
# CLAS12 Event Reconstruction

Veronique Ziegler

CLAS12 Collaboration Meeting

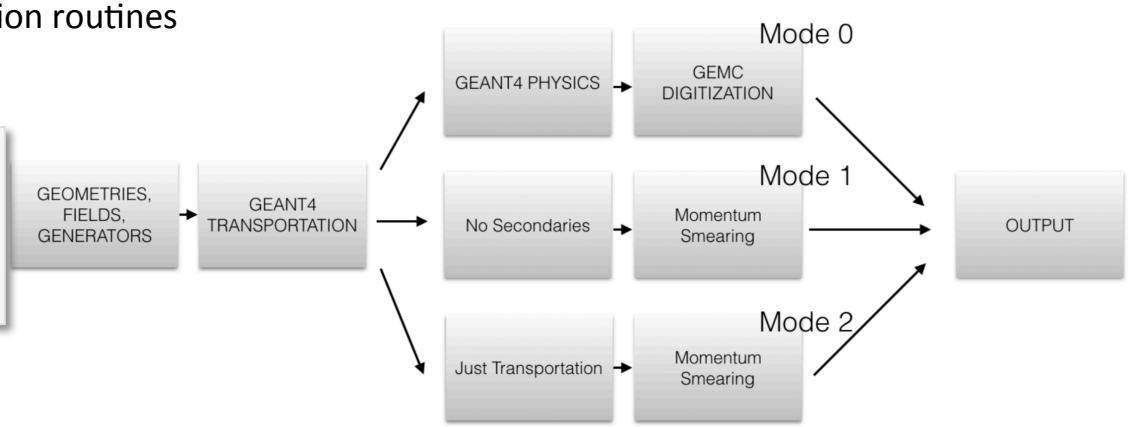
03/29/2017

# GEMC Updates (M. Ungaro)

- GEMC development for CLAS12 is mature.
  - gemc: **2.5**
    geant4: **10.2.p03** (JLAB_VERSION: 2.0)
  - Next gemc: devel (**2.6**) (JLAB_VERSION: devel) Next geant4: **10.3.p01**
  - GEMC tagging schemes: https://github.com/gemc/clas12Tags
    - latest tag: 4a.0.1 (FTOF geometry fix)

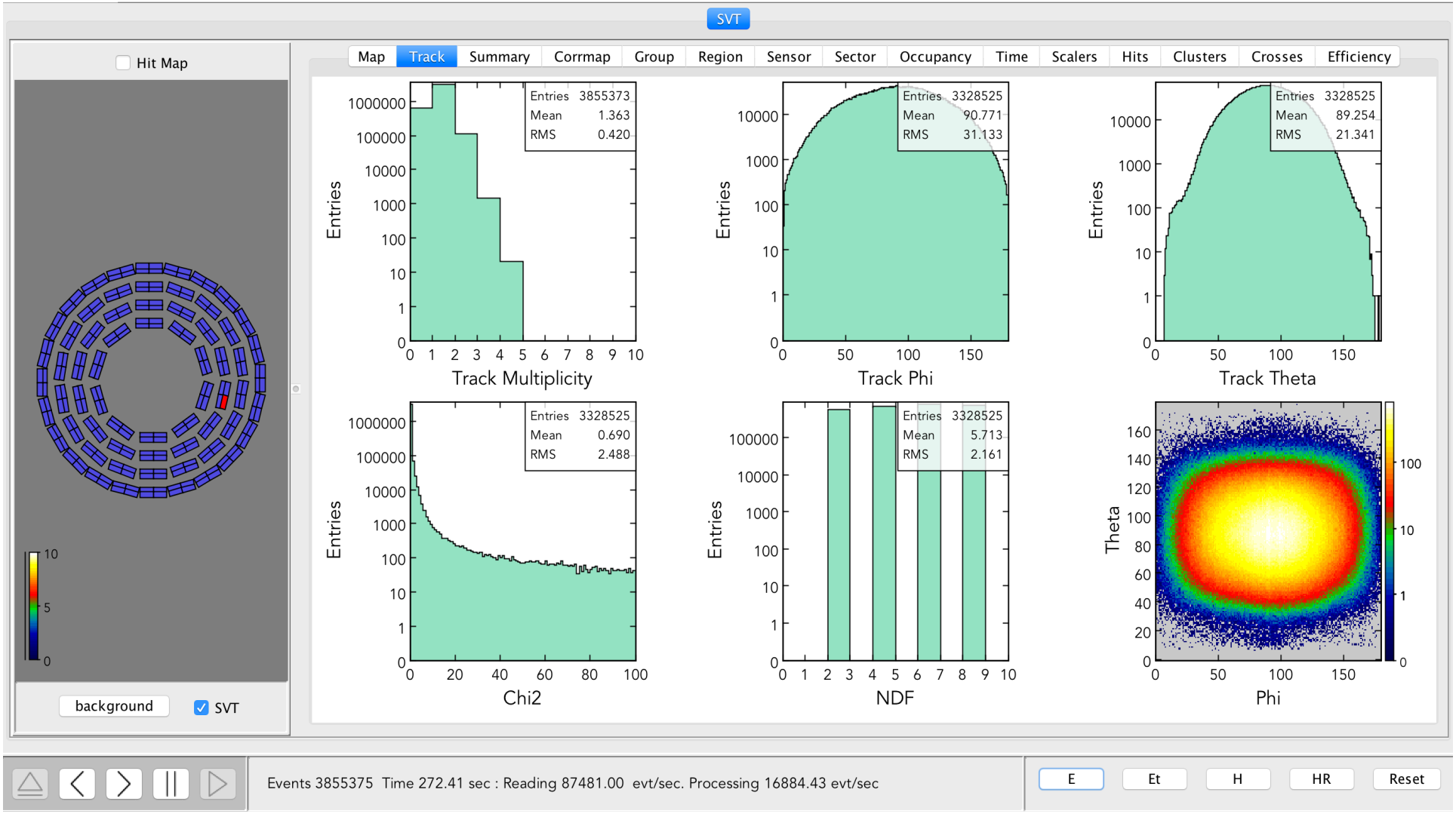
- GEMC new features
  - Event Generators (LUND++, event processing, bank outputs)
  - CAD geometry import, Volume information added
  - B field information added in digitization routines
  - FASTMCMODE option

Mode 0: is the full geant4 simulation.
Mode 1: turns off secondaries.
Mode 2: turns off all physics except transportation.
Mode 10: Same as mode 1 but with process routines enabled.
Mode 20: Same as mode 2 but with process routines enabled.

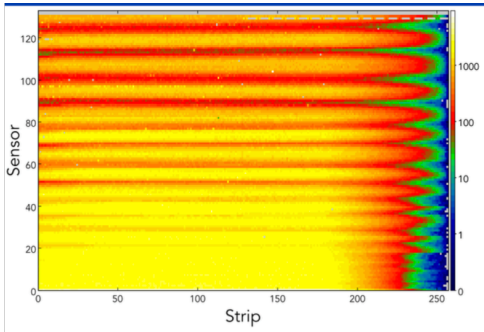



- GEMC development
  - FADC and Digitization for CLAS12: make simulation as realistic as possible
  - Code more modularity and optimization
  - New Geant-4 (multithreaded running)

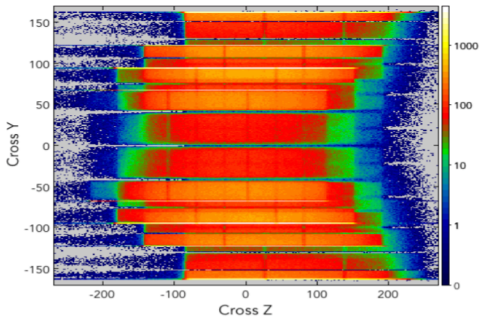
# Online/Offline Detector Monitoring GUI development (Y. Gotra)



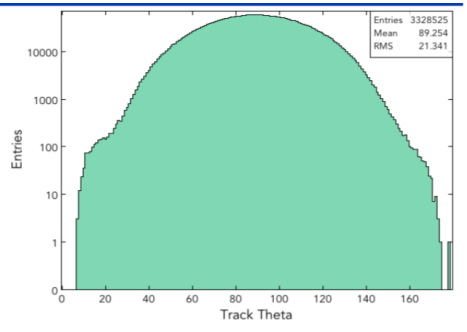
# SVT Monitoring (Y.Gotra)



