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New Measurement of the EMC effect for Light Nuclei and Global Study of the A-Dependence

Patricia Solvignon

Argonne National Laboratory

ECT 2008 Workshop

Nuclear Medium Effects on the Quark and Gluon Structure of Hadrons

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Outline

- **JLab E03-103 preliminary results:**
  - ***Q^2-dependence study with Carbon***
  - ***^3He and ^4He***
  - ***Heavy nuclei and Coulomb distortion***

- **Nuclear dependence of the EMC effect**
  - ***World data re-analysis***
  - ***New extrapolation to nuclear matter***

- **Resonance data and target mass corrections**

The EMC ratio

Ratio of cross sections per nucleon:

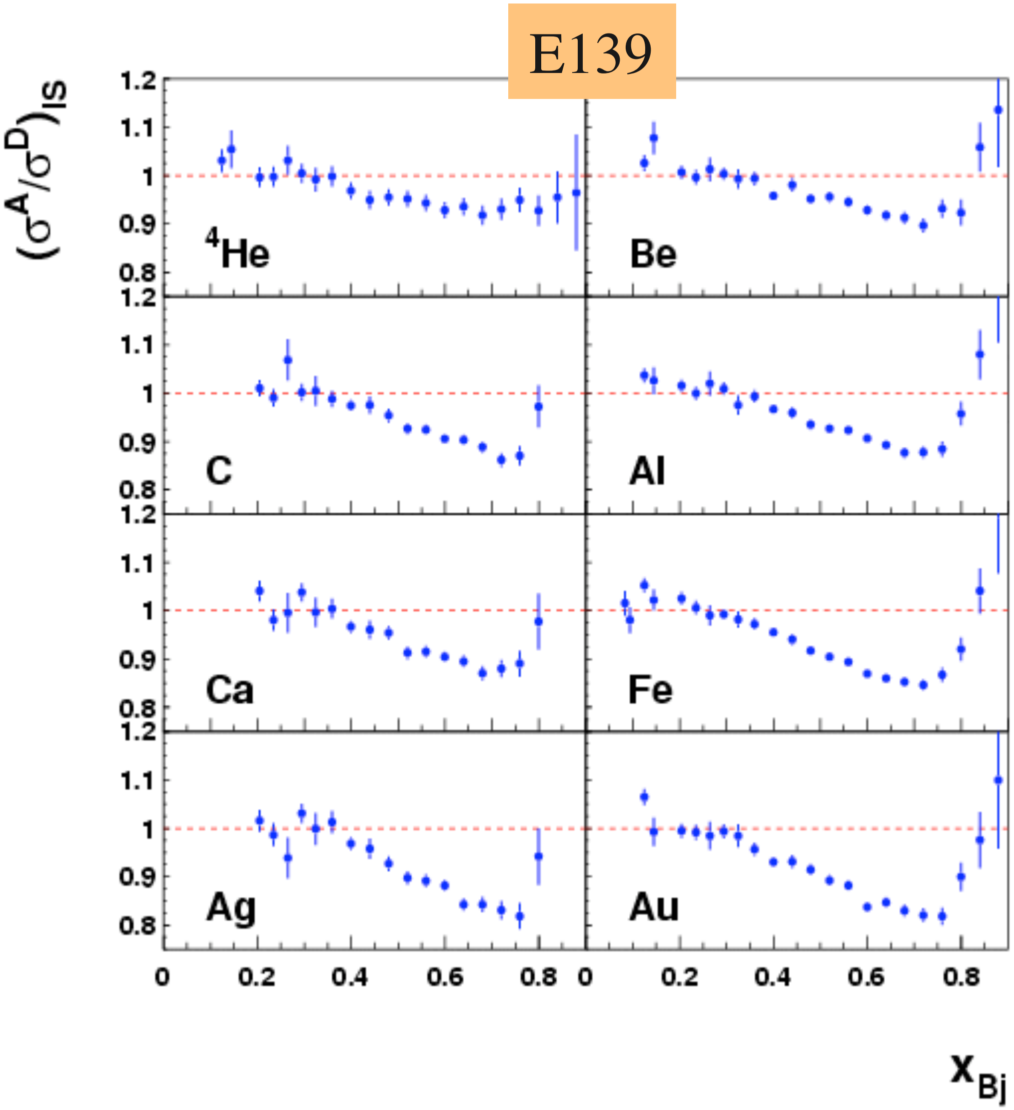
$$R_{EMC} = \frac{\sigma_2^A / A}{\sigma_2^D / 2} \cdot \left(\frac{1 + F_2^n / F_2^p}{Z + N F_2^n / F_2^p} \right)$$

Isoscalar correction

Existing EMC Data

- SLAC E139 most complete and precise data set for x>0.2

- σ_A/σ_D for A=4 to 197
  - ^{4}He, ^{9}Be, ^{12}C, ^{27}Al, ^{40}Ca, ^{56}Fe, ^{108}Ag, and ^{197}Au
  - Size at fixed x varies with A, but shape is nearly constant



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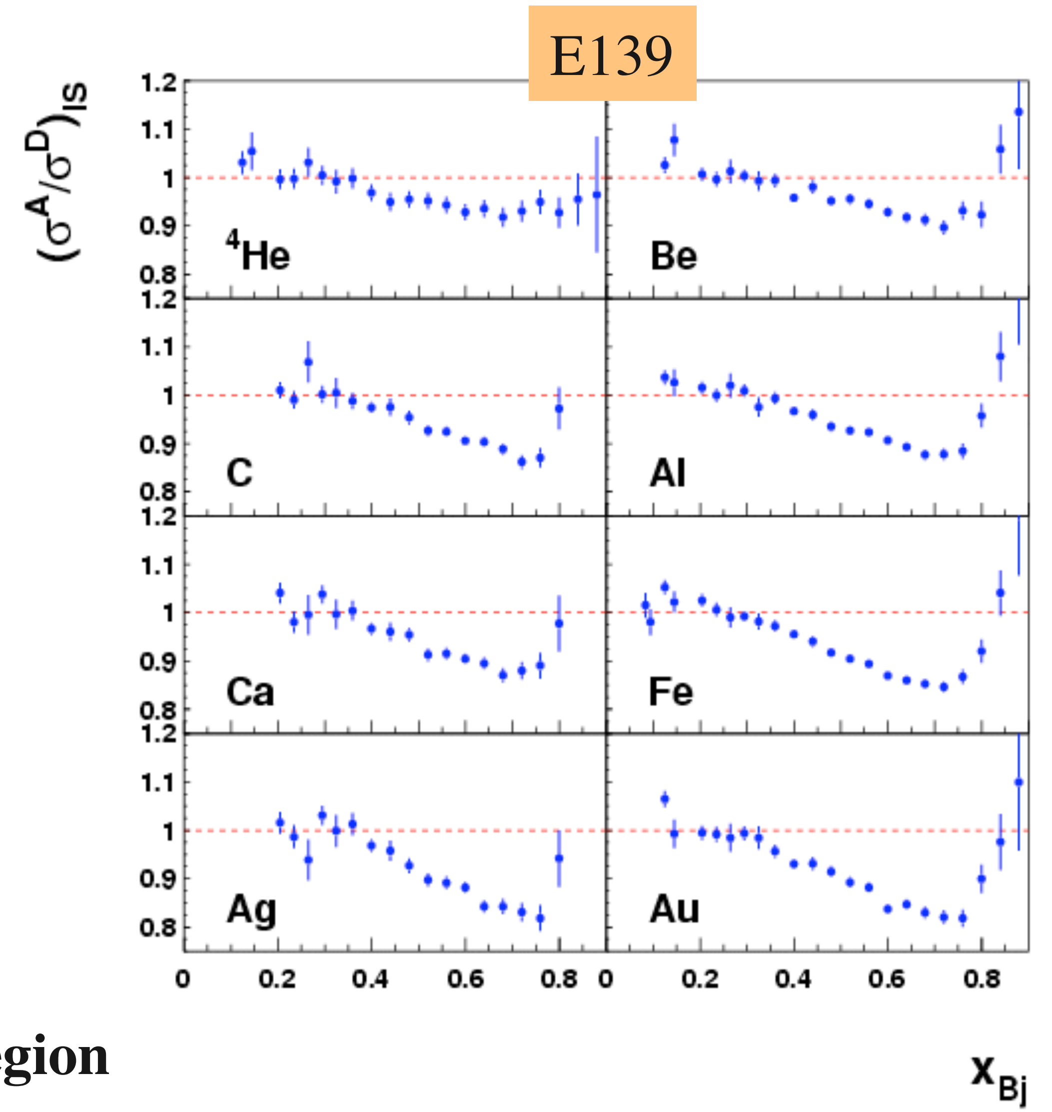


- **E03-103 will improve with**
  - Higher precision data for ^{4}He
  - Addition of ^{3}He data
  - Precision data at large *x* and on heavy nuclei

