Inclusive electron scattering in the resonance region at high Q^2

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Science at the Luminosity Frontier: Jefferson Lab at 22 GeV, Frascati, Italy

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Disclaimer:

This is just GN's $0.02 worth...

- Many people contributed (directly or indirectly) to this talk (and they will hopefully be acknowledged as appropriate). Especially:
- **Valerii Klimenko (PhD student, UConn)**
- ...and they all have done their level best! Thanks!
- Therefore, all **inaccuracies, misstatements, controversial, or just plain wrong statements** are mine alone!
- That said, onward to ...

Outline:

- Motivation
- Exp. Setup & Results
- Conclusion

Motivation (I)

Inclusive lepton–nucleon scattering...

- Epitomizes (one of) the overarching goals of the field: represent the nucleon structure* in terms of parton distribution functions (PDFs)
- **(Inclusive) cross–section** $\rightarrow$ **Structure function(s)** $\rightarrow$ **PDFs**.
- While one can access the latter through other means (Drell-Yan, lepton & W charge asymmetry, jets, etc.), the bulk of the data comes from $p(e, e')X$.
- Over the past 50+ years, the $p(e, e')X$ reaction has be probed over a large kinematic range: $x \in (\sim 10^{-4}, 0.9)$, Q^2 from ~ 1 to 10^4 GeV^2.
- **However...** most of the data is in the DIS region (low x, high W)
- In the high x, low(-ish) W...

Motivation (II)

High x inclusive scattering...

- Substantial difficulties in separating perturbative/non–perturbative processes:
  - higher twists
  - target mass corrections
  - resonance contributions
- "the" region to study if one is interested in **strong QCD** ($\alpha_s/\pi \sim 1$)
- *ditto* if one wants to chart the transition between strongly coupled & perturbative QCD regimes.

"The fact that something seems impossible shouldn't be a reason to not pursue it, that's exactly what makes it worth pursuing."
F. W. Nietzsche

Motivation (III)

...

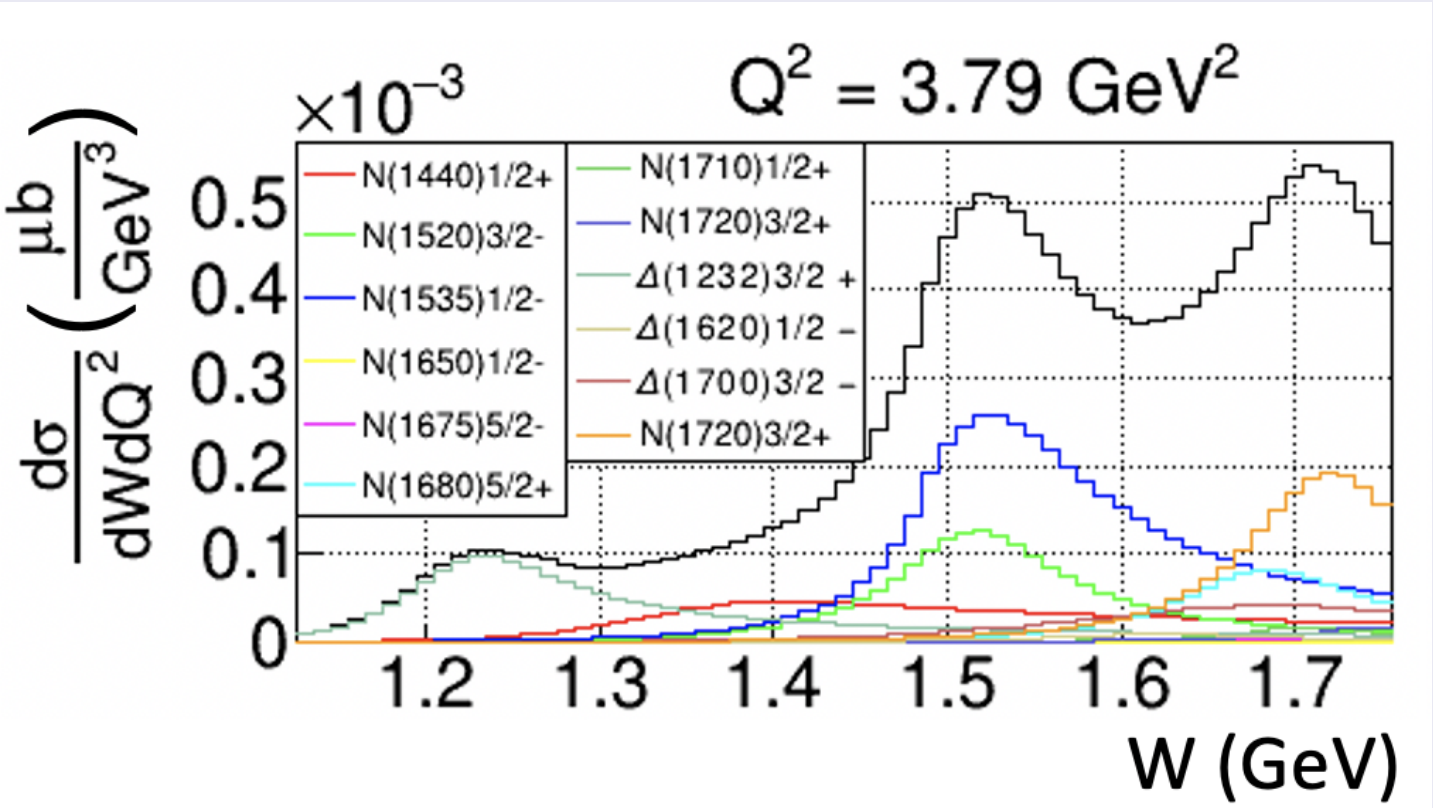
- Several approaches/models/prescriptions available
- Inclusive scattering: "stress testing" ground for such
- (dis)agreement might hint to **emerging phenomena**

(incomplete) list of approaches:

- CSM: Predictions on pion and nucleon PDF within a common framework under connection to QCD (A. Hiller Blin *et al.*)
- Phenomenologic fit: (SLAC, IN, Christy & Bosted, etc.)
- Quark–hadron duality (Bloom–Gilman, etc.)
- QCD–based/inspired (Ma, Radyushkin, Alexandrou, etc.)
- LQCD...
- AI/ML–based (nnpdf, GN)

Motivation (IV)

Examples...



