CCπ^0 Reconstruction in MINERvA

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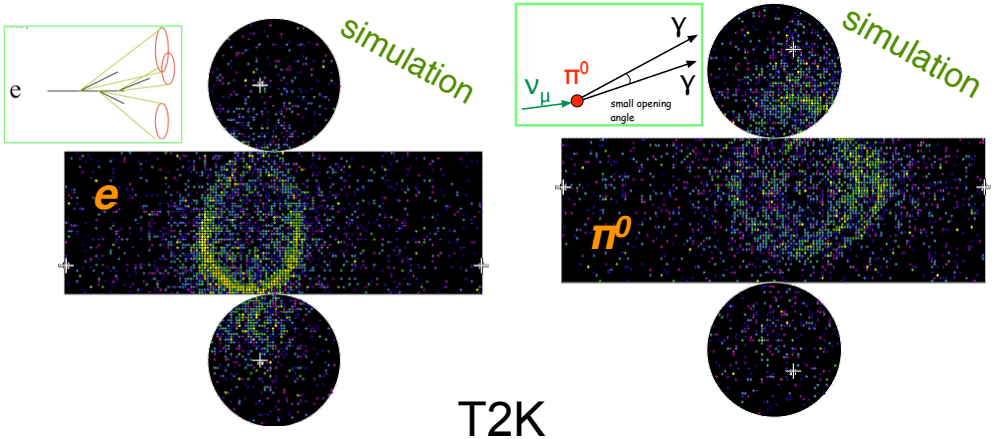
Outline of Talk

- Why π^0 production?
- Algorithm to reconstruct π^0 in CC events.
- Neutrino events selection and reconstruction MC - Data.

Why π^0 production?

- For accelerator-based neutrino oscillation experiments the uncertainties in neutrino cross sections in the GeV energy range are a major source of systematic errors.

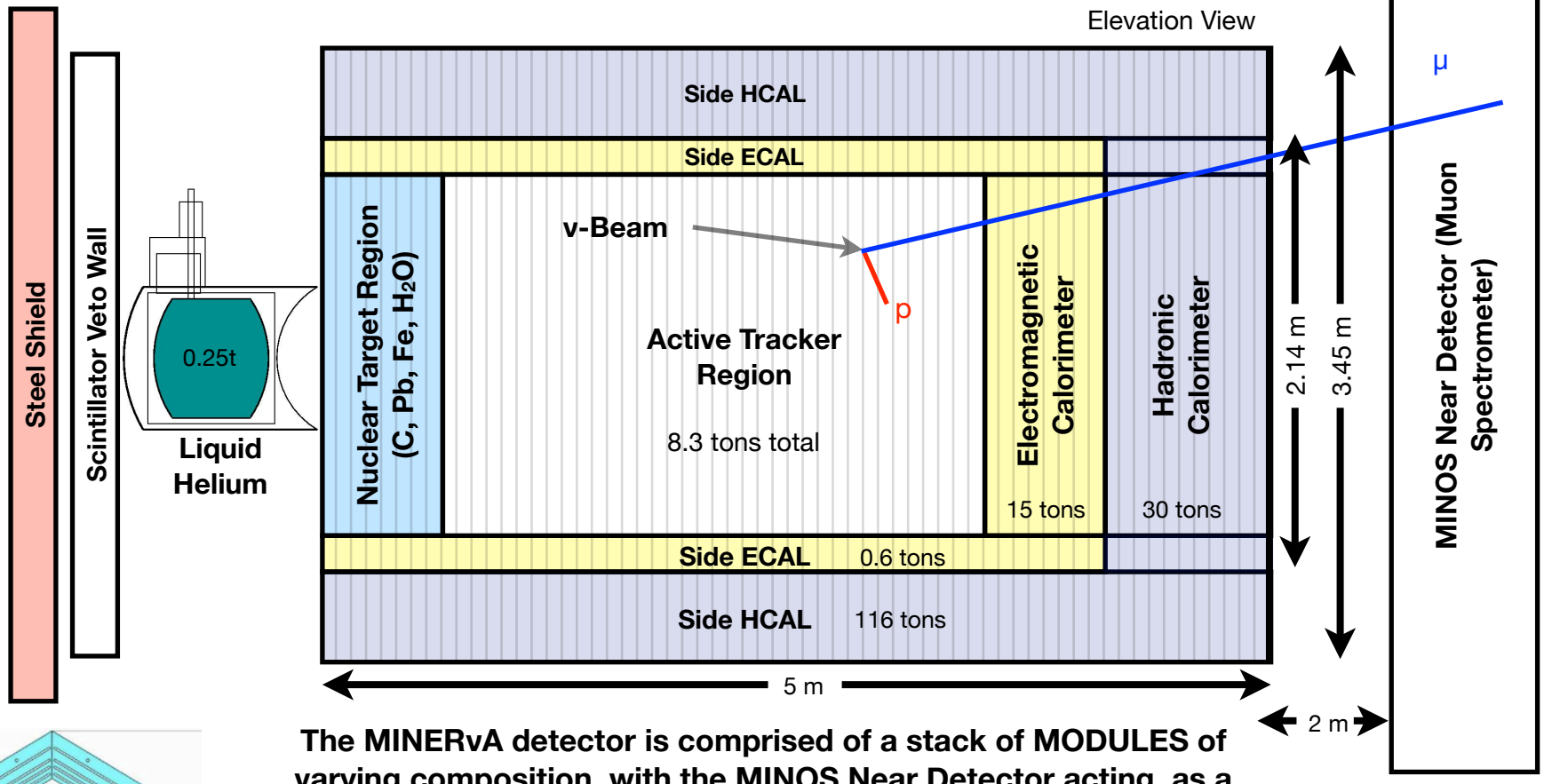
- Specifically about $\nu_\mu \rightarrow \nu_e$, one of the main background comes from $NC\pi^0$.

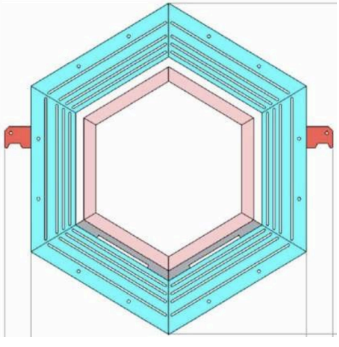


T2K

- Experimental input on the rate of the related CC/NC channel, and measurement of the production π^0 momentum spectrum, allows a better understanding of this background.

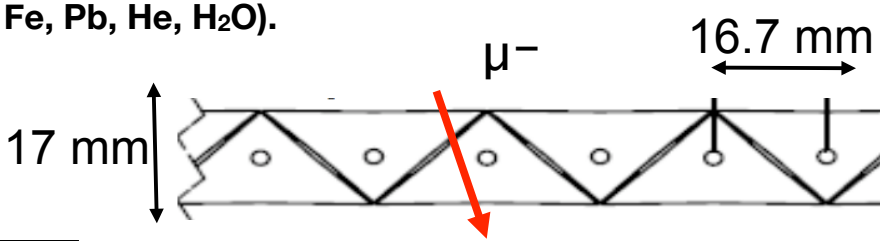
MINERvA Detector

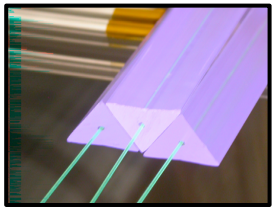




The MINERvA detector is comprised of a stack of MODULES of varying composition, with the MINOS Near Detector acting as a muon spectrometer. It is finely segmented (~32 k channels) with multiple nuclear targets (C, CH, Fe, Pb, He, H_2O).

127 scintillator strips per plane.

