LArSoft

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http://cdcvs.fnal.gov/redmine/projects/larsoftsvn

Outline

- LArSoft Overview
- Reconstruction Paradigm
- Reconstruction Progress/Performance

LArSoft spans ArgoNeuT, MicroBooNE, LBNE, LAr1, LArIaT, LongBo, 35Ton, ...

- LArSoft is a complete set of Simulation/Reconstruction/Analysis tools.
- Philosophy: LArSoft code to be shared by all experiments, to the extent possible. Code written detector agnostically to the extent possible.

Infrastructure

- Codebase lives at FNAL. Enjoys Computing Division support. Analysis and Reconstruction Toolkit (ART), derived from CMSSW, is the framework.

- ArgoNeut/MicroBooNE/LBNE collaborators work on their own machines at FNAL, write to their own experiment's disks. Their analysis code lives in their own repositories.

- Compute farm: Can submit to thousands of FNAL nodes with job management tool condor

- There are in fact remote LArSoft installations which use their own compute resources. This is an area where there may be large improvements soon.

ART benefits

- It provides an "easy" apparatus for access into an Event record and looping over and analyzing/building Events.
- ART is used by mu2e, g-2, NOvA also, & certainly others in Intensity Frontier in future.

“fcl” script snippets

Set up basic Services

```
services:
{
  # Load the service that manages root files for histograms.
  TFileService: { fileName: "genie_hist.root" }
  Timing:       {}
  SimpleMemoryCheck:     { ignoreTotal: 1 } # default is one
  RandomNumberGenerator: {} #ART native random number generator
  user:         @local::microboone_simulation_services
}
```

These are modules that add data onto the Event

```
producers:
{
  generator: @local::microboone_genie
  largeant:  @local::microboone_largeant
  daq:       @local::microboone_simwire
  opdigi:    @local::microboone_opdigi
}
```

These modules do not modify, merely *use* Event data Histograms/TTrees produced here, typically.

```
analyzers:
{
  largana:  @local::microboone_largeantana
  sptana: @local::microboone_spacepoint
  trkana: @local::standard_trackana
}
```

Each of these producer/analyzers corresponds to a C++ class written according to a specific template.

Over-ride parameters

```
physics.producers.trackkal.MomErr3: [.01, .01, .03] // GeV
physics.producers.trackkal.MomStart3: [0.5, 0.5, 1.8]   // GeV

physics.analyzers.sptana.ClusterModuleLabel: "fuzzy"
physics.analyzers.trkana.TrackModuleLabel: "trackkal"
```

LArSoft: events

- Create events in the detector: GENIE/NuANCE/ NuWRO/CRY/SingleParticle/FileParticles
- Simulate: Geant4 (with drift electrons)+DetSim
- Or, better, Data: (ArgoNeuT!)

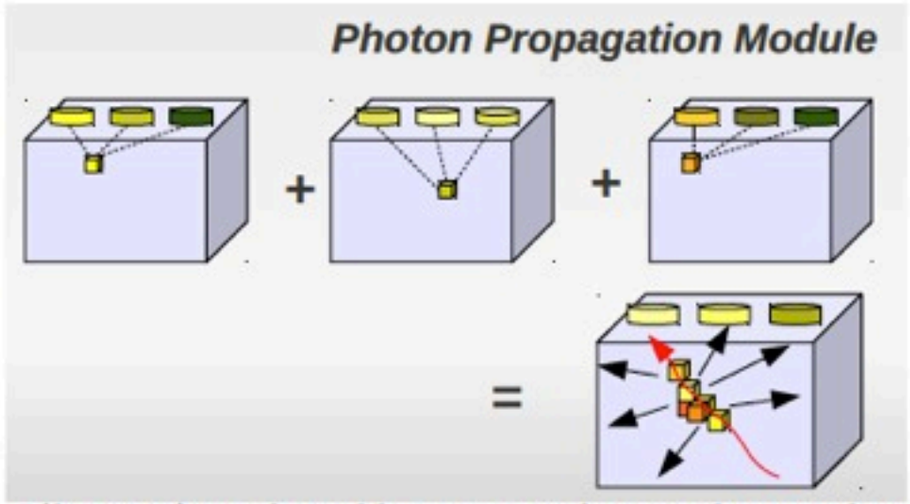
electron drift

- ~10000 ionization electrons/mm
  - too many to step at each ~mm stepsize
- Instead, break into N clouds at each step, apply recombination and lifetime effects, and impose a transverse and longitudinal diffusion for each, and drop that cloud onto one wire.
  - presumes, so far, a uniform E-field
- Convolve with a field (Induction/Collection) response and electronics response.

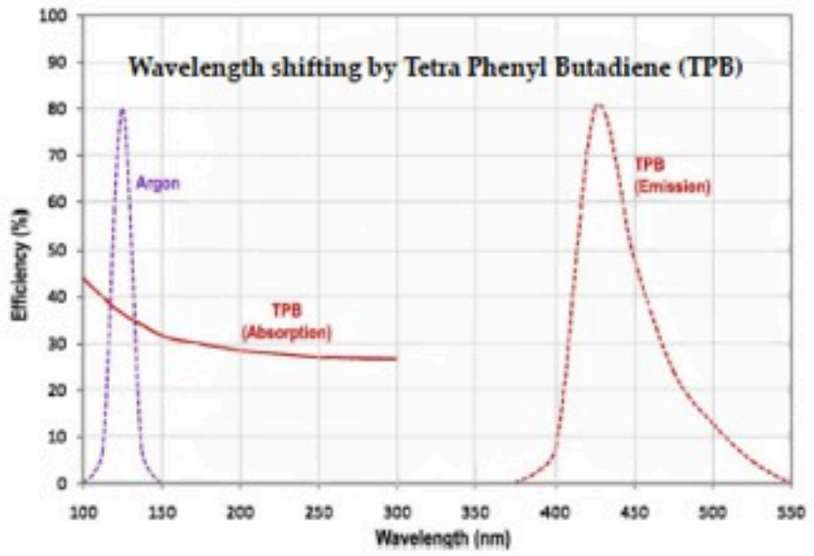
Photons

vis-a-vis MicroBooNE

- LAr is an extremely bright scintillator, so we have copious (~40000/MeV)amounts of UV photons to deal with.
  - ArgoNeuT has no light collection, MicroBooNE has ~30 PMTs, LBNE?
  - For MicroBooNE the PMT signals will assist in triggering.
- Simulating all photons in an event is CPU intensive. A fast simulation relying on voxels and a library of voxel/PMT responses has been introduced to simplify the process.
- Wavelength shifter is coated on PMTs to help collect the UV photons...this shift, and the PMT efficiency, is included in simulation. Wire plane transparency included too.



Library of voxels and how many photons they send to each PMT is part of the fast simulation.

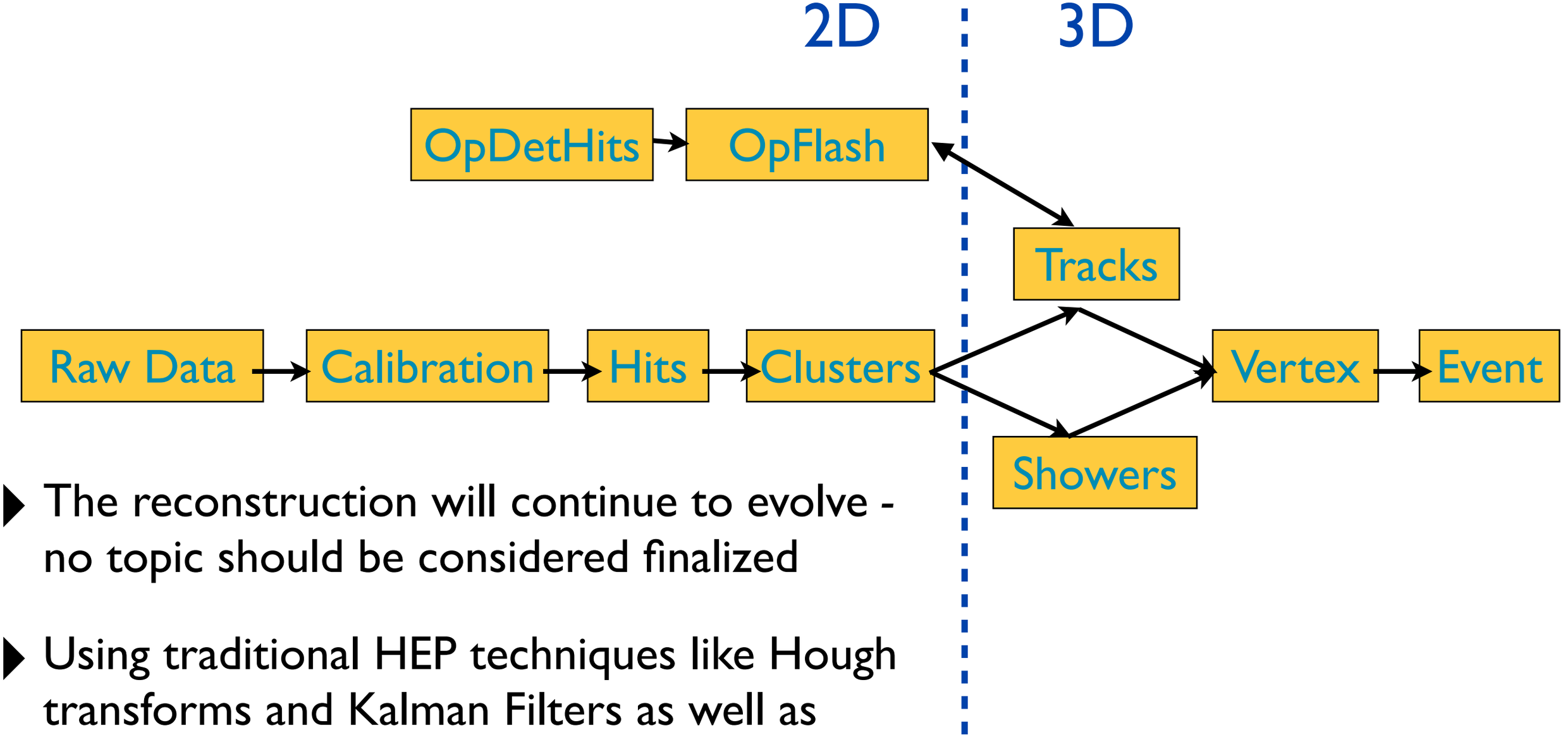


So far, simulation is quite specific to MicroBooNE, but is serving as a nice starting point for LBNE FD.

