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Does a nucleon appears different when inside a nucleus ?

Patricia Solvignon

Argonne National Laboratory

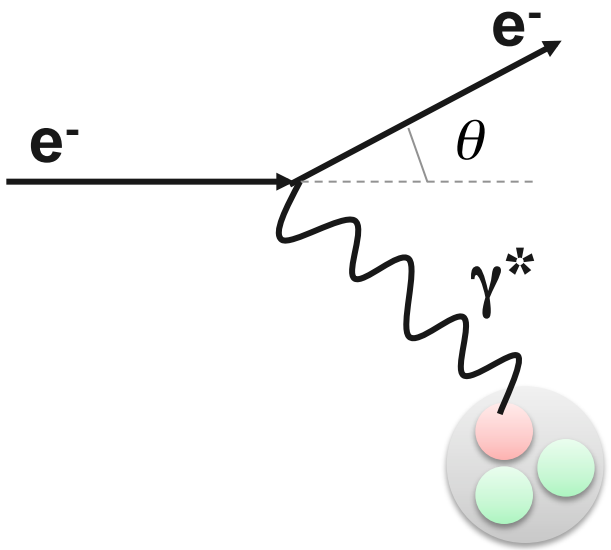
Postdoctoral Research Symposium
September 11-12, 2008

Outline

- **Brief introduction to the EMC effect**
- **JLab E03-103 preliminary results:**
  - ***Q^2-dependence study with Carbon***
  - ***^{3}He and ^{4}He***
  - ***Heavy nuclei and Coulomb distortion***
- **New extrapolation to nuclear matter**

The structure of the nucleon

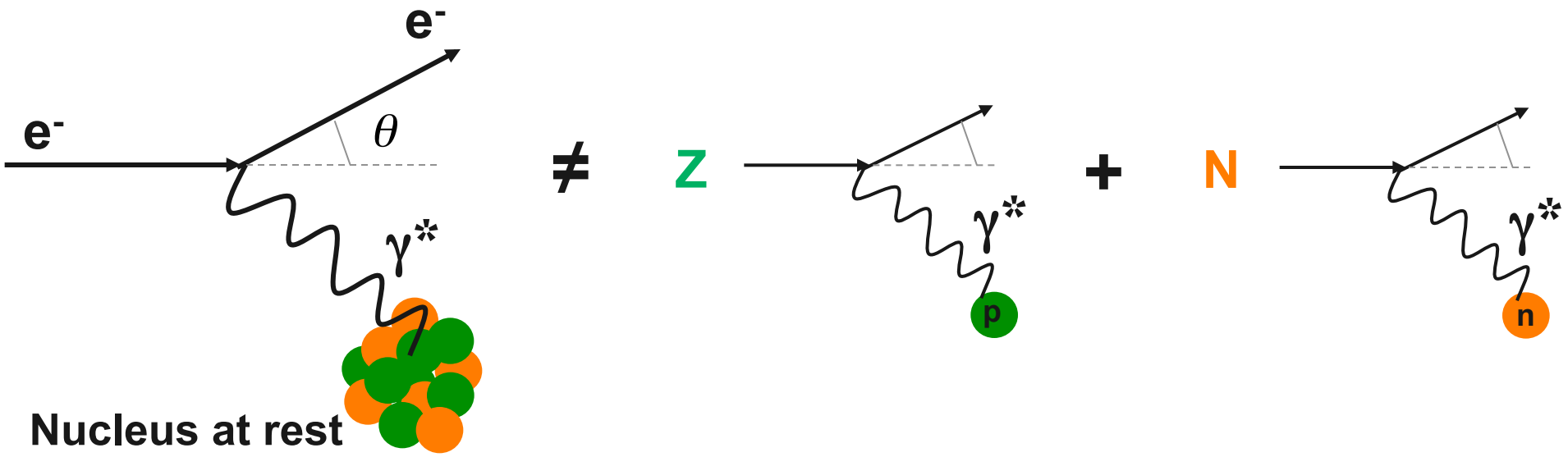
Deep inelastic scattering ➔ probe the constituents of the nucleon: the quarks and the gluons



To increase the luminosity, physicists decided to use heavy nuclei to study the structure of the proton instead of a hydrogen target.

But …

What is the EMC effect ?

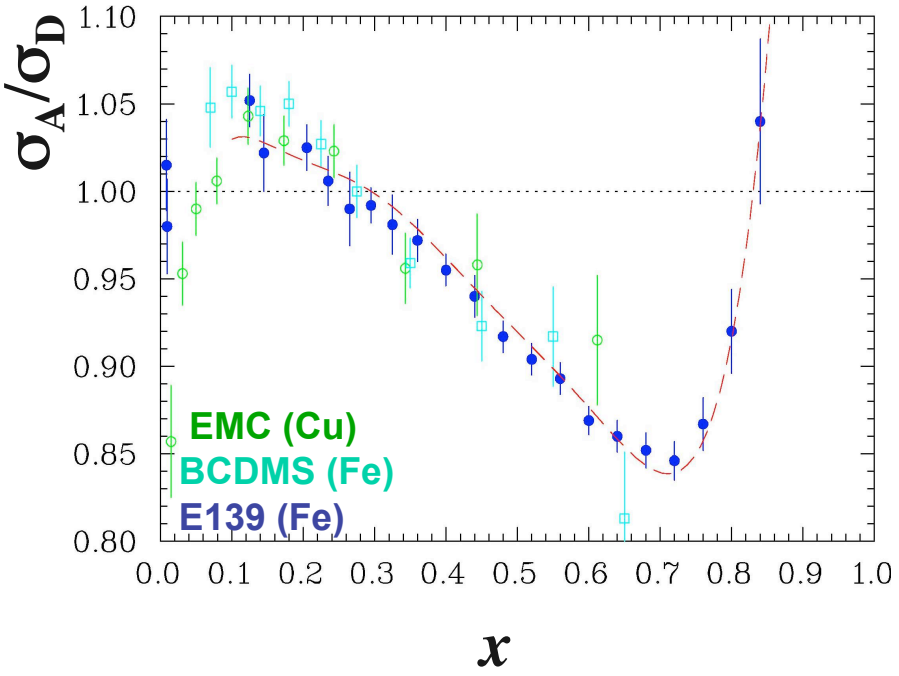


Nucleus at rest
(**A** nucleons = **Z** protons + **N** neutrons)

Nuclear structure:

$$\sigma_A \neq Z.\sigma_p + N.\sigma_n$$

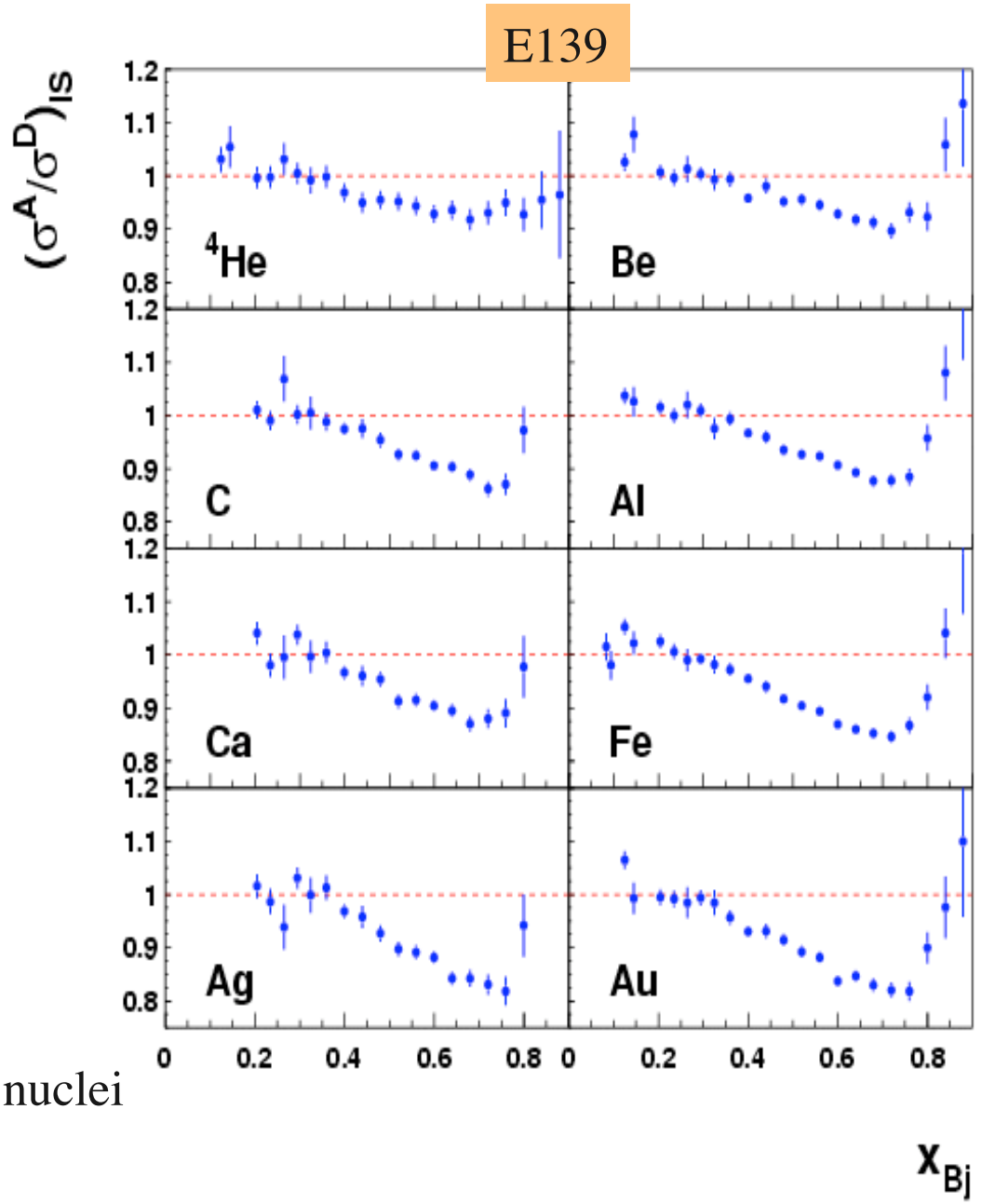
Effects found in several experiments at CERN, SLAC, DESY



Existing EMC Data

- **SLAC E139**
  - Most complete data set: A=4 to 197
  - Most precise at large *x*
    - → Q^2-independent
    - → universal shape
    - → magnitude dependent on A
- **E03-103 will improve with**
  - Higher precision data for ^{4}He
  - Addition of ^{3}He data
  - Precision data at large *x* and on heavy nuclei

⇨ **Lowering Q^2 to reach high *x* region**



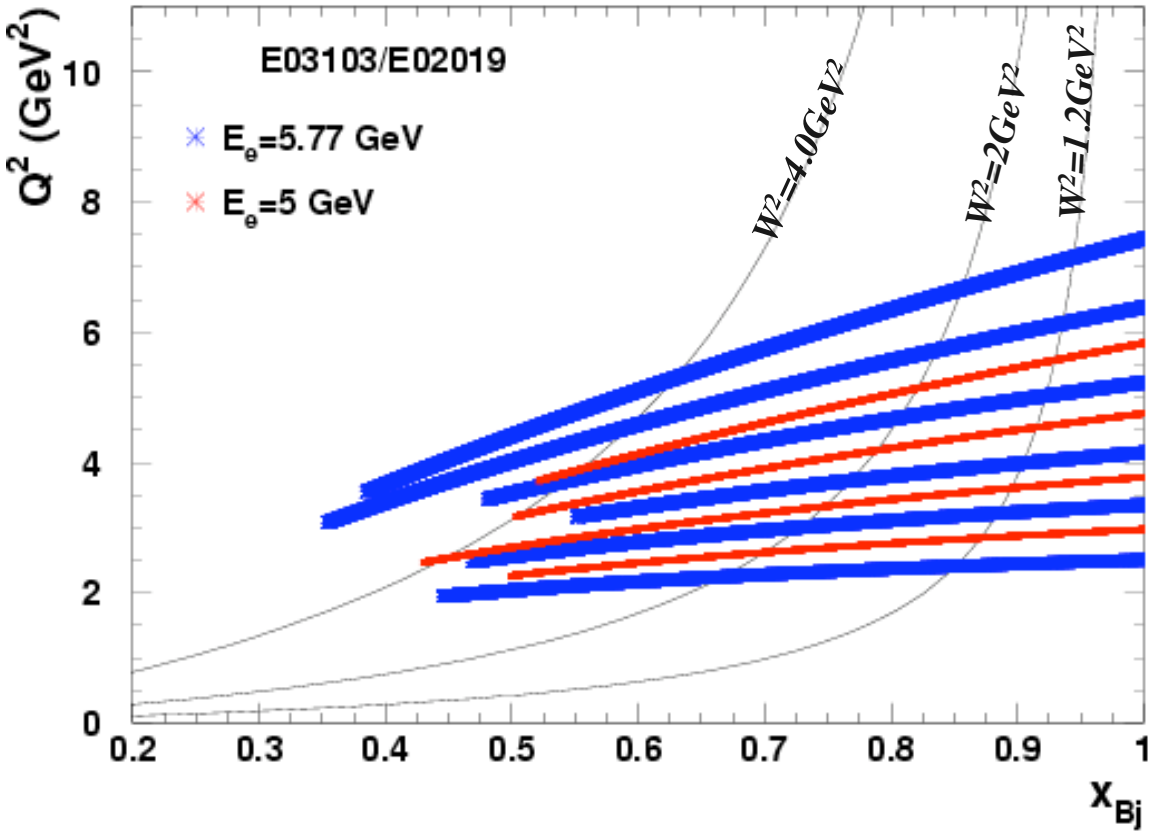
JLab Experiment E03-103

Spokespersons: D. Gaskell and J. Arrington
Post-doc: P. Solvignon
Graduate students: J. Seely and A. Daniel