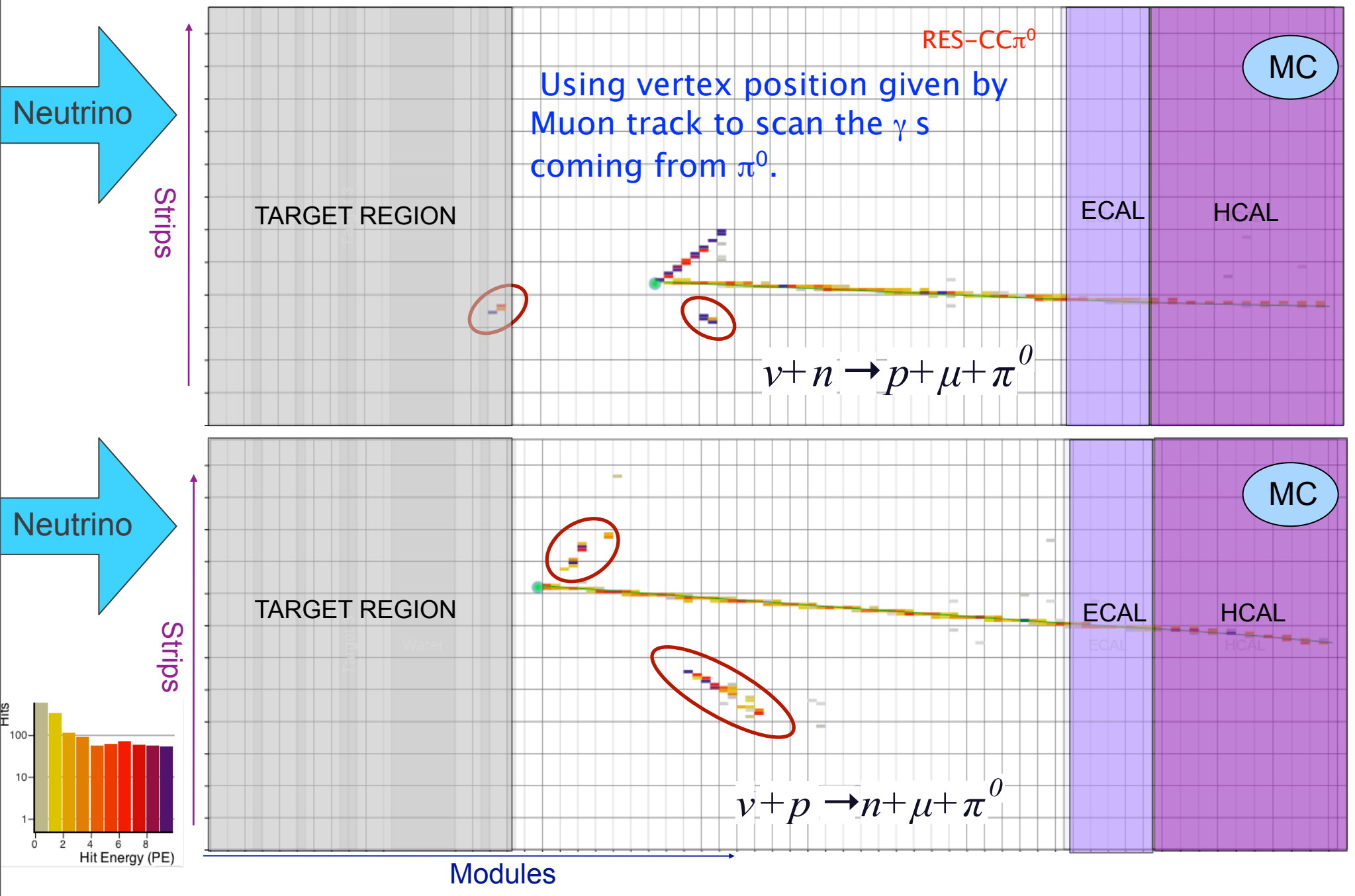




Triangular strip to allow charge sharing

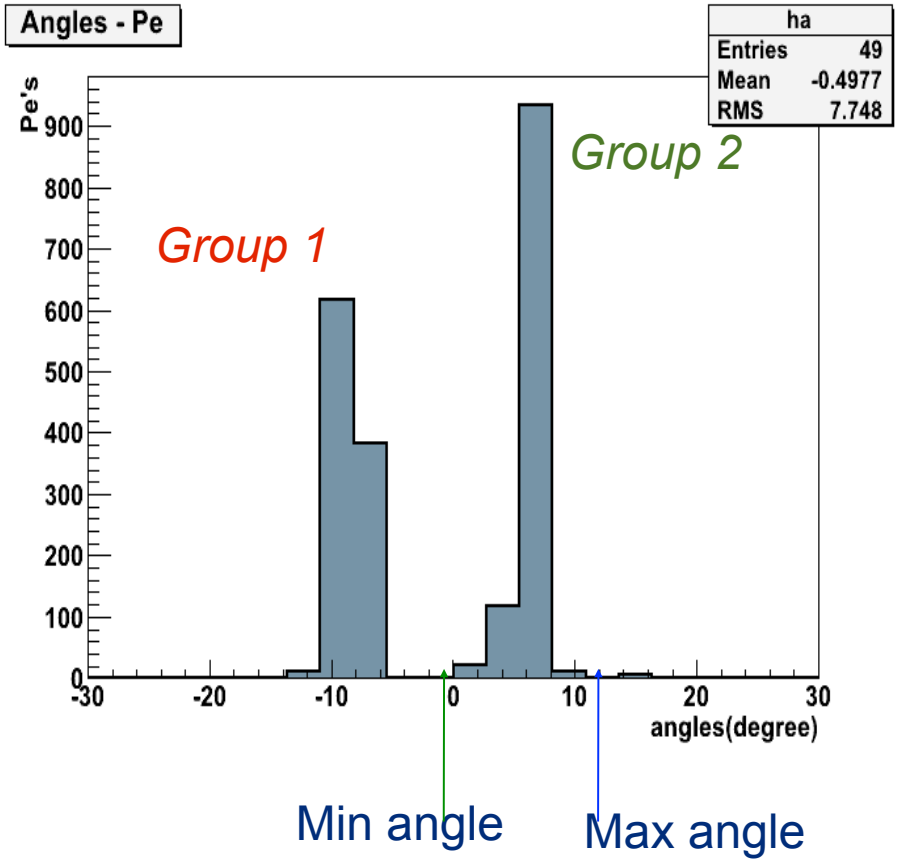
Tracker module = 2 planes
ECAL module = 2 planes + 2 (2 mm thick) sheet of lead
HCAL module = 1 plane + 1 (1 inch thick) sheet of steel

