EMC effect in few-body nuclei at large x

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Elba X Workshop

Electron-Nucleus Scattering X

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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***

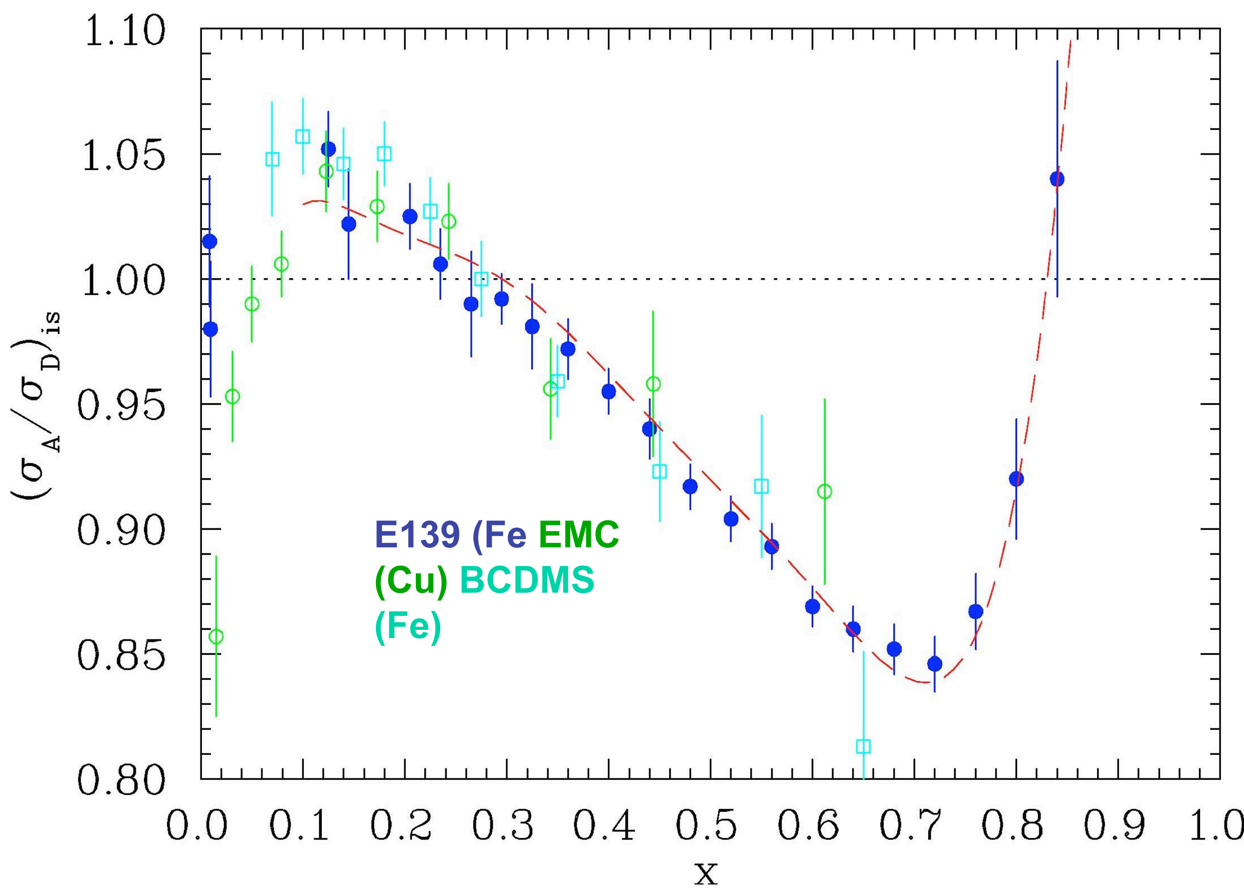
- **New extrapolation to nuclear matter**

Nuclear structure functions and the EMC effect

- **Nuclear structure: $\sigma_A \neq Z.\sigma_p + N.\sigma_n$**
  - Effects found in several experiments at CERN, SLAC, DESY

- **Same *x*-dependence in all nuclei**
  - Shadowing: $x<0.1$
  - Anti-shadowing: $0.1<x<0.3$
  - EMC effect: $x>0.3$

- **The size of the effect is a function of A**



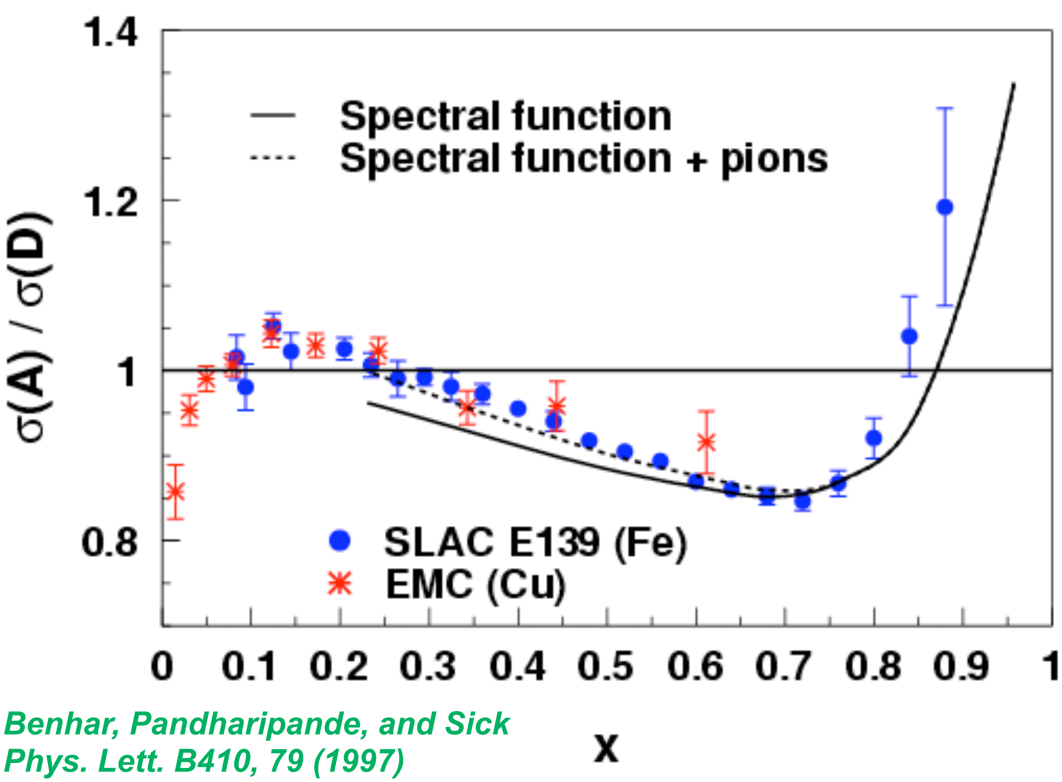
Mapping the EMC Effect

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:

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

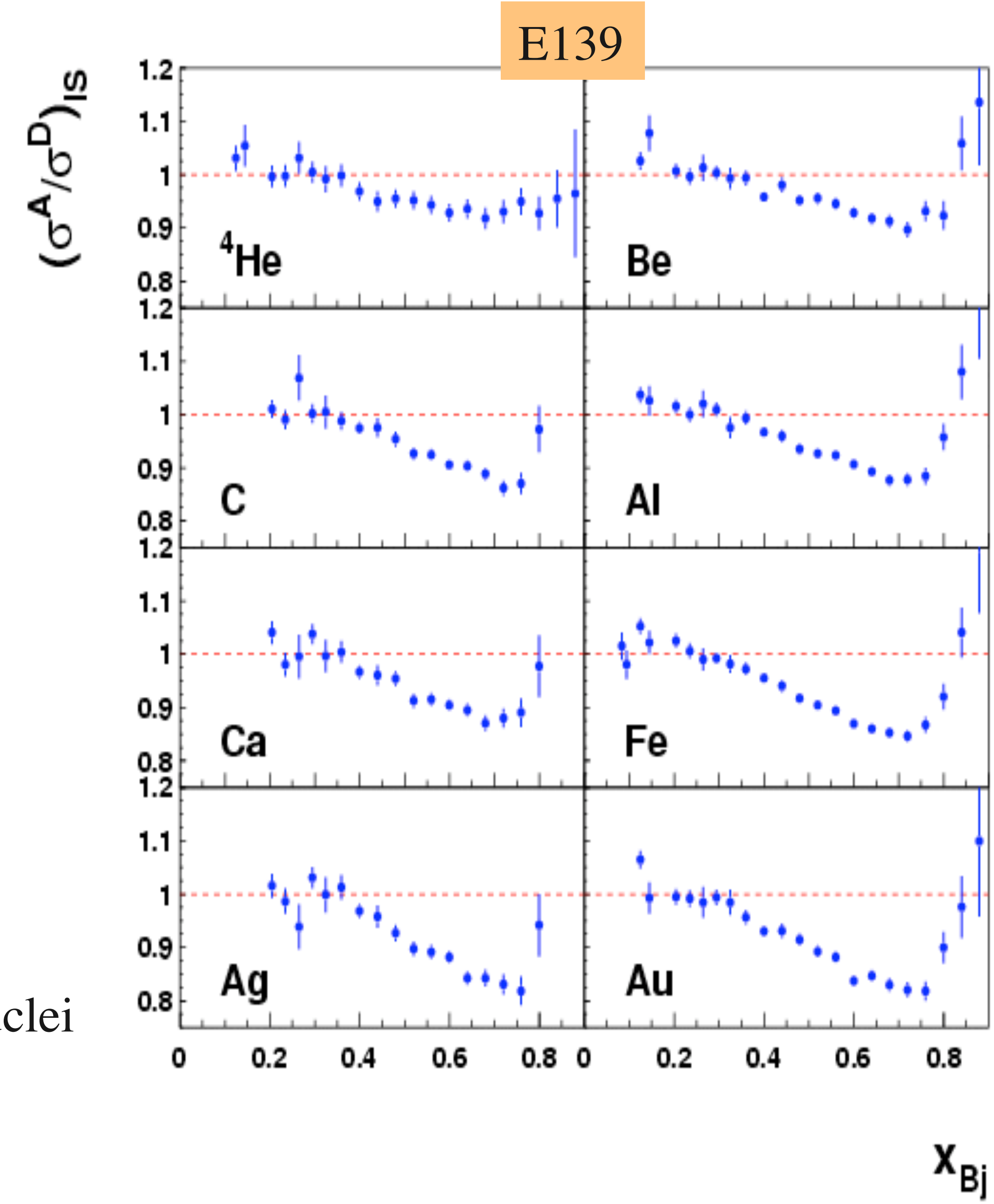


Benhar, Pandharipande, and Sick
Phys. Lett. B410, 79 (1997)

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.

