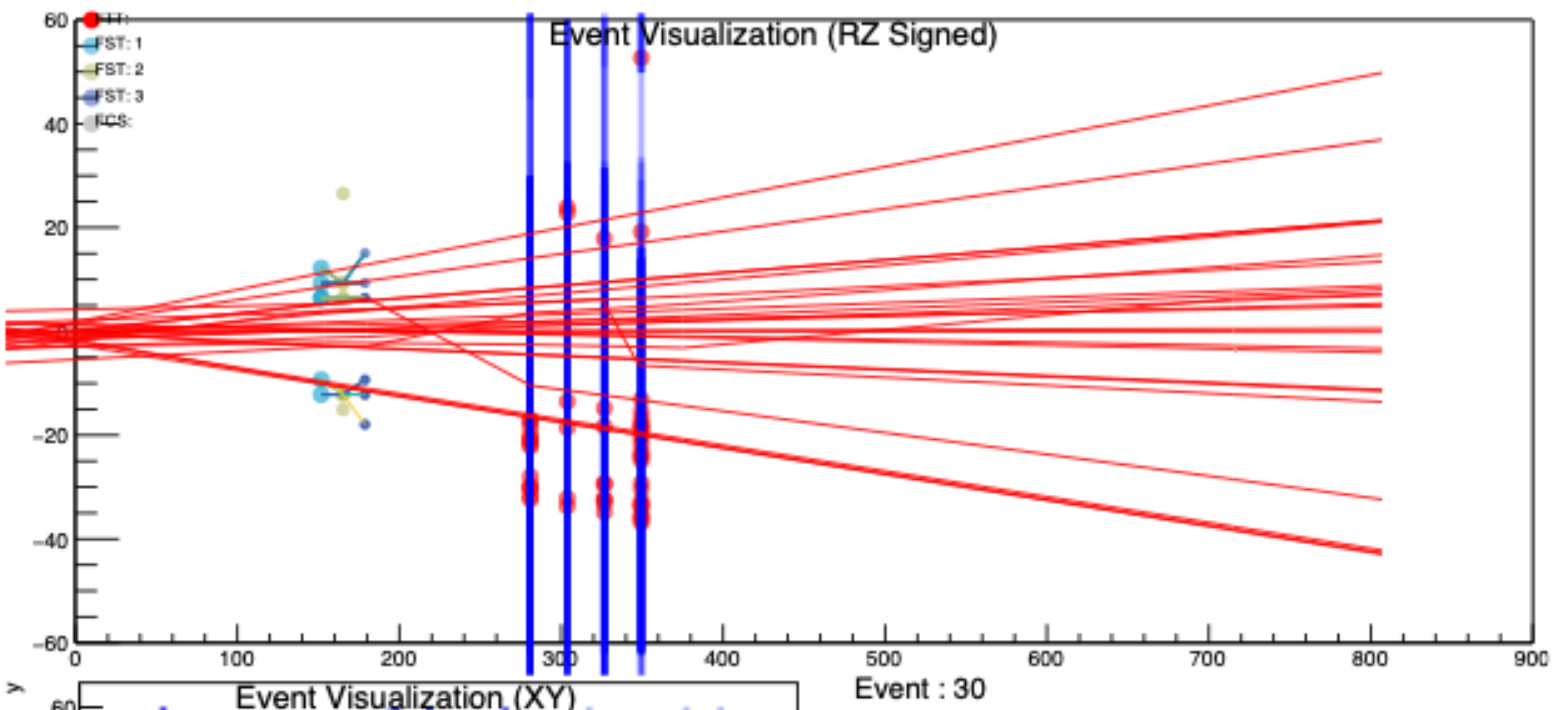
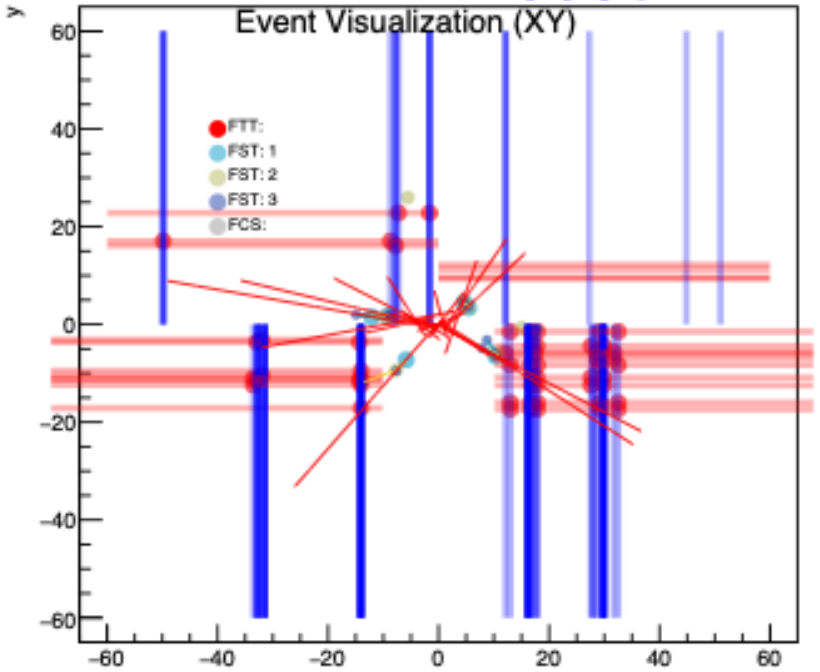




2D event display
Amarise Edgell (OSU undergrad)

Can be run on thousands of events, helpful in debugging/analysis

STAR FWD Upgrade Progress, Status, Plans

Daniel Brandenburg
(and the FWD team)

Jan 22, 2025

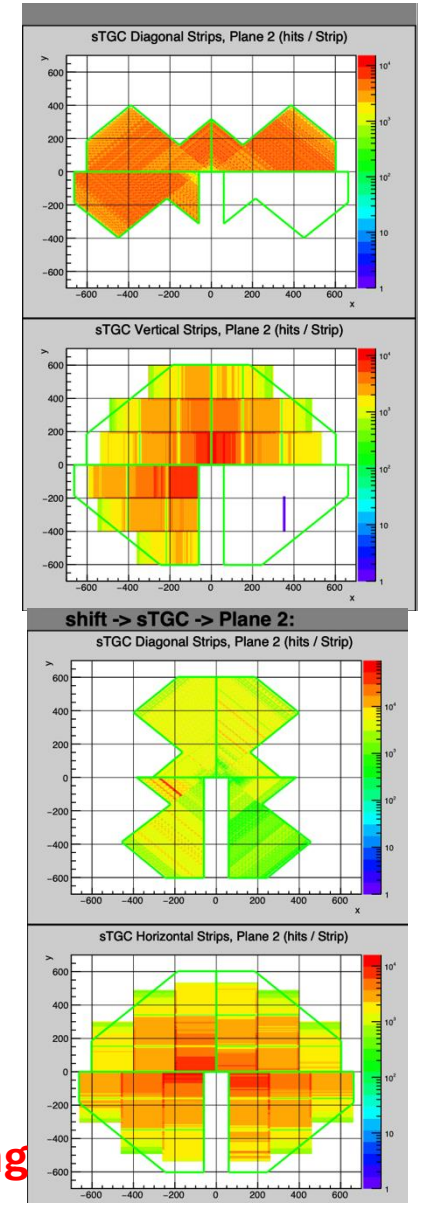
Recent updates / status

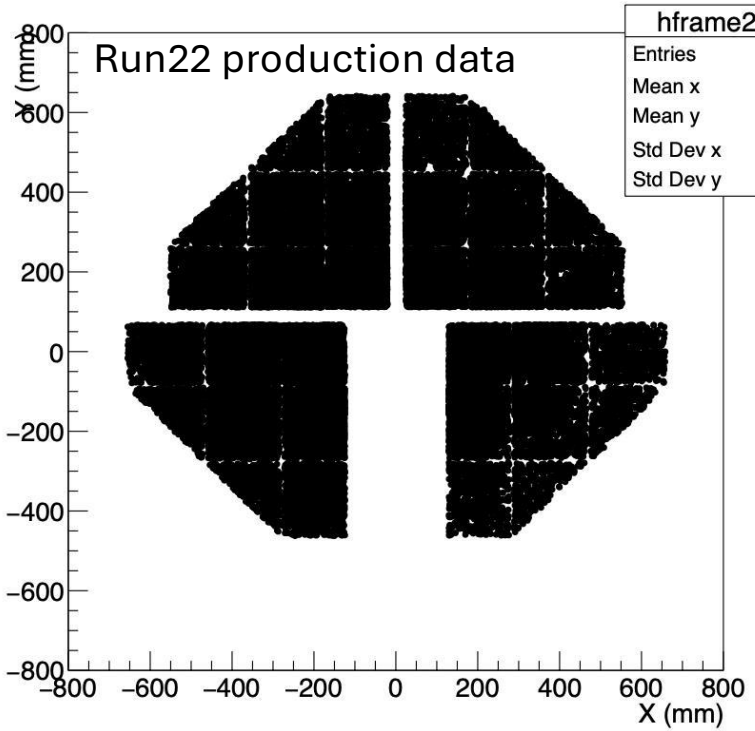
- Large scale simulation “analyses” w/full output (StEvent, MuDst, PicoDst)
  - 1M Pythia events fully processed with Fwd Tracking + Calorimeter matching
  - Various single particle gun samples – for closure tests
- Fwd picodst integration FWD#639 – code is ready, will push when others have investigated some
- Several other minor updates (FCS projections, Vertex handling)
- sTGC status
  - Slow simulator, reconstruction chain completed during Zhen-wang’s summer stay at OSU
  - Fully tested in private code
  - Code uses local text files for hardware mapping (strip centers, left/right edge, etc.)
  - Zhen has been working on databases, but slow progress
- New people involved:
  - Xihe Han – alignment (working with Gavin)
  - Jasleen sandhu – Working on track-cluster matching in field on data
  - Sam corey – Working with Zhen Wang on sTGC codes

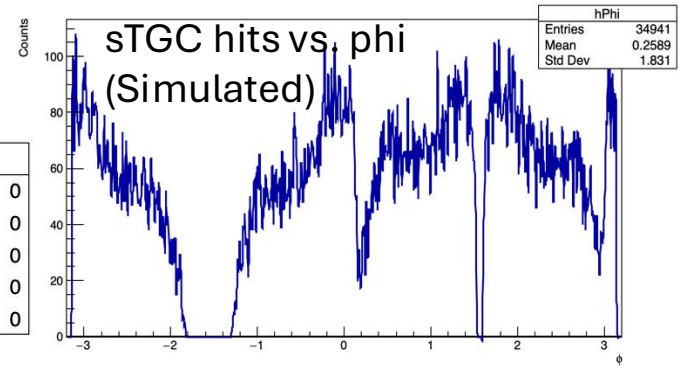
sTGC Spacepoint Reconstruction

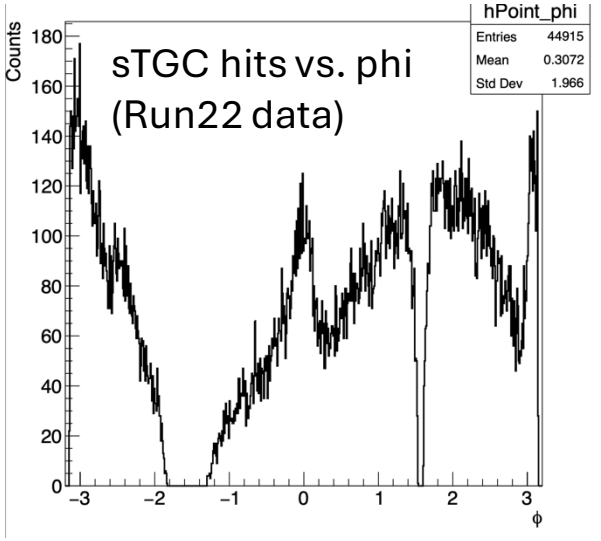
- Algorithm for spacepoint reconstruction utilizing x, y and diagonal (u) strips.
- Good correlation observed between layers: (x+y)-u shows peak at 0, sigma determined by 3.2 mm strip width
- Completion of realistic simulator needed for embedding. Injects signals at lowest level of data reconstruction.
- Alternative algorithm completed to utilize sTGC planes with inoperable module
- Consistent performance from Run22 – Run24

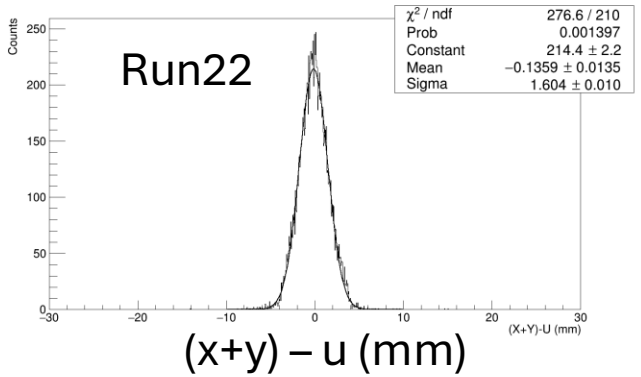
Huge effort from Zhen Wang



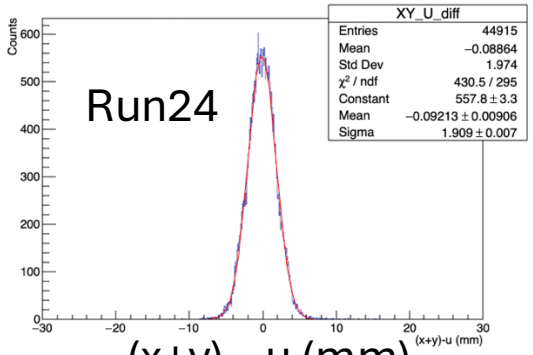








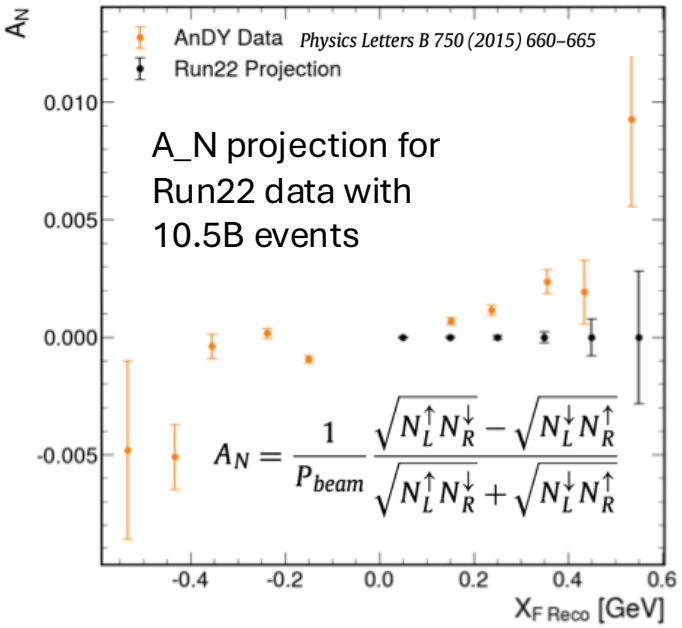
(x+y) – u (mm)

