LArSoft

9-June-2011, GLA2011

Eric Church, LArSoft co-convener
Yale University

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

LArSoft spans ArgoNeuT, MicroBooNE, LBNE

- LArSoft neutrino analysis is relatively new in the US
- LArSoft organizes this imposing effort under one banner.
- LArSoft is a complete set of Simulation/ Reconstruction/Analysis tools.
- Philosophy: LArSoft code to be shared by all three (four?) experiments. Code written detector agnostically.

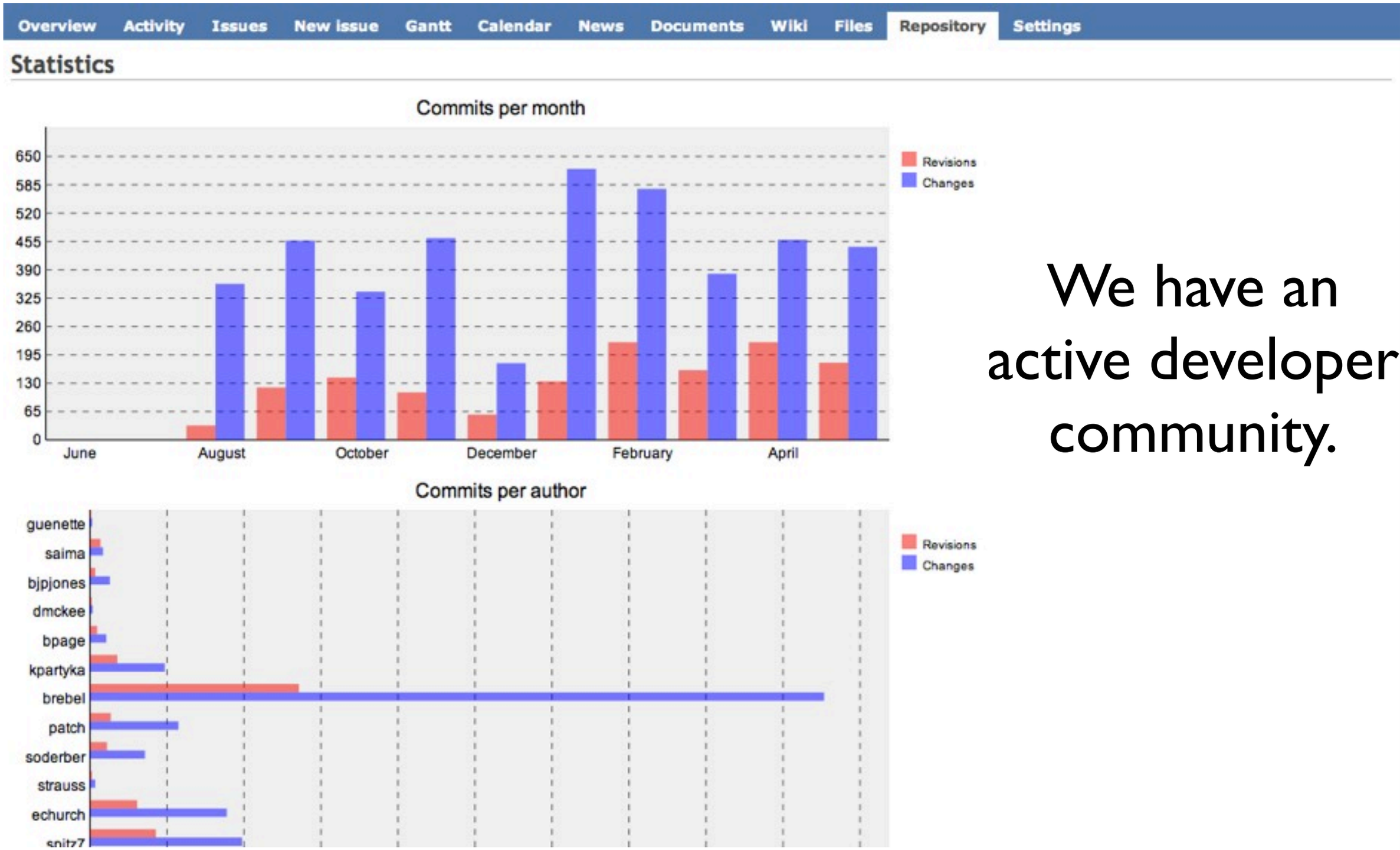
Infrastructure

- Codebase lives at FNAL. Enjoys CD support. ART, derived from CMSSW, is the framework.
- Externals (Root, Geant4, GENIE, LHAPDF, Boost, ..., 20-ish packages) + ART are supported and released in relocatable UPSes. That is nice.
- ArgoNeut/MicroBooNE/LBNE collaborators live on their own machines at FNAL, write to their own disks. Their analysis code lives in their own repositories.
- Everyone sees the core code in the central LArSoft svn repository.
- Build system: SRT. Allows a nice private/public environment.
- Compute farm: Can submit to thousands of FNAL nodes with job management tool condor
- There are in fact remote installations at KSU, Nevis, Bern, Warwick, ... They use their own compute resources, sync up to the repository regularly.

ART benefits

- A sophisticated C++ State machine, deriving from the CMSSW framework. Is an "easy" apparatus for access into an Event record and looping over and analyzing/ building Events.
- FNAL CD's maintenance of ART and other externals (ROOT, Geant4, ...) is invaluable.
- Used by mu2e, NOvA also, & certainly others in High Intensity program in future.

LArSoft code repository statistics



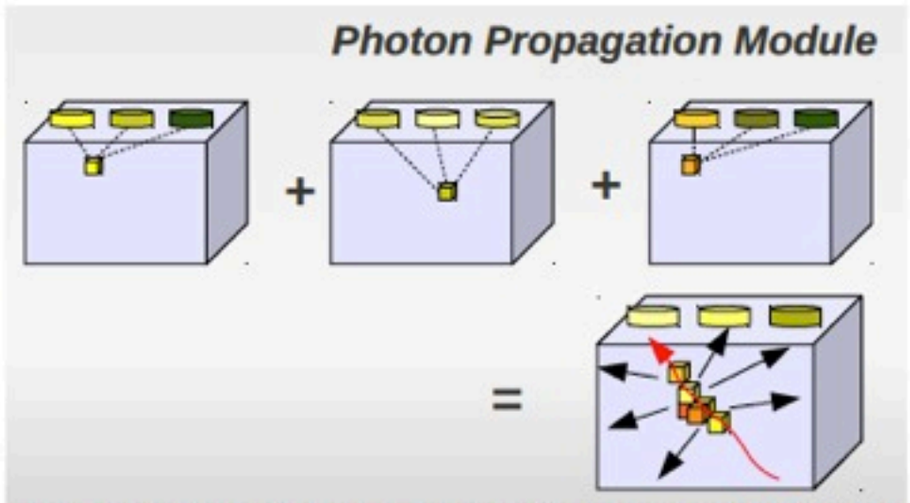
We have an active developer community.

LarSoft: events

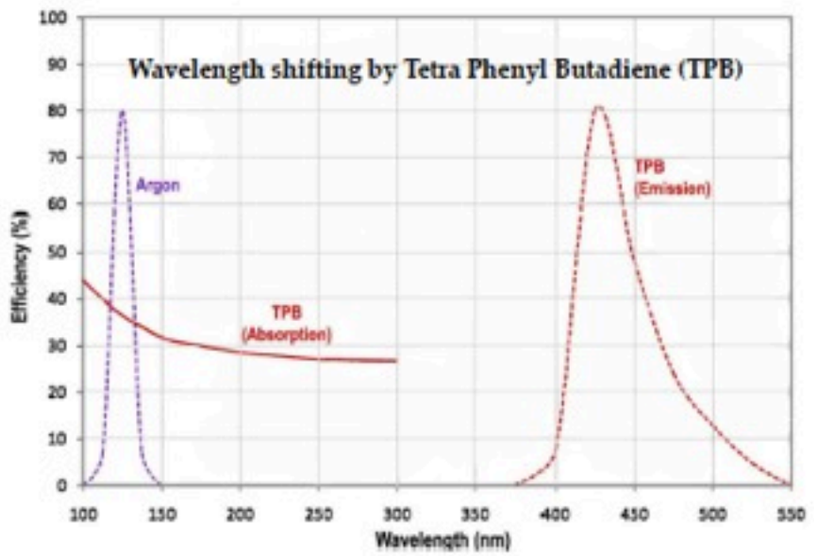
- Create events in the detector: GENIE/NuANCE/ CRY/SingleParticle/FileParticles
- Simulate: Geant4 (with drift electrons)+DetSim:
- Or, better, Data: (ArgoNeuT!): RawDigits

Photons

- 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.

