Inclusive Cross Sections with CLAS12 RG-A Data

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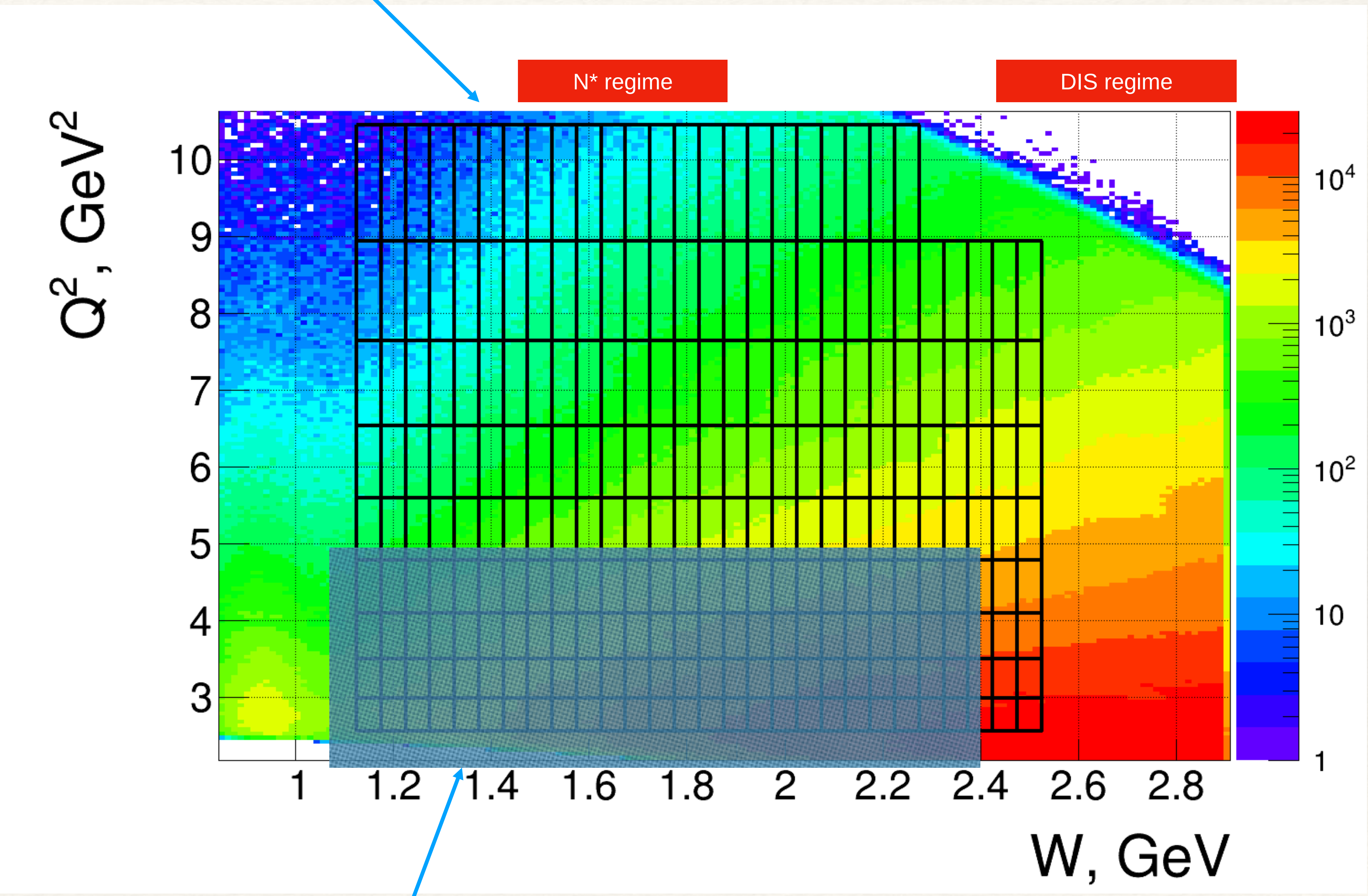
(e,e'X) Cross Sections from New CLAS12 Dataset (RG-A Inbending Runs)

- RG-A Fall 2018
- Beam energy: 10.6 GeV
- Torus/Solenoid: -100%/-100% (inbending)
- Beam current: 45 – 55 nA
- Faraday cup charge: 3 * 10^7 nC
- CLAS kinematic coverage:
  - $0.225 < Q^2 < 4.5$ GeV^2
  - $1.0815 < W < 2.4$ GeV
- CLAS12 kinematic coverage:
  - $0.5 < Q^2 < 10$ GeV^2
  - $0.1 < W < 2.5$ GeV

Extension of the inclusive electron scattering cross sections up to Q^2~10 GeV^2 within a broad W-range W<2.5 GeV in each bin of Q^2

First CLAS12 measurement



CLAS Data

Inclusive Cross Section from (e,e′X) Event Yield

$$\frac{d\sigma}{dQ^2 dW} = \frac{1}{\Delta Q^2 \Delta W} \cdot \frac{N}{\eta \cdot R \cdot BS \cdot N_0} \cdot \frac{1}{N_A \rho t / A_\omega} \quad (1)$$

- η - product of geometrical acceptance and electron detection efficiency
- R - radiative correction factor
- BS – bin-size correction

Acceptance Corrections

- Measurement is distorted and transformed by various effects such as finite resolution, limited acceptance of the detector, and detection efficiency so a correction is required

- Basic method for acceptance correction is **bin-by-bin** method that was used as a reference

$$Acceptance = \frac{\#\ Events\ Reconstructed}{\#\ Events\ Generated}$$

- Matrix deconvolution method was used as a nominal method to minimize bin migration and EG dependence

Matrix Deconvolution

- **Acceptance Matrix:** $A_{(i,j)}$ describes both acceptance (geometrical acceptance and detector efficiency) and bin migration:

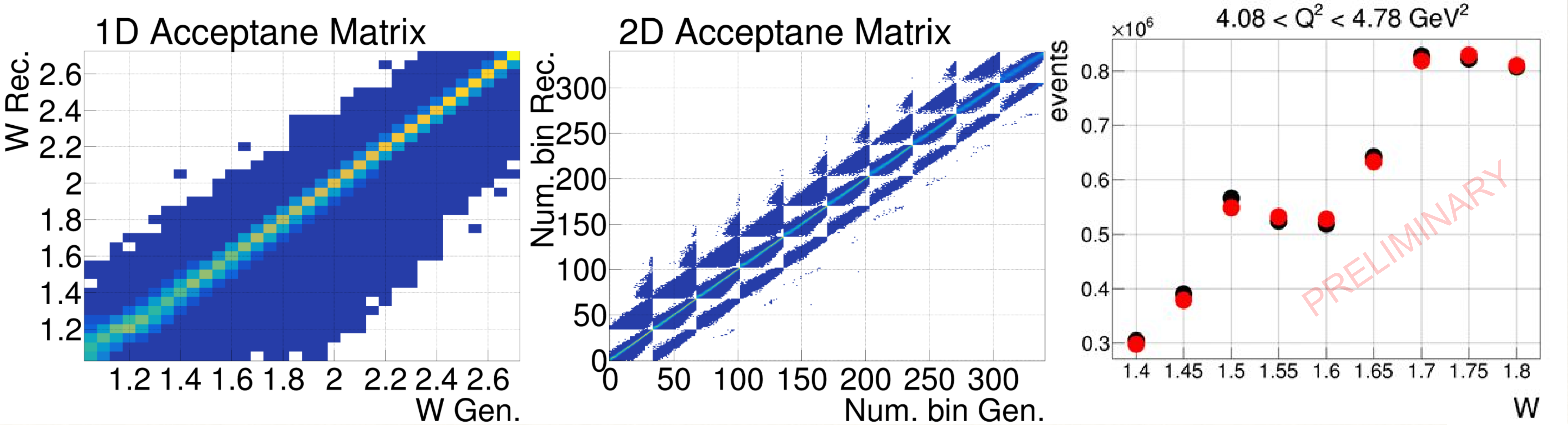
CERN RooUnfold package was used:
https://gitlab.cern.ch/RooUnfold/RooUnfold

$$A_{(i,j)} = \frac{\#\ Events\ Generated\ in\ bin\ j\ but\ Reconstructed\ in\ bin\ i}{Total\ number\ of\ Events\ Generated\ in\ the\ jth\ bin}$$

Acceptance unfolding: $Y_i = A_{(i,j)} X_j \Rightarrow X_j = A^{-1}_{(i,j)} Y_i$ where Y_i number of measured events in i-th bin, X_j is number of acceptance corrected events in j-th bin

We studied two different methods:

1. SVD
2. Bayesian Matrix 2D



Red - 2D Bayesian method
Black - Bin-by-bin method

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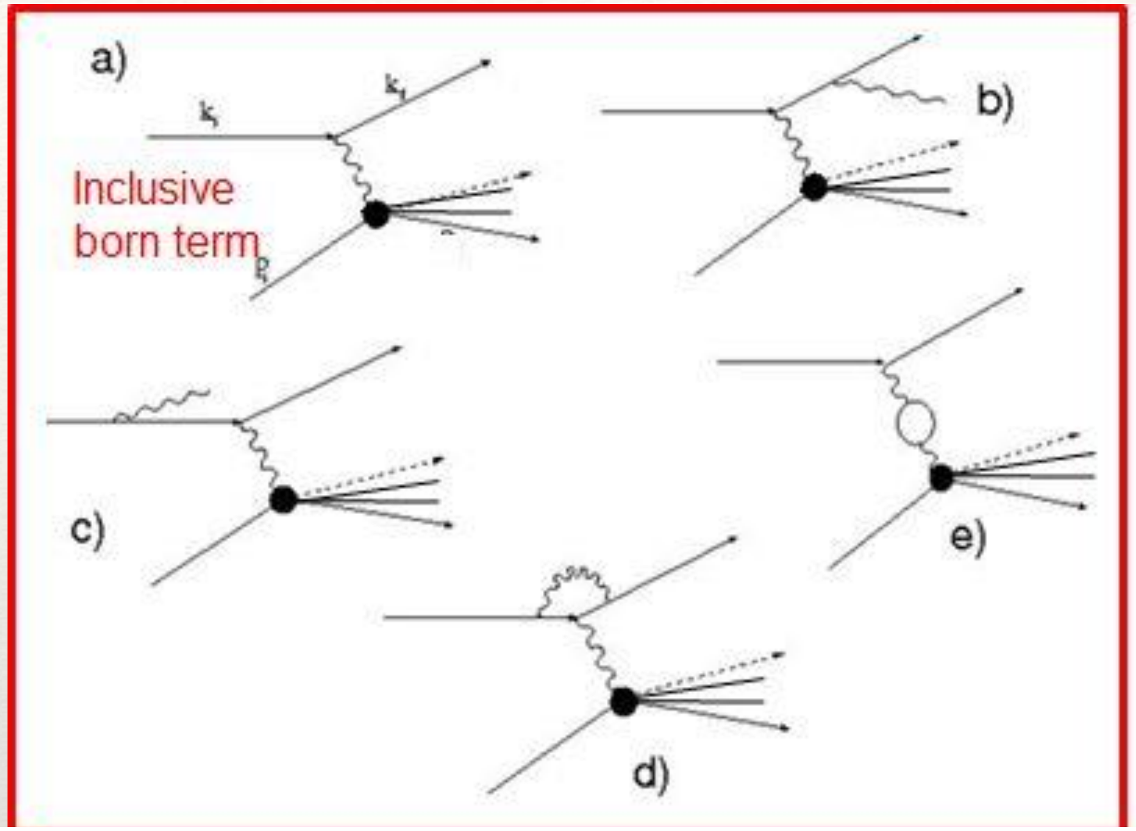
Radiative Corrections

Each (Q^2,W) bin was divided into 21x11 sub-bins. Cross Sections with rad. effects on and off were calculated in every sub-bin.

