Update on the reconstruction with lens-based optical readout in GRAIN

SAND Physics/Software meeting
06/05/2022

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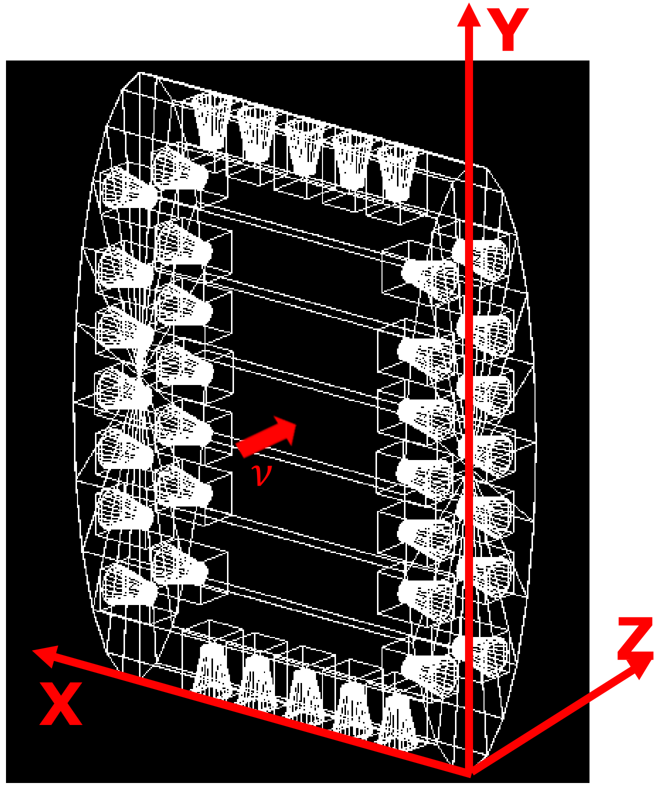
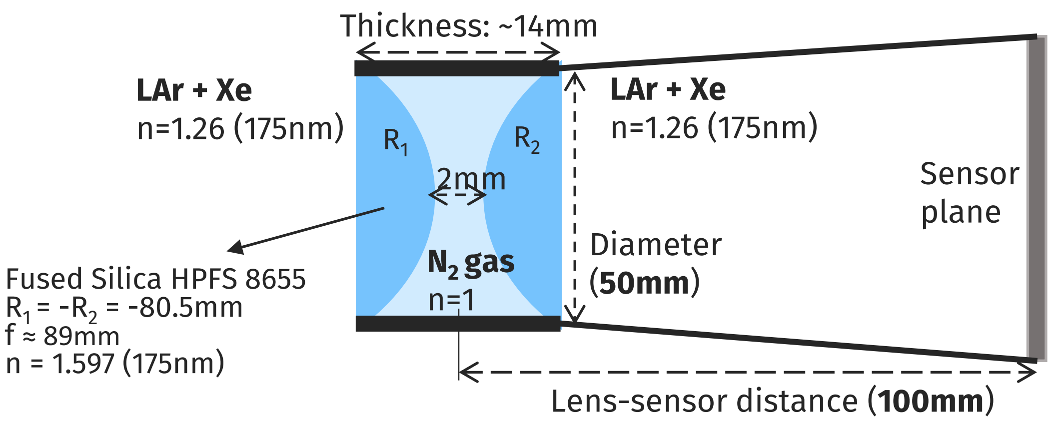
RECAP: lens geometry in GRAIN

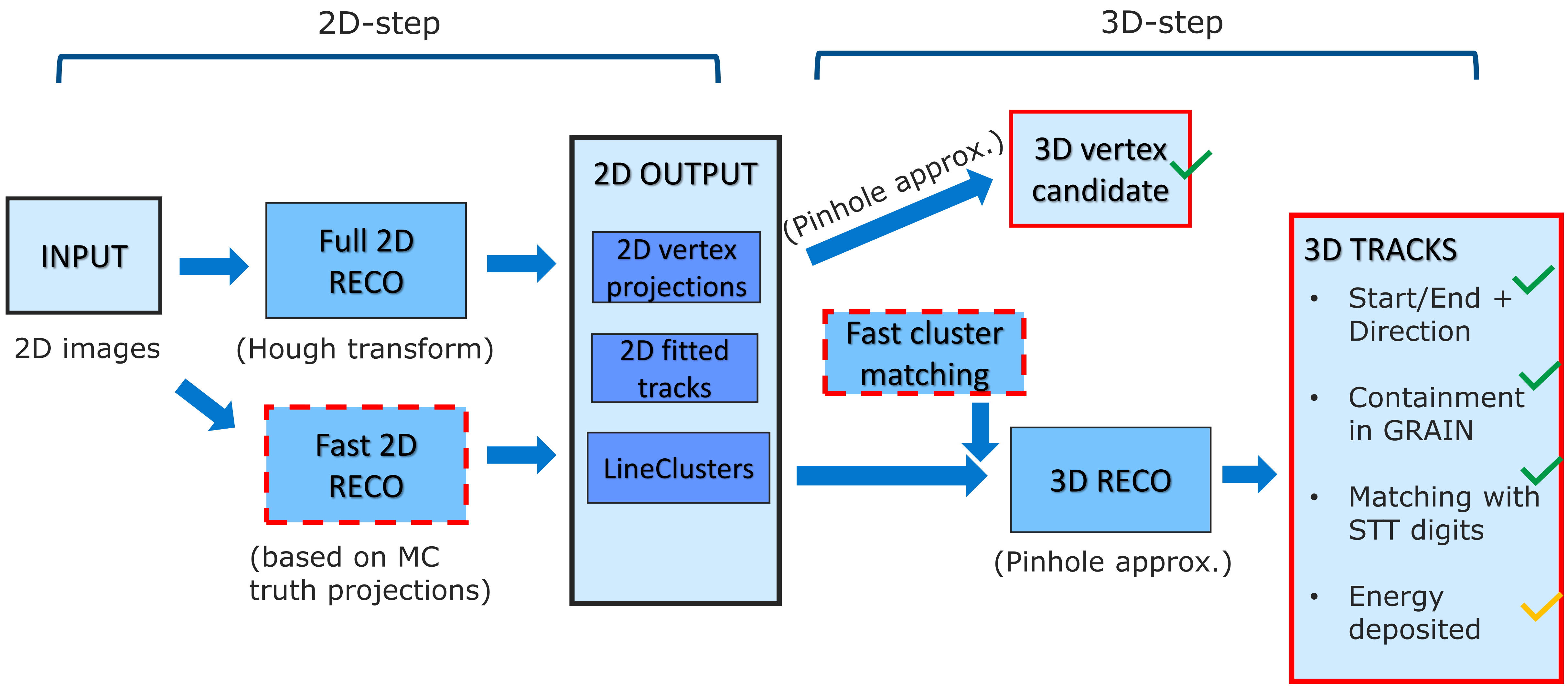
- Latest GRAIN geometry
  - Except $L_x = 1000\ mm$
- Equipped with lens-cameras inside the LAr volume.
- 38 cameras, for maximum coverage:
  - 14 pairs on the sides (at optimal distance)
  - 5 pairs on top/bottom
- Assuming 32x32 matrix sensors, with 2 mm pixels and 20% QE.

GDML:



