Status of the 35ton Prototype

Michelle Stancari

January 19, 2016

Fermilab

DUNE

35ton Phase 2 detector

Characteristics

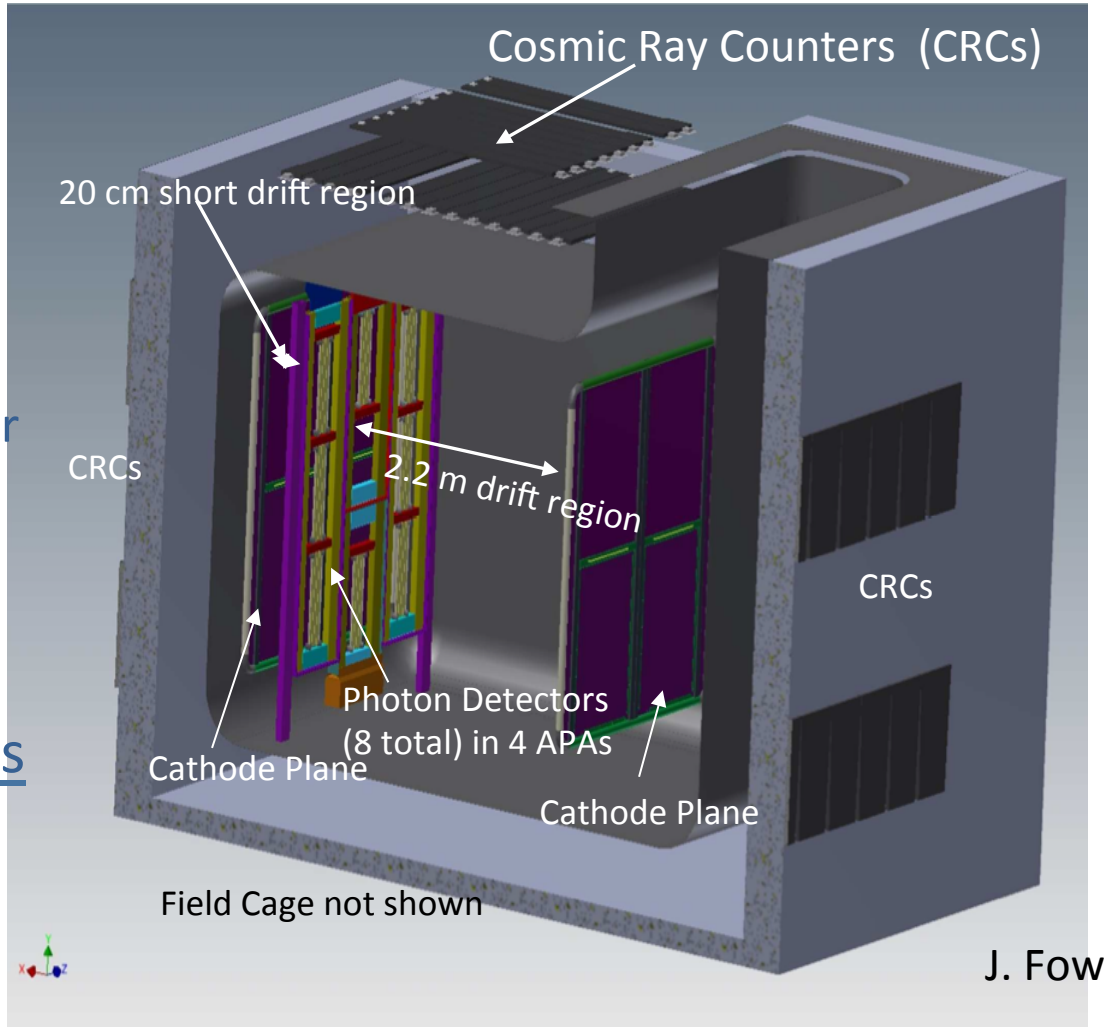
- 2.5m x 1.5m x 2m active volume
- 2 drift volumes (long/short)
- 8 sets of wire planes

Data Sample

- Expect ~1 cosmic ray muon per 1.6 ms drift window
- CRC trigger rate ~60 Hz (vertical) + ~3 Hz (horizontal-ish)

Performance measurements

- S/N ratio for MIPs
- Electron lifetime from muon tracks
- Photon detector event time resolution

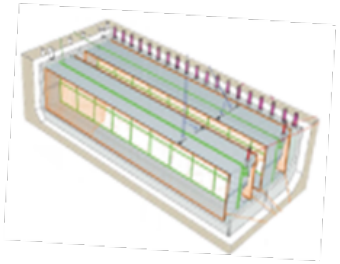


J. Fowler

Fermilab DUNE

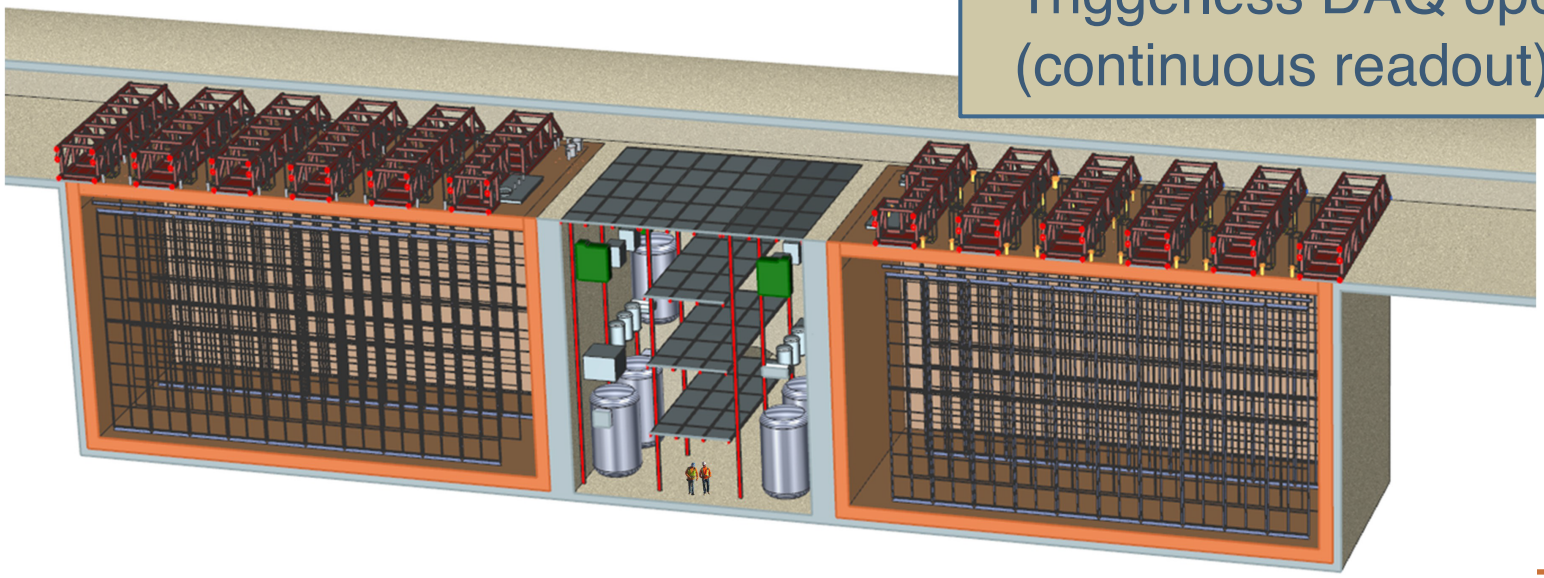
Why build another prototype?

ICARUS 0.6 kTon



MicroBooNE – 0.2 kTon

DUNE – four 10 kTon modules



Features of the 35ton and SP-FD

- Membrane Cryostat
- FR4 printed circuit board field cage
- Light-guide+SiPM style photon detectors
- Wrapped wire planes
- Multiple drift volumes
- Cold electronics: FE ASIC + ADC ASIC
- Triggerless DAQ operation (continuous readout)

Basic deliverables

- Construct and test TPC components and the interfaces between elements
- Demonstrate low noise operations after implementing the same grounding and shielding scheme as the FD
- Integrated system test – event displays of particle interactions

Timescale: Few days

- Exercise continuous readout, test zero suppression algorithms
- Characterize cold electronics, channel uniformity

Timescale: Few weeks

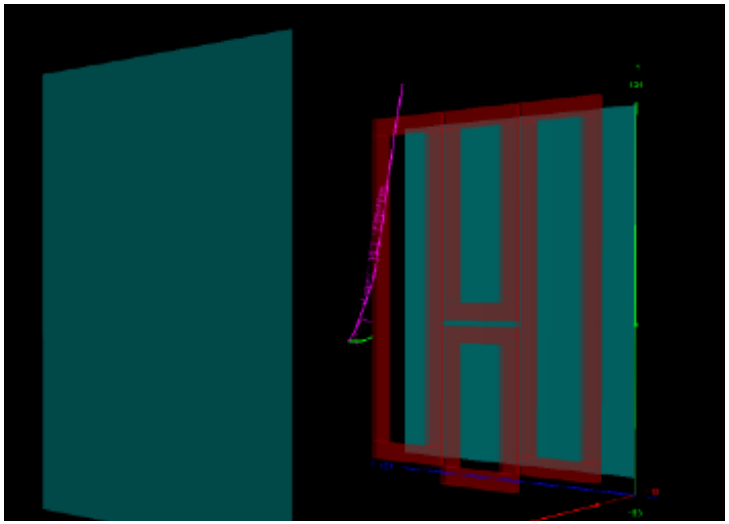
- S/N measurement for MIPs
- Event time from photon detectors
- Electron lifetime from muon tracks
- Investigate how wrapped wires and gaps between modules affect track reconstruction and energy resolution

