E03-103 – Study of Structure Functions in Light Nuclei

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XEM Collaboration Meeting

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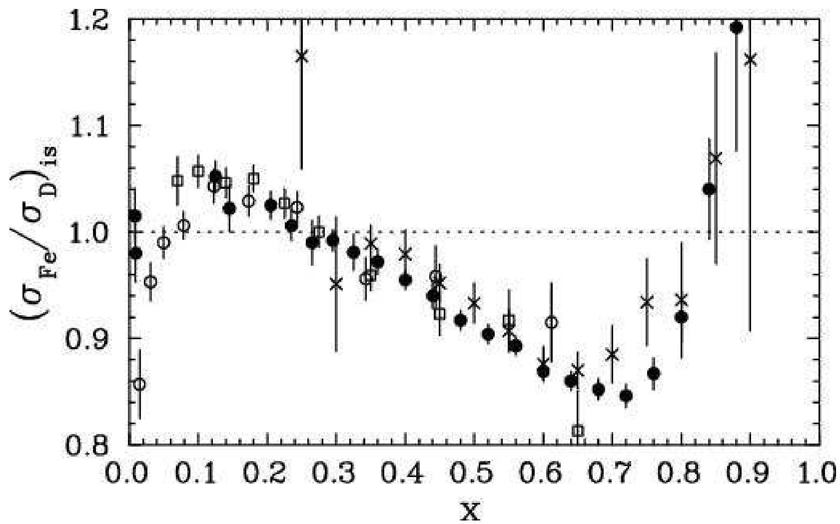
- The EMC Effect
- Models of the EMC Effect
- What can we add?

The EMC Effect

- Measurements of F_A^2 / F_D^2 (EMC, SLAC, BCDMS) demonstrate modification of quark distributions in nuclei
- Magnitude of effect depends on A, but not the shape



- Typically broken in 3 regions
  - -> x<0.1, shadowing
  - -> 0.1<x<0.3, small enhancement (nuclear pions?)
  - -> x>0.3, suppression -> "EMC Effect"
- Fourth region at x>0.7 -> ratio increases, crosses 1.0
  - Attributed to Fermi smearing

Explaining the EMC Effect

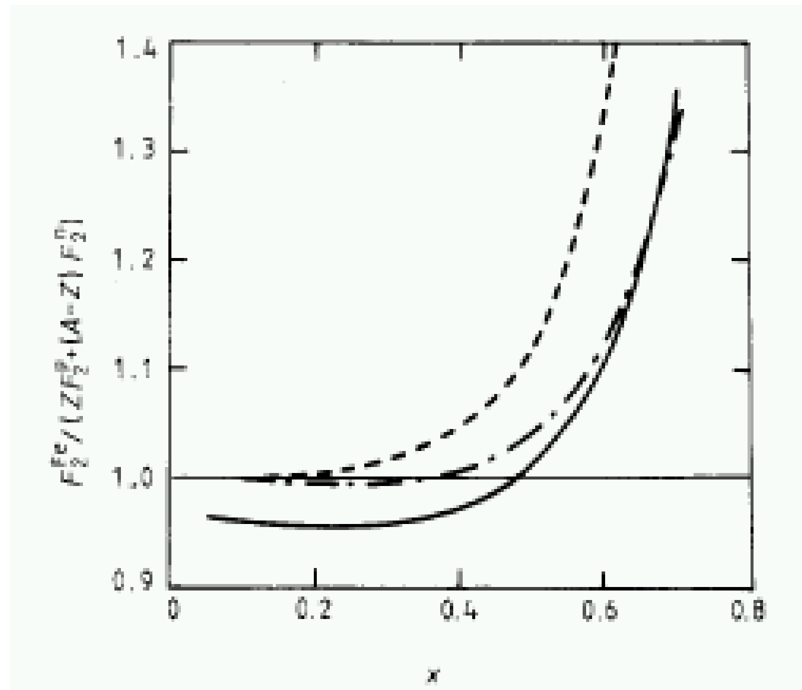
- Non-exotic models
  - Fermi motion -> reproduces large x rise
  - Binding
  - Fermi motion + binding + nuclear pions
- Exotic models
  - Multiquark clusters
  - Dynamical rescaling
- All of these models have varying degrees of success describing the EMC Effect in certain x regions – none can describe the effect in its entirety