NEST

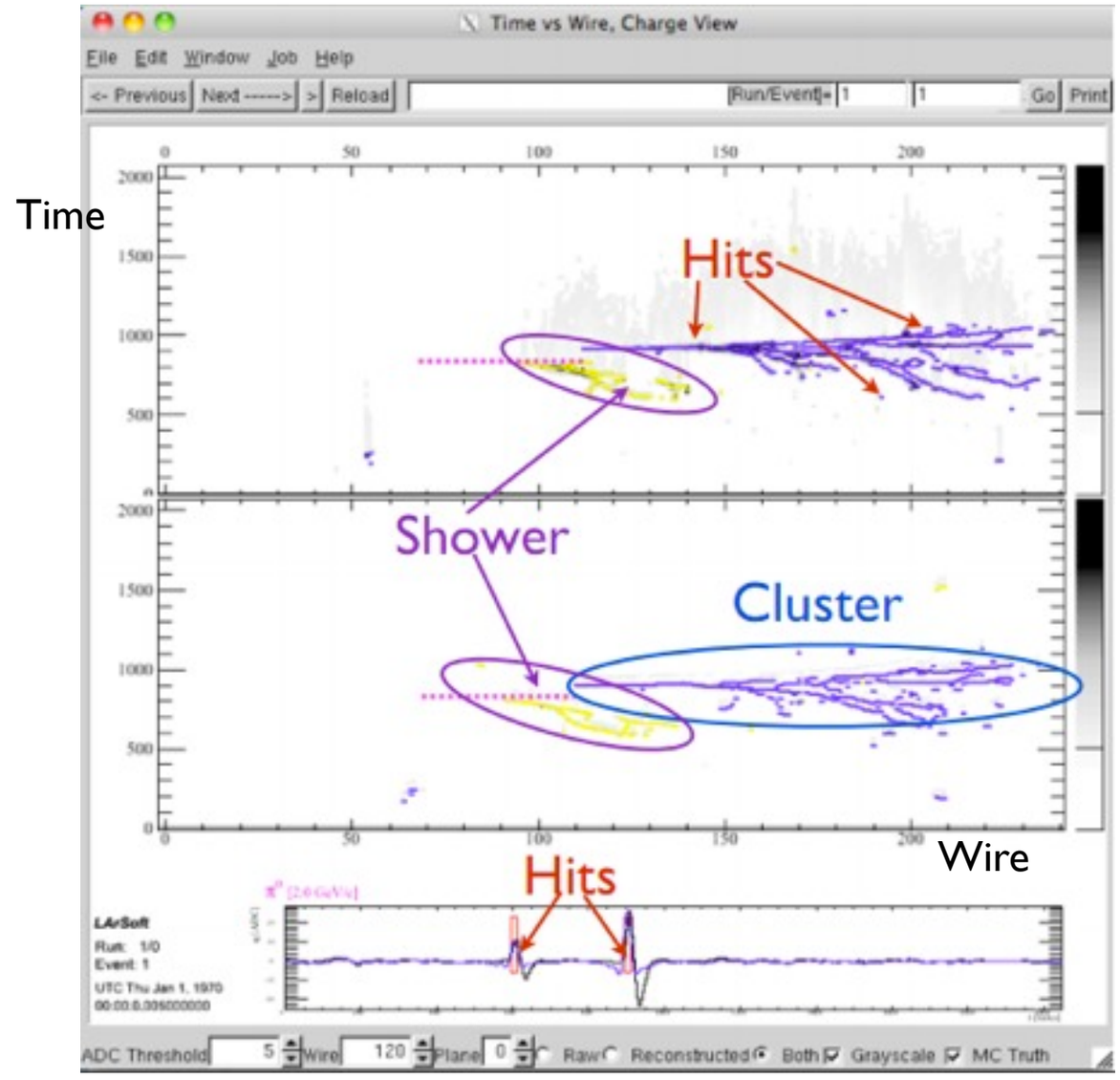
- We could instead take the G4 E_deposited and hand it to NEST to release the quanta to photons/electrons with its recombination, etc.
- This is on Matthew's/my agenda

Reconstruction Objects



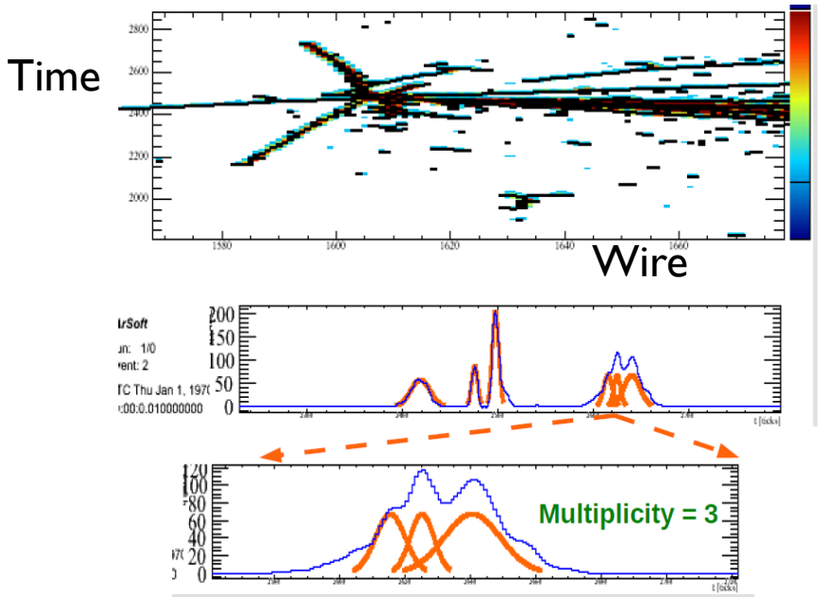
- The reconstruction will continue to evolve - no topic should be considered finalized
- Using traditional HEP techniques like Hough transforms and Kalman Filters as well as non-traditional image processing techniques
- DOE has urged more effort, faster progress for all LAr experiments' reconstruction and LArSoft, generally.

In a picture:


Time vs Wire, Charge View
File Edit Window Job Help
<- Previous
Next ----->
Reload
Run/Event
Go
Print
Time
Hits
Shower
Cluster
Wire
Hits
LArSoft
Run: 1/0
Event: 1
ADC Threshold
Wire
Plane
Raw
Reconstructed
Both
Grayscale
MC Truth

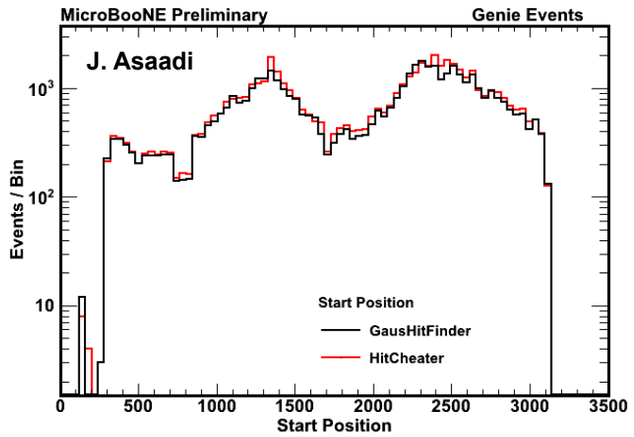
HitFinding

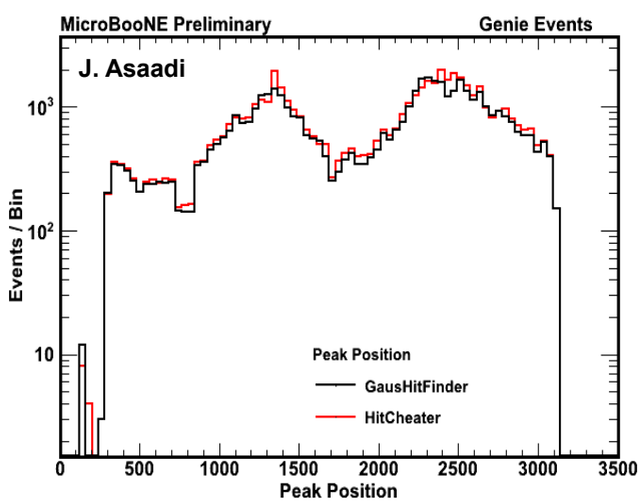
MicroBooNE HitFinder



Hitfinder has the ability to separate charge deposited very close into distinct pulses

We reconstruct both the start and peak position of the hit with 98% efficiency across the detector

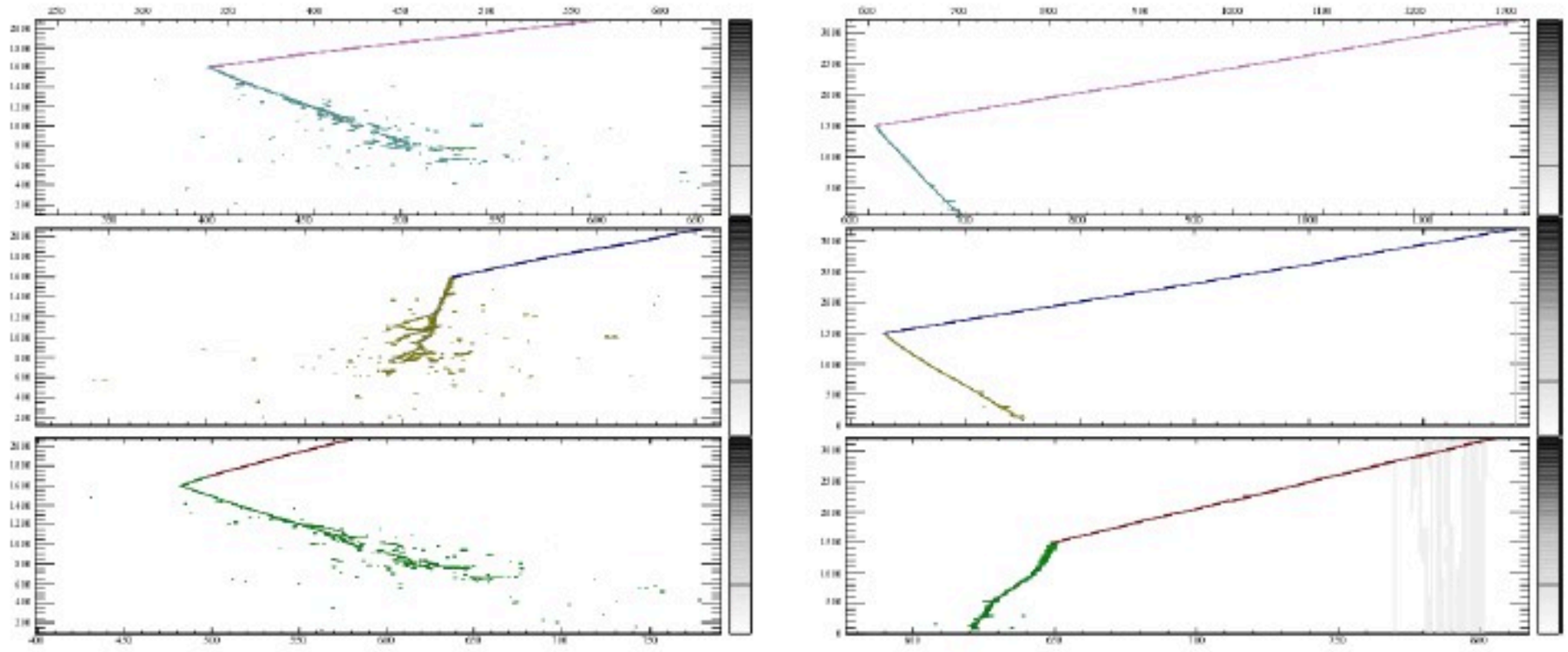




Clustering

MC CCQE event
in MicroBooNE

Fuzzy clustering



Hits assigned a degree of belonging-ness to N possible clusters. i<N clusters chosen by Xie-Beni optimization. Merging based on Hough lines follows.

