

RG-E Inclusive DIS with Pass 1 data

Ryan Milton, UC Riverside
CLAS Collaboration Meeting
06/30/26



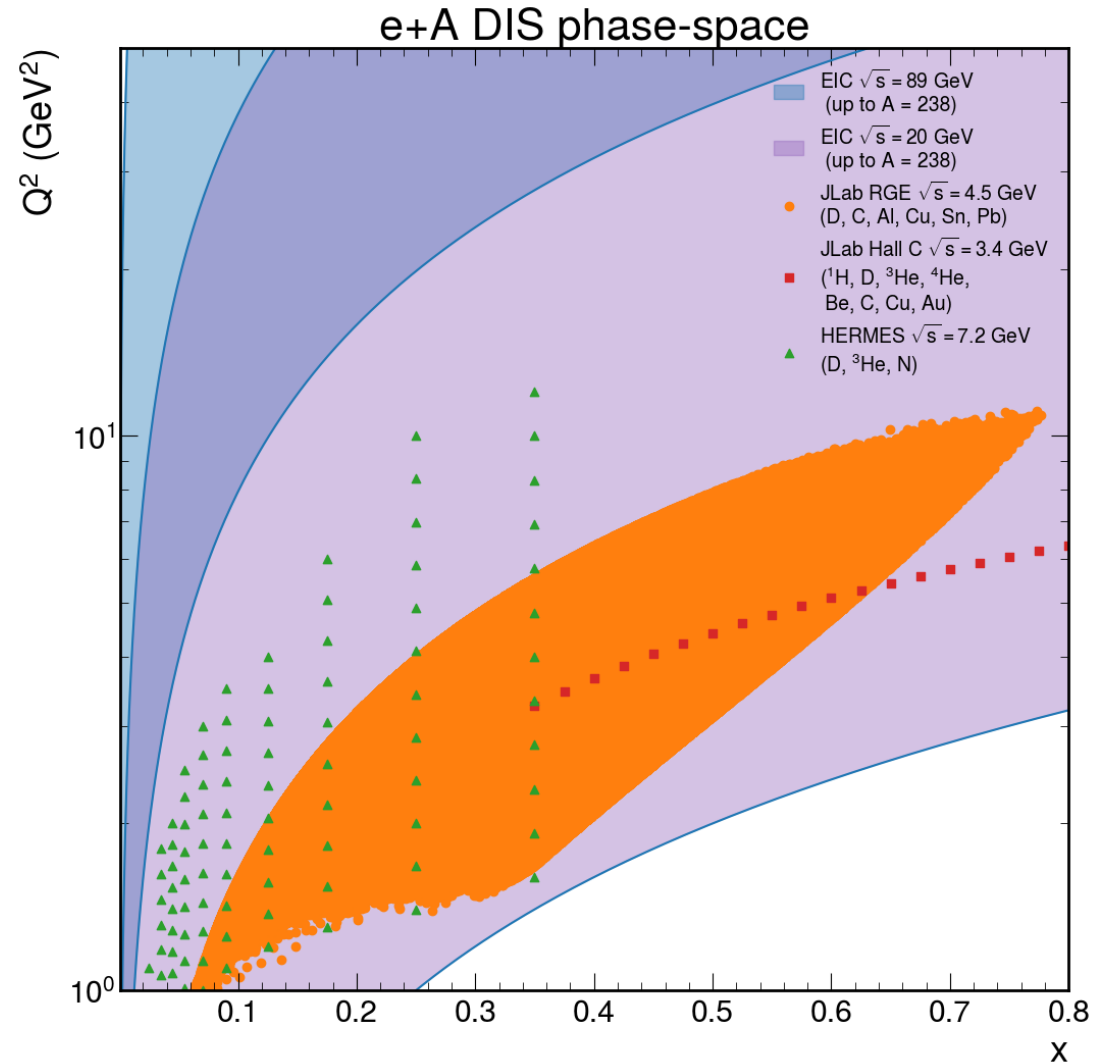
RG-E Overview

- Took data in 2024 using a dual target system of LD2 and Al, C, Cu, Sn, Pb
- Recently finished our pass 1 cooking



Motivation

- Goal: $d\sigma/dxdQ^2$ for different nuclei
- Measurements of more nuclei in CLAS and HERMES phase space
- Use run 20030 as a “reference run” to develop the cuts
- Using LD2 + C today with $\sim 50\%$ of the data ($11.9 \text{ fb}^{-1}/24.56 \text{ fb}^{-1}$) for cross sections





Outline

Common electron selection:

- Fiducial cuts
- Partial sampling fraction cuts
- SF vs. Edep cuts
- Target vertex cuts
- Simulations

Inclusive DIS analysis:

- Efficiency corrections
- Comparison to theory
- Unfolding



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Event builder electrons and kinematic cuts

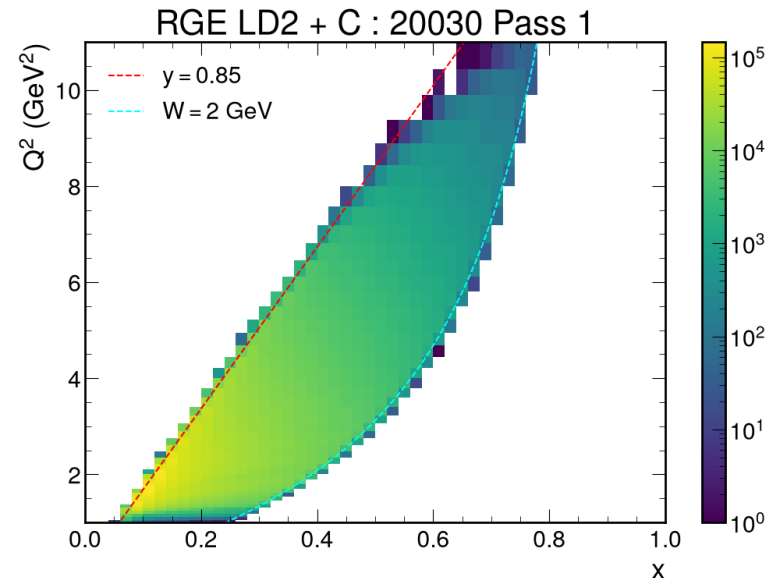
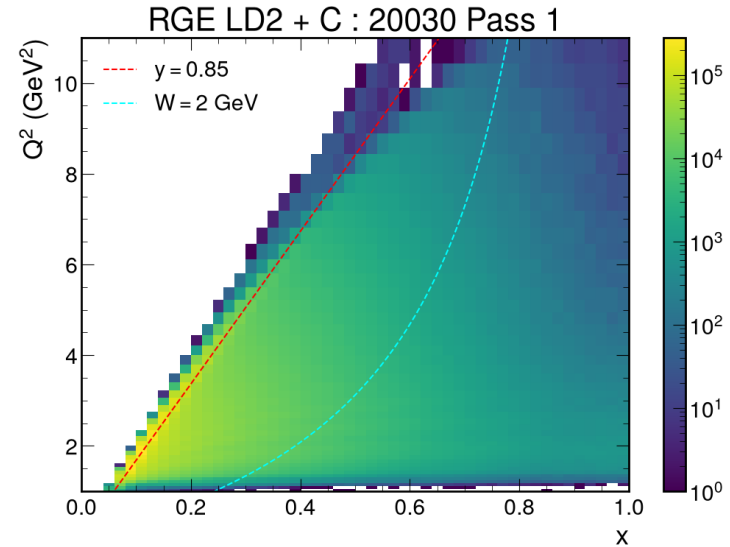
- Start with particles assigned as electrons by event builder in the forward detector

- These cuts include:

- HTCC $N_{\text{phe}} > 2$
- SF vs $E_{\text{dep}} \mu \pm 5\sigma$
- $E_{\text{PCAL}} > 0.06 \text{ GeV}$

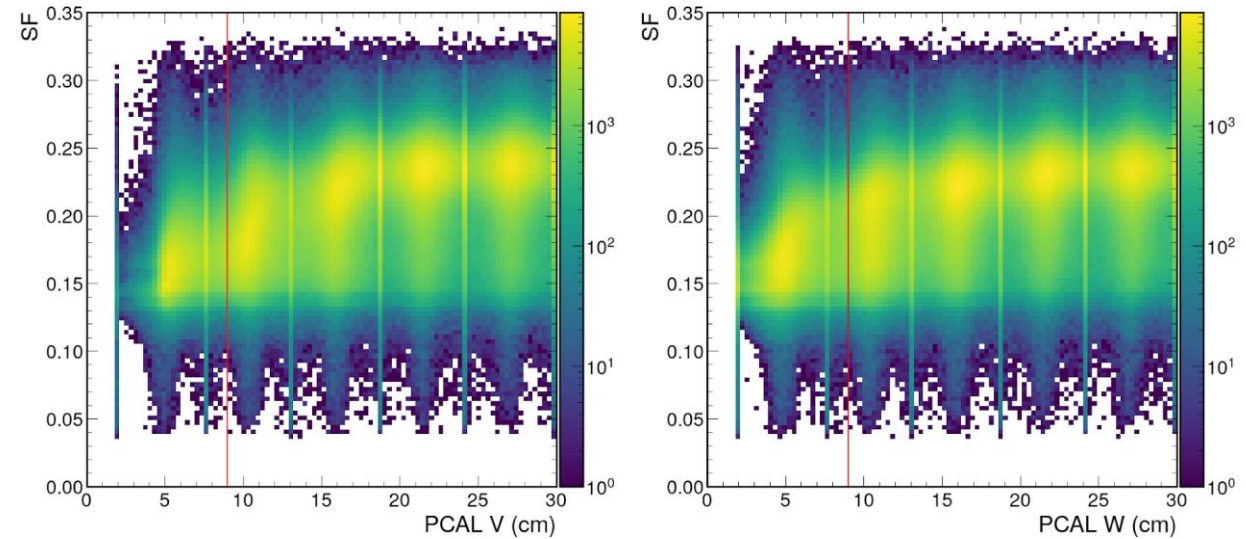
- Apply DIS cuts:

- $y < 0.85$
- $Q^2 > 1 \text{ GeV}^2$
- $W > 2 \text{ GeV}$

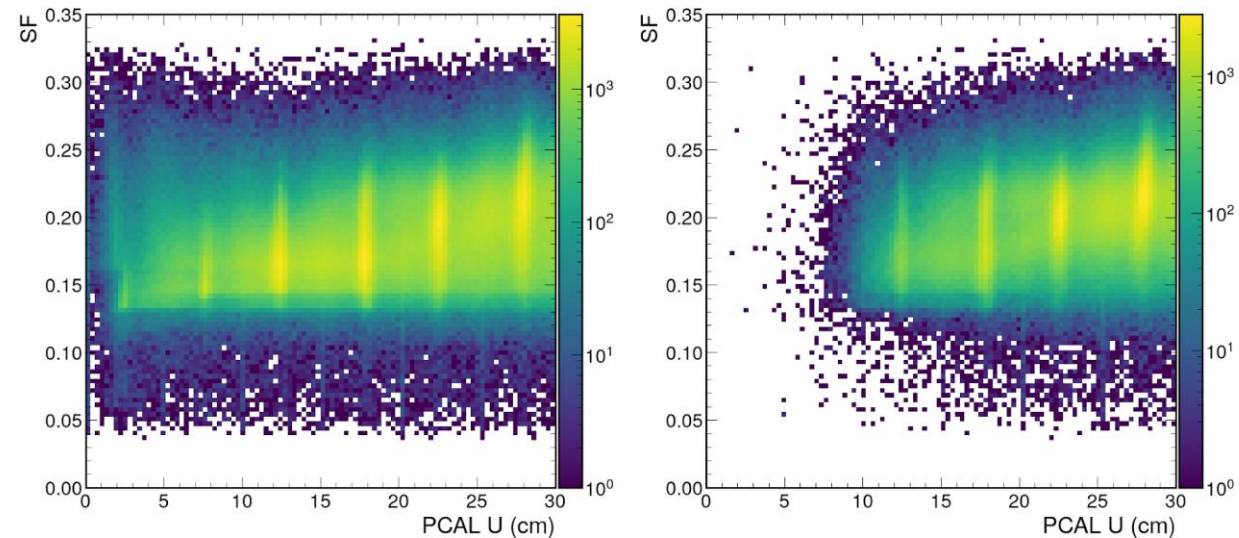


PCAL Fiducial cuts

- Near the edge of the PCAL, get a lower sampling fraction
- Remove this region by applying a PCAL $W > 9$ cm and PCAL $V > 9$ cm cut



