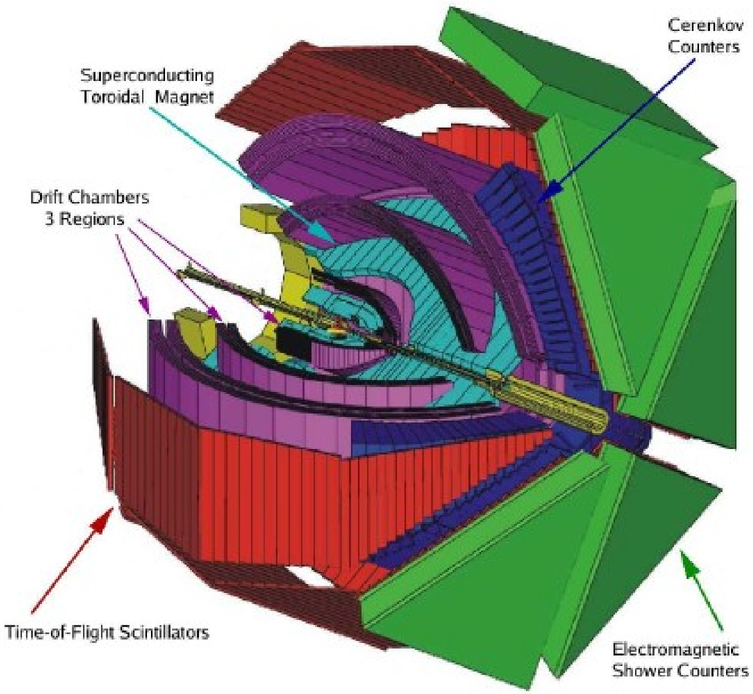
DIS and the EMC Effect



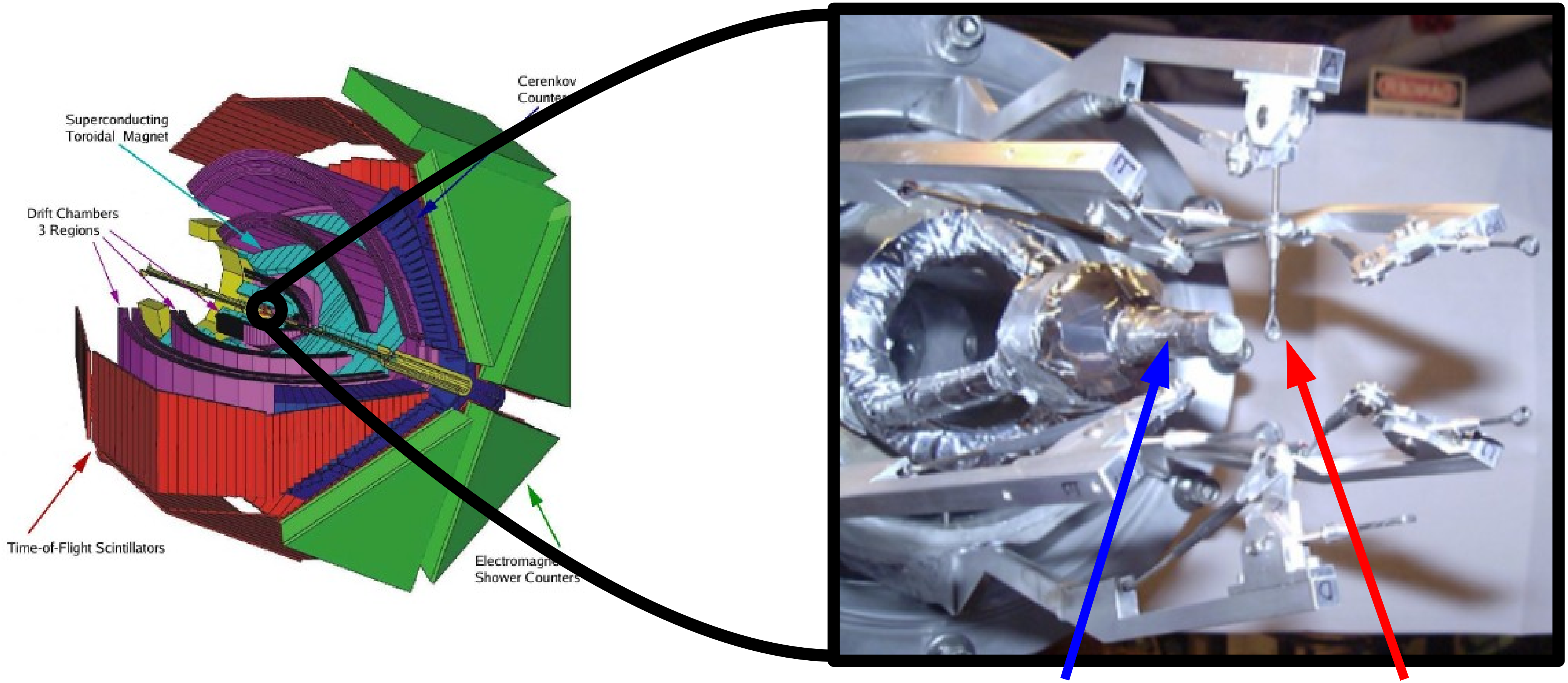
Thomas Jefferson National Accelerator Facility (JLab)



The CLAS Detector in Hall B at JLab



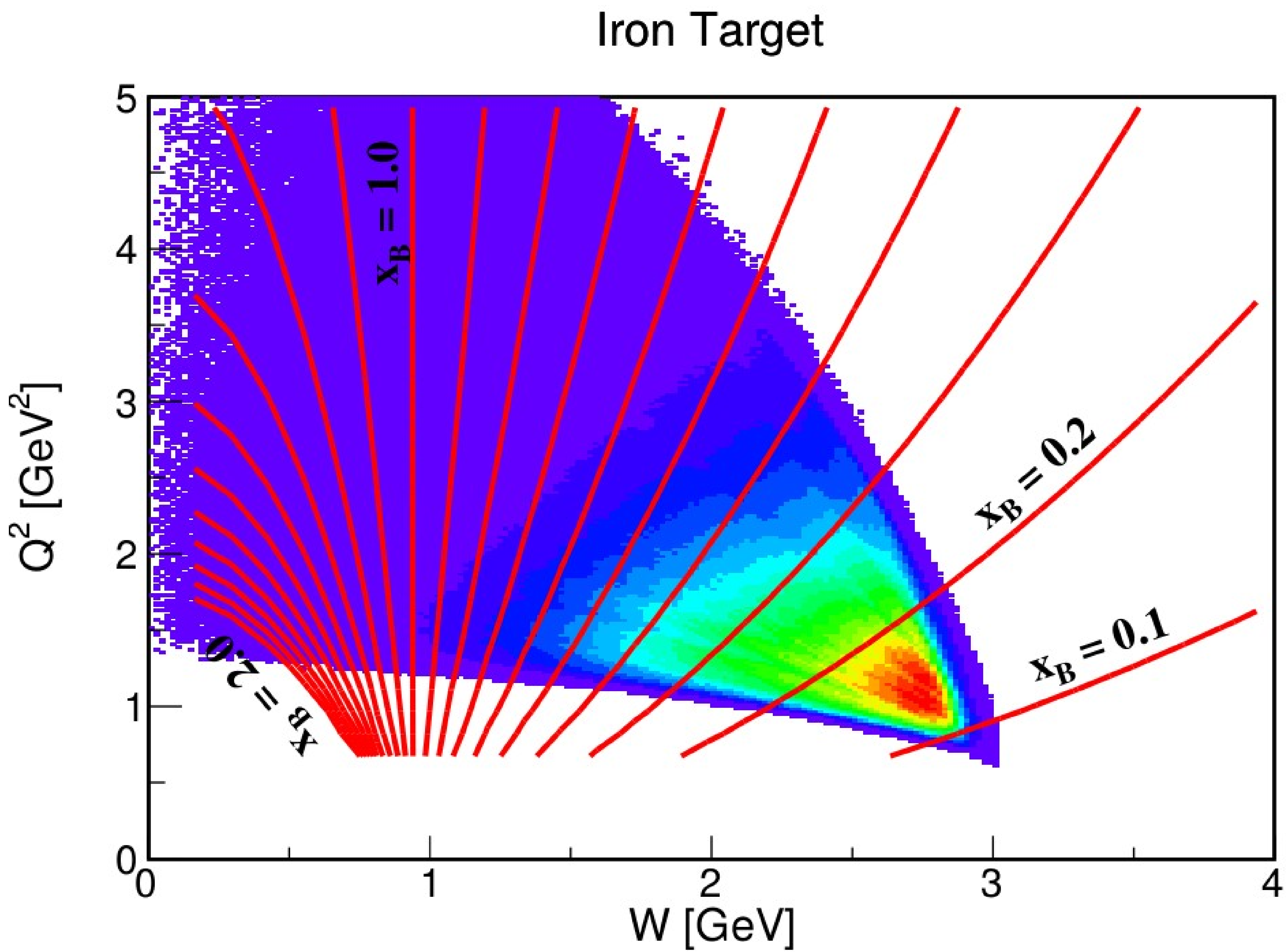
The CLAS Detector in Hall B at JLab

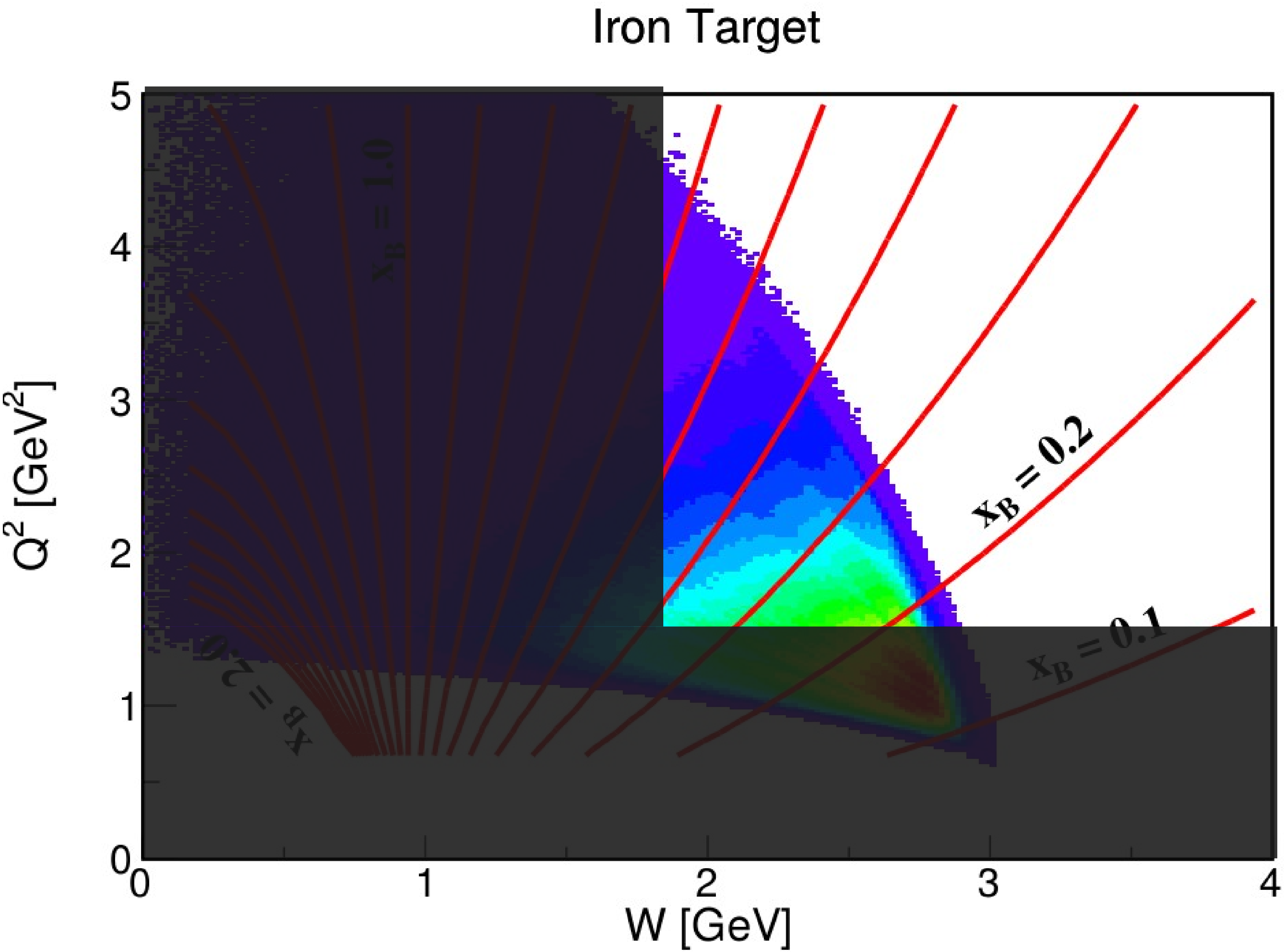


Liquid Hydrogen or Deuterium

C, Al, Fe, or Pb

5.01 GeV Incident Electrons


Iron Target
$x_B = 1.0$
$x_B = 0.2$
$x_B = 0.1$
$x_B = 2.0$
Q^2 [GeV^2]
W [GeV]
0
1
2
3
4
5



Iron Target
Q^2 [GeV^2]
W [GeV]
0
1
2
3
4
5
x_B = 1.0
x_B = 2.0
x_B = 0.2
x_B = 0.1

