Elastic Scattering : Benchmark for Cross Section Measurement with CLAS12

CLAS Collaboration Meeting
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November, 2025

Keys Objectives

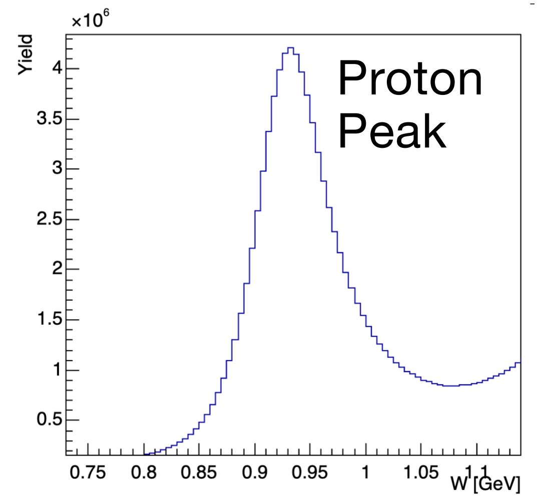
We present an analysis of the elastic scattering cross section as a crucial benchmark for understanding CLAS12 detector performance, providing a foundation for more complex cross section measurements. By using the well-established elastic cross section as a reference and comparing measured events to previous parametrization, we provide a tool to validate the detector's accuracy, efficiency, and calibration.

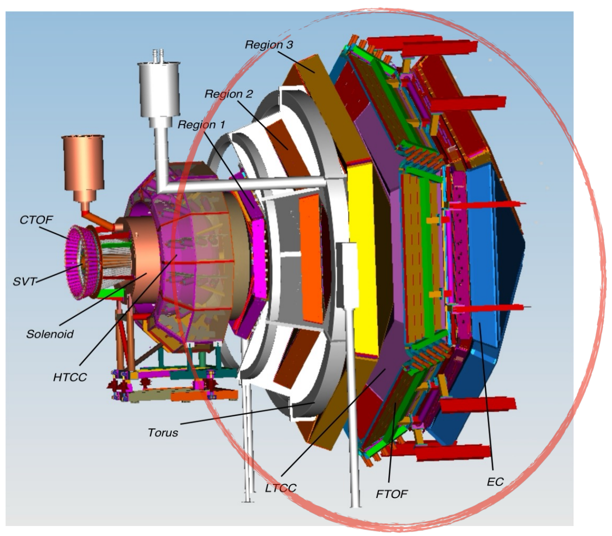
Key objectives: providing feedback to CLAS Collaboration:

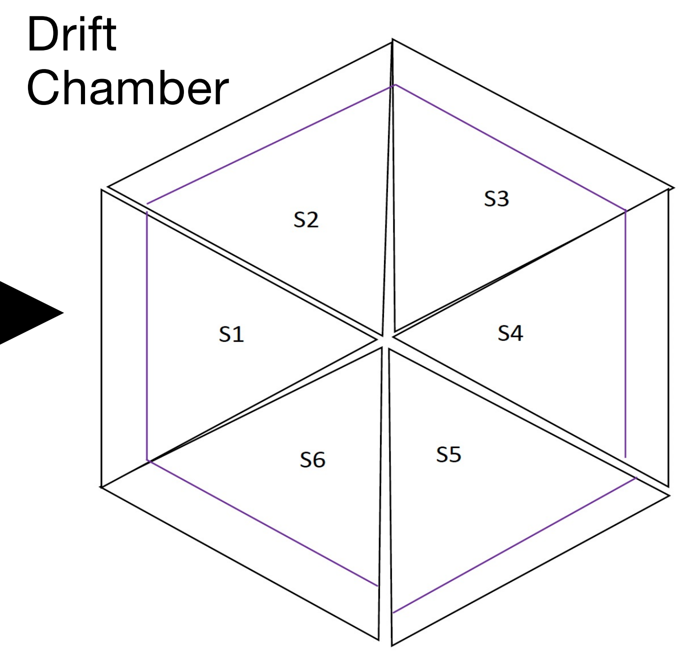
- Software: tracking improvements
- Calibration procedures
- Energy & momentum correction
- Efficiency determination
- Resolution characterization
- Alignment & geometry validation
- MC simulations & cross section normalization
- Others

Inclusive Elastic Scattering – Focus on the Forward Detector

- **Inclusive Elastic as first step**
- **RGK data**
- **Focus on the forward detector**

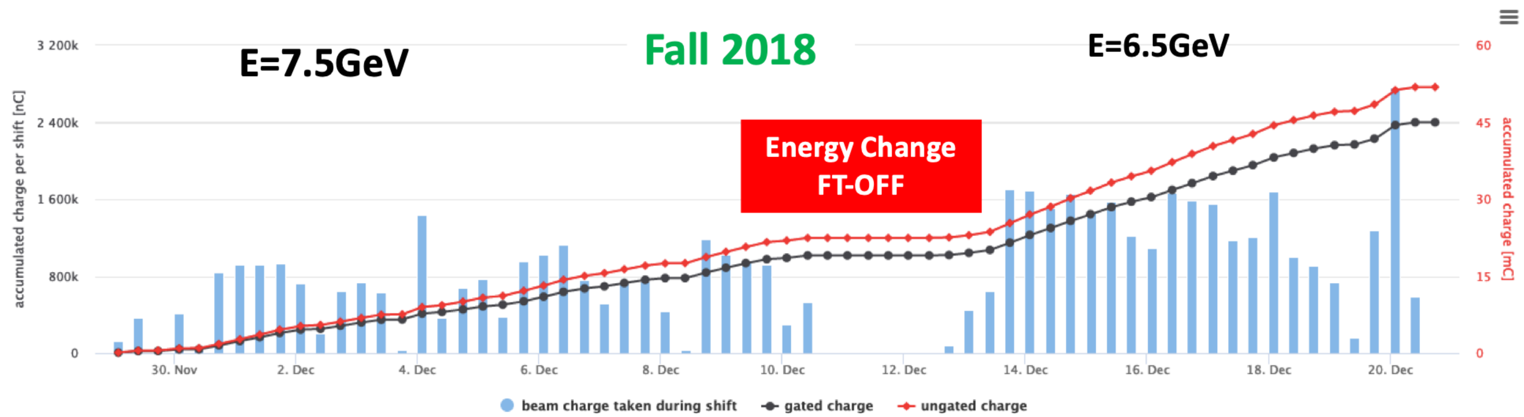


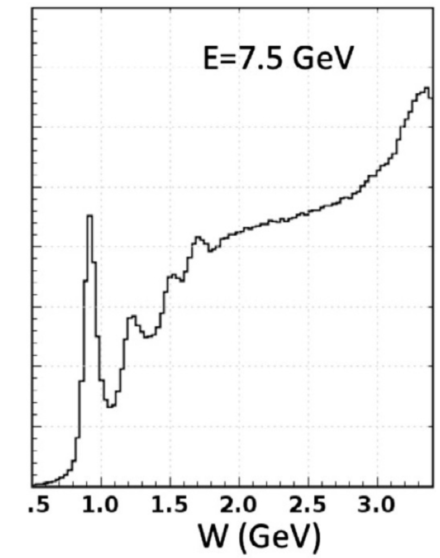




LH2 Target

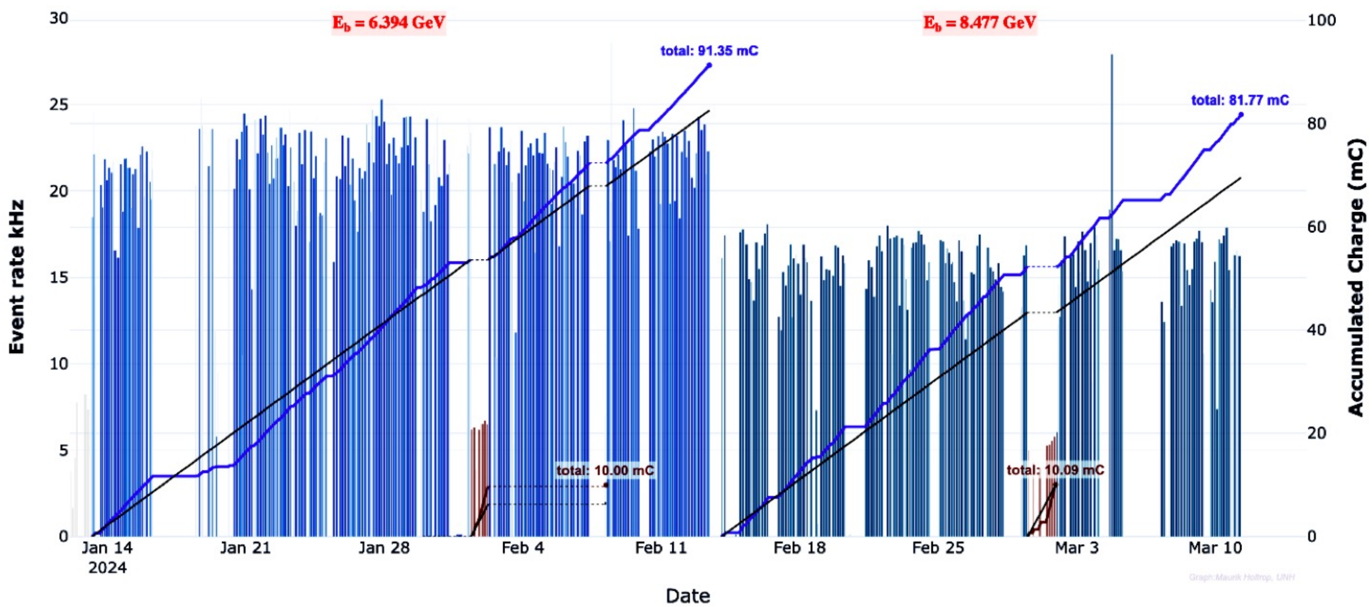
RGK Fall2018

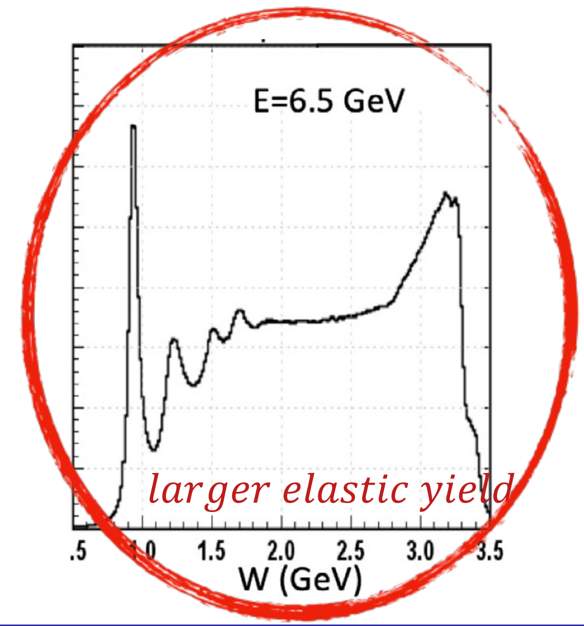




RGK Spring2024

In preparation.
Partially processed.





