NOvA: θ_{13} is Large, So Now What?
(ou, o que há de novo com o NOvA?)

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Passa Quatro, MG

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θ_{13} is Larger Than Expected: Great News for NOvA!

- Now that $\theta_{13} \sim 9^{\circ}$ has been measured, the prospects for NOvA to make some exciting discoveries are very bright!
- Long-baseline $\nu_\mu \rightarrow \nu_e$ experiments have the potential to simultaneously measure θ_{13}, δ_{CP}, sign(Δm_{31}^2), sign(θ_{23}-45°):

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The NuMI Off-Axis ν_e Appearance (NOvA) Experiment

Argonne National Laboratory
University of Athens
California Institute of Technology
Institute of Physics of the Academy of Sciences of the Czech Republic
Charles University in Prague
University of Cincinnati
Fermi National Accelerator University
Harvard University
India Universities Consortium
Indiana University
Iowa State University
Lebedev Physical Institute
Michigan State University
University of Minnesota, Crookston
University of Minnesota, Duluth
University of Minnesota, Twin Cities
The Institute of Nuclear Research, Moscow
University of South Carolina, Columbia
Southern Methodist University
Stanford University
University of Sussex
University of Tennessee, Knoxville
University of Texas, Austin
Tufts University
University of Virginia, Charlottesville
Wichita State University
The College of William and Mary

A growing collaboration of over 150 scientists and engineers from almost 40 institutions and 6 countries.

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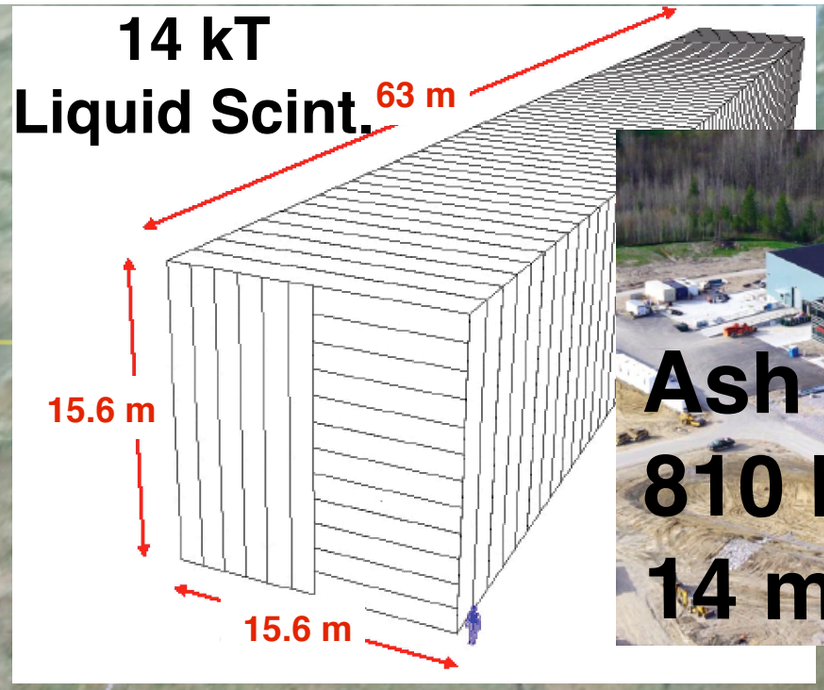


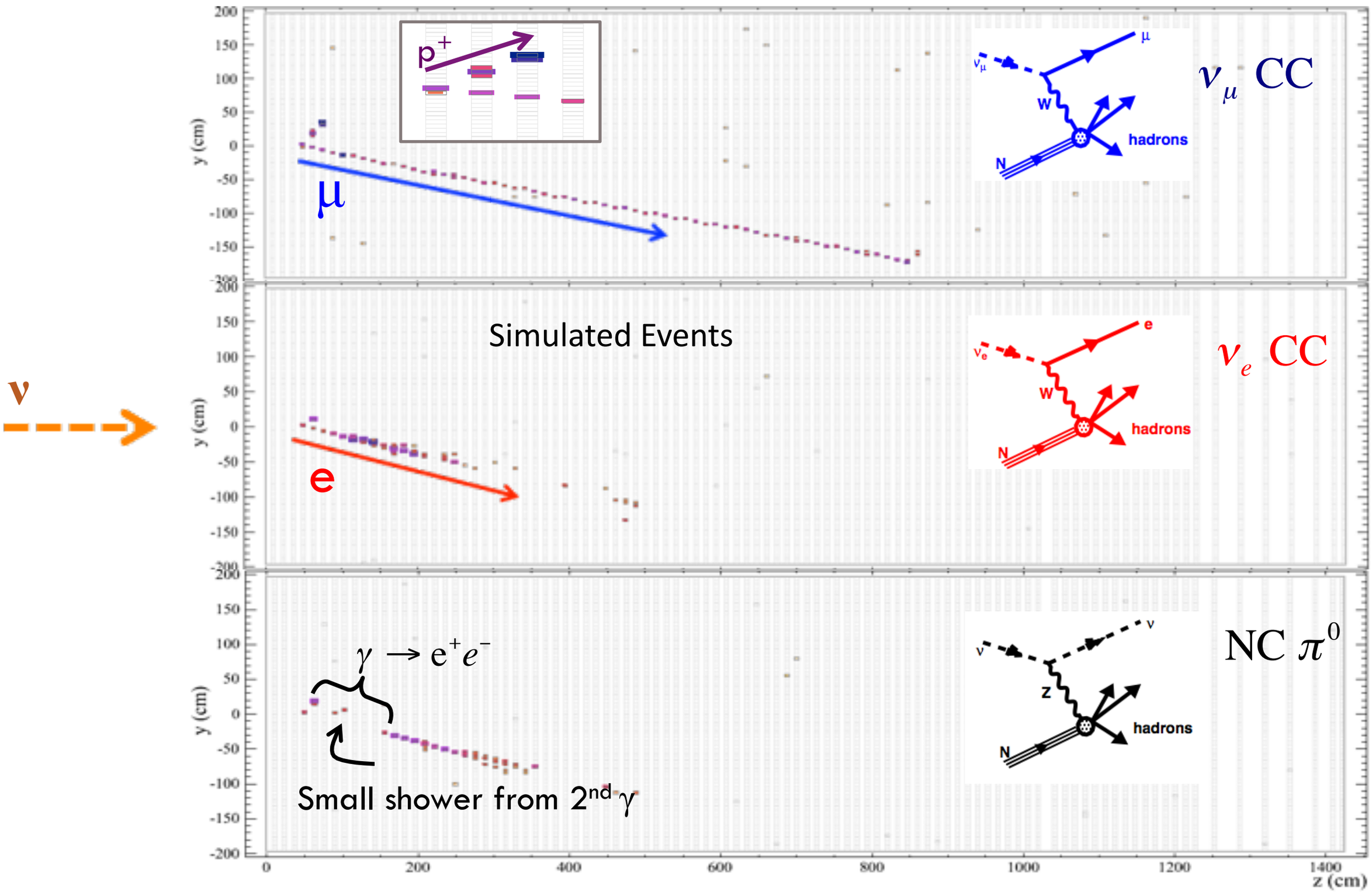
Existing NuMI ν Beam from FNAL

Upgrade from 360 kW to 700 kW in progress

- Goals:
- Observe $\nu_\mu \rightarrow \nu_e$ and measure the mixing angle θ_{13} .
- Resolution of the neutrino mass hierarchy
- Search for CP violation in the neutrino sector
- Determine the octant of θ_{23}
- Improved measurements of $\sin^2(2\theta_{23})$ by ~10x.

Nearly identical ~300 ton detector located at FNAL, 14 mrad off-axis & 1 km from source will measure ν spectrum before oscillations occur.

