The NOνA Experiment

P5 Meeting

SLAC

21 February 2008

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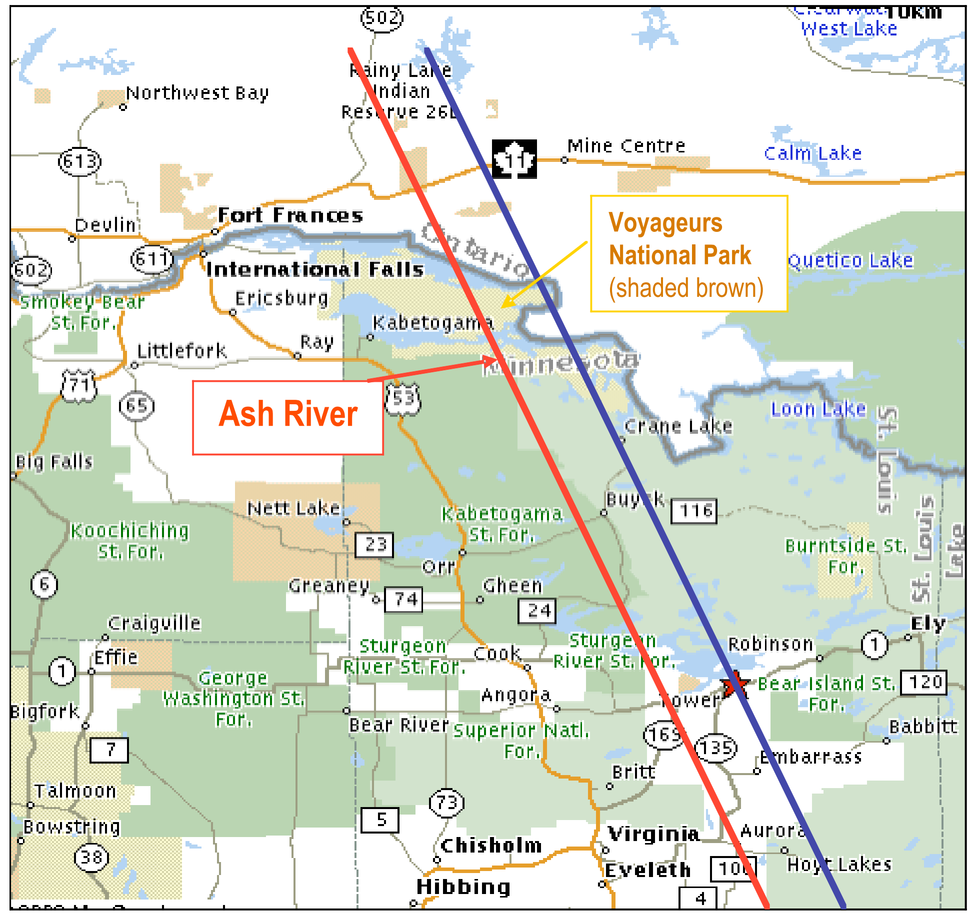
What is NOνA?

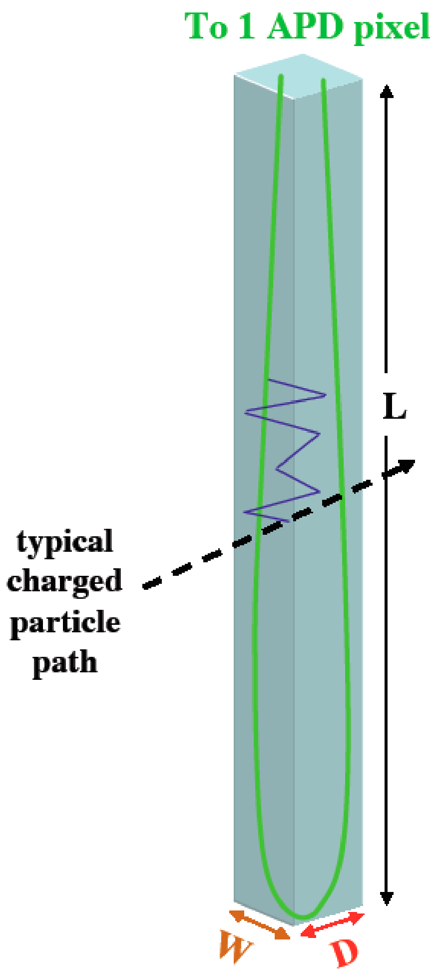
- NOνA is a second-generation experiment on the NuMI beamline, which is optimized for the detection of $\nu_\mu \to \nu_e$ oscillations.
  - It will give an order of magnitude improvement over MINOS in measurements of ν_e appearance and ν_μ disappearance.
- NOνA is a “totally active” tracking liquid scintillator calorimeter, sited off-axis to take advantage of a narrow-band beam.
- The NOνA project also includes accelerator upgrades to bring the beam power from 400 kW to 700 kW.
- NOνA’s unique feature is its long baseline, which gives it sensitivity to the neutrino mass ordering.
- NOνA is complementary to both T2K and Daya Bay.

NOvA Site



The Ash River site is the furthest available site from Fermilab along the NuMI beamline. This maximizes NOνA's sensitivity to the mass ordering.

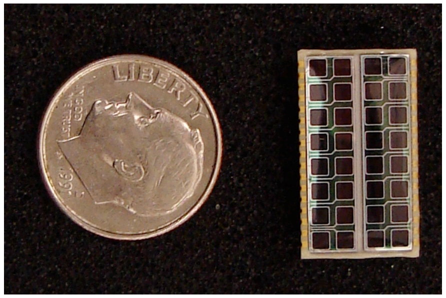
NOνA Basic Detector Element



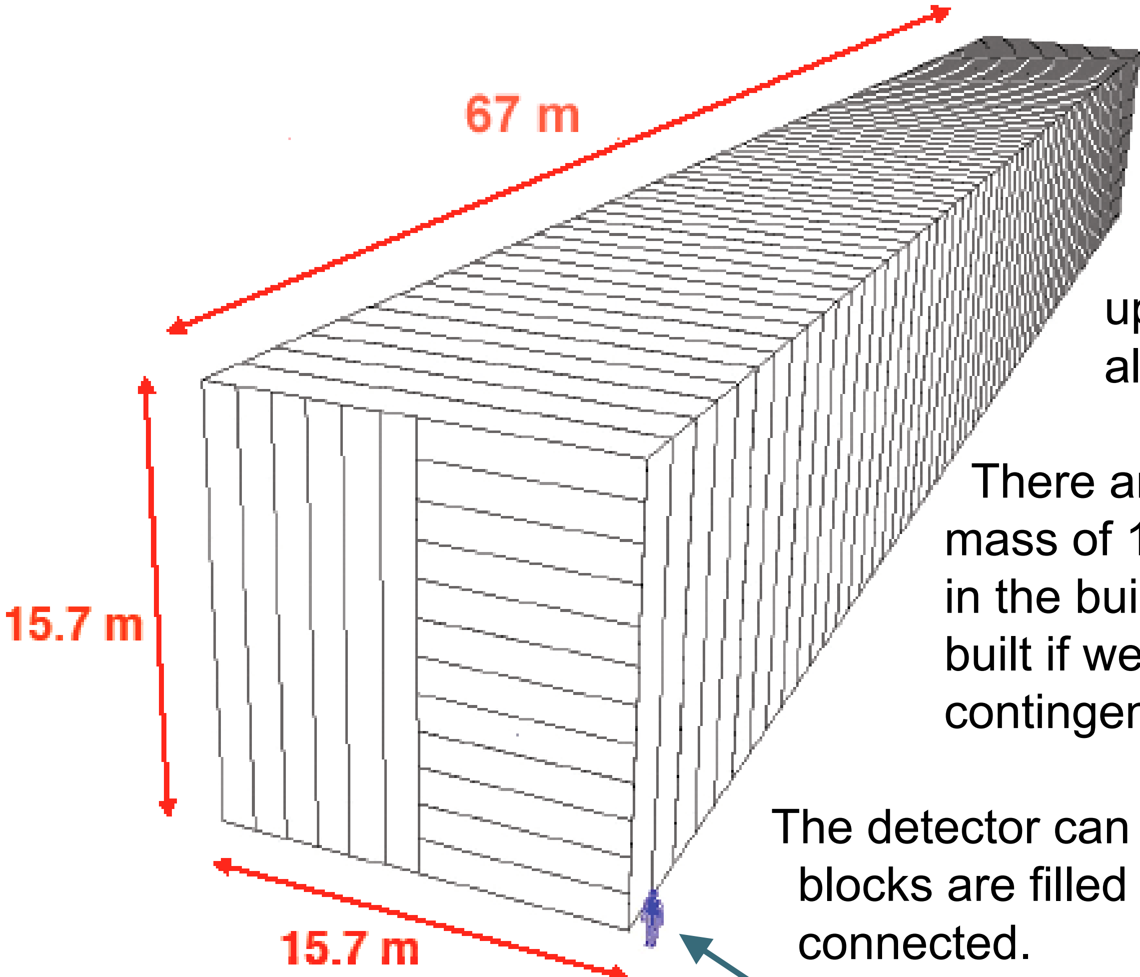
Liquid scintillator in a 4 cm wide, 6 cm deep, 15.7 m long, highly reflective PVC cell.

