The NOνA Experiment - Present and Future

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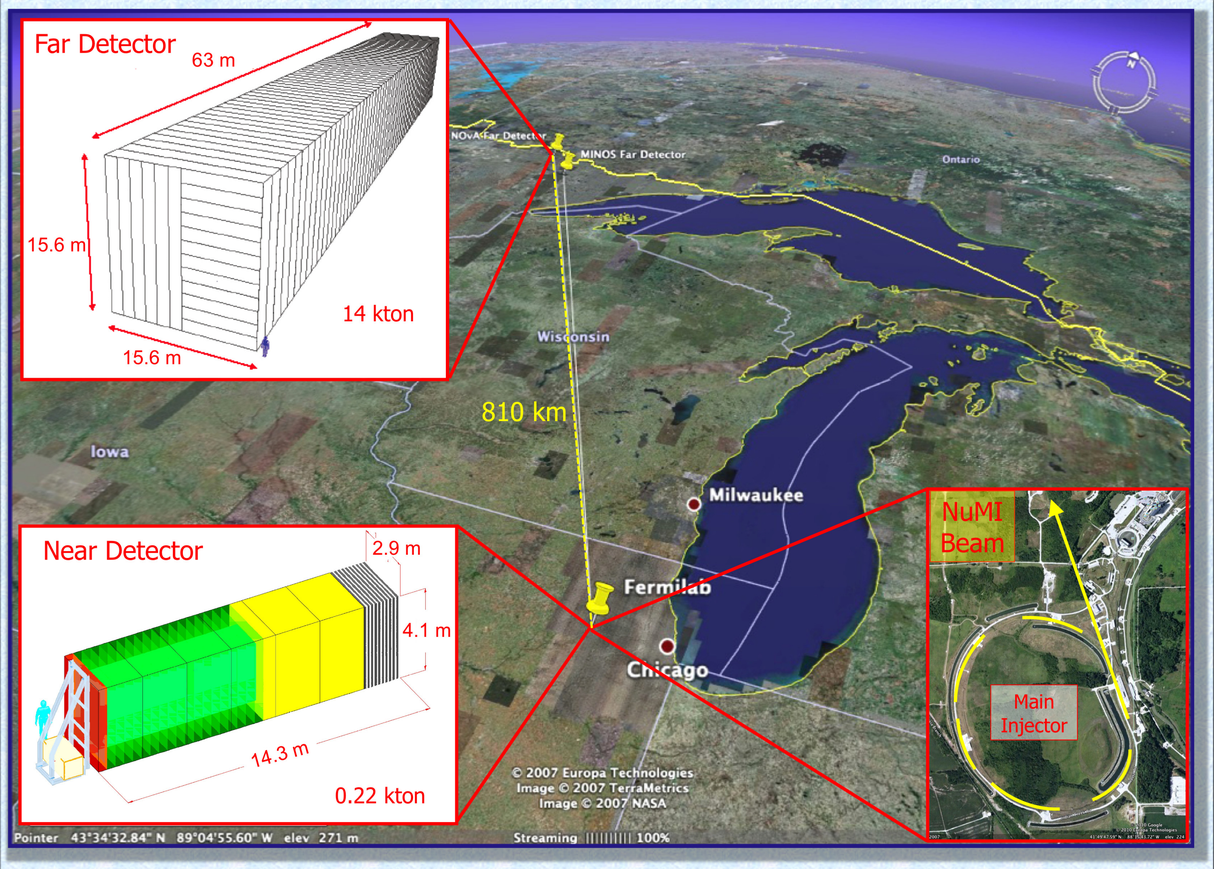
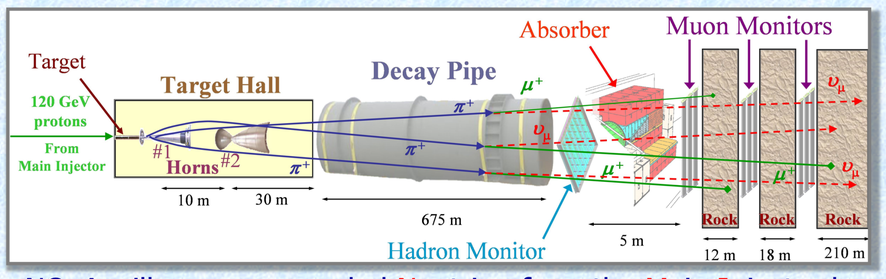
On behalf of the NOνA Collaboration

