Timelike Compton Scattering on a polarized target with CLAS12, at Jefferson Lab

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Intro

Theory

The Timelike Compton Scattering (TCS) process

Observables accessible with TCS

Experimental Setup

RGC Longitudinally Polarized Target

Experimental Procedure

Preliminary Results

Simulation Studies

Nuclear Background

Kinematic Comparisons

Timelike Compton Scattering (TCS)

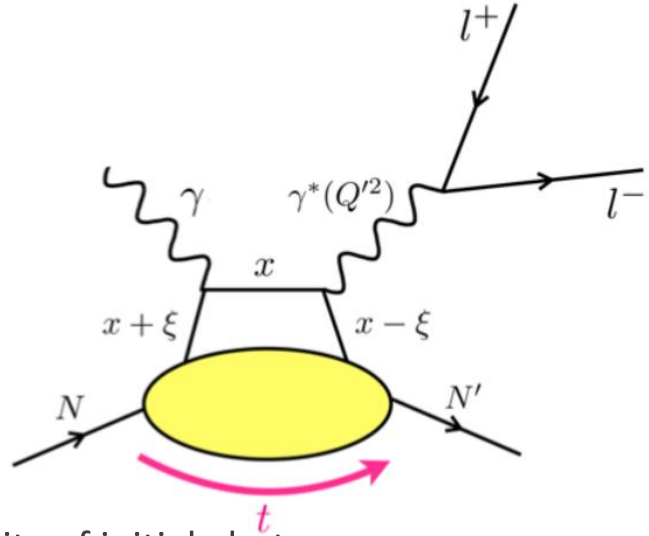
- A quasi real photon interacts with the target nucleon, causing release of virtual photon.

$$ep \rightarrow e'p'\gamma^*$$
$$\gamma^* \rightarrow \mu^+\mu^- \; or \; e^+e^-$$

- A QED process with identical final state, Bethe-Heitler (BH), interferes with TCS at the amplitude level

- TCS gives access to Generalised Parton Distributions via cross section and polarization asymmetry measurements.

[1]



Q^2 = virtuality of initial photon

$Q'^2 = q'^2 = (l^+ + l^-)^2$ virtuality of final state photon

$t = (p'(N') - p(N))^2 = (q - q')^2$ four momentum transfer to struck quark

x = longitudinal momentum fraction of struck quark

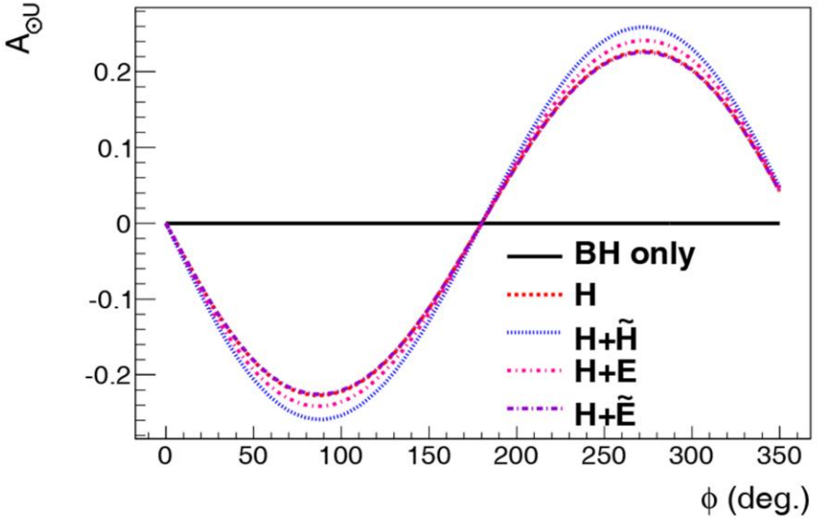
2ξ = longitudinal momentum fraction gained/lost by struck quark

Observable Predictions

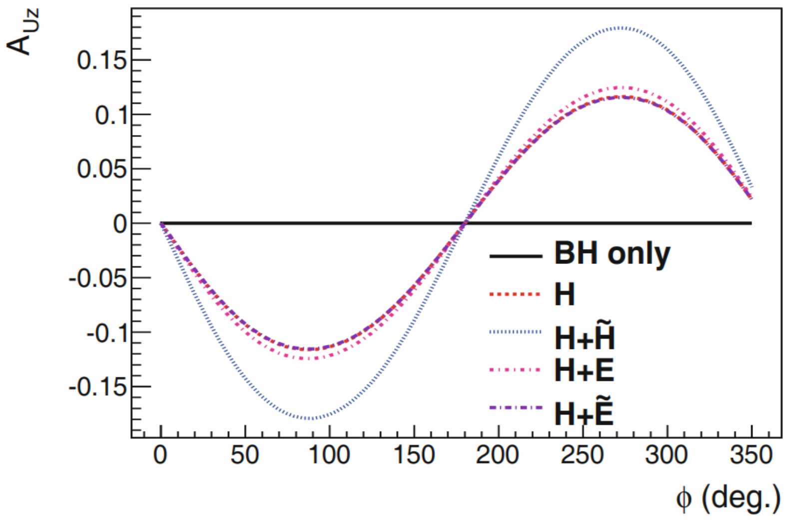
- Beam Spin Asymmetry – H dominates, first ever measurement of TCS in 2021[2], continuation of this effort on a polarized target.
- Target spin asymmetry – Access to H and $\widetilde{H}$
- Measurements accessing H allow investigation into GPD universality, $\widetilde{H}$ is less known, both Deeply Virtual Compton Scattering (DVCS) and TCS provide complementary access.

[3]

BSA



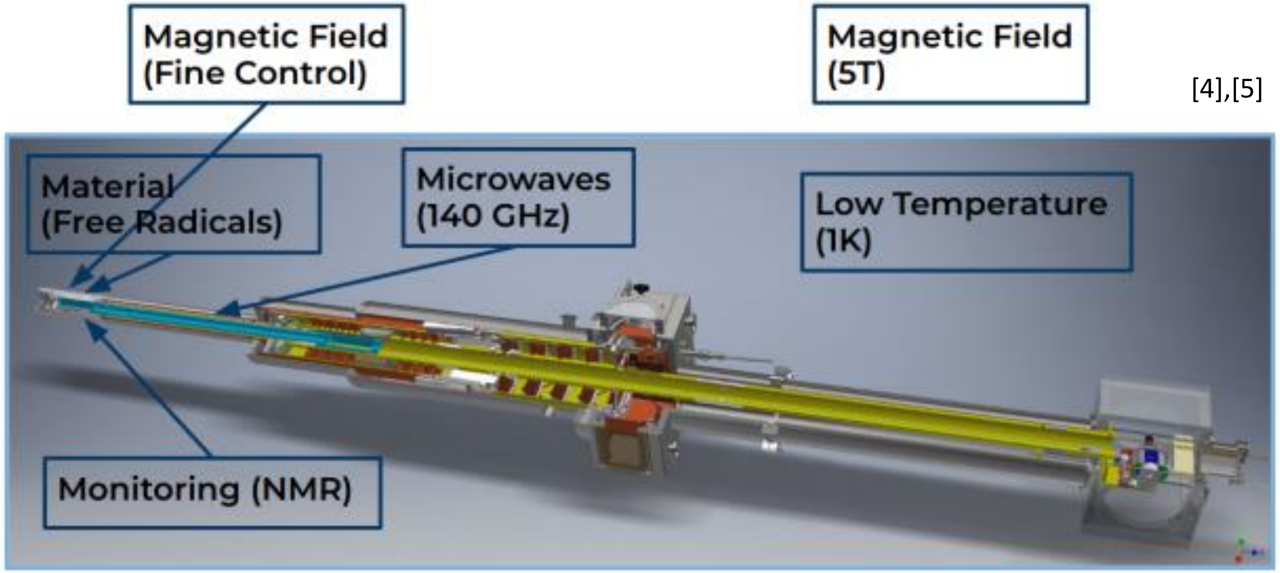
TSA



Longitudinally Polarized Target

- Paramagnetic target material dynamically polarized using microwaves
- Target material kept under conditions of low temperature and high magnetic field
- Target polarization monitored using NMR
- Beam moved uniformly across surface of target material to prevent localized depolarization

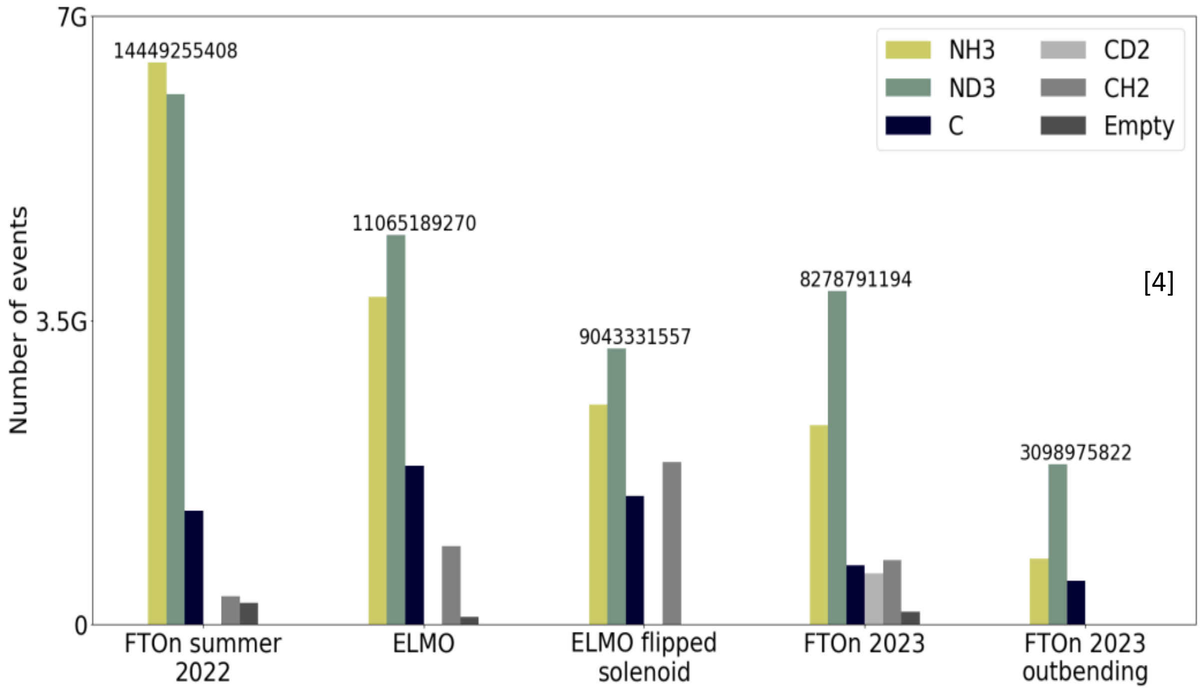
[4],[5]