We want to Extract Cross-Section Ratios to Deuterium

- Bin data in x_B

We want to Extract Cross-Section Ratios to Deuterium

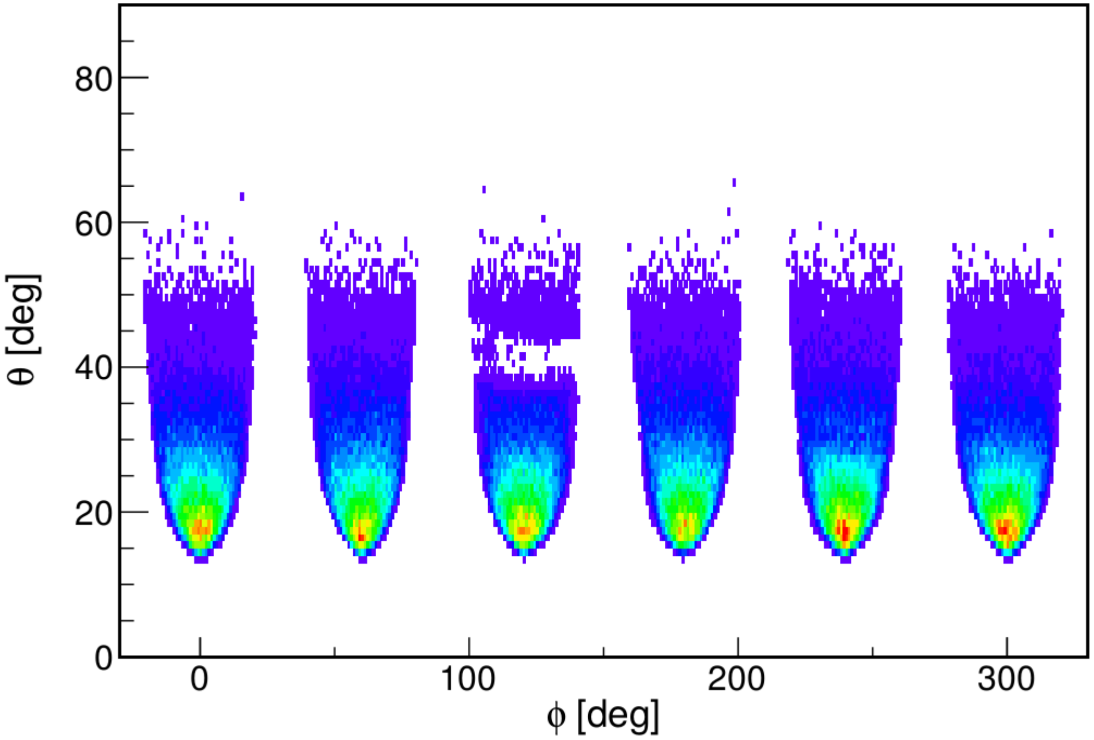
- Bin data in x_B
- Apply the following corrections:

We want to Extract Cross-Section Ratios to Deuterium

- Bin data in x_B
- Apply the following corrections:
  - ✓ Luminosity Corrections

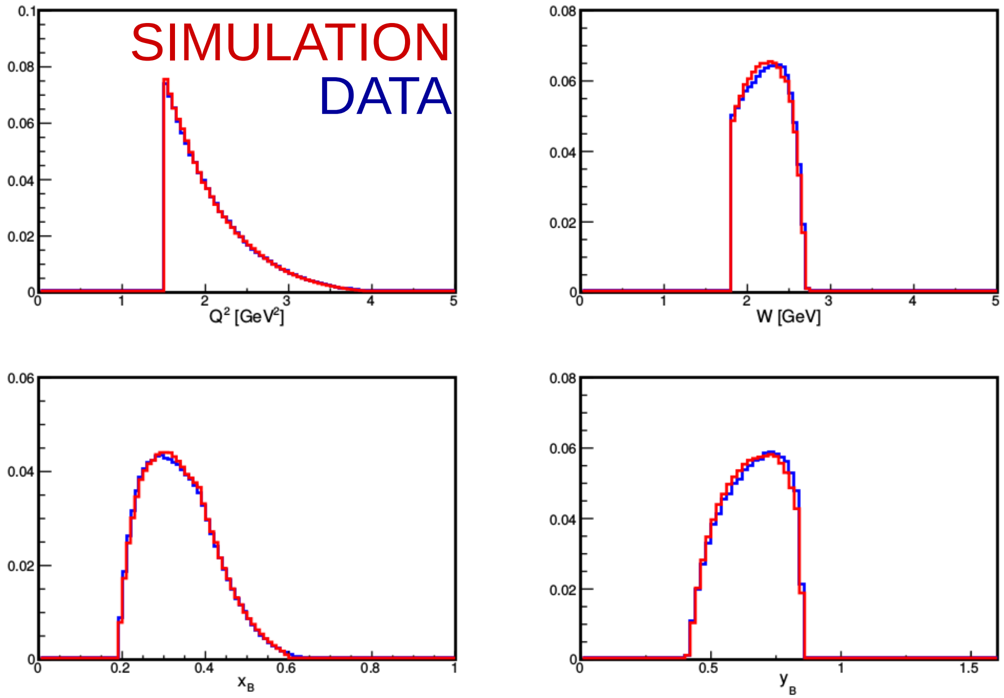
We want to Extract Cross-Section Ratios to Deuterium

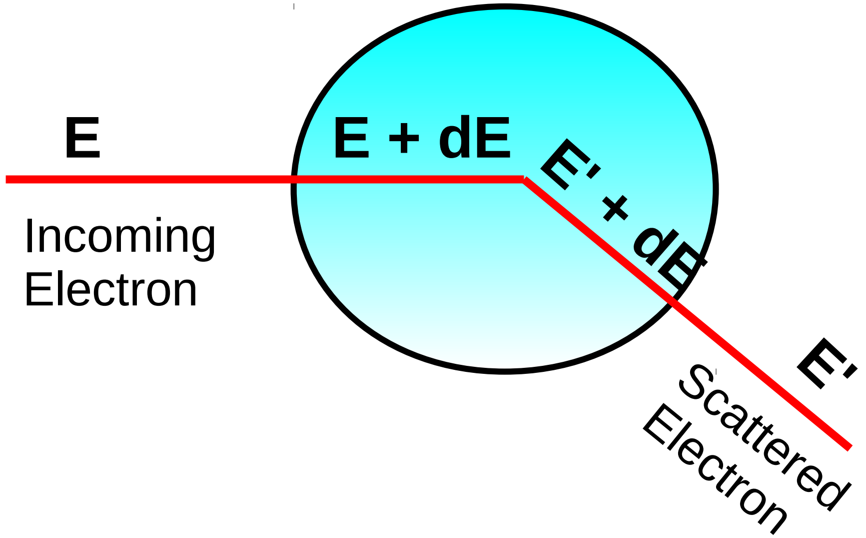
- Bin data in x_B
- Apply the following corrections:
  - ✓ Luminosity Corrections
  - ✓ Acceptance Corrections



We want to Extract Cross-Section Ratios to Deuterium

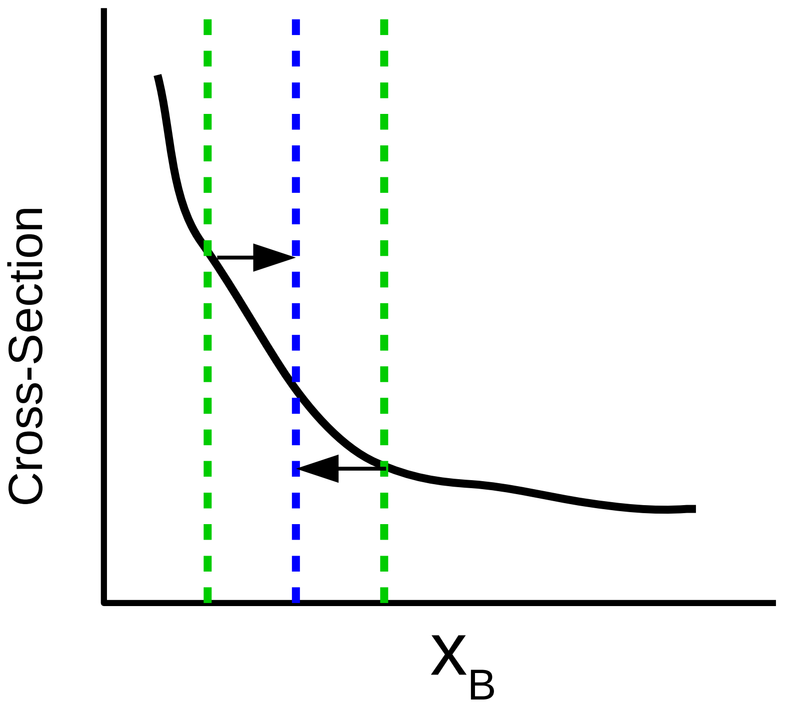
- Bin data in x_B
- Apply the following corrections:
  - ✔ Luminosity Corrections
  - ✔ Acceptance Corrections
  - ✔ Radiative and Coulomb Corrections





We want to Extract Cross-Section Ratios to Deuterium

- Bin data in x_B
- Apply the following corrections:
  - ✓ Luminosity Corrections
  - ✓ Acceptance Corrections
  - ✓ Radiative and Coulomb Corrections
  - ✓ Bin-Centering Corrections



We want to Extract Cross-Section Ratios to Deuterium

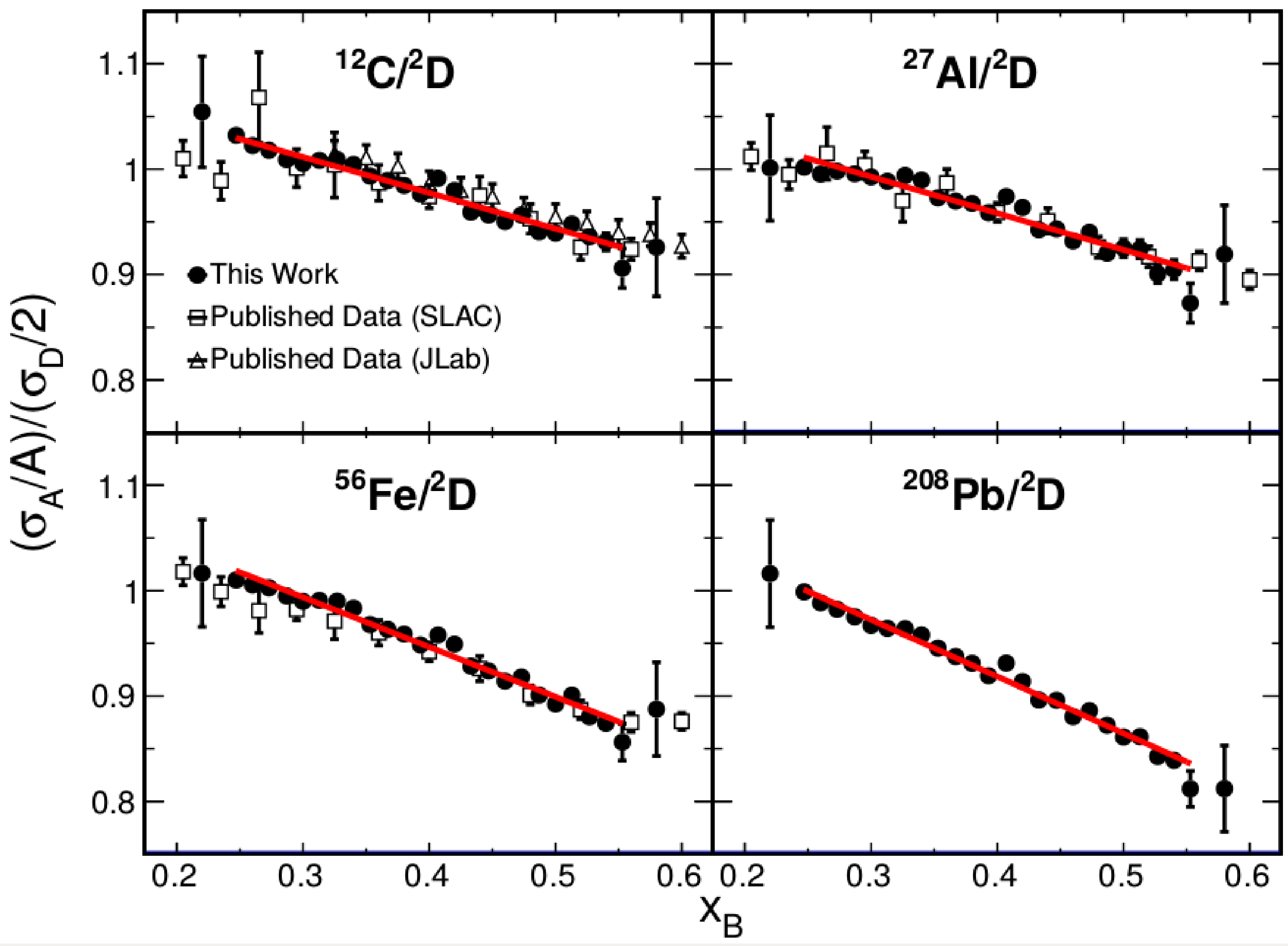
- Bin data in x_B
- Apply the following corrections:
  - Luminosity Corrections
  - Acceptance Corrections
  - Radiative and Coulomb Corrections
  - Bin-Centering Corrections

$$\left(\frac{\sigma(A)/A}{\sigma(D)/2}\right) = \frac{Y_A^{Weighted}}{Y_D^{Weighted} - Y_{Empty}^{Weighted}}$$

