RG-A DVCS Cross Section Measurement

Status of the analysis – 3rd iteration

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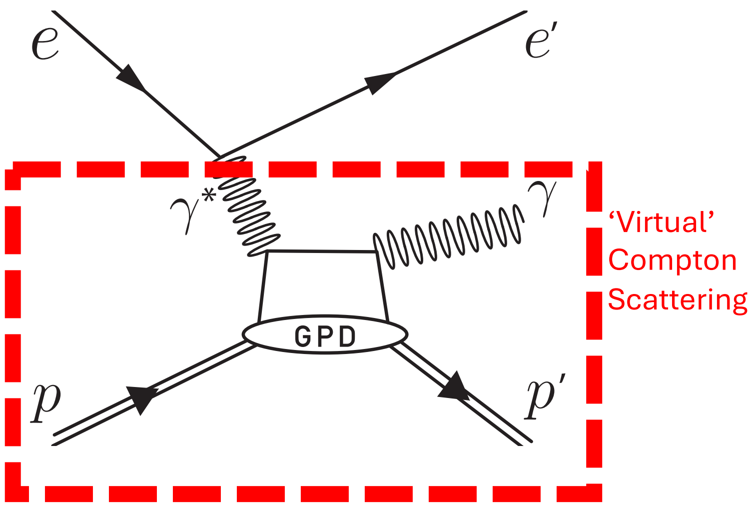
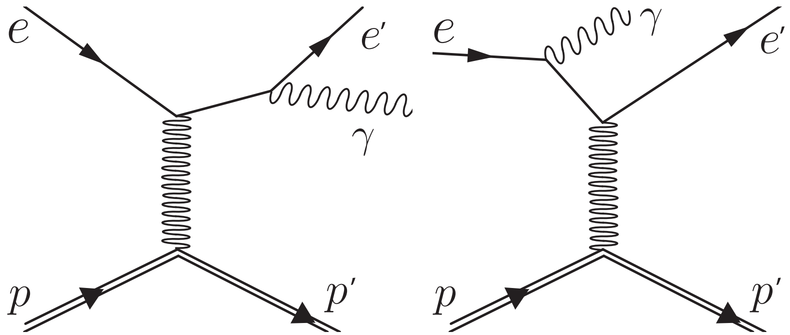
Physics Motivation

- Generalized Parton Distributions (GPDs) is a well-established tool to study the mass and spin distributions, and the mechanical properties.
- Experimentally determined differential cross sections of DVEP → Factorization → CFFs → GPDs
  - DVCS is the cleanest channel to probe the quarks
  - Defined as $\gamma^{*}p \rightarrow \gamma p$
  - Often referred to $ep \rightarrow e'p\gamma$
    - Interfered with the Bethe-Heitler processes
- Extracting CFFs and GPDs requires the measurements at large phase space
  - Absolute cross sections
  - Asymmetry

DVCS

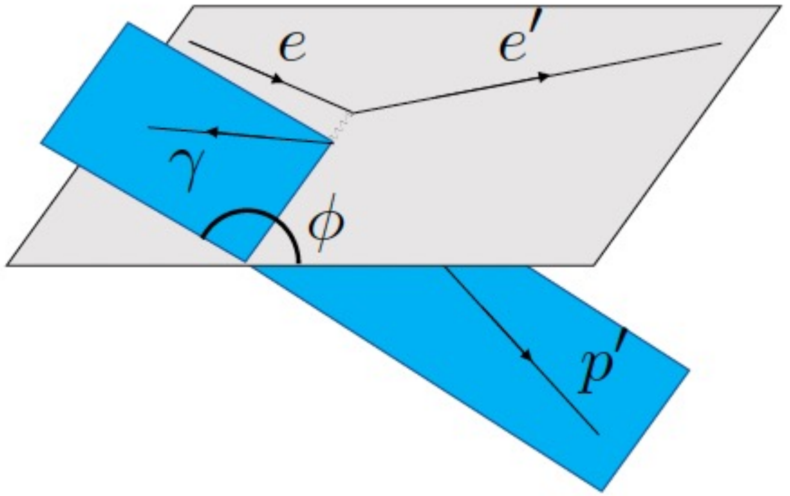


BH



DVCS Cross Section Measurement

- Five binning variables
  - Bjorken x, x_B
  - Virtual photon four-momentum Q^2
  - Momentum transfer at nucleon $|t|$
  - Azimuthal angle between two planes ϕ
  - Nucleon spin direction
    - Integrated out for the unpolarized target

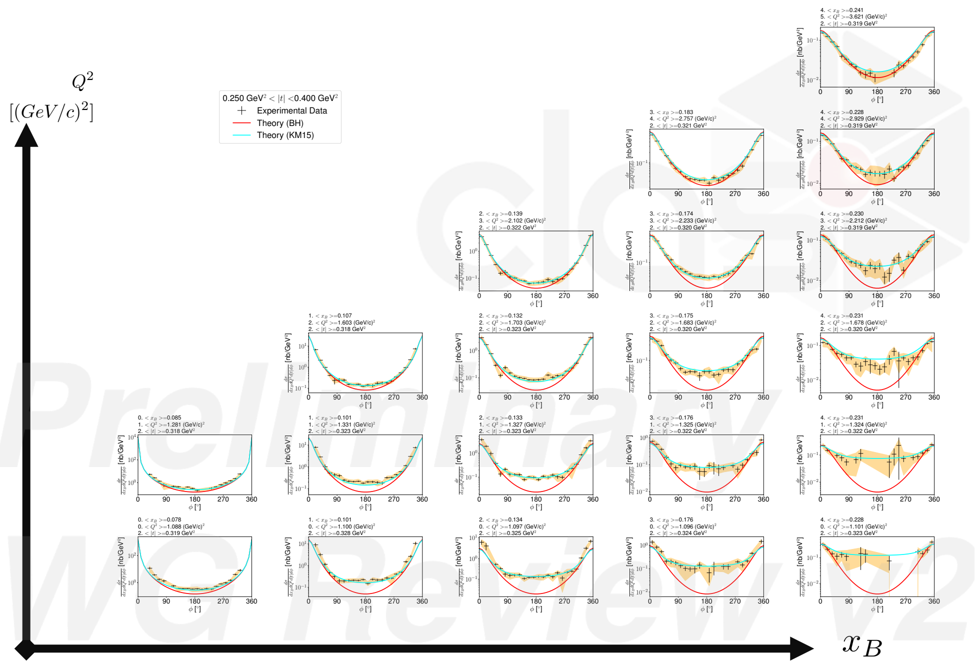


- Binned cross section determination
  - Count the events passes exclusivity condition
  - Divide it by luminosity, bin volume, efficiency, and correction factors

$$\left.\frac{d\sigma}{dx_B dQ^2 d|t| d\phi}\right|_{\mathrm{bin\ center}} = \frac{N_{bin}}{\mathcal{L}\Delta x_B \Delta Q^2 \Delta|t| \Delta\phi} \frac{1}{\epsilon} \frac{1}{F_{correction}}$$

