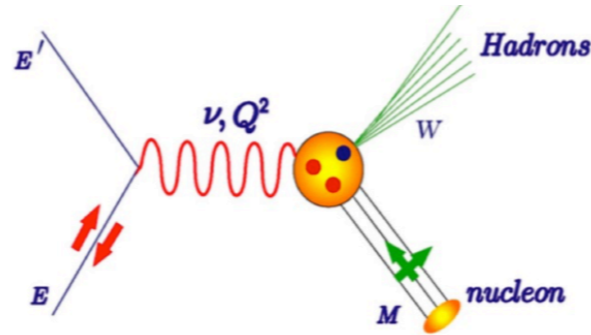


New Measurements of the Deuteron to Hydrogen F2 Structure Function Ratio

F2 Experiment in Hall C

$$\frac{d^2\sigma}{d\Omega dE'} = \frac{\alpha^2}{4E^2 \sin^4\left(\frac{\theta}{2}\right)} \left(\frac{2}{M} F_1(x, Q^2) \sin^2\left(\frac{\theta}{2}\right) + \frac{1}{\nu} F_2(x, Q^2) \cos^2\left(\frac{\theta}{2}\right) \right)$$

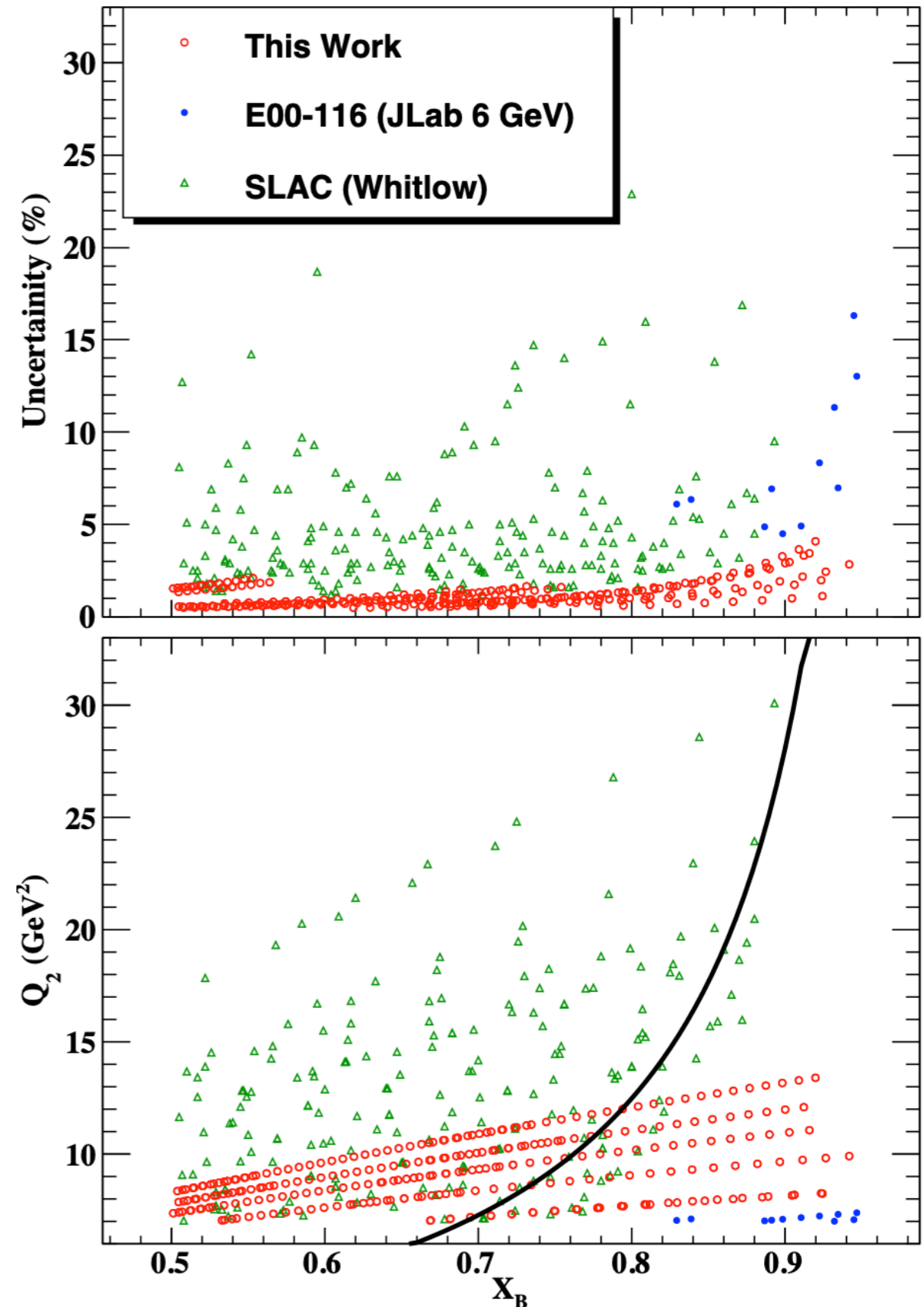
$Q^2 = 4EE' \sin^2(\theta/2)$ 4-momentum transfer
 $\nu = E - E'$ Energy transfer
 $W = M^2 + 2M\nu - Q^2$ Final state hadronic mass
 θ Scattering angle
 $x = Q^2/2M\nu$ Quark fractional momentum



- 12 GeV Commissioning Experiment
- Ran in Spring 2018
- Single Arm (Inclusive) measurement
- Scattered e- detected in spectrometers
- Hydrogen and Deuterium Liquid Targets

Physics motivation

- Constrain PDFs
- Quark hadron duality
- Non singlet moments
- Resonance /DIS modelling



F2 Experiment in Hall C

Hall C Spectrometers

71% of total data were taken by SHMS

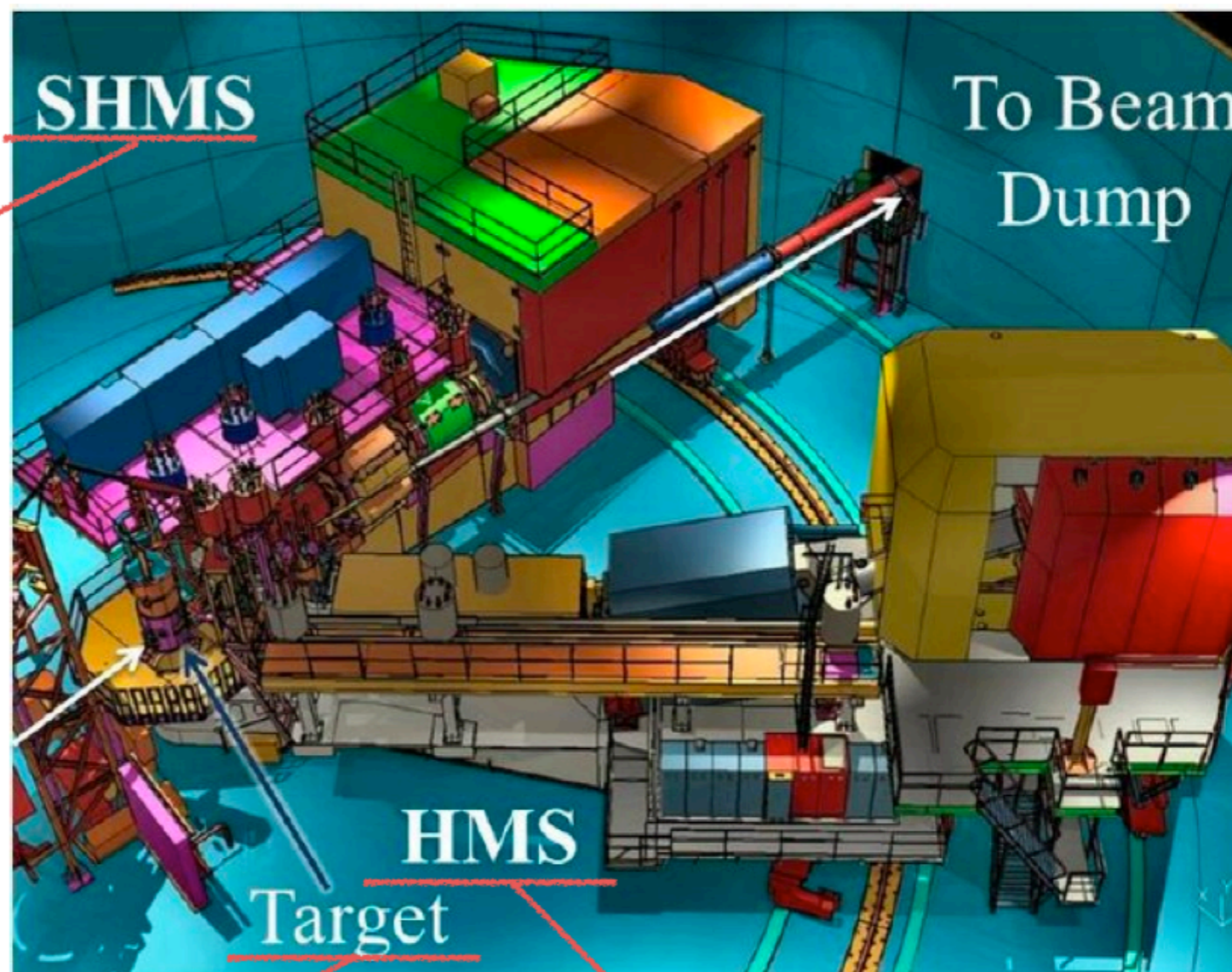
SHMS

| Angle | Momentum(GeV/c) |
|-------|--------------------|
| 21 | 2.7, 3.3, 4.0, 5.1 |
| 25 | 2.5, 3.0, 3.5, 4.4 |
| 29 | 2.0, 2.4, 3.0, 3.7 |
| 33 | 1.7, 2.1, 2.6, 3.2 |
| 39 | 1.3, 1.6, 2.0, 2.5 |

We will extract H,D(e,e') cross sections.

positron data

| Angle | Momentum(GeV/c) |
|-------|-----------------|
| 21 | 2.7 |
| 29 | 2.0, 2.7 |
| 39 | 1.3, 1.8 |



LH₂, LD₂, Al

Push to high Q²

F2 Cross Section Extraction

Data Yields

Number of scattered particles from the tracks in drift chambers and pass through all the PID (cerenkov and calorimeter) cuts

| Acceptance Cuts for SHMS |
|--------------------------|
| $-10.0 < y_{tar} < 10.0$ |
| $-0.1 < y'_{tar} < 0.1$ |
| $-0.1 < x'_{tar} < 0.1$ |
| $-10.0 < \delta < 22.0$ |
| PID Cuts for SHMS |
| $N_{cer} > 2.0$ |
| $E_{calo}/E' > 0.7$ |
| Current Cut for SHMS |
| $I_{BCM\ AC} > 5.0$ |

Total efficiency :

$$\epsilon_{tot} = \epsilon_{track} \times \epsilon_{cerenkov} \times \epsilon_{calorimeter}$$

$$Y_{data} = \frac{N^{e^-} - BG}{\epsilon_{tot} E_{LT} C_{LT}} \times PS$$

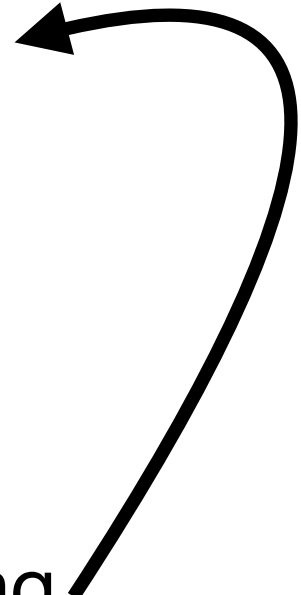
Pion contamination +
~~Charge Symmetric background~~ +
 Cryo Cell Contribution

Prescale
 Computer live time
 Electronic live time

See talk at Winter Collaboration meeting for more analysis details
 (Pion contamination, Charge Symmetric Background, Livetime, PID, radiative corrections, etc)

F2 Cross Section Extraction

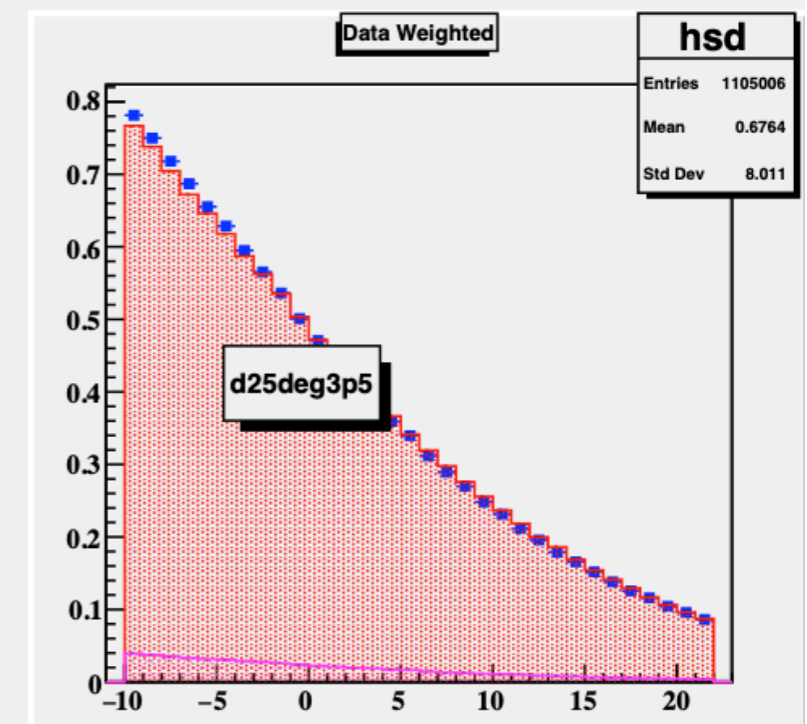
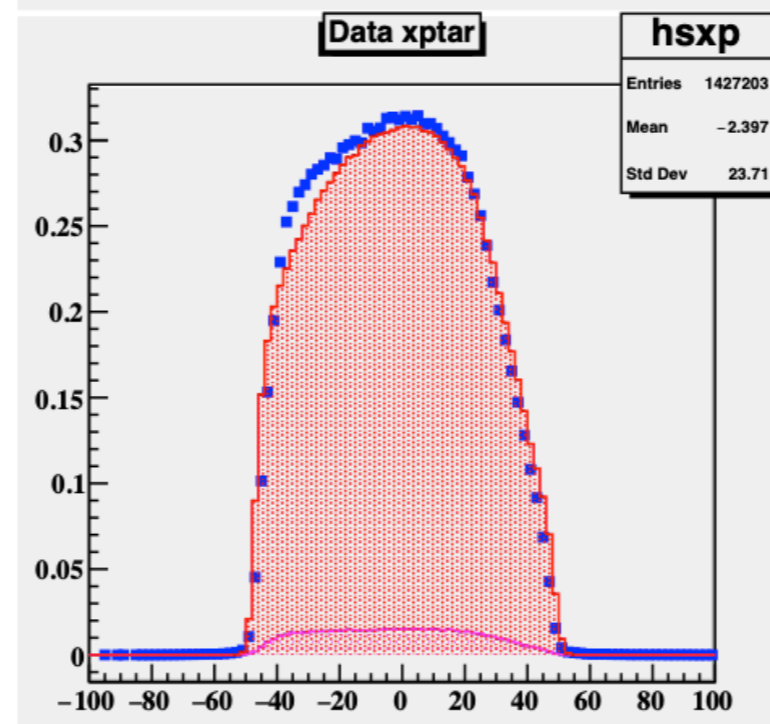
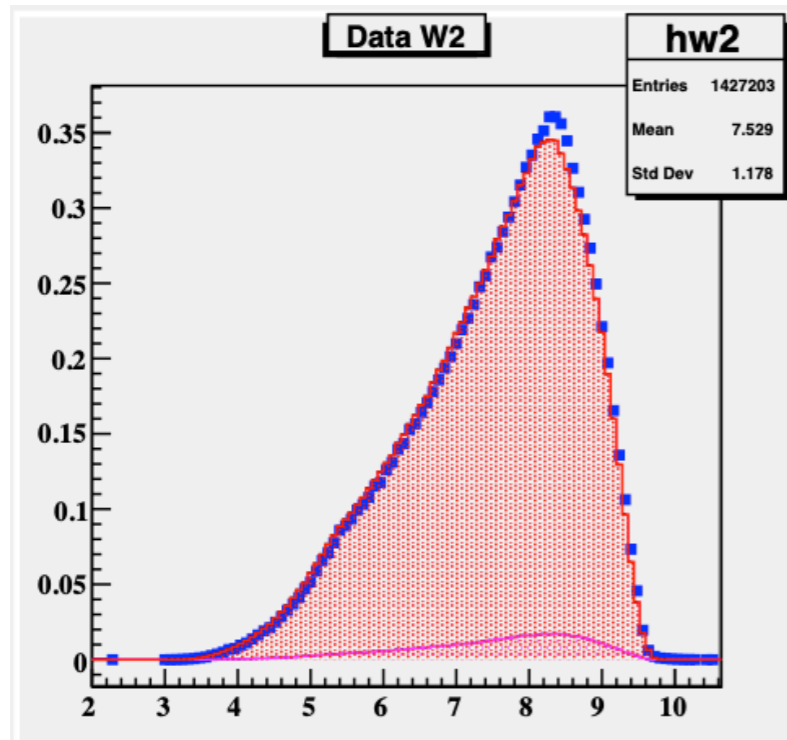
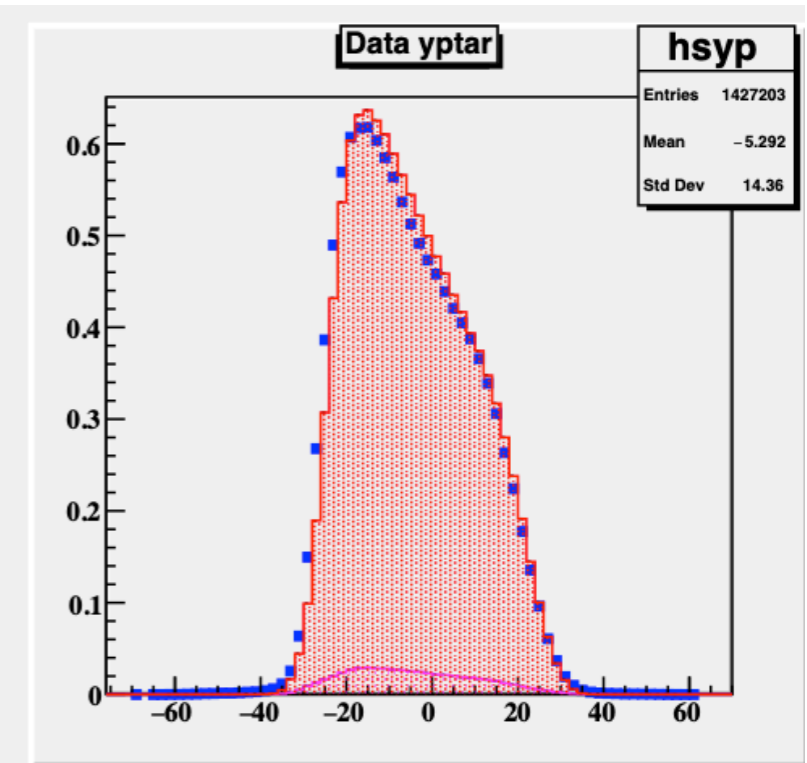
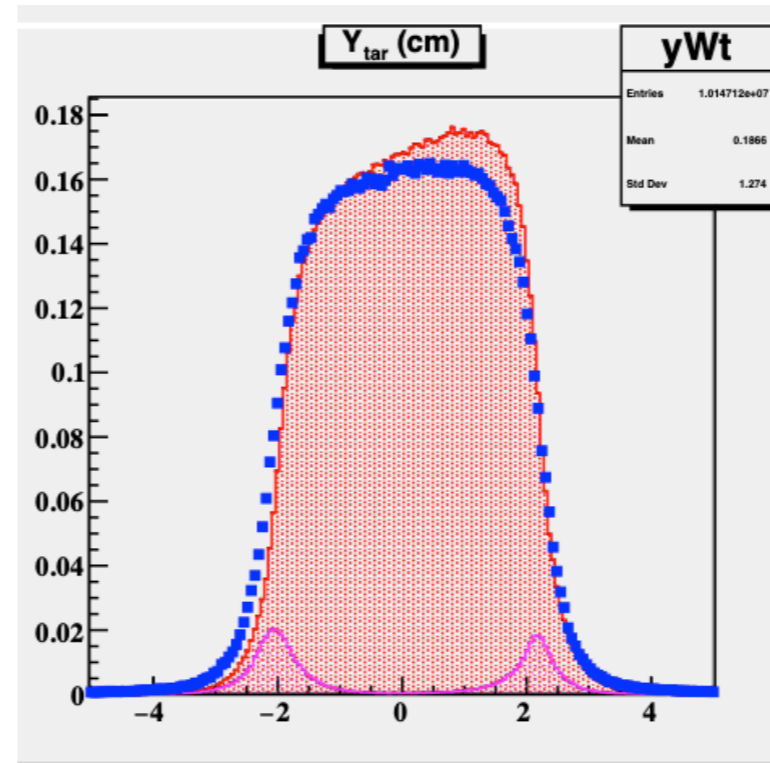
Monte Carlo (MC) Ratio Method

$$\left(\frac{d\sigma}{d\Omega dE'} \right)_{exp} = \left(\frac{d\sigma}{d\Omega dE'} \right)_{model} \frac{Y_{data}}{Y_{MC}}$$