Timescale: Several weeks

More challenging measurements

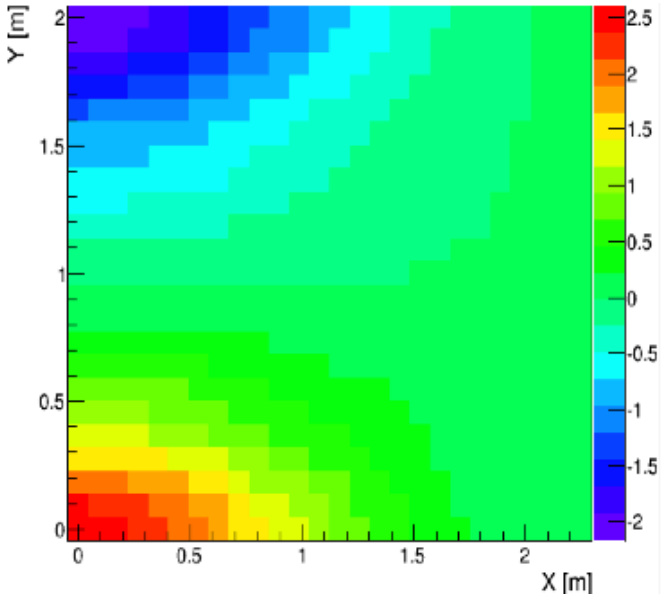
Timescale: months

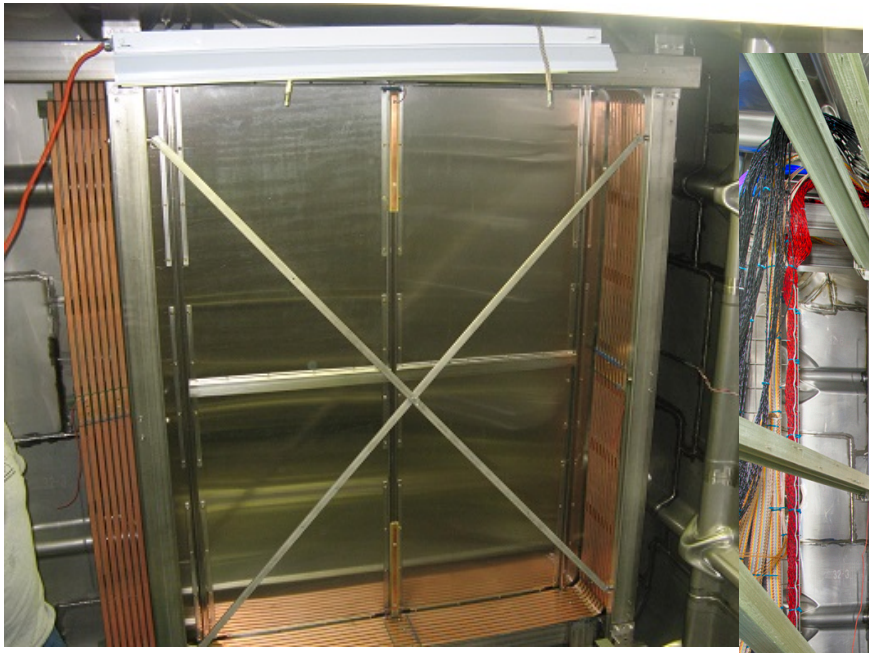
- Energy resolution and scale from Michel electrons, π^0 reconstruction, charged hadron residual range
- Scintillation light yield and ionization charge yield at varied drift fields
- Validate space charge model and field edge effects by measuring track distortions at varied drift fields (LBNE docdb 9587 and 10404)



Event display for simulated muon decay
Jonathan Insler, LSU

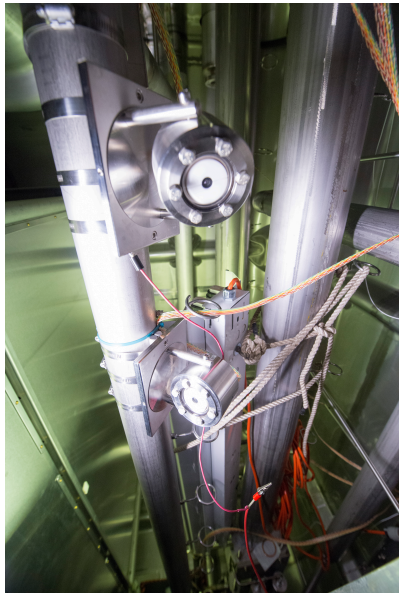
Predicted track distortions (cm) from space charge ion build up
Michael Mooney, BNL





Detector Installation

Sept-Nov 2015



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Component status

DAQ – ready for data taking!

Special thanks to all the shifters

- Read out all 3 sub-components together 13 days ago. Synchronization looks good, detailed checks ongoing.
- Zero Suppression is not yet ready to be implemented, possible first tests with DAQ at the end of this week. Final tuning requires an operating detector (all colde and HV on)
- Implementing different run configurations and calibration modes
- Still debugging trigger and optimizing data throughput rate

Amazing progress the last 8 weeks.

- Subsystem experts met three times a week to ensure that nothing fell behind schedule
- Everyone worked tirelessly through the holidays - Nuno Barros, Giles Barr, Matt Graham, Alan Hahn, Tim Nicholls, Erik Blaufuss, John Freeman, Kurt Biery
- Continual exercise of the DAQ by the shifters has been fundamental for finding problems and tracking reliability.

Component status

Cryogenic system - waiting for liquid argon, storage tank being filled this week. (slides to follow)

- November – installed pumps and piping inside cryostat, pressure tests required for safety approval, leak checking and fixing
- December – safety approval (many stages), piston purge of storage tank (LAPD) and 35ton, commissioned filtration system.
- January – purity monitors commissioned

Many thanks to Russ Rucinski, Mike Zuckerbrot, Fritz Schwartz, Terry Tope, Bryan Johnson, Bob Kubinski, Shreya Ponkia, Dan Markley, Alan Hahn

TPC – A few disconnected wires (2%), a few bad electronics channels, (3%), stuck ADC codes, a bit more noise than expected (50%). Nothing severe enough to compromise data quality.

PDS – One of 8 modules/bundles not connected inside cryostat. Others ready for liquid argon.

Lessons learned (dedicated talk Wed morning)

- Special attention is being paid to what works and what can be done better next time.
- Lessons learned are noted, documented and communicated to sub-detector working groups/managers

