Status of NOvA

NuMI Off-axis ν_e Appearance

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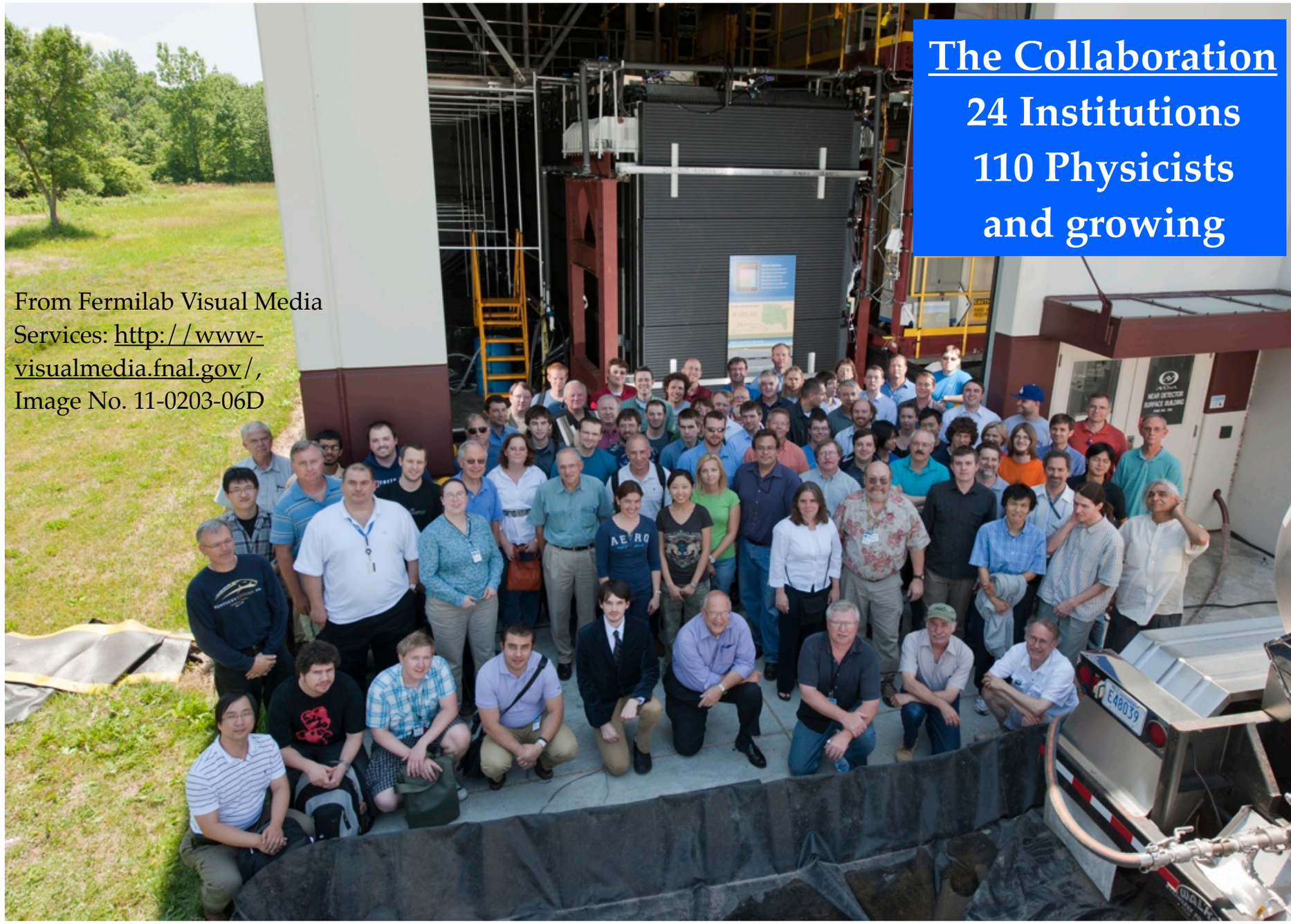
Advances in Neutrino Technology
Philadelphia, PA - 2011 Oct. 10

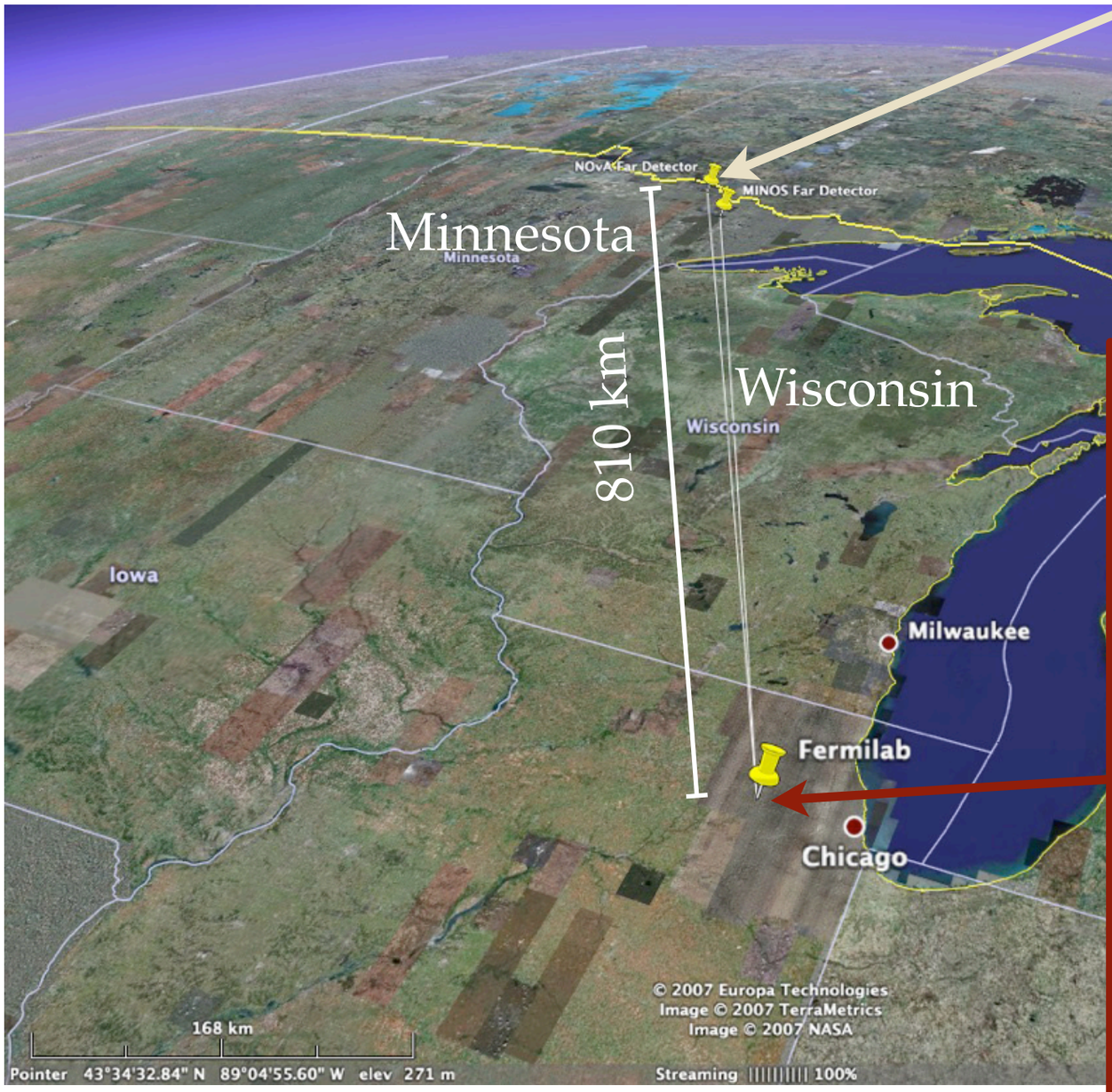
Outline

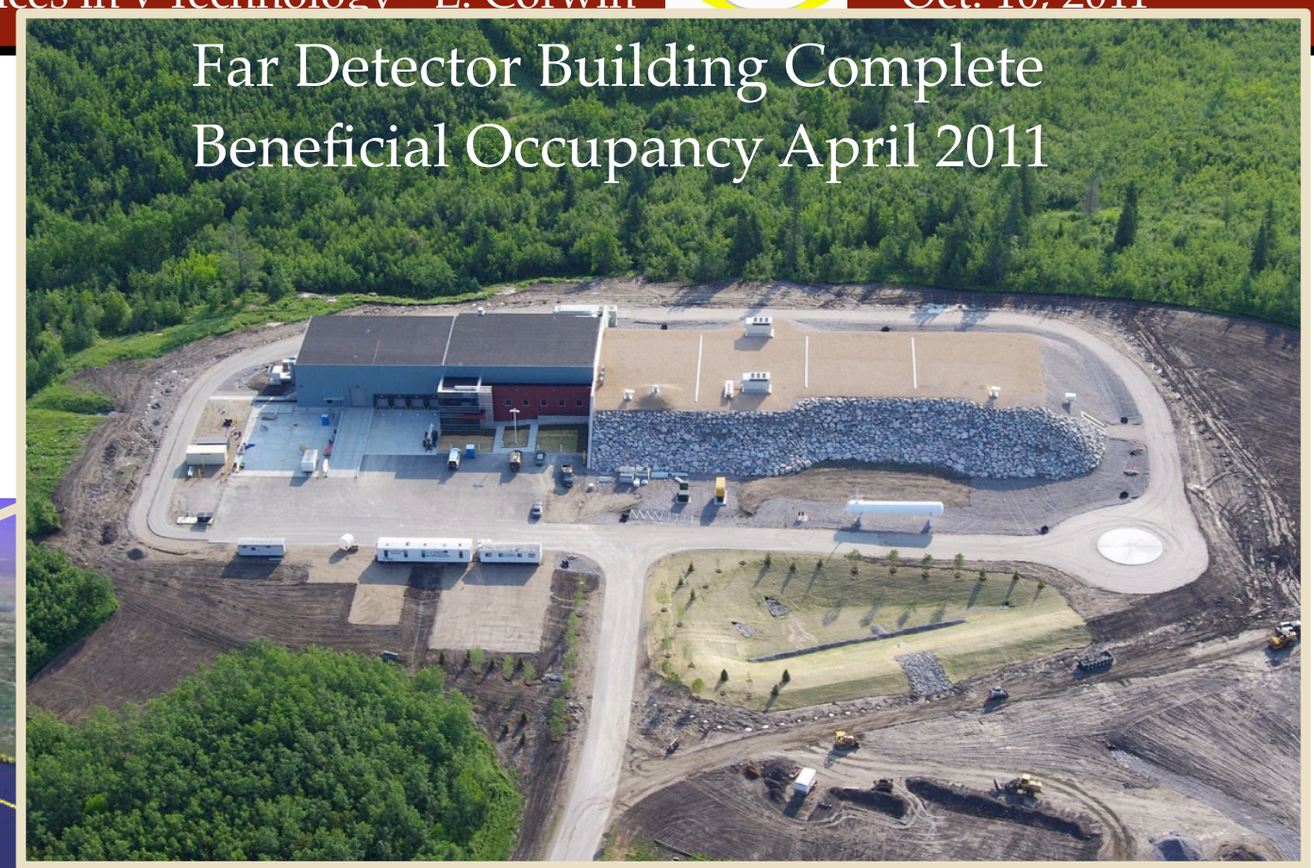
- Brief Experimental Overview
- Scintillator
- **PVC Extrusions**
- **Avalanche Photodiodes (APDs)**
- Schedule

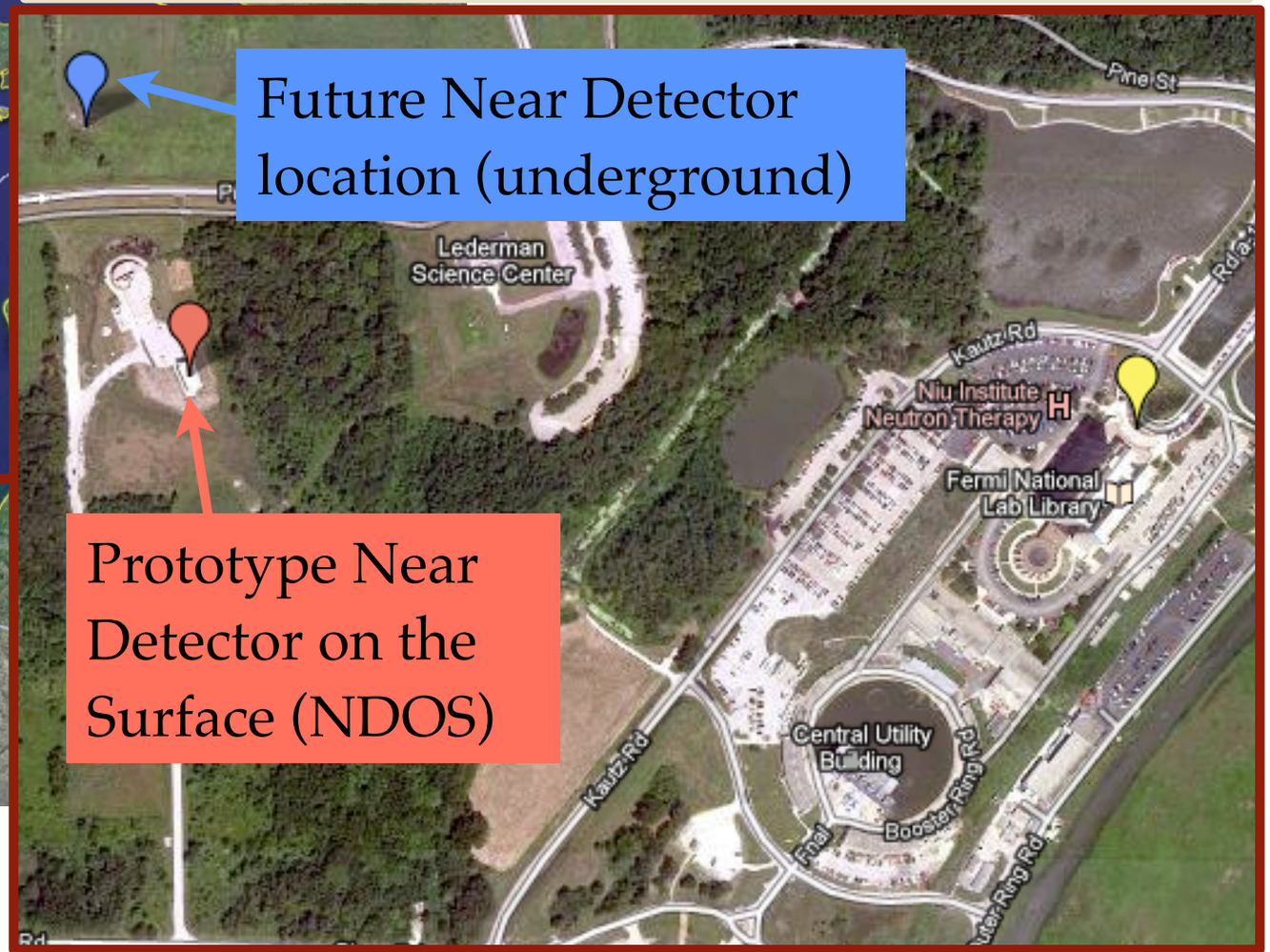


ANL, Athens, Caltech, Institute of Physics of the Czech Republic, Charles University, Czech Technical University, FNAL, Harvard, Indiana, Iowa State, Lebedev, Michigan State, Minnesota/Duluth, Minnesota/Twin Cities, INR Moscow, South Carolina, SMU, Stanford, Tennessee, Texas/Austin, Tufts, Virginia, WSU, William and Mary

