CLAS12 Detection Efficiency (Task Force)

CLAS collaboration meeting

Nick Markov for the CLAS Efficiency Task Force

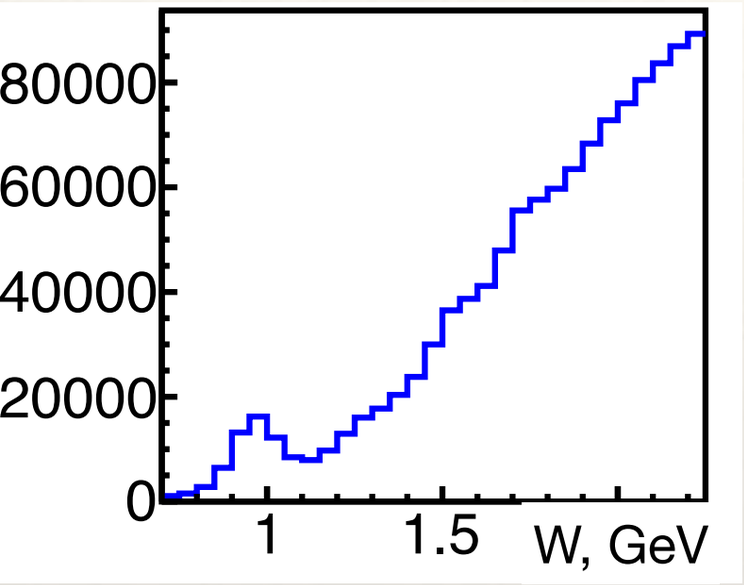
11 November 2020

Outline

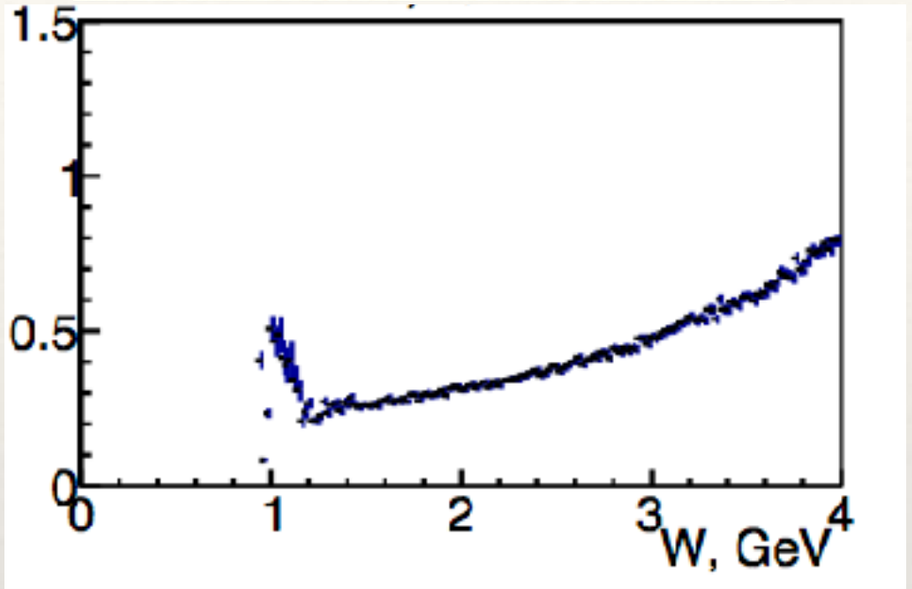
- Introduction;
- Efficiency Task Force;
- Efficiency estimation;
- Efficiency implementation;
- Future plans.

Cross section, Acceptance Corrections and Efficiency

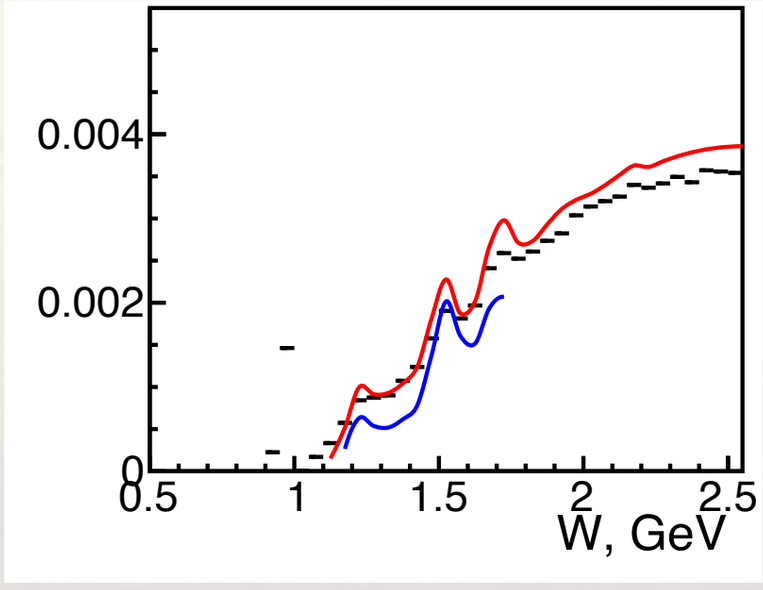
Data



Acceptance Correction from simulation



Cross section



Shown for the inclusive electron scattering):

