

The Tool-based Reconstruction Algorithm for Characterising Showers*

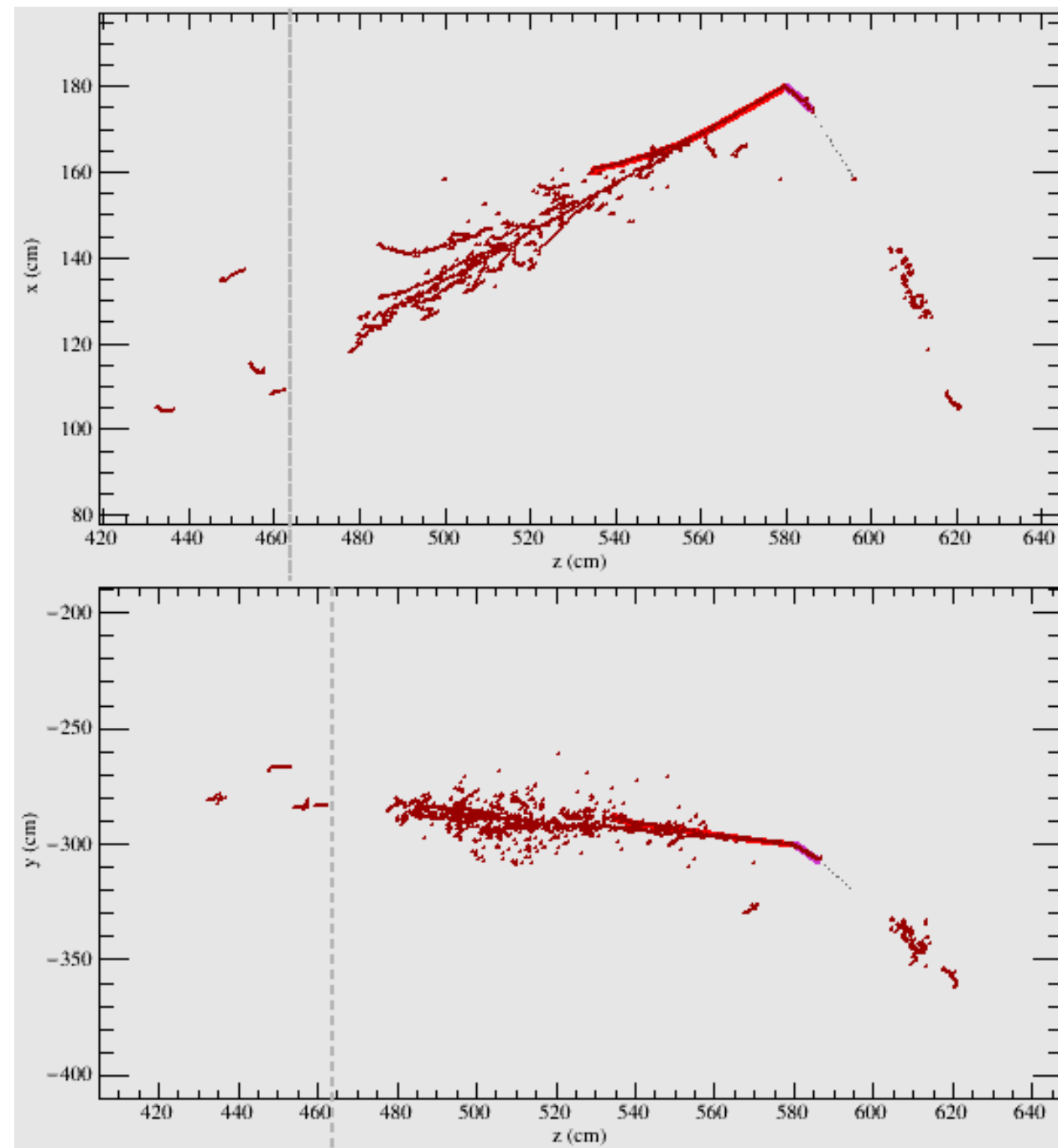
Dom Brailsford
FD sim/reco Meeting
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***Primary authors**

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Ed Tyley**

Shower characterisation

- Shower characterisation == the bit you do after the pattern recognition
- Shower reconstruction is hard, particularly in a LArTPC
- The difficulty is frustrating because you primarily only need to know a few key pieces of information for physics analyses:
 - Start position
 - Initial direction
 - Energy
 - dE/dx
 - *ID of the initial track stub



Not another shower characterisation module?

- The Tool-based Reconstruction Algorithm for Characterising Showers (TRACS) is a shower characterisation module
 - Developed by Dom Barker and Ed Tyley as part of the SBN shower reconstruction WG
- TRACS takes a `recob::PFParticle` as input and outputs a `recob::Shower`
 - Just like PandoraShower and EMShower
- The key difference is TRACS outsources all of the characteristic calculations to a set of art tools where a tool has a specific purpose
 - A tool to calculate the shower's direction
 - A tool to find the initial track stub's hits
 - A tool to calculate the initial track's dE/dx

Quick technical details

```
388 physics.producers.tracsshowertest.ShowerFinderTools: [
389     @local::dune10kt_showerstartpositionfinder,
390     @local::dune10kt_showerdirectionfinder,
391     @local::dune10kt_showerenergyfinder,
392     @local::dune10kt_shower3dtrackhitfinder,
393     @local::dune10kt_showerpmatrackfinder,
394     @local::showertracktrajectorypointdirection,
395     @local::dune10kt_showerdedxfinder
396 ]
```

- You specify an arbitrarily sized list of the tools in FCL to configure the shower characterisation
- The only caveat is enough tools need to be run to characterise start *position, direction, energy* and dE/dx^*
 - *All current dE/dx need an initial track stub to function
- Every tool is exposed to the PFParticle under consideration, the `art::Event` and the `ShowerElementHolder`
 - ShowerEleHolder holds the characteristics that each tool calculates, it can also hold an arbitrary number of transient objects as well as art data products destined for the ARTROOT output file

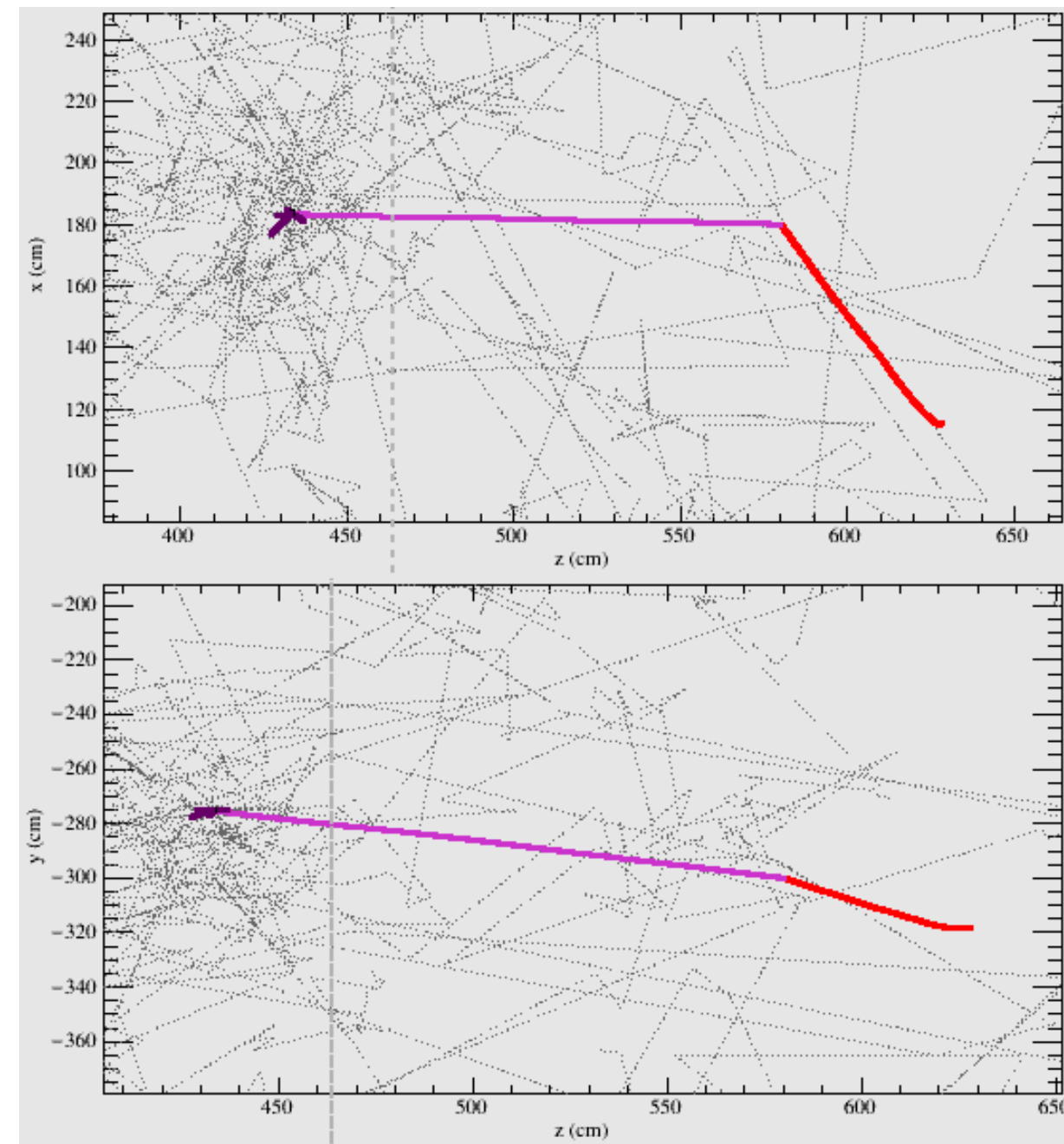
```
int ShowerTrackTrajectoryPointDirection::CalculateElement(const art::Ptr<recob::PFParticle>& pfparticle,
    art::Event& Event,
    reco::shower::ShowerElementHolder& ShowerEleHolder){
```

Tools to be shown today

- **Shower start position**
 - *ShowerStartPosition_tool*: Takes the PFParticle's vertex position as the start position (a la pandoraShower)
- **Initial track stub finder**
 - *Shower3DTrackHitFinder_tool*: Tags space points contained in a cylinder whose axis is the calculated shower direction and starting at the calculated shower start position
- **Initial track fitter**
 - *ShowerPMATrackFinder_tool*: Uses the Projection Matching Algorithm to form a track using the found initial track hits
- **Shower direction**
 - *ShowerPCADirection_tool*: Applies a charge-weighted PCA to the shower space points; the primary axis is the shower direction (similar to pandoraShower)
 - *ShowerTrackTrajectoryPointDirection_tool*: Takes the starting direction of the fitted track stub (`recob::Track::DirectionAtPoint(1)`)
- **dE/dx**
 - *ShowerStandardCalodEdx_tool*: Calculates a per-view dE/dx using the initial track hits. The tool calculates a per-view pitch by projecting the calculated shower direction into each view

