The NOνA Experiment Status

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(for the NOνA collaboration)

Fermilab Users' Meeting 2009

The NOvA Collaboration

The NOνA Experiment

- NuMI Off-Axis ν_e Appearance Experiment
- Uses a 15kT detector, NOνA
- Positioned off axis of the Fermilab NuMI beam
- Run for 6 years
- Goals:
  - Observation of the transition $\nu_\mu \rightarrow \nu_e$
  - Measurement of θ_{13}
  - Measurement of $\sin^2(2\theta_{23})$
  - Determination of mass hierarchy (sign of Δm^2_{23})
  - Begin to localize δ_{CP}


NOvA Far Detector
MINOS Far Detector
Ontario
Minnesota
Wisconsin
Iowa
Milwaukee
Michigan
Fermilab
Chicago
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Image © 2007 TerraMetrics
Image © 2007 NASA
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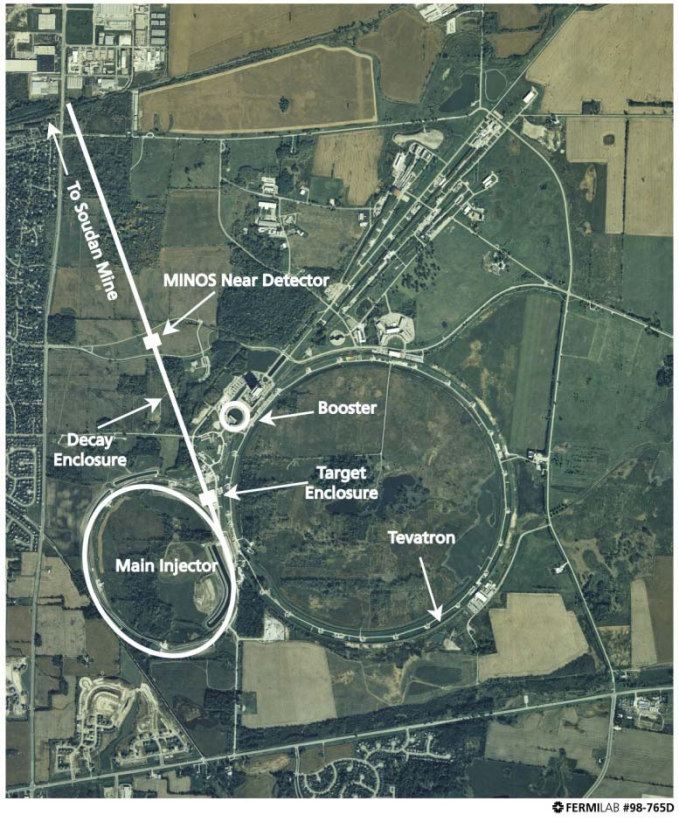
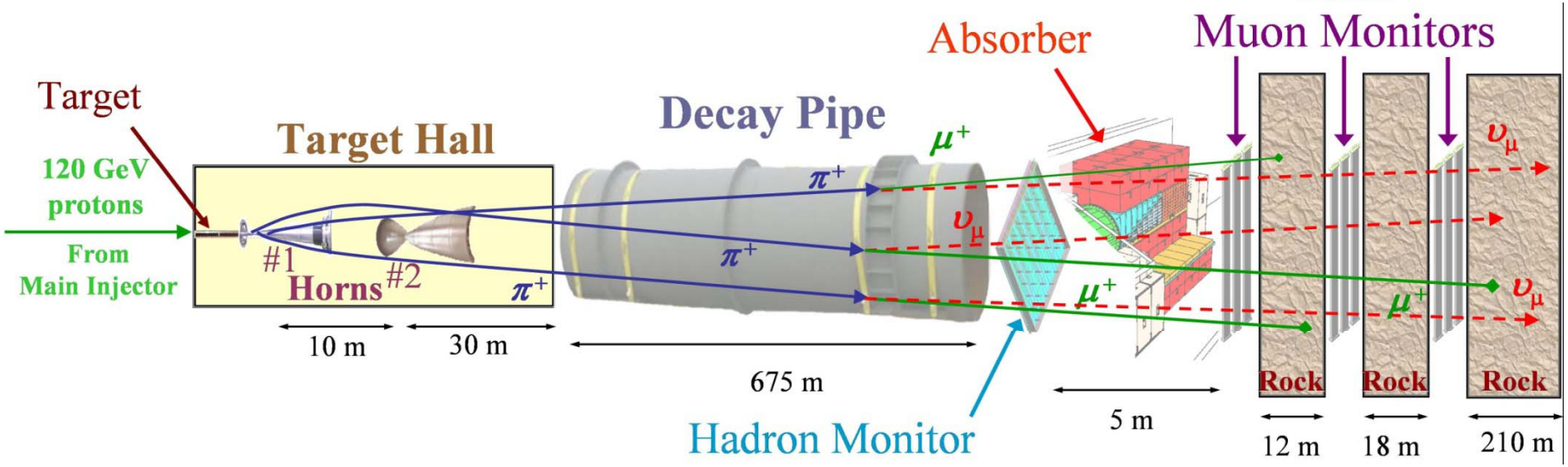
168 km
Pointer 43°34'32.84" N 89°04'55.60" W elev 271 m
Streaming 100%
Eye alt 545.86 km

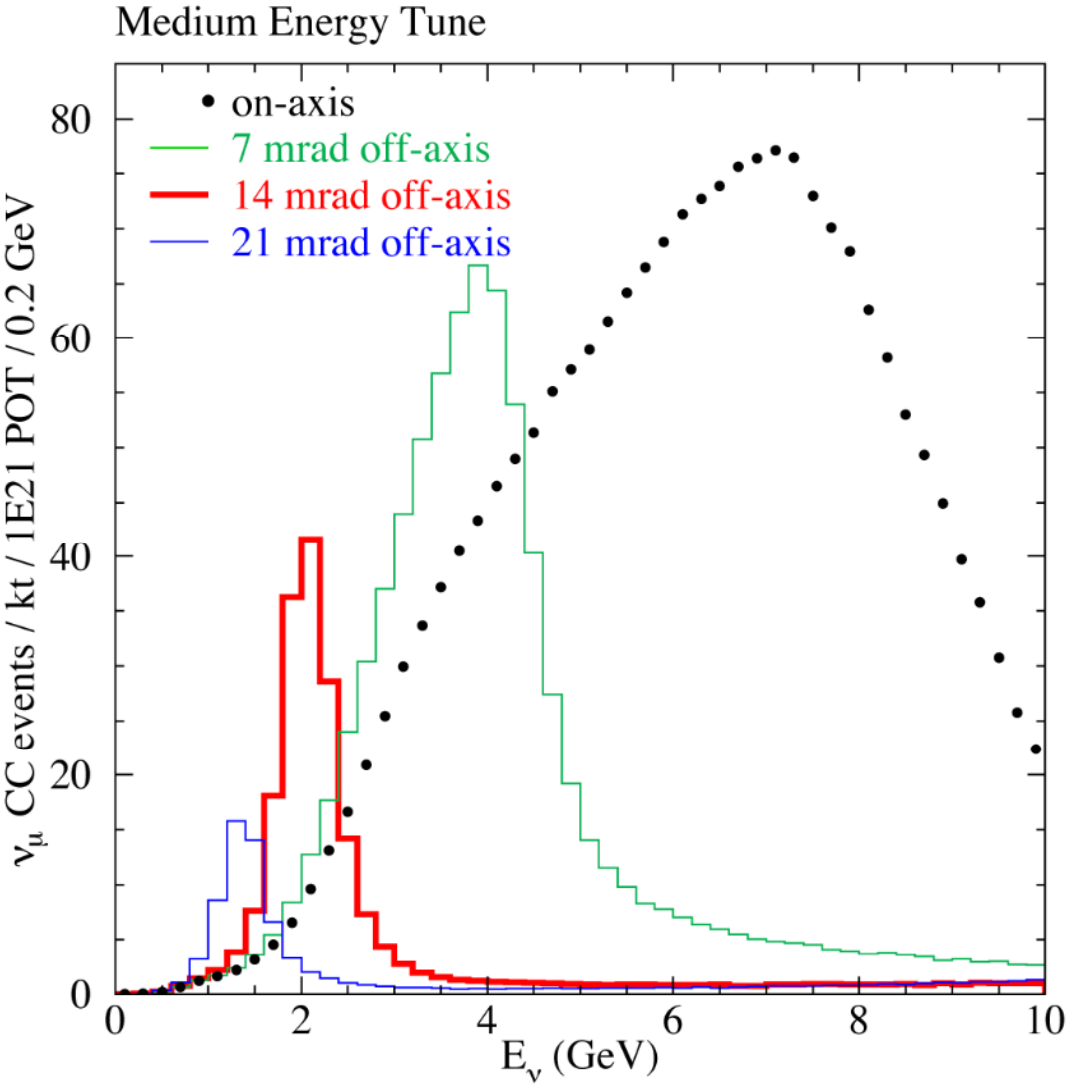
Fermilab NuMI Beam





Off-Axis beam features

- Narrow energy distribution
- Tuned Energy by selecting off-axis angle
  - Maximize ν_e appearance
  - Minimize ν_μ
- Higher Intensity at a given energy
- Suppressed high energy tail
  - Reduces NC contamination