Experimental Procedure

- Quasi-real photoproduction data taken using electron beam at 10.6 GeV
- Data taking finished on March 23rd
- There were 6 target configurations – NH_3 is the subject of my analysis
- Total NH_3 accumulated charge = 13.06mC

- Current status of data = 28 runs processed for analysis, 0.835mC $\approx 6\%$ of total dataset, equally split between P_t^+ and P_t^-



- FTOn = Forward Tracker on
- ELMO = Extra Large Möller Shield

Simulation Studies

GRAPE and TCSGen

GRAPE [6]

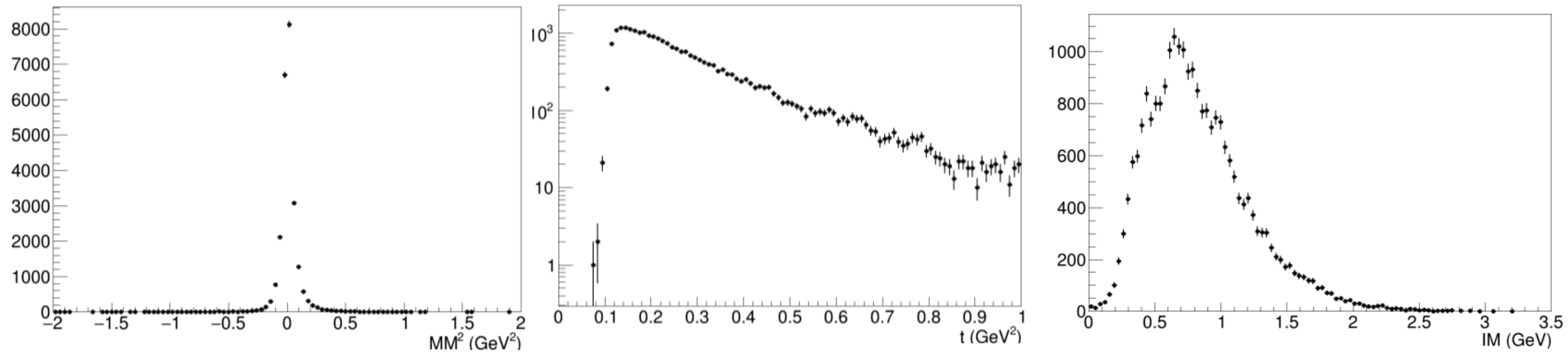
- Unweighted
- Conditions – 10.6GeV electron beam, elastic dilepton production, full invariant mass range
- Simulates Bethe Heitler and QED Feynmann diagrams
- 2.2M events generated

TCSGen[7]

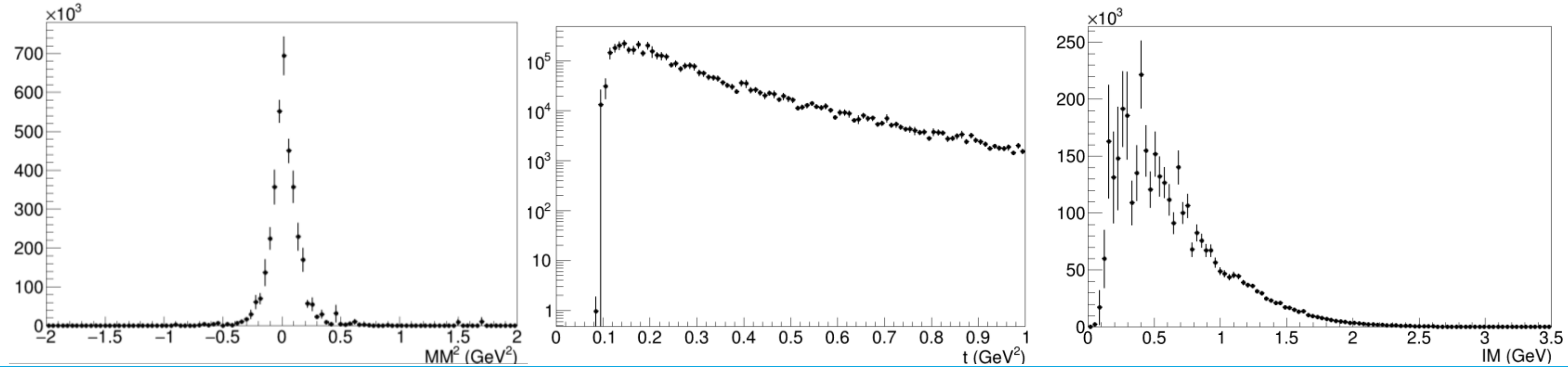
- Weighted
- Conditions – full invariant mass range
- Simulates BH and TCS + BH interference
- 1M events generated

Both simulations passed through OSG with RGC Summer FTON configuration, no background merging.

GRAPE



TCSGen



Normalising events to data

- Q = 0.835mC
- l = 5cm
- N_t = 3 (three free protons in NH_3)
- N_A = 6.02×10^{23}
- C = conversion factor from $cm^{-2} \rightarrow pb^{-1}$
- e =electron charge $1.602 \times 10^{-19}\ C$
- M_t = molar mass of NH_3 $17.03\ g/mol$
- ρ = the density of target material $0.817 g.cm^{-3}$ (density of solid NH_3 at $-80\ °C$)

$$L_{INT} = N_{beam} \times n_{Target} = \frac{Q}{e} \times \frac{l \cdot \rho \cdot N_t \cdot N_A \cdot C}{M_t}$$

$$L_{INT} = 2163.328\, pb^{-1}$$

$$\omega_{\{GRAPE\}} = L_{INT} \times \frac{\sigma_{GRAPE}}{N_{GEN}} = 2163.328 \times \frac{387.096}{N_{Gen}}$$

$$\omega_{\{TCSGen\}} = L_{INT} \times \frac{p_{beam} \times e_{beam} \times w_{gen}}{N_{GEN}} = 2163.328 \times \frac{W}{N_{Gen}}$$

Accounting for Nuclear Background

Carbon Runs

Four carbon runs currently cooked with CJ 8.7.0 - same cooking as NH_3

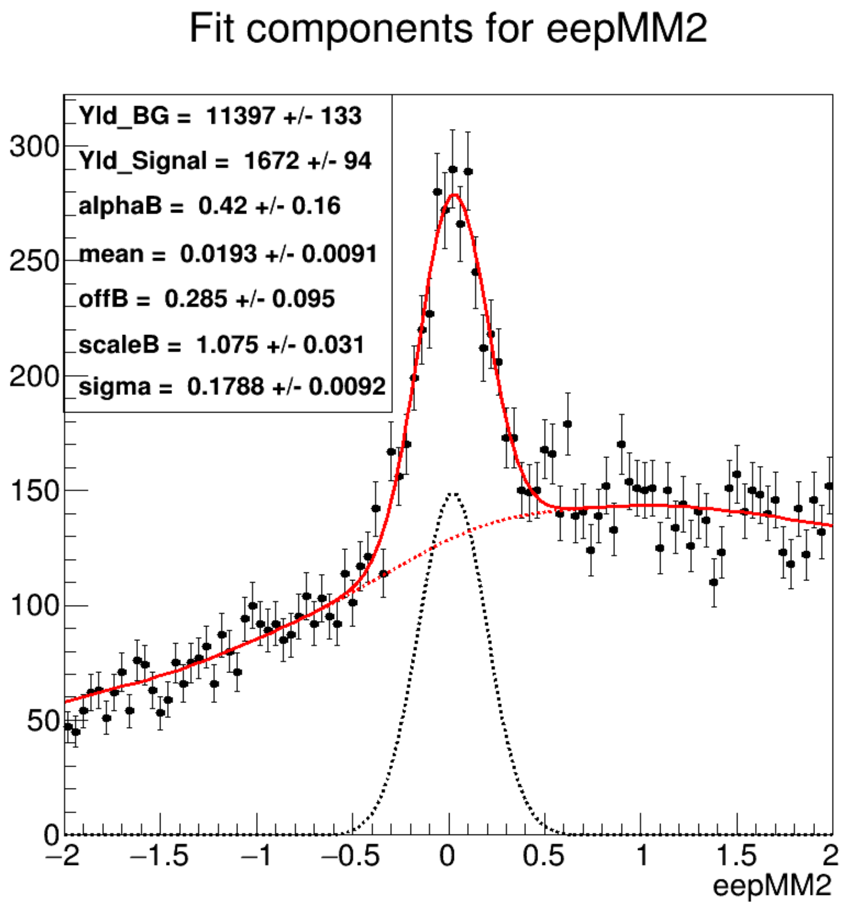
$Run_{\#}$	$FCup_+$	$FCup_-$	$FCup_{run}$	$RCDB\ events$
16291	20552.1	20439.9	0	75,923,511
16293	20244.4	20203.4	43098.1	76,182,597
16296	6855.84	6805.26	0	28,293,211
16297	8882.86	8834.19	0	33,118,517

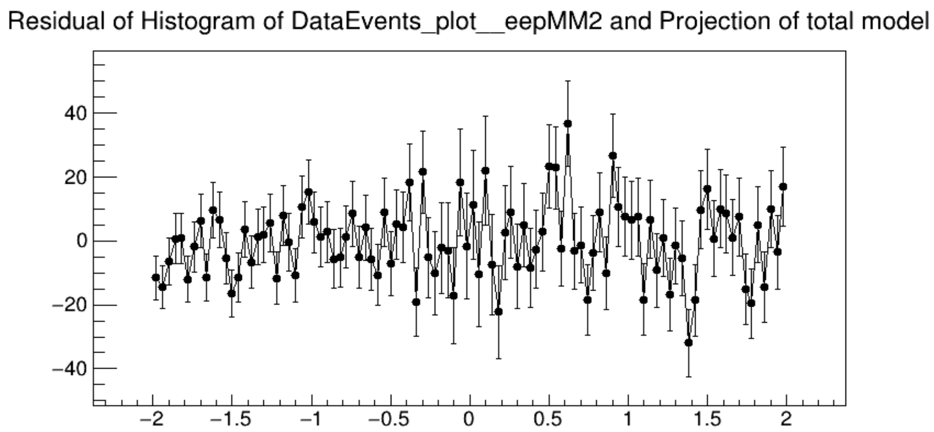
Info from:

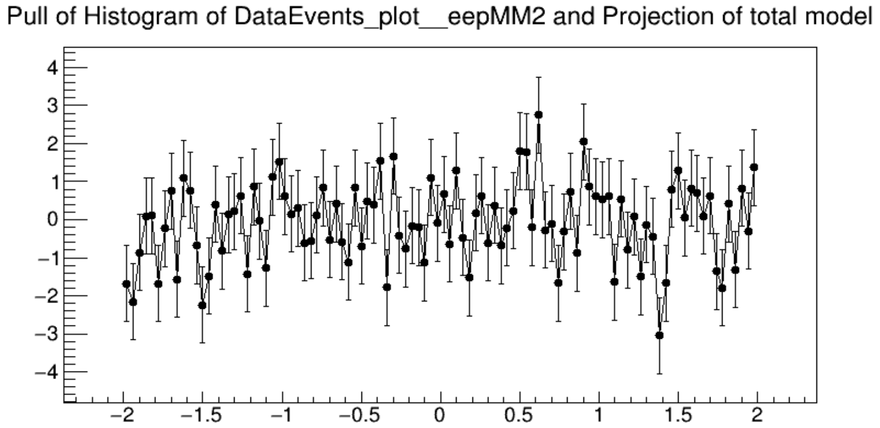
- RUN::config – gives run number
- HEL::SCALER – gives gated $FCup_+$ and $FCup_-$ values
- RUN::SCALER – gives gated $FCup_{run}$ value

C_{FCup} --> $\sum_{Runs}(FCup_+ + FCup_-)$ = 0.113mC ~ 3% of total carbon data

Weighting by nuclear background







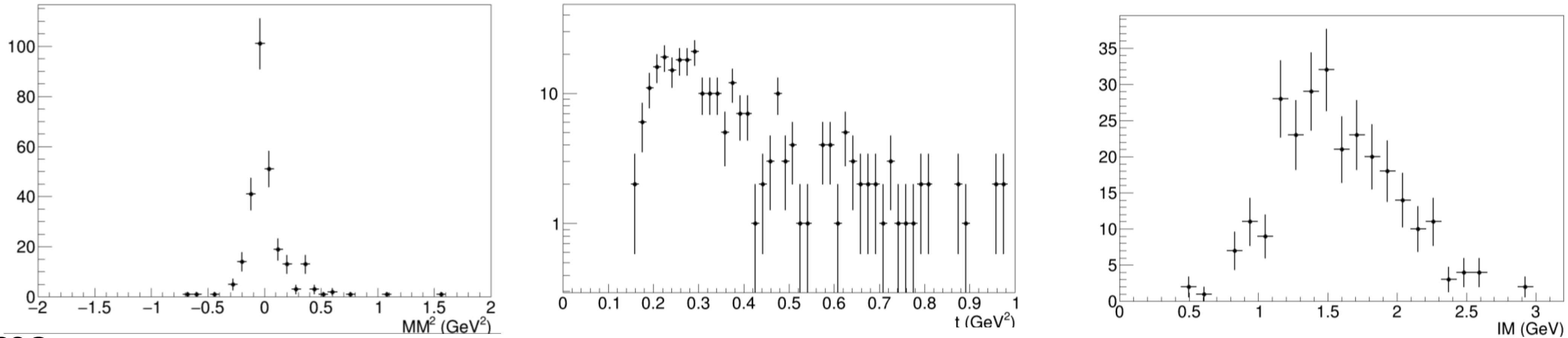
Cuts

- $\frac{Pt_X}{P_X} < 0.05$
- $-2GeV^2 < MM_X^2 < 2GeV^2$
- e^+, e^- in FD
- Electron Sampling Fraction cut 3σ
- PCAL $E_{Dep_{MIN}}$ $60MeV$
- $\frac{E_{inner}}{p} < 0.2 - \frac{E_{PCAL}}{p}$
- $-10\text{cm} < vz_{electron} < 5cm$

