Preliminary Results on H(e,e’) and D(e,e’) Cross Sections from an Early 12 GeV Hall C Experiment at Jefferson Lab: E12-10-002

Simona Malace

Jefferson Lab

Outline

- Expected physics output:

  → constraints for PDF global fits

  → quark-hadron duality studies and push to get the theory community to pursue a fundamental understanding of the phenomenon

  → non-singlet moments to higher Q^2

  → modeling of resonance and deep inelastic scattering process

- Analysis:

  → experimental setup and kinematic coverage

  → detector performance

  → analysis highlights

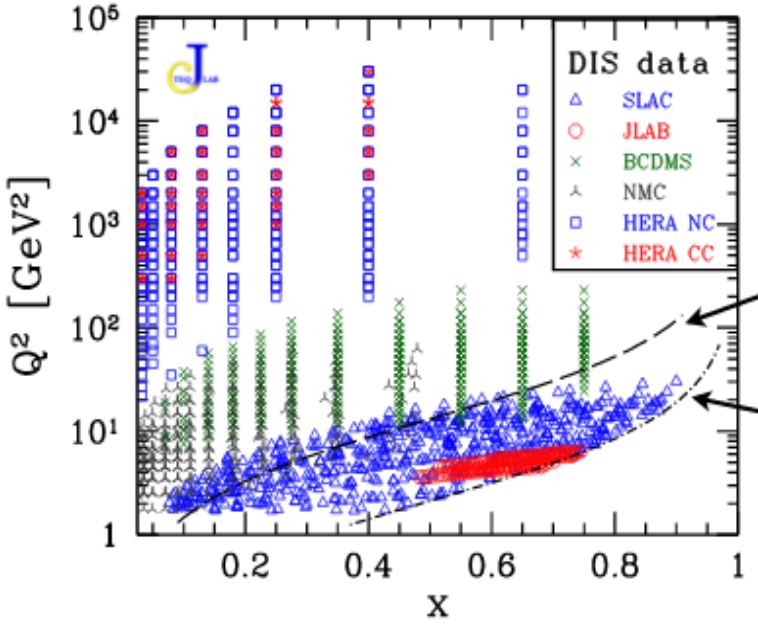
- Preliminary results:

  → cross sections and D/H ratios

Constraints for PDFs

Theory-experiment Collaboration: CTEQ-Jefferson Lab Collaboration

- Performs global QCD fits of PDFs from data including deep-inelastic lepton-nucleon scattering, proton-proton collisions (lepton pair creation, W-boson and jet production), etc., **with particular focus on the large-x region**



Kinematic cut of almost all other PDF analyses before CJ

$W^2 > 12.25$ GeV^2

$W^2 > 3$ GeV^2

CJ cut includes more data at large x

- Include non-perturbative corrections: data with low W are used
- Include nuclear corrections: **use of deuterium data** requires careful treatment of **nuclear corrections**

Constraints for PDFs

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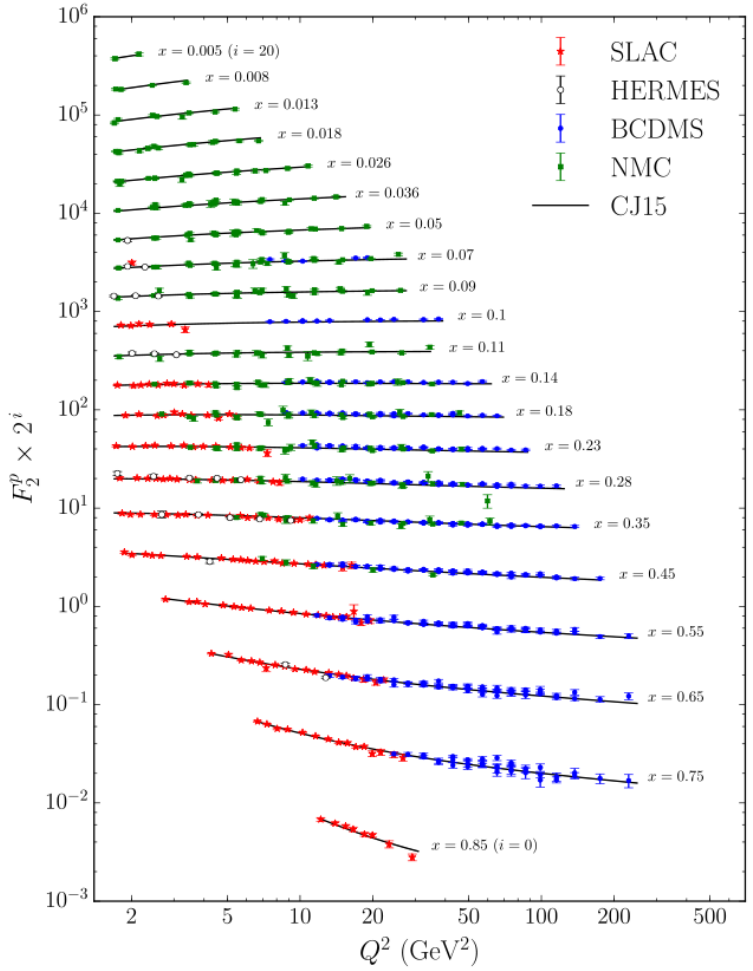
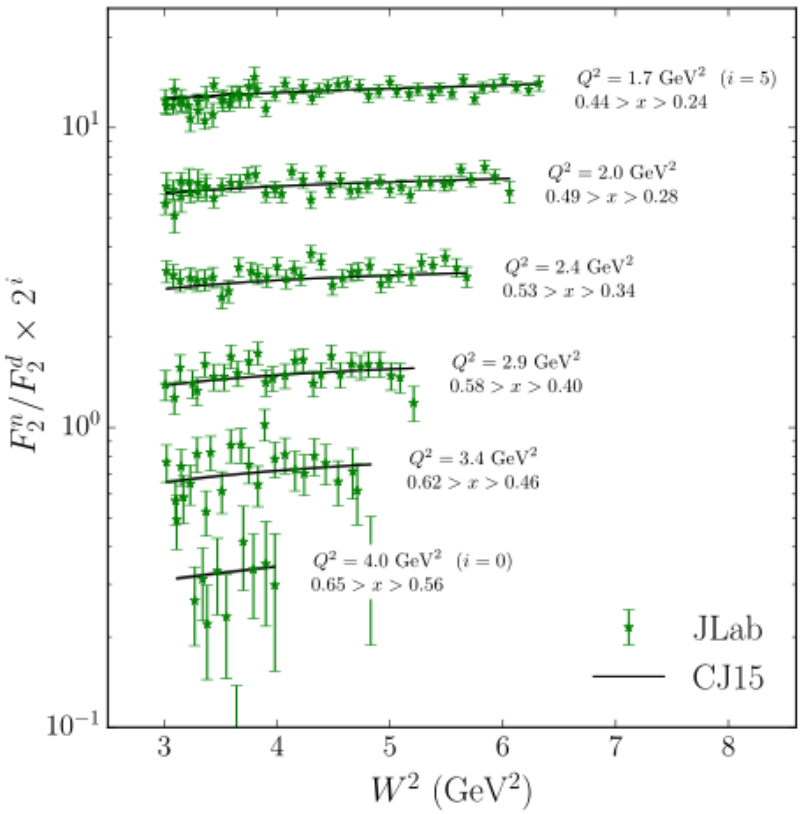
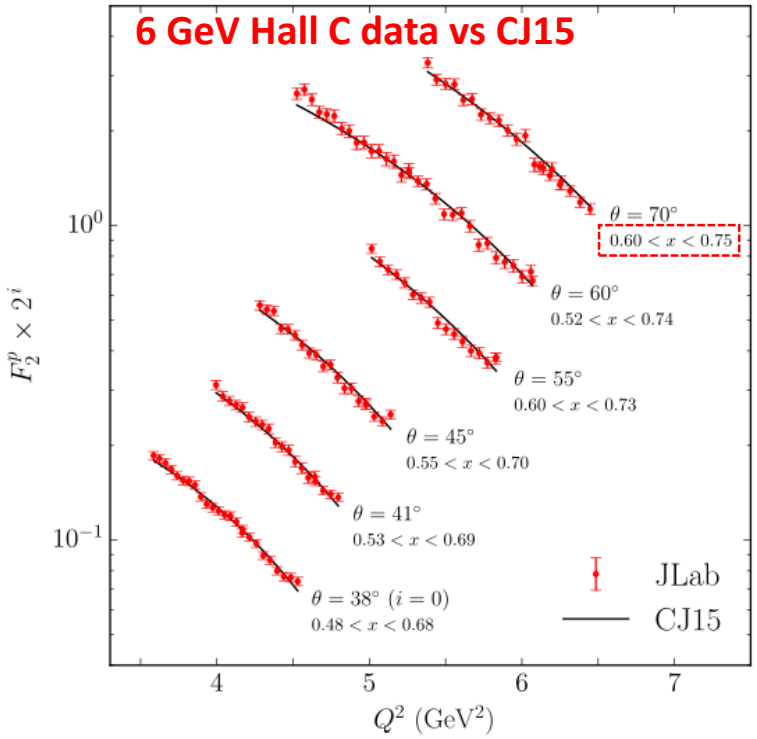


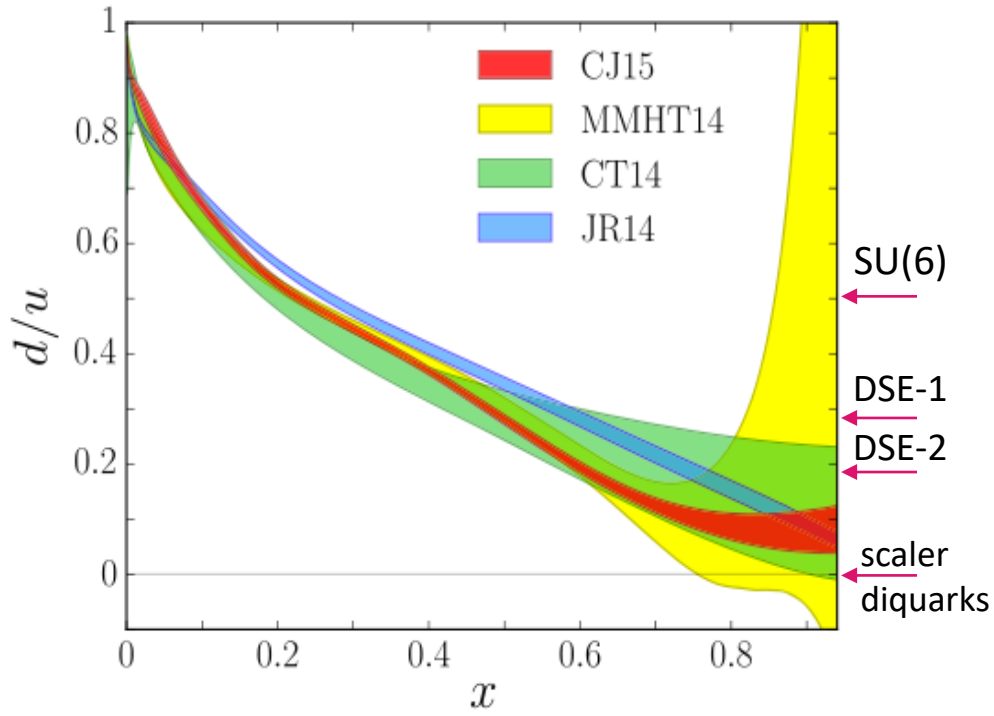


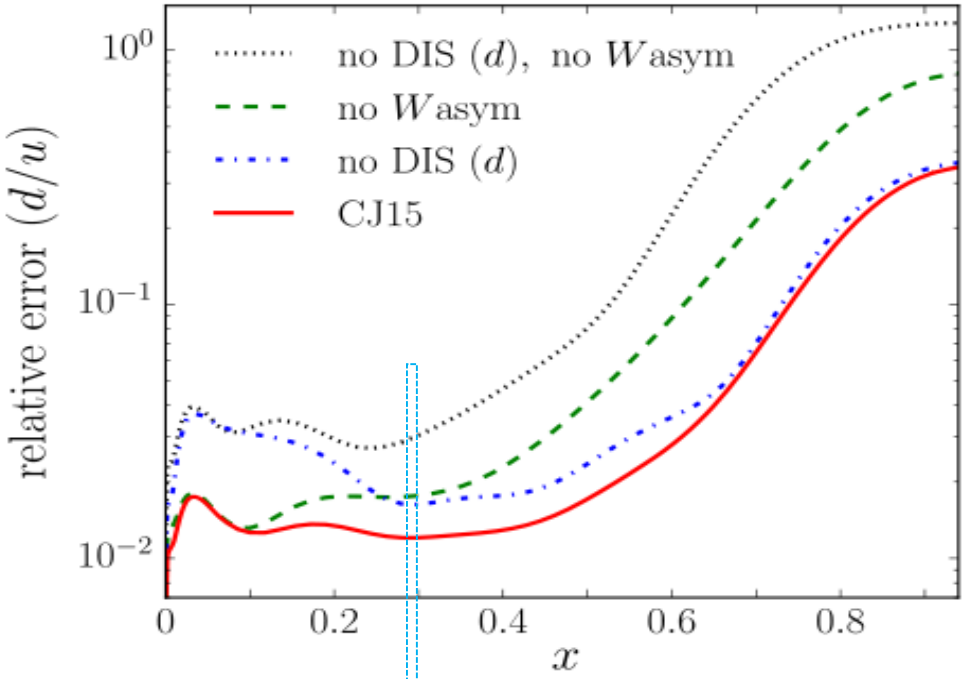


Constraints for PDFs

Theory-experiment Collaboration: CTEQ-Jefferson Lab Collaboration

(One of the many) Highlights: Improvement in uncertainty of d/u extraction





Deuterium data allow for precise determination of d/u

D0 asymmetries determine the "free nucleon" d-quark AND Deuterium data determine the off-shell correction

Quark – Hadron Duality

Complementarity between *quark* and *hadron* descriptions of observables

$$\sum_{hadrons} = \sum_{quarks}$$

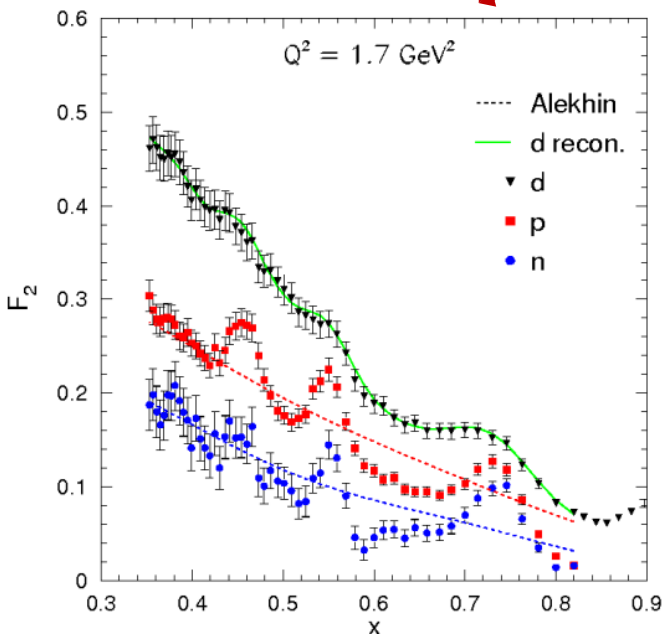
Can use either set of complete basis states to describe all physical phenomena