$$Weight = \frac{1}{NORM} \times \frac{RC \times CC \times ISO}{ACC} \times BC$$

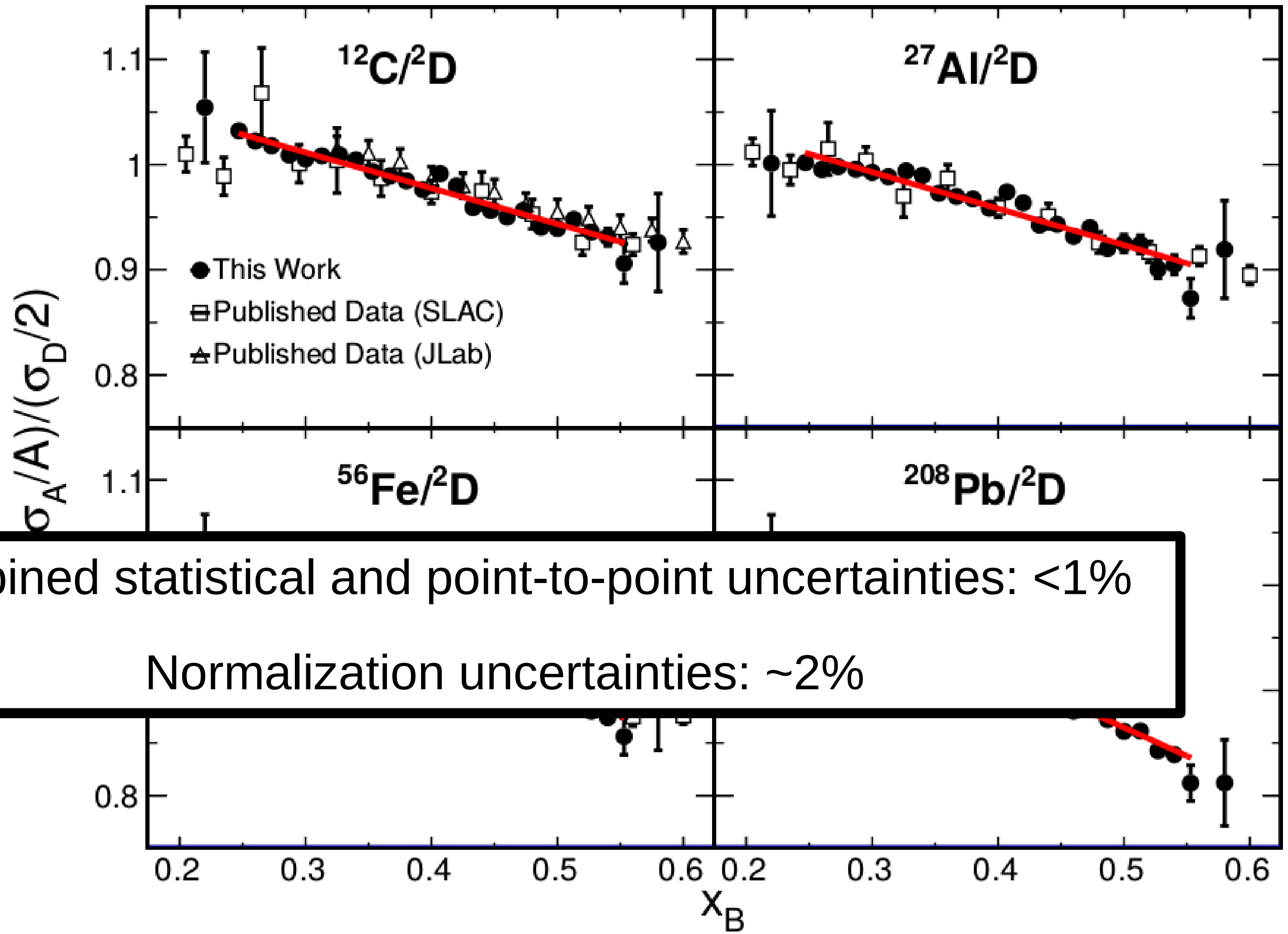
Our New EMC Effect Measurements

Kinematic Cut: Q^2>1.5 GeV^2, W>1.8 GeV, y_B<0.85



Our New EMC Effect Measurements

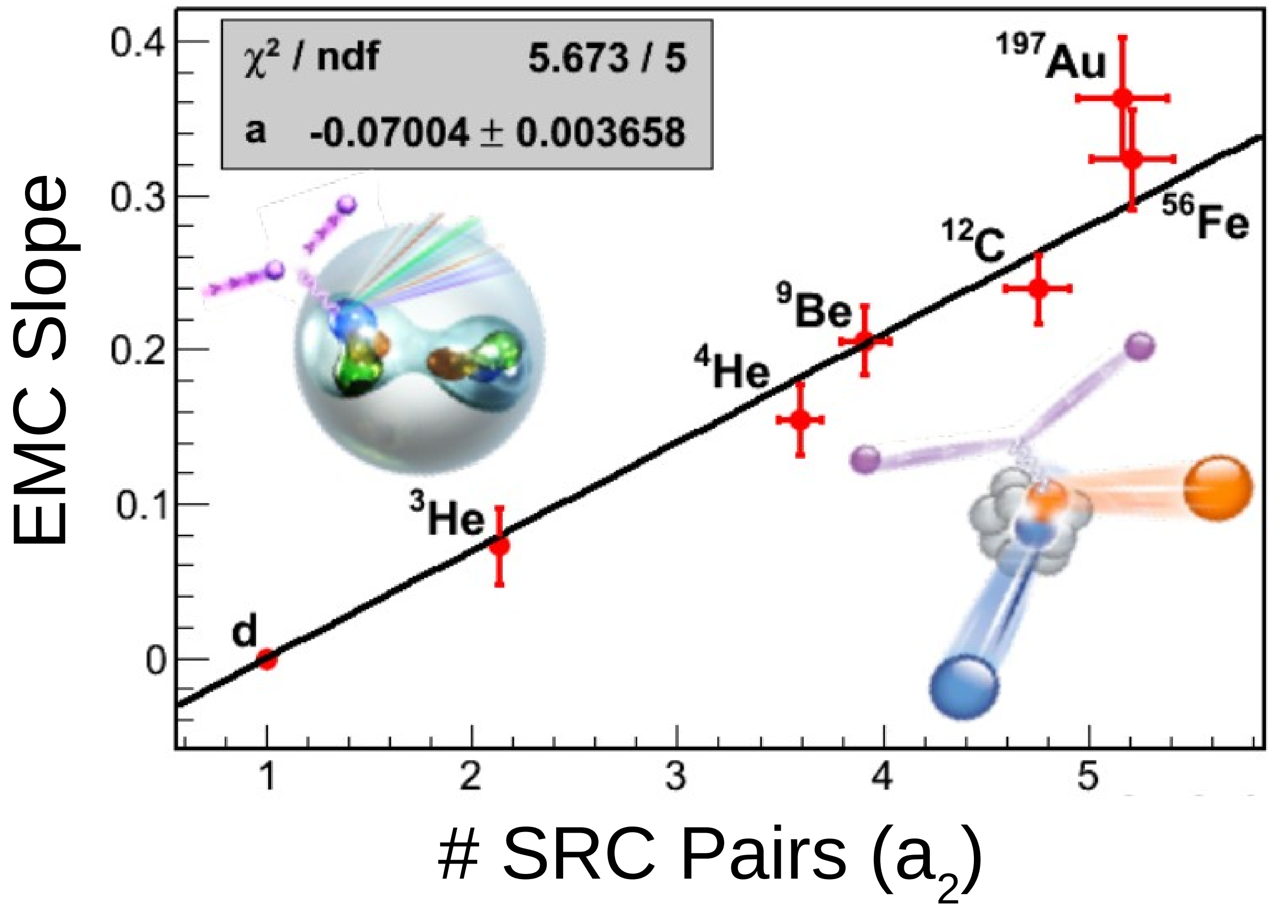
Kinematic Cut: Q^2>1.5 GeV^2, W>1.8 GeV, y_B<0.85



Combined statistical and point-to-point uncertainties: <1%

Normalization uncertainties: ~2%

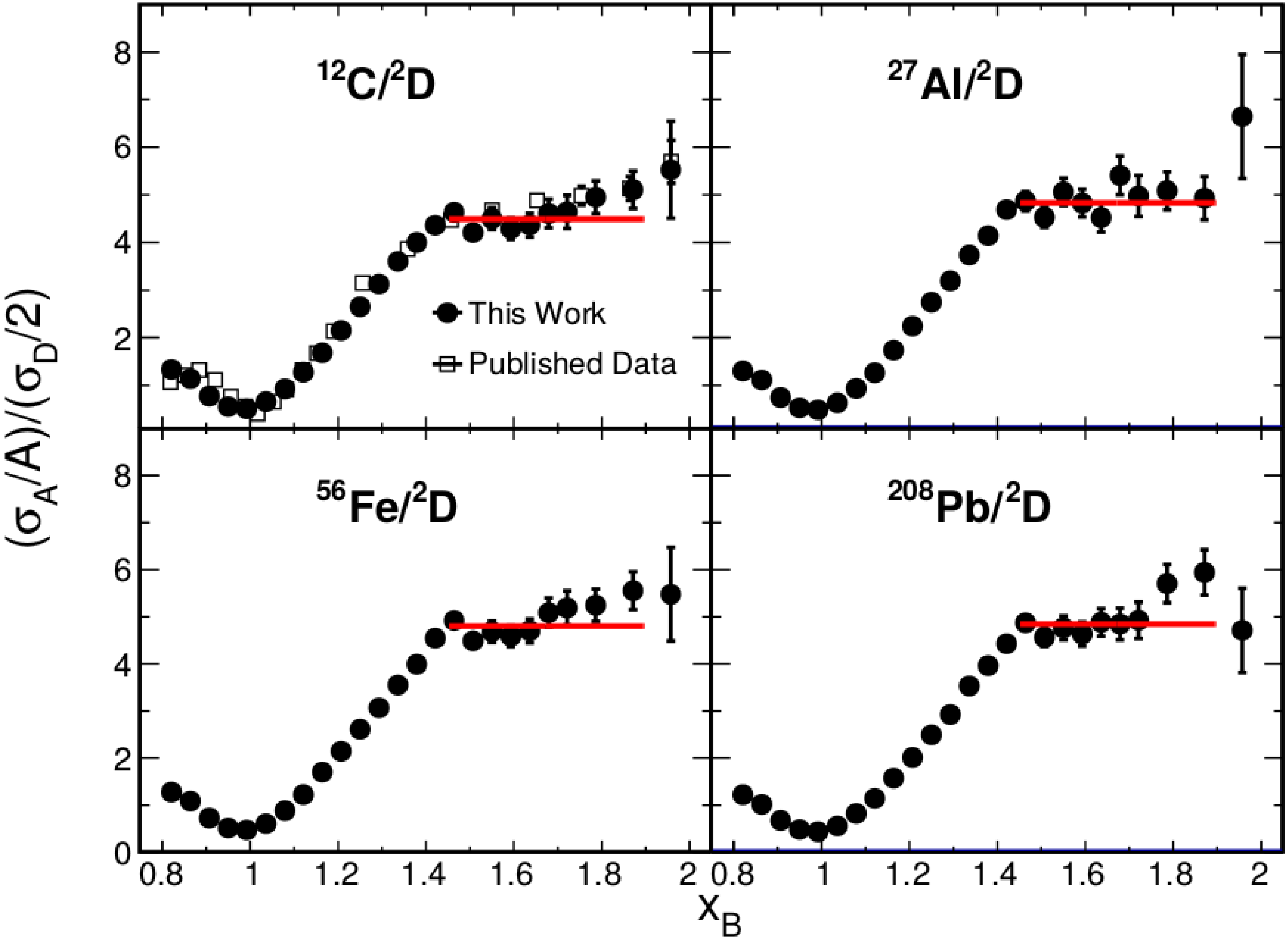
Observed EMC-SRC Correlation



L. Weinstein et. al., Phys. Rev. Lett.06, 052301 (2011).
O. Hen et al. Phys. Rev. C 85 047301 (2012).
O. Hen et al., Rev. Mod. Phys. 89, 045002 (2017).

