Update on the F_2 experiment

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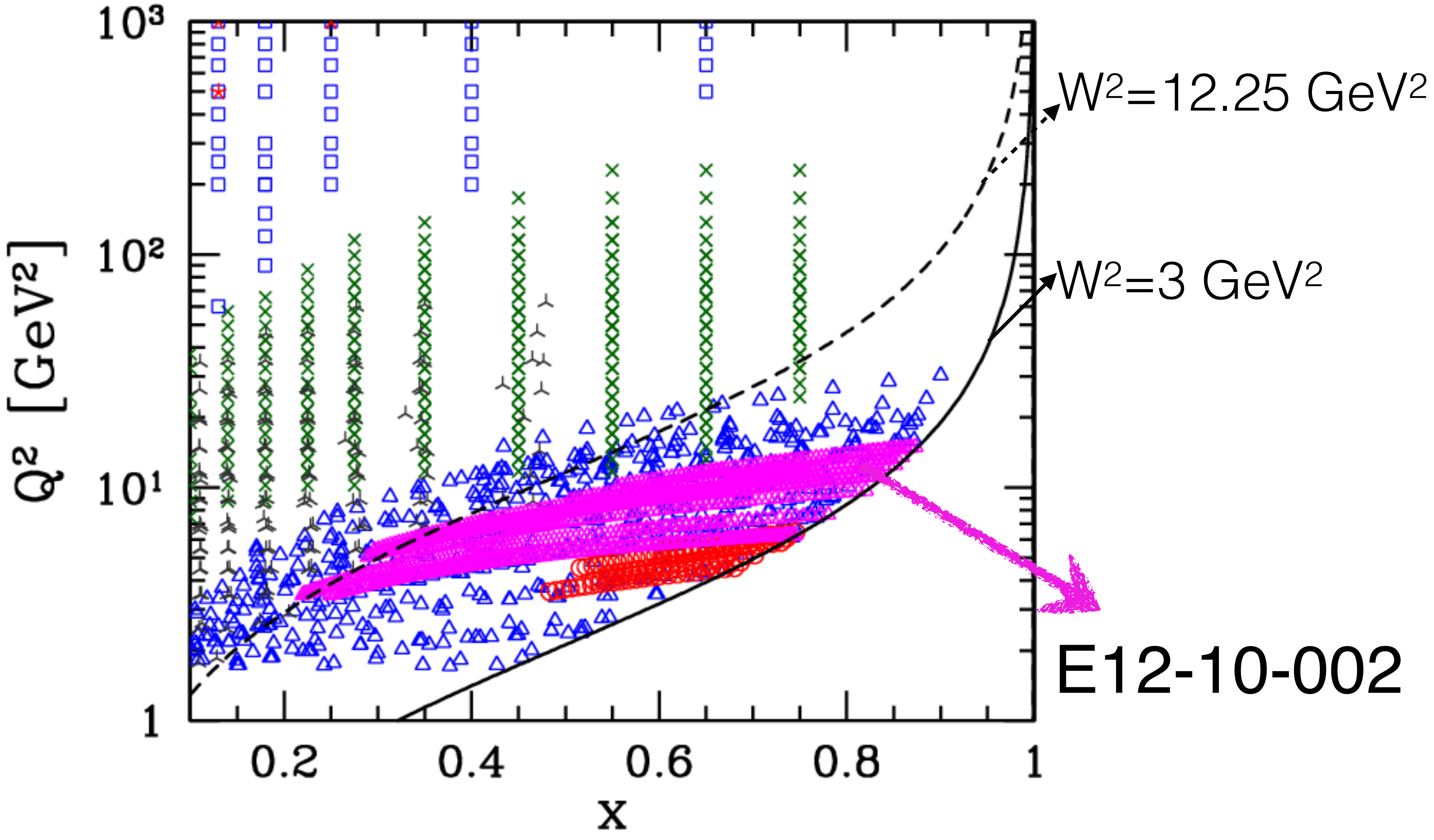
Hall C Collaboration Meeting, Jan 28-29, 2020, Jefferson Lab

Outline

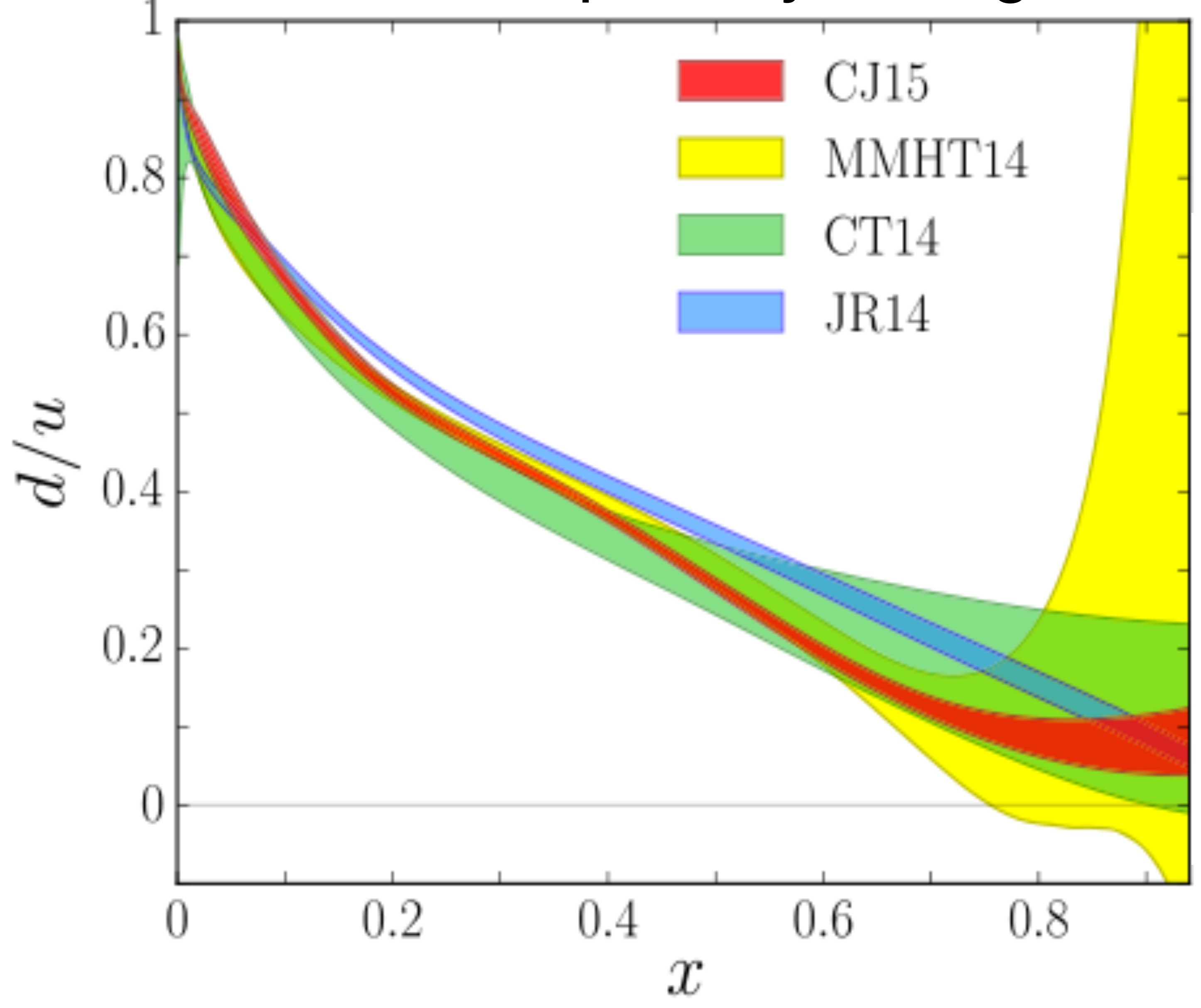
- **Physics Motivations**
  - Constraints for pdf global fits
  - Quark-hadron duality
  - Moments
  - Resonance and deep inelastic scattering modeling
- **Analysis**
  - Timing cuts
  - Calibrations
  - Detector efficiency studies
  - Background: pion contamination, charge symmetric background
  - Other corrections: radiative effects
- **Preliminary Results**
  - Cross sections
  - D/H ratios
  - F_2 structure functions

Constraints for PDFs

- CTEQ-JLab (CJ) 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**



To improve uncertainty in d/u extraction specially at large X

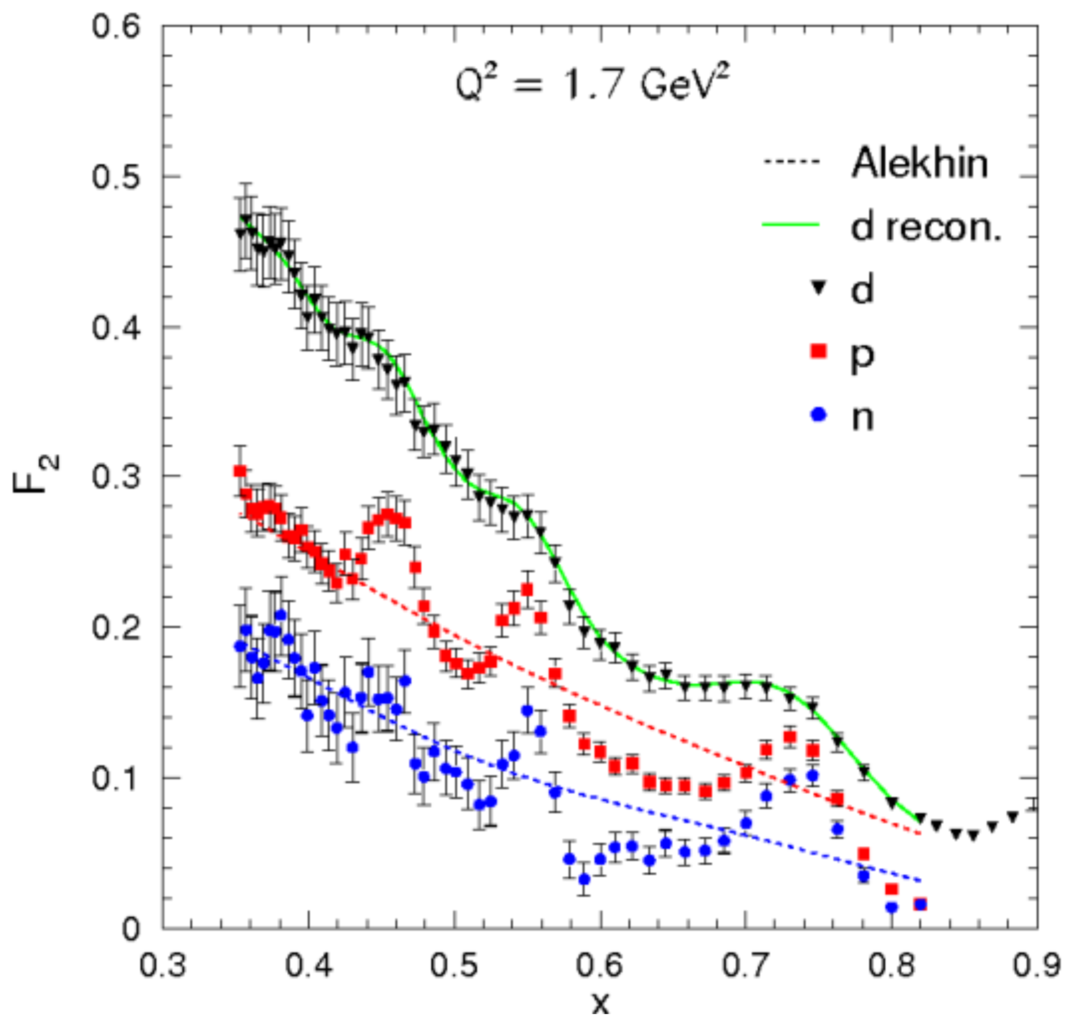


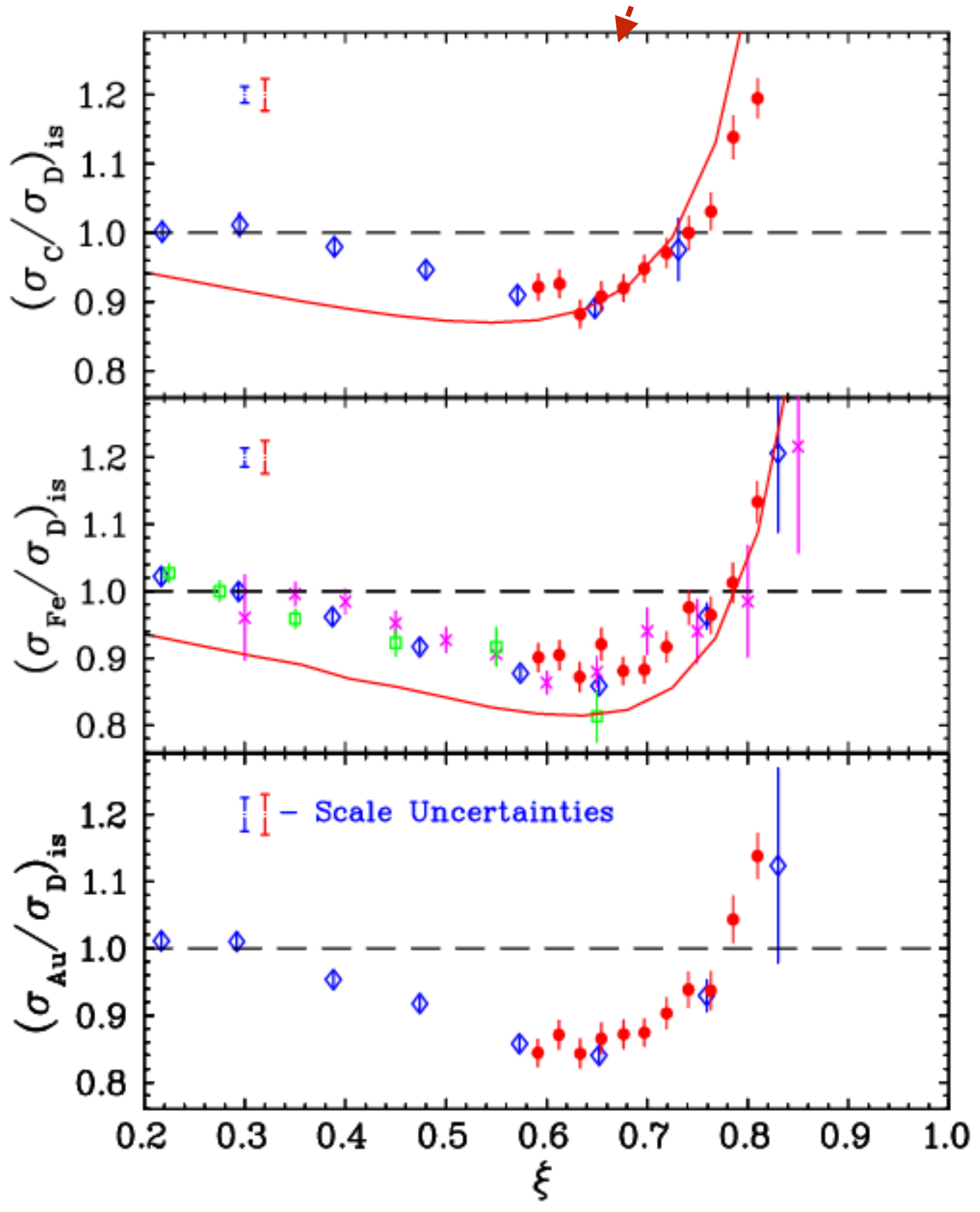
- We measured both H and D cross sections (free protons and bound neutrons)

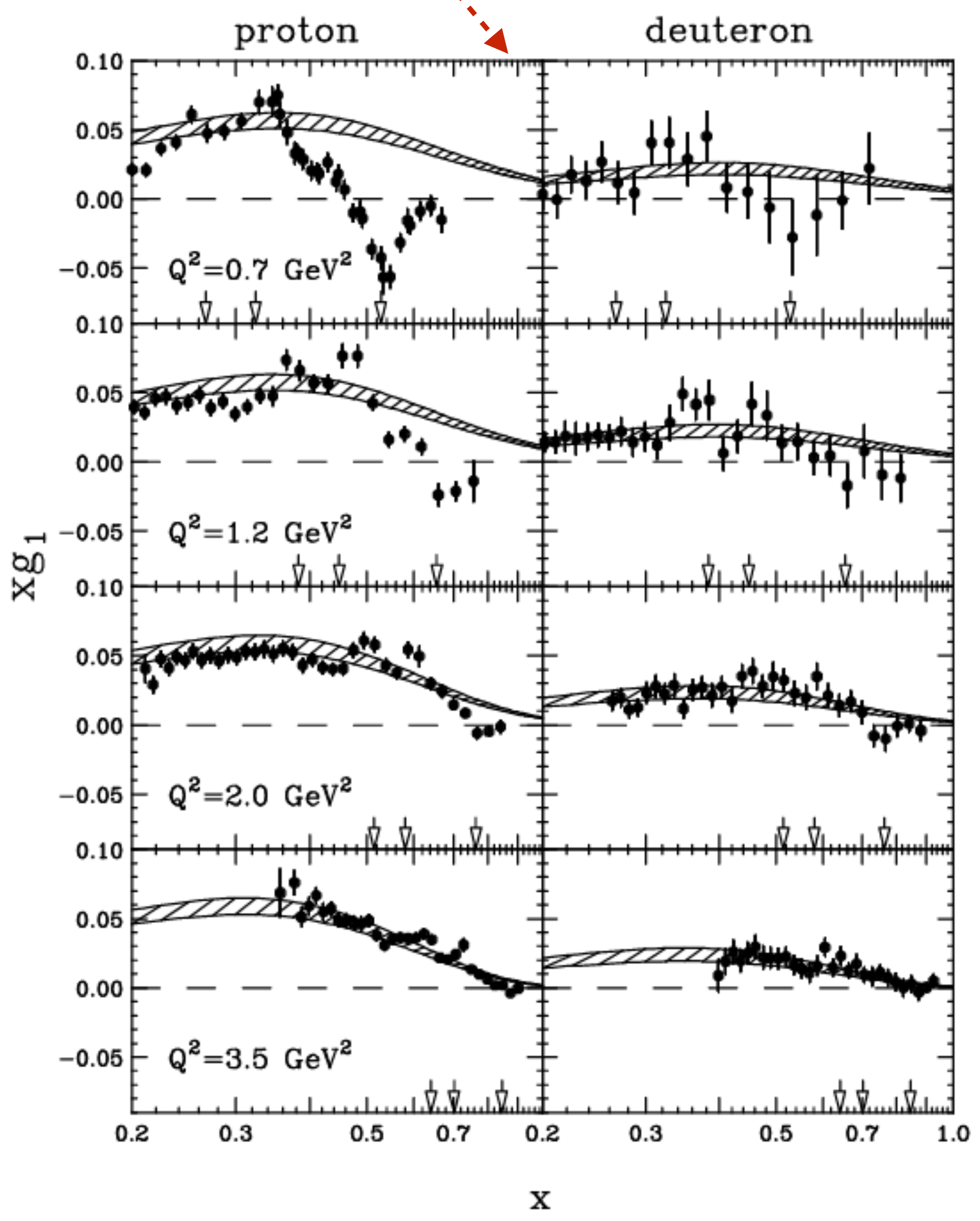
Quark-hadron duality

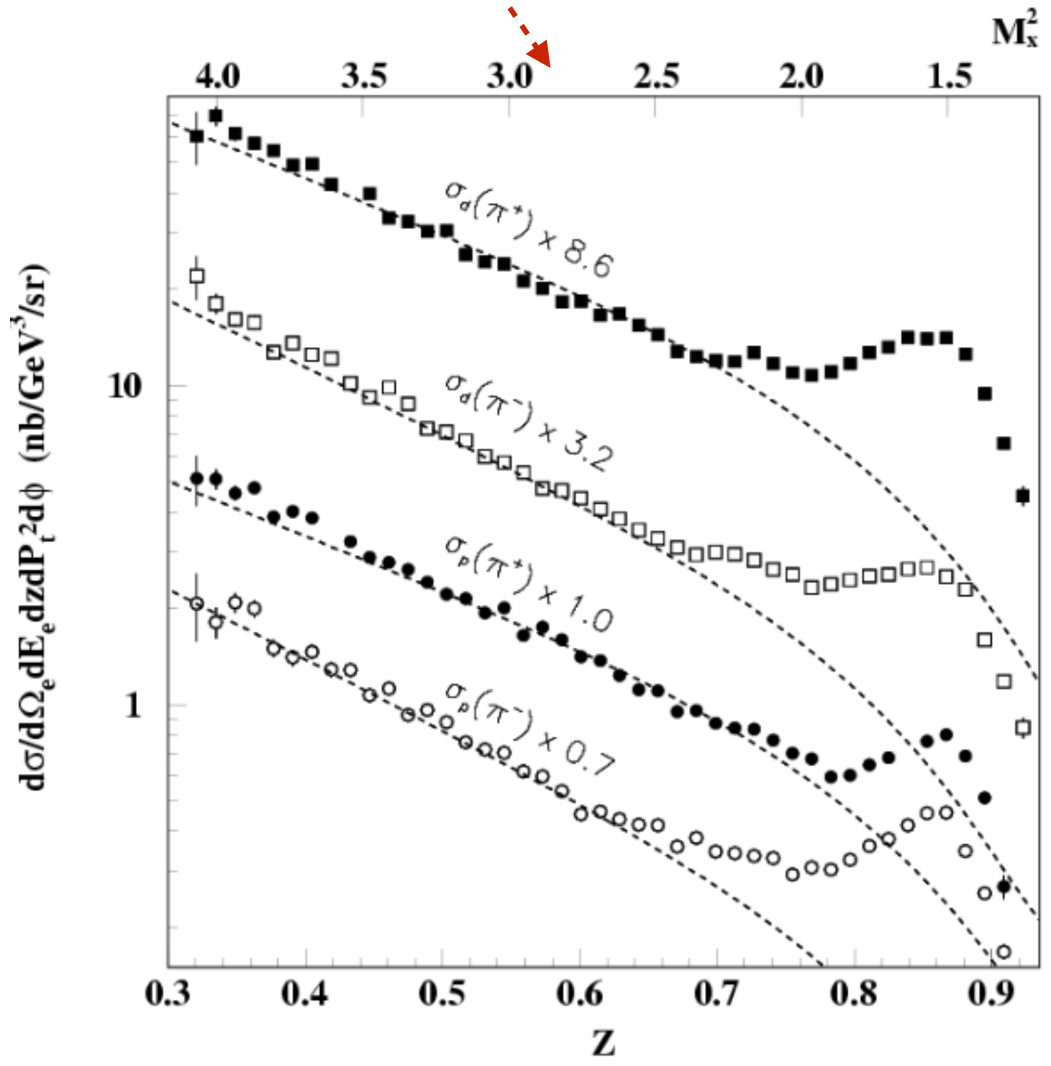
- Structure functions in resonance region on average behave like structure functions in DIS regime.