Distinguishing Neutrino Events in NOvA



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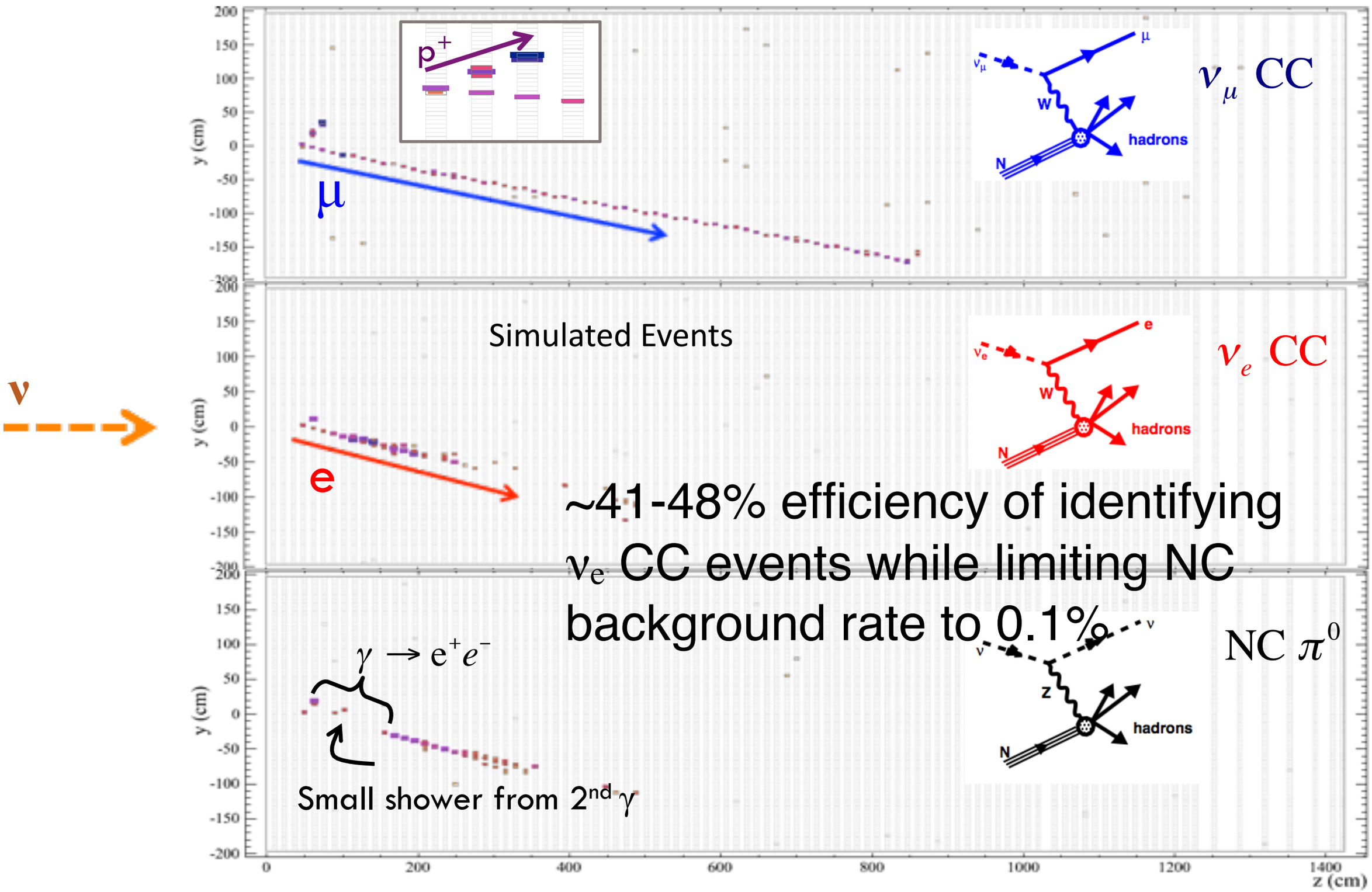
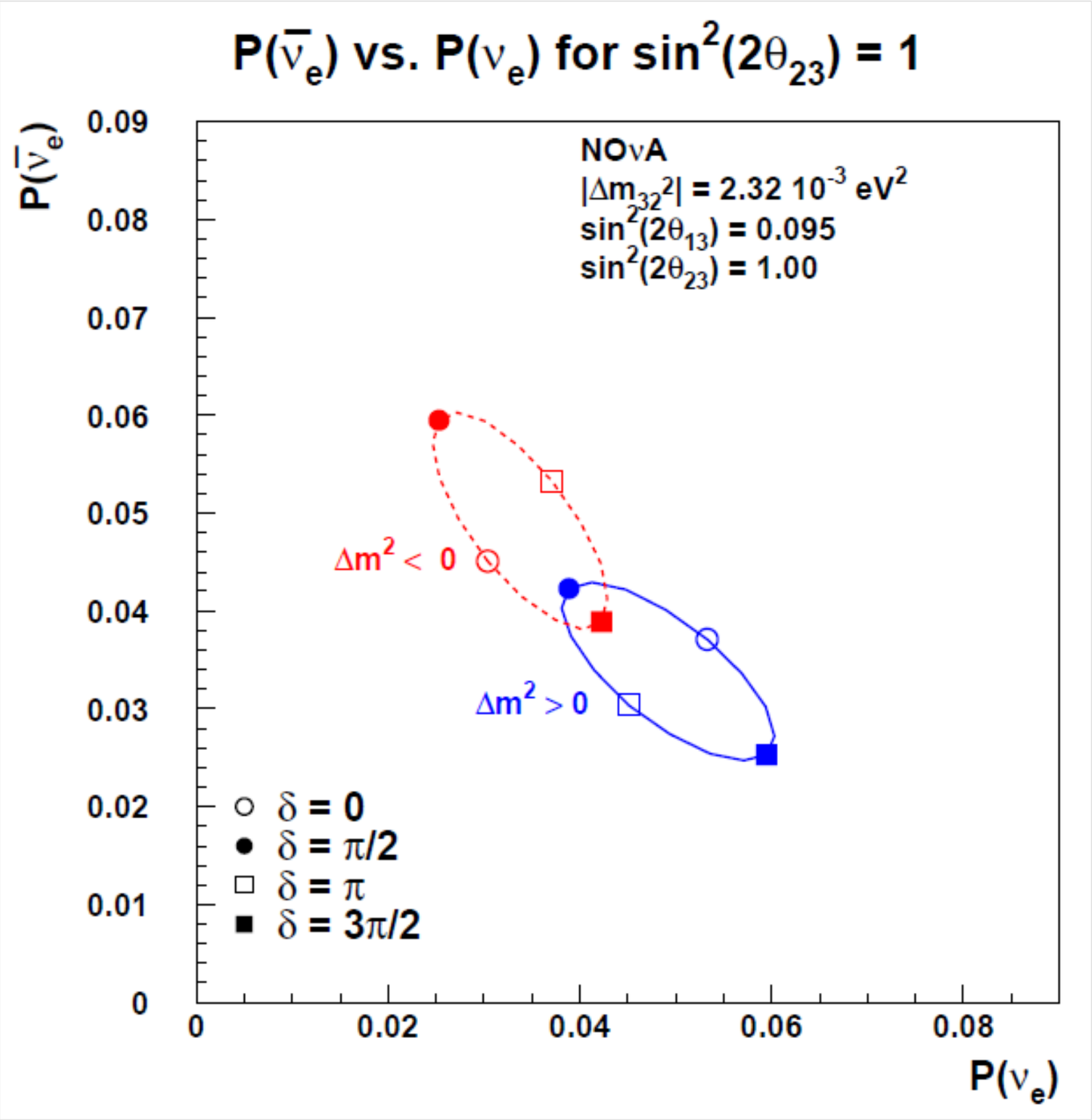


ν

~41-48% efficiency of identifying ν_e CC events while limiting NC background rate to 0.1%

NOvA Measurements



- The strategy in NOνA is to compare the oscillation probability of $\nu_\mu \rightarrow \nu_e$ and $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$.

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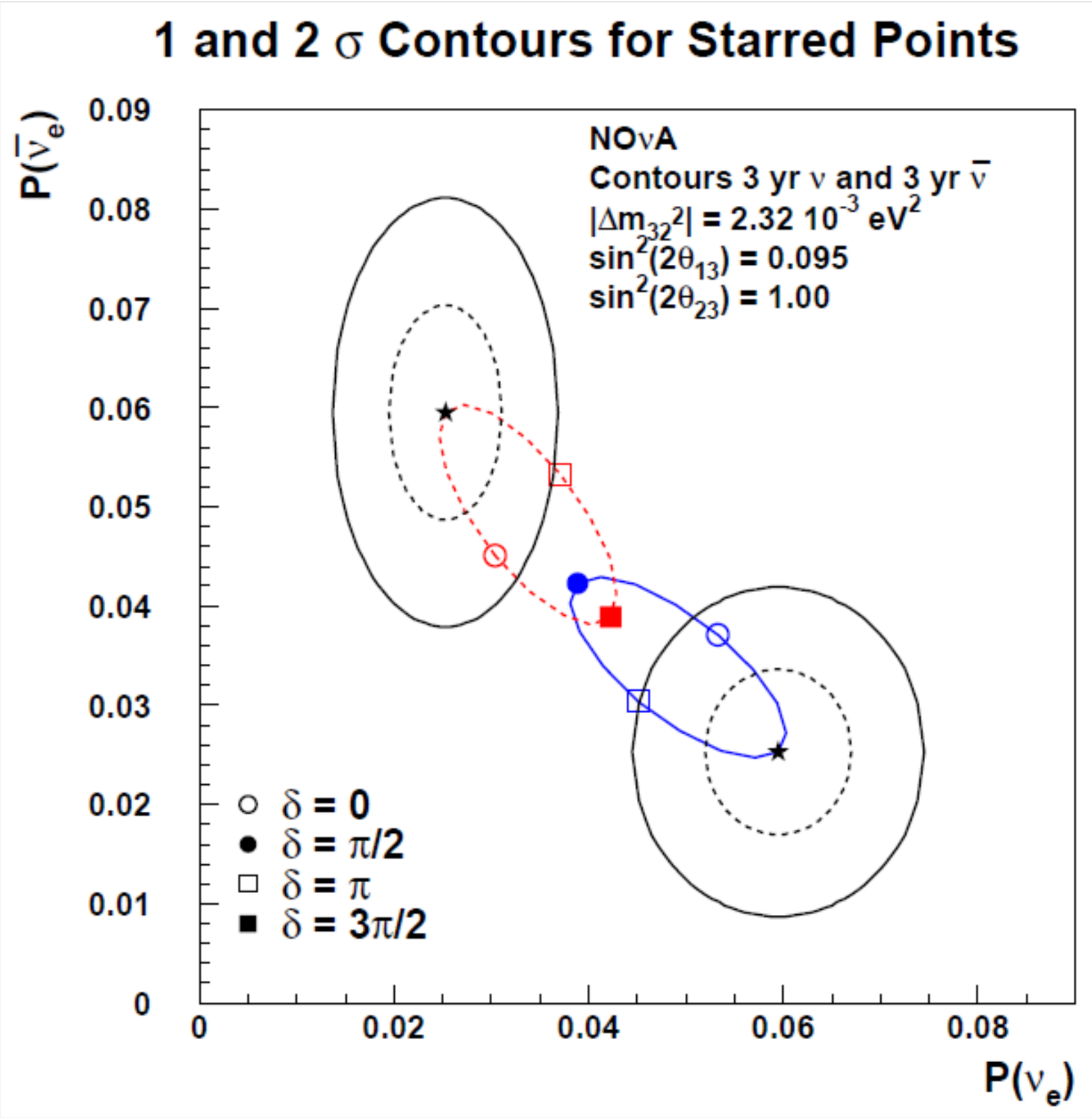