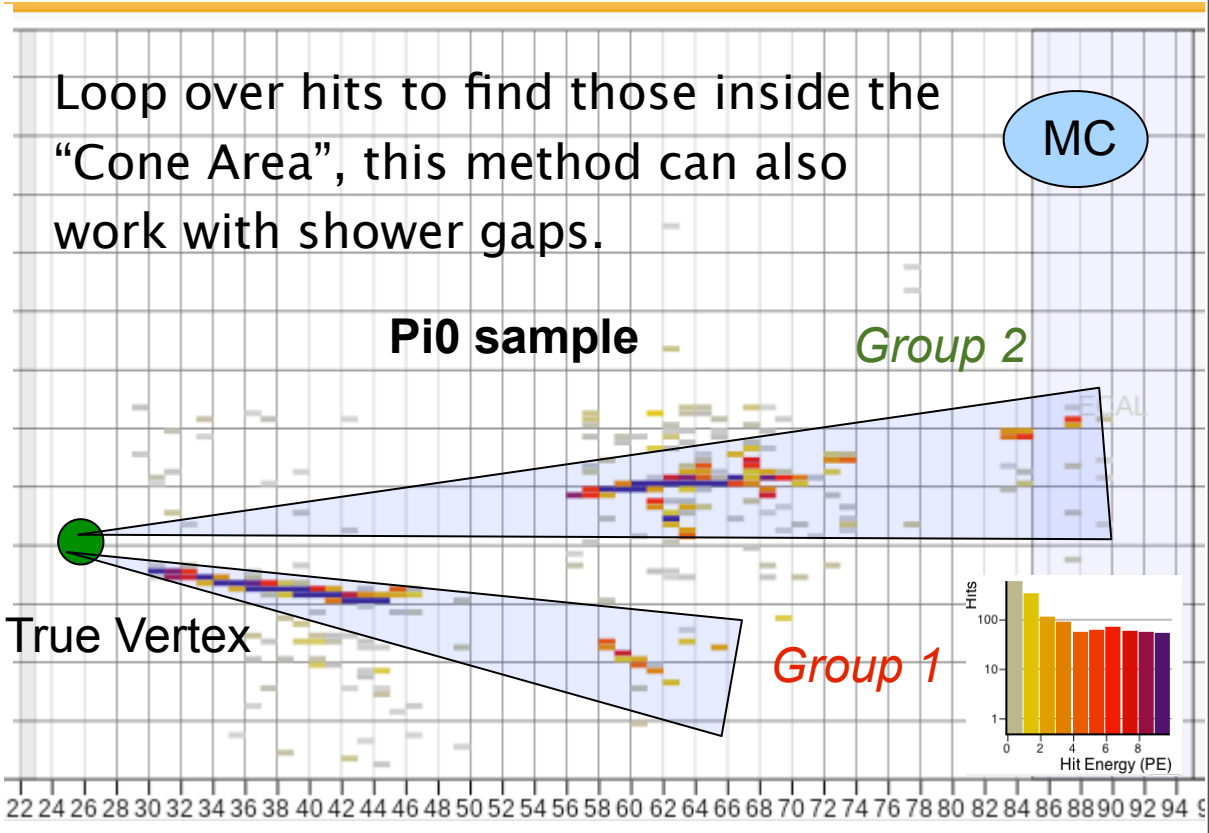
Event Topology



Reconstructing Photons for π^0's

**Pe: photon electron*

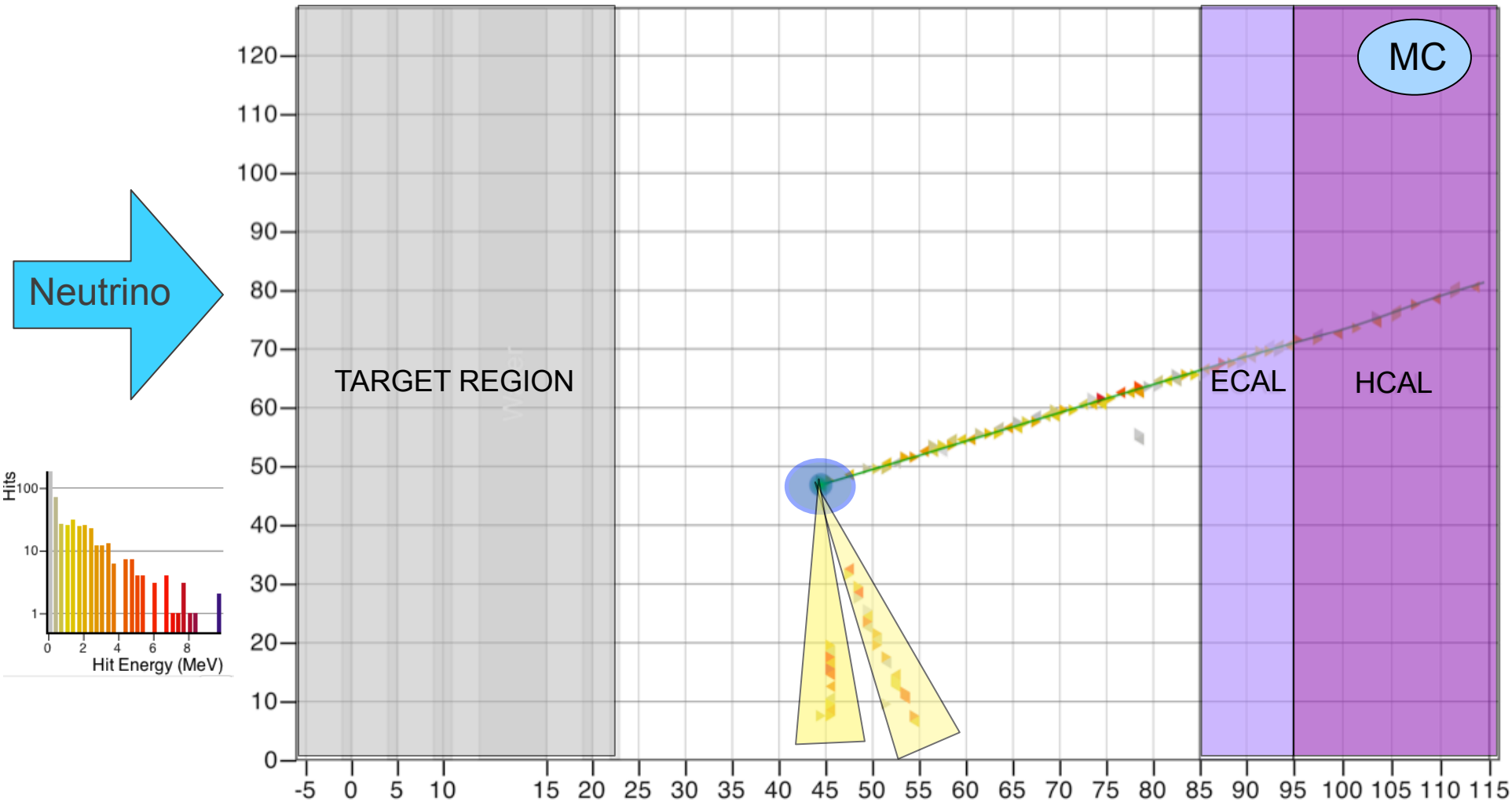




Every group (particle) inside the histogram will have a minimum angle and maximum angle

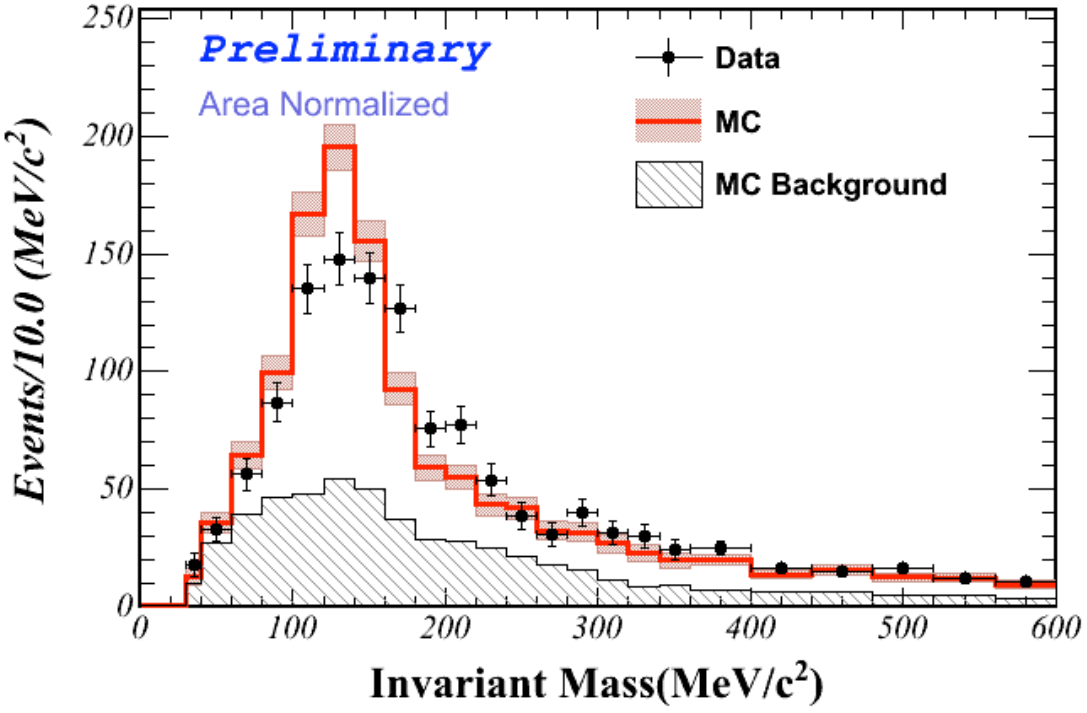
Using vertex like reference point, It fills out a 1D histogram, where every entry is the angle between every hit and the vertex, weighted by its charge. Similar to Hough Transformation with r fixed.

