EMC EFFECT IN FEW NUCLEON SYSTEMS

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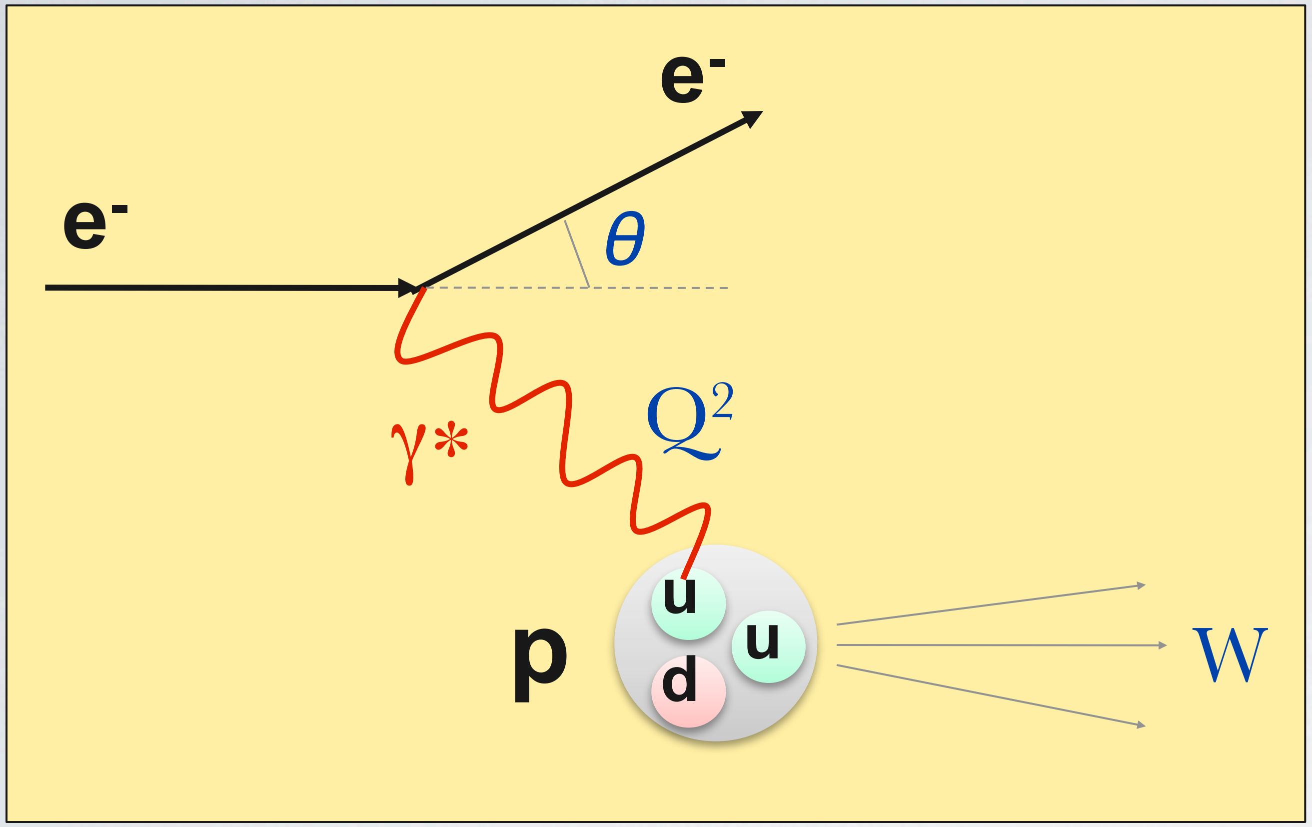
Outline:

- Introduction to the EMC effect
- New results from JLab
- First extraction of R_{NM}
- Future measurements

Marciana Marina, Isola d'Elba, Italy.

Elba XI
June 21-25, 2010

THE QUEST TO HIGHER PRECISION

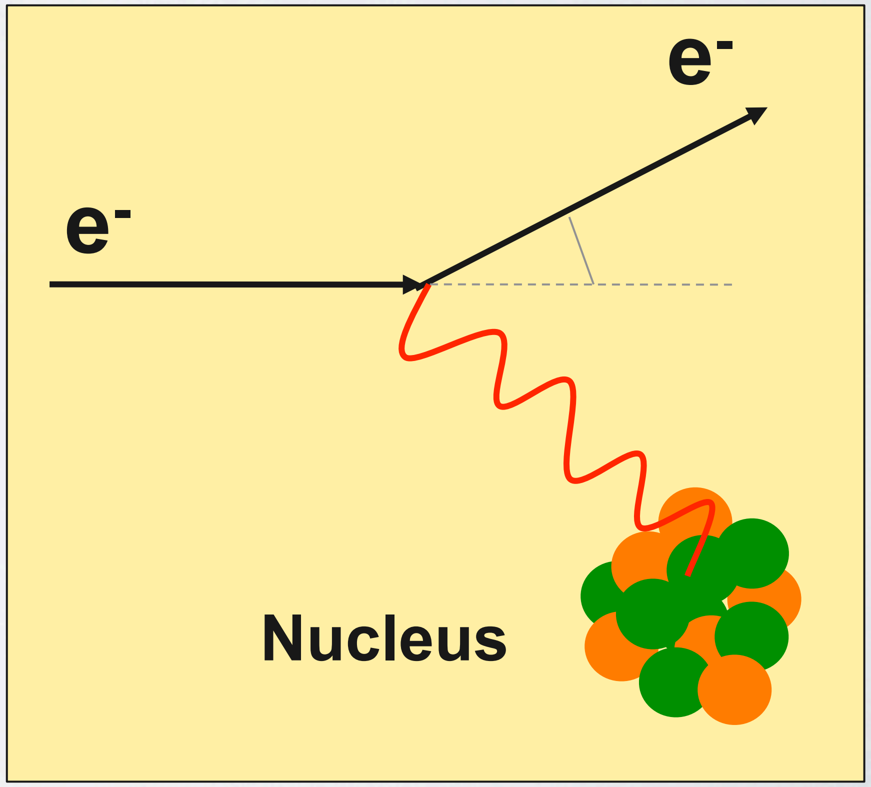


To increase the luminosity, physicists decided to use heavy nuclei to study the structure of the proton instead of a hydrogen target.

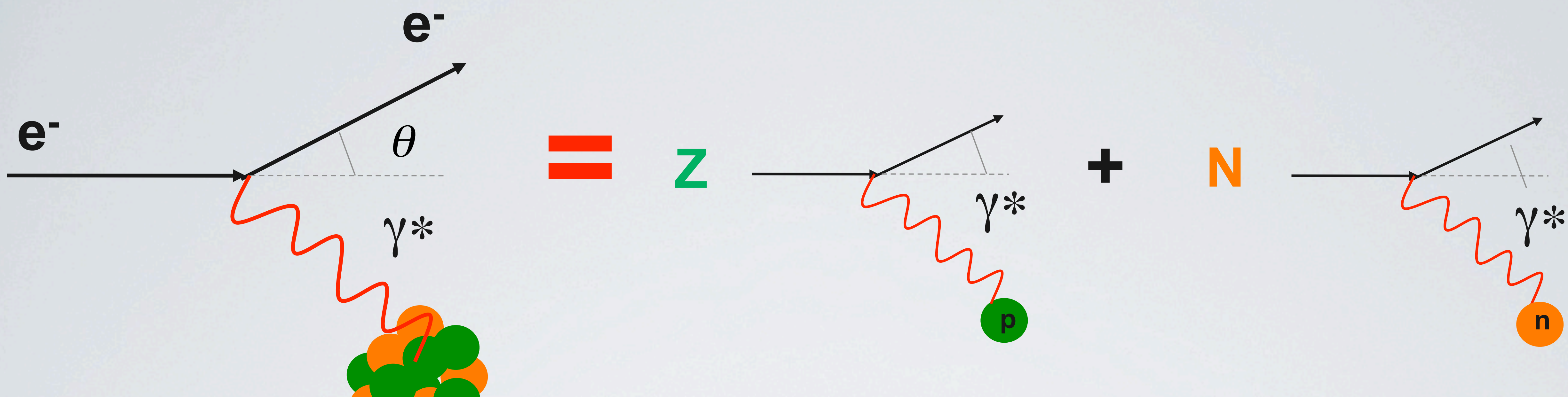
For nuclei,
binding energies << energy scale of the probe

Expected

$$F_2^A(x) \approx Z\, F_2^p(x) + N\, F_2^n(x)$$

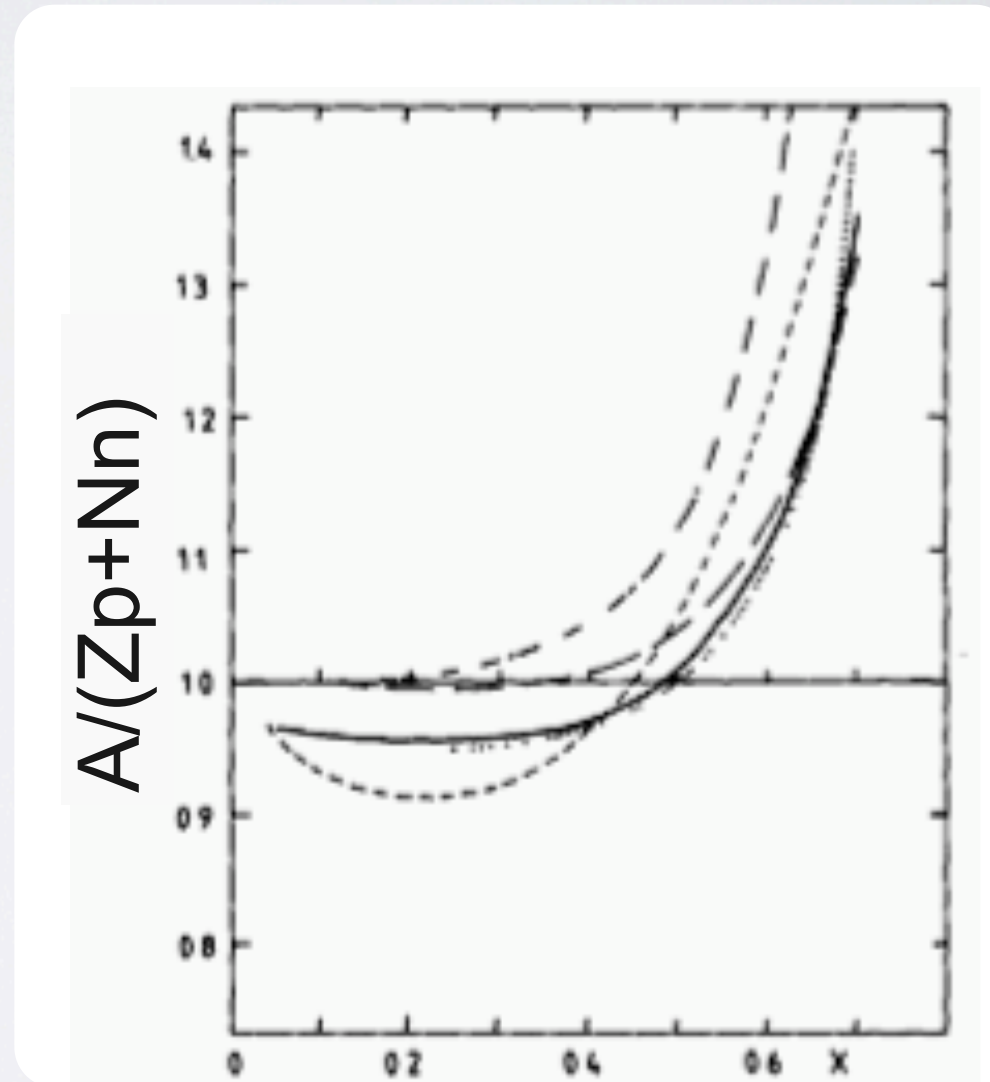


THE EMC EFFECT



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

Expected nuclear effects:
Fermi motion



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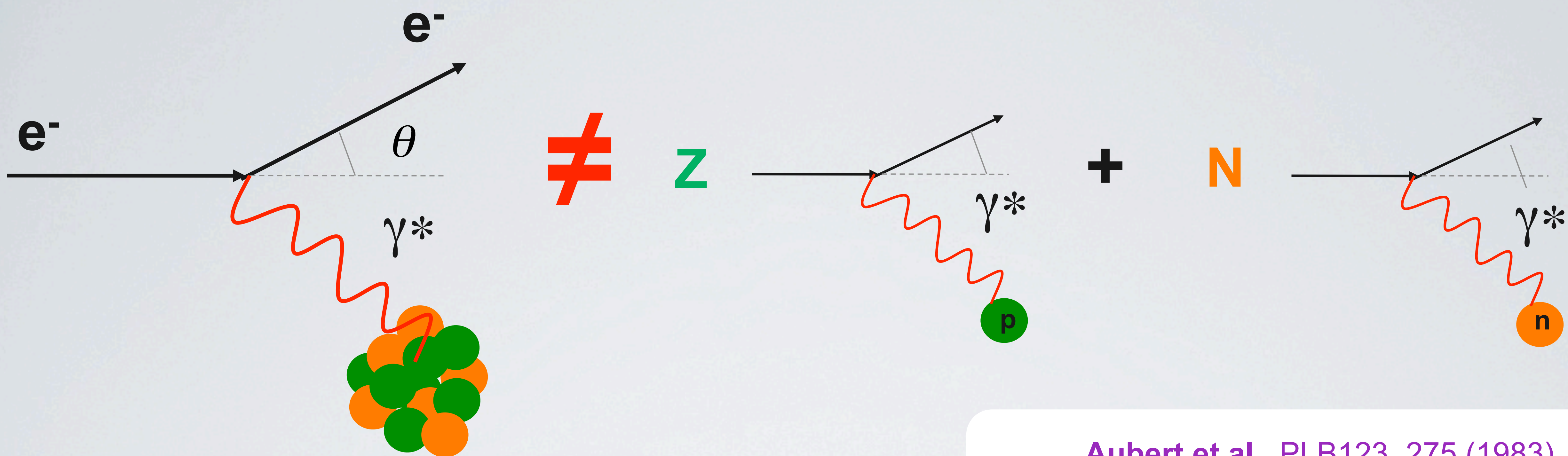
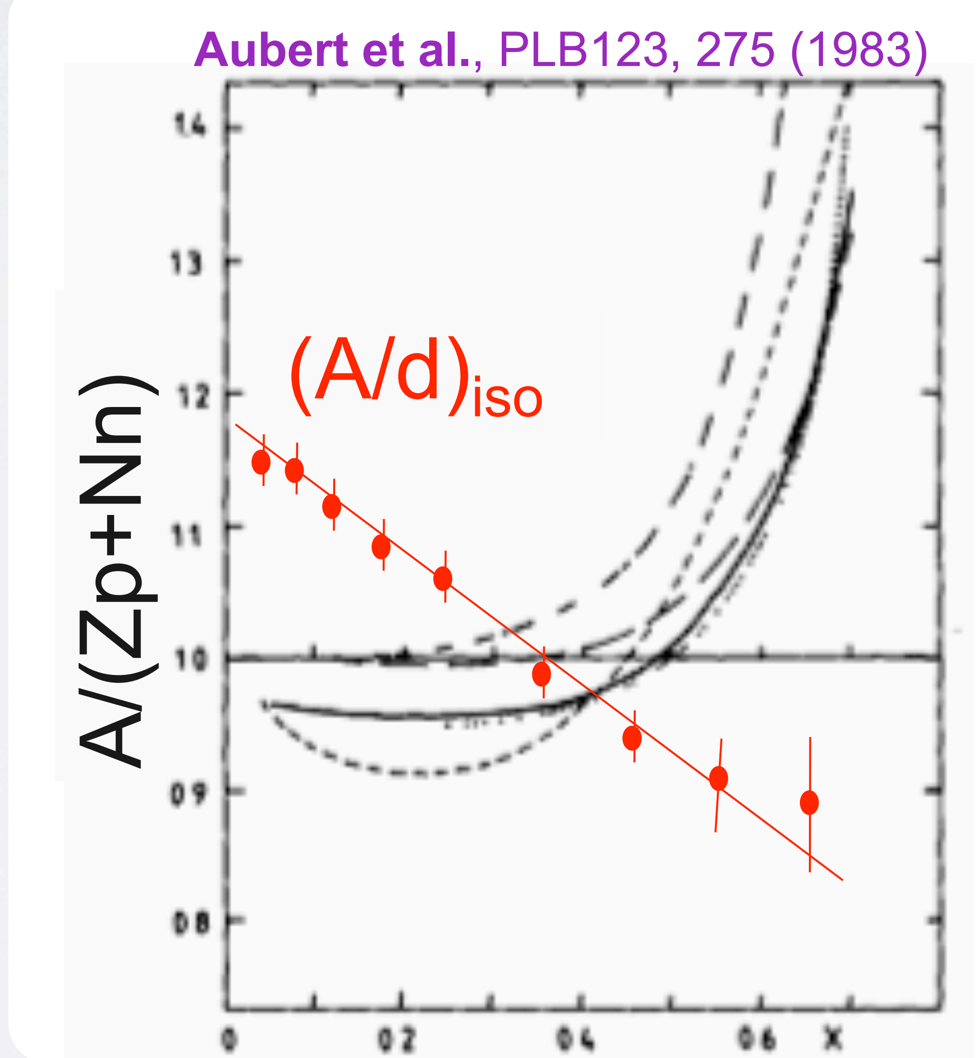
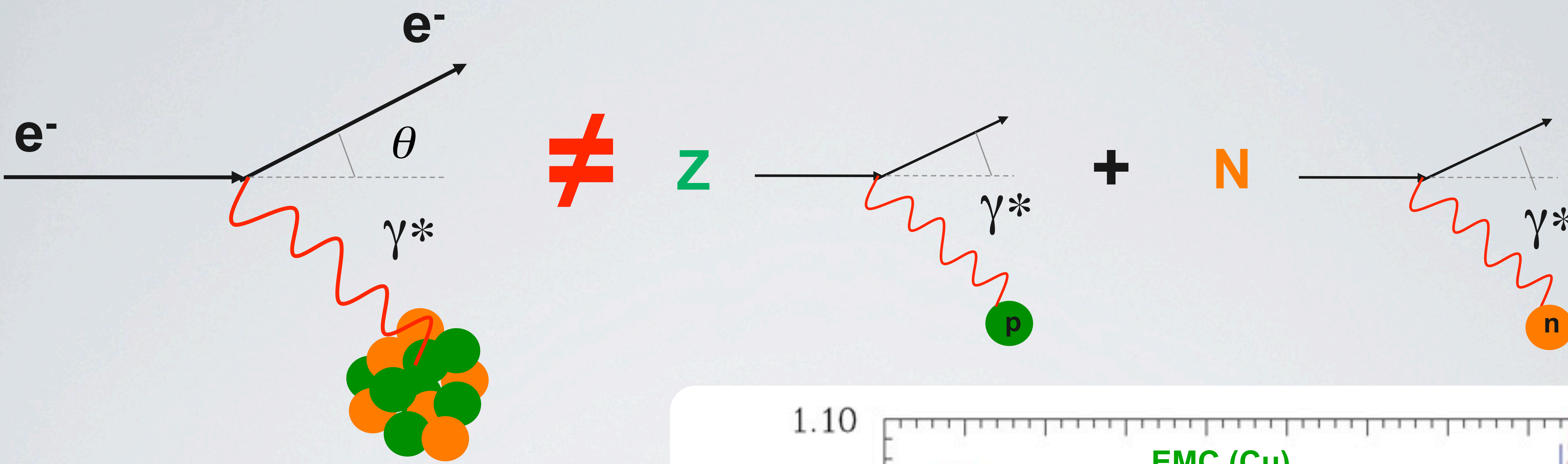


Nuclear structure: $$\boxed{F_2^A \neq ZF_2^p + NF_2^n}$$

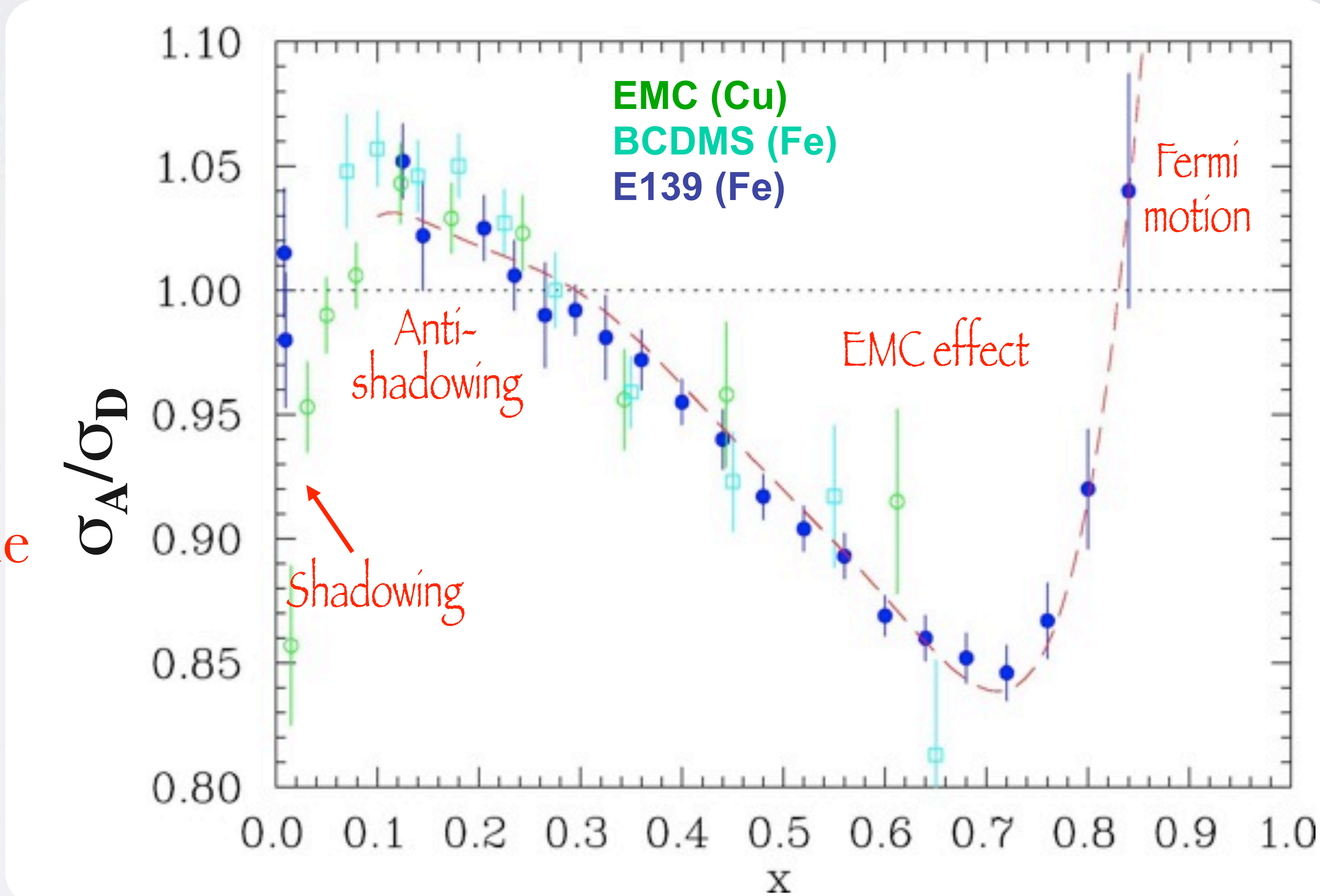


First measurement by the EMC collaboration (1983) found an excess of low-x quarks, deficit of high-x quarks in heavy nuclei

THE EMC EFFECT



Effects found in several experiments at CERN and SLAC



The EMC effect correspond to the region of depletion of high momentum quarks inside the nucleus

THEORETICAL MODELS

1. Conventional nuclear physics based explanations (convolution calculations)
   - Fermi motion alone clearly not sufficient
   - Early attempts to combine Fermi motion effects and binding were fairly simplistic
   - Even more sophisticated approaches (spectral function) fail unless one includes "nuclear pions"

     Size of contributions from nuclear pions typically used in DIS calculations inconsistent with nuclear dependence of Drell-Yan

2. "Exotic" effects
   - Medium effects on quark distributions themselves: dynamical rescaling, multiquark clusters, etc.

Uncertainties in 1 make it difficult to determine what role mechanisms in 2 play in observed EMC effect

EXISTING EMC DATA

SLAC E139:

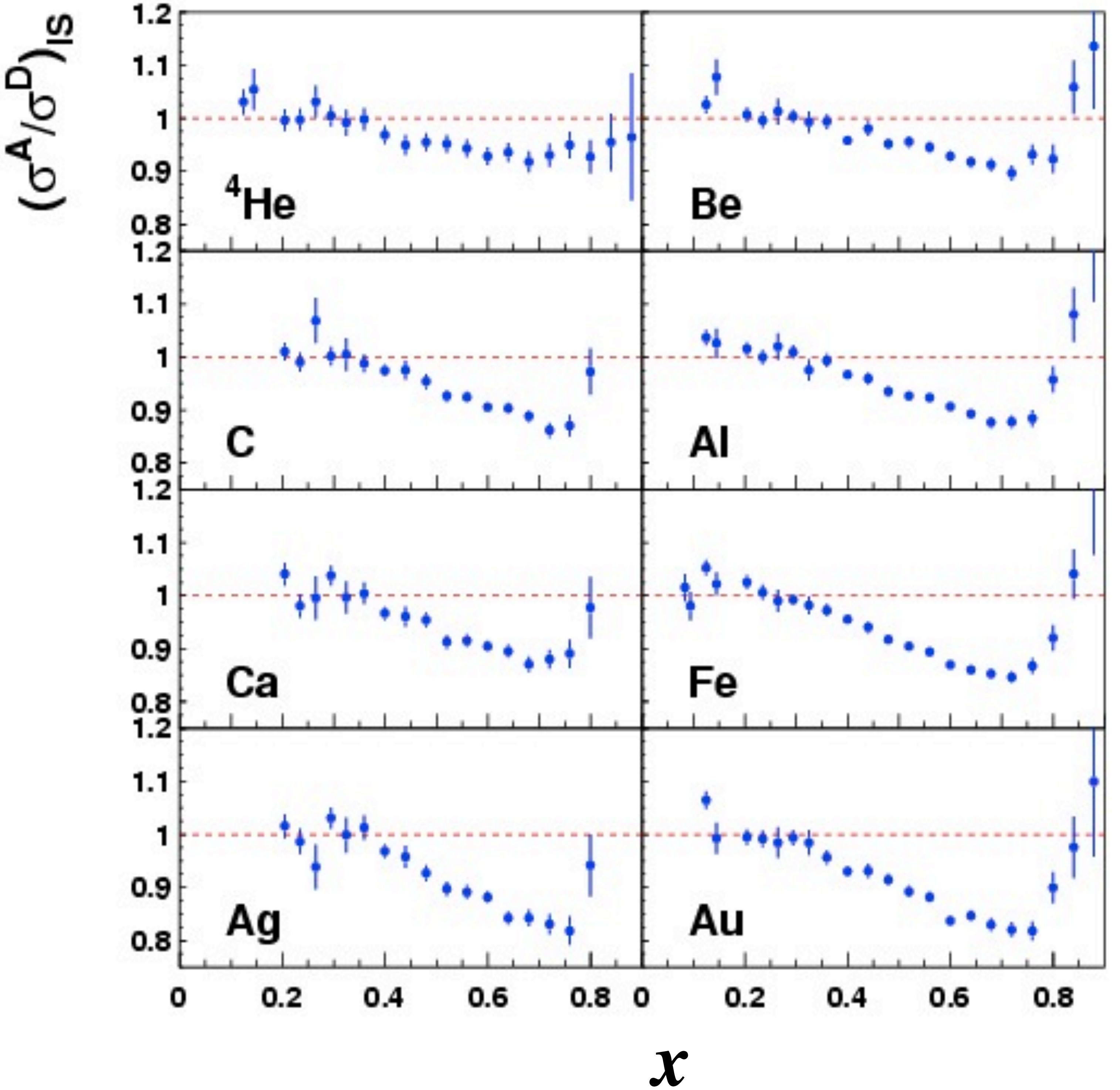
- Most precise large x data
- Nuclei from A=4 to A=197

Observations:

1) Universal x-dependence shape
2) Q^2-independent
3) Magnitude varies with A:
   - ➡ Scale with $A^{-1/3}$
   - ➡ Scale with average density

     Density calculated assuming a uniform sphere of radius:
     $R_e (r=3A/4pR_e^3)$

J. Gomez et al, PRC49, 4348 (1994)

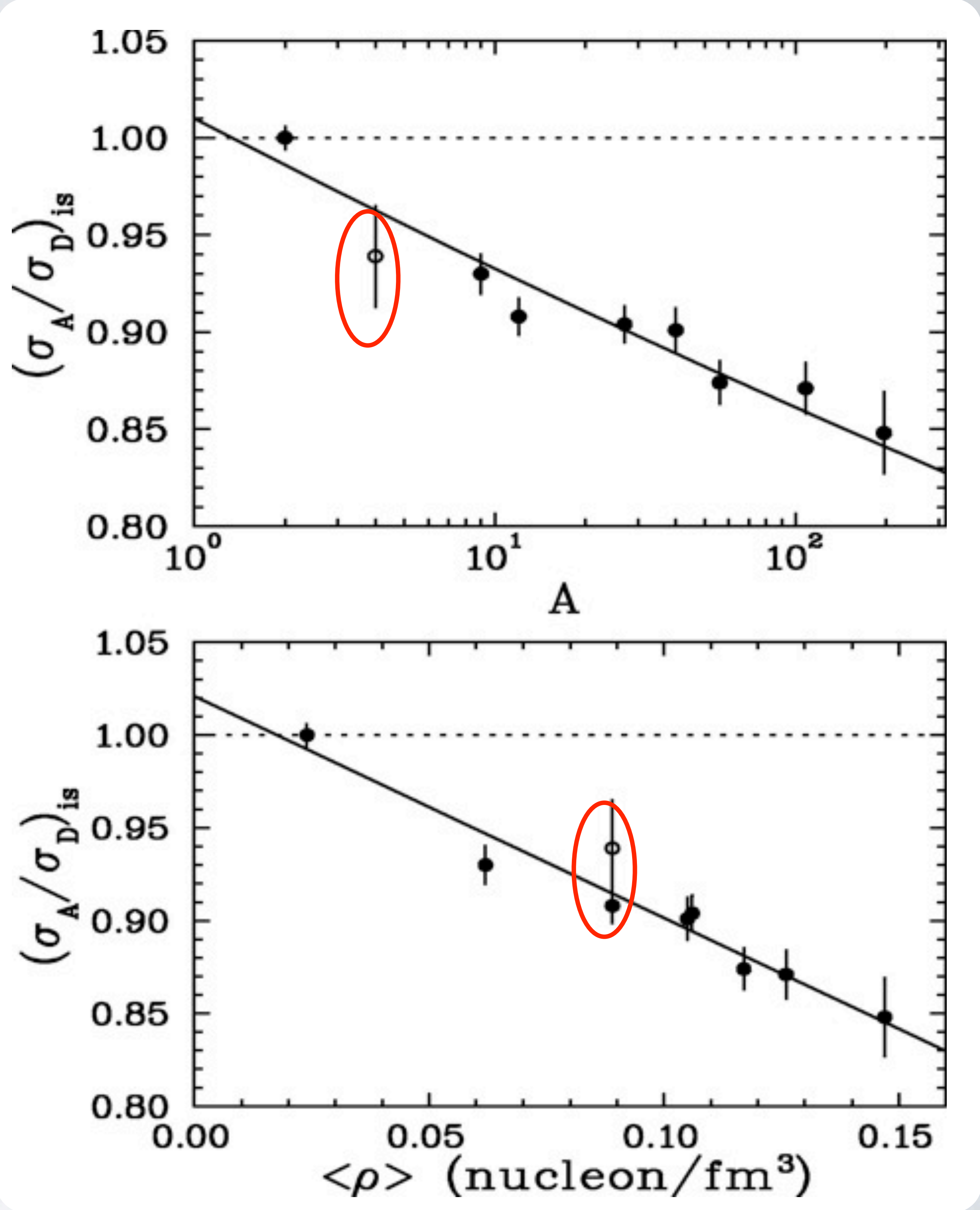


LIMIT OF EMC DATA

➡ ^{4}He much lighter than ^{12}C, but has similar average density
Compare A vs <ρ>

➡ ^{3}He has low A and low density; expect smaller EMC effect

➡ Both nuclei allow for precise, few-body calculations



JLAB EXPERIMENT E03-103

JLab E03-103, "*EMC effect in few-body nuclei*"
J. Arrington and D. Gaskell: spokespersons
J. Seely, A. Daniel, (N. Fomin): Ph.D. students

