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New Results on the EMC Effect at Large x in Light to Heavy Nuclei

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For the E03-103 Collaboration

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Hall C Summer Workshop

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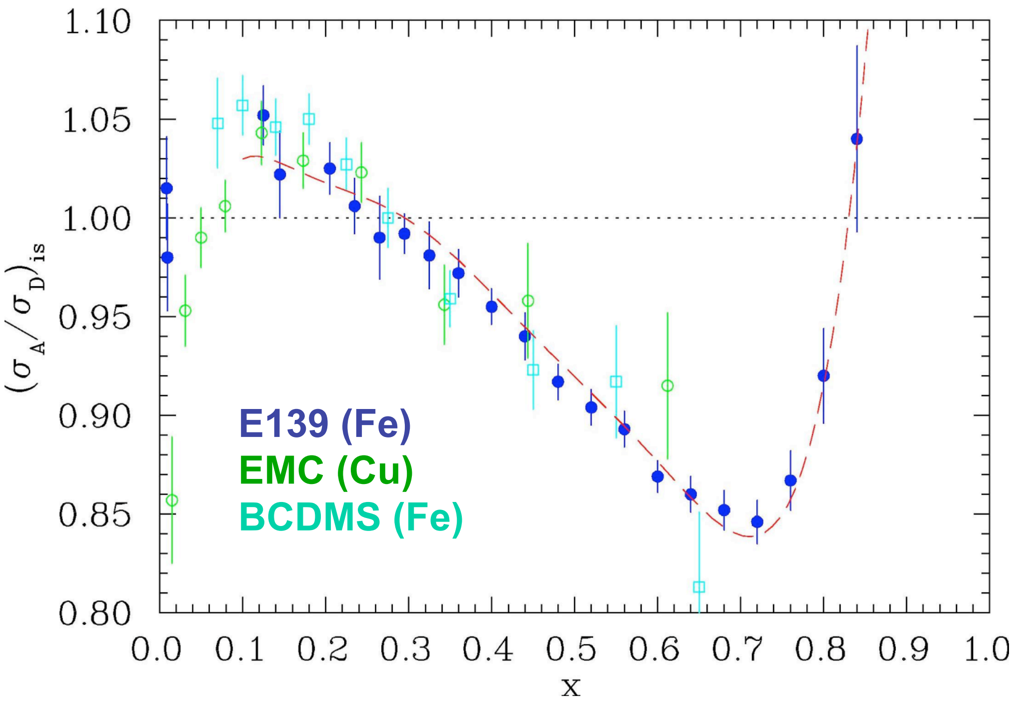
Nuclear structure functions and the EMC effect

- **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**



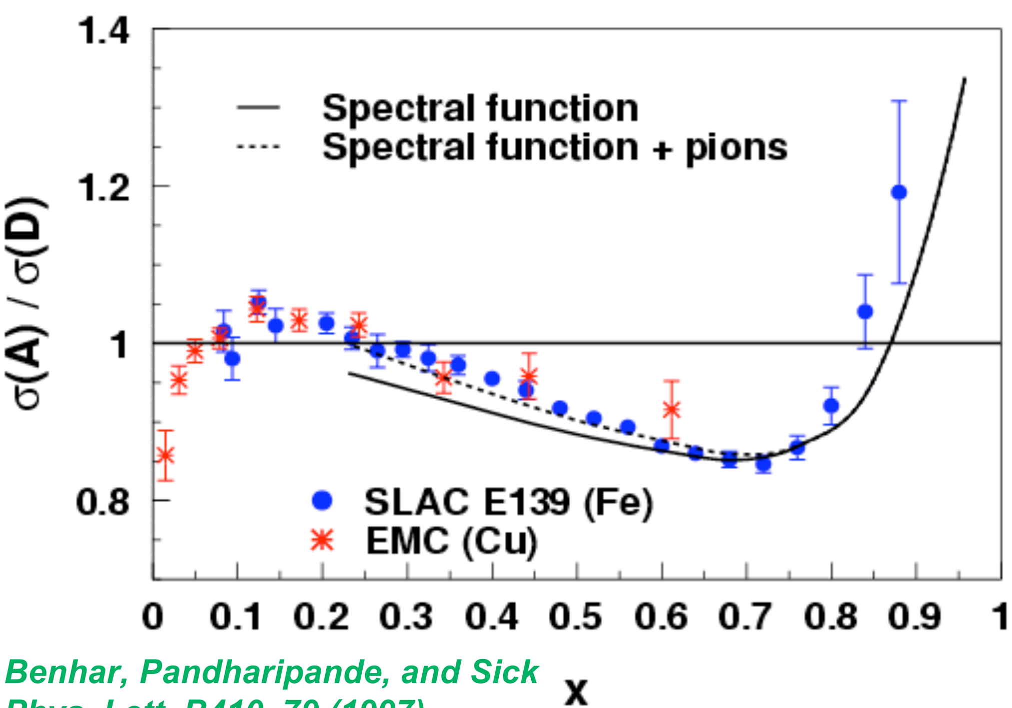
Mapping the EMC Effect

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*



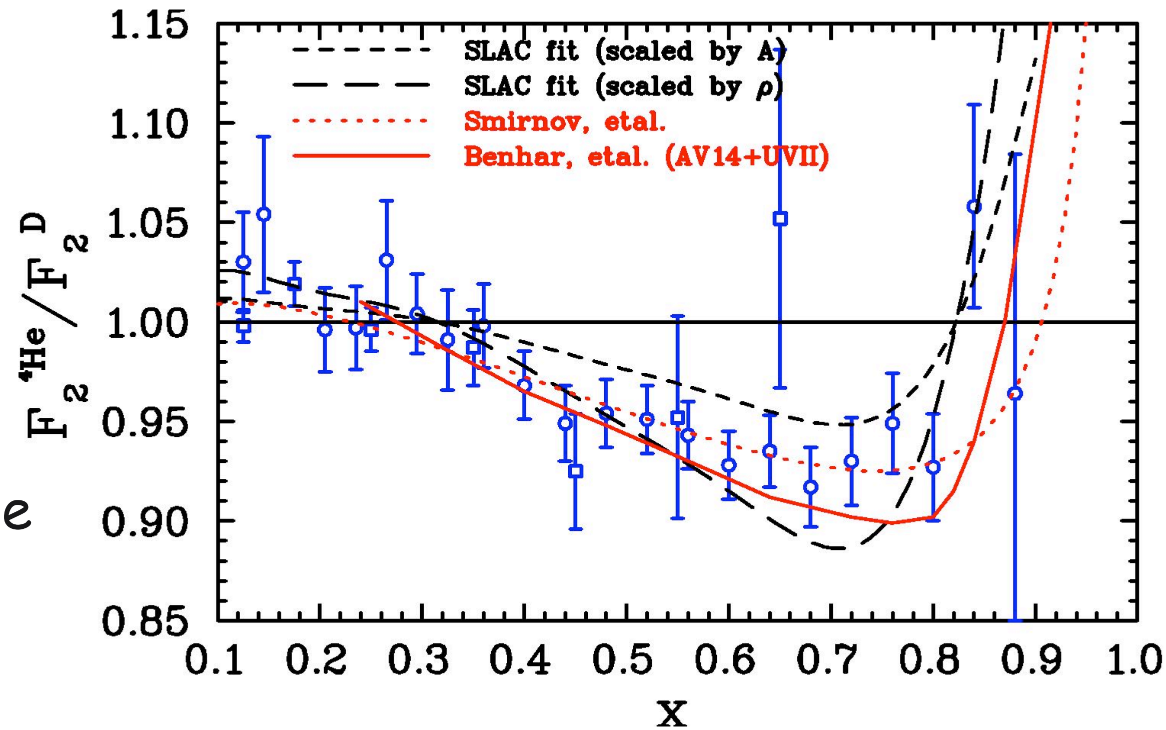
Benhar, Pandharipande, and Sick
Phys. Lett. B410, 79 (1997)

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.

EMC effect in few-body nuclei

- **Calculations predict different x-dependence for ^{3}He and ^{4}He**
  - Different models predict different x-dependence
  - Some models predict different shapes for ^{3}He and ^{4}He
  - Spectral functions are easier to calculate for light nuclei

- **Data lower quality**
  - Lower precision for ^{4}He
  - No data at large x for ^{3}He



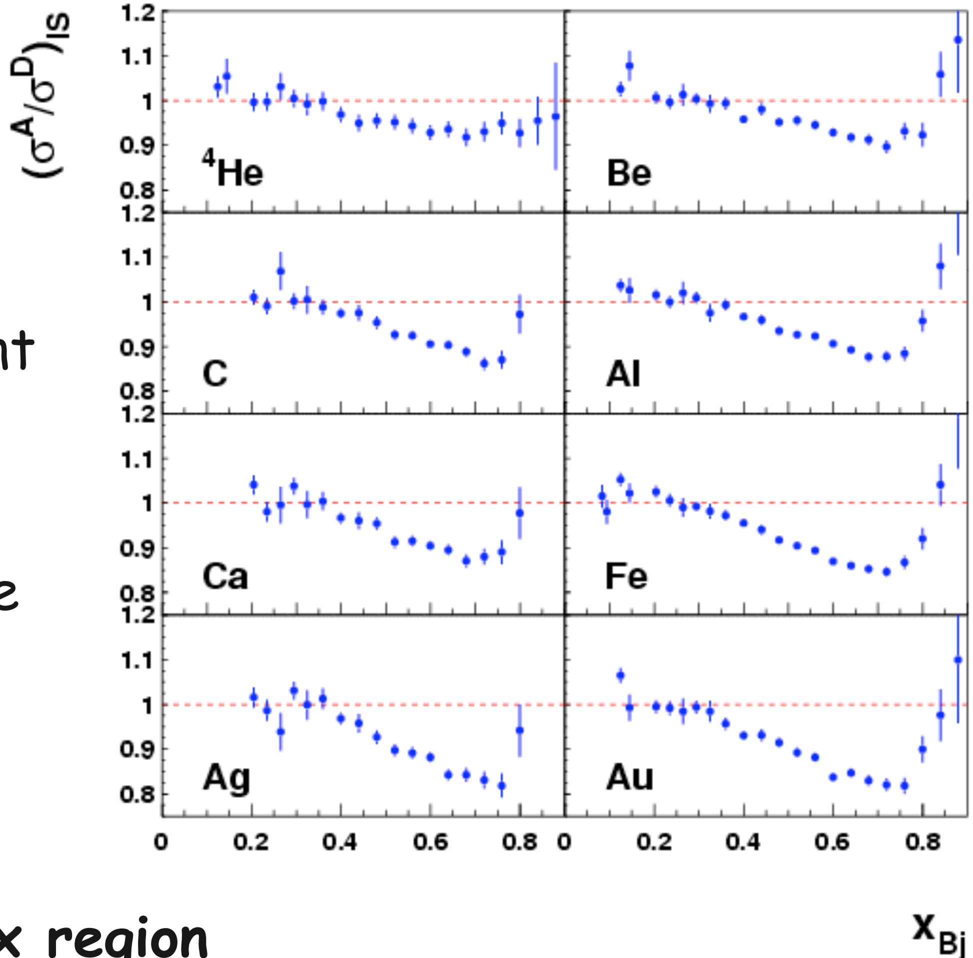
Existing EMC Data

- SLAC E139 most extensive 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

- 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

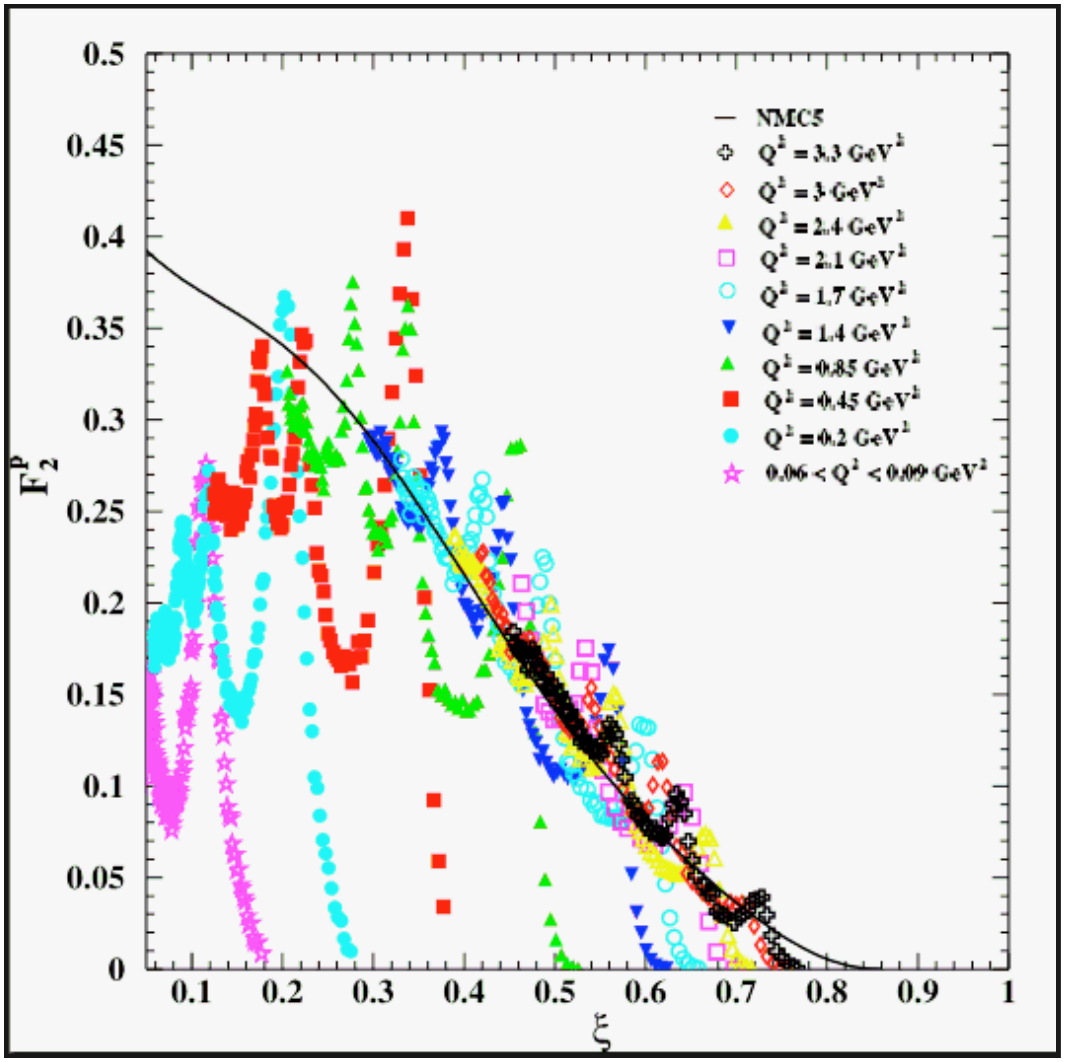


Quark-hadron duality

First observed by Bloom and Gilman in the 1970's on F_2:

Scaling curve seen at high Q^2 is an accurate average over the resonance region at lower Q^2

I. Niculescu et al., PRL85:1182 (2000)



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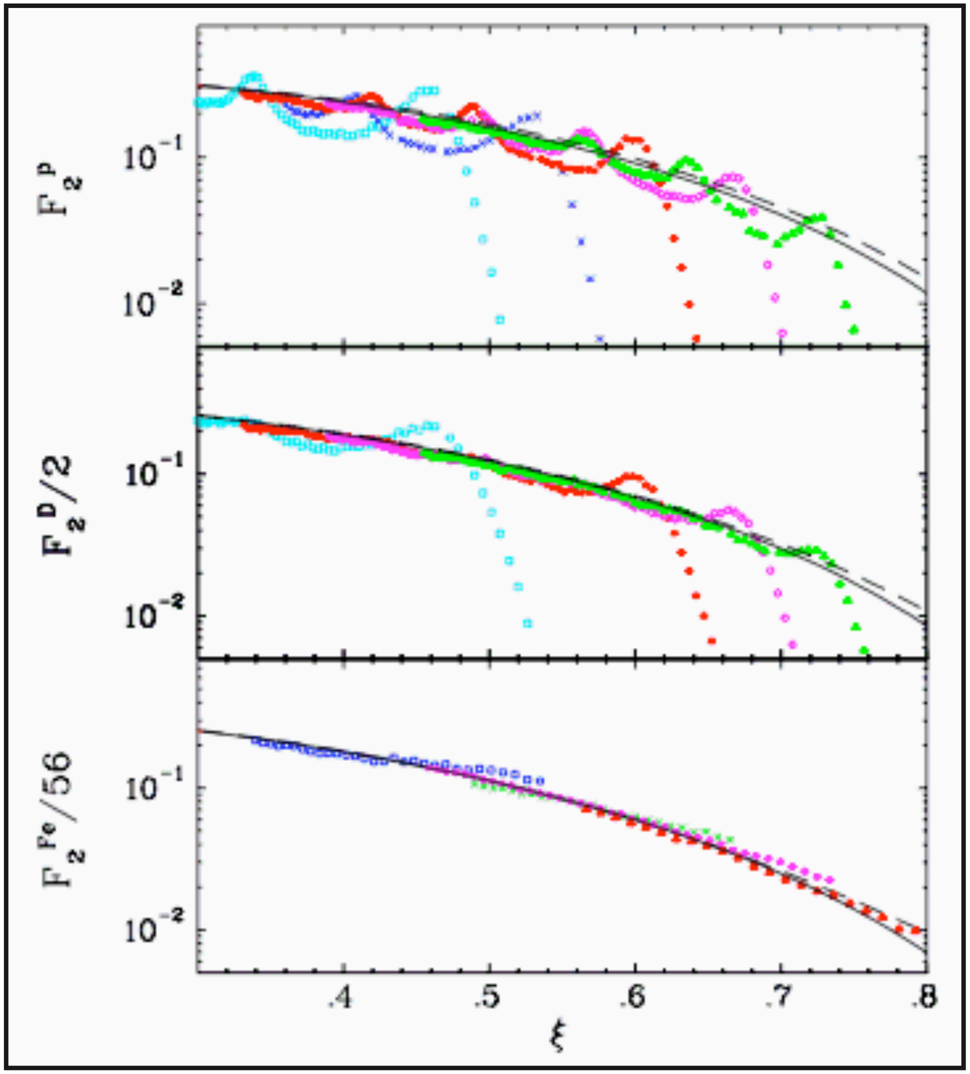
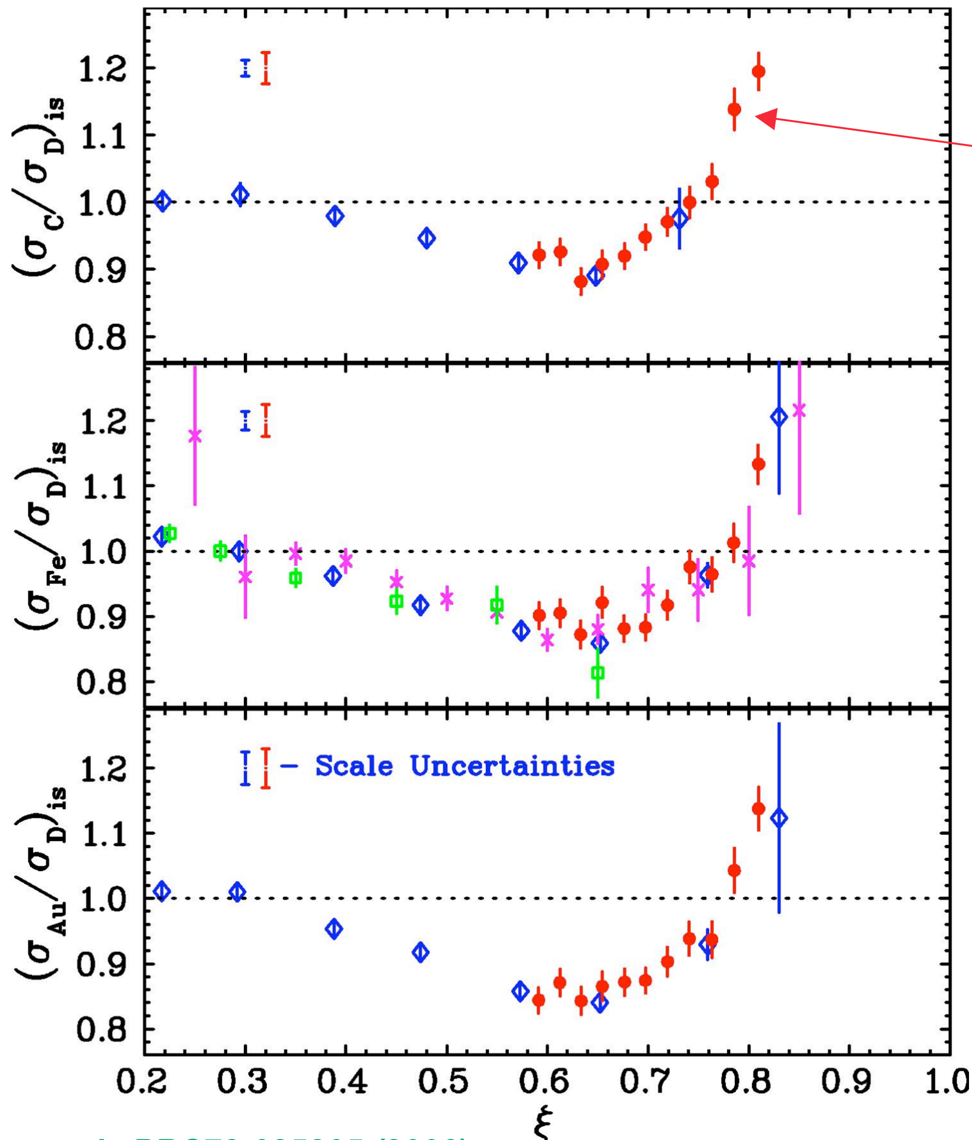
Scaling curve seen at high Q^2 is an accurate average over the resonance region at lower Q^2

In nuclei, the averaging is in part done by the Fermi motion.

J. Arrington, et al., PRC73:035205 (2006)



EMC effect: Scaling at lower Q^2, W^2



JLab E89-008:
$Q^2 \sim 4\ GeV^2$
$1.3 < W^2 < 2.8\ GeV^2$
data in the resonance region

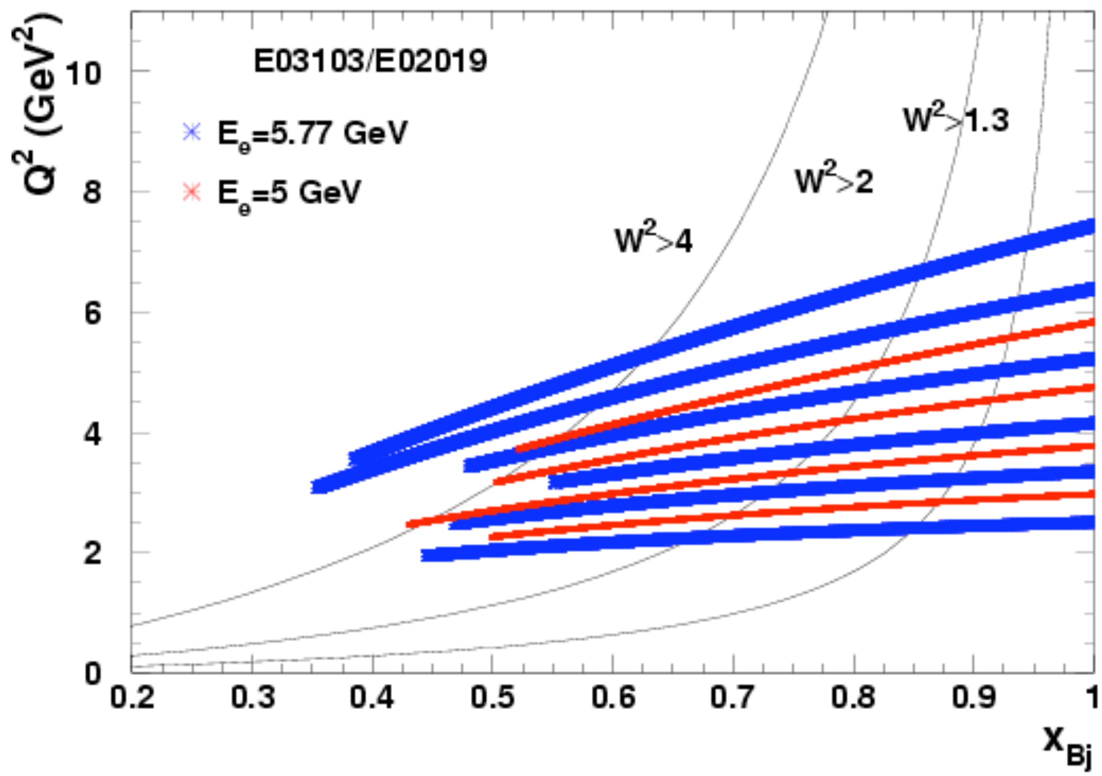
E03-103 data at higher Q^2, with precise measurement of Q^2-measurement

J. Arrington, et al., PRC73:035205 (2006)

JLab Experiment E03-103

- Ran in Hall C at Jlab Summer and Fall 2004 (w/E02-019 → x>1)

- A(e,e') at 5.77 GeV
  - Targets:
    H, ^{2}H, ^{3}He, ^{4}He,
    Be, C, Al, Cu, Au
  - 10 angles to measure
    Q^2-dependence



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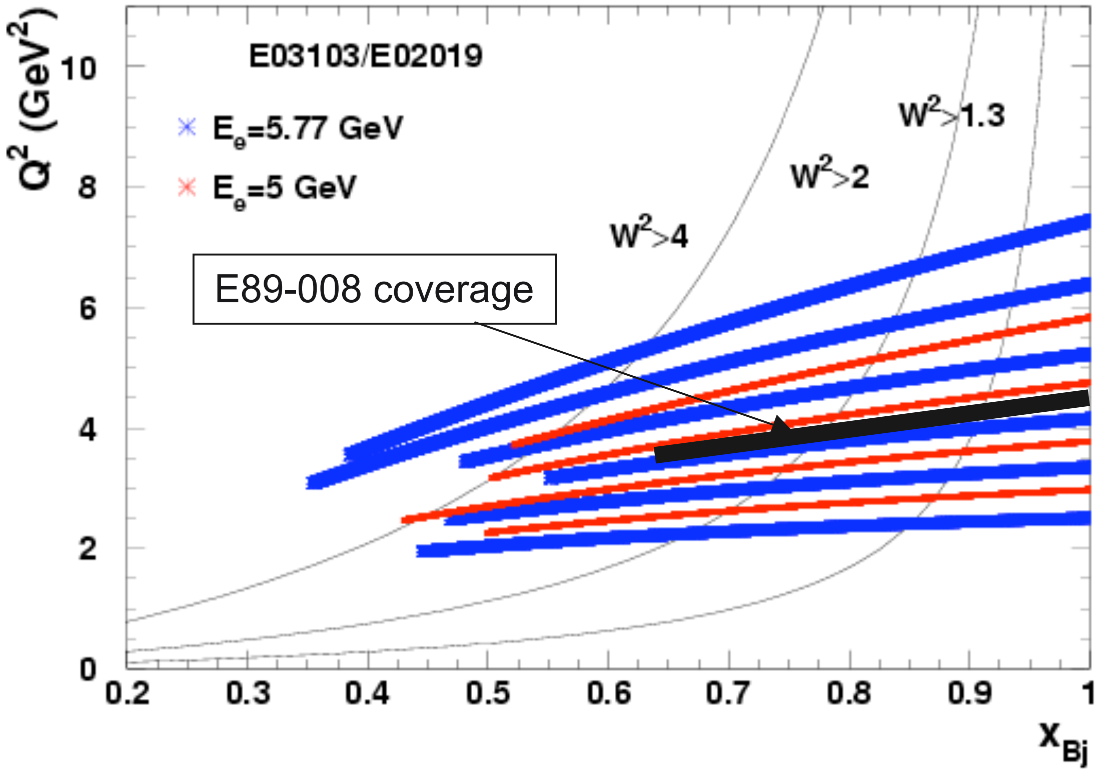

