Fermilab - New Perspectives 2017

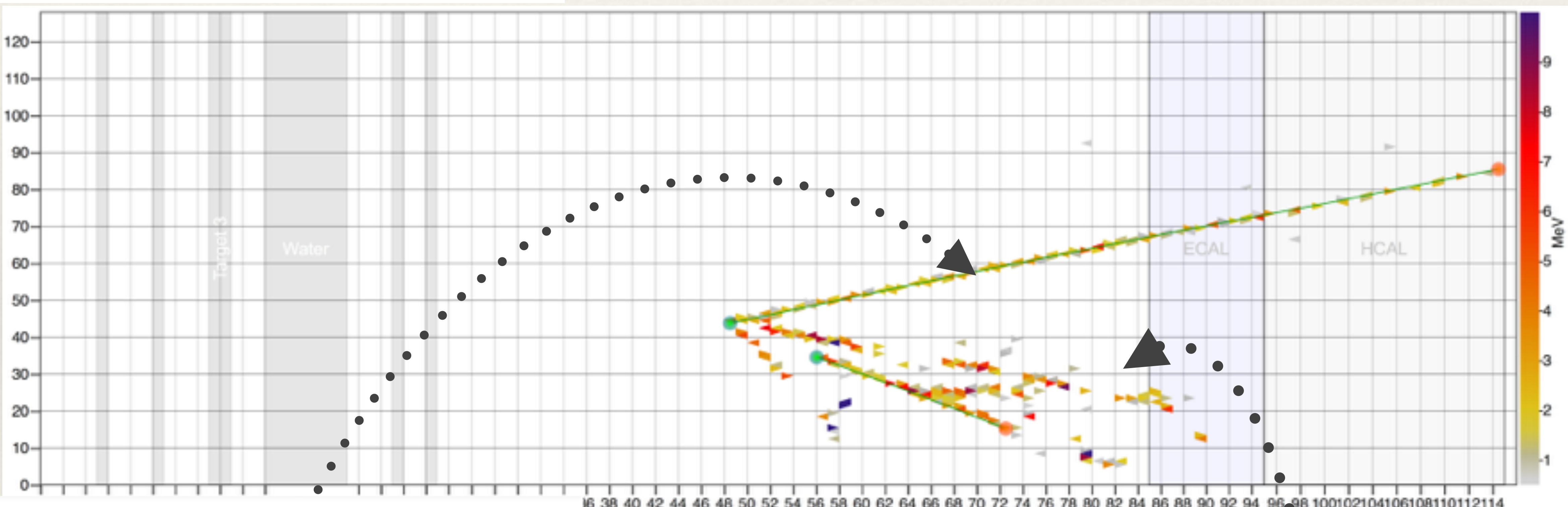
Neutral Pion Reconstruction for NuMI at ME in MINERvA

Roger Galindo
Universidad Tecnica Federico Santa Maria.
June 5th, 2017

Particle Reconstruction

Hits or Digits
Every registered particle interaction with the detector.

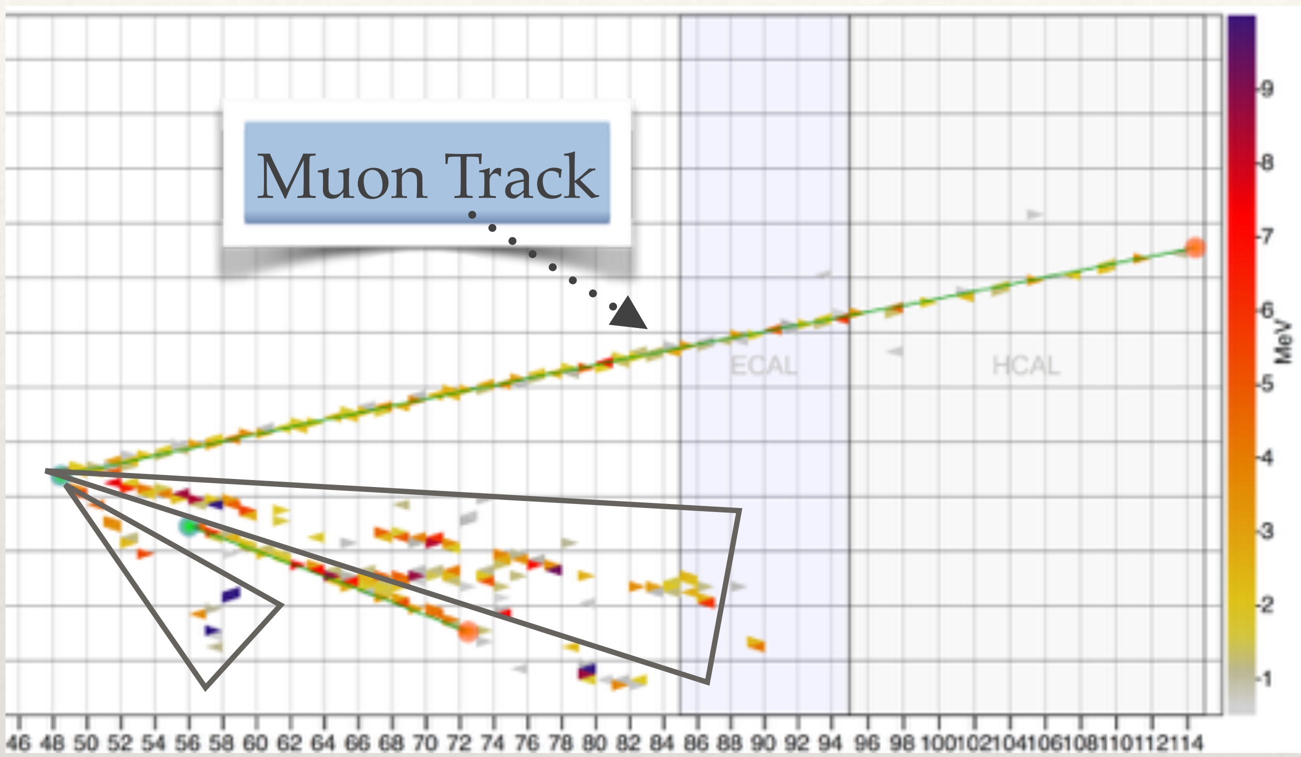
Clusters
Groups of neighbor hits.



Prongs
Group of Trackable clusters
Ideal for Muons,
charged pions and protons.

Blobs
Group of Non-trackable clusters
Ideal for particle showers.

Neutral Pion Identification



Angle Scan

Look over "unused" clusters that are inside of a Cone "Volume" around to the interaction vertex. aka Found Blobs.

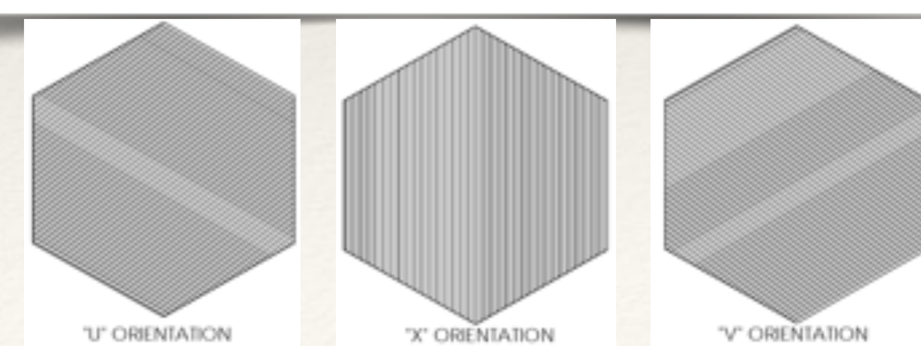
Cone Blobs

Clusters grouped by Angle Scan, each one most to have at least 2 views position for direction reconstruction, aka Good Blobs.

Best Two Blobs

From all Good Blobs, select the best two candidates to be EM showers according to the closest value of the invariant mass

$$m_{\gamma\gamma} = \sqrt{2E_1E_2\left(1 - cos\Theta_{\gamma\gamma}\right)}$$

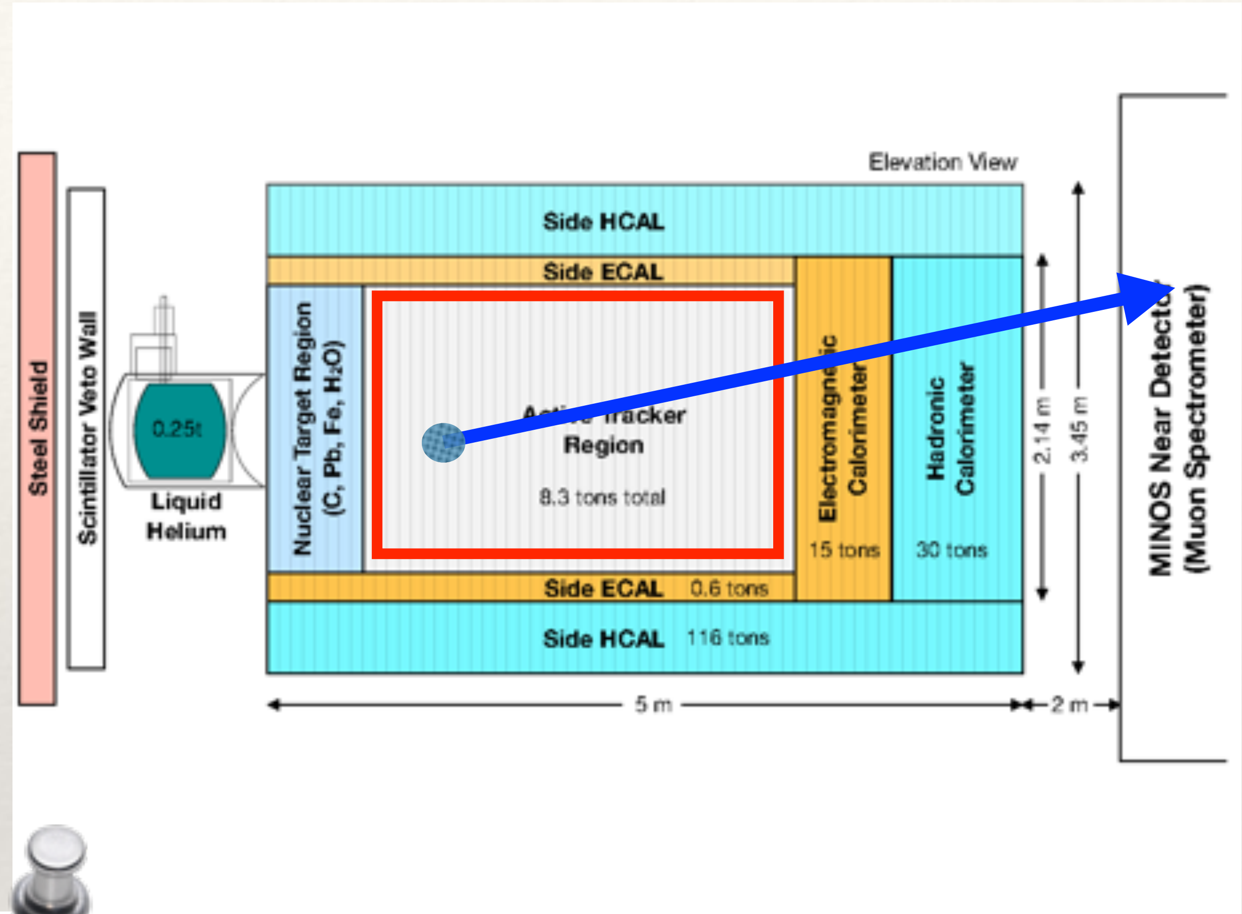


Signal Definition - MC

$$\nu_\mu + N \to \mu^- + \pi^0 + X$$

Signal Definition:

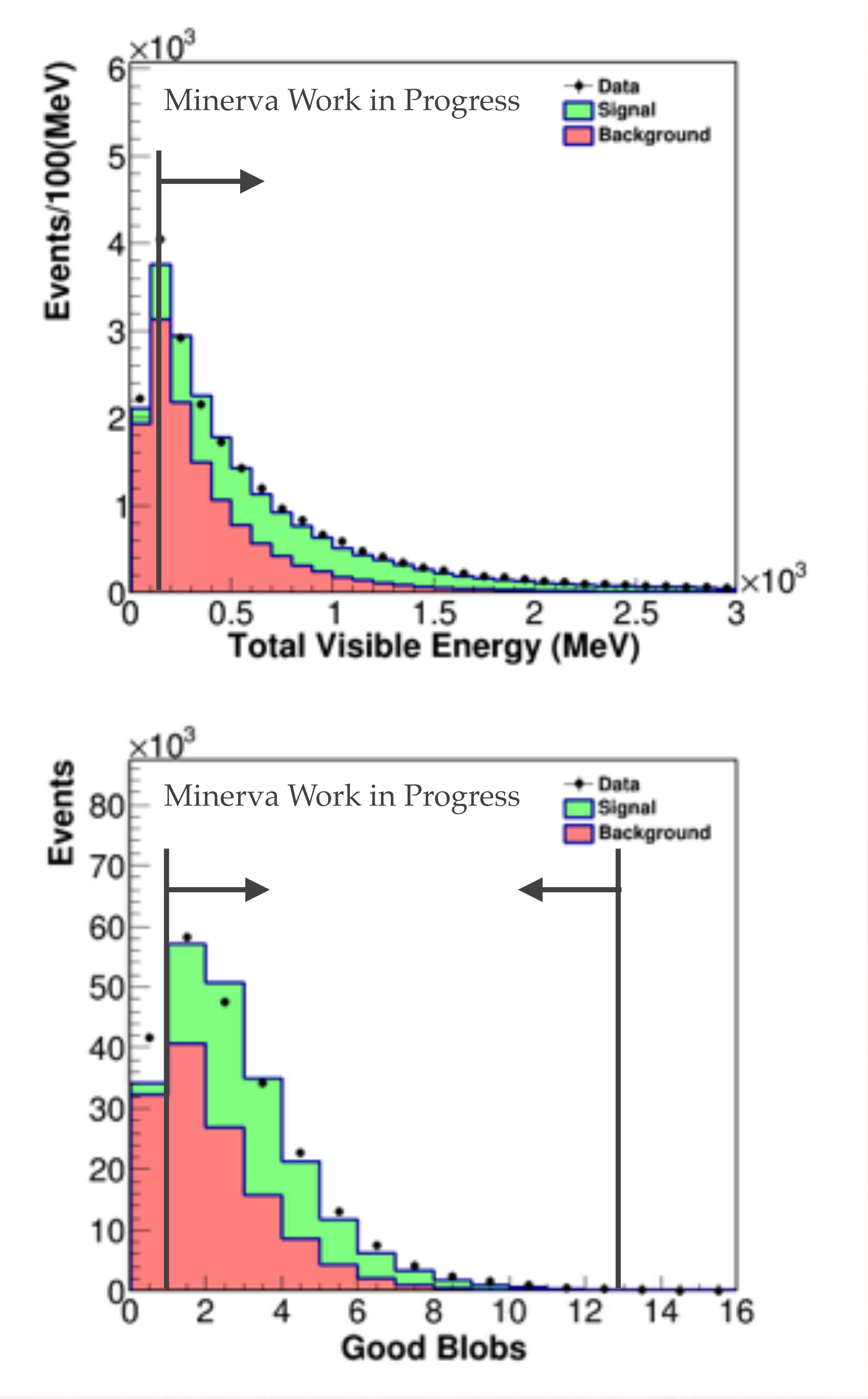
- Negative Muon.
- At least 1 neutral pion
- No restrictions on baryons or other mesons

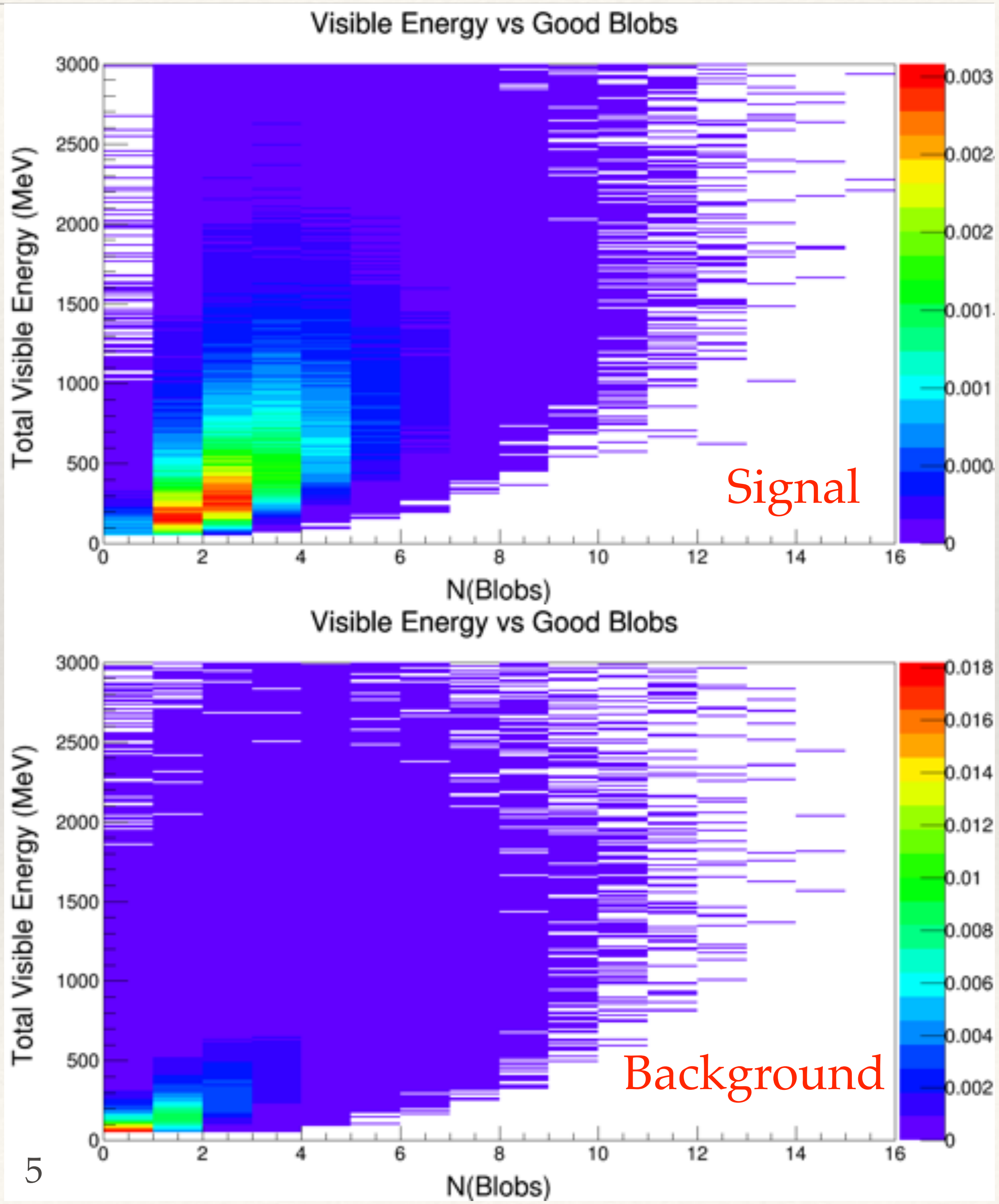


Once this kind of events are selected. This is the start point for the neutral pion reconstruction

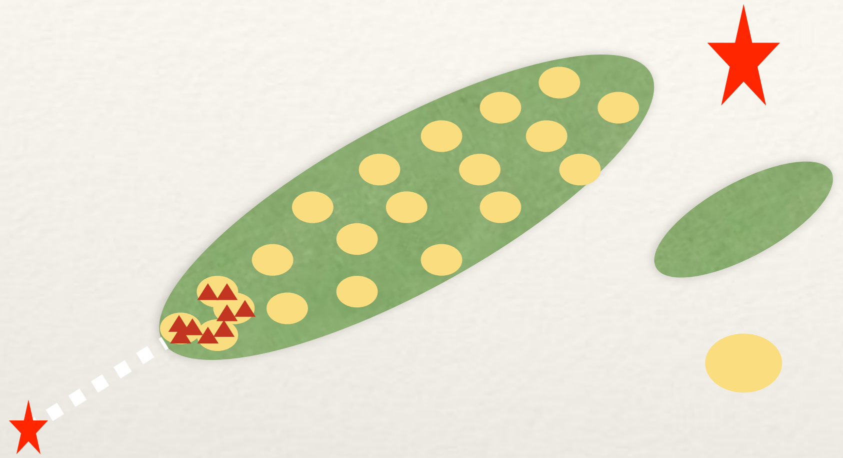
Using TMVA - GA
Toolkit for MultiVariable Analysis - Genetic Algorithm

$$E_{vis} = E_{Target} + E_{Tracker} + E_{ECAL} + E_{HCAL}$$





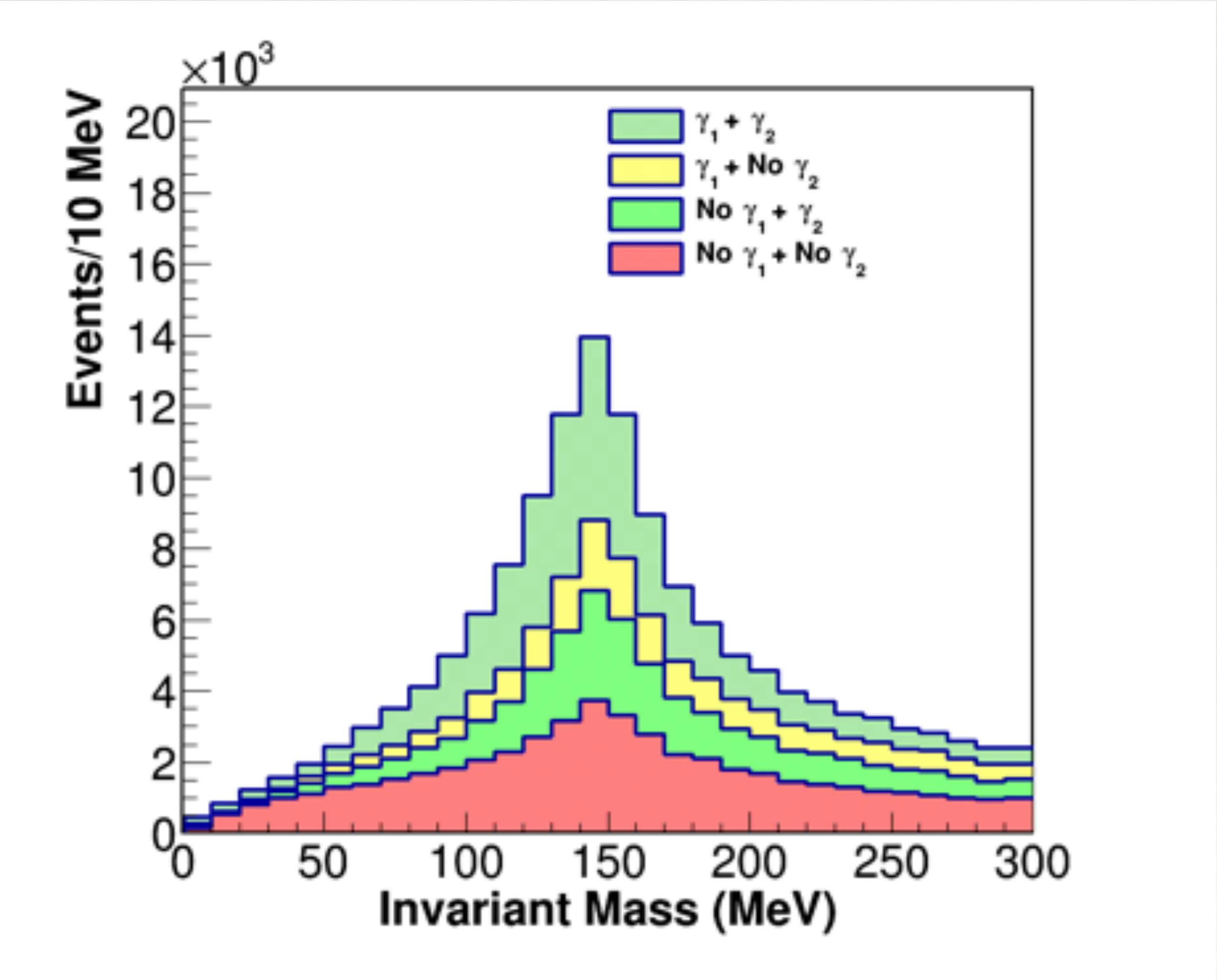
Best Two Blobs -EM Showers?

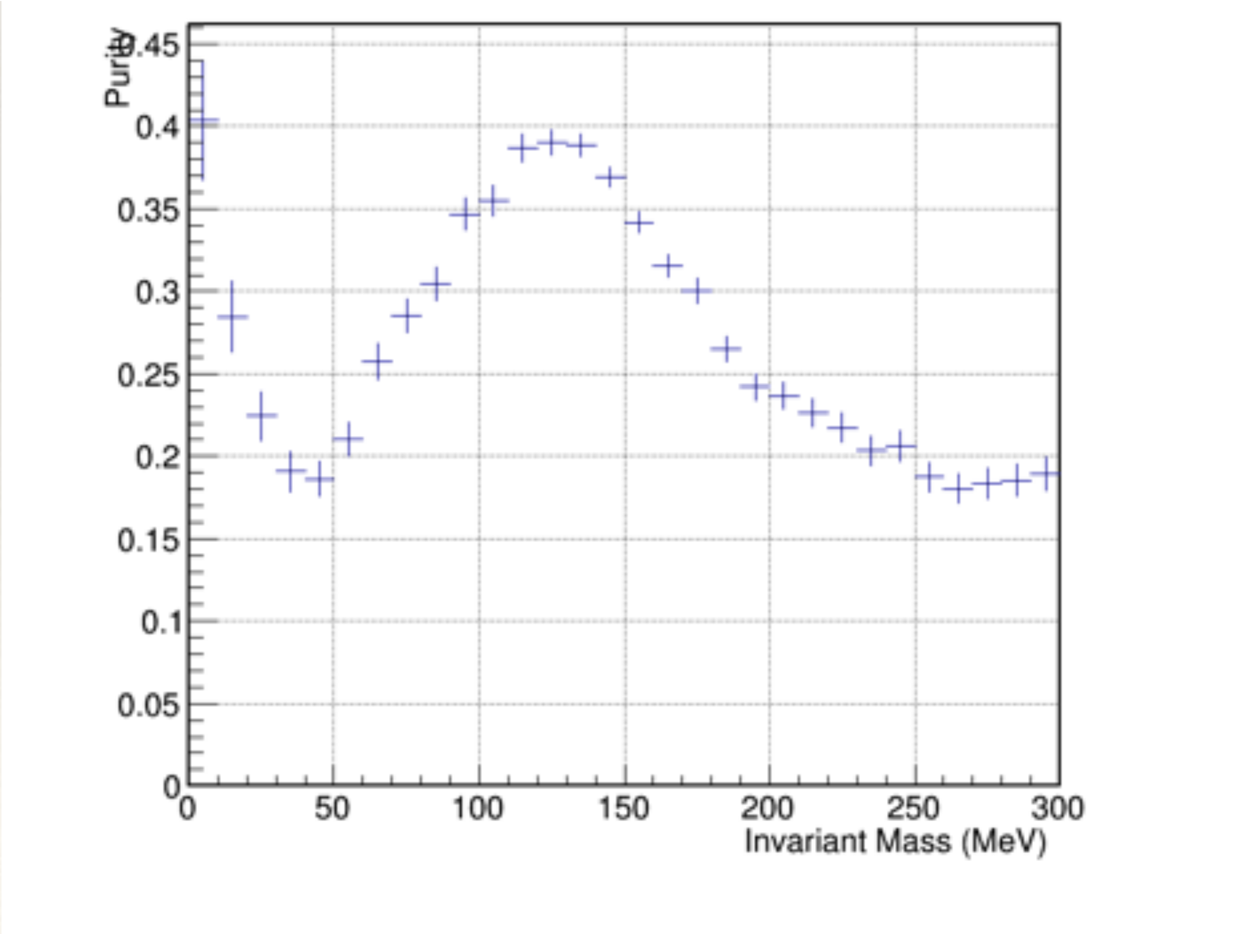


From MC

We can “track” down the shower:

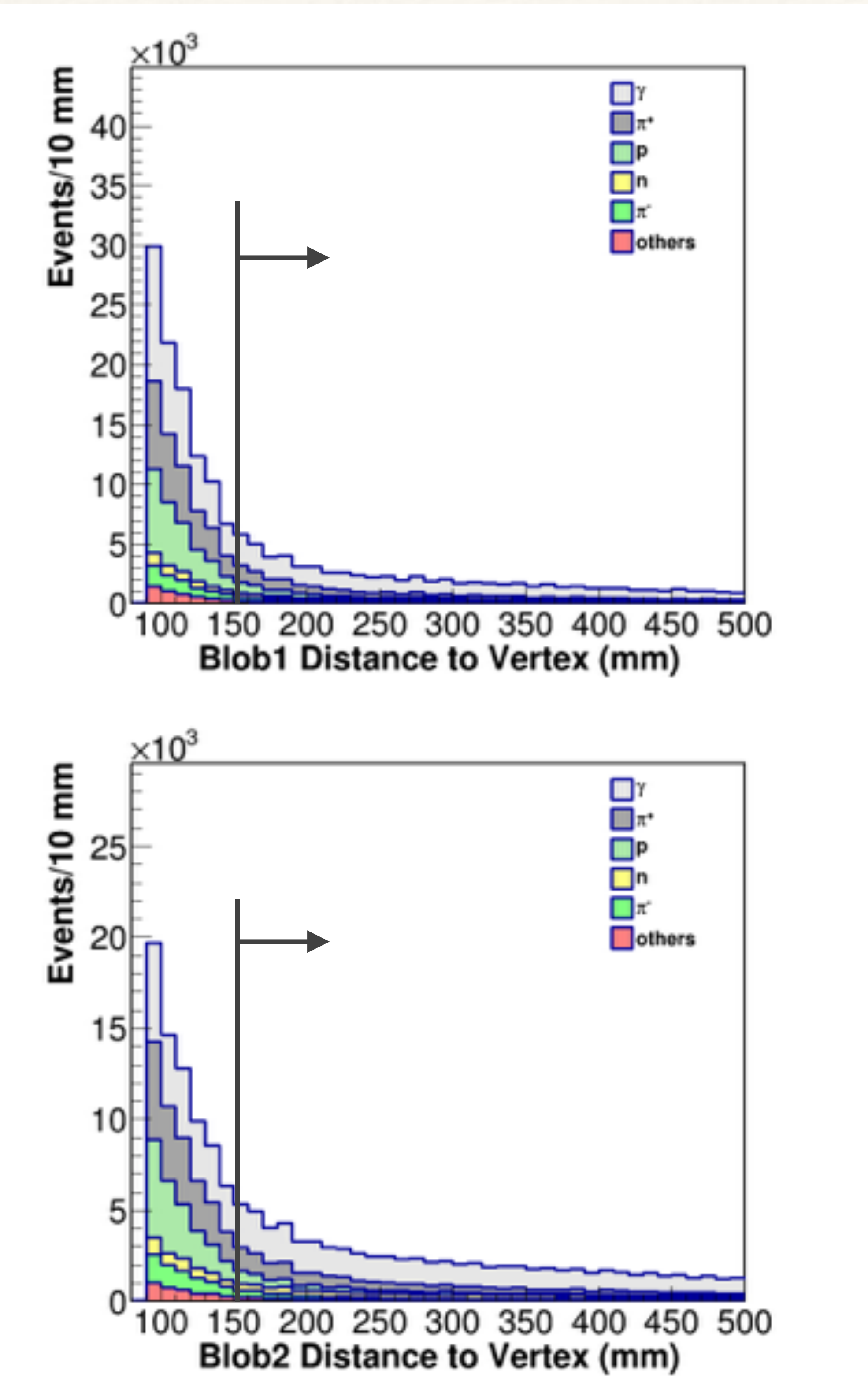
1. Look for the particle that create the shower (closest hit to the interaction vertex).
2. Record the PDG code of it.

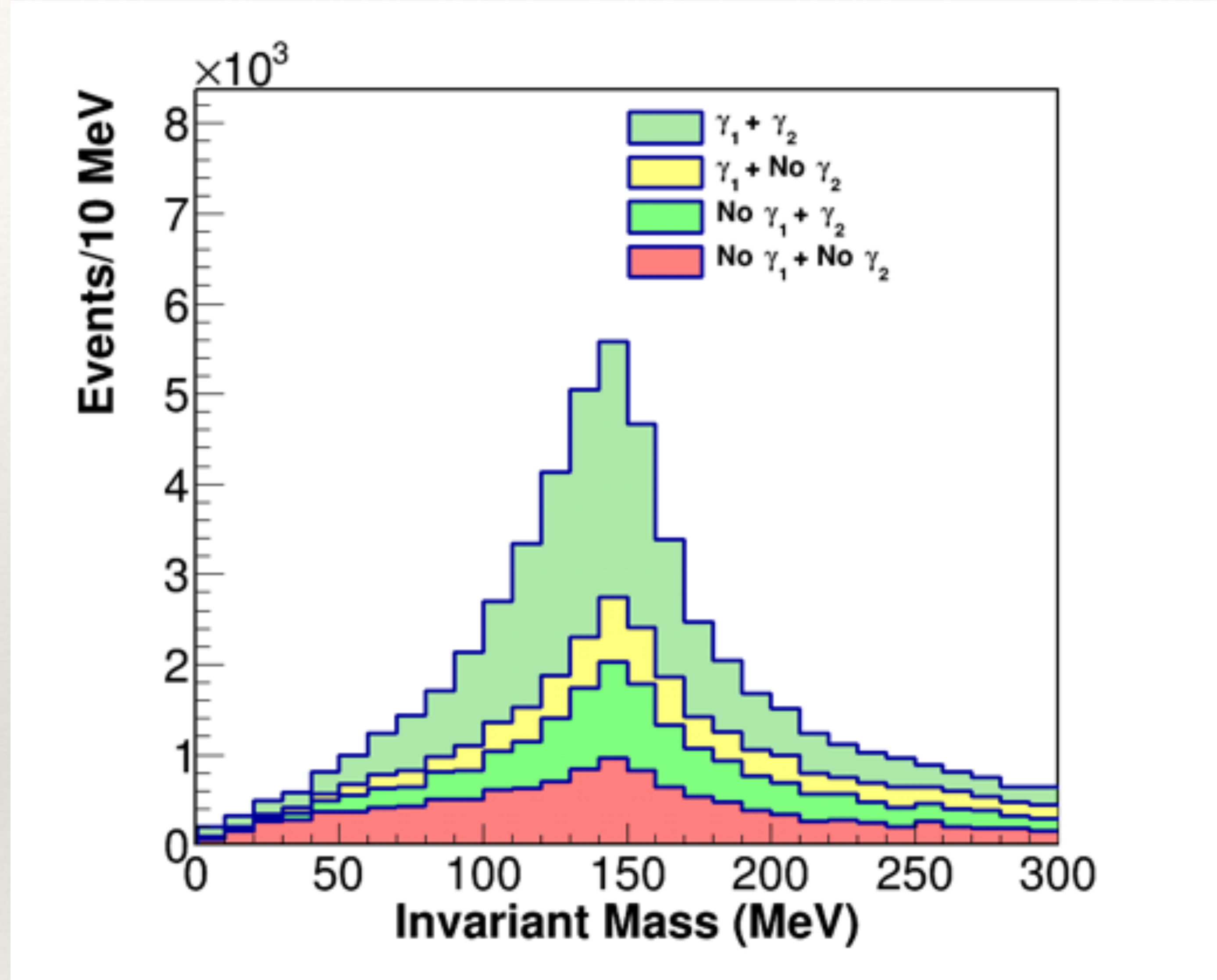




$X_{CH} = 0.375 X_0$

Conversion Length



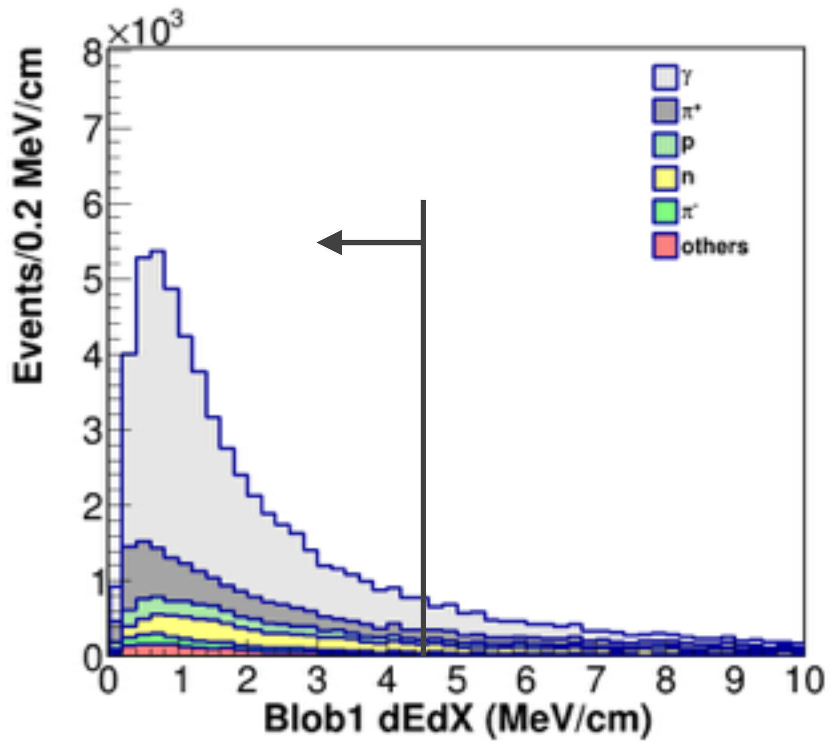


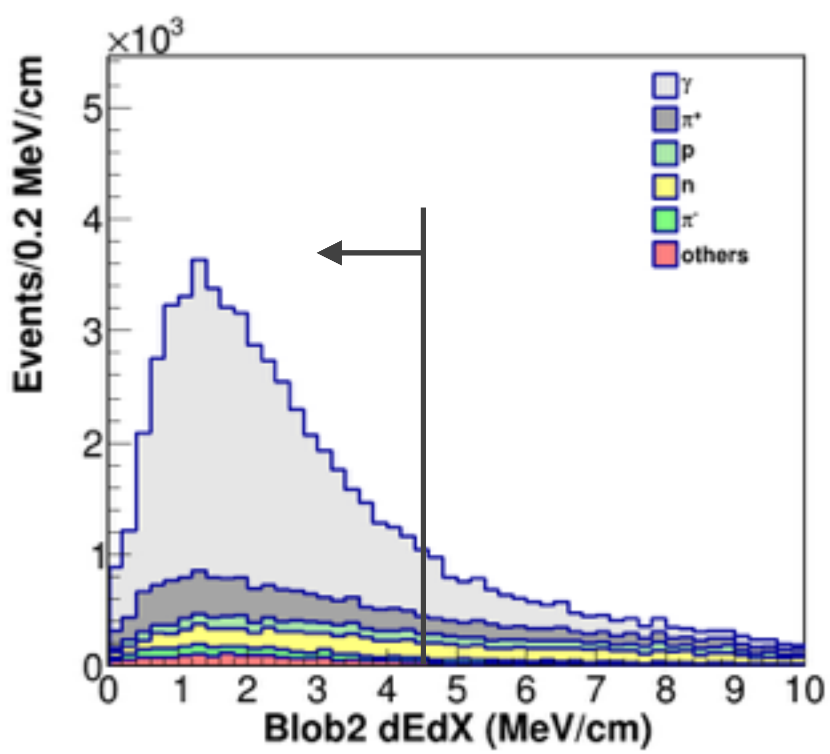
The EM showers selection seems to improve the pion selection, but the photon misidentification still being a problem.