NOvA Experiment Overview

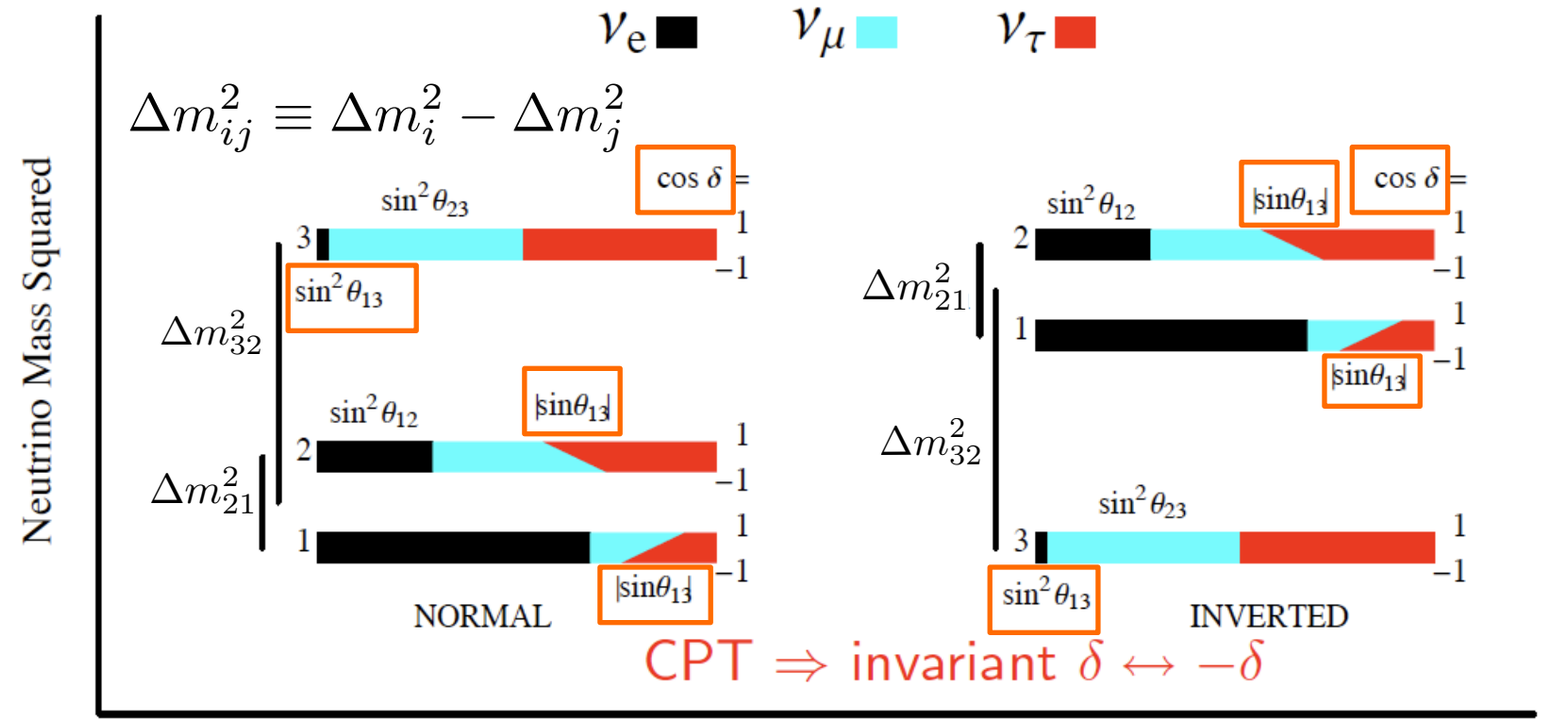


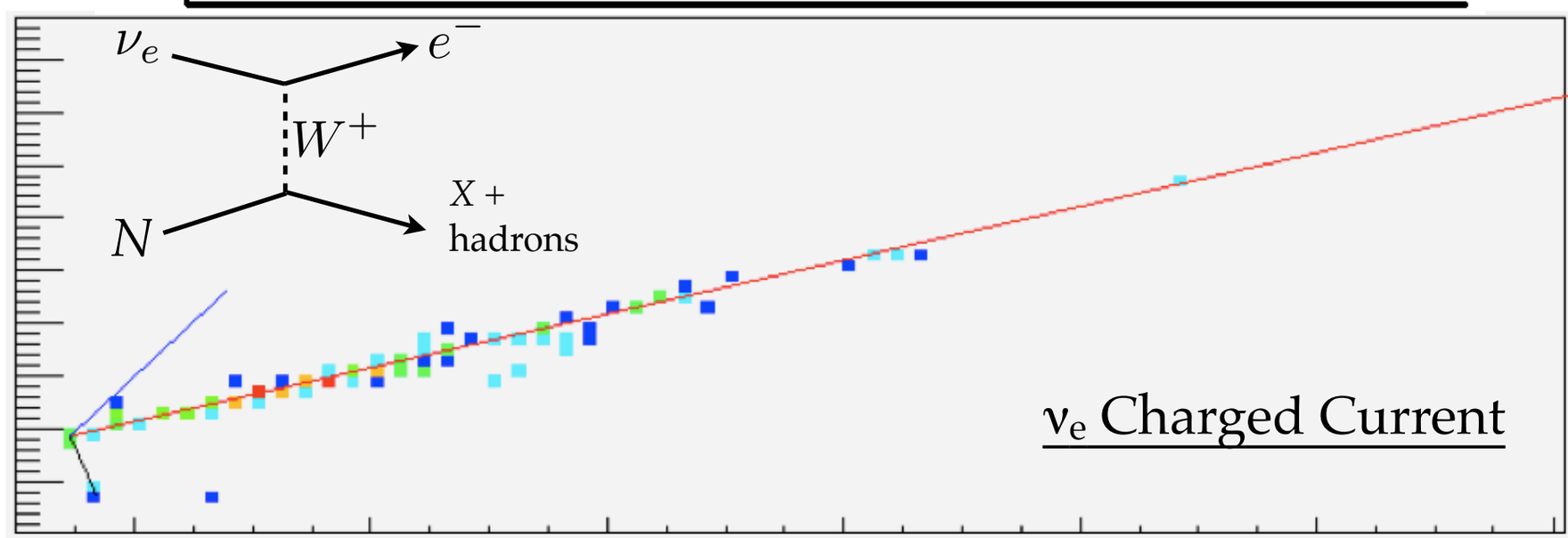


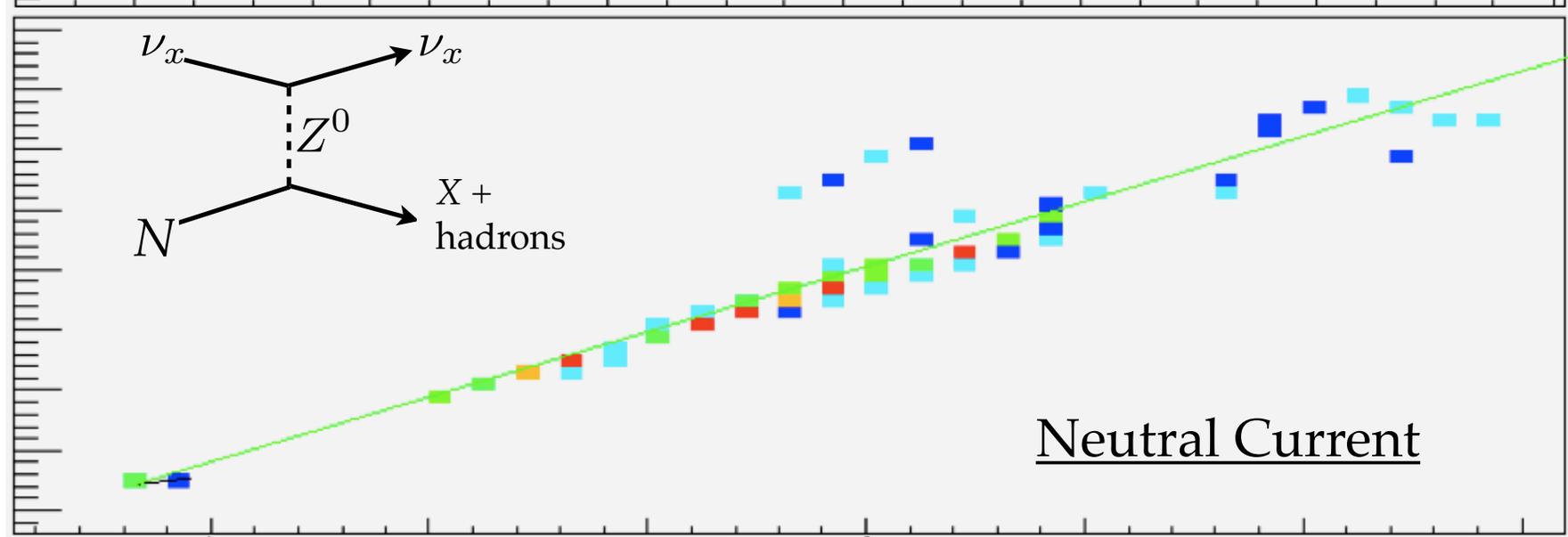


Physics Goals

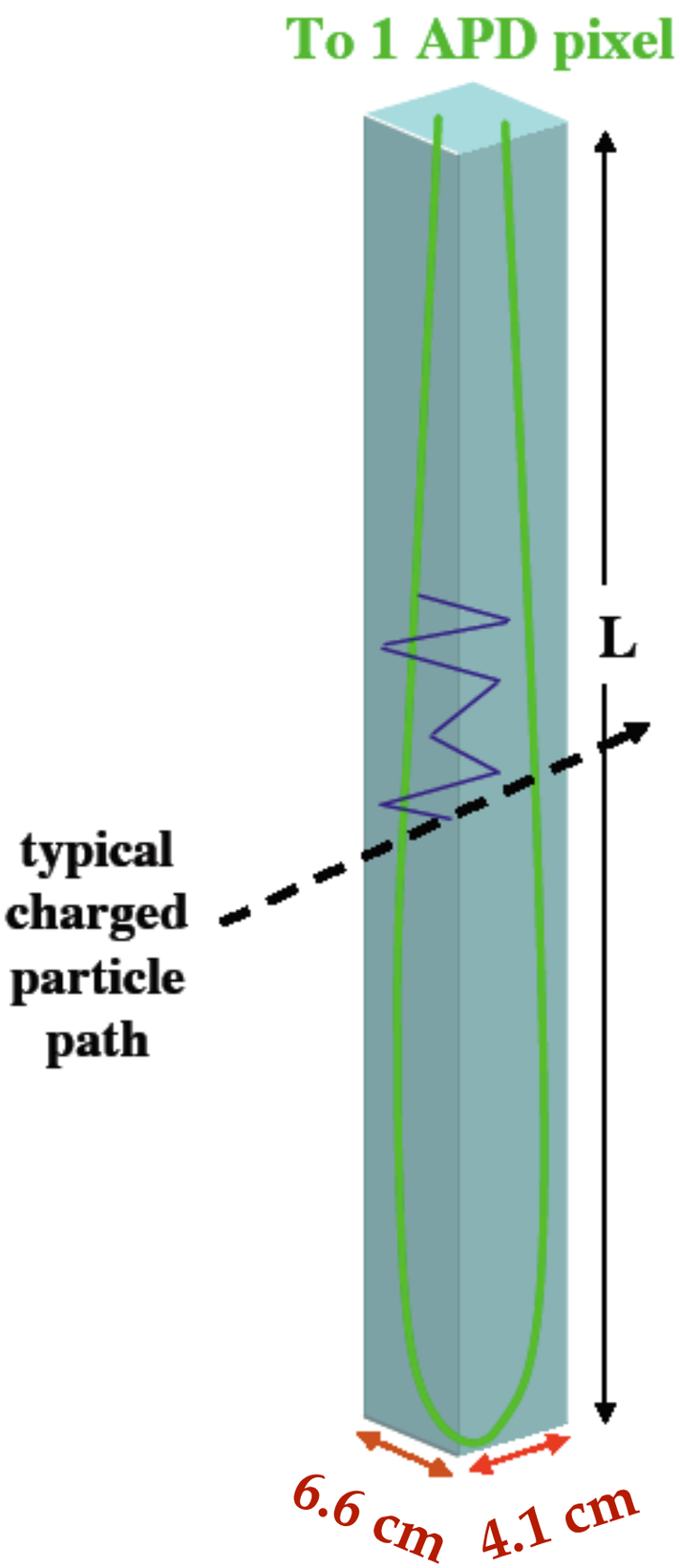
- Observe ν_e Appearance
  - Measure θ_{13}
  - Determine Mass Hierarchy
  - Measure δ_{CP}
- Need high resolution (low density) and high mass