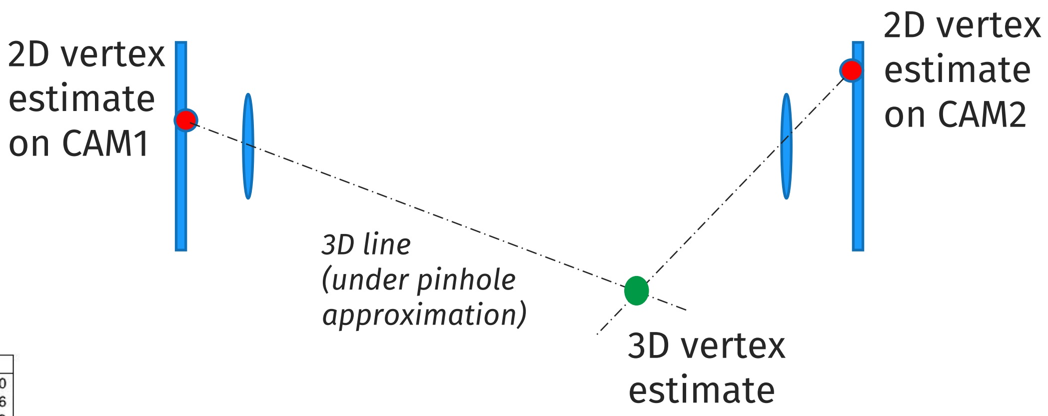


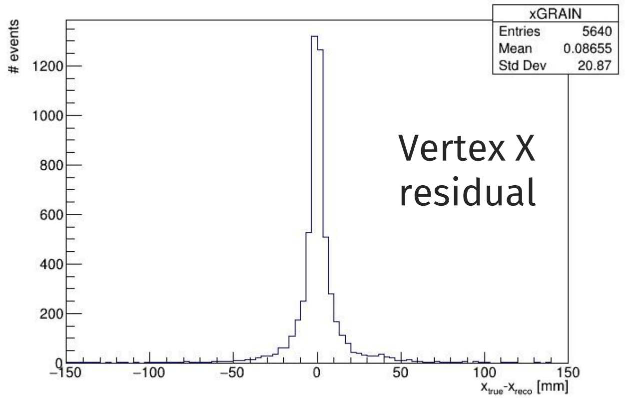
Current status of the reconstruction

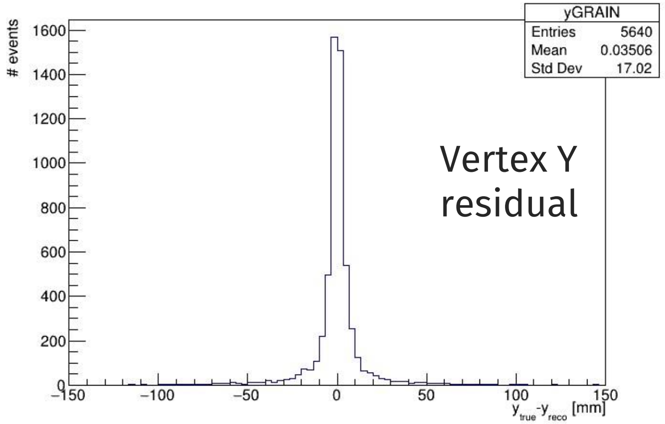


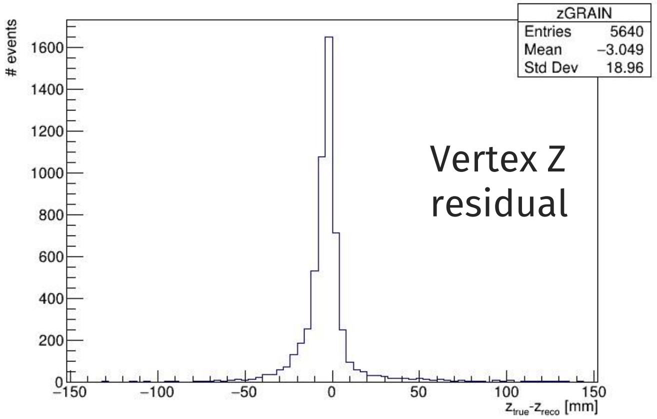
3D vertex: visible tracks in GRAIN

- Fit on 2D **visible tracks (MC truth**, with **>10 pixels)**
  - **Simple line fit** (one visible track at a time), intersect to find 2D estimate
  - Propagate to 3D (pinhole approx.), intersect and find the average