- It's a 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









Quark-Hadron Duality Studies

- What scaling curve and scaling variable should we use?

- 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

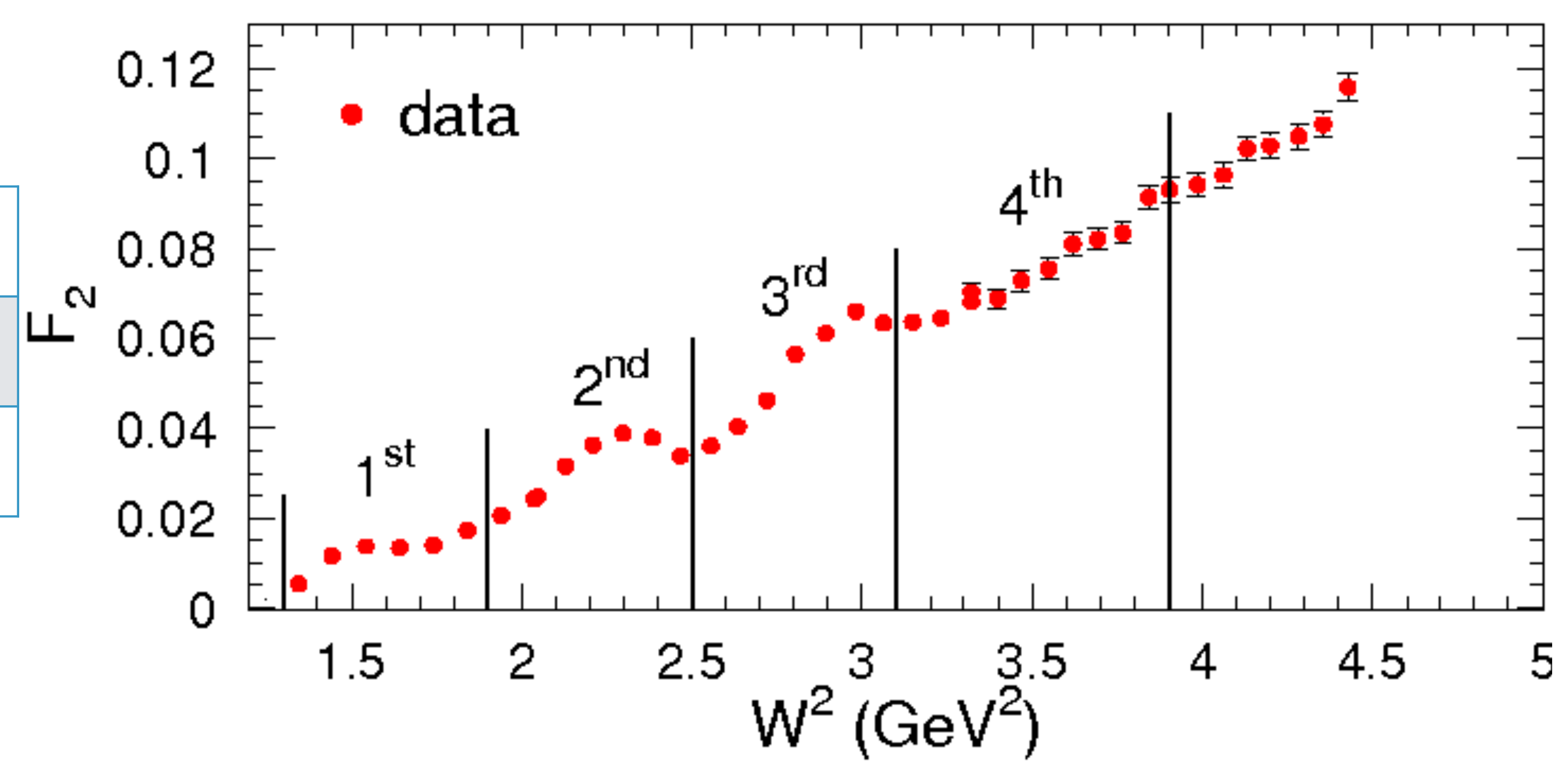
- How well resonance data average to the scaling curve?

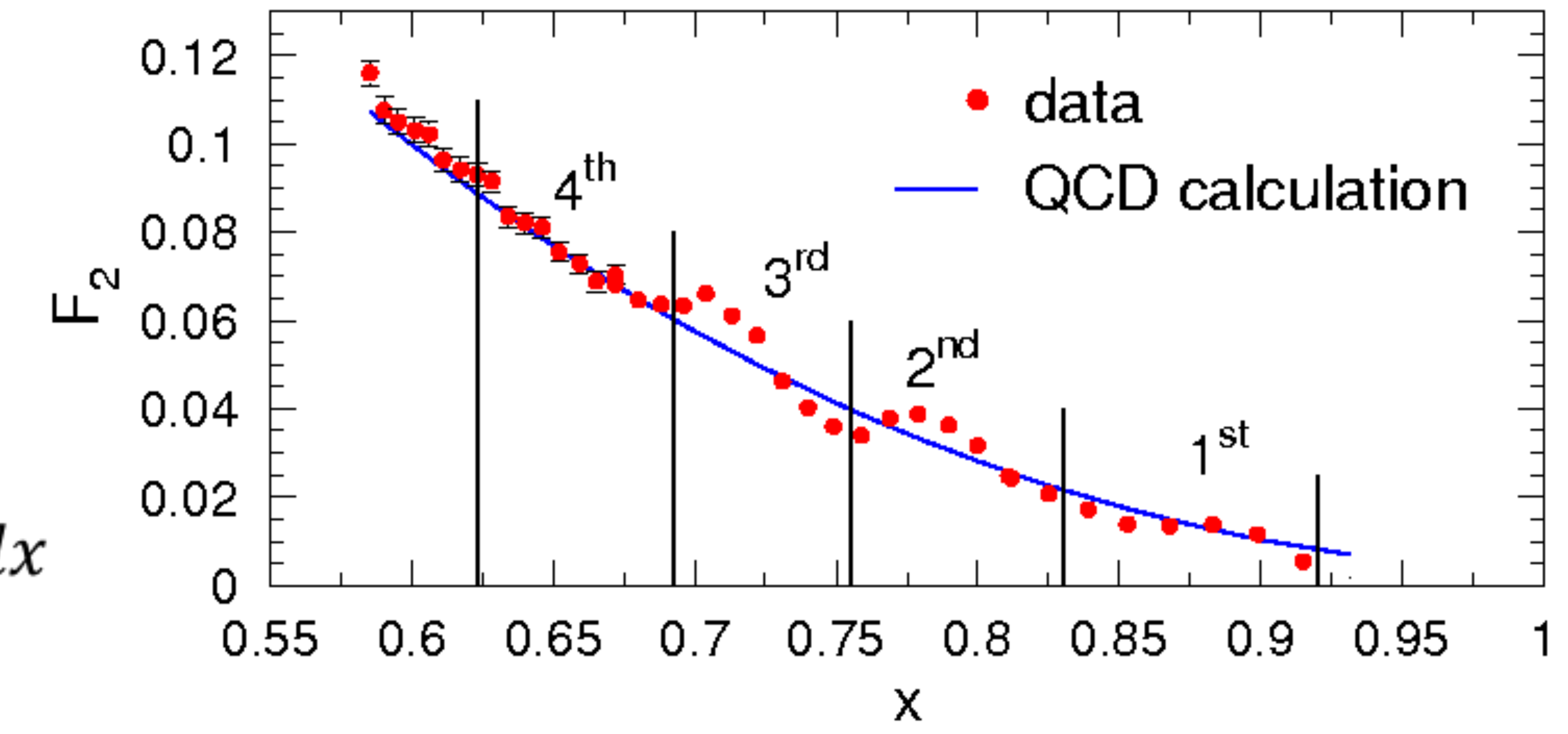
- Calculate moments:

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

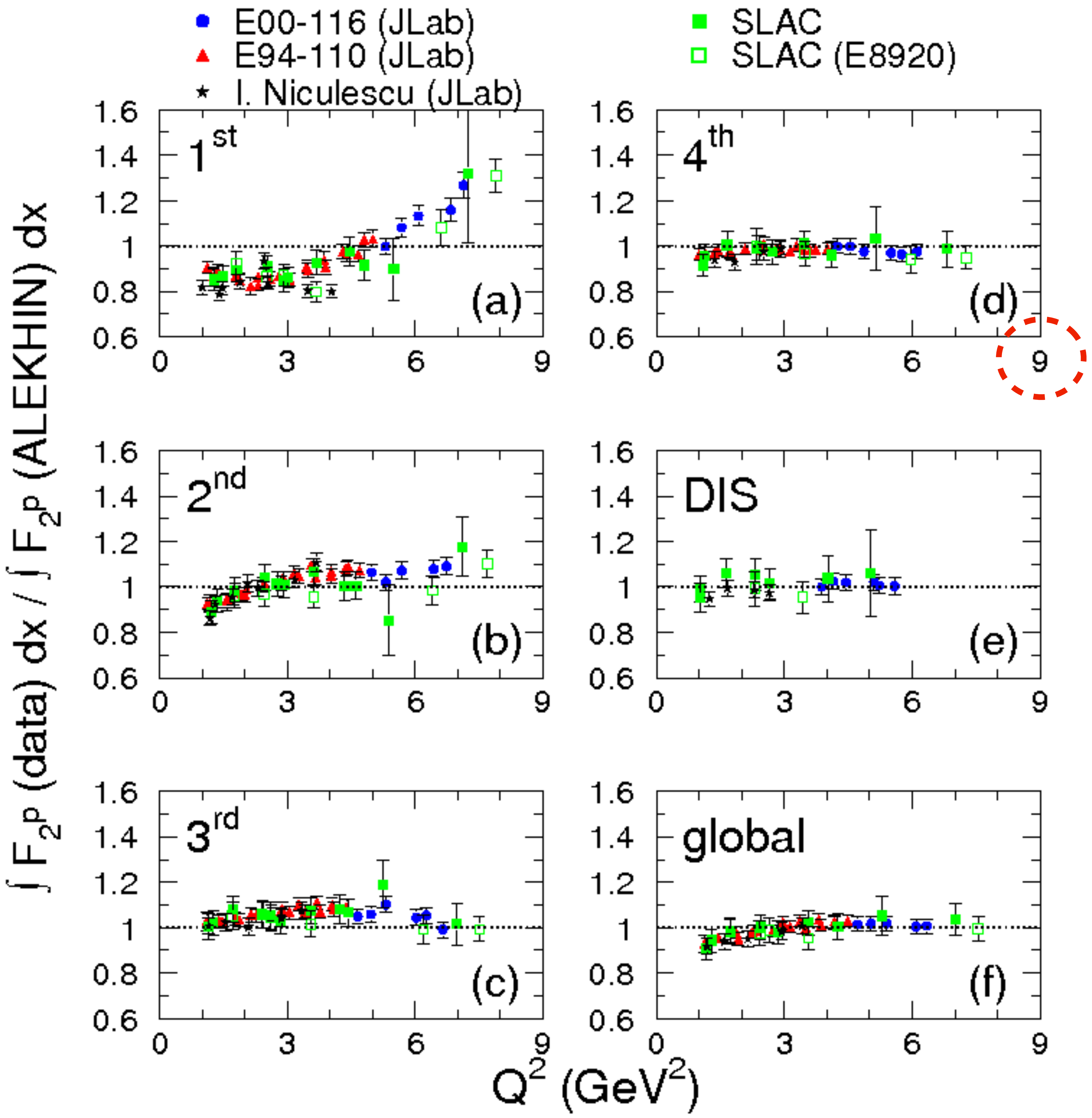
In Resonance region

From DIS data only





Quark-Hadron Duality Studies: Example

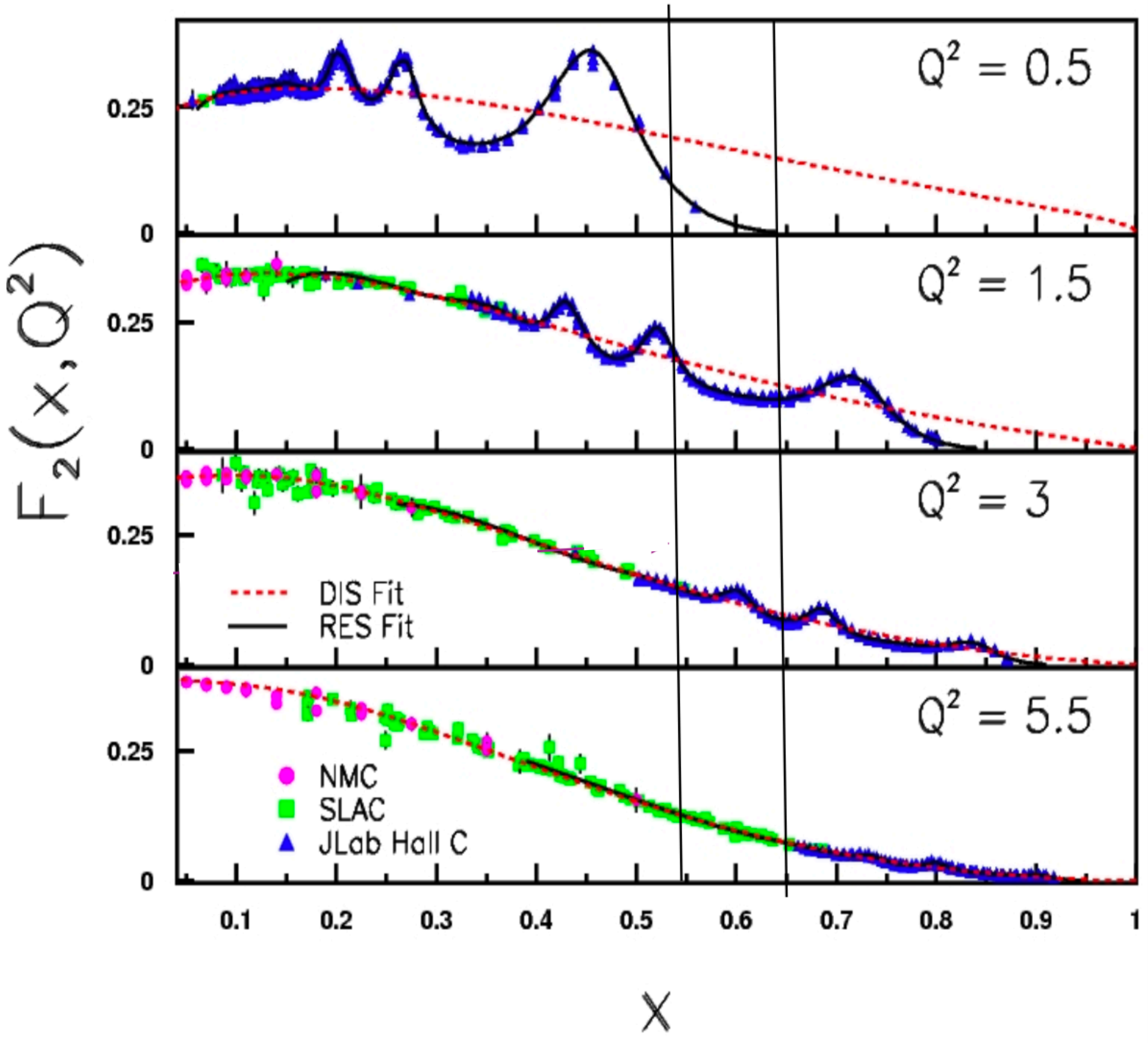


S. Malace, et al., Phys.Rev. C80 (2009) 035207

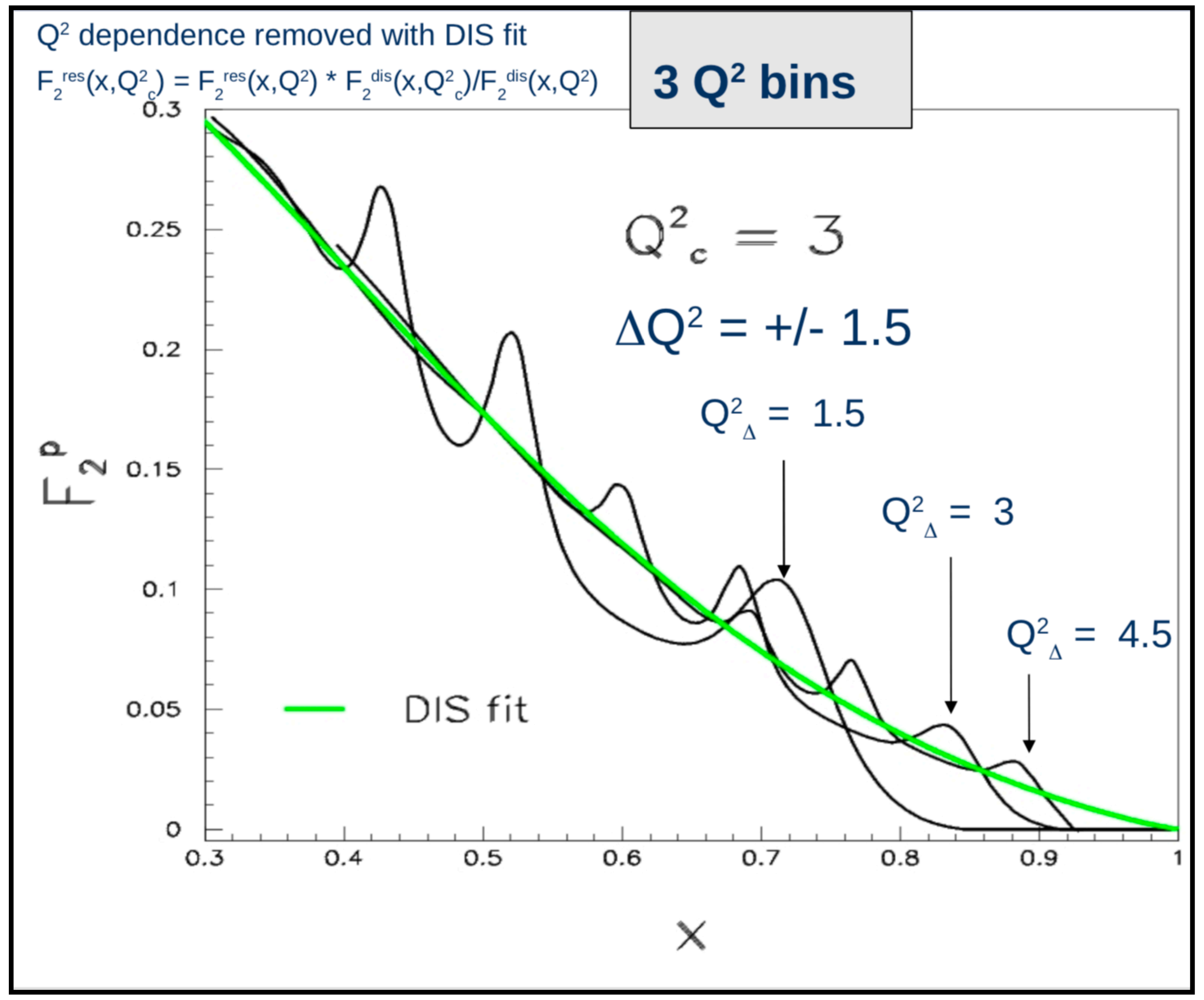
Quark-Hadron Duality Studies: Example

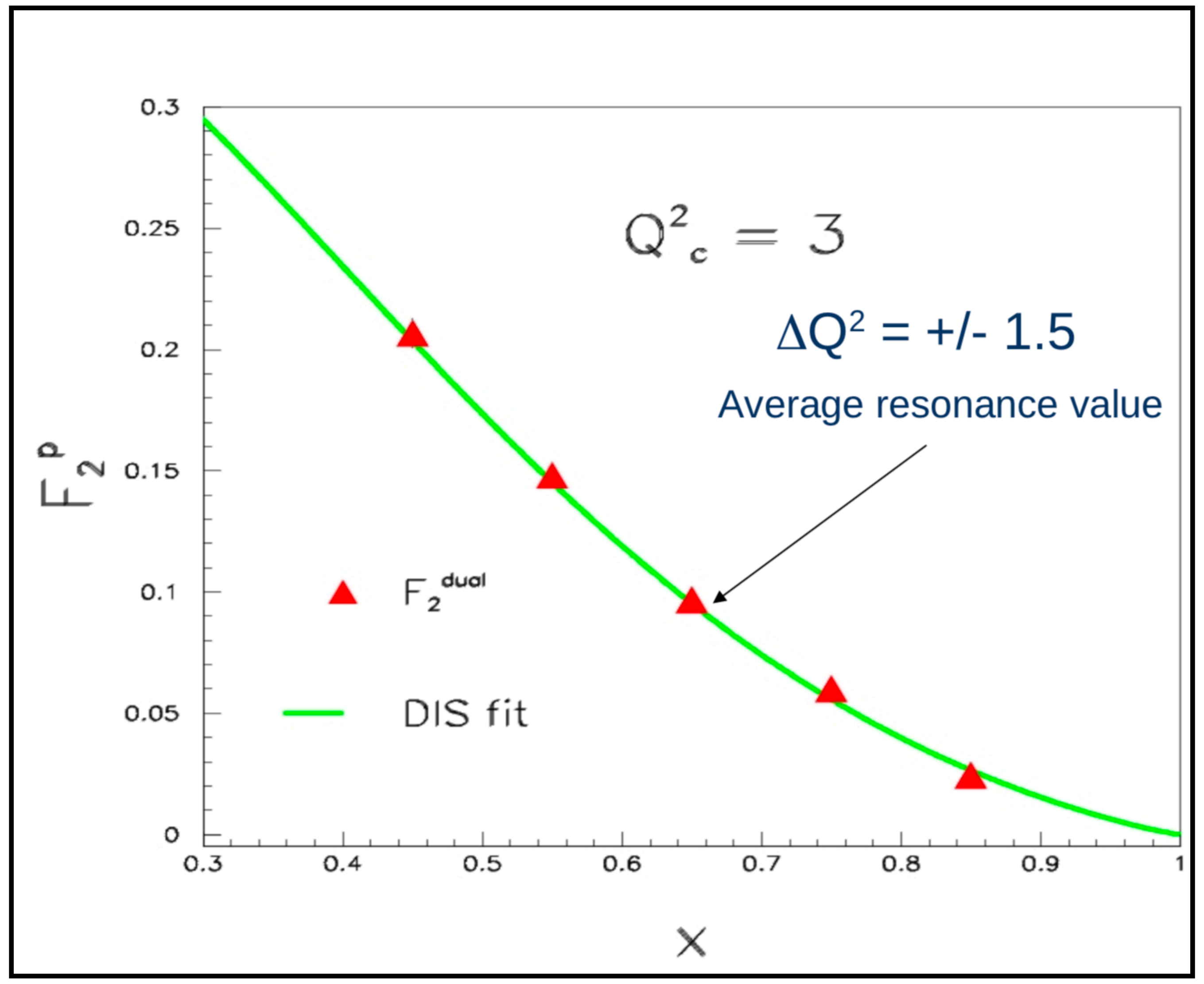
- New duality averaging method to include resonance region data in global PDF fits

DIS fit – 'F2ALLM' H.Abramowicz and A.Levy, hep-ph/9712415
Res fit - E.C. and P.E. Bosted, PRC 81,055213



from Eric Christy





- Take out the Q^2 dependence using the DIS curve
- Average over a range of Q^2 at fixed x over a number of resonances including peaks and valleys

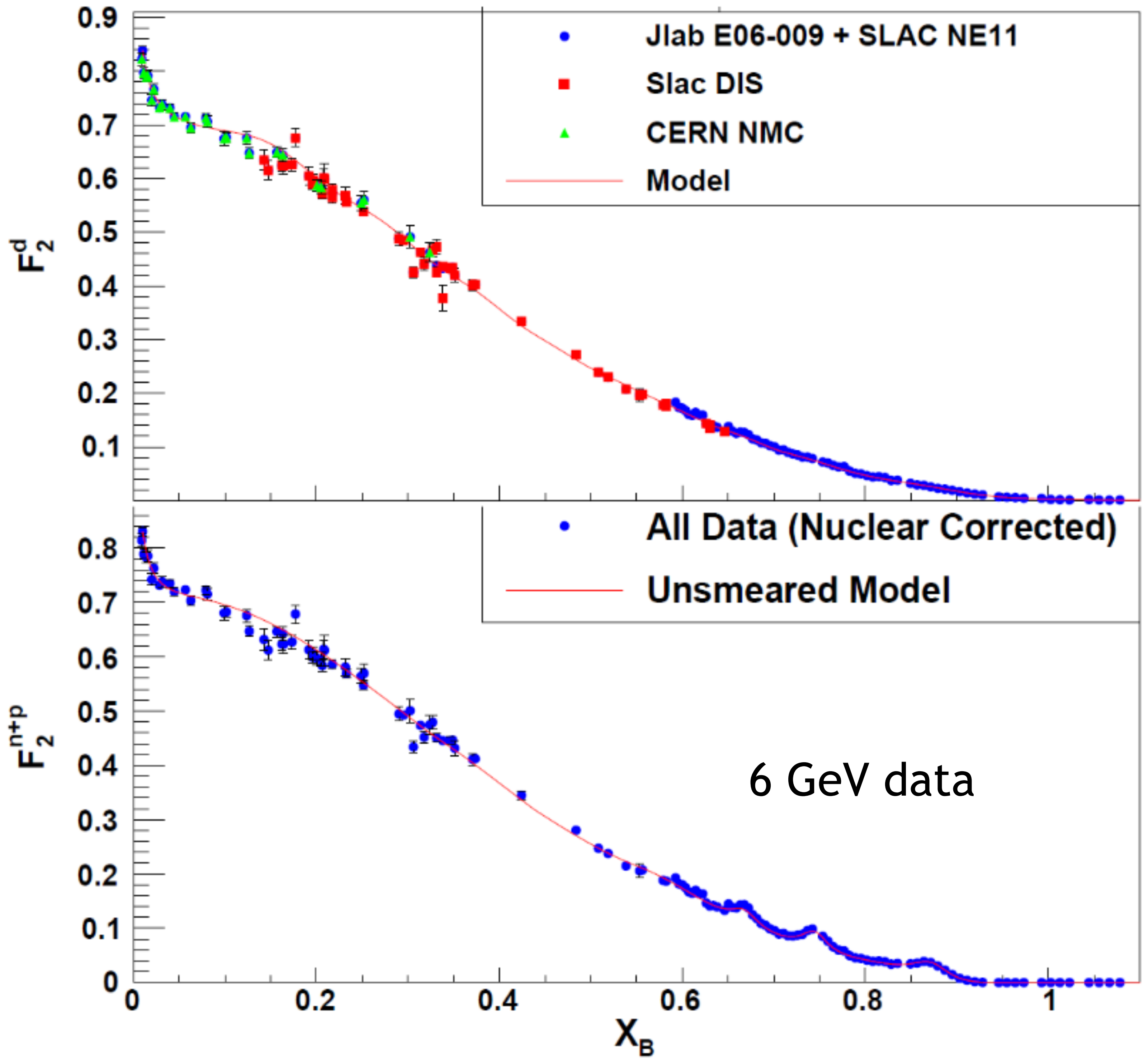
Non-Singlet Moments as Tests of LQCD

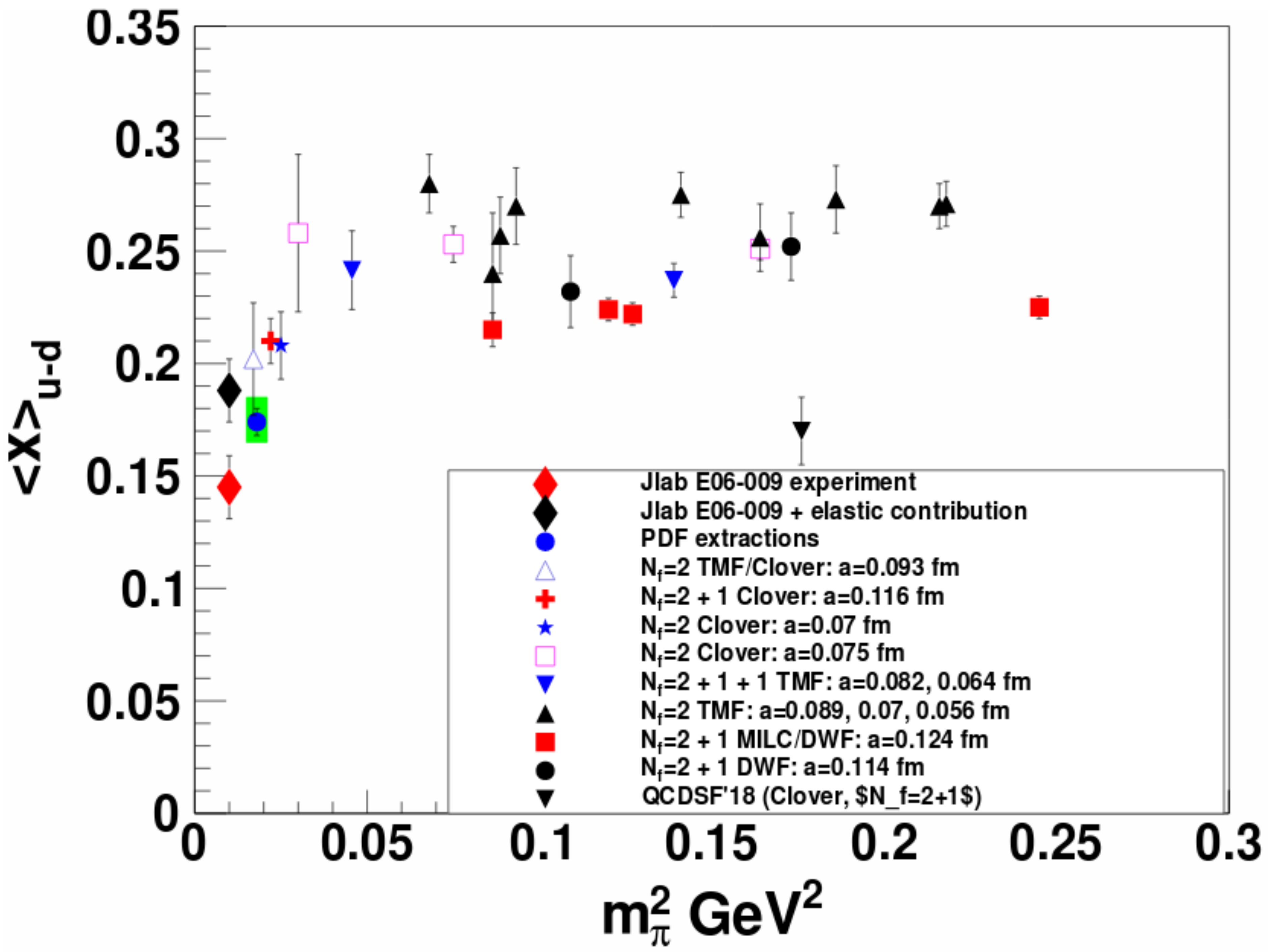
- Test LQCD calculations by comparing non-singlet moments from LQCD to those extracted from data.

$$M_2^{(N)}(Q^2) = \int_0^1 dx \frac{\xi^{N+1}}{x^3} \times \left(\frac{3+3(N+1)r+N(N+2)r^2}{(N+2)(N+3)}\right) F_2(x, Q^2)$$

$$M_2^{NS} = M_2^p - M_2^n = \frac{1}{3} C_N^v \langle x \rangle_{u-d}$$

Data: $2M_2^p - M_2^{p+n}$



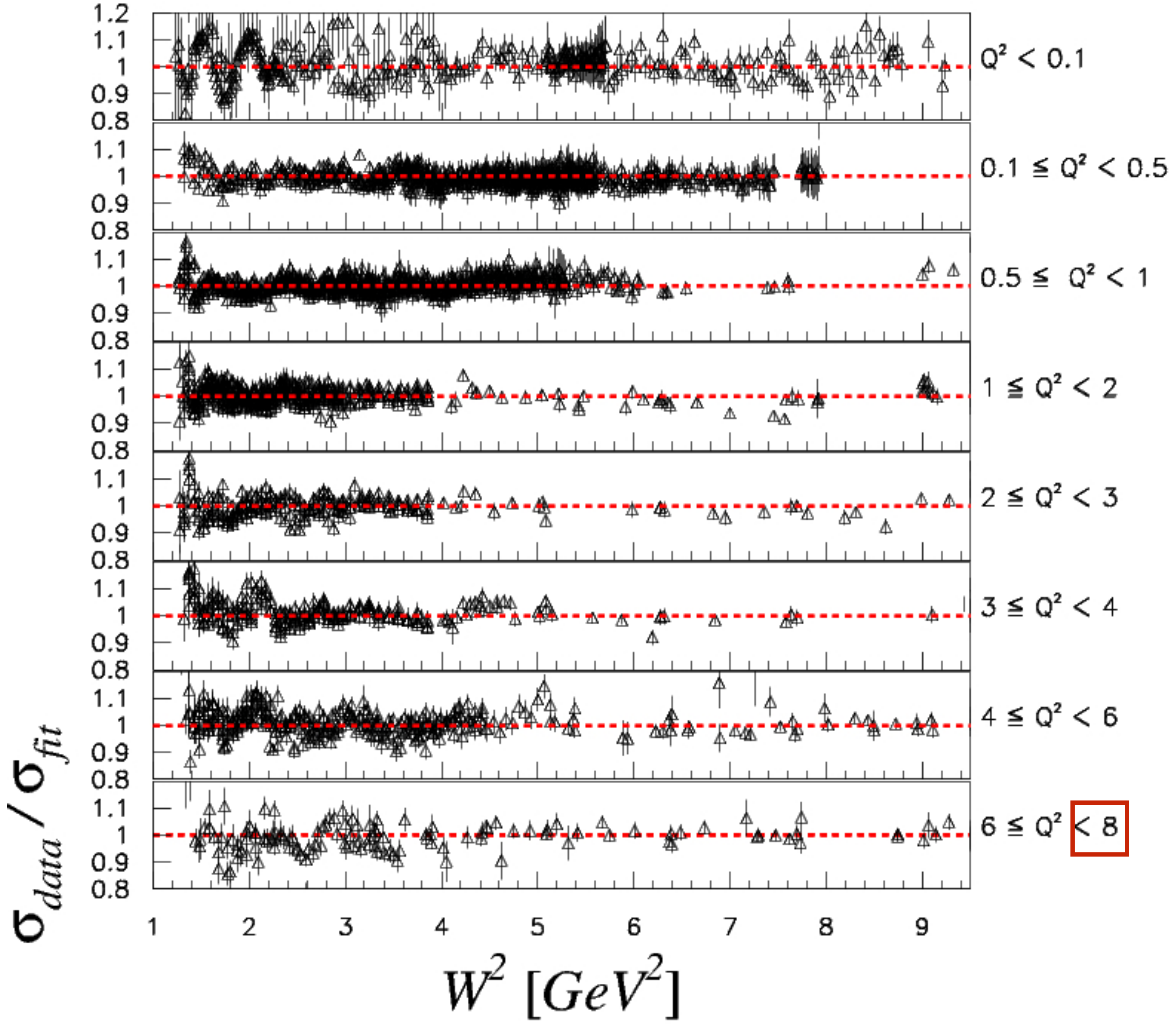


work by Ibrahim Albayrak

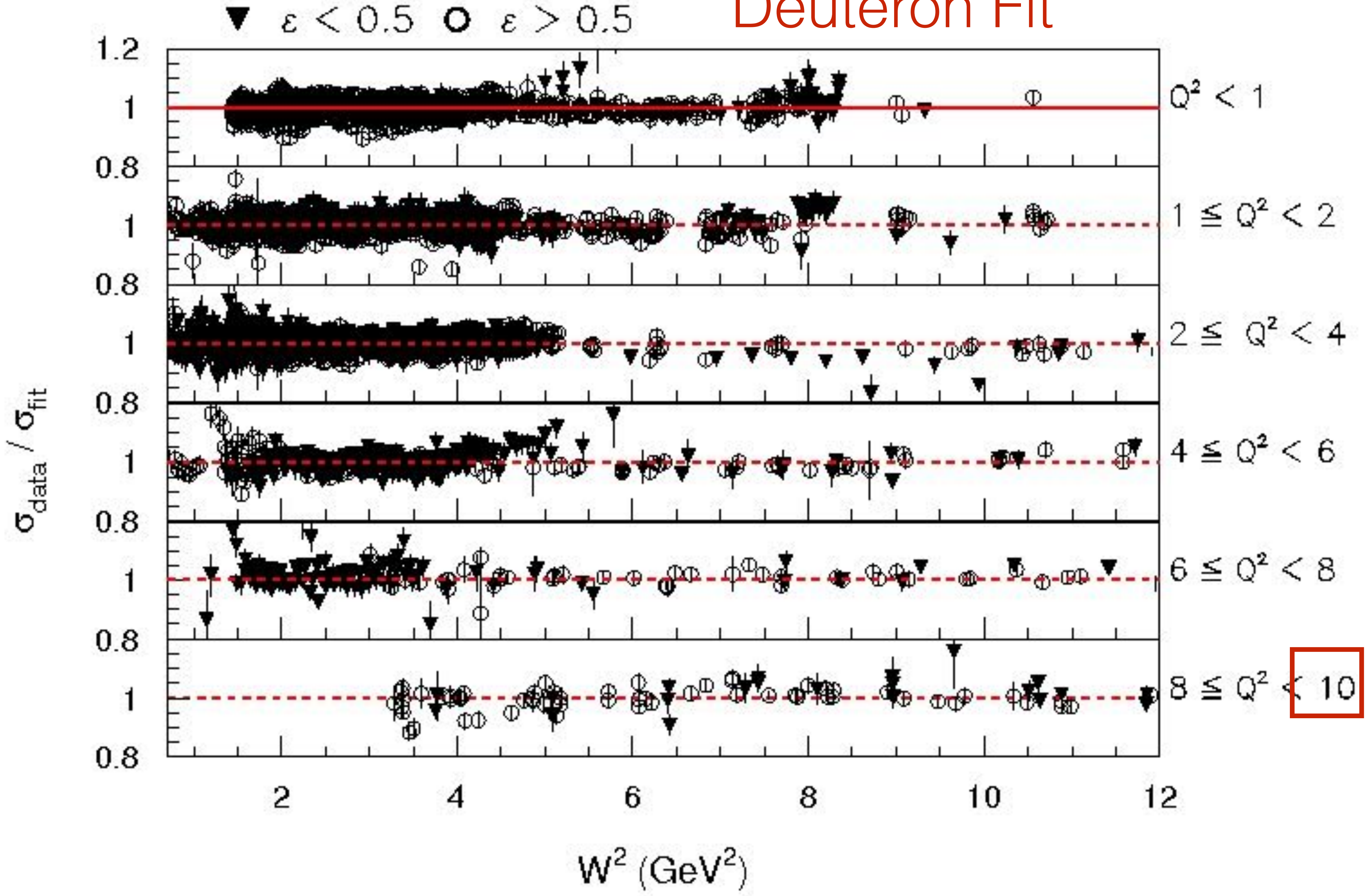
Resonance / DIS Modeling

- A physics driven global fit to inclusive cross section is very valuable: radiative and bin-centering corrections, rates, moments of structure functions and duality studies, dilution factors in spin structure functions, physics of nucleon resonances