Proton Plans

	Present Operating Conditions (May 2007)	Proton Plan Multi-batch Slip-stacking in MI	NOvA Multi-batch Slip-stacking in Recycler
8 GeV Intensity (p/Batch)	4.3 - 4.5x10^{12}	4.3x10^{12}	**4.3x10^{12}**
Number of 8 GeV Batches to NuMI	7	11	**12**
MI Cycle Time (sec)	2.4	2.2	**1.3**
MI Intensity (protons per pulse or ppp)	3.3x10^{13}	4.5x10^{13}	**4.9x10^{13}**
MI to NuMI (ppp)	2.45x10^{13}	3.7x10^{13}	**4.9x10^{13}**
NuMI Beam Power (kW)	192	320	**700**
Protons/year to NuMI	2x10^{20}	3x10^{20}	**6x10^{20}**
MI Protons/hour	4.95x10^{16}	7.3x10^{16}	**1.3x10^{17}**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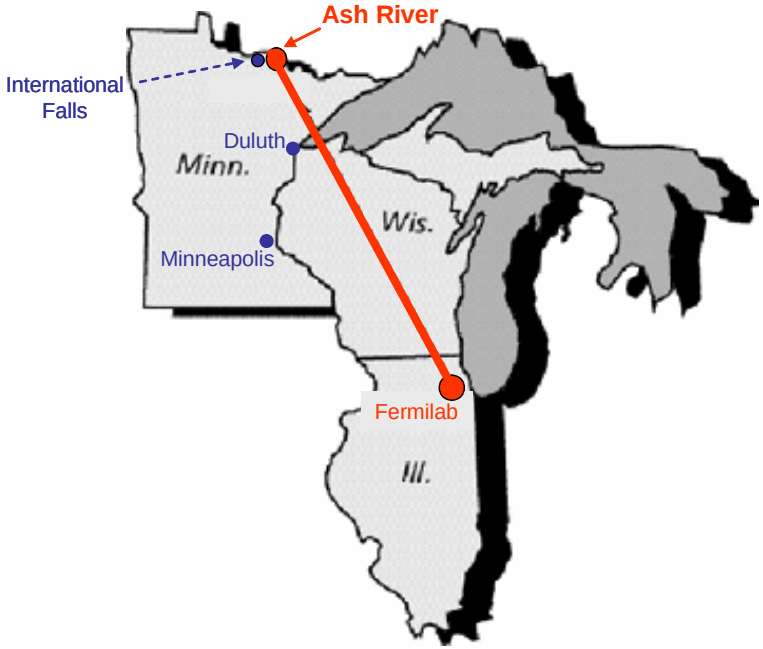
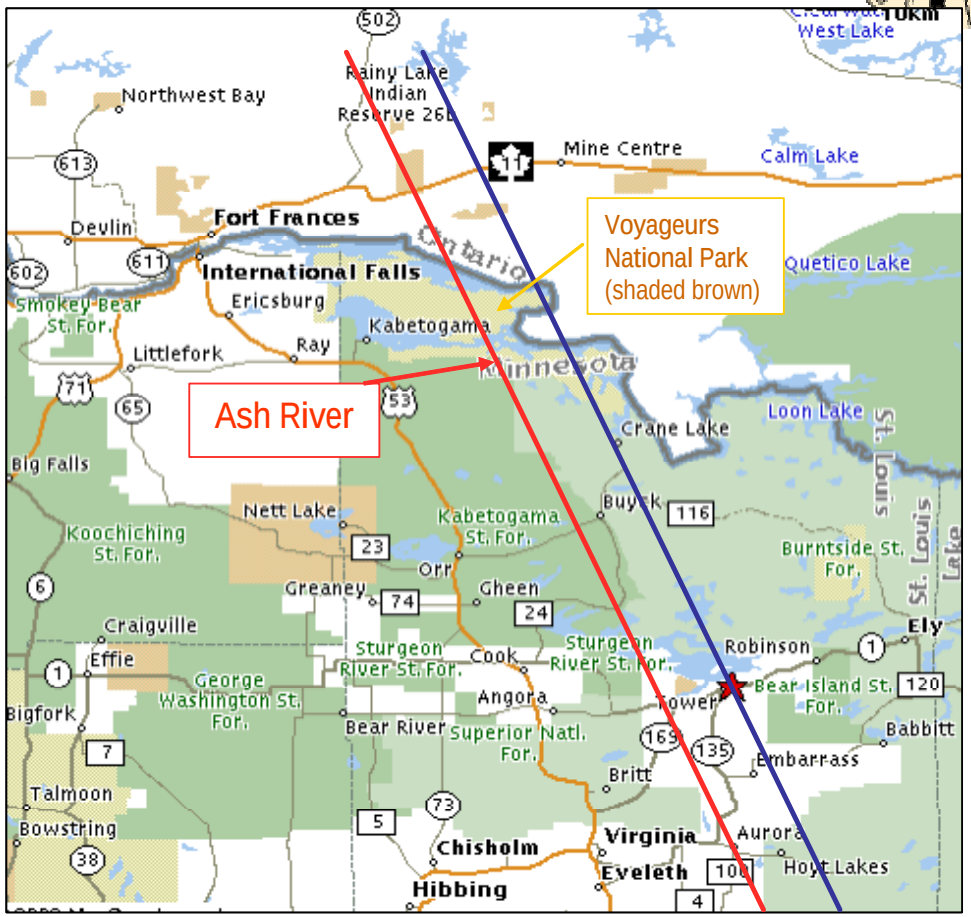
168 km
Pointer 43°34'32.84" N 89°04'55.60" W elev 271 m
Streaming 100%
Eye alt 545.86 km

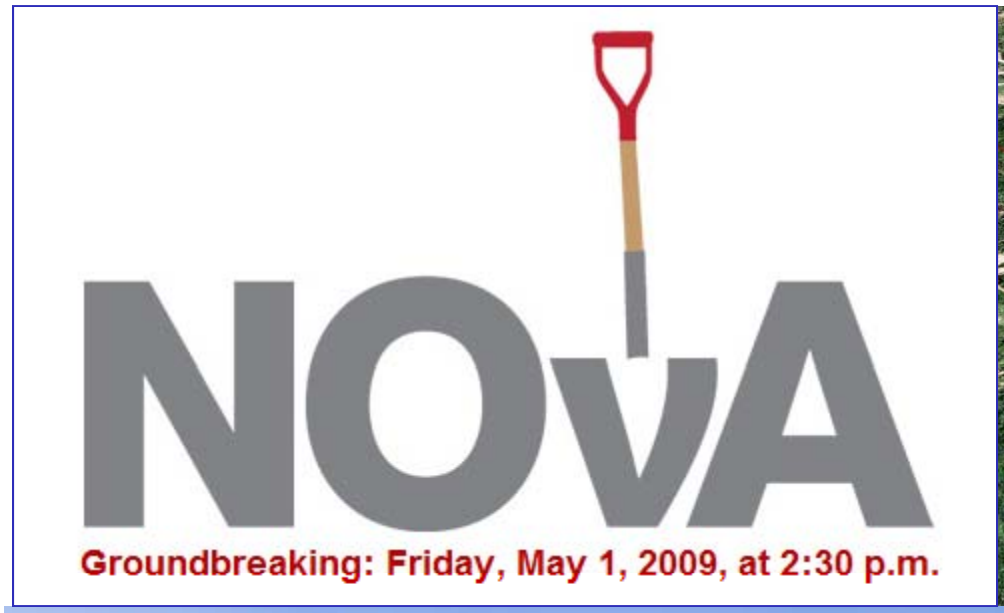
Site for Far Detector: Ash River, MN





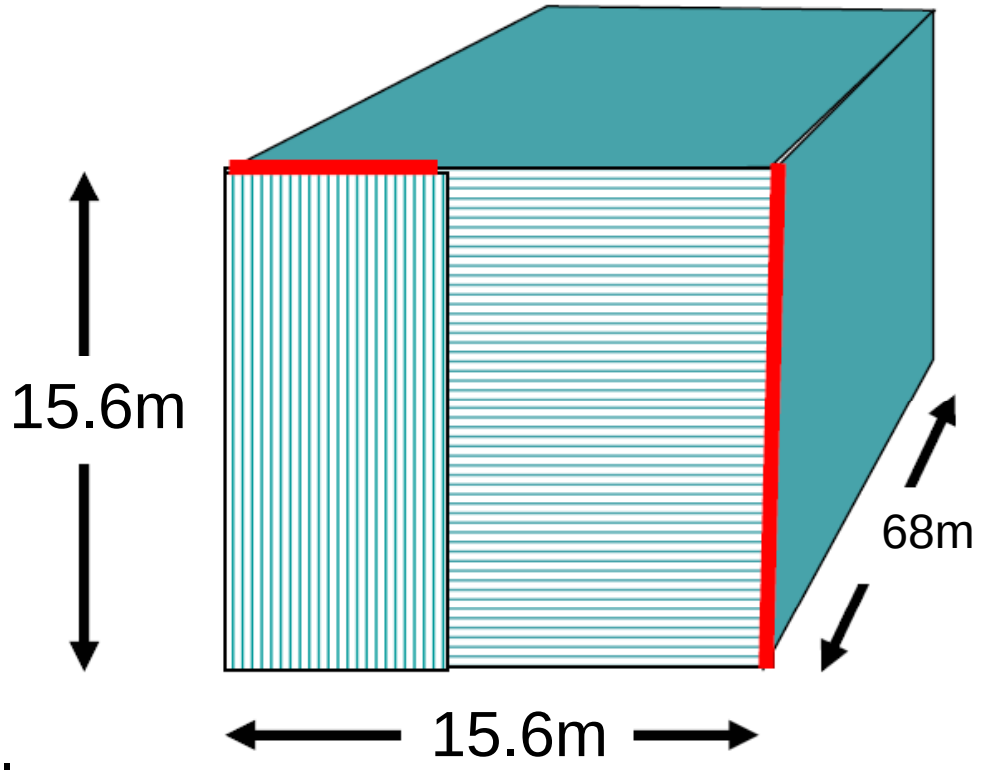
- This site is at 810 km from Fermilab, 11.77 km off-axis
- Farthest available site in the U.S. along the NuMI beam
  - US 53, St. Louis County Road 129 - all weather access

Far Site Status

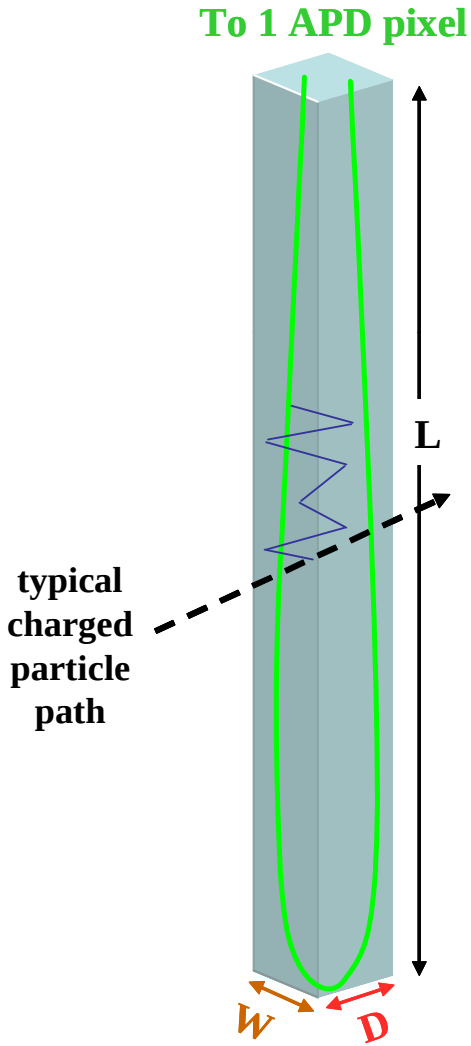


NOvA Far Detector

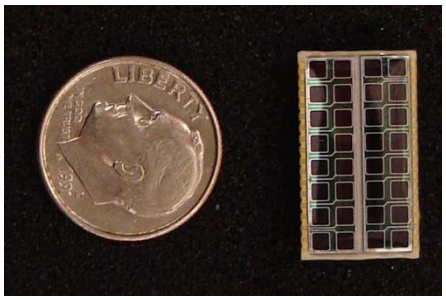
- 15 ktons
- 15.6m x 15.6m x 68m
- 1003 liquid scintillator planes, (~73% active)
- Scintillator cells 3.8 x 6.0 x 1540 cms
- Read out from one side per plane with APDs
- Expected average signal at far end of 30pe