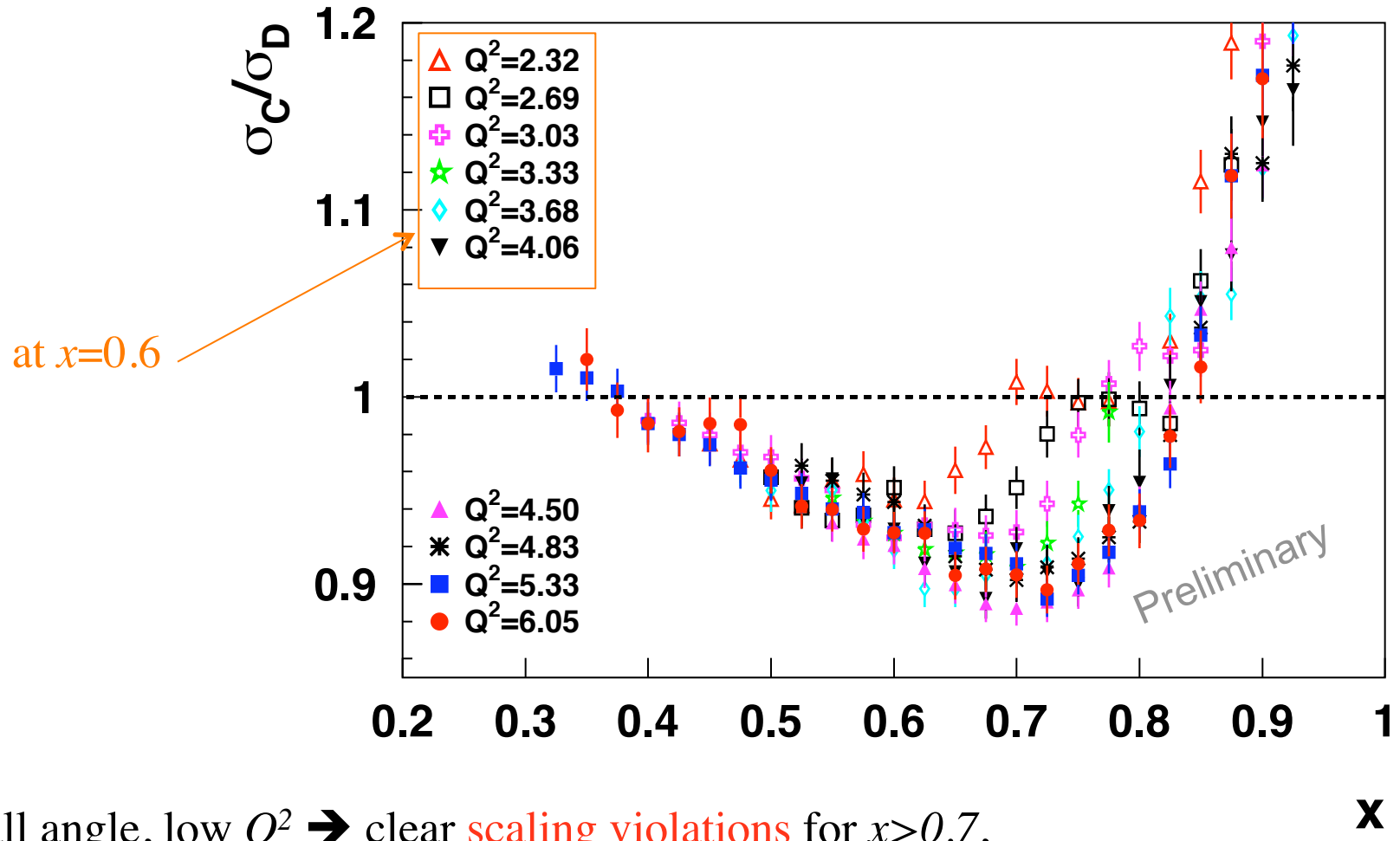
A(e,e') at 5.0 and 5.8 GeV in Hall C

- Targets:
  H, ^{2}H, ^{3}He, ^{4}He,
  Be, C, Al,
  Cu, Au

- 10 angles to measure Q^2-dependence

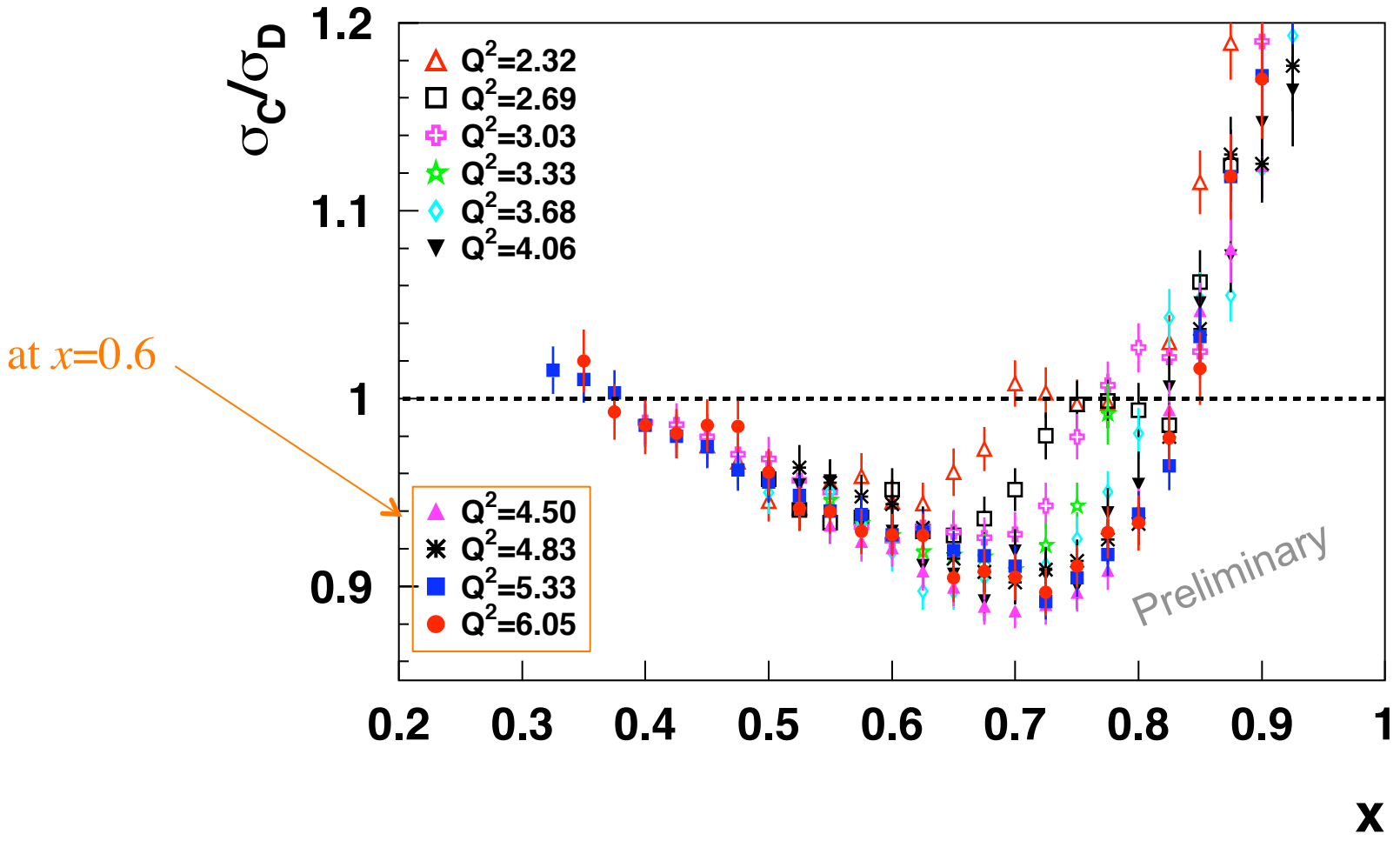


E03-103: Carbon EMC ratio and Q^2-dependence



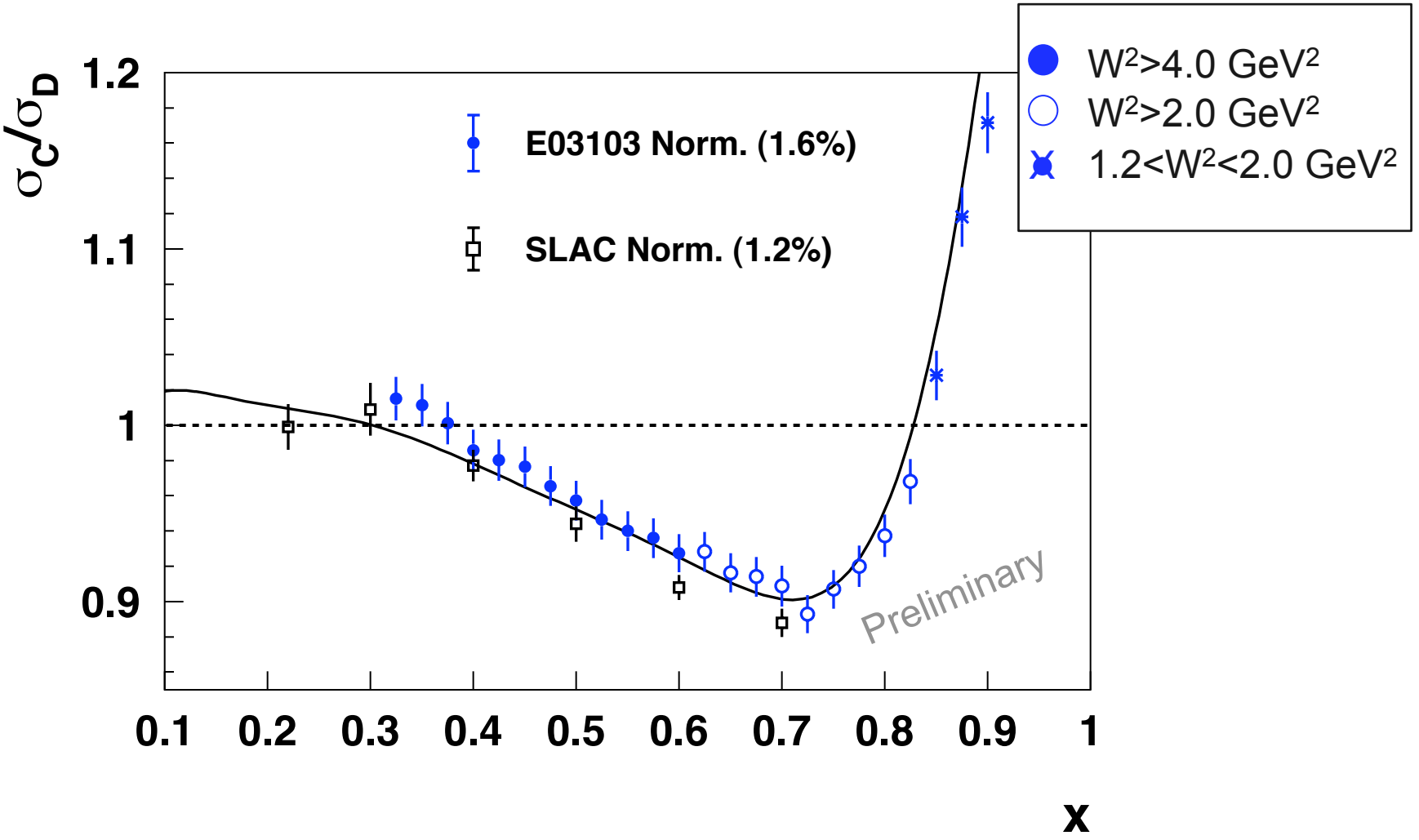
Small angle, low Q^2 ➔ clear scaling violations for $x>0.7$,
but surprisingly good agreement at lower x

