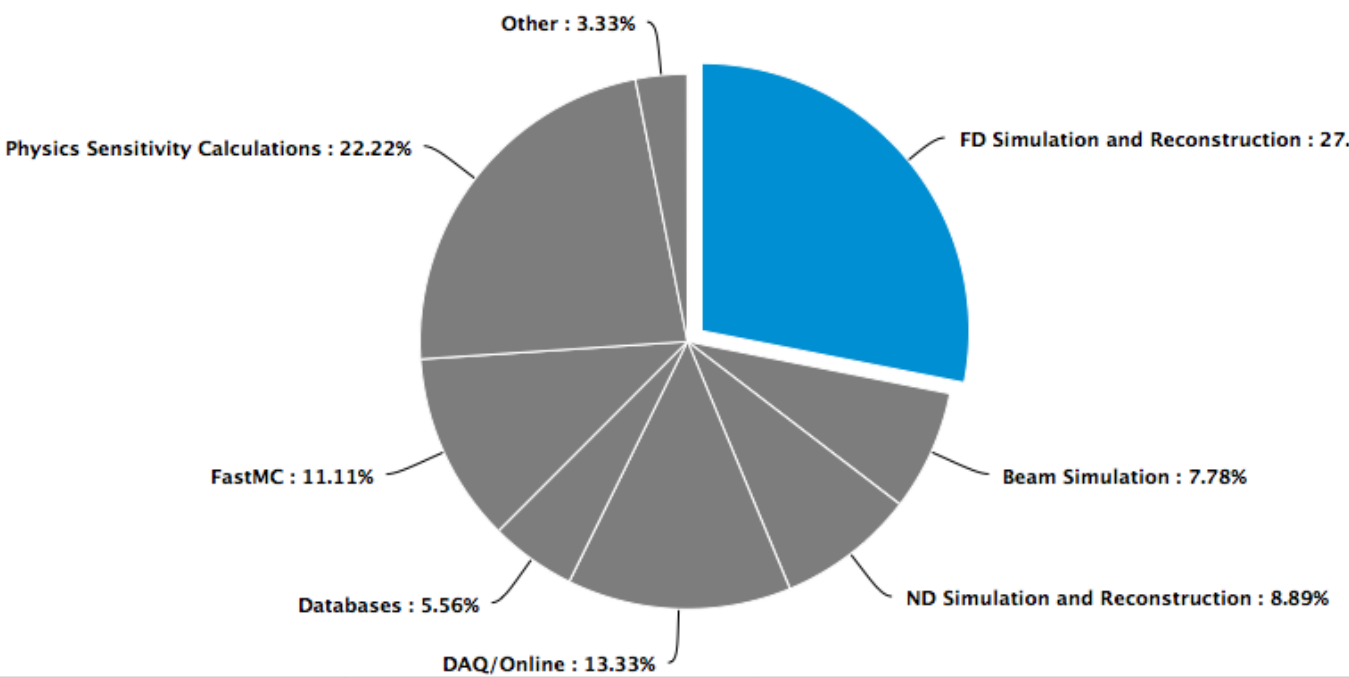
Status and Plans Deliverables for FD Simulation and Reconstruction

Tom Junk
Fermilab

- Simulation Jobs Left To Do
- Reconstruction
- Documentation and Timescales

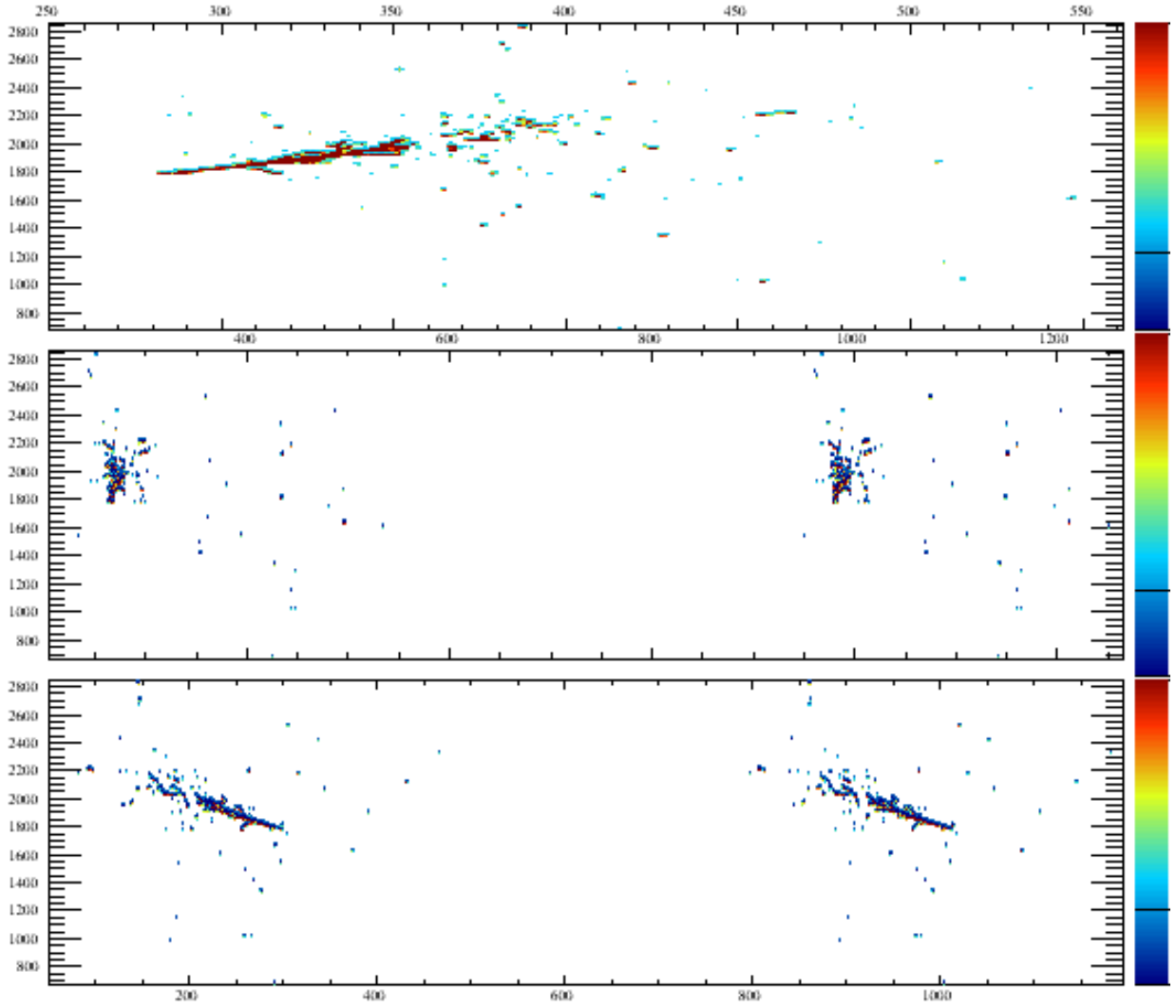
Quite a lot of work has been done! Thanks!