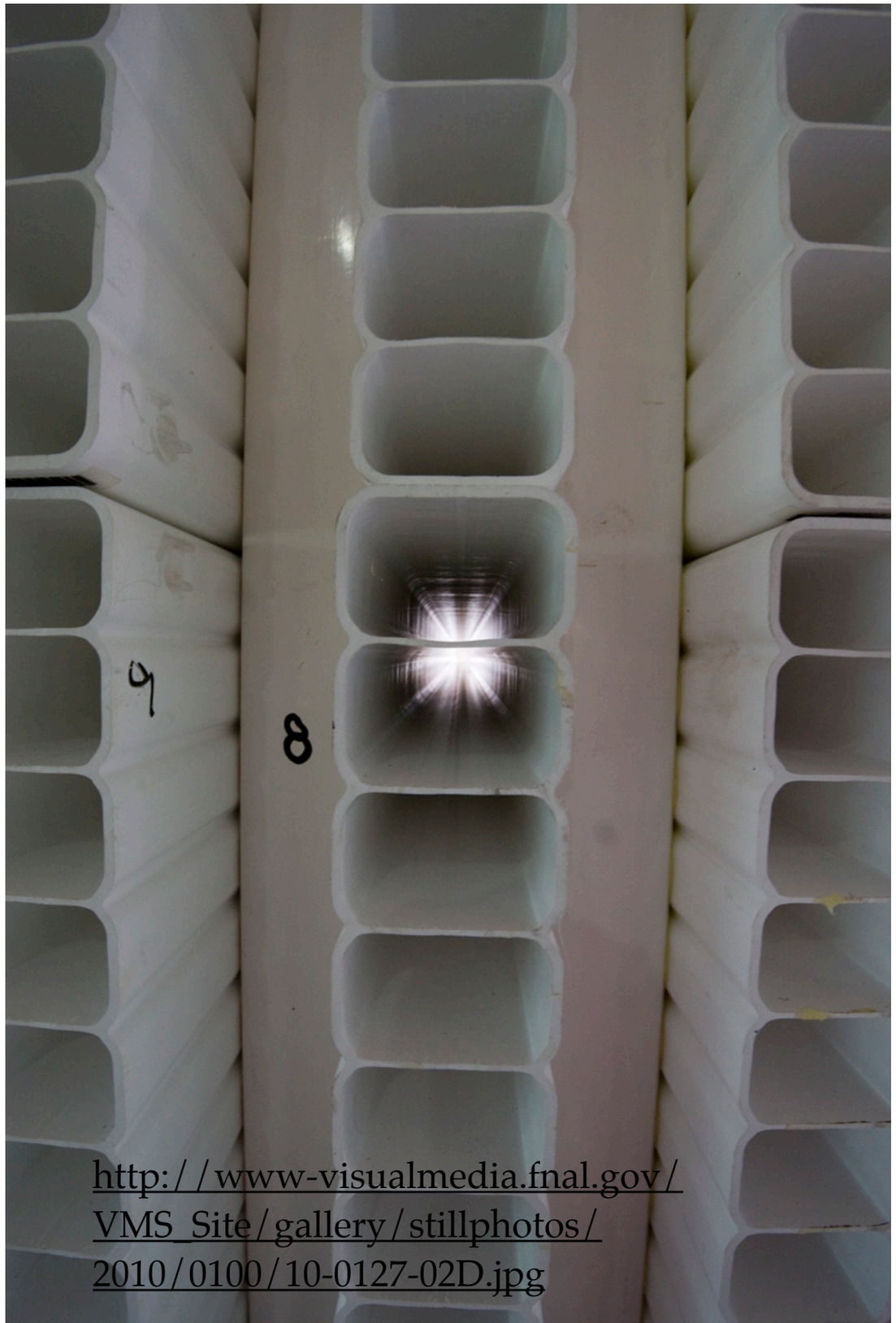






Detector Elements



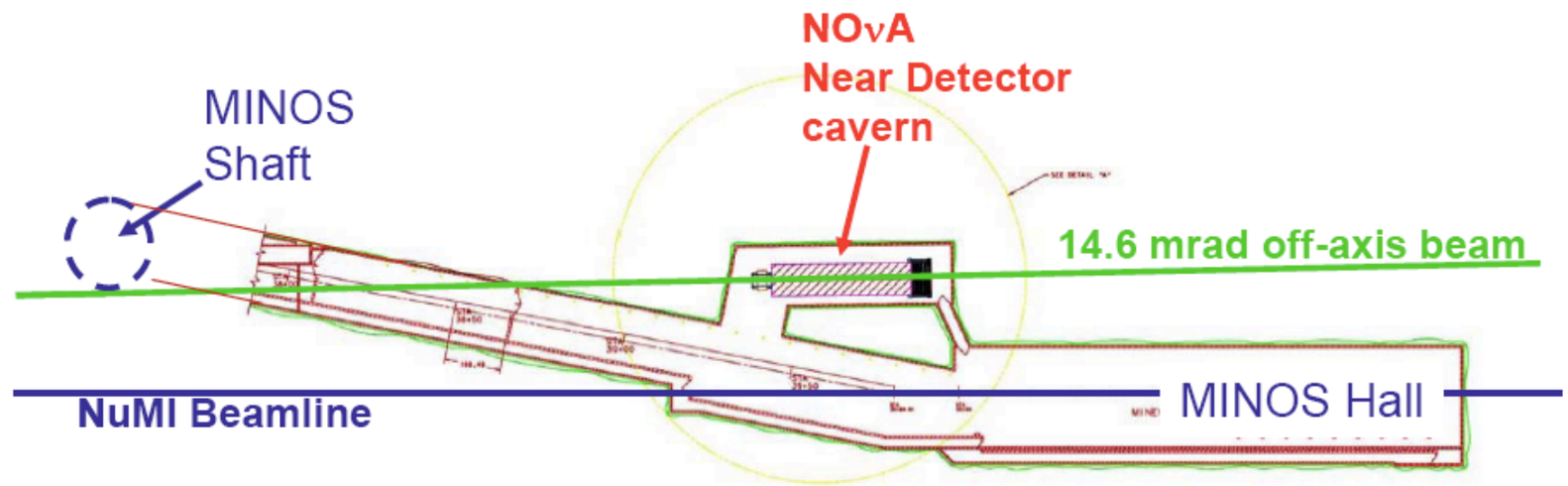


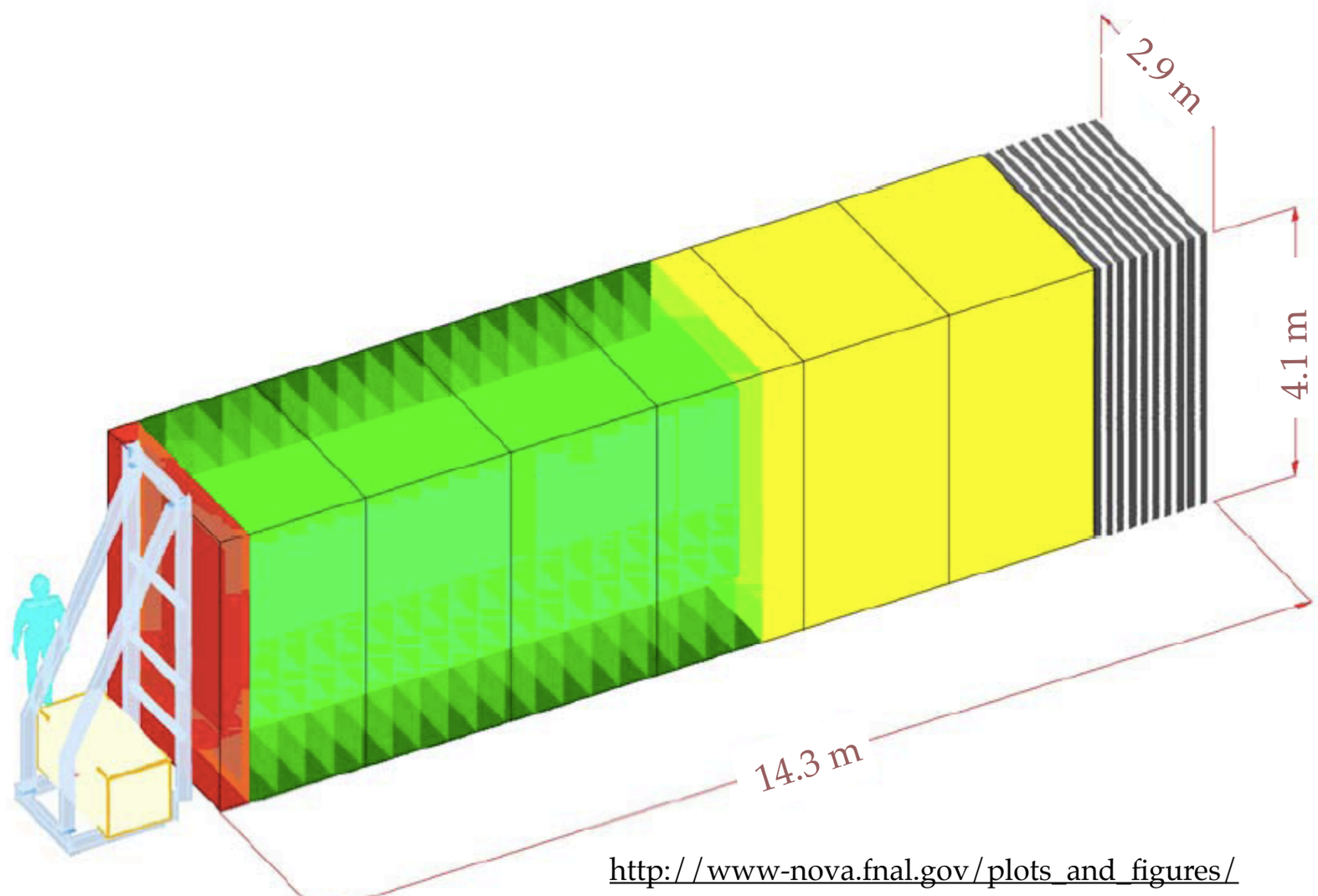
http://www-visualmedia.fnal.gov/VMS_Site/gallery/stillphotos/2010/0100/10-0127-02D.jpg

- PVC Cells are filled with liquid scintillator and grouped into alternating planes

Near Detector

- 220 tons
- Will be placed in a new cavern attached to the current MINOS cavern
- Characterize beam before oscillations





http://www-nova.fnal.gov/plots_and_figures/

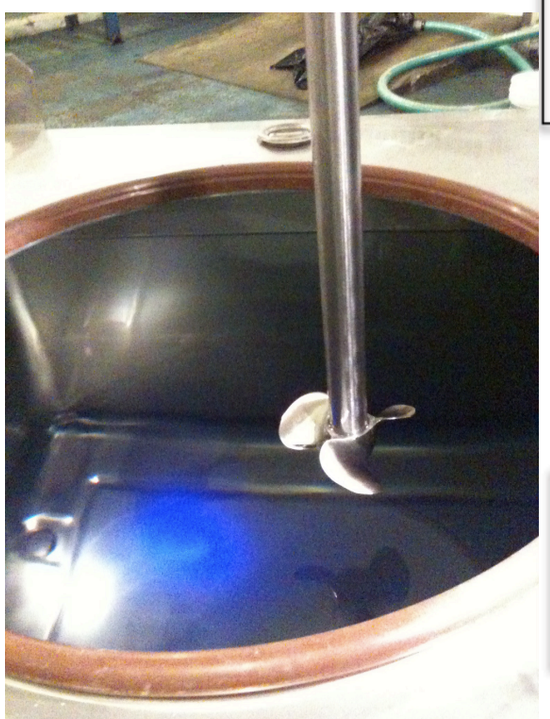
Far Detector Building

Near Detector On the Surface (NDOS)

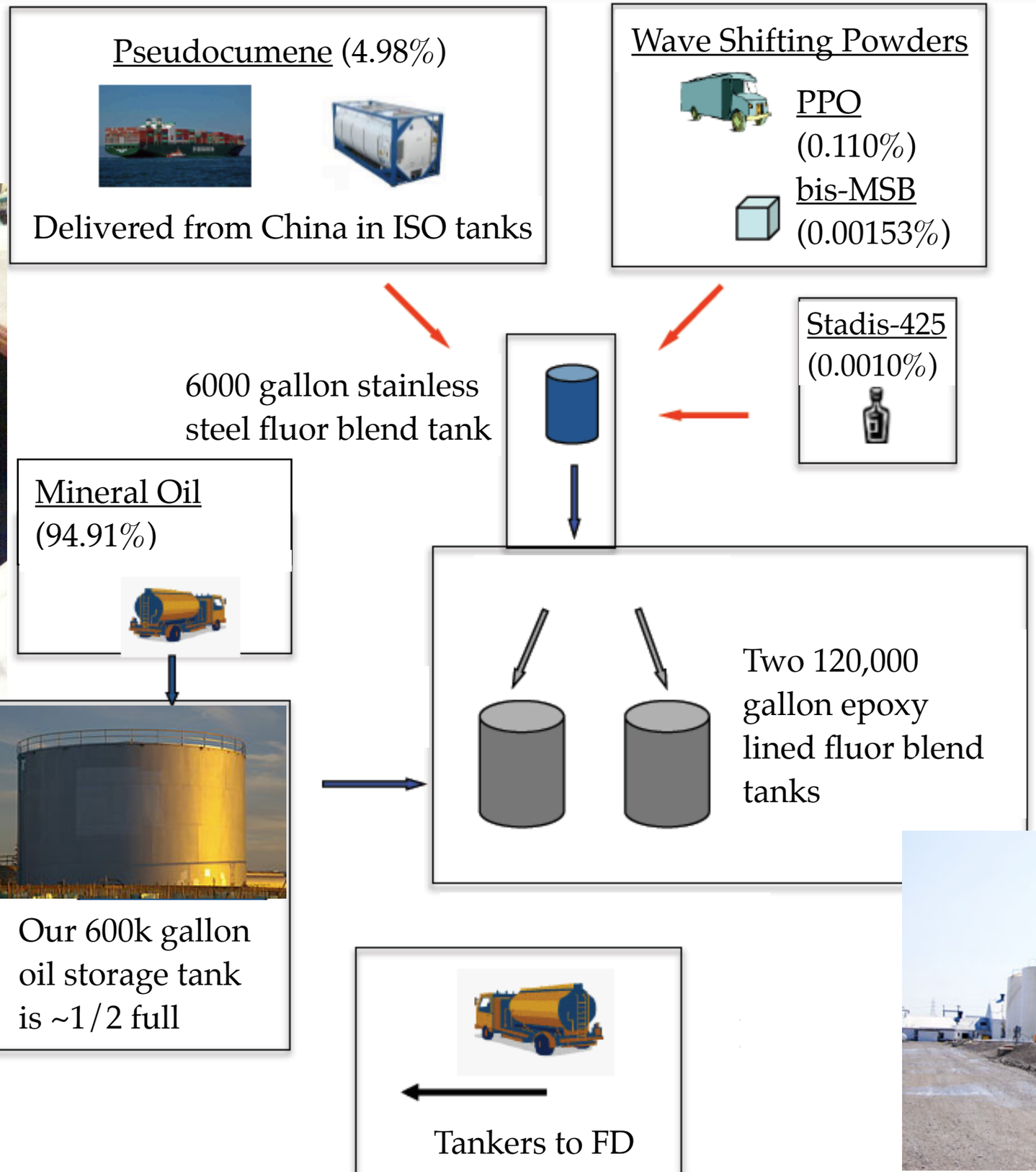
- **Prototype** built to the original design of the near detector
- Instrumented, operational and taking data for 1 year
- Results
  - Taught us many lessons
  - Several design and procedure change
  - No broken fibers


From Fermilab Visual Media Services: http://www-visualmedia.fnal.gov/, Image No. 11-0124-13D

Mixing The Scintillator (3×10^6 gallons)



storage tank cleaned and holding our oil

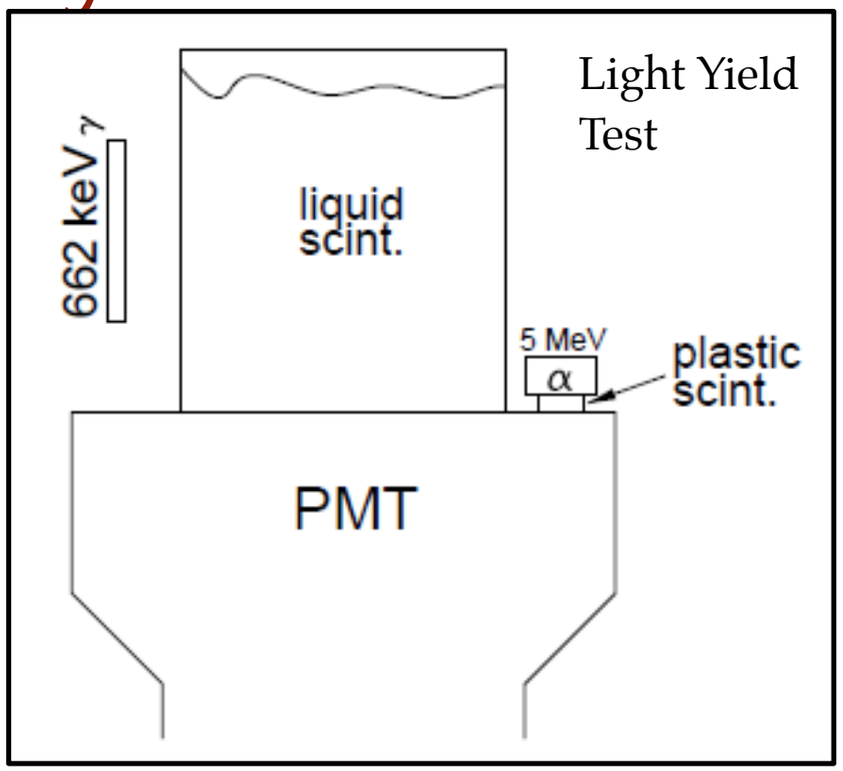


Have enough of everything except mineral oil and pseudocumene for far detector

Hired private contractor (Renkert Oil) to deliver mineral oil and mix ingredients

