Update on Inclusive Cross Sections with CLAS12 RG-A Data

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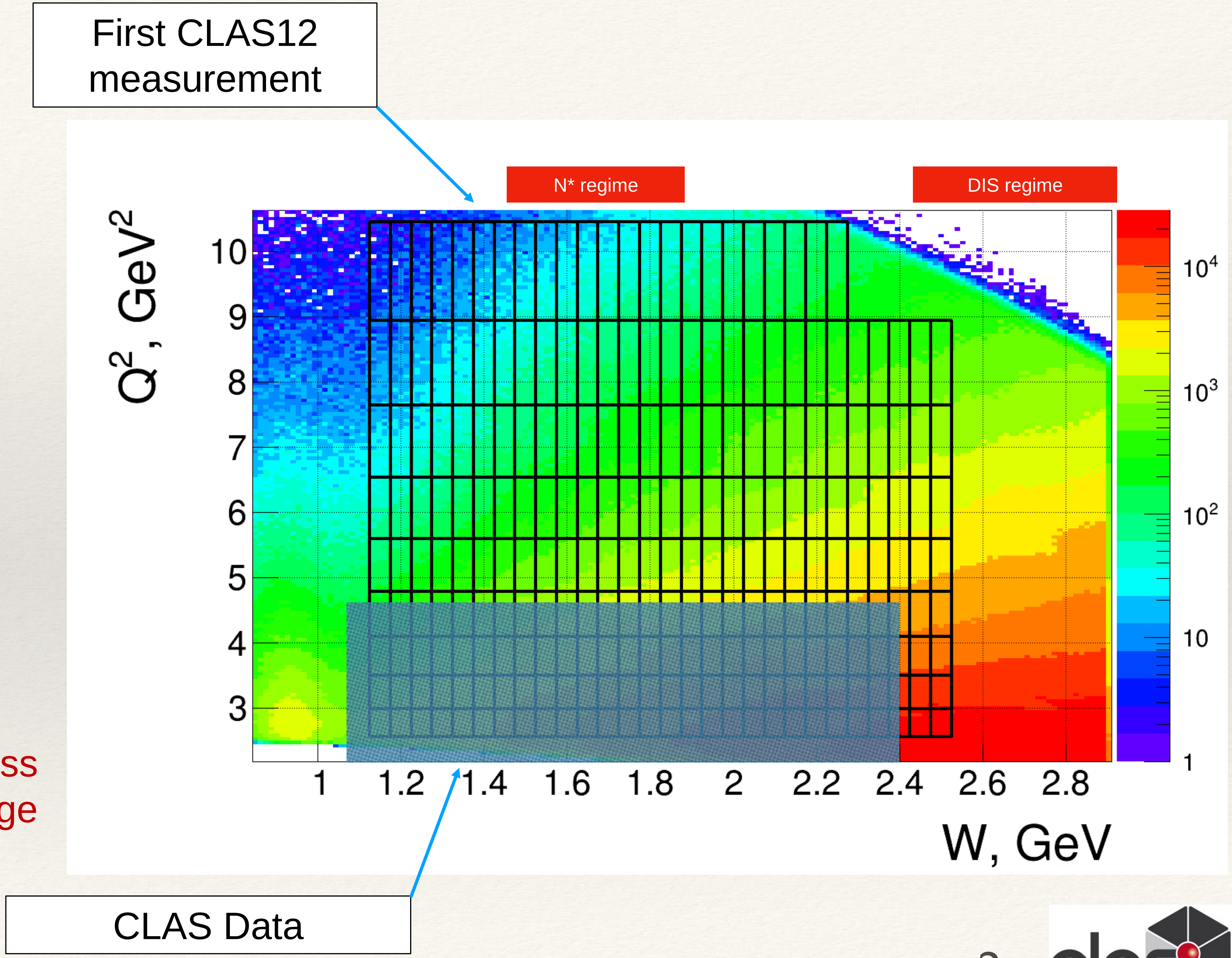
(e,e'X) Cross Sections from New CLAS12 Dataset (RG-A Inbending Runs)

- 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:
  - $2.5 < Q^2 < 10.4$ GeV^2
  - $1.0815 < W < 2.5$ 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



Status and Path Towards Publication

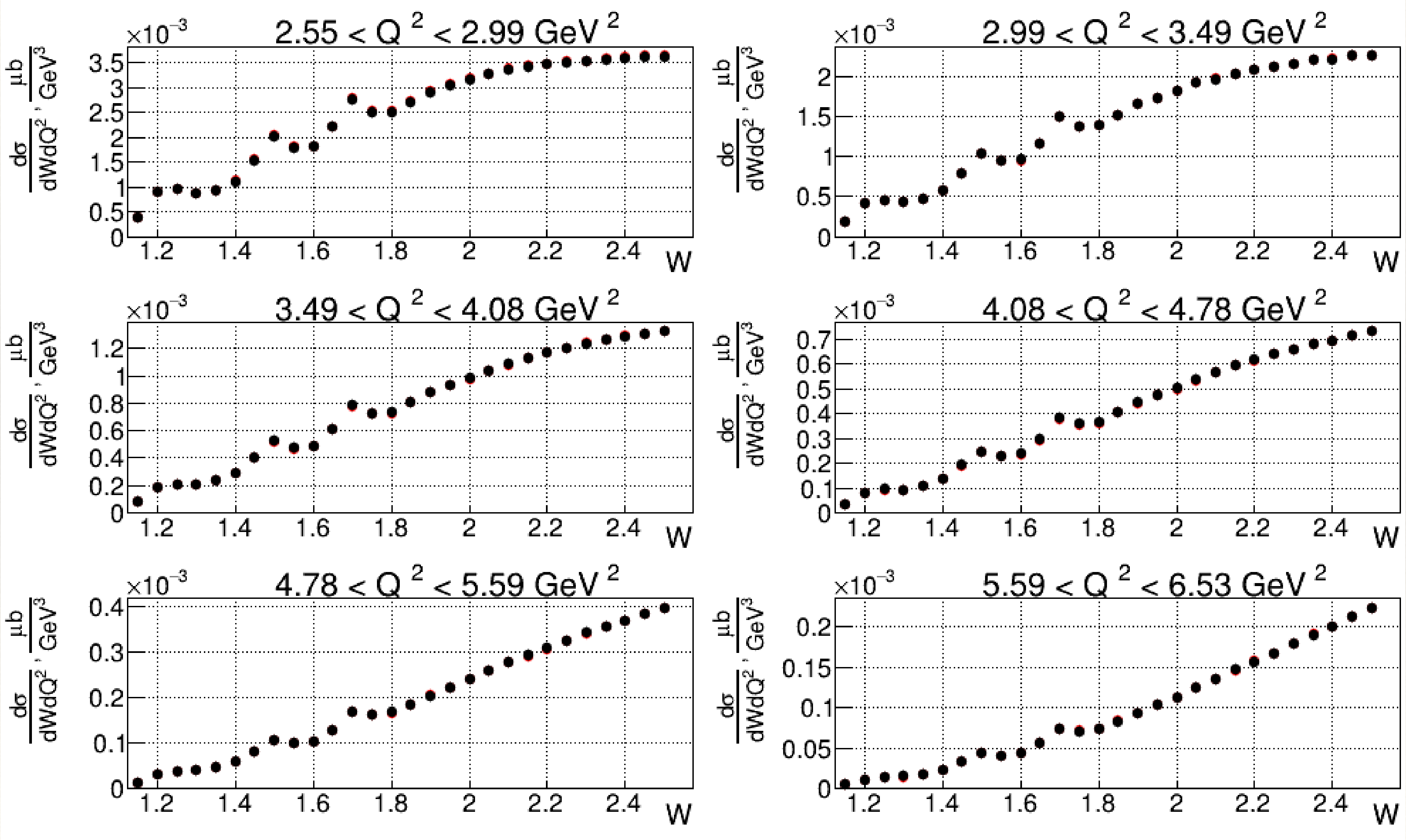
- Reply document to the first round review comments was submitted on February 12
- New updates from the previous CLAS Collaboration meeting:
    - Studies of Beam Rotations and Transverse Shifts
    - Charge symmetric background estimation
    - π^- contamination estimation
    - RC straggling estimation
    - Updates to systematic uncertainty sources (FC charge, background merging)
- Working on paper draft. Will be further developed for upcoming ad hoc review.