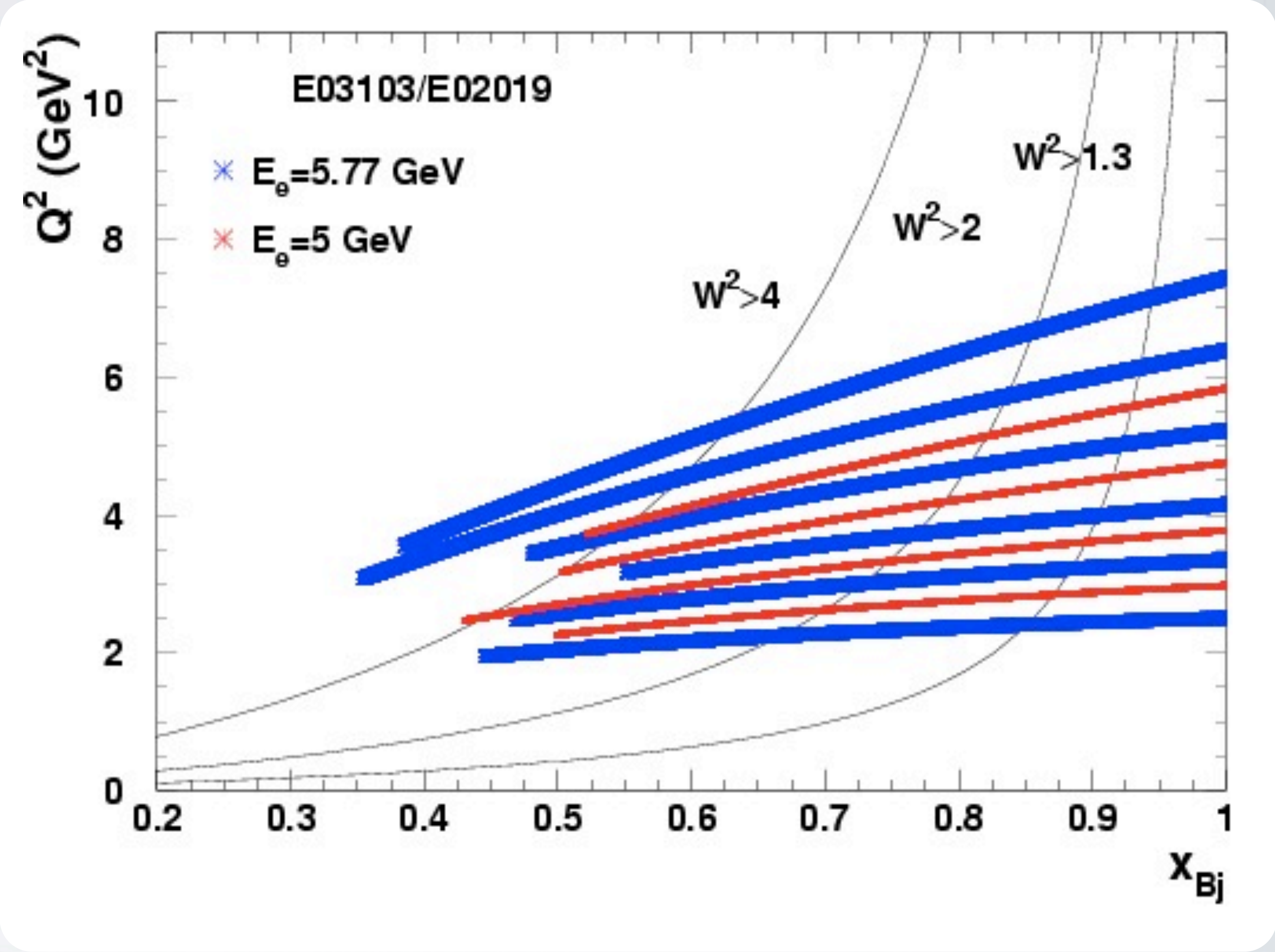
A(e,e') at 5.0 and 5.8 GeV in Hall C

10 angles to measure Q^2-dependence

Targets: H, ^{2}H, ^{3}He, ^{4}He, ^{9}Be, ^{12}C, ^{63}Cu, ^{197}Au

Isoscalar correction

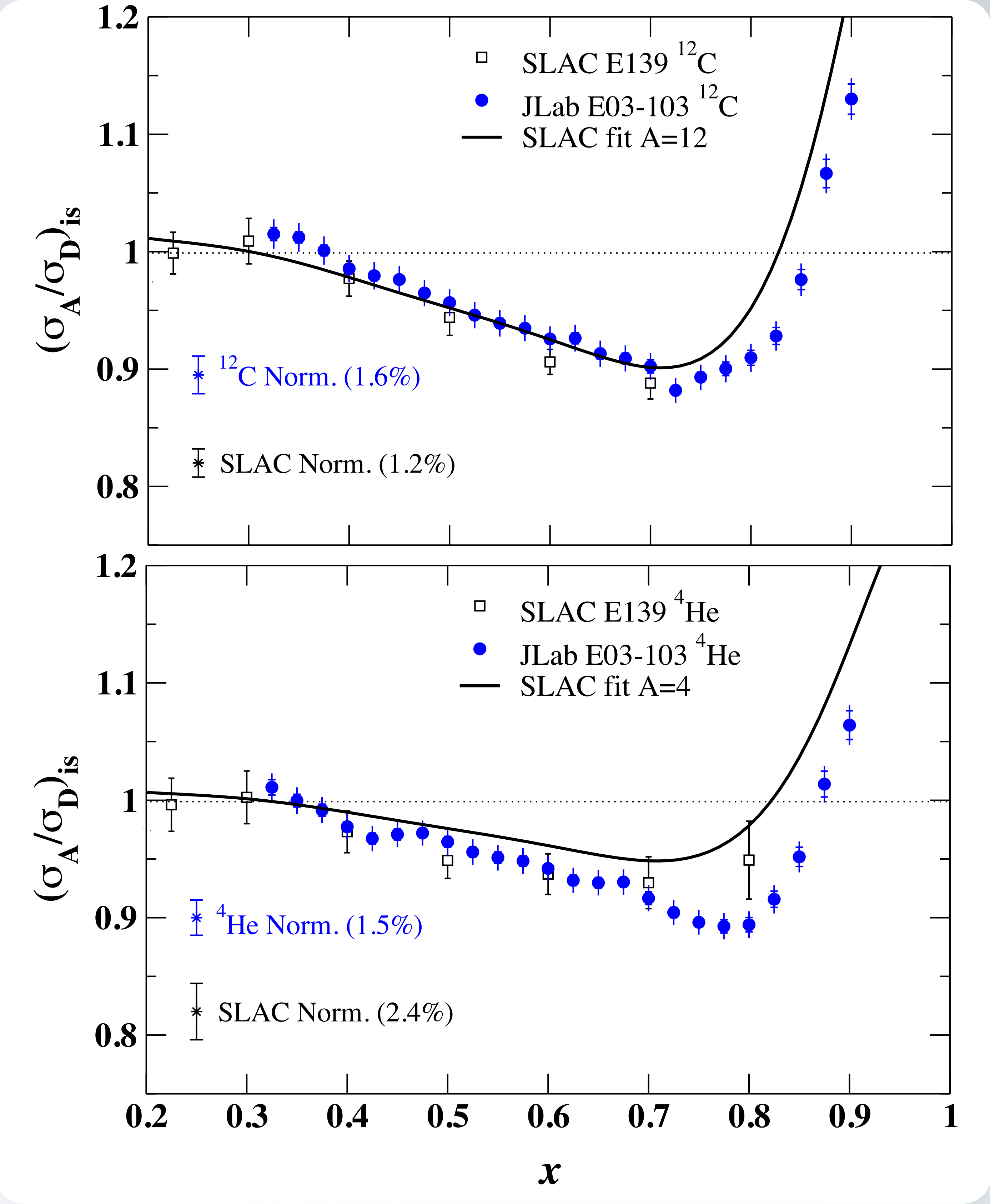
Coulomb correction



E03-103: ^{12}C AND ^{4}He EMC RATIOS

JLab results consistent with SLAC E139

→ Improved statistics and systematic errors



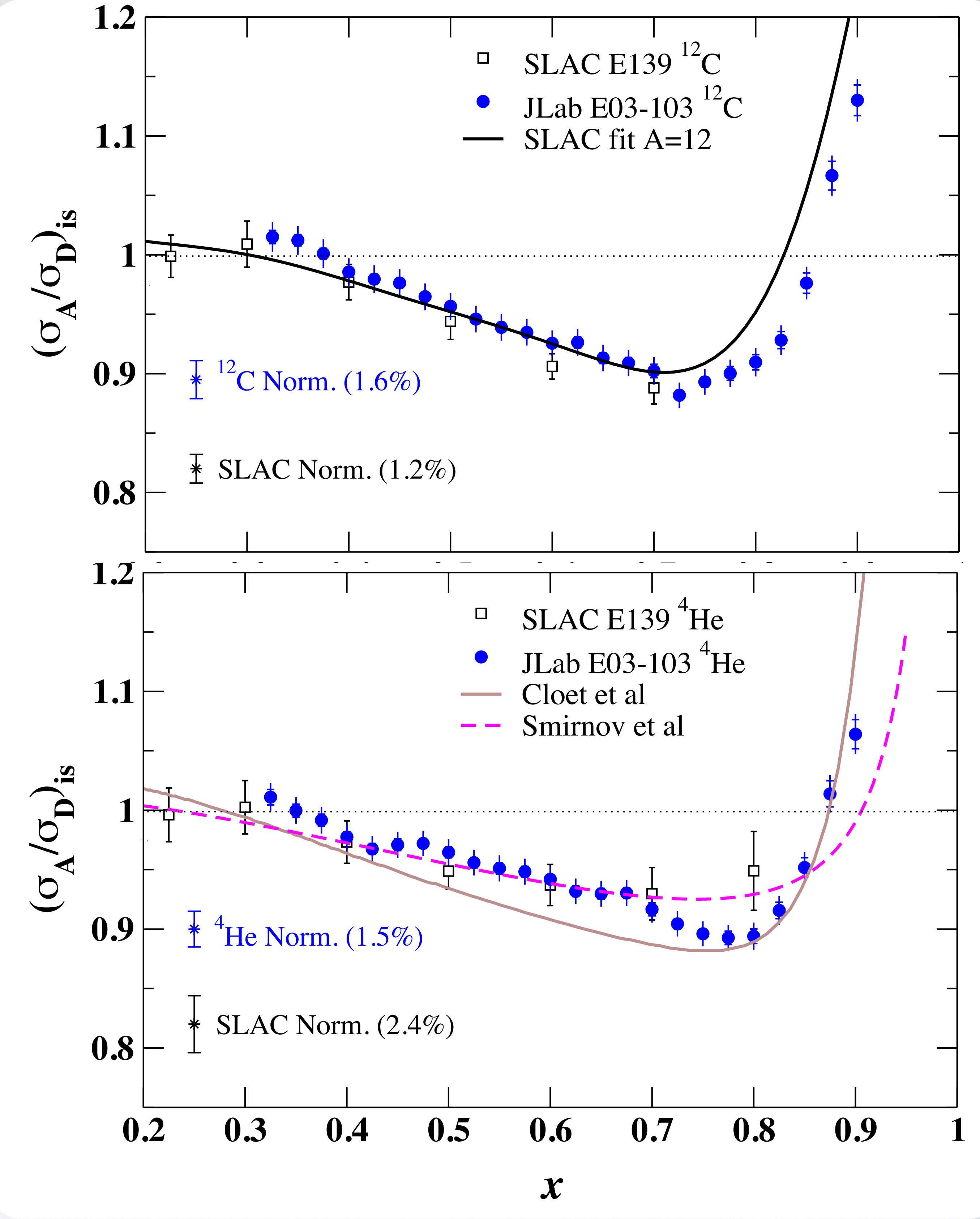
E03-103: ^{12}C AND ^{4}He EMC RATIOS

JLab results consistent with SLAC E139

→ Improved statistics and systematic errors

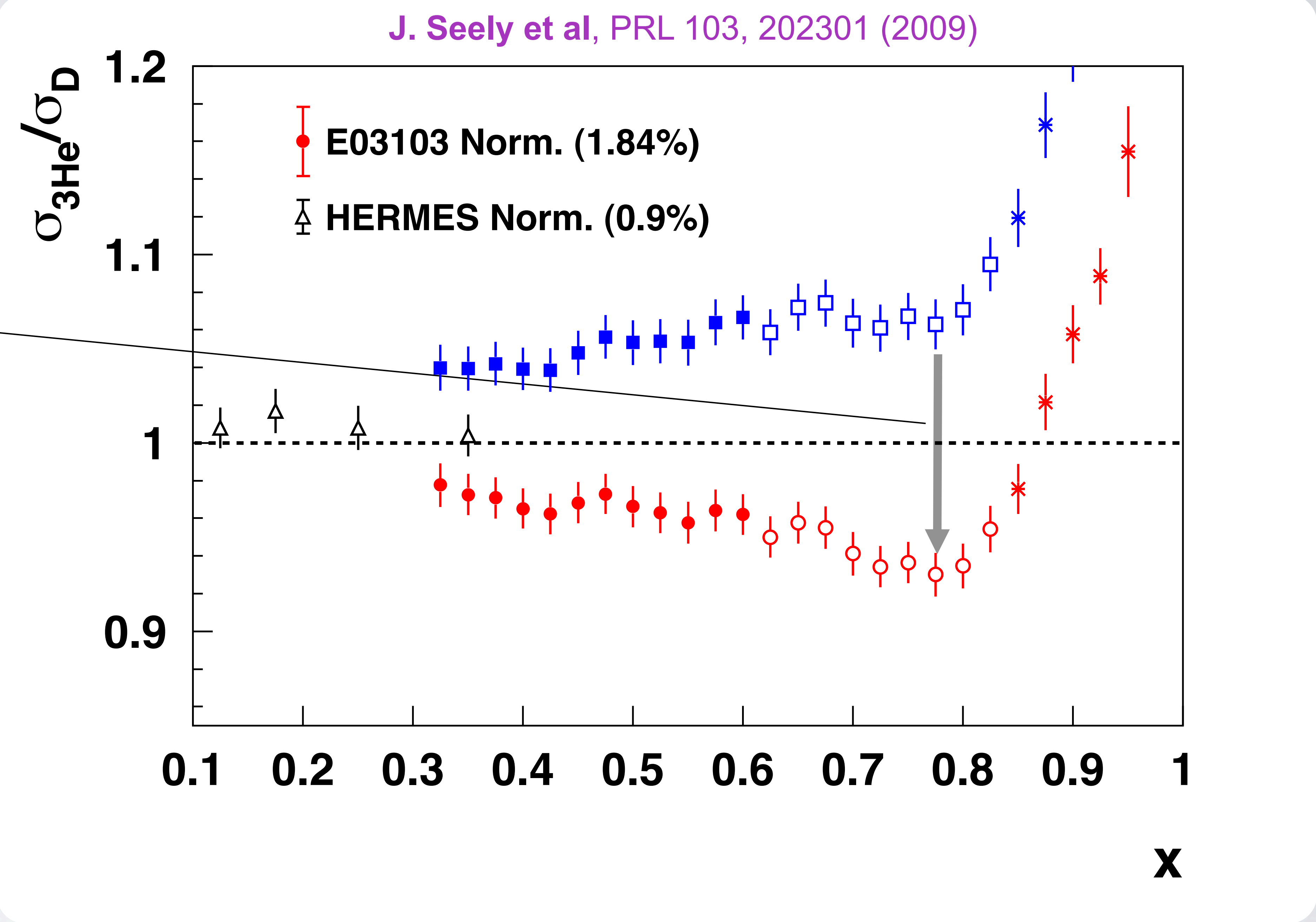
Models shown do a reasonable job describing the data.

But very few real few-body calculations (most neglect structure, scale NM)



E03-103: ^{3}He EMC Ratio

Large proton excess correction



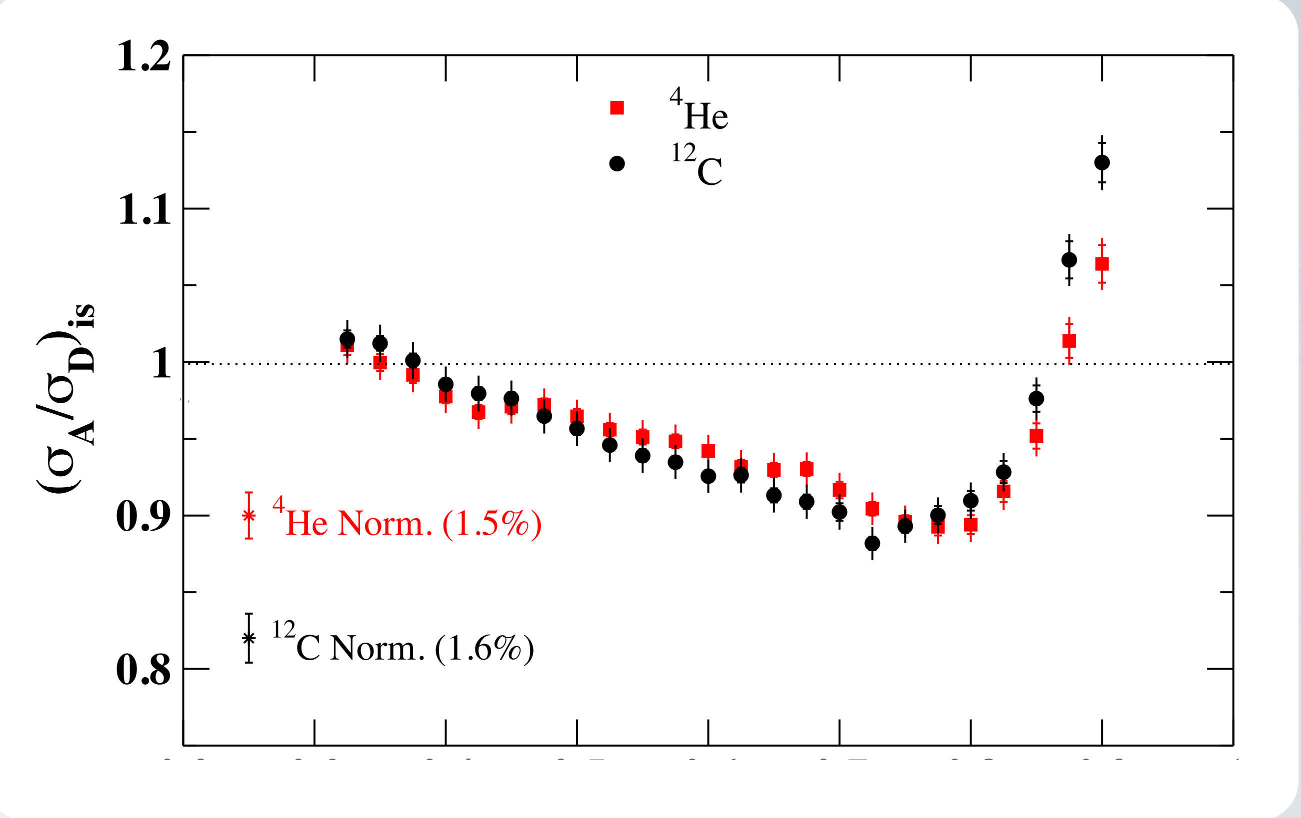
Isoscalar correction done using ratio of bound neutron to bound proton at E03-103 kinematics

A OR ρ-DEPENDENCE ?

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

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

^{4}He suggests ρ–dependent



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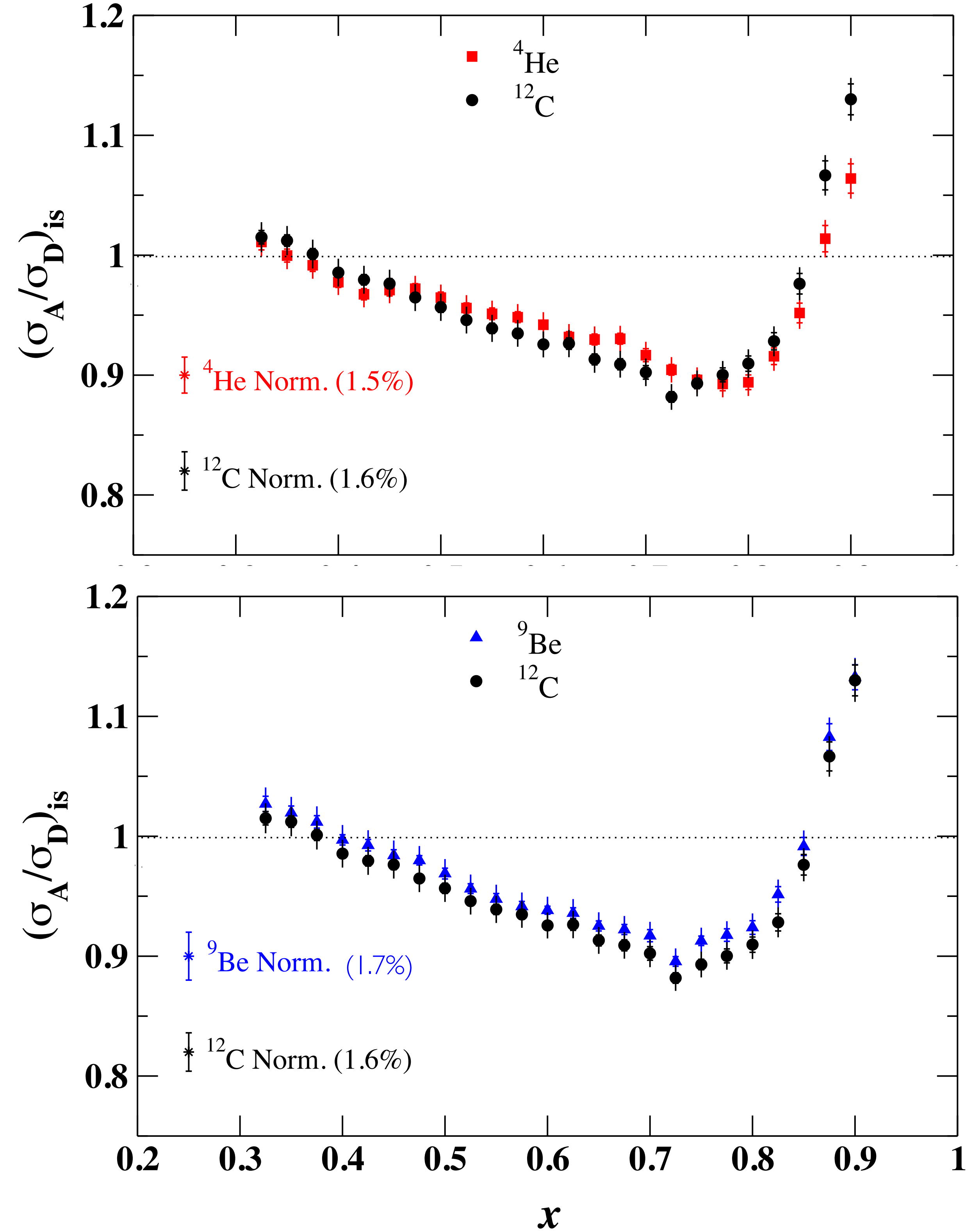
$\rho(^4\mathrm{He}) \sim \rho(^{12}\mathrm{C})$

^{4}He suggests ρ–dependent

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

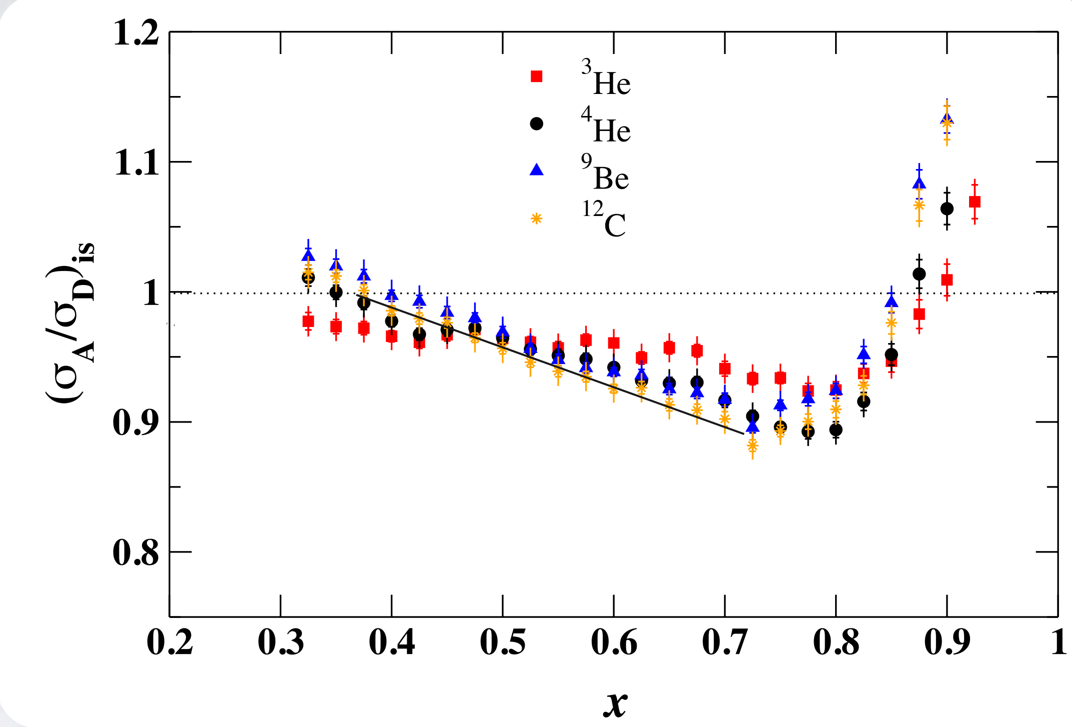
$\rho(^9\mathrm{Be}) << \rho(^{12}\mathrm{C})$

^{9}Be suggests A-dependent



A OR ρ-DEPENDENCE ?

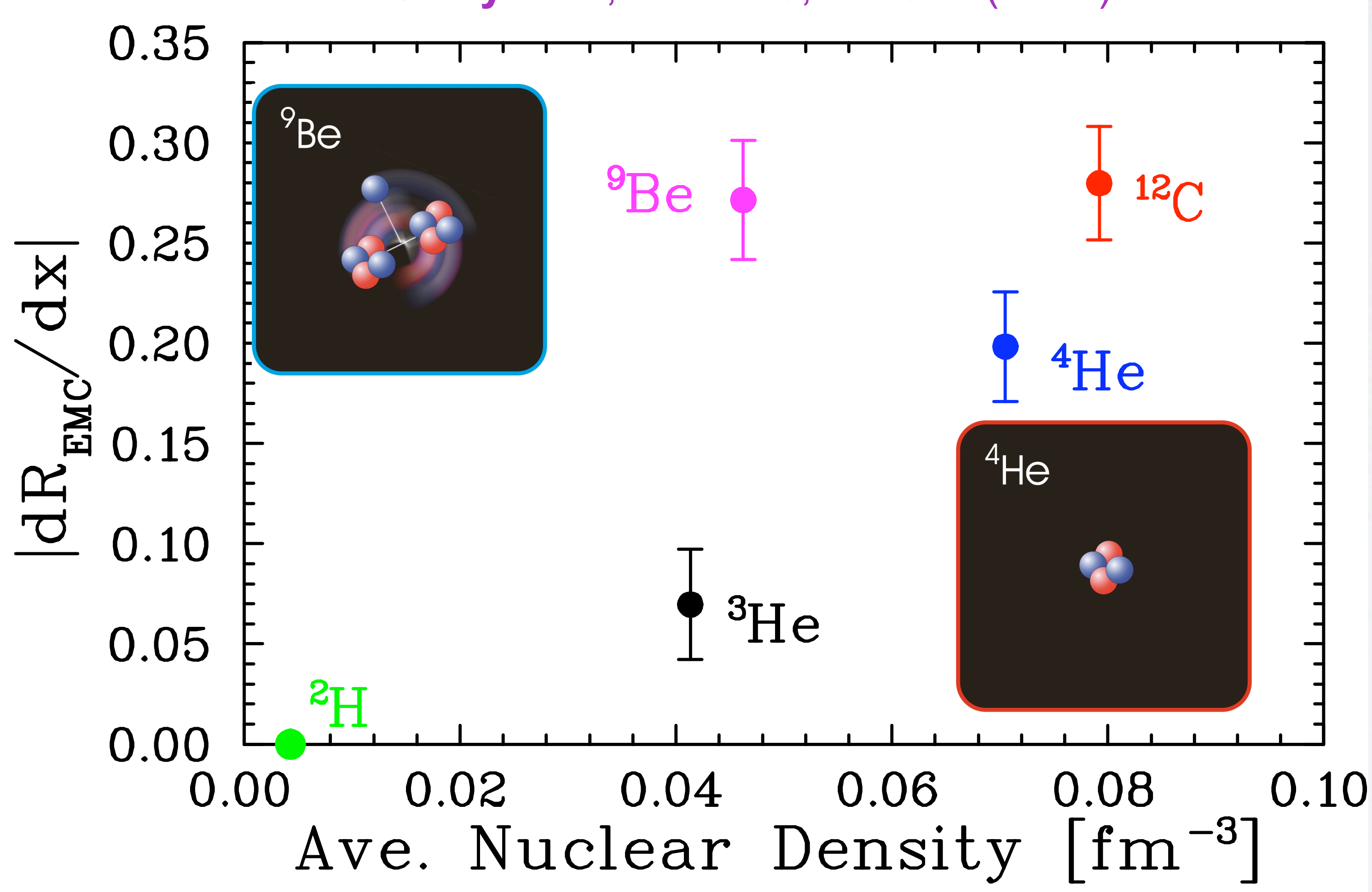
Fit of the EMC ratio for $0.35<x<0.7$ and look at A- and density dependence of the slope



Density determined from ab initio few-body calculation

S.C. Pieper and R.B. Wiringa, Ann. Rev. Nucl. Part. Sci 51, 53 (2001)

J. Seely et al, PRL 103, 202301 (2009)



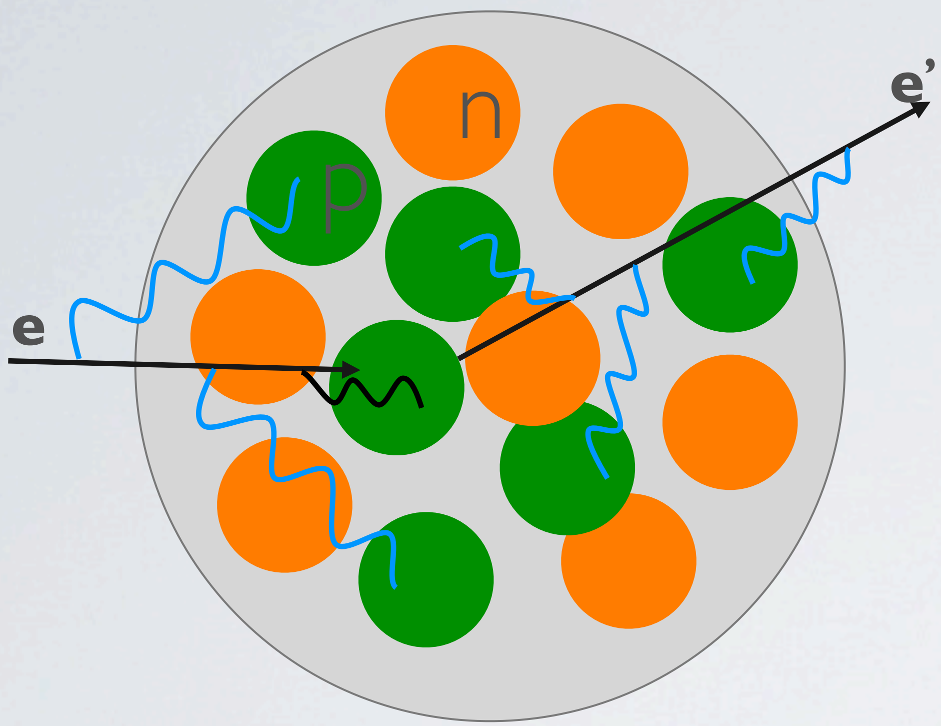
^{9}Be has low average density, but large component of structure is 2α+n most nucleons in tight, α-like configurations

Heavy nuclei

and

EMC effect in nuclear matter

HEAVY NUCLEI AND COULOMB DISTORTION



Exchange of **one or more (soft) photons** with the nucleus, in addition to the **one hard photon** exchanged with a nucleon

Incident (scattered) electrons are accelerated (decelerated) in the Coulomb well of the nucleus.

$$\cancel{\sigma_{tot}^{PWBA} = \sigma_{Mott}\, S_{tot}^{PWBA}(|\vec{q}|, \omega, \theta)}$$