NuMI Off-Axis ν_e Appearance Experiment



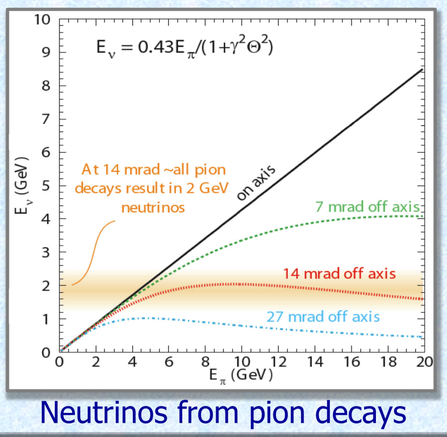
- NOνA is an off-axis long-baseline neutrino experiment using the NuMI neutrino beam and two detectors to look for ν_e appearance
- The Near Detector will be located at Fermilab, 14 mrad off the NuMI beam axis, 100 m underground, 1 km downstream of the beam production target
- The Far Detector will be located at Ash River, in northern Minnesota, 14 mrad off the NuMI beam axis, 810 km downstream of the beam production target

Off-Axis Neutrino Beam

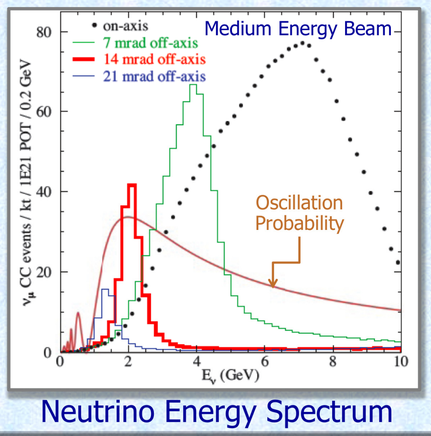


- Medium Energy beam
- 700 kW beam power
- 1.33 s cycle time (2.2 s in MINOS)
- 4.9×10^{13} ppp intensity
- 6.0×10^{20} protons/year

- NOνA will use an upgraded Neutrino from the Main Injector beam running in the Medium Energy target-horns configuration
- At 14 mrad off-axis, narrow band beam peaks at ~2 GeV, near $\nu_\mu \rightarrow \nu_e$ osc. maximum
- Reduced neutral current background from higher energy neutrinos



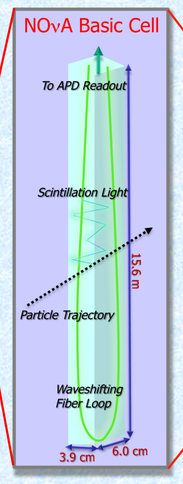
Neutrinos from pion decays

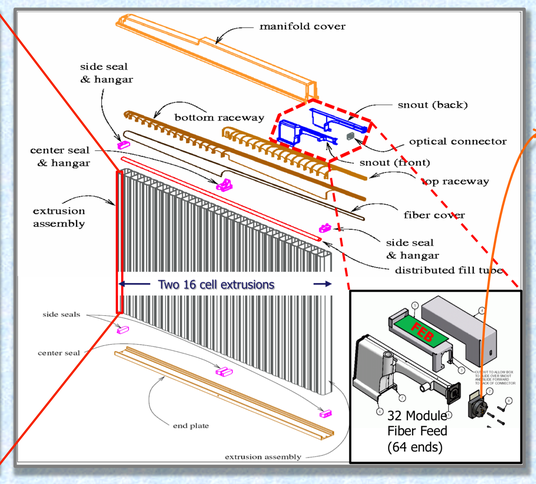


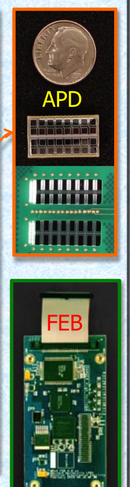
Neutrino Energy Spectrum

Detector Technology

- The two NOνA totally-active detectors are composed of extruded PVC modules filled with mineral oil based liquid scintillator and are functionally identical







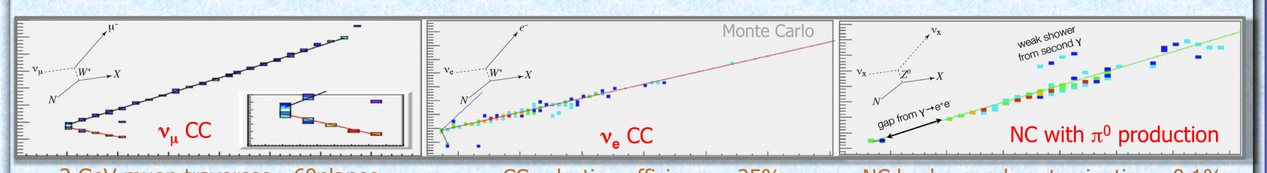
- Highly reflective (15% TiO_2) PVC cells are filled with liquid scintillator
- Scintillation light is collected by a loop of wavelength shifting optical fiber
- Readout by 32-pixel Avalanche Photo-Diode (APD)
- APD signal digitized by low-noise amplifiers in Front End Board (FEB)