Light is collected in a U-shaped 0.7 mm wavelength-shifting fiber, both ends of which terminate in a pixel of a 32-pixel avalanche photodiode (APD).

The APD has peak quantum efficiency of 85%. It will be run at a gain of 100. It must be cooled to -15°C and requires a very low noise amplifier.



NOνA Far Detector



The cells are made from 32-cell extrusions.

12 extrusion modules make up a plane. The planes alternate horizontal and vertical.

There are 1003 planes, for a total mass of 15 kT. There is enough room in the building for 18 kT, which can be built if we can preserve half of our contingency.

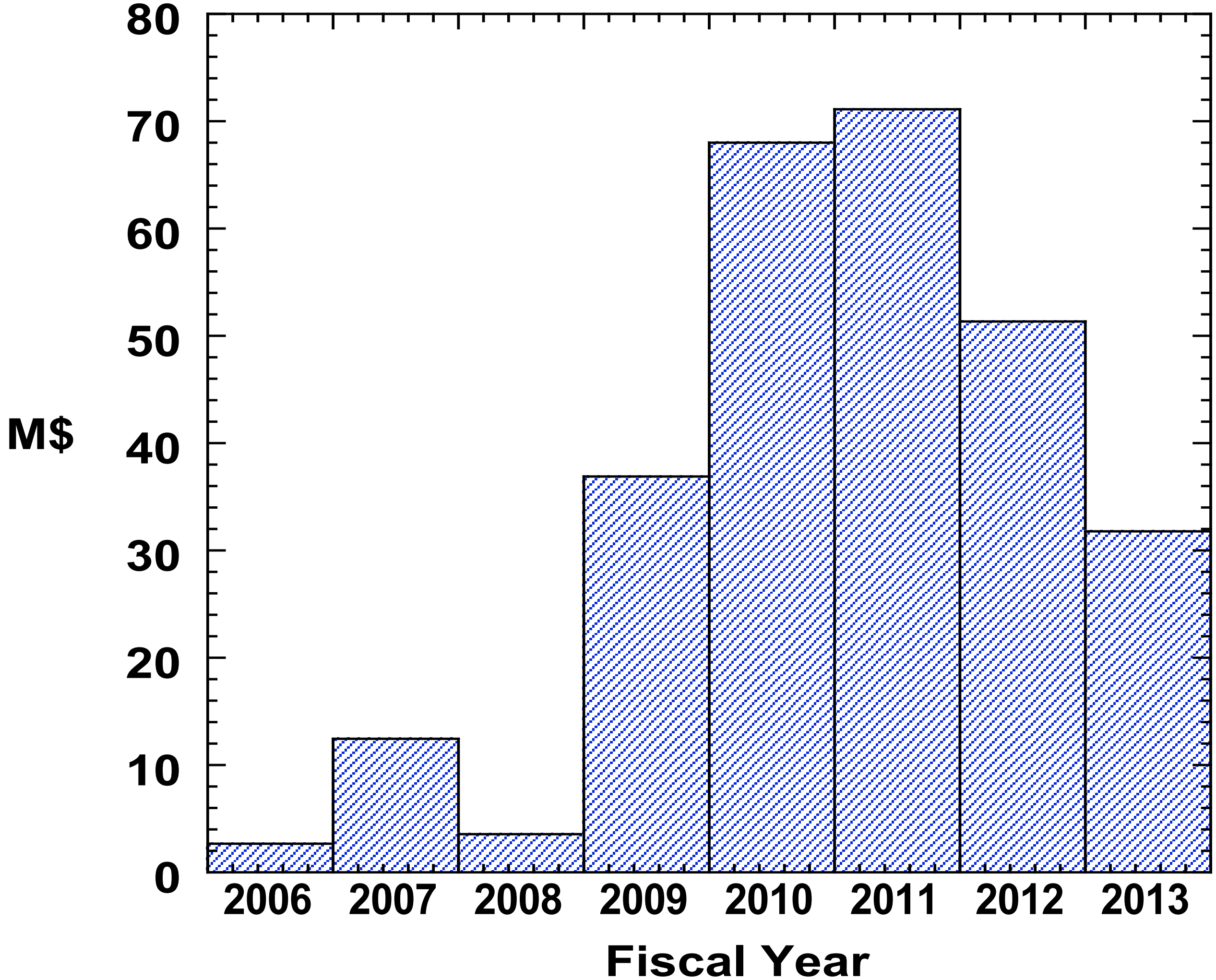
The detector can start taking data as soon as blocks are filled and the electronics connected.

An admirer

NOvA Timeline

May 2002	1st Workshop
Jun 2002	Letter of Intent
Mar 2004	Proposal to the Fermilab PAC
Mar 2005	Revised Proposal to the PAC
Apr 2005	Fermilab Stage 1 Approval
Nov 2005	CD-0 Granted
Feb 2006	Recommended by NuSAG
Oct 2006	Recommended by P5
May 2007	CD-1 Granted
Oct 2007	Passed CD-2/3a Review
May 2008	CD-2/3a Granted
Nov 2008	CD-3b Granted
Apr 2009	Start of Construction
Jun 2011	Far Detector Building Beneficial Occupancy
Aug 2012	1st 2.5 kT of the Far Detector Online
Jan 2014	Full Far Detector Online

DOE Funding Profile

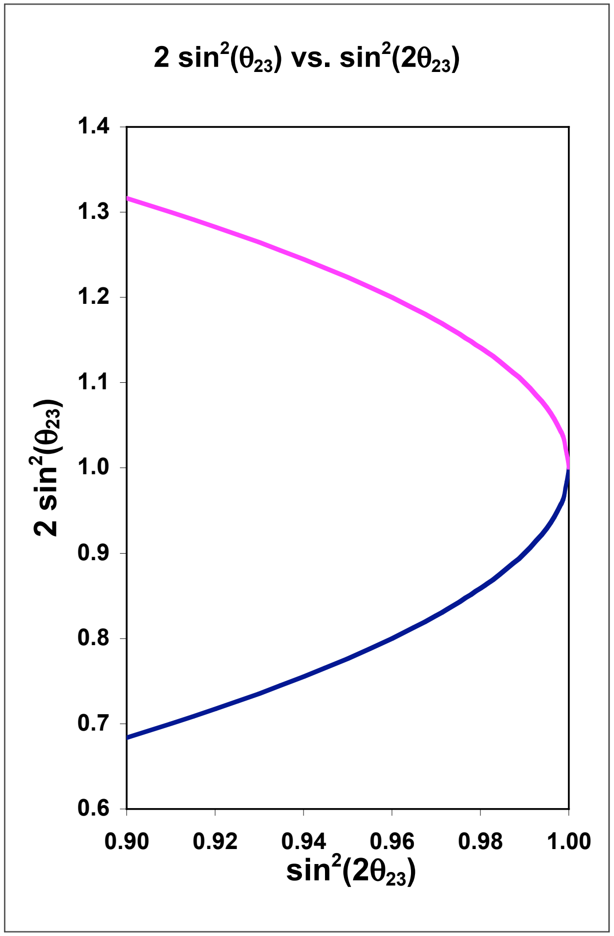


Reactor vs. Accelerator

Peter explained the physics of neutrino oscillations well, so I need not repeat it. However, I would like to expand on a couple of points.

Reactor and accelerator experiments do not measure the same thing. Reactors are sensitive to $\sin^2(2\theta_{13})$, while accelerators are sensitive to $\sin^2(\theta_{23})\,\sin^2(2\theta_{13})$. If $\theta_{23} \neq \pi/4$, these quantities can be quite different.