⇨

σ_{tot}^{DWBA}

- Focusing of the electron wave function
- Change of the electron momentum

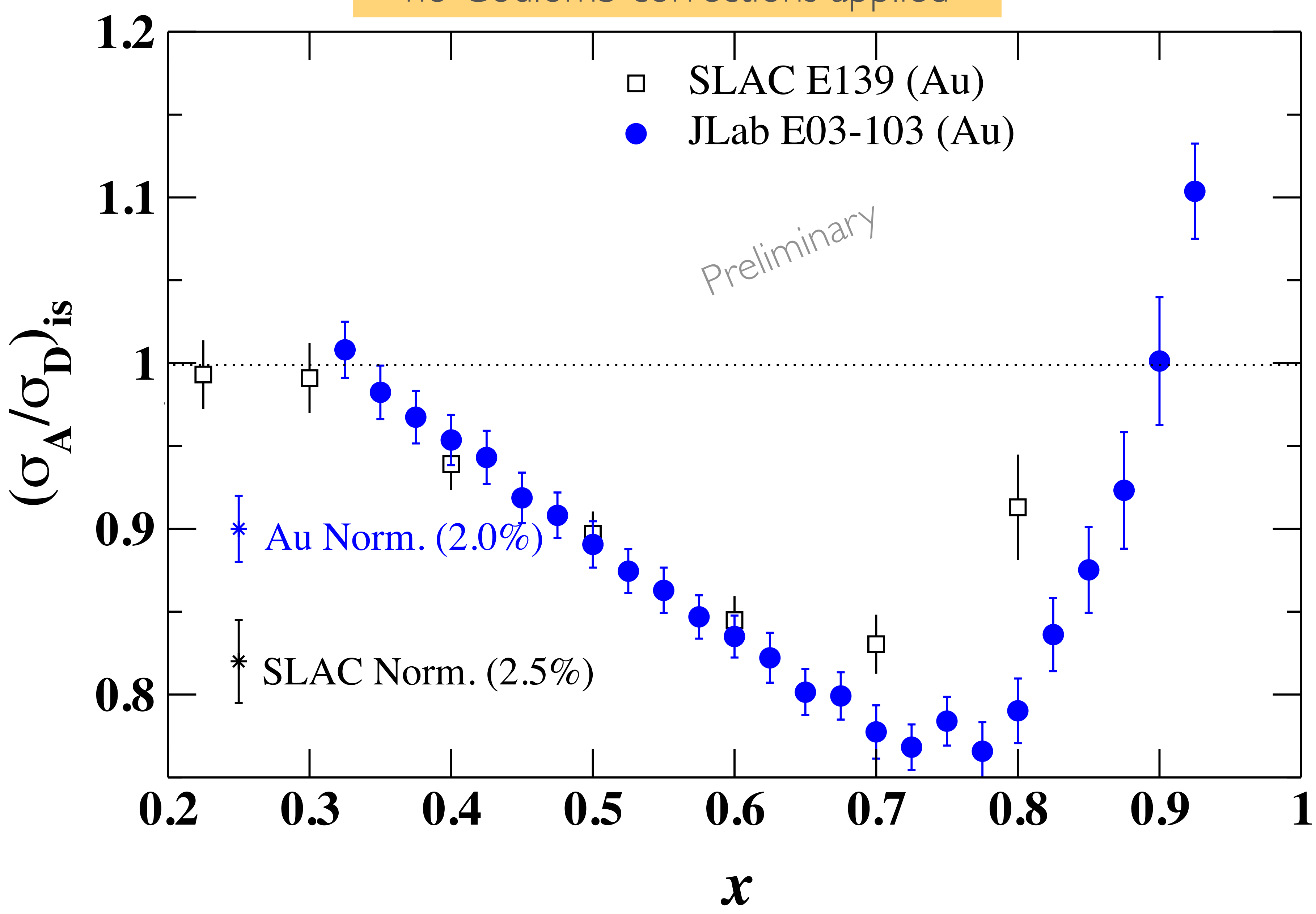
Effective Momentum Approximation (EMA)

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

$$\left.\begin{array}{l} E \rightarrow E + \bar{V} \\ E_p \rightarrow E_p + \bar{V} \end{array}\right\} \quad Q^2_{eff} = 4(E + \bar{V})(E_p + \bar{V})\sin^2(\frac{\theta}{2})$$

COULOMB DISTORTION EFFECT ON E03-103

no Coulomb corrections applied



COULOMB DISTORTION EFFECT ON E03-103

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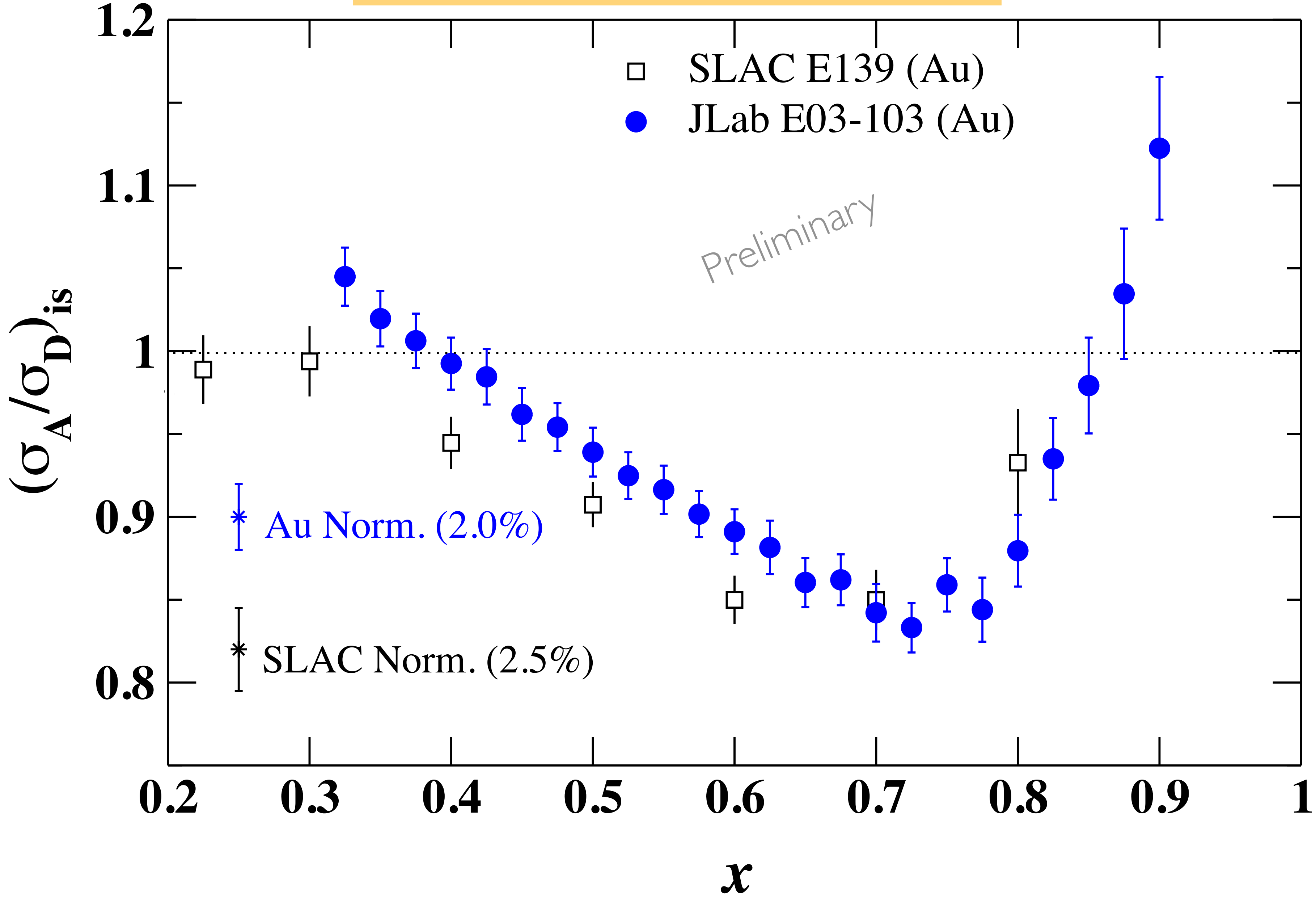
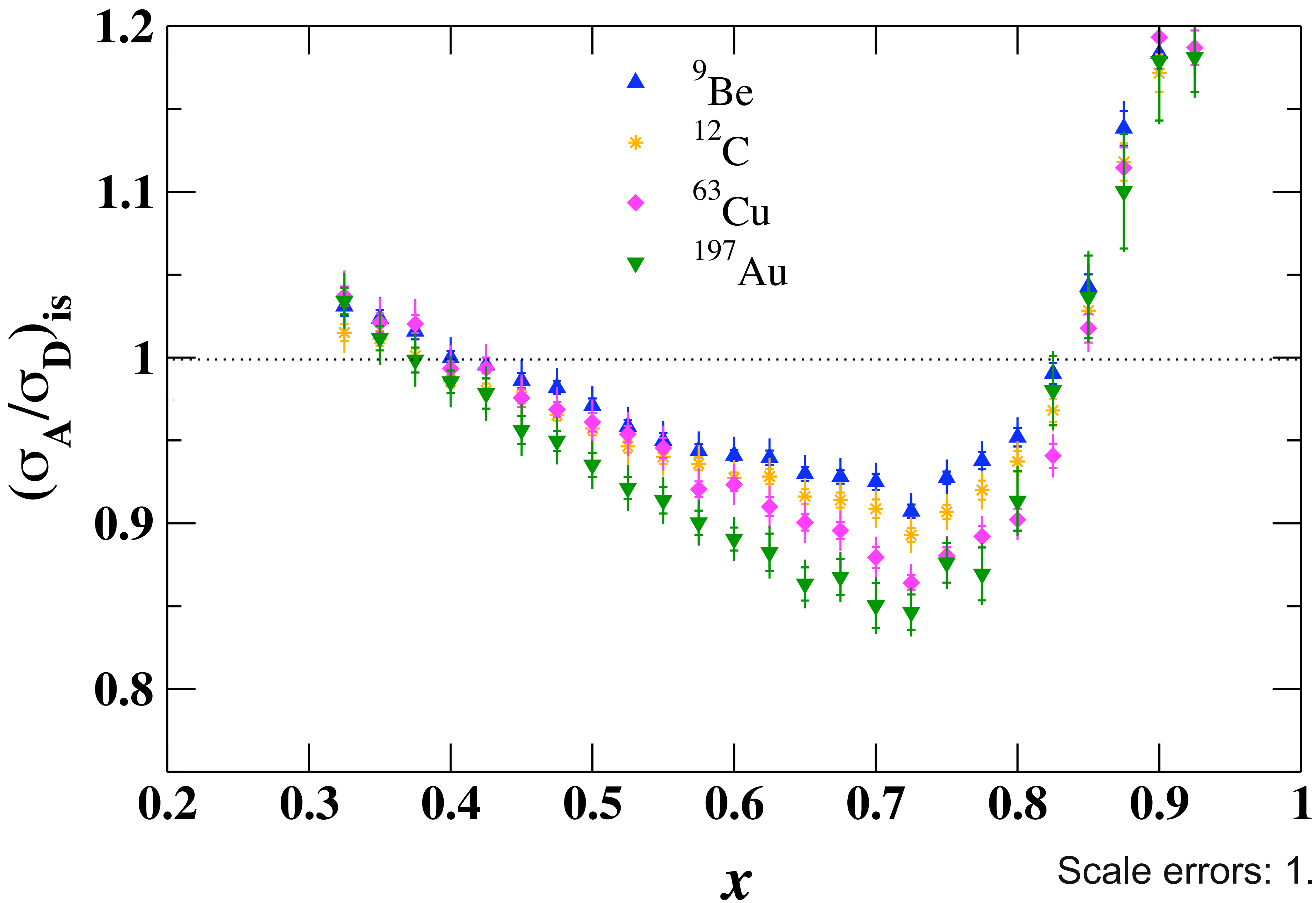


HEAVIER NUCLEI DATA FROM E03-103

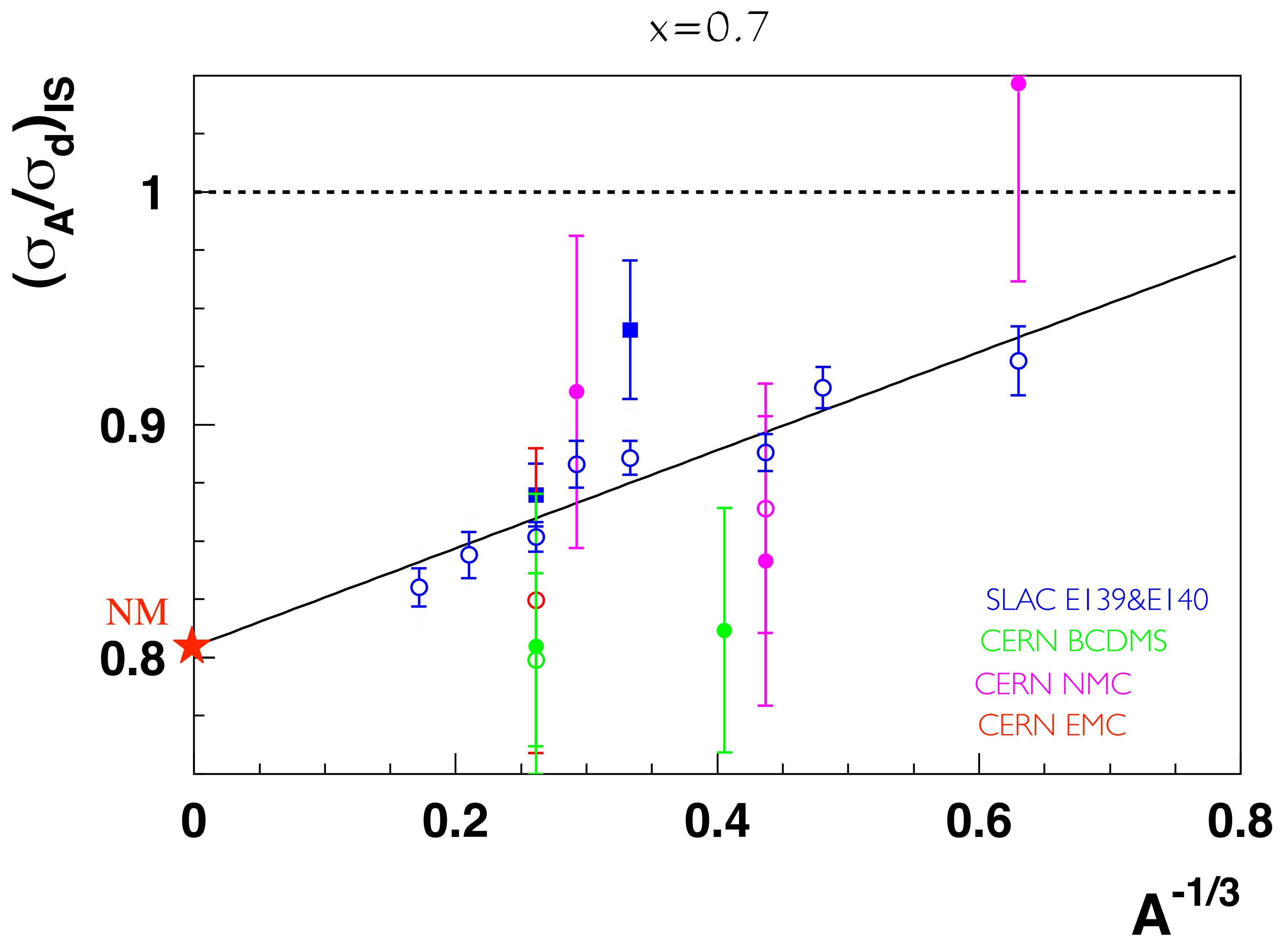


Scale errors: 1.6-2%

EXTRAPOLATION TO NUCLEAR MATTER

Exact calculations of the EMC effect exist:

- for light nuclei
- for nuclear matter



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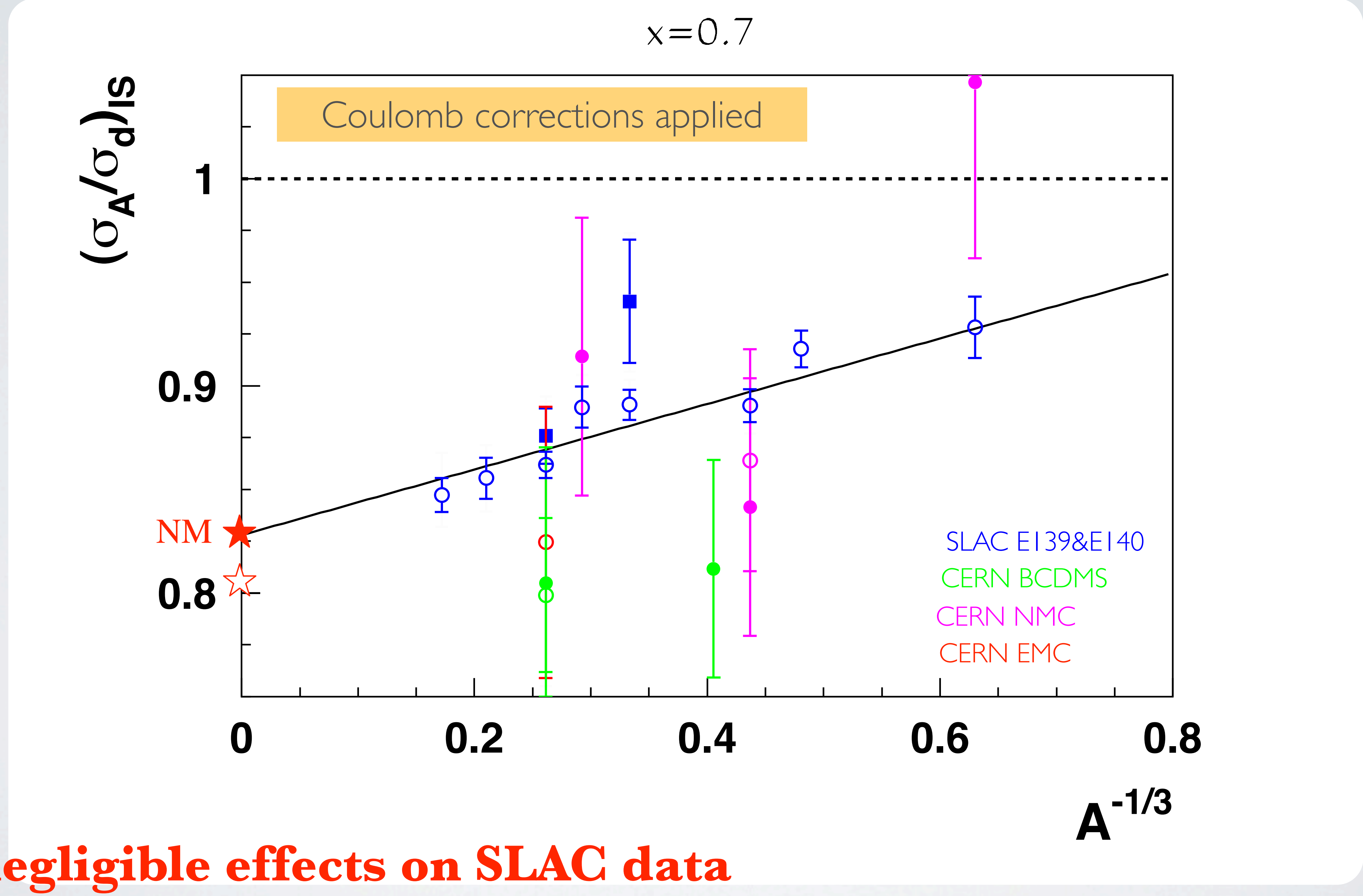

Non-negligible effects on SLAC data

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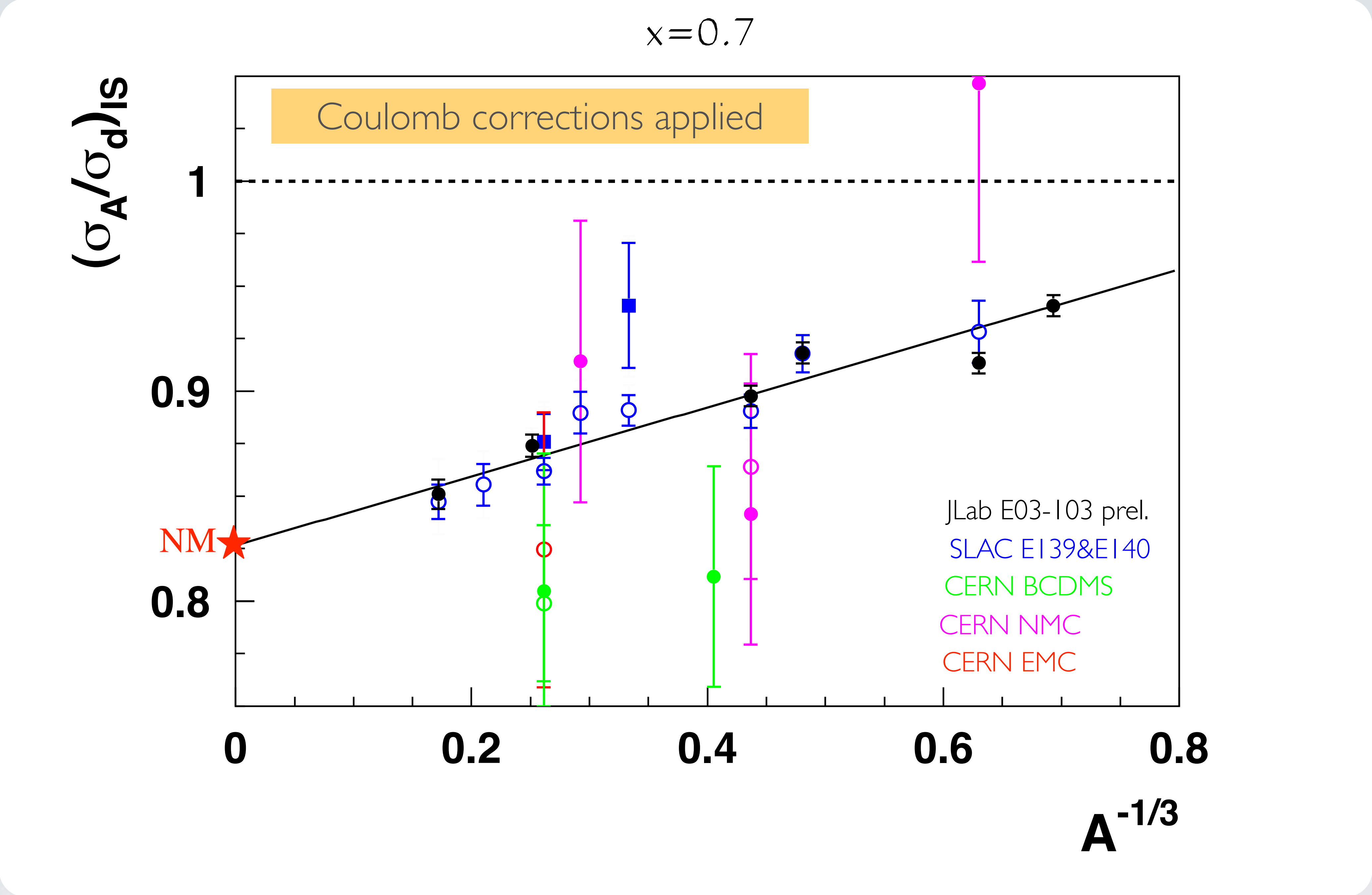
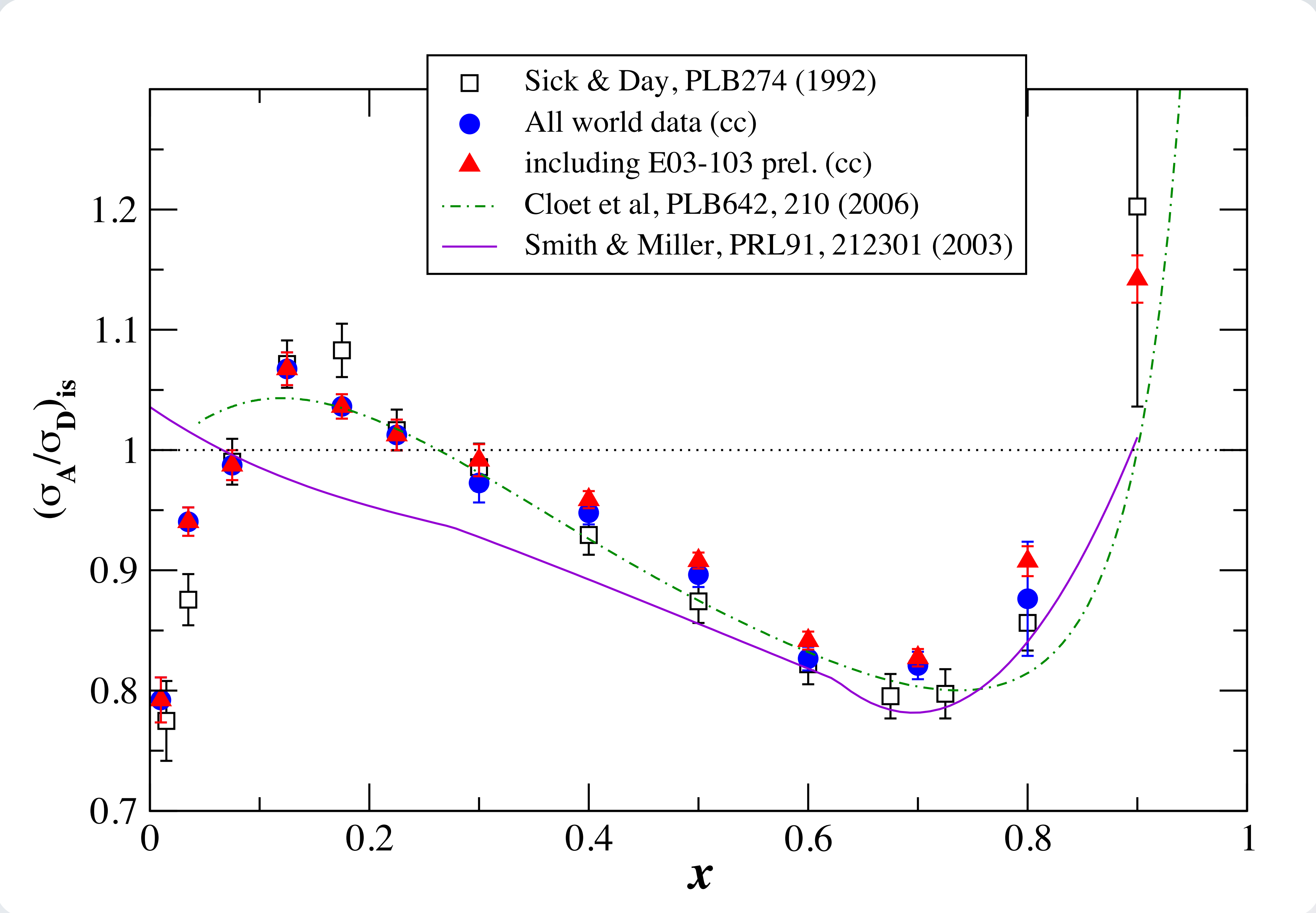


EXTRAPOLATION TO NUCLEAR MATTER

EMC effect in nuclear matter



Nuclear dependence of R

$R(X,Q^2)$

$$\frac{d\sigma}{d\Omega dE'} = \Gamma\left[\sigma_T(x,Q^2) + \varepsilon\sigma_L(x,Q^2)\right]$$

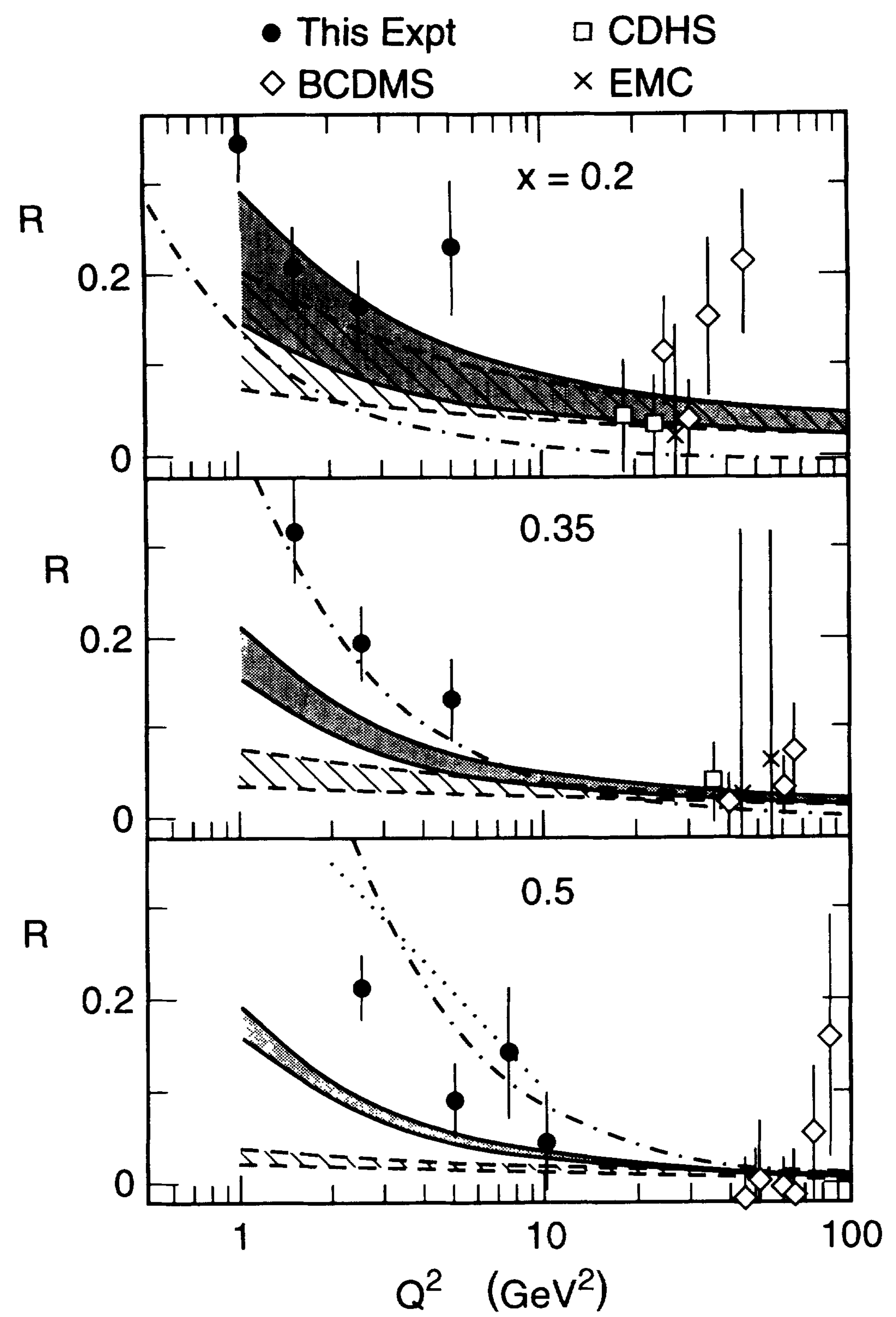
$$\boxed{R(x,Q^2) = \frac{\sigma_L(x,Q^2)}{\sigma_T(x,Q^2)}}$$

In a model with:

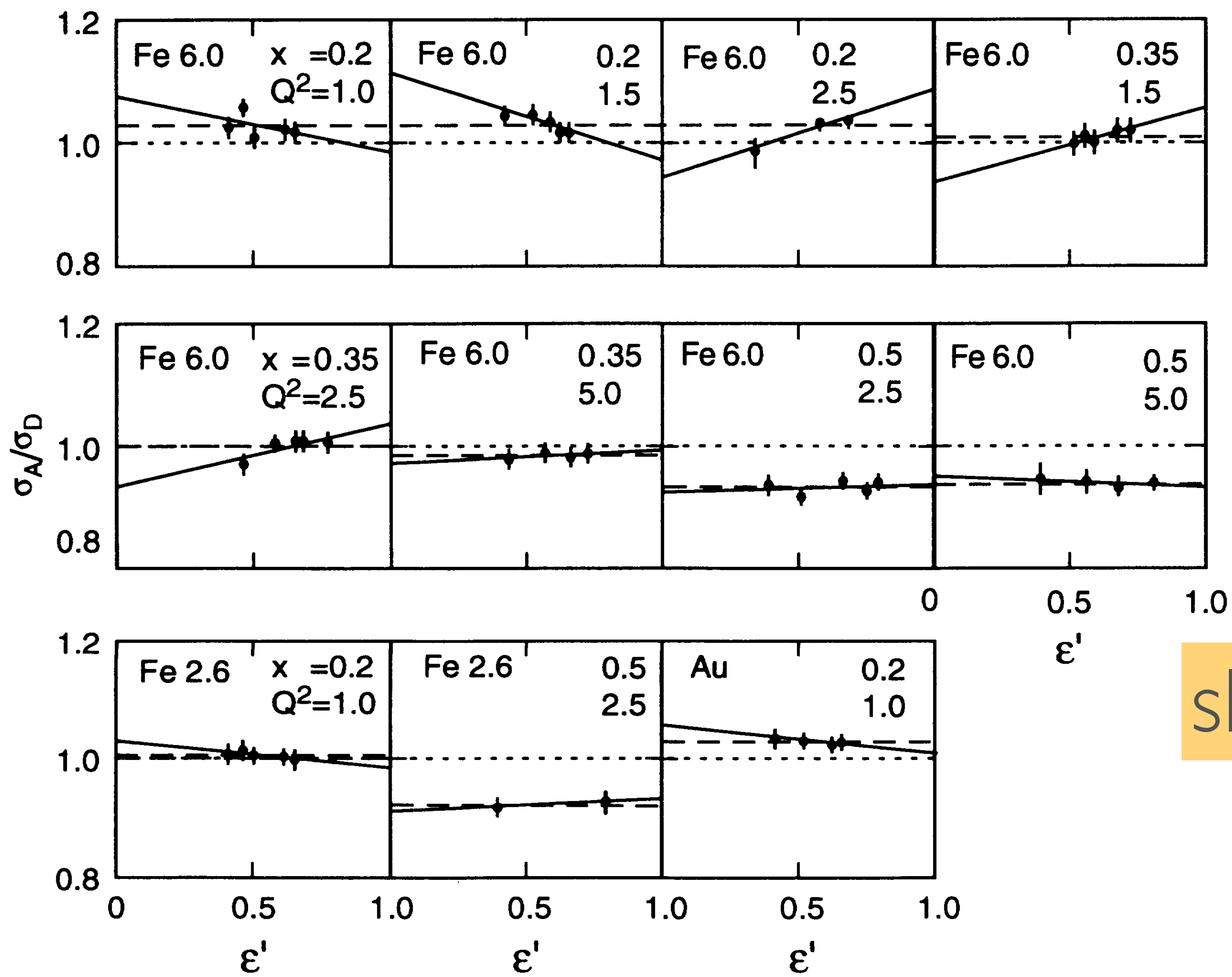
a) spin-1/2 partons: R should be small and decreasing rapidly with Q^2

b) spin-0 partons: R should be large and increasing with Q^2

Dasu et al., PRD49, 5641(1994)