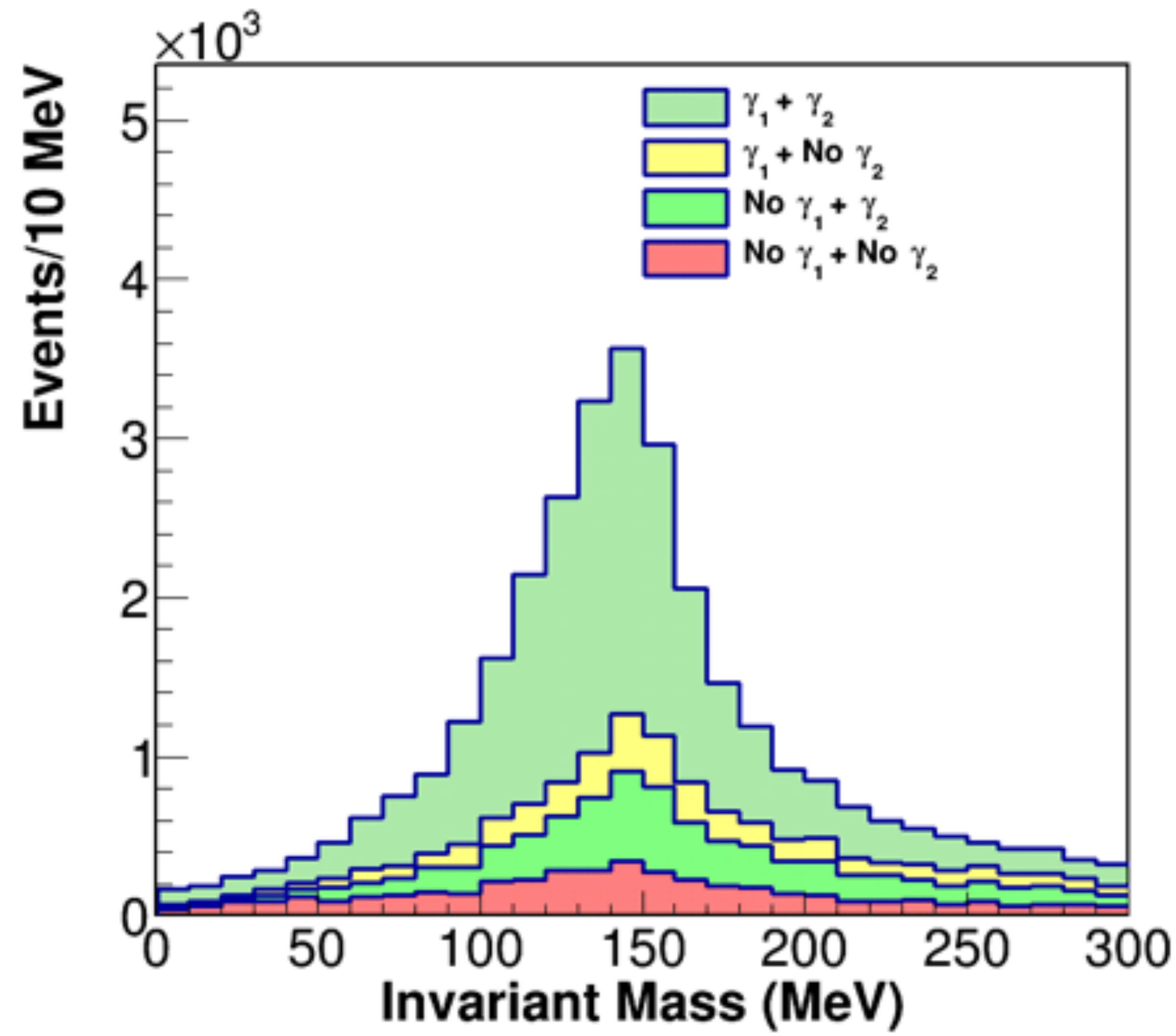
$$\frac{dE}{dX} = \frac{E^{dep}_{Total}}{l}$$

Energy Loss

$$l = \frac{1.7N_{planes}}{cos\theta}$$

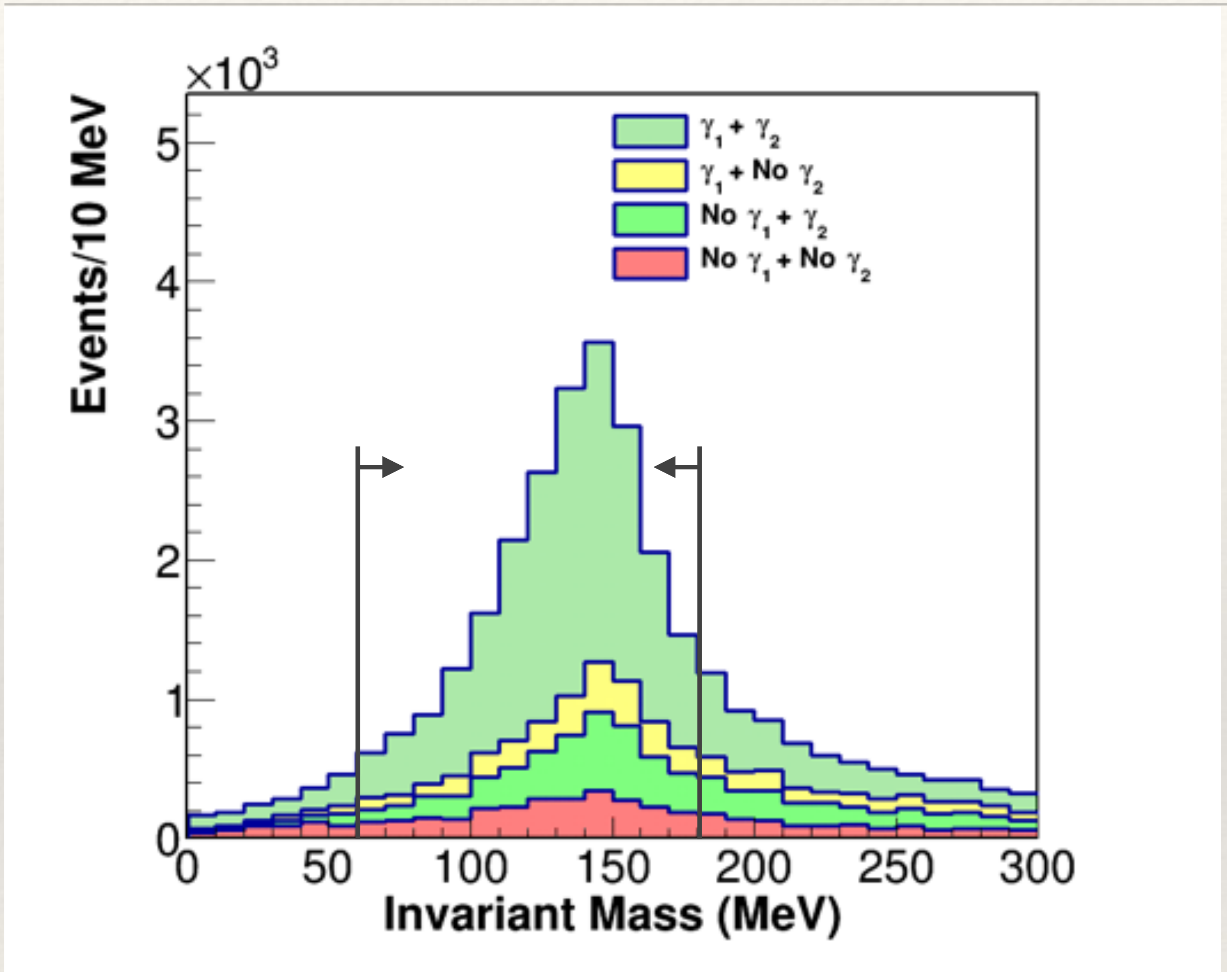


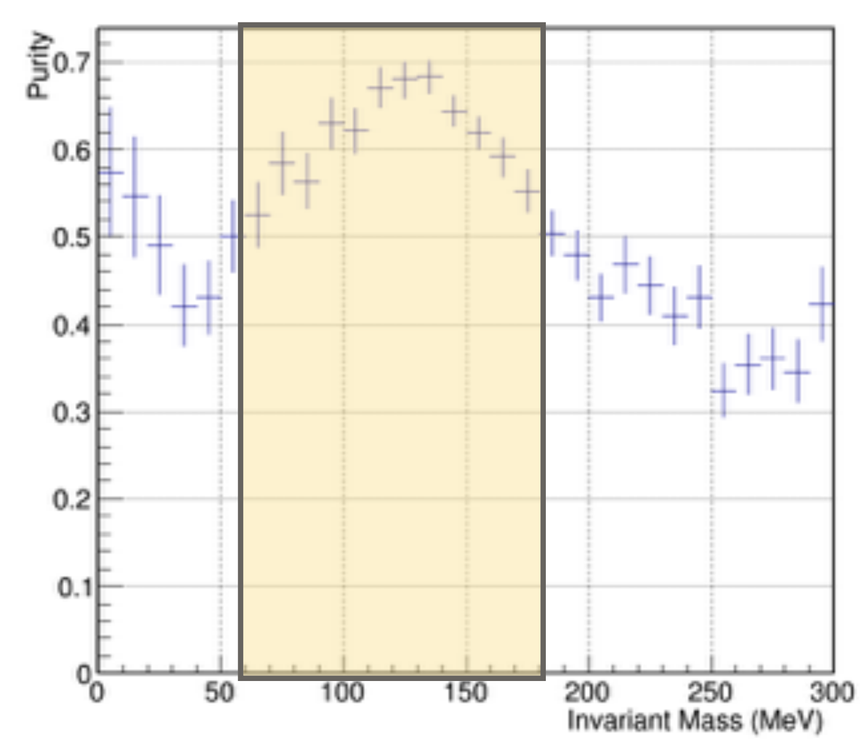


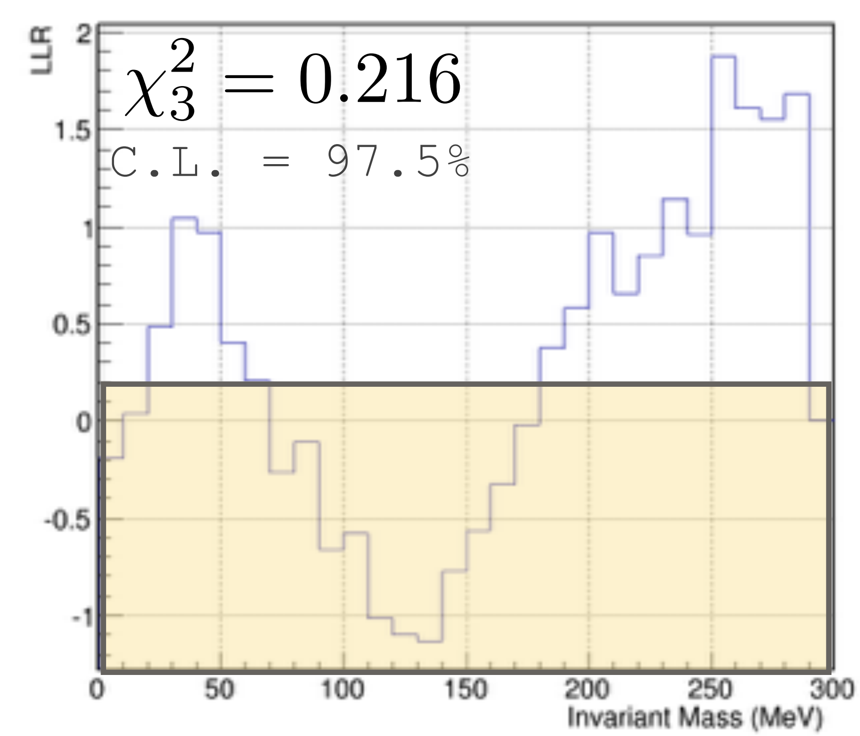


dEdX helps a lot!, now we know that the EM showers are misidentified mainly by non-trackable pions and neutrons.