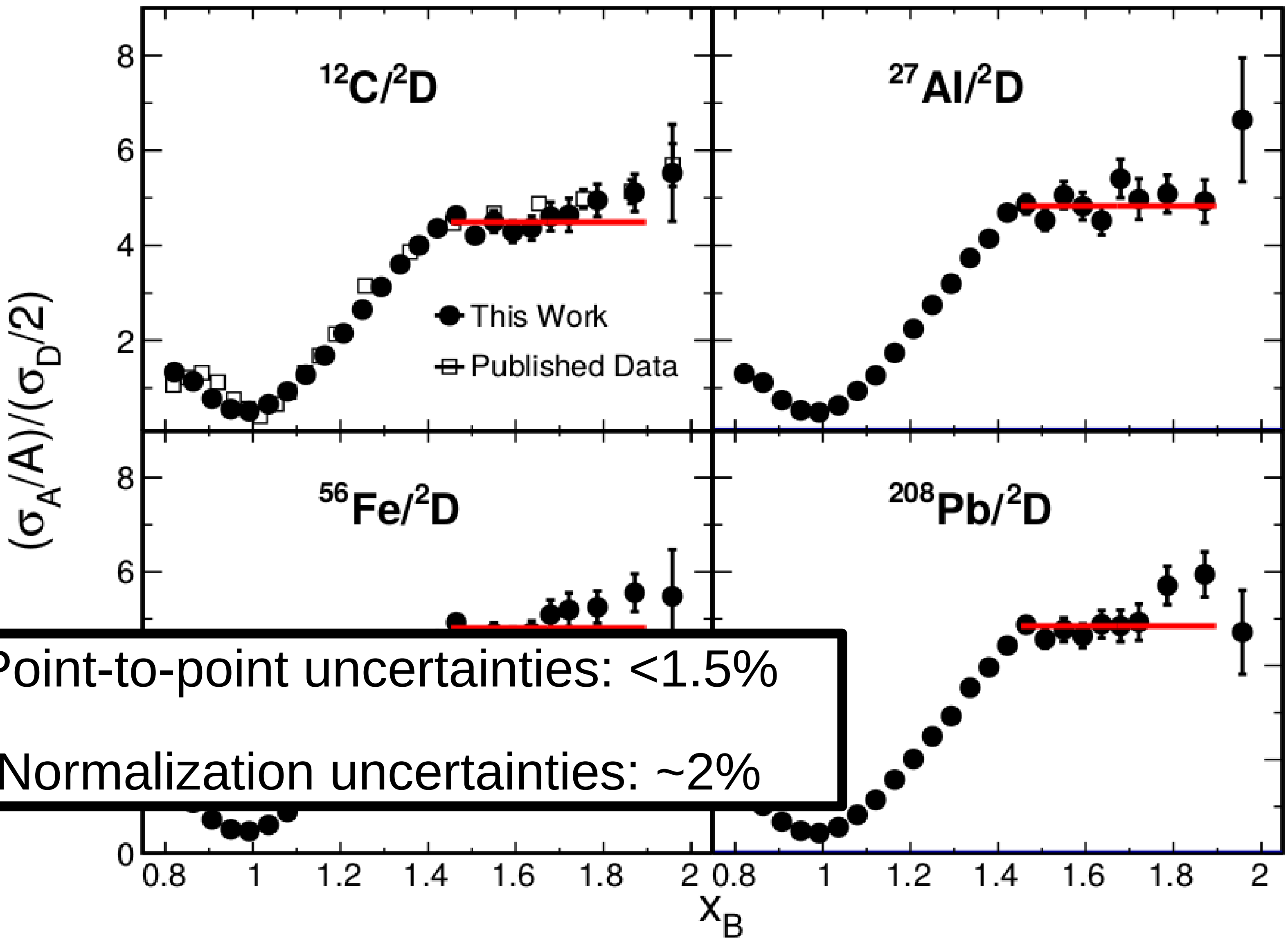
Our New a_2 Measurements

Kinematic Cut: Q^2>1.5 GeV^2



Our New a_2 Measurements

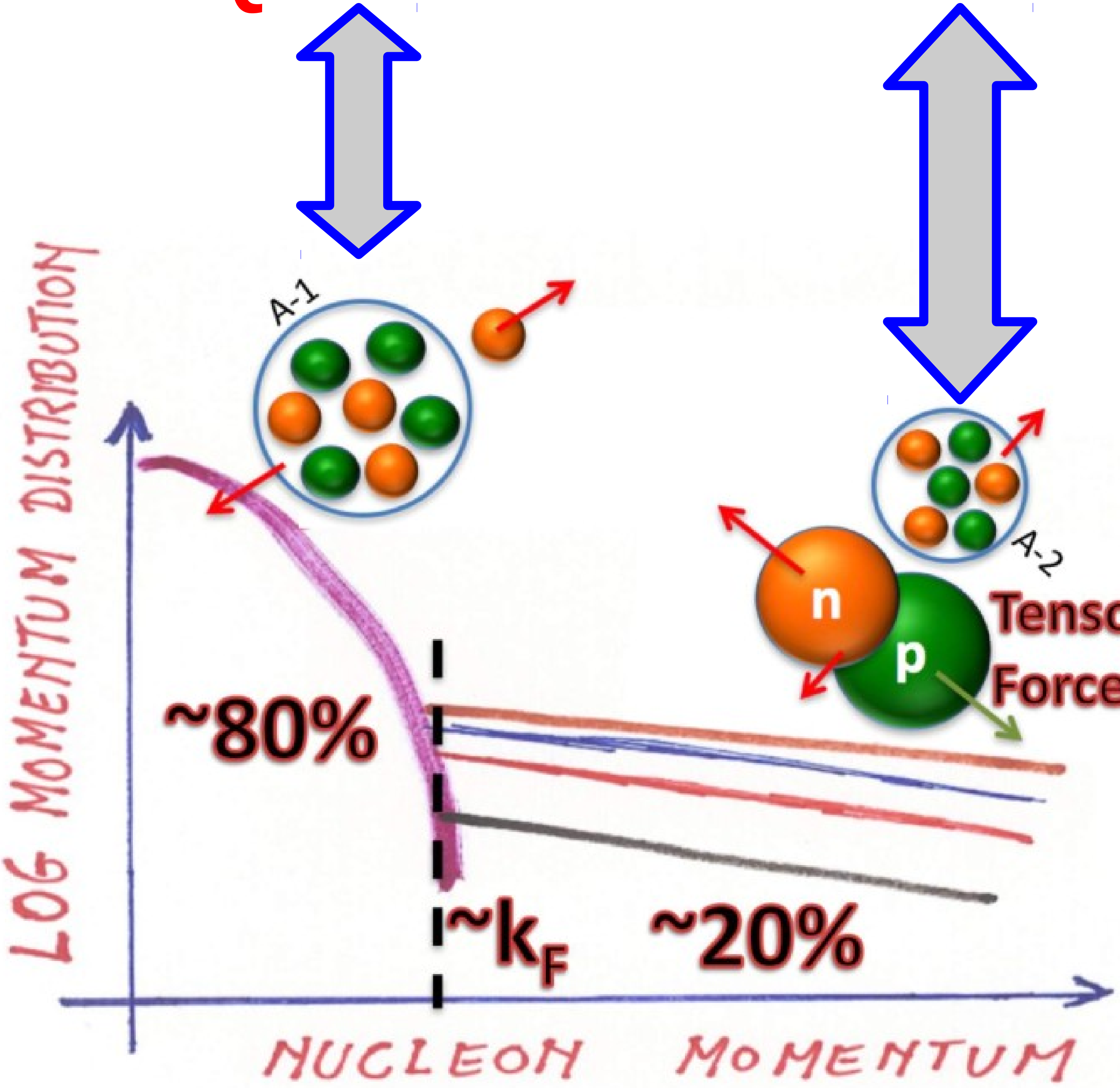
Kinematic Cut: Q^2>1.5 GeV^2



Point-to-point uncertainties: <1.5%

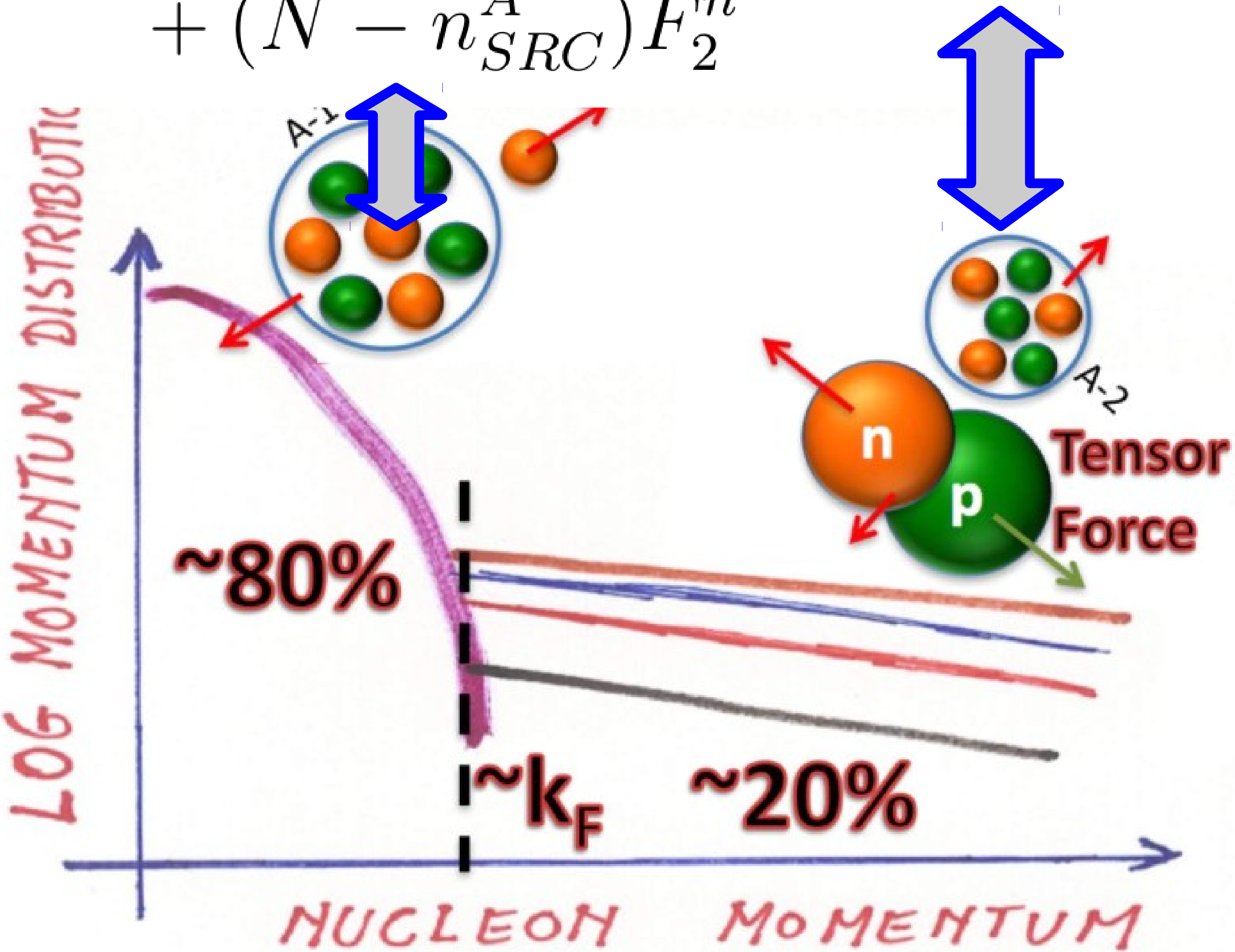
Normalization uncertainties: ~2%

Bound = 'Quasi Free' + Modified SRCs



Bound = 'Quasi Free' + Modified SRCs

$$F_2^A = (Z - n_{SRC}^A)F_2^p + n_{SRC}^A(F_2^{p*} + F_2^{n*}) + (N - n_{SRC}^A)F_2^n$$



Bound = 'Quasi Free' + Modified SRCs

$$F_2^A = (Z - n_{SRC}^A)F_2^p + n_{SRC}^A(F_2^{p*} + F_2^{n*}) + (N - n_{SRC}^A)F_2^n$$

$$= ZF_2^p + NF_2^n + n_{SRC}^A(\Delta F_2^p + \Delta F_2^n)$$

$$\Delta F_2^{p(n)} = F_2^{p*(n*)} - F_2^{p(n)}$$

Bound = 'Quasi Free' + Modified SRCs

$$F_2^A = (Z - n_{SRC}^A)F_2^p + n_{SRC}^A(F_2^{p*} + F_2^{n*}) + (N - n_{SRC}^A)F_2^n$$

$$= ZF_2^p + NF_2^n + n_{SRC}^A(\Delta F_2^p + \Delta F_2^n)$$

$$\Delta F_2^{p(n)} = F_2^{p*(n*)} - F_2^{p(n)}$$

$$F_2^d = F_2^p + F_2^n + n_{SRC}^d(\Delta F_2^p + \Delta F_2^n)$$

Our Model's Prediction for the EMC Effect

$$\frac{F_2^A/A}{F_2^d/2} = (a_2 - 2\frac{N}{A})(n^d_{SRC}\frac{\Delta F_2^p + \Delta F_2^n}{F_2^d}) + 2 \cdot \frac{Z-N}{Z+N} \cdot \frac{F_2^p}{F_2^d} + 2\frac{N}{A}$$

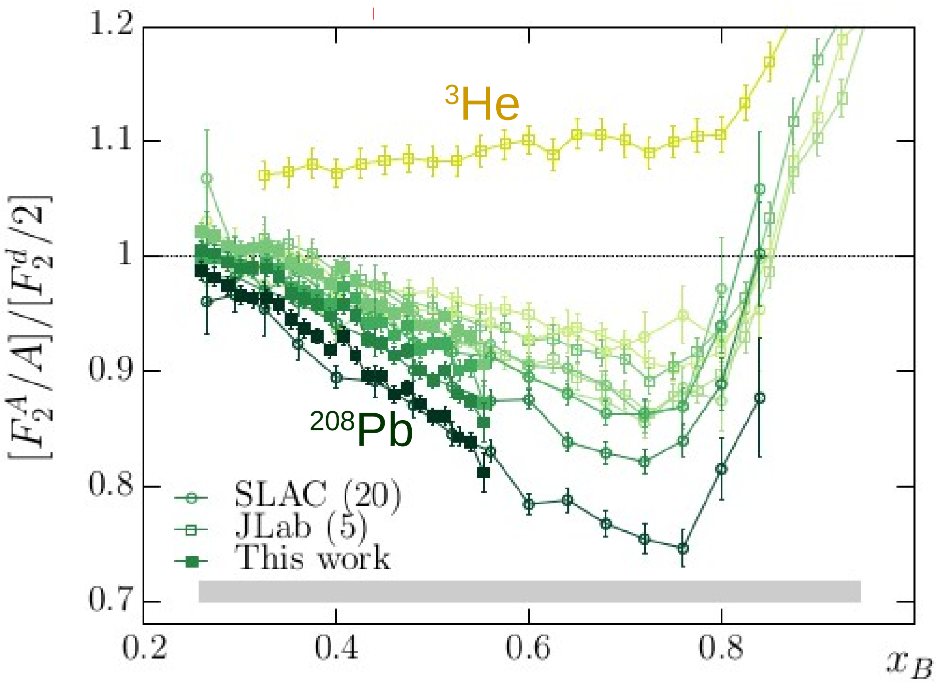
$$\boxed{a_2 \;=\; \frac{n^A_{SRC}/A}{n^d_{SRC}/2}}$$

Our Model's Prediction for the EMC Effect

$$\frac{F_2^A/A}{F_2^d/2} = (a_2 - 2\frac{N}{A})(n^d_{SRC}\frac{\Delta F_2^p + \Delta F_2^n}{F_2^d}) + 2\cdot\frac{Z-N}{Z+N}\cdot\frac{F_2^p}{F_2^d} + 2\frac{N}{A}$$

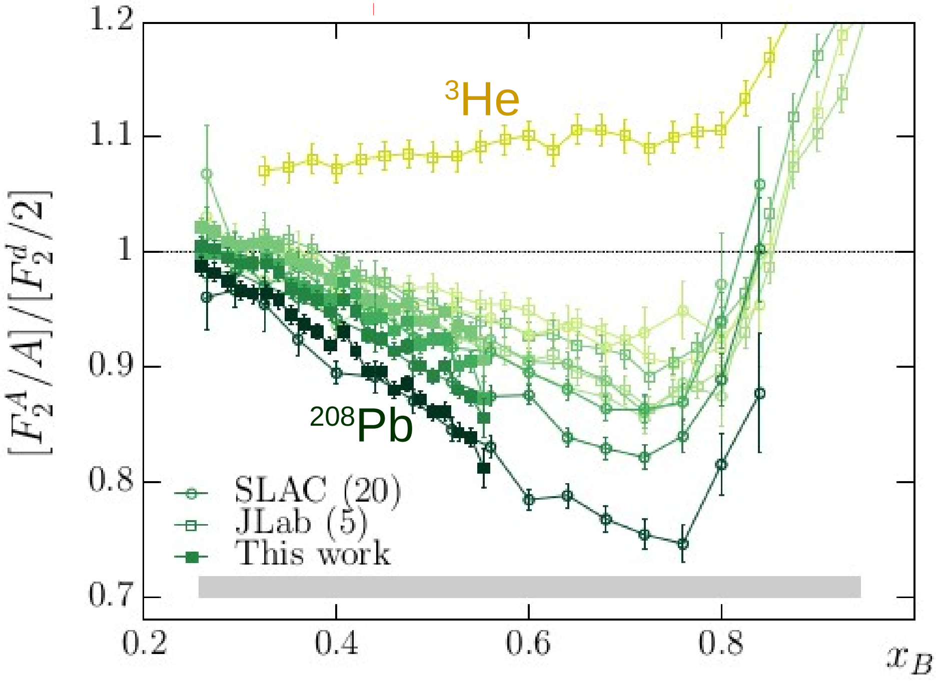
Universal?