The RG-A DVCS cross section measurement

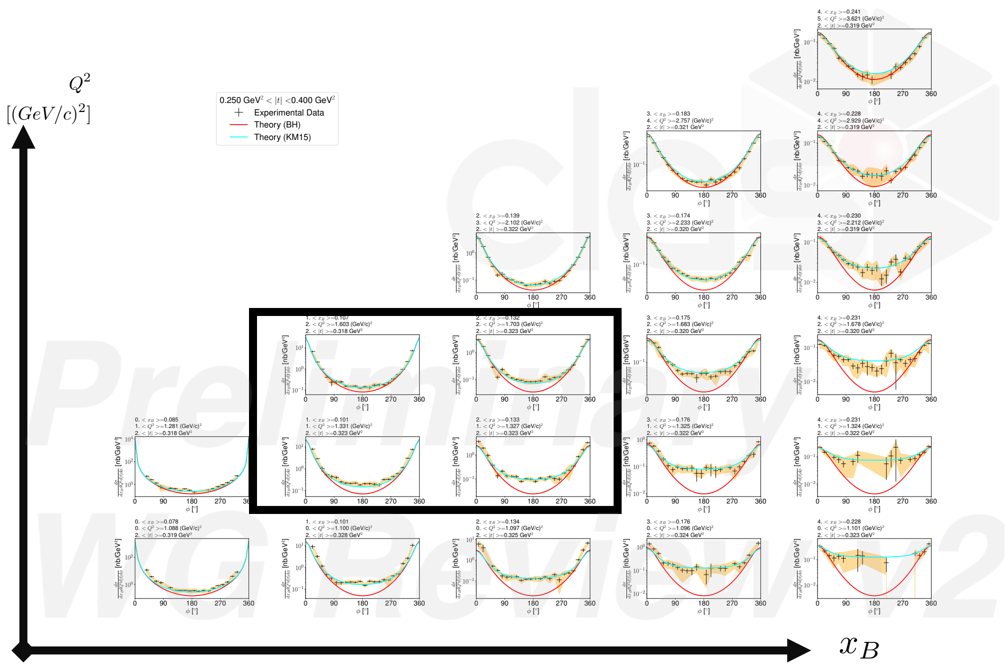
- Data set:
  - Run Group A, Pass-1, Fall 2018
    - Inbending: 30.0 mC, 39.7 fb^{-1}
    - Outbending: 31.8 mC, 42.0 fb^{-1}

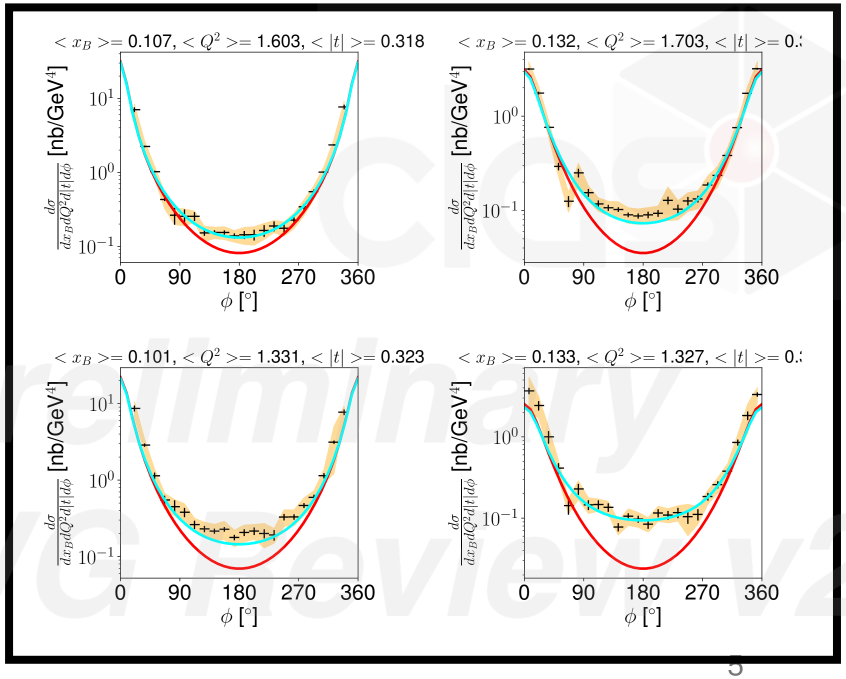


- The analysis review within the DPWG is in progress
  - 2nd round review is done
  - 3rd iteration is ongoing, which majorly requires
    - Understanding of the normalization
    - New simulation with the relaxed radiative corrections
  - *This talk is about the updates to the analysis for 3rd iterations.*

Update – Cross Section Model

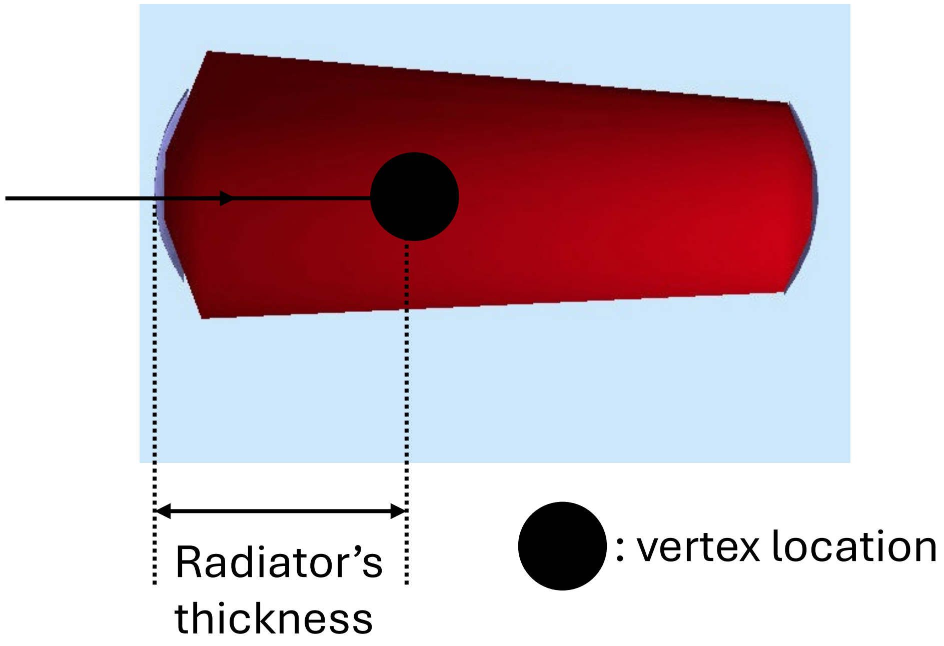
- Event generation using the KM15 model is added.
- Why KM15 model?
  - based on all DVCS experimental data prior to 2015
  - Analysis v2 of this work agreed the most w/KM15
    - Black dots are data, cyan curves are the model
  - matches well with the Hall A measurement
- Why more realistic model?
  - to reduce the systematics in the acceptance
  - to estimate the normalization at the detector level
- https://gitlab.com/sangbaek/km15gen