Proton Fit



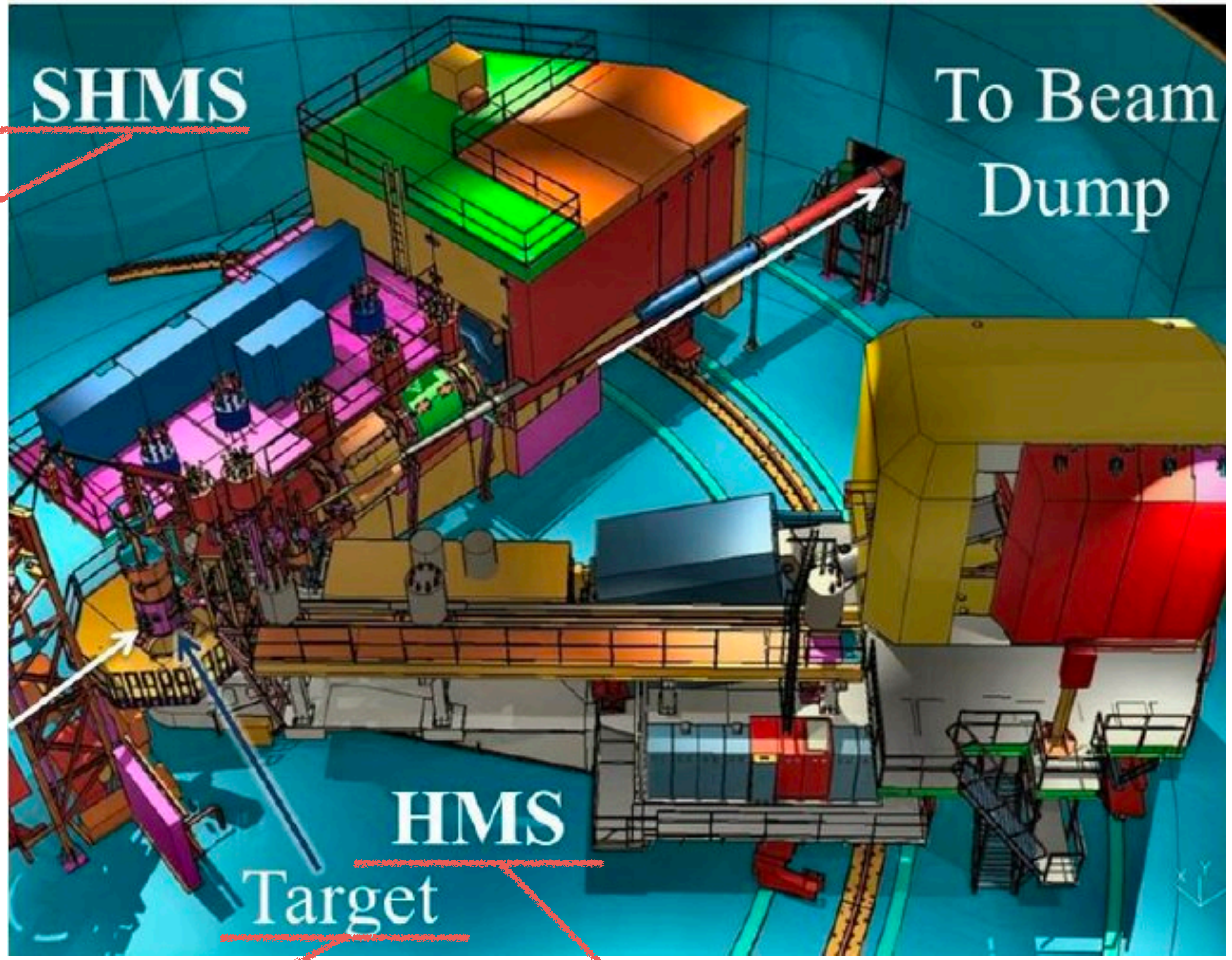
Deuteron Fit



- Provides constraints to larger Q^2
  – up to 16 GeV^2 for both proton and deuteron fit
- Provides a complete data set (proton and deuteron) for a precise neutron extraction

Hall C Spectrometers

71% of total data were taken by SHMS

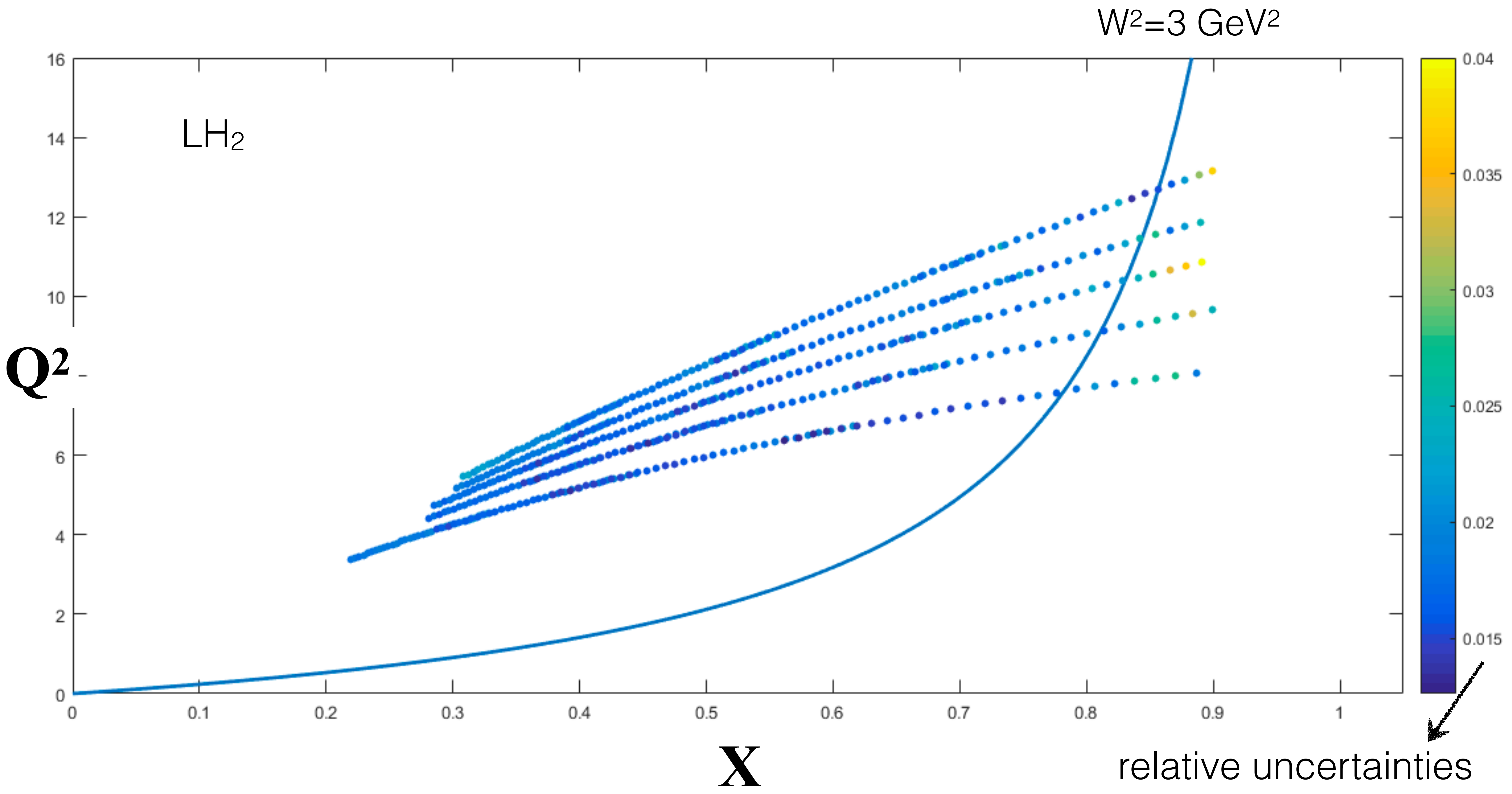


LH_2, LD_2, Al

Push to high Q^2

- Run in spring 2018
- Beam energy: 10.6 GeV

E12-10-002: Measurements of H(e,e') and D(e,e')



SHMS

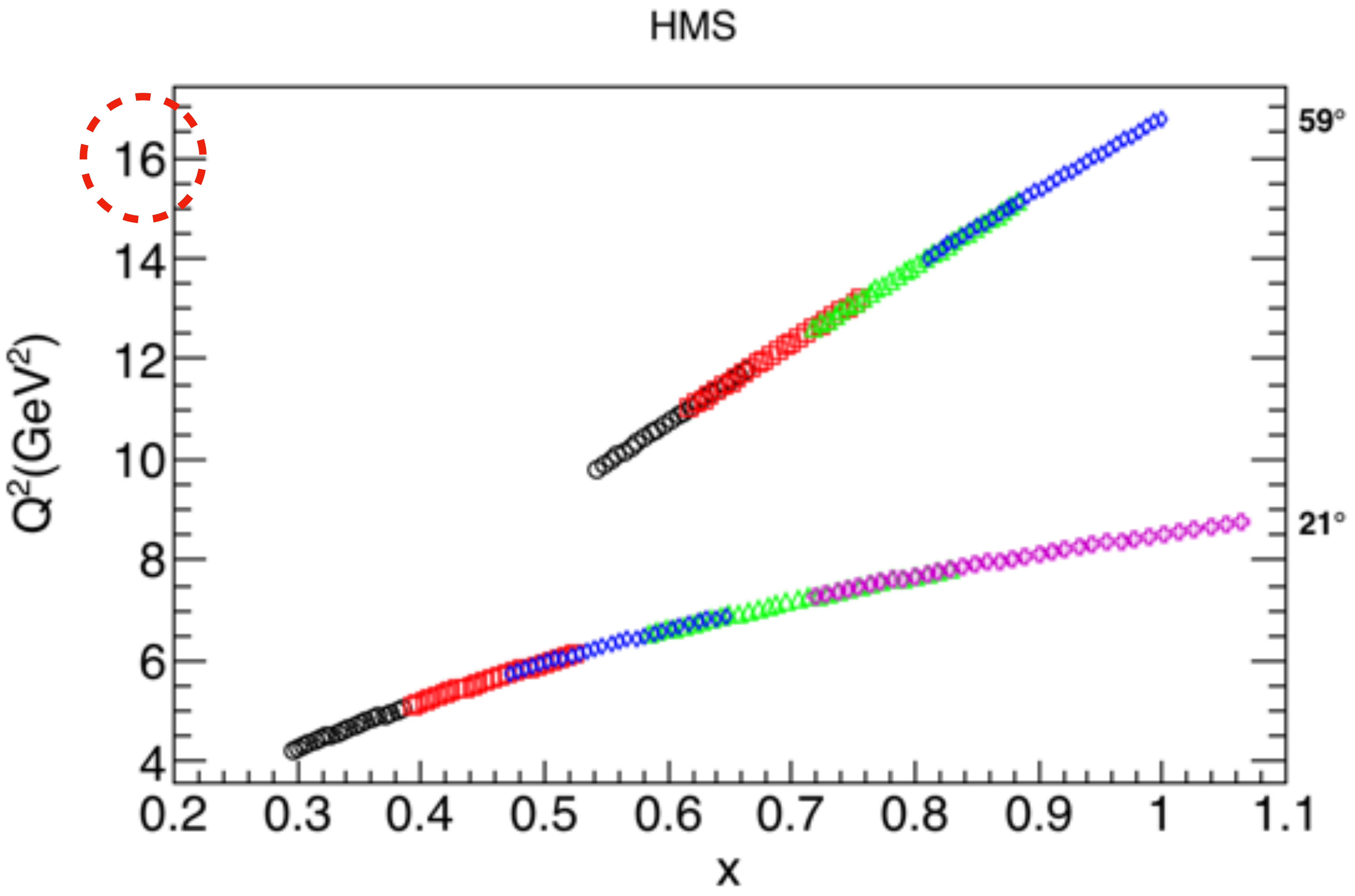
Angle	Momentum(GeV/c)
21	2.7, 3.3, 4.0, 5.1
25	2.5, 3.0, 3.5, 4.4
29	2.0, 2.4, 3.0, 3.7
33	1.7, 2.1, 2.6, 3.2
39	1.3, 1.6, 2.0, 2.5

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

E12-10-002: Measurements of H(e,e') and D(e,e')



HMS

Angle	Momentum(GeV/c)
21	3.3, 4.0, 4.5, 5.1, 5.7
59	1.05, 1.18, 1.35, 1.50

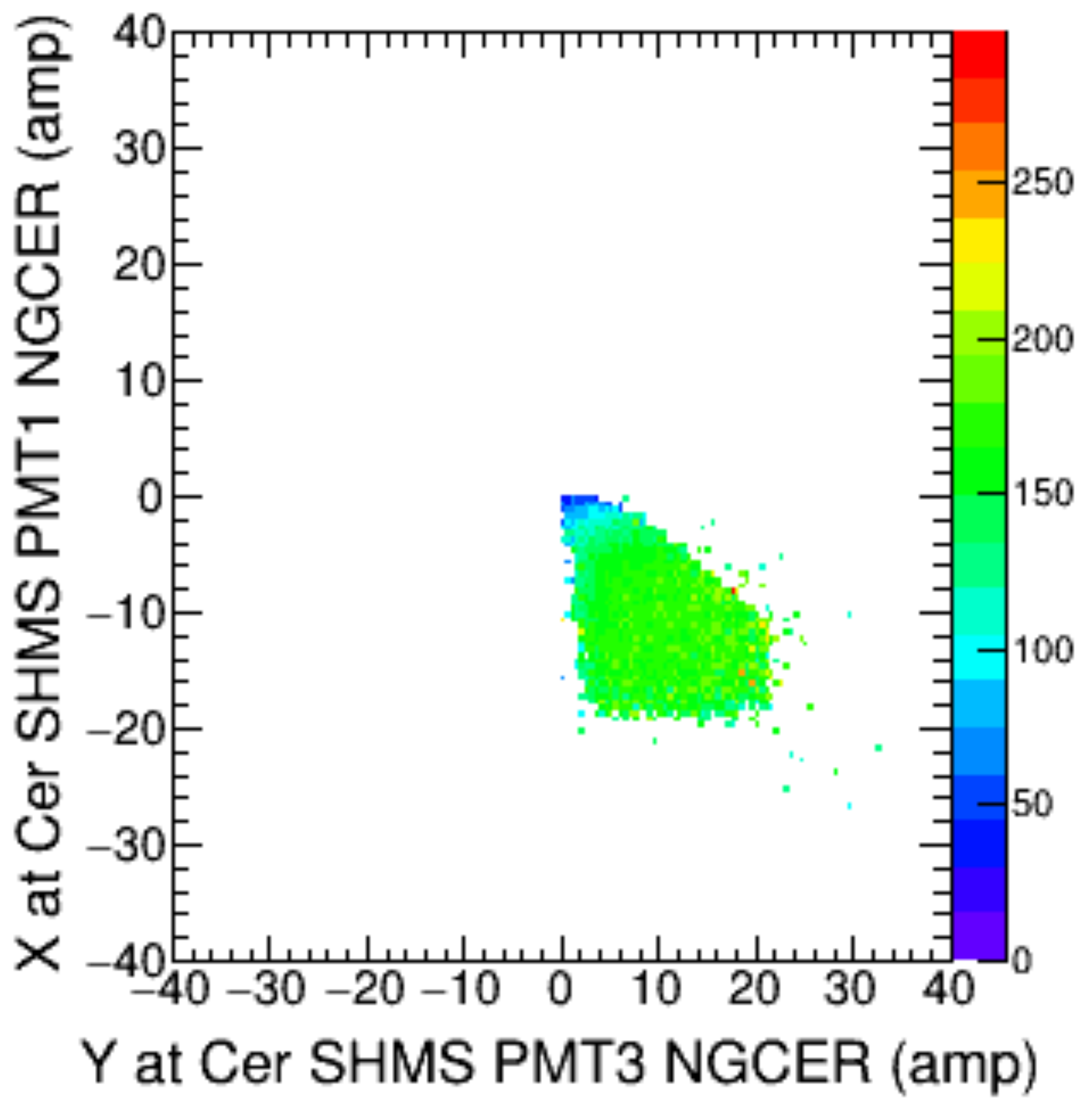
- 59 deg: pushed to higher Q^2, up to 16 GeV^2
- 21 deg: to cross calibrate with SHMS data
- Larger angle has lower rate. Ample amount of time was given for data taking.

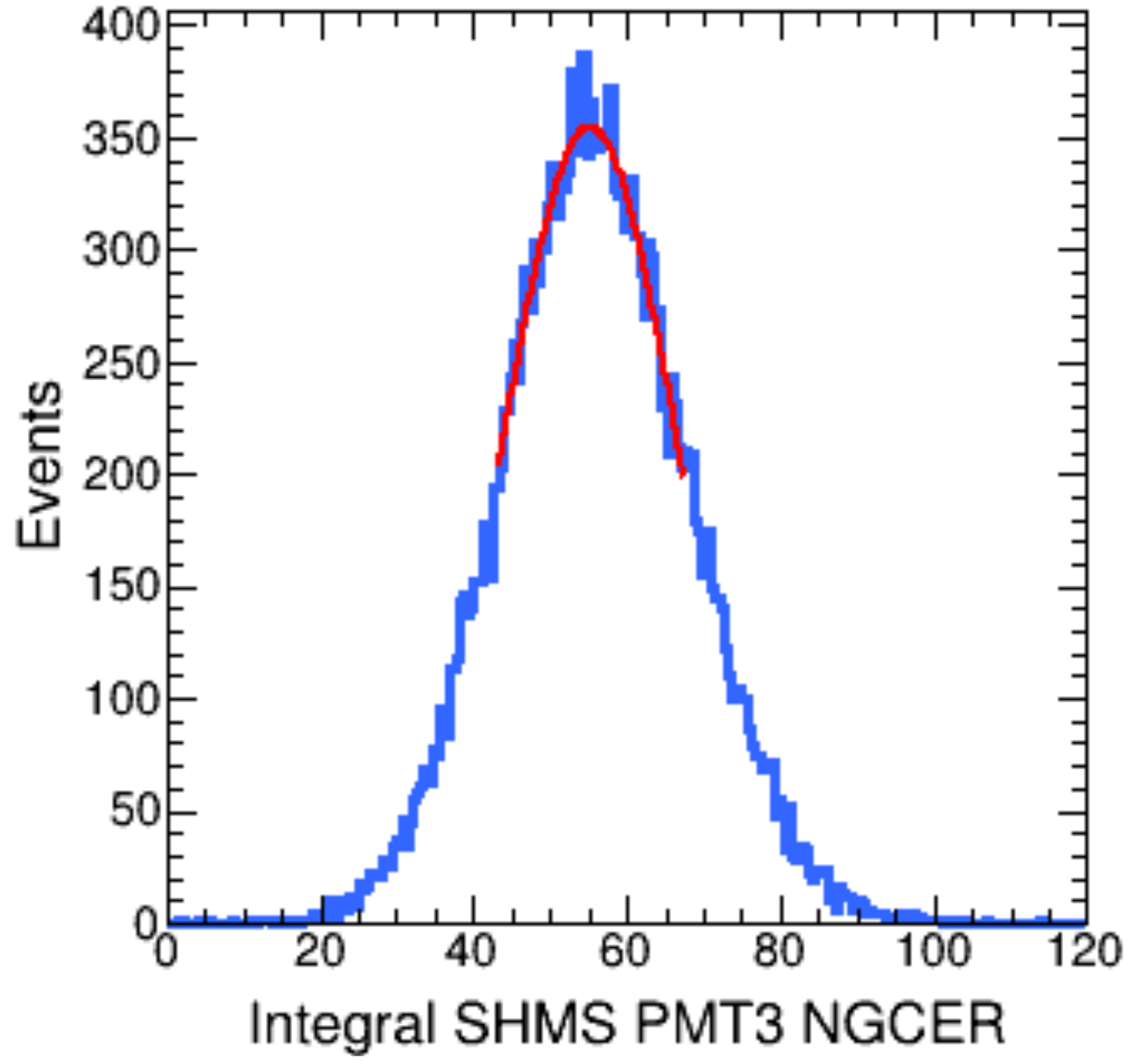
Analysis Flow and Status

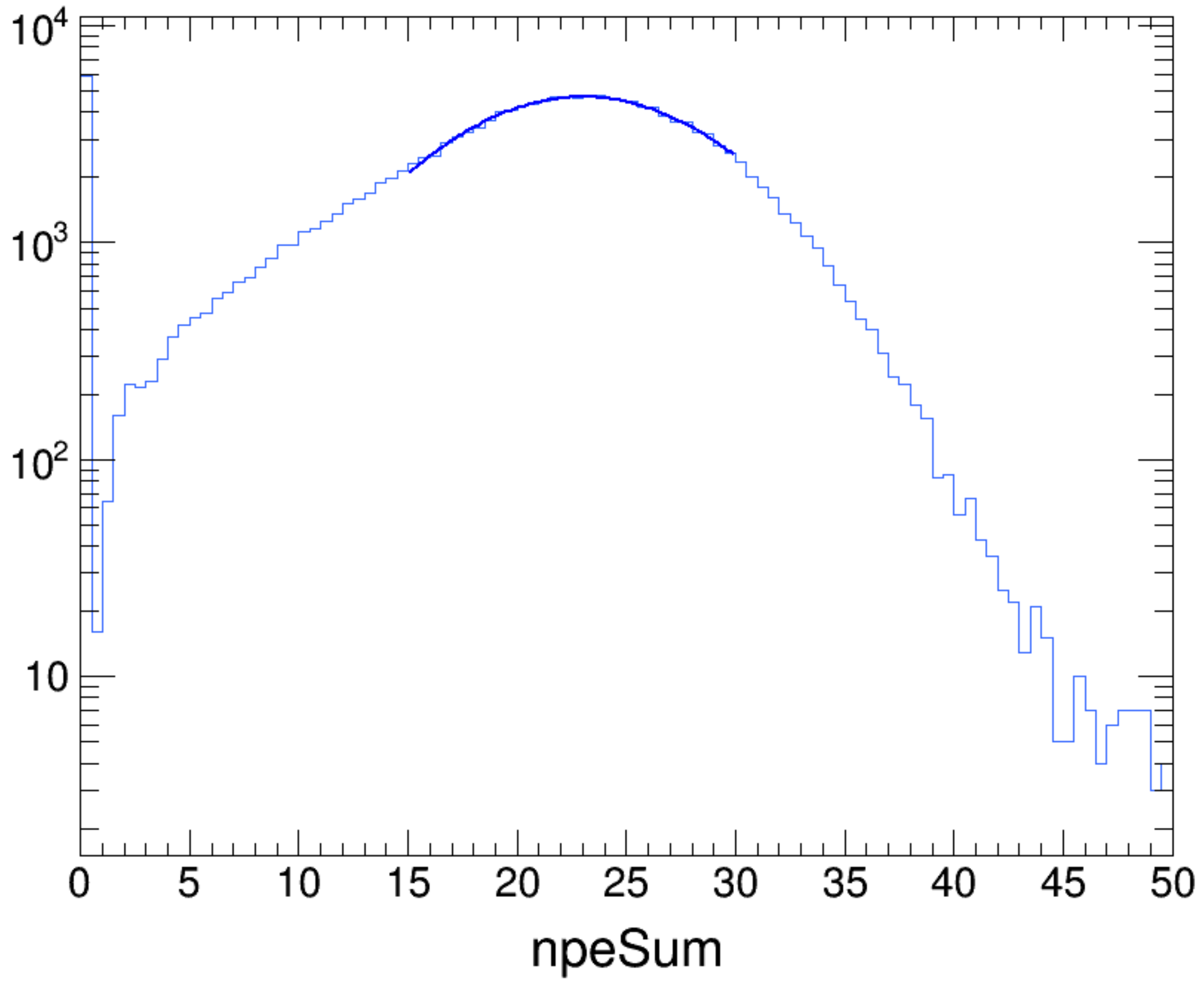
1. **Timing Cuts (✓)**
2. **Calibration (✓)**
    - BCM - Deb's talk
    - Hodoscope
    - Drift Chamber
    - Calorimeter
    - Cherenkov
3. **Efficiency Study - in progress**
    - Tracking Efficiency Study
    - Trigger Efficiency Study
    - Computer Dead Time
    - Calorimeter and Cherenkov Cut Efficiency
    - Pion Contamination
4. **Charge Symmetric Background - in progress**
5. **Acceptance Study - understand via Monte Carlo**
6. **Radiative corrections - calculated using existed model**
7. **Cross Section Calculation - extracted**

- Achieved 100 % statistical goal for all the kinematics.