- MC ran for 50M events mc-single-arm
- Events are weighted after using radiated using rc_externals and f1f221 model
- Charge Symmetric Background added to MC

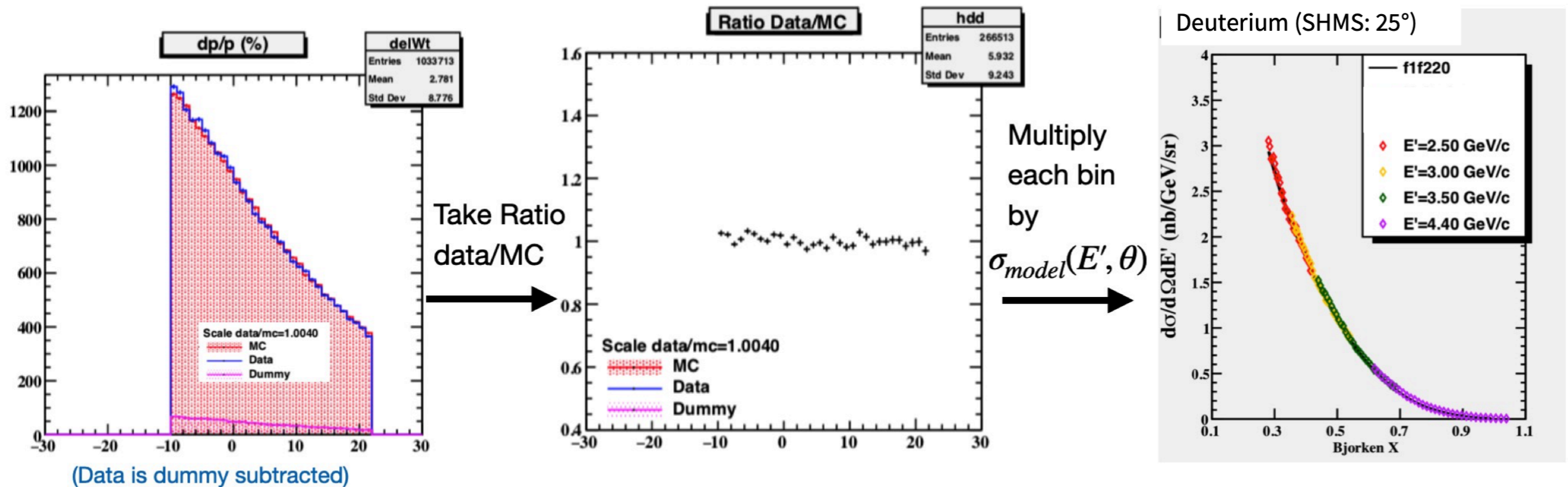
F2 Cross Section Extraction

Data vs MC



F2 Cross Section Extraction

Cross Section Extraction (MC Ratio Method)



1) MC (weighted with radiative cxsec) and corrected data yields are binned in delta

2) Take ratio of data and MC

3) Multiply each bin by model (not radiated) to get cross section

F2 Cross Section Extraction: Acceptance Method

$$1) \quad \frac{d\sigma}{dE'd\Omega} = \frac{Y(E', \theta)}{\Delta E' * \Delta\Omega * A(E', \theta) * \mathcal{L}}$$

$A(E', \theta) = \text{Acceptance}$

$$2) \quad A(E', \theta) = \frac{N_{\text{accepted}}(E', \theta)}{N_{\text{Thrown}}(E', \theta)}$$

$\Delta\Omega = \text{Solid Angle generated in}$

$\Delta\Omega_{\text{Eff}} = \text{Effective Solid Angle}$

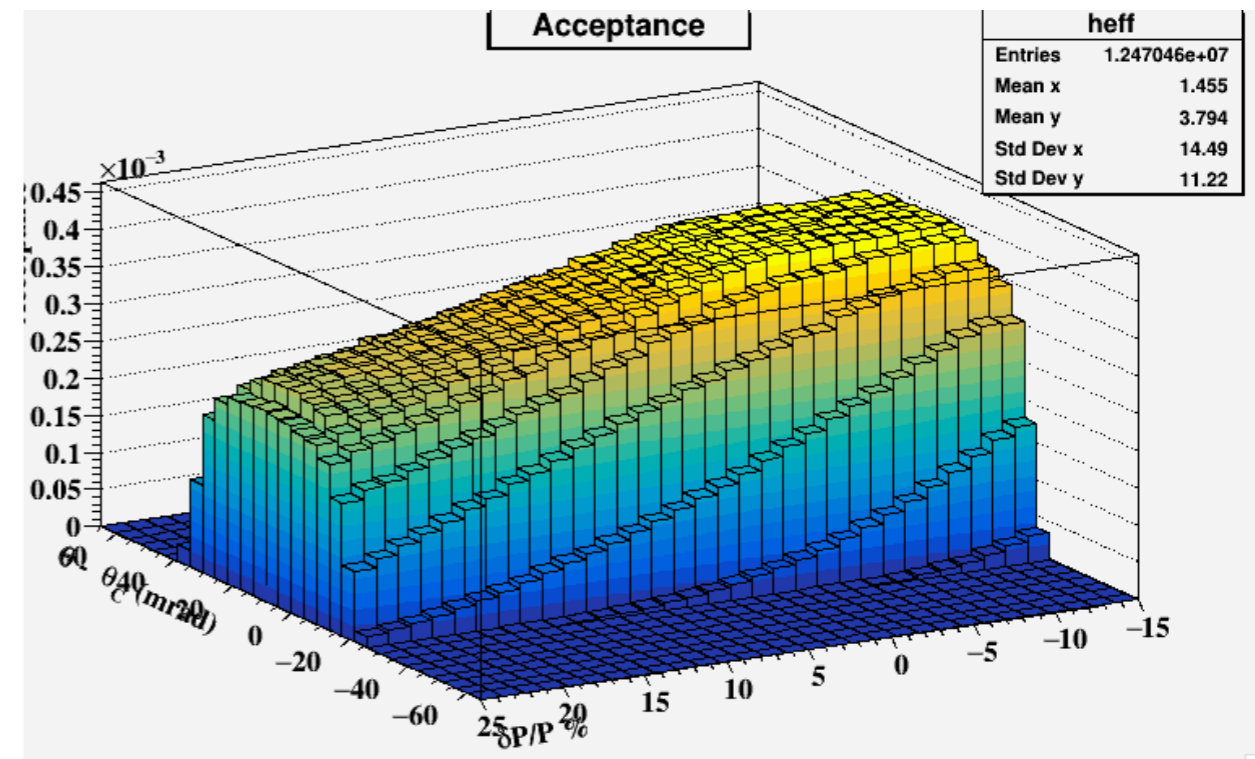
$Y(E', \theta) = \text{data yield}$

$\Delta E = \text{width of delta bin (GeV)}$

$\mathcal{L} = \text{Luminosity(targets/nb)}$

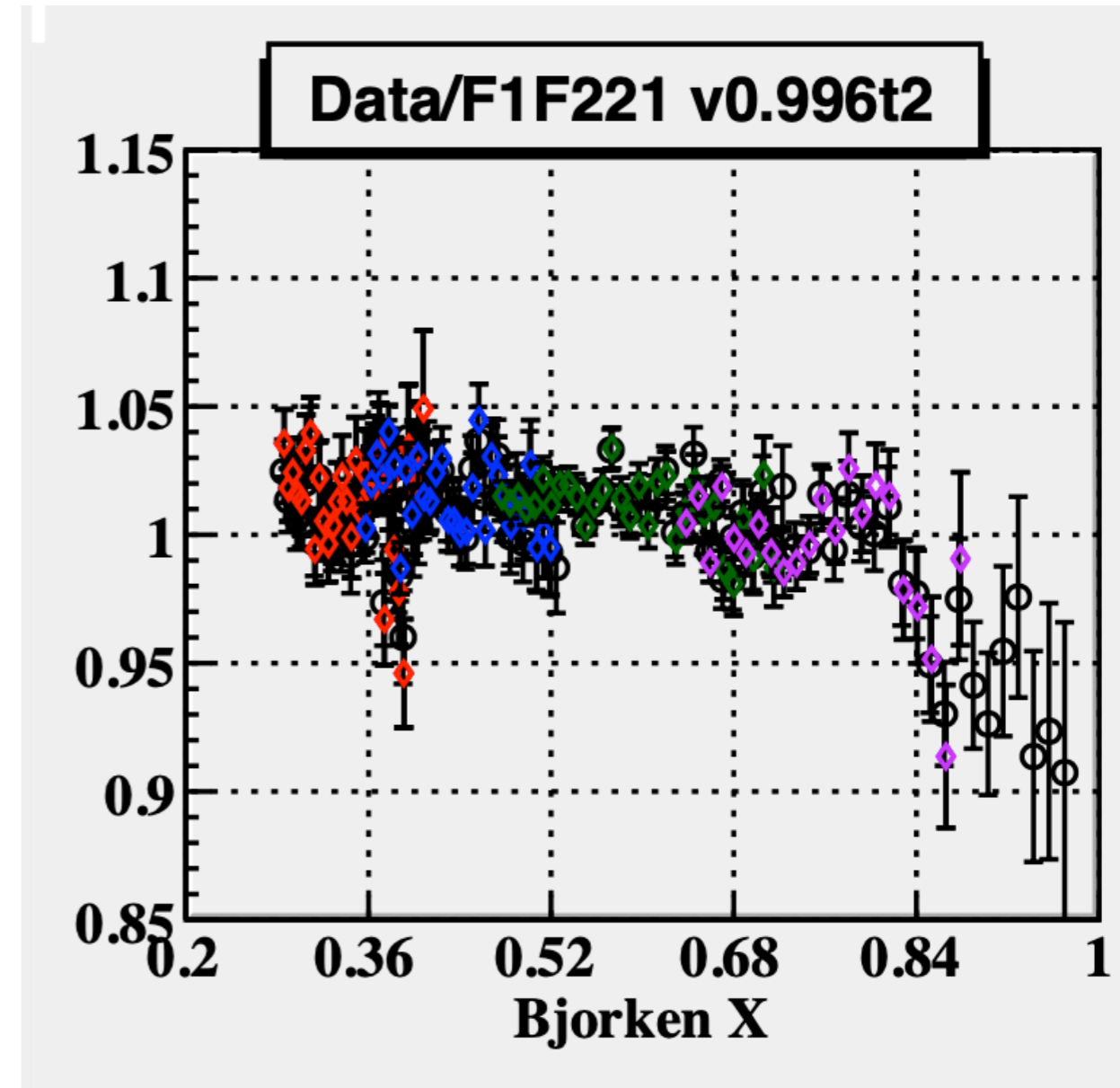
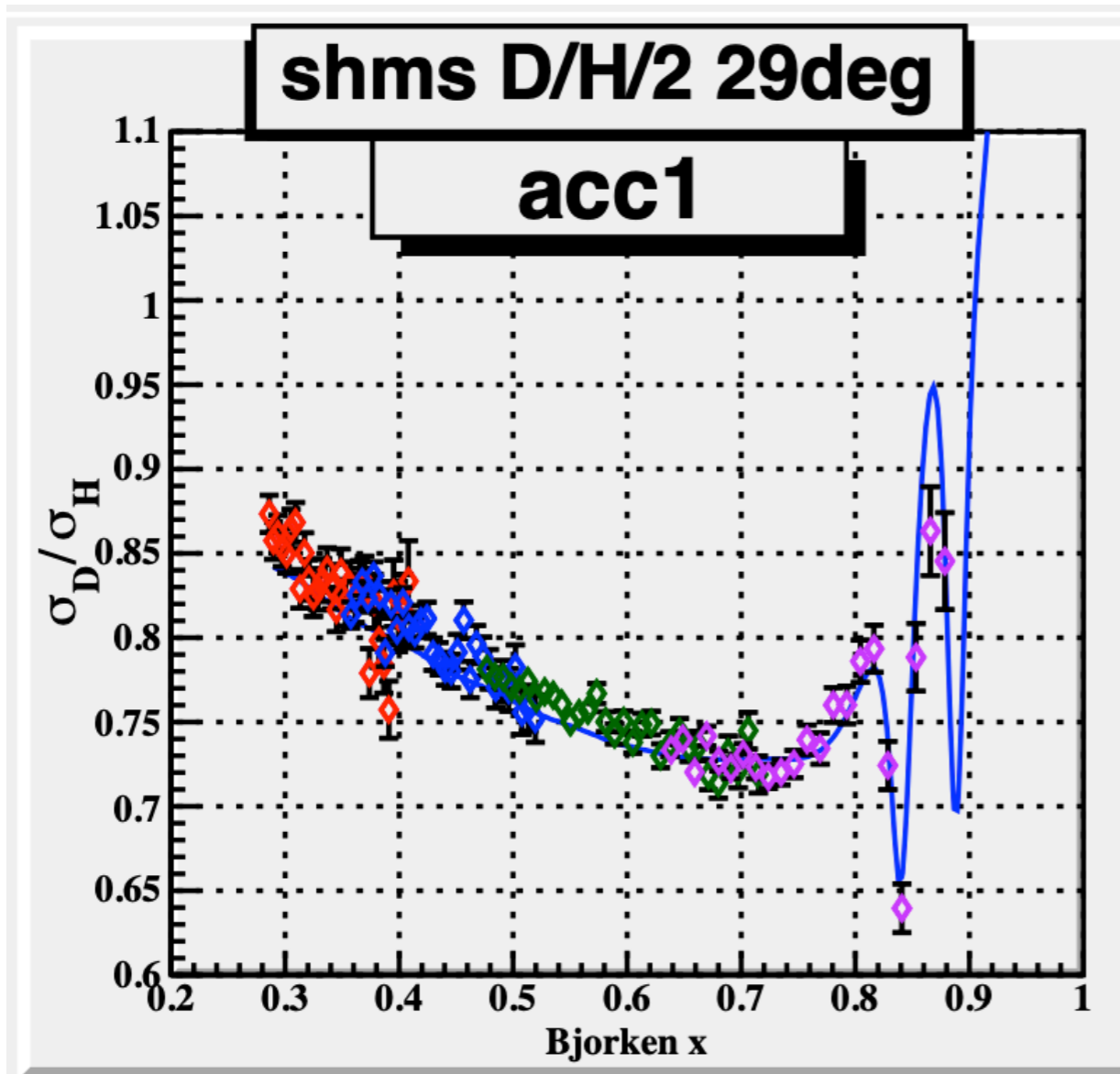
$$3) \quad \Delta\Omega_{\text{Eff}} = A(E', \theta) * \Delta\Omega$$

$$4) \quad \frac{d\sigma}{dE'd\Omega} = \frac{Y(E', \theta)}{\Delta E' * \Delta\Omega_{\text{Eff}} * \mathcal{L}}$$



F2 Cross Section Extraction: Acceptance Method

Monte Carlos Ratio Vs Acceptance Methods



F2 Results

HMS and SHMS @ 21 degrees

CJ15

Constraints on large- x parton distributions from new weak boson production and deep-inelastic scattering data

A. Accardi (Hampton U. and Jefferson Lab), L.T. Brady (Jefferson Lab and UC, Santa Barbara), W. Melnitchouk (Jefferson Lab), J.F. Owens (Florida State U.), N. Sato (Jefferson Lab)
Feb 9, 2016

KP Hybrid

Nuclear effects in the deuteron in the resonance and deep-inelastic scattering region

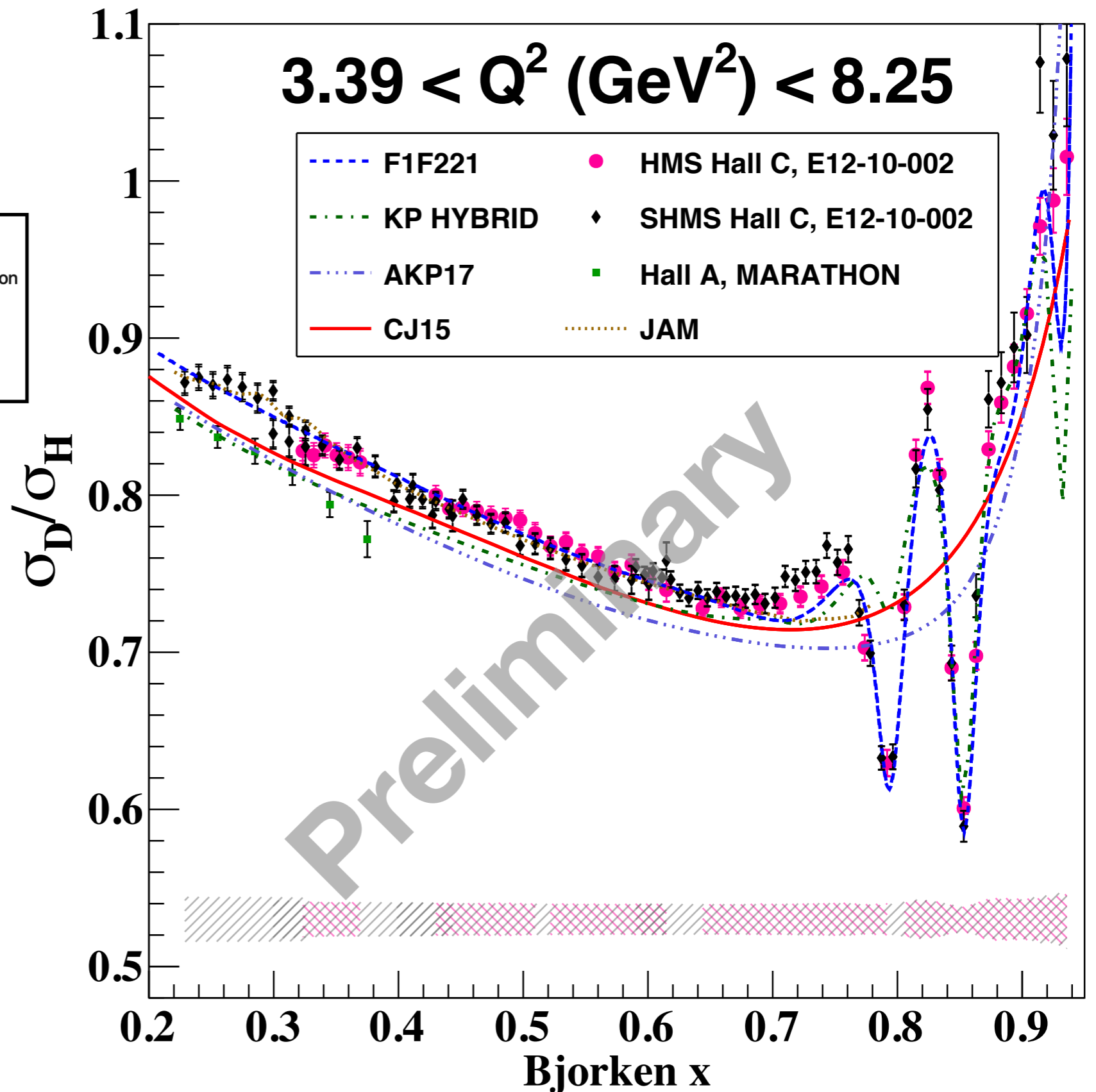
S.A. Kulagin (Moscow, INR)
Dec 31, 2018

AKP17

Nuclear Effects in the Deuteron and Constraints on the d/u Ratio

S.I. Alekhin (Serpuukhov, IHEP), S.A. Kulagin (Moscow, INR), R. Petti (South Carolina U.)
Apr 1, 2017

New Results!