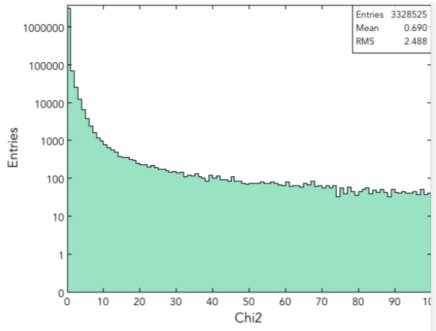

Hit occupancy




Track crosses

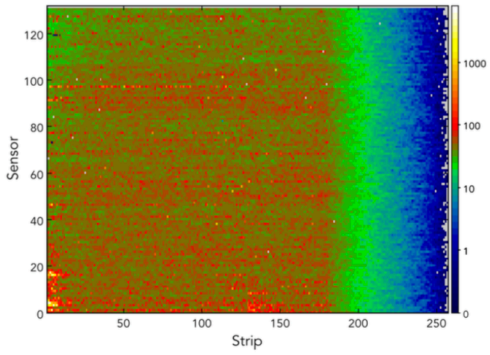



Track θ angle

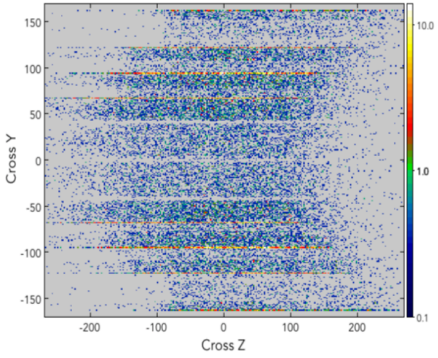



Normalized $\chi^2$

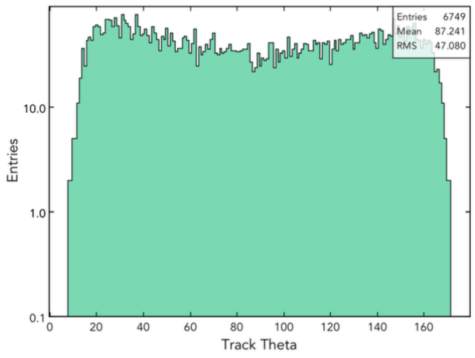
**SVT Cosmic trigger data**



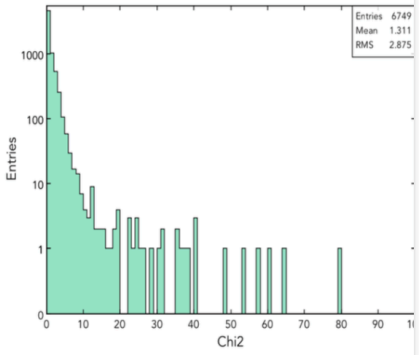

Hit occupancy




Track crosses

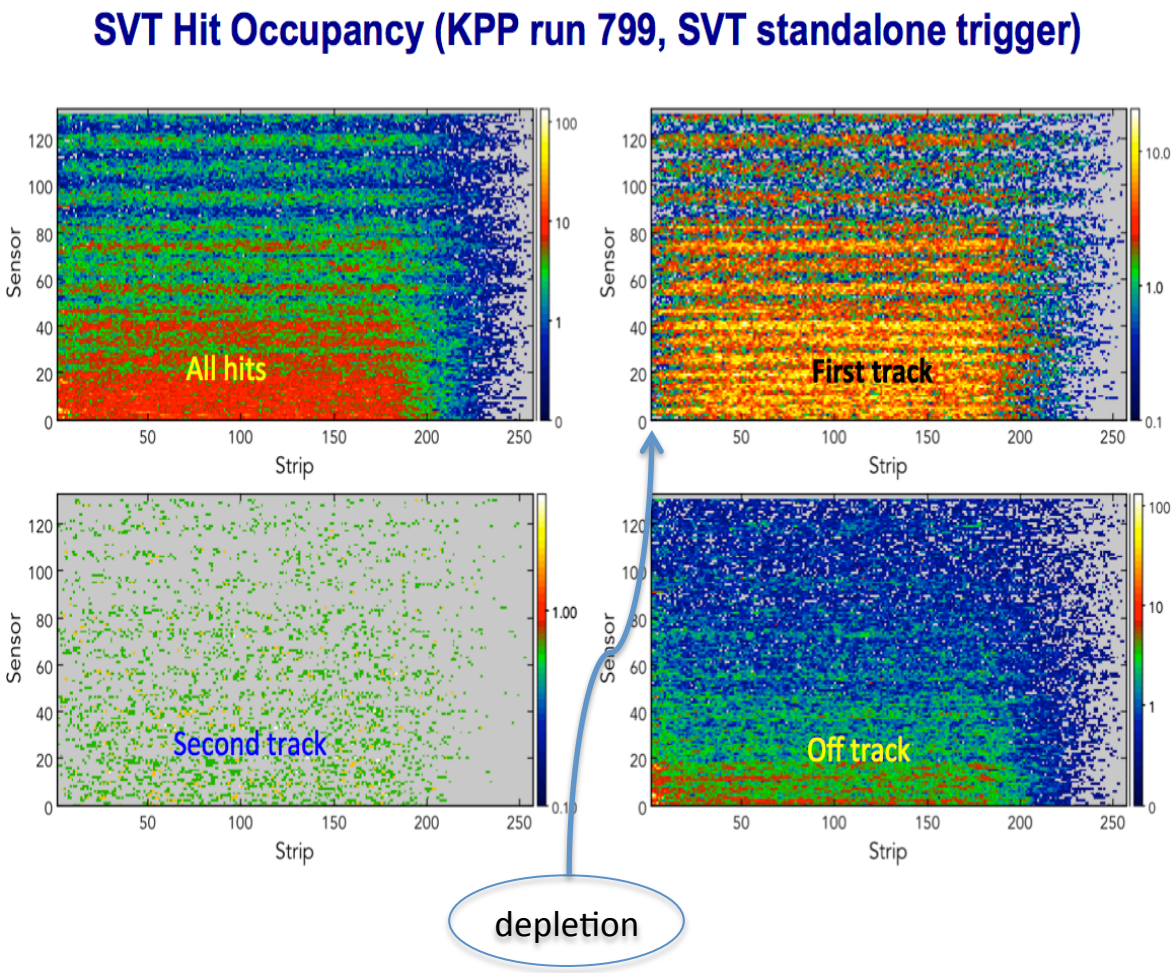


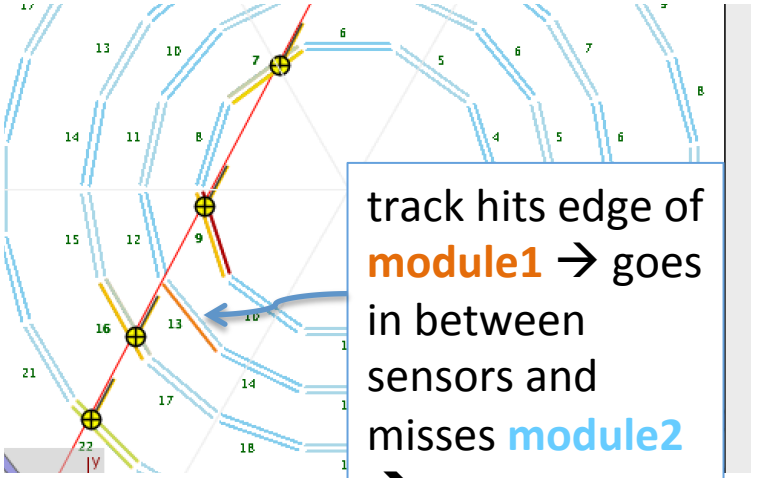

Track θ angle




Normalized $\chi^2$

# SVT Tracking developments



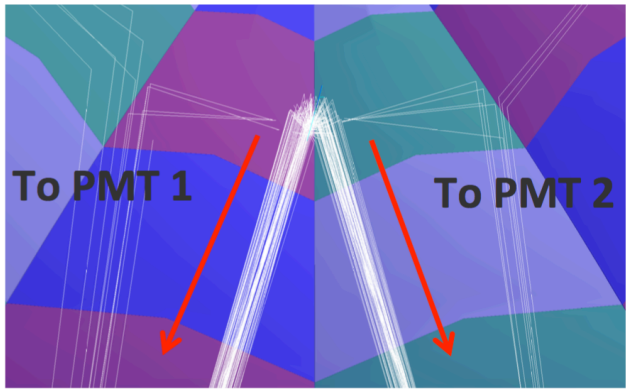



track hits edge of **module1** → goes in between sensors and misses **module2** ➔ no cross, **hence hits were not used to fit the track**

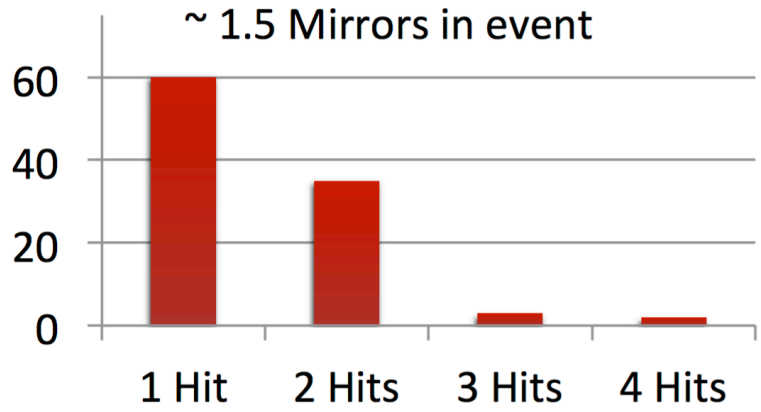
After fitting search for unassociated hits on track trajectory (|calcCentroid – clusterCentroid| <3)

