NOνA: NuMI Off-Axis ν_e Appearance Experiment

136 scientists and engineers from 22 institutions

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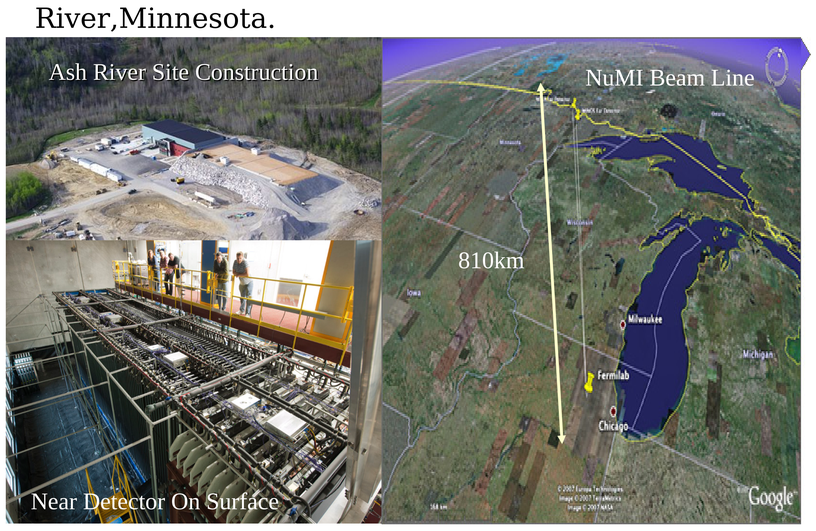
Introduction

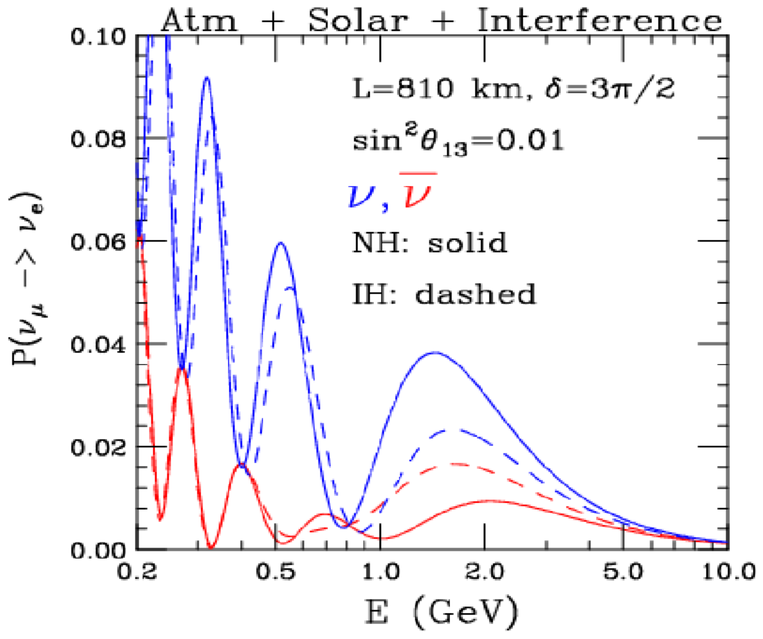
The NOνA experiment is a two-detector experiment searching for electron neutrino appearance in the NuMI muon neutrino and antineutrino beams. The near detector is being set up at FermiLab and the far detector will be constructed in Ash River,Minnesota.



Neutrinos Oscillate!

Neutrinos can be described in one of two bases, the weak (ν_e ,ν_μ,ν_τ) eigenstates when they are created and detected and the mass (ν_1,ν_2,ν_3) eigenstates when they travel through space. So, there is a nonzero probability that a neutrino created in one flavor state can change (oscillate) into another during its trip!

$$\begin{bmatrix}\nu_e\\ \nu_\mu\\ \nu_\tau\end{bmatrix} = \begin{pmatrix}1 & 0 & 0\\ 0 & \cos\theta_{23} & \sin\theta_{23}\\ 0 & -\sin\theta_{23} & \cos\theta_{23}\end{pmatrix}\begin{pmatrix}\cos\theta_{13} & 0 & \sin\theta_{13}e^{-i\delta}\\ 0 & 1 & 0\\ -\sin\theta_{13}e^{i\delta} & 0 & \cos\theta_{13}\end{pmatrix}\begin{pmatrix}\cos\theta_{12} & \sin\theta_{12} & 0\\ -\sin\theta_{12} & \cos\theta_{12} & 0\\ 0 & 0 & 1\end{pmatrix}\begin{bmatrix}\nu_1\\ \nu_2\\ \nu_3\end{bmatrix}$$