Studies of Beam Rotations and Transverse Shifts

Beam Shift XSEC

- The maximum beam offset was found for run 5303 with (x, y) = (0.0391, -0.1395) cm (from CCDB tables)
- An additional simulation was performed where we shifted v_x and v_y by this maximum offset
- XSECs with and without offset were compared

Black – XSECs, MC no offset
Red – XSECs, MC with offset
XSECs is the same within uncertainties



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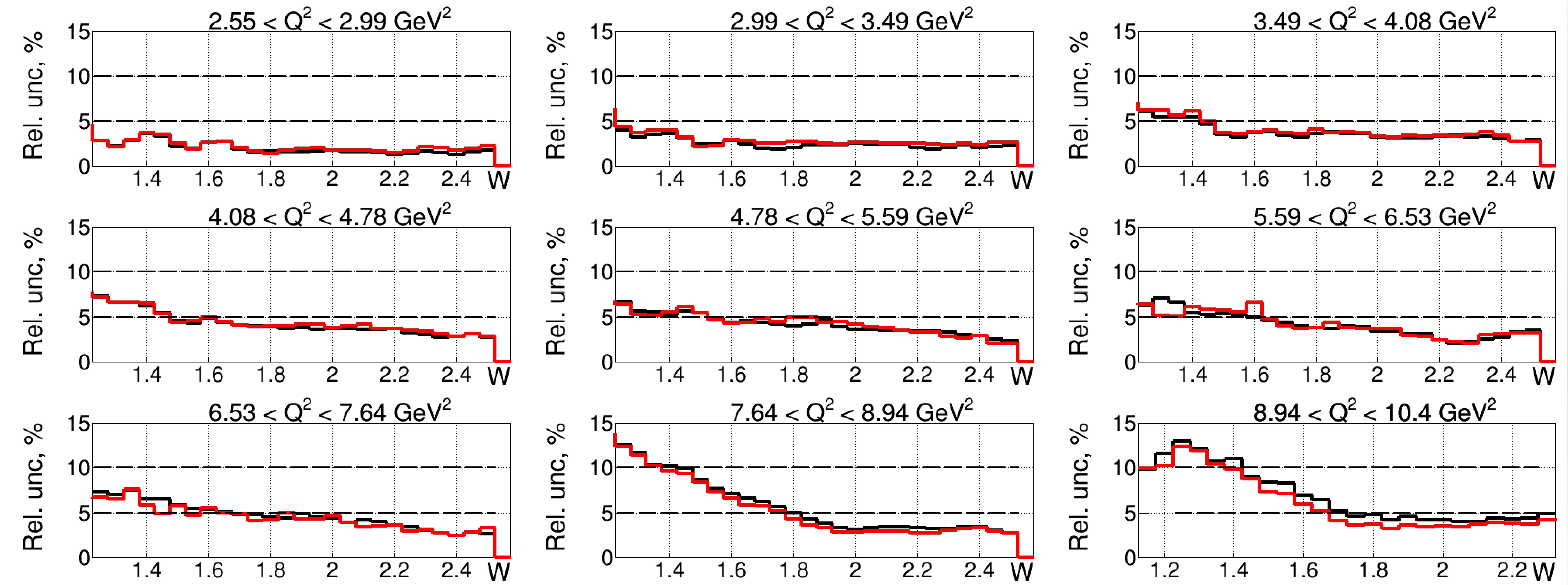
Beean Shift RMS (sectors)

Black – no offset
Red – with offset

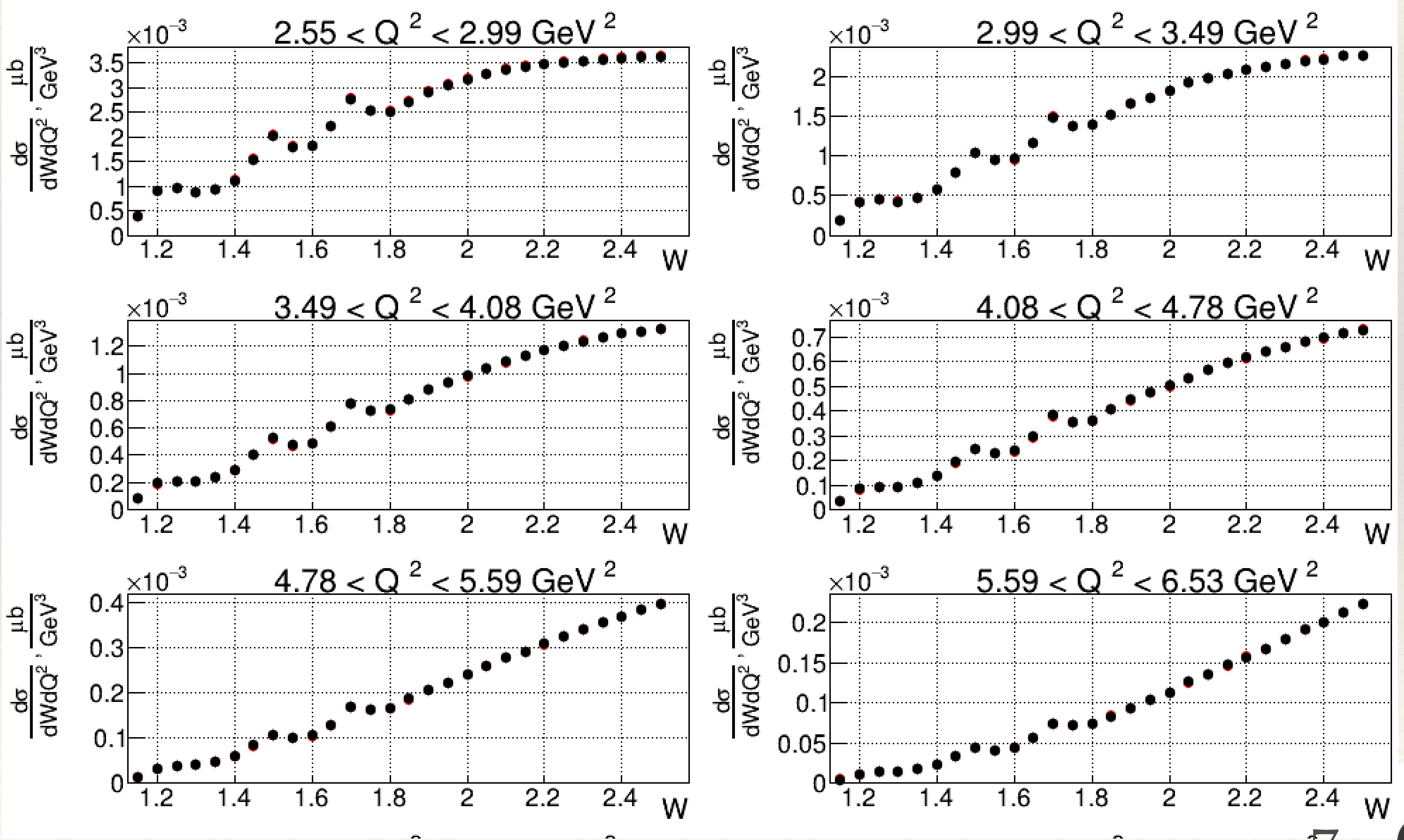
- The maximum beam offset was found for run 5303 with (x, y) = (0.0391, -0.1395) cm (from CCDB tables)
- An additional simulation was performed where we shifted v_x and v_y by this maximum offset
- RMS (calculated from six sectors) with and without offset were compared