F2 Results

HMS and SHMS @ 21 degrees

CJ15

Constraints on large- x parton distributions from new weak boson production and deep-inelastic scattering data

A. Accardi (Hampton U. and Jefferson Lab), L.T. Brady (Jefferson Lab and UC, Santa Barbara), W. Melnitchouk (Jefferson Lab), J.F. Owens (Florida State U.), N. Sato (Jefferson Lab)
Feb 9, 2016

KP Hybrid

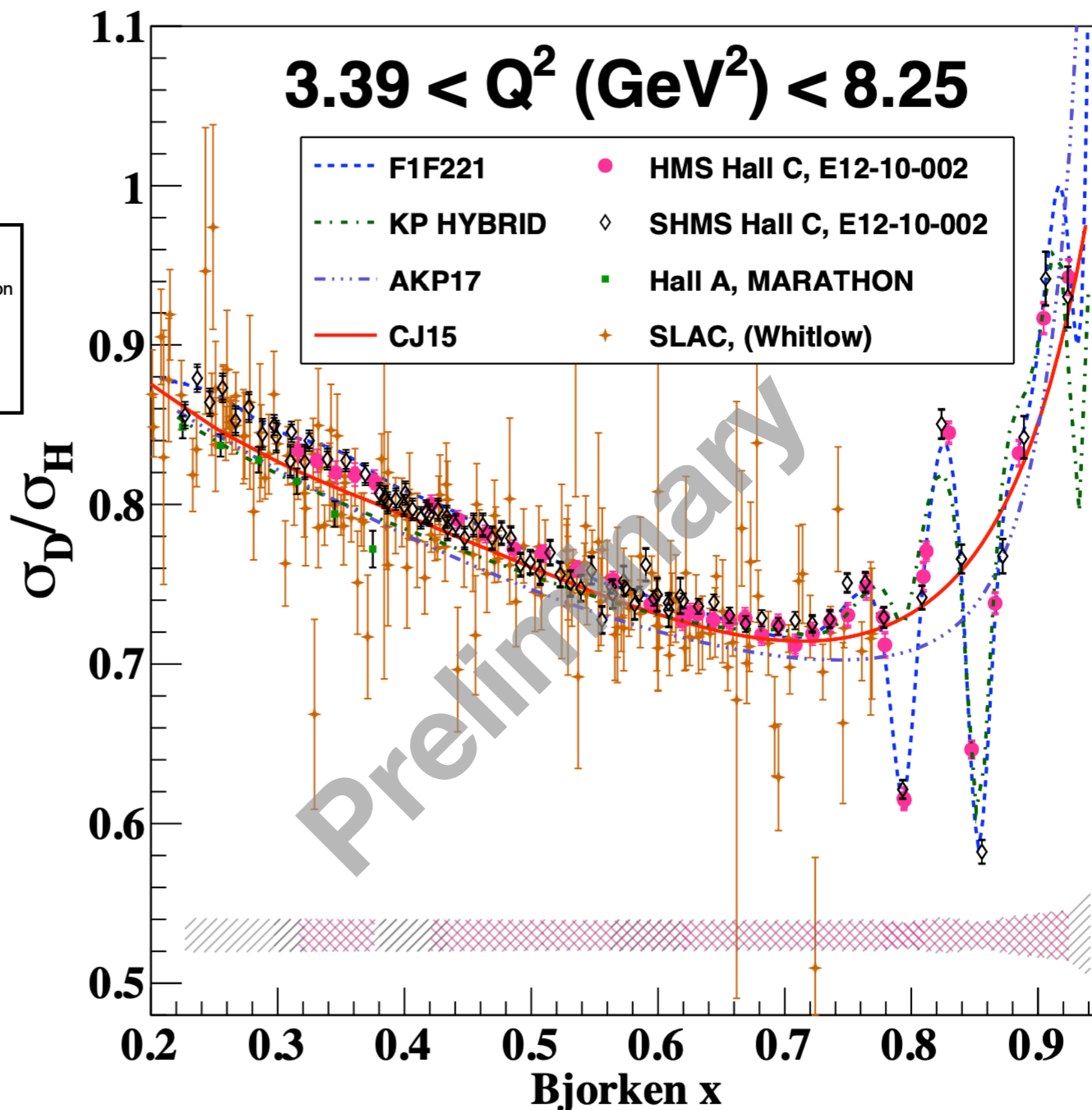
Nuclear effects in the deuteron in the resonance and deep-inelastic scattering region

S.A. Kulagin (Moscow, INR)
Dec 31, 2018

AKP17

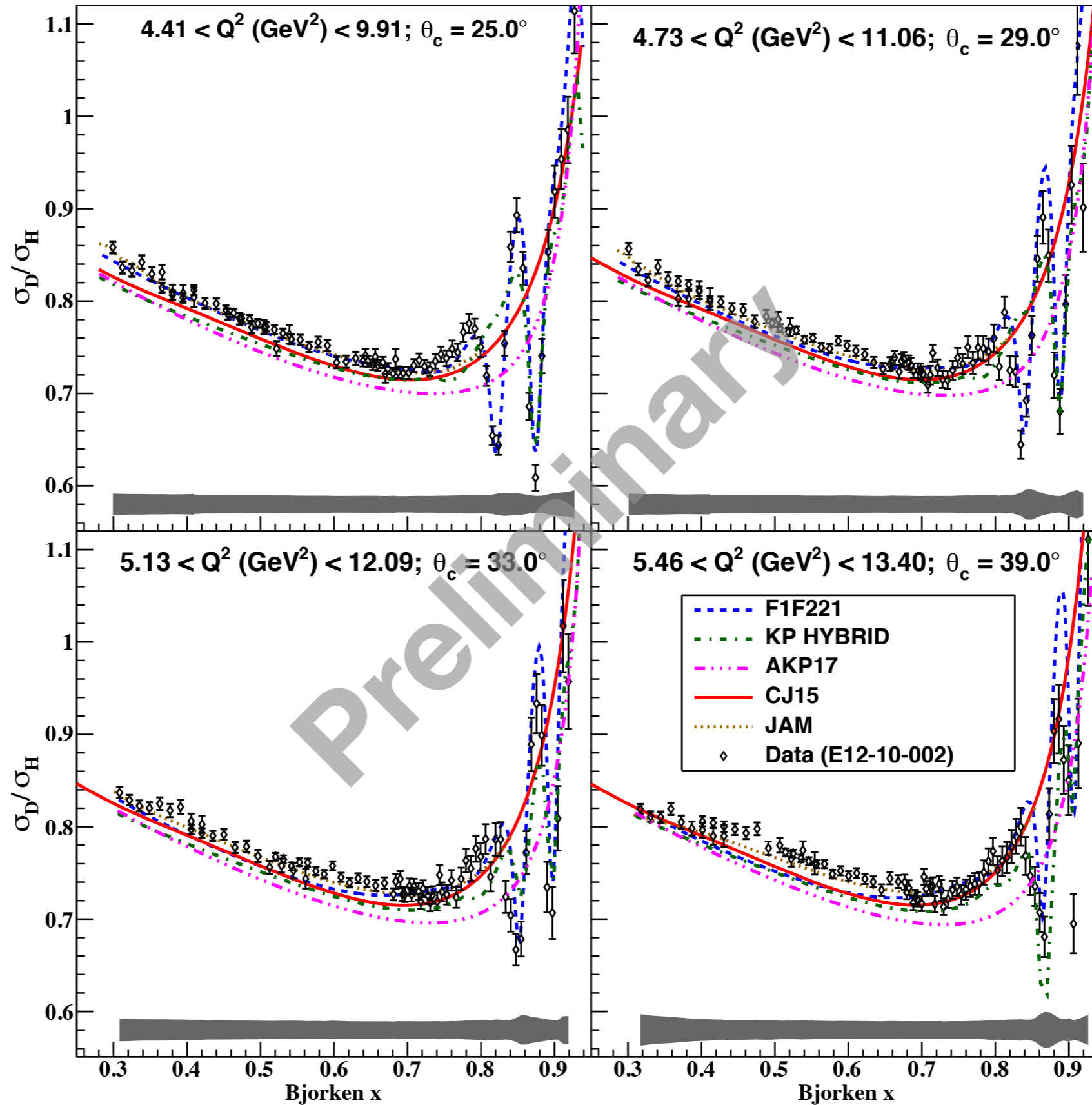
Nuclear Effects in the Deuteron and Constraints on the d/u Ratio

S.I. Alekhin (Serpukhov, IHEP), S.A. Kulagin (Moscow, INR), R. Petti (South Carolina U.)
Apr 1, 2017



F2 Results

New
Results!



D/H Ratio Error Budget

| Error | Pt. to Pt (%) | Correlated (%) |
|------------------------|----------------|----------------|
| Statistical | 0.6 – 5.6(2.9) | |
| Charge | 0.1 – 0.6 | |
| Target Density | 0.0 – 0.2 | 1.1 |
| Livetime | | 0.0 – 1.0 |
| Model Dependence | | 0.0 – 2.6(1.2) |
| Charge Sym. Background | | 0.0 – 1.4 |
| Acceptance | | 0.0 – 0.6(0.3) |
| Kinematic | | 0.0 – 0.4 |
| Radiative Corrections | | 0.5 – 0.7(0.6) |
| Pion Contamination | | 0.1 – 0.3 |
| Cerenkov Efficiency | | 0.1 |
| Total | 0.6 – 5.7(2.9) | 1.3 – 2.9(2.1) |

TABLE I. Error budget for the cross section ratio σ_D/σ_H . The error after a cut of $W^2 > 3 \text{ GeV}^2$ is shown in parenthesis, this is a typical cut applied to eliminate the resonance region while performing PDF fits.

Publication Status

PRL paper to be submitted this summer

New Measurements of the Deuteron to Hydrogen F_2 Structure Function Ratio

D. Biswas,⁵ F. Gonzalez,² W. Henry,³ A. Karki,⁴ C. Moore,⁵ A. Nadeeshani,¹ A. Sun,⁶ D. Abrams,⁷ Z. Ahmed,⁸ B. Aljawrneh,⁹ S. Alsalmi,¹⁰ R. Ambrose,⁸ W. Armstrong,¹¹ A. Asaturyan,¹² K. Assum-Gyimah,⁴ C. Ayerbe Gayoso,^{13,4} A. Bandari,¹³ S. Baner,¹⁴ V. Berdnikov,¹⁴ H. Bhatt,⁴ D. Bhetwal,⁴ W. U. Boeglin,¹⁵ P. Bosted,¹³ E. Braash,¹⁶ M. H. S. Bukhari,¹⁷ H. Chen,⁷ J. P. Chen,³ M. Chen,³ M. E. Christy,³ S. Covrig,³ K. Craycraft,¹⁵ S. Danagoulian,⁹ D. Day,⁷ M. Dieffenthaler,³ M. Dlamini,¹⁸ J. Dunne,⁴ B. Duran,¹¹ D. Dutta,⁴ R. Ent,³ R. Evans,⁹ H. Fenker,³ N. Fomin,⁵ E. Fuchey,¹⁹ D. Gaskell,³ T. N. Gautham,¹ F. A. Gonzalez,² J. O. Hansen,³ F. Hauenstein,²⁰ A. V. Hernandez,¹⁴ T. Horn,¹⁴ G. M. Huber,⁸ M. K. Jones,³ S. Joosten,²¹ M. L. Kabir,⁴ C. Keppel,³ A. Khanal,¹⁵ P. M. King,¹⁵ E. Kinney,²² M. Kohl,¹ N. Lashley-Colthirst,¹ S. Li,²³ W. B. Li,¹³ A. H. Liyanage,¹ D. Mack,³ S. Malace,³ P. Markowitz,¹⁵ J. Matter,⁷ D. Meekins,³ R. Michaels,³ A. Mkrtchyan,¹² H. Mkrtchyan,¹² S. J. Naezer,¹ S. Nanda,⁴ G. Niculescu,²⁴ I. Niculescu,²⁴ D. Nguyen,⁷ Nuruzzaman,²⁵ B. Pandey,¹ S. Park,² E. Pooser,³ A. Pickett,²³ M. Rebuffo,¹¹ J. Reinhold,¹⁵ B. Sawatzky,³ G. R. Smith,³ H. Saumila-Vance,³ A. Tadepalli,²⁵ V. Tadevosyan,¹² R. Trotta,¹⁴ S. A. Wood,³ C. Yero,¹⁵ and J. Zhang²

(for the Hall C Collaboration)

¹Hampton University, Hampton, Virginia 23669, USA

²Stony Brook University, Stony Brook, New York 11794, USA

³Thomas Jefferson National Accelerator Facility, Newport News, Virginia 23806, USA

⁴Mississippi State University, Mississippi State, Mississippi 39762, USA

⁵University of Tennessee, Knoxville, Tennessee 37996, USA

⁶Carnegie Mellon University, Pittsburgh, Pennsylvania 15213, USA

⁷University of Virginia, Charlottesville, Virginia 22903, USA

⁸University of Regina, Regina, Saskatchewan S4S 0A2, Canada

⁹North Carolina A & T State University, Greensboro, North Carolina 27411, USA

¹⁰Kent State University, Kent, Ohio 44240, USA

¹¹Temple University, Philadelphia, Pennsylvania 19122, USA

¹²A.I. Alikhanov National Science Laboratory (Yerevan Physics Institute), Yerevan 0036, Armenia

¹³The College of William & Mary, Williamsburg, Virginia 23185, USA

¹⁴Catholic University of America, Washington, DC 20064, USA

¹⁵Florida International University, University Park, Florida 33199, USA

¹⁶Christopher Newport University, Newport News, Virginia 23806, USA

¹⁷Jazan University, Jazan 45142, Saudi Arabia

¹⁸Ohio University, Athens, Ohio 45701, USA

¹⁹University of Connecticut, Storrs, Connecticut 06269, USA

²⁰Old Dominion University, Norfolk, Virginia 23529, USA

²¹Argonne National Laboratory, Lemont, Illinois 60439, USA

²²University of Colorado Boulder, Boulder, Colorado 80309, USA

²³University of New Hampshire, Durham, New Hampshire 03824, USA

²⁴James Madison University, Harrisonburg, Virginia 22807, USA

²⁵Rutgers University, New Brunswick, New Jersey 08854, USA

(Dated: June 20, 2023)

Nucleon structure functions, as measured in lepton-nucleon scattering, have historically provided a critical observable in the study of partonic dynamics within the nucleon. However, at very large parton momenta, it is experimentally and theoretically challenging to extract parton distributions due to the onset of non-perturbative contributions. Extraction of the neutron structure and the d -quark distribution have been further challenging due to the necessity of applying nuclear corrections when utilizing scattering data from a deuteron target to extract free neutron structure. A program of experiments have been carried out recently at the energy upgraded Jefferson Lab electron accelerator aimed at significantly reducing the uncertainties on the d -quark distribution function at large partonic momentum, as well as providing insight into possible isospin dependent effects in $A=3$ nuclei. In this paper we present new data from experiment E12-10-002 carried out in Jefferson Lab Experimental Hall C on the deuteron to proton cross section ratio at large Bjorken- x that significantly improves on the precision of existing data, as well as a first look at the expected impact on global parton distribution function fits.

Measurements of the nucleon F_2 structure function in inelastic lepton-nucleon scattering and the kinematic evolution of F_2 occupy a prominent place in the historical

development and testing of the theory of the strong interaction, Quantum Chromodynamics (QCD). Such measurements have provided critical data in perturbative

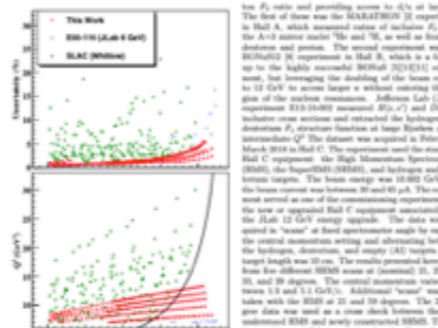


FIG. 1. The deuteron to proton ratio of structure functions F_2 as a function of Bjorken- x for different spectrometer angles θ of 20, 30, 40, and 50 degrees. The data points are shown with error bars, and the solid lines represent the fit to the data.

QCD (pQCD) fit to extract quark and gluon distributions and to testing universality of the pQCD evolution equations of these parton distribution functions (PDFs). While tremendous progress has been made in this endeavor over the last few decades, much is still to be fully explored. One such example is the logarithmic and non-linear distribution of the down quark at large Bjorken- x ($x > 1$), where the nucleon's momentum is predominantly carried by a single valence quark. While there exists a number of effective theory predictions for the ratio of the down to up quark distributions (d/u) at large x , additional experimental data is required to adequately test them. The first few years have seen the completion of three complementary experiments performed at Jefferson Lab utilizing the energy upgraded CEBAF accelerator and aimed at extracting the neutron to proton

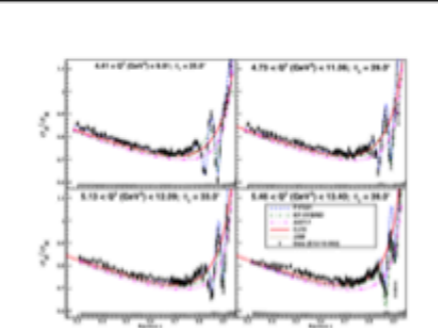


FIG. 2. The relative change in the deuteron to proton ratio of structure functions F_2 as a function of Bjorken- x for different spectrometer angles θ of 20, 30, 40, and 50 degrees. The data points are shown with error bars, and the solid lines represent the fit to the data.

the relative correction included a contribution from the model and also the model. The model dependence was determined by varying the varying and model-like contributions to the model. The error associated with the model fit is shown in the legend. The model of the deuteron to proton ratio is shown in Fig. 1. The error bars include the uncorrelated point to point statistical errors. The error bars include the systematic error and an overall contribution of 1.0% (see the text). The error bars are positive values obtained using the model fit to the data. The model of the deuteron to proton ratio is shown in Fig. 1. The error bars include the uncorrelated point to point statistical errors. The error bars include the systematic error and an overall contribution of 1.0% (see the text). The error bars are positive values obtained using the model fit to the data. The model of the deuteron to proton ratio is shown in Fig. 1. The error bars include the uncorrelated point to point statistical errors. The error bars include the systematic error and an overall contribution of 1.0% (see the text). The error bars are positive values obtained using the model fit to the data.

obtained by repeating the analysis using different models and comparing the final d/u ratio, the largest relative error is at $x > 0.8$, but also reduced the relative error by 20% to 30% across the entire range. Furthermore, the data provide additional constraints on the approximation used in higher twist corrections, the individual d and

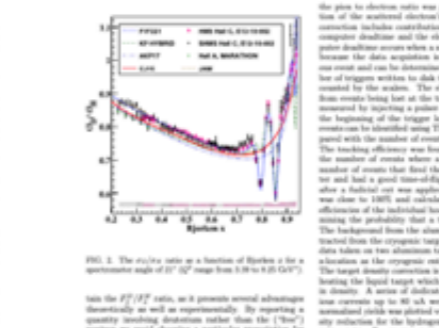


FIG. 3. The deuteron to proton ratio of structure functions F_2 as a function of Bjorken- x for different spectrometer angles θ of 20, 30, 40, and 50 degrees. The data points are shown with error bars, and the solid lines represent the fit to the data.

the deuteron to proton ratio of structure functions F_2 as a function of Bjorken- x for different spectrometer angles θ of 20, 30, 40, and 50 degrees. The data points are shown with error bars, and the solid lines represent the fit to the data. The error bars include the uncorrelated point to point statistical errors. The error bars include the systematic error and an overall contribution of 1.0% (see the text). The error bars are positive values obtained using the model fit to the data. The model of the deuteron to proton ratio is shown in Fig. 1. The error bars include the uncorrelated point to point statistical errors. The error bars include the systematic error and an overall contribution of 1.0% (see the text). The error bars are positive values obtained using the model fit to the data.

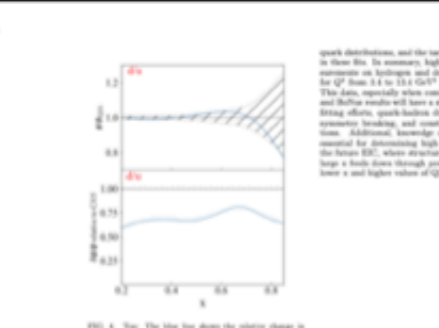


FIG. 4. The relative change in the deuteron to proton ratio of structure functions F_2 as a function of Bjorken- x for different spectrometer angles θ of 20, 30, 40, and 50 degrees. The data points are shown with error bars, and the solid lines represent the fit to the data.

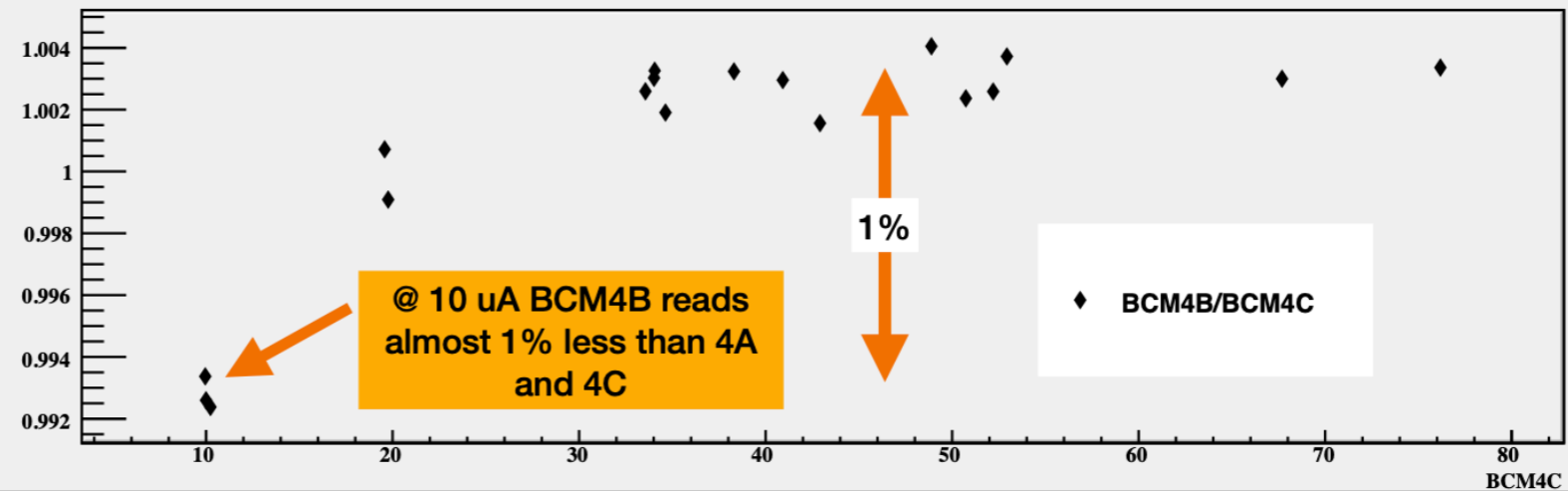
quark distributions, and the target mass corrections used in these fits. In summary, high precision inclusive measurements on hydrogen and deuterium were performed for Q^2 from 2.0 to 11.0 GeV^2 and x_B from 0.1 to 0.8. The data, especially when combined with the Mott and Bethe data, will have a significant impact on PDF fitting efforts, quark-hadron duality studies, spin structure functions, and constraints on nuclear corrections. Additionally, knowledge of PDF fit at large x is essential for determining high energy cross sections at the future EIC, where structure function information at large x will be used through perturbative QCD evolution to lower x and higher values of Q^2 .

