# Recent NOvA Experiment Results

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For the NOvA Collaboration

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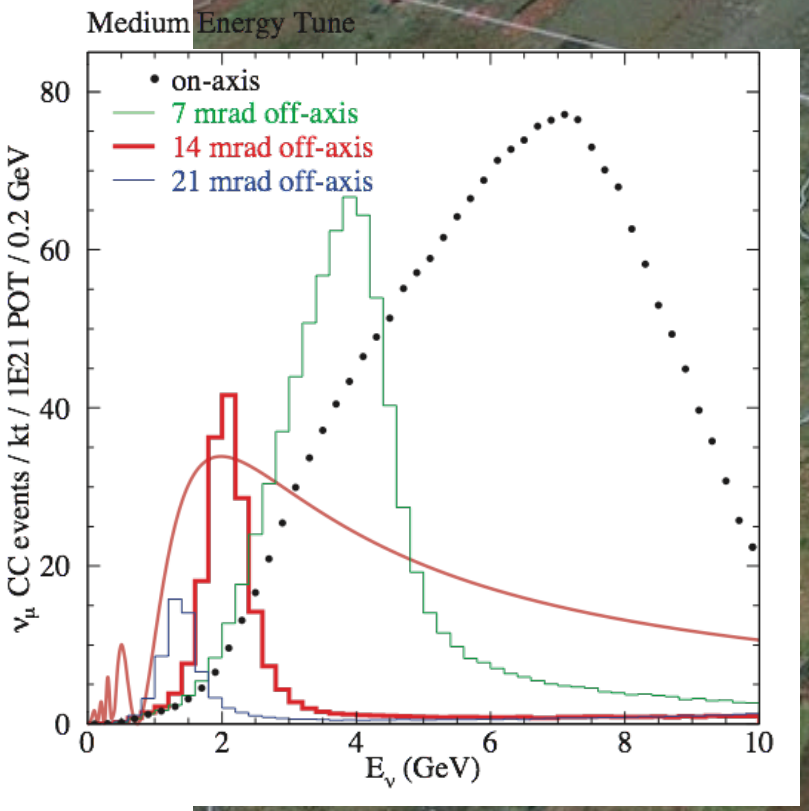
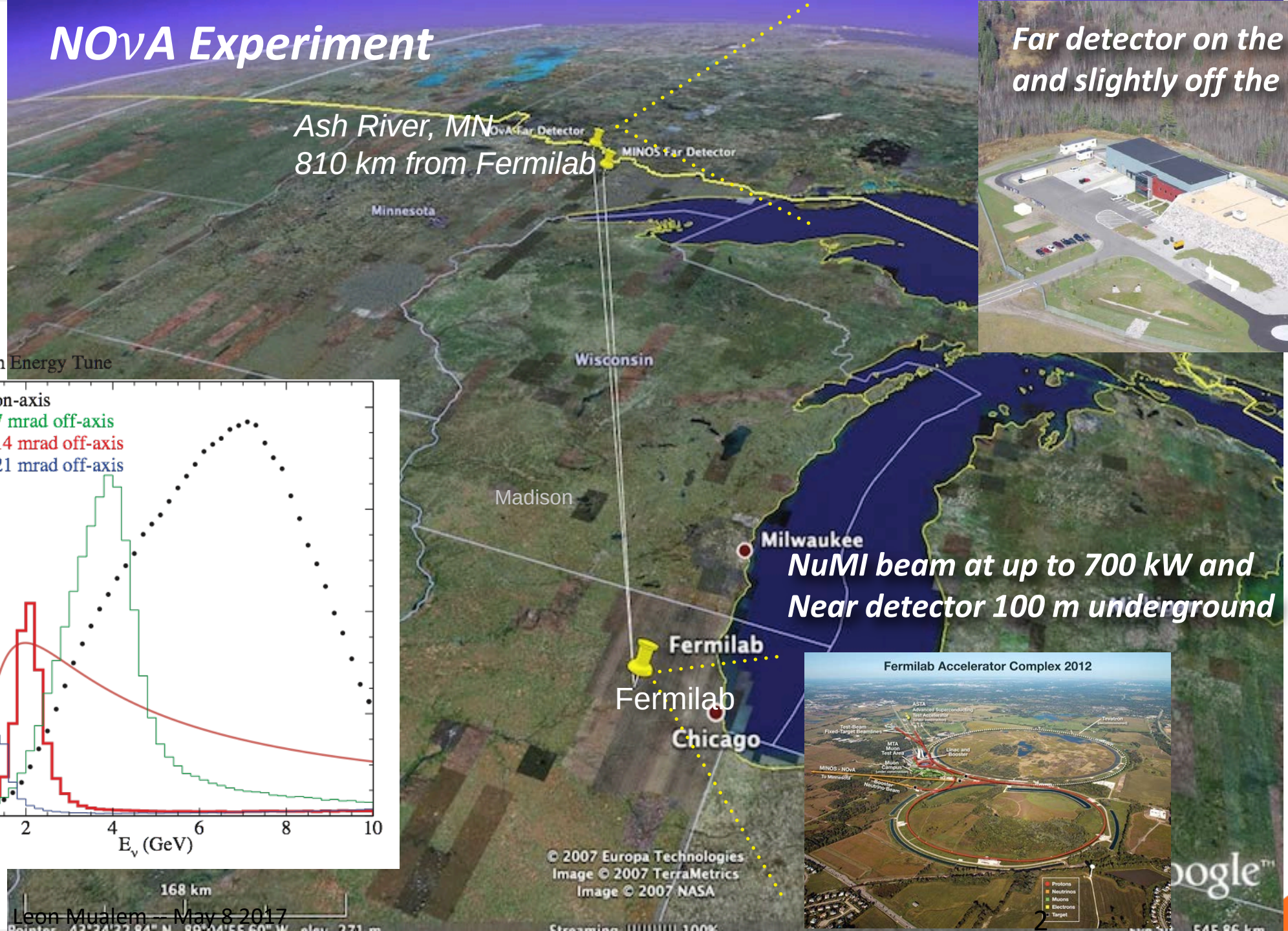
# NOνA Experiment