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

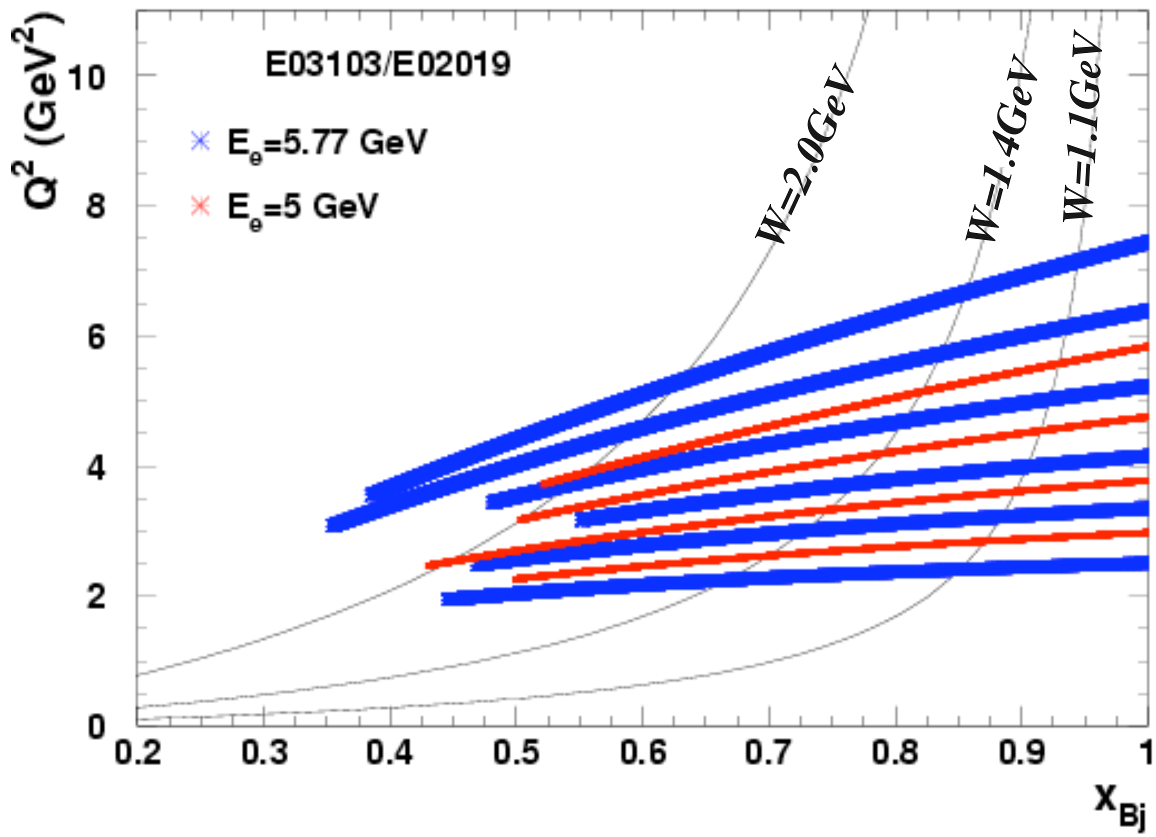
JLab Experiment E03-103

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

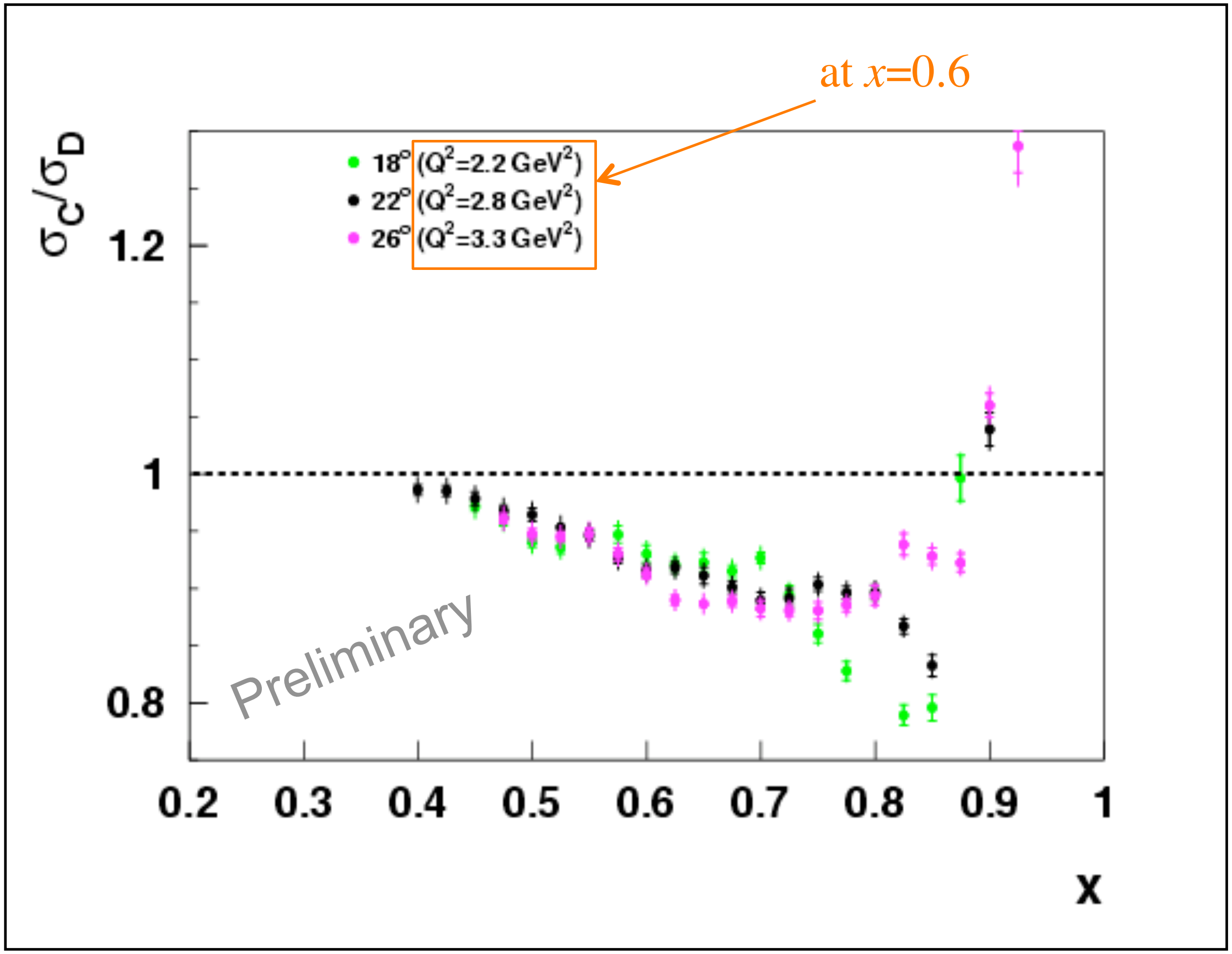
A(e,e') at 5.0 and 5.8 GeV in Hall C

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

- 10 angles to measure
  Q^2-dependence

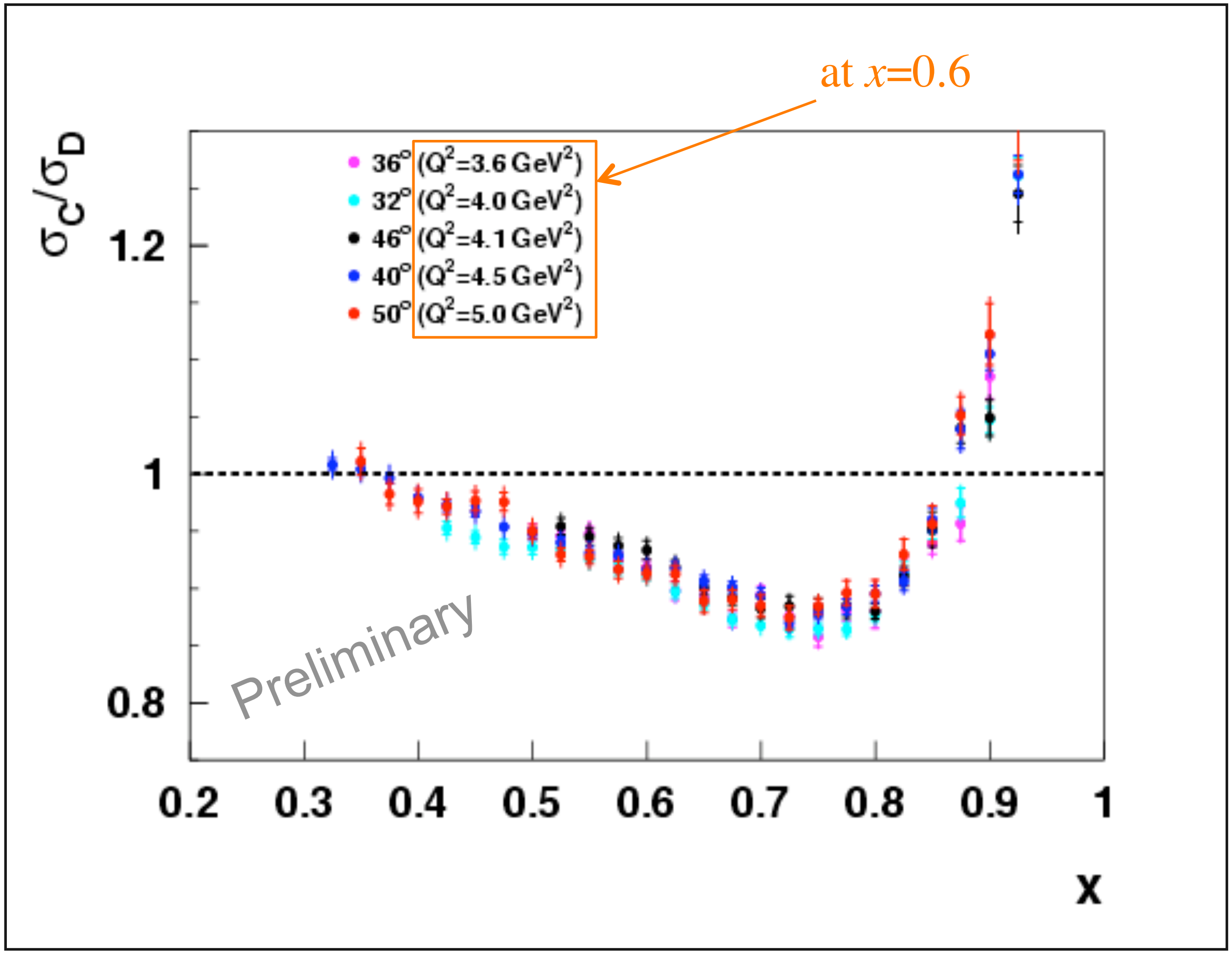


E03-103: Carbon EMC ratio and Q^2-dependence



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*

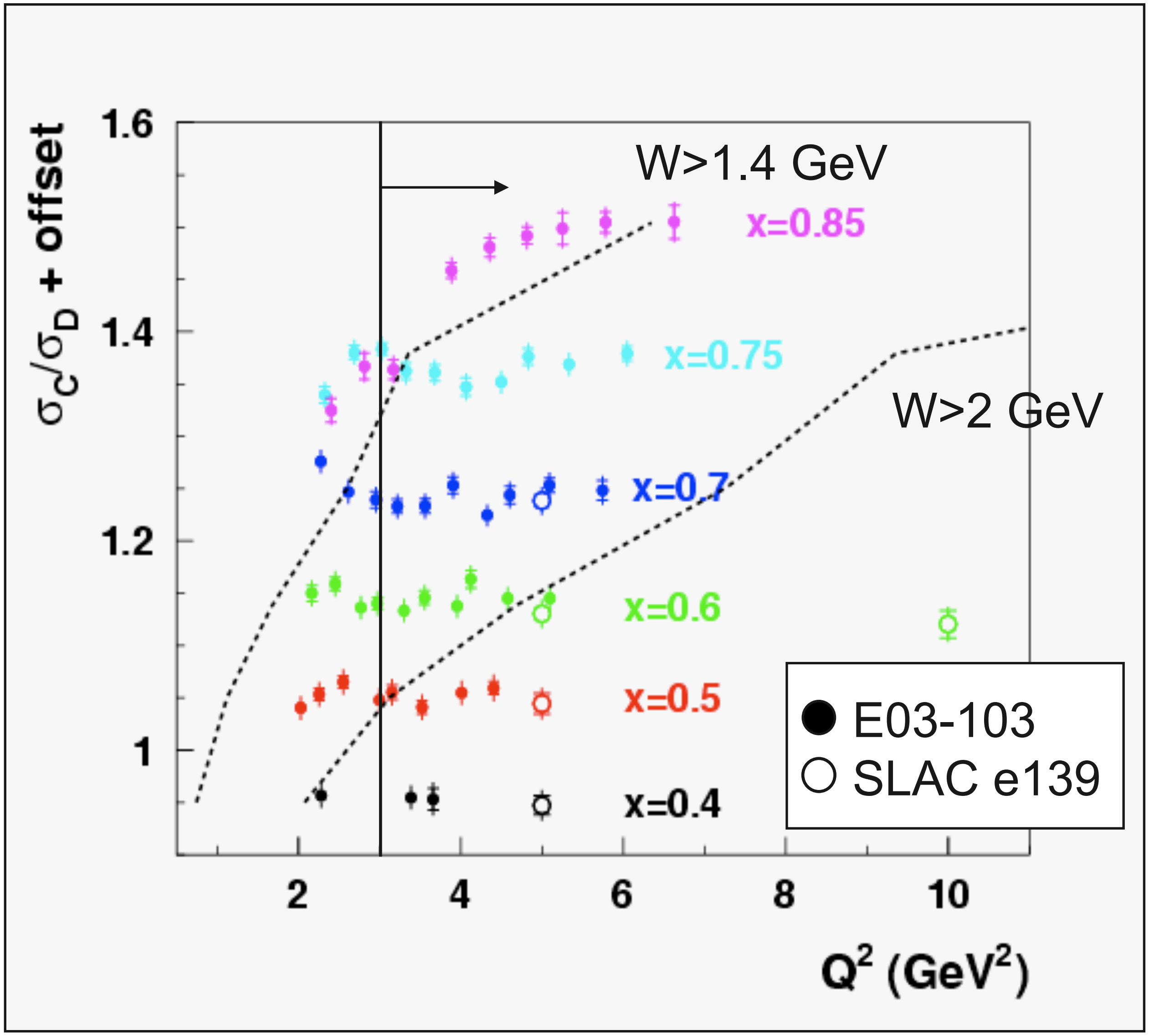
More detailed look at scaling

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

W>1.4 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



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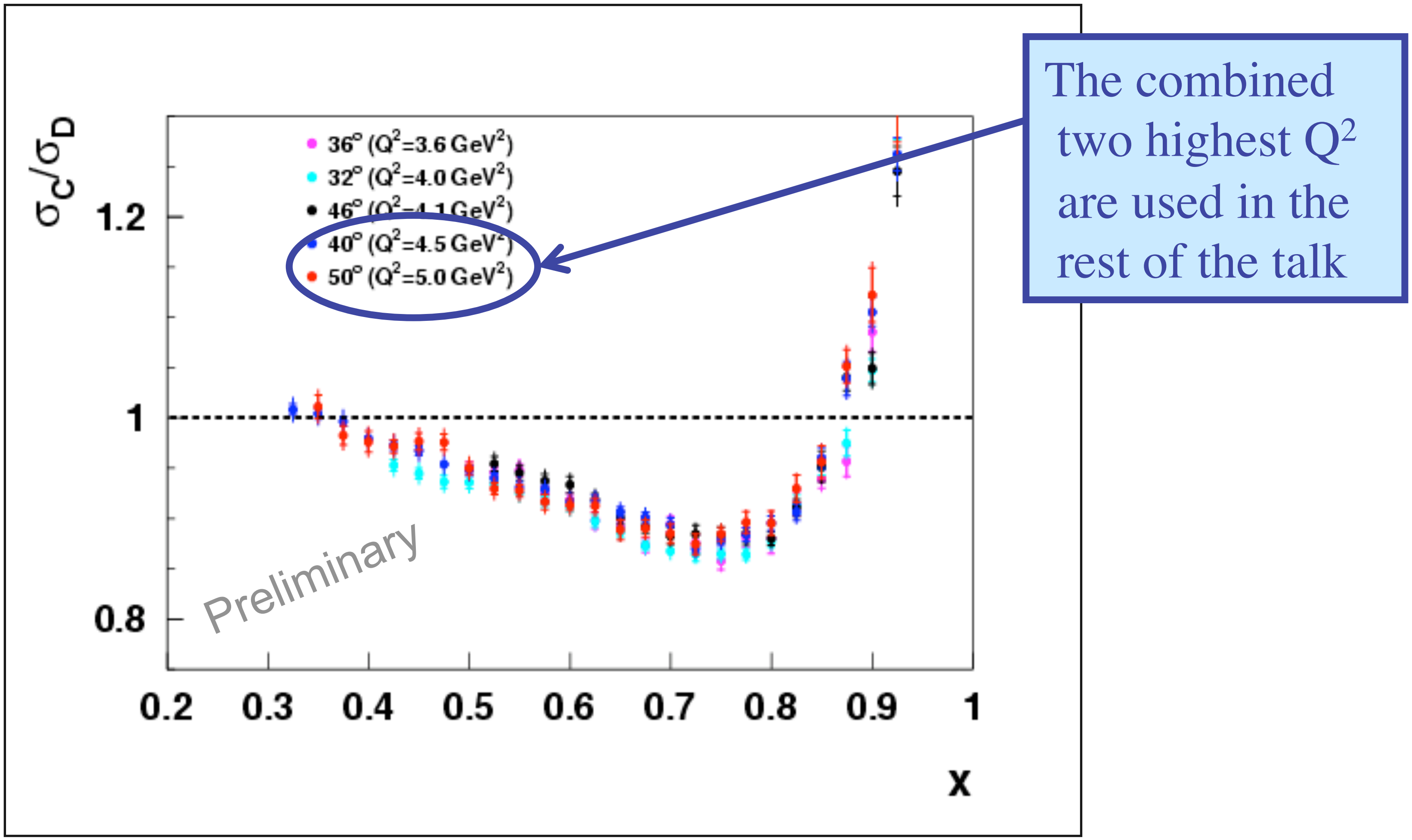

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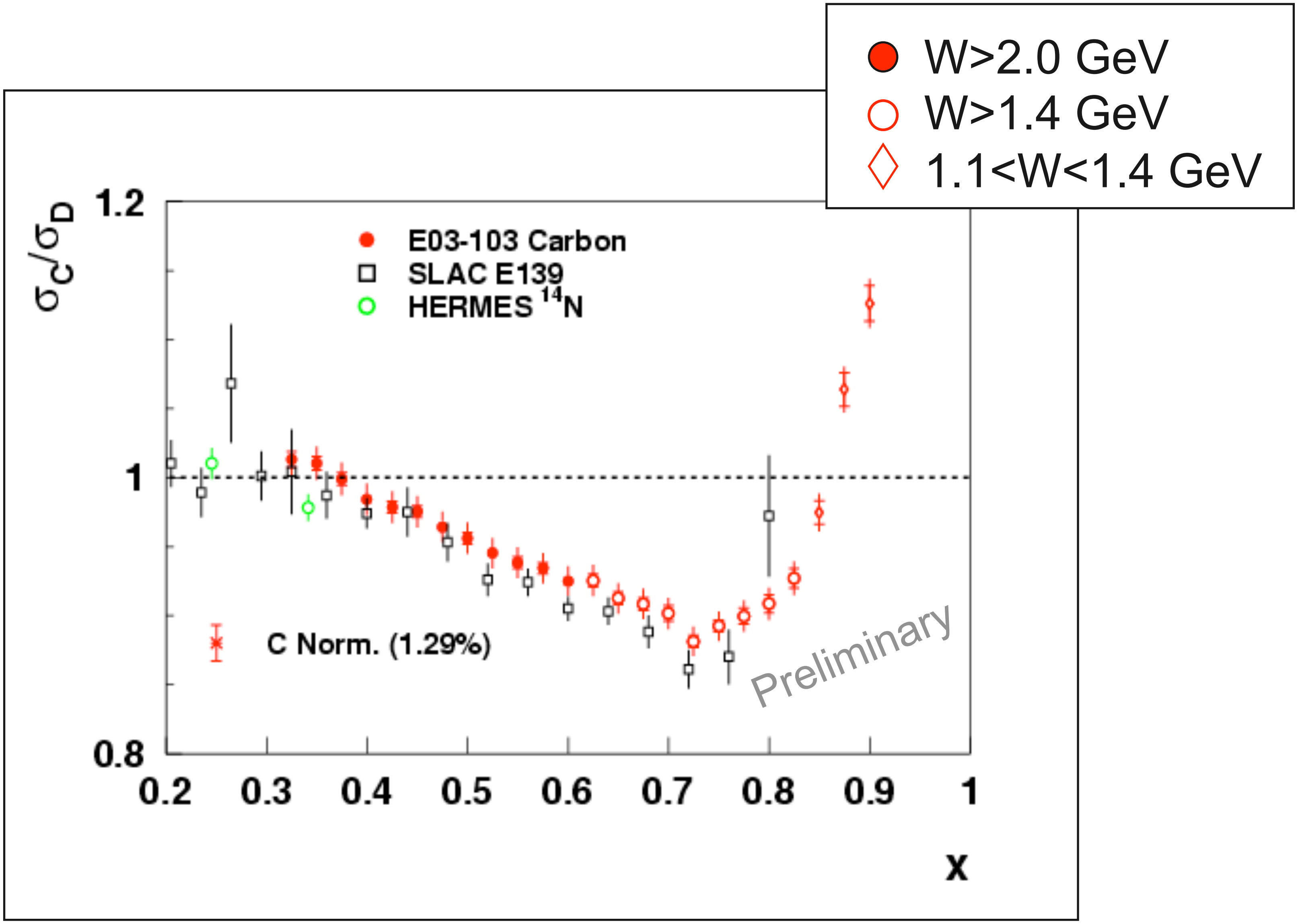
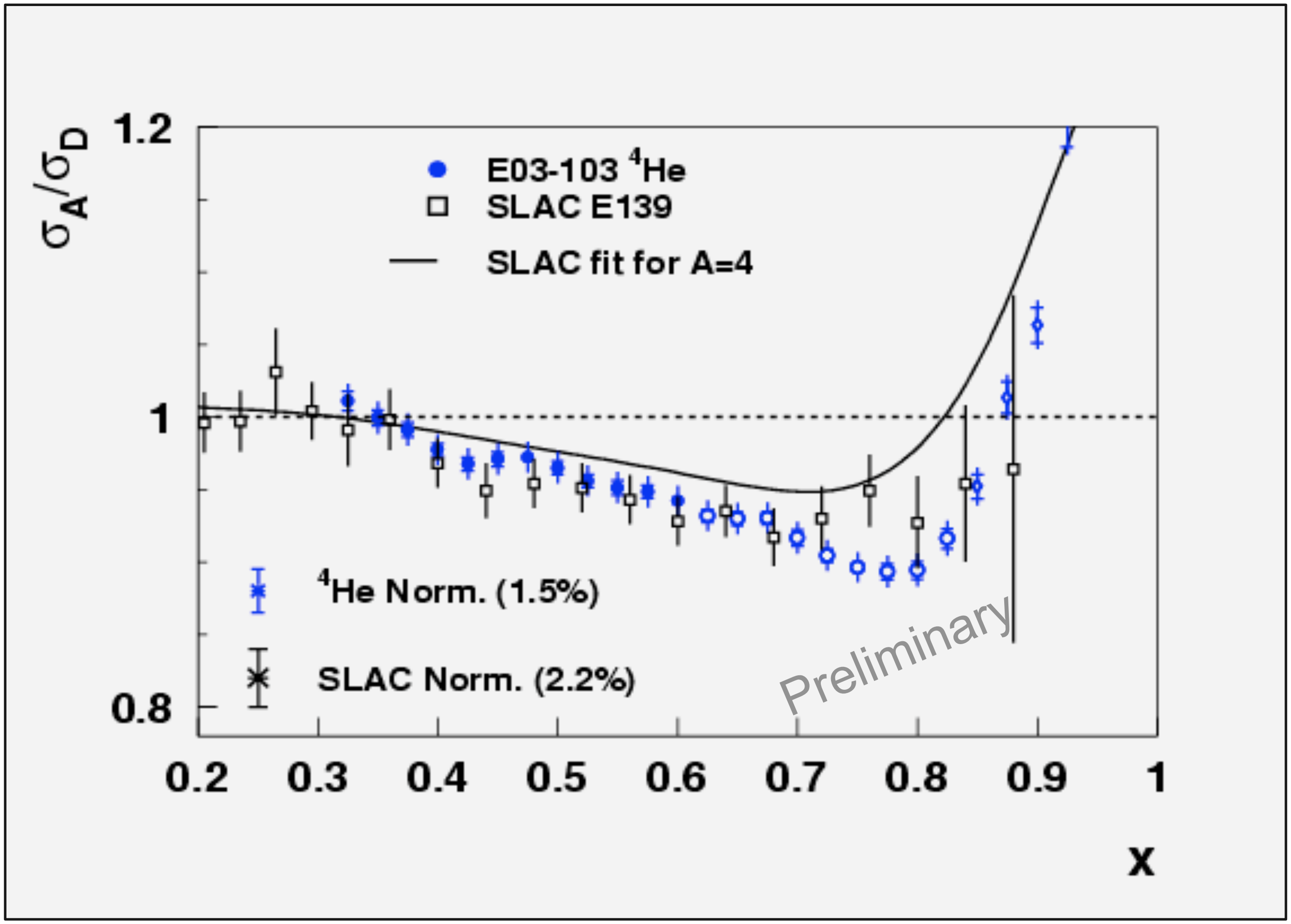
E03-103: Carbon EMC ratio