NOνA Far Detector by the numbers

- 11 280 kL of scintillator, 4.99% pseudocumene
- 12 050 km of 0.7 mm-diameter optical fiber
- 11 160 PVC modules
- 357 120 electronics channels
- APD quantum efficiency: 85%; Gain of 100
- APD operating temperature: -15 °C

NOνA Physics Reach

- The NOνA detectors are optimized for detection of ν_e charged-current interactions: 1 plane ~ 0.15 X_0, Molière radius = 10 cm



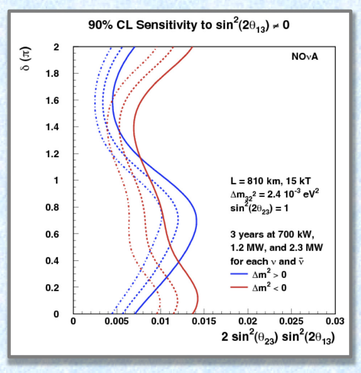
2 GeV muon traverses ~60planes | ν_e CC selection efficiency ~25% | NC background contamination ~0.1%

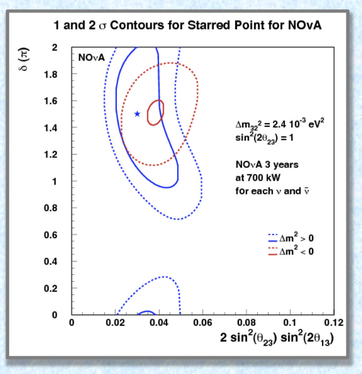
Measurement of θ_{13} and δ_{CP} via ν_e Appearance

- NOνA is sensitive to $\nu_\mu \rightarrow \nu_e$ oscillations described by the probability:

$$P(\overset{(-)}{\nu}_\mu \rightarrow \overset{(-)}{\nu}_e) \approx \sin^2\theta_{13}\sin^2\theta_{23}\frac{\sin^2(A-1)\Delta}{(A-1)^2}$$
$$\overset{(+)}{-} 2\alpha\sin\theta_{13}\sin\delta_{CP}\sin 2\theta_{12}\sin 2\theta_{23}\frac{\sin A\Delta}{A}\frac{\sin(A-1)\Delta}{(A-1)}\sin\Delta$$
$$+ 2\alpha\sin\theta_{13}\cos\delta_{CP}\sin 2\theta_{12}\sin 2\theta_{23}\frac{\sin A\Delta}{A}\frac{\sin(A-1)\Delta}{(A-1)}\cos\Delta$$
$$\alpha = \Delta m^2_{21}/\Delta m^2_{31} \qquad \Delta = \Delta m^2_{31} L/(4E) \qquad A = \overset{(-)}{+} G_F n_e L/(\sqrt{2}\Delta)$$

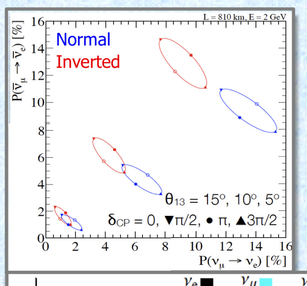
- NOνA's sensitivity to θ_{13} is one order of magnitude better than the present limits
- NOνA will begin constraining of the possible values of δ_{CP}

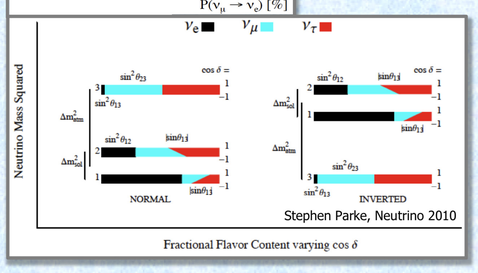




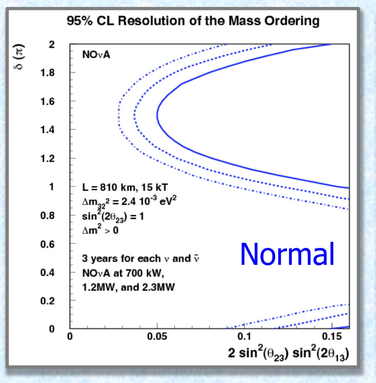
Determination of the Neutrino Mass Hierarchy