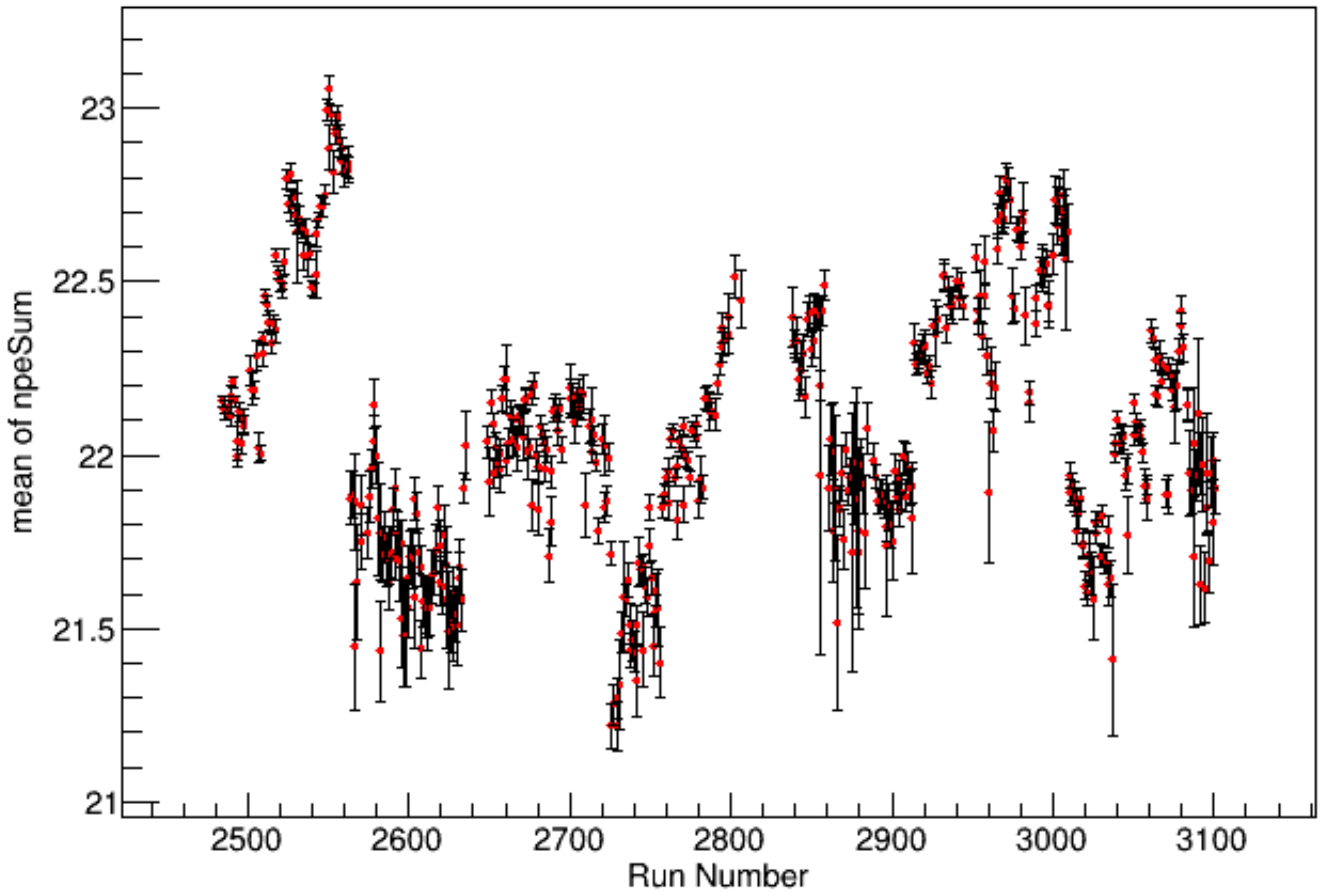
Cherenkov calibration



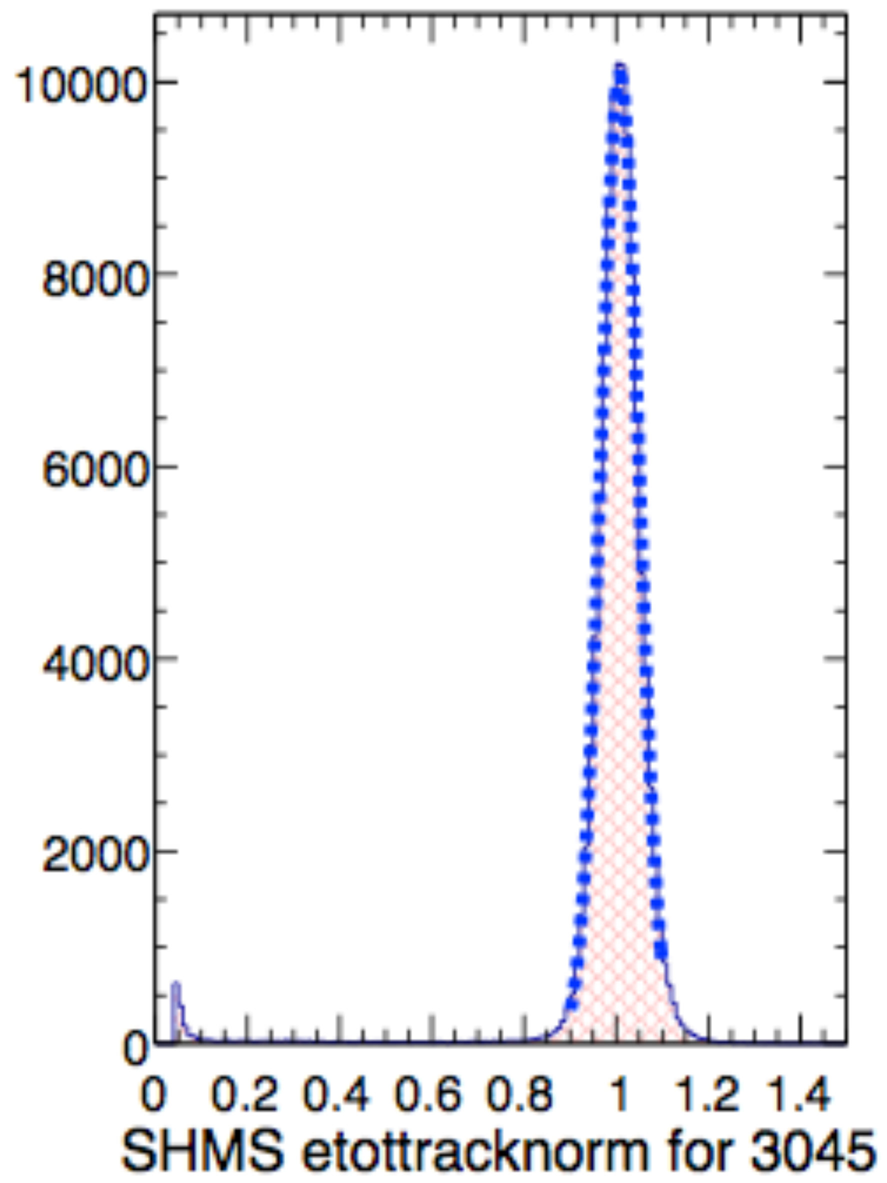


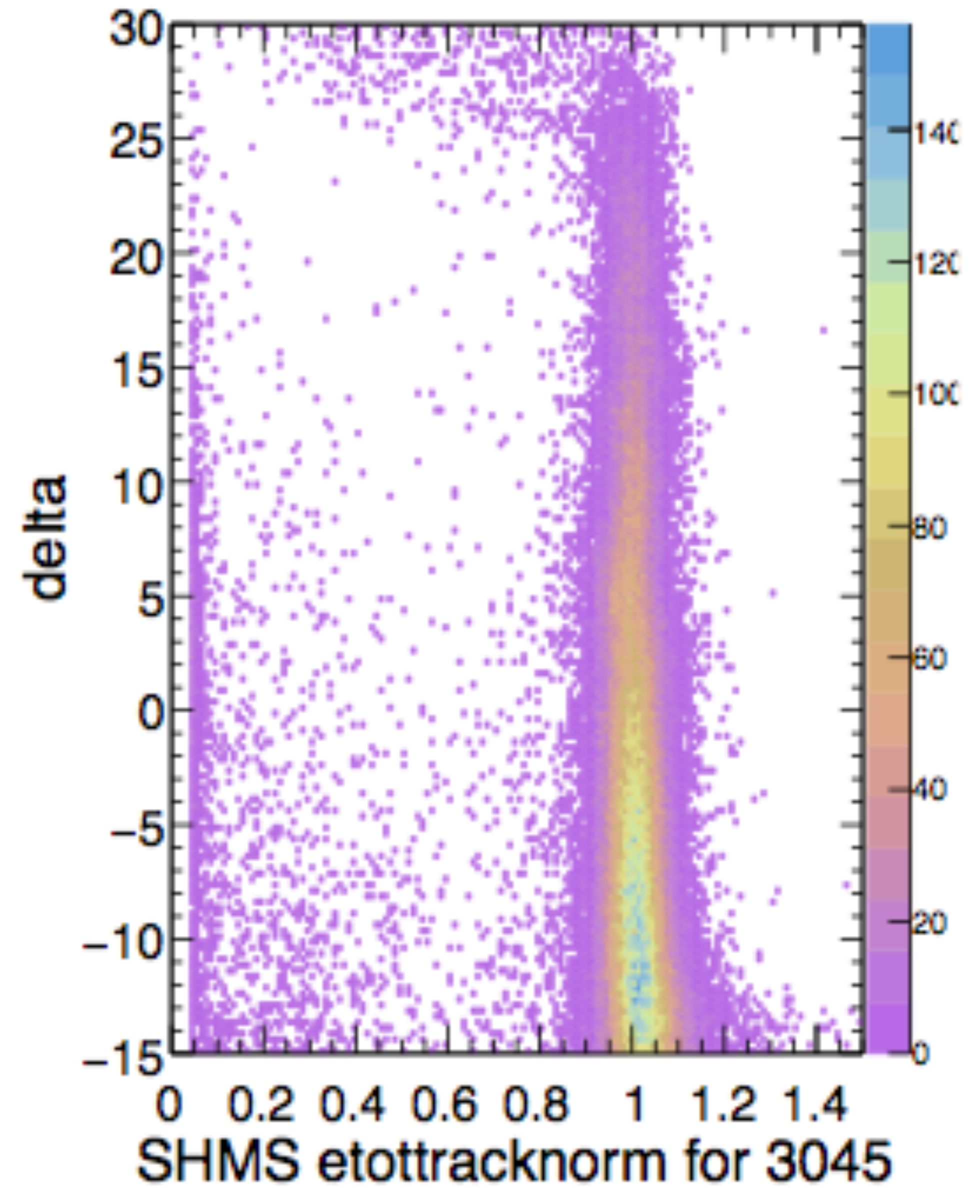


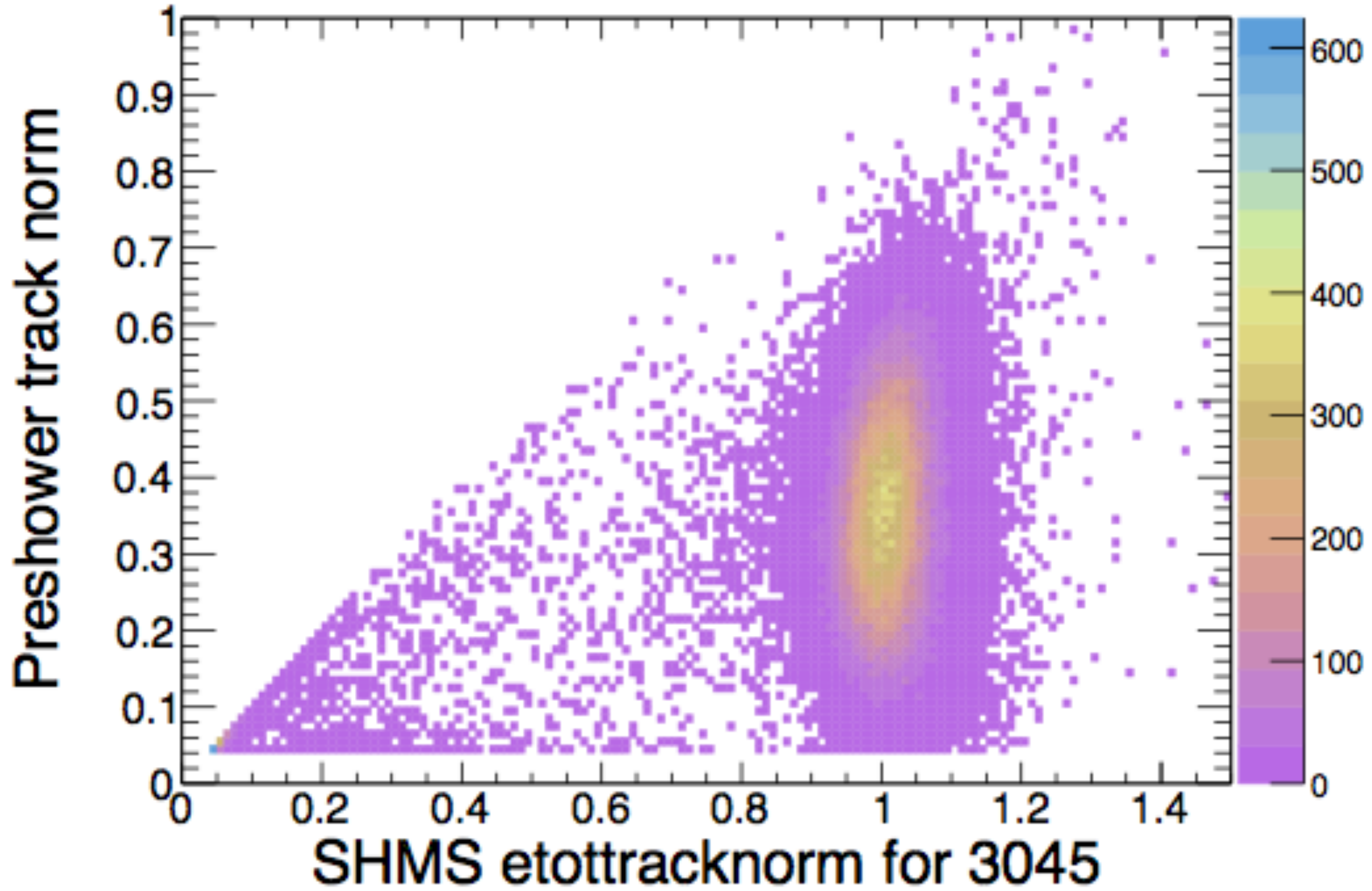
npeSum monitor plot

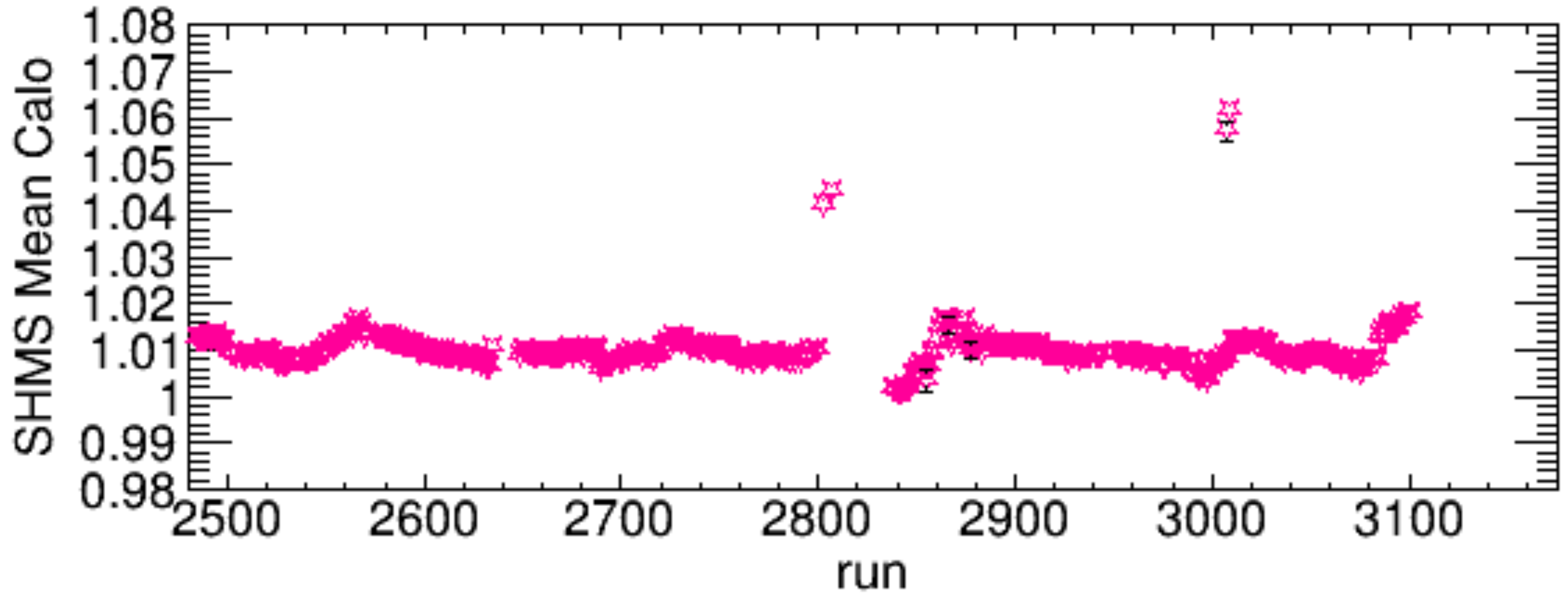


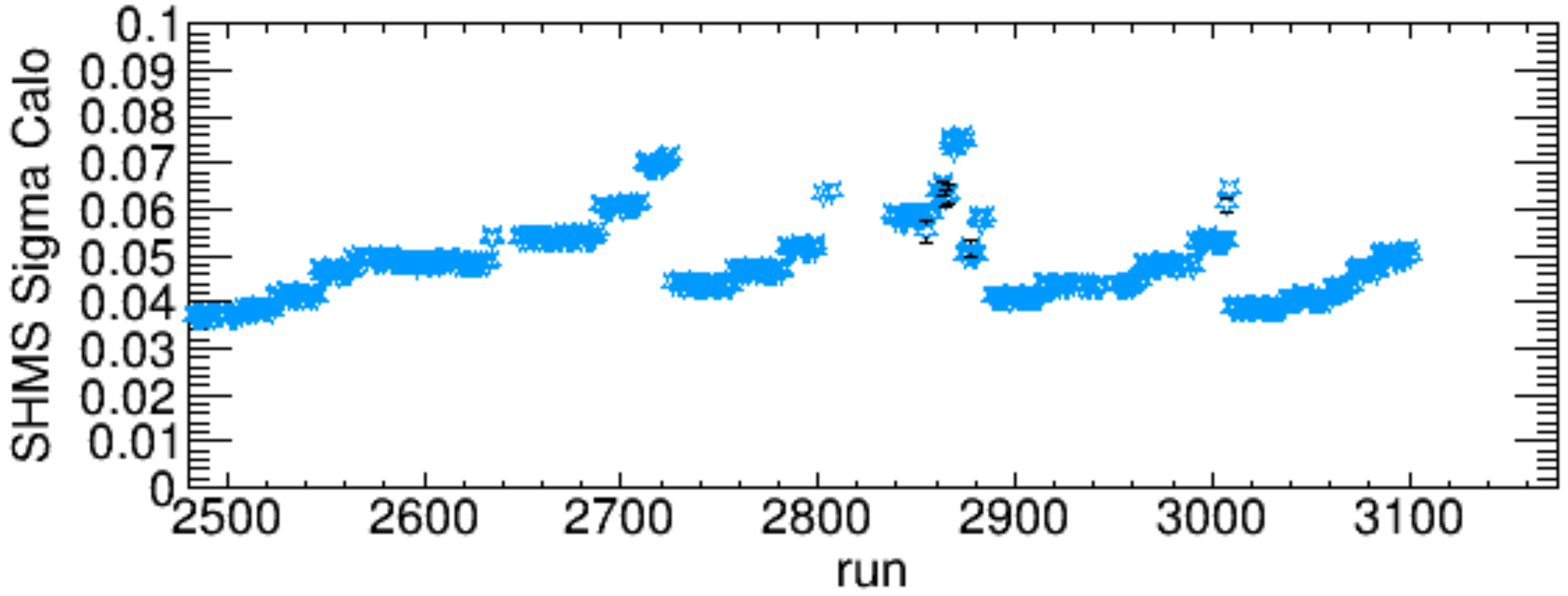
Calorimeter calibration







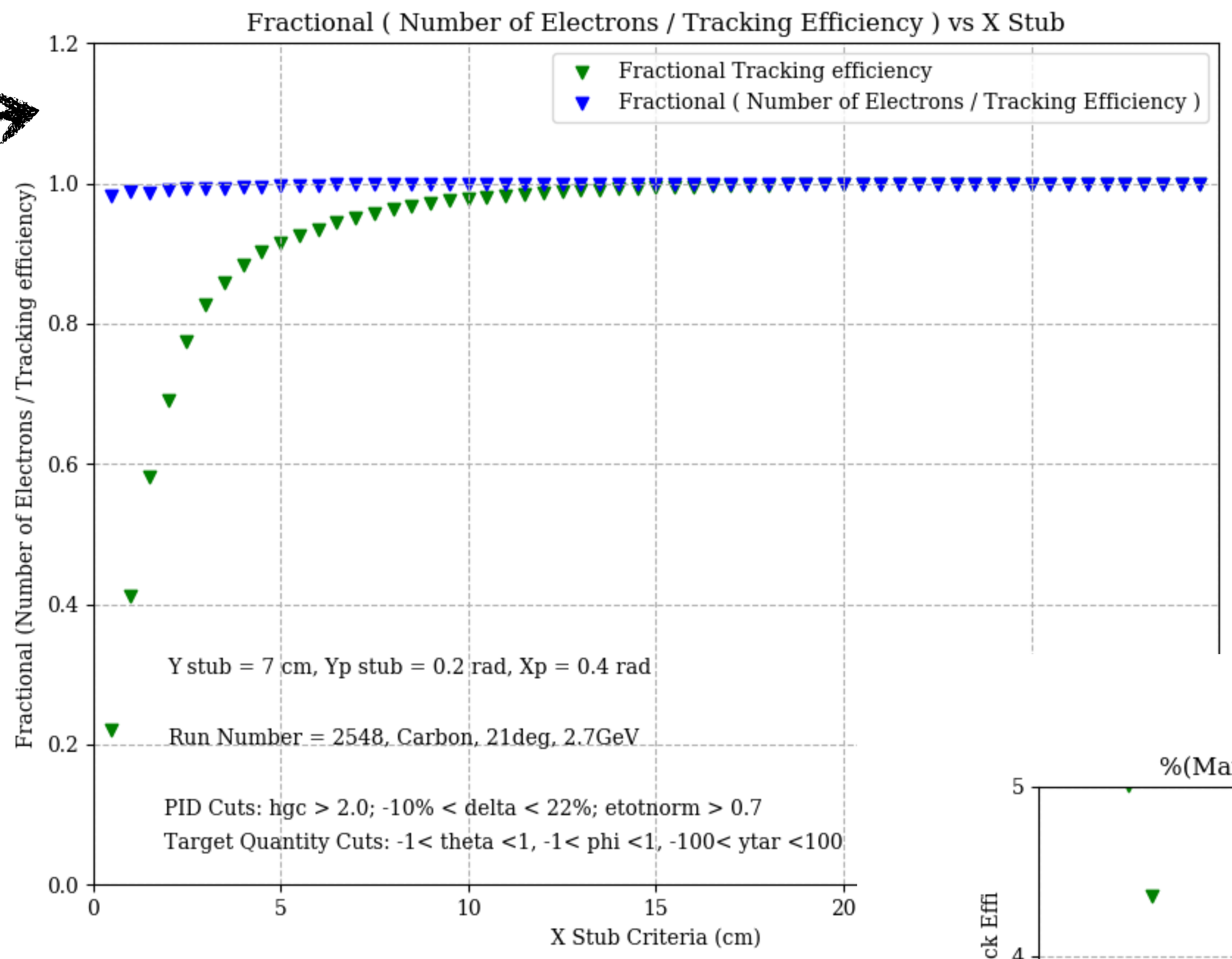




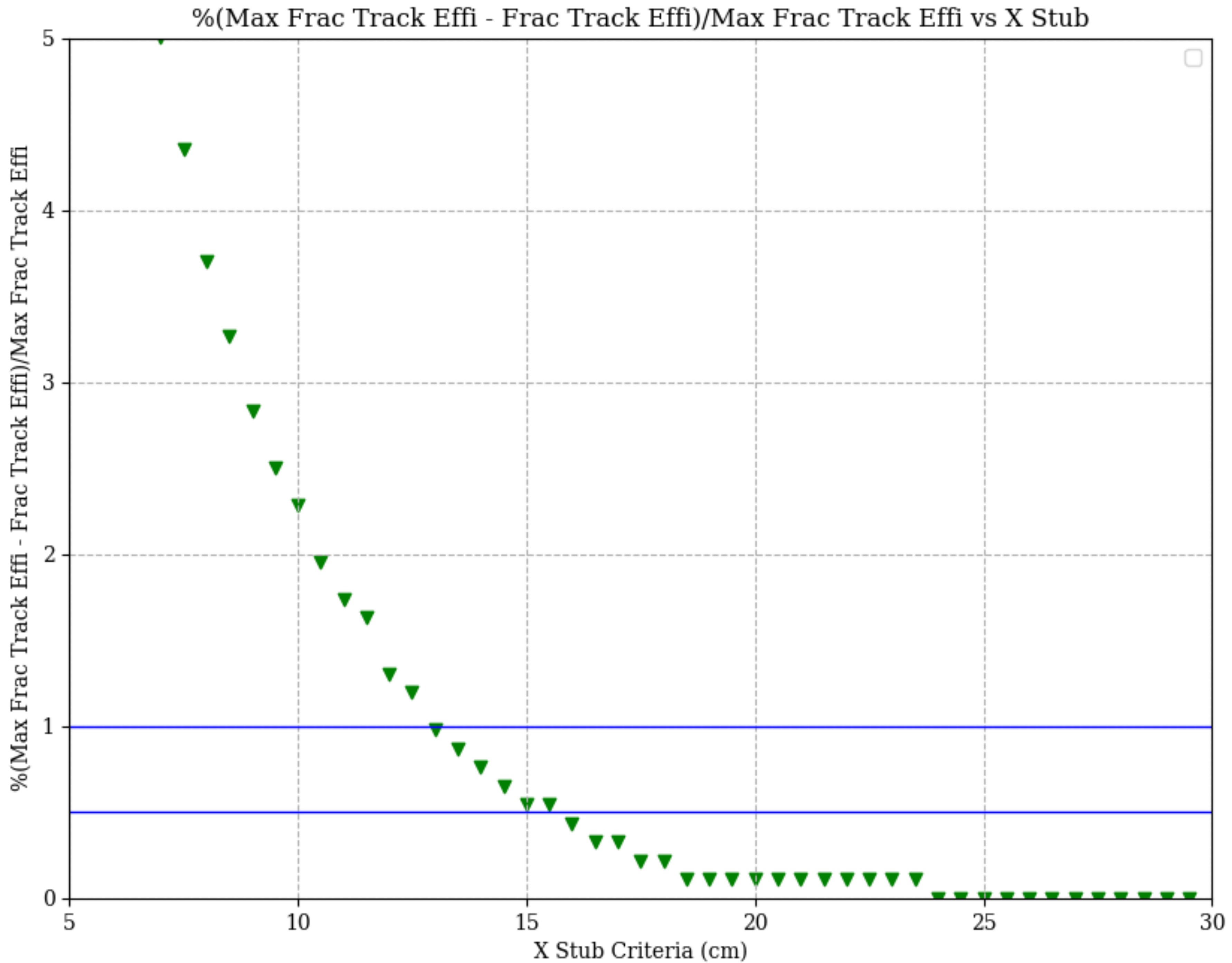
Tracking Efficiency Study

Important tracking parameters

X stub	25 (cm)
Xp stub	0.7 (rad)
Y stub	7 (cm)
Yp stub	0.2 (rad)
pmax_pr_hits	25,25
pmin_combos	4,4
Space point criterion	1.2, 1.2 (cm)
pmin_hit	5,5

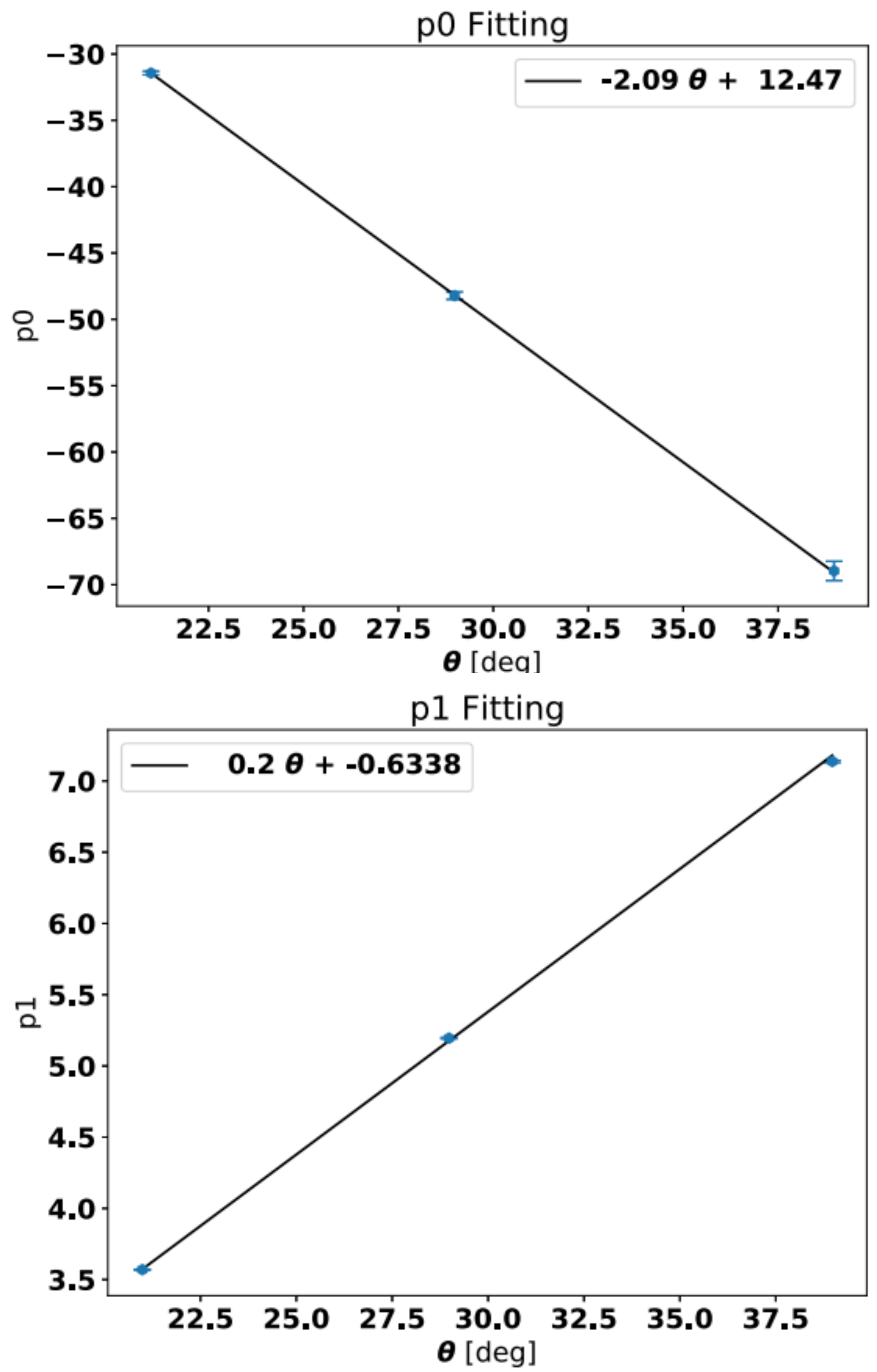


from Deb



Charge Symmetric Background

