Precise Measurement of Nuclear Dependence of Structure Functions in Light Nuclei

(JLab expt E03-103 ; Spokepersons: John Arrington and Dave Gaskell)

For the E03-103 collaboration

Aji Daniel

University of Houston.

Thesis advisor: Ed V. Hungerford

Outline

- Introduction
- JLAB experiment E03-103
- Work in progress
- Summary

The EMC Effect

- Energy scale of DIS interactions (GeV). Energy scale of nuclear processes (MeV) ⇨ result doesn't depend on nuclear target.
  (not true!!!)

- Measurements of F_2^A/F_2^D (EMC, SLAC, BCDMS) have demonstrated modification of quark distributions in nuclei.

EMC- CERN 1982
SLAC- 1994
BCDMS-CERN 1987

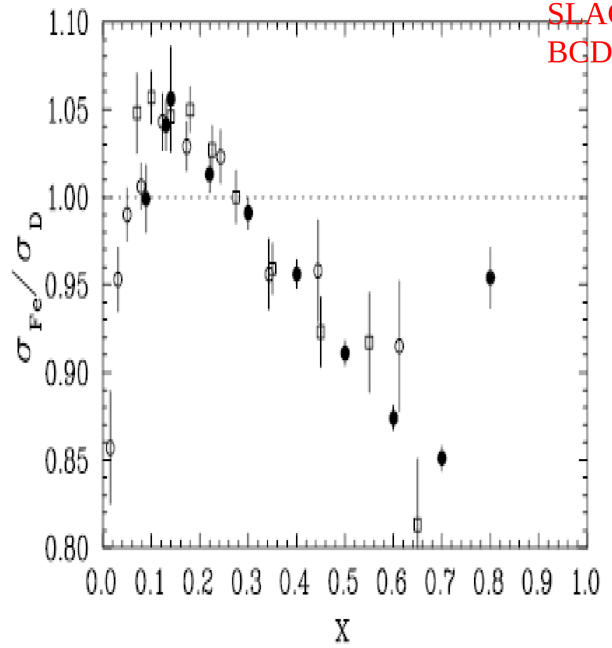


Figure 1: $(\sigma_{Fe}/\sigma_{2H})$ ratios as a function of x from EMC (hollow circles), SLAC (solid circles), and BCDMS (squares). The data have been averaged over Q^2 and corrected for neutron excess.

The EMC Effect

- The nuclear EMC effect shows that quark distribution is different in nuclear systems

- Magnitude depends on A but shape more or less same.

- Several models, but valid only in certain kinematical regions.

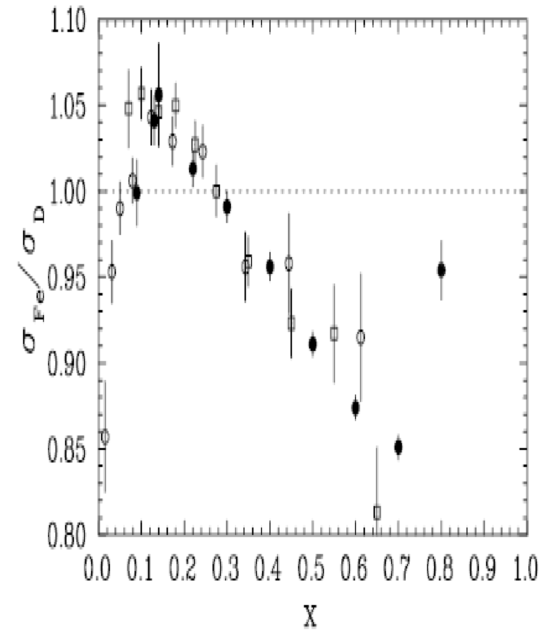
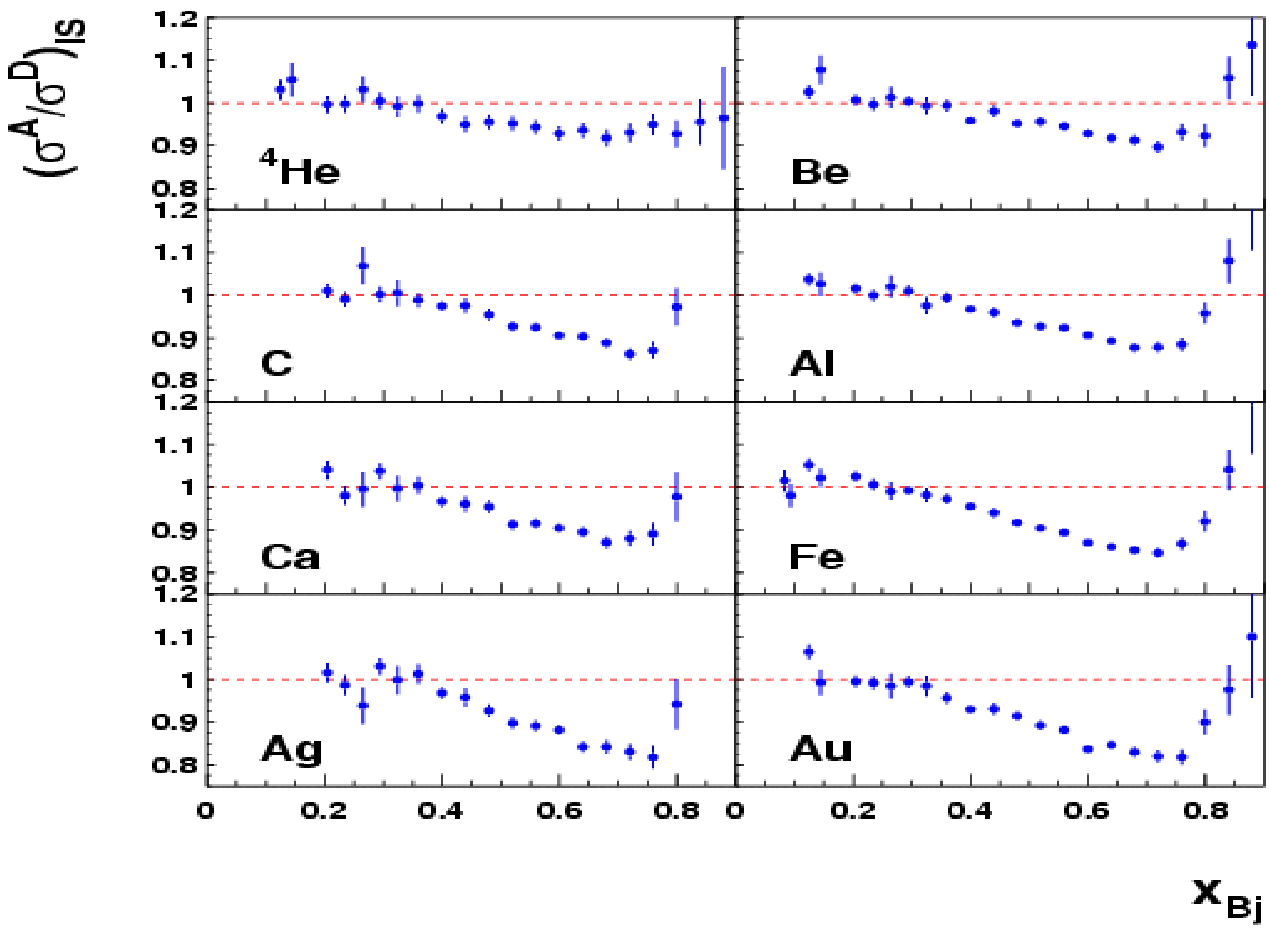


Figure 1: $(\sigma_{Fe}/\sigma_{^2H})$ ratios as a function of x from EMC (hollow circles), SLAC (solid circles), and BCDMS (squares). The data have been averaged over Q^2 and corrected for neutron excess.