E03-103: ^{4}He

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



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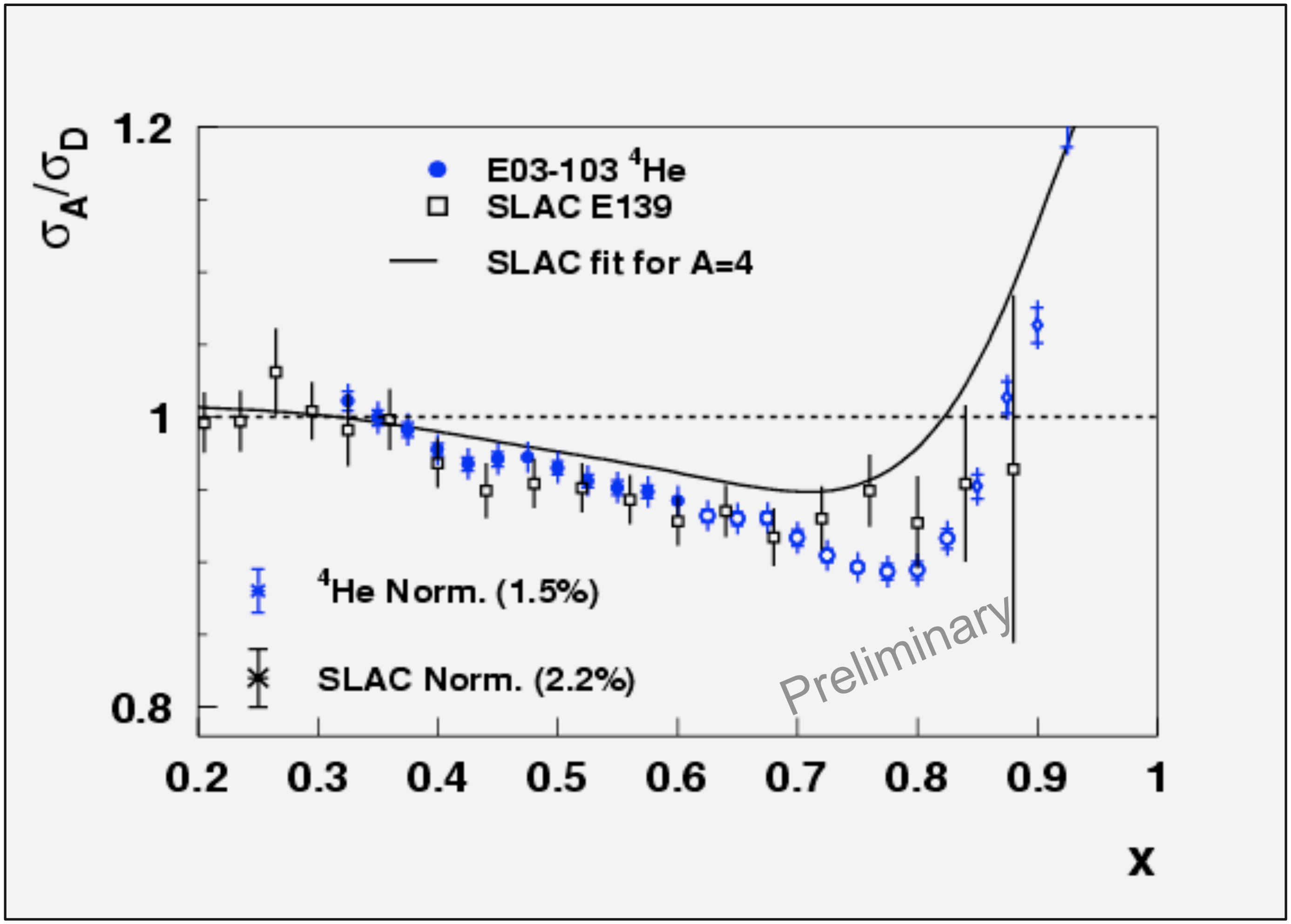
Large x shape more clearly consistent with heavier nuclei



E03-103: ^{4}He

JLab results consistent with SLAC E139
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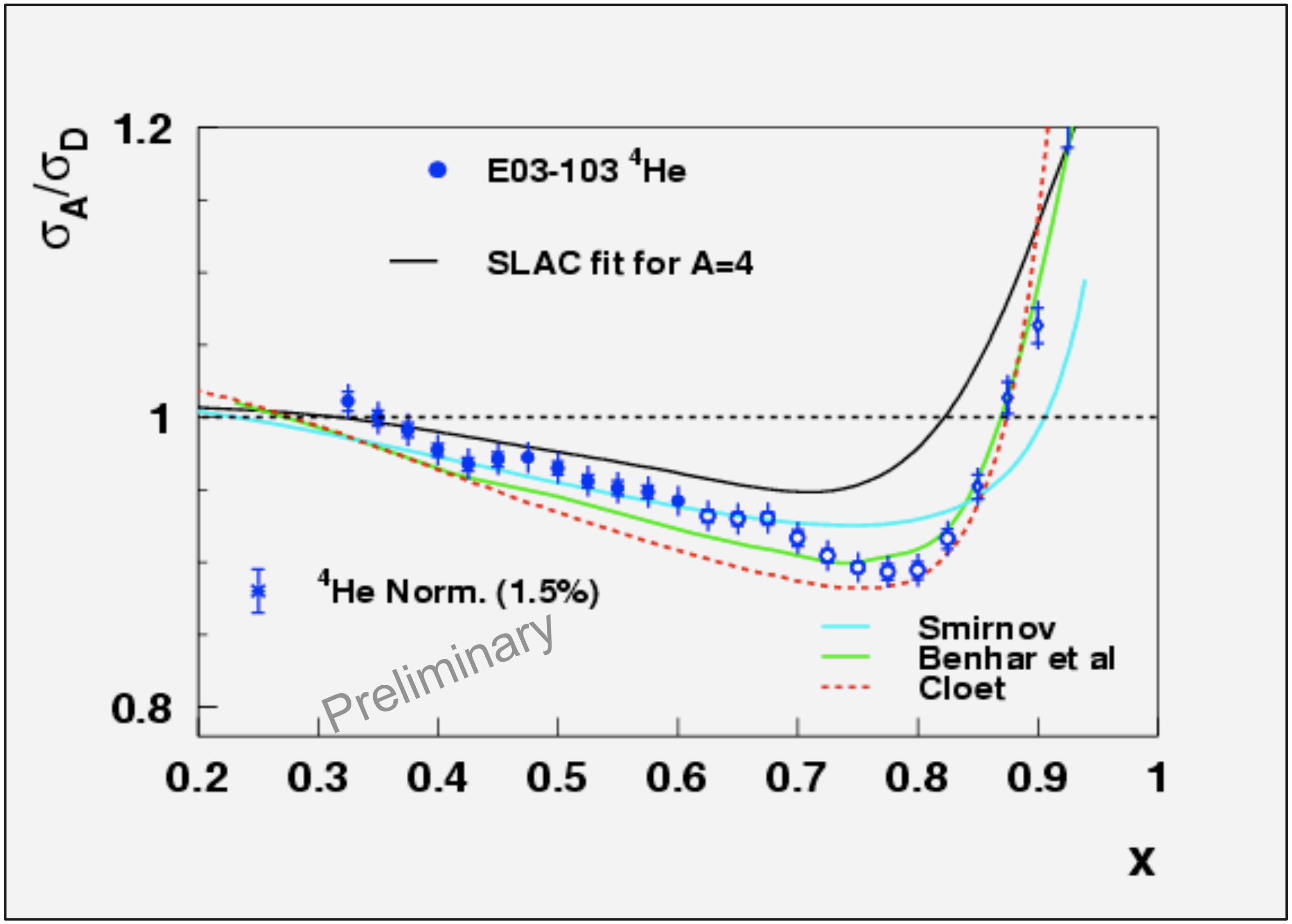
Large *x* shape more clearly consistent with heavier nuclei

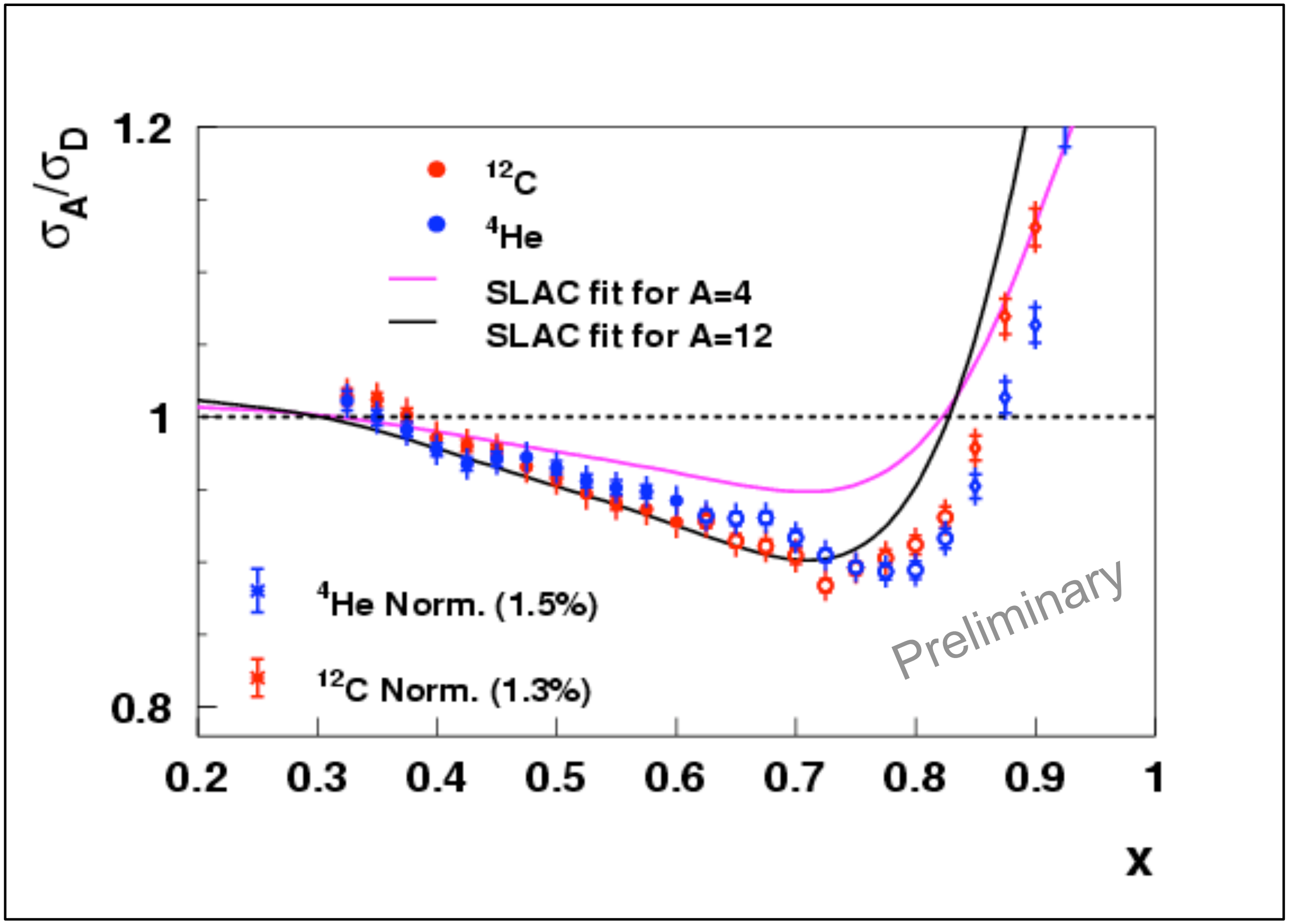
Models shown do a reasonable job describing the data



E03-103: comparison carbon and ^{4}He

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

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



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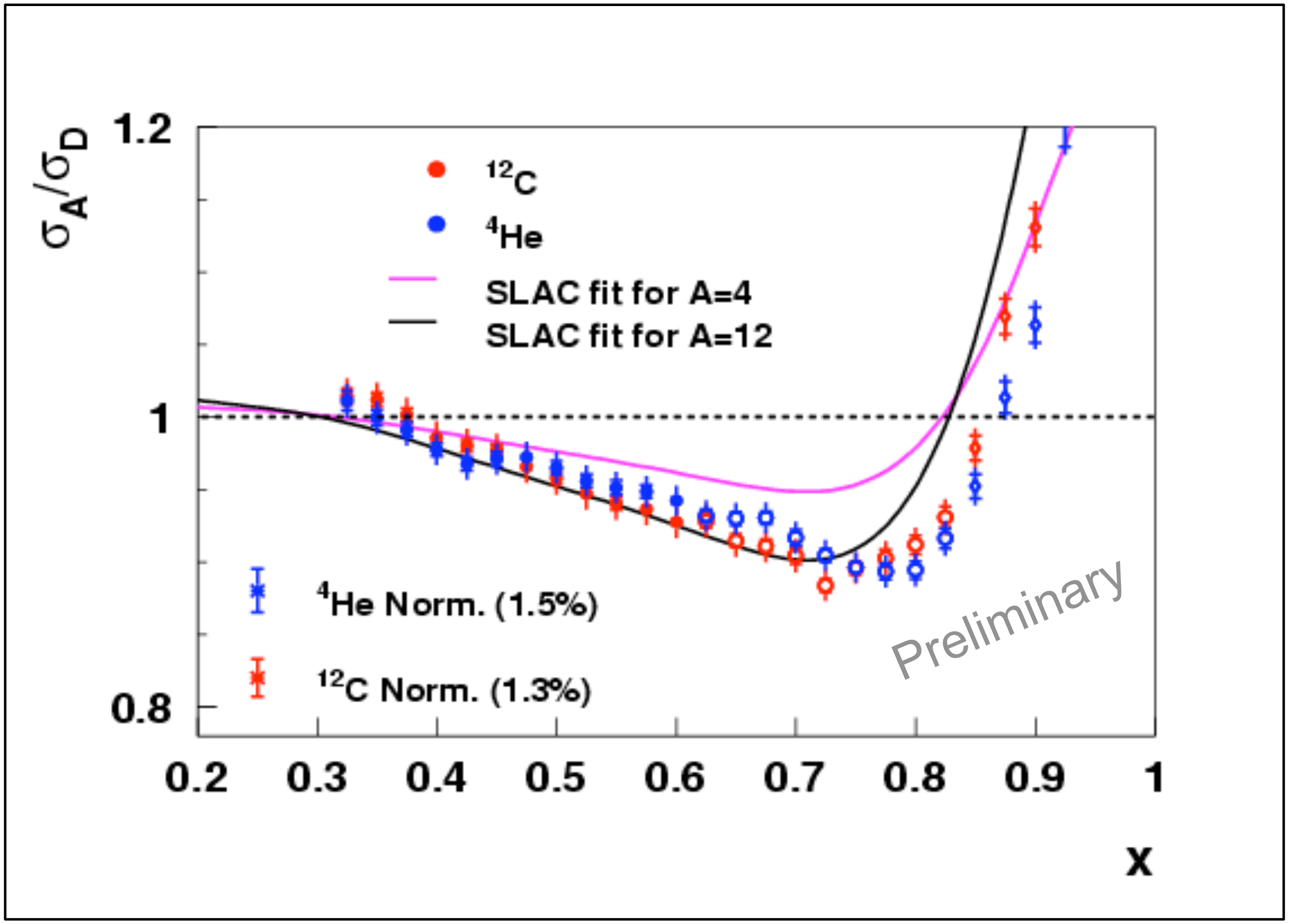
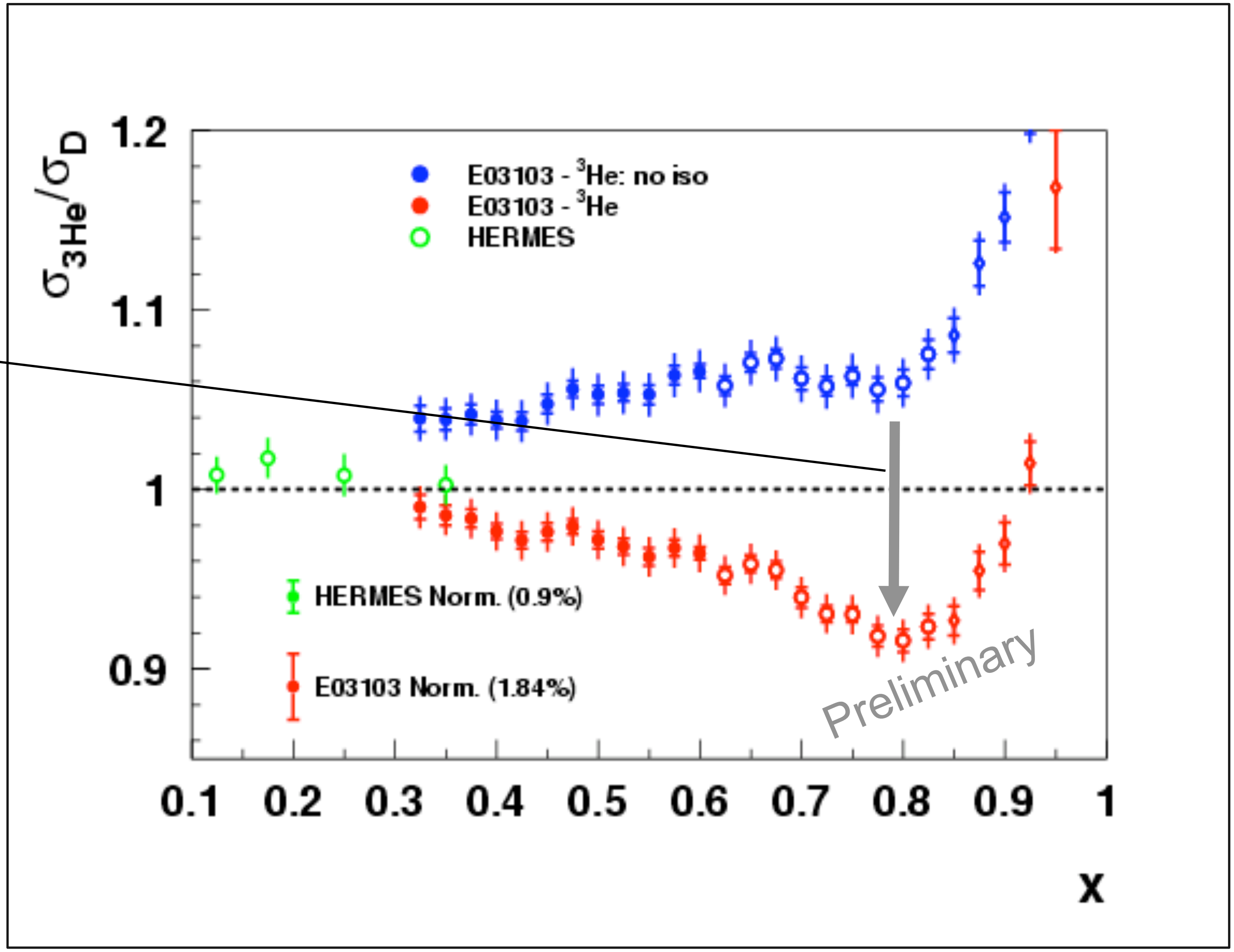