Motivation (V)

Therefore...

- It is in this rich and diverse theoretical landscape and taking aim at a substantial, multi–pronged scientific payoff, we frame our experimental efforts.

- Q: What would be the tool(s) of choice for this endeavor?
- A: I would be more than happy to enlighten you with that...

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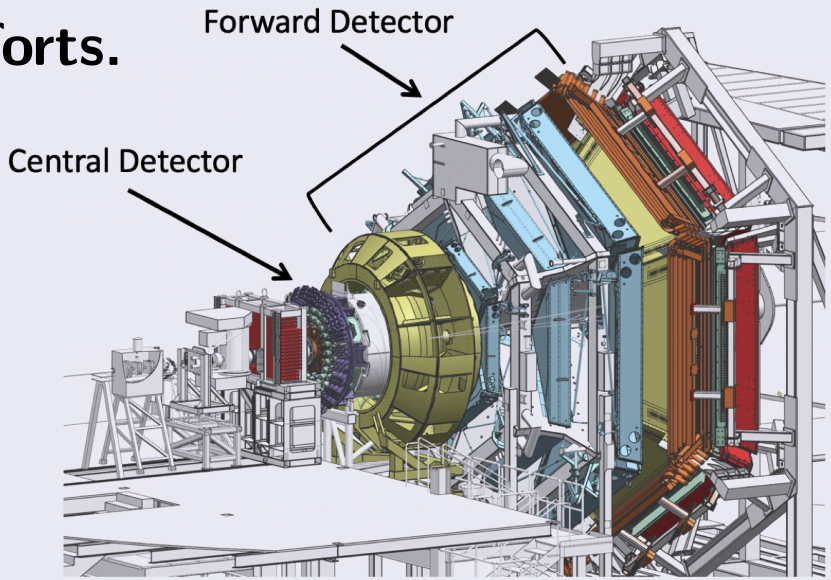

