CLAS12 Detector Efficiency

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June 4 2021

CEBAF Large Acceptance Spectrometer

Jefferson Lab

Outline

- Introduction
- Individual detector efficiency
- Related issues and tools
- Future plans

Understanding efficiency

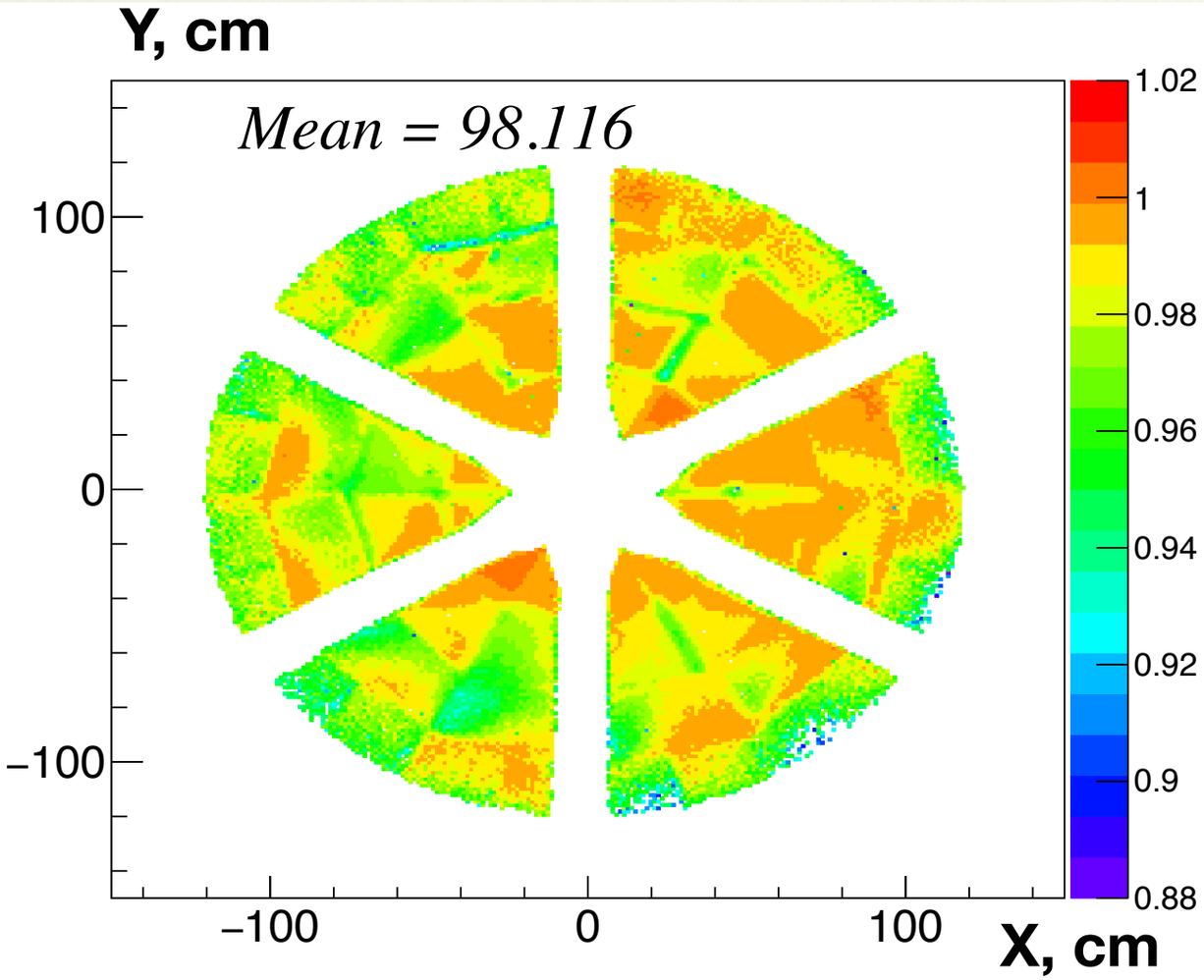
- We need to have an understanding of the detector efficiency for each subsystem;
- Efficiency estimation is not a one time effort;
- Each subsystem should have a software package dedicated to it;
- Should work on data and simulation;
- We should be able to compare data and simulation and adjust simulation or provide correction if needed;
- Efficiency can and most likely will be time-dependent (detector performance can change, GEMC implementation of the detector can change, reconstruction software can change, etc);
- Efficiency estimation should be used during passN preparation;
- Should be used to define and improve detector fiducialization.

HTCC Efficiency

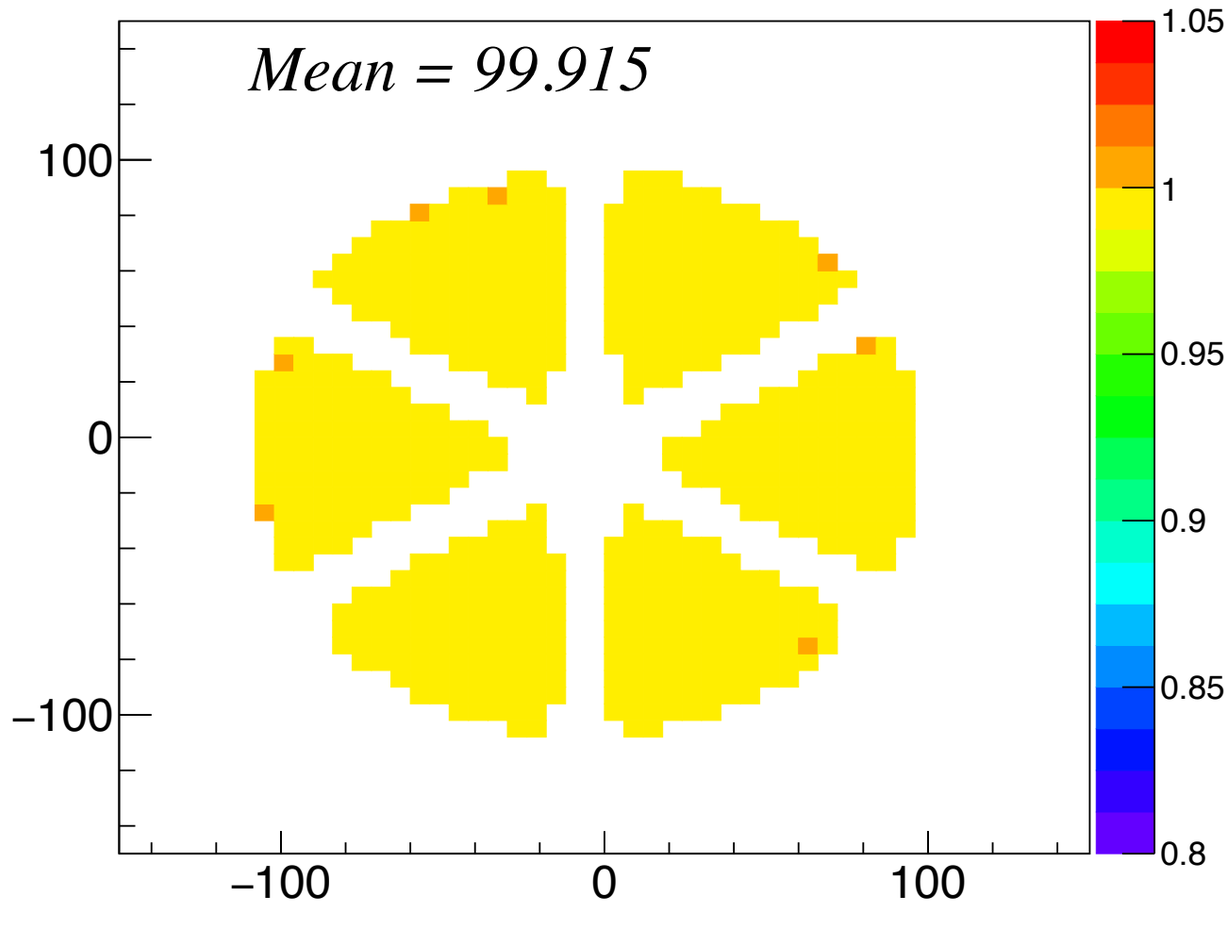
Estimation

HTCC electron detection efficiency

Data



Simulation



There is a noticeable difference;
Need to tune simulation.

DC Efficiency

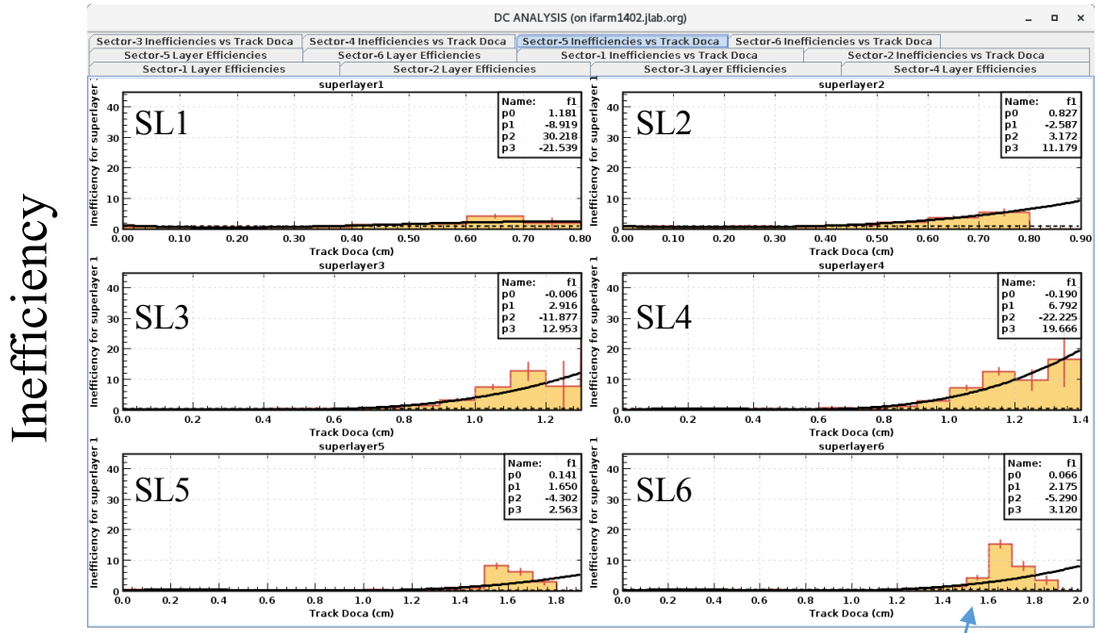
Simulating Intrinsic Inefficiency vs. DOCA

- Run 'layer efficiency' script on data
- ``finds track segment excluding one layer → did that layer fire? "
- fit inefficiency to function
- same function used in GEMC

→ tune GEMC parameters to match data (hit rejected if random number less than function)

✓ already implemented, needs tuning

Run 5443 Sector 5 HV "9 10 10"



Inefficiency

DOCA

Inefficiency is larger far from the wire
- these are 'corner clippers'
- fewer ions → smaller signal

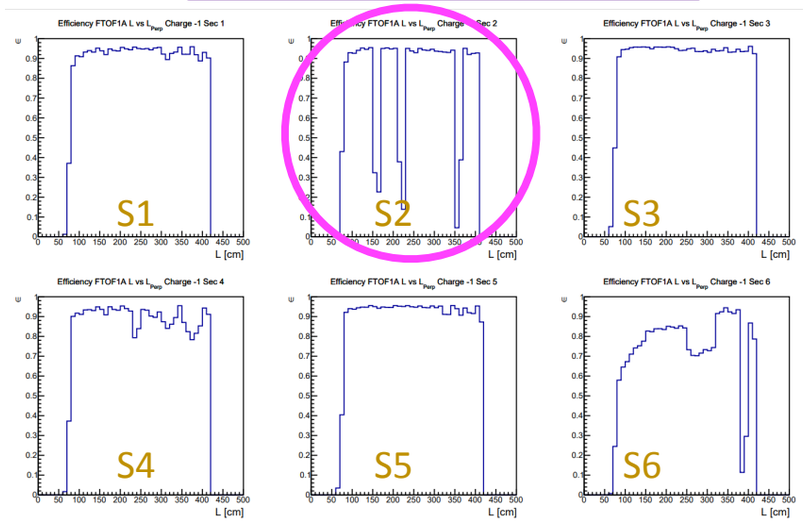
FTOF Efficiency Studies

FTOF Efficiency Definition:

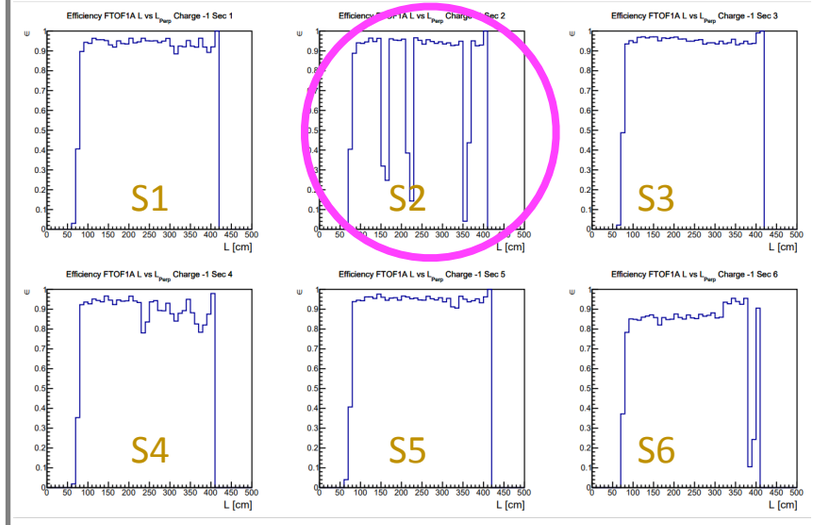
- Method #1: "Single Track" - ε_{FTOF} = (FTOF hit & DC track & ECAL hit) / (DC track & ECAL hit)
- Method #2: "Exclusive" - $ep \rightarrow e'p\pi^+\pi^-$ detect e', h1, h2, and look for h3

panel-1a

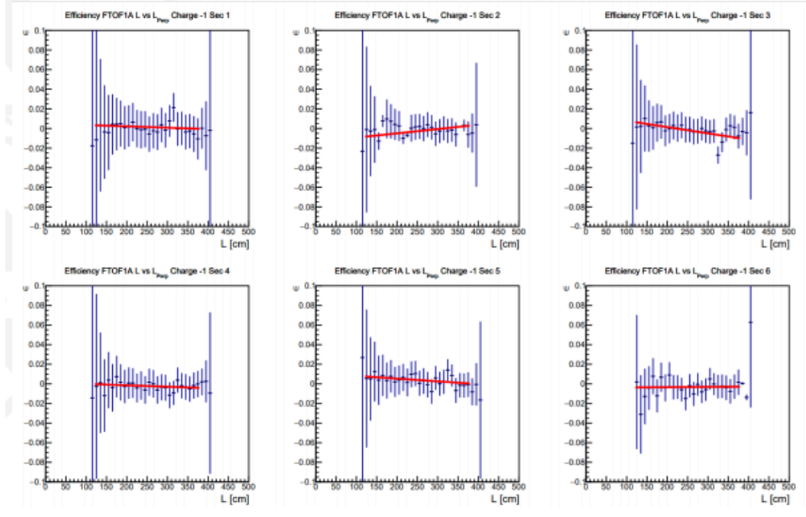
Track-based (neg)