The EMC Effect

- EMC effect has been measured for many targets and over a large kinematic range

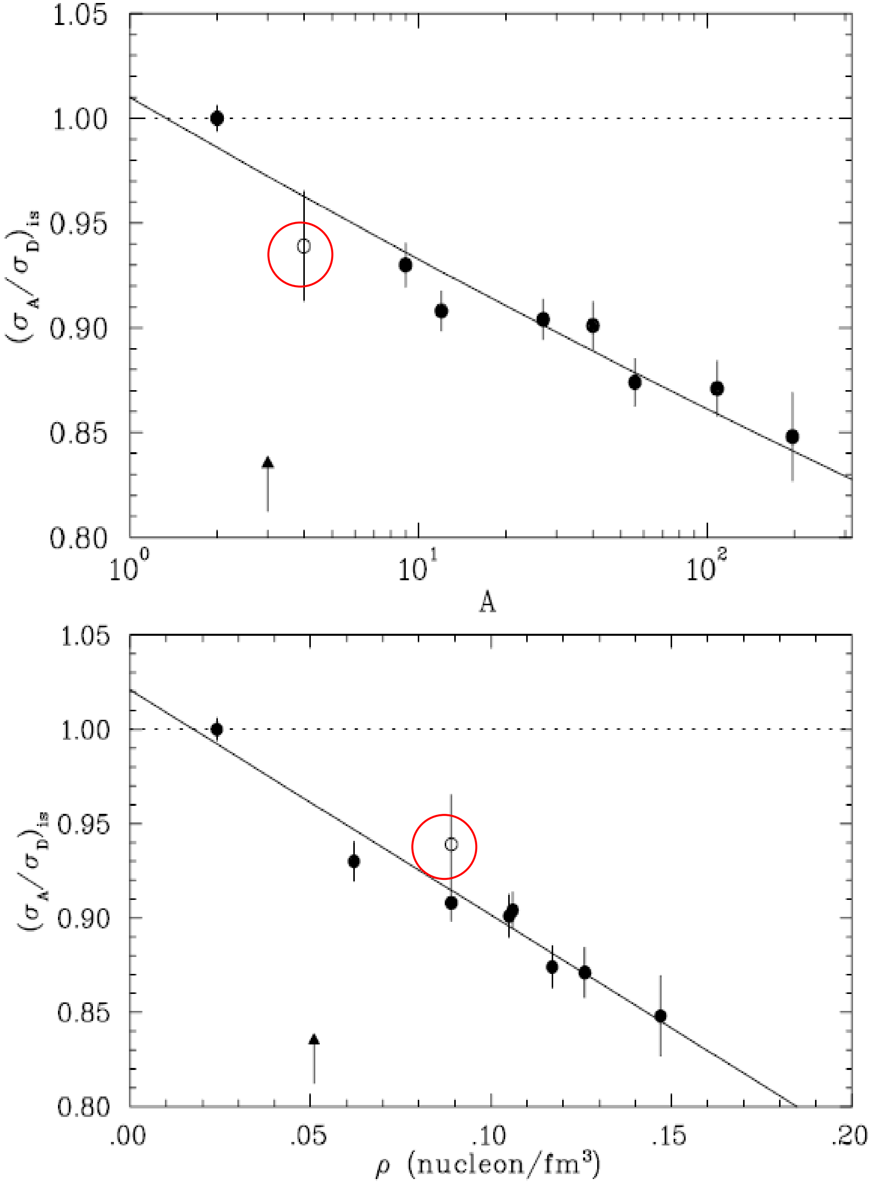


Extensive measurements on heavy targets

SLAC E139

The EMC Effect

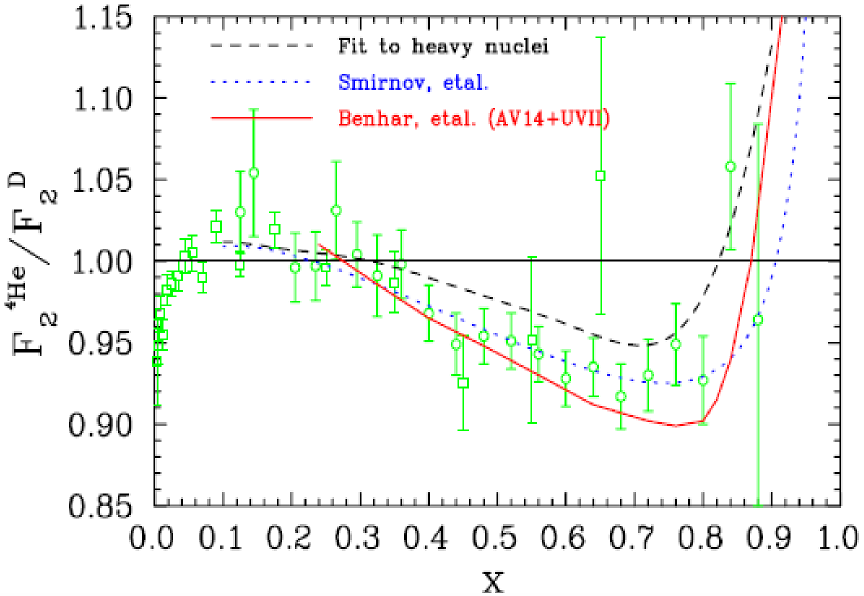
- Ratios can be parameterized as log(A) or linear density dependence
- $^4He/D$ is more sensitive , but uncertainty is large for existing data and consistent with both parameterizations
- Addition of ^3He data will impose new constraints on the parameterization

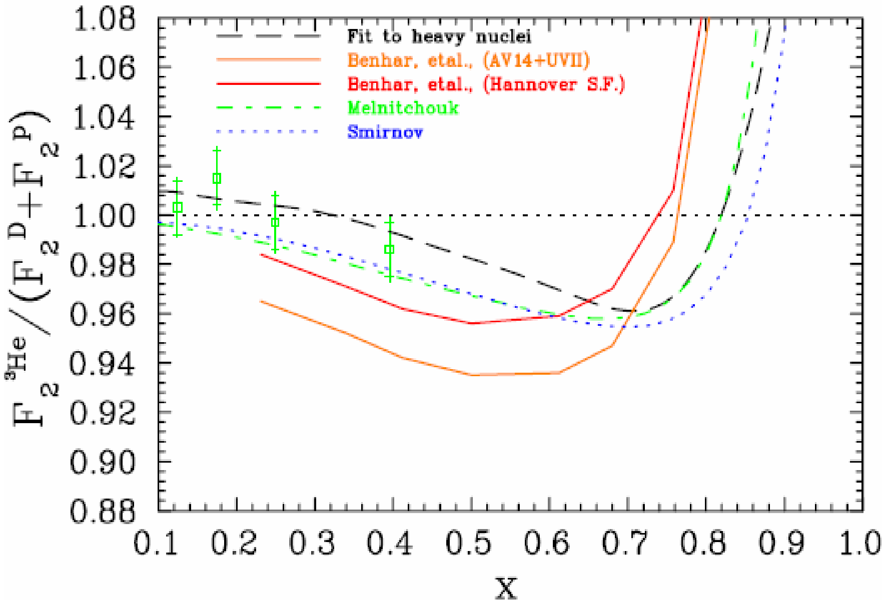


The EMC Effect

- For heavy nuclei magnitude of EMC effect varies with A but shape more or less same.
- Observed x dependence in ^{4}He consistent, but uncertainties are large.
- Recent predictions ⟶ size and magnitude may be different for light nuclei

(point of maximum suppression and cross over of ratio at large x)





Experiment

E03-103 @ JLAB

- Inclusive electron scattering from cryo targets ^{1}H, ^{2}H, ^{3}He, ^{4}He and solid targets Al, C, Be, Cu , Au over a broad range of kinematics.
- Precise measurement on ^{4}He, over SLAC E139.
- First measurement of EMC effect on ^{3}He for $x > 0.4$
- Test models of the EMC effect in “exact” few-body calculations.
- Guidance for calculations of nuclear effects in deuterium.
- Information on the neutron structure function.