E03-103: Experimental details

Main improvement over SLAC due to improved ^{4}He targets:

Source of uncertainty	SLAC E139	JLab E03-103
Statistics	1.0-1.2%	0.5-0.7%
*Density fluctuations	1.4%	0.4%
Absolute density	2.1%	1.0% (1.5% for ^{3}He)

* - *size* of correction is 8% at 4 uA vs. 4% at 80 uA

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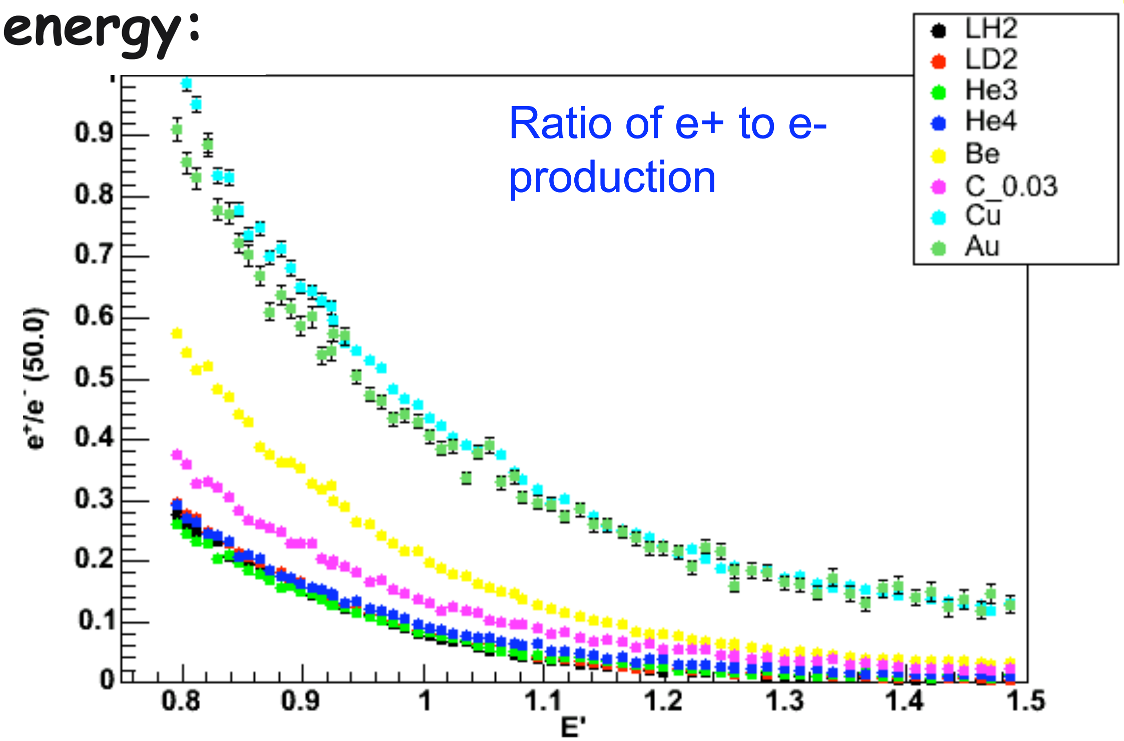
Main drawback is lower beam energy:

Requires larger scattering angle to reach same Q^2

→ Larger π^- contamination

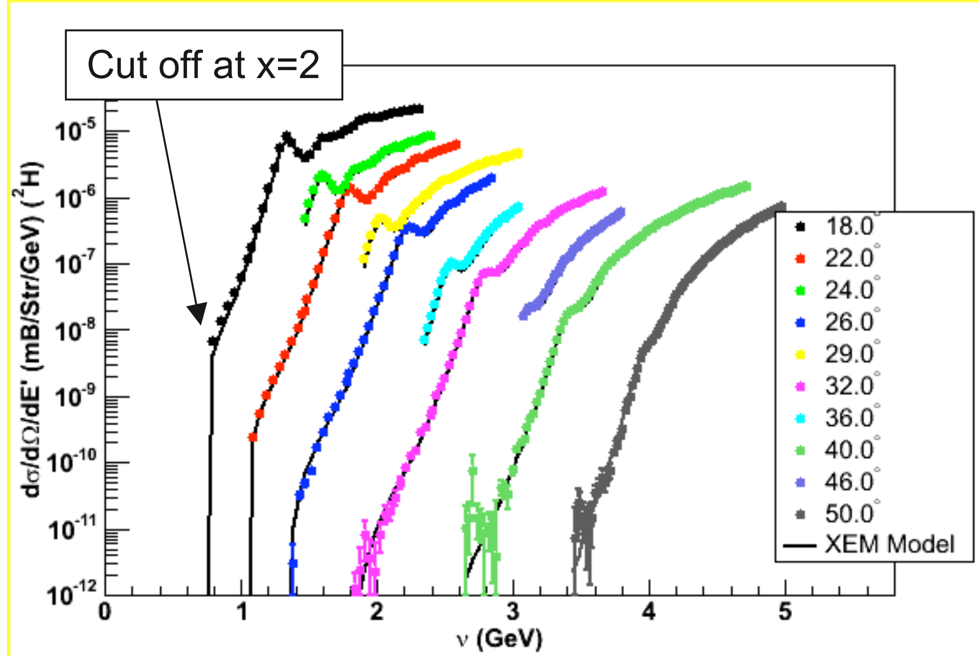
→ Large charge-symmetric background

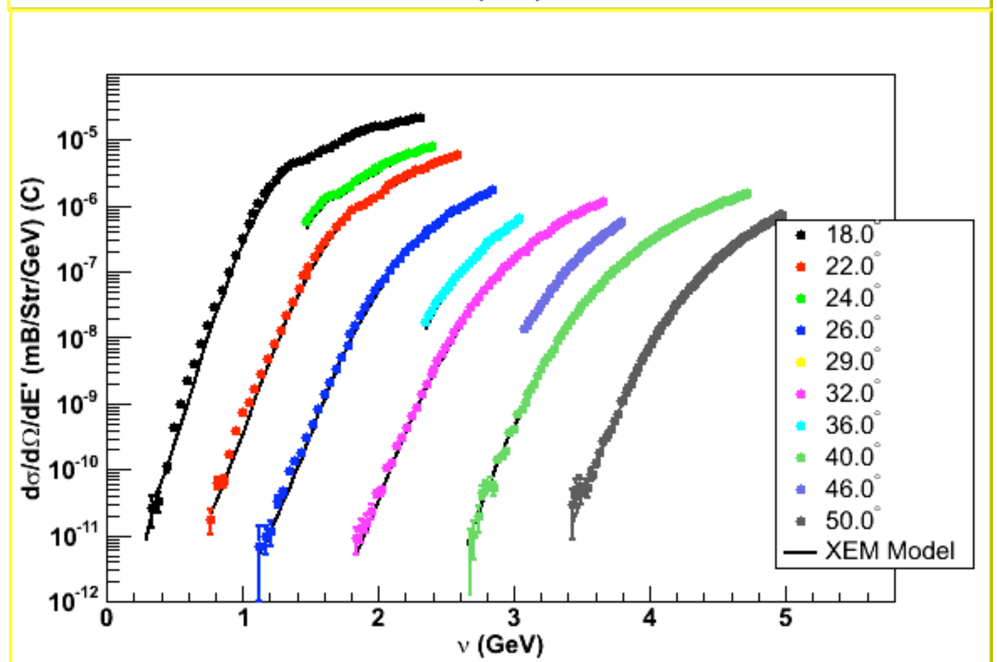
→ Larger Coulomb distortion corrections



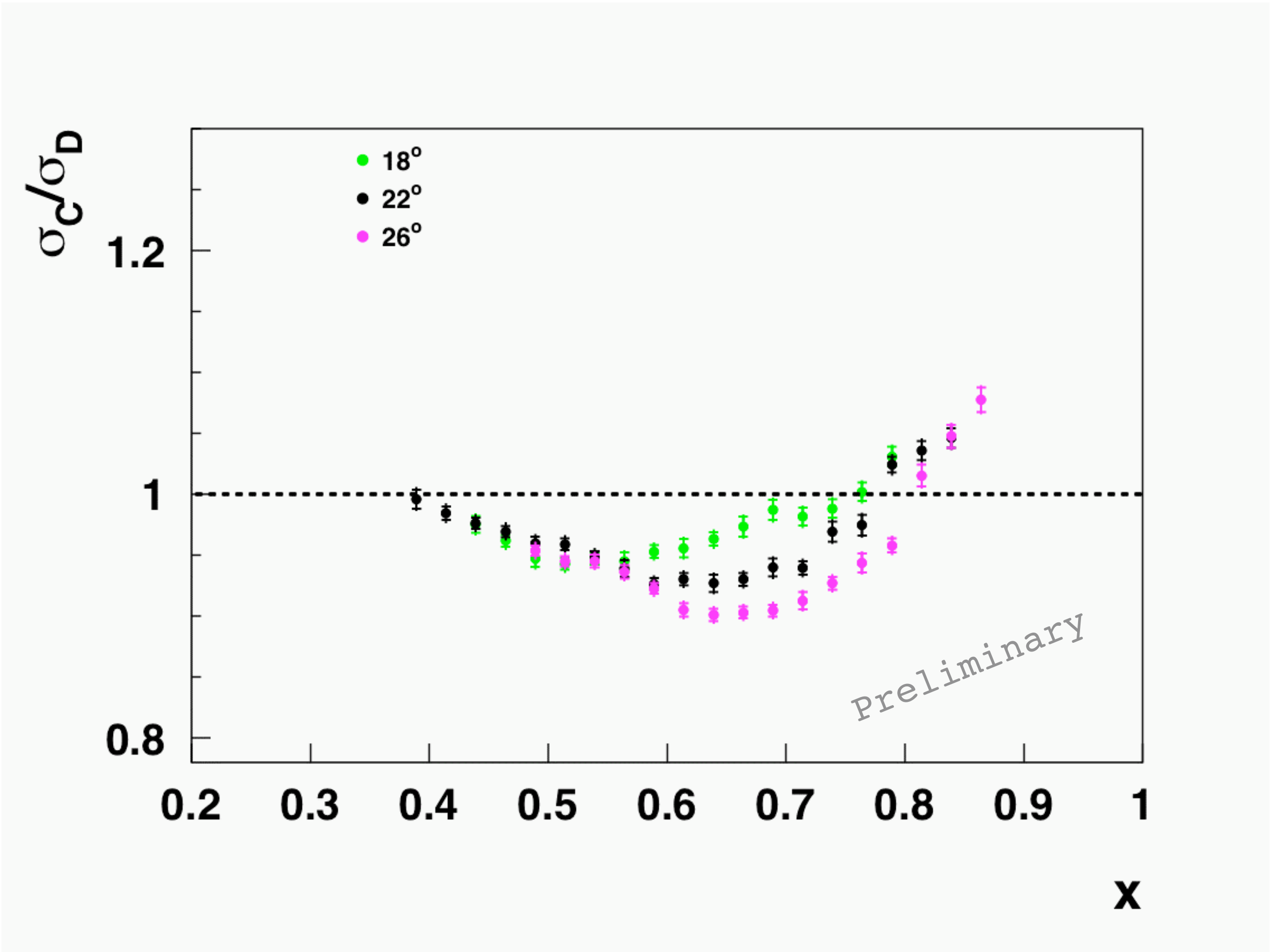
E03-103: Analysis status

- **Analysis is in the final stage**
- **Cross section extraction**
  - ✓ Calibrations, efficiency corrections, background subtraction completed
  - ✓ Finalizing model-dependence in radiative corrections, bin centering, etc…
  - ✓ Investigating Coulomb distortion corrections (heavy nuclei)
- **EMC Ratios:** Isoscalar EMC correction (requires σ_n/σ_p)





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



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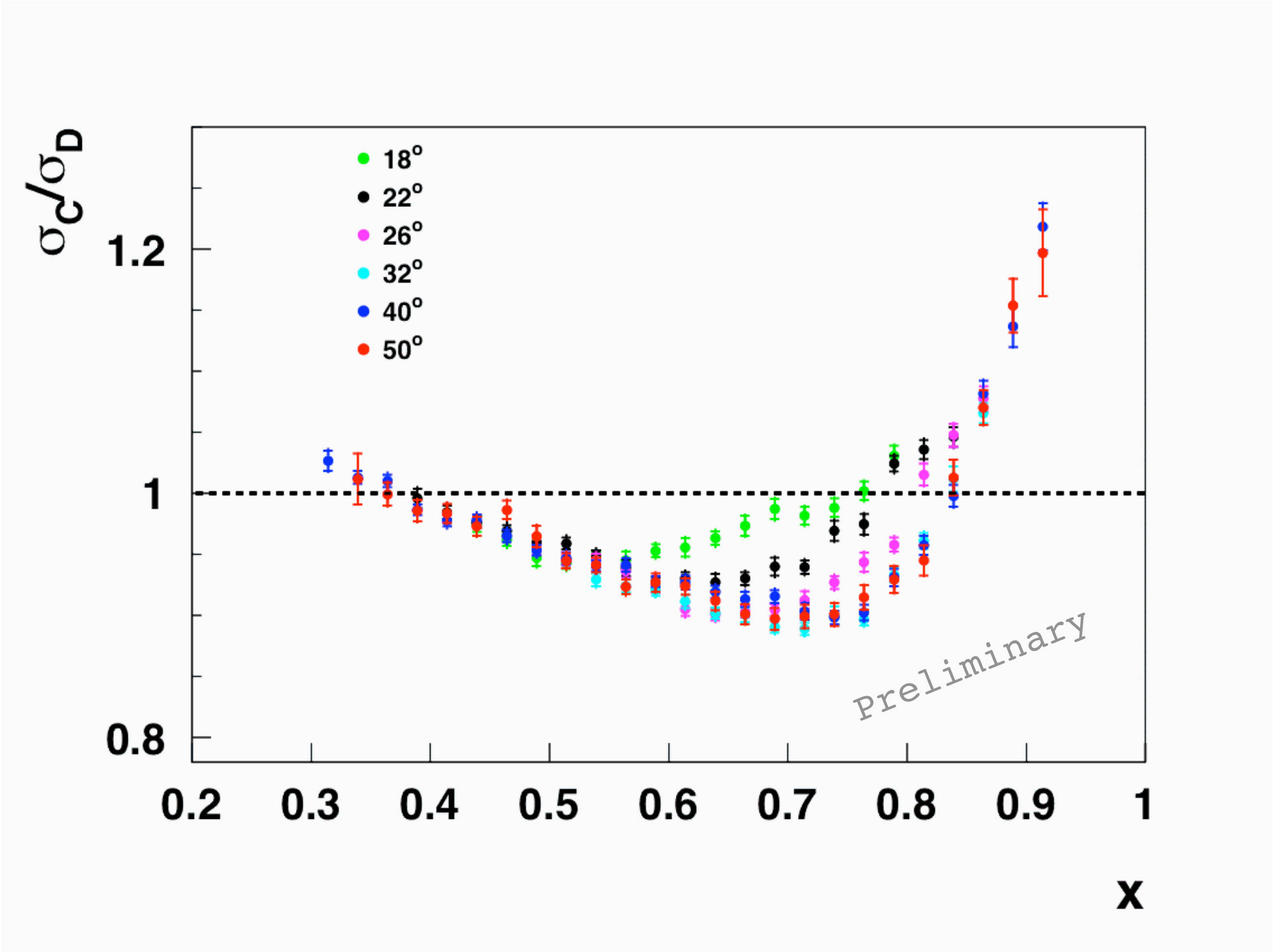