Beam Rotations XSEC

- We introduced a rotation such that the beam is not parallel to the z-axis
- Considering a 2 mm beam position shift between the 2C24 and 2H01 BPMs the maximum possible rotation as θ = asin(2 mm/16.257 m) = 0.007° (0.1231 mrad)
- An additional simulation was performed where the beam was rotated about the y-axis by 0.01°
- It caused less than a 2 MeV effect on electron's transverse momentum components p_x and p_z on average

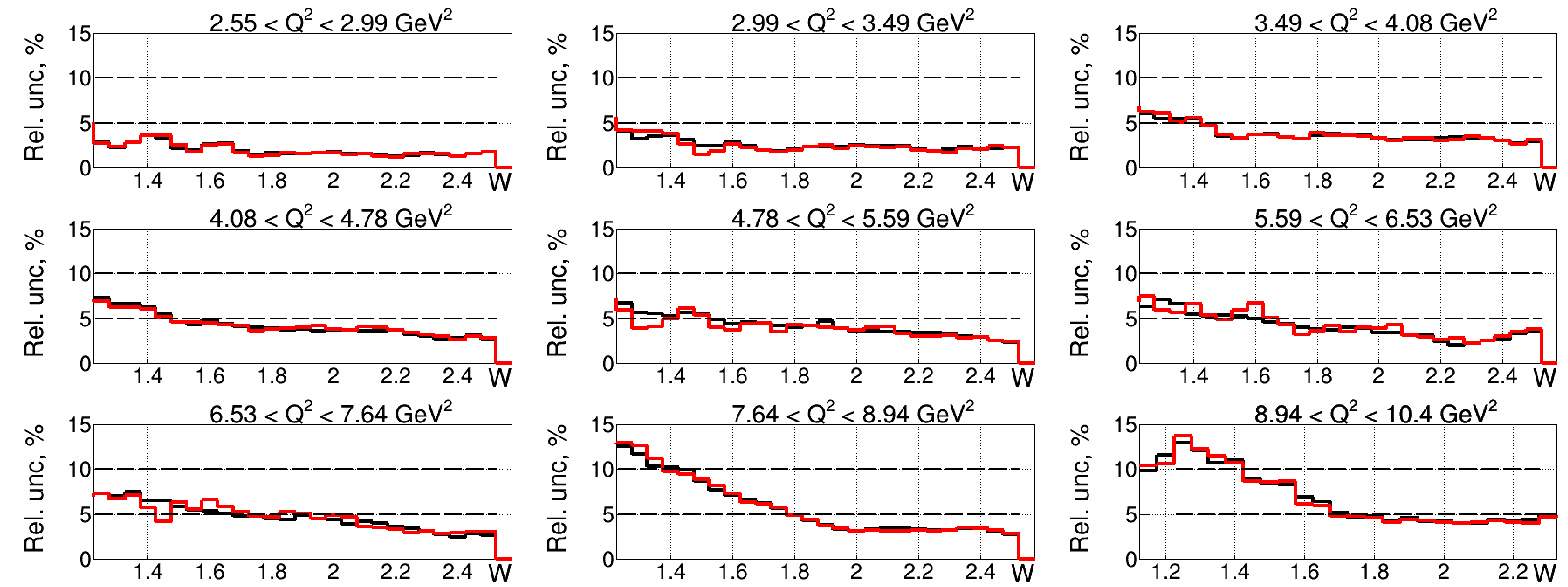
Black – XSECs, MC no beam rotation
Red – XSECs, MC with beam rotation
XSECs almost the same



Beam Rotations RMS (sectors)

Black – RMS, no beam rotation
Red – RMS, with beam rotation

- An additional simulation was performed where beam was rotated about the y-axis by 0.01°
- It caused less than a 2 MeV effect on electron's transverse momentum components p_x and p_z on average
- RMS (calculated from six sectors) with and without beam rotation were compared



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Beam Rotations and Transverse Shifts

Accounting for the beam rotations and transverse shifts did not decrease sector variance in any significant way so it cannot be the leading cause of the sector variance.

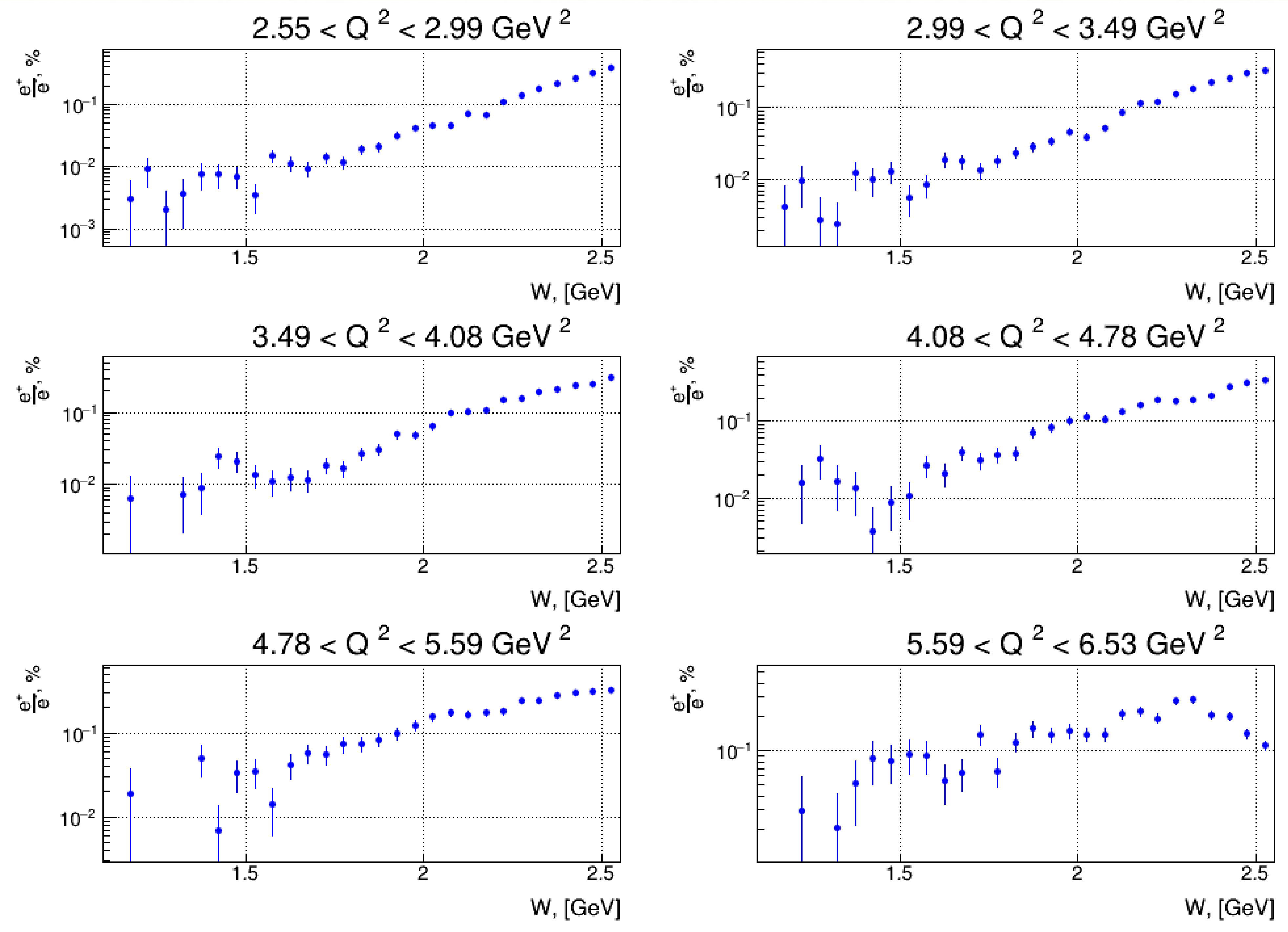
Charge Symmetric Background

Charge Symmetric Background

- The positrons in outbending data should behave like the charge symmetric background electrons in inbending data
- We looked at e^+X and e^-X signals in outbending and inbending data using similar ID as we have in inbending data:

Ratio of positron event yield from the RG-A F18 outbending dataset to the electron event yield from the RG-A F18 inbending dataset (in percent) after applying all cuts.