Nucleon Fermi Motion

- Nuclear structure function modeled as a simple convolution of nucleon distribution and F_2

$$F_2^A(x) = \sum_i \int_x^{M_A/m_N} dy f_i(y) F_2^N(x/y)$$

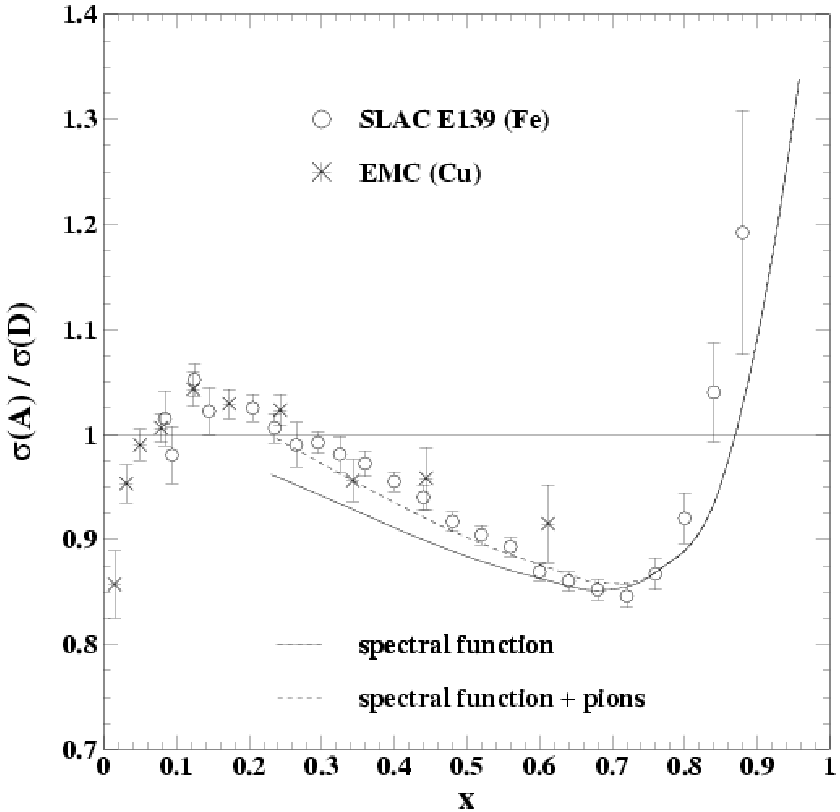
- Ignores binding effects – uses simple Fermi gas for description of nucleon momentum distribution



Bodek and Ritchie
PRD 23, 1070 (1981)

Nuclear Pions

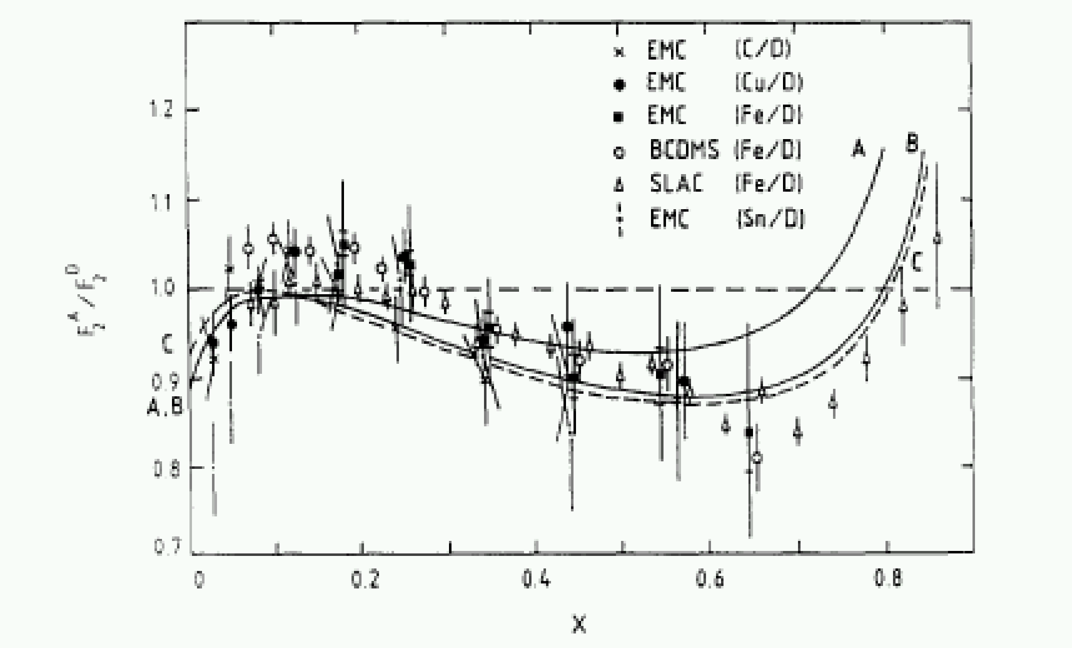
- Start with a "realistic" description of nucleons in the nucleus – use spectral function rather than simple Fermi gas
- Start with convolution picture – allow virtual photon to scatter from quarks in pions in the nucleus
- Fair agreement is achieved at large x – including nuclear pions improves agreement at lower x