→ ^{4}He acts like a "real nucleus"

→ Some hint of difference in shape, but hard to tell with existing errors

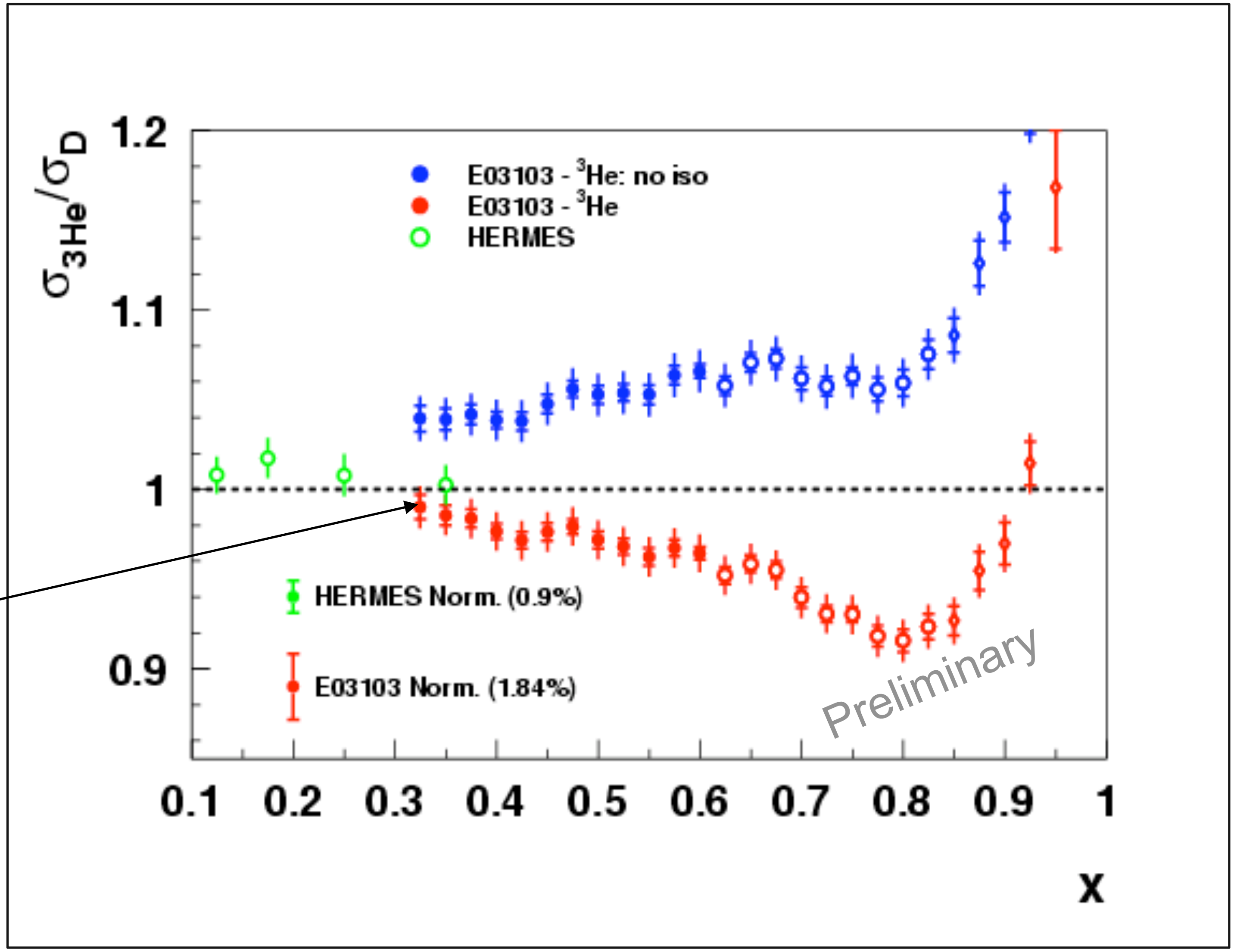
E03-103: Preliminary ^{3}He EMC ratio

Large proton excess correction



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

Good agreement with HERMES in overlap region



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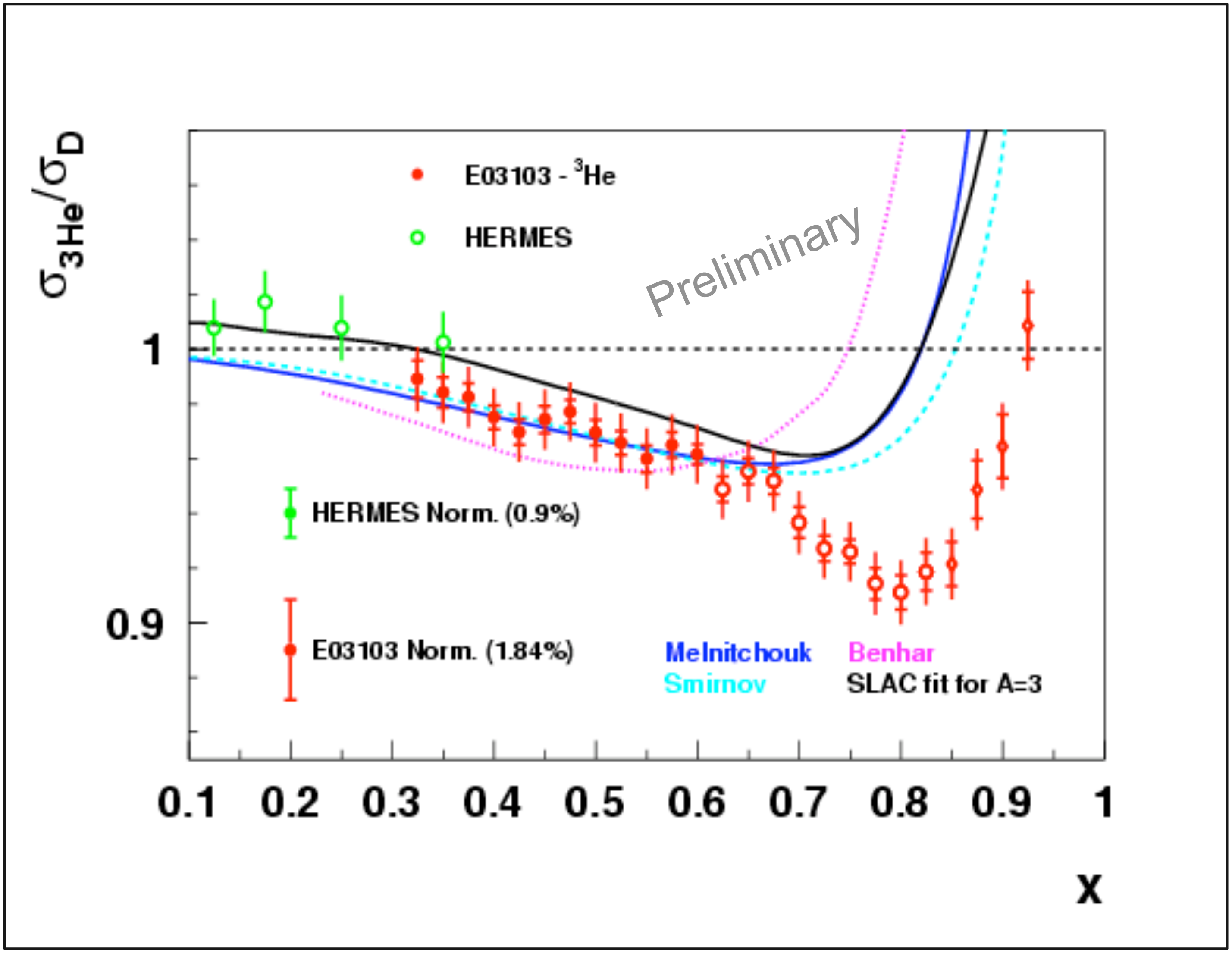
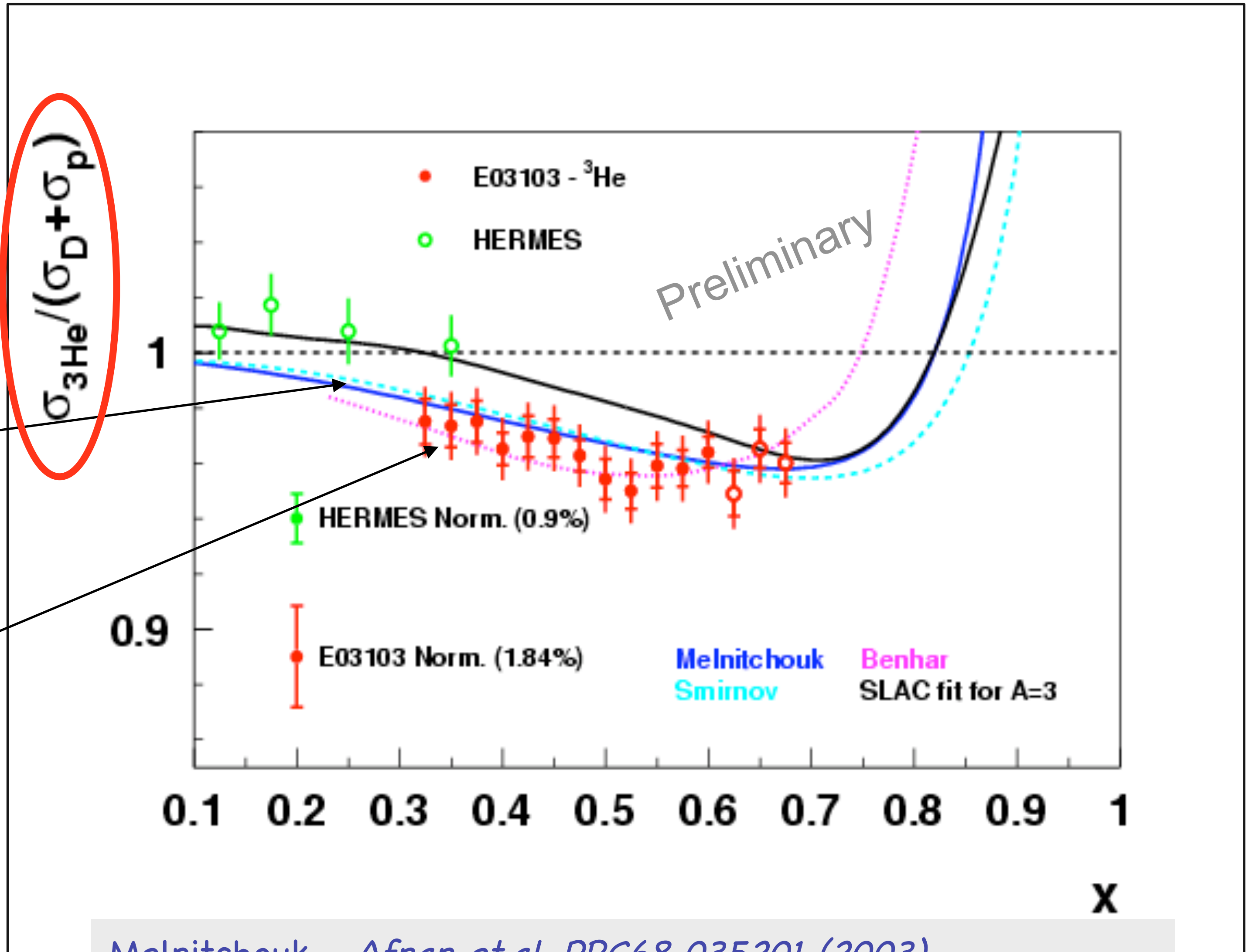


E03-103: Preliminary ^{3}He EMC ratio

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!)***

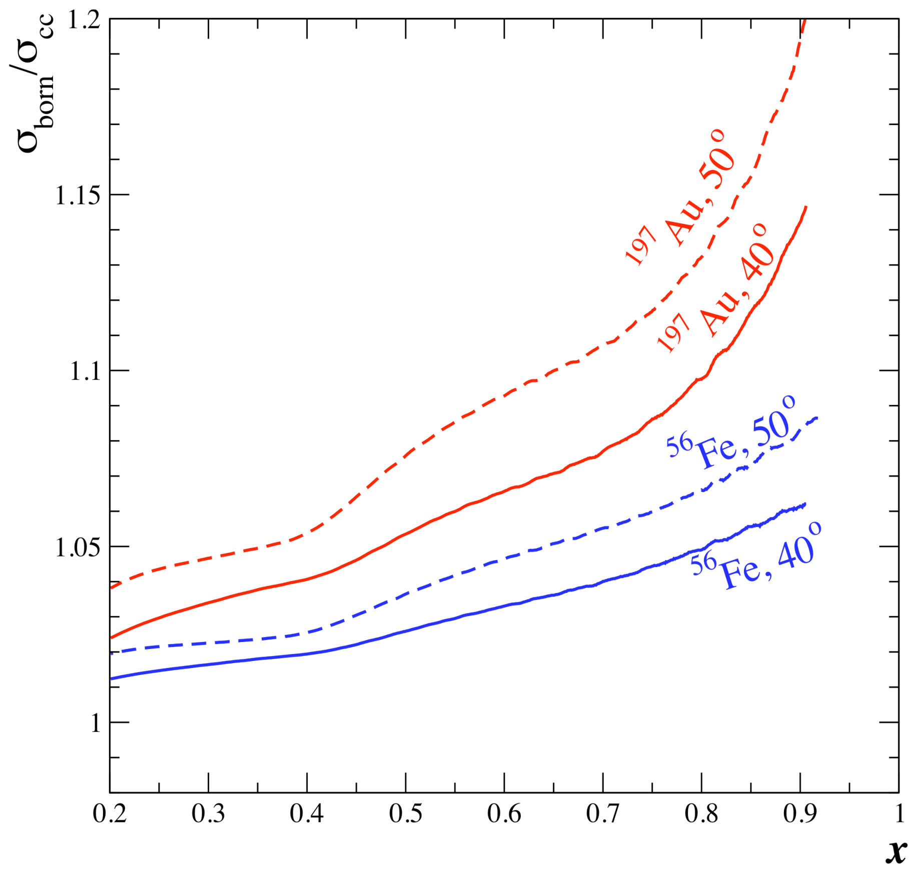
E03-103 uses modified Effective Momentum Approximation (EMA)