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**

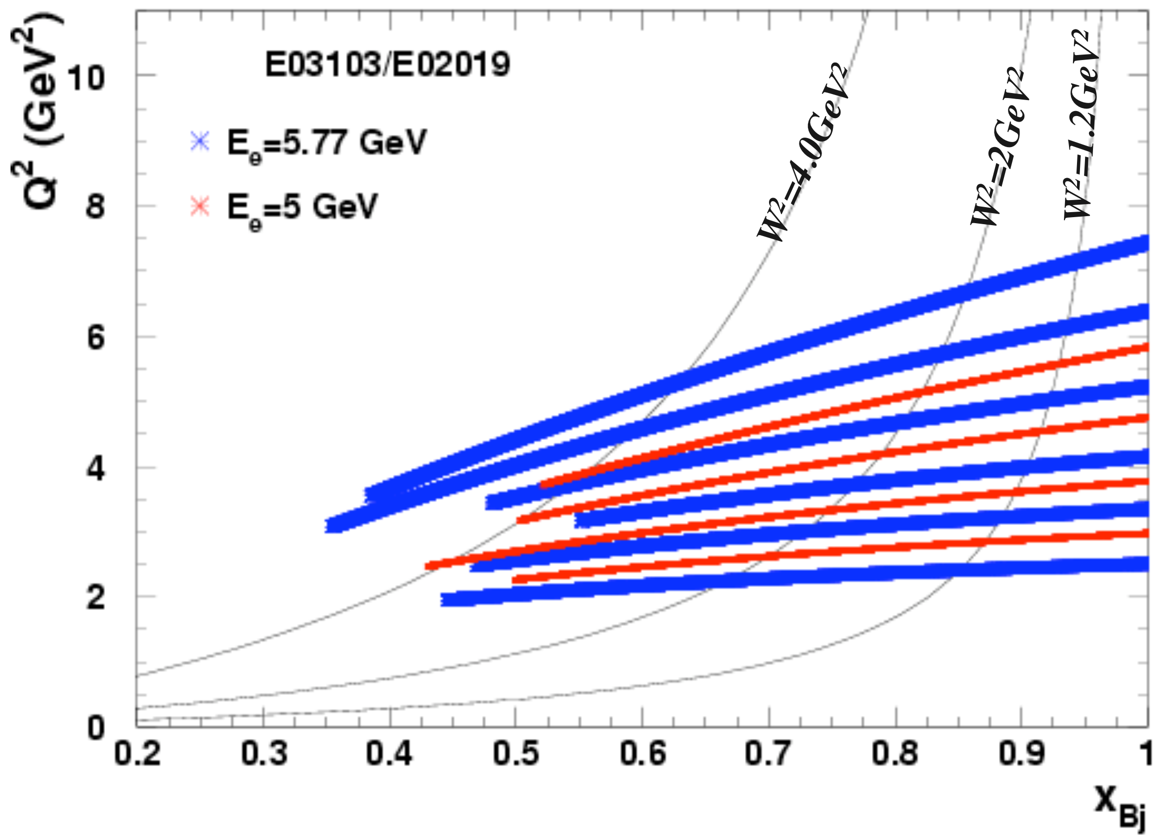
JLab Experiment E03-103

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

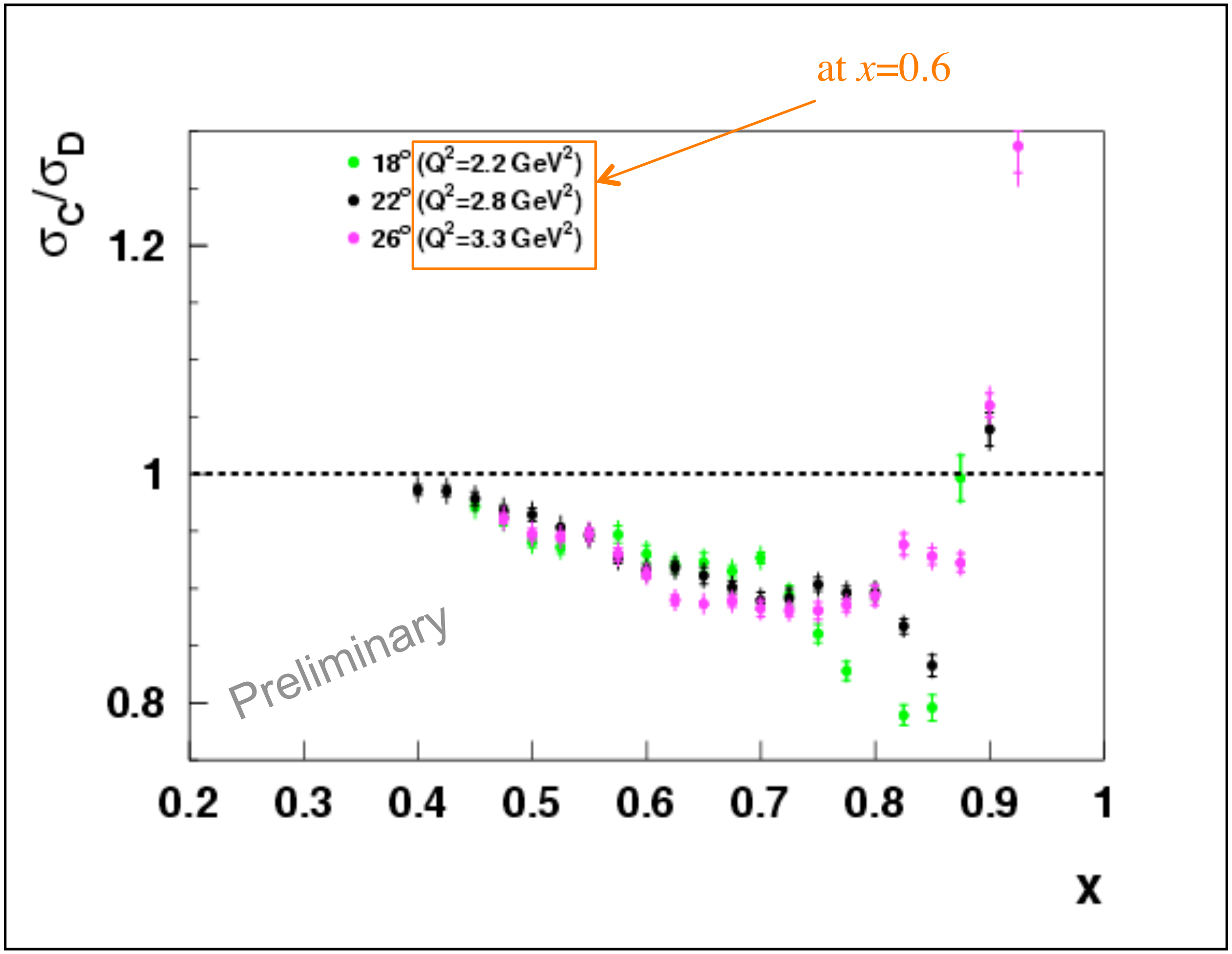
A(e,e') at 5.0 and 5.8 GeV in Hall C

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

- 10 angles to measure Q^2-dependence

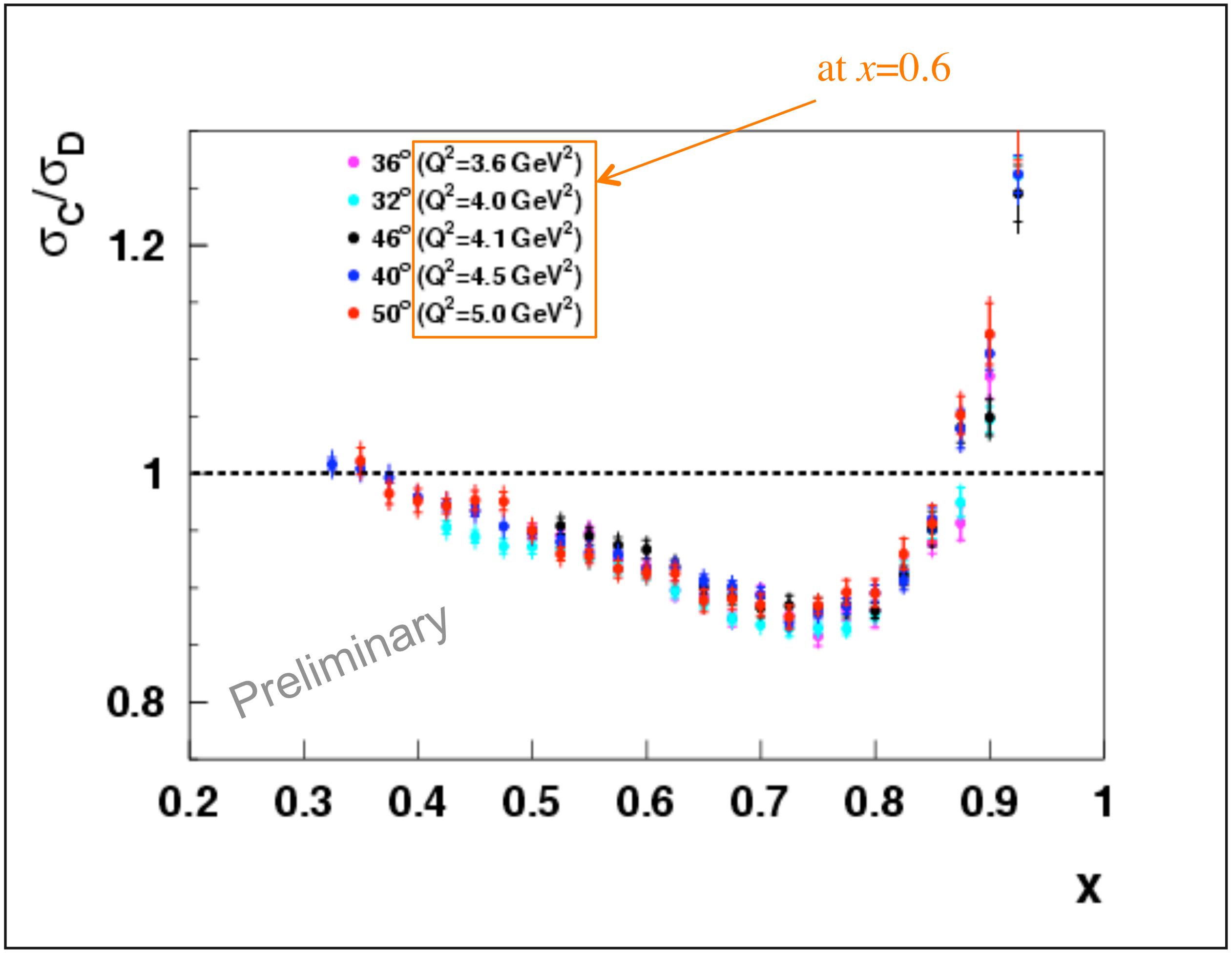


E03-103: Carbon EMC ratio and Q^2-dependence



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

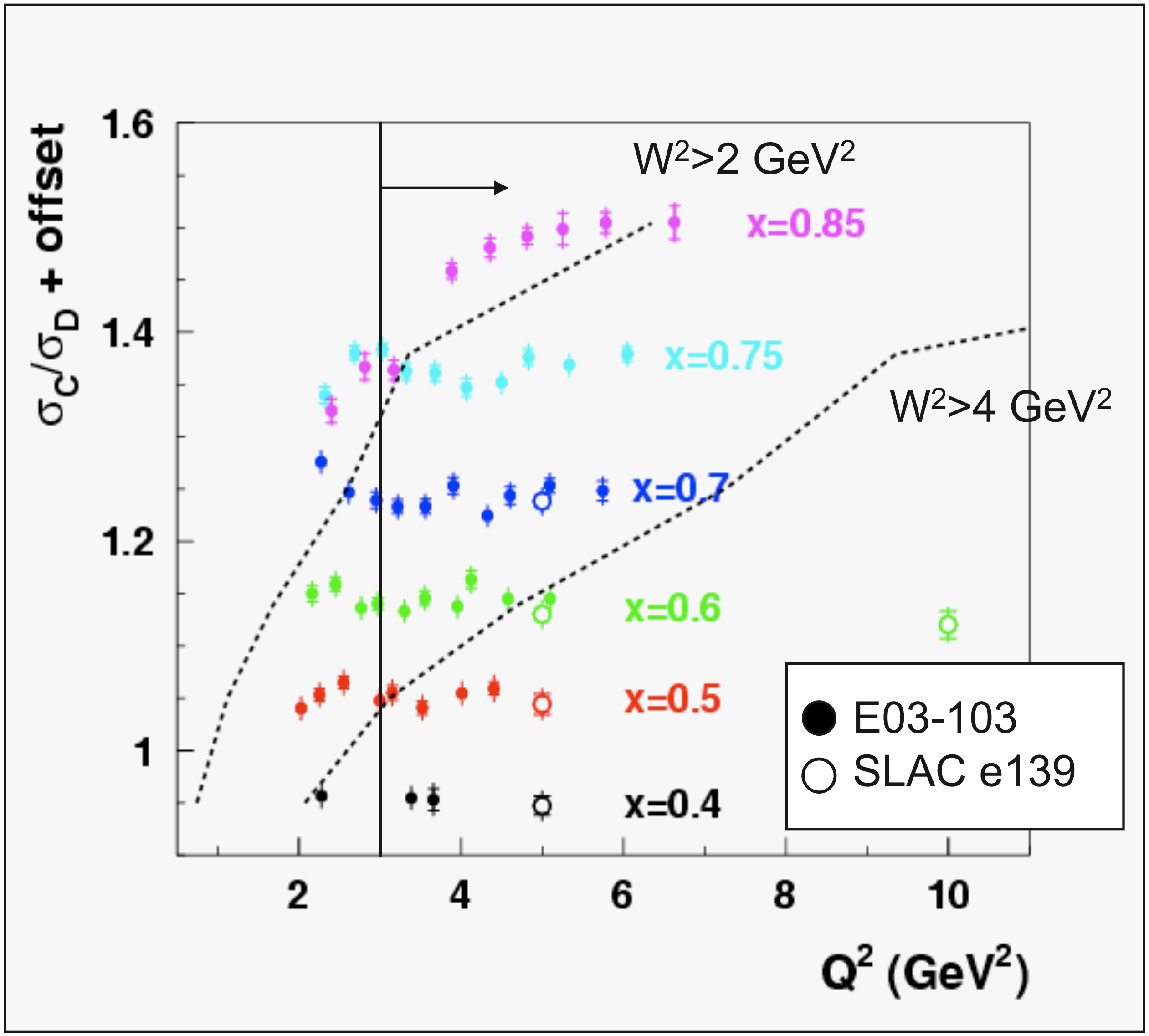
More detailed look at scaling

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

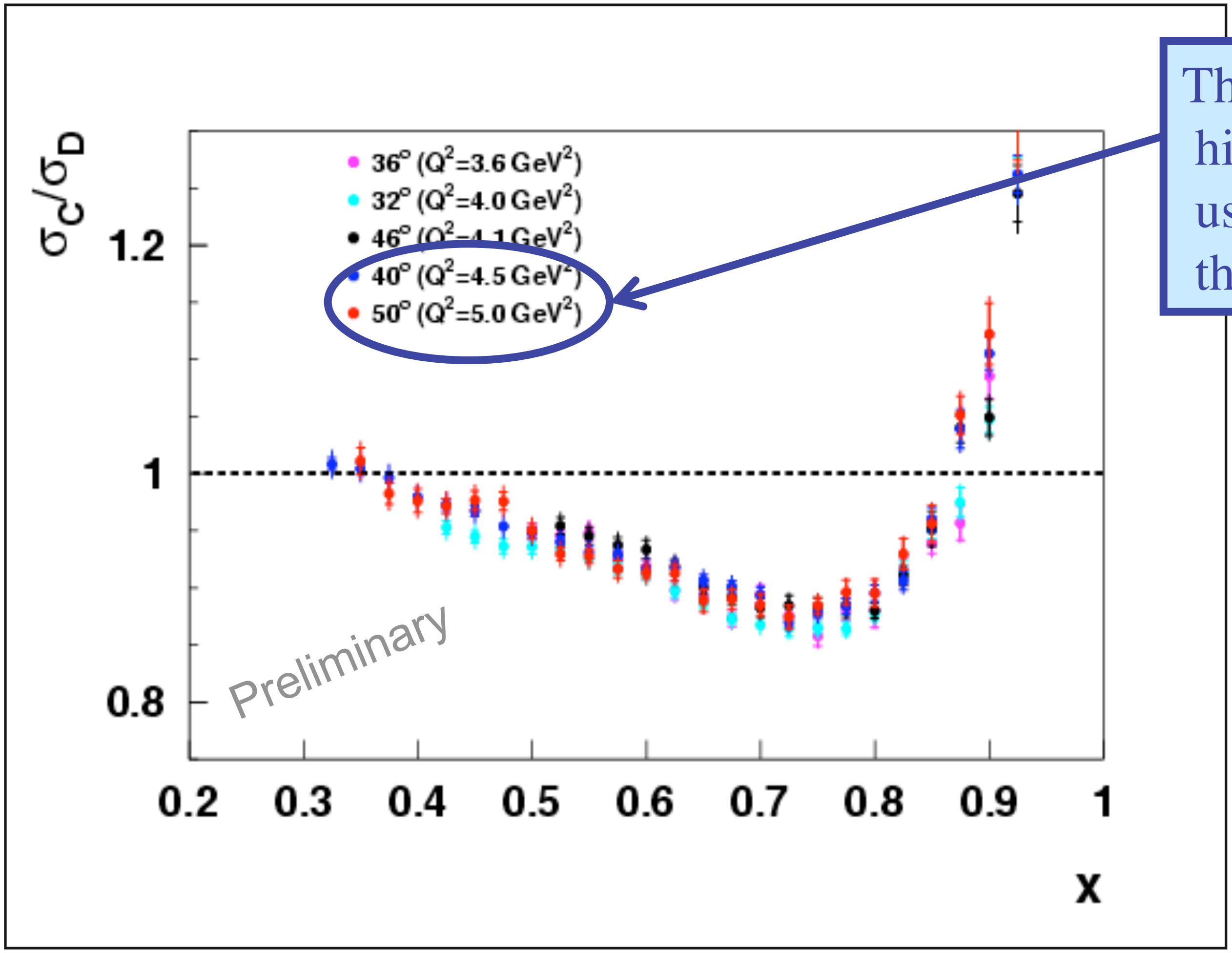
W^2>2 GeV^2
and
Q^2>3 GeV^2

limits E03-103 coverage to x=0.85

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