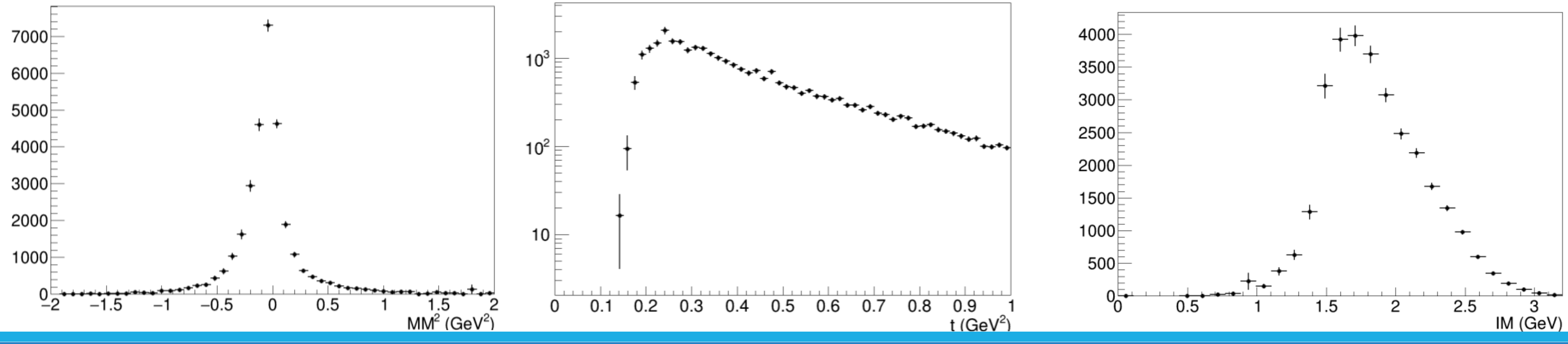
Comparing Sim to Data

GRAPE and TCSGen

GRAPE



TCSGen



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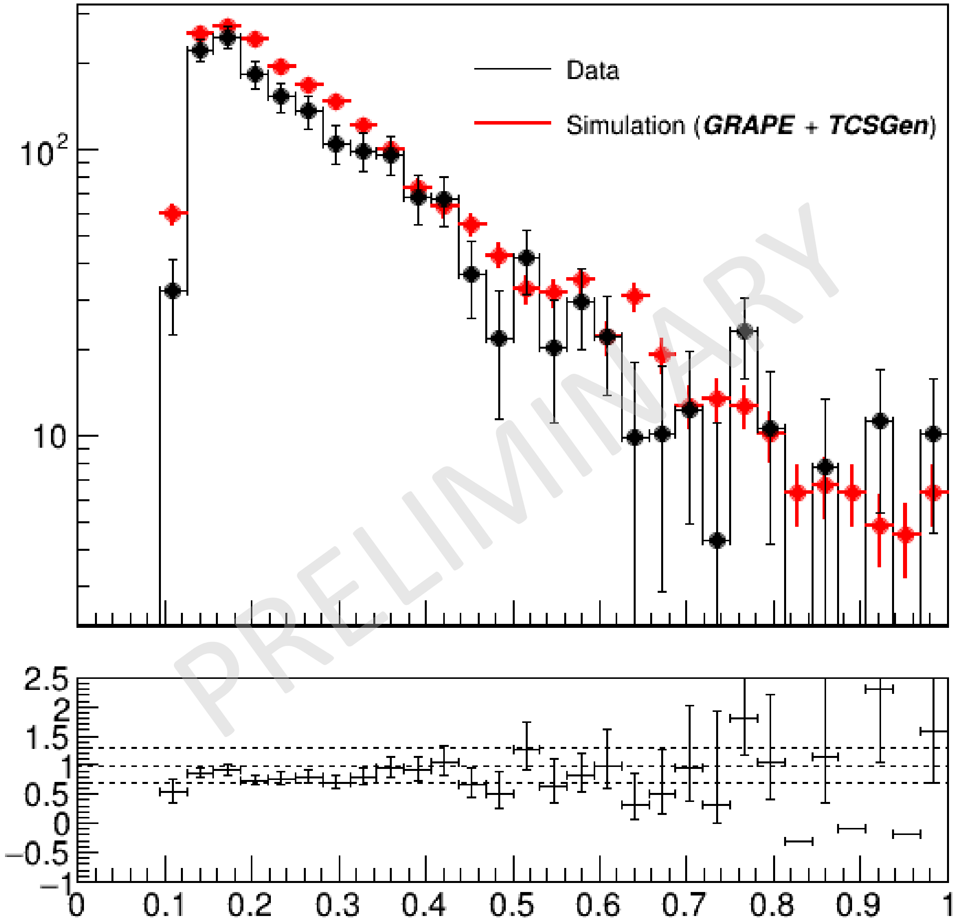
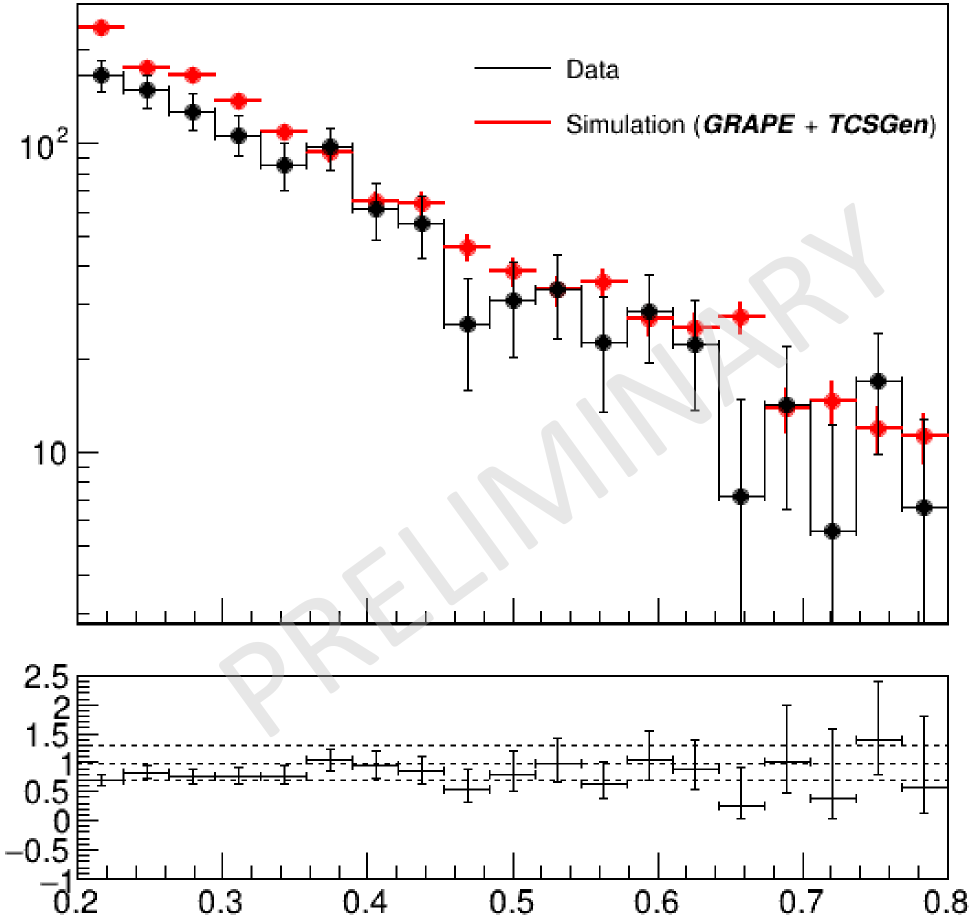
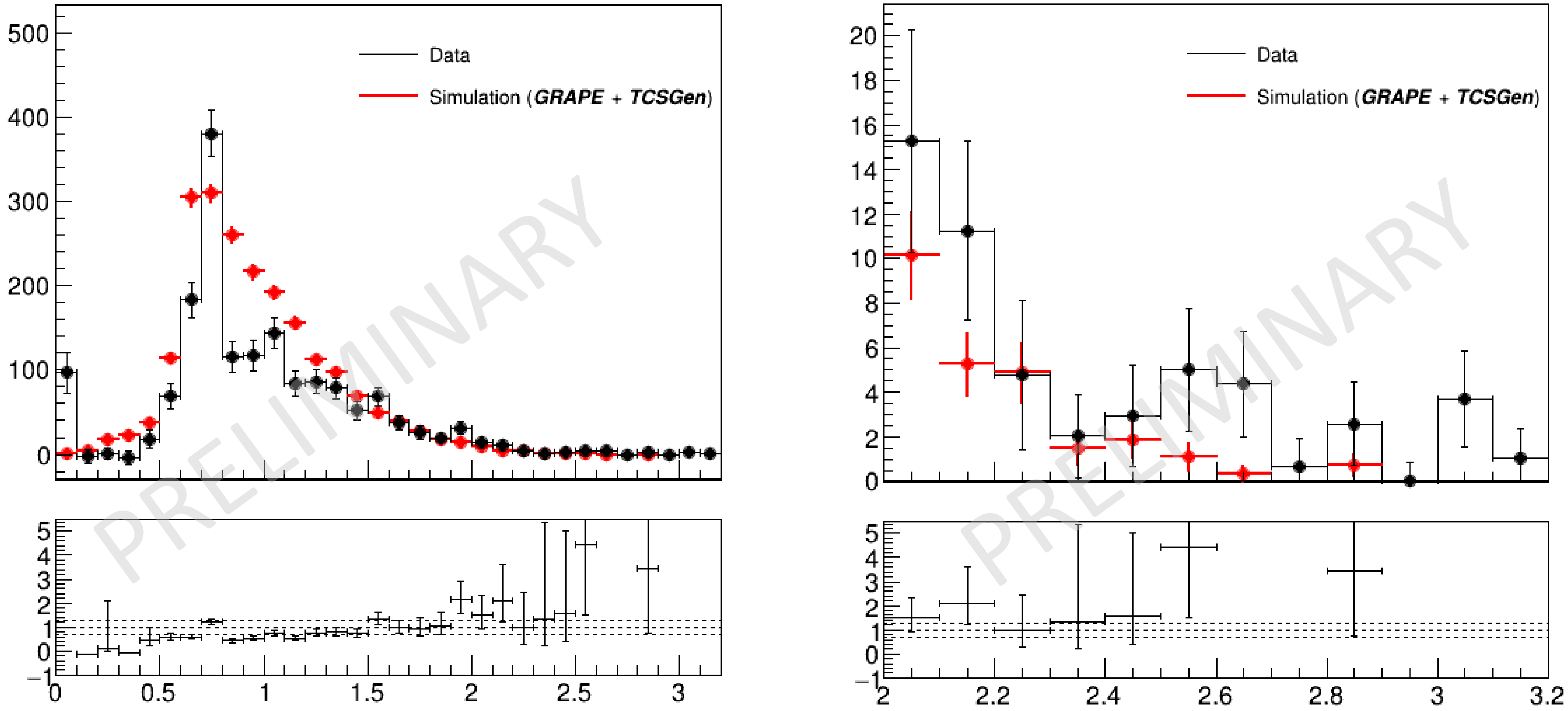


Data
Simulation (GRAPE + TCSGen)
PRELIMINARY



Data
Simulation (GRAPE + TCSGen)
PRELIMINARY

IM = $M_{\{e^{+}+e^{-}\}}$



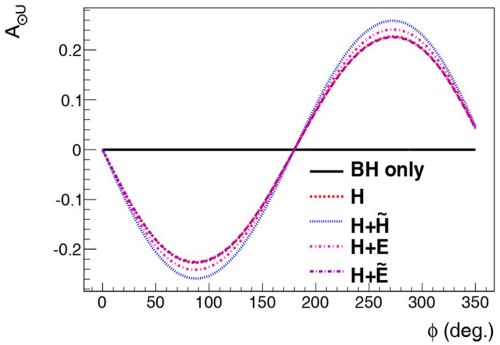
Data
Simulation (GRAPE + TCSGen)
PRELIMINARY
Data
Simulation (GRAPE + TCSGen)
PRELIMINARY

BSA and TSA – calculation procedure

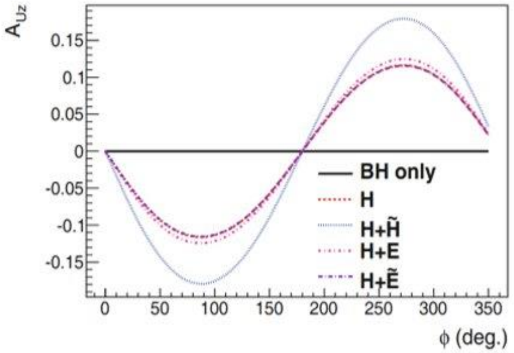
$$A_{LU} = \frac{P_t^-(N^{++} - N^{-+}) + P_t^+(N^{+-} - N^{--})}{Pb \times (P_t^-(N^{++} + N^{-+}) + P_t^+(N^{+-} + N^{--}))}$$

$$A_{UL} = \frac{N^{++} + N^{-+} - N^{+-} - N^{--}}{Df \times (P_t^-(N^{++} + N^{-+}) + P_t^+(N^{+-} + N^{--}))}$$

BSA



TSA



$N^{\{ij\}}$ = number of counts in ϕ histogram with beam helicity i and target polarization j

Pt^+/Pt^- = Value of positive/negative target polarisation, calculated using elastic analysis (N.Pilleux)

P_b = beam polarization – taken to be 83% after averaging across Möller run measurements

D_f = Dilution factor ~ 12% based on sPlot Signal to Background split

Conclusions/Next Steps

- Can see trends comparable to published TCS result at this stage, can pick out expected features in preliminary kinematic distributions.
- Improvements in CVT reconstruction and AI tracking mean that the next round of cooking is predicted to show improvements in many areas, notably reconstruction of the scattered proton.
- Calibrations for this run period still in progress – these are progressing on schedule, some resolutions will be expected to improve when these are complete.
- With the fully cooked dataset we can also expect significant improvement in statistics.

REFERENCES

[1] *Science Requirements and Detector Concepts for the Electron-Ion Collider: EIC Yellow Report* e-Print: 2103.05419 [physics.ins-det]

[2] First Measurement of Timelike Compton Scattering. P. Chatagnon et al. (CLAS Collaboration) Phys. Rev. Lett. 127, 262501 – Published 22 December 2021

[3] Boër, M., Guidal, M. & Vanderhaeghen, M. Timelike Compton scattering off the proton and generalized parton distributions. *Eur. Phys. J. A* **51**, 103 (2015). https://doi.org/10.1140/epja/i2015-15103-3

[4] N. Pilleux *RGC end of run report* RG-C end of run and first look at physics (in2p3.fr) *Accessed:* 29/03/2023

[5] J. Brock *Performances of the longitudinally polarized target for CLAS12* International workshop on CLAS12 physics and future perspectives at JLab (21-24 March 2023): Performances of the longitudinally polarized target for CLAS12 · IJCLab Events Directory (Indico) (in2p3.fr) *Accessed:* 29/03/2023

[6] Abe, T., 2001. GRAPE-Dilepton (Version 1.1): A generator for dilepton production in ep collisions. *Computer physics communications*, *136*(1-2), pp.126-147.

[7] GitHub - JeffersonLab/TCSGen: Generator for Timelike Compton Scattering.

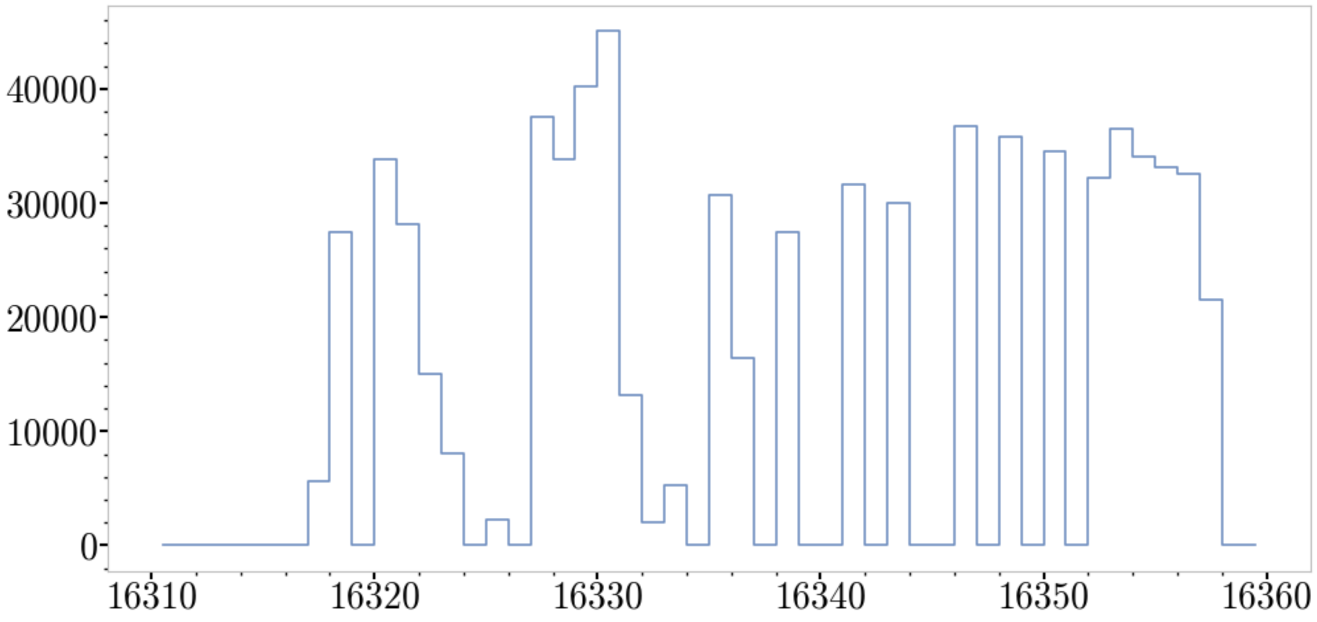
Thank you for your attention

Questions?