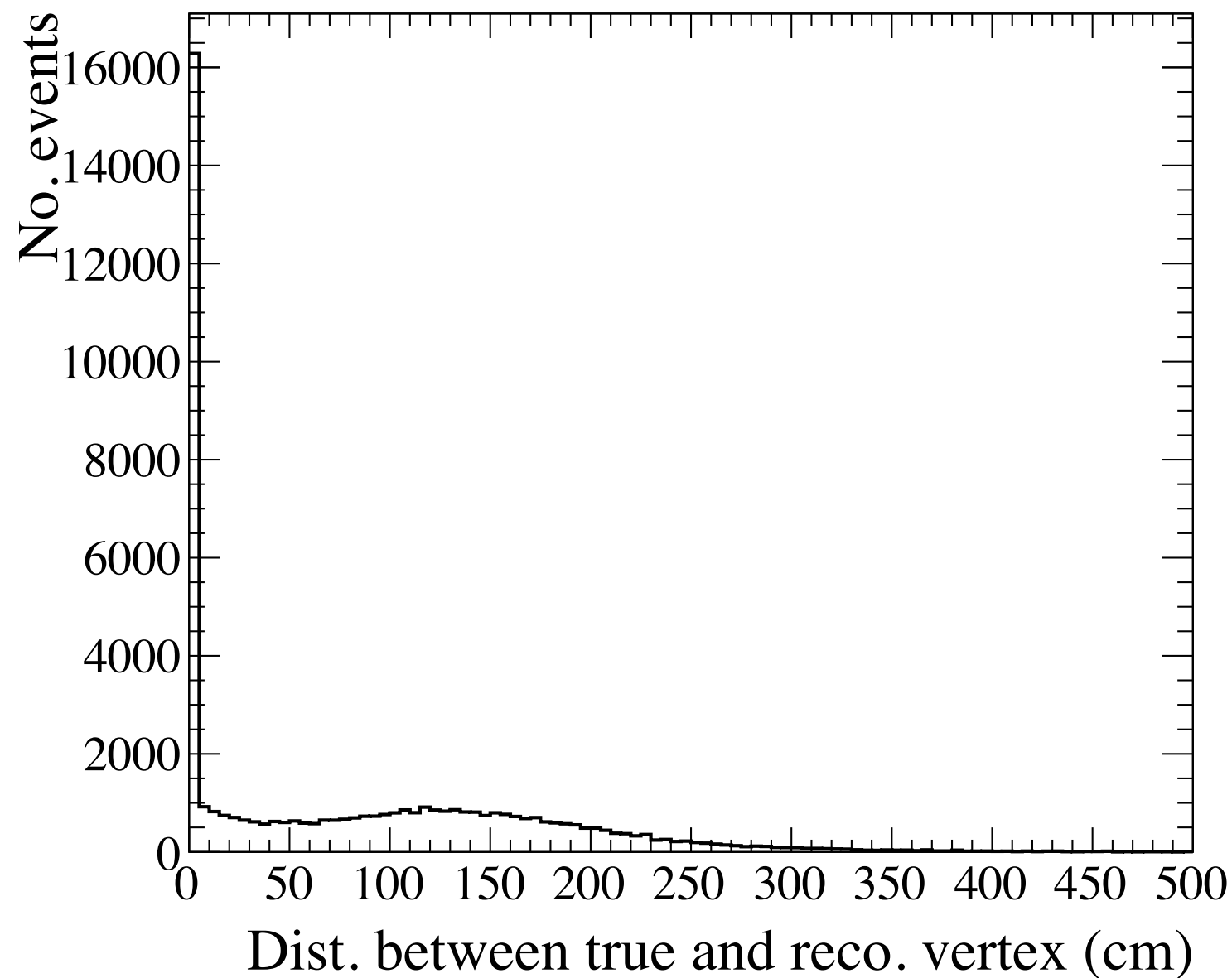
The sample used

- Vertex-like particle gun
 - Electron ($0 < p < 4.5$ GeV)
 - Pi^+ ($0.5 \text{ GeV} < p < 2.0$ GeV)
 - Fixed start pos (180,-300,580)
 - Isotropic angle
- Downstream fcls:
 - standard_g4_nooptical_dune10kt_1x2x6.fcl
 - Disables the light sim
 - standard_detsim_dune10kt_1x2x6.fcl
 - standard_reco_dune10kt_nu_1x2x6.fcl
- **For assessing the recob::Shower parameters, I only consider recob::Showers with the highest number of hits in an event AND which are also truth matched to the primary electron**

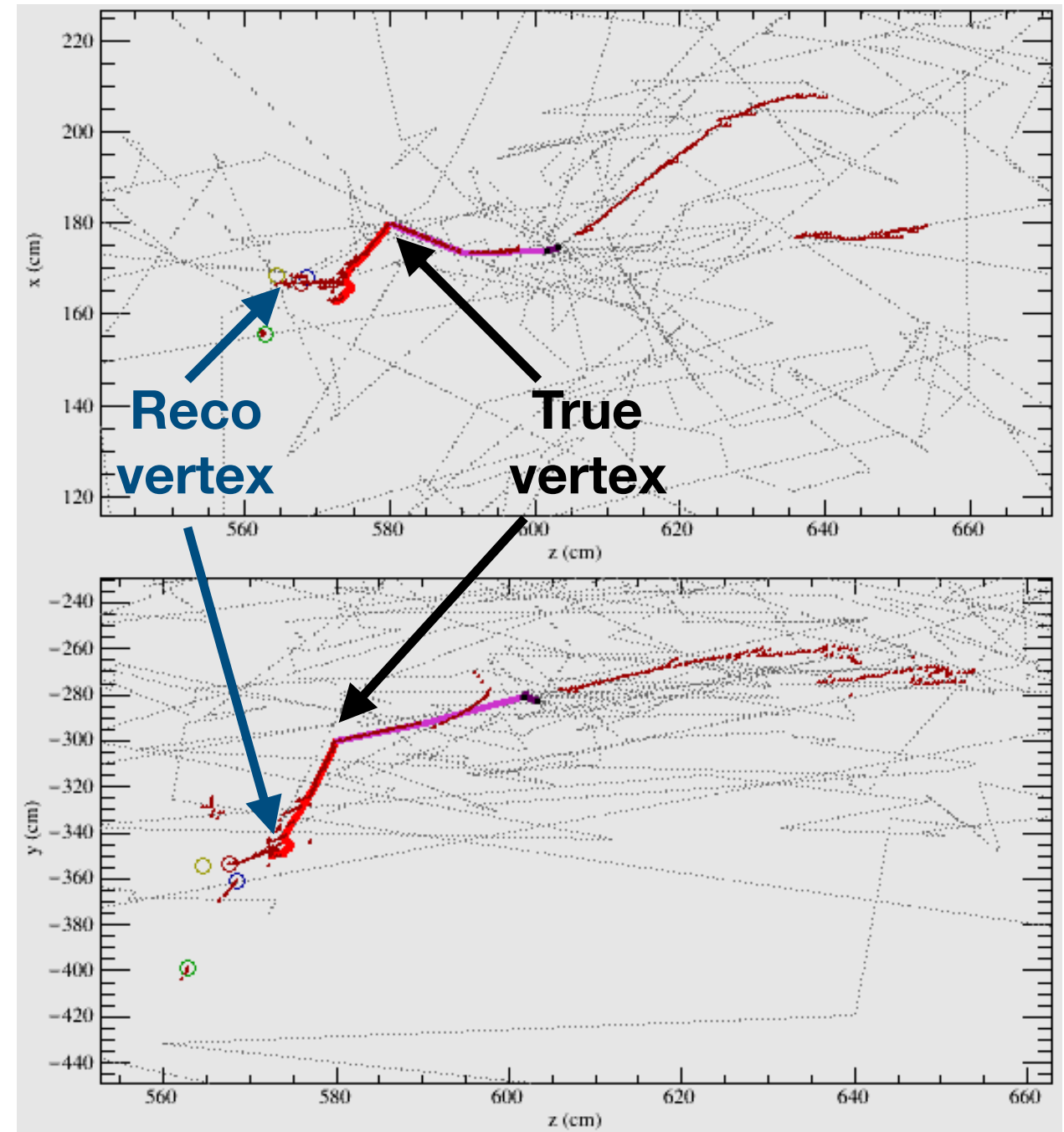
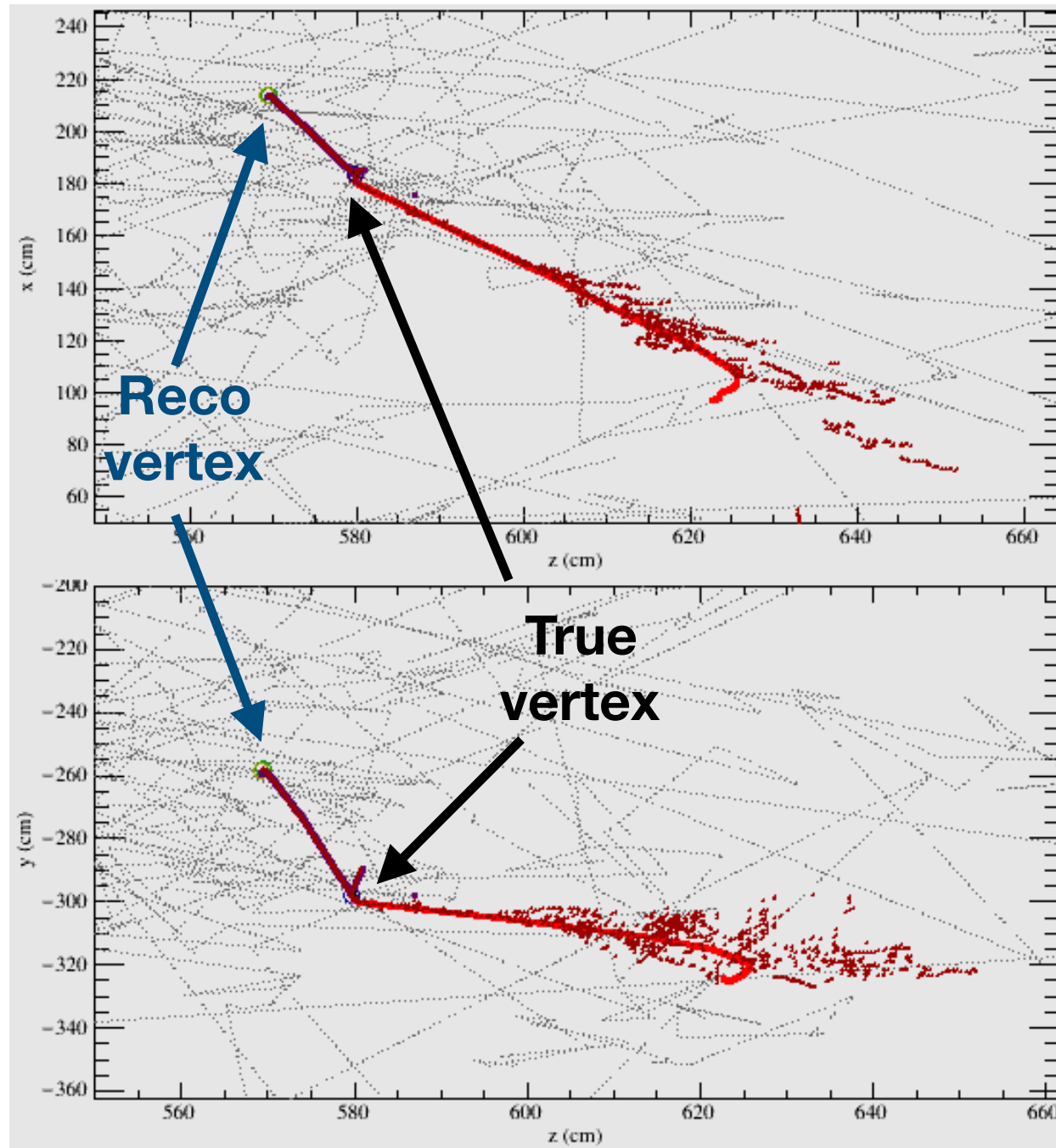