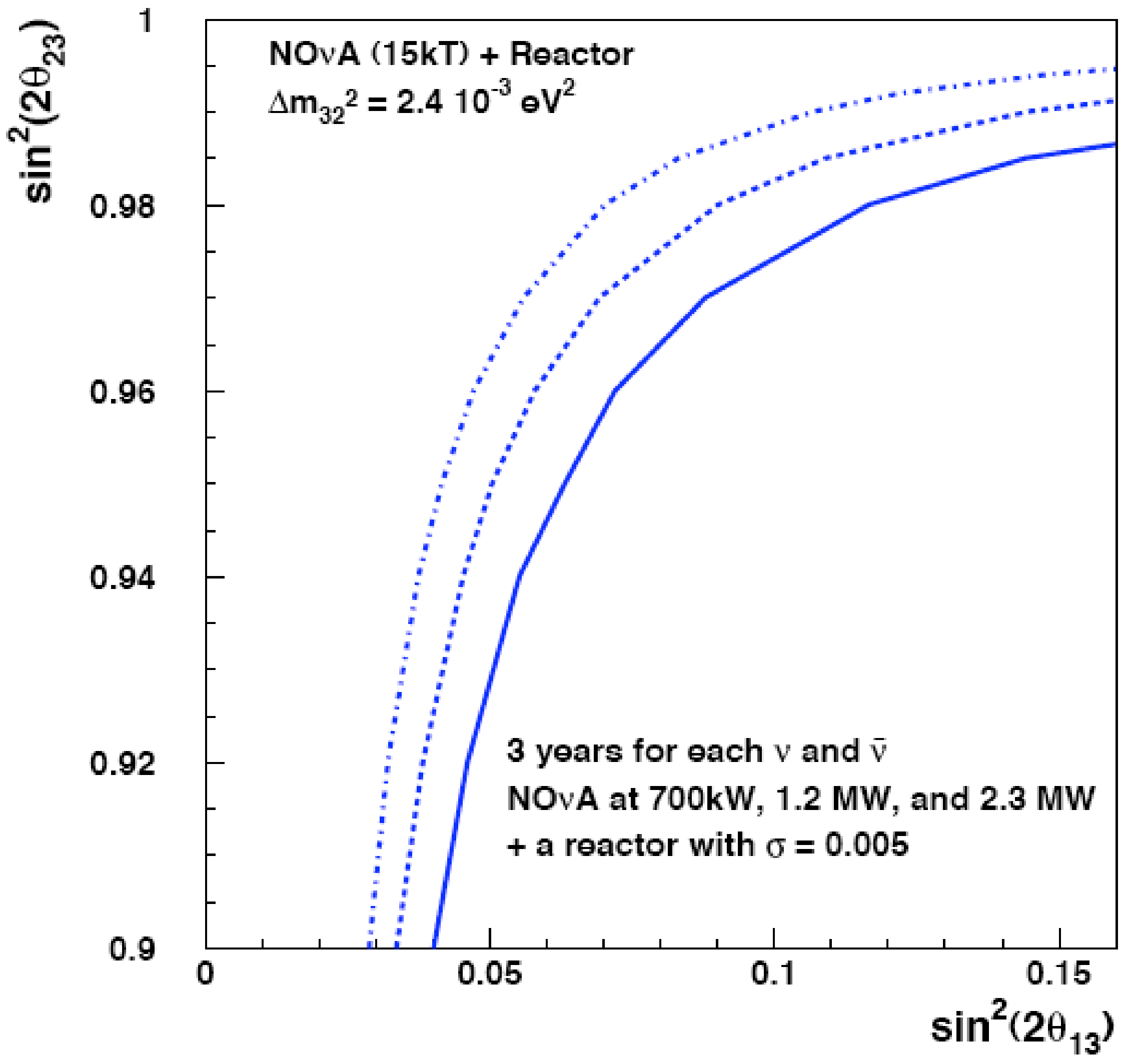
The good news is that a comparison of NOνA and Daya Bay can break this ambiguity and determine whether ν_3 couples more to ν_μ or ν_τ.



95% CL Resolution of the θ_{23} Ambiguity

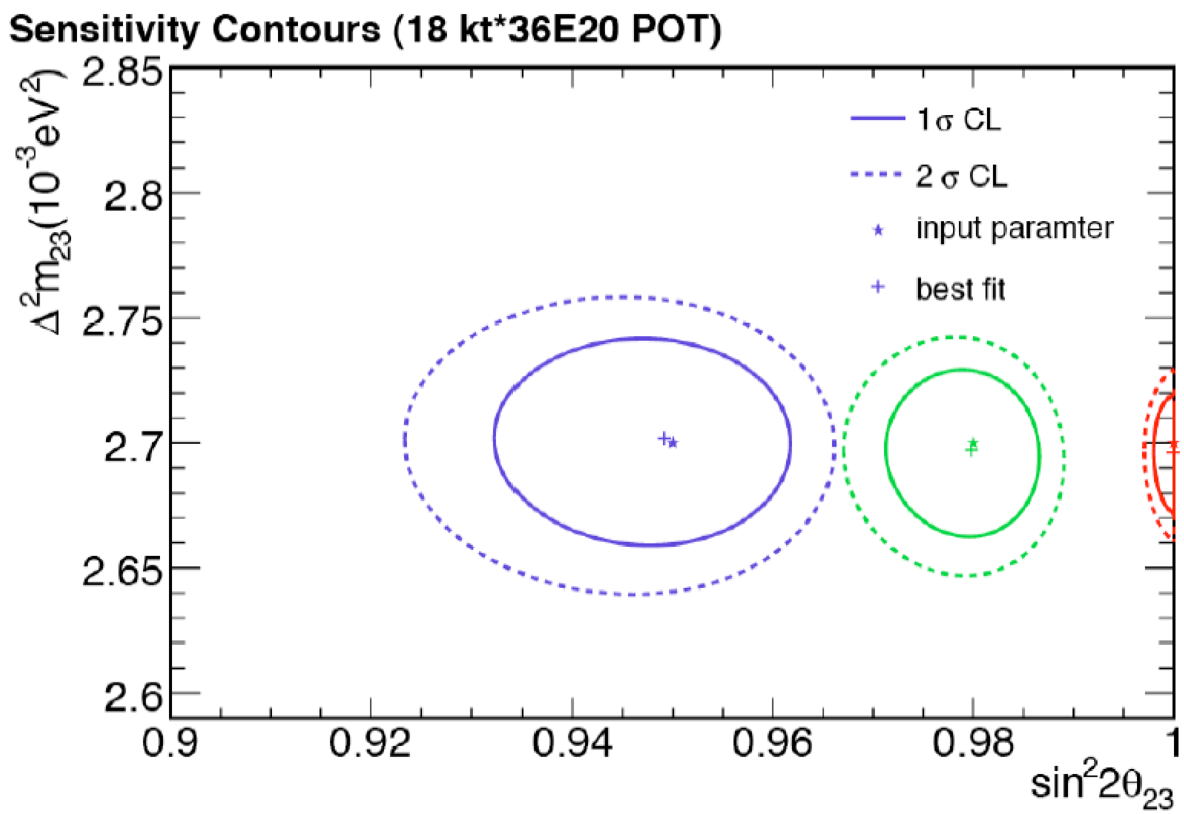
The ambiguity can be resolved in the region below and to the right of the curves.

The sensitivity depends on the mass ordering, δ, and the sign of the ambiguity itself. The curves represent an average over these parameters.