EXTRAS

Dataset

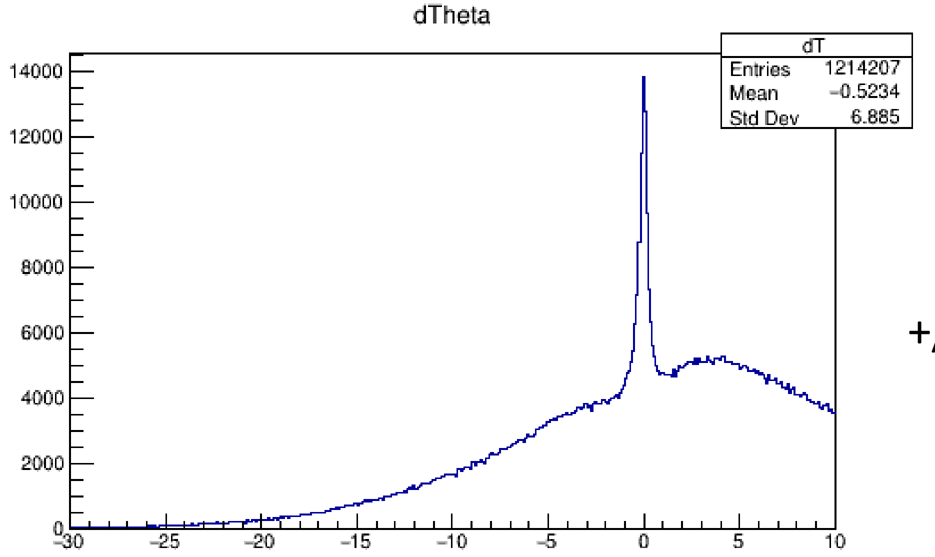
- 28 runs cooked with CJ 8.7.0 ≈ 0.8mC ≈ 6% of full dataset (13.06mC)
- 14 runs $Tpol^{+}$, 14 runs $Tpol^{-}$ FTOn configuration



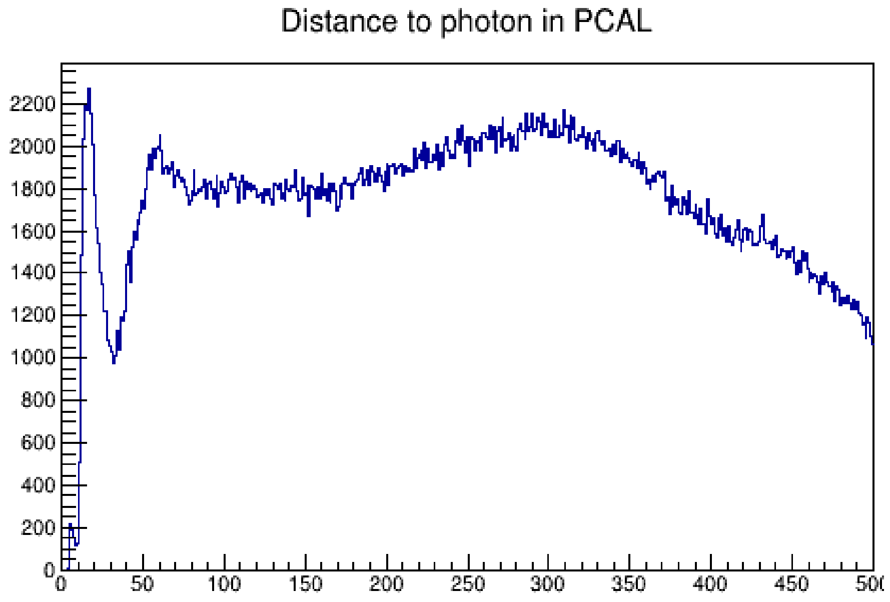
Rad Corrections

- When electron theta – photon theta is small, masking is applied to region to correct electron energy deposition calculation.
- When distance between electron and photon in the PCAL is small, this is the region where we get split offs, these are corrected by the calorimeter masking class
- To avoid double masking, condition is applied in radiative photon correction class that;

if abs(dTheta)<0.7 && dR > 30   i.e. if the event is low dTheta and wont be corrected by the calorimeter masking class, mask it.