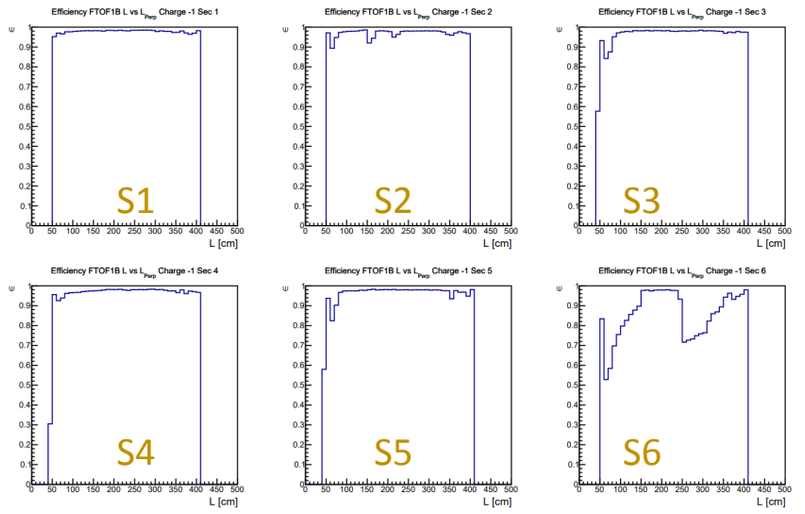
2π Reaction (π^-)

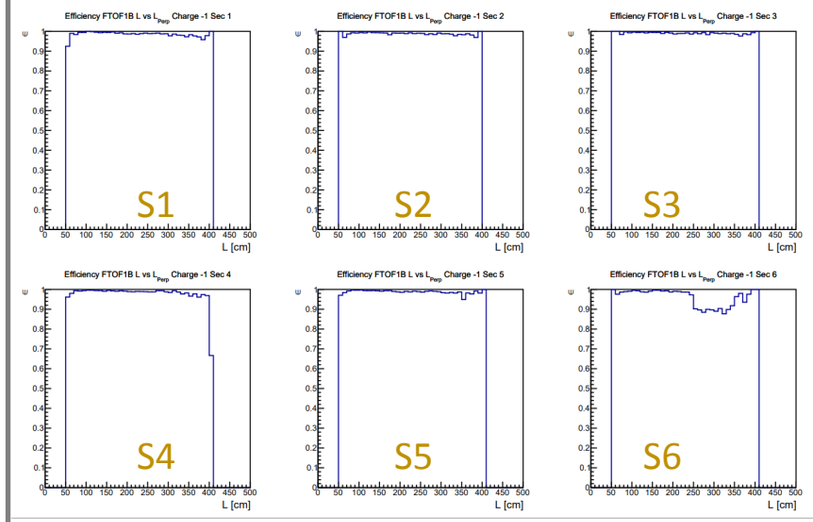


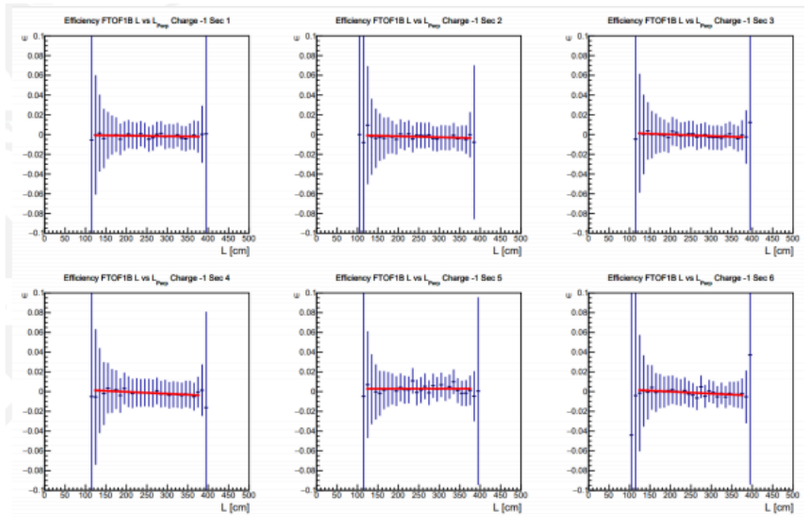
Efficiency Diff



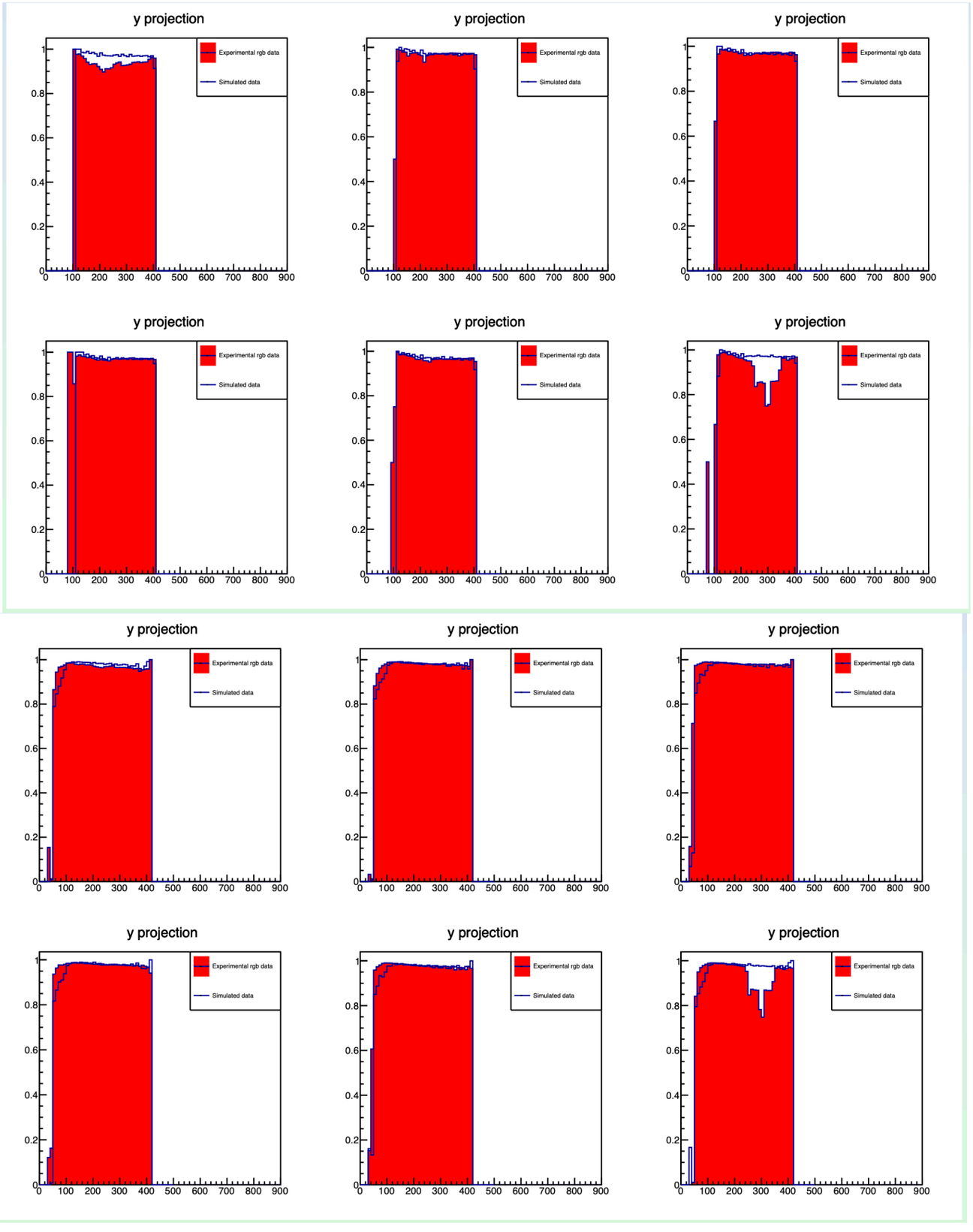
panel-1b







FTOF Efficiency



panel-1b

RG-B Spr19 inbending

vs.

Monte Carlo with FTOF energy threshold applied (in analysis code)

$$E^{L}_{dep} = E_L \exp(y/\lambda_L)$$

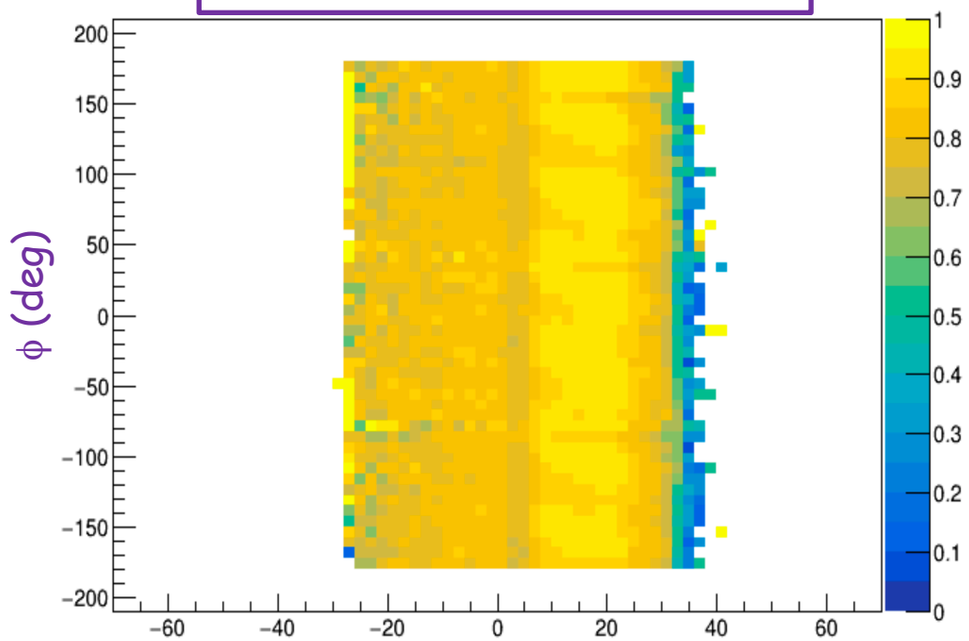
$$E^{R}_{dep} = E_R \exp(-y/\lambda_R)$$