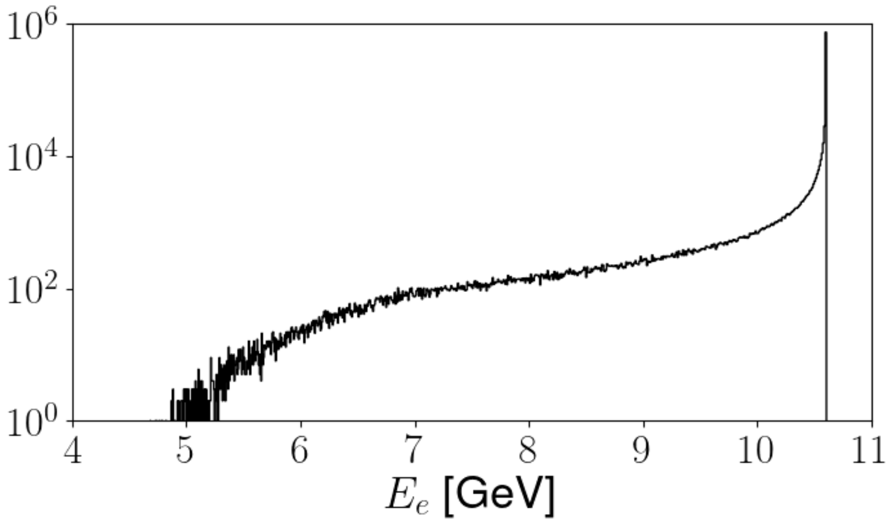




Update – Radiative Corrections (External)

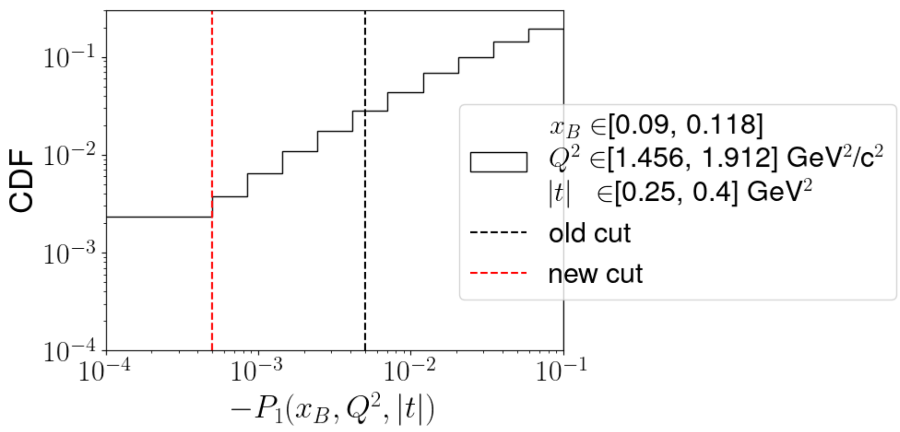
- Electron loses its energy through the interaction with the target system.
  - GEMC simulates the energy loss for the final state particles from the detectors
  - The energy loss should be manually simulated for the incoming electron beam
  - External radiation does not occur frequently, but once it happens, it dramatically shifts kinematics, then cross section
  - Following steps are implemented in each event generator (Mo & Tsai)
    - Randomly simulate vertex location
    - Calculate the length in radiation length
    - 30 μm Al window = 3.3 ×10-4 X0
      5 cm LH2 = 5.4 ×10-3 X0





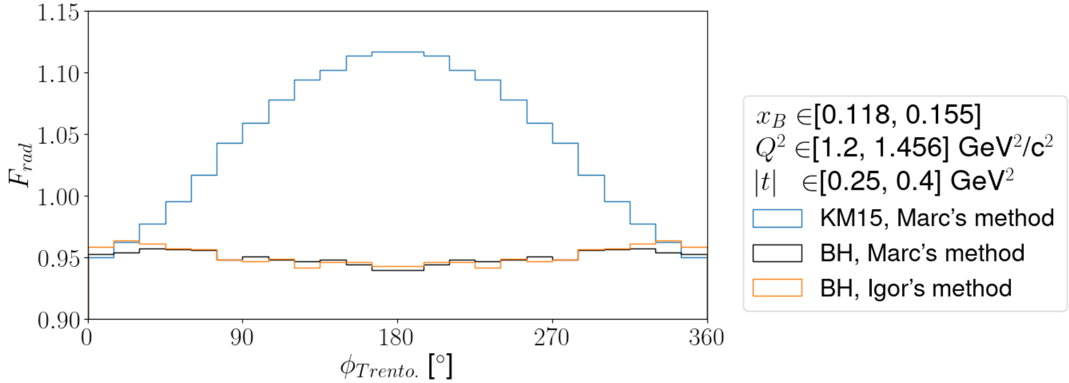
Update – Radiative Corrections (Internal)

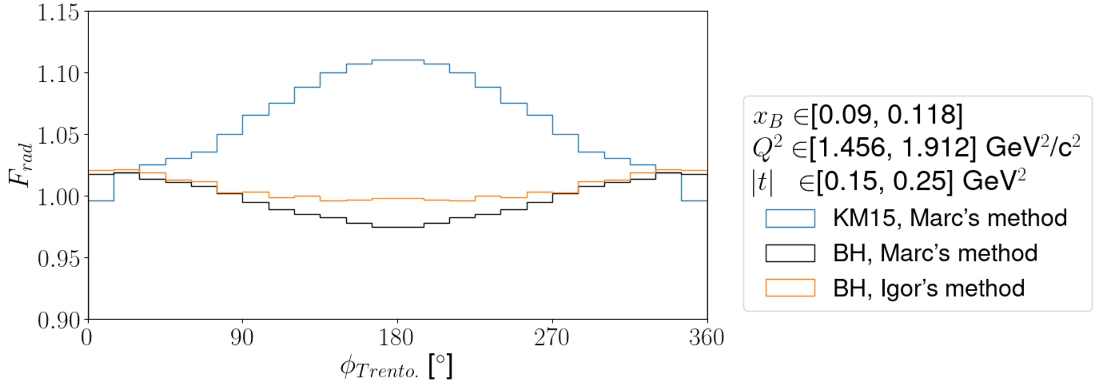
- Why do we update the internal radiative corrections?
  - There is a cut in y_{col} to suppress BH from blowing up, especially in $\phi \sim 0$ bin
  - At the same time this bin is BH-dominant and important in normalization
  - Practically, this cut was done by the equivalent cut in P_1 (propagator term)
  - This limit on P_1 was relaxed from 0.005 to 0.0005
    - Most bins are not affected. The example is at the right plot.
    - One of the major request from the committee



Update – Radiative Corrections (Internal)

- Marc Vanderhaeghen et al.'s method
  - Simulate the radiated photons with the effective external radiator thickness
  - Calculate the shifts in kinematics, and calculate the cross section there
  - Apply other exact RC factors to the cross section
- Igor Akushevich & Alexander Ilyichev's method
  - Exact radiative correction factor at the given phase space
  - Simulate the radiated photon based on the probability
    - Caveat) requires $MM^2_{e'p}$ cut
- The RC factor from two methods roughly agrees for the BH.
- The RC factor using the KM15 model significantly differs from the BH's (~10%).