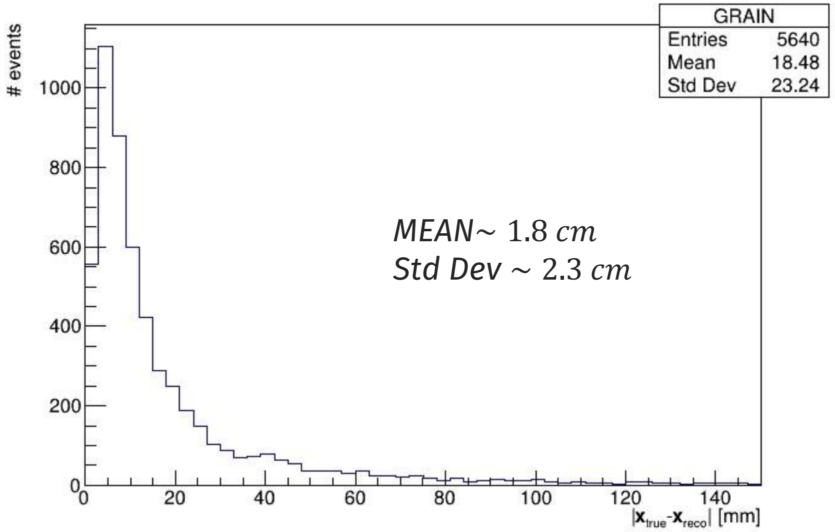






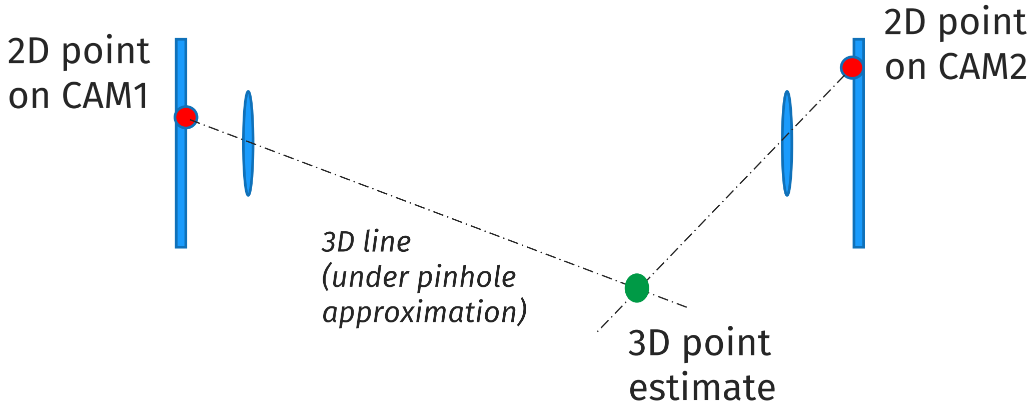


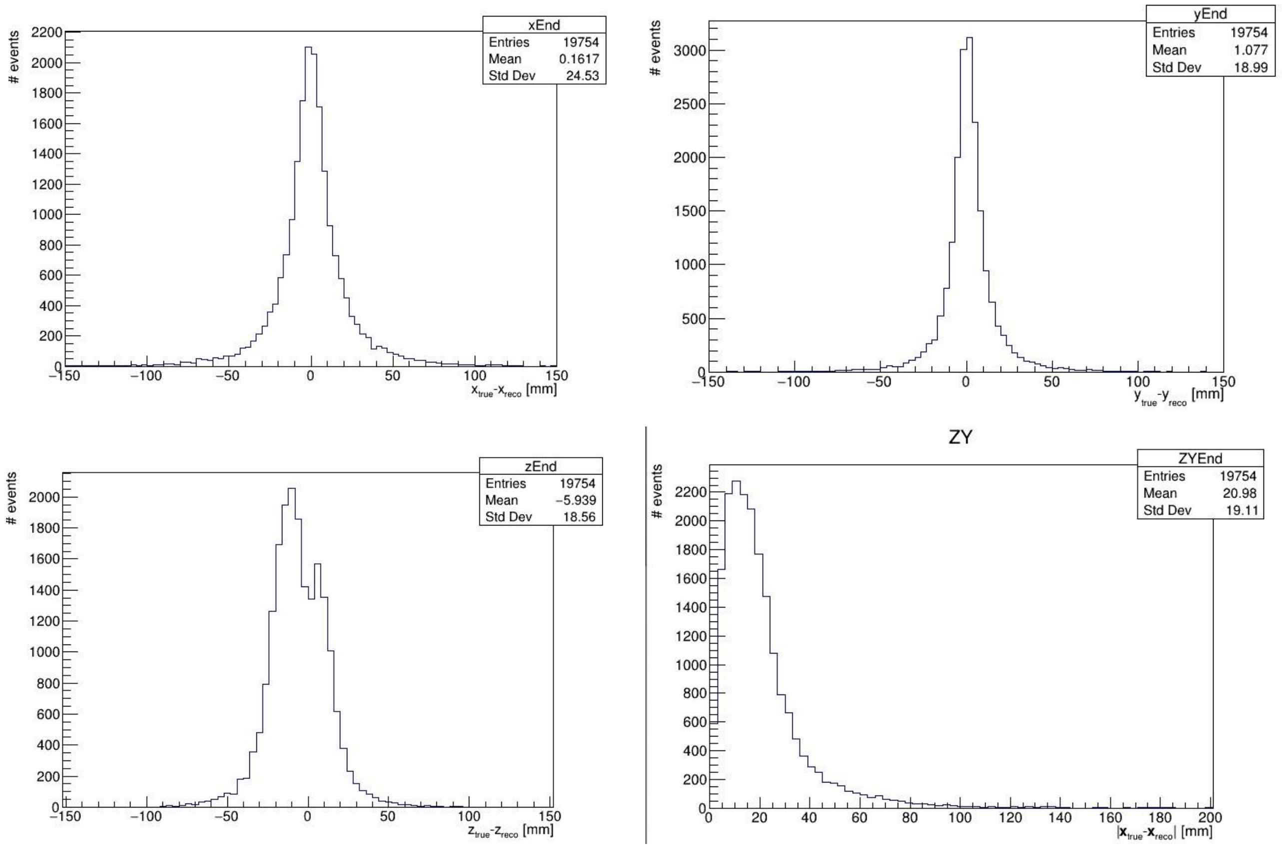
Vertex 3D residual



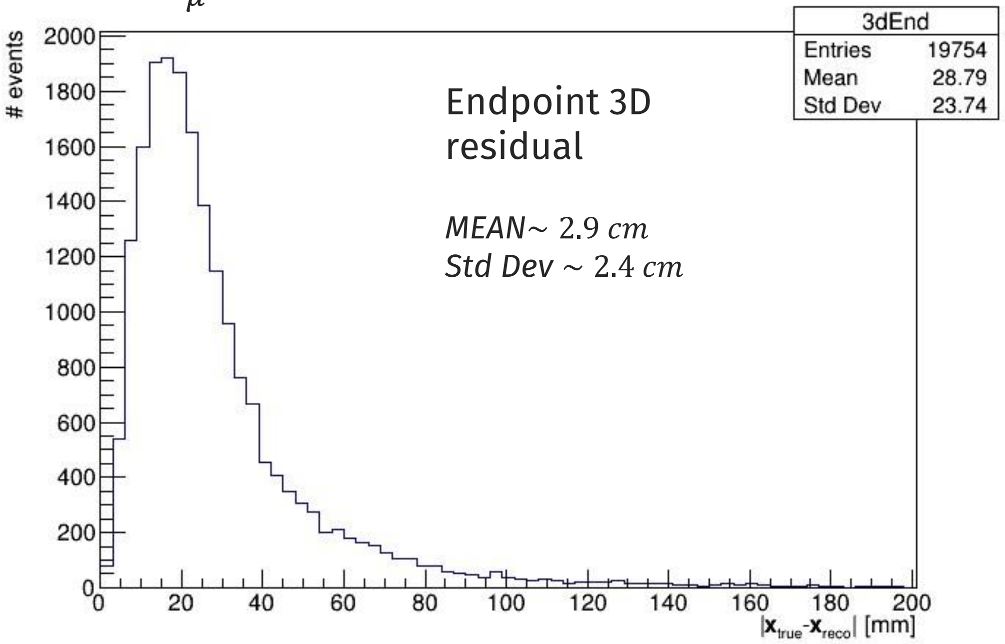
Sample:
$15k\ \nu_\mu CC$

3D track endpoints



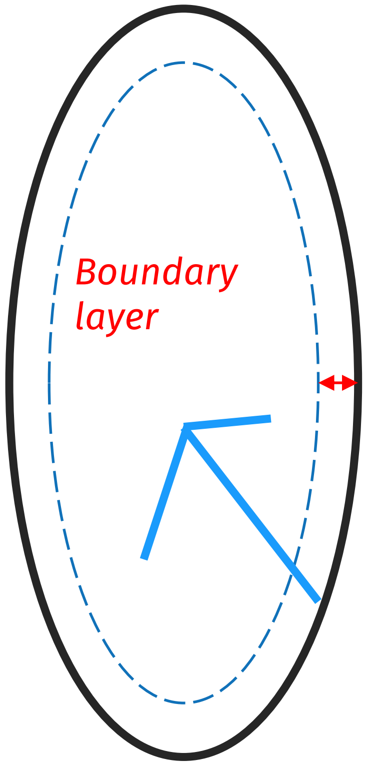


Sample:
$15k\ \nu_\mu CC$

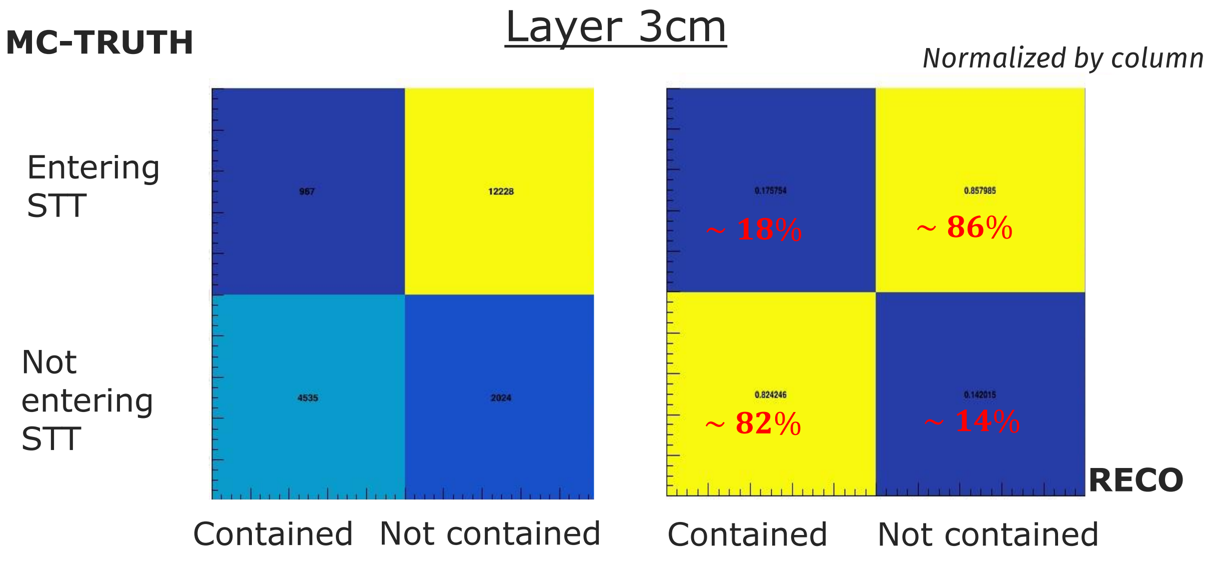


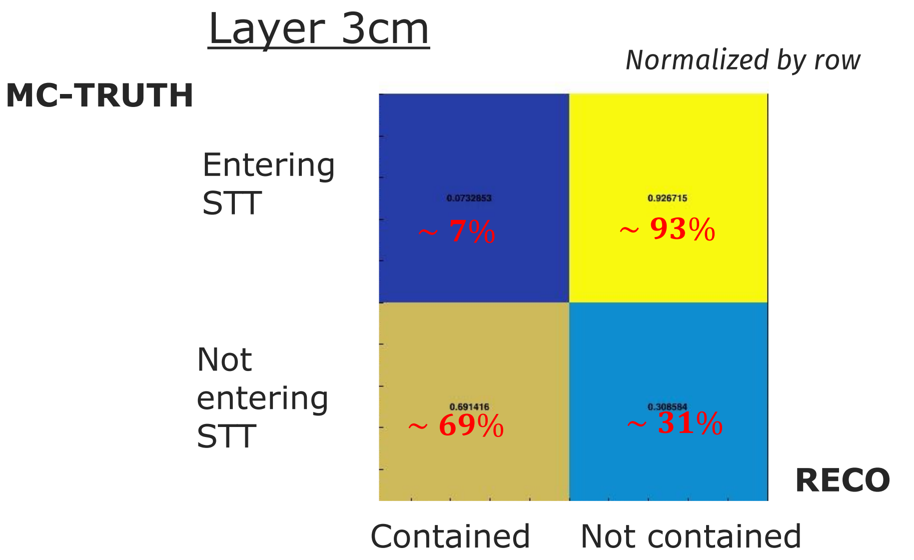
Containment in GRAIN

<u>Sample</u>:
$15k\ \nu_\mu CC$



Check if the endpoint falls in a layer close to the internal surface of the cryostat





- **>80% purity** in contained/not-contained RECO samples
- >90% efficiency for labelling exiting tracks
- ~ 70% efficiency for labelling not-exiting tracks (worse, but STT will know better)

Energy reconstruction in GRAIN

- **Total energy** released in GRAIN
  - → by summing up all collected photons from all cameras
  - This calorimetric approach is under study with the coded mask readout (with nice results!)
  - Possible with lenses also, but not investigated yet
- Energy released in GRAIN **track by track** → **this update**
  - Exploits clear track separation in the images to associate collected photons to each track
  - The concept works, still some issues for complex events → work in progress.

Simple algorithm for track energy reconstruction

- For a given track, in the i-th camera:

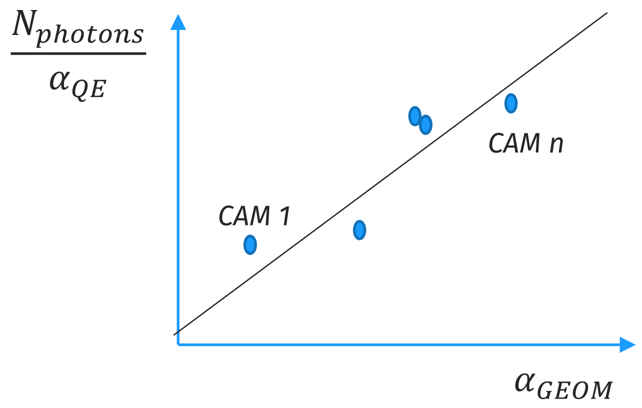
$$N^i_{photons} = \alpha^i_{QE} \alpha^i_{GEOM} N_0$$