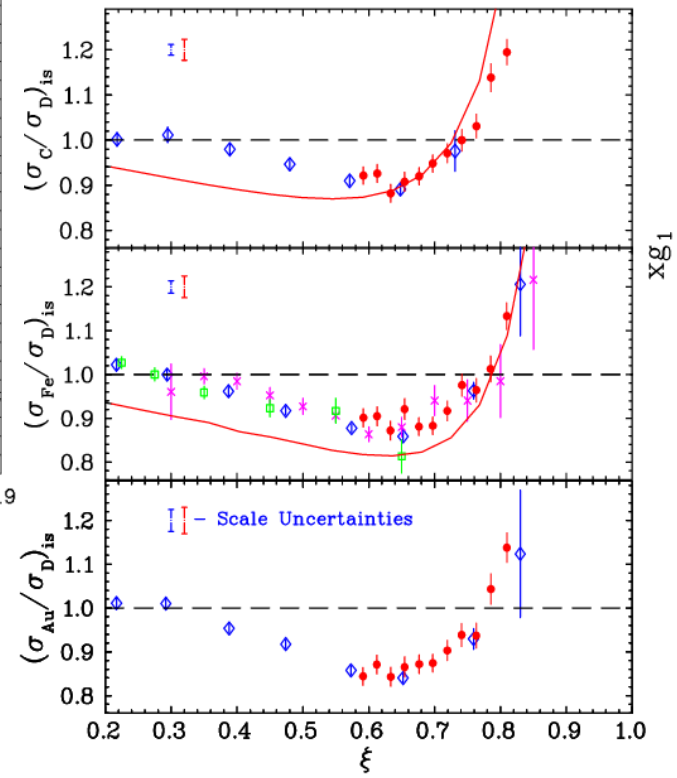
From W. Melnitchouk

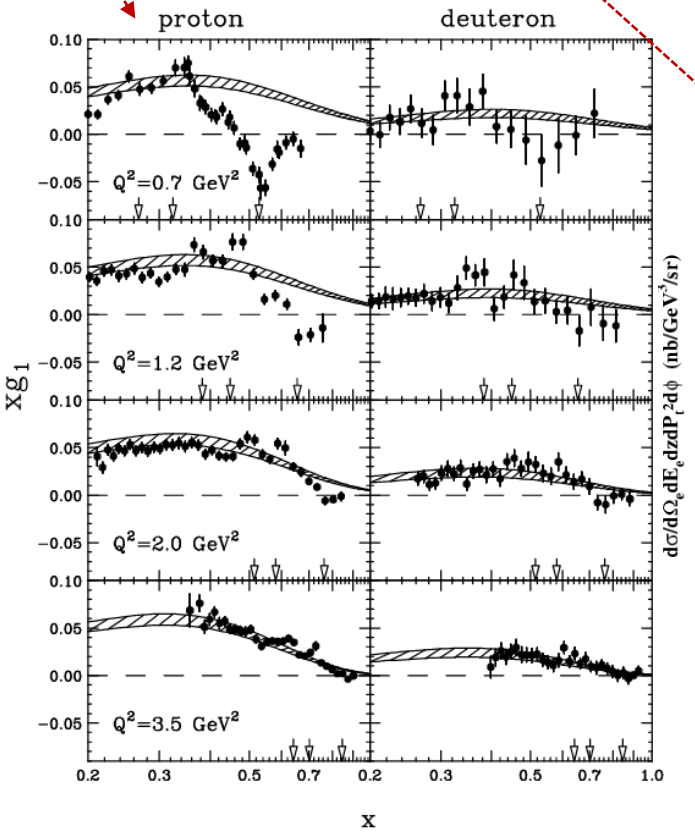
Quark – Hadron Duality

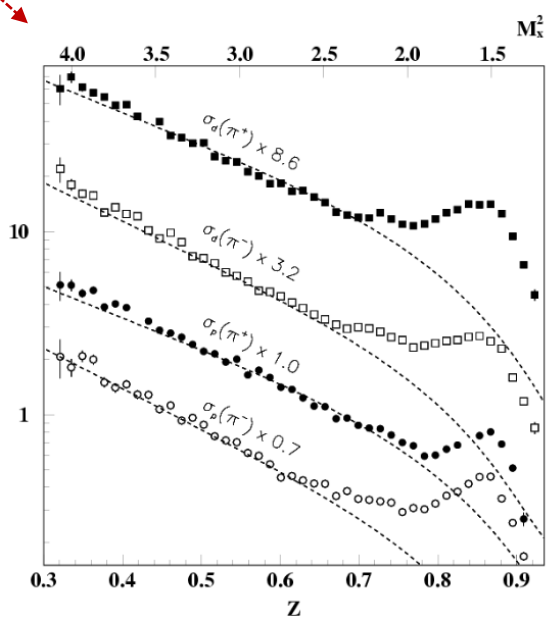
- **Quark – hadron duality**: fundamental property of nucleon structure

→ Observed in: F_2^p, F_1^p, F_L^p, F_2^n, F_2^d, F_2^C, F_2^{Fe}, F_2^{Au}, A_1^p, g_1^p, g_1^d, g_1^n, $g_1^{^3He}$, SIDIS



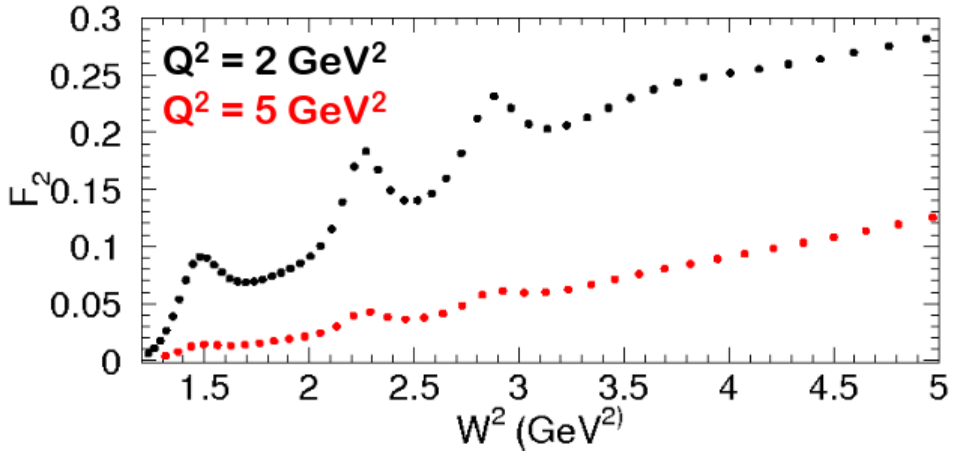


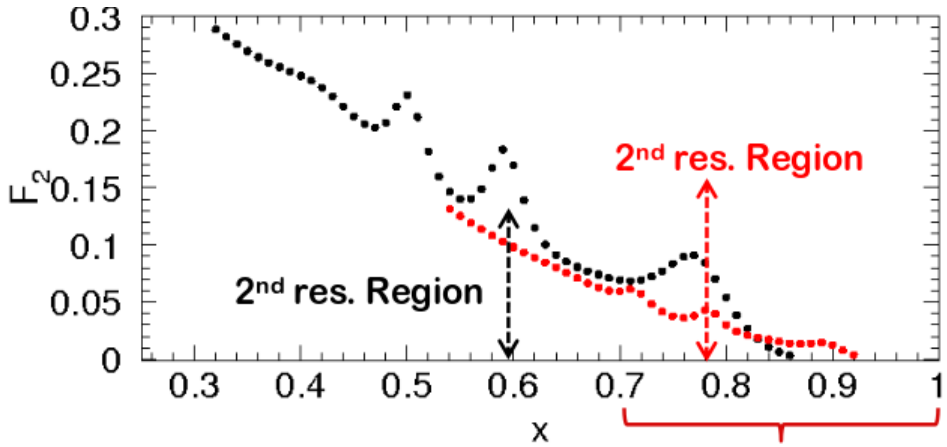




Duality Studies in F_2 – Highlights from 6 GeV JLab

- Jefferson Lab 6 GeV experiment, E00-116, pushed duality studies to higher Q^2 and highlighted an obvious, fundamental question: what's an appropriate scaling curve to verify duality?





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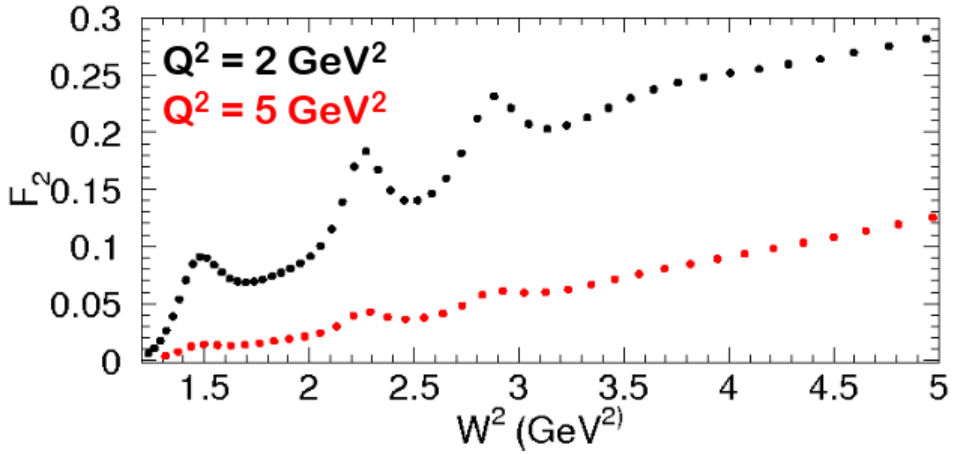
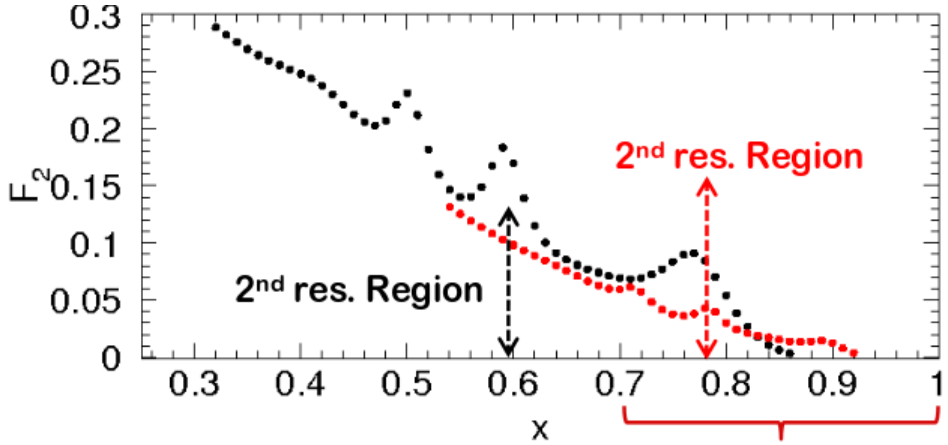
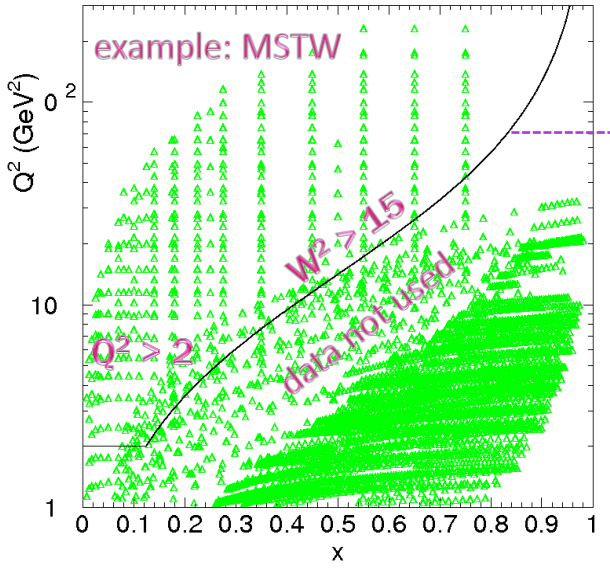
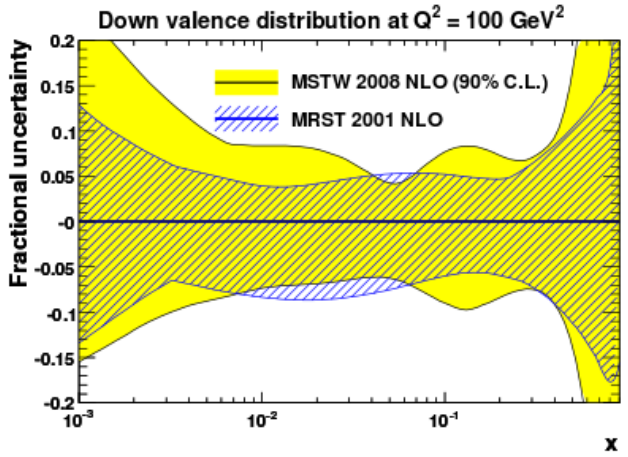


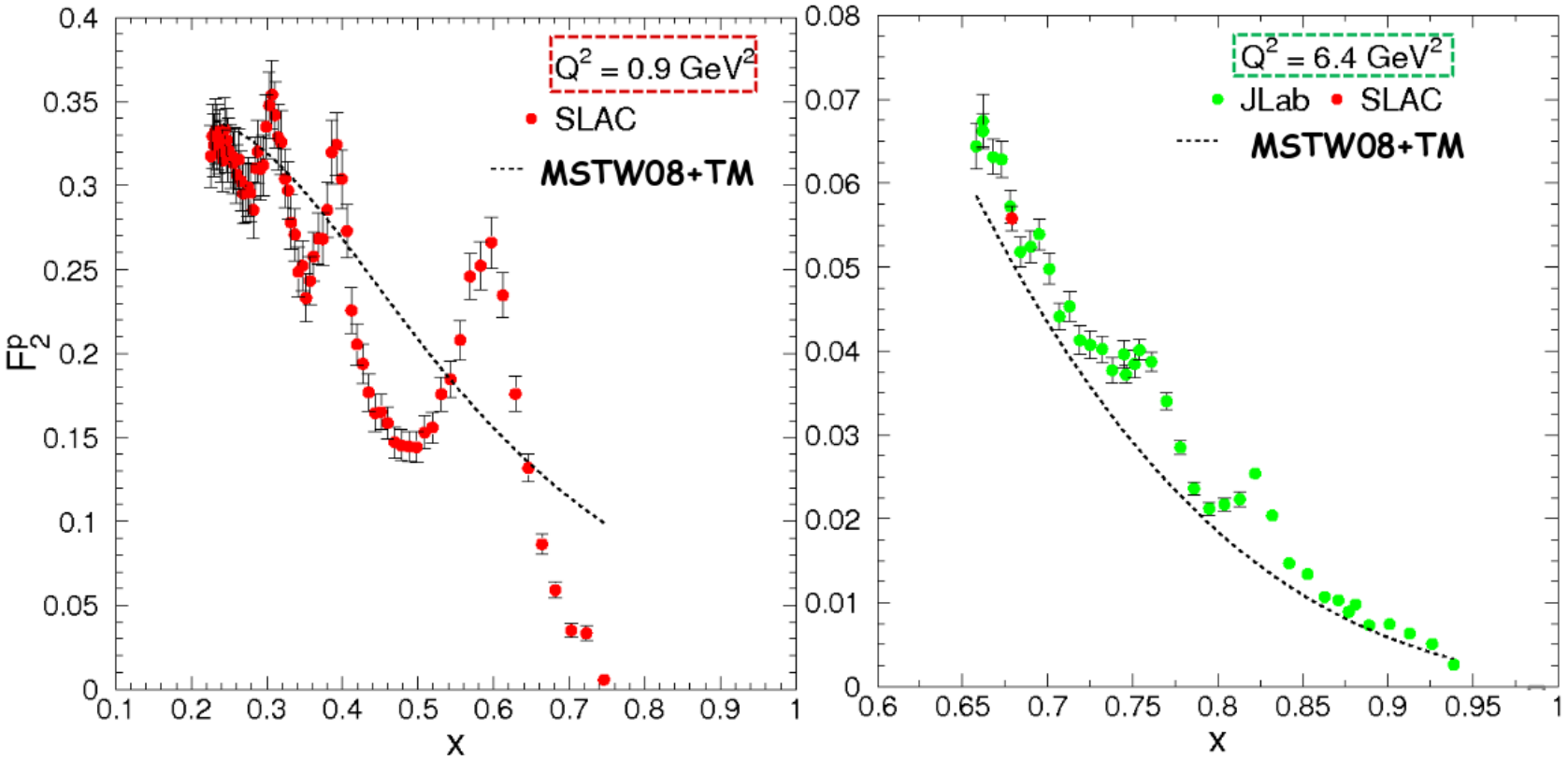






Duality Studies in F_2 – Highlights from 6 GeV JLab

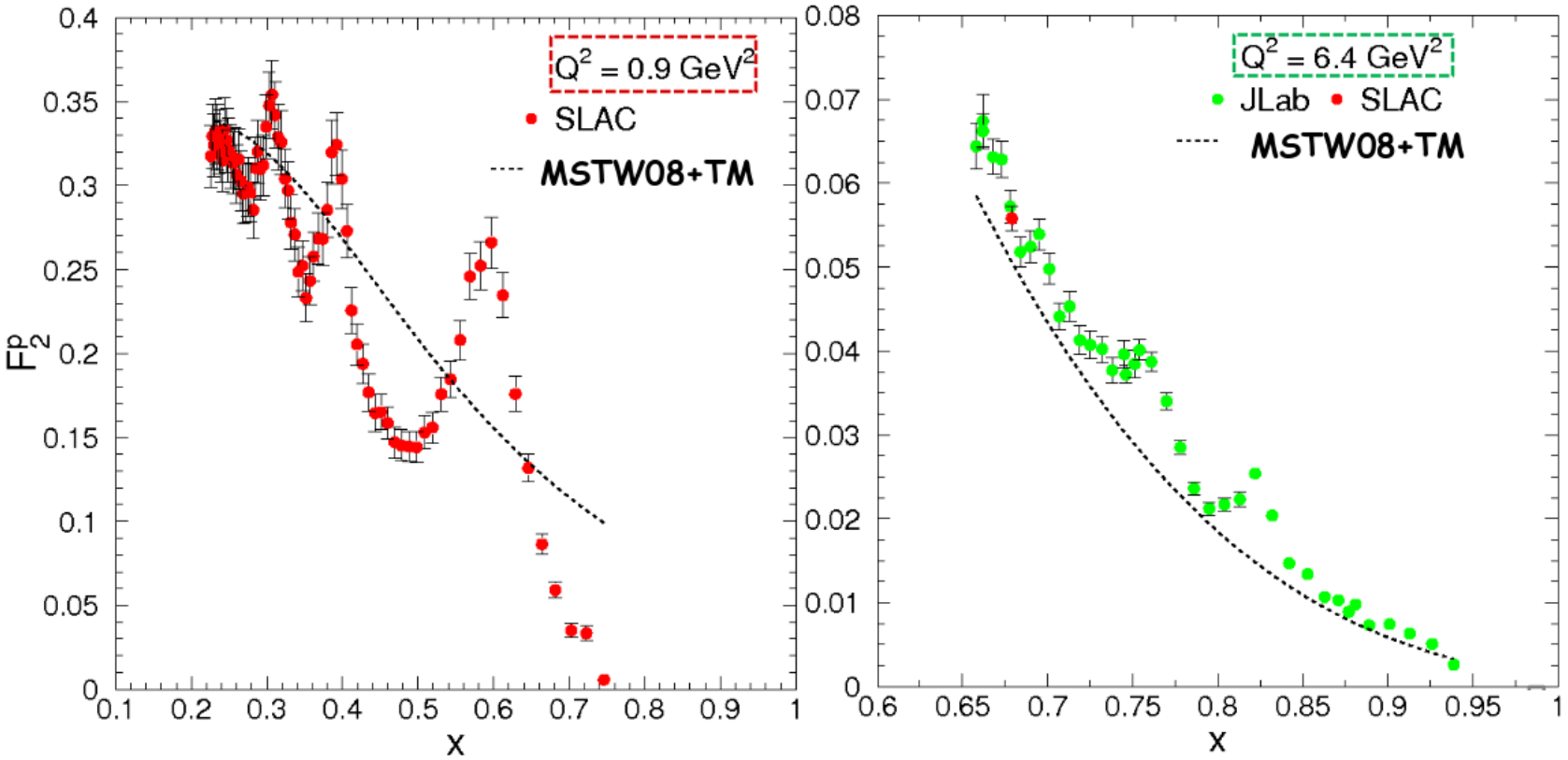
- Poorly constrained PDFs at large x hinder verification of quark-hadron duality at high Q^2



Duality Studies in F_2 – Highlights from 6 GeV JLab

- Poorly constrained PDFs at large x hinder verification of quark-hadron duality at high Q^2

Resonance region data average to MSTW08 at a Q^2 of 0.9 GeV^2 but not at 6.4 GeV^2 ?!?!