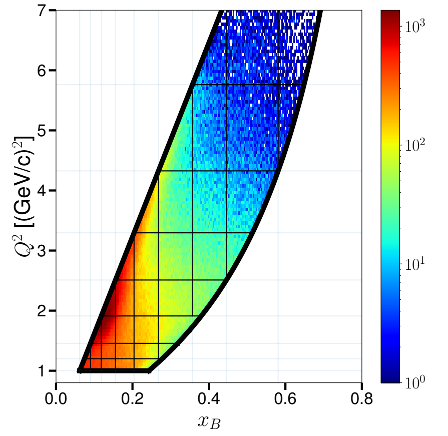


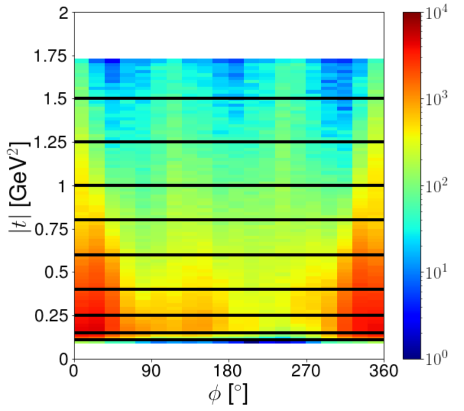


Update – Simulation Data

Job	Bins? (bulk	Rad?	Polarity	Lund file location	OSG	Rec root	Rec pkl	Gen root	Gen pkl
dvcs-km15	bulk	y	inb	/volatile/clas12/sangbaek/dvcs_related/sim_rad_gen/dvcs_km15/fall2018_inb	7145	/volatile/clas12/s	ongoing	/volatile/clas12/sangb	ongoing
dvcs-km15	bulk	n	inb, N/A	/volatile/clas12/sangbaek/dvcs_related/sim_norad_gen/dvcs_km15/fall2018_inb	N/A	N/A	N/A	N/A	/volatile/clas12/s
dvcs-km15	fringe	y	inb	/volatile/clas12/sangbaek/dvcs_related/sim_rad_gen/dvcs_km15_fringe/fall2018_inb	7176	/volatile/clas12/s	ongoing	/volatile/clas12/sangb	ongoing
dvcs-km15	bulk	y	outb	/volatile/clas12/sangbaek/dvcs_related/sim_rad_gen/dvcs_km15/fall2018_outb	7146	/volatile/clas12/s	ongoing	/volatile/clas12/sangb	ongoing
dvcs-km15	bulk	n	outb, N/A	/volatile/clas12/sangbaek/dvcs_related/sim_norad_gen/dvcs_km15/fall2018_outb	N/A	N/A	N/A	N/A	/volatile/clas12/s
dvcs-km15	fringe	y	outb	/volatile/clas12/sangbaek/dvcs_related/sim_rad_gen/dvcs_km15_fringe/fall2018_outb	7199	/volatile/clas12/s	ongoing	/volatile/clas12/sangb	ongoing
pi0	bulk+fringe	y	inb	/volatile/clas12/sangbaek/dvcs_related/submission_scripts/sim_rad_gen/pi0/pi0_inb_1	7230				
pi0	bulk+fringe	y	inb	/volatile/clas12/sangbaek/dvcs_related/submission_scripts/sim_rad_gen/pi0/pi0_inb_3	7251				
pi0	bulk+fringe	y	outb	/volatile/clas12/sangbaek/dvcs_related/submission_scripts/sim_rad_gen/pi0/pi0_outb_1	7256				
pi0	bulk+fringe	y	outb	/volatile/clas12/sangbaek/dvcs_related/submission_scripts/sim_rad_gen/pi0/pi0_outb_3	7293				
pi0	bulk+fringe	y	inb	/volatile/clas12/sangbaek/dvcs_related/submission_scripts/sim_rad_gen/pi0/pi0_outb_2	7281				
pi0	bulk+fringe	y	outb	/volatile/clas12/sangbaek/dvcs_related/submission_scripts/sim_rad_gen/pi0/pi0_inb_2	7246				
dvcs-vgg	bulk	y	inb	/volatile/clas12/sangbaek/dvcs_related/sim_rad_gen/dvcs_vgg/fall2018_inb	7220				
dvcs-vgg	bulk	n	inb, N/A	/volatile/clas12/sangbaek/dvcs_related/sim_norad_gen/dvcs_vgg/fall2018_inb	N/A	N/A	N/A	N/A	
dvcs-vgg	fringe	y	inb	/volatile/clas12/sangbaek/dvcs_related/sim_rad_gen/dvcs_vgg_fringe/fall2018_inb	waiting for submission				
dvcs-vgg	bulk	y	outb	/volatile/clas12/sangbaek/dvcs_related/sim_rad_gen/dvcs_vgg/fall2018_outb	7311				
dvcs-vgg	bulk	n	outb, N/A	/volatile/clas12/sangbaek/dvcs_related/sim_norad_gen/dvcs_vgg/fall2018_outb	N/A	N/A	N/A	N/A	
dvcs-vgg	fringe	y	outb	/volatile/clas12/sangbaek/dvcs_related/sim_rad_gen/dvcs_vgg_fringe/fall2018_outb	waiting for submission				
pureBH	bulk	y	inb	/volatile/clas12/sangbaek/dvcs_related/sim_rad_gen/pureBH/fall2018_inb	7205				
pureBH	bulk	n	inb, N/A	/volatile/clas12/sangbaek/dvcs_related/sim_norad_gen/pureBH/fall2018_inb	N/A	N/A	N/A	N/A	
pureBH	fringe	y	inb	/volatile/clas12/sangbaek/dvcs_related/sim_rad_gen/pureBH_fringe/fall2018_inb	waiting for submission				
pureBH	bulk	y	outb	/volatile/clas12/sangbaek/dvcs_related/sim_rad_gen/pureBH/fall2018_outb	7212				
pureBH	bulk	n	outb, N/A	/volatile/clas12/sangbaek/dvcs_related/sim_norad_gen/pureBH/fall2018_outb	N/A	N/A	N/A	N/A	
pureBH	fringe	y	outb	/volatile/clas12/sangbaek/dvcs_related/sim_rad_gen/pureBH_fringe/fall2018_outb	waiting for submission				
dvcs-km15	bulk	y	inb	/volatile/clas12/sangbaek/dvcs_related/sim_rad_gen/dvcs_km15/fall2018_inb2	waiting for submission				/volatile/clas12/s
dvcs-km15	bulk	n	inb, N/A	/volatile/clas12/sangbaek/dvcs_related/sim_norad_gen/dvcs_km15/fall2018_inb2	N/A	N/A	N/A	N/A	/volatile/clas12/san
dvcs-km15	fringe	y	inb	/volatile/clas12/sangbaek/dvcs_related/sim_rad_gen/dvcs_km15_fringe/fall2018_inb2	waiting for submission				/volatile/clas12/s
dvcs-km15	bulk	y	outb	/volatile/clas12/sangbaek/dvcs_related/sim_rad_gen/dvcs_km15/fall2018_outb2	waiting for submission				/volatile/clas12/s
dvcs-km15	bulk	n	outb, N/A	/volatile/clas12/sangbaek/dvcs_related/sim_norad_gen/dvcs_km15/fall2018_outb2	N/A	N/A	N/A	N/A	/volatile/clas12/s
dvcs-km15	fringe	y	outb	/volatile/clas12/sangbaek/dvcs_related/sim_rad_gen/dvcs_km15_fringe/fall2018_outb2	waiting for submission				/volatile/clas12/s
DVCS			inb	/cache/clas12/rg-a/production/recon/fall2018/torus-1/pass1/v1/dst/train/DVCSWagon	N/A	/volatile/clas12/sangbaek/dvcs_re		N/A	N/A
Pi0			outb	/cache/clas12/rg-a/production/recon/fall2018/torus-1/pass1/v1/dst/train/DVPi0P	N/A	/volatile/clas12/sangbaek/dvcs_re		N/A	N/A
DVCS			inb	/cache/clas12/rg-a/production/recon/fall2018/torus+1/pass1/v1/dst/train/DVCSWagon	N/A	/volatile/clas12/sangbaek/dvcs_re		N/A	N/A
Pi0			outb	/cache/clas12/rg-a/production/recon/fall2018/torus+1/pass1/v1/dst/train/DVPi0P	N/A	/volatile/clas12/sangbaek/dvcs_re		N/A	N/A

