The NuMI Off-axis ν_e Appearance Experiment (NOνA)

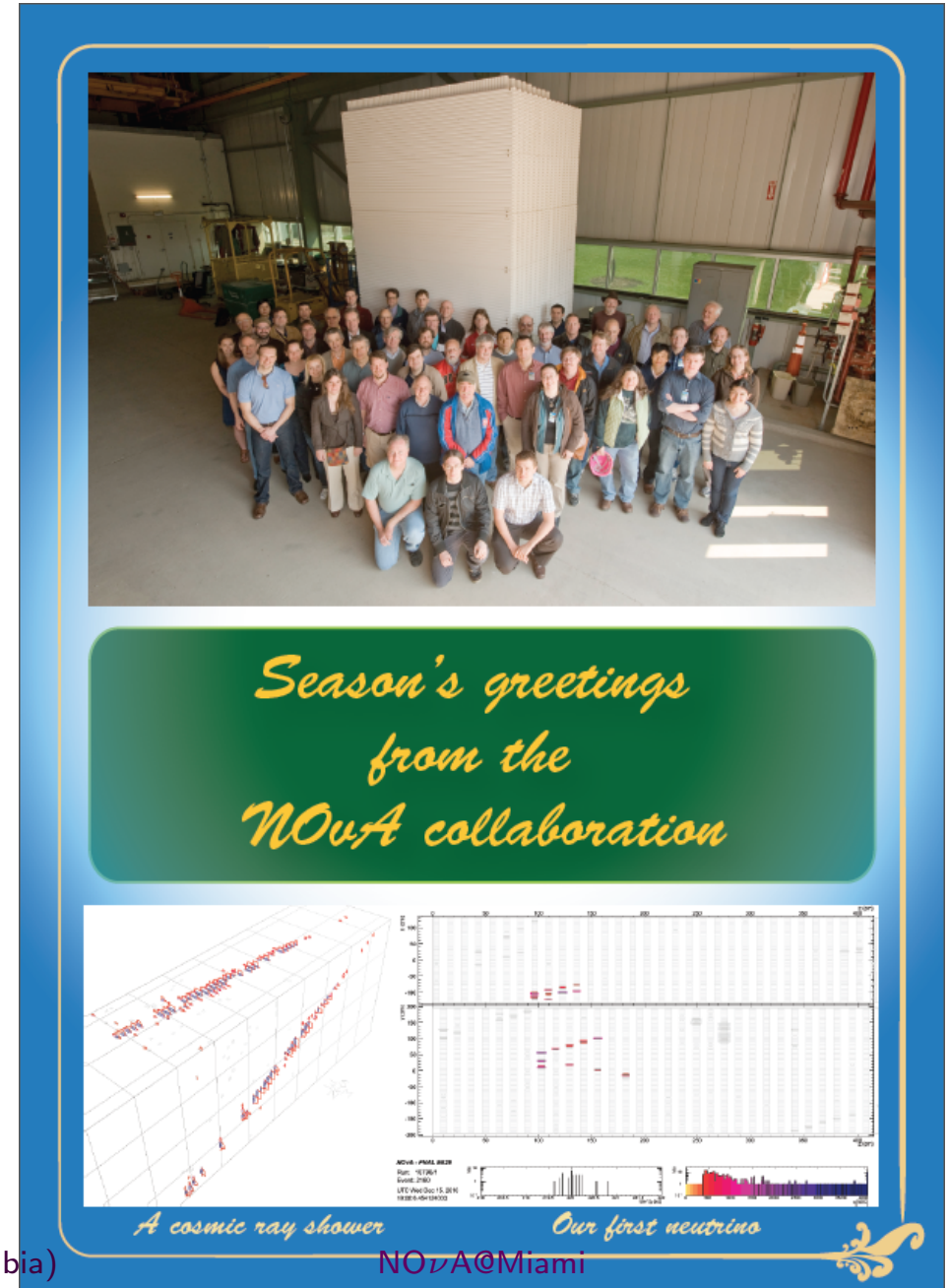
THE FIRST NEUTRINO INTERACTION WAS "OFFICIALLY" OBSERVED DEC. 15, 2010.

Xinchun Tian

Department of Physics and Astronomy

Miami 2010, 2010/17

THE FIRST NEUTRINO EVENT - Dec. 15, 2010



Outline

NOνA Physics Potential

NOνA Experiment
- NuMI Beam
- The NOνA Detectors

Current Status
- Near Detector on the Surface (NDOS)
- Far Detector

Summary

NOνA Physics Potential[1]

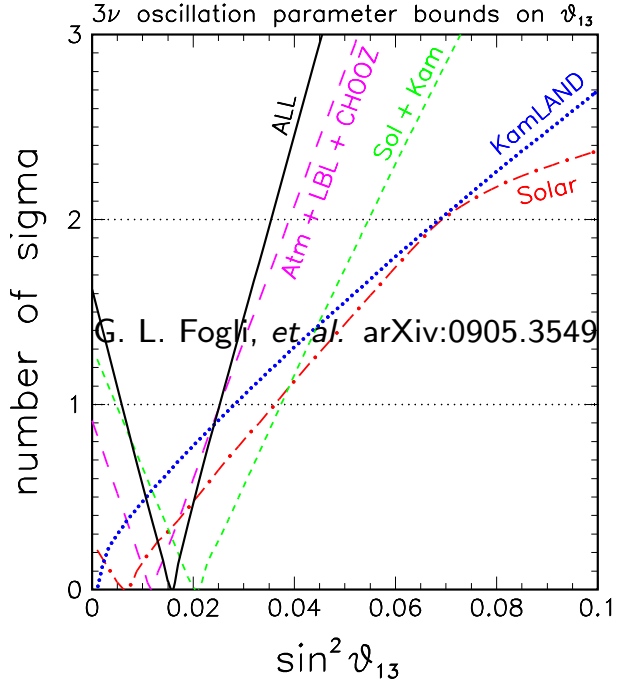
NOνA can address 7 of the 8 questions posed by the P5 strategic plan for neutrino physics by:

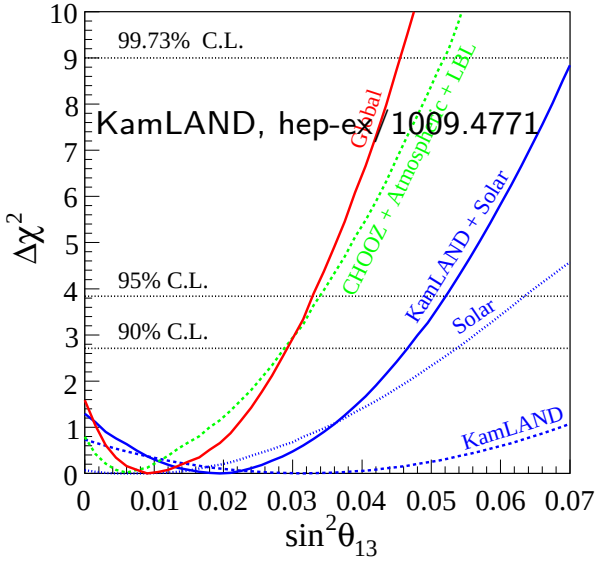
- intense ν beam - 700 kW
- Off-axis (lower backgrounds)
- Long baseline (810 km)
- 73% active detector
- 14 kt total mass

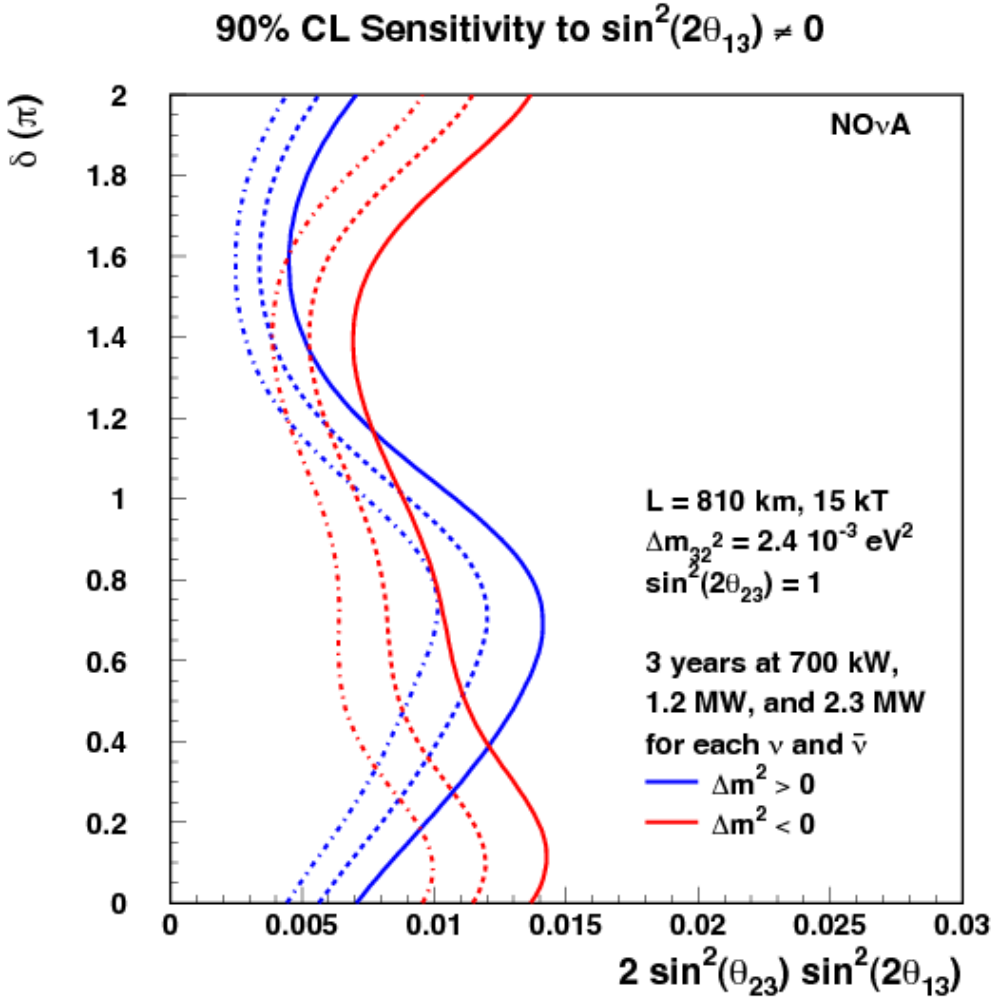
- What is the value of θ_{13}?
- Do neutrino oscillations violate CP?
- What are the relative masses of the three known neutrinos?
- Is θ_{23} maximal (45 degrees)?
- Are neutrinos their own anti-particles?
- What can we learn from observation of the intense flux of neutrinos from a supernova within our galaxy?
- What can neutrinos reveal about other astrophysical phenomena?
- What can neutrinos tell us about new physics beyond the SM, dark energy, extra dimensions? Do sterile neutrinos exist?

[1] Assume 3 years neutrino + 3 years anti-neutrino beam at 0.7, 1.2 , or 2.3 MW.