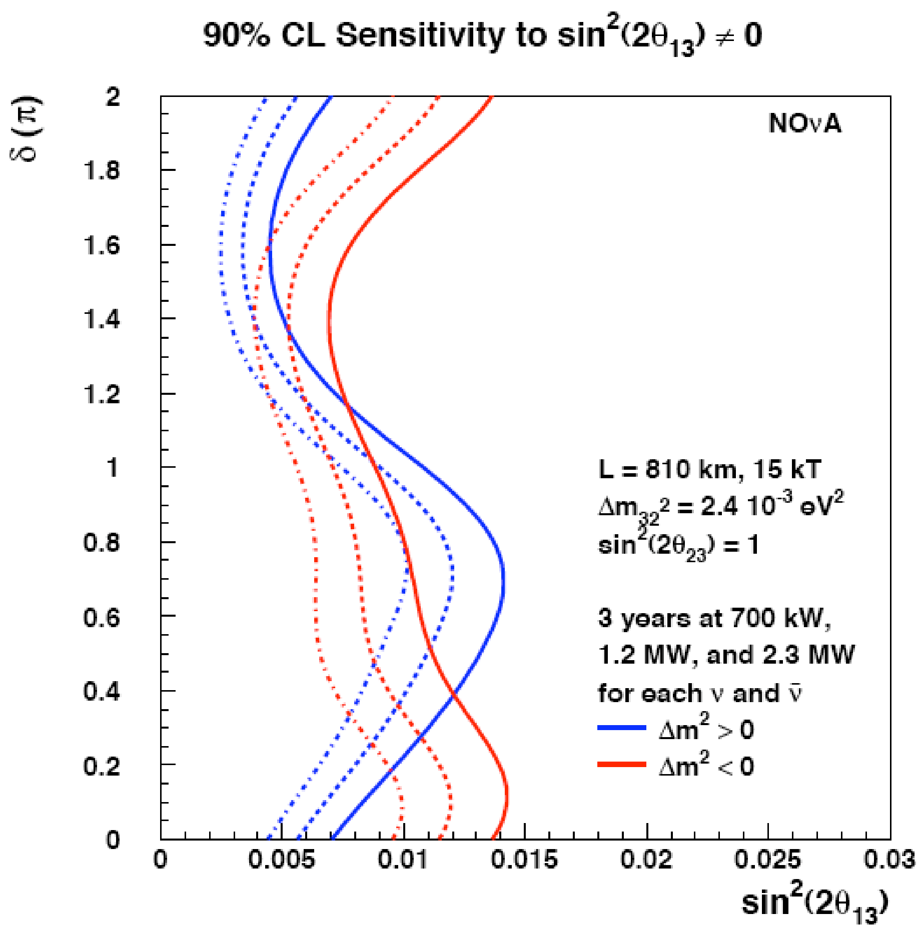
Measurement of $\sin^2(2\theta_{23})$

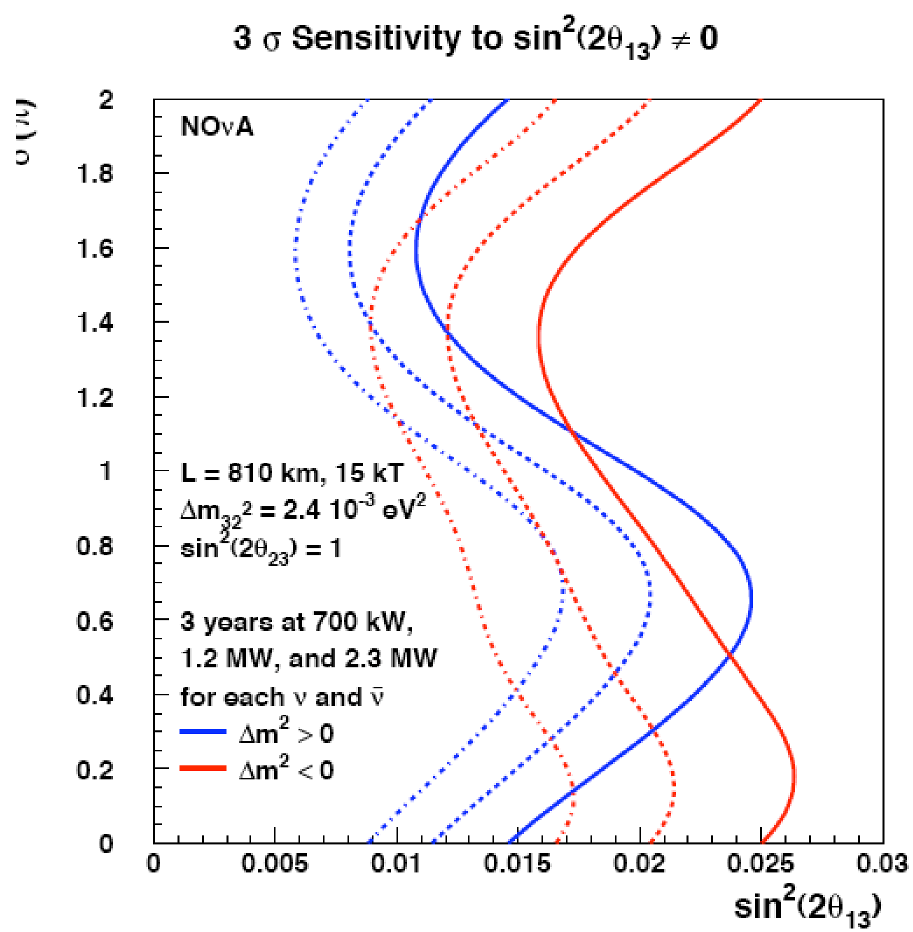
This calculation uses NOνA's excellent energy resolution on ν_μ CC events.



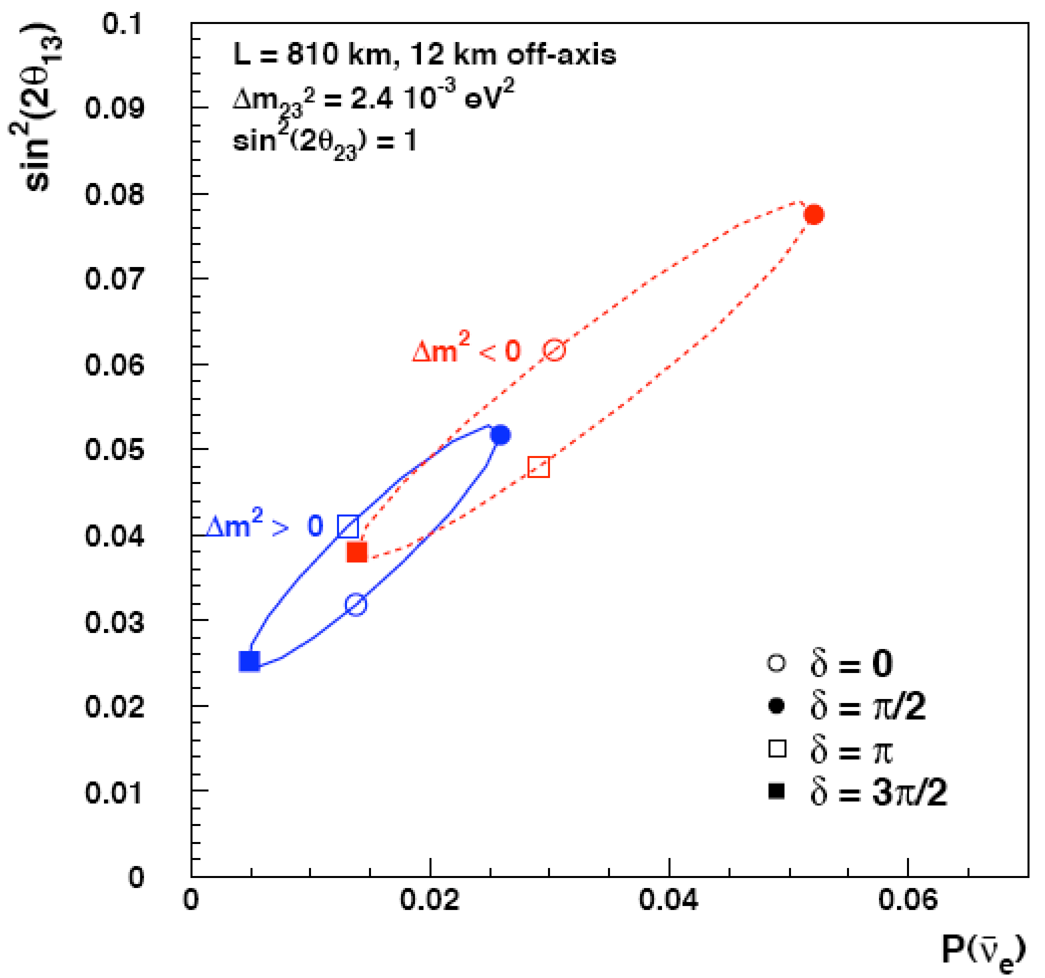
It is a parameterized calculation, which needs to be redone with a full reconstruction.

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





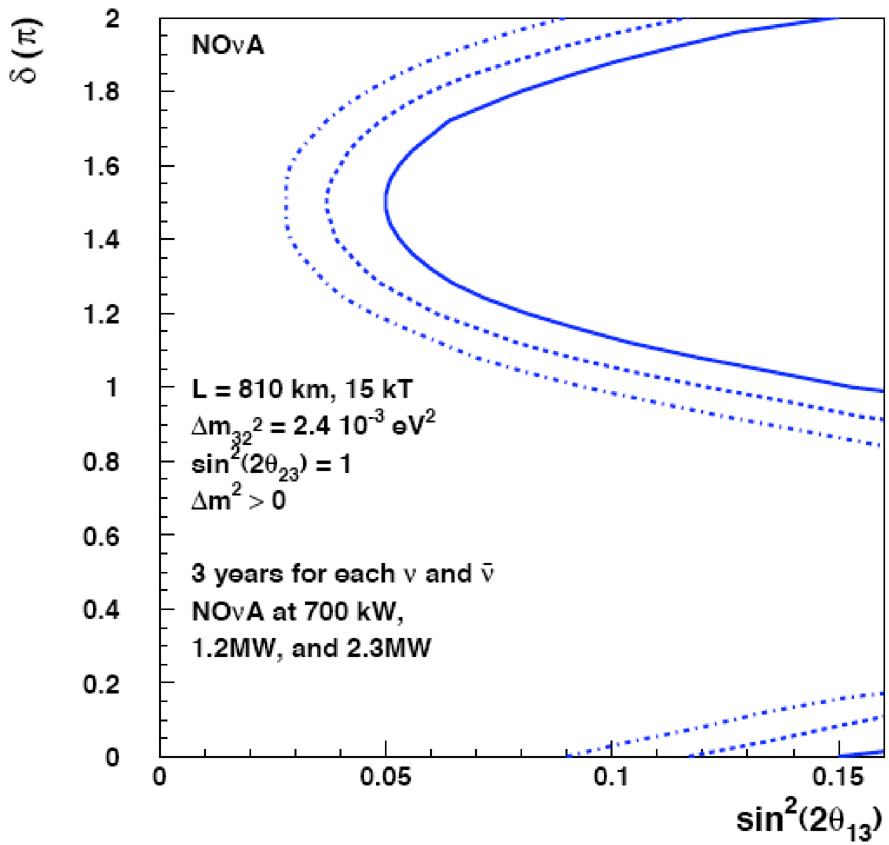
Parameters Consistent with a 2% $\nu_\mu \to \nu_e$ Oscillation Probability



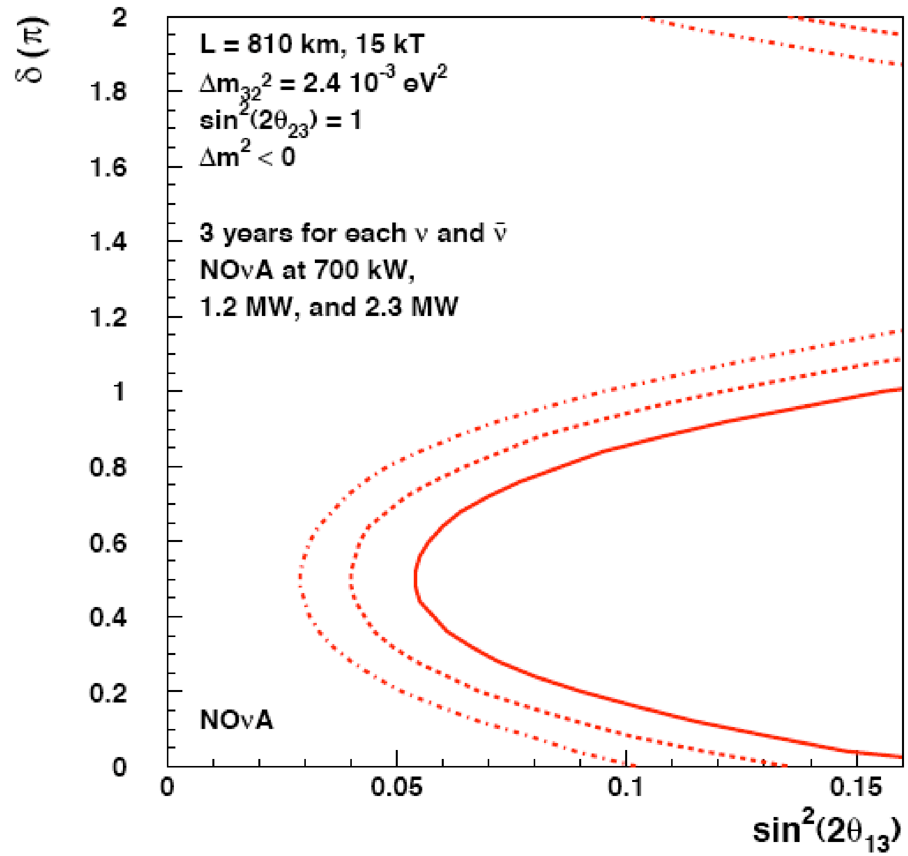
Strategy for Determining the Mass Ordering