Ash River, MN
810 km from Fermilab

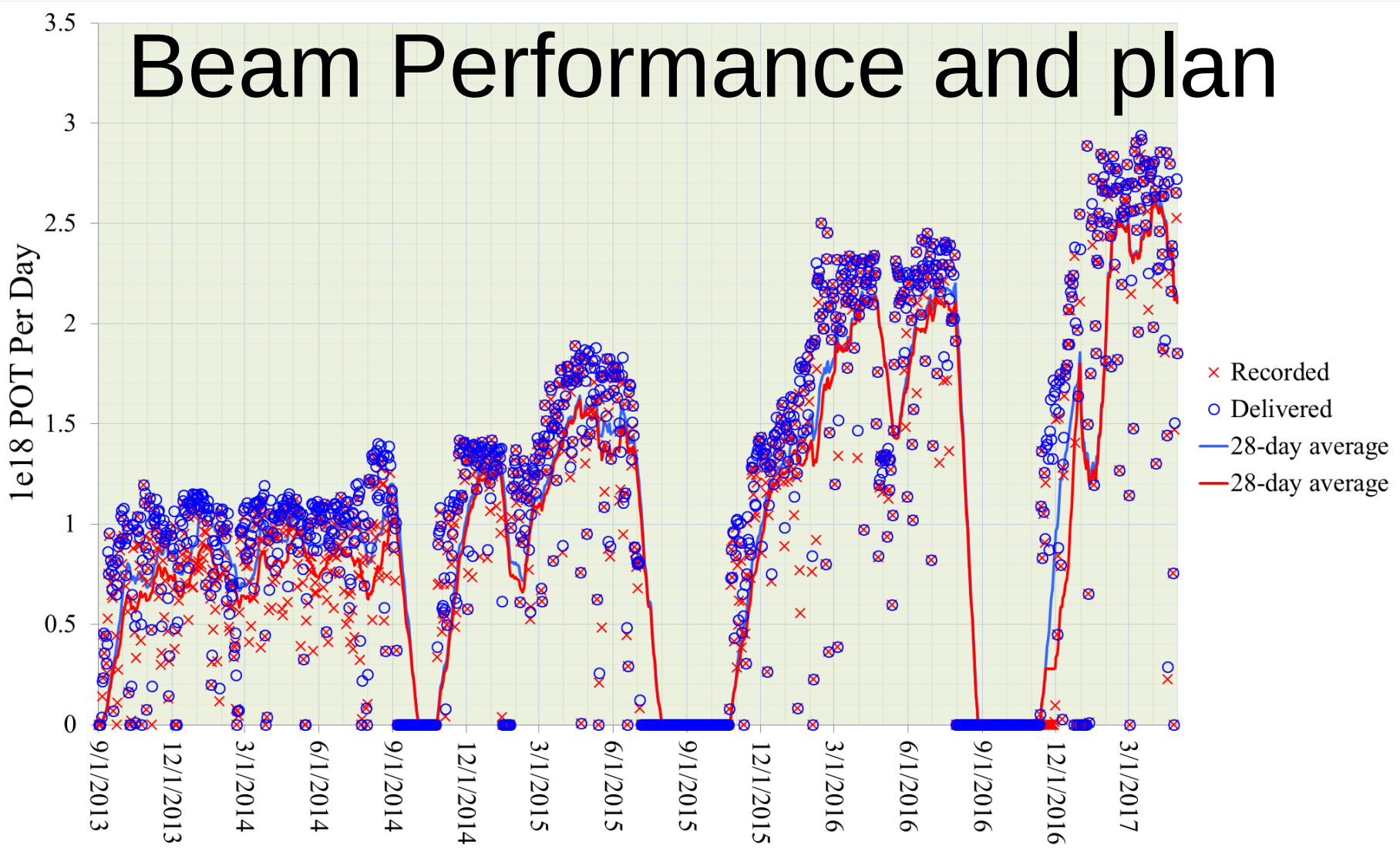




NuMI beam at up to 700 kW and
Near detector 100 m underground

# Beam Performance and plan

- 700kW running achieved routinely in FY17
- Antineutrino running
  - ~July 2016 for tuning
  - Feb 20, 2017 until ~summer shutdown planned for 6/24/2017



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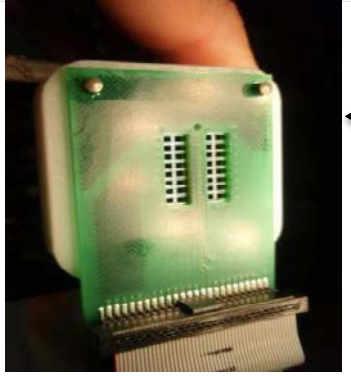
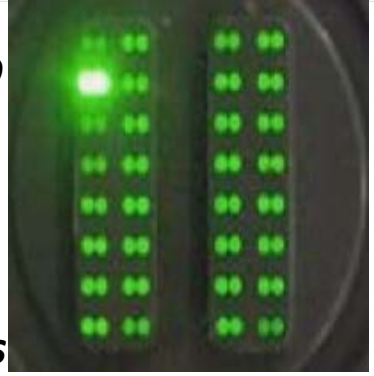
# NO$\nu$A Detectors:

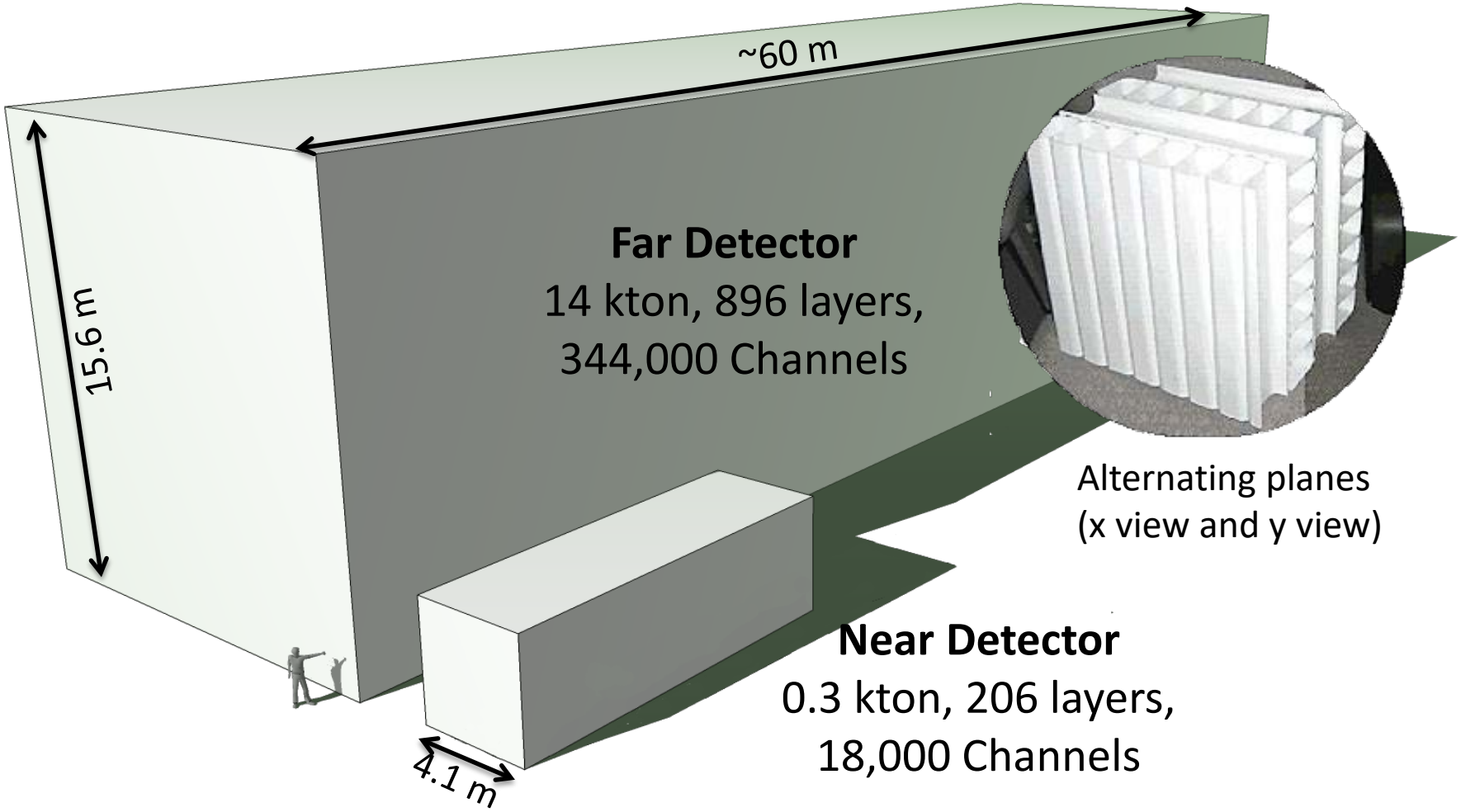
- Fine-grained, low-*Z*, highly-active tracking calorimeters
- 11 M liters of scintillator
- $\lambda$-shifting fiber and APDs