Neutral Pion Candidates







Applying a hypotheses test
Log Likelihood Ratio (LLR)

$$LLR = -2ln\left(\frac{L\left(x|\gamma+\gamma\right)}{L\left(x|No\gamma+\gamma\right)+L\left(x|\gamma+No\gamma\right)+L\left(x|No\gamma+No\gamma\right)}\right)$$

Some Results

Signal Definition:

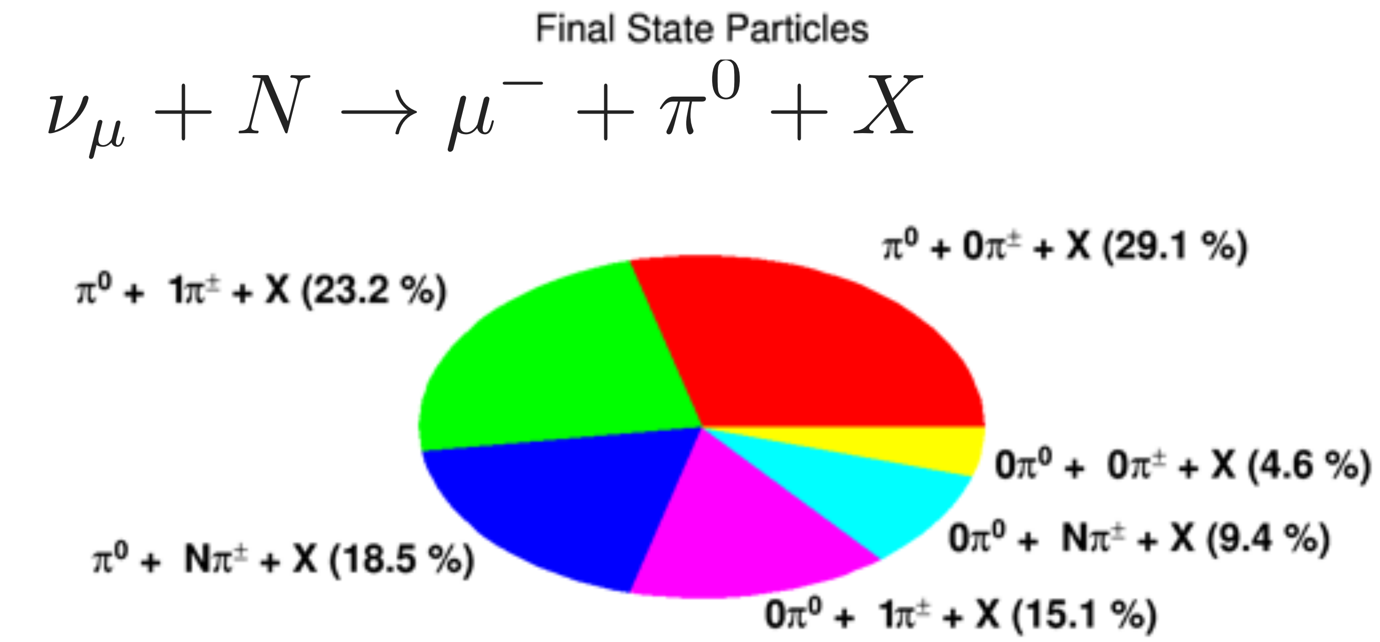
- Negative Muon.
- At least 1 neutral pion
- No restrictions on baryons or other mesons

Signal Selection

The events are selected with an efficiency of ~5% and a purity ~71%.

This selection seems to favor RES events over DIS according with MC.

All events are selected only on plastic scintillator



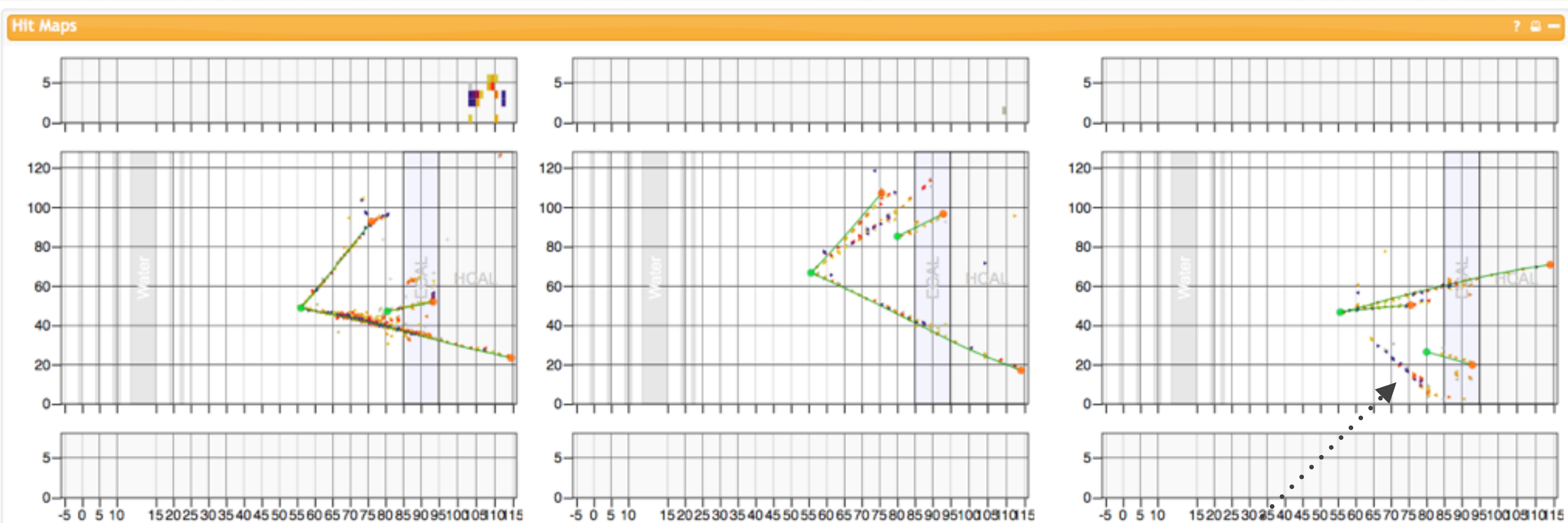
Background

Events without pions are rejected very efficiently.

My background is dominated by events with charged pions

Some Events Displays

X-View U-View V-View



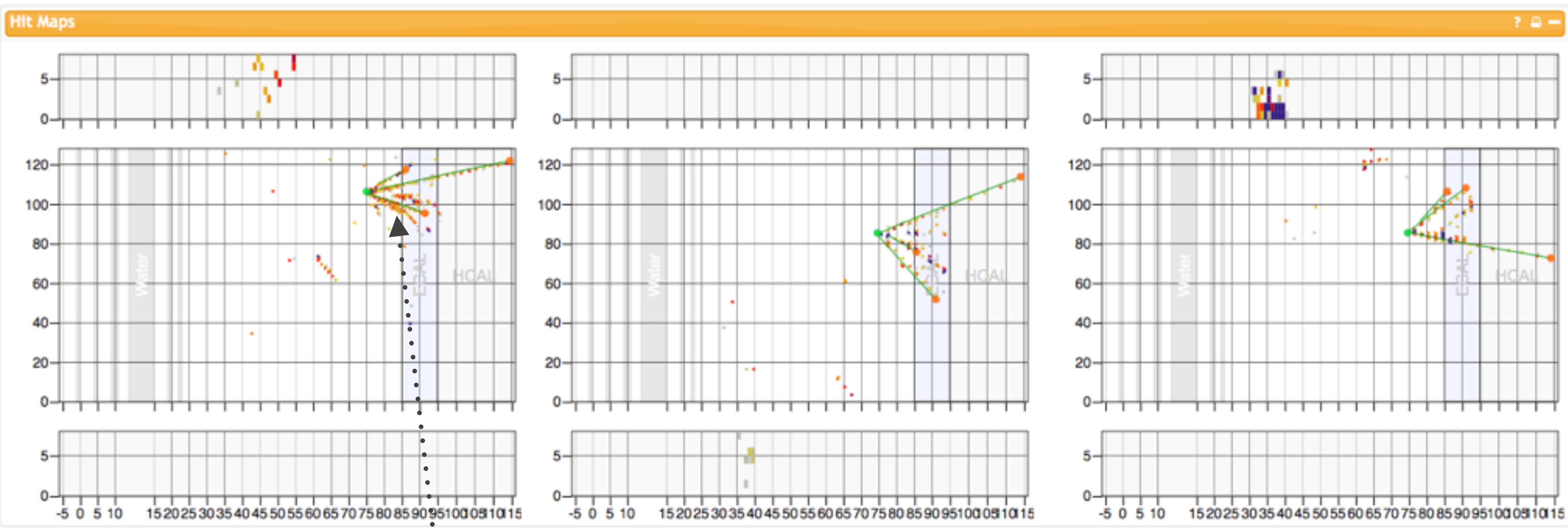
Final State

$$\mu^- + \pi^0 + \pi^+ + n$$

Sometimes the gamma showers travel close to each other.
This selection can recognize it!!

Some Events Display

X-View U-View V-View



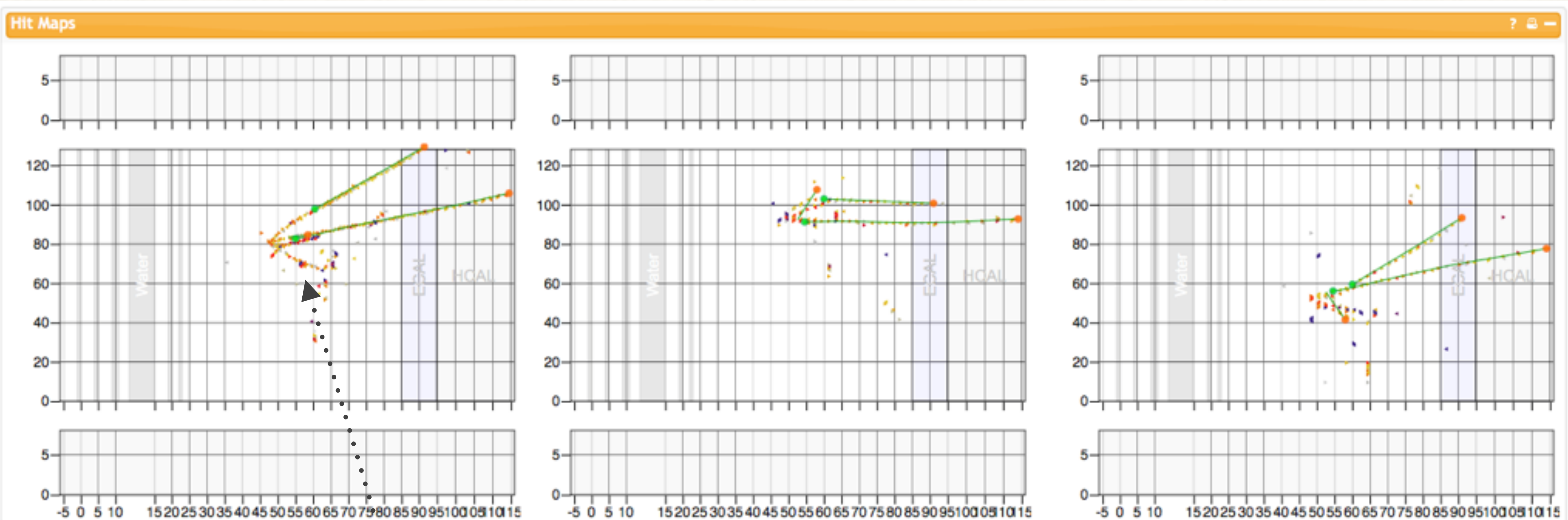
Final State

$$\mu^- + 2\pi^0 + 2\pi^\pm + n$$

Sometimes multiple pi0s are created.
This selection can recognize one of them!!

Some Events Display

X-View U-View V-View



Final State

$$\mu^- + 0\pi^0 + 3\pi^\pm + p$$

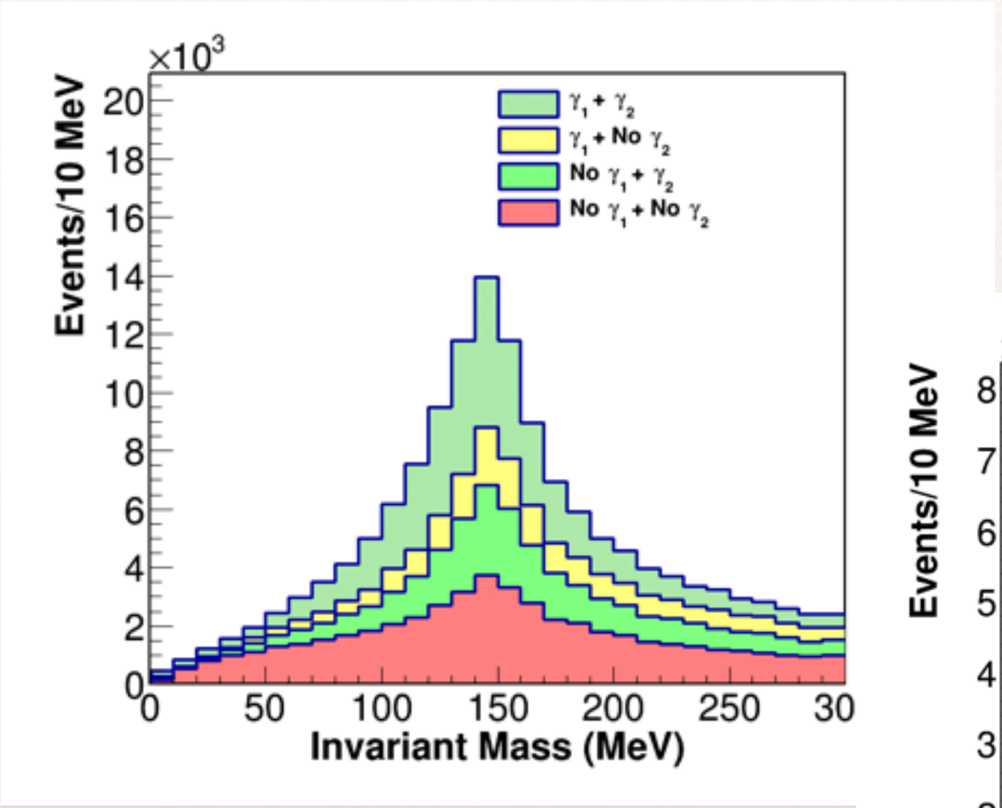
Sometimes fake gammas are seeing as pi0 candidates. Hard to recognize them, (30% of the time)