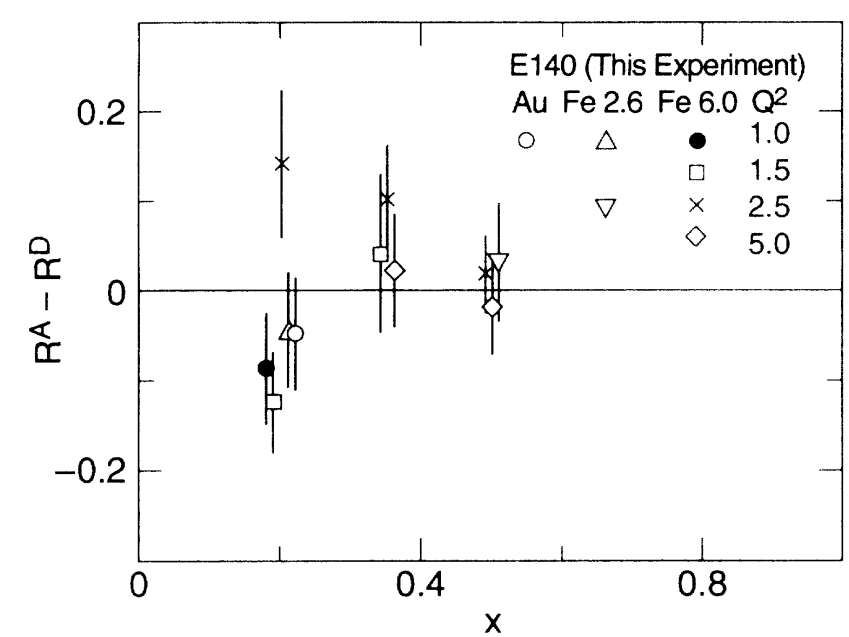
ACCESS TO NUCLEAR DEPENDENCE OF R



Dasu et al., PRD49, 5641(1994)

FIG. 13. The fits to the differential cross section ratio σ_A/σ_D versus $\epsilon' = \epsilon/(1 + R^D)$ are shown for each (x, Q^2) point. The errors on the cross section include statistical and point-to-point systematic contributions added in quadrature.

slopes $\Rightarrow$ R_A-R_D



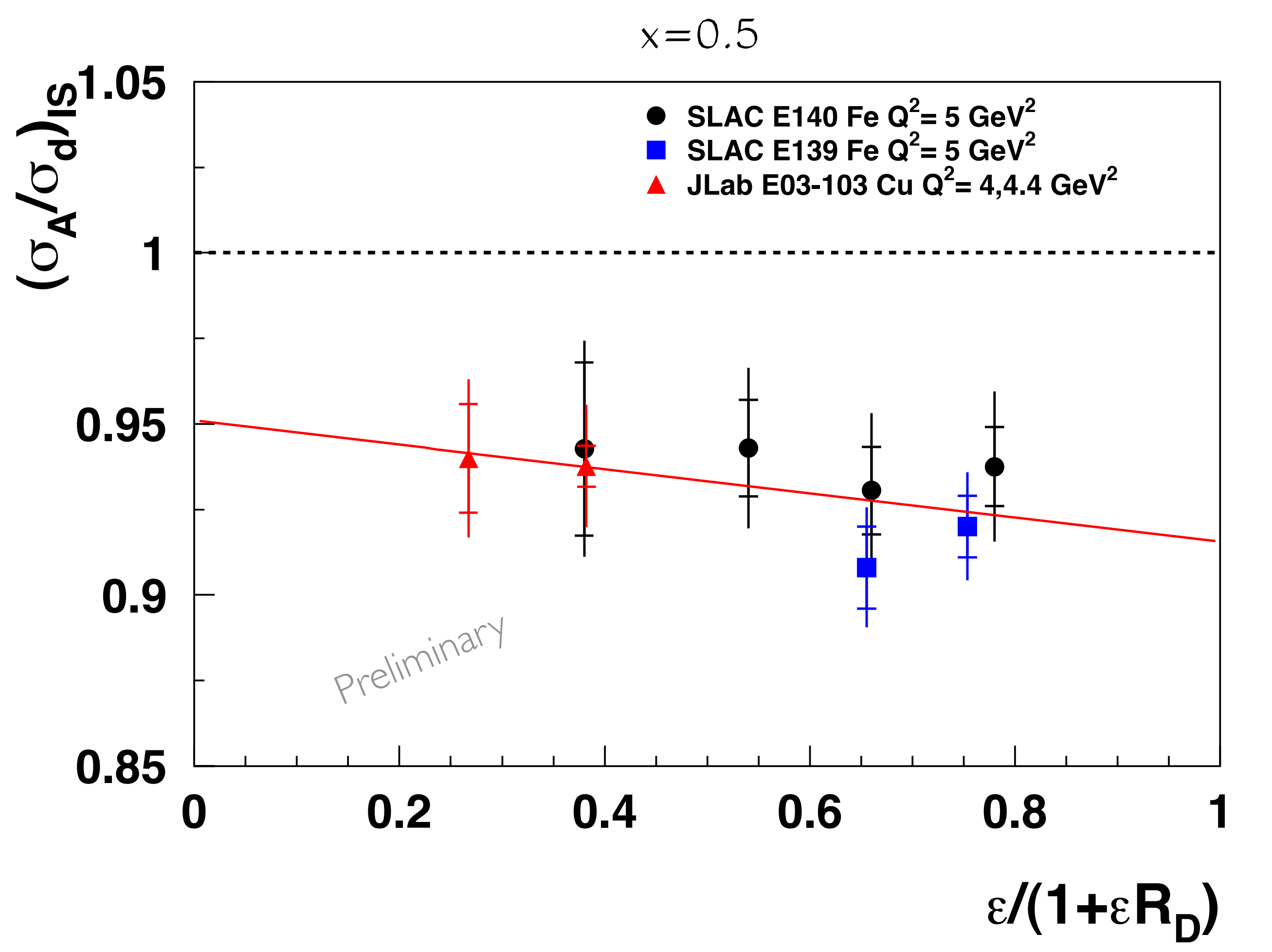
Nuclear higher twist effects and spin-0 constituents in nuclei: same as in free nucleons

$\Leftarrow$ R_A-R_D=0

ACCESS TO NUCLEAR DEPENDENCE OF R

Iron-Copper

No Coulomb corrections applied



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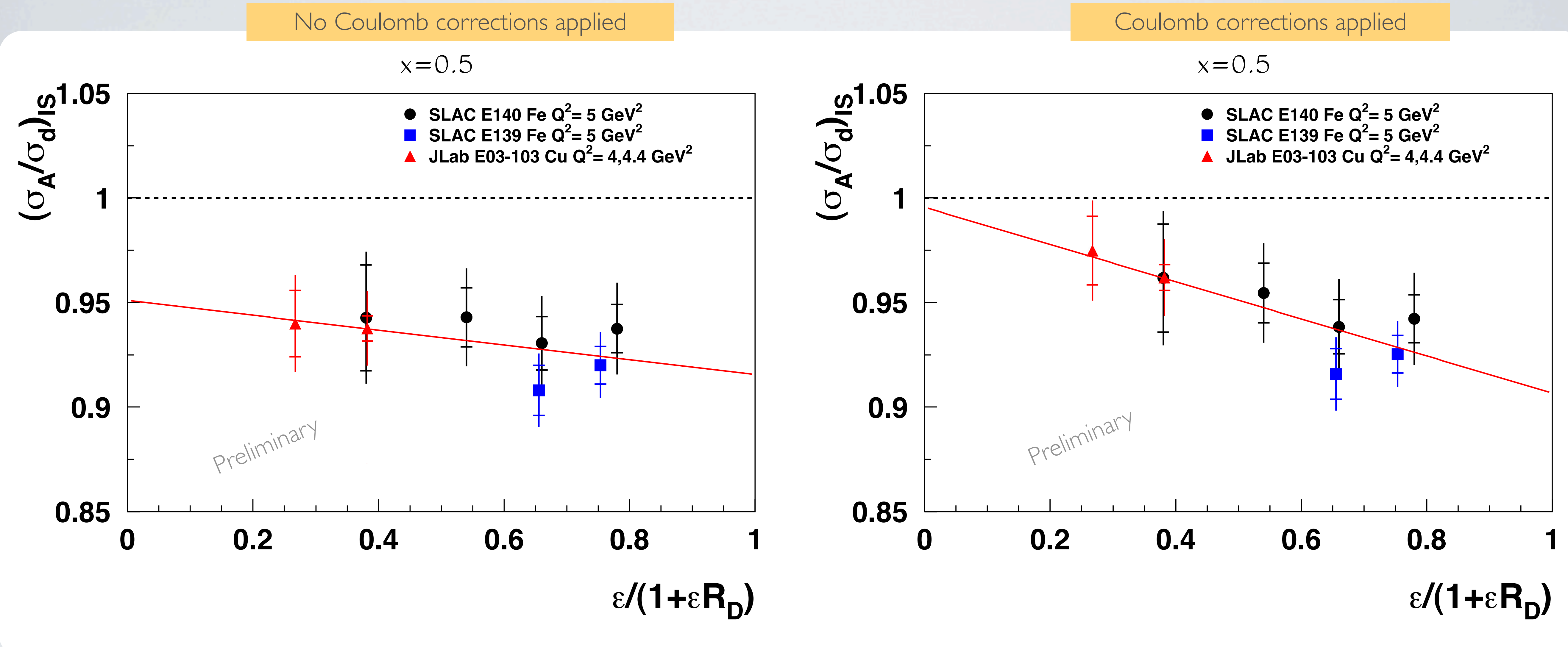


New data from JLab E03-103: access to lower ε

After coulomb corrections: $R_A - R_D = -0.08 \pm 0.04$

EXTRACTION OF R_{NM}

✓ Need several ε values with enough nuclei coverage

✓ Remove ^{3}He data from the extrapolation

At constant Q^2 and x:

➡ at each ε, fit the cross section ratios σ_A/σ_D vs. $A^{-1/3}$ or ϱ

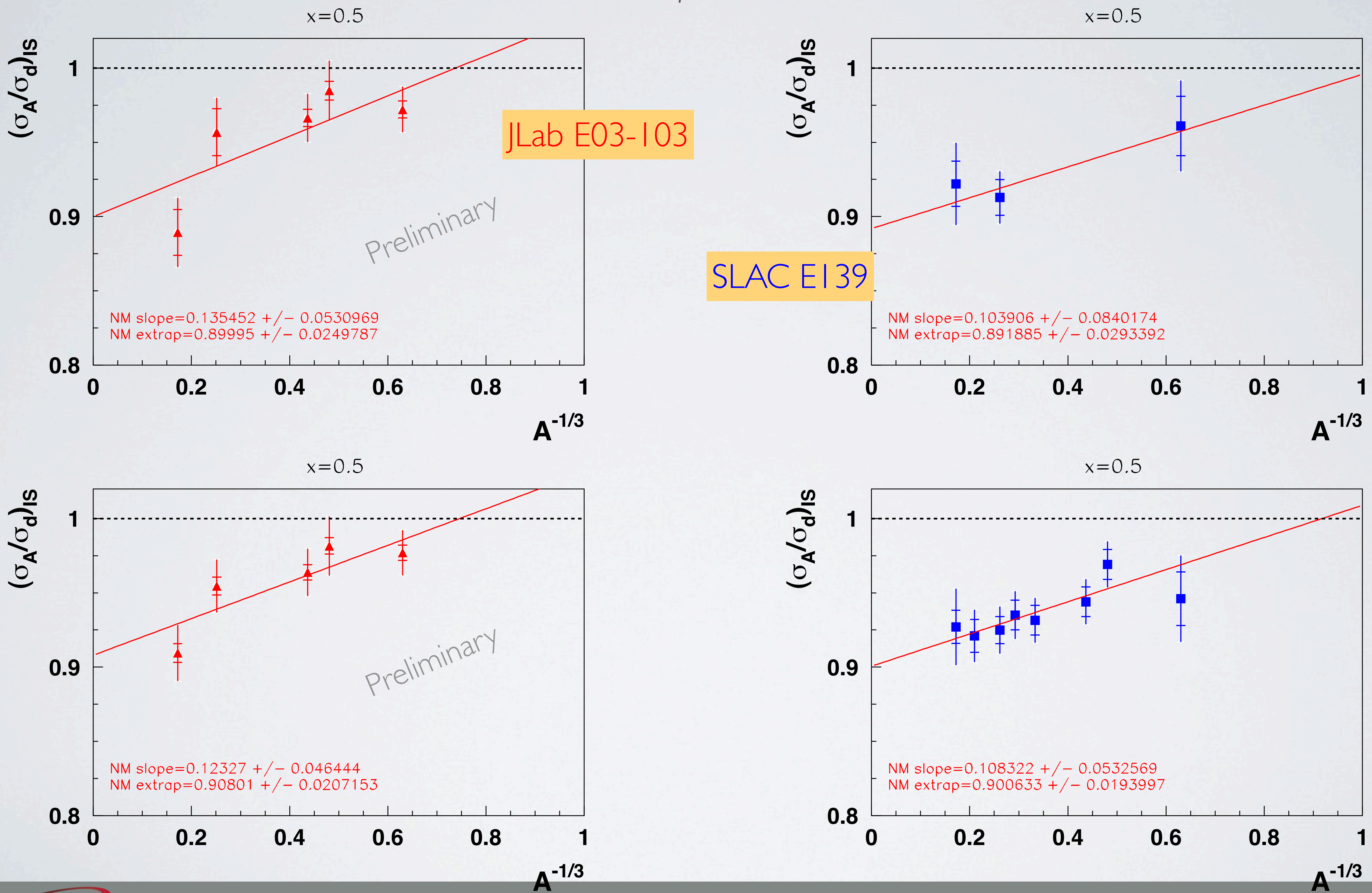
➡ extrapolate the fit to infinite nuclear matter: $A^{-1/3} \rightarrow 0$ or $\varrho \rightarrow 0.17$. Get σ_{NM}/σ_D for each ε.

➡ plot nuclear matter cross section ratios vs. $\varepsilon/(1+\varepsilon R_D)$

➡ slope of the fit gives $R_{NM}-R_D$

RNM: X=0.5, NO COULOMB CORRECTION

A-dependence



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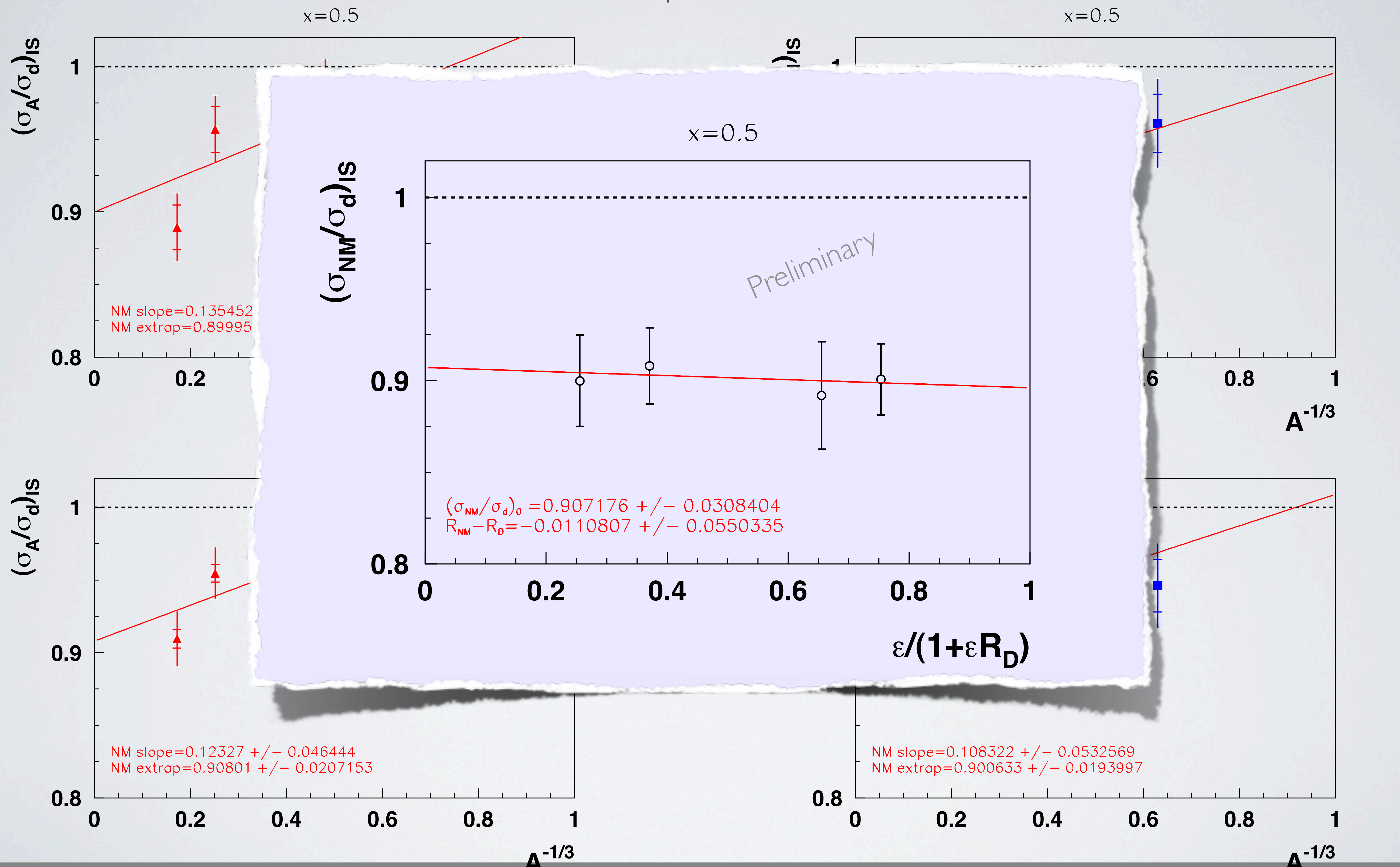

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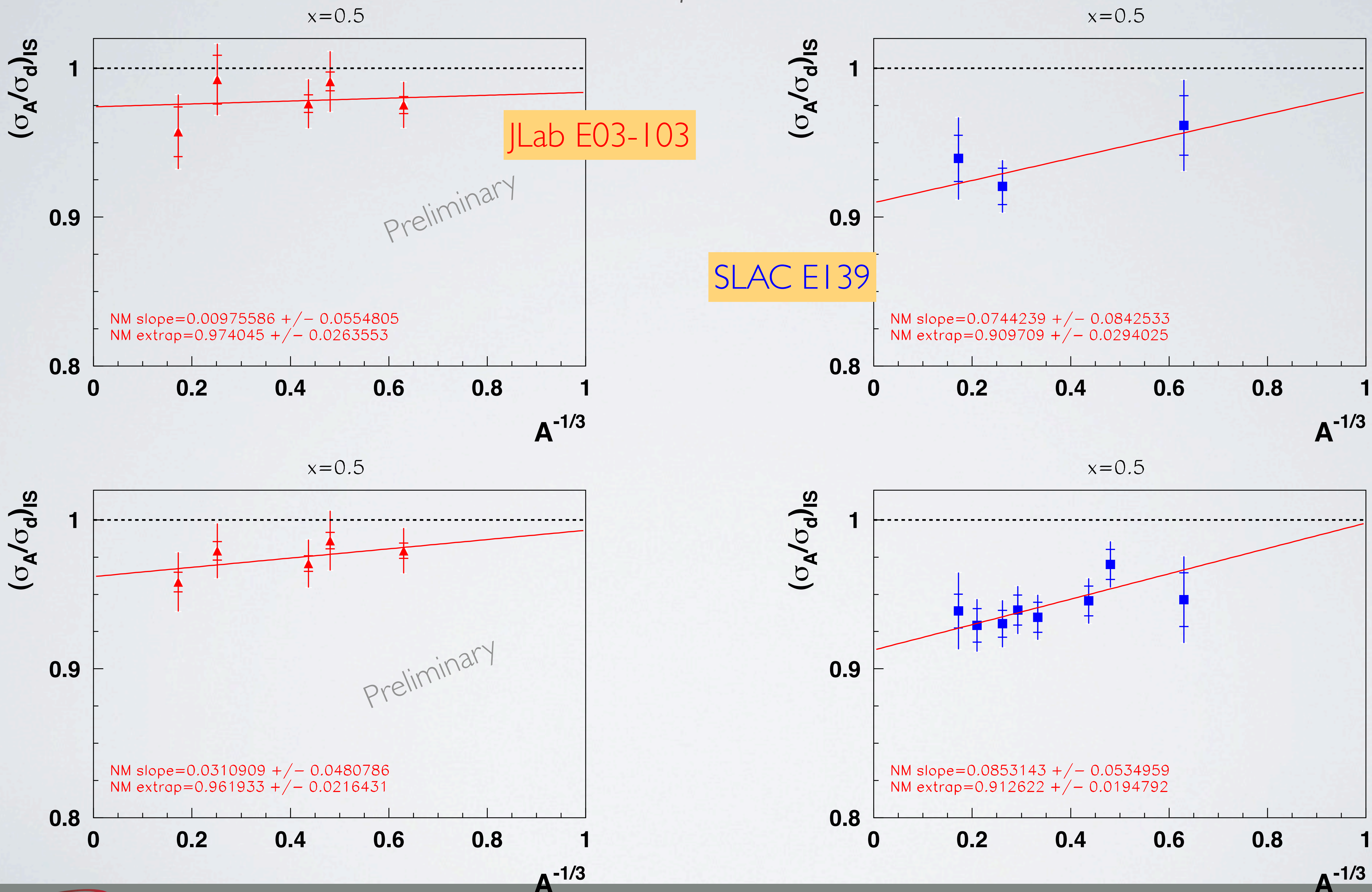

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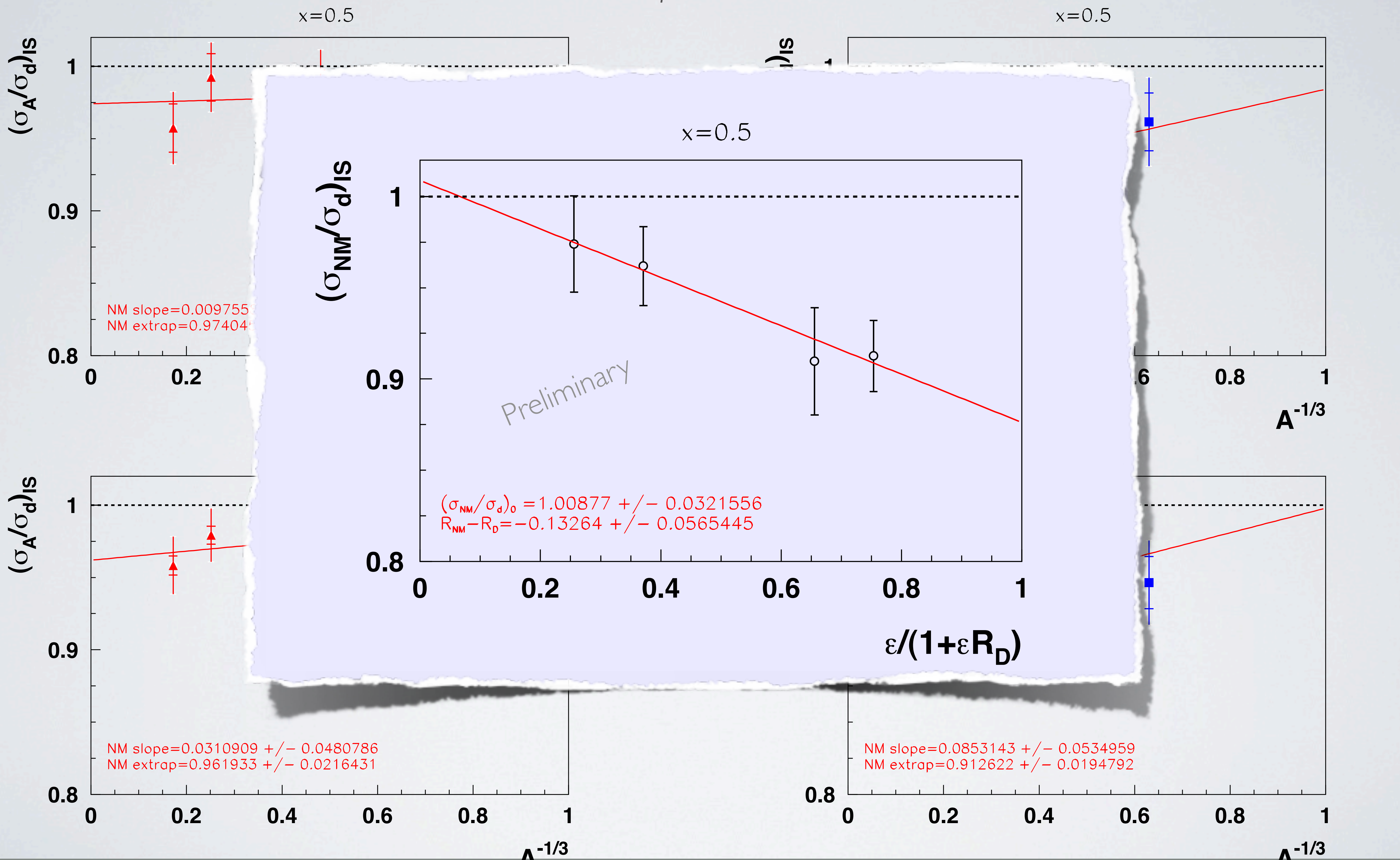
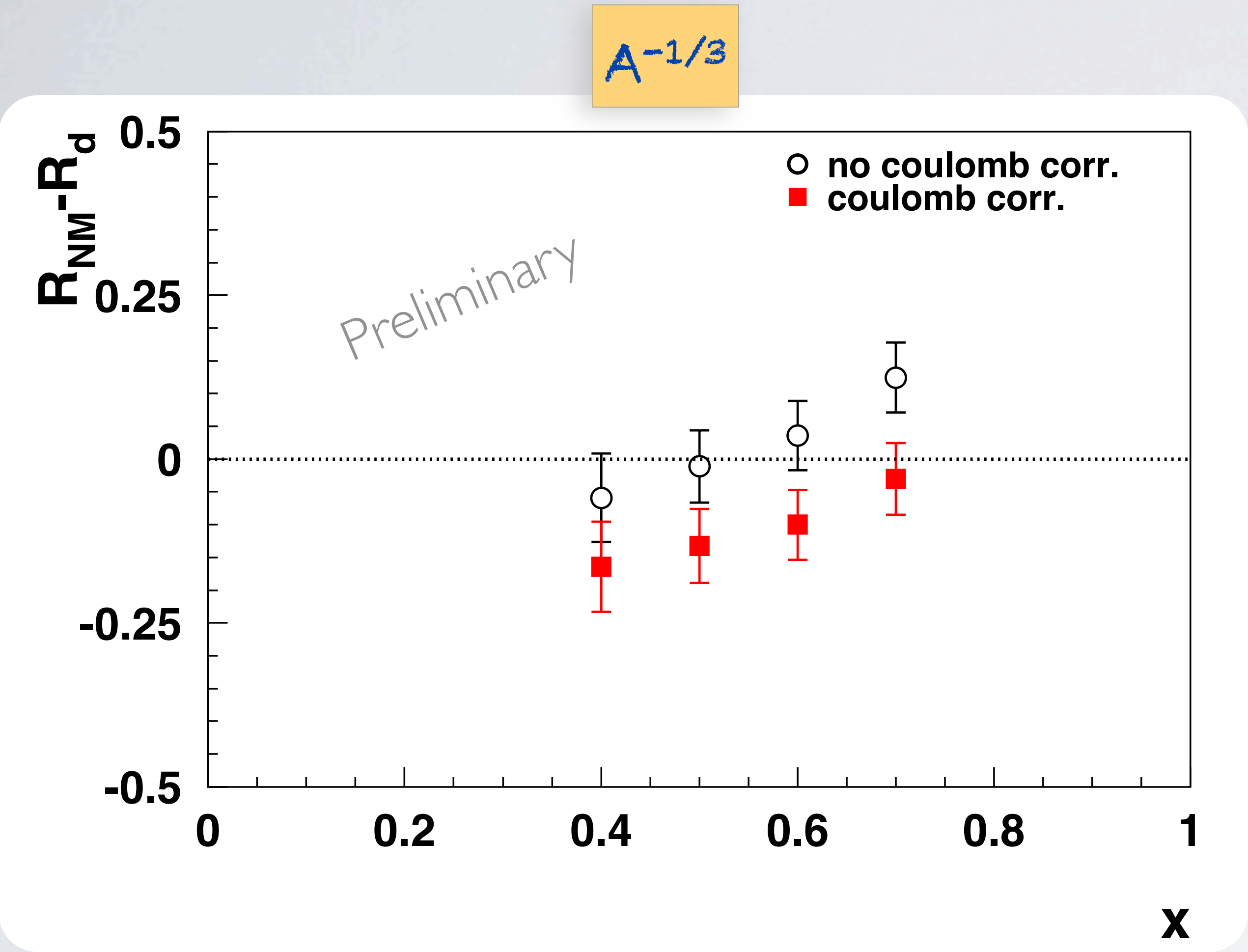
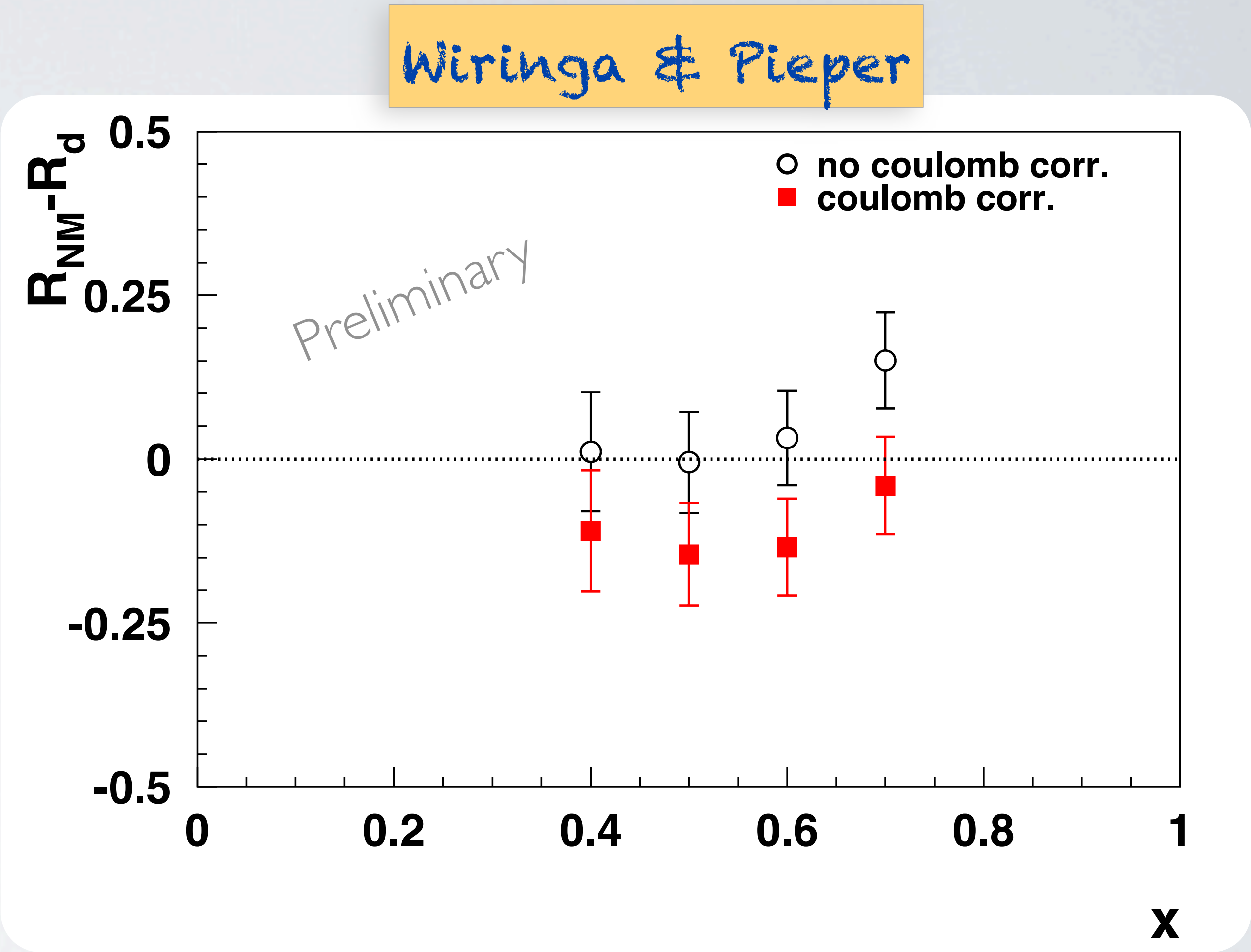