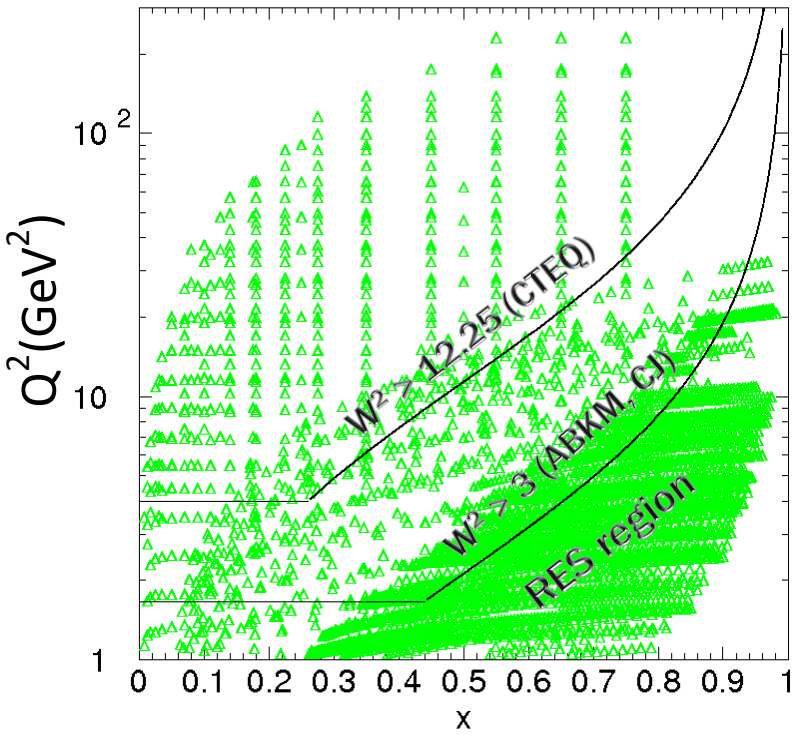


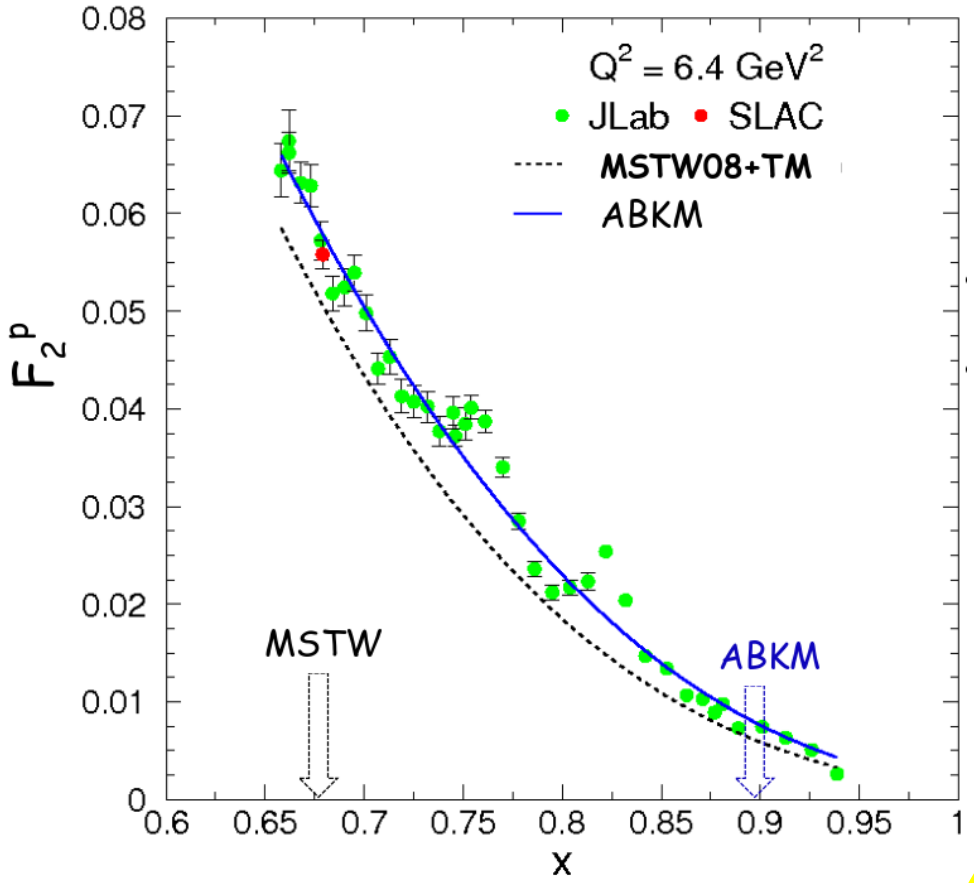
This is not a violation of duality but due to the underestimation of PDFs strength at large x

Duality Studies in F_2 – Highlights from 6 GeV JLab

- Appropriate scaling curve for quark-hadron duality verification: PDF fits better constrained at large x

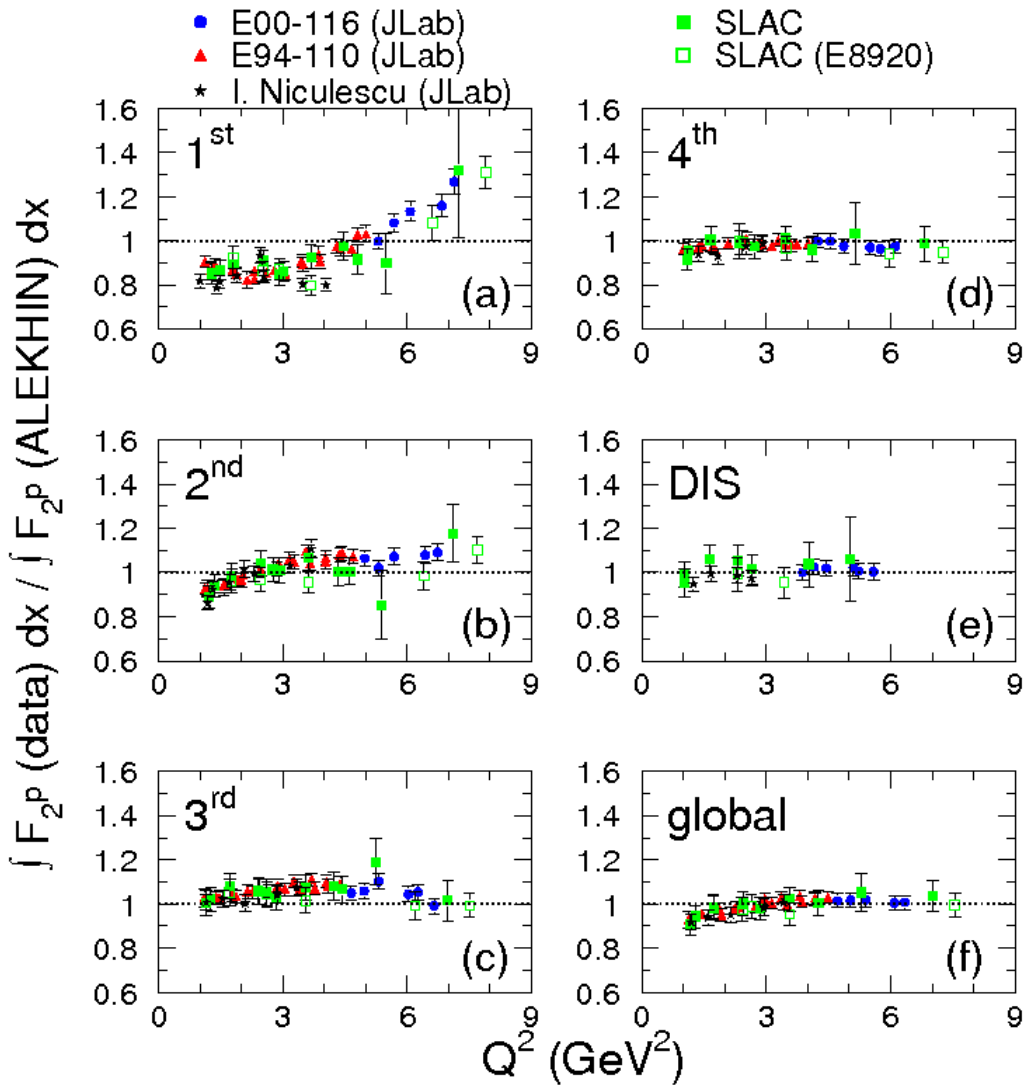
→ Early 2000s: few collaborations (ABKM and then CJ) extended their PDF extraction to larger x by lowering the W^2 kinematic cut to include more large x DIS data





Duality Studies in F_2 – Highlights from 6 GeV JLab

Duality verified against scaling curve from ABKM



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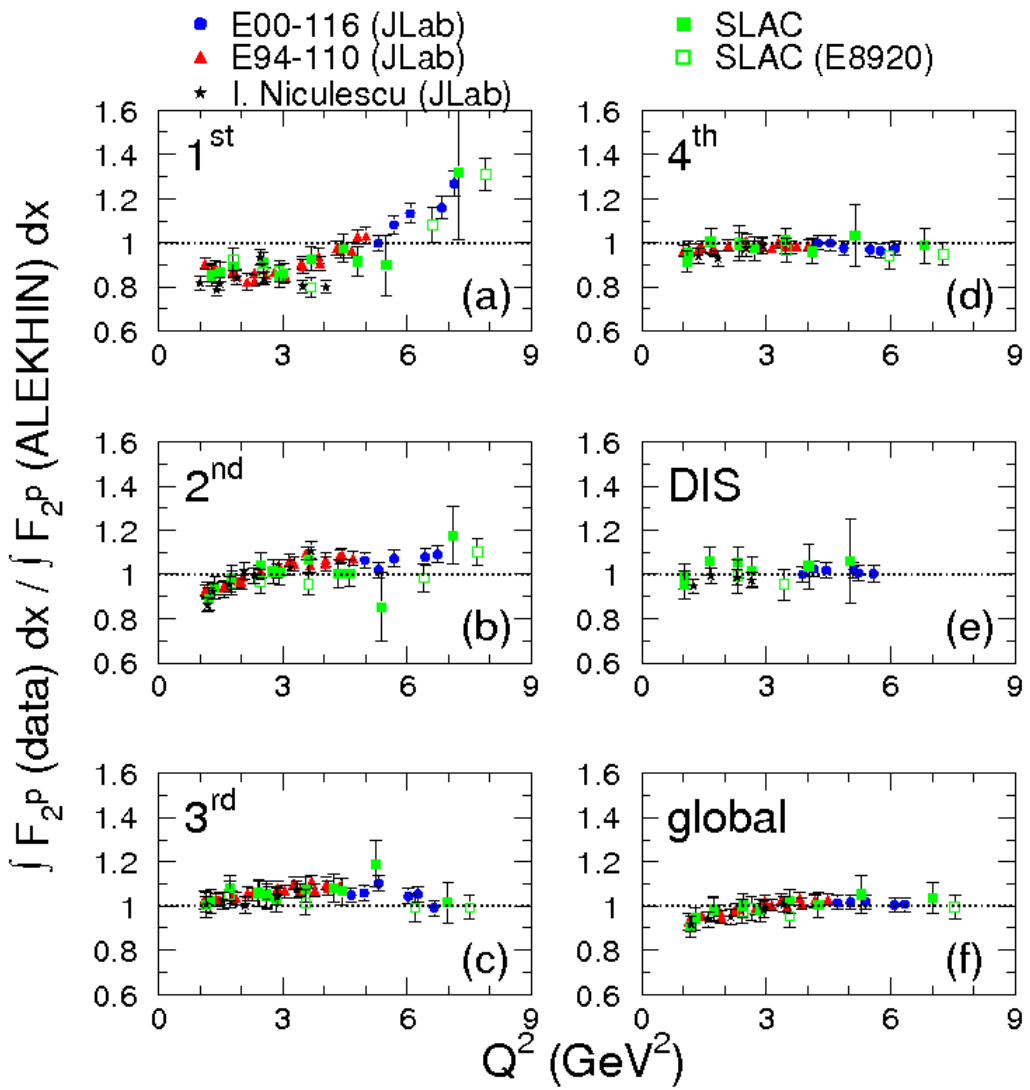
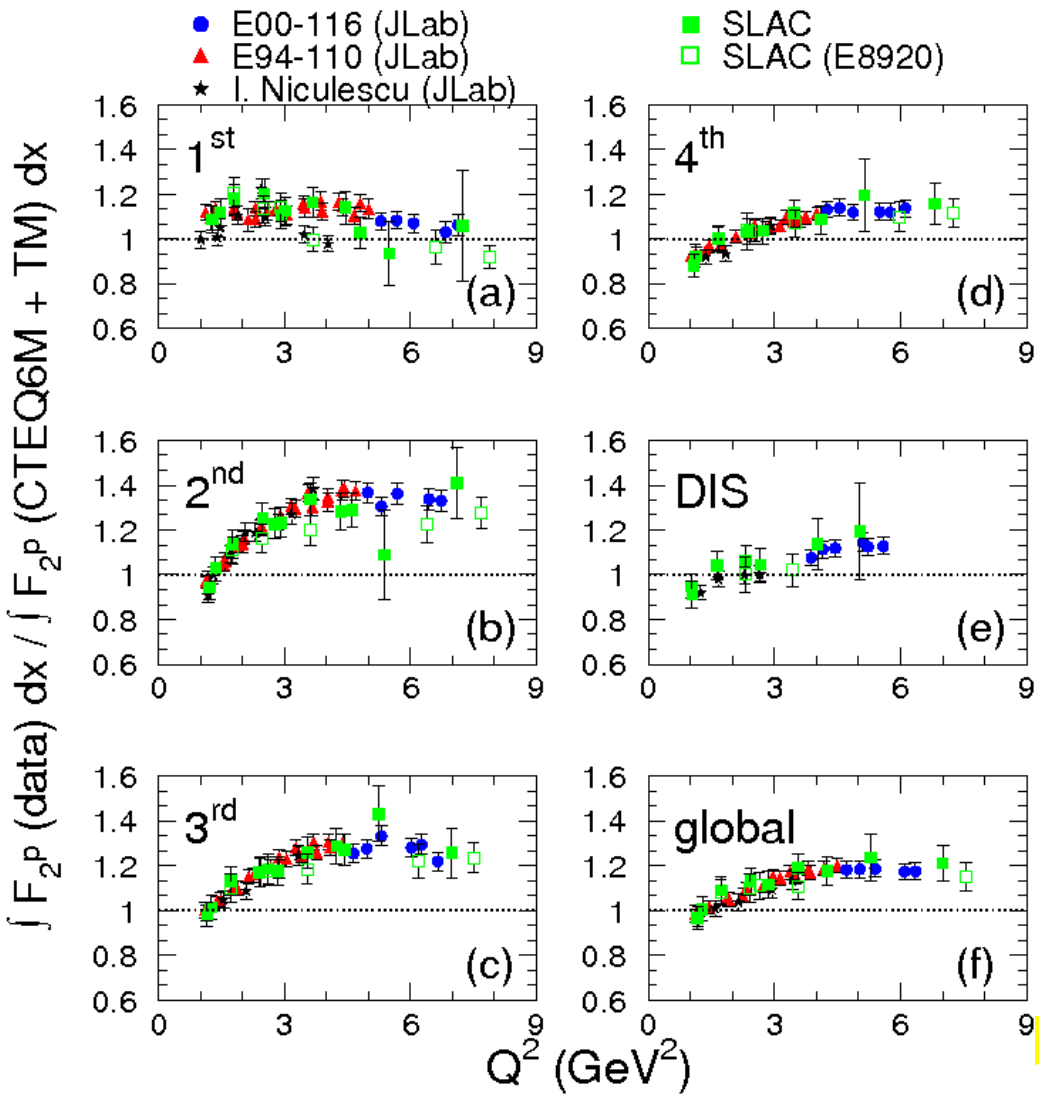
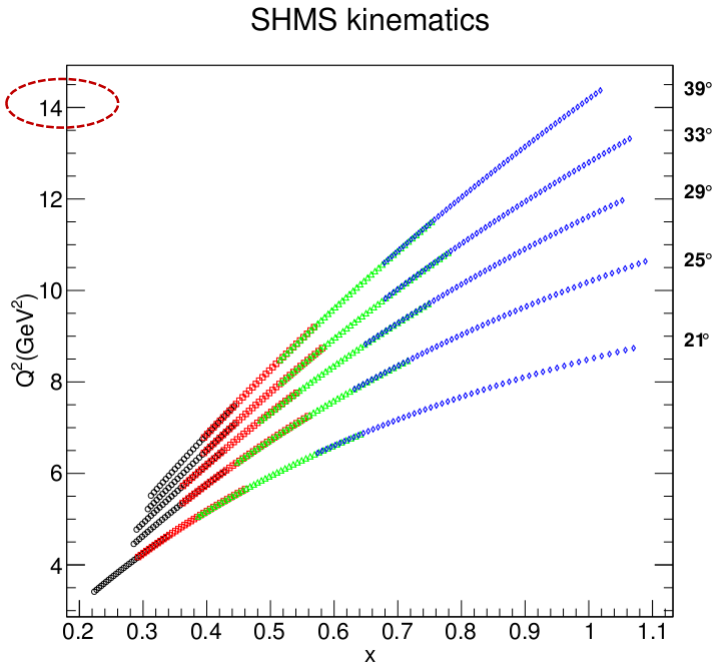