RGK Data

- **And the following software upgrades:**

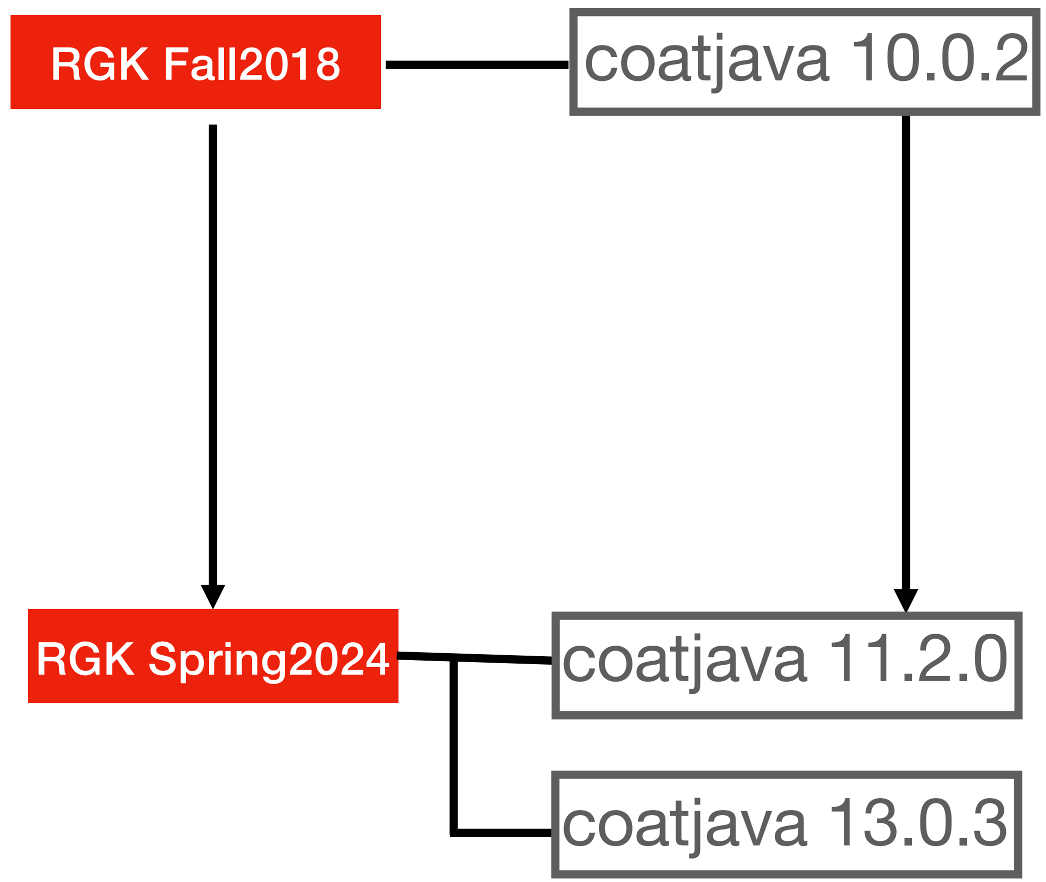
Thermal Contraction Alignment
New DC alignment includes 5 mm cryotarget contraction (since RG-D 2023).

Improved Time-to-Distance Calibration
Enhanced momentum resolution and reduced angle-dependent bias (since RG-K 2024)

New TDC Window Cut
Removes late background hits; improves hit efficiency and Data/MC consistency (RG-K 2024 Spring).

Decoder Bug Fix
Out-of-time hits no longer overwrite good hits, removing angle-dependent inefficiency (RG-K 2024 Spring).

And so on…



Guard Wire Mini-Stagger Fix
±300 µm offset restored; electric-field distortion corrected (CJ 11.0.0).

Updated DC Monte-Carlo Geometry
Sense-wire positions re-aligned; missing/extra wire issue fixed (CJ 11.0.0).

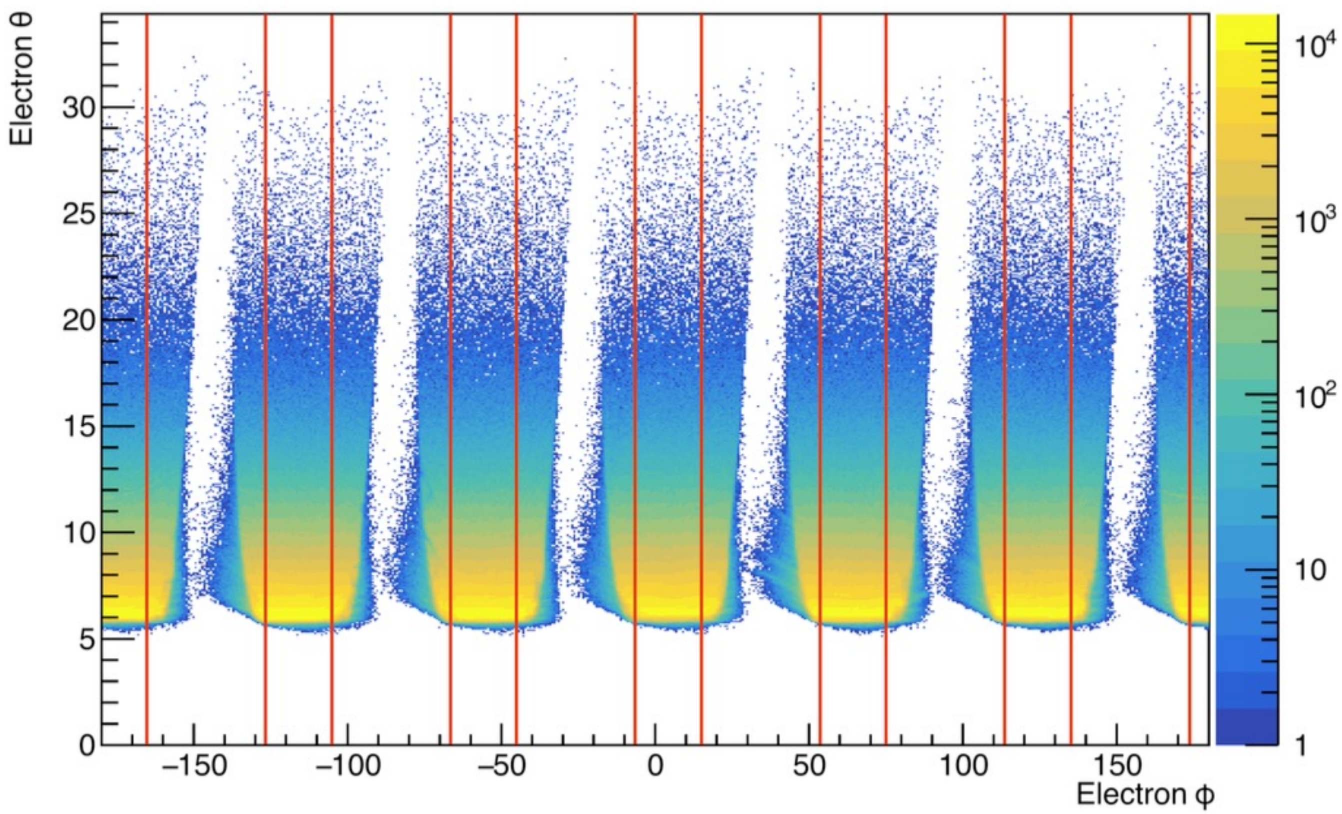
Realistic Wire Bending Model
200 µm length-dependent shift implemented for sense wires (CJ 11.0.0).

DC Hexagonal-cell geometry
DC geometry package now generates GEANT4 superlayer volumes to support hexagonal-cell geometry (CJ 11.0.4).

DC Clustering Improvement
(CJ 11.1.2).

And so on…

Fiducial Cut



	ϕ_{min}/deg	ϕ_{max}/deg
Sector 1	-7	15
Sector 2	53	75
Sector 3	113	135
Sector 4	173	195
Sector 5	233	255
Sector 6	293	315

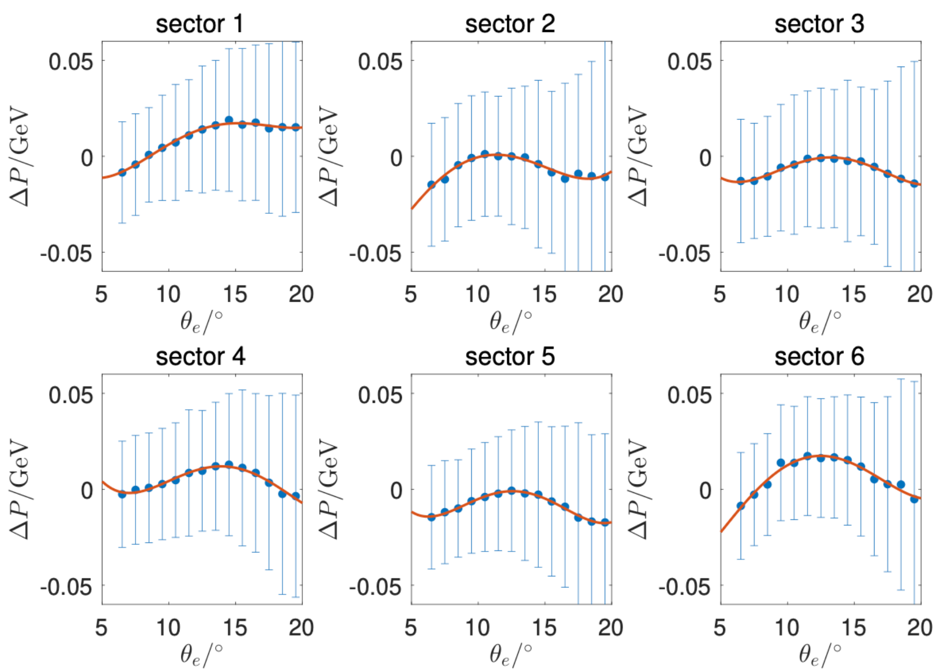
A strict fiducial cut is applied to avoid low-quality regions and provide rectangle bins.

Inclusive Elastic Events Selection

W Spectrum

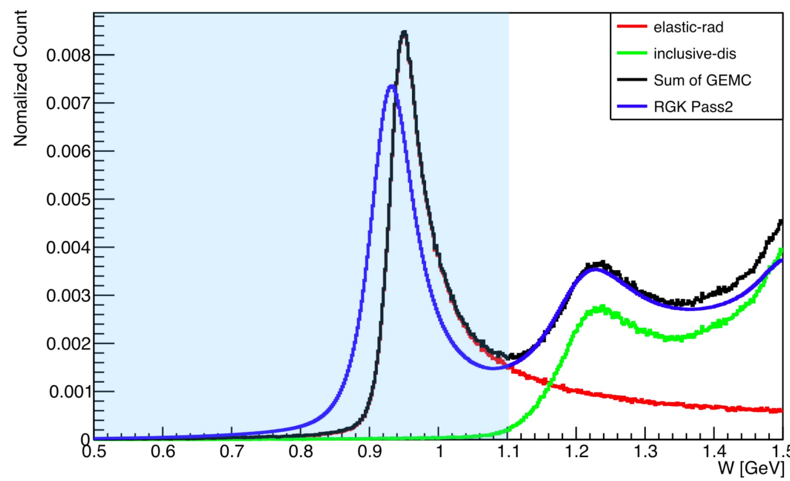
Momentum Correction

$$\Delta P(\theta) = a_0 + a_1\theta + a_2\theta^2 + a_3\theta^3 + a_4\theta^4$$



Then First Stage Cut:

$$W < 1.1\ \mathrm{GeV}$$

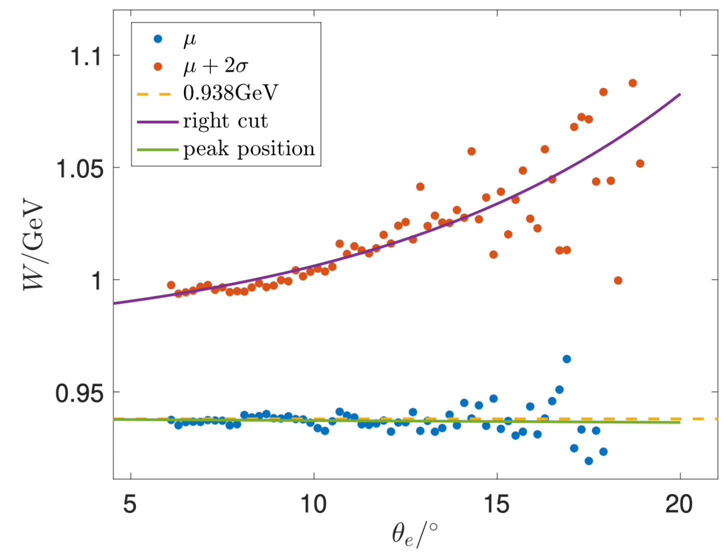


Momentum correction is not applied for this plot.