***32-pixel APD***



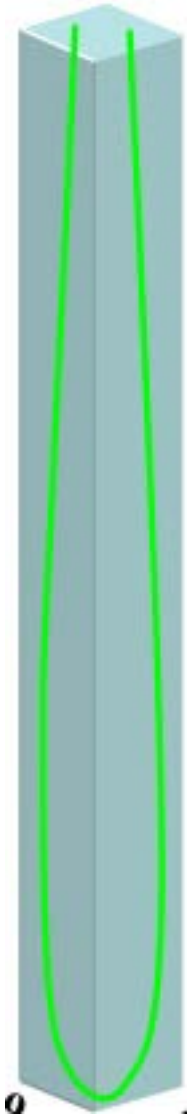
***Fiber pairs from 32 cells***




**Far Detector**
14 kton, 896 layers,
344,000 Channels

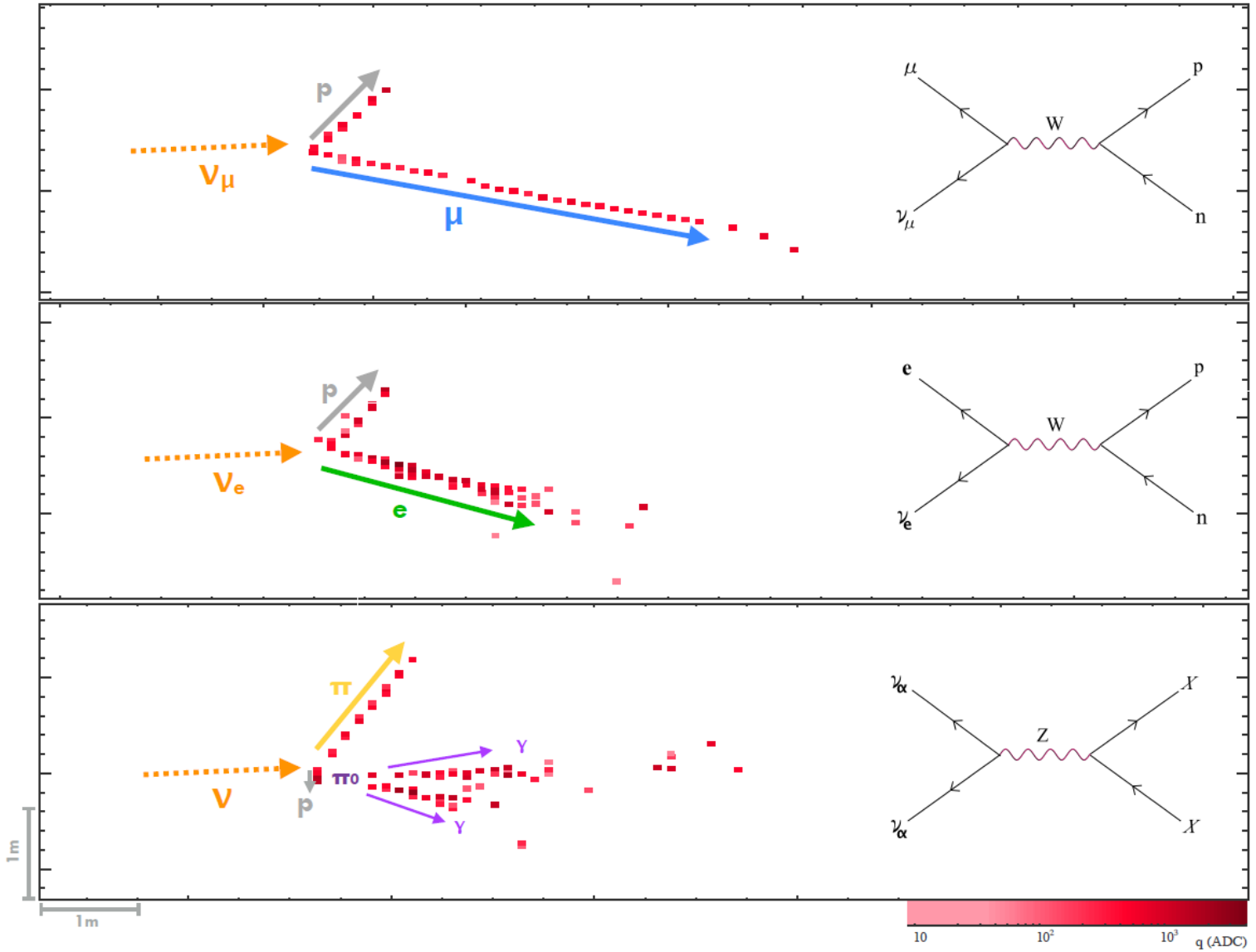
Alternating planes
(x view and y view)

**Near Detector**
0.3 kton, 206 layers,
18,000 Channels



# Event Topologies

- Muon Neutrino Charged Current
- Electron Neutrino Charged Current
- Neutrino Neutral Current