- Simulation data can be reduced into the smaller files with the momentum and detector information for the PID
  - a spreadsheet to maintain the data efficiently
  - these days, /volatile/ is busy
    - My simulation done in Feb. are already being deleted.
  - Experimental data is stored in /mss/ (/cache/)
    - Train 16: DVCS
    - Train 18: DVπ^0P
  - Strategy) flat distribution (weighted) event generations
  - 147 bins in central kinematics
  - 159 surrounding bins to study the migration
  - 28k events simulated for each (x_B, Q^2, $|t|$, ϕ) bin.





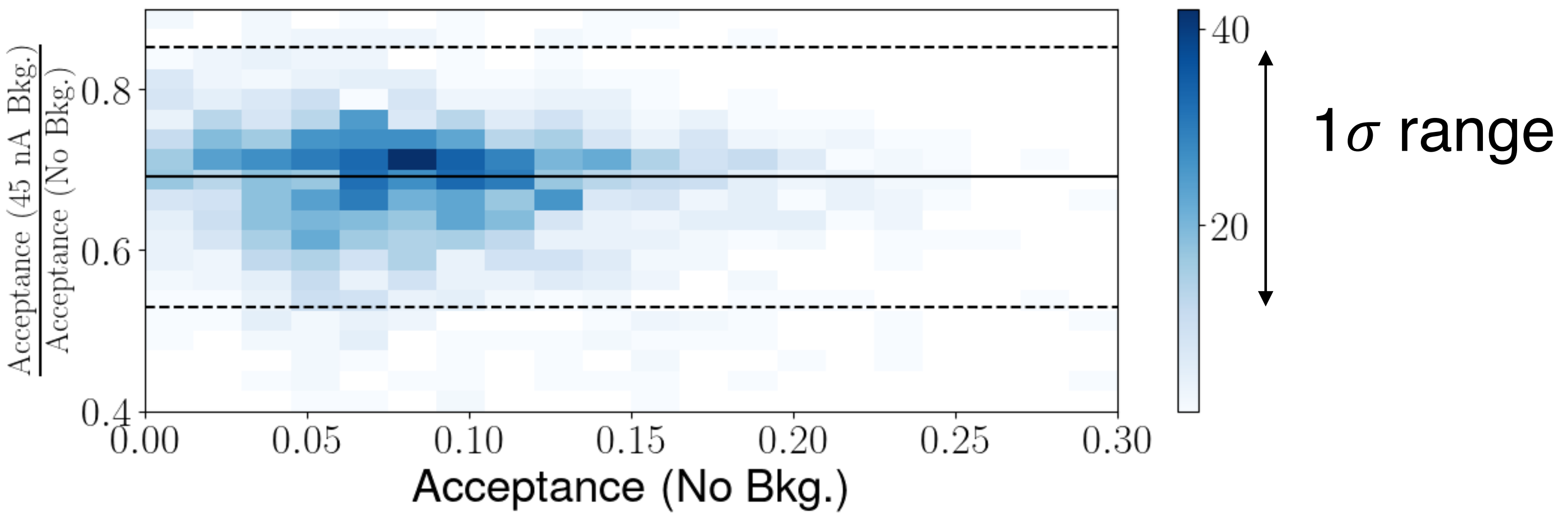
Other updates

- Consistency with the inclusive analysis
  - Electron momentum correction by Richard Capobianco
    - https://clasweb.jlab.org/wiki/index.php/CLAS12_Momentum_Corrections_from_richcap:All_Channels#tab=Correction_Code__28All_29
  - Luminosity – Attenuation factor for runs

- Proton energy loss at high polar angle for the Central Detector was updated to avoid the overcorrection
  - Attenuation factor for runs 5249−5340 should be corrected
  - 1.5% luminosity overestimation for the inbending runs

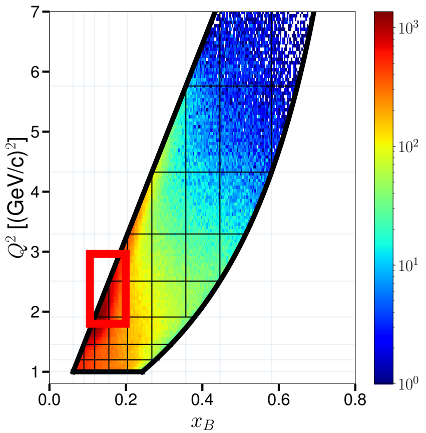
Background merging

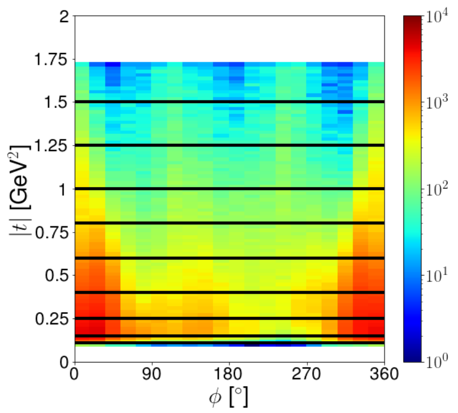
- The efficiency depends on the beam current and can be effectively counted with the background merging
  - The effect of the background merging was studied at v2, and presented at the CCC+DPWG meeting.
- For the third iteration, so far, no background merging was used for maximizing the number of reconstructed events
  - The event counts multiplied by the efficiency studied at the v2, weighted by the charges in each beam current setting.
  - Inbending: 45 nA, 50 nA, 55 nA/ Outbending: 40 nA, 50 nA