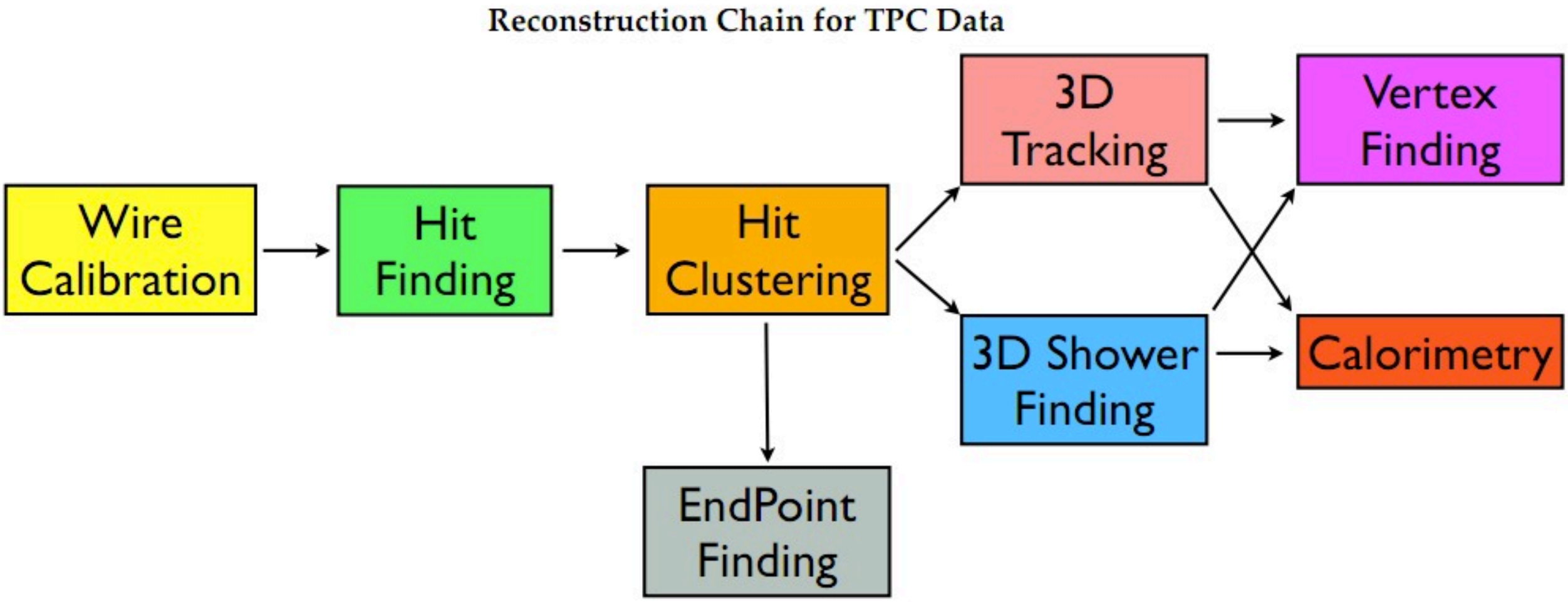


Library of voxels and how many photons they send to each PMT is part of the fast simulation.



See Ben Jones's talk from yesterday

Development Goals: LArSoft



•User chooses which experiment to run on, and sets parameters to get at geometry and electronics specific to that experiment.

LArSoft: Recon Chain

- CalibratedData
- FFTHitFinder
- ClusterFinder
- HoughLineFinder (2d tracks)
- LineEndPtFinder (end points)
- Track3DFinder
- Shower3DFinder
- Vertex3DFinder

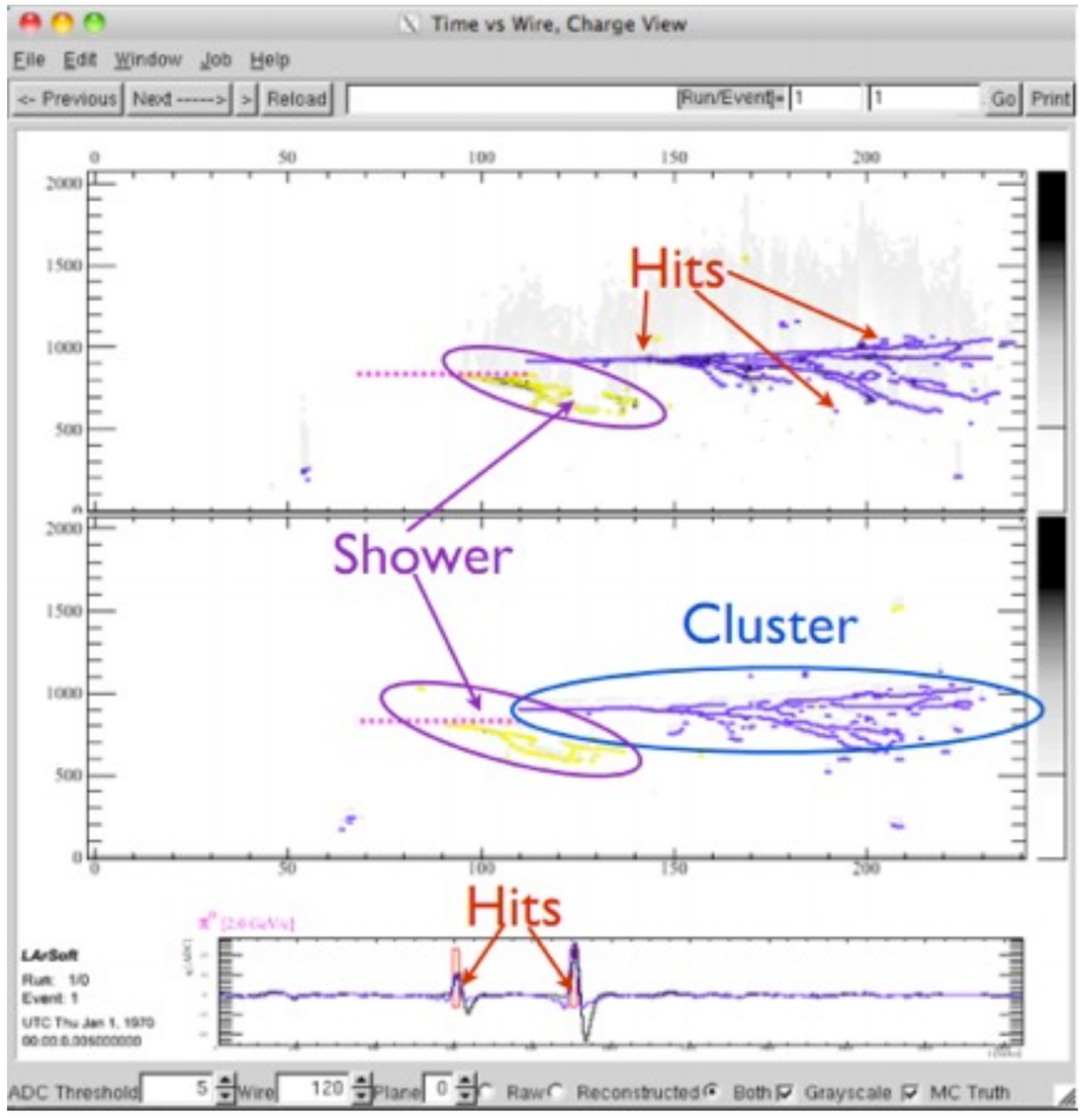
Inherit from "Prong"

(1) Hits matched along 2D tracks with matching endpoints in clusters. 2Dtracks=>3Dtrack.

(2) Same hits, Kalman fitter=>3Dtrack.

2D clusters in each plane, projected to 3D

In a picture:


Time vs Wire, Charge View
File Edit Window Job Help
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Reload
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Hits
Shower
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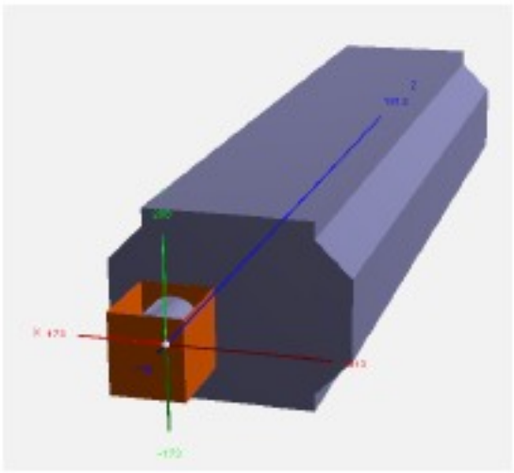
ADC Threshold
Wire
Plane
Raw
Reconstructed
Both
Grayscale
MC Truth