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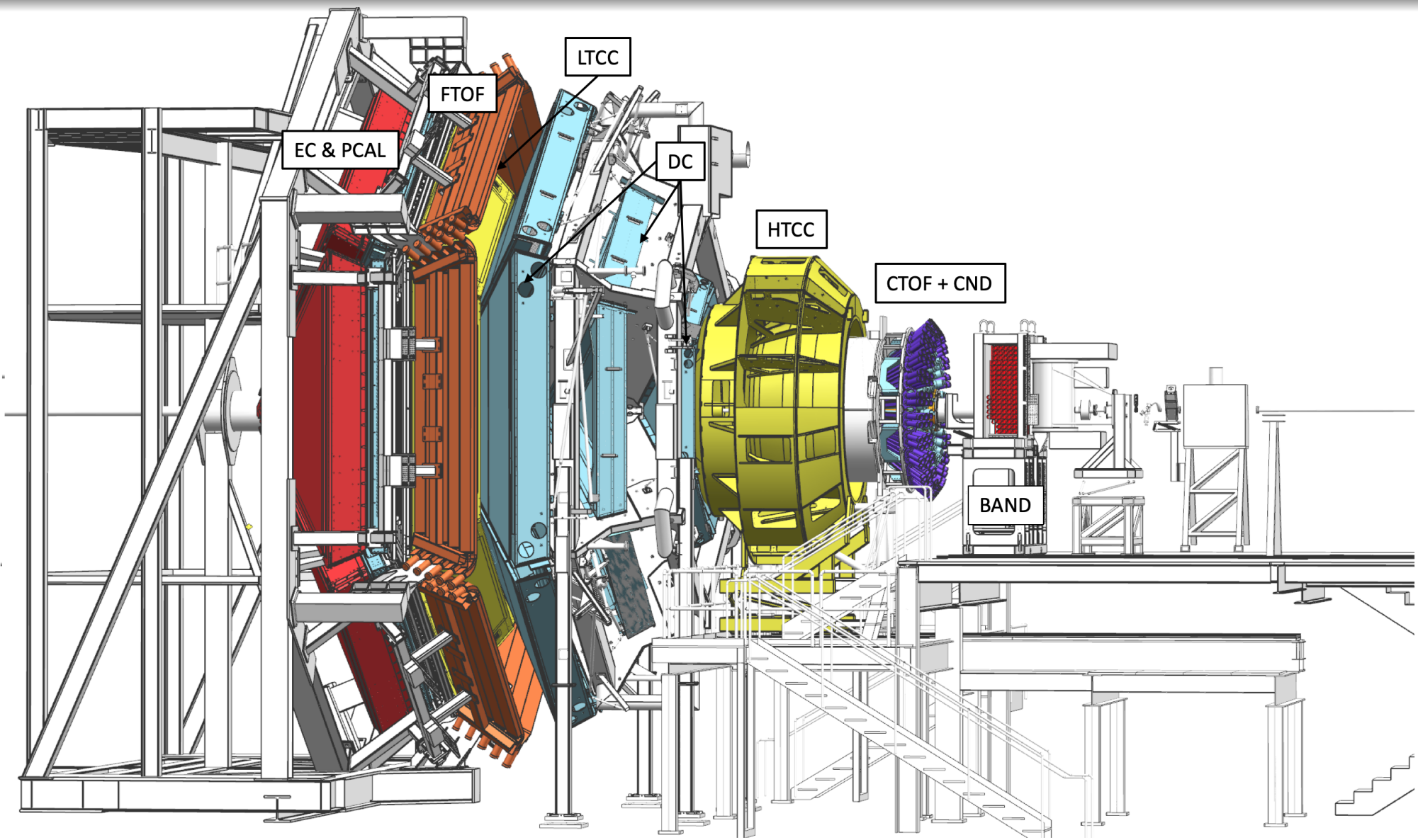
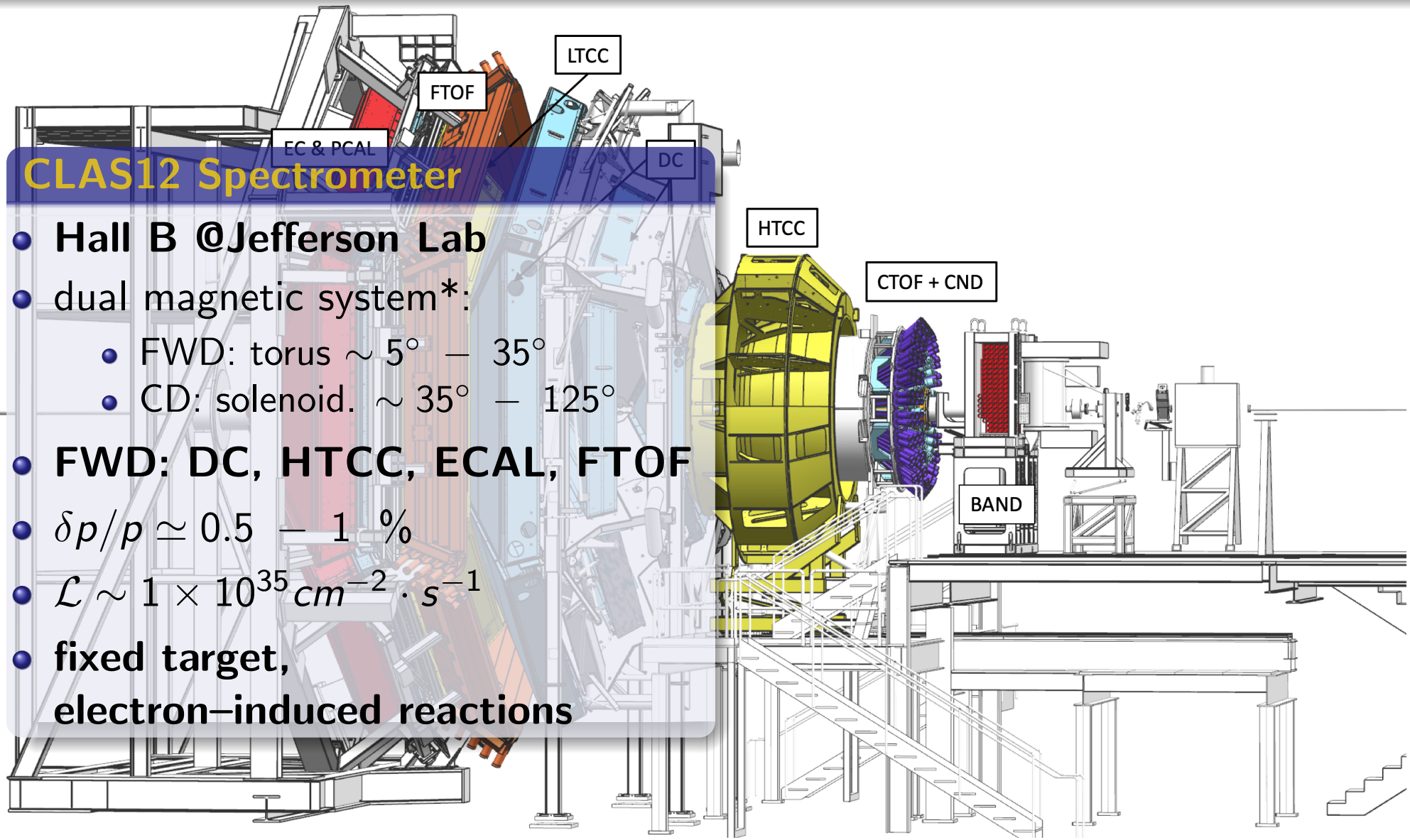
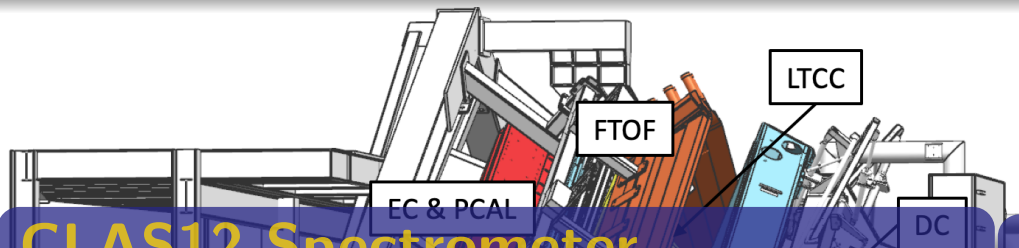

LTCC
FTOF
EC & PCAL
DC
HTCC
CTOF + CND
BAND



CLAS12 Spectrometer

- **Hall B @Jefferson Lab**
- dual magnetic system*:
  - FWD: torus $\sim 5^\circ - 35^\circ$
  - CD: solenoid. $\sim 35^\circ - 125^\circ$
- **FWD: DC, HTCC, ECAL, FTOF**
- $\delta p/p \simeq 0.5 - 1$ %
- $\mathcal{L} \sim 1 \times 10^{35} cm^{-2} \cdot s^{-1}$
- **fixed target, electron–induced reactions**