Neutrino MC - Data



Event Selection:

1 muon track + 2 EM showers + Energy in Target Region < 20 MeV



Every analysis needs a pure sample.

Background events could be Pion charge exchange in detector and wrong reconstruction.

Background is still being studied and can be furthered reduced!!!!!

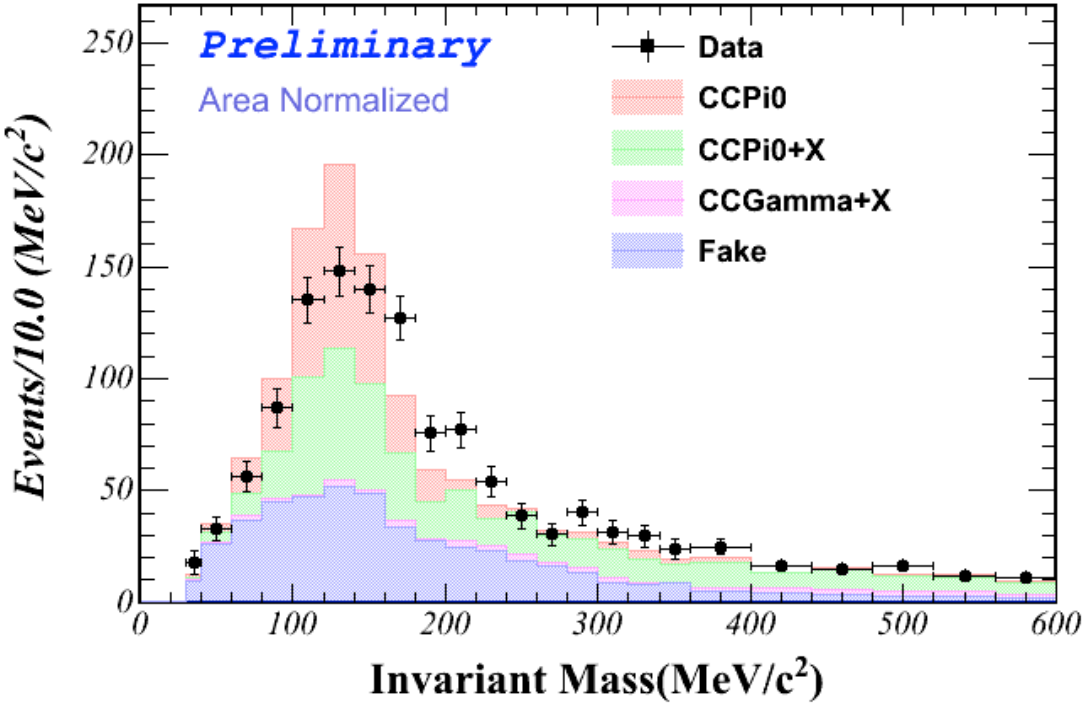
$$m_{\gamma\gamma} = \sqrt{2E_{\gamma_1} E_{\gamma_2} (1 - \cos\theta_{\gamma\gamma})}.$$

Cuts:

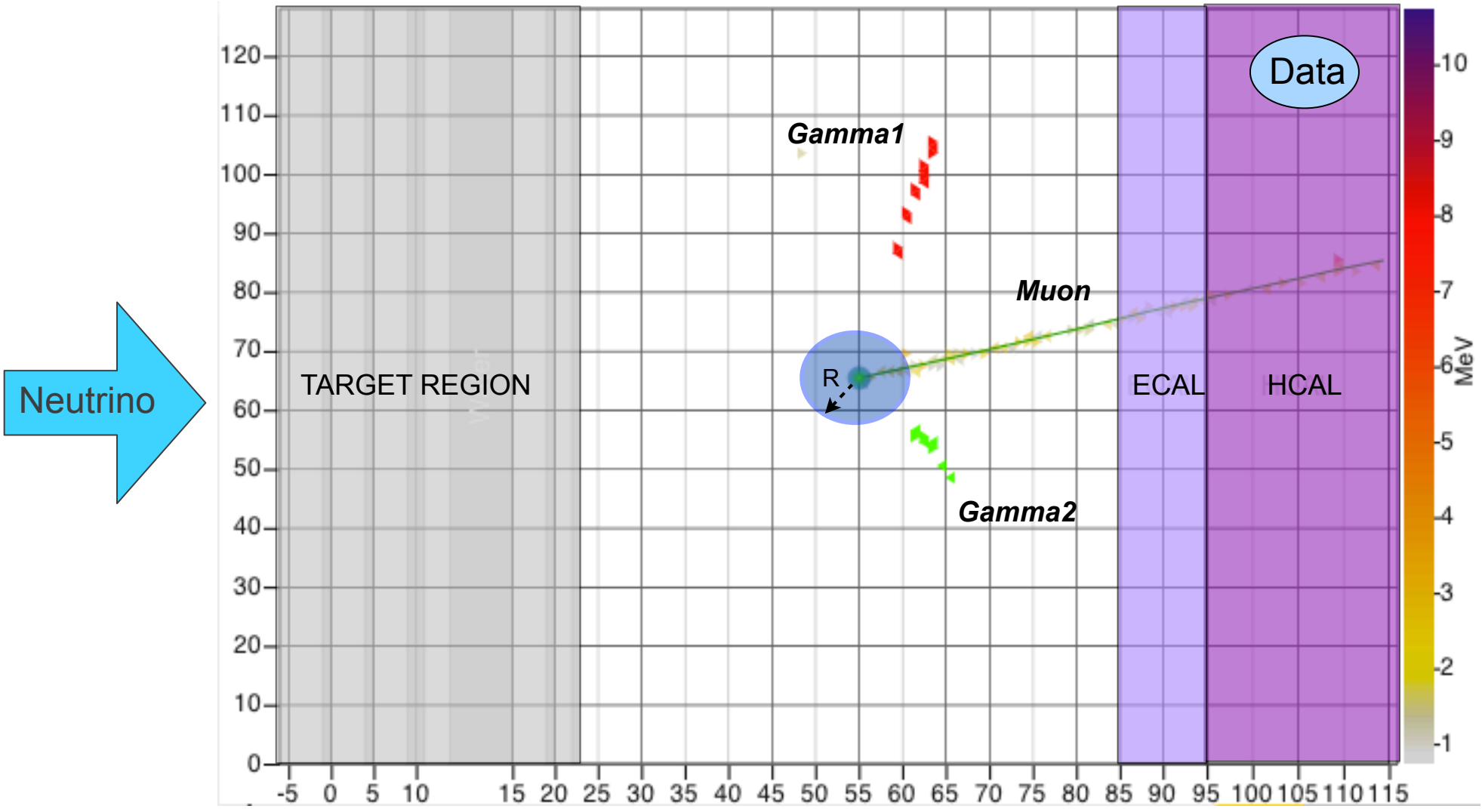
Opening Angle > 25 *degrees*

1 muon track + 2 EM showers

+ Energy in Target Region< 20 MeV

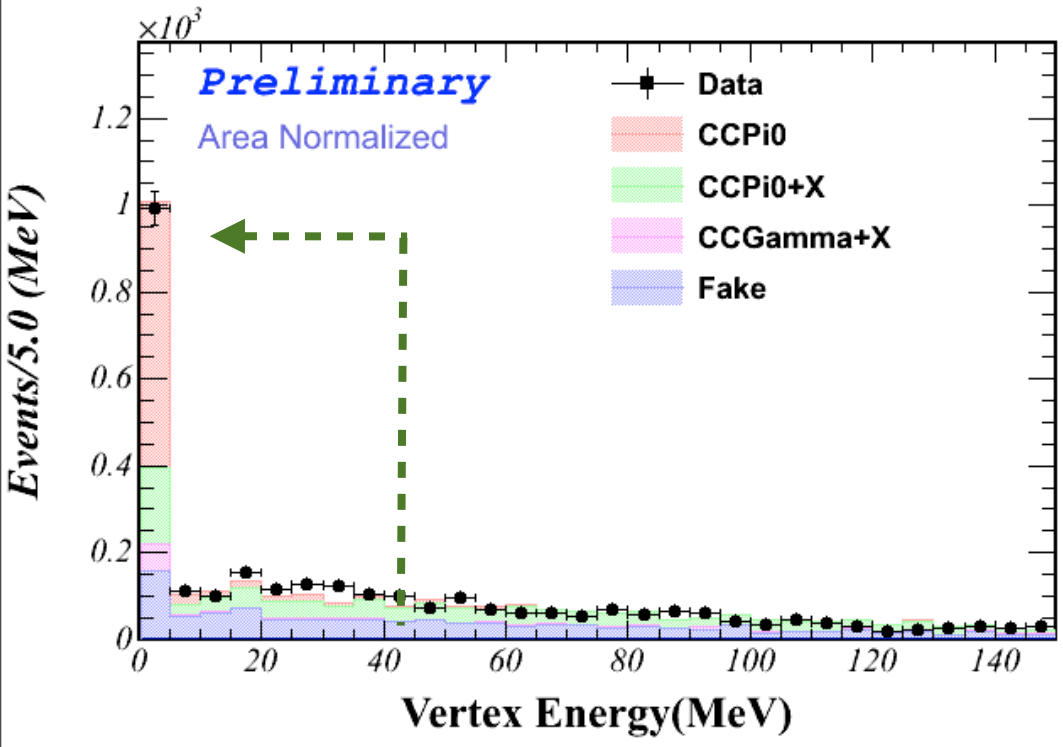


CCπ^0 reconstruction



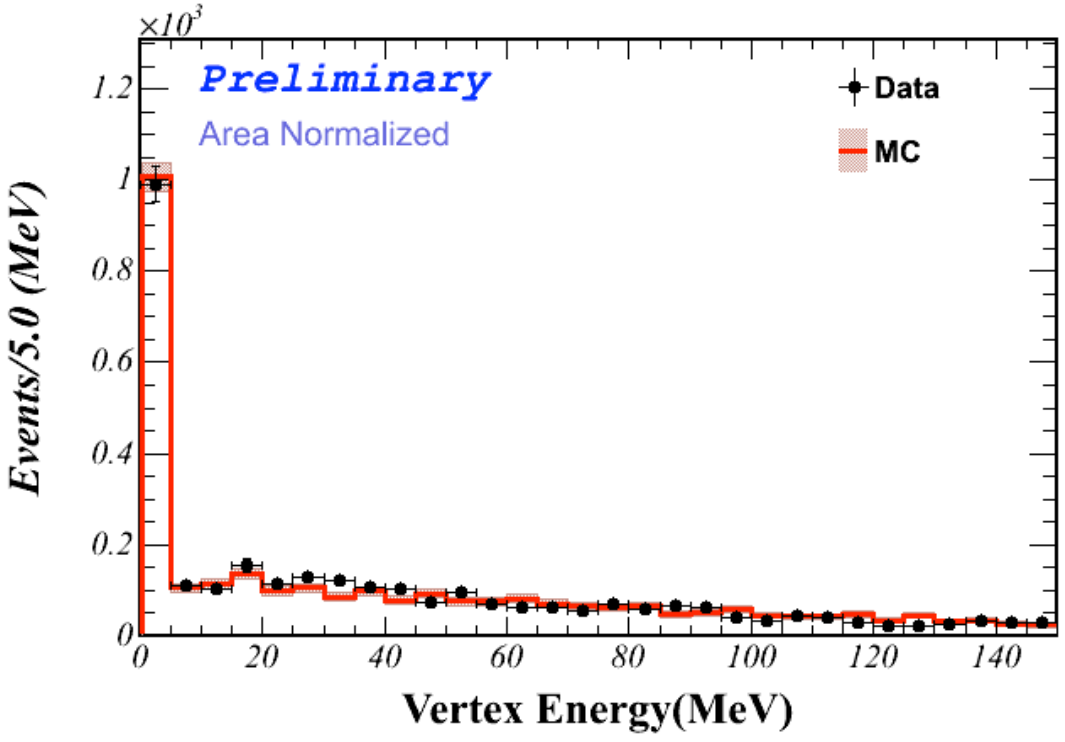
Vertex Activity:
Energy contained inside R = 100*mm*

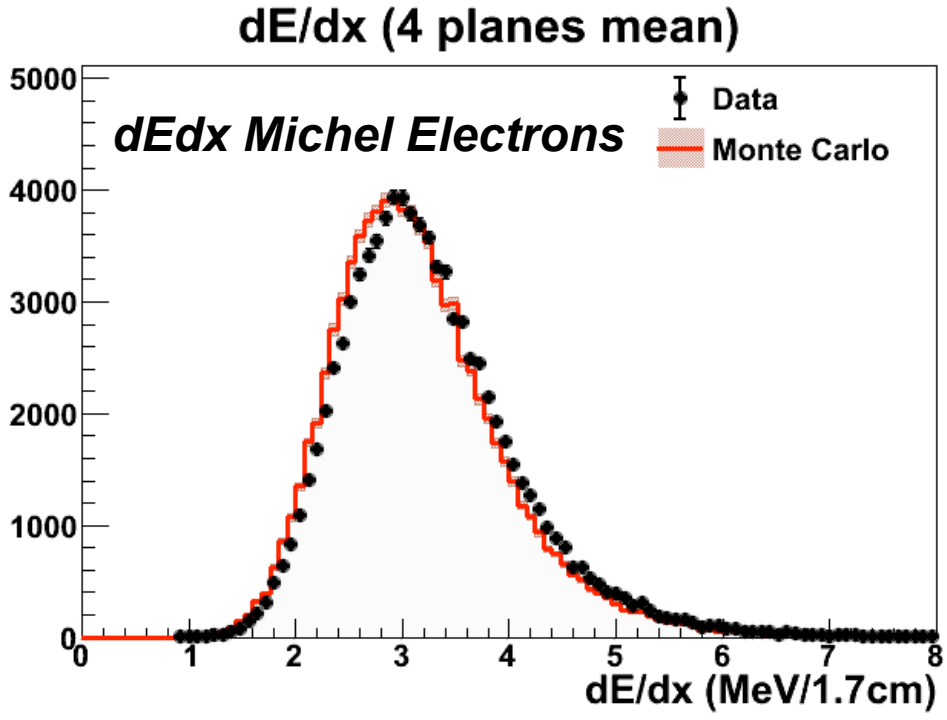
Reconstructed info:
Mass = 135.537 *MeV/c^2*
Gamma Energy 1 = 150.6 *MeV*
Gamma Energy 2 = 73.5 *MeV*



To remove Background, we are looking at energy around event vertex.

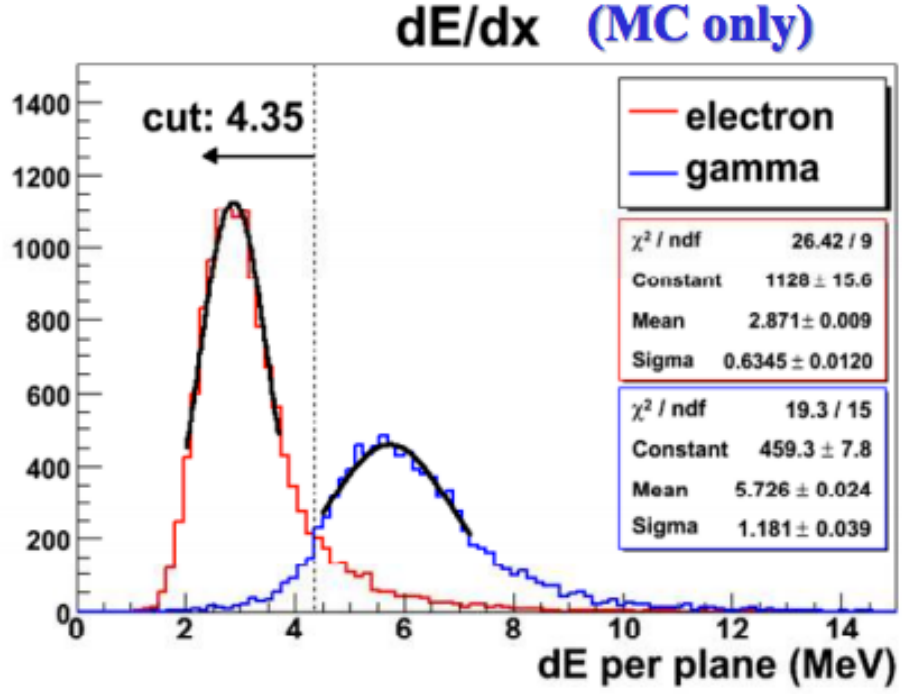
	CCπ⁰	CCπ⁰+X	Fake
Vertex Activity < 40MeV	(94%)	(35%)	(44%)
Vertex Activity < 10MeV	(84%)	(16%)	(20%)