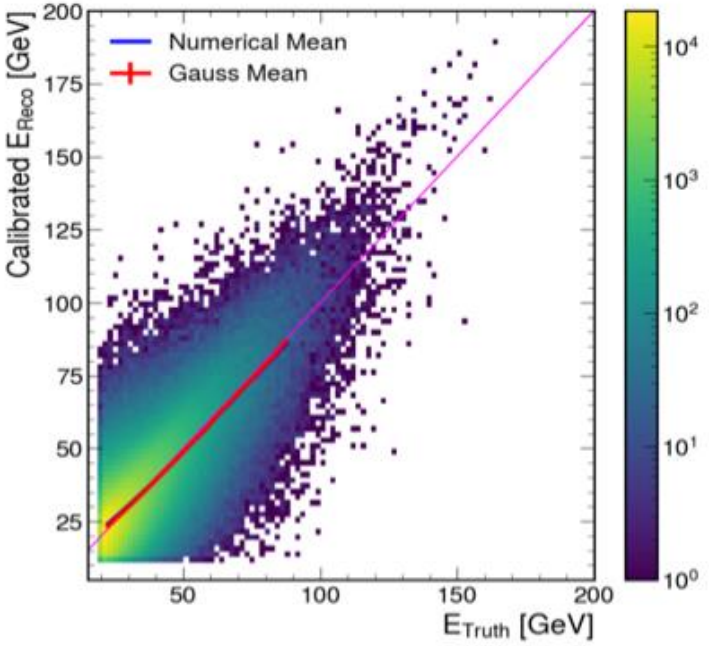


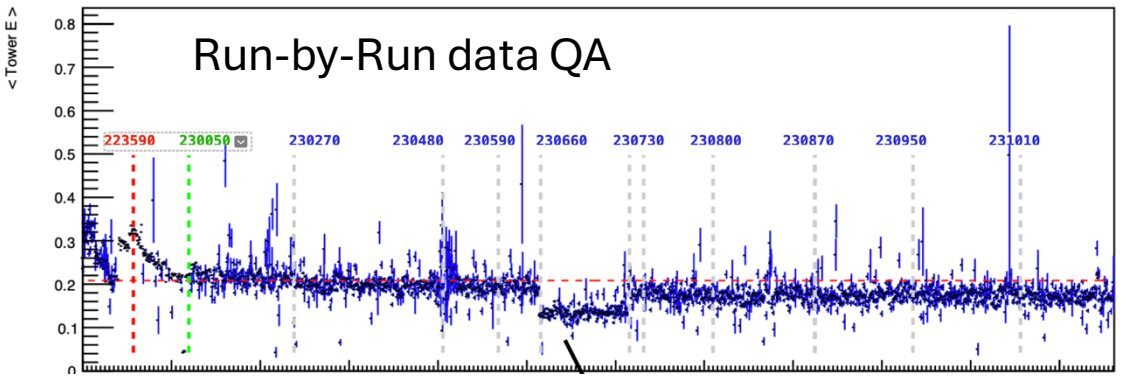
(x+y) – u (mm)

Ongoing Analyses

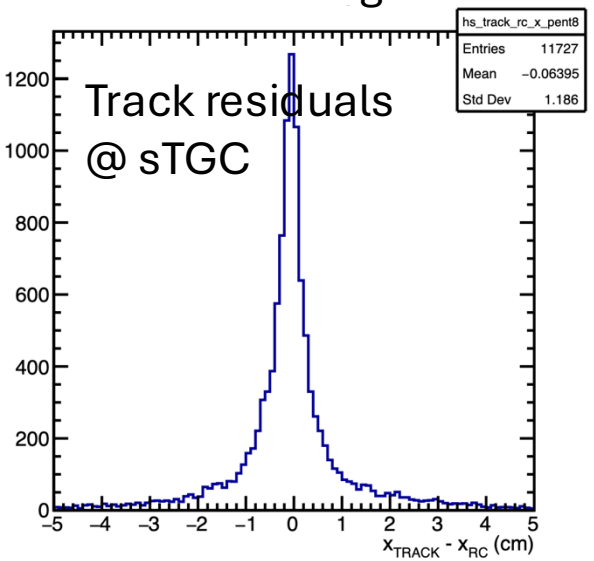
- First production of Run22 data with FWD detectors is complete (as of mid-Aug, 2024
  - QA of data throughout production process
  - Analysis of transverse single spin asymmetry with pi0 ongoing (and part of a PhD thesis)
- Jet energy calibration studies & comparisons with Pythia 6 & 8 simulation
- Lambda and J/psi investigations ongoing (simulation studies and first look in data)
- Undergraduates involved in tracking optimization and calibration studies

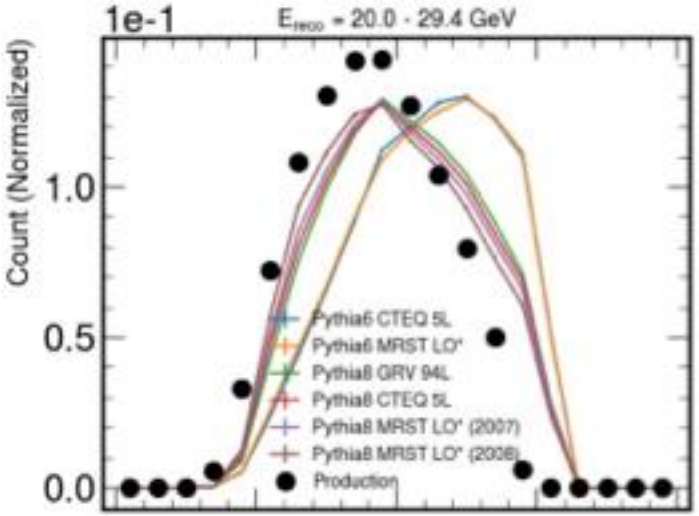






Data driven alignment



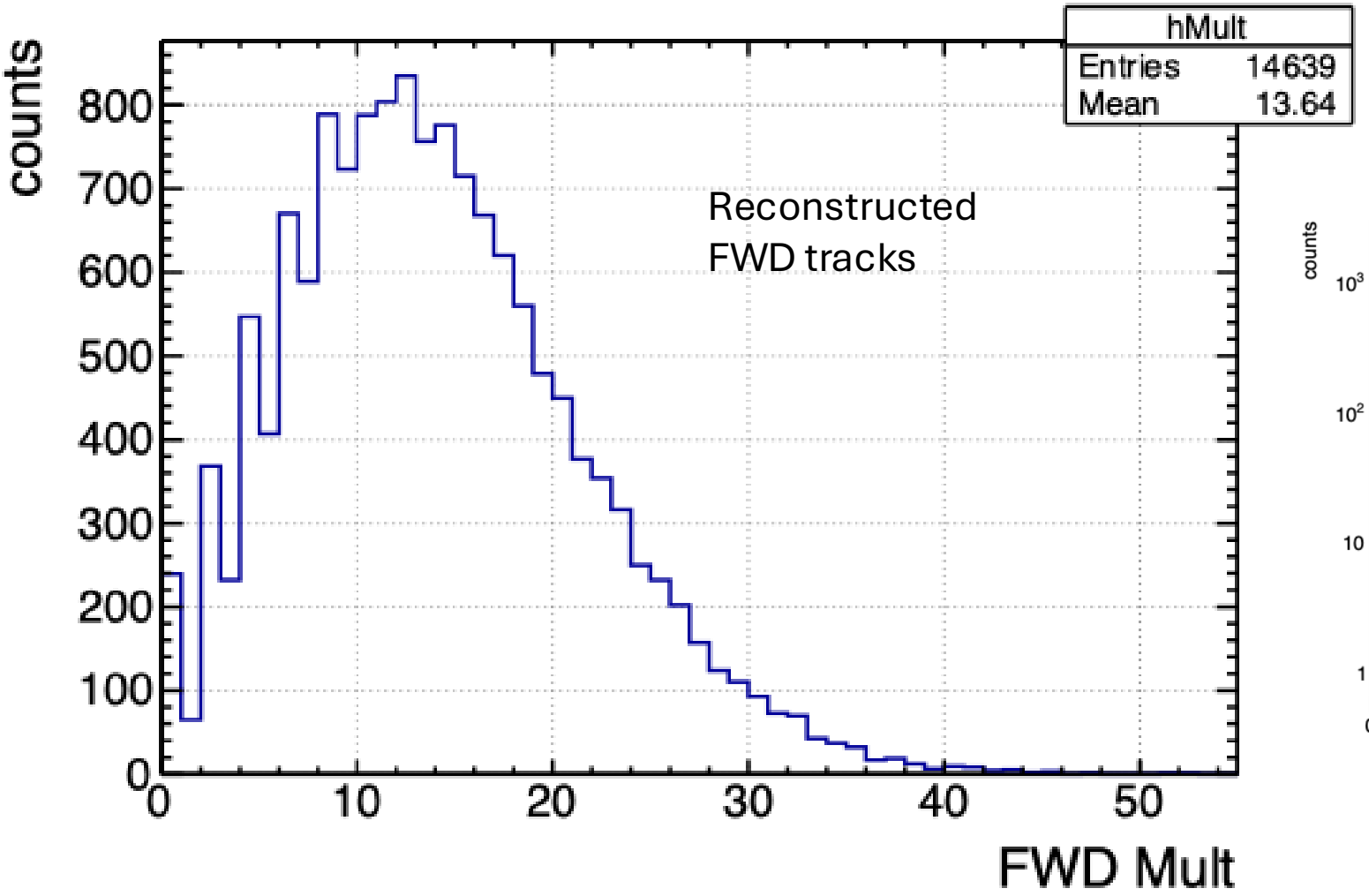


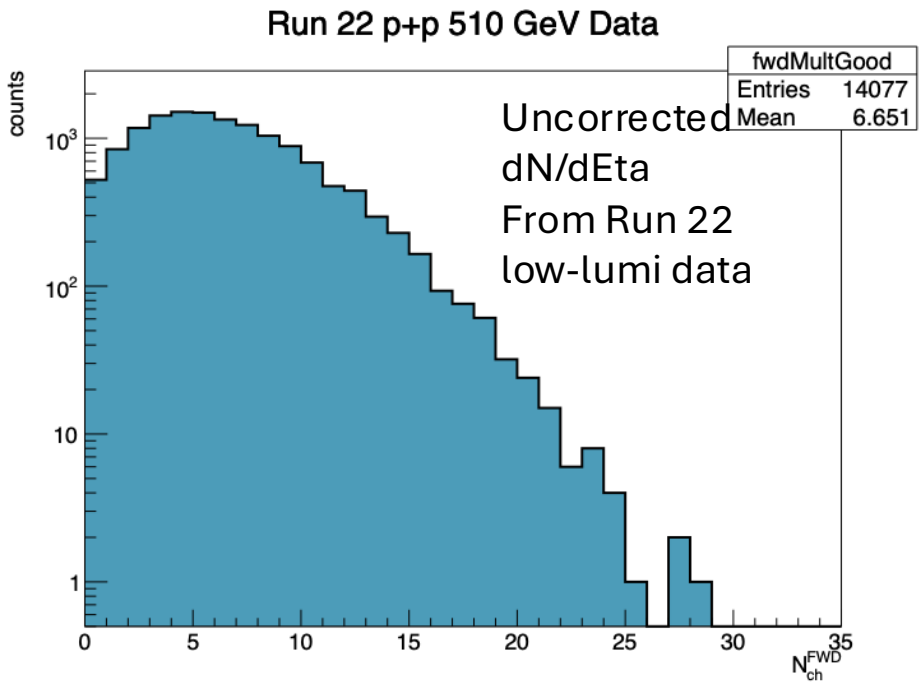
•Discrepancy between MC and data may be caused by different triggers, and/or the generator may need to be tuned for high pseudorapidity

Pythia Study

- **Pythia Samples**
  - **510 GeV p+p samples with no filter**
  - **/gpfs01/star/pwg/mrosales/jetFinderTest2024/star-sw/Jet_Data_NoFilter_500/**
  - **~1M events, 100 files with 10k events each**
  - **Detailed information about pythia configuration etc. on Fwd Wiki**
  - **Look here at tracking performance in full events**

Tracking performance

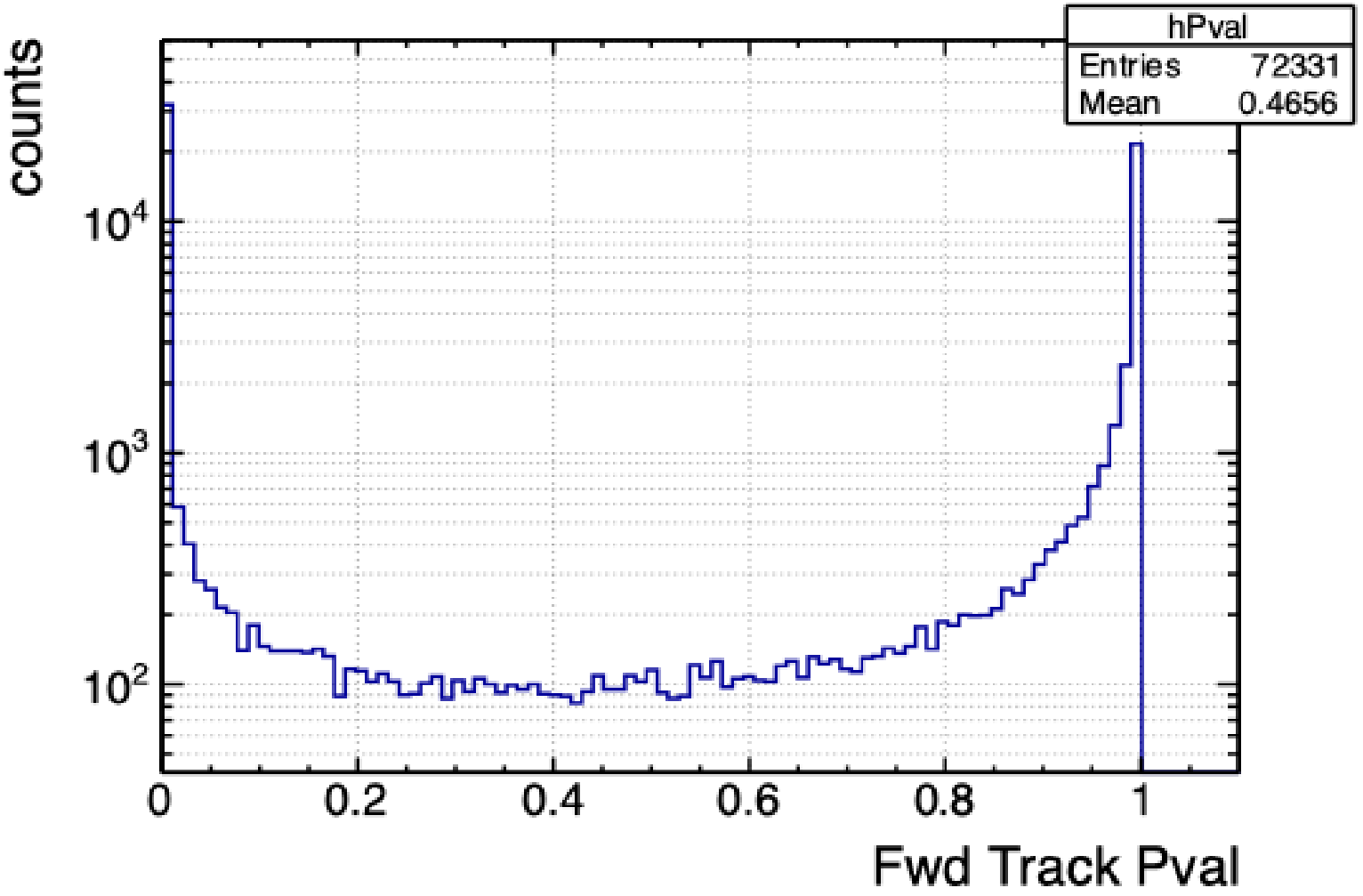




Qualitative agreement with data, healthy mult.