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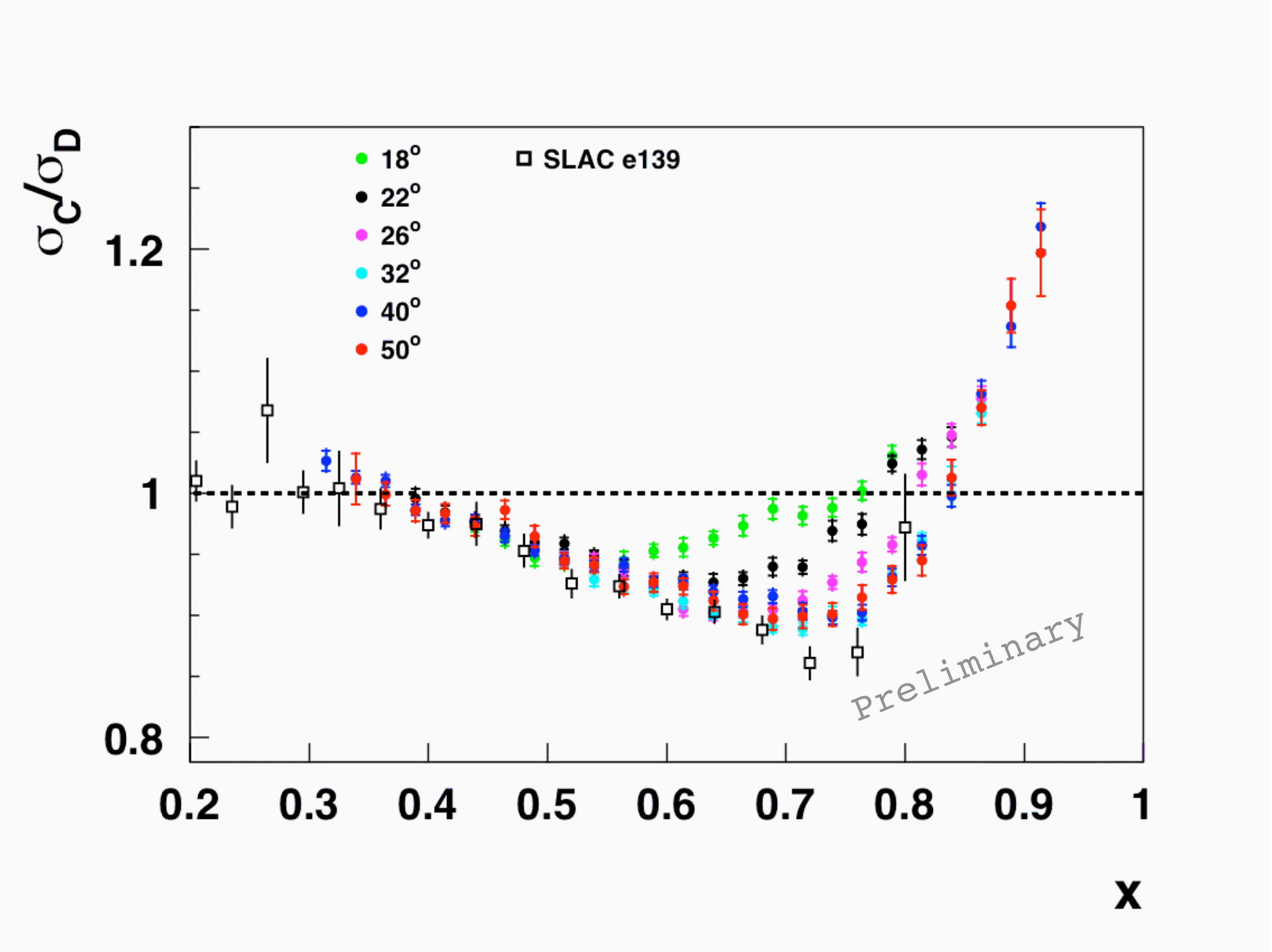
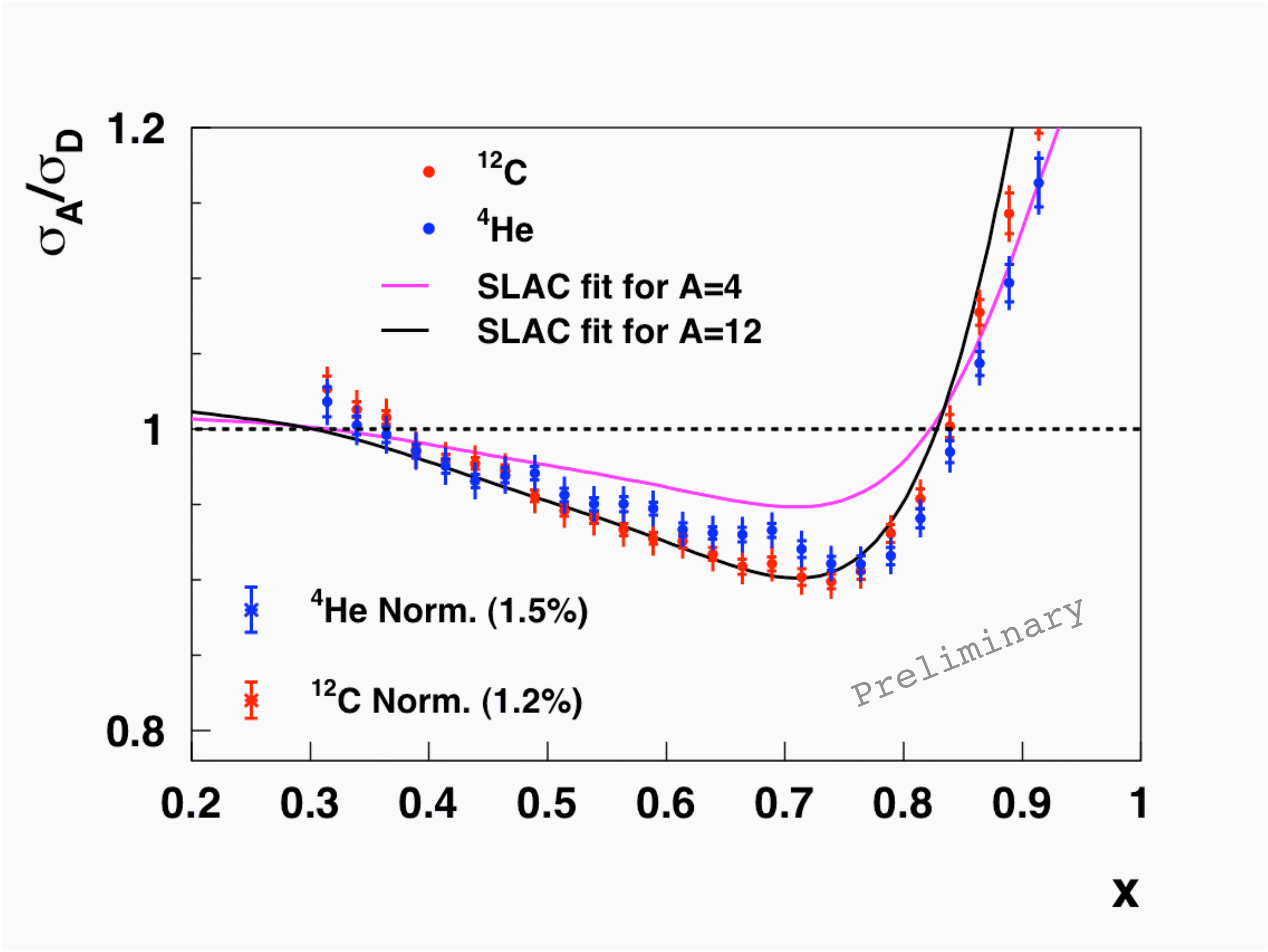