Final Cut:

$$W < \mu + 2\sigma$$

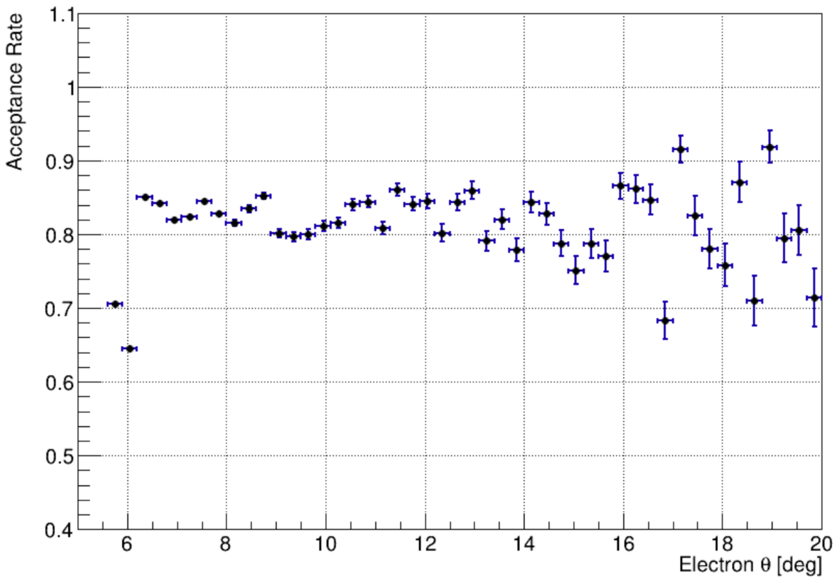
$$W_{\mathrm{cut}}(\theta) = a_1 + a_2\, e^{-a_3\theta}$$



Corrections

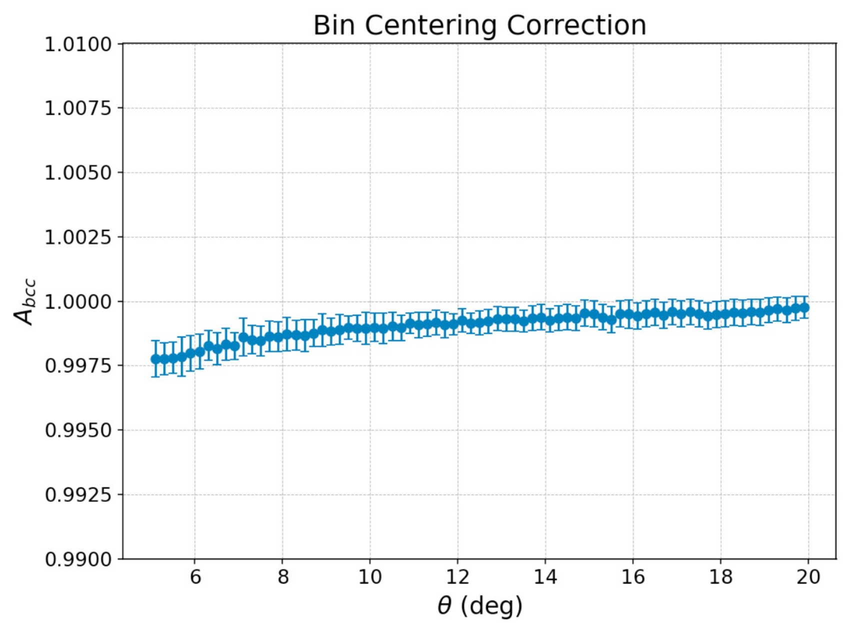
Acceptance Correction

$$A_{acc} = \frac{N_{rec}(Q^2)}{N_{gen}(Q^2)}$$



Bin Centering Correction

$$A_{bcc} = \frac{\sigma(Q^2_{\text{center}})}{\langle\sigma(Q^2)\rangle_{\text{bin}}} \text{ or } A_{bcc} = \frac{\sigma(\theta_{\text{center}})}{\langle\sigma(\theta)\rangle_{\text{bin}}}.$$

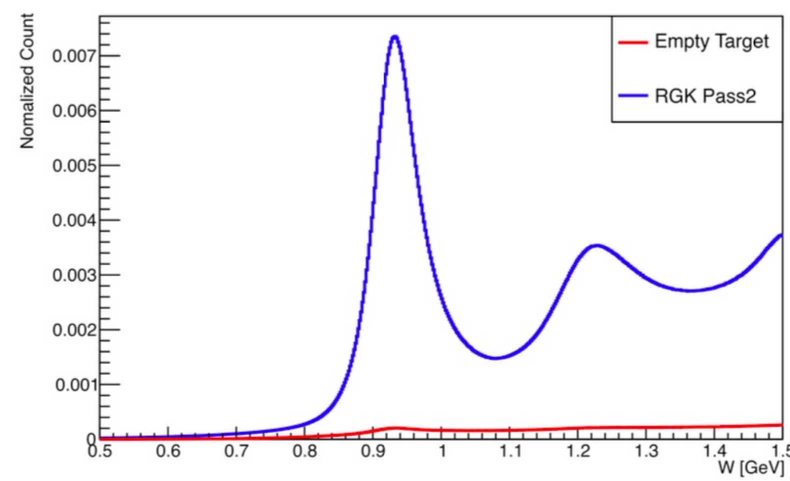


Empty Target Correction

$$N_{\text{empty, norm}} = N_{\text{empty}} \cdot \frac{\mathcal{L}_{\text{full}}}{\mathcal{L}_{\text{empty}}},$$

$$N_{\text{corr}} = N_{\text{full}} \cdot A_{etc}$$

$$A_{etc} = 1 - \frac{N_{\text{empty, norm}}}{N_{\text{full}}}$$

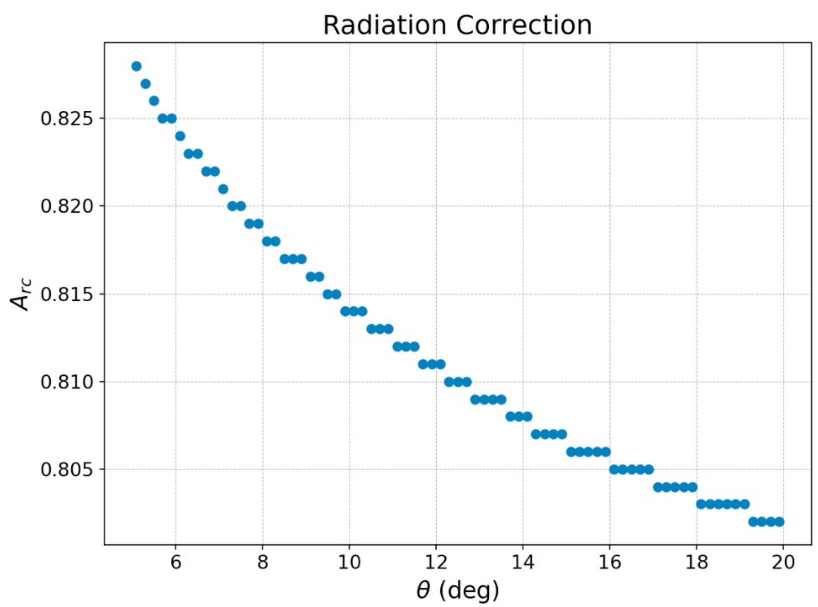


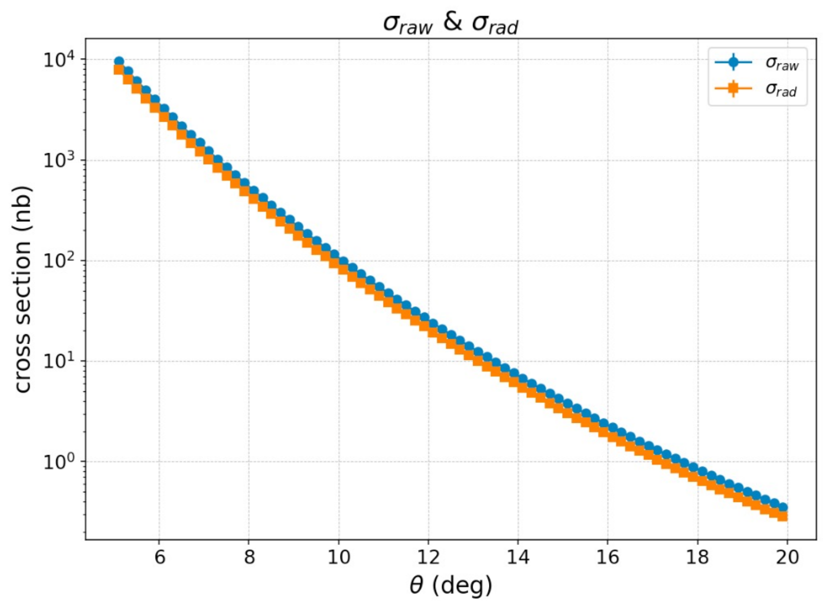
Corrections

Radiation Correction

We are going to show this.

$$\left.\frac{d\sigma}{d\Omega}\right|_{\text{measure}} = \left.\frac{d\sigma}{d\Omega}\right|_{\text{Rosenbluth}} \exp\left(\delta + \delta_t\right)$$





Form Factor Parameterization:
Brash parameterization of Hall A measurement: Brash, Ed J., et al. "New empirical fits to the proton electromagnetic form factors." *Physical Review C* 65.5 (2002): 051001.