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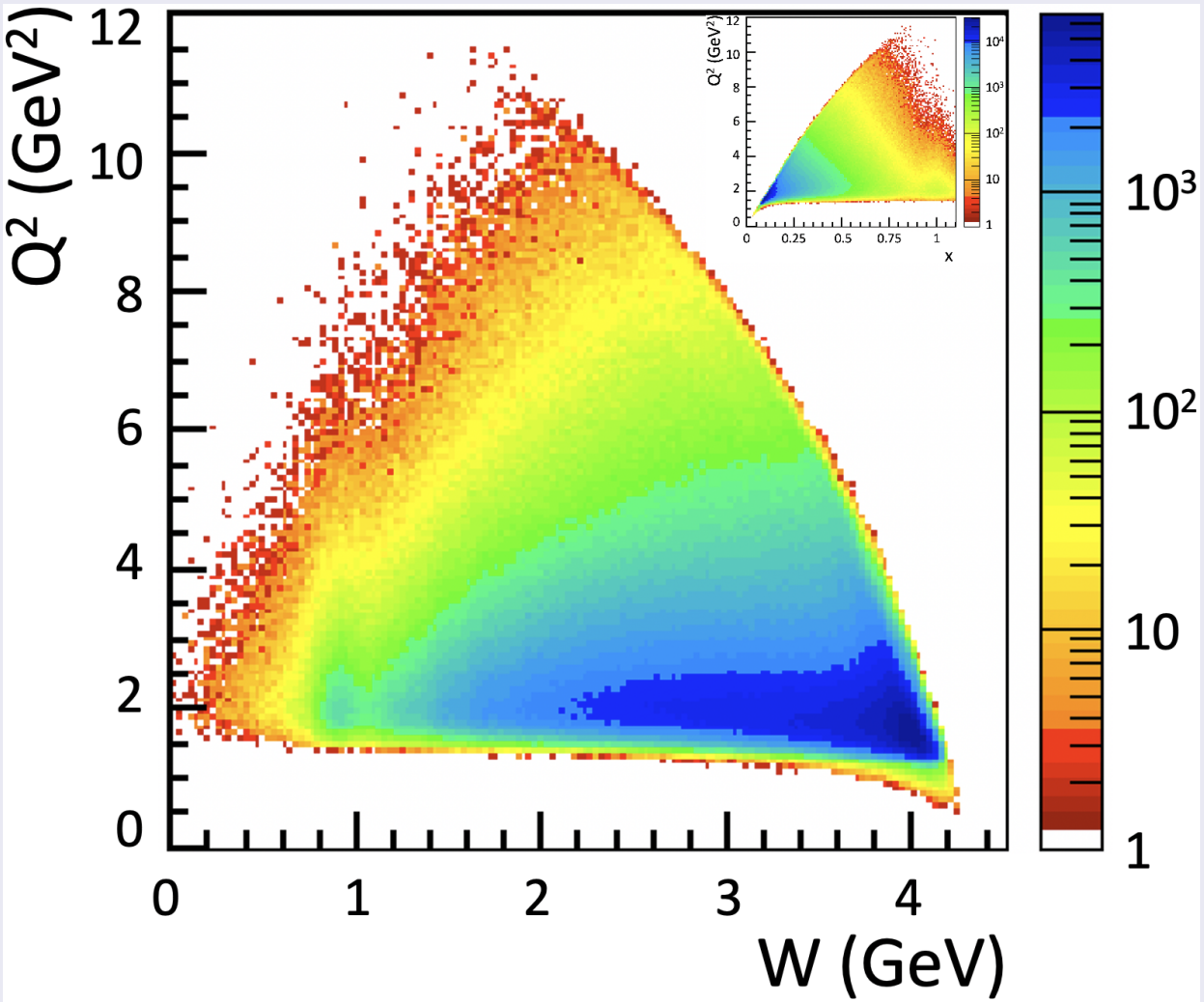
RGA Fall 2018

- **Run Group A (RGA)**
- **Fall 2018 (commissioning exp)**
- $E_{beam} = 10.604\ GeV$
- $I_{beam} \in (45, 55)\ nA$
- **target: 5 cm LH2**
- **DAQ: ∼15 kHz, 500 MB/s**
- **Live time: ∼ 90 %**
- **only “inbending” data shown**