*Higher efficiency expected in future productions

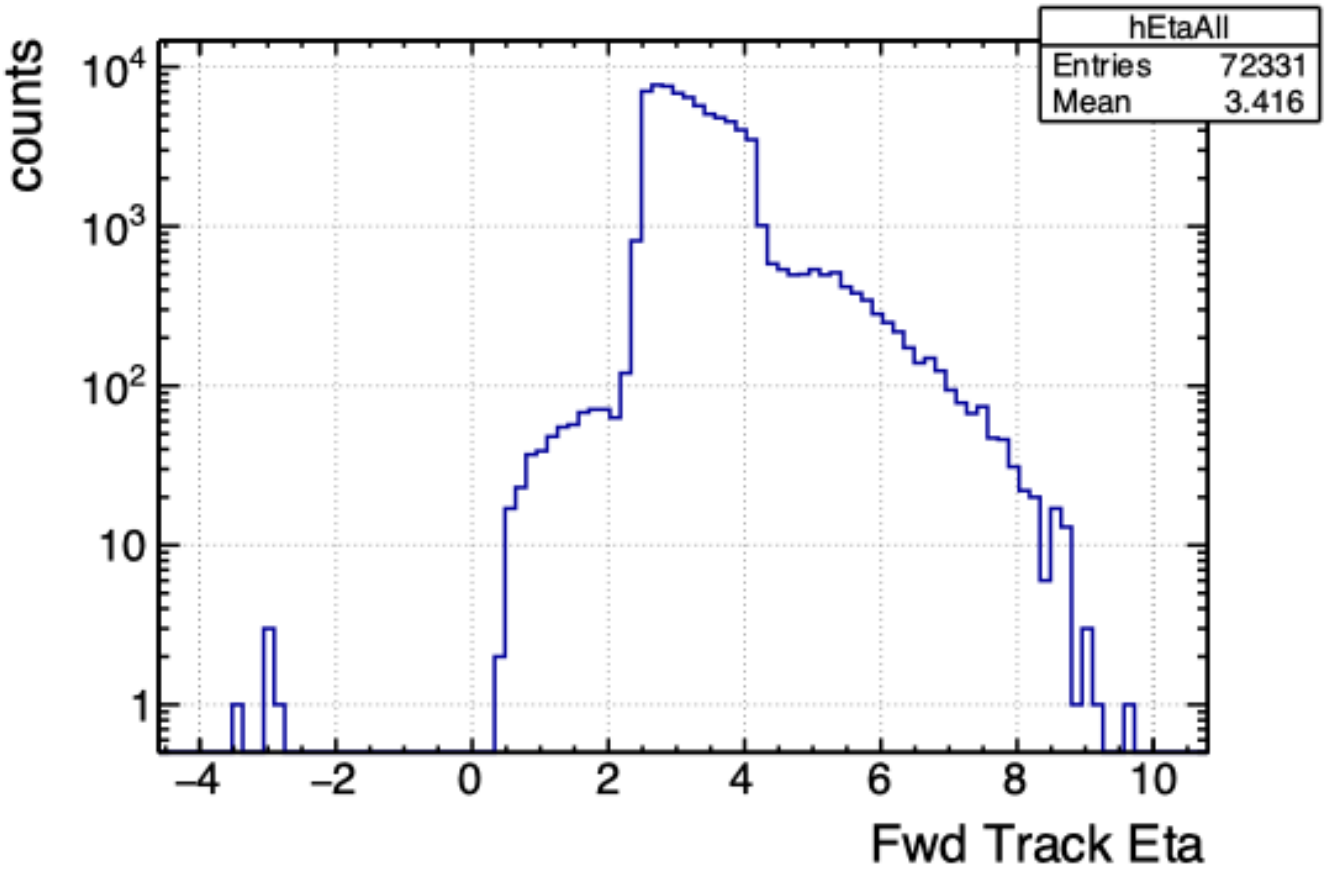
Track fit Pval

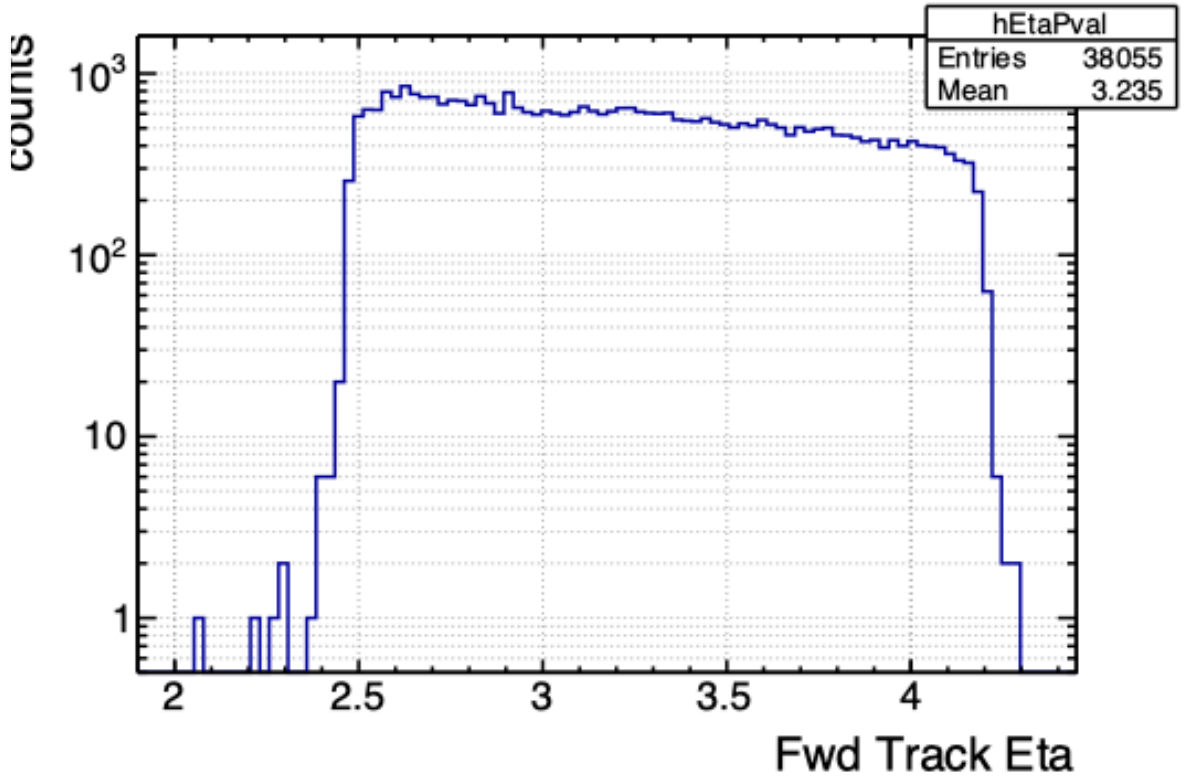


Track fit Pval is healthy across all Pythia events / tracks

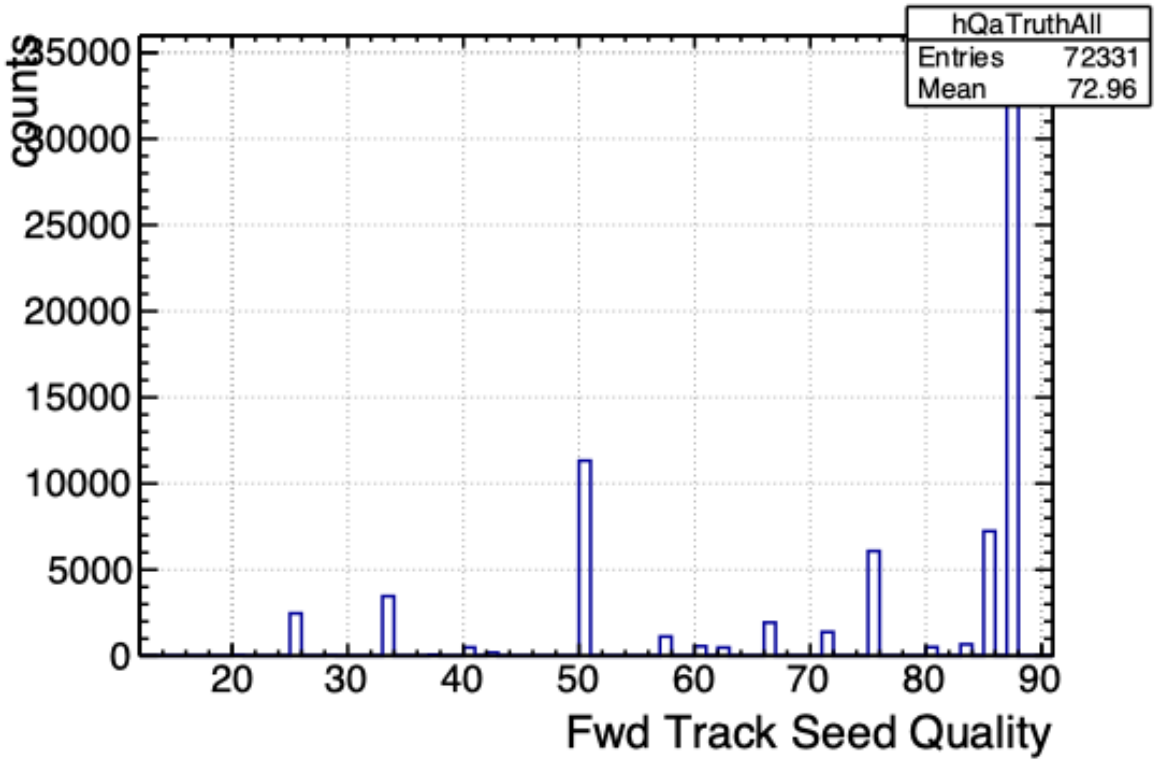
Pval also useful for distinguishing “good“ tracks