Which Components of LBNE Software Would Your Group Like to Get Involved in Over the Next Two Years? -- Survey as of September 2013

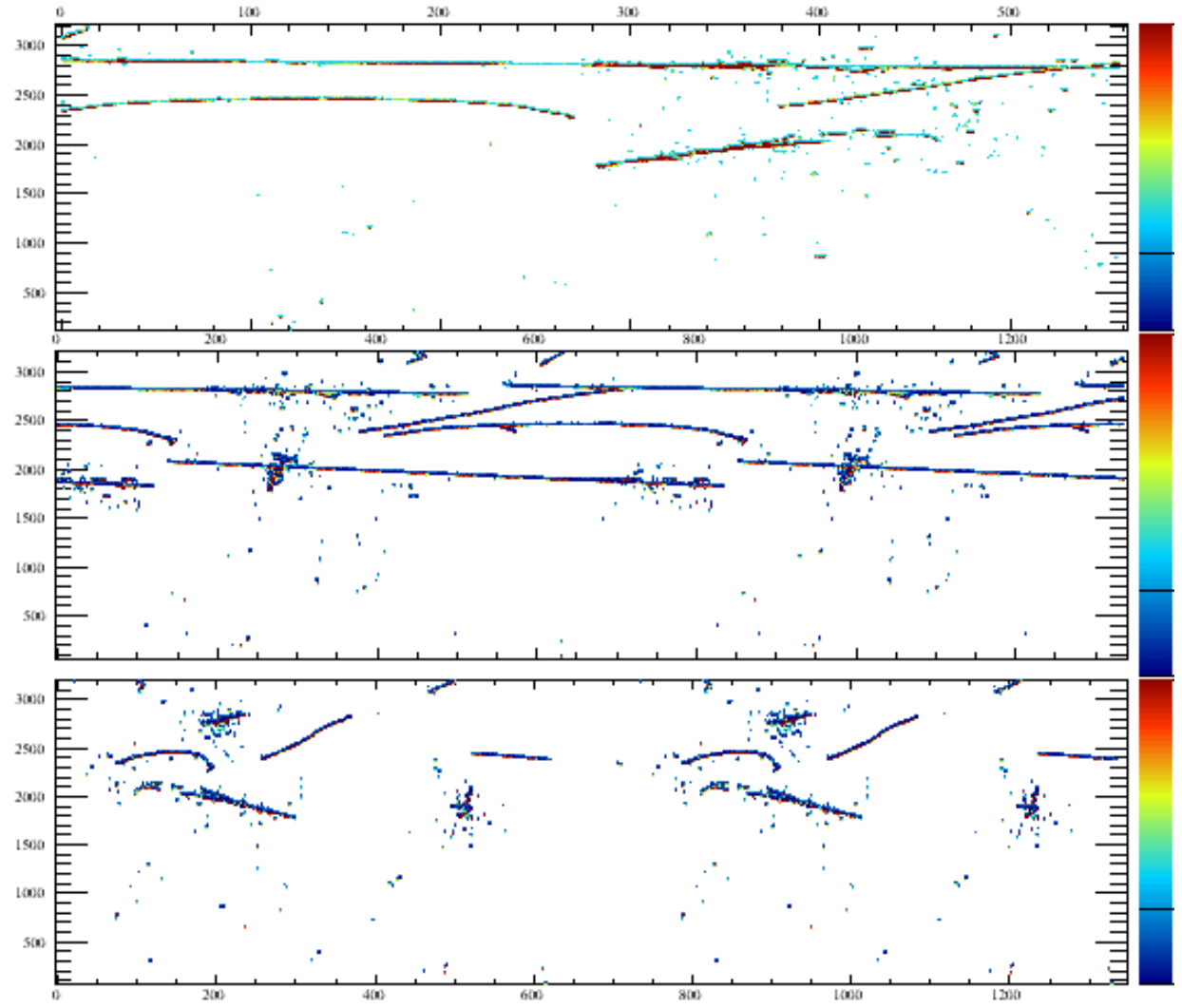


Answer	Count	Percent
1. FD Simulation and Reconstruction	25	27.78%
2. Beam Simulation	7	7.78%
3. ND Simulation and Reconstruction	8	8.89%
4. DAQ/Online	12	13.33%
5. Databases	5	5.56%
6. FastMC	10	11.11%
7. Physics Sensitivity Calculations	20	22.22%
8. Other	3	3.33%
Total	90	100%

A CC nue Event in the 10 kt FD Simulation – No cosmics. Cryostat 1. TPC 54



The Same Event, Re-Simulated, with Surface Cosmic-Ray Overlay



Simulation TODO List

- Finish Validating NEST photon and electron production modeling
- Compare predictions of NEST with LArSoft's current parameterization

- Seek ways to reduce memory consumption:
  - Can we use GEANT4's geometry replica mechanism to our advantage?