The Basic Detector element

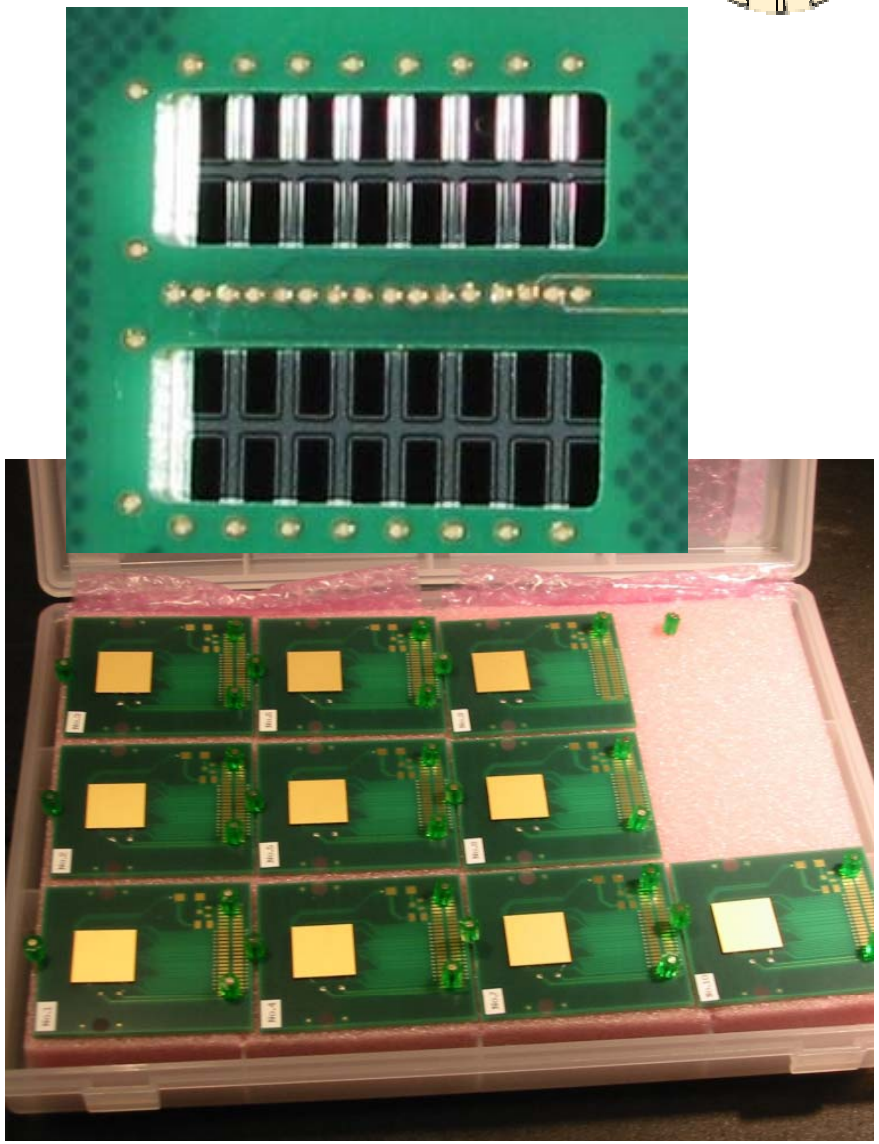


- Liquid Scintillator
  - 4.1% pseudocumene as scintillant
  - Mineral oil and waveshifters (PPO, bis-MSB)
- PVC cell for primary containment
  - Horizontals:3.87 cm x 6.0 cm x 15.4 m long
  - Verticals: 3.76 cm x 5.7 cm x 15.4 m long
  - Highly reflective, 15% titanium dioxide
- Looped wavelength shifting fiber to collect light
  - 0.7 mm diameter, double clad, K27 waveshifter
  - Almost perfect mirror, 3.6*light in 1 fiber
- Avalanche Photodiode
  - 85% quantum efficiency
  - Gain of 100, operate at -15^{o}C
- Low noise amplifier

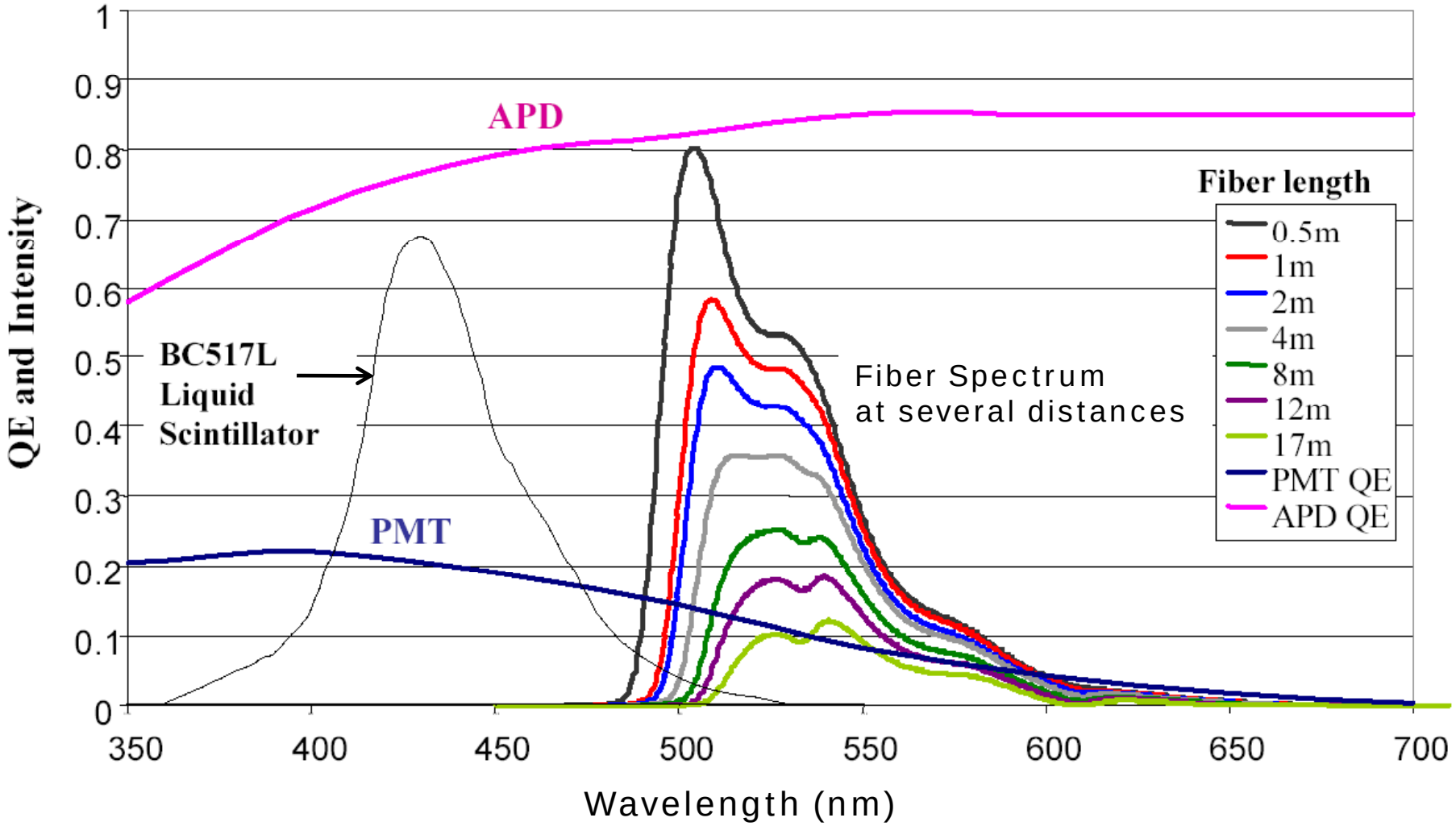


APD Photodetector

- Hamamatsu Si Avalanche Photodiode (APD)
  - S11211(X) Custom Variant of commercial S8550 SiAPD
  - Custom design to match to fiber aspect ratio
  - Bare die mounted to PCB via bump bonding