Quick aside: Pandora neutrino vertex position displacement

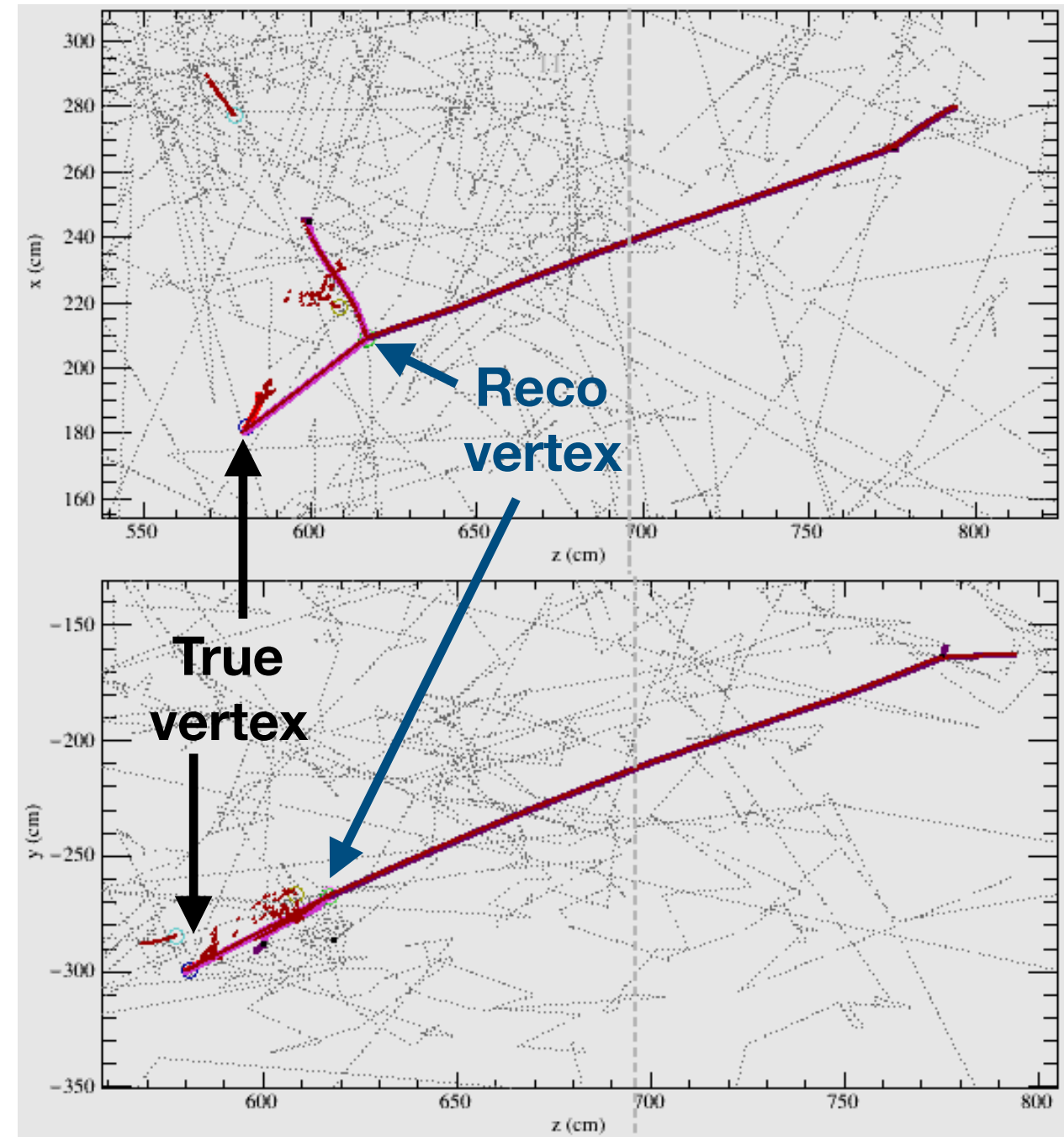
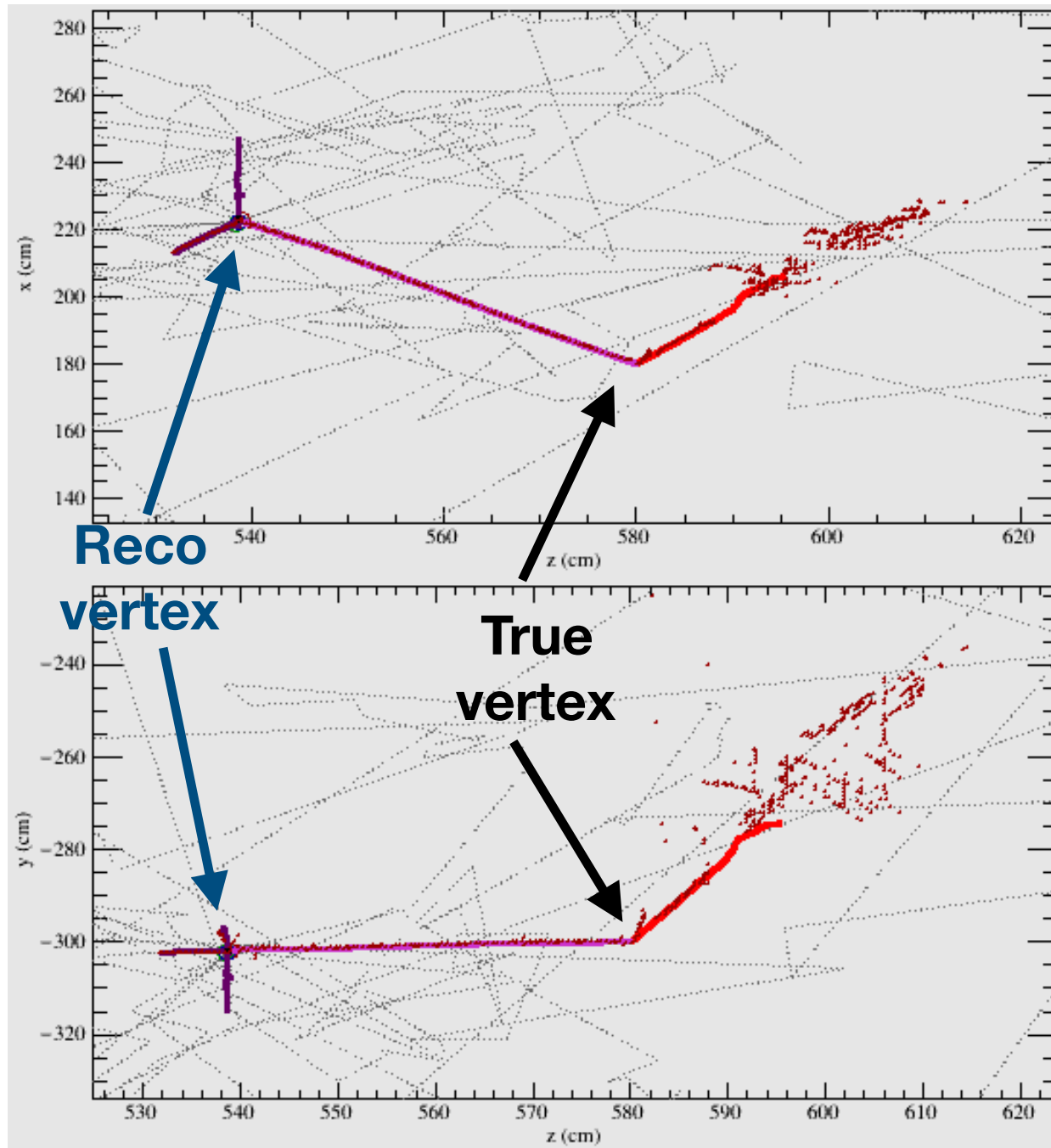
- $|\text{vertex_reco} - \text{vertex_true}|$
- Nice sharp peak at 0 cm
- Very broad second peak at ~120 cm
- Displacement is within 10 cm 34.6% of the time