The positron cross-section is parametrized as $\frac{d\sigma}{d\Omega dE'} = e^{p_0}(e^{p_1(E-E')} + 1)$



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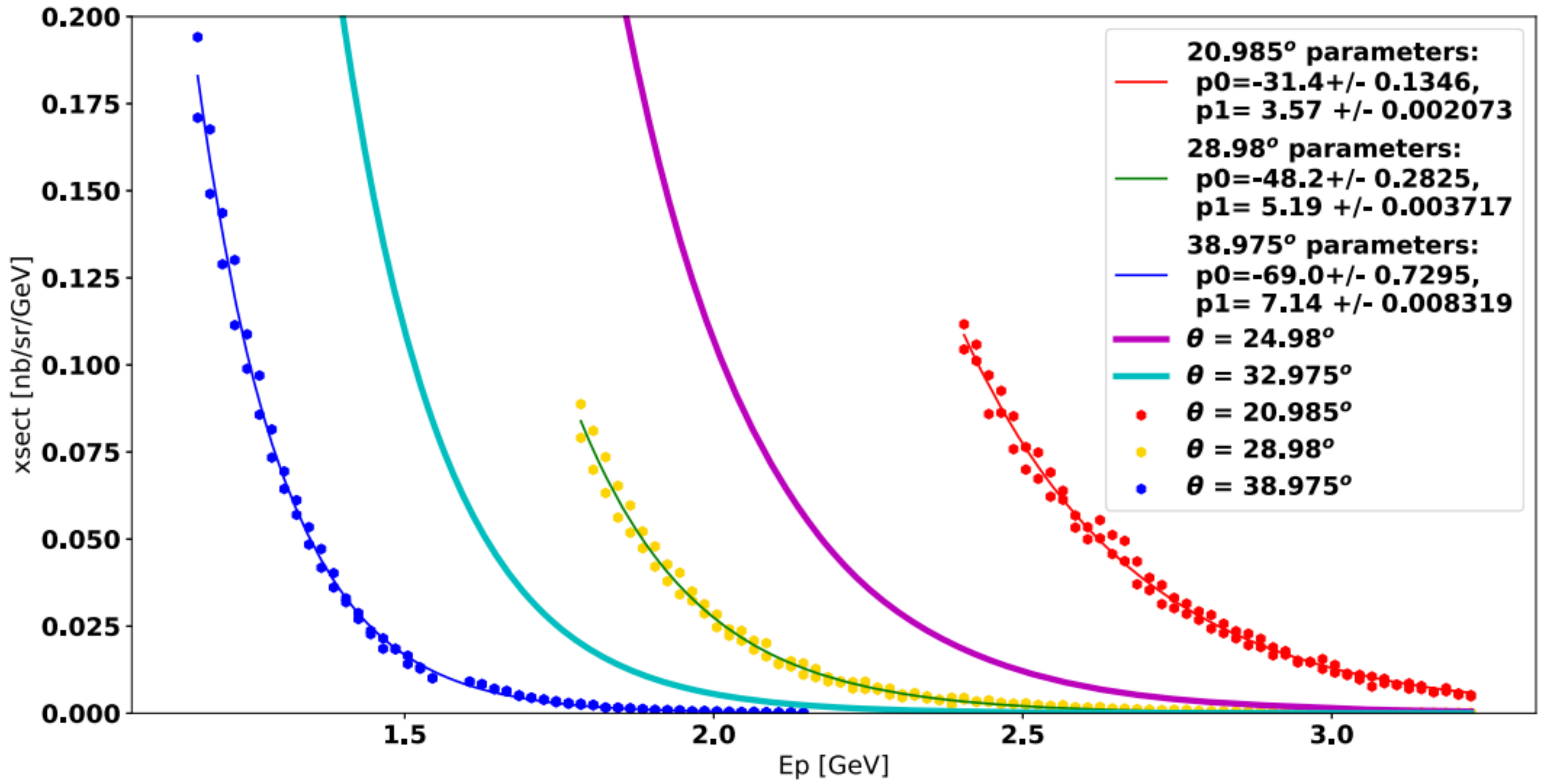


from Gabriel and Ioana Niculescu

Preliminary Results

Cross Section Extraction

solid angle luminosity

$$Y_{DATA}(E',\theta) = (\frac{d^2\sigma}{d\Omega dE'})_{DATA}[(\Delta\Omega\Delta E') * A_{DATA}(E',\theta) * L]$$

acceptance

$$Y_{MC}(E',\theta) = (\frac{d^2\sigma}{d\Omega dE'})_{model}[(\Delta\Omega\Delta E') * A_{MC}(E',\theta) * L]$$

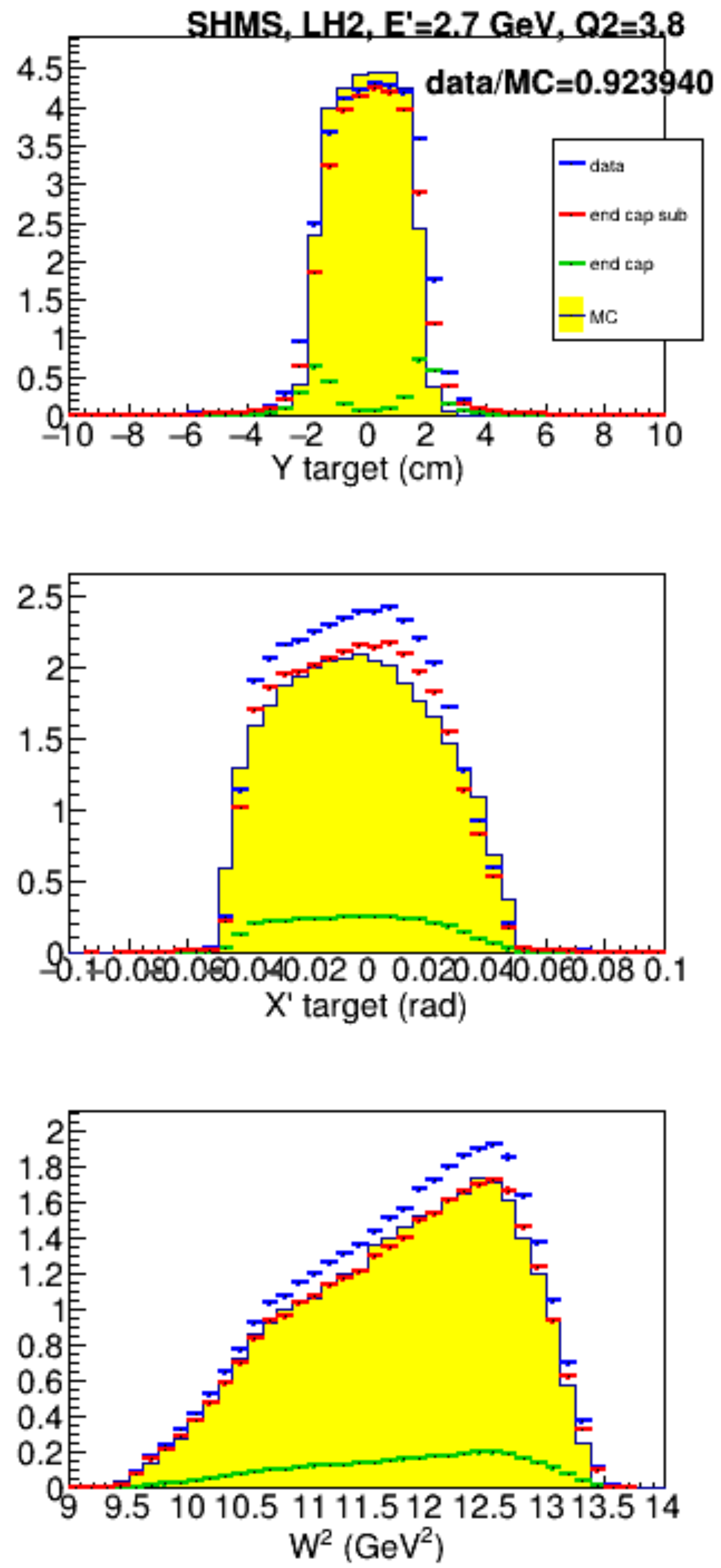
$$\frac{d^2\sigma}{d\Omega dE'} = Y_{DATA}(E',\theta)/[(\Delta\Omega\Delta E') * A_{DATA}(E',\theta) * L]$$