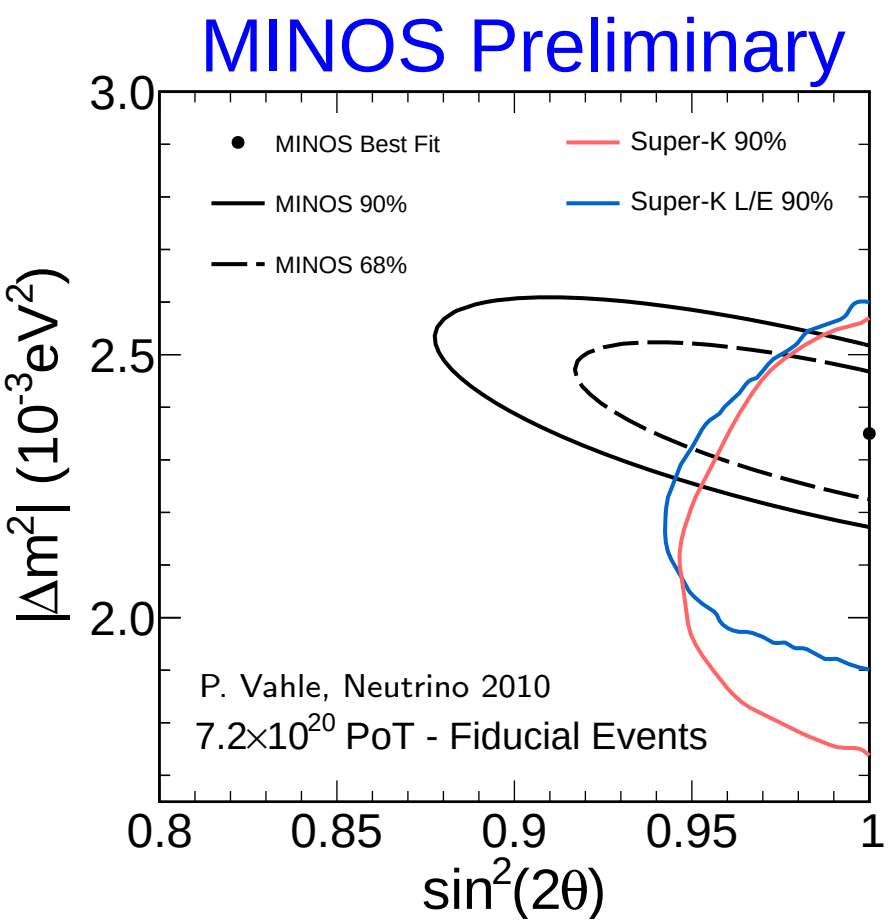
NOνA Physics Potential - θ_{13}

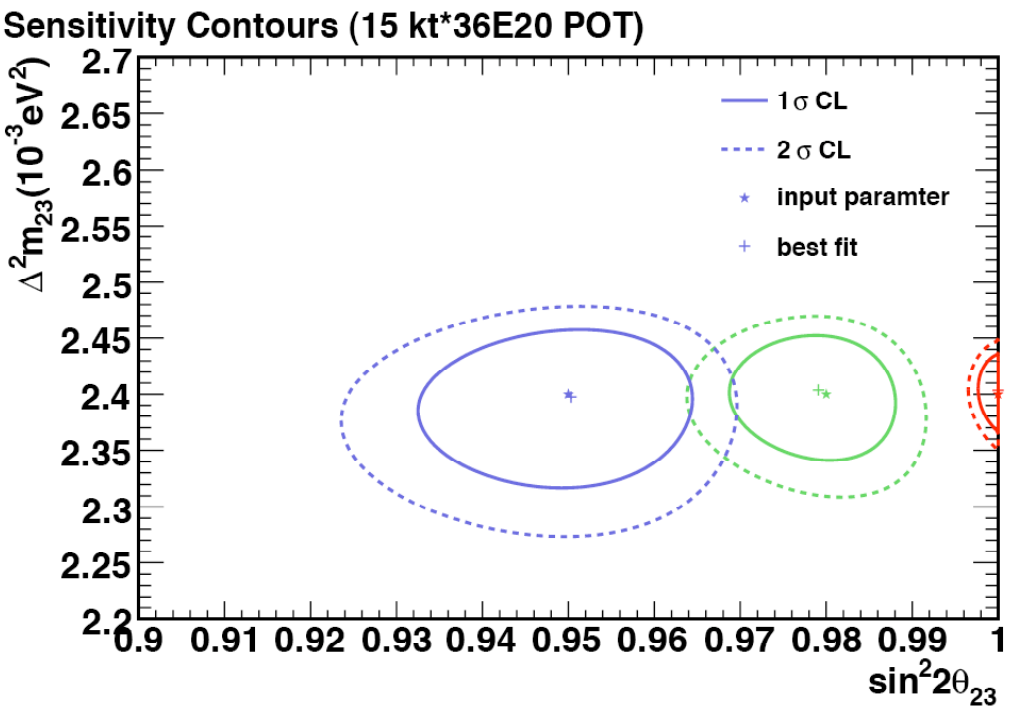






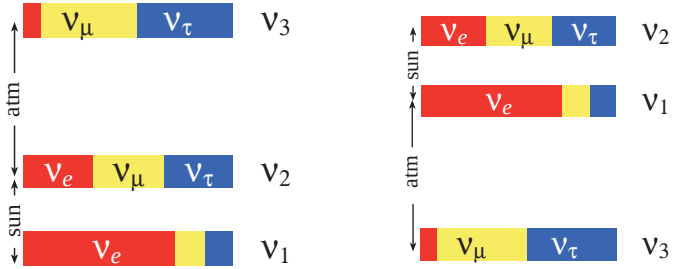
NOνA Physics Potential - θ_{23}



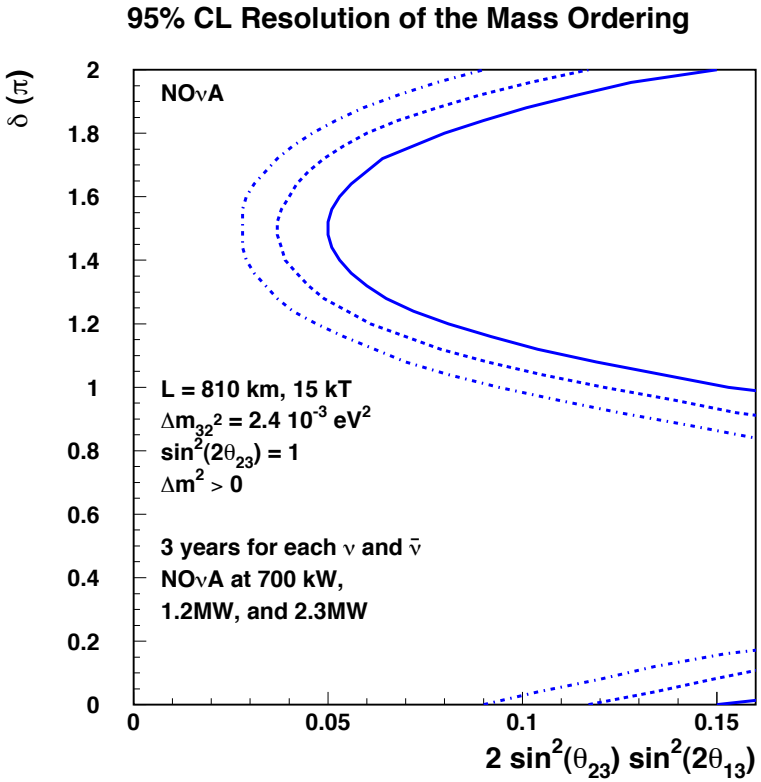


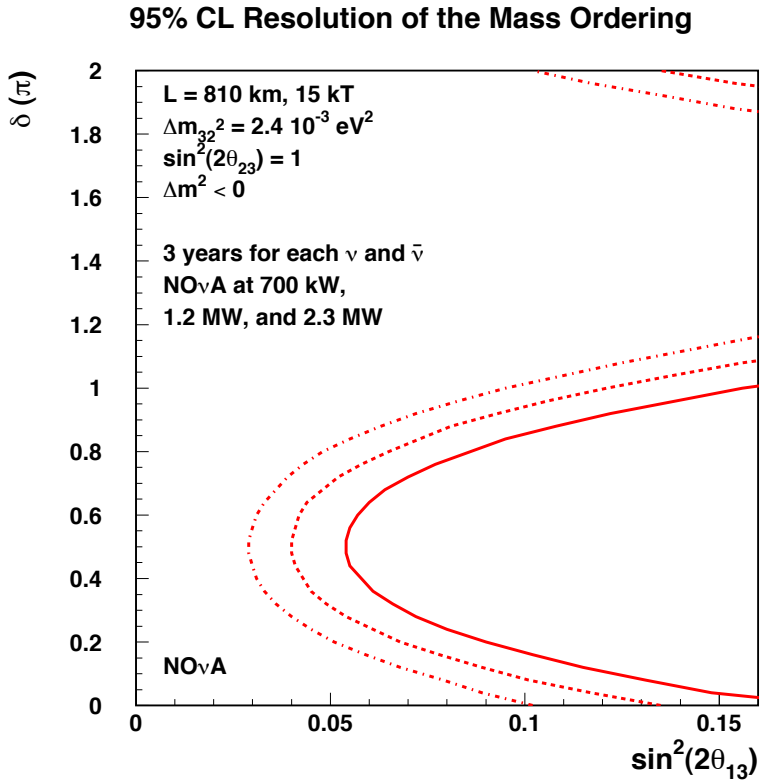
NOνA can improve the precision of the $\nu_\mu \rightarrow \nu_\tau$ mixing angle by over an order of magnitude over MINOS.

NOνA Physics Potential - Mass Hierarchy[2]