Mis-vertexing examples

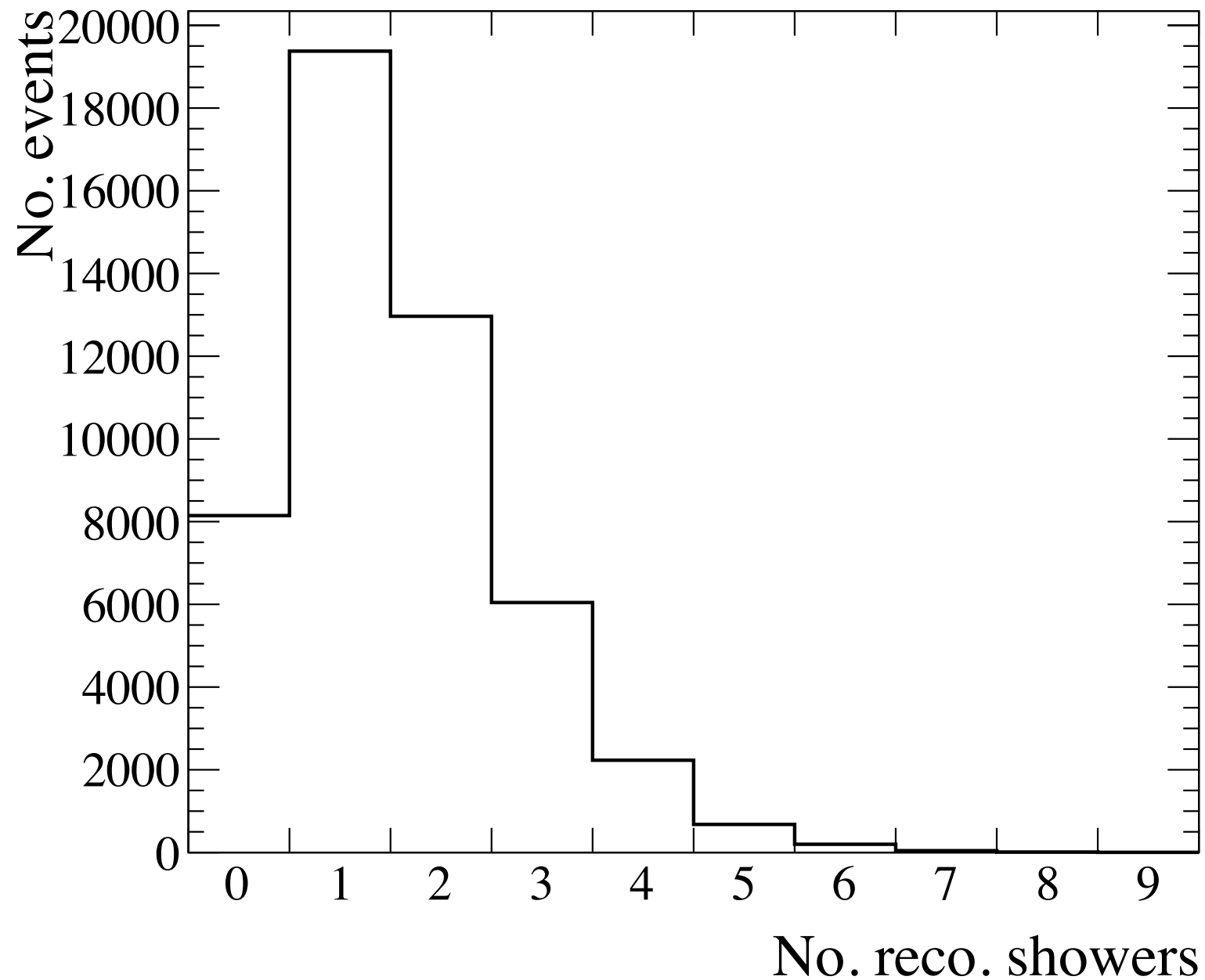


Mis-vertexing examples



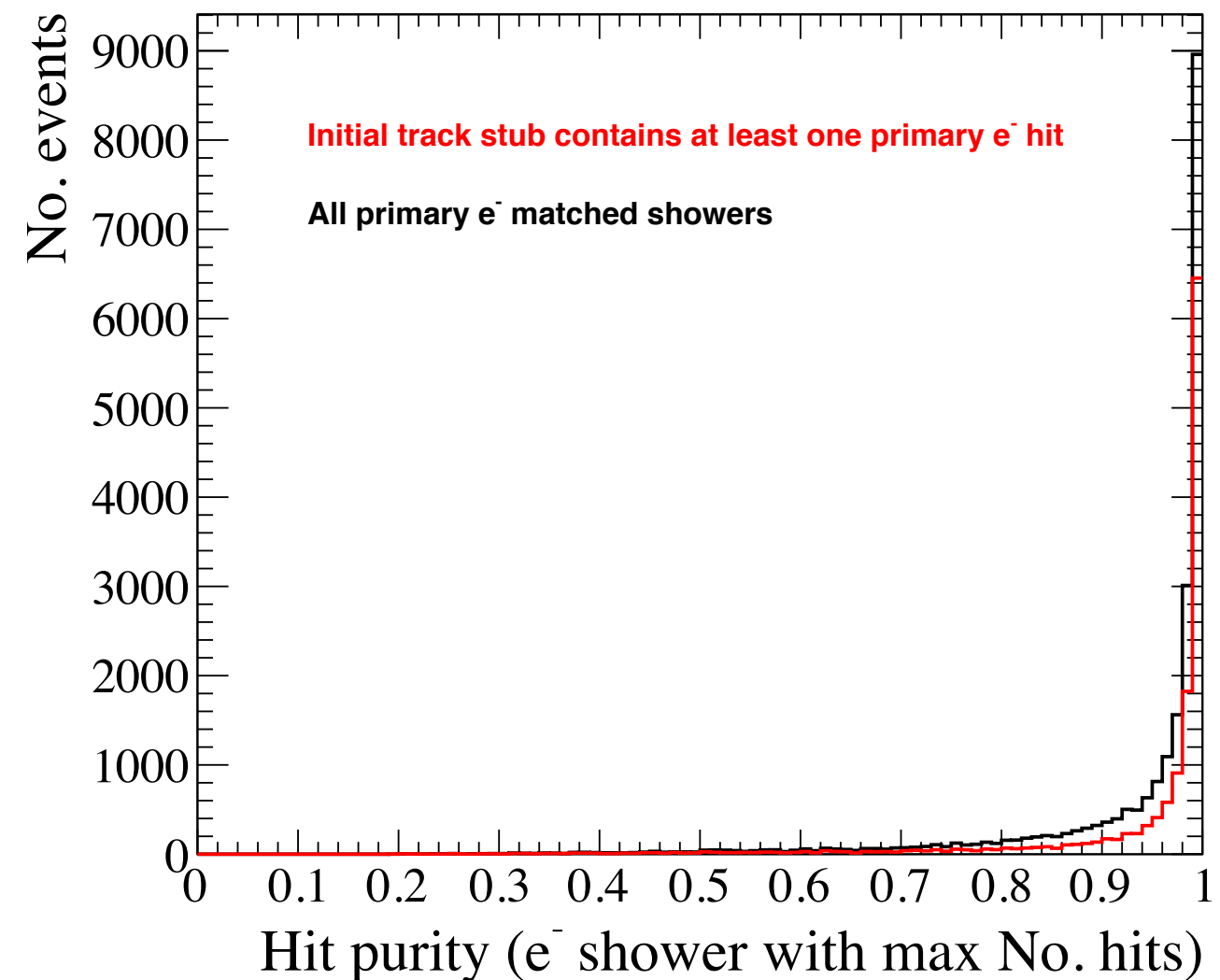
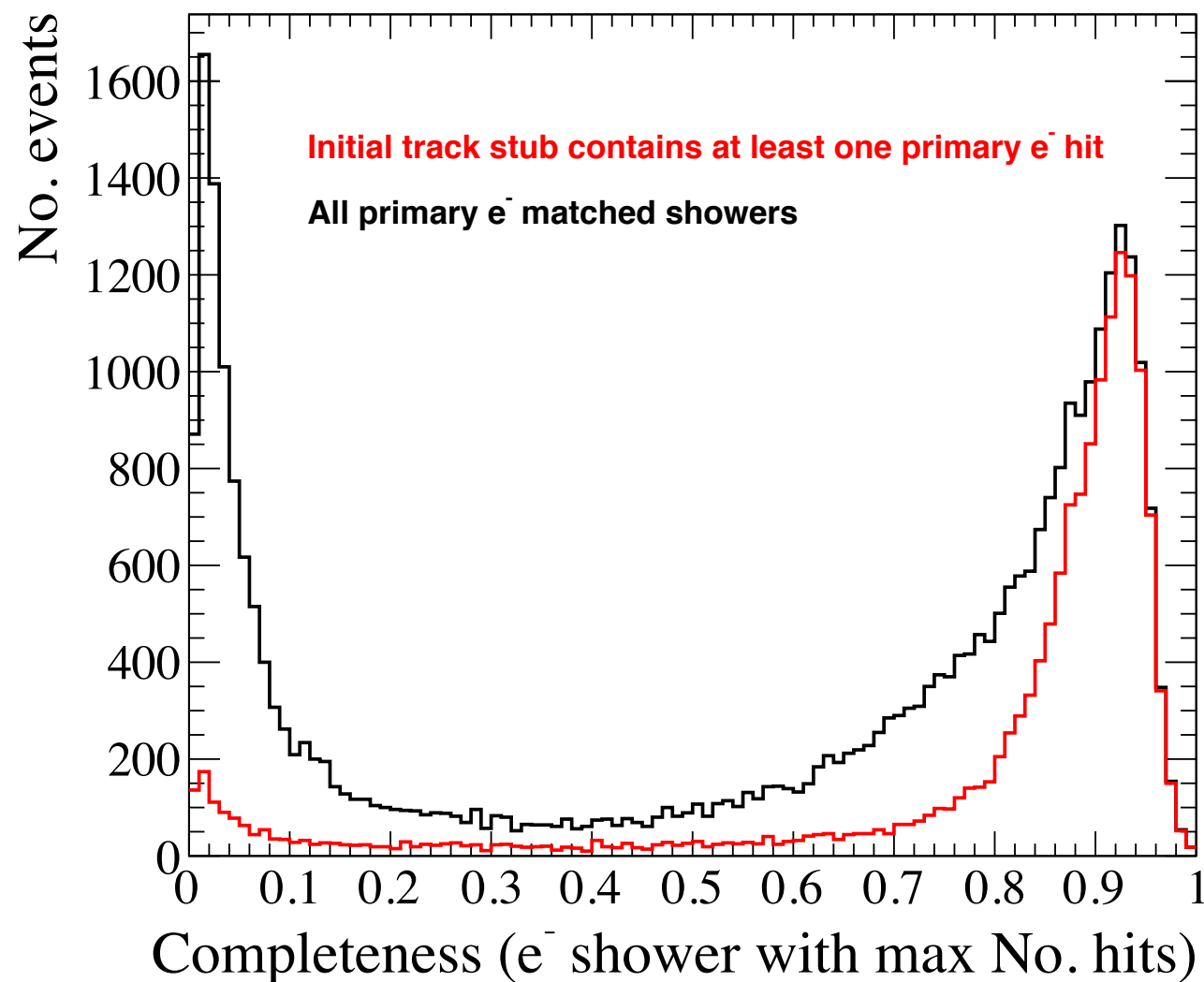
Number of reco. showers

- The number of ALL `recob::Showers` in each particle gun event
- Total stats: 49700
- 16.4% of particle gun events do not contain a `recob::Shower`



***Shown for showers which contain the max no. of hits AND truth match to the primary electron**

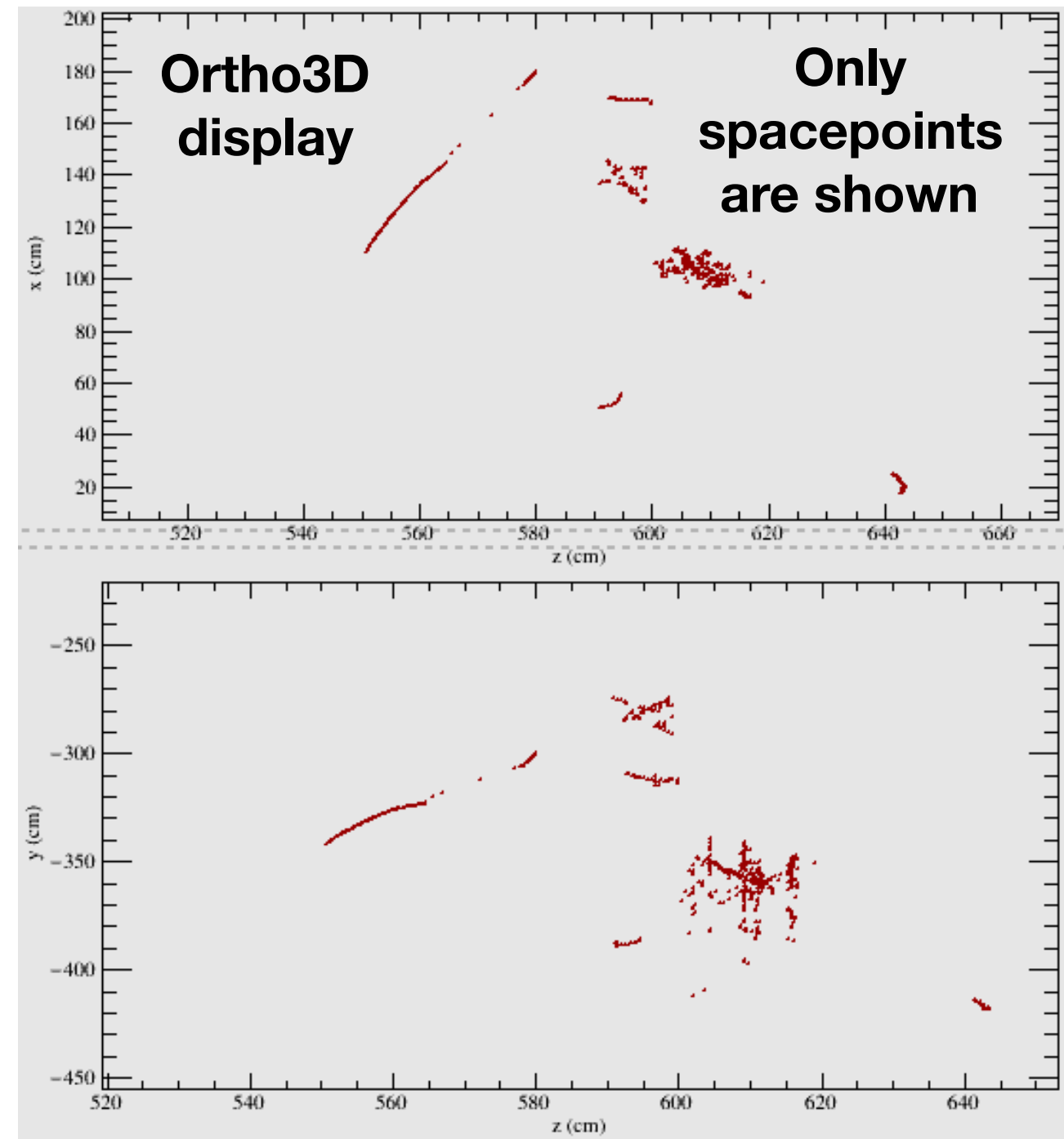
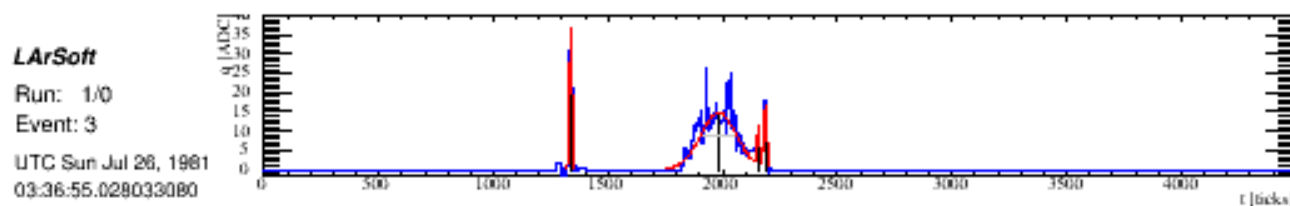
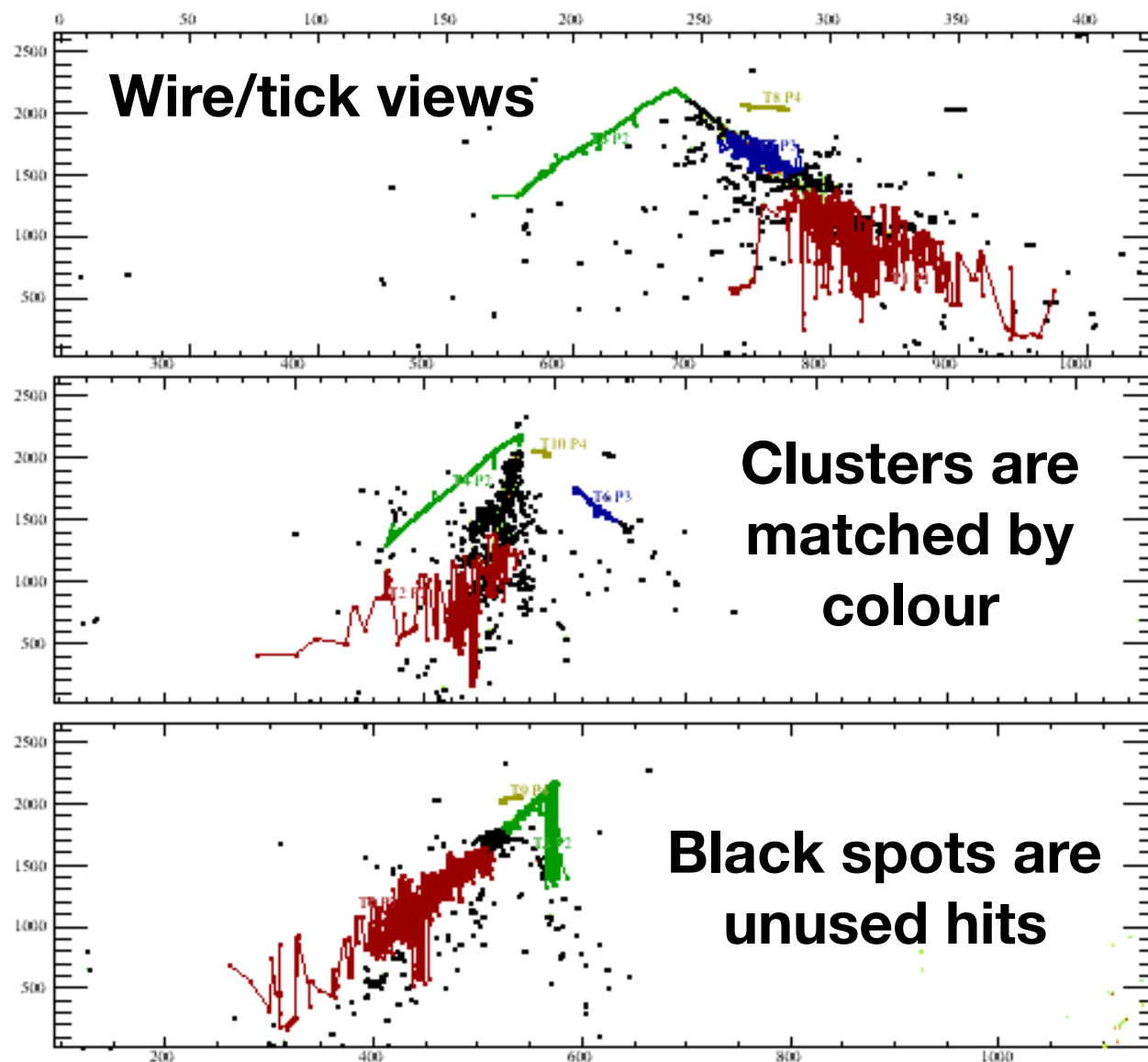
Completeness/hit purity