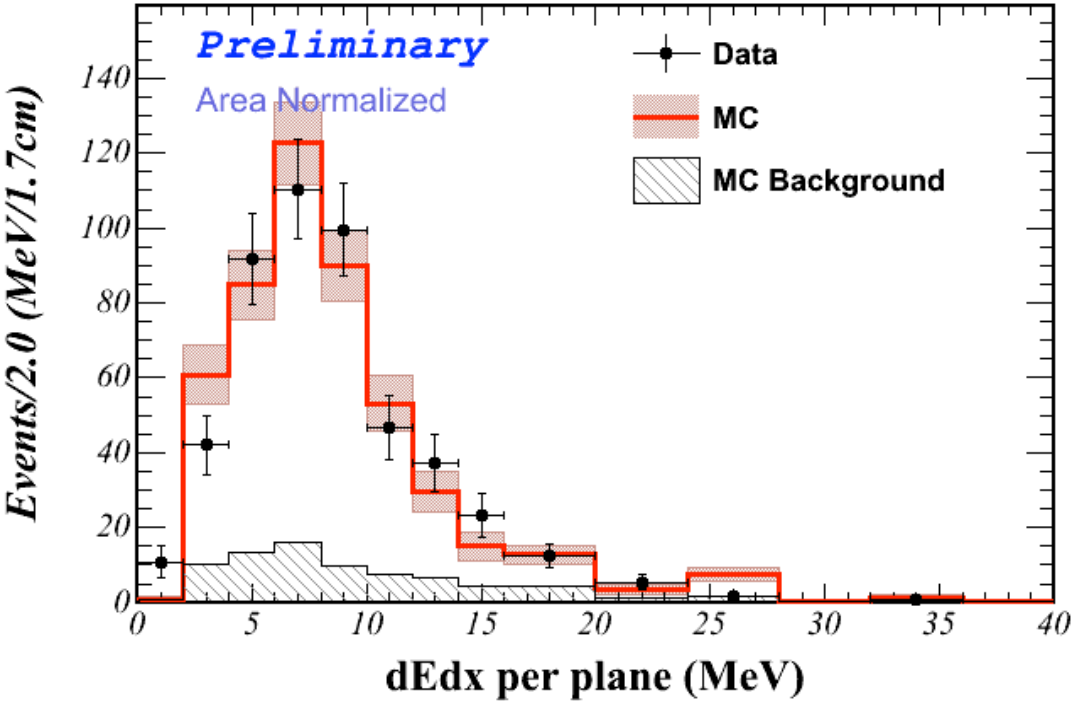


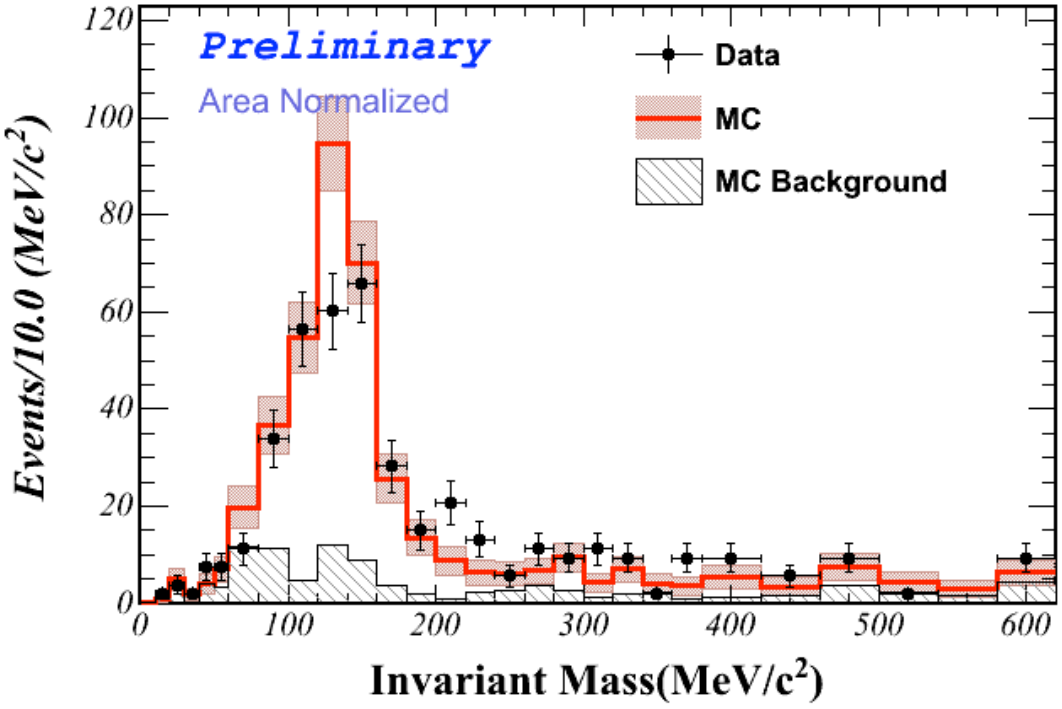


MINERvA detector allow us identify Gammas and Electrons. dEdx tool is good for pid particles on EM showers.

To remove Background, we can look at dEdx to isolate gammas.

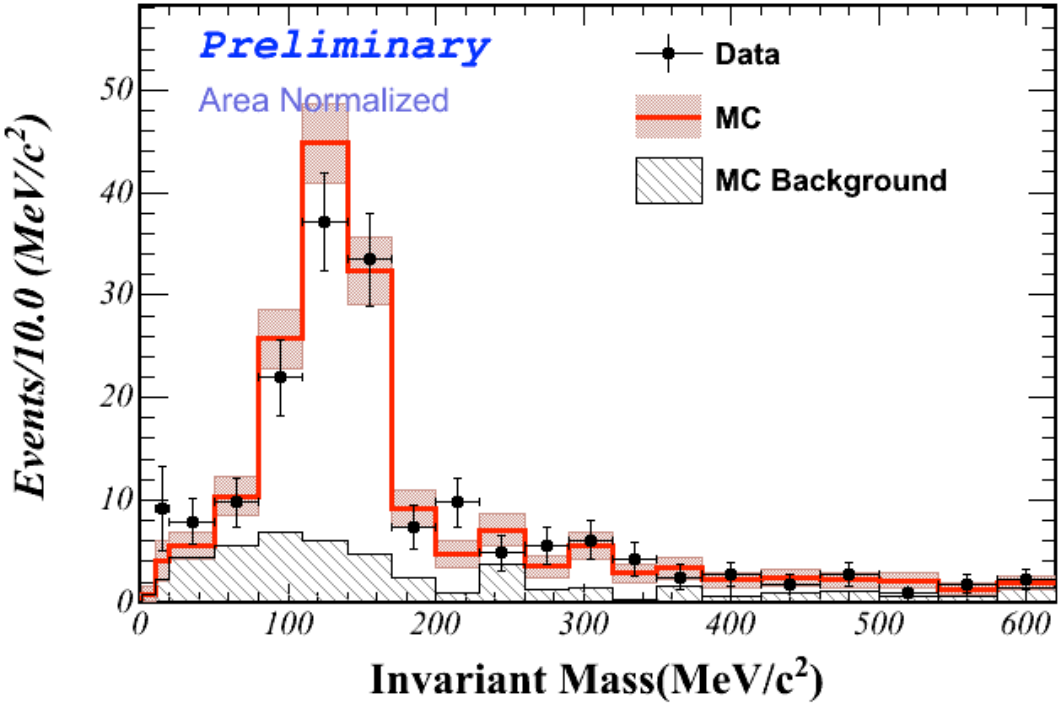






Cuts:
Energy Vertex < 40 *MeV*
Energy Photon 1 > 100 *MeV*
Energy Photon 2 > 50 *MeV*
Angle Photon 1 < 50 *degrees*
Angle Photon 2 < 50 *degrees*
Opening Angle > 25 *degrees*