WORK IN PROGRESS

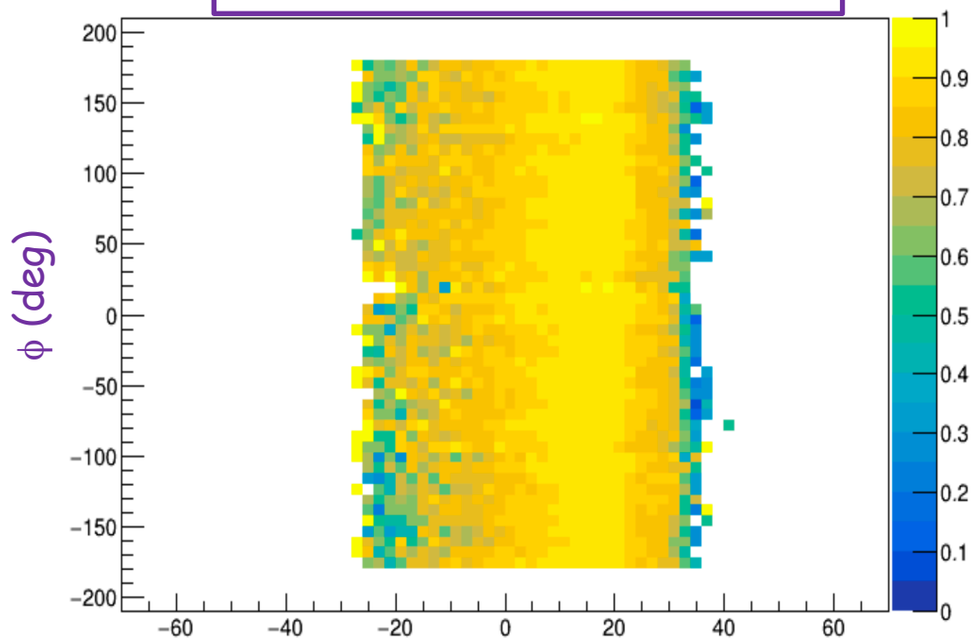
CTOF Efficiency

ε_{CTOF} with hit in CND
MC getting underway

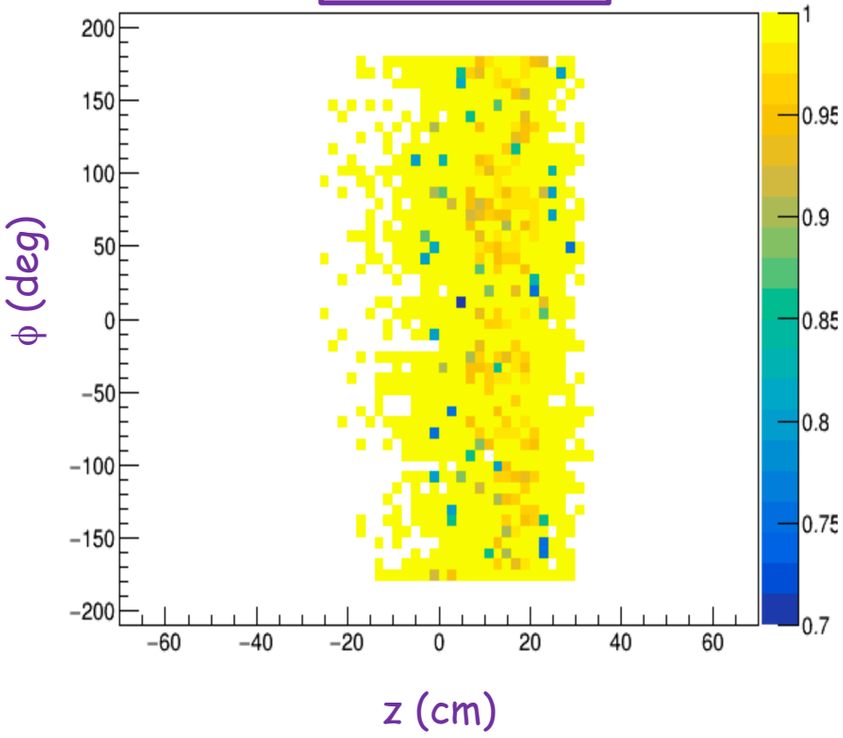
Track-based positives



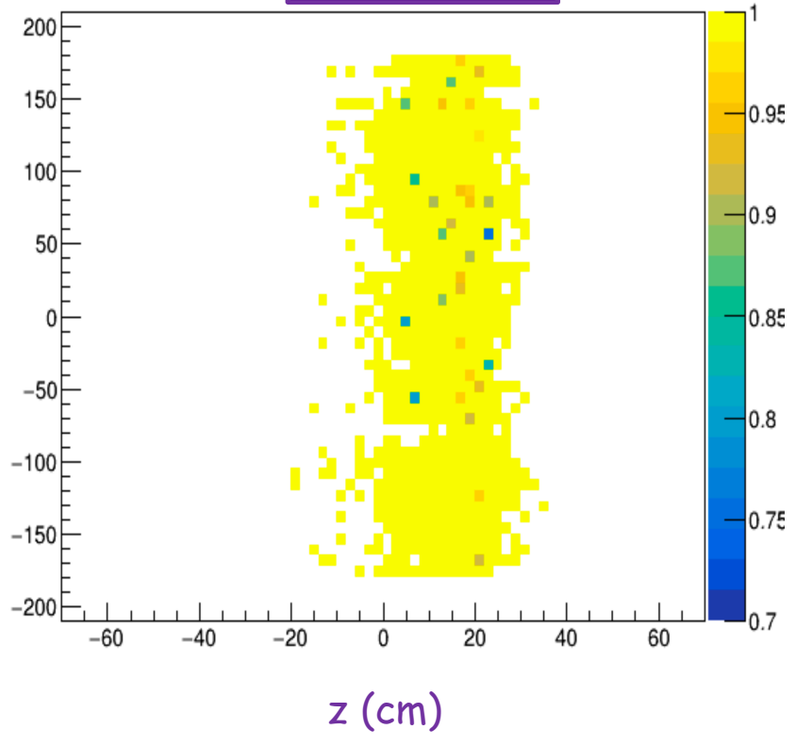
Track-based negatives



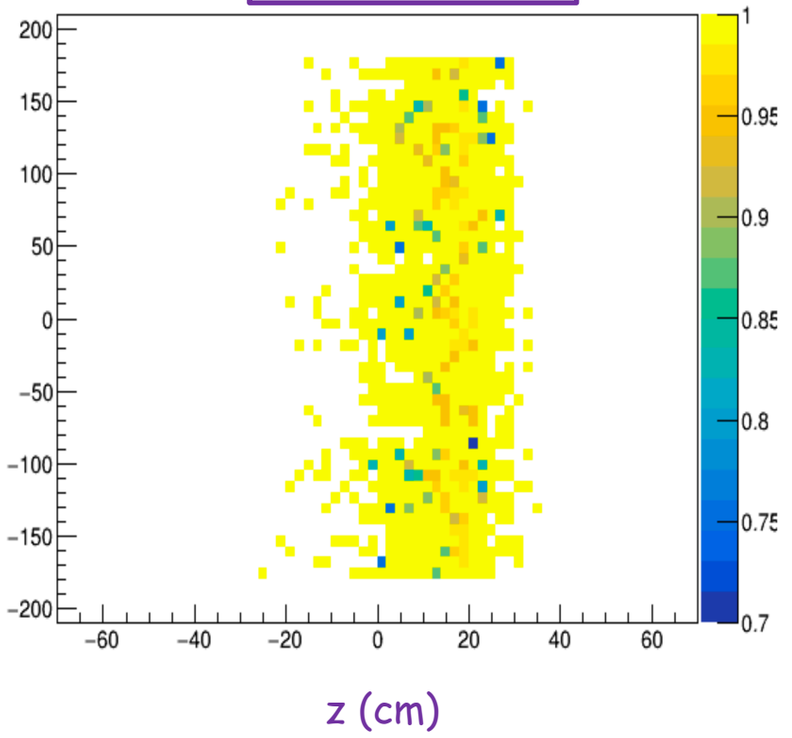
2π Rx (π^-)



2π Rx (p)



2π Rx (π^+)



EC/PCAL Efficiency

Electrons

- Absolute efficiency studies so far only with MC and ideal detector (fixed attenuation and gain).
- Random or non-electron triggers may have insufficient yield for detailed 2D efficiency maps.
- Relative efficiency studies planned using radiated photons or CD elastic protons to tag negative tracks with missing PID.

Minimum Ionizing (pions, muons)

- PCAL efficiency defined relative to DC track projection (pions) or FTOF 1B (cosmic muons).
- ECIN, ECOUT efficiency defined relative to PCAL.
- For pions efficiency losses dominated by nuclear interactions.
- In general MIP efficiency losses affected by light attenuation from longest strips.

Neutrals

- Neutrons: MC efficiencies compared to data using tagged neutrons from $p(e,e'\pi^+)n$.
- Photons: MC studies only with ideal detector.

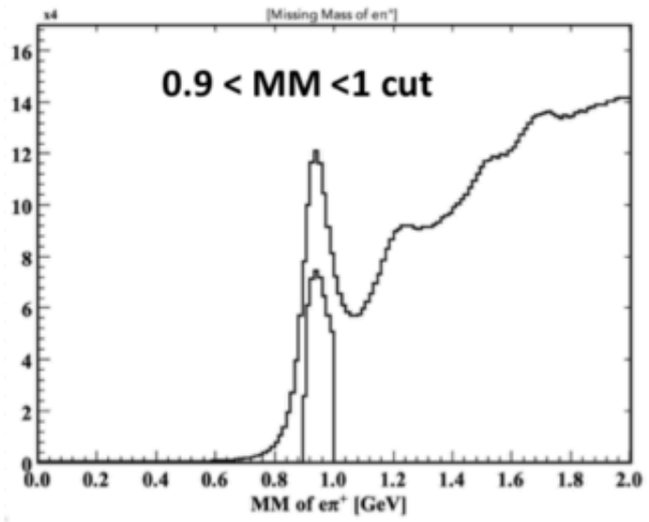
General observations

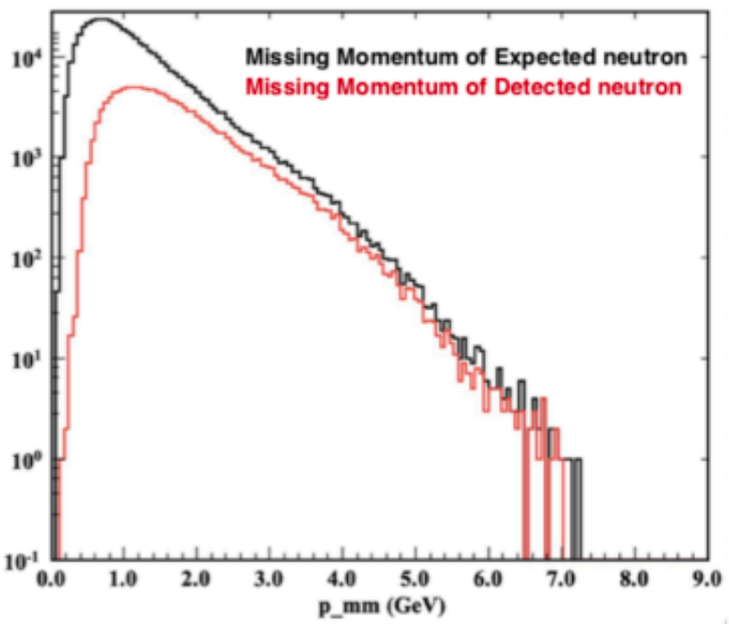
- Cross check of data/MC derived efficiencies essential to ensure consistency.
- MIP studies offer best opportunity of data/MC comparison with realistic detector.
- Neutral efficiency studies hampered by reconstruction issues (extra, merged clusters, PID).

