F_2^p and F_2^d extractions at large Bjorken X from $h(e,e')$ & $d(e,e')$ cross sections measured during E12-10-002 in Hall C at Jefferson Lab

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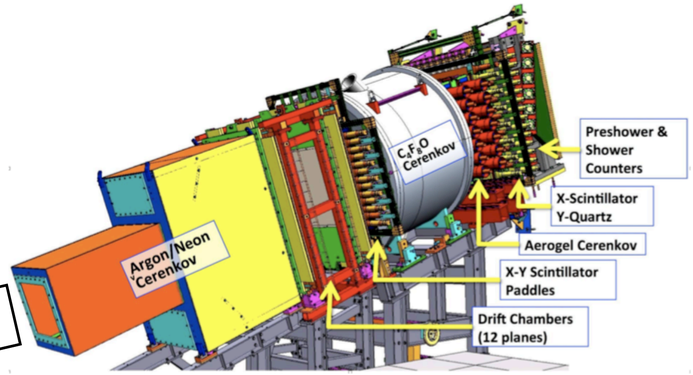
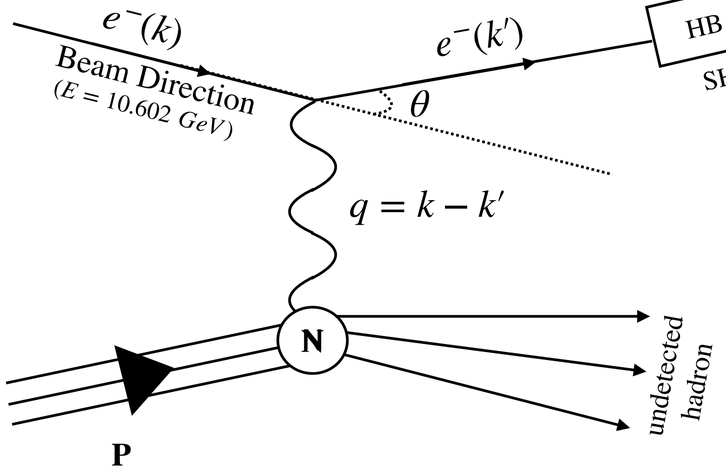
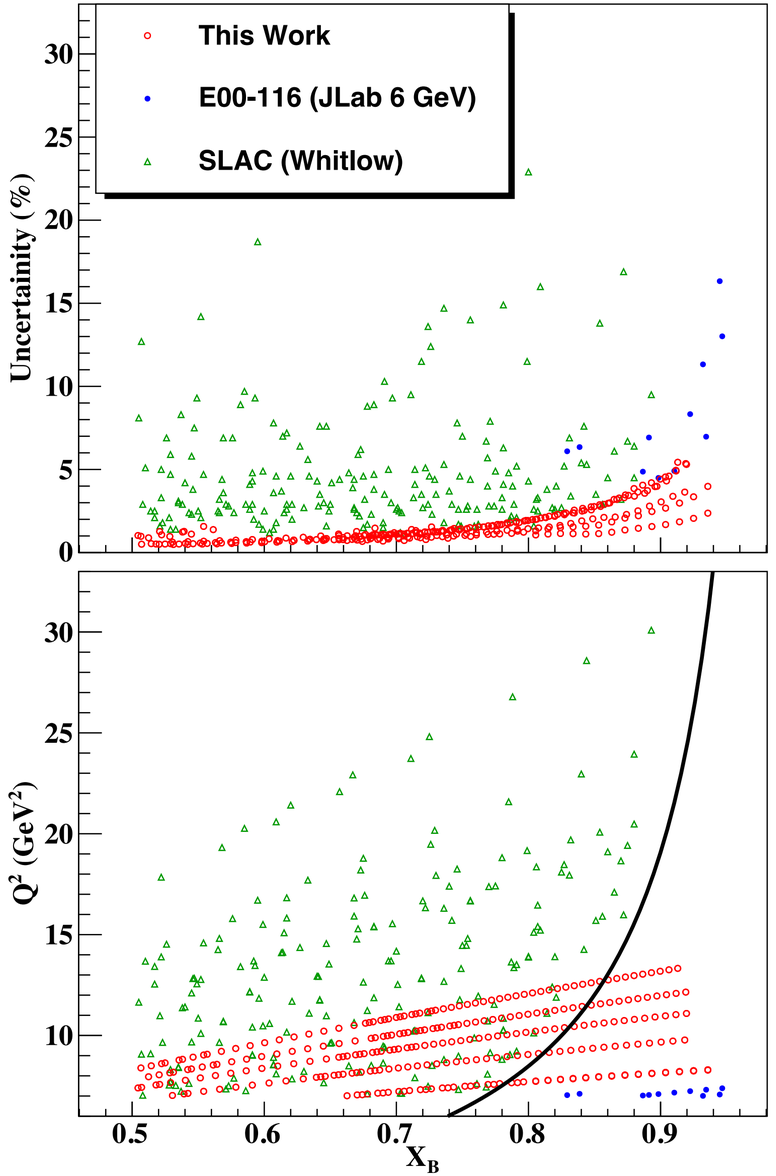
Unique features of the E12-10-002 data

- Ran in the spring of 2018 in parallel with EMC experiment
- Targets used : liquid hydrogen and liquid deuterium
- Large Bjorken x coverage
- Large Q^2 coverage using both the HMS and SHMS spectrometers



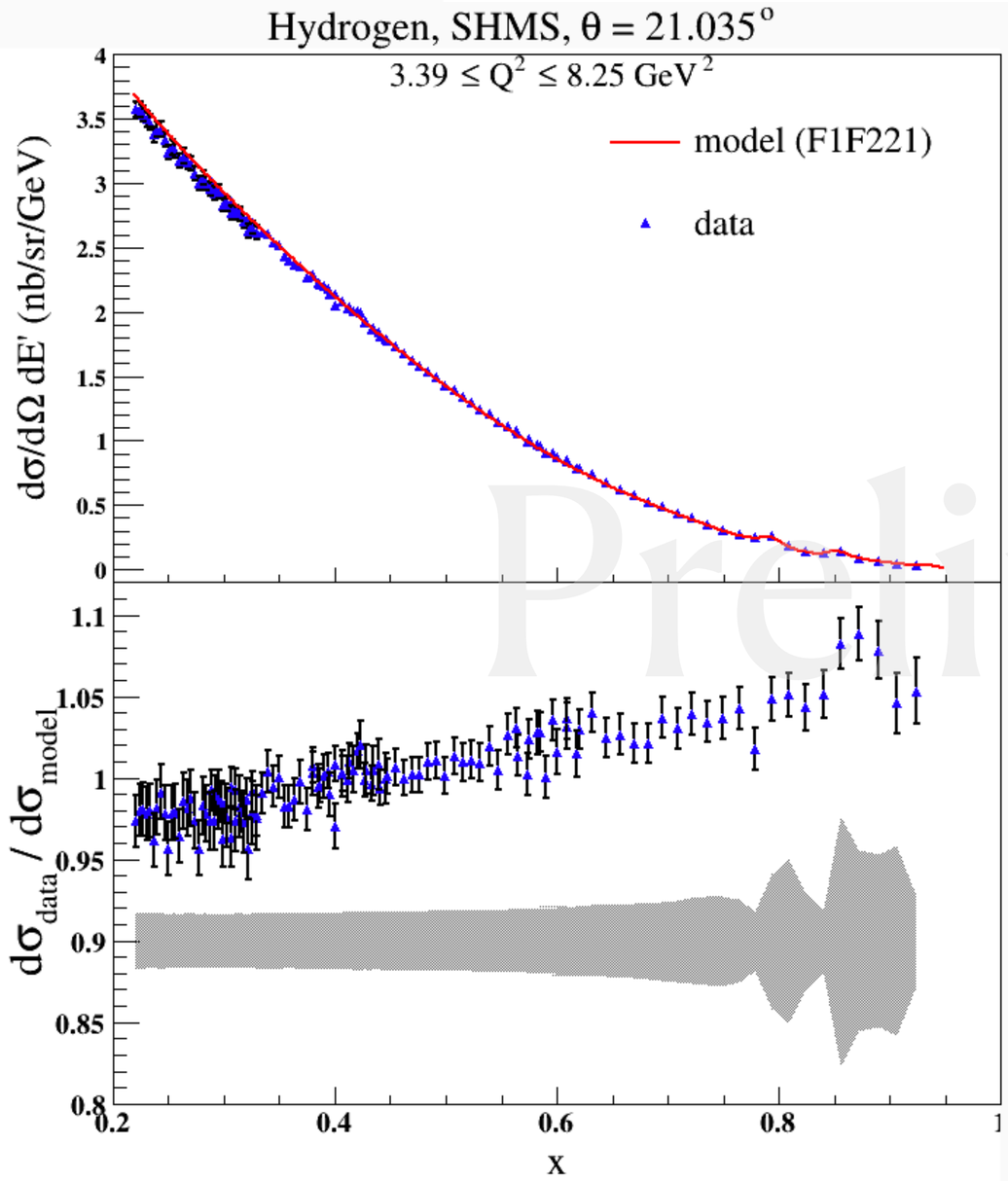
Basic Feynman diagram for deep inelastic electron-proton scattering