- If the solar-atmospheric interference term goes in the same direction as the matter effect, then there is no ambiguity and NOνA can determine the mass ordering by itself, given sufficient integrated beam.
- If the solar-atmospheric interference term goes in the opposite direction as the matter effect, then there is an inherent ambiguity and NOνA cannot determine the mass ordering by itself. But it can be determined, in principle, by comparing NOνA and T2K.
  - If the neutrino oscillation probability is larger in NOνA than in T2K, it is the normal mass ordering; if the opposite, it is the inverted mass ordering.

95% CL Resolution of the Mass Ordering NOνA Alone

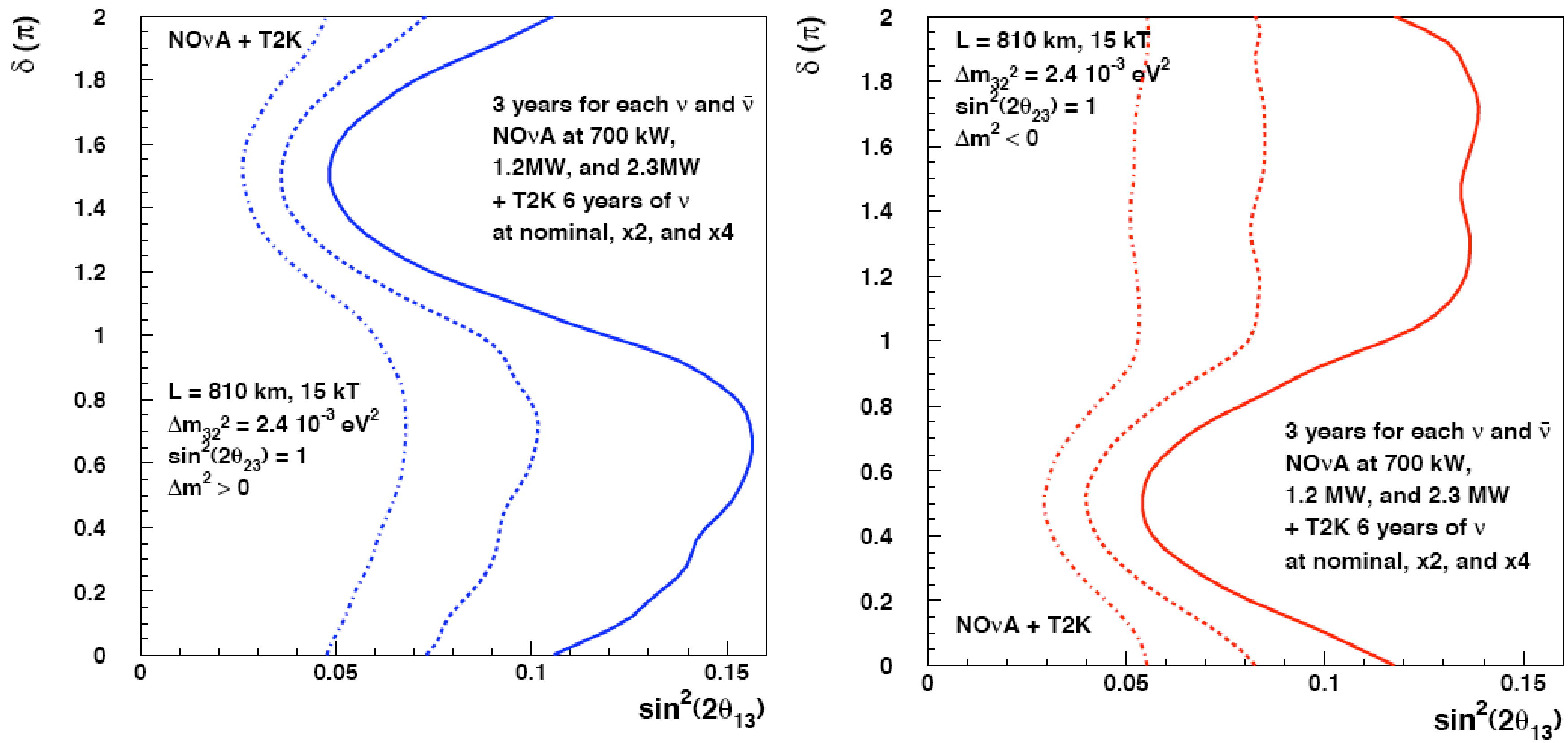


Normal Ordering



Inverted Ordering

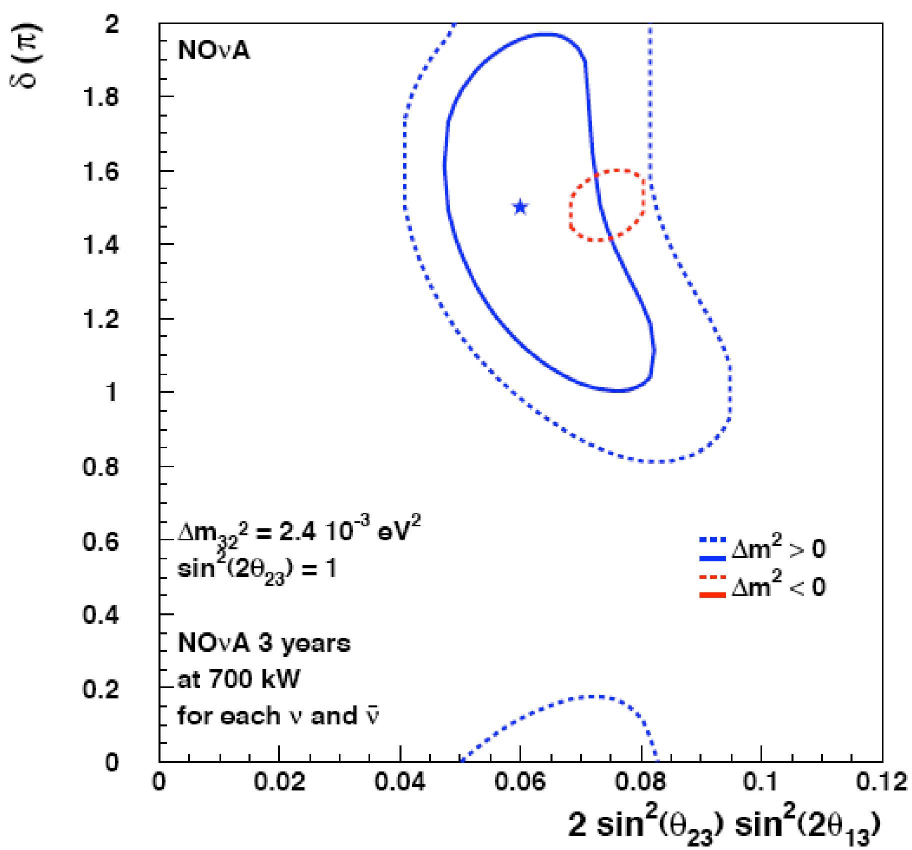
95% CL Resolution of the Mass Ordering NOνA Plus T2K