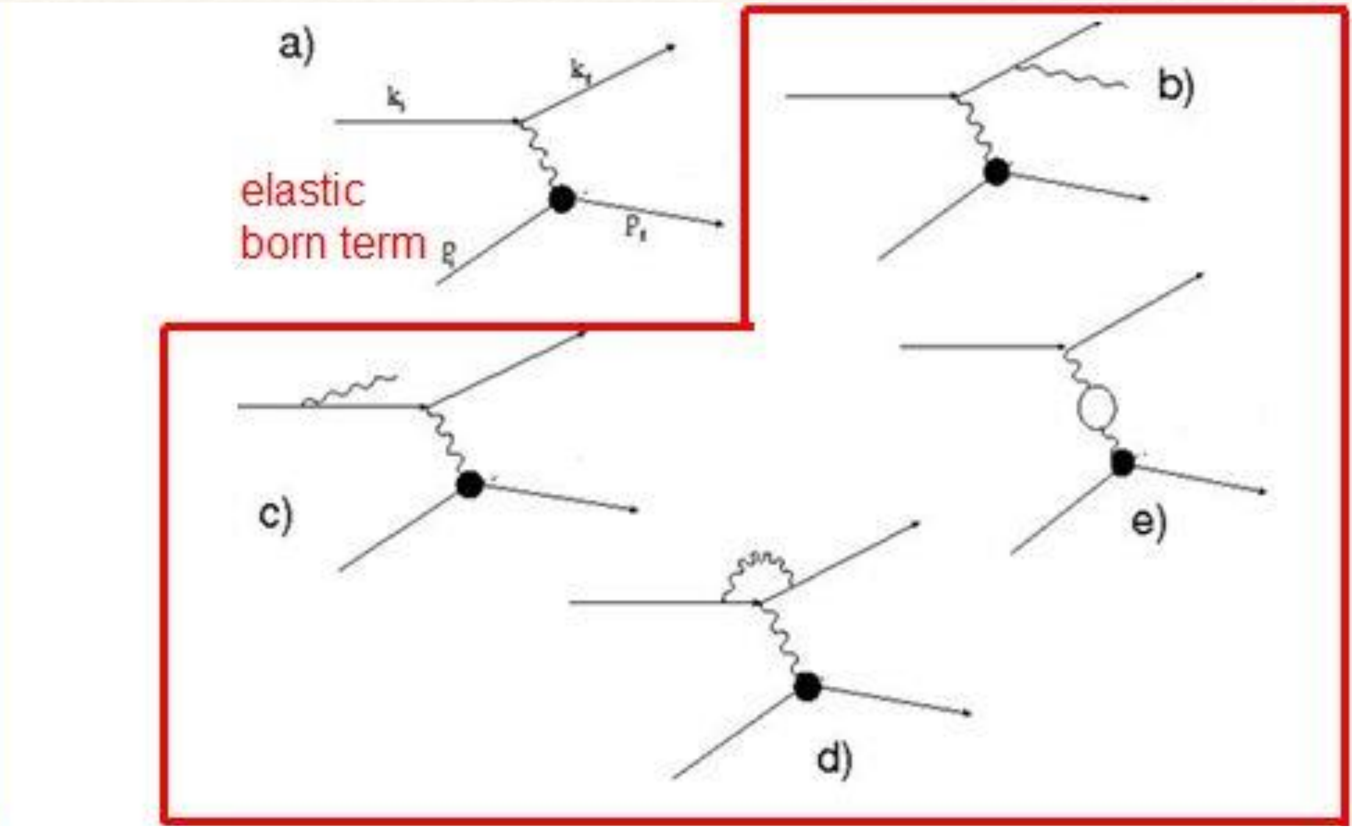
Radiative Correction factor:

$$\frac{Mean\ Cross\ Section\ (Rad)}{Mean\ Cross\ Section\ (No\ Rad)}$$

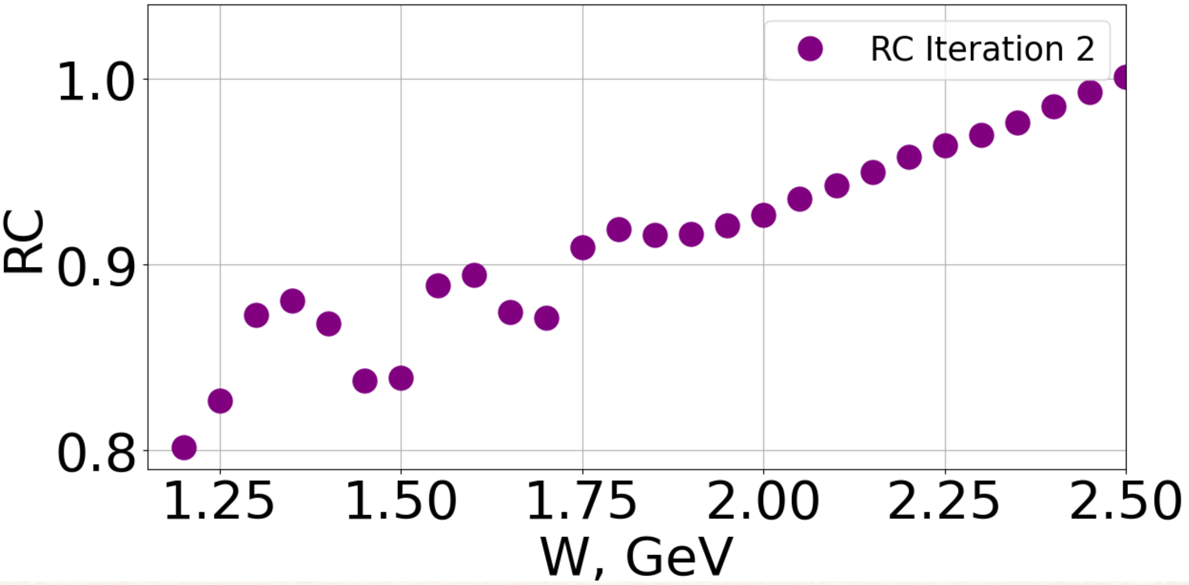
Inclusive with radiative effects



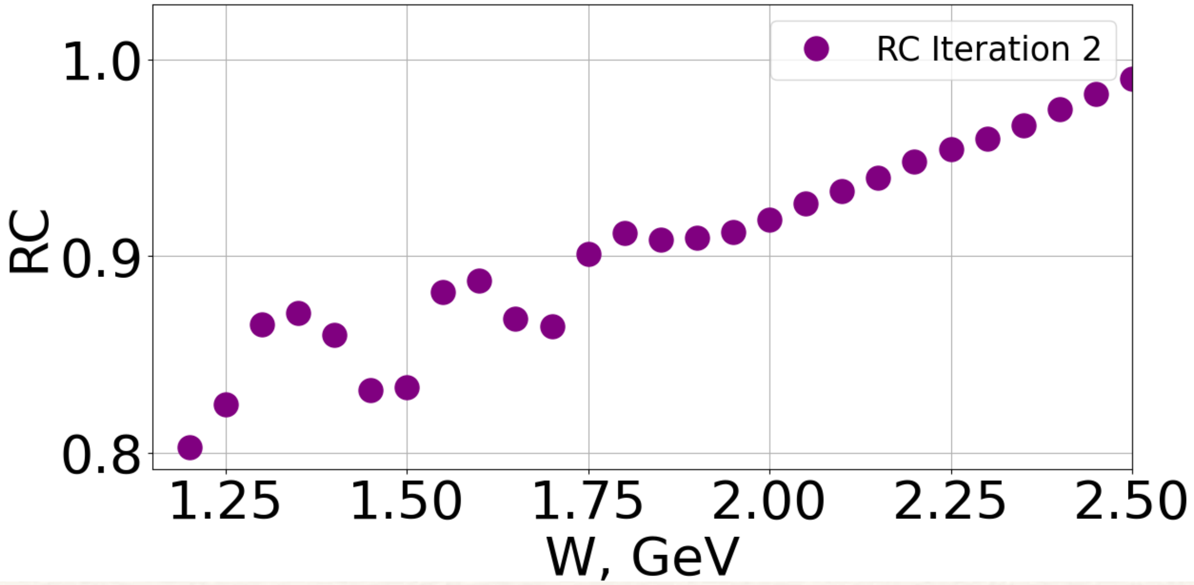
Elastic with radiative effects



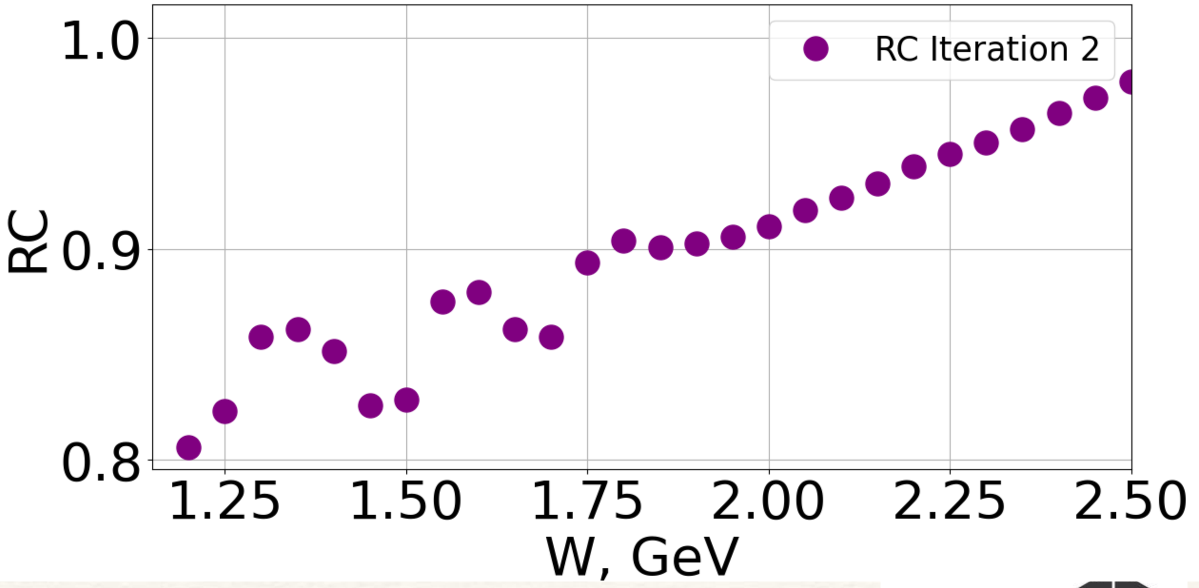
$2.55 < Q^2 < 2.99\ GeV^2$



$2.99 < Q^2 < 3.49\ GeV^2$



$3.49 < Q^2 < 4.08\ GeV^2$

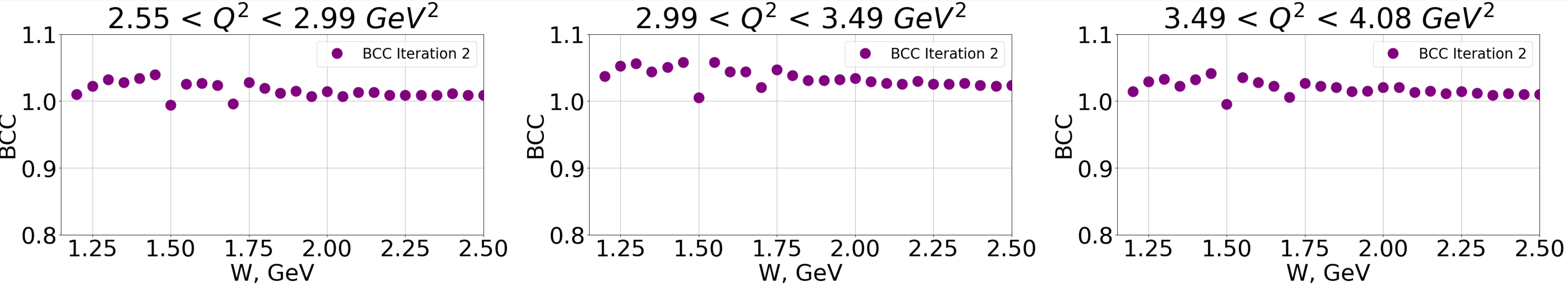


Bin-Size Corrections

$$\frac{d\sigma}{dQ^2dW} = \frac{1}{\Delta Q^2 \Delta W} \cdot \frac{N}{\eta \cdot R \cdot \boxed{BS} \cdot N_0} \cdot \frac{1}{N_A \rho t / A_\omega}$$

Each (Q^2,W) bin was divided into (the same) 21x11 sub-bins.

$$\text{BS Corrections (BSC)} = \frac{\textit{Mean Cross Section (No Rad)}}{\textit{Cross Section (No Rad) in the central point}}$$



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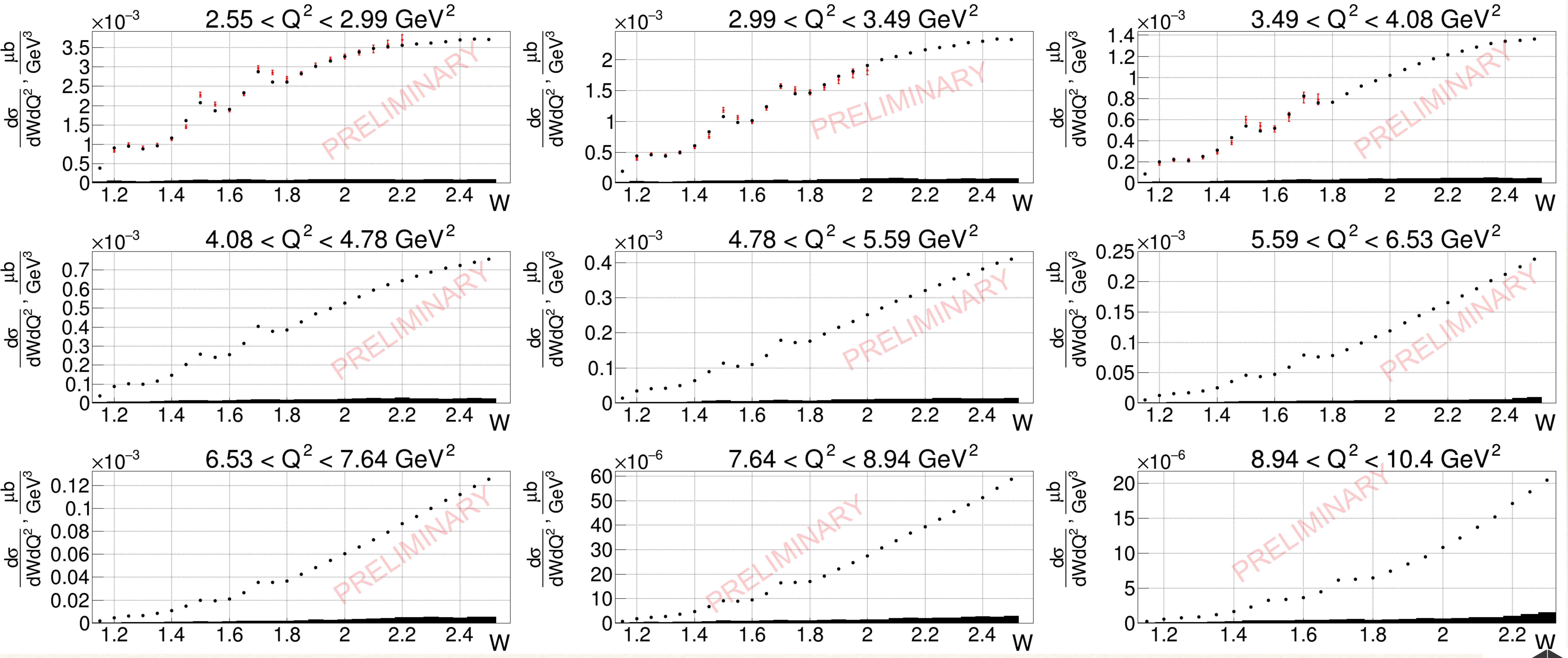
Preliminary (e,e′X) Cross Sections

- Preliminary CLAS12 measurements
- CLAS data (after interpolation into the grid of our experiment), Phys. Rev. D67, 092001 (2003)



Status and Path Towards Publication

- Analysis Note submitted on August 9 for Working Group review
- First round review comments received on September 11 (69 comments)
- Main issues have been worked out:
    - New torus field map (non-symmetric field map)
    - Target position and size
    - Momentum smearing procedure
    - Updates to systematic uncertainty sources (FC charge, background merging)
    - Improved explanations of procedures based on review questions/comments
- We are working on finalizing the answers (prepare updated analysis note + reply document to address each comment from the analysis review
- Draft of a paper is prepared. Will be further developed for upcoming ad hoc review.

Studies of Non-Symmetric Torus Map

We used two torus maps:

- Symm_torus_r2501_phi16_z251_24Apr2018 (symmetric)
- Full_torus_r251_phi181_z251_25Jan2021 (non-symmetric)

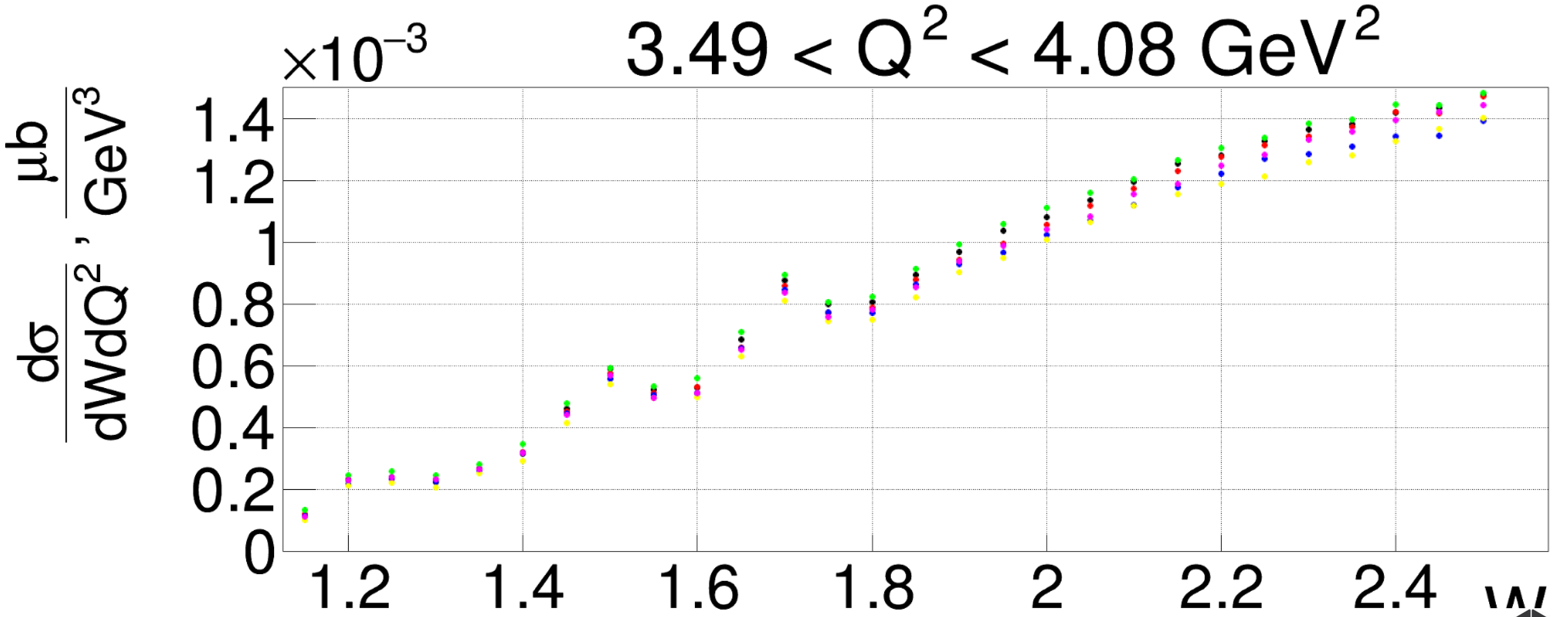
We performed two MCs:

GEMC 5.4 symm. map + REC 5.0.2_6.5.6.2 symm. map
GEMC 5.4 non-symm. map + REC 5.0.2_6.5.6.2 symm. map

We then extracted the cross sections and compared them

Updated Torus Map Sectors Grouping

Cross sections sector by sector **for symmetric map**. Sectors 1-6 are shown in black, red, green, blue, yellow, and magenta respectively.