Experiment

E03-103 @ JLAB

Source	Absolute Uncertainty	Relative Uncertainty	$\delta\sigma/\sigma(\%)$	$\delta R/R(\%)$ point-to-point	$\delta R/R(\%)$ scale	$\delta R/R$ (%) Statistical
HMS Momentum	<0.1%	0.01%	0.2	-	-	
Beam Energy	<0.1%	<0.02%	0.2	0.1	-	
θ	0.5mr	0.2mr	0.1	0.1	0.1	
t_D	0.5%		0.5	-	0.5	
t_{He}	1.0%		1.0	-	1.0	
Charge	0.4%	0.3%	0.5	0.42	0.2	
Target Boiling	<1.0%	0.5%	<1.0	0.3	0.3	
Endcap Subtraction	<1.0%	0.2%	<1.0	0.1	0.1	
Acceptance	1.0-2.0%	0.2%	1.0-2.0	0.2	-	
Radiative Corrections	2.0%	0.5%	2.0	0.3	0.4	
Detector Efficiency	0.5%	0.2%	0.5	0.2	-	
Deadtime Correction	<0.5%	0.2%	<0.5	0.1	0.2	
Total			2.7-3.3	0.7%	1.3	0.5-0.7
E139			3.3-3.7	1.6%	2.2	1.0-2.2

Table 4: Systematic uncertainties in the ratio $\sigma_{He}/\sigma_{^2H}$, compared to E139 uncertainties (for ^{4}He).

Experiment

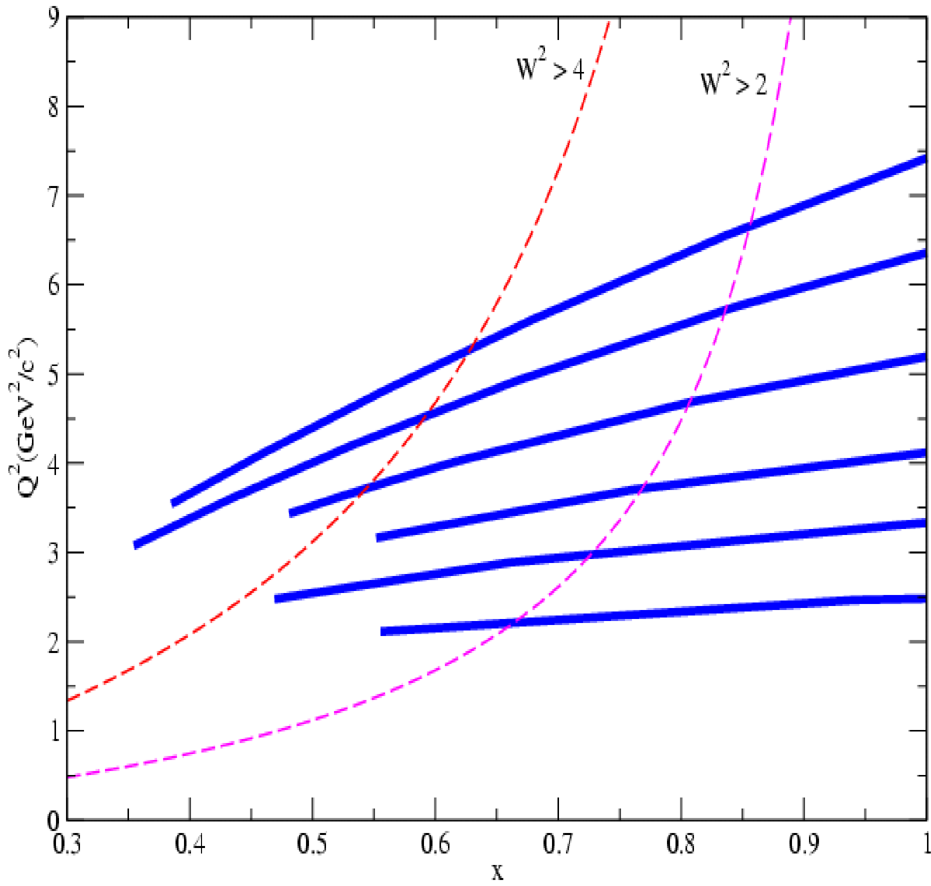
E03-103 @ JLAB

- Ran last summer and fall along with E02-019 at HALL C of Jlab with 5.77 GeV beam energy.
- Increased beam current (due to improvement in target cooling system) allowed for extensive background and elastic studies.
- Data on