B. Carls

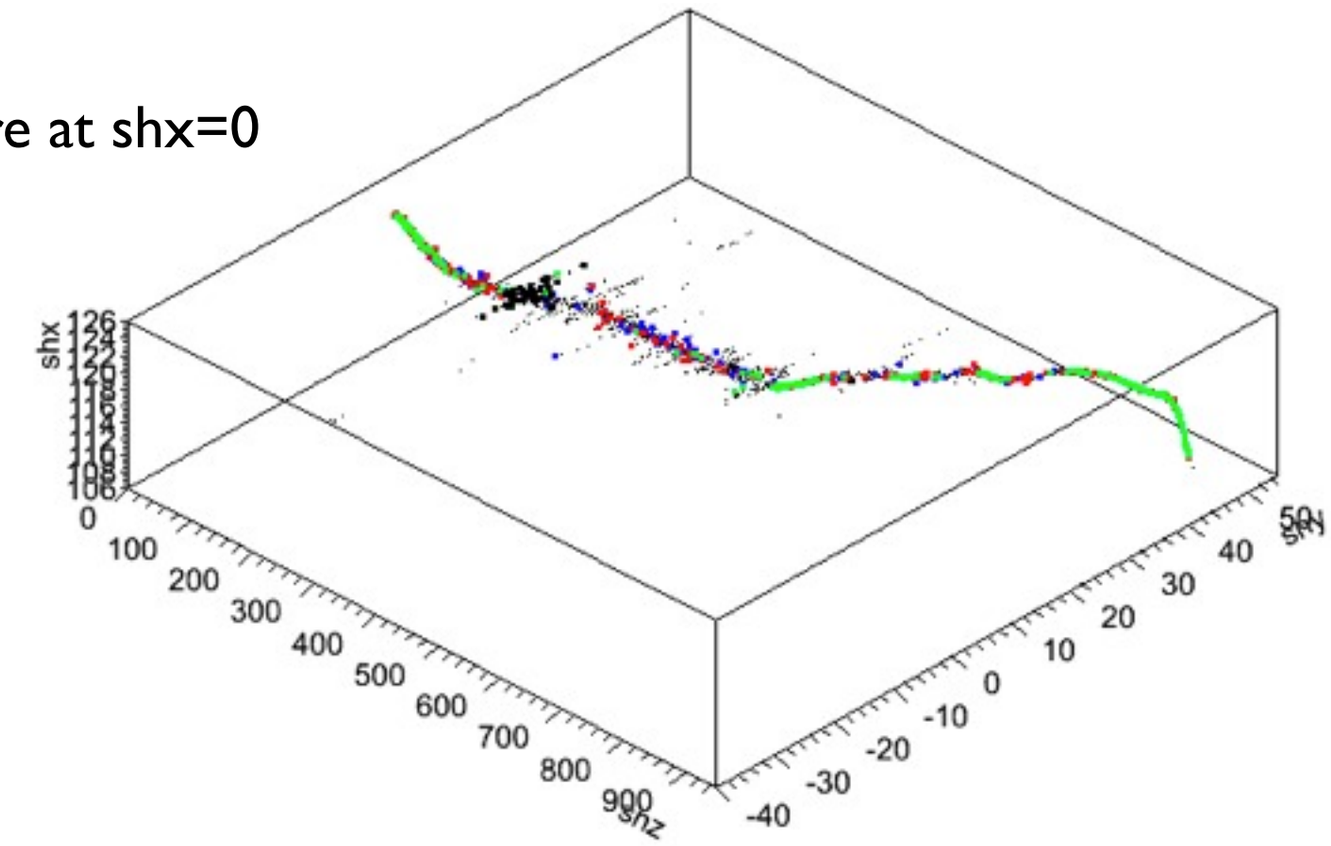
Spacepoints

- Hits in Clusters are matched for consistency
  - in wire crossing
  - in time
- Triplets (Doublets) of hits in the 3 (2) planes are projected up into vectors of 3d spacepoints

H. Greenlee

Spacepoints for a MC muon track

wireplanes are at shx=0



Green (red) are (next) best Chi2 spacepoints

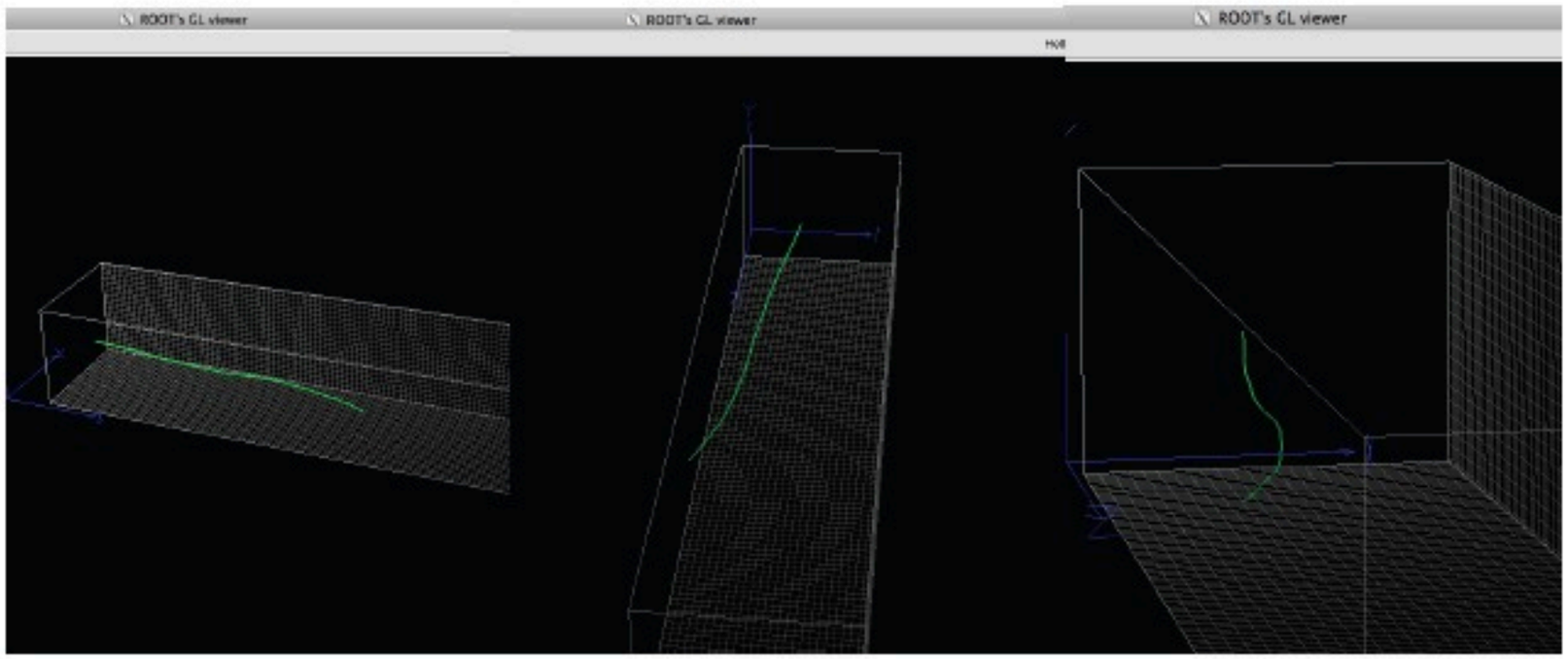
Note the the "ghost" spacepoints largely wherever track is flat wrt the wireplanes.

Tracking in MicroBooNE MC

- Three 3D tracking modules currently
  - Bezier Tracking
    - connecting "seeded" spacepoints with polynomials in 3D
  - Track3dSpacepoints
    - running a Kalman fit through spacepoints
  - TrackKalmanHit
    - Creating the 3d track whose projections best run through the Hits

Bezier MC muon Track

Bezier track in 3D

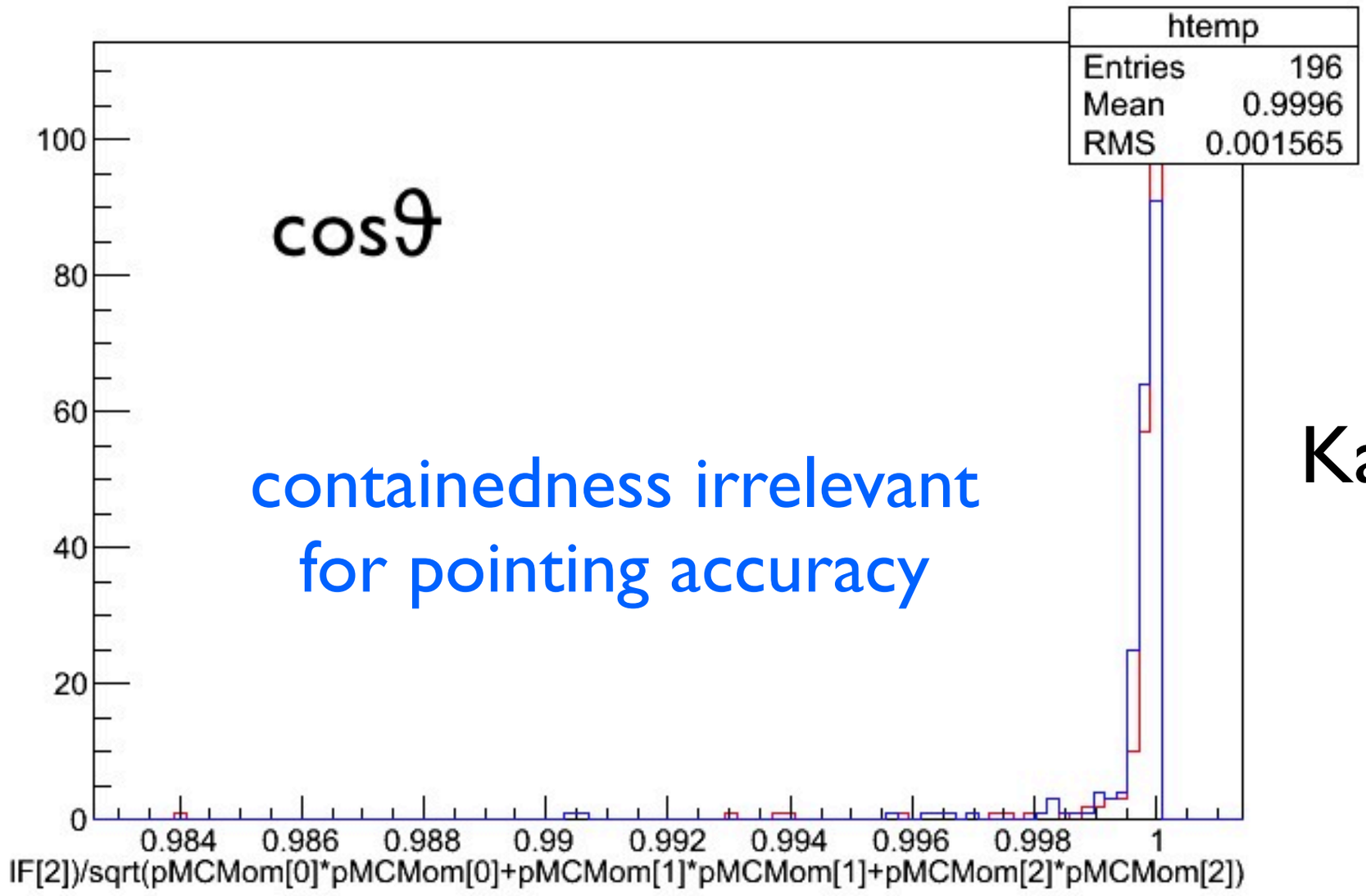


B. Jones

LArSoft has 2 Kalman track fitters under development

- One is based on running a 3d track through TPC whose projection best explains the hits in the 3 planes
- The other runs tracks through the vectors of spacepoints themselves.