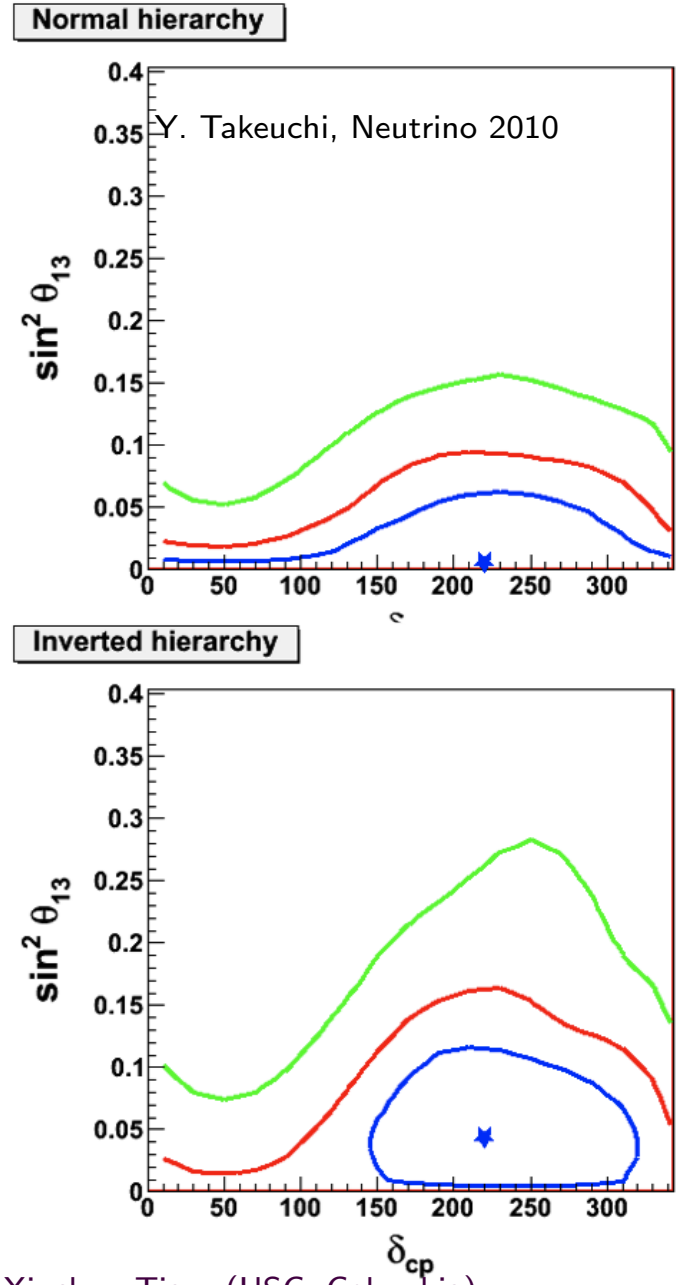
Normal Inverted

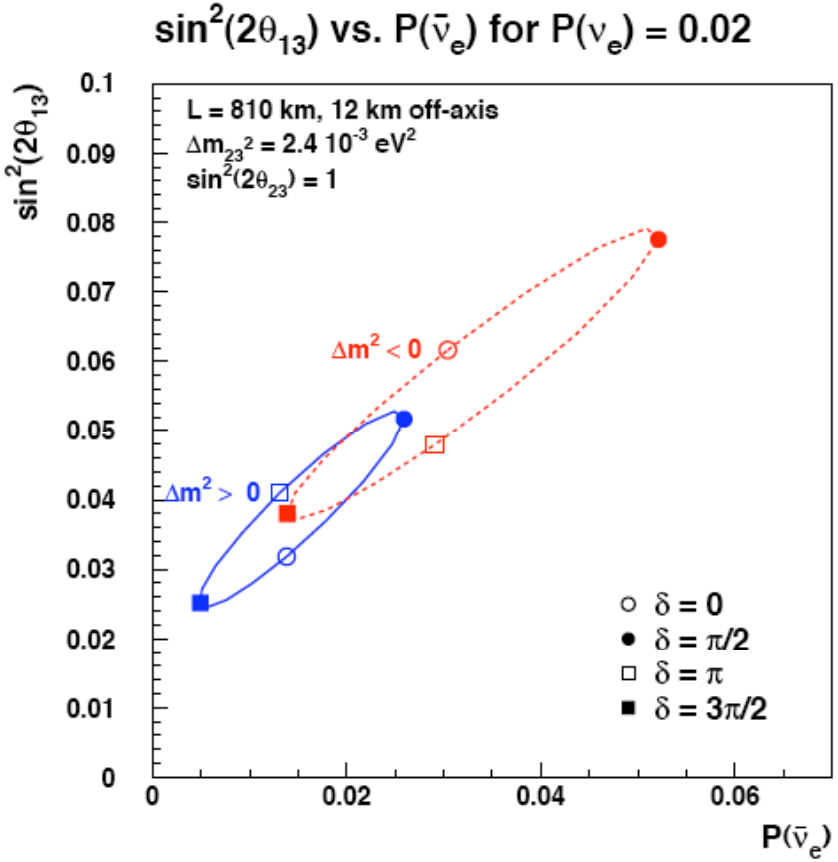




[2]Matter effect: NOνA$\sim$ 30%, T2K $\sim$ 11%.

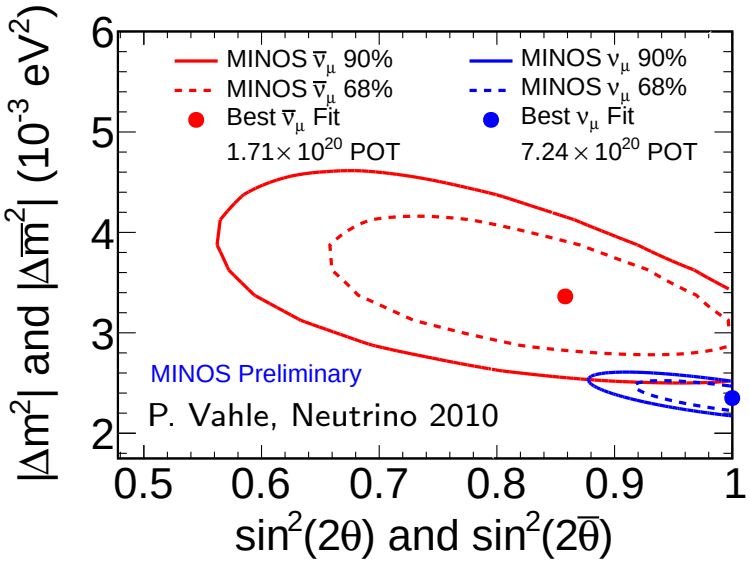
NOνA Physics Potential - *CP* phase + Mass Hierarchy



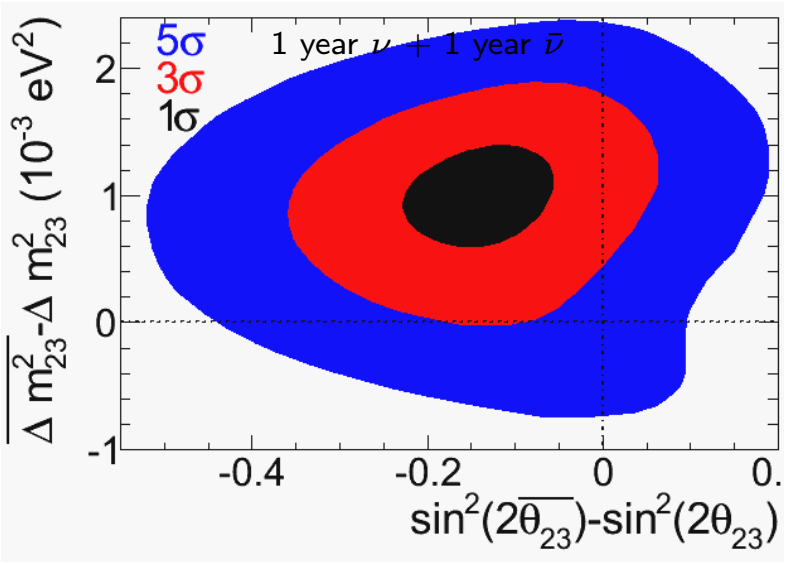


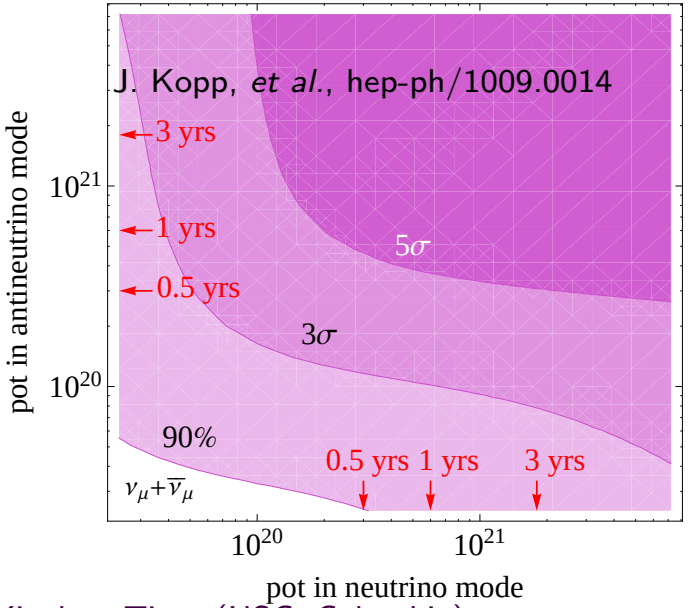
Finite group family symmetry $T' \times SU(5)$: $\delta = 227$ Degree [M. C. Chen *et al.*, Neutrino 2010]

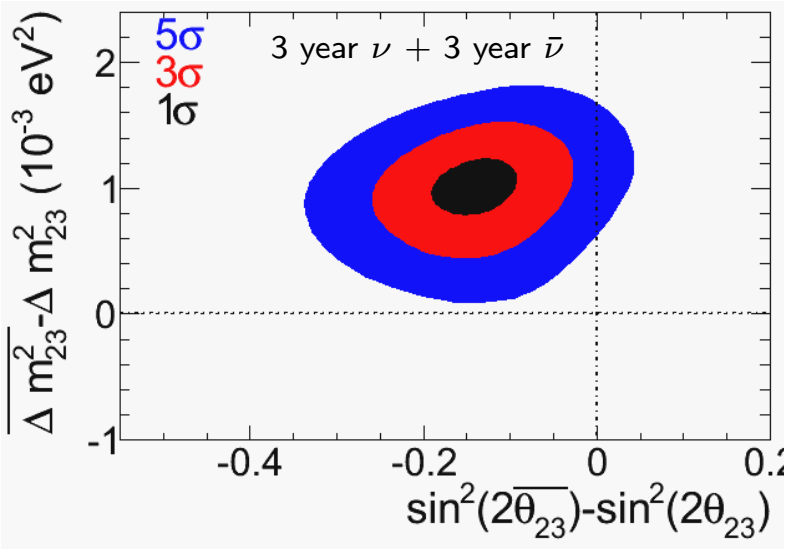
NOνA Physics Potential - ν_μ - $\bar{\nu}_\mu$ tension



CC NSI discovery reach in NOνA







Outline

NOνA Physics Potential

NOνA Experiment
- NuMI Beam
- The NOνA Detectors

Current Status
- Near Detector on the Surface (NDOS)
- Far Detector

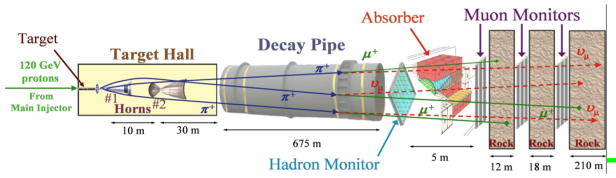
Summary

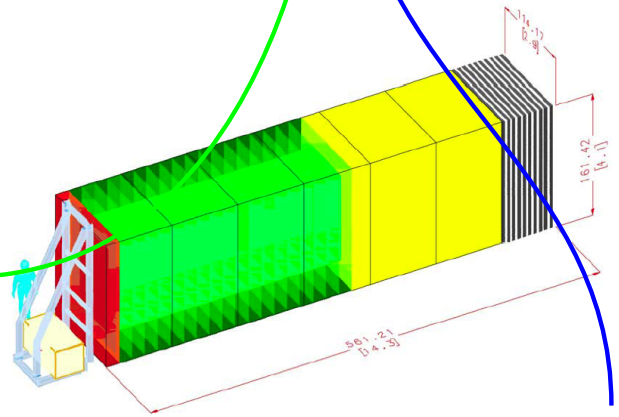
The NOνA Collaboration

Argonne
Athens
Caltech
College de France
Fermilab
Harvard
Indiana
Lebedev Physical Institute
Michigan State
Minnesota-Twin Cities
Minnesota-Duluth
INR Moscow
T U Mnchen
Northern Illinois
Northwestern
Ohio State
P.U.C. Rio de Janeiro
South Carolina
SMU
Stanford
SUNY Stony Brook
Tennessee
Texas-Austin
Texas-Dallas
Texas A&M
Tufts
UCLA
Virginia
William and Mary