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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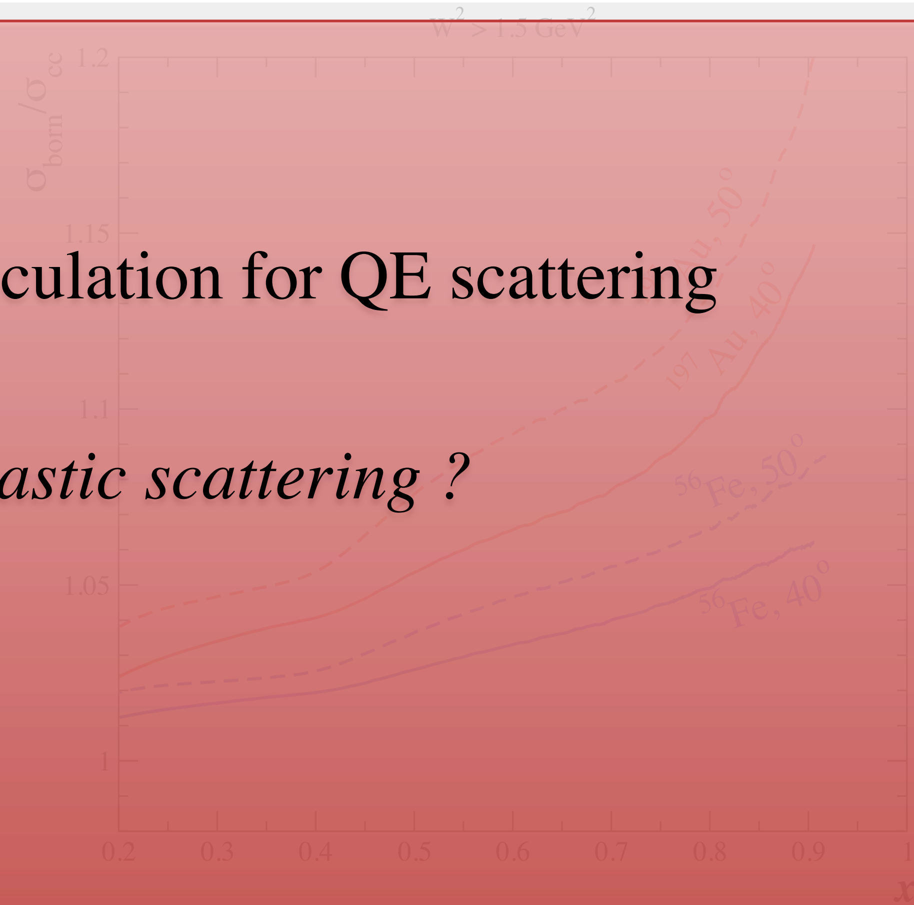
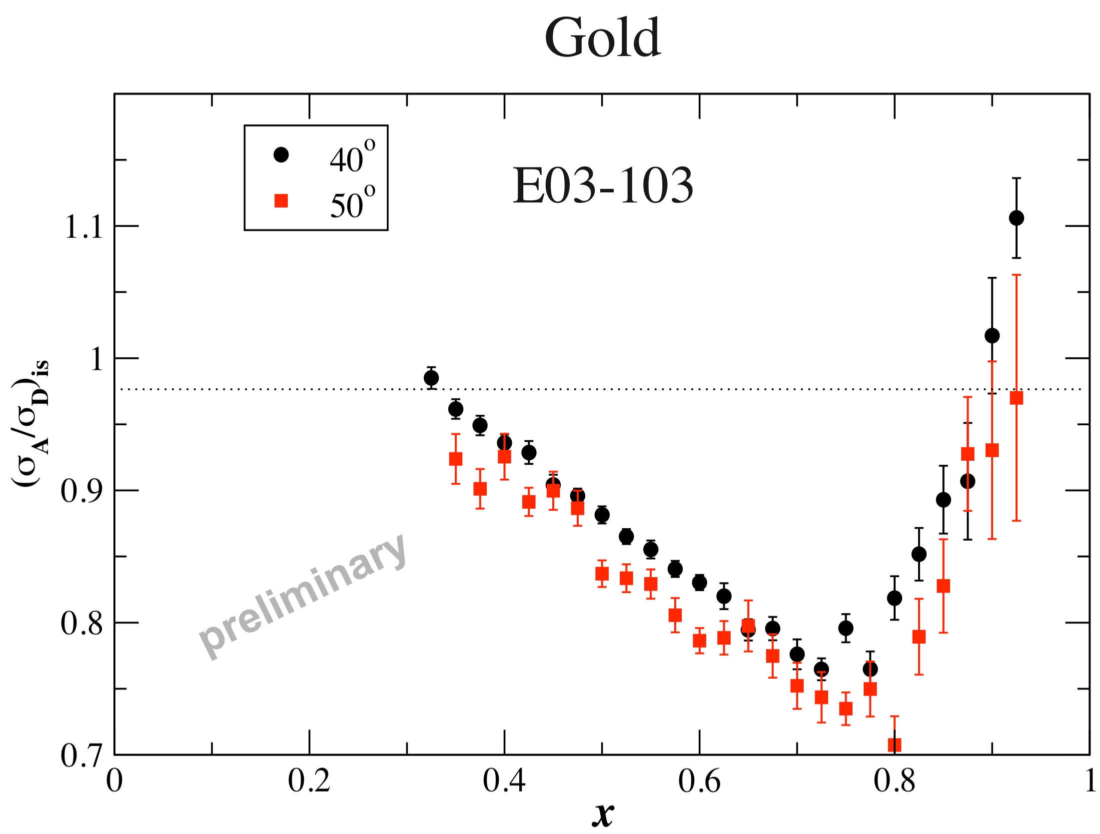


EMA tested against DWBA calculation for QE scattering

➔ *application to inelastic scattering ?*

Effect of the coulomb distortion on E03-103 data

Before coulomb corrections



Effect of the coulomb distortion on E03-103 data

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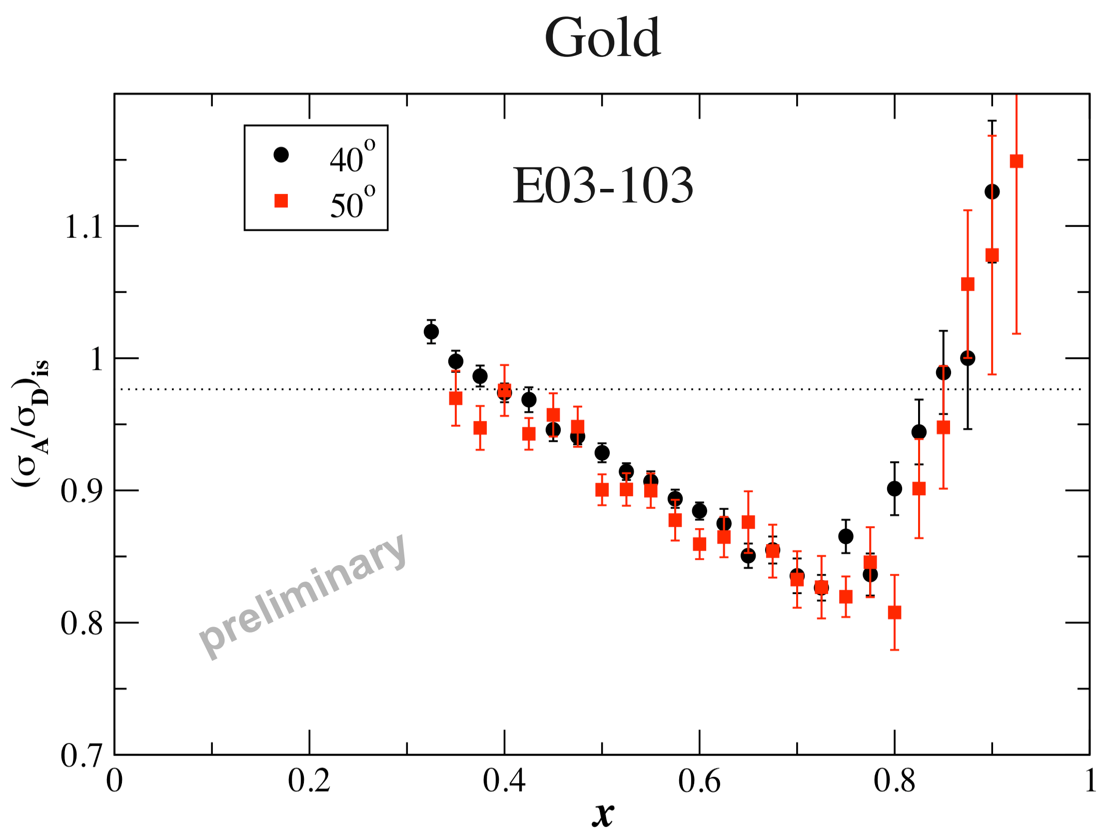
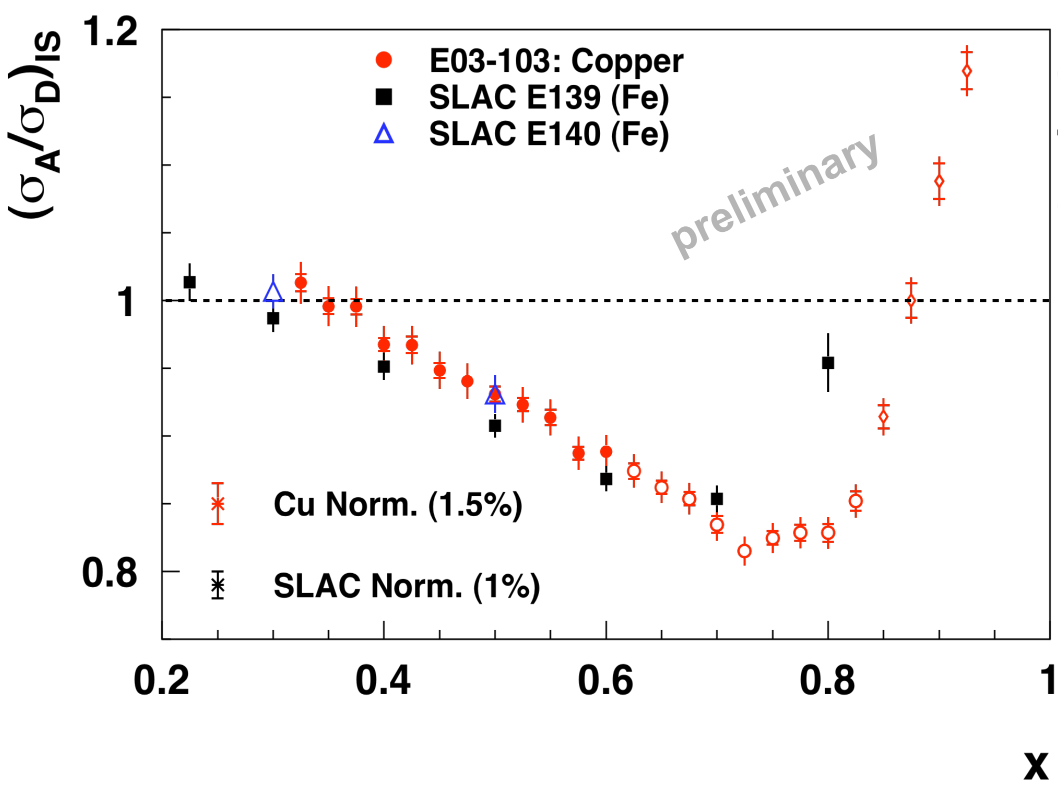
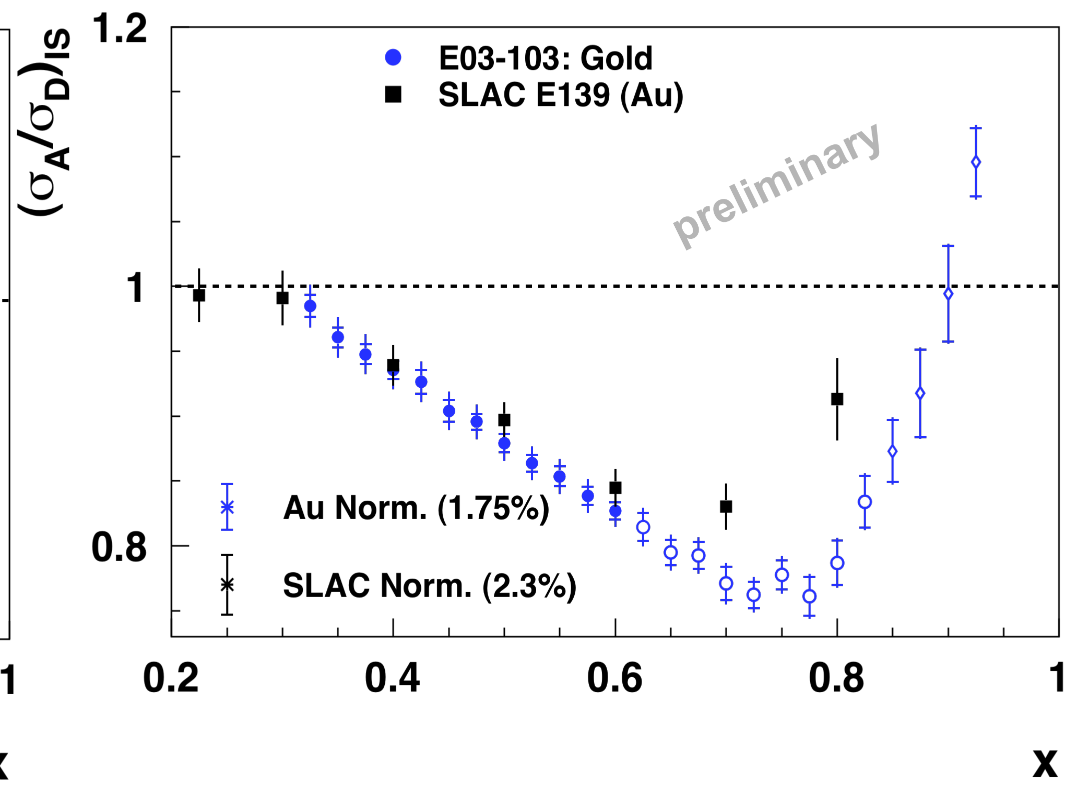