APD Advantage



e CC event

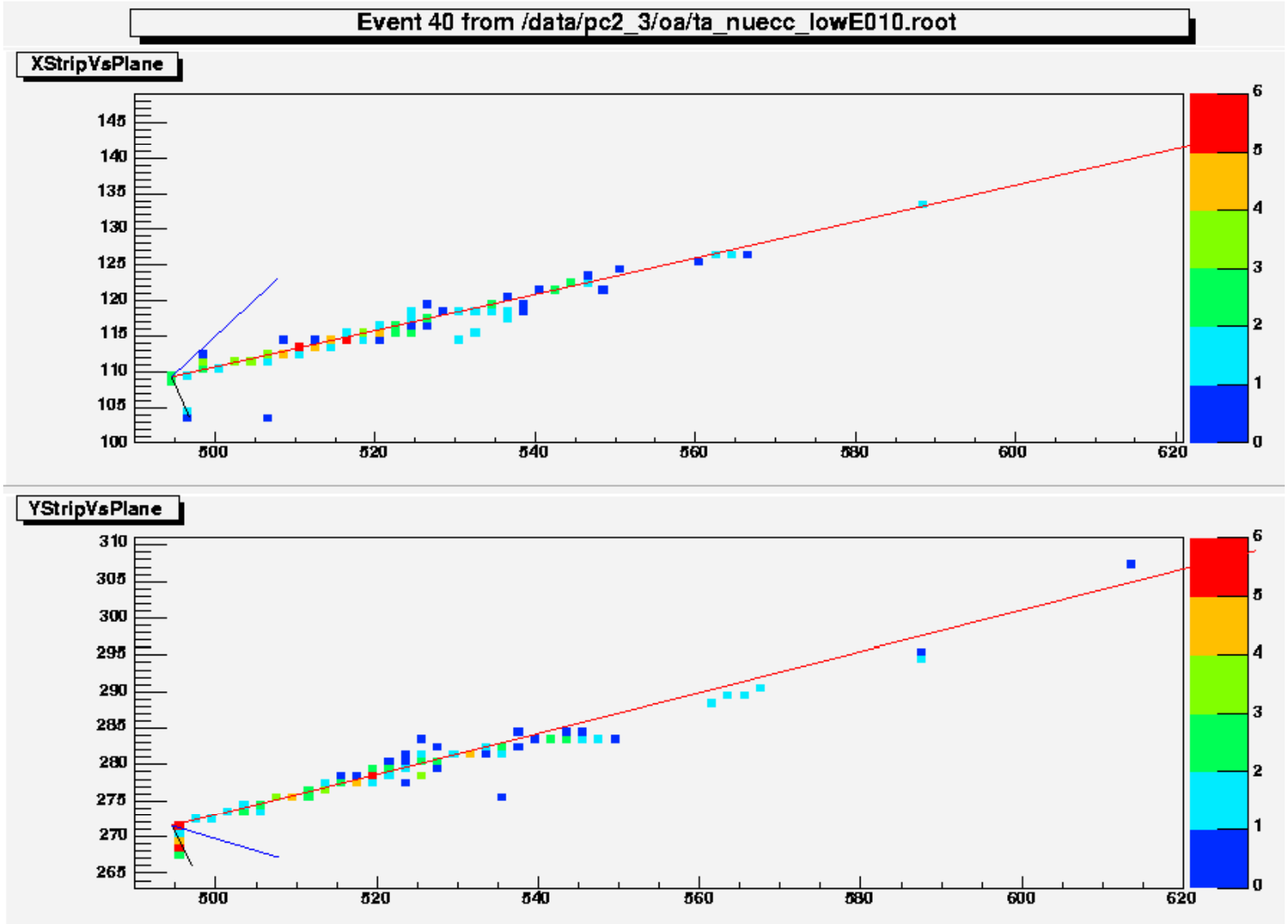
$\nu_e p \rightarrow e^- p \pi^+$

E_ν=2.5GeV

E_e=1.9GeV

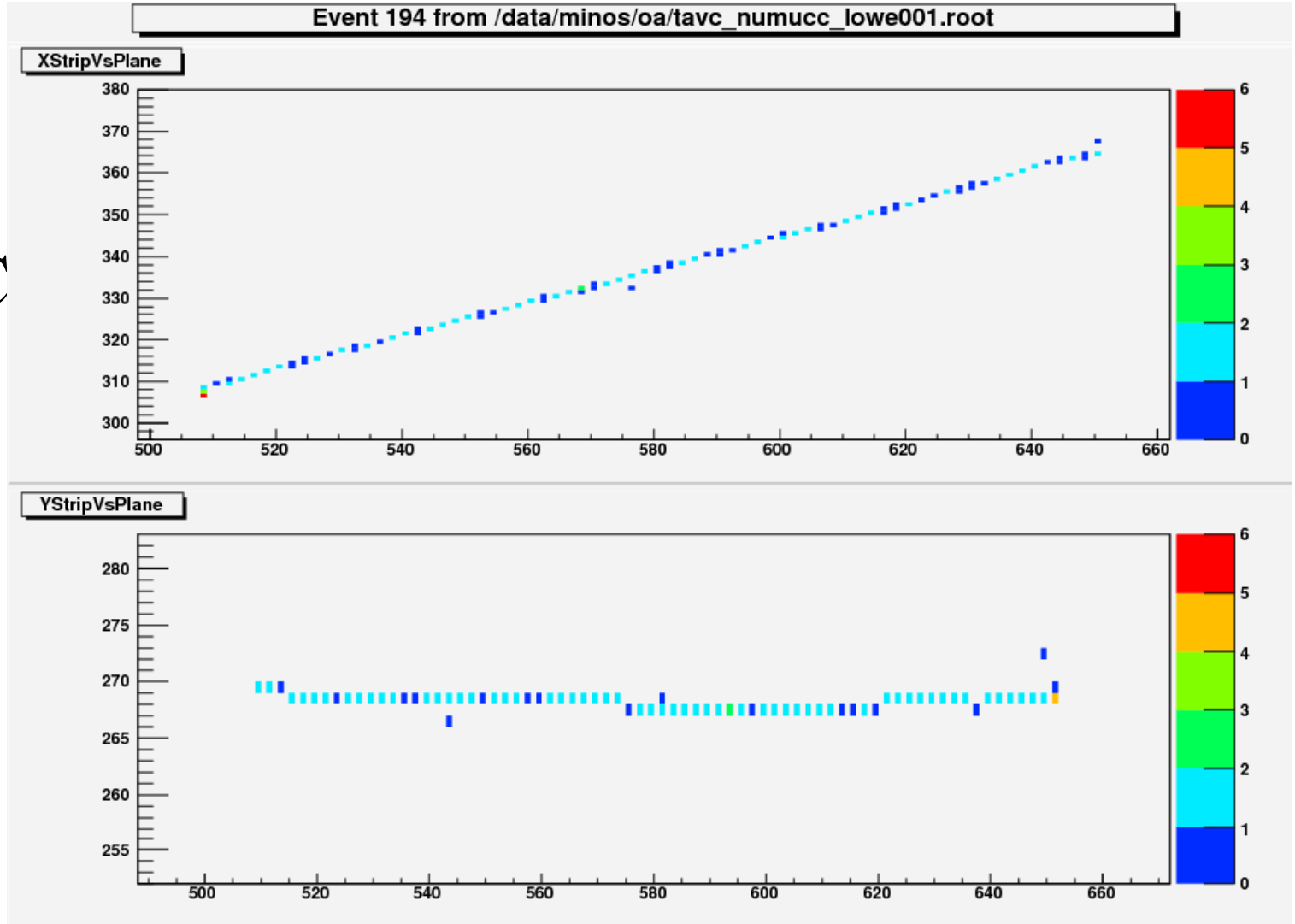
E_p=1.1GeV

E_π=0.2GeV



μ CC event

- 2GeV muon CC event



μ CC event

$\nu_\mu n \rightarrow \mu^- n \pi^+ \pi^o$

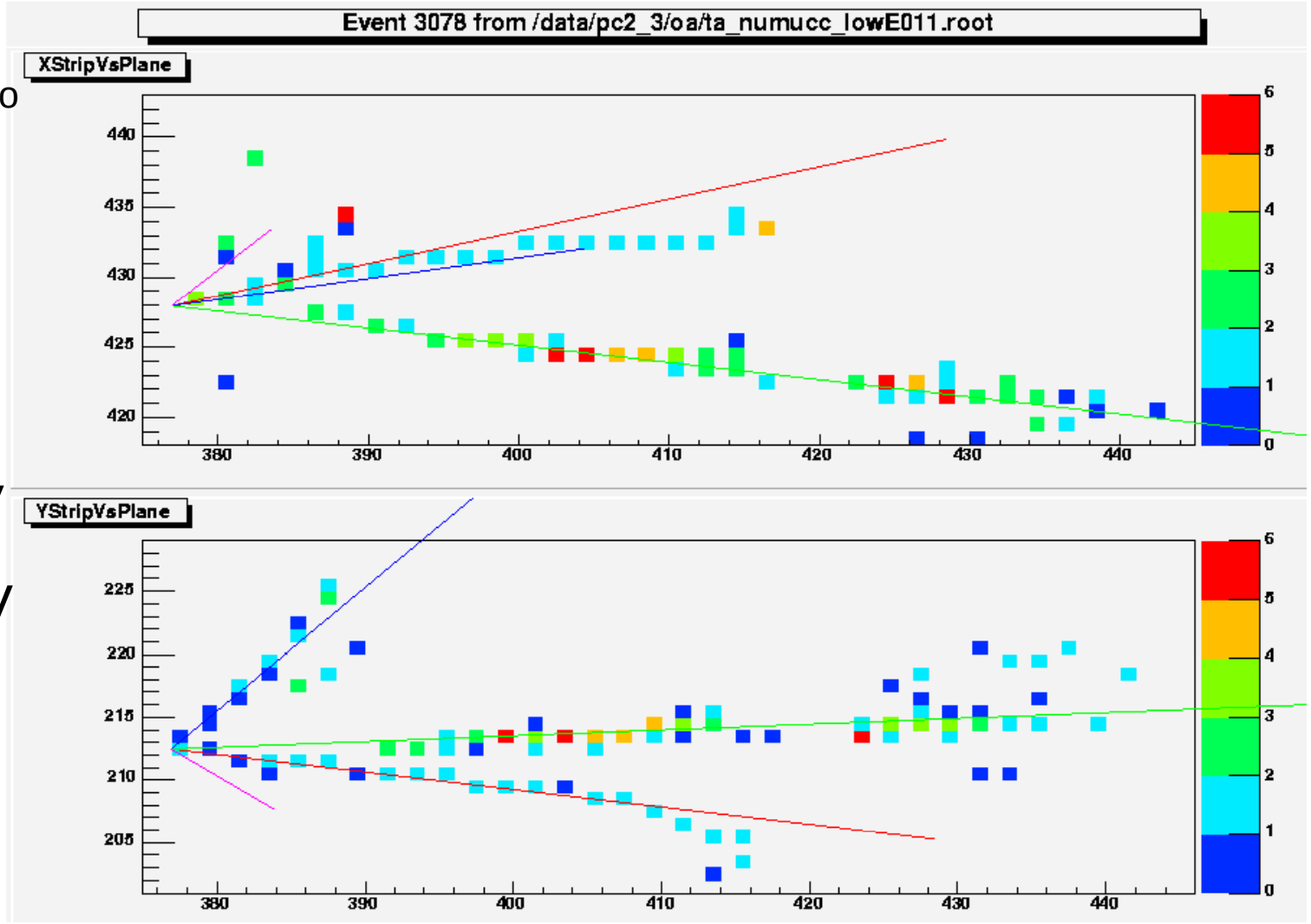
E_ν=2.8 GeV

E_μ=0.5GeV

E_n=1.0GeV

$E_{\pi+}$=0.4GeV

$E_{\pi o}$ =1.8GeV