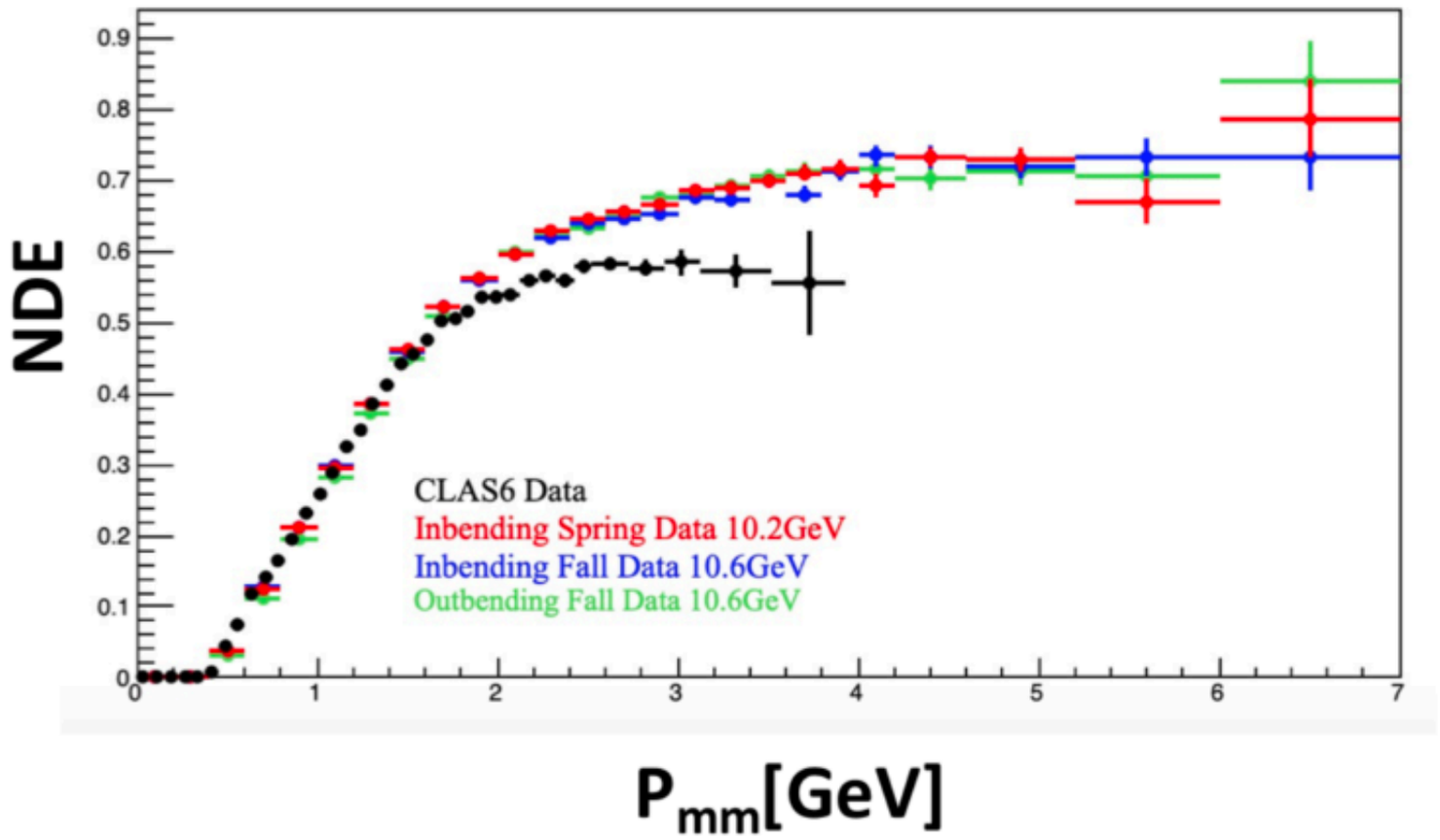
ECAL

Neutron efficiency

inb_Spring Data at 10.2 GeV



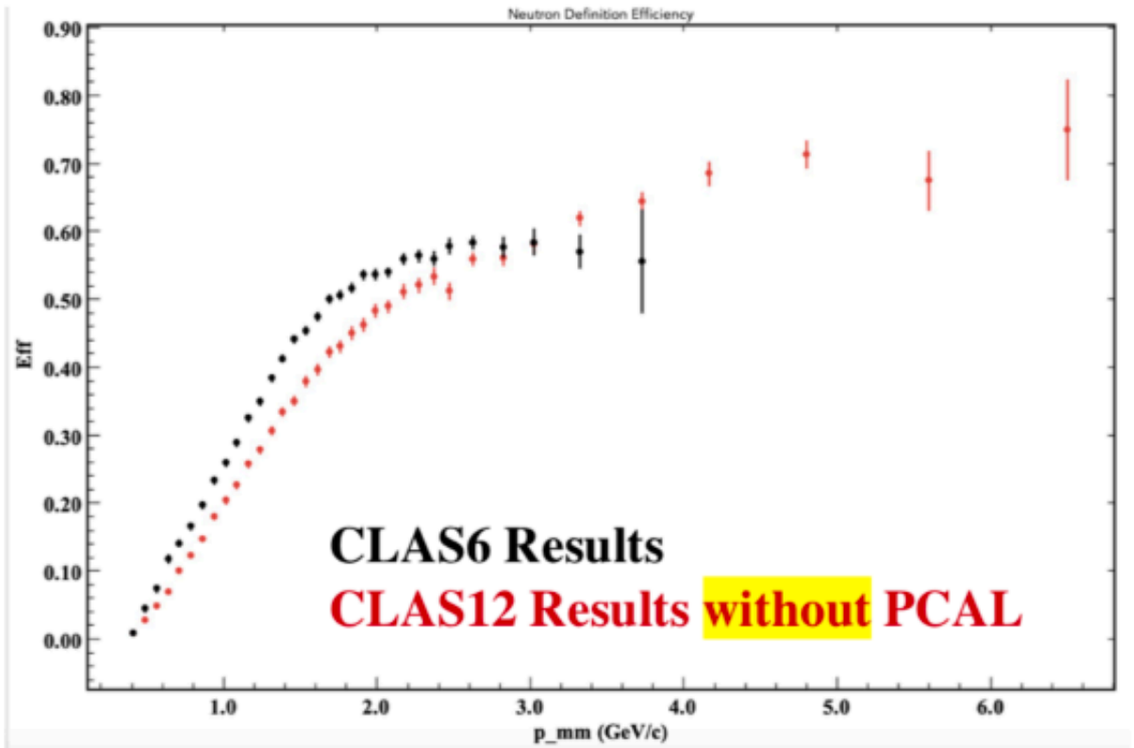




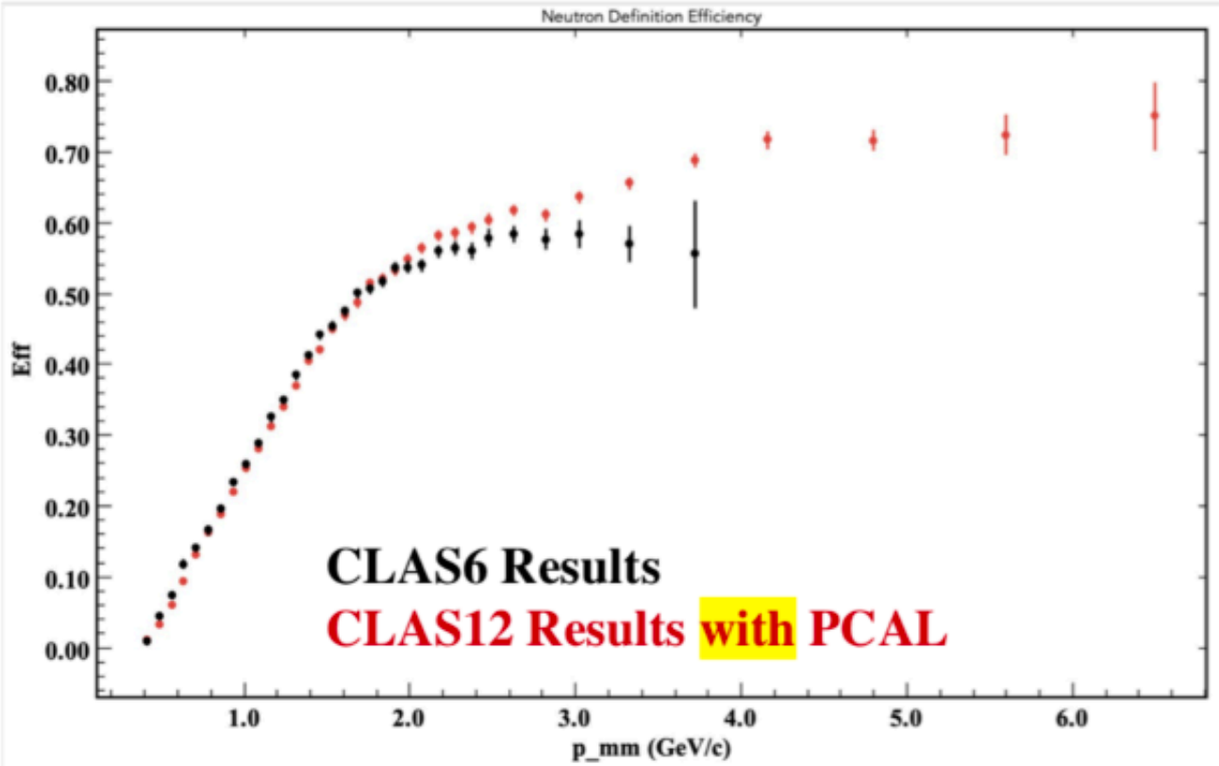
ECAL

Neutron efficiency

NO PCAL



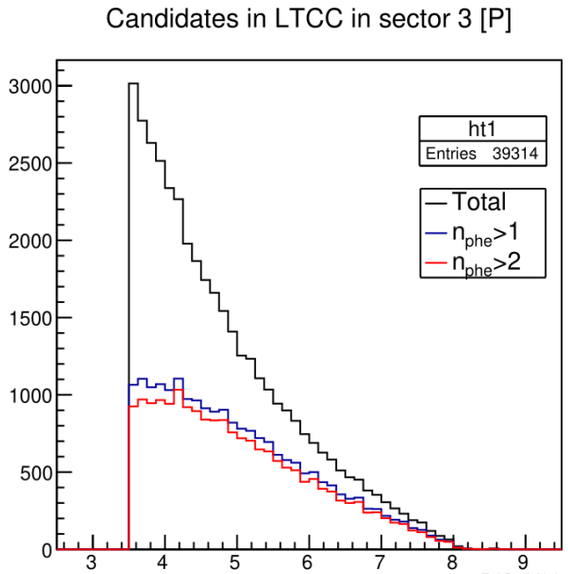
with PCAL

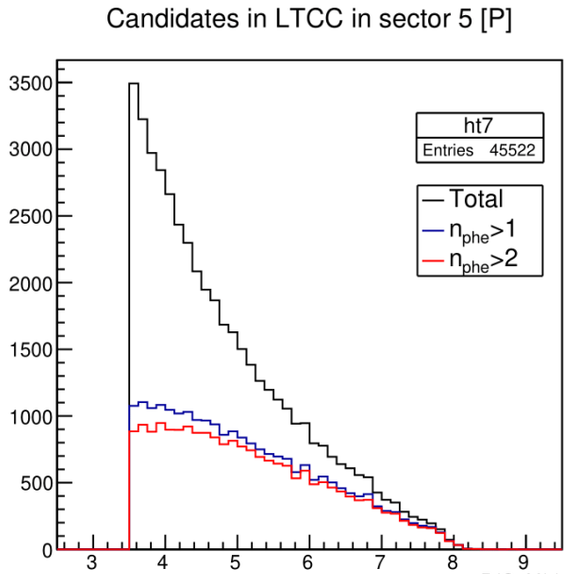


Results & Discussion

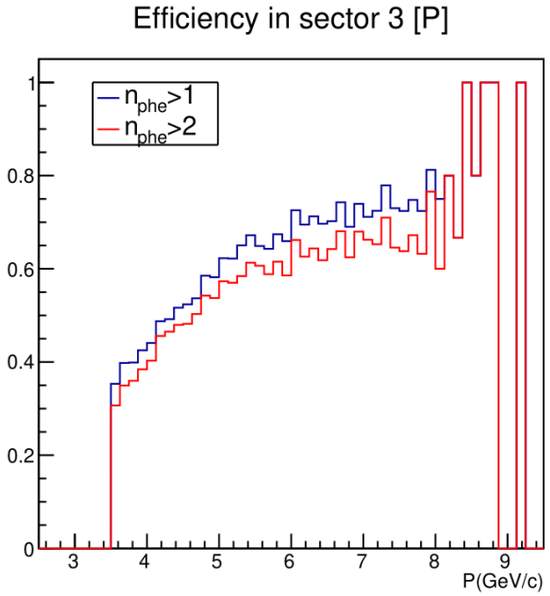
Momentum:

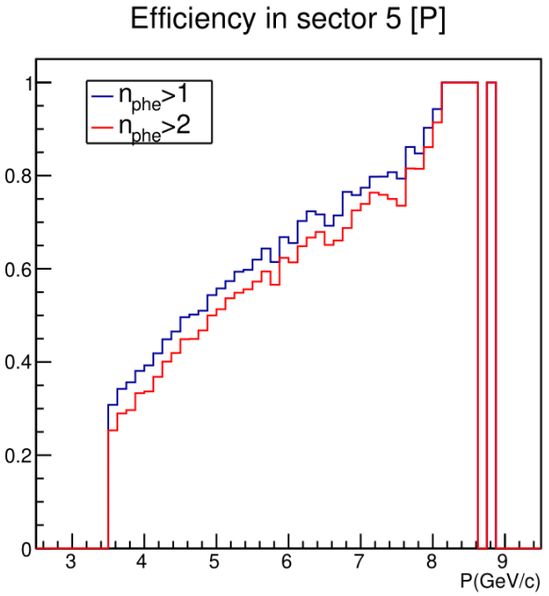
- Selection for sections 3 and 5 separately
- Number of photoelectrons (n_{phe}) greater than 1 or 2
- Pions appear at 3.5 GeV/c → cuts in skim13





- Max efficiency in pions region ~80 – 85 %
- Slightly better for sector 5 above 7 GeV/c
- Differences between the two active sectors are visible (see also the other variables histograms) → more counts in sector 5





Results & Discussion

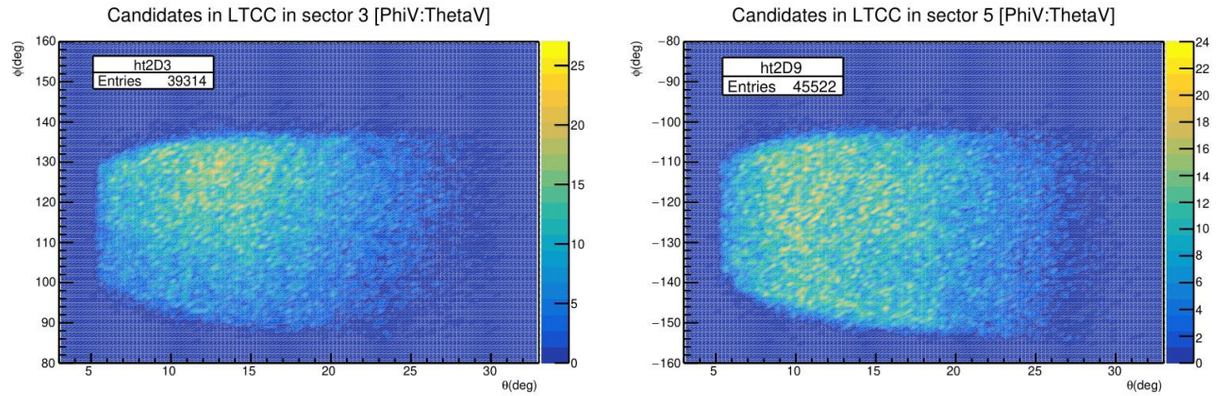
Theta vs Phi:

- Total candidates + candidates with signal in LTCC (n_{phe}>2) + efficiencies

- A substructure is clearly visible in rows 2 and 3 of the figures → mirrors+PMTs

- Sector 5: no events for Theta ~15 – 18 deg and Phi ~ -120 – -90 deg

- Discontinuities in efficiency in correspondence of mirrors edges

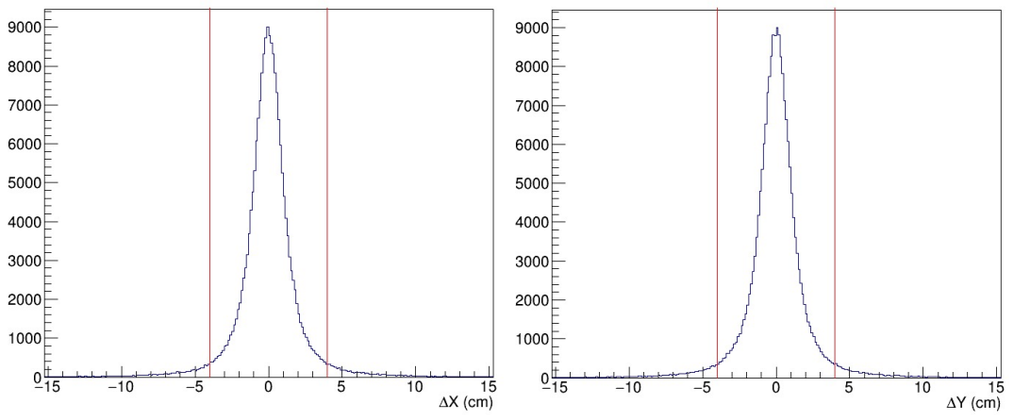


FT Efficiency

- Inefficiencies can arise from thresholds or malfunctioning components
- Use exclusive two pion reaction to measure the efficiency:
  - Select events with pi+, pi-, p measured in FD-CD
  - Use missing mass to select events with an electron going in the FT acceptance
  - Check if an electron is detected in the FT
- Perform the study for both data and MC
- Tune MC to properly account for thresholds
- Use status tables to knock-out malfunctioning/dead component
- Need to find suitable reactions to study photon efficiency

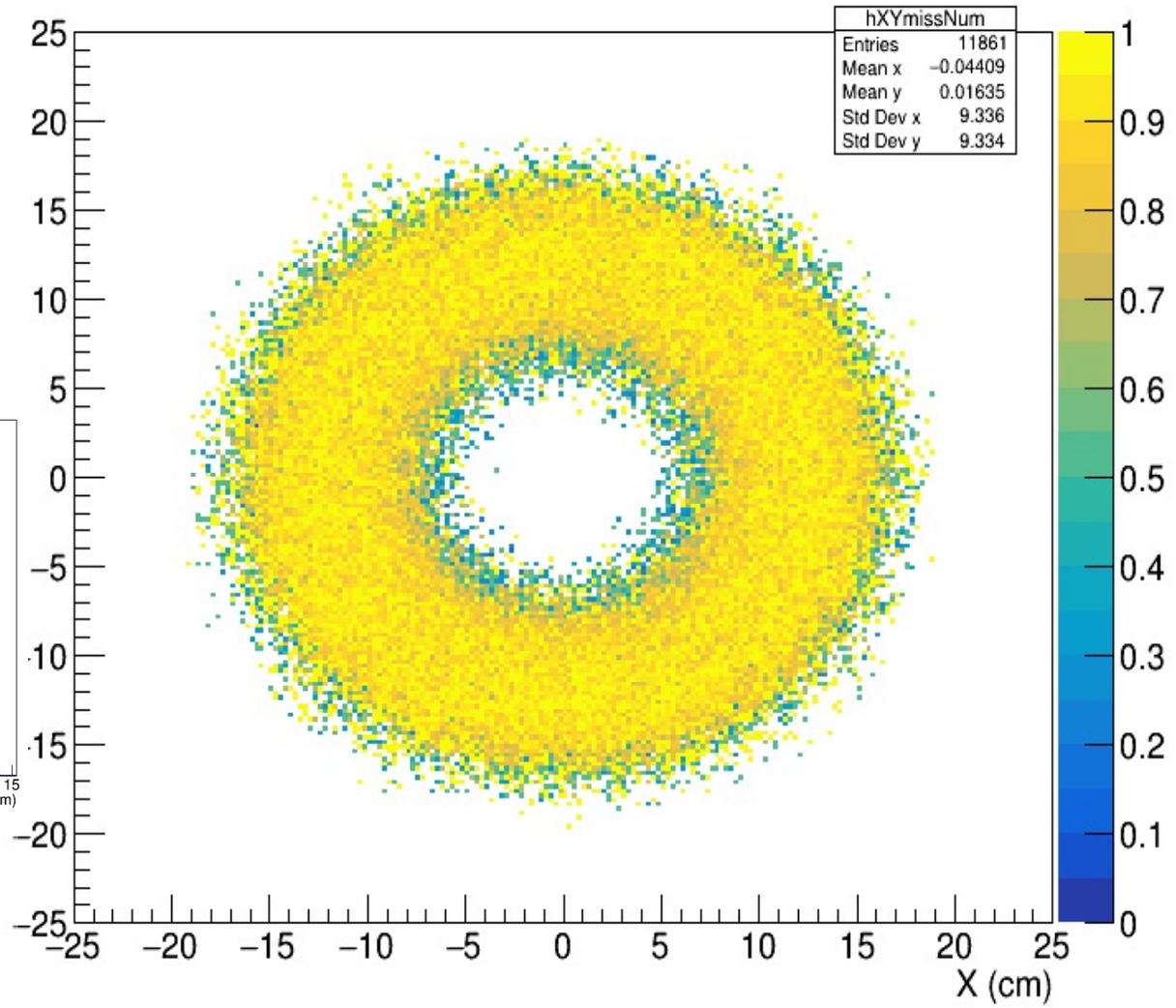
FT efficiency – MC electron efficiency

- X vs Y – coordinate hits at the FTcal
  - X and Y determined using θ and ϕ from missing electron ($ep \rightarrow p\,,\pi^+, \pi^-, p$ X) and swimming electron from vertex to the FTcal position
  - X/Y Hit position reconstructed from missing momentum→ does not represent exact cluster position in FTCal