# HTCC Reconstruction (N. Markov [ODU])

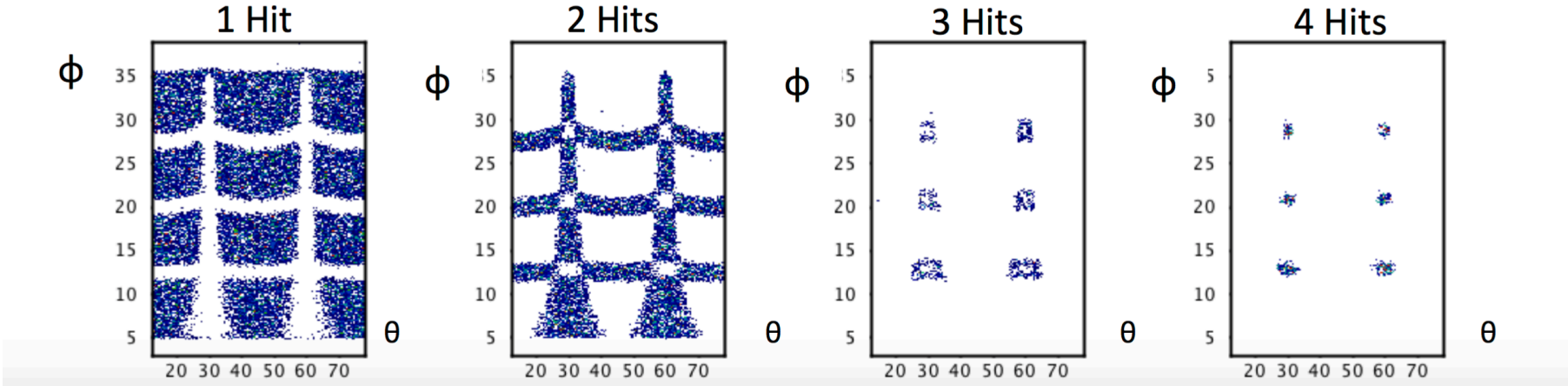
- Clustering




Cerenkov radiation from single electron may split between mirrors and is collected by different PMTs




***Geometrical pattern of single- and multiple hit events:***



# LTCC Reconstruction (Temple University)

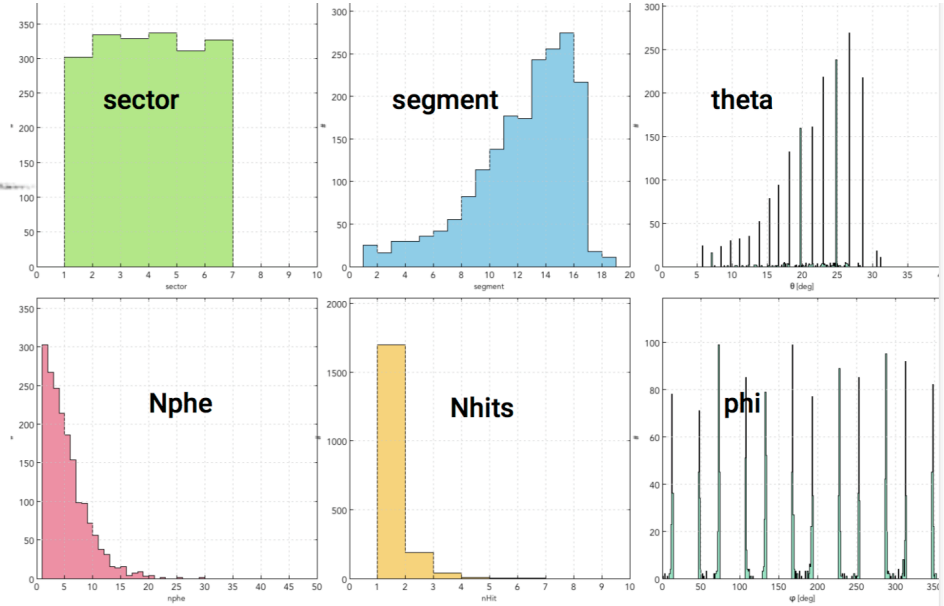
✧ Clustering

Based on GEMC simulations

**LTCC Clustering plugin:**

- Implemented in COATJAVA
- simple clustering algorithm:
  - **(1)** scan for highest multiplicity hit
  - **(2)** add neighbors (in space and time)
  - **(3)** Repeat until done

https://github.com/sly2j/clasrec-ltcc

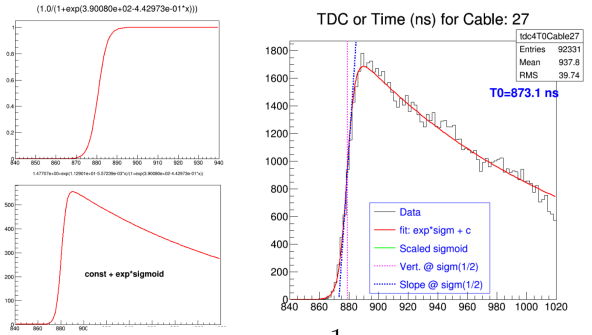



**Testing the plugin on data:**

- TODO, **need LTCC calibrations** and timing data to properly study KPP data!

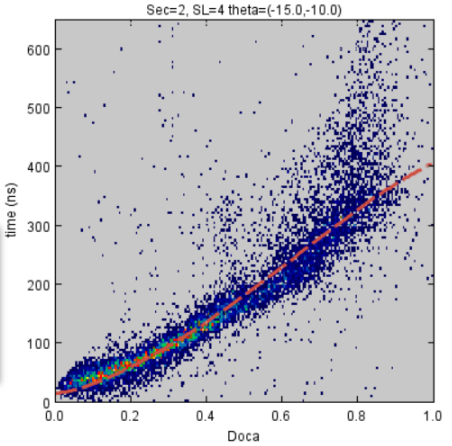
# Time-Based Tracking Updates

- T0 subtraction
  - method to fit the TDC distributions rising edge (K. Adhikari)

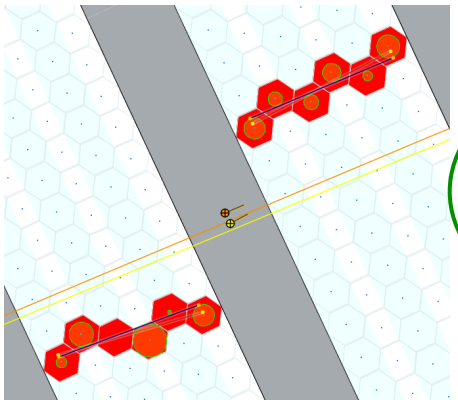



$$f(t) = e^{p_0+p_1 t}\frac{1}{1+e^{p_2+p_3 t}} + p_4$$

- Distance estimate in reconstruction
  - time vs distance function —> multi-dimentional array, interpolate in 3 dimensions (local angle, time, B) bins
  - validation with cosmics




Parameters extracted from fits to doca vs time distributions in data [KPP run 758] (K. Adhikari)

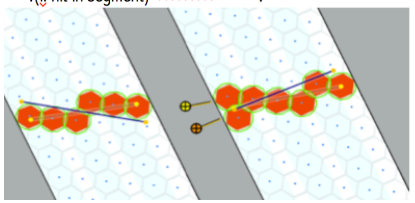


docas calculated from T2D tri-dimentional interpolation using constants (in ccdb) from Garfield simulations

Out-of-time-hits rejection

Out-of-timers signature

$\Sigma_{i(i;\ \text{hit in segment})}$ doca ~ $\Sigma_i$ cell-size



# Other DC Tracking Updates

- Five-Out-Of-Six superlayer tracking
  - Recover over 90% of lost track due to missing a superlayer
  - Minimal resolution degration
- Improved Kalman Filter code
- Ongoing validation using KPP data
  - Understanding tracking inefficiencies and tuning the algorithms

# New Tracking Results

**Torus Current *-1900A outbending* negative tracks**

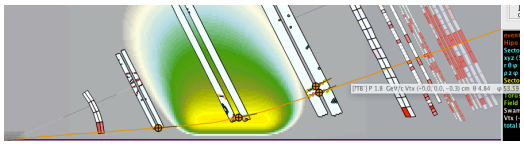
Previous Results

- ✧ **old Kalman Filter**
- ✧ **6 out of 6 superlayer tracking**
- ✧ **T0 values fixed at 135 ns**

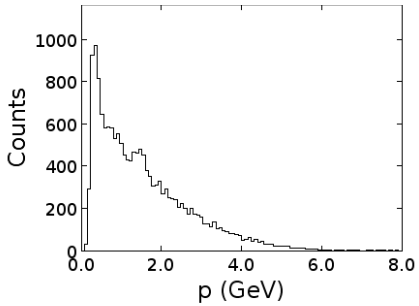
New Results

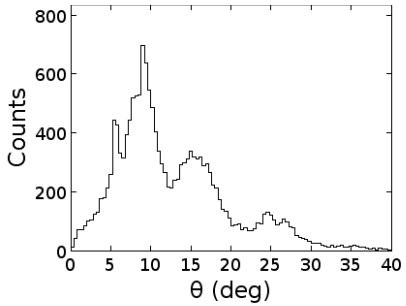
- ✧ **new Kalman Filter**
- ✧ **5 out of 6 superlayer tracking (unoptimized selection)**
- ✧ **T0 values from calibration (Krishna)**

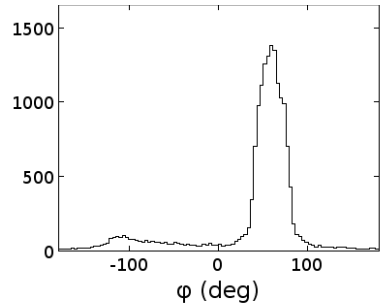
* very low θ tracks produce tail in z-vtx distribution