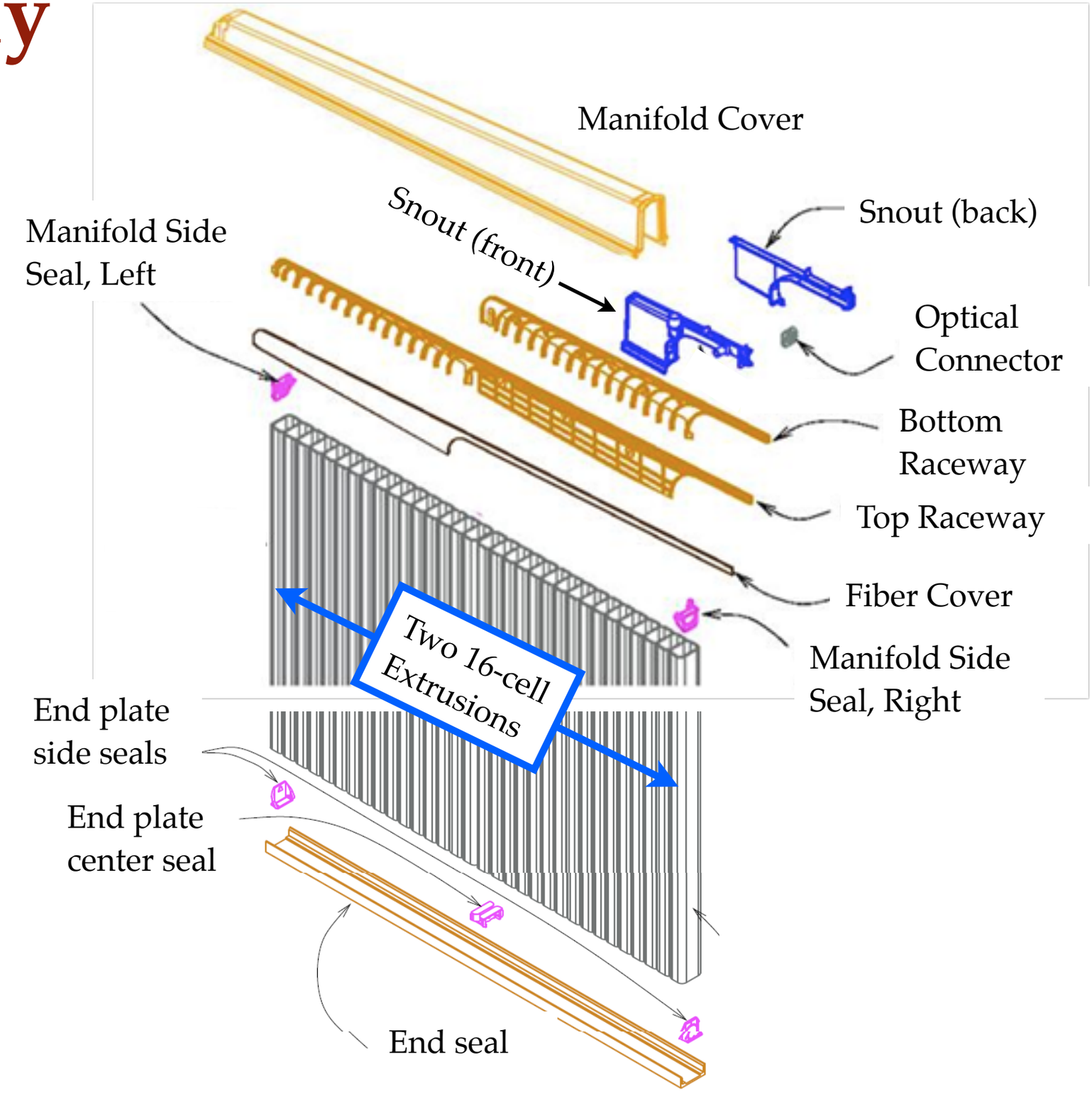
Scintillator Quality Control

- Light Yield
  - Use radioactive sources to verify sufficient scintillator light
- Clarity tested using a commercial tintometer
  - UV spectrophotometer
- Verify correct chemical composition.
  - Done at Indiana Univ. Chemistry Dept.



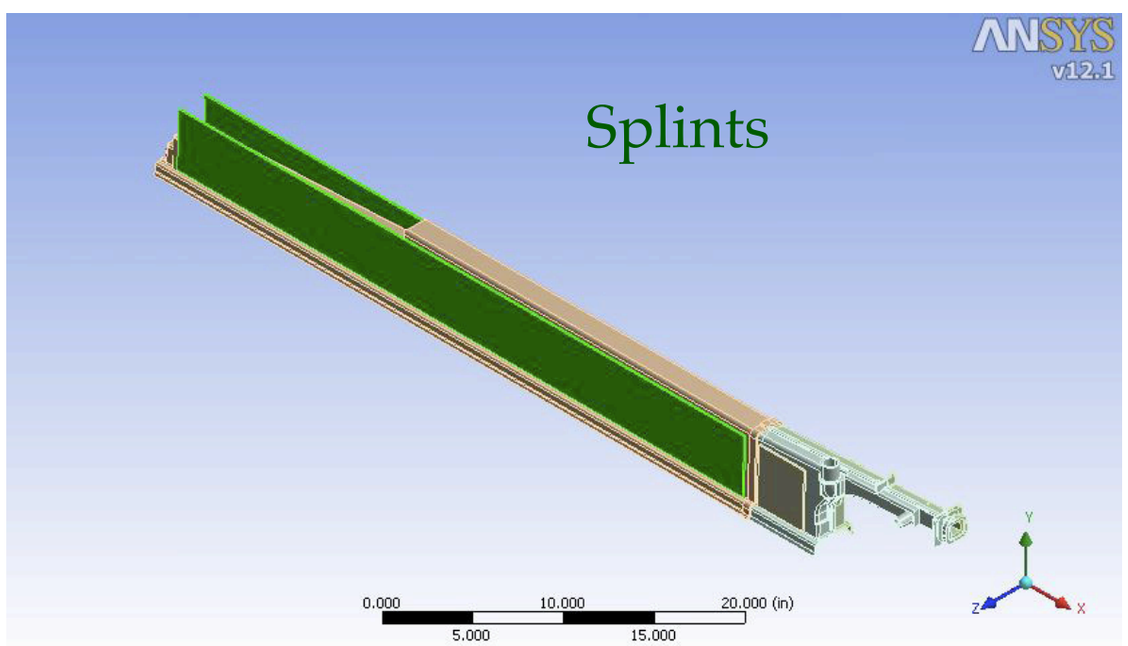
Module Assembly

- Many pieces must be brought together to form an active detector module
- Cell interiors must be very reflective so scintillation light is not lost.

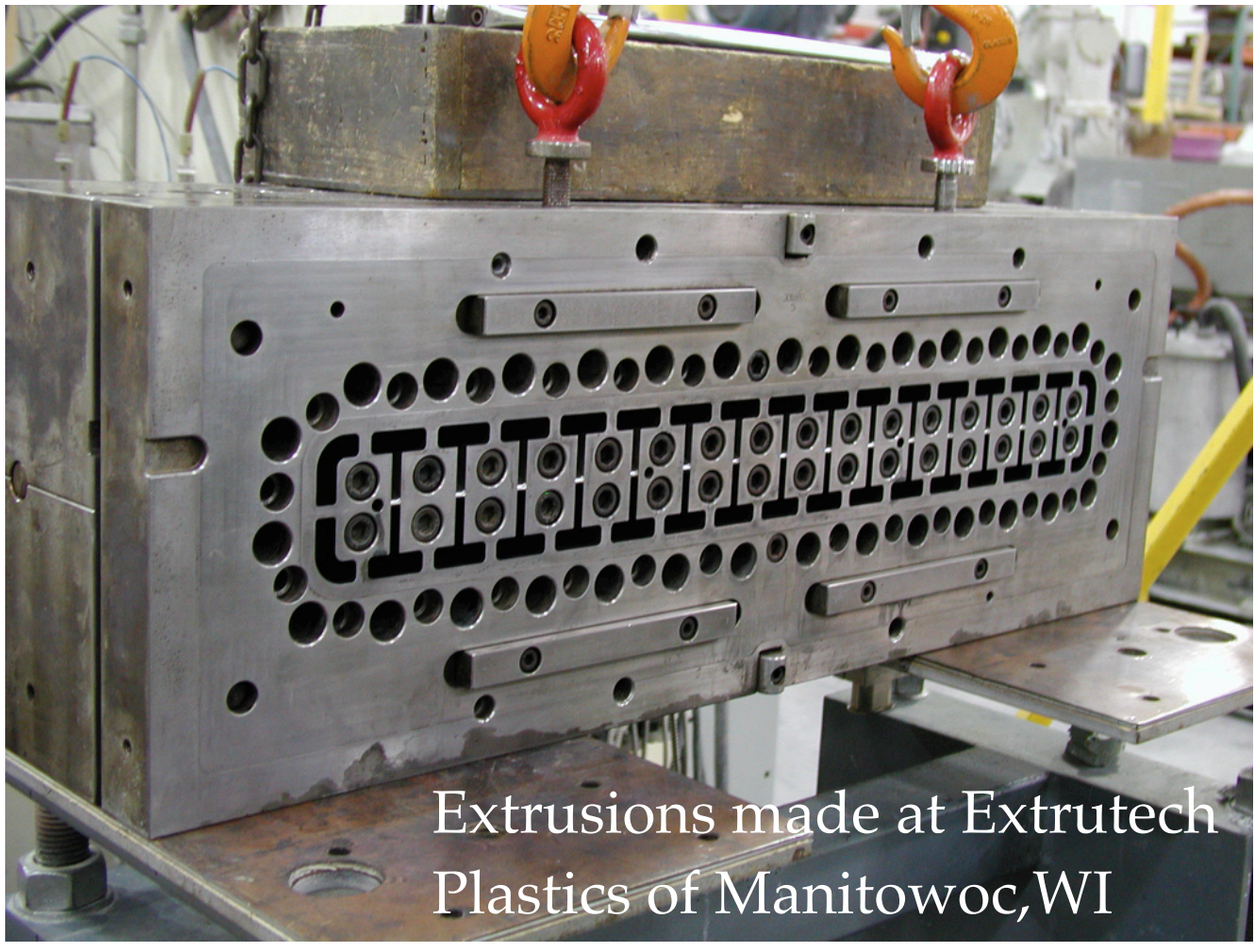


Manifold Issues

- Manifolds have developed cracks (22%)
  - Splinted the NDOS manifolds
  - Redesigned manifolds to remove stress points for near and far detectors



PVC Extrusions


Extrusions made at Extrutech Plastics of Manitowoc,WI

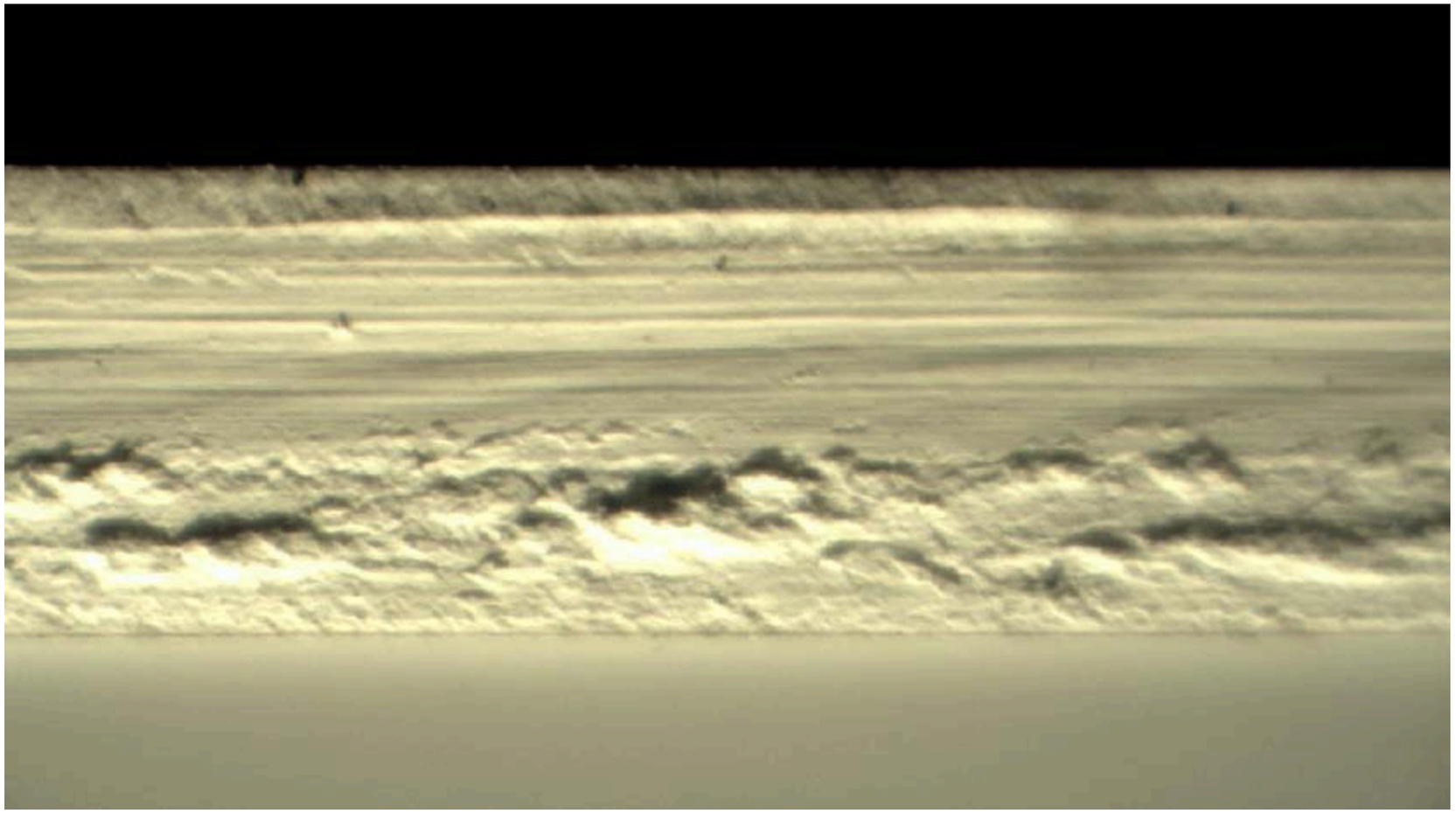
- PVC extruded through die to form 15m extrusions
- ~24,000 required for Far Detector.
- Currently have ~2300 useable extrusions in hand.