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- These cases represent best-case scenarios for determining the mass hierarchy after 3 years of running each mode each. Contours are 1- and 2-sigma measurements.

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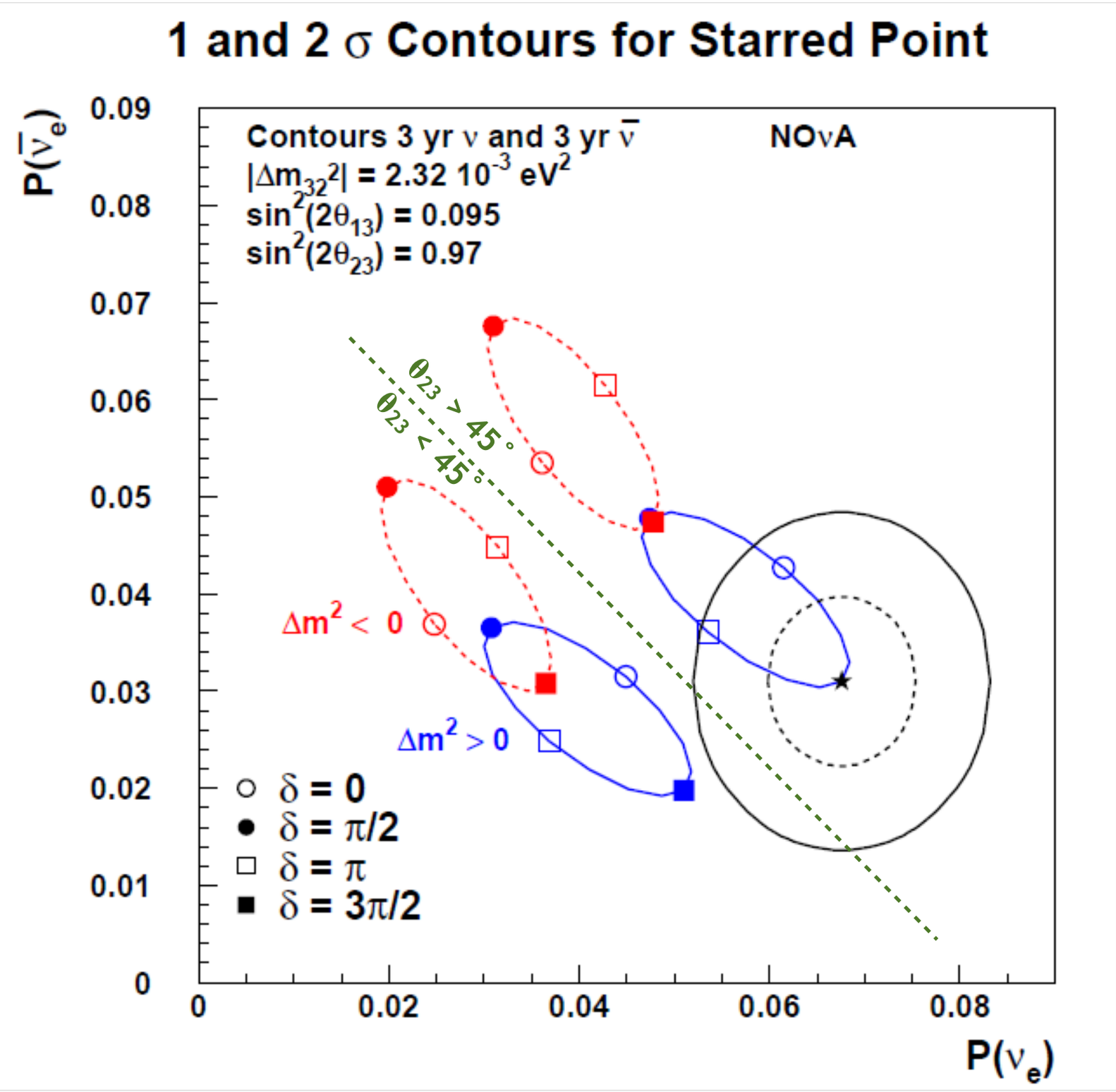
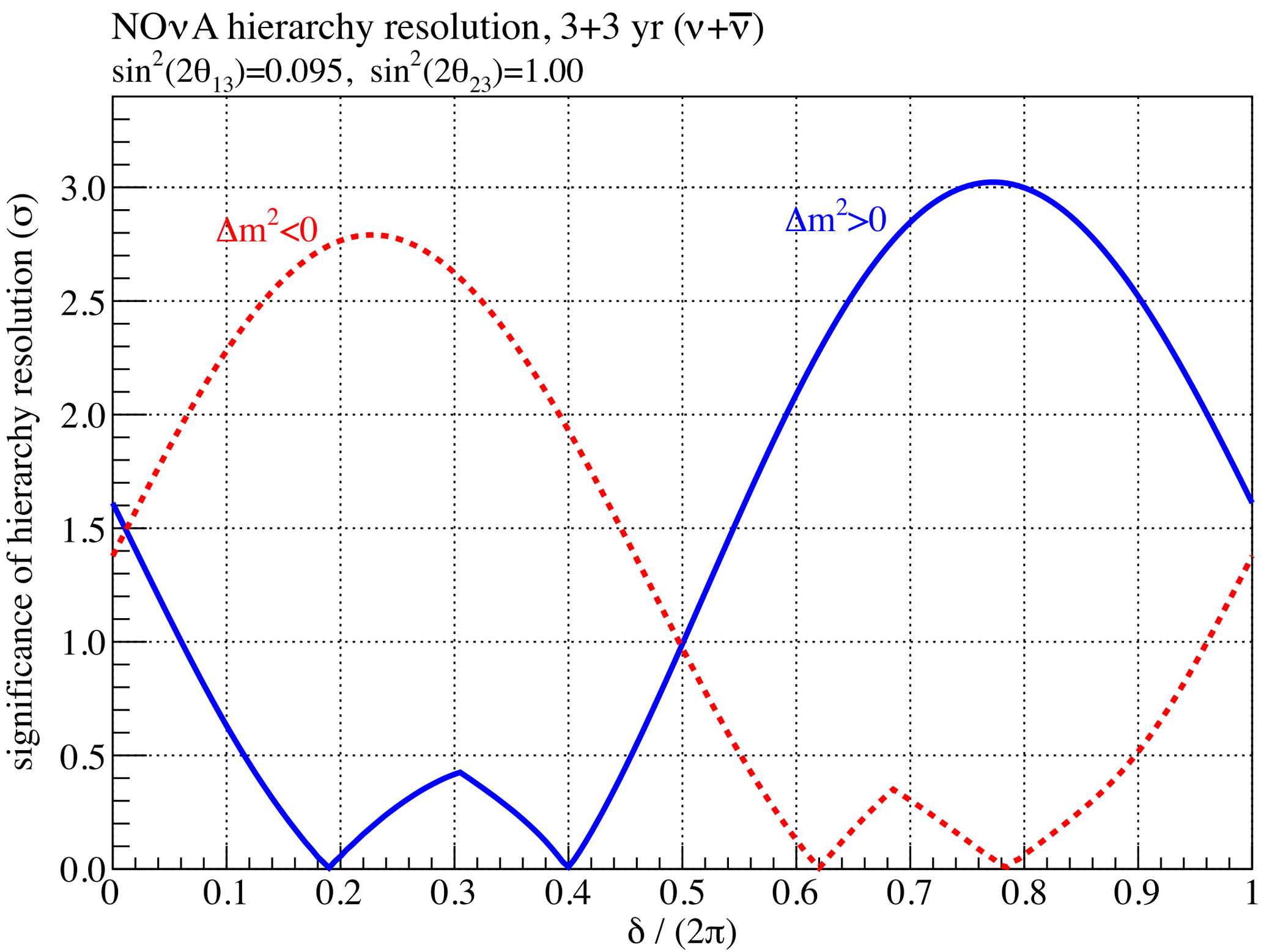


- The strategy in NOνA is to compare the oscillation probability of $\nu_\mu \rightarrow \nu_e$ and $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$.
- If θ_{23} is non-maximal, then we also have the capability of determining the octant; this tells us whether or not ν_μ couples more strongly to ν_2 or ν_3.