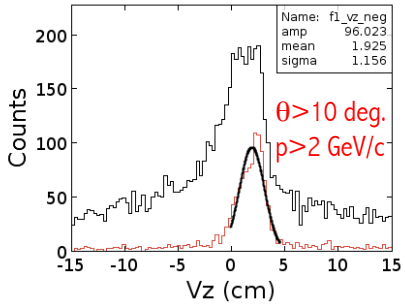


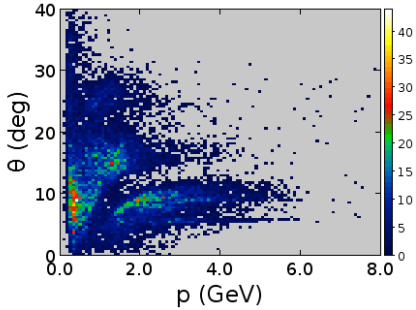
**Negative Time-Based Tracks**

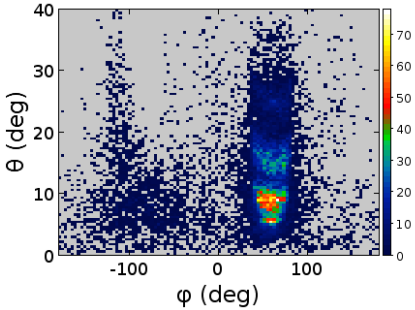


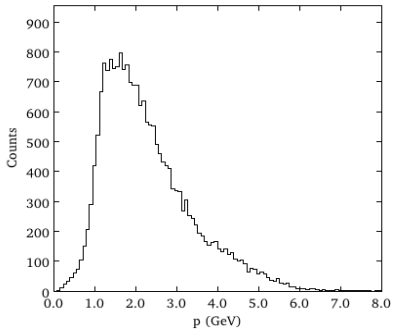



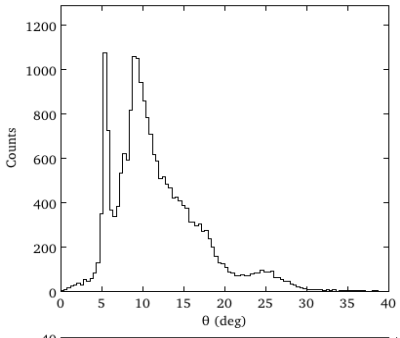



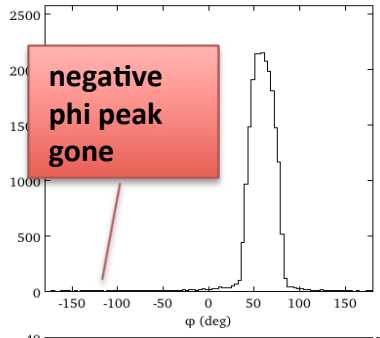



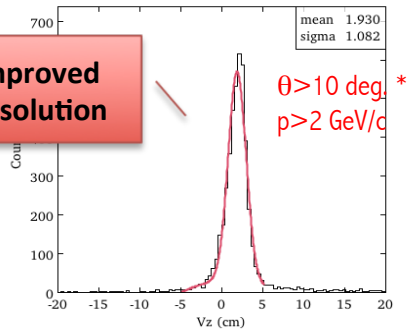



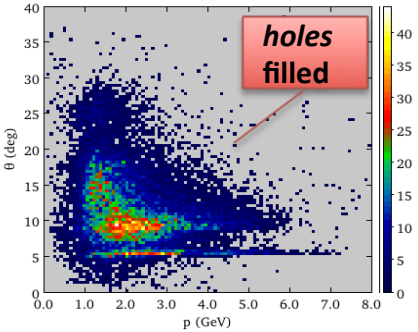



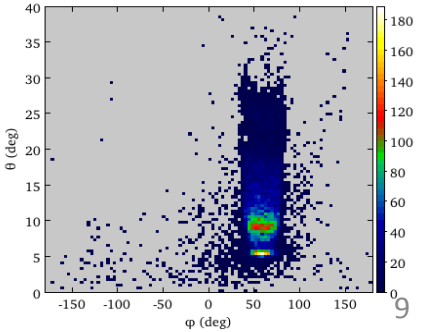




improved resolution



# TOF reconstruction

TOF reconstruction code determines:

- hit times ($t_L$, $t_R$, <t>)

$$t_{L,R} = (C_{TDC} \cdot TDC_{L,R}) - t^{walk}_{L,R} \pm \frac{C_{L,R}}{2} + C_{p2p}$$

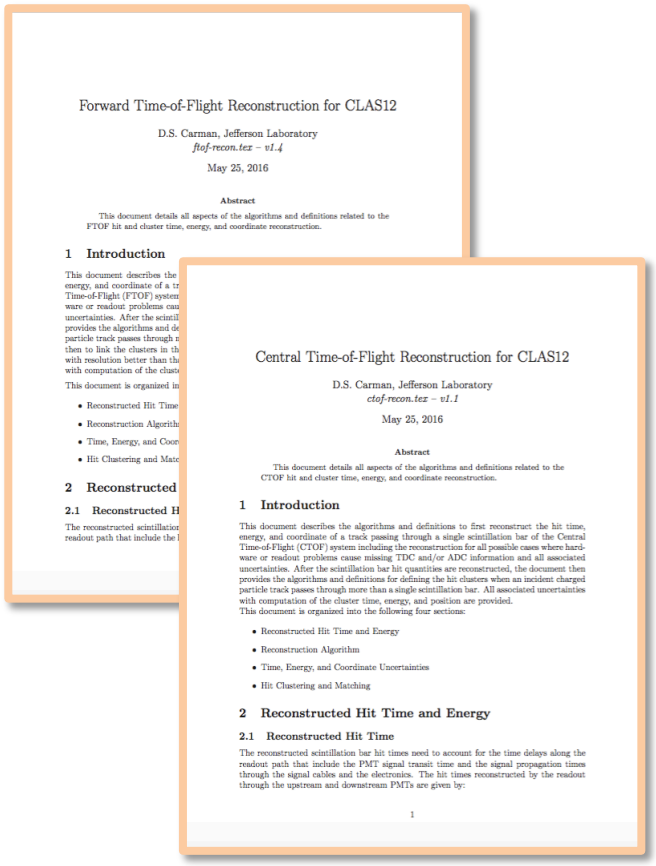
- hit coordinates (x)

$$x = \frac{v_{eff}}{2}(t_L - t_R)$$

- deposited energies ($E_L$, $E_R$, <$E_{dep}$>)

$$E_{L,R} = (ADC_{L,R} - PED_{L,R}) \left[ \frac{(\frac{dE}{dx})_{MIP} \cdot t}{ADC_{MIP}} \right]$$

- associated time, coordinate, and energy uncertainties
- performs hit clustering and matching
- combines hit times from panel-1a and panel-1b



Forward Time-of-Flight Reconstruction for CLAS12

D.S. Carman, Jefferson Laboratory

*ftof-recon.tex – v1.4*

May 25, 2016

Abstract

This document details all aspects of the algorithms and definitions related to the FTOF hit and cluster time, energy, and coordinate reconstruction.

1 Introduction

Central Time-of-Flight Reconstruction for CLAS12

D.S. Carman, Jefferson Laboratory

*ctof-recon.tex – v1.1*

May 25, 2016

Abstract

This document details all aspects of the algorithms and definitions related to the CTOF hit and cluster time, energy, and coordinate reconstruction.

1 Introduction

This document describes the algorithms and definitions to first reconstruct the hit time, energy, and coordinate of a track passing through a single scintillation bar of the Central Time-of-Flight (CTOF) system including the reconstruction for all possible cases where hardware or readout problems cause missing TDC and/or ADC information and all associated uncertainties. After the scintillation bar hit quantities are reconstructed, the document then provides the algorithms and definitions for defining the hit clusters when an incident charged particle track passes through more than a single scintillation bar. All associated uncertainties with computation of the cluster time, energy, and position are provided.
This document is organized into the following four sections:

- Reconstructed Hit Time and Energy
- Reconstruction Algorithm
- Time, Energy, and Coordinate Uncertainties
- Hit Clustering and Matching