E03-013 heavy target results and world data

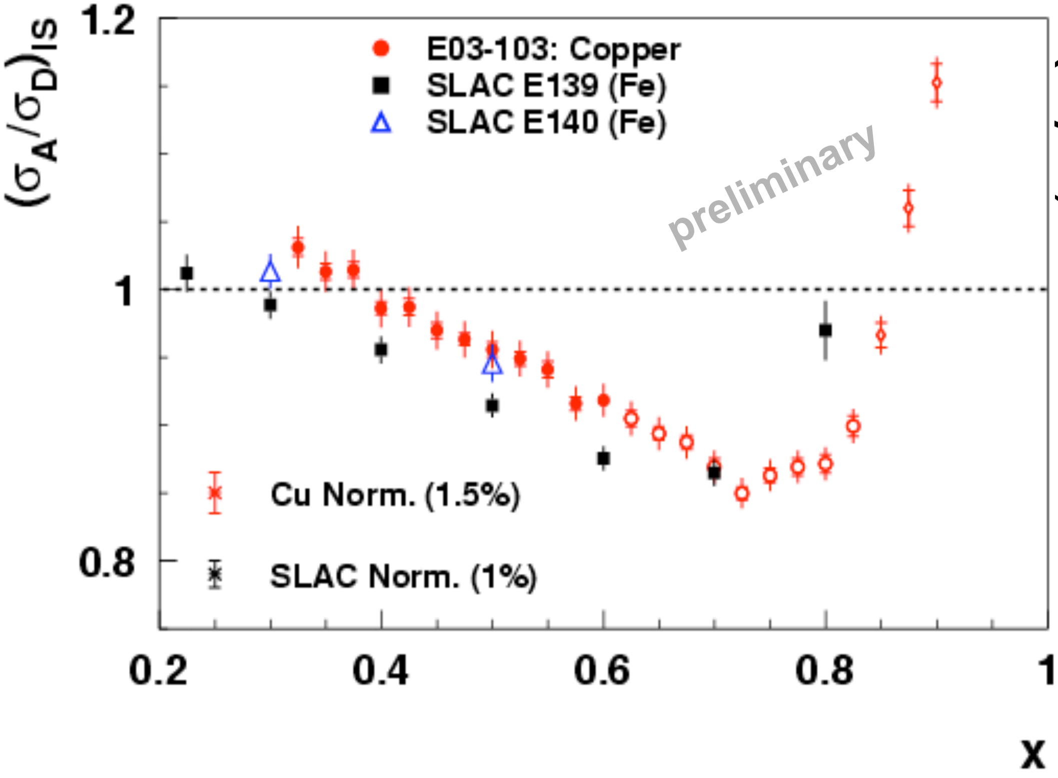
Before coulomb corrections

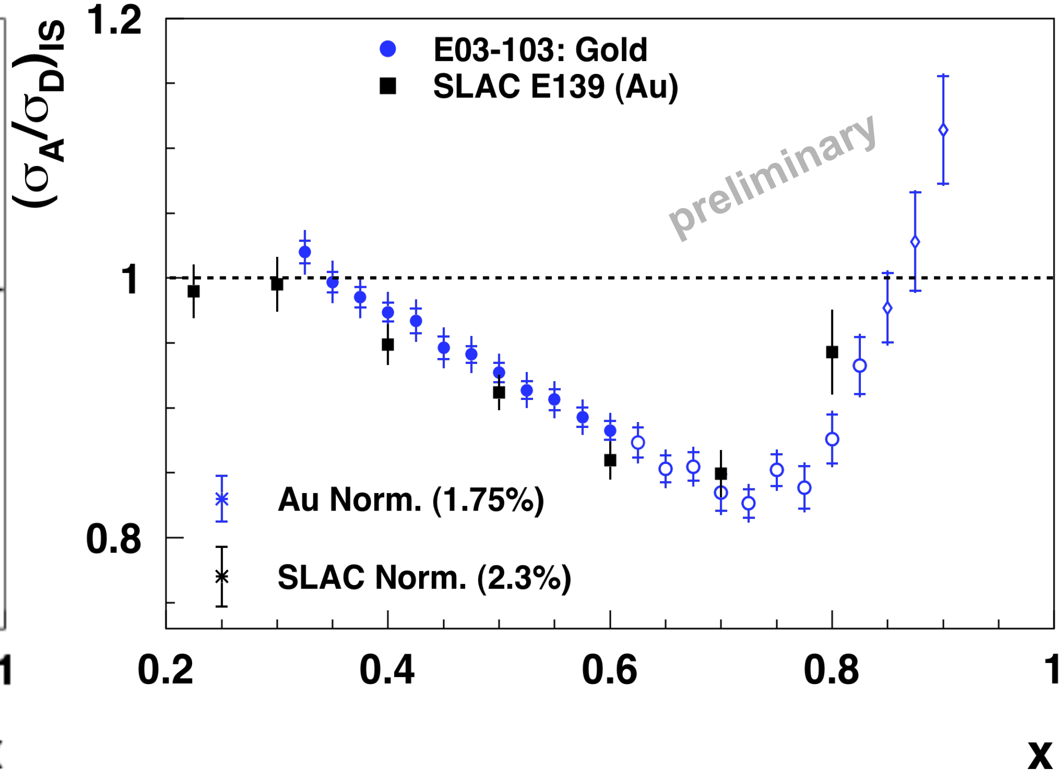




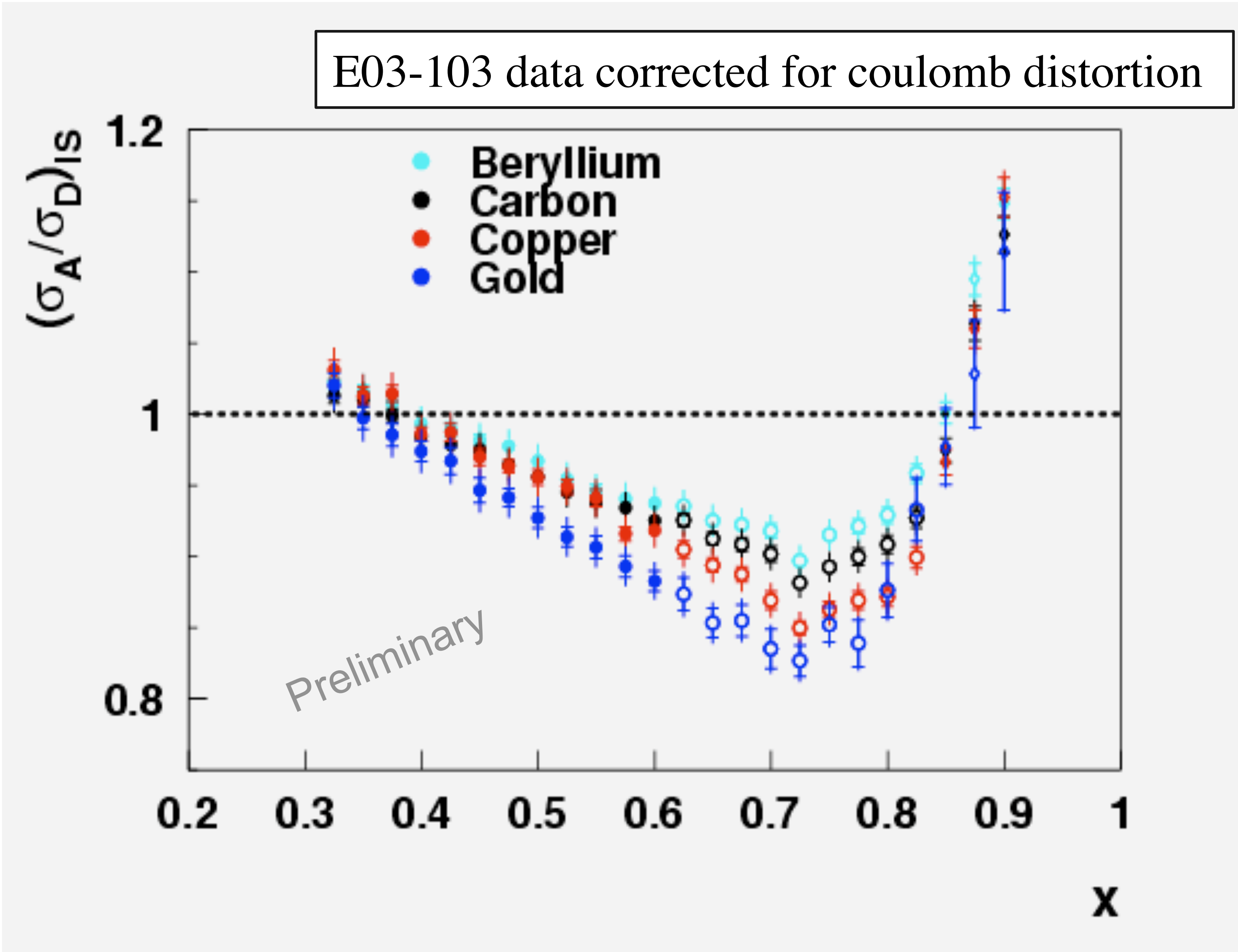
E03-013 heavy target results and world data

After coulomb corrections on all data





E03-103: EMC effect in heavy nuclei



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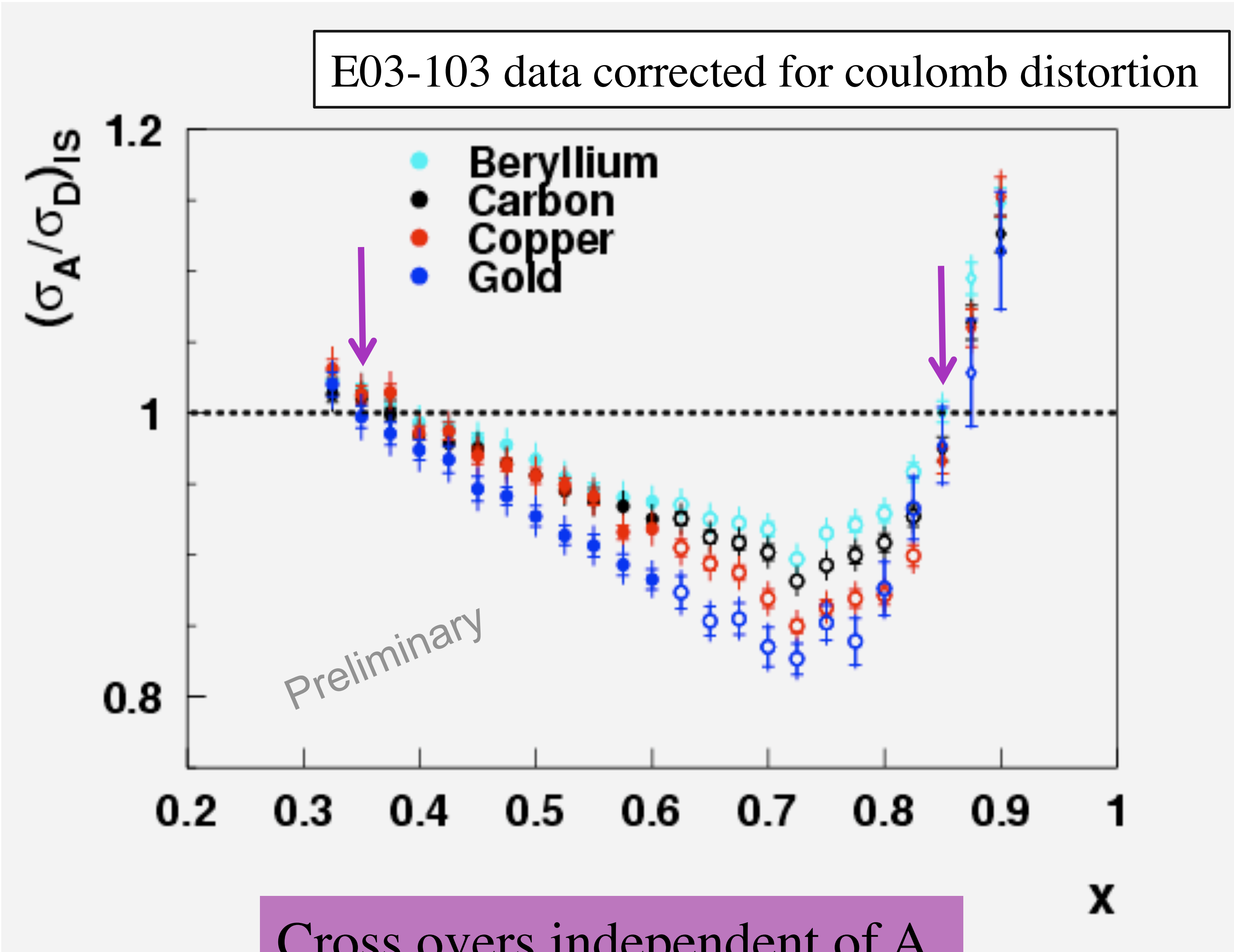
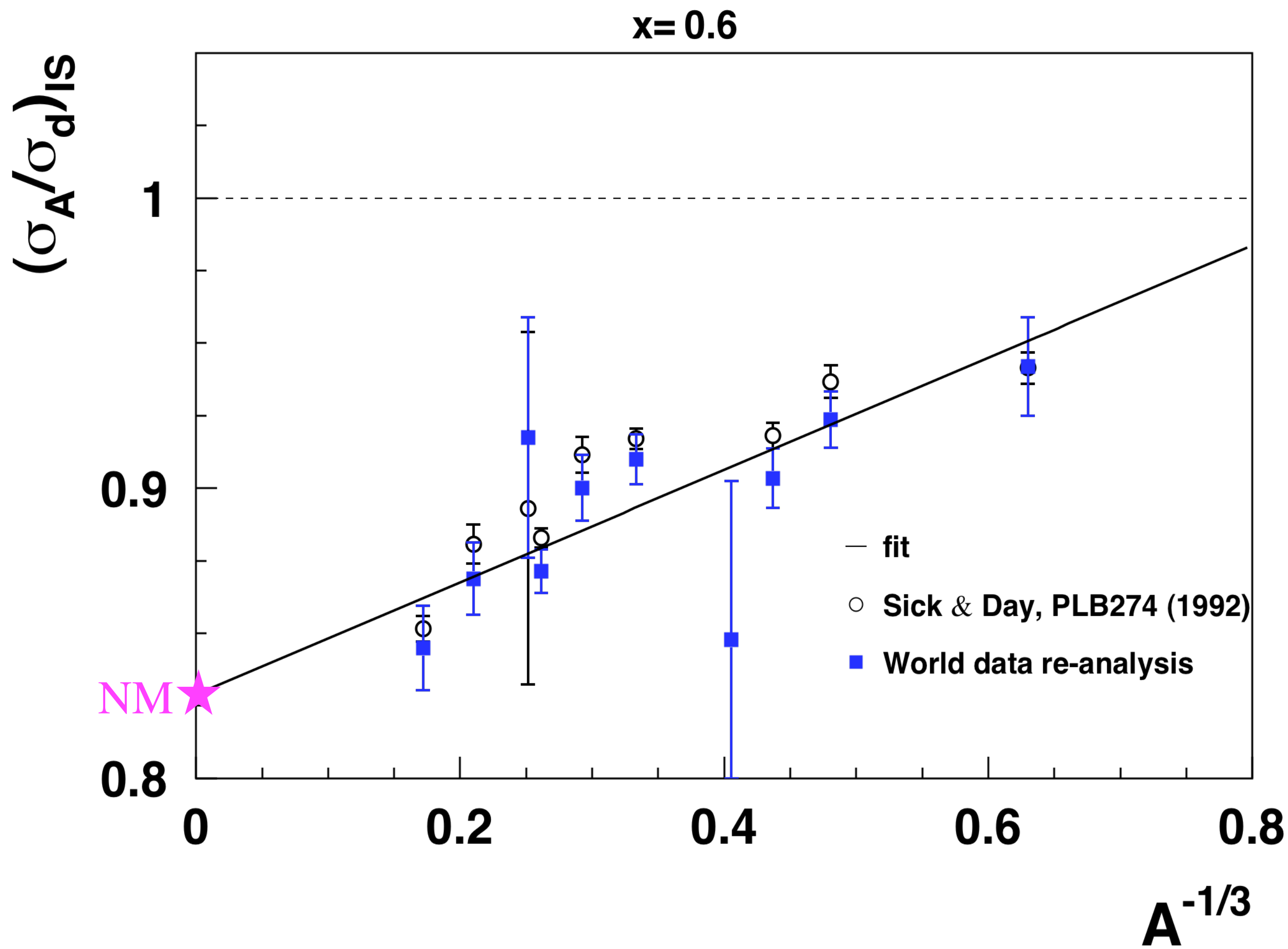