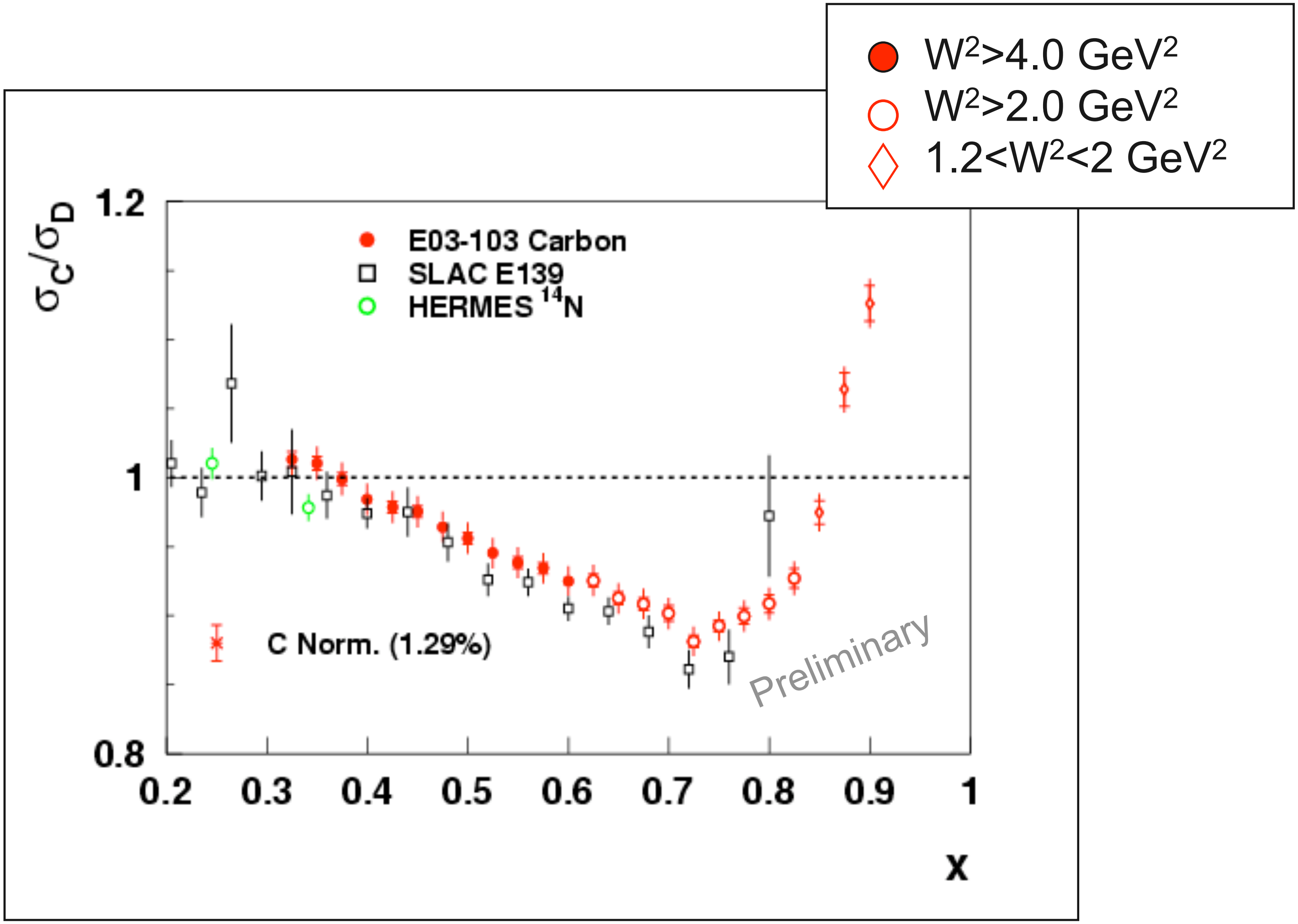
E03-103: Carbon EMC ratio and Q^2-dependence



The combined two highest Q^2 are used in the rest of the talk

At larger angles ➔ indication of scaling to very large *x*

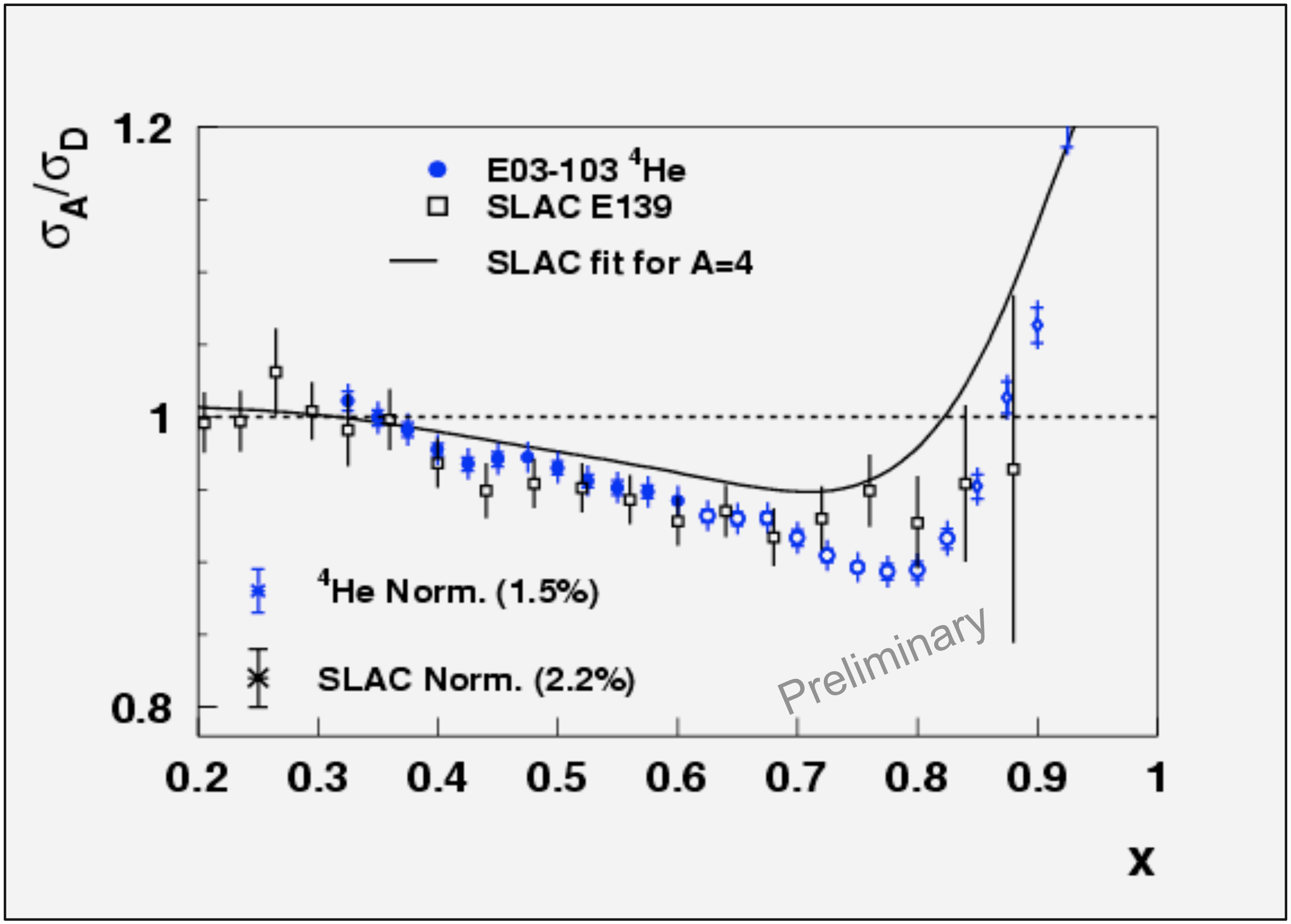
E03-103: Carbon EMC ratio



E03-103: ^{4}He

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

Large *x* shape more clearly consistent with heavier nuclei



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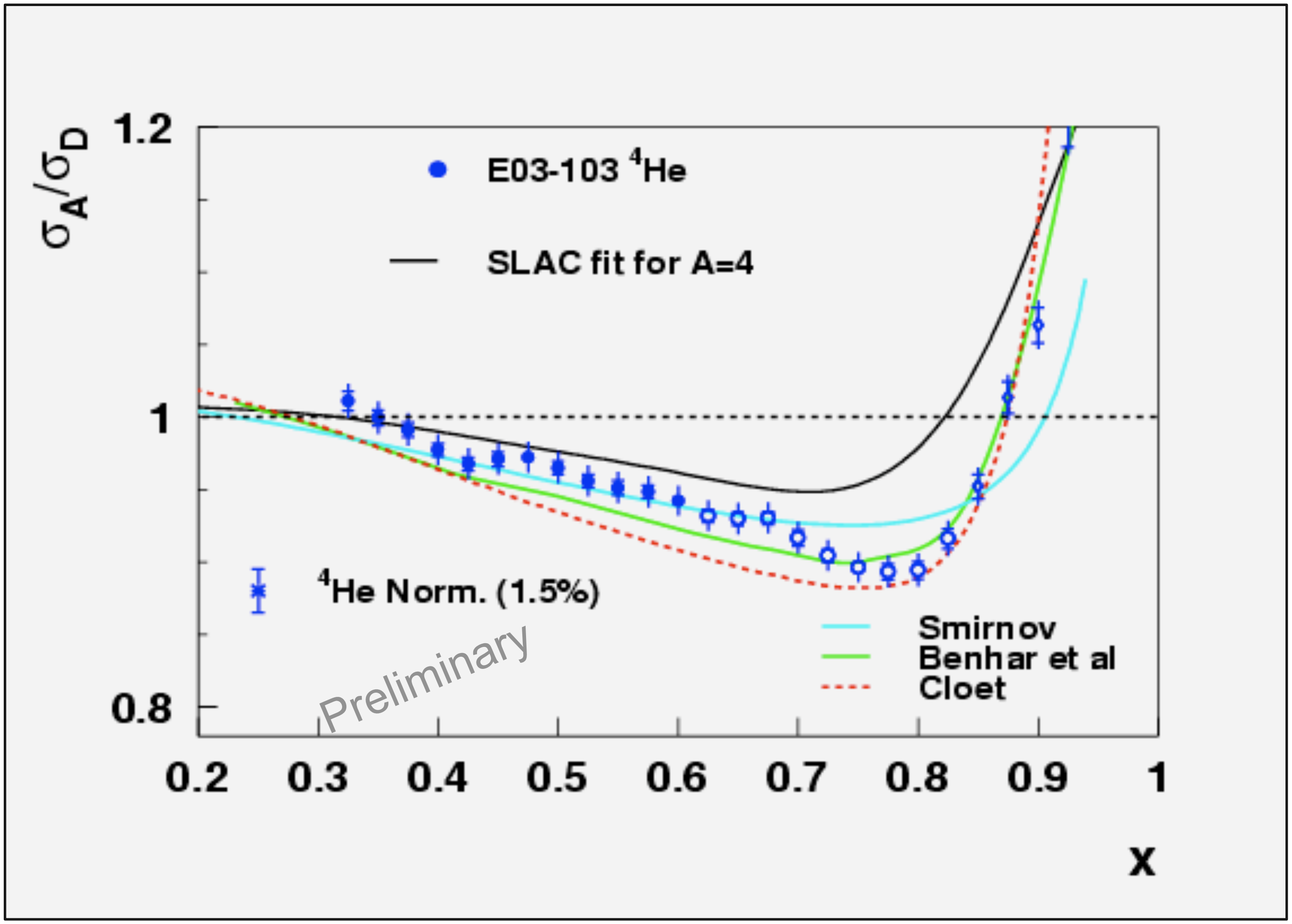
Models shown do a reasonable job describing the data

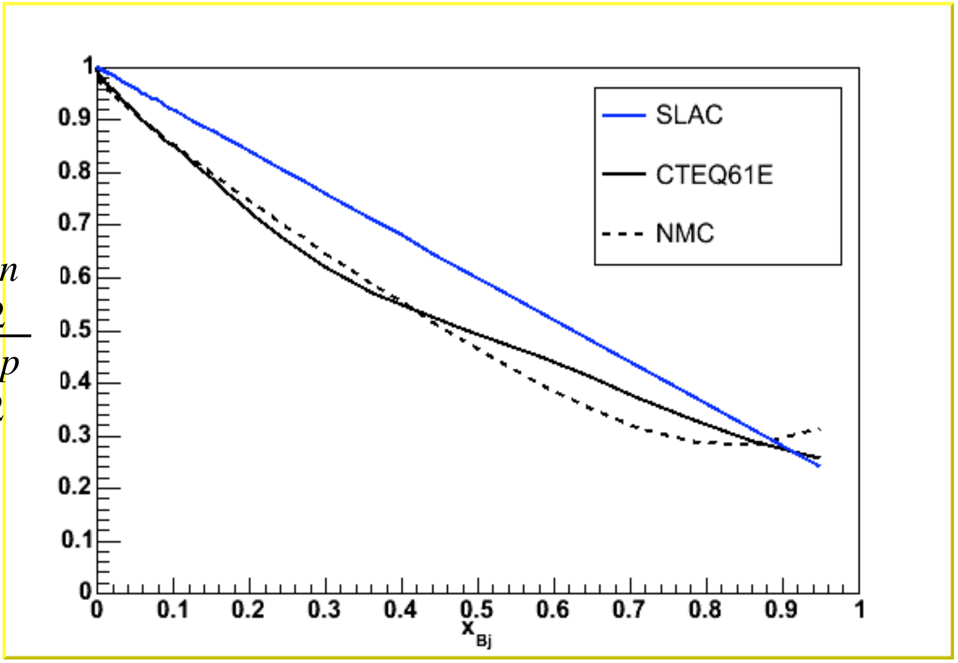


Isoscalar correction

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

Isoscalar correction

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



SLAC fit: (1-0.8x)