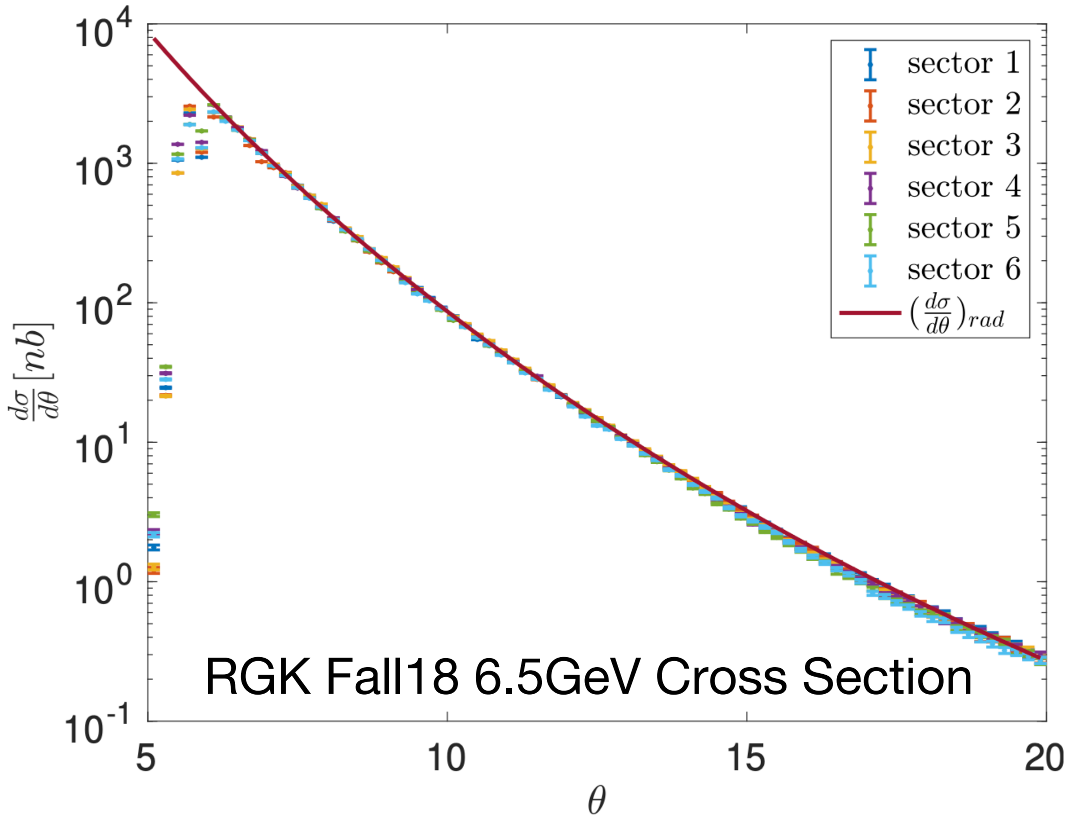
Radiation Correction Method:
Yung-Su Tsai, "Radiative corrections to electron-proton scattering," Phys. Rev. 122, 1898–1907 (1961).

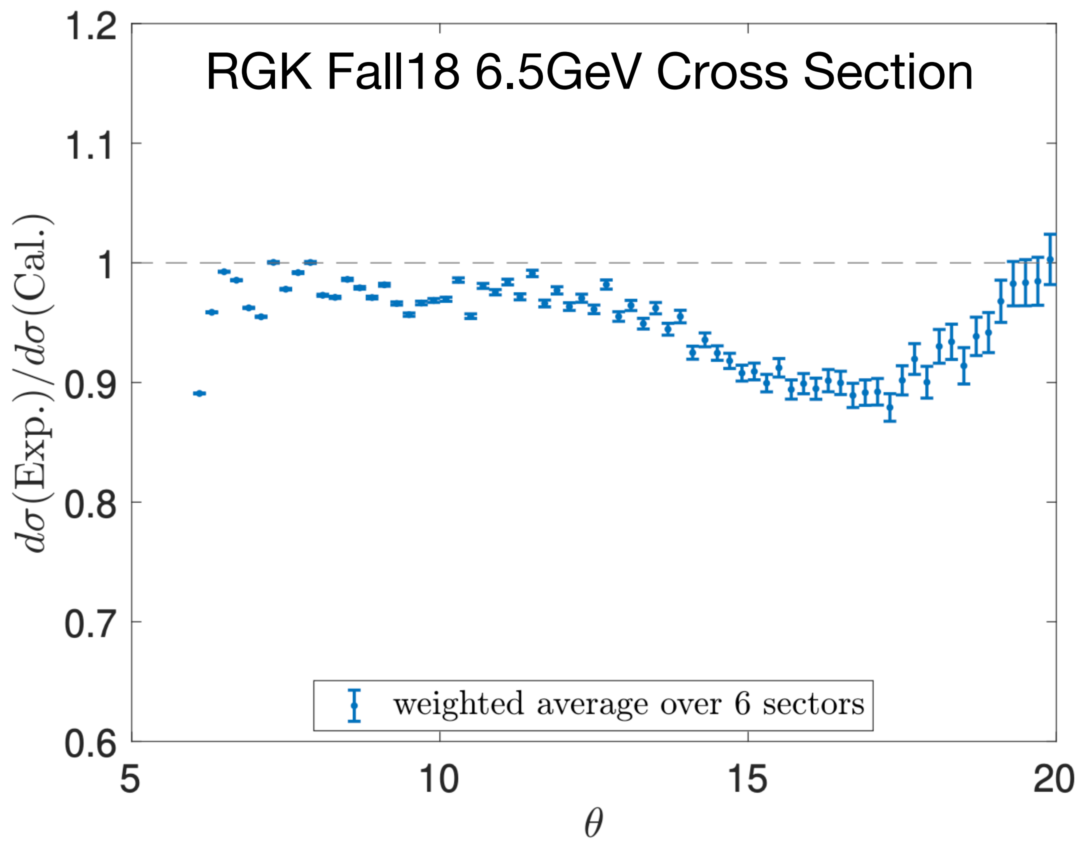
Cross Section Measurement Results

Cross Section Extraction Method

$$\frac{\mathrm{d}\sigma}{\mathrm{d}\Omega} = \frac{N_{\text{event in bin}}}{\mathcal{L}\,\Delta\Omega} \cdot \frac{1}{A_{\text{acc}}} \cdot \langle A_{\text{etc}} \rangle \cdot A_{\text{bcc}} \qquad \mathcal{L} = \frac{N_A\, l\, \rho\, Q_{\text{beam}}}{e}$$

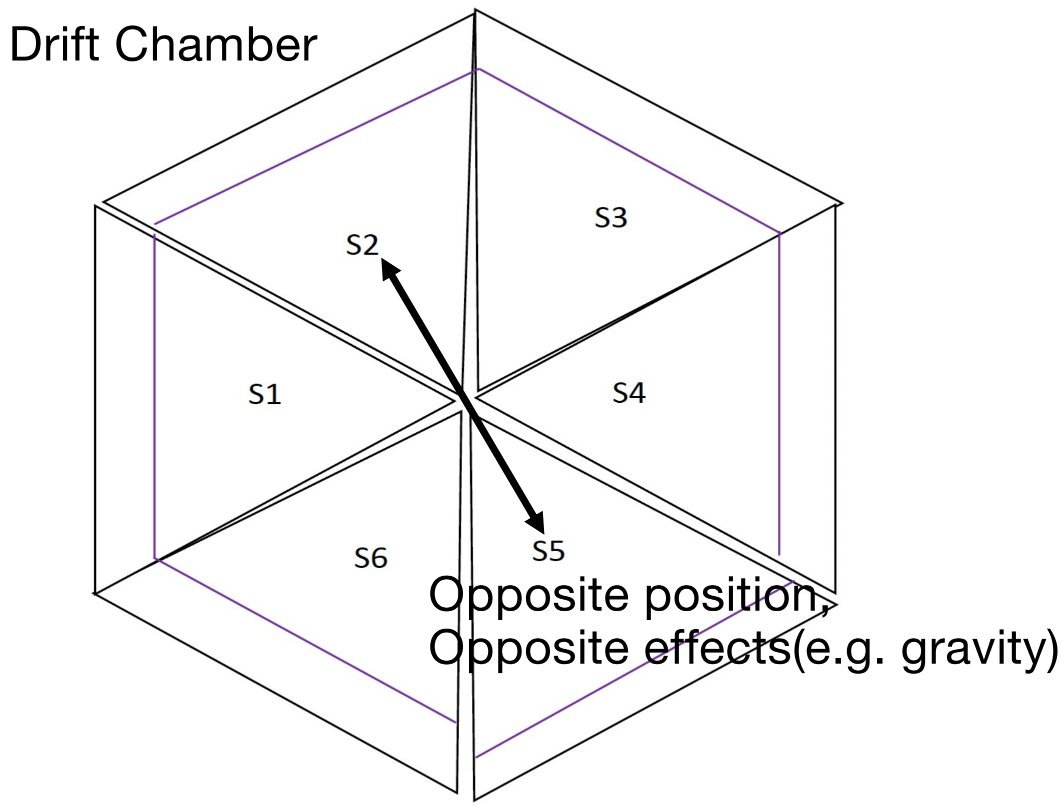
Radiation correction is going to be applied to model prediction. We are showing model prediction with radiation correction.