Recent Changes to Analysis

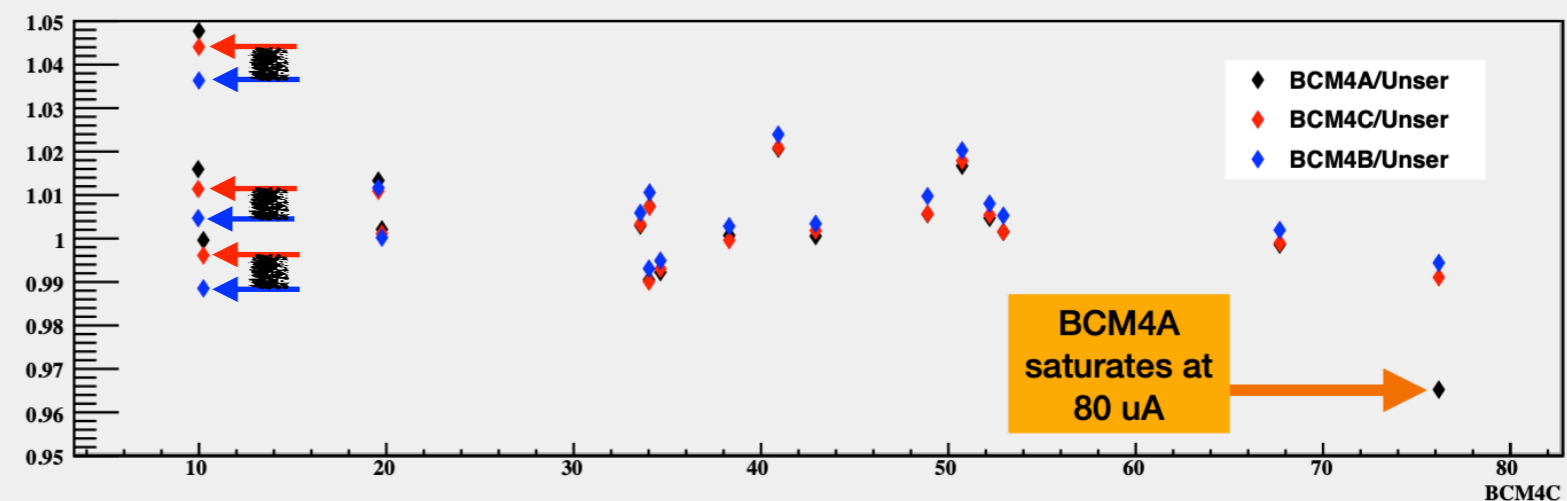
BCM= Beam Current Monitor

New Target Boiling Correction

BCM4B and BCM4C are in disagreement at the % level



Comparing with the Unser shows BCM4C is the most stable

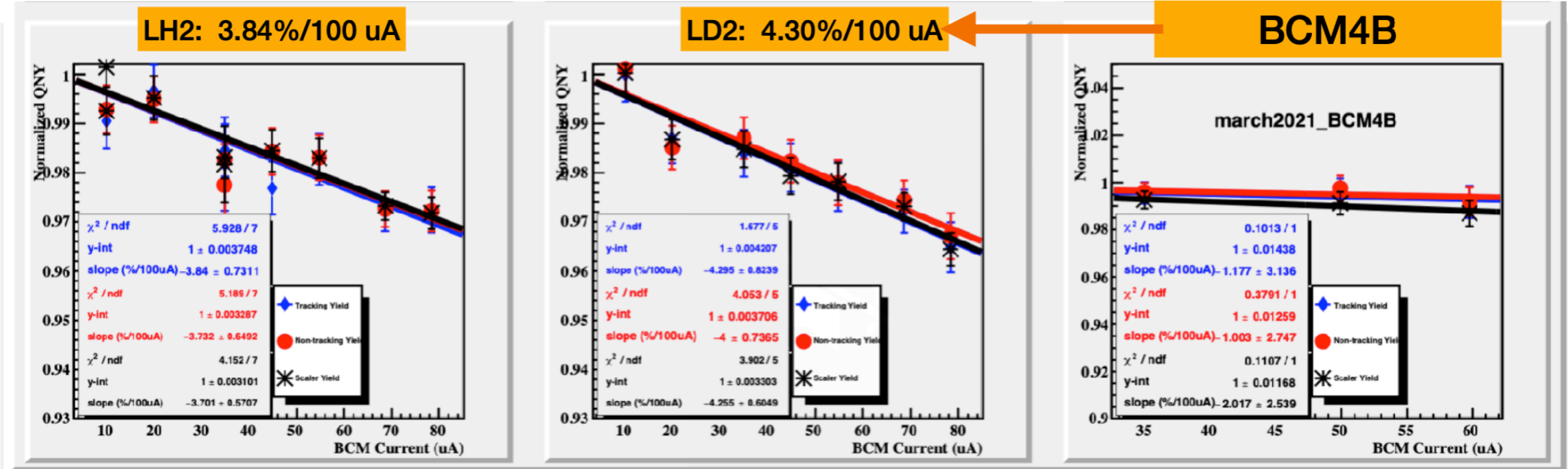


- Old boiling analysis used BCM4B
- BCM4B was not stable during luminosity scans
- BCM4A Saturated at the highest current settings
- BCM4C is the best BCM to use

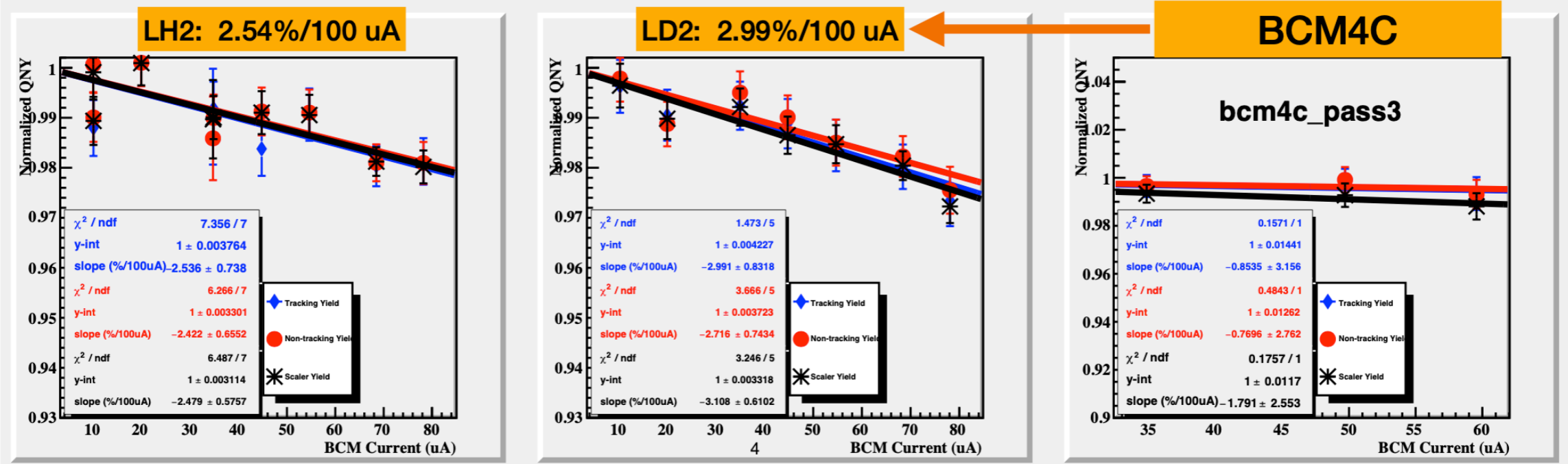
Recent Changes to Analysis

New Target Boiling Correction

OLD



NEW



Recent Changes to Analysis

New Target Boiling Correction

Dave Mack's Scaler Analysis on Fall 2018 data.

Our analysis on Spring 2018 Data

| Target | Measured El Real Slope (%/100muA) | El Real Slope with Window Correction (%/100muA) | Total Error |
|--------|--------------------------------------|--|-------------|
| C | -0.10 | n/a | +/-0.2 |
| LH2 | -2.26 | -2.50 | +/-0.30 |
| LD2 | -2.71 | -2.84 | +/-0.32 |

New F2 Boiling Slopes

LH2: 2.55 +/- 0.74

LD2: 3.09 +/- 0.84

Good agreement when comparing Fall and Spring Boiling Slopes

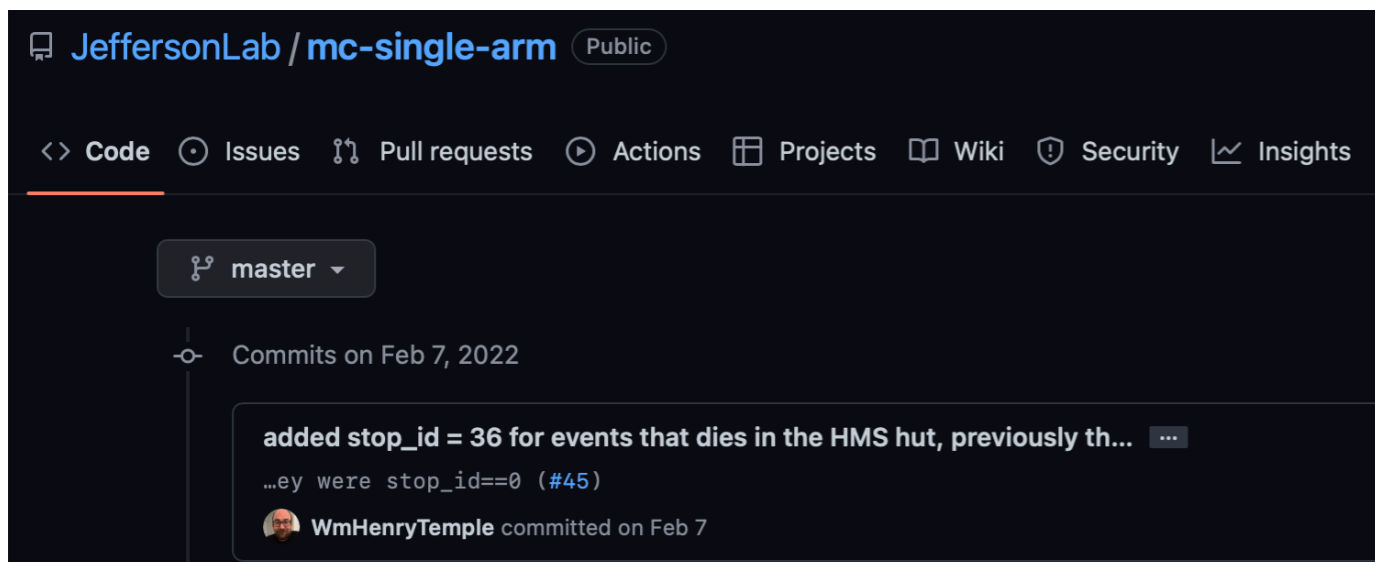
*The LH2 fan speed was different between Fall and Spring Runs so we can't compare those results

*Slightly different slopes than shown in previous slide because the PID cuts were changed to match the the cuts used in the main analysis

Recent Changes to Analysis

Monte Carlo Update

- A bug was found in mc-single-arm. Events that would make it into the detector hut but miss the detector stack were being included as successful events
- It was corrected and pushed to the JeffersonLab github in February of 2022
- After the fix, raw cross sections change by ~5%?
- Little impact of D/H ratio



JeffersonLab / mc-single-arm Public

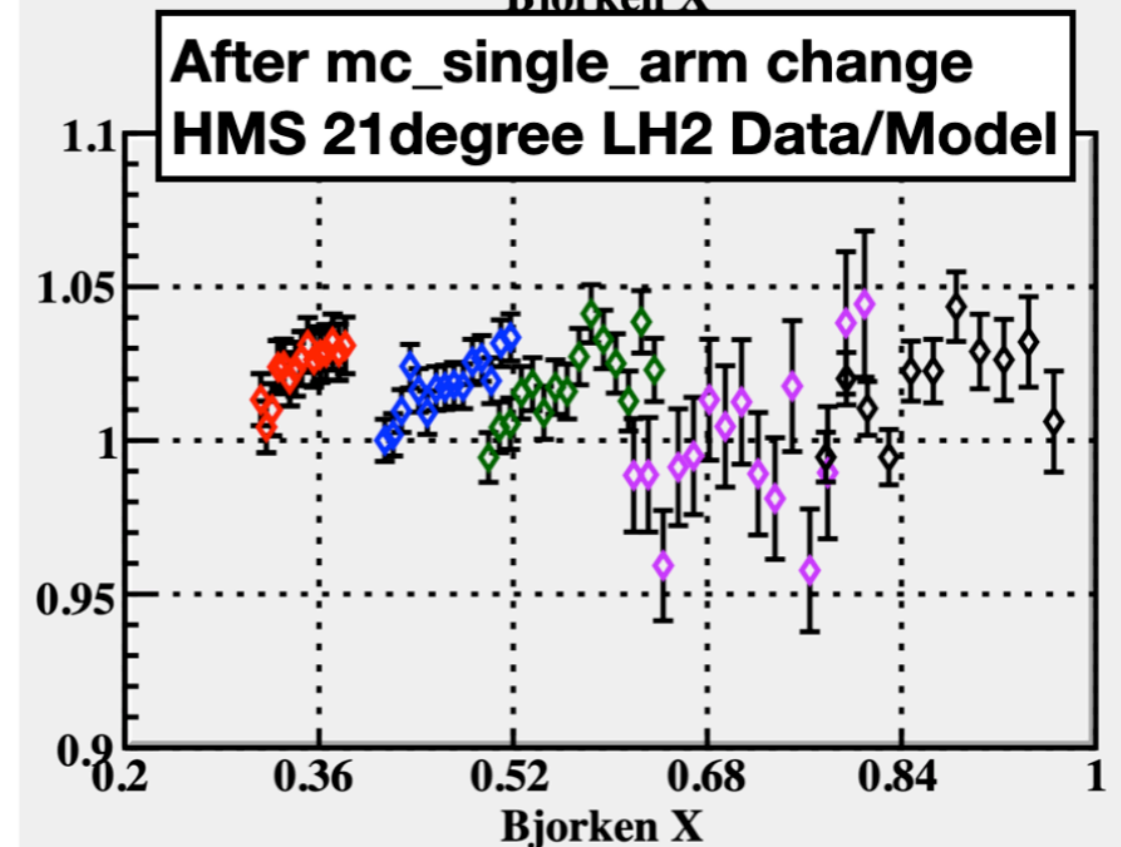
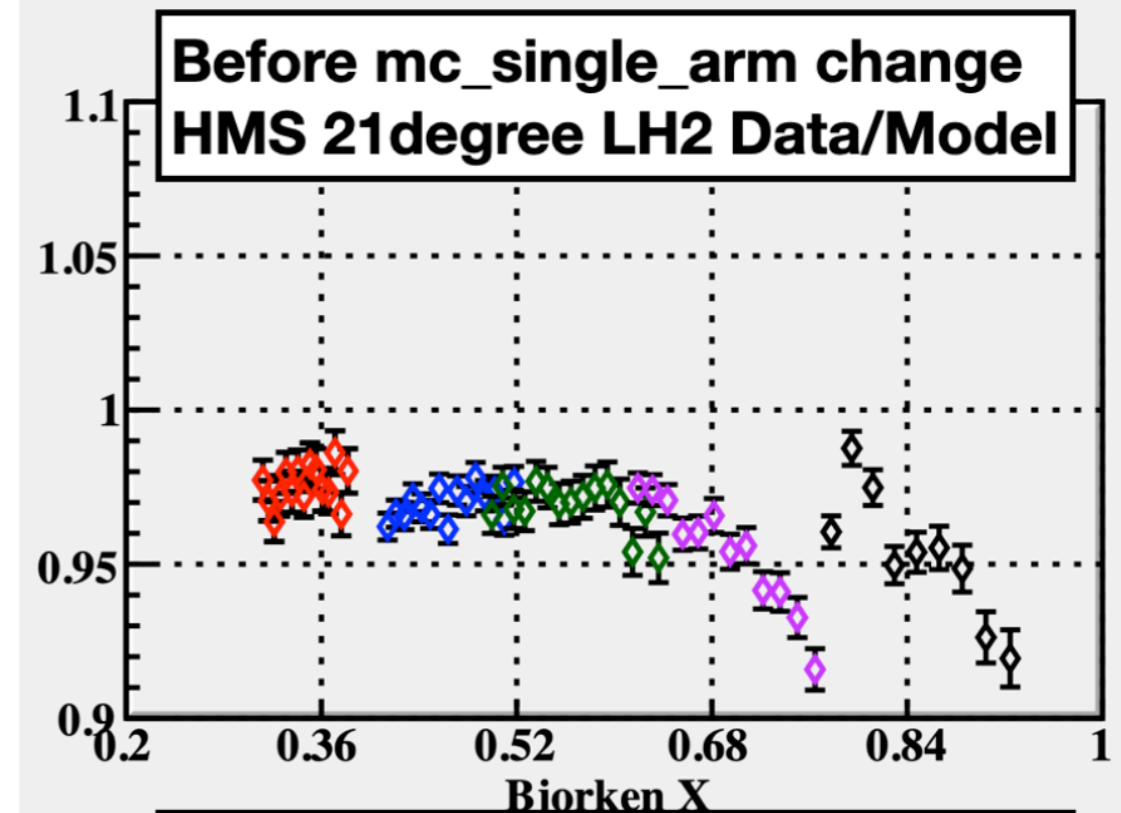
<> Code Issues Pull requests Actions Projects Wiki Security Insights

master

Commits on Feb 7, 2022

added stop_id = 36 for events that dies in the HMS hut, previously th...
...ey were stop_id==0 (#45)