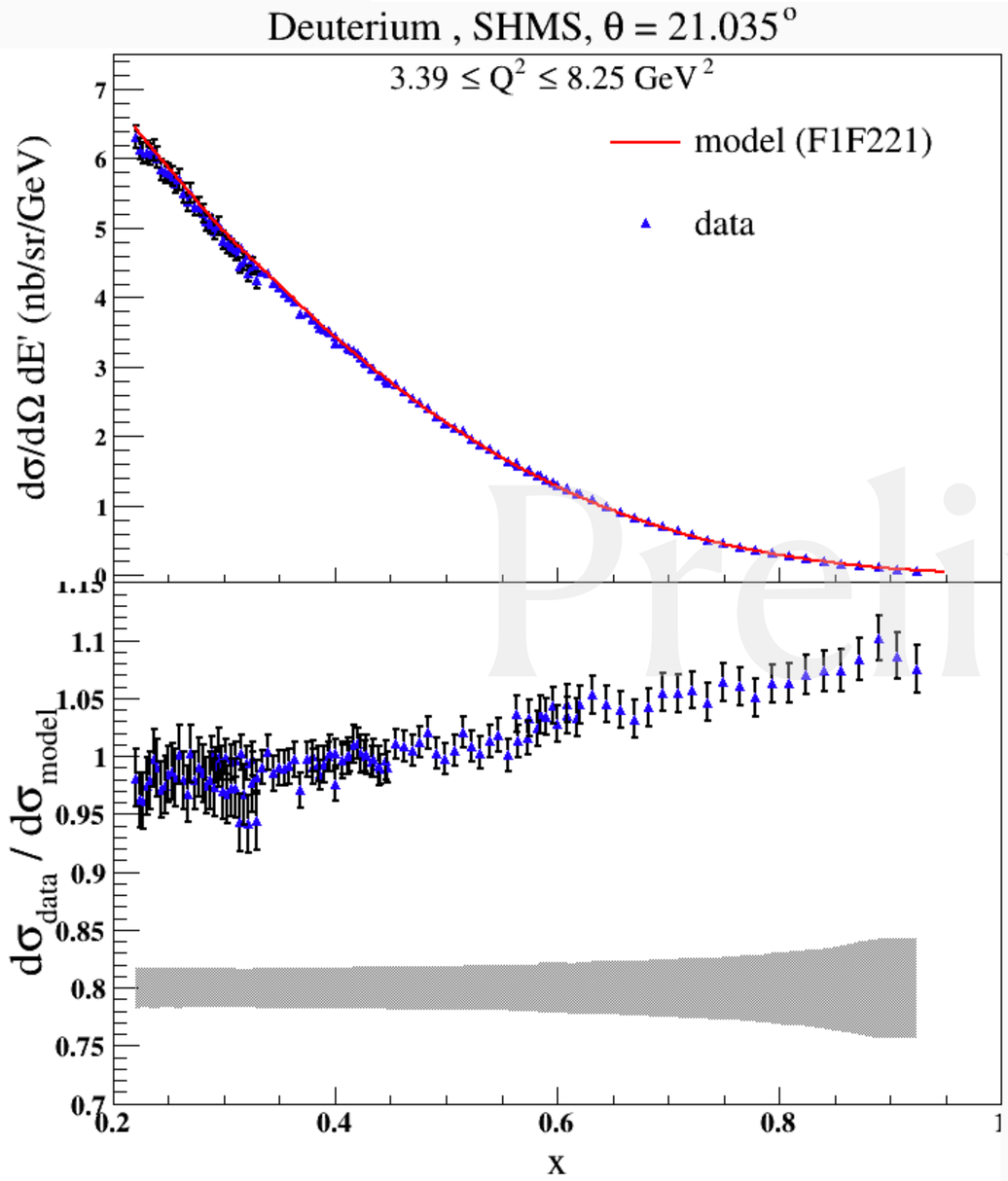
$$Q^2 = 4EE'sin^2(\frac{\theta}{2}) \qquad X = \frac{Q^2}{2M\nu} \qquad W^2 = M^2 + 2M\nu - Q^2$$

Extraction of proton cross-section



- Proton cross-section is extracted for SHMS at 21.035^o
- Proton cross-section is extracted also for four other SHMS angles 24.98^o, 28.99^o, 32.975^o, 38.975^o
- Compared with F1F221 (red solid line)
- F1F221 model is a fit to the world data of inclusive cross-sections
- In this plot model does not include the data from this experiment (E12-10-002)
- The model is valid for wide range for $W^2 < 30\ GeV^2$ and $Q^2 < 30\ GeV^2$
- For $x = 0.2$ to 0.7, the data matches with the model within better than 3%
- At large x the model is not well constrained, which is one of the biggest motivation for this experiment

Extraction of deuterium cross-section



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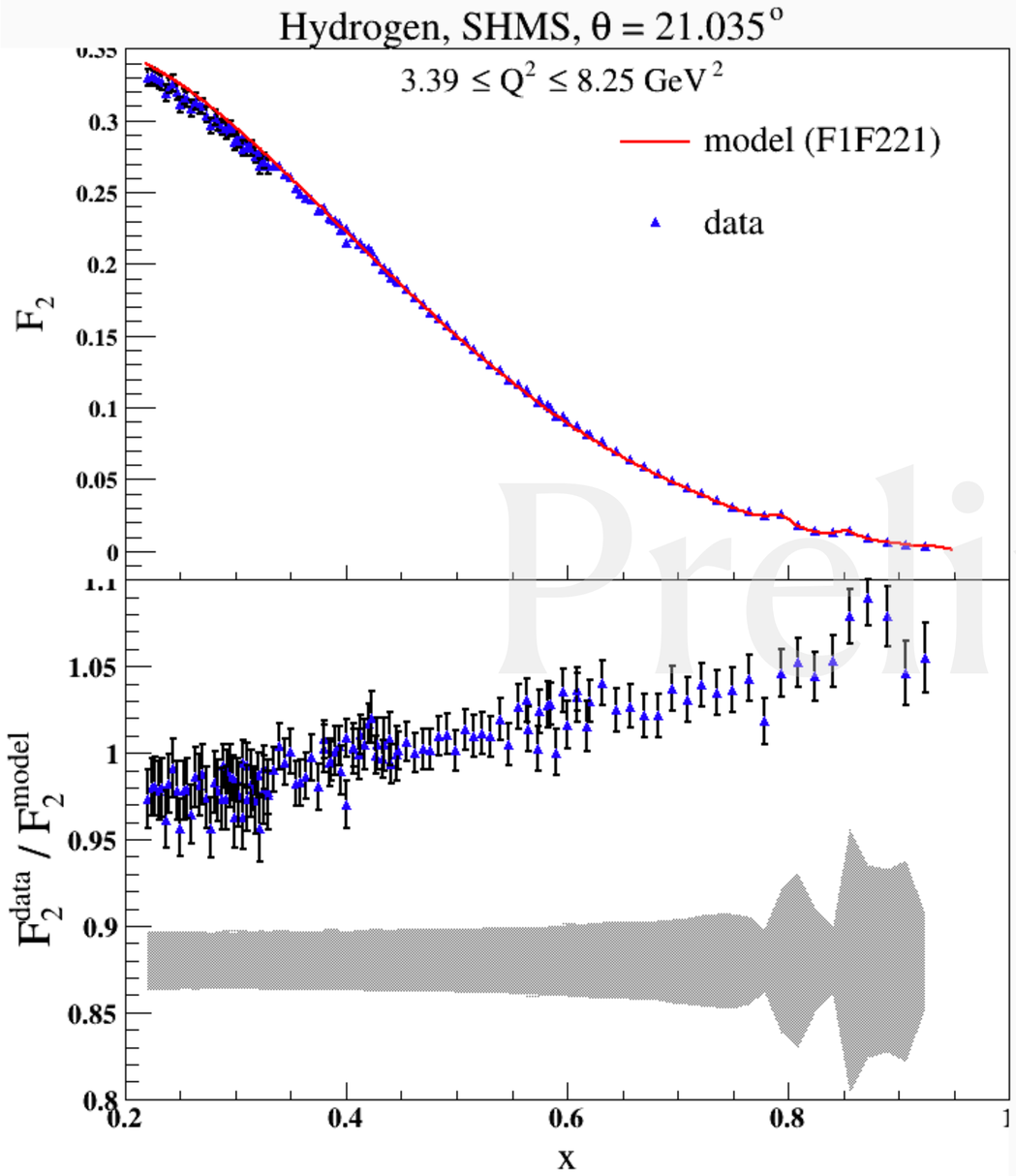
Extraction of proton F_2



$$\sigma_T = \frac{4\pi\alpha}{KM}F_1, \quad \sigma_L = \frac{4\pi^2\alpha}{KM\nu}[(1+\frac{\nu^2}{Q^2})MF_2 - \nu F_1]$$

$$\frac{d^2\sigma}{d\Omega dE'} = \Gamma[\sigma_T(x,Q^2) + \epsilon\sigma_L(x,Q^2)]$$

- Proton structure function F_2 for SHMS at 21.035^o
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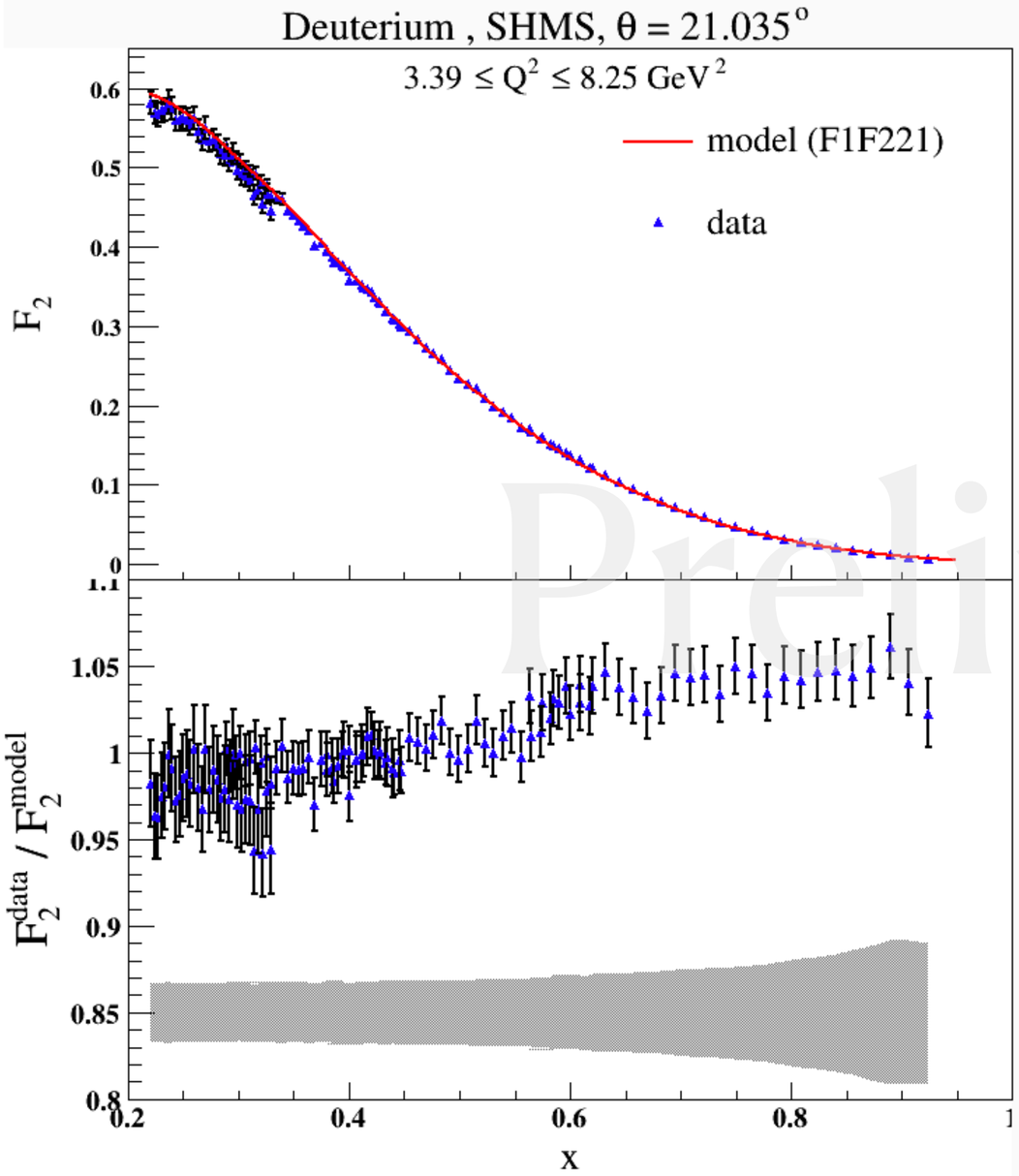