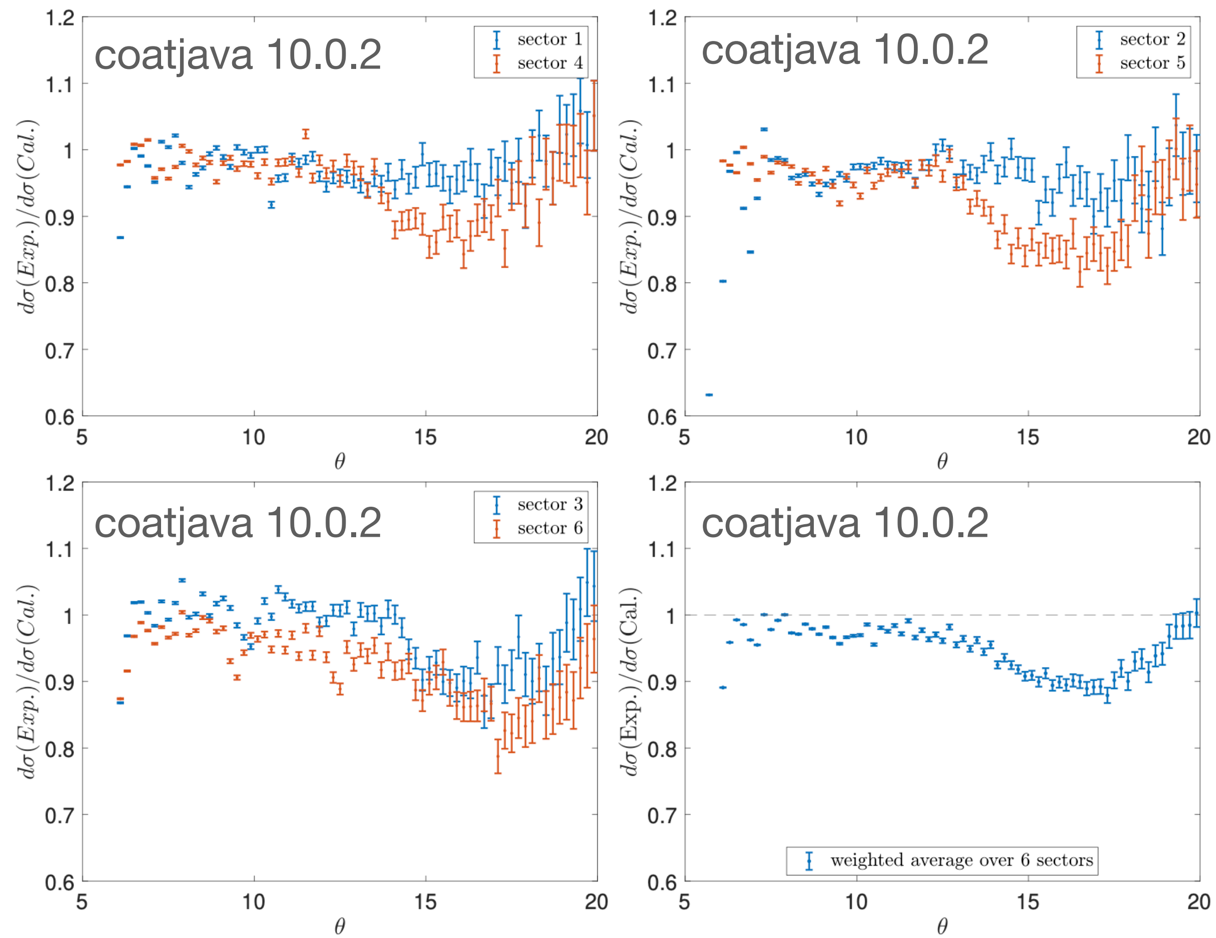




Cross Section By Sectors

RGK Fall18 6.5GeV Cross Section

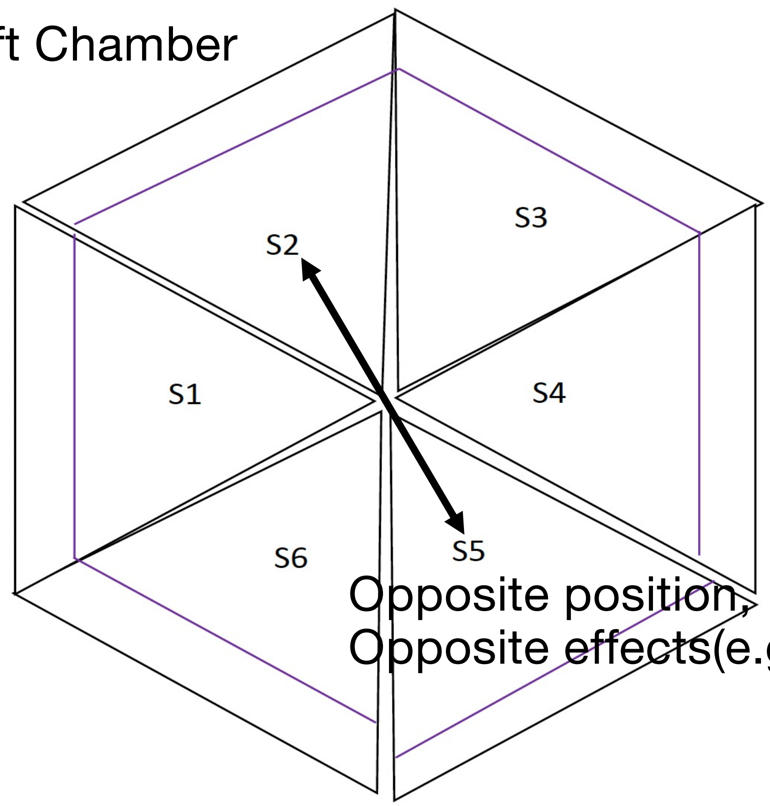




Cross Section Measurement Results

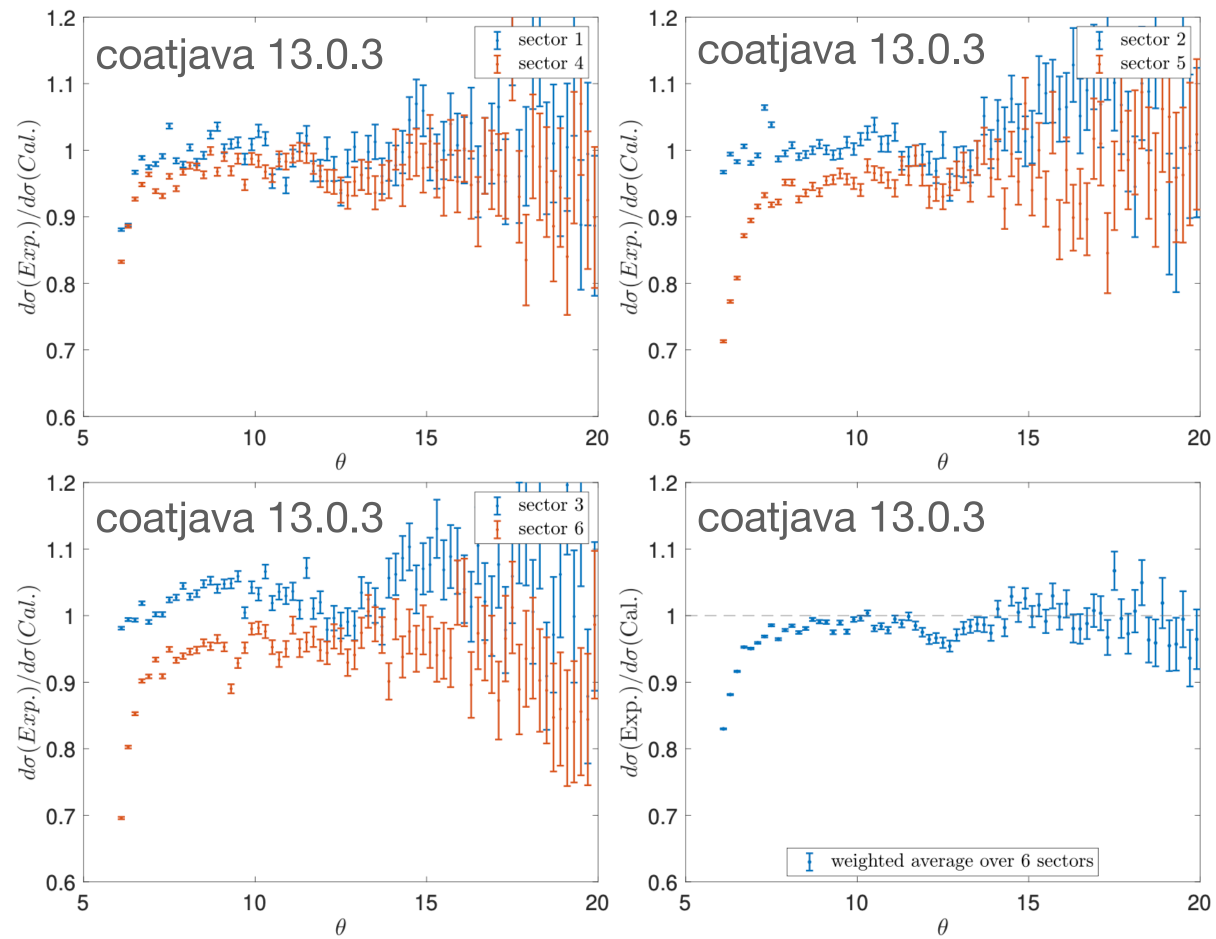
Cross Section By Sectors

Drift Chamber



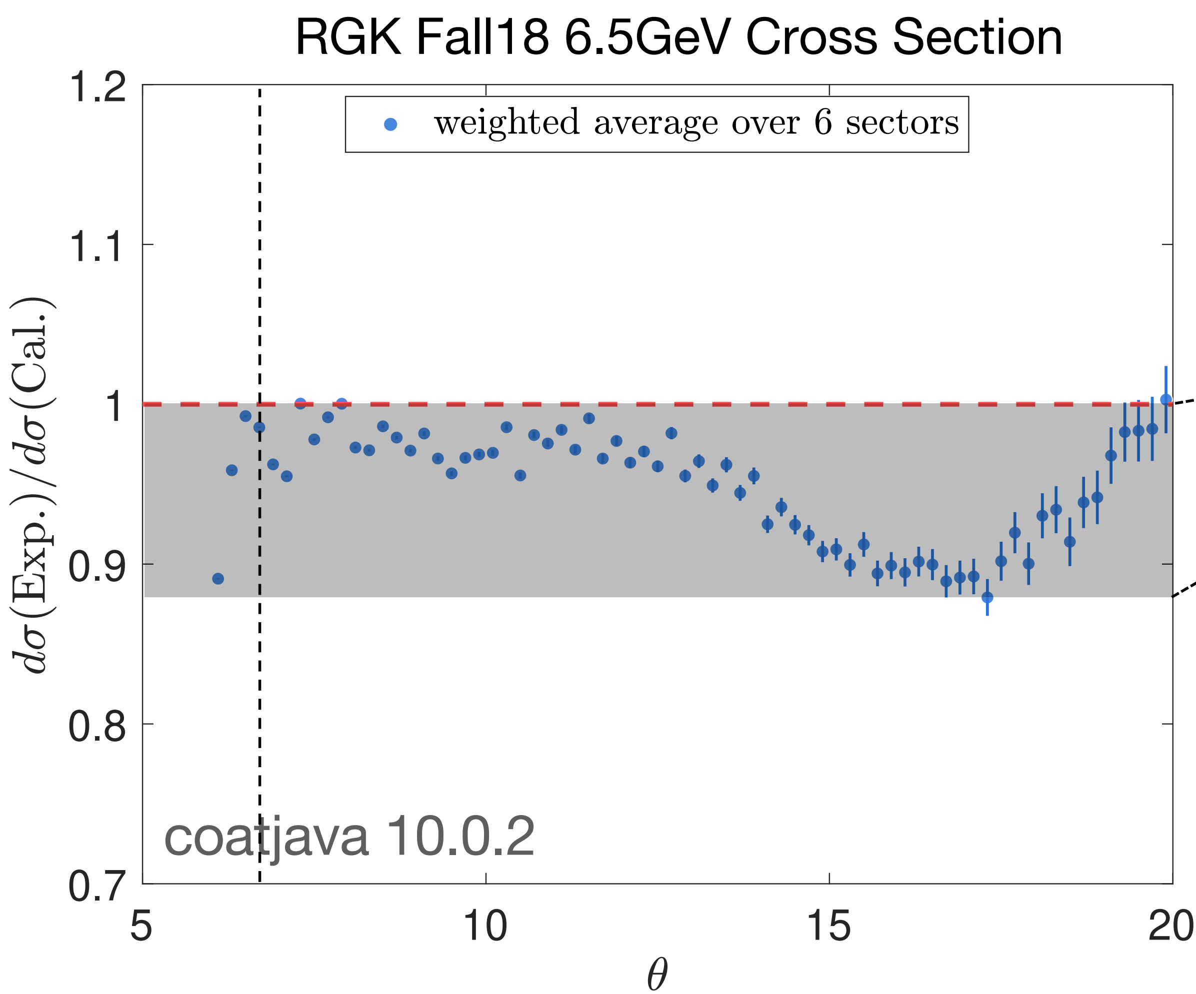
Opposite position,
Opposite effects(e.g. gravity)