E03-103: Carbon EMC ratio and Q^2-dependence



At larger angles ➔ indication of scaling to very large x

E03-103: Carbon EMC ratio

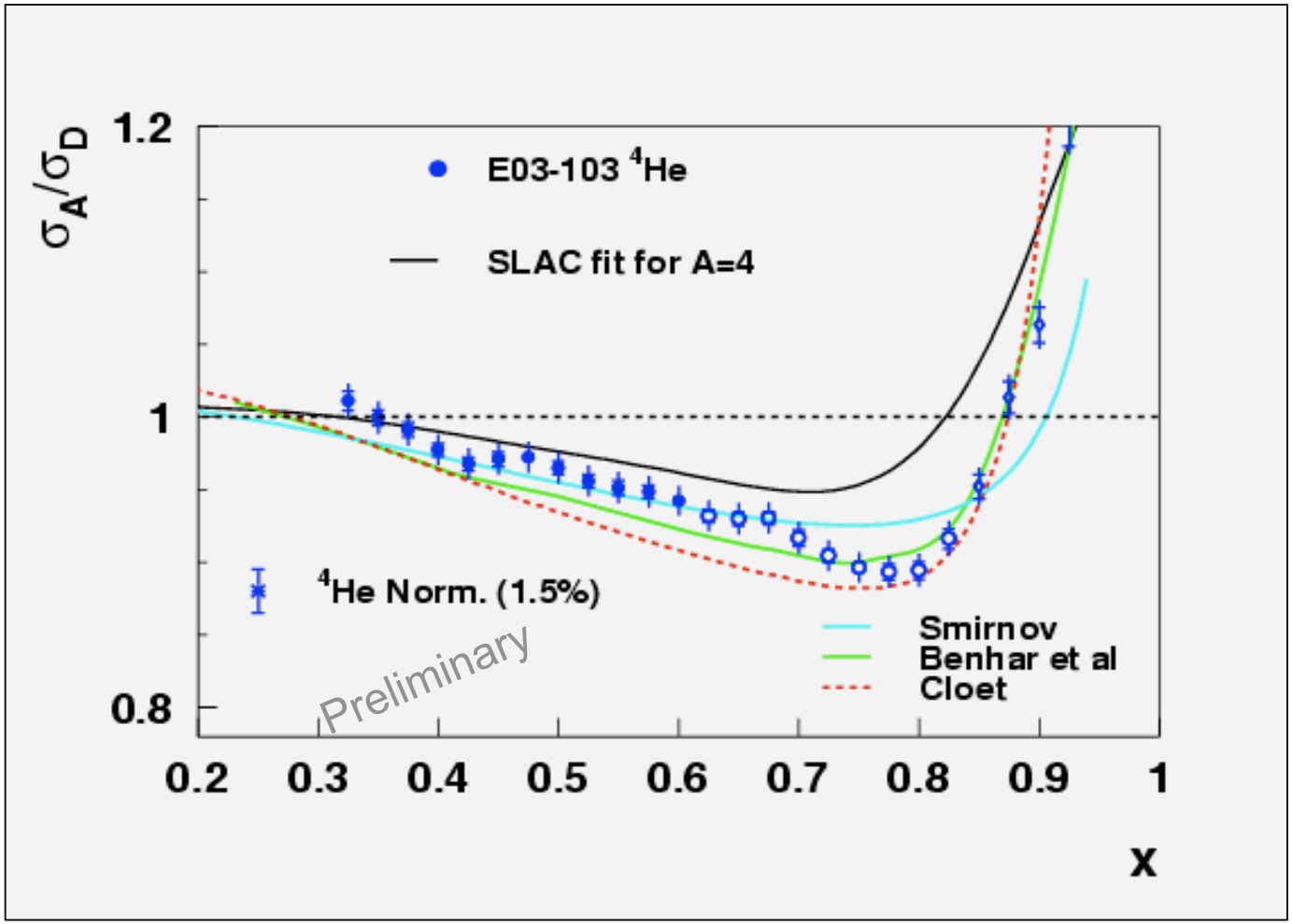


E03-103: ^{4}He

JLab results consistent with SLAC E139
→Improved statistics and systematic errors

Large *x* shape more clearly consistent with heavier nuclei

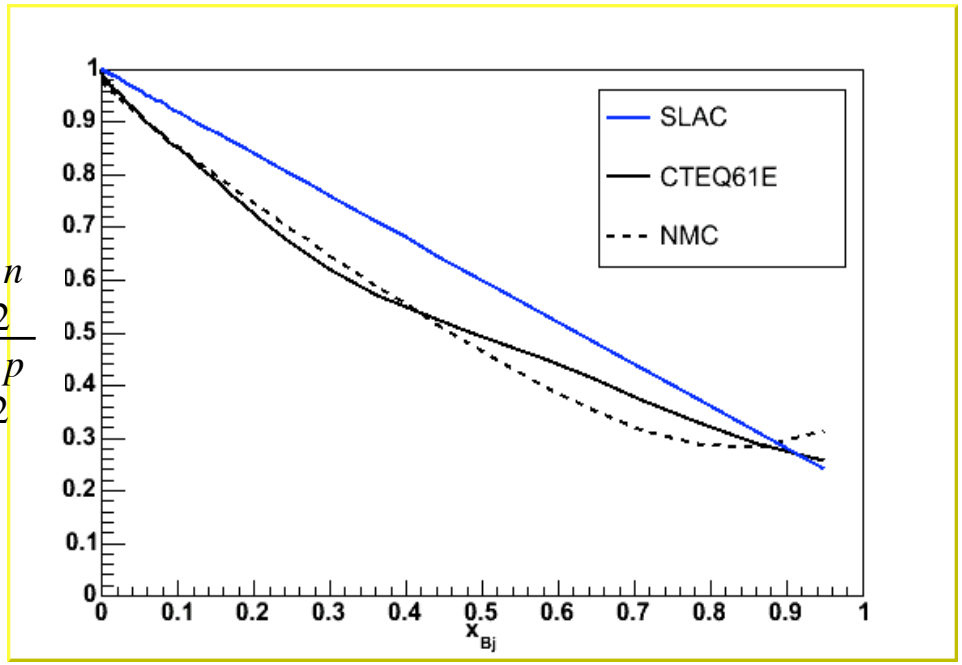
Models shown do a reasonable job describing the data



Isoscalar correction

$$R_{EMC} = \frac{\sigma_2^A / A}{\sigma_2^D / 2} \cdot \left(\frac{1 + F_2^n / F_2^p}{Z + N F_2^n / F_2^p} \right)$$

Isoscalar correction



SLAC fit: (1-0.8x)

Isoscalar correction

$$R_{EMC} = \frac{\sigma_2^A / A}{\sigma_2^D / 2} \cdot \left(\frac{1 + F_2^n / F_2^p}{Z + N F_2^n / F_2^p} \right)$$

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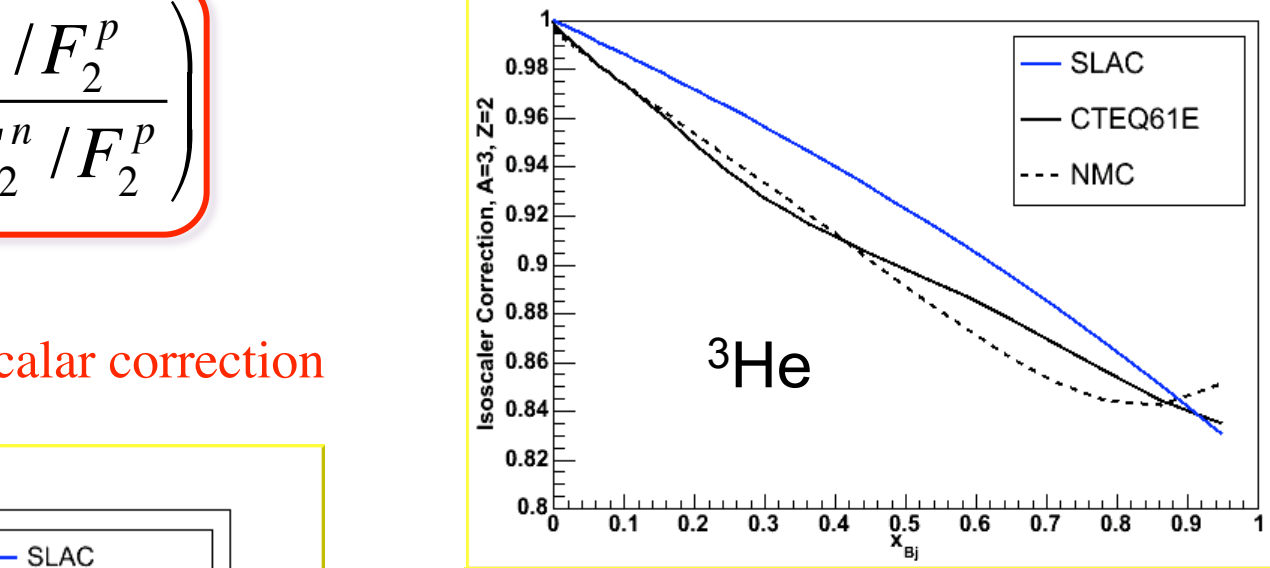
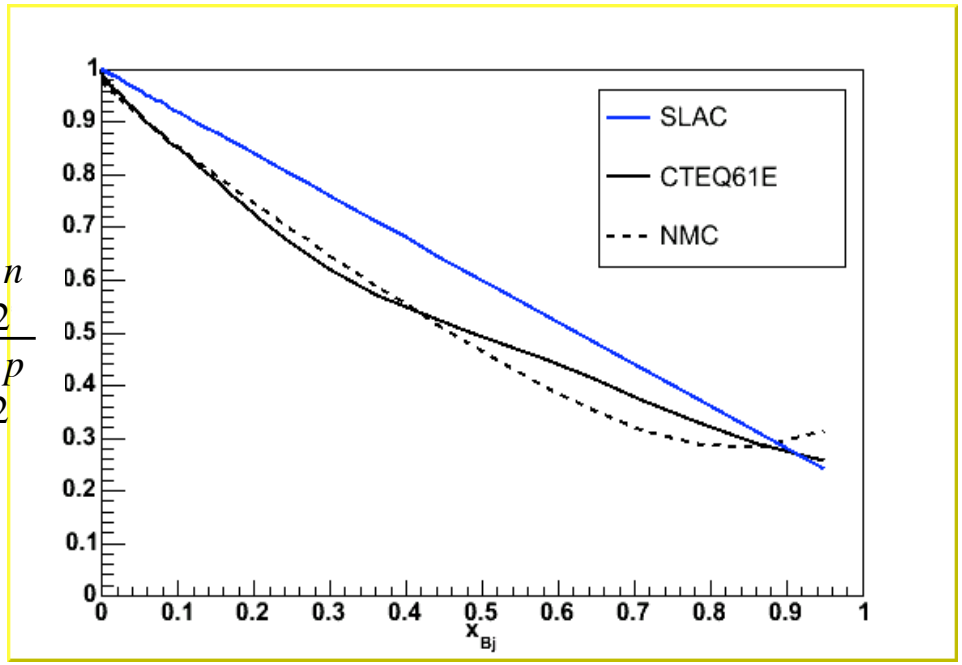
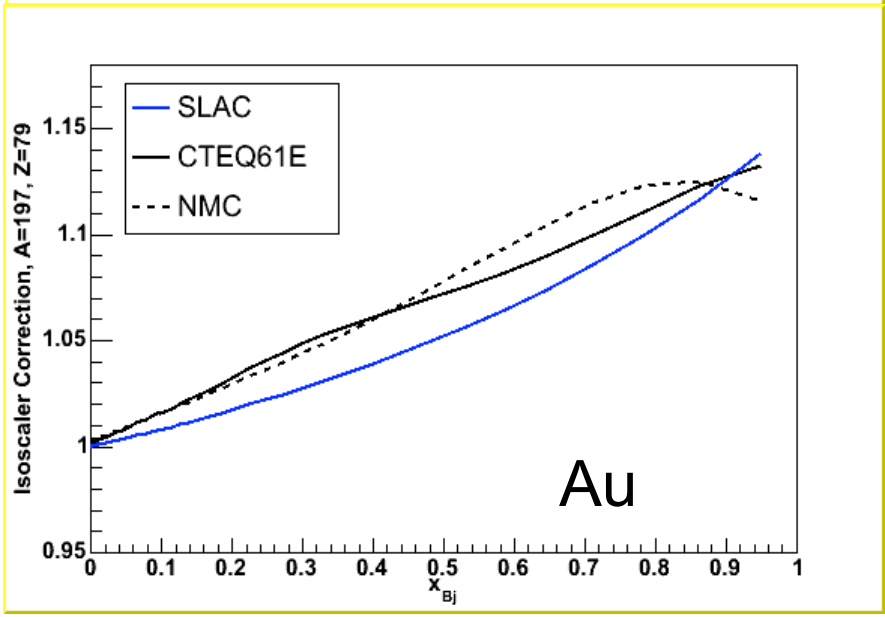