2 Reconstructed Hit Time and Energy

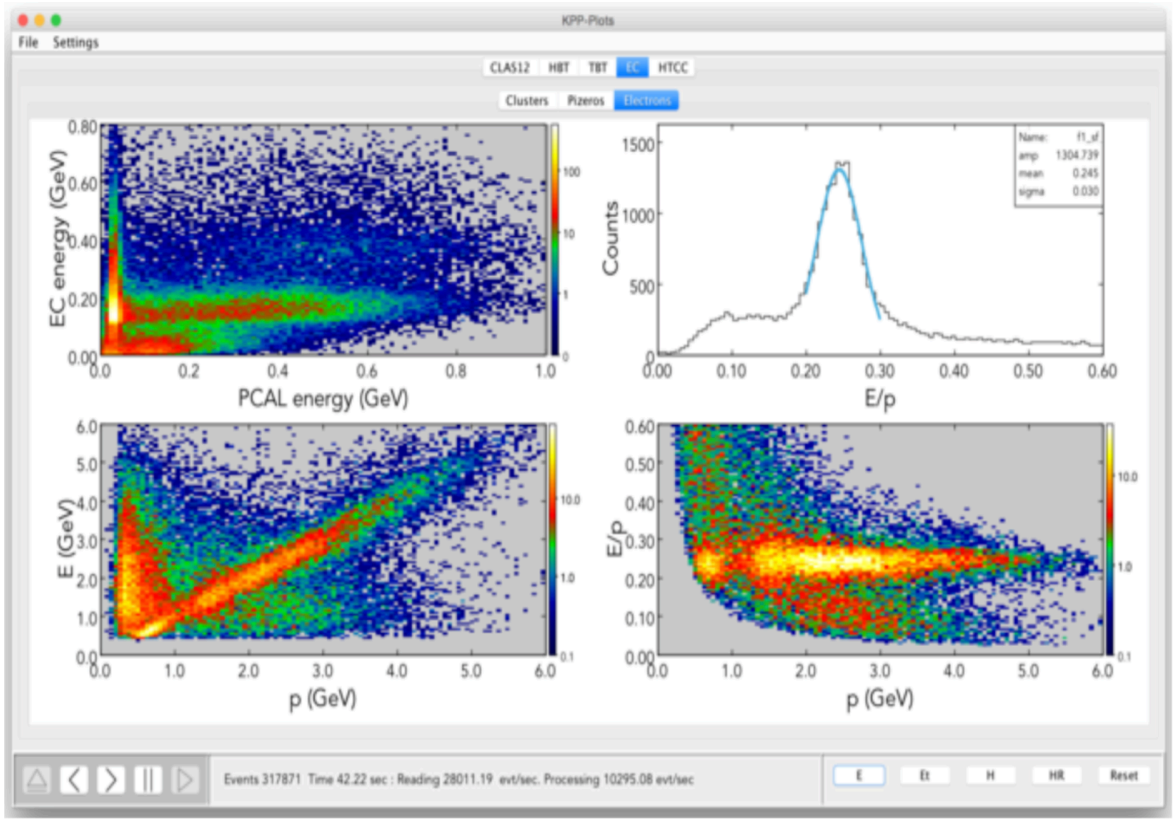
2.1 Reconstructed Hit Time

The reconstructed scintillation bar hit times need to account for the time delays along the readout path that include the PMT signal transit time and the signal propagation times through the signal cables and the electronics. The hit times reconstructed by the readout through the upstream and downstream PMTs are given by:

1

- Code designed to function for all “allowable” hardware conditions
- Most of the code validated in detail; work remains on combining hit times

# EC Reconstruction




C. Smith

**PCAL/EC calibration satisfied KPP requirements.**

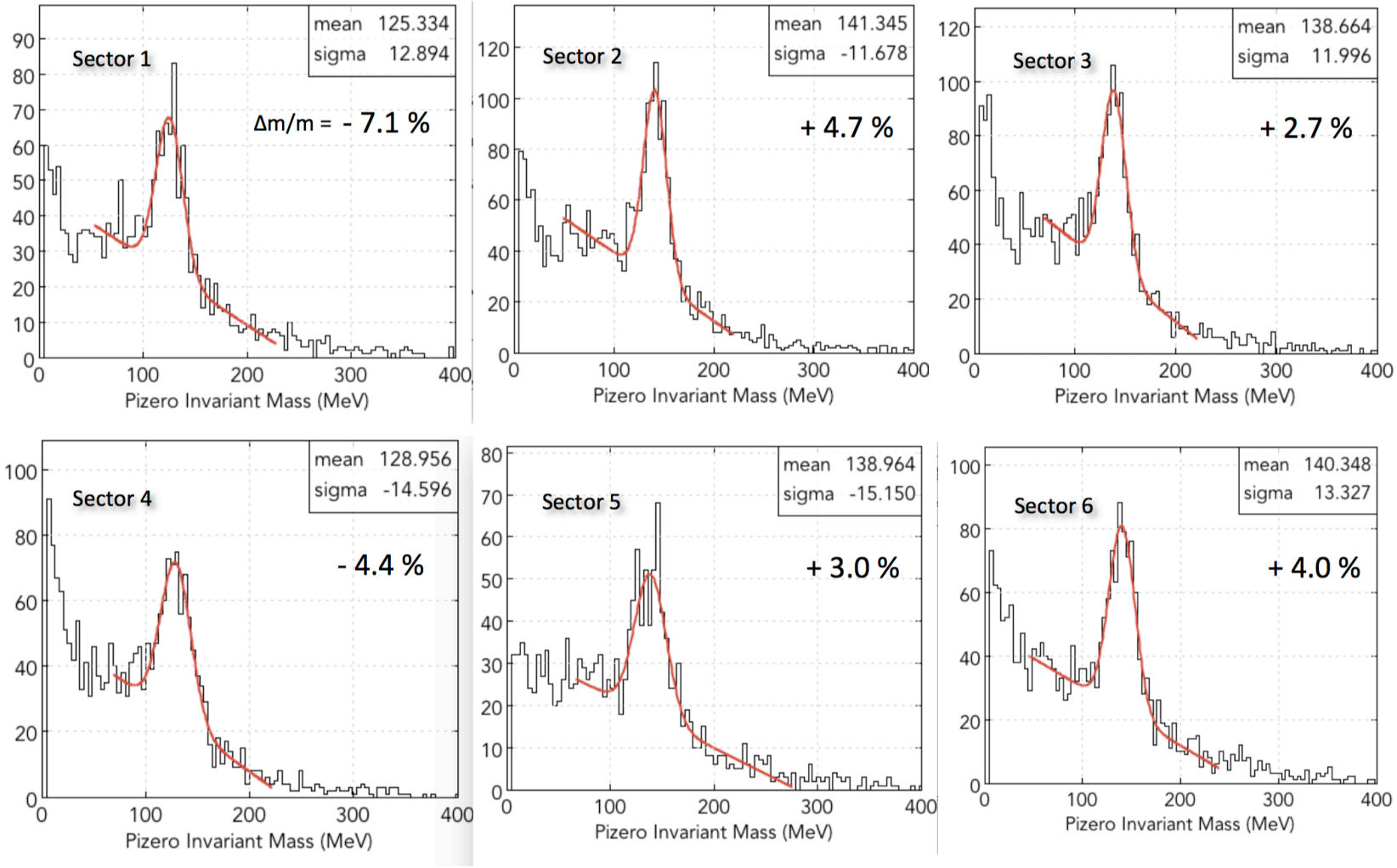
1. What can KPP data tell us about calibration quality?
   a) Pions vs. muons
   b) Pizero invariant mass
   c) Electron E/P

2. What can be done to improve absolute energy calibration and resolution?

- Rejection of Vertical Cosmic Triggers: Cluster Multiplicity Cut
- Rejection of cosmics using track pathlengths
- Selection cuts for various triggers

# $\pi^0$ Mass Reconstruction (C. Smith)

**Run 809: High Threshold Six-Sector Trigger – Pizero Invariant Mass from Two-Photon Decay**



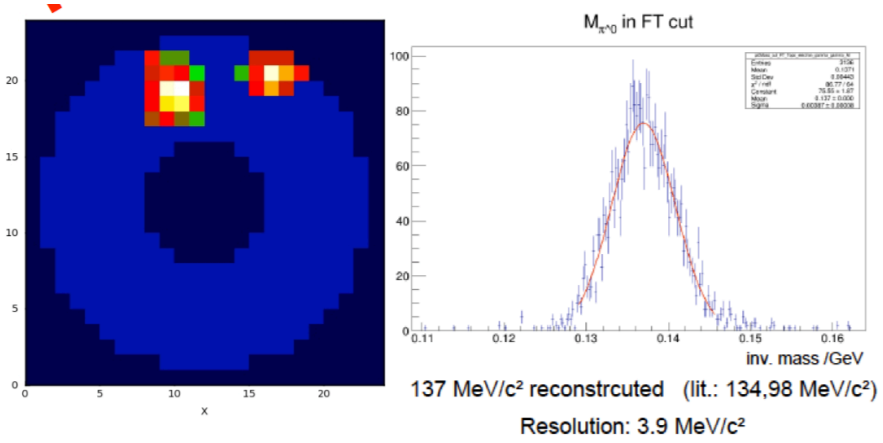

Notes:
1. Lower mass in S1 as expected from Run 760 calibration check
2. Worst resolution in S5 due to variance between PCAL and EC Inner calibration

# Forward Tagger Reconstruction

(R. deVita [INFN], & U. Edinburgh)

F T-Cal:

- Read raw hits from hipo bank
- Read calibration constants from DB
- Create hits, converting from digitized info to E and T
- Reconstruct cluster and determining cluster E, T and position




F T-Hodo:

- Read raw hit from evio bank
- Read calibration constants from DB
- Create hits, converting from digitized info to E and T
- Match hits in the hodoscope layers

F T- Track:

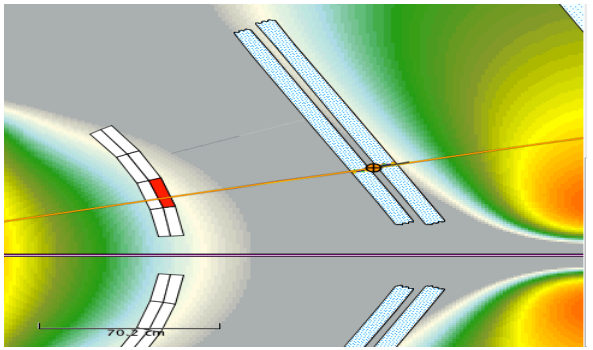
- started based on algorithm developed by G. Charles

F T-Match:

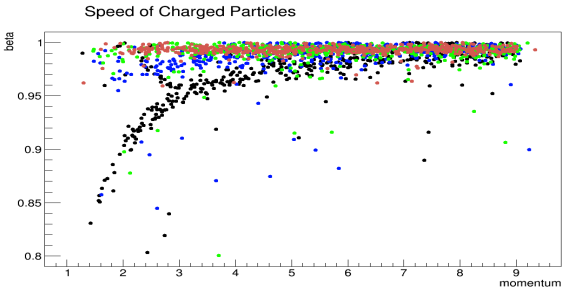
- Match reconstructed clusters with hits in hodoscope
- Output of final reconstructed particles
  - Code available in present COATJAVA distribution