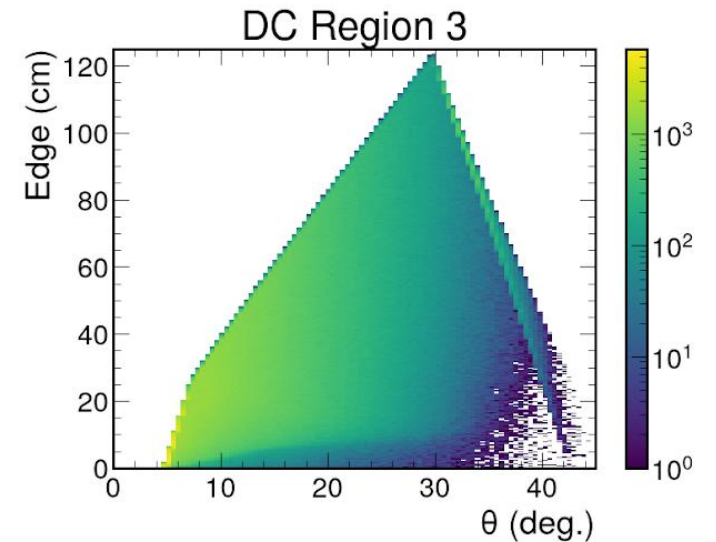
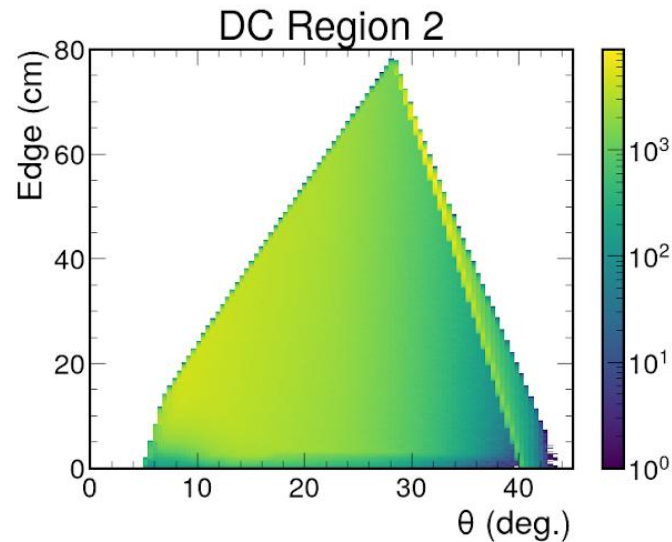
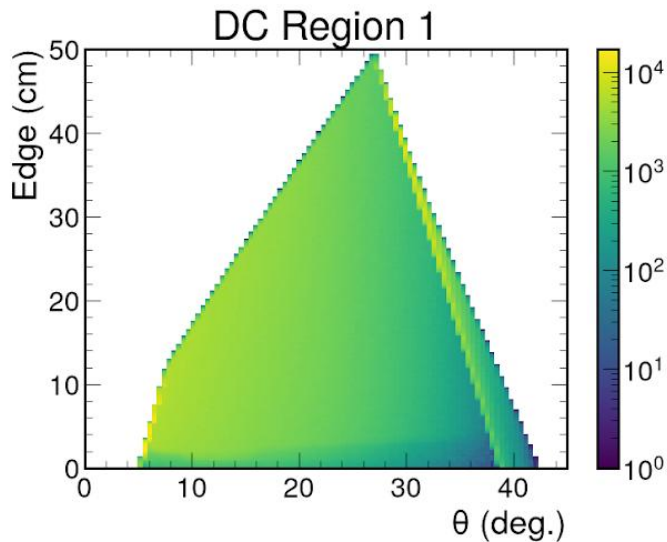
RGE LD2 + C : 20030 Pass 1



DC Fiducial cuts (new!)

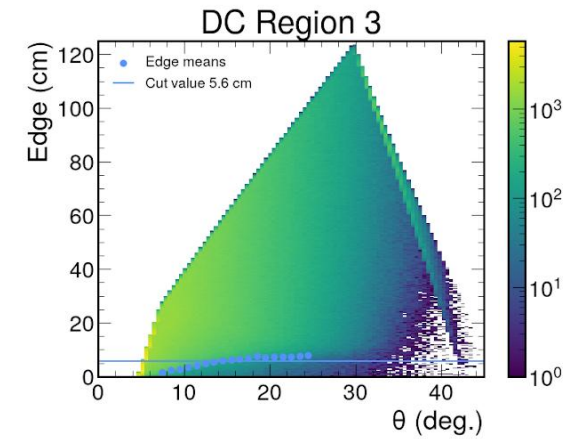
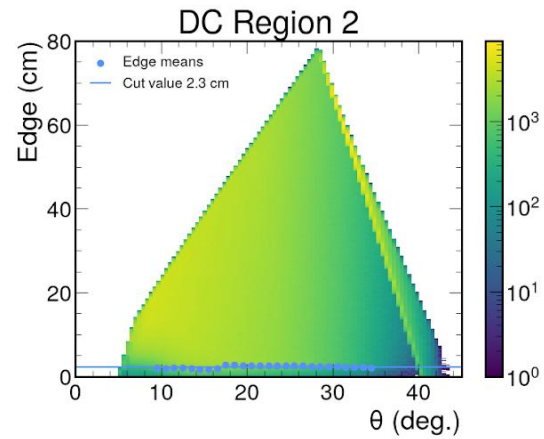
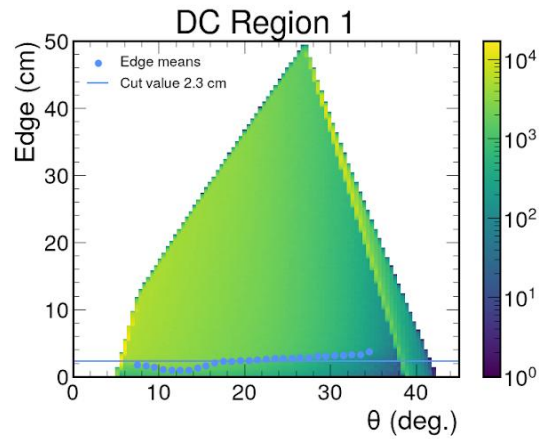
- Particles near the edge of the drift chambers have poor reconstruction quality and they can be removed by cutting on the yield
- See Udi's talk for more details!

RG-E LD2+C: 20030 Pass 1
All sectors

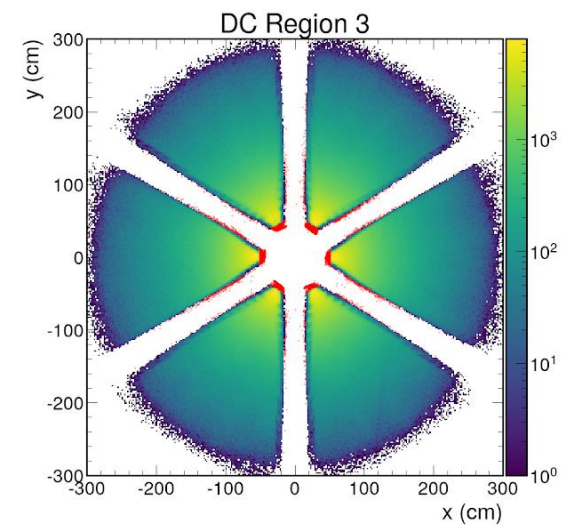
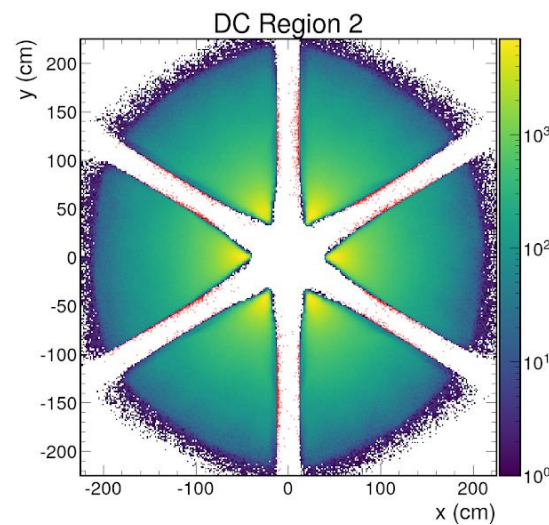
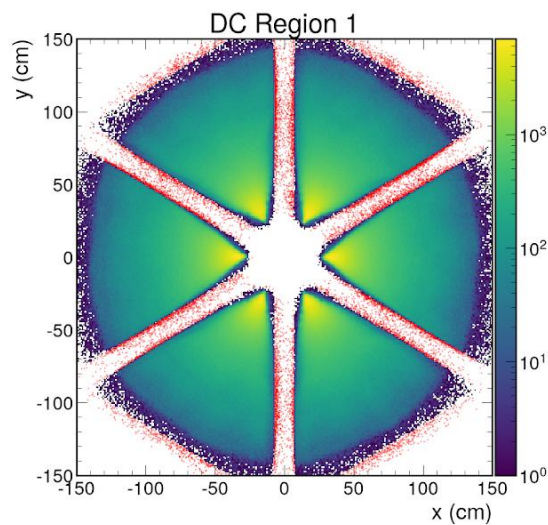


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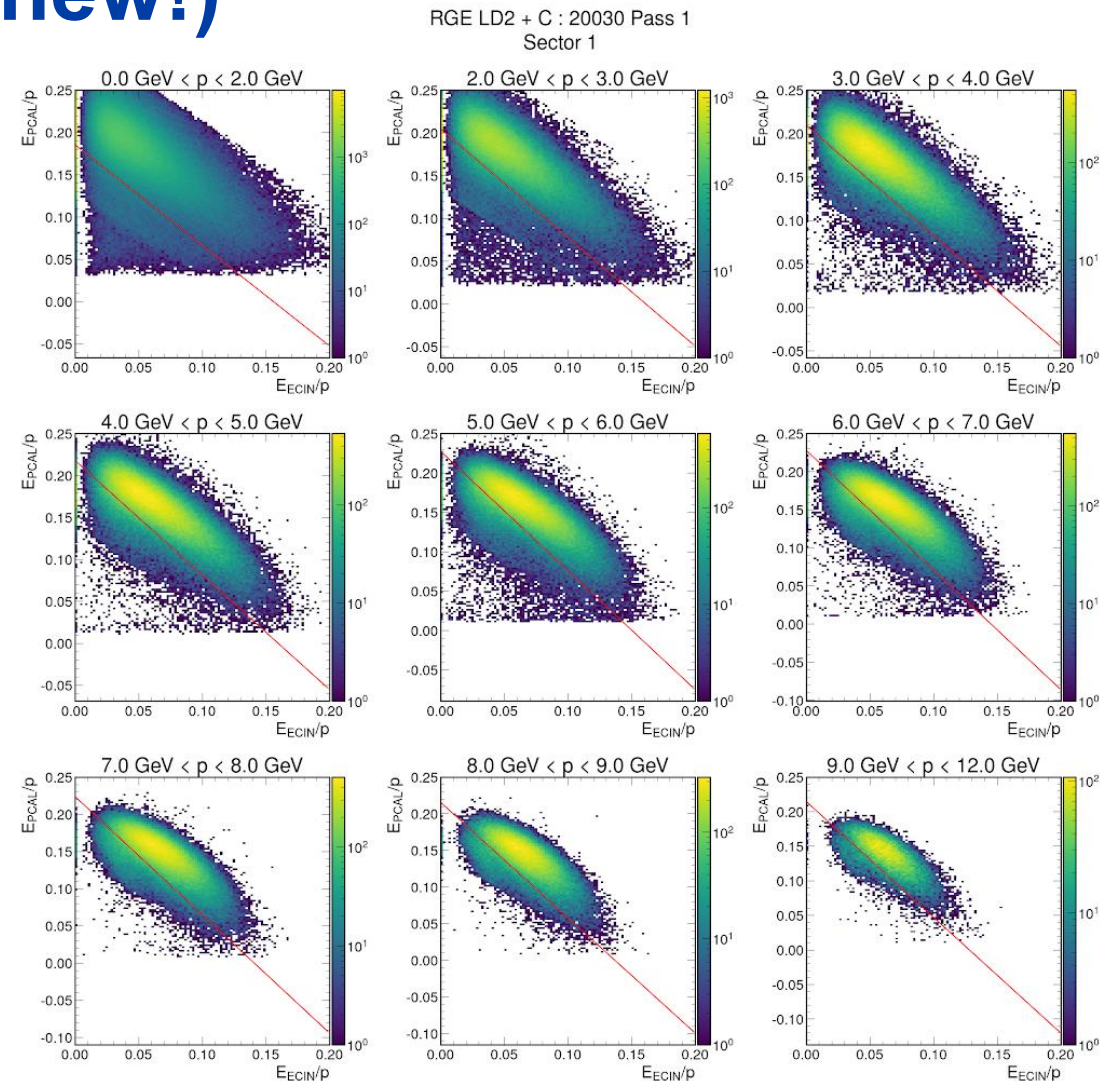