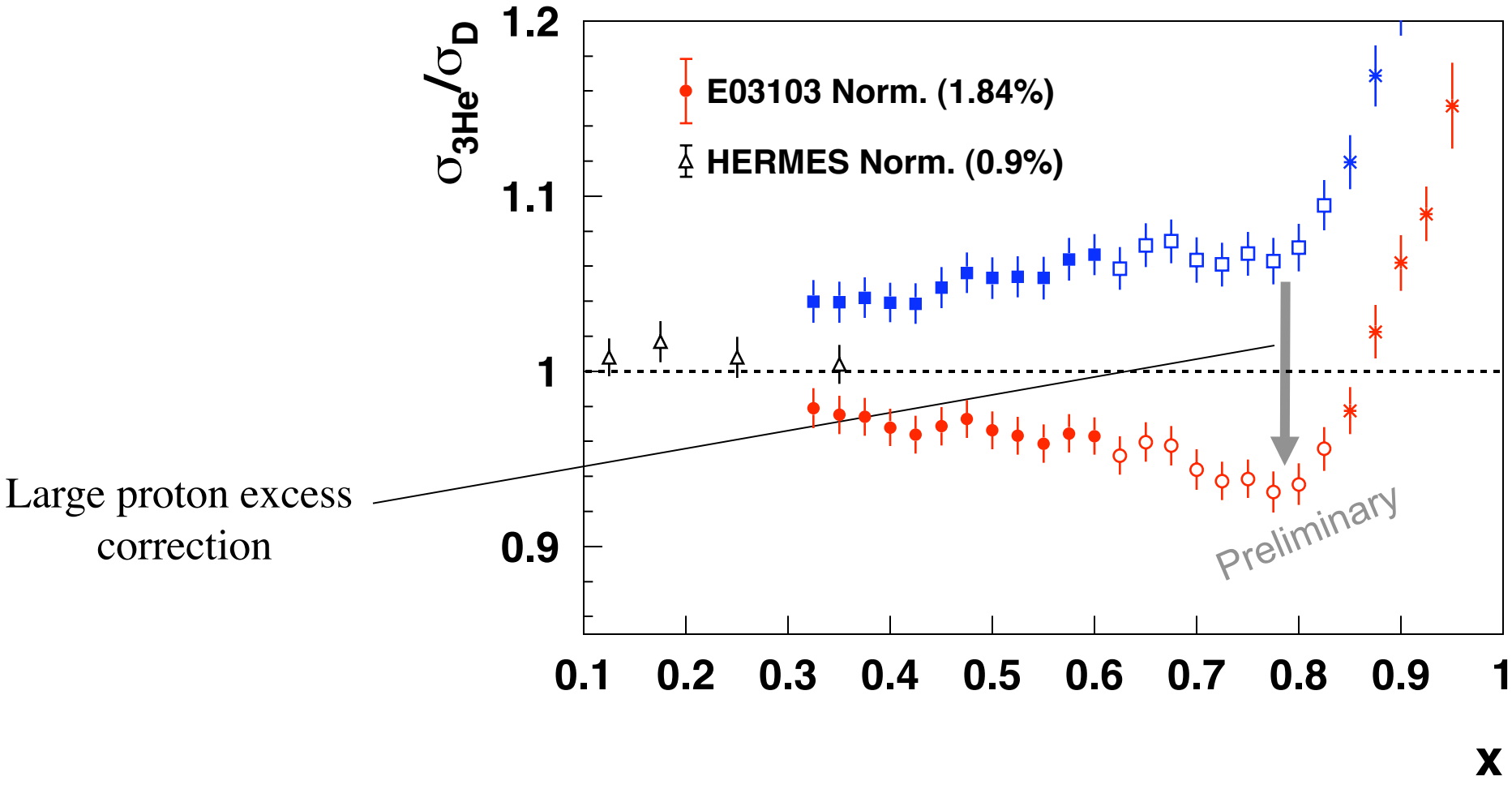
$$\frac{F_2^n}{F_2^p}$$





SLAC fit: (1-0.8x)

E03-103: Preliminary ^{3}He EMC ratio

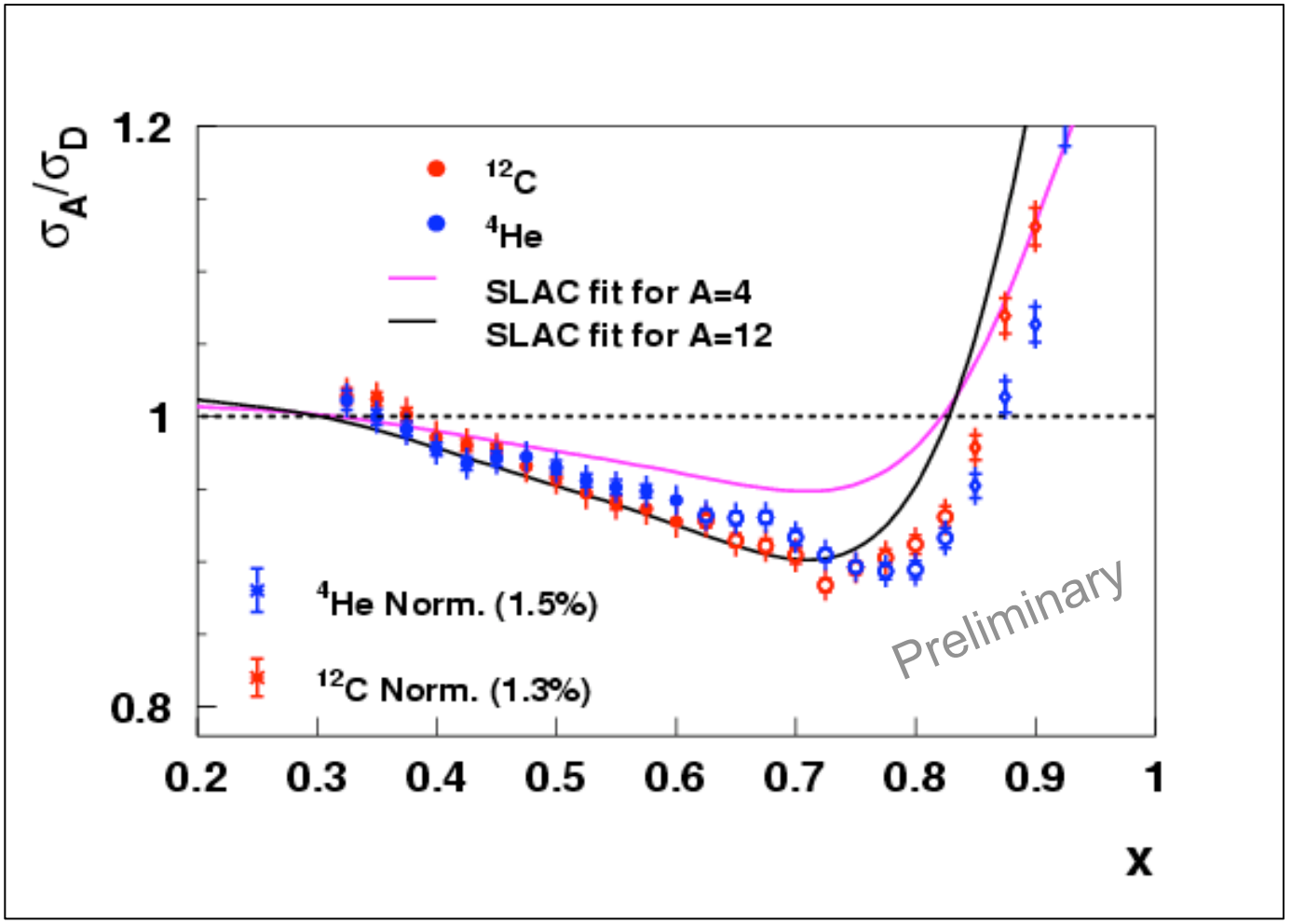


A or density dependence ?

Magnitude of the EMC effect for C and ^{4}He very similar

^{4}He more consistent with SLAC A=12 fit than A=4

$\rho(^4\text{He}) \sim \rho(^{12}\text{C})$



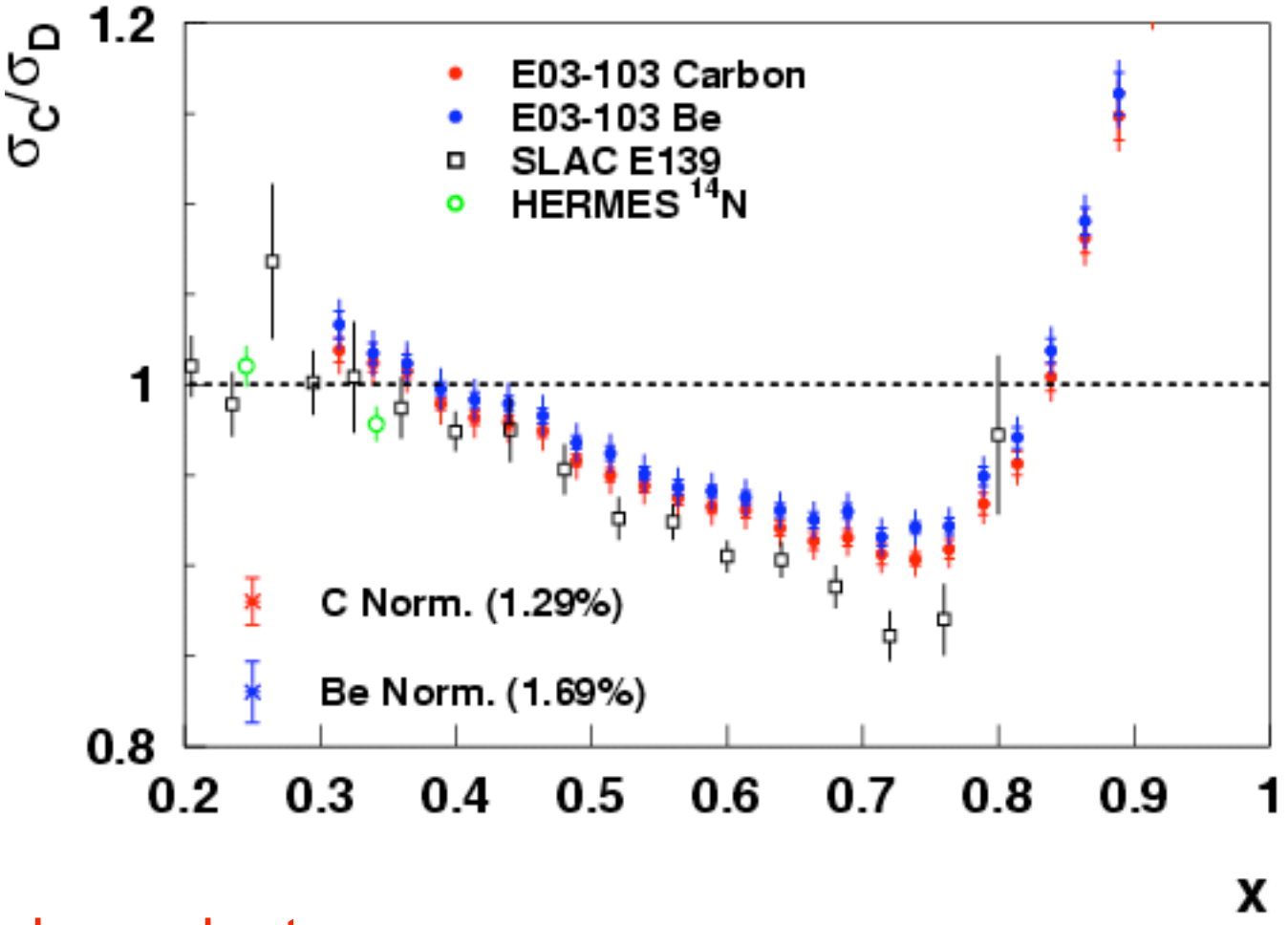
EMC effect: ρ−dependent

A or density dependence ?