Normal Ordering　　　　Inverted Ordering

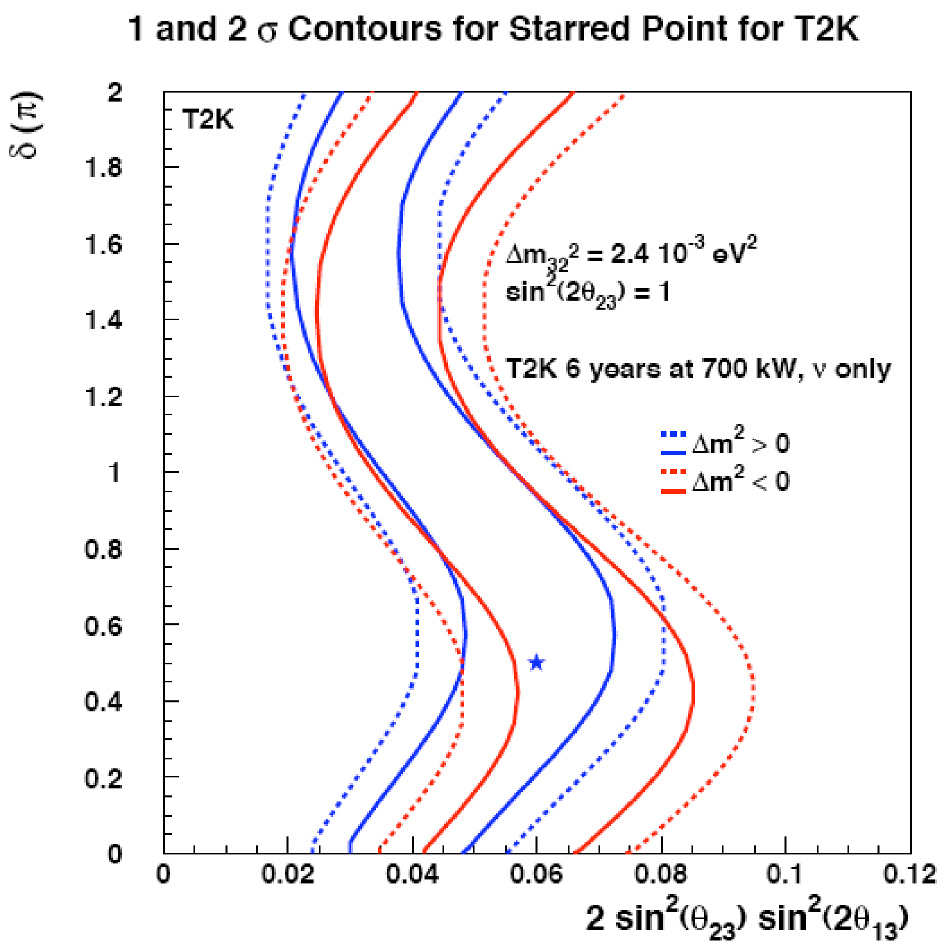
δ vs. θ_{13} Contours: Best Possible δ

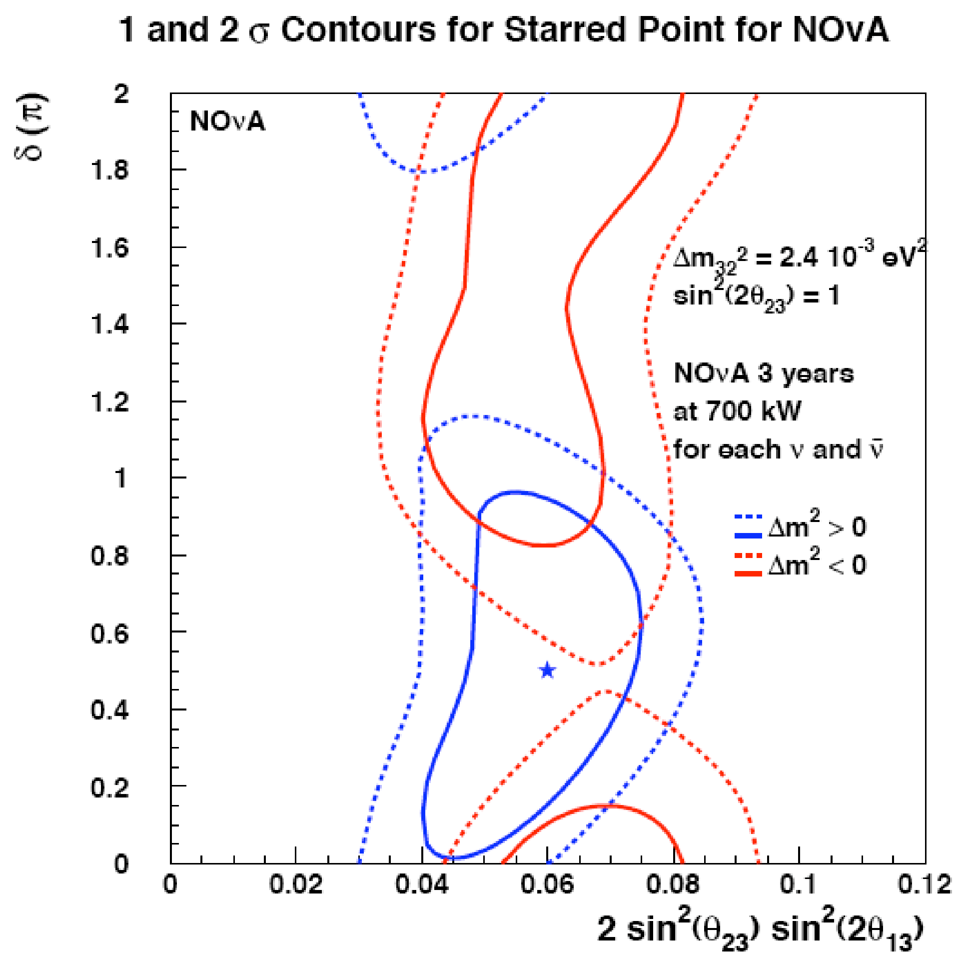
1 and 2 σ Contours for Starred Point for NOvA



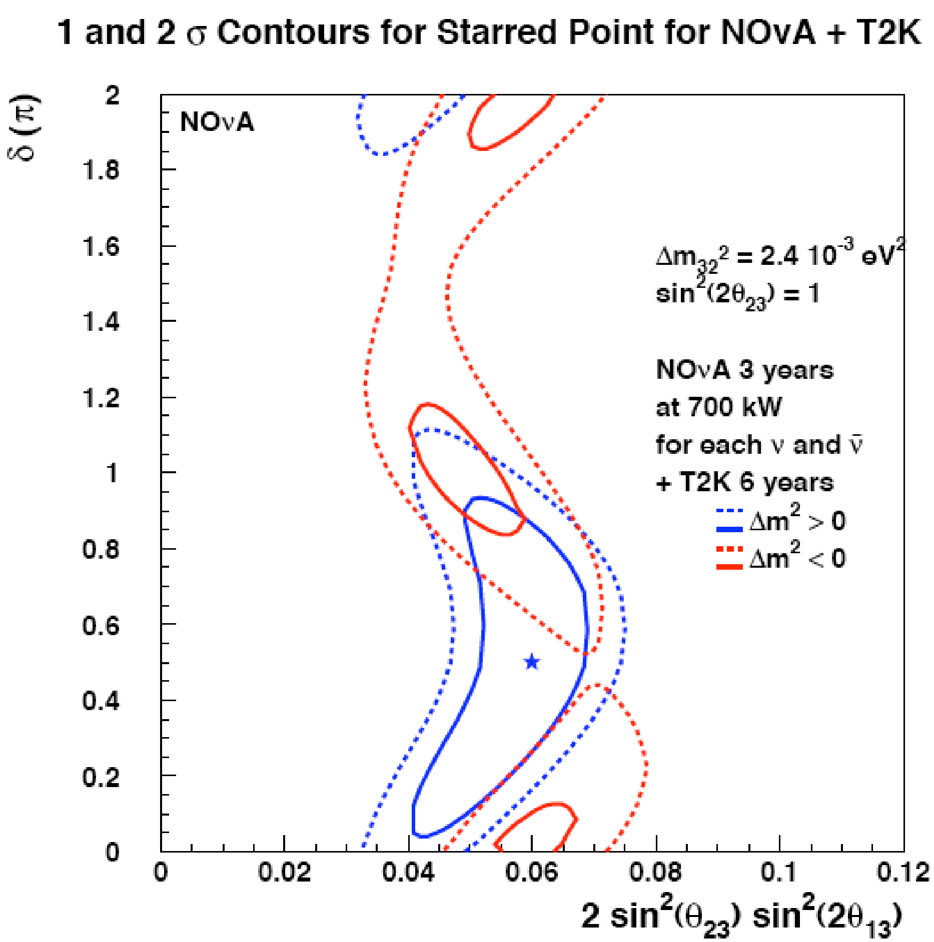
Plot for $\sin^2(2\theta_{13}) = 0.03$ goes here