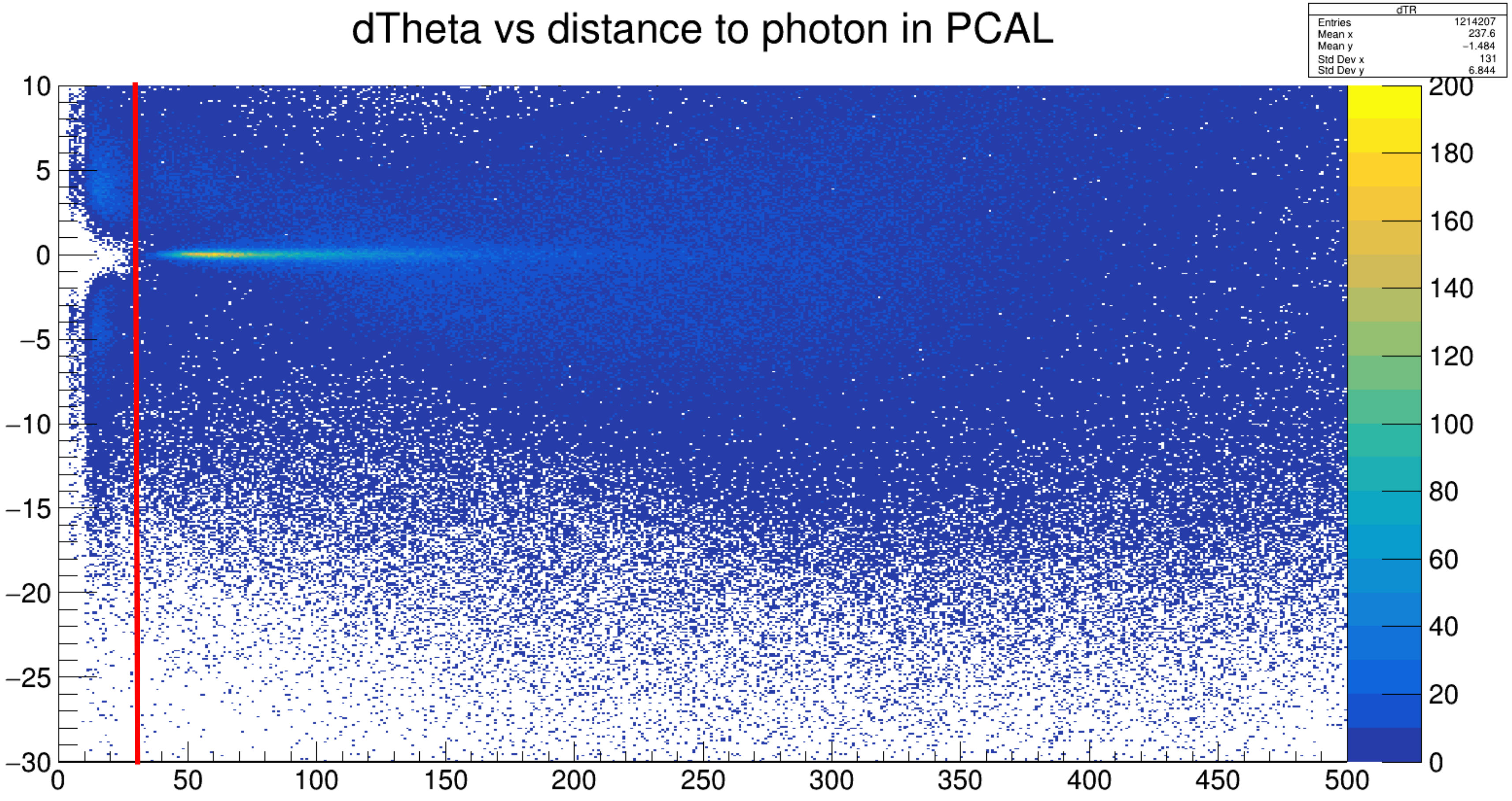


+/-0.7 degrees



30cm

2D dR dTheta RGC

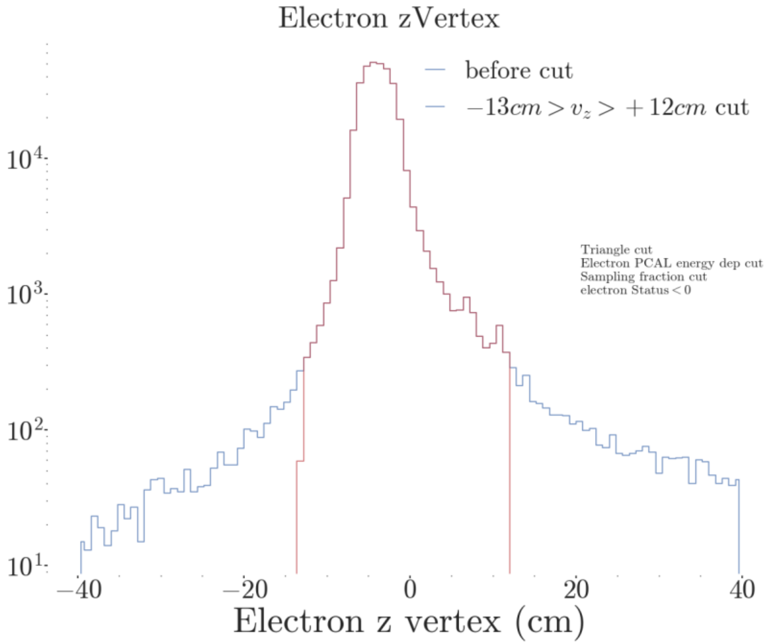


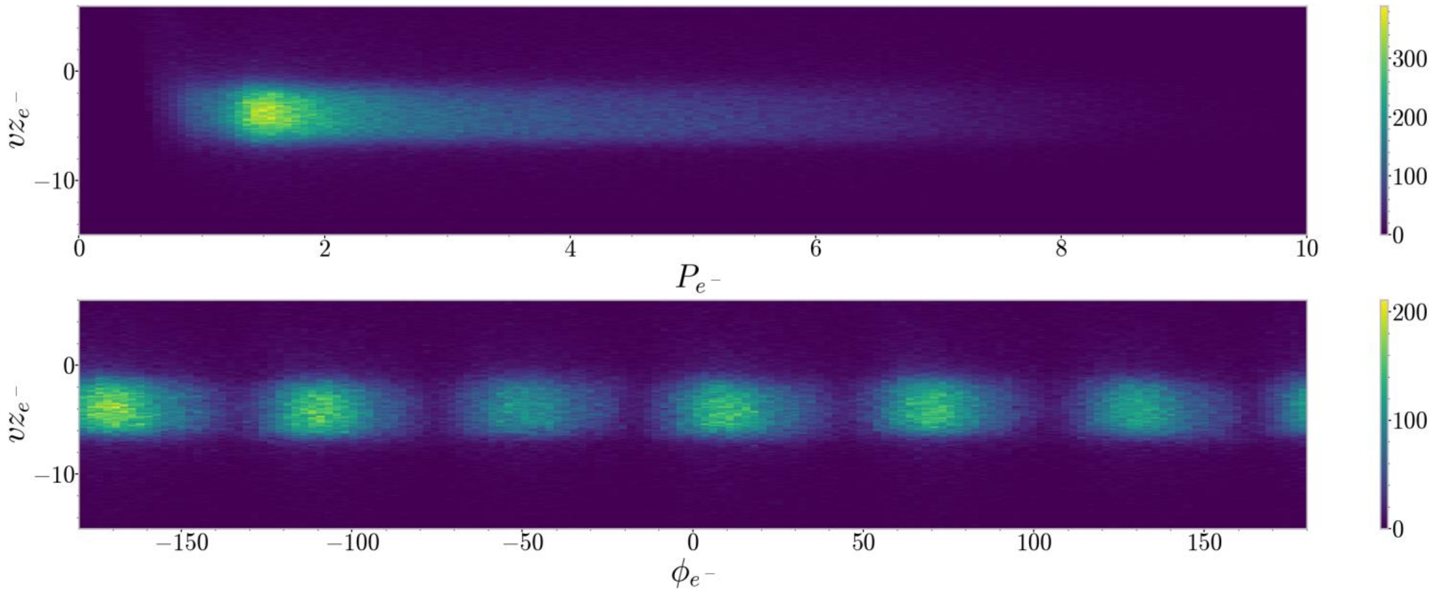
Target checks

5cm long cells

FTOn 15mm target diameter

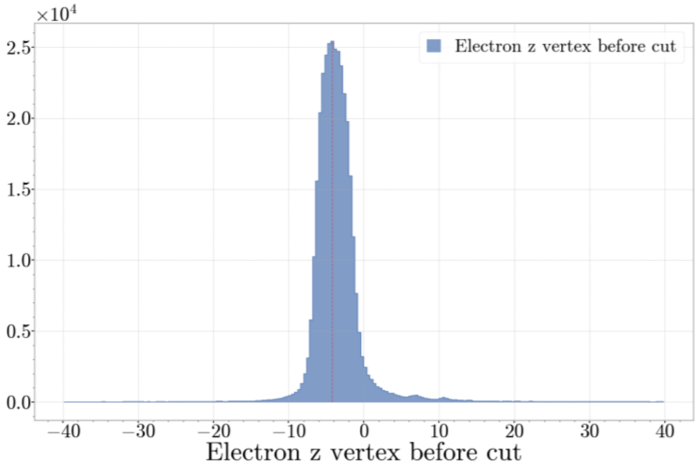
FTOff 20mm target diameter

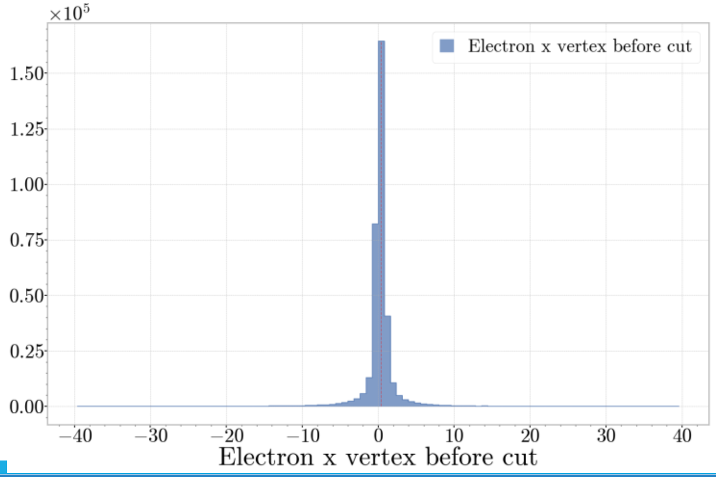


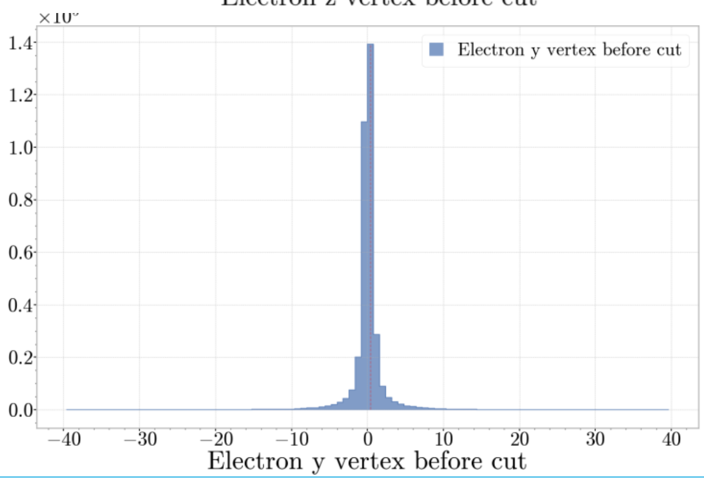


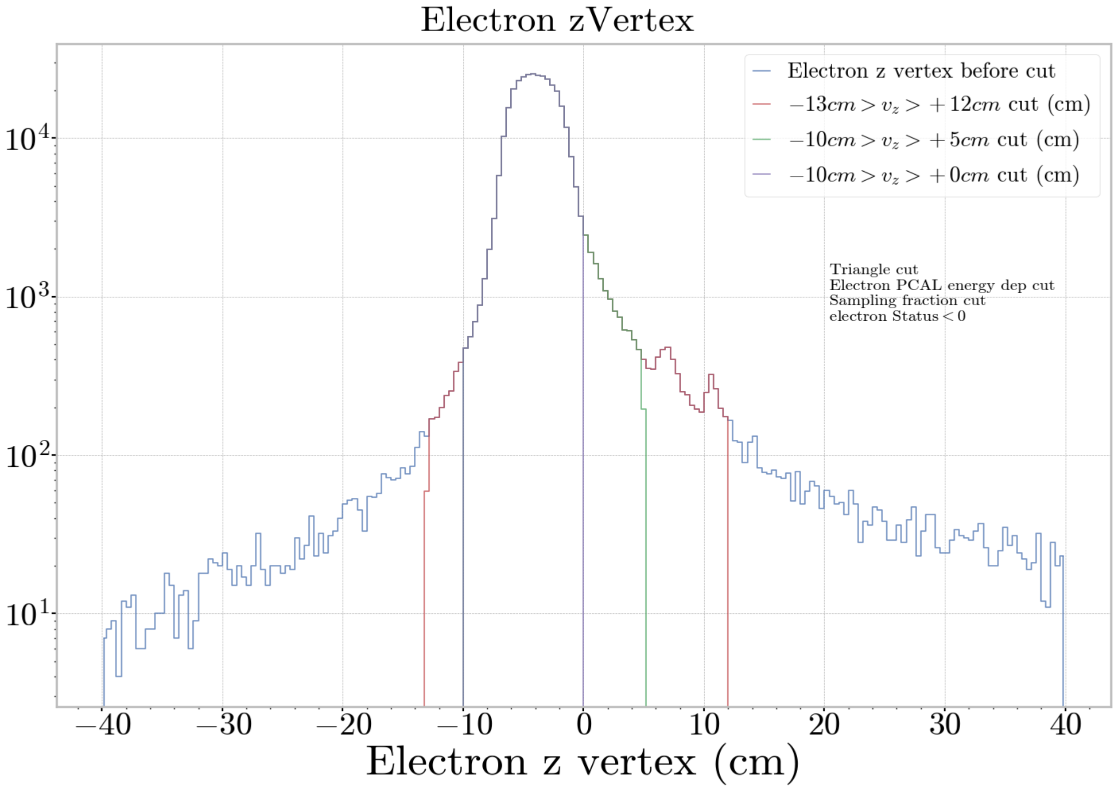
Target checks

- Target is 5cm long, vx,vy,vz peaks at coordinates ~ (0.39,0.39,-4.2)