Cuts:
Opening Angle > 25 *degrees*
dEdx: 4-12 *MeV*/1.7*cm*



Neutrino Energy Reconstruction on CCπ^0

A CCπ^0 event is the form $\overline{\nu} + p \rightarrow \mu^+ + n + \gamma + \gamma$

Using 4 momentum conservation:

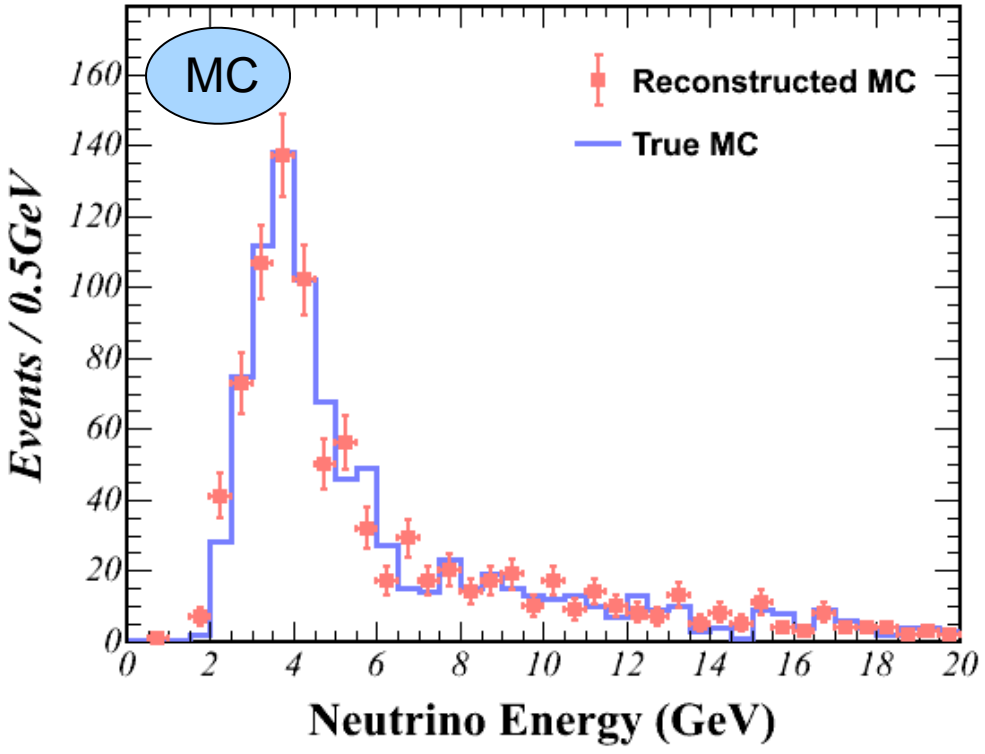
$$(P_{\overline{\nu}} + P_p - P_X)^2 = P_n^2 \quad , P_X \equiv P_\mu + P_{\gamma 1} + P_{\gamma 2}$$

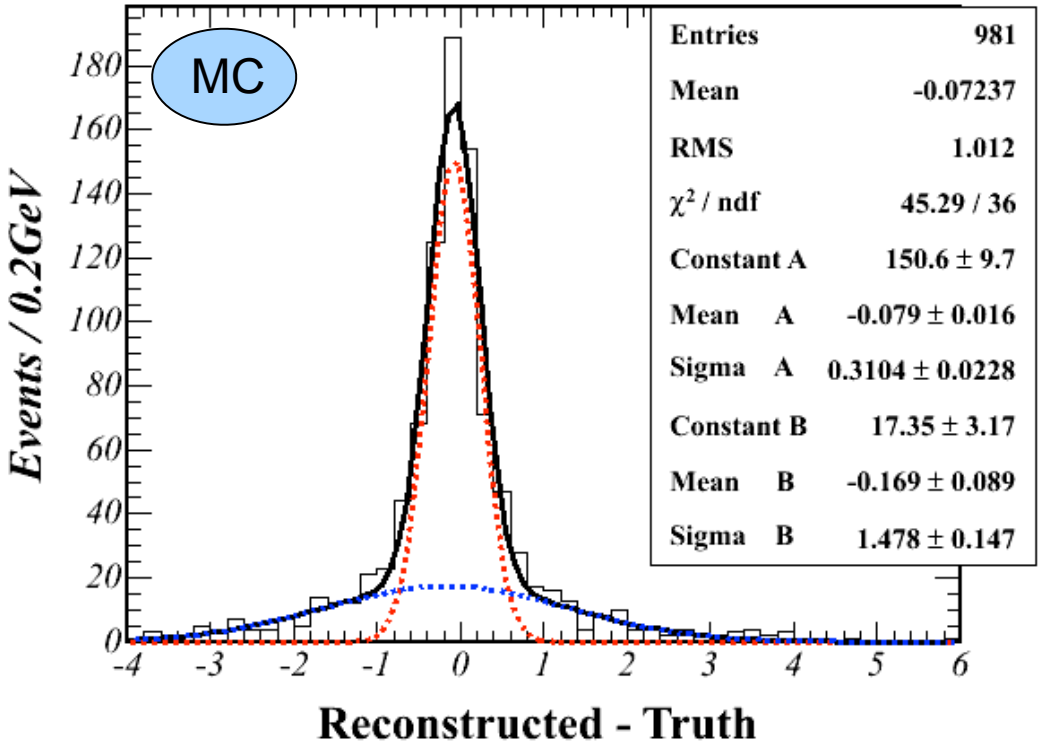
$$E_{\overline{\nu}} = \frac{1}{2} \frac{M_n^2 - M_p^2 - M_X^2 + 2M_p E_X}{M_p - E_X + 2|\overline{p}_X| cos\theta_{\overline{\nu}X}}$$

Where, X replaces the typical lepton momentum used to derive the standard QE Neutrino energy formula.

R.H.Nelson, MiniBooNE
arXiv:0909.1238v1

Neutrino Energy Reconstruction





True CCπ^0 sample: Fiducial volume, Using Muon vertex like anchor, 2 EM showers

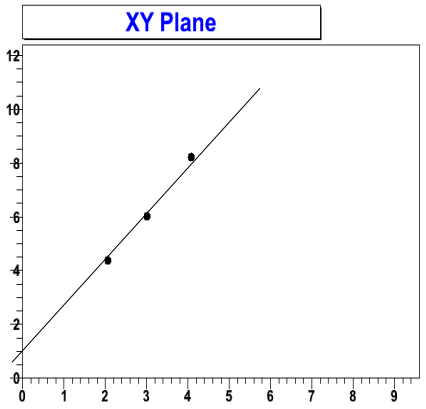
Summary

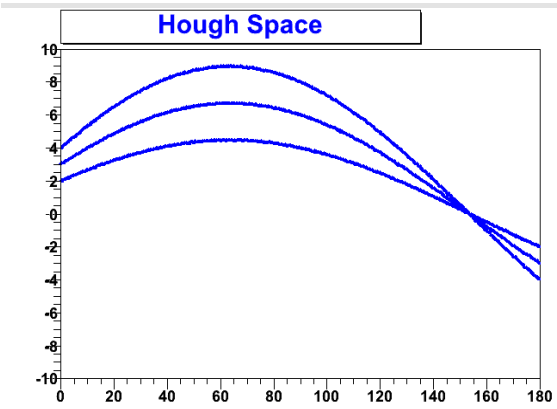
- MINERvA has the capability to study π^0 production in various nuclei for both neutrino and anti-neutrino. π^0 production is a large background to neutrino oscillation backgrounds.