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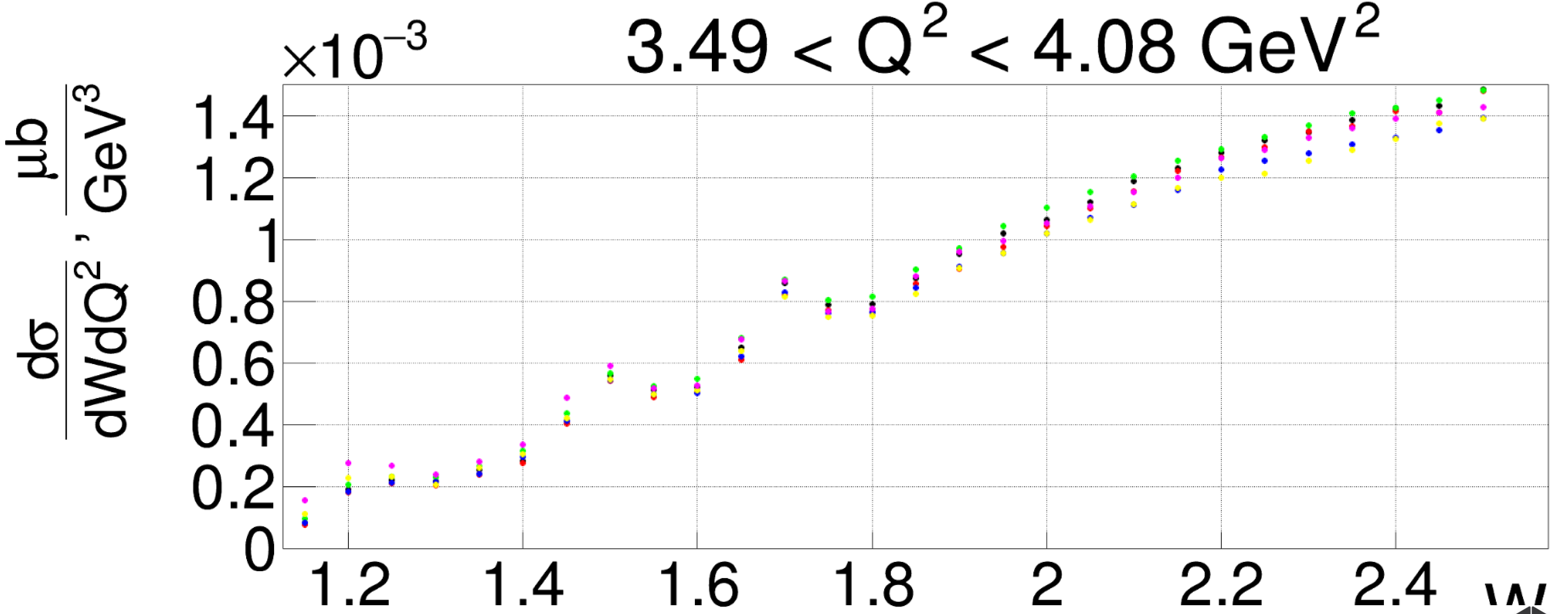
Updated Torus Map Sectors Grouping

Cross sections sector by sector for **non-symmetric map**. Sectors 1-6 are shown in black, red, green, blue, yellow, and magenta respectively.



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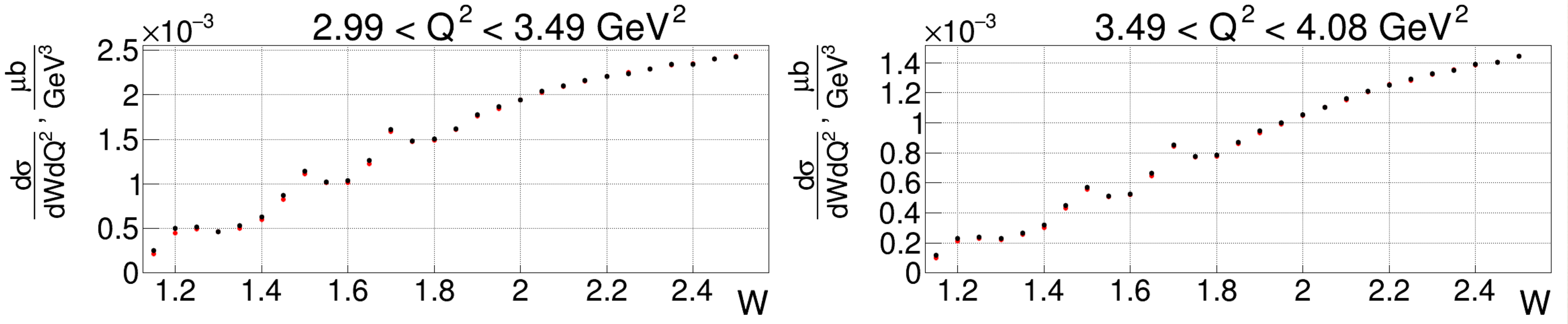
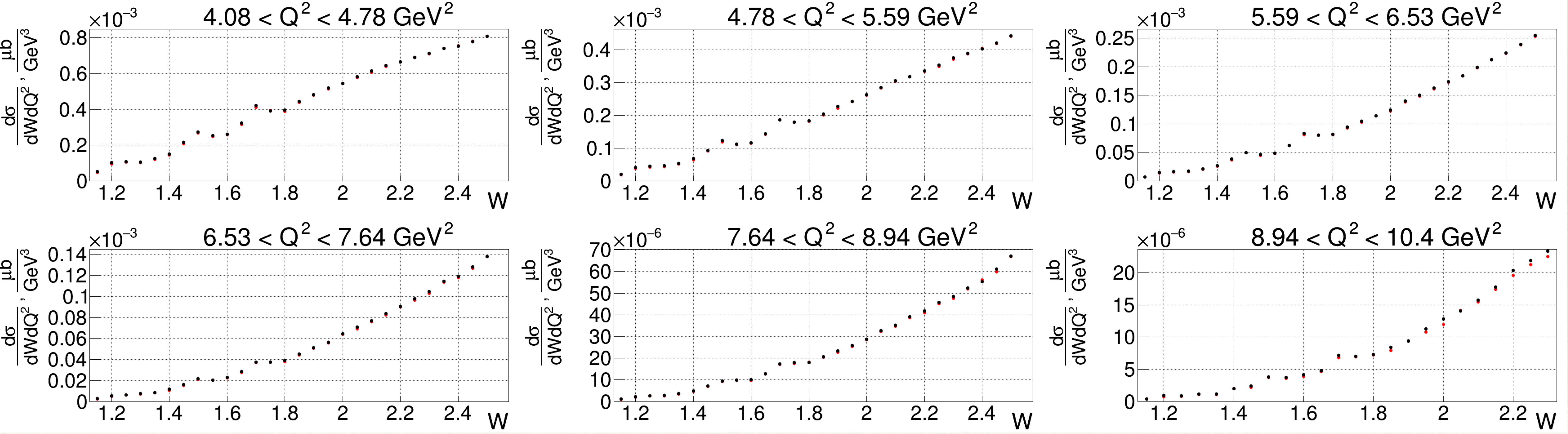
Updated Torus Map

Black – Symmetric
Red – Non-symmetric

Cross sections with updated torus map:

- Almost no effect on sector dependence
- 3% effect on integrated XSECs on average





Z Vertex Shift

- Finite Element Analysis of the RG-A cryotarget showed that the center of the target cell moves upstream by -4.858 mm when the target is cooled to its operating temperature relative to its z position at room temperature.

- Target length is 5.0+/-0.05 cm with +/-0.05 cm being the dimensional tolerance. The effect of the differential pressure when filling with liquid hydrogen is negligible due to how the cell was constructed.