Isoscalar correction

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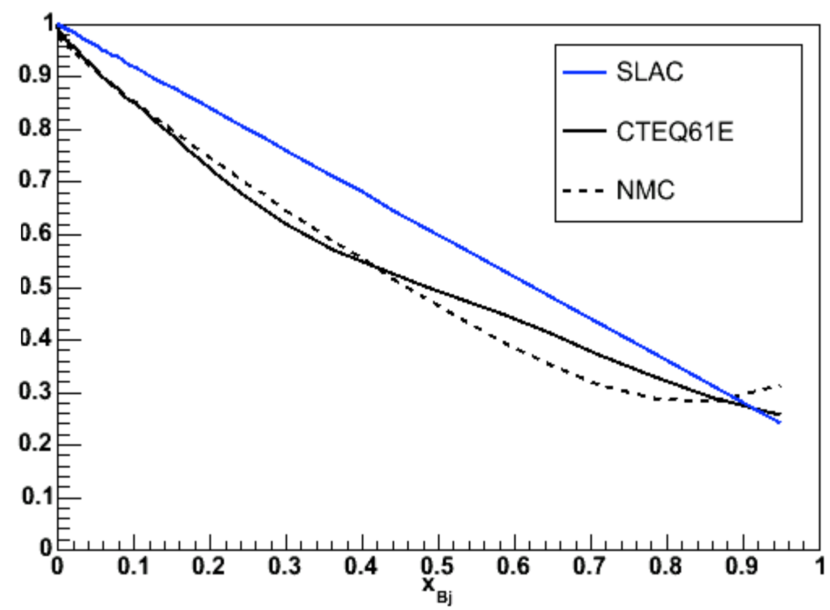
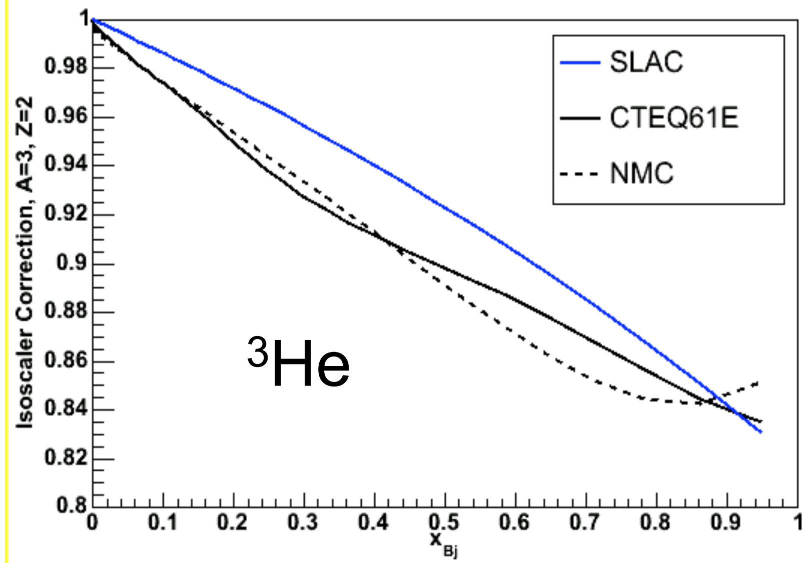
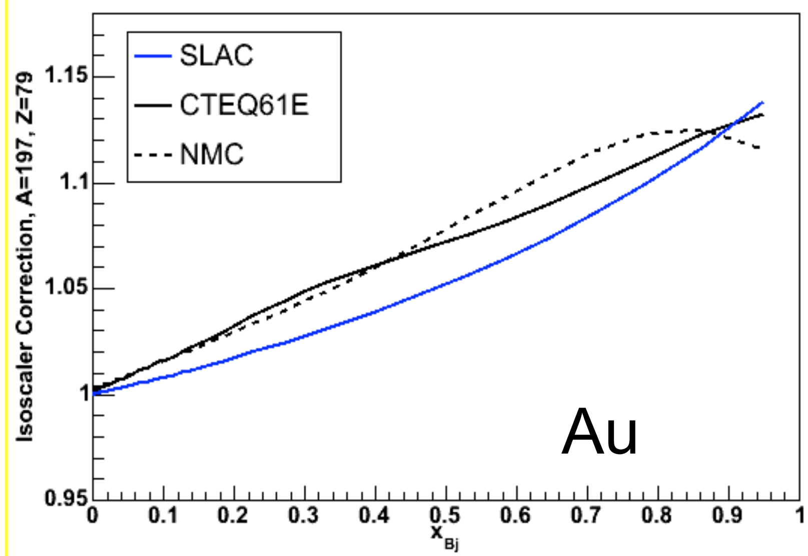


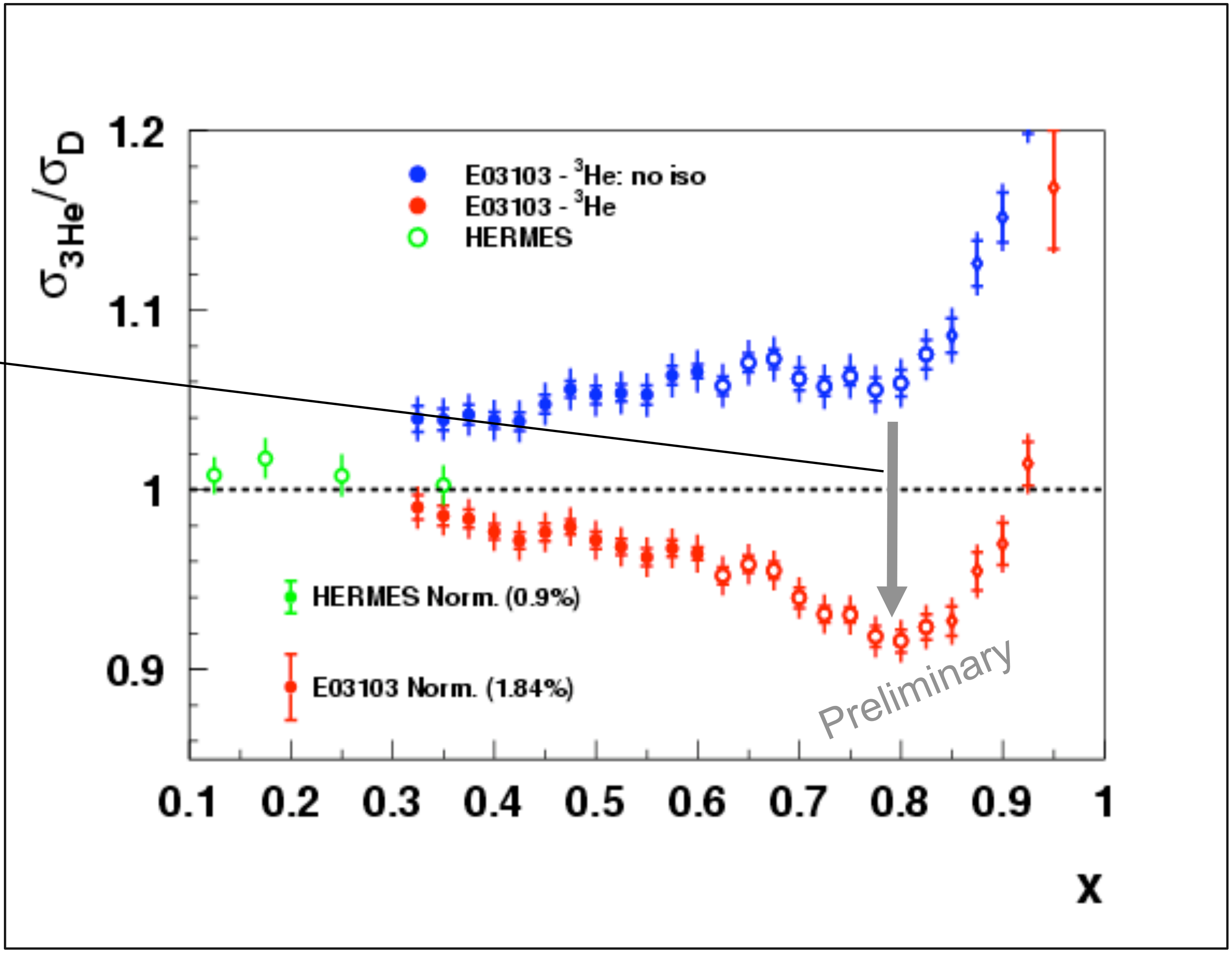
SLAC fit: (1-0.8x)





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

Large proton excess correction



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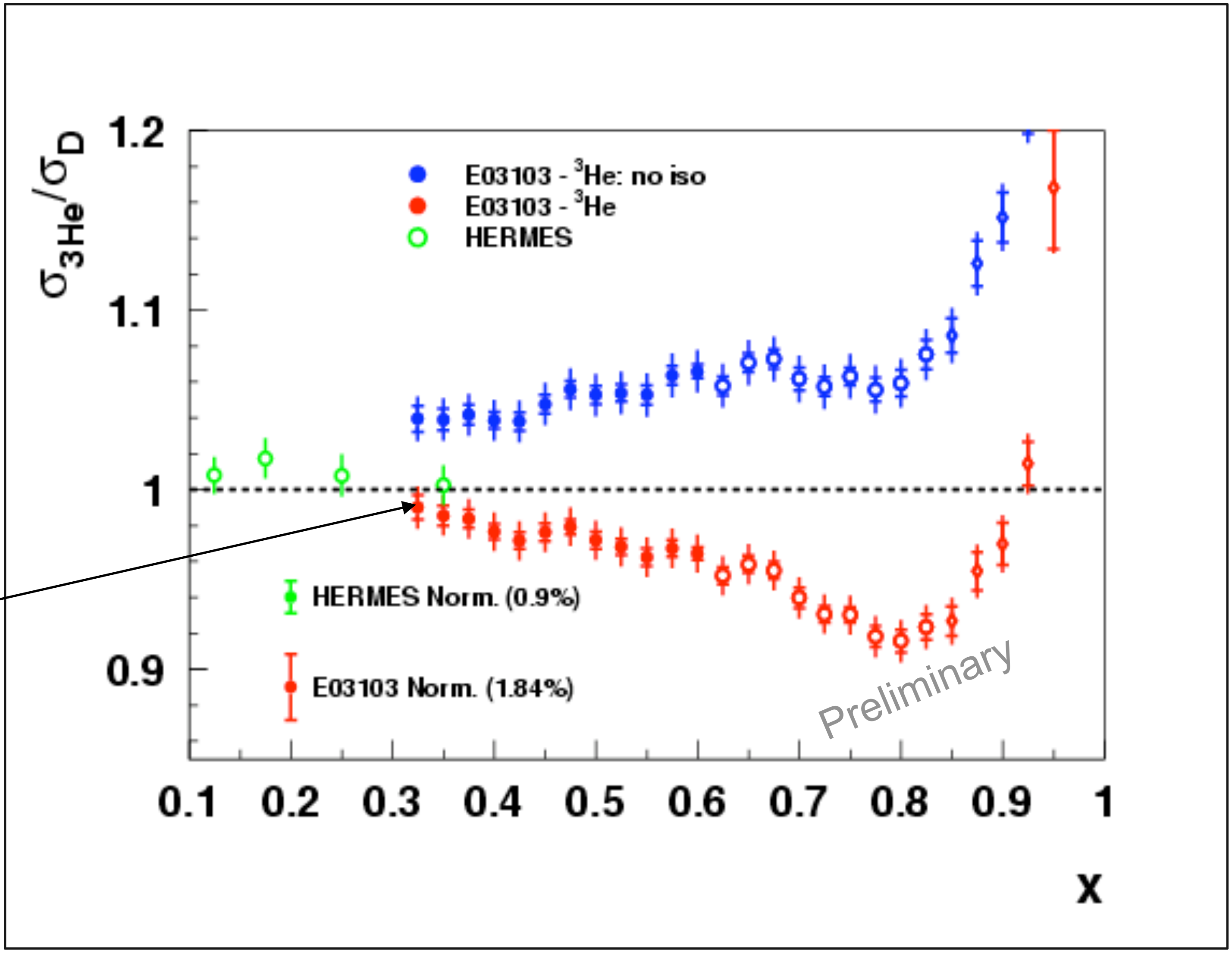
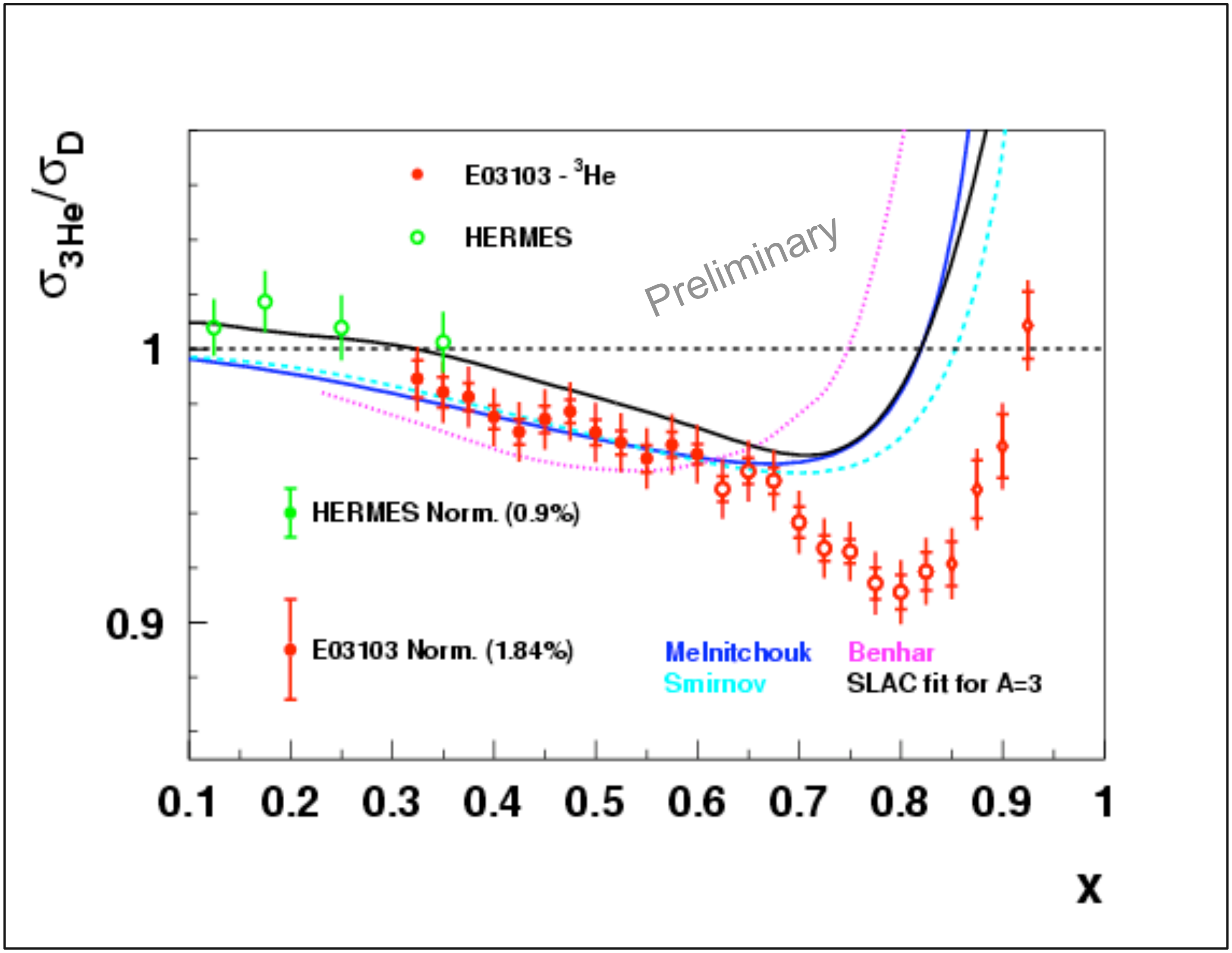