DUNE Document 913-v1

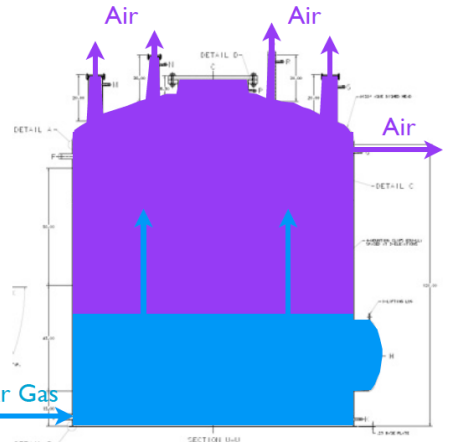
35ton Lessons Learned So Far

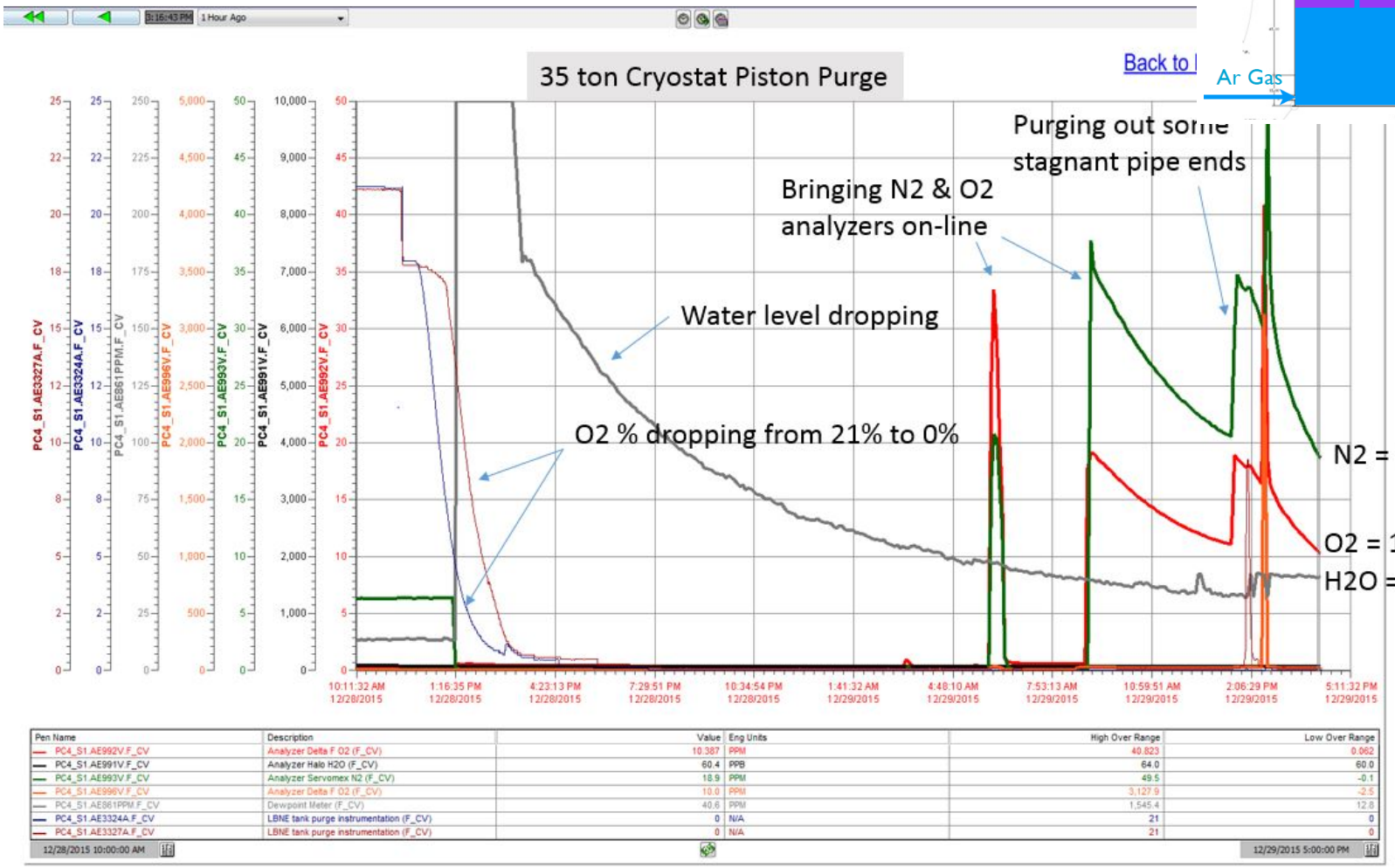
Abstract:
collection of lessons learned

Files in Document:

- APA winding, Lee Greenler (PSL) (APA Winding - Lessons Learned - LAr1ND Presentation o...pptx, 15.1 MB)
- Grounding and Shielding and Electronics Testing from L. Bagby and M. Johnson (lessons (002).pptx, 362.1 kB)
- Installation and Cabling from Jack Fowler, Lee Scott (2015-09-17- cabling comments from 35t.pdf, 181.8 kB)
- PDS data rate from Alex Himmel (FNAL) (2016-01-05-SSP-Data-Rate-Lesson-Learned.pptx, 56.7 kB)

Piston Purge of the 35ton: Dec 28-29

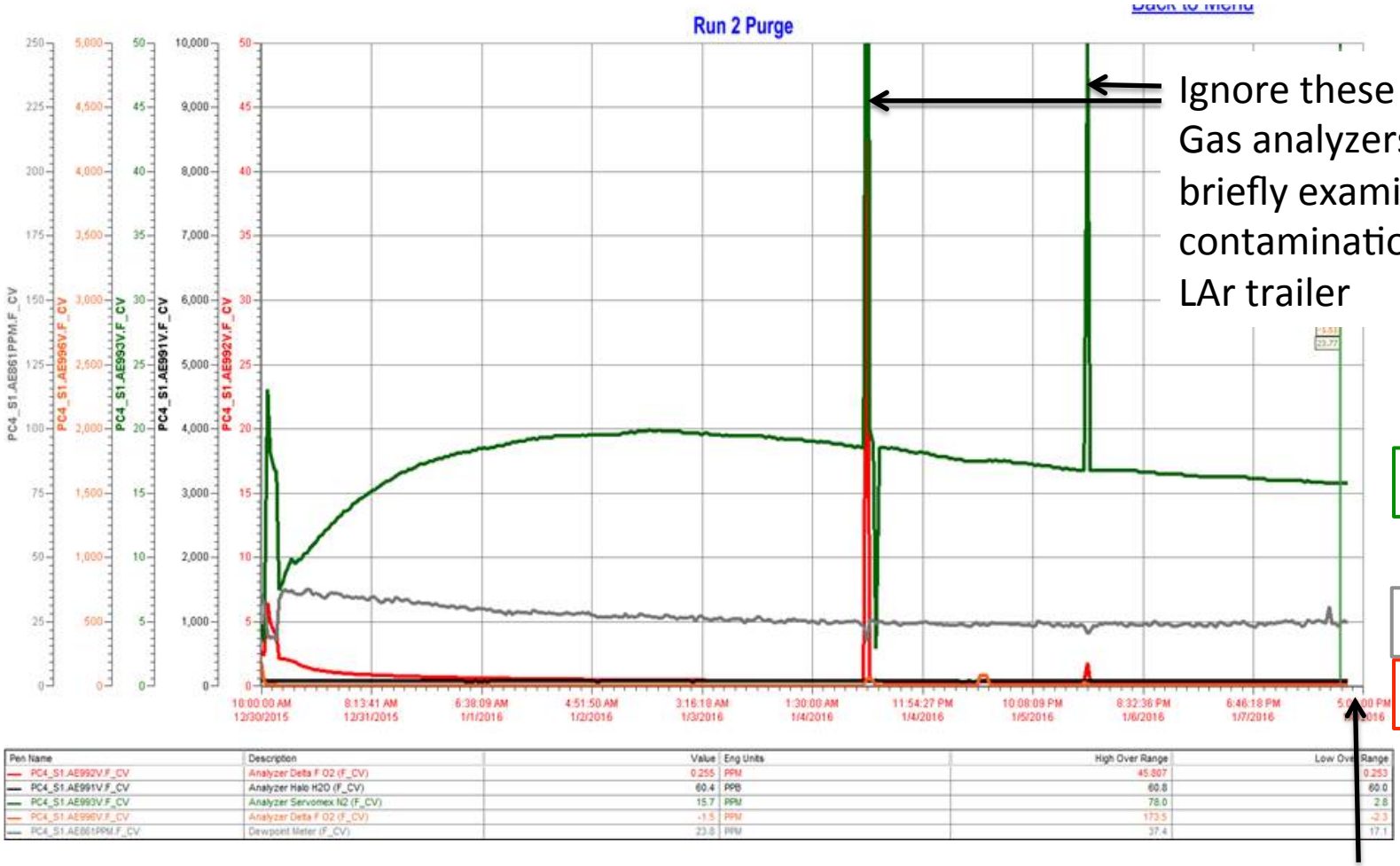




Pen Name	Description	Value	Eng Units	High Over Range	Low Over Range
PC4_S1.AE992V.F_CV	Analyzer Delta F O2 (F_CV)	10.387	PPM	40.823	0.062
PC4_S1.AE991V.F_CV	Analyzer Halo H2O (F_CV)	60.4	PPB	64.0	60.0
PC4_S1.AE993V.F_CV	Analyzer Servomex N2 (F_CV)	18.9	PPM	49.5	-0.1
PC4_S1.AE996V.F_CV	Analyzer Delta F O2 (F_CV)	10.0	PPM	3,127.9	-2.5
PC4_S1.AE861PPM.F_CV	Dewpoint Meter (F_CV)	40.6	PPM	1,545.4	12.8
PC4_S1.AE3324A.F_CV	LBNE tank purge instrumentation (F_CV)	0	N/A	21	0
PC4_S1.AE3327A.F_CV	LBNE tank purge instrumentation (F_CV)	0	N/A	21	0

12/28/2015 10:00:00 AM — 12/29/2015 5:00:00 PM

Gas Recirculation through filtration system: Dec 30 – Jan 8



Ignore these spikes. Gas analyzers were briefly examining contamination in the LAr trailer