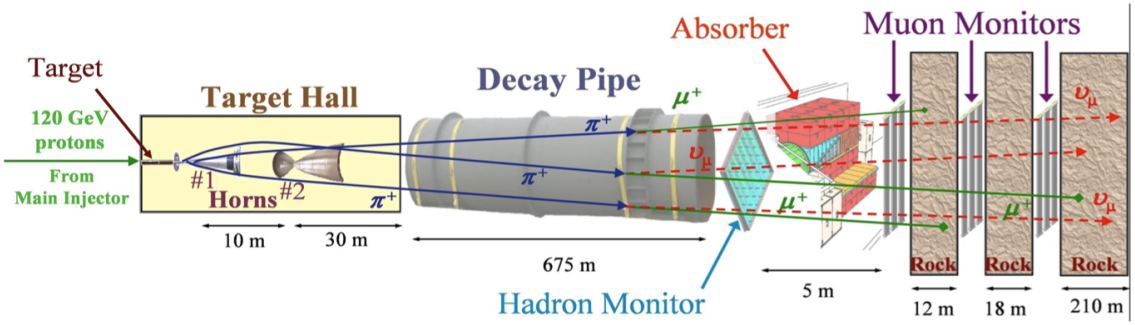
Wichita State

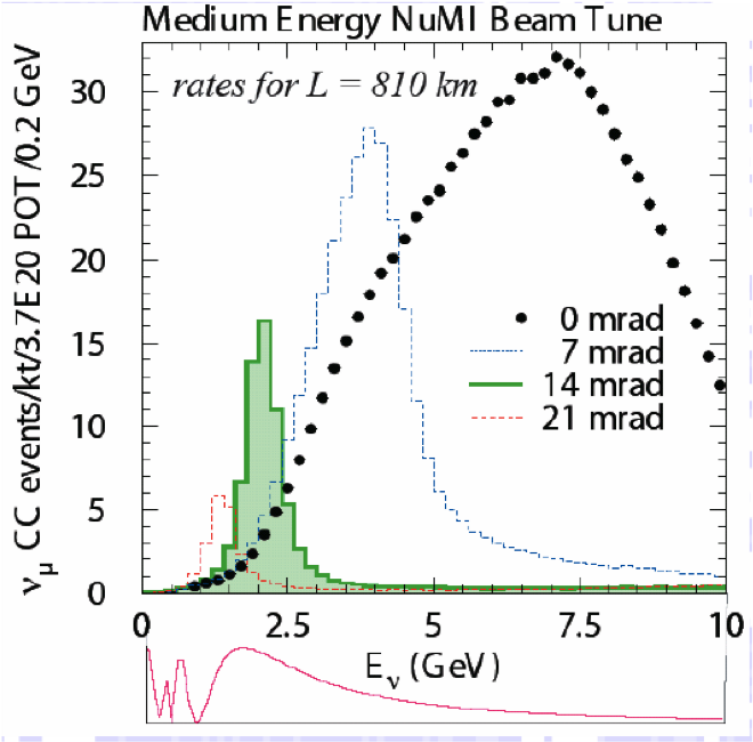
The NOνA Experiment





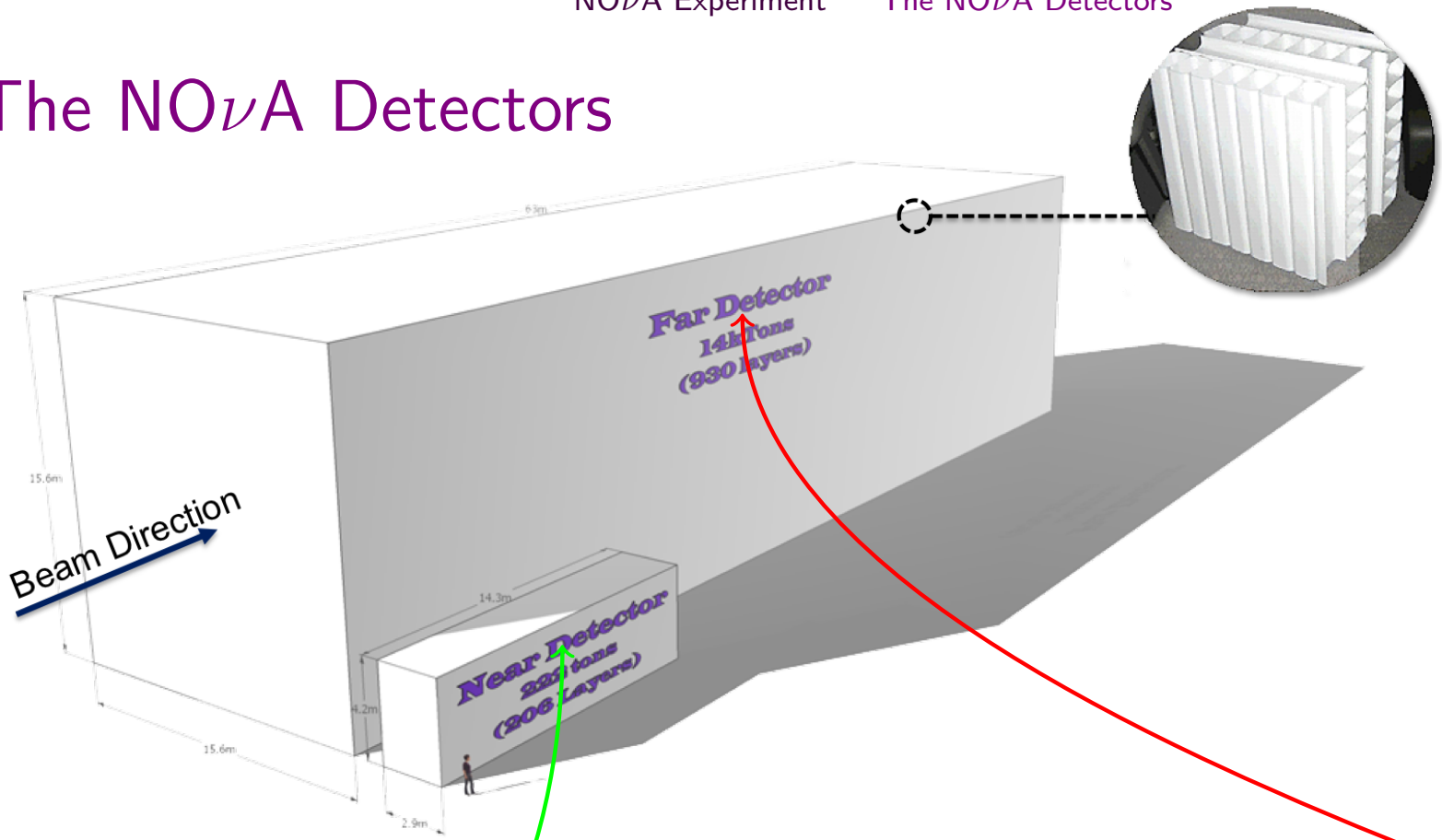
NuMI (Neutrinos at the Main Injector) Beam





- Beam Spectrum tunnable by horn currents, relative placement of target horns
  - ν or $\bar{\nu}$ predominant beam depending on horn current polarity
- 10 μs beam spill
  - Current every 2.2 sec ($\rightarrow$ 1.33)
- Operating since 2005
  - MINOS, MINERνA, ArgoNEUT
- Routinely delivers $\sim$300 kW beam power ($\rightarrow$ 700 kW)
- Most operations to-date in "Low Energy" mode optimized for MINOS on-axis location

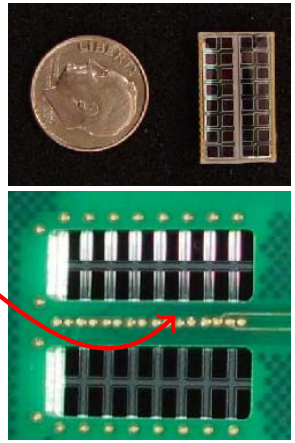
The NOνA Detectors

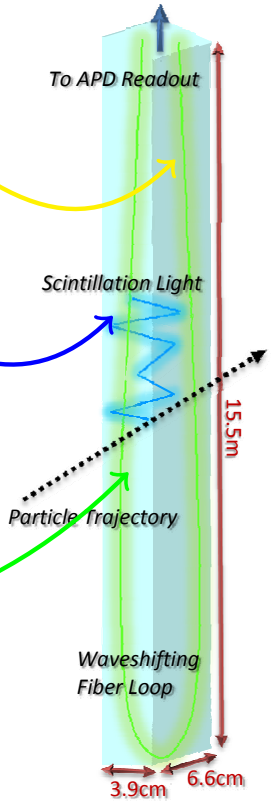


- 222 Tons - 206 layers (4.2 m $\times$ 2.9 m $\times$ 14.3 m)
- Includes muon catcher for ranging out μ's
- Each plane just 0.15 X_0, great for electrons
- 14 kTons - 930 layers (15.6 m $\times$ 15.6 m $\times$ 68 m)
- Alternating X/Y measuring planes
- Over 357,000 independent measurement cells
- $>$ 70% of total mass is active

Detector Components

- Avalanche photodiode (APD) converts light to electrical signal (11,160 devices, each 32 pixels)
  - 85% quantum efficiency
- Liquid Scintillator (3 million gallons)
  - Contained in 3.9 cm$\times$6.6 cm$\times$15.6 m cells
  - 3.9 cm as seen by the beam
- Cell walls are rigid PVC (5 kilotons)
  - Loaded with 15% anatase form of titanium dioxide
  - Diffuse reflection at walls keeps light near (within $\sim$1 m) particle path
- Looped wavelength-shifting fiber collects light (11,160 km)
  - Fiber diameter 0.7 mm
  - Fiber shifts wavelength to $\sim$ 520-550 nm along the fiber





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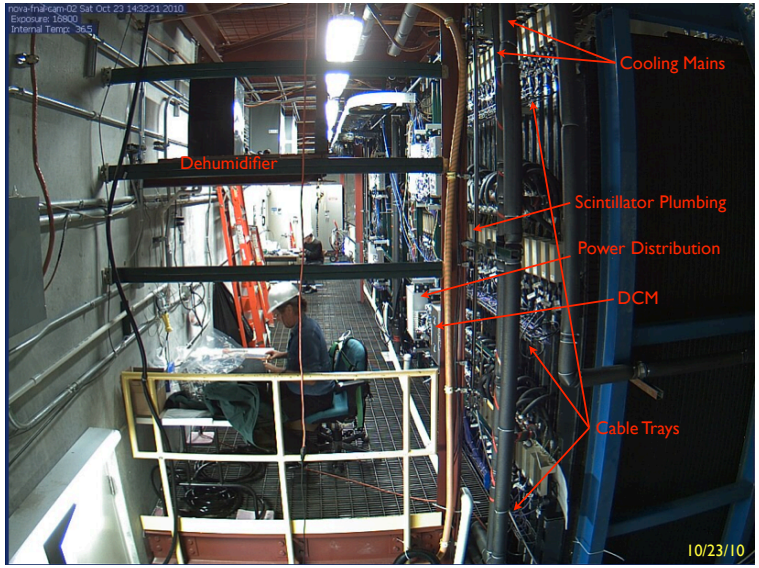
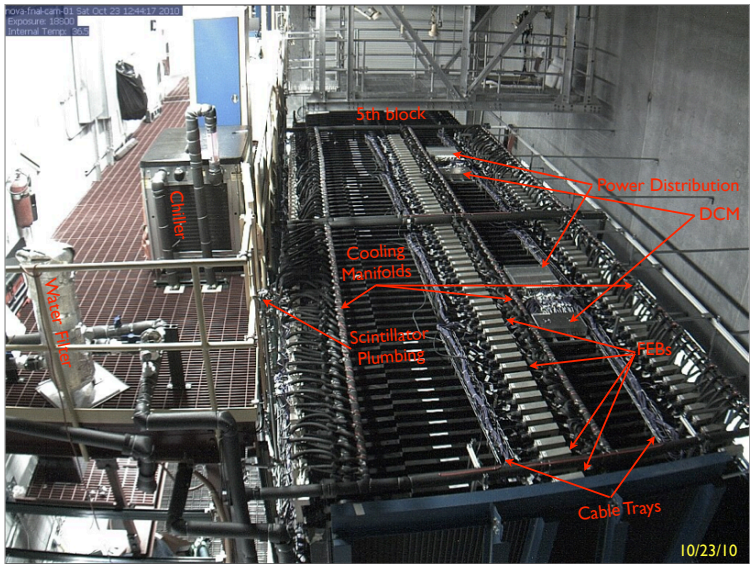
Summary

NOνA Schedule

September 15, 2008	DOE CD-2 Approved (Project Baseline)
April 2009	NOνA Receives Recovery Act and FY09 Funding
May 1, 2009	NOνA Far Detector Laboratory Groundbreaking
July 2009	DOE CD-3 Review (Full Construction Start)
November 24, 2010	Integration Prototype Near Detector ready to take data
December 15, 2010	First Neutrino Event Observed
	ND move underground Spring 2013
March 7, 2011	Far Detector Building Beneficial Occupancy
	FD construction 2011 through 2013