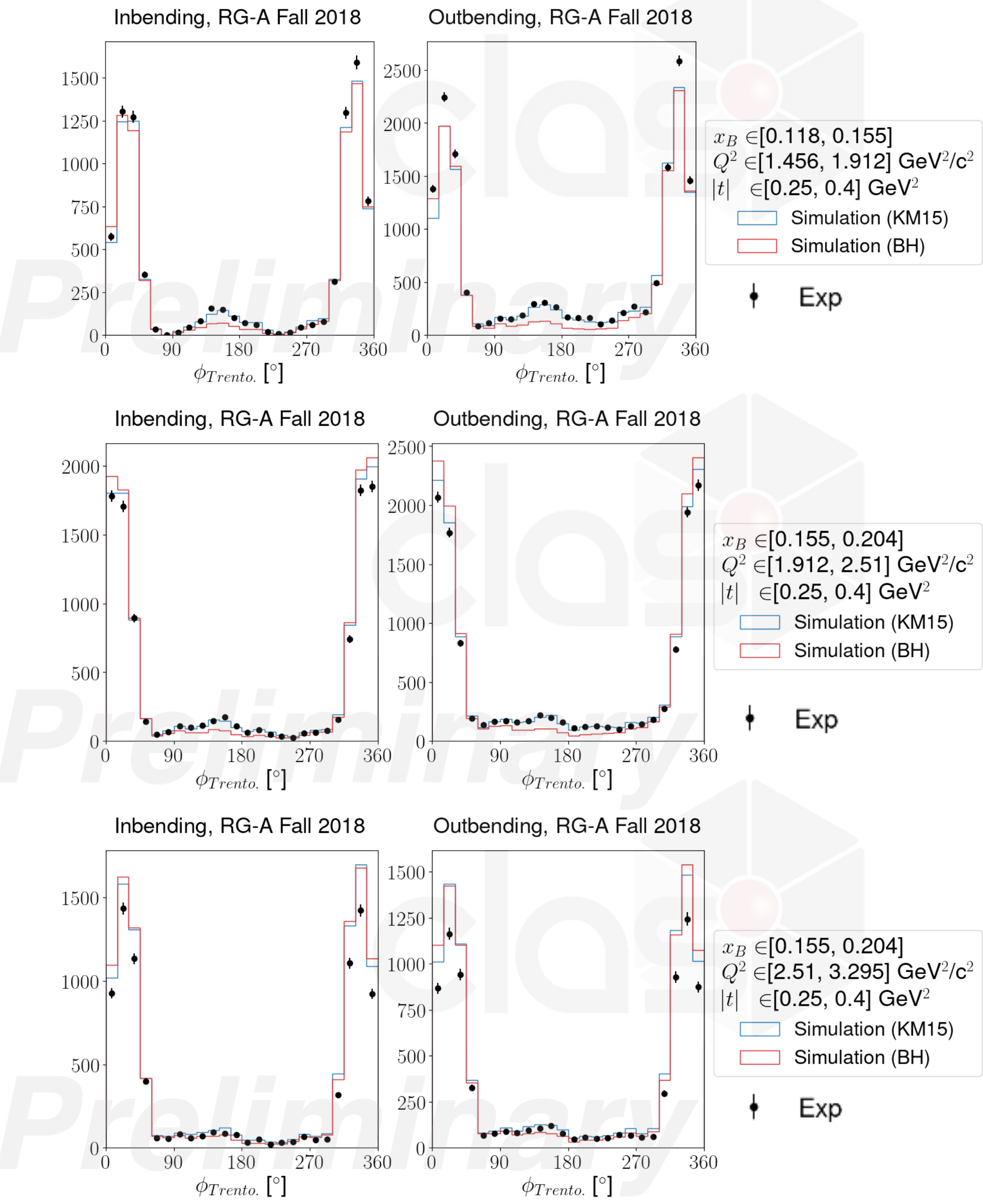


Reconstructed Events

- Simulated events are normalized to
  - Luminosity × Phase space volume × Cross section/ Total events
    - See Pierre and Rafo's document on the normalization https://clasweb.jlab.org/rungroups/tlc/wiki/images/e/e7/Normalization_MC_Data-5.pdf