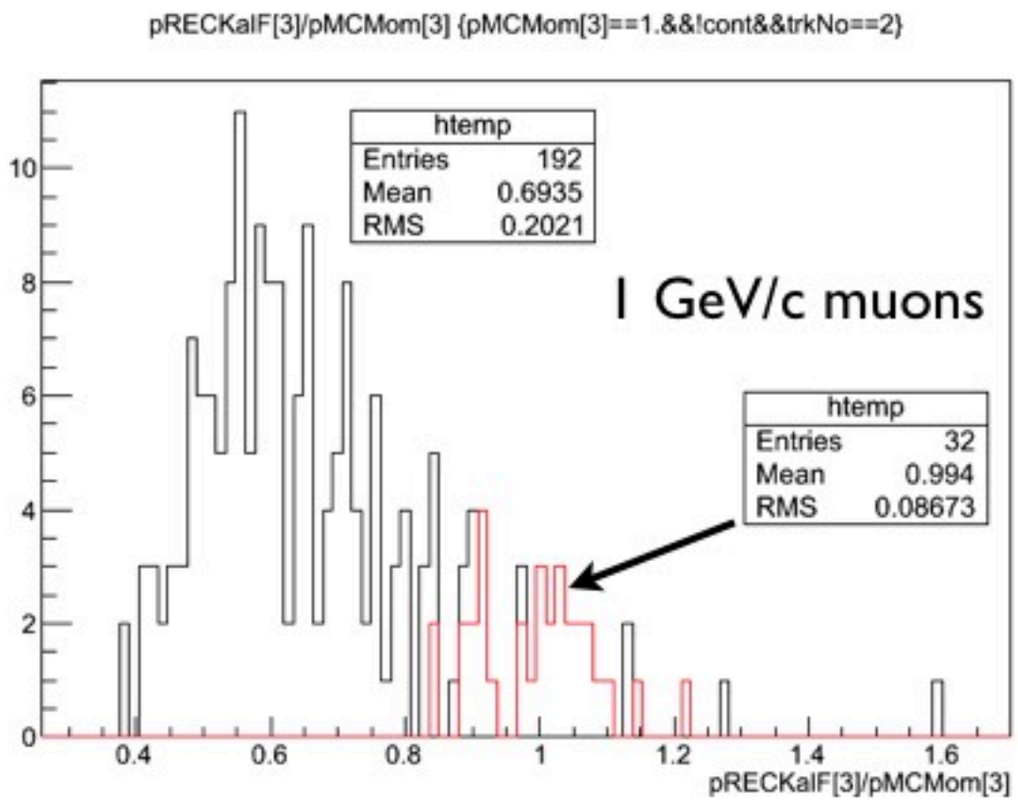
Pointing: 1 GeV/c



Kalman3DSPS

multiple scattering MC

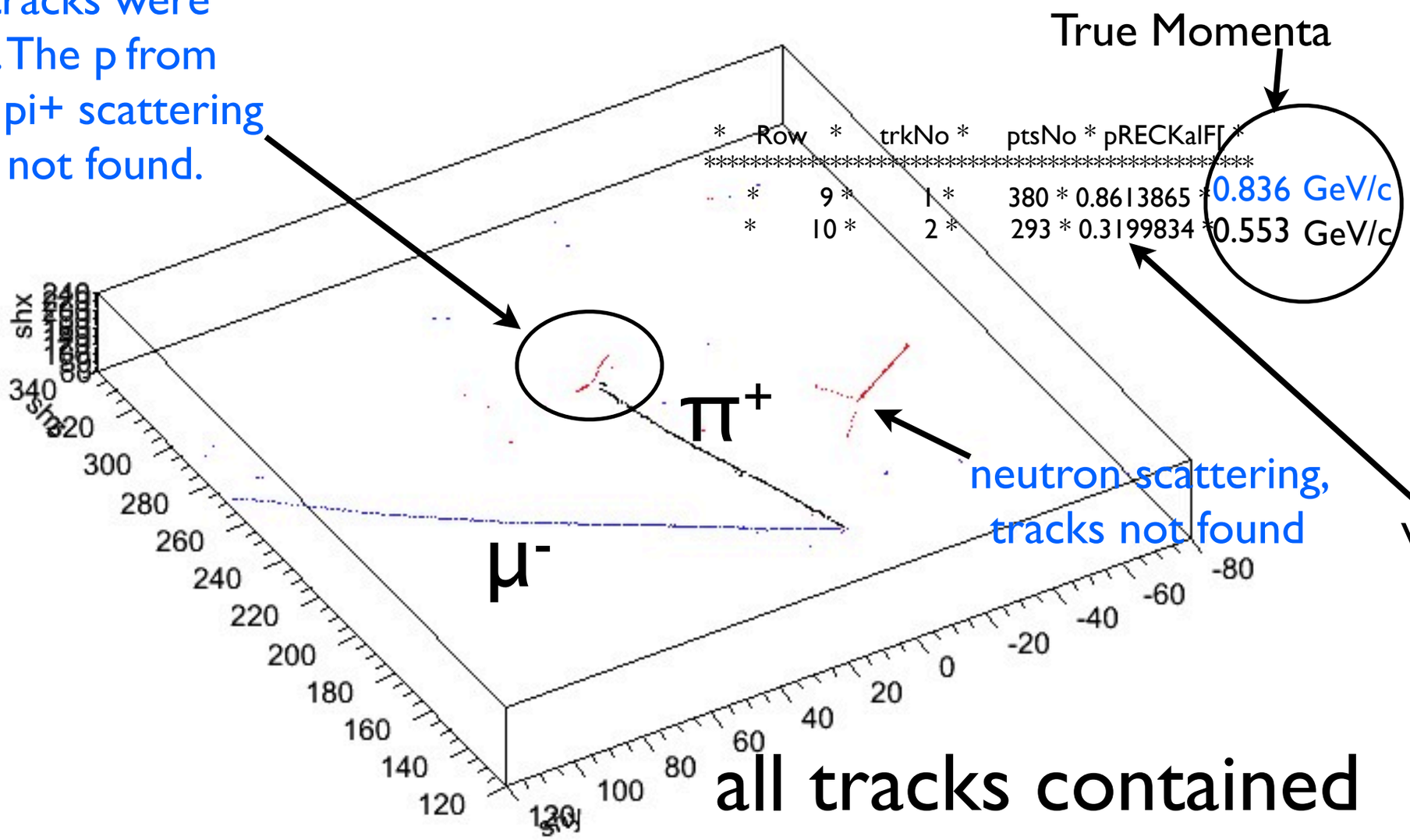
~20% (red) of 1 GeV/c muons reconstructed
with 10% resolution
(require 20 **15 cm**-separated spacepts)



These cuts effectively enforce seeing 50-60% of the track, meaning, had it been fully contained in the liquid argon it would have gone ~1.7-2x farther.

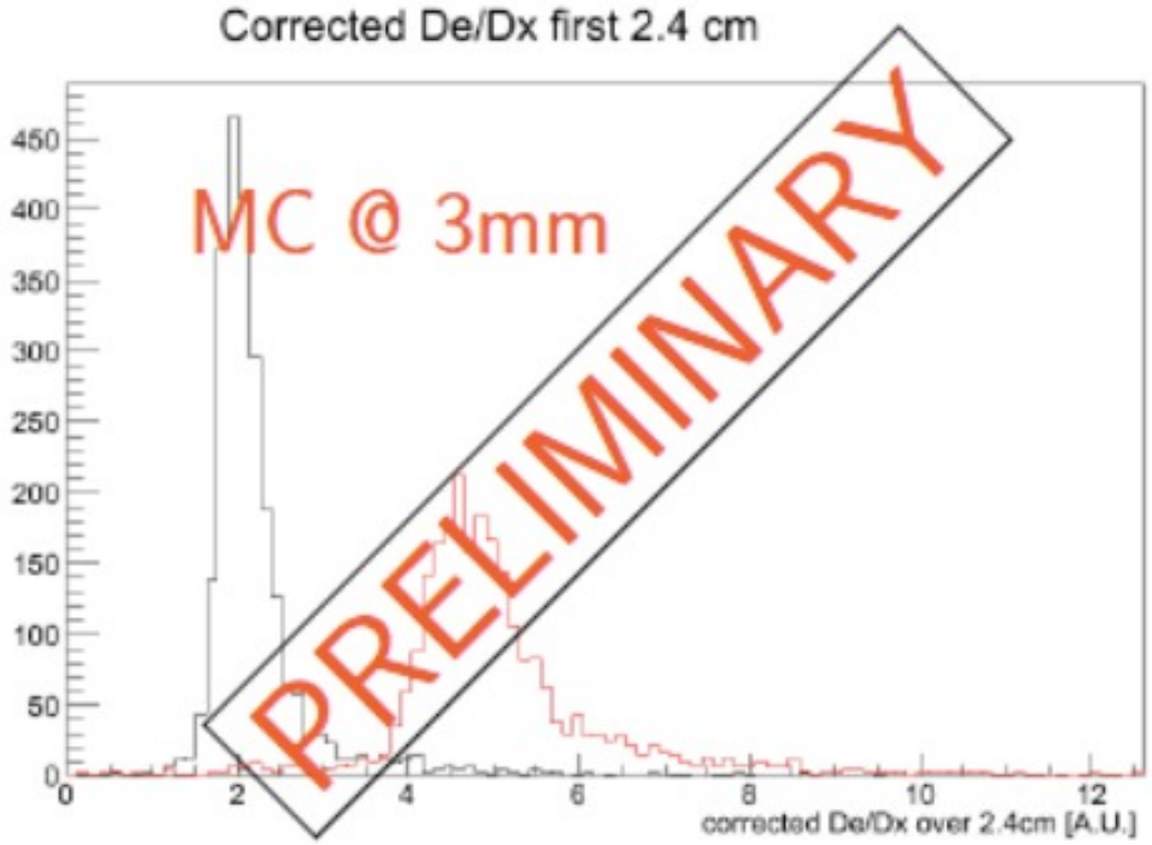
numu CC MC evt

Two tracks were found. The p from inelastic pi+ scattering were not found.