PVC Reflectivity Issues

- We require predicted light yield to the APD to be ≤14.6% of a perfect reflector.
  - Achieved using anatase TiO_2 in PVC
- Low reflectivity in some batches correlated with high fraction of rutile TiO_2
  - Requested <2% rutile contamination, and so far that is what we have received.

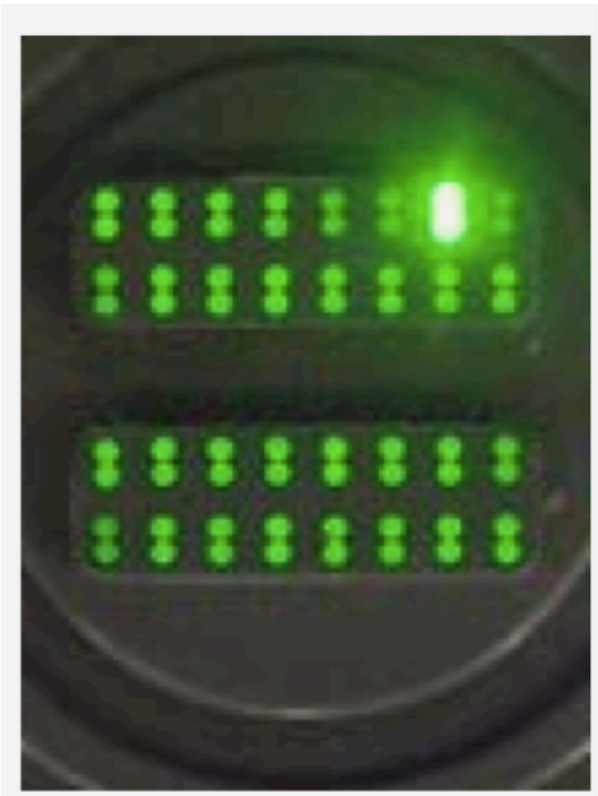
PVC knitting issues

- PVC knitted is less than ideal
- Ongoing iterations with manufacturer greatly improving results
  - No voids found in extrusions, so they are still useable

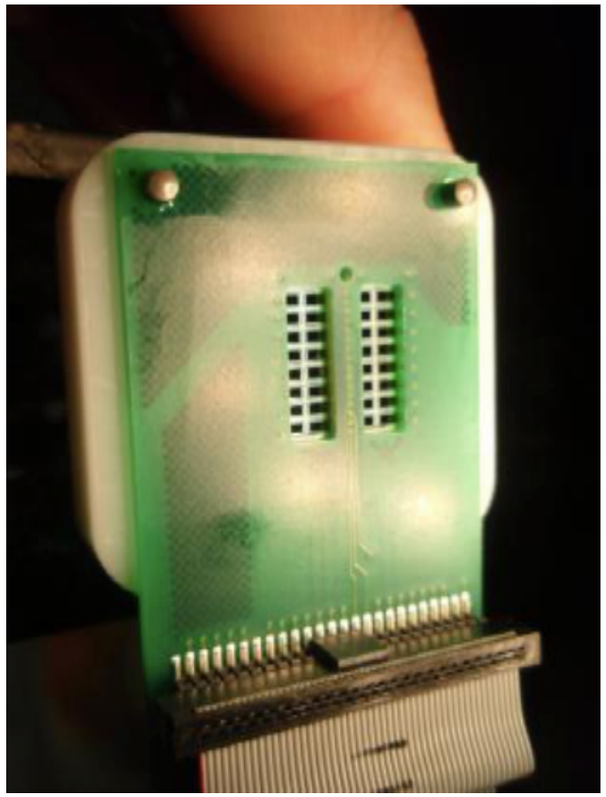


Extrusion samples are often cracked in QC testing, revealing smooth regions in the cross-section, such as the central region in this example, that are not ideally knitted.

Light Chain



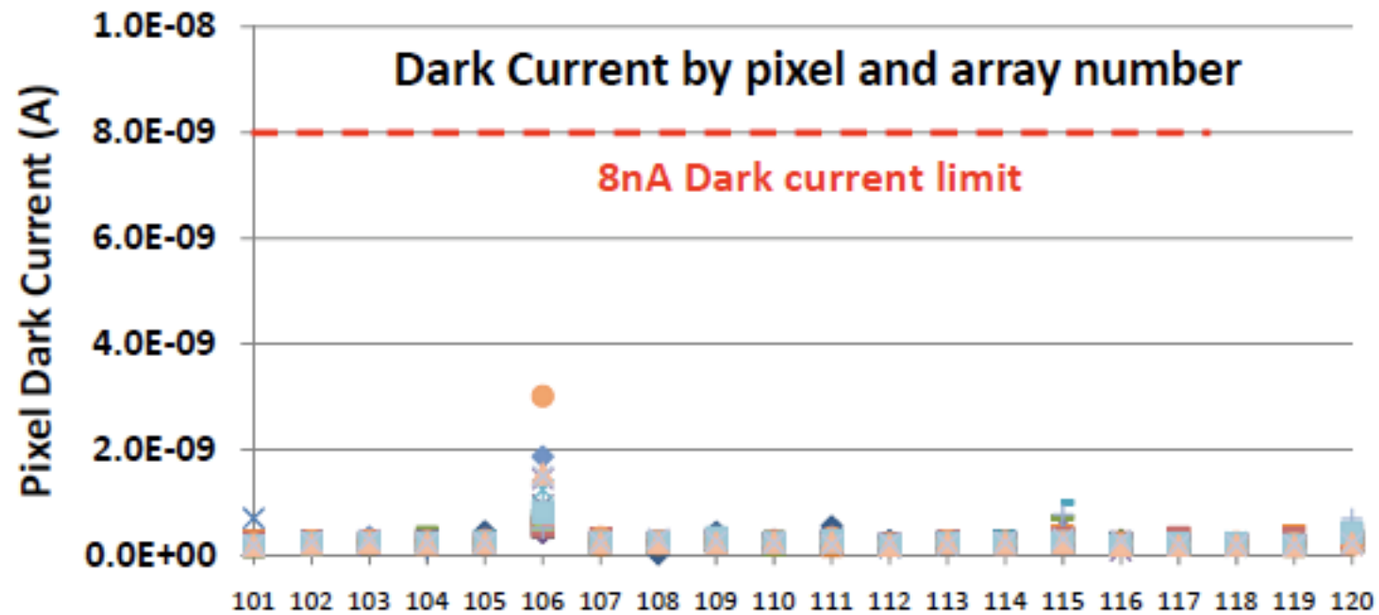
Scintillation light travels along wavelength shifting fibers to end of manifold

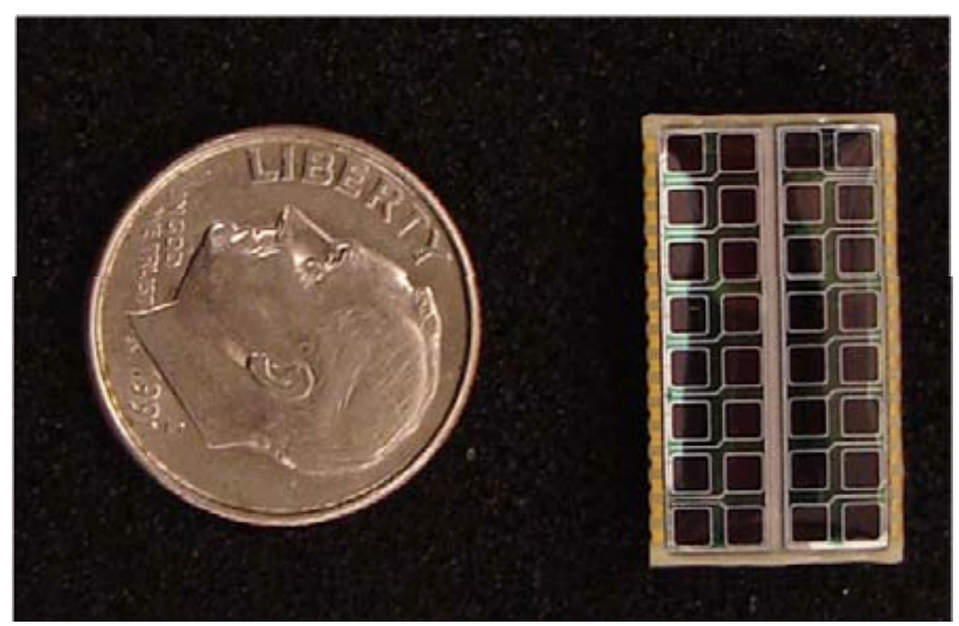


Light detected in by avalanche photodiodes (APDs) that are sealed, cooled (to -15 °C) and mated to the detector data acquisition system.

APD Performace

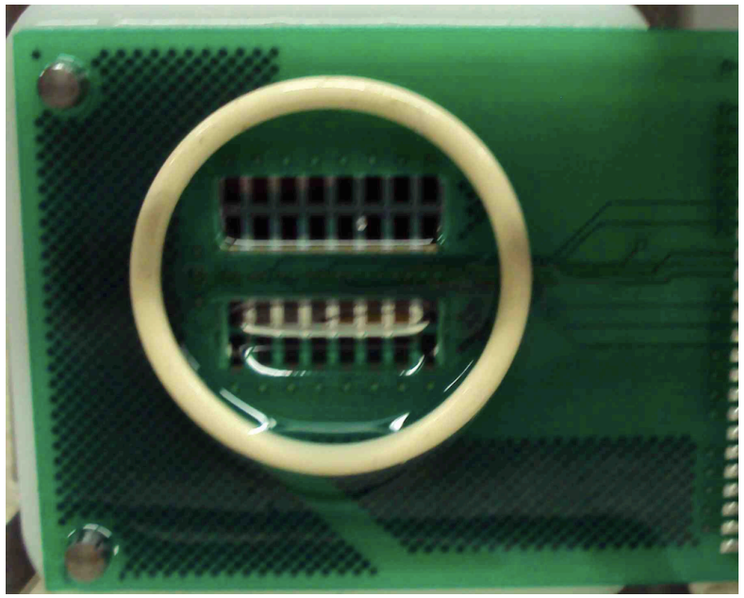
- Quantum Efficiency of 85%
- Gain of 100
- Low Dark Current
- NDOS has taught us much about installing them.

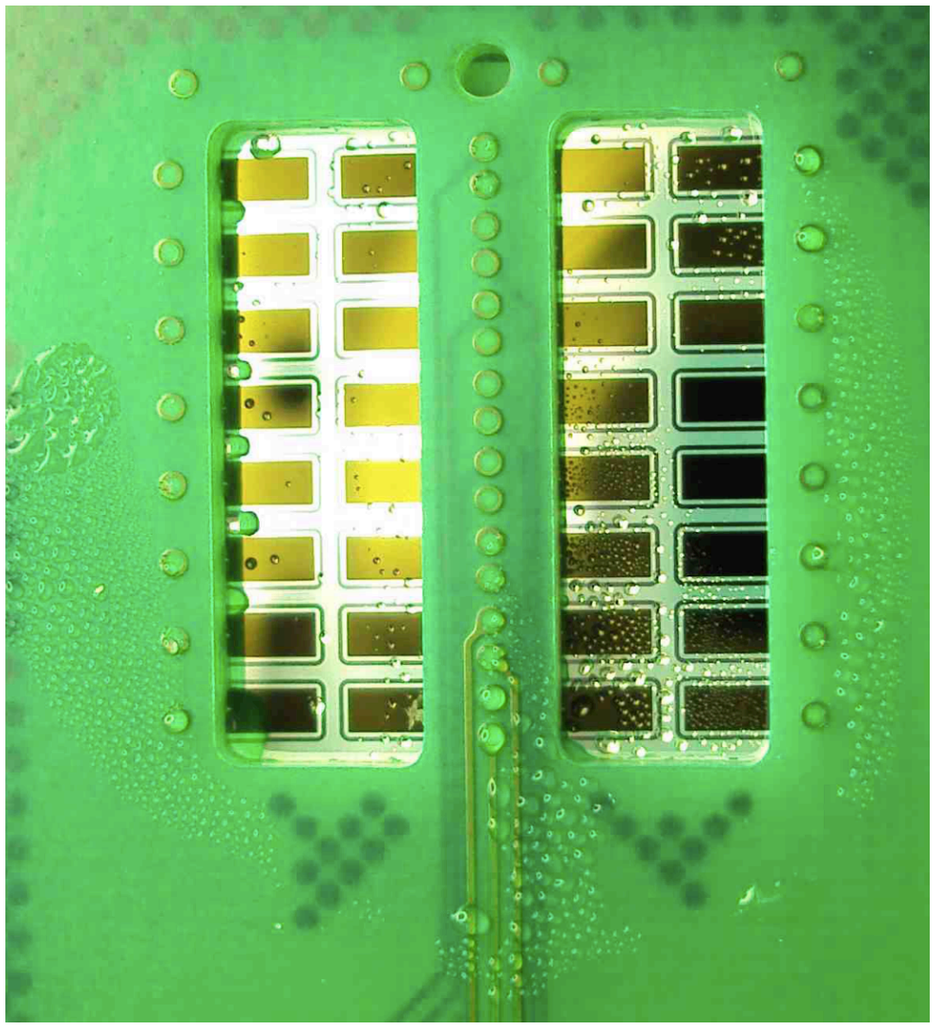




APD Noise Issues

- We have received a total of ~420 APDs for the NDOS
  - ~150 of them are still working
- Causes
  - Dirt and oil
  - Corrosion
  - Contact with fibers
  - Poor seals: condensation or ice when cooled
  - Installation Errors
- Rearranging surviving APDs