RGE LD2 + C : 20030 Pass 1



Partial sampling fraction cut (new!)

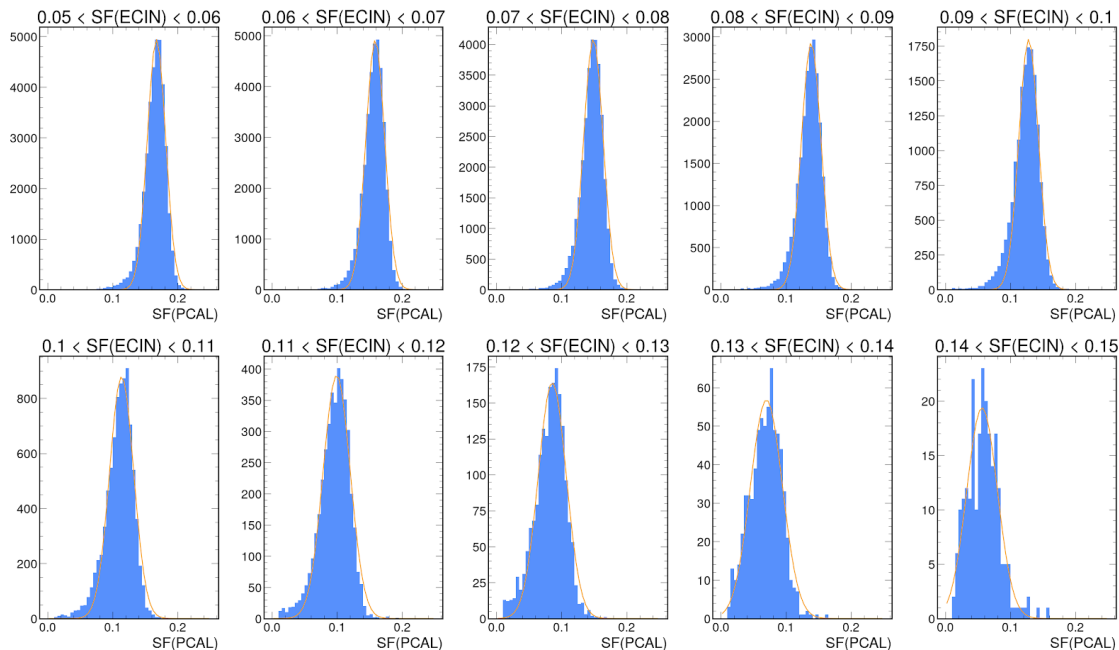
- Can remove pion contamination further
- Apply fiducial cuts prior to this procedure



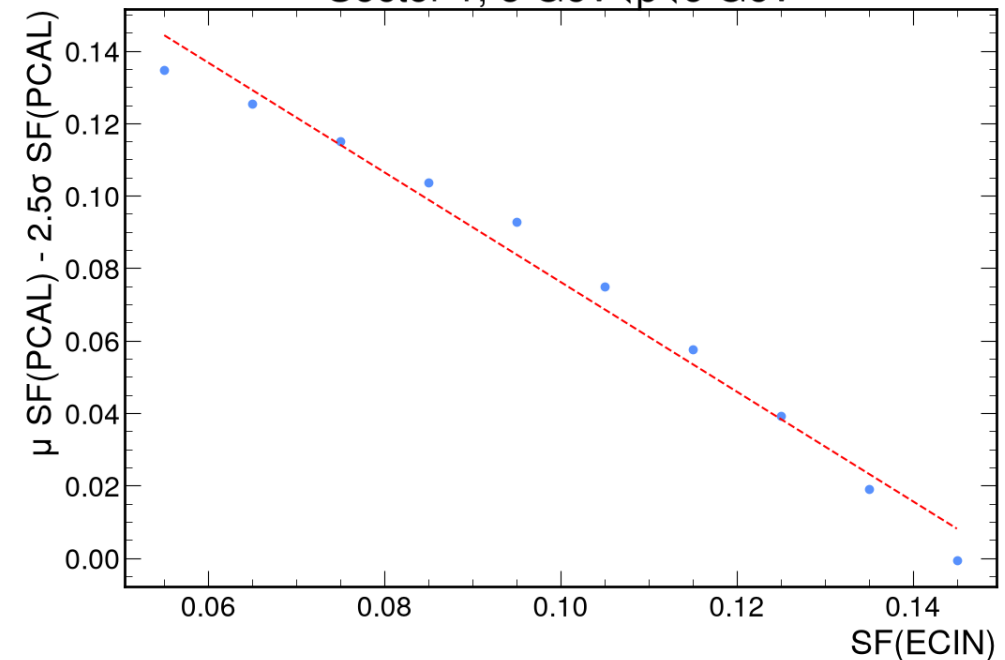
Partial sampling fraction cut (new!)

- In Each SF(ECIN) bin, fit SF(PCAL) with Gaussian
- Fit $\mu - 2.5\sigma$ from these fits with a line in each momentum bin
- Procedure developed by RG-A