  - where $i = 1, \dots, n_{CAM}$
  - N_0: number of photons emitted isotropically by the whole track
  - α^i_{QE}: quantum efficiency (**KNOWN**)
  - α^i_{GEOM}: solid angle, geometrical acceptance →**ESTIMATED** after 3D track reconstruction (using a simple geometrical MC)
  - $N^i_{photons}$: total number of photons collected in the image from that track → **MEASURED**

$$\alpha^i_{GEOM} = \frac{n_{emit}}{n_{coll}}$$

- So plotting a point for each camera:

$$\frac{N^i_{photons}}{\alpha^i_{QE}} = N_0 \cdot \alpha^i_{GEOM}$$

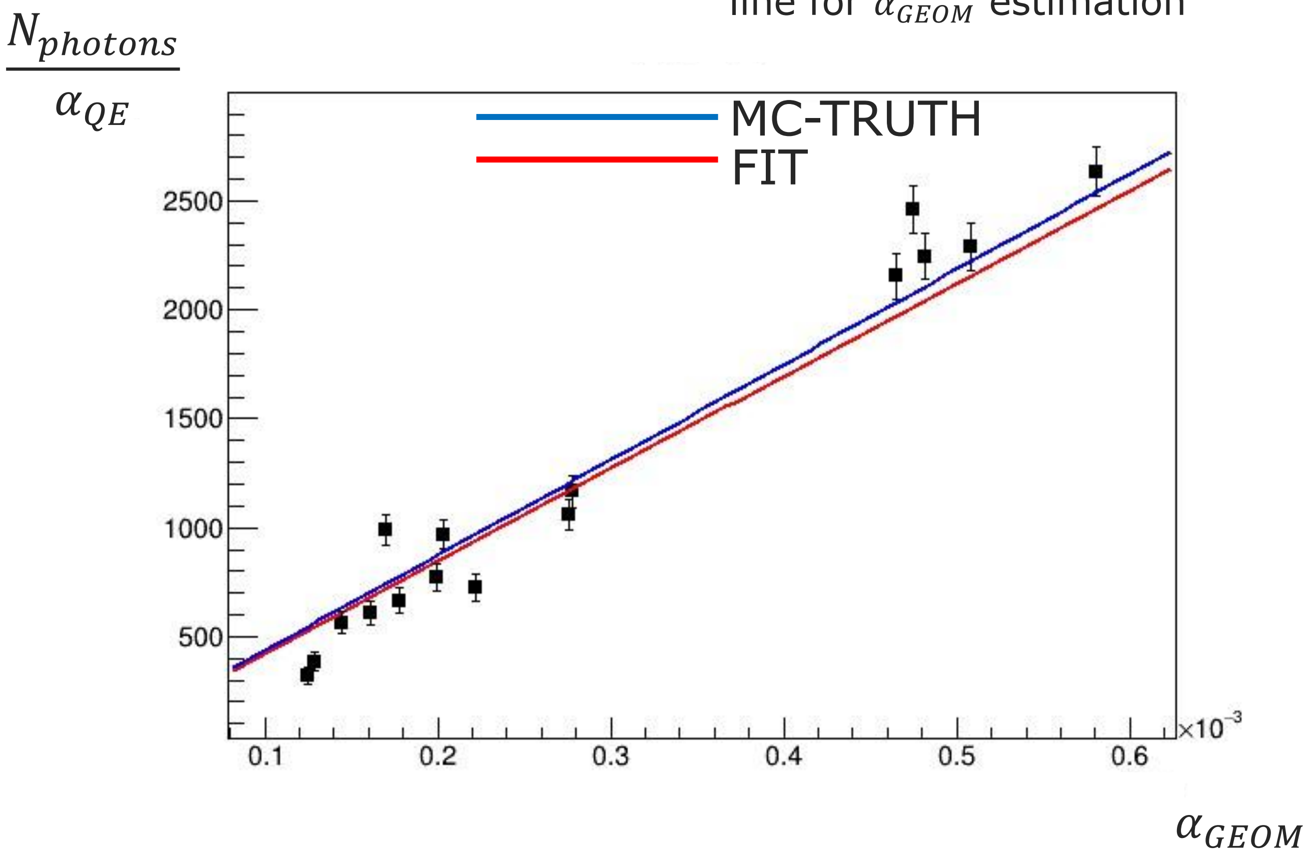


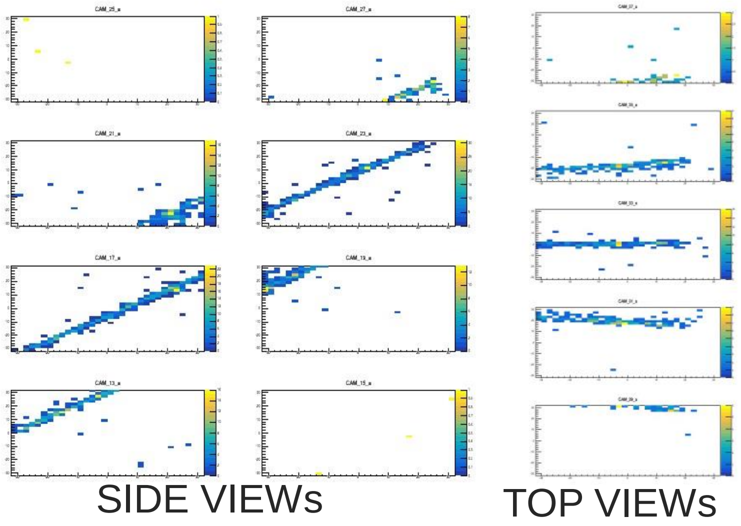
- N_0 is the slope → convert to energy using nominal light yield

Example: simple muon track

START (0,0,-230)mm
DIR (0,1/√2,1/√2)