$$\frac{d\sigma}{dWdQ^2} = N_{ev}\frac{1}{L}\frac{1}{C}\frac{1}{\boxed{Acc}}$$

$$\boxed{Acc} = Geom \cdot Eff$$

Luminosity

Rad Corrections
BC corrections

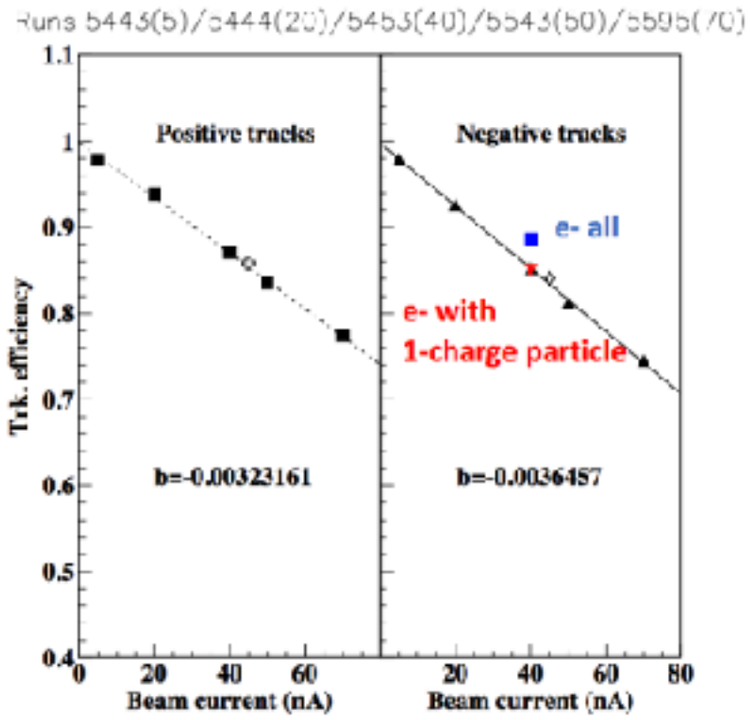
Our focus

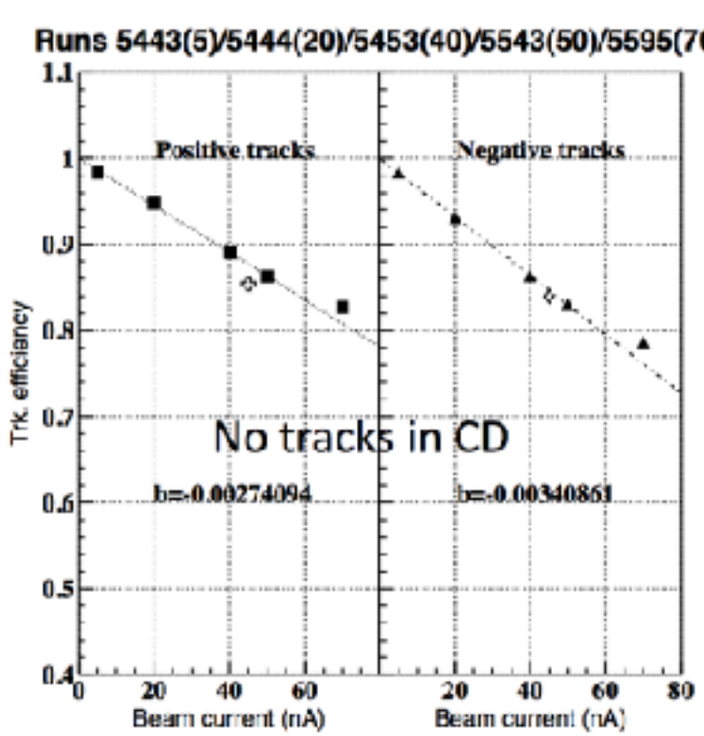
Drawings, alignment data

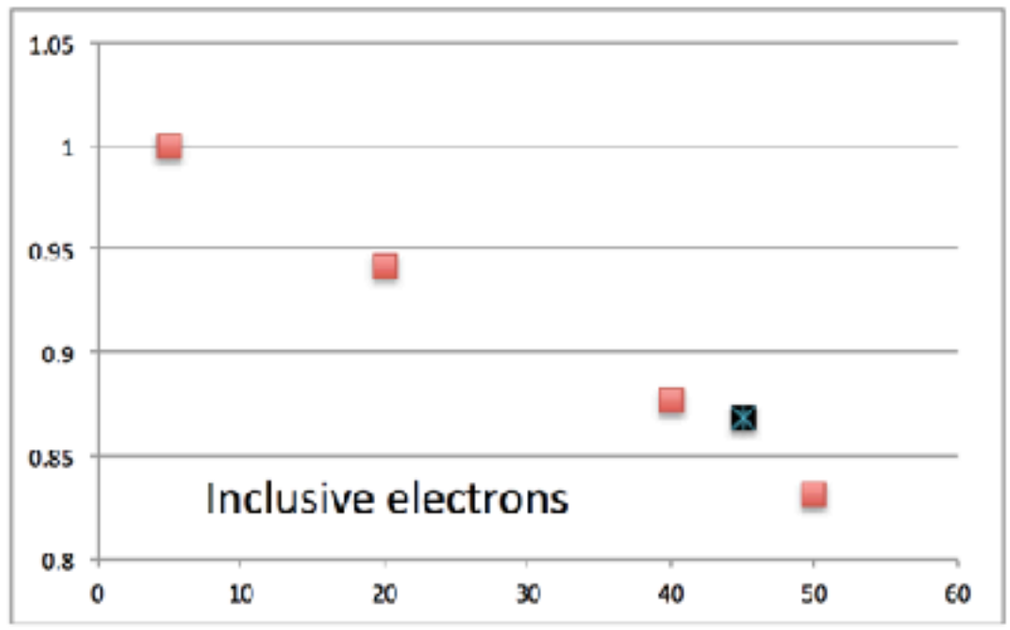
Introduction

Background merging

Understand the efficiency change as a function of the beam current







Using background from high-luminosity data and data collected at different luminosity we were able to reproduce the change in efficiency as a function of current in data and simulation for the Forward Detector.
Similar background merging procedure can be applied to the CD/FT.

Procedure is validated and established and implemented on the OSG for different run periods.

Next step is to study absolute detector efficiency

Detector efficiency

- Using the default GEMC acceptance we imply that efficiency is the same in data and MC;
- We either have to validate it to use acceptance from the MC or adjust MC to the data or add a correction;
- **First step is to understand detector efficiency.**

Task Forces

Charge

CLAS12 CD/FD efficiency assessment

Goal

Determine the CLAS12 CD and FD efficiency considering each sub-detector and propose the proper way to make it available for the physics analyses

Charge

- Define a staged plan to extract CLAS12 efficiency providing timelines and needed resources to accomplish it
- With the help of sub-detector experts, determine a procedure to extract the efficiency map for each CLAS12 sub-detector and each run period from collected data
- With help of sub-detector experts, and GEMC expert, extract from simulations a similar efficiency maps to compare to data and, in case of disagreement, suggest a procedure to match sim to data
- With the help of sub-detector experts, validate the efficiency map for each CLAS12 sub-detector defining the range of applicability and the systematic error associated
- With the help of sub-detector experts, the SW Group and GEMC expert, provide the efficiency maps in a way usable by the physics analysis(data and simulations)
- In collaboration with CLAS12 Physics WGs define a procedure to validate, use and receive feedback from physics analyses
- Evaluate synergies with other projects at the lab providing a list of shared resources and common goals

Resources

- Time: 5 months (October 15 1st, March 15)
- Deliverable: prepare the staged work plan to Nov '20 CLAS Coll Meeting; provide the sub-detector efficiency maps and documentation as soon as ready; at the end of the term summarize the work done in a short 2 page report; update a dedicated wiki page with full documentation and minutes of meetings/presentations
- Task force: N.Markov (PI), S.Stepanyan (Bg merging), M.Mestayer (DC), R.Paremuzyan (Forward Tracking), Y. Gotra (CD TRK), C.Smith (EC/PCAL), Y.Sharabian (HTCC), M.Ungaro (LTCC and GEMC), V.Kubarovsky (RICH an Trigger), D.Carman (FTOF/CTOF), S.Niccolai (CND), R.De Vita (FT), E.Segarra (BAND), V.Ziegler (SW and TRK), N.Baltzell (SW), H.Avagyan (Validation)

Team

Team

Trigger (Valery Kubarovsky, Rafayel Paremuzyan)

FD

- **Electrons**
  - **DC** (Mac Mestayer , Veronique Ziegler, Rafayel Paremuzyan)
  - **EC/PCAL** (Cole Smith)
  - **FTOF** (Daniel, Raffaella DeVita, Matthew Nicol, Stepan Stepanyan)
  - **HTCC** (Youri Sharabian, Nick Markov)
- **Charged Hadrons**
  - **DC** (Mac Mestayer, Veronique Ziegler, Rafayel Paremuzyan)
  - **FTOF** (Daniel Carman, Stepan Stepanyan)
  - **LTCC** (Maurizio Ungaro)
  - **RICH** (Valery Kubarovsky)
- **Neutrals (photons and neutrons)**
  - **EC/PCAL** (Cole Smith)

FT

- **Electron**
  - **FTC** (Raffaella DeVita)
  - **TFH** (Raffaella DeVita)
- **Photons**
  - **FTC** (Raffaella DeVita)

CD

- **Charged Hadrons**
  - **CTOF** (Daniel Carman, Raffaella DeVita, Matthew Nicol)
  - **CVT** (Yuri Gotra, Veronique Ziegler, Rafayel Paremuzyan)
- **Neutrals (photons and neutrons)**
  - **CND** (Silvia Niccolai)

BAND

- **Neutrons**
  - **BAND** (Efrain Segarra)

Software Nathan Baltzell, Veronique Ziegler
Simulation Maurizio Ungaro
Validation Harut Avagyan
Background merging Stepan Stepanyan

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.

Implementing efficiency

Efficiency workflow:

- Estimate the efficiency from data;
- Estimate the efficiency from simulation;
- Understand how to tune GEMC to match efficiencies;
- Tune the existing **GEMC**;
- Design, fill and apply status tables (bad, ineffective, nonfunctional elements) **in reconstruction;**
- Design and implement **efficiency tables** (last resort).

- GEMC modification (thresholds for TDC/ADC);
- GEMC modification (trigger logic).

Illustration of the efficiency

Estimation

HTCC electron detection efficiency

- Map the HTCC response in bins over X and Y (X and Y are coordinates of the intersection of the track with the mirror surface);
- For each X, Y bin (2.5cmx2.5cm) get the spectrum of the NPE;
- Fit individual spectrum in X, Y bin with Poisson;
- Integrate signal under Possion [0, 50] (full signal) and [2, 50] (signal after HTCC electron ID cut);
- Ratio of them is what we lost with the NPE > 2 cut;
- Create the “efficiency map”, i.e. calculate the efficiency in each X, Y bin;
- Do all the same steps for the simulation;
- The final, overall efficiency correction to go to cross section calculation will be ratio of the simulation and data efficiency.