RGE LD2 + C : 20030 Pass 1
Sector 1, 6 GeV < p < 7 GeV

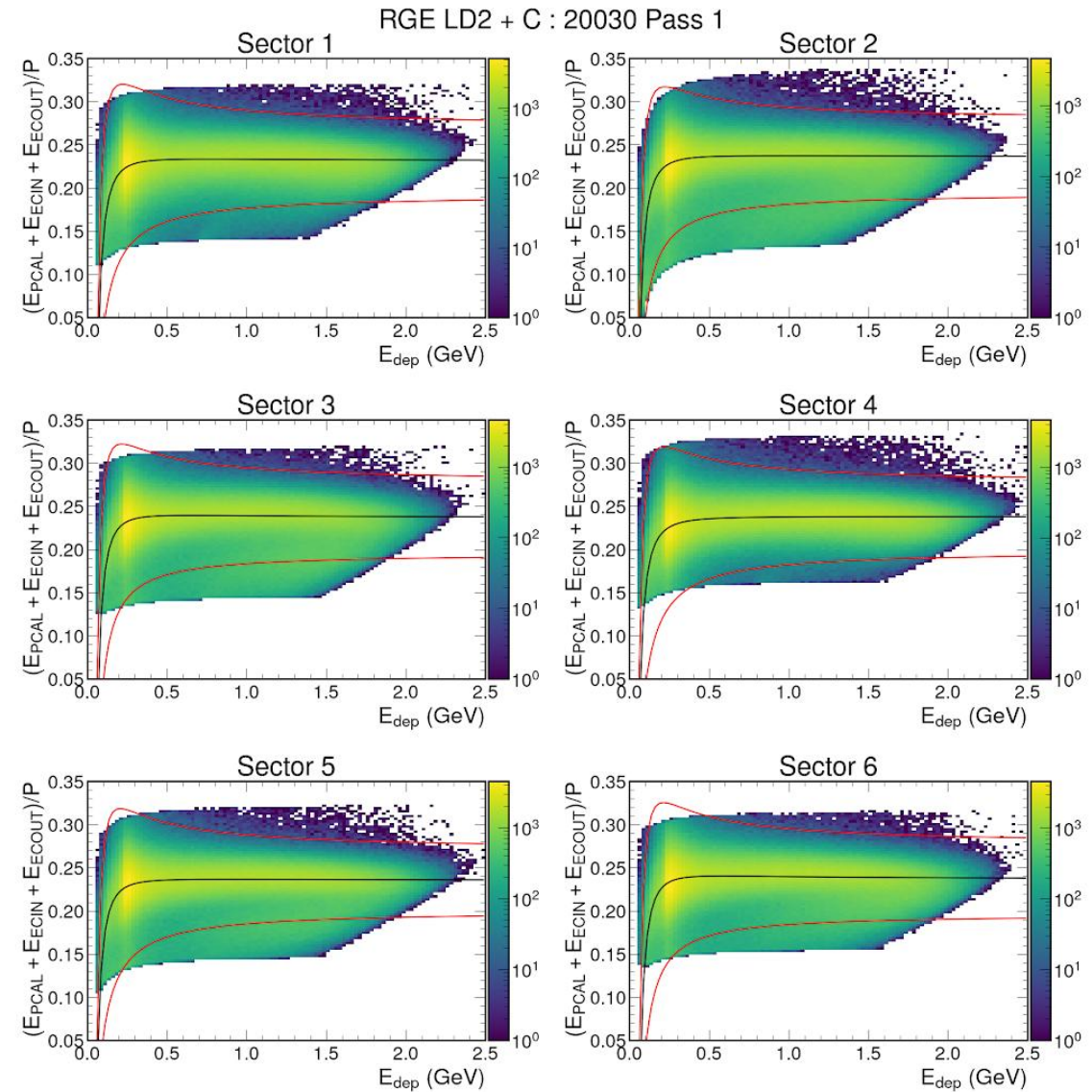


RGE LD2 + C : 20030 Pass 1
Sector 1, 5 GeV < p < 6 GeV



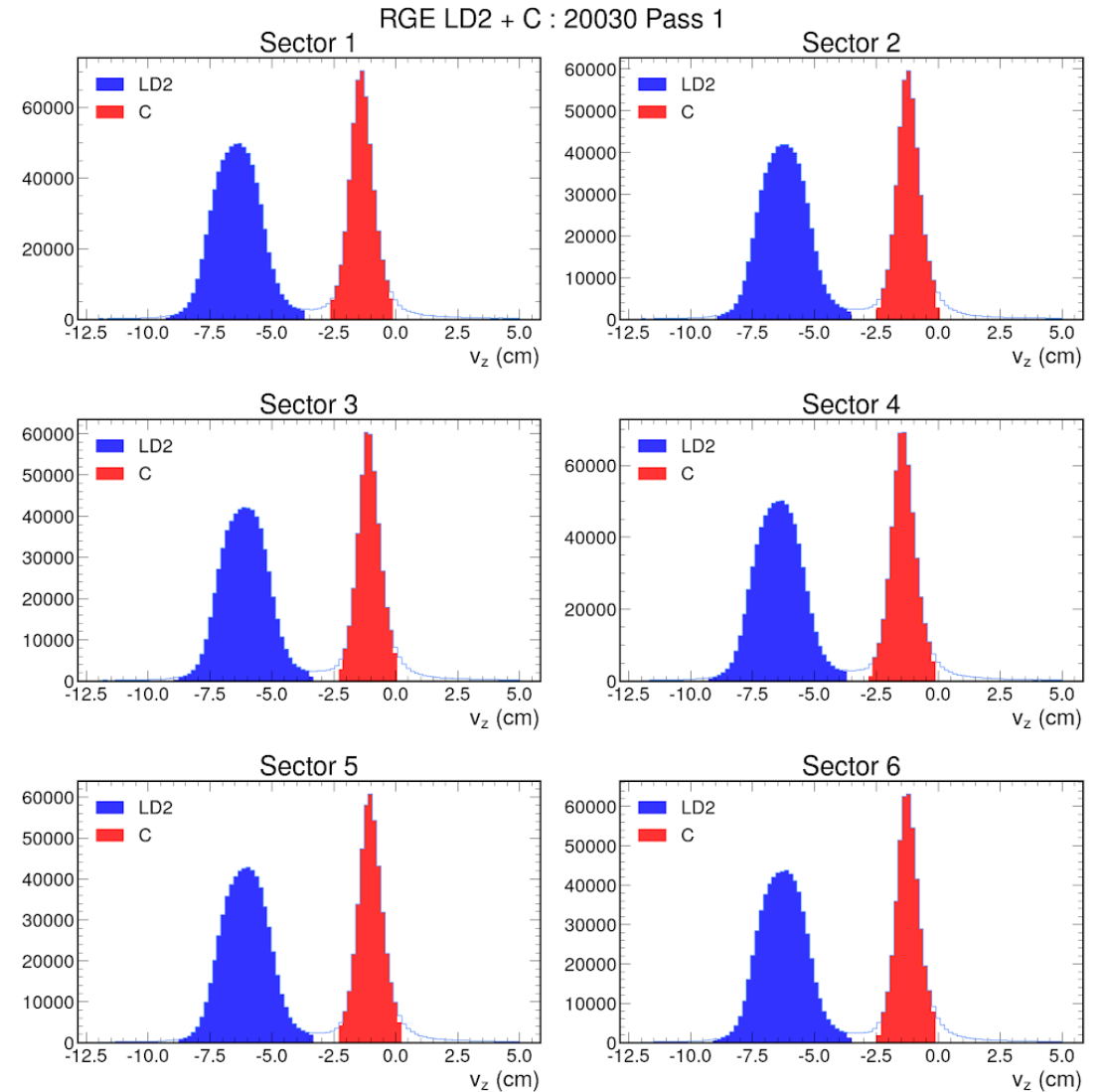
SF vs Edep fit

- Can tighten the SF vs E_{dep} $\mu \pm 5\sigma$ cut from event builder to $\mu \pm 3.5\sigma$
- Apply fiducial cuts beforehand



Vertex cuts

- Apply all previous cuts and then fit with a double gaussian to isolate the targets
- Isolate LD2 peak with $\mu_{LD2} \pm 3\sigma_{LD2}$ cut and carbon peak with $\mu_C \pm 5\sigma_C$
- See Udi's talk for more developments!



Impact of cuts on event builder electron yield

- Apply cuts one-by-one and quantify electrons removed

Cut name	% of Event Builder electrons remaining after cut
Event builder electrons	100%
DIS	65.8%
PCAL & DC Fiducial	56.1%
Partial Sampling fraction	46.1%
SF vs. E_{dep}	46.0%
Vertex	41.9%

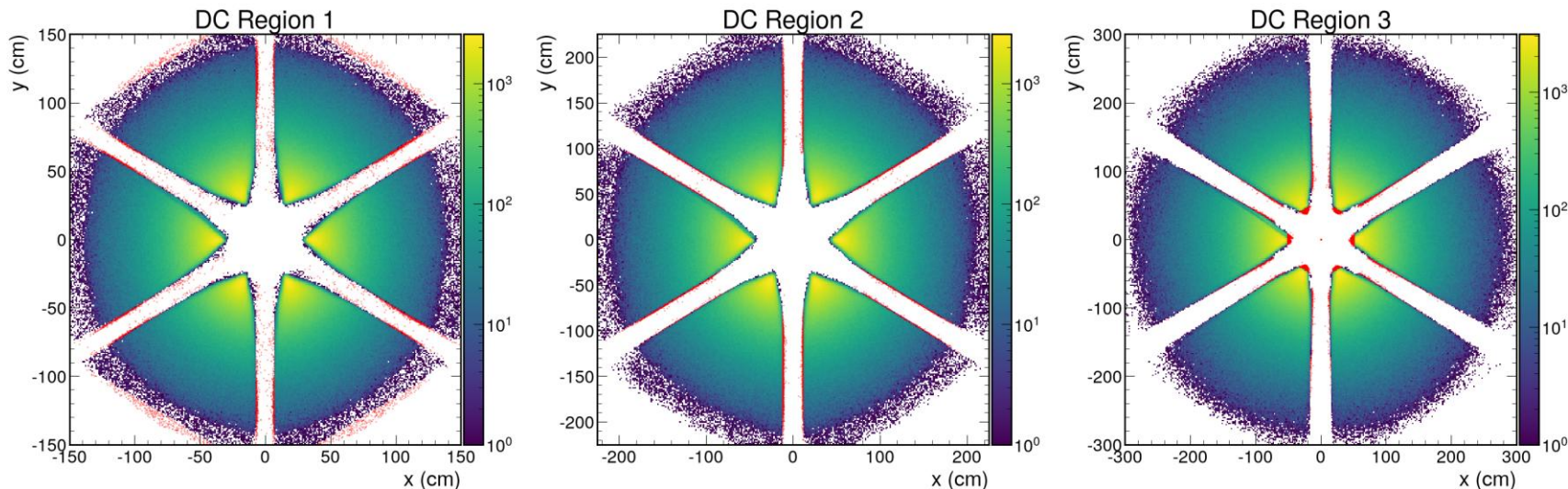
Simulations

- Two main simulators so far in RG-E: clasdis + GiBUU
- Can be used for efficiency corrections and unfolding
- Use a different set of fits but same cut flow
- **Note:** Need to regenerate simulations with more statistics and latest software versions but showing old clasdis files today

Simulations

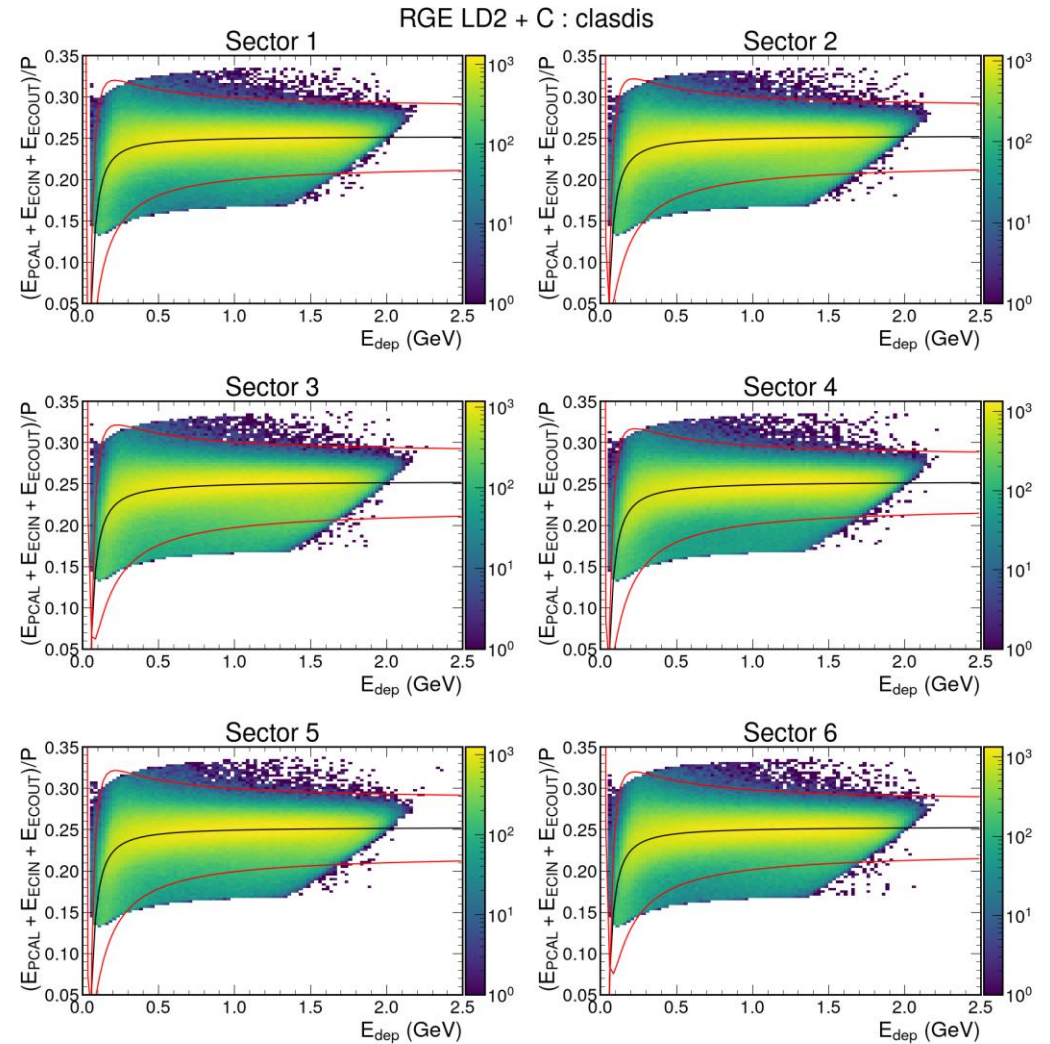
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RGE LD2 + C : clasdis



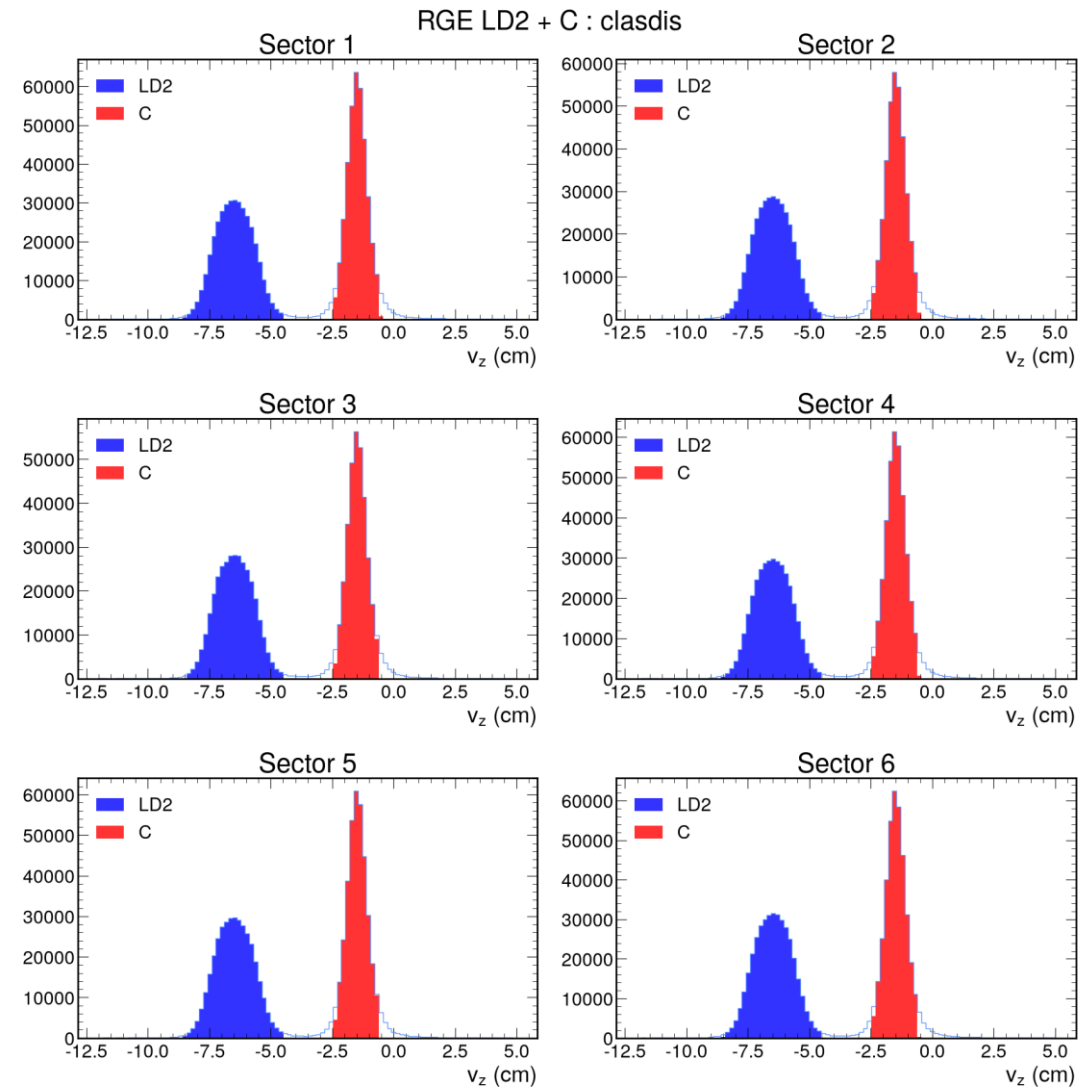
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Wrapping up common analysis techniques

- To-do:

- Test sector + target dependence
- Regenerate simulations

- Aiming to document all of this in a common note and submit it for review by the end of summer... Feedback welcome!