N_2: 16 ppm

H_2O: 24 ppm

O_2: 0.2 ppm

Last Friday

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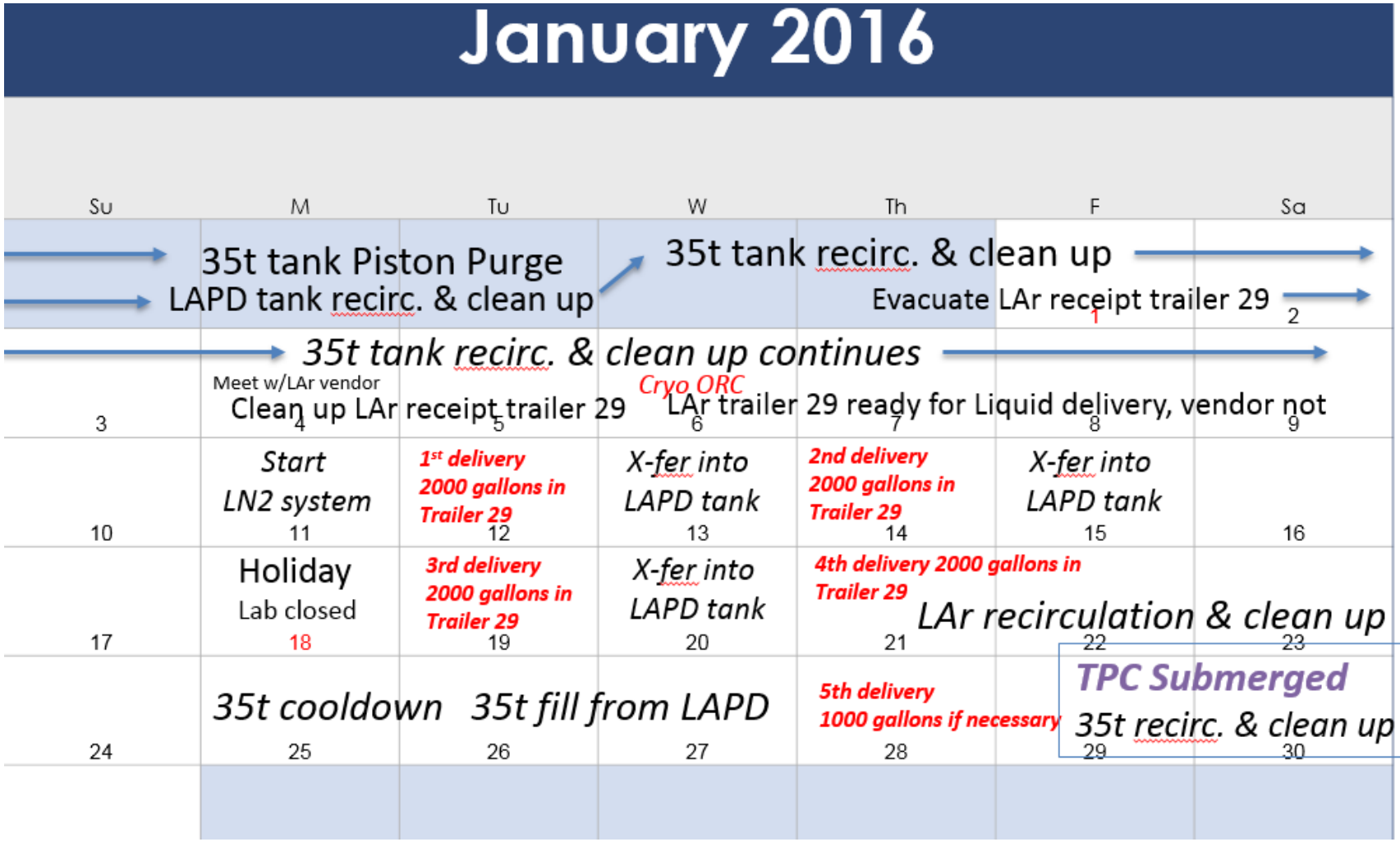
Cryo schedule . . . .



Run Plan

Start detector commissioning ~February 1
Expect 2-3 months for commissioning and data taking.

Basic running modes of the DAQ have been defined in part from planned measurements

Current list of commissioning studies and run plan:

https://cdcvs.fnal.gov/redmine/projects/35ton/wiki/Details

(slightly outdated as the bottleneck in DAQ throughput is now ~100 Mbytes/sec instead of 50)

An important part of run planning is keeping the data rate below the DAQ throughput limits. (lesson being learned!)

- Estimates of the Photon System data rate are in DUNE docdb 919
- Estimates of TPC data rate are in the wiki document.

Run Plan (assuming zero suppression)

Commissioning – February 1-28

Data taking: March 1-31

Week 1: data at 250 V/cm, low rate trigger that passes all horizontal-ish muons for studies.
S/N ratio, event time resolution, electron lifetime, space charge

Week 2: ramp field up in 50 V/cm steps. Data as above at each step.
Charge and light yield

Week 3: untriggered running at full field for high statistics measurements.
Muon decay, Michel electrons, PID for hadrons, π^0, space charge.

Week 4: low rate trigger, horizontal-ish muons, scan drift field. These data will have the best electron lifetime. Diffusion, electron lifetime, charge yield

Week 5-8 (April) : miscellaneous studies and buffer if things take longer than expected.

How do we know that we are taking good data?

Online monitoring – immediate
- ADC mean and rms (PDS, TPC)
- Count rates (external scintillation counters)
- Crude event display
- Wire plane transparency

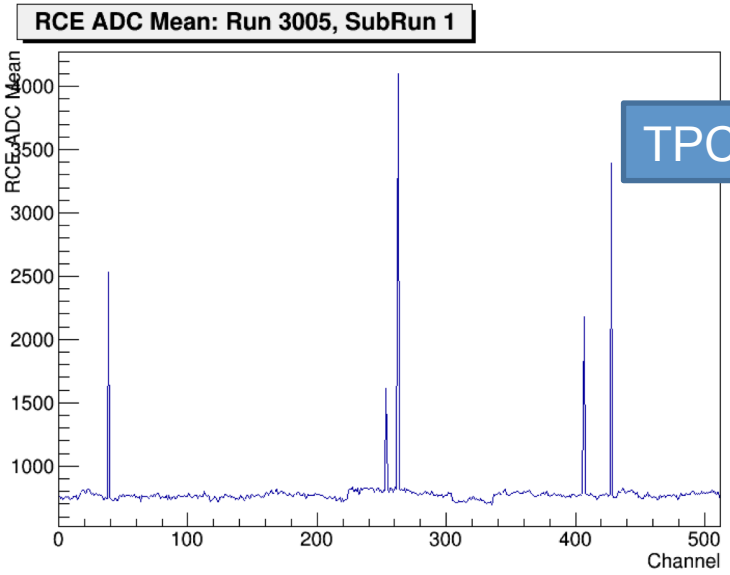
Much more needs to be added!

Near-line monitoring – 1-100 minutes – needs hit level reconstruction
- Argon purity from TPC data (LBNE docdb 10979, 11145)
- Timing t0-tpc (t0 from counters)
- Event display not yet
- Drift field / drift velocity not yet

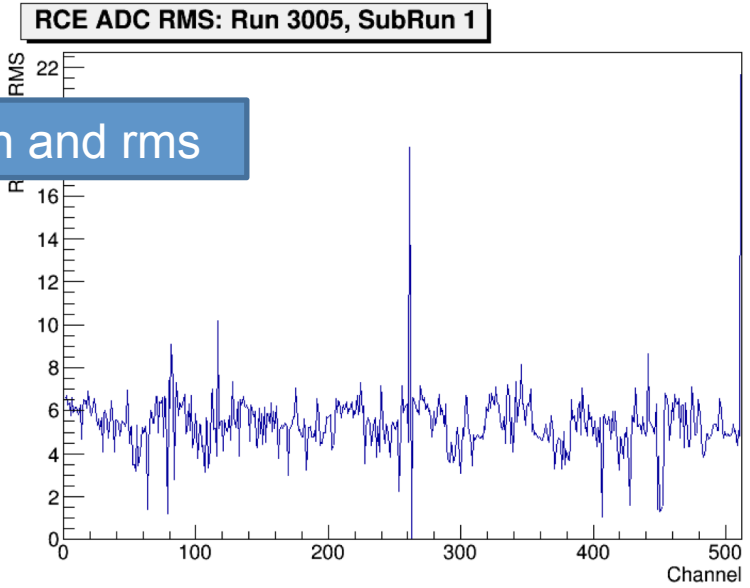
Offline monitoring – daily – needs full reconstruction chain, not even close
- External counter efficiency monitoring
- Through going muon rate
- . . . .

Online monitoring plots

Mike Wallbank, Sheffield

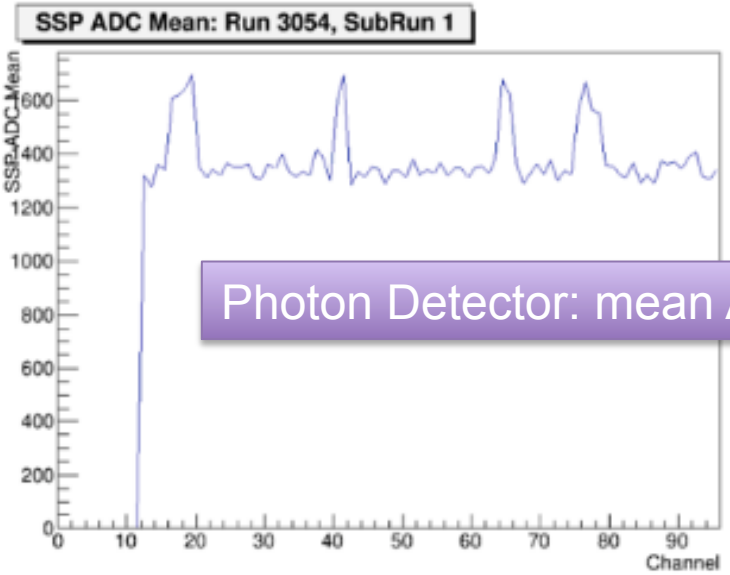


Mean ADC values for each channel read out by the RCEs (profiled over all events read)