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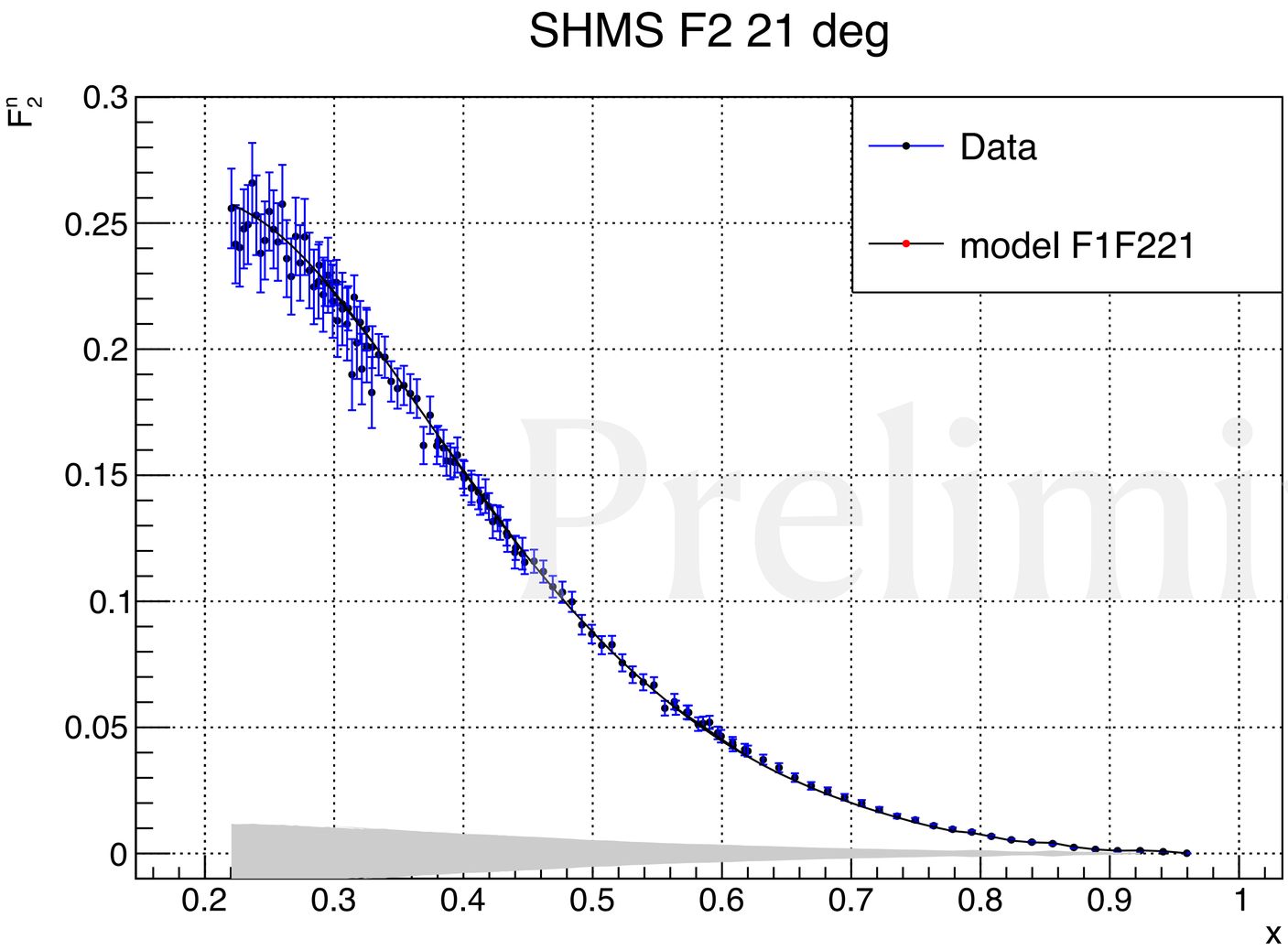
Extraction of neutron F_2 (from A. Nadeeshani)

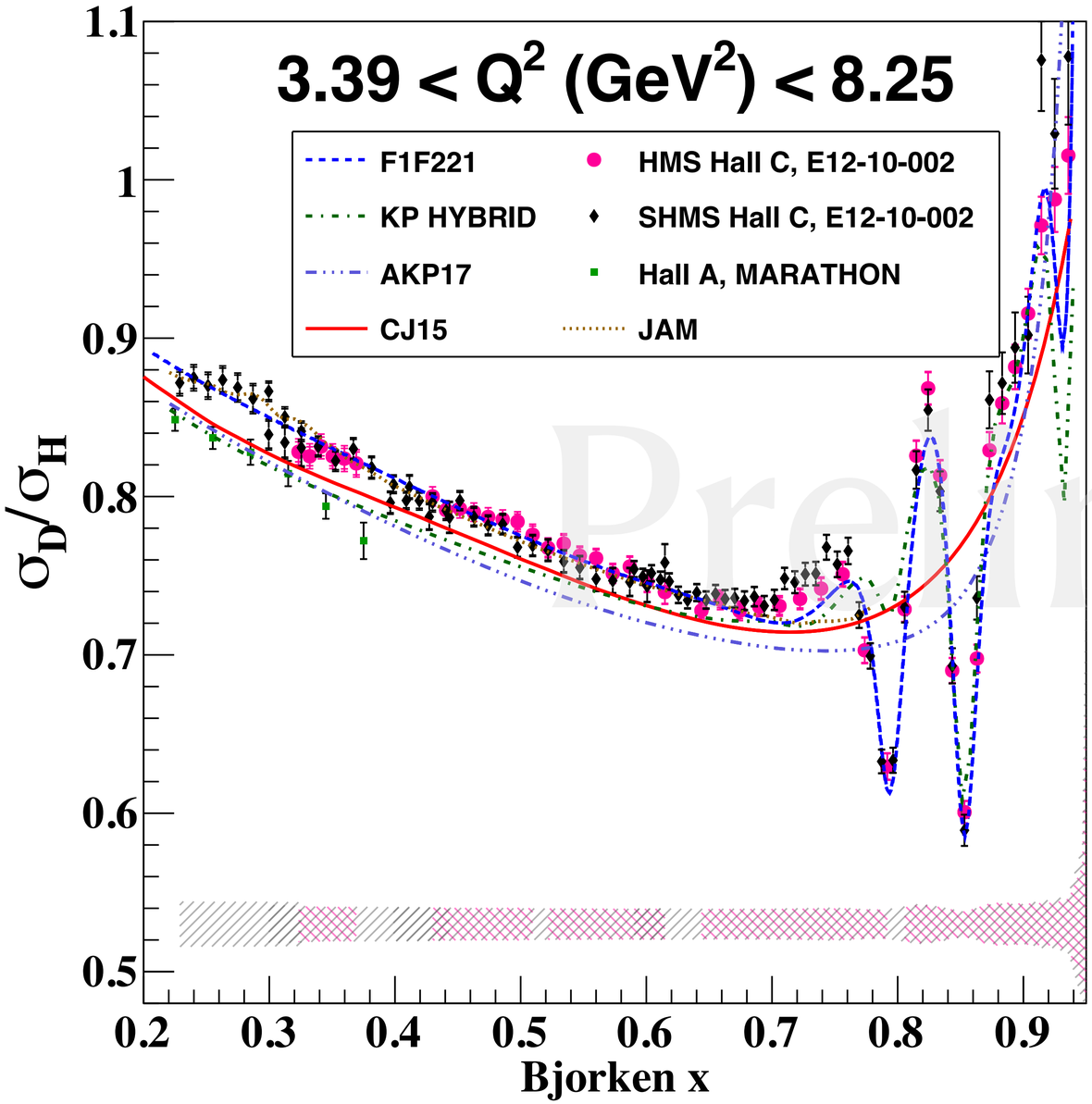


- In deuterium proton and neutron are in bound state
- Neutron cross-section can be calculated by subtracting the proton cross-section from the deuteron and nuclear effects removed
- To get the unbound p+n cross-section from the bound p+n state inside deuterium-

$$\sigma_{p+n} = \frac{\sigma_{p+n}^{model}}{\sigma_d^{model}} \times \sigma_d^{data}$$

$$\sigma_{data}^{n} = \sigma^{p+n} - \sigma_{data}^{p}$$

σ_D/σ_H ratio (from W. Henry)



- σ_D/σ_H is shown as a function of x for angle 21.035^o
- Data is compared with four of the available models-
  - CJ15
  - KP Hybrid
  - AKP17
  - JAM
- Data is also compared with F1F221 which is a fit to the world data
- All models are shown here does not include the data from this analysis
- The error bars include point to point and statistical