X-DEPENDENCE OF R_{NM}-R_D





After Coulomb correction, indication of a small but non-negligible nuclear dependent of R and $R_{NM} < R_D$

X-DEPENDENCE OF σ_{NM}/σ_D AT $\varepsilon'=0$

$$\frac{d\sigma}{d\Omega dE'} = \Gamma\left[\sigma_T(x,Q^2) + \cancel{\varepsilon\sigma_L(x,Q^2)}\right]$$

at ε'=0= ε

$$\frac{\sigma_{(NM)}}{\sigma_{(D)}} \xrightarrow{\varepsilon\to 0} \frac{\sigma_{T\,(NM)}}{\sigma_{T\,(D)}}$$

and

$$F_1(x, Q^2) = \frac{K}{4\pi^2\alpha} M\sigma_T(x, Q^2)$$

$$\boxed{\frac{\sigma_{(NM)}}{\sigma_{(D)}} \xrightarrow{\varepsilon\to 0} \frac{F_{1\,(NM)}}{F_{1\,(D)}}}$$

$$2xF_1(x) = x\sum_q e_q^2(q(x) + \bar{q}(x))$$

X-DEPENDENCE OF σ_{NM}/σ_D AT $\varepsilon'=0$

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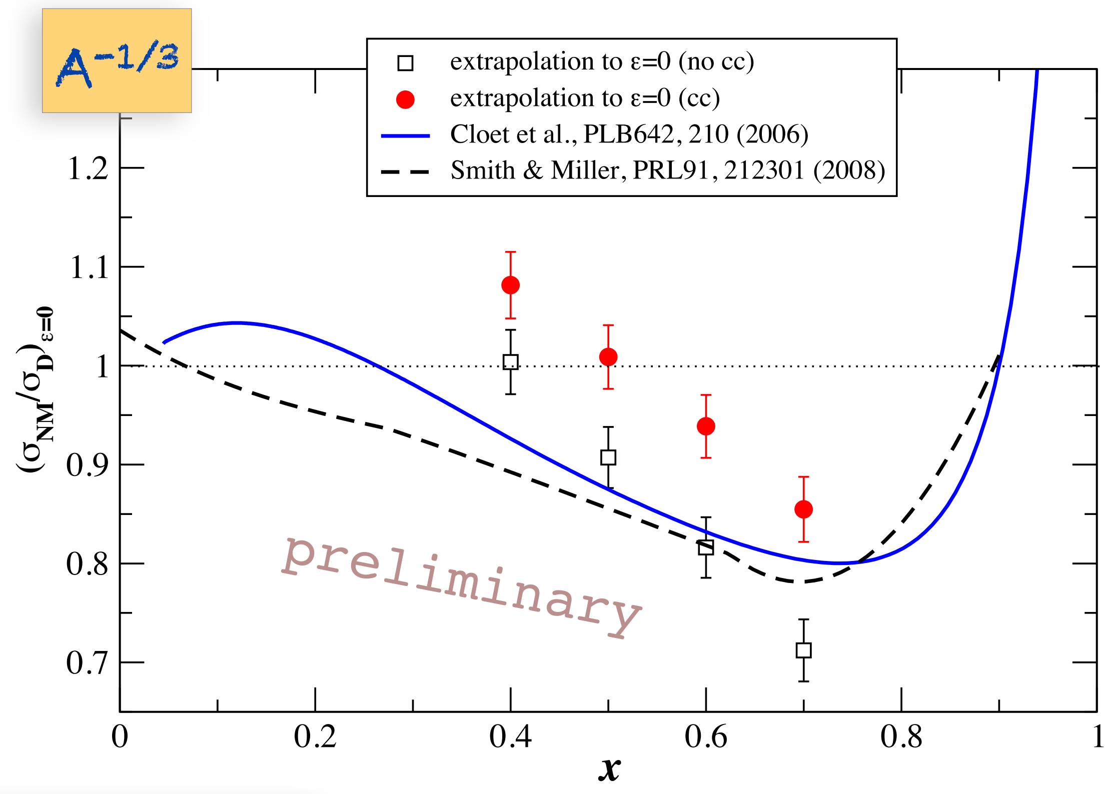
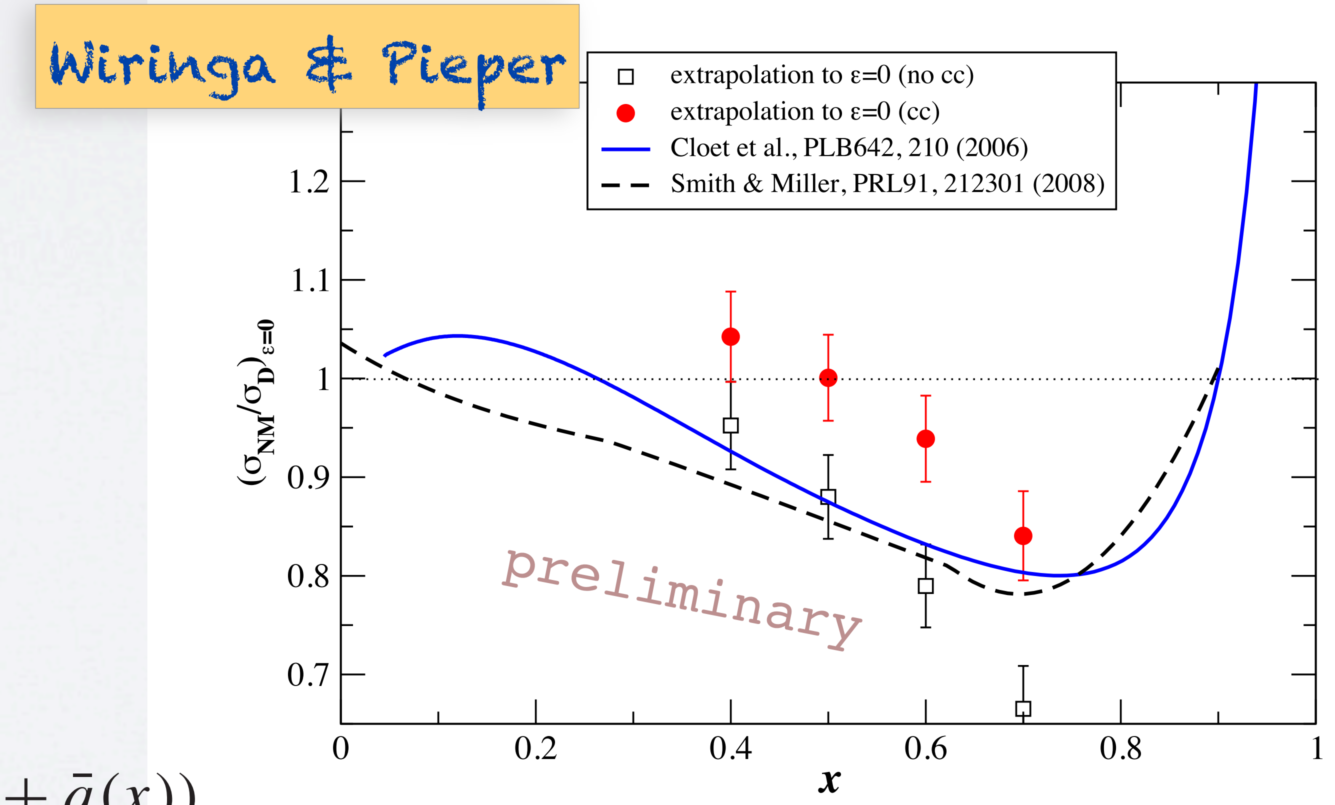




SUMMARY

JLab experiment E03-103 brings a wealth of new results:

- Light nuclei:
  - *contain key information on the EMC effect*
  - *hint of local density dependence of the EMC effect*
  - *can be compared to realistic calculations*
- Heavy nuclei, low ε data and Coulomb distortion:
  - *affects the extrapolation to nuclear matter which is key for comparison with theoretical calculations*
  - *has a real impact on the A-dependence of R: clear ε-dependence*
  - *Some of these conclusions depends mostly on the re-analysis of the SLAC data including Coulomb corrections.*
  - *No solid Coulomb correction prescription exists in DIS*

Inclusive future JLab 12GeV experiment:

- E12-06-118: $^{3}He/^{3}H$: key measurement to understand nuclear medium effect
- E12-10-008: detailed study of the nuclear structure effect with H, ^{2}H, ^{3}He, ^{4}He, ^{6}Li, ^{7}Li, ^{9}Be, ^{10}B, ^{11}B, ^{12}C

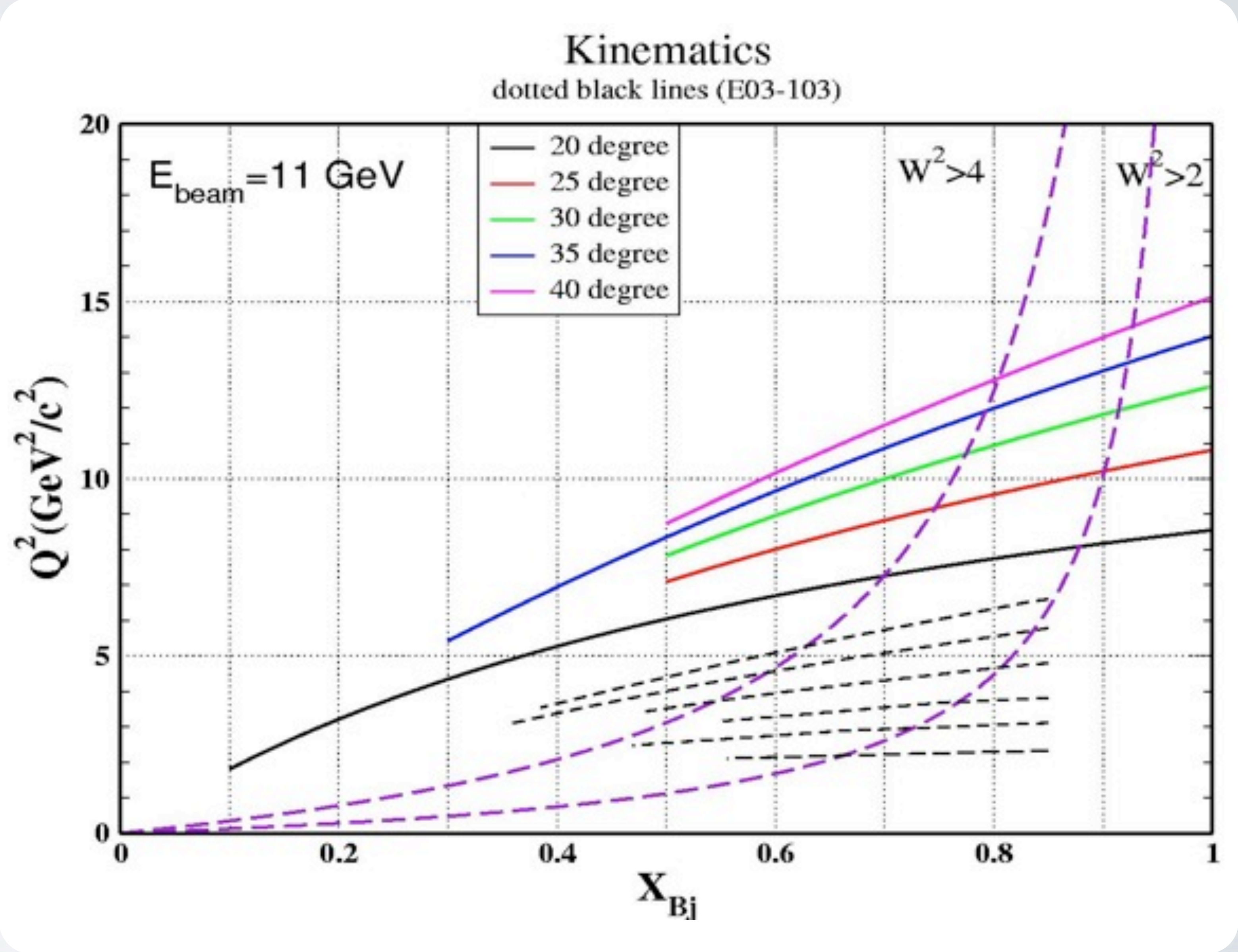
Future Measurements at 12GeV

E12-10-008: DETAILED STUDIES OF THE NUCLEAR DEPENDENCE OF F_2 IN LIGHT NUCLEI

- ✓ Higher Q^2, expanded range in x (both low and high x)
  DIS extends to x=0.8, $W^2>2$ extends to x=0.92

- ✓ More complete set of light nuclei
  Test models of A-dependence:
  H, ^{2}H, ^{3}He, ^{4}He, ^{6}Li, ^{7}Li, ^{9}Be, ^{10}B, ^{11}B, ^{12}C

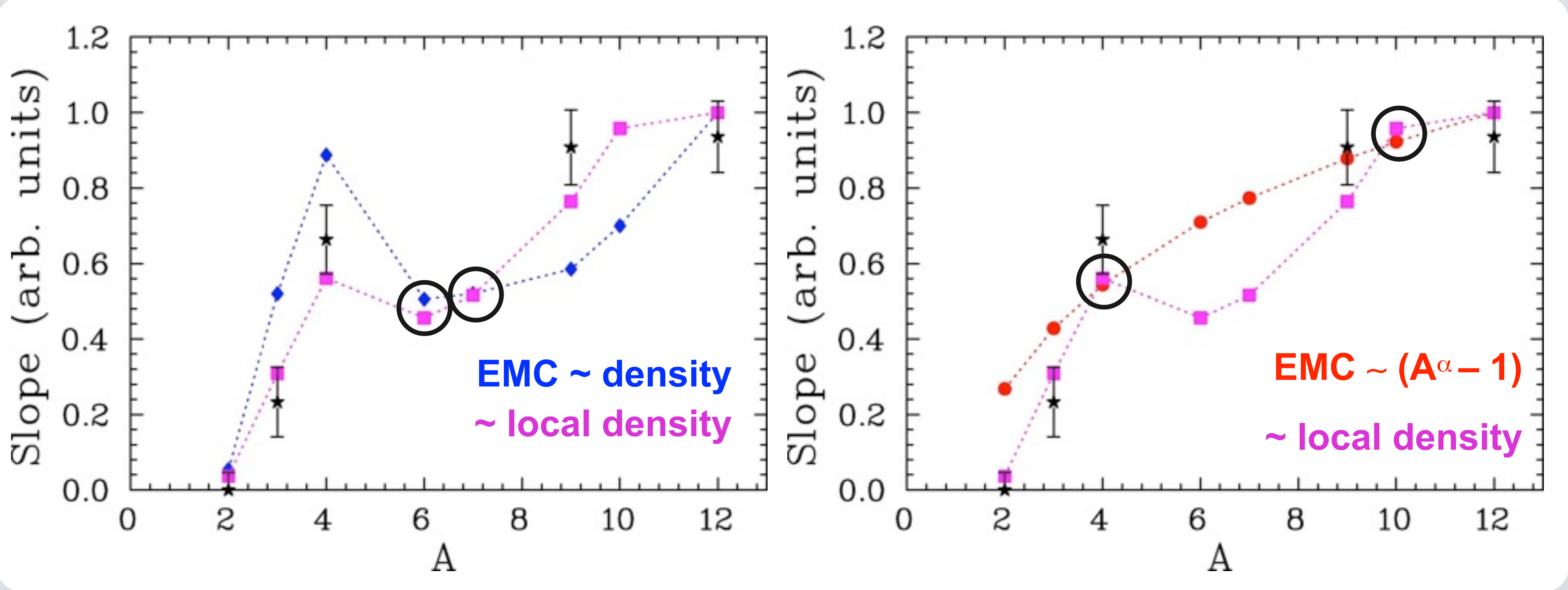
- ✓ ^{40}Ca, ^{48}Ca comparison
  Isospin-dependence



E12-10-008: DETAILED STUDIES OF THE NUCLEAR DEPENDENCE OF F_2 IN LIGHT NUCLEI

➡ **Map out A-dependence in more detail**

"Local density" works well, provides different predictions (use ab initio GFMC calc. of 2-body correlation function to calculate average nucleon 'overlap')



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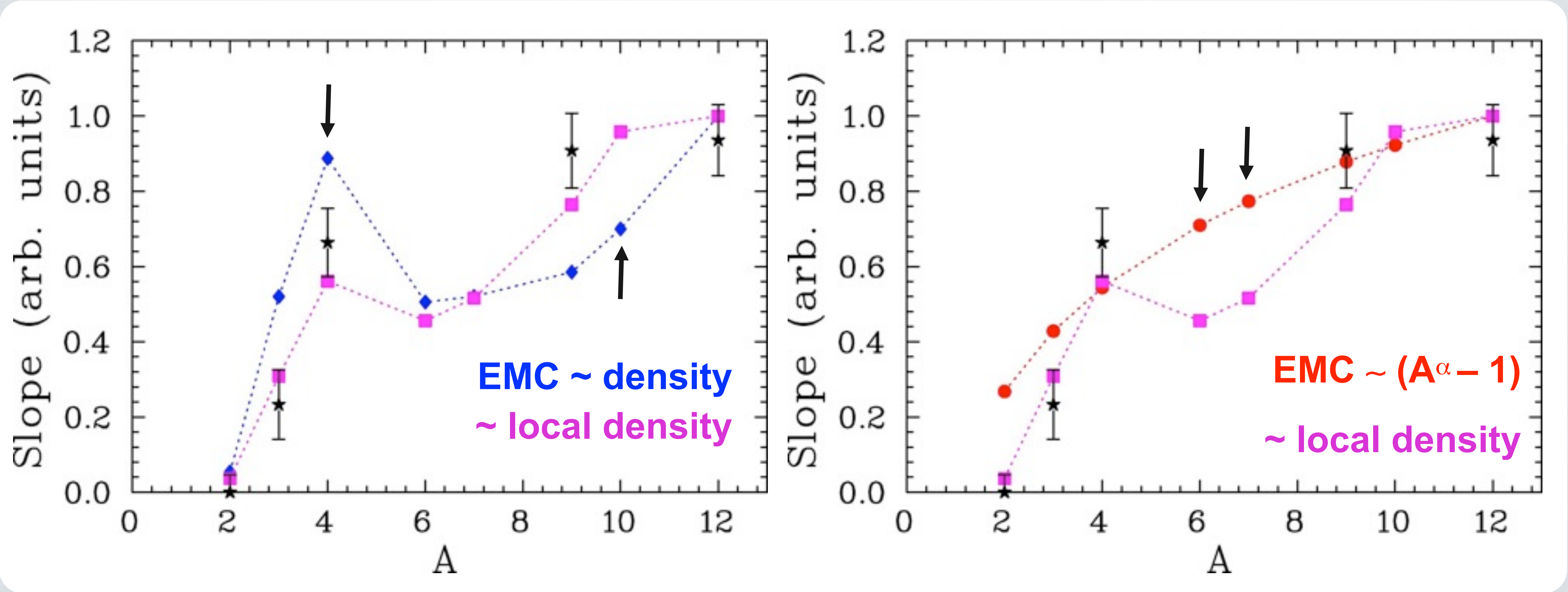


WHY IS F_2^N/F_2^P SO INTERESTING?

SU(6)-symmetric wave function of the proton in the quark model (spin up):

$$|p\uparrow\rangle = \frac{1}{\sqrt{18}}\left(3u\uparrow[ud]_{S=0} + u\uparrow[ud]_{S=1} - \sqrt{2}u\downarrow[ud]_{S=1} - \sqrt{2}d\uparrow[uu]_{S=1} - 2d\downarrow[uu]_{S=1}\right)$$

u and d quarks identical, N and Δ would be degenerate in mass.

In this model: $d/u = 1/2$, $F_2^n/F_2^p = 2/3$.

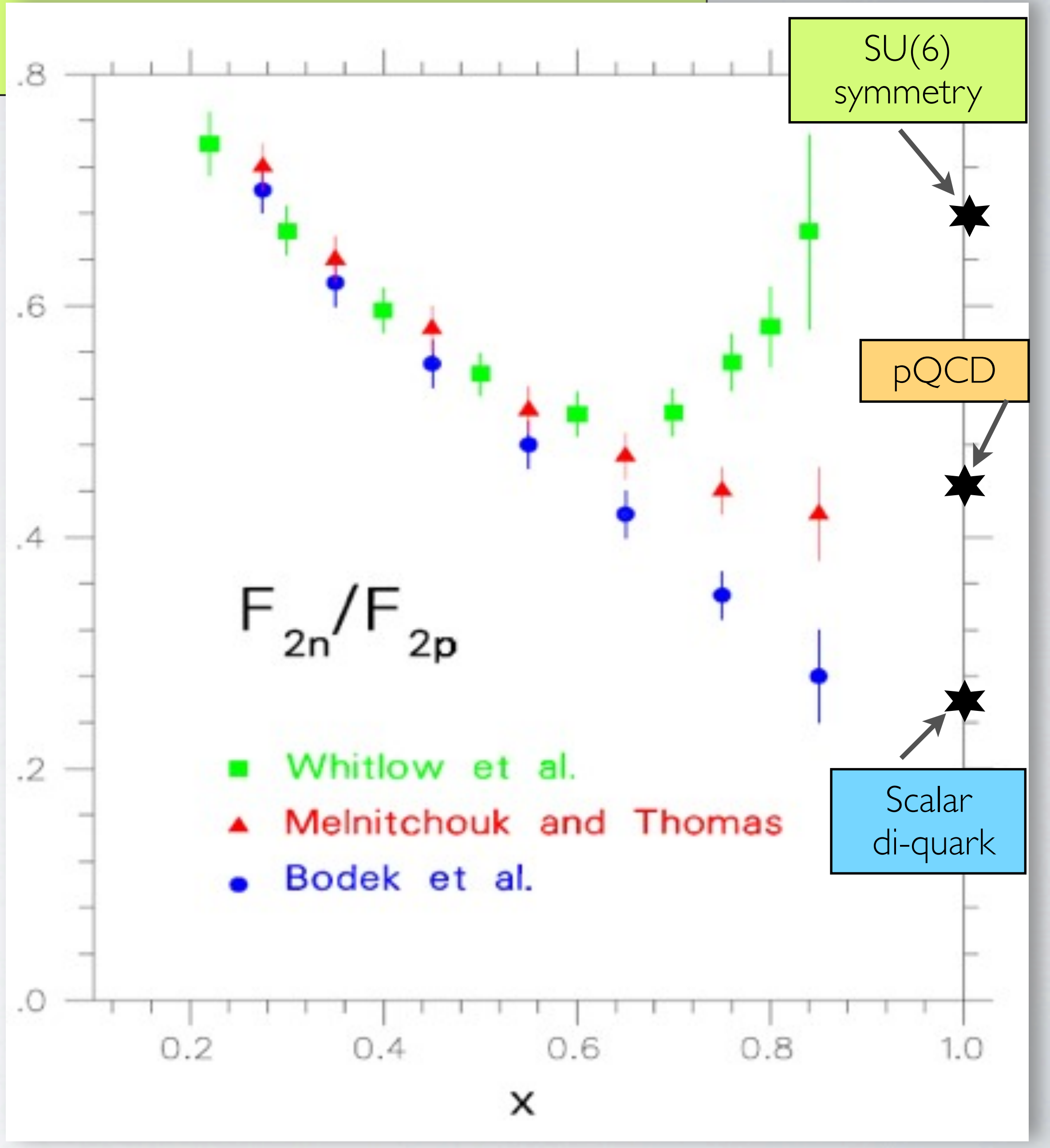
pQCD: helicity conservation ($q\uparrow\uparrow p$)

=> $d/u \approx 2/(9+1) = 1/5$, $F_2^n/F_2^p \approx 3/7$ for $x \to 1$

SU(6) symmetry is broken: N-Δ Mass Splitting

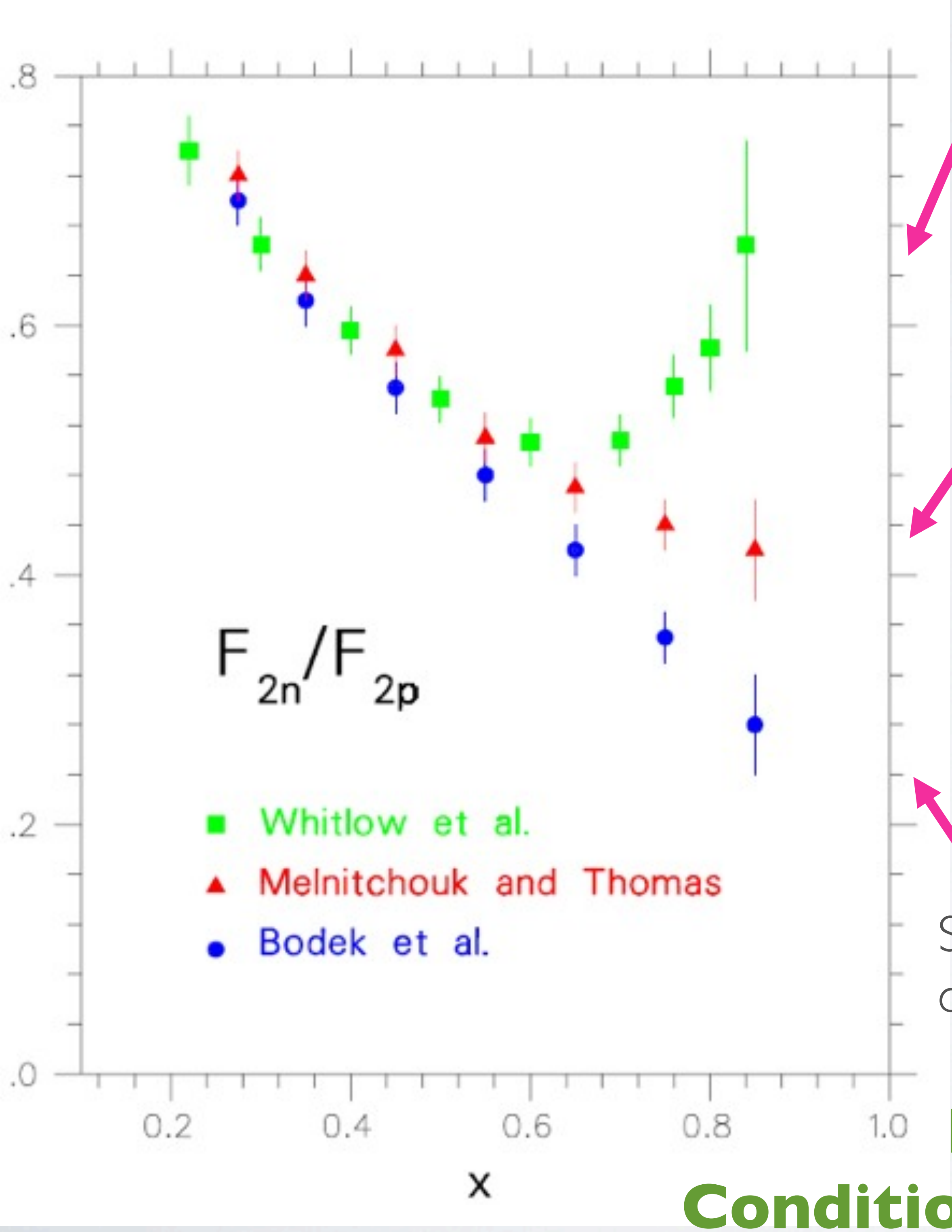
- Mass splitting between S=1 and S=0 diquark spectator.
- symmetric states are raised, antisymmetric states are lowered (~300 MeV).
- S=1 suppressed

=> $d/u = 0$, $F_2^n/F_2^p = 1/4$, for $x \to 1$



E12-06-118: n/p AT LARGE x

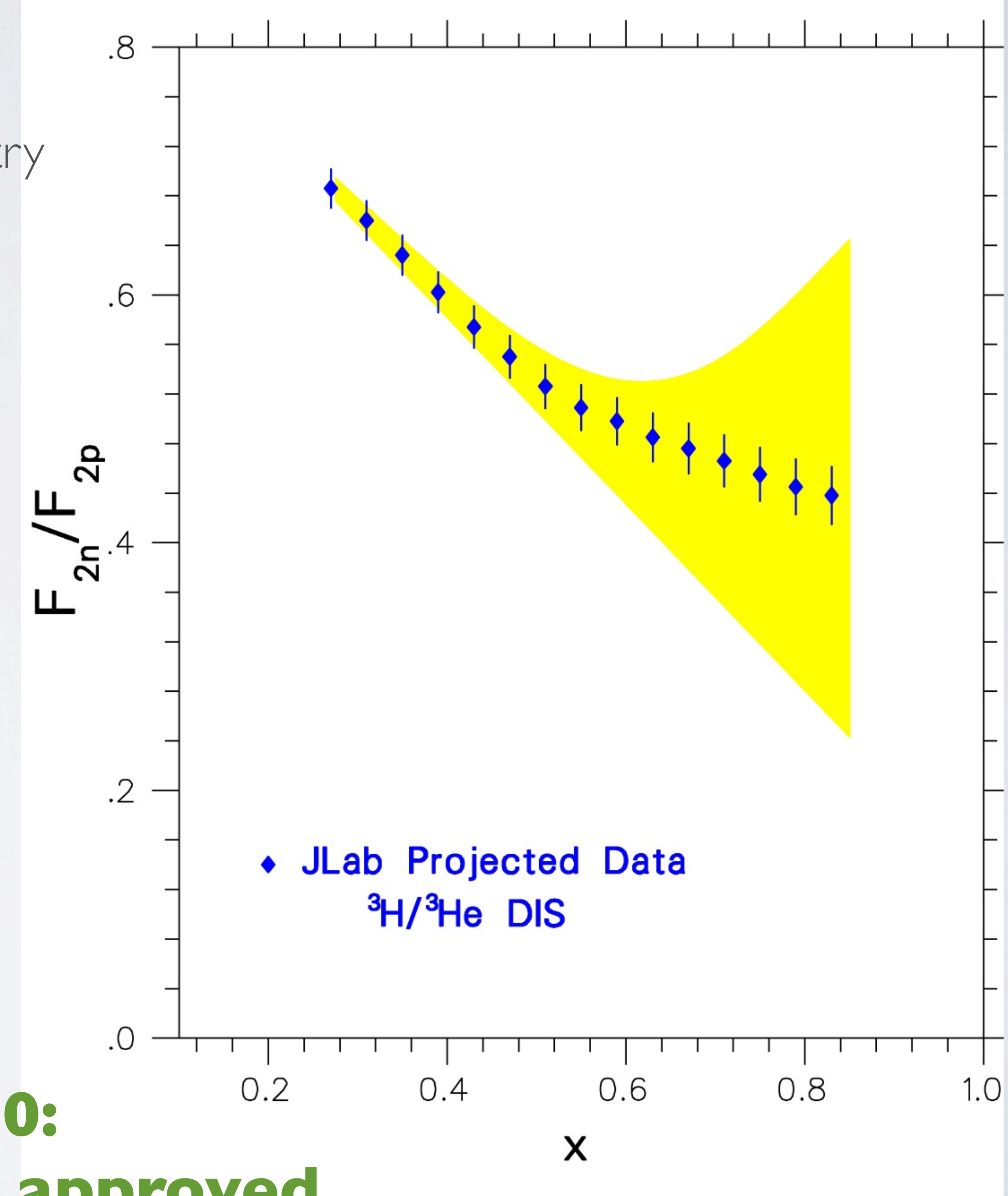
JLab E12-06-118:
G. Petratos, J. Gomez, R. J. Holt, R. Ransome