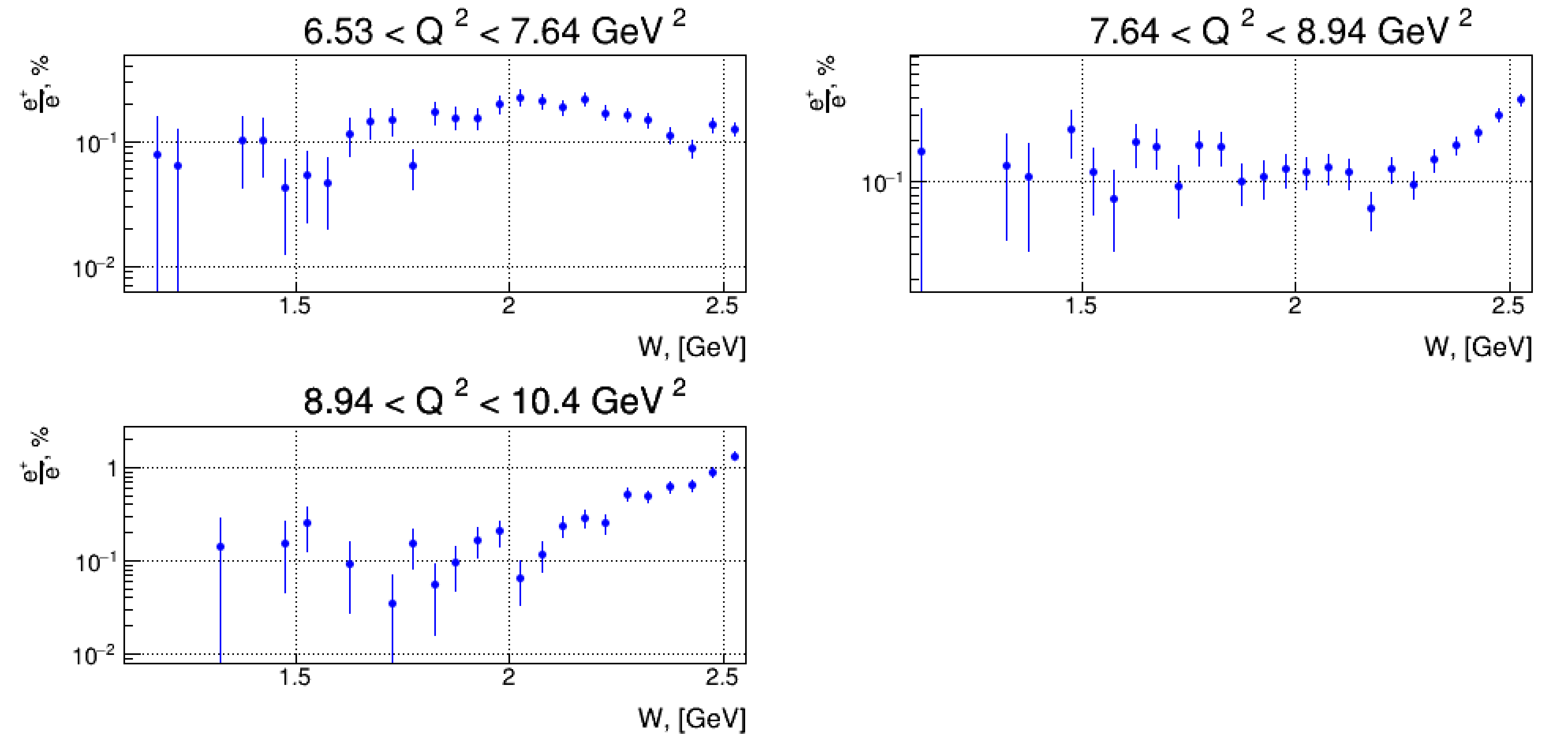
The ratio is below 0.5% in all our kinematics.



Charge Symmetric Background More Q^2 bins

Ratio of positron event yield from the RG-A F18 outbending dataset to the electron event yield from the RG-A F18 inbending dataset (in percent) after applying all cuts.

The ratio is below 0.5% in all our kinematics (W = 2.25 GeV is our last W bin in the very last Q2 bin).



scale-type systematic uncertainty of 0.5% was assigned

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Charge Symmetric Background from Bosted Model

Model is based on a fit of the inclusive pion photoproduction reaction from SLAC data.

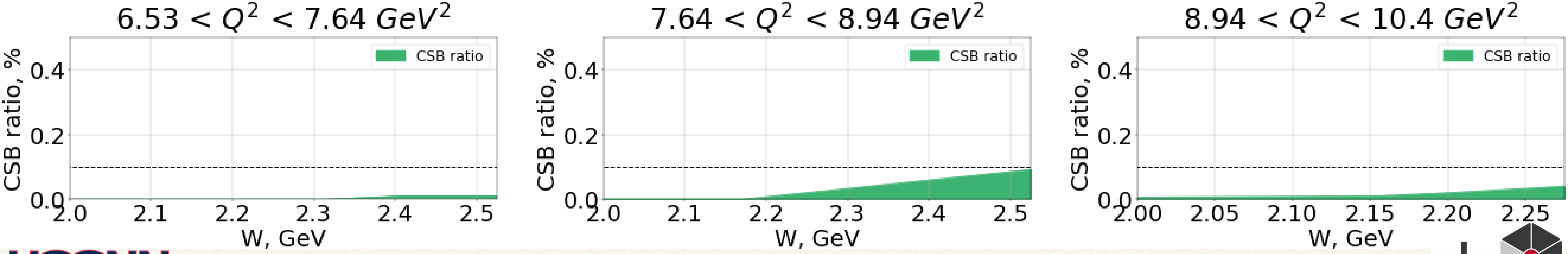
Calculations are done by Gabriel Niculescu, JMU

The code generates π^0 over the full kinematic range of the CLAS12 RG-A data. It then performs the decays $\pi^0 \rightarrow \gamma\gamma$ over all possible polar angles and energies. Finally, it decays the two gammas into $e^+ e^-$.

The code selects the charge symmetric background electrons in our (W, Q^2) bins at the input beam energy and calculates the ratio to the Born cross section.

The computation shows that we do not have any significant contamination (less than 0.1%) because W is less than 2.525 GeV for all but the last Q^2 bin.

The minimum momentum of electrons in our analysis is more than 2.77 GeV, while the charge symmetric background electrons have lower momenta in general.