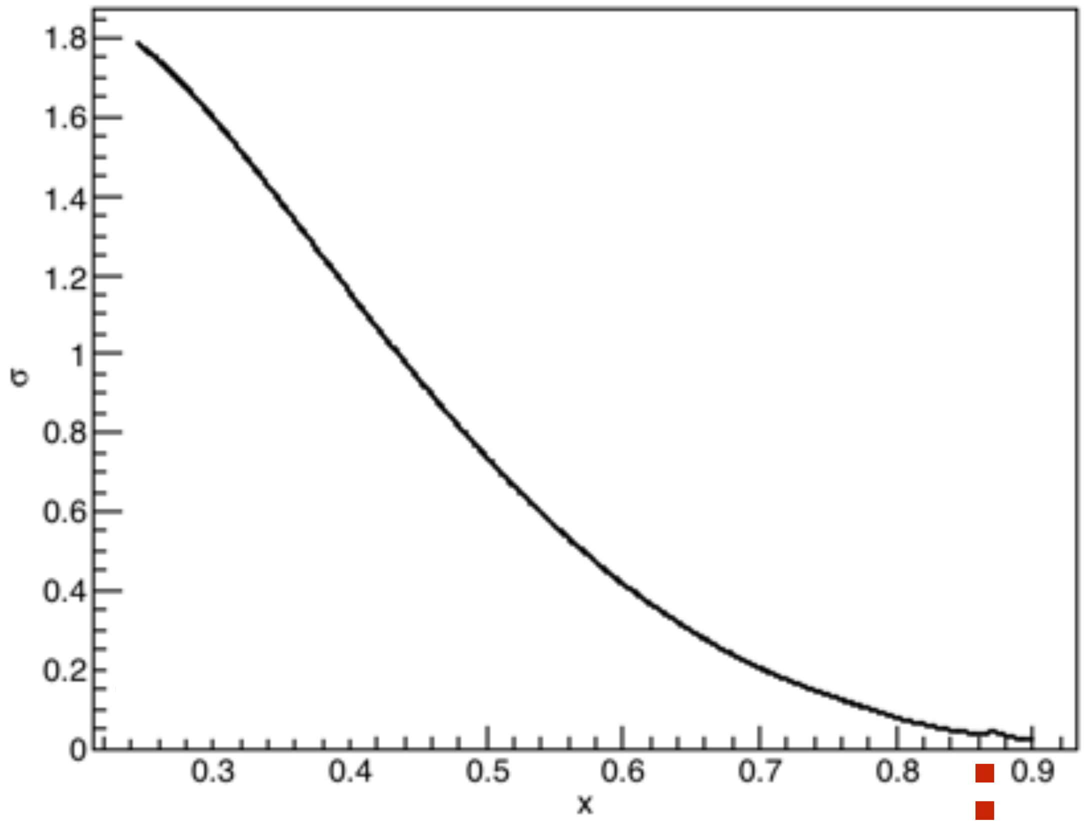
Acceptance correction method

$$\frac{d^2\sigma}{d\Omega dE'} = \sigma_{model} * [Y_{DATA}(E',\theta)/Y_{MC}(E',\theta)]$$

Monte Carlo ratio method

Cross Section Extraction - Monte Carlo Ratio Method



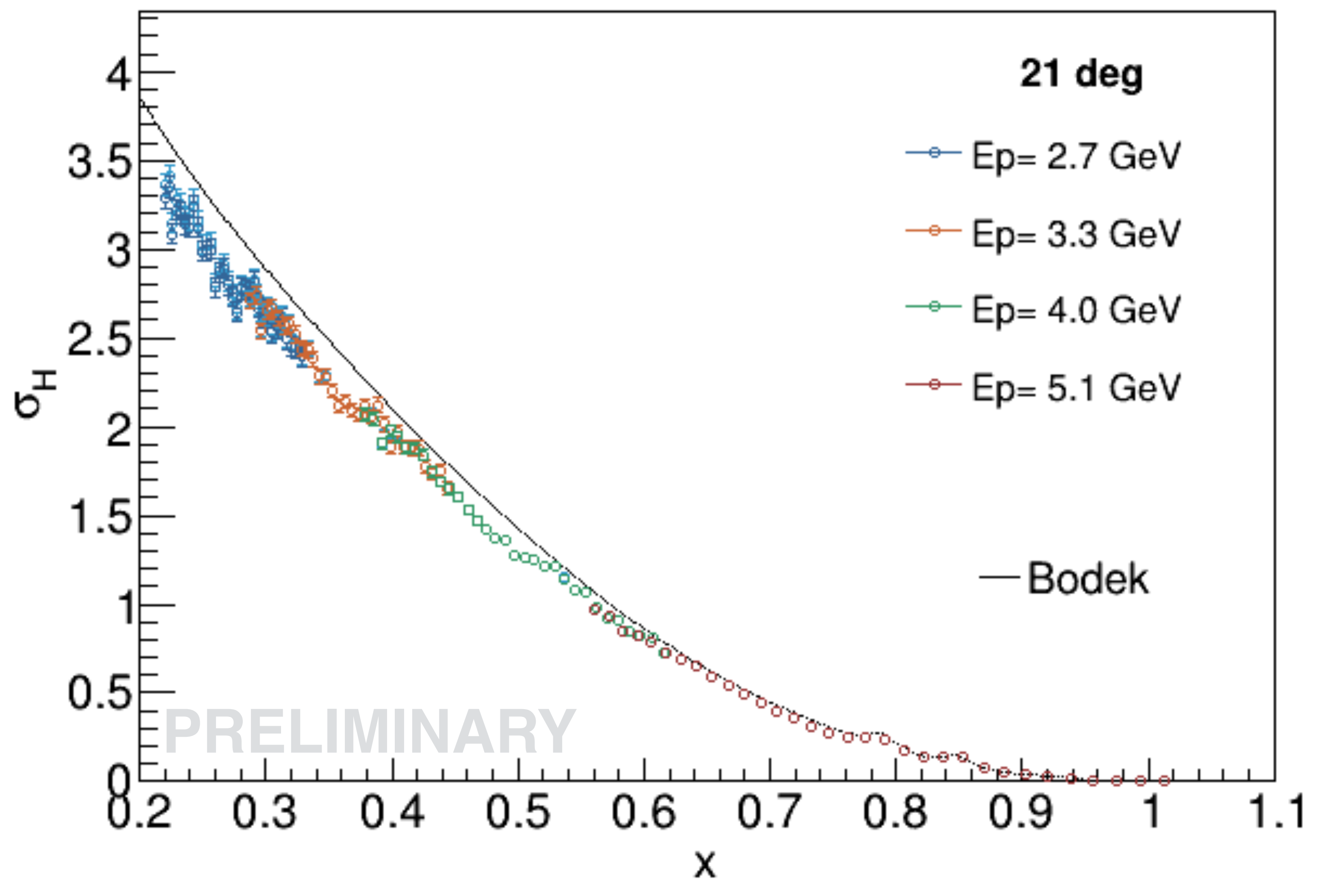


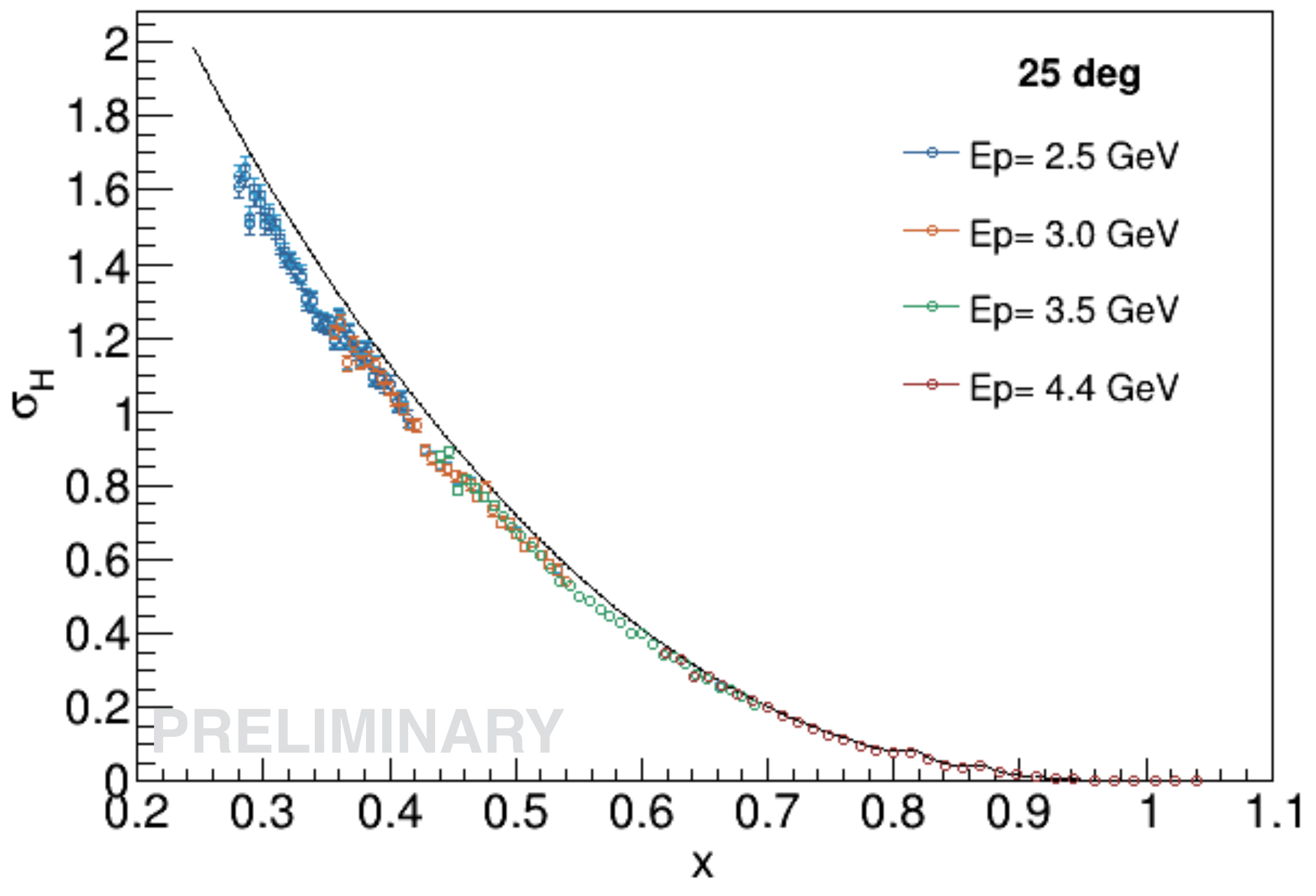
$$\sigma_{data} = \frac{Yield_{data}}{Yield_{MC}} * \sigma_{MC}$$

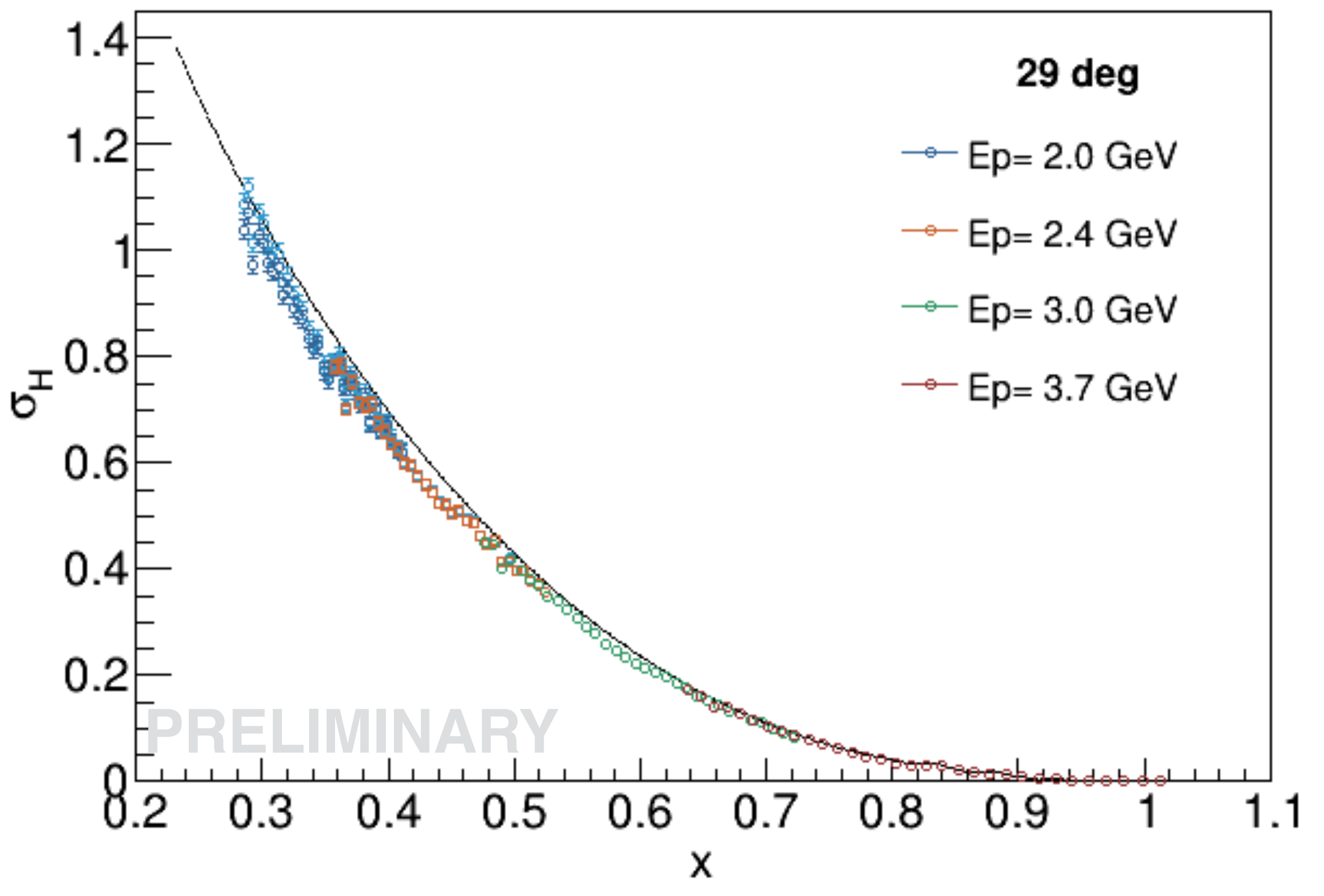
red: data

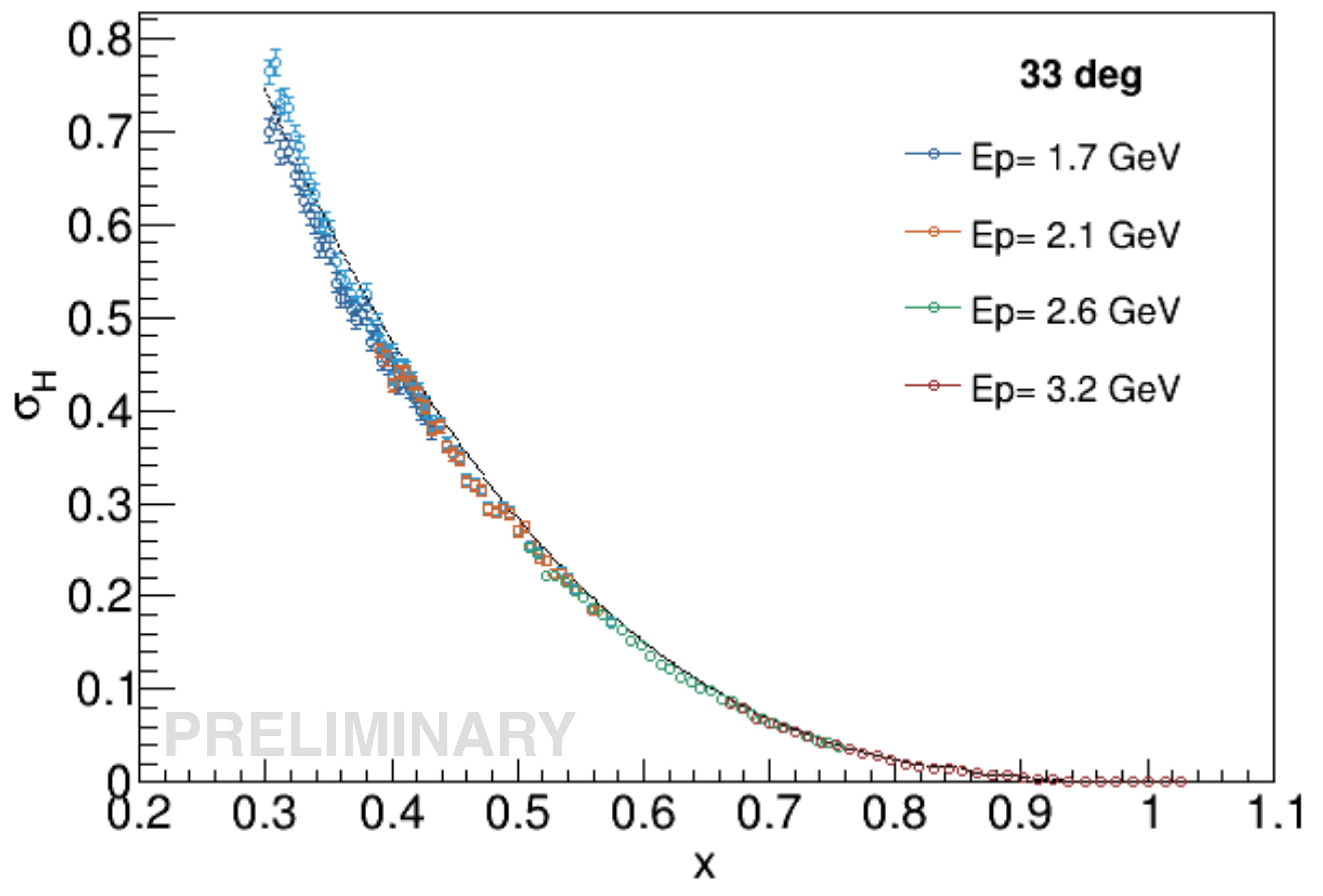
Yellow: MC

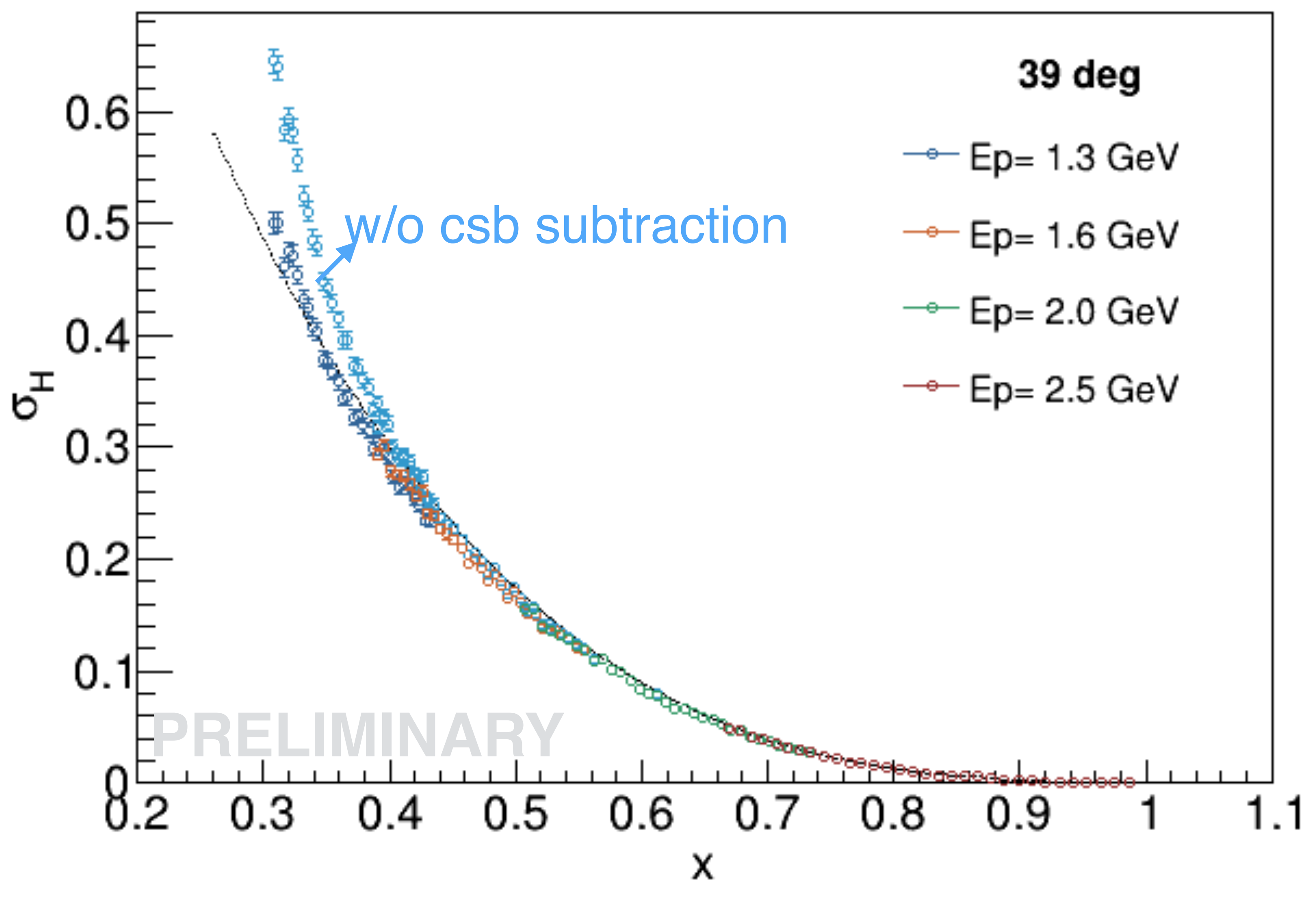
Preliminary H(e,e') Cross Sections - Monte Carlo Ratio Method