Disclaimer: here using true 3D line for α_{GEOM} estimation

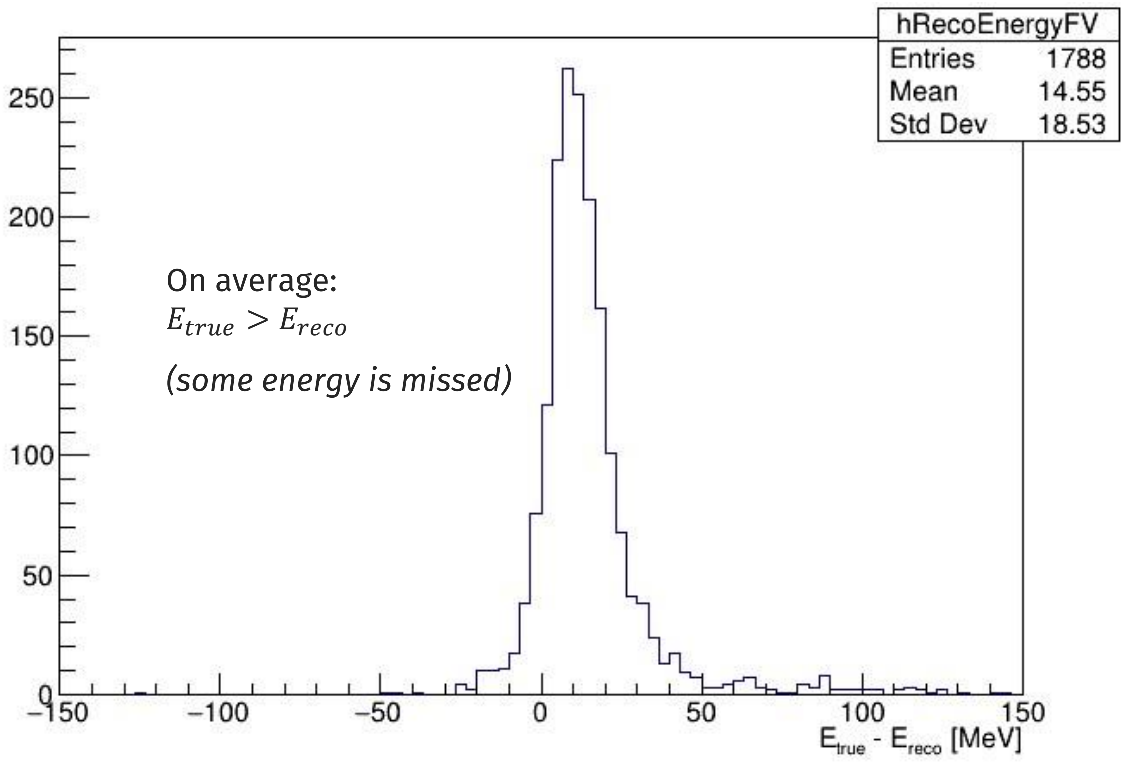


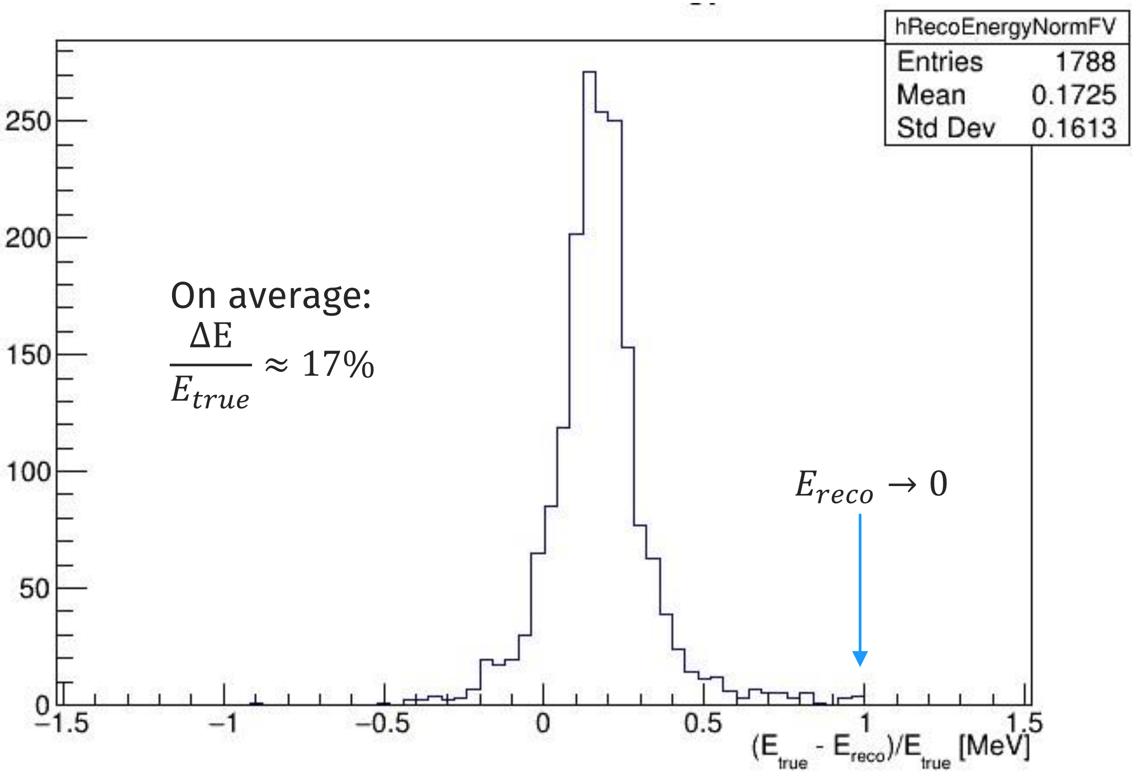


Reco $N_0 = 4.24 \times 10^6$
True E: 109.335 MeV
Reco E: 106.012 MeV

5k muons tracks in FV

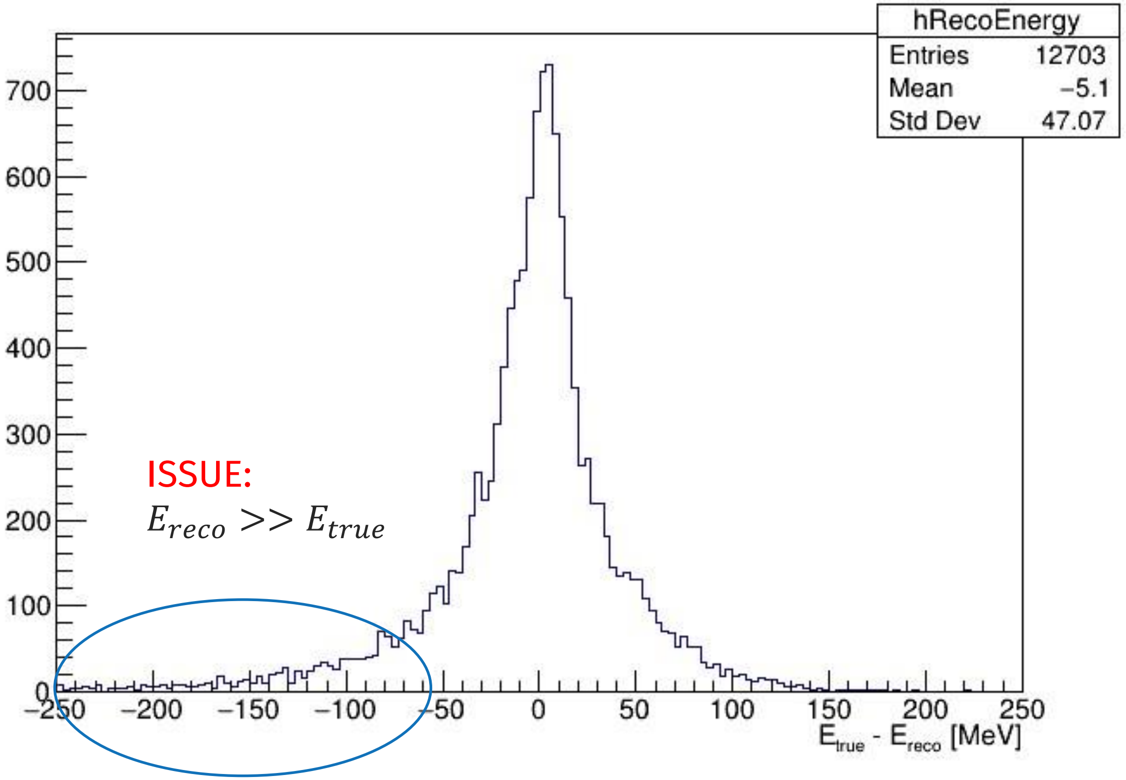
- Random position in FV (|x|<450mm, |y|<500mm, z<150mm), selection: $\vec{r} \cdot \hat{z} > 0.1$

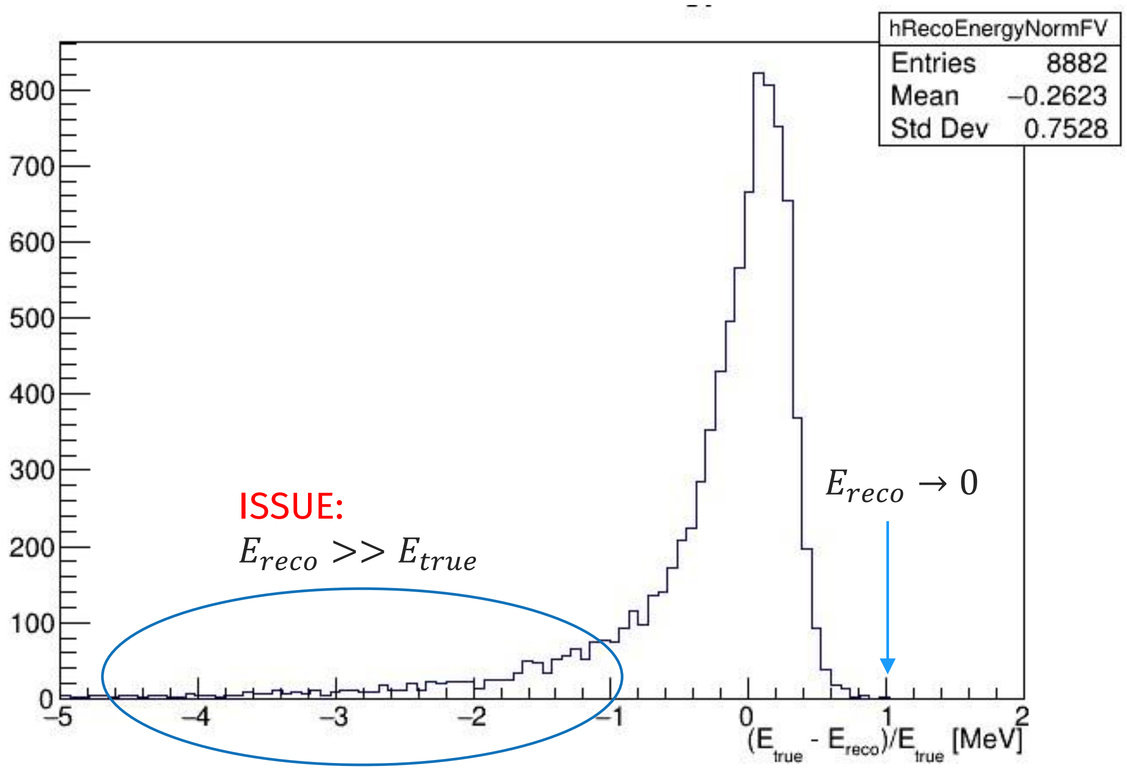




15k ν_μCC events

- FV cut (|x|<450mm, |y|<500mm, z<150mm)





Related to events with **tracks overlapping** in the images (sometimes too short and not visible) → collected photons from a given track are overestimated

Looking at a sub-sample…

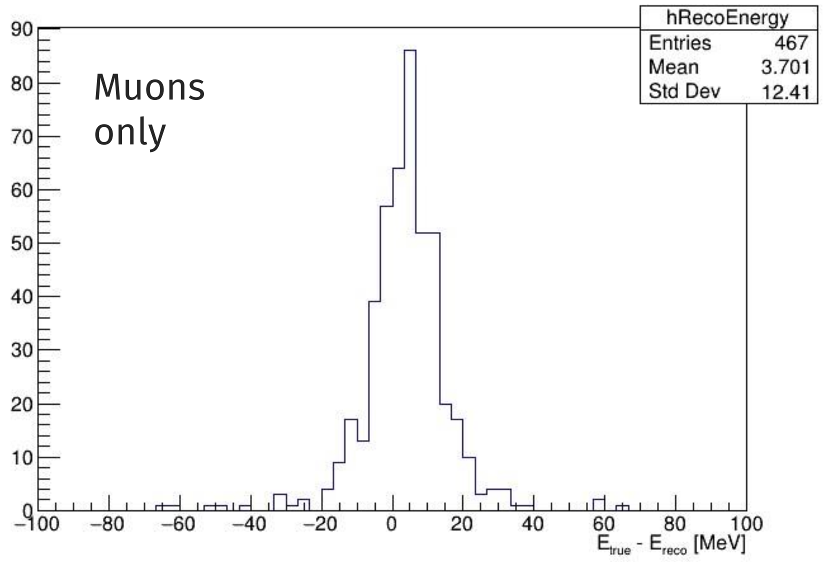
- Simple topology: QE interactions
- For example, focusing on **protons:** lower acceptance for STT comparing with other species (→see Nibir's past talks). **How well can GRAIN reconstruct them?**