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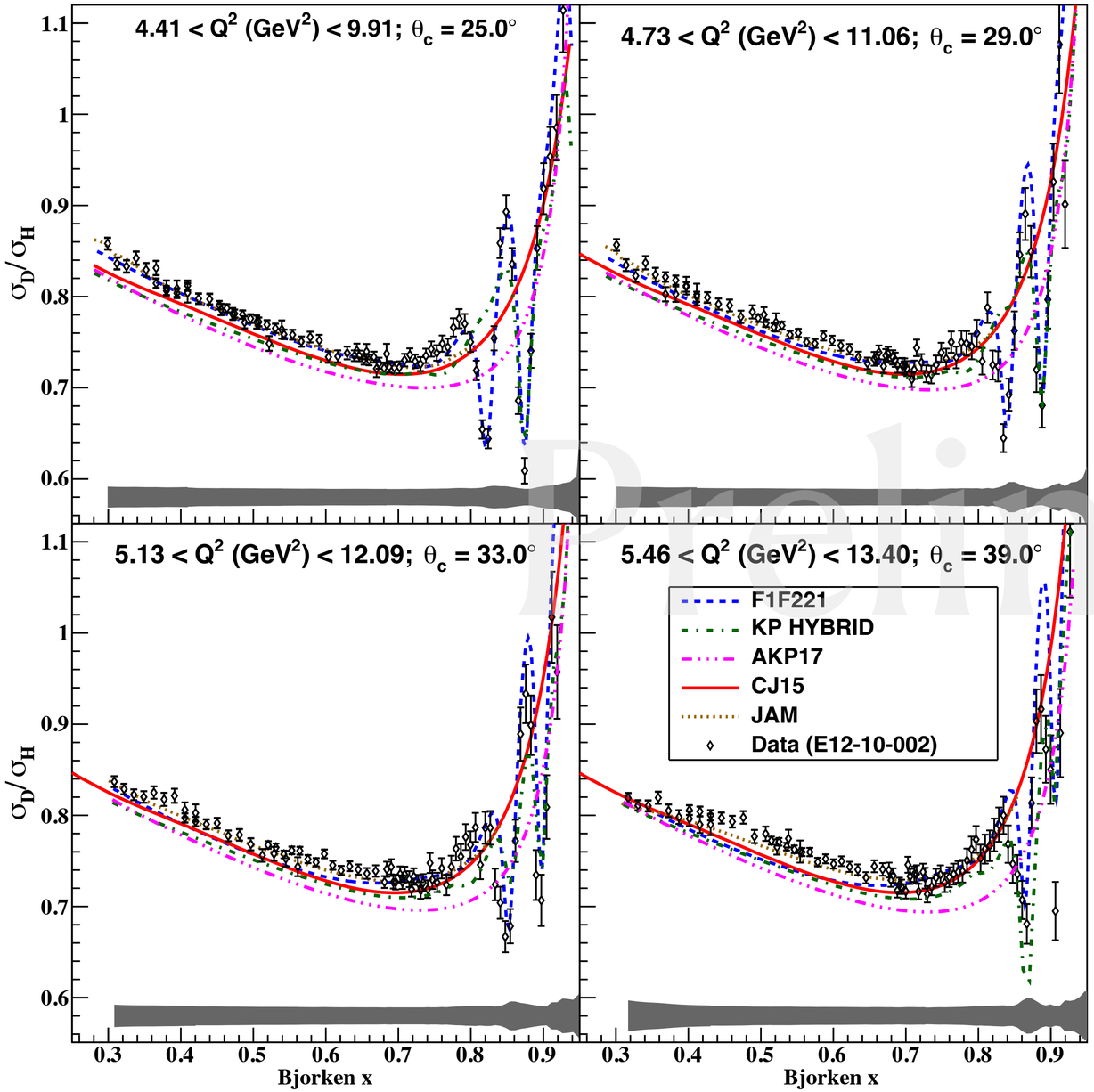

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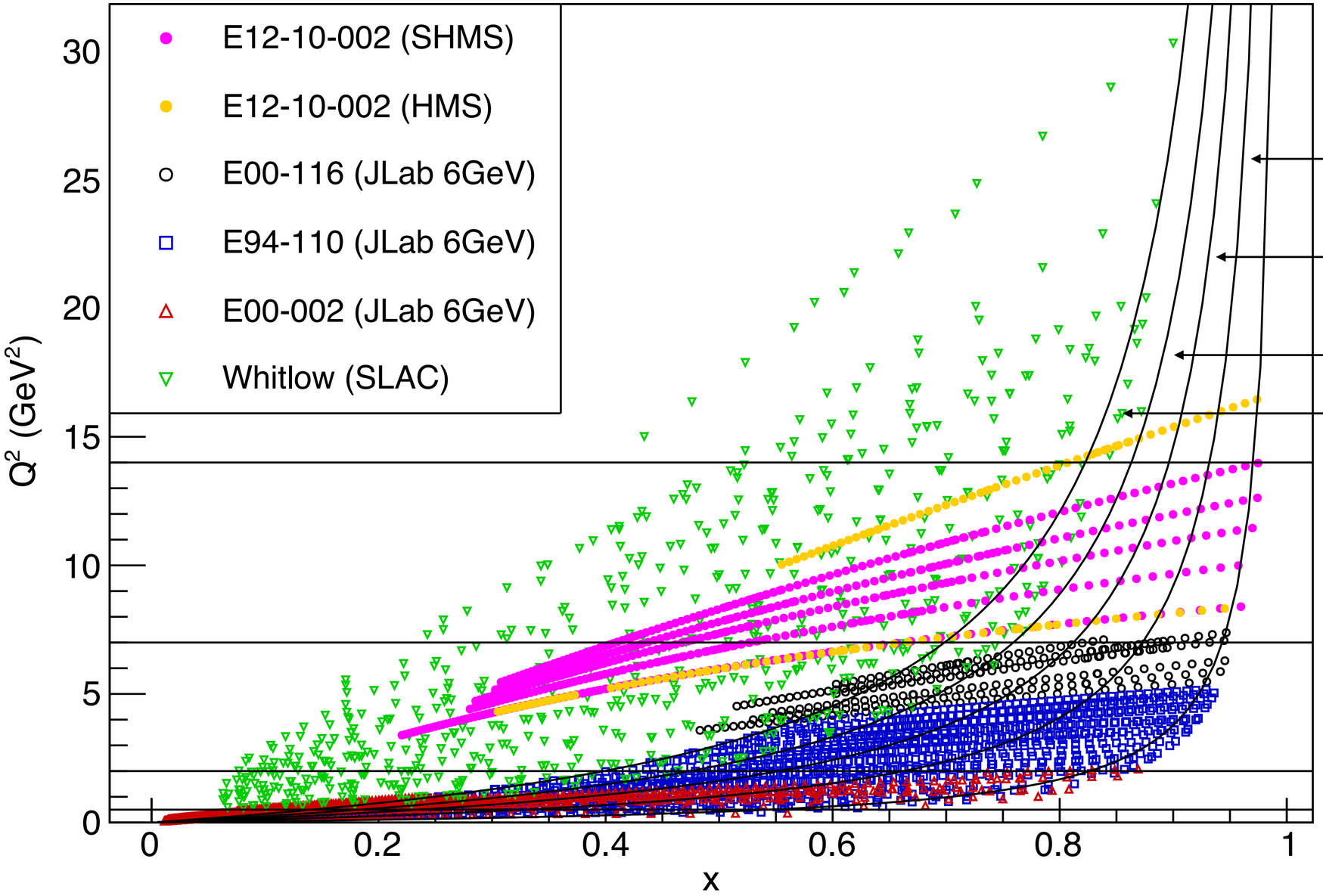
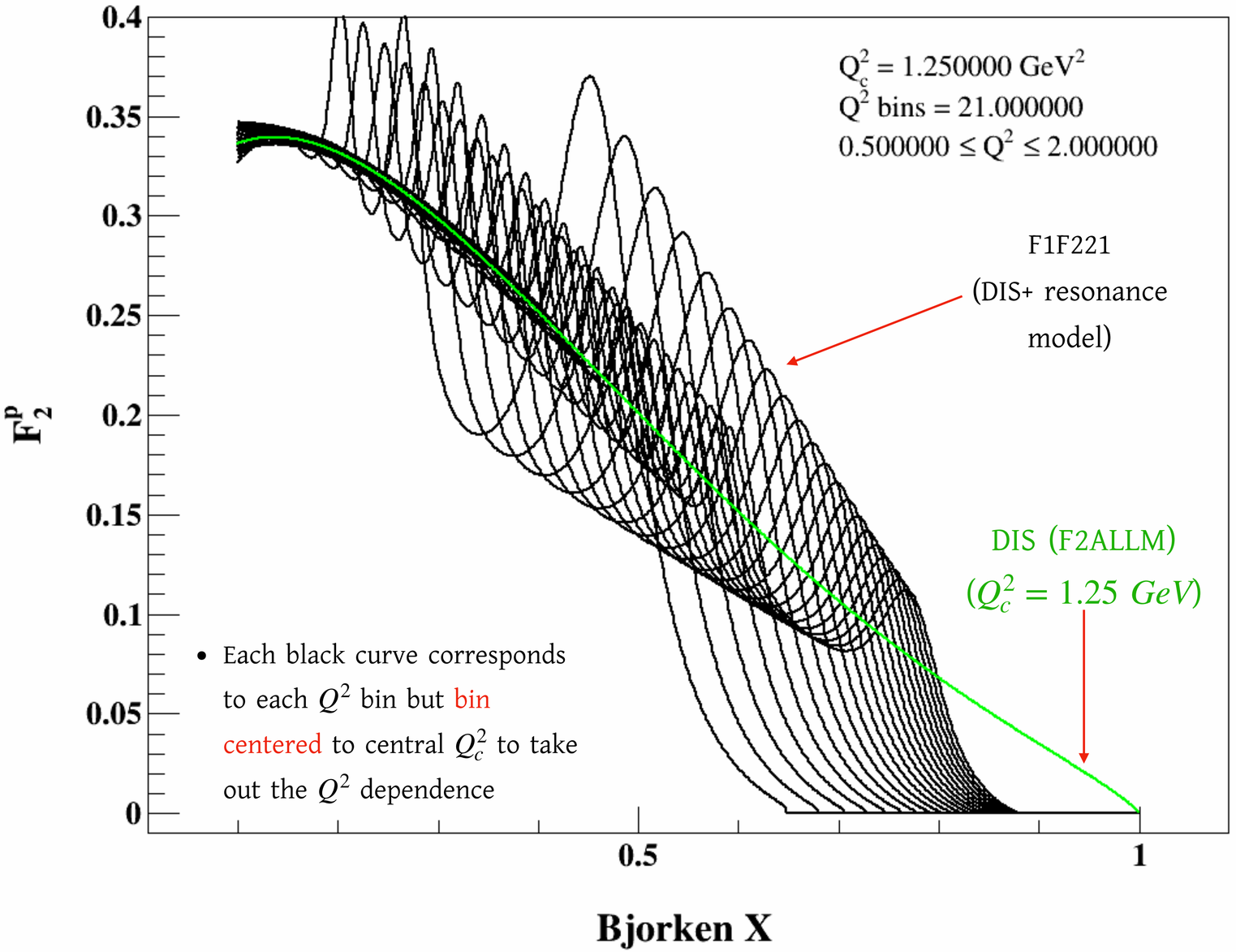
E12-10-002 data enriches the world data