$$F_2^A(x) = \int_x^1 dy f_N(y) F_2^N(x/y) + \int_x^1 dy f_\pi(y) F_2^\pi(x/y)$$

Multiquark Cluster Model

- Multiuark cluster model assumes that in nuclei, quarks may combine into clusters that include more than 3
- Nuclear structure function is then a convolution over contribution from nucleons (F_2^N) and 6-quark clusters (F_2^6)
- Requires $F_2^N \neq F_2^6$ to get an EMC effect



K.E. Lassila and U.P. Sakhatme
Phys. Lett. B209, 343 (1988)

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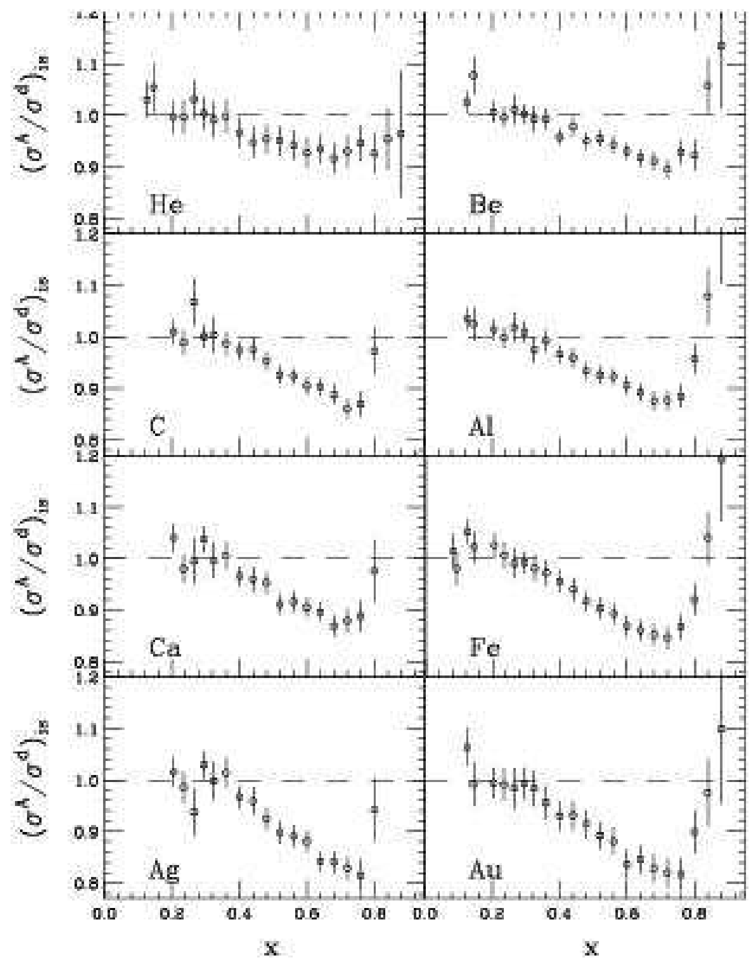
How do we improve our understanding of the EMC Effect?