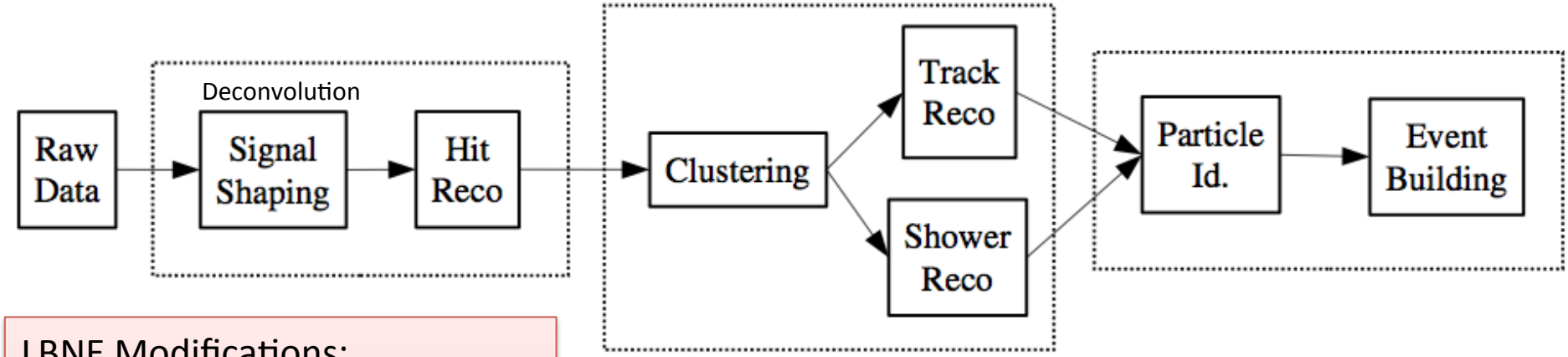
- Many samples we need to simulate
  - GENIE neutrino interactions – already have some at

    https://cdcvs.fnal.gov/redmine/projects/lbne-fd-sim/wiki
    Simulated from Dan Cherdack's GENIE files produced for FastMC tasks

    To do (or only partially done):
  - Cosmic rays (underground and 35t surface)
  - Proton Decay, in several modes
  - Atmospheric Neutrinos
  - Supernova interactions
  - Rock interactions
  - Interactions of atmospheric and beam neutrinos with detector material (APA frames, etc).
  - Simulate ICARUS events? Reconstruct some we get from ICARUS?

LArSoft FD Reconstruction Chain

As used by ArgoNeuT and MicroBooNE



LBNE Modifications:
Raw Data are zero-suppressed, and likely other compression algorithms applied. Cannot unpack
it all at once.

One wire at a time, and apply deconvolution and hit reco on blocks of nonzero data

Need a fast version for software triggering

LBNE Modifications:
Ambiguity breaking for induction-plant hits.

Reconstruct one APA at a time vs. global tracking and shower finding.

Cosmic-ray rejection may be done at a faster, more approximate level and events selected for further processing

Deliverables for FD Reconstruction: Physics Performance: Single Particles in the TPC

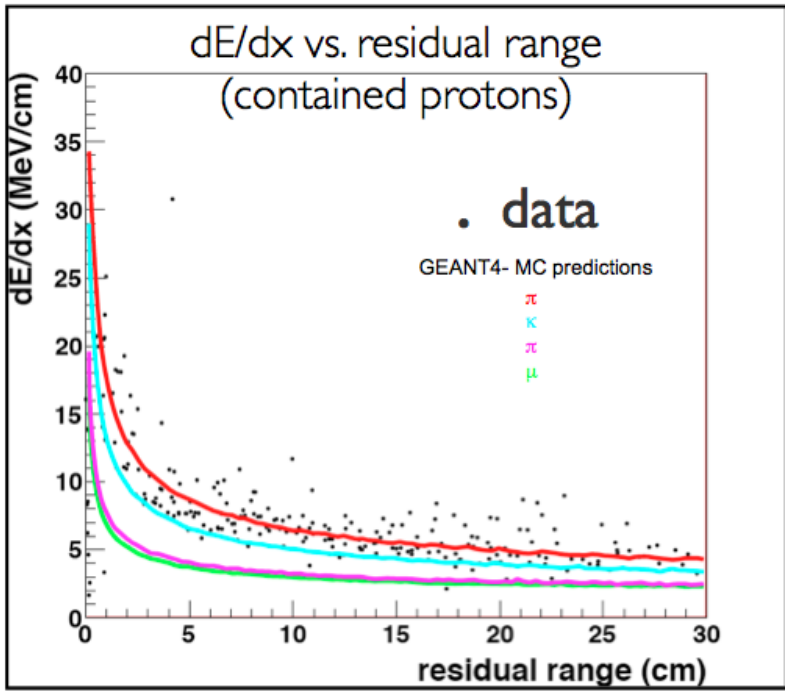
Monte Carlo predictions of, and systematic uncertainties on the following:

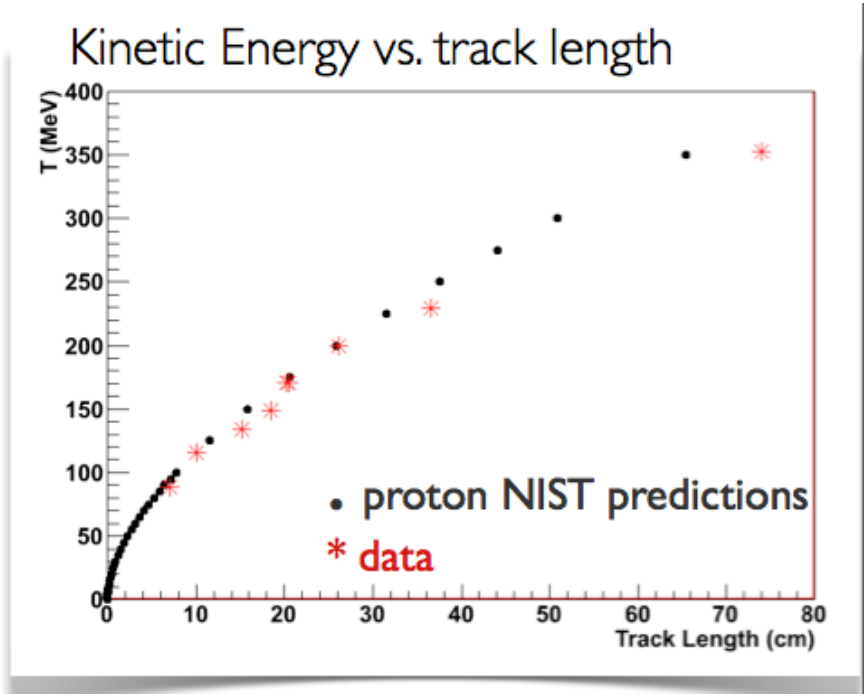
- **Efficiency** for detecting muons, electrons, protons, pions, and kaons as functions of
  - Energy
  - Whether they exit or not (and how much is detected)
  - Angle
  - Whether they cross a gap or cross the APA

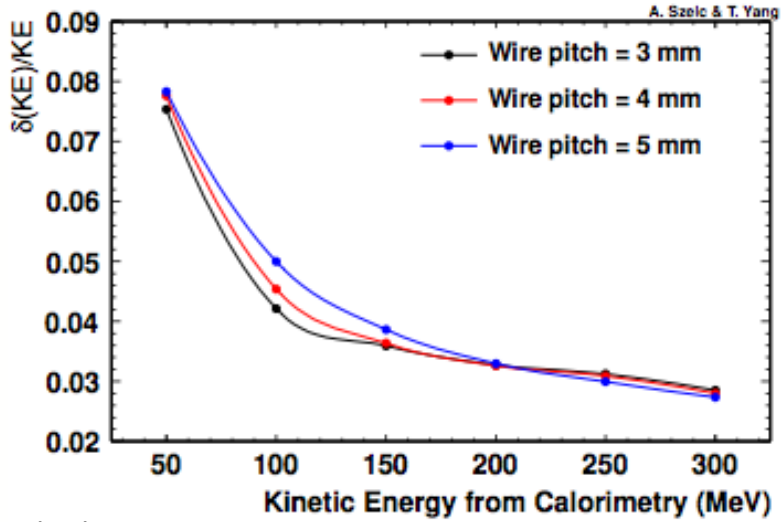
- **Energy Resolution** for muons, electrons, protons, pions, and kaons as functions of
  - Energy
  - Whether they exit or not (and how much is detected)
    Energy resolution for exiting muons and electrons is difficult – scattering angles and extrapolations needed. Extended readout window helps for some tracks.
  - Angle
  - Whether they cross a gap or cross the APA

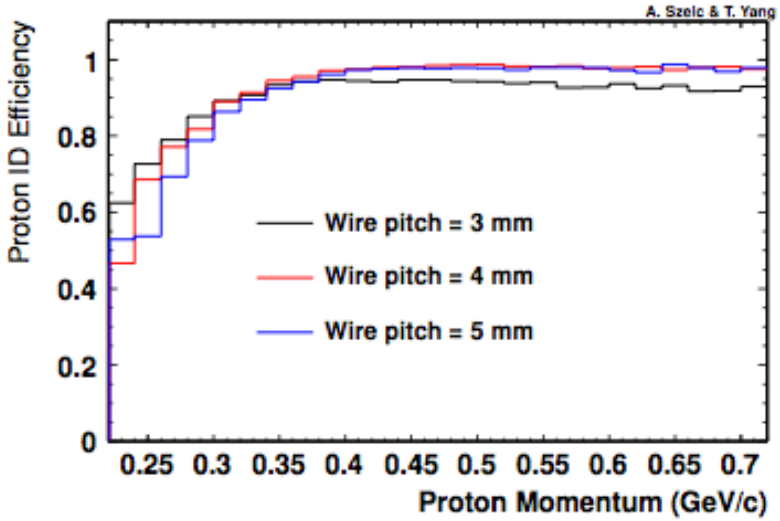
- **PID** fake-rate matrices for each of the particles
  - dE/dx performance plot
  - Functions of energy, angle, and position.
  - Optimize cuts on PID MVA's and fiducial cuts on events

Examples of Delivered Performance Plots (ArgoNeuT)