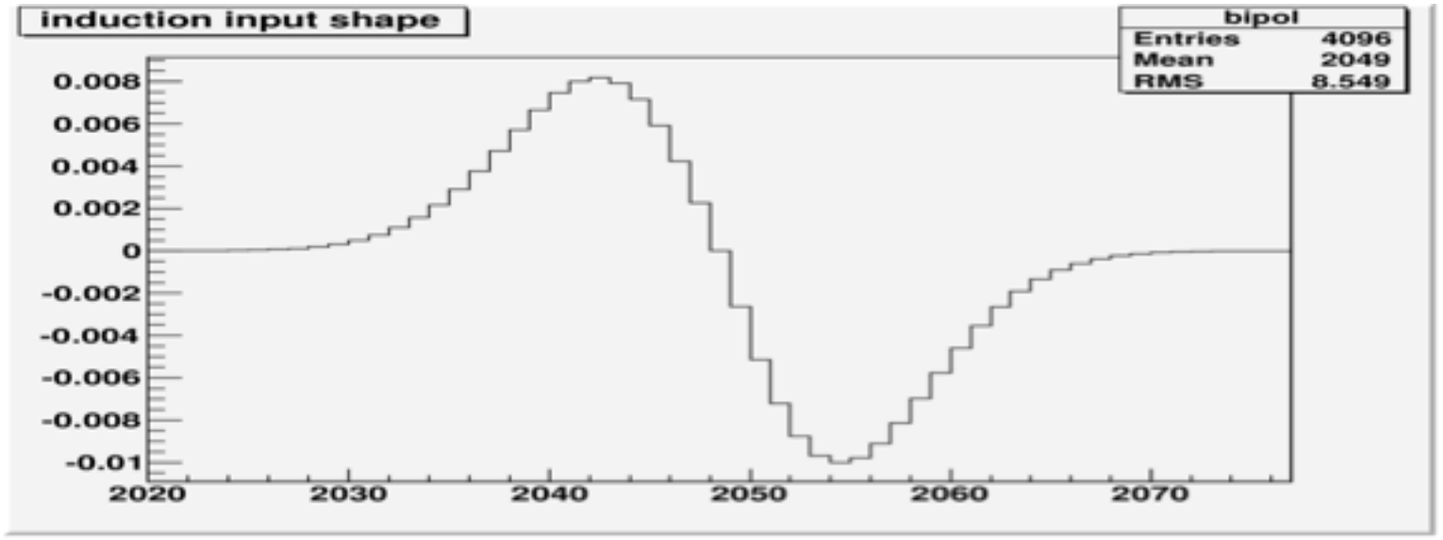
Real Work

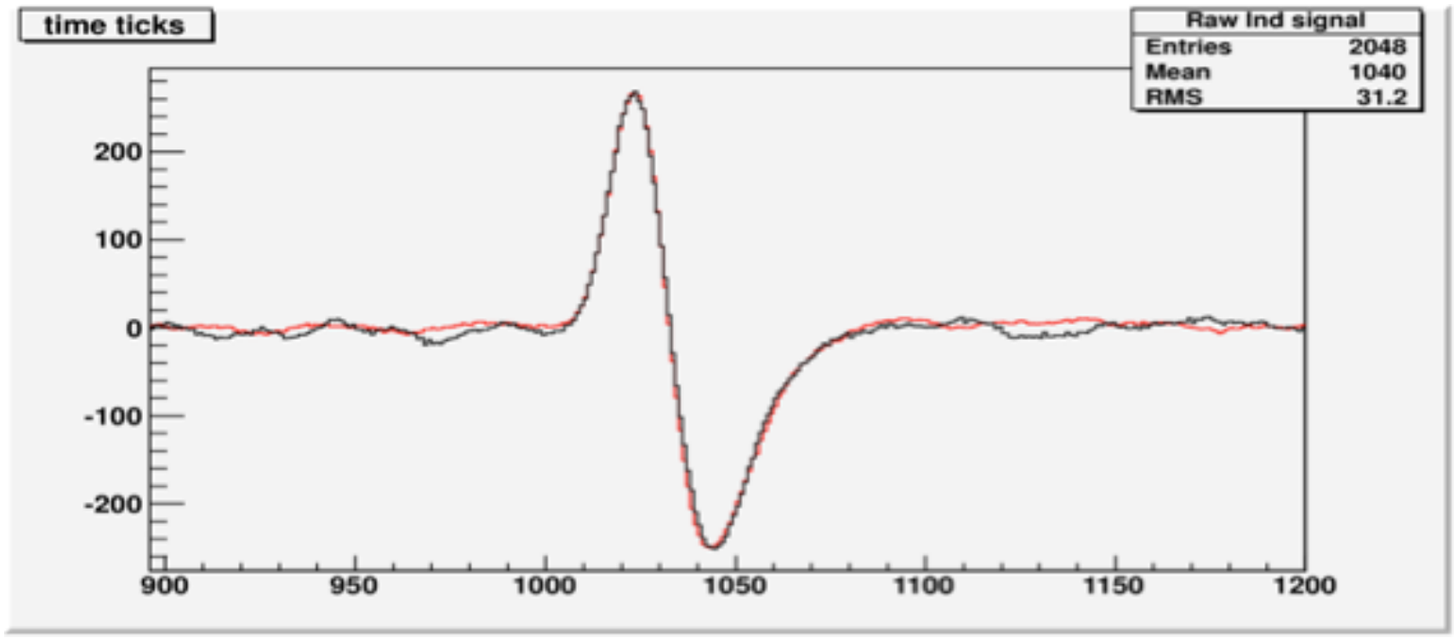
ArgoNeuT+MINOS ND



- ArgoNeuT: Leading the way.
- Have nicely matched MC wire signals to Data.
- Developed MergeData package to match tracks to MINOS muons using Kalman 3D tracking algorithm.
- e- lifetime studies have been performed.
- 3D Shower algorithm to do particle ID
- 3D Vtxing to help identify sub-samples

Signals&Hits MC/Data in ArgoNeuT





Through-going Induction plane data Muons vs MC after convolving w above response function.

Leads to better than 0.2,0.5 mm hit residuals on straight lines.

ArgoNeuT Clusters

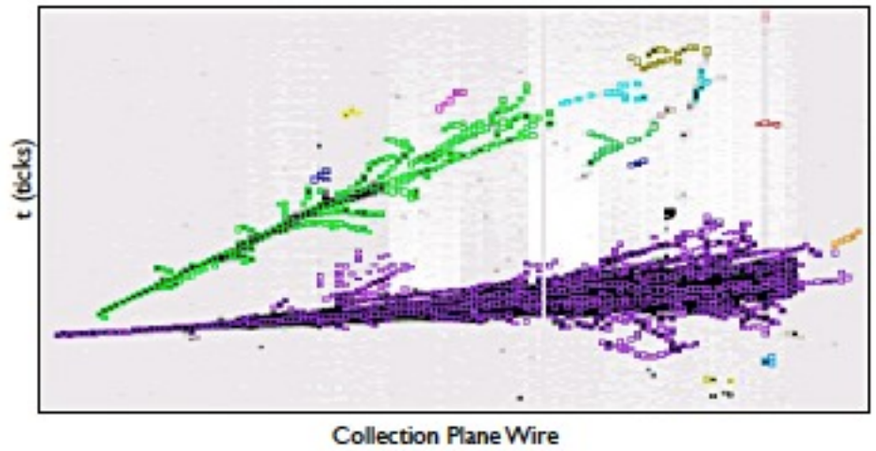


FIG. 4: Example of 2D hit-clustering on a neutrino event using DBSCAN. The gray scale displays raw data while colors are used to indicate the various clusters.

ArgoNeuT data: pID, Calorimetry

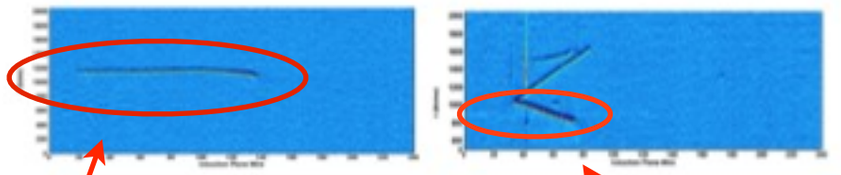


Figure 3. A stopping particle [left] and a zoomed view of a neutrino interaction [right].

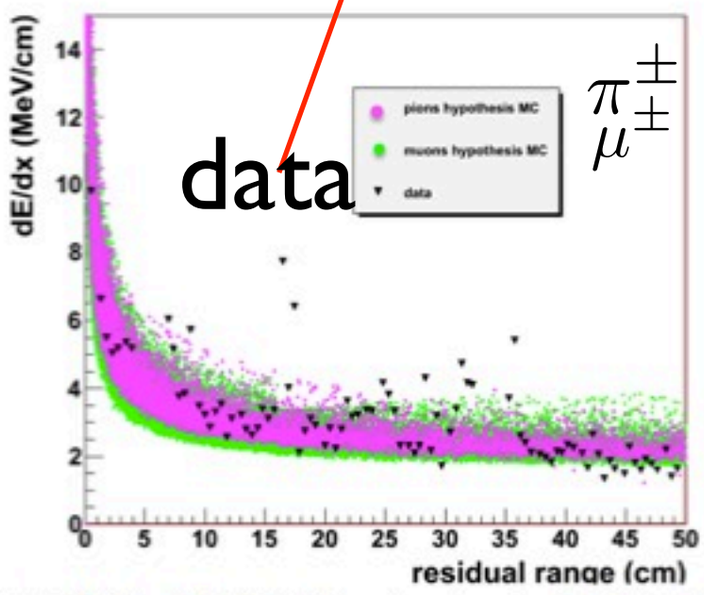


Figure 4. Particle ID of the stopping track in Fig. 3[left].

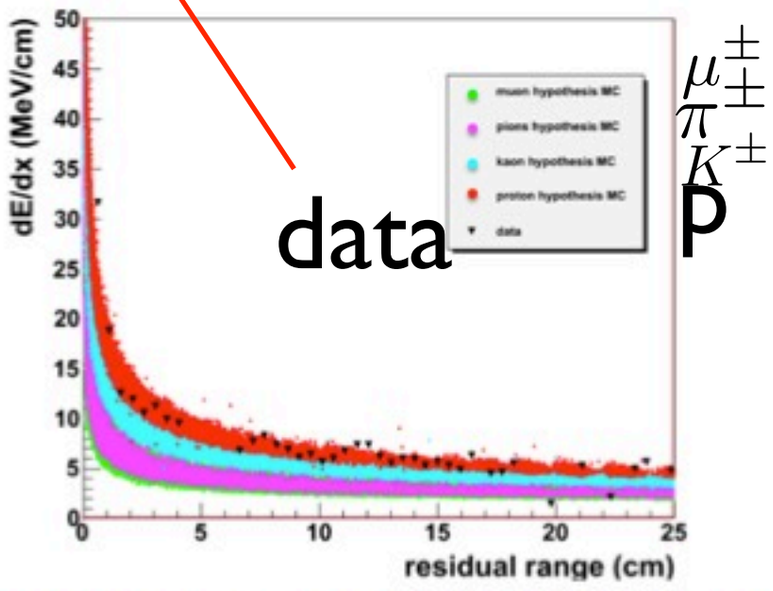


Figure 5. Particle ID of the darker stopping track emanating from the interaction vertex in the event shown in Fig. 3[right].