33024 (66.4%) events contain at least one reco. shower truth matched to the primary electron

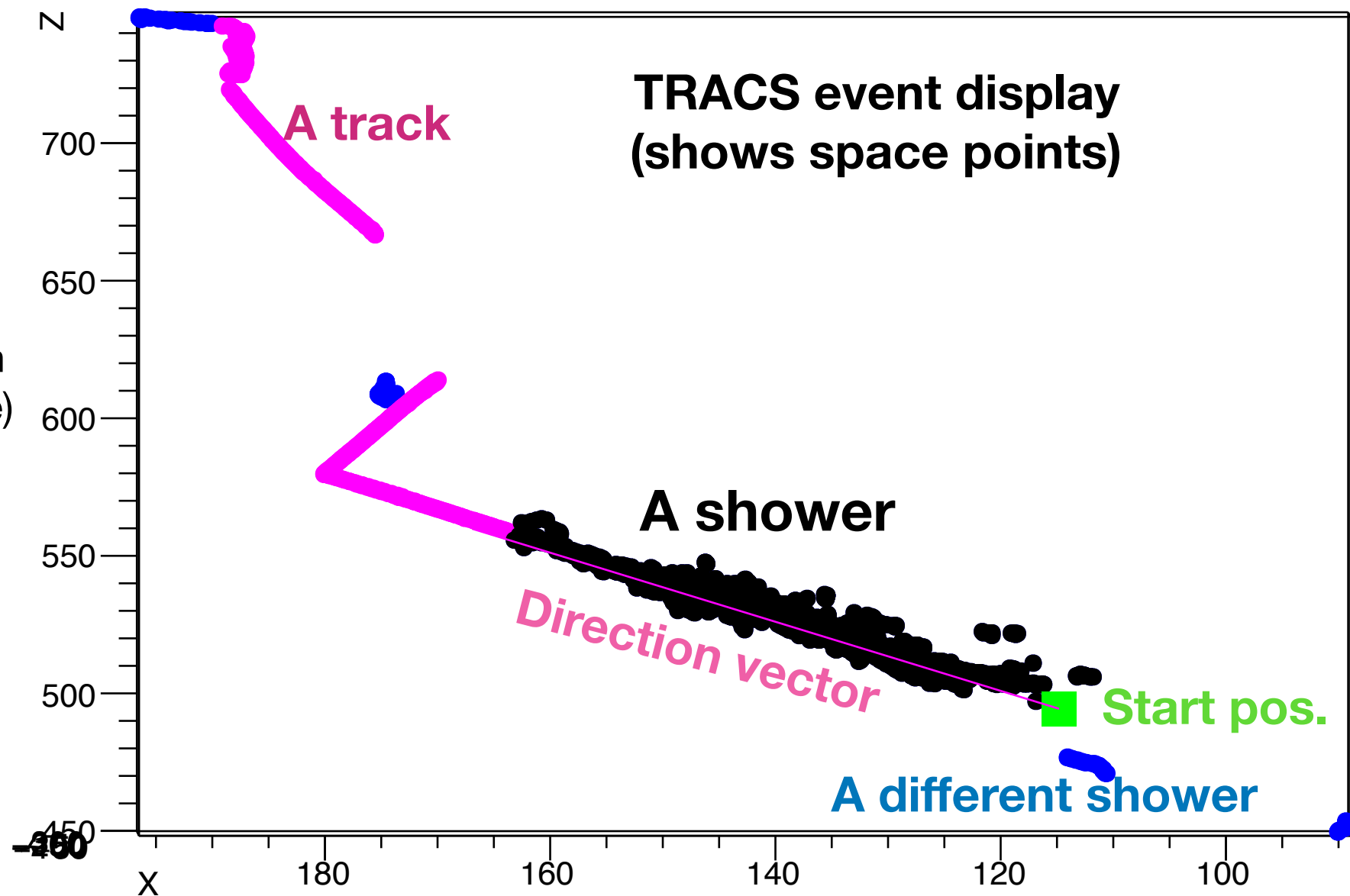
15110 (30.4%) events contain a primary electron-matched shower where the initial track stub contains at least one primary electron hit

Low completeness events

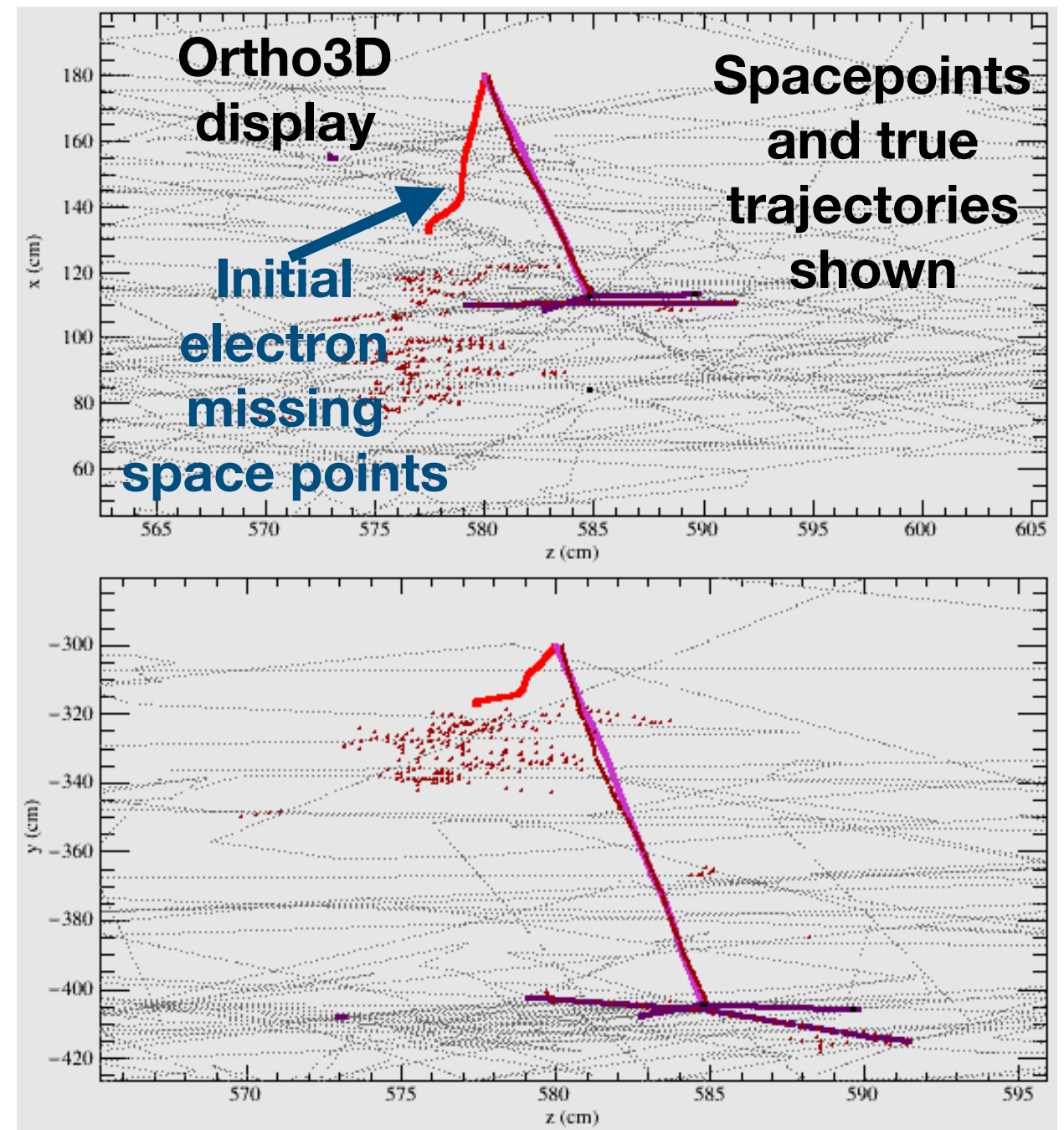
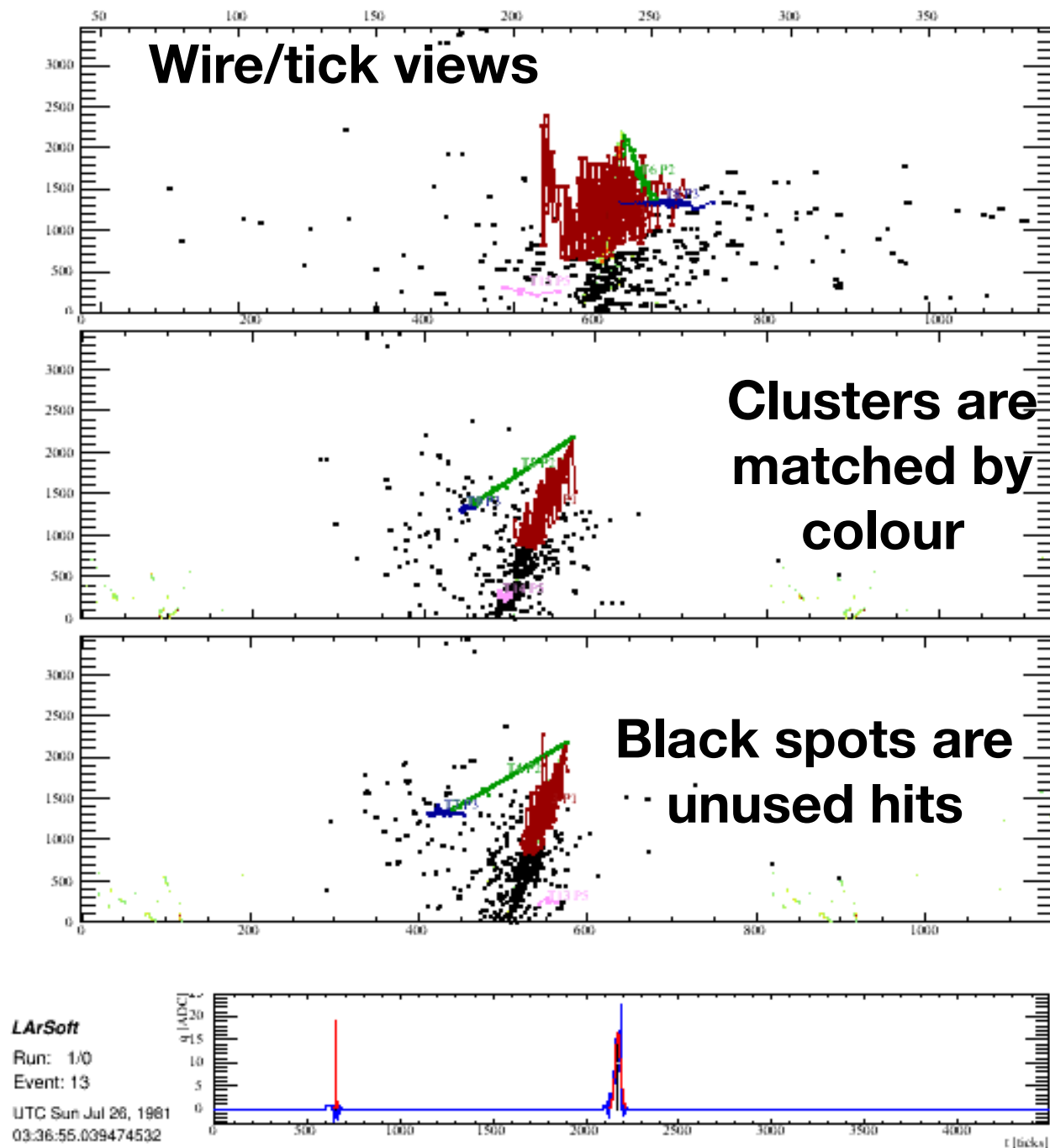