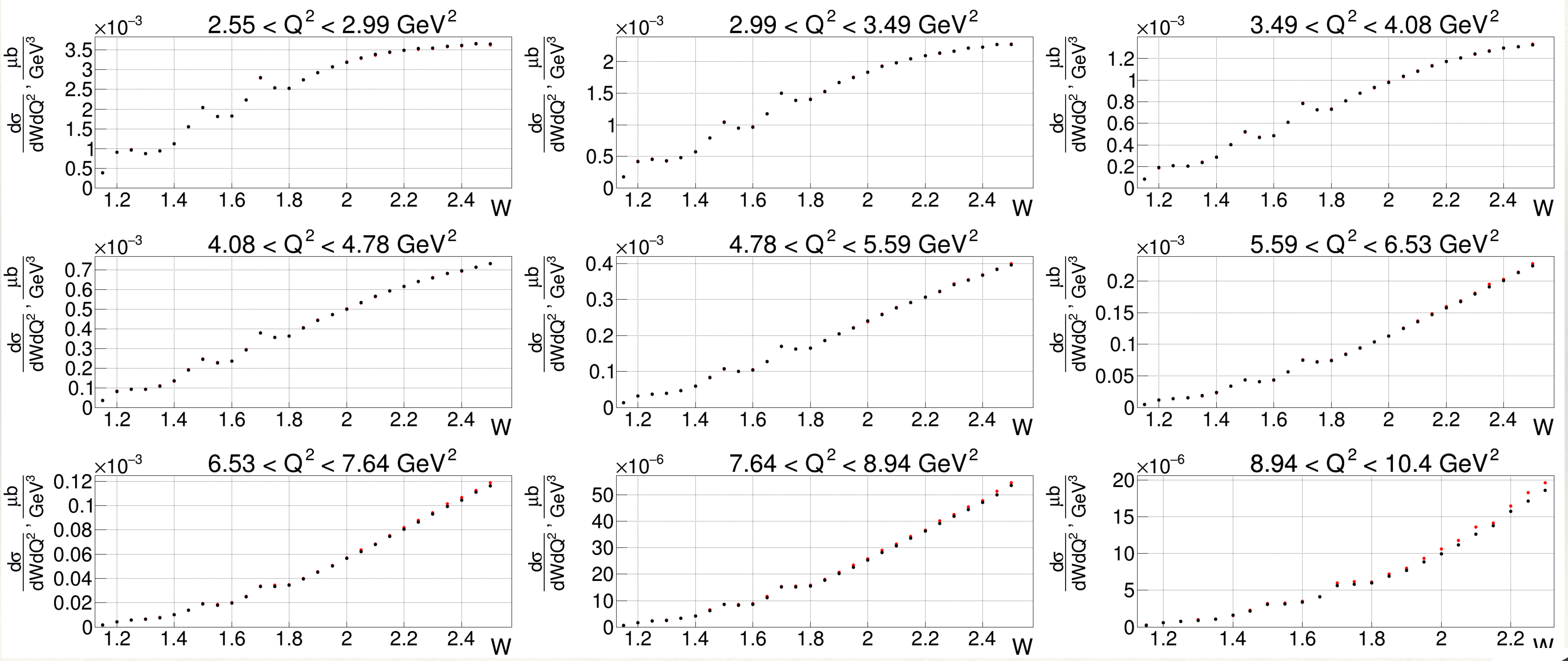
Work done by Bob Miller, Hall B Engineer

https://wiki.jlab.org/Hall-B/engineering/hallb_eng_wiki/images/8/8f/Thermal_Expansion_of_Hall_B_Saclay_Target_Cell_at_Operating_Temperature.xlsx

Z Vertex Shift

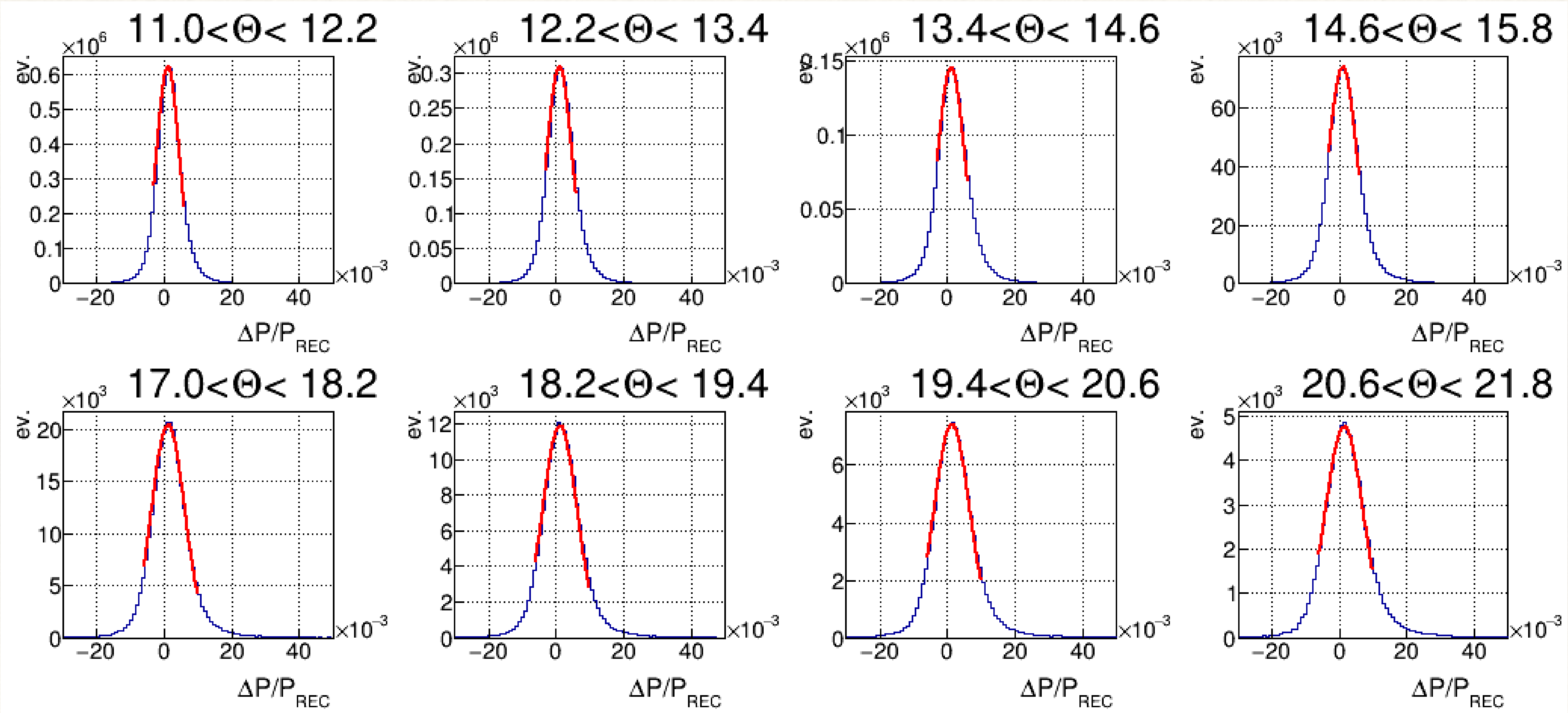
Black – nominal
Red – shifted z

- We performed additional MC studies generating events with a z vertex coordinate in the range [-0.9858: -5.9858] cm,
- The effect is about 5% for the last Q^2 bin.



Momentum Resolution Studies

- In order to extract GEMC resolution functions we fit $\frac{P_{gen} - P_{rec}}{P_{rec}}$ in Θ, P bins to obtain $\sigma(\Theta,P)$ from both inclusive and exclusive MC samples



Examples of $\frac{P_{gen} - P_{rec}}{P_{rec}}$ for electrons in ($ep \rightarrow e\pi^{+}n$) MC

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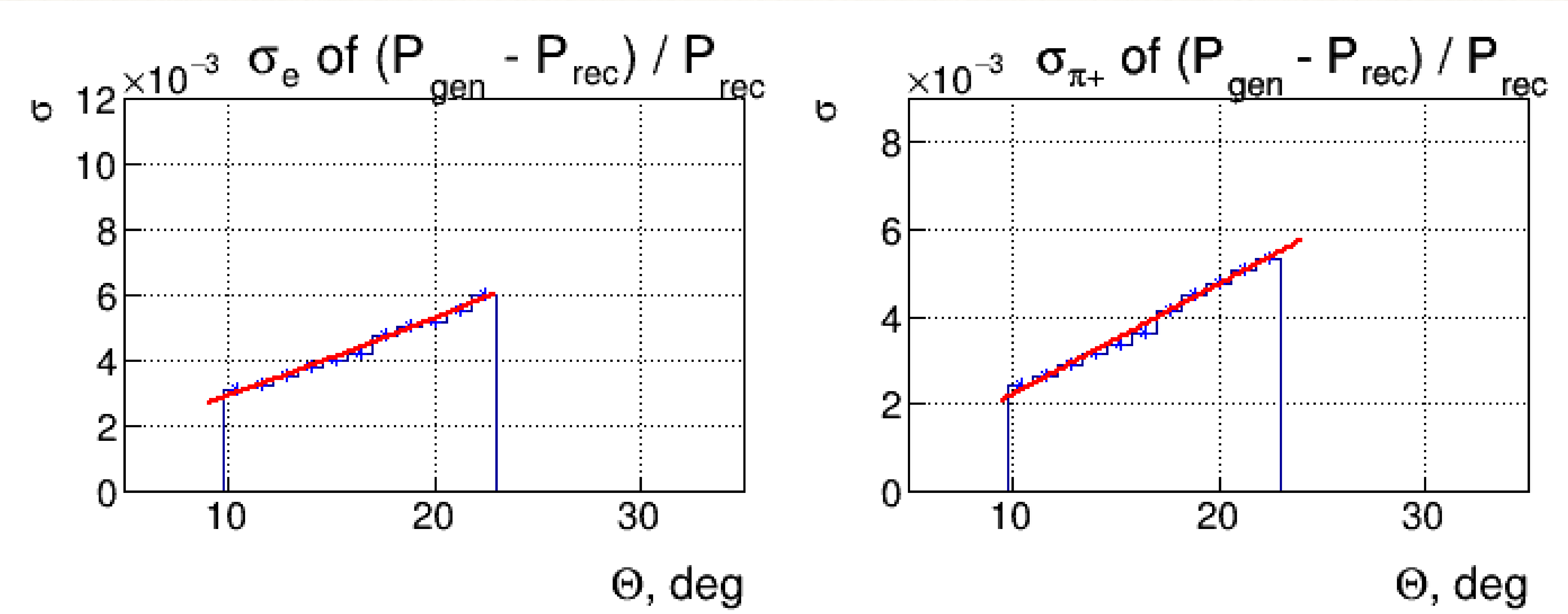
Momentum Resolution Studies

Example of GEMC resolution as a function of theta for e and π^+ ($ep \to e\pi^+ n$) MC