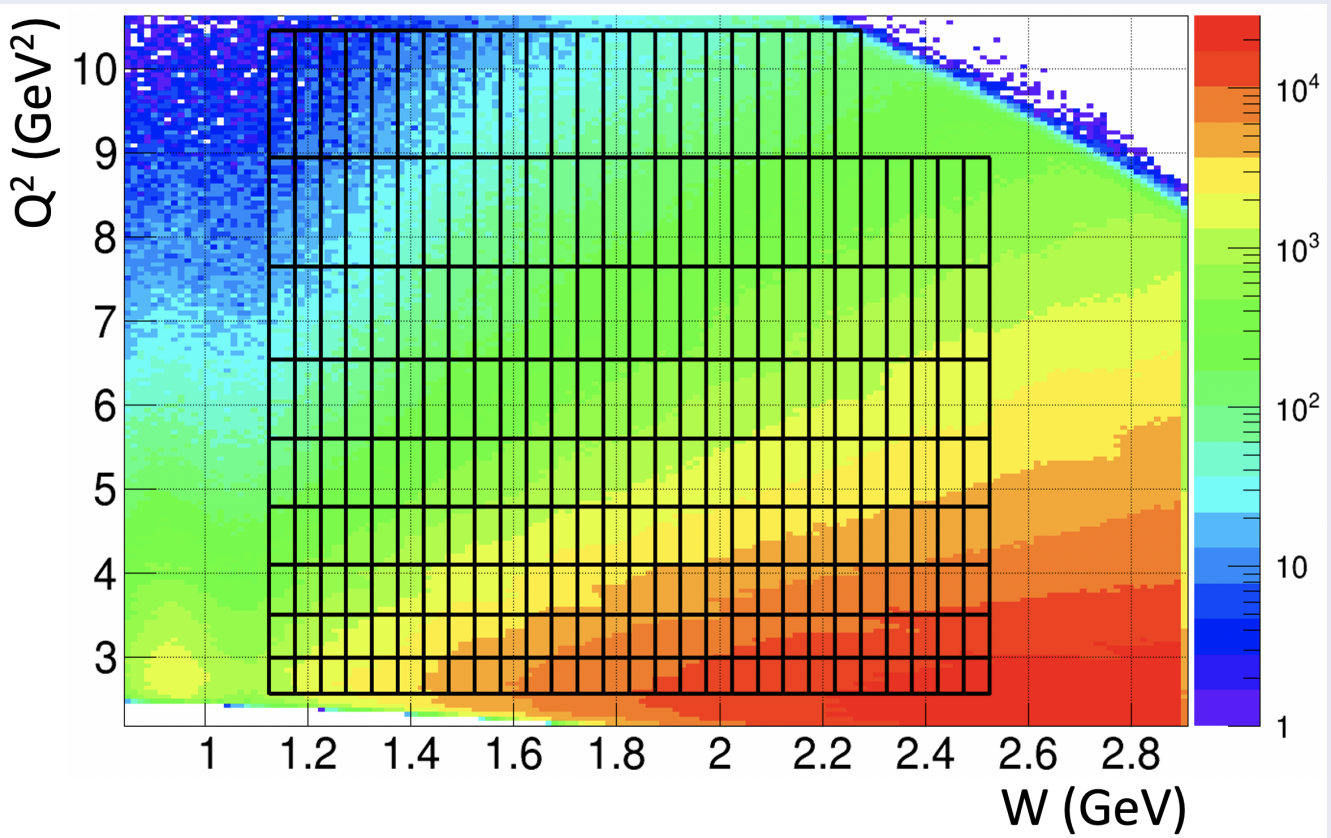
RGA Fall18 Inbending data



Data Coverage

- W **to ∼4 GeV***
- $Q^2 \in (\sim 1, 10)\ GeV^2$
- $p(e, e')X$ reaction, so
- **good statistics**

Data Binning



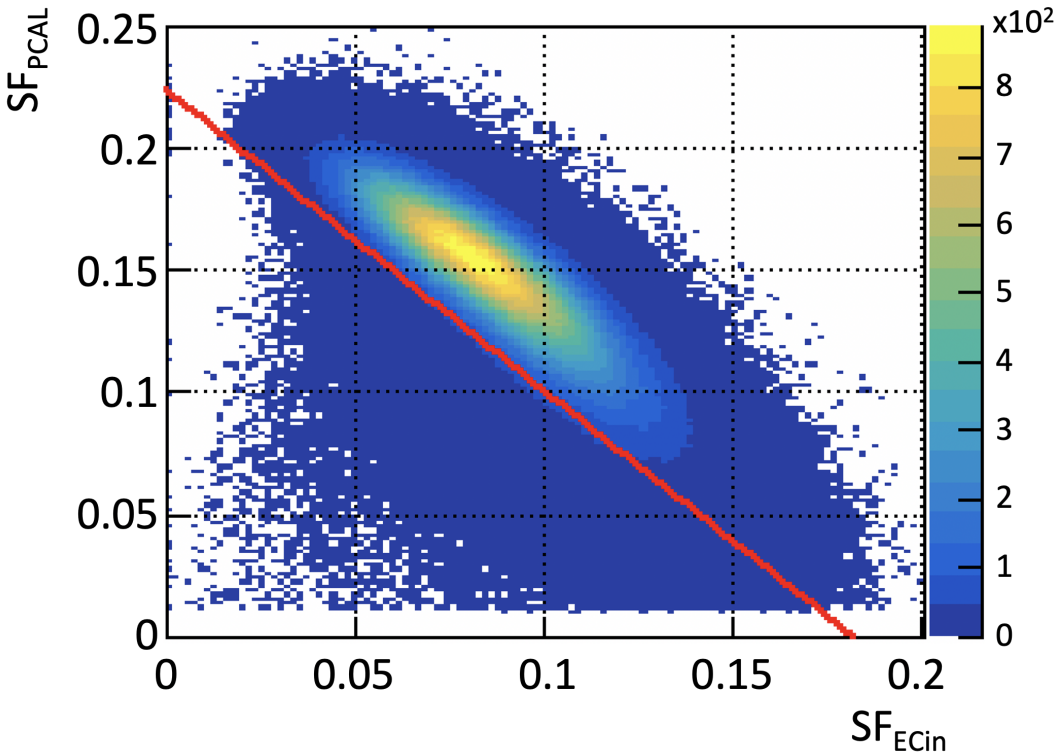
Bin Choices

- W: **50** *MeV*
- Q^2: **9 bins**
  2.5 – 10.5 GeV^2
- **log scale**

Cross–Section extraction

Data Analysis (Valerii K.)

- **electron PID:** DC, HTCC, PCAL, ECAL, FTOF
- **cuts:** CLAS12 fiducial cuts, target, etc.
- **corr.:** RC, BC, MT, etc.
- **unfolding*:** Bayesian deconvolution
- **iterations...**



$$\frac{d\sigma_i}{dQ^2 dW} = \frac{1}{(\Delta Q^2 \Delta W)} \cdot \frac{Y_i}{\eta_i \; N_0 \; R_i \; BC_i} \cdot \frac{CMB}{(N_A \; \rho \; t/A)}.$$

Cross–Section Validation

Comparison with published data

- **compare** RGA result w/ overlapping, published $p(e, e')X$ cross-section results
- **CLAS (M. Osipenko), Hall C (S. Malace)**
- **NOTE:** only valid for lower Q^2 bins