WmHenryTemple committed on Feb 7



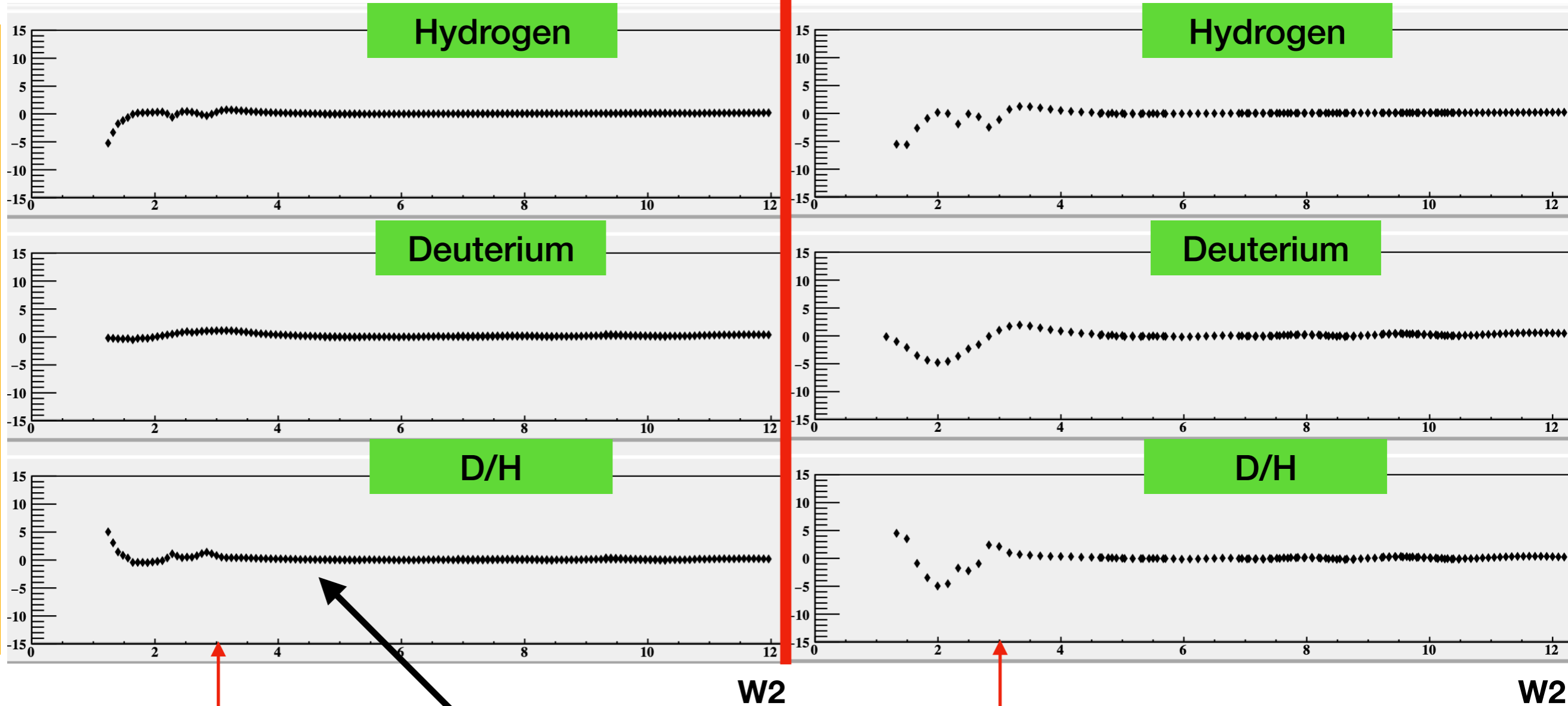
Recent Changes to Analysis

Change in extracted cross section when using different input models

W2 Binning

Delta Binning

Percent Difference



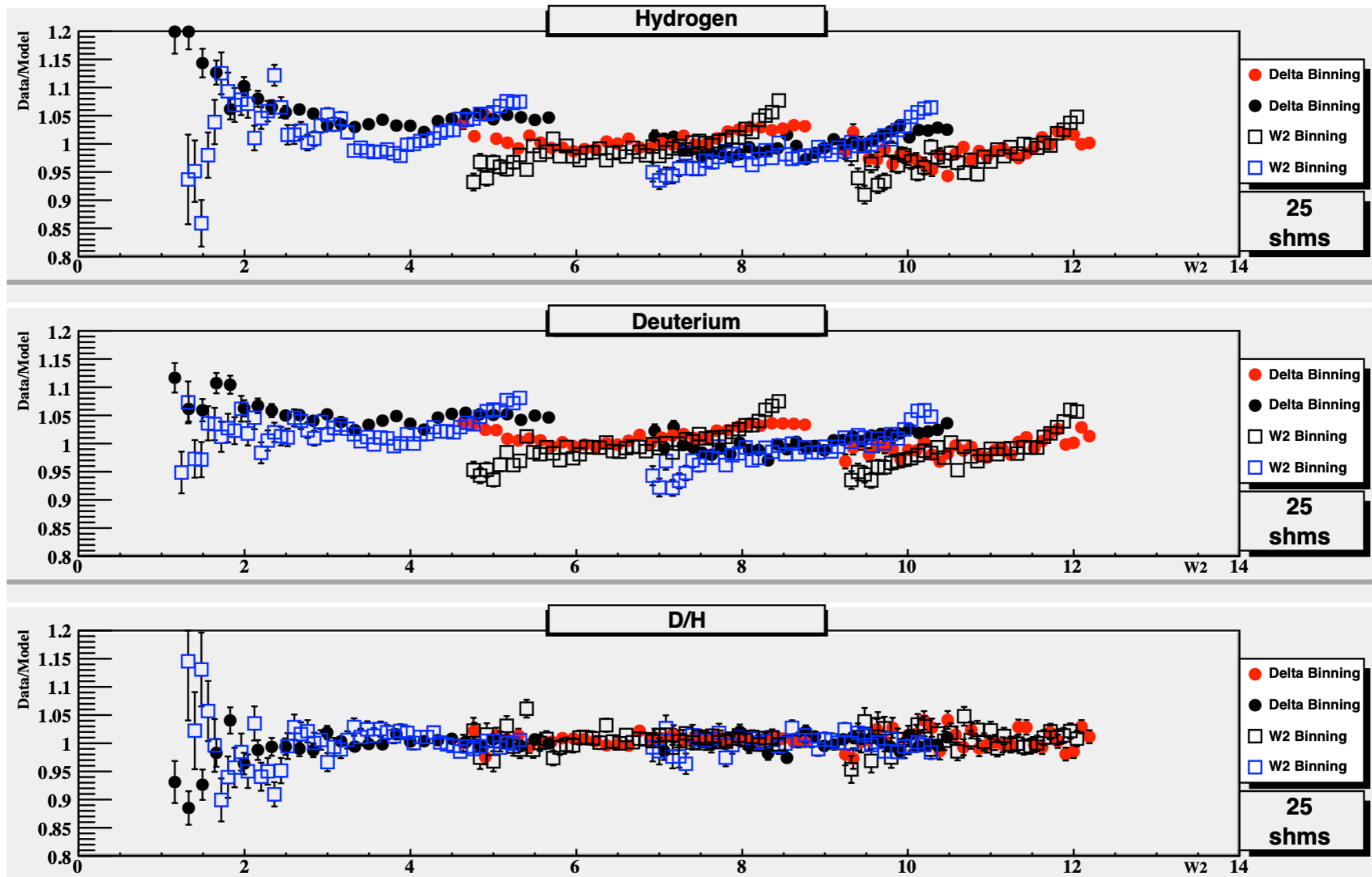
• Apply as additional systematic error

• W2 Binning is less sensitive to model dependence, especially in the resonance region!

Recent Changes to Analysis

Cross section extraction: W2 vs Delta binning

Cross Section / Model



- Overlap region in cross section is worst with W2 binning but vanishes in D/H ratio
- Needs to be addressed for absolute cross sections

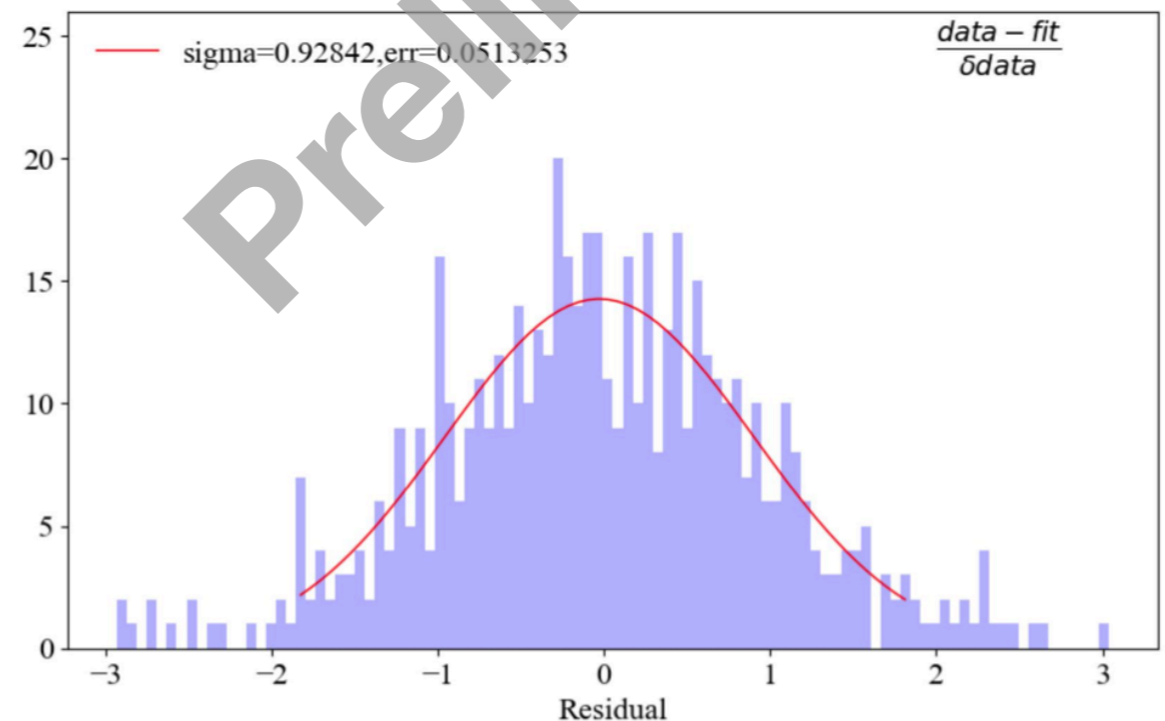
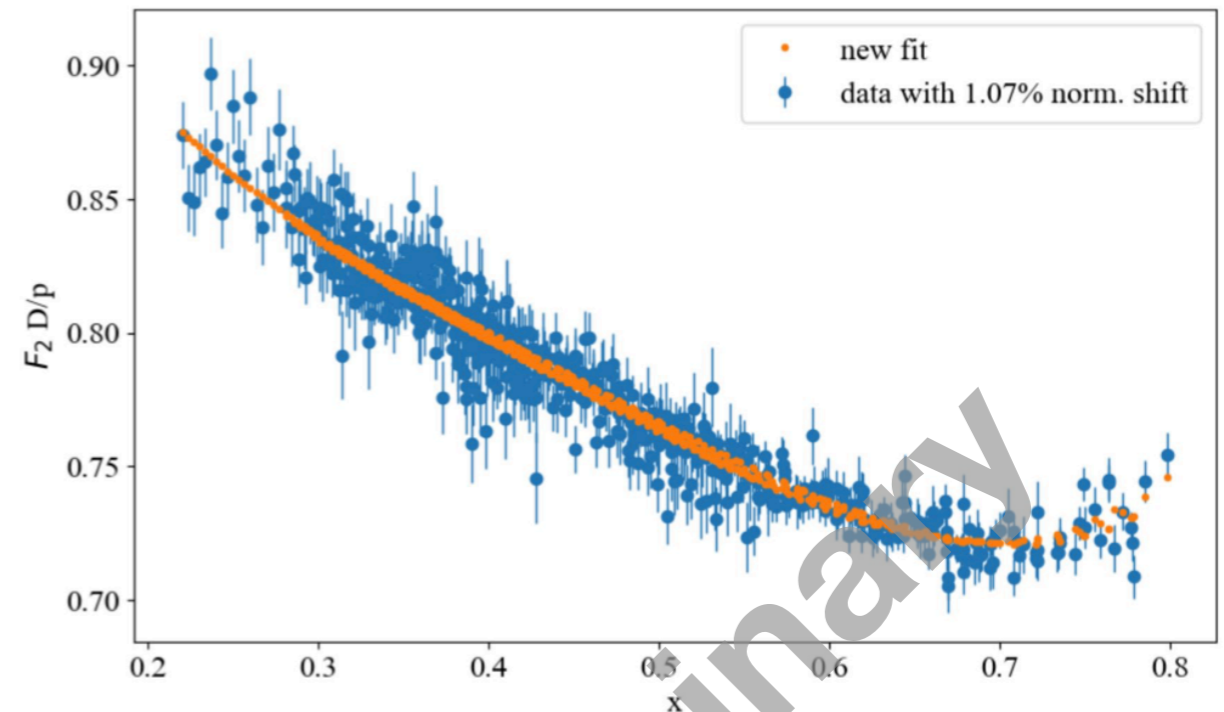
F2 Results

CJ Impact Study

1. Data set from Bill: Normalization=1.1%, correlated/uncorrelated ptp errors are provided.
2. Perform a new fit with this new dataset together with the CJ15 original datasets. The fit will shift data points within given normalization and correlated errors.
3. Compare the modified data with calculation from new fit. The residual = $(\text{data} - \text{fit}) / \text{data_err}$ should be a gaussian with width close to 1

Courtesy of Alberto Accardi and Shujie Li

(Analysis needs to be revisited with new data)



F2 Results

CJ15 Impact Study

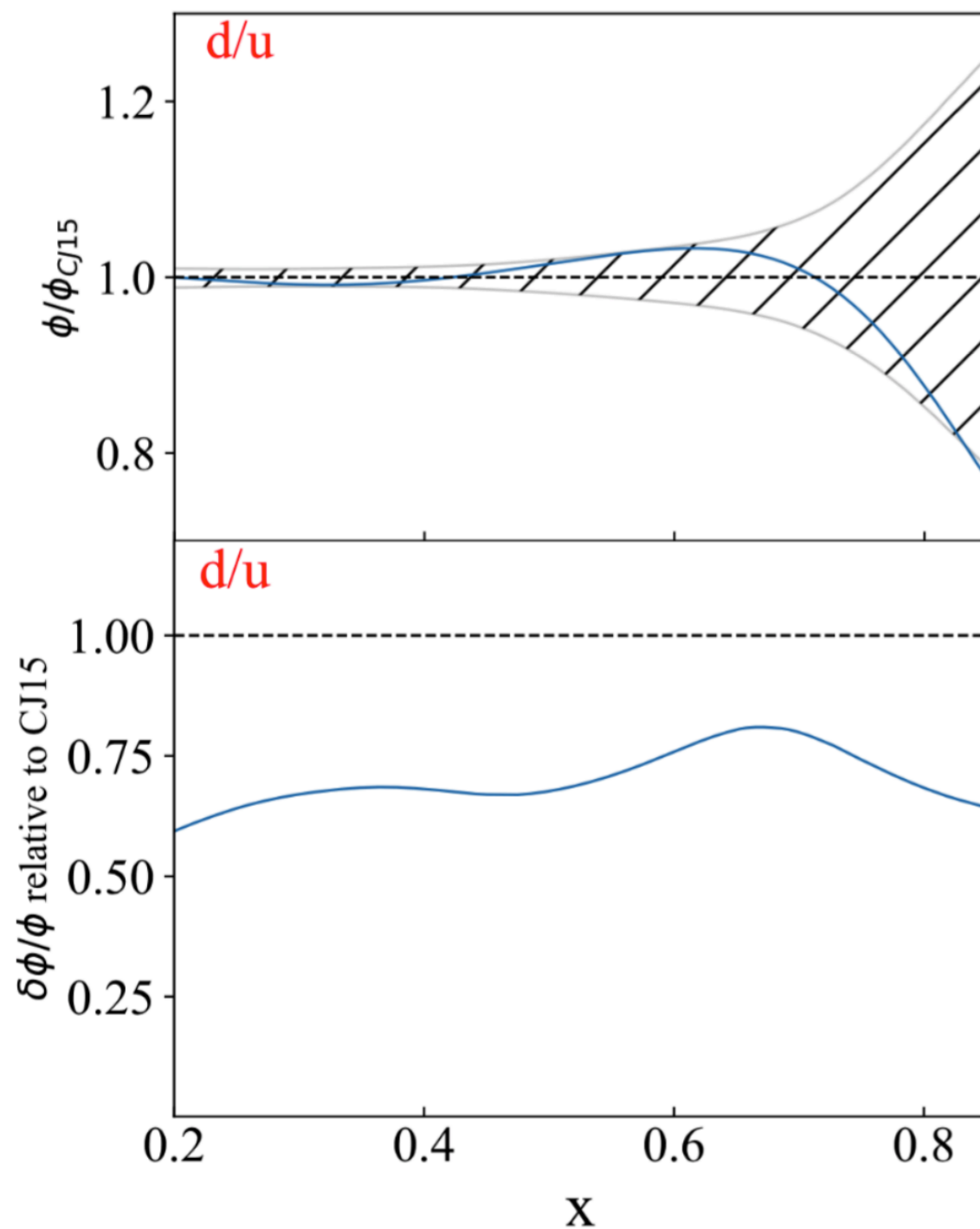


FIG. 4. Top: The blue line shows the relative change in the CJ15 central value of the d/u PDF after data from this analysis is included in the fit. The band represents the error of the fit before inclusion of this data. Here the lack of data on deuterium at high-x is reflected in the large error. Bottom: The relative error on the CJ15 PDF fit after including data from this experiment. Inclusion of this new data results in a 20-40% reduction of the uncertainty in the d/u PDFs. A cut of $W^2 > 3 \text{ GeV}^2$ is applied to the data that enters the fit.

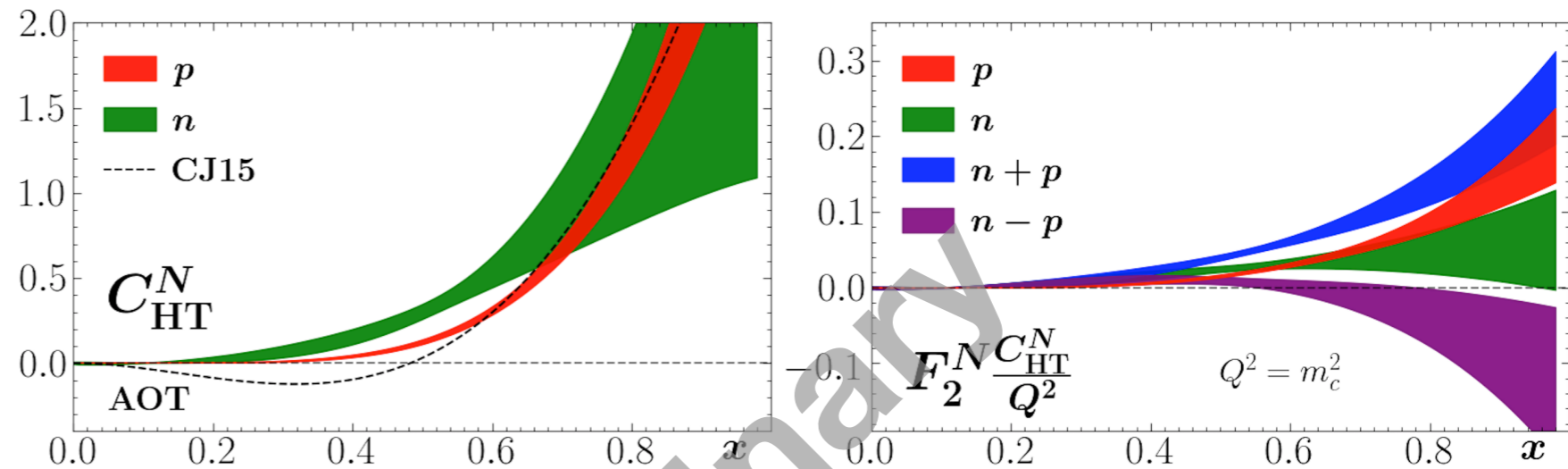
JAM Impact Study

<https://www.jlab.org/theory/jam>

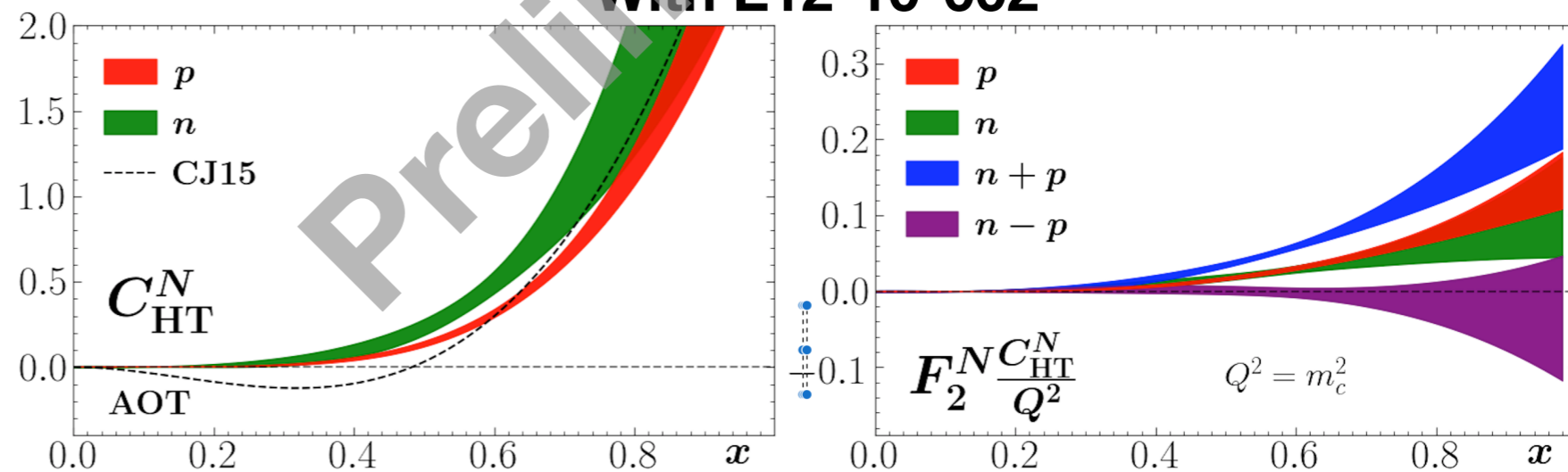
- D/H ratio was provided to Jefferson Lab Angular Momentum Collaboration (JAM) to incorporate into their global QCD analysis of PDFs
- New F2 data significantly improves the uncertainty of higher twist corrections to F2

$$F_2(x, Q^2) = F_2^{\text{LT}}(x, Q^2) \left(1 + \frac{C_{\text{HT}}(x)}{Q^2} \right)$$