all tracks contained

Showers

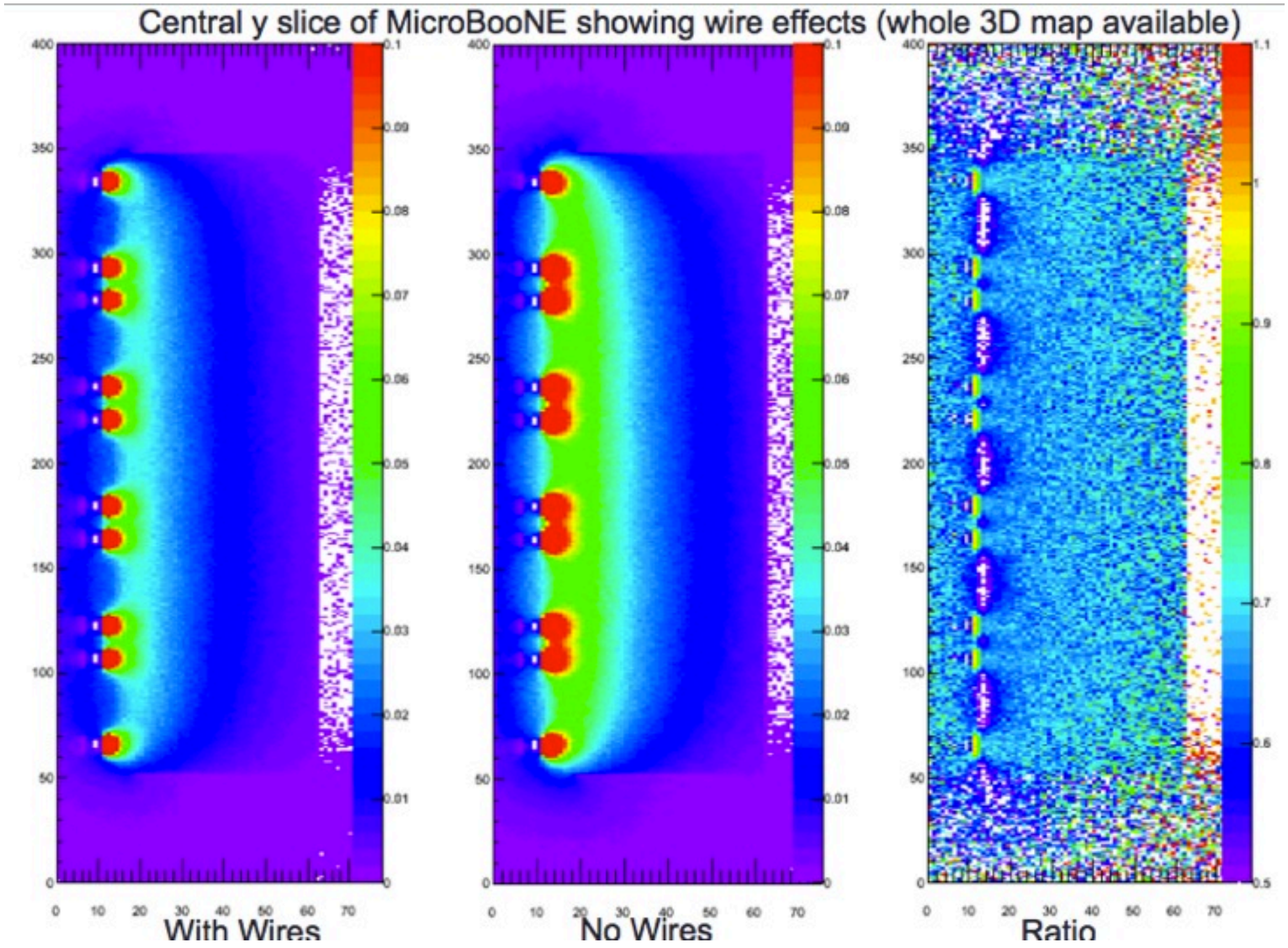


e/gamma separation from single particle MC

Here, the hard work is in finding the original vertex. The shower axis follows.

A. Szelc

Building photon Look-up library



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Flash finder resolution

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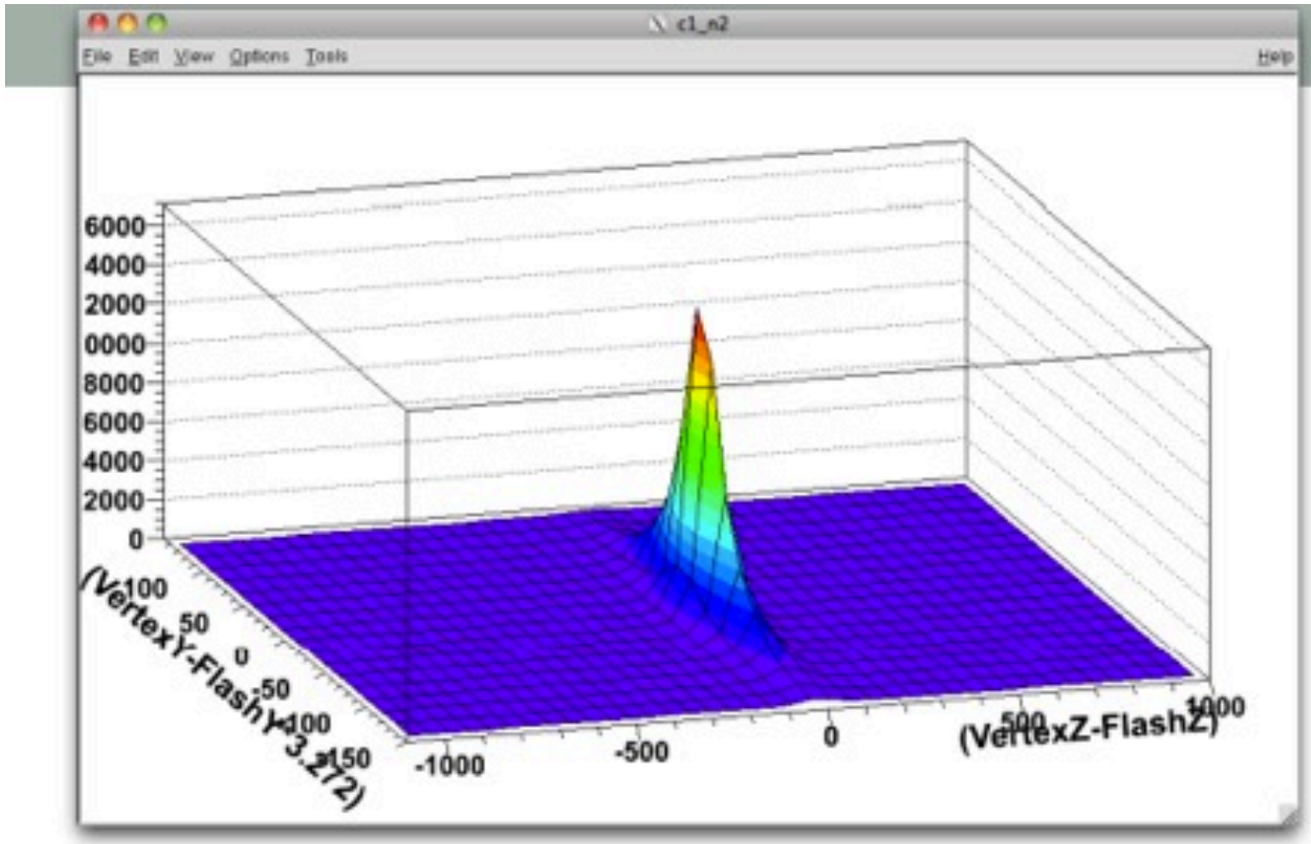
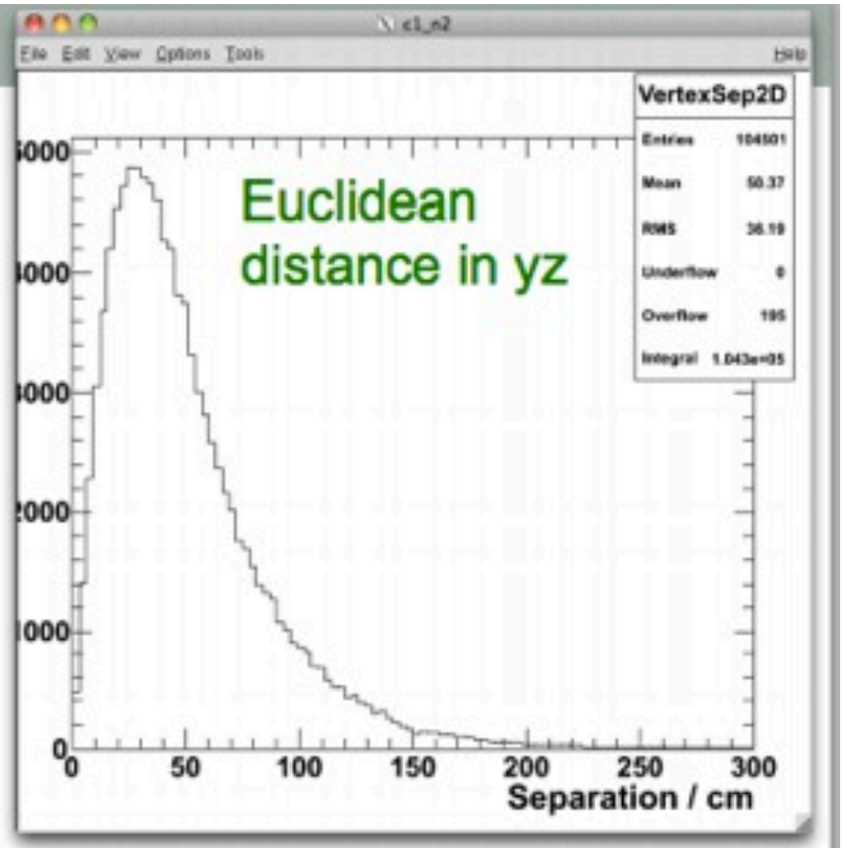
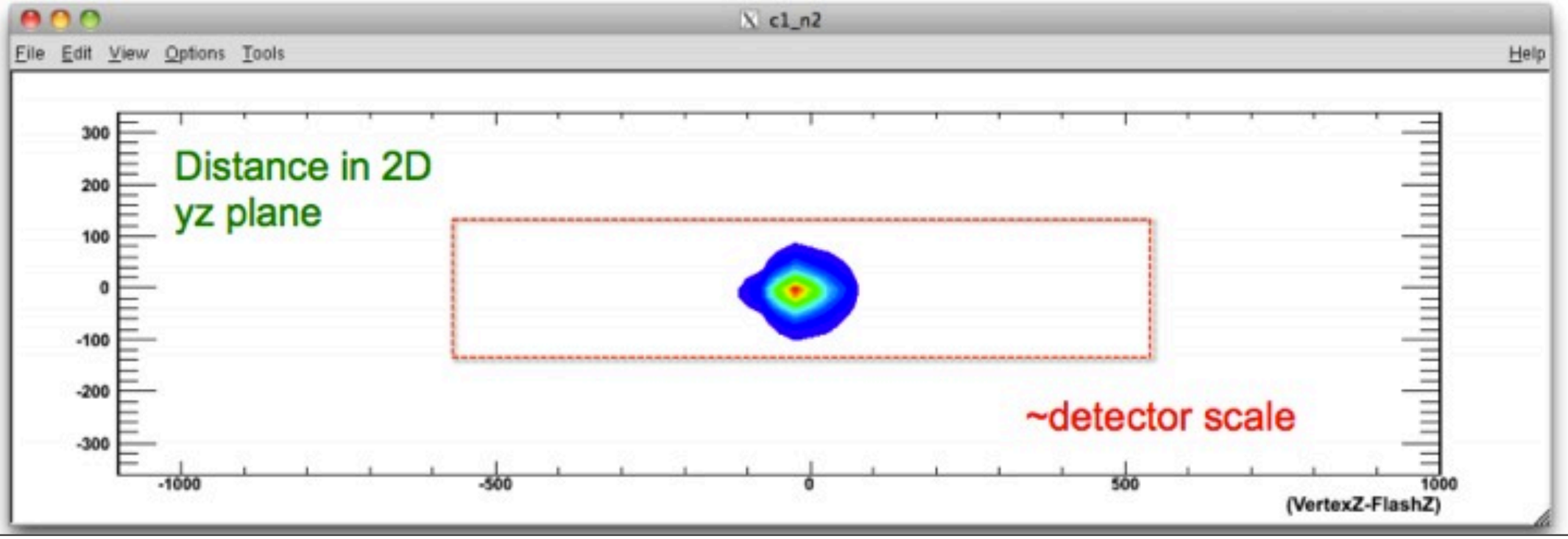