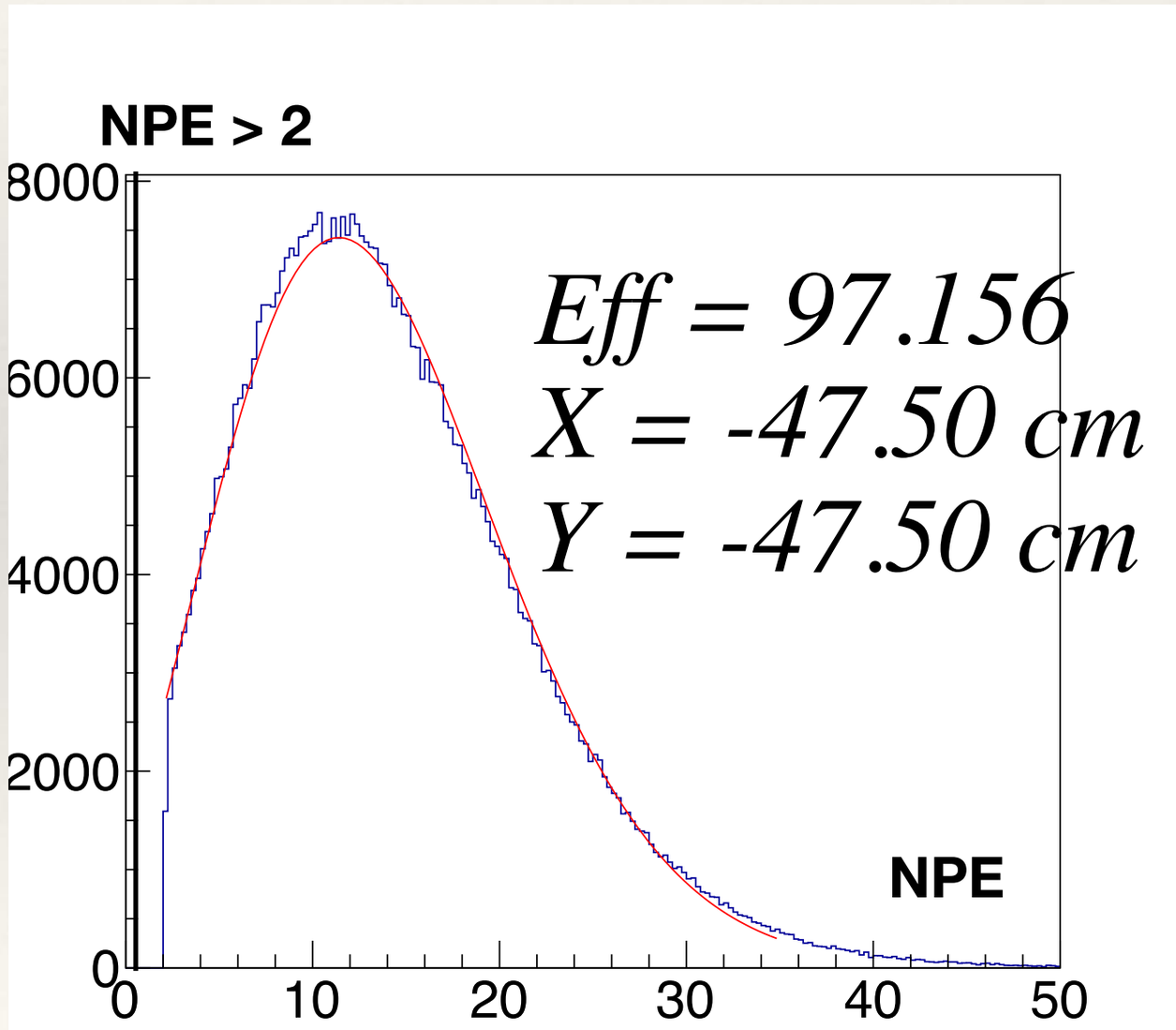
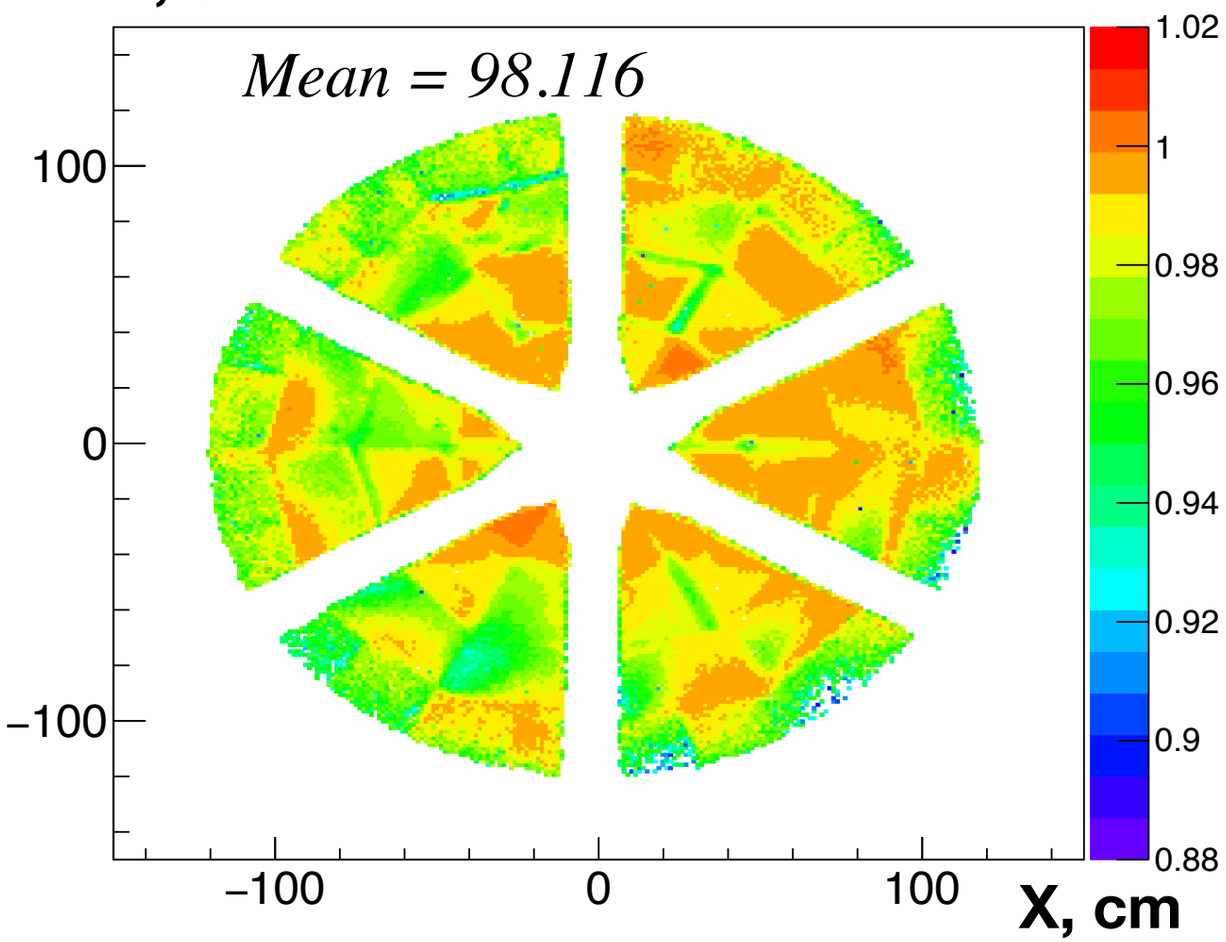