O. Palamara for the ArgoNeuT Collaboration, Proceedings from NOW 2010

ArgoNeuT data: e-lifetime

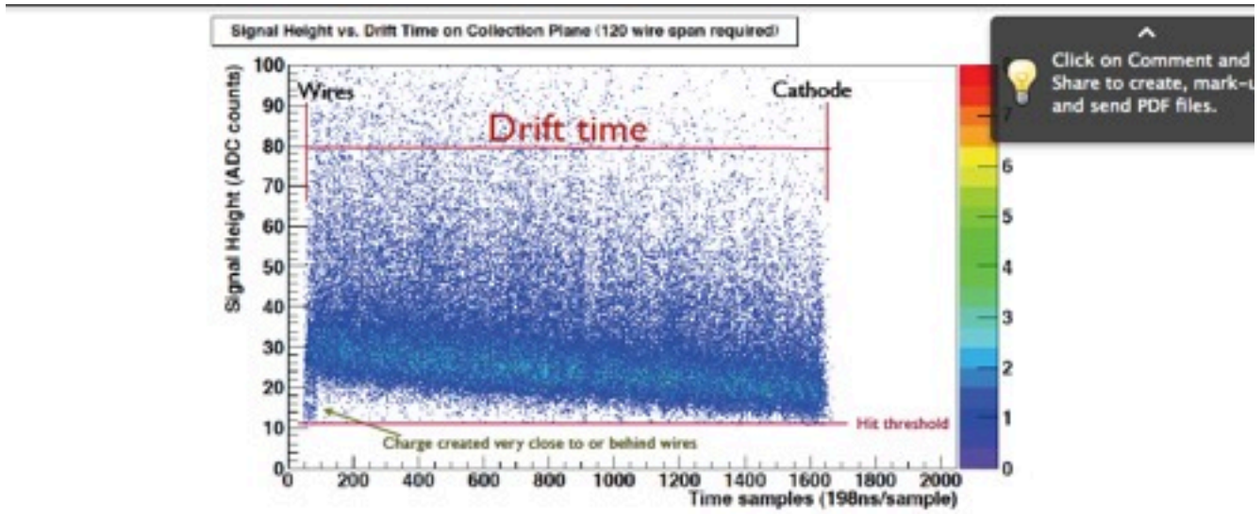


FIG. 14: A 2D scatter plot of signal height vs. drift time showing every hit associated with a long track on the collection plane in ~26 hours worth of ArgoNeuT neutrino-mode beam data.

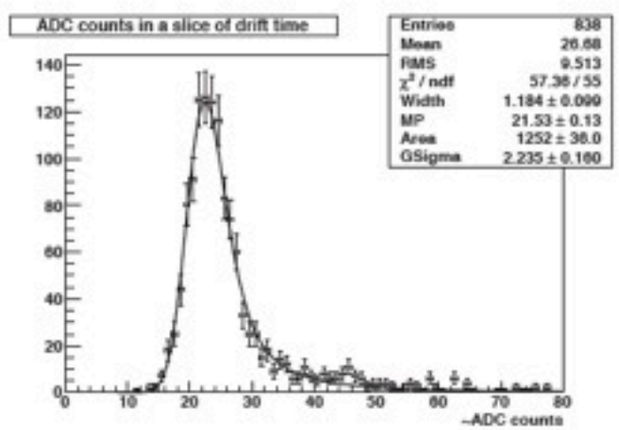
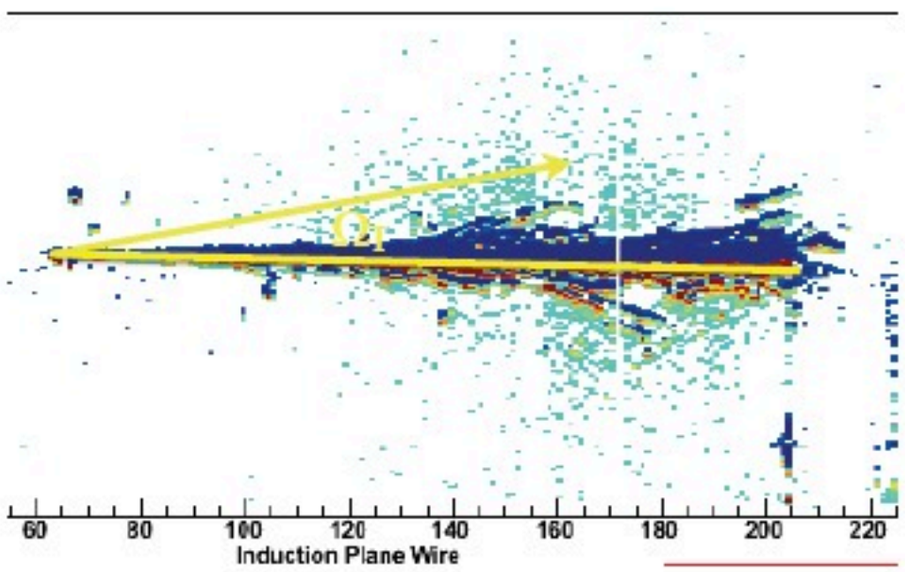
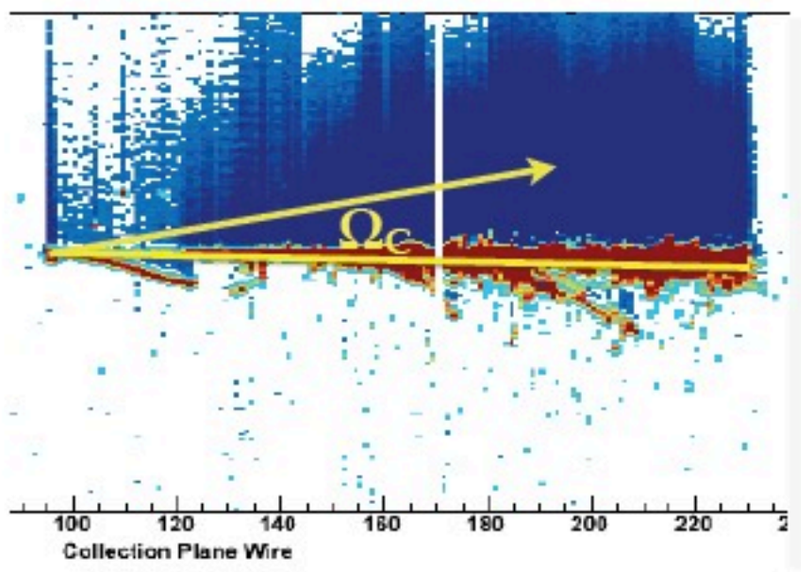


FIG. 15: A convoluted Landau-Gaussian fit overlaid on all of the signal heights (ADC counts) in an arbitrary time slice from the 2D scatter plot of signal height vs. drift time on the collection plane (see Figure 14). The time slice is 8 time samples wide.

Argo ShowerFinder slide

- Three methods to distinguish π^0s from electrons (*i.e.* - NCπ^0 vs. CCQE ν_e)
  - Check event for two showers pointing back to common vertex
  - Look for gap between shower vertex and primary vertex
  - Analyze energy deposition in early part of showers (gamma/electron ~ 2)
- Early work has started on reconstructing showers in 3D and analyzing the dE/dx information at the beginning of the shower.
- Fit is performed of #Hits (or related quantity) vs. Angle (Ω) to find direction of shower. These angles can be used to determine the 3D θ-ϕ direction of the shower.





Kalman filter in Icarus

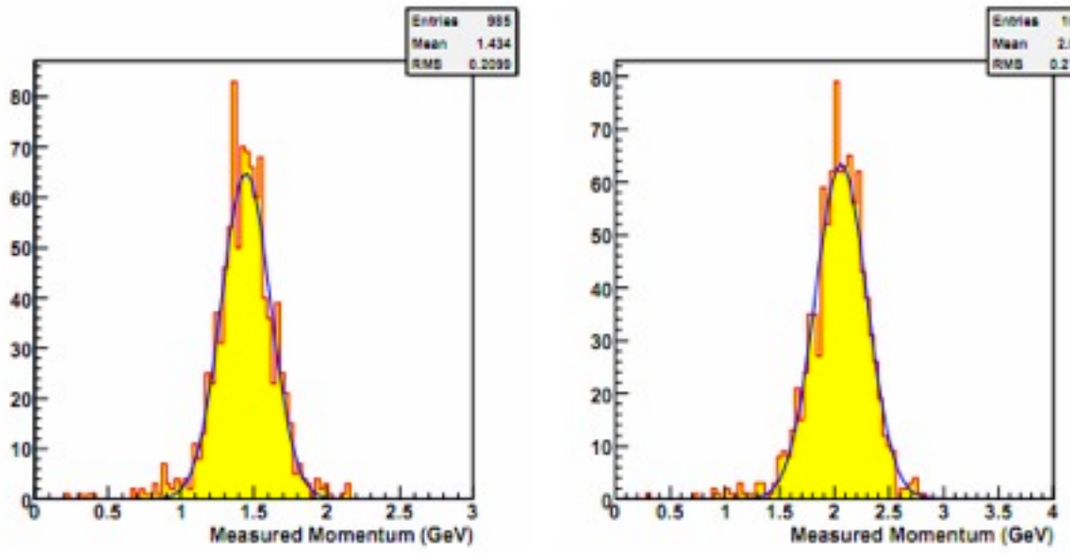


Fig. 5. Momentum distributions as given by the Kalman Filter for simulated muons of 1.5 and 2.0 GeV.