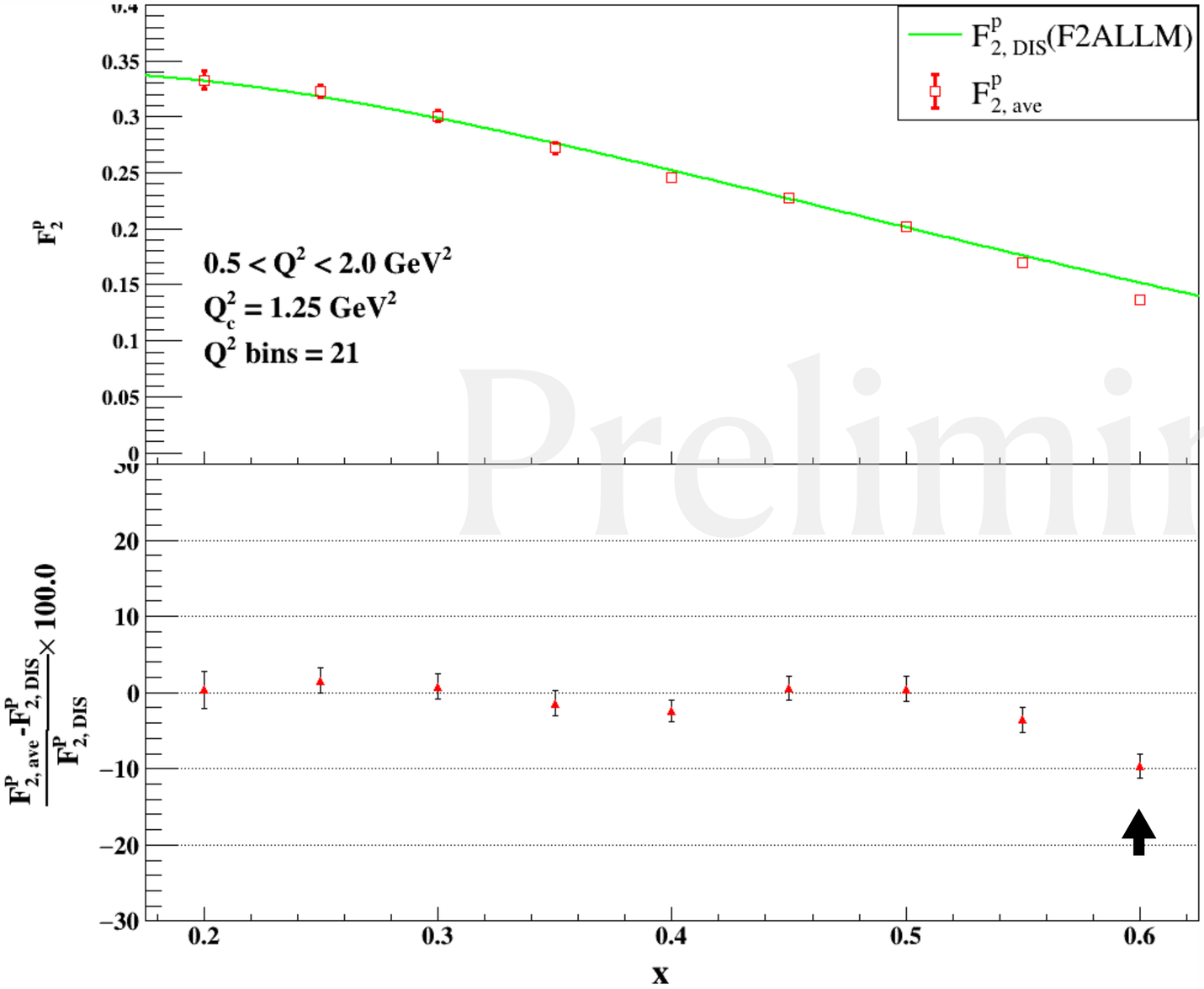
Resonance regions' boundaries defined by W^2 (GeV^2)
1.3 < 1st Resonance < 1.9
1.9 < 2nd Resonance < 2.5
2.5 < 3rd Resonance < 3.1
3.1< 4th Resonance < 3.9

Quark-Hadron duality

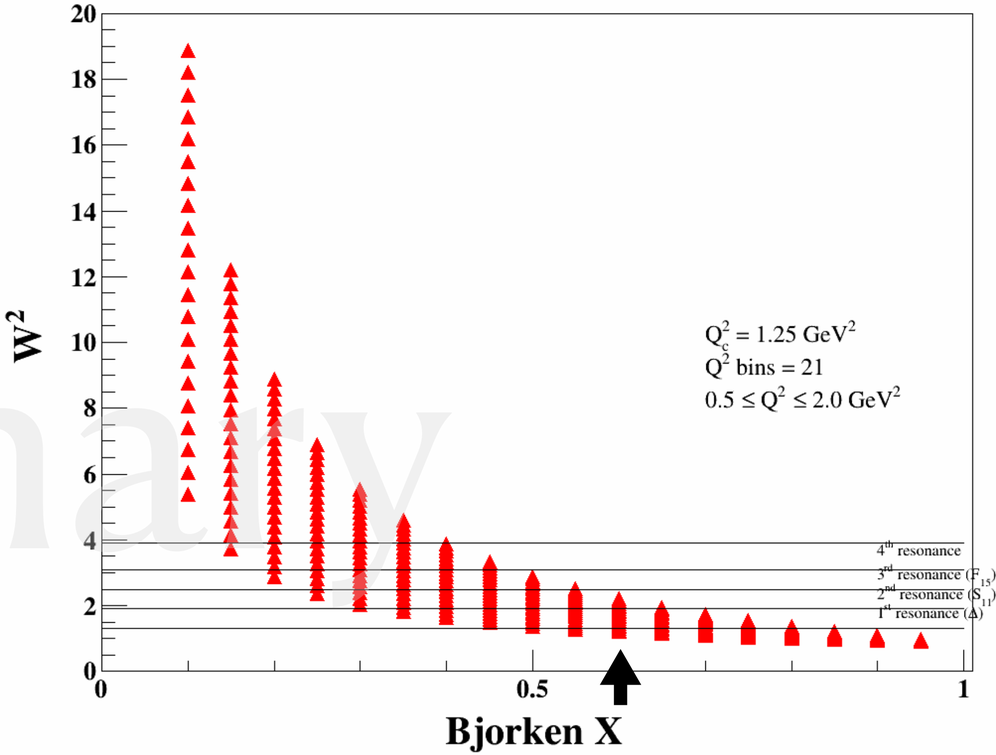


- From the pioneering work of Bloom and Gilman at SLAC we know F_2 structure function data at DIS region also describe the average resonance region F_2 data at same Q^2
- For a broad range of Q^2 the dips and peaks (defined byW^2) of different resonances passes through a particular x
- Hence averaging a large enough Q^2 region should recover the scaling curve
- As the resonances are defined by W^2 it is important to check the W^2 coverage for each x bin (next slide)

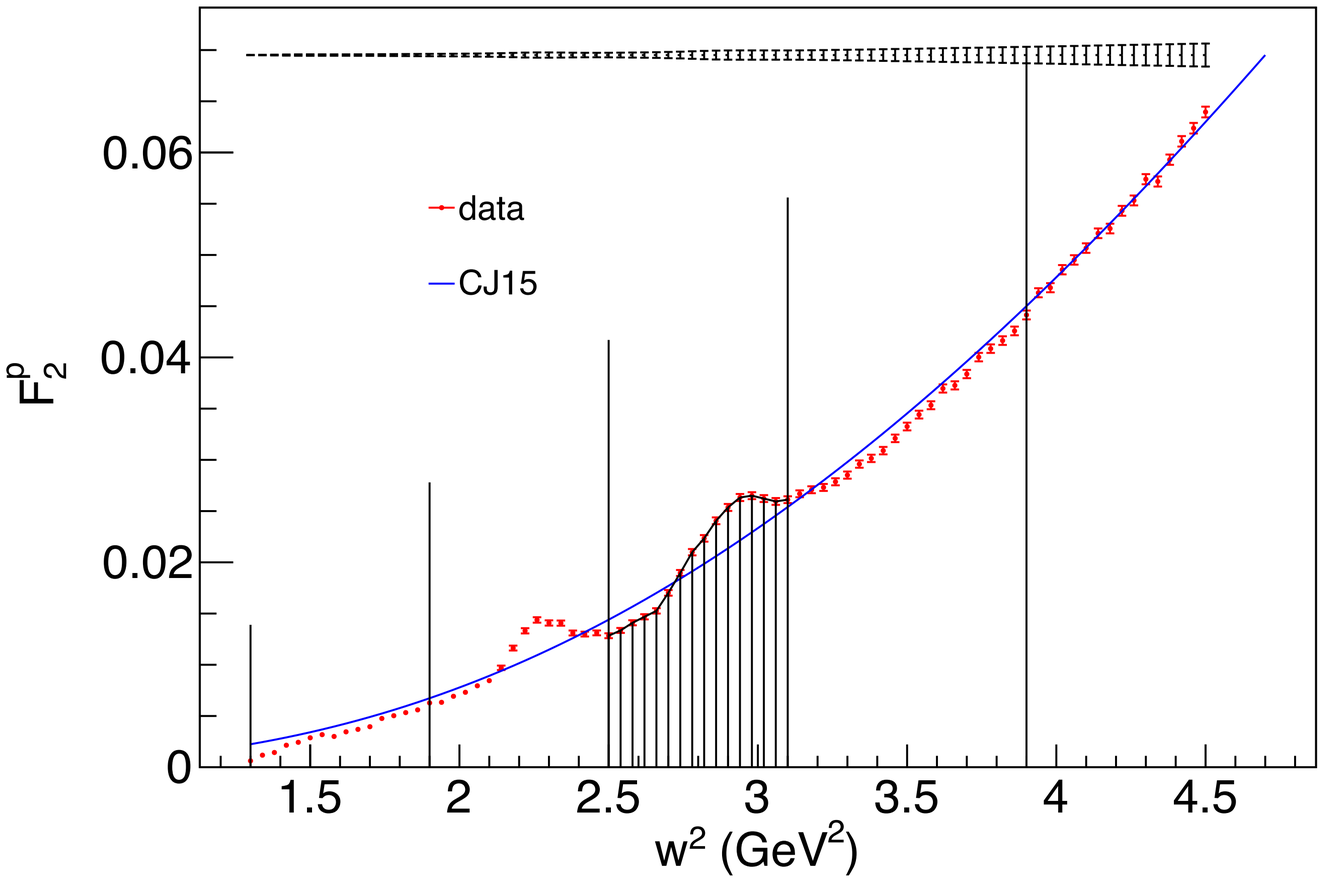
Quark-Hadron duality



W^2 coverage of the each X bin



Local Quark-Hadron duality (from A. Sun)