# Event Builder Updates (J. Newton [ODU])

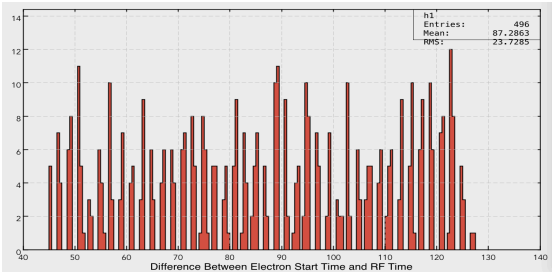
- Geometrical matching between HTCC hits and DC tracks
- Particle Identification
- CCDB parameters access
- New Output Banks
  - REC::Cherenkov = All Cherenkov Hits and their positions and number of photoelectrons
  - REC::Tracks = All Tracks Found at Hit-Based and Time-Based levels
  - REC::Event = Contains event-by-event information such as the event start time



HTCC Hit Matching based off reconstructed angles

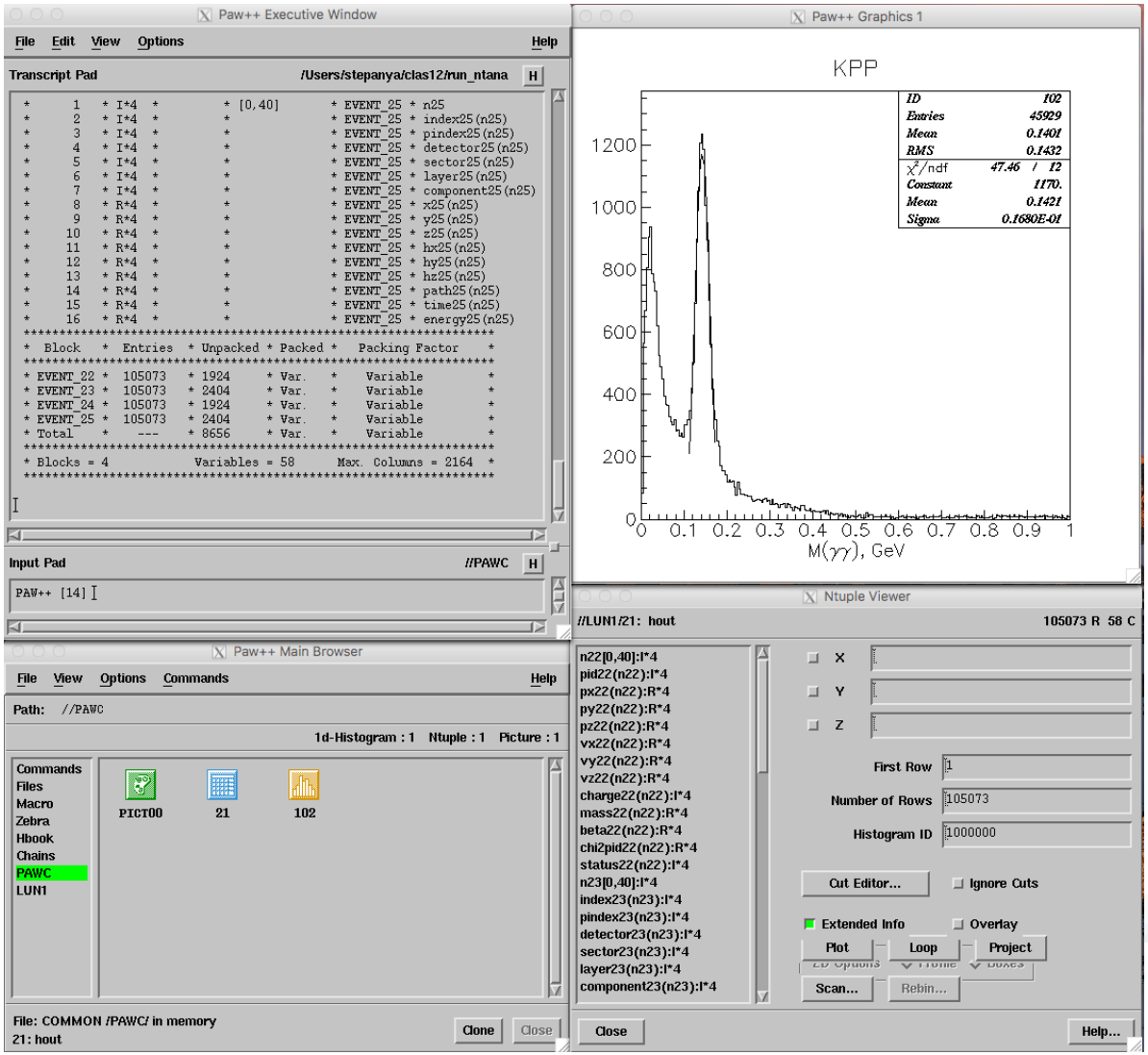



Particle identification based off speed of tracks, which is reliable at low momentum




Difference between the electron vertex time and the RF beam bunch time

# HIPO to ROOT conversion




- **C/FORTRAN API**
  - reading HIPO banks
  - convert to HBOOK
- **HBOOK conversion**
  - HEADER bank
  - EVENT bank
  - DETECTOR bank
- **SCRIPTS (PERL)**
  - automated include file generation for banks
  - automated fill code generation (F)
- **H2ROOT**
  - ROOT tree conversion
  - NT10 emulation

produced by S. Stepanyan

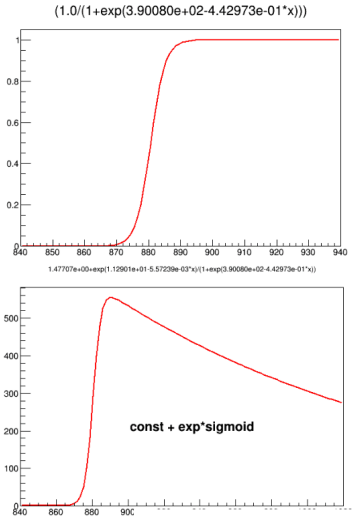
# Concluding Remarks

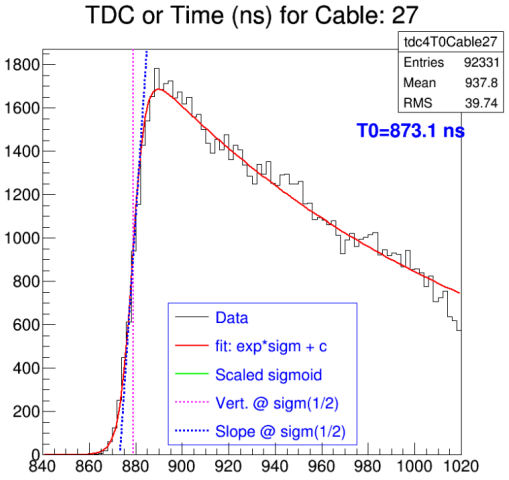
- Code used to cook & recook (after calibration) KPP data
  - * Code in github (see Nathan's talk on CLAS12 organization at First Experiment Workshop)
- KPP data used to improve reconstruction, find issues that are better revealed under realistic conditions with backgrounds
- Monitoring suites advanced stage
- Reconstruction in good shape
  - * Further work to be done for development and tuning of algorithms for nominal configuration including MM, CND.
- On track for engineering run

# BACK-UP SLIDES

# Automated Estimation of T0 (Signal Cable Time Delay) Correction (K. Adhikari)

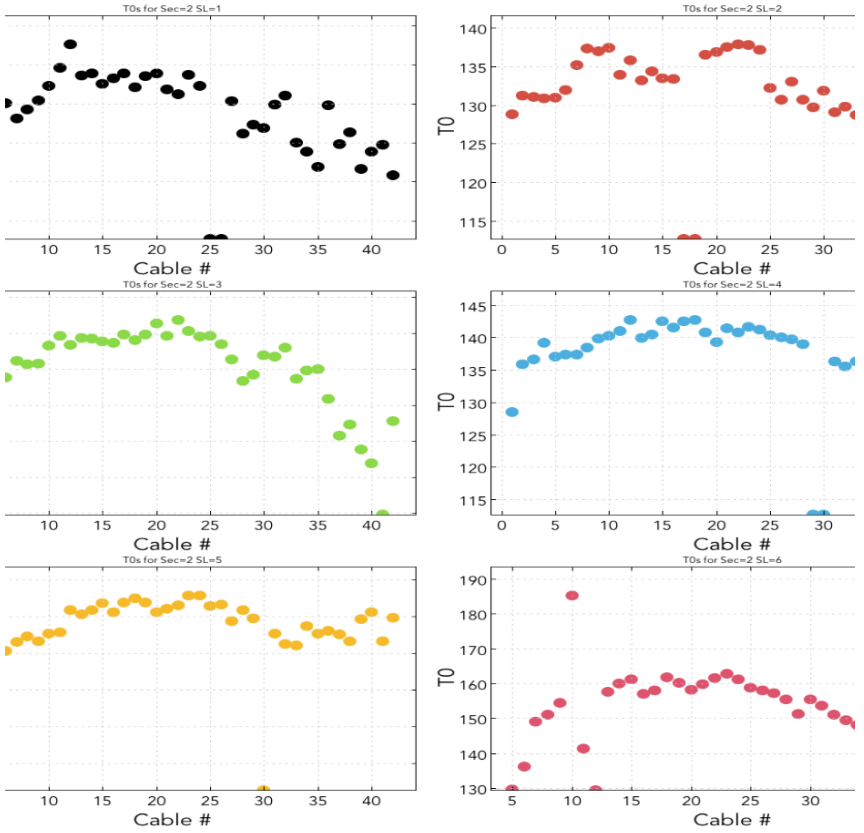
**Method to fit the TDC distributions rising edge**