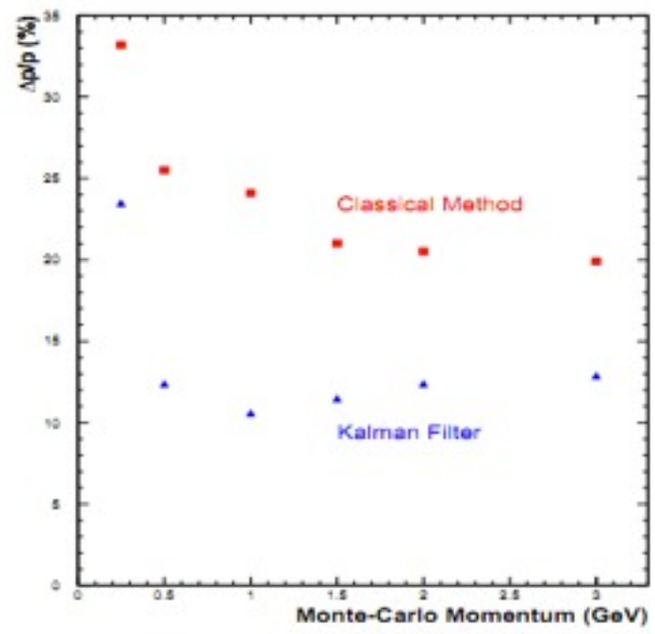


Fig. 7. Comparison between the resolutions for *classical* and Kalman Filter methods.

Eur.Phys.J.C48:667–676,2006.

Kalman track filter

$$\vec{x} = \begin{pmatrix} \frac{q}{|p|} \\ \frac{du}{dz} \\ \frac{dv}{dz} \\ u \\ v \end{pmatrix}$$

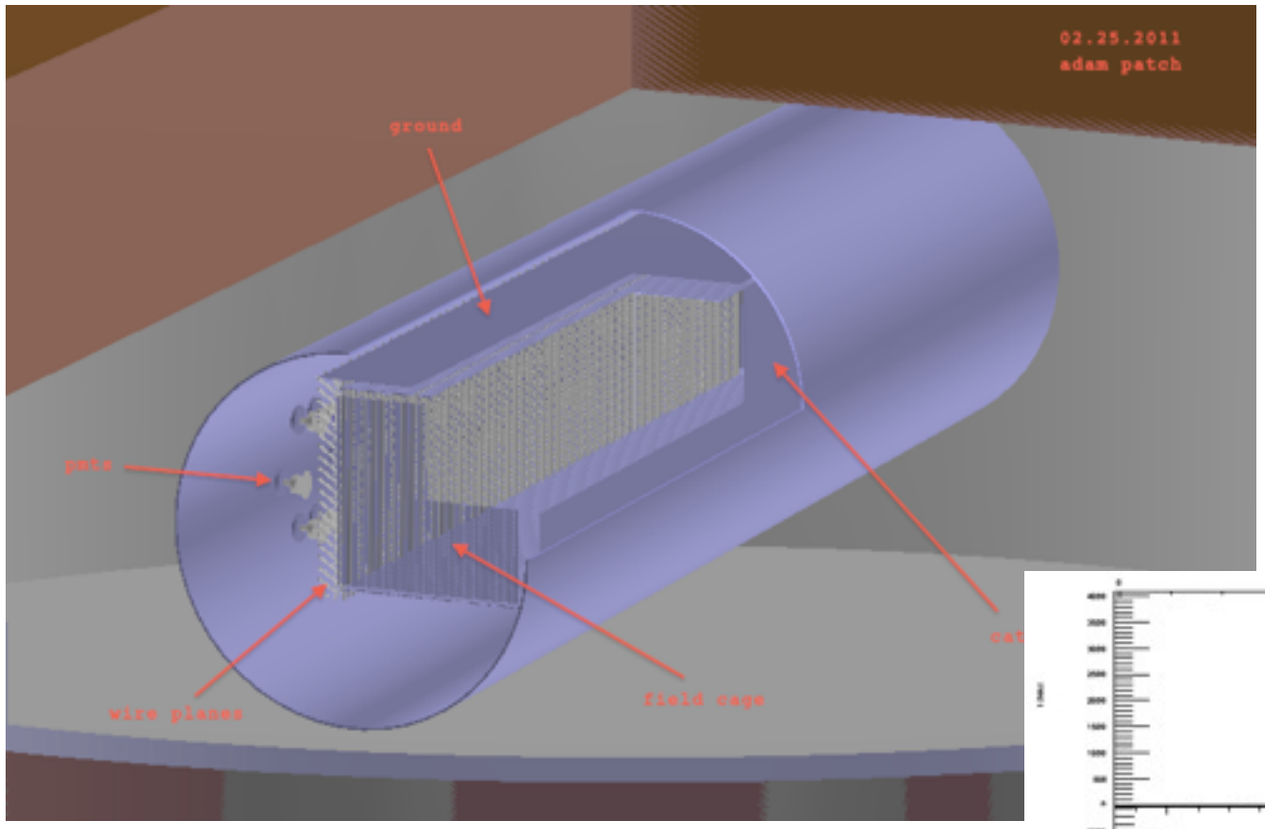
Sum over all spacepoints, k=1,N.

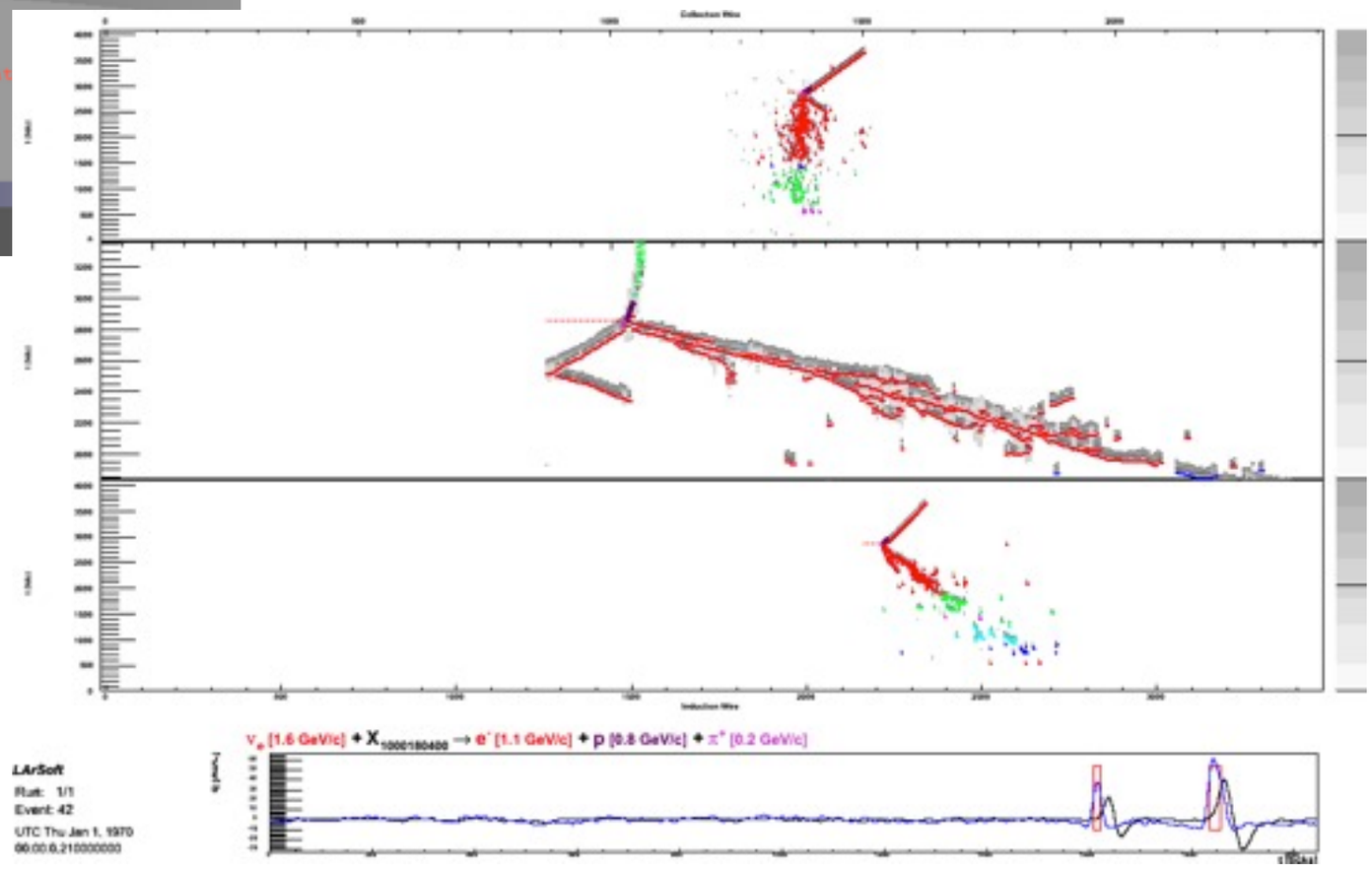
$$\chi^2 = \vec{r_k}^T (V_k - H C_k H^T)^{-1} \vec{r_K}$$

Kalman tracking: Status & Next Steps

- In use now for ArgoNeuT for pointing to MINOS-ND
- Pointing errors fall out naturally from Kalman fit. Nice for vertexing. Gives Start/Exit angles.
- 1/Momentum of track falls out naturally.
- We only await SpacePoint finding -- detector agnostic version to use this in MicroBooNE. Will be nice to see muon momentum resolution at that point.