- Note:** While these cuts will serve as a common baseline for our run group, analyzers can tighten cuts as desired



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Definition of cross section

$$\frac{d^2 \sigma_i}{dx dQ^2} = \frac{1}{\Delta x \Delta Q^2} \cdot \frac{N_i}{R_i \epsilon_i \mathcal{L}_{\text{int}}} \cdot C_{c,i}$$

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- \mathcal{L}_{int} : integrated luminosity for runs

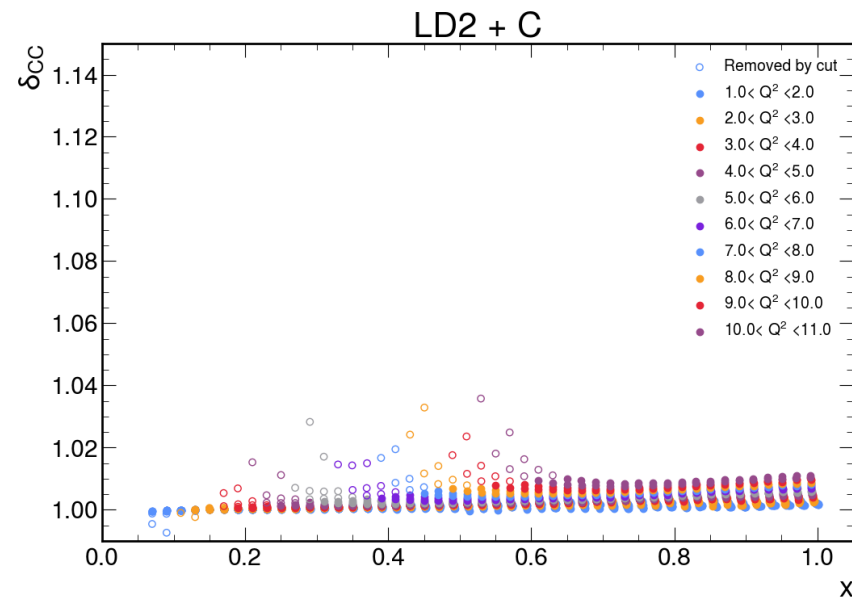
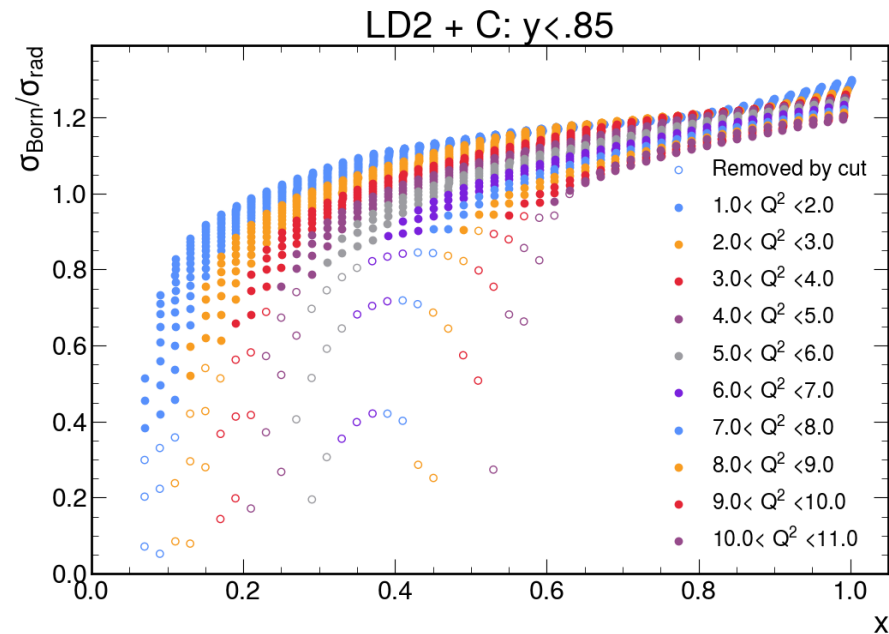
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- Motivated by Equation 4 from V. Klimenko, et al. (CLAS Collaboration), Phys. Rev. C **112**, 025201 (2025).

Radiative and Coulomb corrections

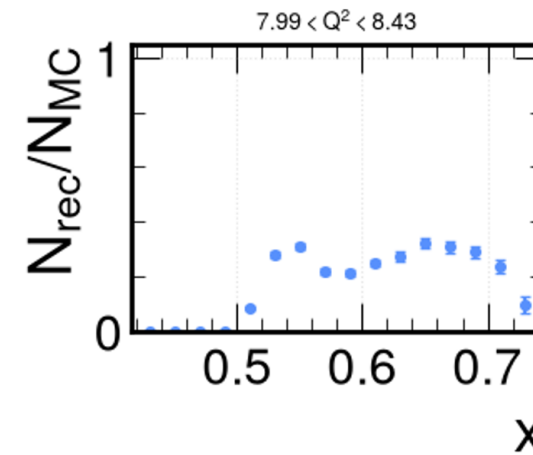
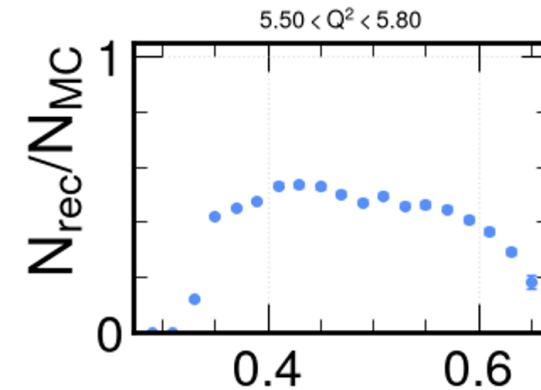
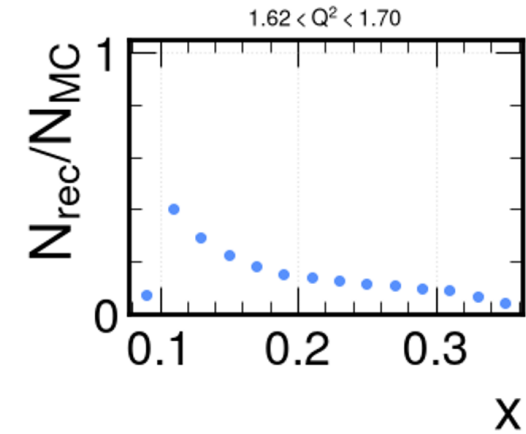
- Get radiative and coulomb corrections with EXTERNALS
 - More details: S. Moran et al., Phys. Rev. C **110**, 025202 (2024)
- Note Coulomb corrections are ~ 1 for carbon but bigger for other targets



Efficiency corrections

- Use clasdis to correct for efficiency in each bin

• $\epsilon_i = \frac{N_{rec,i}}{N_{gen,i}}$ each bin where $N_{rec,i}$ is the number of electrons that pass event builder reconstruction and cuts in bin i

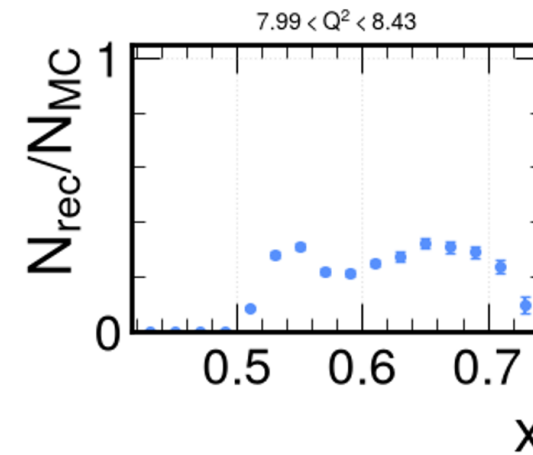
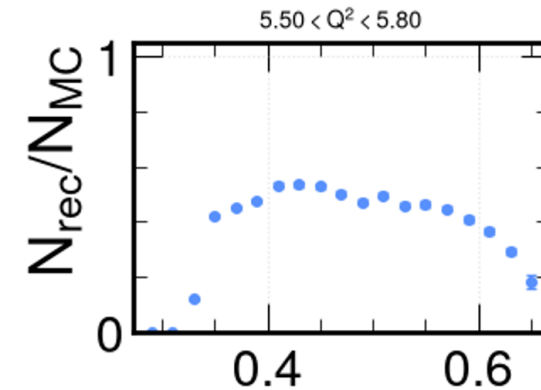
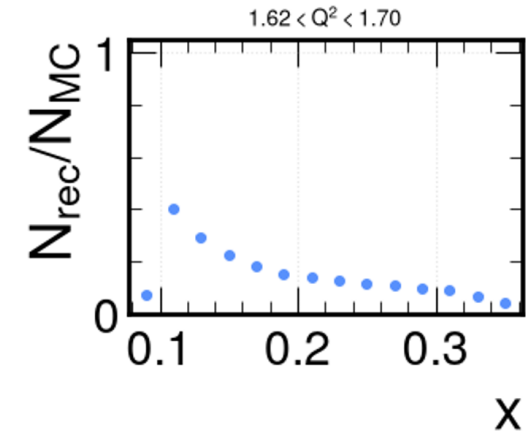


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- **Note:** this will change when unfolding is fully implemented