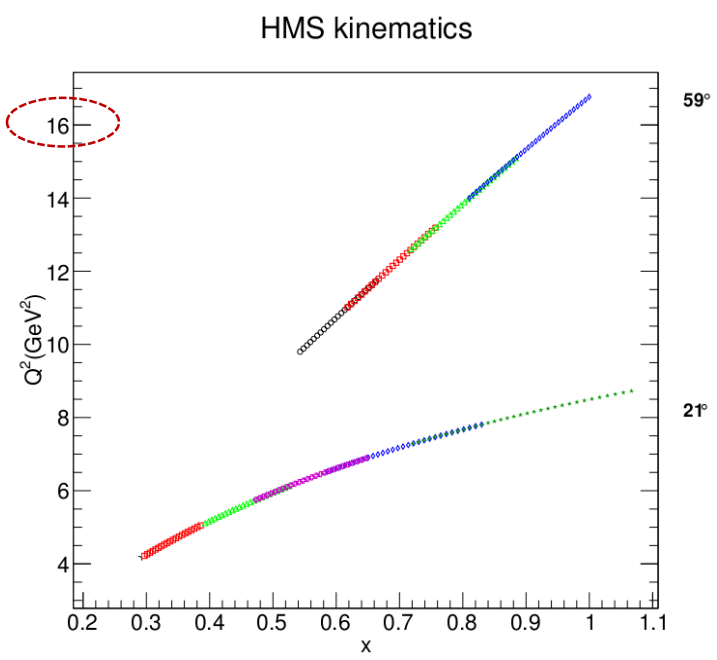
The Q^2 dependence is what matters, right?



Future Duality Studies in F_2 – E12-10-002

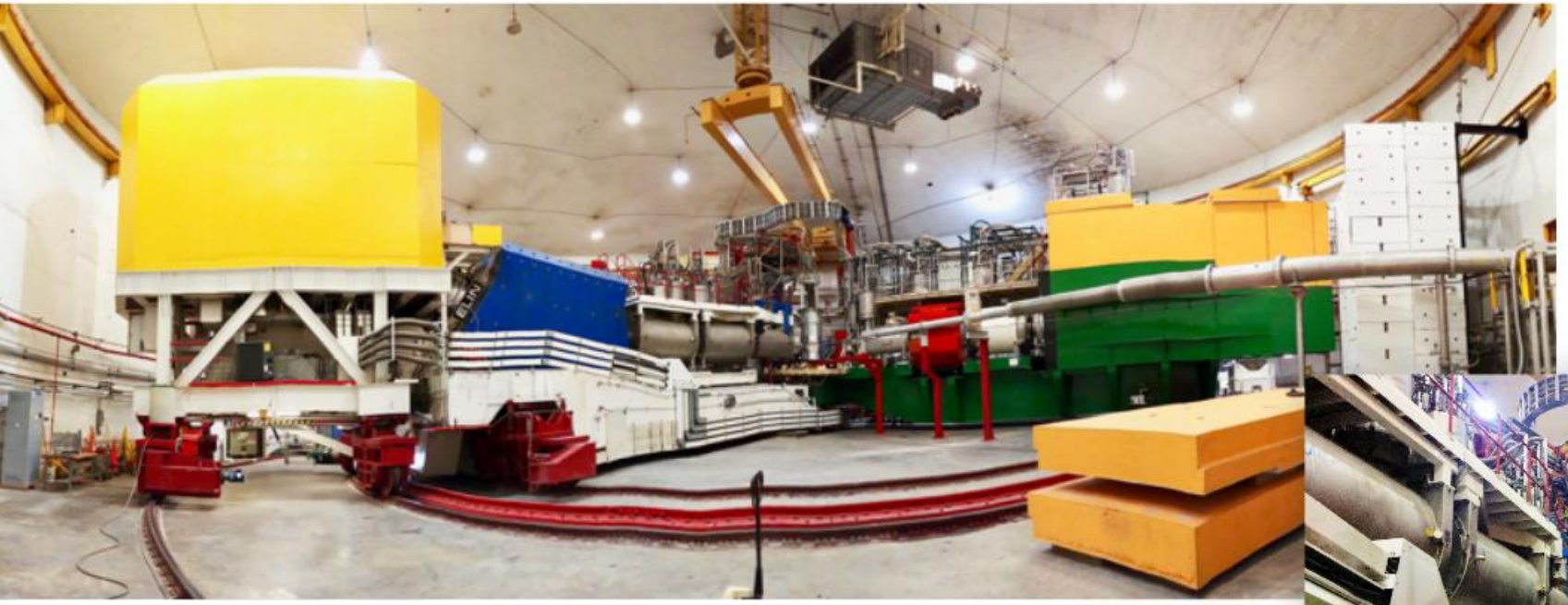
- Jefferson Lab experiment **E12-10-002**: pushing duality studies to even higher Q^2 and reviving the discussion on what's an appropriate scaling curve and scaling variable for duality studies

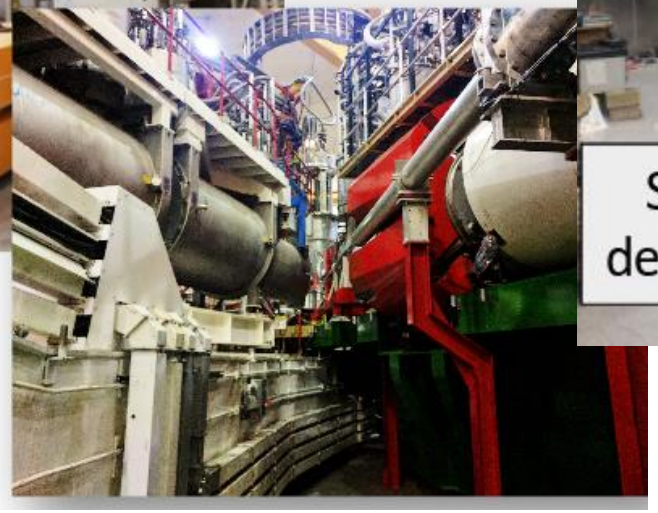




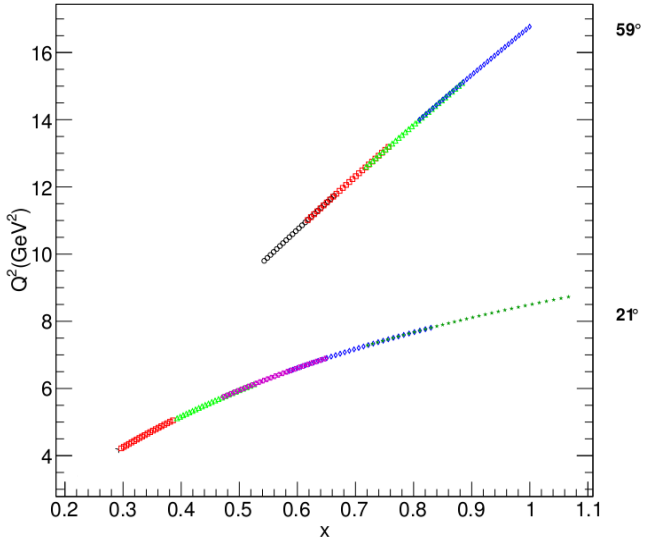
- Test duality for various scaling curves and scaling variables
- Perfect duality averaging procedures to include duality averaged data in PDF fits

E12-10-002: Setup and Kinematic Coverage

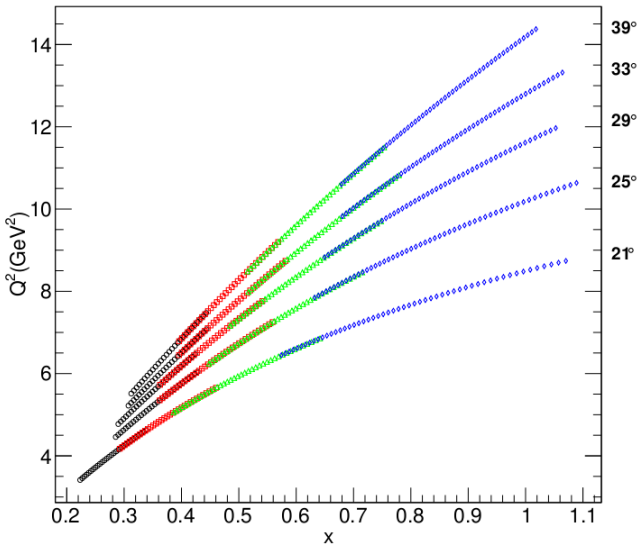




HMS kinematics



SHMS kinematics



- → Beam: 10.6 GeV, unpolarized
- → Targets: LH2, LD2, Al
- → Trigger: ELREAL (ELCLEAN for background measurements)
- → Measured positrons at: 59 deg (HMS) and 39, 29, 21 deg (SHMS)

Analysis Flow and Status

We finished taking data in March of 2018

done

1. **Timing Cuts**
2. **Calibrations**
   - BCM
   - Hodoscope
   - Drift Chamber
   - Calorimeter
   - Cherenkov

in progress

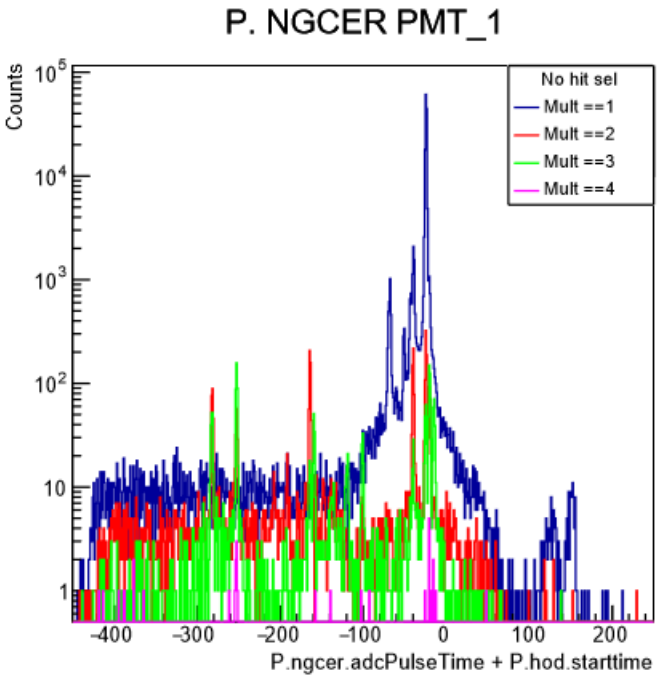
3. **Efficiency Studies**
   - Tracking Efficiency Study (DC)
   - Trigger Efficiency Study
   - Computer Dead Time
   - Calorimeter and Cherenkov Cut Efficiency
   - Pion Contamination

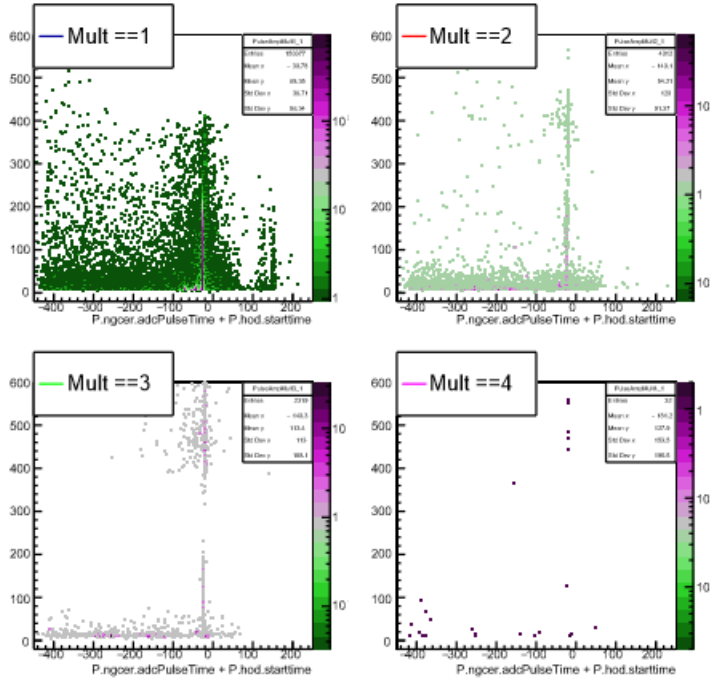
in progress

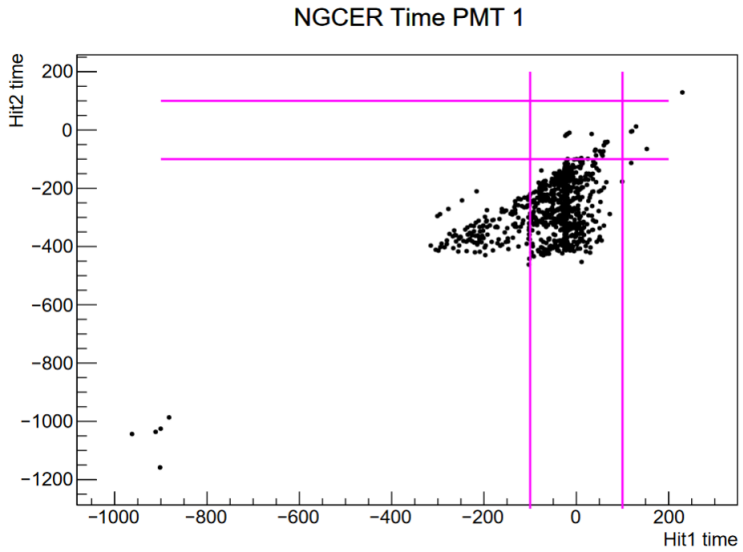
4. **Charge Symmetric Background (measured)**
5. **Spectrometers Acceptance Study**
6. **Radiative corrections**
7. **Cross Section Calculation**