Data vs. MC Comparison - Resolution Studies

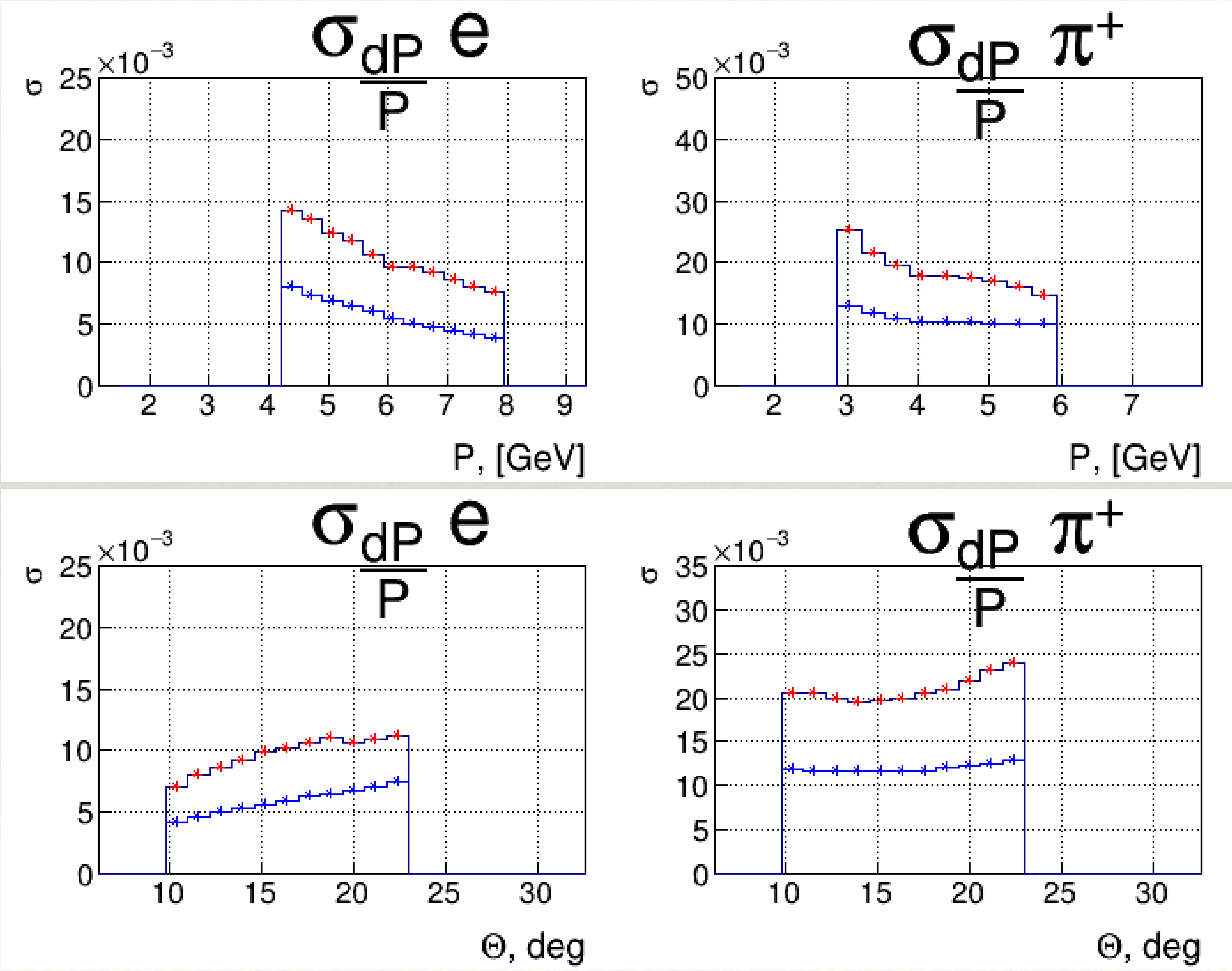
- We introduce smearing function $P_{new} = P_{rec} * (1 + \sigma(\Theta,P) * \mathbf{F} * gaus(0,1))$ where **F** is a smearing factor
- Smearing factor obtained from matching $\frac{\Delta P}{P}$ for data and MC (ΔP is calculated using angles)
- **F** = 0 does not introduce additional smearing $P_{new} = P_{rec}$

Data vs. MC Comparison - Resolution Studies

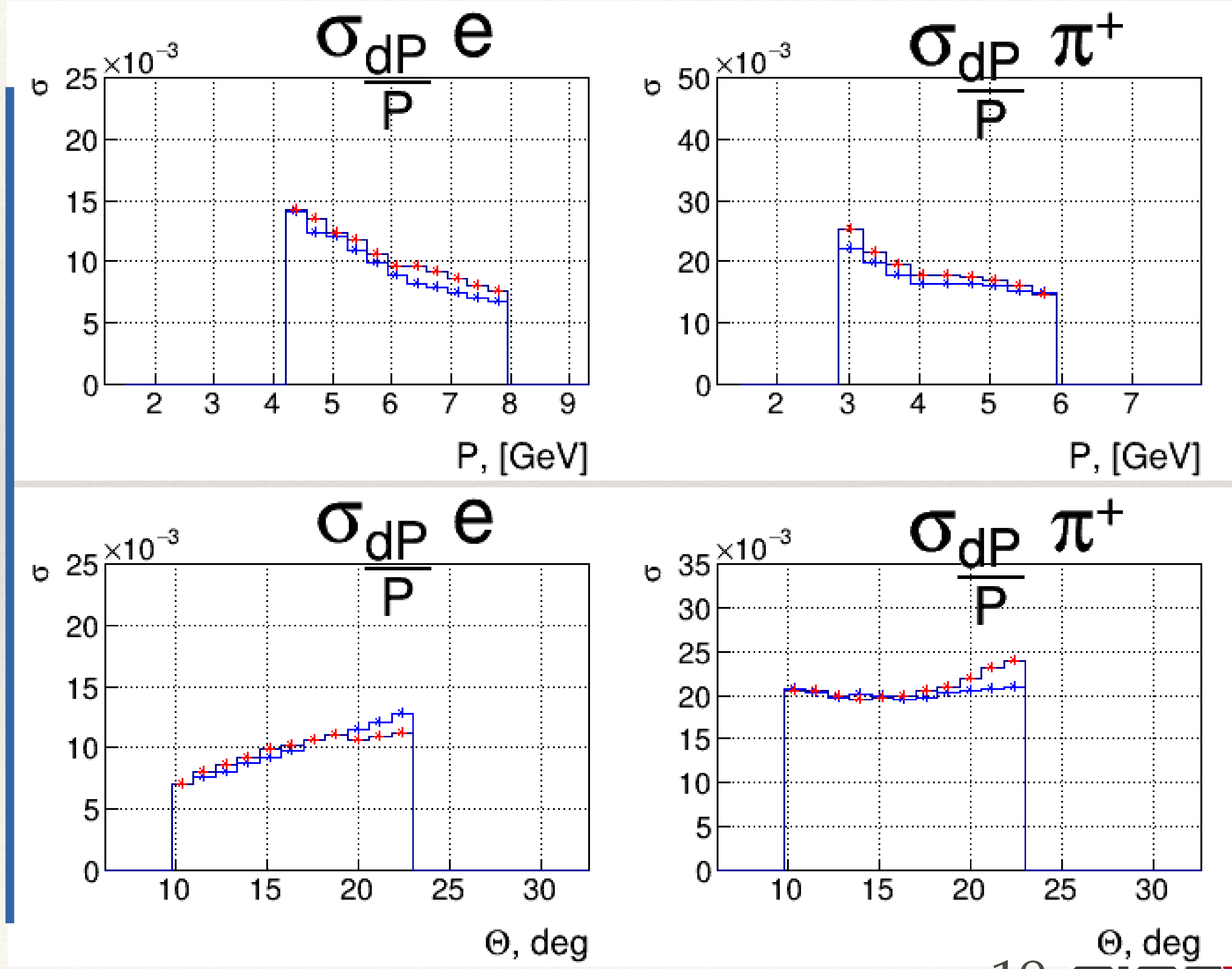
- $2.55 < Q^2 < 10.4$ GeV^2 , $1.15 < W < 2.5$ GeV
- Theta and P range truncated to make sure that fits are reliable

- **Red** – data
- **Blue** – MC

No smearing (F = 0)