$\Delta X = X_{miss} - X_{cluster}$ for events where the electron is detected

- Efficiencies are lower for crystals closer to the edges as expected



Efficiency map from RGA coming soon

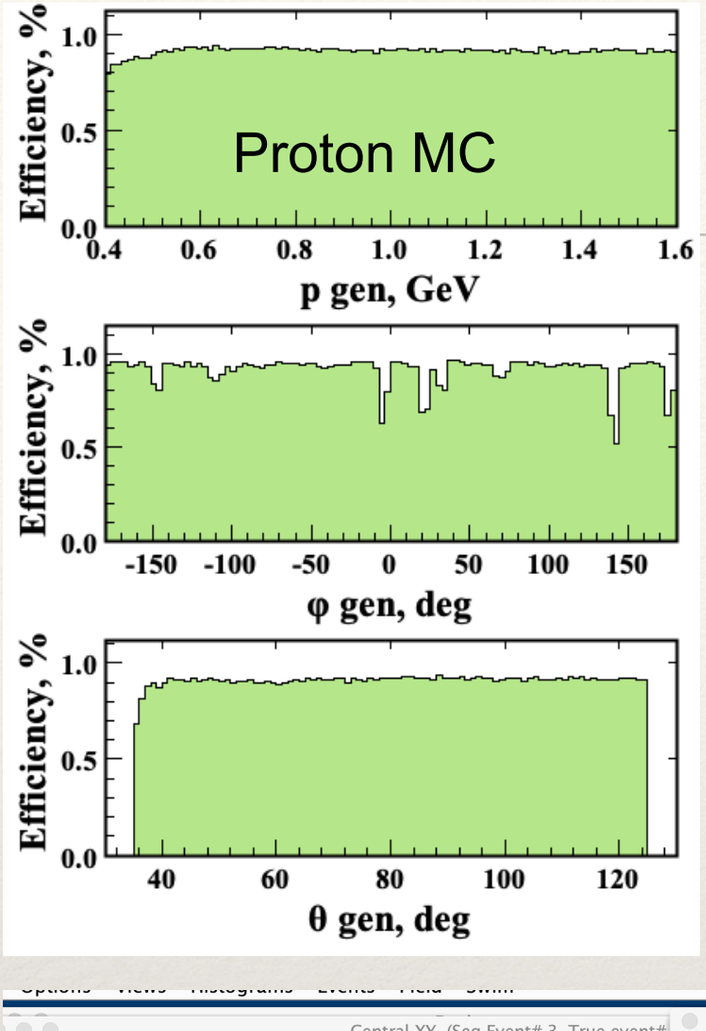
CVT

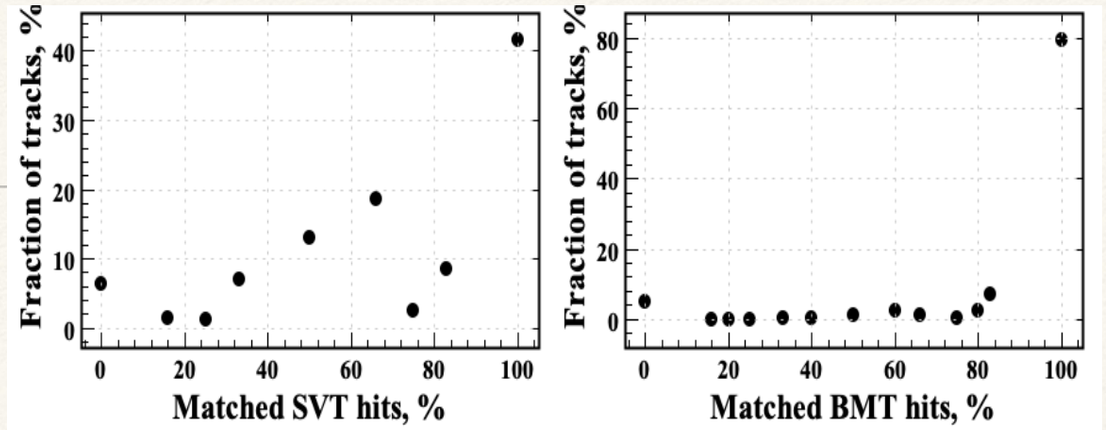
- **Tracking:**
  - Algorithm inefficiencies have been addressed, improved Kalman Filter, track seeding and efficiency of reconstruction of low-momenta tracks, ongoing work on removing ghost/split/ duplicate tracks
  - added 2nd algorithm for tracks passing through the BMT sector gaps
  - TracTools-ExLayr branch developed with an option to exclude layer(s) from tracking, latest improvements with helical, straight, and cosmic tracking
  - CVT geometry framework developed to allow tracker rotation/translation in reconstruction
- **MC truth matching:**
  - Algorithm has been validated, banks are used in efficiency studies (no BG)
- **BG merging:**
  - Validated on RG-A (45 nA) and RG-B (50 nA) BG files
  - Issue with BG merging for the CVT zero ADC hits is fixed in TracTools-ExLayr
- **Out-of-time hit rejection:**
  - RG-B 50 nA, hit occupancy reduced from 1.6% to 1.1% while gaining 2% of CTOF+CND matched tracks with 50 nA cut on BMT hit timing; SVT timing studies in progress
- **Detector studies:**
  - Ongoing work on detector calibration, status tables, Lorentz angle calibrations, efficiency maps

The CVT is not fully aligned yet. Work on extraction of the misalignment constants has higher priority as it affects tracker efficiency.

CVT

RG-A 45 nA BG merged

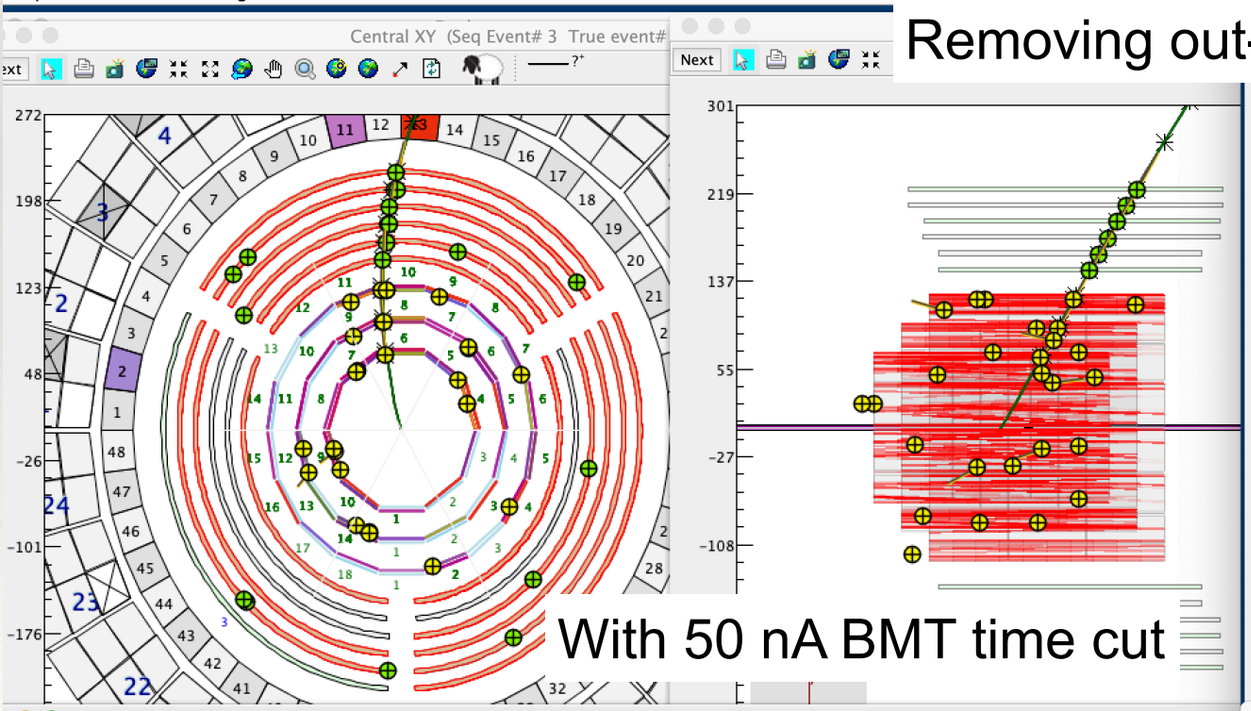


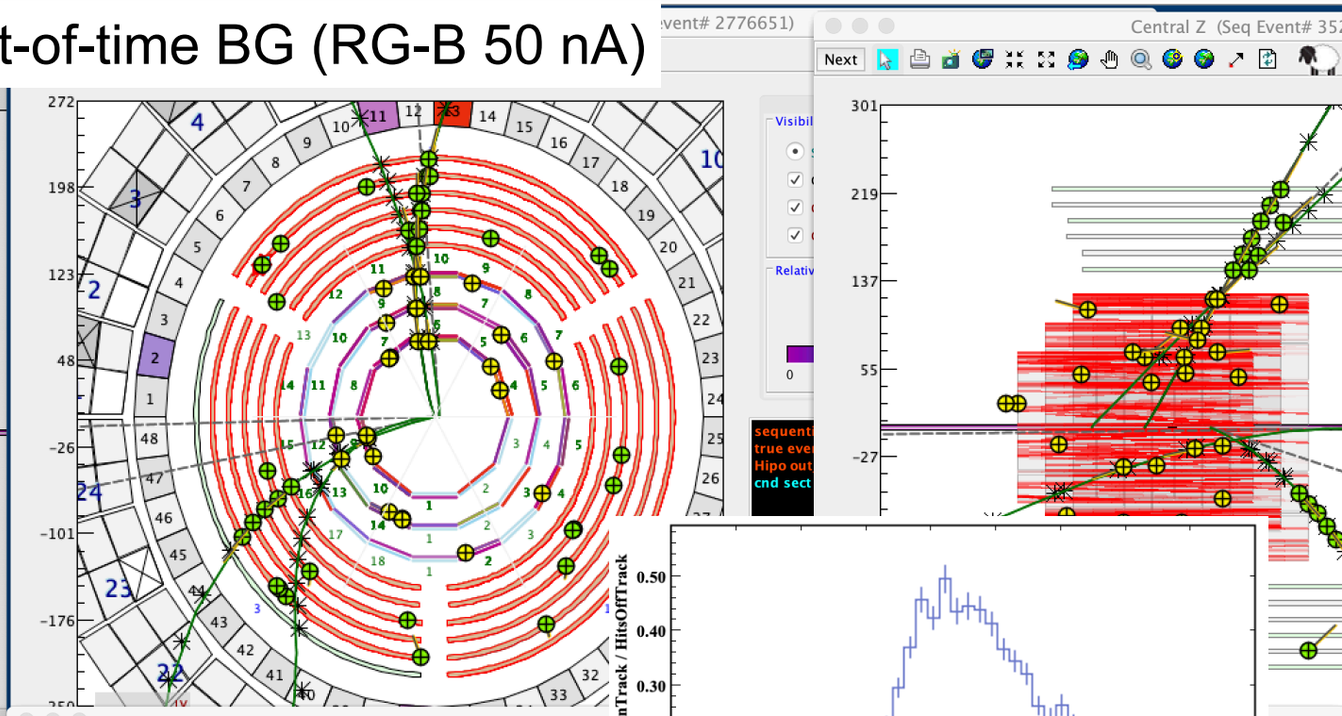


BG merging	proton 0.4-1.6 GeV	with 45 nA RG-A BG
Events with reconstructed tracks,%	95	97
passed 3σ cut (Δp/p=5% Δφ=5 mrad, Δθ=10 mrad), %	91	71
Δp/p resolution, %	2.6	3.1
Δφ resolution, mrad	1.5	3
Δθ resolution, mrad	5	6

Momentum, angular, and vertex resolutions are within the specs

Removing out-of-time BG (RG-B 50 nA)





BAND

$$\eta_{BAND} = \frac{\#(e,e'pn)}{\#(e,e'p)n - BKGD}$$

(e,e'p)n Cuts:

- $p_{miss} > 200MeV$
- $\vec{p}_{miss}$ points to BAND
- $0.84[GeV] < m_{miss} < 1.04[GeV]$

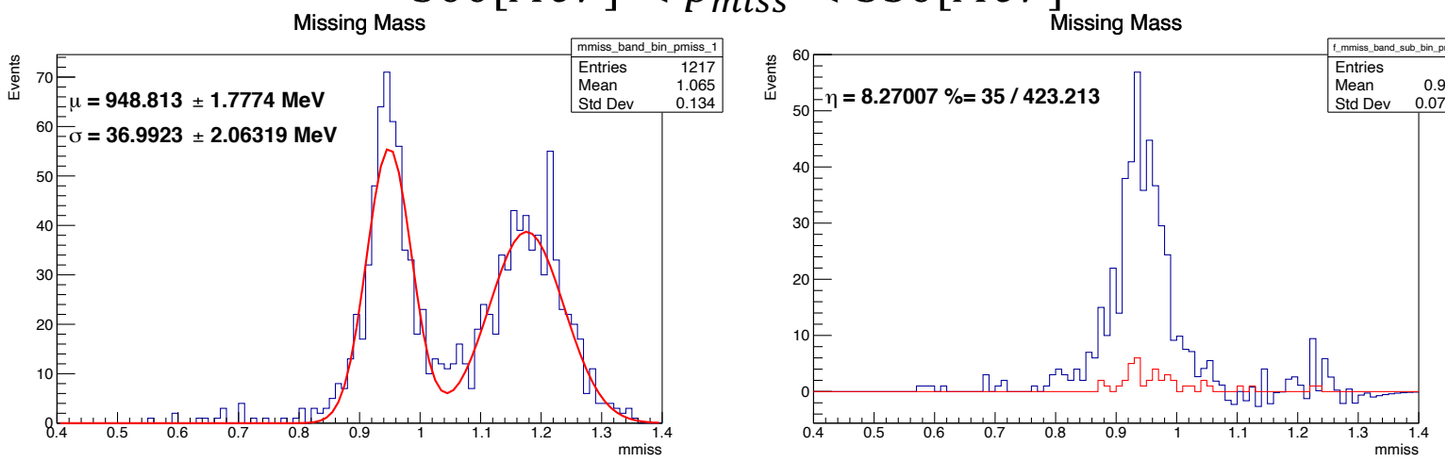
(e,e'pn) Cuts

- Subset of (e,e'p)n
- $E_{Dep} > 2MeV$
- $6\frac{[ns]}{[m]} < \frac{Time\ of\ Flight}{Flight\ path\ Length} < 15\frac{[ns]}{[m]}$