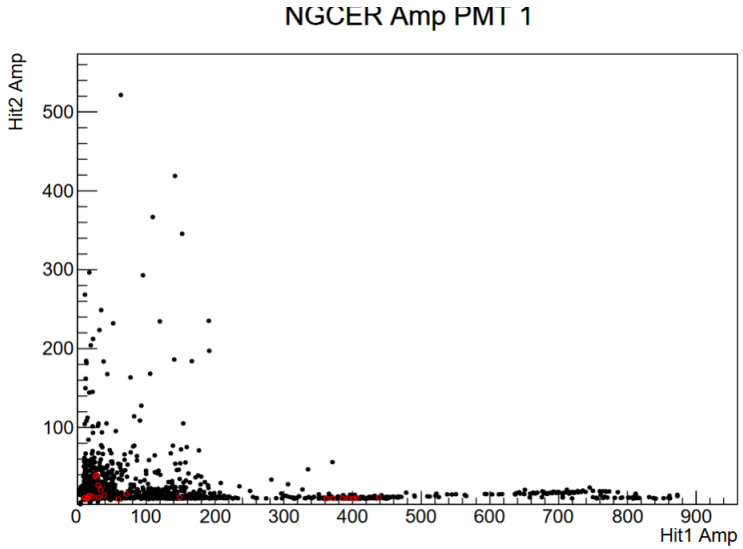
Timing Cuts

- Both TDC1190s and F250s used in the Hall C DAQ system have multi-hit capability
- Timing cuts are needed to select those hits per event that are in time with the trigger (only one hit per event is selected)
- Timing cuts are applied for every detector channel; this is a very important first step in the analysis

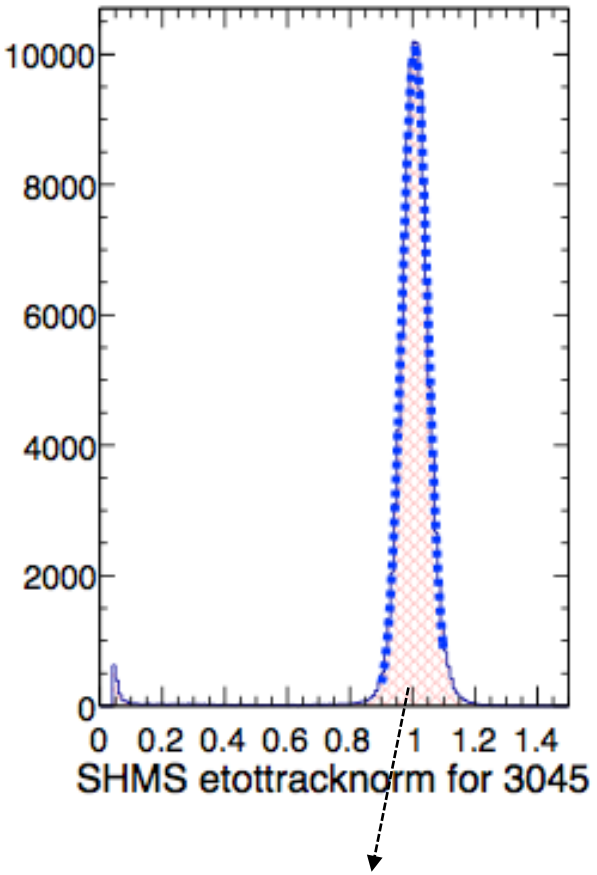




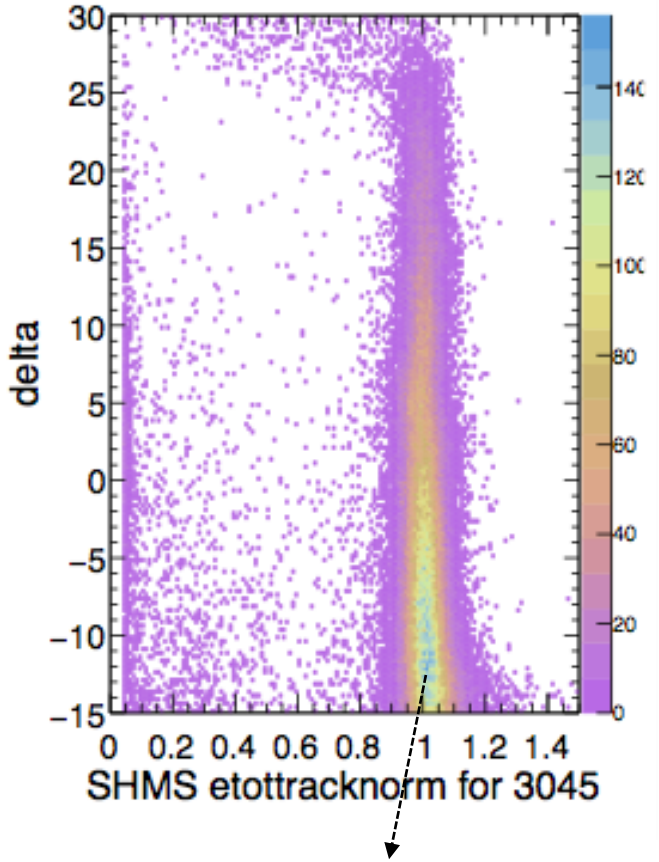




Calibrations: Calorimeter



Electrons peak at 1 after calibration because they deposit their entire energy in the calorimeter



All calorimeter blocks appear to be well calibrated

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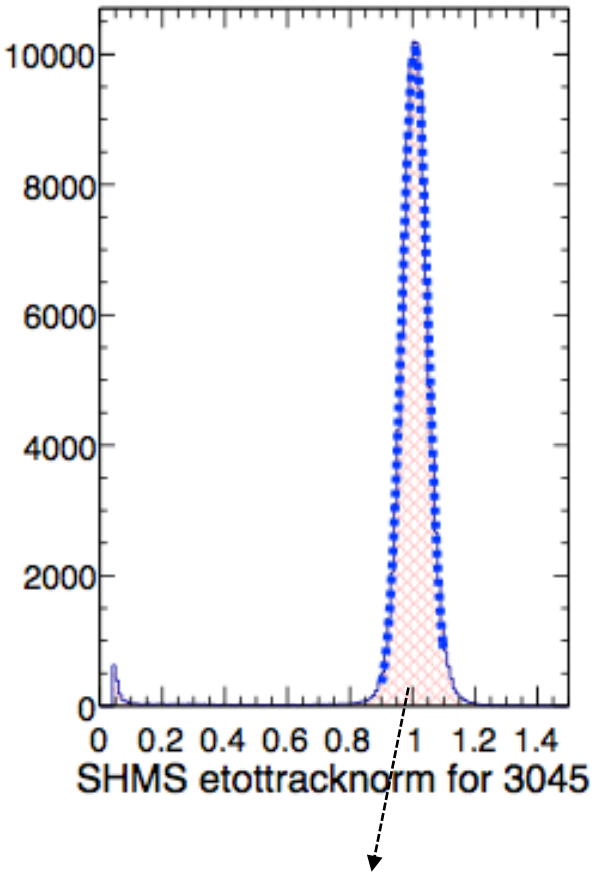

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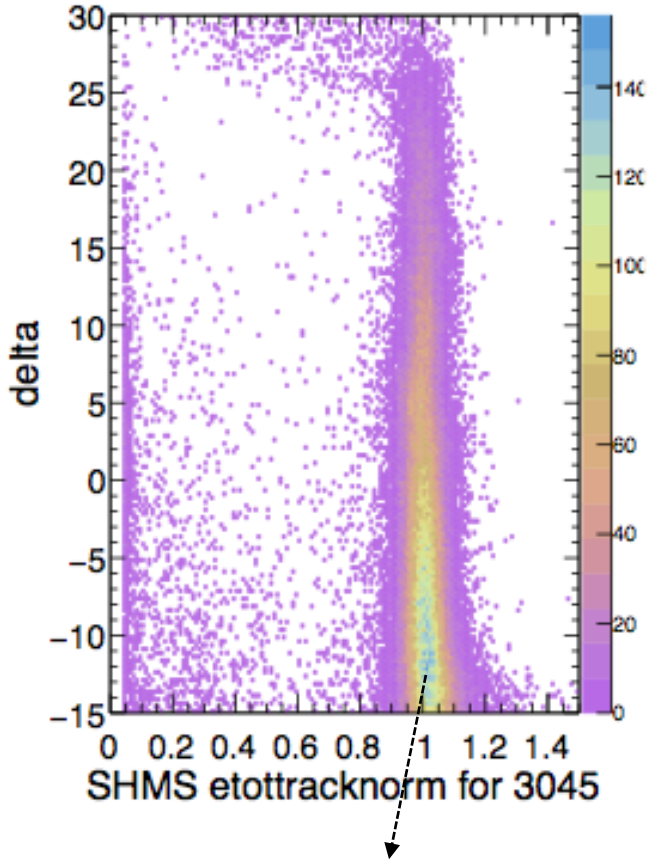

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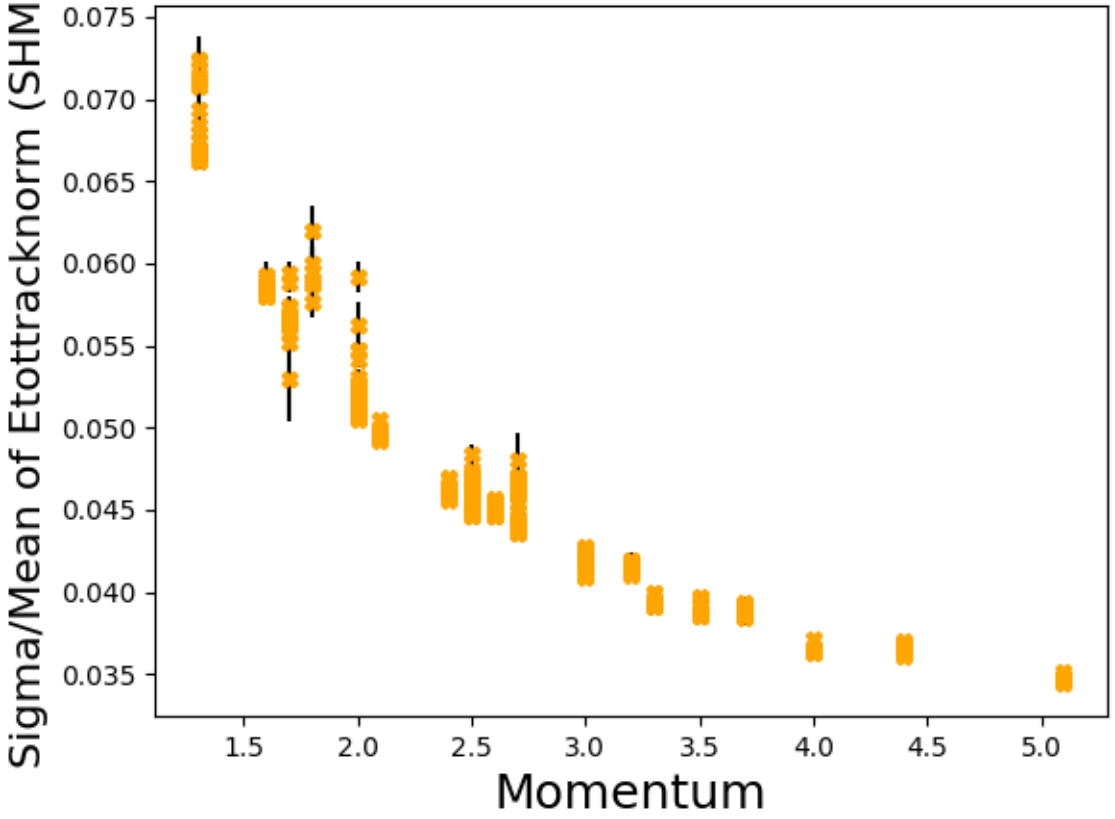
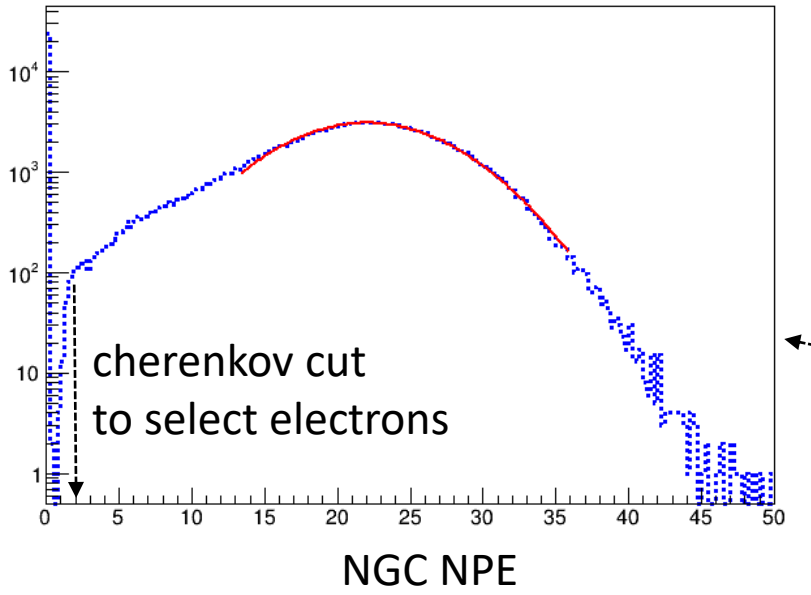
SHMS calorimeter resolution: to be extracted