Cryo targets ^3He, ^4He, LD_2,LH_2

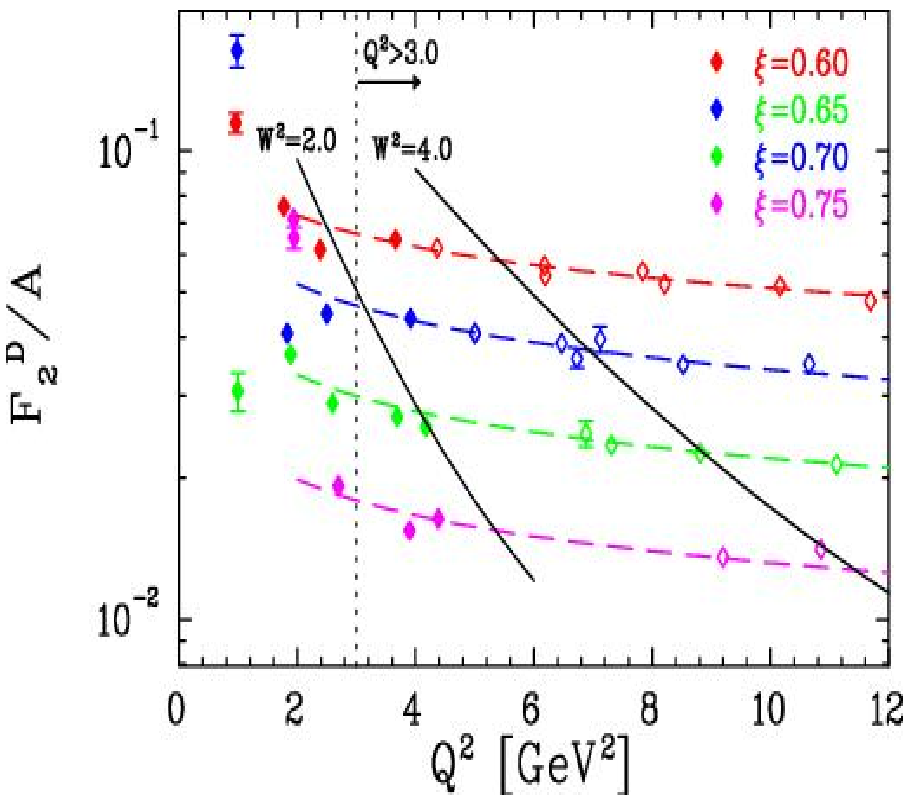
Solid targets Al, C, Be, Cu ,Au

at 18, 22, 26, 32, 40 and 50 degrees

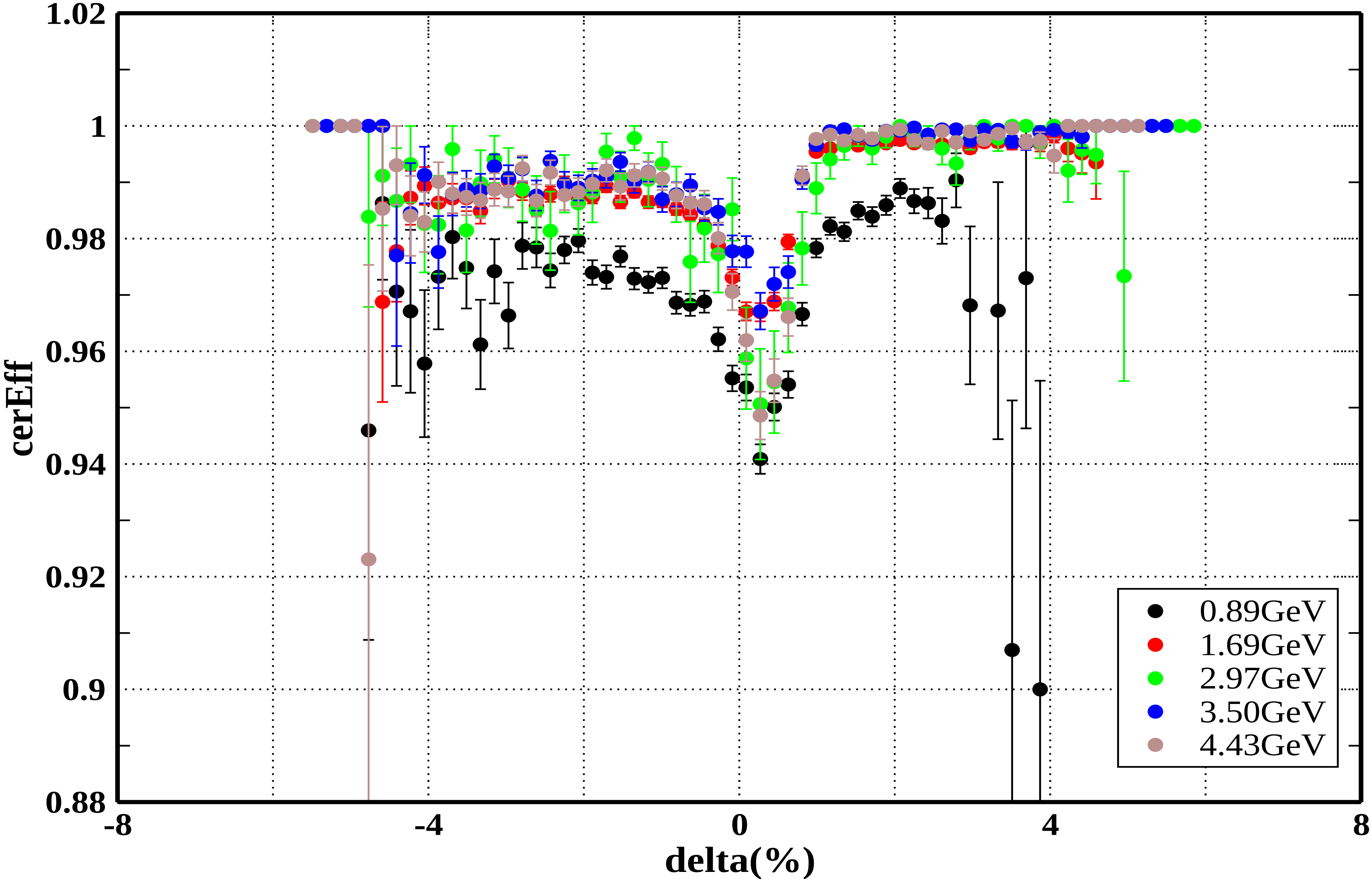


EMC effect at large x

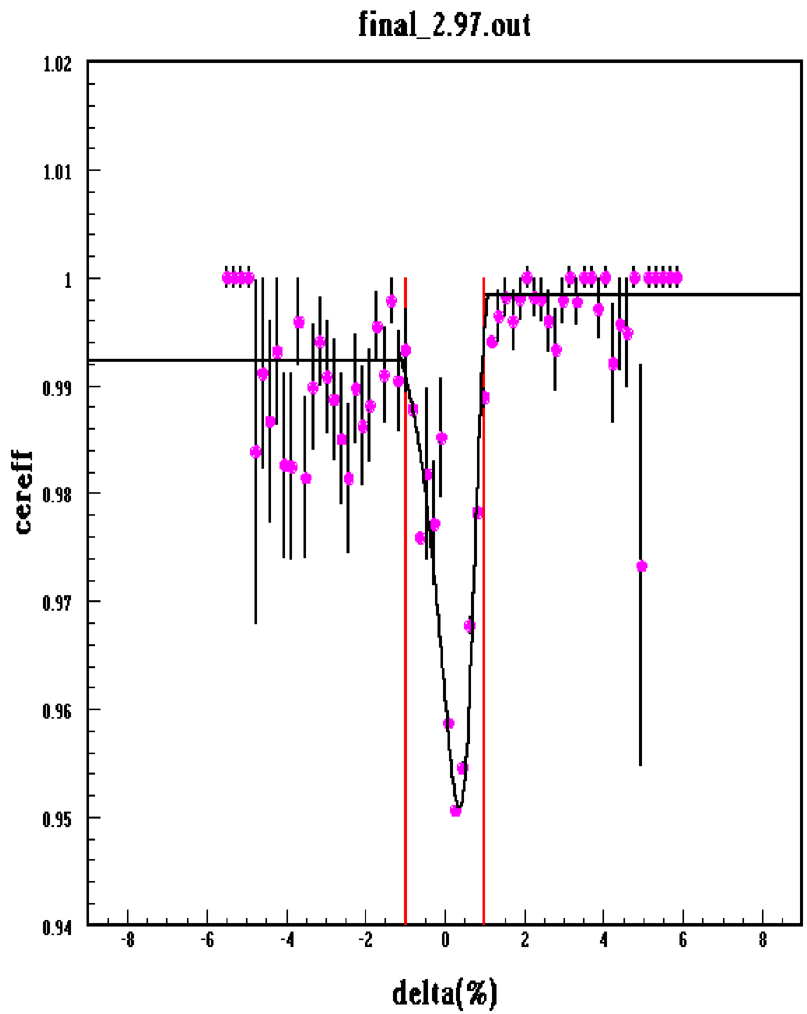
- For x>0.6, E03-103 data at W<4 GeV (resonance region)
- Recent data from JLab suggest that even in the resonance region inclusive cross sections scale.
- Hall C data (E89-008) taken at 4 GeV, sees no apparent deviation (at the 10% level) from scaling for $W^2>2\ GeV^2$ (for $Q^2 > 3\ GeV^2$)