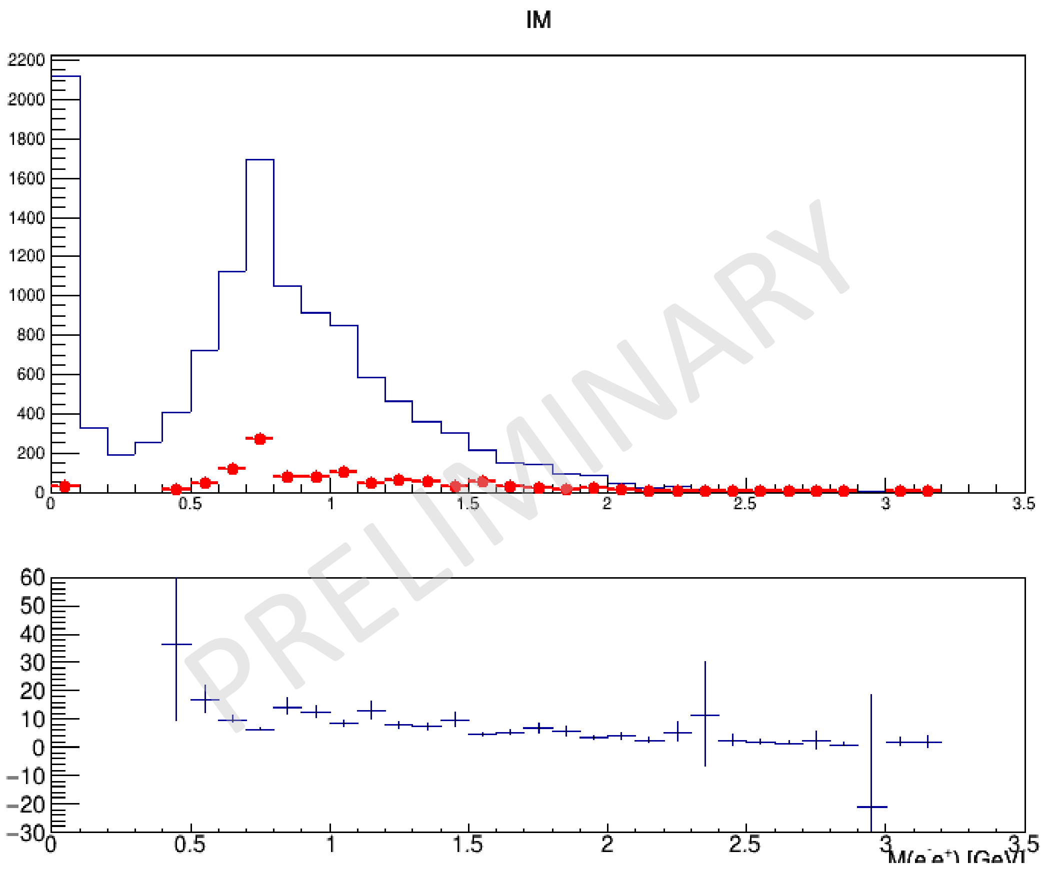


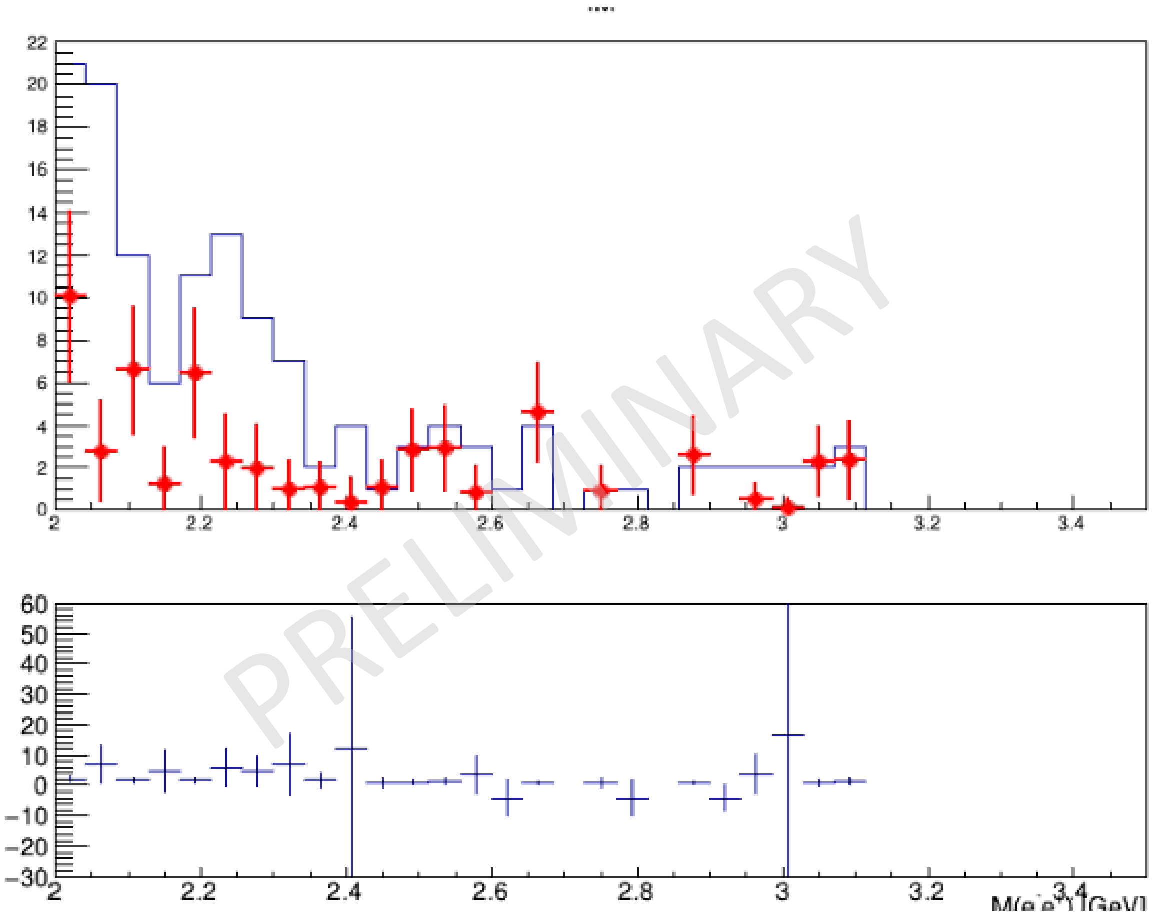




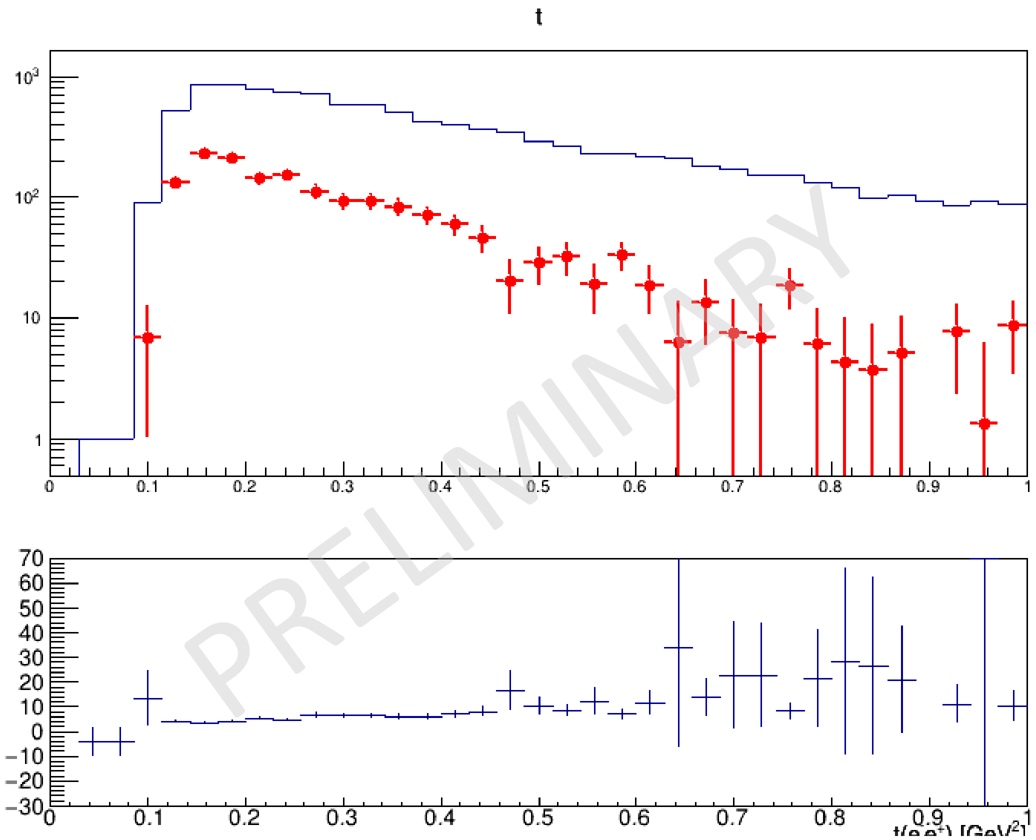


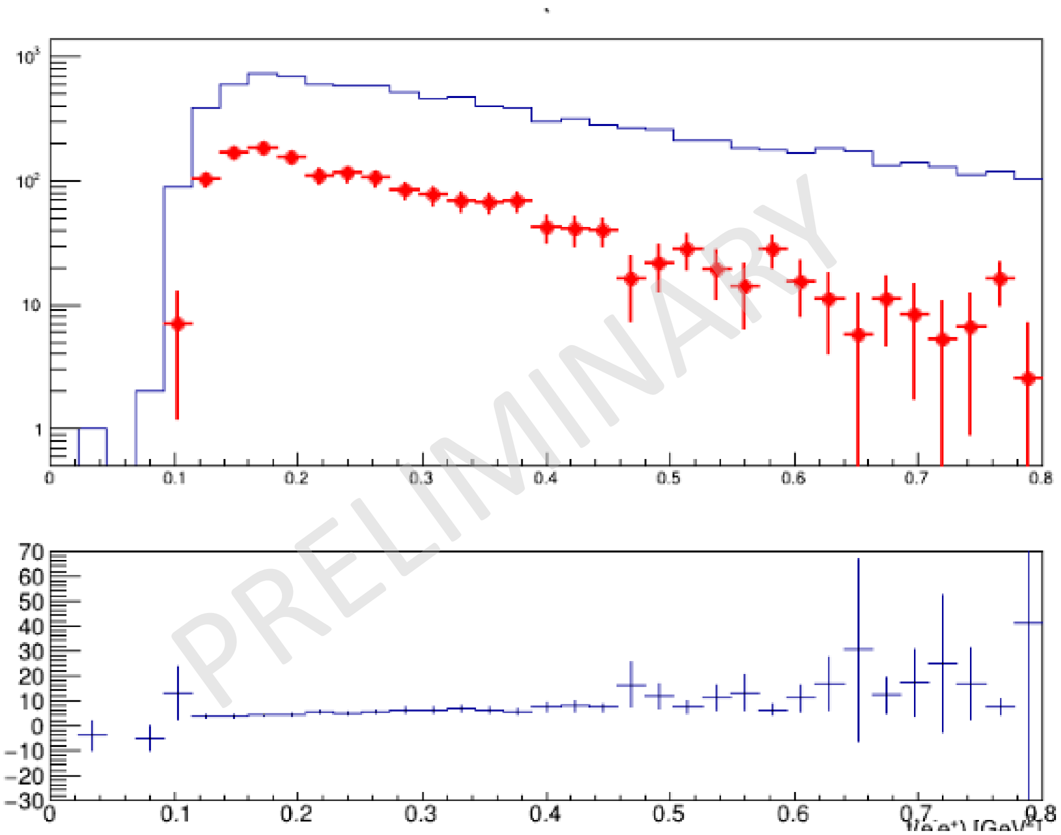
IM weighted



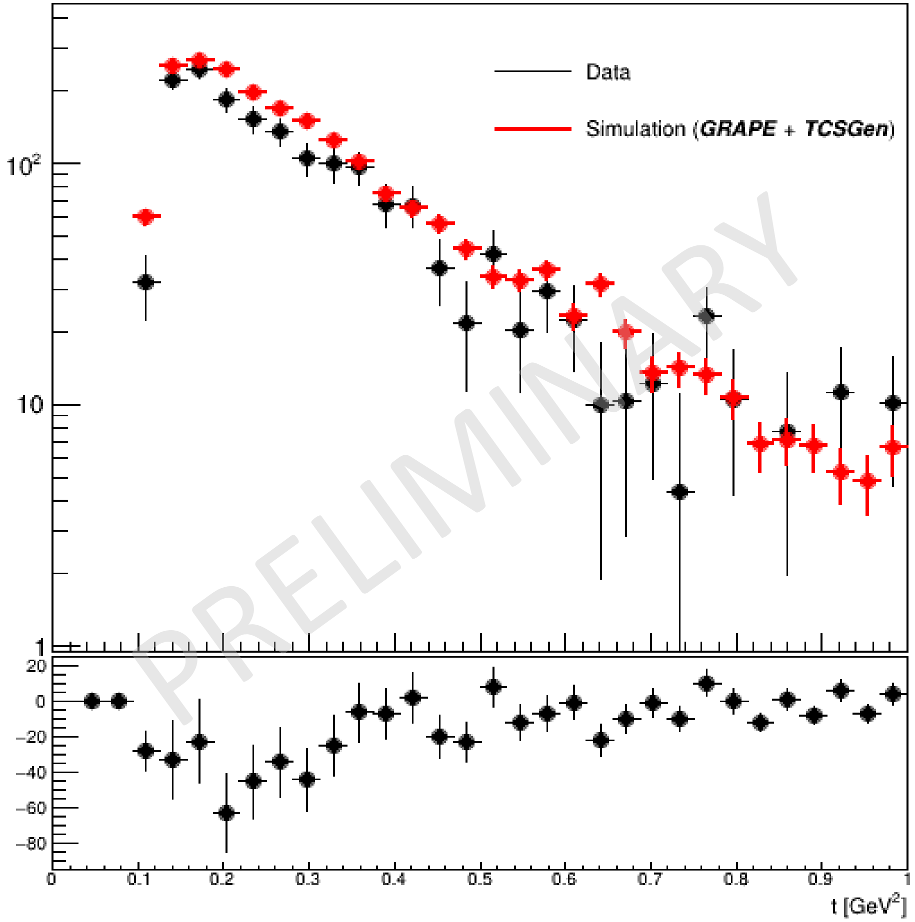


t weighted

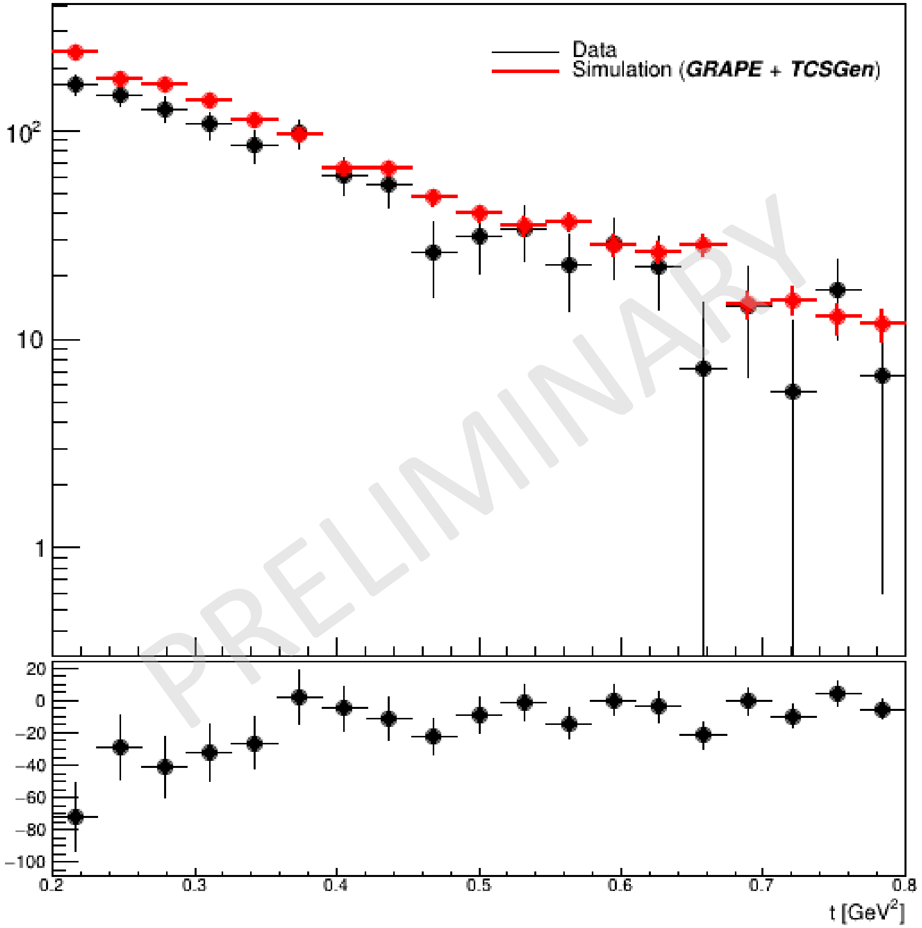




$$t = (p' - p)^2$$