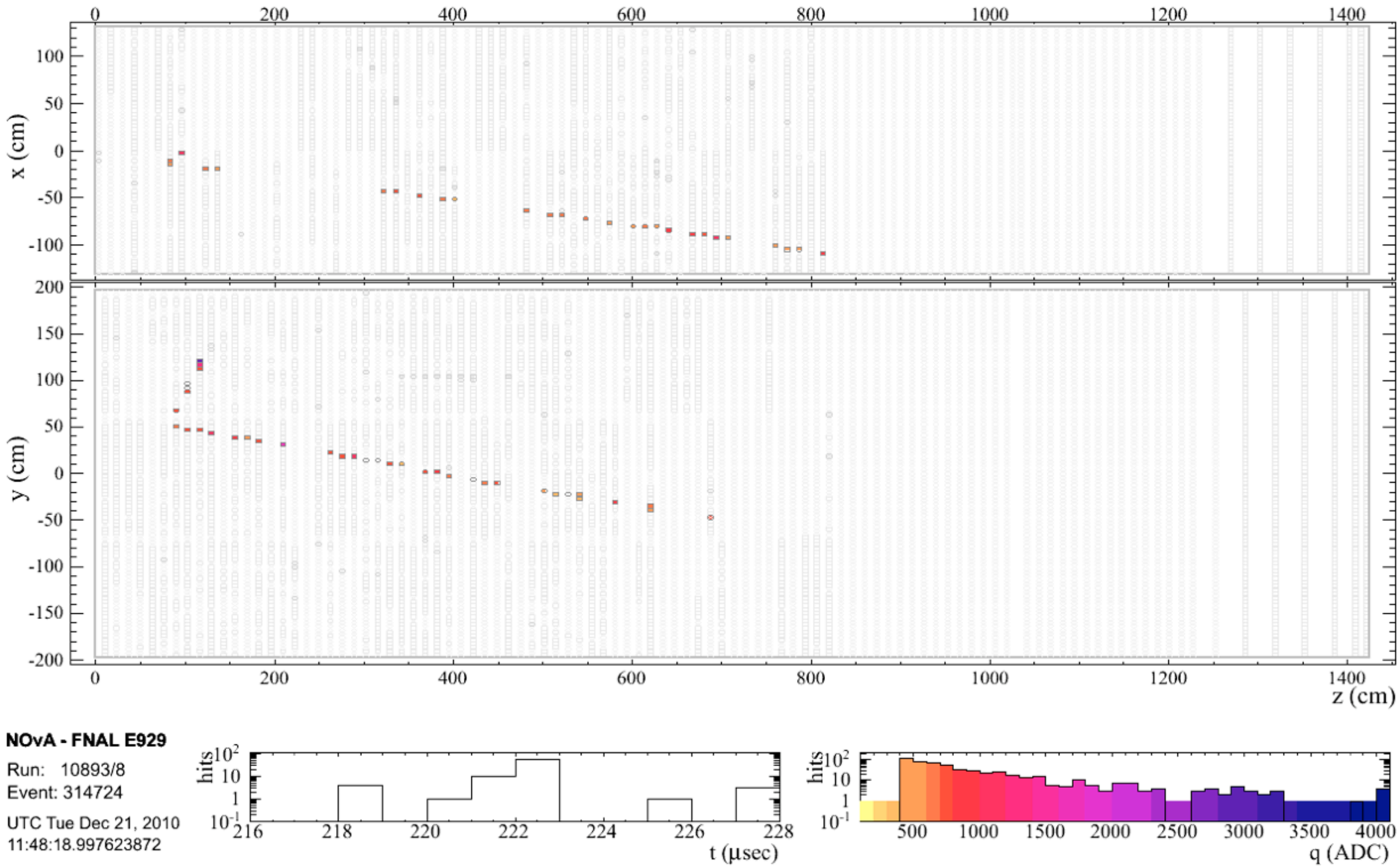




APD Potential Solutions

- "Cable-ectomy"
  - Remove cable from noisiest pixel
  - Sometimes successful in reducing noise on neighboring pixels
- Attempting to clean/repair some non-functioning APDs
- **Coated APDs**
  - Did not order APDs with coating because the standard coatings produced optical cross-talk
  - In discussions with manufacturer to produce APDs with protective coatings that will avoid cross-talk
  - Testing coatings (silicone and parylene) NDOS APDs

First Neutrino Data!



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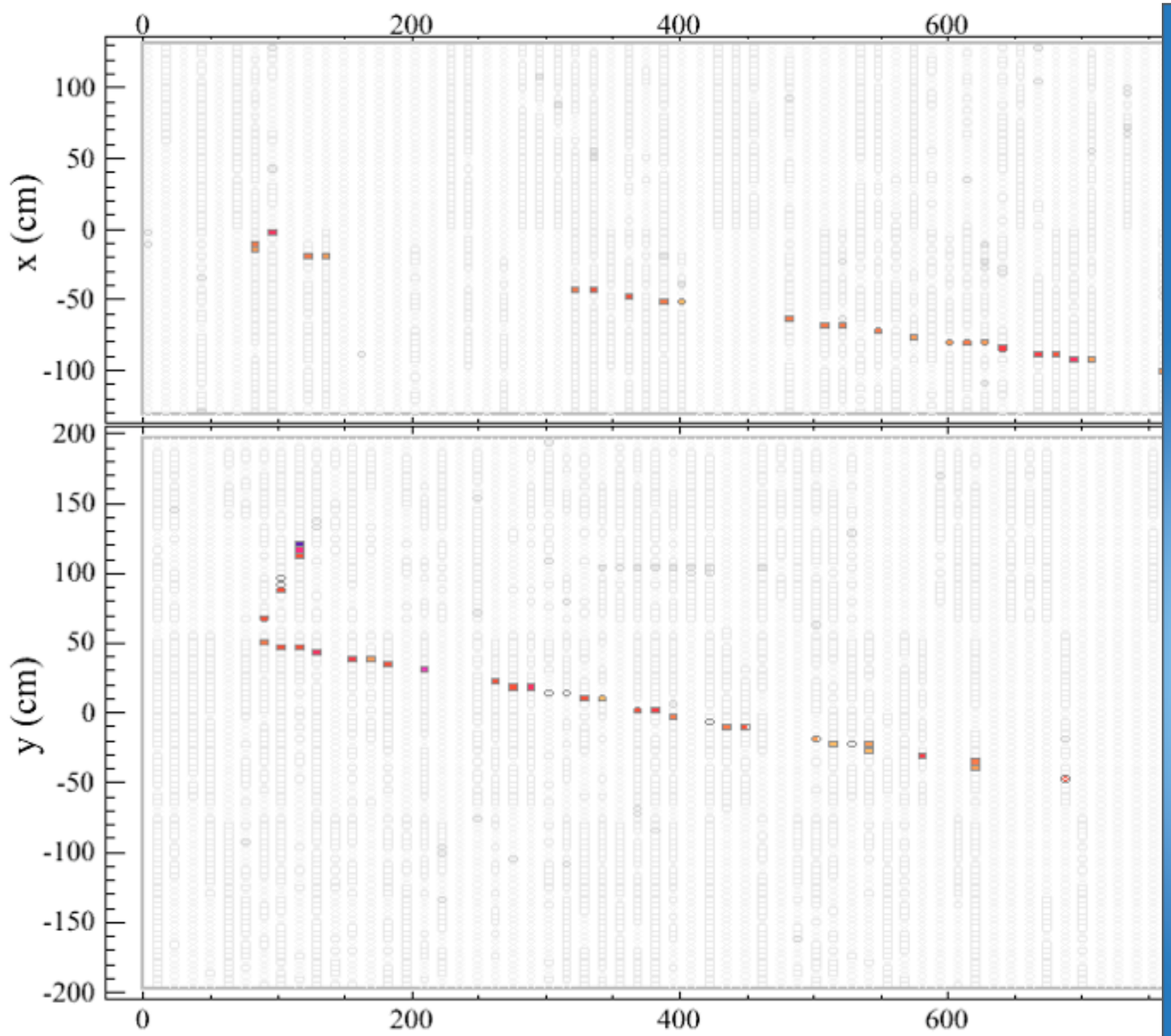
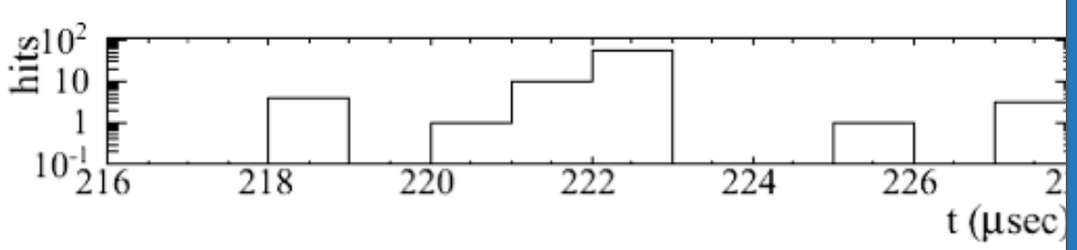
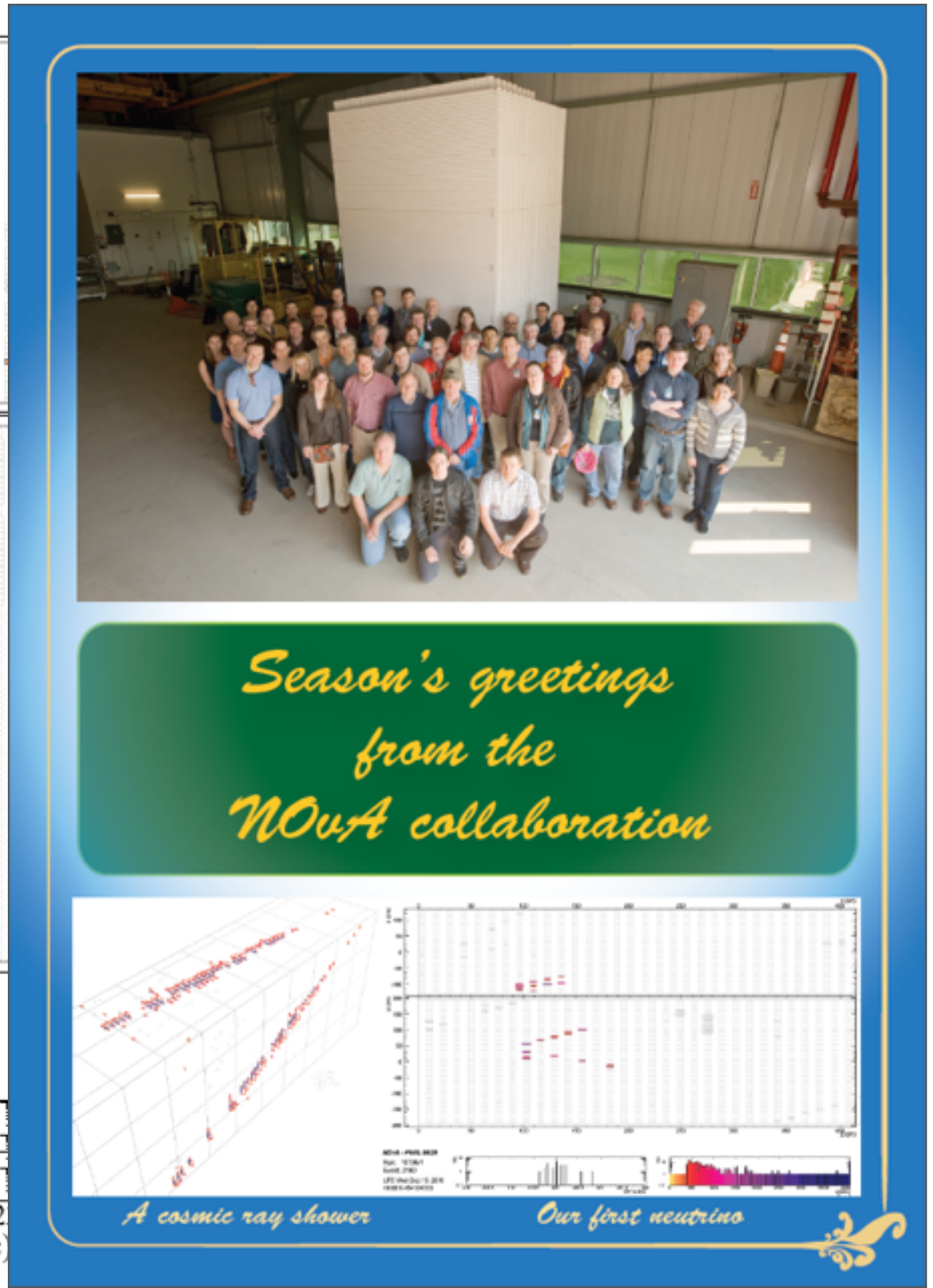