Resolution of Mass Hierarchy



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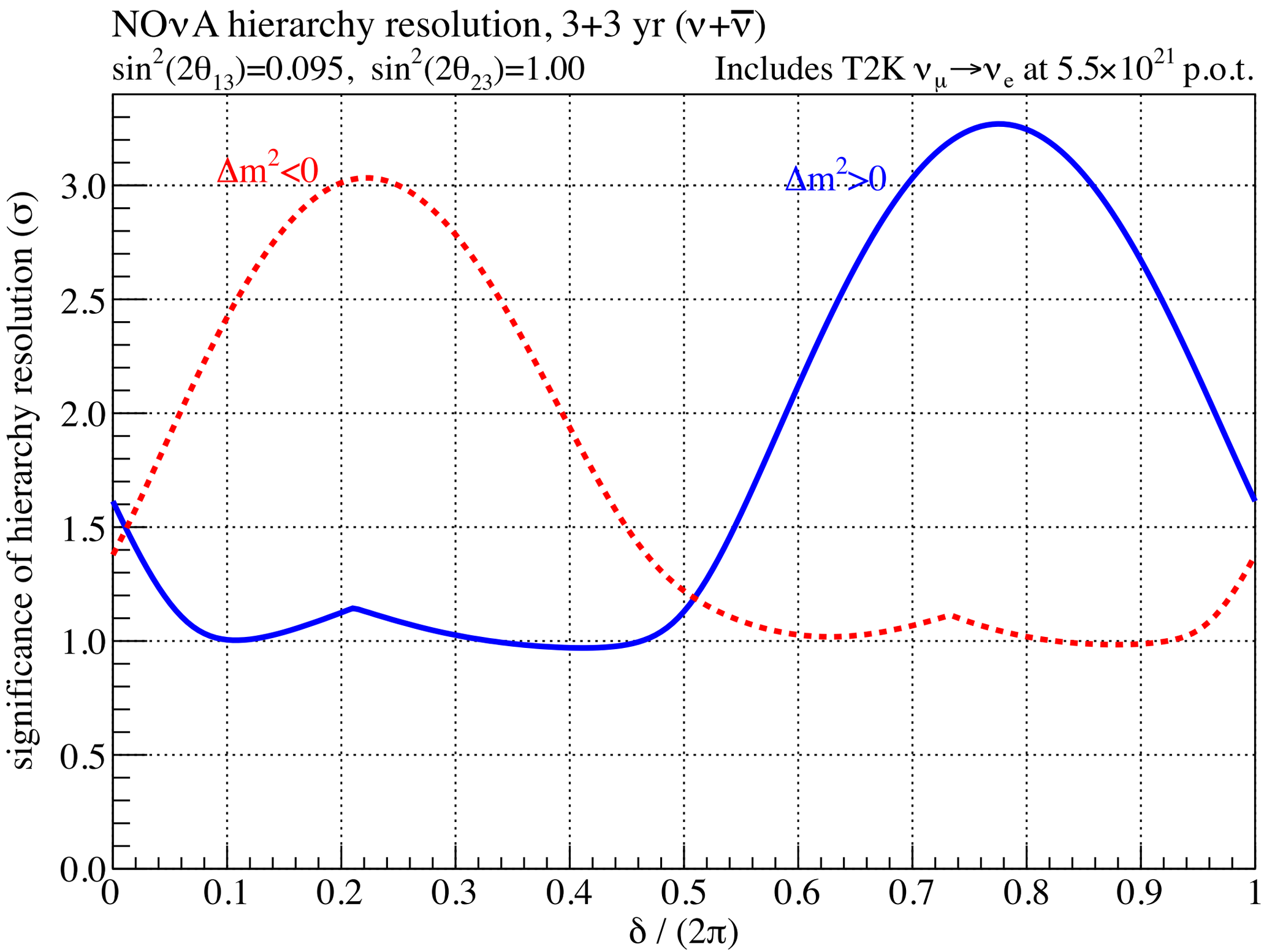
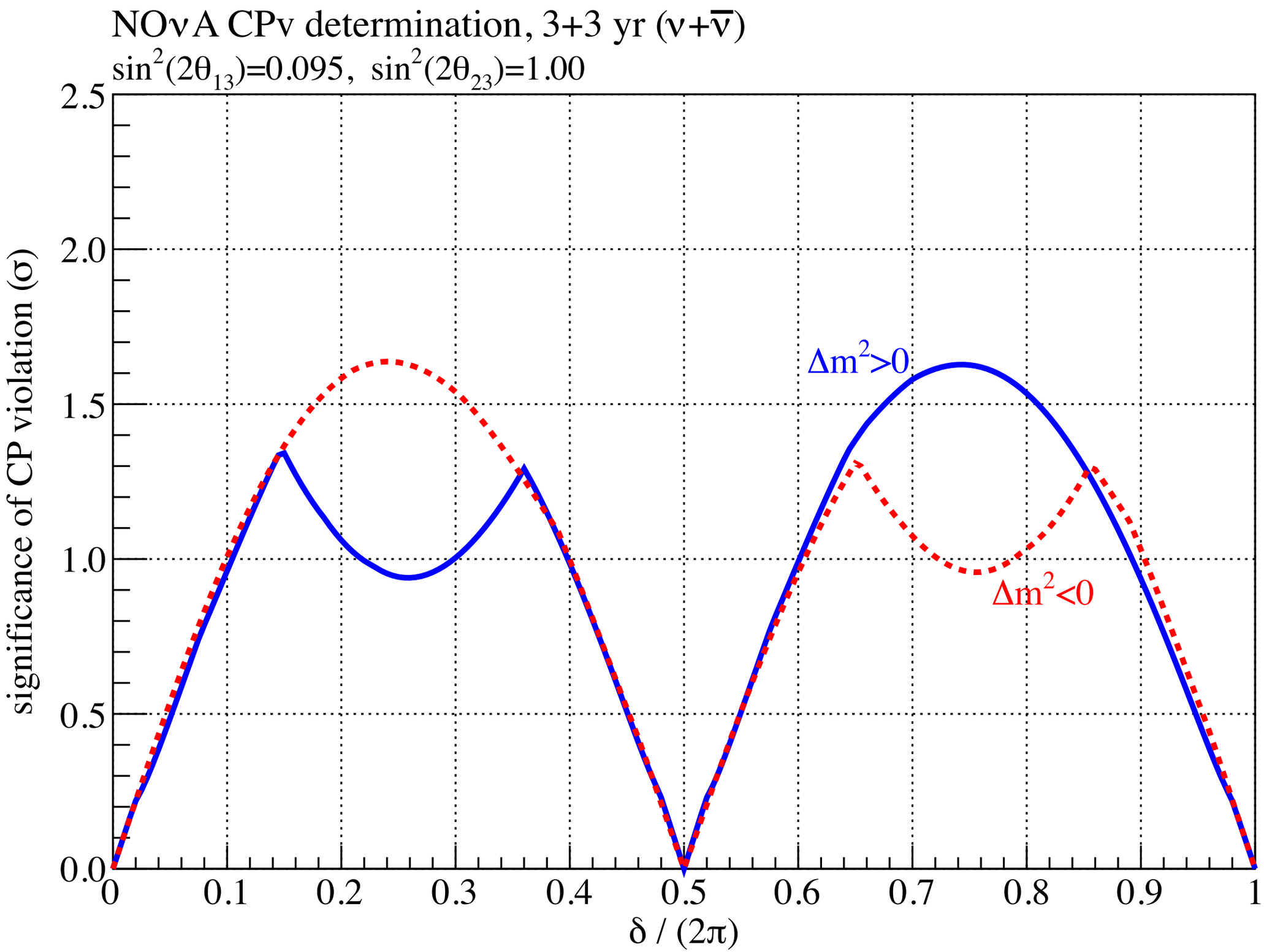