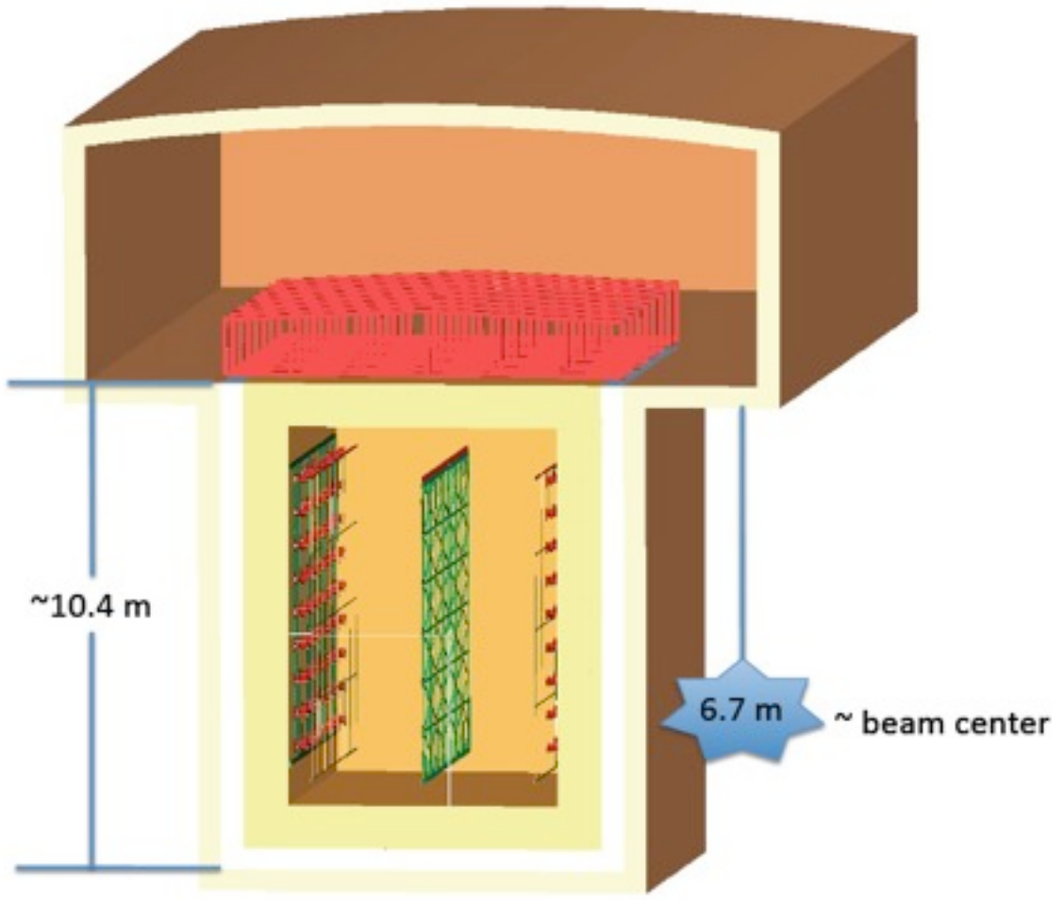
MicroBooNE


02.25.2011
adam patch
ground
pmts
wire planes
field cage

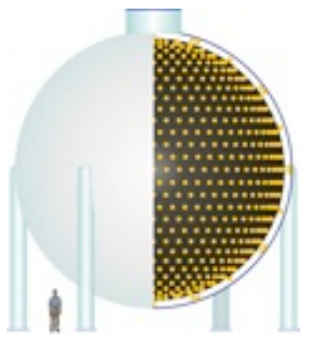

LArSoft
Run: 1/1
Event: 42
UTC Thu Jan 1, 1970
00:00:0.210000000

LAr1

- D0 hall, BNB?

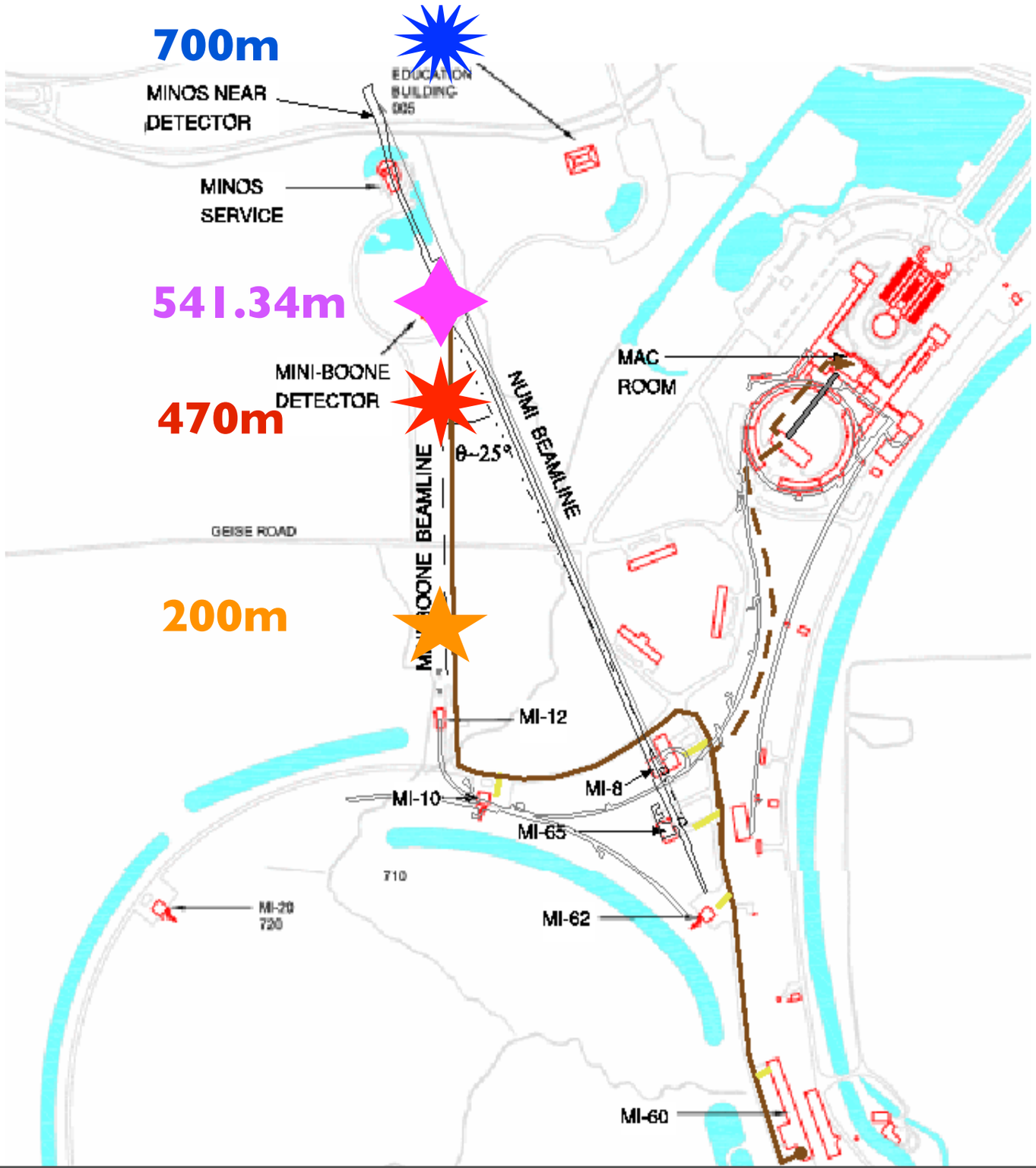


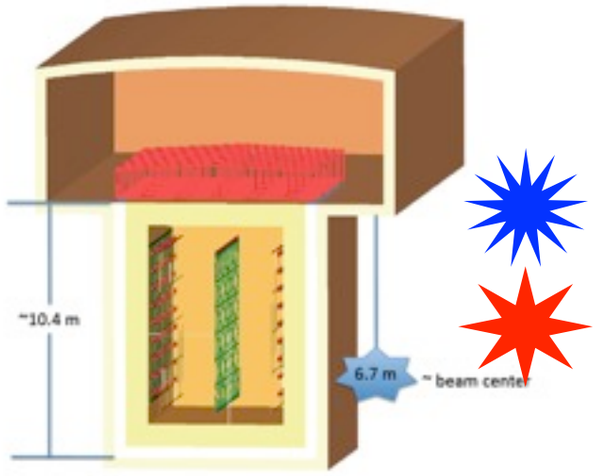
MicroBooNE+"LarLAr" at FNAL (Booster Beam)