Cross sections

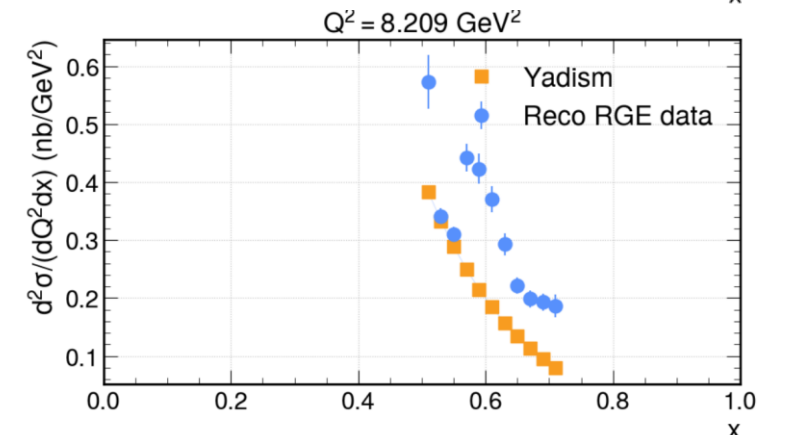
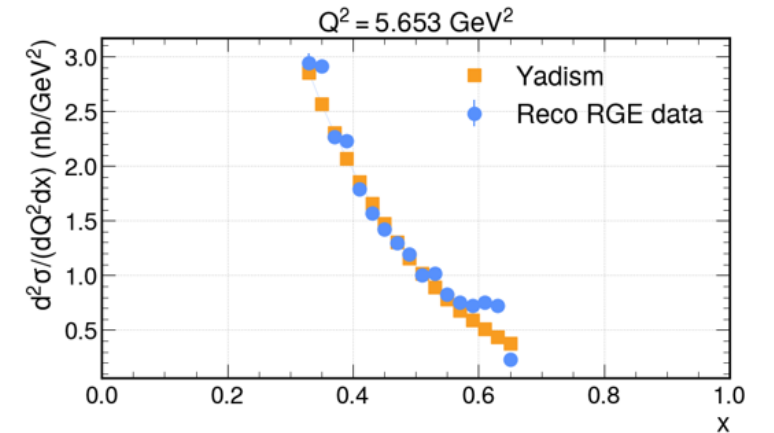
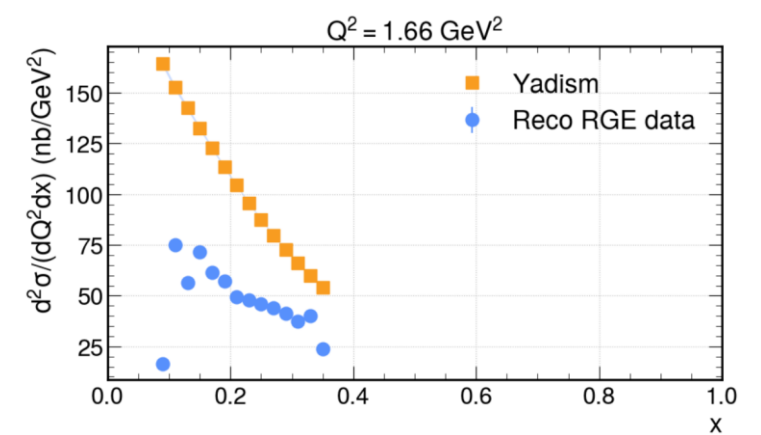
- Compare obtained cross sections to theory predictions from Yadism

 - A. Candido, et al., Eur.Phys.J.C 84 (2024) 7, 697

- Using nCTEQ15HIX PDF set

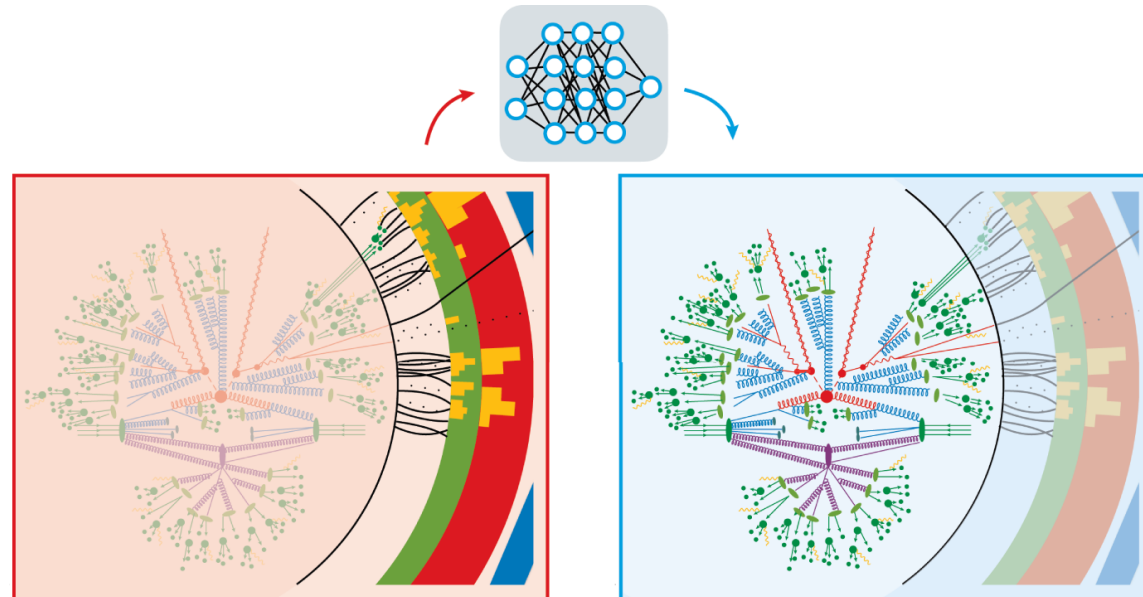
 - E. P. Segarra, et al., Phys. Rev. D **103**, 114015

- Good agreement $3 \text{ GeV}^2 < Q^2 < 7 \text{ GeV}^2$, off at lower and higher values



Next step: Unfolding

- Given the measured data, want to remove detector effects and bin migration to get true physics information
- Unfolding with an ML-based version of Iterative Bayesian Unfolding
 - IBU used in V. Klimenko, et al. (CLAS Collaboration), *Phys. Rev. C* 112, 025201 (2025)
 - IBU version we'll use detailed here: R. Milton, et al., *JINST* 20, P05034 (2025)
- Doing the unfolding with multiple observables simultaneously





Summary

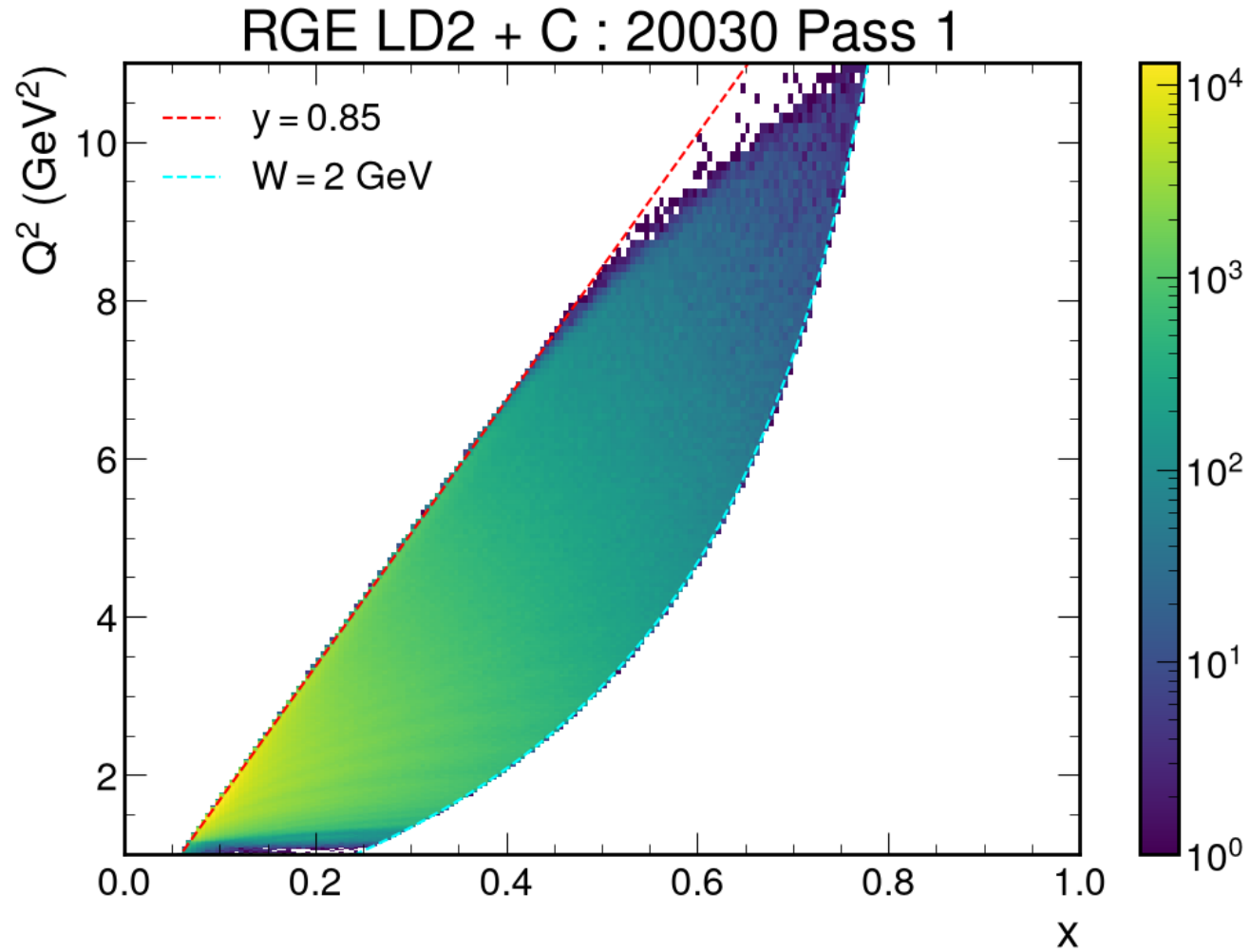
- Cut procedure for pass 1 is working well with sector and target dependence still needing investigation
- Inclusive DIS cross sections look promising for carbon so far, but new simulation is needed and unfolding needs to be implemented
- Plan to submit common electron analysis note during summer, so feedback is more than welcome!

Thank you!