- Quark hadron duality is tested by plotting the quantity : $I(res/DIS) = \dfrac{\int F_2^{DATA}\, dW^2}{\int F_2^{scaling}\, dW^2}$
- CJ15 curve is used for the DIS / scaling curve
- Vertical lines show the boundaries for the different resonance regions
- Where $\int F_2^{data} = \sum_i \dfrac{(F_2(W_i^2) + F_2(W_{i+1}^2))\Delta W^2}{2}$
- I is plotted vs the average Q^2 for different resonance regions, DIS region and for global (next slide)
- This experiment extends the previous study to larger Q^2

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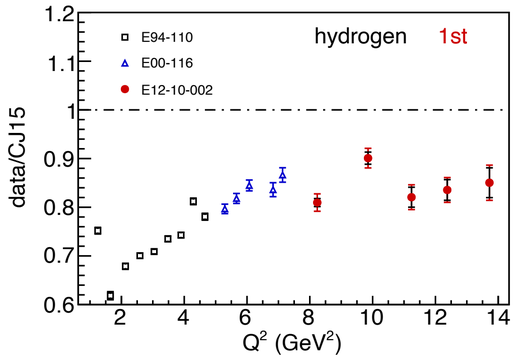

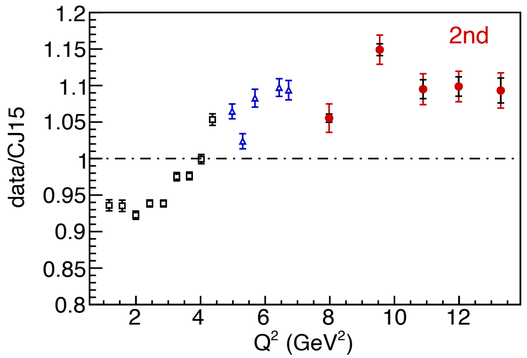

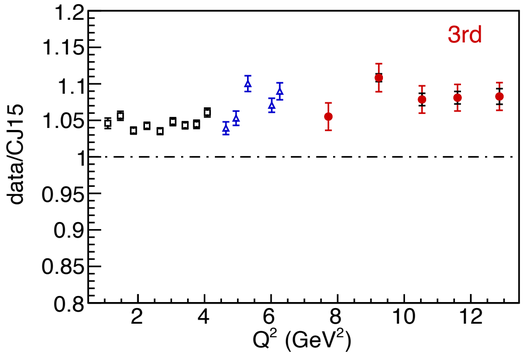

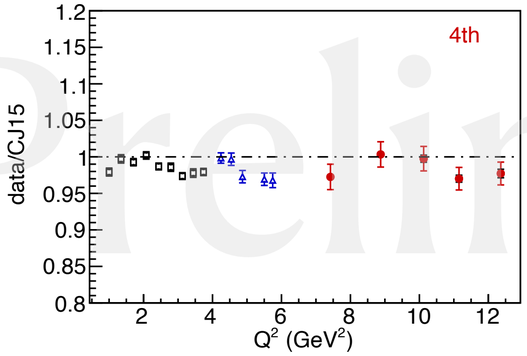

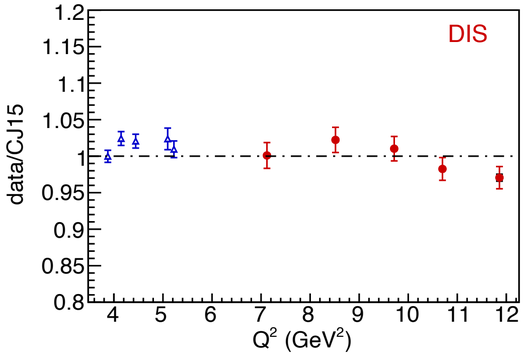

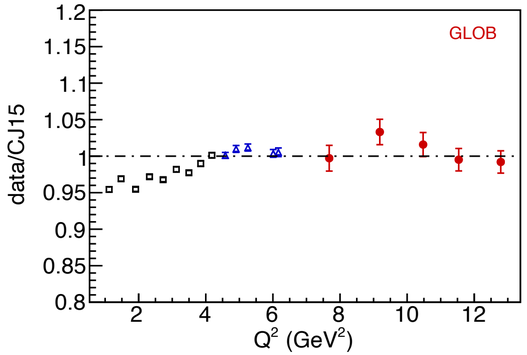

- Duality also can be checked for each resonance
- E12-10-002 data extends the work previously done by S. Malace in 6 GeV era
- Left plot for hydrogen
- Each point in every plot indicated an particular angle
- Six panels corresponds to 1st resonance, 2nd resonance, 3rd resonance, 4th resonance, 5th resonance, DIS, and Global

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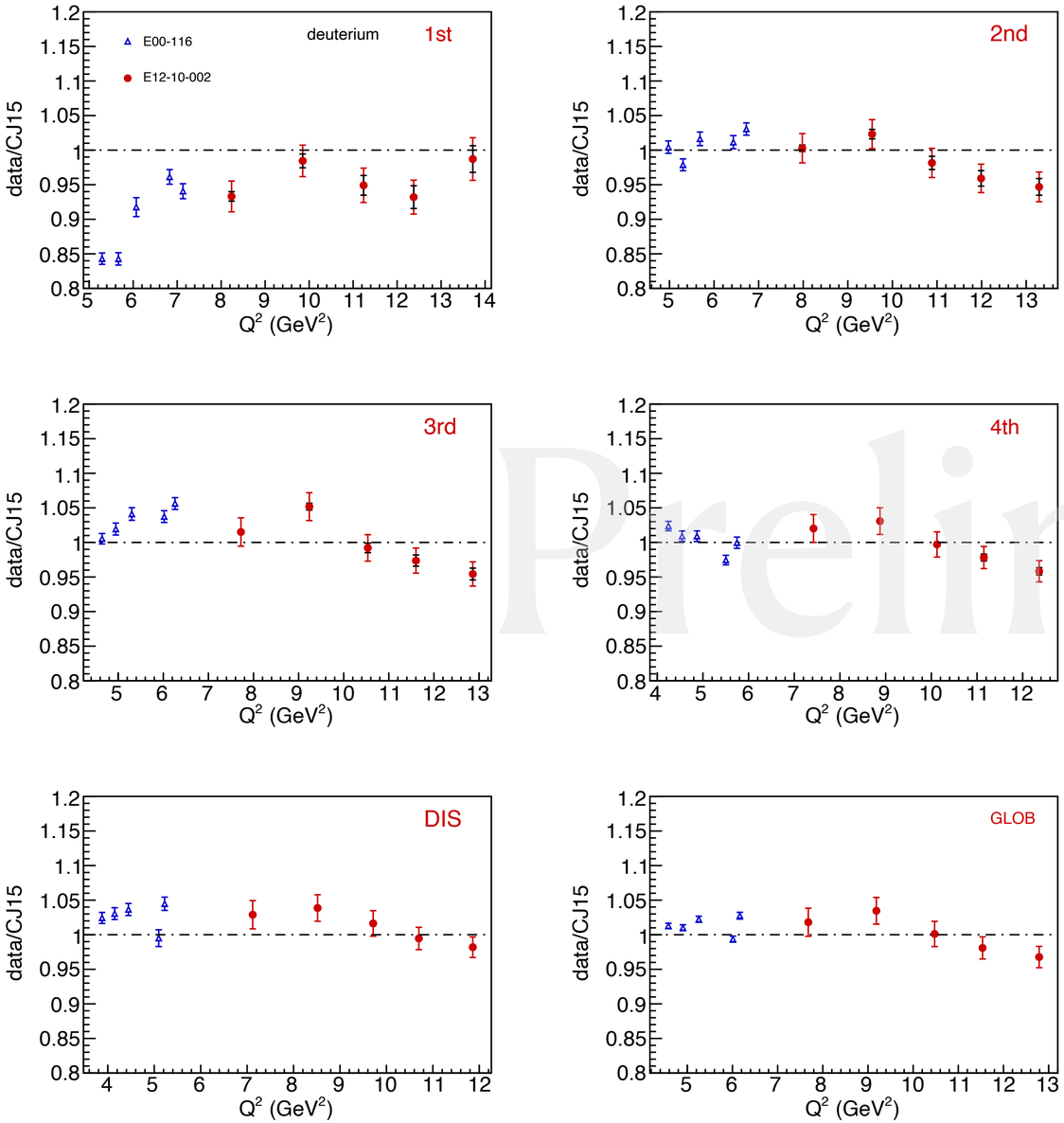