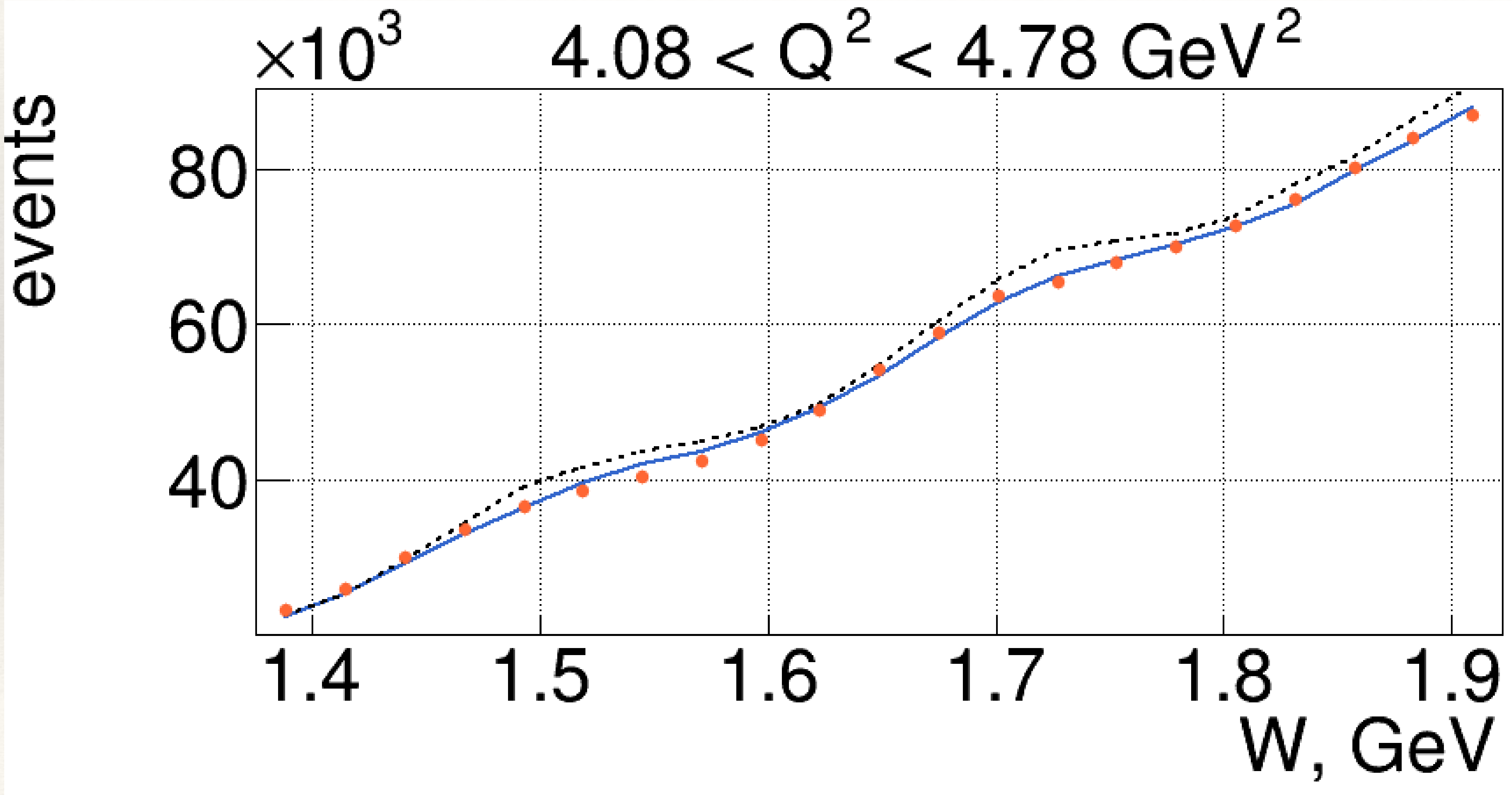


After smearing, F =1.7



Data vs. MC Comparison - Resolution Studies

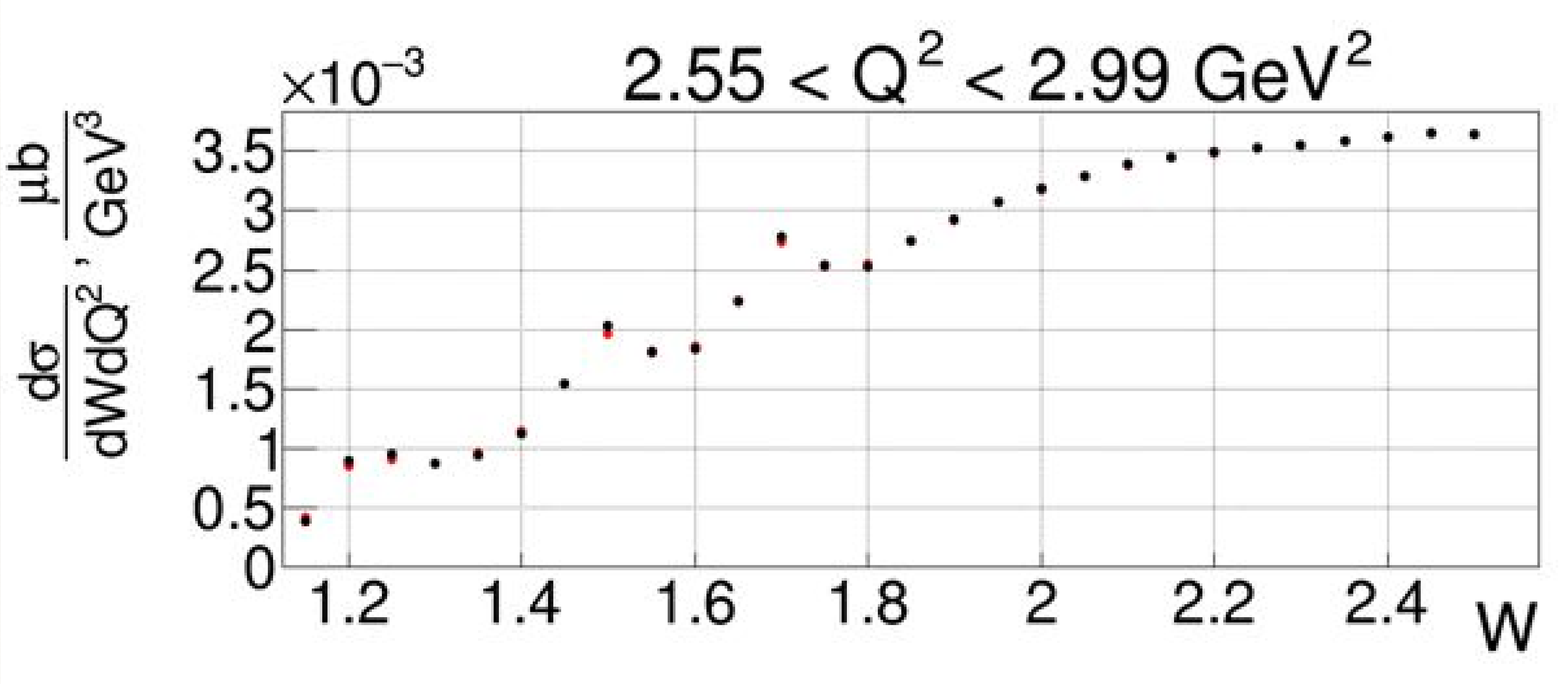
- **Orange** – Data
- **Blue** – MC after smearing
- **Black** – MC no smearing



Momentum Smearing

- Momentum smearing makes peaks more pronounced

- **Red** – no Smearing
- **Black** – with Smearing



Summary

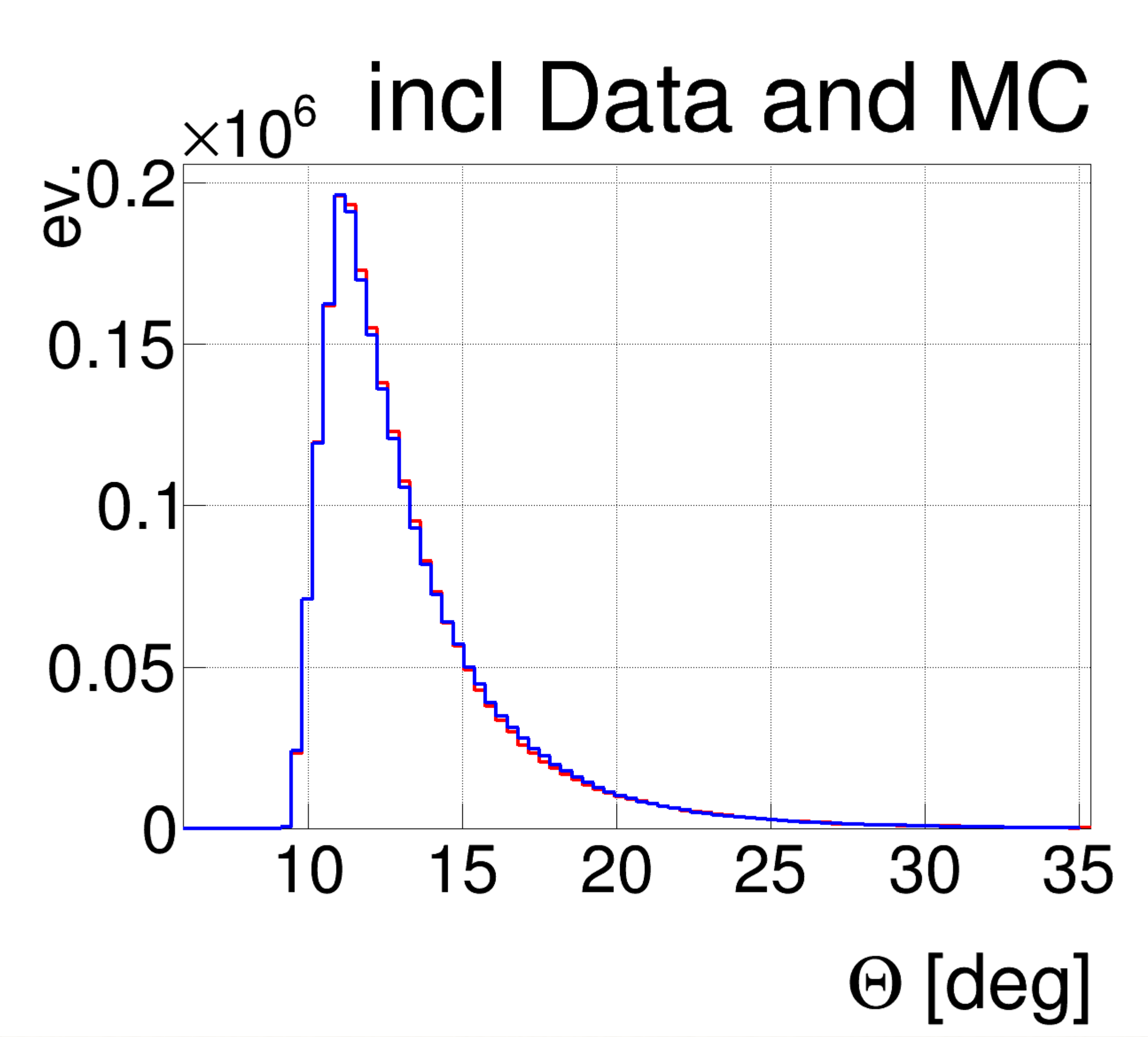
- Main issues have been worked out, we are working on finalizing the responses. Should be ready soon.

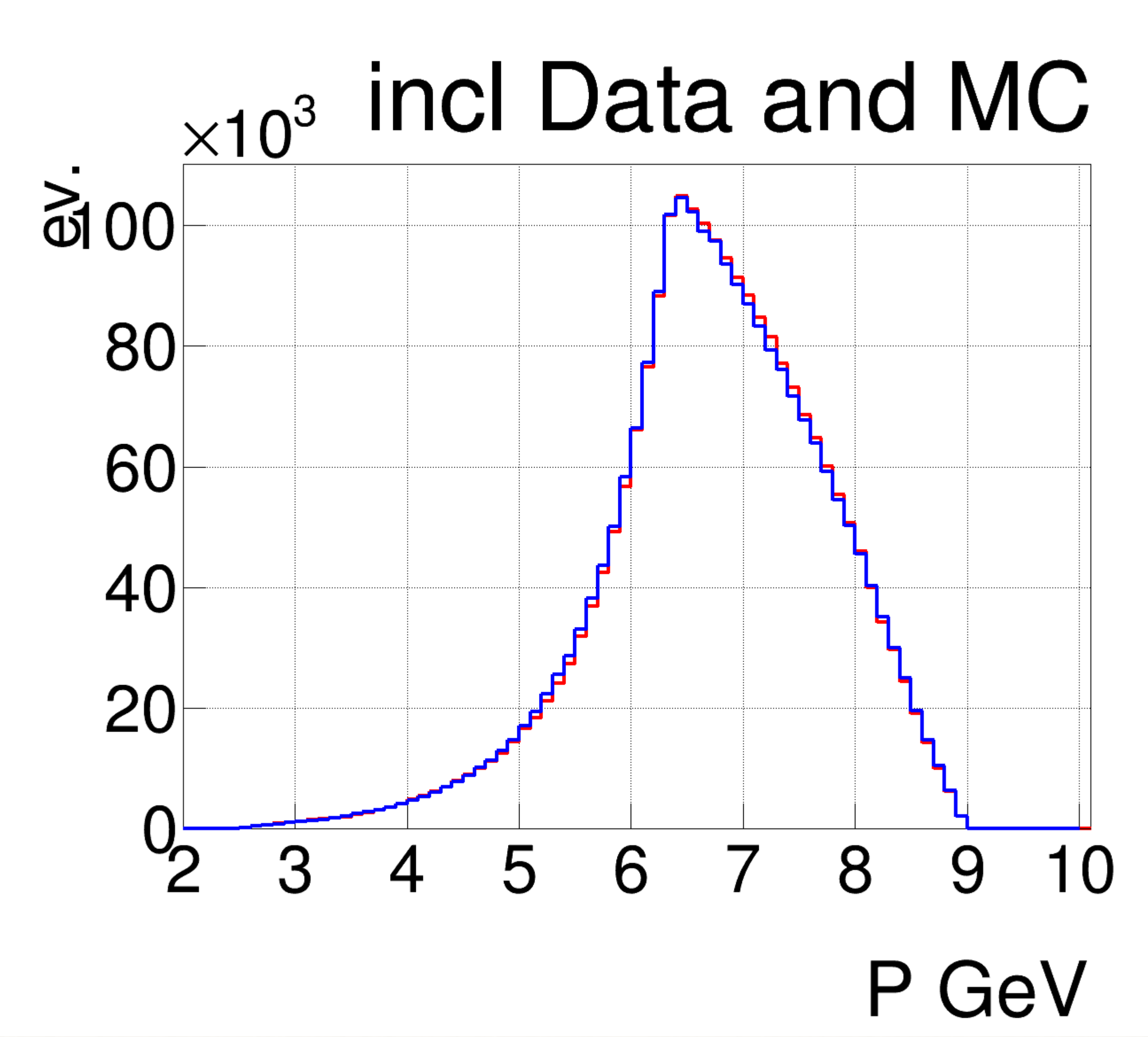
- Preliminary results on inclusive electron scattering cross sections are available from CLAS12 in the kinematic range of $1.15 < W < 2.5$ GeV and $2.55 < Q^2 < 10.4$ GeV^2. Our new measurements show reasonable agreements with world data in overlapping Q^2 regions. Our data extend the knowledge towards high Q^2 .