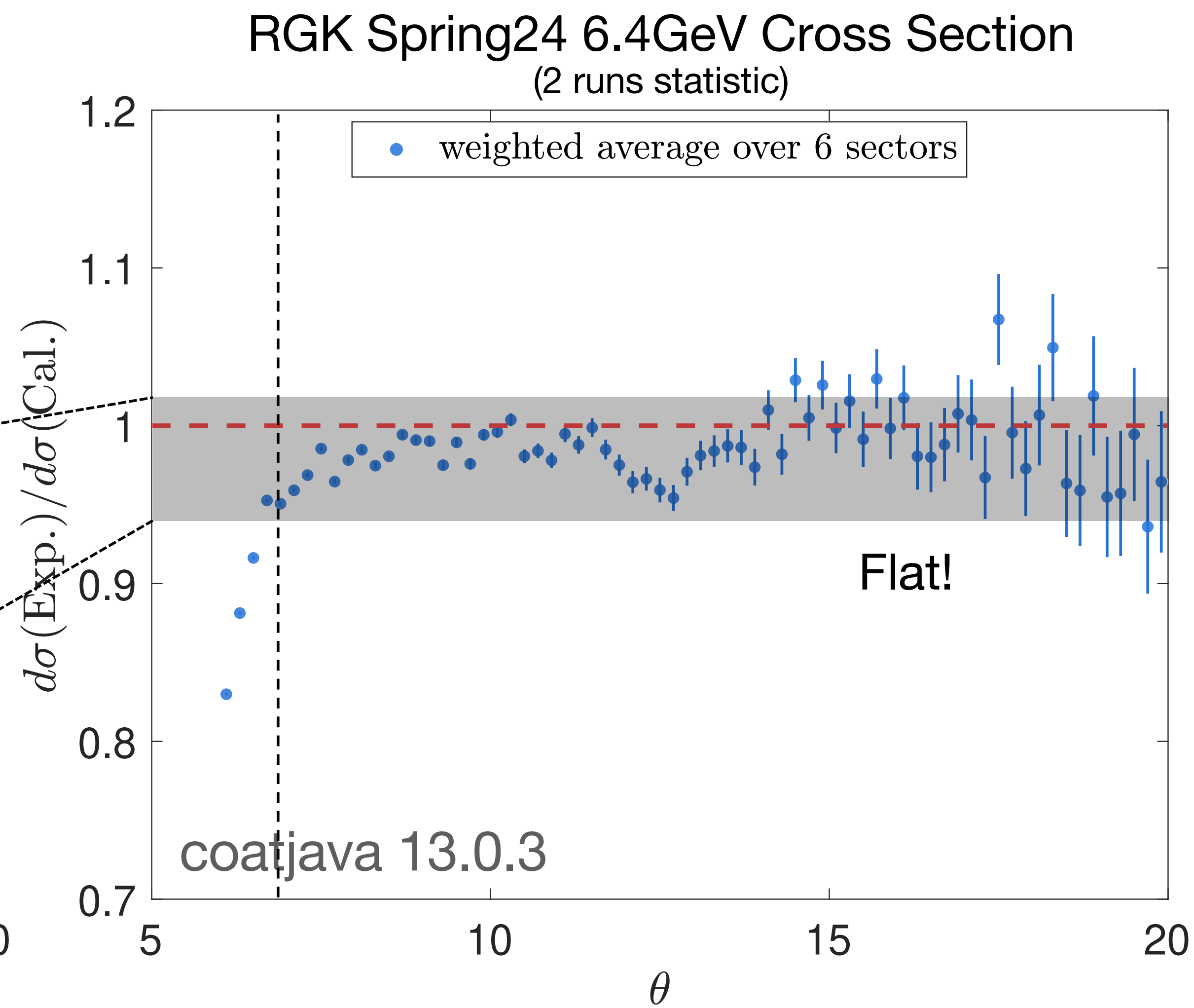
RGK Spring24 6.4GeV Cross Section
(2 runs statistic)



Cross Section Measurement Results

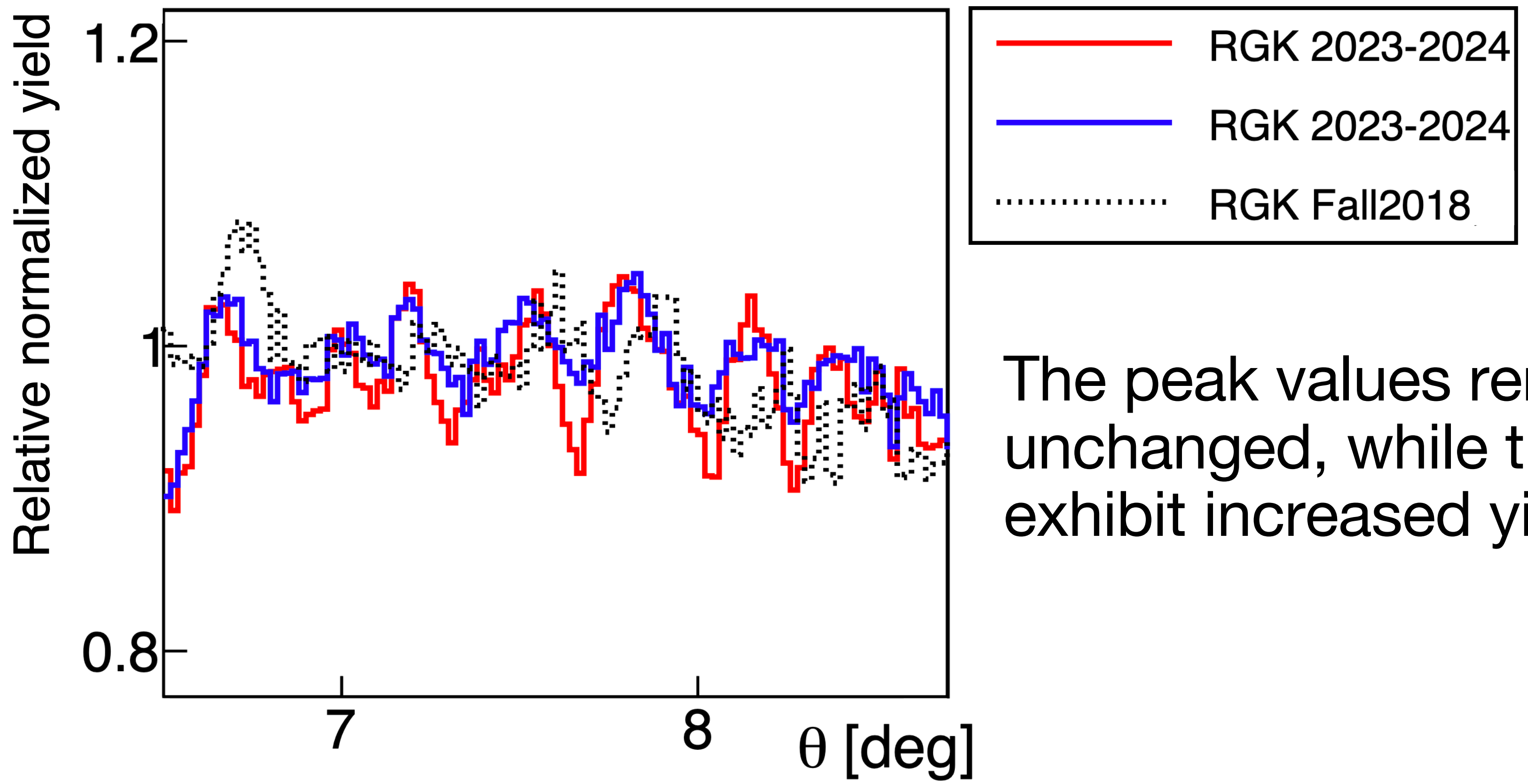
Cross Section Comparison





Finite Cross Section Measurement "Structure"

Yield's Distribution in Drift Chamber

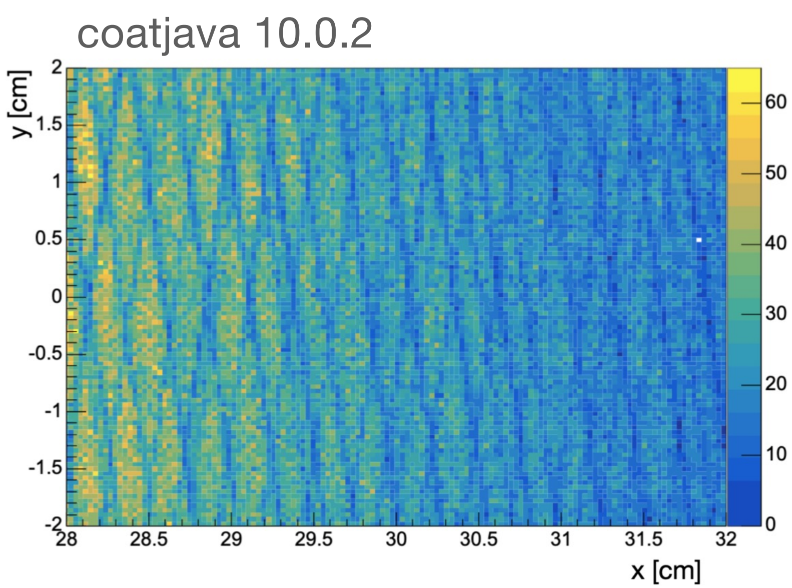


coatjava 11.2.0
coatjava 13.0.3
coatjava 10.0.2

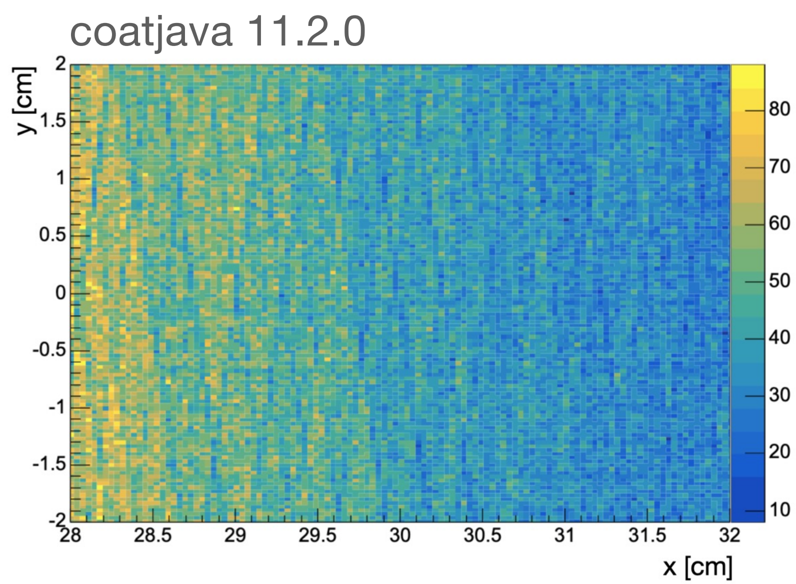
The peak values remain essentially unchanged, while the local valleys exhibit increased yields

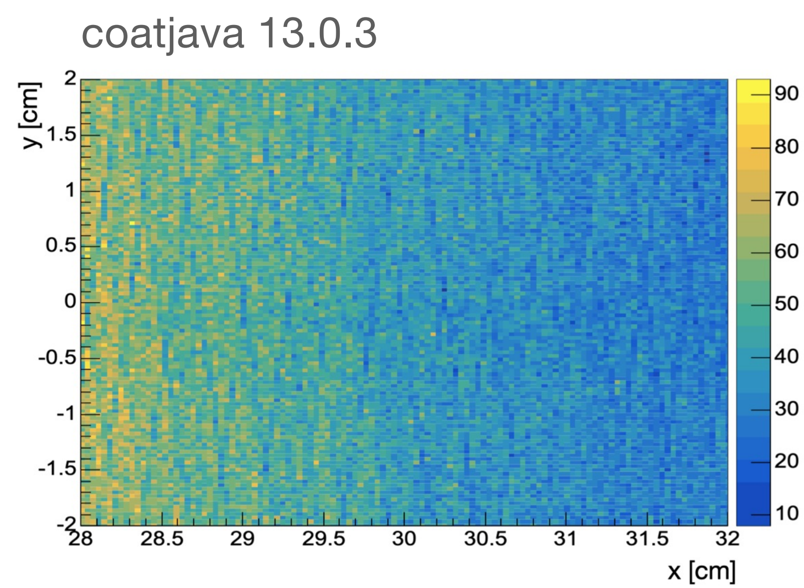
Finite Cross Section Measurement “Structure”