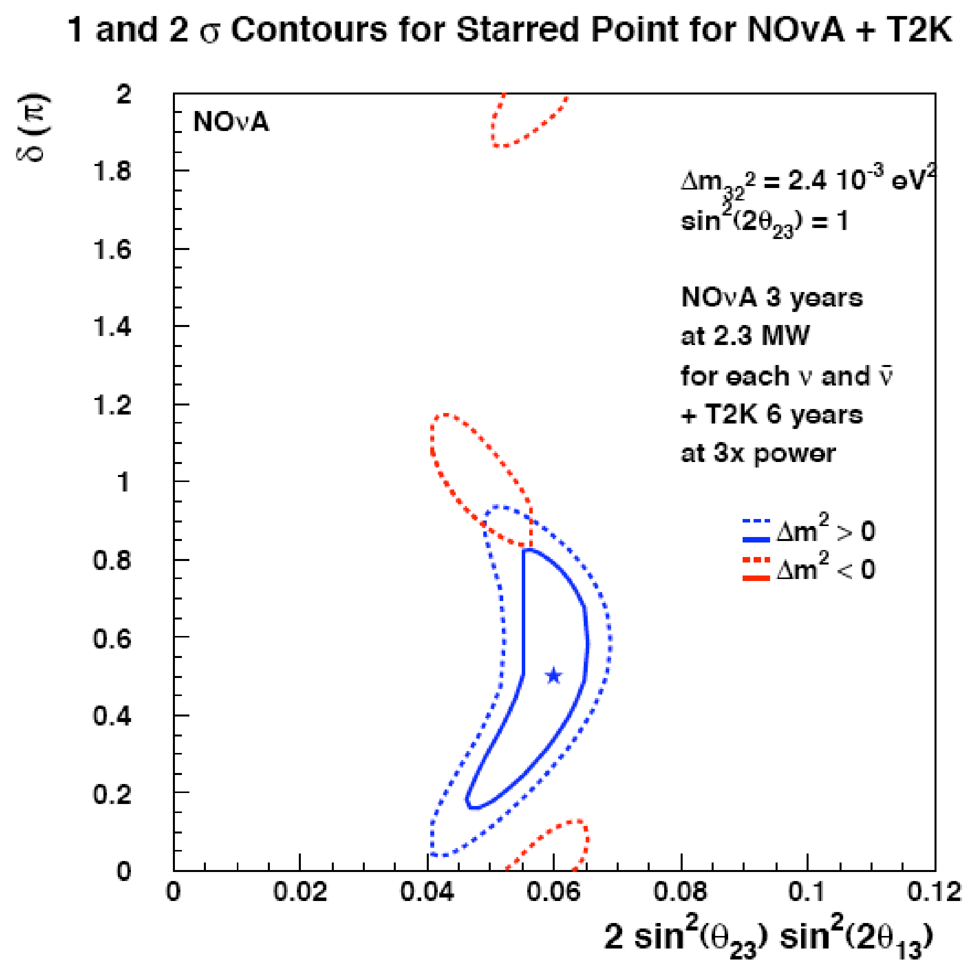
δ vs. θ_{13} Contours: Worst Possible δ T2K and NOvA Alone





δ vs. θ_{13} Contours: Worst Possible δ T2K and NOνA Combined





Conclusions I

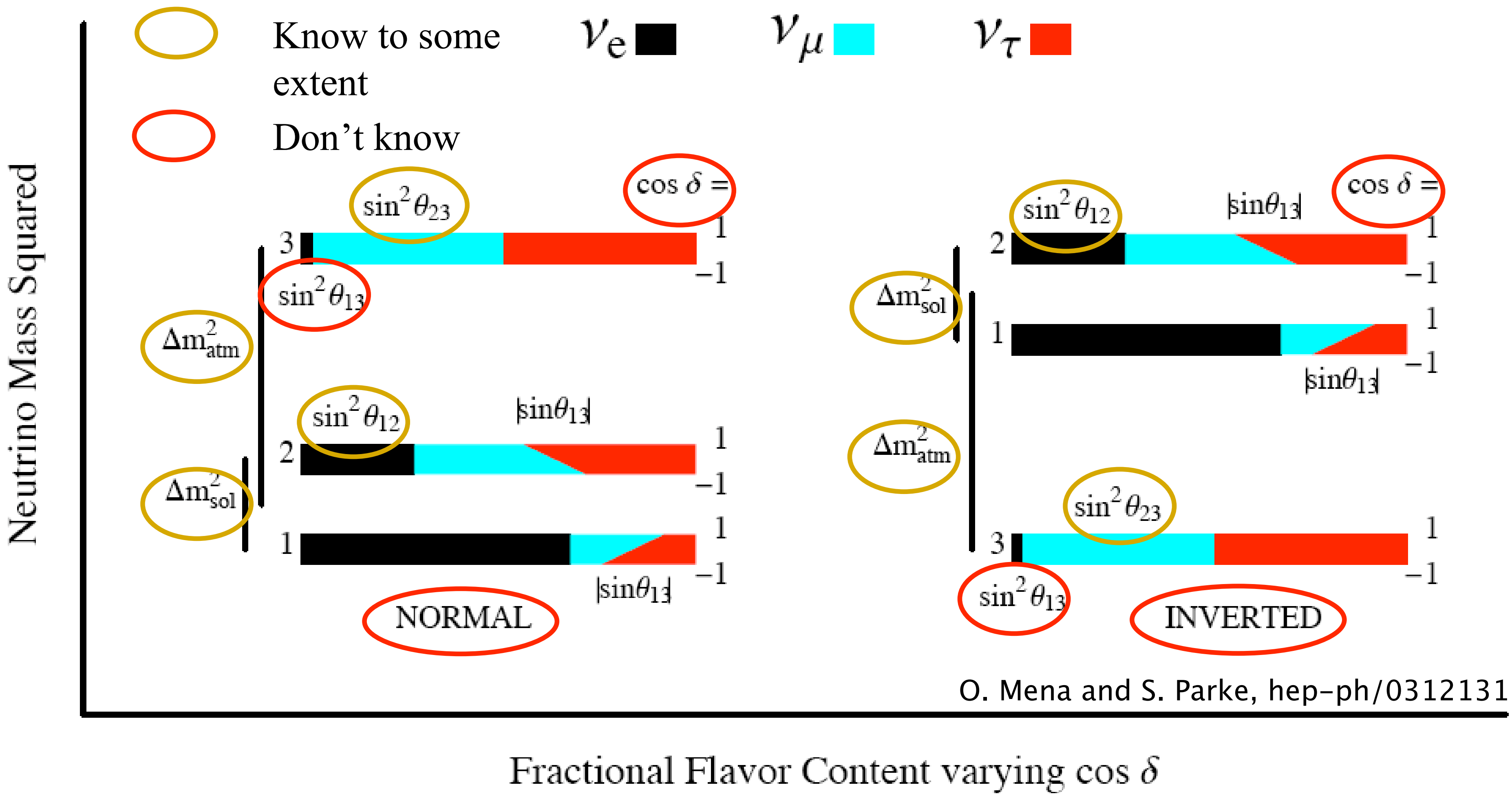
- Due to its long baseline and ease of running antineutrinos, NOνA will produce important results unavailable from any other experiment in its time frame.
- It is complementary to both T2K and Daya Bay.
- What was to become NOνA had its first workshop in May 2002. It has now passed all of its reviews and is ready to start construction in the spring of 2009, assuming funding will be available. All of the other major US neutrino accelerator initiatives being discussed today are in the workshop phase.

Conclusions II

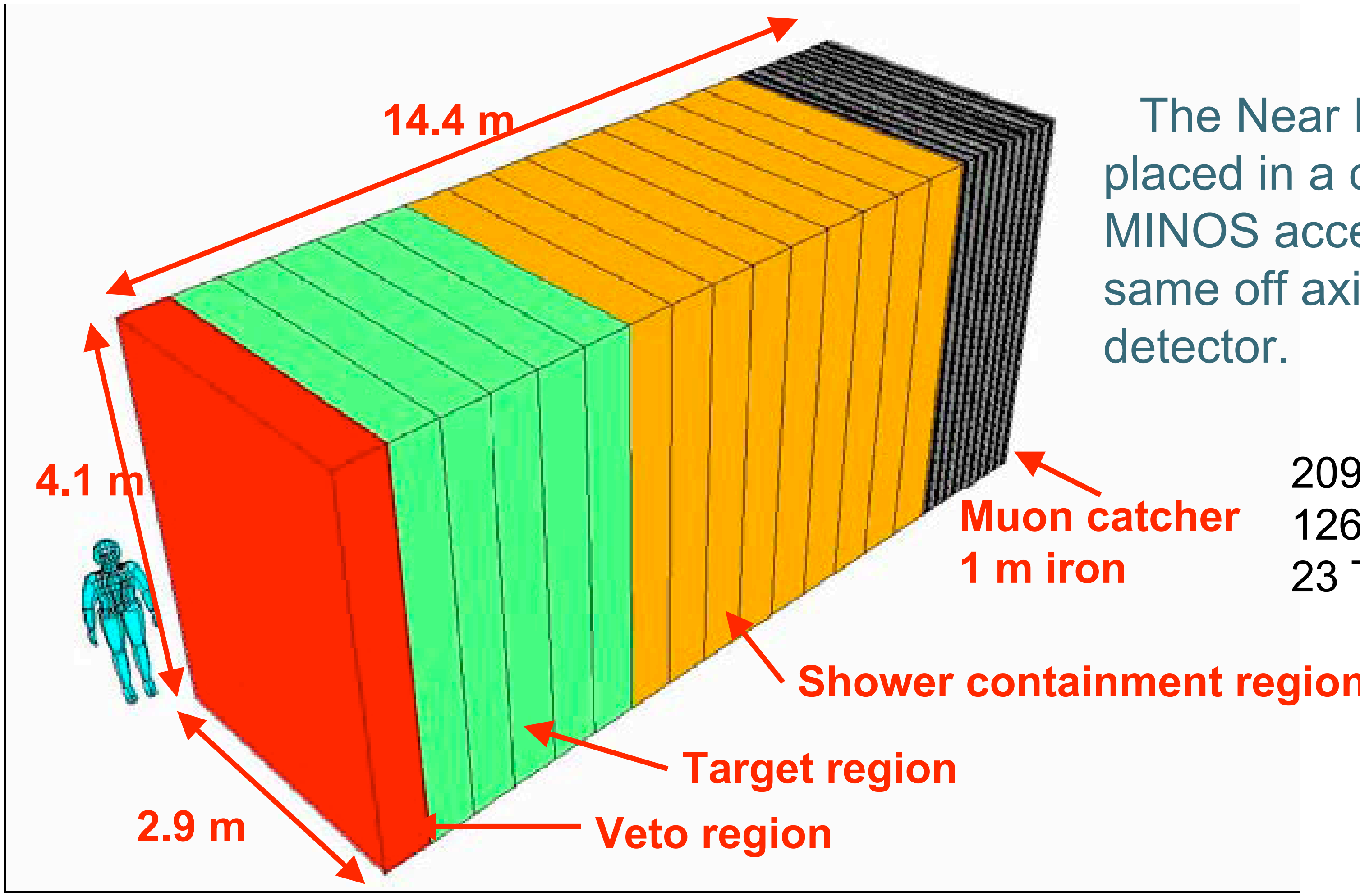
- NOνA will be the anchor of the US accelerator neutrino program. In addition to its unique physics contributions,
  - It will provide the incentive to increase the NuMI beam power from 400 to 700 kW, and then to either 1.2 MW (SNuMI) or 2.3 MW (Project X), depending on available funding.
  - It will provide the physics rationale for building LAr5, i.e., doubling the capacity of NOνA.
  - It will provide the continuity necessary to keep the program running smoothly, e.g. training experimental and accelerator physicists.