Good agreement with HERMES in overlap region

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



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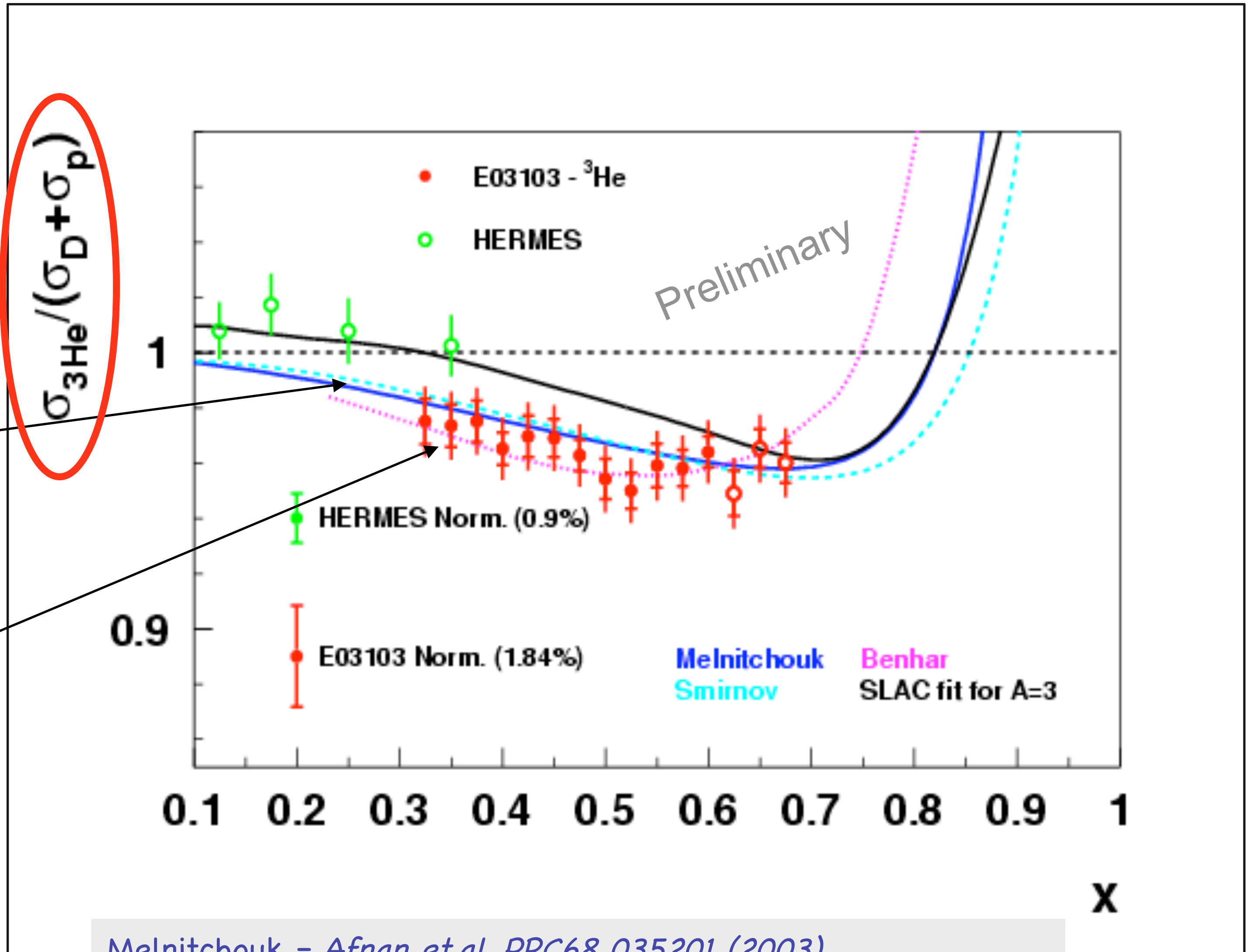
E03-103: Preliminary ^{3}He EMC ratio

All calculations shown use convolution formalism at some level

$$\frac{F_2^{^3He}}{(F_2^D + F_2^p)}$$

$$\frac{F_2^{^3He}}{(2F_2^p + F_2^n)}$$



Melnitchouk = *Afnan et.al. PRC68 035201 (2003)*
Smirnov = *Molochkov and Smirnov Phys. Lett. B 466, 1 (1999)*
Benhar = *private communication (Hannover SF, Paris potential)*

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!)***

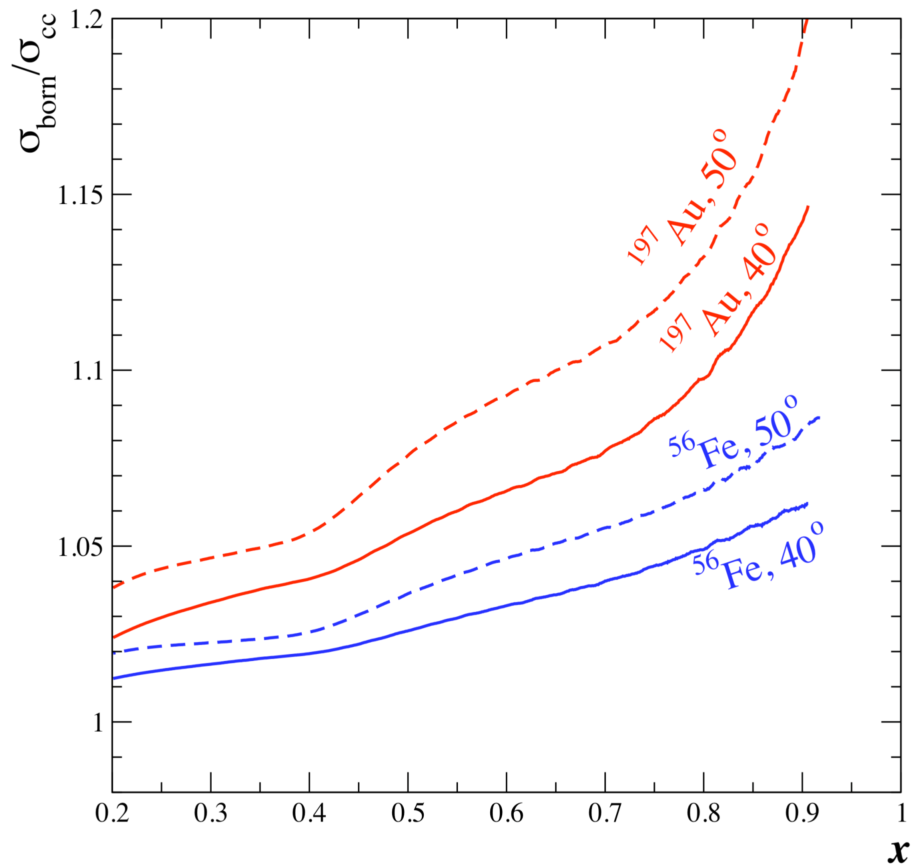
E03-103 uses modified Effective Momentum Approximation (EMA)

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

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

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

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



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Aste and Tr...

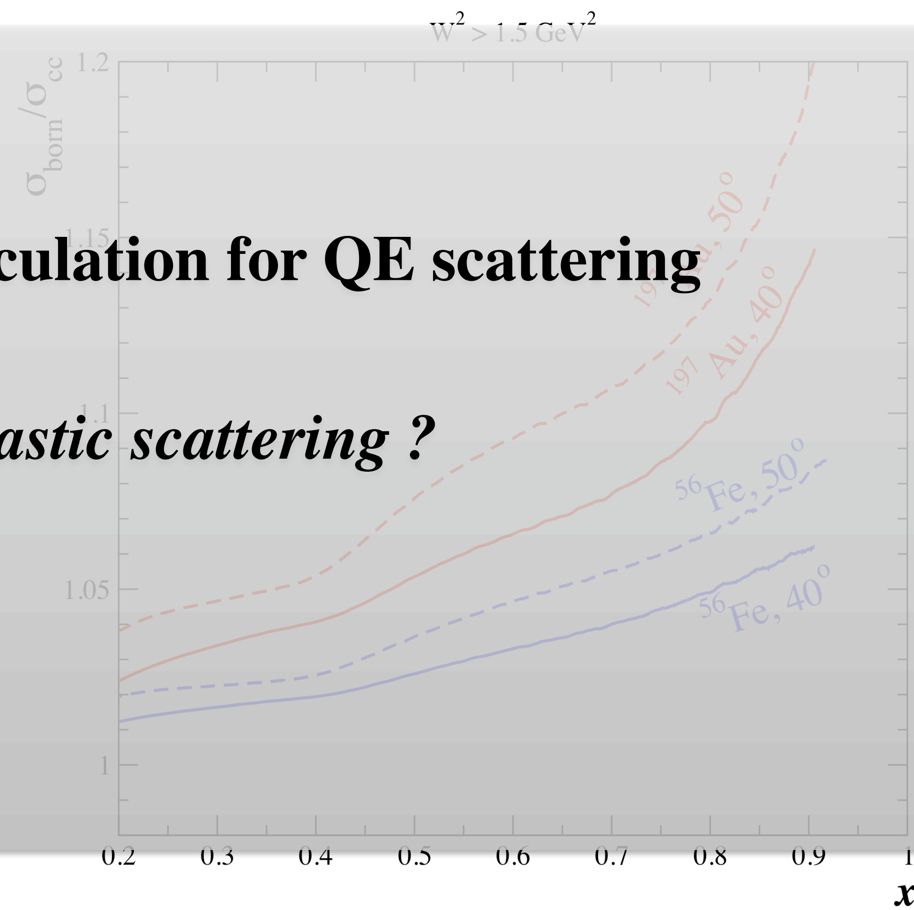
$E \rightarrow E+\Delta$

$E' \rightarrow E'+\Delta$

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

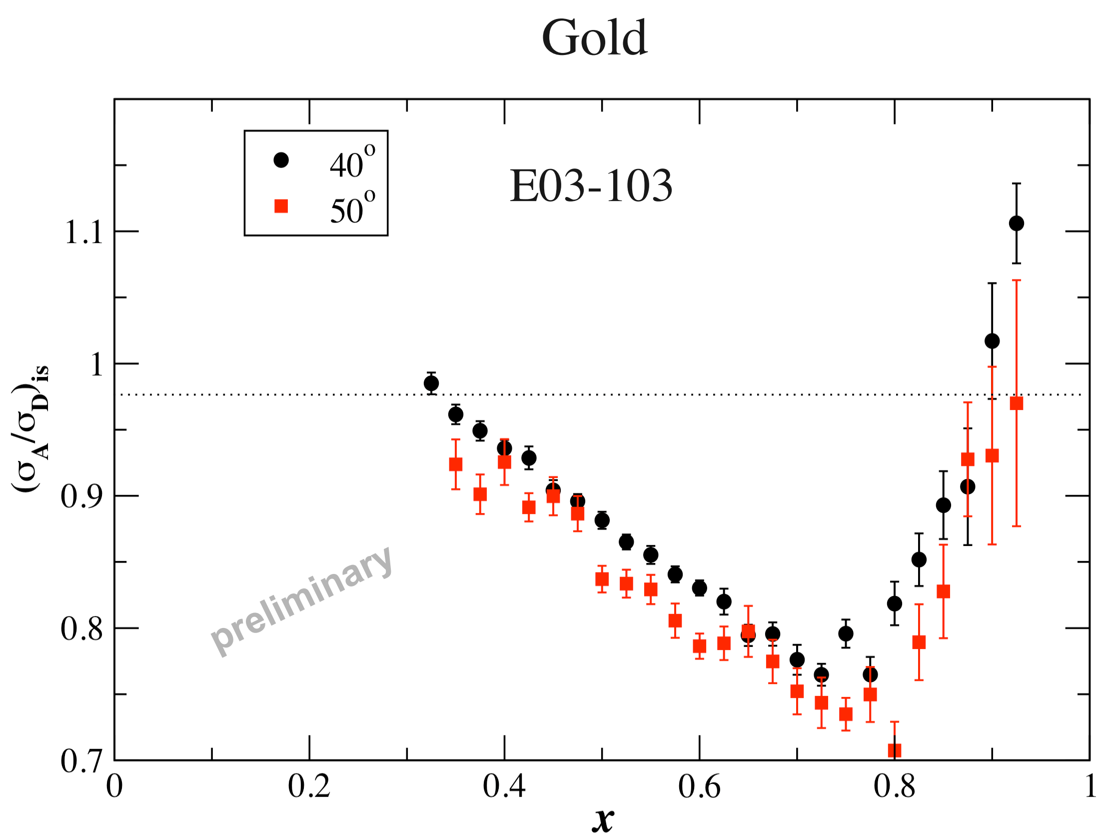
EMA tested against DWBA calculation for QE scattering