Yield’s Distribution in Drift Chamber



RGK Fall18 6.5GeV Cross Section
(2 runs statistic)

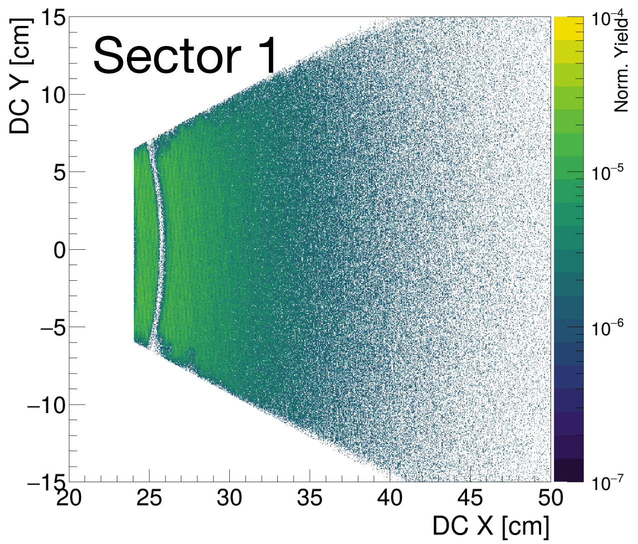




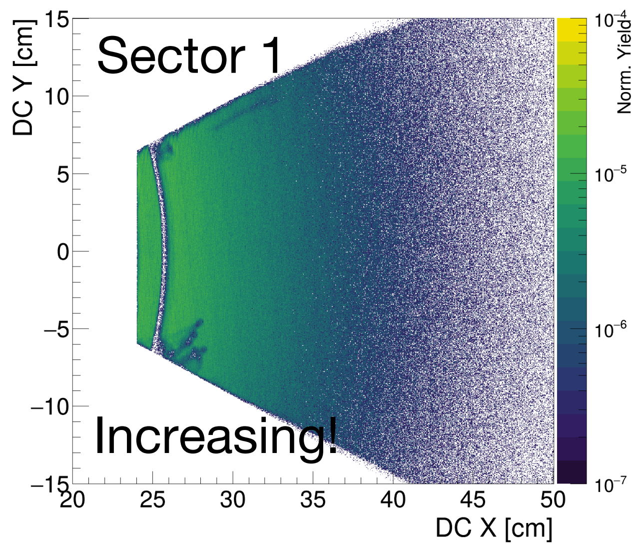
RGK Spring24 6.4GeV Cross Section
(2 runs statistic)

“Large Scale Structure”

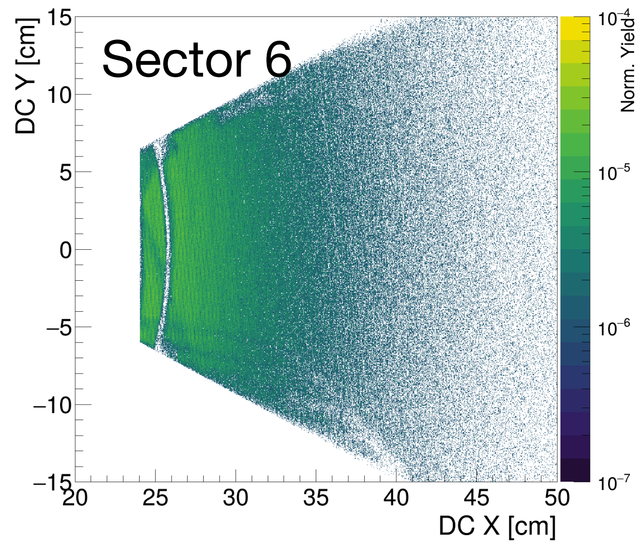
Yield’s Distribution in Drift Chamber



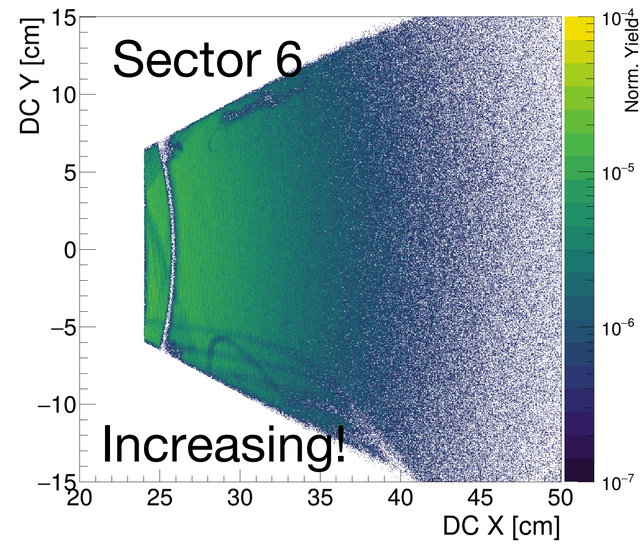
RGK Fall18 6.5GeV
Cross Section
(2 runs statistic)



RGK Spring24 6.4GeV
Cross Section
(2 runs statistic)



RGK Fall18 6.5GeV
Cross Section
(2 runs statistic)



RGK Spring24 6.4GeV
Cross Section
(2 runs statistic)

Summary

We presented an analysis of the elastic scattering cross section as a crucial benchmark for understanding CLAS12 detector performance, providing a foundation for more complex cross section measurements. By using the well-established elastic cross section as a reference and comparing measured events to theoretical predictions, we provide a tool to validate the detector's accuracy, efficiency, and calibration.

We submitted this work as CLAS12 note: CLAS12 Note 2025-004

We successfully extract the elastic cross section within ~3% agreement with Brash parameterization, and indicate the following understanding of the data:

- Software tracking improves as the finite fluctuation structure decreases.
- Calibration procedures, alignment & geometry validation improve as we are seeing a flatter extraction.
- For inclusive electron, not seeing a need for efficiency correction at this point.
- For detector, large inefficiency structure may indicate aging of detectors, need further studies

Next Step

- Exclusive ep->ep elastic analysis, better understanding of the CD&FD performance and alignment
- Use beam energy as a new tool to understand the detector alignment.

Working Group: Yijie Wang, Volker Burkert,
Latifa Elouadrhiri, Francois-Xavier Girod, Cole Smith

Massachusetts Institute of Technology
Jefferson Lab
University of Virginia

Thank you for your listening!

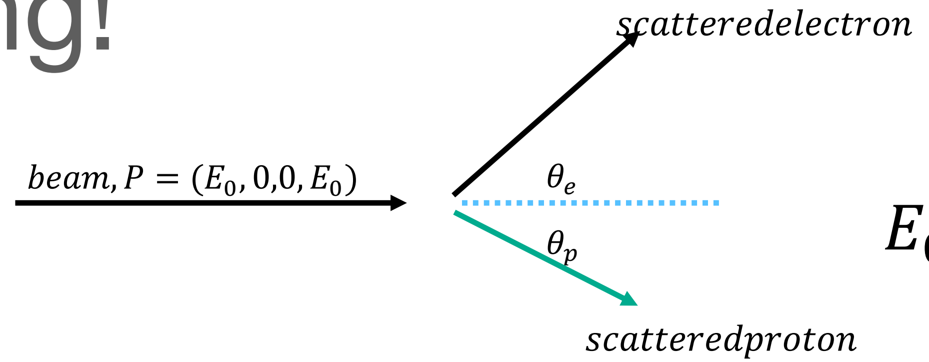
Working Group: Yijie Wang, Volker Burkert,
Latifa Elouadrhiri, Francois-Xavier Girod, Cole Smith

Massachusetts Institute of Technology
Jefferson Lab
University of Virginia

November, 2025

Ongoing!

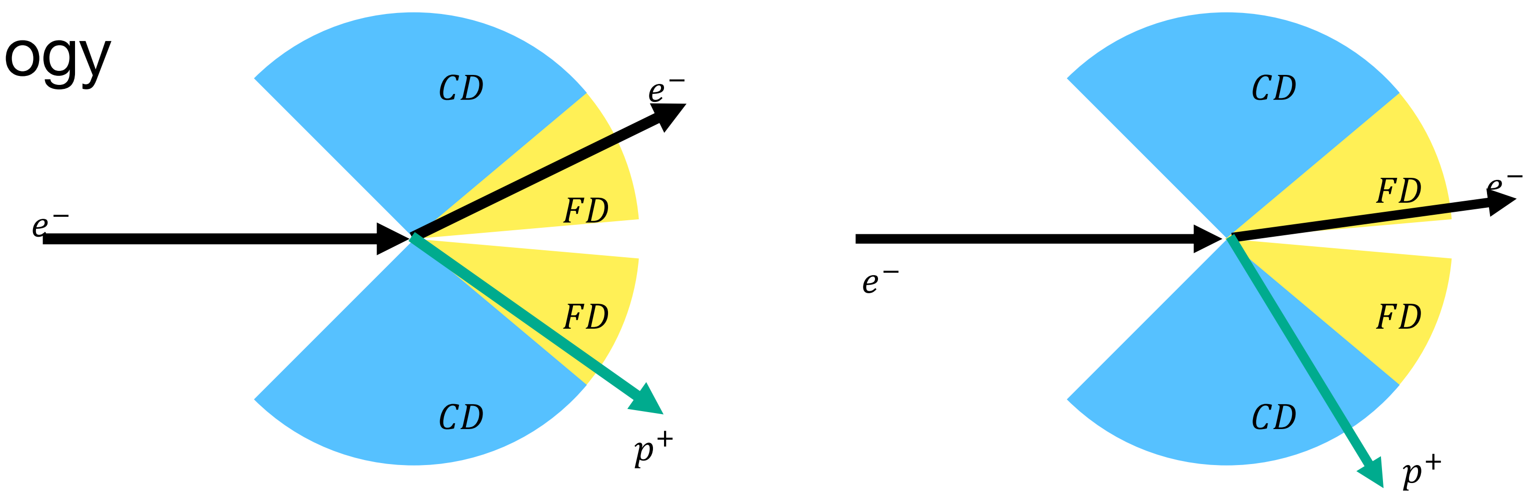
Elastic Event:



$$E_0 = f(\theta_e, \theta_p) = \frac{\cos\theta_e + \cos\theta_p \cdot \frac{\sin\theta_e}{\sin\theta_p} - 1}{2\sin^2(\theta_e/2)} \cdot r$$

It’s a pure kinematics and geometry question!