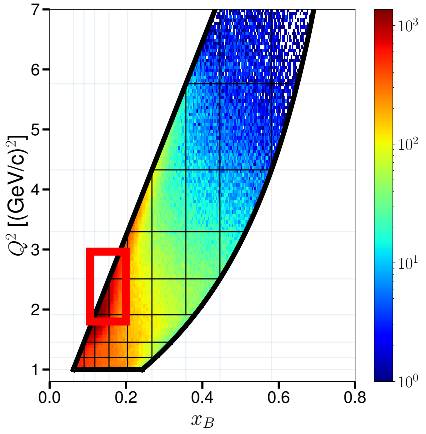


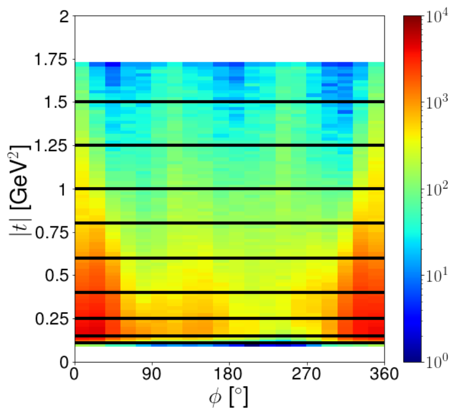


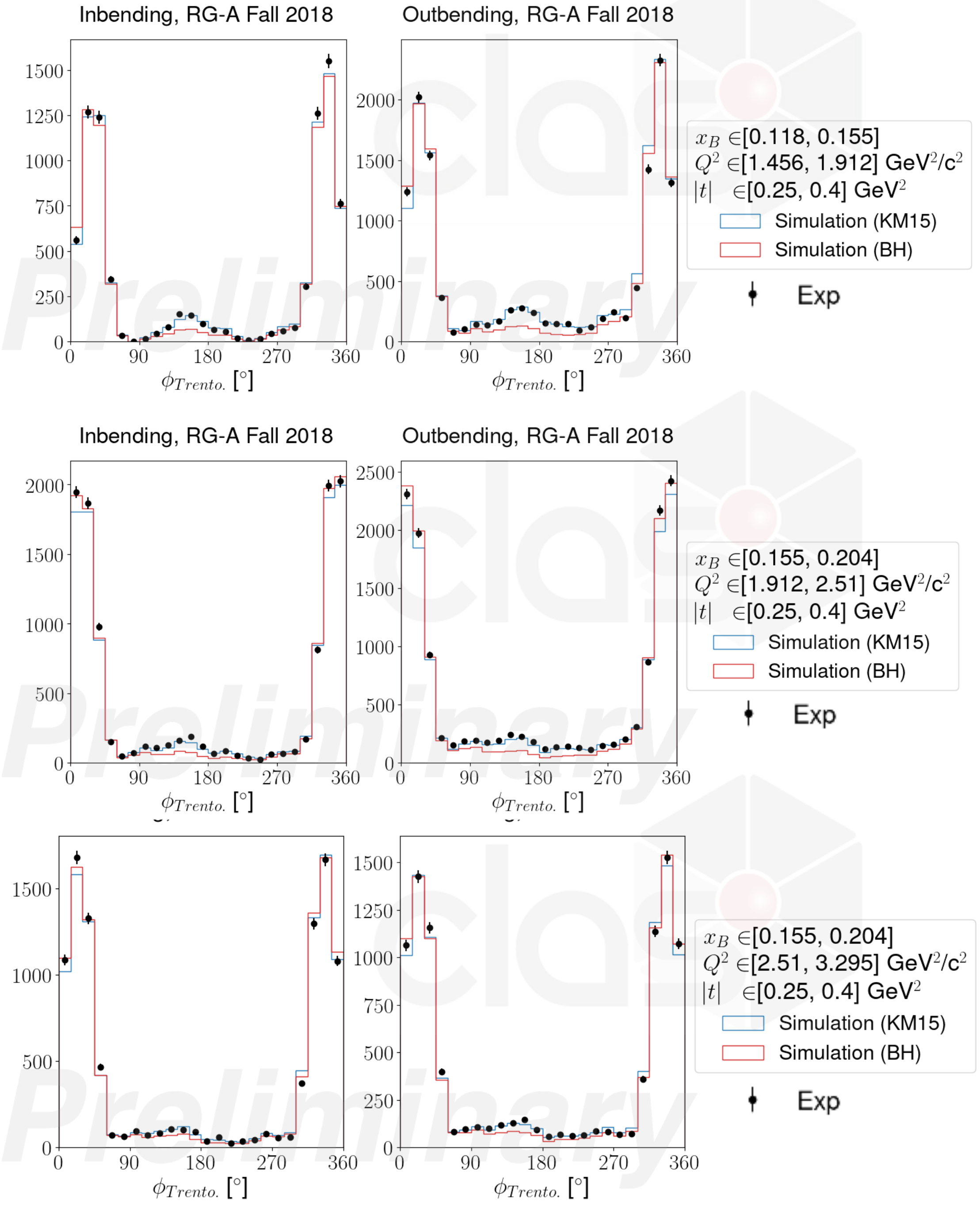


Normalization to the BH

- Simulated events are normalized to
  - Luminosity ✕ Phase space volume ✕ Cross section/ Total events
    - See Pierre and Rafo’s document on the normalization https://clasweb.jlab.org/rungroups/tlc/wiki/images/e/e7/Normalization_MC_Data-5.pdf
- Applied normalization to the edge