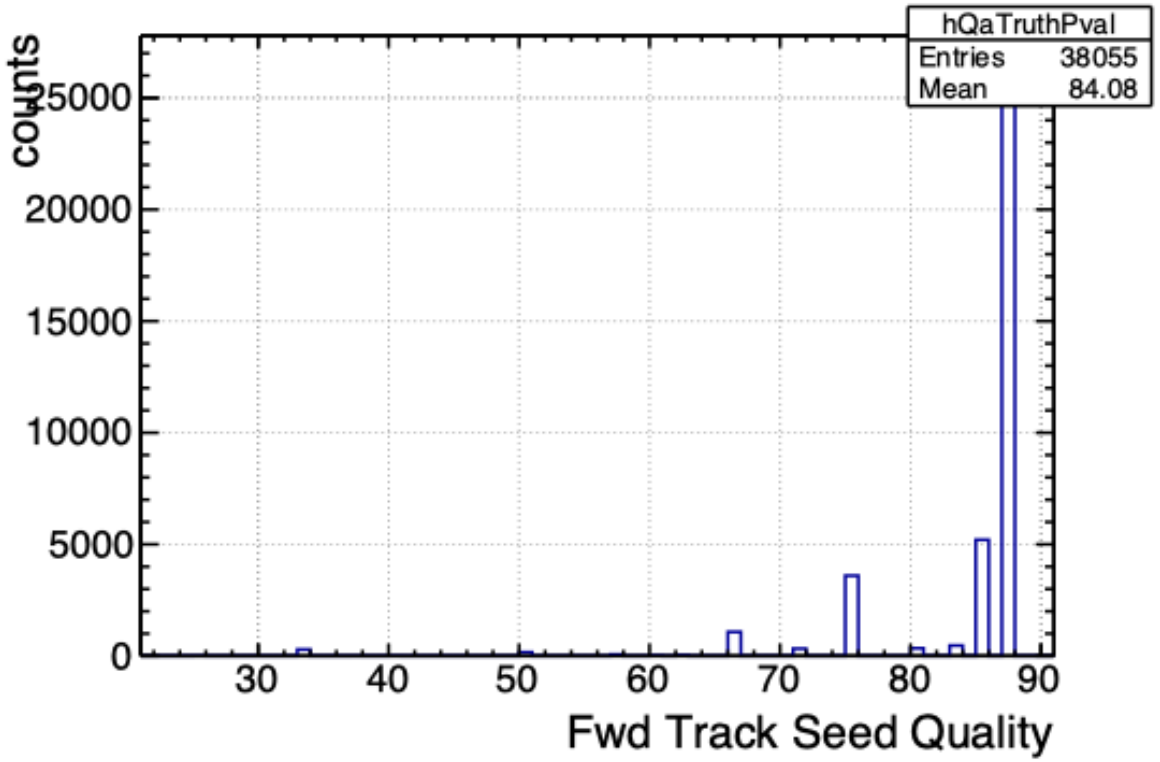
Reconstructed Eta





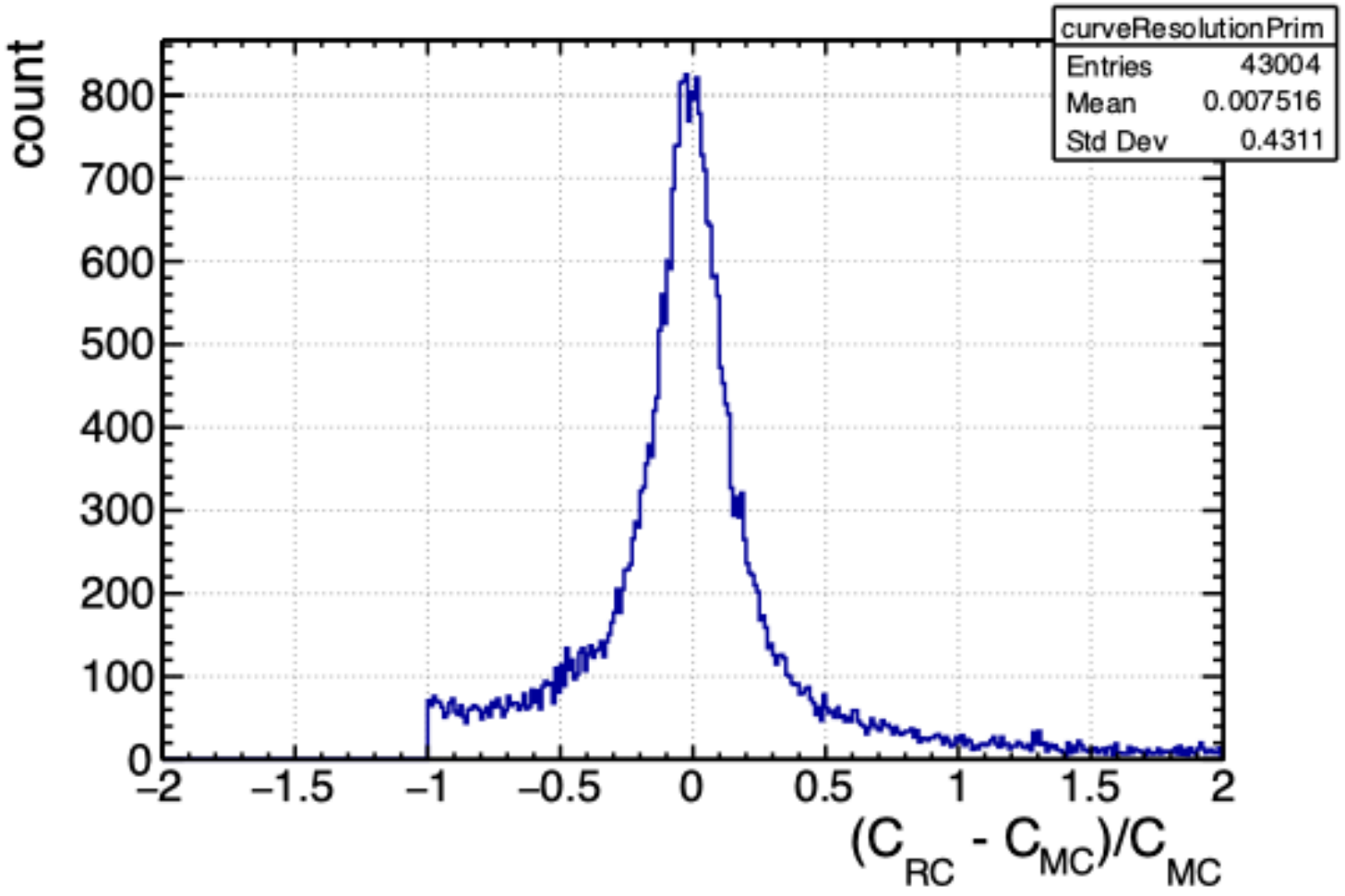
Track Seed Finding in full Pythia Events





With loose Pval cut (>0.1) – seed quality is already quite high (~0.85)
Can be further improved by requiring more hits on track

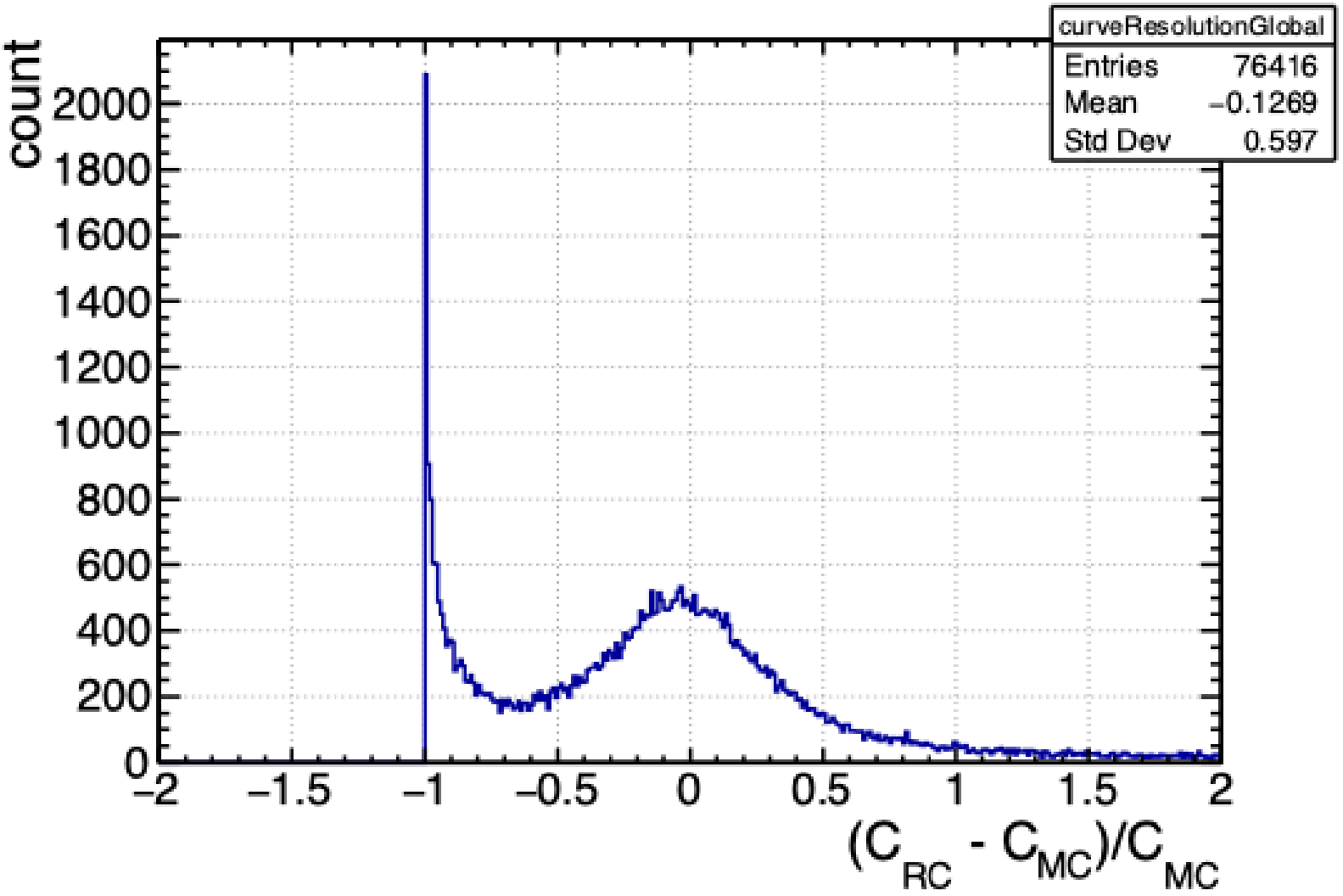
Transverse Momentum Resolution



Curvature ~ 1/Pt

Very healthy and good average resolution (for FWD)

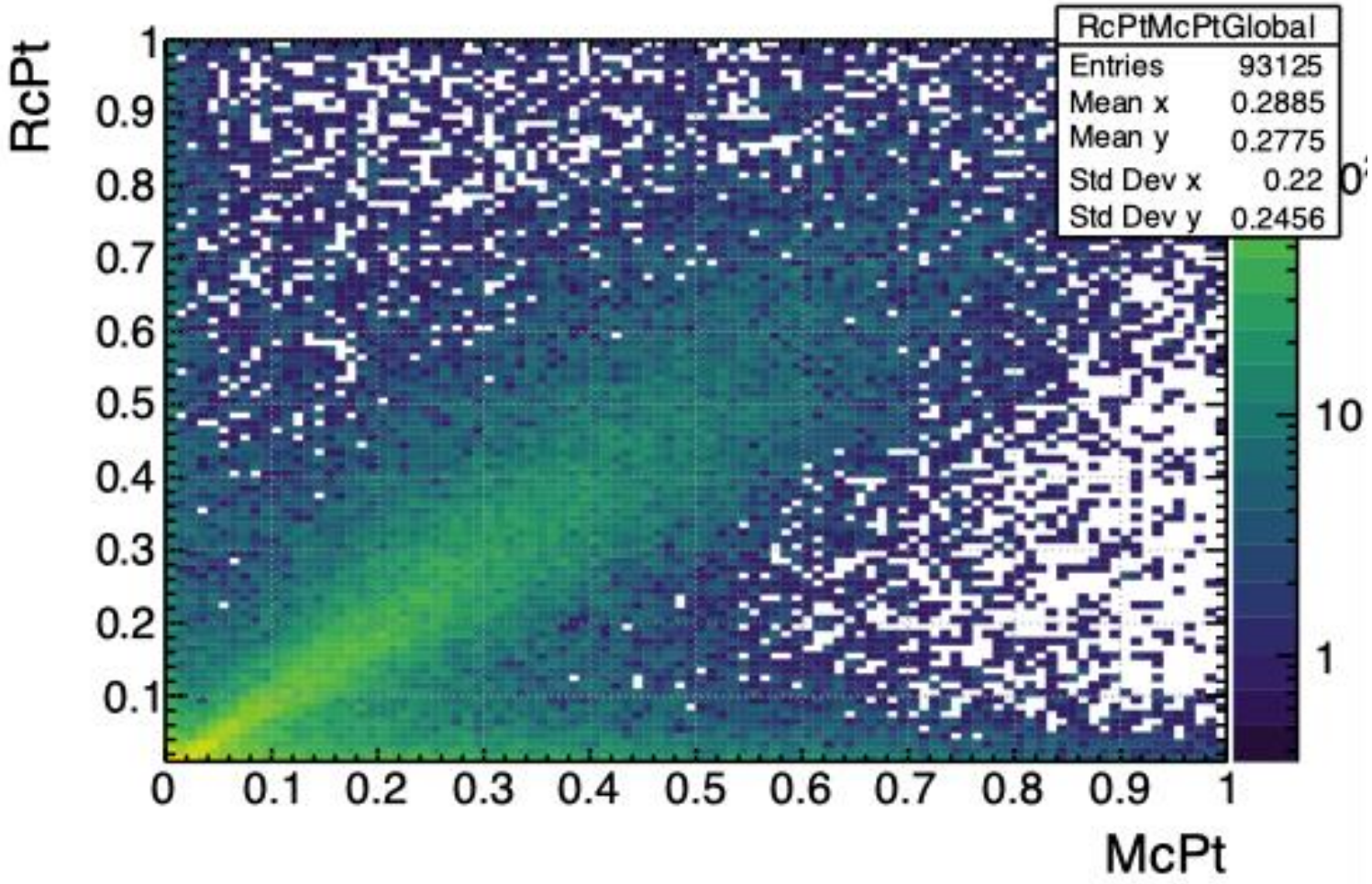
Transverse Momentum Resolution

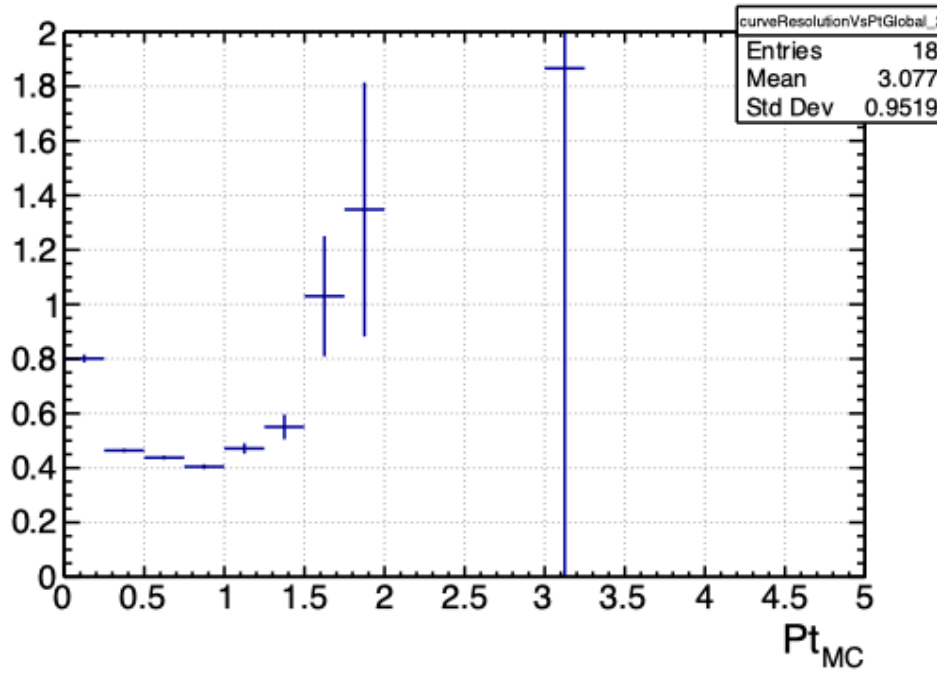


Primary vertex clearly improves the resolution

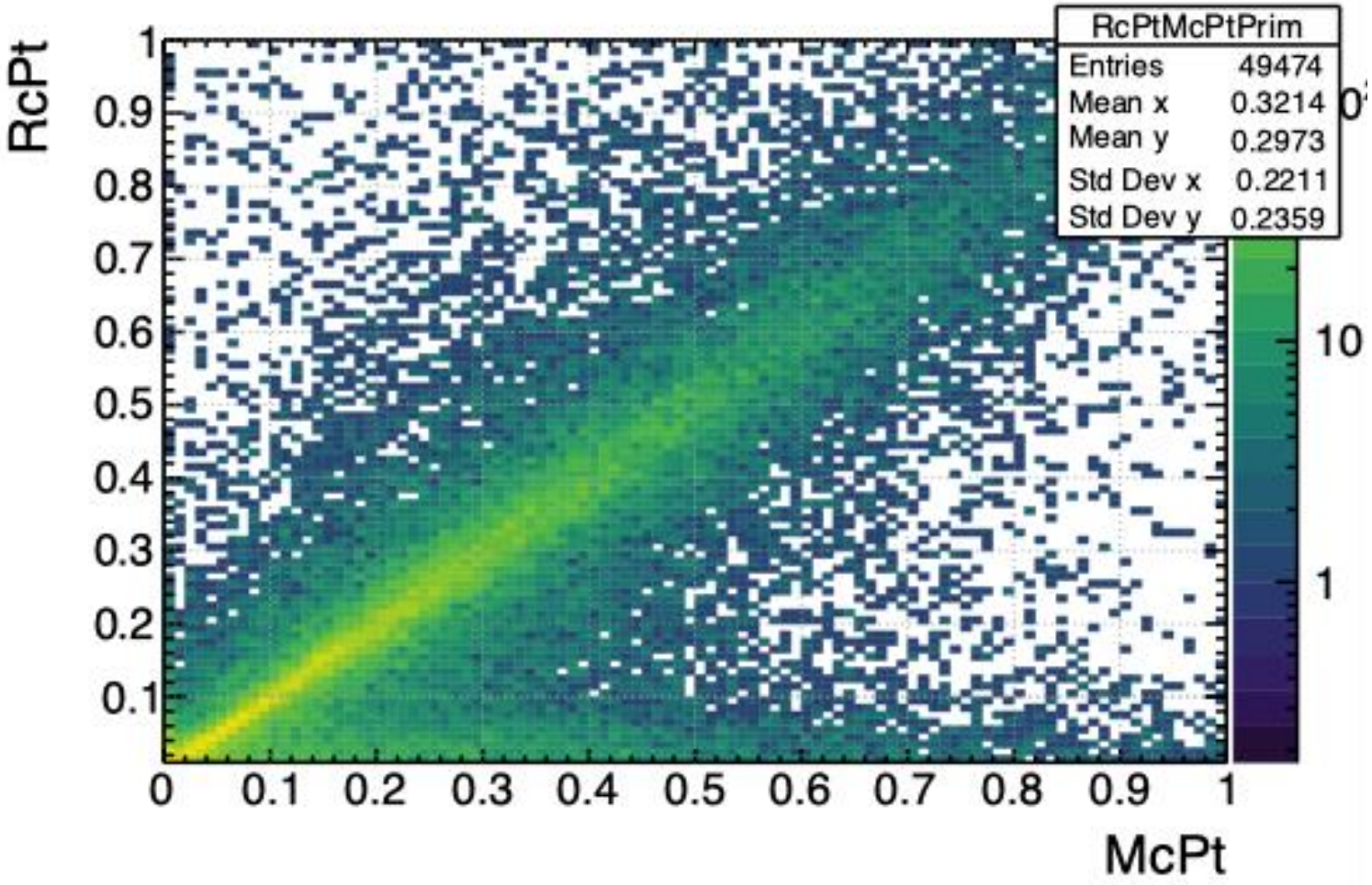
But global tracks still show correlation