Magnitude of the EMC effect for C and ^{9}Be very similar

But:

$\rho(^{9}Be) << \rho(^{12}C)$



EMC effect: A-dependent

Coulomb distortions on heavy nuclei

Initial (scattered) electrons are accelerated (decelerated) in Coulomb field of nucleus with *Z* protons

- Not accounted for in typical radiative corrections
- Usually, not a large effect at high energy machines – ***not true at JLab (6 GeV!)***

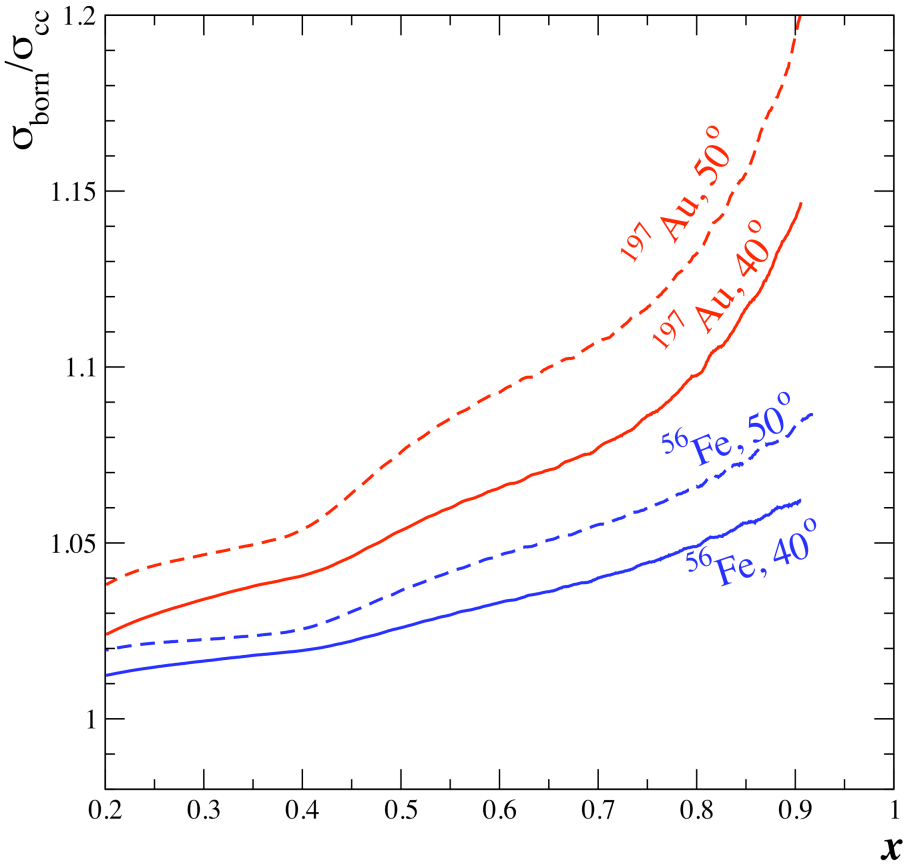
E03-103 uses modified Effective Momentum Approximation (EMA)

Aste and Trautmann, Eur, Phys. J. A26, 167-178(2005)

$$E \rightarrow E+\Delta$$
$$E' \rightarrow E'+\Delta$$

with $\Delta = -\frac{3}{4} V_0$

$V_0 = 3\alpha(Z-1)/(2r_c)$



Coulomb distortions on heavy nuclei

Initial

(scattered)

e

lectrons are accelerated (decelerated) in Coulomb field of nucleus with *Z* protons

- Not accounted for in typical radiative corrections
- Usually, not a large effect at high energy machines *not true at JLab (6 GeV!)*

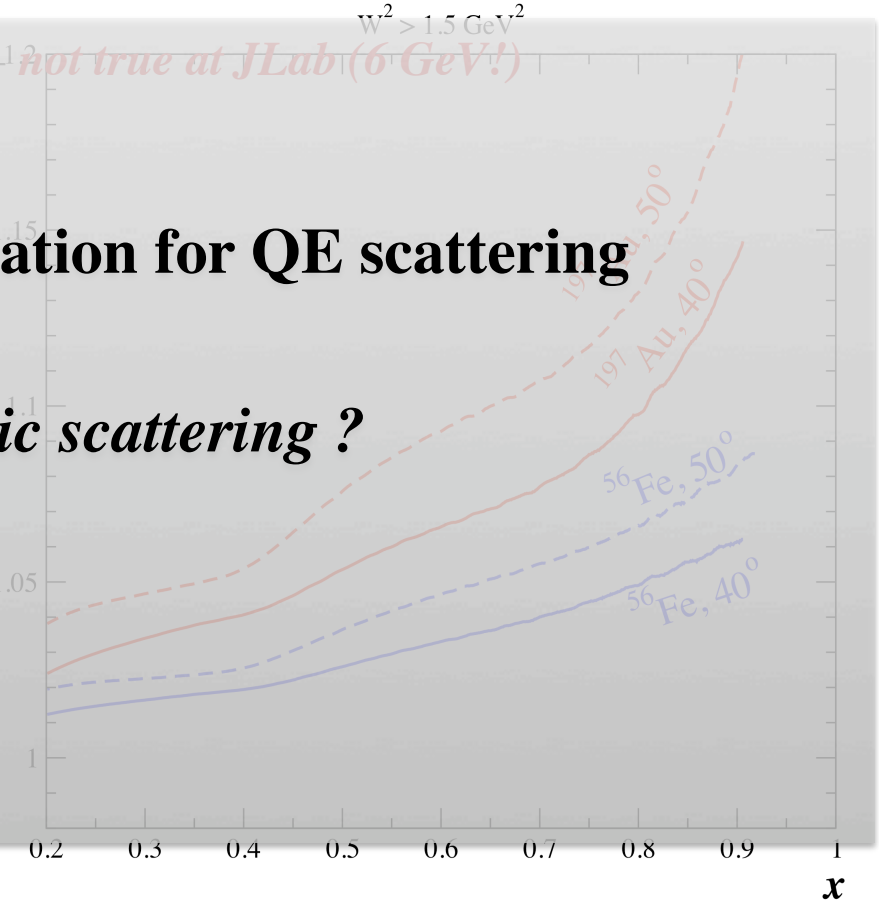
EMA tested against DWBA calculation for QE scattering

➔ ***application to inelastic scattering ?***

$E \rightarrow E+\Delta$

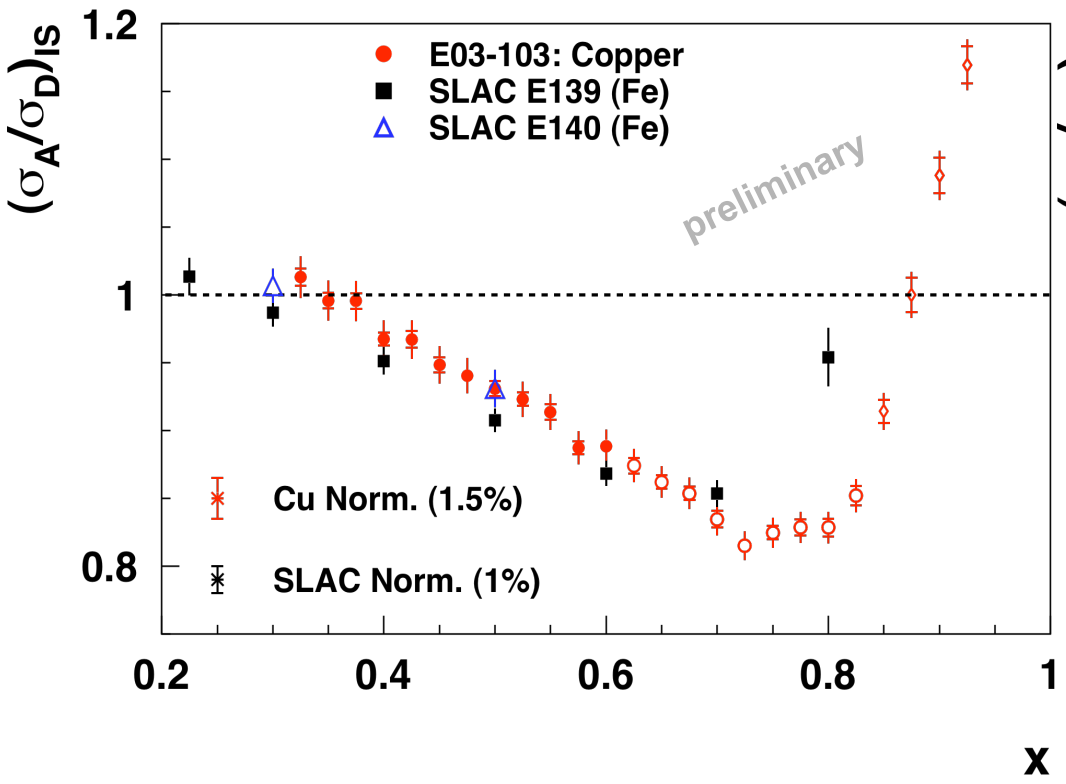
$E' \rightarrow E'+\Delta$

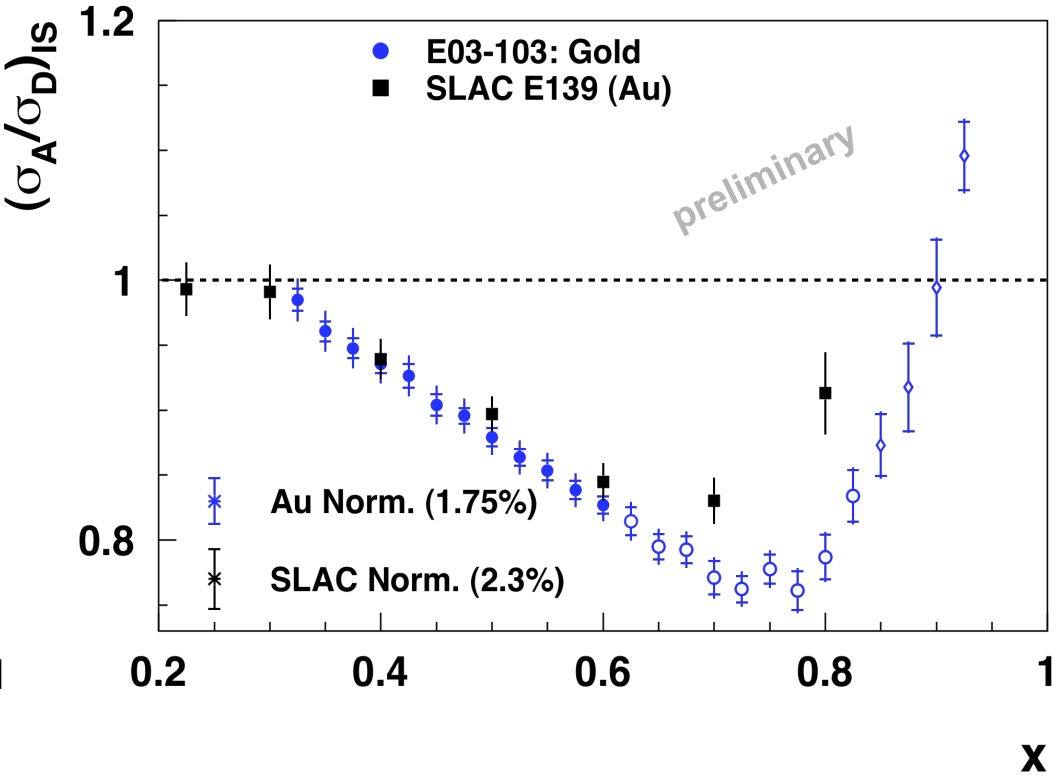
$\Delta = -\frac{3}{4} V_0,\ V_0 = 3\alpha(Z-1)/(2r_c)$