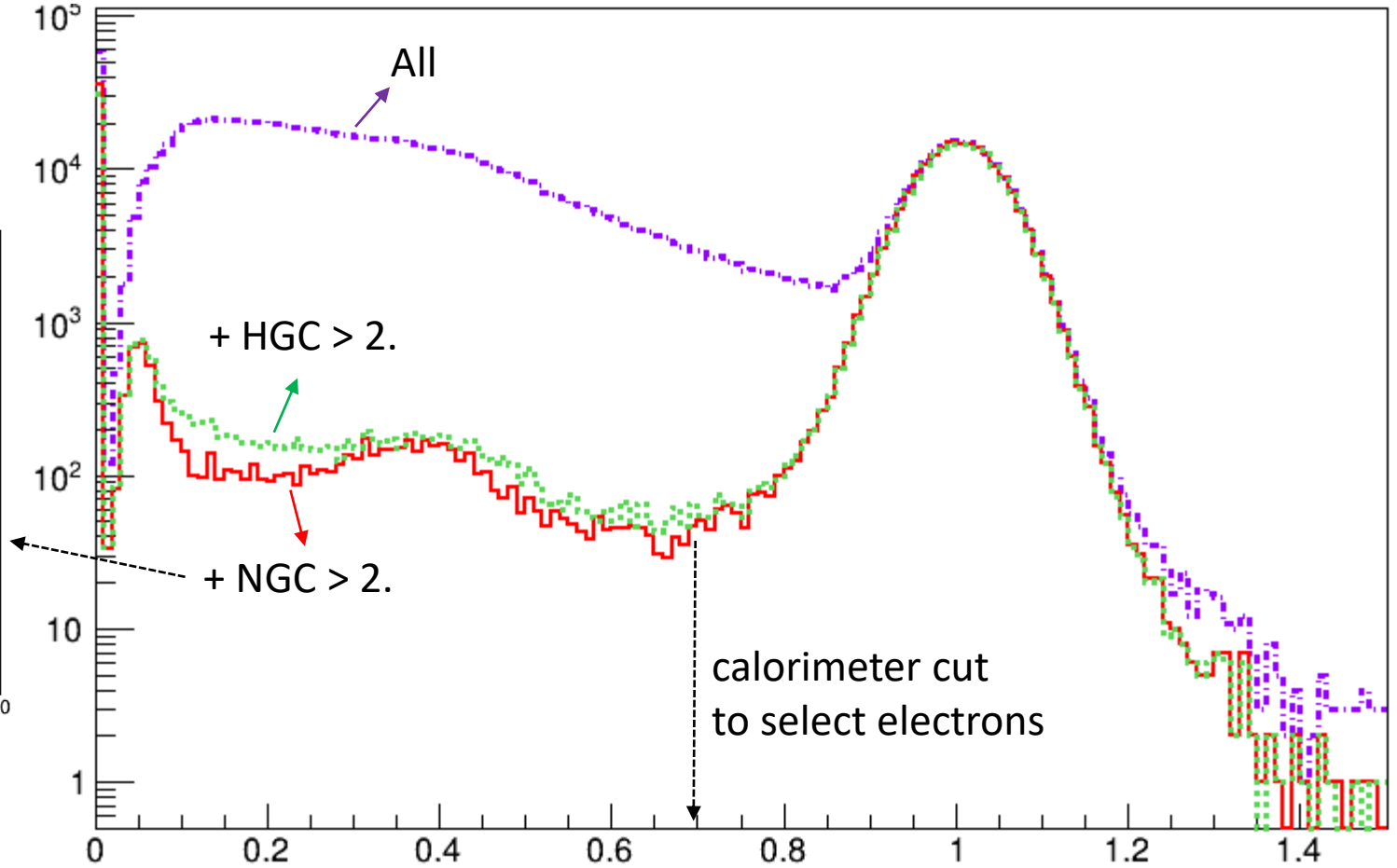


Efficiencies: Particle Identification Detector Cuts

Example: SHMS at E’ = -2.1 GeV and theta = 33 deg

Cherenkov response: number of photoelectrons



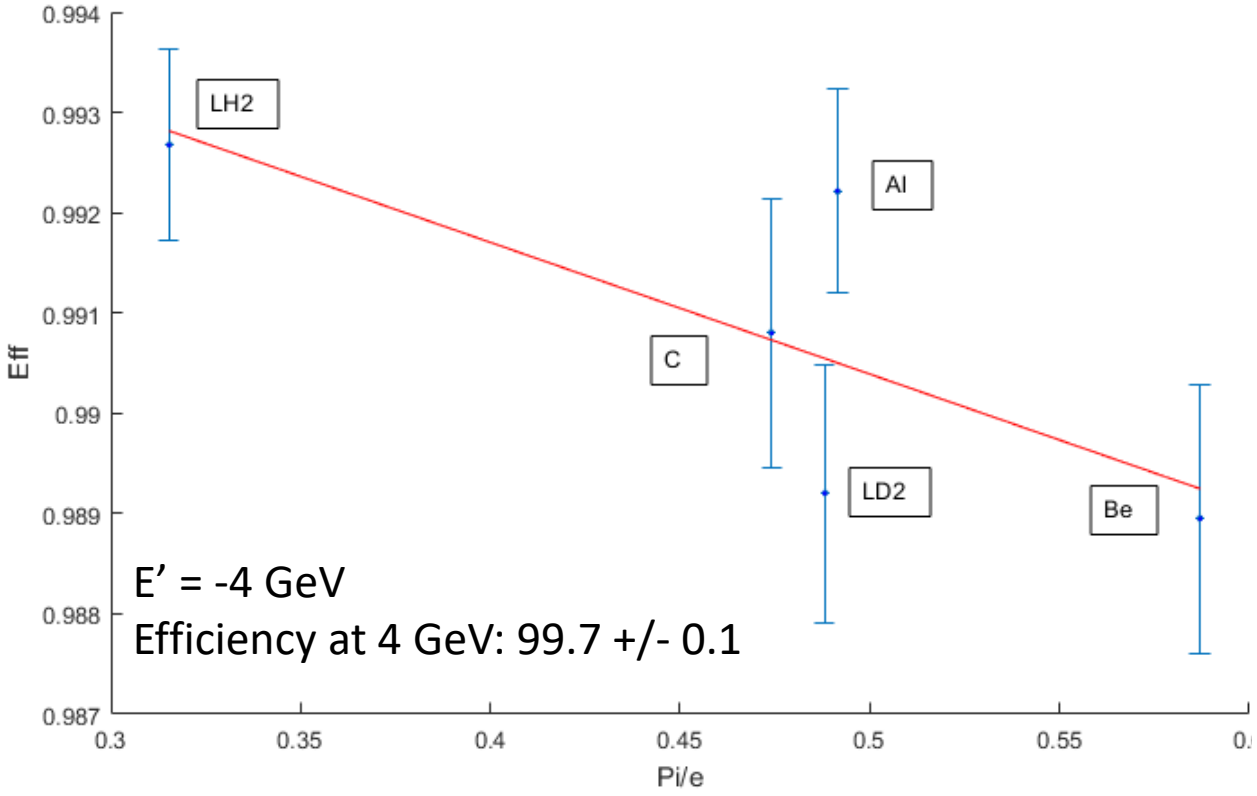


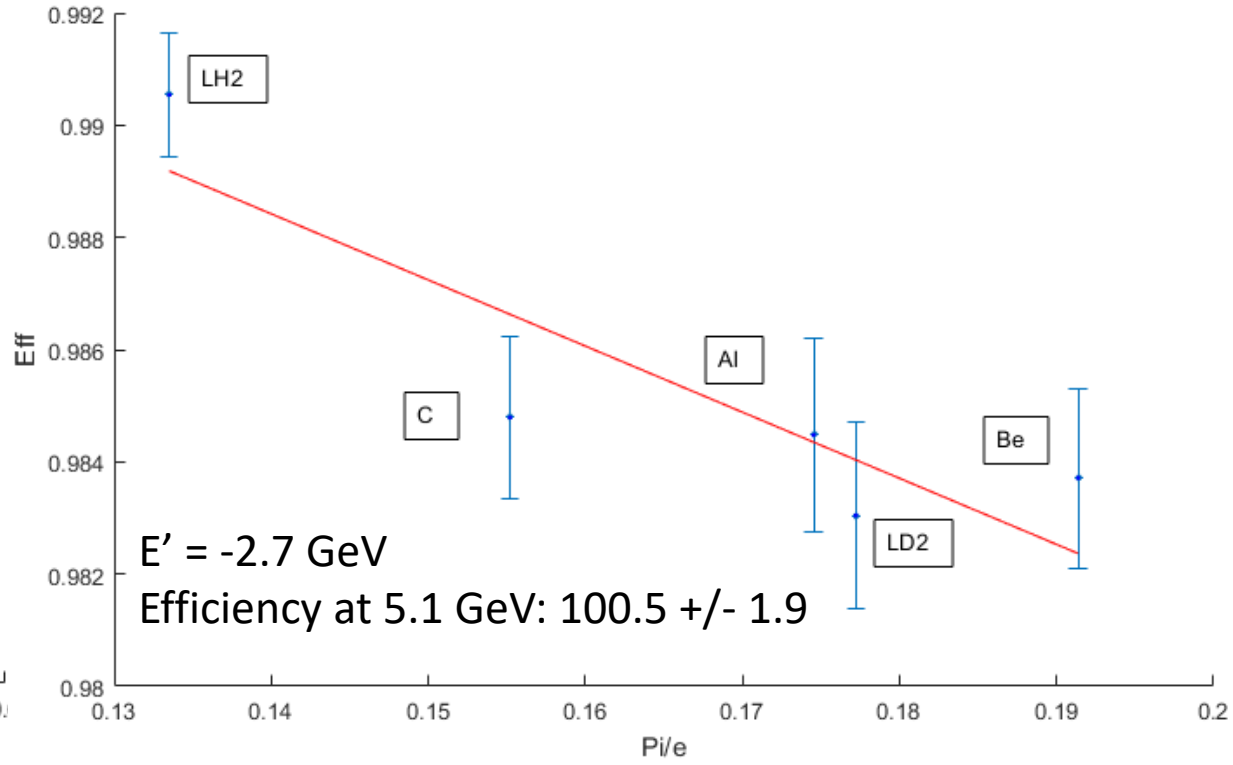
calorimeter response: energy deposited by particle normalized to momentum of particle

Efficiencies: Calorimeter Cut

- A “clean” sample of electrons is selected with a tight Cherenkov cut; only those electrons that went through the part of the trigger that did not involve the calorimeter are selected (ELLO without PRLO)
- Then the effect of the calorimeter > 0.7 cut is tested on this sample
- The cut efficiency is obtained per momentum setting by extrapolating to zero pion/electron ratio

→ calorimeter cut efficiency is high





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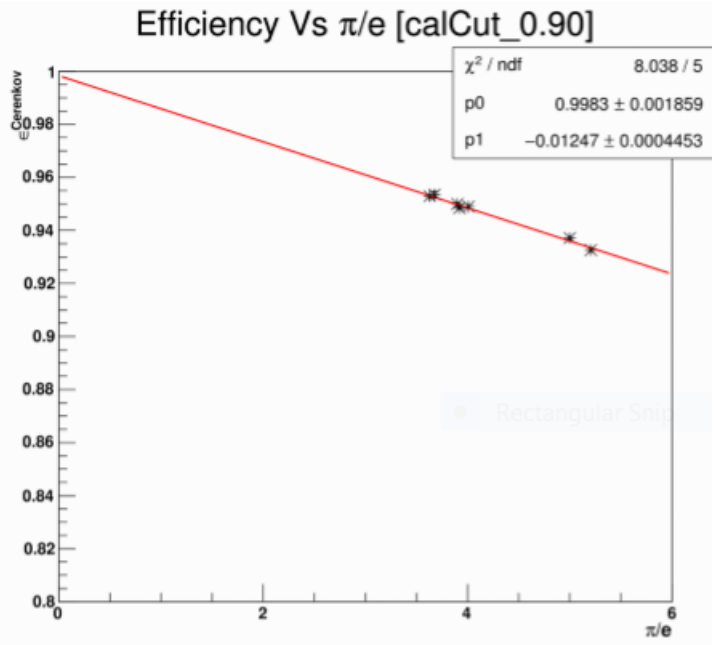
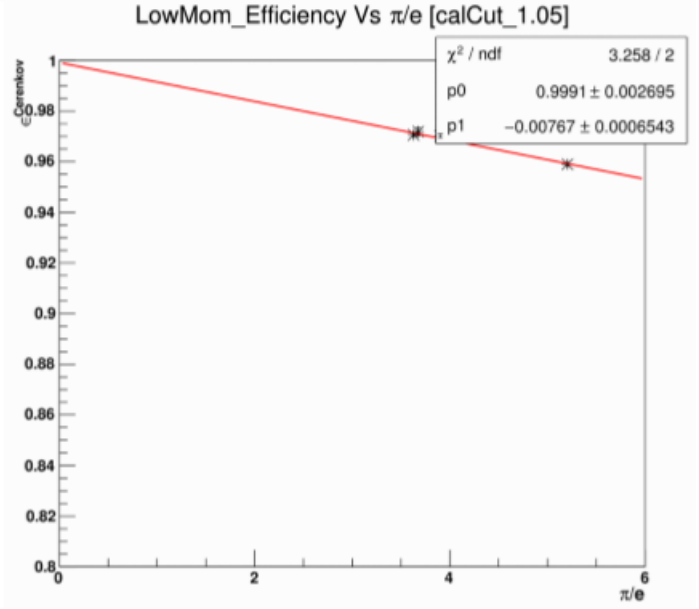
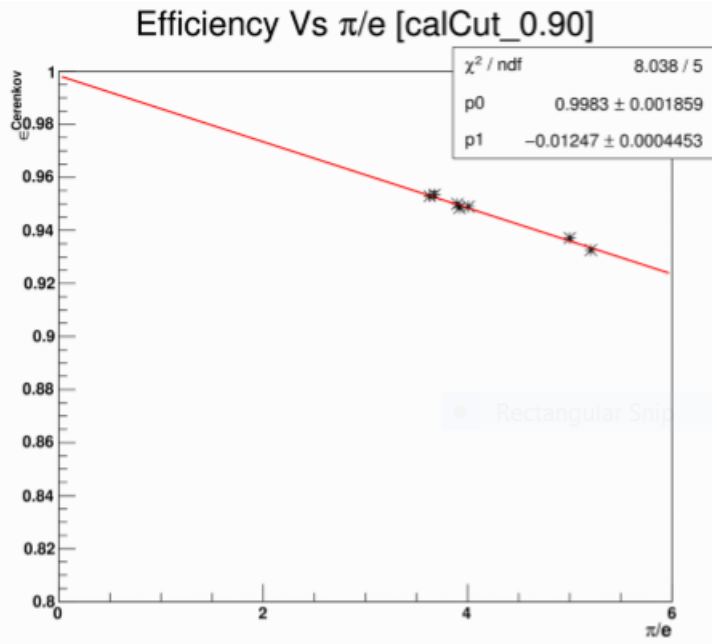


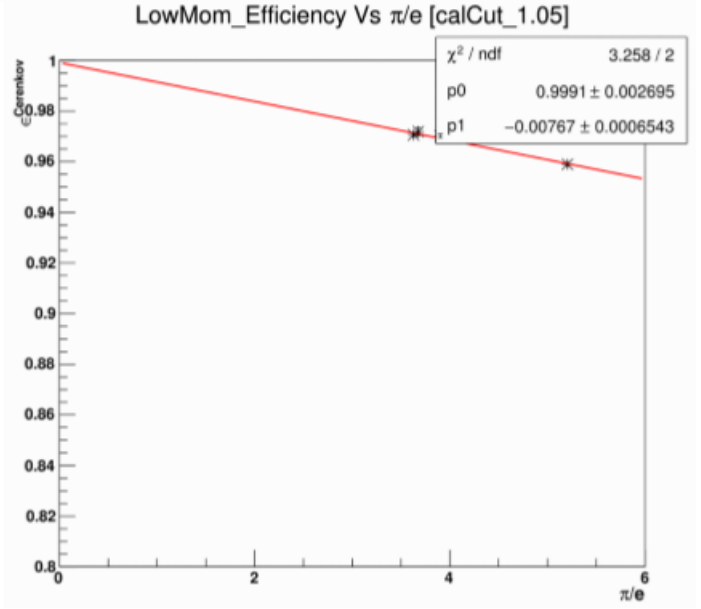


- A “clean” sample of electrons is selected with a tight calorimeter cut; only those electrons that have made it through the ELHI trigger leg (no Cherenkov input) are used
- The Cherenkov npe > 2. cut is tested on this sample
- The cut efficiency is obtained by extrapolating to zero pion/electron ratio

→ The Cherenkov cut efficiency is high

Efficiencies: Cherenkov Cut





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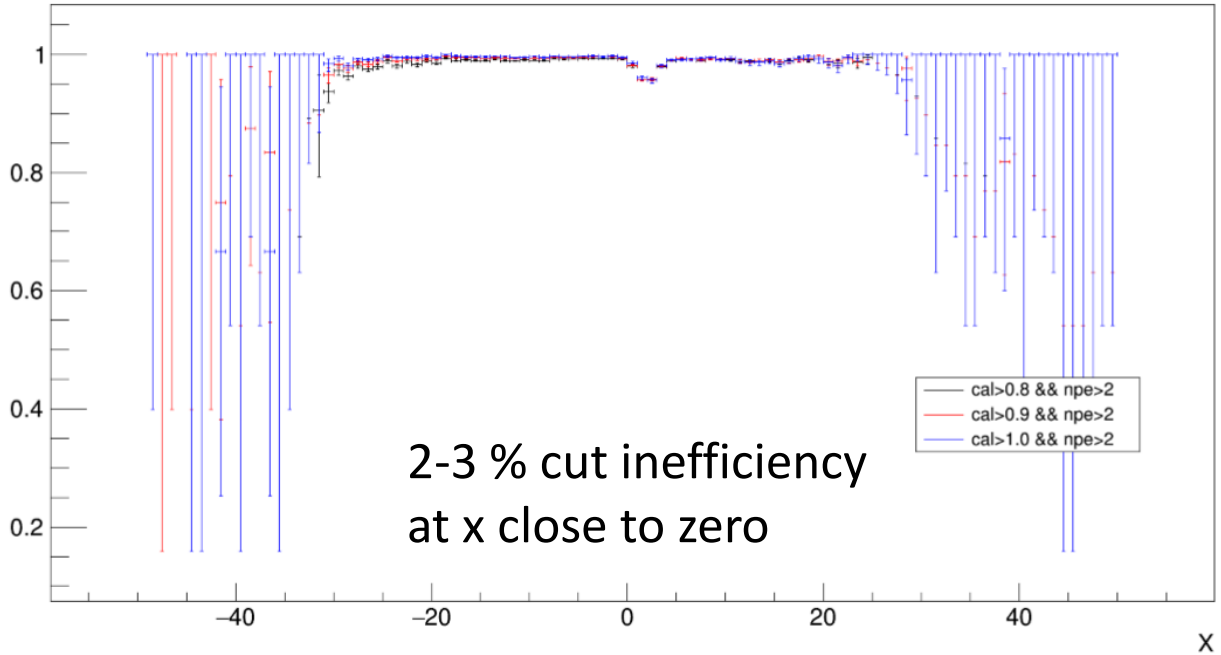
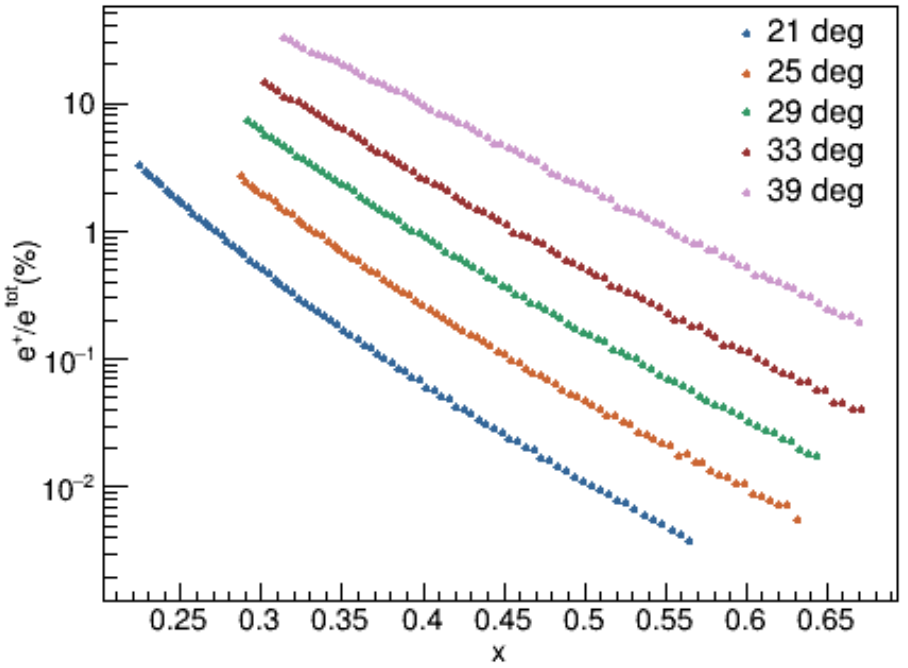
NGC cut efficiency vs x (SHMS E’ = -5.1 GeV, theta = 21 deg)