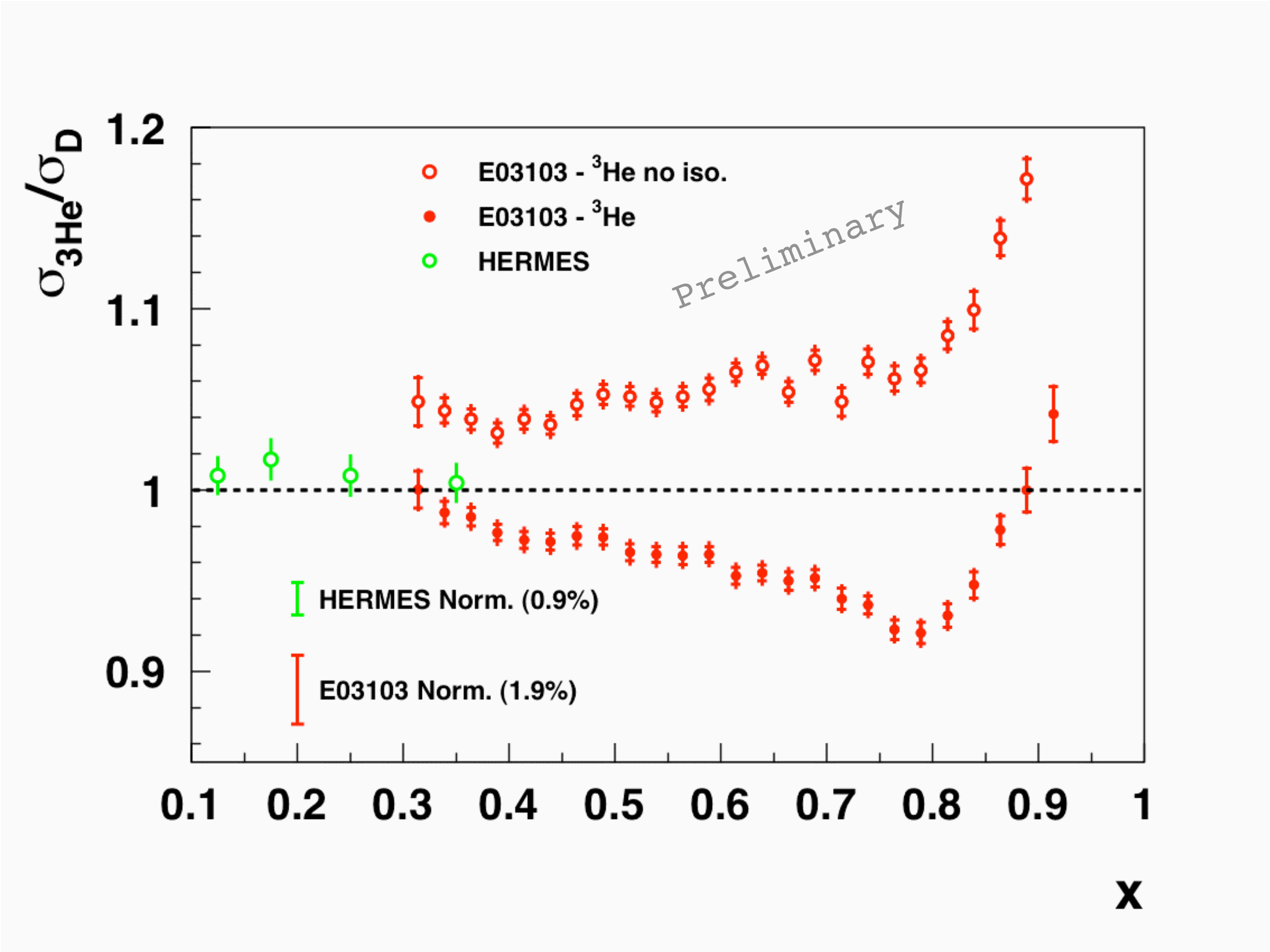
E03-103:Comparison of Carbon and ^{4}He

Nuclear dependence of cross sections



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

Large correction for proton excess



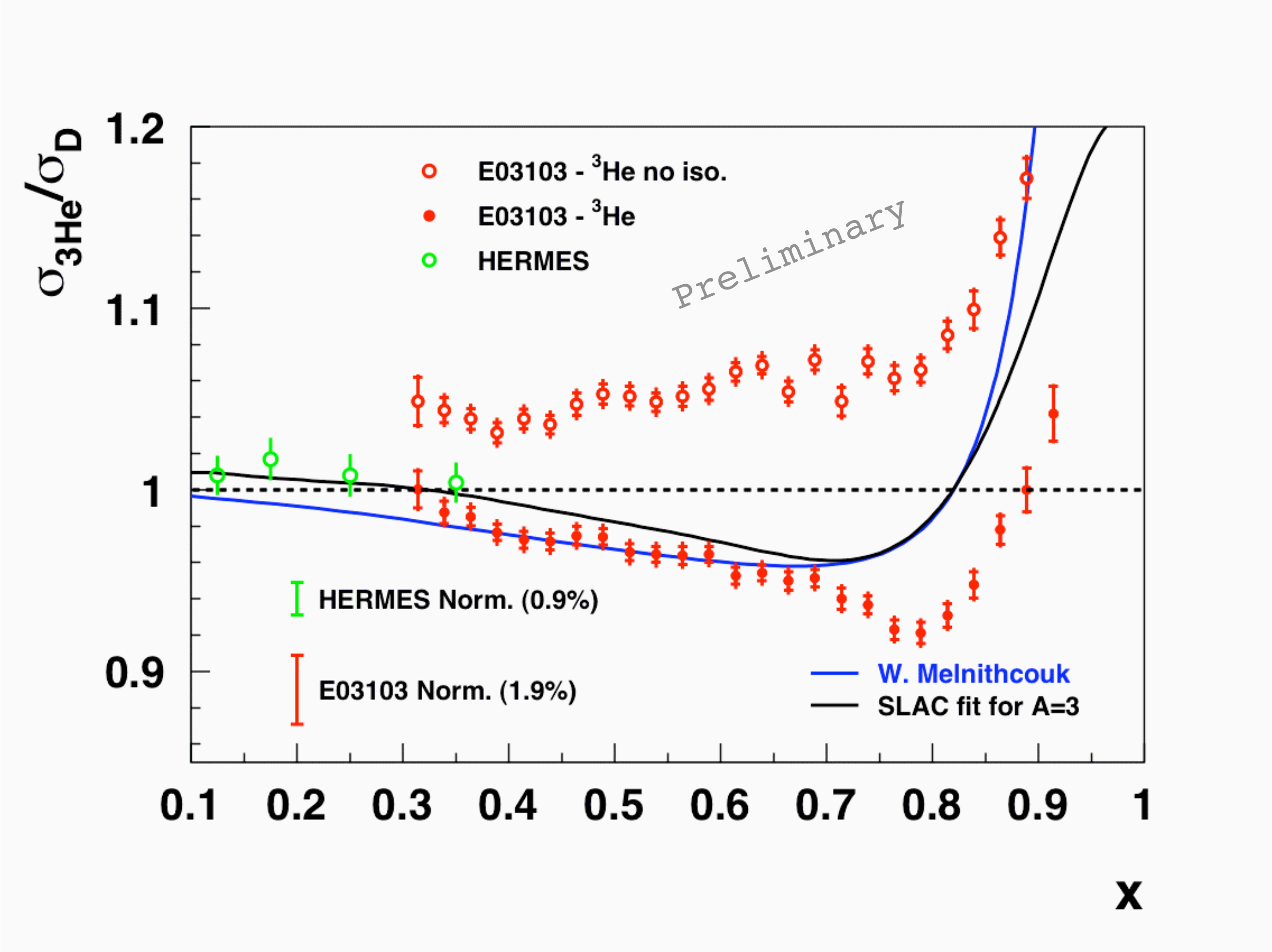
E03-103: Preliminary ^{3}He EMC ratio

Large correction for proton excess

Significant EMC effect

- Different shape at large x than for the heavier nuclei

- Calculations underestimate the effect



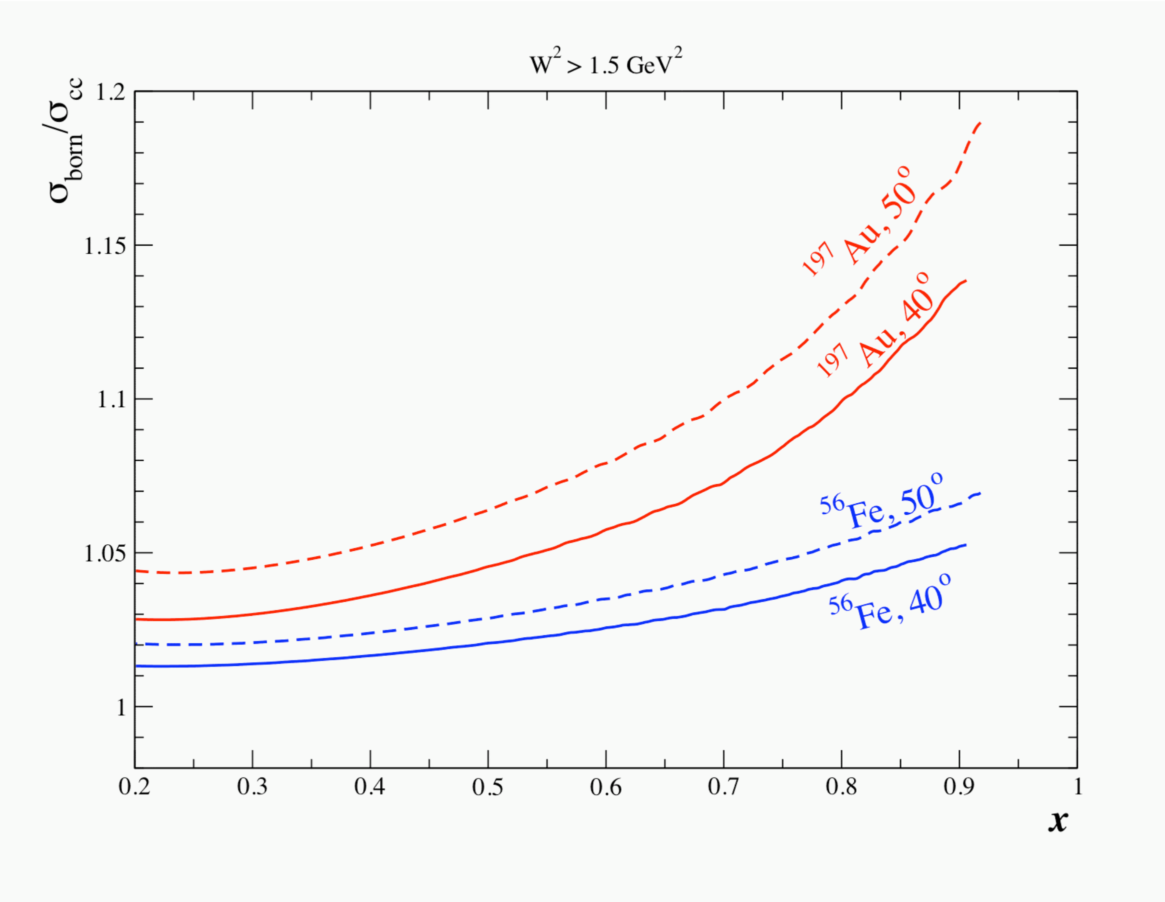
Coulomb distortions on heavy nuclei

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!)***

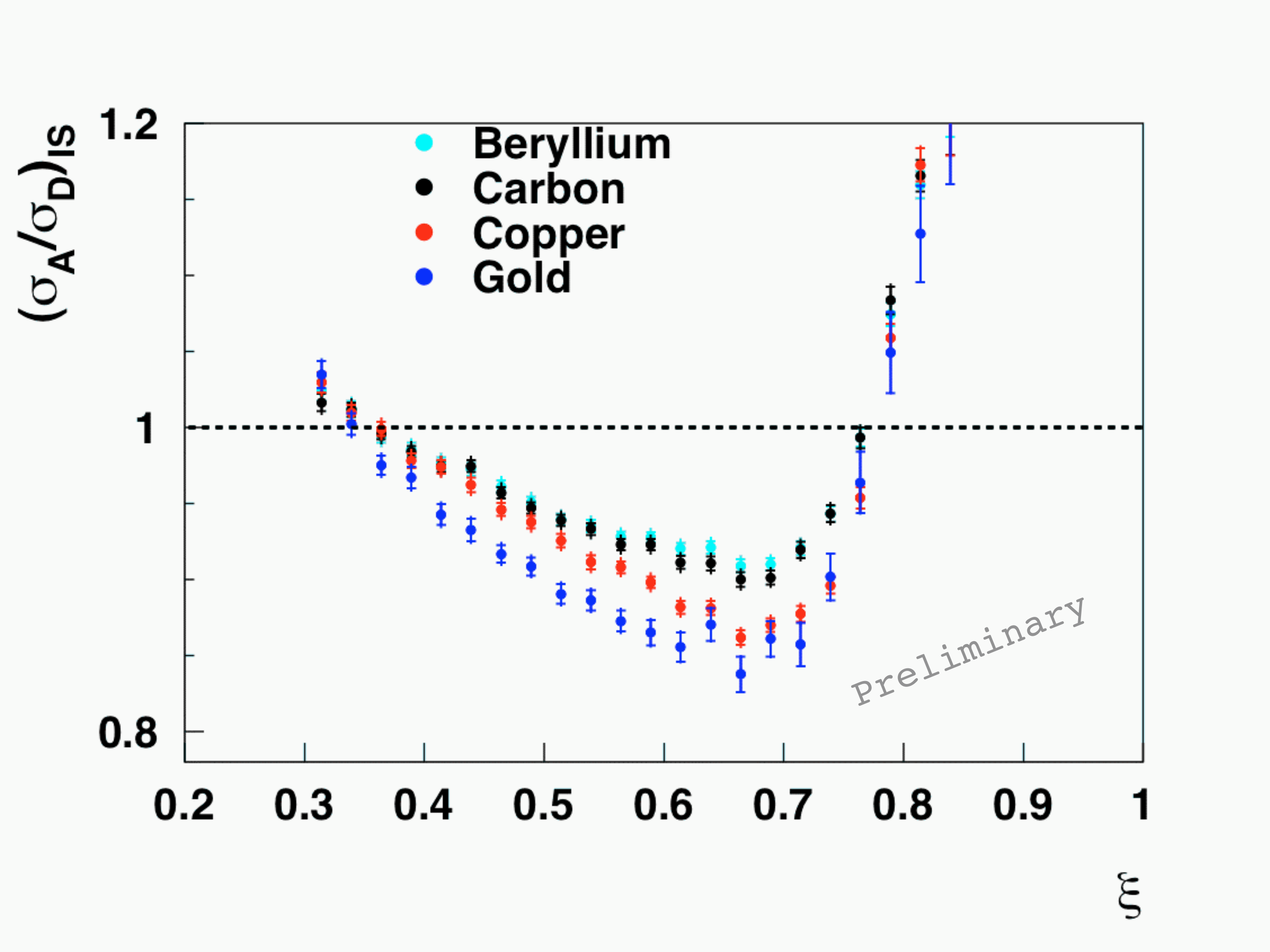
E03-103 uses modified Effective Momentum Approximation (**EMA**)

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



E03-103: EMC effect in heavy nuclei

E03-103 data corrected for coulomb distortion



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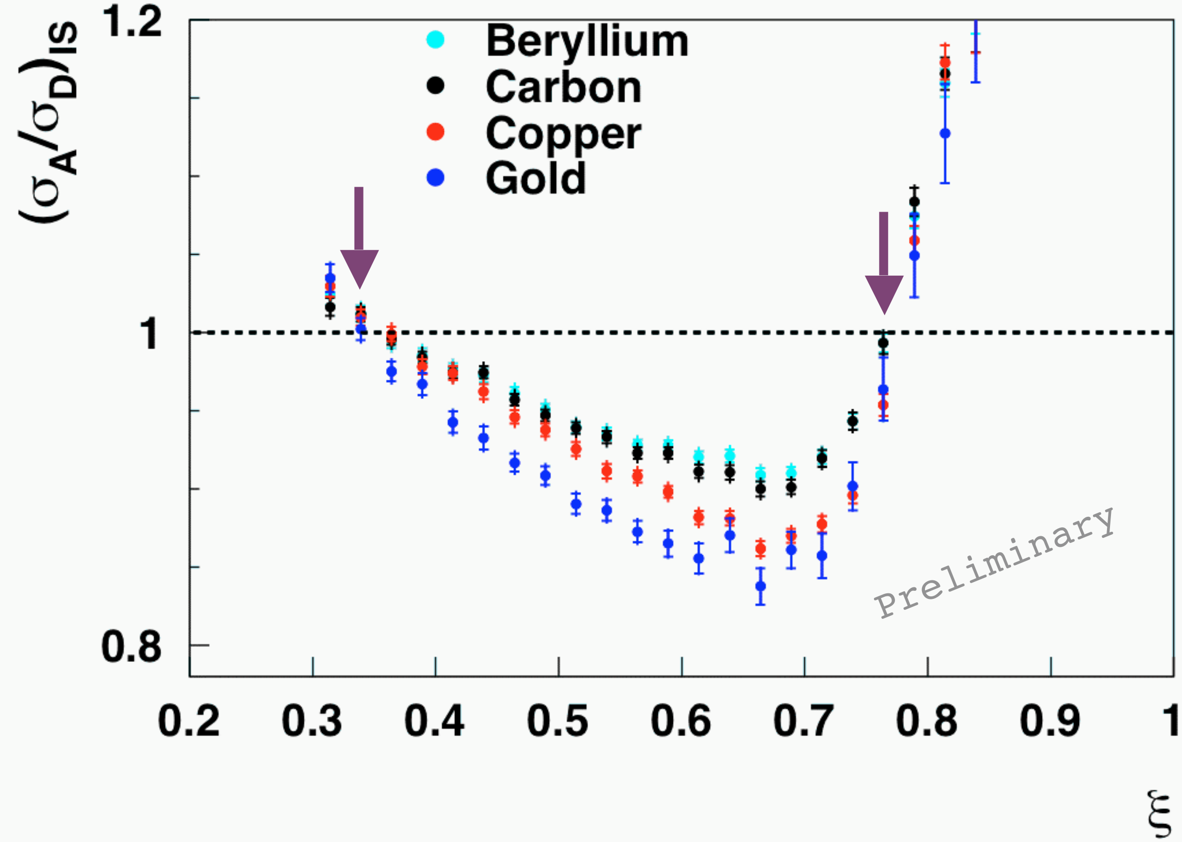
Preliminary observation:

- Large and low x cross-overs A-independent



EMC effect in heavy nuclei

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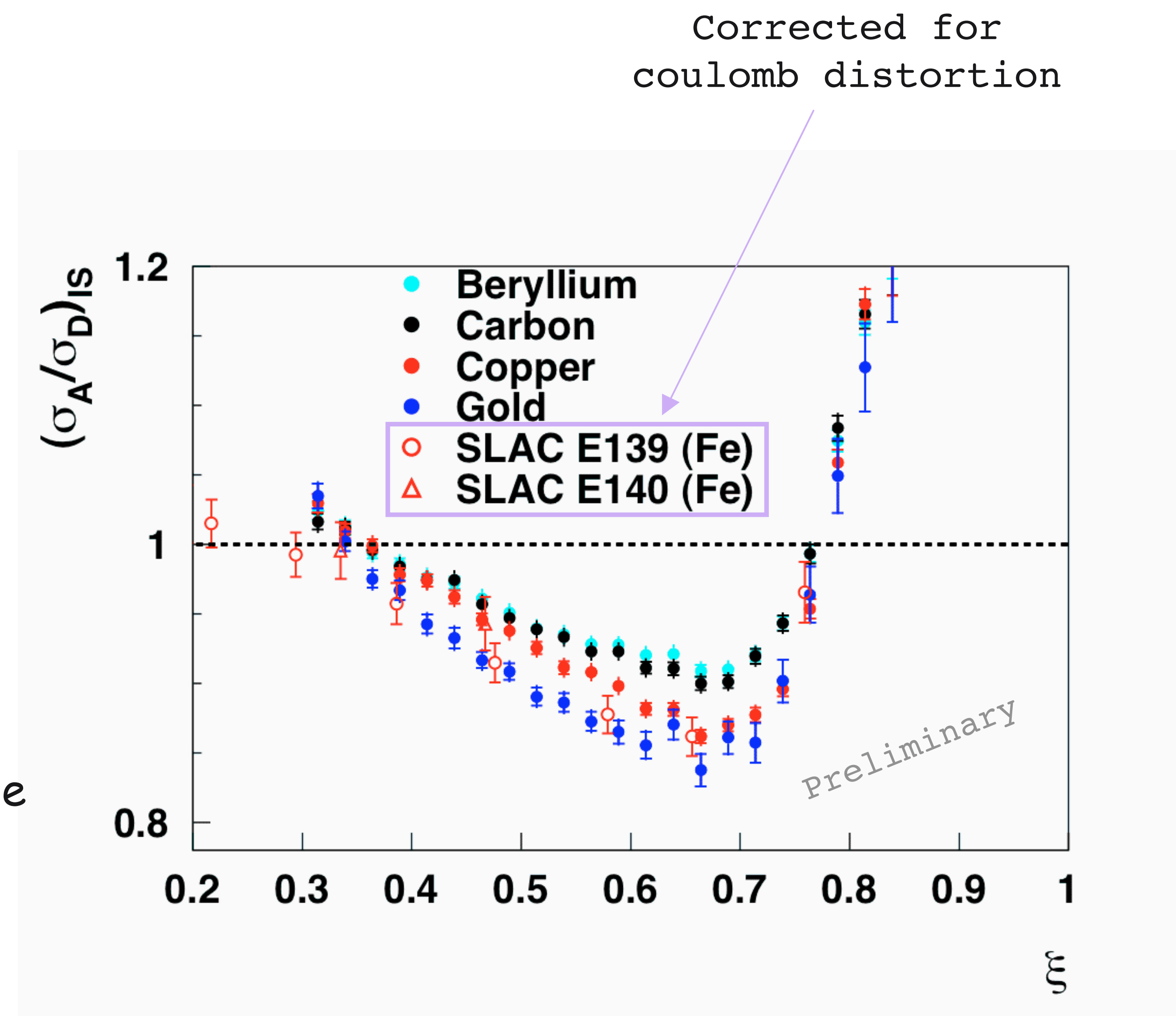
- Good agreement with the SLAC data for Fe



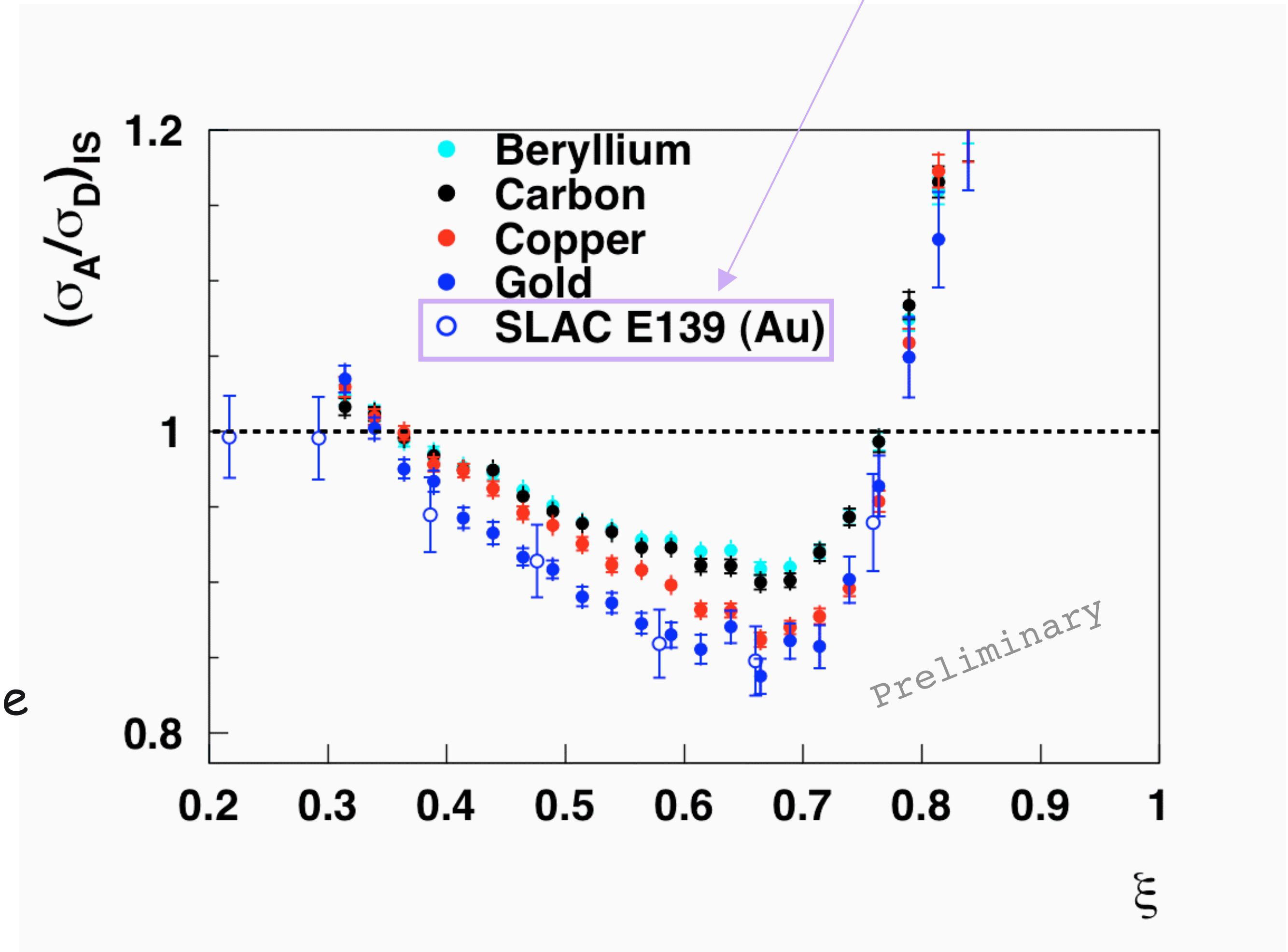
EMC effect in heavy nuclei

Corrected for
coulomb distortion

E03-103 data corrected for coulomb distortion

Preliminary observation:

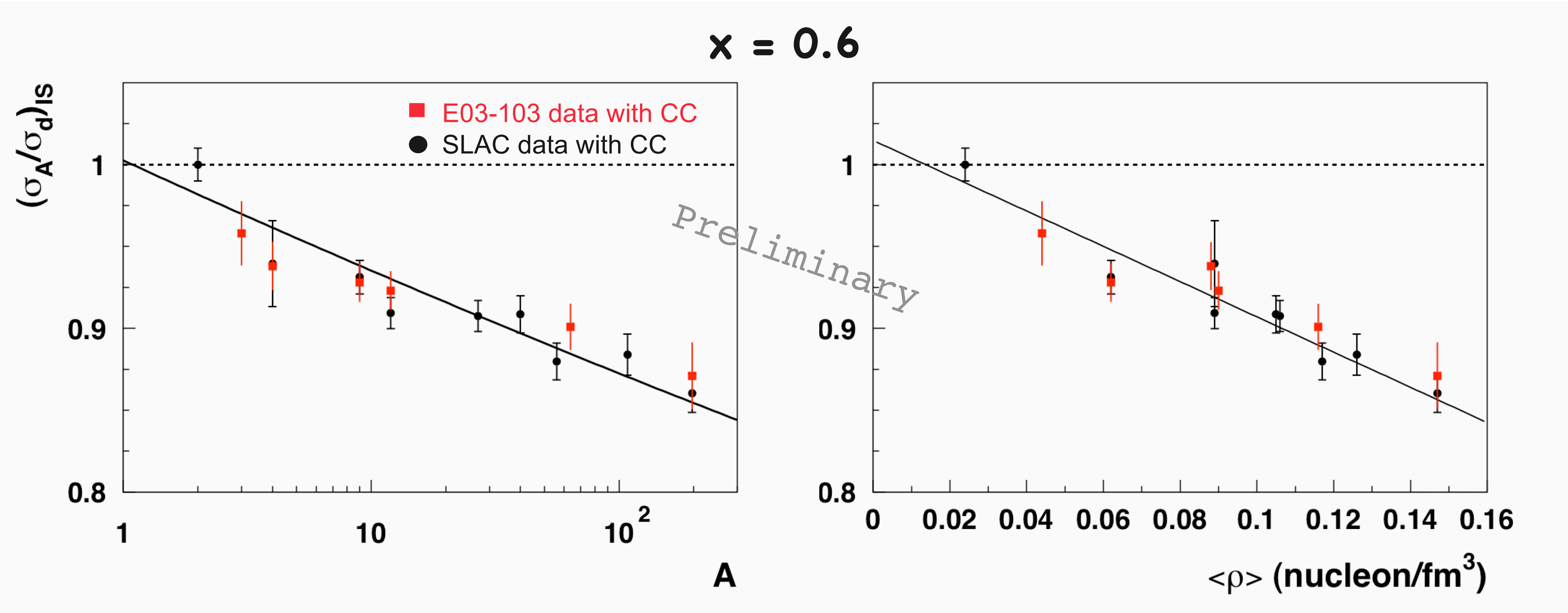
- Large and low x cross-overs A-independent
- Good agreement with the SLAC data for Fe and Au



A or ρ(A) dependence of the EMC effect ?

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

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



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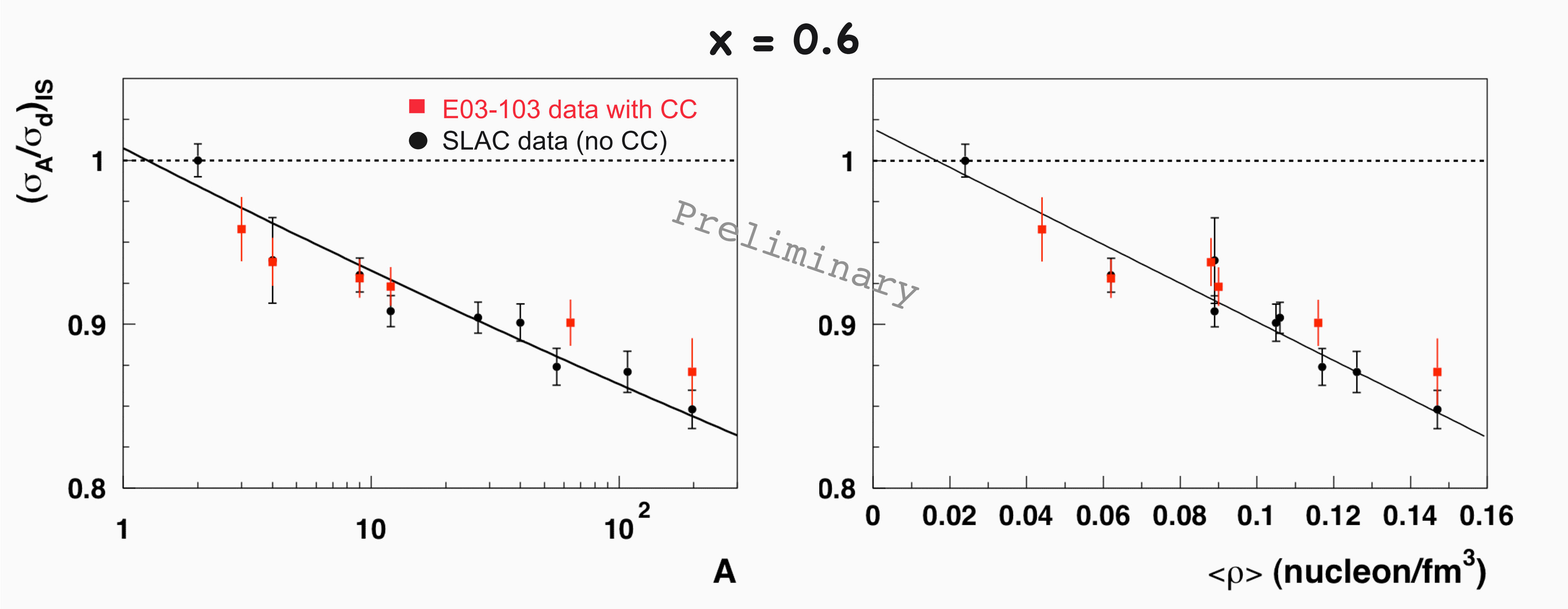

Summary

- 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
  - ✓ Carbon and ^{4}He have the same EMC effect
  - ✓ Large EMC effect in ^{3}He
  - ✓ Similar large x shape of the structure function ratios for A>3