E03-013 heavy target results and world data

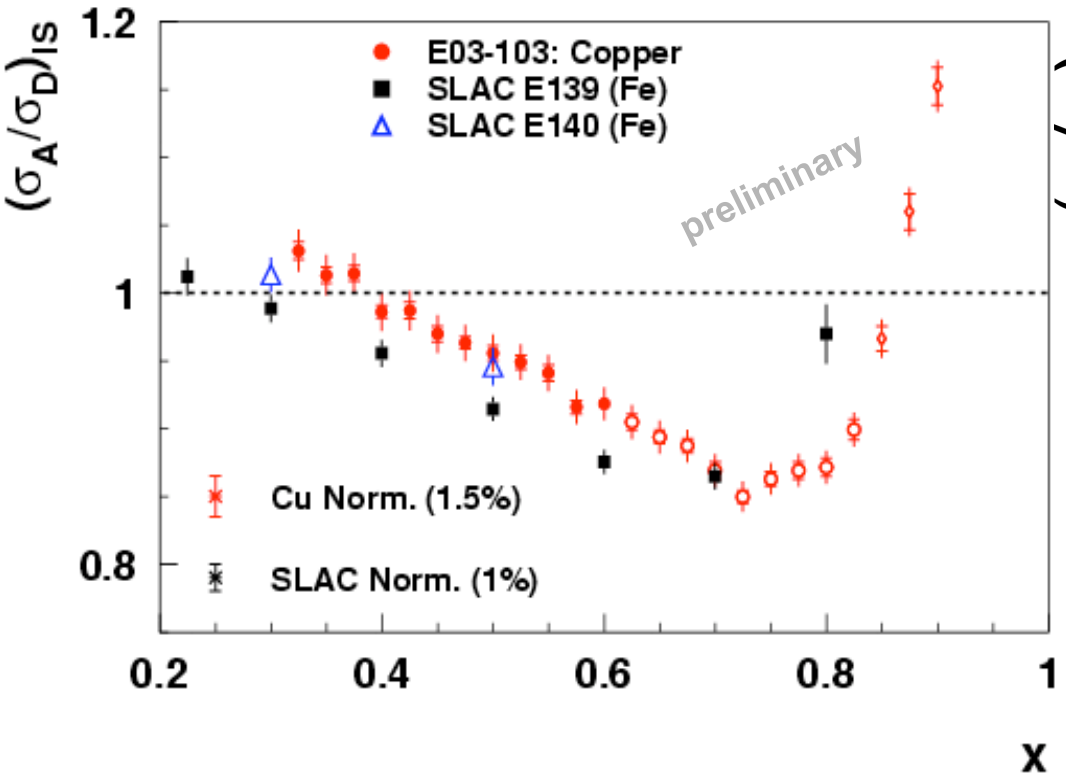
Before coulomb corrections

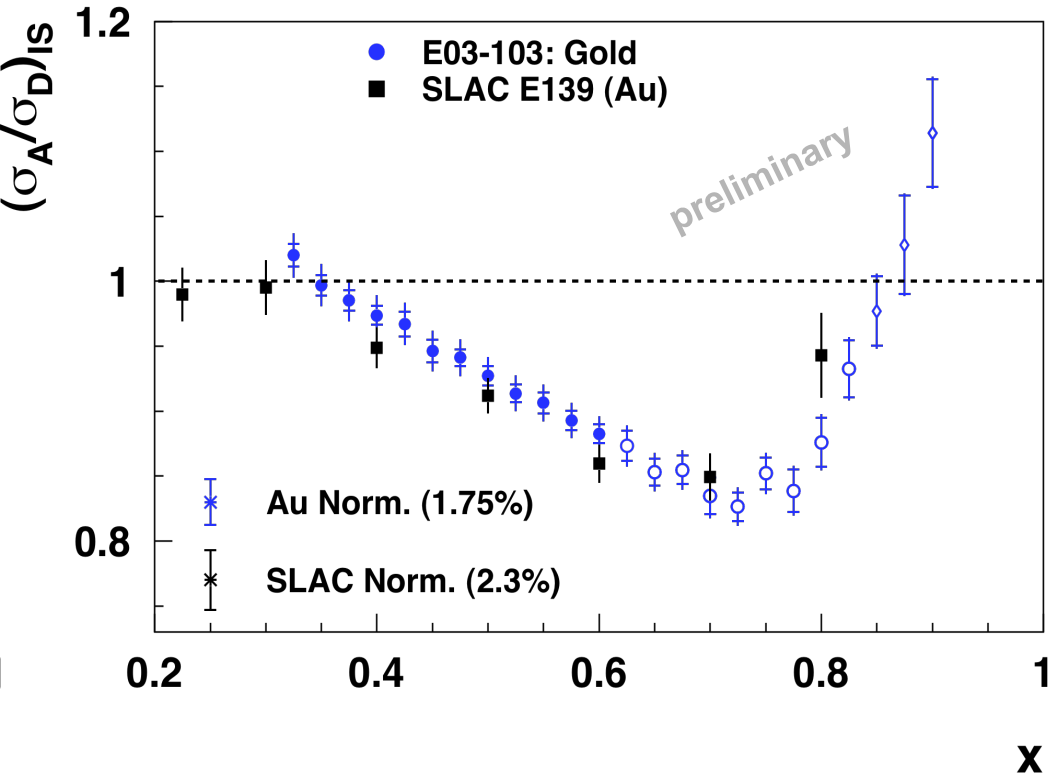




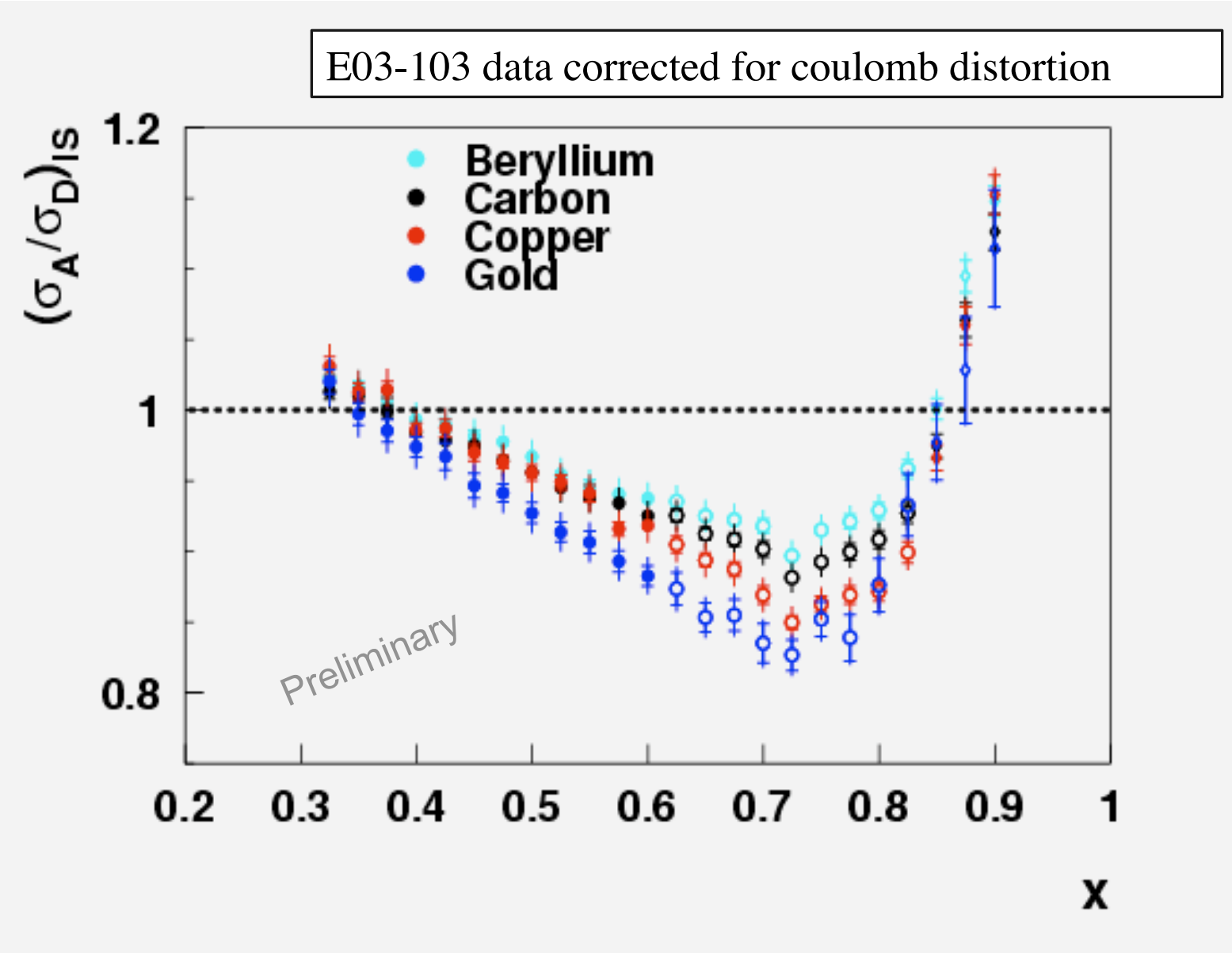
E03-013 heavy target results and world data