Charge Symmetric Background

- $e^+/(e^+ + e^-)$ from model based on fit from SLAC to π^+ and π^- production



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- We measured:

Angle	Momentum(GeV/c)
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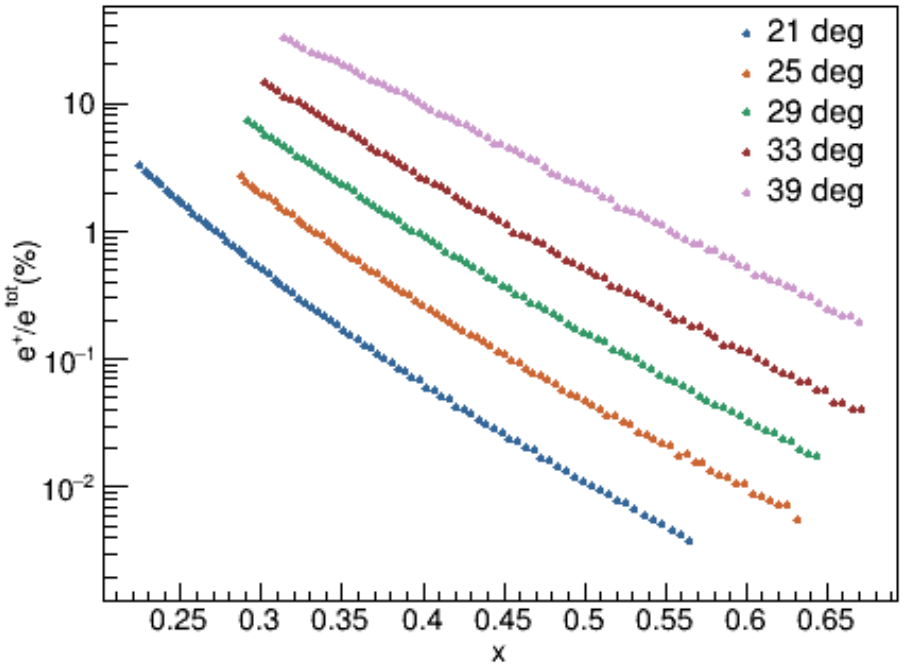
29	2.0, 2.7
39	1.3, 1.8



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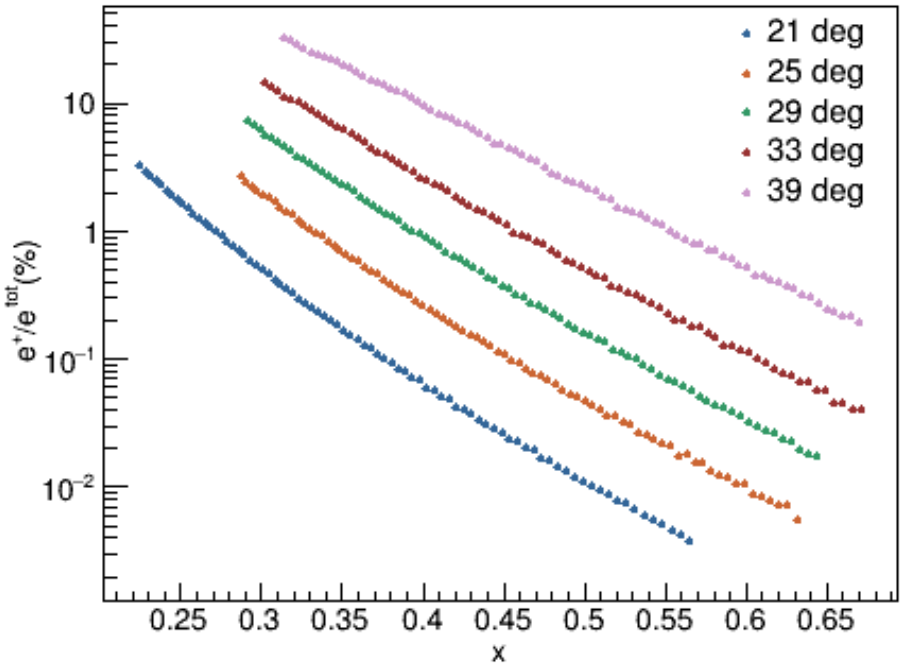
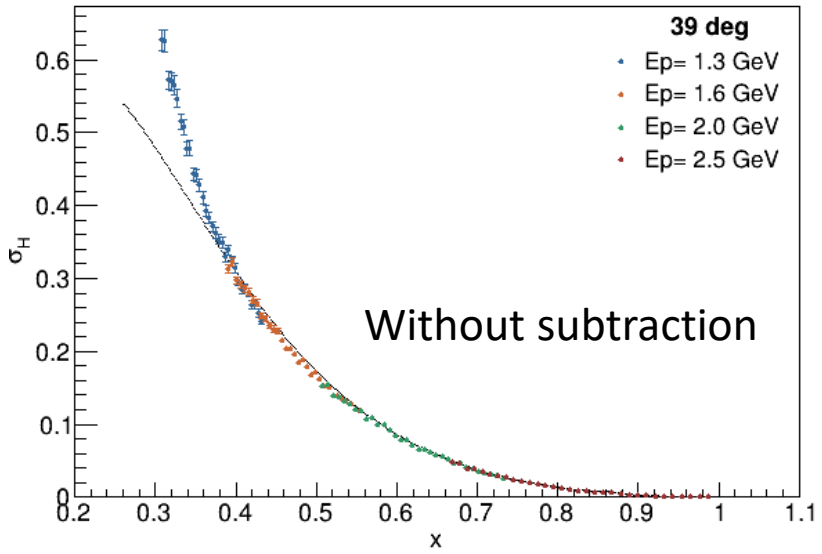
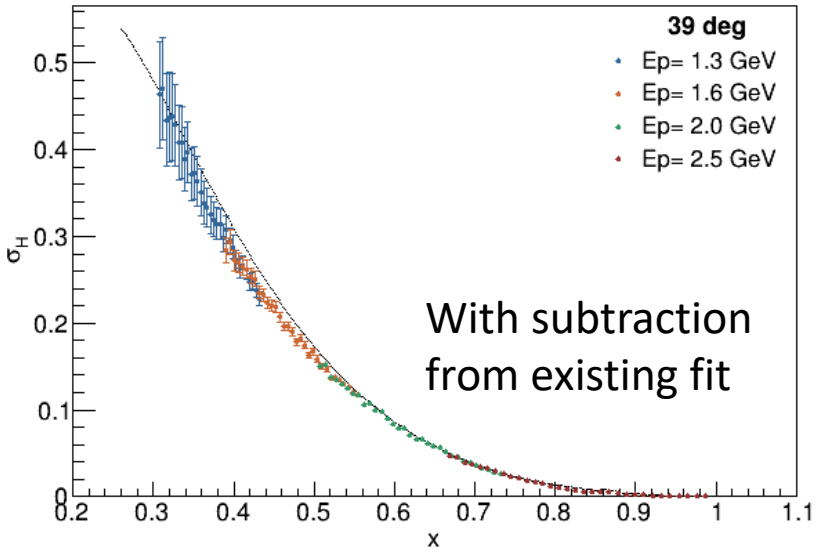
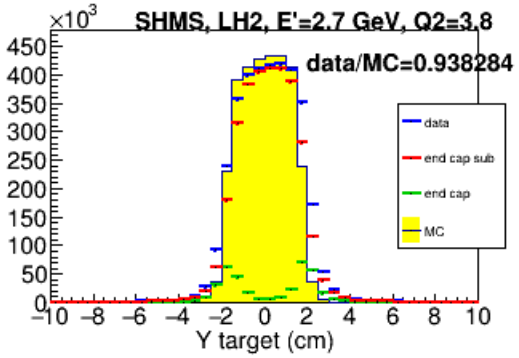
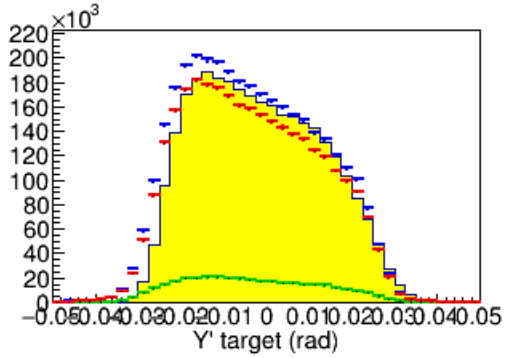


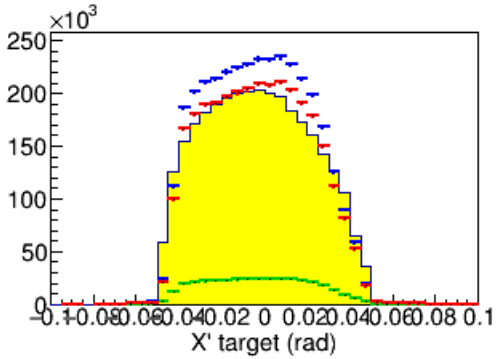


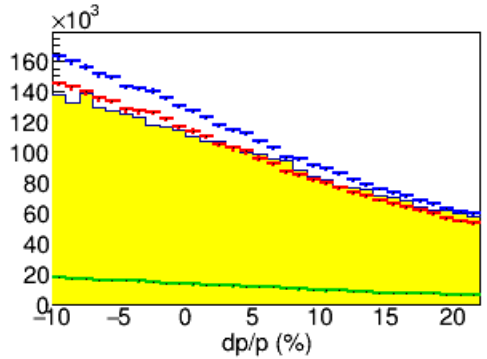


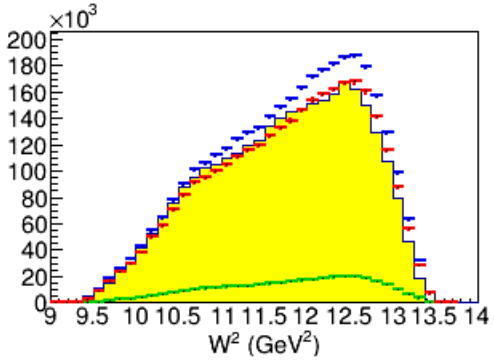
Cross Section Extractions

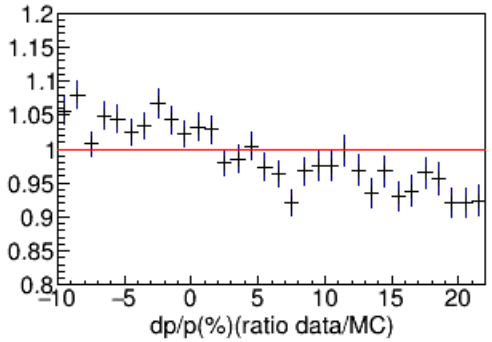




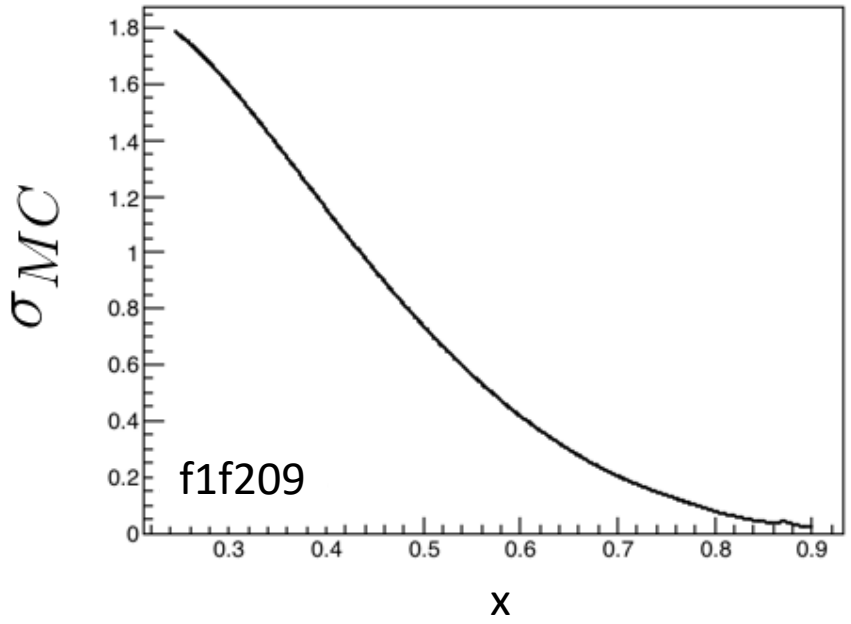




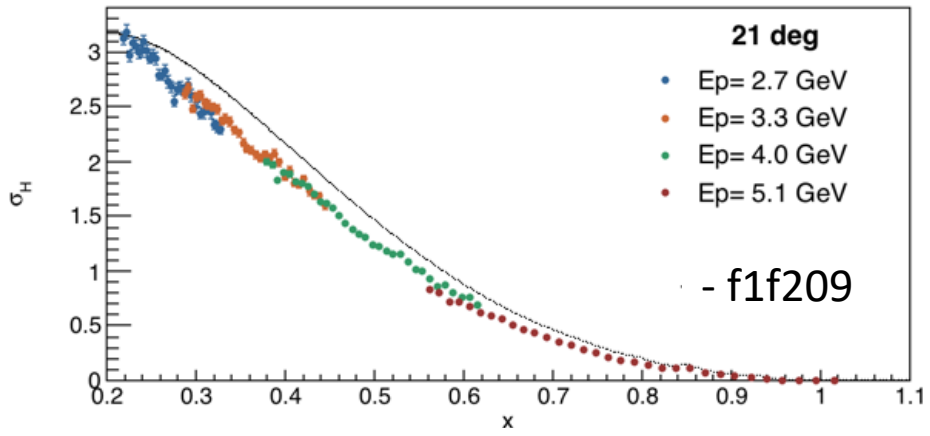


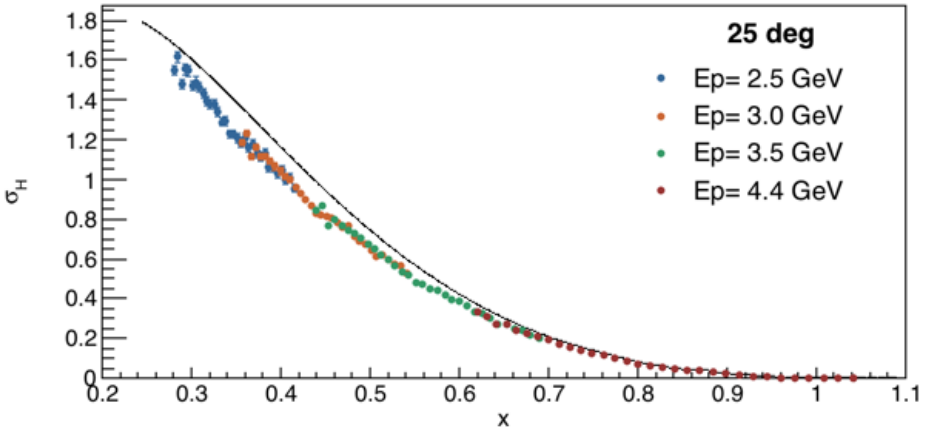


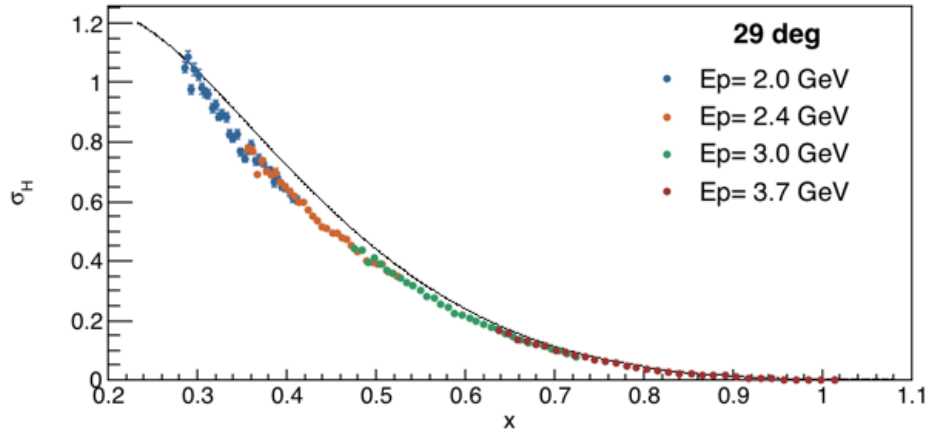
$$\sigma_{data} = \frac{Yield_{data}}{Yield_{MC}} * \sigma_{MC}$$