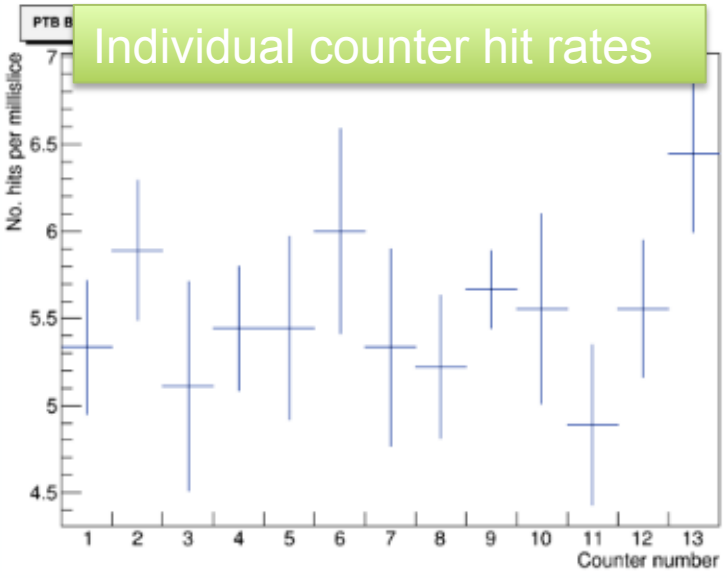


RMS of the ADC values for each channel read out by the RCEs (profiled over all events read)

TPC: mean and rms

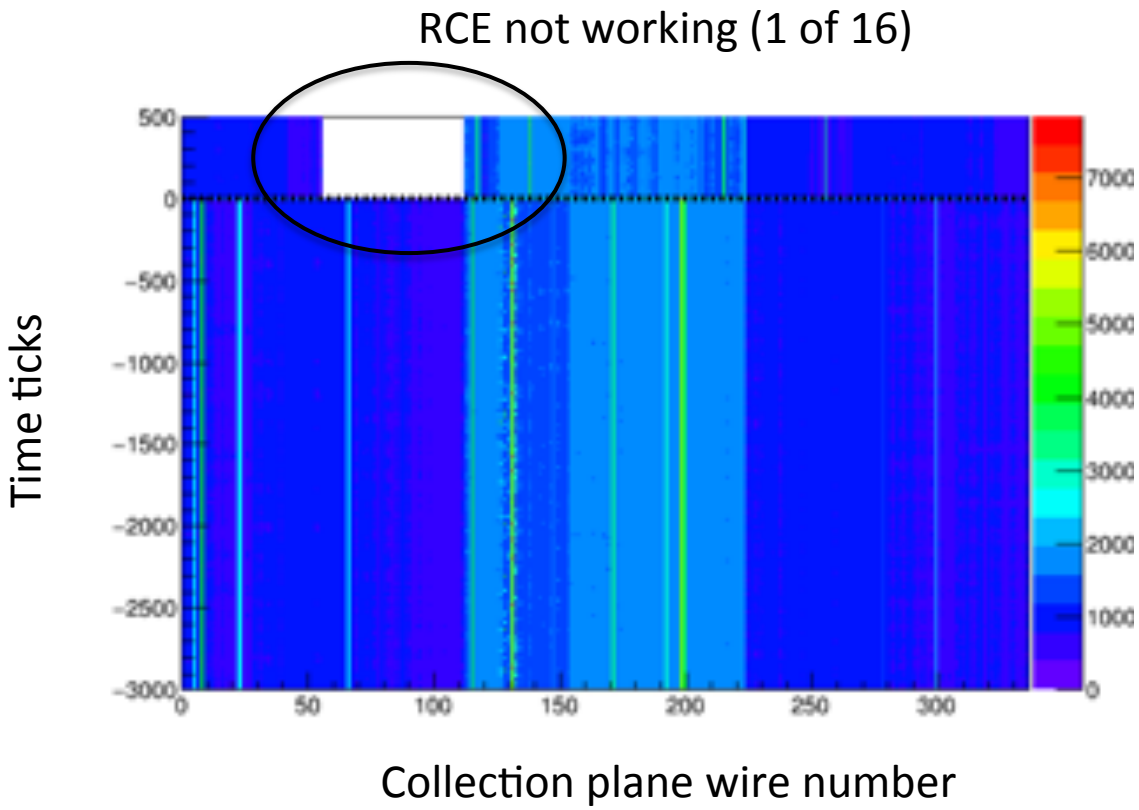


Photon Detector: mean ADC



Individual counter hit rates

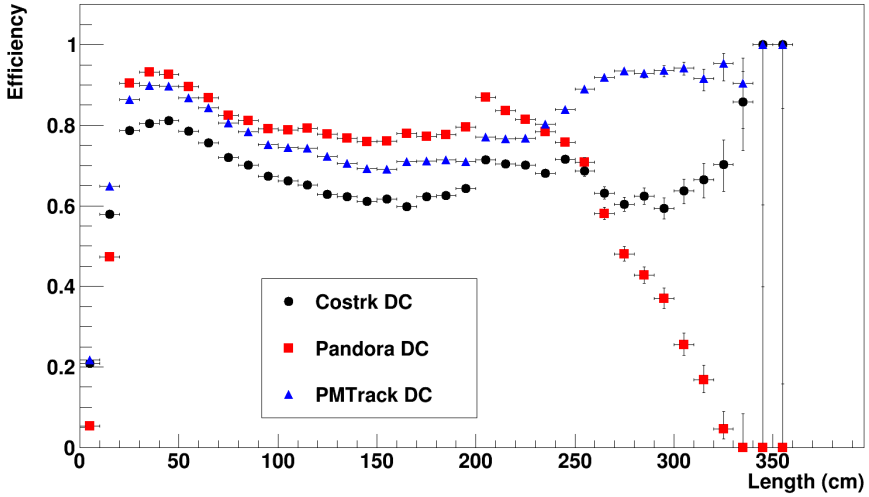
Crude online event display

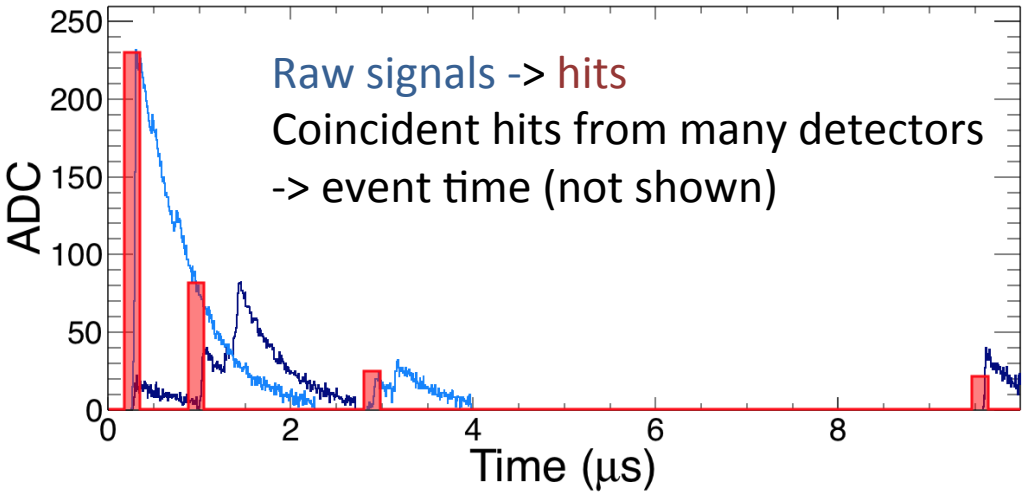


35ton Reconstruction is ready for data! (Sept 2015)

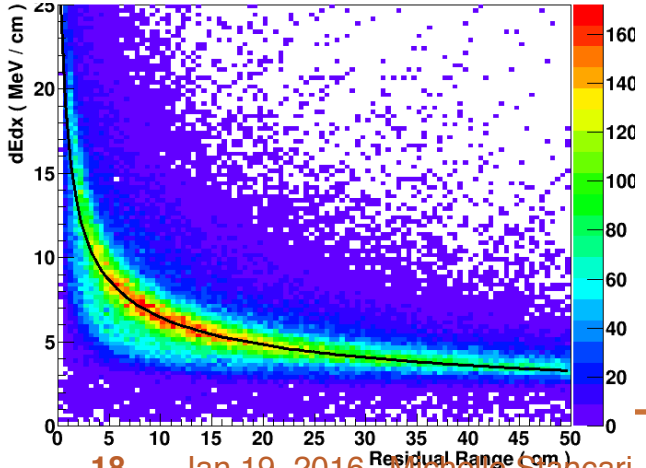
3 tracking algorithms

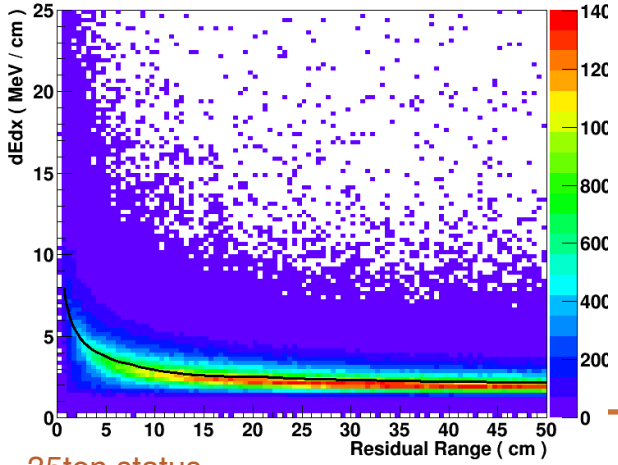
Event time from photon detector signals





Robert Sulej, Dorota Stefan, Tingjun Yang, Andy Blake, Alex Himmel, Gleb Sinev, Karl Warburton





Reconstructed dE/dx vs residual range for simulated protons (left) and muons (right).
Uses reconstructed event time from PD signals and PMA tracks as input.