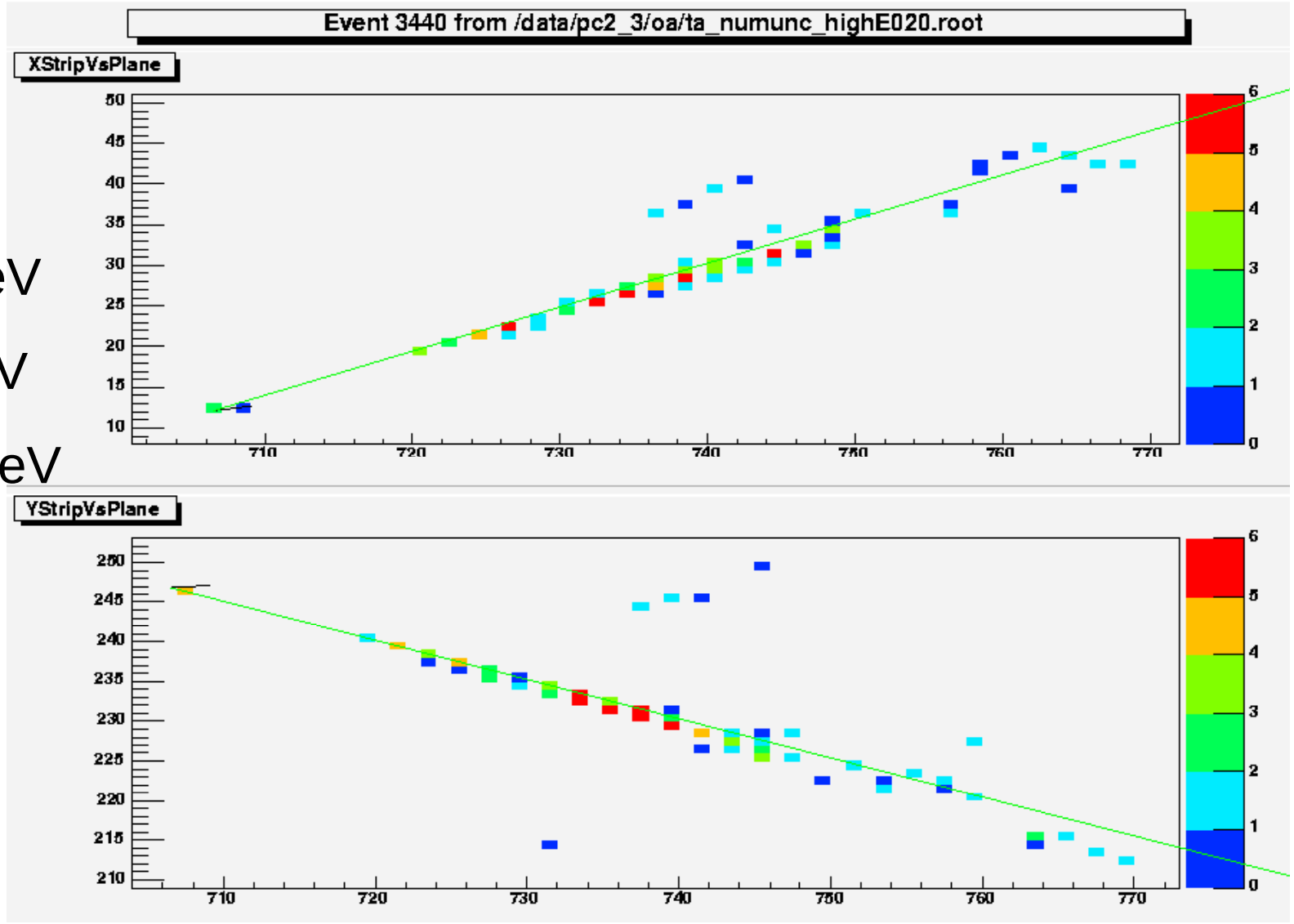
NC event

$\nu_\mu N \rightarrow \nu_\mu p \pi^o$

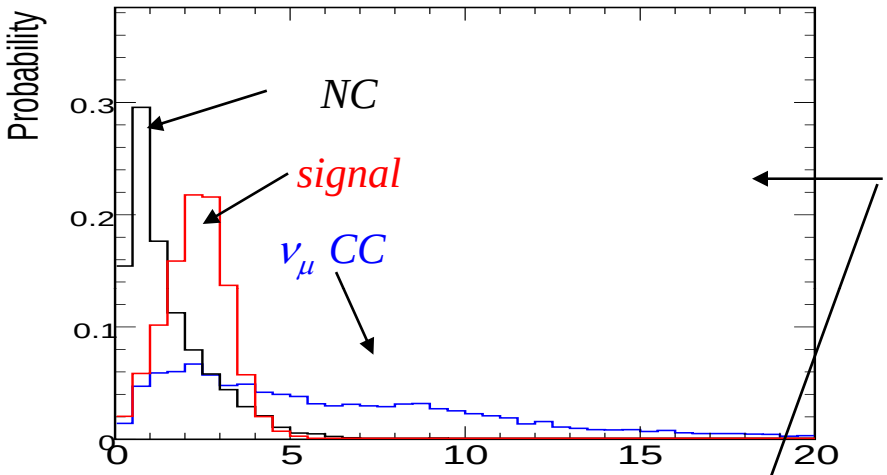
E_ν=10.6 GeV

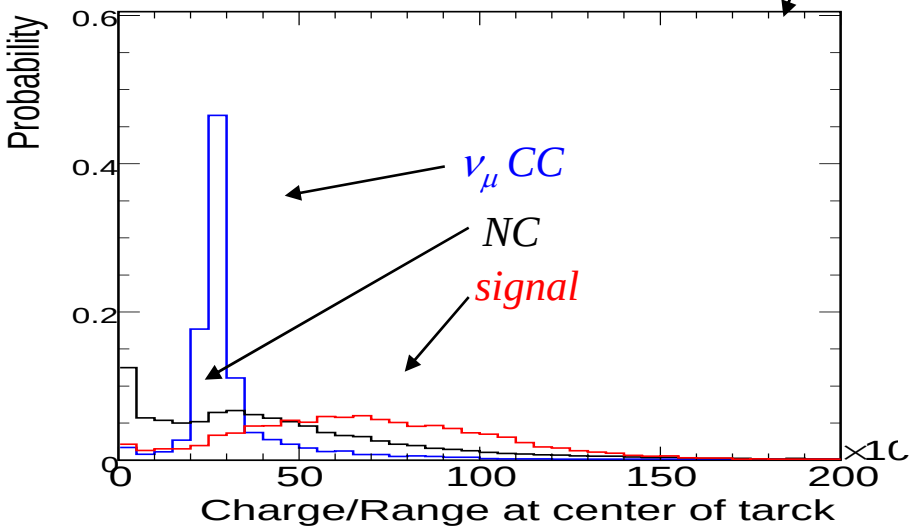
E_p=1.04GeV

$E_{\pi o}$ =1.97GeV



Electron Identification for NOvA (TDR Analysis)

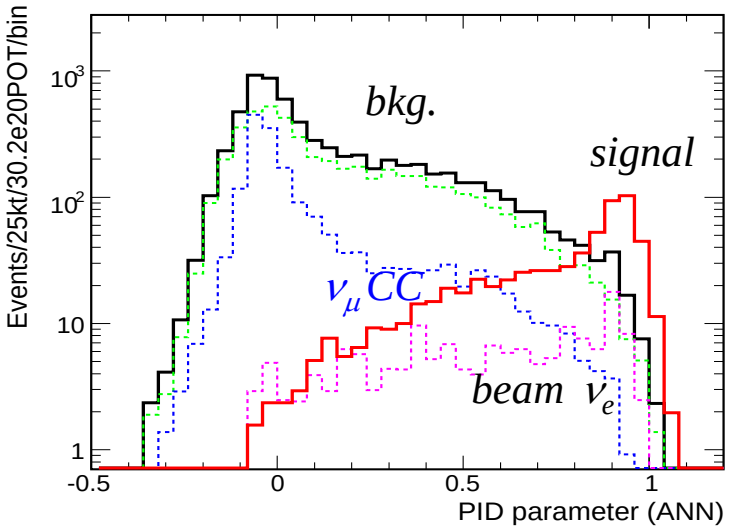




~20 variables in Neural Net

Example distributions

Overall efficiency ~30% (optimizable)