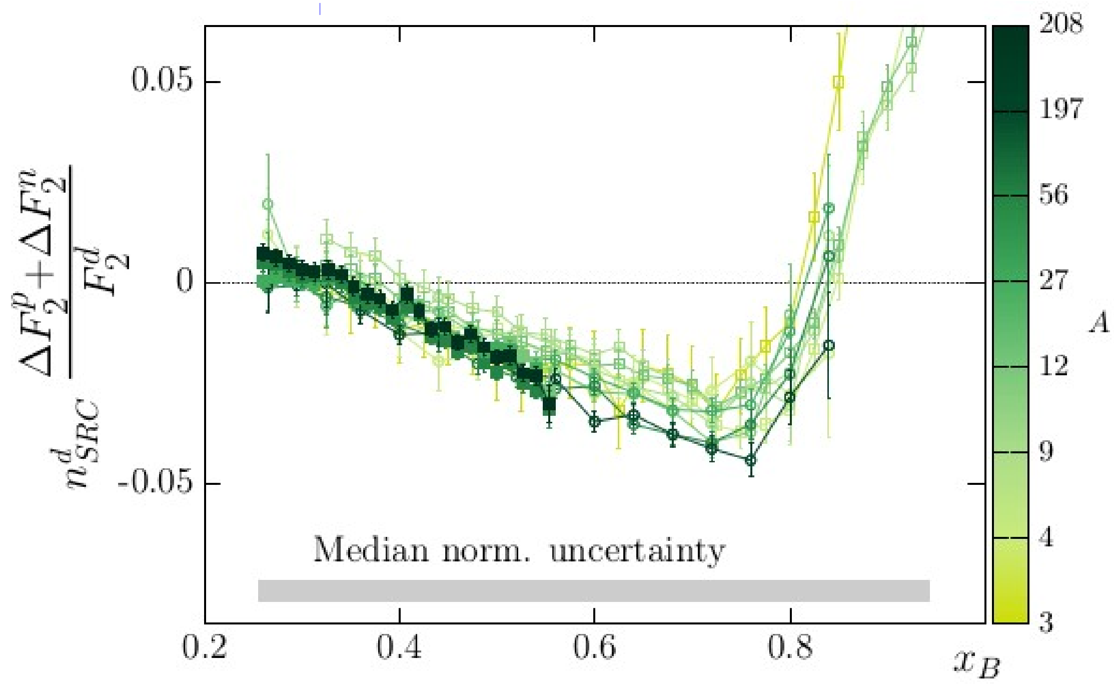
$$\frac{F_2^A/A}{F_2^d/2} = (a_2 - 2\frac{N}{A})(n_{SRC}^d \frac{\Delta F_2^p + \Delta F_2^n}{F_2^d}) + 2 \cdot \frac{Z-N}{Z+N} \cdot \frac{F_2^p}{F_2^d} + 2\frac{N}{A}$$



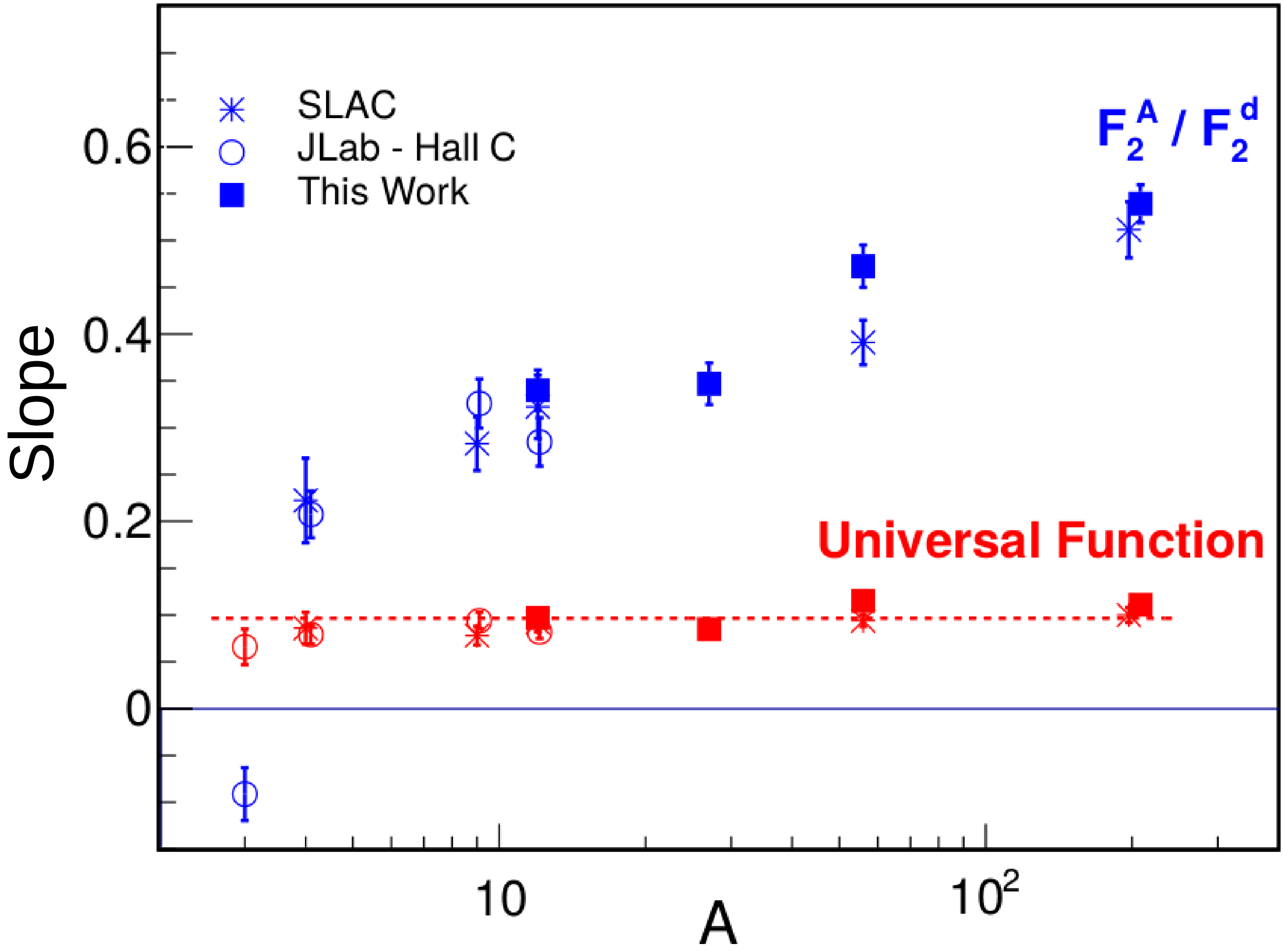
$$\frac{F_2^A/A}{F_2^d/2} = (a_2 - 2\frac{N}{A})\left(n^d_{SRC}\frac{\Delta F_2^p + \Delta F_2^n}{F_2^d}\right) + 2\cdot\frac{Z-N}{Z+N}\cdot\frac{F_2^p}{F_2^d} + 2\frac{N}{A}$$

Universal!!

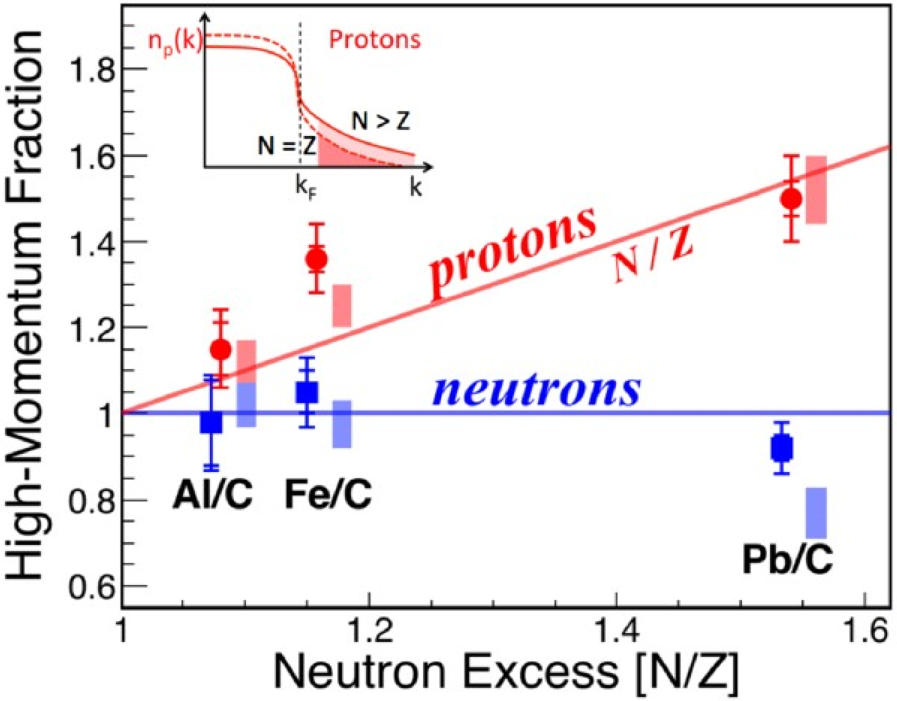




EMC Universal Modification Function



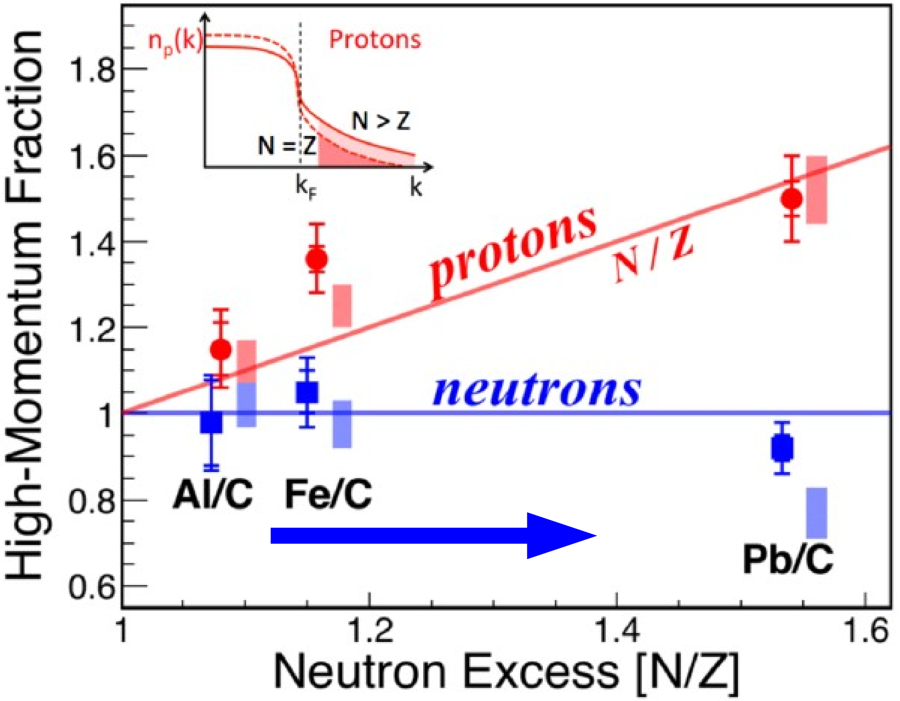
Focus on Neutron-Rich Nuclei



M.Duer, CLAS Collaboration, Nature 560, 617 (2018)

Focus on Neutron-Rich Nuclei

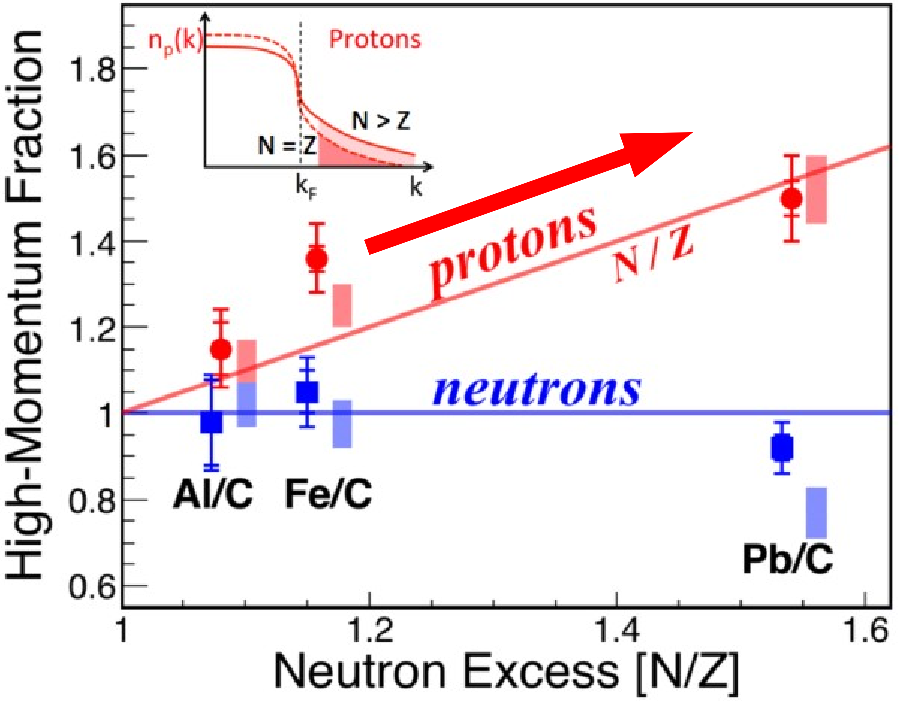
Prediction: EMC effect will show no growth for neutrons ...