Final Comments

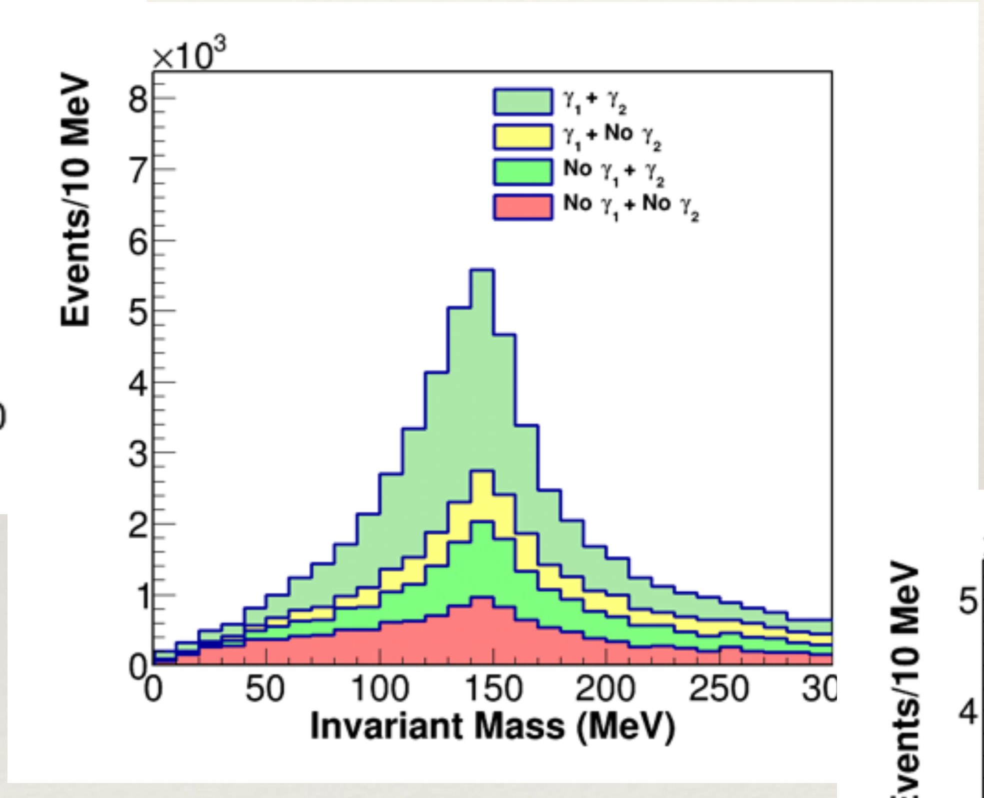
- The selection is very promising, considering that I only used 25% of the MC POT for ME.
  - MC POT Used: 3.27×10^{20}
- In a LE MINERvA analysis with **1304 events** with neutral pions was selected with a **purity of 55%.**
  - In this "dirty" scenario we can recognize **98803 events** with at least 1 pi0 with a **purity of 71%.**
- According with MC, the neutral pion selection is showing:
  - a preference of 66% of the signal events come with at least one charged pion.
  - 84.2% of the background is dominated by charged pion production.