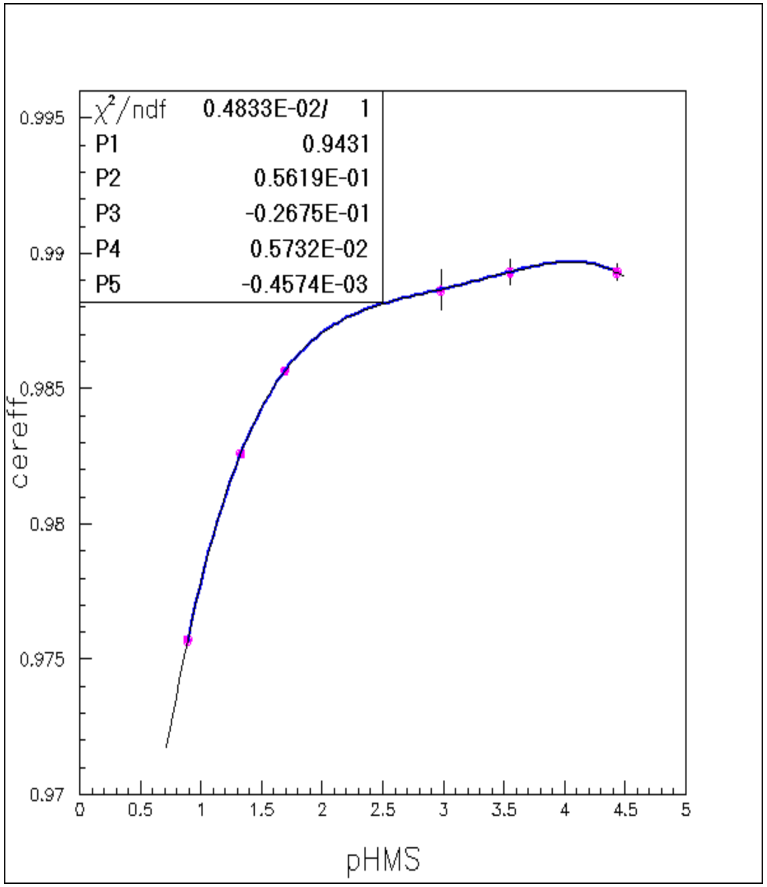


Analysis

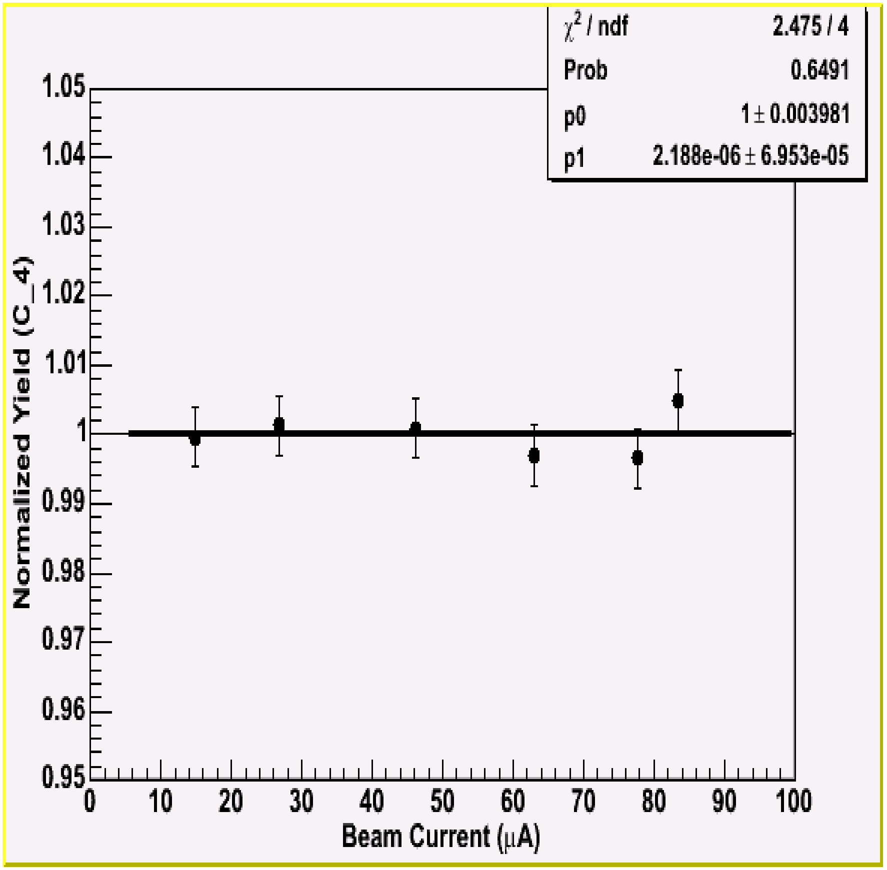

1.02
1
0.98
0.96
0.94
0.92
0.9
0.88
-8
-4
0
4
8
cerEff
delta(%)
0.89GeV
1.69GeV
2.97GeV
3.50GeV
4.43GeV