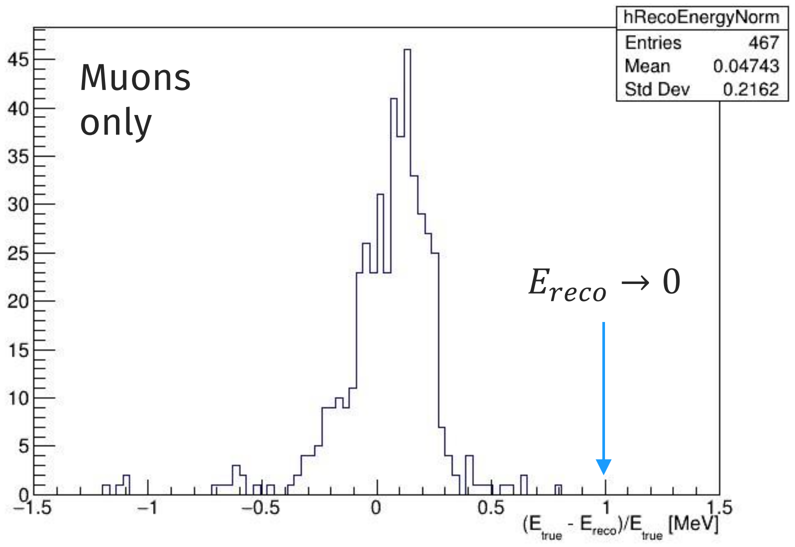
Sample:
$15k\ \nu_\mu CC\ \rightarrow 1.9k\ QE\ (12.7\%)$ → FV (|x|<450mm, |y|<500mm, z<150mm): **890** events

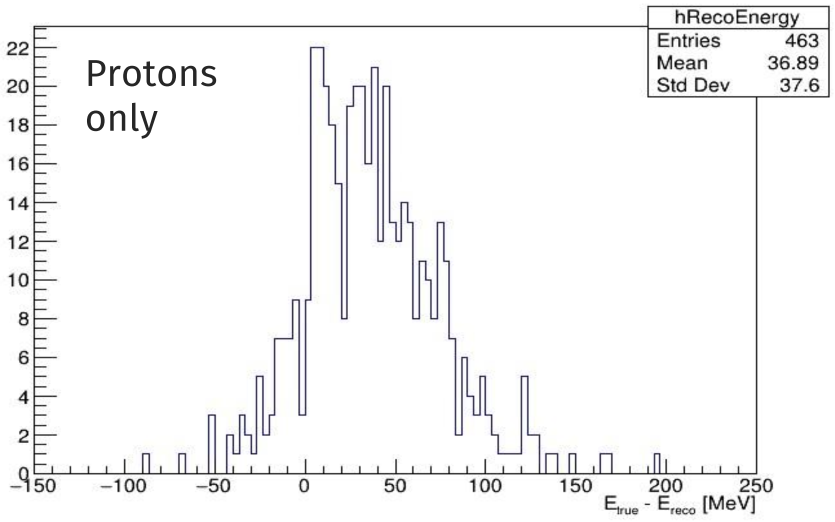
Visible protons **(>10 pixels** from MC truth)	**664** (74.6%)	209 (23,5%)	Not contained (seen also by STT)	↔	Total number of protons with >6 STT digits is 220, so GRAIN sees most of them (95%)
		455 (51,1%)	Contained (**not seen by STT**)		
Not visible* (too short…)	**226** (25.4%)				

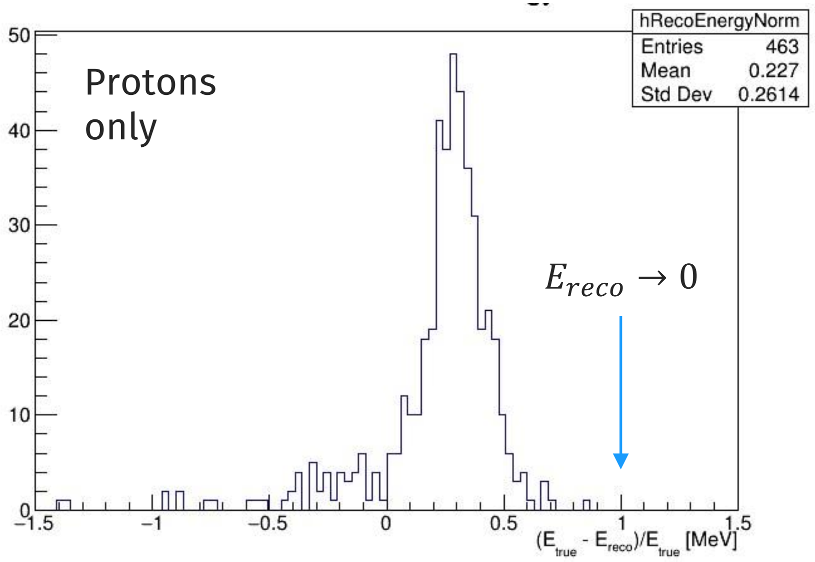
*sometimes requirement is too strict, can be seen by eye

Looking at a sub-sample…









Visible protons
664/890 (74.6%)

581/890 (65,3%)
(endpoint reconstructed)

463/890 (52%)
(energy reconstructed)

Next steps

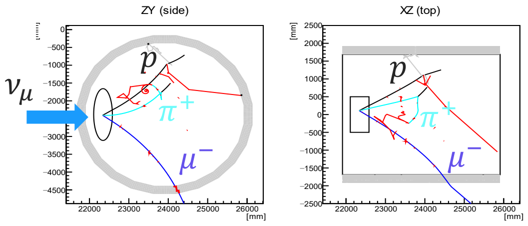
- **Improve energy reconstruction: mitigate issue of overestimation of track energy. Cross-check consistency with total energy deposit.**

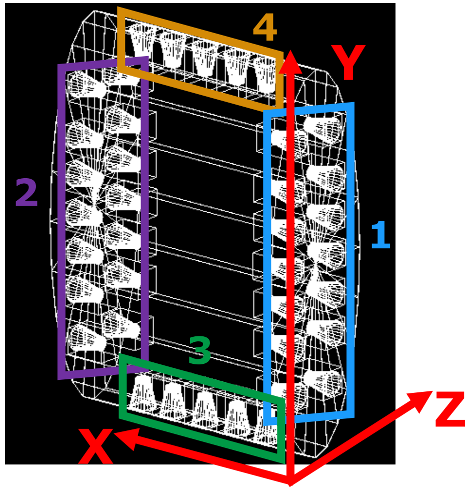
- **Start putting together GRAIN info with STT + ECAL**
  - Current effort to combing them using FastReco (https://baltig.infn.it/dune/FastReco/-/tree/grain-events)
    - ➢ Use GRAIN info if track is contained
    - ➢ Use GRAIN info to correct STT momentum estimate