Measurement of CP-violation



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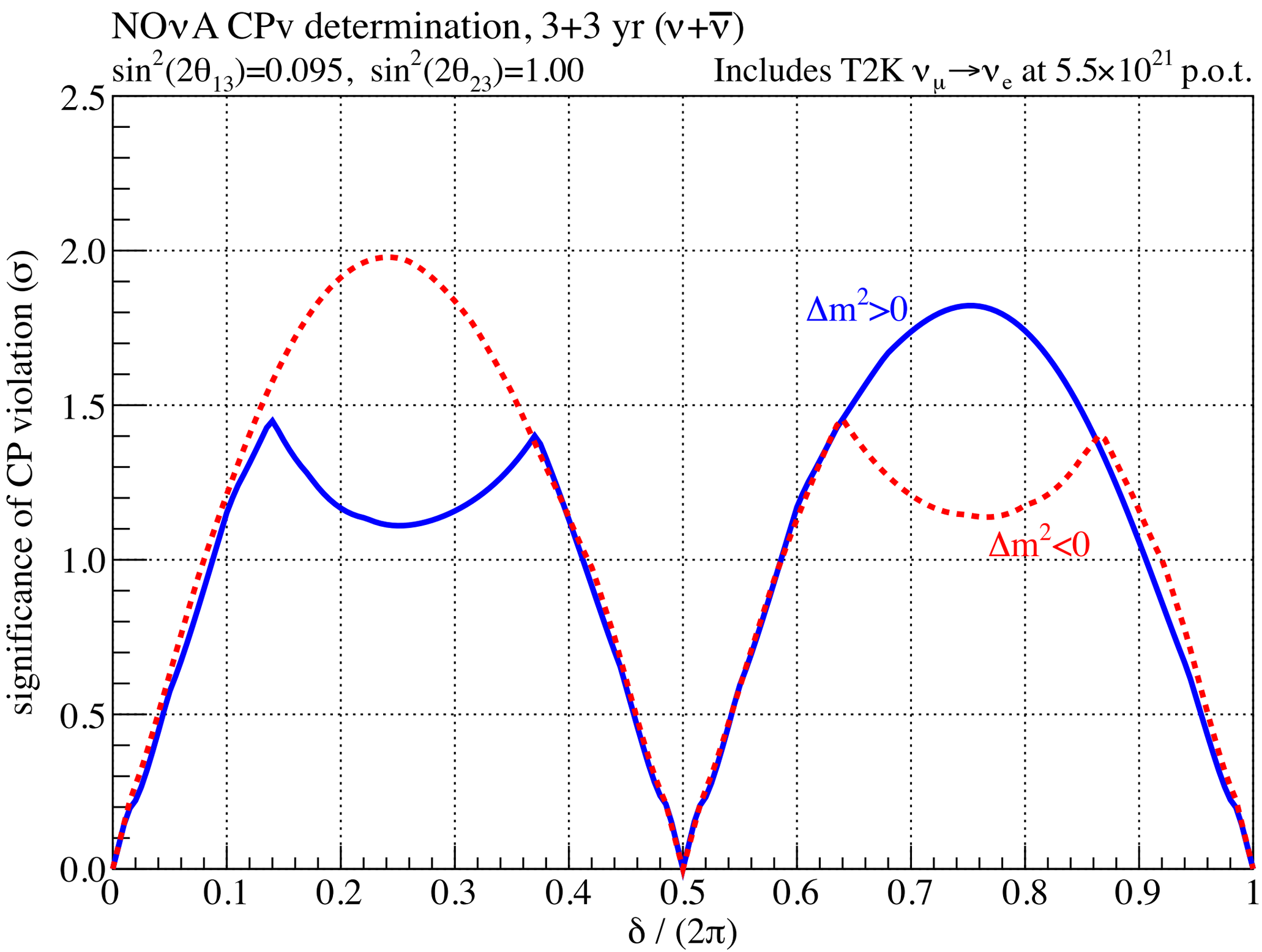
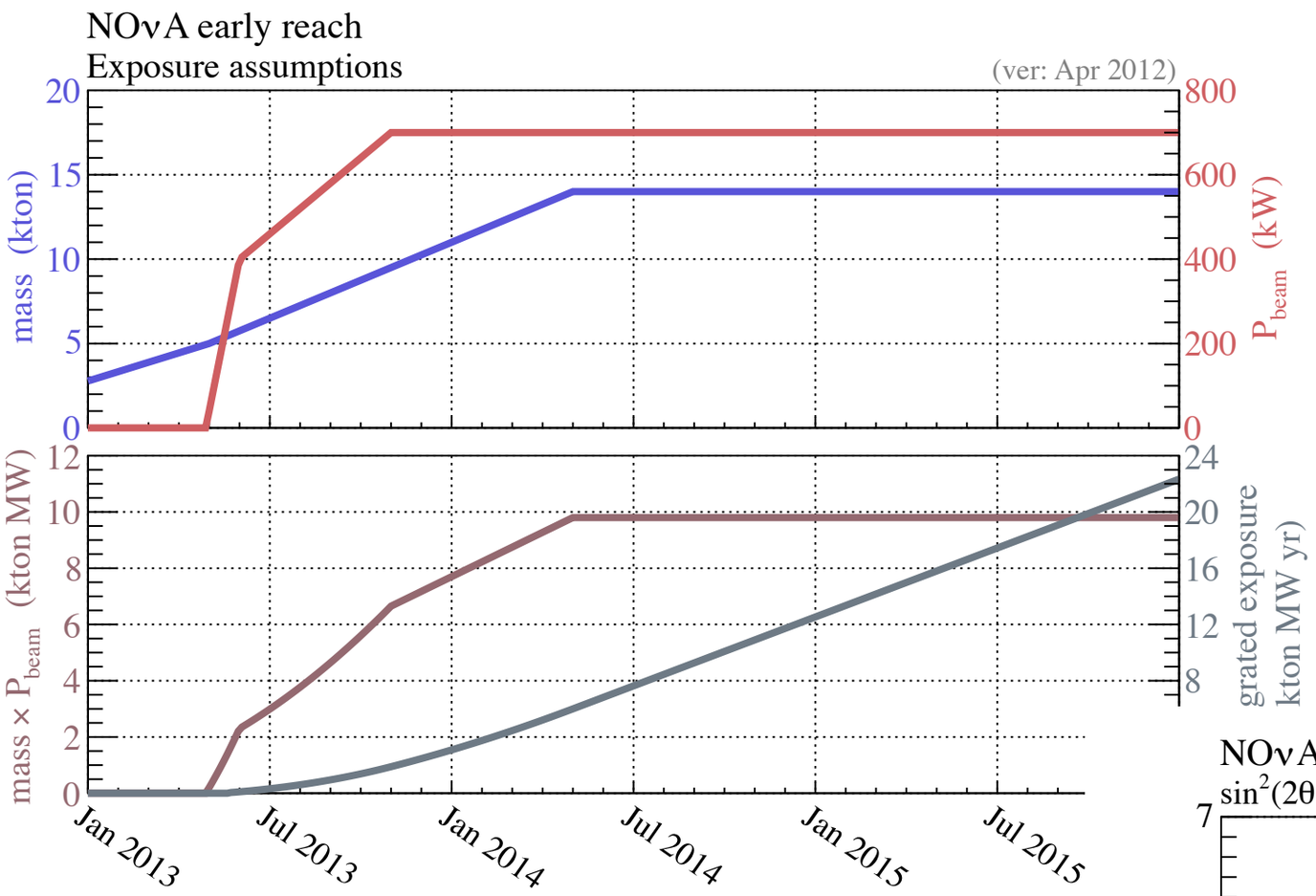
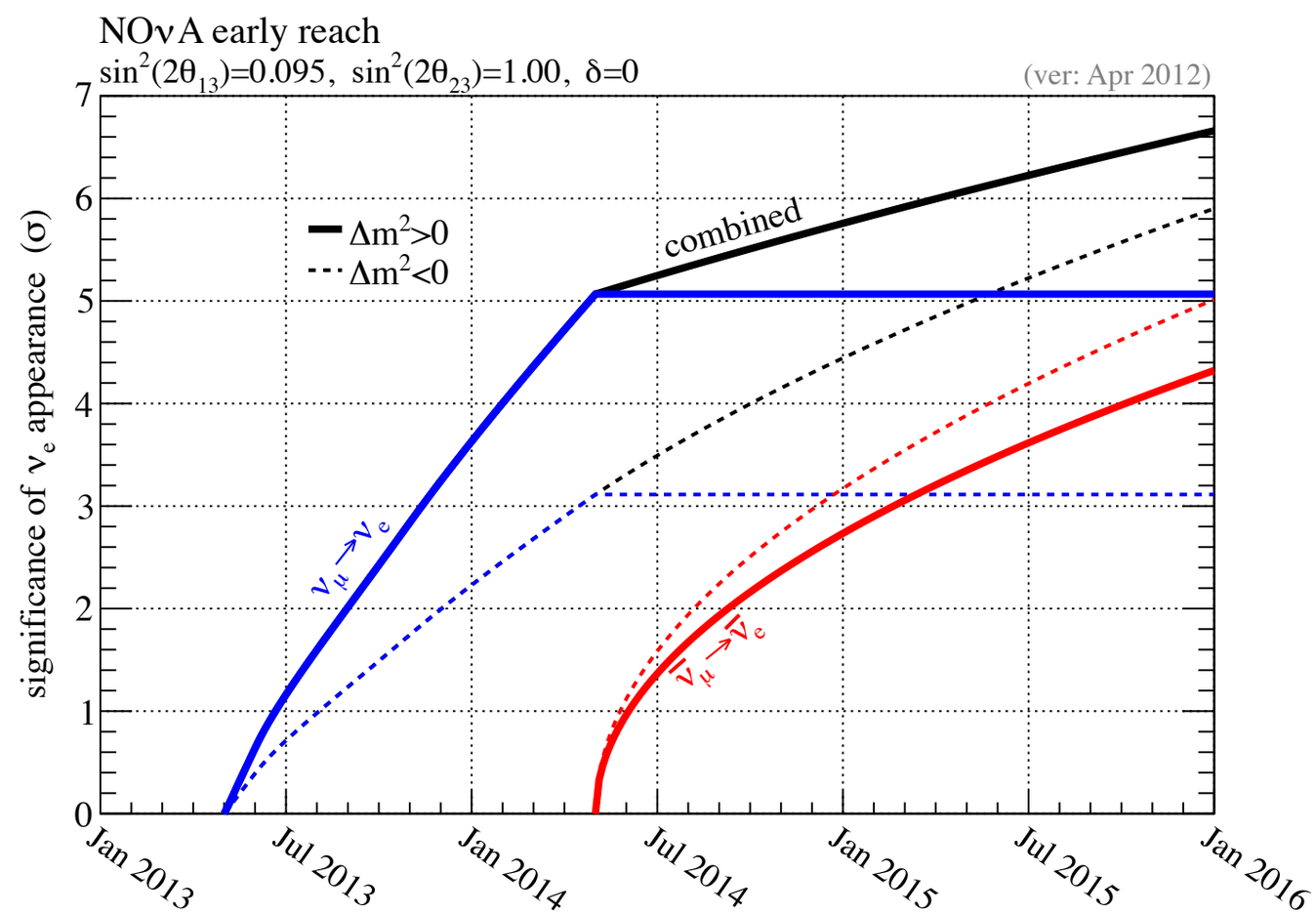