- Duality also can be checked for each resonance
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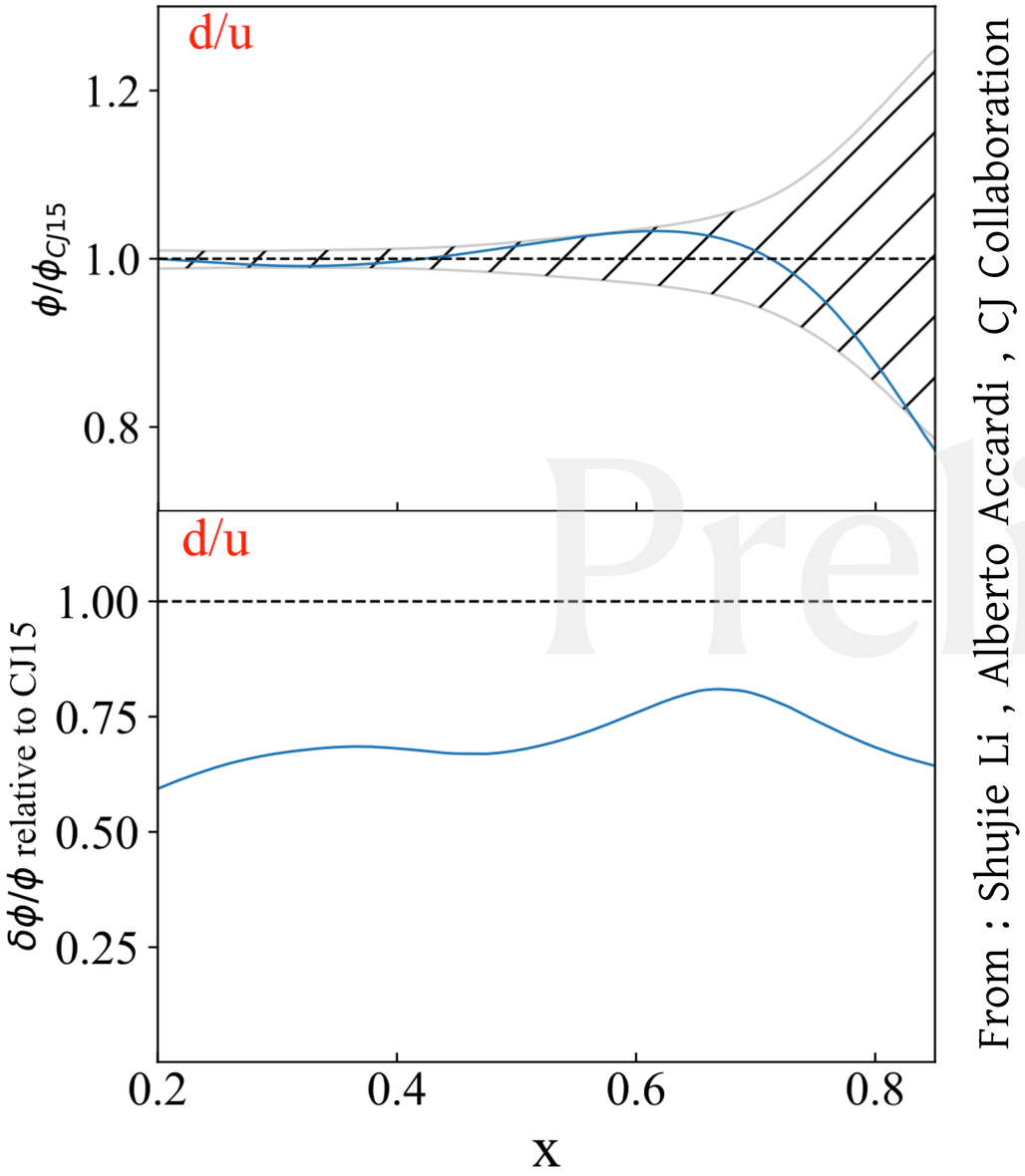
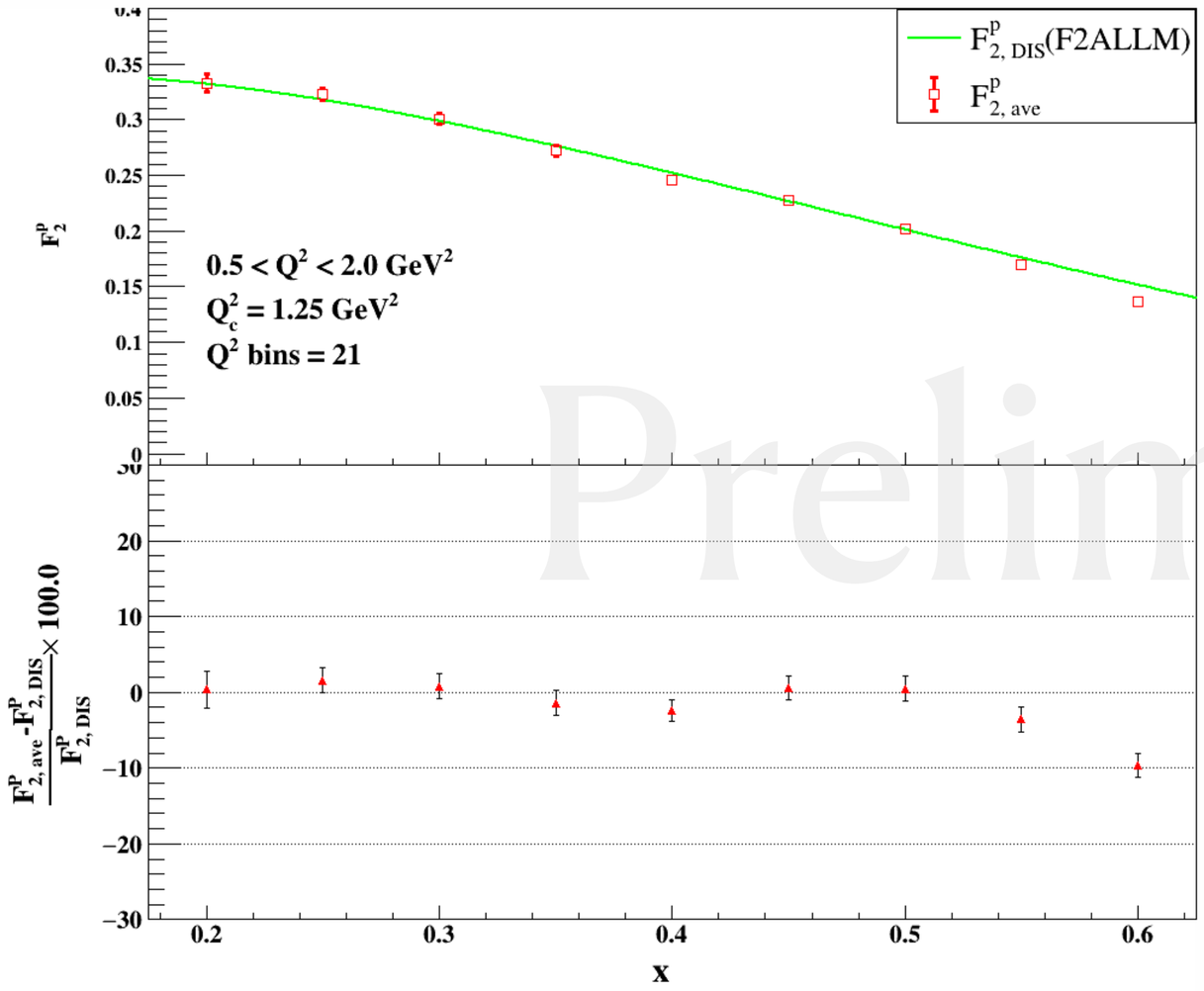
Impact of the E12-10-002 data on d/u PDF fit by CJ



From : Shujie Li , Alberto Accardi , CJ Collaboration

- TOP Panel :
  - Blue Line : Relative change in CJ15 central value of d/u PDF when data from this analysis is included
  - The band is the error on the fit before inclusion of this data
- Bottom Panel :
  - The relative error on CJ15 PDF fit after inclusion of the data from this experiment
  - Inclusion of this data results in 25-30% reduction of uncertainty in d/u PDFs
- A cut of $W^2 > 3\ GeV^2$ applied to the data that enters the fit

Summary



- σ_D/σ_H ratio paper is to be published soon : Stay tuned
- Individual cross-sections of proton, deuterium and neutron papers is being finalized : Next publication after ratio paper
- This data can be used along with other experimental data to extend the study of Quark-Hadron duality to even higher Q^2
- Previous study of non-singlet moment (Ibrahim H. Albayrak et. al.) as a test of LQCD can be extended with the data
- Together with other experiments like Bonus, Marathon this data set can be very useful for different studies

Thanks to All Collaborators

Spokespersons and Collaborators

- C. Keppel (Jefferson Lab)
- M. Eric Christy (Jefferson Lab)
- S. Malace (Jefferson Lab)
- D. Gaskell (Jefferson Lab)
- W. Henry (Jefferson Lab)
- I. Niculescu (JMU)
- G. Niculescu (JMU)
- A. Accardi (Hampton)

PhD's From E12-10-002

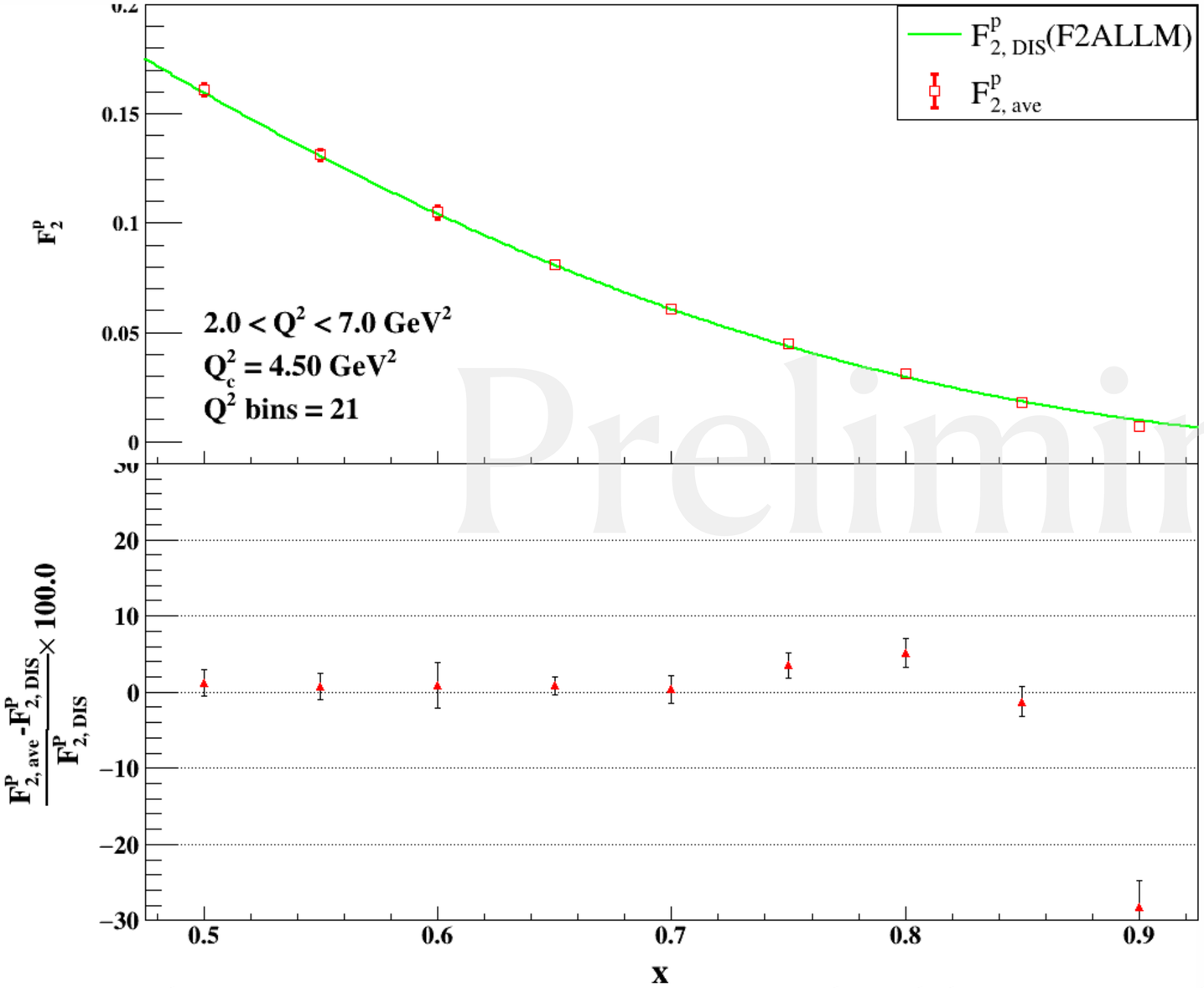
- D. Biswas (PhD from Hampton University, Postdoc @ Virginia Tech)
- A. Sun (PhD from Carnegie Mellon University)
- A. Nadeeshani (PhD from Hampton University, Postdoc @ Missisipi State University)
- F. Gonzalez (PhD from Stony Brook University)