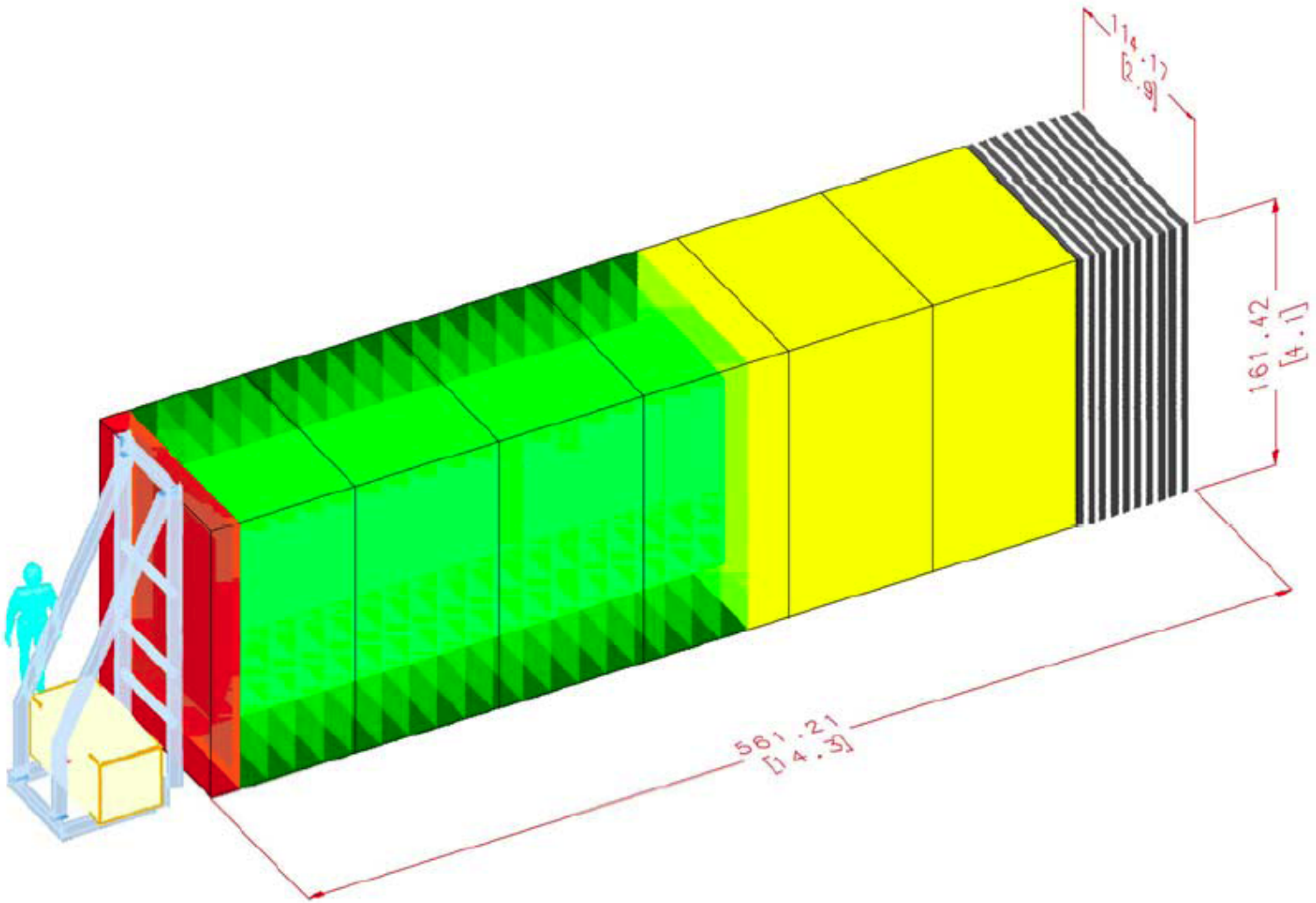
Near Detector on the Surface (NDOS)





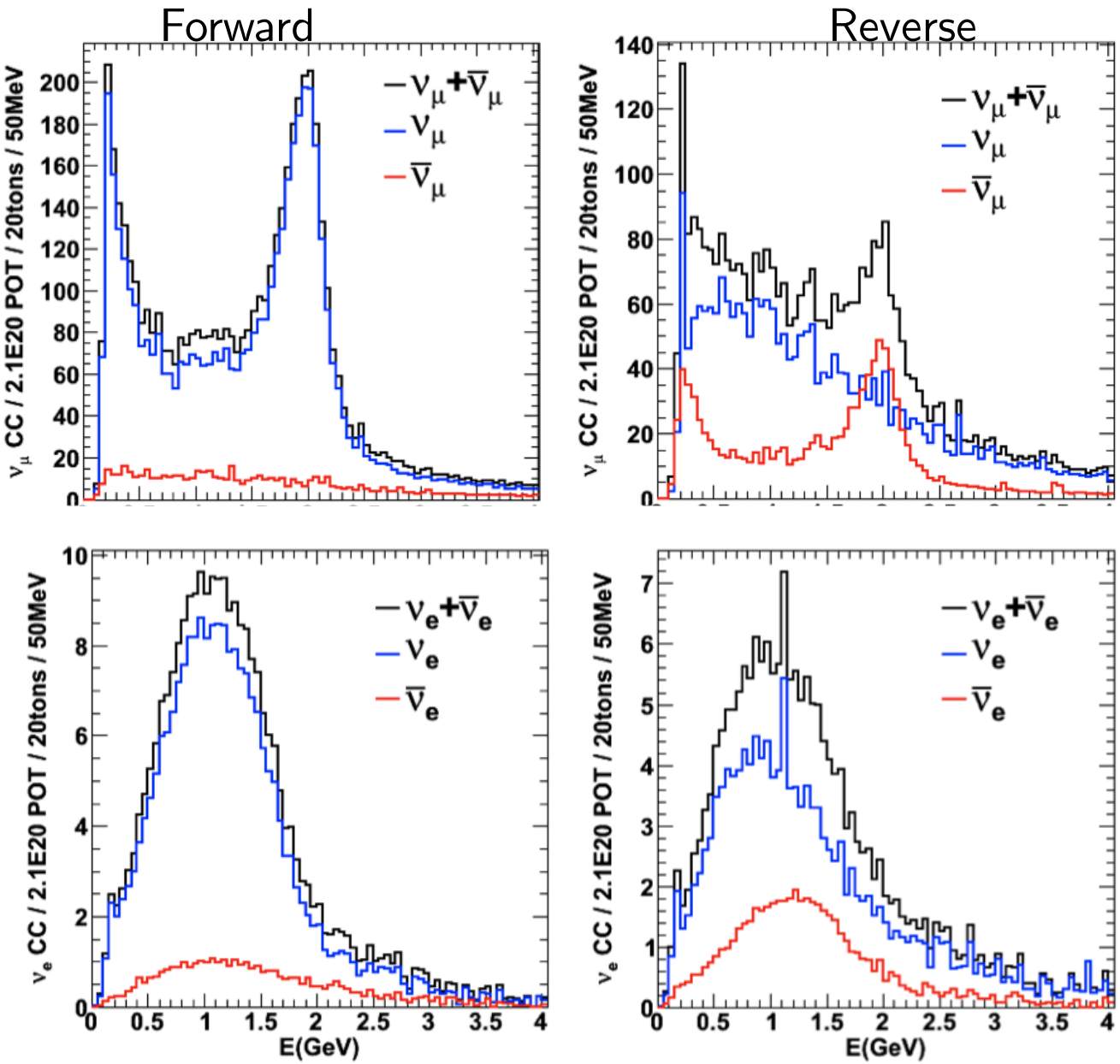
NDOS

- Only two di-blocks instrumented, 0-820 cm in the z direction



NDOS - NuMI LE Spectrum

- Assuming 2.1E20 Protons-On-Target (POT) Forward and Reverse horn current each
- Study the detector response prior to operation of the Far Detector



NDOS - Physics

Forward - 2.1E20 POT

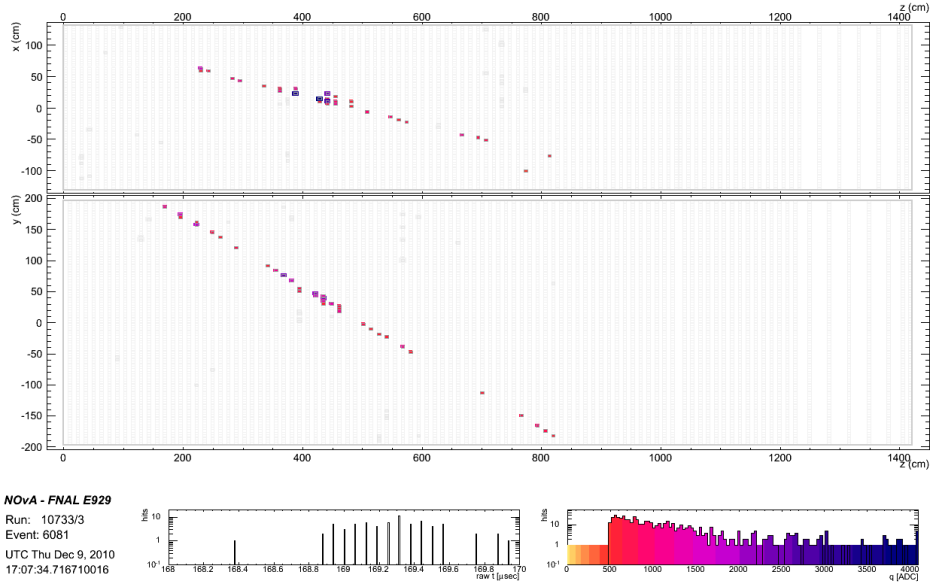
Type	Total CC	CC-QE	CC-RES	CC-DIS	CC-COH	NC
ν_μ	4751	2288	1533	861	38	1911
1.6-2.4GeV	1931	559	842	511	20	699
ν_e	340	166	119	50		125
1.6-2.4GeV	57	17	25	39		20
anti-ν_μ	624	323	179	103	14	353
1.6-2.4GeV	132	50	55	24		142
anti-ν_e	37	19	12	5		19

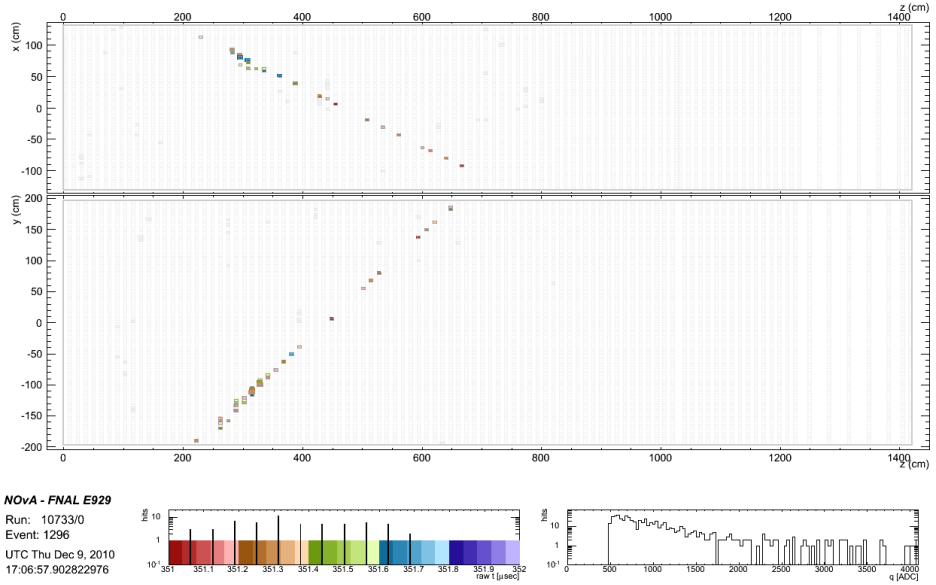
Reverse - 1.7E20 POT

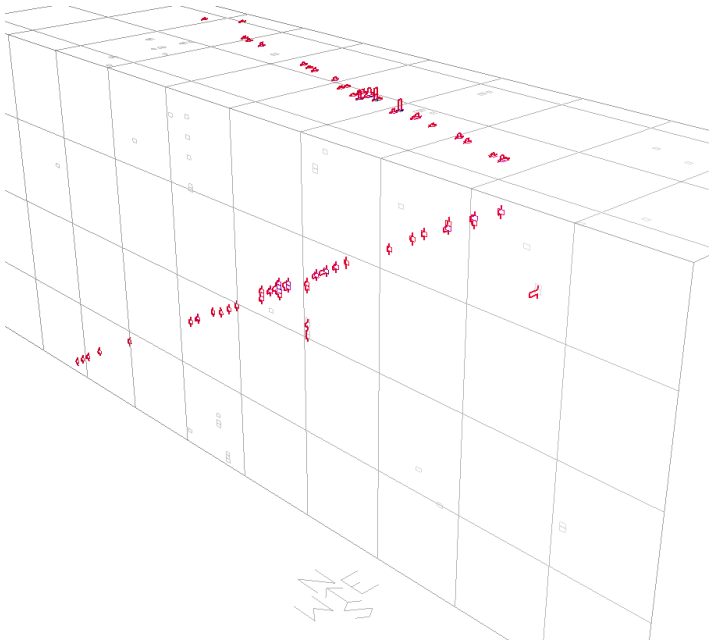
Type	Total CC	CC-QE	CC-RES	CC-DIS	CC-COH	NC
ν_μ	2157	1019	638	409	17	855
1.6-2.4GeV	402	116	174	108		146
ν_e	248	120	86	39		92
1.6-2.4GeV	42	12	18	11		15
anti-ν_μ	873	471	262	119	19	507
1.6-2.4GeV	363	139	151	65		170
anti-ν_e	42	22	14	5		22