Data
Simulation (GRAPE + TCSGen)
PRELIMINARY
t [GeV²]



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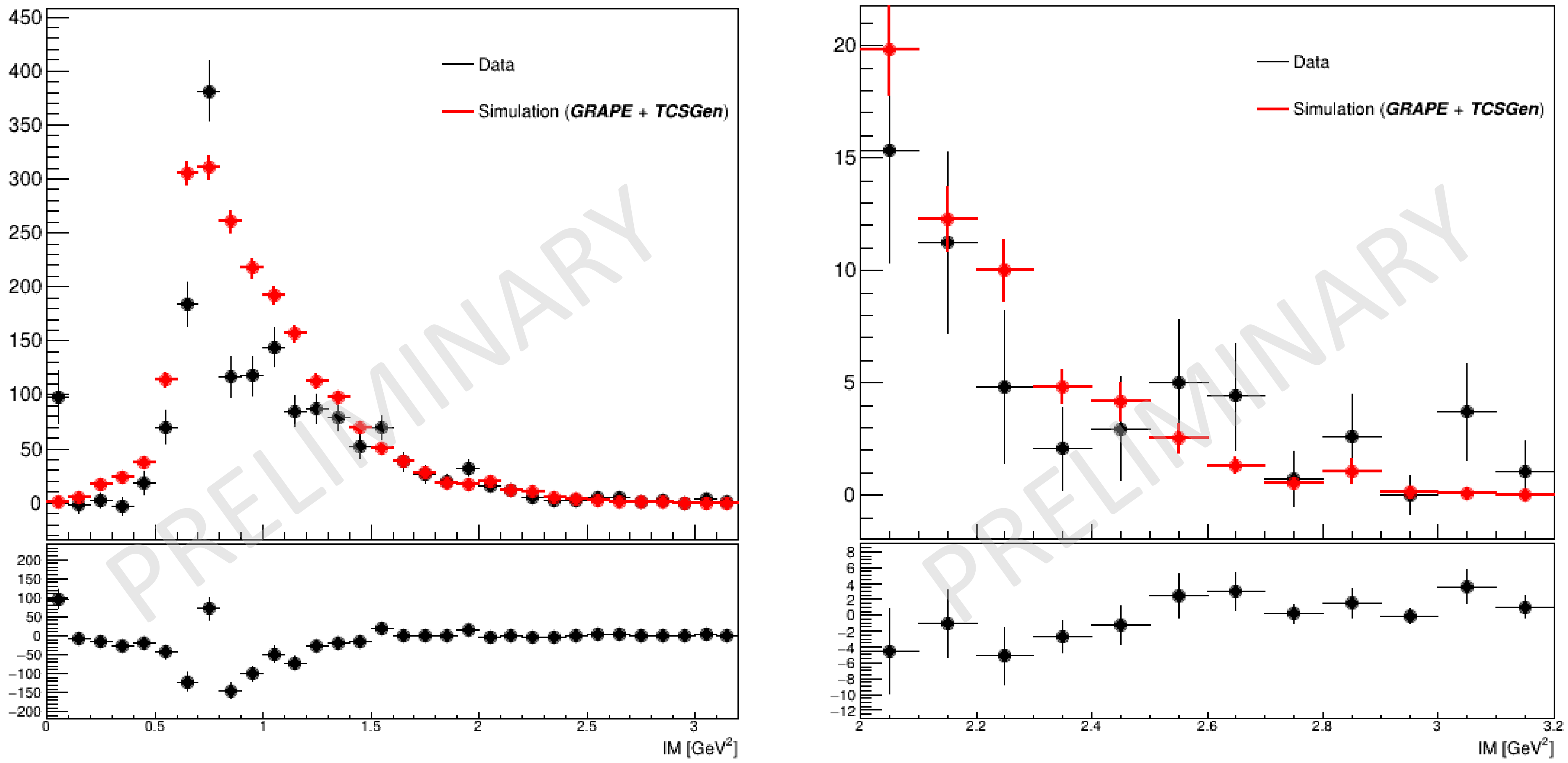

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PRELIMINARY
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PRELIMINARY
IM [GeV²]