- The algorithm to isolate, reconstruct and identify electromagnetic showers works for π^0 identification. The data analysis tools are almost finish, preliminary results are close.

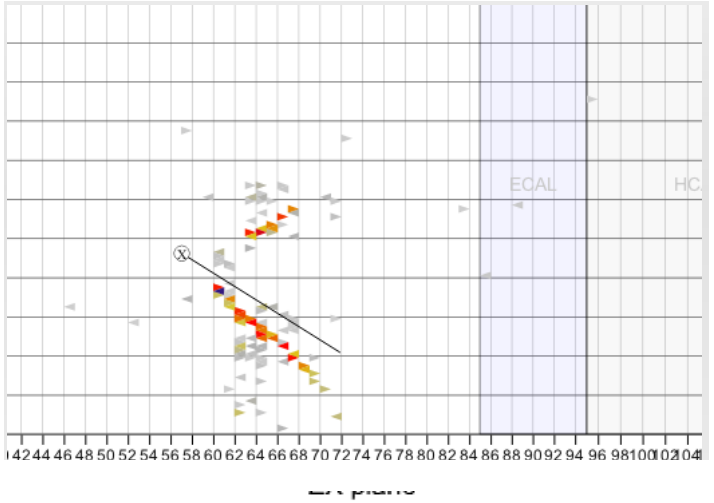
Backup Slides

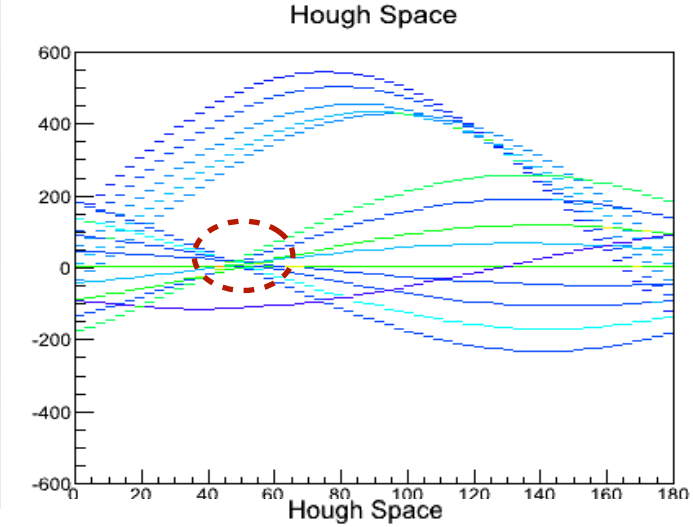
Hough Transform



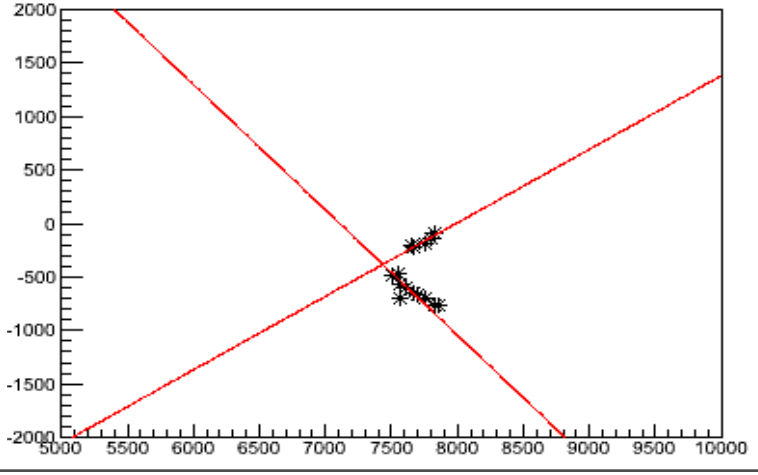


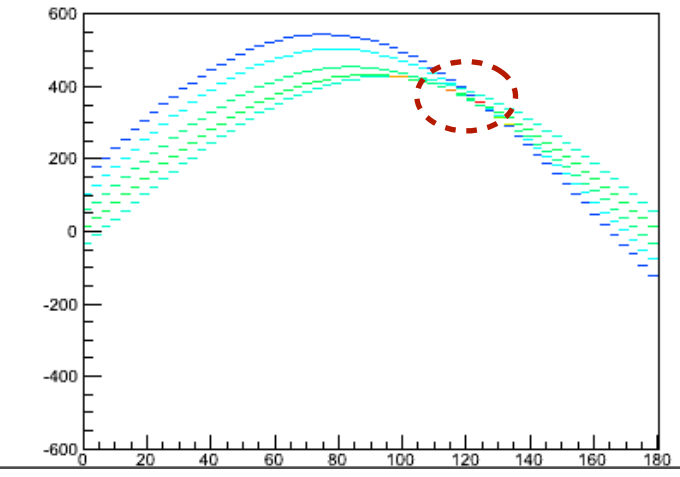
For each point in xy plane we can obtain an pair of (r,θ) in Hough Space
r=ysin(θ)+ xcos(θ)





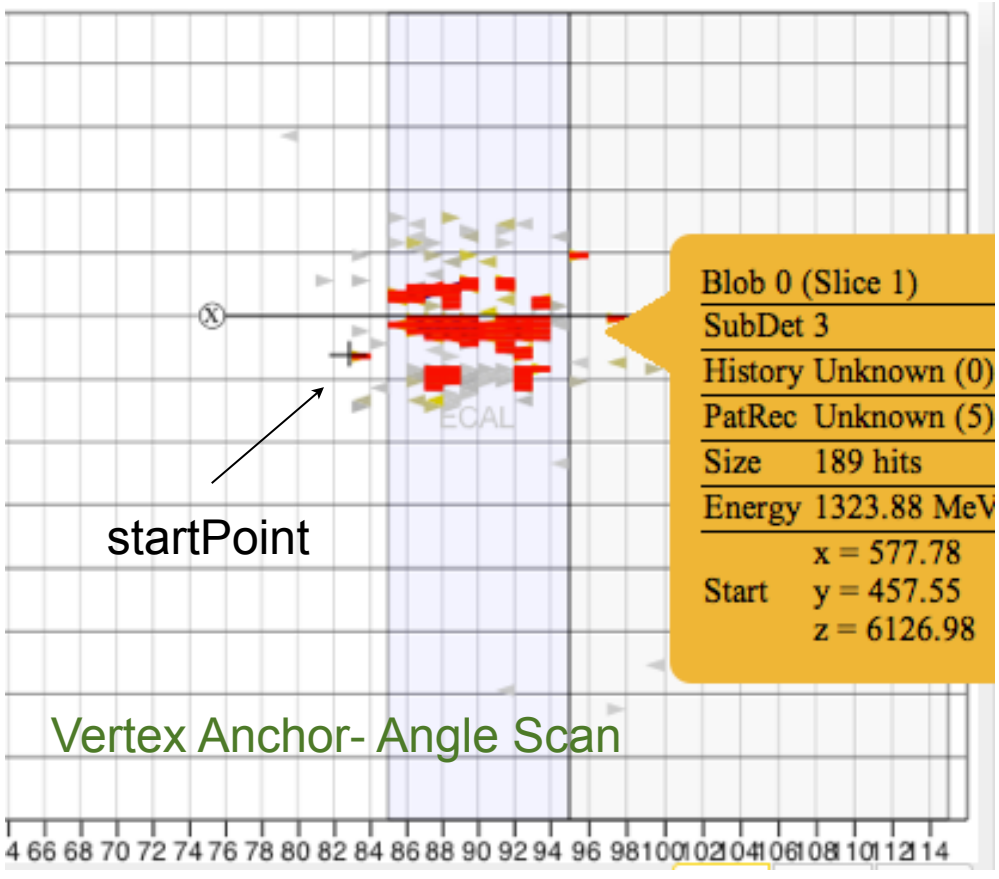
First loop to remove energetic Blob





Second loop to remove extra Blob

Anchor Angle Scan vs Hough Transform



Hough Transform works better when opening angle < 25 degrees