Cross overs independent of A

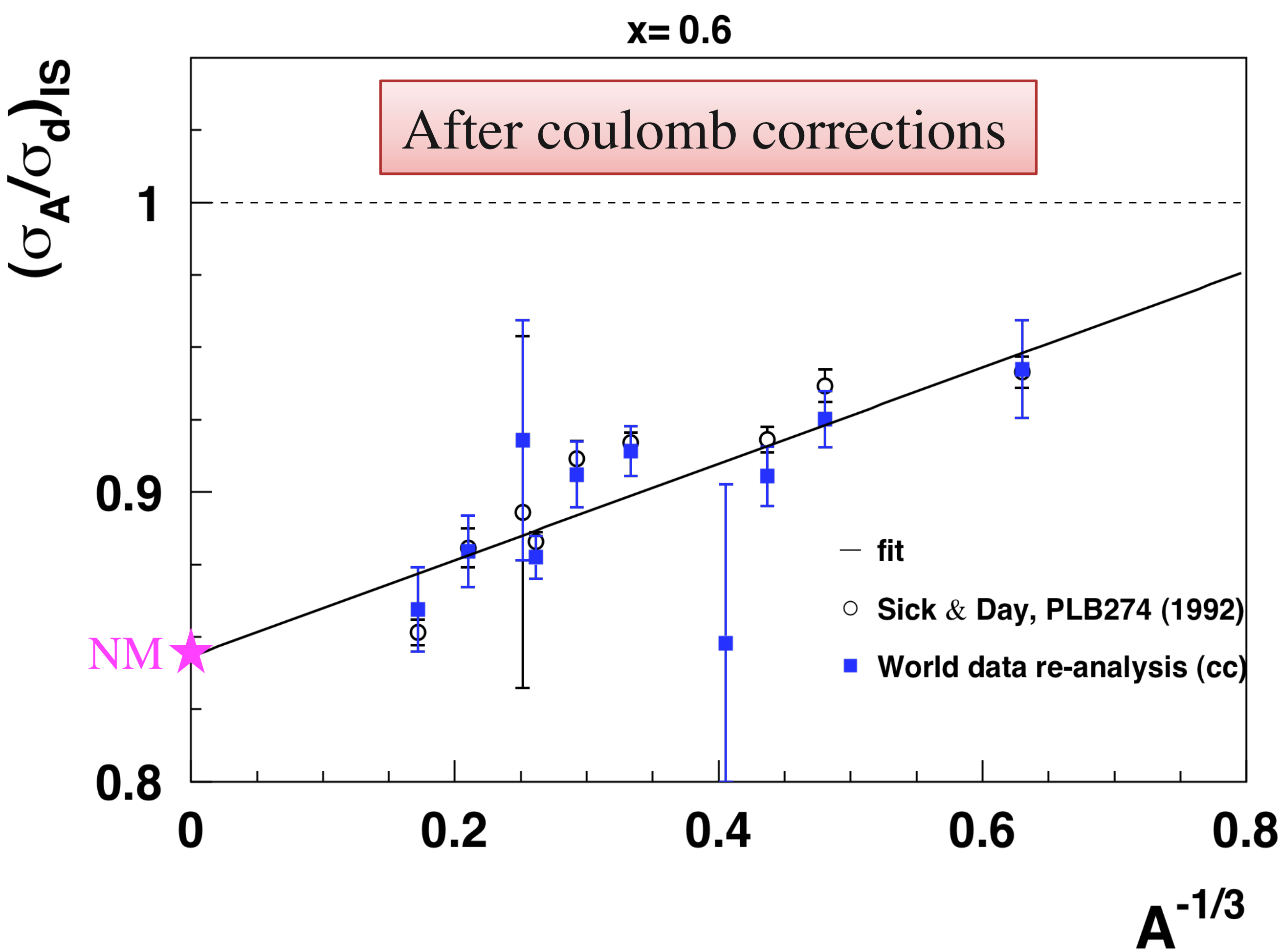
Nuclear dependence of the EMC effect



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



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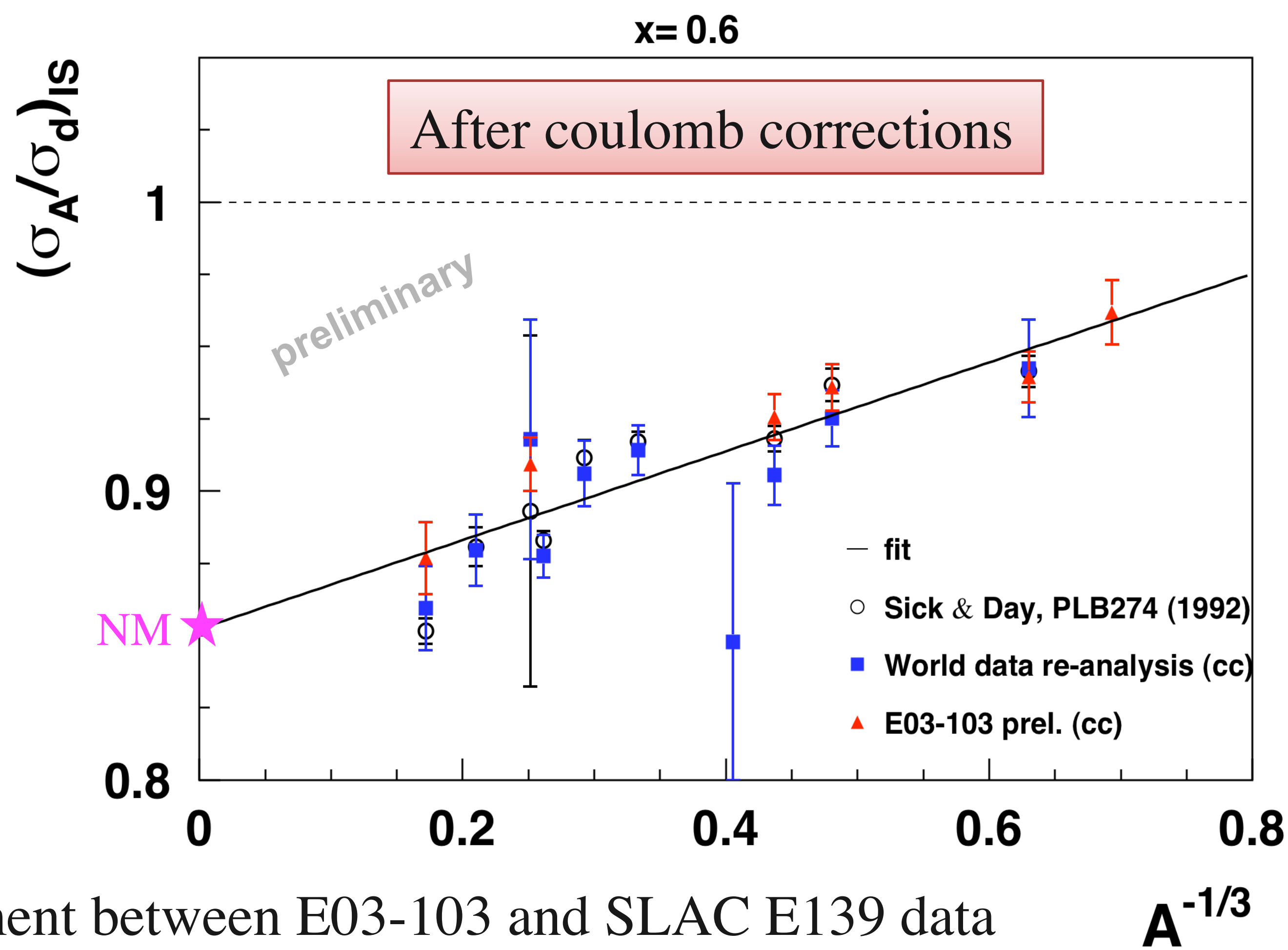
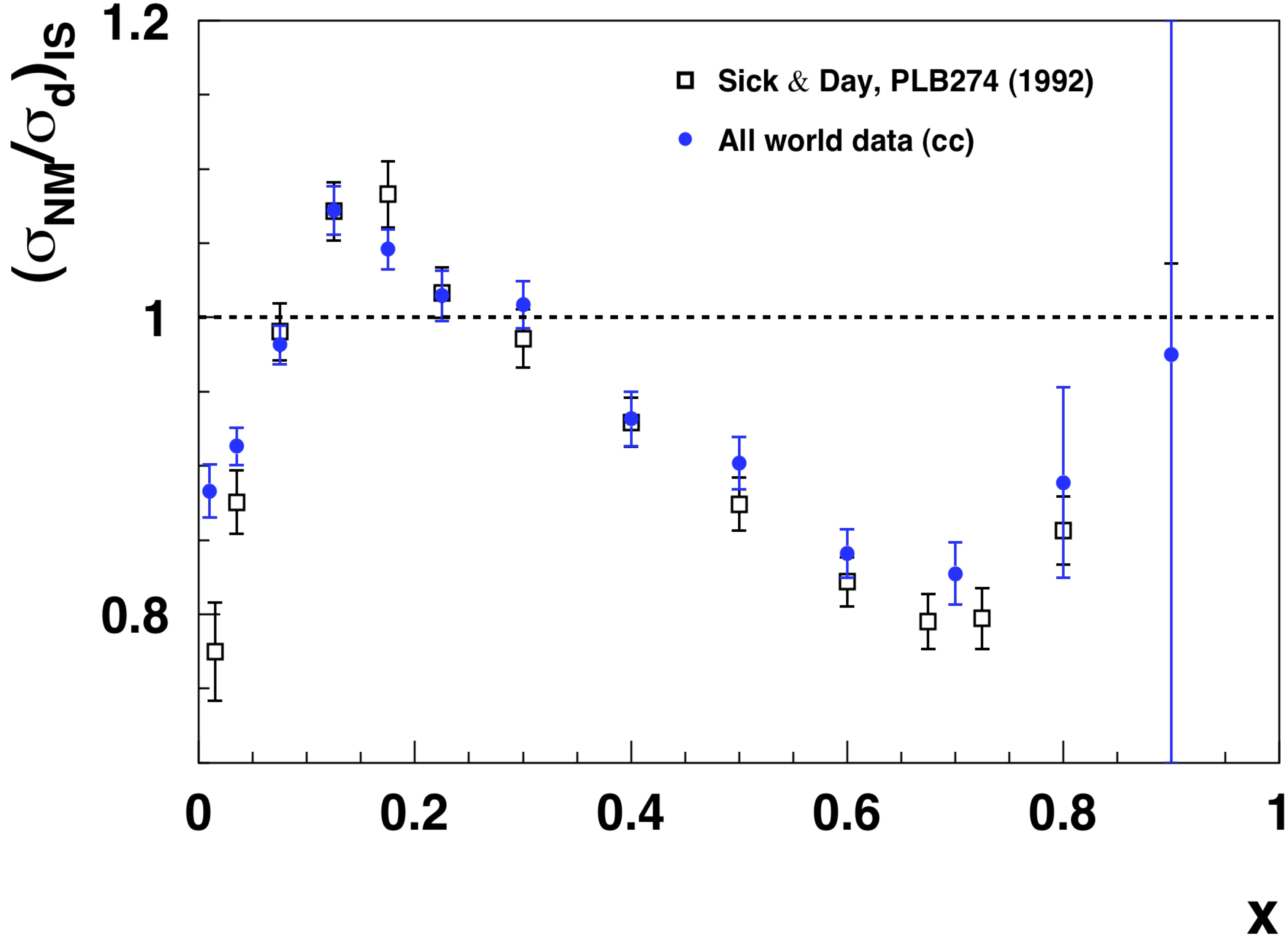


- Good agreement between E03-103 and SLAC E139 data after Coulomb corrections.

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

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

Nuclear matter



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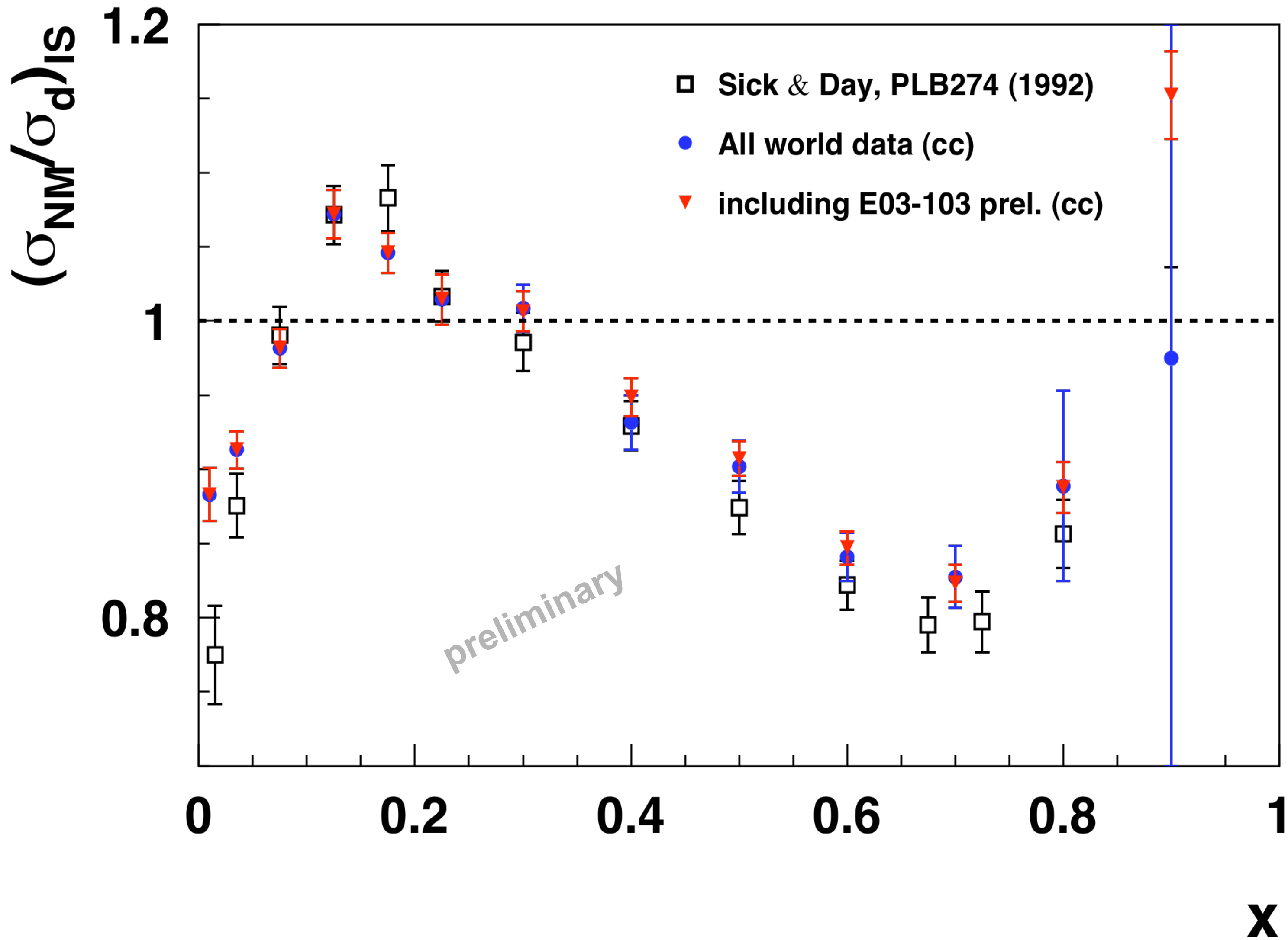

Target Mass Correction on the EMC ratio

$$F_2(x,Q^2) = F_2(x,Q^2;M=0) + \frac{M^2}{Q^2} F_2^{(1)TMC}(x,Q^2) + \frac{h(x,Q^2)}{Q^2} + O(1/Q^4)$$

from experiments

from pQCD

- Purely kinematic effects: finite value of $4M^2x^2/Q^2$
- Need to be applied before calculating higher twist effects
- TMCs are expressed by higher moments of $F_2(x,Q^2;M=0)$

Target Mass Correction on the EMC ratio

$$F_2(x,Q^2) = \frac{x^2}{r^3}F(\xi) + 6\frac{M^2}{Q^2}\frac{x^3}{r^4}\int_\xi^1 d\xi'\ F(\xi')$$

$$+ 12\frac{M^4}{Q^4}\frac{x^4}{r^5}\int_\xi^1 d\xi' \int_{\xi'}^1 d\xi''\ F(\xi'')$$

$$\xi = \frac{2x}{1+r} \qquad r = \sqrt{1+4x^2M^2/Q^2}$$

Target Mass Correction on the EMC ratio

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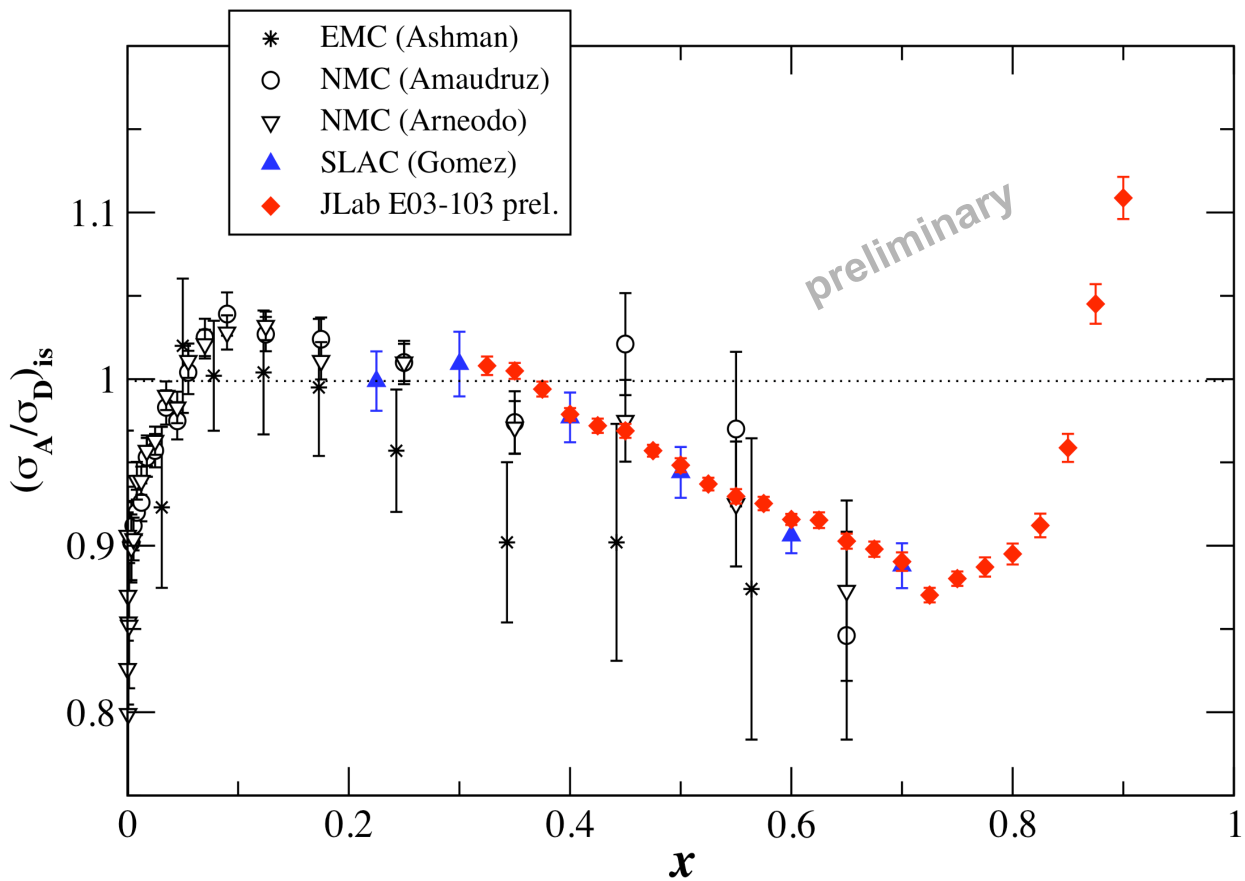
$$+ 12\frac{M^4}{Q^4}\frac{x^4}{r^5}\int_\xi^1 d\xi' \int_{\xi'}^1 d\xi''\, F(\xi'')$$

A-independent

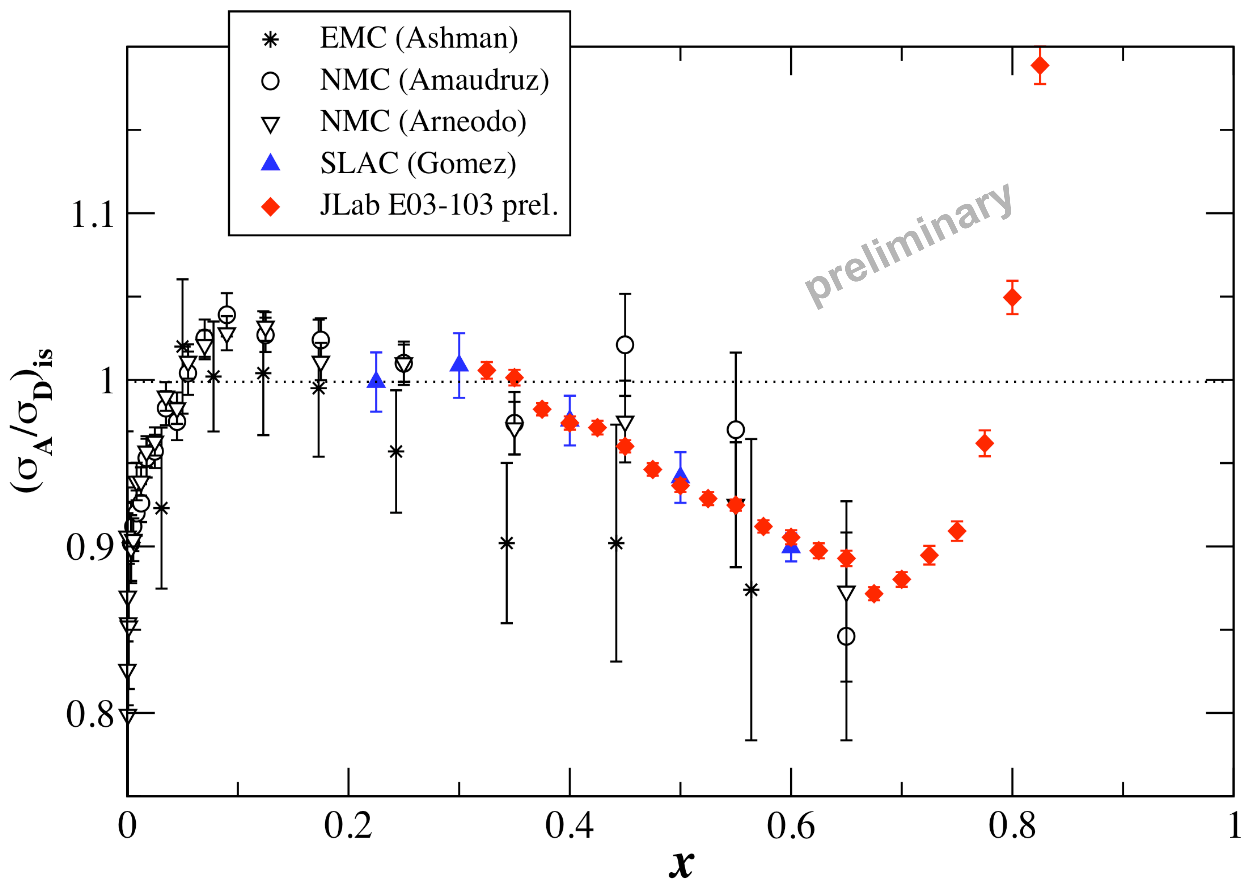
➔ mostly cancel in the ratio

At first order, the TM correction on the EMC ratio is equivalent to express them versus ξ and plot versus *x*