NOvA - FNAL E929

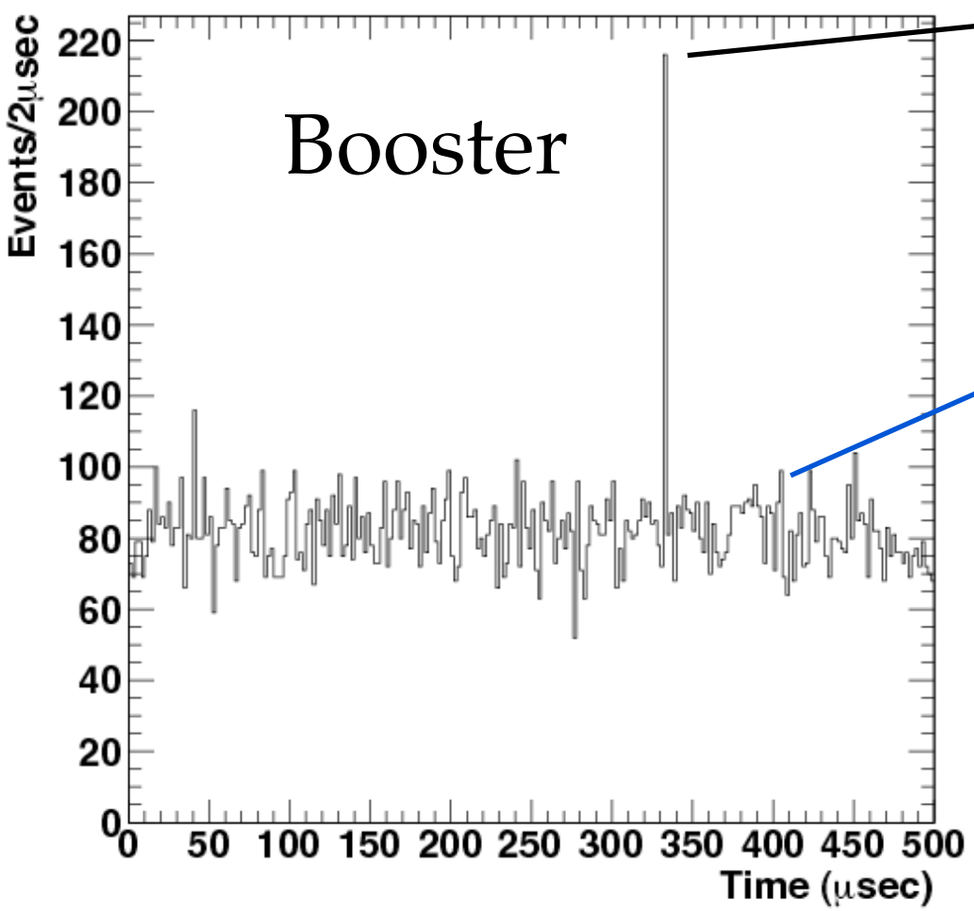
Run: 10893/8
Event: 314724

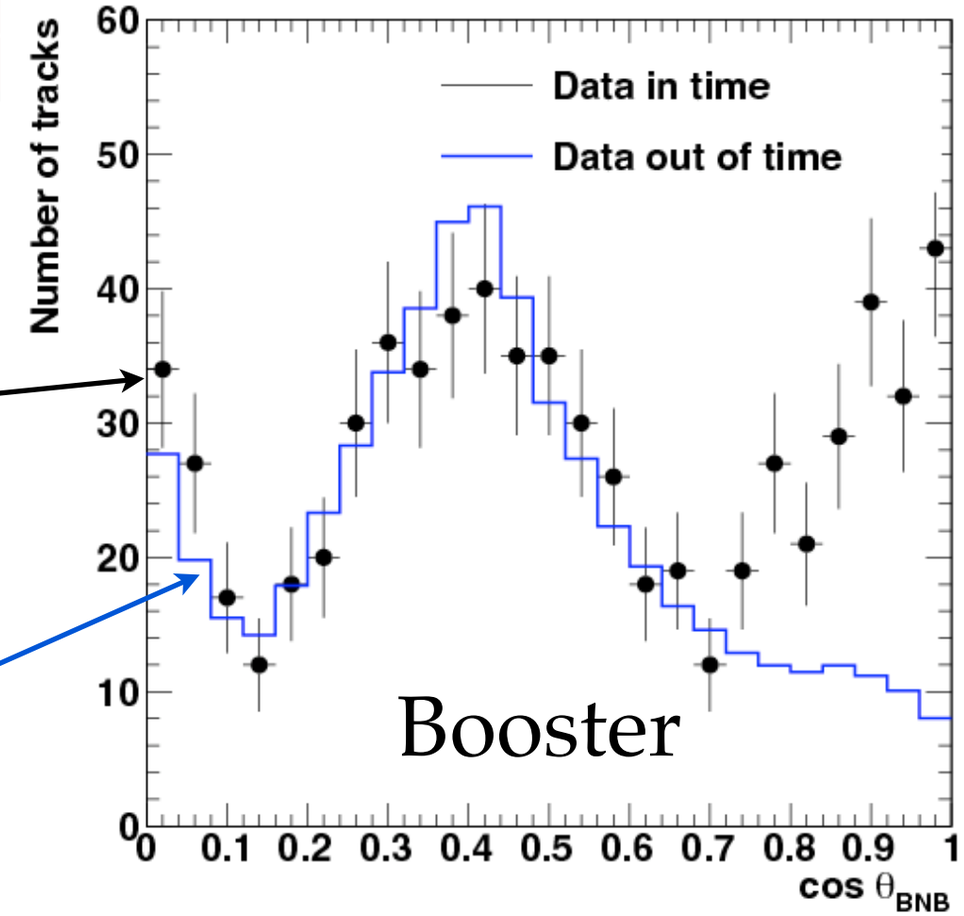
UTC Tue Dec 21, 2010
11:48:18.997623872

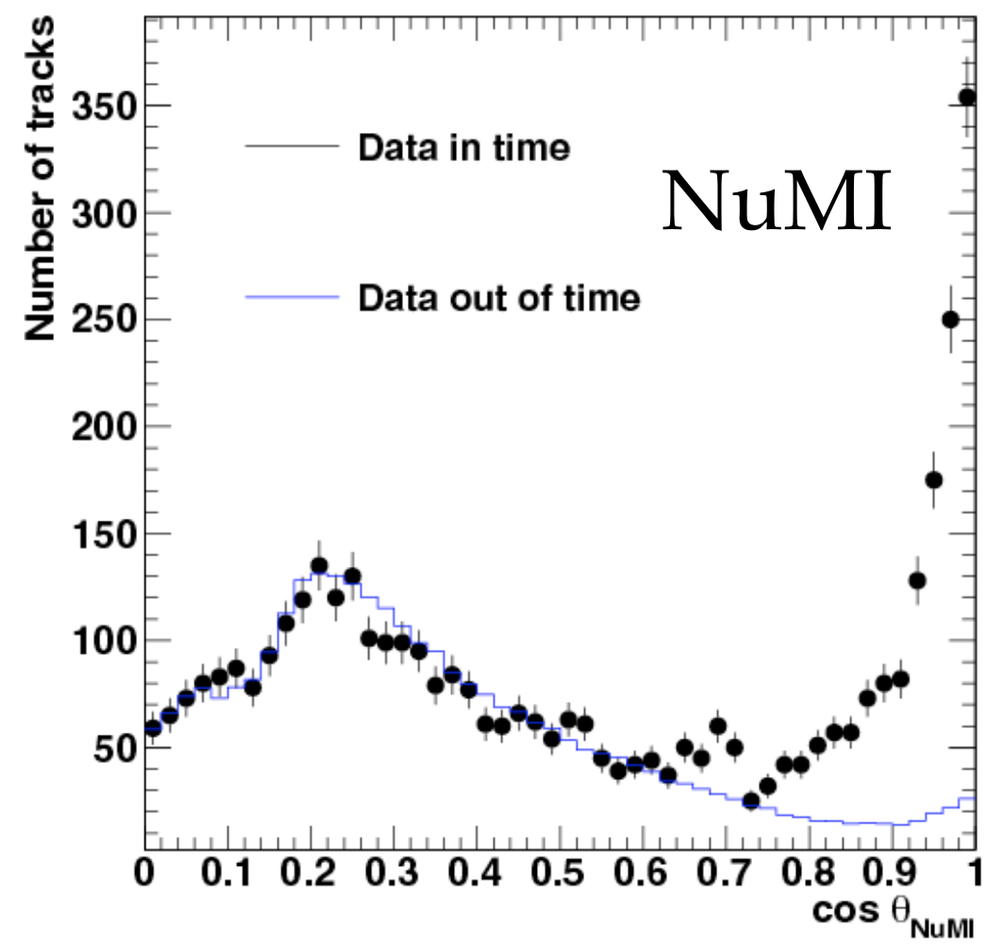




Finding the Beams



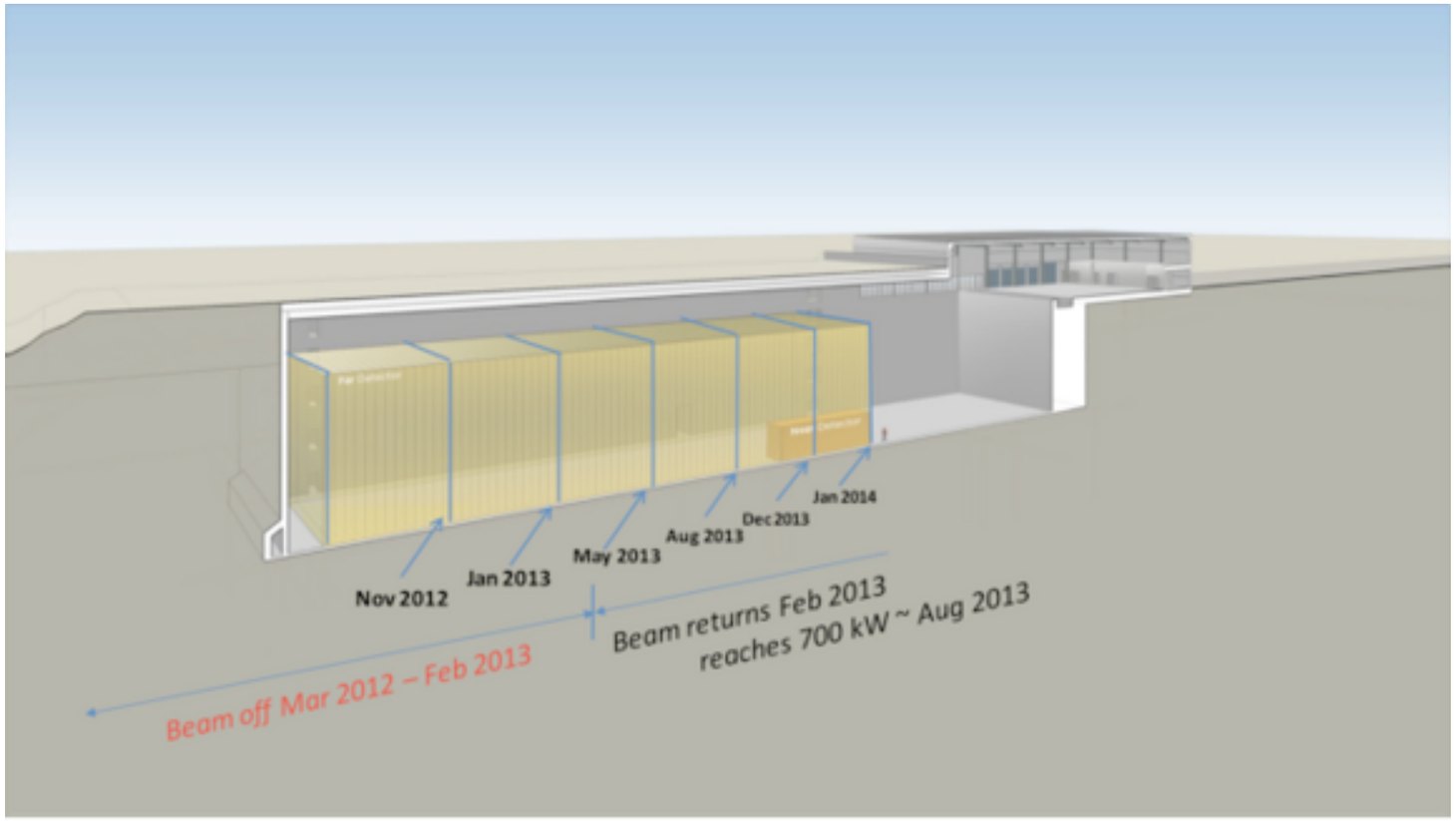




http://www-nova.fnal.gov/plots_and_figures/

Schedule

- Tevatron shutdown on Sep. 30, 2011
- First large scale fluor blend later this month
- Ready to begin FD construction Jan. 2012

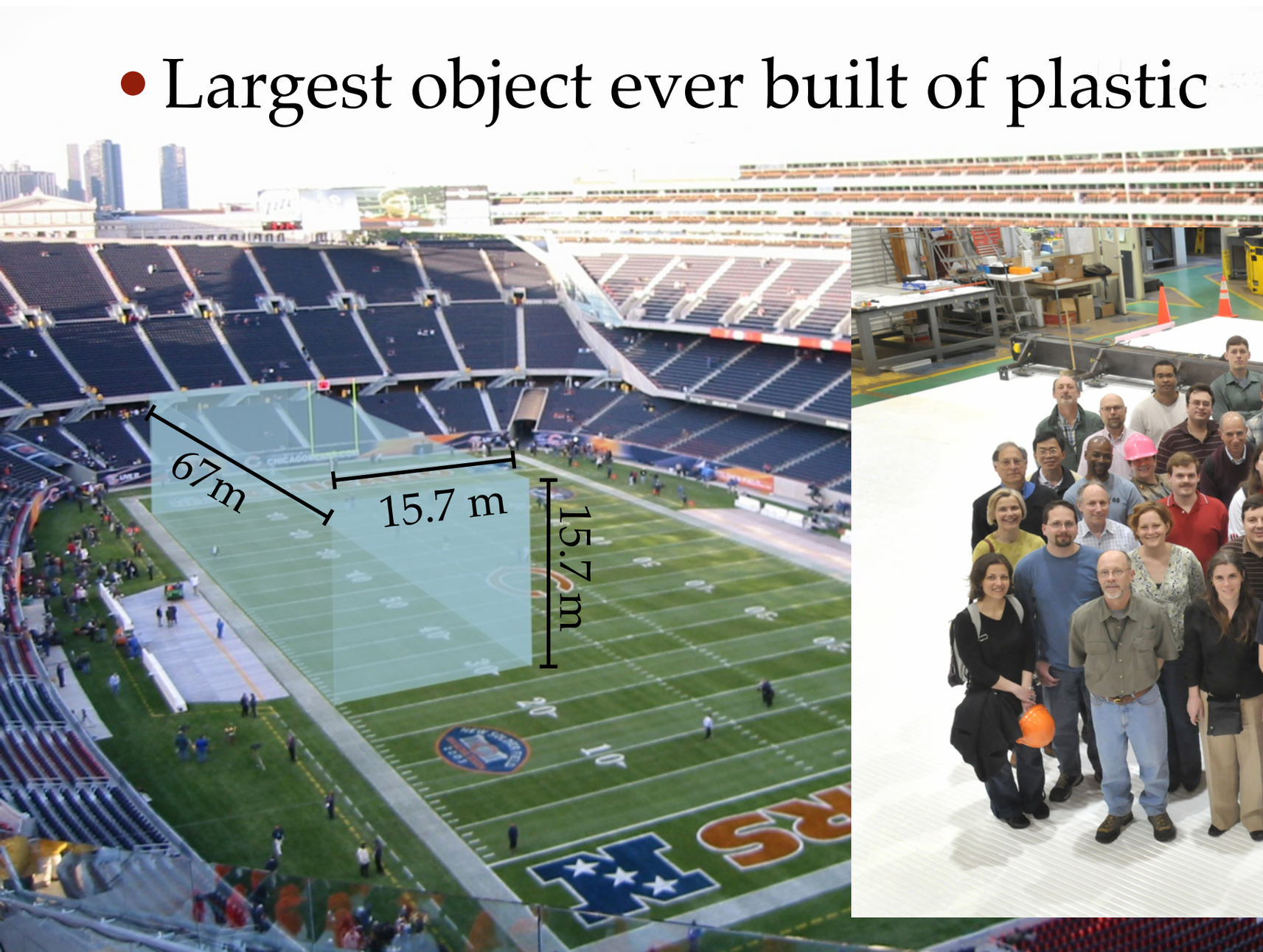


- Accelerator shutdown begins Mar. 2012
- ND cavern excavation during accelerator shutdown
- NOvA beam turns on Feb. 2013
- FD finished in early 2014

Backup

Far Detector

- 14,000 - 18,000 tons
- Will detected oscillated beam
- Largest object ever built of plastic



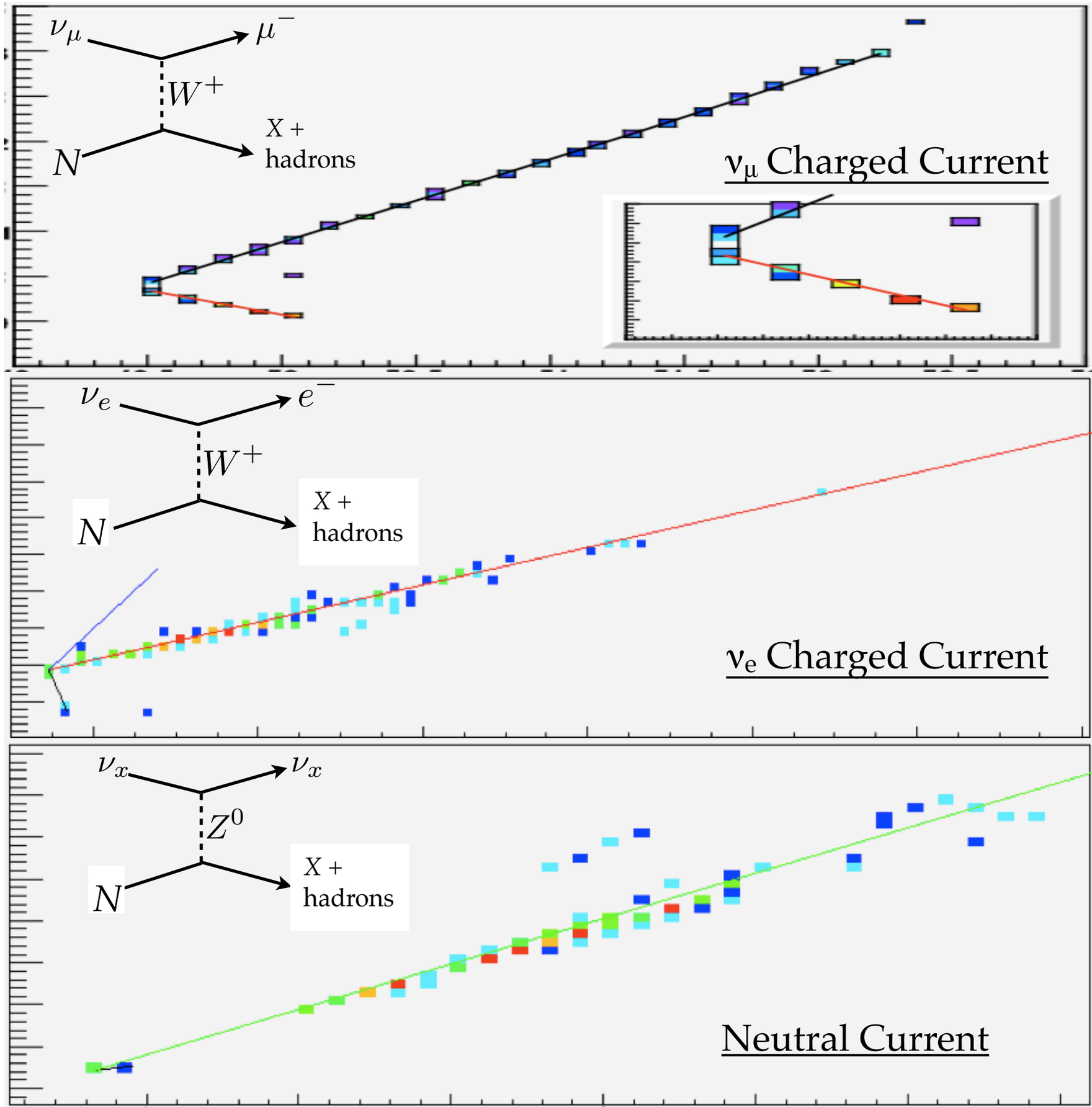
Quality Control

- Light Yield
  - Use radioactive sources to verify sufficient scintillator light
- Chemistry
  - Verify correct chemical composition.
- Clarity (15 m long far detector cells)
  - Use a "tintometer"
  - Maintaining cleanliness critical at every stage!