- More to come:
  - ✓ 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

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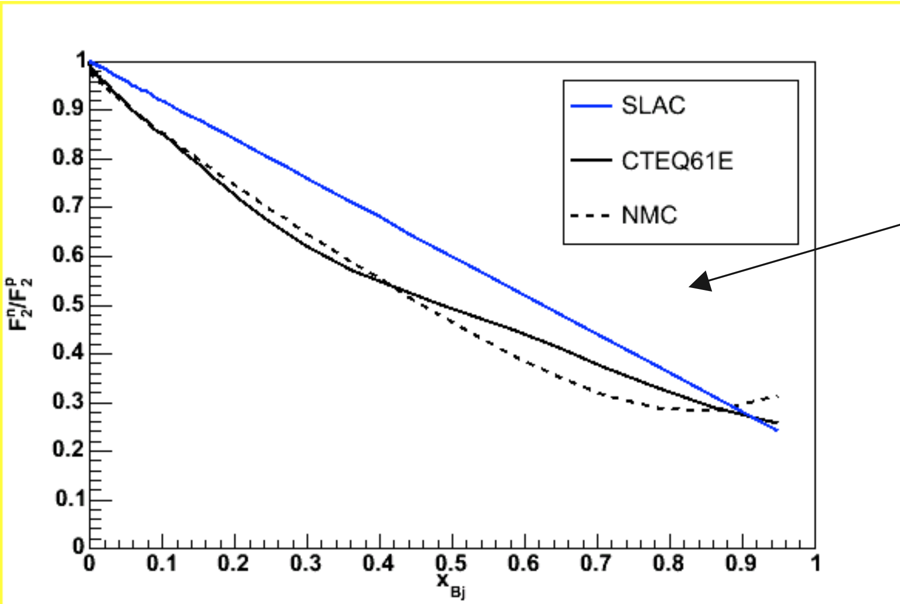
Extra slides

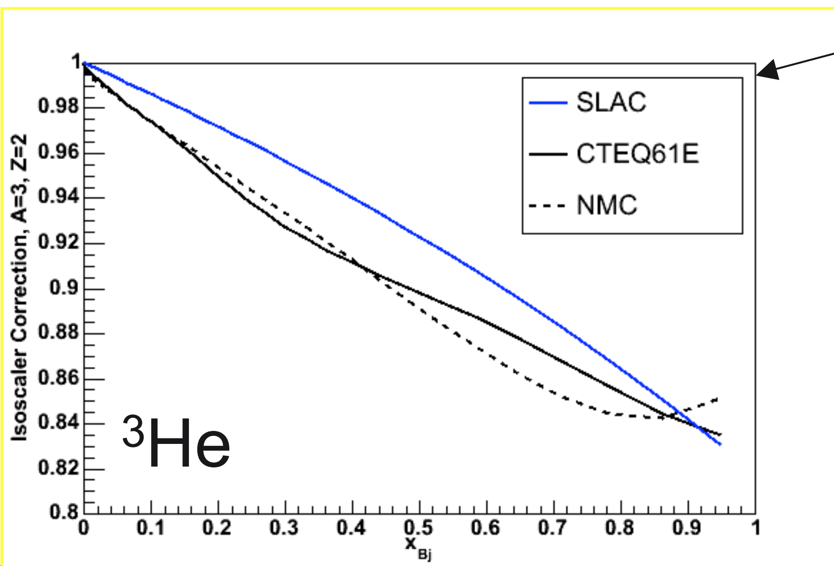
Isoscalar Corrections

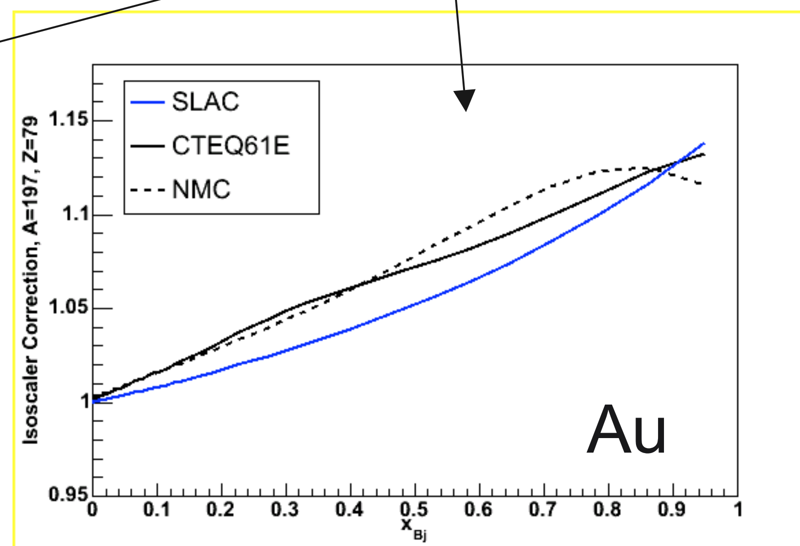


$$\frac{F_2^n}{F_2^p}$$

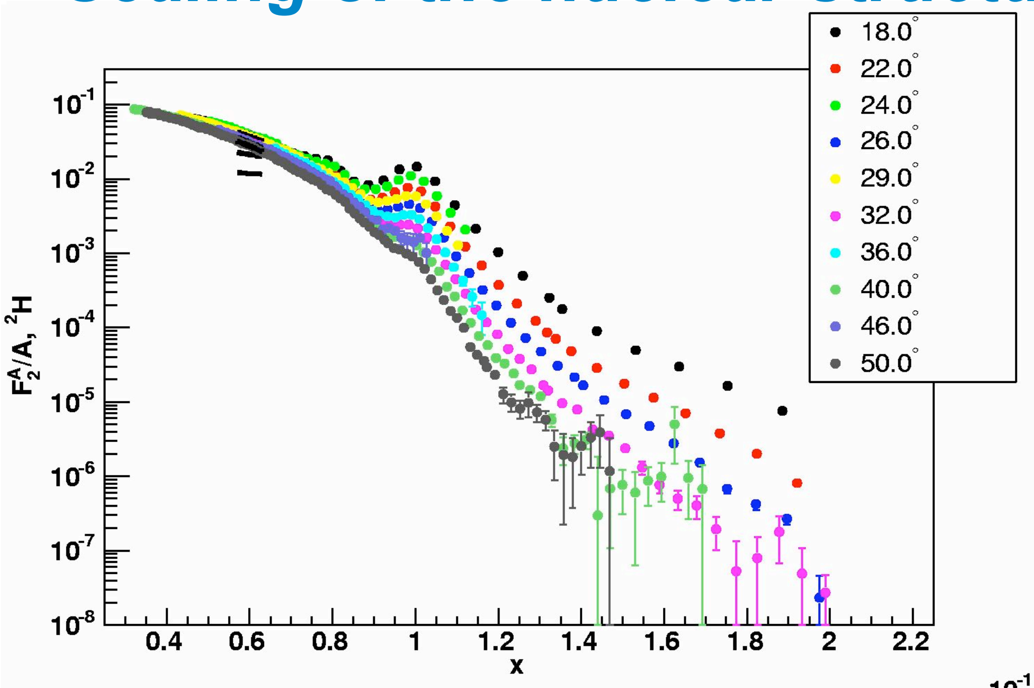
1. SLAC param. *(1-0.8x)*
2. CTEQ
3. NMC fit

Isoscalar correction applied to data





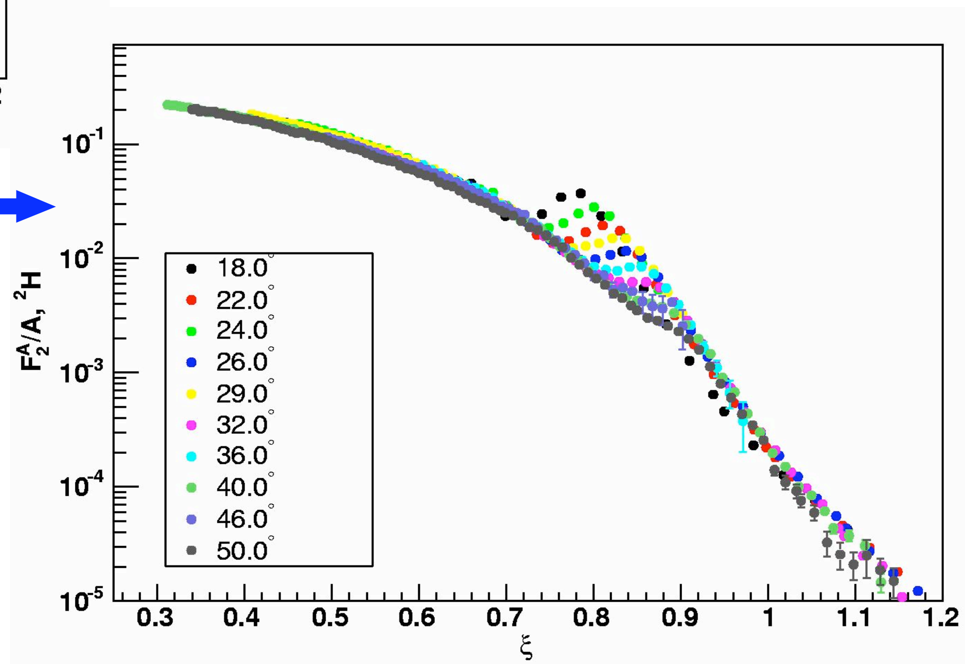
Scaling of the nuclear structure functions



$F_2(x,Q^2)$ consistent with QCD evolution in Q^2 for low x values (x<0.5)

Huge scaling violations at large x (especially for x>1)

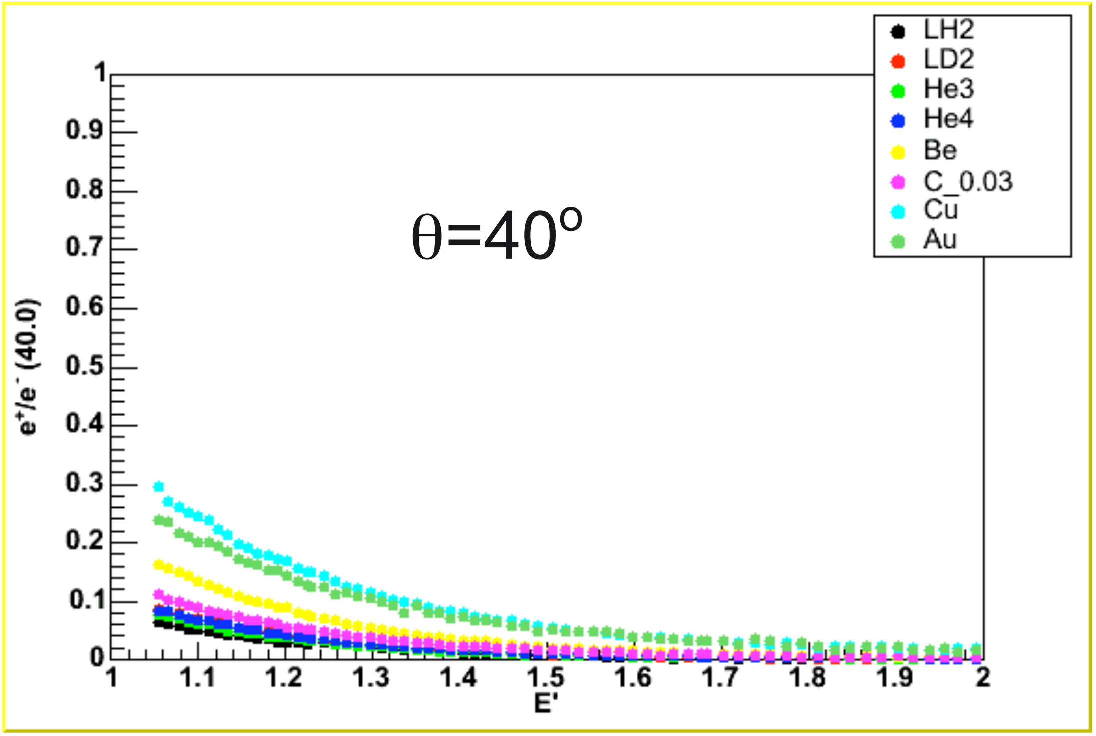
F2(ξ,Q^2) consistent with QCD evolution in Q^2 to much larger ξ values



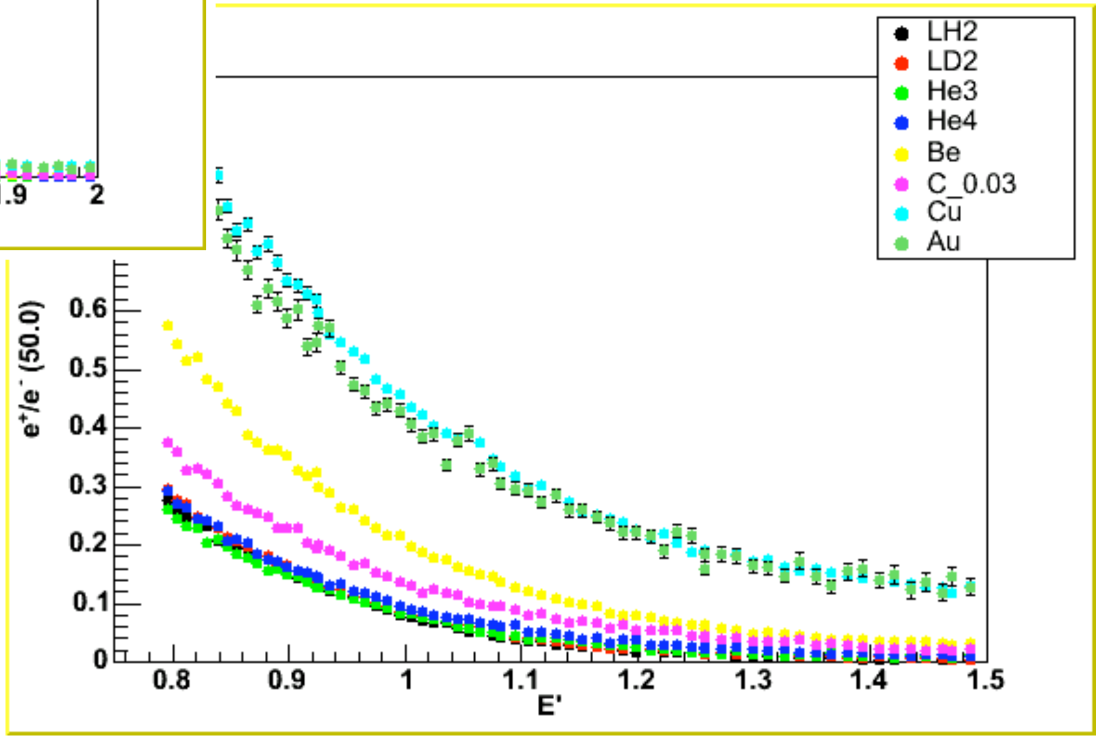
Scaling violations are mostly the "target-mass" corrections
(plus a clear contribution from the QE peak)