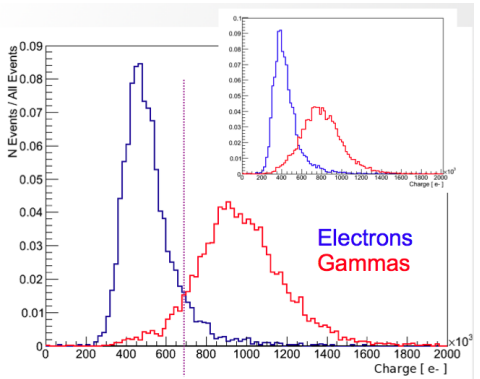




e/γ Separation

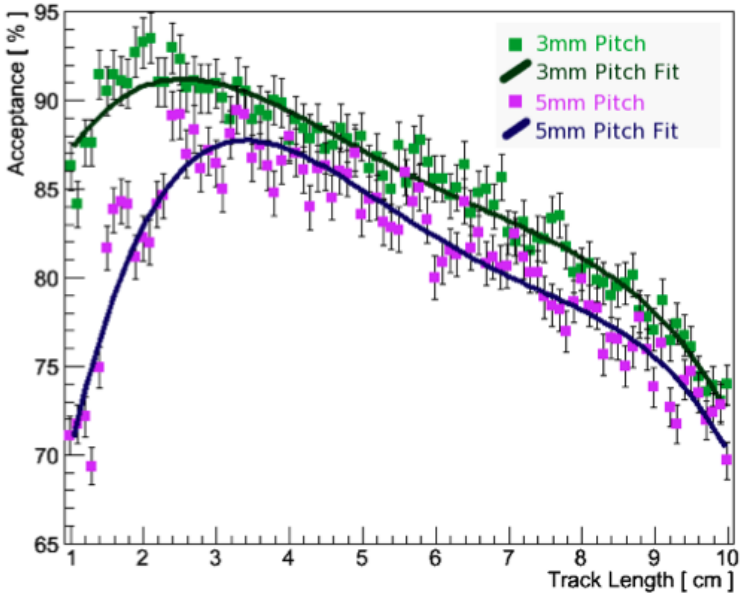
Matthew Szydagis, Daniel Coelho

Measured charge in the first part of an EM shower used to tell one MIP from two

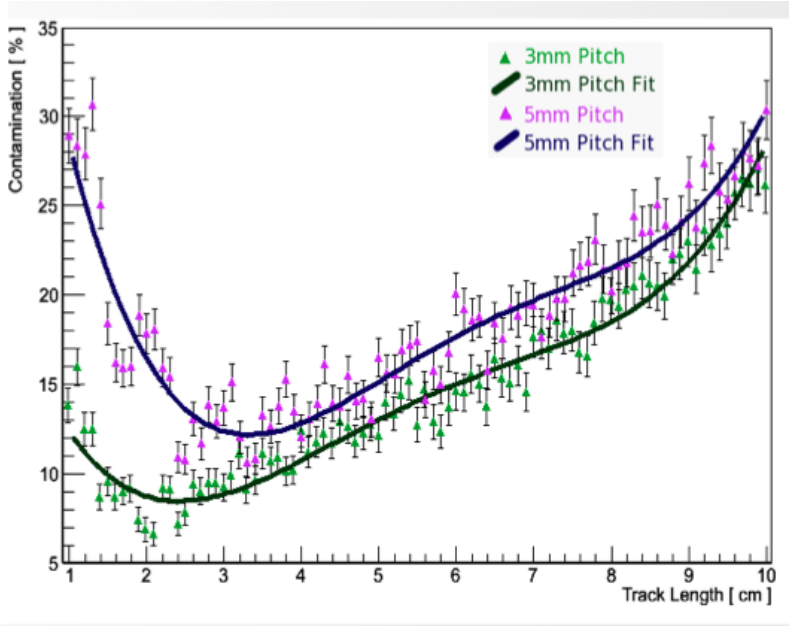


Consulting with ICARUS colleagues to optimize performance

Acceptance for selecting electrons



Fraction of selected events that are misID



Recent update – Negligible impact on the performance of this metric if we use 36 degree induction-plane wires instead of 45-degree induction-plane wires

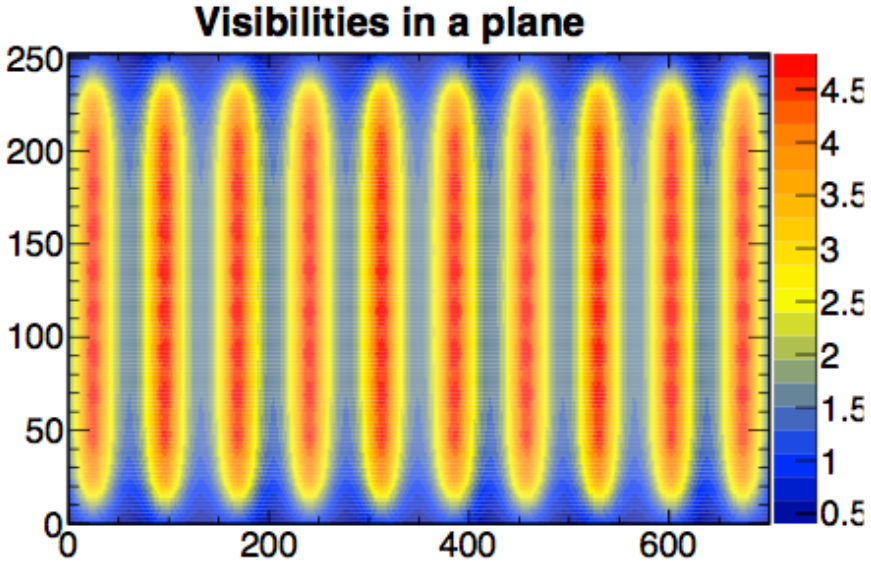
Deliverables for FD Reconstruction: Physics Performance: Neutrino Events

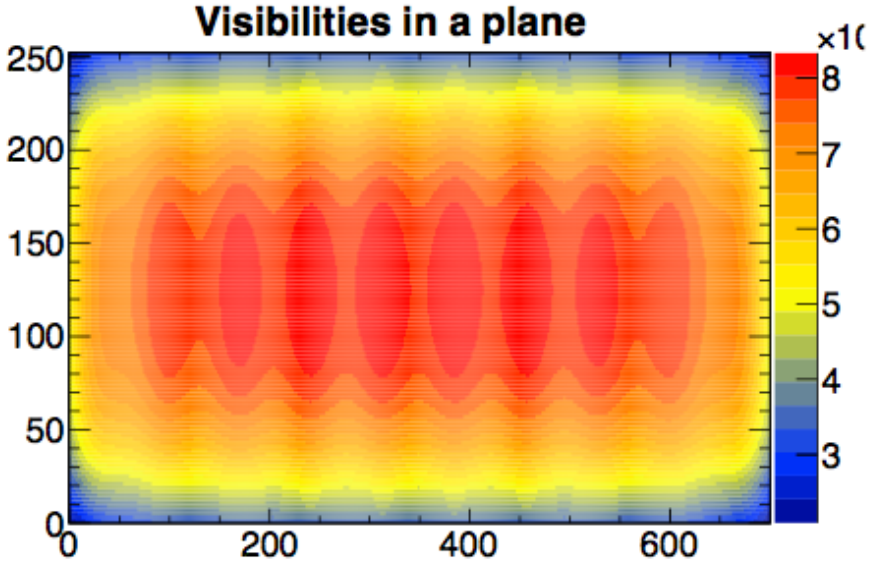
- Event Detection Efficiency as a function of incident neutrino energy
  - $CC\nu_\mu$, $CC\nu_e$, $CC\nu_\tau$
  - Separately for QE, Resonant, and DIS interactions
  - NC interactions