- Clearly – there are many models on the market that describe some of the gross features of the EMC effect
- How do we sort out which ones are right?
- Clearly, "conventional" nuclear physics must play some role
  - "conventional" = nucleons/hadrons
- The challenge is to determine what part of the EMC Effect can be described using our "common sense" picture of the nucleus – then appeal to more exotic explanations to make up the difference

(Some) Existing Data

- SLAC E139 probably the most extensive data set
- Measured σ_A/σ_D for ^4He, ^9Be, ^{12}C, ^{27}Al, ^{40}Ca, ^{56}Fe, ^{108}Ag, and ^{197}Au
- Kinematics:
  - Q^2=2,5 GeV^2 for x<0.3
  - Q^2=2,5,10 GeV^2 for 0.3<x<0.5
  - Q^2=5,10 GeV^2 for x>0.5

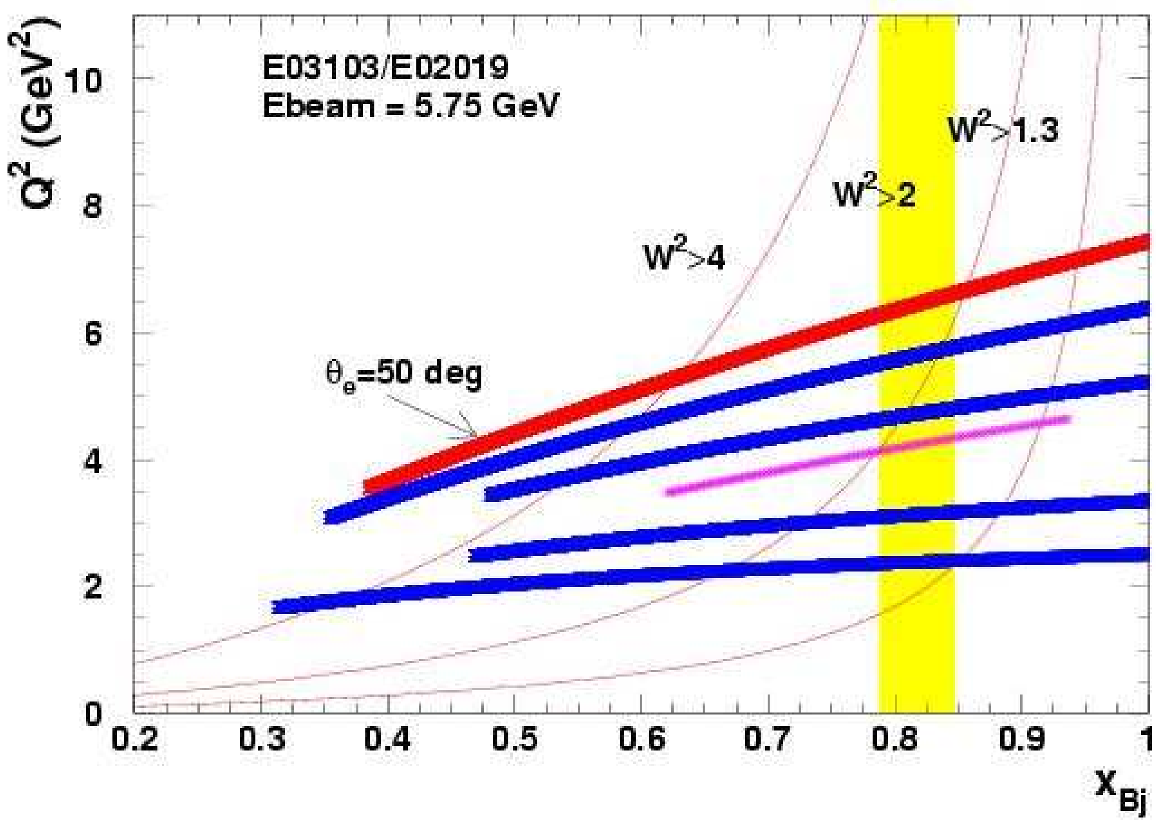


SLAC E139

Avenues for Further Experimental Study

- Measure the EMC Effect on very light nuclei (3He, 4He)
  - "Exact" nuclear wave functions exist – no need for simple Fermi gas calculations
  - Determine whether the EMC Effect depends on *A* or ρ
- Measure the EMC Effect at large x
  - This region is thought to be dominated by Fermi smearing and conventional nuclear physics effects
  - Precise data will constrain this "conventional" component of models – put limits on exotic effects at low x