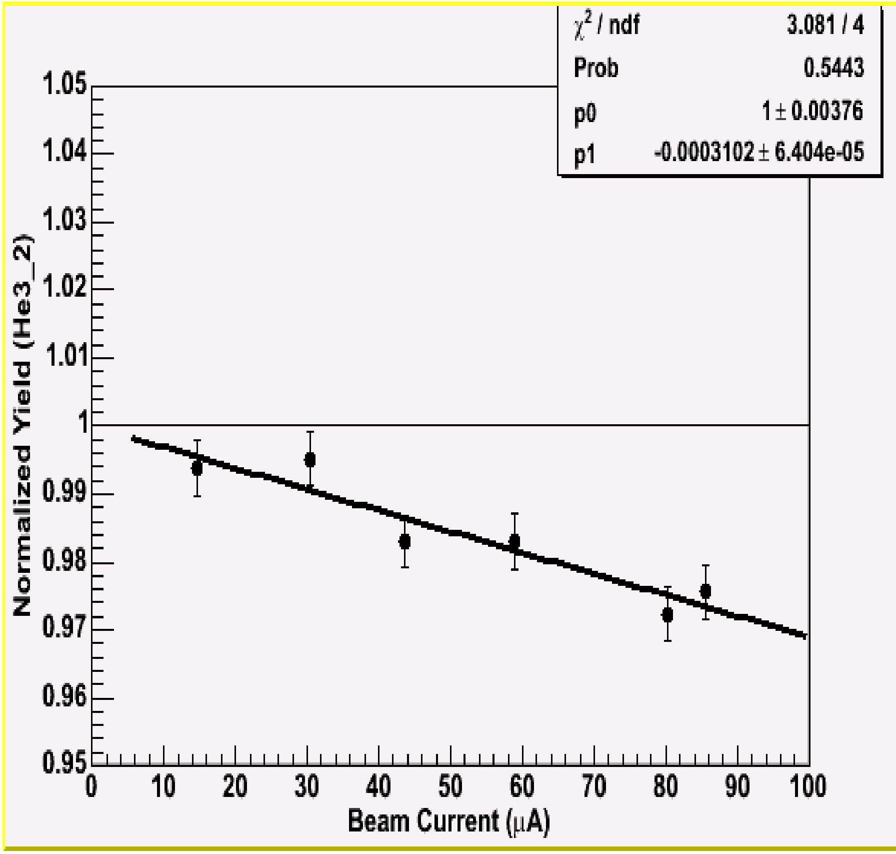
Analysis
Cerenkov efficiency correction





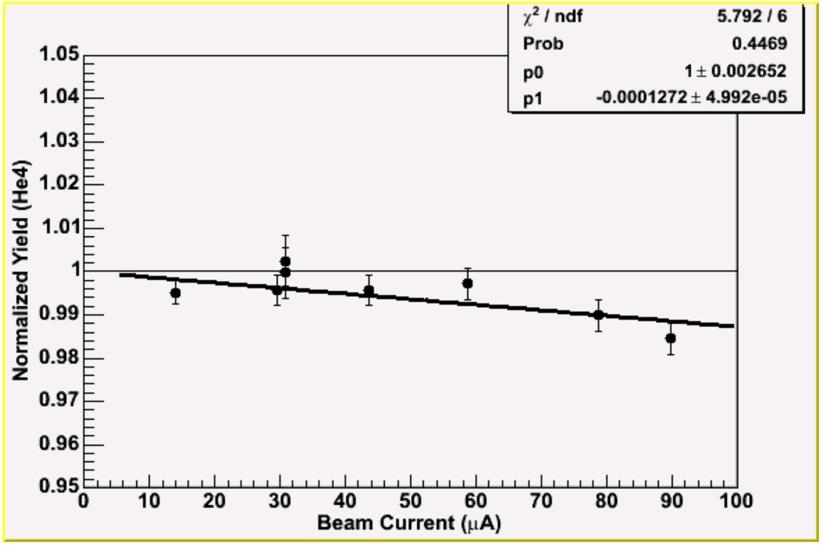
Analysis
Luminosity scan

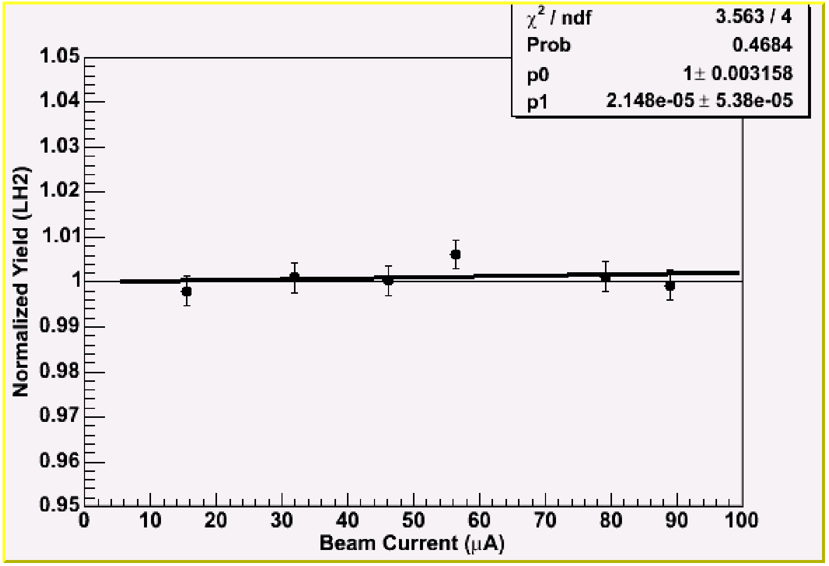


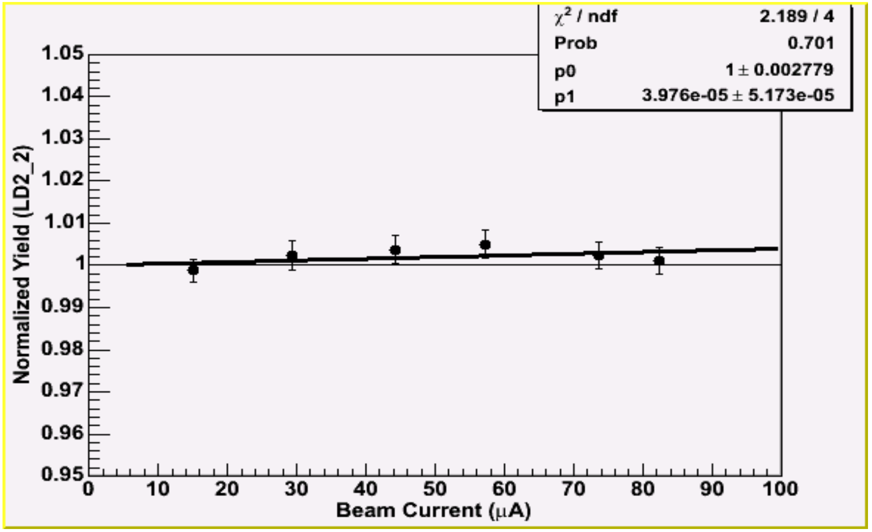


Jason

Analysis
Luminosity scan

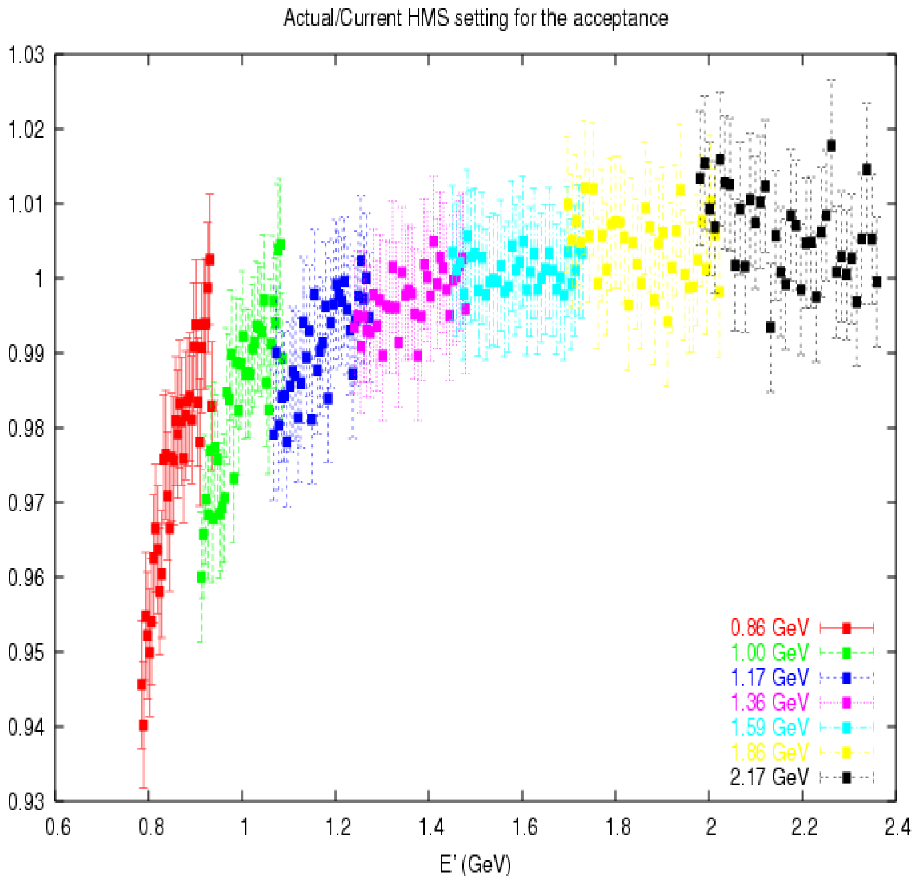


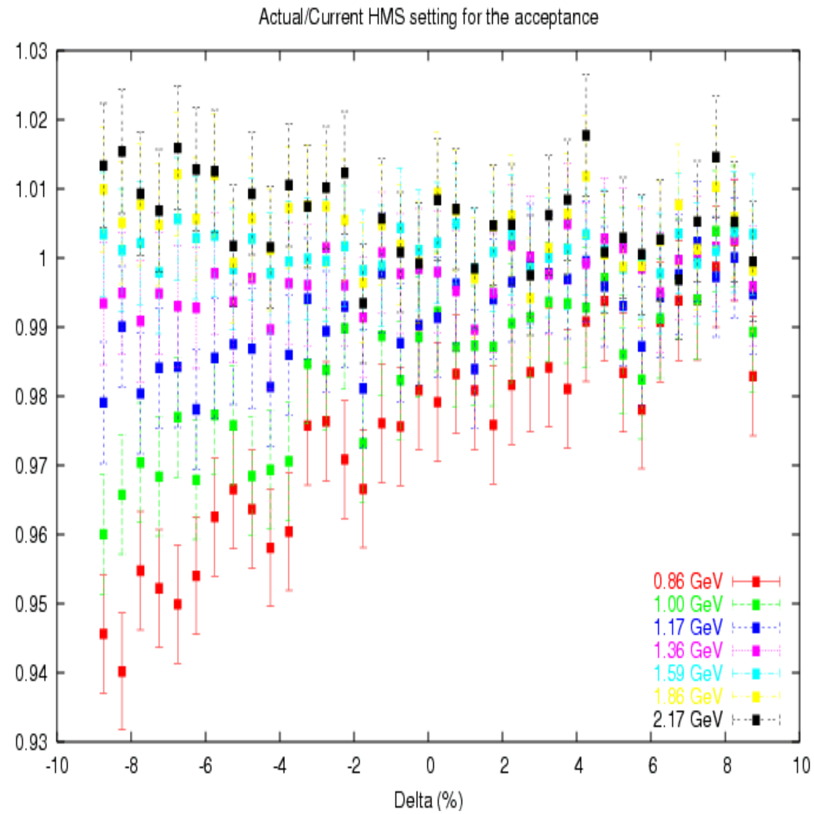




Jason

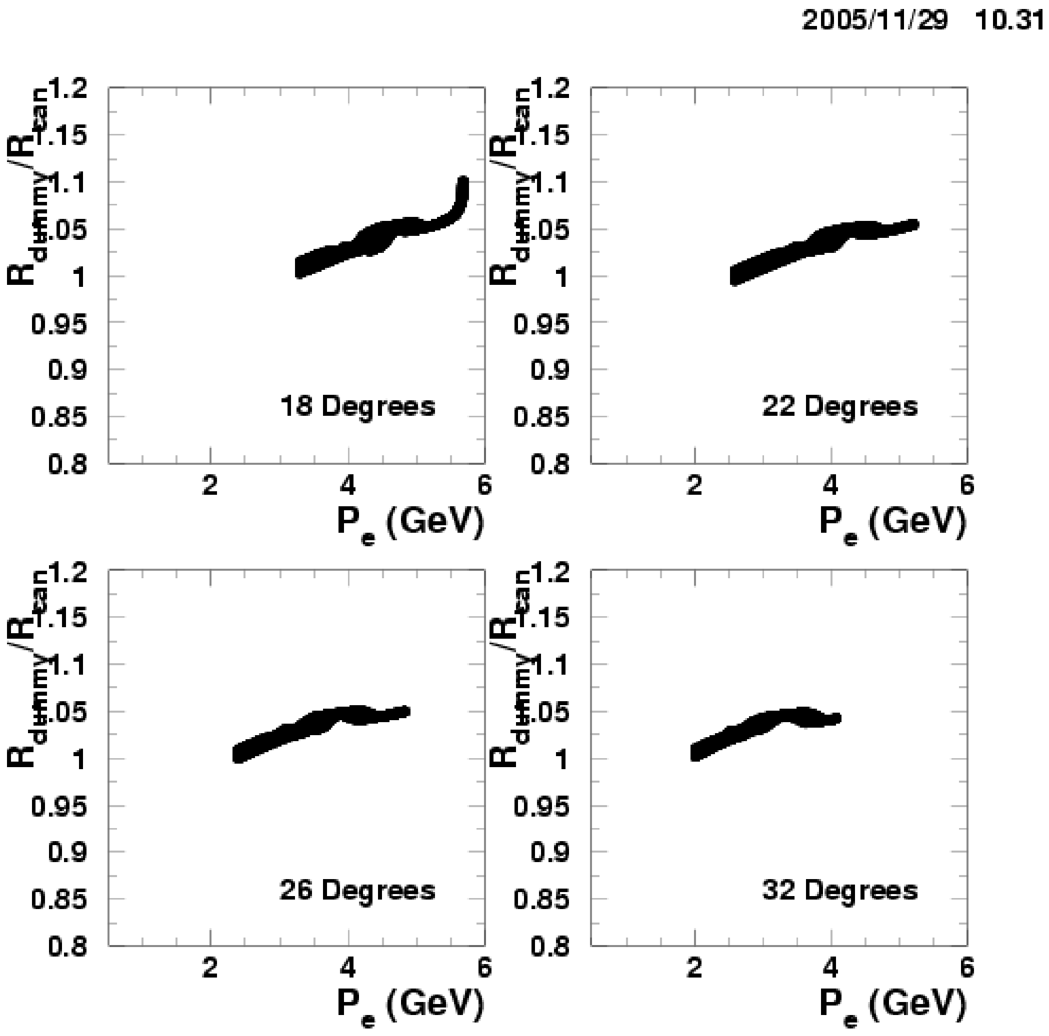
Analysis
Acceptance correction:- multiple scattering