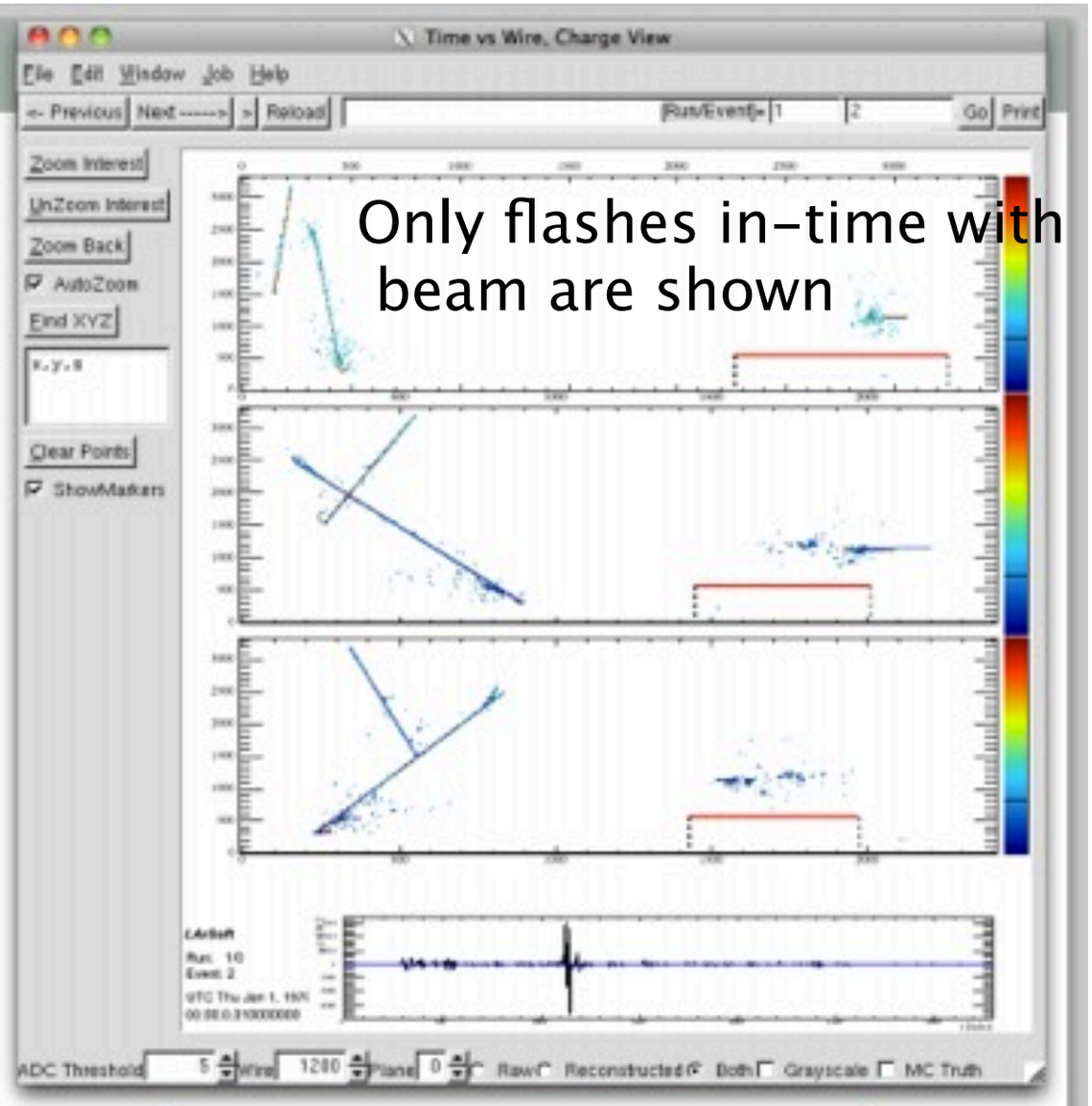




with cosmic overlay on GENIE evts

The FlashFinder:

- 1. Invert bipolar pulses to unipolar
- 2. Sum all unipolar pulses into a broad binned "superpulse"
- 3. Look for isolated spikes in this superpulse.
- 4. Each spike is a starting point for looking for a flash. Go back to each individual PMT waveform and look for the peak in this window.
- 5. For each channel, count the charge in some region around the peak, normd to 1PE
- 6. Combine all this information into a global object.



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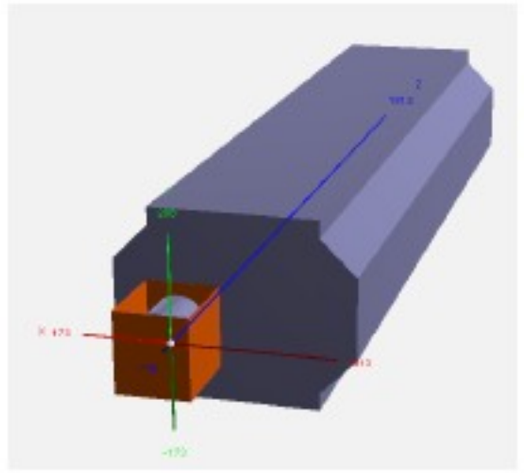
Flash properties:
Time,
TotalPE,
PE(pmt),
Center and width in yz,
Center and width in uv,

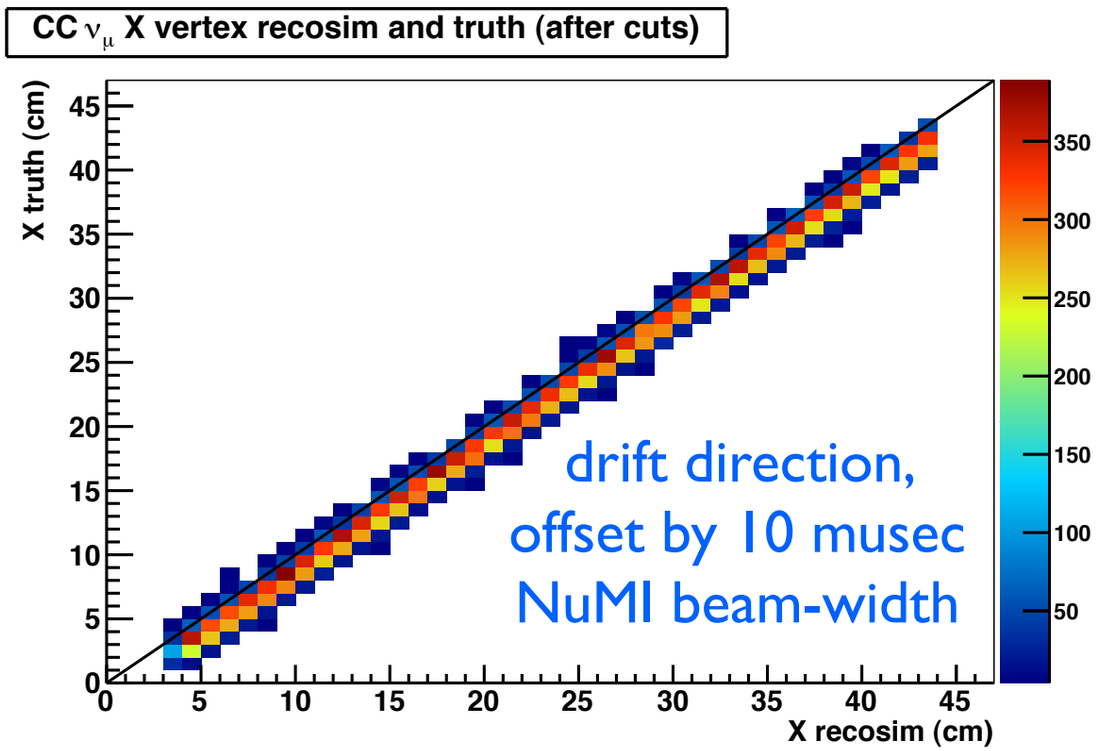
Real Data

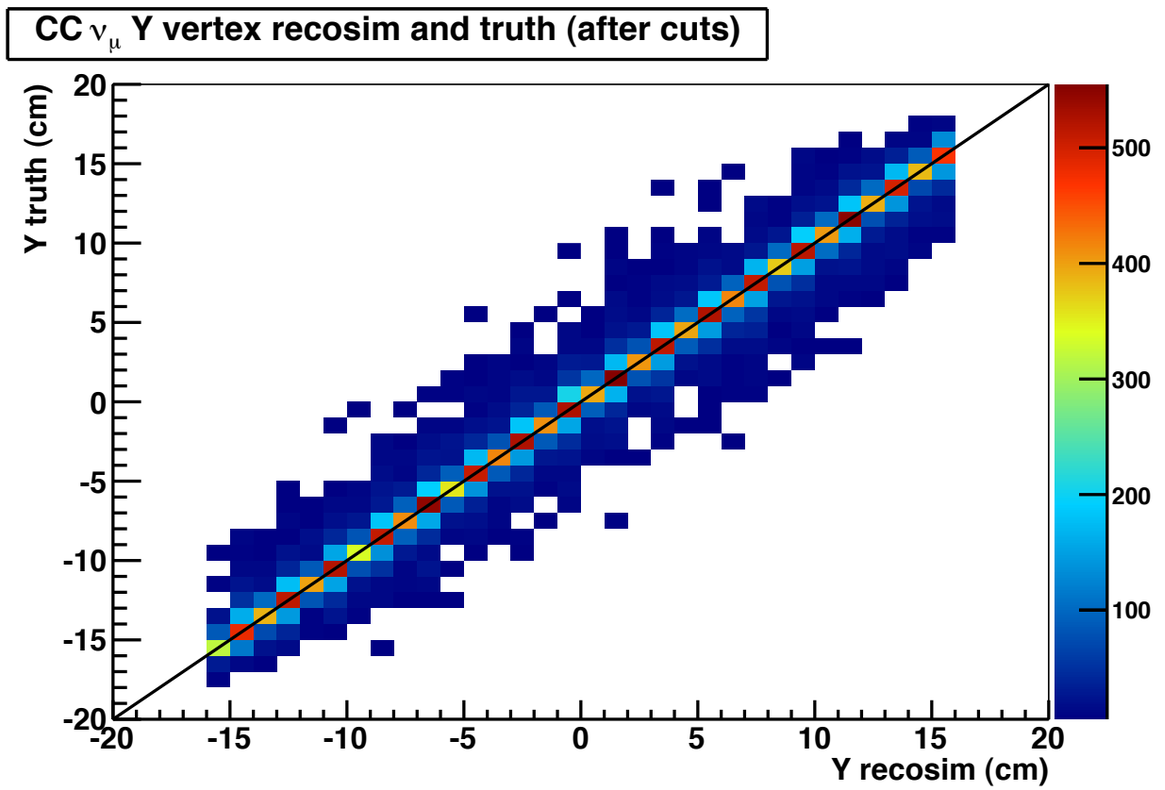
ArgoNeuT+MINOS ND

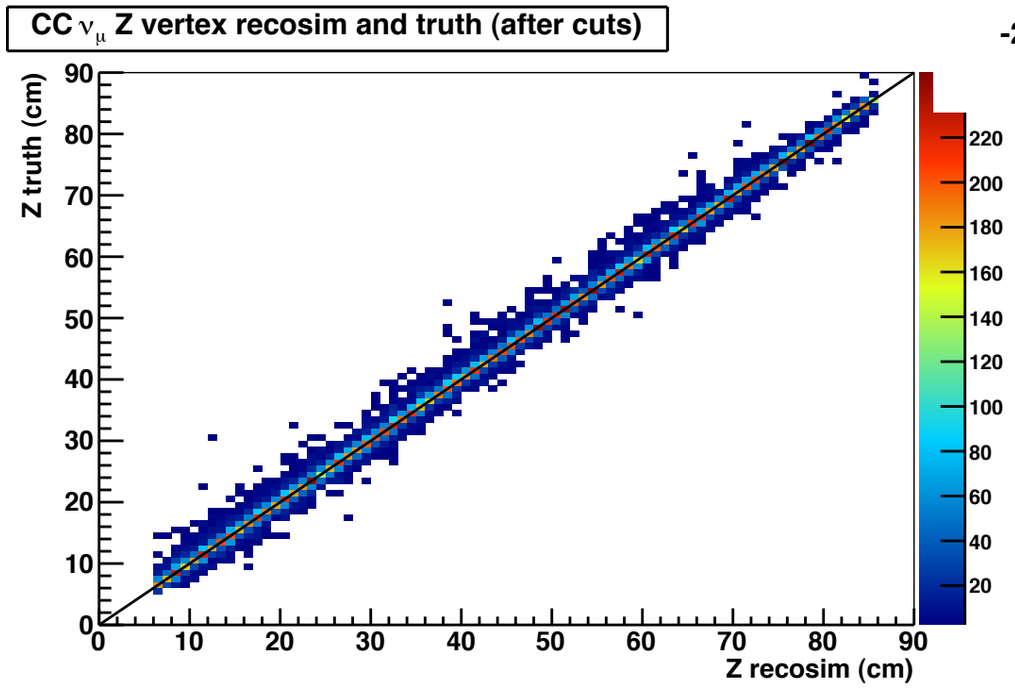


- ArgoNeuT: Leading the way.
- Automated Reconstruction for the CC inclusive numu analysis on the NuMI beam line: Physical Review Letters (PRL) 108 (2012), 161802. Antineutrino mode CCInc paper coming imminently, Recombination study imminent, "0πNproton" paper coming also very soon.