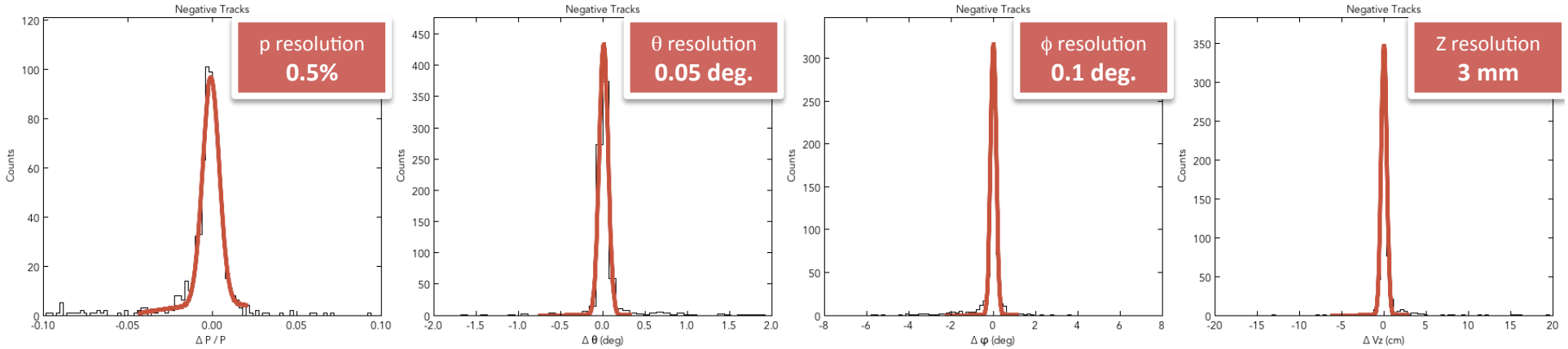

$$f(t) = e^{p_0+p_1 t}\frac{1}{1+e^{p_2+p_3 t}} + p_4$$

**Estimated T0 versus cable number (sector 2 - KPP data)**

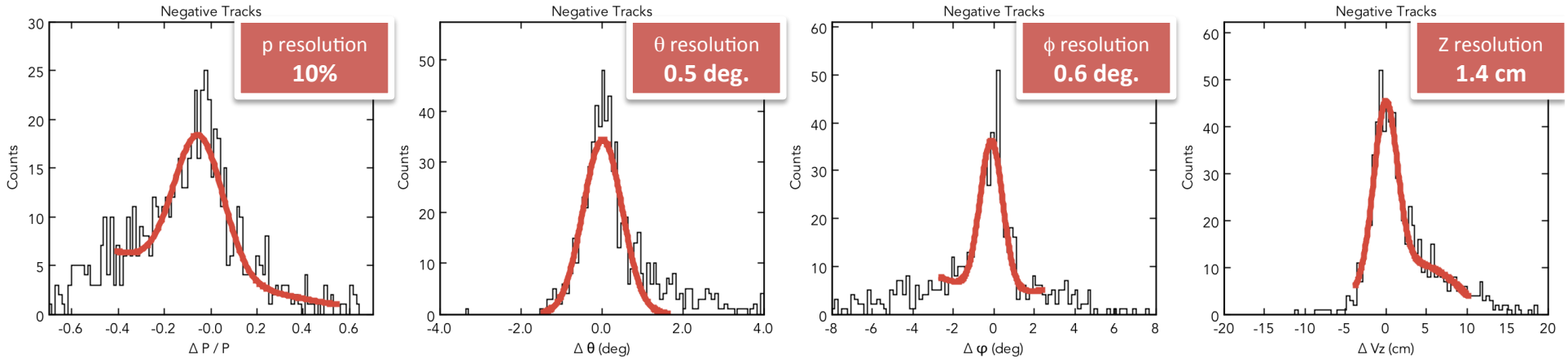


# Can we use this for 2-regions tracking ?

- only 1 superlayer missing




- 2-regions tracking (superlayers 5 & 6 missing): ~79% efficient



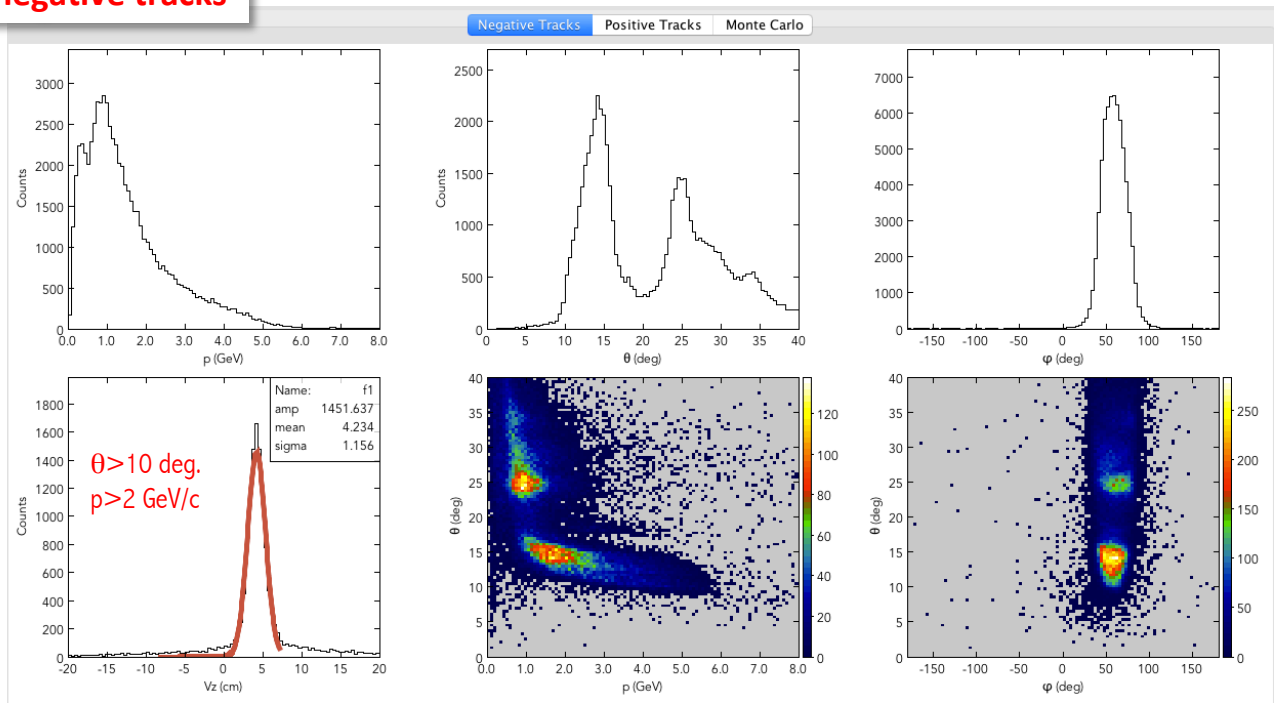

- Needs testing using low momentum tracks

# New Tracking Results

Chef Raffaella

**Torus Current *1900A***
***inbending* negative tracks**

**negative tracks**

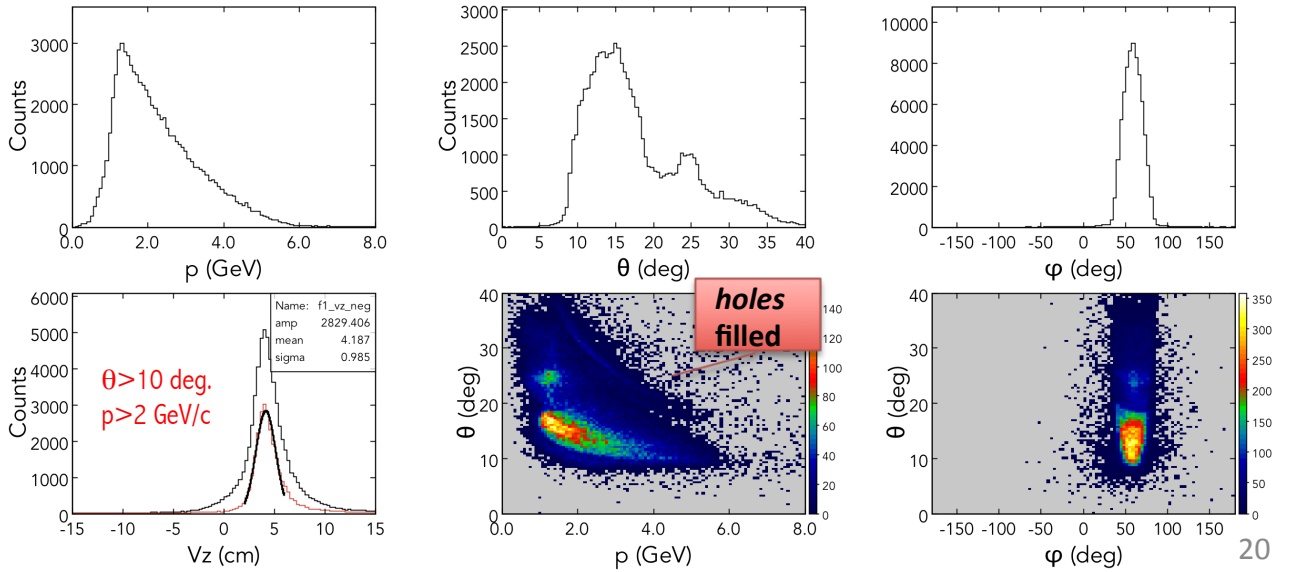



Previous Results
Runs 805--808

- ✧ **old Kalman Filter**
- ✧ **6 out of 6 superlayer tracking**
- ✧ **T0 values fixed at 135 ns**