Timeline for Actual Data



- Accelerator upgrades are underway at FNAL.
- Construction of the Far Detector has begun.
- Preparations for the excavation of a new cavern for the Near Detector underway at FNAL.



- Expect to have 5 kton built by the time beam returns in Spring of 2013 and we will be able to collect data as we build.
- Far detector to be complete by April 2014.
- Near detector to be complete in 2013.

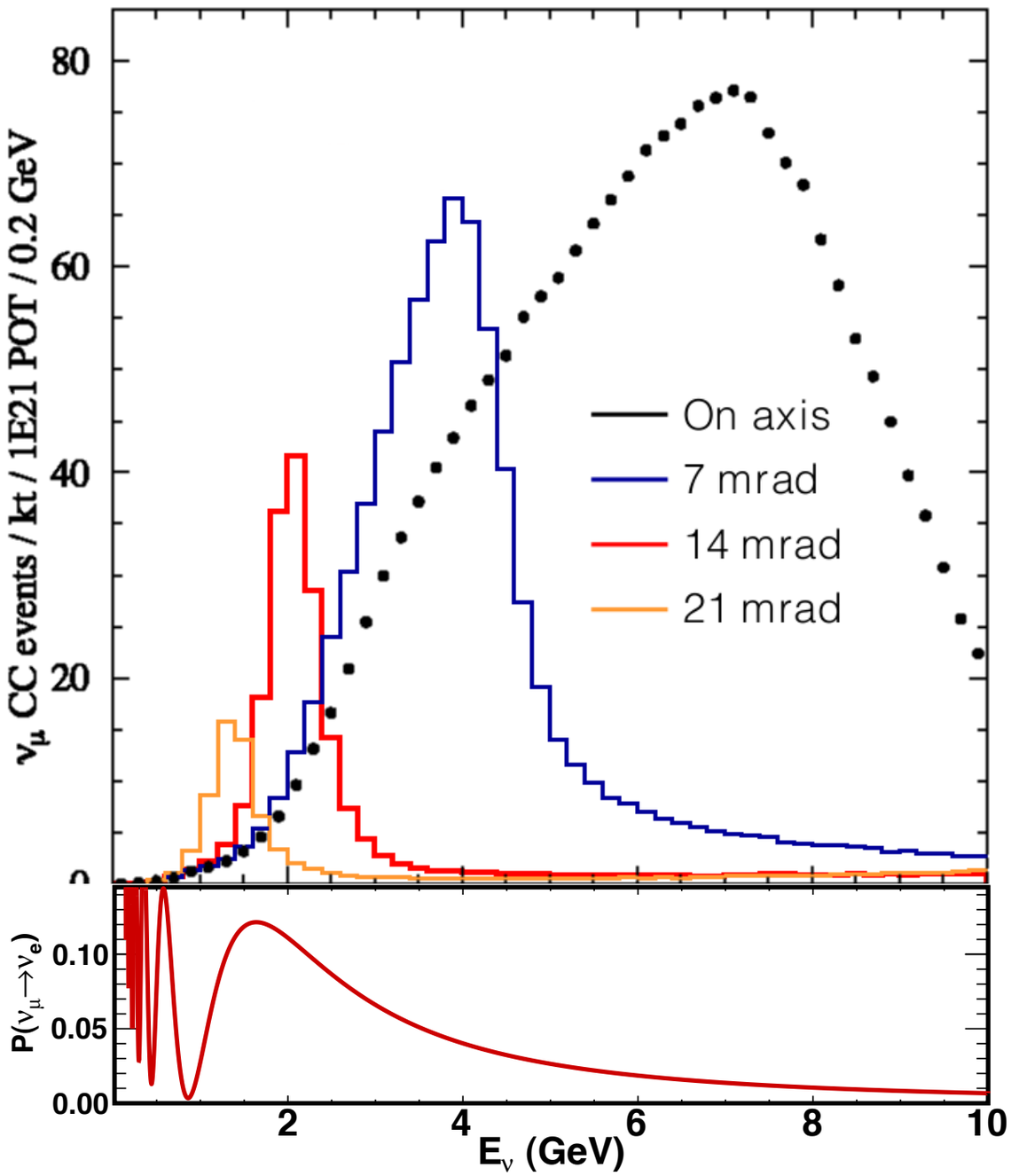
Summary

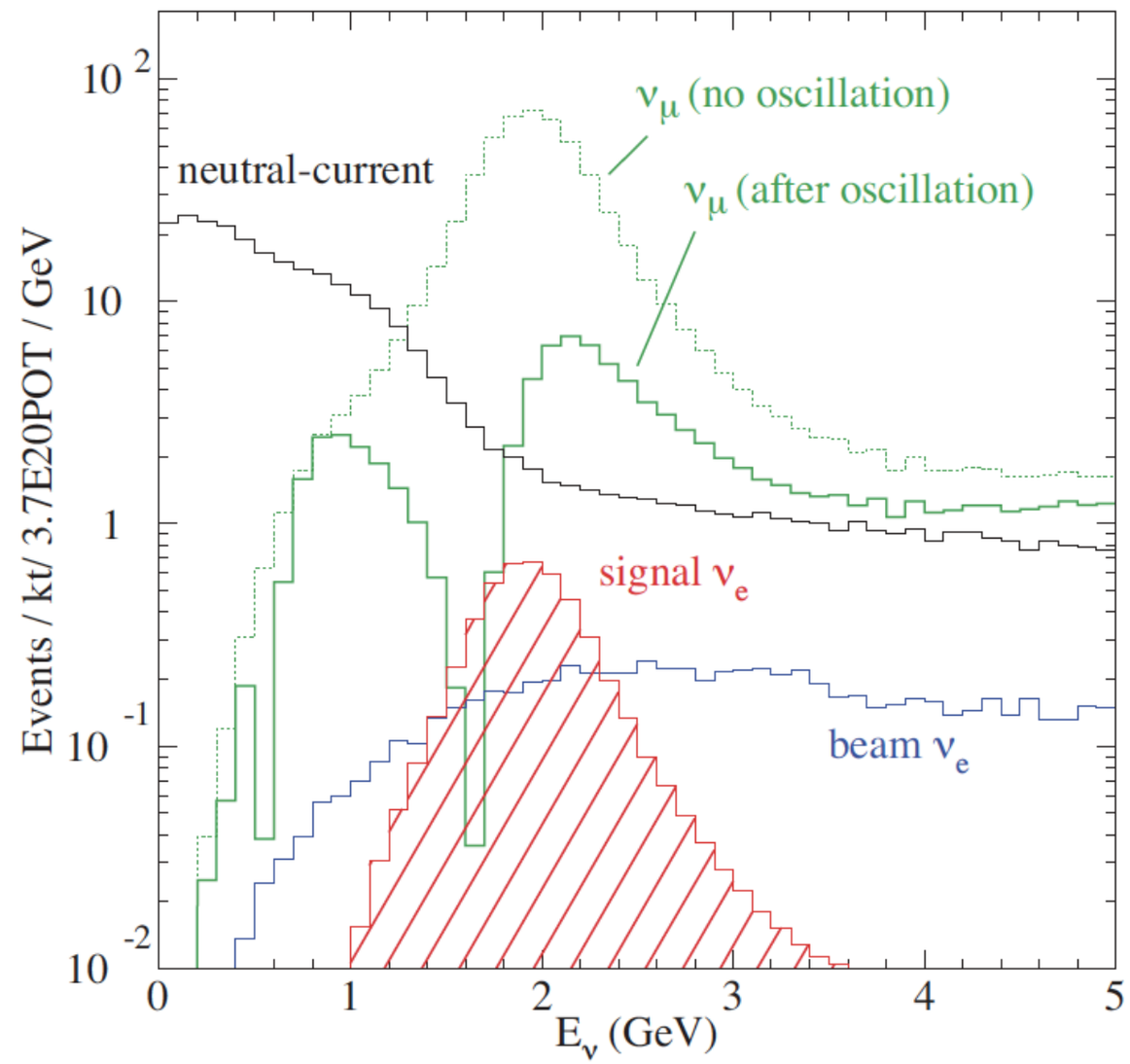
- NOvA will make many important contributions to neutrino physics:
  - Measurement of θ_{13}
  - Important first information on the neutrino mass hierarchy and CP violating phase
  - Determination of the θ_{23} octant