This is what we found when we looked inside of one of the fluor blending totes for the NDOS. The green substance was not identified (my guess was Mountain Dew). It was thoroughly cleaned by the blending company before any scintillator components were added.

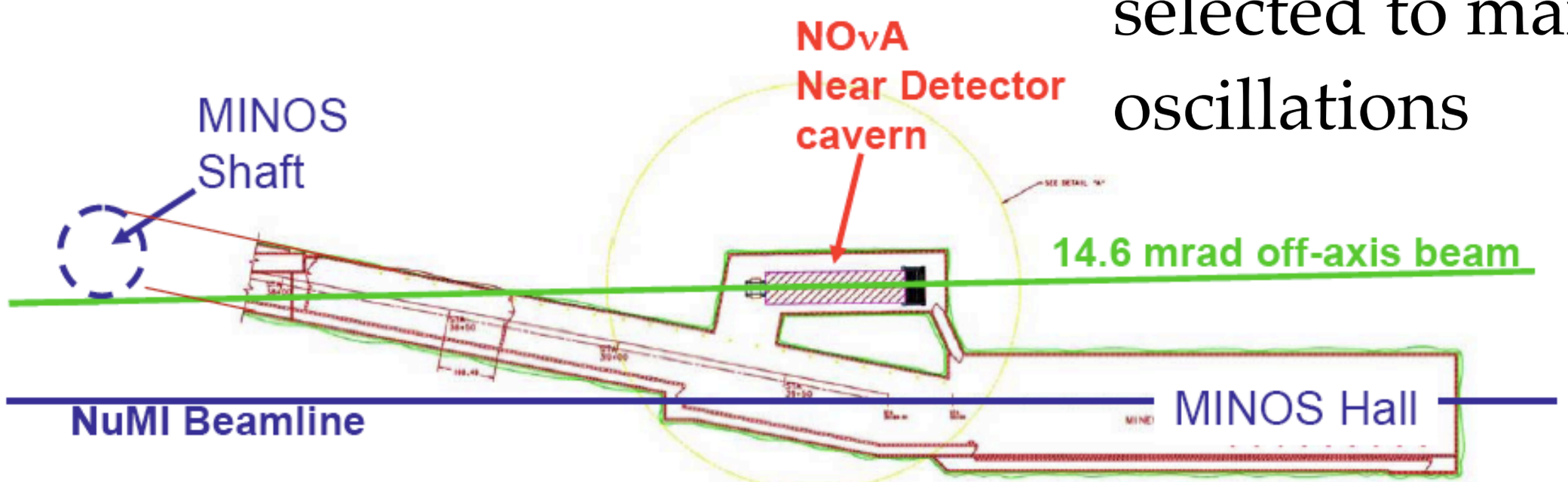
Neutrino Interactions

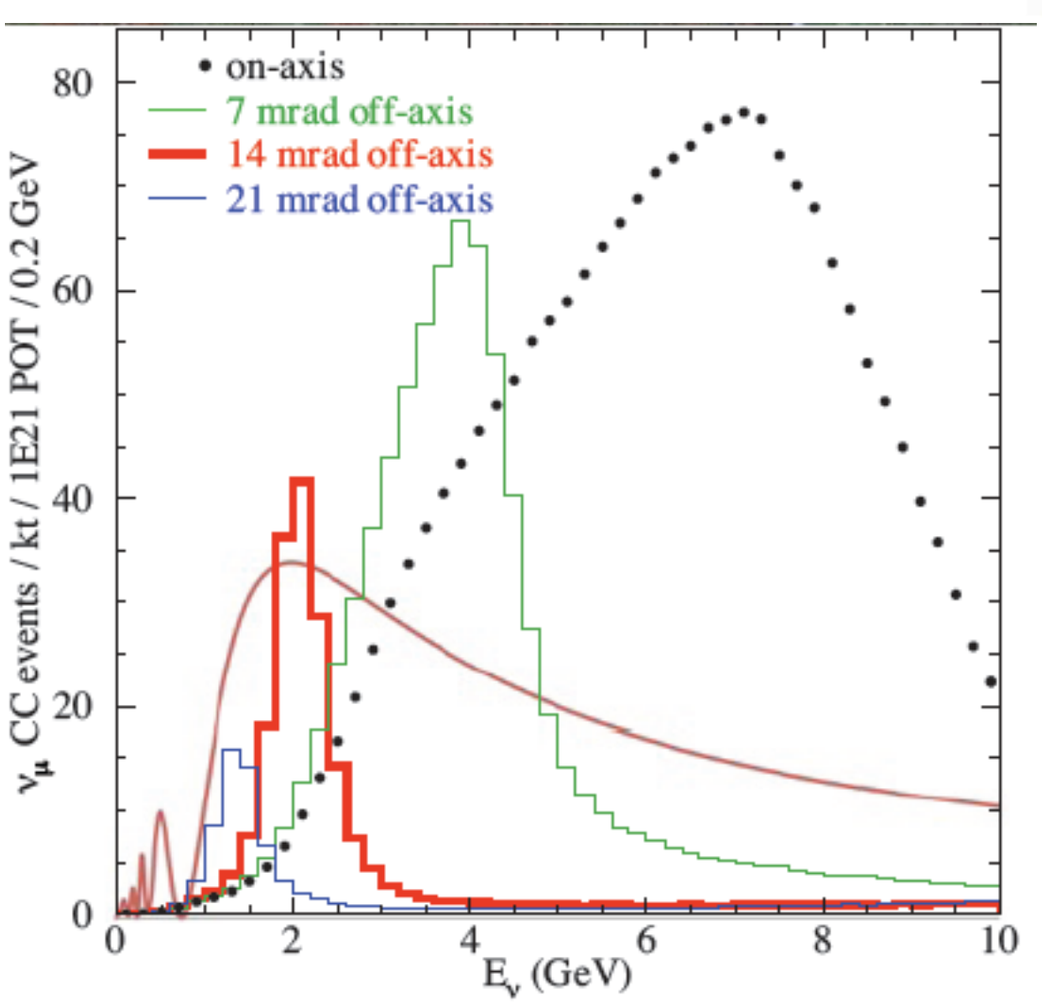
- Like the wind, you can't see neutrinos, but you can see their effects.
- Simulated events at right

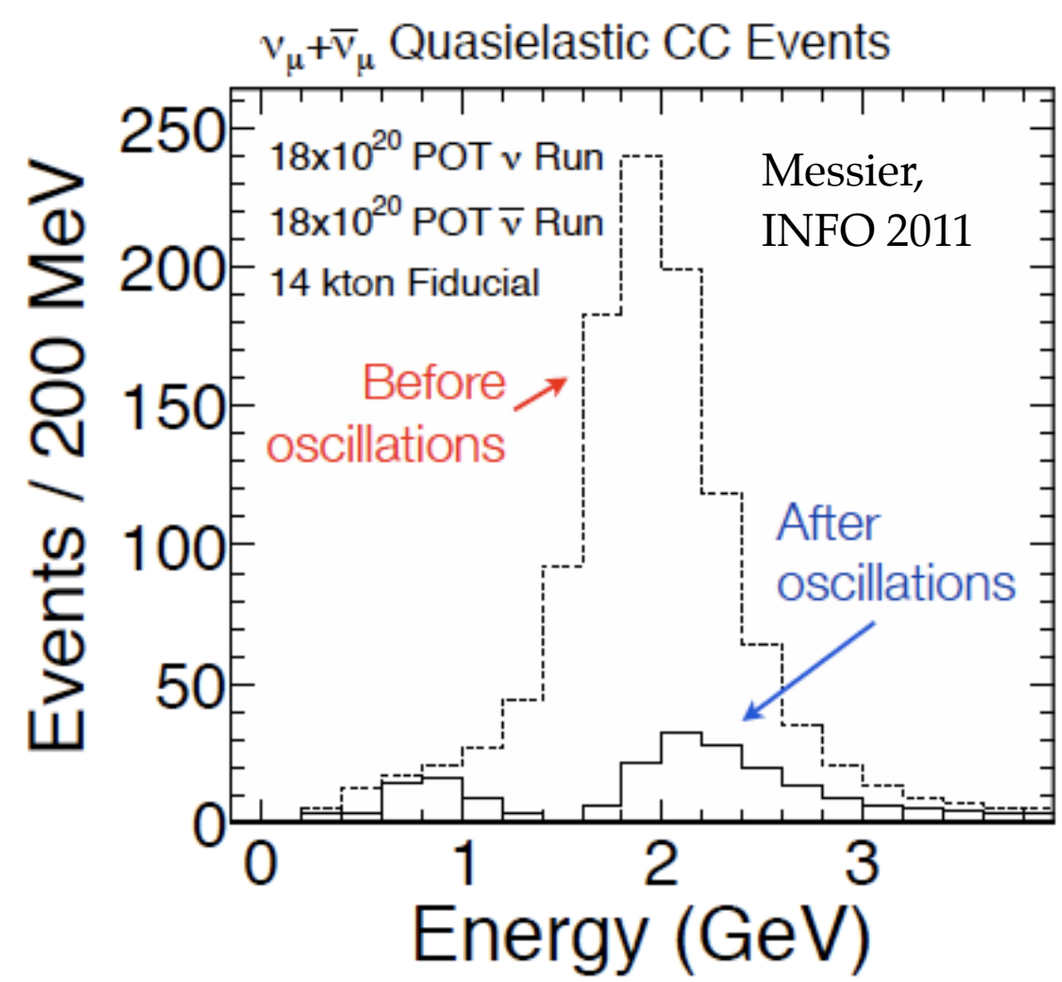


Off-axis

- Baseline (L) and E selected to maximize oscillations





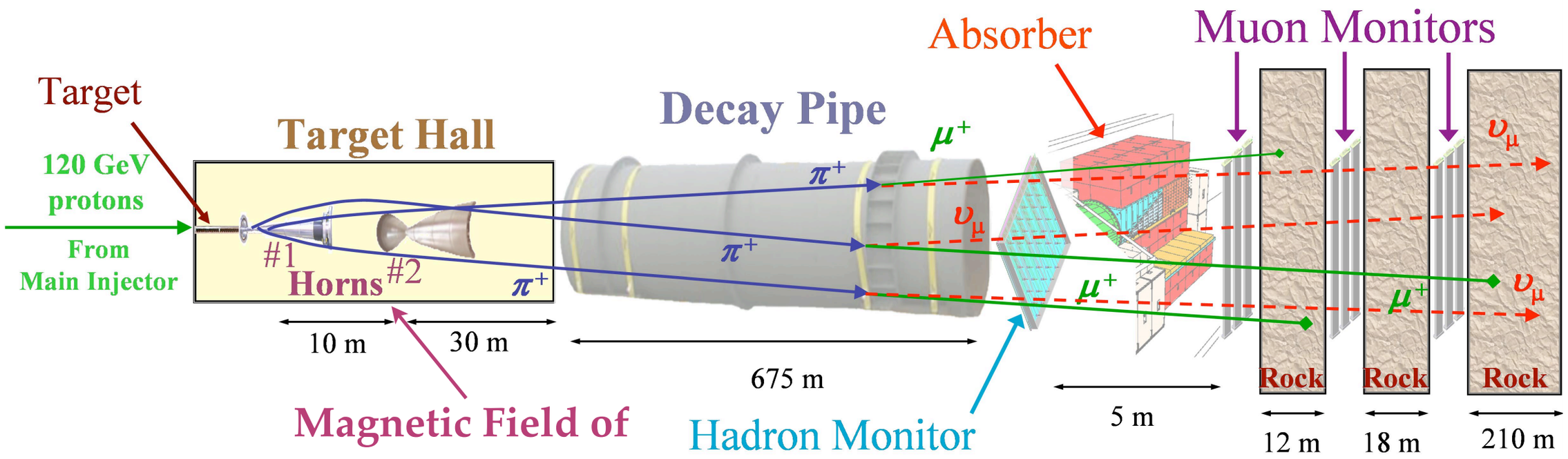


Filling

- NDOS is filled with high-quality scintillator
- Pumping and piping systems being developed for Far Detector
- 6 tankers per week to Far Detector planned
- ~3,000,000 gallons

The NuMI Beam

- Small Cross section ⇒ we need large number of neutrinos ⇒ we need an intense beam



Magnetic Field of Horns can be reversed to produce antineutrino beam

Our Scintillator Recipe

Liquid Scintillator

94.91% food grade mineral oil
4.98% pseudocumene (scintillant)
0.110% parts PPO (powder, wave shifter)
0.00153% bis-MSB (powder, wave shifter)
0.0010% Stadis-425 (anti-static)
0.0010% Vitamin E (antioxidant)

1. Mix PPO, bis-MSB, Stadis-425, and Vitamin E into pseudocumene to produce fluor blend.

2. Mix fluor blend into mineral oil to produce NOvA liquid scintillator

Preserving and Redistributing APDs

- Running remaining APDs without cooling to preserve them
- Have begun be rearranging surviving APDs on the NDOS to collect highest quality data possible.