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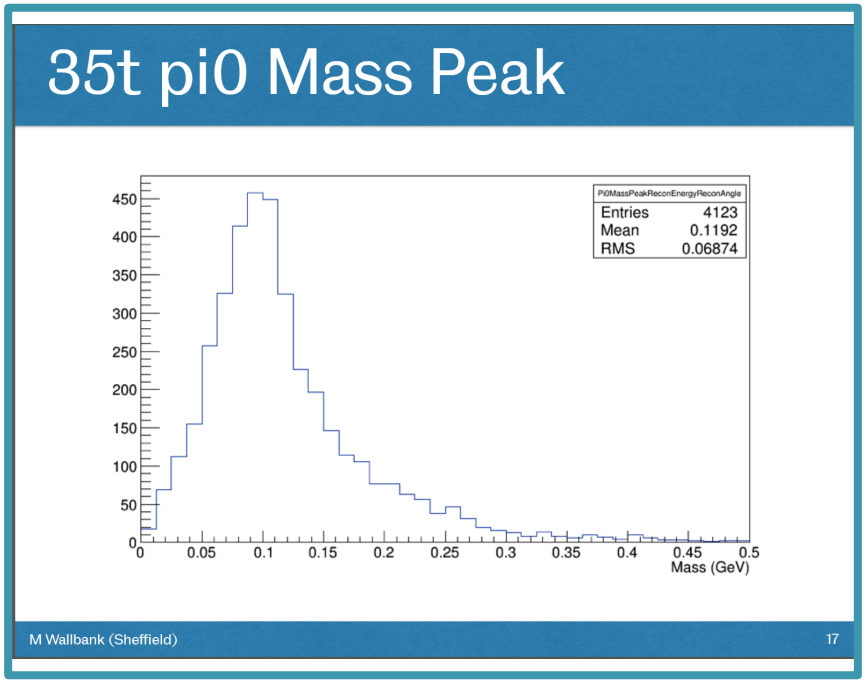
Status of simulation/reconstruction

- Tracks and PID ready to go since last summer
- Vertex and shower reconstruction now ready
- Currently tuning algorithms on simulated data with measured noise levels and known dead channels implemented

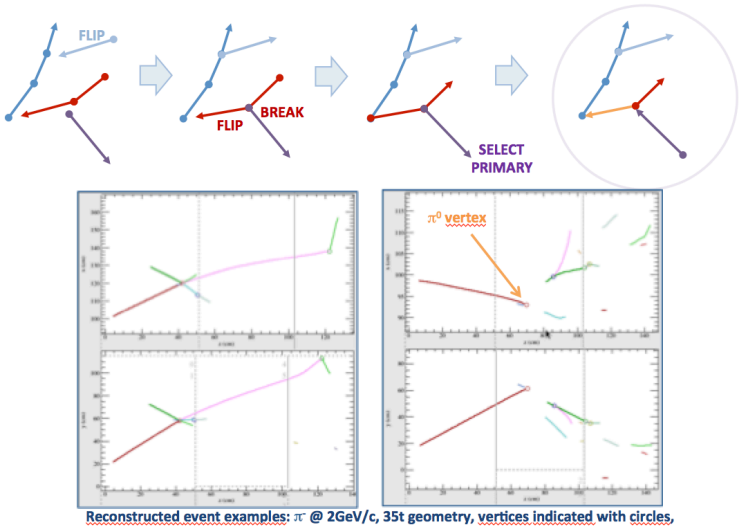


- Transition from simulated to actual data is keeping up with the the DAQ development, will have to scramble to get ready once the final data format is available. (See Event splitter/stitcher talk)

Shower, Vertex and π^0 Reconstruction!

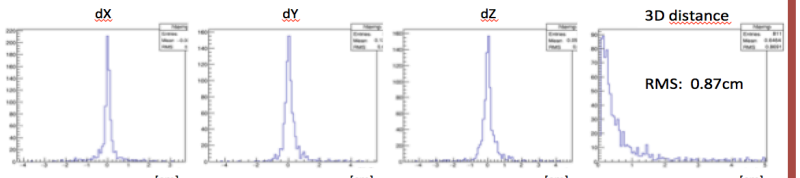
NEW!

Track-vertex structure building with Projection Matching Algorithm

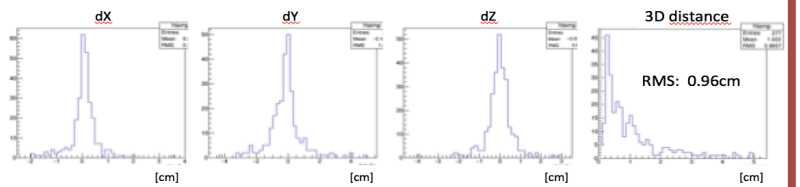


Reconstructed event examples: π^- @ 2GeV/c, 35t geometry, vertices indicated with circles, red track: incident particle.

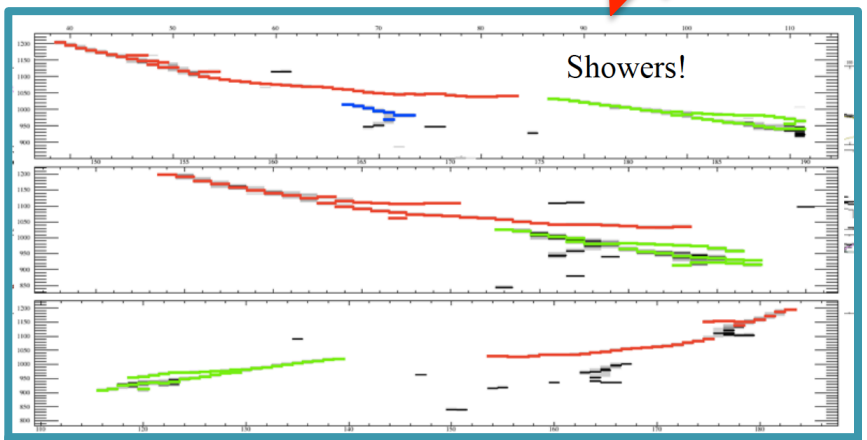
Vertex resolution for π^0 in the hadronic system and $\mu \rightarrow e$ decay



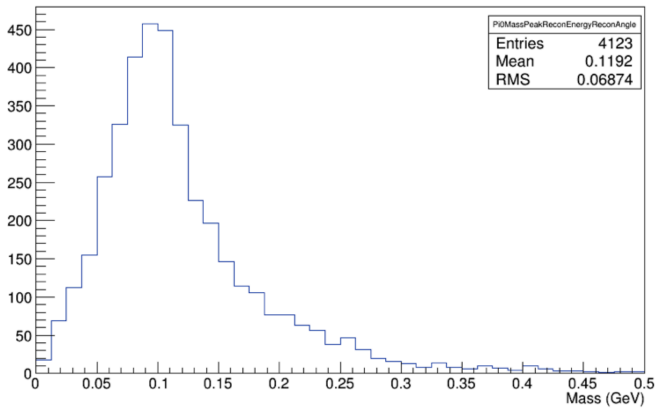
Distance of MC truth vertex with π^0 produced to the nearest vertex reconstructed in the hadronic system; fiducial volume cut is 1 cm from each TPC wall.



Distance of MC truth vertex with anti-μ decay to the nearest reconstructed vertex; fiducial volume cut is 1 cm from each TPC wall.



35t pi0 Mass Peak



M Wallbank (Sheffield) 17

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Shifts and Operations

Shifts . . .

- Planning to run day and evening shifts only
- Current schedule through March 31 is complete
- If we continue to run in April, need to recruit shifters from outside current pool or use local experts but significantly reduce shift workload
- Manpower to run beyond April is unlikely to materialize.