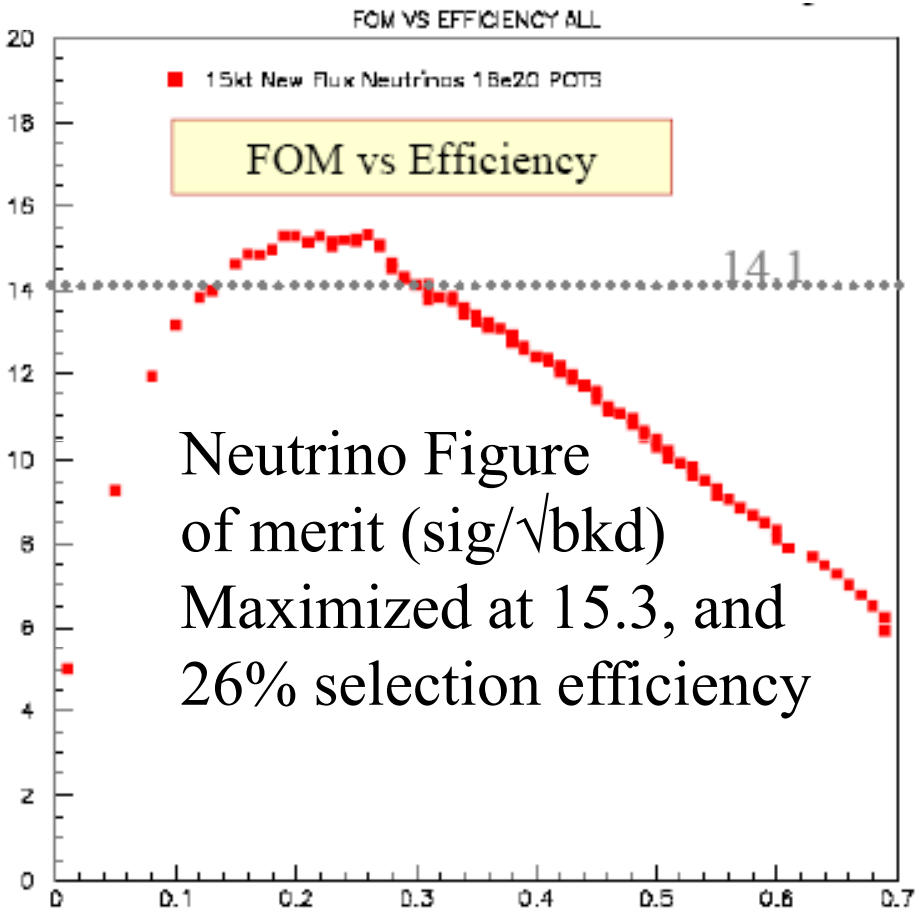
ANN Output

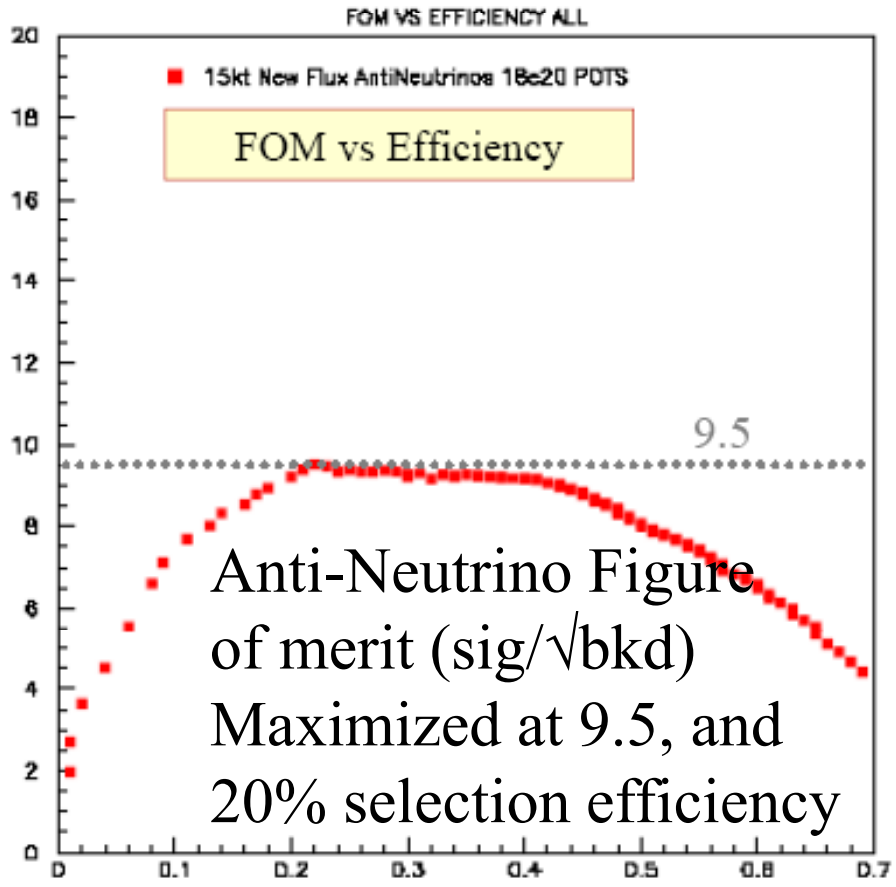
Detector Performance

- Optimize Figure of Merit (FOM=sig/√bkd) performance separately for ν and anti-ν
- Use 18E20 POT, $\sin^2(2\theta_{13})$ =0.1, Δm^2=2.4E-3, no matter effects
- Upgrades to neutrino event generator
- Updates to predicted neutrino flux
- Updated detector mass and configuration
  - 15kT, slightly shorter modules, photodetector readout