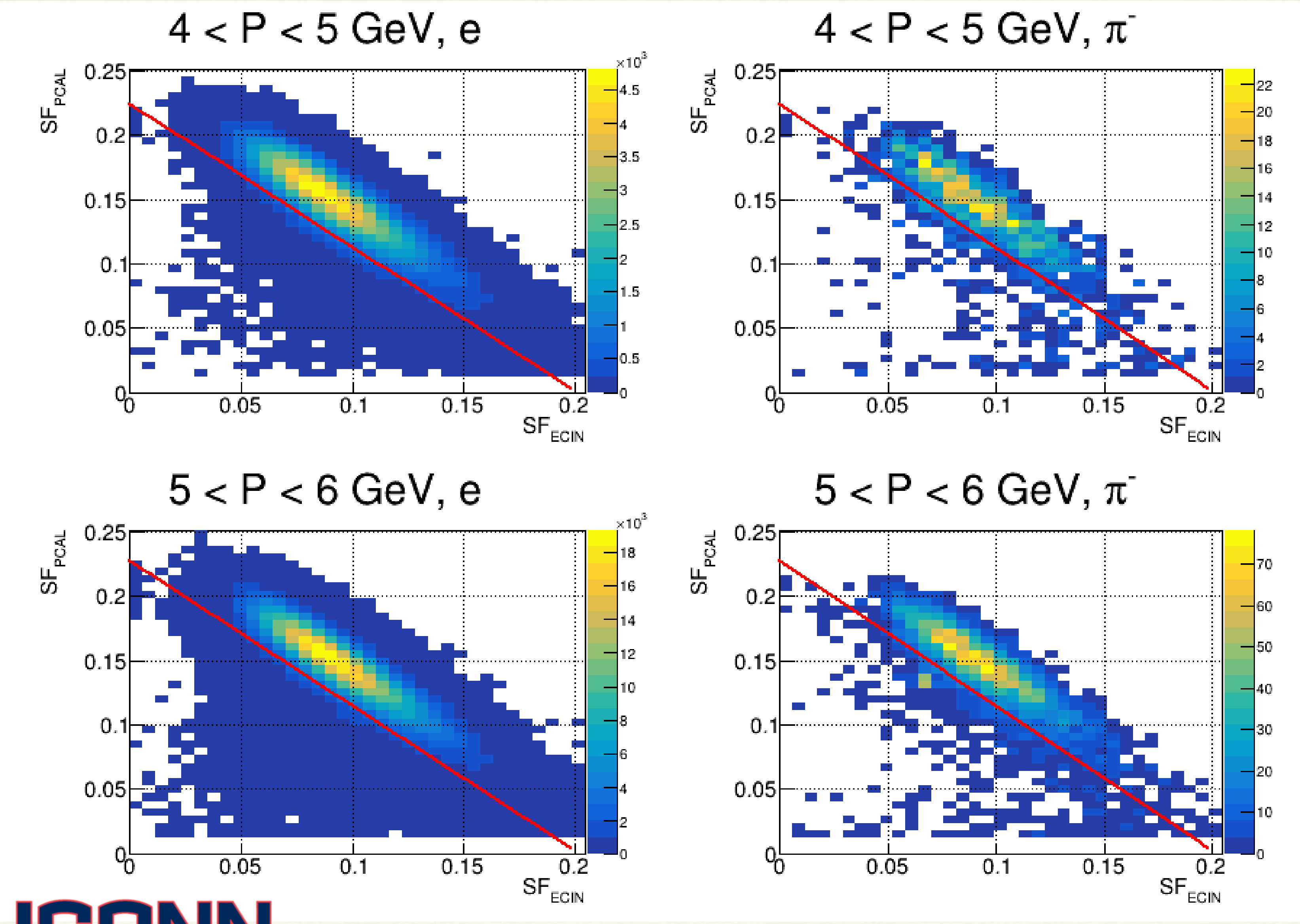
π^- Contamination

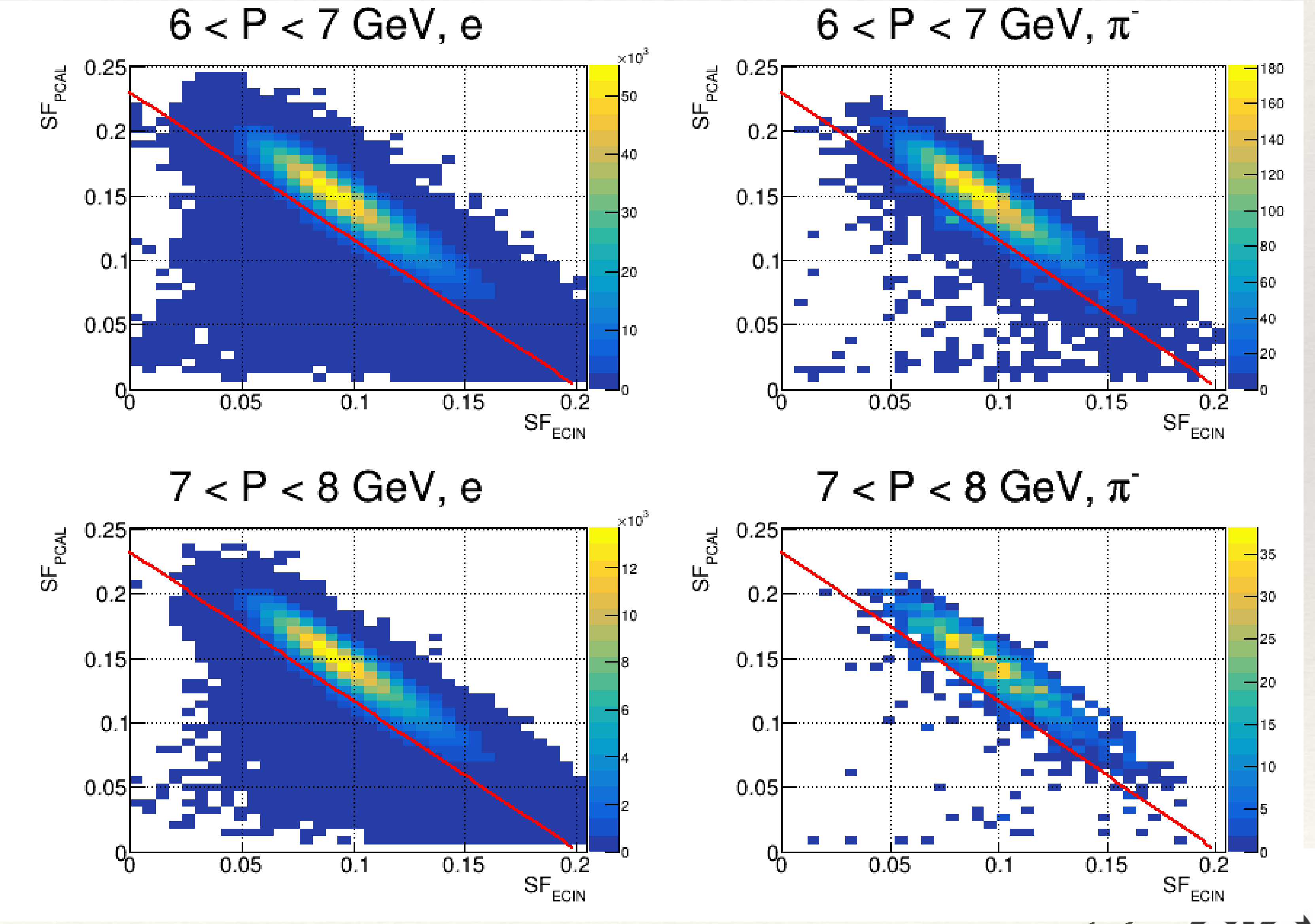
π^- Contamination

- We used already available MC that is done with clasdis EG
- Assumptions:
    - The DIS process is responsible for the creation of the dominant fraction of high-momentum pions in the RG-A dataset. These pions only appear for W $\gtrsim$ 2 GeV.
    - The physics model in the clasdis EG contains accurate ratios of final state π^- and electrons in its designed DIS kinematic region to quantitatively estimate the π^- contamination for $Q^2 > 1$ GeV^2 and $W > 2$ GeV.
    - The contamination of π^- in our electron sample for $W > 2$ GeV can be used to set an upper limit on the π^- contamination in the entire kinematic range of this analysis for W from 1.125 GeV to 2.5 GeV.
- All reconstructed negative tracks were matched with the generated particles using theta and phi angles.