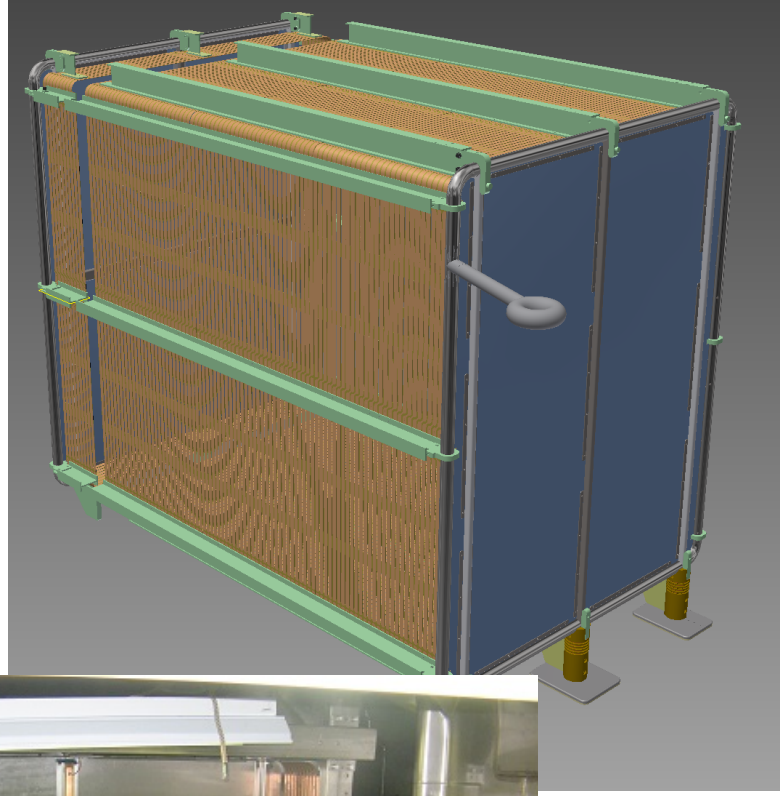
Operations

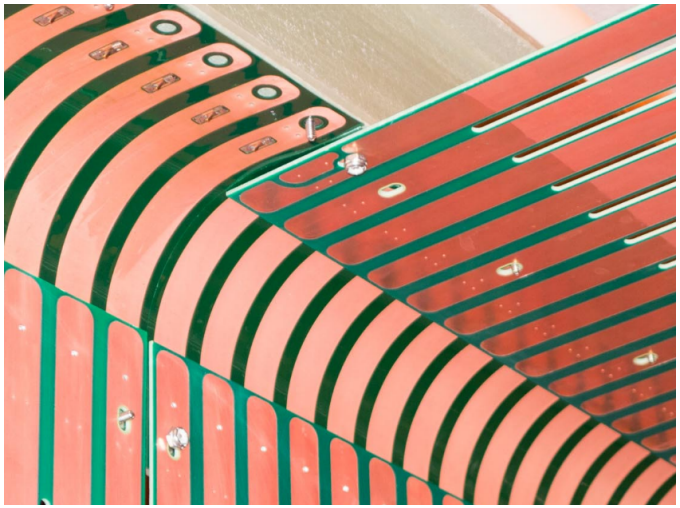
- Experts on call for various sub-systems
- Deputy run coordinator rotates every week among 8 people – 3 not available to continue in April
- Invaluable support from ARTDAQ team, Computing Division and Neutrino Division Ops Support Team
- Need more manpower for data transfer and data quality monitoring

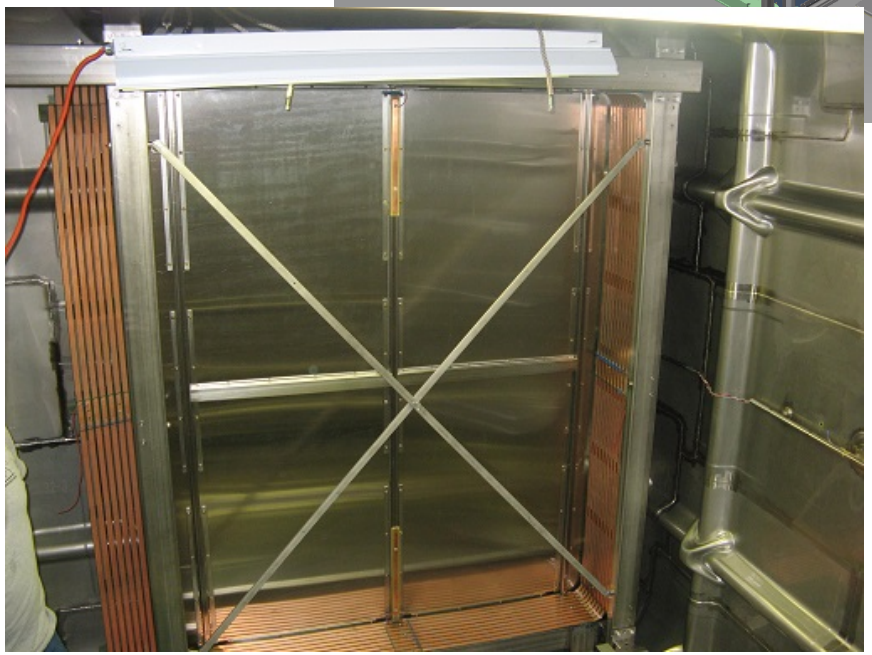
Backup Slides

Field Cage

- FR4 printed circuit board based construction.
- All edges of the copper strips are covered by solder mask to reduce high field exposure in LAr.
- Integrated inter-strip capacitors to minimize over voltage condition in a spark
- 0.2mm thick FR4 used for the rounded field cage corners.

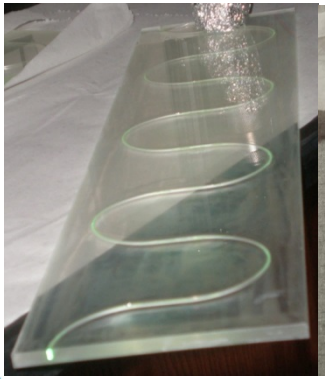


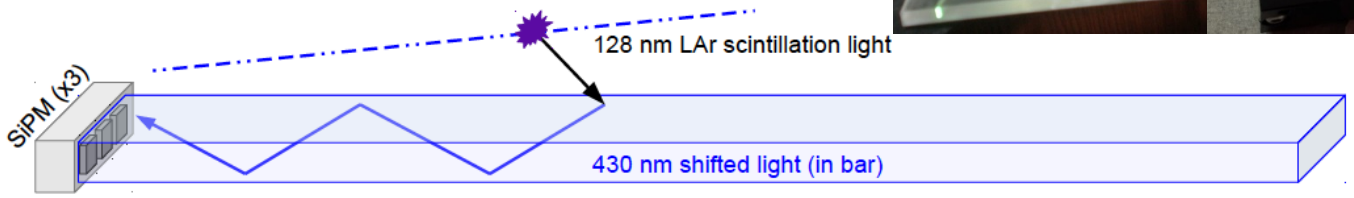




Photon Detectors

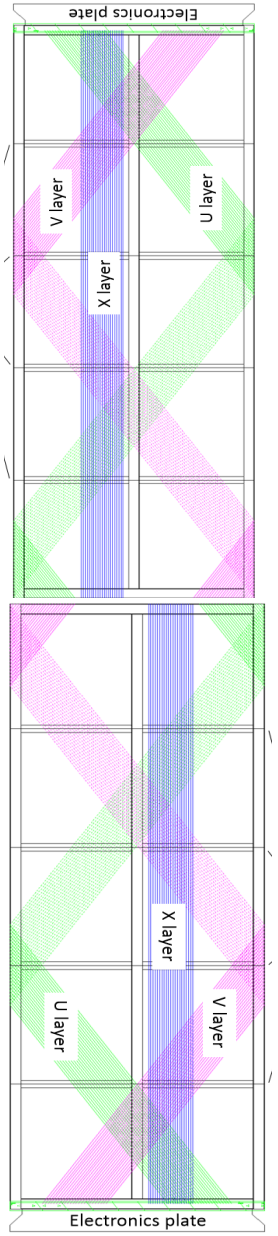
- First integrated test with a TPC
- Measure signal strength and shape for all track orientations and refine simulation
- Determine the event time resolution from the PD signals
- Study signals from Michel electrons, optimize small signal detection
- Verify/refine signal simulation algorithms
- First generation PDs





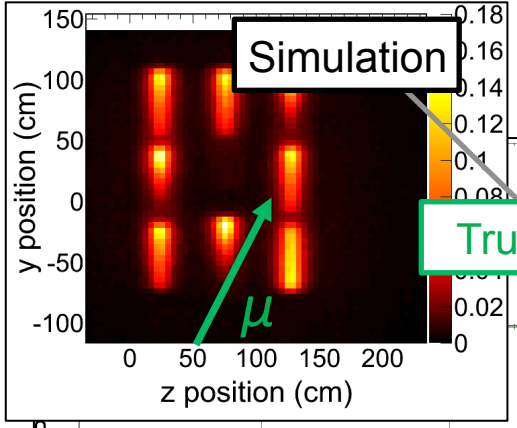
Modular TPC performance

- Reconstruct straight tracks across gaps
- Resolve the disambiguity of hits on wrapped wires
- Measure the distortion of the signal shape near the wire plane edges and gaps and refine simulation
- Develop calibration techniques utilizing tracks crossing the APAs and CPAs.

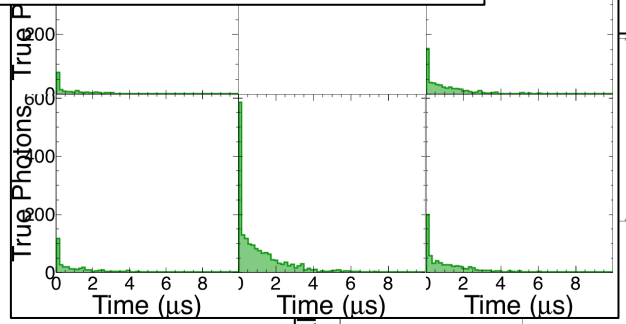


Photon Detector Simulation and Reconstruction

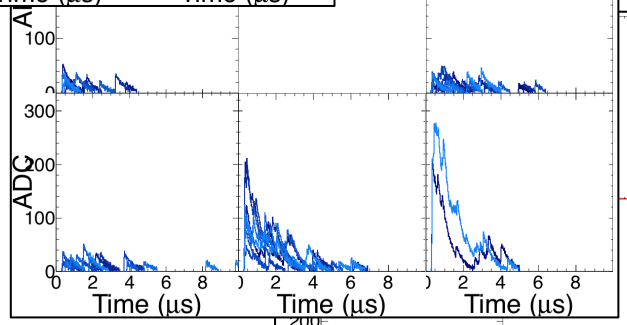
- The "full chain," from simulation to t_0 finding, now running
- Prepared for 35ton, but applicable to FD as well