Backup

Invariant Mass

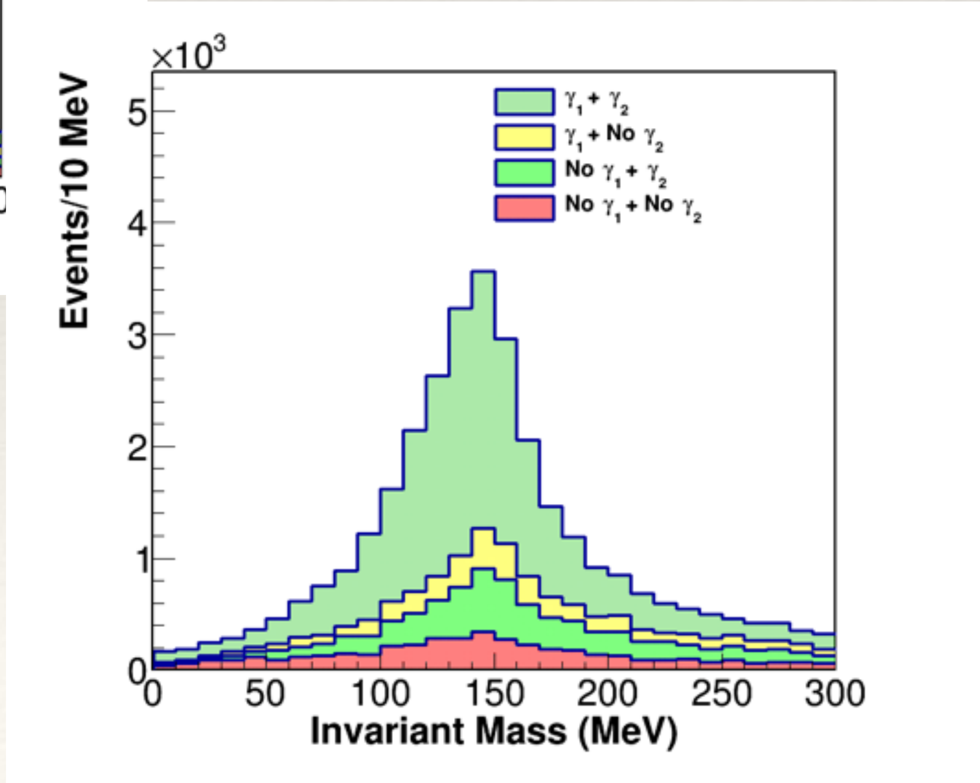


Best 2 shower candidates

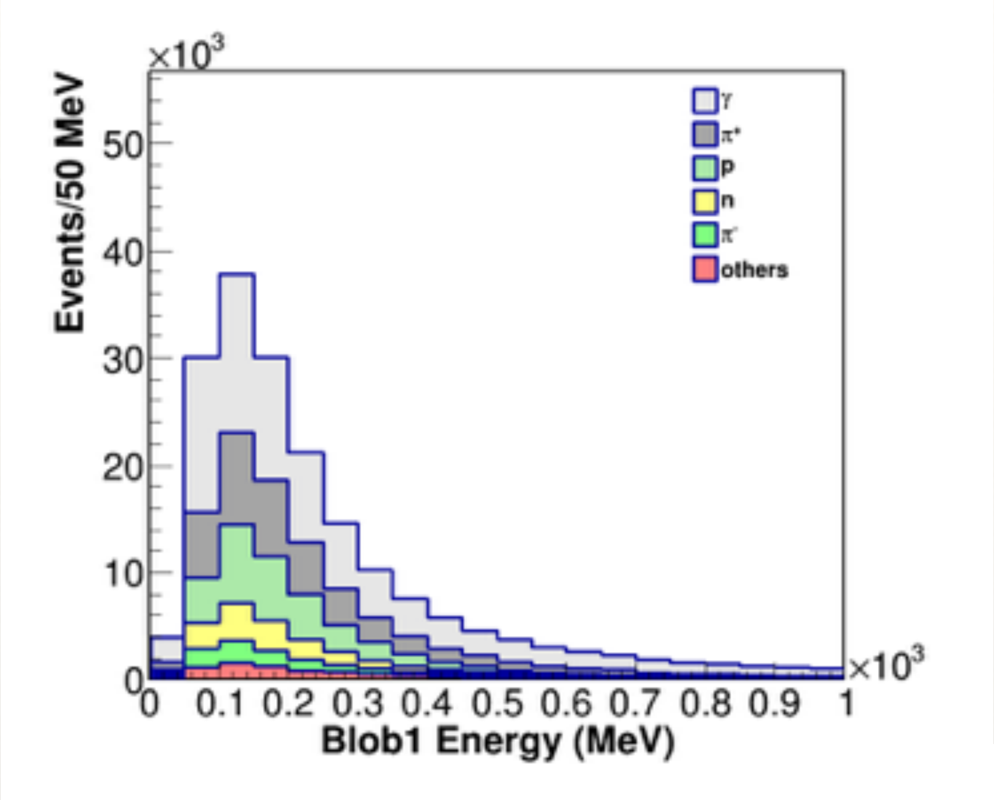


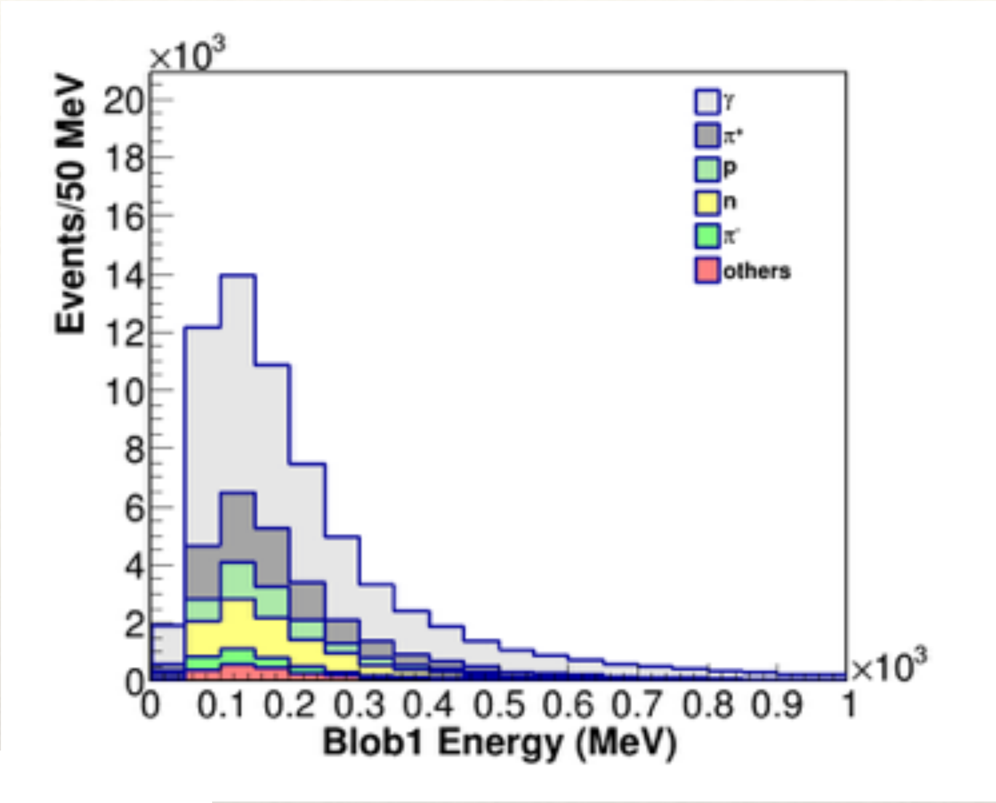
After Conv. Length Cut

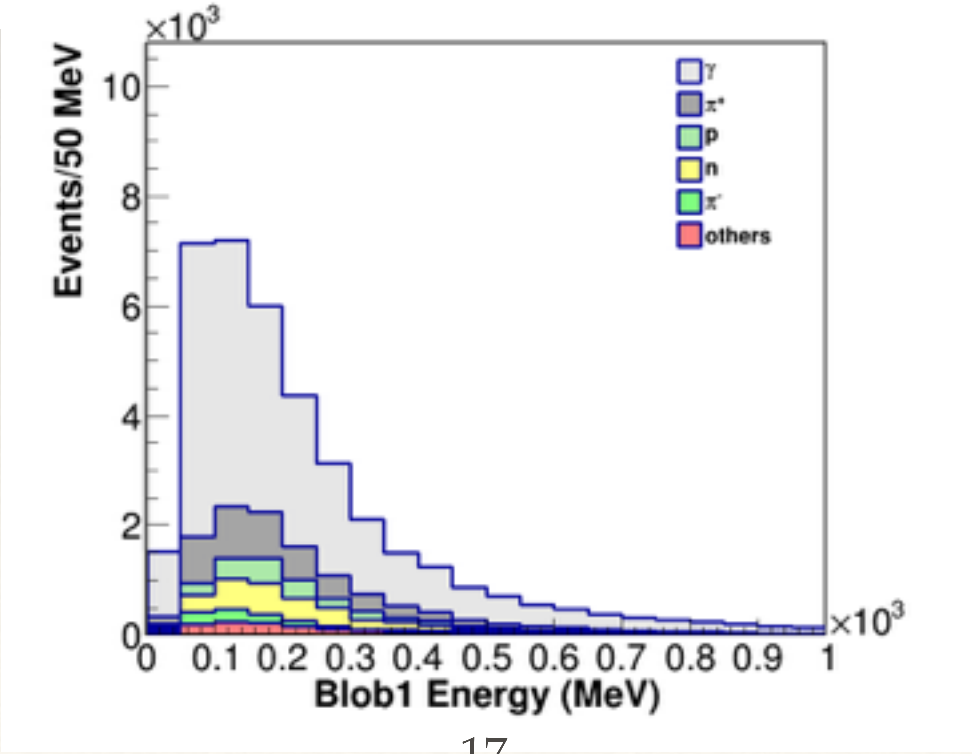
After dEdX Cut



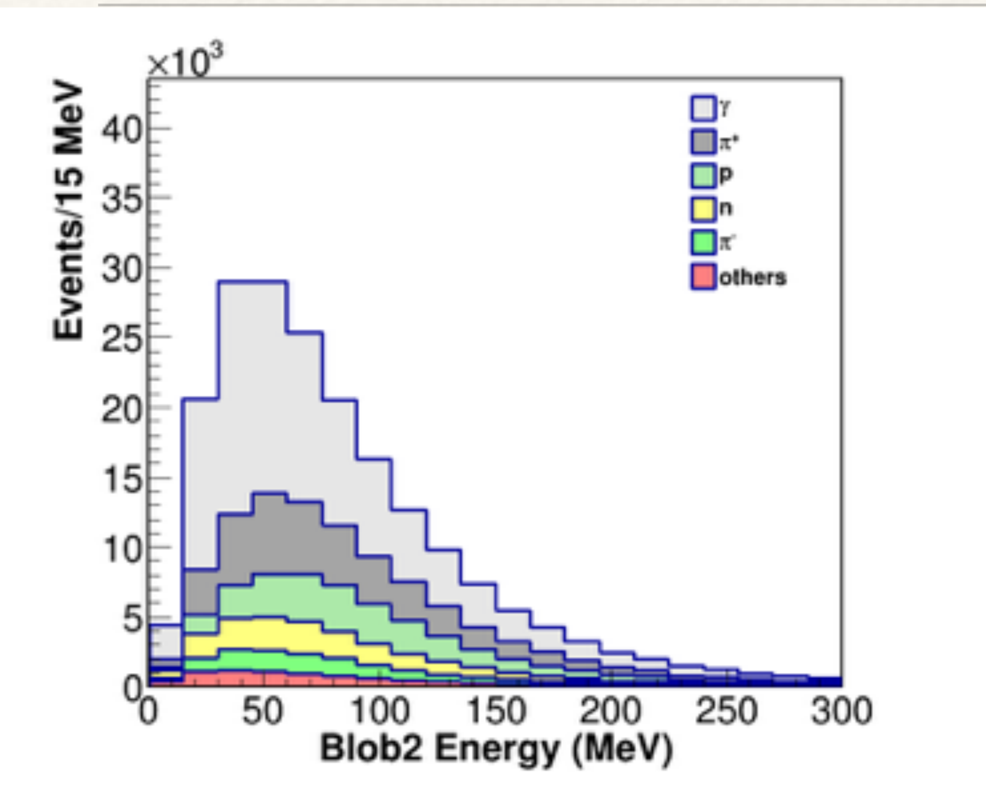
Shower 1 Energy

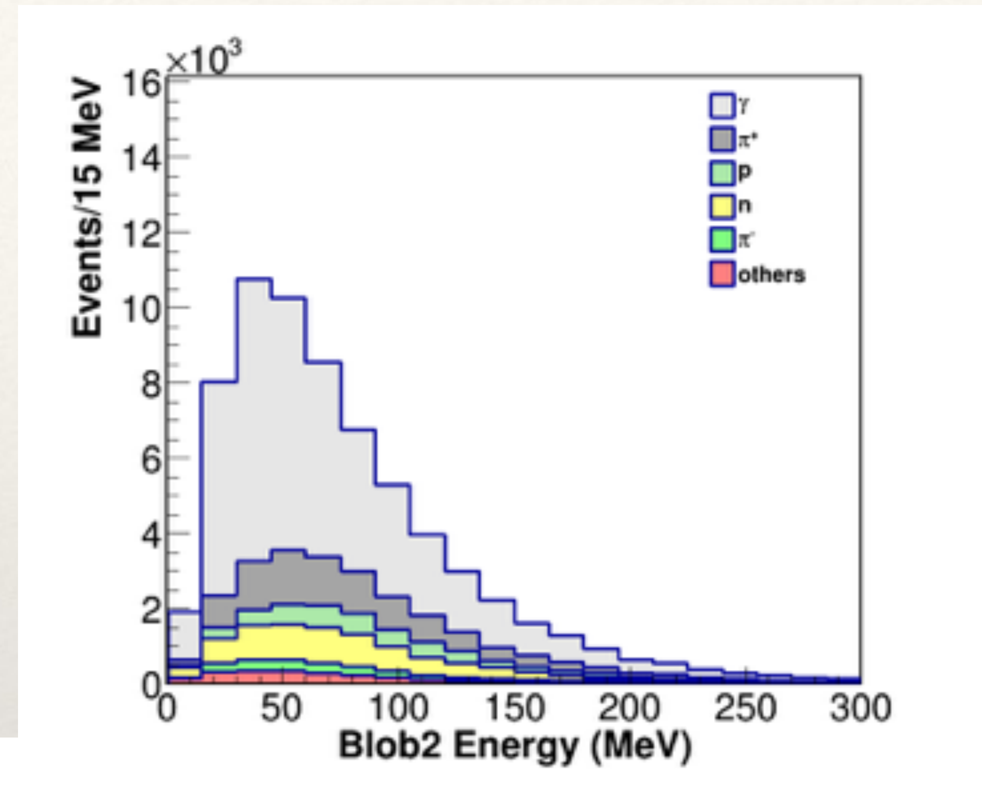


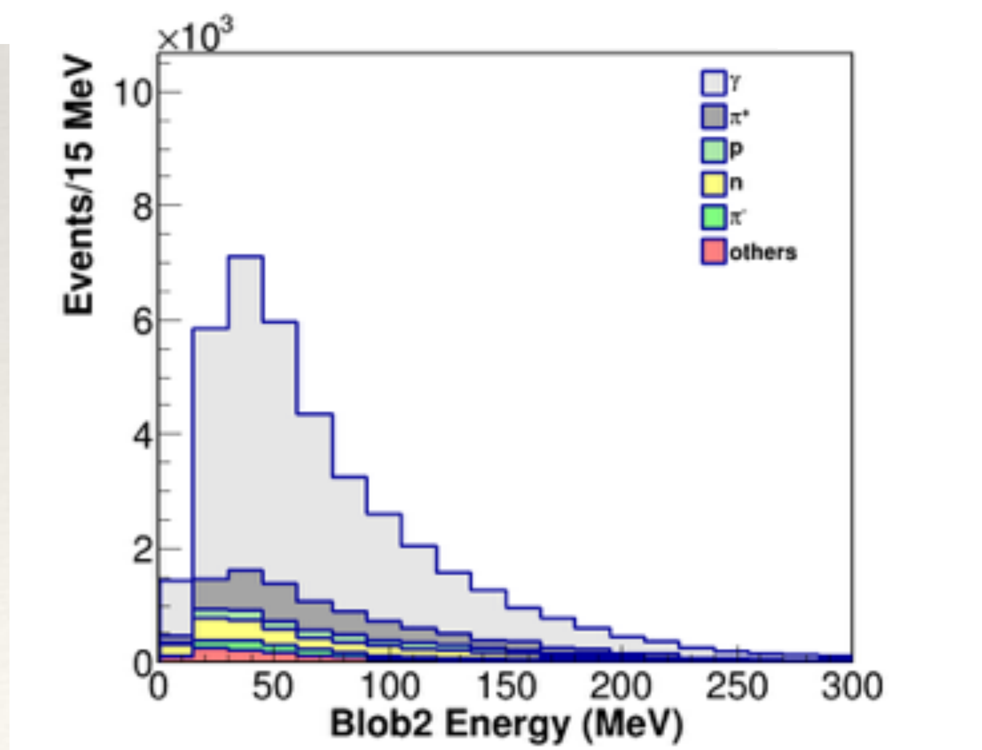




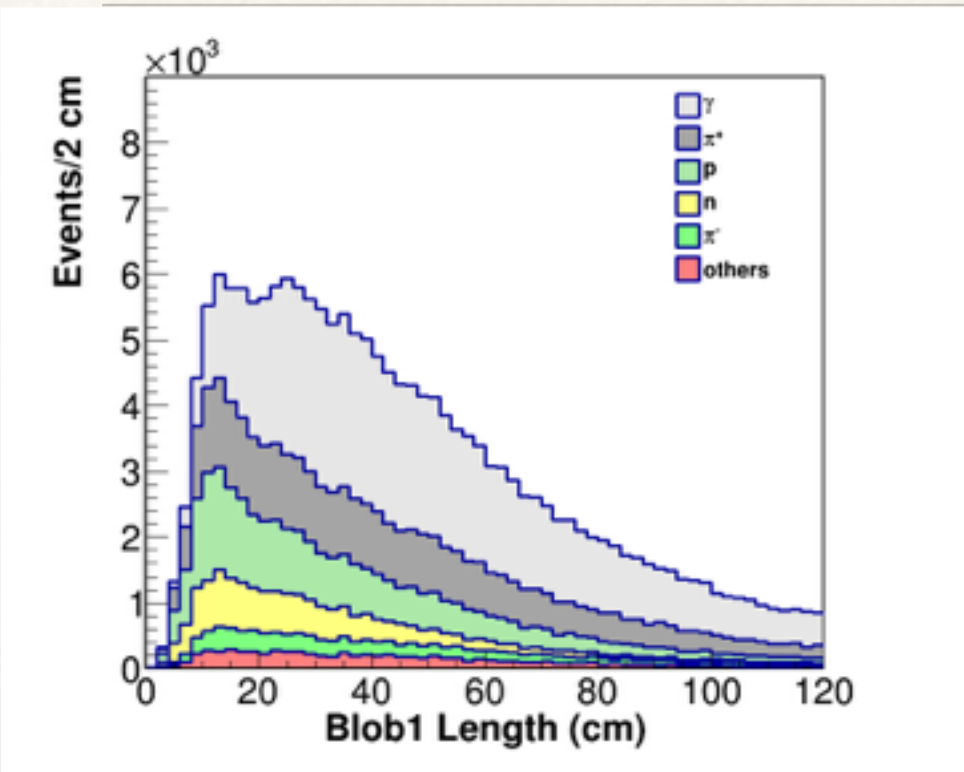
Shower 2 Energy

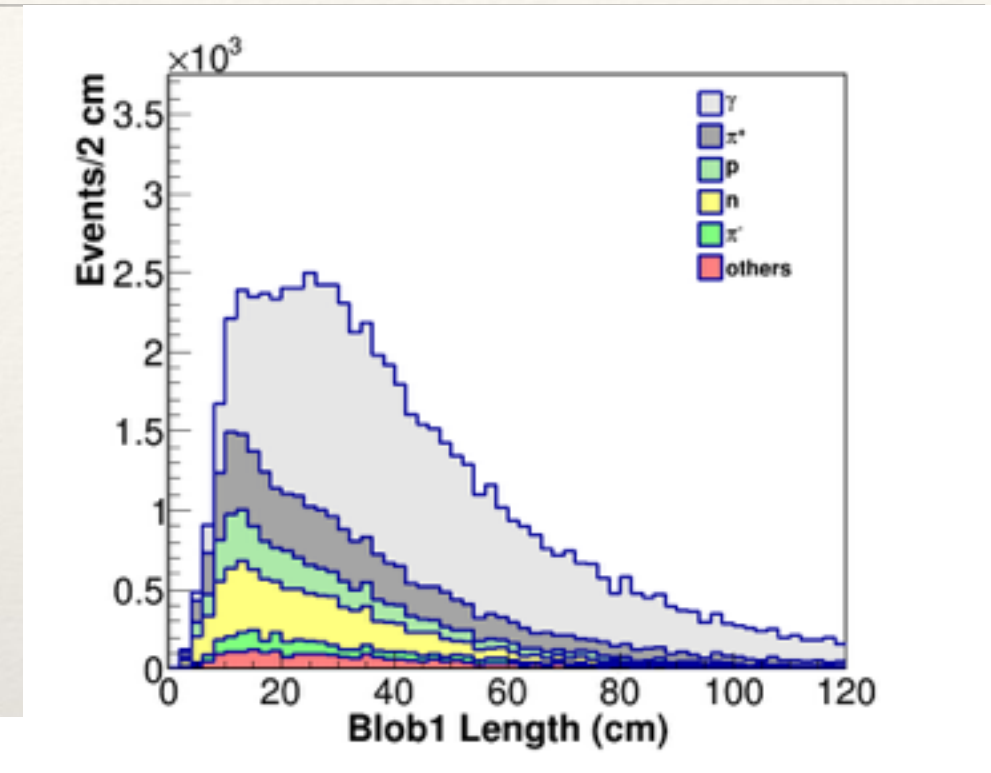


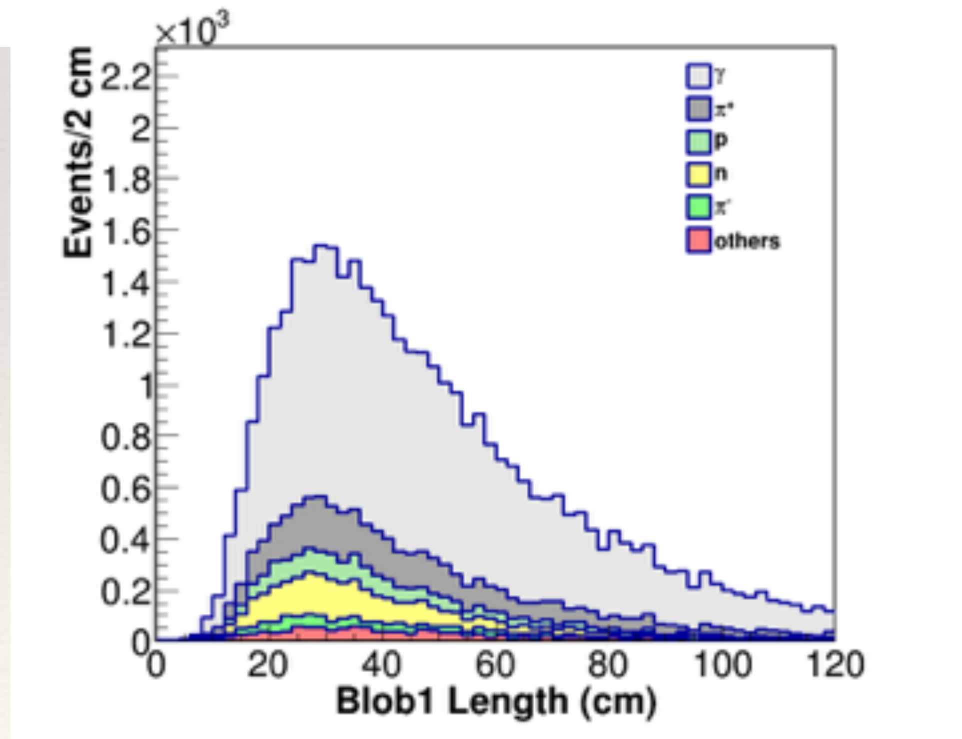