Without E12-10-002



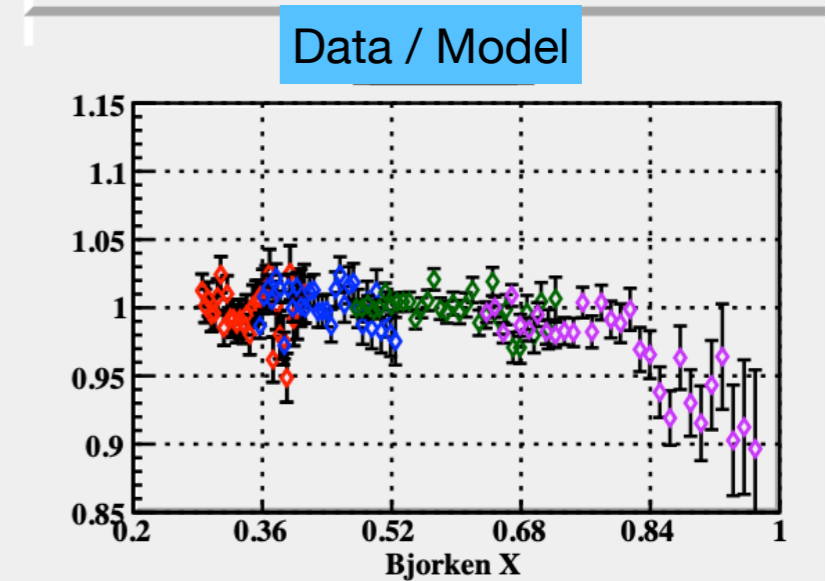
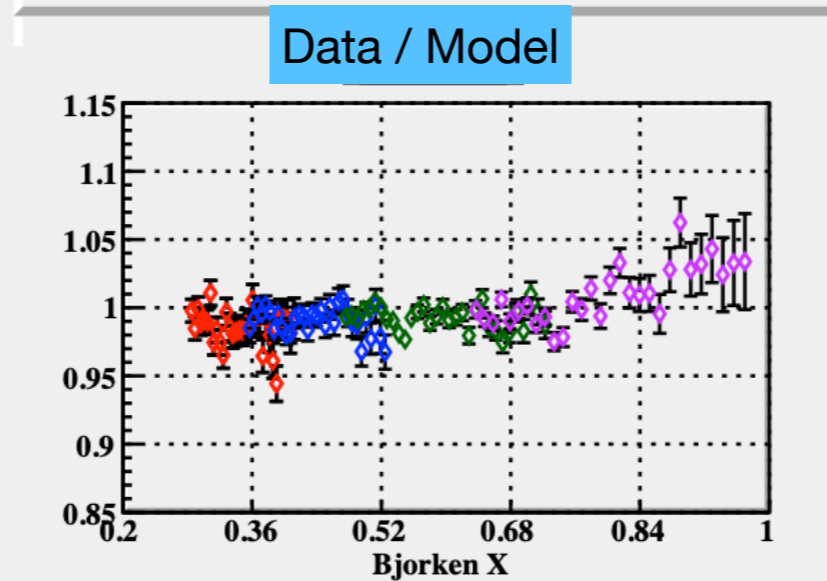
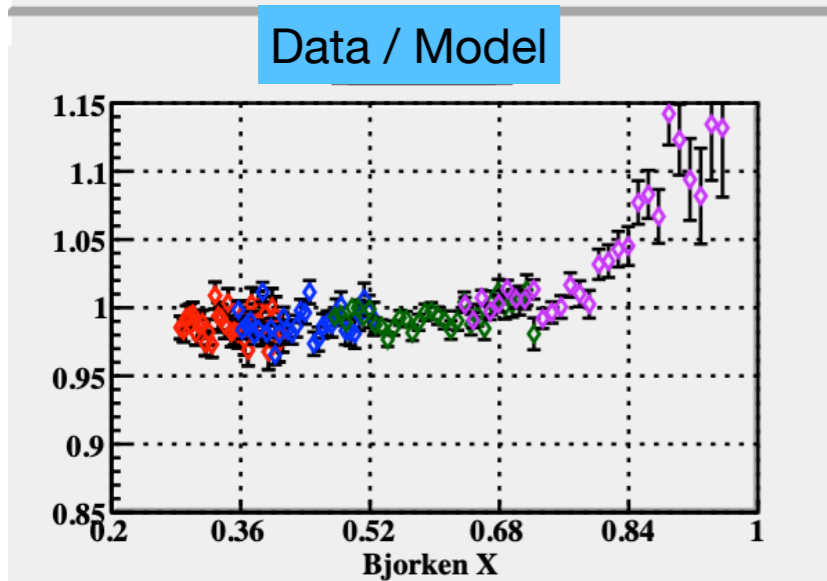
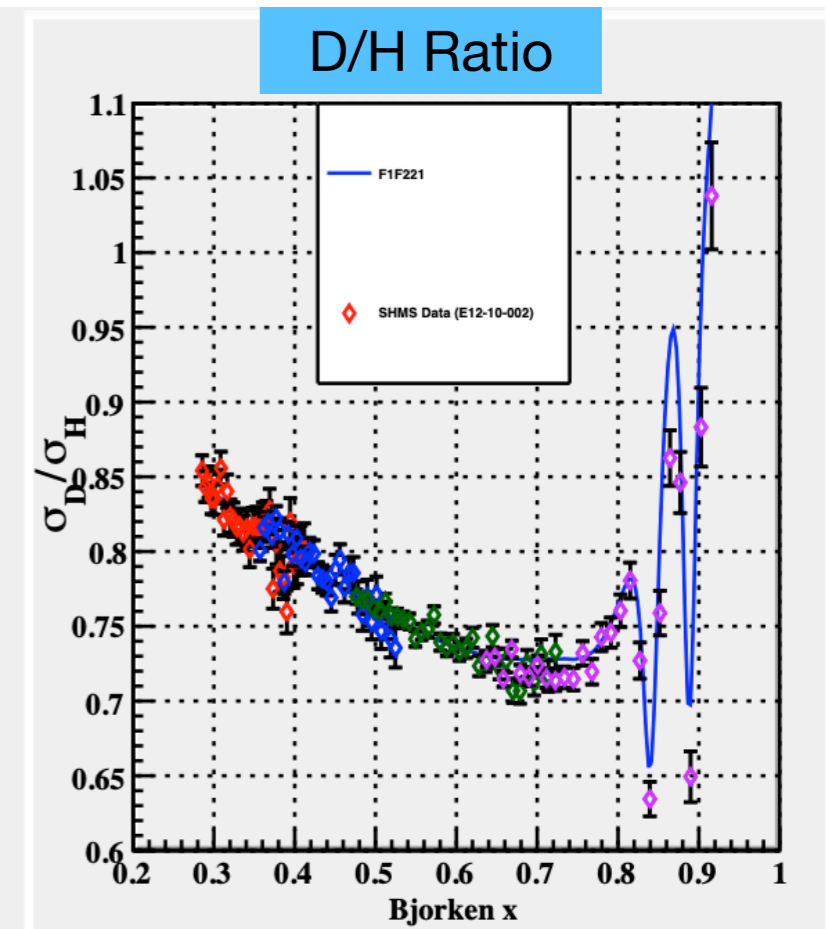
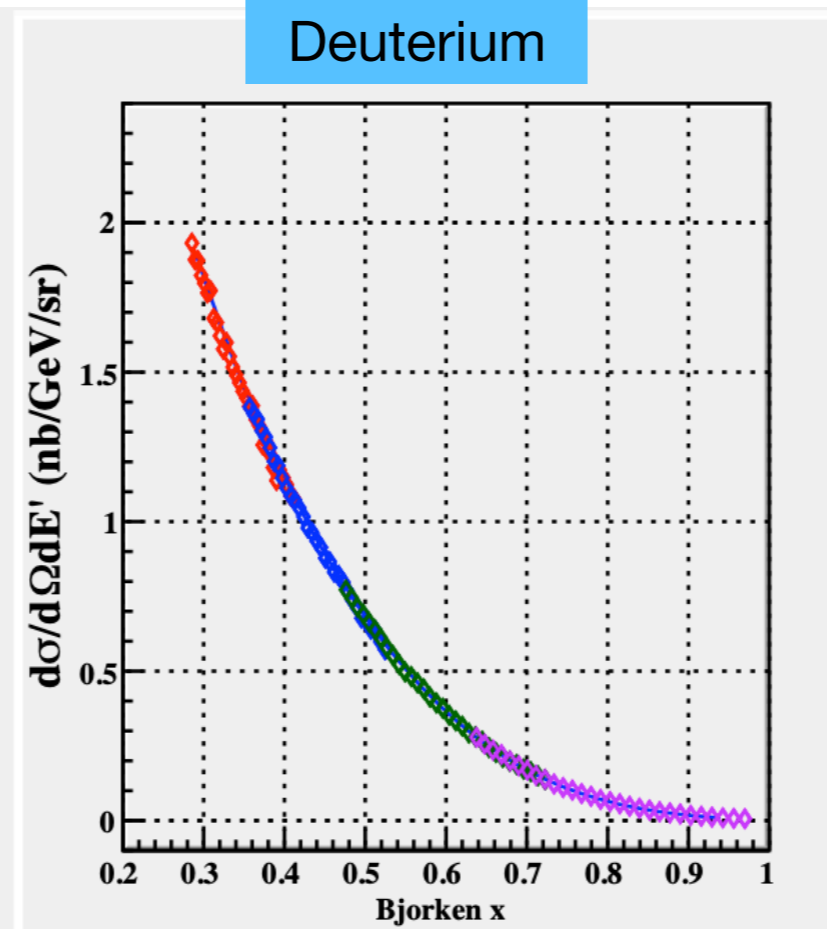
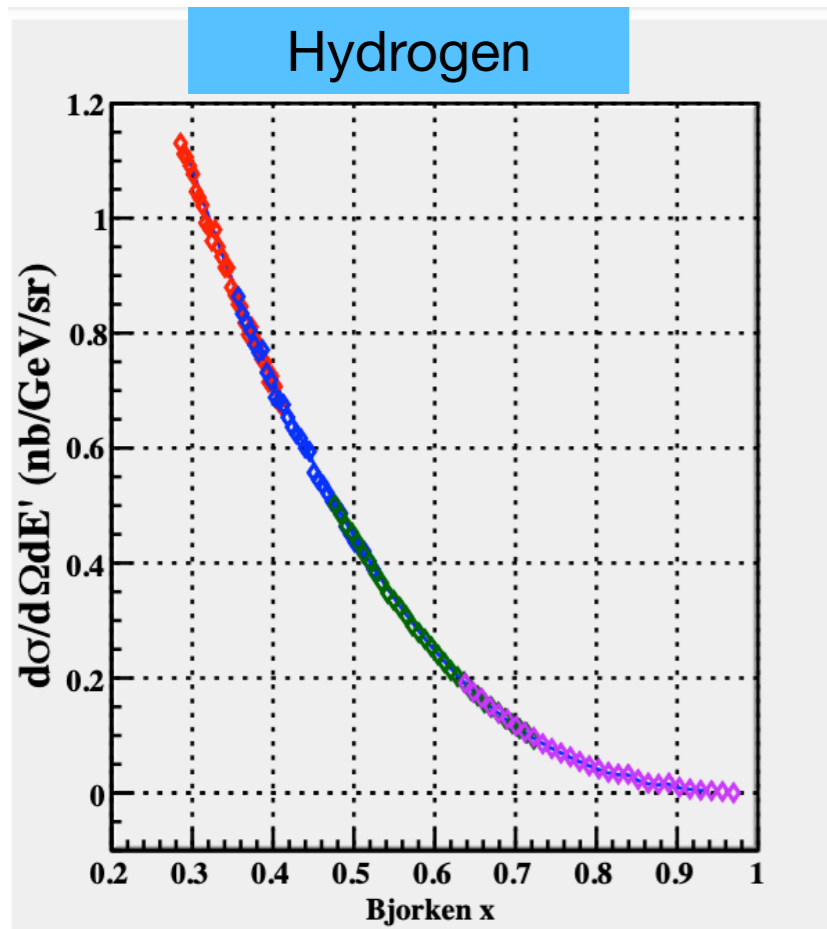
With E12-10-002



Courtesy of Chris Cocuzza, Andreas Metz, W. Melnitchouk, and N. Gonzalez

Absolute Cross Sections Tasks

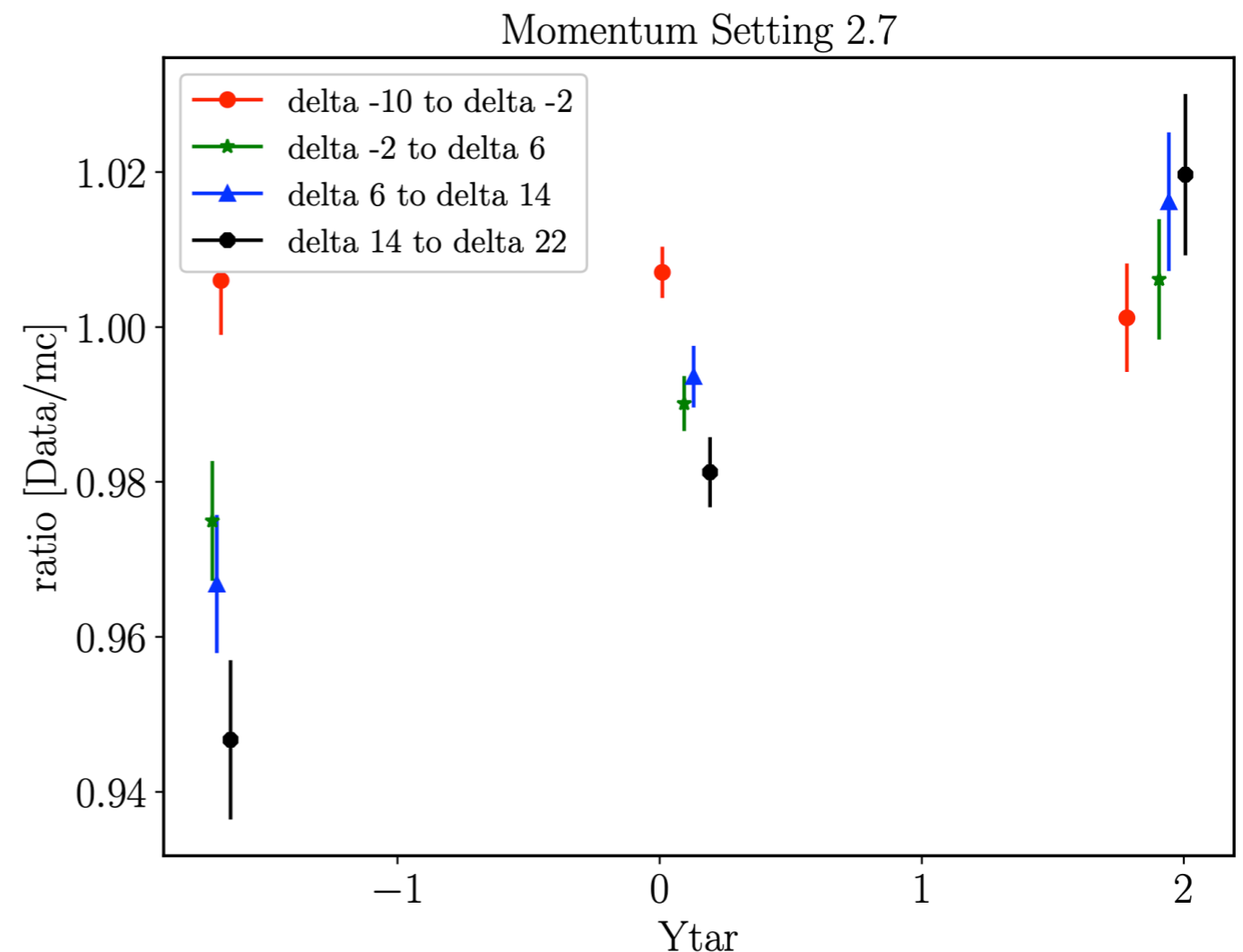
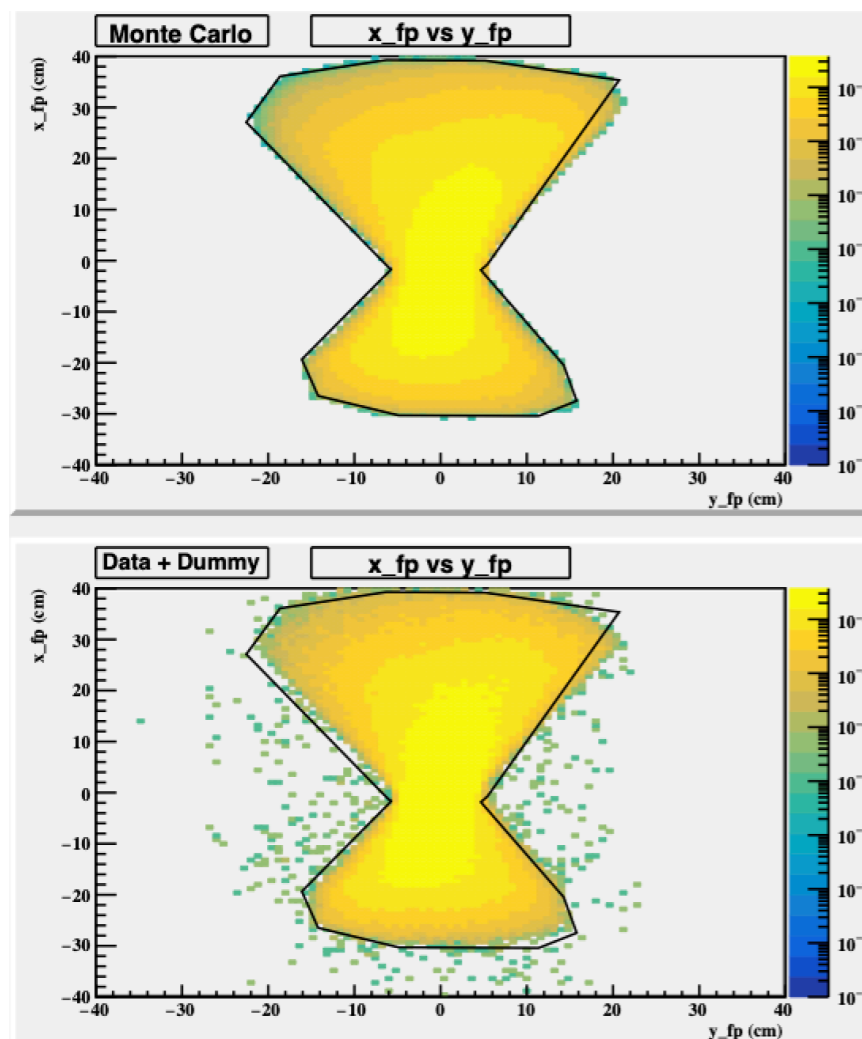
SHMS @ 29 degrees



Future Work

Absolute Cross Sections Tasks

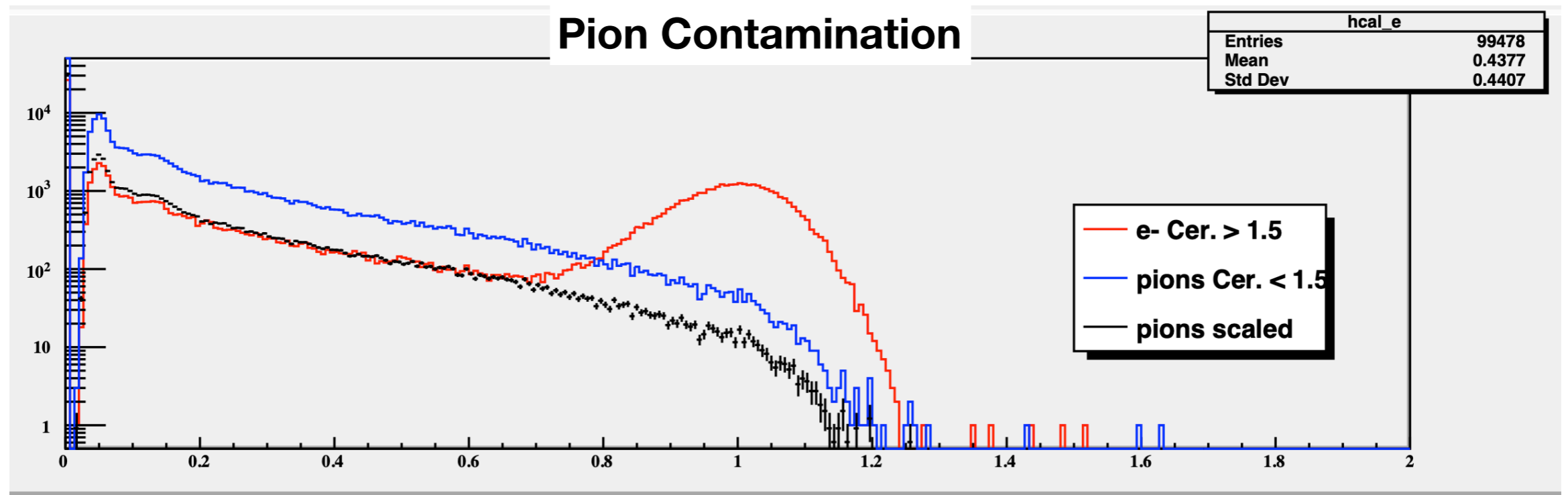
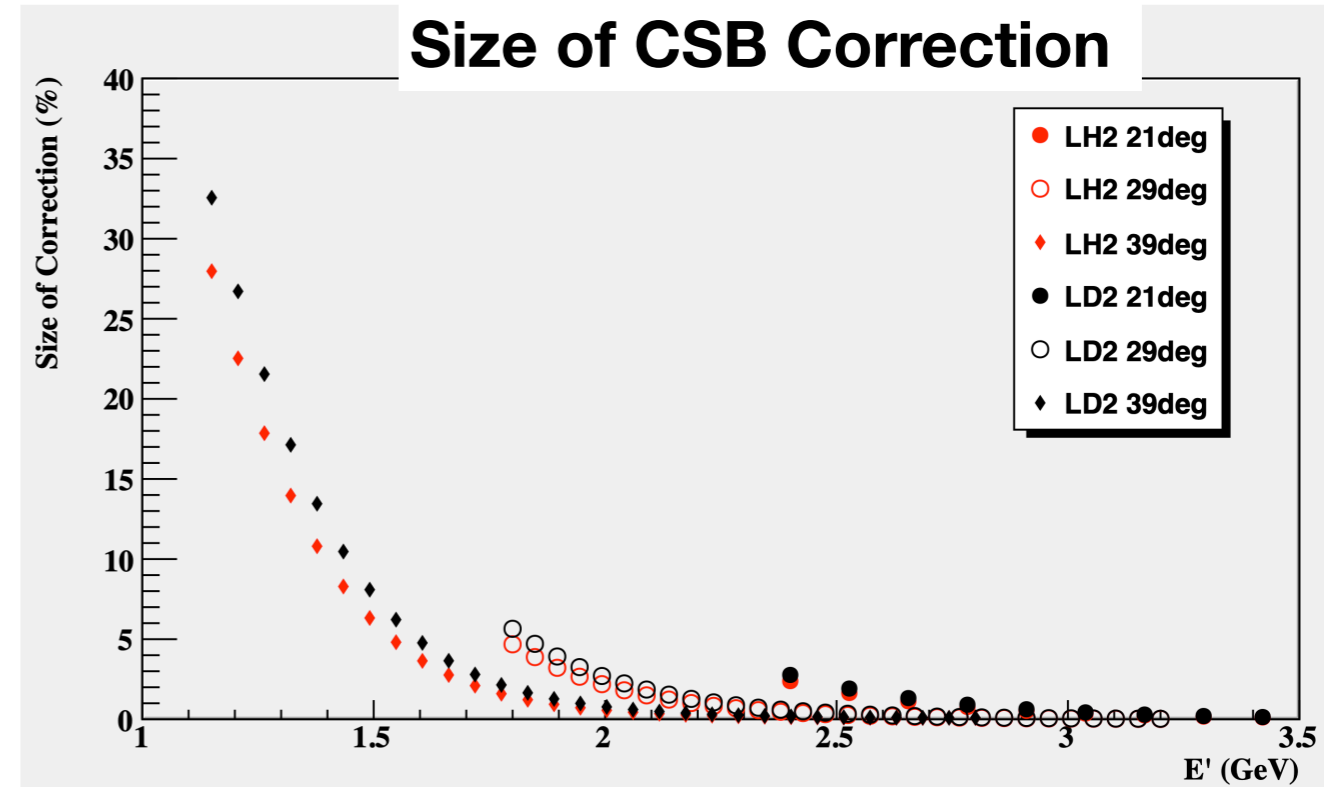
- Revisit Calorimeter Efficiency
- Understand Y_{target} acceptance dependence
- Monte Carlo studies (Matrices, aperature check,)