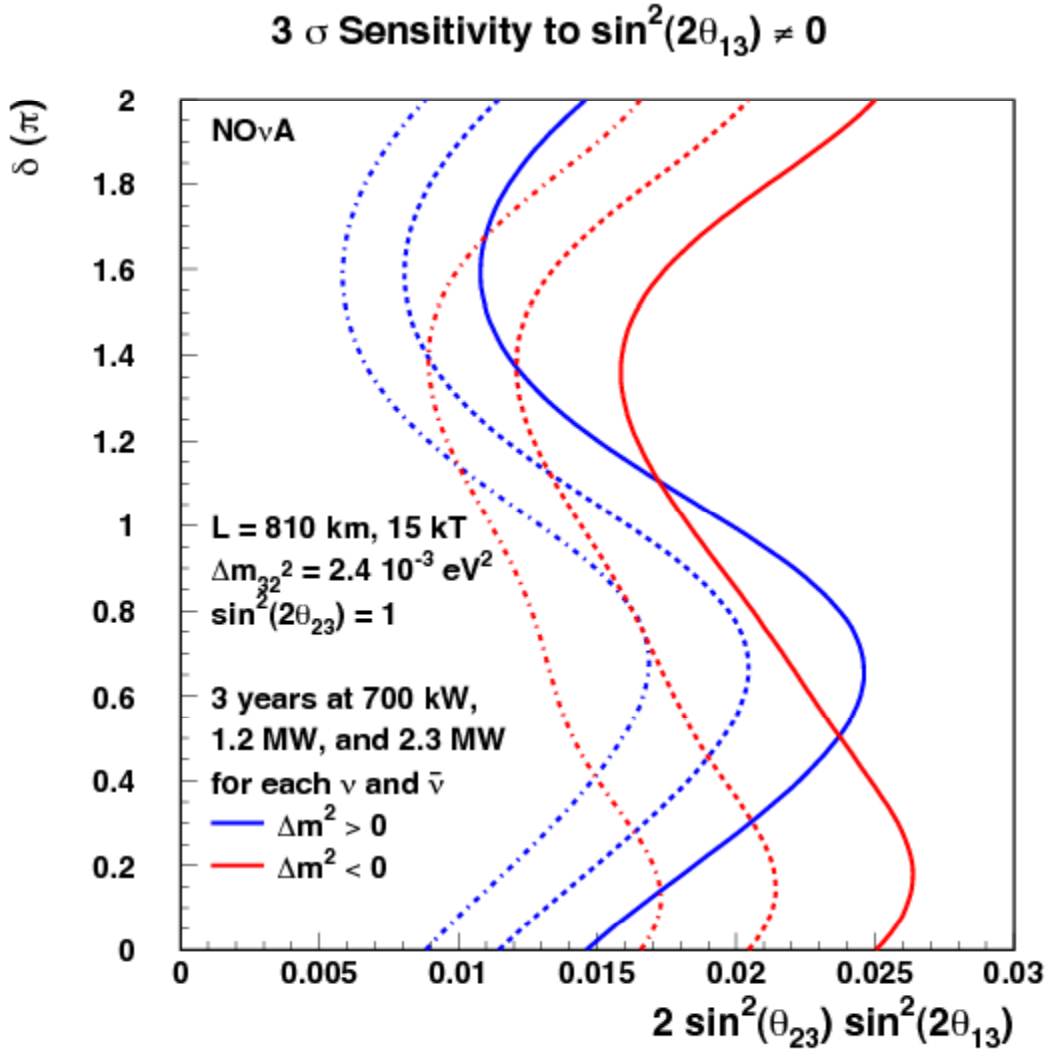
Performance optimization

Combined Figure of merit 18.0





3 σ Sensitivity to $\sin^2(2\theta_{13}) \neq 0$

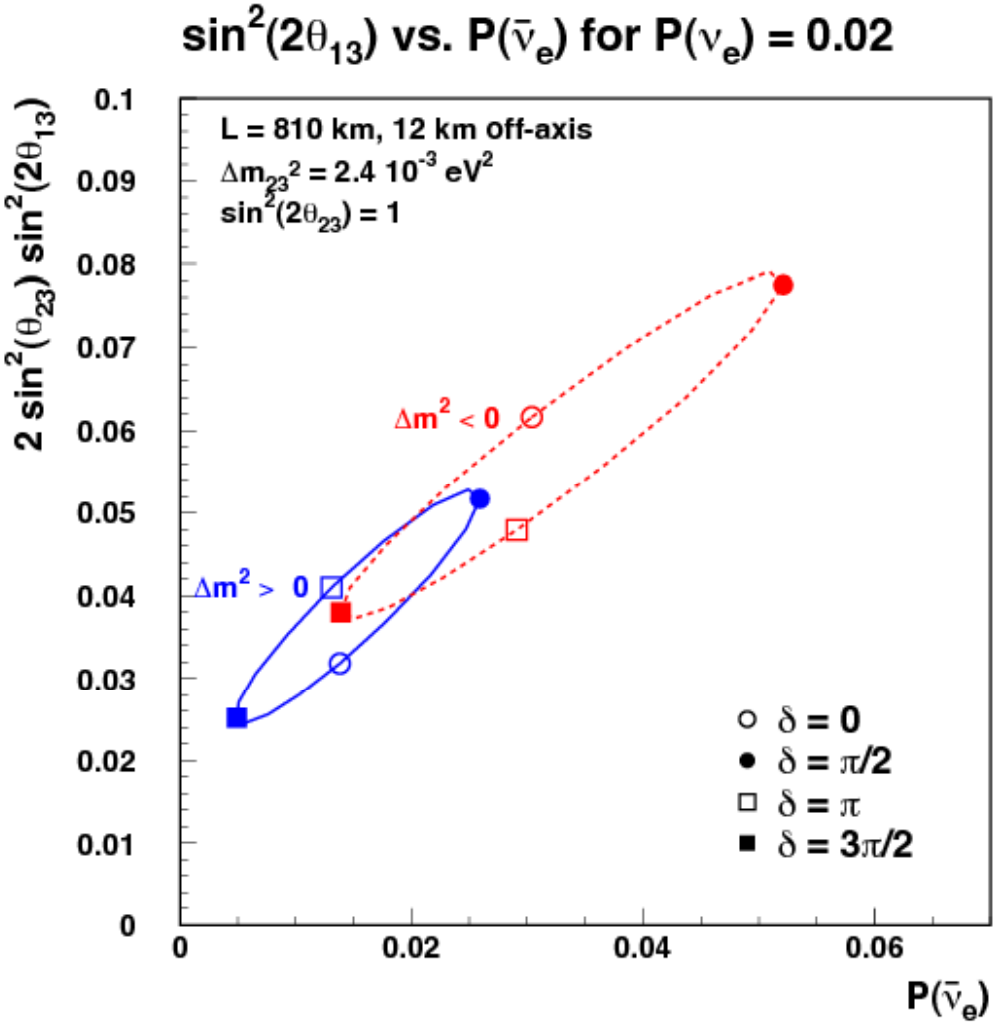


Sensitivity vs δ for non-zero $\sin^2(2\theta_{13})$ at 700kW, 1.2MW, and 2.3MW

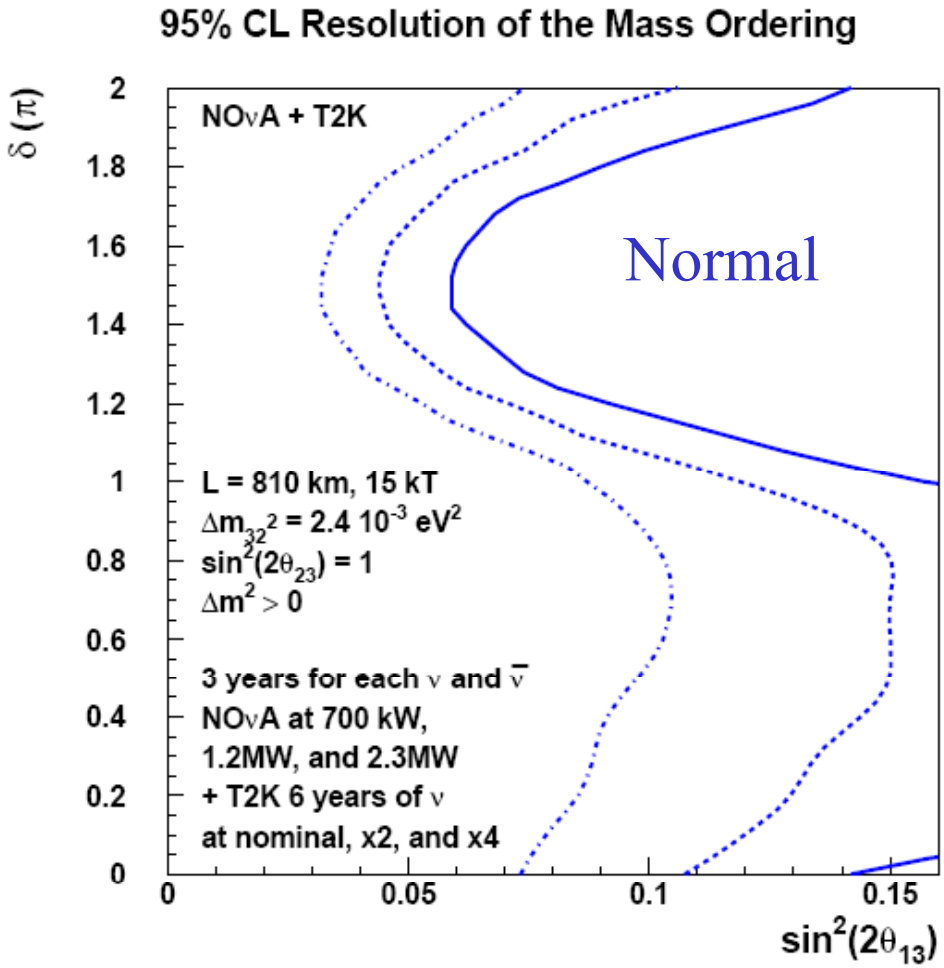
Mass Hierarchy Resolution

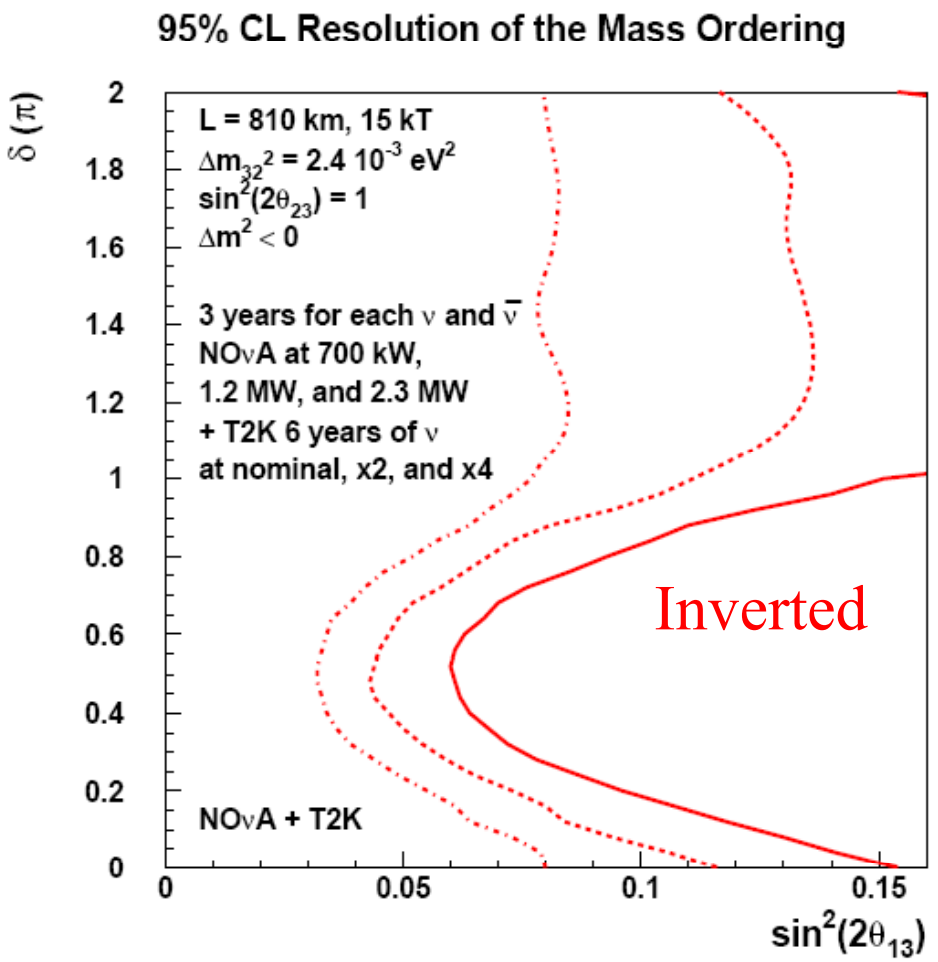
If you assume a measurement of $P(\nu_e)$=0.02, what does that imply about θ_{13} and the mass hierarchy, and how can you distinguish them.

Determine P using anti-neutrinos and/or measure θ_{13} in reactor experiment.