M.Duer, CLAS Collaboration, Nature 560, 617 (2018)

Focus on Neutron-Rich Nuclei

Prediction: EMC effect will show no growth for neutrons and grow for protons



M.Duer, CLAS Collaboration, Nature 560, 617 (2018)

Calculate Per-Neutron (Per-Proton) Ratios

Per-Neutron: $$\frac{\sigma_A/N}{\sigma_D/1}$$

Per-Proton: $$\frac{\sigma_A/Z}{\sigma_D/1}$$

Calculate Per-Neutron (Per-Proton) Ratios

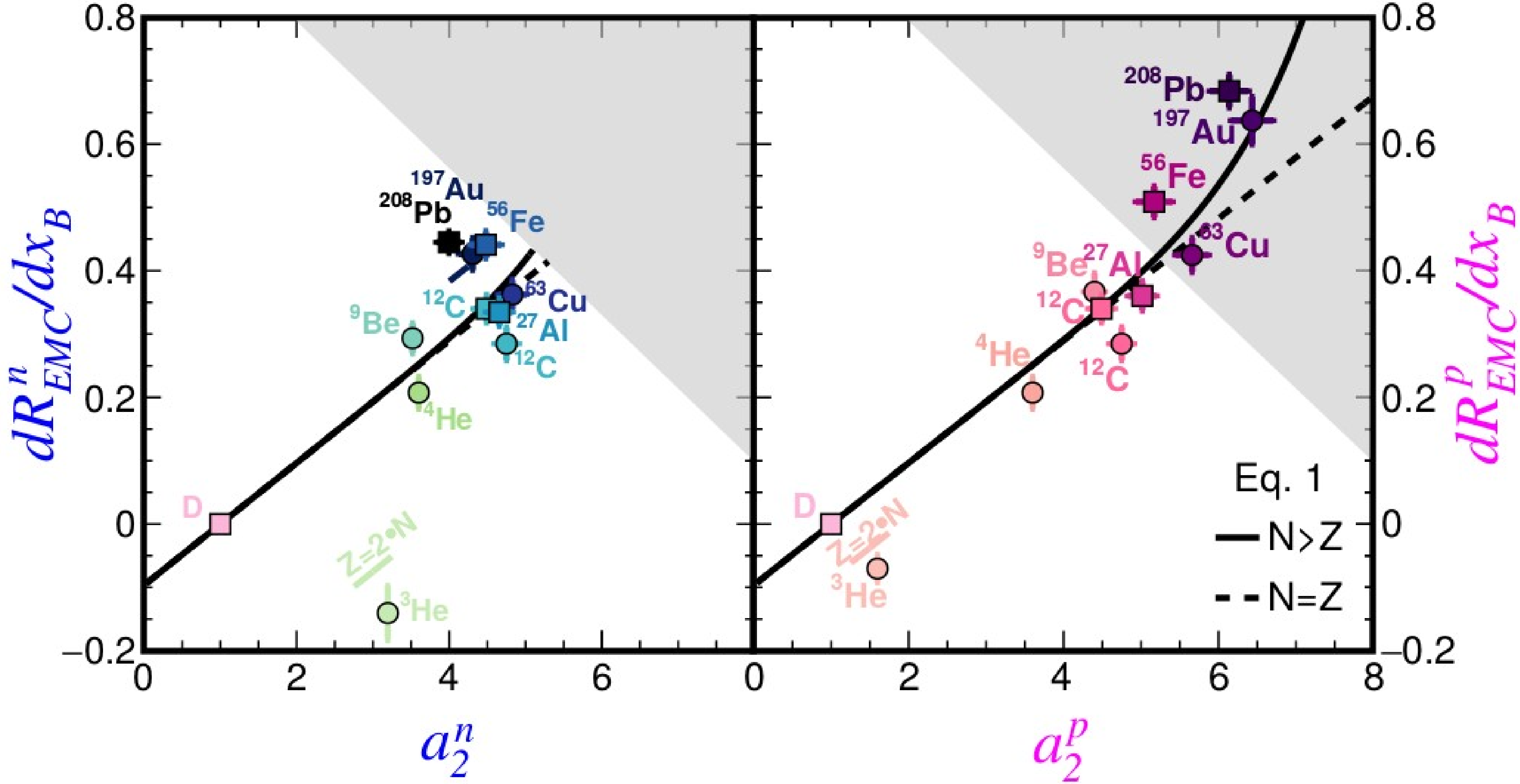
Per-Neutron: $\frac{\sigma_A/N}{\sigma_D/1}$

$$\frac{F_2^A/N}{F_2^d/1} = (a_2^n - 1)(n_{SRC}^d \frac{\Delta F_2^p + \Delta F_2^n}{F_2^d}) + (\frac{Z}{N} - 1) \cdot \frac{F_2^p}{F_2^d} + 1$$

Per-Proton: $\frac{\sigma_A/Z}{\sigma_D/1}$

$$\frac{F_2^A/Z}{F_2^d/1} = (a_2^p - \frac{N}{Z})(n_{SRC}^d \frac{\Delta F_2^p + \Delta F_2^n}{F_2^d}) + (\frac{Z}{N} - 1) \cdot \frac{F_2^p}{F_2^d} + \frac{N}{Z}$$

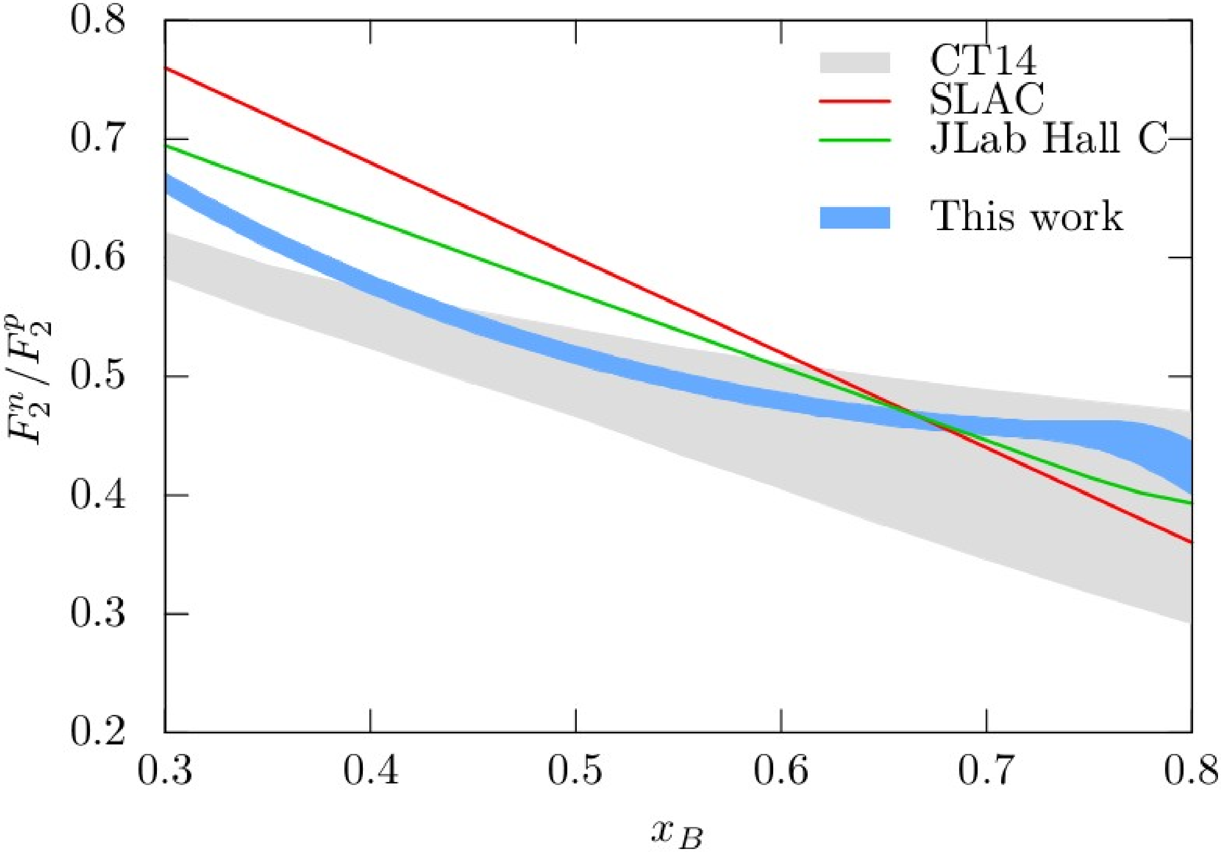
New EMC-SRC Correlation



Isoscalar Corrections for DIS Ratios

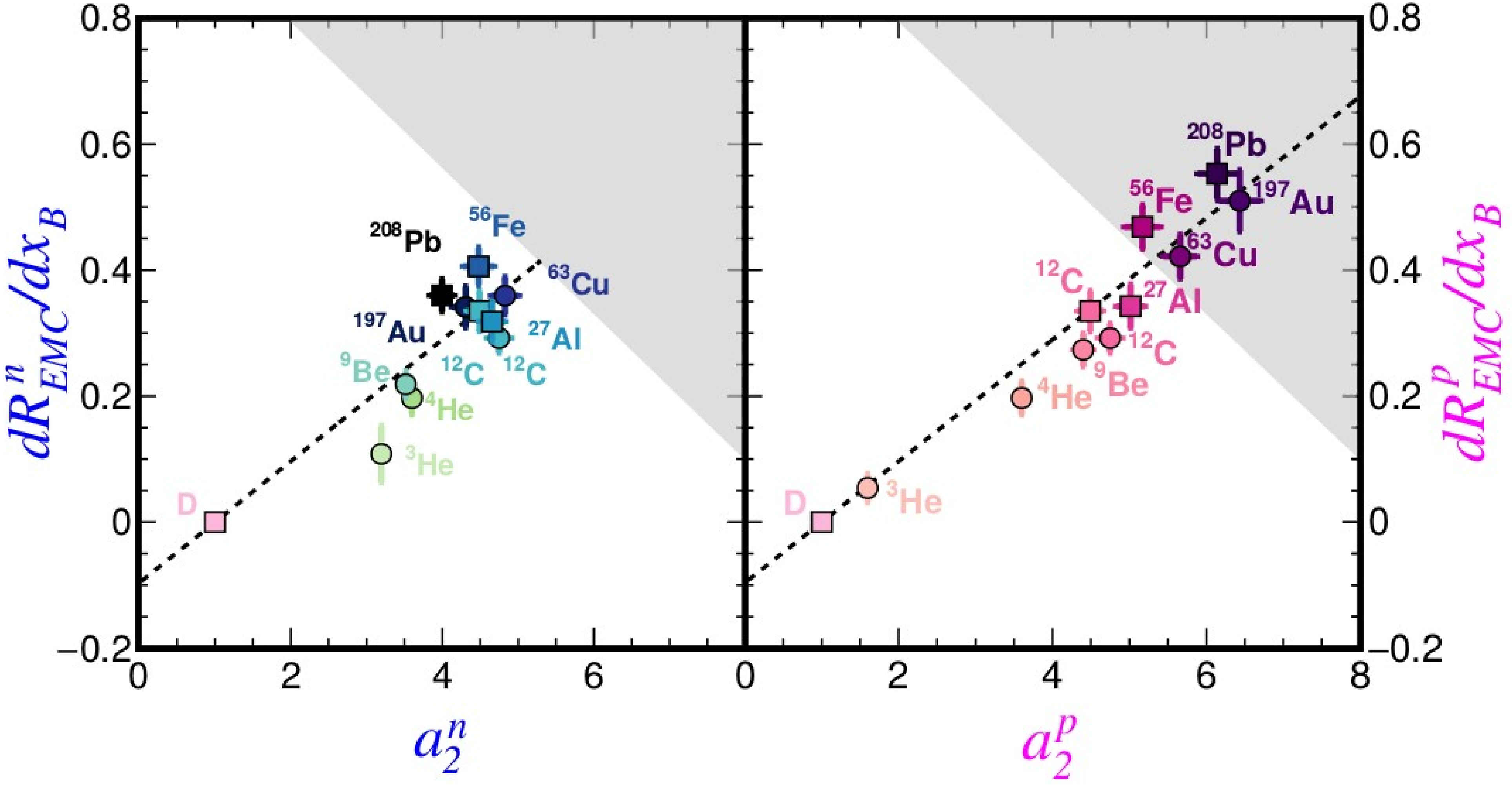
Correction Factor:

$$\frac{\frac{A}{2} \cdot \left(1 + \frac{F_2^n}{F_2^p}\right)}{Z + N \cdot \frac{F_2^n}{F_2^p}}$$