Nadia

Analysis
External radiative corrections

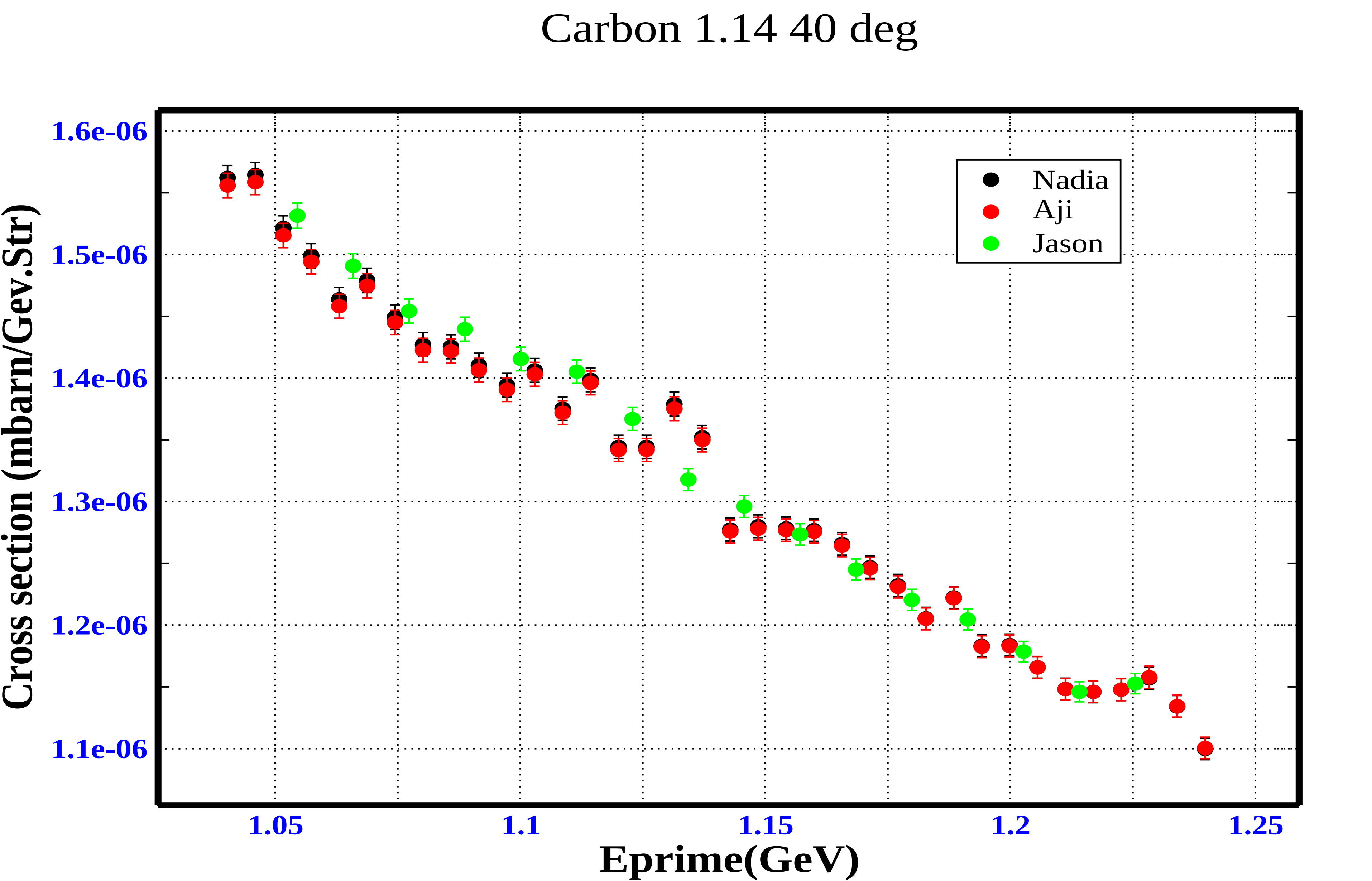


External radiative corrections are different for the dummy target than for the cryotarget walls

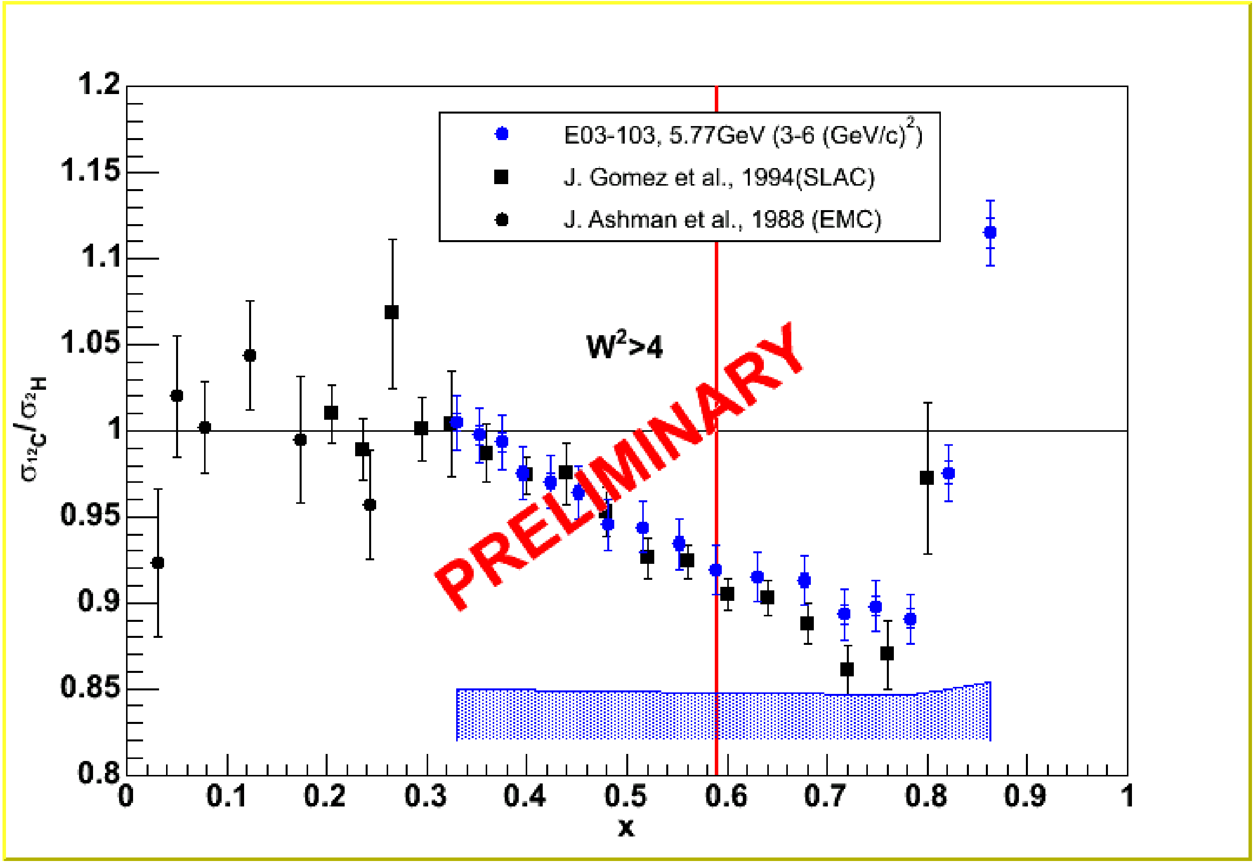
$$R^{ext} = R_d \Big/ R_{cryo}$$

Dave

Comparison:


Carbon 1.14 40 deg
Nadia
Aji
Jason
1.6e-06
1.5e-06
1.4e-06
1.3e-06
1.2e-06
1.1e-06
Cross section (mbarn/Gev.Str)
1.05
1.1
1.15
1.2
1.25
Eprime(GeV)

Analysis
Preliminary ratios:- Carbon

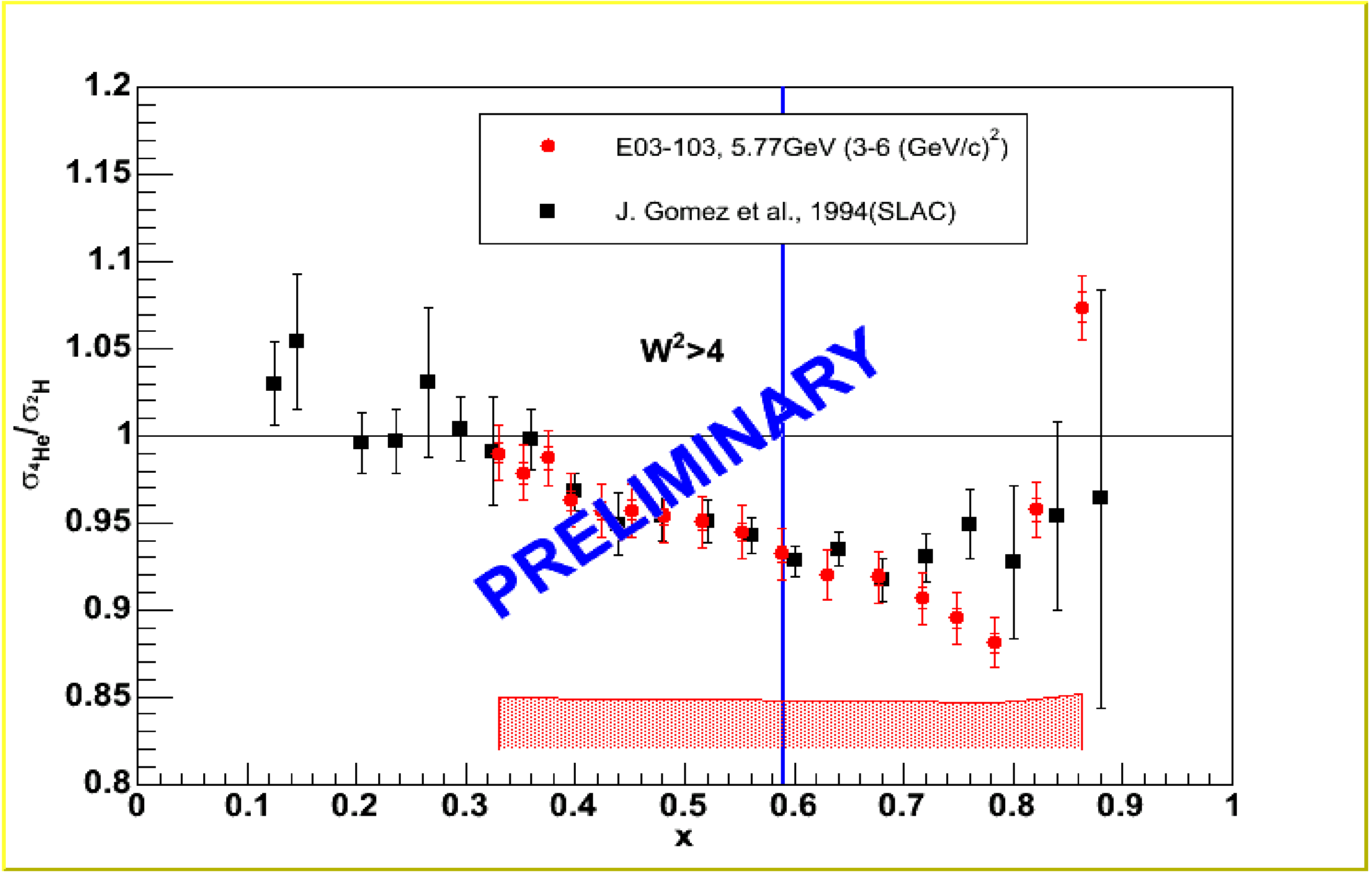


includes1.5% point-to-point systematic uncertainty

3% normalization uncertainty (target thickness, radiative and bin centering corrections)

Jason

Analysis
Preliminary ratios:-He4



Jason

To do

- Acceptance corrections at low momentum need to be worked out
- Need to iterate input model for bin centering and radiative corrections
- Need to study variation of beam position, beam angle
- Need to include Coulomb corrections

Summary

- Study of the EMC effect in light nuclei will help us to distinguish between models and impose new constraints

- E03-103 will increase the precision of ^{4}He ratios, and will be the first precise measurement for ^{3}He at $x>0.4$

- E03-103 data at $W<4$ GeV and $x>0.6$ (resonance region) allows to study EMC effect at large x

- Analysis well underway and data processing almost complete

E03-103 Collaboration

J. Arrington (spokesperson), L. El Fassi, K. Hafidi, R. Holt,
D.H. Potterveld, P.E. Reimer, E. Schulte, X. Zheng
Argonne National Laboratory, Argonne, IL

B. Boillat, J. Jourdan, M. Kotulla, T. Mertens, D. Rohe, G. Testa,
R. Trojer
Basel University, Basel, Switzerland

B. Filippone
California Institute of Technology, Pasadena, CA

C. Perdrisat
College of William and Mary, Williamsburg, VA

D. Dutta, H. Gao, X. Qian
Duke University, Durham, NC

W. Boeglin
Florida International University, Miami, FL

M.E. Christy, C.E. Keppel, S. Malace, E. Segbefia, L. Tang,
V. Tvaskis, L. Yuan
Hampton University, Hampton, VA

G. Niculescu, I. Niculescu
James Madison University, Harrisonburg, VA

P. Bosted, A. Bruell, V. Dharmawardane, R. Ent, H. Fenker,
D. Gaskell (spokesperson), M.K. Jones, A.F. Lung, D.G. Meekins, J. Roche, G. Smith,
W.F. Vulcan, S.A. Wood
Jefferson Laboratory, Newport News, VA

B. Clasie, J. Seely
Massachusetts Institute of Technology, Cambridge, MA

J. Dunne
Mississippi State University, Jackson, MS

V. Punjabi
Norfolk State University, Norfolk, VA

A.K. Opper
Ohio University, Athens, OH

H. Nomura
Tohoku University, Sendai, Japan

M. Bukhari, A. Daniel, N. Kalantarians, Y. Okayasu, V. Rodriguez
University of Houston, Houston, TX

F. Benmokhtar, T. Horn
University of Maryland, College Park, MD

D. Day, N. Fomin, C. Hill, R. Lindgren, P. McKee, O. Rondon,
K. Slifer, S. Tajima, F. Wesselmann, J. Wright
University of Virginia, Charlottesville, VA

R. Asaturyan, H. Mkrtchyan, T. Navasardyan, V. Tadevosyan
Yerevan Physics Institute, Armenia

S. Connell, M. Dalton, C. Gray
University of the Witwatersrand, Johannesburg, South Africa