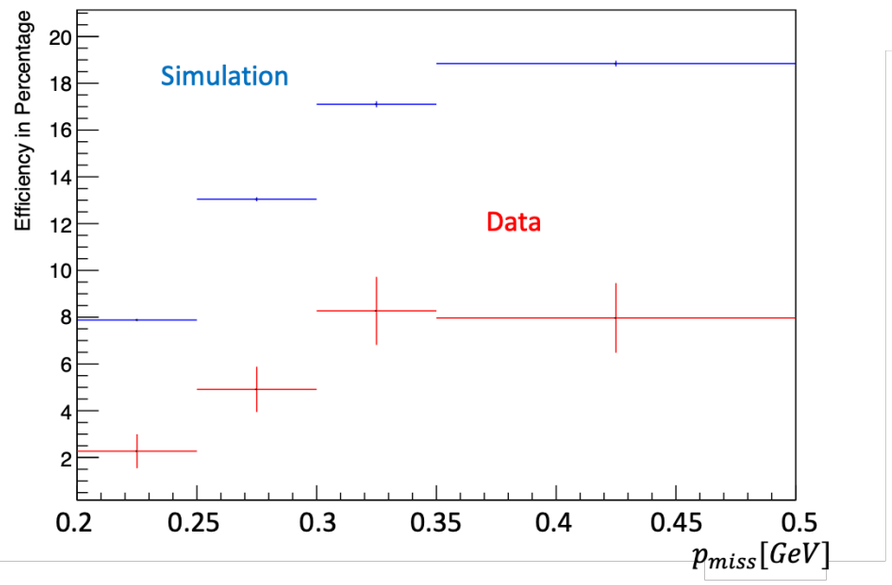
Background Subtraction

- Double Gaussian fit in m_{miss} distributions
- Made in 4 bins of p_{miss}

$$300[MeV] < p_{miss} < 350[MeV]$$



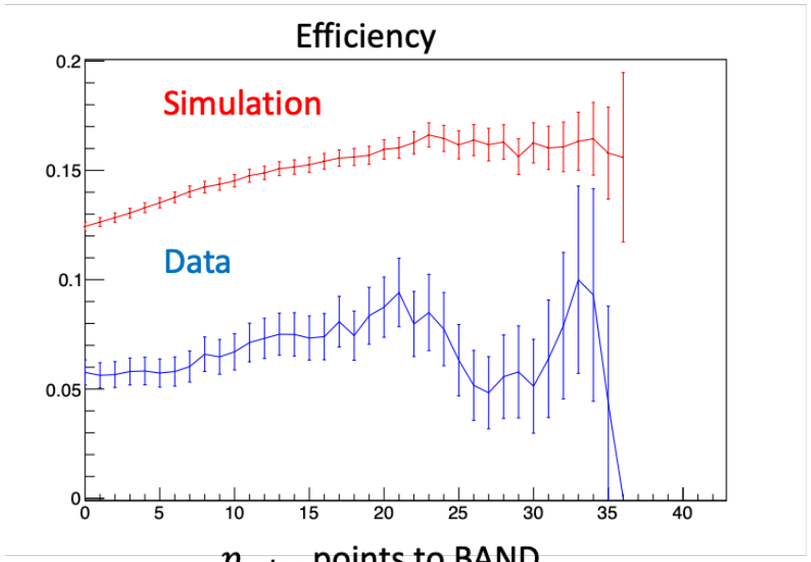
Eff vs. pmiss

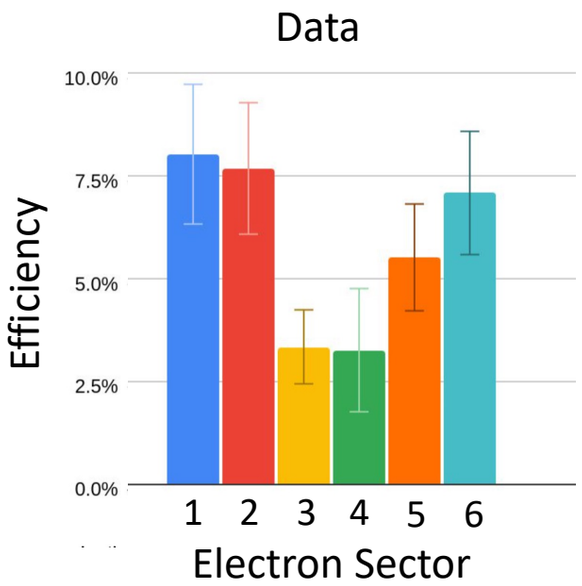


BAND

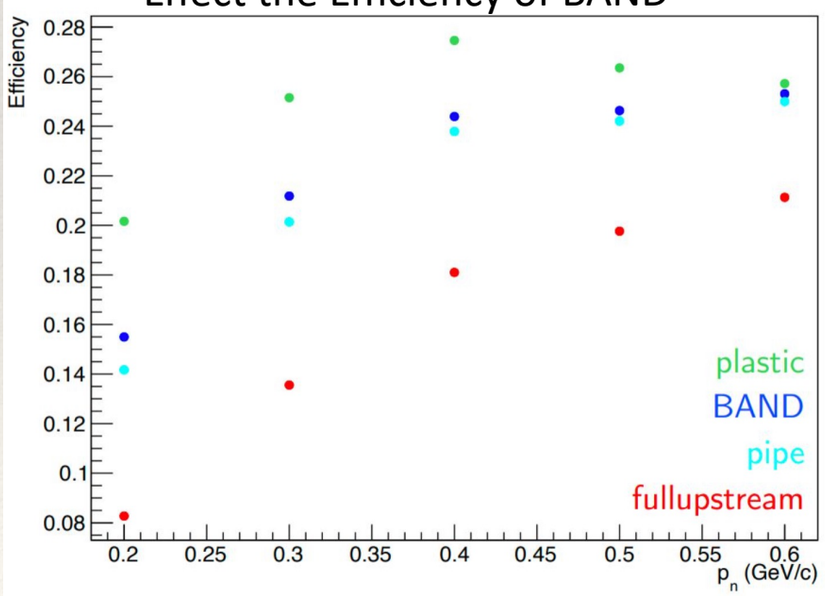
Understanding the discrepancy

- GEMC geometry effects are included
- BAND fiducial Cuts do not explain discrepancy
- Smearing to GEMC (e,e'p) may explain discrepancy
- BAND Efficiency is electron sector dependent

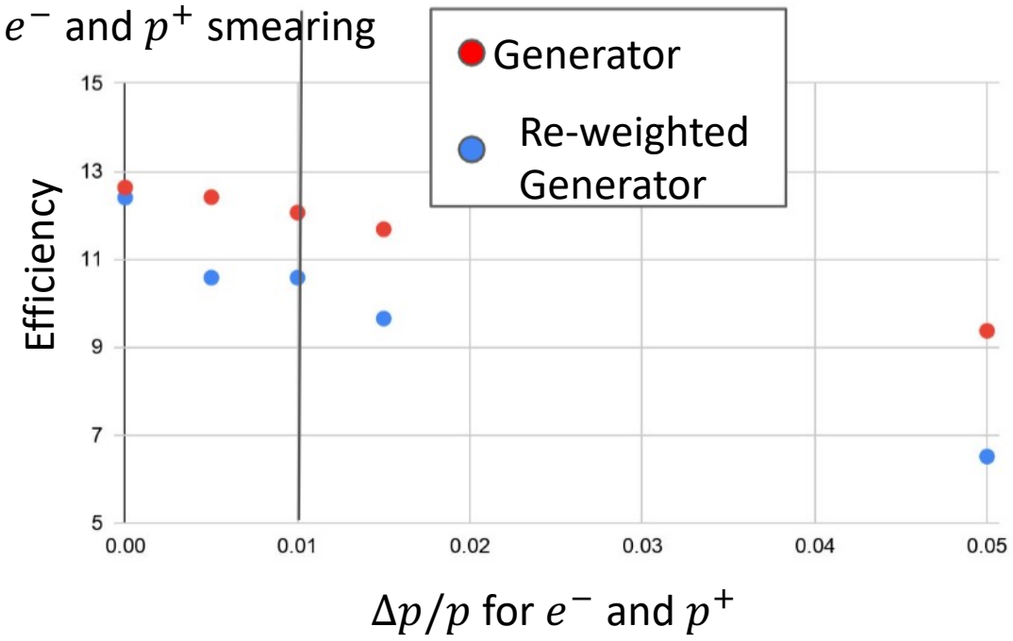




How different GEMC geometries Effect the Efficiency of BAND



Simulation Efficiency as a function of e^- and p^+ smearing



General issues and tools

- Radiative photon and electron efficiency;
- Bad components and status word;
- Thresholds in GEMC;
- Possible geometry issues.

e^+ and e^- efficiency

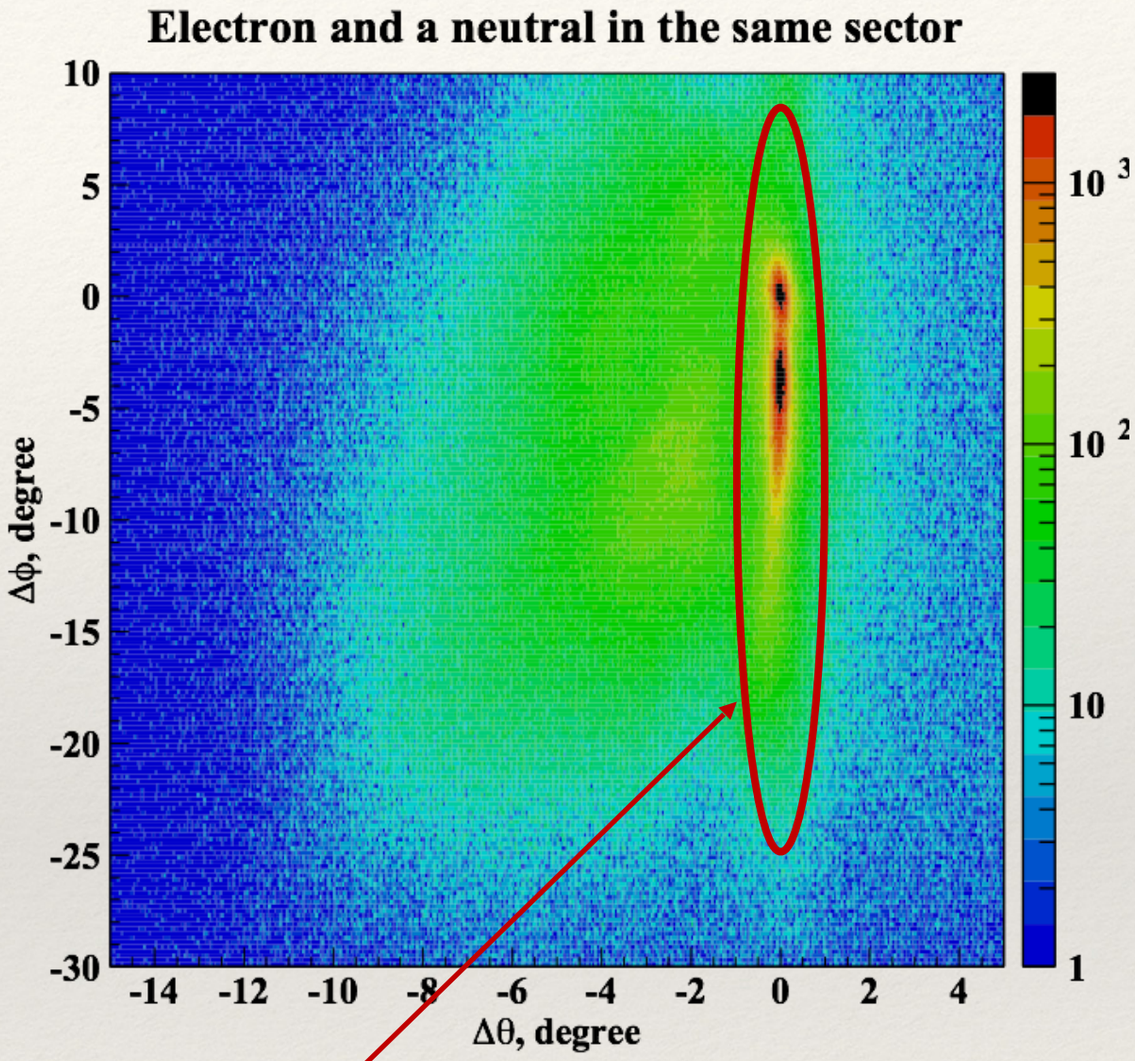
- A radiated photon accompanying the scattered electron in ECal has been observed by many
- The radiated photon has the same angles as the electron at the point of the radiation
- In the longitudinal field of the solenoid, at the point of the radiation, the polar angle of the electron is the same as at the production vertex. The azimuthal angle, on other hand, depends on the electron 3-momentum and the distance from the production vertex.

$$\vartheta_\gamma \approx \vartheta_e^r \approx \vartheta_e^v \qquad \varphi_\gamma \approx \varphi_e^r \neq \varphi_e^v$$

- Radiated photons in ECal can be identified by analyzing the differences of reconstructed angles of the electron and that of a neutral hit

$$\Delta\vartheta = \vartheta_\gamma - \vartheta_e^v \qquad \Delta\varphi = \varphi_\gamma - \varphi_e^v$$

- Events with an electron and at least one neutral particle are used for this study