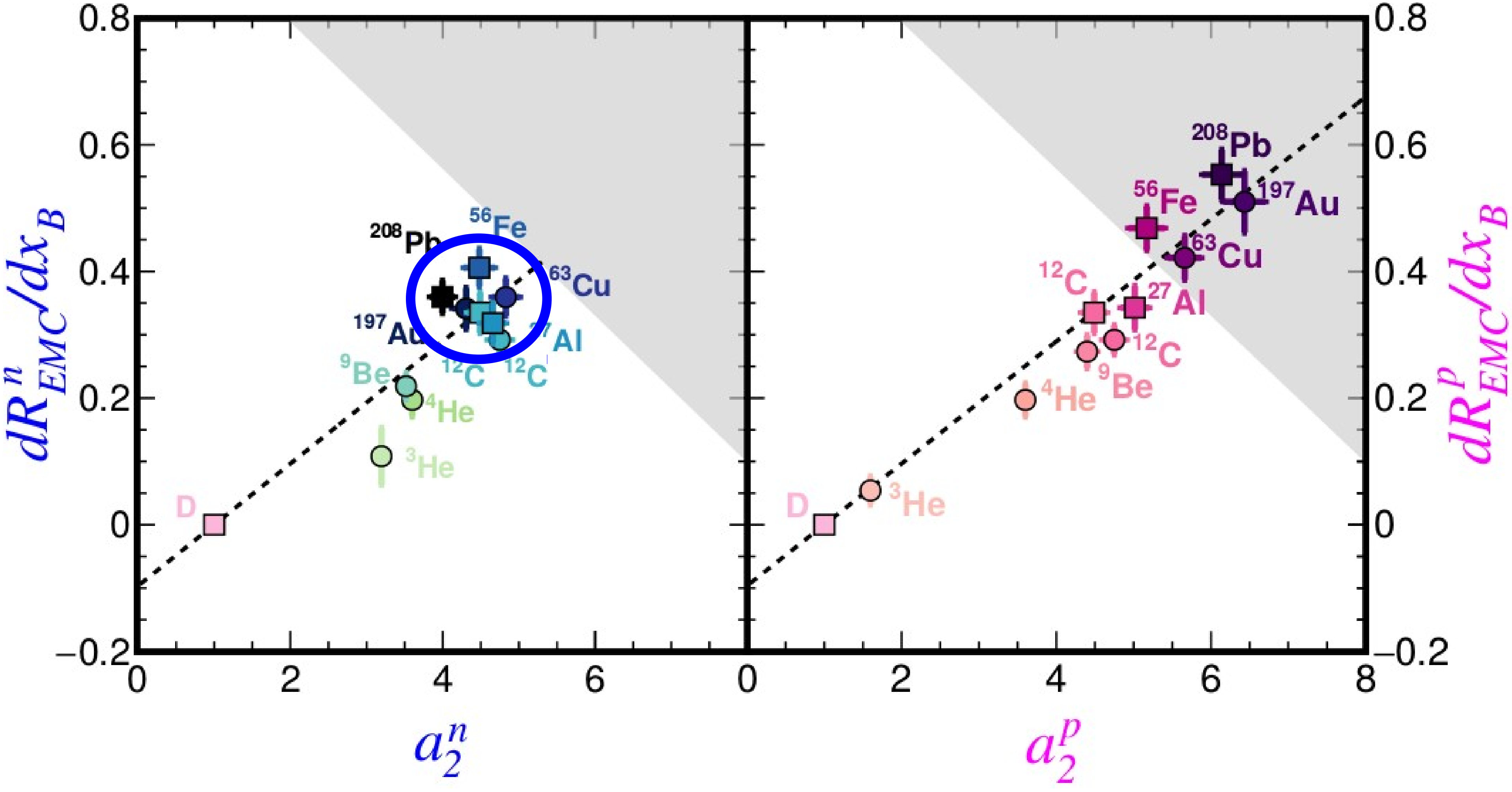


$$F_2^d = F_2^p + F_2^n + n_{SRC}^d(\Delta F_2^p + \Delta F_2^n)$$

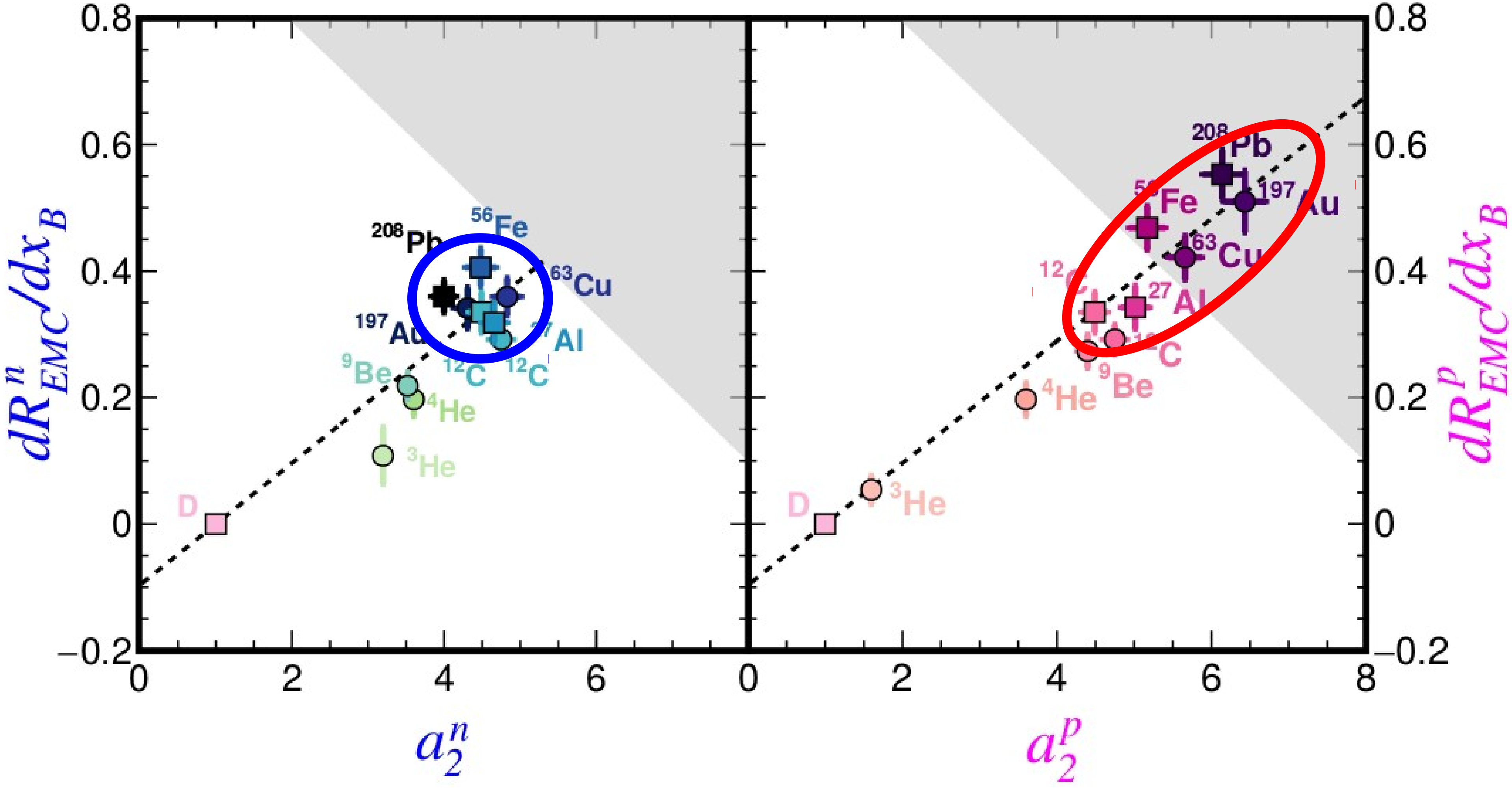
New EMC-SRC Correlation: Version II



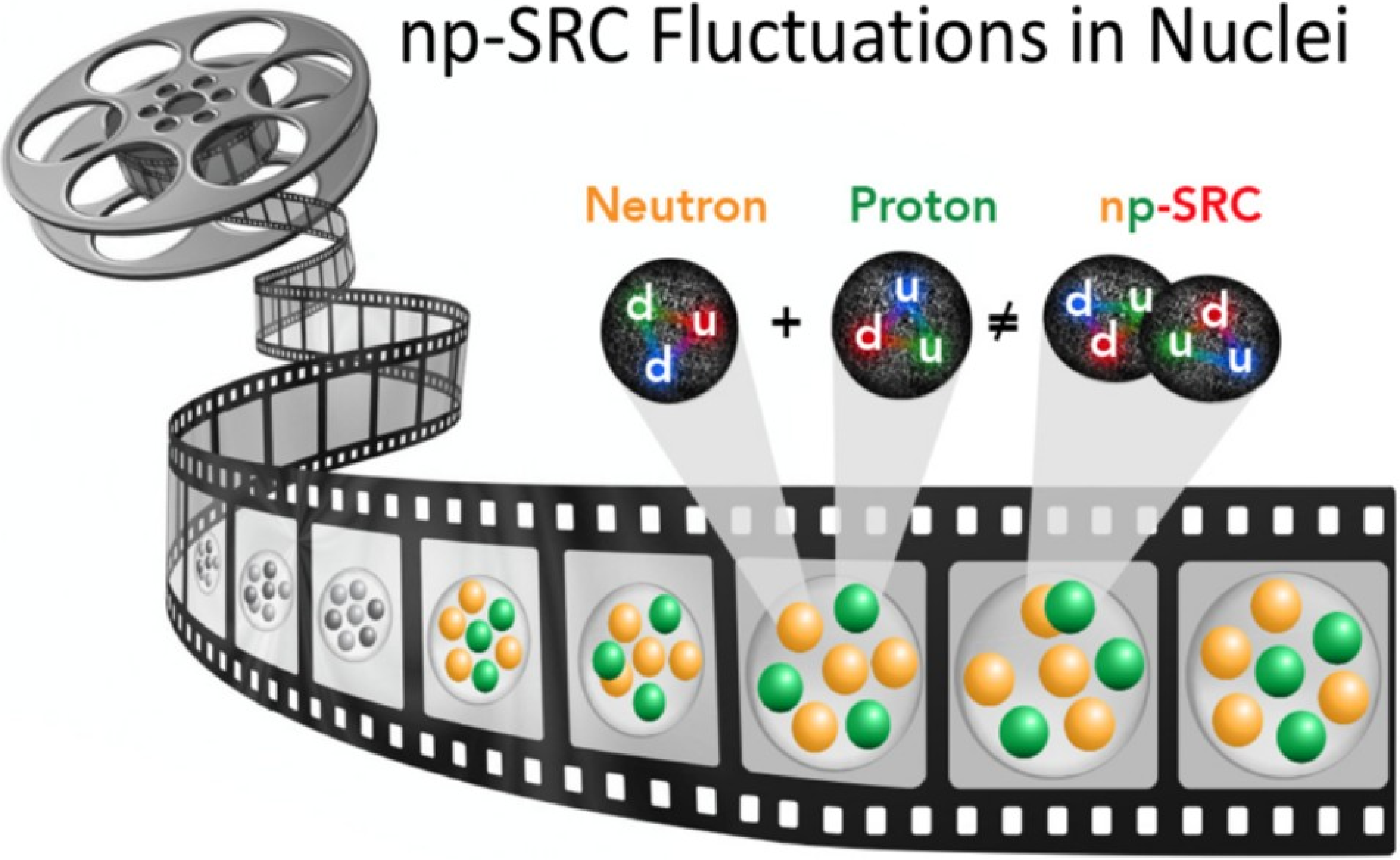
New EMC-SRC Correlation: Version II



New EMC-SRC Correlation: Version II



np-SRC Fluctuations in Nuclei



Additional Slides

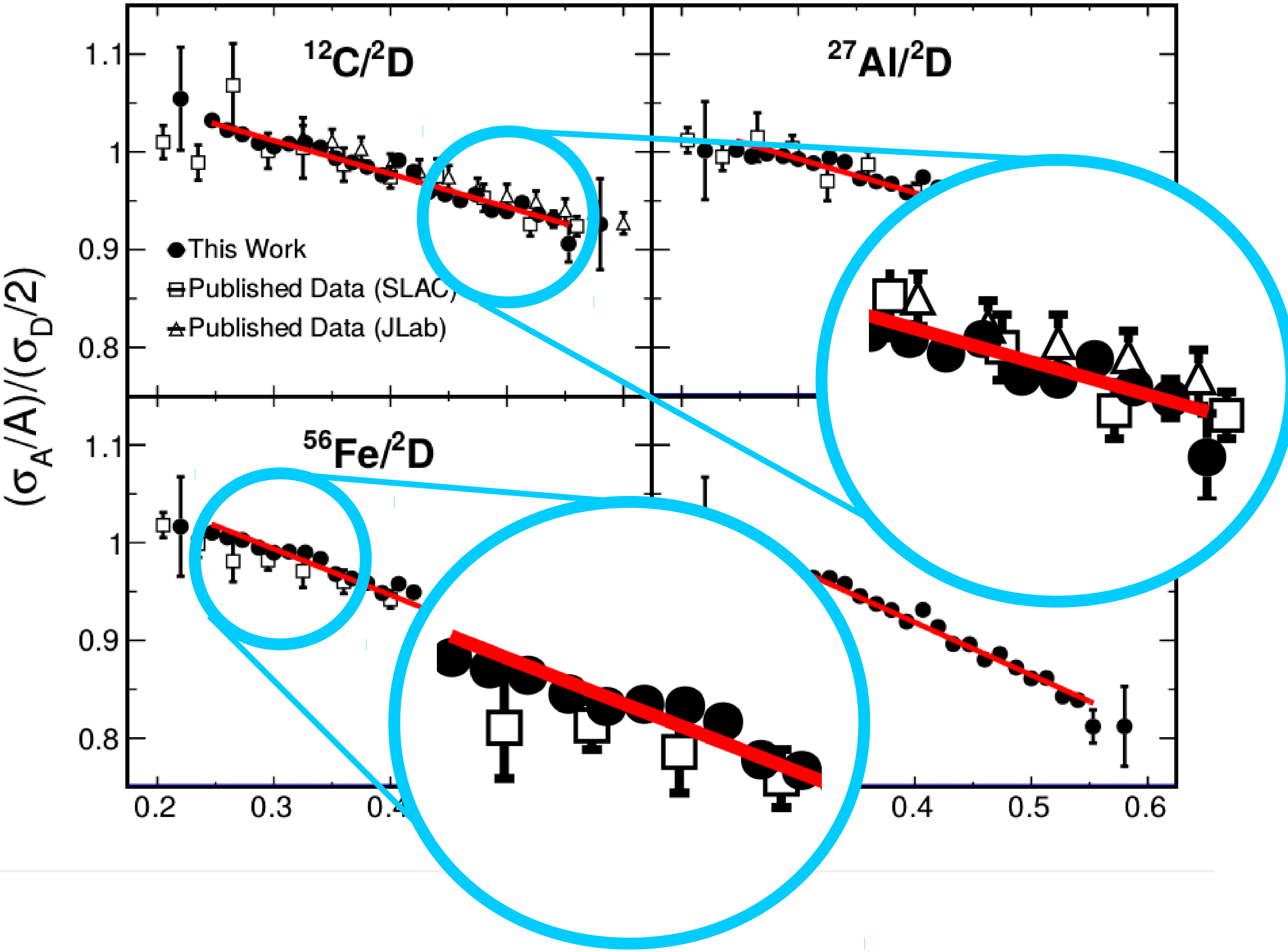
Uncertainties on DIS Cross-Section Ratios