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



Effect of the coulomb distortion on E03-103 data

Before coulomb corrections



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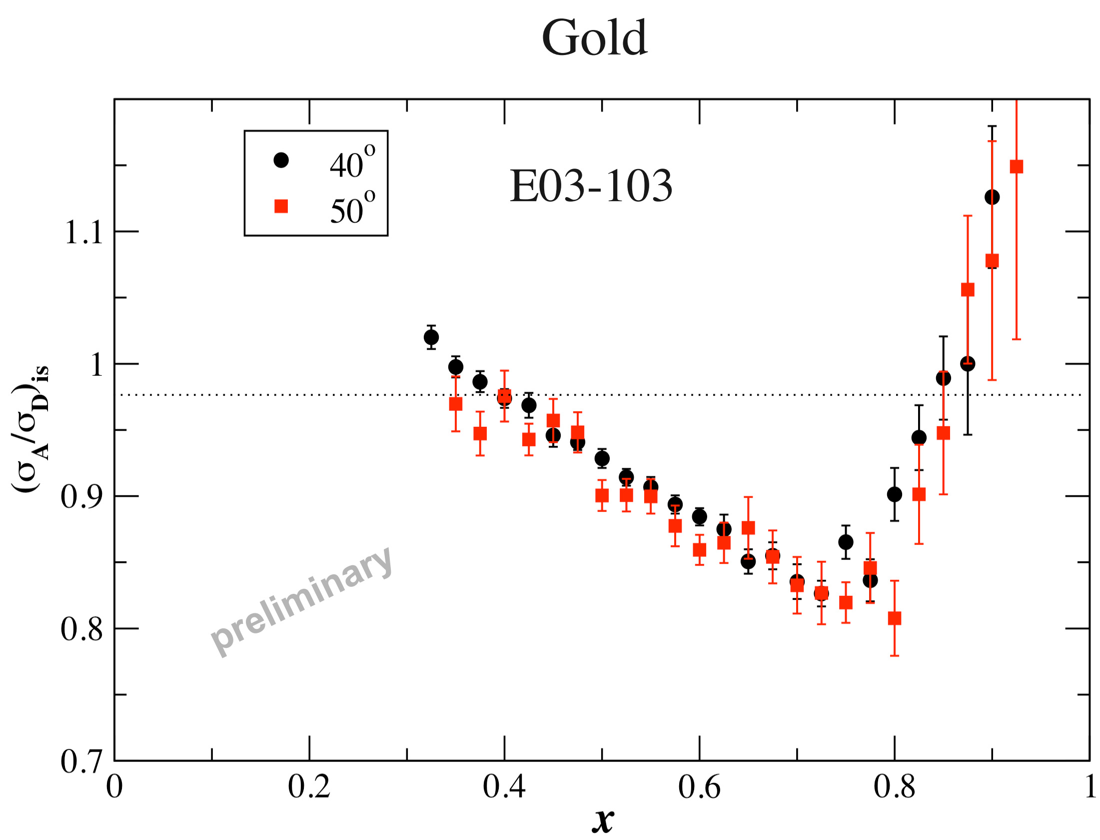
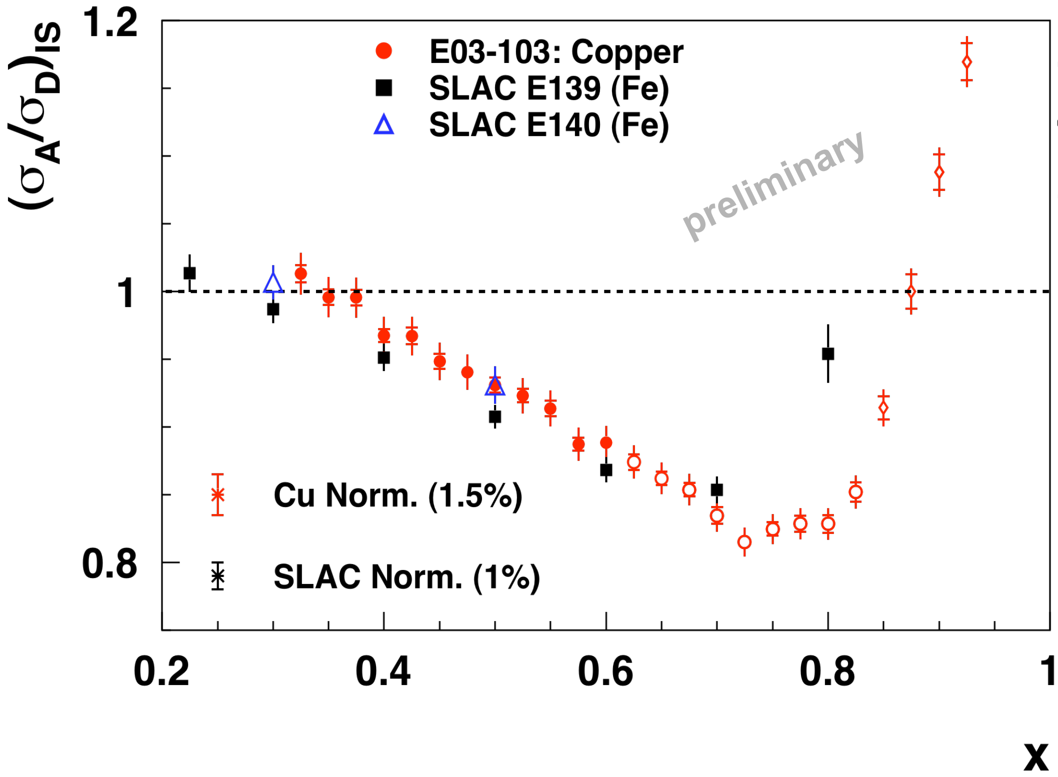
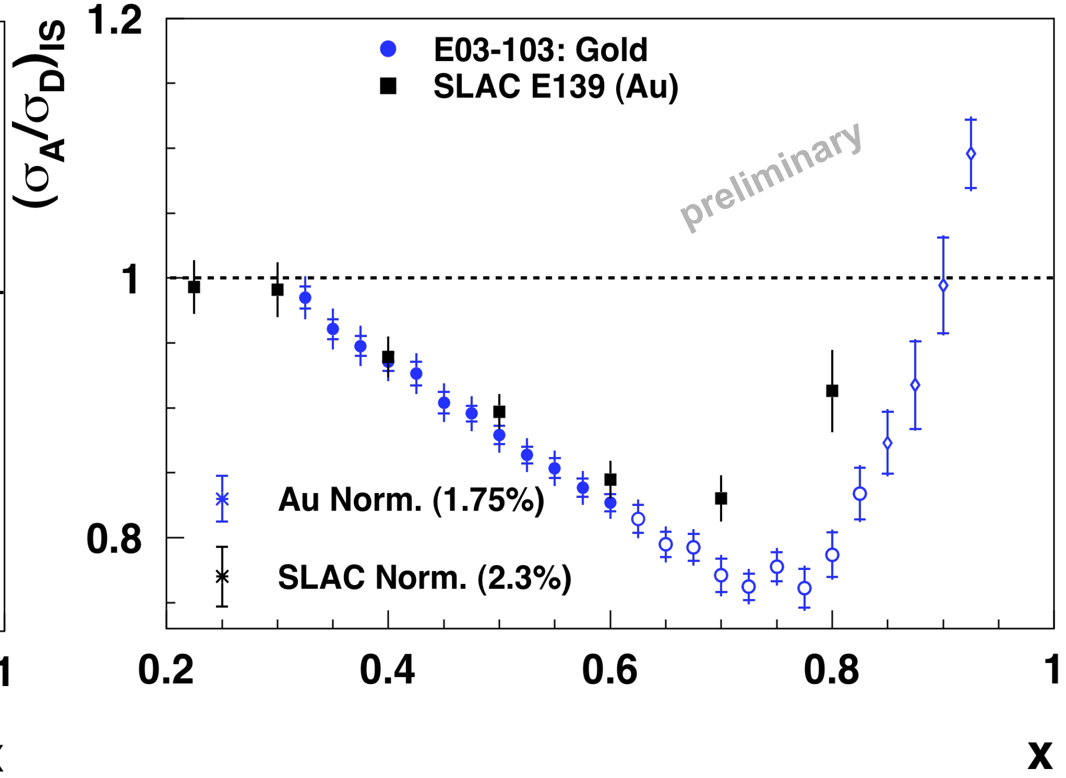


E03-013 heavy target results and world data

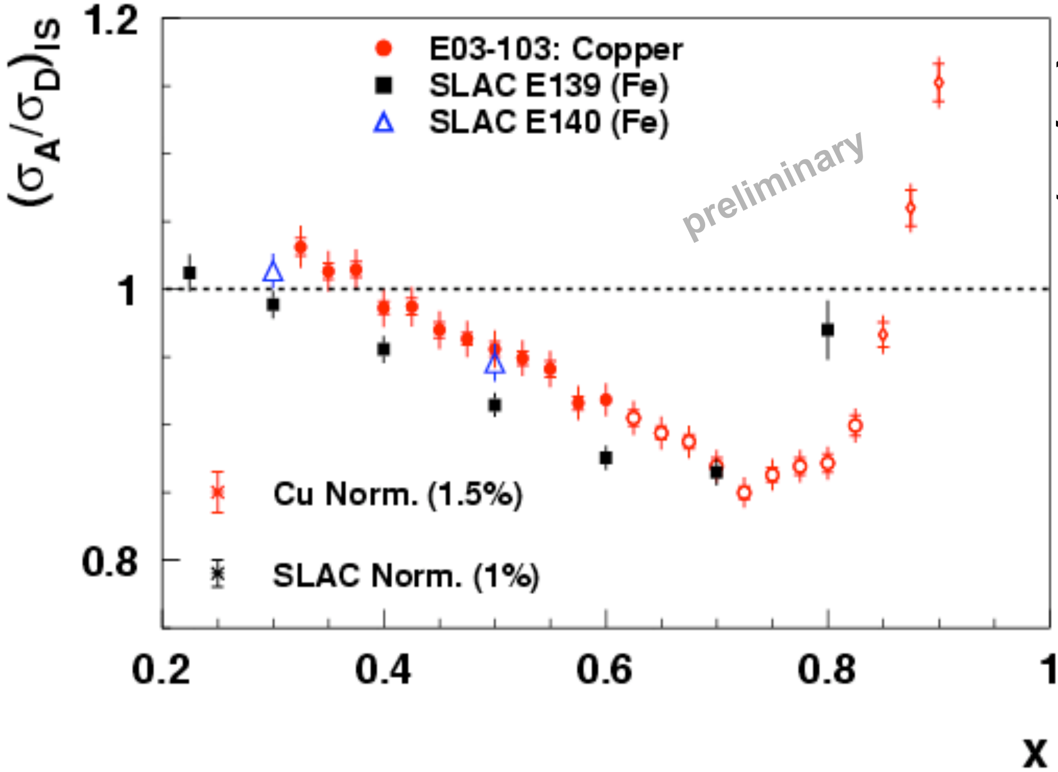
Before coulomb corrections

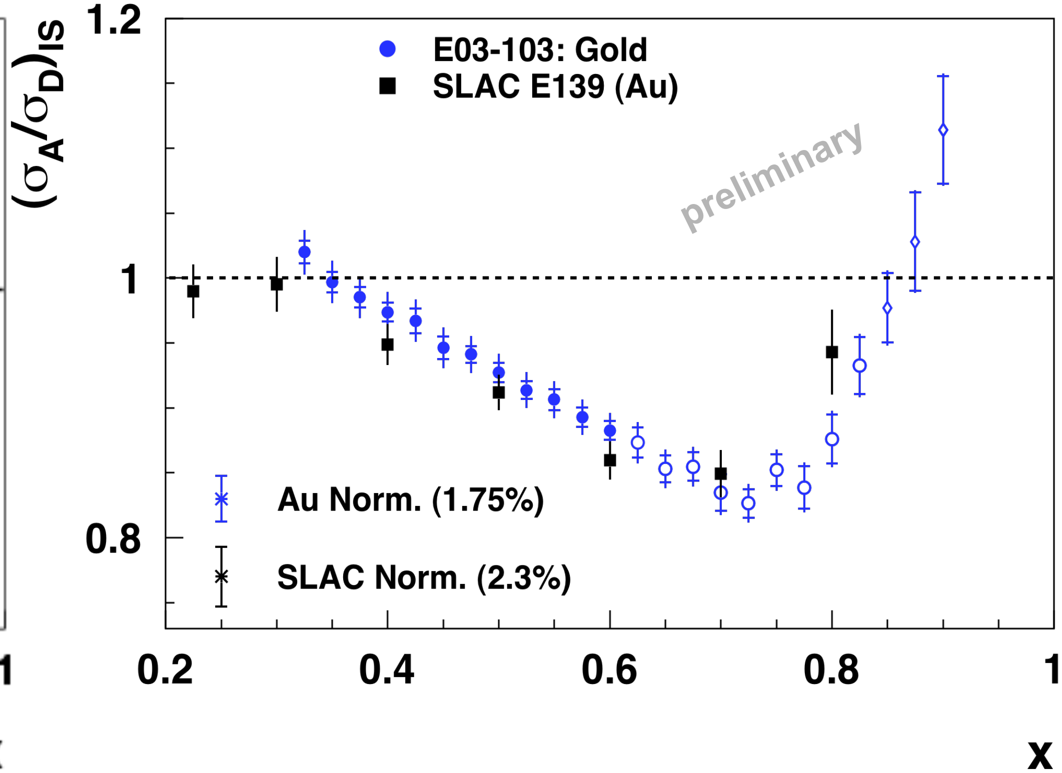




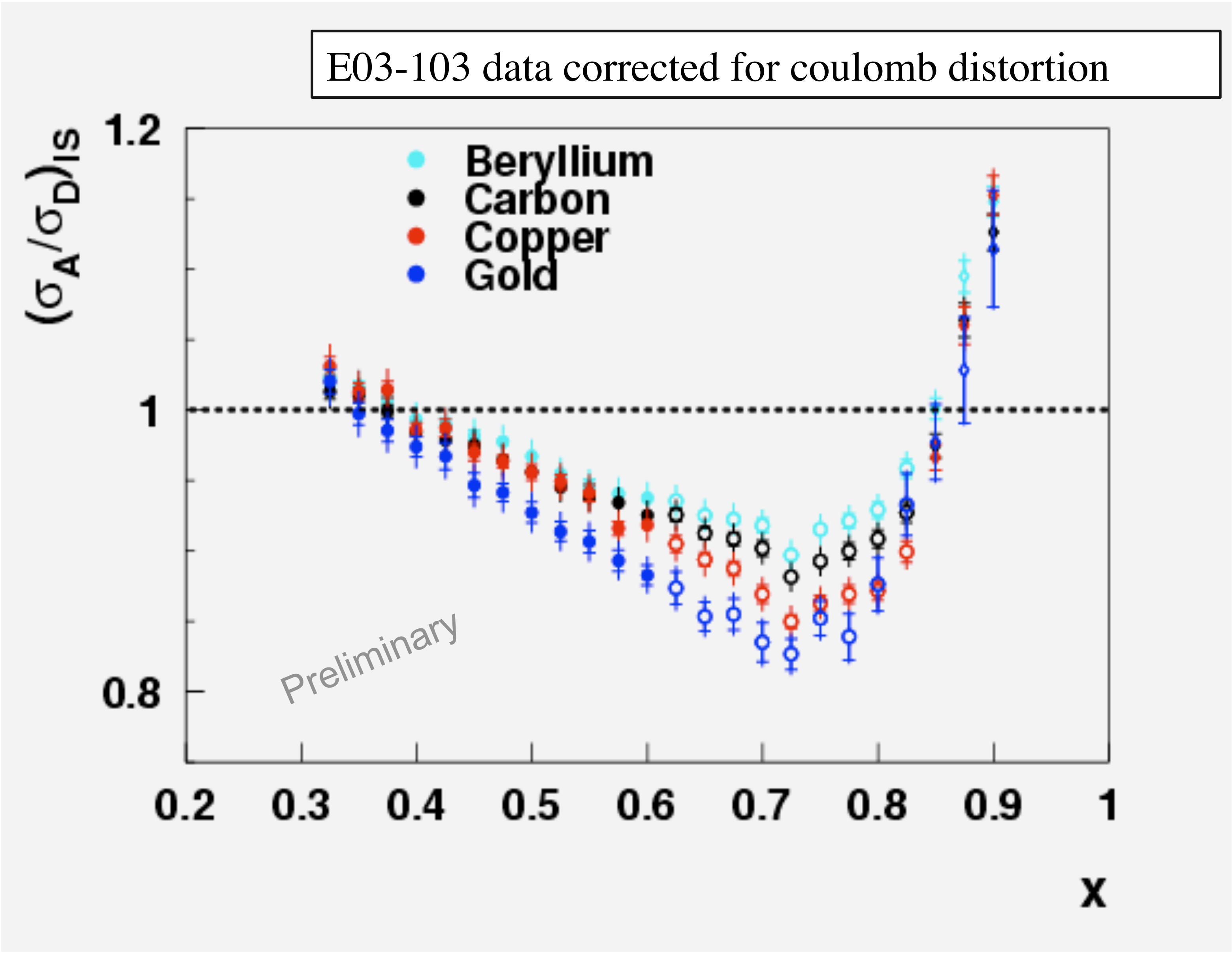
E03-013 heavy target results and world data