  - More precise measurements of Δm_{32}^2 and $\sin^2(2\theta_{23})$
- NOvA is under construction:
  - surface prototype detector is operational, taking data, and has taught us many lessons
  - first far detector blocks will be installed and collecting cosmic ray data this fall
  - 1/3 FD expected to be complete by the time beam returns, full detector operational a year later
  - early physics results possible as early as 2014
- Additional collaborators welcome!

OBRIGADO!

PERGUNTAS?

Why Go Off-Axis?

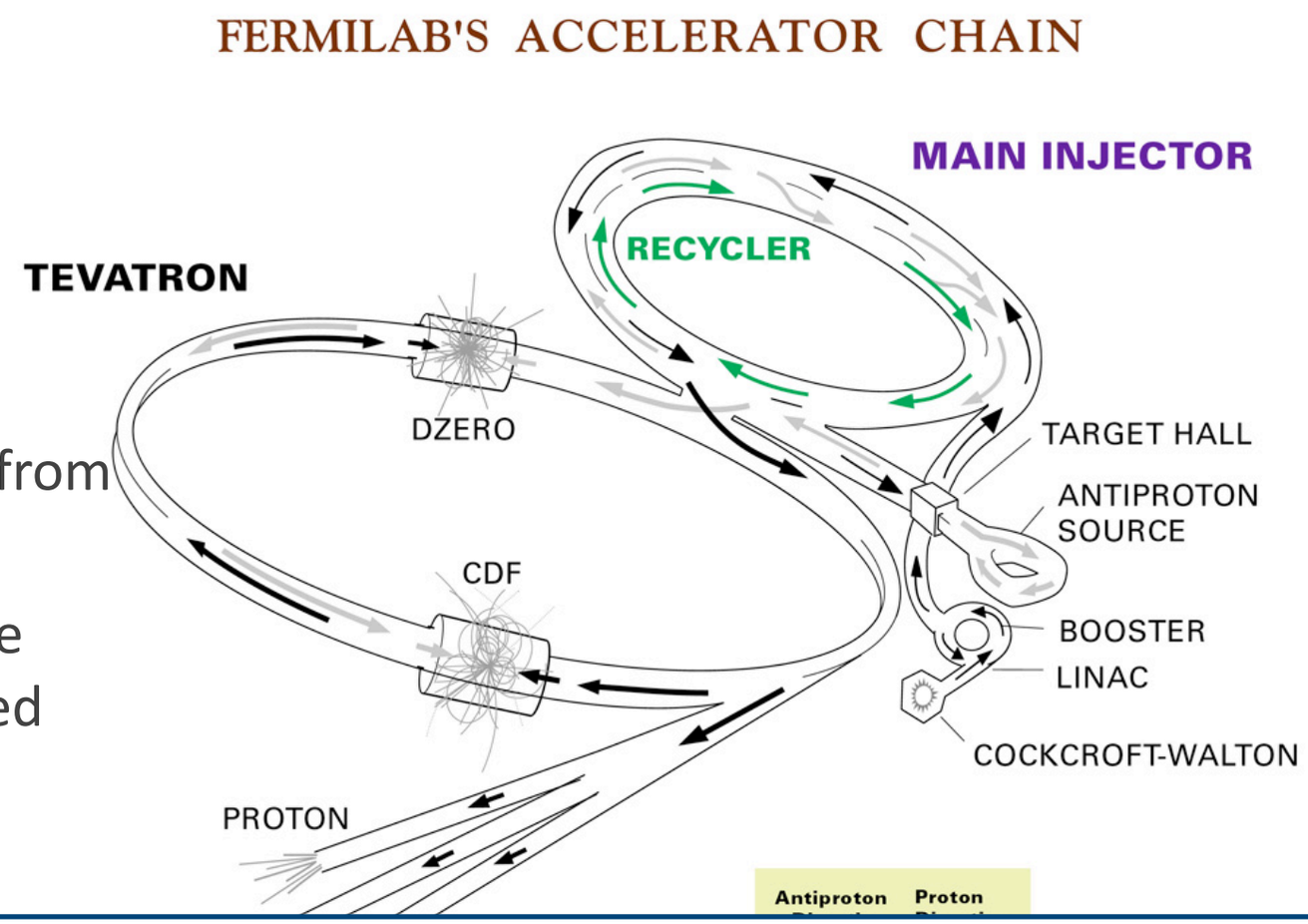


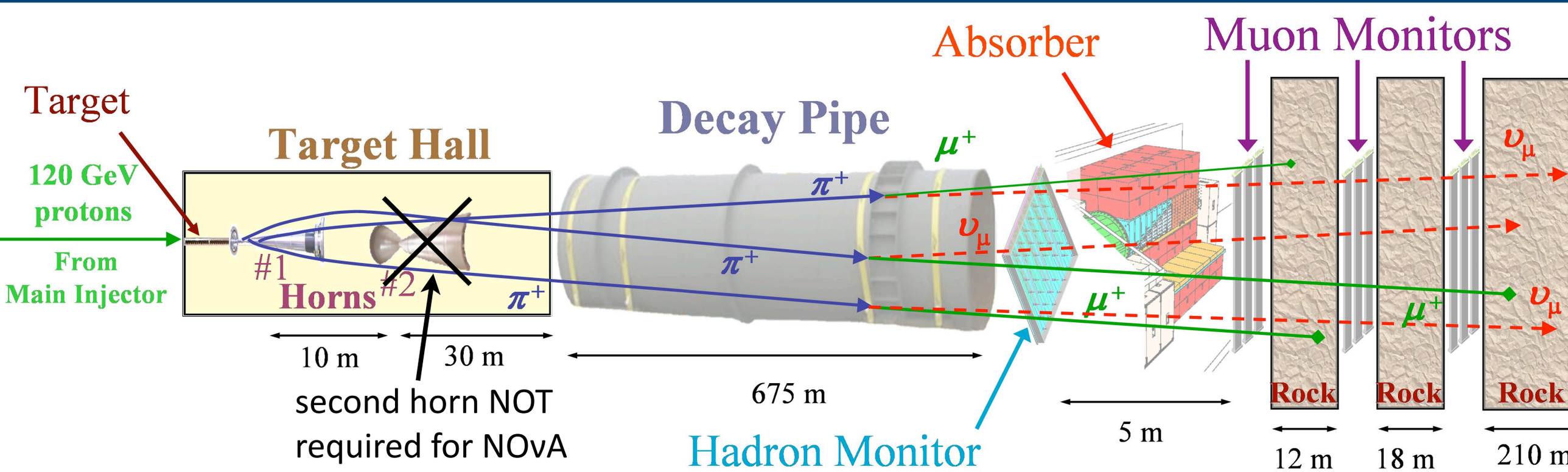


- Narrow-band beam, in conjunction with topology of final state particles, allows one to more easily reject potential backgrounds.