After coulomb corrections on all data

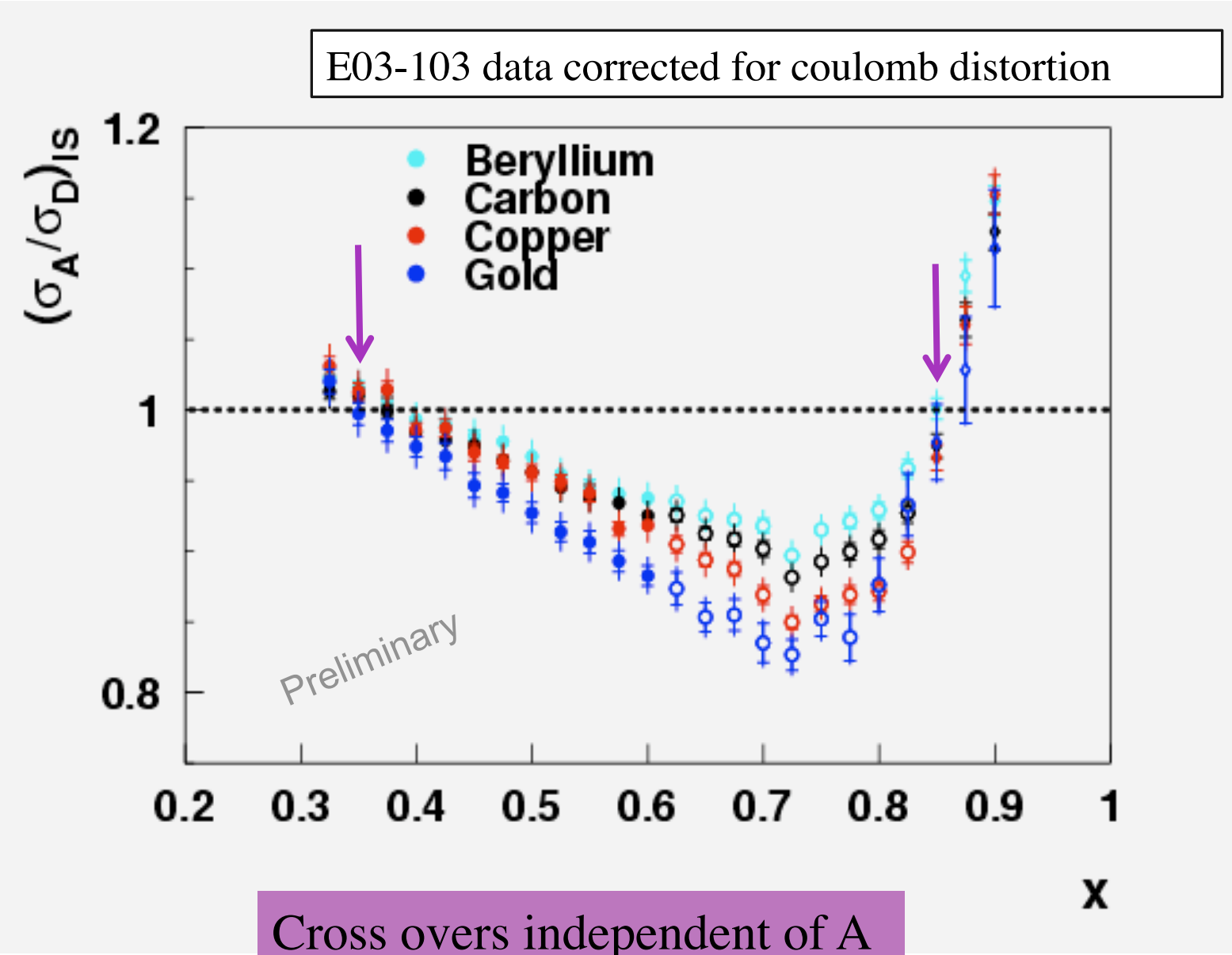




E03-103: EMC effect in heavy nuclei

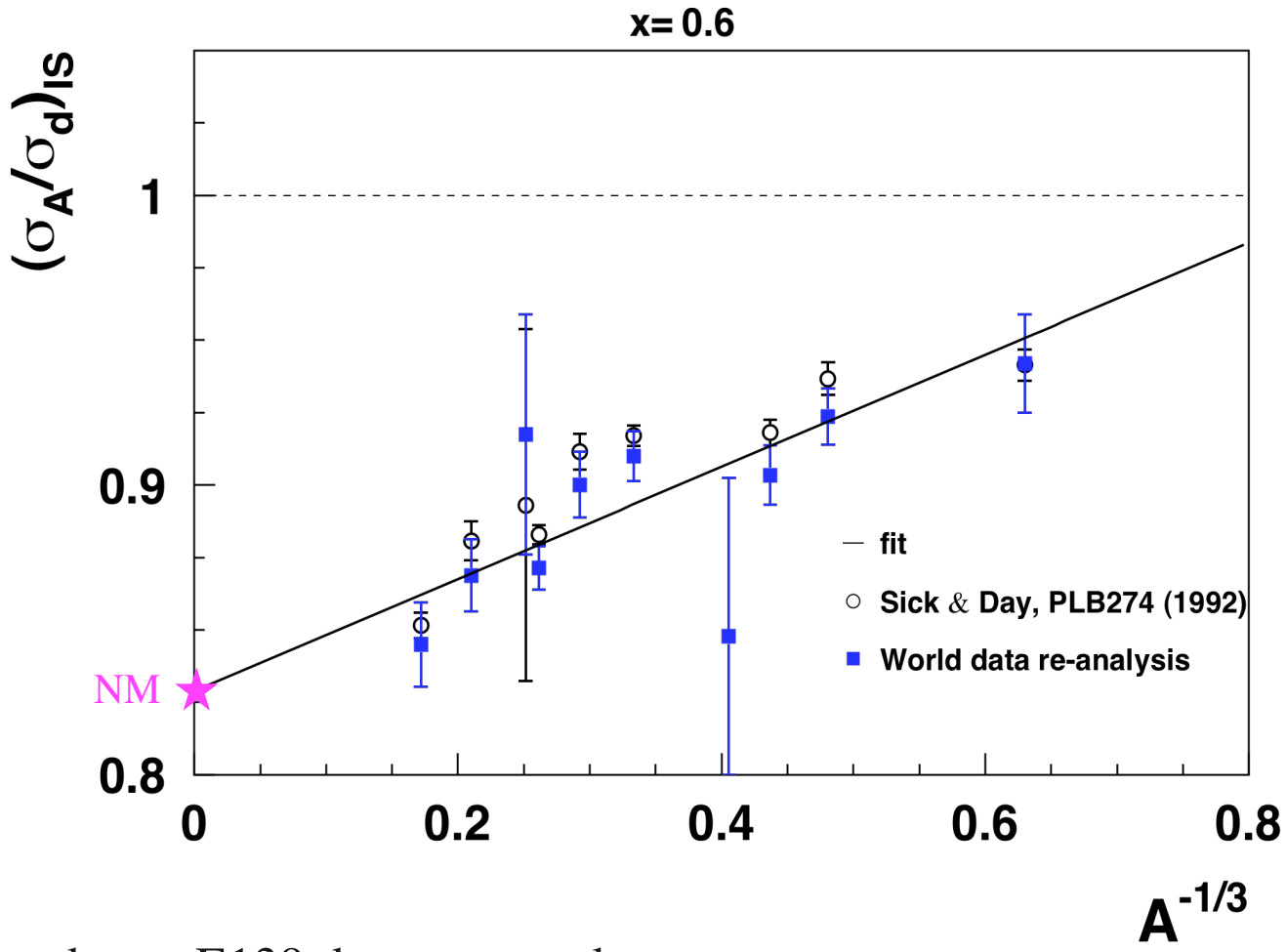


E03-103: EMC effect in heavy nuclei



Cross overs independent of A

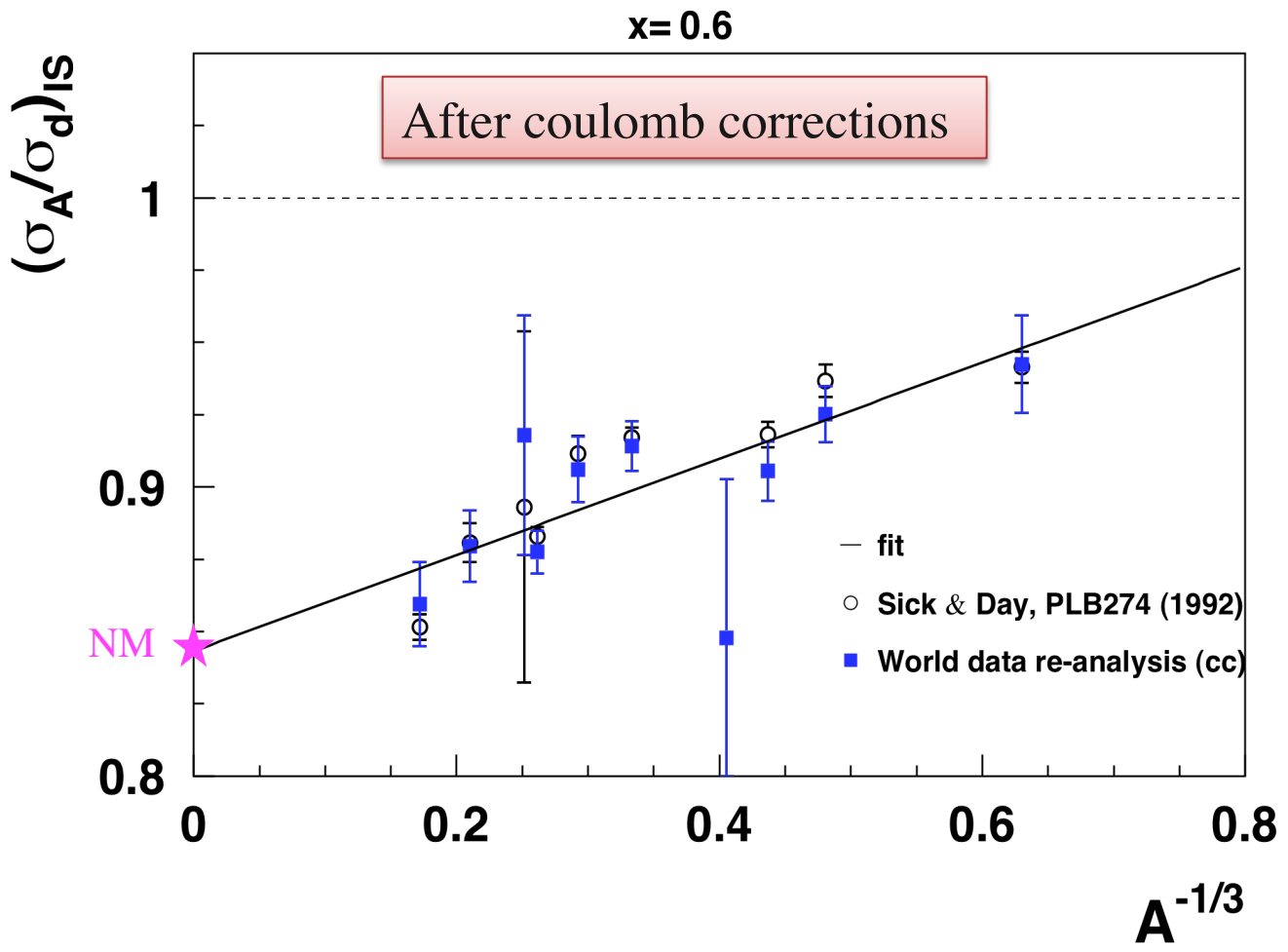
Nuclear dependence of the EMC effect



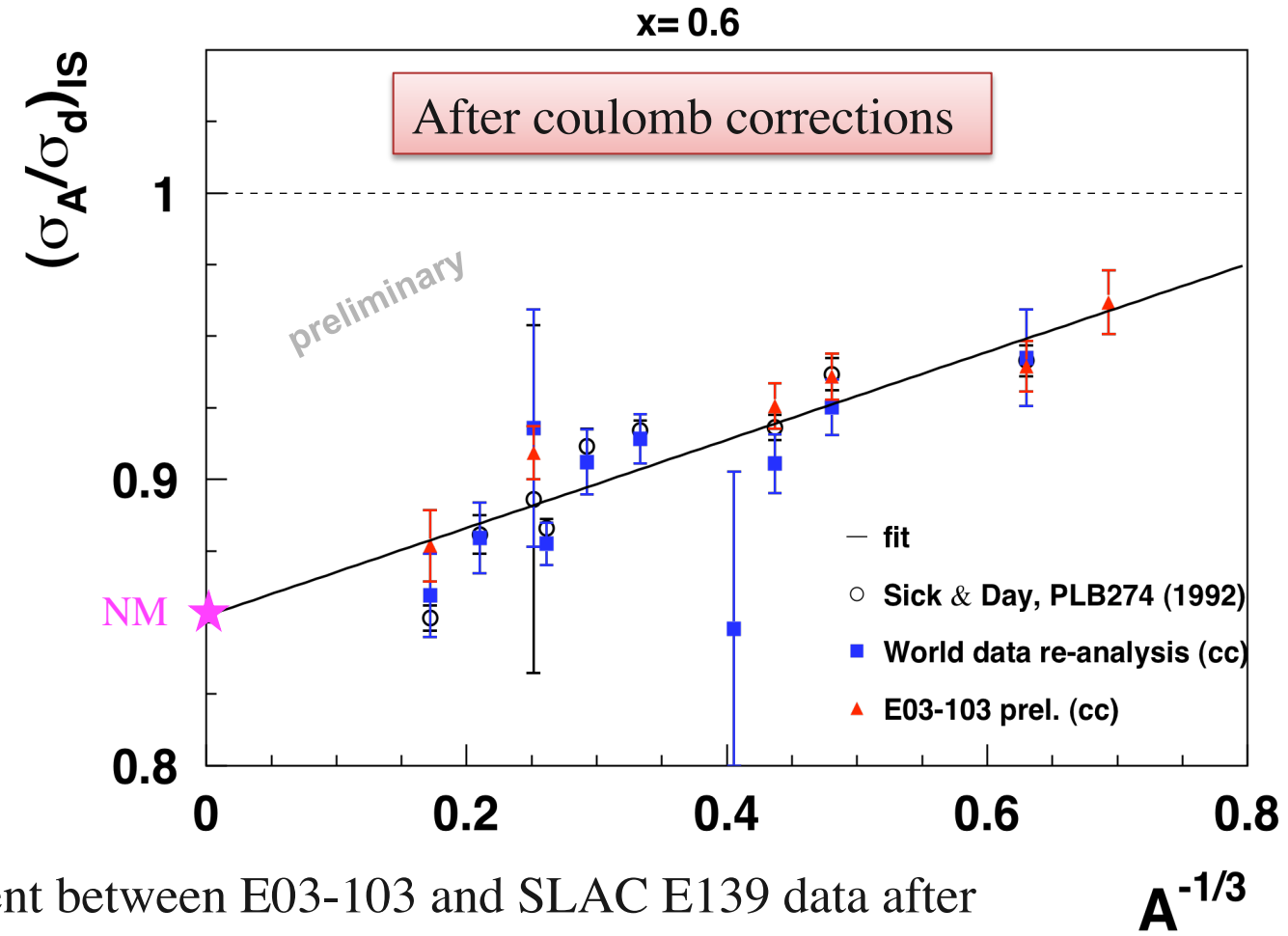
Main difference due to E139 data sets used:

- Sick & Day used E139 Q^2-avg tables
- we used E139 constant Q^2 to be able to apply CC

Nuclear dependence of the EMC effect



Nuclear dependence of the EMC effect

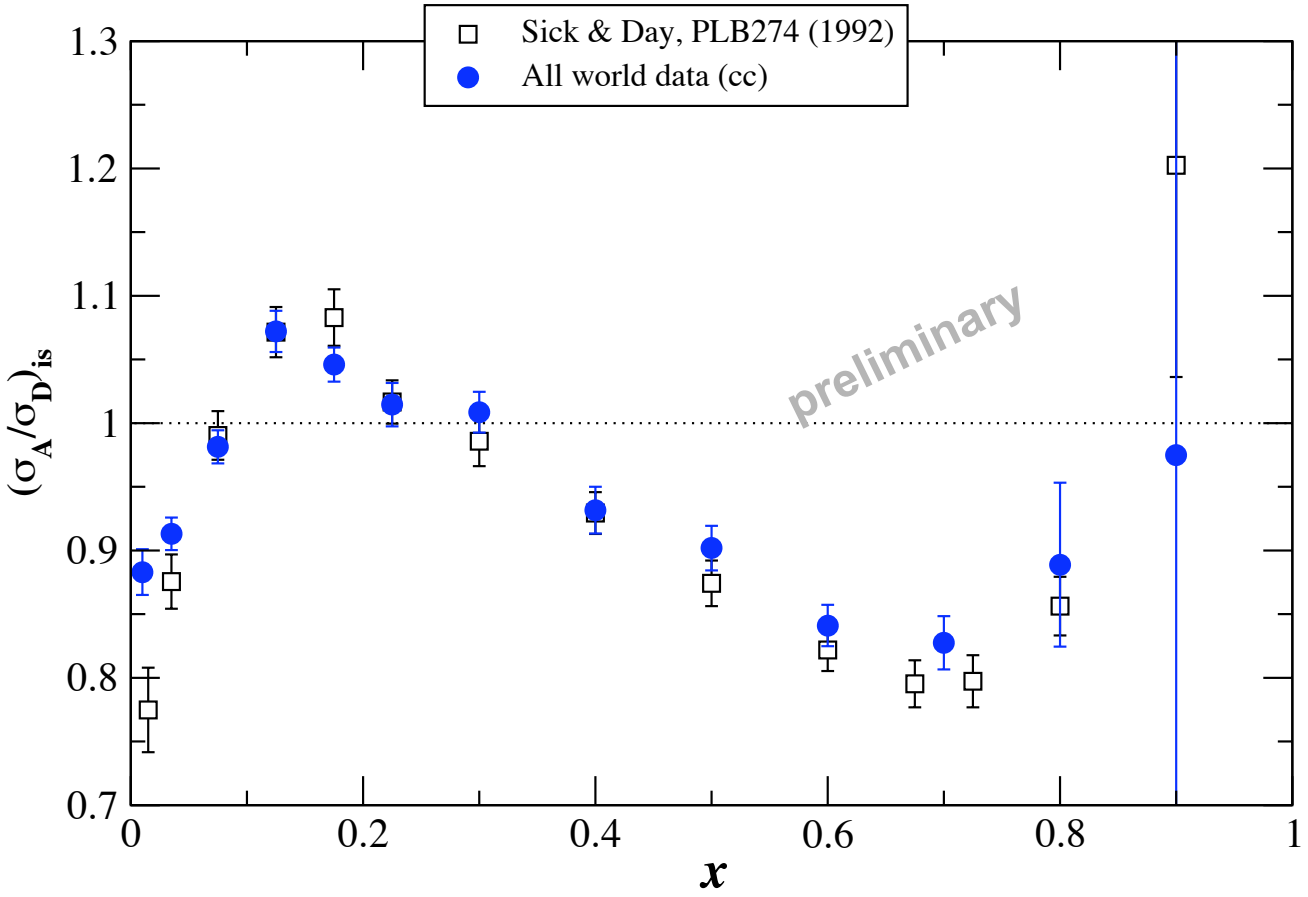


➢ Good agreement between E03-103 and SLAC E139 data after Coulomb corrections.