- Energy Resolution for
  - $CC\nu_\mu$, $CC\nu_e$, $CC\nu_\tau$
  - Separately for QE, Resonant, and DIS interactions
    -- or better yet, parameterized as functions of observable quantities like reconstructed hadronic recoil particles
  - Separately for contained and non-contained events

- Energy transfer function for NC interactions

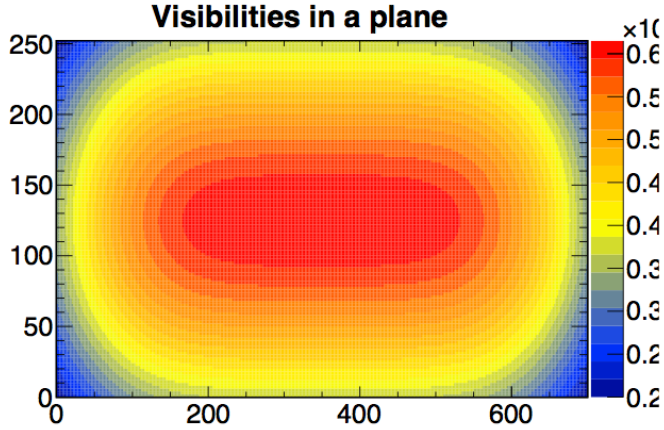
Parameterized Photon Simulation – 10 kt





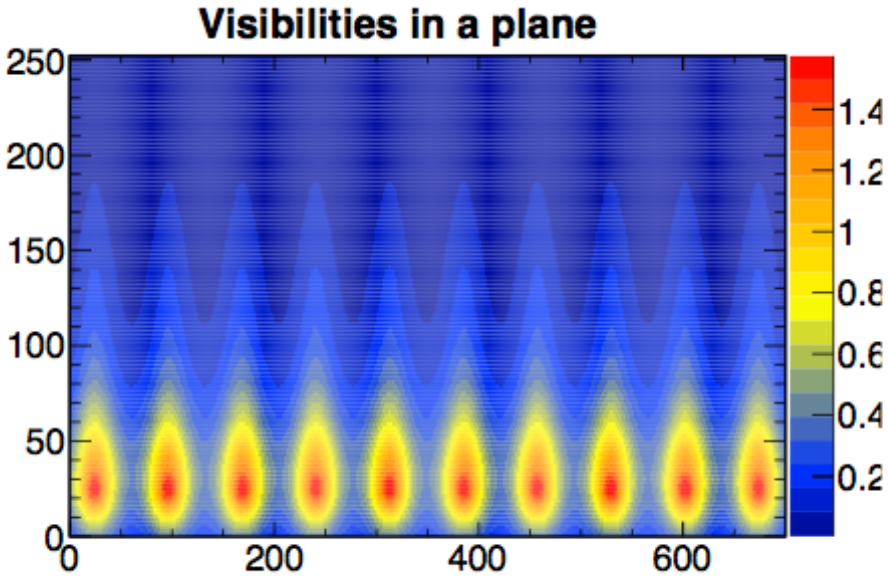
Just visibilities to the bars, no attenuation function in the bars on this page.

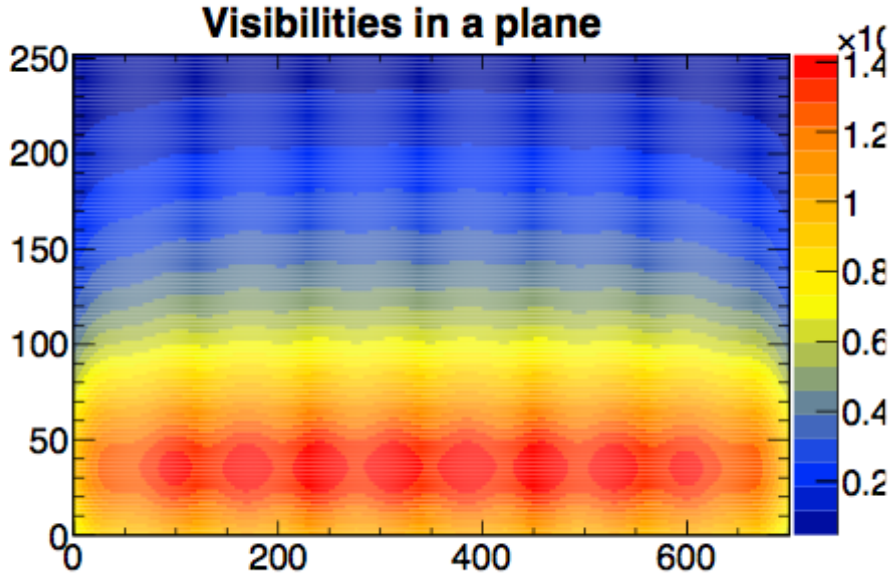
200 cm from APA



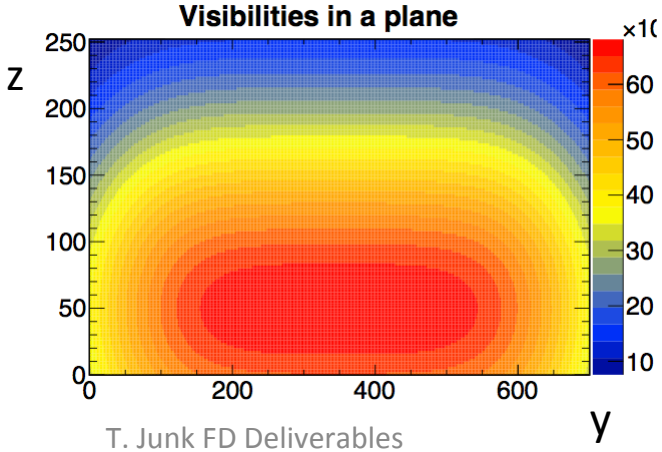
Visibilities within an APA. Pattern continues for many APA's and fills in edges.