→ Nearly independent of A

E03-103: Charge-symmetry background



Ratio of e+ to e- production



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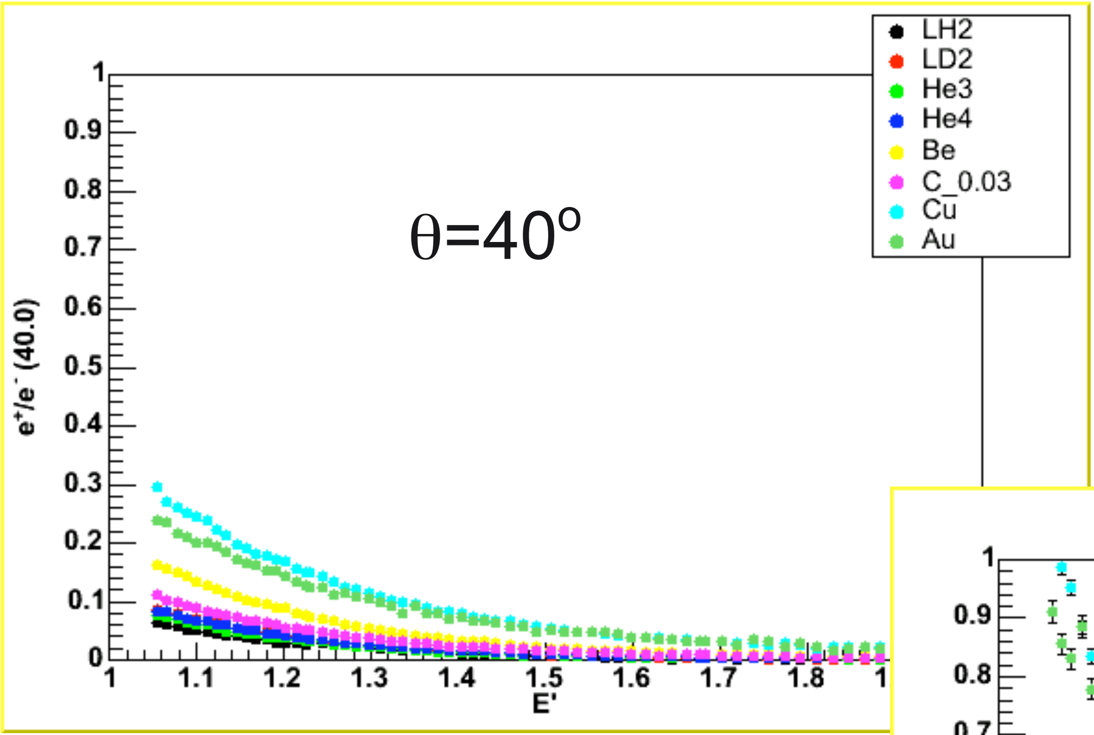

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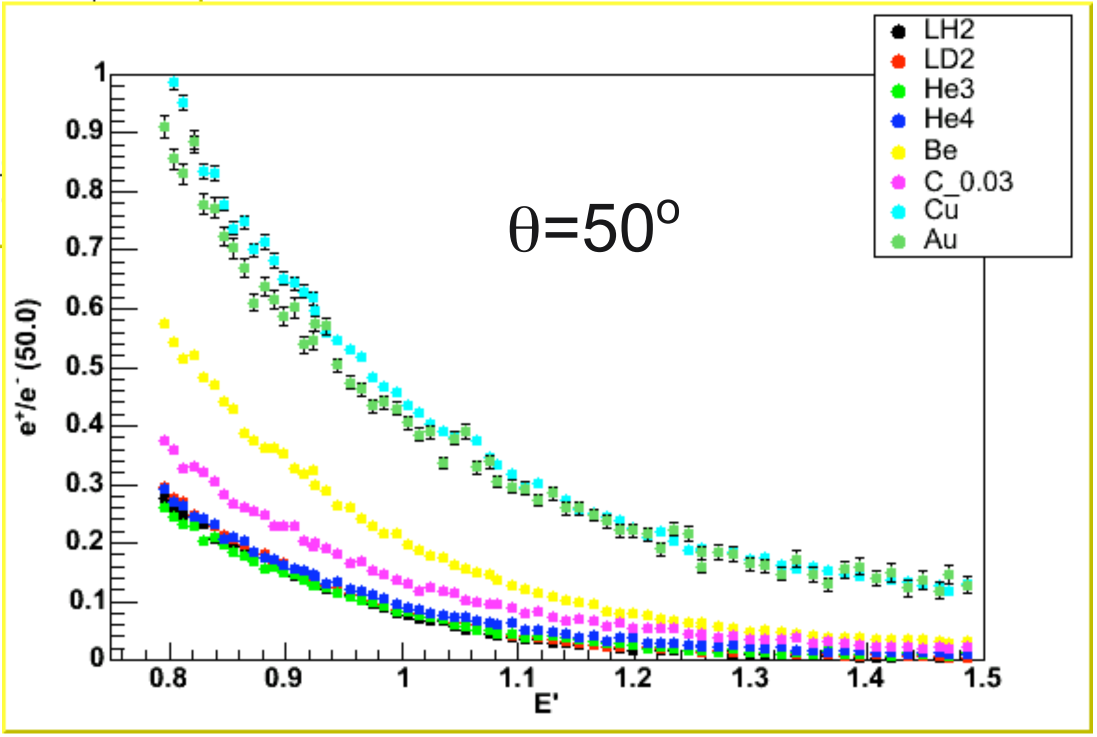
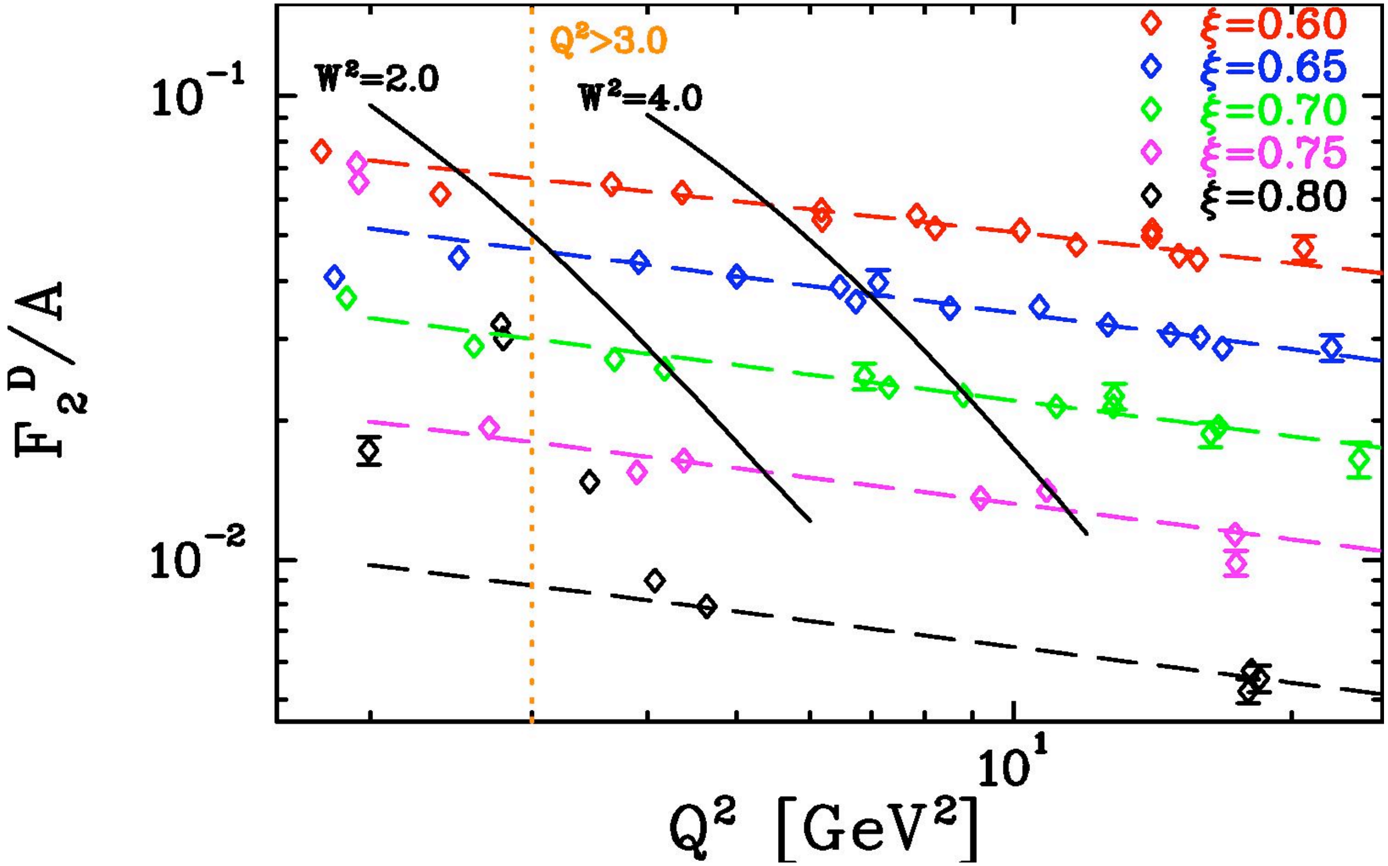


Scaling of the nuclear structure functions

- **Low Q^2 JLab data** (from E89-008, 4 GeV) **are consistent with extrapolated structure function from high Q^2 SLAC data** [fixed dln(F_2)/dln(Q^2)]
- **Above ξ=0.65, there is a large gap between JLab, SLAC data, but there are indications of scaling up to ξ=0.75**



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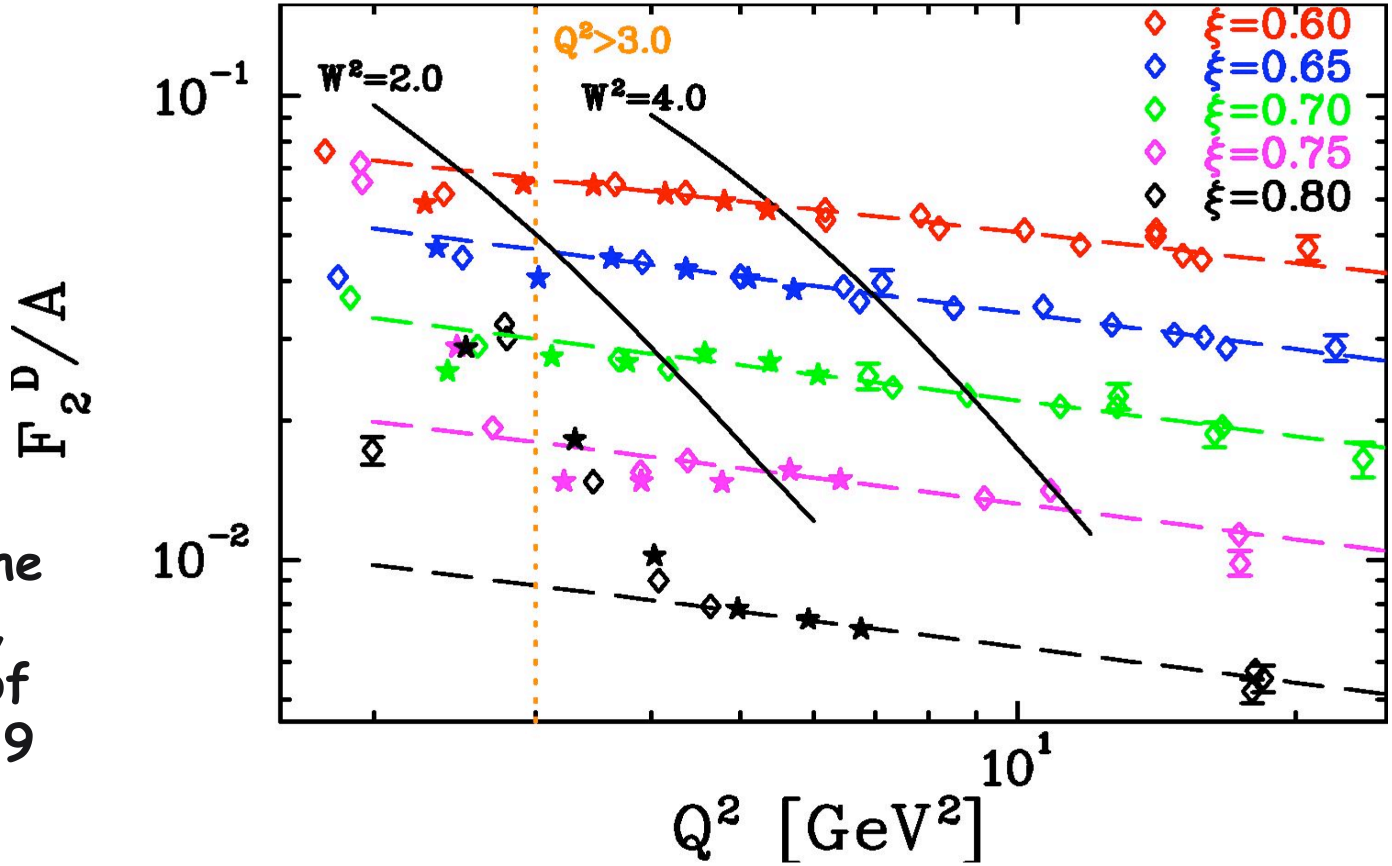

- **Our data fill in the gap up to ξ~0.75, show indications of scaling up to ξ~0.9**