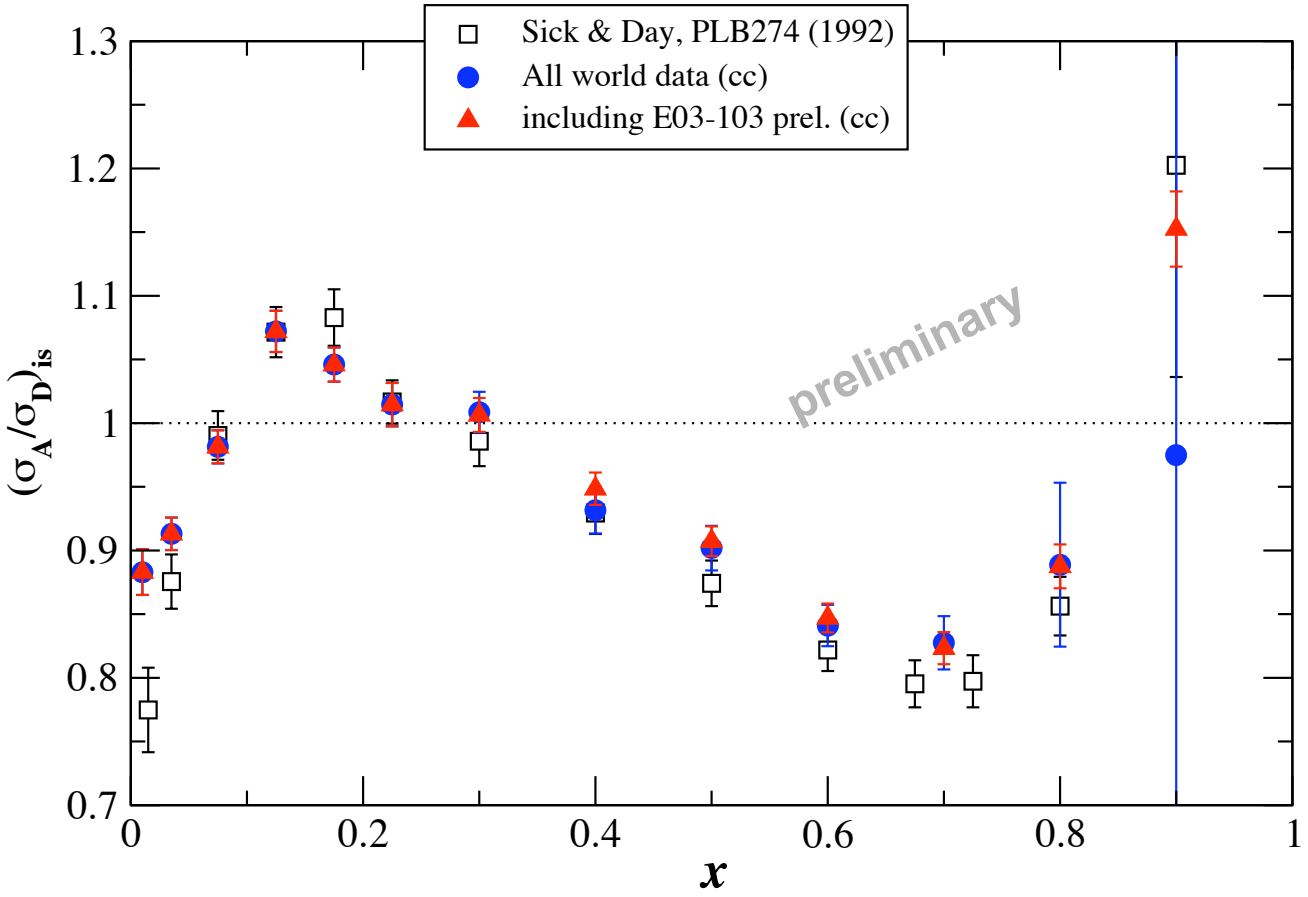
➢ Preliminary E03-103 results confirm A-dependence of the EMC effect.

Note: n/p correction is also A-dependent !

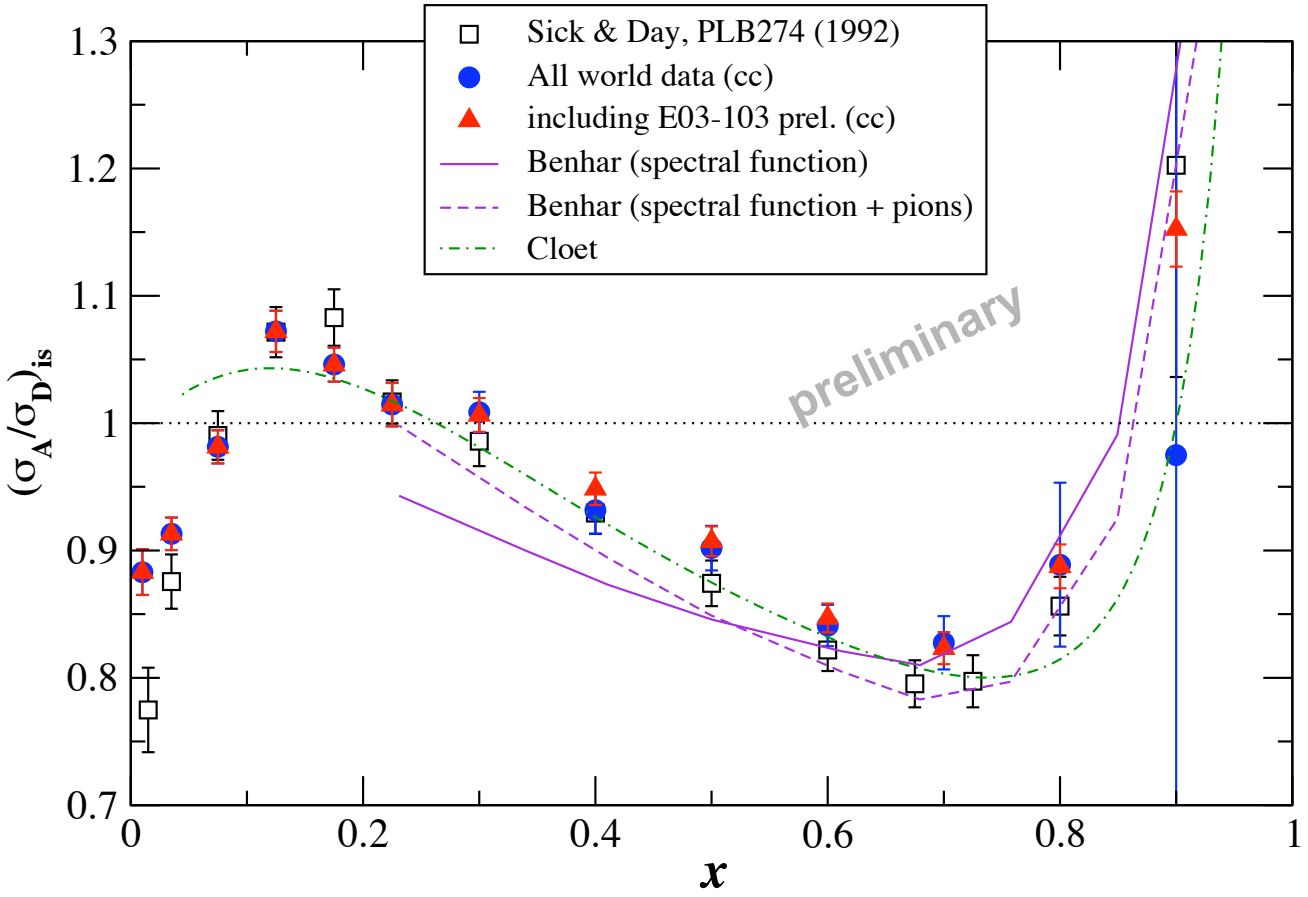
Nuclear matter



Nuclear matter



Nuclear matter



Summary

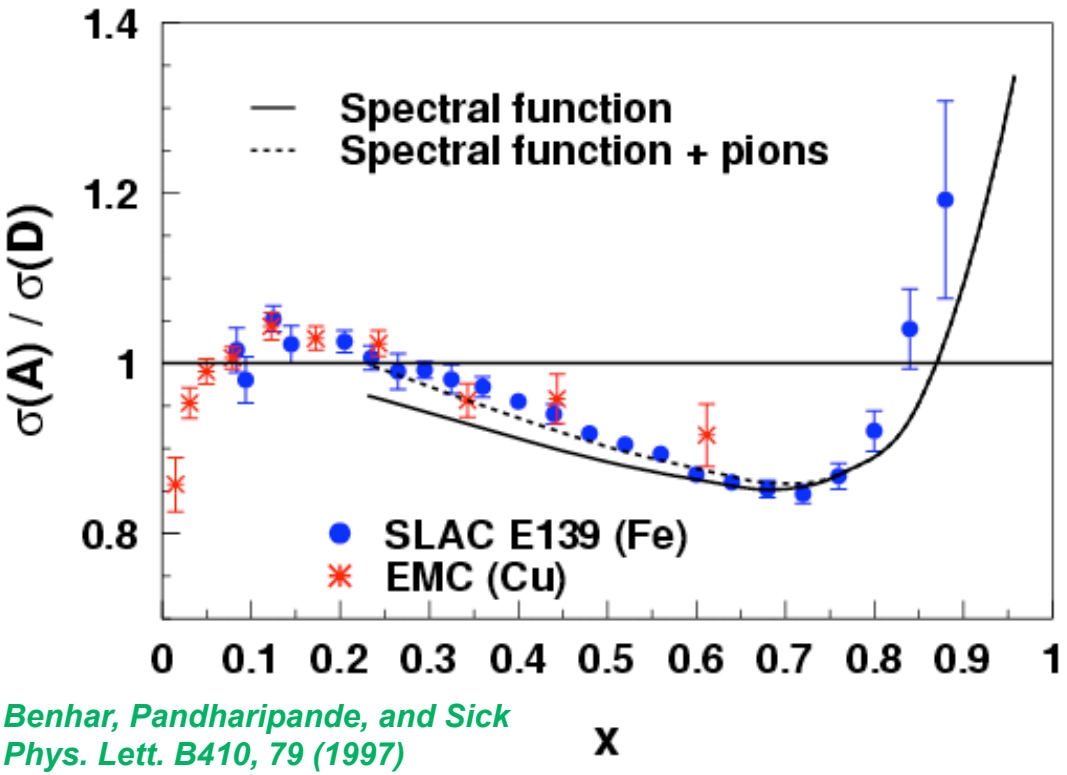
- JLab E03-103 provides:
  - Precision nuclear structure ratios for light nuclei
  - Access to large *x* EMC region for $^{3}He \rightarrow {}^{197}Au$
- Preliminary observations:
  - Scaling of the structure function ratios for W<2GeV down to low Q^2
  - Large EMC effect in ^{3}He
  - Similar large *x* shape of the structure function ratios for A>3
- In progress:
  - Absolute cross sections for ^{1}H, ^{2}H, ^{3}He and ^{4}He: test models of σ_n/σ_p and nuclear effects in few-body nuclei
  - Quantitative studies of the Q^2-dependence in structure functions and their ratios
  - Coulomb distortion
  - Nuclear density calculations
  - Target mass correction

Mapping the EMC Effect

Models should include conventional effects:

- Fermi motion and binding dominate at high x
- Binding also affects quark distribution at all x

Then more "exotic" explanations may be added if these effects are not enough to describe the data like:



Benhar, Pandharipande, and Sick
Phys. Lett. B410, 79 (1997)

- ➢ *Nuclear pions*
- ➢ *Multiquark clusters*
- ➢ *Dynamical rescaling*

Many of these models can reproduce the large x region but failed in other x-regions or for other data (Drell-Yan) or didn't include conventional effects.

More detailed look at scaling

C/D ratios at fixed x are Q^2 independent for:

W^2>2 GeV^2
and
Q^2>3 GeV^2

limits E03-103 coverage to x=0.85

Note: Ratios at larger x will be shown, but should be taken cautiously