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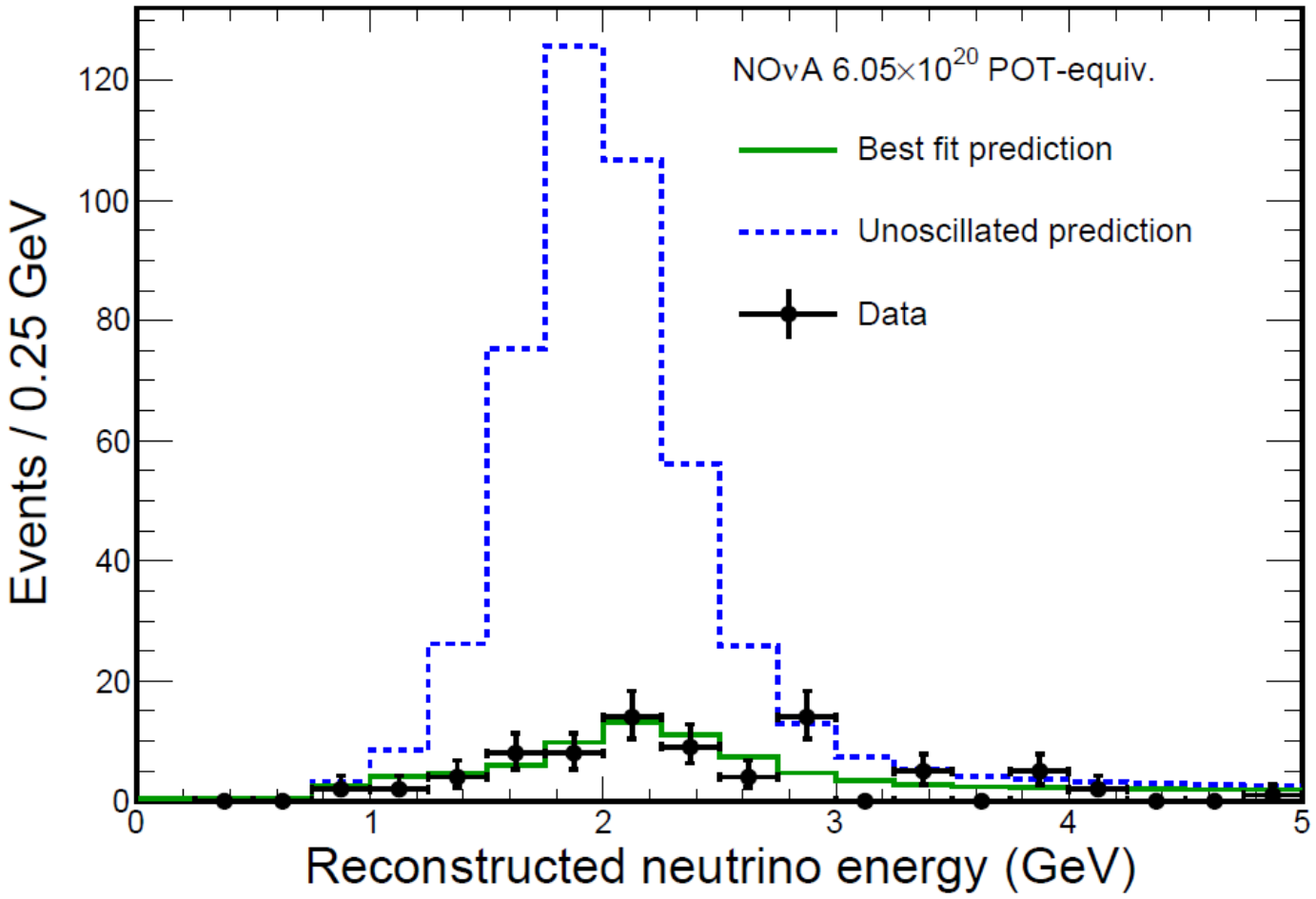
# Muon Neutrino Disappearance

- Spectrum predicted in absence of oscillations has 473 events
- Observed spectrum has 78 events