S. Parke, "Neutrino Oscillation Phenomenology" from Neutrino Oscillations: Present Status and Future Plans, edited by J. Thomas and P. Vahle

Motivations & Goals

By observing $\nu_\mu \rightarrow \nu_e$ and $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$, which has never been seen, what physics can we do?

Measuring θ13:

This matrix parameter corresponds to the $\nu_\mu \rightarrow \nu_e$ oscillation.

At least, it is small. Is it non-zero?

Mass Hierarchy:

Two possible mass hierarchies:
A "normal" order has two light mass states and one heavy state.
An "inverted" order has one light mass state and two heavy states.

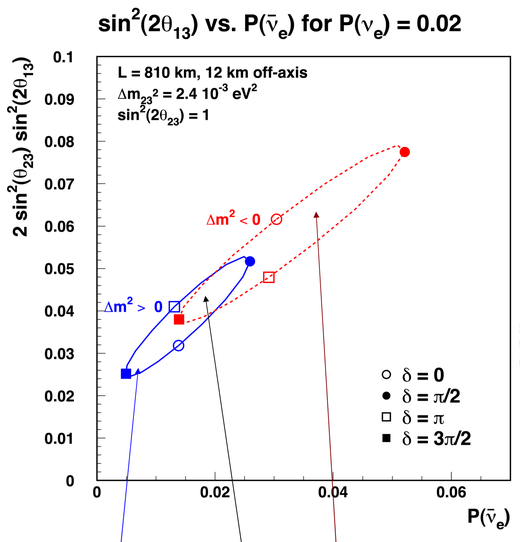
Which one does nature prefer?

CP Violation:

The occurrence $\nu_\mu \rightarrow \nu_e$ would open the avenue to measure CP violation in neutrino sector.

Theoretically

We measure two oscillation probabilities, one in neutrino mode and one in anti-neutrino mode. The ellipses to the right were generated for each mass hierarchy. Depending on the neutrino and anti-neutrino oscillation probabilities we have a chance at distinguishing mass hierarchy. If the ellipses do not overlap at the measured oscillation probability then the hierarchy is determined. The point on the ellipse also indicates which CP phase and θ_{13} values fit with the measured probabilities.