SU(6) symmetry

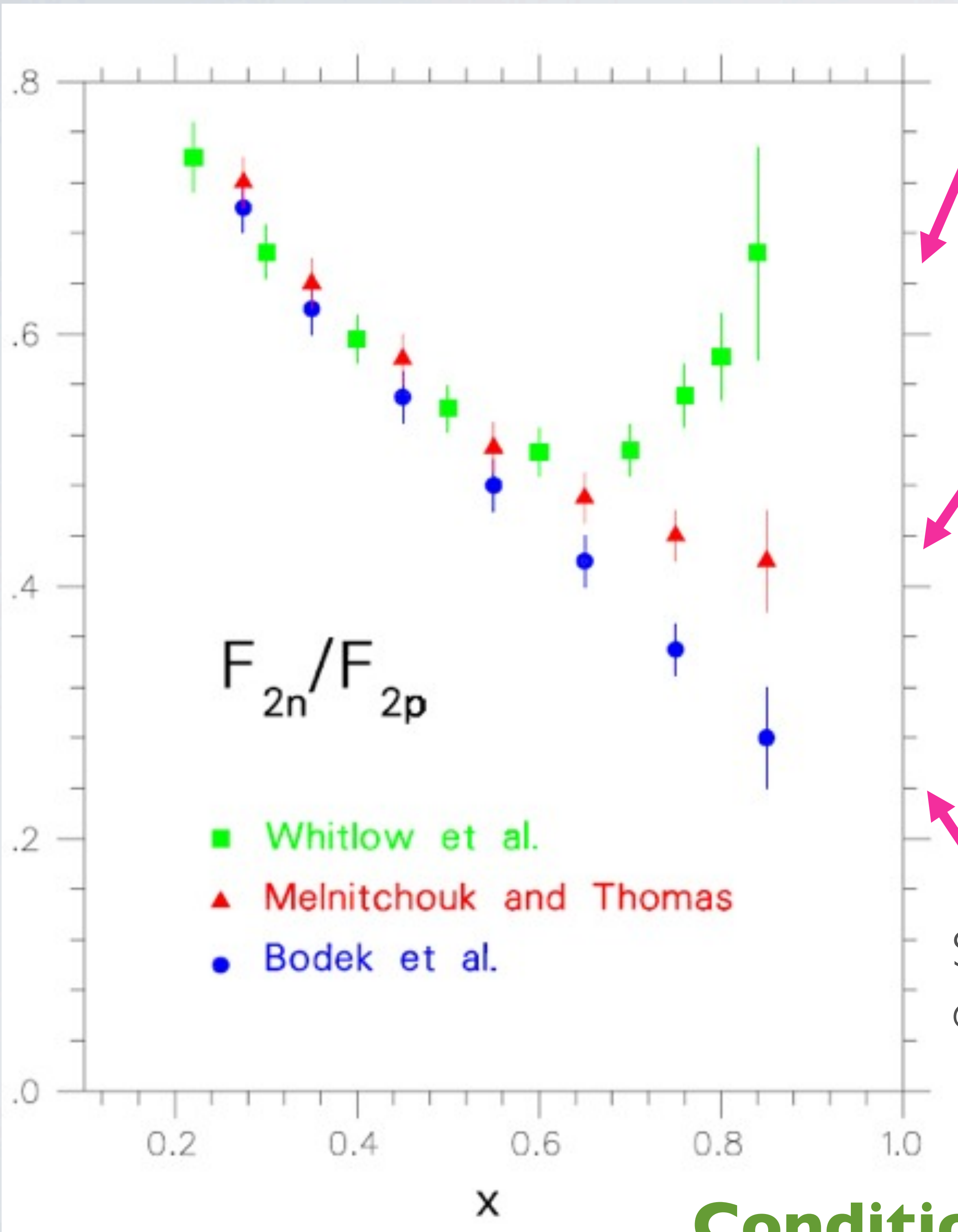
pQCD

Scalar di-quark



PAC30: Conditionally approved

E12-06-118: d/u AT LARGE x

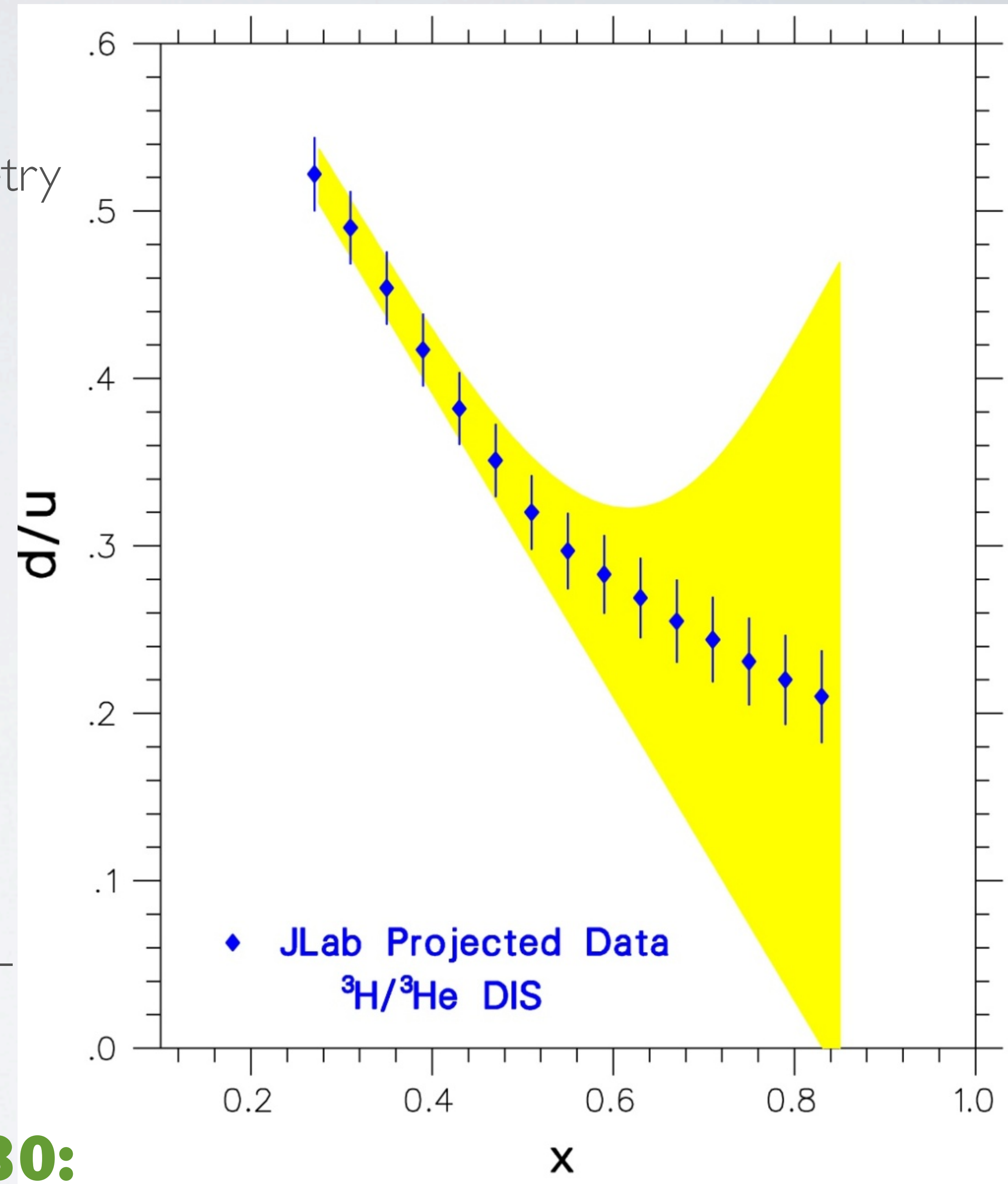


SU(6) symmetry

pQCD

Scalar di-quark

JLab E12-06-118:
G. Petratos, J. Gomez, R. J. Holt, R. Ransome

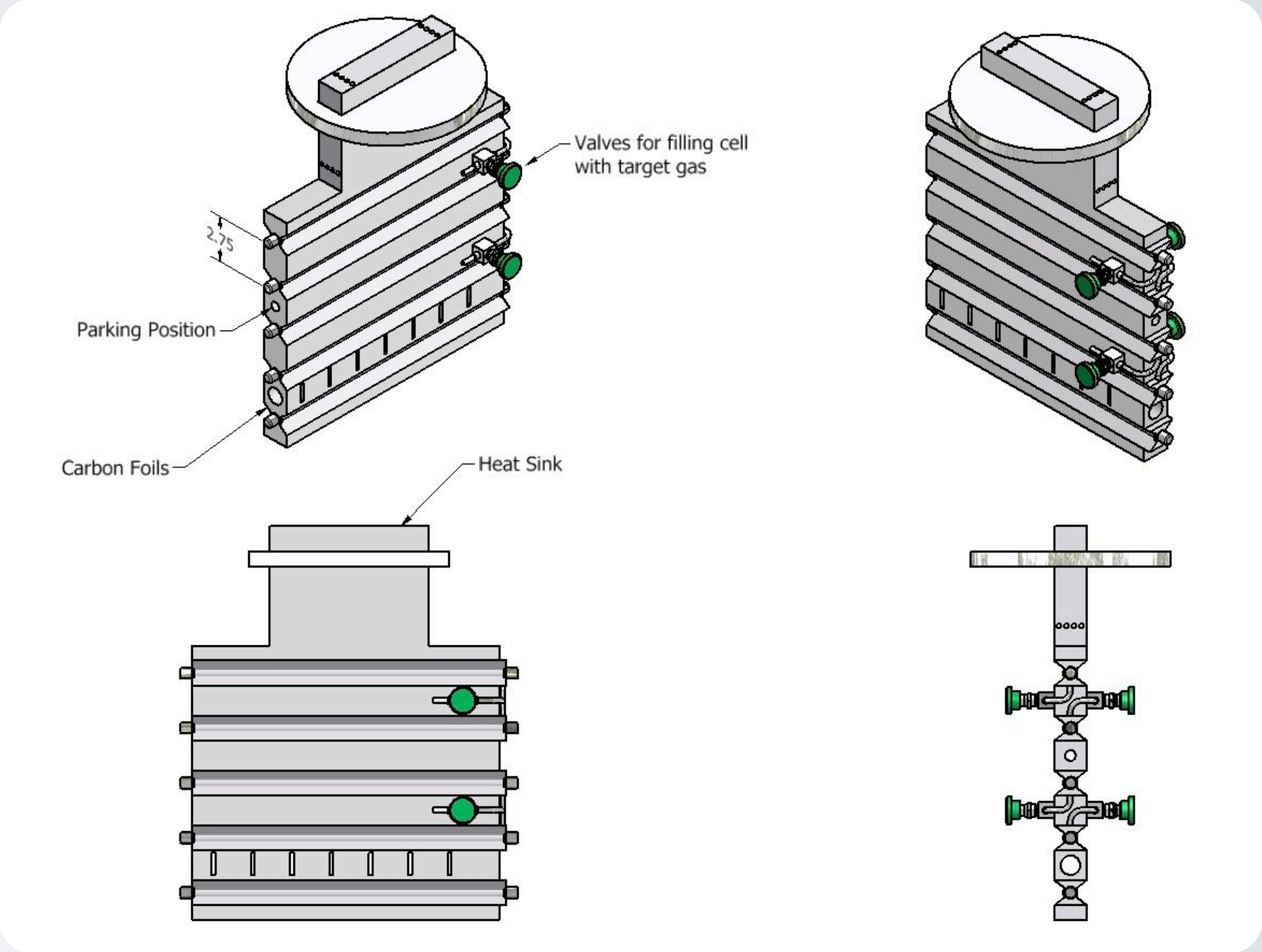


PAC30: Conditionally approved

THE TRITIUM TARGET CONCEPTUAL DESIGN

E. J. Beise (U. of Maryland), **B. Brajuskovic** (ANL), **R. J. Holt** (ANL),
W. Korsch (U. of Kentucky), **T. O'Connor** (ANL), **G. G. Petratos** (Kent State U.),
R. Ransome (Rutgers U.), **P. Solvignon** (JLab), and **B. Wojtsekhowski** (JLab)
Tritium Target Task Force

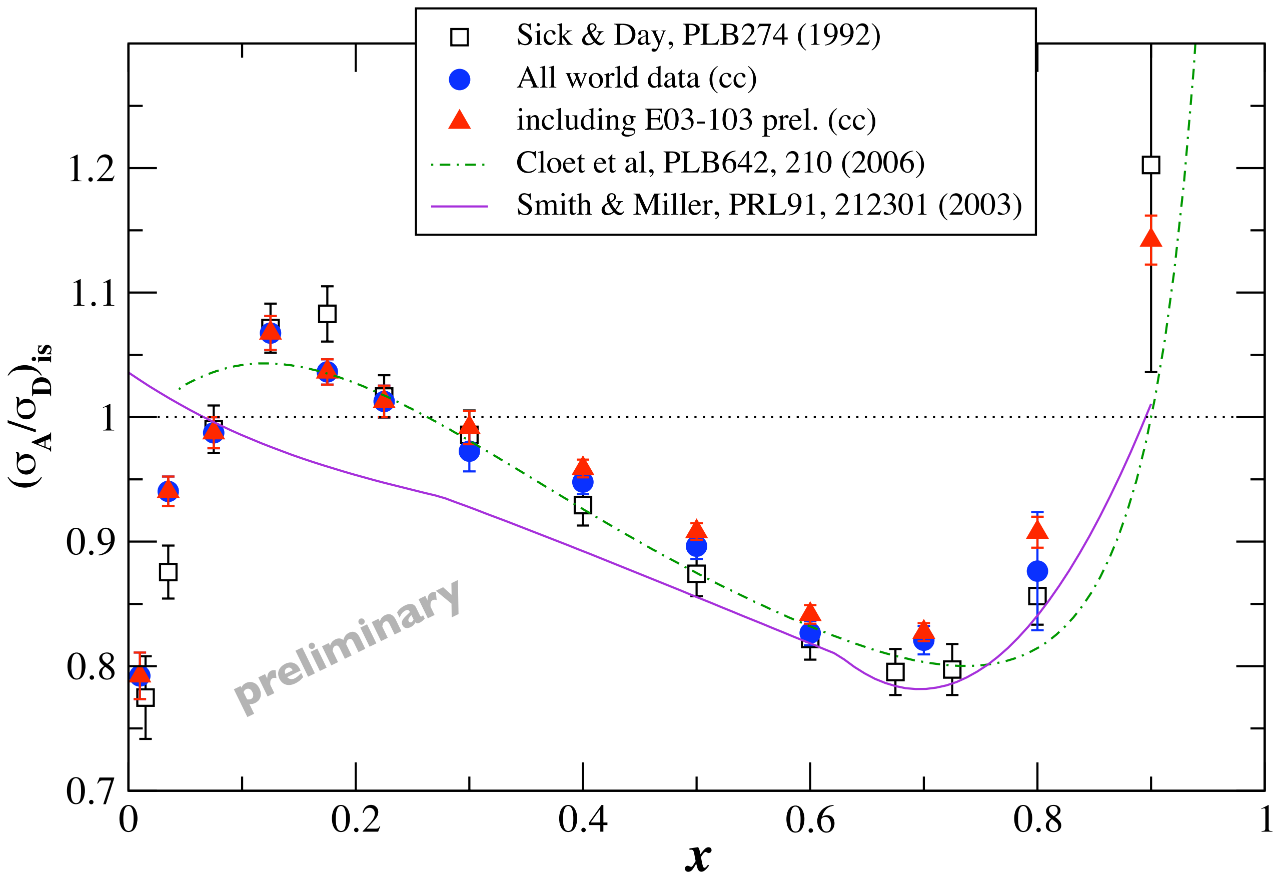
- 1563 Ci of tritium gas
- 40cm long x 1.25cm diam.
- Aluminum (2219): weldable and relatively high yield strength
- entrance, exit and side windows: 0.018" thick
- 10 atm at room temperature initially, with slow increase as tritium decays to ^{3}He



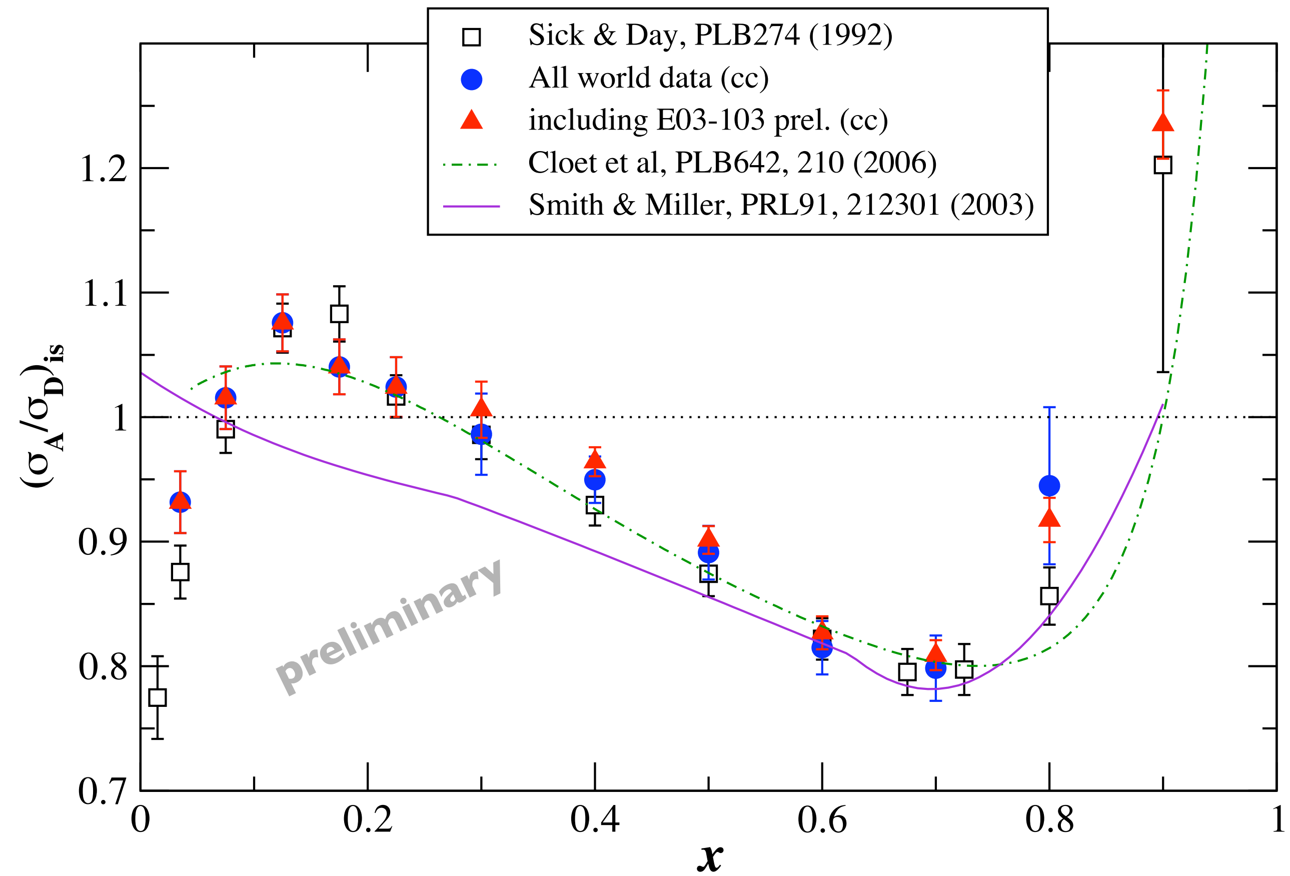
Extra slides

EMC EFFECT IN NUCLEAR MATTER

From $A^{-1/3}$ dependence



From ρ-dependence



using same method as in Sick & Day

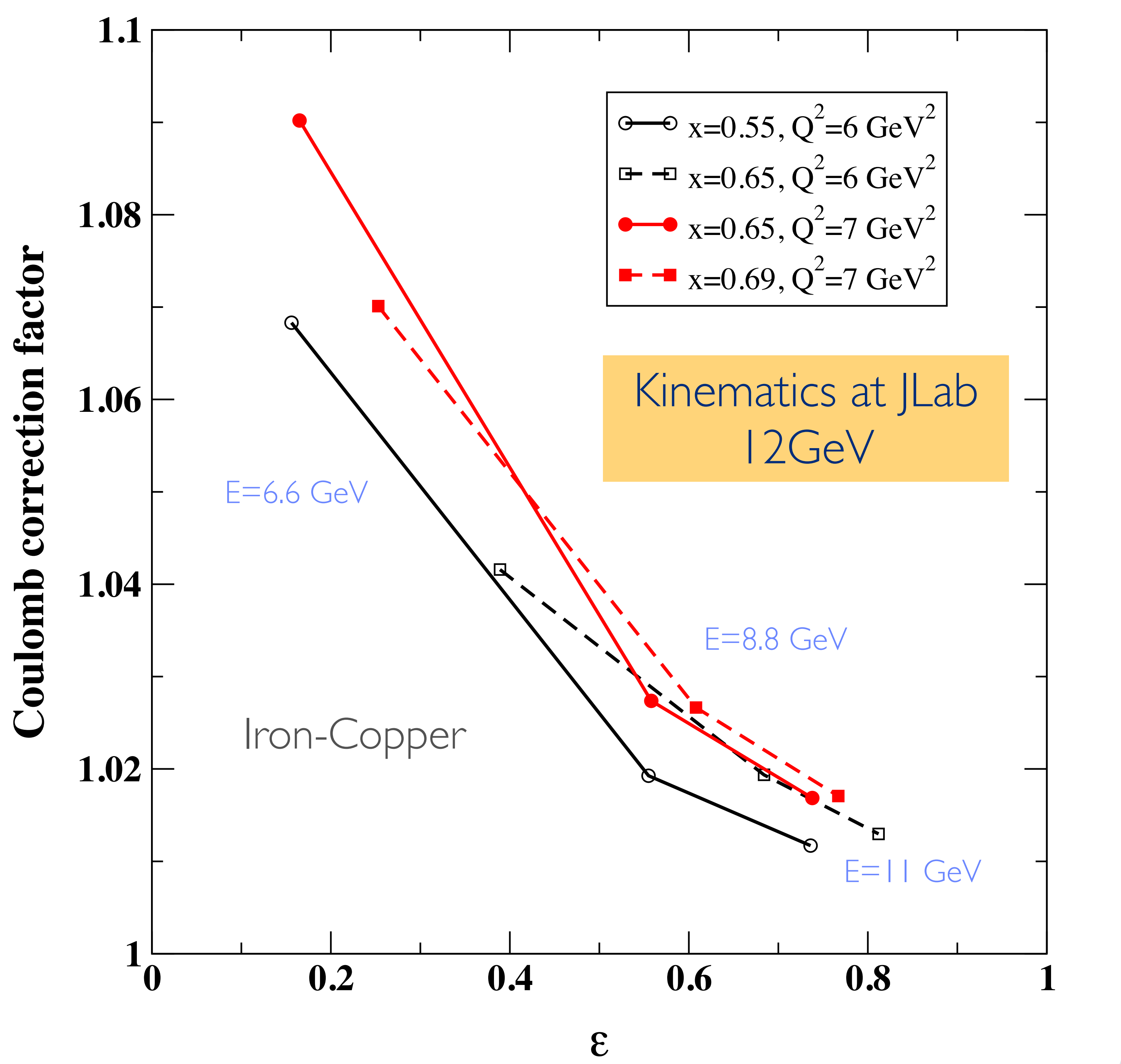
World data: large $\varepsilon \rightarrow$ L and T parts of the cross section enter with the same kinematic factor

COULOMB DISTORTION: ε-DEPENDENCE

The ε-dependence of the Coulomb distortion has effect on the extraction of R in nuclei.

$$\epsilon = \frac{1}{1 + 2\left[1 + \frac{\nu^2}{Q^2}\tan^2\left(\frac{\theta}{2}\right)\right]}$$

$$\theta = 0^\circ \rightarrow \epsilon = 1$$
$$\theta = 180^\circ \rightarrow \epsilon = 0$$



RNM

	Uniform sphere			Wiringa&Pieper calcs	
	A-1/3	ρ	ρ(A-1)/A	ρ	ρ(A-1)/A
x=0.4	-0.059 +/- 0.068 -0.164 +/- 0.069	-0.007 +/- 0.070 -0.092 +/- 0.072	-0.009 +/- 0.073 -0.070 +/- 0.075	-0.011 +/- 0.091 -0.088 +/- 0.046	+0.020 +/- 0.100 -0.067 +/- 0.100
x=0.5	-0.011 +/- 0.055 -0.132 +/- 0.057	-0.004 +/- 0.059 -0.119 +/- 0.060	-0.022 +/- 0.062 -0.118 +/- 0.063	-0.005 +/- 0.077 -0.120 +/- 0.039	-0.040 +/- 0.085 -0.148 +/- 0.086
x=0.6	0.036 +/- 0.053 -0.100 +/- 0.054	+0.025 +/- 0.055 -0.110 +/- 0.057	-0.012 +/- 0.059 -0.128 +/- 0.060	-0.032 +/- 0.072 -0.157 +/- 0.036	-0.035 +/- 0.081 -0.169 +/- 0.081
x=0.7	+0.125 +/- 0.053 -0.030 +/- 0.055	+0.114 +/- 0.056 -0.042 +/- 0.057	+0.063 +/- 0.059 -0.076 +/- 0.060	+0.150 +/- 0.073 -0.076 +/- 0.038	0.063 +/- 0.081 -0.099 +/- 0.083

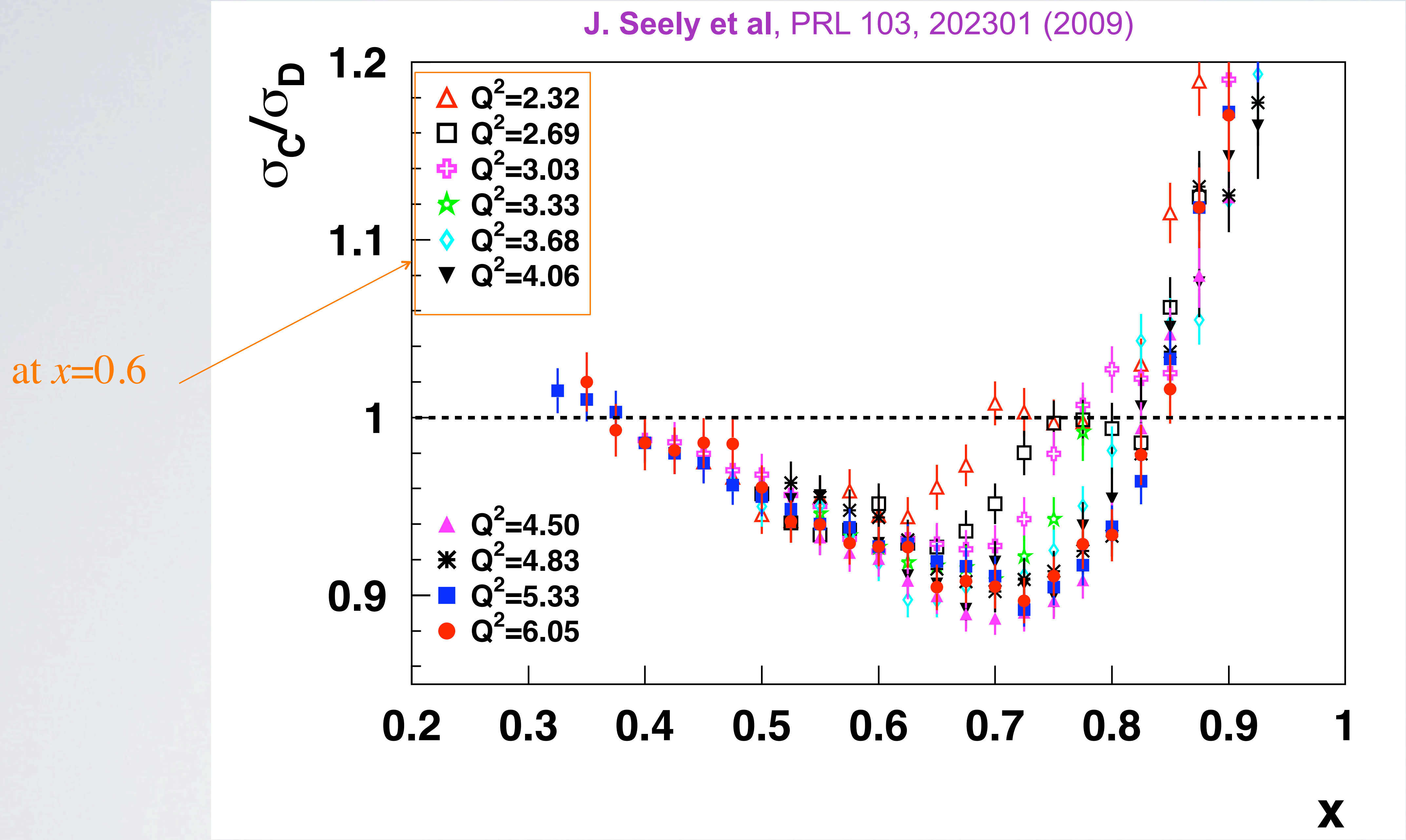
R_{NM}

		Uniform sphere		Wiringa&Pieper calcs	
	A-1/3	ρ	ρ(A-1)/A	ρ	ρ(A-1)/A
x=0.4	-0.05[illegible] 0.068 >2σ -0.1[illegible] 0.069	-0.007 +/- 0.070 -0.092 +/- 0.072	-0.009 +/- 0.073 -0.070 +/- 0.075	-0.01[illegible] 0.091 2σ -0.08[illegible] 0.046	+0.020 +/- 0.100 -0.067 +/- 0.100
x=0.5	-0.0[illegible] 0.055 >2σ -0.1[illegible] 0.057	-0.00[illegible] 0.059 2σ -0.11[illegible] 0.060	-0.02[illegible] 0.062 2σ -0.11[illegible] 0.063	-0.00[illegible] 0.077 3σ -0.12[illegible] 0.039	-0.04[illegible] 0.085 2σ -0.14[illegible] 0.086
x=0.6	0.03[illegible] 0.053 2σ -0.10[illegible] 0.054	+0.0[illegible] - 0.055 2σ -0.11[illegible] 0.057	-0.01[illegible] 0.059 2σ -0.12[illegible] 0.060	-0.0[illegible] 0.072 >4σ -0.1[illegible] 0.036	-0.03[illegible] 0.081 2σ -0.16[illegible] 0.081
x=0.7	+0.125 +/- 0.053 -0.030 +/- 0.055	+0.114 +/- 0.056 -0.042 +/- 0.057	+0.063 +/- 0.059 -0.076 +/- 0.060	+0.15[illegible] 0.073 2σ -0.07[illegible] 0.038	0.063 +/- 0.081 -0.099 +/- 0.083

WORLD DATA RE-ANALYSIS

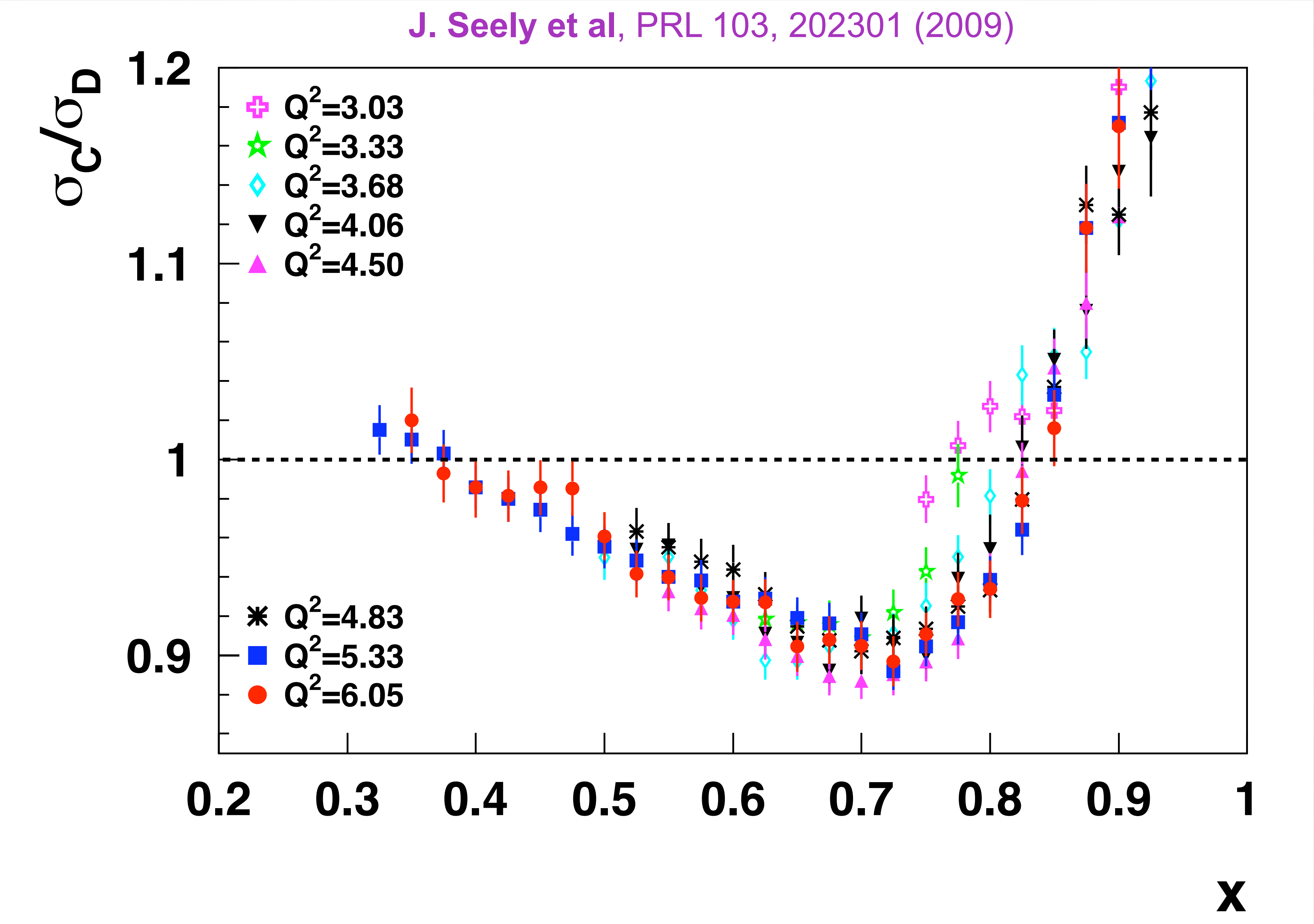
Experiments	E (GeV)	A	x-range	Pub. 1st author
CERN-EMC	280	56	0.050-0.650	Aubert
		12,63,119	0.031-0.443	Ashman
CERN-BCDMS	280	15	0.20-0.70	Bari
		56	0.07-0.65	Benvenuti
CERN-NMC	200	4,12,40	0.0035-0.65	Amaudruz
	200	6,12	0.00014-0.65	Arneodo
SLAC-E61	4-20	9,27,65,197	0.014-0.228	Stein
SLAC-E87	4-20	56	0.075-0.813	Bodek
SLAC-E49	4-20	27	0.25-0.90	Bodek
SLAC-E139	8-24	4,9,12,27,40,56,108,197	0.089-0.8	Gomez
SLAC-E140	3.7-20	56,197	0.2-0.5	Dasu
DESY-HERMES	27.5	3,14,84	0.013-0.35	Airapetian