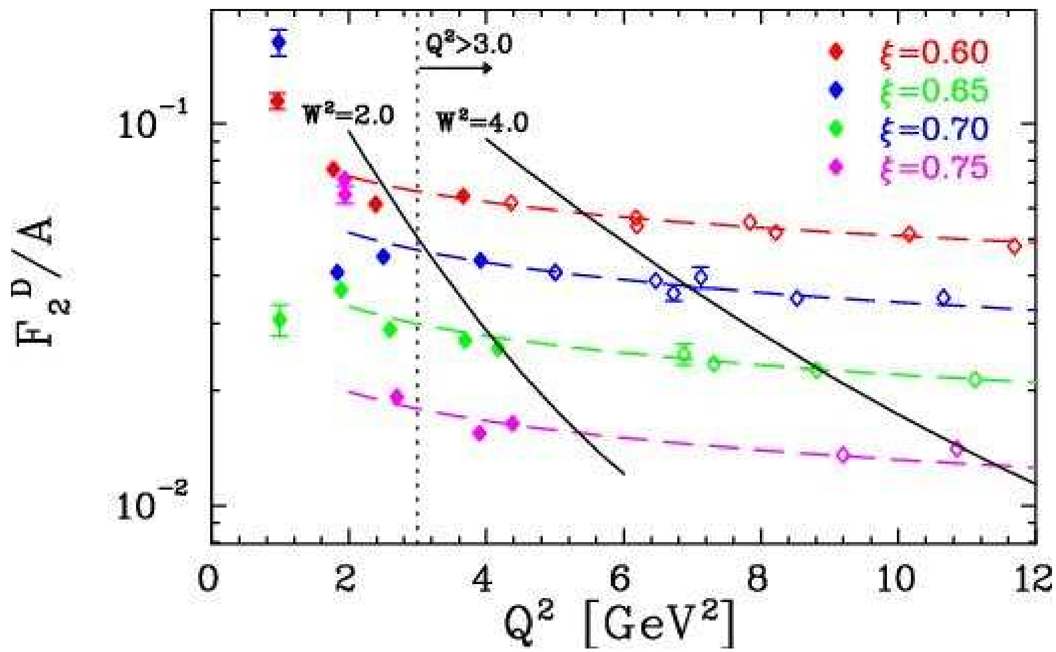
E03103



- Took data on H, 2H, 3He, 4He, 9Be, 12C, 27Al, 63Cu, and 197Au at 18-50 degrees
- $W^2>2$ GeV^2 will allow us to extract EMC ratios up to x=0.8

"Scaling" at W<2 GeV

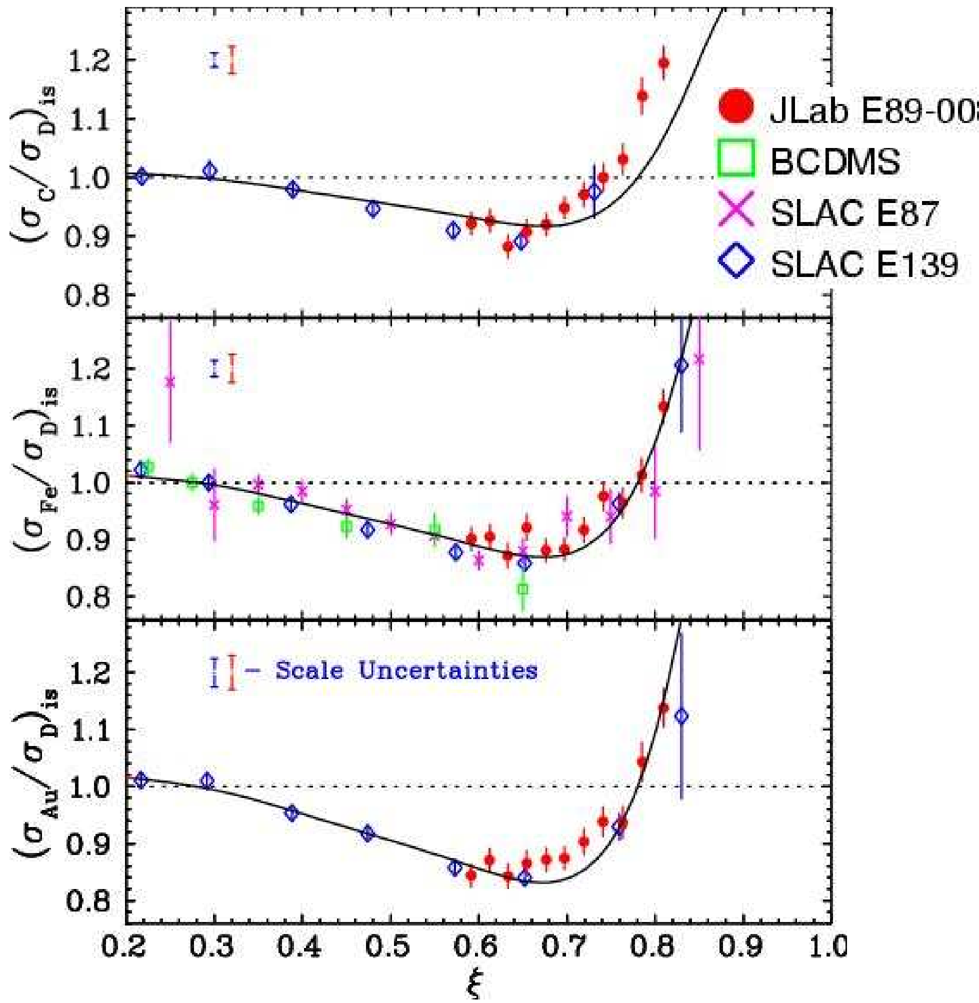
- Even at 4 GeV, see small deviations from scaling for $W^2>2$ GeV^2
- 6 GeV E03103 data has $W^2>2$ up to x=0.85 at larger Q^2
  - $W^2>4$ GeV^2 up to x=0.62