Illustration of the efficiency

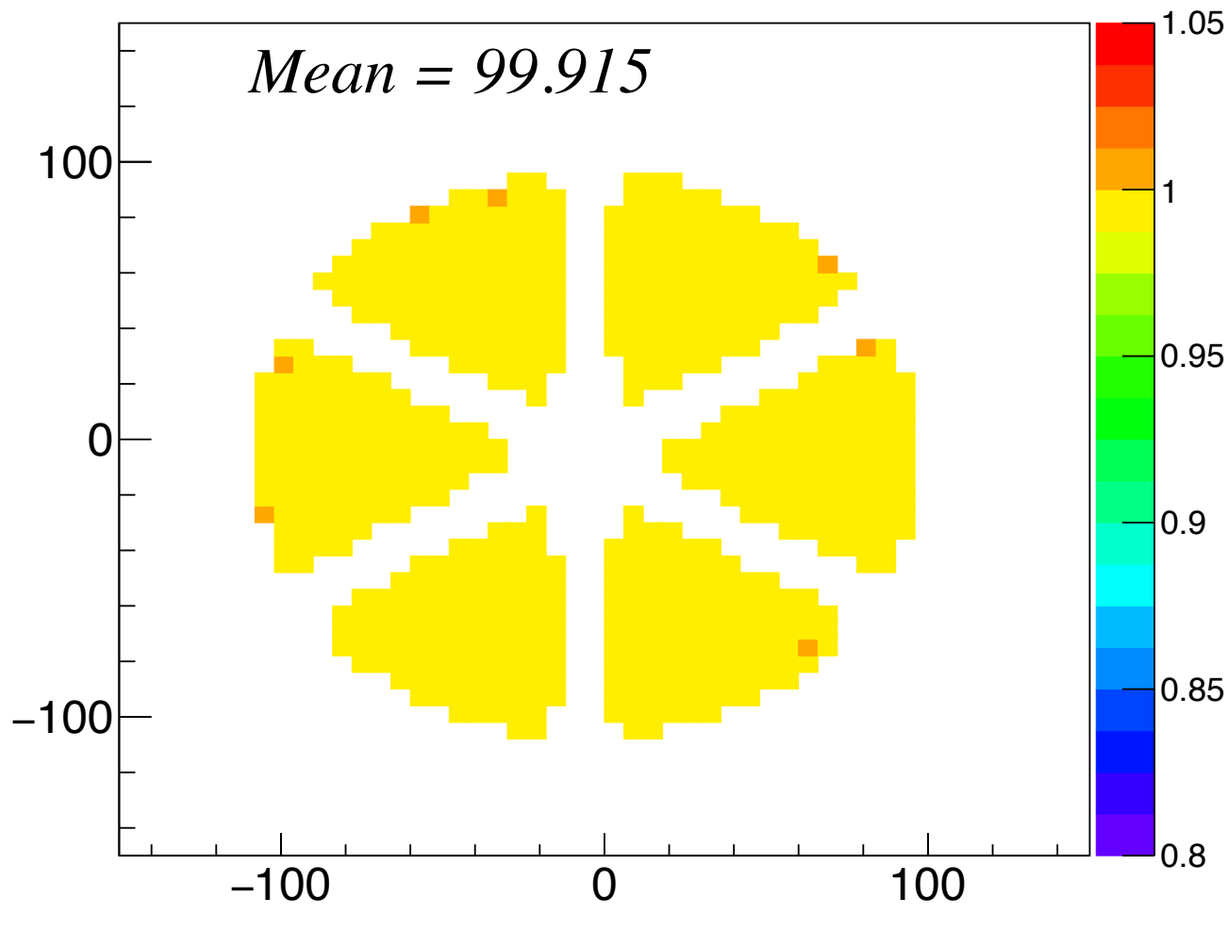
Estimation

HTCC electron detection efficiency

Data



Simulation



There is a noticeable difference;
Need to tune simulation.

Illustration of the efficiency

GEMC adjustment

- Need to identify the issue - what is responsible for different efficiency?
- Can we adjust it?
- Do we have tools to adjust it properly?
- Can we introduce tools to adjust it?

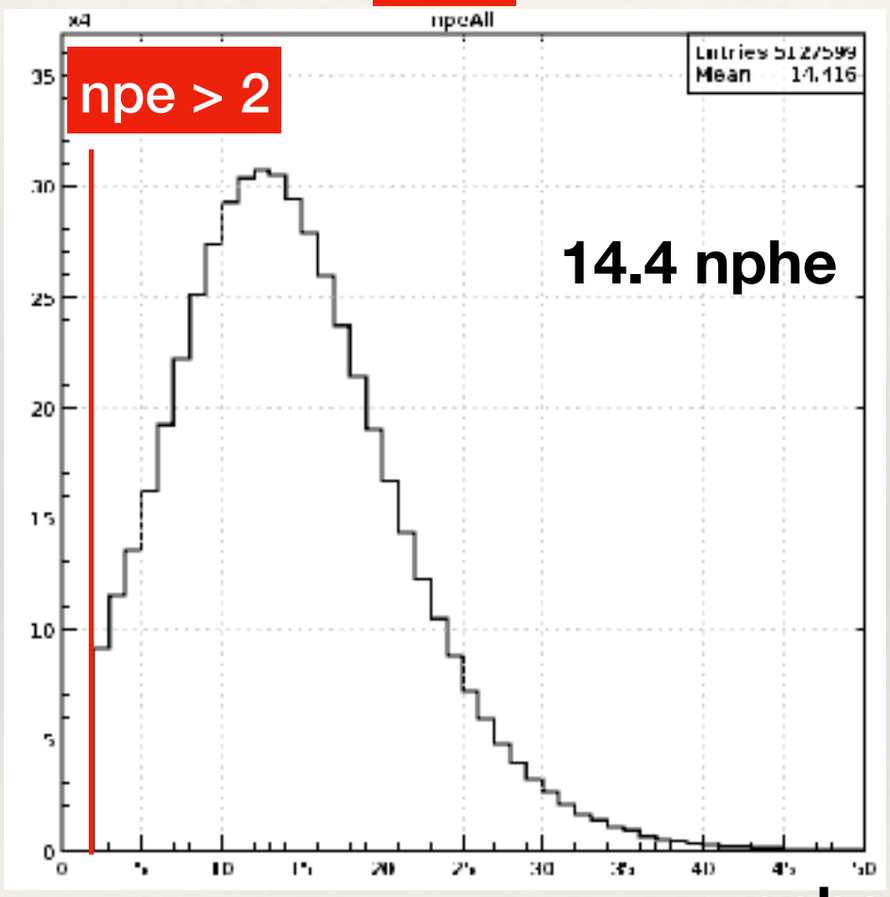
Illustration of the efficiency

GEMC adjustment

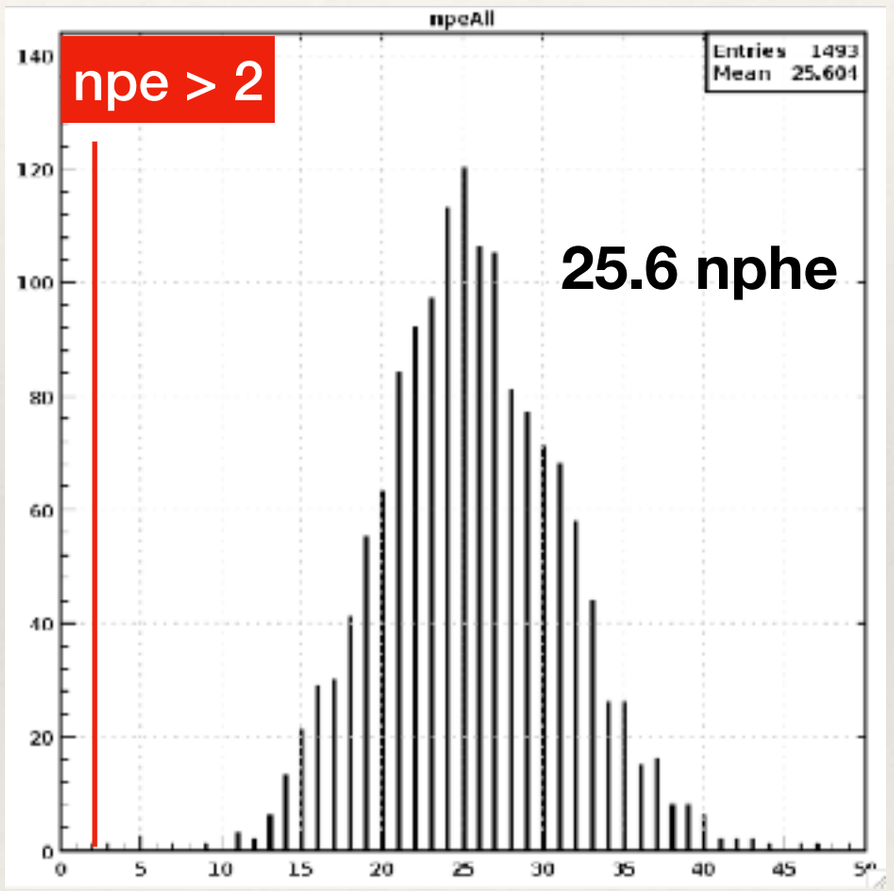
- HTCC **signal strength** is different in data and simulation;
- Need to adjust simulation.