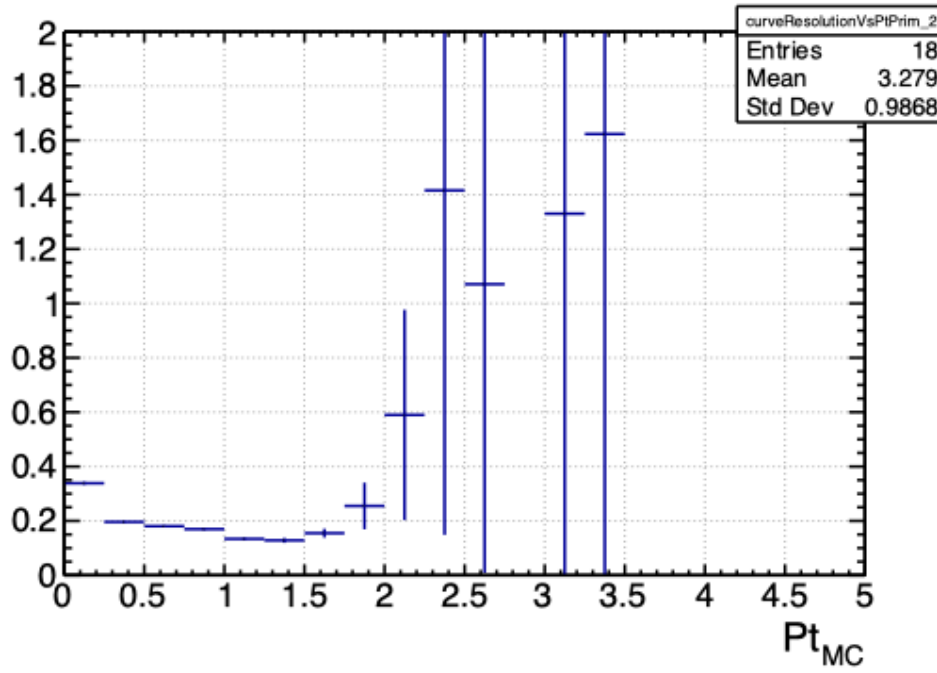
Transverse Momentum Resolution



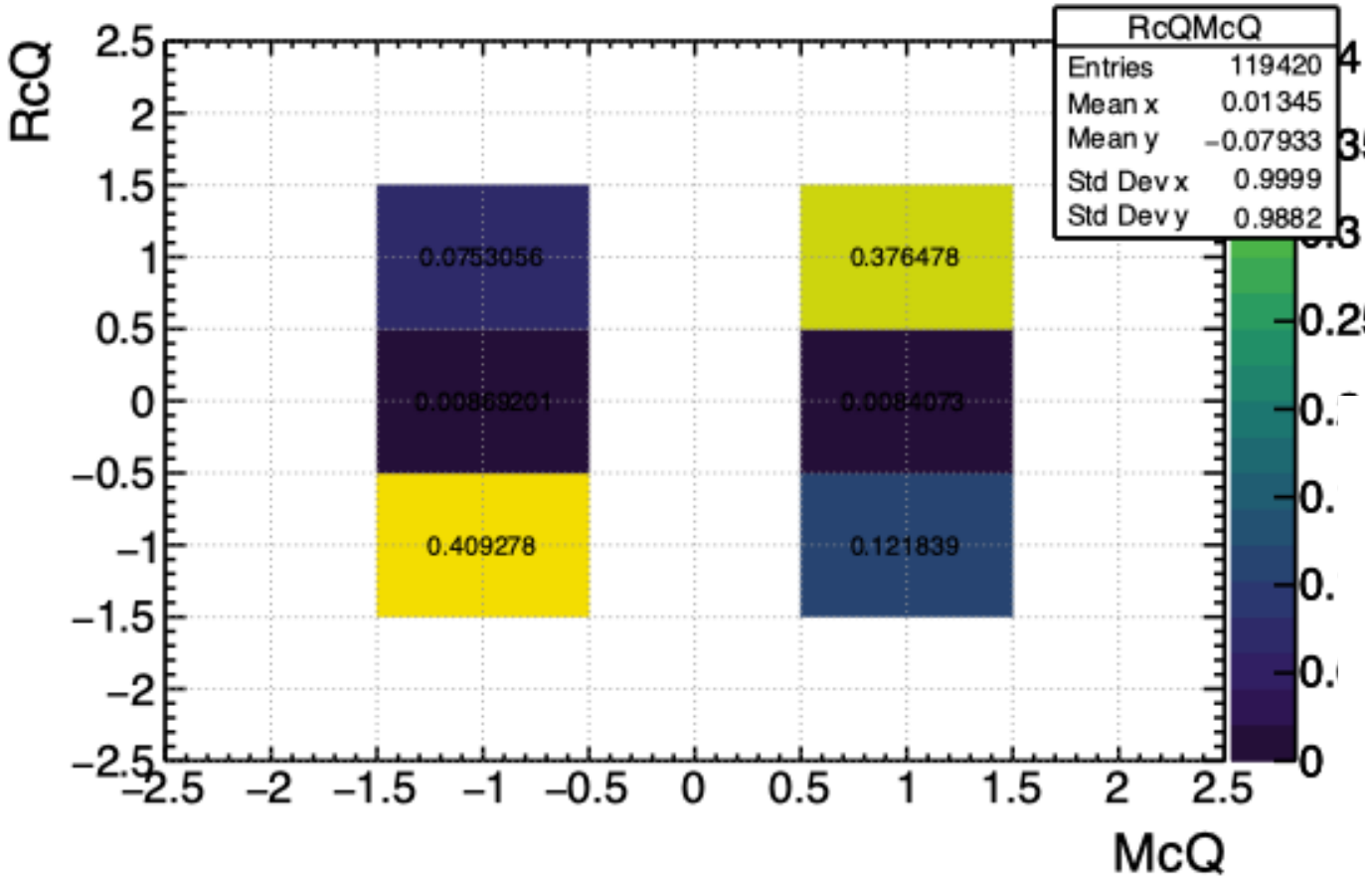


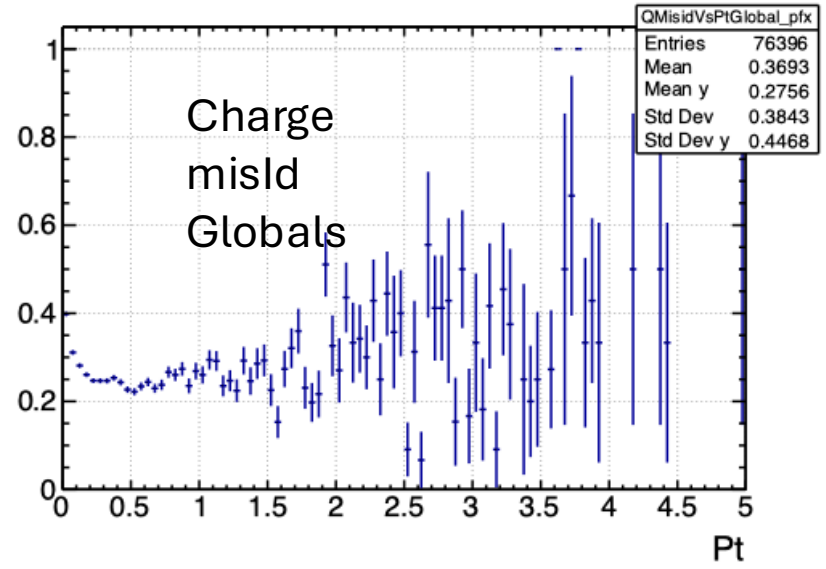
Transverse Momentum Resolution

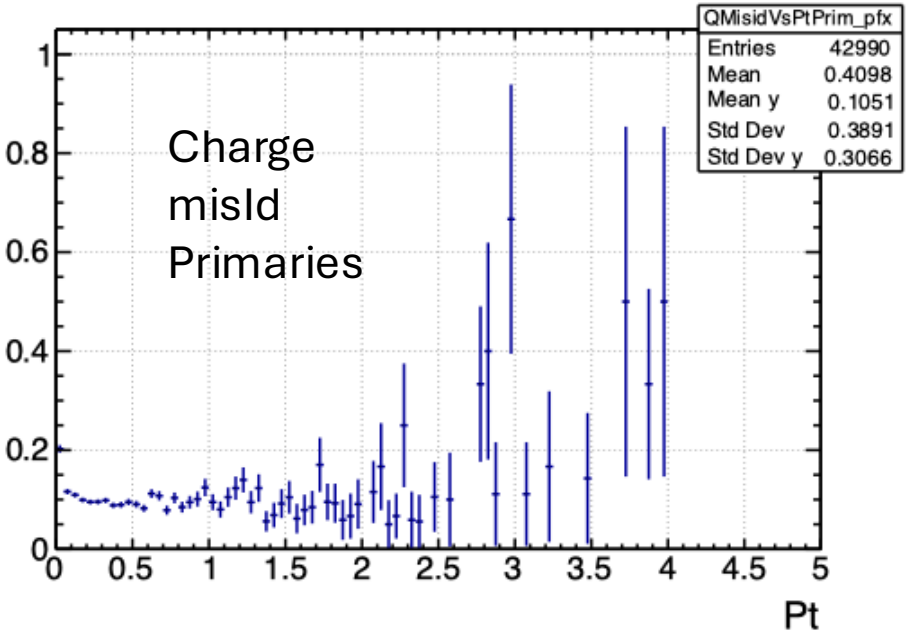




Charge Identification





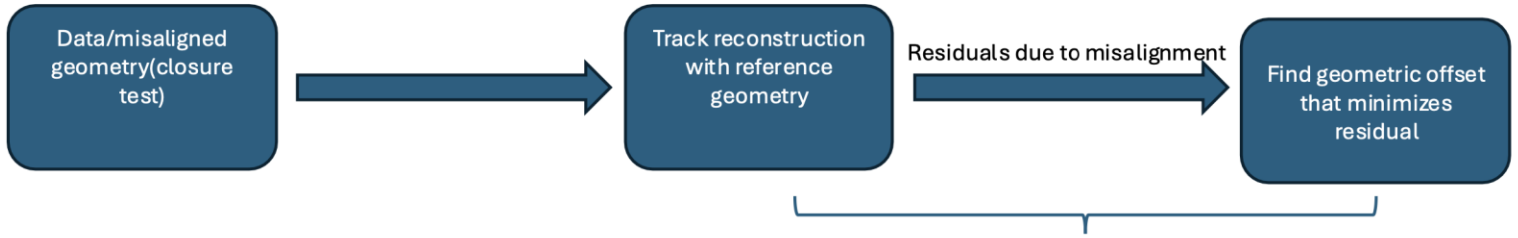


Alignment:

Alignment is needed for data to be consistent (momentum resolution / charge id rate) with pythia simulations

- Obtain shifts in the tracker geometry through tracking-based alignment.
  - Statistical uncertainty should be lower than hit resolution (10s of micron)

- Highest level workflow



Alignment process: record + minimize chisq

- To linear order, minimizing chi^2 reads:

$$\chi^2(\mathbf{g},\mathbf{l}) = \sum_j^{\text{tracks}} \sum_i^{\text{hits}} \frac{1}{\sigma_{ij}^2} \left(\mathbf{m}_{ij} - \mathbf{p}_{ij}(\mathbf{g}_0,\mathbf{l}_0) - \frac{\partial \mathbf{p}_{ij}}{\partial \mathbf{g}} \Delta\mathbf{g} - \frac{\partial \mathbf{p}_{ij}}{\partial \mathbf{l}_j} \Delta\mathbf{l}_j \right)^2$$

  - Where m is measured value, p is predicted value(from fit), g is global(geometrical) parameters, and l is local(track) parameters.
  - Our goal is to find Delta g. Therefore, we must provide the following:
    - Variance Matrix σ
    - Global derivatives
    - Local derivatives
    - Residuals m-p

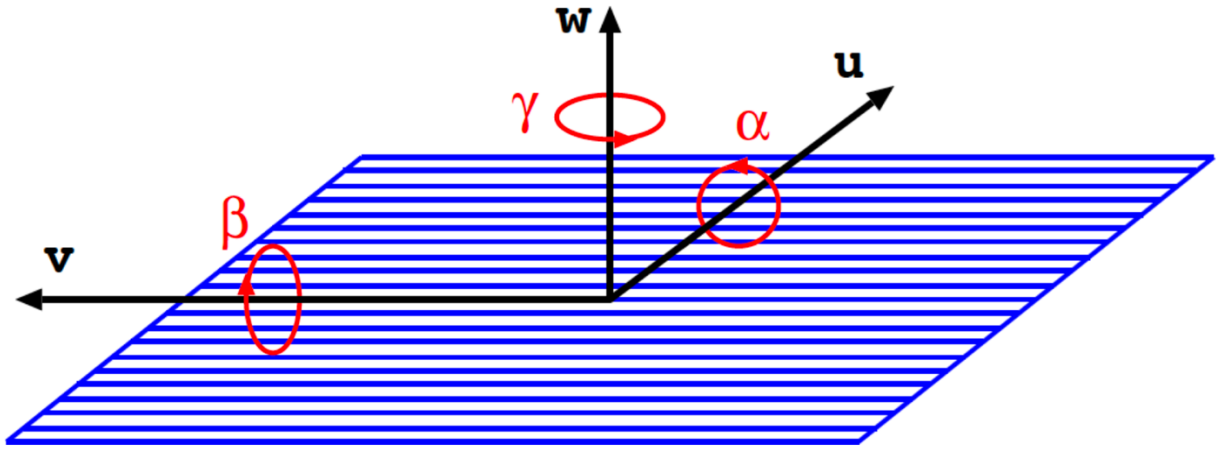
Alignment Parameters FST

FST

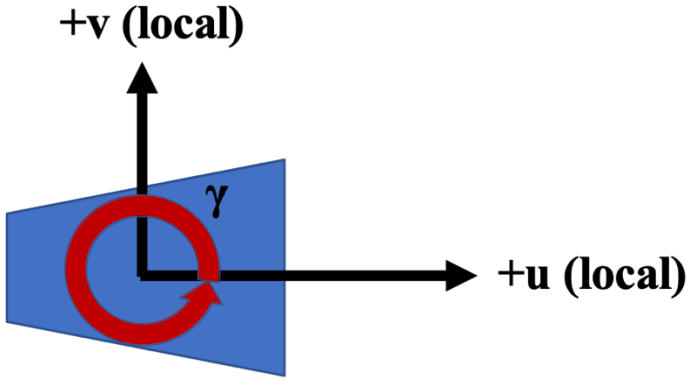
Translations: $\Delta u,\ \Delta v,\ \Delta w$

Rotations: $\Delta\alpha, \Delta\beta, \Delta\gamma$

- 3 alignment parameters for a sensor (108 sensors).
  - $\Delta w,\ \Delta\alpha,\ \Delta\beta = 0$, since we assume they lie flat on the wedge.
- 6 per wedge (36 wedges).
- 6 per FST half (2 halves).
- 6 for FST.
- 558 alignment parameters.