Source	Point-to-point (%)	Normalization (%)
Time-Dependent Instabilities	—	1.0
Target Thickness and Cuts	—	1.42–1.58
Acceptance Corrections	0.6 (2,5)	—
Radiative Corrections	—	0.5
Coulomb Corrections	—	0.1
Bin-Centering Corrections	0.5	—
Total	0.78	1.81–1.94

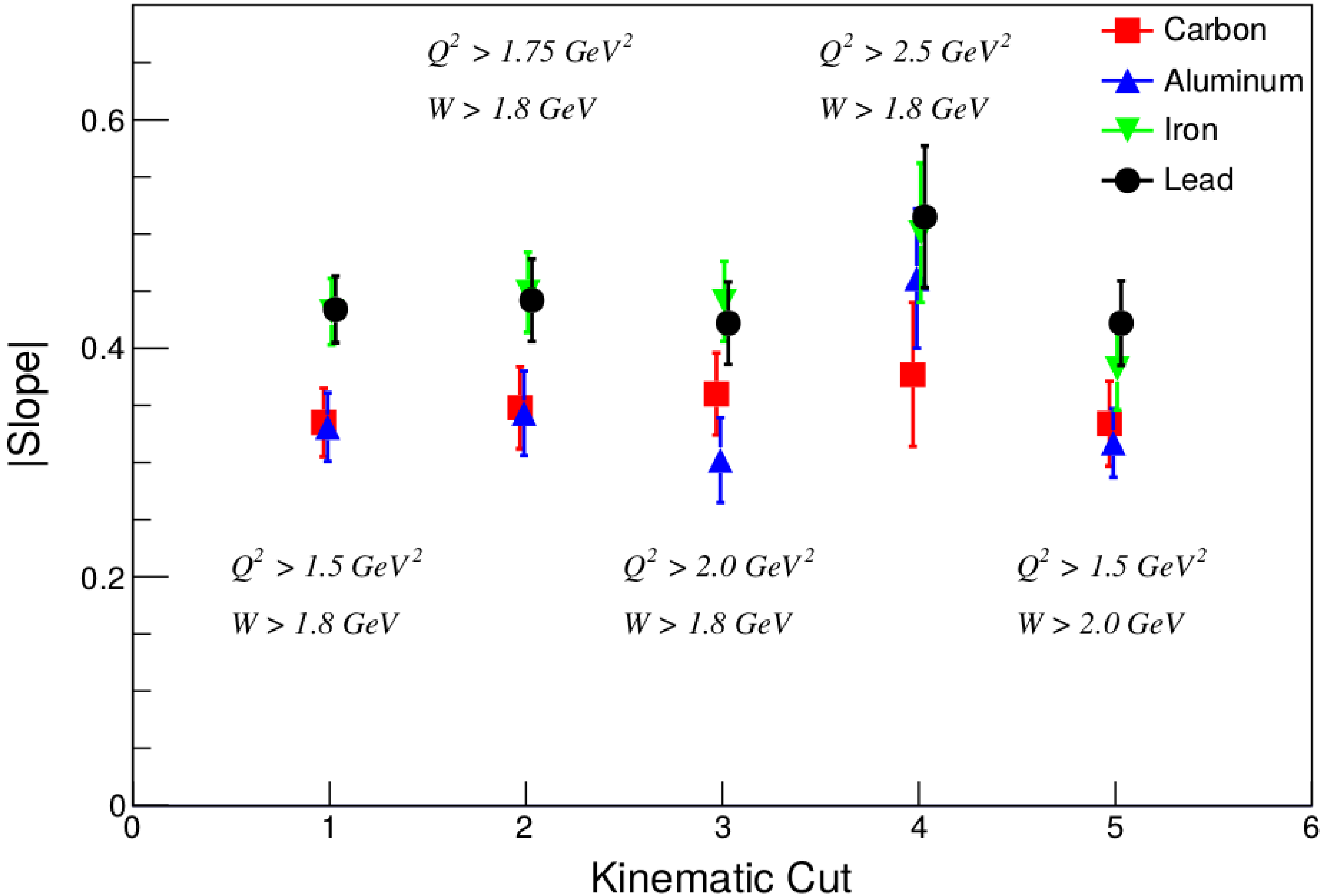
Uncertainties on QE Cross-Section Ratios

Source	Point-to-point (%)	Normalization (%)
Time-Dependent Instabilities	—	1.0
Target Thickness and Cuts	—	1.42–1.58
Acceptance Corrections	1.2 (2.5,10)	—
Radiative Corrections	—	0.5
Coulomb Corrections	—	0.2–1.0
Bin-Centering Corrections	0.5	—
Kinematical Corrections	0.3	—
Total	1.33	1.82–2.18

Our New EMC Effect Measurements

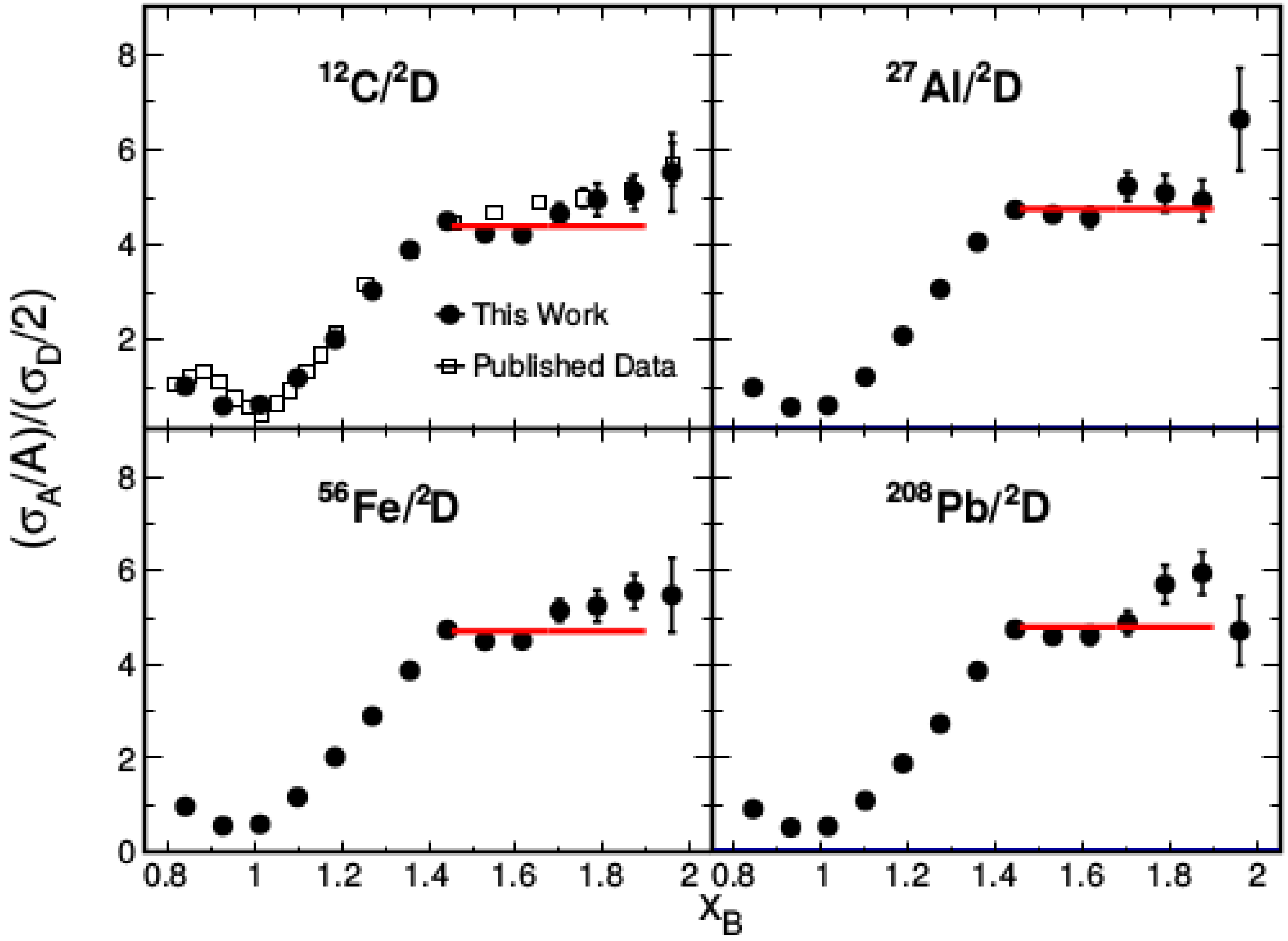


EMC Slopes are Stable to Kinematic Cut

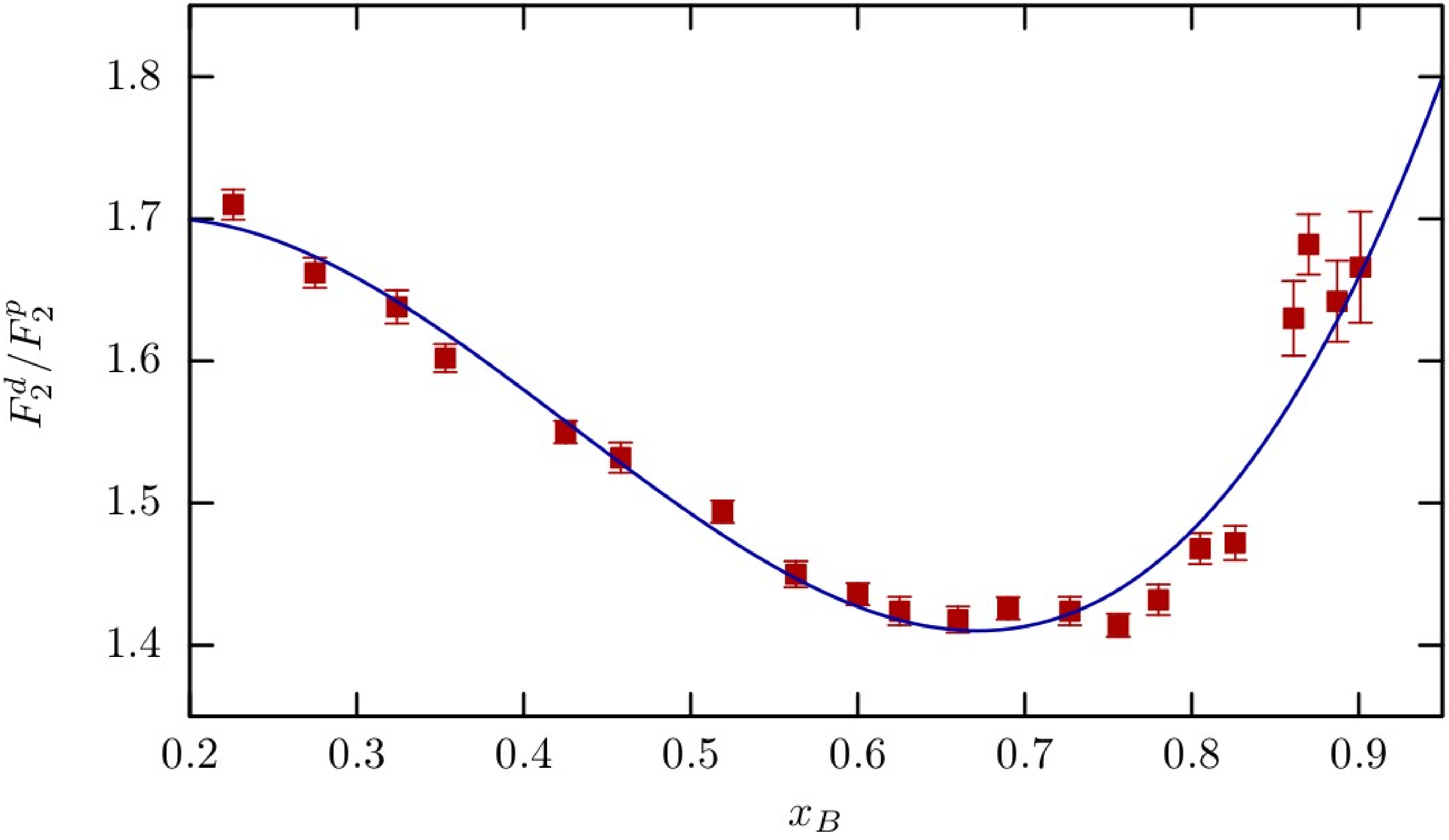


QE Results with Wider Binning

Kinematic Cut: Q^2>1.5 GeV^2



Compare DIS on Deuterium



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