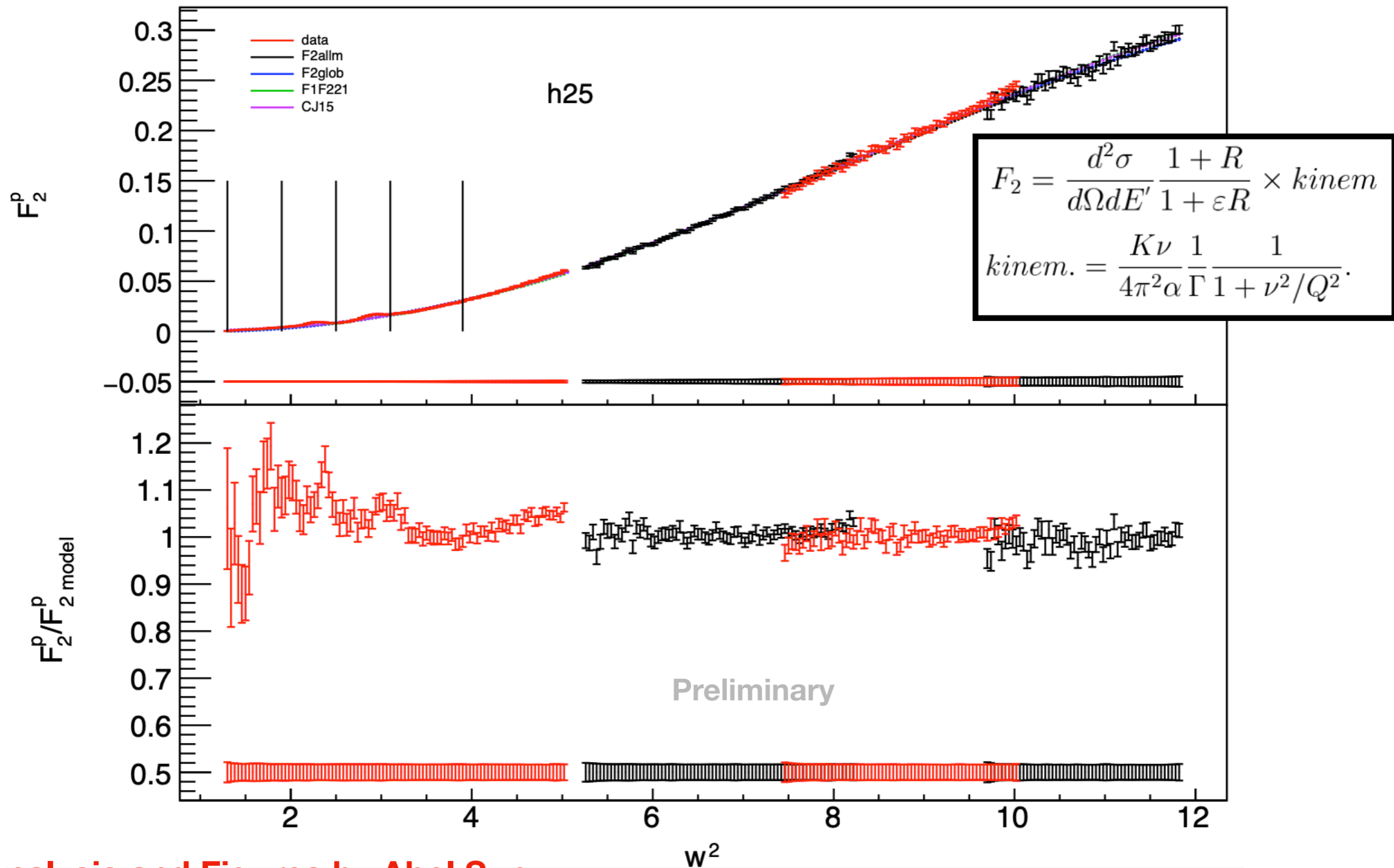
Future Work

HMS Highest Q2 setting

- 59 Degree data taken with HMS still needs to be analyzed
- Work is ongoing to finalize Charge Symmetric Background and pion contamination

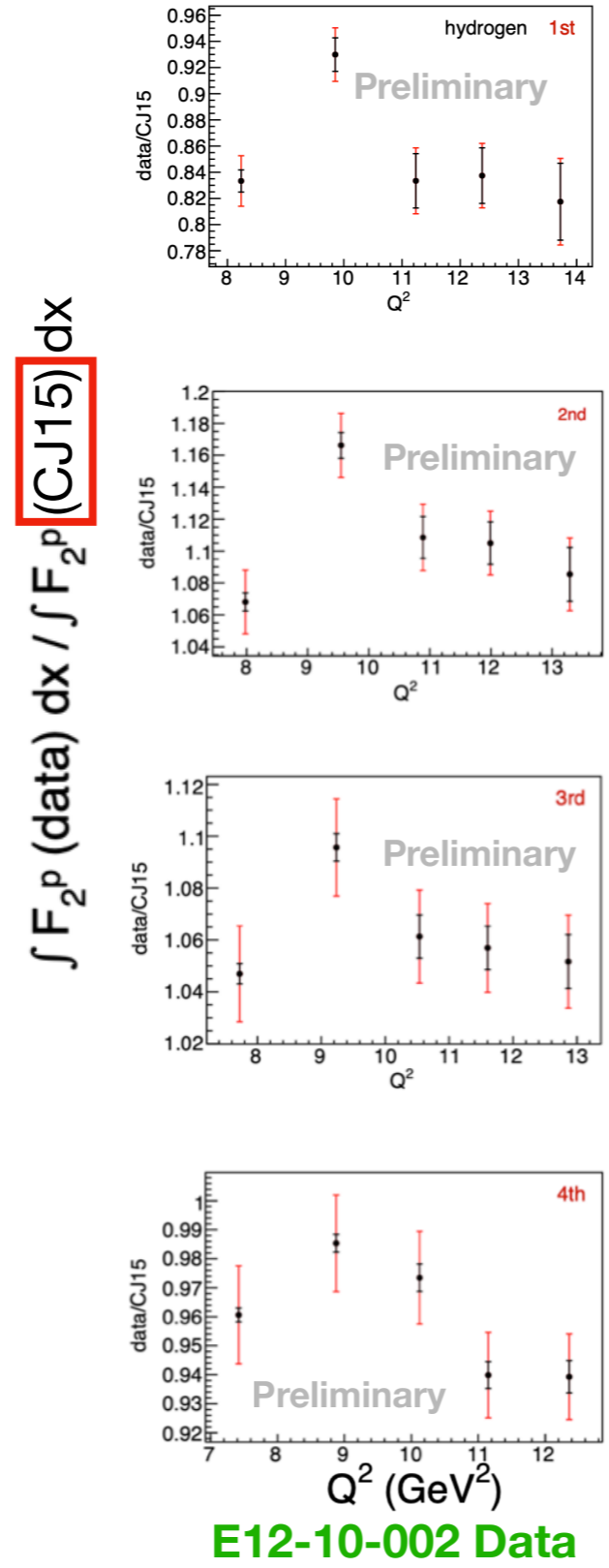
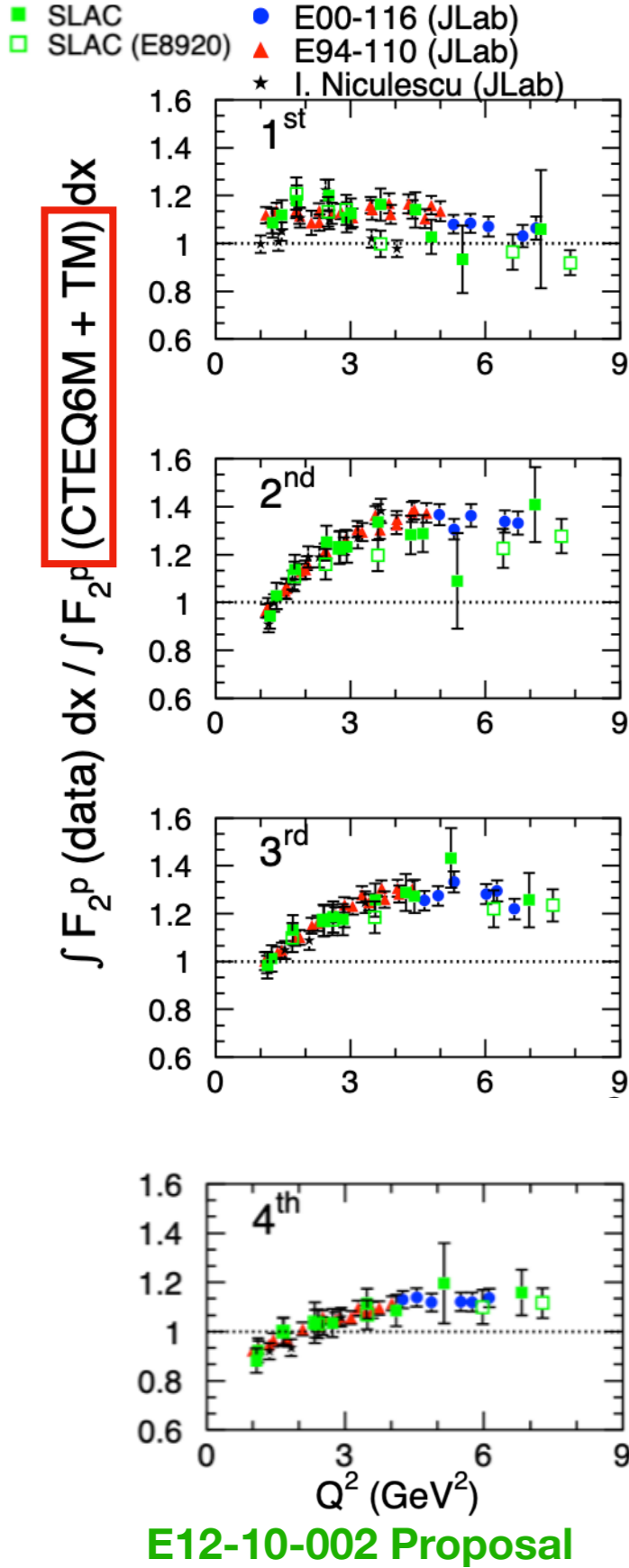


Quark Hadron Duality Studies



Analysis and Figures by Abel Sun

Quark Hadron Duality Studies



Define duality intervals

| Region | 1 st | 2 nd | 3 rd | 4 th | 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

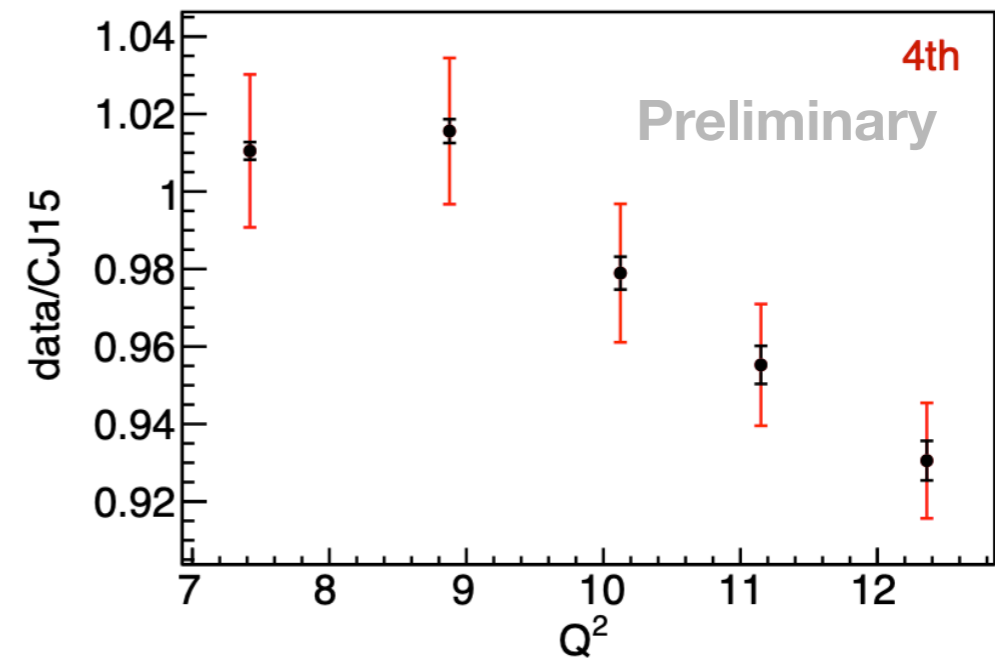
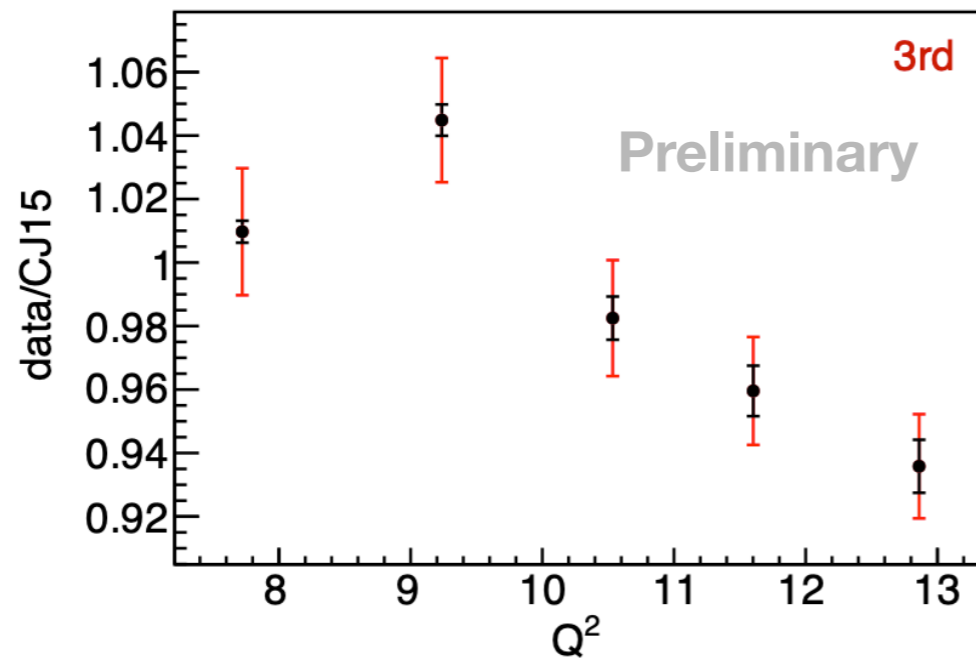
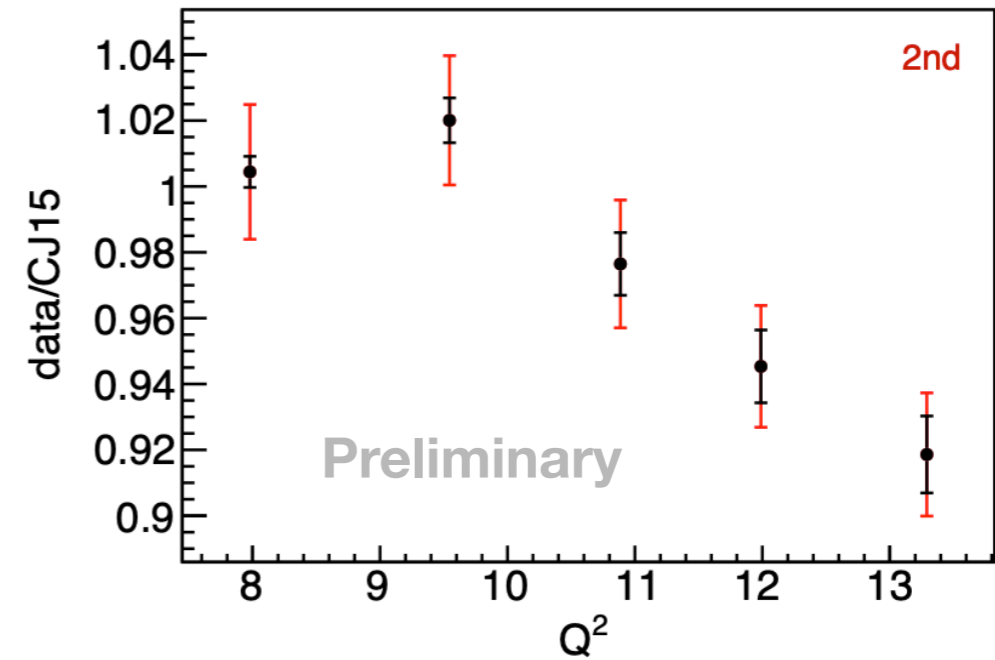
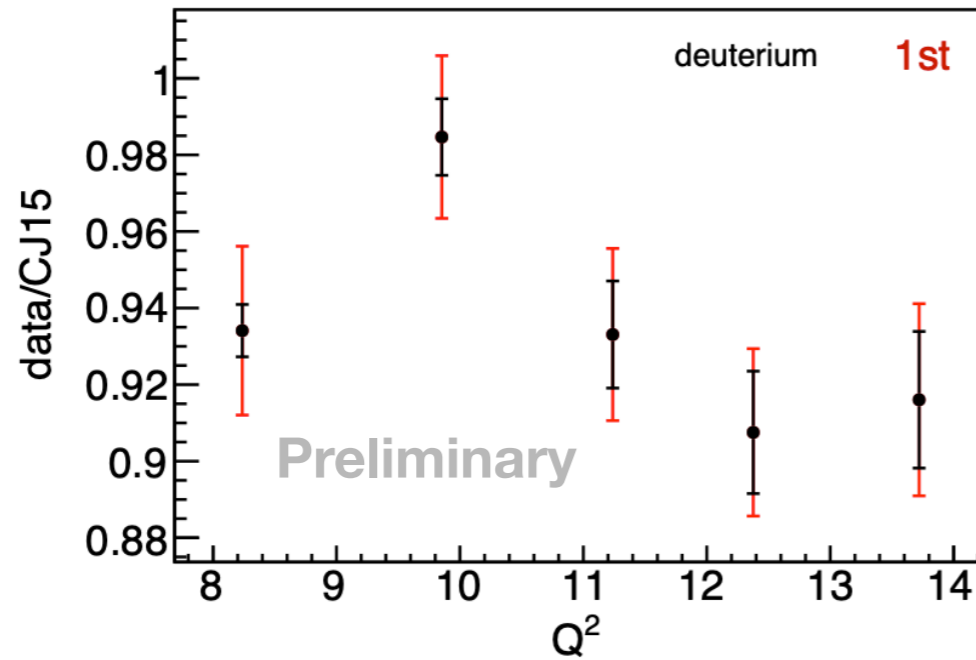
- Calculate ratio:

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

- Very preliminary since analysis on absolute cross sections not nearly complete
- This data can push duality integrals to higher Q^2