Low completeness events

- Chain of trip ups
- Pat. rec. separates track stub and cascade bulk (pink line [track] attached to black splodge [shower])
- Start position of cascade bulk then placed at wrong end (green square)
- The track stub finder fails to find any initial hits
- Shower is thrown away as it is incomplete
- One of the much smaller showers (blue splodges) becomes the shower with the highest hits

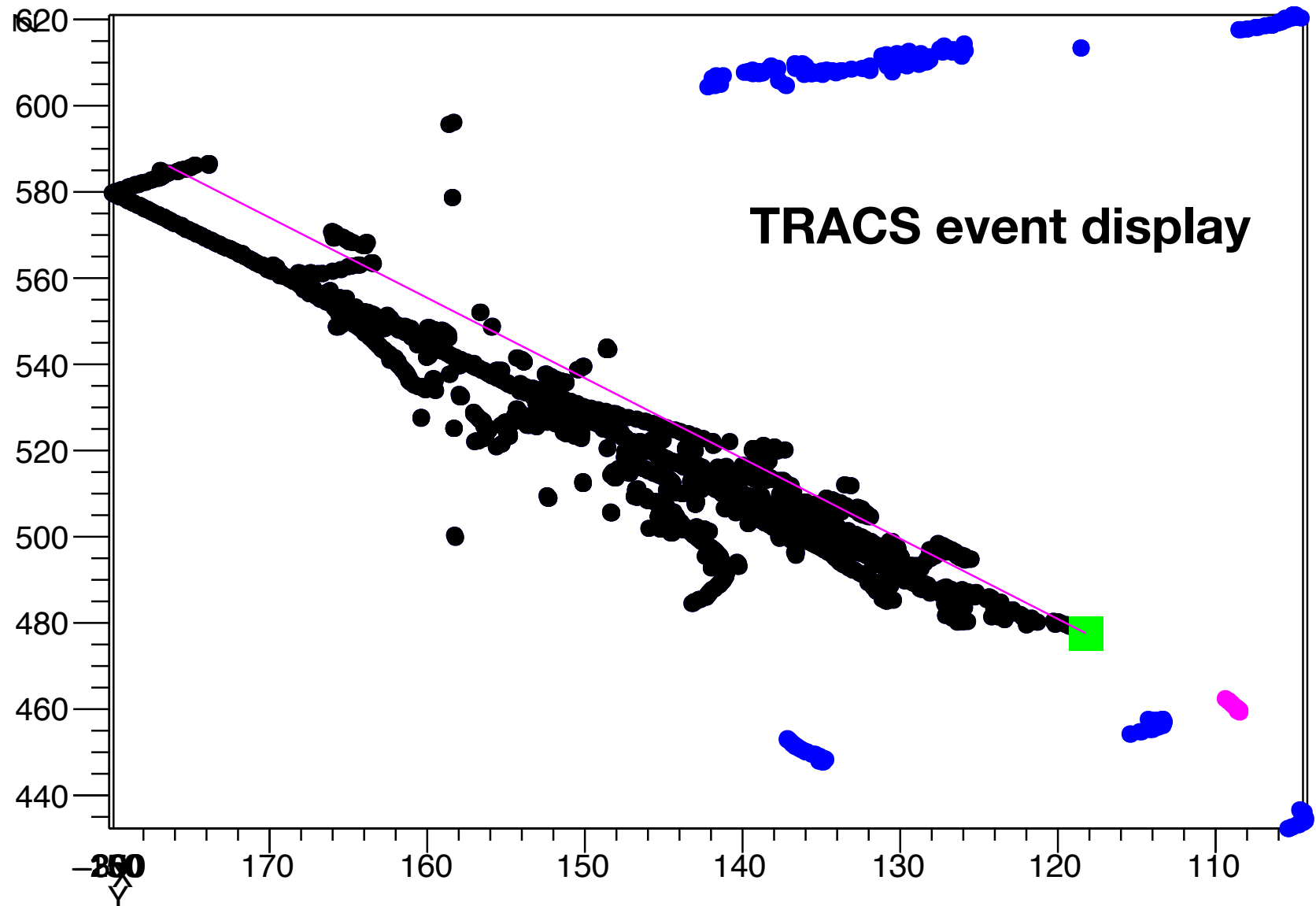


Low completeness events



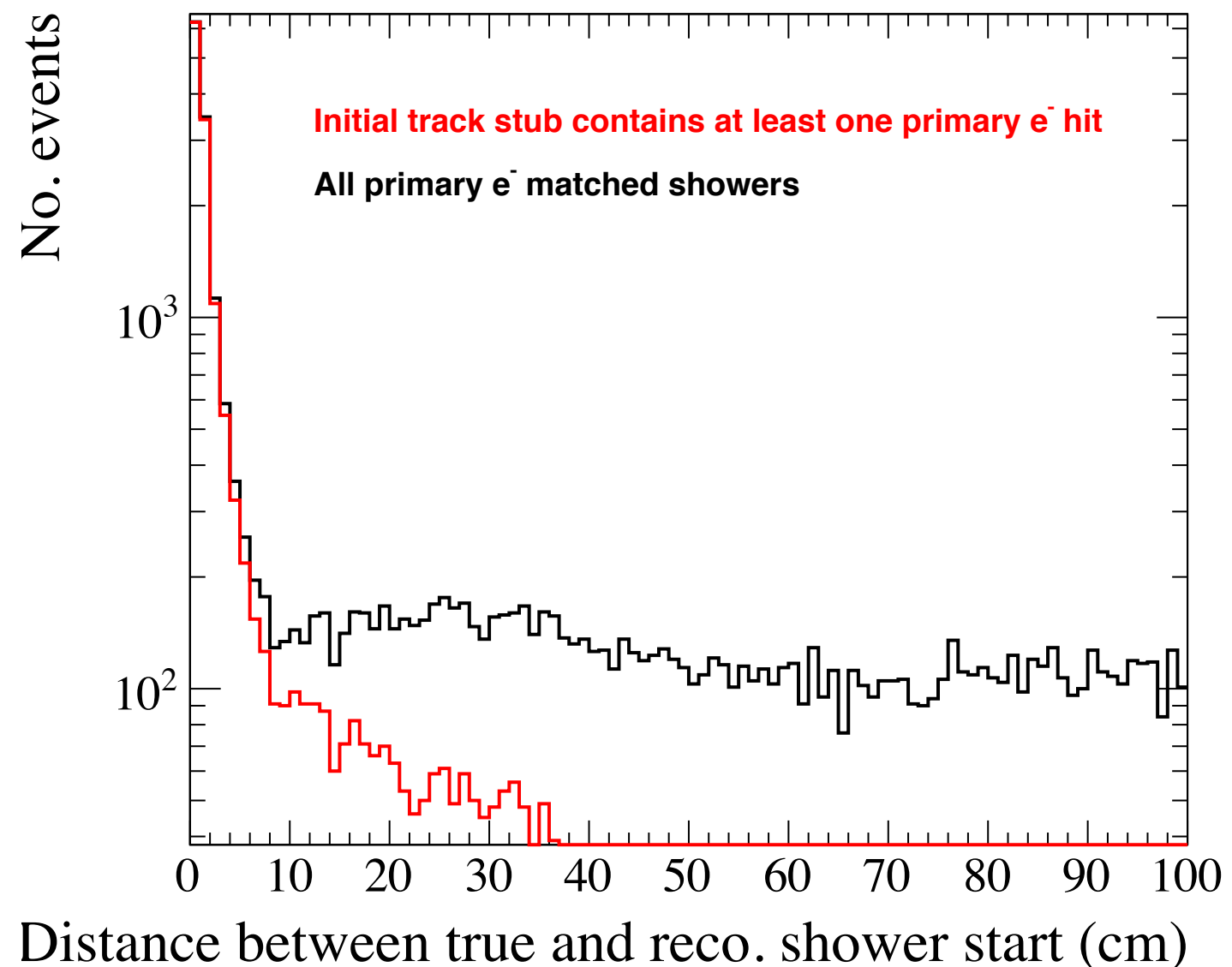
Low completeness events

- Another chain of trip ups
- Pat. rec. merges charged pion track with the whole electron shower
- Start position then picked to be the very end of the shower
- Charge-weighted PCA is biased towards centre of the pion track
- Track stub finder misses the shower space points as direction is mis-aimed
- Shower is thrown away due to being incomplete
- One of the much smaller showers (blue splodges) becomes the shower with the highest hits



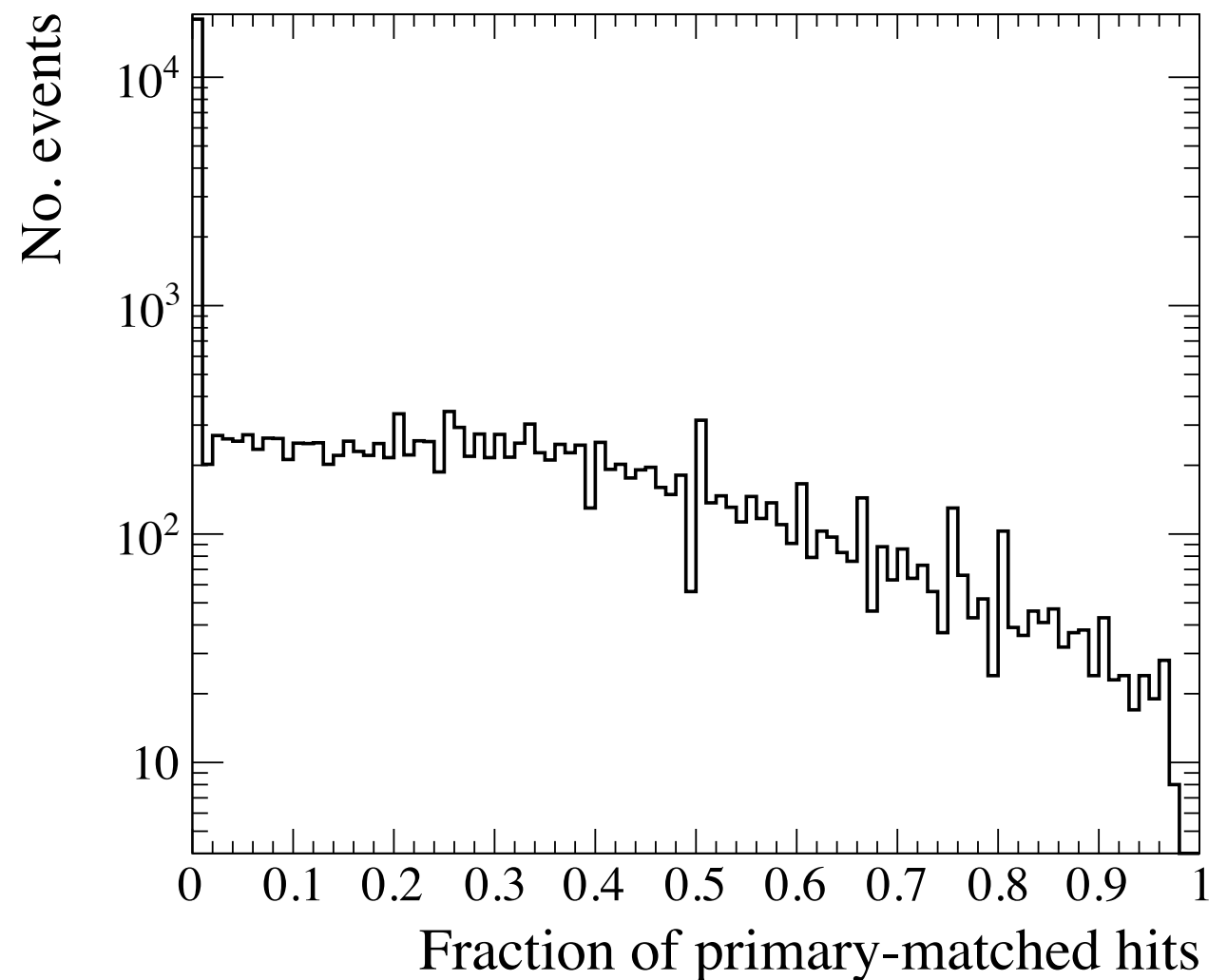
Shower start position

- Using *ShowerStartPosition_tool*
 - Takes the PFP's vertex as the shower start position
- Plot shows the distance between the true and reco shower start positions
- Nice sharp spike at 0 cm in all cases
- Wide tail is largely eliminated for showers in which the track stub contains a primary hit