E89008 – 4 GeV

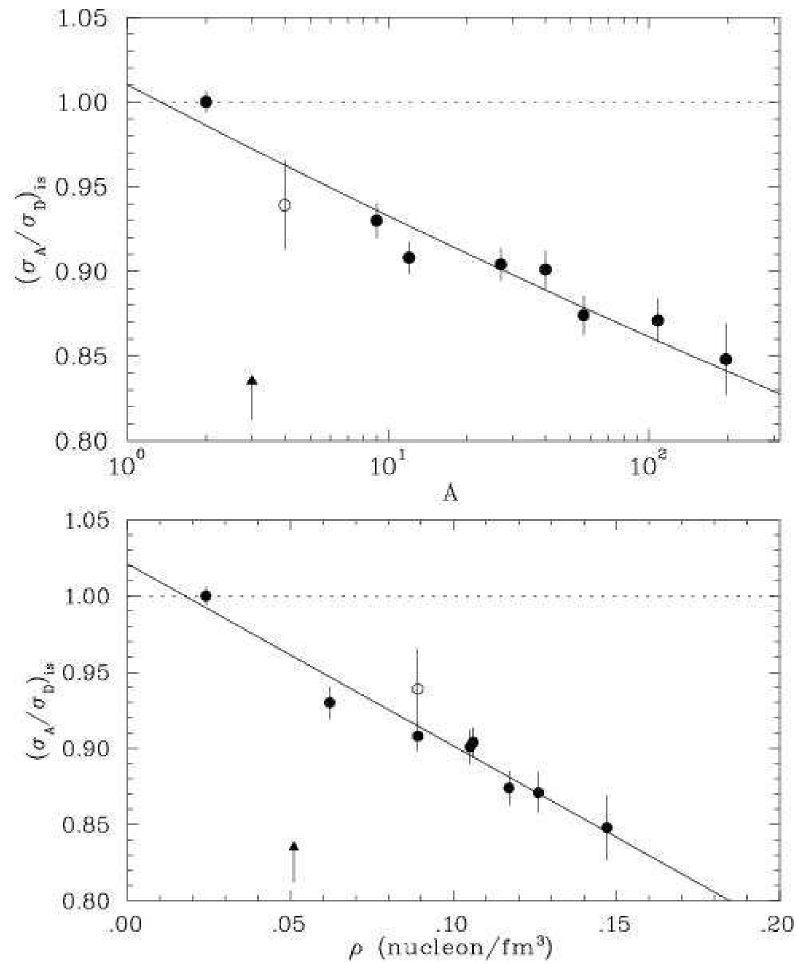
EMC Measurements at 4 GeV

- EMC ratio extracted using resonance region data from E89008
  - $1.2<W^2<3.0$ GeV^2 at $Q^2\approx 4$ GeV^2
- Where there is overlap, JLab resonance data agrees well with SLAC (DIS) results
- The large x region is found to be A dependent -> crossover shifts to larger x (ξ) as A increases