E03-103: Q^2-DEPENDENCE



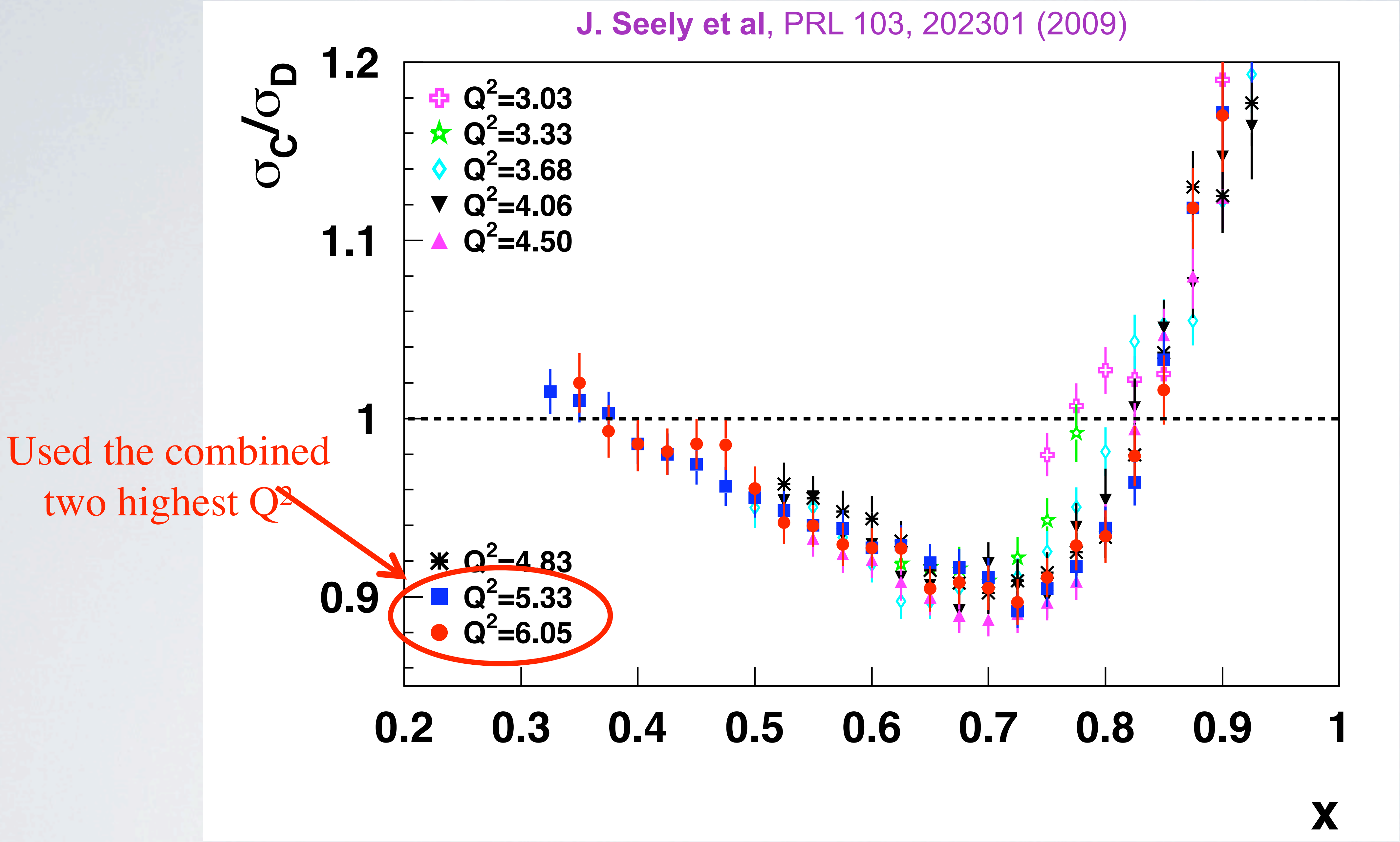
Small angle, low Q^2 ➔ clear scaling violations for $x>0.6$-0.7

E03-103: Q^2-DEPENDENCE



At larger angles ➔ indication of scaling to very large x

E03-103: Q^2-DEPENDENCE



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

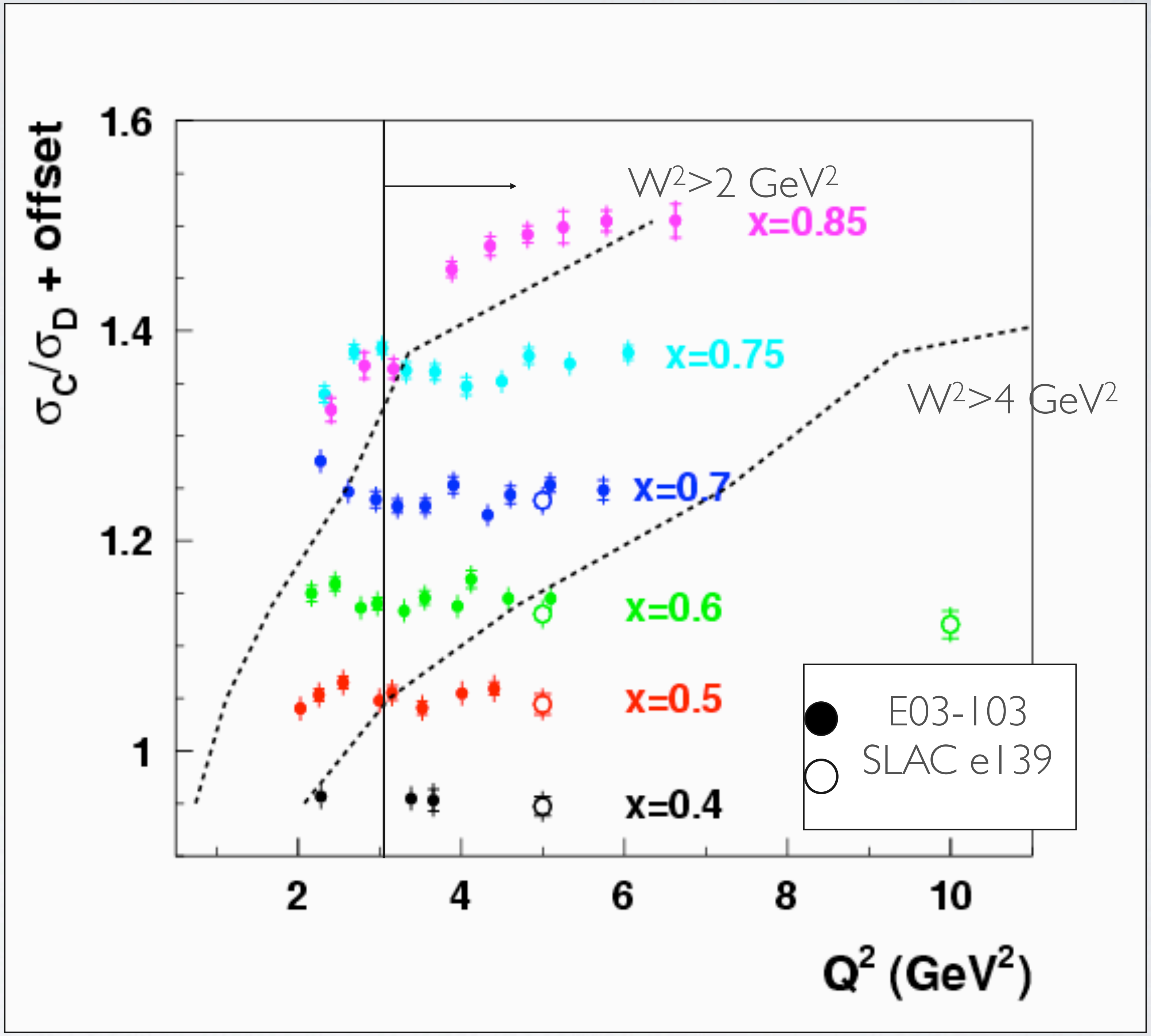
MORE DETAILED LOOK AT SCALING

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

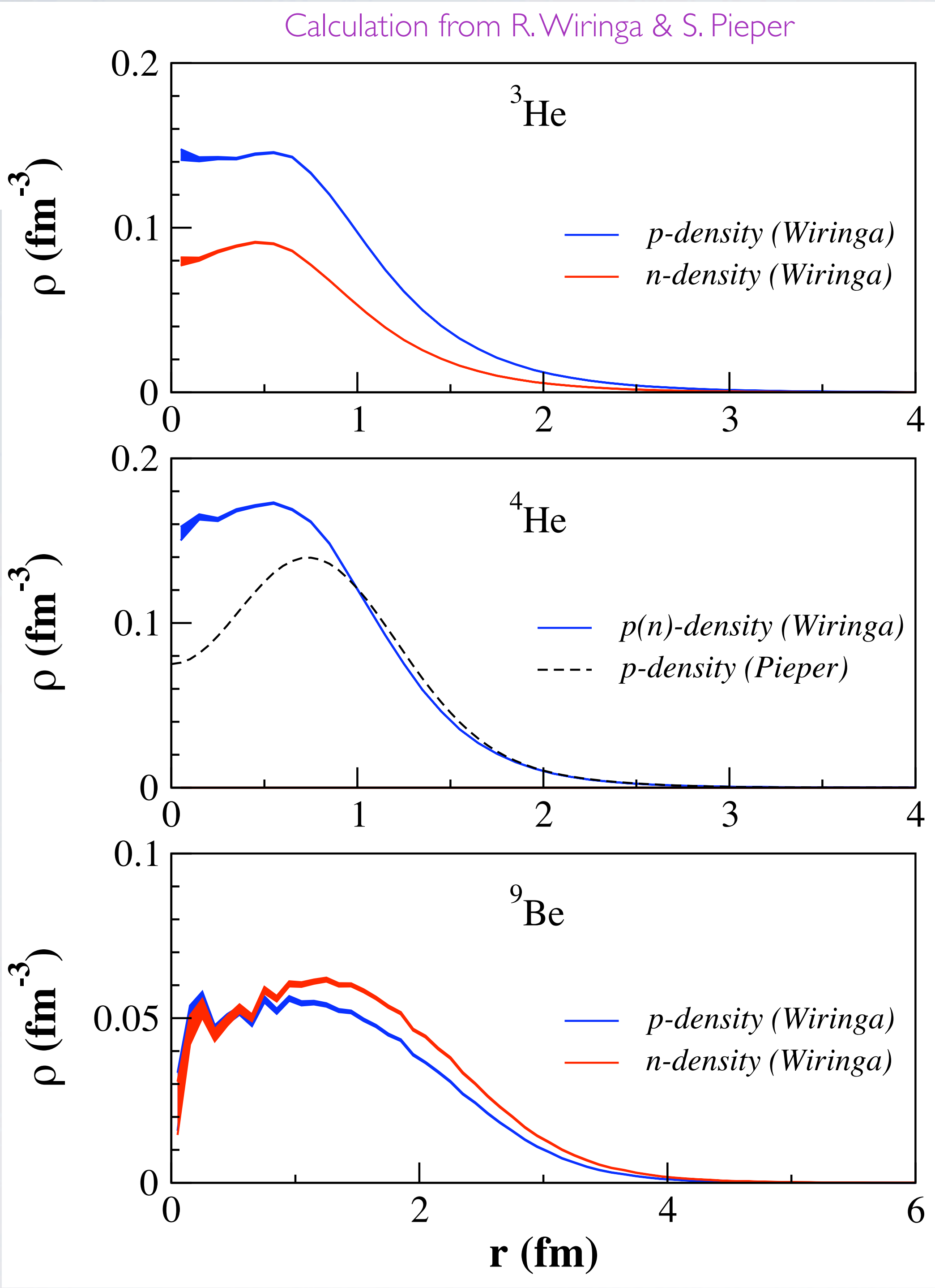
W^2>2 GeV^2
and
Q^2>3 GeV^2

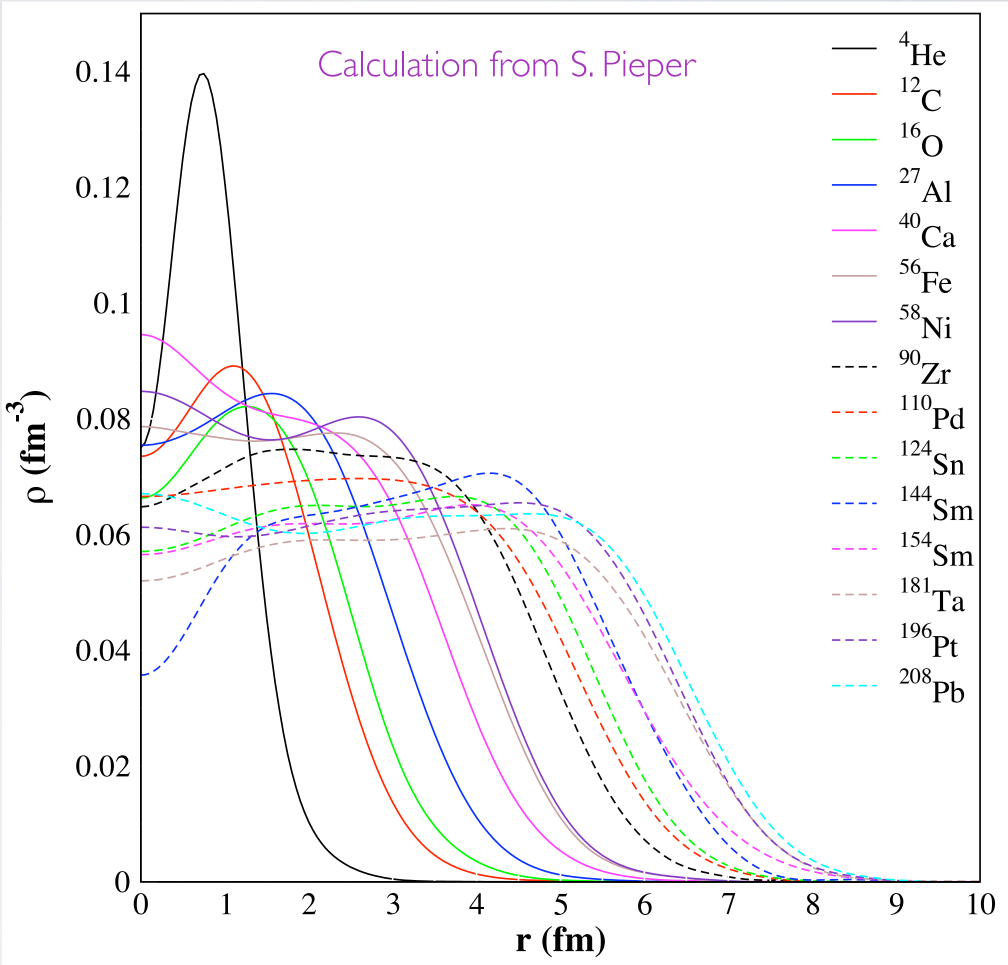
limits E03-103 coverage to x=0.85

Note: Ratios at larger x will be shown, but could have small HT, scaling violation



DENSITY CALCULATIONS





Average density:

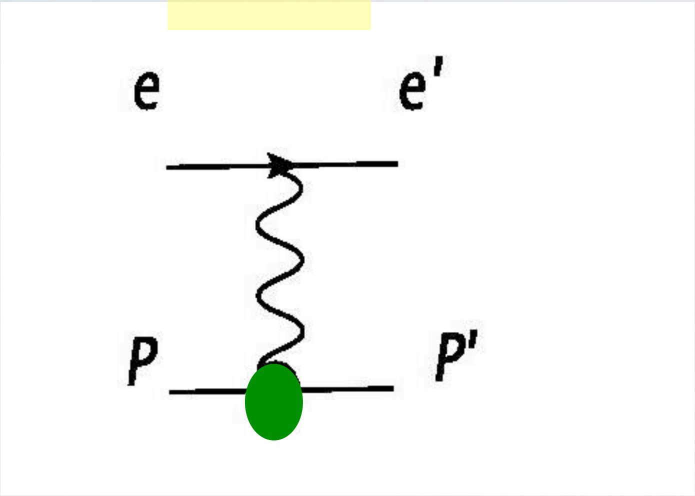
$$\langle \rho_{n,p} \rangle = \frac{\int \rho_{n,p}^2 d^3 r}{\int \rho_{n,p} d^3 r}$$

$$\langle \rho_p \rangle + \langle \rho_n \rangle = \langle \rho_A \rangle \xrightarrow{\text{finite proton size correction}} \langle \rho_A \rangle \cdot \left(\frac{\langle r \rangle}{r_{eff}} \right)^3$$

with $r_{eff} = \sqrt{\langle r \rangle^2 + 0.9^2}$

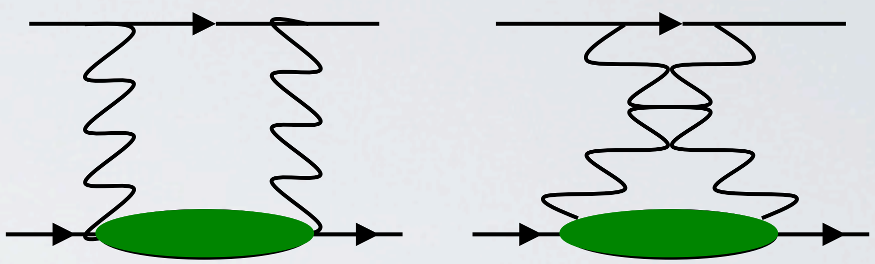
COULOMB DISTORTION AND TWO-PHOTON EXCHANGE

OPE



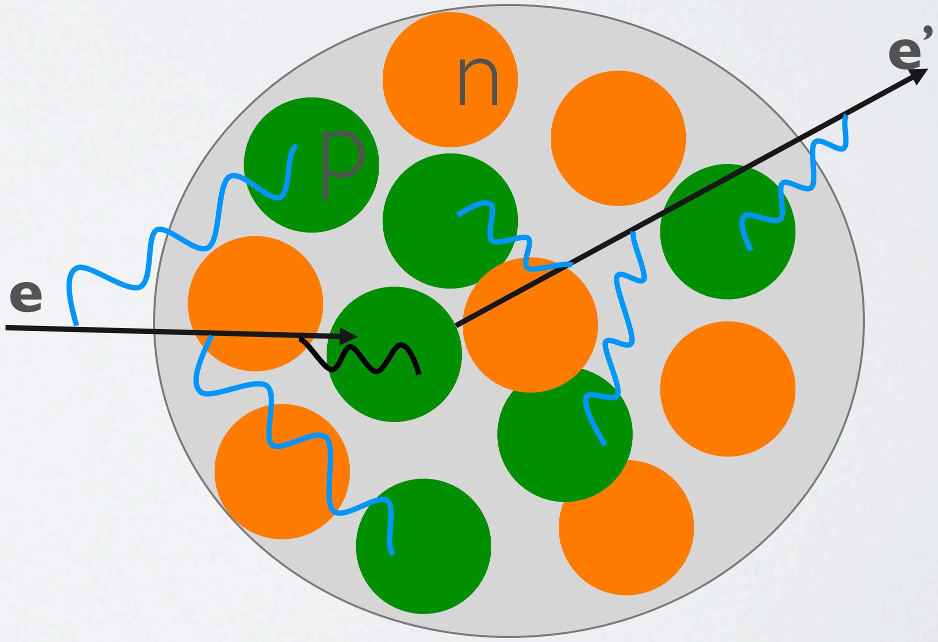
TPE

Exchange of 2 (hard) photons with a single nucleon



Coulomb distortion

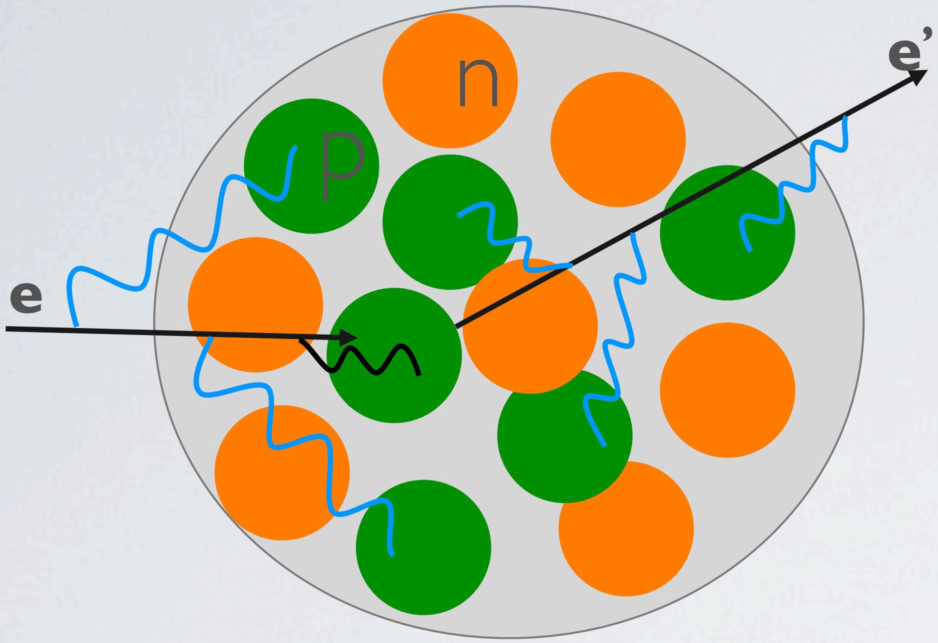
Exchange of one or more (soft) photons with the nucleus, in addition to the one hard photon exchanged with a nucleon



Incident (scattered) electrons are accelerated (decelerated) in the Coulomb well of the nucleus.

Opposite effect with positrons

COULOMB DISTORTION

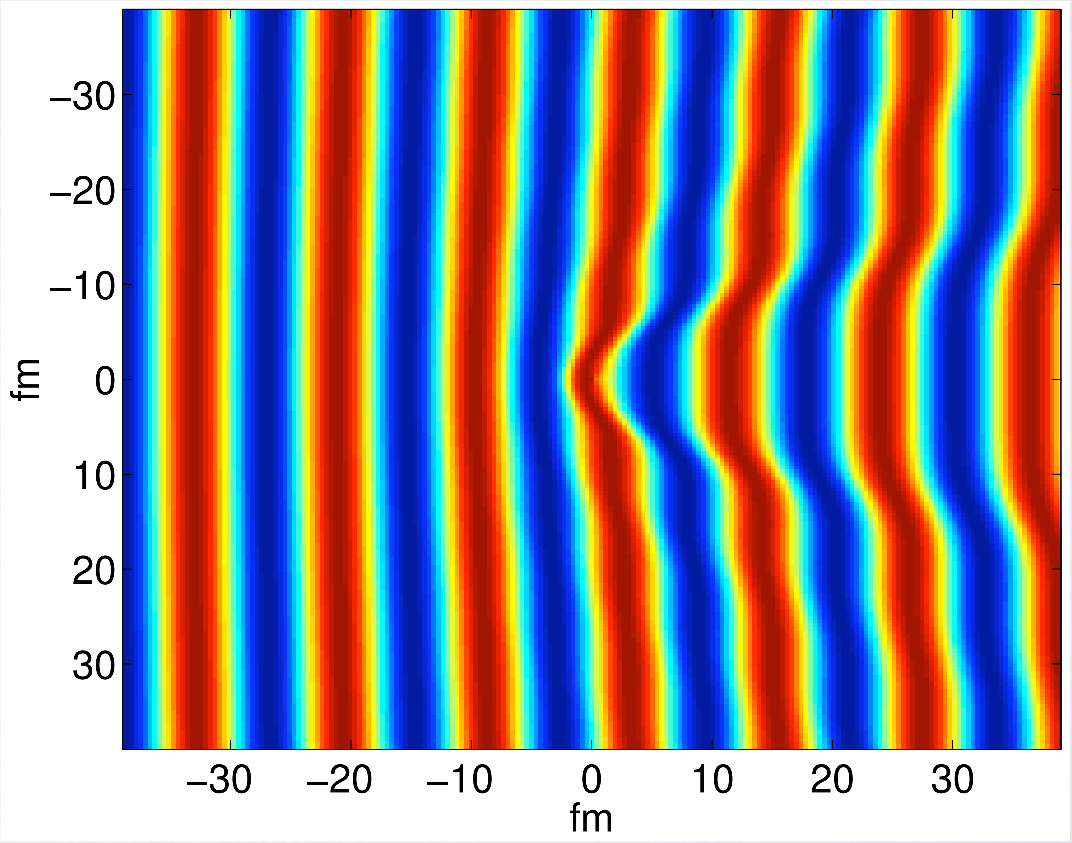


Exchange of **one or more (soft) photons** with the nucleus, in addition to the **one hard photon** exchanged with a nucleon

Incident (scattered) electrons are accelerated (decelerated) in the Coulomb well of the nucleus.

$$\cancel{\sigma_{tot}^{PWBA} = \sigma_{Mott}\, S_{tot}^{PWBA}(|\vec{q}|, \omega, \theta)}$$

Fig. from **A. Aste** at Mini-Workshop on Coulomb Distortion, JLab May 2005



Coulomb Distortion could have the same kind of impact as TPE, but gives also a correction that is A-dependent.

HOW TO CORRECT FOR COULOMB DISTORTION ?

$$\cancel{\sigma_{tot}^{PWBA} = \sigma_{Mott}\, S_{tot}^{PWBA}(|\vec{q}|, \omega, \theta)} \Rightarrow$$

σ_{tot}^{DWBA}

- Focusing of the electron wave function
- Change of the electron momentum

Effective Momentum Approximation (EMA)

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

$$Q^2_{eff} = 4(E + \bar{V})(E_p + \bar{V})\sin^2(\frac{\theta}{2})$$

1st method

$$S_{tot}^{PWBA}(|\vec{q}|, \omega, \theta) \longrightarrow S_{tot}^{PWBA}(|\vec{q}_{eff}|, \omega, \theta)$$

$$\boxed{\sigma_{tot}^{CC} = \sigma_{Mott} \cdot S_{tot}^{PWBA}(|\vec{q}_{eff}|, \omega, \theta)}$$

$\Leftrightarrow$

2nd method

$$S_{tot}^{PWBA}(|\vec{q}|, \omega, \theta) \longrightarrow S_{tot}^{PWBA}(|\vec{q}_{eff}|, \omega, \theta)$$

$$\sigma_{Mott}^{eff} = 4\alpha^2\cos^2(\theta/2)(E_p + \bar{V})^2/Q^4_{eff}$$

$$F^i_{foc} = \frac{E + \bar{V}}{E}$$

$$\boxed{\sigma_{tot}^{CC} = (F^i_{foc})^2 \cdot \sigma_{Mott}^{eff} \cdot S_{tot}^{PWBA}(|\vec{q}_{eff}|, \omega, \theta)}$$

HOW TO CORRECT FOR COULOMB DISTORTION ?

$$\cancel{\sigma_{tot}^{PWBA} = \sigma_{Mott}\, S_{tot}^{PWBA}(|\vec{q}|, \omega, \theta)}$$

$\Rightarrow$

σ_{tot}^{DWBA}

- Focusing of the electron wave function
- Change of the electron momentum

Effective Momentum Approximation (EMA)

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

E

Ep

$$Q^2_{eff} = 4(E + \bar{V})(E_p + \bar{V})\sin^2(\frac{\theta}{2})$$

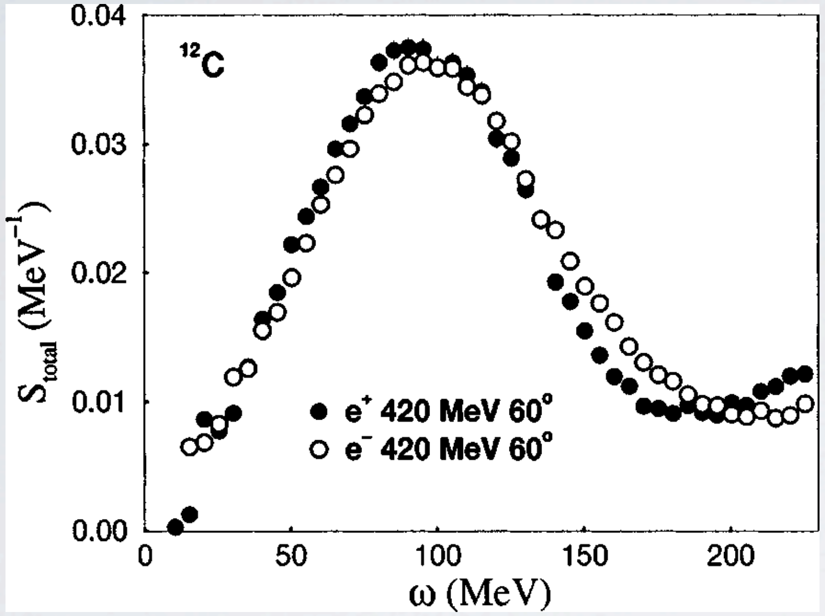
S_{tot}^{PWB}

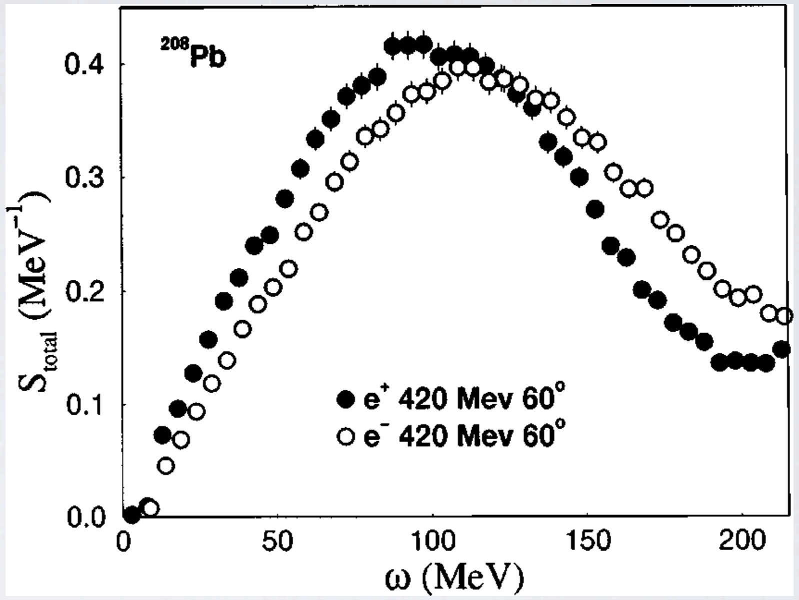
One-parameter model depending only on the effective potential seen by the electron on average.

$$F^i_{foc} = \frac{E + \bar{V}}{E}$$

$$\sigma_{tot}^{CC} = \sigma_{Mott} \cdot S_{tot}^{PWBA}(|\vec{q}_{eff}|, \omega, \theta) \Leftrightarrow \sigma_{tot}^{CC} = (F^i_{foc})^2 \cdot \sigma_{Mott}^{eff} \cdot S_{tot}^{PWBA}(|\vec{q}_{eff}|, \omega, \theta)$$