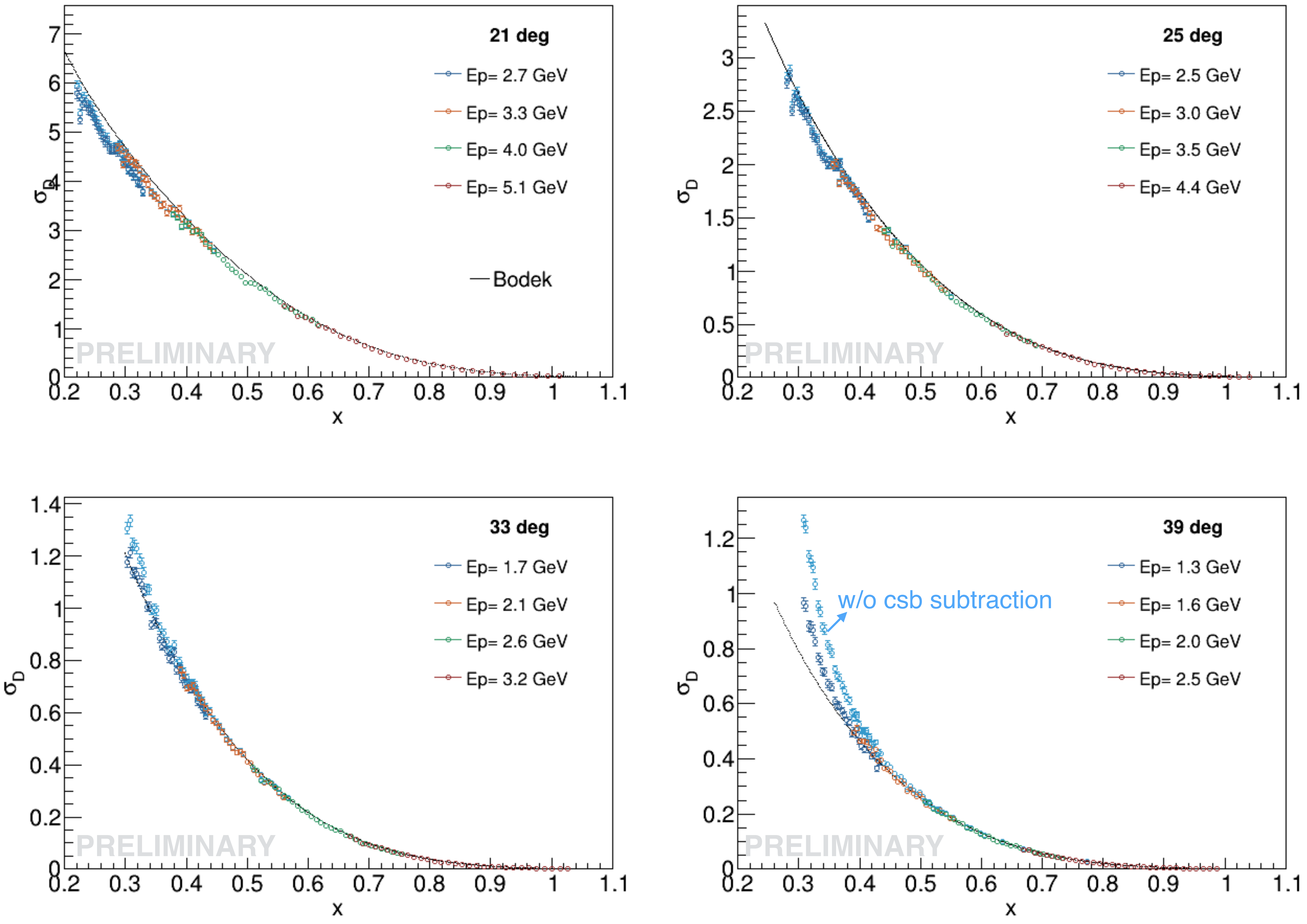






- Overlap between momentum settings looks pretty good.
  ->We understand acceptance fairly well.
- Bodek model is used (solid curve)
  (Only statistical errors shown)

Preliminary D(e,e') Cross Sections - Monte Carlo Ratio Method



- Overlap between momentum settings looks pretty good.
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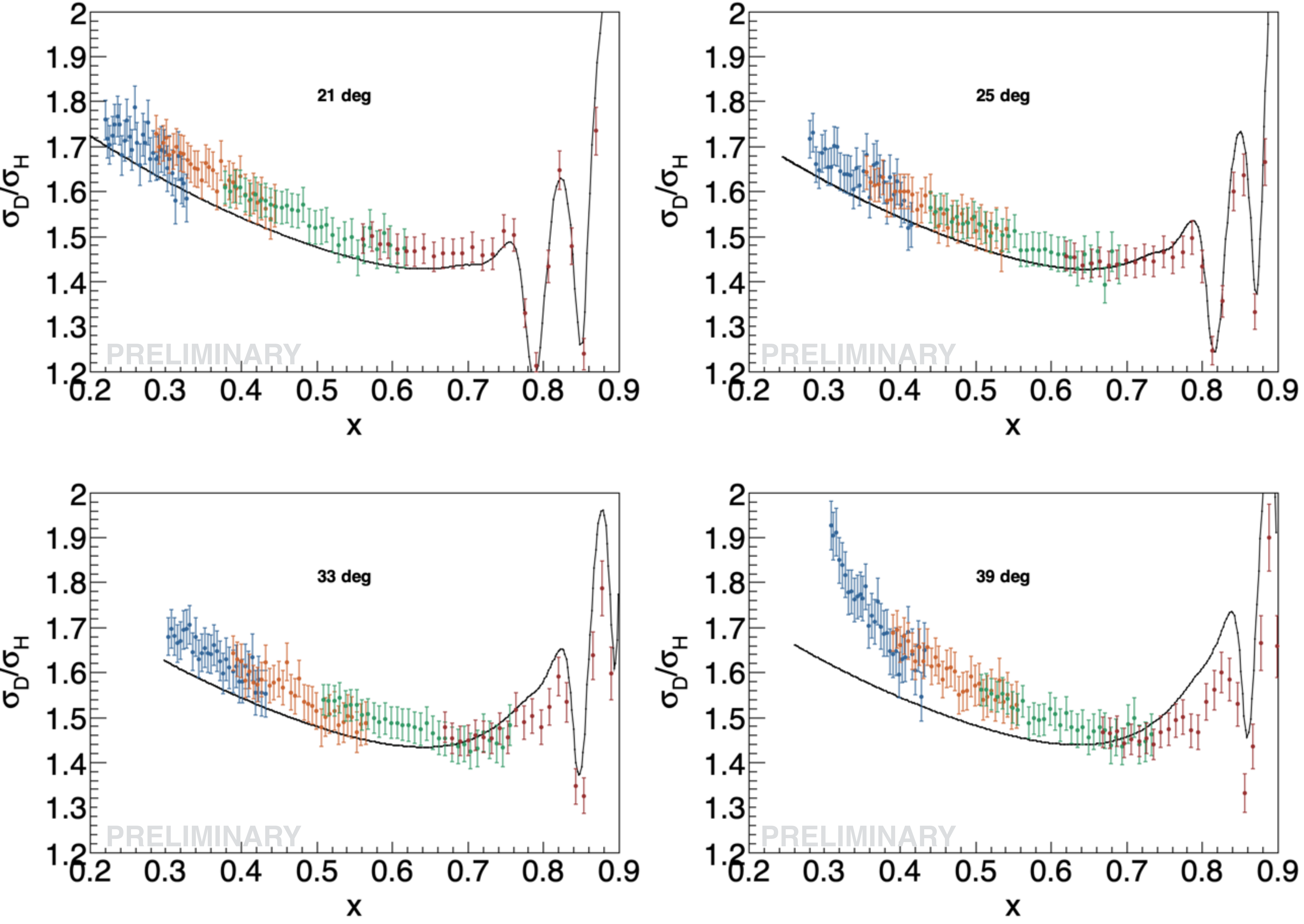
- Bodek model is used (solid curve)
  (Only statistical errors shown)

Preliminary σ_D/σ_H Ratios

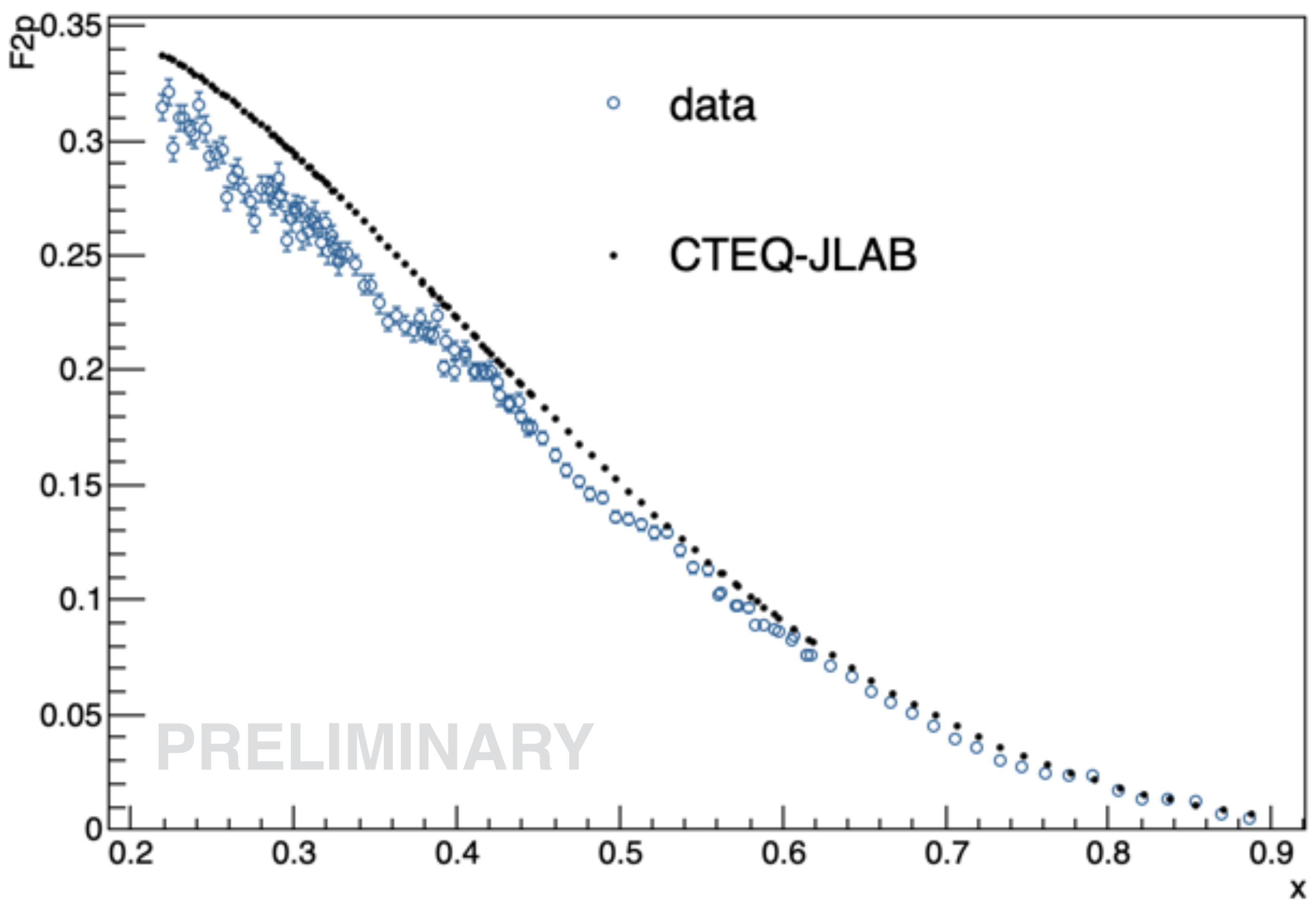


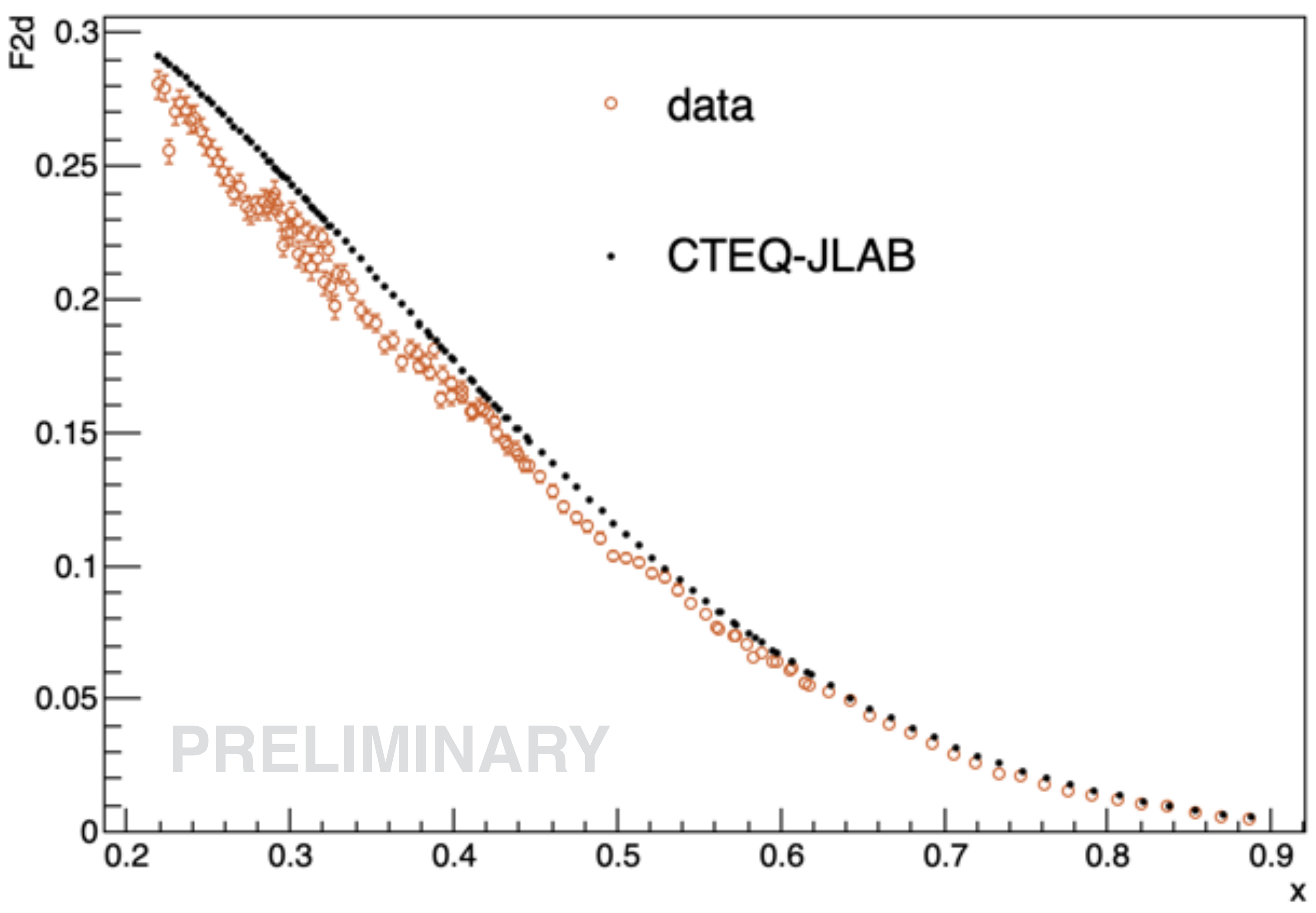
- Data from MC ratio method
- Only statistical uncertainties are shown

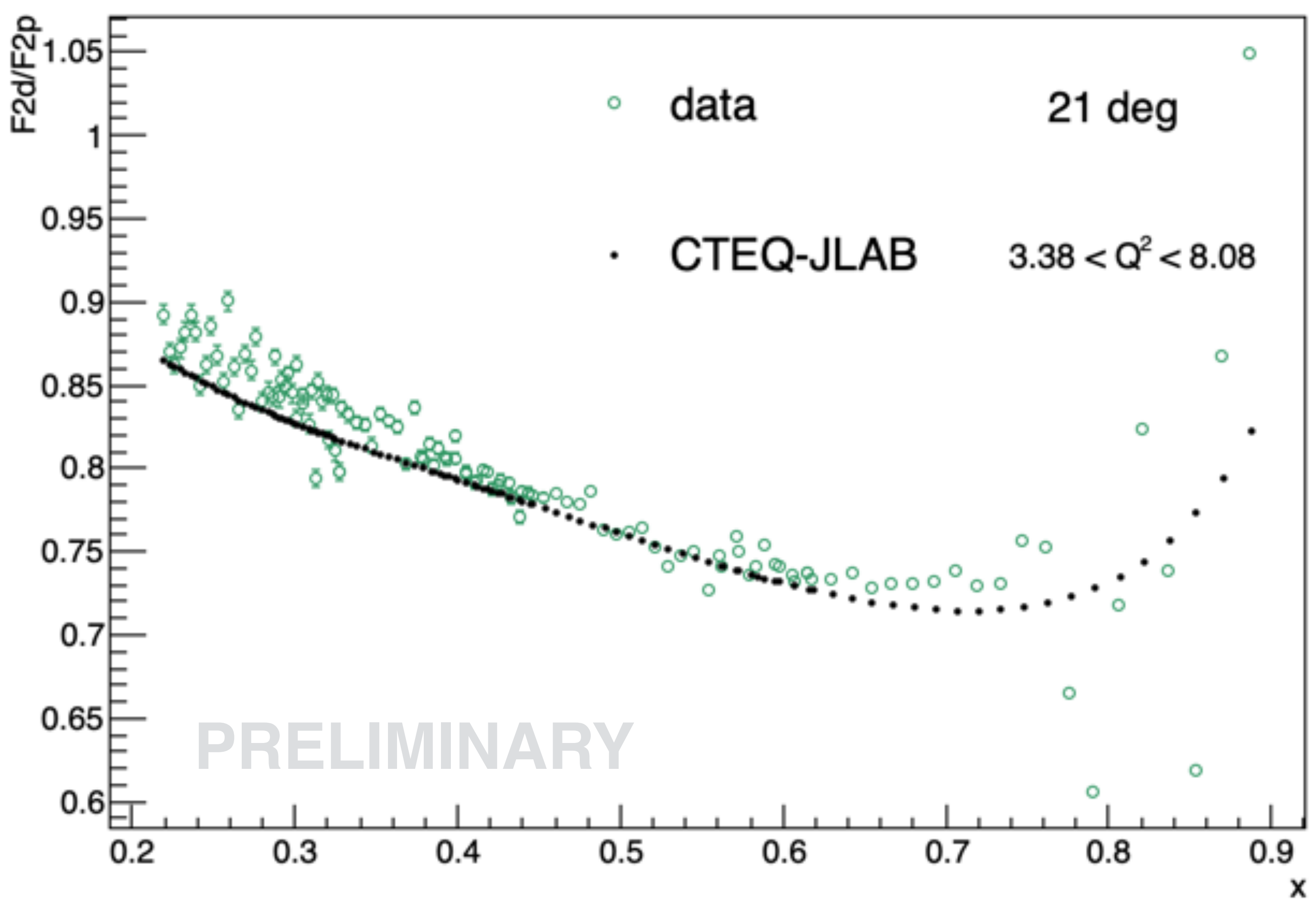
Preliminary F_2

$$\frac{d^2\sigma}{d\Omega dE'} = \sigma_{Mott}(\frac{2}{M}F_1(x,Q^2)tan^2\frac{\theta}{2}+\frac{1}{\nu}F_2(x,Q^2)) \qquad \frac{d^2\sigma}{d\Omega dE'} = \Gamma(\sigma_T(x,Q^2)+\epsilon\sigma_L(x,Q^2))$$

$$F_2 = \frac{\sigma}{\sigma_{Mott}}\nu\epsilon\frac{1+R}{1+\epsilon R} \quad , \ where \ R \equiv \frac{\sigma_L}{\sigma_T}, \ \epsilon = [1+2(1+\frac{\nu^2}{Q^2})tan^2\frac{\theta}{2}]^{-1}$$







Summary

- Preliminary H(e,e’) and D(e,e’) cross sections and D/H ratios look promising.
- We are looking forward to a varied physics output:
  PDF extraction, quark-hadron duality studies, resonance and DIS modeling…

Thanks for listening!