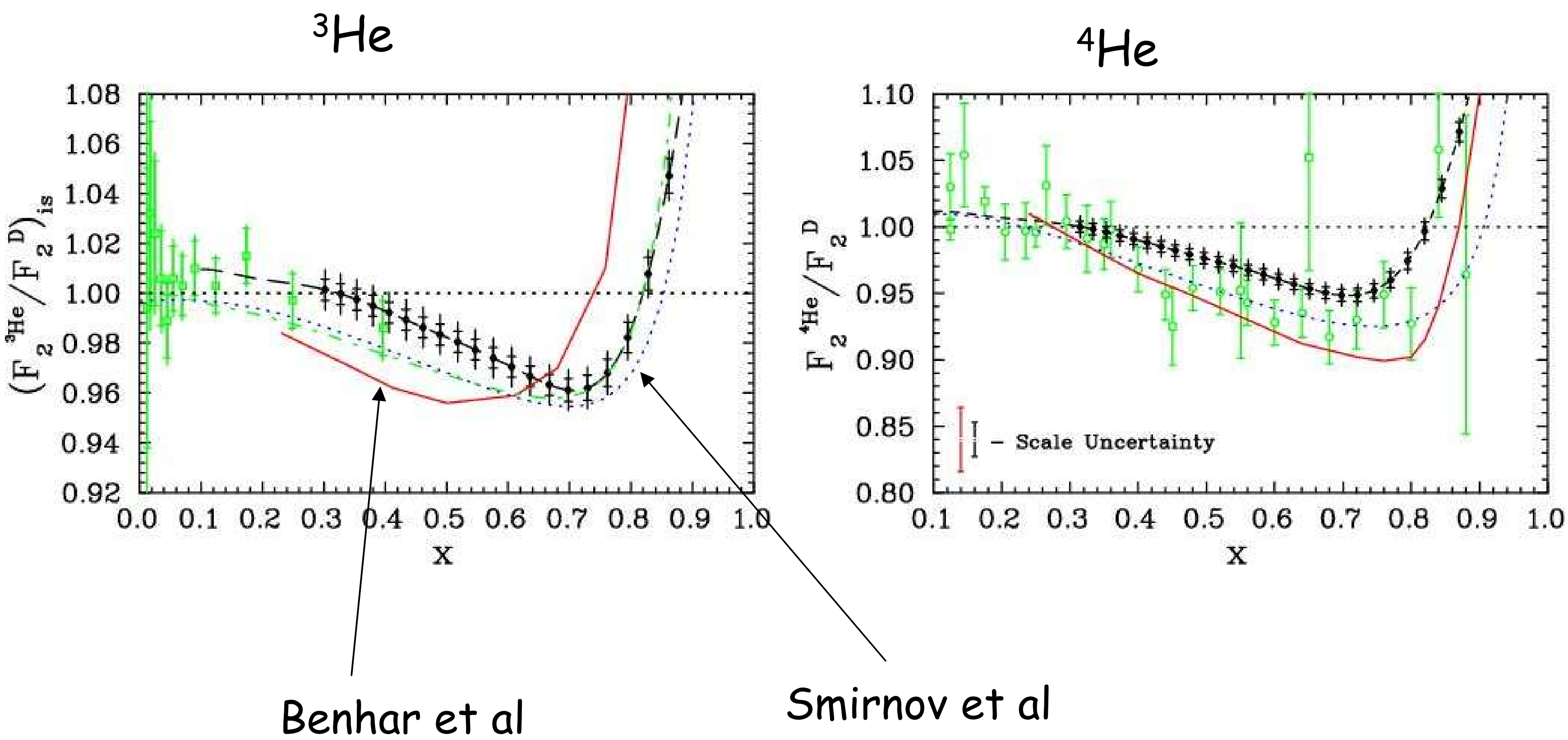


A-Dependence

- ^{4}He very sensitive to distinguishing between A dependence and ρ dependence of EMC Effect
- Existing data lacks precision
- ^{3}He will add further constraint



Projected Uncertainties on ^{3}He and ^{4}He



Conclusions

- Measurement of EMC Effect in light nuclei and at large x will provide precise constraints on "conventional" nuclear physics calculations
- In particular, exact wave functions for ^3He and ^4He will reduce ambiguity often caused by simplifying assumptions required to do these calculations
- Although conventional effects are thought to dominate at large x, they likely play a significant role at small x
- Only after understanding these effects can we start to look for new physics