The initial track stub finder

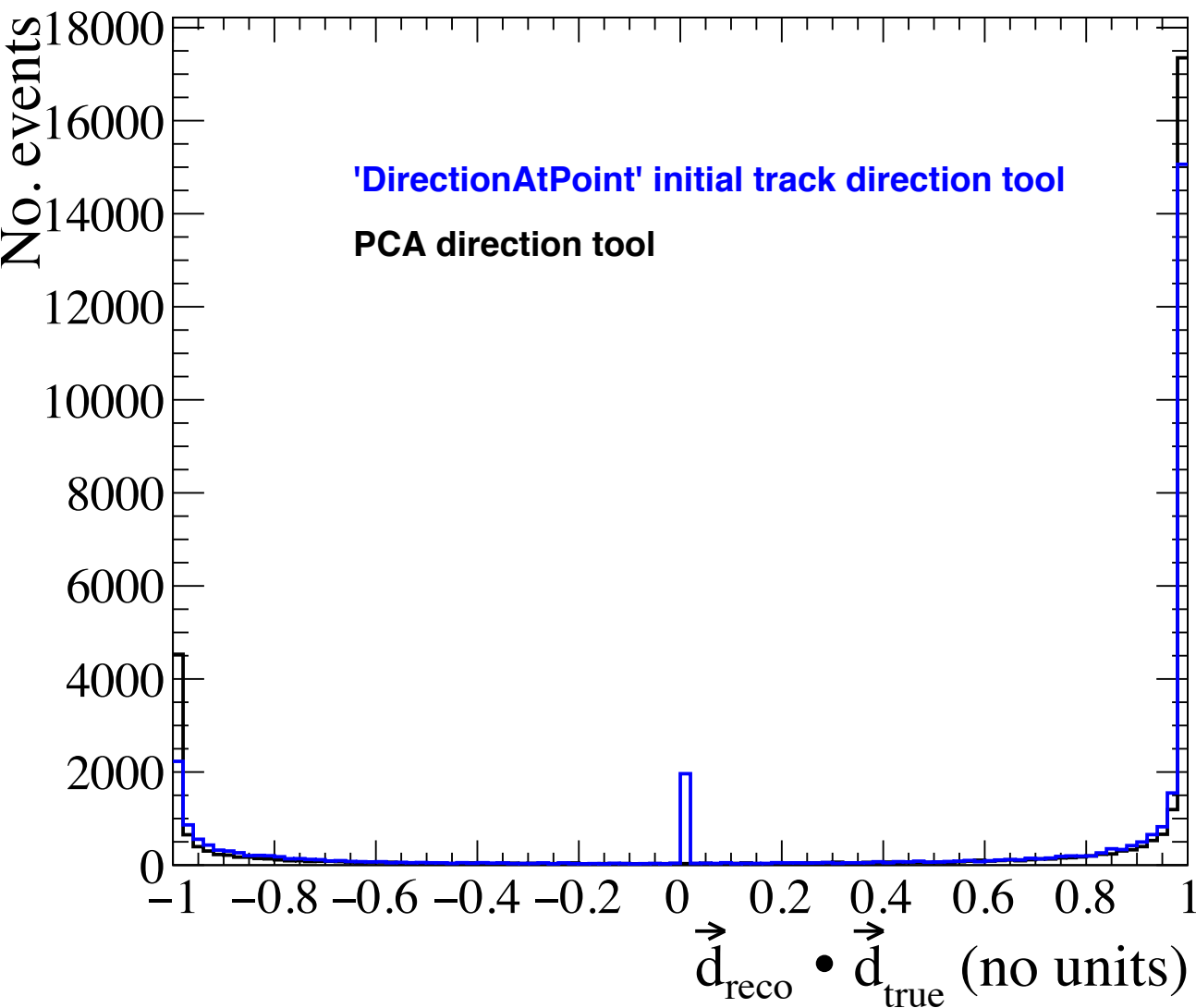
- Shower3DTrackHitFinder_tool
 - IDs track space points as those enclosed in a cylinder at the start of the shower
- Plot shows the fraction of shower-contained primary electron hits that are part of the initial track stub
 - **Not the same as completeness**
- 45% of initial track stubs contain a non-zero fraction of primary electron hits



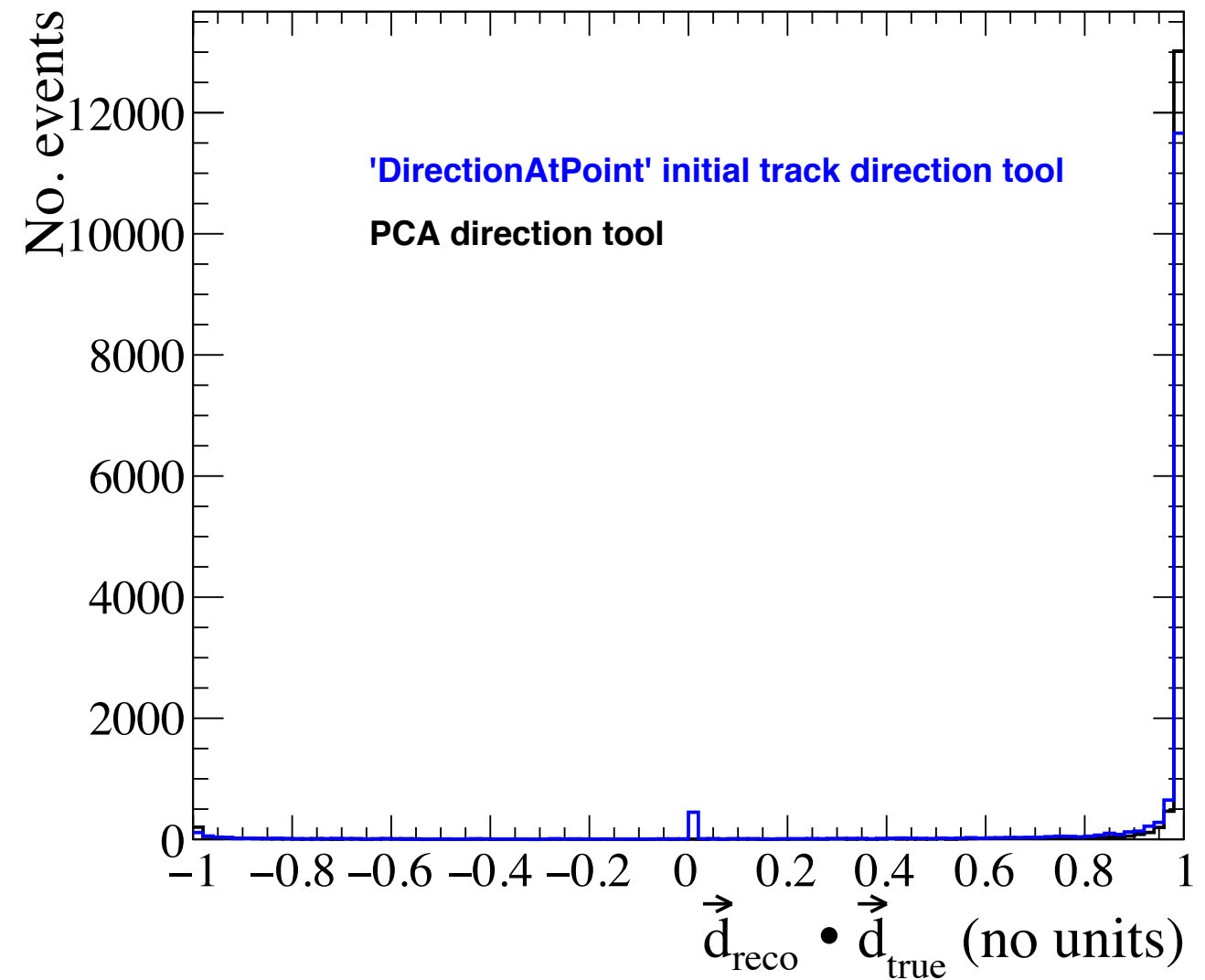
***Shown for showers which contain the max no. of hits AND truth match to the primary electron**

Direction

**Primary electron showers with
max. no. hits**



**Initial track contains one primary
electron hit**

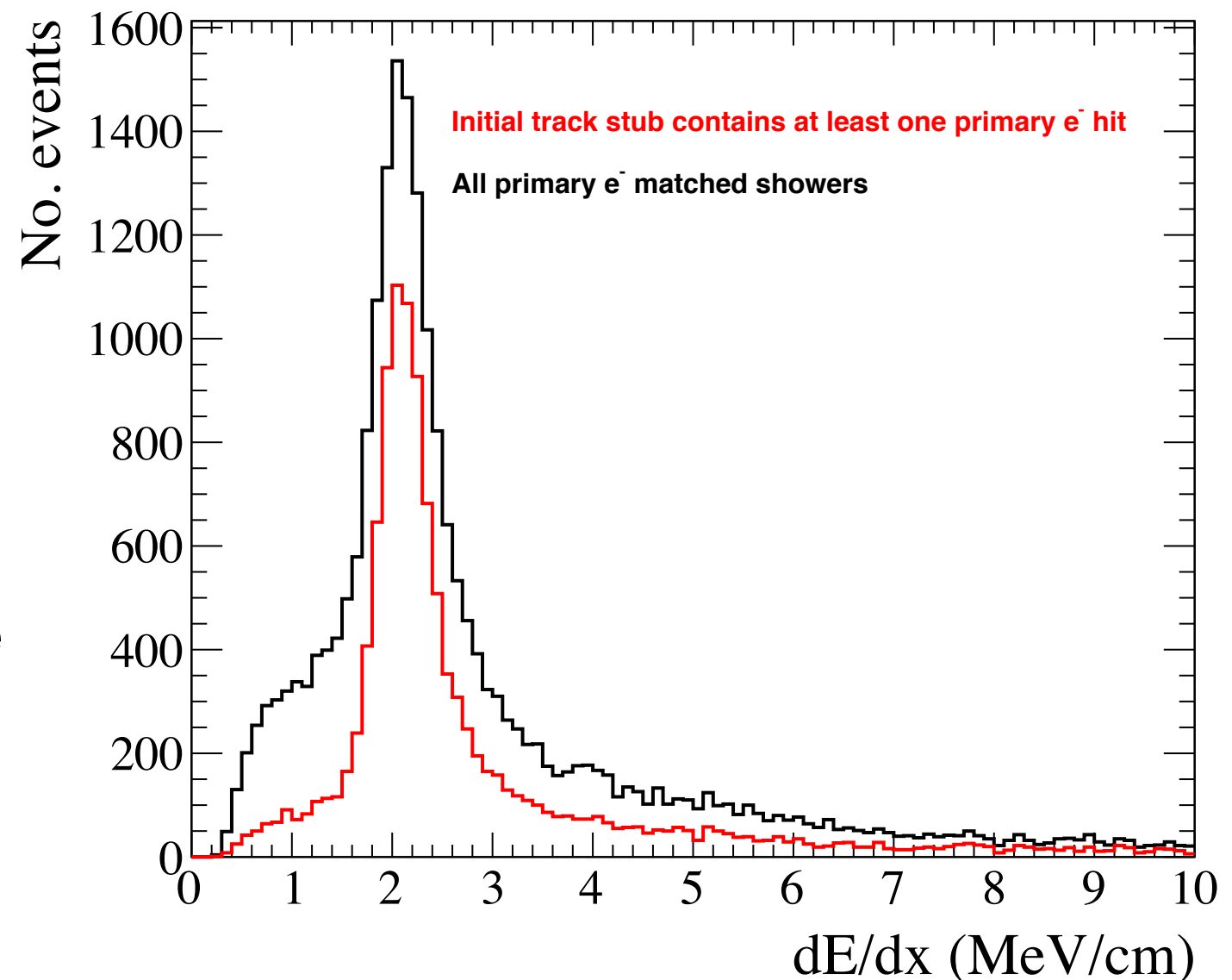


- PCA outperforms the direction from the initial PMA track in all cases
- This study will be redone with a new tool which uses pandora's sliding linear fit once it becomes available