- Revised analysis note will be submitted as soon as possible.

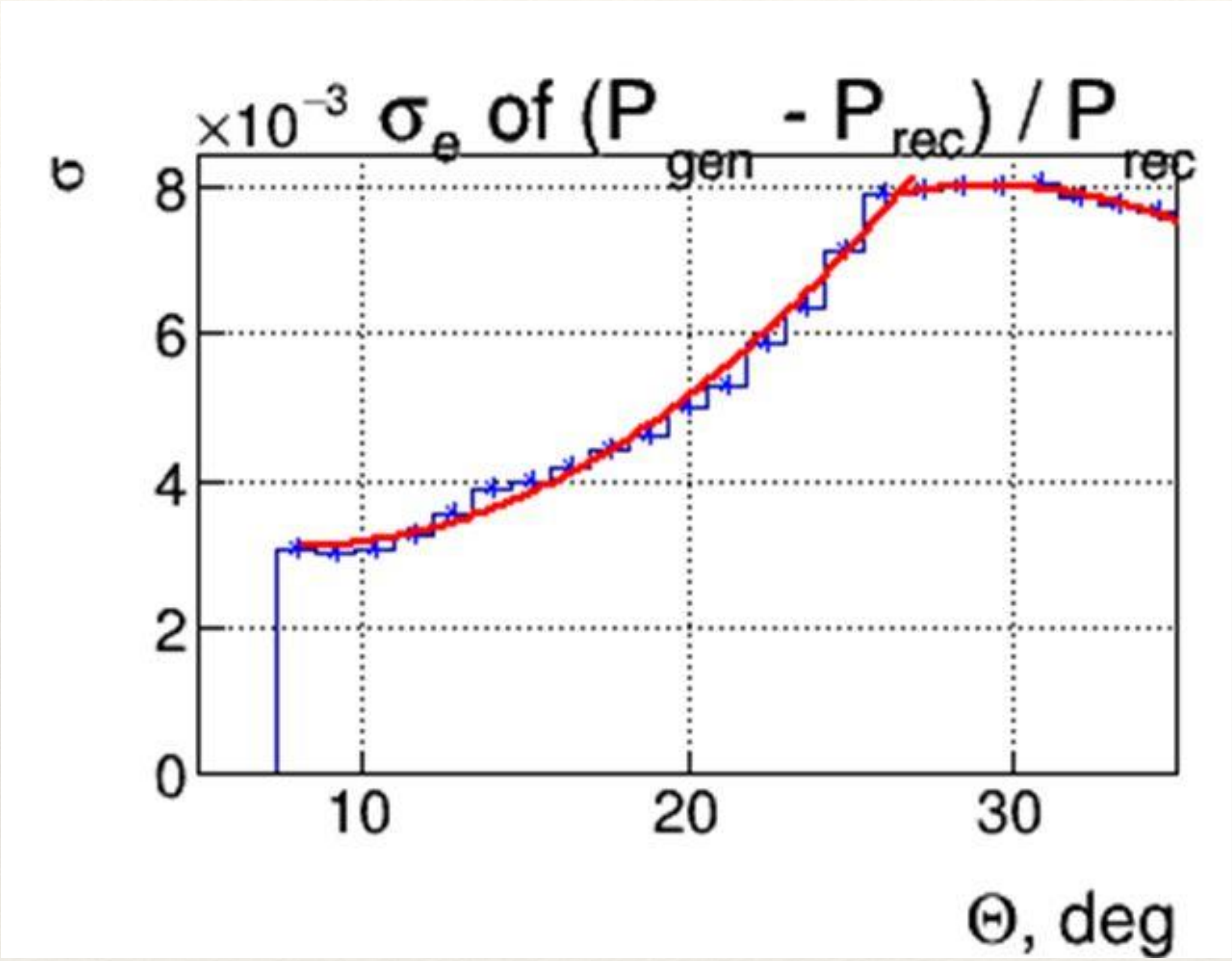
Back Up

Inclusive Kinematics



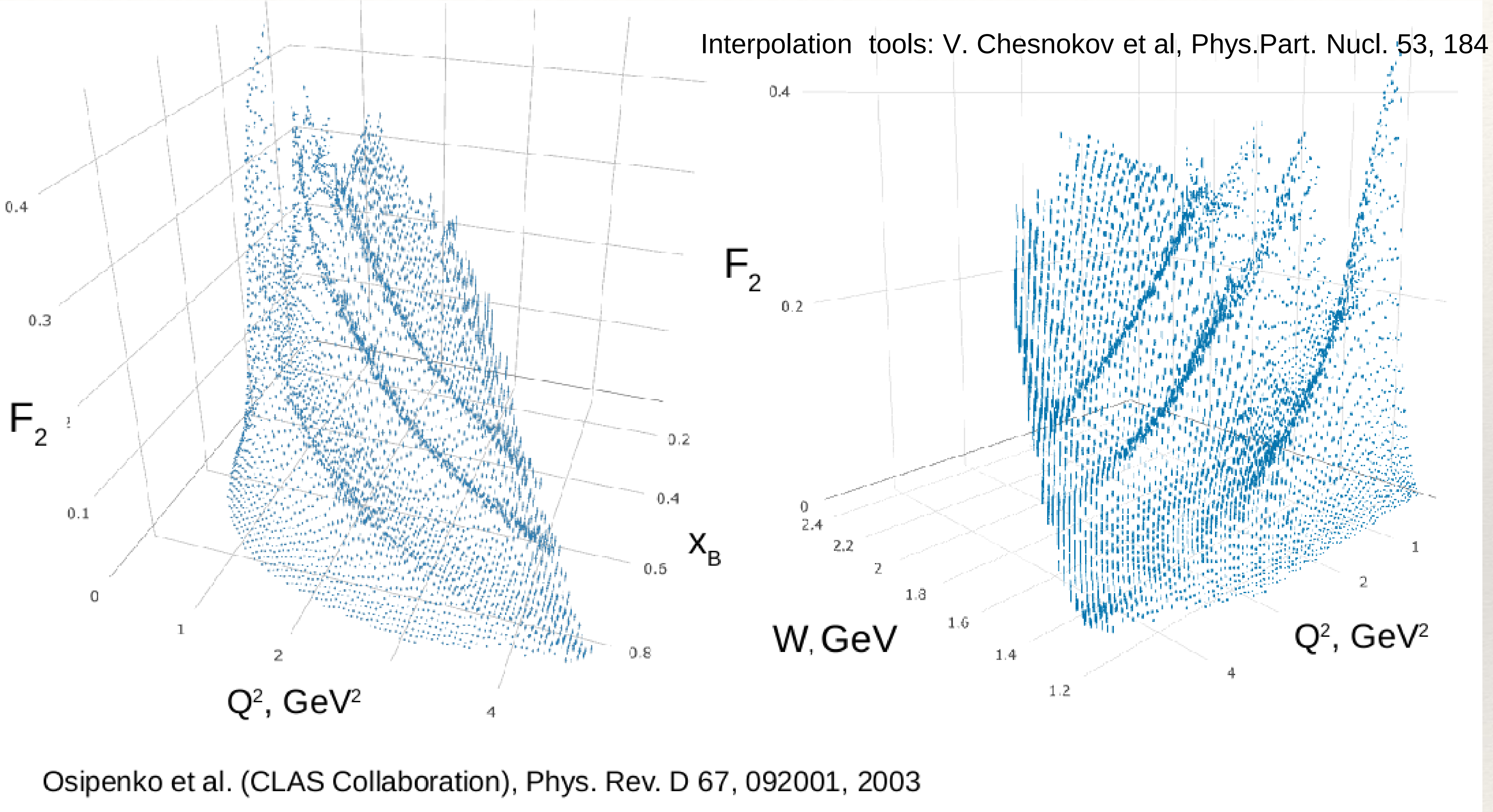


Inclusive Resolution



Evaluation of the Inclusive Structure Functions F_1 and F_2 at 1.07 GeV <W< 4.0 GeV and 0.7 GeV^2 <Q^2<4.0 GeV^2

F_2 (W,Q^2) structure functions were measured with CLAS in the N* region and interpolated onto the kinematic grid of interest by employing 2D polynomial interpolation



Outside of the region covered by CLAS data, the parameterization of the world data was used: M.E. Christy and P.E. Bosted, Phys. Rev. C81, 055213 (2010).
F_1(W,Q^2) structure functions were computed from F_2 (W,Q^2) by employing the values of $R=\sigma_l/\sigma_t$ from the parameterization A.N. Hiller Blin et al., Phys. Rev. C104, 025201 (2021).