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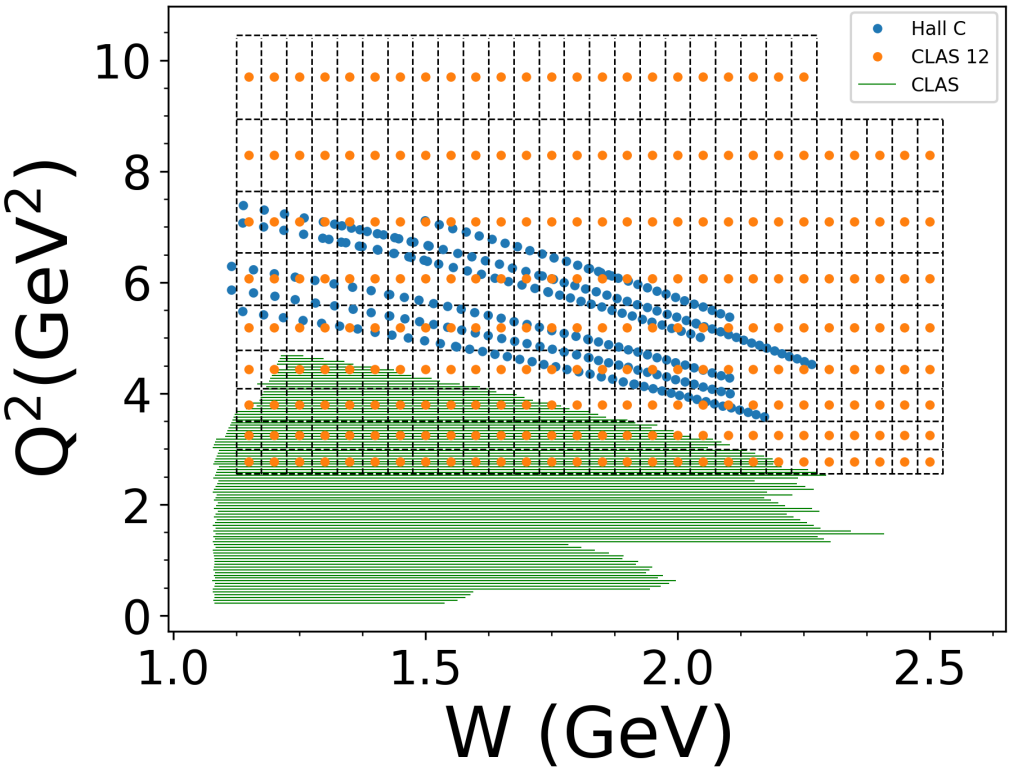

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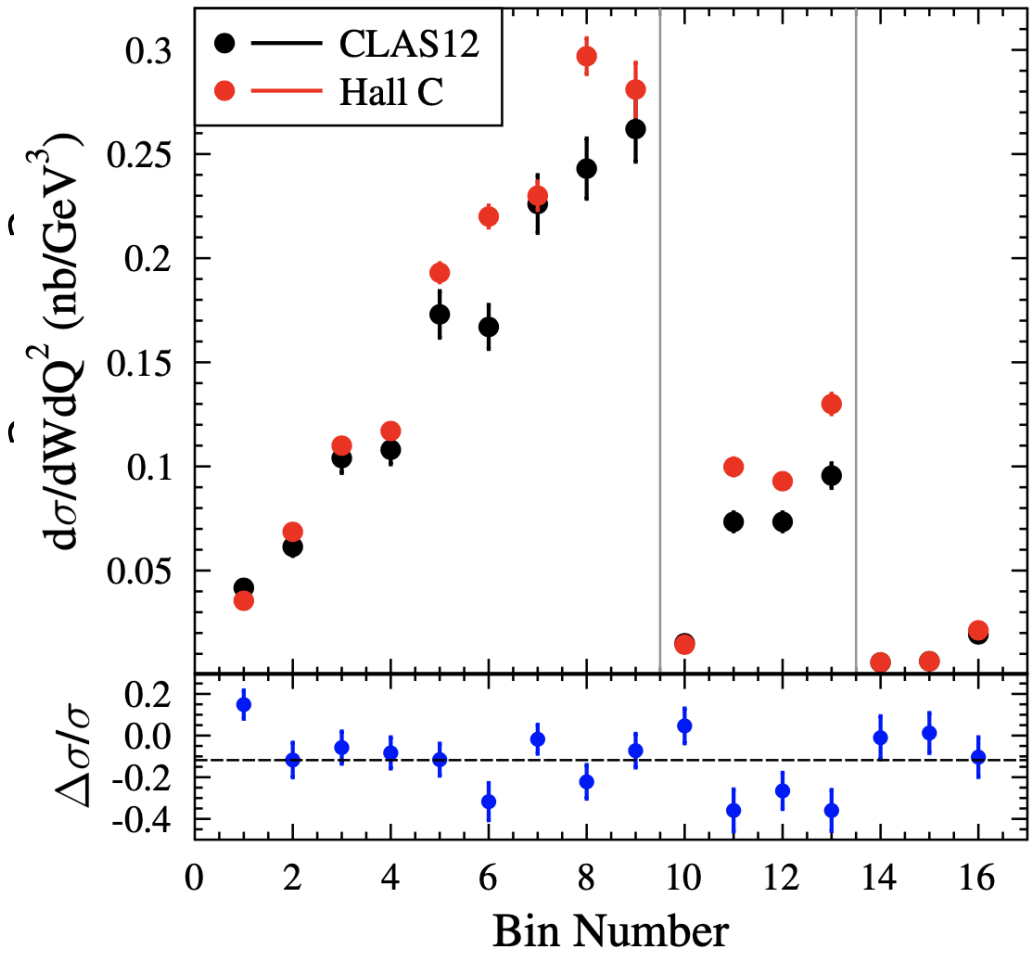