miniBooNE

microBooNE





LarLAr

microBooNE II

Phases 0-1

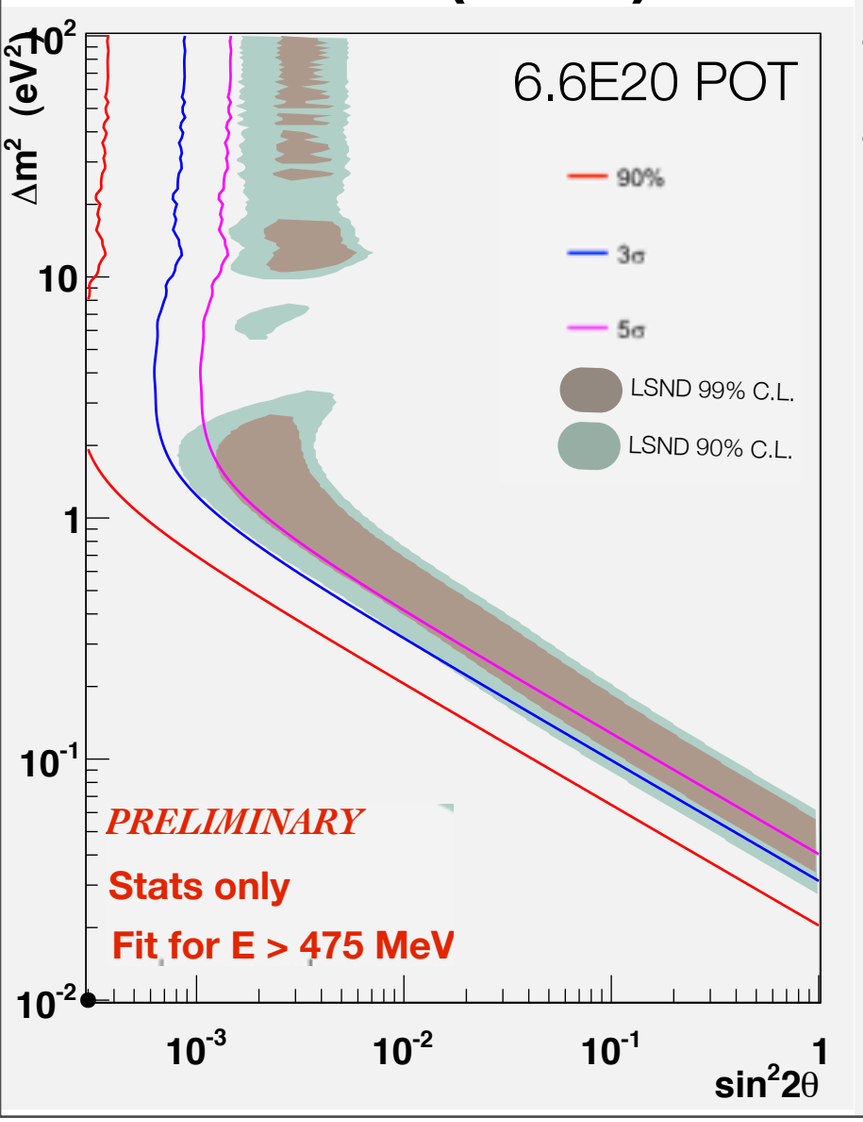
Phase 2 scenarios

LArSoft MC truth studies ...

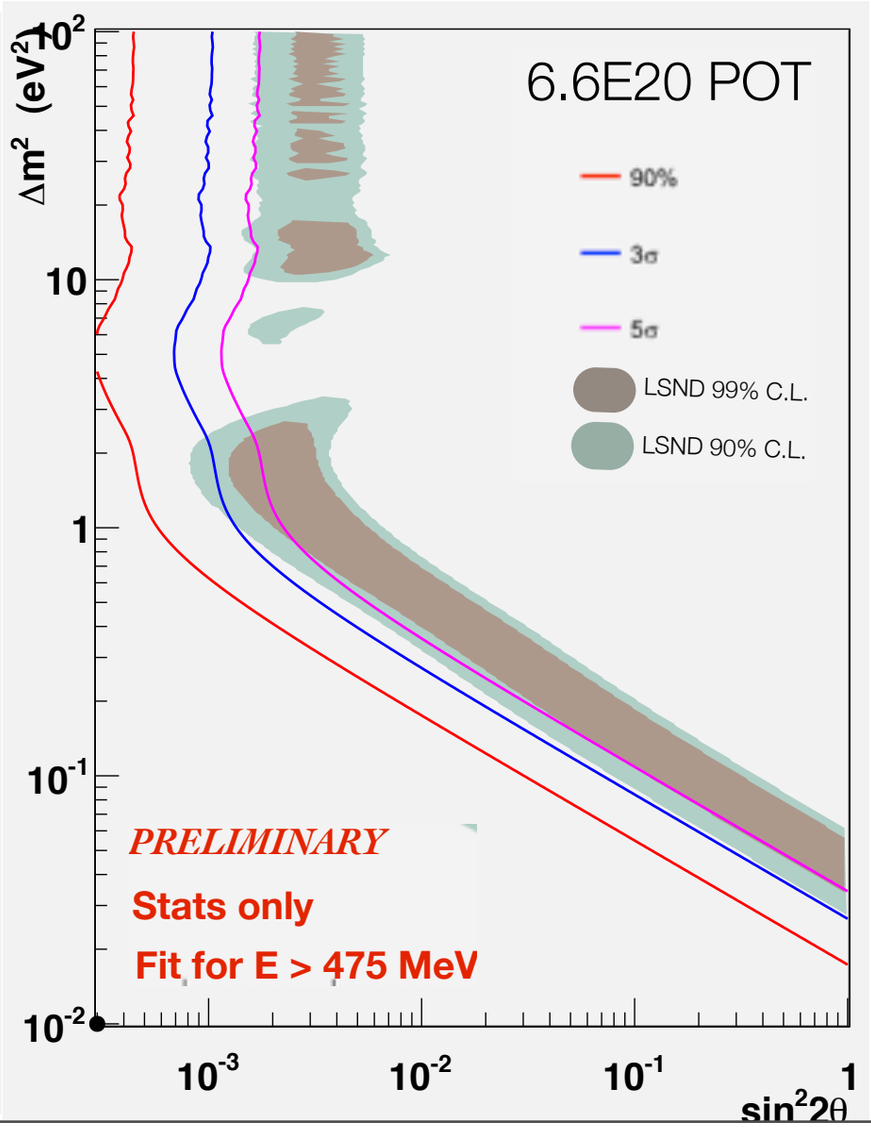
Sensitivities* in **anti-neutrino** mode for microBooNE II and LarLAr

See Roxanne Guenette's talk from yesterday

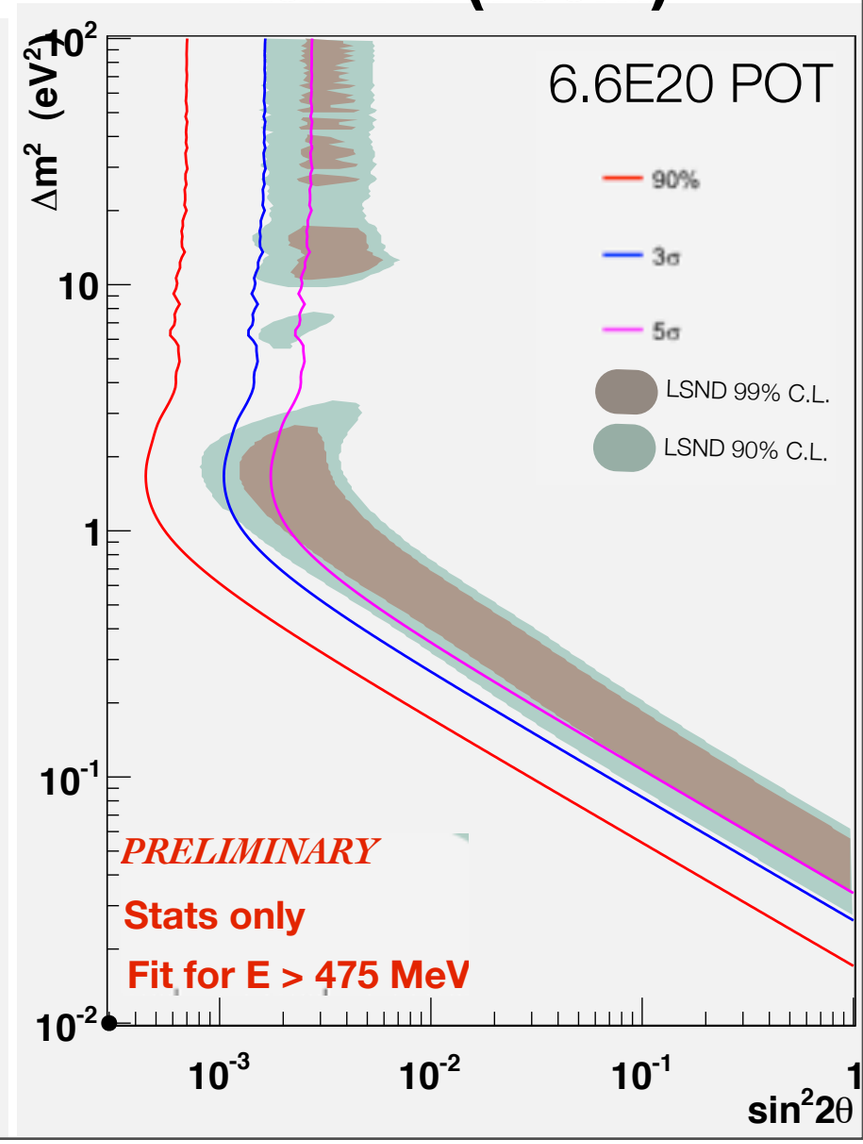
MicroBooNE II (200m) + LarLAr (470m)