Current Graduate Student

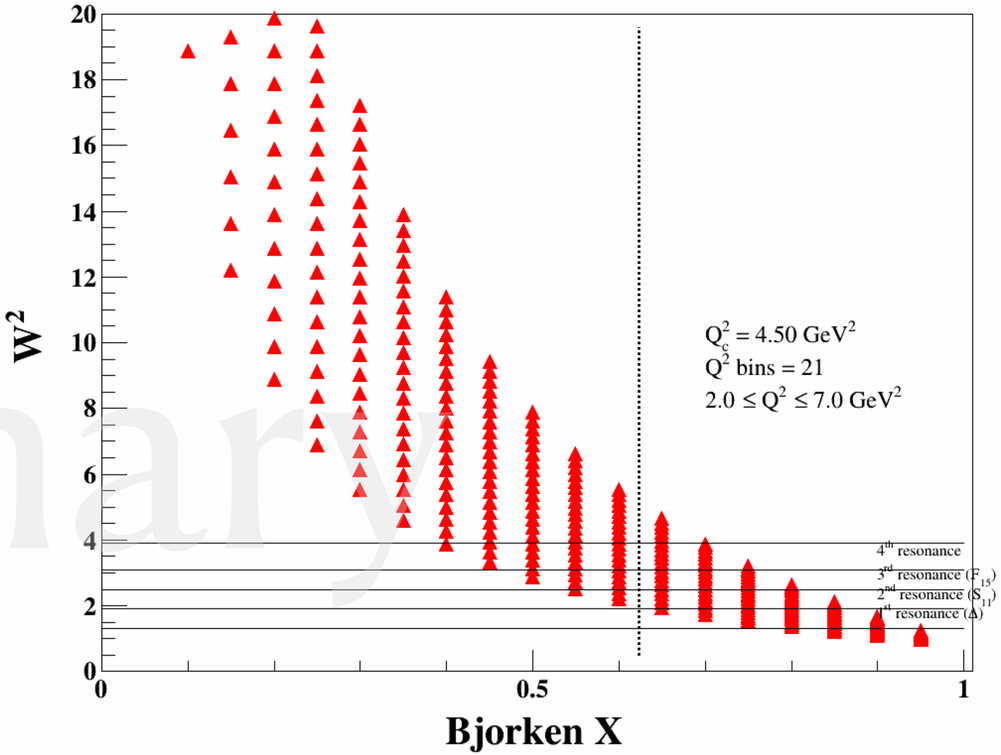
- Gyang Chung (Virginia Tech)

Back up Slides

Quark-Hadron duality



W^2 coverage of the each X bin



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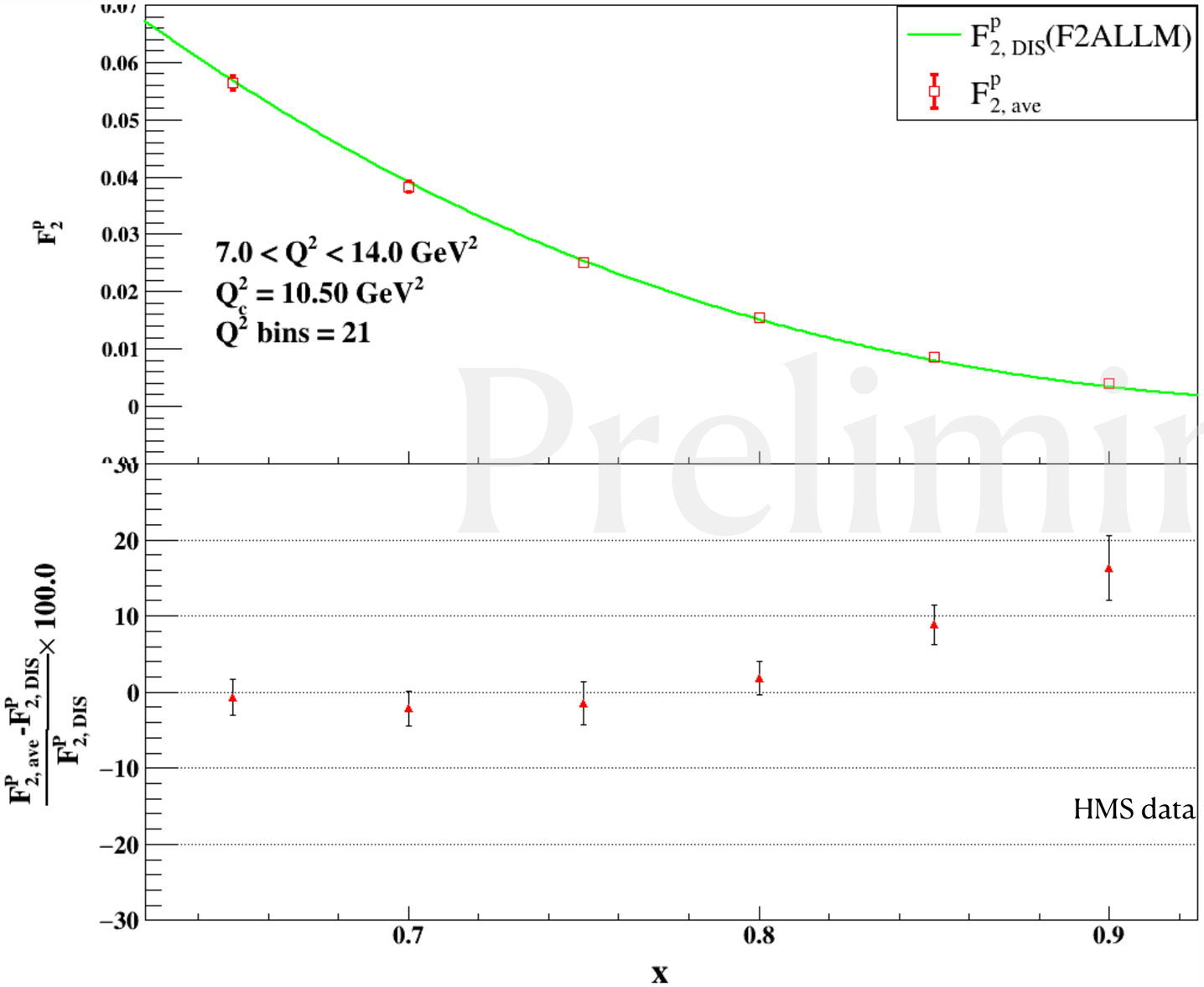

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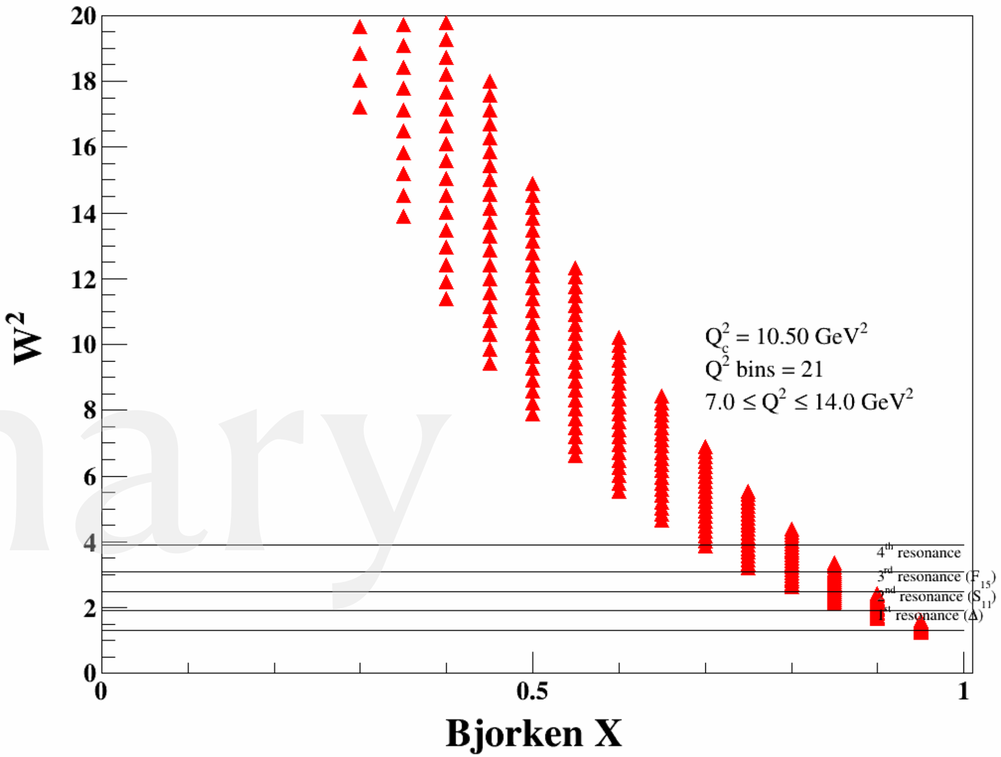

HMS data for 59 deg will be included later

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