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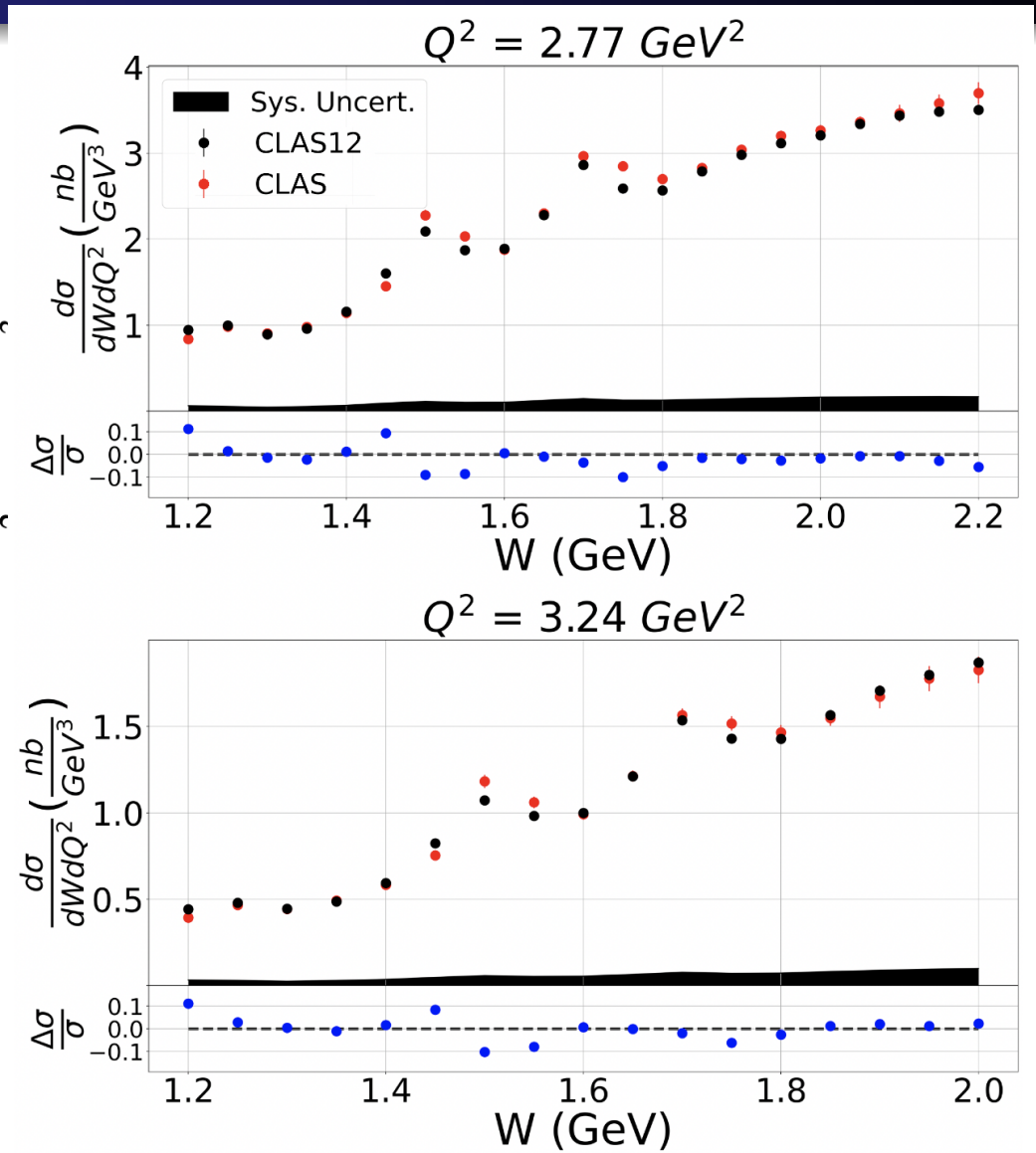
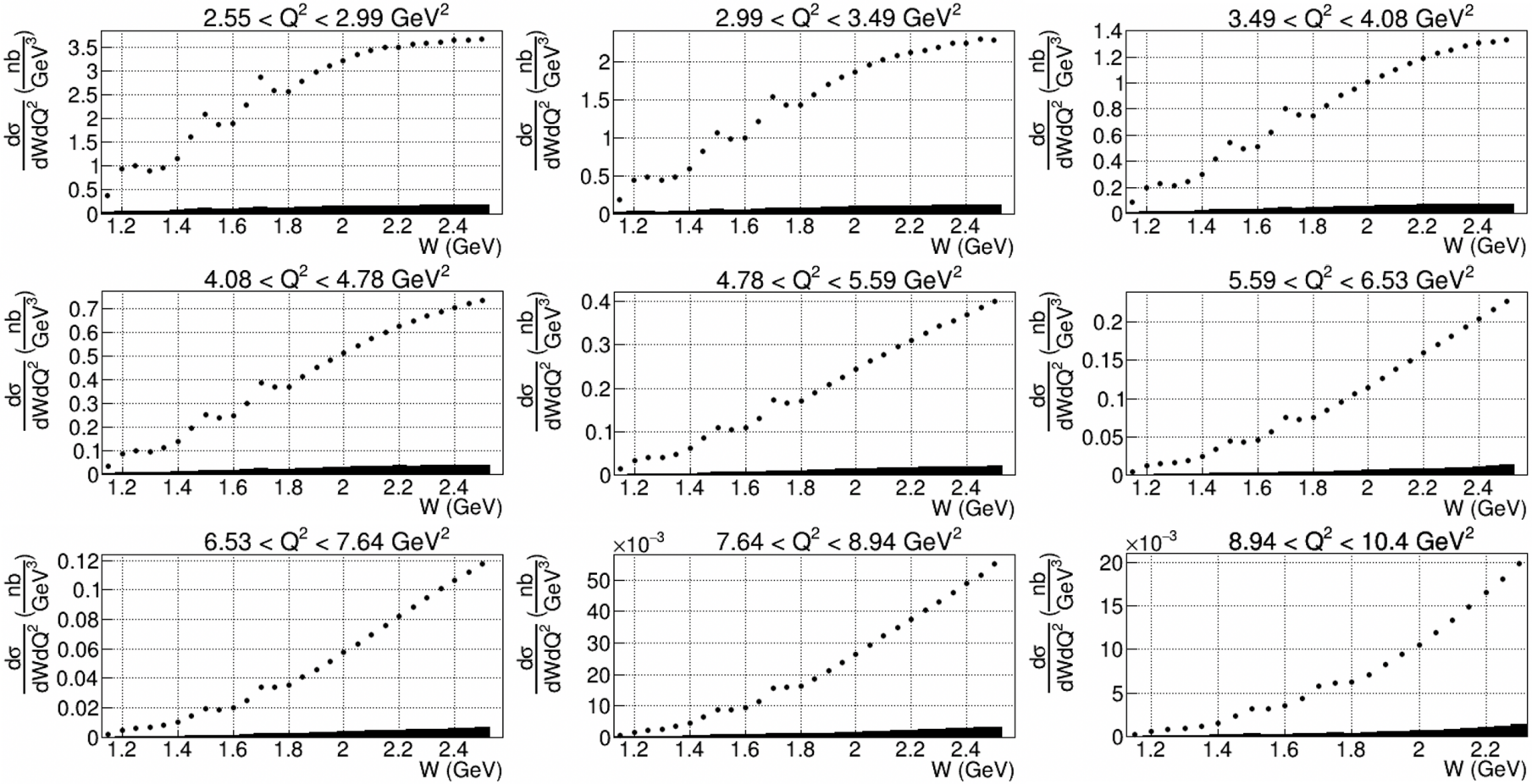


RGA $p(e, e')X$ Cross–Sections



Uncertainties: ~ 4.5 % (scale), ~ 4.8% (bin–2–bin)

Paper under collaboration review.