CMS, doi:10.1088/1748-0221/9/06/P06009.



Alignment Closure Tests

Single Sensor Alignment Results

No Misalignment

Parameter	Input	Output	Error
Δu (μm)	0.0	-0.3	2.9
Δv (μm)	0.0	0.0	1.5
Δγ (mrad)	0.0	4.3E-3	1.7E-2

w-axis rotation

Parameter	Input	Output	Error
Δu (μm)	0.0	-0.2	3.2
Δv (μm)	0.0	-2.1	1.7
Δγ (mrad)	2.00	1.91	0.02

u shift

Parameter	Input	Output	Error
Δu (μm)	50.0	46.4	2.9
Δv (μm)	0.0	-1.2	1.5
Δγ (mrad)	0.0	1.0E-2	1.7E-2

v shift

Parameter	Input	Output	Error
Δu (μm)	0.0	1.6	2.9
Δv (μm)	50.0	44.1	1.6
Δγ (mrad)	0.0	2.9E-2	1.8E-2

Alignment Closure Tests

Single Sensor Alignment Results

u,v shift + w-axis rotation (~50k tracks)

Parameter	Input	Output	Error
Δu (μm)	50.0	46.1	3.2
Δv (μm)	50.0	43.2	1.7
Δγ (mrad)	2.0	1.92	0.02

u,v shift + w-axis rotation (~850k tracks)

Parameter	Input	Output	Error
Δu (μm)	50.0	49.3	0.9
Δv (μm)	50.0	41.5	0.5
Δγ (mrad)	2.0	1.938	0.006

- Single FST inner sensor can be aligned to some degree with GenFit + Millepede II.
  - Slight discrepancy between input and output parameters.
  - Perhaps due to correlation between u and v coordinates?
    - Covariance is diagonalized for use in Millepede.

Summary

- Huge amounts of progress in recent months
- Thank you to the entire FWD team
- Next steps:
  - **Feedback on PicoDst format and tracking in Pythia**
  - **Run first production with FWD tracking included (S&C team ready – we need PWG input for amount of data for e.g. J/psi study)**
  - Data-driven alignment (Thank you Gavin Wilks) + new student Xihe han (OSU)
  - Thank you to the S&C team for lots of support
  - Pythia “data” is available now in StMuDst and PicoDst formats!

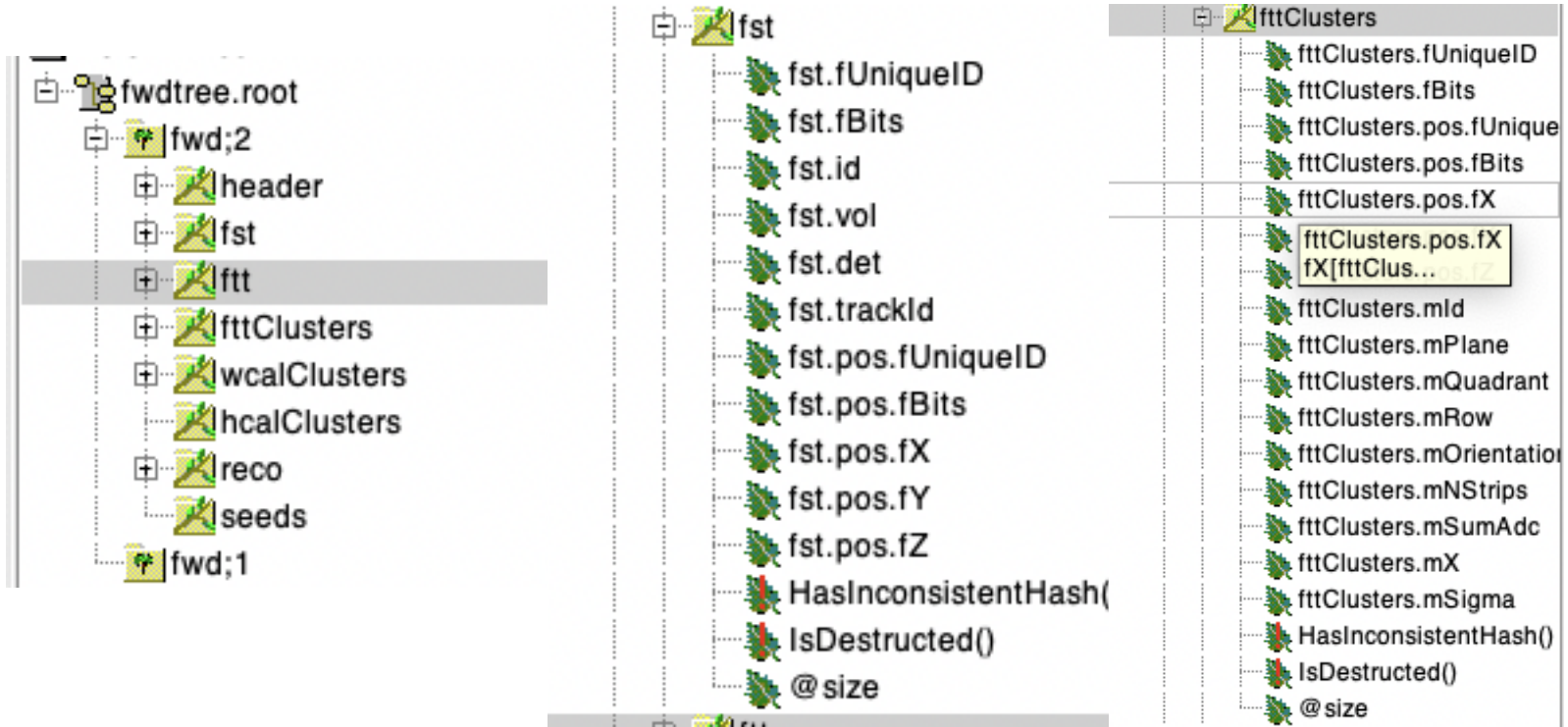
  - Details + examples on wiki:
  - https://github.com/jdbrice/star-sw-1/wiki

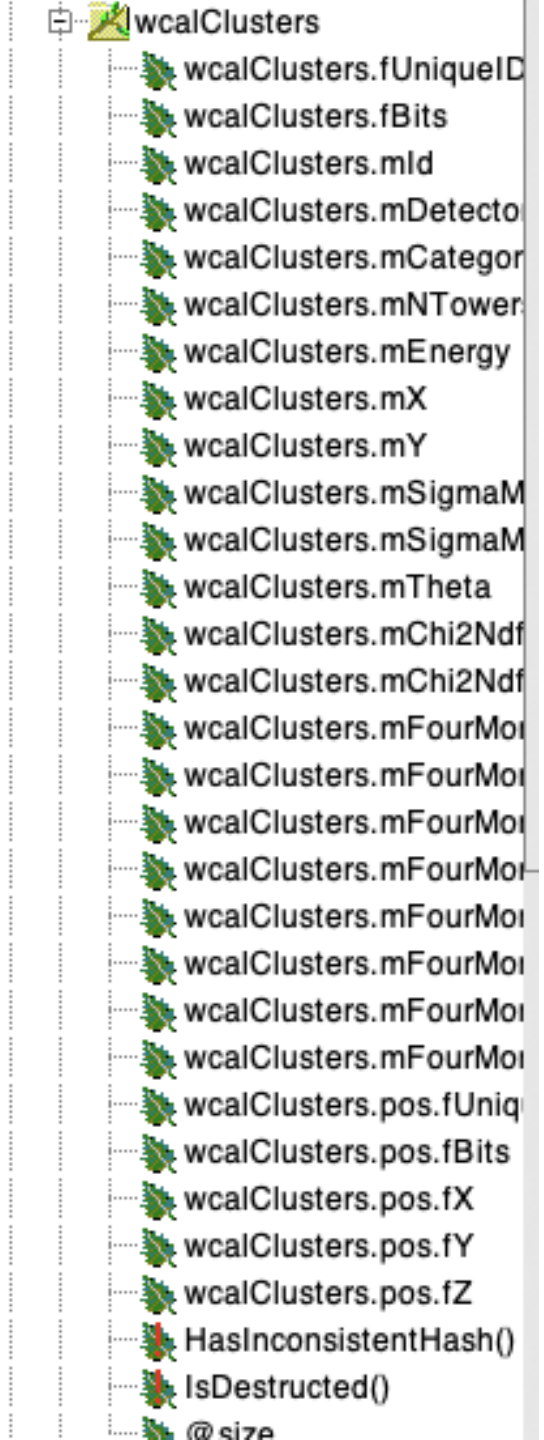
StFwdQAMaker

- FST group, operations groups, fast offline QA, etc. all requesting QA on tracking – more than individual detector
- OSU student Nick will work on this.
- I made a core “StFwdQAMaker” to facilitate
  - Now TTree output is removed from StFwdTrackMaker
  - StFwdQAMaker makes Ttrees with all Fwd info (see next slide)
  - Can be used to make QA – event-by-event / average etc.
  - Trees can be used to visualize events (next slides)

StFwdQAMaker

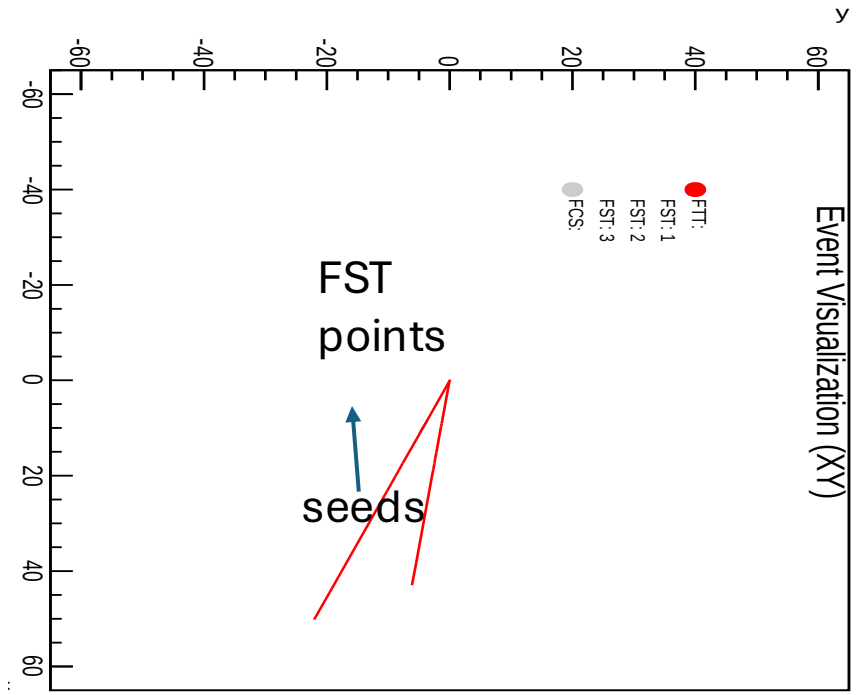
- Remove Ttree generation from core StFwdTrackMaker
- Improved trees from StFwdQAMaker
- Woring on adding EPD hits, CALO matches, FCS hits ...





PicoDst Integration

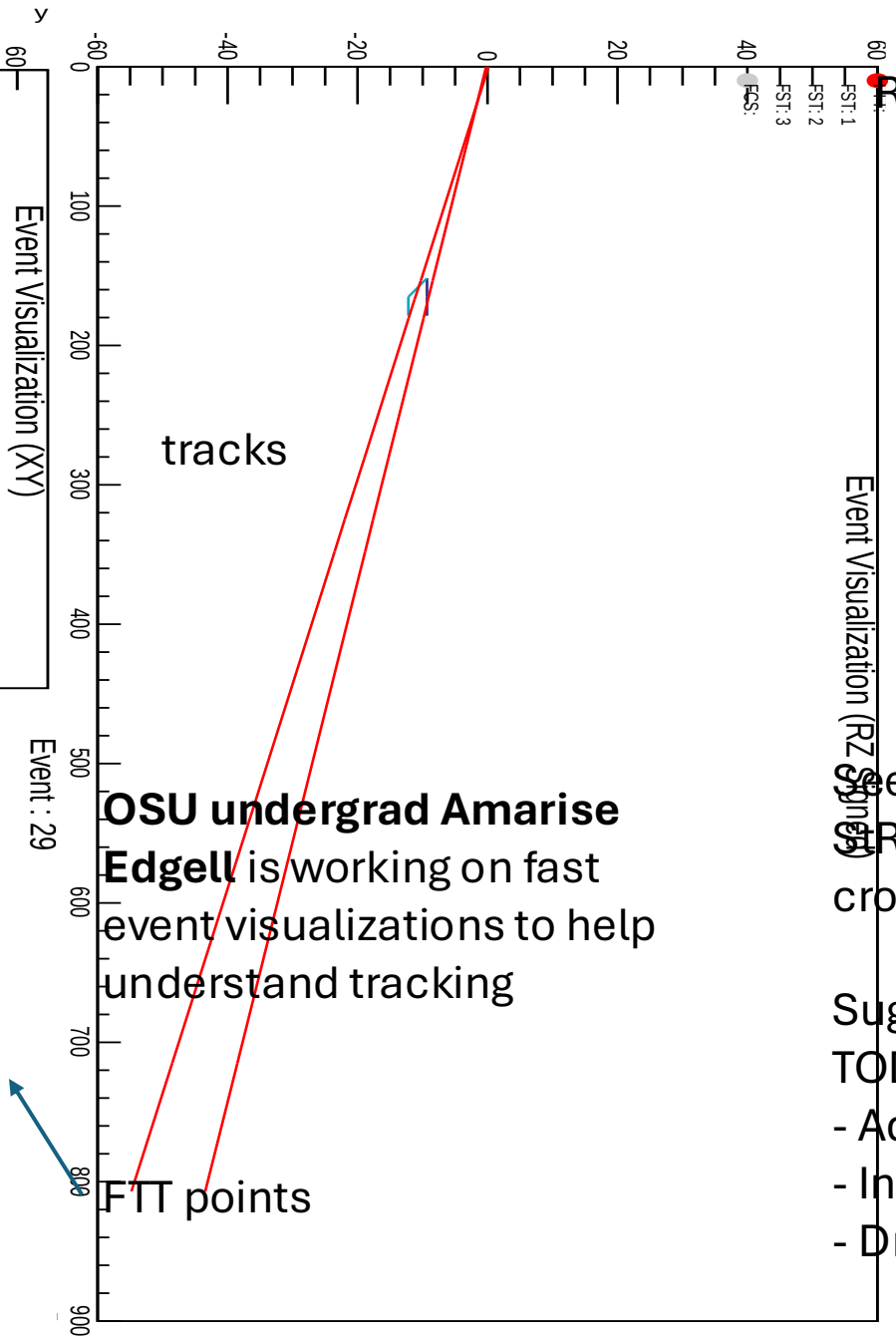
- Additions:
  - StPicoFwdTrack
  - StPicoFcsHits
  - StPicoFcsClusters
- Some questions about Spin info
- Status:
  - Ongoing testing by FWD group
  - J/psi analysis has been ported to PicoDst
  - Final check is to ensure consistency between StEvent/MuDst/PicoDst then ready from my POV.