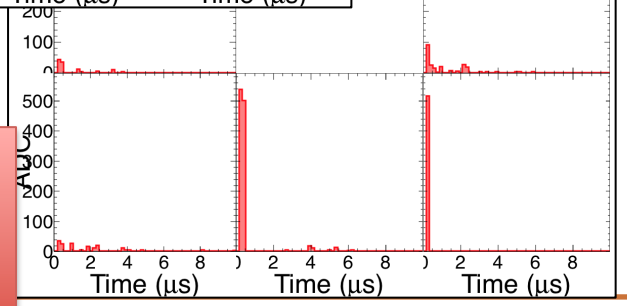
True Photons



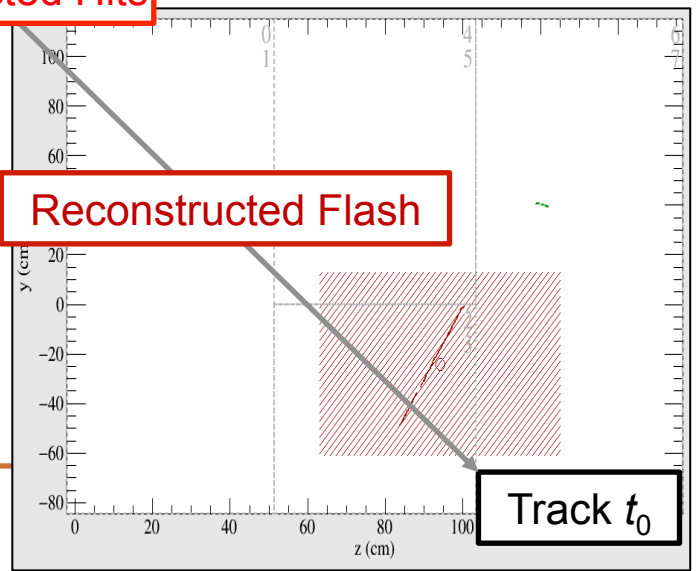
Digitized Waveforms



Reconstructed Hits



Reconstructed Flash

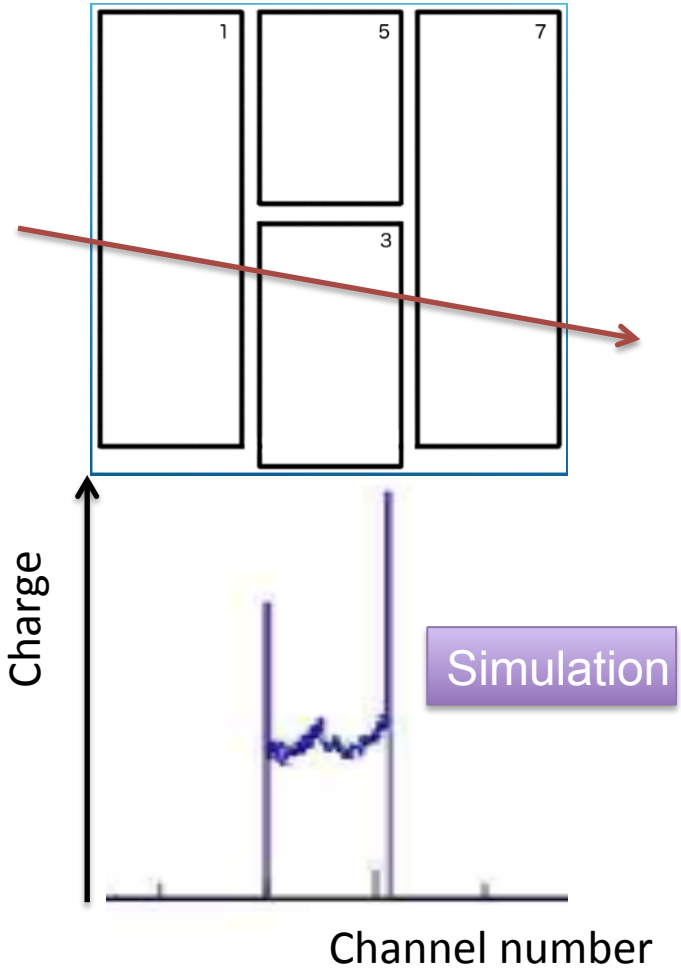


Track t_0

Gleb Sinev, Duke
Karl Warburton, Sheffield
Alex Himmel, Fermilab

How to measure charge loss in APA gaps

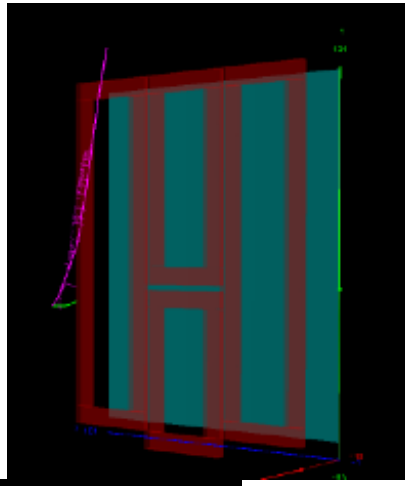
- Trigger on horizontal-ish muons
- Determine the gap width that makes track segments line up
- Use dE/dx and gap width to calculate how much charge was deposited in the gap. Look for excess charge on (collection plane) end wires.
- Play with voltages on the electrode in (one of the) gaps to push electrons toward the edge wires



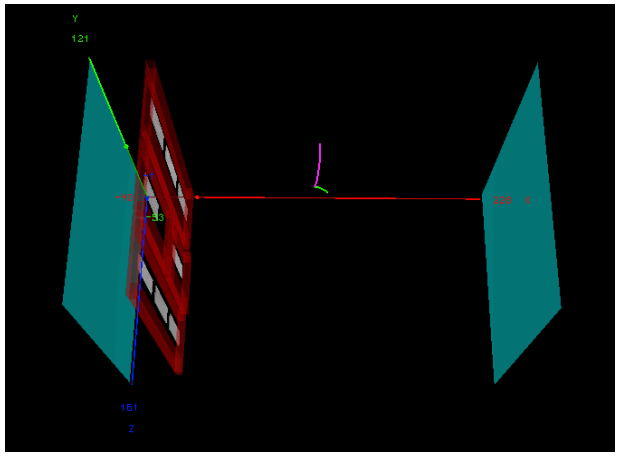
We have software that does this now!
See talk by Tristan Blackburn, Sussex

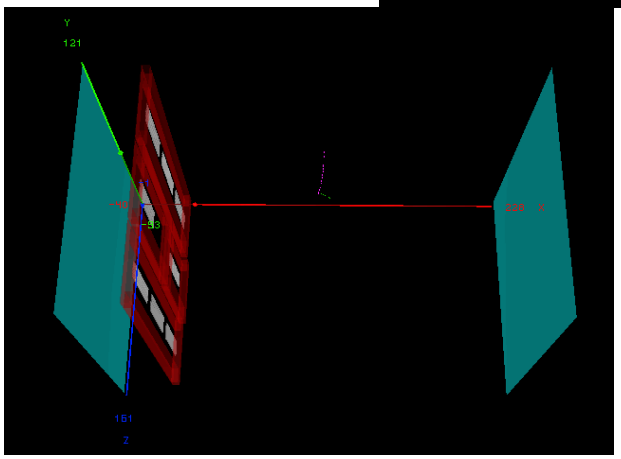
Stopping Muon Event Reconstruction

- Software filter: require containment in the central upper TPC, 95% purity and 6% efficiency. (<4 hits outside, >18 hits inside)
- Special raw hit finder developed for monitoring

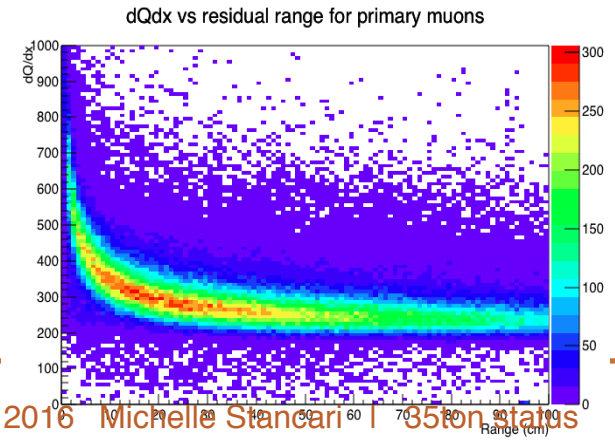


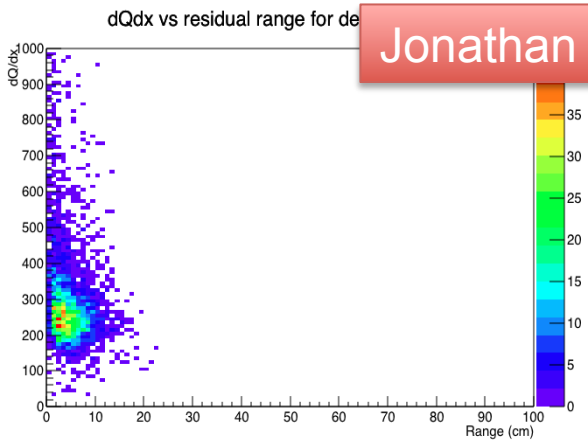
MC Truth stopping muon and decay electron





Reconstructed stopping muon and decay electron, PMA tracker





Jonathan Insler, LSU