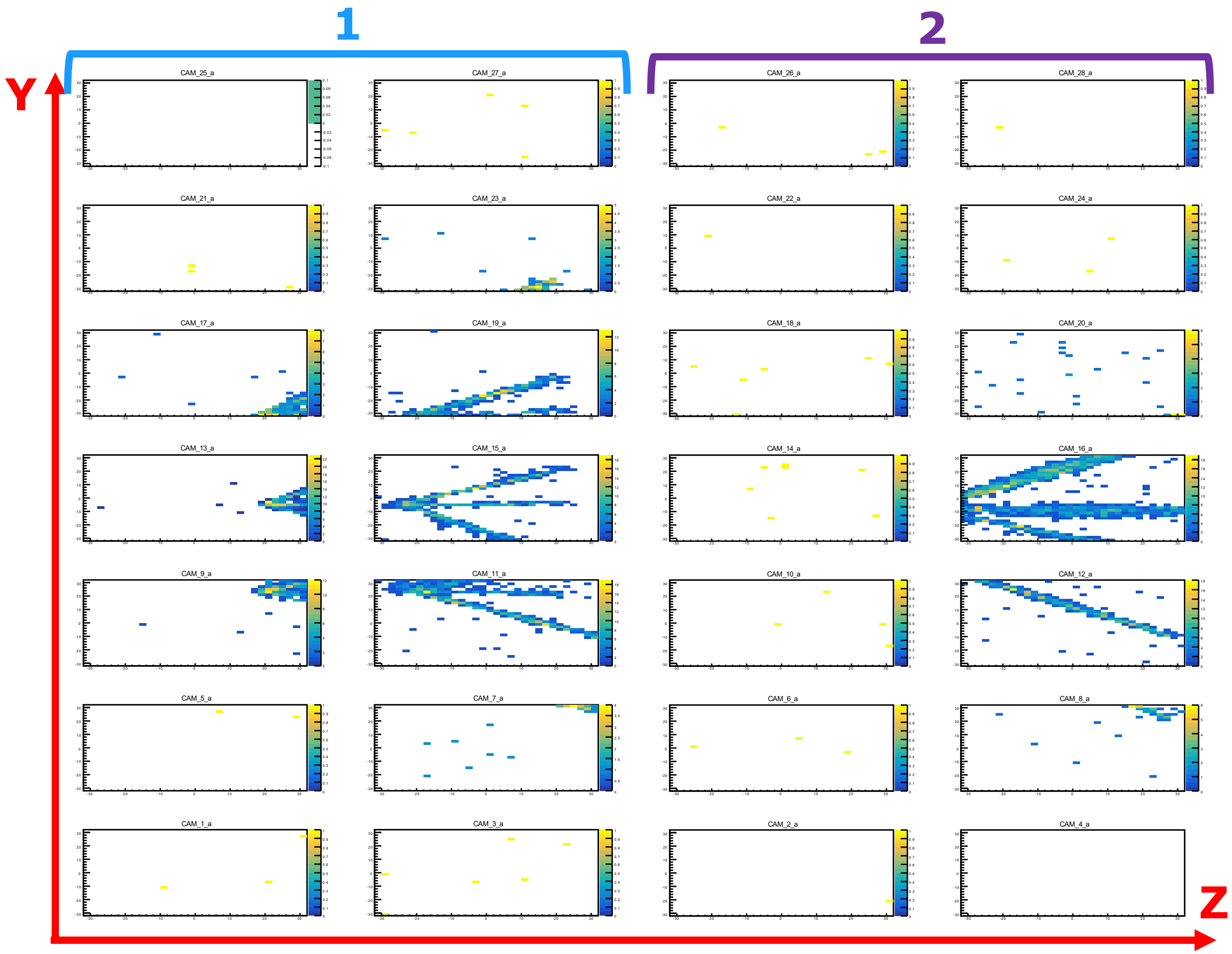
Back-up

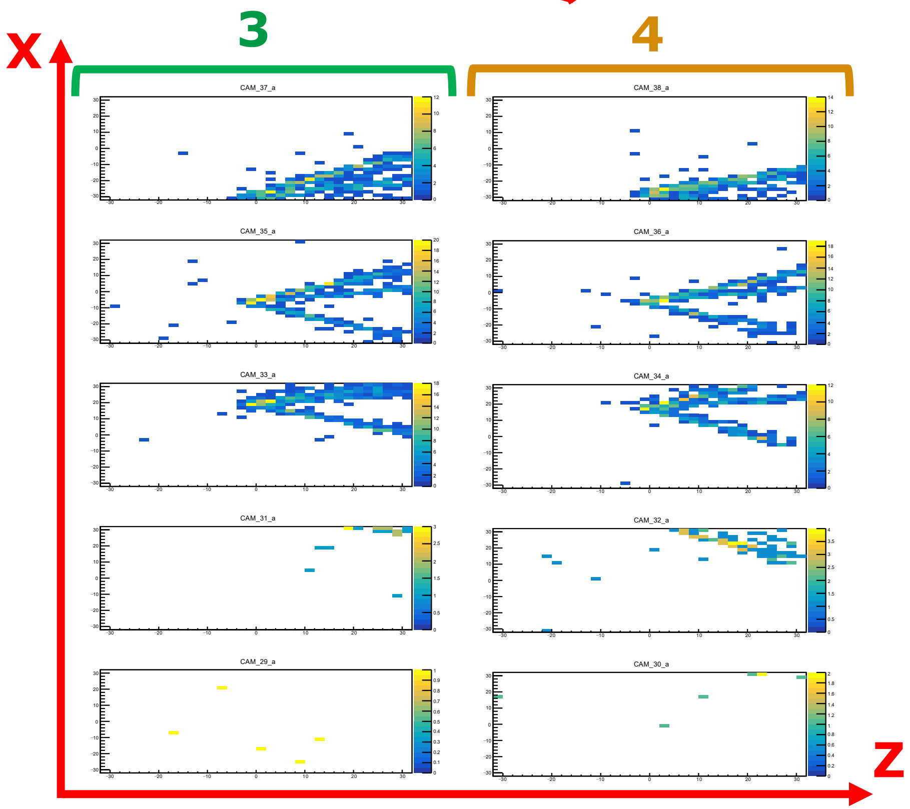
Event in GRAIN

- Example of $\nu_\mu CC$ interaction inside GRAIN



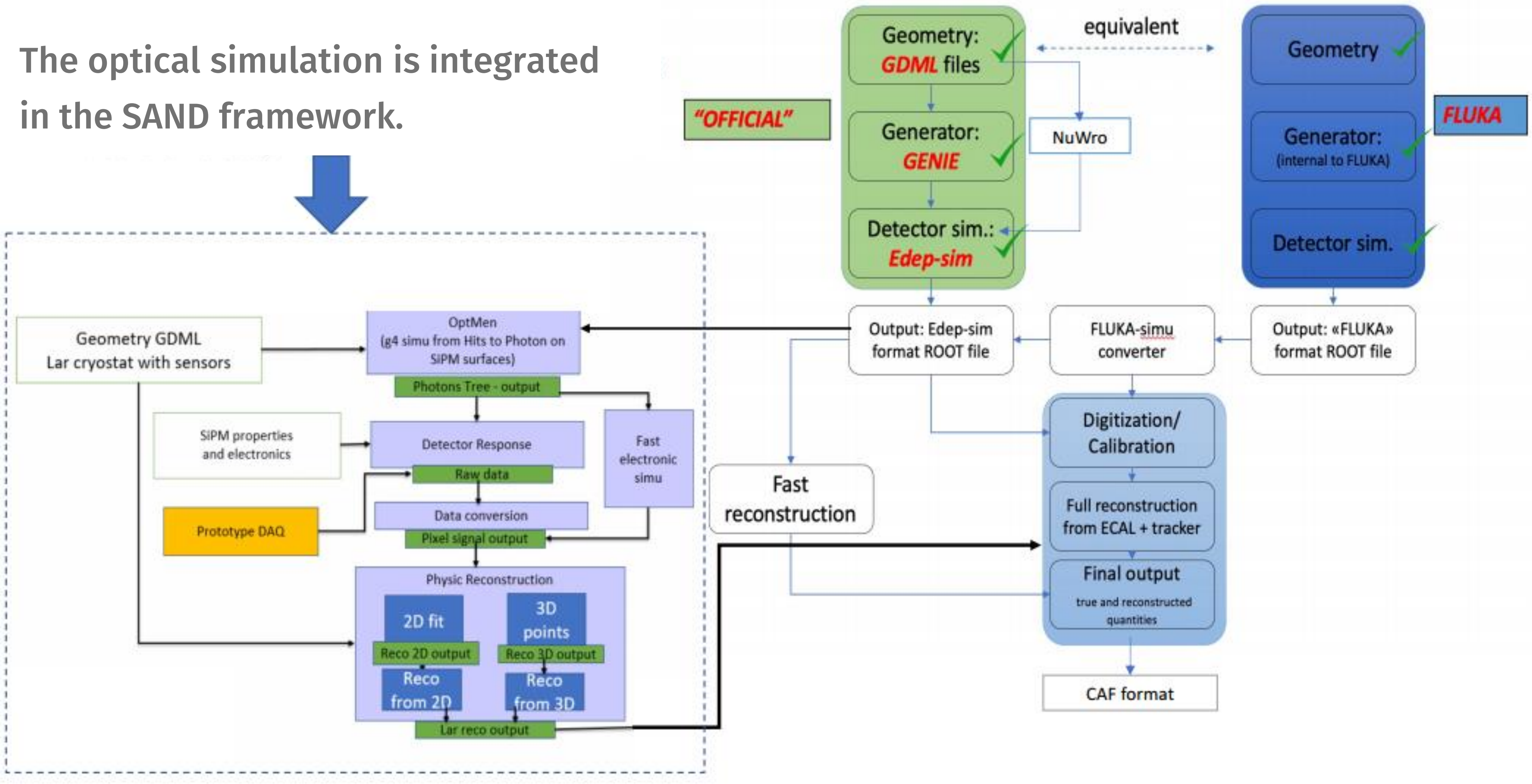






Optical simulation

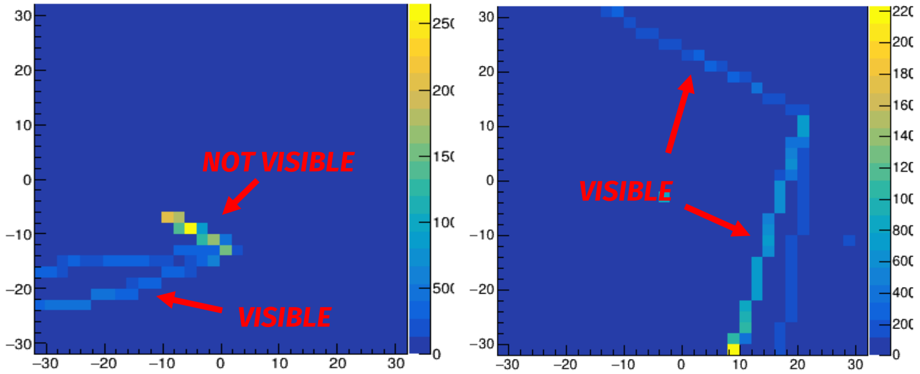
- The optical simulation is integrated in the SAND framework.