Initial state
(EID cuts nothing):

Data



GEMC4.3.2



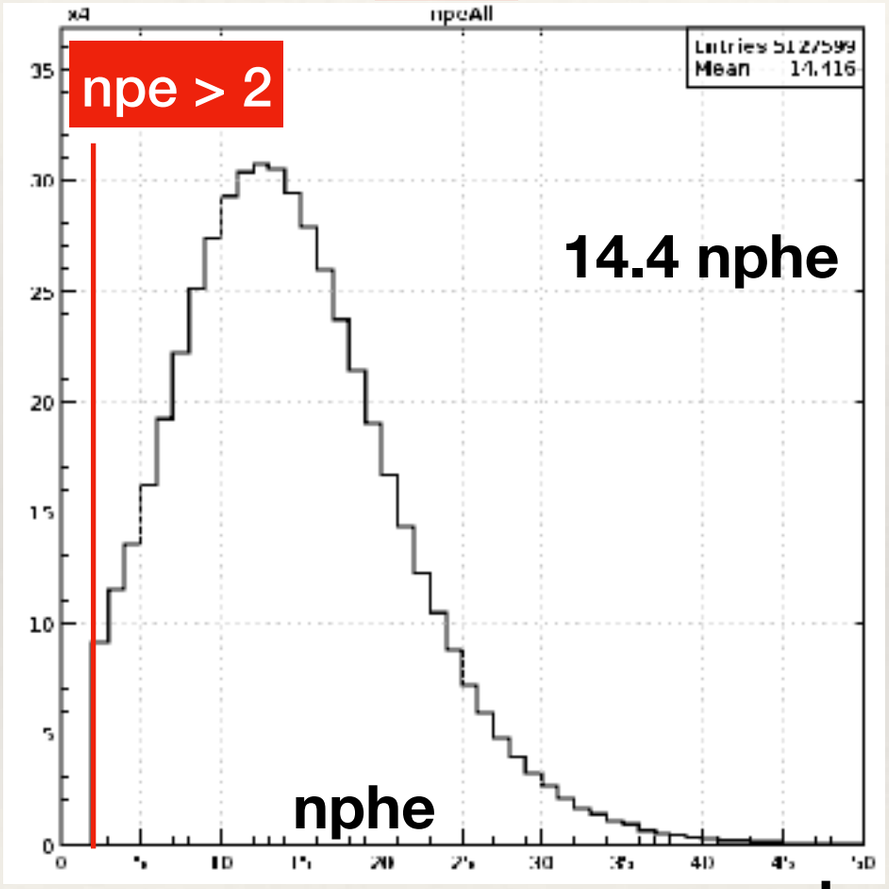
npe > 2 cuts nothing in simulation.

Illustration of the efficiency

GEMC adjustment

We need to identify the internal GEMC parameter to adjust

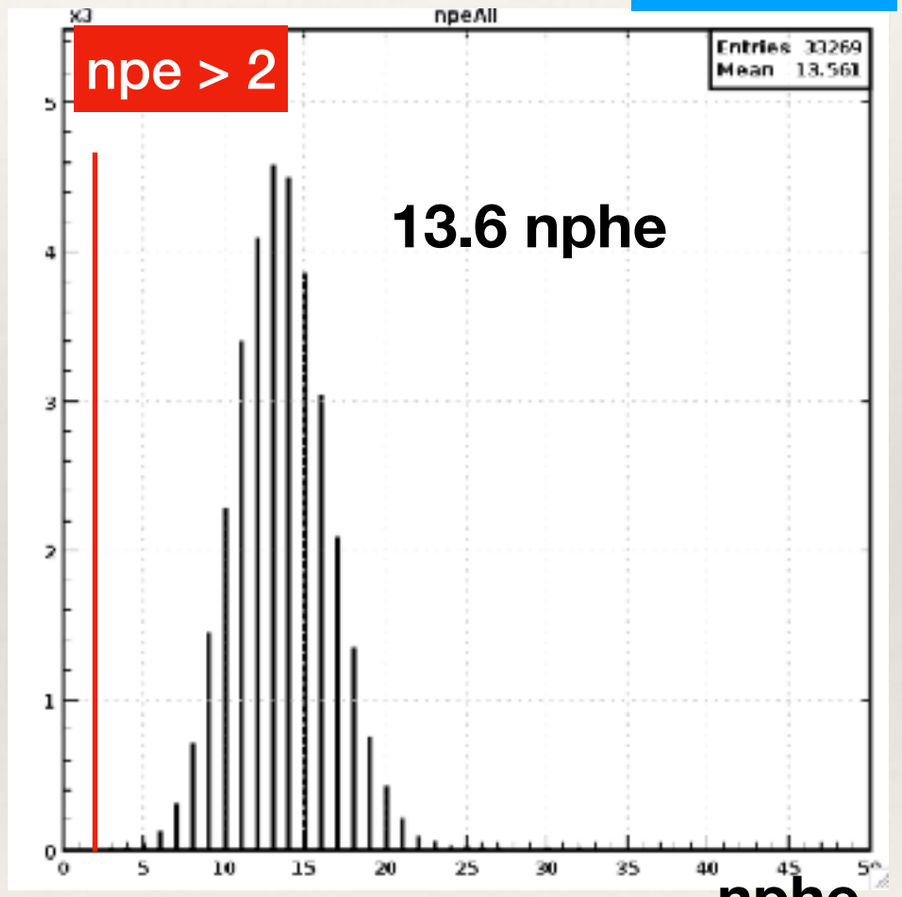
Data



nphe

Gain adjustment.

GEMC4.4



nphe

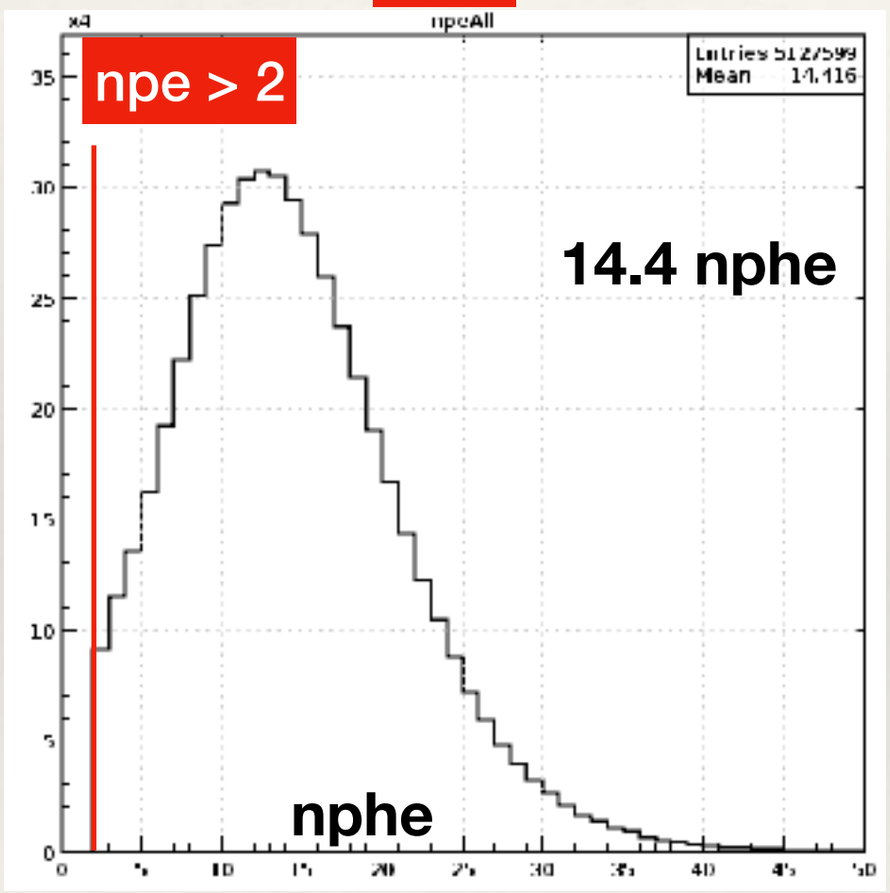
Adjust magnitude of the HTCC response in simulation;
Does not help with the problem, EID cuts still do not work properly.