Parameterized Photon Simulation – 10 kt





Including effects of attenuation in the acrylic bars



Need measured efficiencies and attenuation functions. These are placeholders.

Deliverables for FD Reconstruction: Physics Performance: Photon Detectors

- Efficiency for triggering
  - Beam Neutrino Events
  - Atmospherics
  - Supernova neutrino events
  - Proton Decay

Norm Buchanan
has started up a
PD Simulation/Reconstruction
Group – Meets Tuesdays
at 1:00 PM Central Time
Mailing list:
lbne-ephxportsim@fnal.gov

- Timing Resolution
  - Does it depend on energy?
  - Performance in the presence of backgrounds
- Photon Detector Spatial Resolution
- Energy Resolution
- Association efficiency and purity between PD data and TPC data
  - Under what circumstances is the association ambiguous?

Analysis Strategy: Using Data to Control Backgrounds and Efficiencies

We also need to develop tools for measuring, or at least constraining, using control samples,

- reconstruction efficiency
- PID fake rates
- backgrounds

for the different particle types as functions of energy, angle, and position, using the FD data.

Backgrounds: Lots of beam-off data to constrain cosmics. Non-fiducial events to help constrain rock events. Instrument the volume outside the field cage with photon detectors?

FD MC Challenge Proposal

Shown at
September DOE Briefing

MC Files produced for:

(10 kt + 35t) x (With and Without MC Truth info) x (GENIE and GENIE+CRY)

LBNE nominal spectrum for CC nue+nuebar+numu+numubar unoscillated
(and fully oscillated for nue(bar)). NC events from unoscillated numu spectrum.

Without MC truth info – true input vectors hidden from users but kept around for scoring the results.

Tasks:

1) Identify primary neutrino vertex and give location
2) Identify type of neutrino event – CC nue, numu, or NC
3) Measure energy of primary lepton in CC event candidates
4) Count and identify additional particles produced at the primary vertex
5) Estimate neutrino energy

Questions from the Project – They Need Our Guidance

45-degree or 36-degree induction-plane wires?
Different impact on our physics groups:

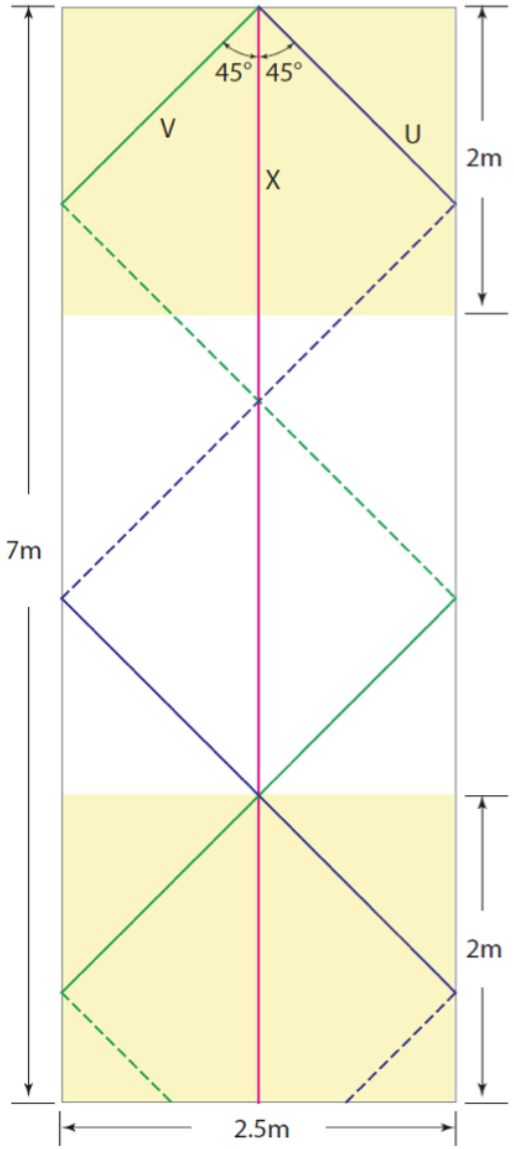
- Underground beam physics – probalby small impact
- Surface beam physics – will be easier with 36 degrees
- Atmospheric neutrinos Nucleon decay – background
- rejection is easier with 36 degrees
- Supernova physics – probably little to no impact

Deeper question – do we need to eliminate wire wrapping entirely?
What physics do we give up with wrapped wires?
(they cannot be good!)

Induction-Plane Wire Wrapping Geometries

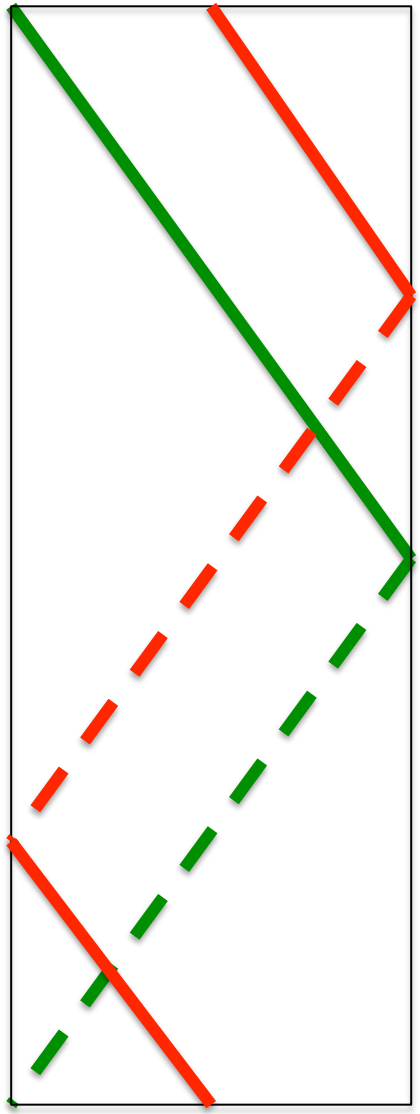
45°

Bo Yu
DocDB 6464



36°

They still wrap, but they do not wrap twice on the same side, intersecting the same collection wire