FST points

seeds

FTT clusters



tracks

FTT points

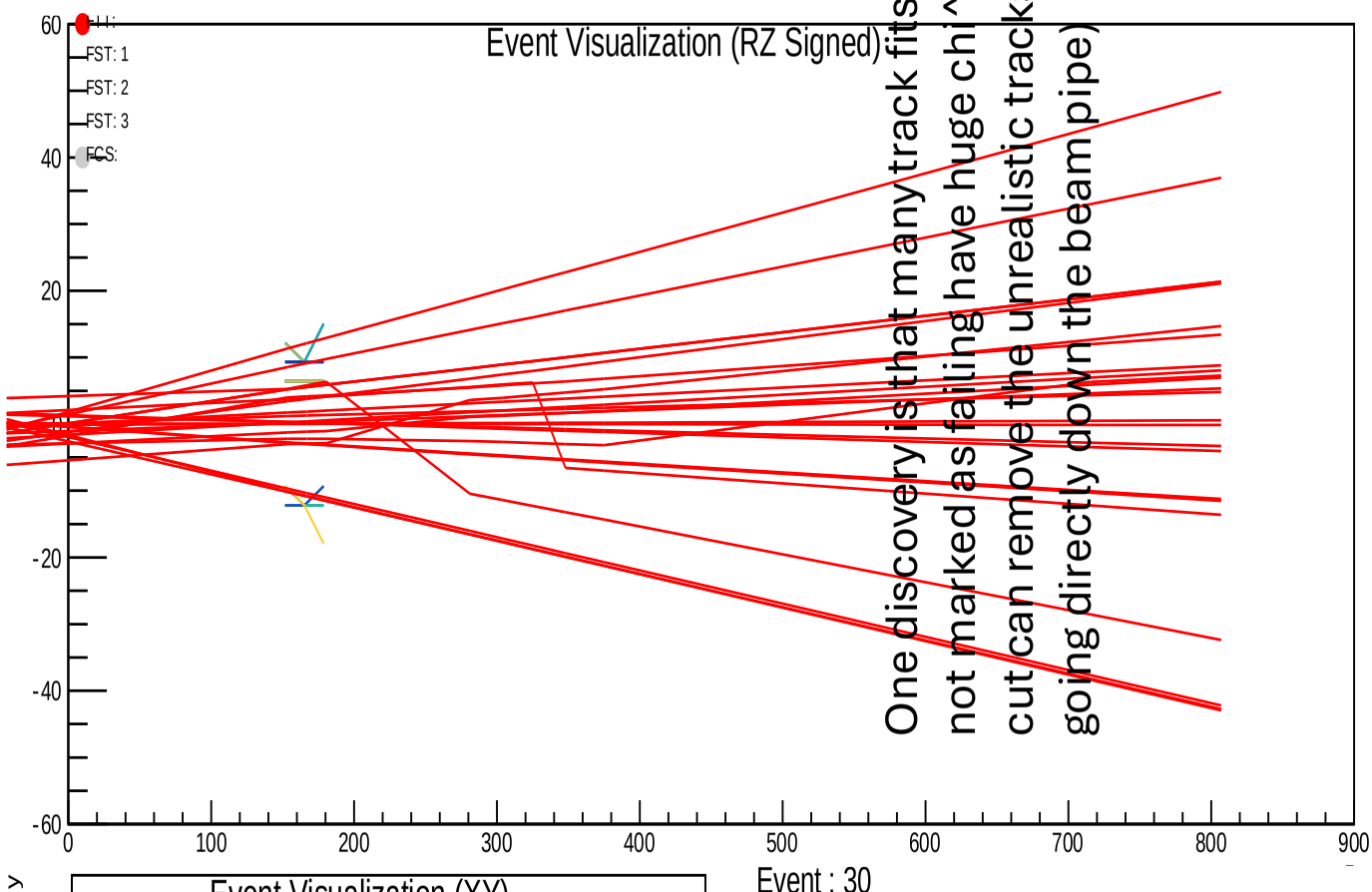
R = sqrt(x^2+y^2)*sgn(y)

This event looks OK,
But why are we missing hits on FTT plane 1 & 2?

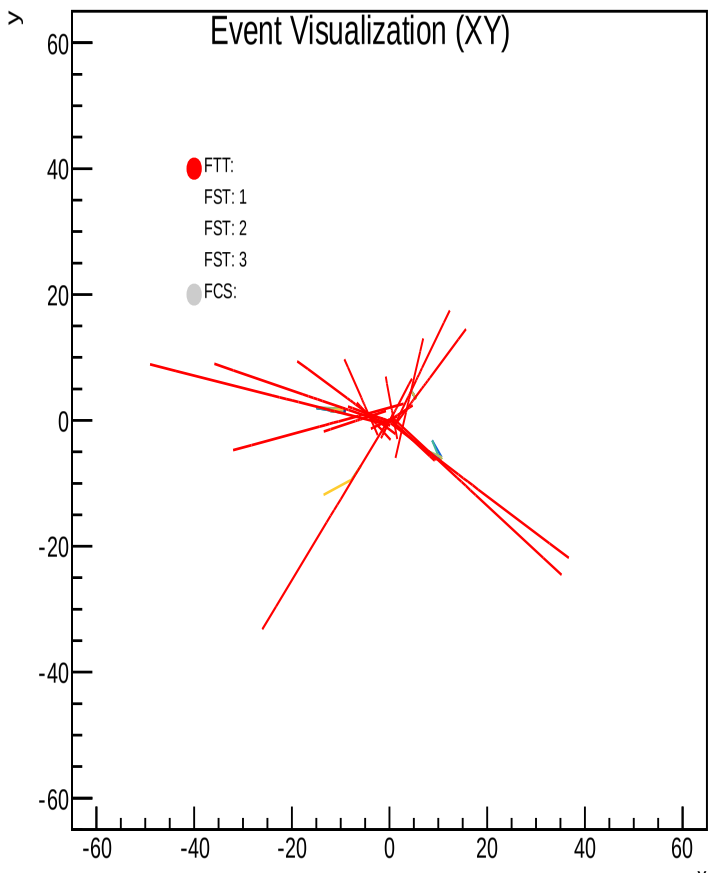
OSU undergrad Amarise Edgell is working on fast event visualizations to help understand tracking

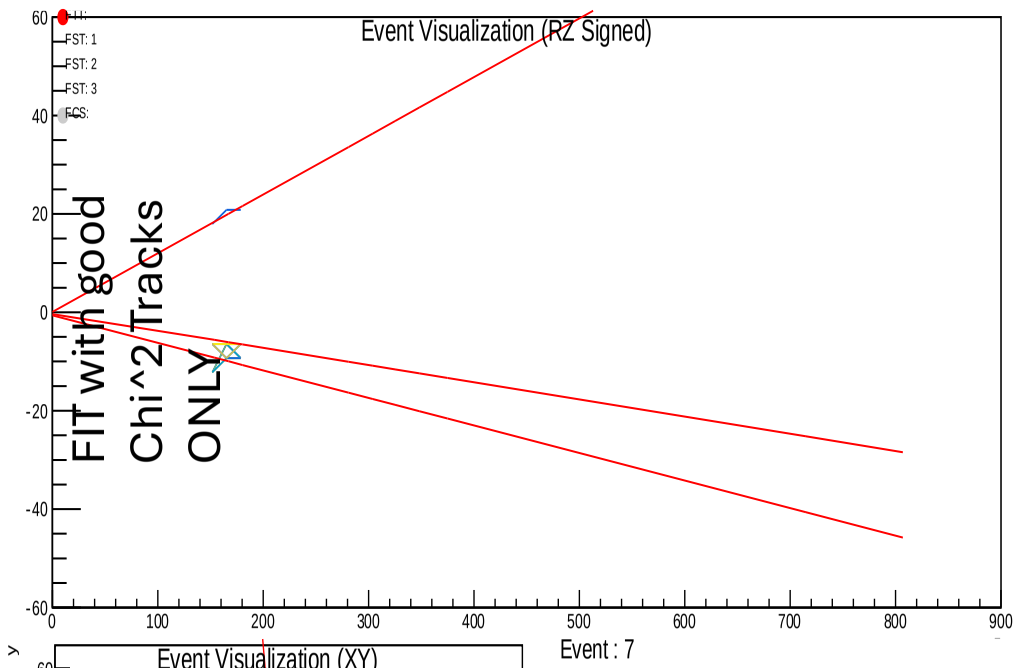
See StRoot/StFwdTrackMaker/macros/viz.C

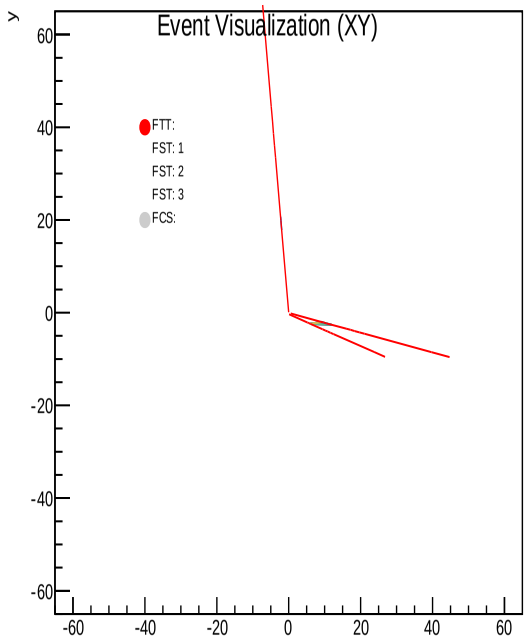
Suggestions welcome
TODO:
- Add CALO towers
- Indicate matches
- Draw event PV

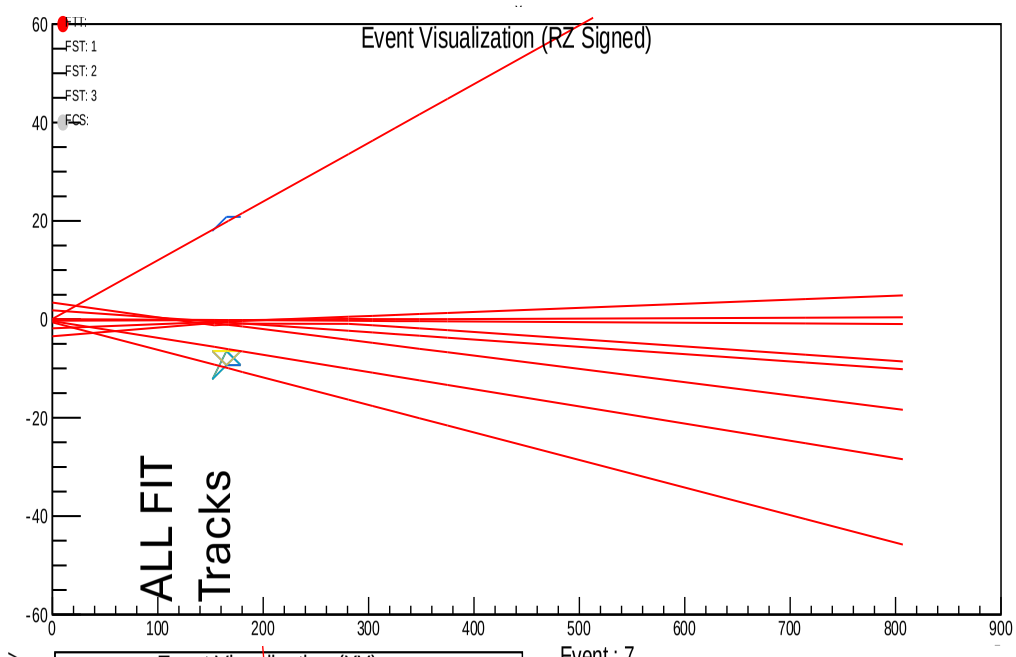


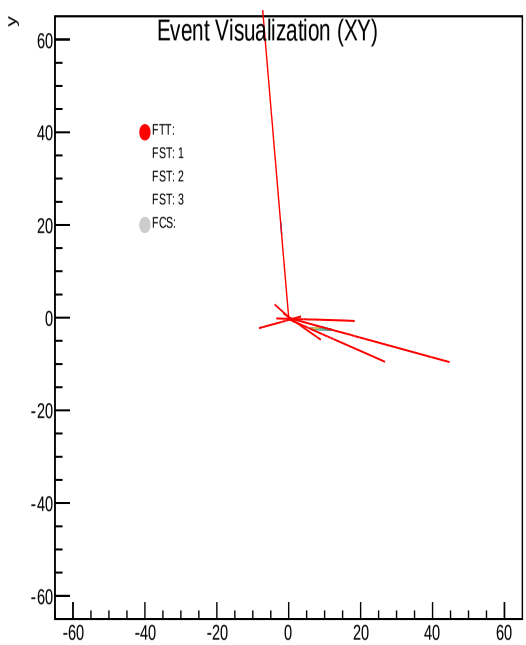
One discovery is that many track fits that are not marked as failing have huge chi^2 – and a cut can remove the unrealistic tracks (those going directly down the beam pipe)