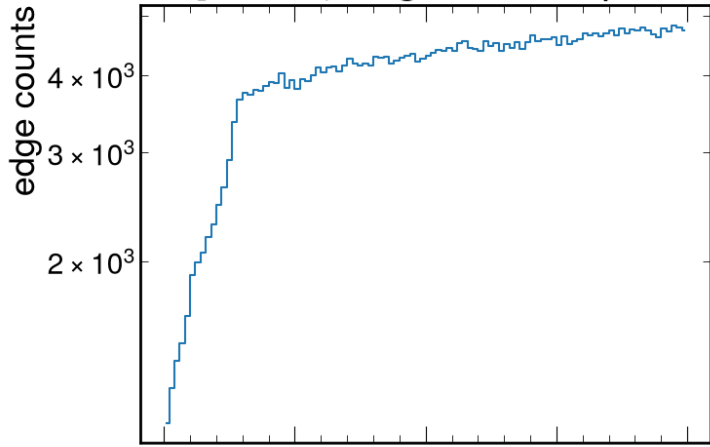
Backup

X-Q2 fine binning

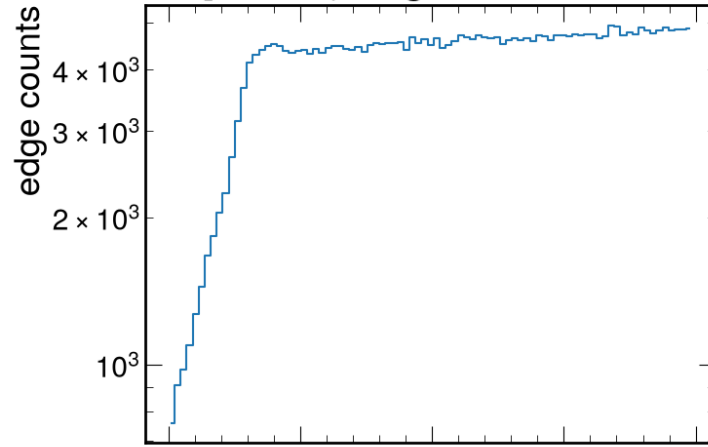


Example of DC fiducial cut

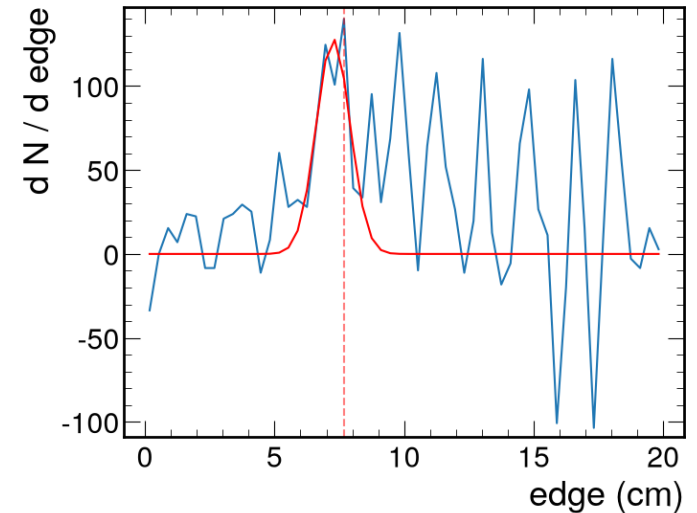
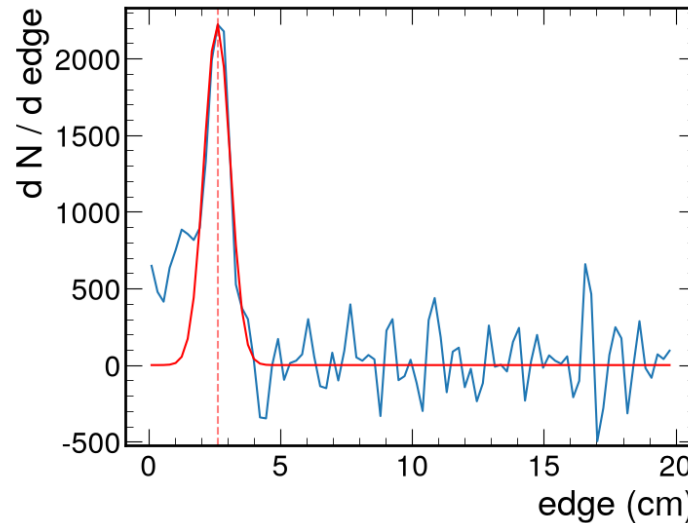
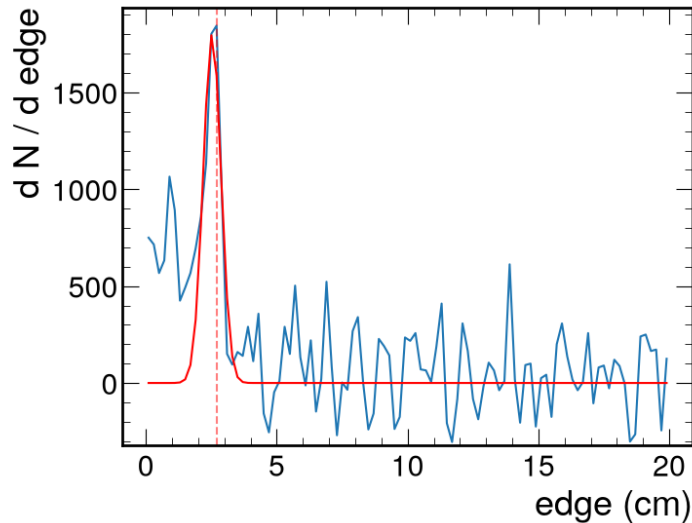
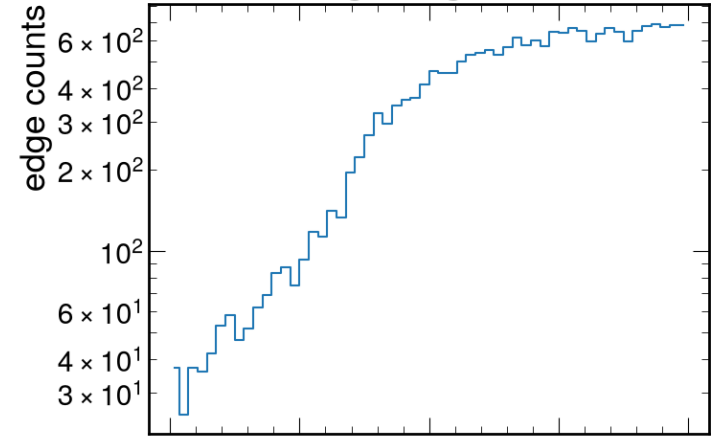
DC Region 1, all sectors
theta [21, 22) deg, Positive particle



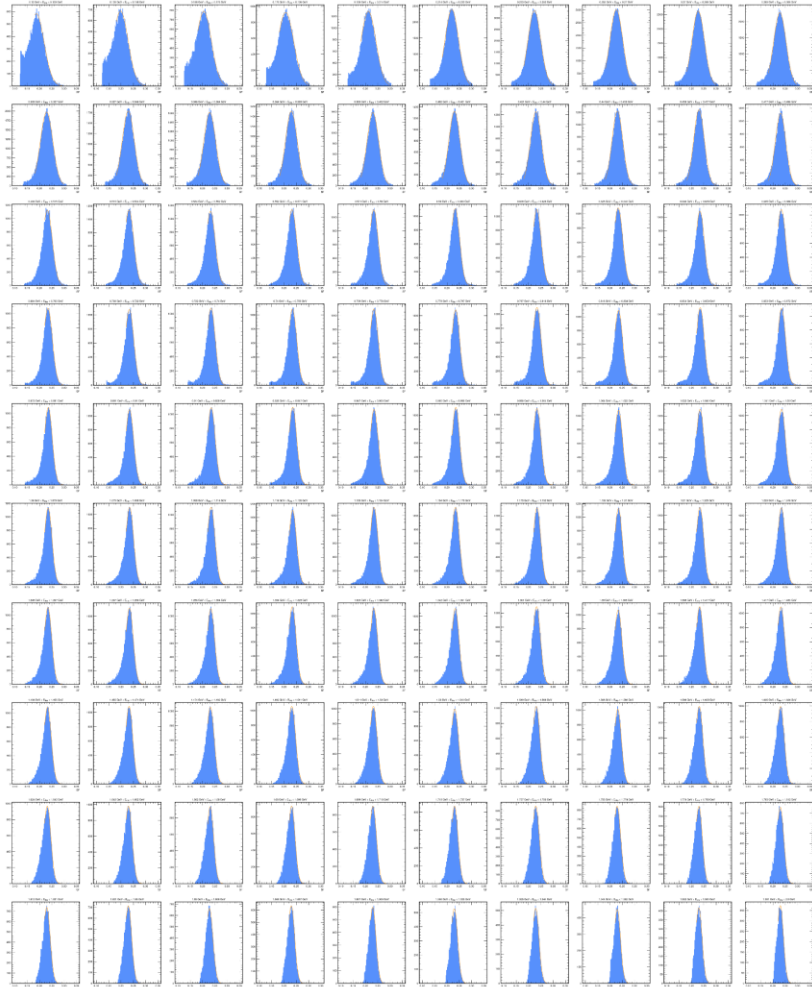
DC Region 2, all sectors
theta [21, 22) deg, All non-electrons



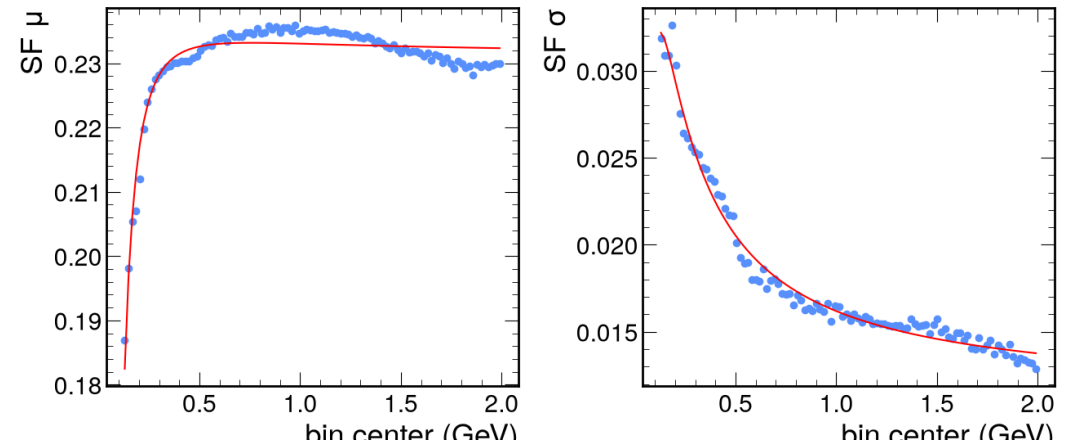
DC Region 3, all sectors
theta [21, 22) deg, Negative non-electrons