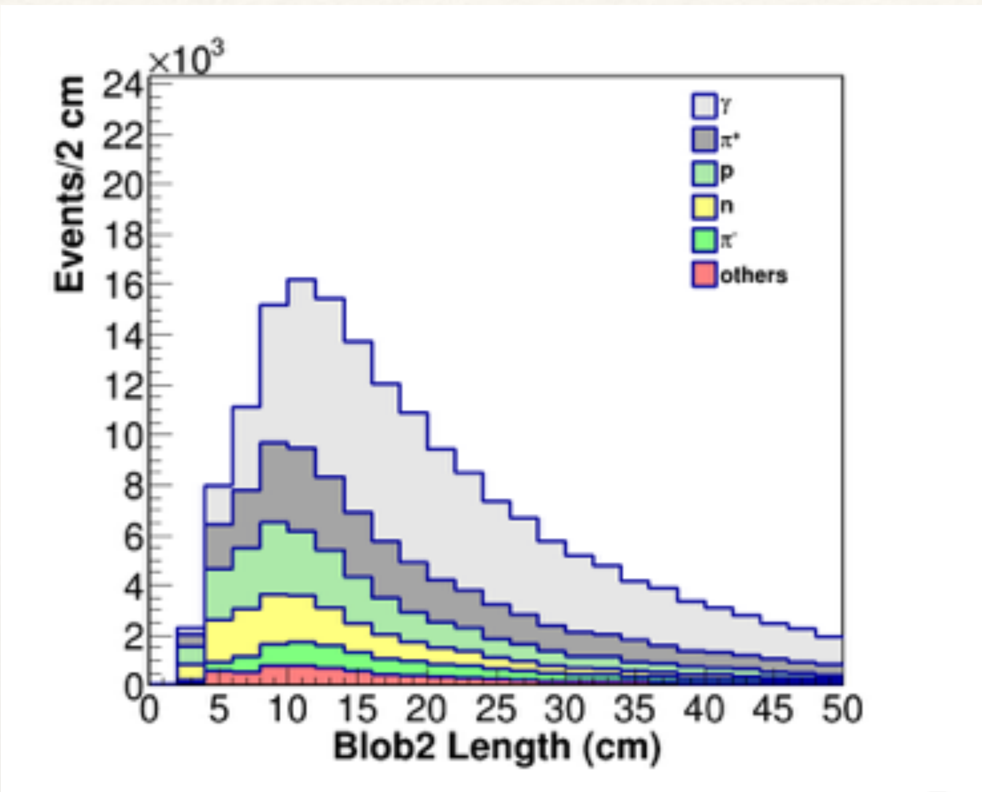
Shower 1 Length

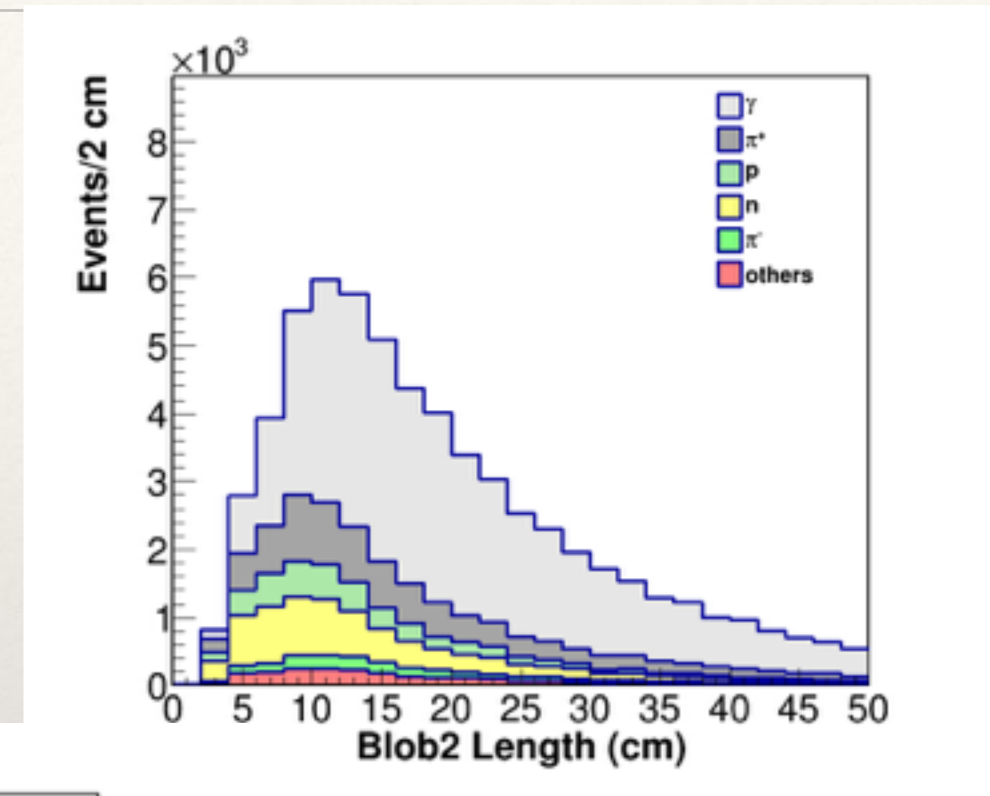


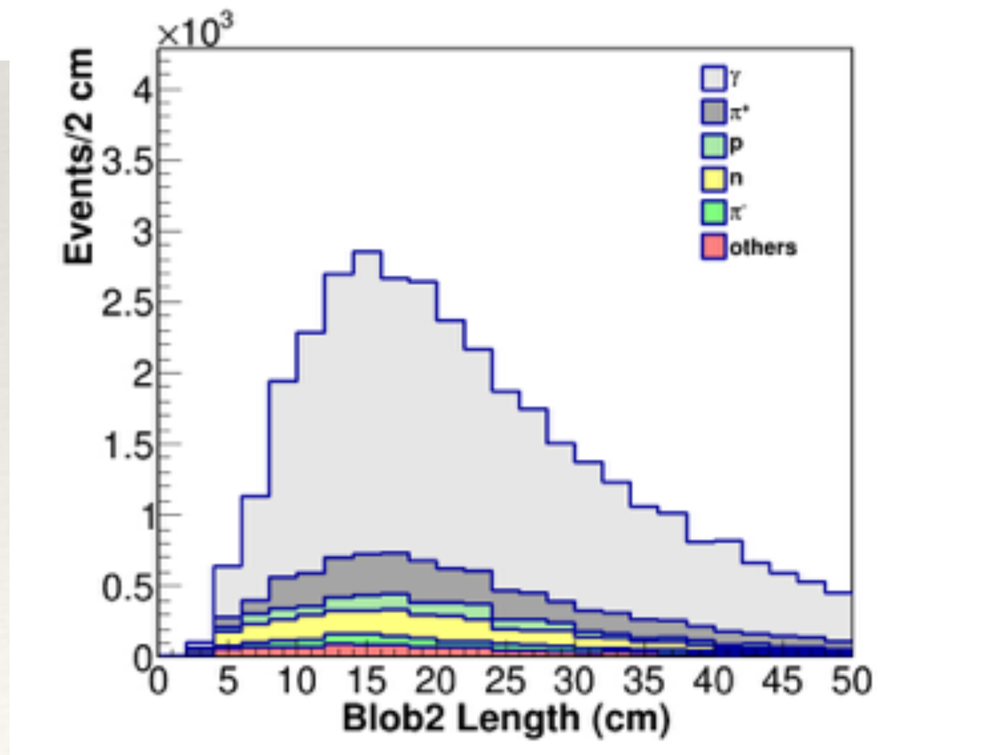




Shower 2 Length

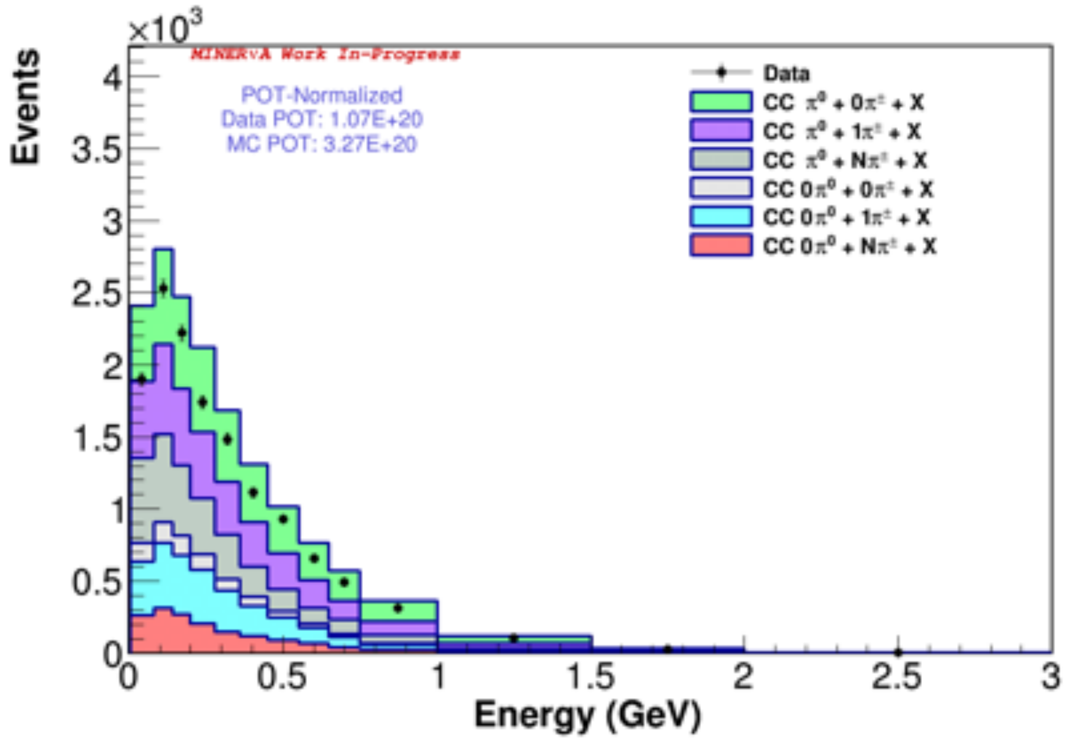




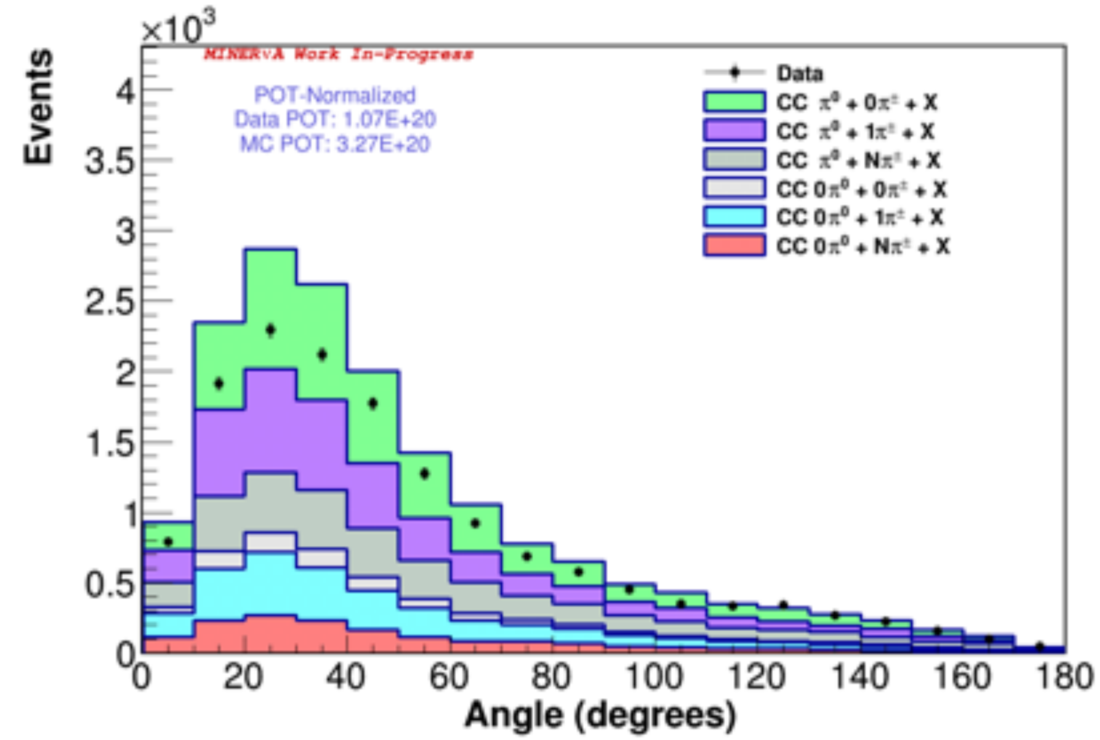


More Results

Kinetic Energy



Angle wrt z-axis



Comments

- Slow pi0s seems to prefer be produced with at least 1 charged pion.
- The reconstruction favors the production of pi0s with KE < 1 GeV.
- Most of the pi0s are produced forwards of the interaction vertex.

Even More Results