After coulomb corrections on all data





E03-103: EMC effect in heavy nuclei



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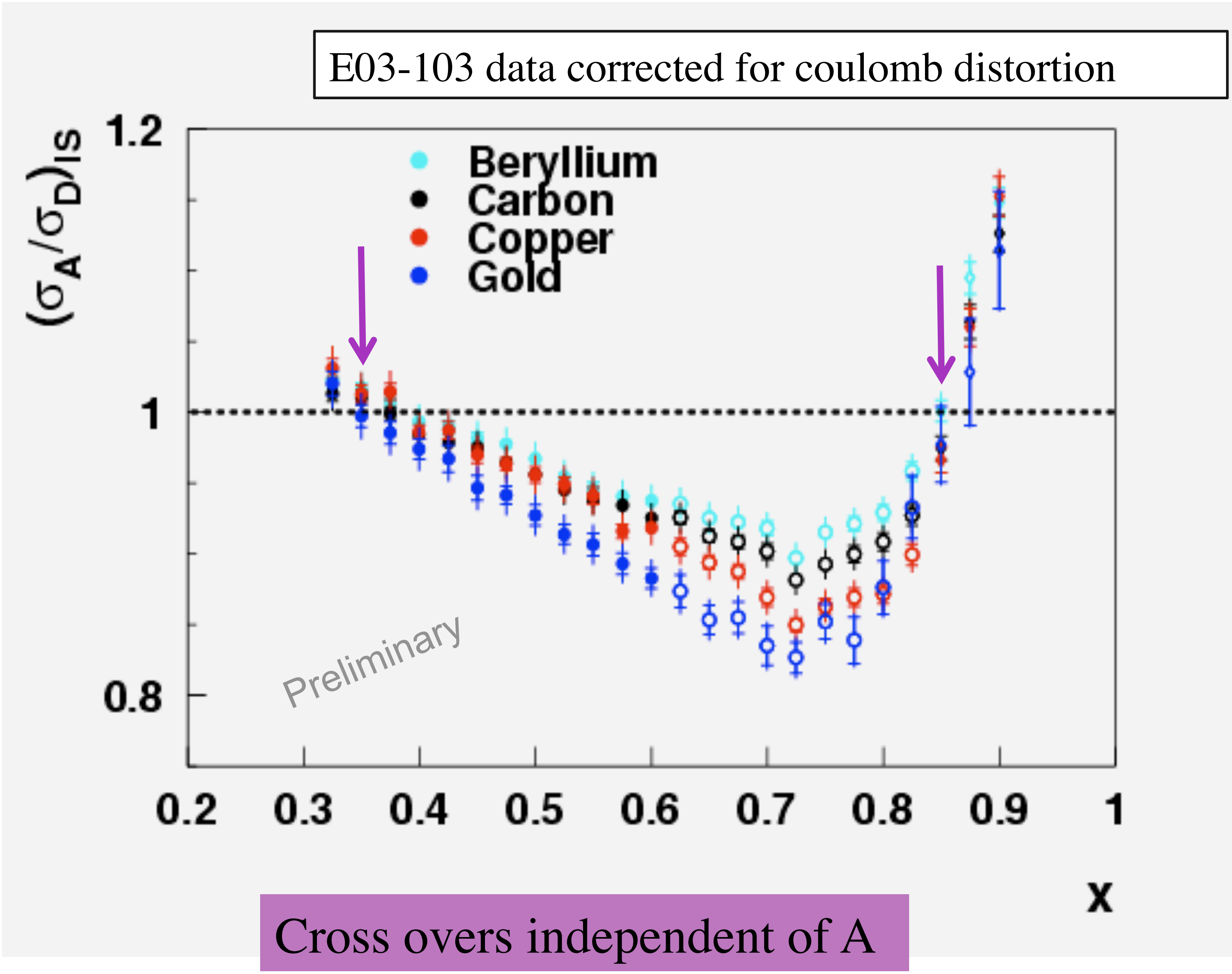
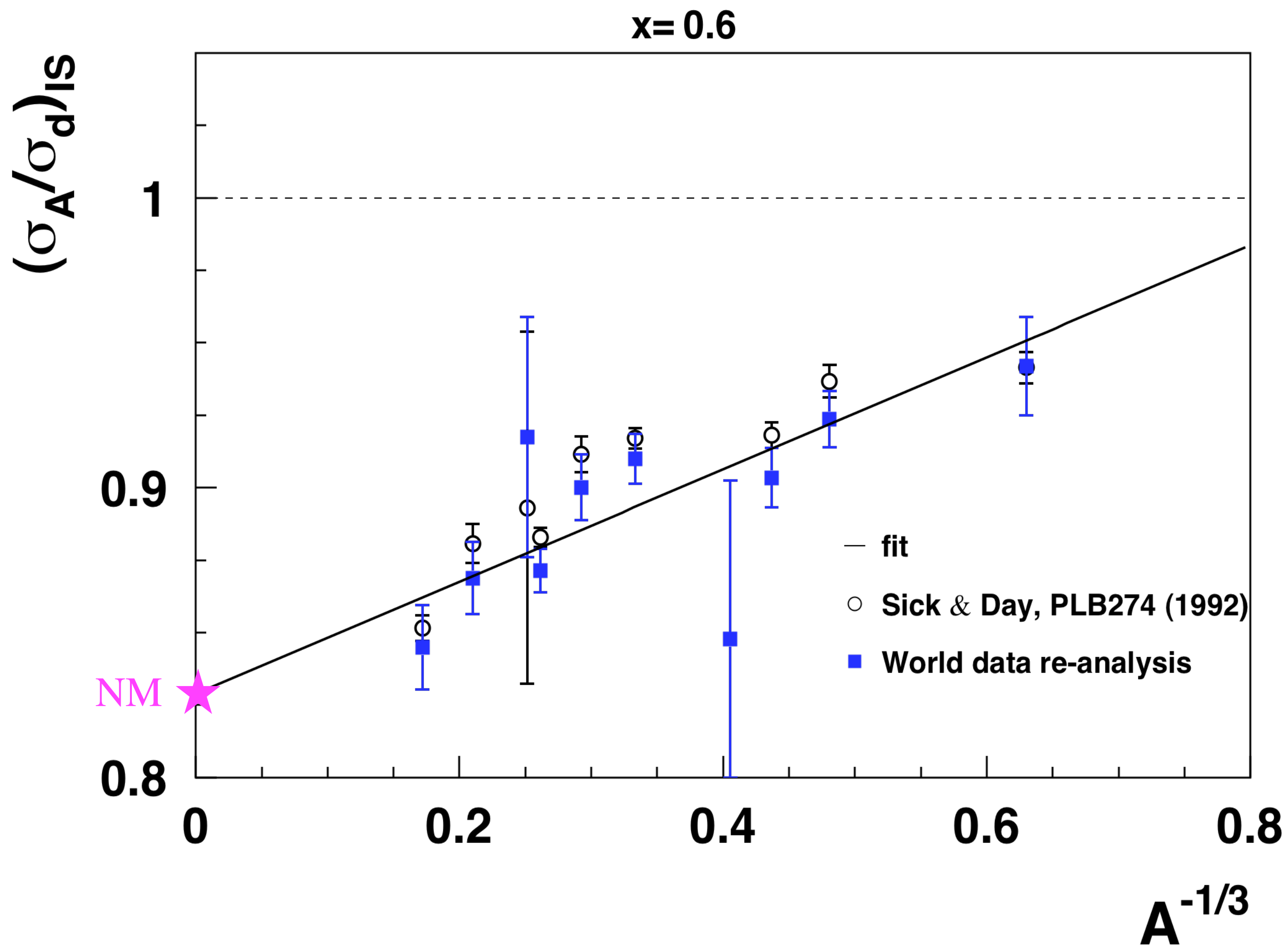