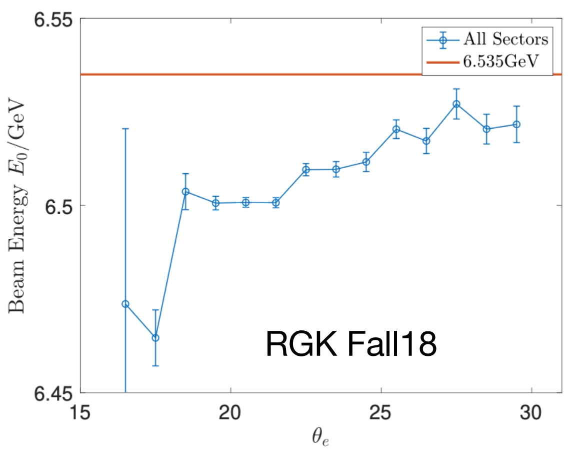
Two Topology

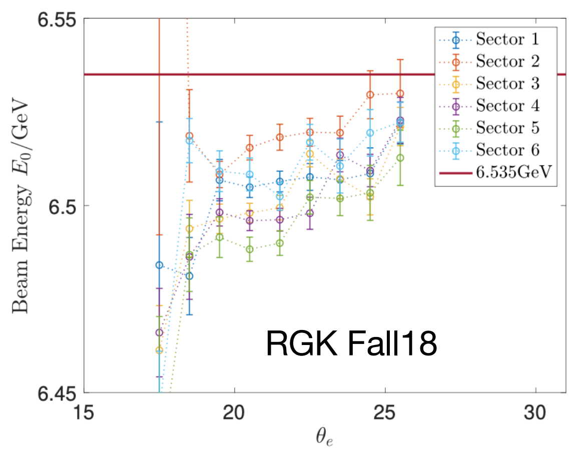


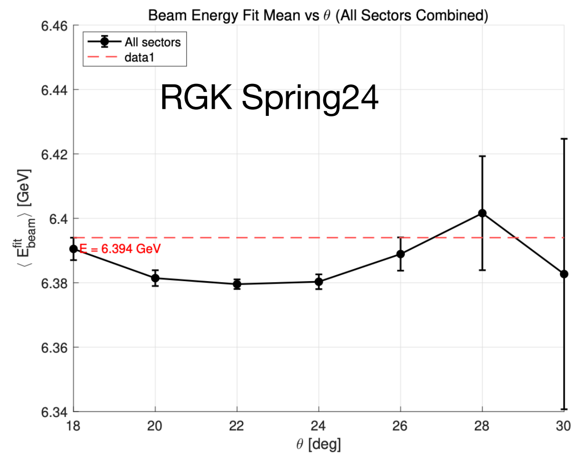
Beam Energy Reconstruction

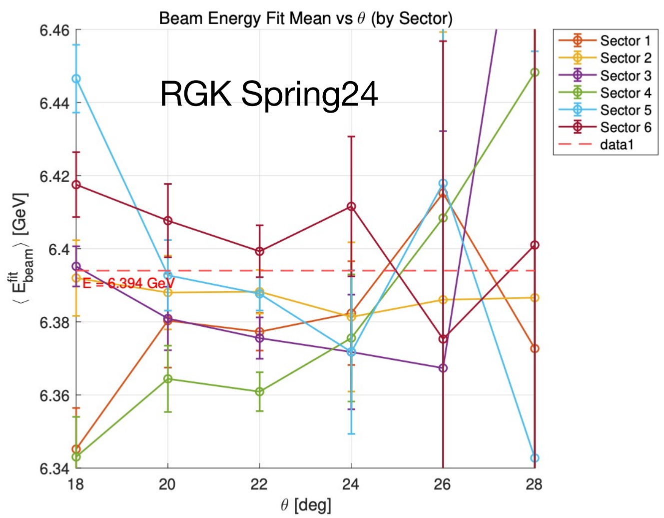
Proton in FD

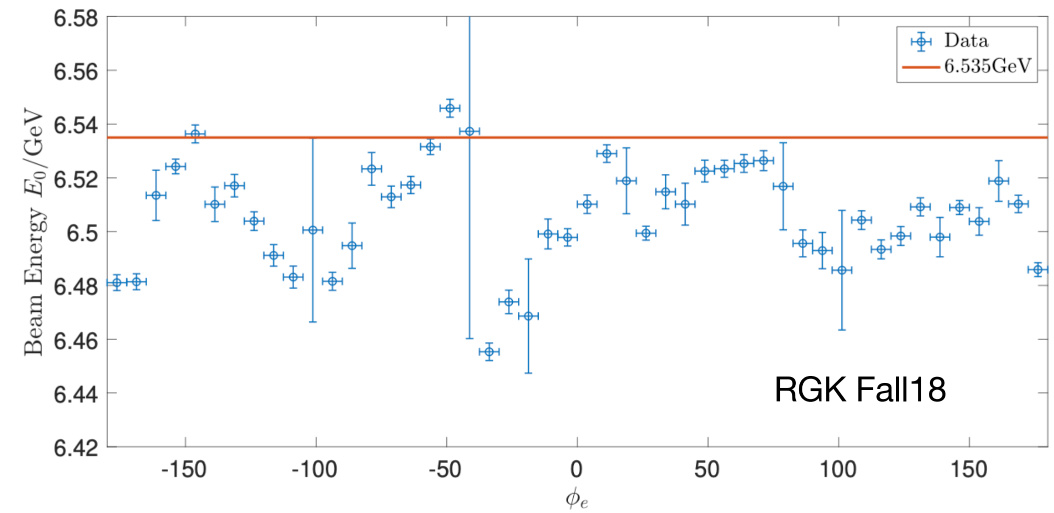
Ongoing!

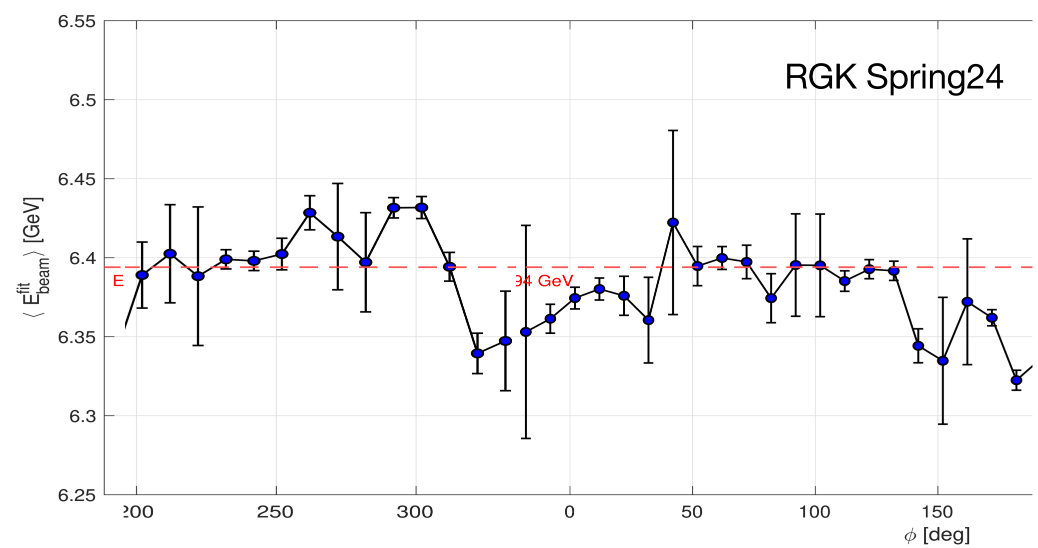






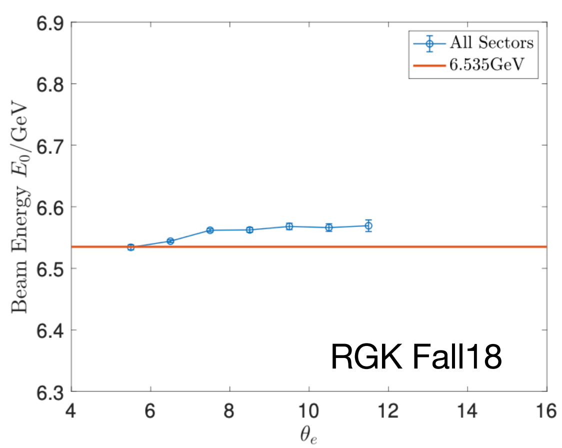


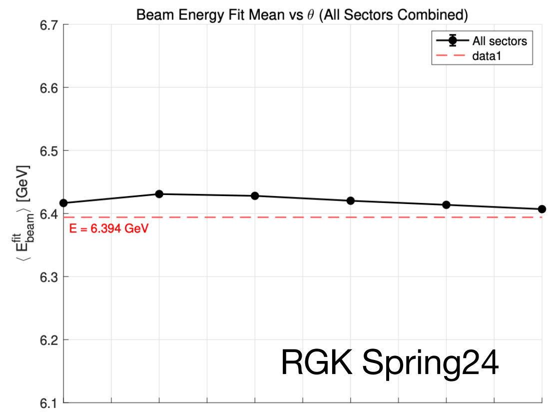


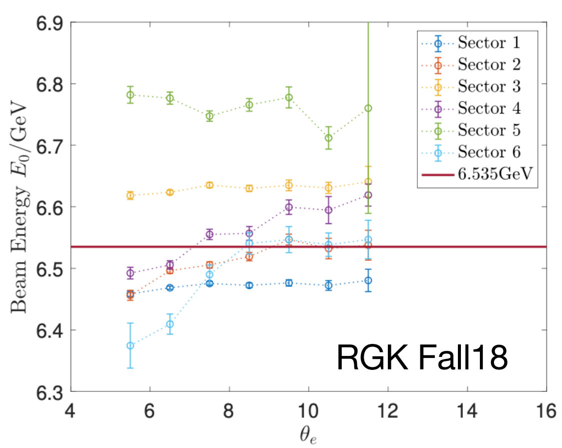


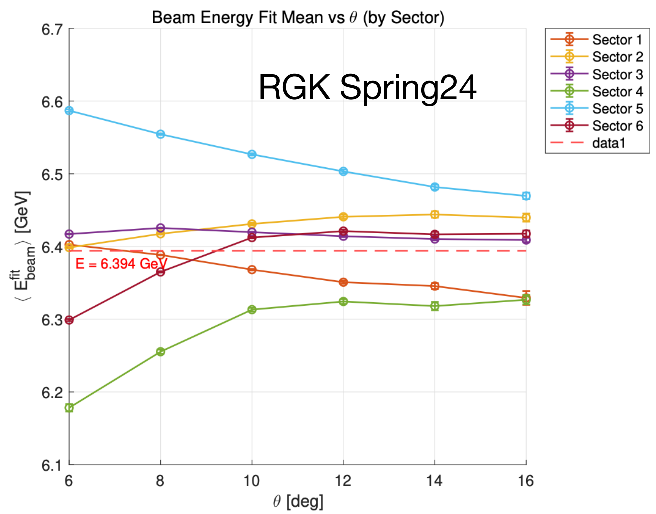
Proton in CD

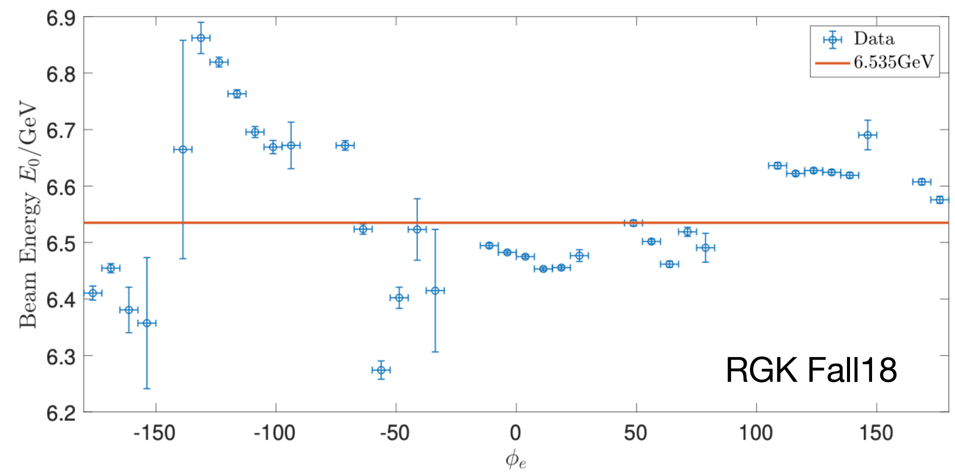
Ongoing!











RGK Spring24