Backup Slides

What We Know and What We Don't Know



NOvA Near Detector



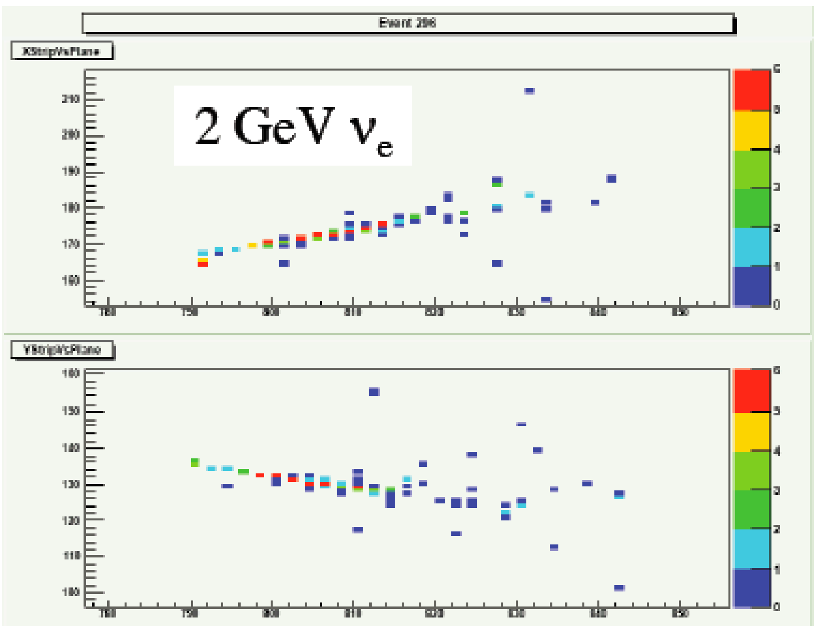
The Near Detector will be placed in a cavern off of the MINOS access tunnel on the same off axis line as the far detector.

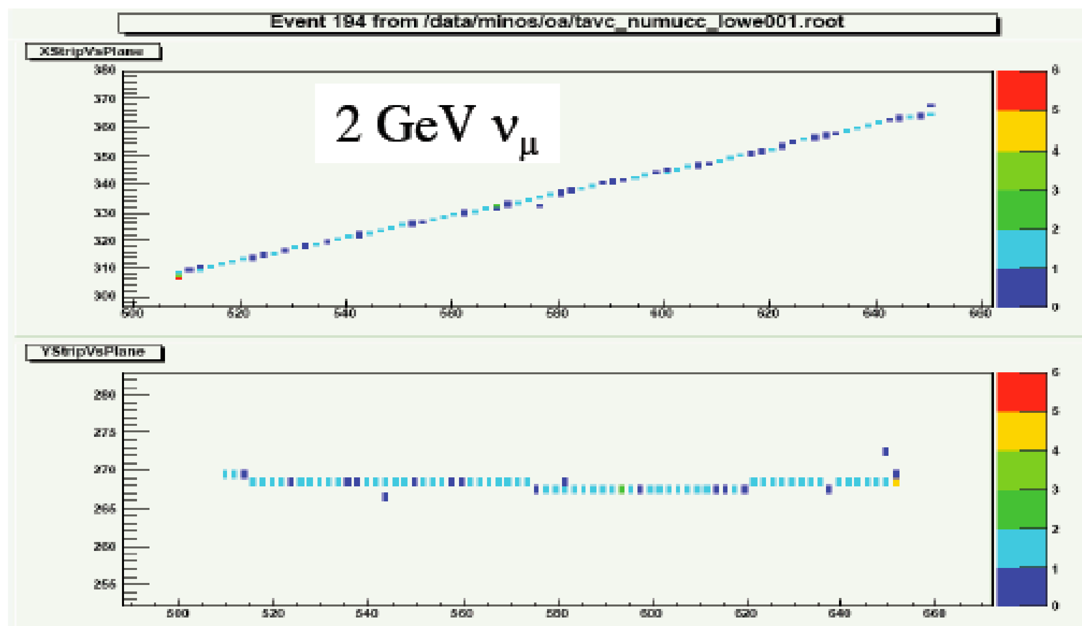
209 T
126 T totally active
23 T fiducial

Event Quality

Longitudinal sampling is 0.15 X0, which gives excellent μ-e separation.

A 2-GeV muon is 60 planes long.





ν_e CC event

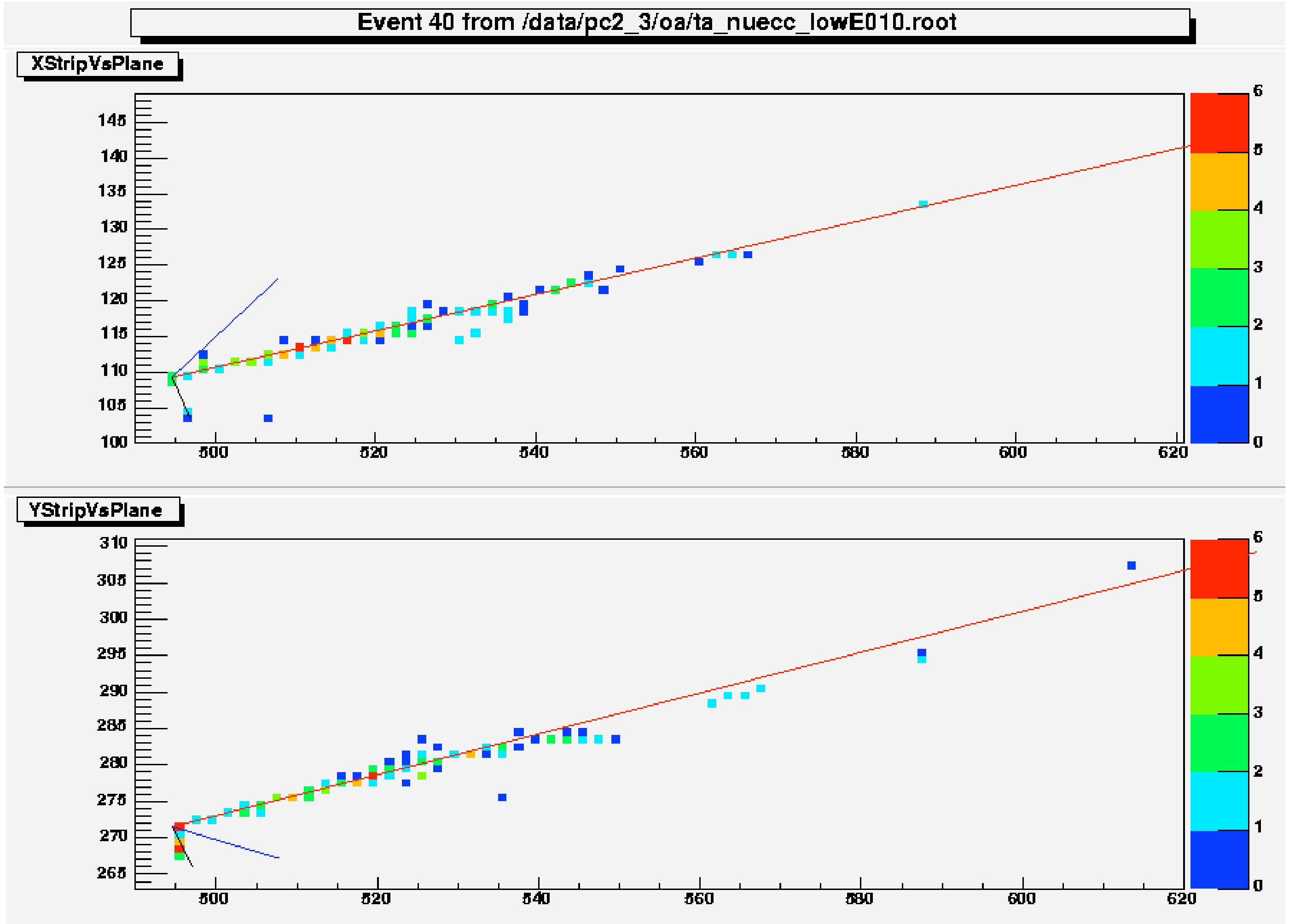
$\nu_e p \rightarrow e^- p \pi^+$

E_ν=2.5GeV

E_e=1.9GeV

E_p=1.1GeV

E_π=0.2GeV



Background 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