SF vs E_{edep} procedure

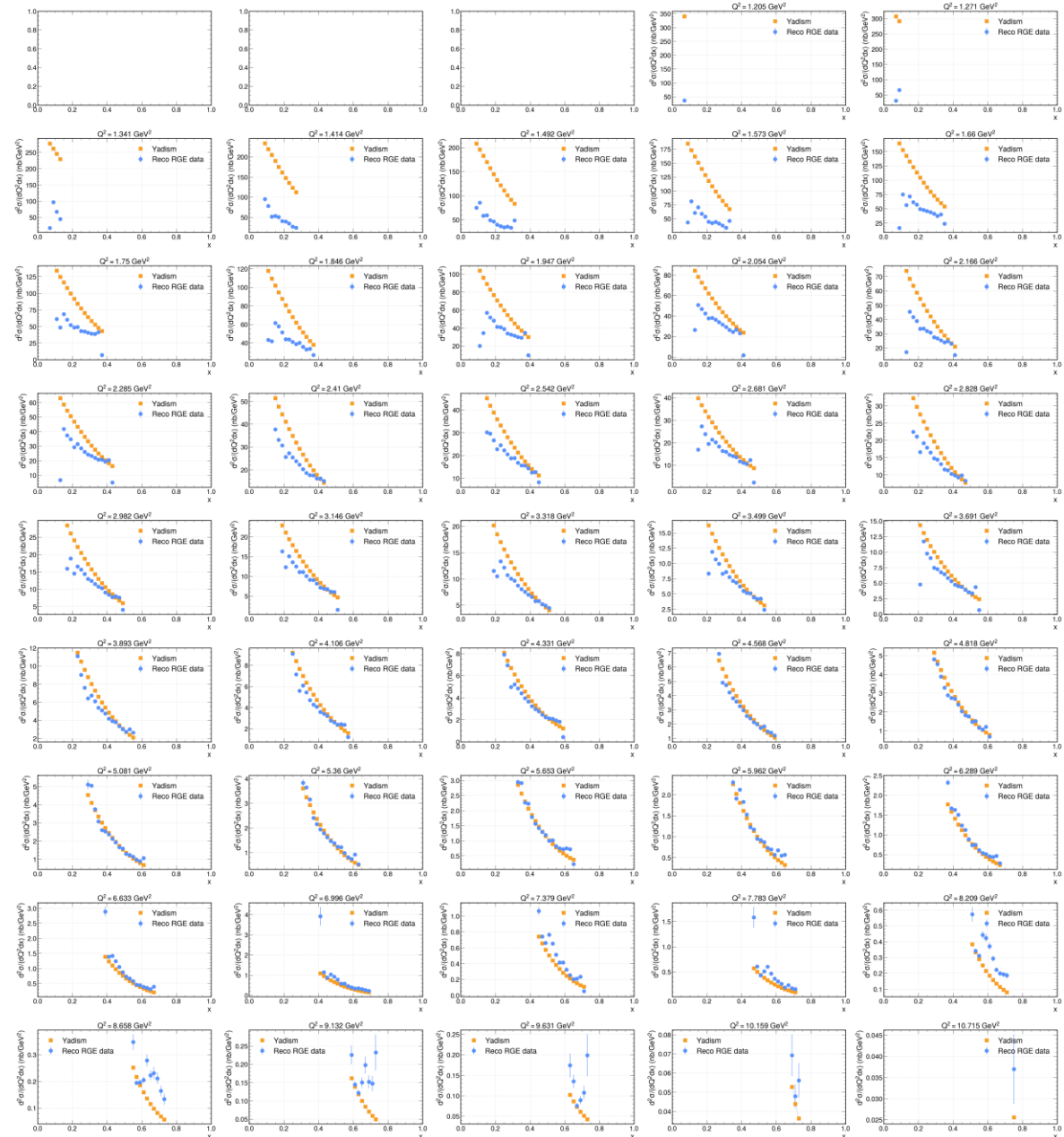


RGE LD2 + C : 20030 Pass 1, Sector 1



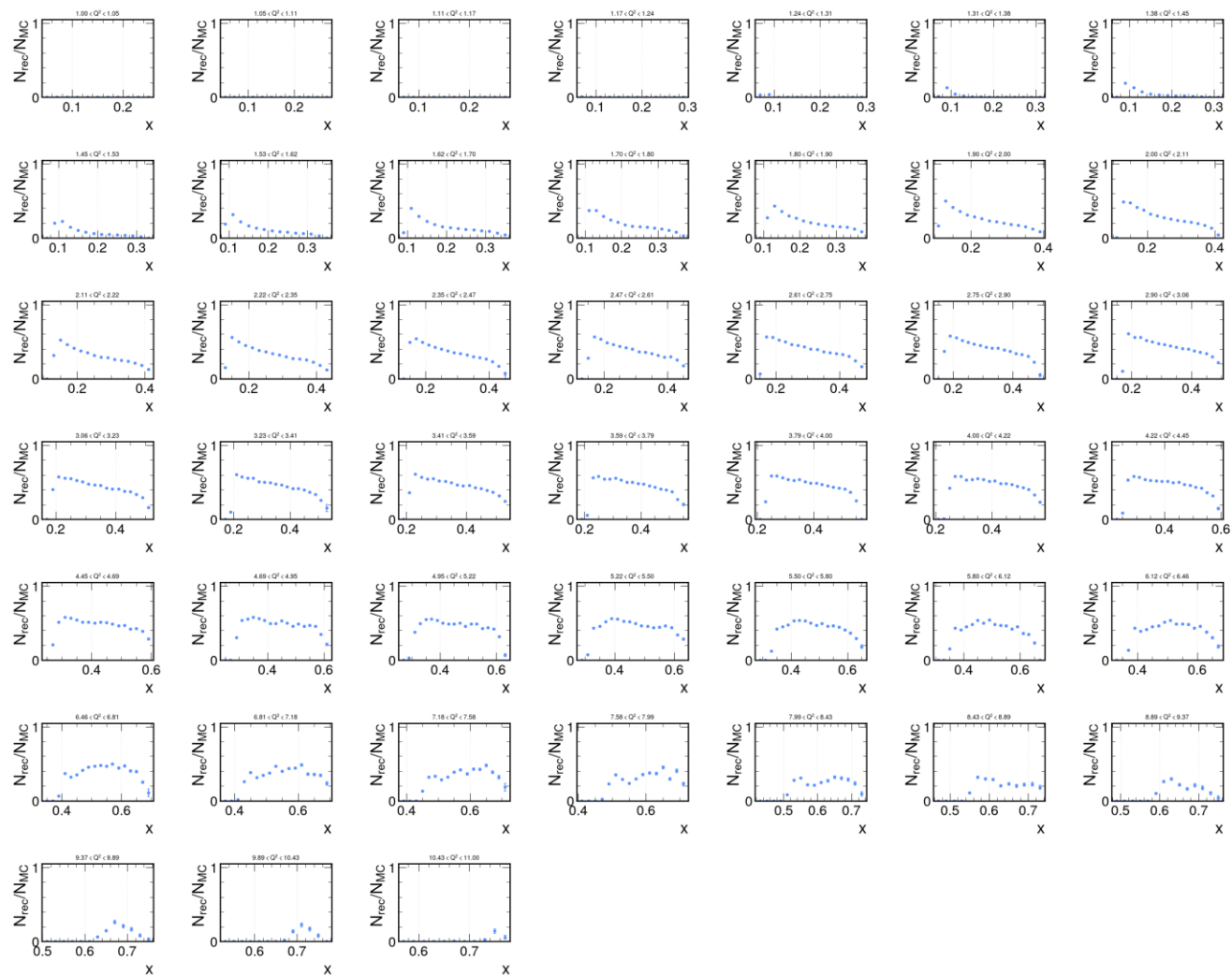
All cross sections

RGE 20030: C reconstructed



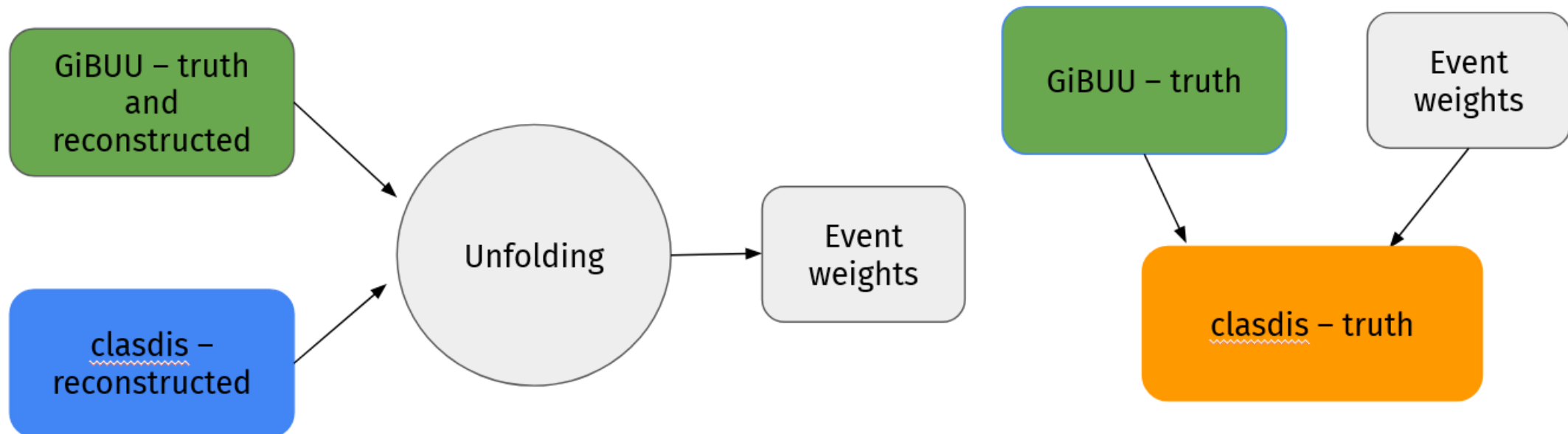
All efficiencies

RG-E LD2+C: cladis



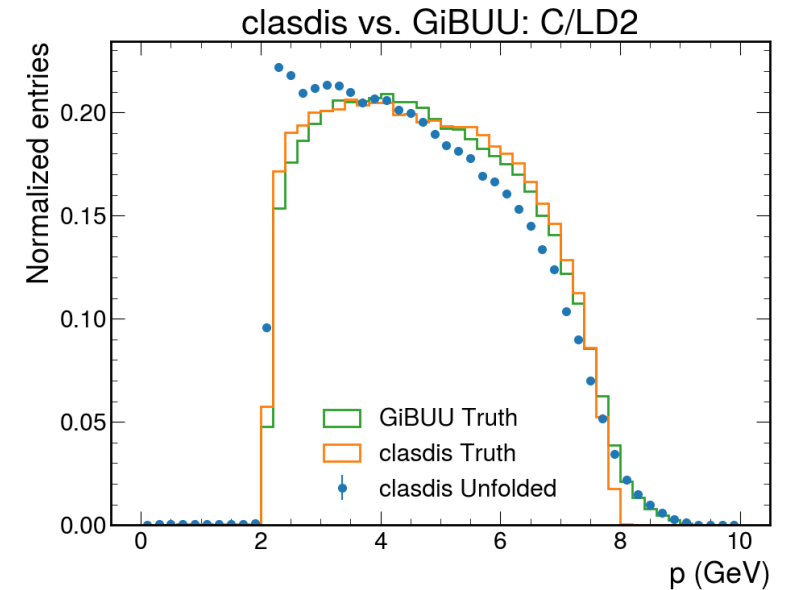
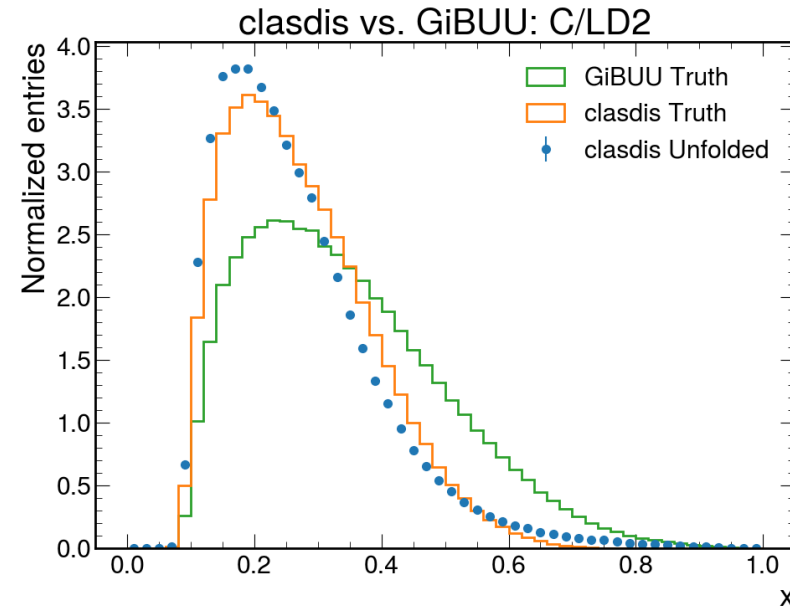
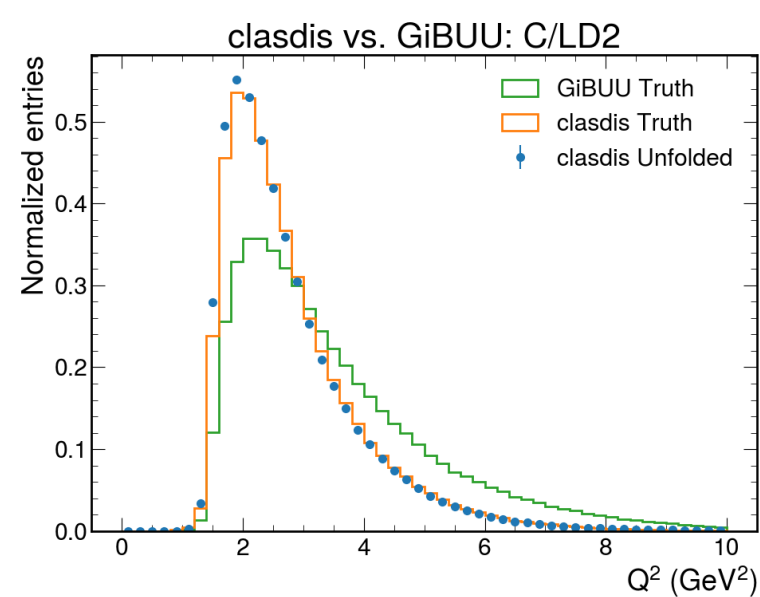
Closure test (old results)

- To test the unfolding procedure, use a closure test with two Monte Carlos
- Use clasdis as pseudodata and GiBUU as simulation data. Run each through electron selection. Currently only using 500k events for unfolding
- After unfolding, should get the truth-level clasdis distributions
- Unfolding variables: Q^2 , x , p , ϕ , Θ



Closure test (old results)

- See overall good agreement between truth and unfolded distributions
- The input to the unfolding are observables from electrons that pass selections. We are not yet correcting for efficiency
- Unfolding multiple observables maintains correlations between them



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