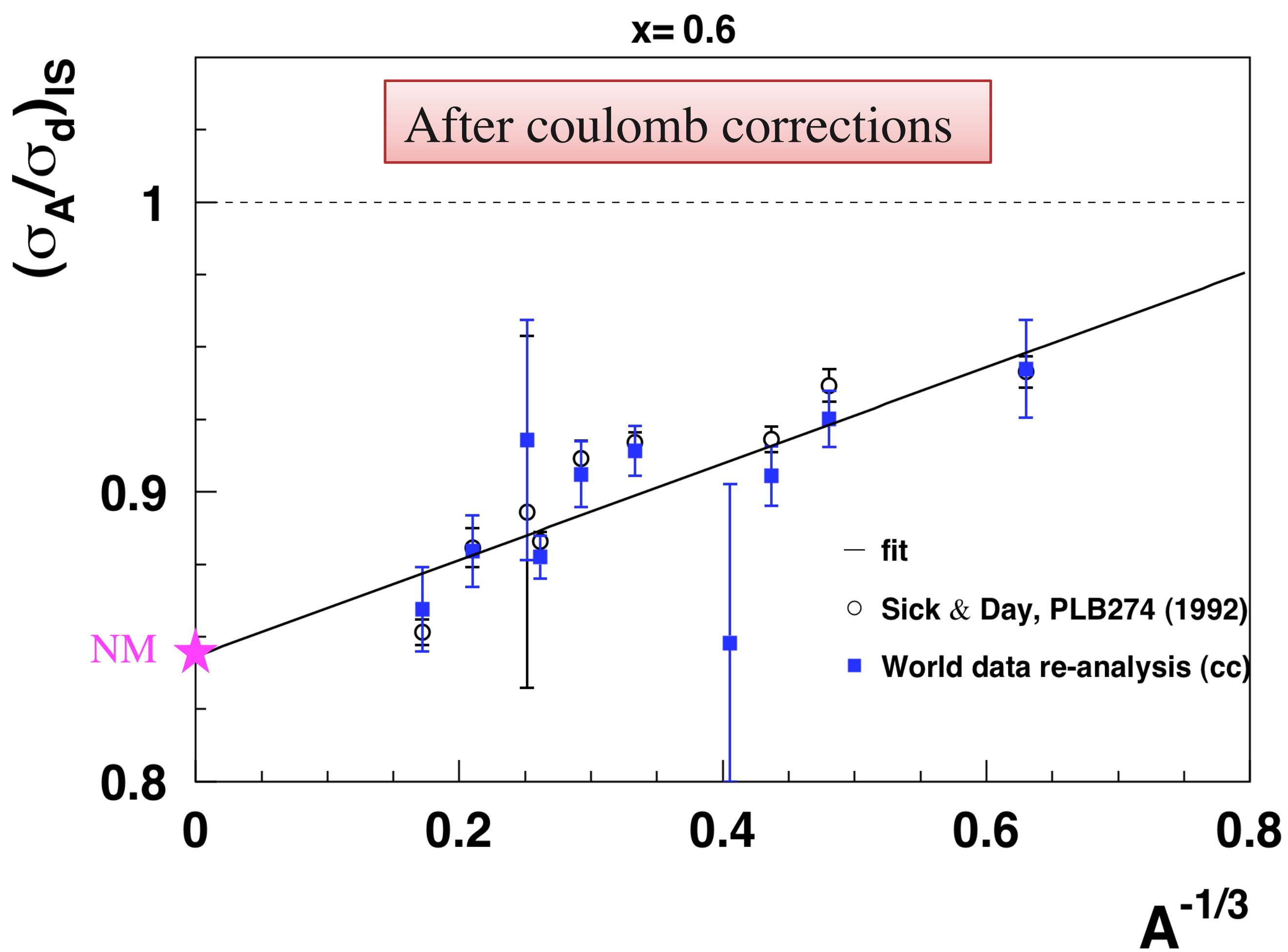
Nuclear dependence of the EMC effect



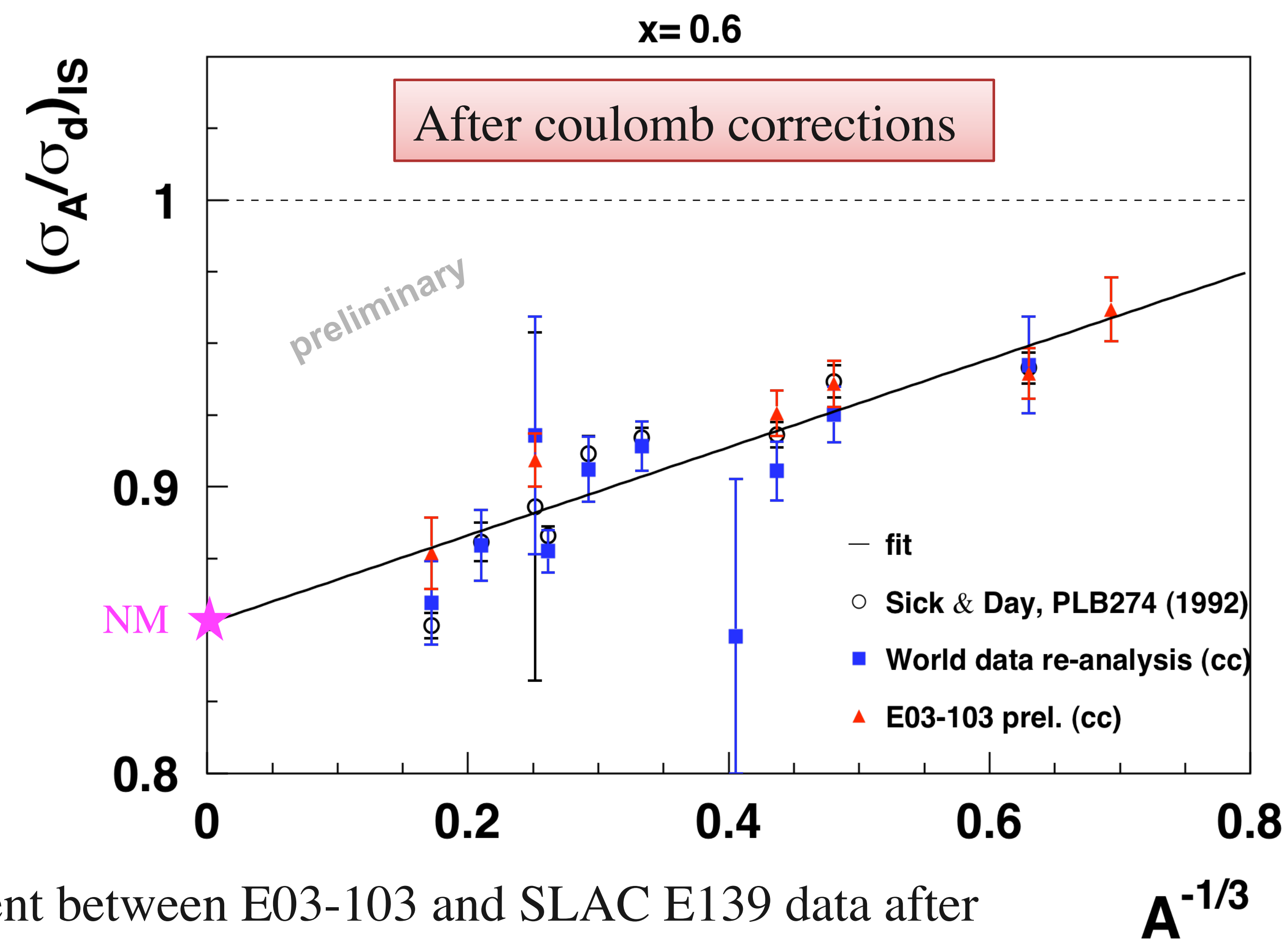
Main difference due to E139 data sets used:

- 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

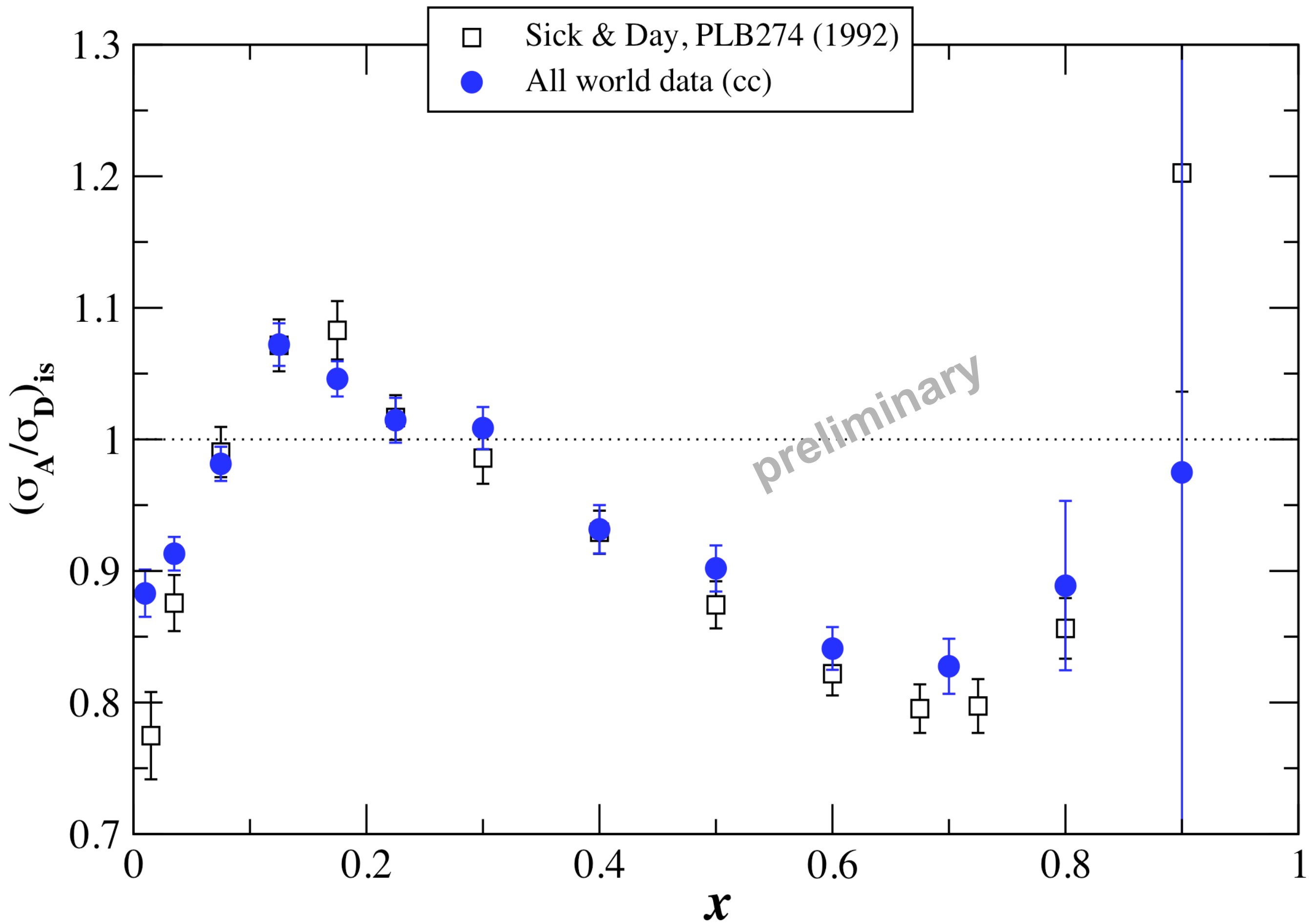


- Good agreement between E03-103 and SLAC E139 data after Coulomb corrections.

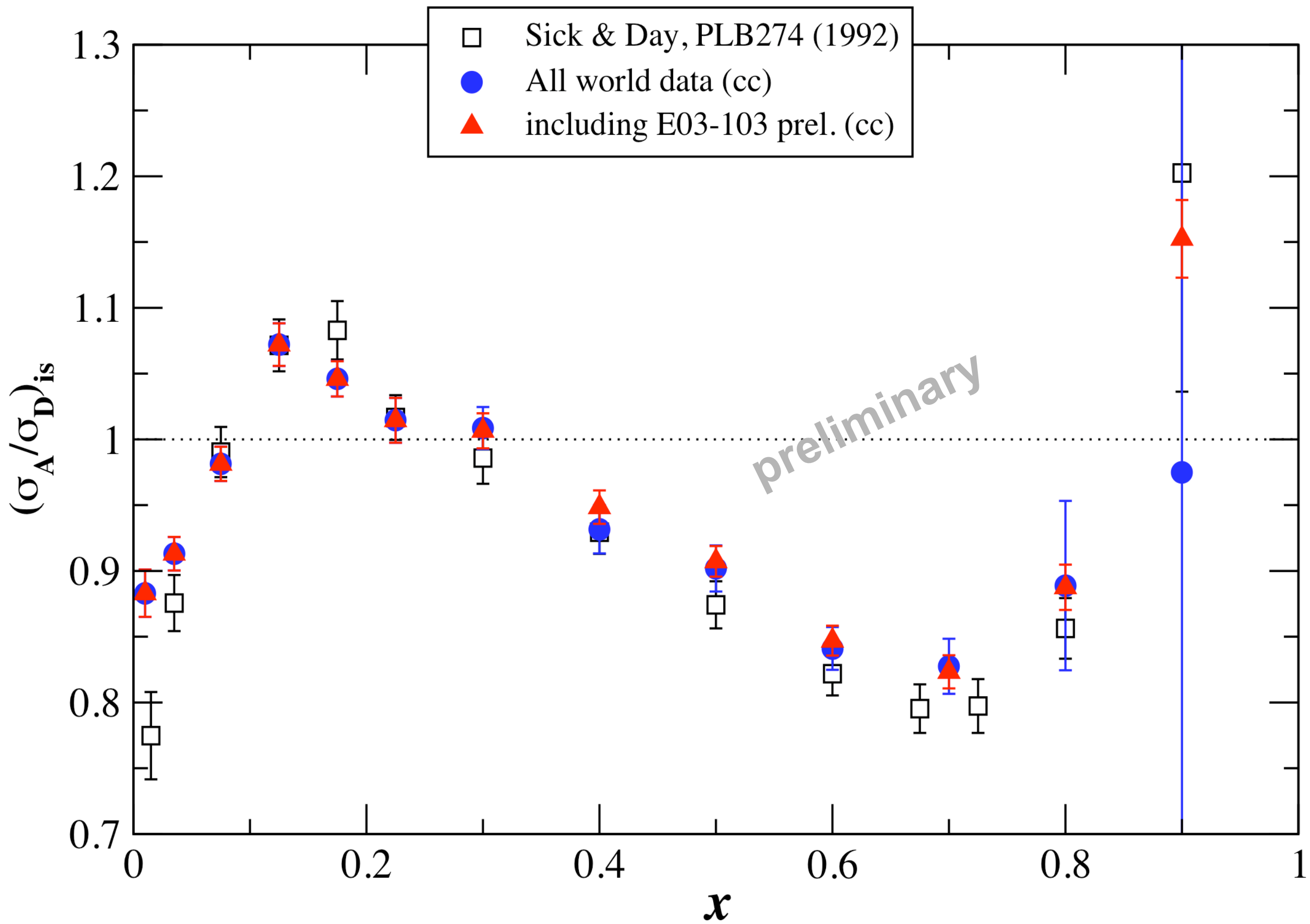
- Preliminary E03-103 results confirm A-dependence of the EMC effect.

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

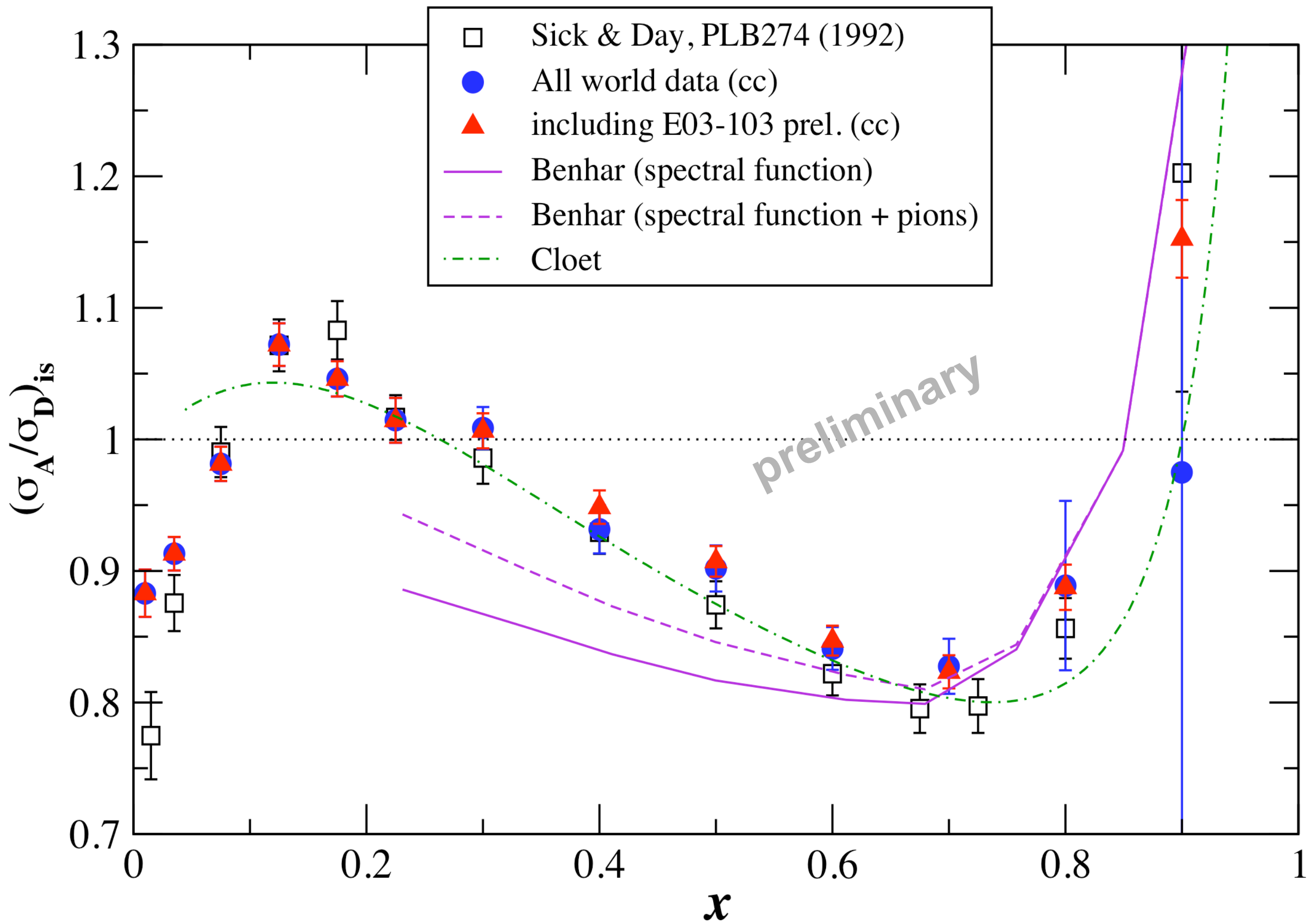
Nuclear matter



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