More Questions from the Project

- What are the requirements on calibration?
  - This is also a question for the physics groups as it affects them differently

- What are the requirements on radiological purity?
- What are the requirements on the detector orientation? And its uncertainty?
- What is the wire pitch uniformity tolerance?
- What is the impact of <100% transparency in the induction planes?
- Impact of gaps between active TPC volumes
  - Horizontal, vertical, and dead space inside the APA frames
- Impact of frame material interactions
- Photon detector performance – is this better with transparent or opaque CPA's?
- Requirement on defective wire/channel count and grouping
- Photon yield requirements
  - Physics analysis dependent
- Impact of different zero suppression strategies and thresholds
  - expand windows in time – how about in wire number too?
- Data compression studies. Lossless: OK – how much loss are we willing to endure?

People Working on Far Detector Simulation Tasks

From meetings and DocDB entries

FD Simulation

Geometry
Tyler Alion (SC)
Xinchun Tian (SC)
Sanjib Mishra (SC)
Mike Kirby (FNAL)
Tom Junk (FNAL)
Brian Rebel (FNAL)
Zepeng Li (Duke)

Electron Drift
Brian Rebel (FNAL)
Eric Church (FNAL)
Matthew Szydagis (UC Davis)
Jonathan Insler (LSU)
Tom Junk (FNAL)

Photon Production and Detector Simulation
Zepeng Li (Duke)
Kate Scholberg (Duke)
Dave Muller (SLAC)
Ben Jones (MIT)
Matt Szydagis (UC Davis)
Eric Church (Yale)
Brian Rebel (FNAL)
Alex Himmel (CIT)
Craig Thorn (BNL)
Stan Seibert (Penn, moved on)
Josh Klein (Penn)
Stuart Mufson (Indiana)

Radiologicals
Tom Junk (FNAL)
Vic Gehman (LBNL)
Xinhua Bai (SDSMT)
Emily Dvorak (SDSMT)
Douglas Tiedt (SDSMT)
Luke Corwin (SDSMT)

Electric/Magnetic Field tools
David McKee (moved on)

Producing Samples
Tom Junk (FNAL)
Zepeng Li (Duke)

People Working on Far Detector Reconstruction Tasks

FD Event Display
- Brian Rebel (FNAL)
- Zepeng Li (Duke)
- Seongtae Park (UTA)

FD Event Scanning
- Sanjib Mishra (SC)
- Libo Jiang (SC)
- Tyler Alion (SC)
- Andrzej Szelc (Yale)
- Kayla Hasbrouck (SC)
- Andrew Svenson
- Jae Kim (SC)
- Xinchun Tian (SC)

Hit Processing
- Jonathan Insler (LSU)
- Amir Farbin (UTA)

Hit-finding Characterization
- Jonathan Insler (LSU)
- Kevin Wood (SC)
- Tyler Alion (SC)

Disambiguation Algorithms
- Tyler Alion (SC)
- Jae Kim (SC)

Clustering
- Andy Blake (Cambridge)
- Mark Thompson (Cambridge)
- John Marshall (Cambridge)
- Ben Carls (FNAL) (MicroBooNE, plays an advisory role)
- Andrzej Szelc (Yale)

Calorimetry
- Andrzej Szelc (Yale)
- Kevin Wood (SC)
- Sanjib Mishra (SC)

Tracking
- Andy Blake (Cambridge)
- Mark Thompson (Cambridge)
- John Marshall (Cambridge)
- Herb Greenlee (FNAL) (MicroBooNE)
- Eric Church (Yale)

FD Reconstruction (cont'd)

dE/dx reconstruction/PID

J. Insler (LSU)

Bruce Baller's the expert on ArgoNeuT

Muon charge sign from absorption

Richard Imlay (LSU)

Energy Calibration -- electrons

Kevin Wood (SC)

Sanjib Mishra (SC)

Energy Calibration -- muons

No one specific to LBNE yet -- range and multiple scattering techniques

Energy Calibration -- other particles

Protons, pions, kaons – need personnel

Energy Calibration -- reconstruction of neutrino energy

Needed. But this is down the road from the above tasks. Maybe it can be worked on making assumptions on the reco of the particles. FastMC does this.

Photon detector reconstruction

Zepeng Li (Duke)

Kate Scholberg (Duke)

Stan Seibert (Penn)

Low-Energy Reco & nuclear de-excitation gammas

Kate Scholberg (Duke)

Zepeng Li (Duke)

Mike Smy (UC Irvina)

Bob Svoboda (UC Davis)

Reconstructing ICARUS Events

Need person(s). And events.

Timescales

January 31 – February 1: FD Workshop/Hackathon @Fermilab
February 2—4: LBNE Collaboration meeting @Fermilab
February 5: Far Detector Engineering meeting @Fermilab

March 20 – 22: R&D and Software & Computing & Physics Tools Internal Review @Argonne

May 12 – 16: DOE Review of R&D, Software & Computing, Physics Tools

Documentation

- Jim Stewart would like us to justify a change request for moving the wire angle from 45^o to 36^o on a short timescale (~week)

- Documentation for May DOE Review
  - Physics Tools Status Document, including FD Sim/Reco
  - Computing Requirements Document (see Maxim's talk in the collab meeting)
  - Software and Computing plans document
  - R&D group document

The first of those, Physics Tools Status, we will have to write/contribute to, and the others we should review as we are clients and/or participants