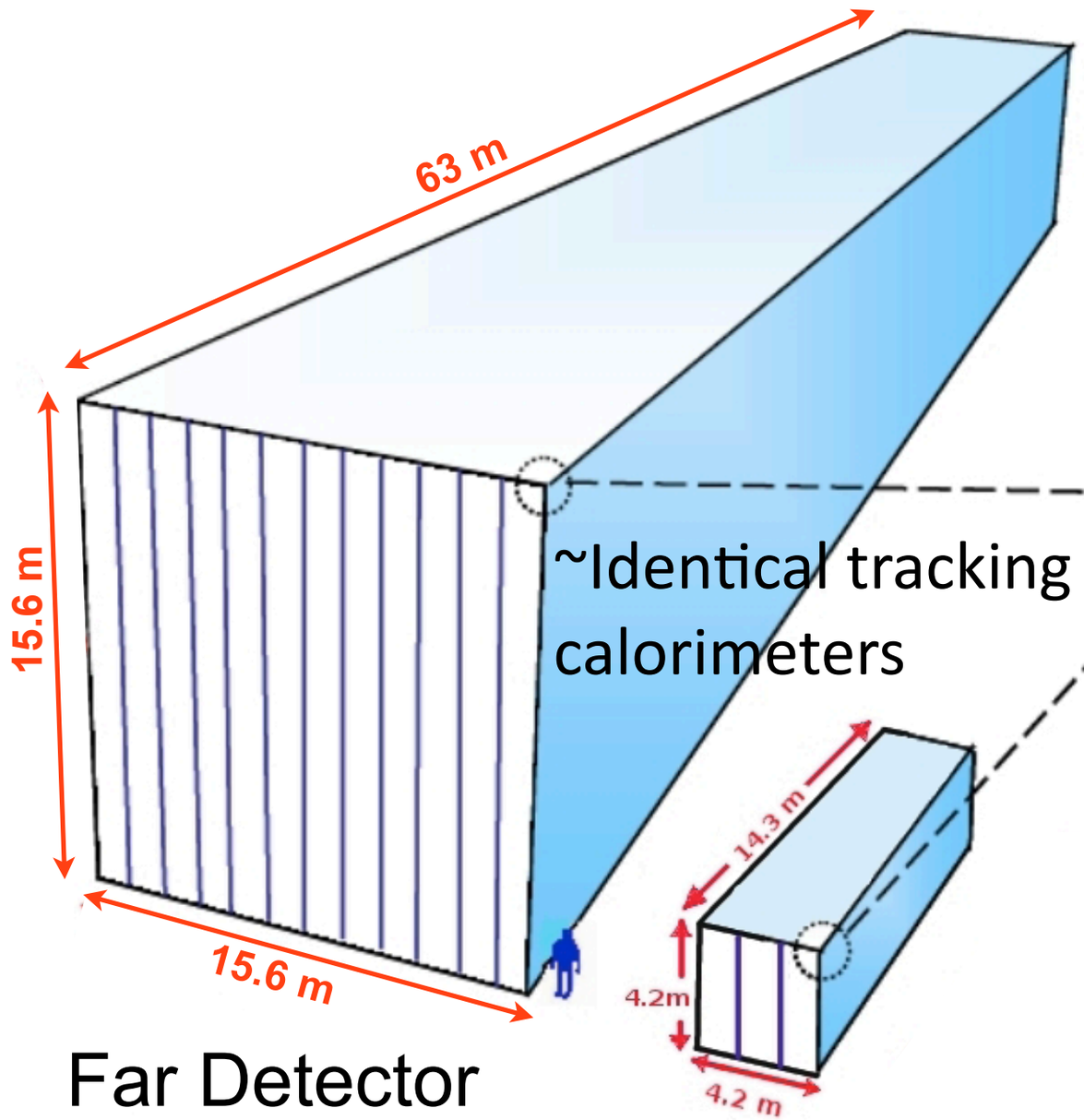
Accelerator Upgrades for NOvA (and beyond)

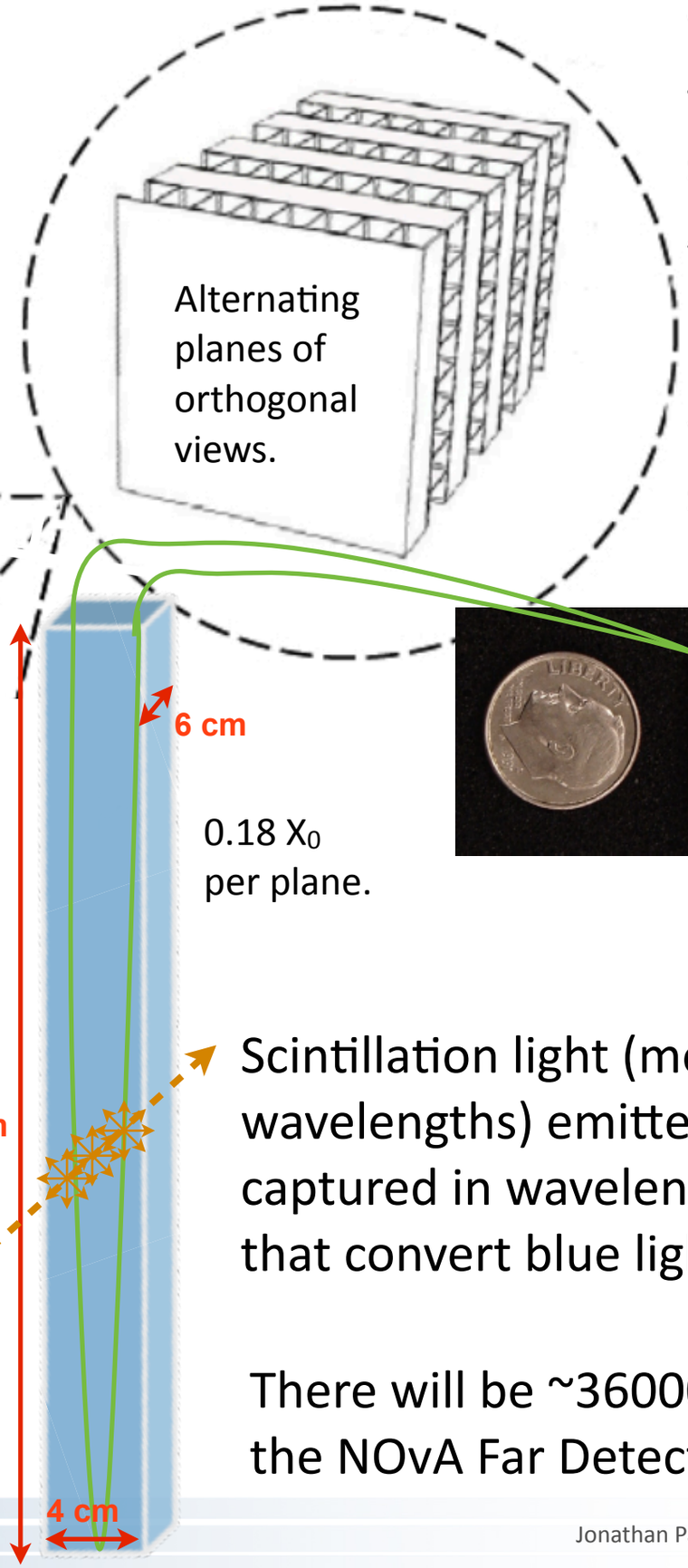
- Require upgrades to Fermilab's accelerator complex to go from 400 kW to 700 kW
- Mostly achieved by:
  - Use Recycler for "slip stacking" protons (instead of storing p-bars)
  - Reduce cycle time in the Main Injector from 2.2 s to 1.33 s
  - Upgrades to target station to handle the increased power and provide the desired neutrino energy beam



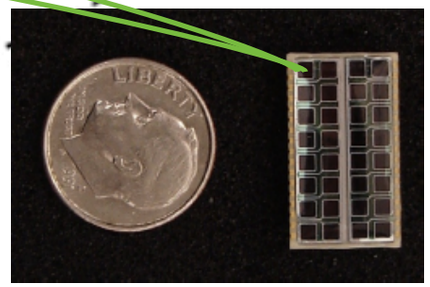


The NOvA Detectors





Wavelength-shifting fibers routed to a single cell on an Avalanche Photodiode (APD) made of materials with greatest sensitivity to green light.



0.18 X_0 per plane.

Scintillation light (mostly blue wavelengths) emitted isotropically and captured in wavelength shifting fibers that convert blue light to green.

There will be ~360000 channels in the NOvA Far Detector!

Tracking calorimeter:

- ~70% active
- muon energy resolution (range): few %
- Moliere radius is ~2.5 cell widths
- EM shower max at ~5 X_0