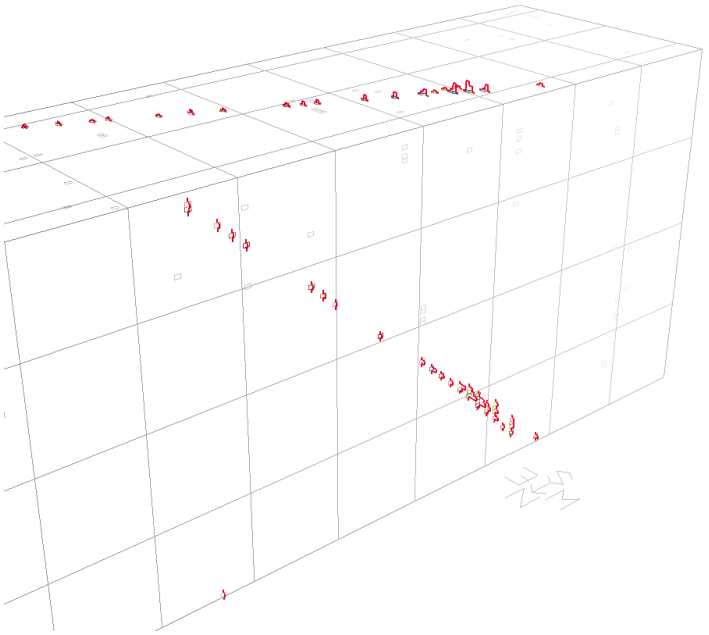
- Measure ν_μ QE cross section
- Measure ν NC/CC single pion production cross section