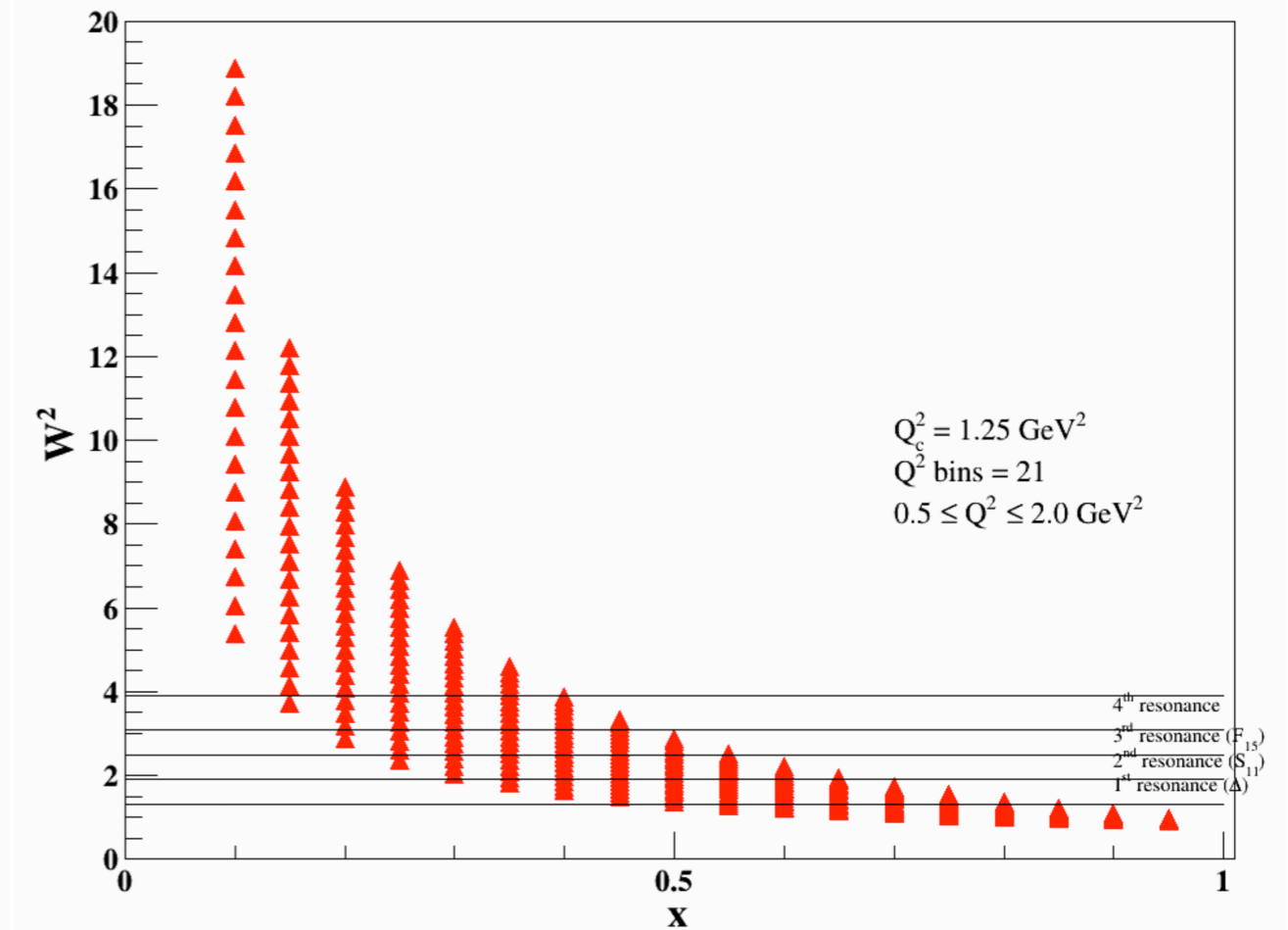
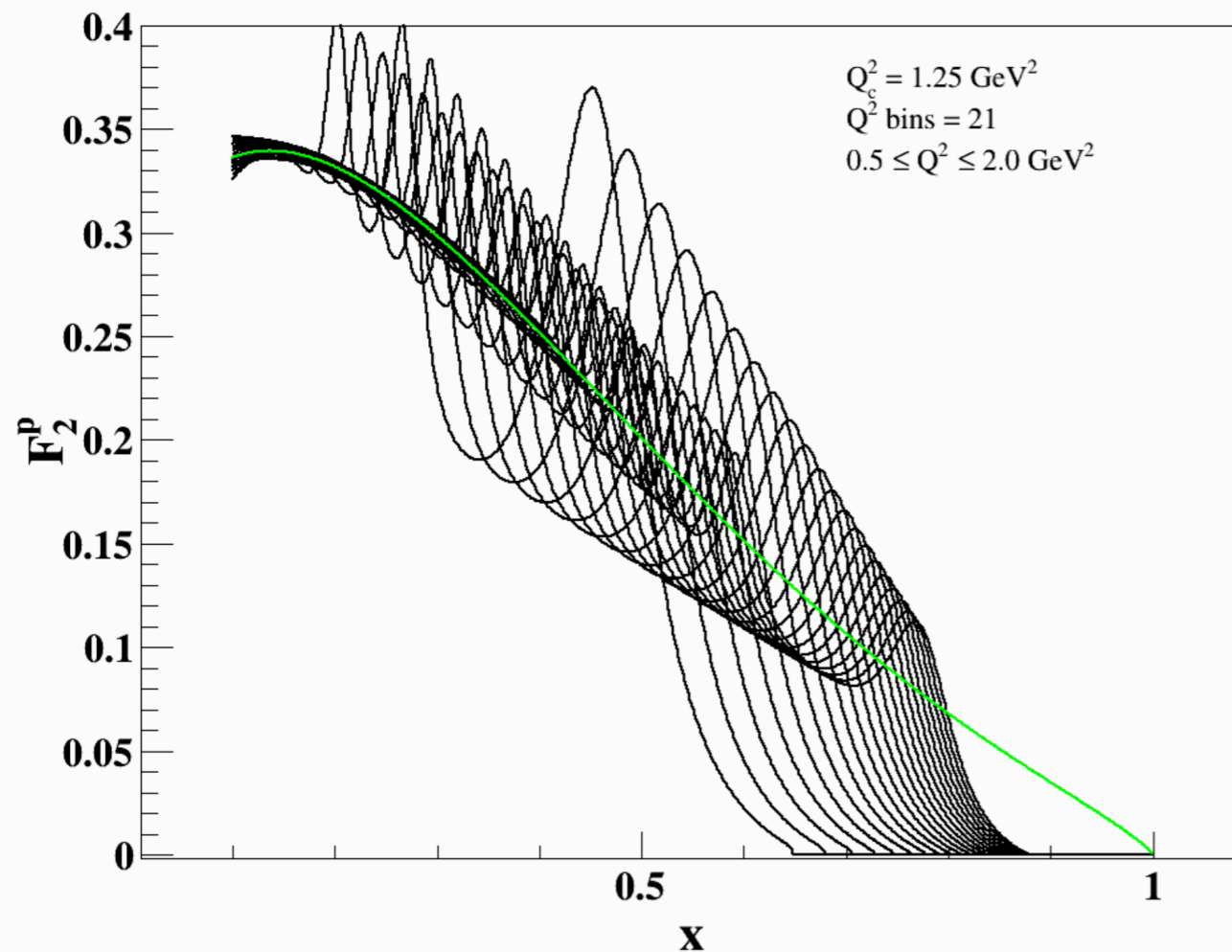
Analysis and Figures by Abel Sun

Quark Hadron Duality Studies



Analysis and Figures by Abel Sun

Quark Hadron Duality Studies



- Duality studies at fixed x over a range of Q^2
- Peaks and valleys in resonance region shift along x as Q^2 changes
- Allows us to average x bins as an alternative method to study duality
- Analysis includes world data + E12-10-002

Analysis and Figures by Debaditya Biswas

Summary and Acknowledgments

To Do List

- D/H ratios complete and impact studies are being finalized. Paper being drafted (PRL)
- High Q2 setting in the HMS (59°) needs to be analyzed
- Absolute Cross Section Tasks
 - Revisit Calorimeter Efficiency
 - Revisit forward and reconstruction matrices
 - F2d and F2n extraction
 - MC Ratio method vs Acceptance Method
- Quark-Hadron duality Averaging
- Compute non single moments
- Improve resonance/DIS modeling

D. Biswas,¹ F. Gonzalez,² W. Henry,³ A. Karki,⁴ C. Morean,⁵ A. Nadeeshani,¹ A. Sun,⁶ D. Abrams,⁷ Z. Ahmed,⁸ B. Aljawrneh,⁹ S. Alsalmi,¹⁰ R. Ambrose,⁸ W. Armstrong,¹¹ A. Asaturyan,¹² K. Assumin-Gyimah,⁴ C. Ayerbe Gayoso,^{13,4} A. Bandari,¹³ S. Basnet,⁸ V. Berdnikov,¹⁴ H. Bhatt,⁴ D. Bhetuwal,⁴ W. U. Boeglin,¹⁵ P. Bosted,¹³ E. Brash,¹⁶ M. H. S. Bukhari,¹⁷ H. Chen,⁷ J. P. Chen,³ M. Chen,⁷ M. E. Christy,¹ S. Covrig,³ K. Craycraft,⁵ S. Danagoulian,⁹ D. Day,⁷ M. Diefenthaler,³ M. Dlamini,¹⁸ J. Dunne,⁴ B. Duran,¹¹ D. Dutta,⁴ R. Ent,³ R. Evans,⁸ H. Fenker,³ N. Fomin,⁵ E. Fuchey,¹⁹ D. Gaskell,³ T. N. Gautam,¹ F. A. Gonzalez,² J. O. Hansen,³ F. Hauenstein,²⁰ A. V. Hernandez,¹⁴ T. Horn,¹⁴ G. M. Huber,⁸ M. K. Jones,³ S. Joosten,²¹ M. L. Kabir,⁴ C. Keppel,³ A. Khanal,¹⁵ P. M. King,¹⁸ E. Kinney,²² M. Kohl,¹ N. Lashley-Colthirst,¹ S. Li,²³ W. B. Li,¹³ A. H. Liyanage,¹ D. Mack,³ S. Malace,³ P. Markowitz,¹⁵ J. Matter,⁷ D. Meekins,³ R. Michaels,³ A. Mkrtchyan,¹² H. Mkrtchyan,¹² S.J. Nazeer,¹ S. Nanda,⁴ G. Niculescu,²⁴ I. Niculescu,²⁴ D. Nguyen,⁷ Nuruzzaman,²⁵ B. Pandey,¹ S. Park,² E. Pooser,³ A. Puckett,¹⁹ M. Rehfuss,¹¹ J. Reinhold,¹⁵ B. Sawatzky,³ G. R. Smith,³ H. Szumila-Vance,³ A. Tadepalli,²⁵ V. Tadevosyan,¹² R. Trotta,¹⁴ S. A. Wood,³ C. Yero,¹⁵ and J. Zhang²
(for the Hall C Collaboration)

Experiment Spokespeople

Eric Christy

Thia Keppel

Simona Malace

Ioana Niculescu

Gabriel Niculescu

Dave Gaskell (EMC)

Graduate Students

Deb Biswas

Aruni Nadeeshani

Abel Sun

Abishek Karki (EMC)

Casey Morean (EMC)

Post Doc

Bill Henry (Contact)

Special Thanks to

Mark Jones

Carlos Yero

Greg Smith

Back-Ups

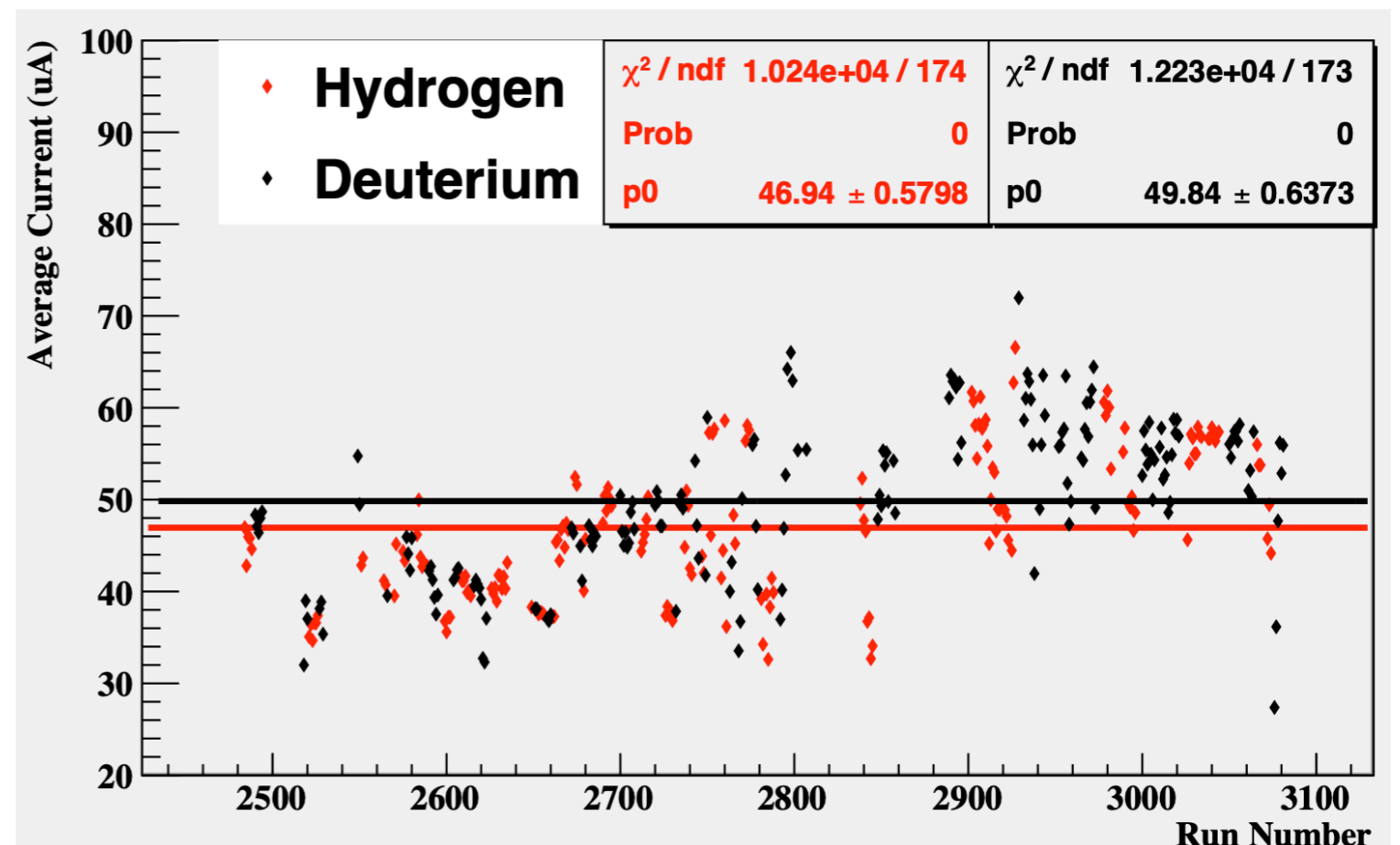
Target Density Uncertainty

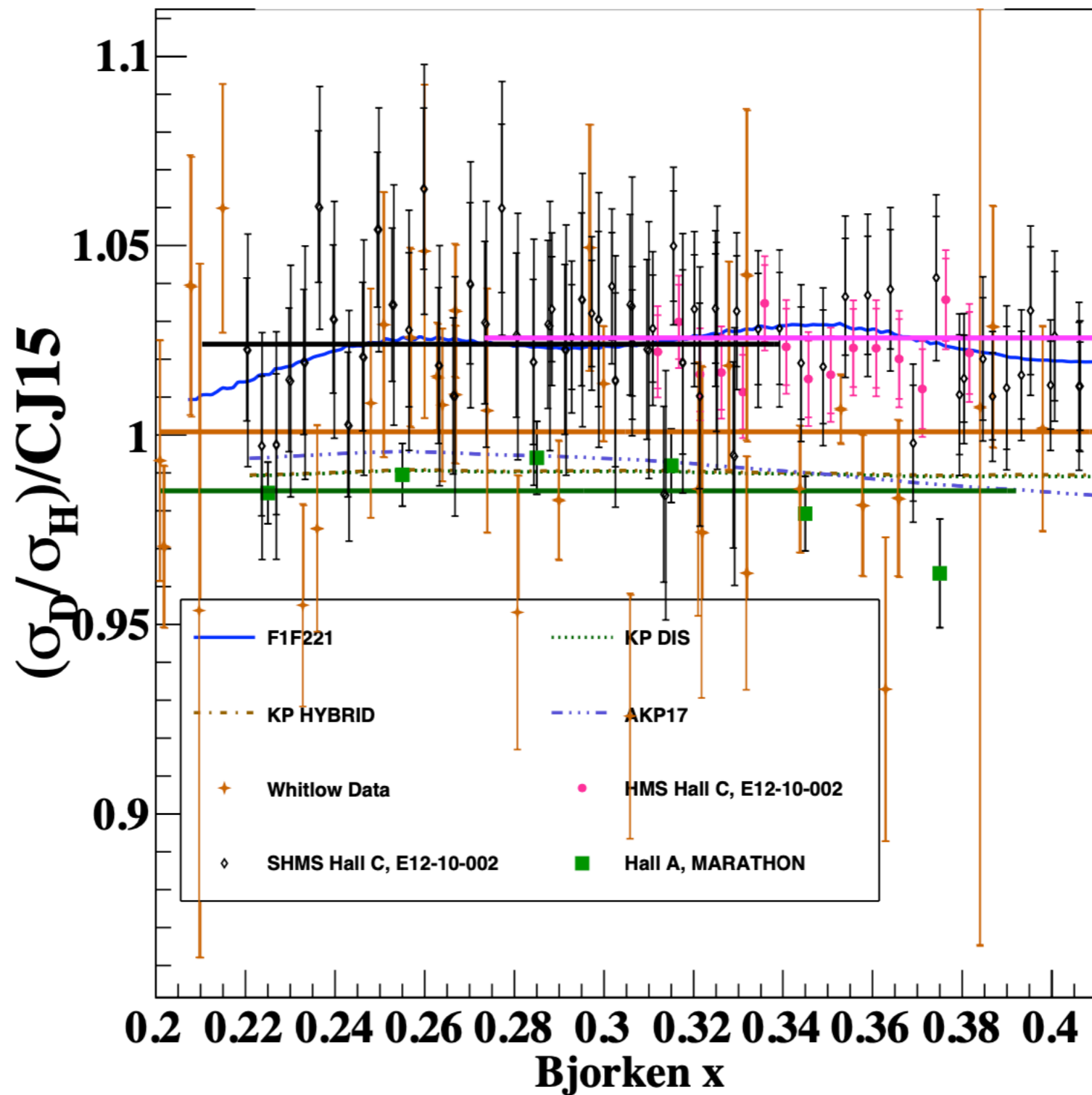
- The overall normalization uncertainty used is slightly larger than the table; 0.75% in cross sections and 1.1% in D/H ratio.

- Global error reflects our lack of knowledge to the target boiling, temperature, density, length and beam position.

- An additional point to point uncertainty is calculated by taking the difference with the average current

| Error | Value | Uncertainty | $\frac{\delta\rho t}{\rho t}$ |
|---------------------------------|---------|--------------|-------------------------------|
| Temperature | 19 K | $\pm 182mK$ | 0.27% |
| Pressure | 25 psia | $\pm 2psia$ | 0.02% |
| Equation of State | | | 0.1% |
| Length Measurement Precision | 100 mm | $\pm 0.26mm$ | 0.26% |
| Length (Inner or Outer?) | 100 mm | $\pm 0.26mm$ | 0.26% |
| Target Contraction | 99.6% | $\pm 0.1\%$ | 0.1% |
| Beam Position | 0 | $\pm 3mm$ | 0.2% |
| Avg Boiling Correction LH2(LD2) | | | 0.30% (0.36%) |
| Total LH2 (LD2) | | | 0.60% (0.63%) |





1.023 +/- 0.004
 1.026 +/- 0.003
 1.001 +/- 0.004
 0.985 +/- 0.004

```

*****
Minimizer is Linear
Chi2      = 24.5957
NDF       = 31
p0       = 1.02398 +/- 0.00374891
TFitEditor::DoFit - using function PrevFitTMP @x21276b10
*****
Minimizer is Linear
Chi2      = 46.0678
NDF       = 34
p0       = 1.00084 +/- 0.00388634
TFitEditor::DoFit - using function PrevFitTMP @x21276b10
*****
Minimizer is Linear
Chi2      = 4.41306
NDF       = 6
p0       = 0.985256 +/- 0.00353582
TFitEditor::DoFit - using function PrevFitTMP @x21276b10
*****
Minimizer is Linear
Chi2      = 46.0678
NDF       = 34
p0       = 1.00084 +/- 0.00388634
TFitEditor::DoFit - using function PrevFitTMP @x21276b10
*****
Minimizer is Linear
Chi2      = 18.5141
NDF       = 31
p0       = 1.02561 +/- 0.00275052
  
```

Isvector EMC effect from global QCD analysis with MARATHON data

C. Cocuzza,¹ C. E. Keppel,² H. Liu,³ W. Melnitchouk,² A. Metz,¹ N. Sato,² and A. W. Thomas⁴

¹*Department of Physics, SERC, Temple University, Philadelphia, Pennsylvania 19122, USA*

²*Jefferson Lab, Newport News, Virginia 23606, USA*

³*Department of Physics, University of Massachusetts, Amherst, Massachusetts 01003, USA*

⁴*CSSM and CoEPP, Department of Physics, University of Adelaide SA 5005, Australia*

Jefferson Lab Angular Momentum (JAM) Collaboration

(Dated: April 15, 2021)

TABLE I. Summary of the χ^2 values per number of points N_{dat} for the data used in this analysis. The MARATHON and JLab E03-103 $^3\text{He}/D$ are separated from the rest of the fixed target data, and their fitted normalizations are shown.

| process | N_{dat} | χ^2/N_{dat} | fitted norm. |
|-----------------------------------|------------------|-------------------------|--------------|
| DIS | | | |
| MARATHON $^3\text{He}/^3\text{H}$ | 22 | 0.63 | 1.007(6) |
| MARATHON D/p | 7 | 0.95 | 1.019(4) |
| JLab E03-103 $^3\text{He}/D$ | 16 | 0.25 | 1.006(10) |
| other fixed target | 2678 | 1.05 | |
| HERA | 1185 | 1.27 | |
| Drell-Yan | 205 | 1.20 | |
| W -lepton asym. | 70 | 0.81 | |
| W charge asym. | 27 | 1.14 | |
| Z rapidity | 56 | 1.04 | |
| jet | 200 | 1.11 | |
| total | 4466 | 1.11 | |

arXiv:2104.06946