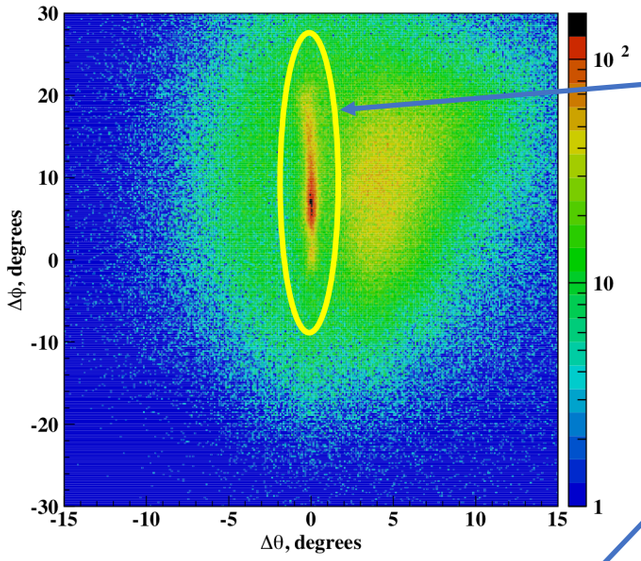


Electron and the radiated photon

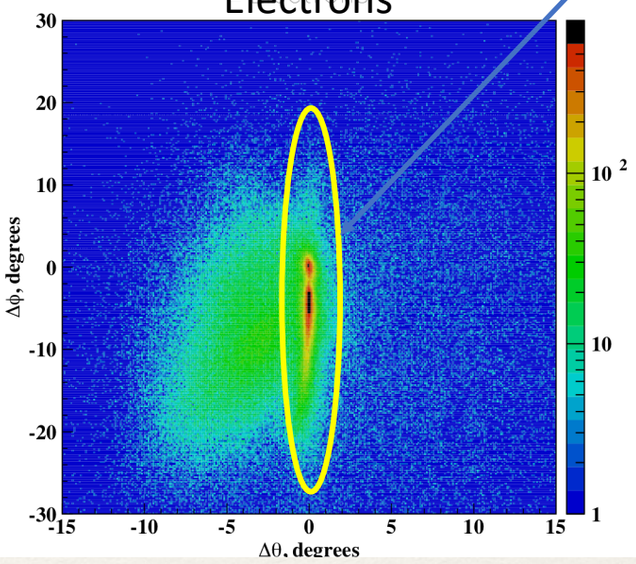
e^+ and e^- efficiency

Last time, e^- and e^+ PID efficiency

Positrons



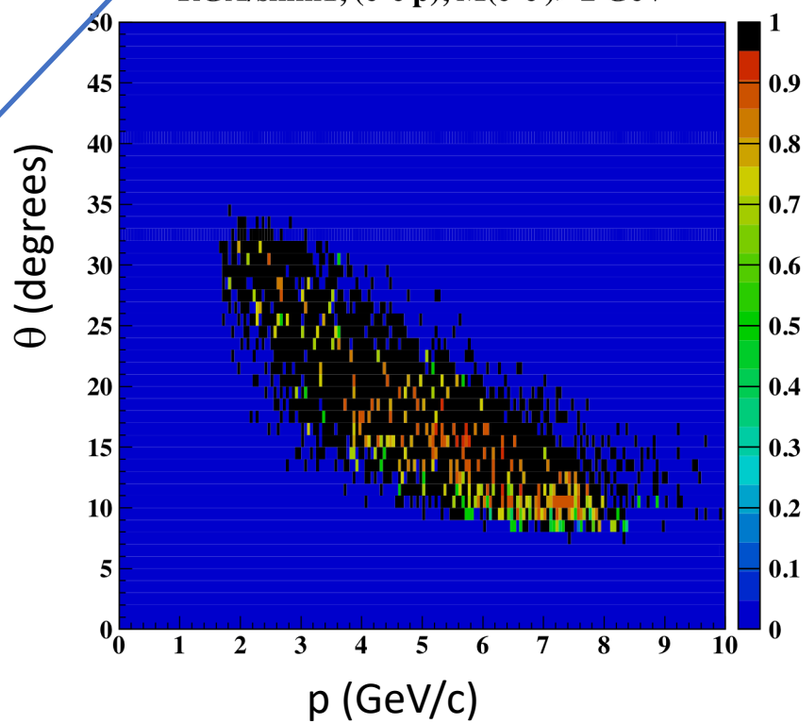
Electrons



Events selected with $|\Delta\theta| < 0.7^o$

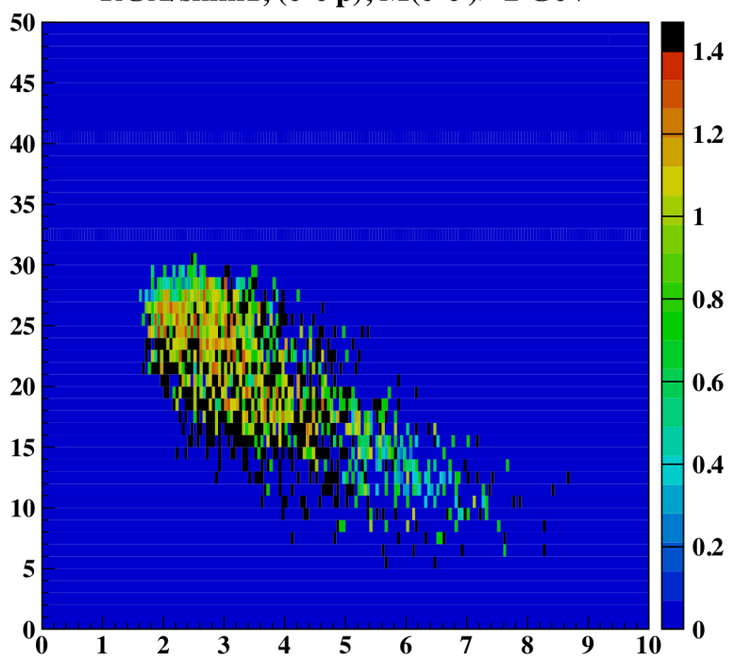
Electrons

The ration of:
PID=11, p>1.5 GeV/c, V/W>9
to + $|\chi^2$PID$|$<3



Positrons

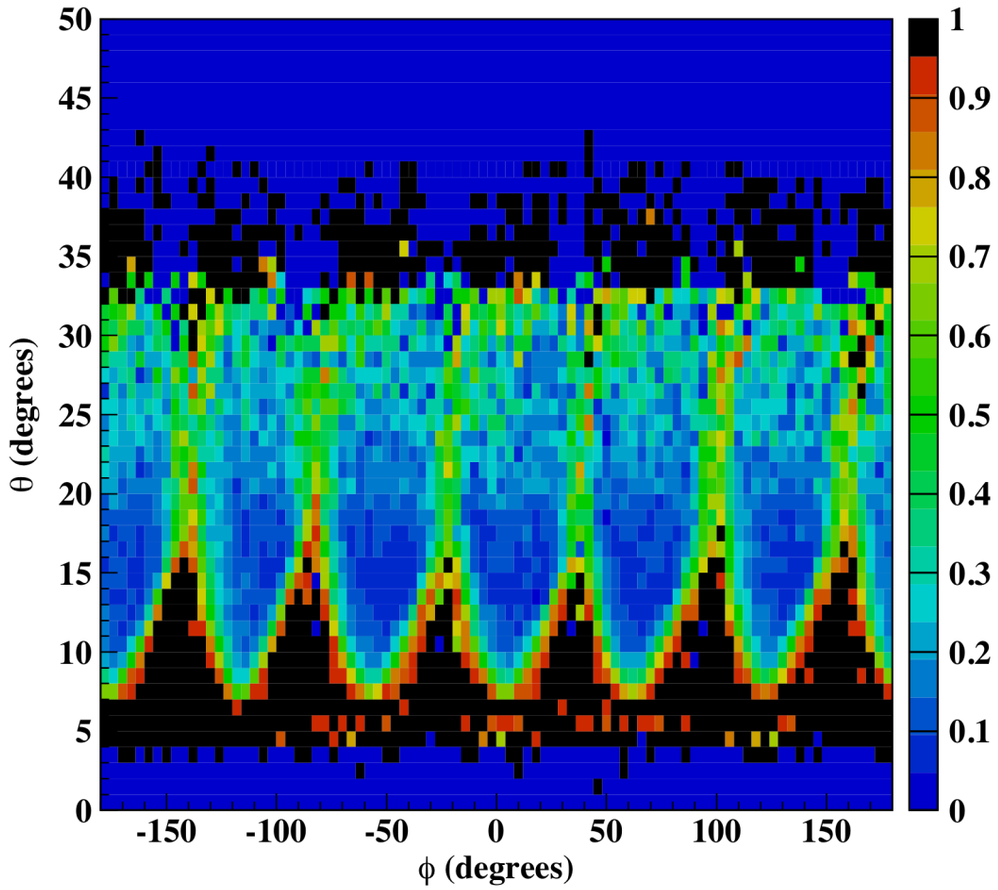
The ration of:
PID=-11, p>1.5 GeV/c, V/W>9
to + $|\chi^2$PID$|$<3 and SF(ECin-Pcal) cut

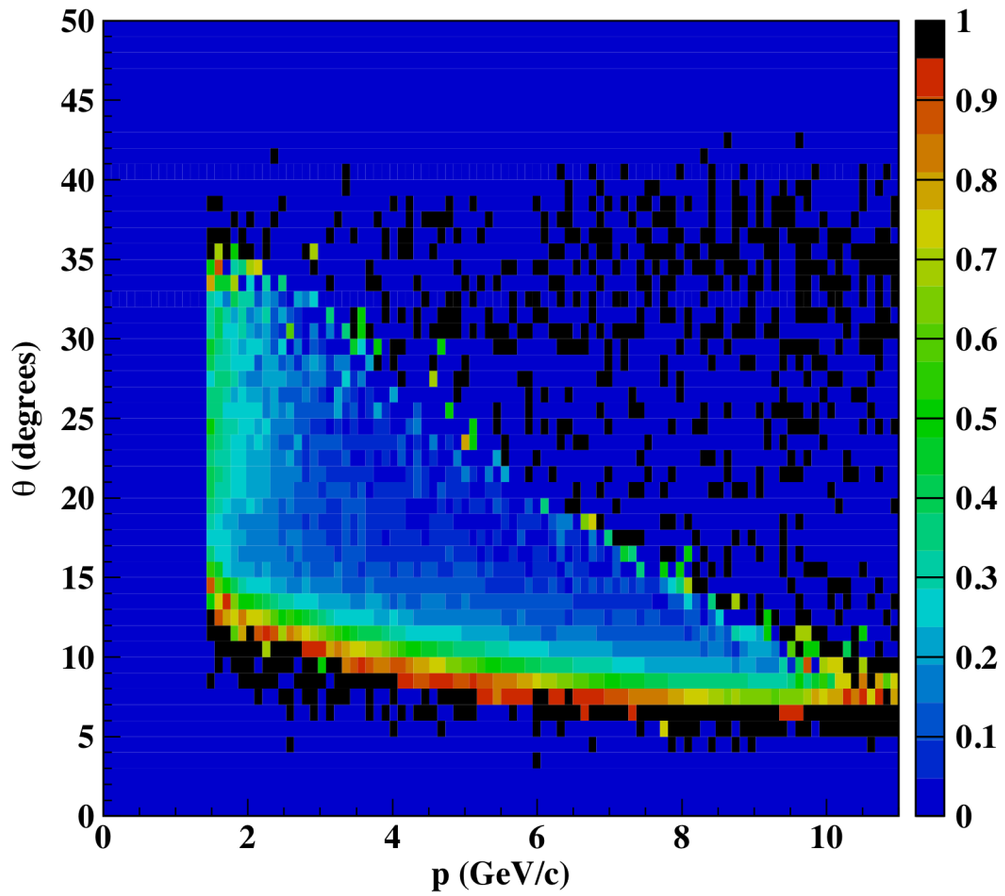


e^+ and e^- efficiency

Electron inefficiency

$$efficiency = \frac{N_{-\gamma}}{N_{e\gamma} + N_{-\gamma}}$$



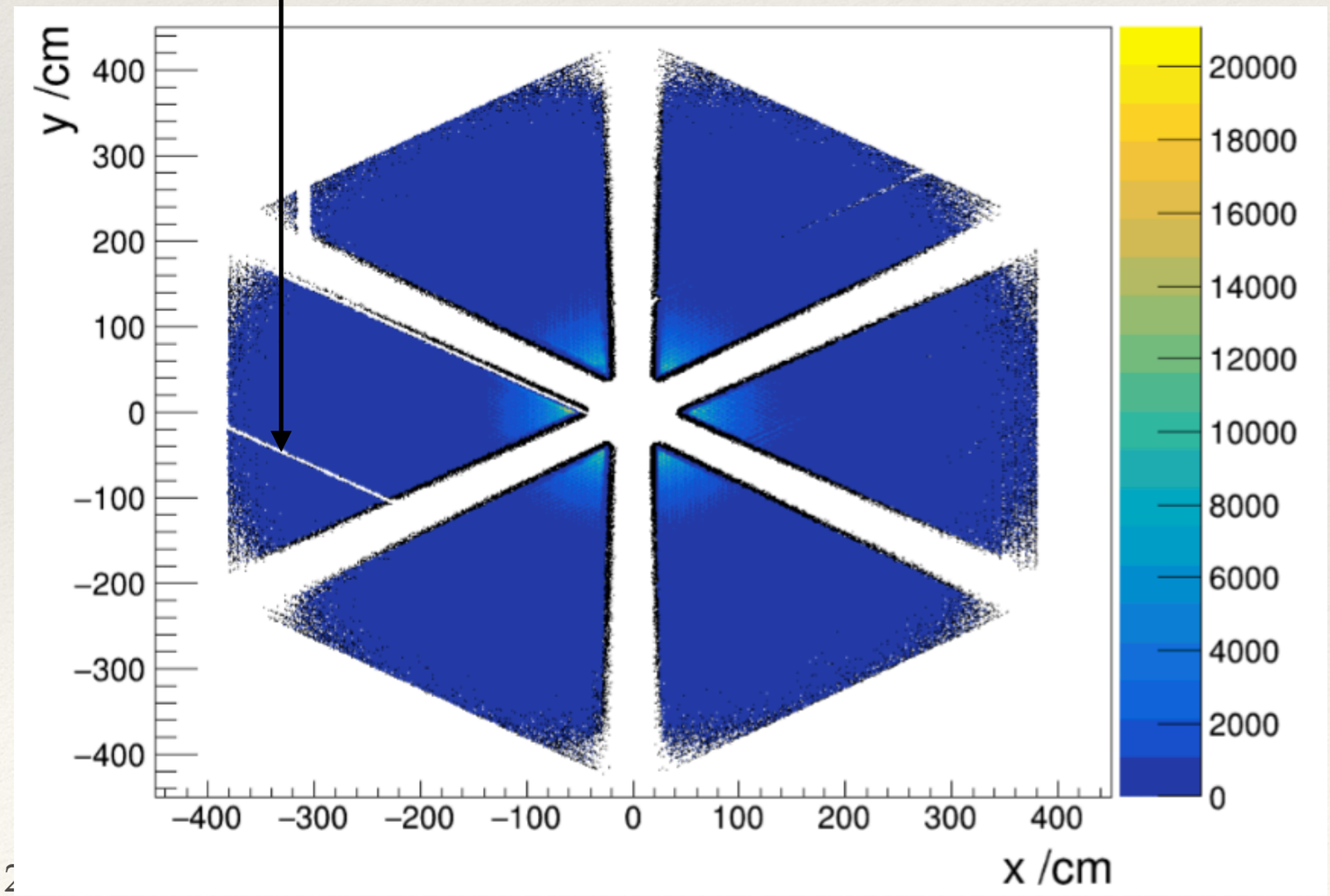


Status tables in GEMC

Address hardware problems in simulation;
GEMC remains “perfect”;
Exclude dead or problematic channels in reconstruction to reproduce the losses caused in data by these malfunctioning elements in simulation as well.

Exclude this in both data and simulation

PCAL



Hardware Status Assignments

- 0 - fully functioning
- 1 - no ADC
- 2 - no TDC
- 3 - no ADC, no TDC (PMT is dead)
- 5 - any other reconstruction problem

Threshold in GEMC

Implementing Hardware Thresholds in GEMC

(do we need to do it in GEMC?)

Solution 1:

- Use ADC (or energy deposited, or nphe, or…?) integrated value
- Add / Load Thresholds values from CCDB
- Hits are not written in the output if threshold not passed
- Currently threshold would apply to both ADC/TDC. Work could be done in GEMC to have 1 ADC and 1 TDC threshold.