Cosmic Ray - Muon

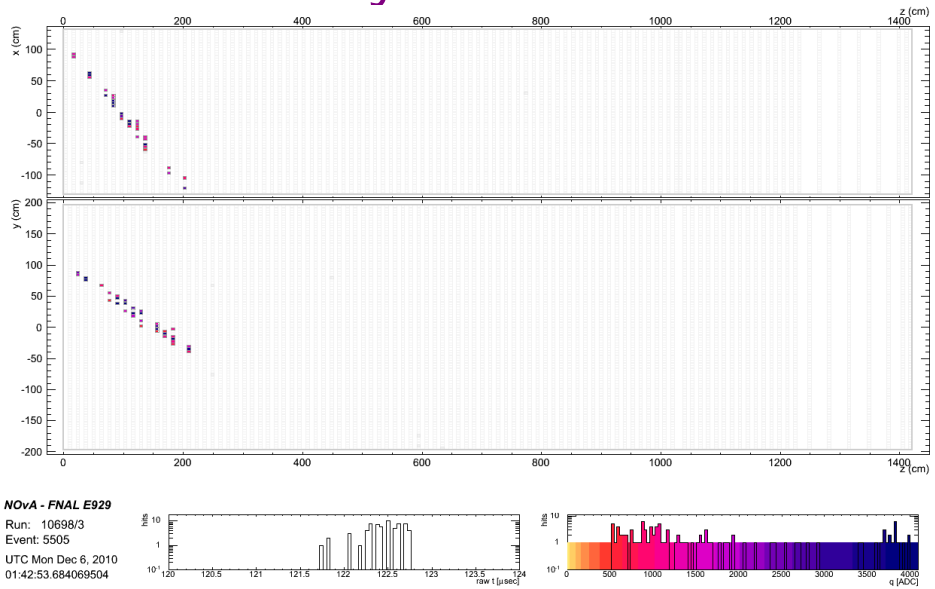


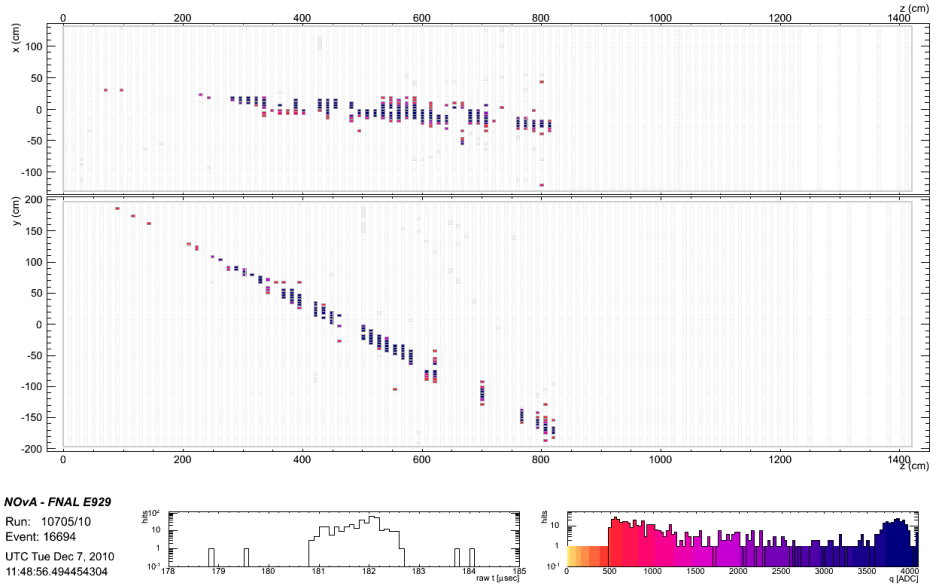


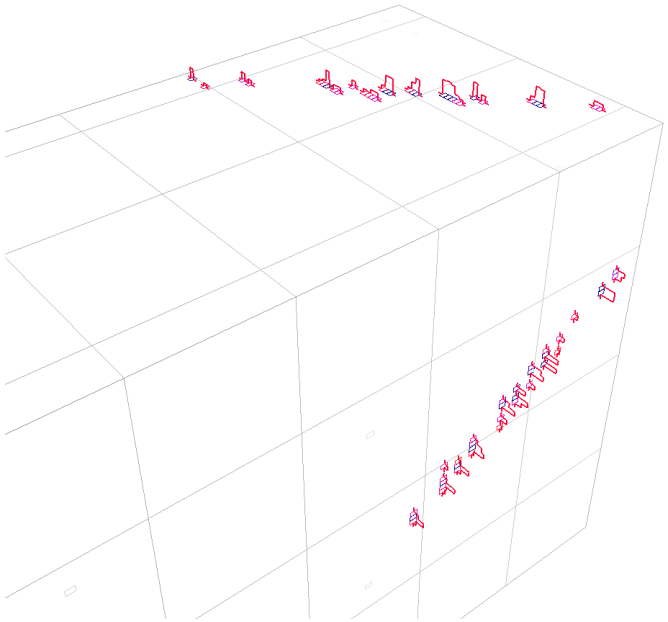


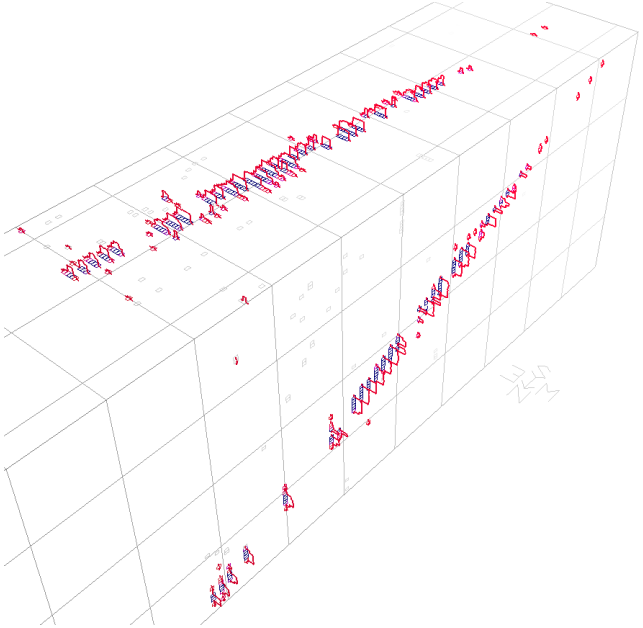


Cosmic Ray - EM Shower

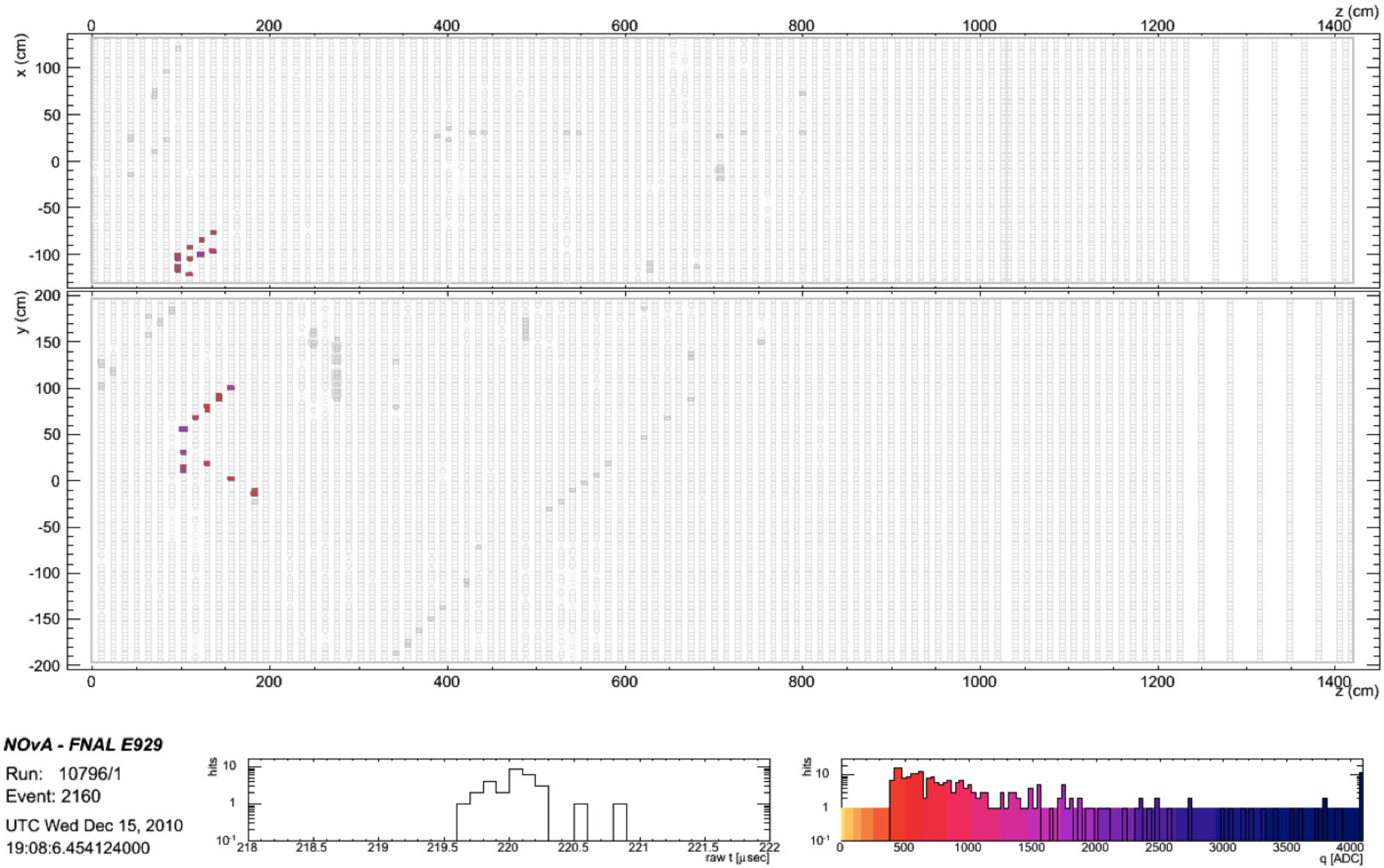






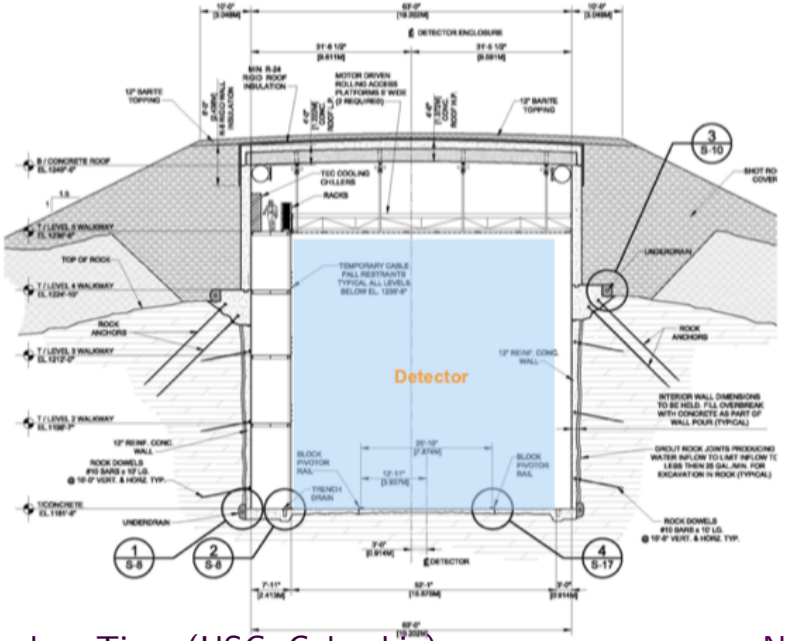


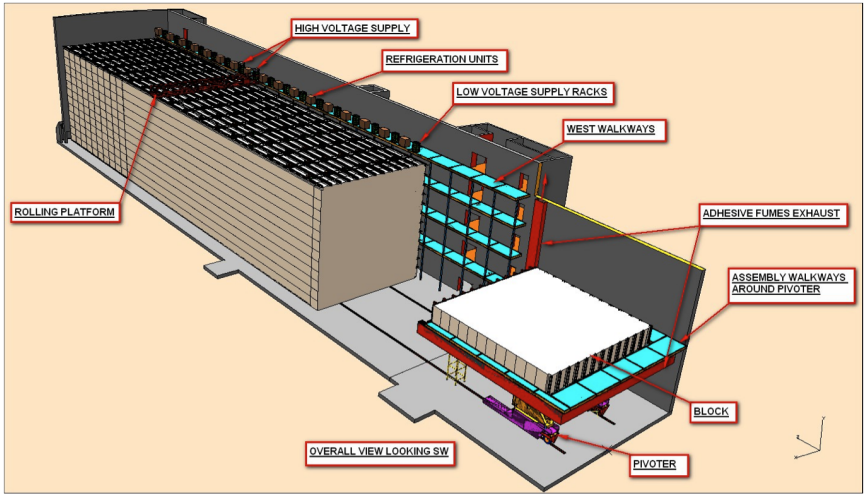
First Neutrino Event from NDOS - 19:08, Dec. 15, 2010



Far Detector

$\sim$ 3 m earth equivalent Barite/Concreate Overburden to reduce cosmic backgrounds





Construction - Site and Building

Full Height Engineering Prototype (FHEP) Pivoter

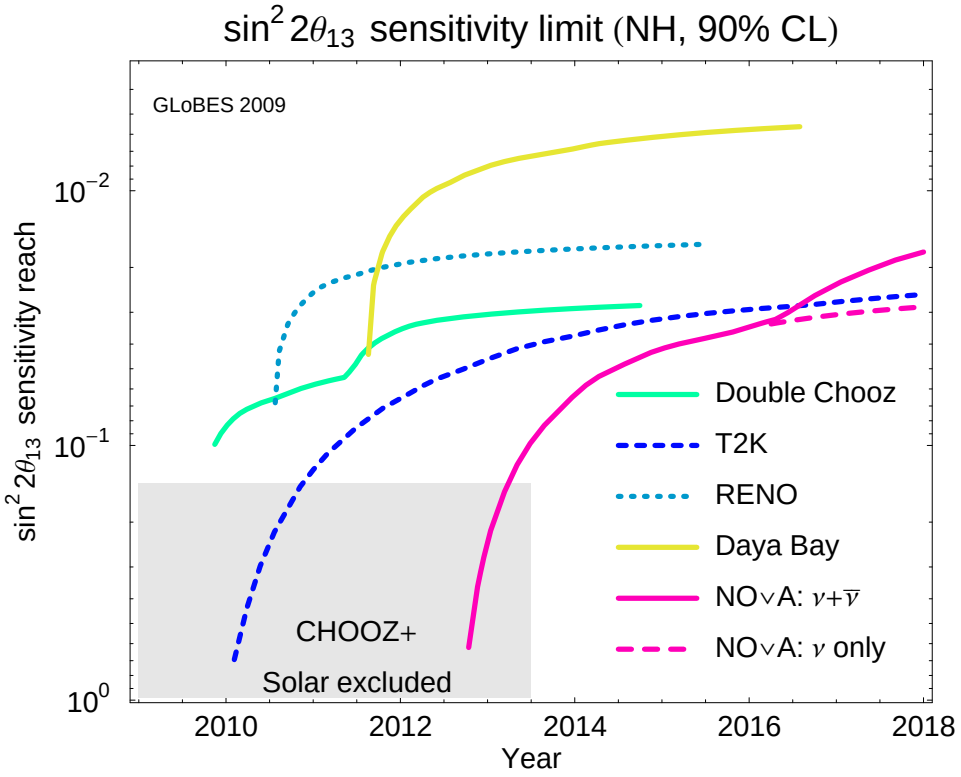
Milestone on Nov. 11, 2010

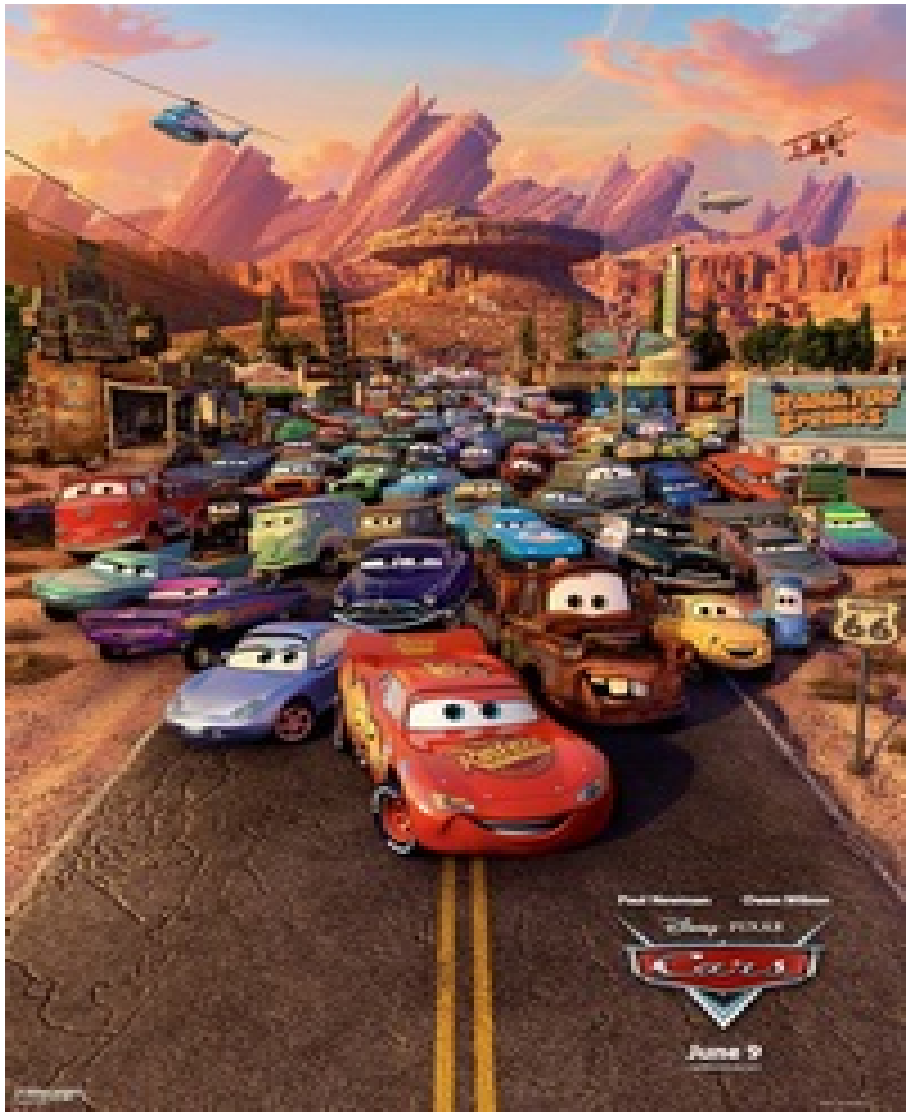
Summary

- The NOνA experiment is the flagship of U.S. accelerator experiments for the coming decade and is the first of the next generation of Intensity Frontier experiments that form the future of the U.S. accelerator physics program
  - θ_{13}, θ_{23}, δ_{CP}, sign(Δm^2_{32})
  - Non-Standard Neutrino Interactions (NSI)?
- 14 kt far detector on schedule to be completed in 2013
  - Push to install the first 2 blocks at Ash River prior to 2012 accelerator shutdown
- NDOS is taking data now

WE HAVE SEEN NEUTRINO EVENTS

Game On

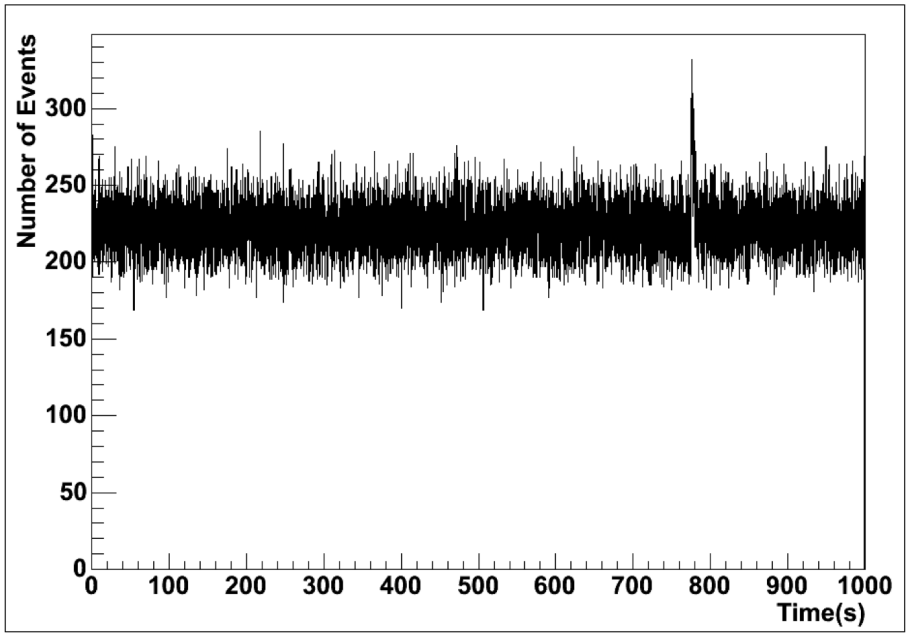

$\sin^2 2\theta_{13}$ sensitivity limit (NH, 90% CL)
GLoBES 2009
$\sin^2 2\theta_{13}$ sensitivity reach
10^{-2}
10^{-1}
10^{0}
2010
2012
2014
2016
2018
Year
Double Chooz
T2K
RENO
Daya Bay
NOνA: $\nu+\overline{\nu}$
NOνA: ν only
CHOOZ+
Solar excluded