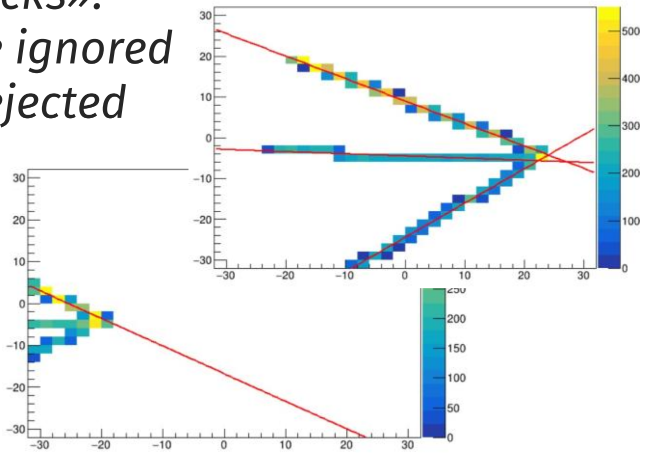
Fast 2D reconstruction algorithm

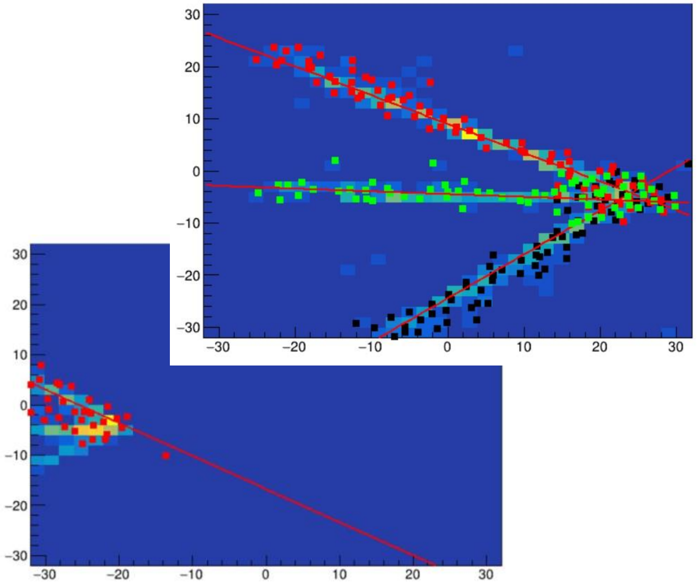
- A primary charged track is assumed **visible in an image if its truth projection is > 10 pixels**.
- Fast reconstruction based on visibile tracks:
  - **STEP 1**: Fit the visible tracks with a line
  - **STEP 2**: Use the resulting line to cluster the full image.

Truth projections: EDepSim tracks projected in the image with the lens scaling



Fit of «visible tracks»:
- *< 10 pixels are ignored*
- *Bad fits are rejected*



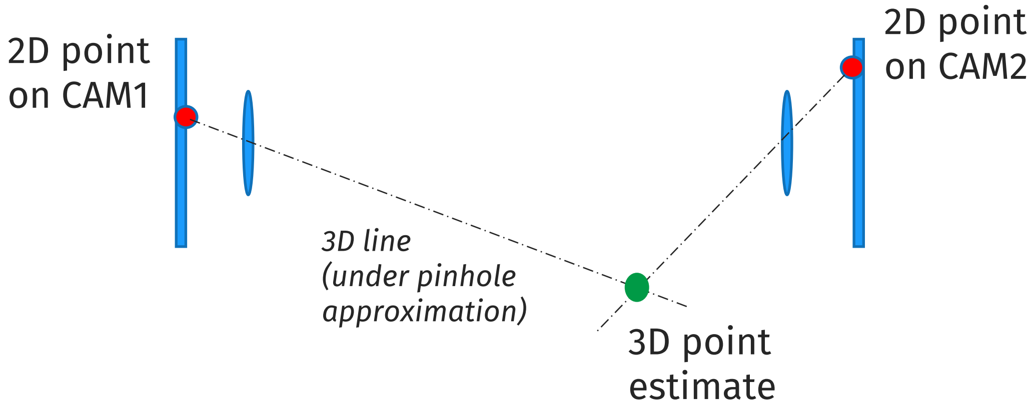


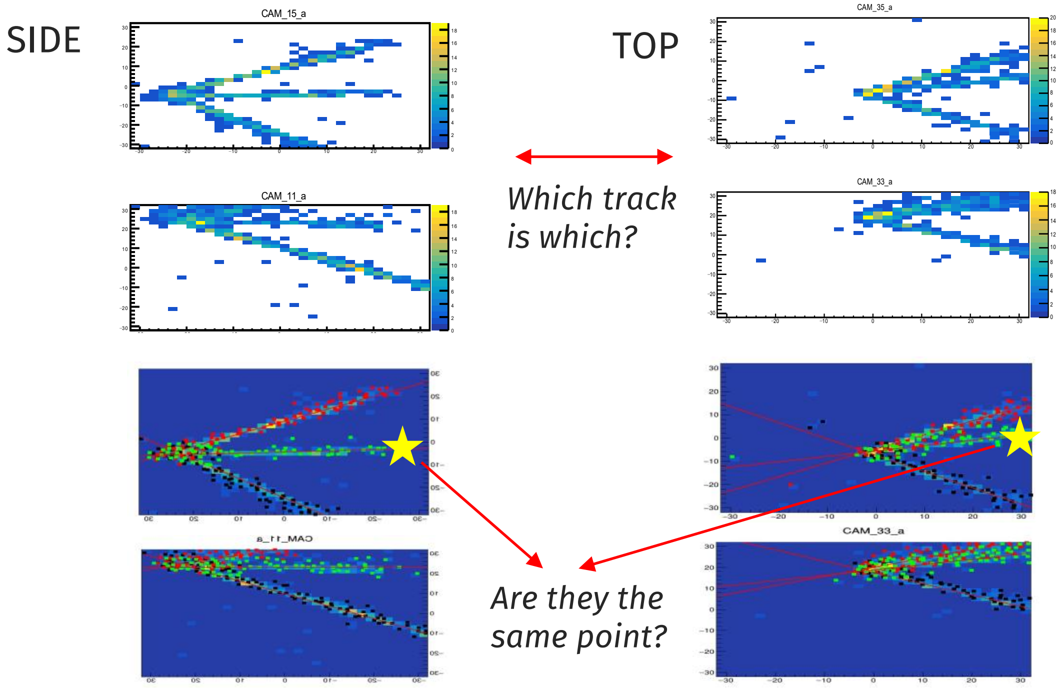
LineClusters:
Built around the fitted line

(currently using fast fitting, but it could also use the full 2D reco fits)

3D track endpoints

- Similarly to the vertex, the 3D endpoints of the tracks can be found starting directly from the 2D projections.
- **Problem**: need to match LineClusters belonging to the same track in different views + match the real endpoints → **MC-Truth** (for now..)





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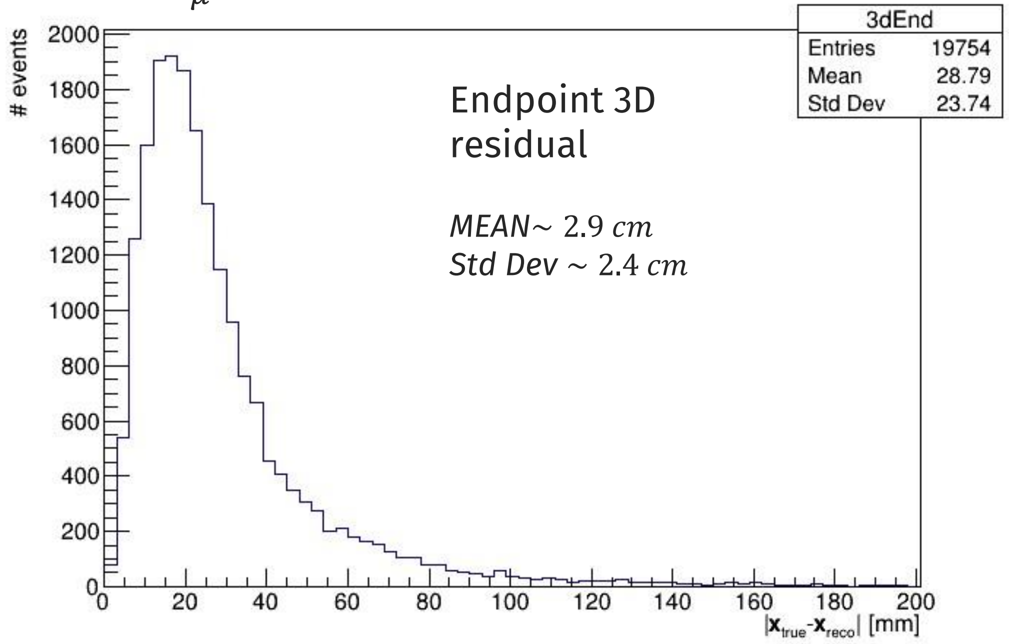
$15k\ \nu_\mu CC$



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