ArgoNeut data: muon vtx resolution



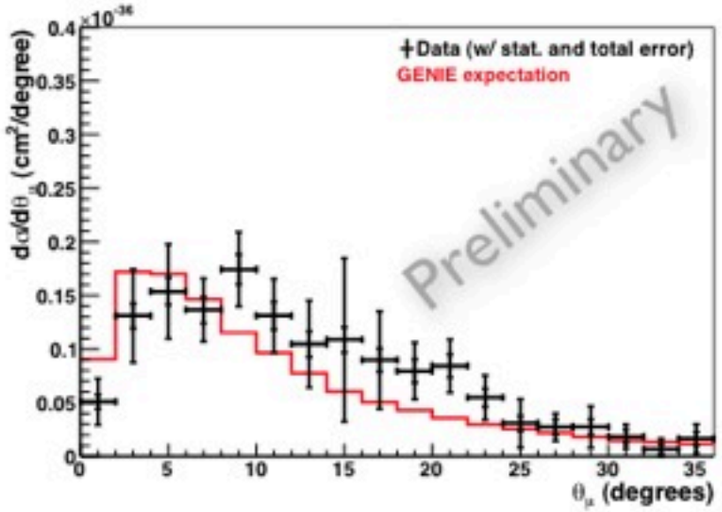


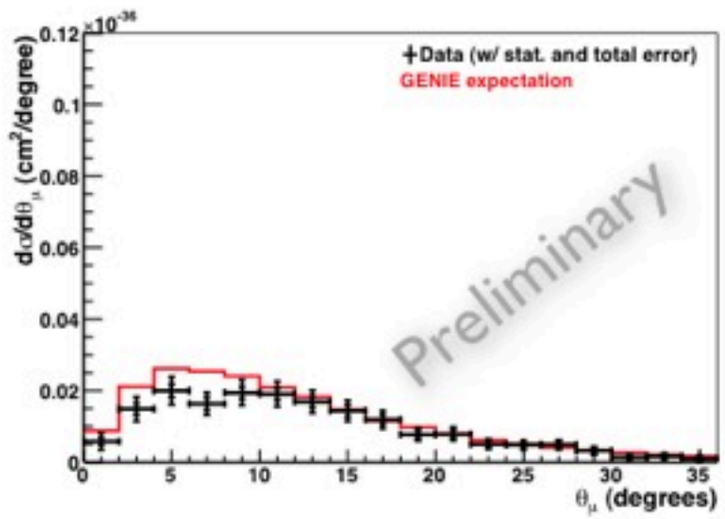


CC inclusive analysis in antineutrino mode of NuMI beam

antineutrino mode NuMI differential cross-sections

ν





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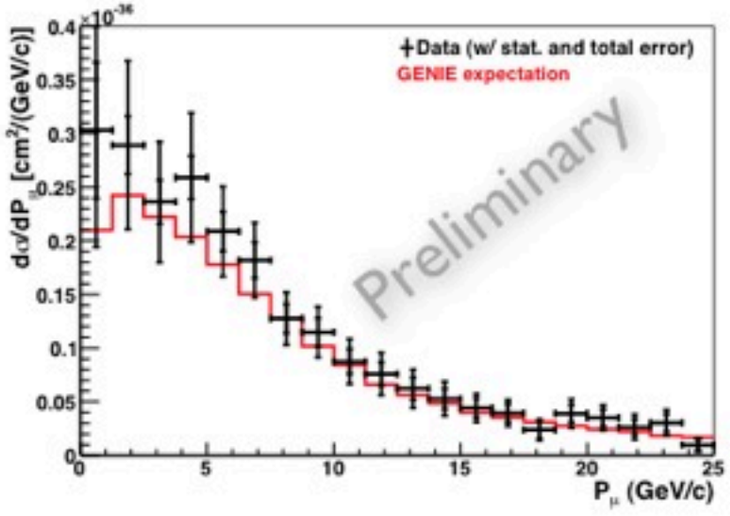
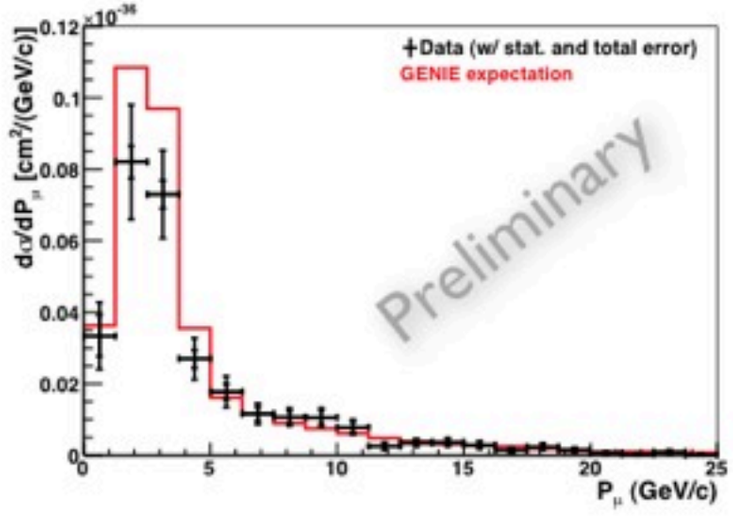
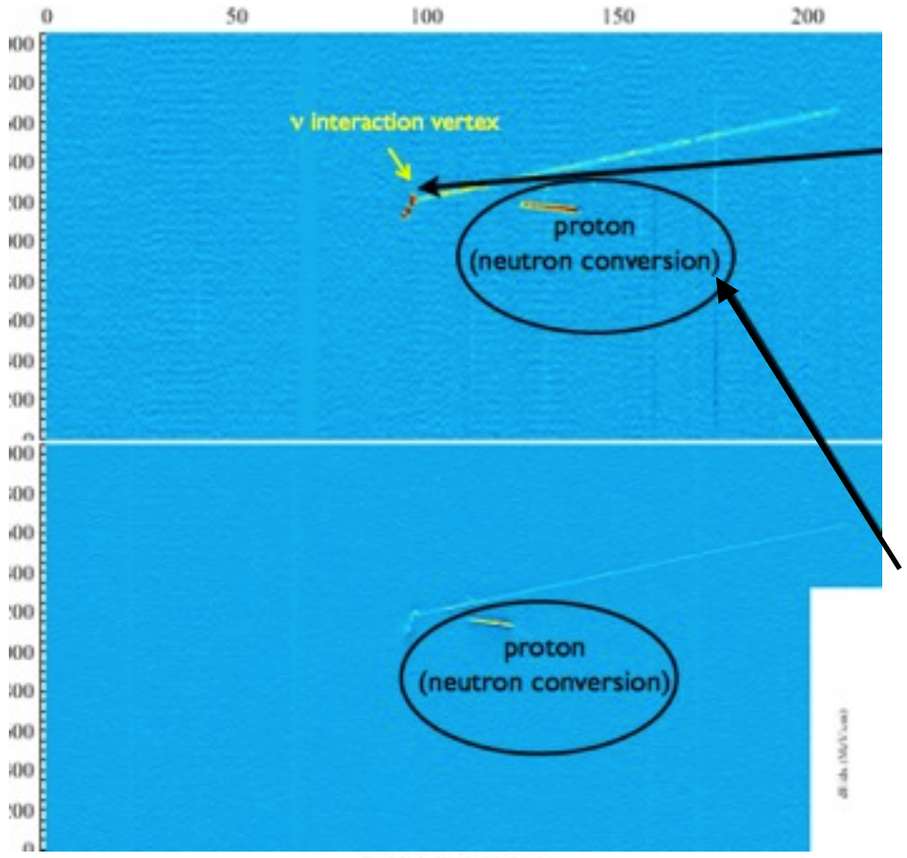


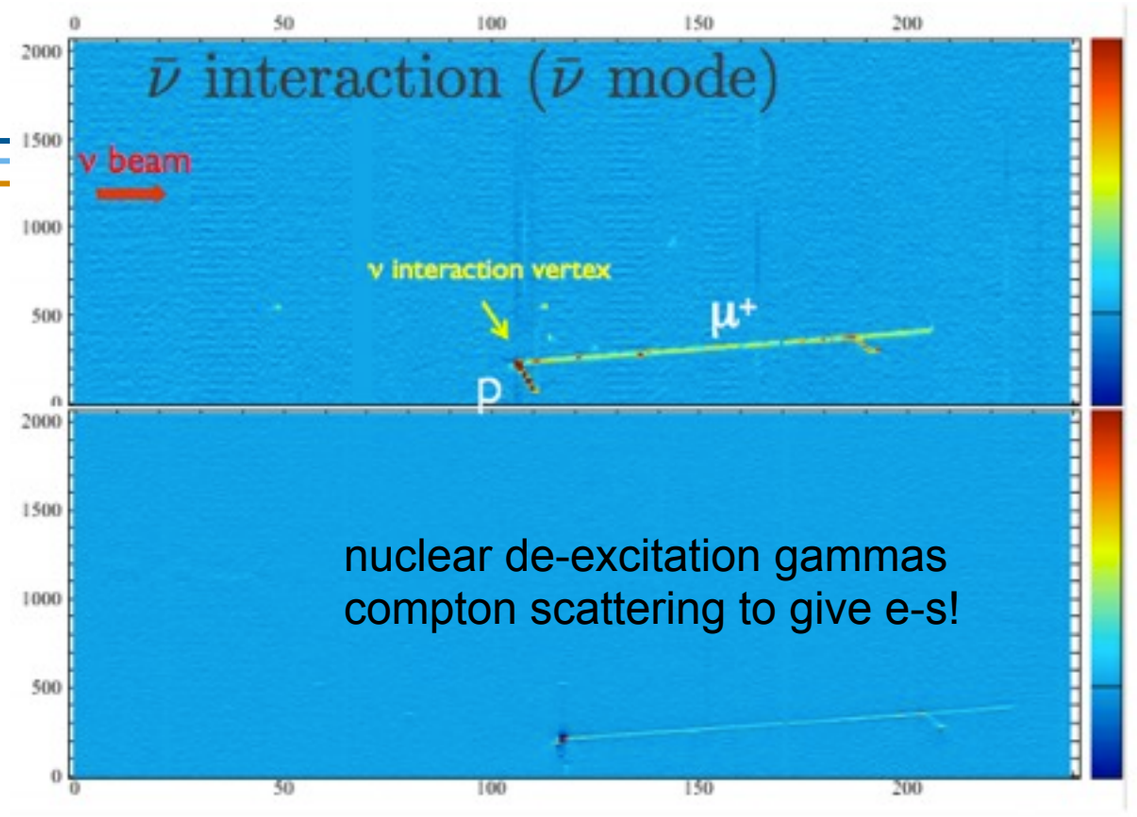


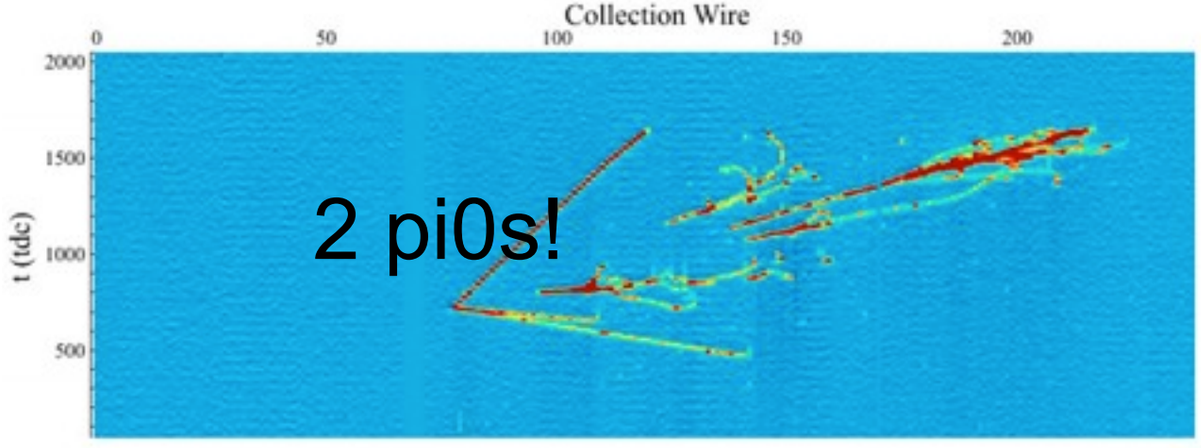
All results subject to final flux normalizations. Paper soon!