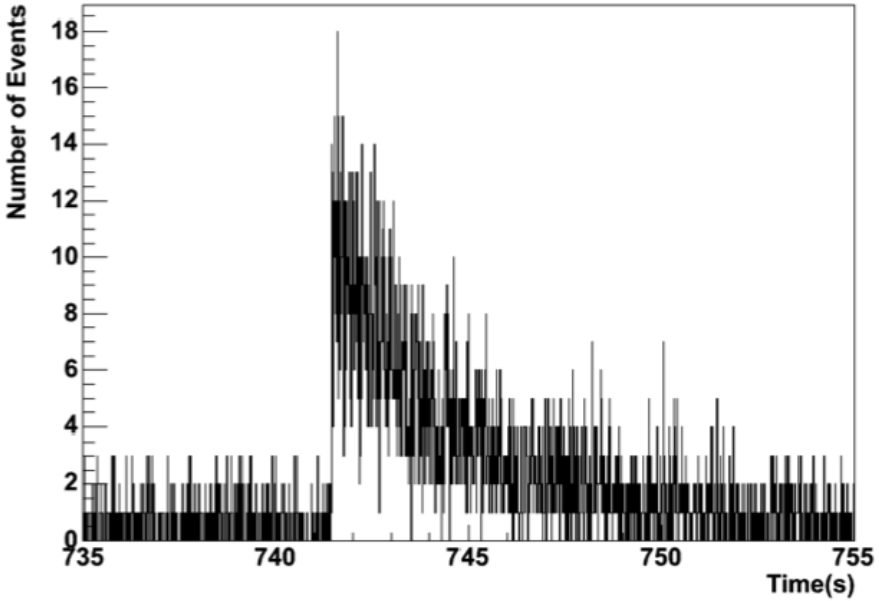


Backup Slides

NOνA Physics Potential - Supernova

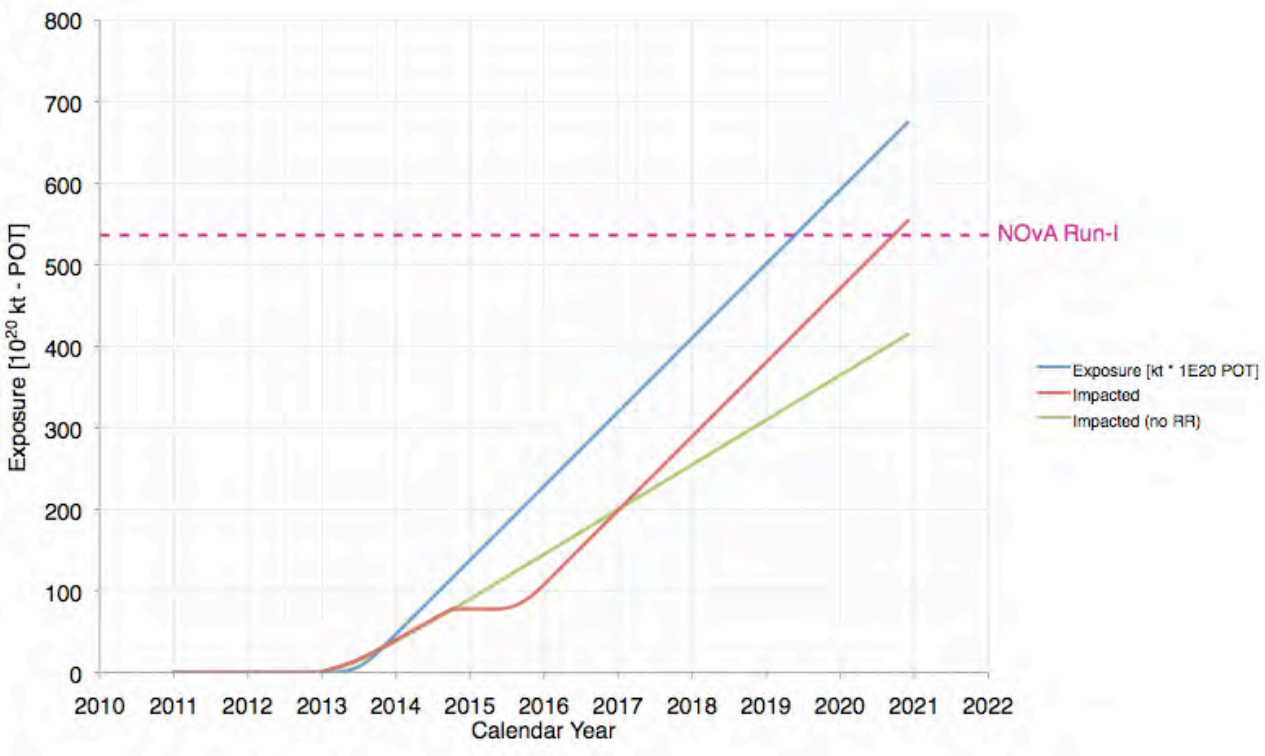
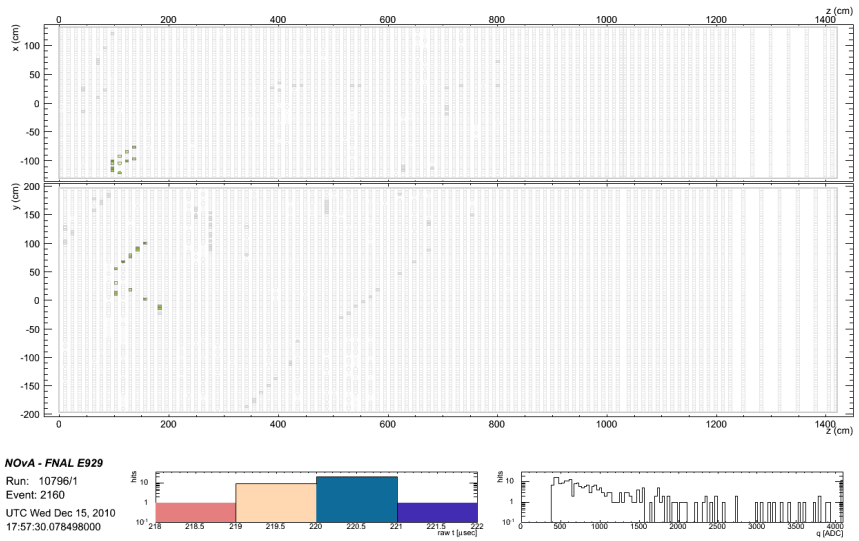
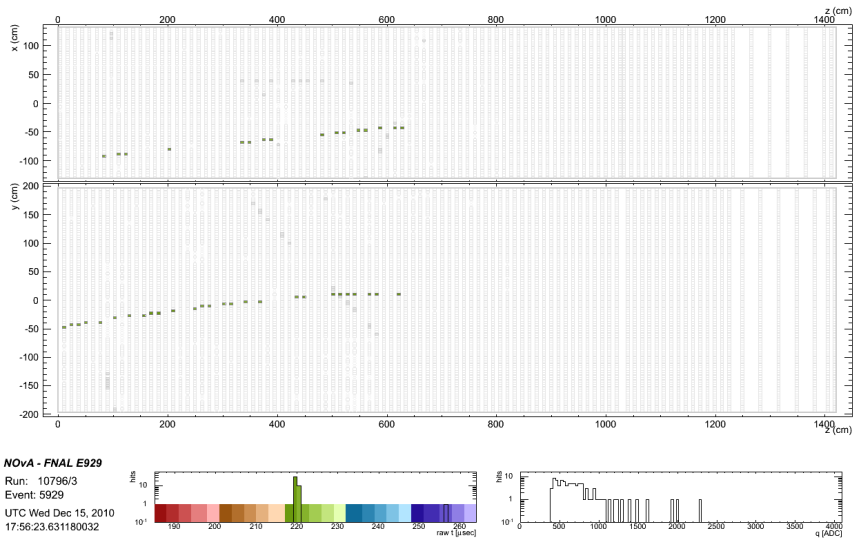
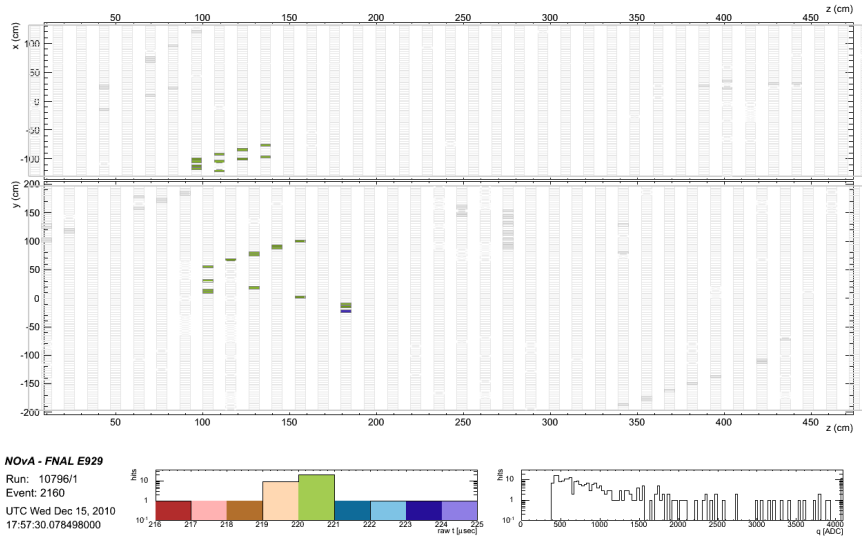
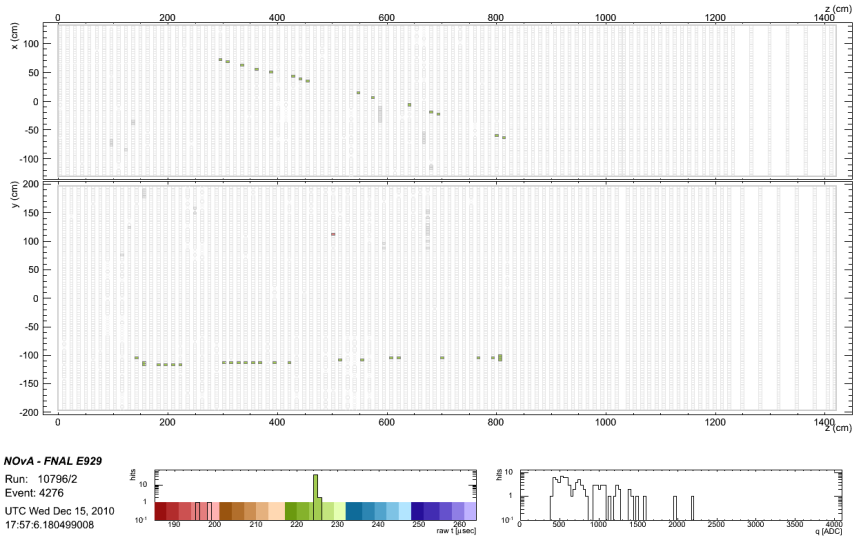
- 10 second 5000event burst for a supernova near the center of galaxy





Tevatron Run II Extension Impact on NOvA

- Reduce the ν $\nu_\mu \rightarrow \nu_e$ data set by roughly a factor of 2 during the 2015-2016 time period
- Delay first results on muon antineutrino oscillations by 2 years
- Delay first results on the mass ordering and the CP violating phase by 2 years
- Delay final results by 1.5 years
- Add an additional 3.7 M$ to the cost of the project



Neutrino Events from NDOS