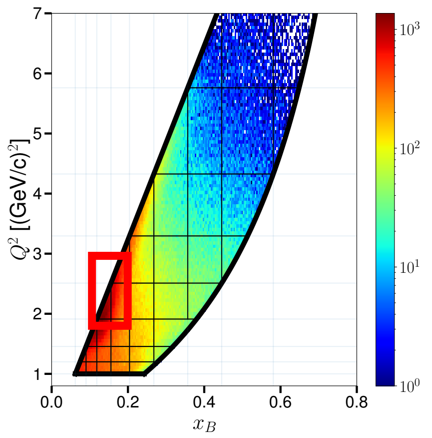


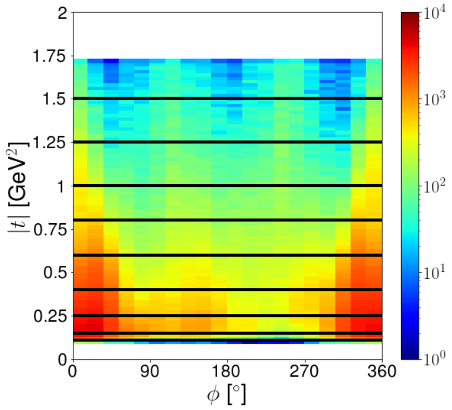


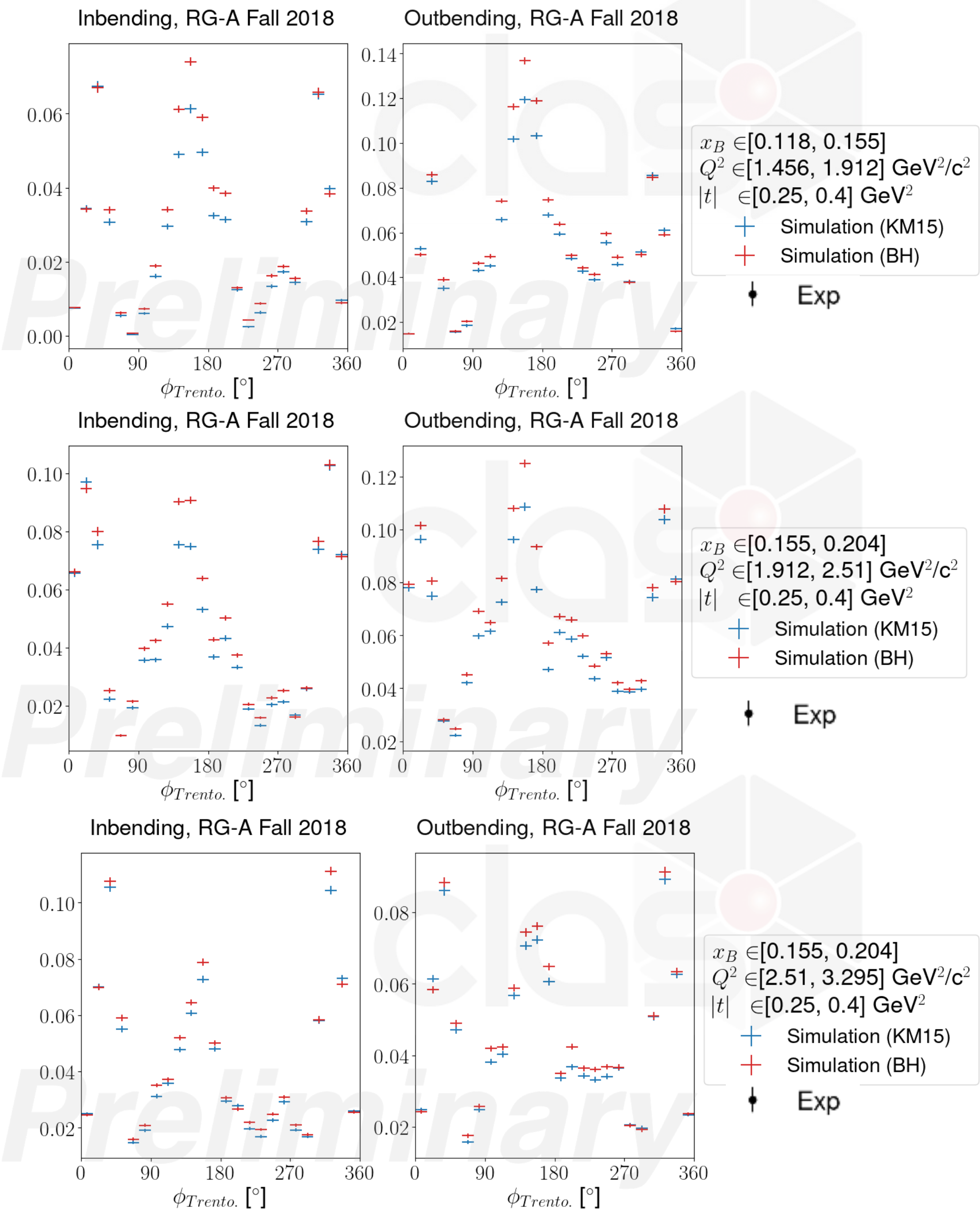


Acceptance Correction

- Acceptance was corrected using the pure BH and the KM15 models

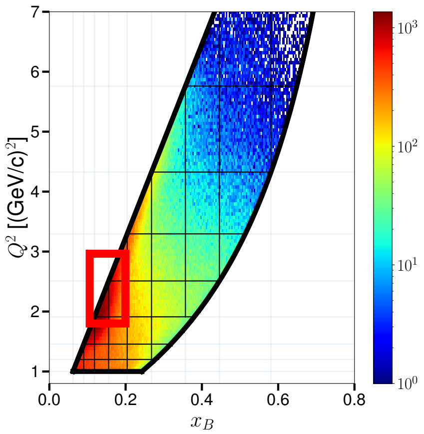


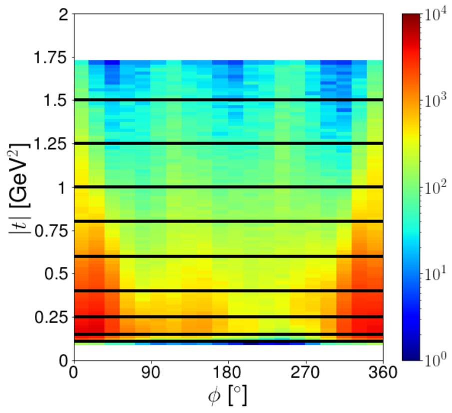


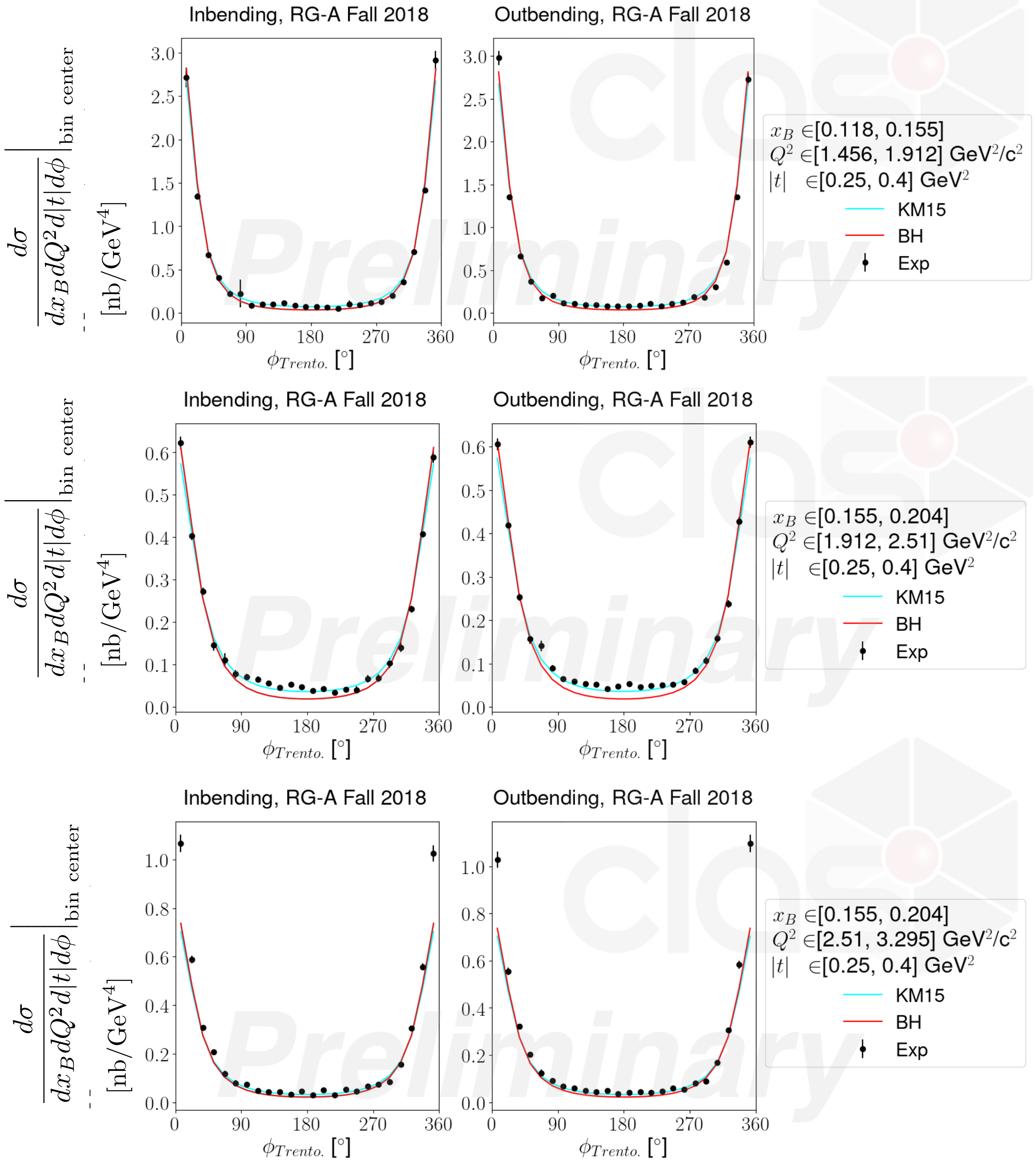


Extracted cross sections

- Statistical uncertainty only.
- Room for the bin center corrections.







Sources of Systematic Uncertainty (from v2 to v3)

Sources	V2 level (%)	How	Expected at v3
Event Selection — Exclusivity	11.8	Alternative exclusivity cuts	Similar
Event Selection — Particle ID	9.9	Alternative sampling fraction/ proton fiducial	Reduced
Resolution Matching	8.8	Alternative smearing factors	Similar
Acceptance Corrections	8.9	Alternative Acc. correction strategy	Similar
Background Estimation	12.8	Alternative Bkg. estimation strategy	Similar
Normalization	10	~~Matching with BH~~ Matching at ϕ=0 at the detector level	Reduced
Radiative Correction	3.5	Alternative CFF model	Increased
Bin Effect	3.6	Alternative CFF model	Increased
Inefficiency by Beam Current	4	Background Merging w/ random trigger	Reduced
Total	26.4		

Summary

- The updates to the RG-A DVCS cross section measurement analysis is presented

- The analysis is advanced and answering the review v2 is ongoing

- The analysis note will be submitted within a month with the manuscript draft