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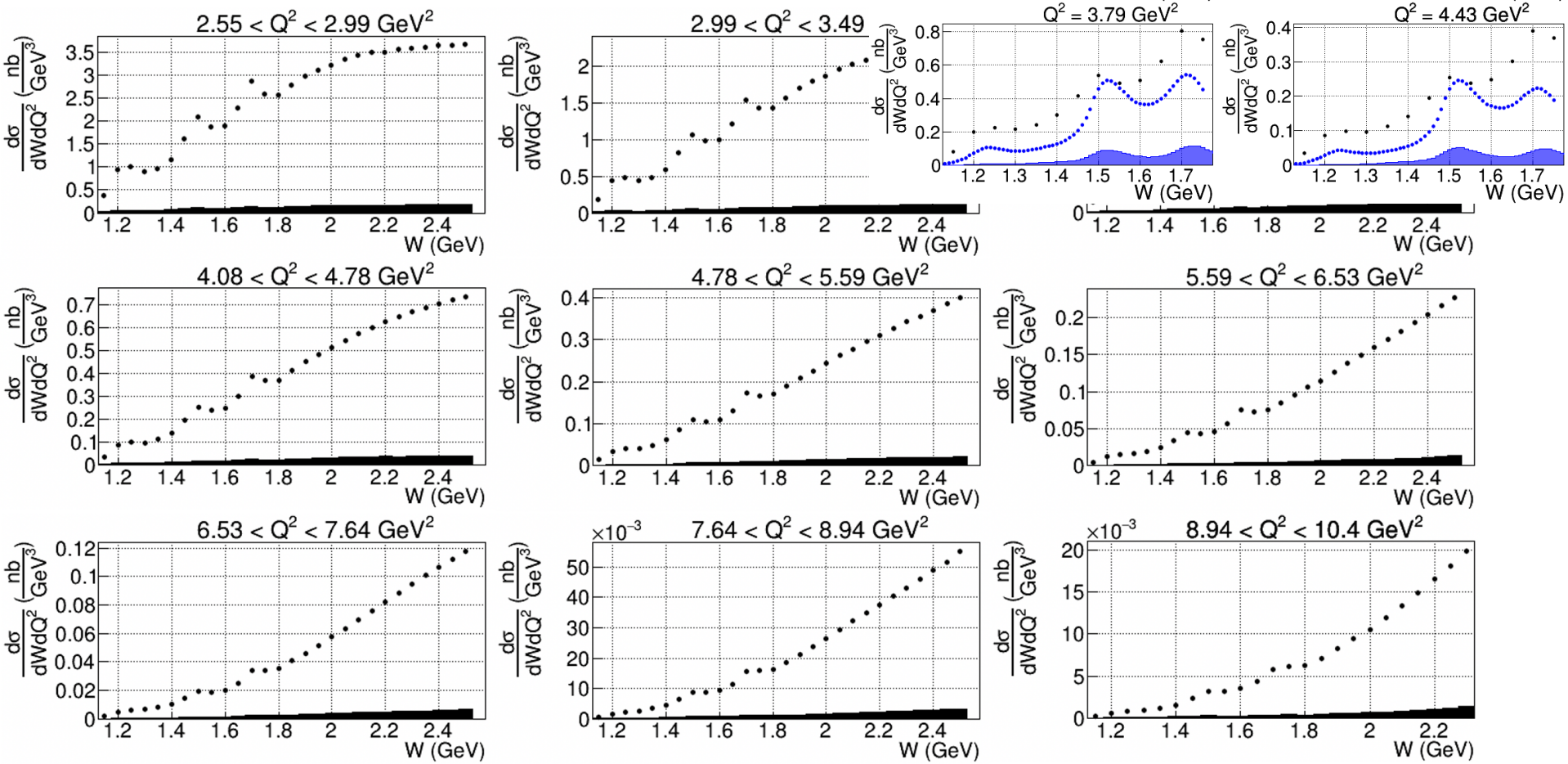

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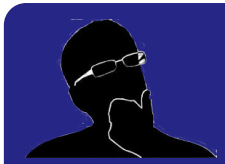
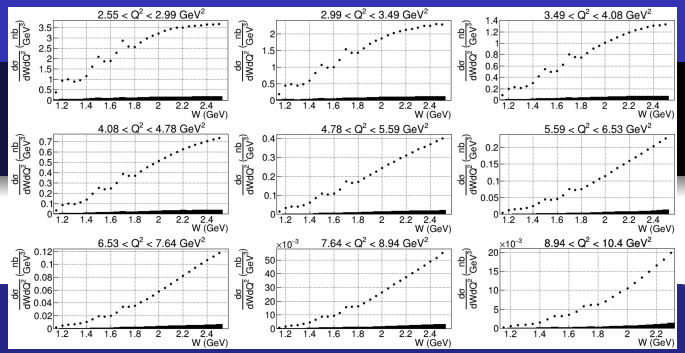


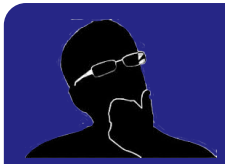
I hope I convinced you...

- CLAS12 data can be used to extract absolute $(p(e,e')X)$ cross–sections
- w/ reasonable precision and extensive kinematic coverage

- **JLab22**:

Quo Vadis?





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- **JLab22**:Charting the Q^2 evolution of the inclusive structure function moments (up to $Q^2 \simeq 30$ GeV^2) will offer a promising opportunity to explore a full range of distances where the nucleon structure emerges in the transition from pQCD to strongly coupled regimes.

THANK YOU!