π^- Contamination

- Plots of the partial sampling fractions (PCAL vs. ECin) for electrons (left column on each plot) and π^-s (right column) that pass our event selection cuts in different momentum bins from the clasdis MC.
- The ratio of π^- to electrons is in the range from 0.2% to 0.5% with the ratio increasing as the particle momentum decreases.
- A single scale-type systematic uncertainty on the cross sections of 0.5% has been assigned.





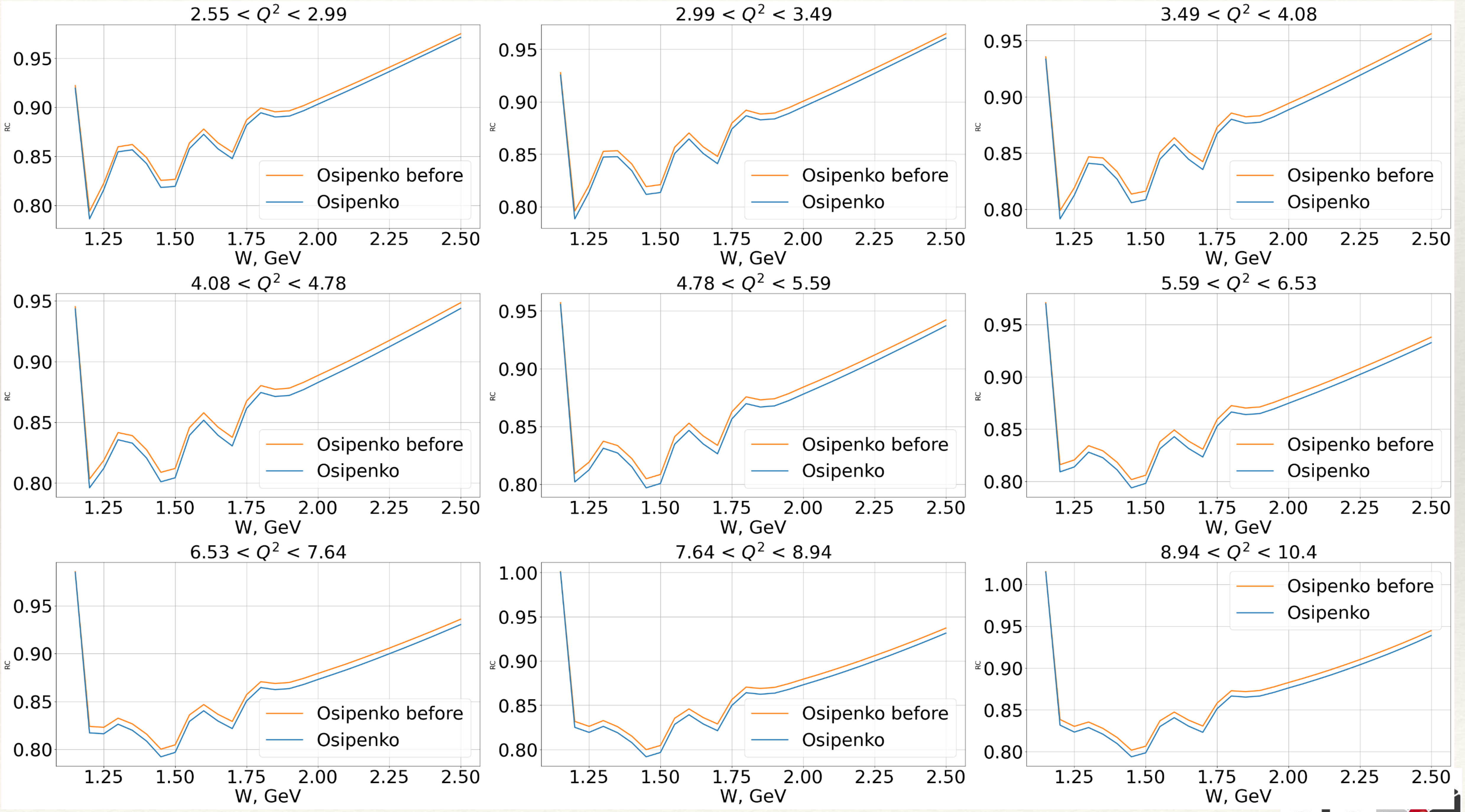
RC Update

Straggling After Interaction

- Straggling effect before the scattering in the RC calculations was introduced at the event generator level.
- We double-counted straggling effects after the scattering since RC calculations include it and GEMC adds the same effect.
- We estimated RC using a separate code accounting for:

1. Only straggling before the interaction (orange)
2. Straggling before and after (blue)

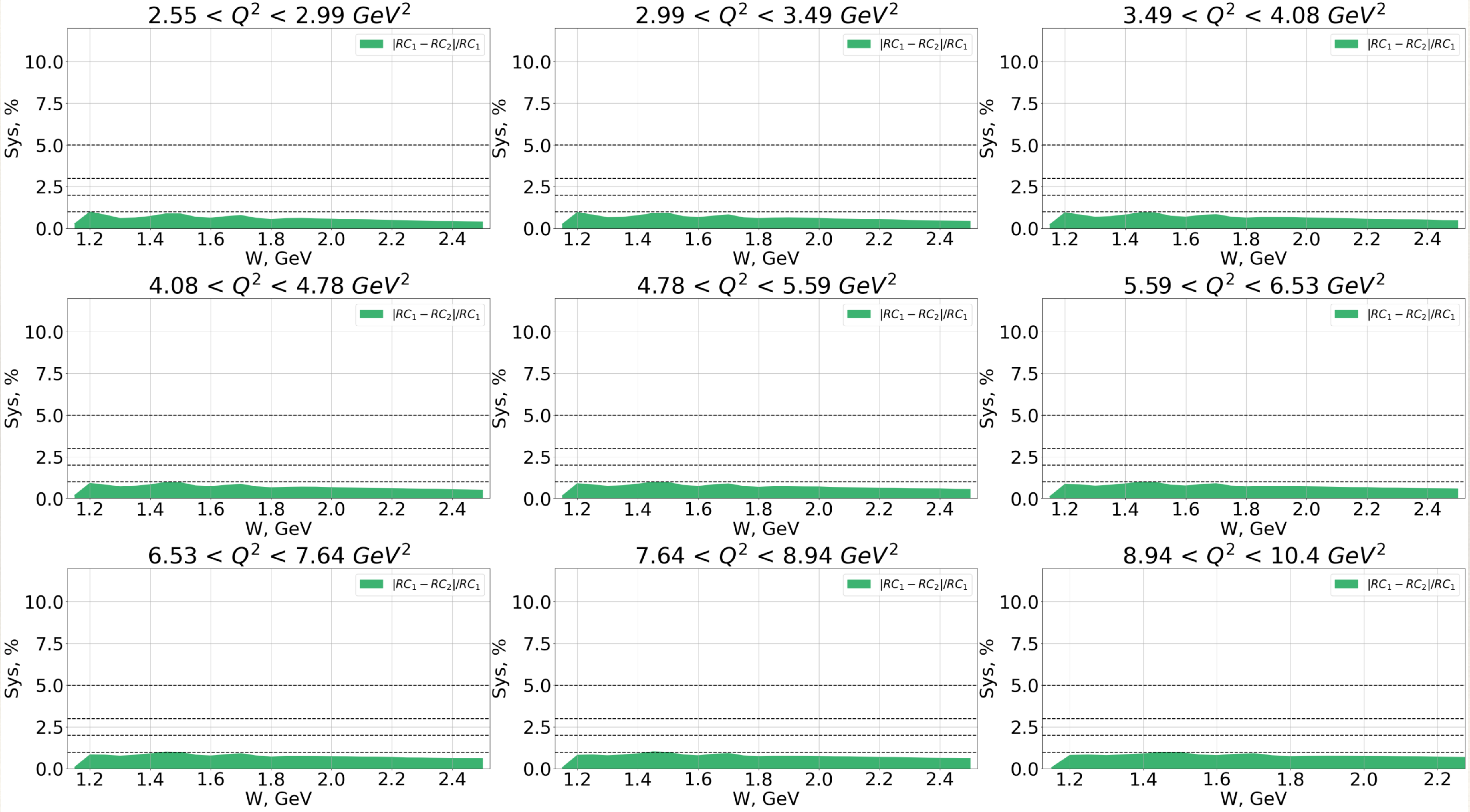
The code is provided by Mikhail Osipenko - Working Group Review Committee member