Implementing Hardware Thresholds in GEMC

Solution 2:

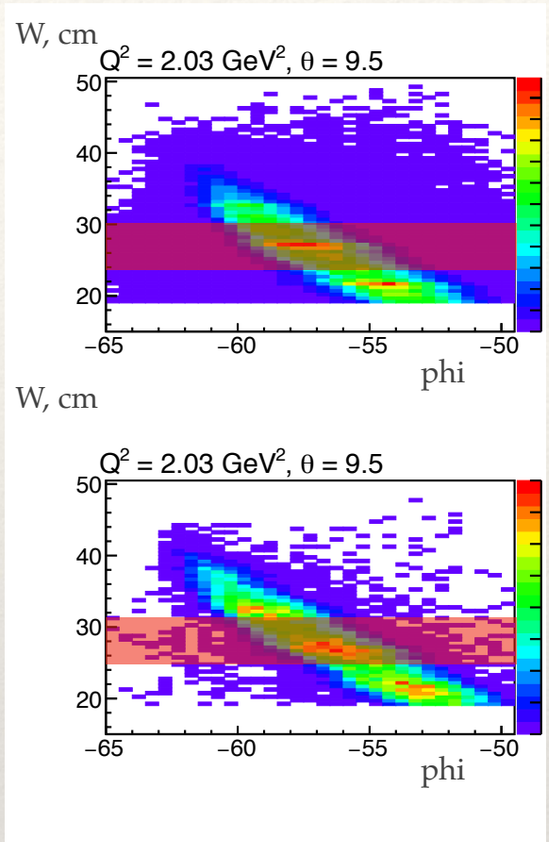
- Use FADC Voltage vs Time signal in GEMC
- Add thresholds (and pedestals) to CCDB
- Hits are not written in the output if threshold not passed
- Currently threshold would apply to both ADC/TDC. Work could be done in GEMC to have 1 ADC and 1 TDC threshold.

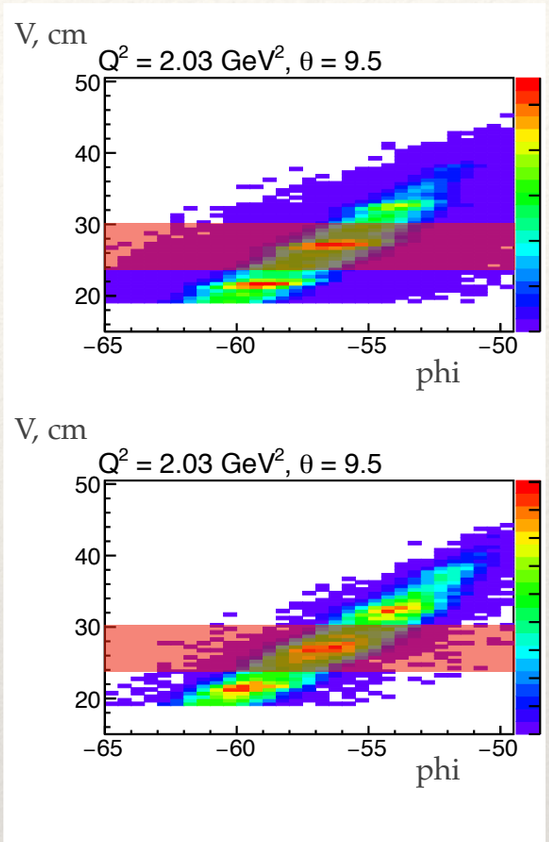
Much more involved but potentially more precise

Possible Geometry Issues

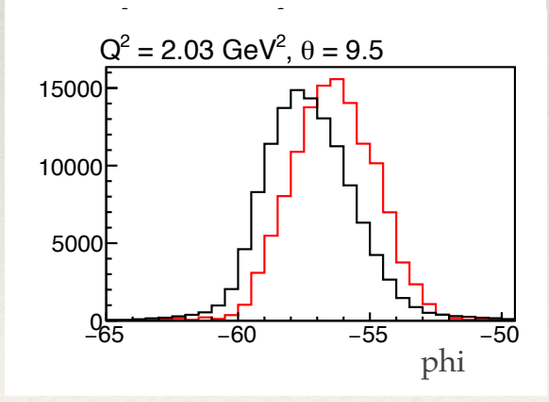
Data

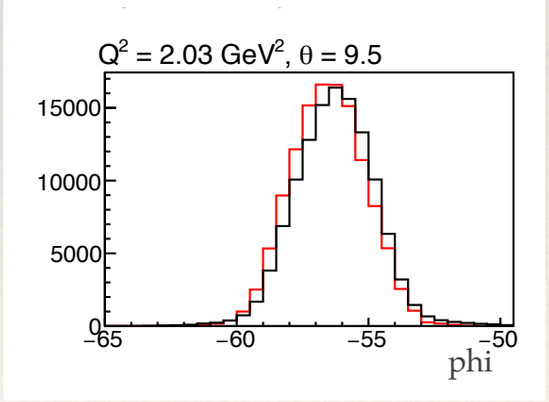
Simulation





Data
Simulation

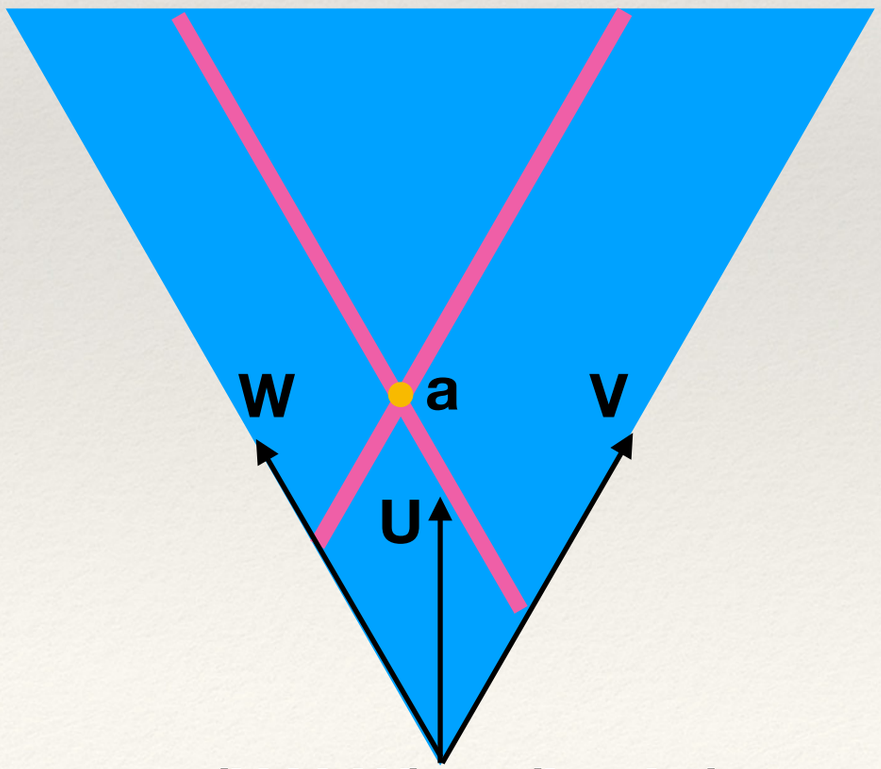




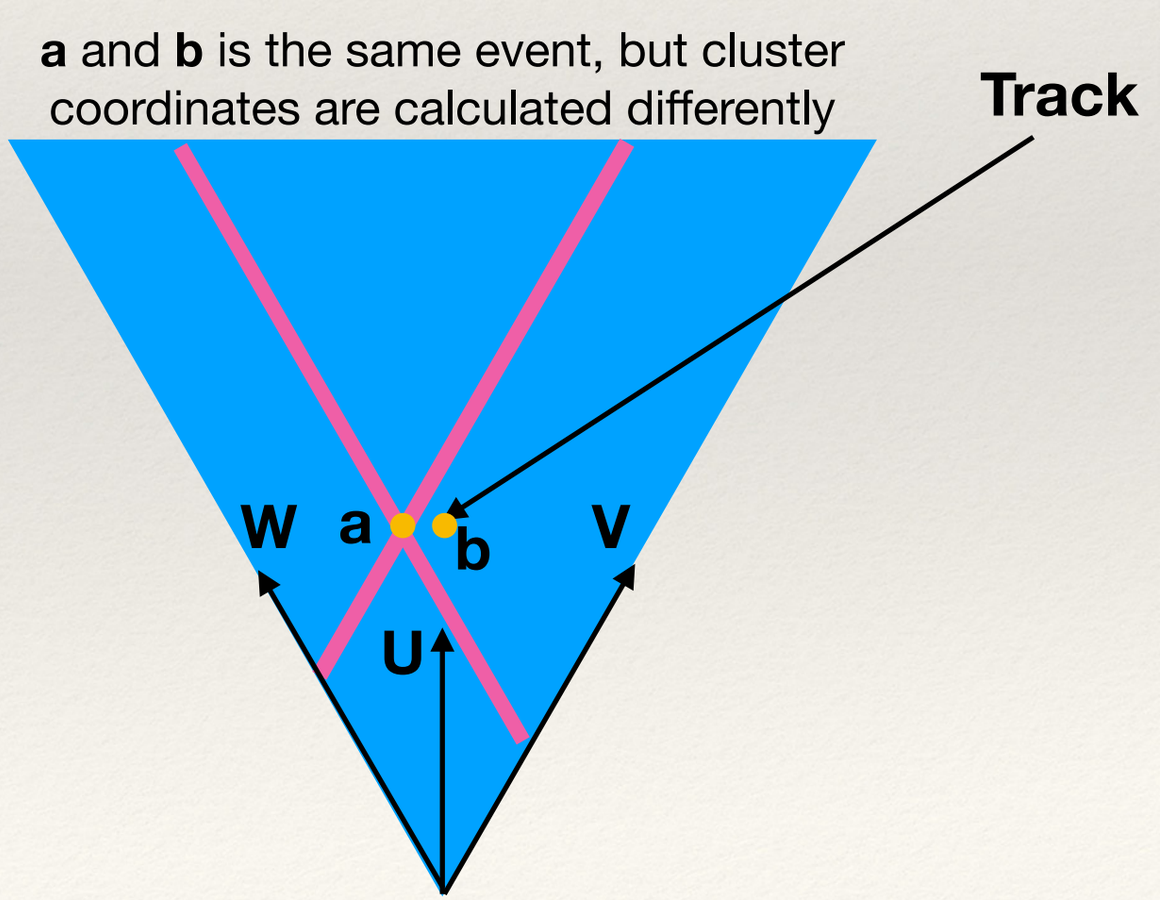
The most interesting one: projection on phi in a limited range of V(W). Effectively, how a single strip is seen from the vertex (see red box on the top plot). Works nicely for V, but clear shift for W.

PCAL Fiducial Cut

- Different ways to calculate position of PCAL cluster
- Before we used U, V and W (internal to PCAL) and/or Lx, Ly (CLAS system) which is calculated from U, V and W
  - Sensitive to PCAL alignment
  - Not very precise (resolution limited by the strip width)
- Lets go for coordinates from tracking: intersection of track with PCAL plane (Hx, Hy)
  - Not sensitive to PCAL alignment (sensitive to DC but it seem to be under control)
  - Very good resolution



a(U,V, W)->a(Lx, Ly)



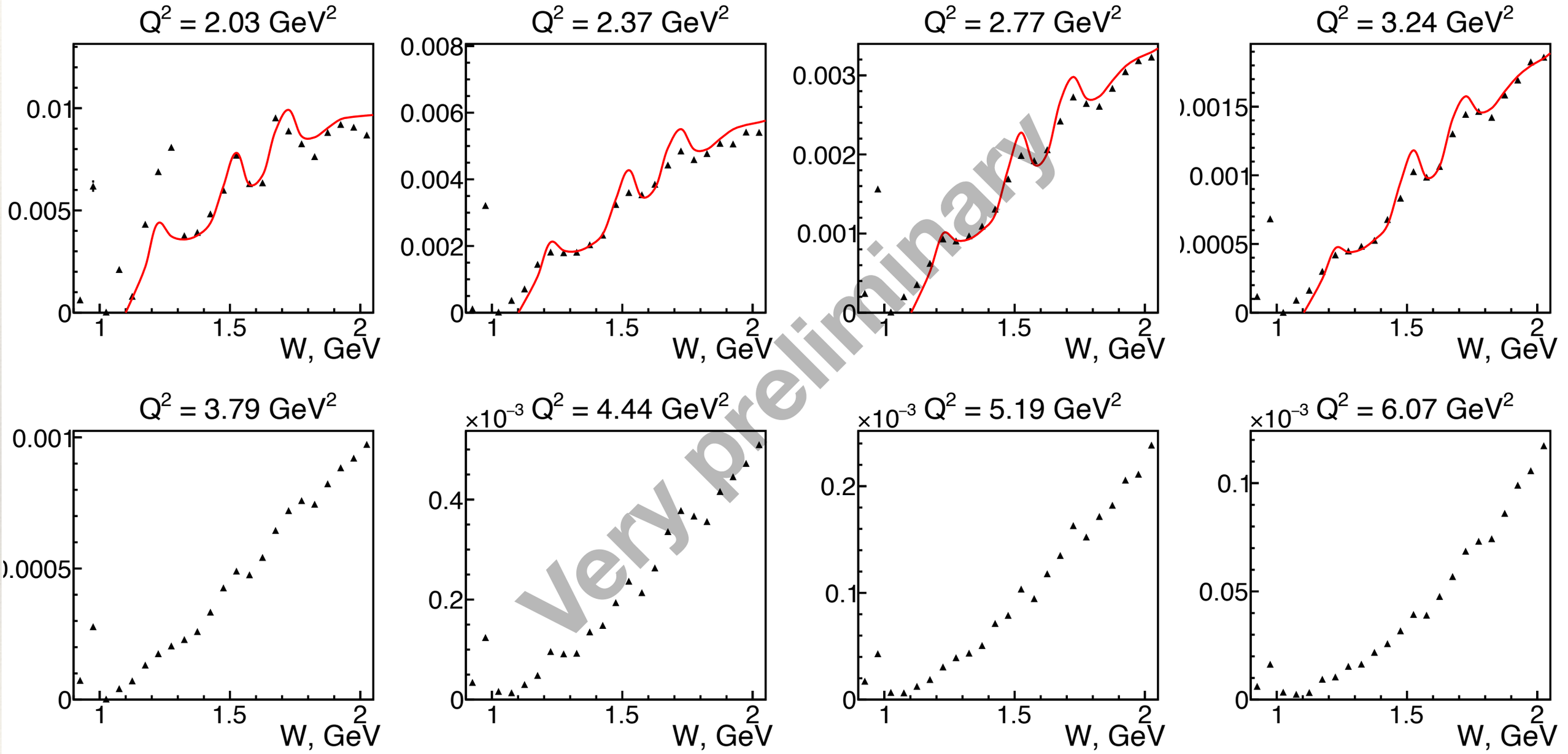
b(Hx, Hy)

Final check

- Successfully measure well known cross sections in the region of overlap with the world data;
- Elastic, elastic with proton detected, inclusive electron, single pion;
- Different run groups might be better suited for different channels.

Electron inclusive cross section

"Good runs" (130 runs, 75% RGA Inbending)



Luminosity and acceptance corrected yield with radiative corrections (selected data).

Interpolation of the CLAS results

Experimental Data

Next steps

- Finalize individual detector efficiency studies
- Implement detector efficiency in GEMC/reconstruction/data analysis
- Fully implement status words in simulation
- Implement thresholds in GEMC
- Validate the efficiency studies with selected benchmark reactions cross sections