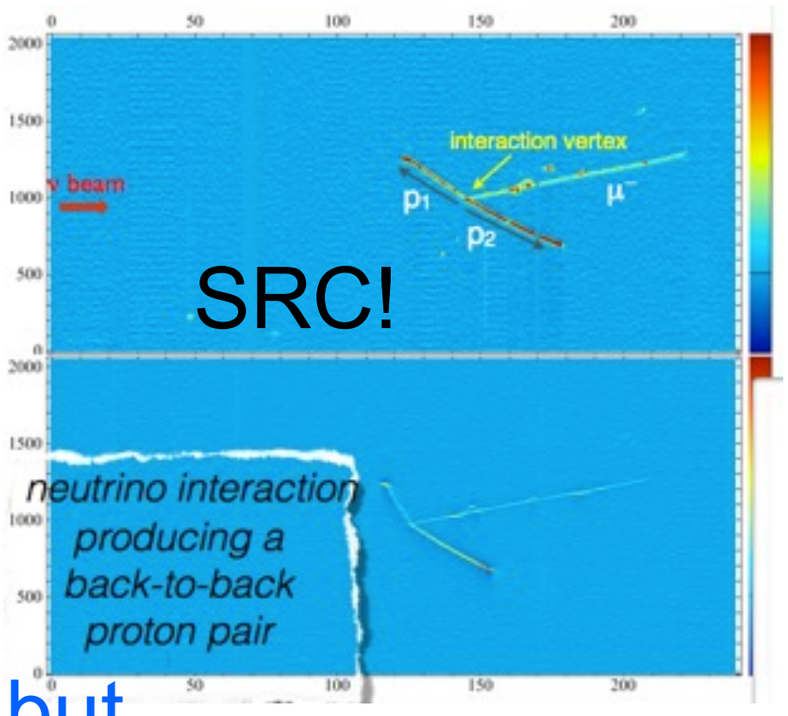
Argoneut Data



proton detached from primary vtx



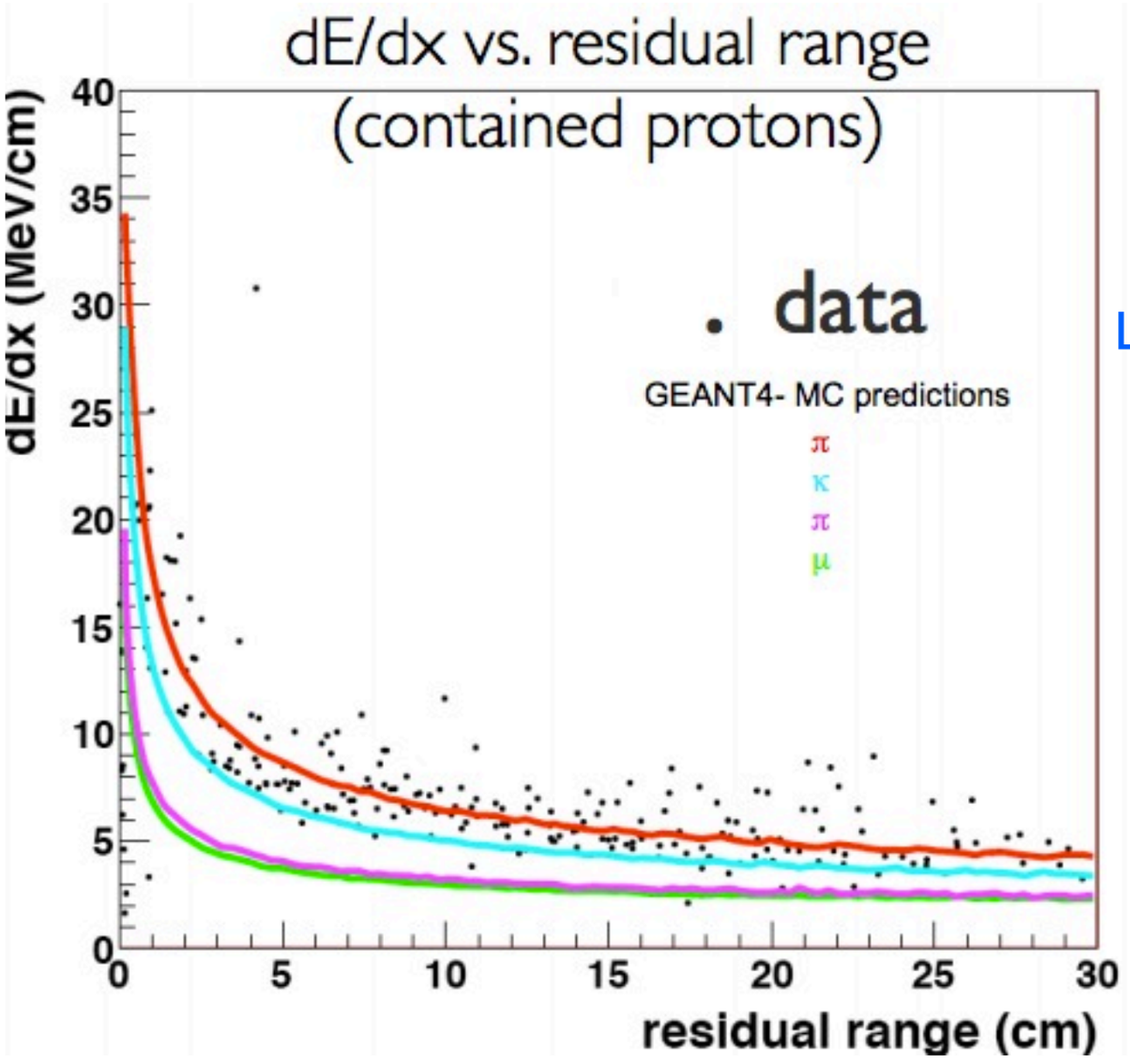




Events found by hand-scanning, but could now be found via automated Recon.

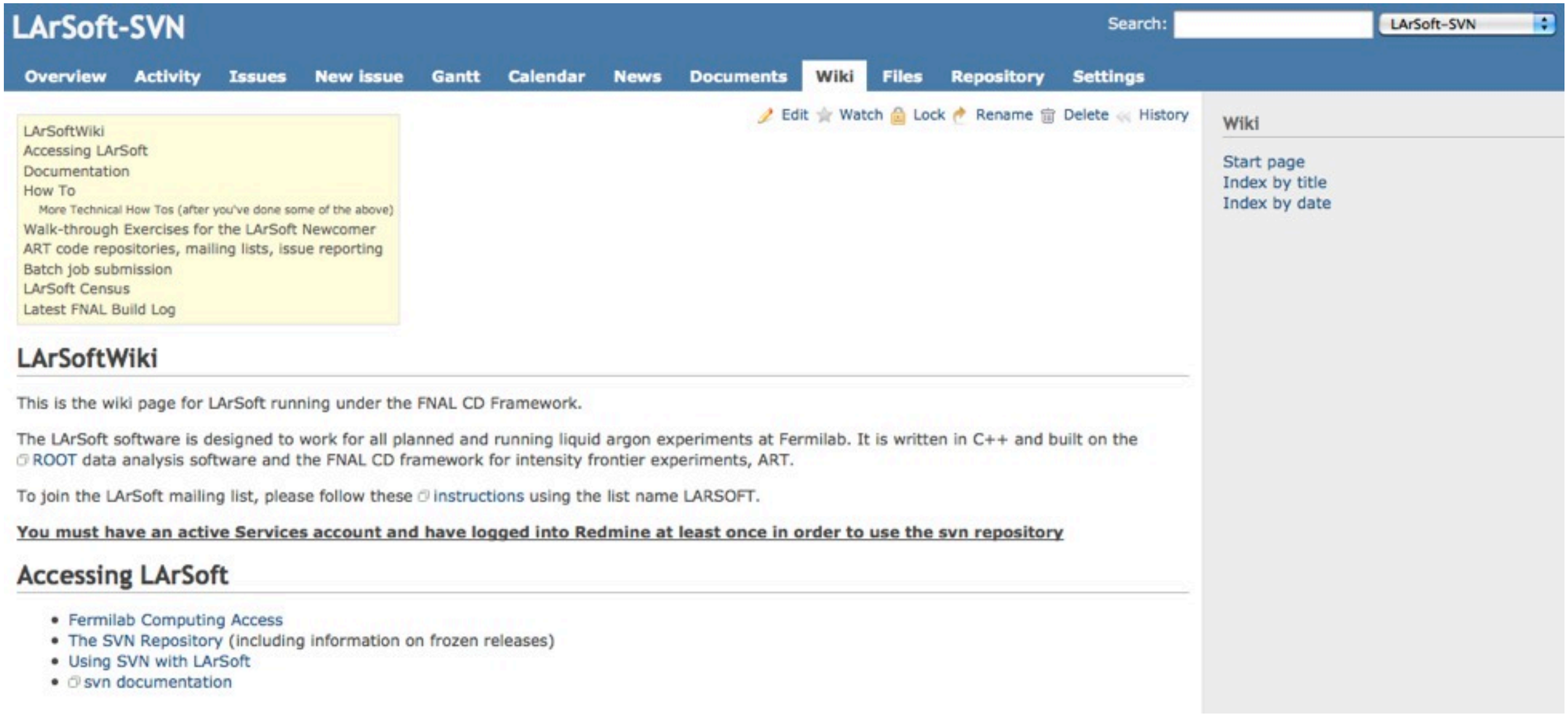
particle ID

ArgoNeuT data



Please see Bruce Baller's talk for his automated, LArSoft-based, particle-ID analysis!

Description



- LArSoft is documented online at
- https://cdcvs.fnal.gov/redmine/projects/larsoftsvn/wiki

Conclusions

- LArSoft is designed to work for multiple detectors
- Simulation and reconstruction work has a solid foundation, but plenty of work to do. Especially for non-trivial topologies.
- Moving from characterizing Reconstruction in single-particle MC events to doing it in CCQE+ events.
- Visit the wiki for information