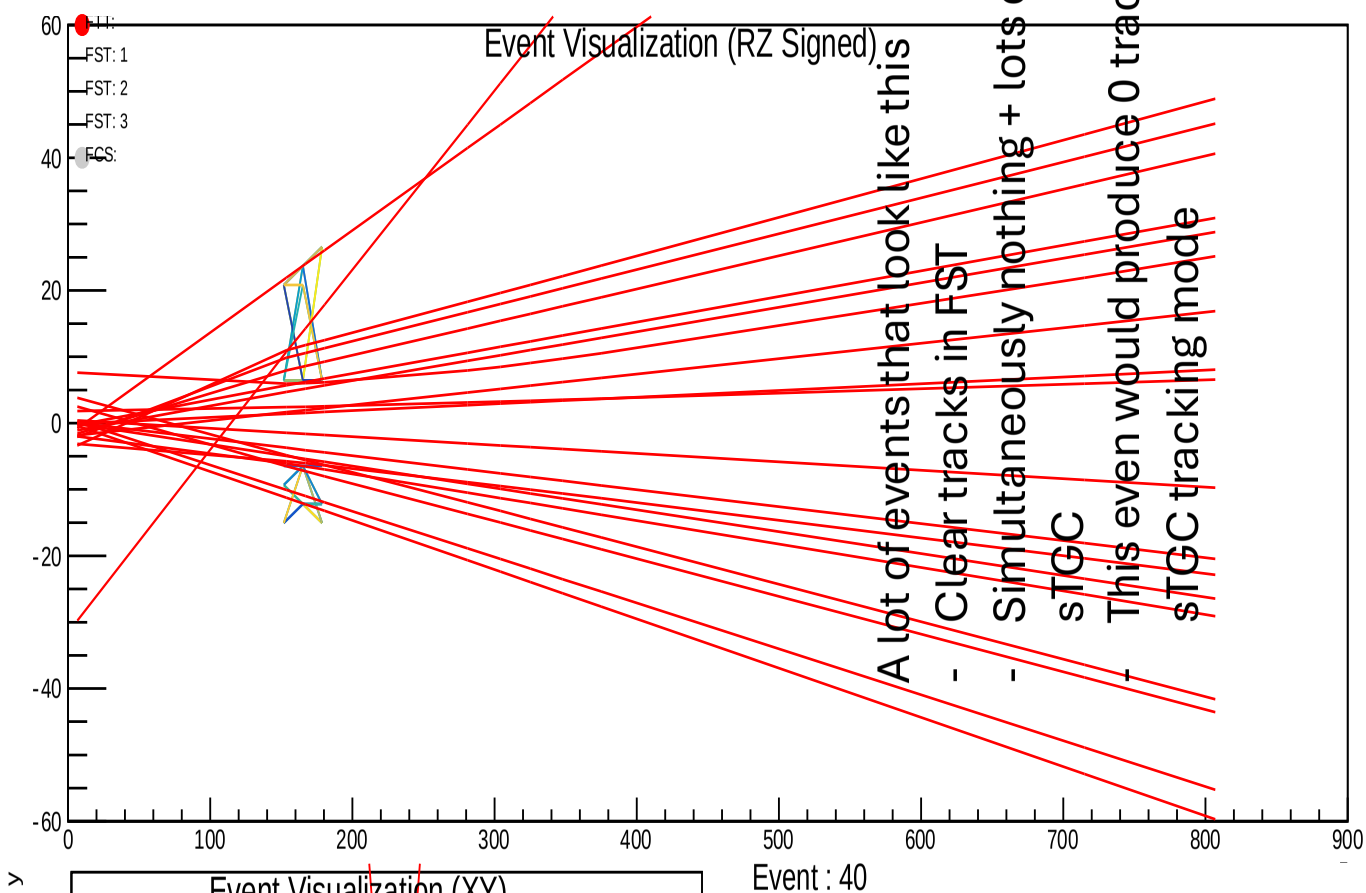


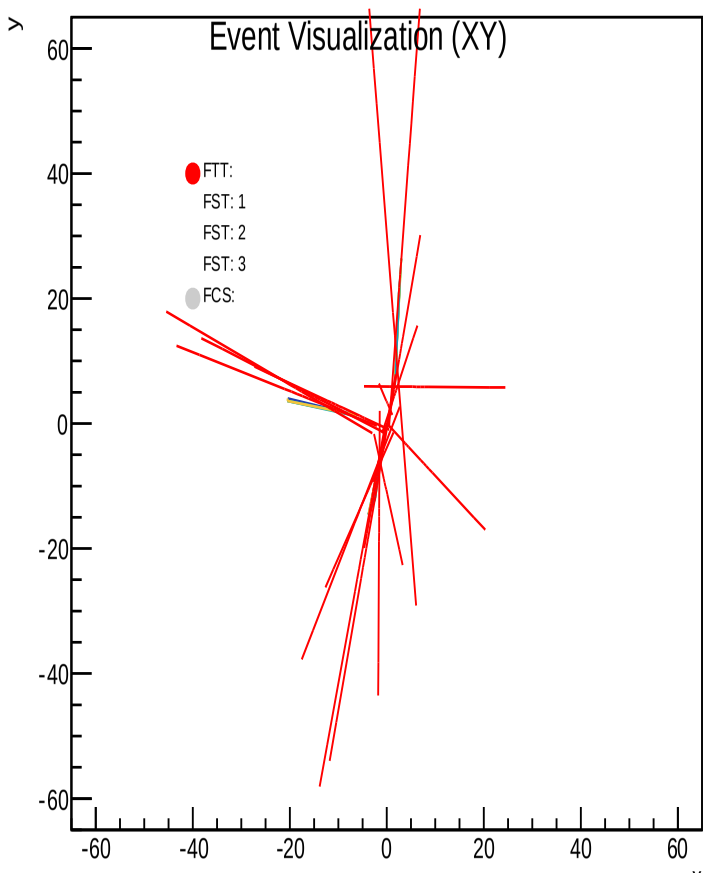

Event Visualization (RZ Signed)
FTT:
FST: 1
FST: 2
FST: 3
FCS:
FIT with good
Chi^2 Tracks
ONLY
Event : 7

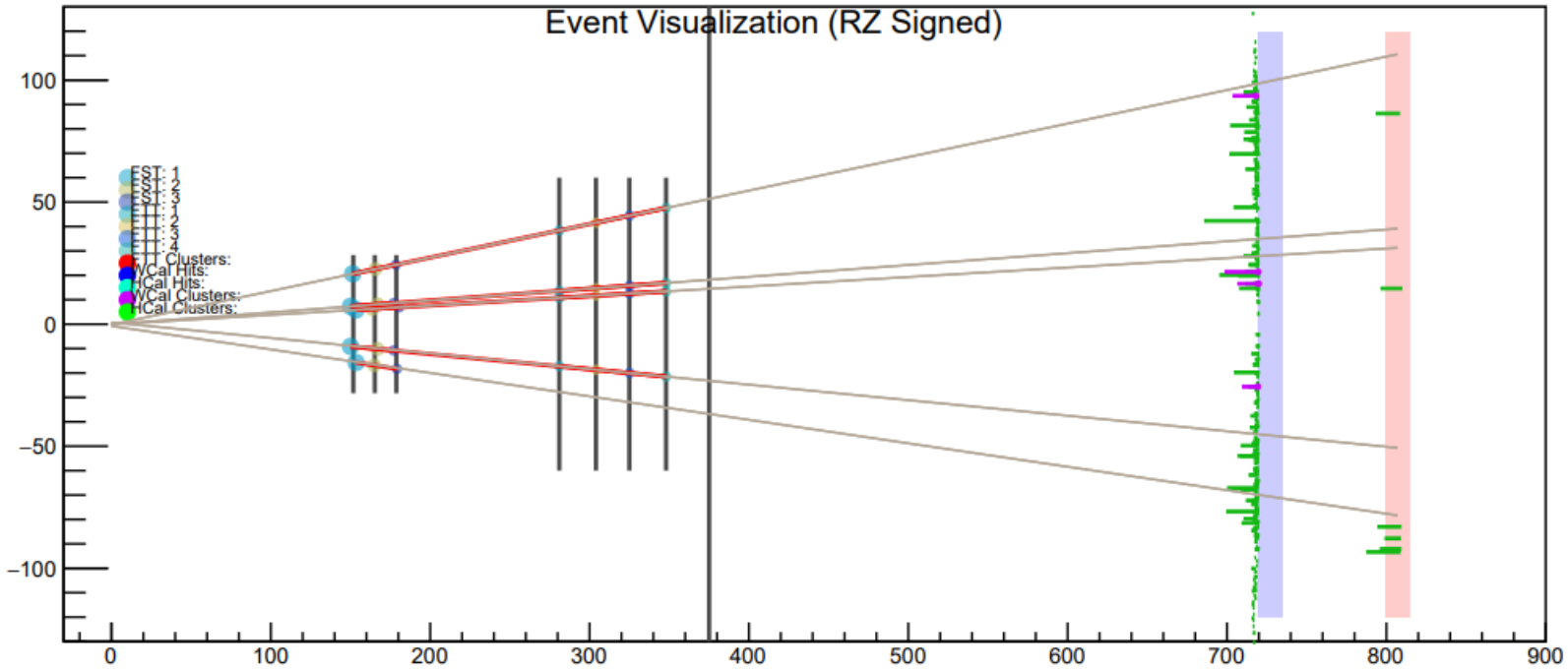

Event Visualization (XY)
FTT:
FST: 1
FST: 2
FST: 3
FCS:
y

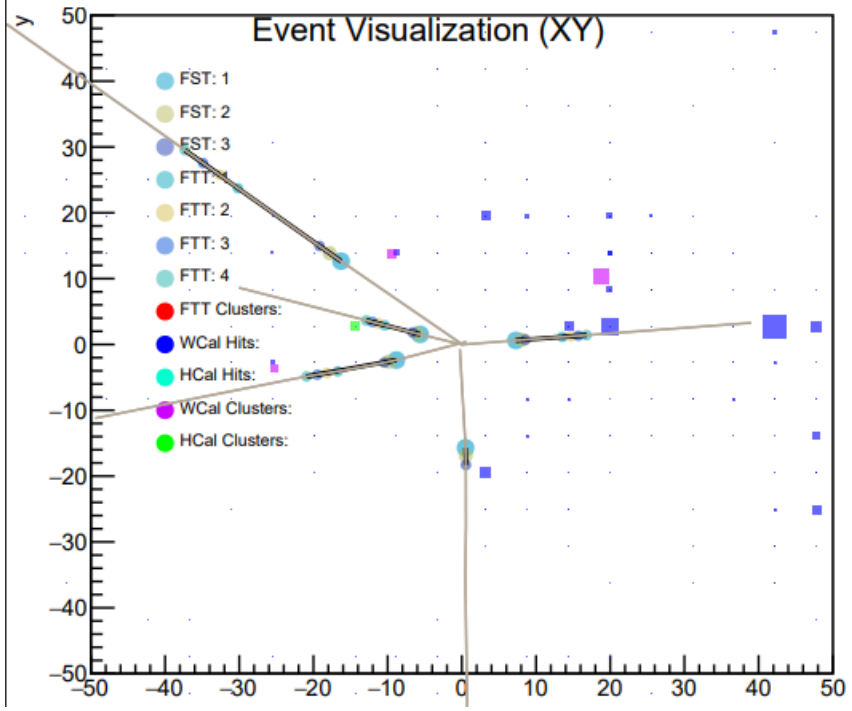

Event Visualization (RZ Signed)
FTT:
FST: 1
FST: 2
FST: 3
FCS:
ALL FIT
Tracks
Event : 7


Event Visualization (XY)
FTT:
FST: 1
FST: 2
FST: 3
FCS:
y


Event Visualization (RZ Signed)
FTT:
FST: 1
FST: 2
FST: 3
FCS:
A lot of events that look like this
- Clear tracks in FST
- Simultaneously nothing + lots of noise in sTGC
- This even would produce 0 tracks via sTGC tracking mode
Event : 40


Event Visualization (XY)
FTT:
FST: 1
FST: 2
FST: 3
FCS:





Event : 6
Tracks : 10
FST Hits : 15
FTT Hits : 16
WCal Hits : 496
HCal Hits : 626
WCal Clusters : 4
HCal Clusters : 2

Addition of HCAL and ECAL hits + clusters

WIP: add matching indicators

Whats taking so long

- ....

PR#571 New FWD tracking mode based on FST-track finding

- Tracking (finding+fitting) works `perfectly` in simulation – fail completely in data
  - sTGC has missing planes and misplaced points
  - sTGC clusters usually have 1 hit, poor spatial resolution
- Significant rewrite of FWD tracking
  - Introduces tracking with FST only
  - Projection and refit using FTT space points (if/when available)
  - Fix major memory issues / leaks
  - Speed and performance optimizations
  - Improved geometry handling
- Merge of PR needed for fwd tracking in central productions

FST: Long uncaught issues

- **ISSUE: SL23f crash in StFstRawHitMaker #631**
- **Fix job crashing for 9 time-bin FST data #634**
- starver SL23f
- root4star -b -q -l 'bfc.C(10,"DbV20231127 pp2022a StiCA fst ftt fstRawHit fstMuRawHit BEmcChkStat -hitfilt","/star/data03/daq/2021/352/22352002/st_fwd_22352002_raw_1500011.daq")'
  - Crashed for some DAQ files
- "Fix" actually made FST data unusable in production

```
52  52    const float kFstrStop[kFstNumRStripsPerWedge] = {7.875, 10.750, 136.25, 16.500, 19.375, 22.250, 25.125, 28.000}; // in cm
53  53
54  54    //general APV chip constants
55      - const unsigned char kFstNumTimeBins = 3;    // 3 time bins for ADC sampling (maximum time bin number)
    55  + const unsigned char kFstNumTimeBins = 9;    // 9 time bins for ADC sampling (maximum time bin number, 3 or 9)
56  56    const unsigned char kFstDefaultTimeBin = 2; // the default time bin number (2nd time bin) for FST raw hits
57  57    const int kFstMaxAdc               = 4096; // ADC value should be less than 4096 (12 bits ADC)
58  58
```

Fixed on June 25th: Updated timebin handling by StFstRawHitMaker #685

Because of this:

- Preproduction ~ bad FST info
- Ongoing FCS production cannot be used for FWD tracking

Recently Closed Pull Requests

Recent progress integrating FWD software into StRoot

- Aug 22 Update Stgm geometry z-plane locations according to survey data #707
- **Aug 10th: Update StFstFastSimMaker to write hits into the StFstHitCollection #700**
- **Aug 5th: Add idTruth to MuDst FttPoint and FttCluster #699**
- **July 30th :Initial version from Amarise summer 2024 project #697**
- **Aug 1: Update StMuMcTrack with num hits to FWD detectors #696**
- **June 1st: Fwd picodst integration #639**
- **July 20th: New FWD tracking mode based on FST-track finding #571**
- **July 16th: StFwdQAMaker for optional QA of fwd systems and tracking #694**
- **June 25th: Patched FTT table for Daniel #689**
- **June 25th: Provide manual timecut control for fast offline production and calibr… #686**
- **June 25th: Updated timebin handling by StFstRawHitMaker #685**
- **May 23rd: StSpinPool FCS trigger simulator and QA Update for run24 #684**
- **April 15th: StFttDbMaker: Warning when DB not found #682**
- **May 8th: Adding FCS online gain used on DEP in offline DB #668**
- **March 14th: Move and modify StFcsPi0FinderForECal to StRoot #667**
- **March 11th: new FCS tables for Akio #665**
- **April 10th: Small fix for StFcsDb and StFcsWaveformFitMaker #664**
- **Jan 15th: Updating StFcsTriggerSimMake to include StMuFcsCollection hit information for trigger reconstruction in simulation. #638**
- **April 18th: QA for StEvent and MuDst FwdTracks #636**
- **March 27th: Updates to StFwdTrackMaker to allow running without XML config file #635**

Major milestones / recent progress

- Resolved all issues with memory / stability of tracking
- Developed robust tracking approach for
  - Data without TPC primary vertex
  - Data with missing sTGC planes
  - Track finding in FST alone
- Completion of sTGC reconstruction chain
- Primary / Global fits with DCA info etc.
- FwdTracks in StEvent, StMuDst, and StPicoDst (private)
- Robust tracking in full (Pythia) events
- QA makers for the Fwd tracking