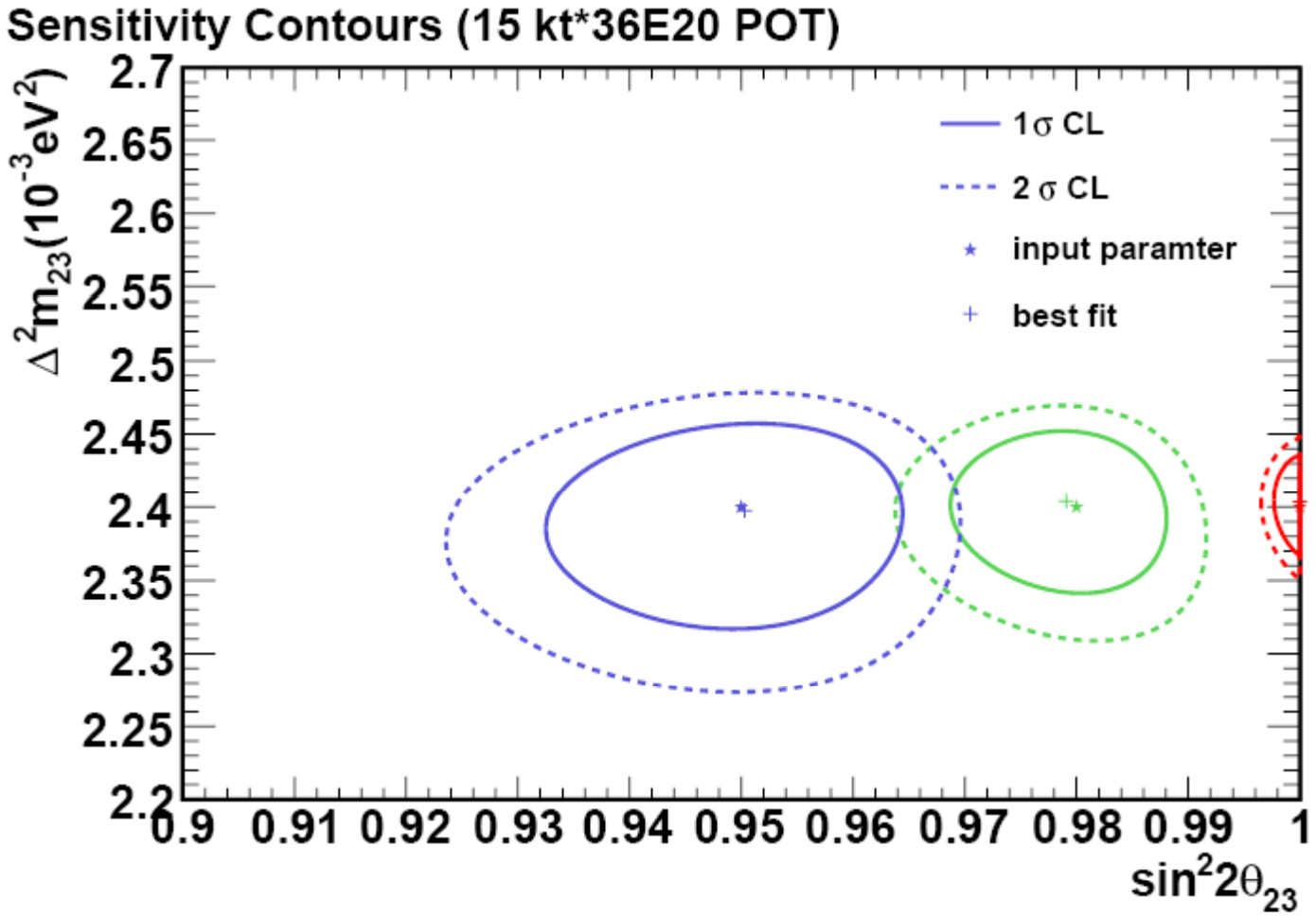


95% CL Sensitivity to the Mass Ordering





Measurement of $\sin^2(2\theta_{23})$

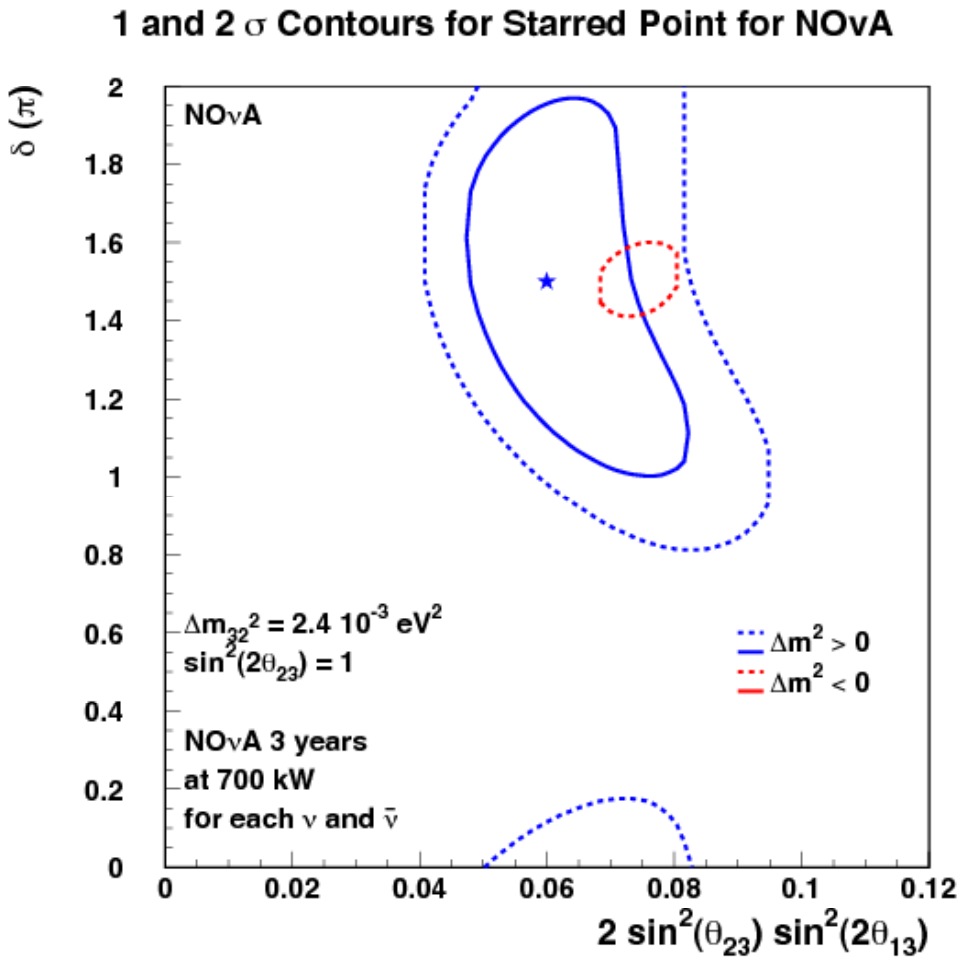


If $\sin^2(2\theta_{23}) = 1$, then it can be measured to 0.004.

Otherwise, it can be measured to ~0.02.

CP phase

- Assuming a normal hierarchy, and oscillation at the starred point, NOvA measurement resolves the mass hierarchy, and constrains δ_{CP} to the top half of the plane.

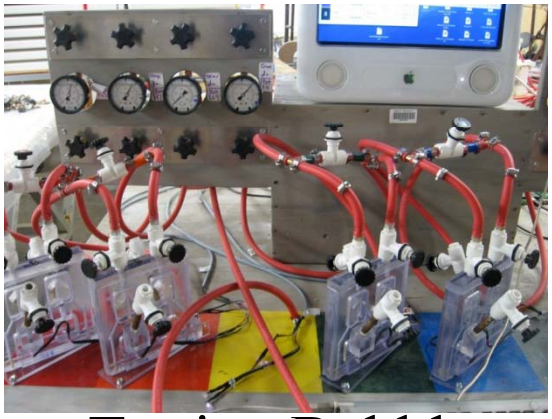


Progress

- Advances on all fronts
  - Accelerator and NuMI Upgrades (ANU) extensive shutdown plans beginning upgrades necessary for 700kW operation.
  - Module components prepared, or contracts made for prototype detector. (Integration Prototype Near Detector (IPND), and more, where approved)
  - Assembly prototypes under construction
    - Static leak tests, full height, in C0, full pressure at UMN
    - FSAP, Full Size Assembly Prototype
      (See collaboration photo “Dance Floor”)
    - FHEP, Full Height Engineering Prototype , 31 planes 2 modules wide

Module Assembly and Testing

Bubbler Construction



Testing Bubblers

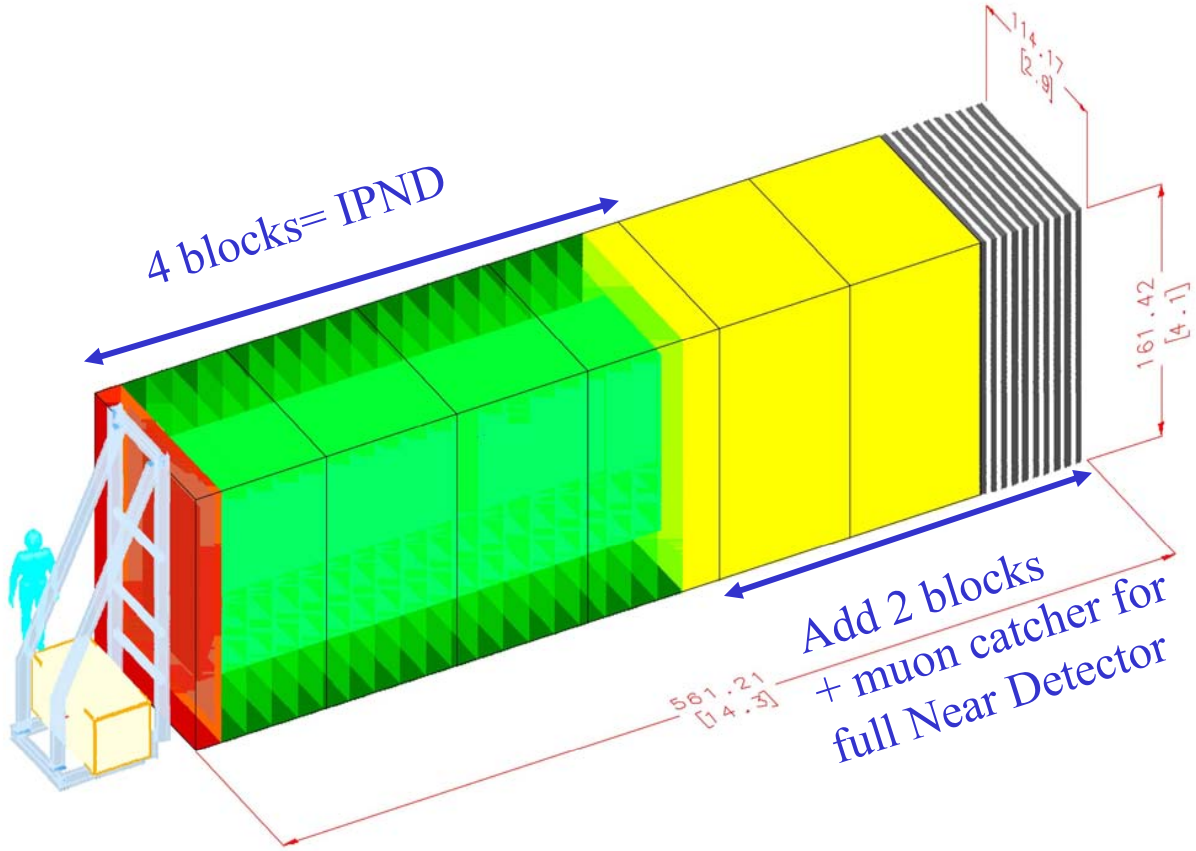
Extrusion production

Rolling Lifting Fixture

Adhesive Dispenser

Integration Prototype Near Detector

- Constructing prototype detector to run on the surface near MINOS Surface Building
- 4 Blocks (6+)
- 2.9m wide
- 4.2m tall
- 8.4m long (15.3m)



Approximate Schedule

- May 2007: US DOE CD-1 Approved
- Sep 2007: Cooperative Agreement signed
- Nov 2007: US DOE CD-2/3A review
  - Baseline, advanced procurement
- Dec 17, 2007 R&D funding for FY08 cut to zero.
- July 1, 2008 Supplementary funding restarts progress
- Sept 15, 2008, Oct 24, 2008: CD-2, CD-3A Approved
- April 2009: Reinvestment Act, and FY09 funding approved
- May 1, 2009 Groundbreaking at Ash River
- Fall 2009 Begin Building IPND modules
- Winter 2009/10 Begin building IPND Blocks
- **Summer 2010 Begin operation of IPND (prototype Near Det.)**
- Summer 2010: Beneficial Occupancy of the Far Detector building
- **Winter 2011: Begin to Install FD, Data taking after a few kT installed**
- **2013 Installation Complete**

Conclusions

- The NOνA experiment exhibits significant sensitivity to the current and future issues of neutrino oscillations
  - Electron neutrino appearance -- $\sin^2(2\theta_{13})$
  - Muon neutrino disappearance -- $\sin^2(2\theta_{23})$
  - mass hierarchy resolution
  - CP violation measurement
- Upgraded beam intensity needed to reach all of these goals
- Final thanks to NOνA Collaborators for their contributions

Extras

Far Detector Neutrino Spectrum

(L=810 km, theta=14 mrad)
Signal at CHOOZ limit