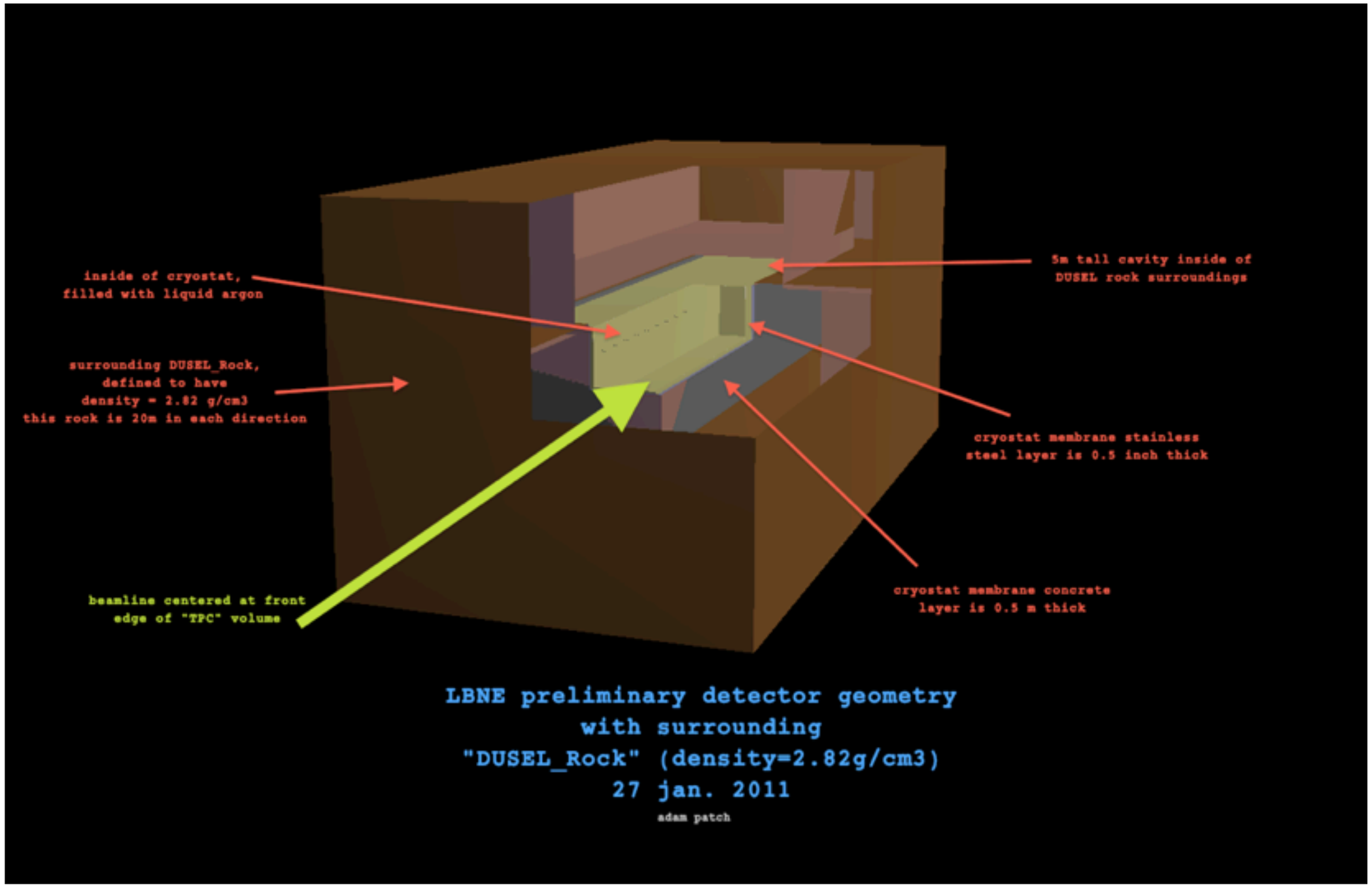
MicroBooNE II (200m) + LarLAr (700m)



MicroBooNE II (470m) + LarLAr (700m)



LBNE in LArSoft



First LBNE task within LArSoft

- Running DUSEL muons at 800 feet through the LBNE geometry in Geant4.
- Will not reconstruct yet, as with Bueno, (arXiv:hep-ph/07011101).

Geant4 techniques for rare processes (variance reduction) as applied to Ndk bgd

- Track Stacking: First, track primary mu+/-.
- Only secondaries that get tracked in rock are K0_{S,L}, Lambdas, neutrons. Track them next.
- Track all secondaries in LAr
- Go and track any other primaries

Event Biasing

- re-toss N secondaries of specified processes and weigh those tracks as 1/N.
- This is really our only hope to get even a few K0s/Lambdas into the LAr.
- Cross-section biasing (in progress). This is trickier.

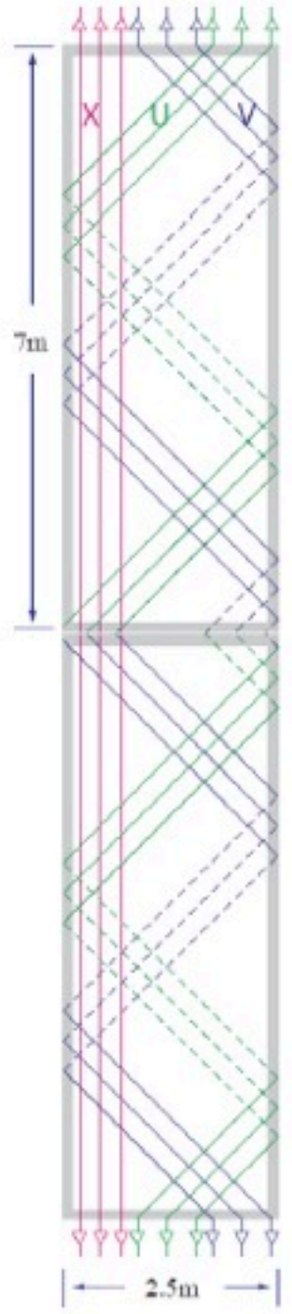
Preliminary Results

- K0L (K0S) travels 48.5 cm (12.5 cm)
- 253 mu/sec into detector (compares to Bueno's 330 shallower, bigger)
- 4.2e-4 neutrons (>20MeV) per above mu. (compares to Bueno's 1.8e-4. Makes sense, as we're deeper, muons are stiffer.)
- 3.8e-6 K0s per above mu. (compares to Bueno's 4.3e-7) I have 14 real evts! total K0s (7 K0Ss+7 K0Ls).
- 8.1e-7 Lambdas per mu (compares to Bueno's 1.7e-8) 3 events!

LBNE specific challenges in LArSoft

What are the big reconstruction hurdles?

- Thus far we have not tried to include the specifics of the LBNE TPC design in the LArSoft geometry. Wrapped wireplanes ("APAs") are quite different from ArgoNeuT/MicroBooNE.
- Reconstruction techniques will have to be adapted to identify Hit locations in APAs, which is more ambiguous due to wrapped wires...this task is made much simpler by the proposal to "offset" TPC wires so that a given set of X,U,V wires only cross in one location.
- Scalability of code (CPU/Memory usage) from ArgoNeuT/MicroBooNE to LBNE will require careful planning. This is only just reaching a noticeable level on our "to-do" list.



Current State of LArSoft

- LBNE geometry is at the point where we can/do run MC jobs: moving quickly toward realistic APA/CPA modules for LBNE, and then reconstructing. MicroBooNE geometry is reconstructing. ArgoNeuT is reconsructing.

- EventDisplay: Has made great strides. Time-wire view available. Can overlay Recon objects: Hits, Clusters, Tracks, ... 3D view now exists. A True "MCCheater" Reconstruction package exists: very handy.

- 3D tracking, 3D Shower awaiting 2->3 plane transition for MicroBooNE/ LBNE. Not an enormous job.

- Need to tune 3D Vertex and Event -- to gather appropriate objects into events in which they belong. Functional code exists here, yet to be fully exercised on, say, neutrino+overlaid cosmic events.

- MicroBooNE/LBNE electronics response functions: In at some place-holder level.

ArgoNeuT/MicroBooNE->LAr40/LBNE

- ArgoNeuT data and postdocs/students are a substantial force on which to build LArSoft development.
- Though ArgoNeuT is small and will have only a few hundred CCQE nue events, it has tools well along to reconstruct e/gamma showers and mu tracks and to do signal/bgd efficiency/rejection studies.
- MicroBooNE will provide the next step of application of LArSoft tools to data, and greater relevance to LBNE vis-a-vis wire pitch, electronics, drift length, containment.

LArSoft Conclusion

- Most of the simulation/reconstruction chain is now automated in LArSoft. Fast progress being made.
- See Carl Bromberg's talk for status of automated reconstruction of events. That of course is just muon inclusive channel.
- A lot is at stake. As important to show analysis tools are robust for LAr as it is the rest of the US LAr technology.
- Development continues at a nice pace.