Illustration of the efficiency

GEMC adjustment

The only available parameter was used.
Added extra one to adjust simulation to data.

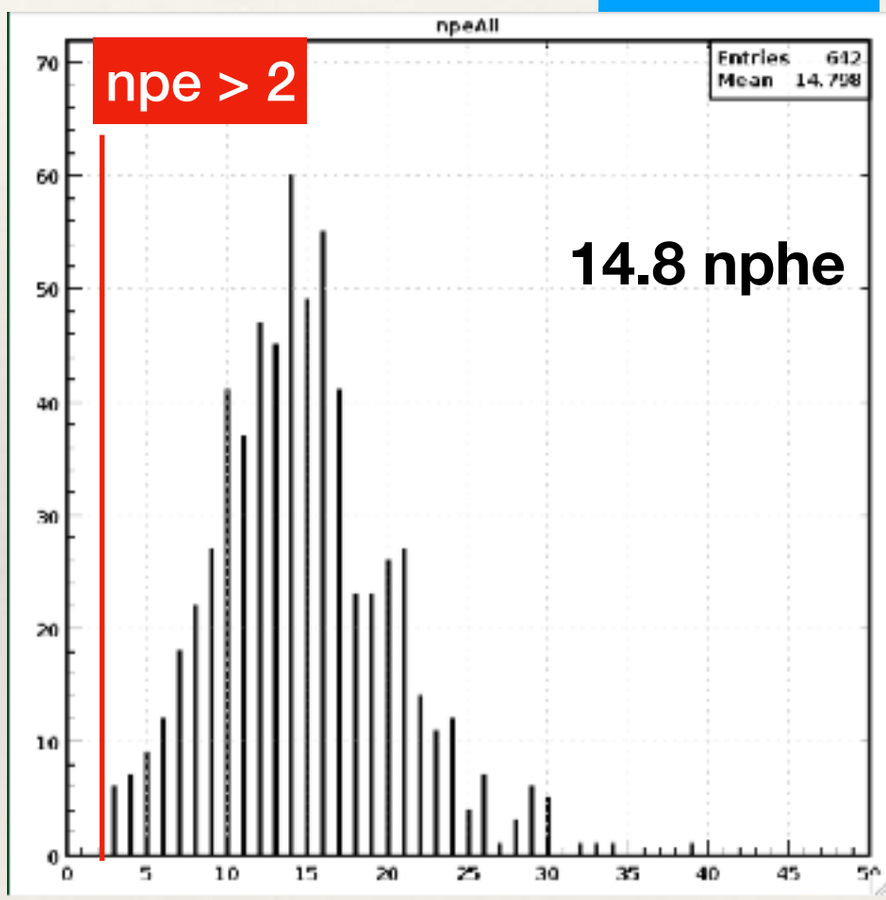
Data



nphe

Response smearing.

GEMC4.4’



nphe

Adjusts width of the HTCC response in simulation;
Helps with the problem, but requires additional work.