Straggling After Interaction Ratio

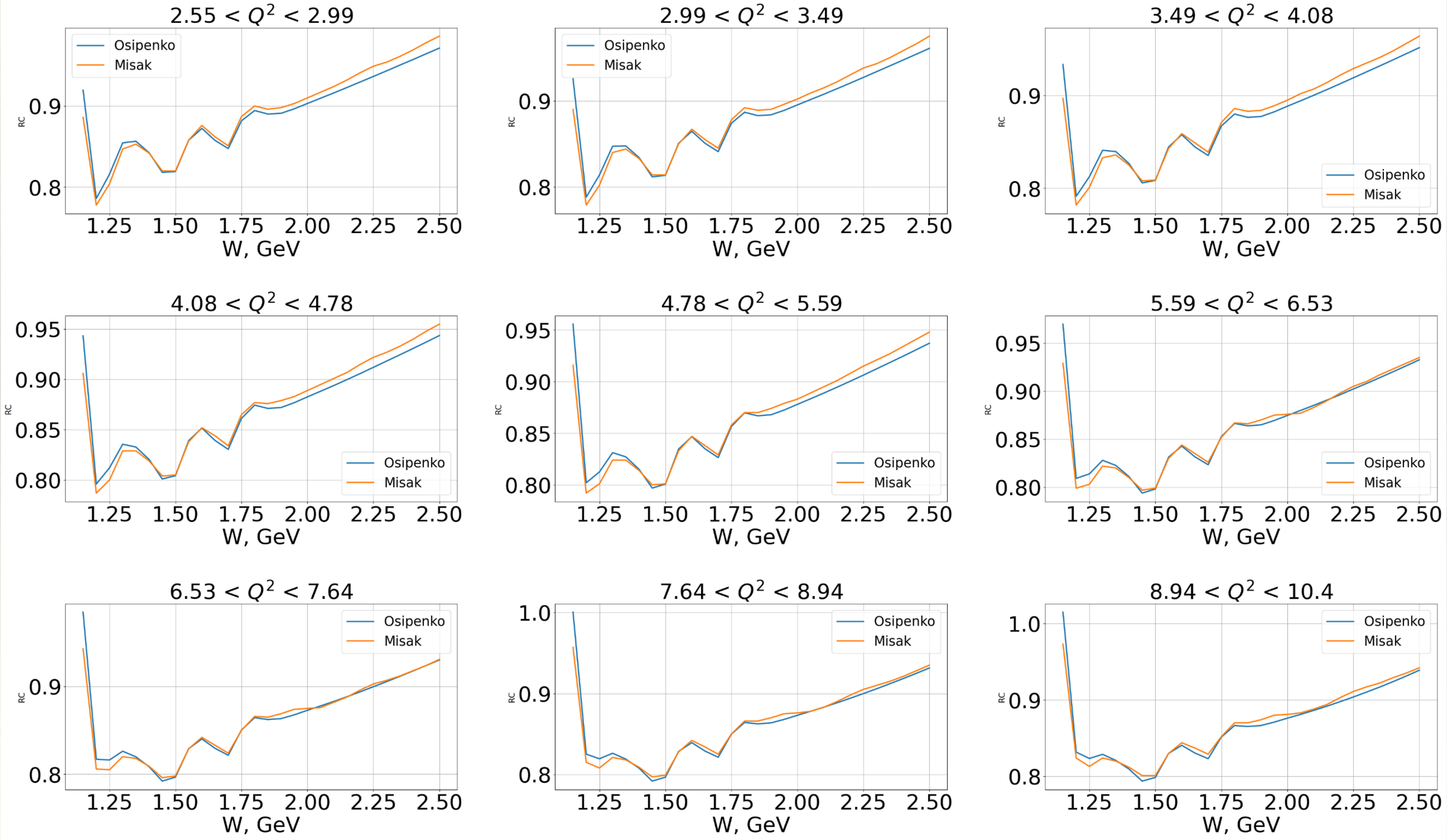
Uncertainty associated with double counting of straggling after the interaction point.

100*abs(RC_full – RC_before_only)/ RC_full



RC Cross Check

- We computed RC using provided code to cross check our RC estimation.
- Both codes uses Arie Bodek parametrization for inelastic cross sections. We put the same parameters that were obtained from the iteration procedure into both codes. Elastic cross sections were the same in both codes.
- We have pretty good agreement between RCs calculated with two independent codes.



Systematic Uncertainties Update

Systematic Uncertainties

- As a result of multiple improvements in analysis procedure we were able to decrease the sector dependence of the inclusive cross sections to 4.4% on average.

- The conclusion of the Task Force Report is that the discrepancy between the efficiency derived from data and from Monte Carlo at the production beam currents for RG-A F18 is "of the order of approximately 3%" link to the report:

https://misportal.jlab.org/mis/physics/clas12/viewFile.cfm/2020-005.pdf?documentId=70

- Beam charge uncertainty: the gated beam charge is calculated as: Charge = BB_attenuation(gated_scaler − offset · t_gated)/slope. Slope is very precise (0.1%). Estimation of the BB_attenuation factor has been estimated to be smaller than 1% based on the variance of this quantity accumulated from the collected data over time. Private communication with Rafayel Paremuzyan.

- The mechanical tolerance of the target call is quoted as 5.0±0.05 cm for a systematic uncertainty of 1% on the overall target length. See R. Miller, Hall B Saclay Target Cell Location When at Operating Temperature for more details.

- Torus field map uncertainty was estimated as 3% based on MCs shown at the last CLAS Collaboration meeting.

Systematic Uncertainties

Average Systematic Uncertainty	
Bin-By-Bin Sources	Uncertainty [%]
Minimum deposited energy in PCAL cut	0.002
Sampling fraction cut	0.02
Bad elements cut	0.074
DC fiducial cut	0.11
PCAL fiducial cut	0.12
Smearing	0.28
Bin-centering corrections	0.32
Empty target contribution subtraction	0.33
Radiative corrections	0.36
Momentum corrections	0.464
Deconvolution method	0.55
Vertex-z cut	0.571
Theta-Phi cut	0.71
Electron pion separation cut	0.787
Sector dependence	4.41
Total Bin-By-Bin	4.85