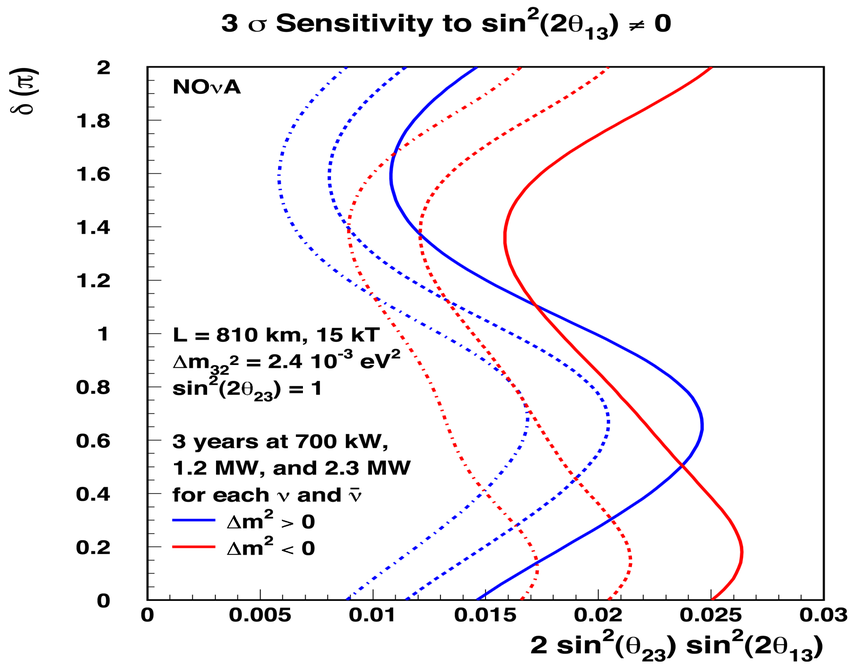


The blue curve is for the normal hierarchy case

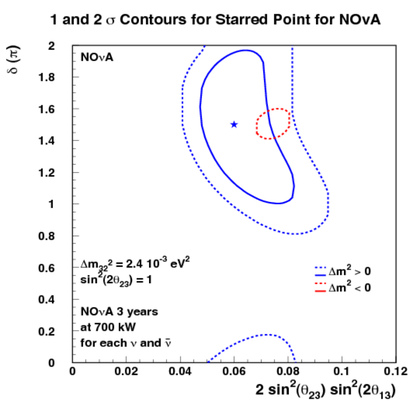
The red curve is for the inverted hierarchy case.

We are not able to tell the mass hierarchy in the overlapped region? This depends on our knowledge of CP phase.

Yes We Can!



The blue curves assume normal mass hierarchy while the red curves show the inverted hierarchy case.



For example, if our measured values are at the starred point to the left, we can resolve the mass hierarchy to 1σ and constrain the CP phase in the upper half plane.

Current Status

NOvA Pivoter at CDF

NuMI Beam:

Horn1 and target design complete
Kicker for Booster-Recycler in use
First recycler injector magnet installed
Accelerator shutdown: March 2012

Far Detector:

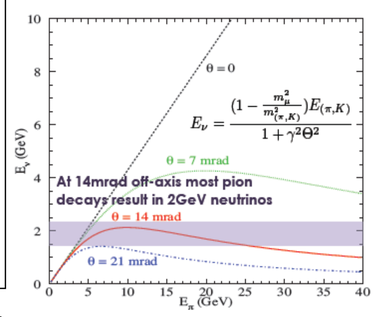
Start construction: Jan 2012
1 block ready by start of shutdown
50% detector by end of shutdown
Complete by early 2014

Near Detector:

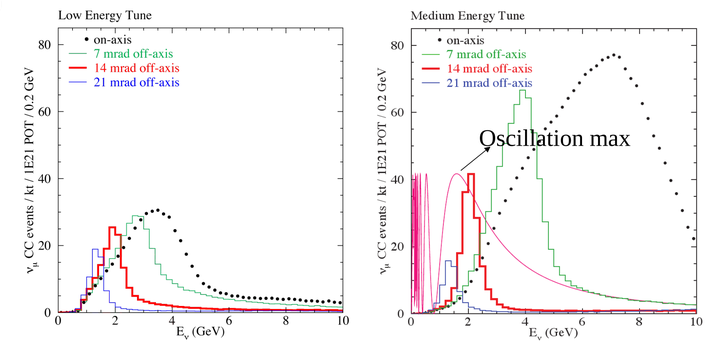
Cavern excavation during shutdown
Prototype in operation at FNAL on the surface
See M. Betancourt's poster for more on NDOS

Why is NOνA Off-Axis?

The NOνA detectors are strategically located 14 milli-radians off-axis from the NuMI line. The beamline will be upgraded to run in a medium energy mode of 700 kW instead of its current 400 kW low energy configuration.

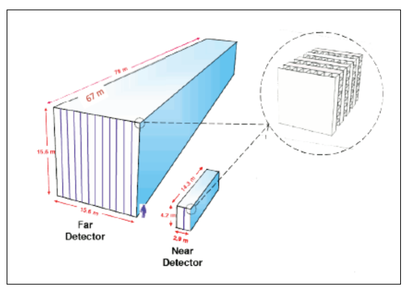


At this angle a pion beam with a broad energy spectrum will create a relatively narrow neutrino beam of 2 GeV. This is the location of the first oscillation maximum.



Comparison of the ν_μ charged current events seen in the low and medium energy beam configurations at different angles. The 14 mrad medium energy beam sits optimally on the oscillation maximum.

The NOνA Detectors



15 kT far detector (65% scintillator)

220 T near detector

Both detectors are made up of alternating vertical and horizontal planes of plastic cells filled with liquid scintillator.

Sample Neutrino Events

Monte Carlo event displays of how NOνA will see neutrino interactions.