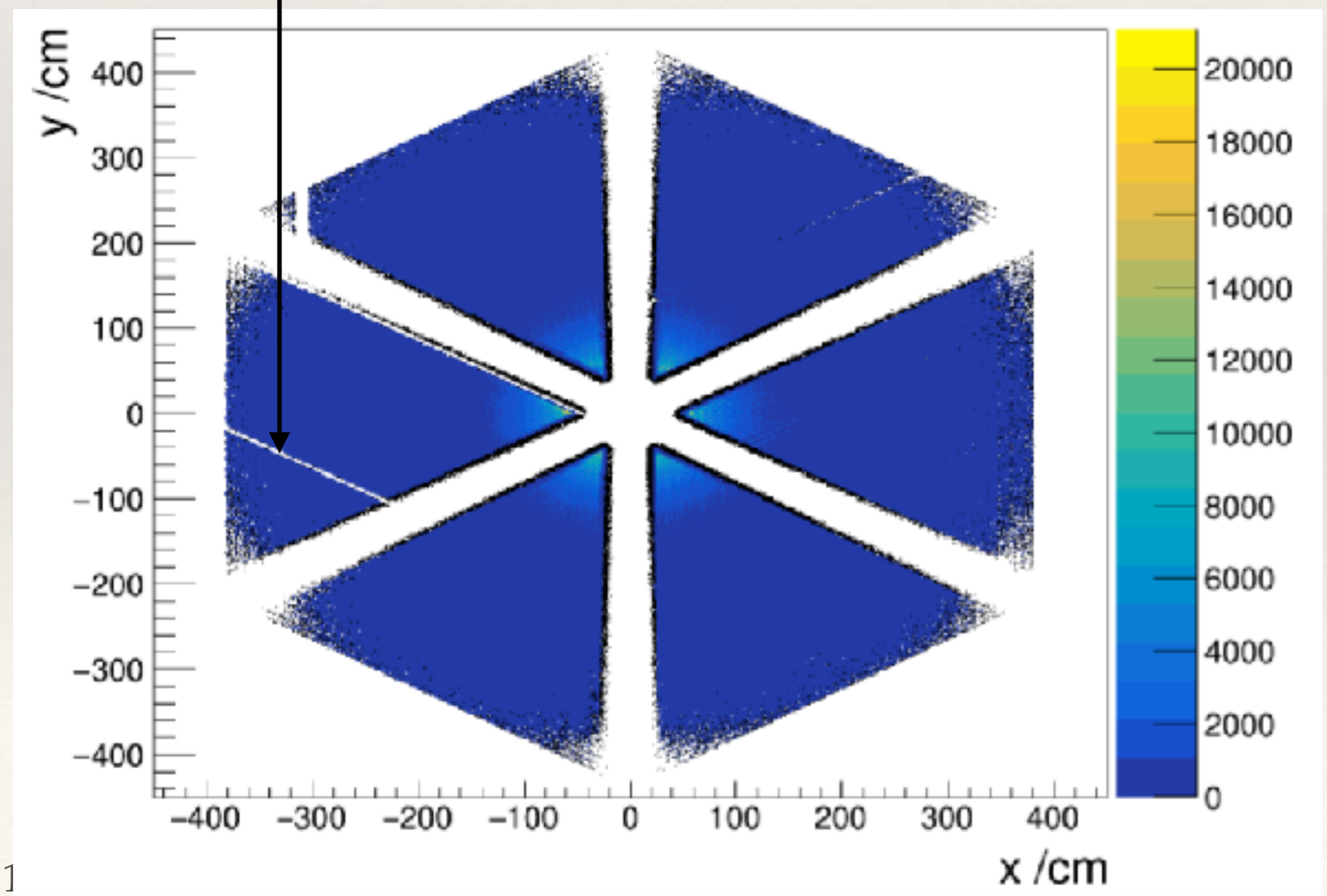
Illustration of the efficiency

Status tables

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



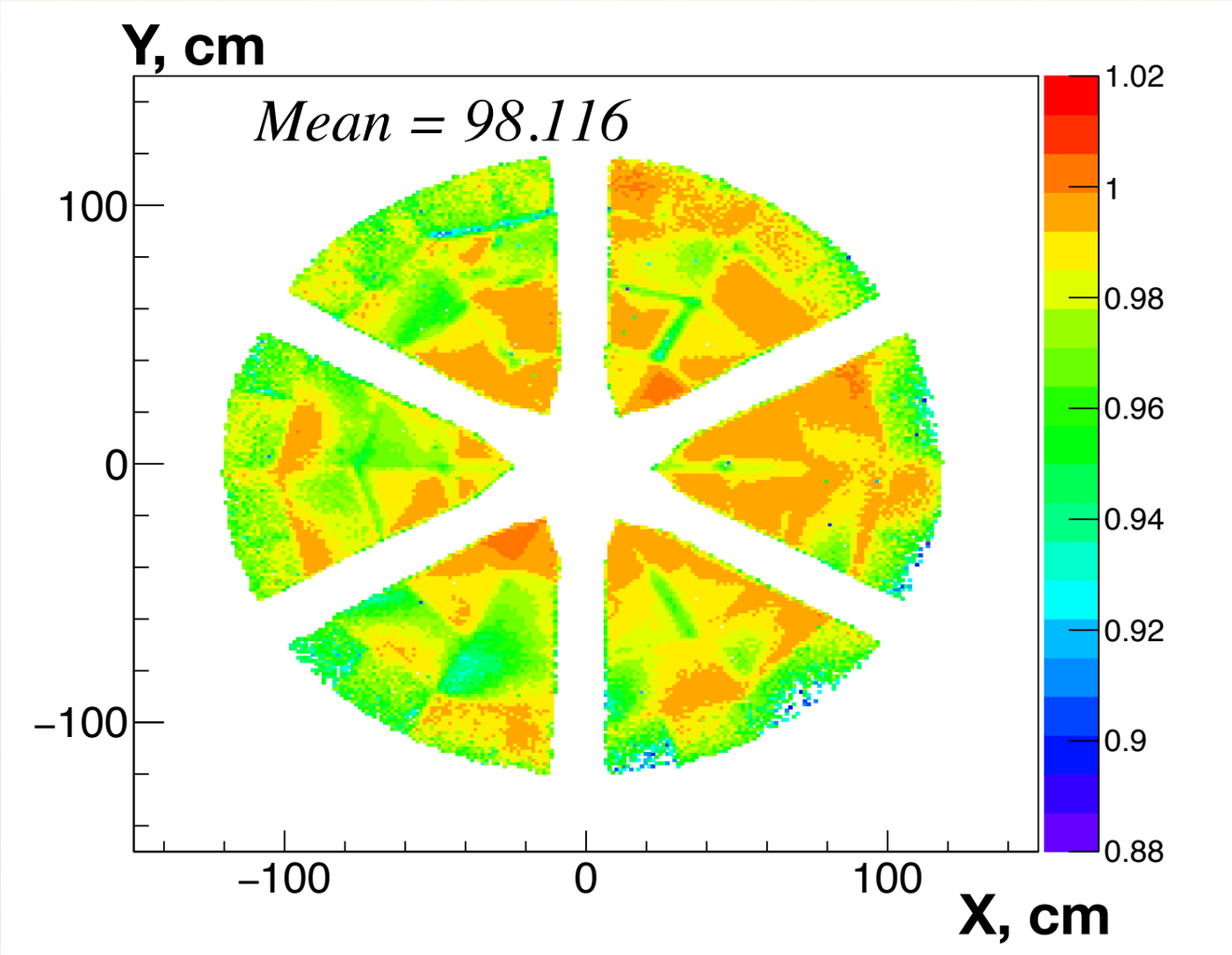
Hardware Status Assignments

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

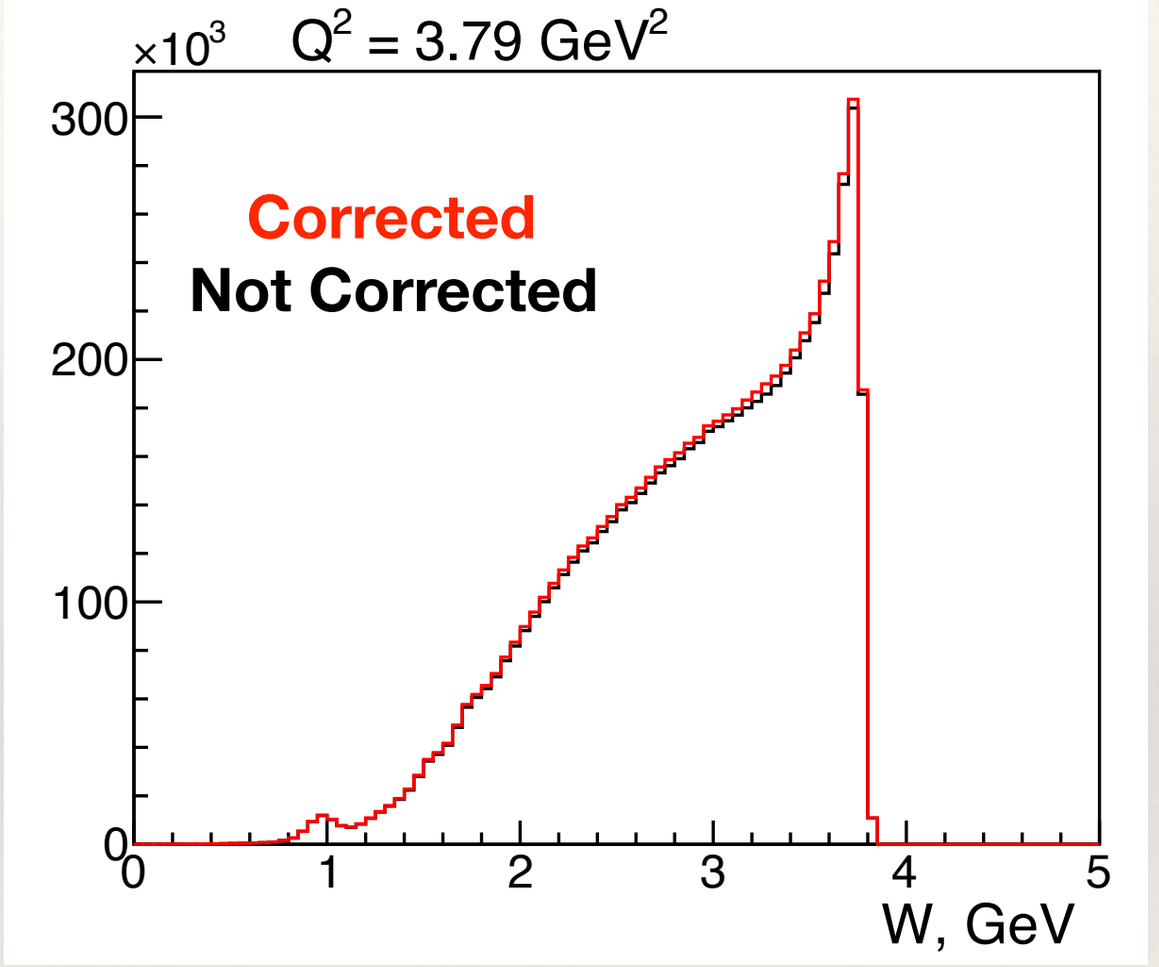
Illustration of the efficiency

Efficiency tables

Efficiency table:



Event distribution:



Electrons only

$$N(W, Q^2) = \Sigma \frac{1}{Eff(X, Y)}$$

Illustration of the efficiency

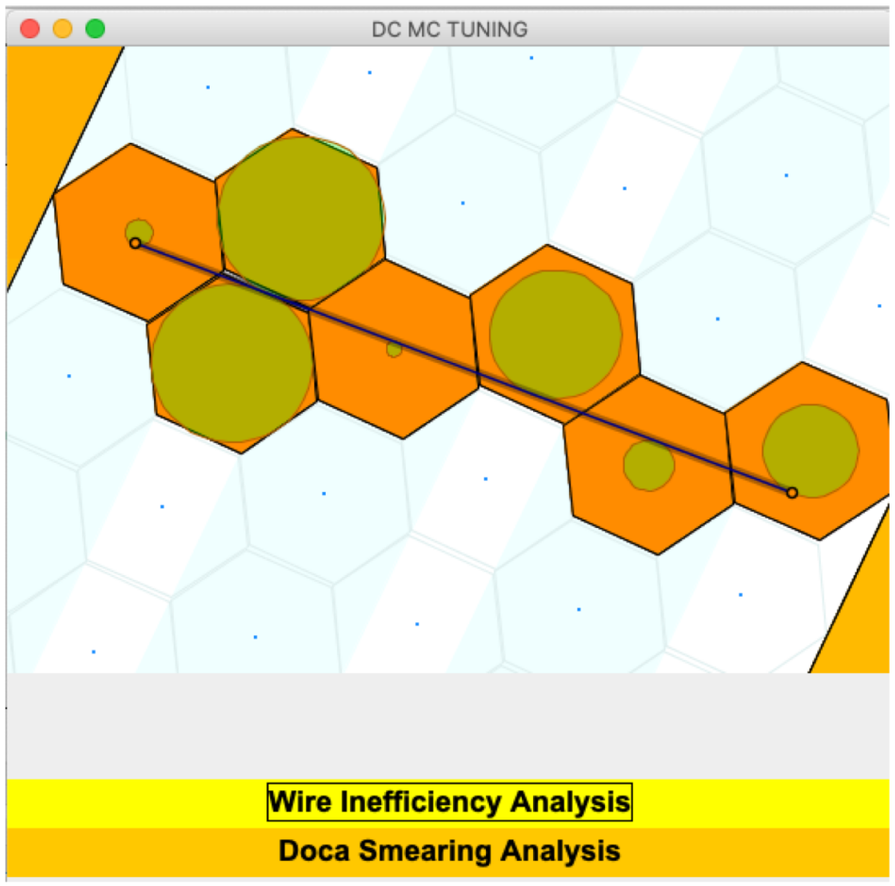
FT Efficiency

Estimation

- 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

DC Efficiency

Wire Intrinsic Inefficiency Tuning using Data



- Extract inefficiency as a function of normalized track doca
  - Fit segment; find hit that is closest to segment line; look over TDC hits (no cuts) and search for match.
  - Fit the distribution
- Wire intrinsic inefficiency function p0[p1/(x^2+p2)^2 +p3/((1-x)+p4)^2]
- Fit spectra to extract function parameters.
- Compare to simulated distribution.
- Distribution from simulation should agree with above function

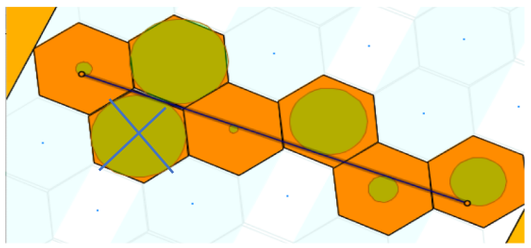
Illustration of the efficiency

DC Efficiency

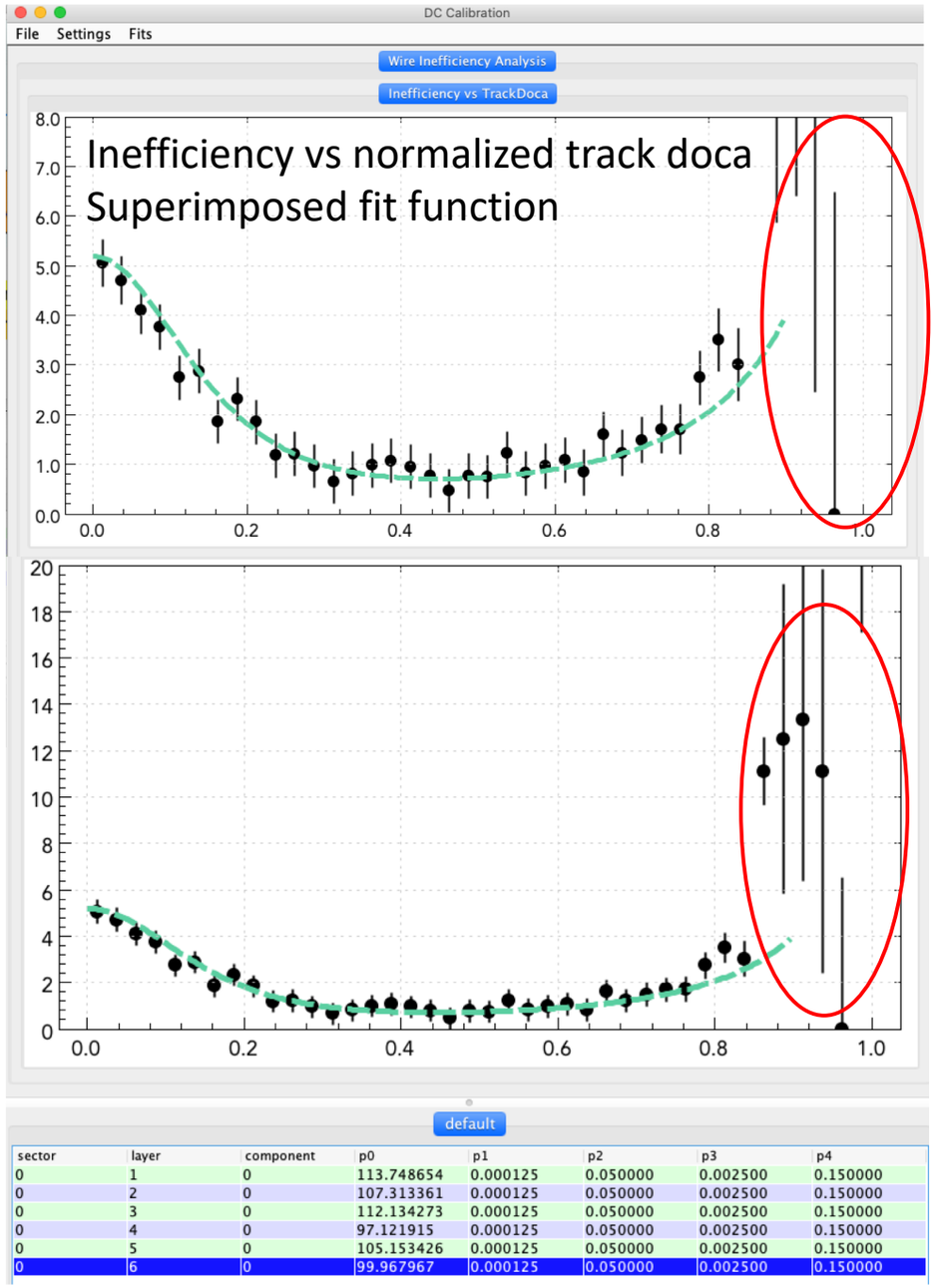
Test using MC

Run on Sidis MC

- Normalization of function set to 1 in ccdb
- Well modeled below 0.8
  - Normalization consistent with input
  - Shape parameters fixed
- Difficult to extract inefficiency at large docas



- Trajectory from segment fit assigns 1 matched hit
- If search within 2 cells → miss inefficiency
- Search within 2 cells for trkdoca > 90% dmax



Ambiguity
In matching
At large DOCAs

- A function of the intrinsic efficiency of a wire to fire if a track hits the cell. This is implemented in GEMC by comparing a random number (between 0 and 1) with this calculated inefficiency. If the random number is below the calculated inefficiency, the hit is not recorded.

Validation of the efficiency

Event sample generation and storage (for efficiency studies/validation purposes)

- Event samples: LUND files from event generators and particle guns gcards (different configurations for different run groups);
- Different beam energy/mag fields/CLAS12 geometry etc;
- Decoded hipo files;
- Data samples (specific event samples, run periods, schemas);
- Stored in a set place with a proper description;
- Well maintained.

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.

Summary and Future Plans

- Develop algorithms to determine efficiency of every subsystem (different for different particles);
- Develop and validate software packages to extract efficiency for each detector from data and simulation;
- Find relevant GEMC parameters and tune GEMC to match efficiency between data and simulation as much as possible;
- Design, fill and apply status tables (bad, ineffective, nonfunctional elements) in reconstruction;
- Design and implement efficiency tables in the workflow (if required);
- Should be finish in March 2021 as stated in the FT Charge.