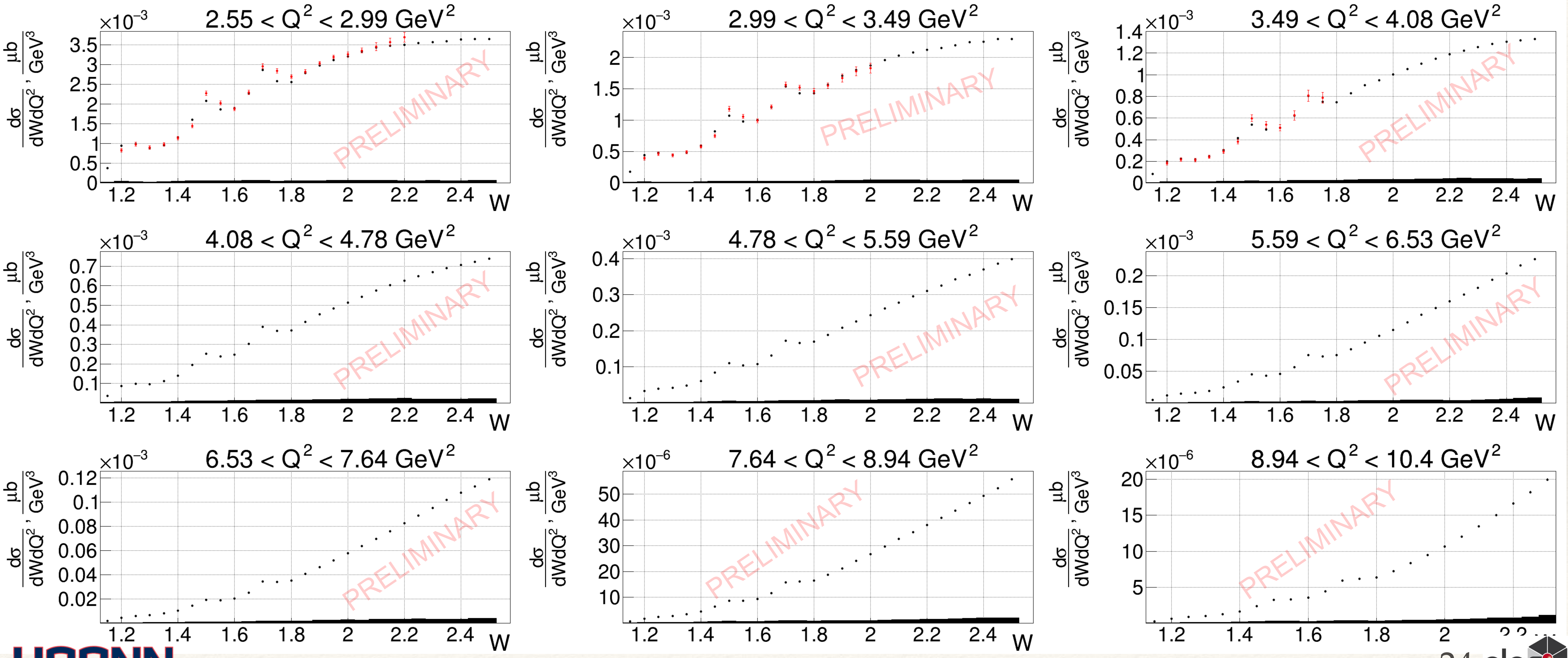
Current estimation of systematic uncertainty is 6.79% on average, where bin-by-bin and scale sources are responsible for equal contributions.

Scale Type Sources	Uncertainty [%]
Pion contamination	0.5
Charge symmetric background	0.5
Target length uncertainty	1.0
Beam charge uncertainty	1.0
Background merging	3.0
Torus field map	3.0
Total Scale Type	4.53

Total Bin-By-Bin and Scale	6.79

Preliminary (e,e′X) Cross Sections

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



Summary

- Round 2 review in progress
- 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 available knowledge towards high Q^2 within a broad coverage over W from 1.15 to 2.5 GeV in every Q^2 bin

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Back Up

Charge Symmetry Background

- Minimal ID:
  - QADB = 'Golden'
  - EventBuilder ID = -11 or 11
  - Forward Detector only
  - $-8 < v_z < 2$ cm
  - $1.15 < W < 2.5$ GeV
  - $2.55 < Q^2 < 10.4$ GeV^2

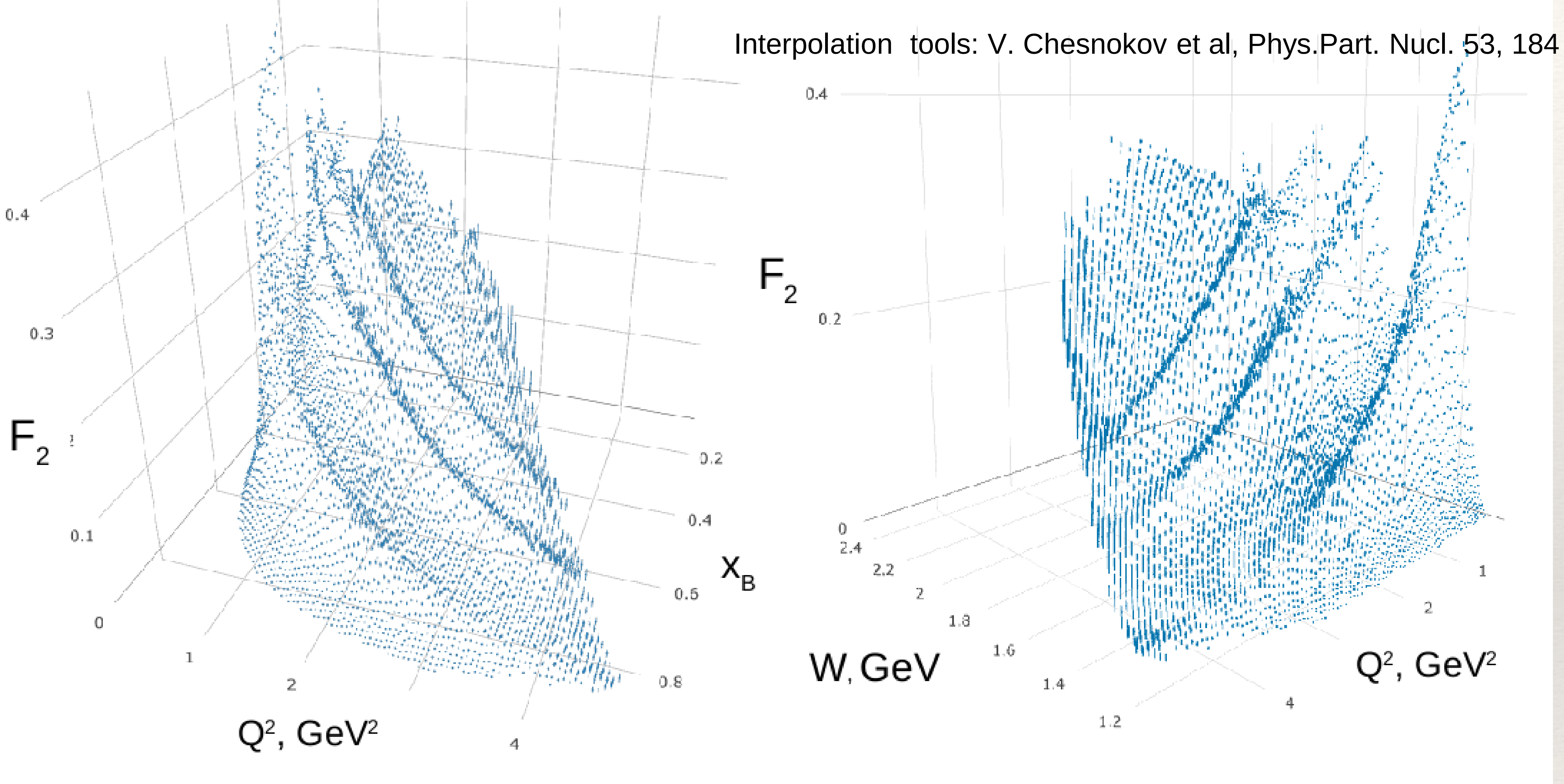
Outbending Run List														
5424	5425	5426	5428	5429	5430	5431	5432	5435	5436	5437	5438	5439	5440	5441
5442	5443	5444	5445	5447	5448	5449	5450	5451	5452	5455	5460	5466	5467	5468
5469	5470	5471	5472	5474	5475	5476	5478	5479	5480	5481	5482	5483	5485	5486
5497	5498	5499	5500	5507	5516	5517	5518	5519	5520	5522	5523	5524	5526	5527
5555	5556	5557	5558	5559	5561	5569	5570	5571	5572	5573	5574	5577	5578	5624

TABLE XIII. Outbending data runs used for the pair symmetric background estimation.

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

Interpolation tools: V. Chesnokov et al, Phys.Part. Nucl. 53, 184 (2022)



Osipenko et al. (CLAS Collaboration), Phys. Rev. D 67, 092001, 2003

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).