New Results
Runs 804--808

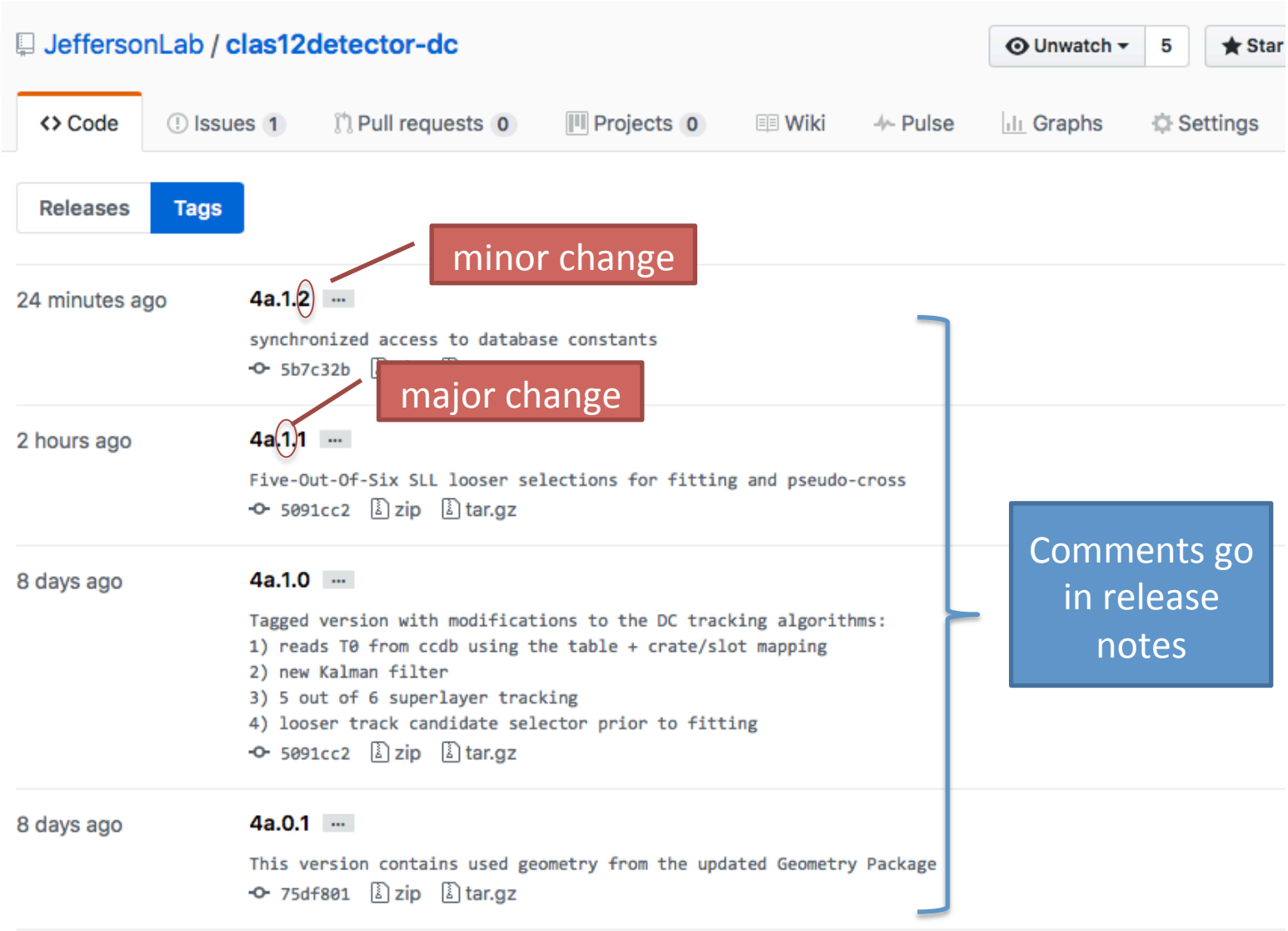
- ✧ **new Kalman Filter**
- ✧ **5 out of 6 superlayer tracking (unoptimized selection)**
- ✧ **T0 values from calibration (Krishna)**



# Code Organization

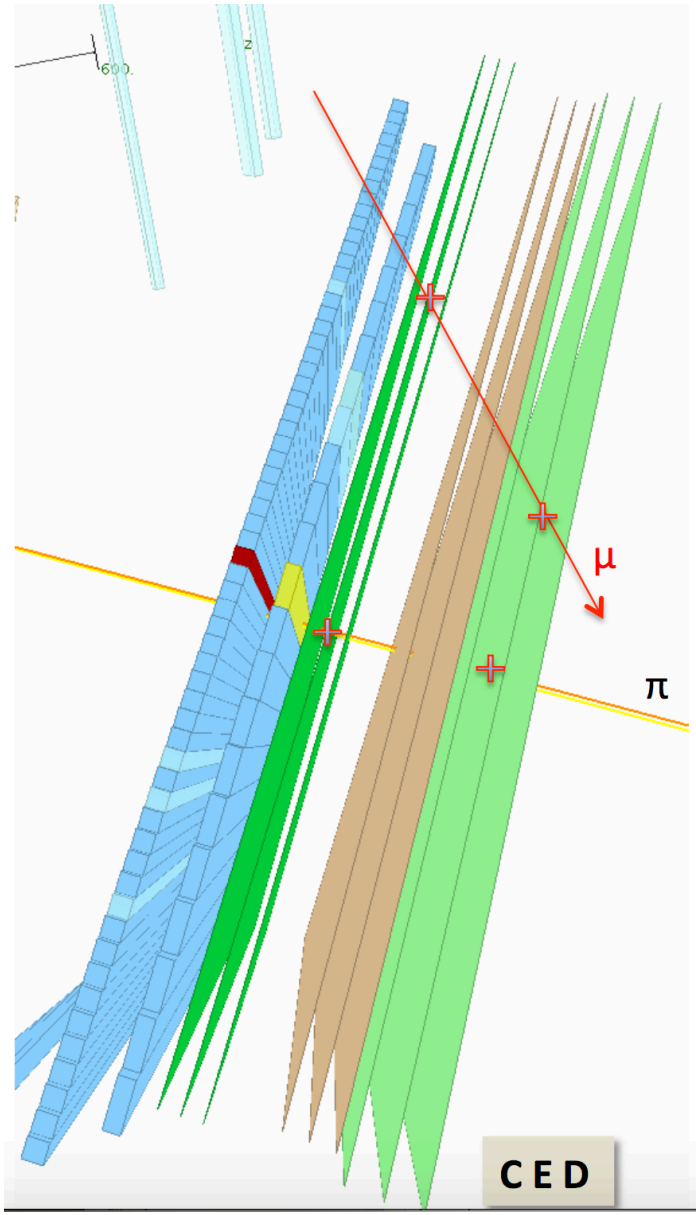
- Reconstruction tagging scheme utilized…

Code in Git




- Github reorganization in progress (Nathan)

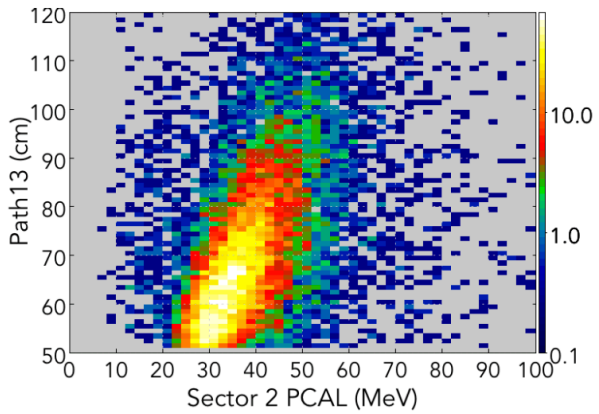
# EC/PCAL Reconstruction (C. Smith)



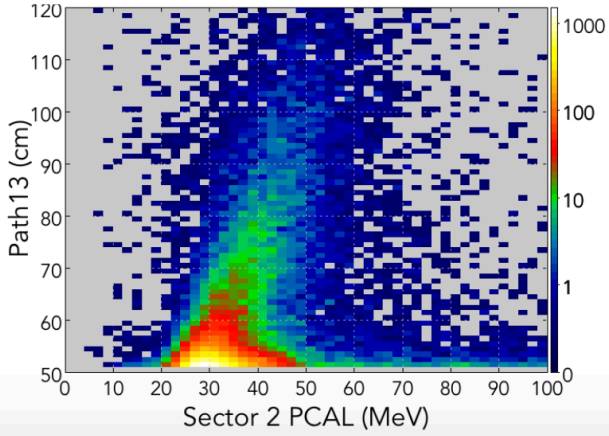

## Rejection of cosmic tracks

Tracks which pass cluster multiplicity cut can still be rejected using track path-length:

$$pathij = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2 + (z_i - z_j)^2} \quad i,j = 1:PCAL \;\; 2:ECin \;\; 3:ECout$$




**Run 760**
Low threshold. Beam off events show pathlength distribution of cosmic triggers.




**Run 809**
High threshold. Triggers dominated by short pathlengths at MIP energy of 30 MeV.