COULOMB DISTORTION IN QE SCATTERING





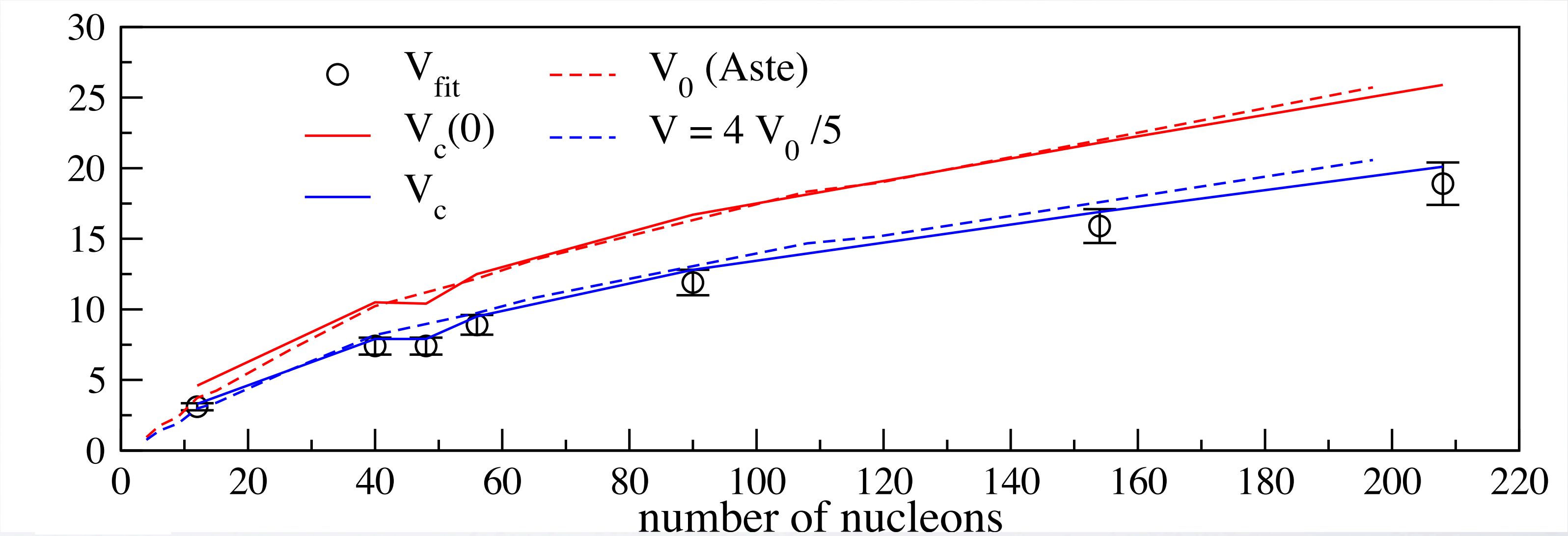
Gueye *et al.*, PRC60, 044308 (1999)

$$\tilde{k} = k - V(z)$$

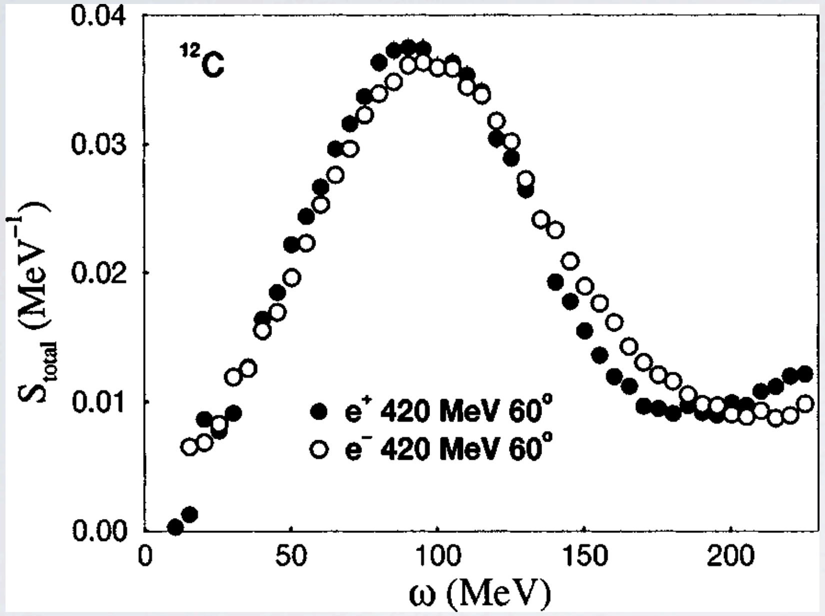
$$V(r) = -\frac{3\alpha(Z-1)}{2R} + \frac{\alpha(Z-1)}{2R}\left(\frac{r}{R}\right)^2$$

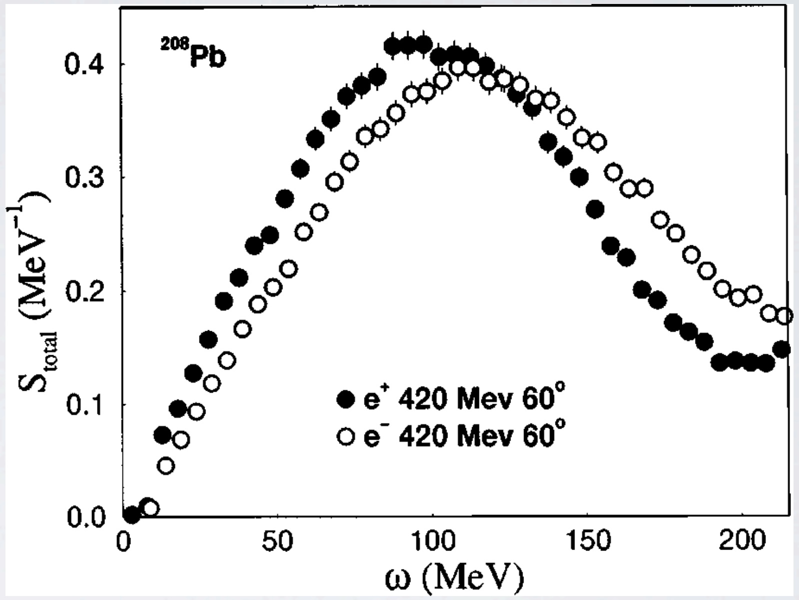
$$R = 1.1A^{1/3} + 0.86A^{-1/3}$$

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



COULOMB DISTORTION IN QE SCATTERING





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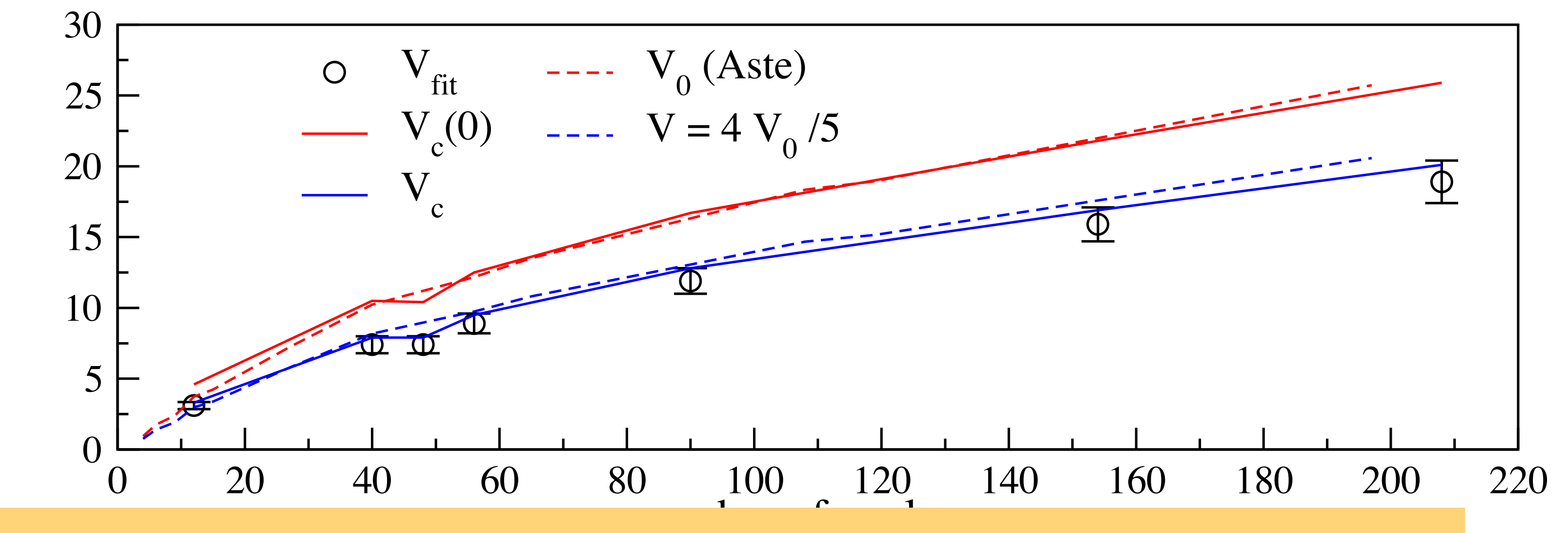
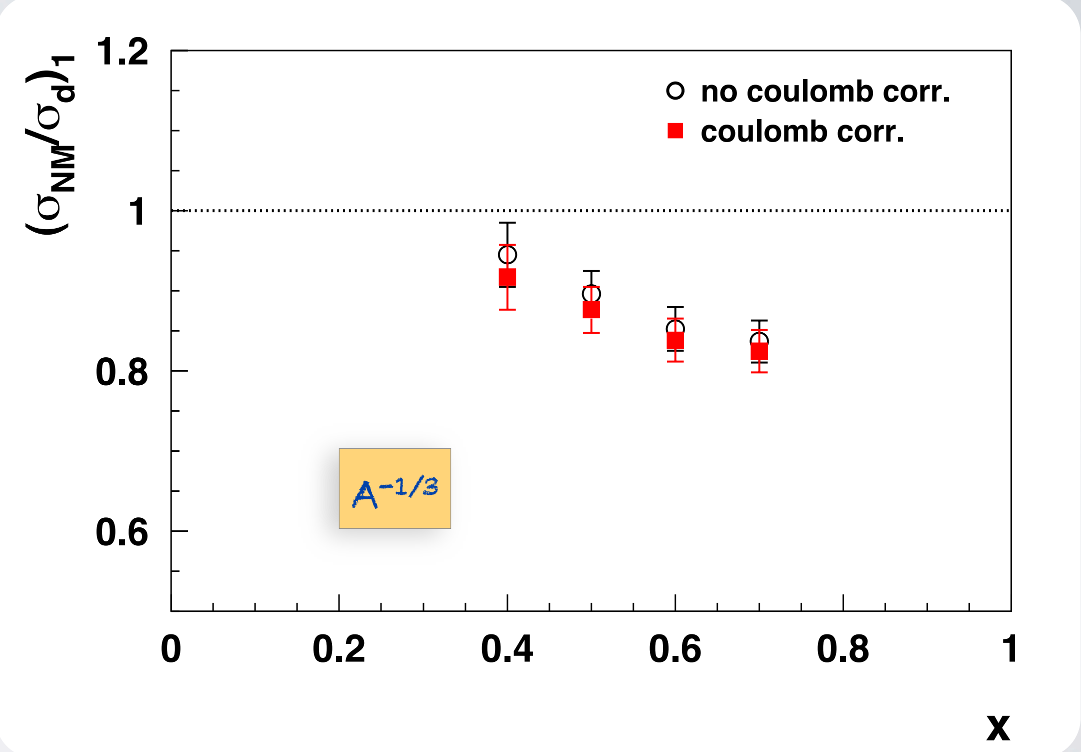
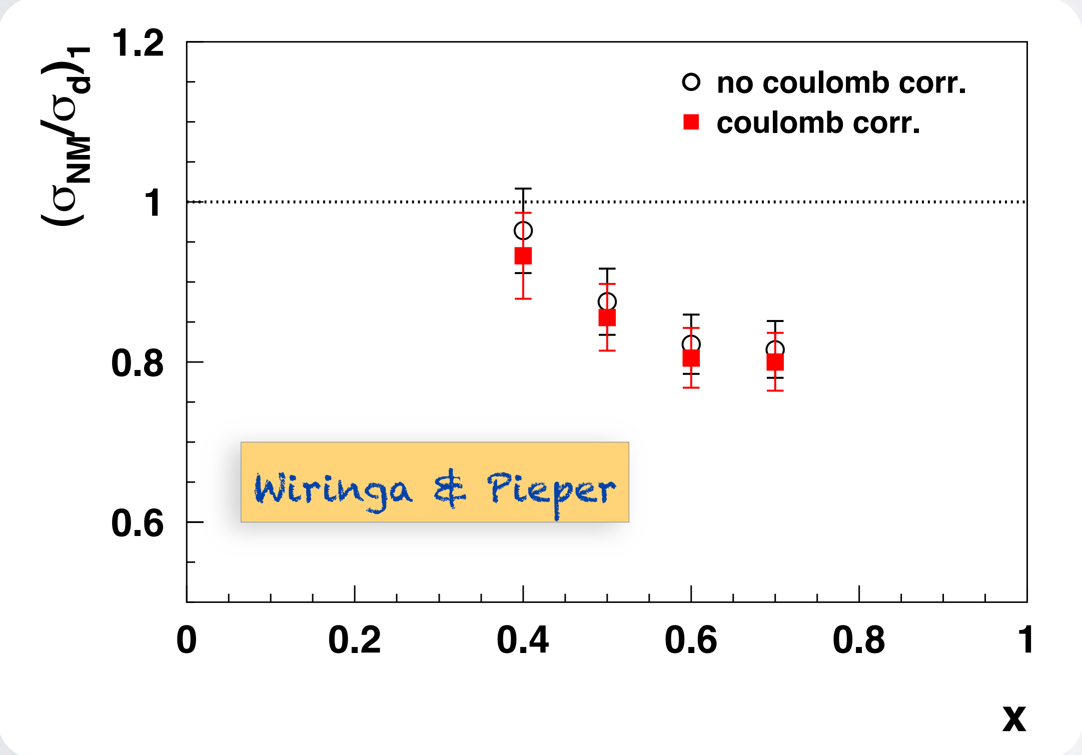
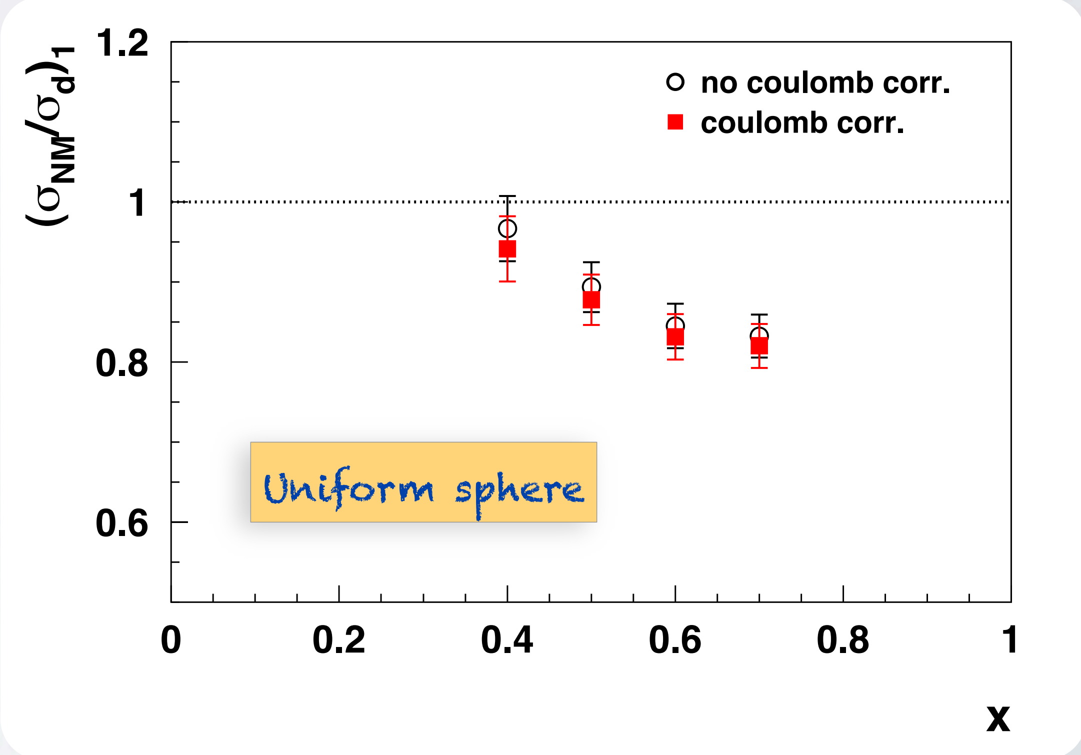


Coulomb potential established in Quasi-elastic scattering regime !

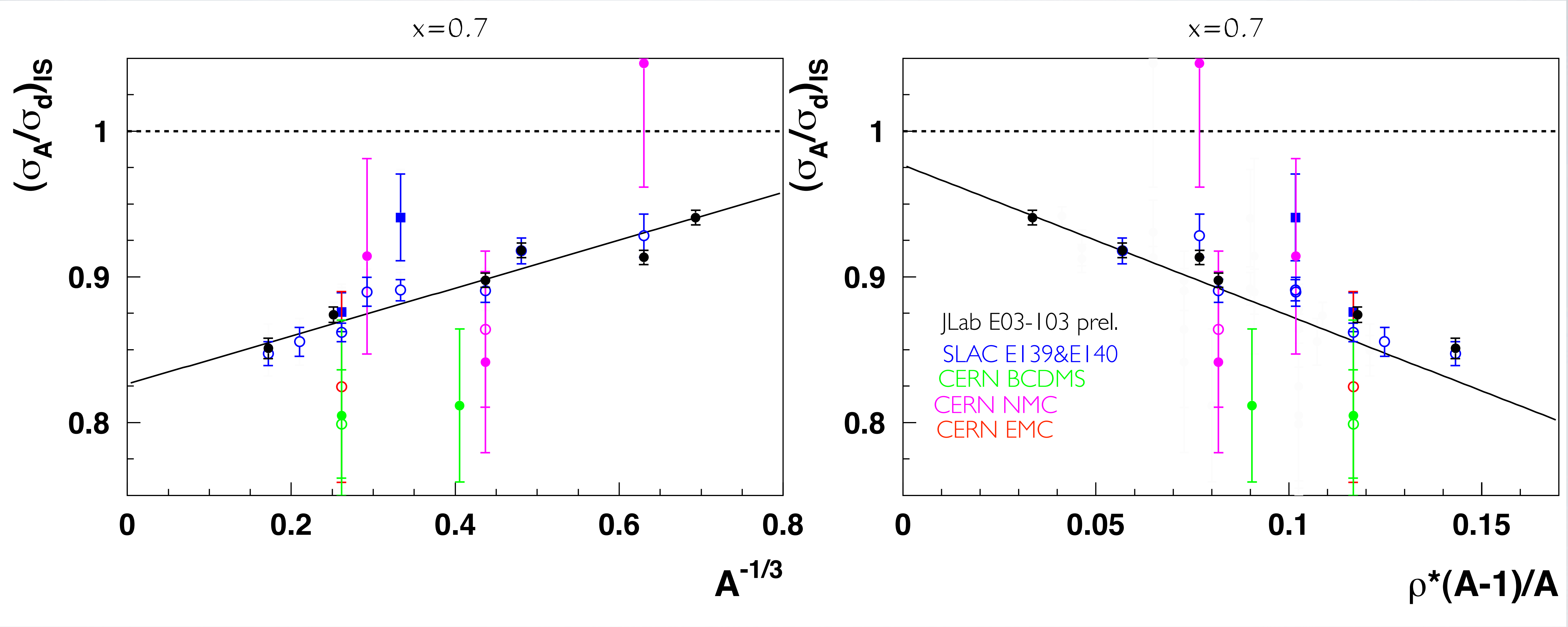
X-DEPENDENCE OF σ_{NM}/σ_D AT $\varepsilon'=1$







A OR ρ-DEPENDENCE ?



- Improved density calculation (calculated with density distributions from R. Wiringa and S. Pieper).
- Apply coulomb distortion correction.
- In progress: review of n/p corrections in world data
- Target mass correction to be looked at.

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

ISOSCALAR CORRECTION

$$Zp + Nn \rightarrow A/2(p+n)$$

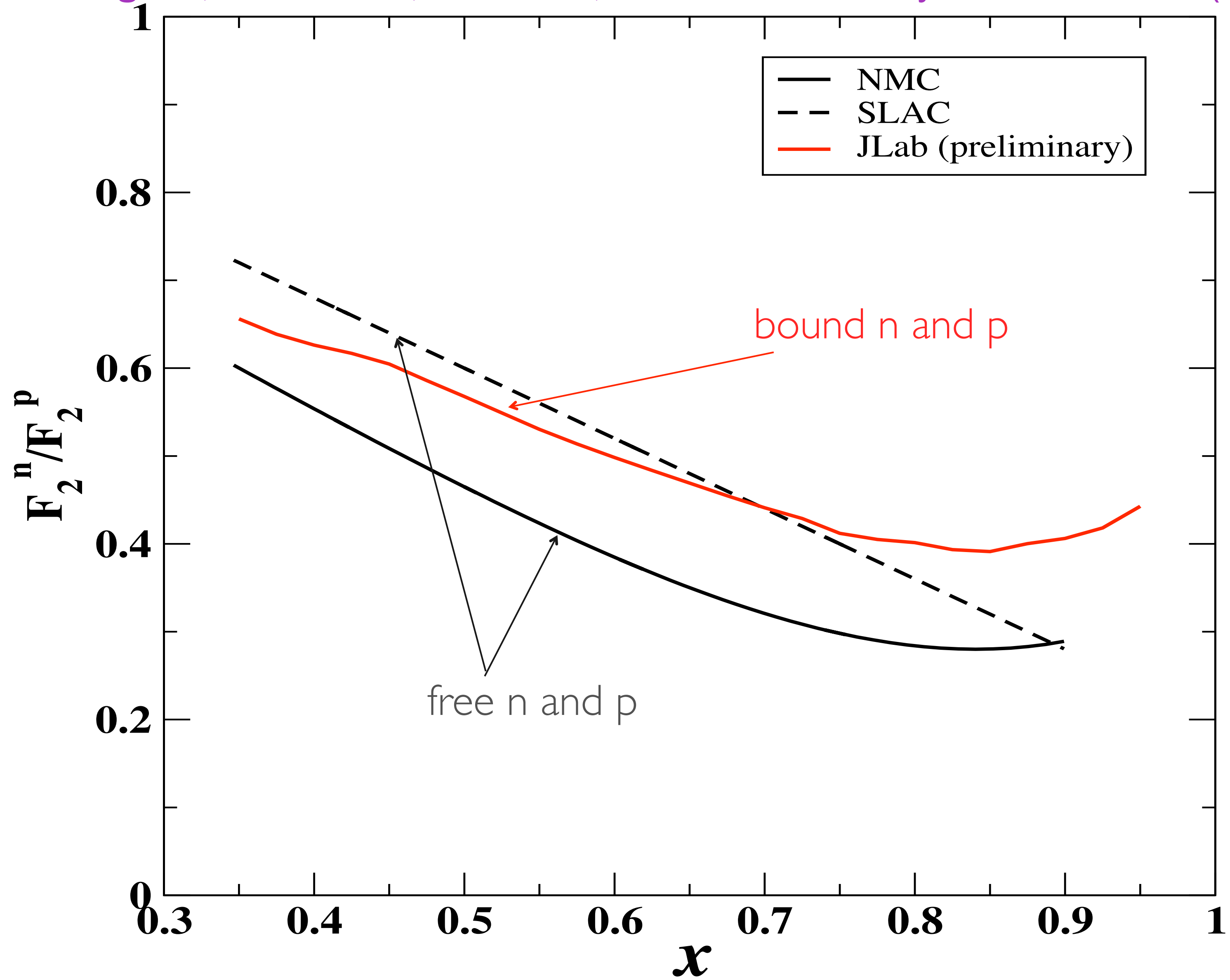
Smeared n/p at the kinematics of the experiment

vs.

high Q^2 free n/p

New extraction from

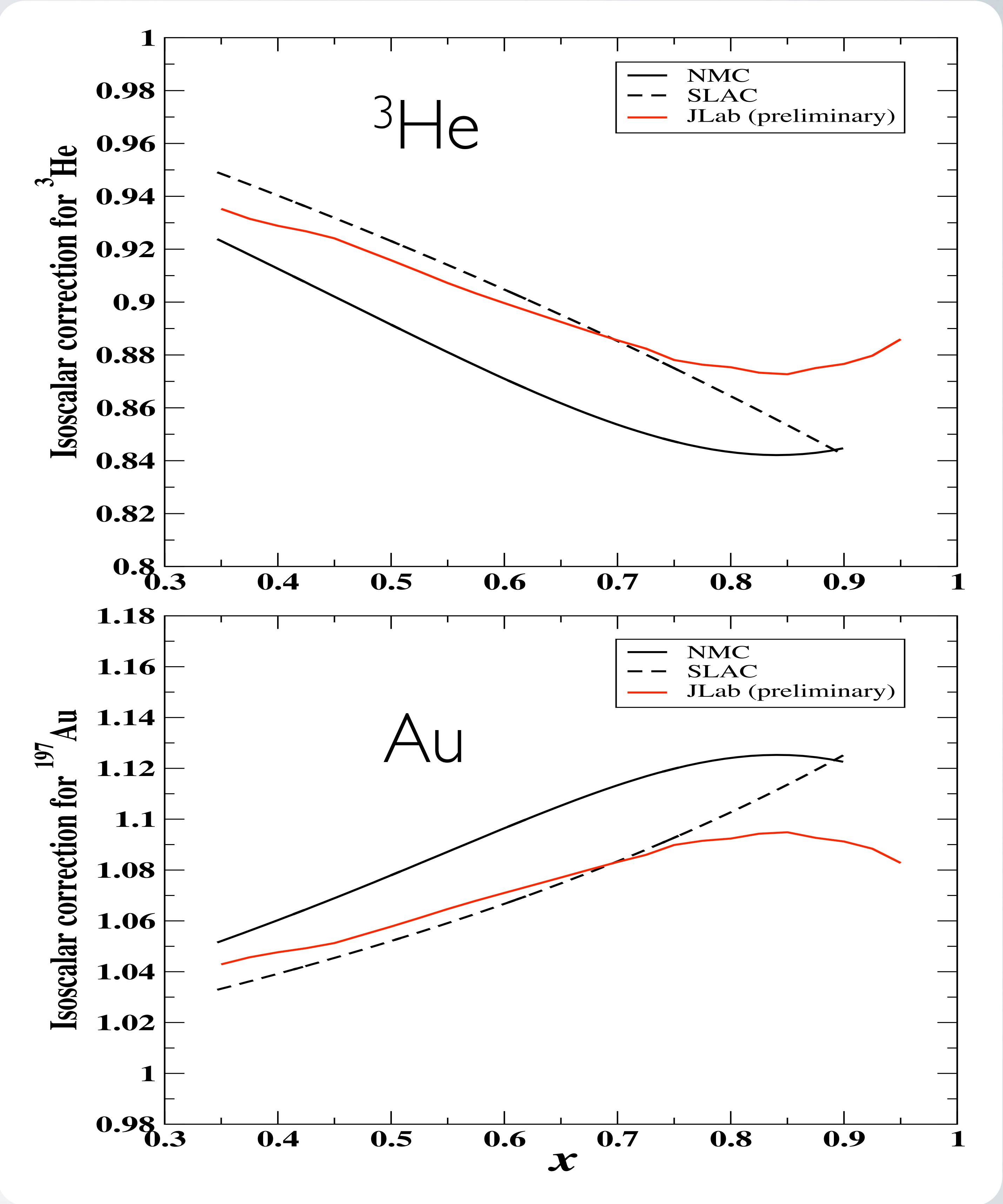
J. Arrington, F. Coester, R.J. Holt, T.-S.H. Lee, J.Phys.G36, 025005 (2009)



ISOSCALAR CORRECTION

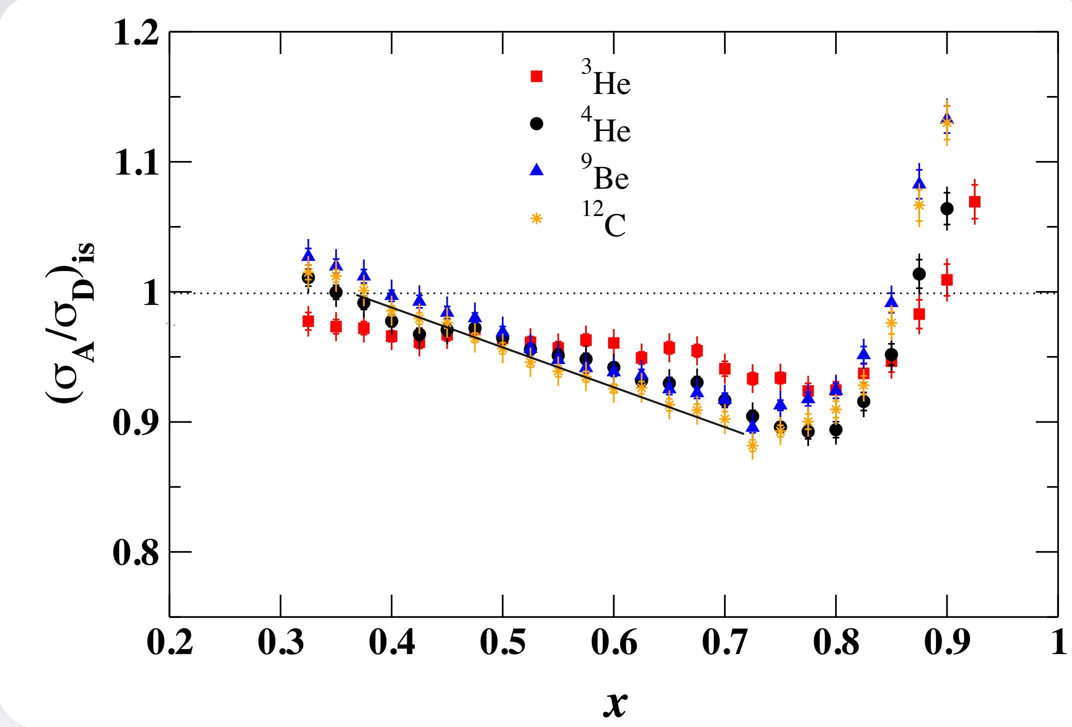
$$R_{EMC} = \frac{\sigma_2^A / A}{\sigma_2^D / 2} \cdot \boxed{\frac{(p+n)/2}{(Zp+Nn)/A}}$$

Isoscalar correction

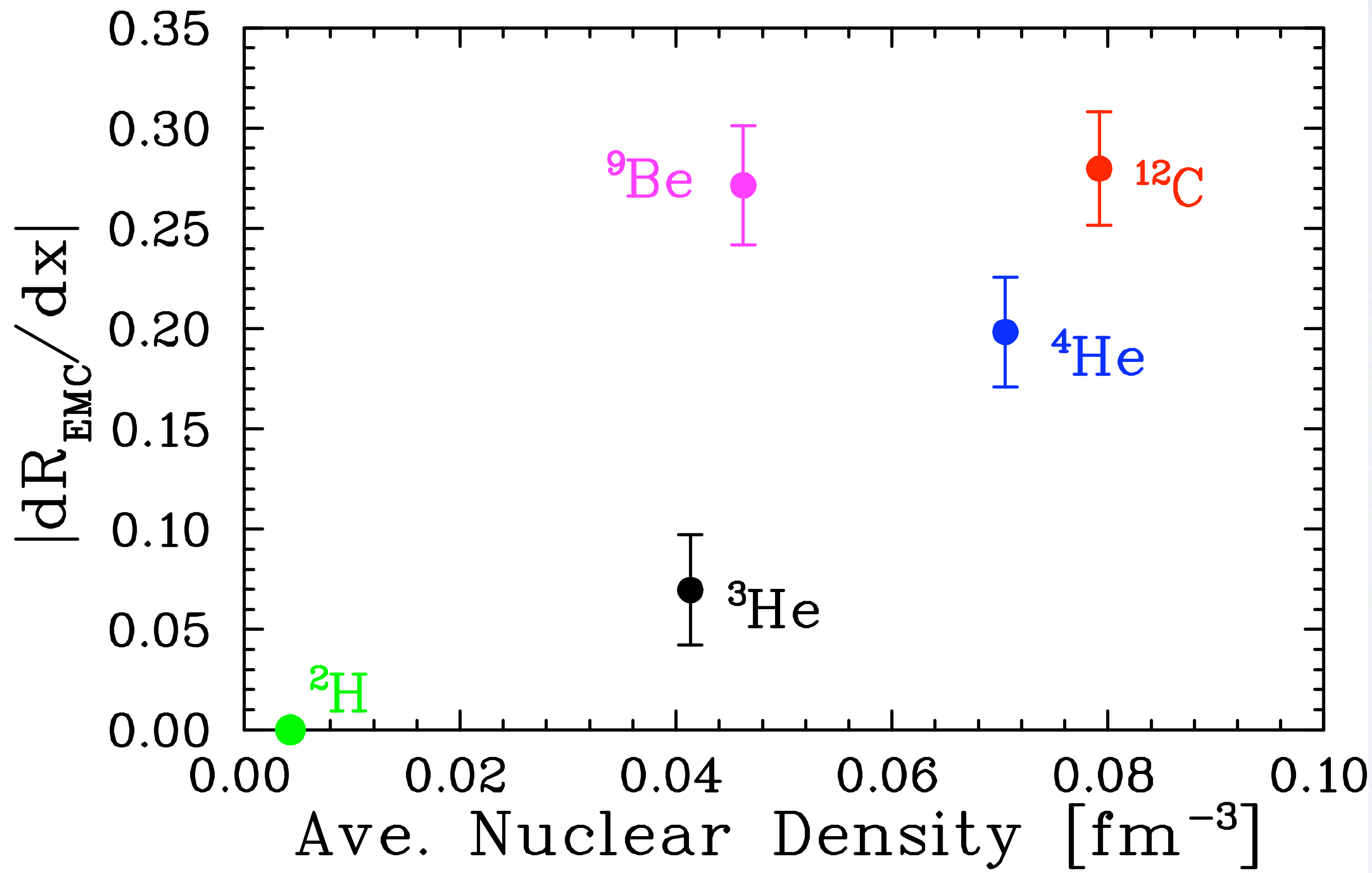


A OR ρ-DEPENDENCE ?

Fit of the EMC ratio for $0.35<x<0.7$ and look at A- and density dependence of the slope



J. Seely et al, PRL 103, 202301 (2009)



Density determined from ab initio few-body calculation

S.C. Pieper and R.B. Wiringa, Ann. Rev. Nucl. Part. Sci 51, 53 (2001)

To remove struck nucleon's contribution, scale density by (A-1)/A

Data show smooth behavior as density increases…

except for ^{9}Be