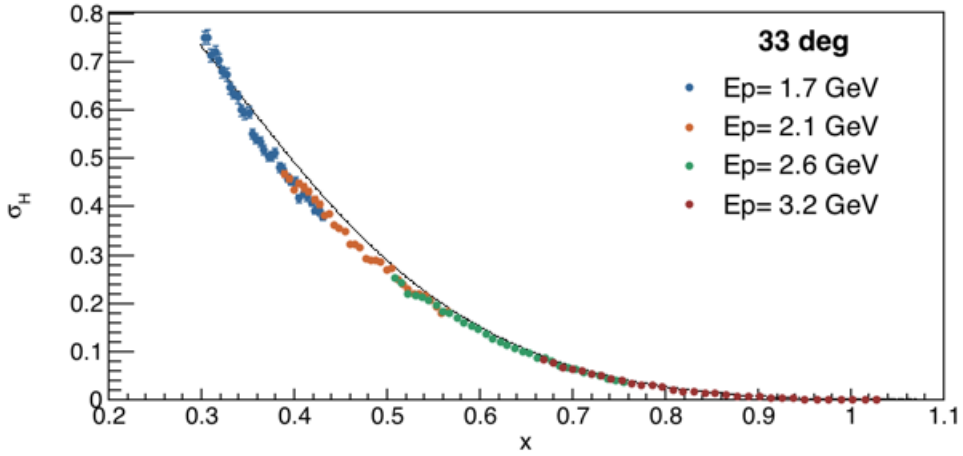


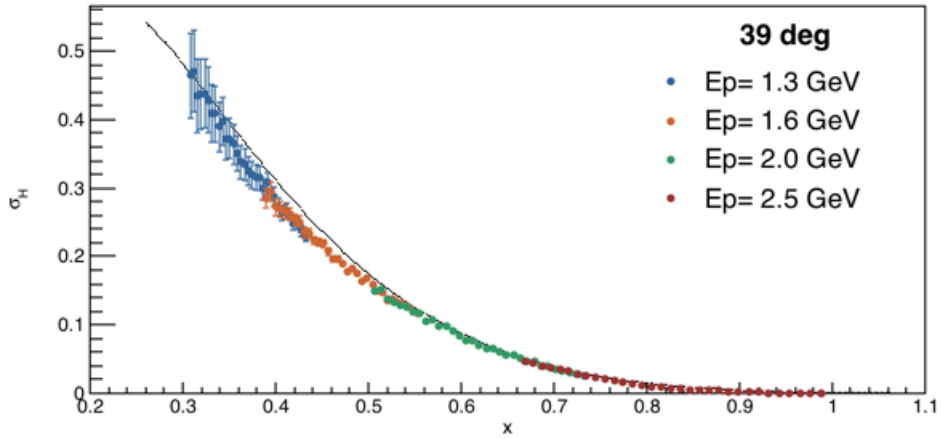
Preliminary Cross Sections: H(e,e’)





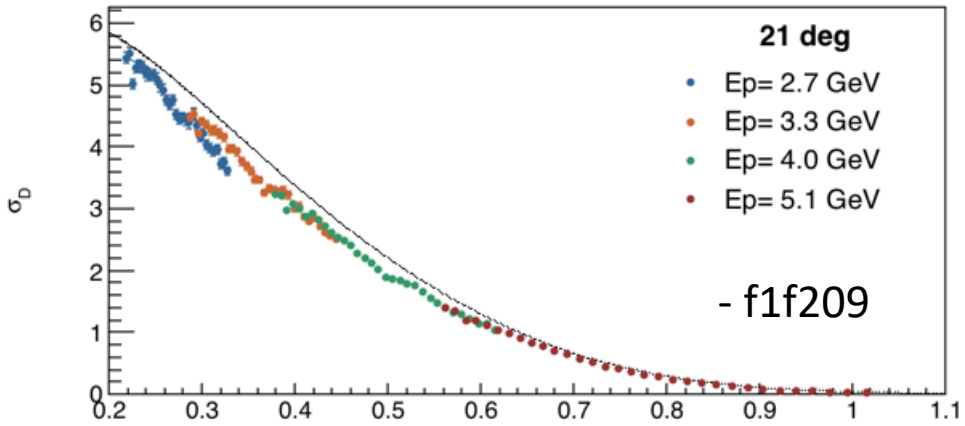


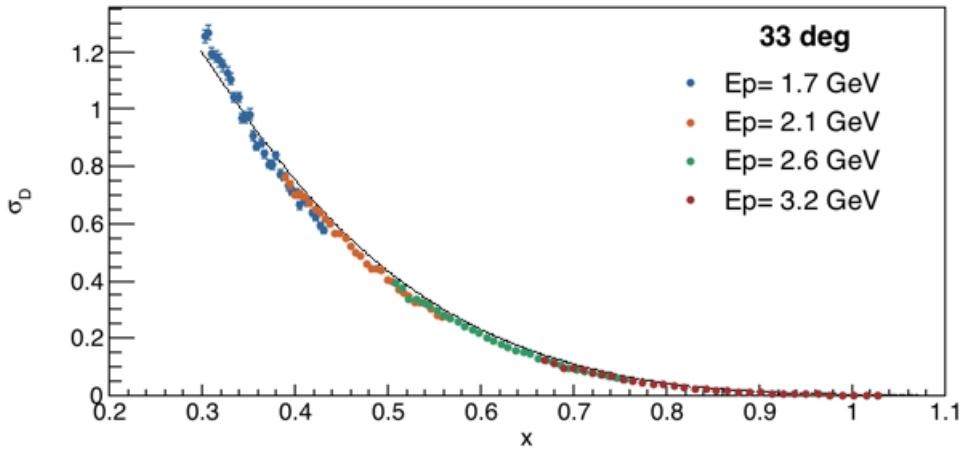


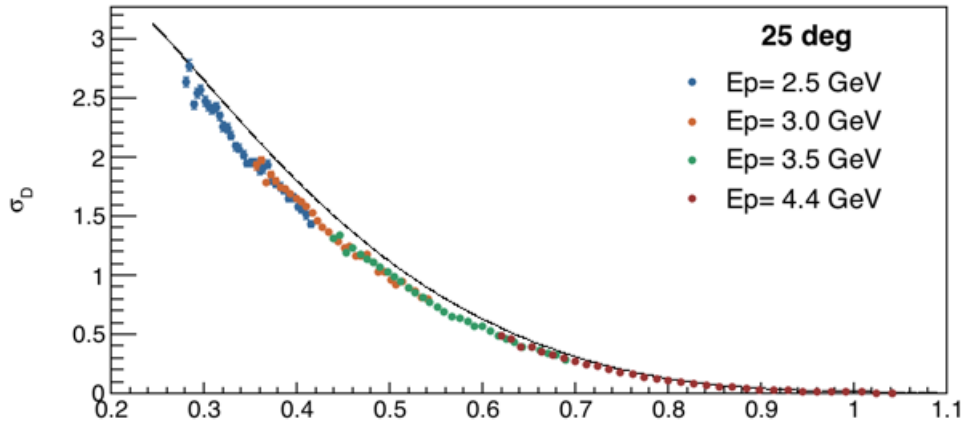


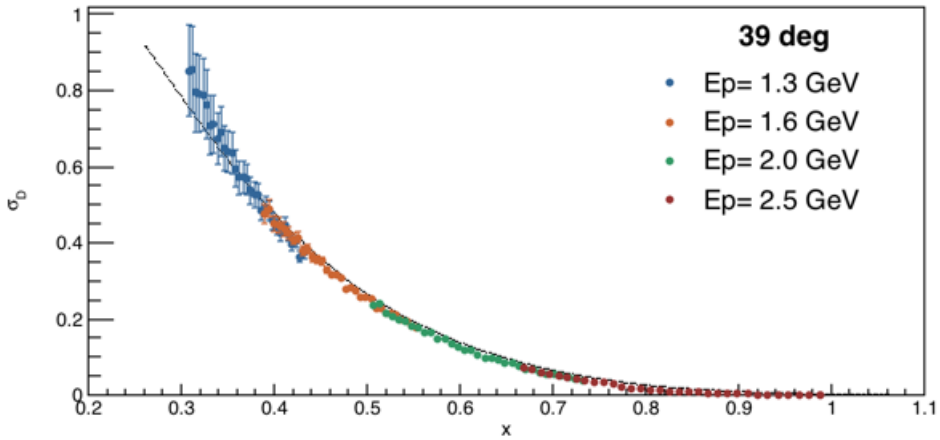
- Overlap between each momentum setting looks good
  → We understand the SHMS acceptance fairly well

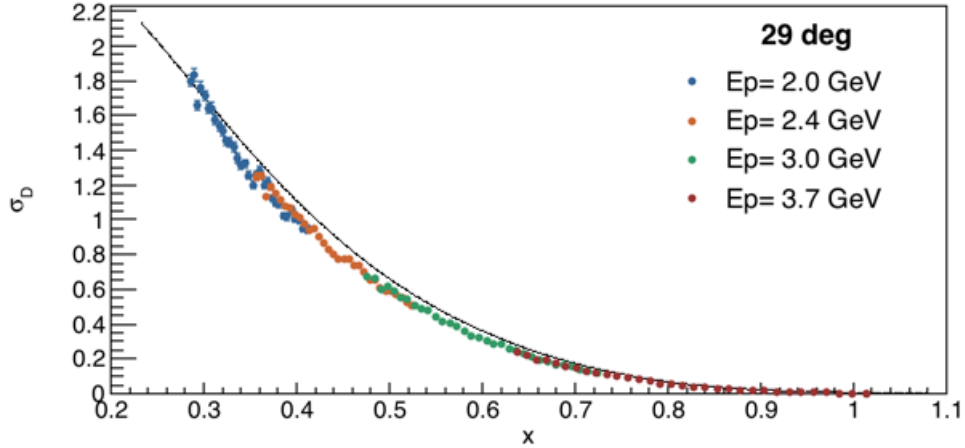
Preliminary Cross Sections: D(e,e’)











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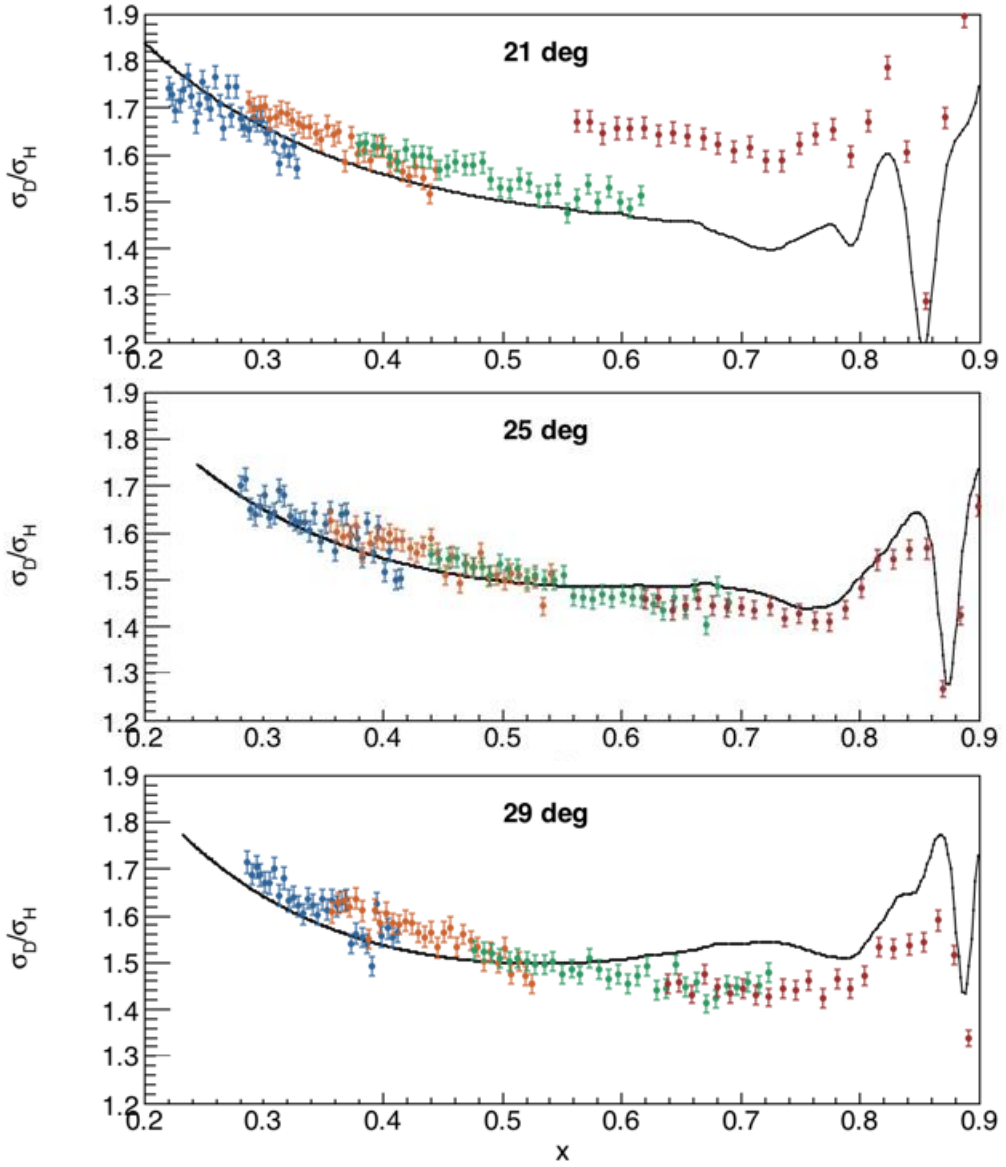
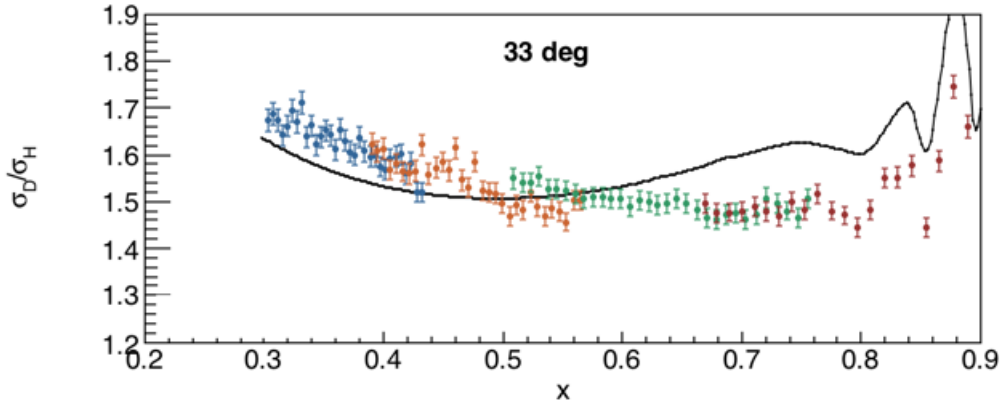
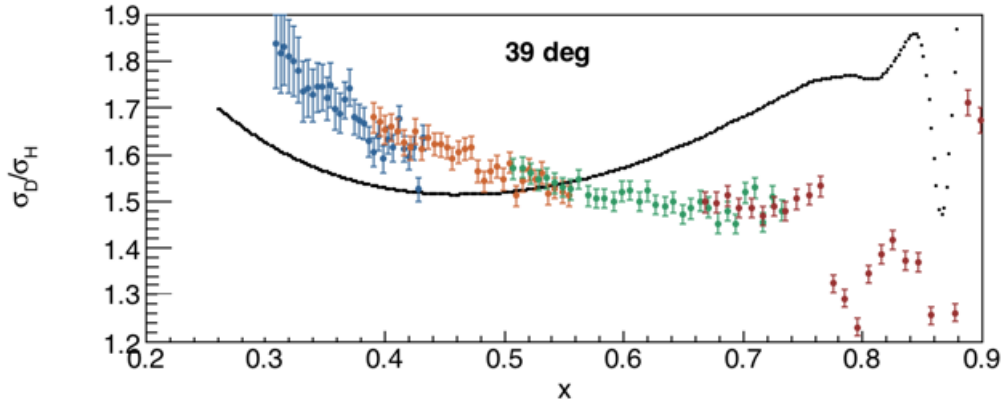
Ratios: D(e,e')/H(e,e')







- The uncertainties shown are statistical and systematic (only the largest three contributors)

Summary

- E12-10-002 ran in Hall C in Spring 2018 to measure H(e,e') and D(e,e') cross sections in the DIS and the resonance region regimes – physics program has been completed
- We expect a varied and exciting physics output: PDF extractions, QHD studies, non-singlet moments and comparisons to LQCD if calculations become available at higher Q^2, resonance and DIS modeling…
- Analysis is progressing well and we hope to push out our first publication this year on D/H ratios and F_2^n/F_2^p extraction

Duality Studies in F_2 – Highlights from 6 GeV JLab

➢ Define duality intervals

Region	1st	2nd	3rd	4th	DIS	global
W_{min}	1.3	1.9	2.5	3.1	3.9	1.9
W_{max}	1.9	2.5	3.1	3.9	4.5	4.5

→ There is arbitrariness in defining the local W intervals; typically try to catch peaks and valleys within one interval

How well resonance data average to the scaling curve?

- Calculate ratio:

$$\int_{x_{min}}^{x_{max}} F^{data}(x,Q^2)\,dx \Big/ \int_{x_{min}}^{x_{max}} F^{param.}(x,Q^2)dx$$