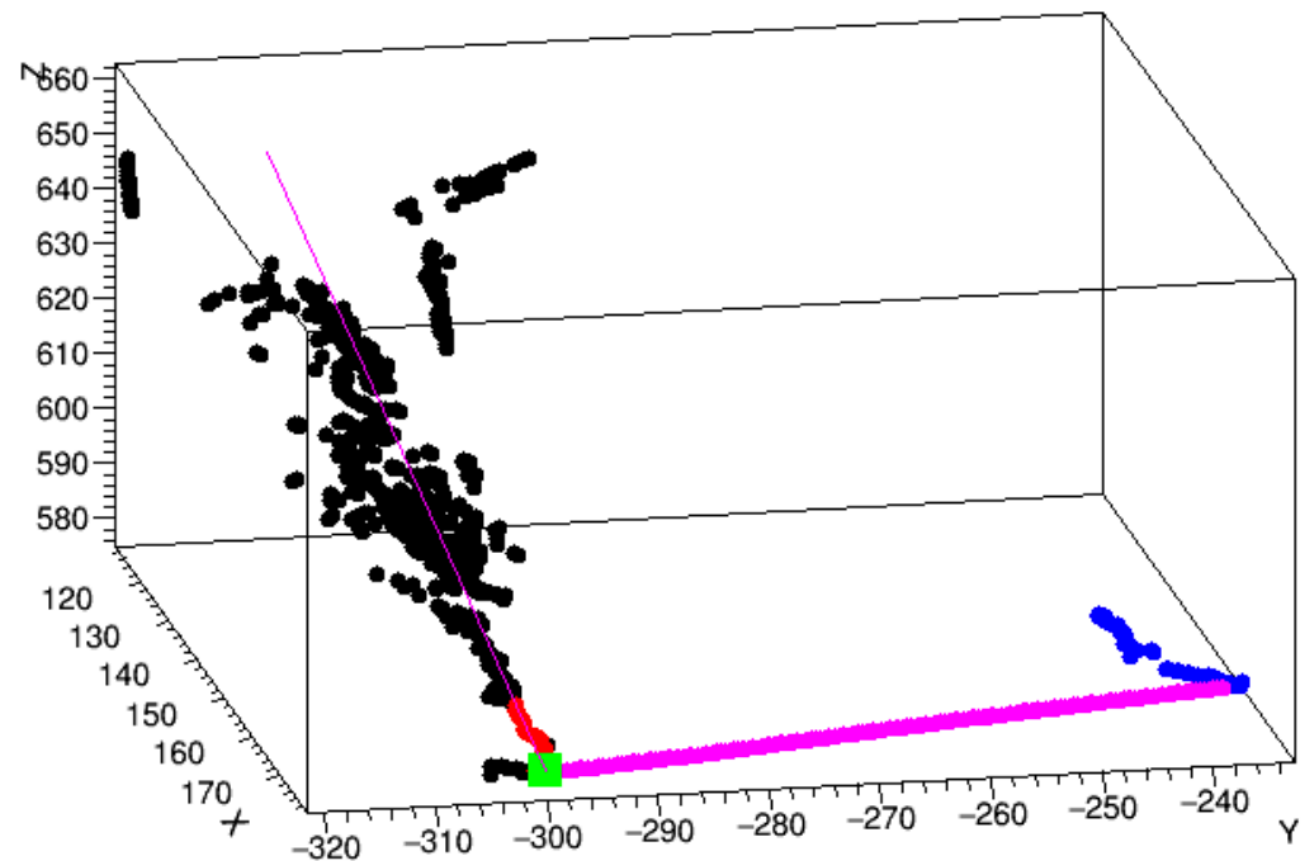
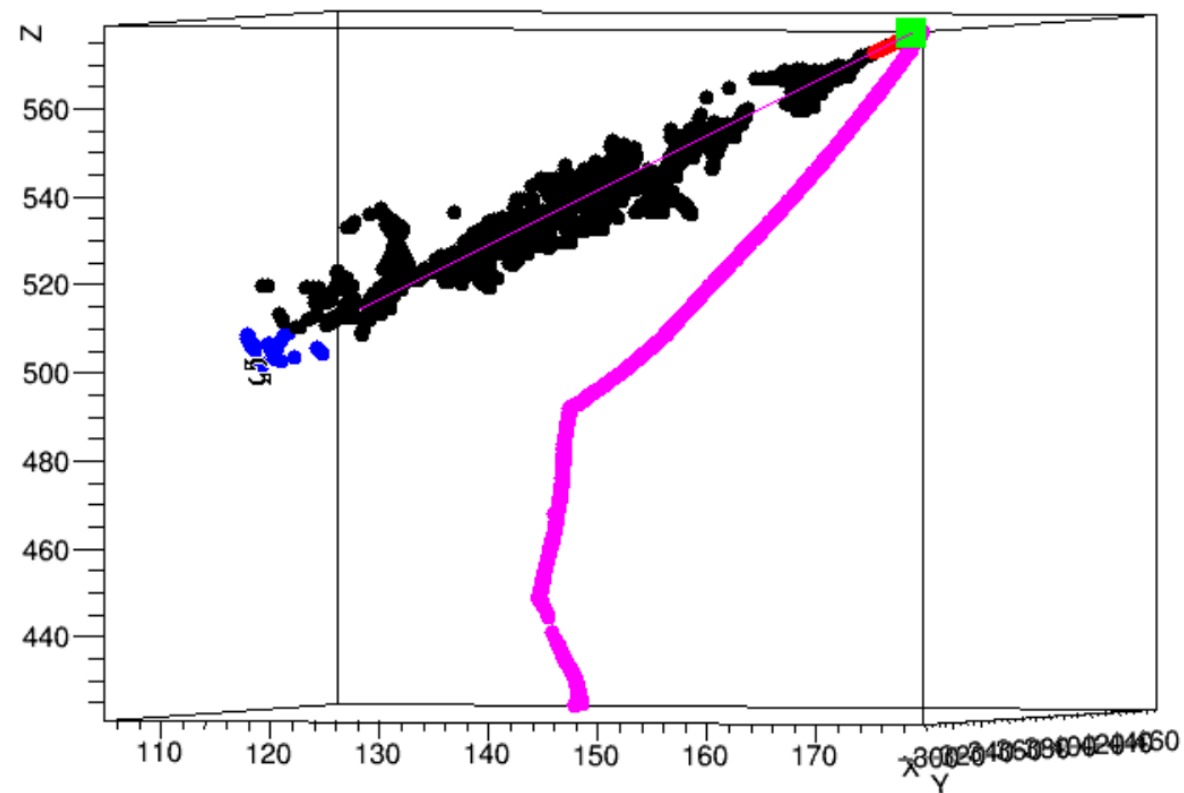
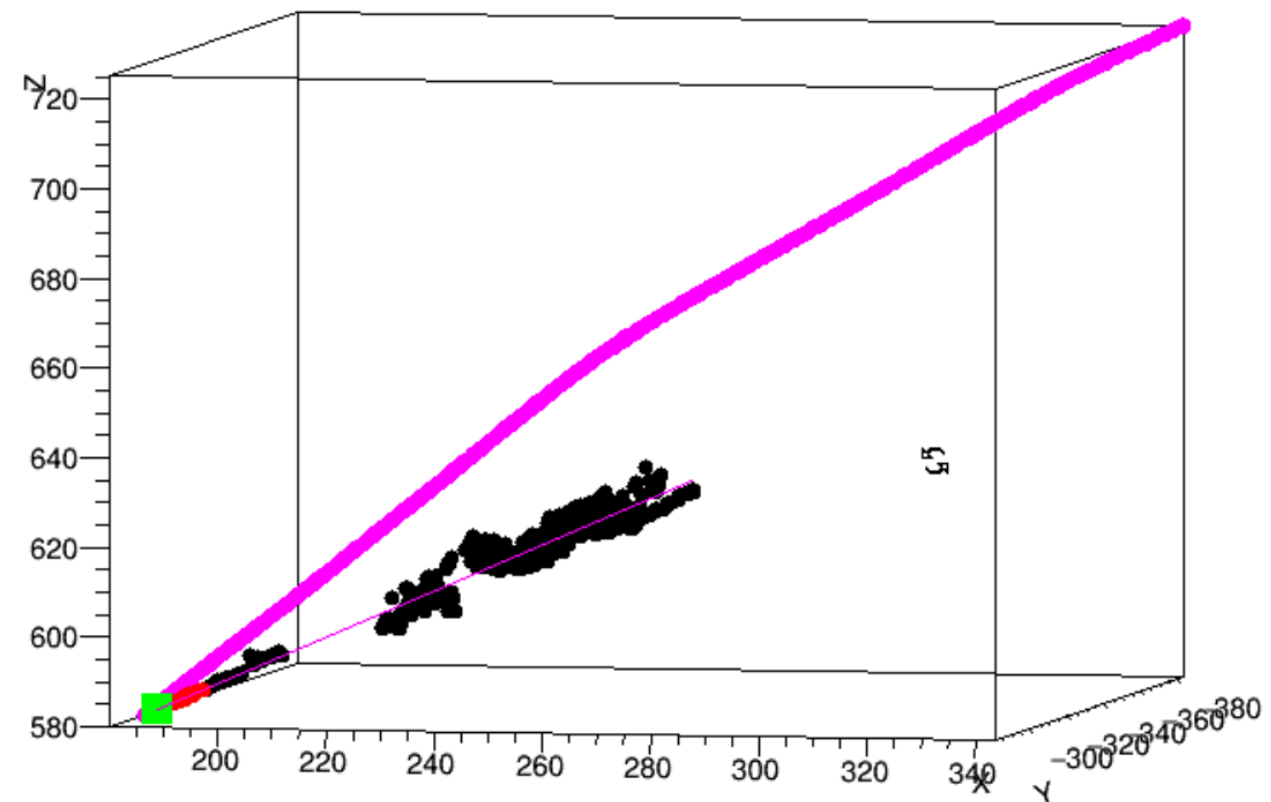
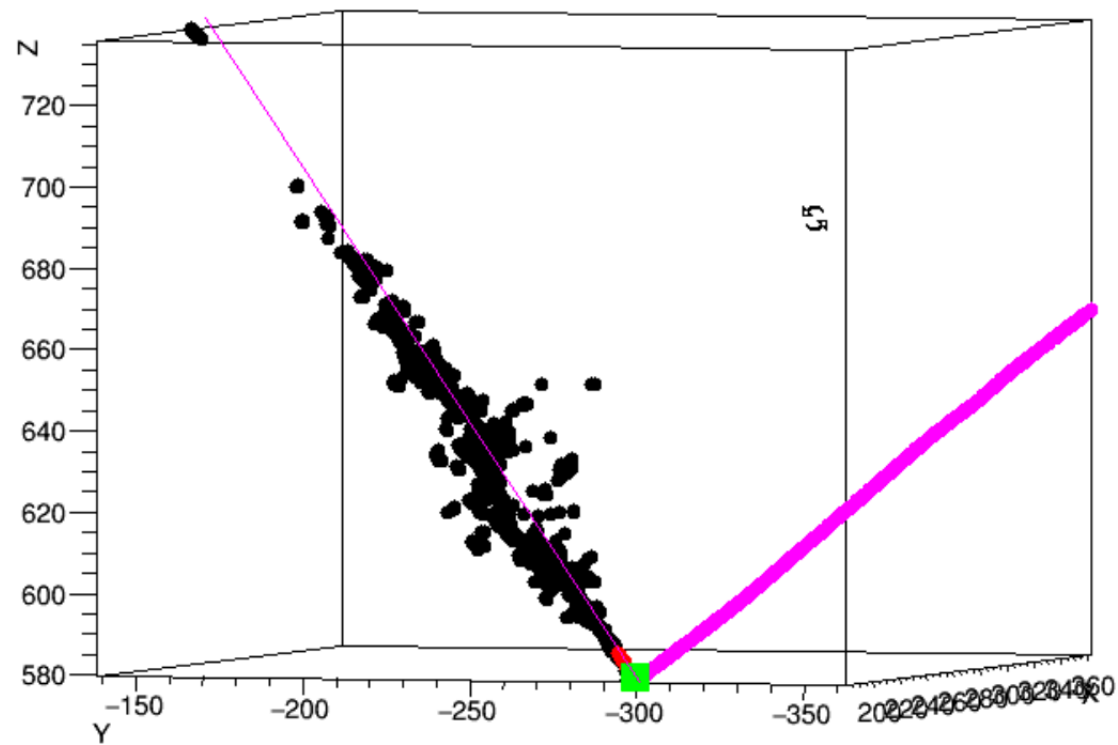
***Shown for showers which contain the max no. of hits AND truth match to the primary electron**

dE/dx

- ShowerStandardCalodEdx_tool
- Shower direction (required to calculate pitch) calculated by PCA tool
- MIP peak sharpens for cases where the track stub contains a primary electron hit



Good recos



Summary and future

- The Tool-based Reconstruction Algorithm for Characterising Showers (TRACS) is a shower characterisation module
 - Developed by Dom Barker and Ed Tyley as part of the SBN shower reconstruction WG
 - Relies on pandora PFParticle input
- TRACS outsources all calculation to an arbitrary set of art tools, each of which calculates a specific shower parameter
- TRACS is now being configured for use in the DUNE FD
- Future tools are under development/will soon be available
 - Fitting the initial track stub with pandora's sliding linear fit
 - An incremental fit-based track stub finder

Backups

What causes the spike at 0