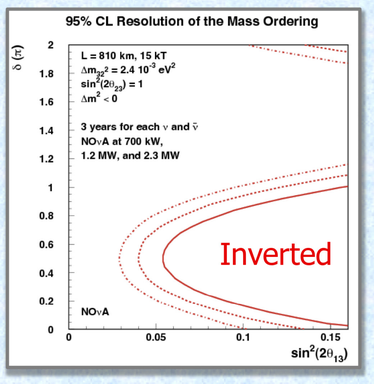
- Due to NOνA's long baseline, matter–induced oscillations affect the oscillation probability by 30%. Matter effects depend on the mass hierarchy sign and change $P(\nu_\mu \rightarrow \nu_e)$ and $P(\bar{\nu}_\mu \rightarrow \bar{\nu}_e)$ differently
- By running for 3 years with a neutrino beam and for 3 years with an antineutrino beam, NOνA may resolve the mass hierarchy if θ_{13} is large enough





Stephen Parke, Neutrino 2010



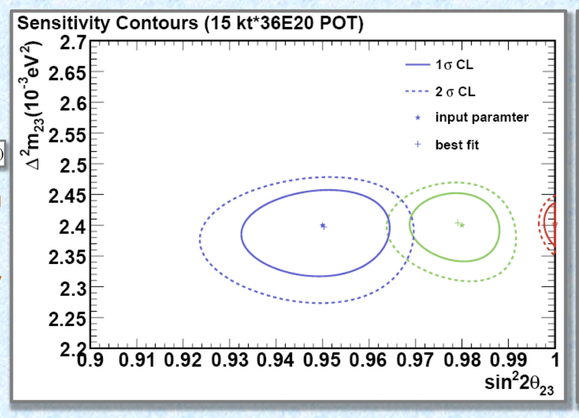


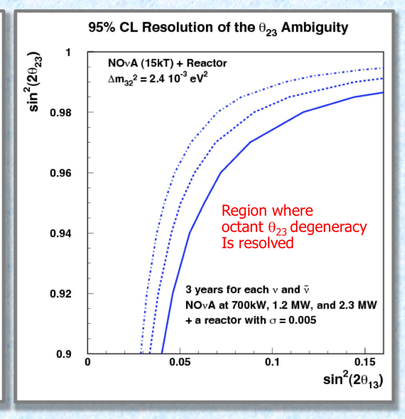
Precision Measurement of Neutrino Oscillation Parameters

- NOνA will improve on measurement of Δm^2 and measure $\sin^2 2\theta_{23}$ to better than 1%

$$P(\overset{(-)}{\nu}_\mu \rightarrow \overset{(-)}{\nu}_\mu) \approx 1 - \sin^2 2\theta_{23}\sin^2(1.27\,\Delta m^2_{32}\,L/E)$$

- In combination with a reactor experiment, NOνA can lift the octant θ_{23} degeneracy *i.e.*: $\theta_{23} > \pi/4$ or $\theta_{23} < \pi/4$





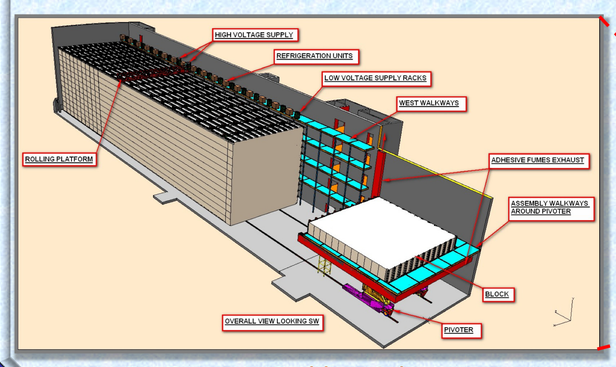
Status and Schedule

- Ongoing – Construction of the Near Detector On the Surface (NDOS)
- Winter 2011 – Start of NDOS operations
- Winter 2011 – Far Detector building complete
- Fall 2011 – Start of Far Detector construction
- Winter 2012 – Beginning of long accelerator shutdown. NuMI upgrades through 2012
- Fall 2012 – Near Detector moved underground
- Spring 2013 – Start Far Detector operations

NOνA collaborators in front of the first block of the NDOS at Fermilab

The NOνA Collaboration

Argonne National Laboratory - University of Athens - California Institute of Technology
University of California, Los Angeles - Fermi National Accelerator Laboratory - Harvard University
Indiana University - Lebedev Physical Institute - Michigan State University
University of Minnesota, Duluth - University of Minnesota, Minneapolis
The Institute for Nuclear Research, Moscow - Technische Universität München, Munich
State University of New York, Stony Brook - Northwestern University
University of South Carolina, Columbia - Southern Methodist University - Stanford University
University of Tennessee - Texas A&M University - University of Texas, Austin
University of Texas, Dallas - Tufts University - University of Virginia, Charlottesville
The College of William and Mary - Wichita State University



Far Detector Building Schematics

ICHEP July 22-28, 2010 Palais des Congrès, Paris 35th International Conference on High Energy Physics

Fermilab | U.S. DEPARTMENT OF ENERGY | NSF | University of Minnesota

http://www-nova.fnal.gov

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