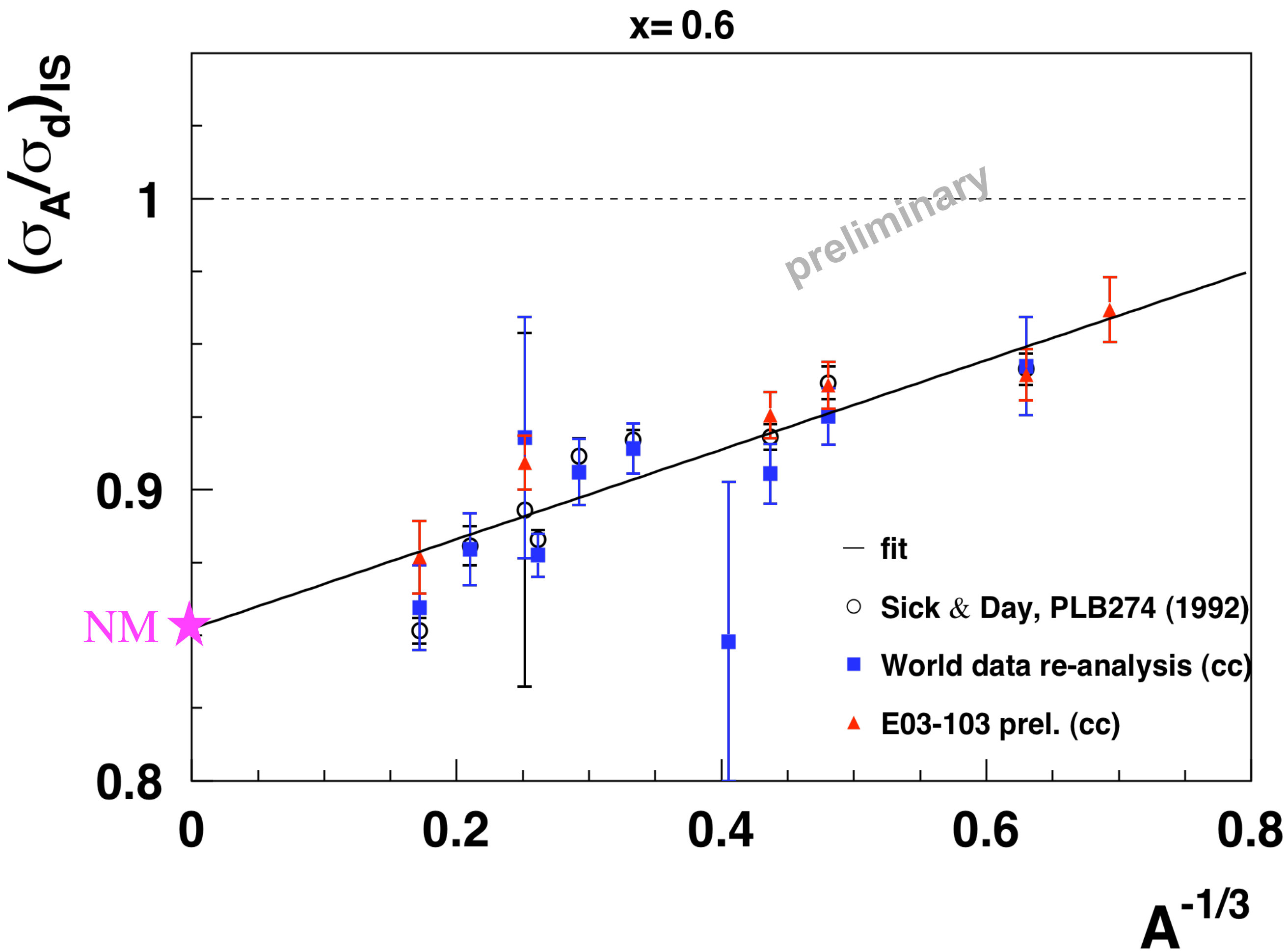
E03-103 data on Carbon



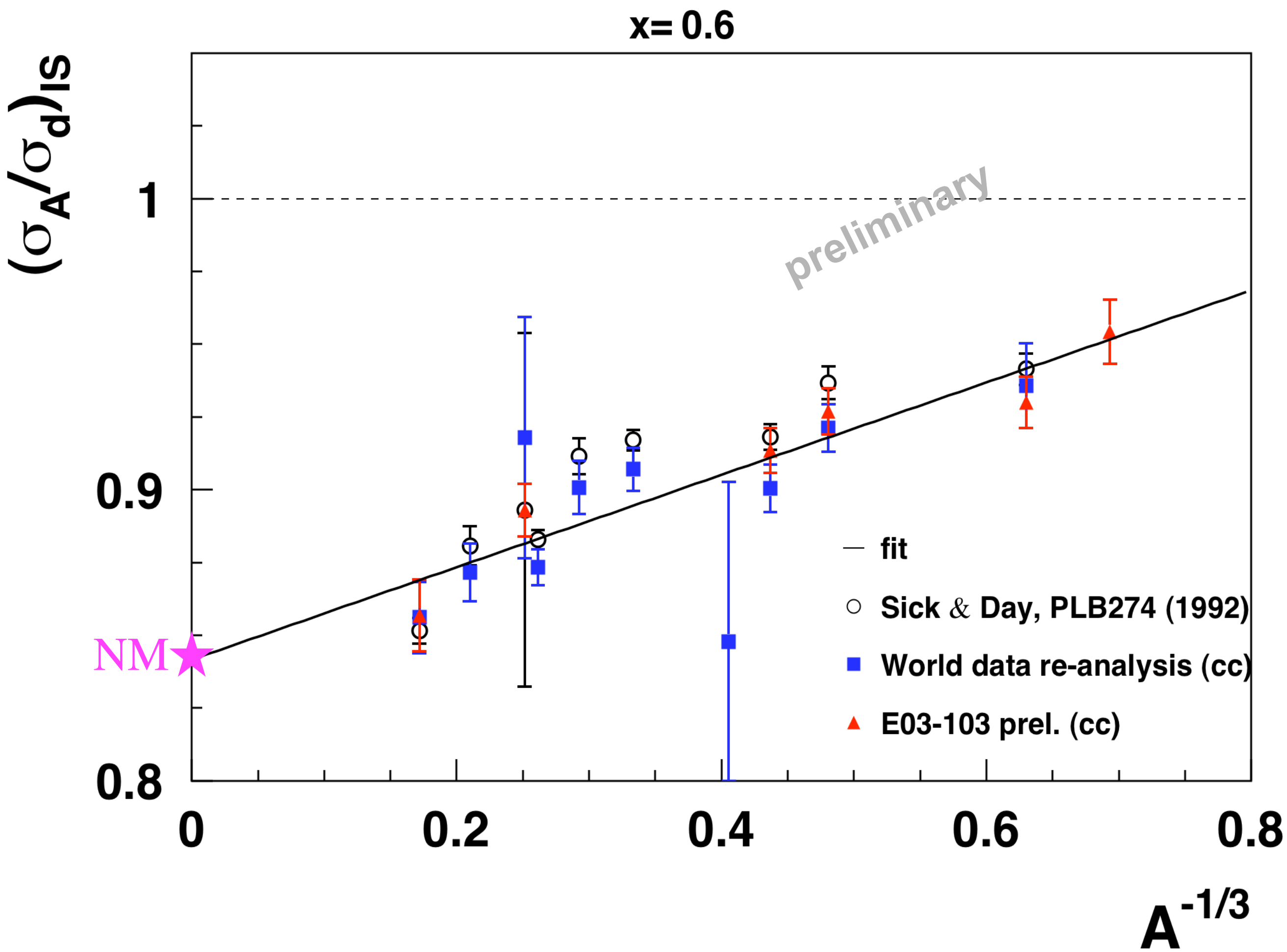
E03-103 data on Carbon with TMC



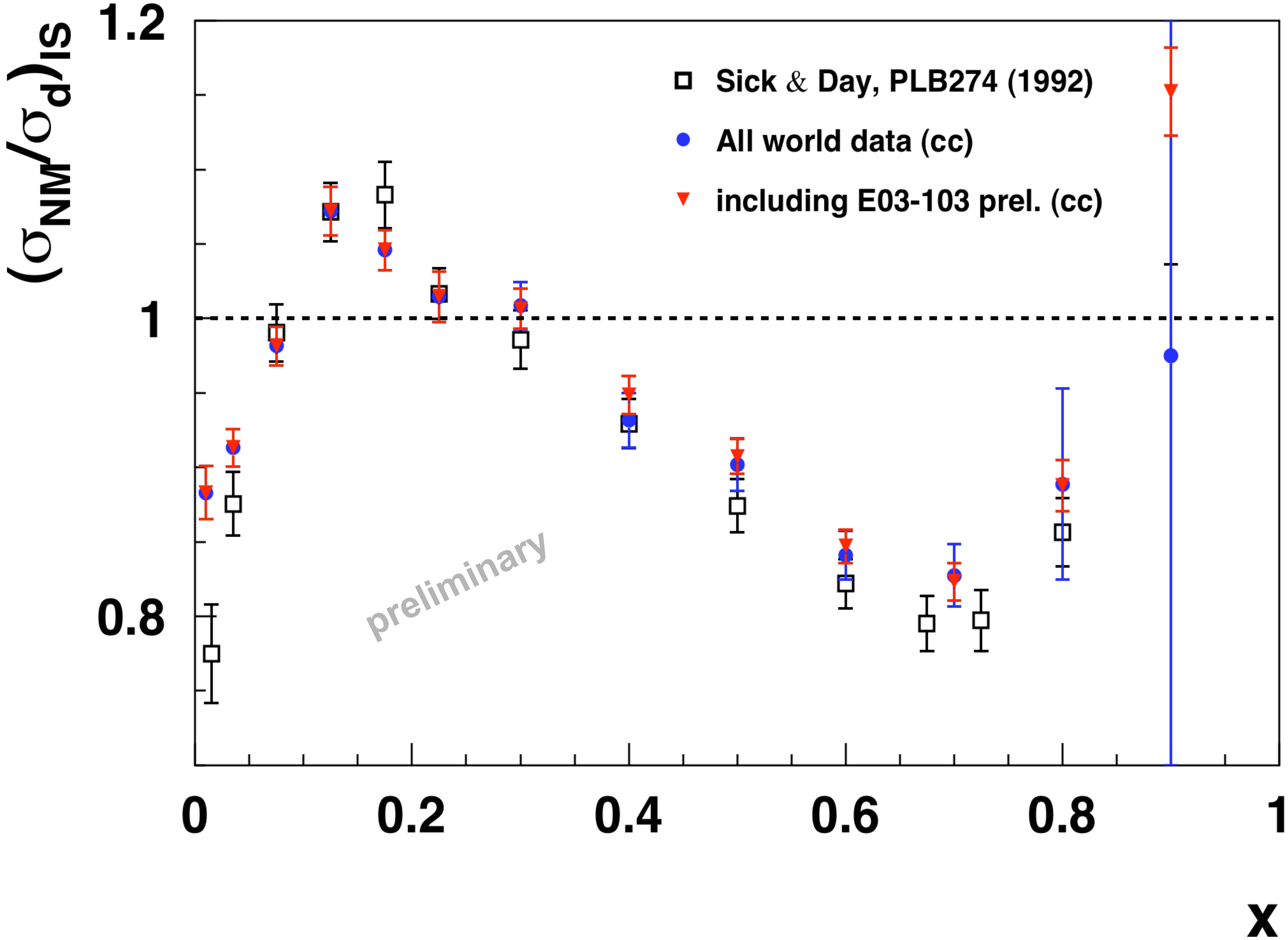
A-dependence



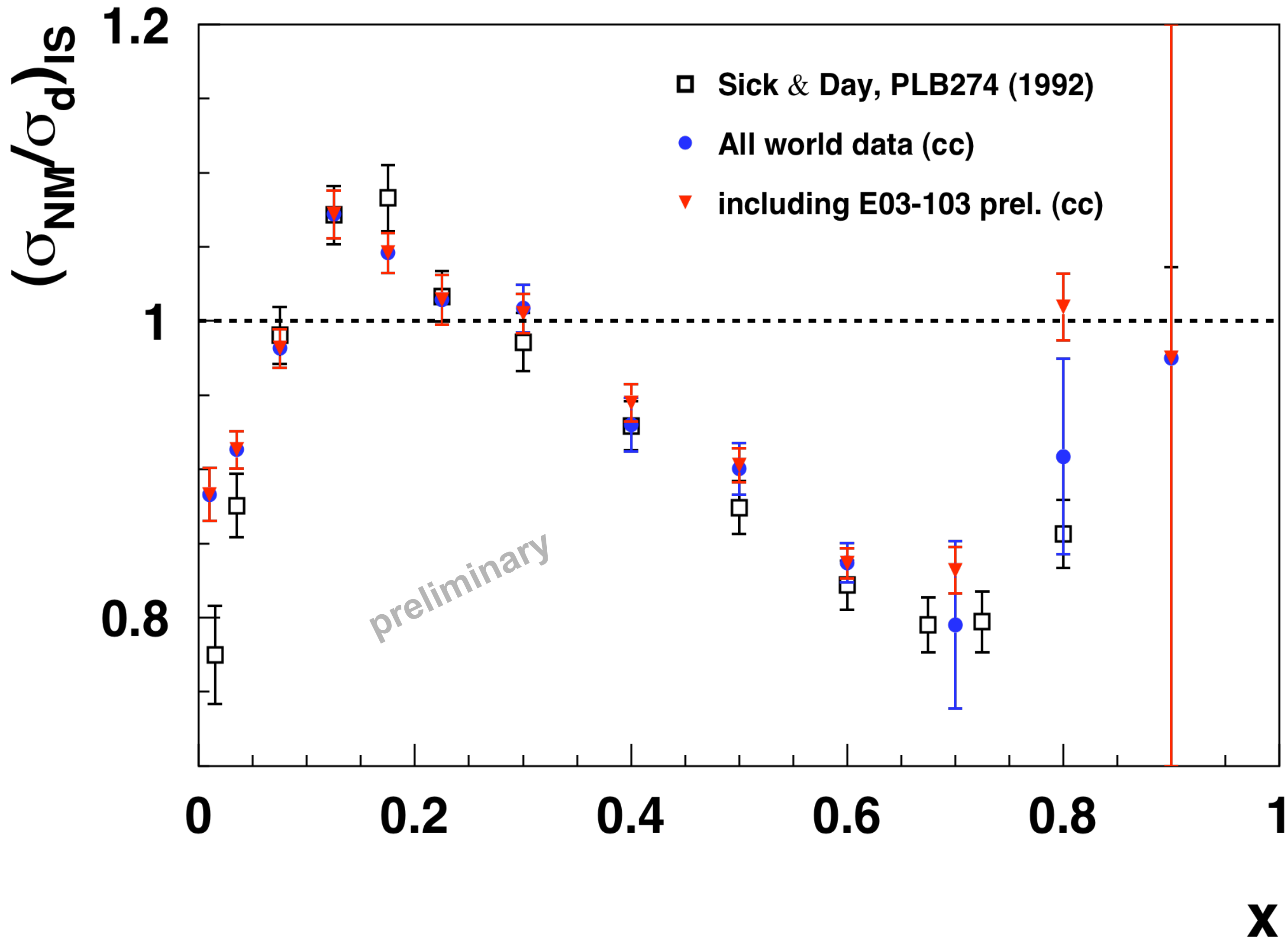
A-dependence with TMC



Nuclear matter



Nuclear matter and TMC



Summary

- JLab E03-103 provides:
  - Precision nuclear structure ratios for light nuclei
  - Access to large x EMC region for $^3He \rightarrow {}^{197}Au$

- Preliminary observations:
  - Scaling of the structure function ratios for W<2GeV down to low Q^2
  - Carbon and ^4He have the same EMC effect
  - Large EMC effect in ^3He
  - Similar large x shape of the structure function ratios for A>3

- In progress:
  - Absolute cross sections for ^1H, ^2H, ^3He and ^4He: 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