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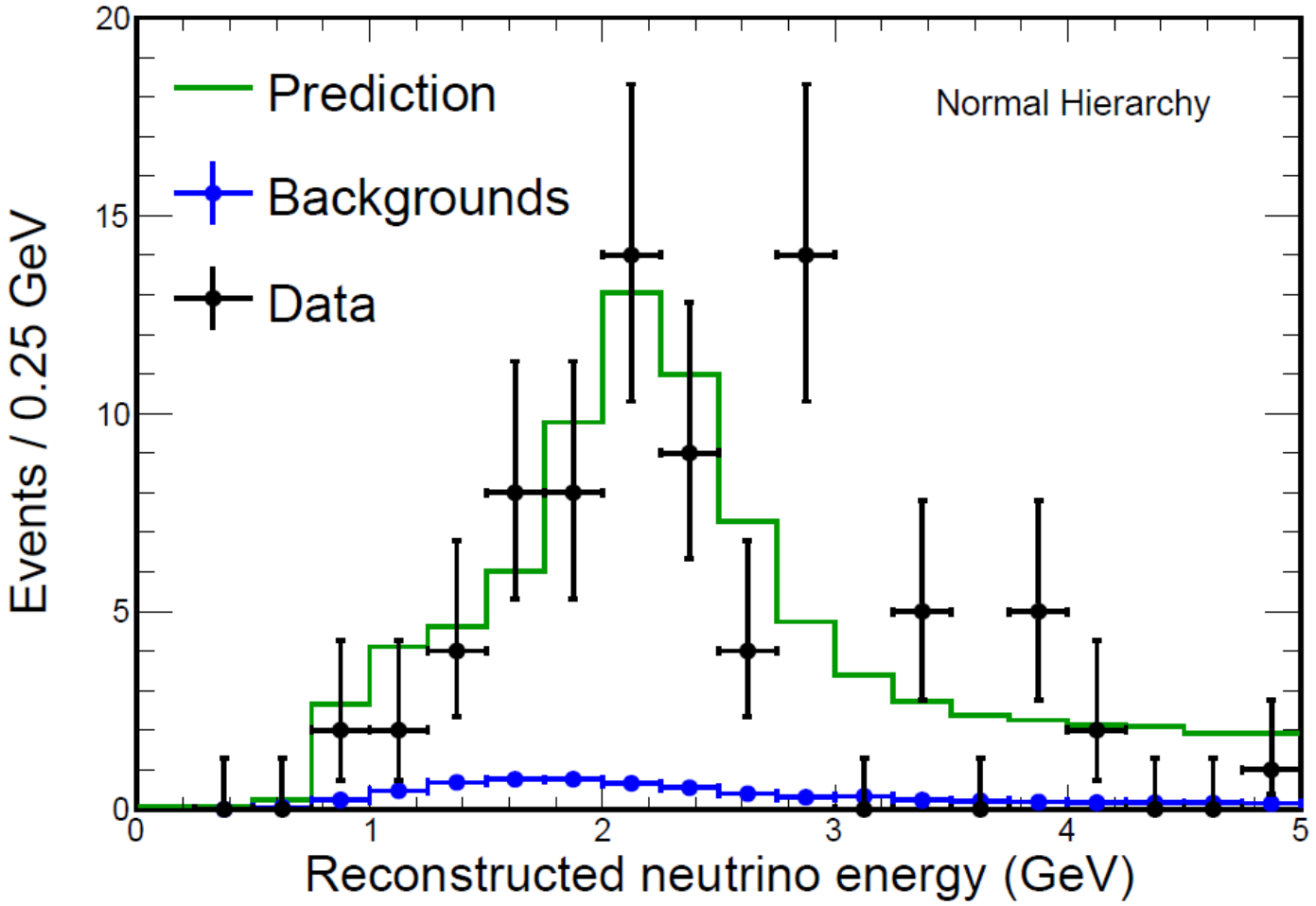
# Muon Neutrino Disappearance

- Energy spectrum of 78 selected events
- Small background determined by extrapolation from near detector data



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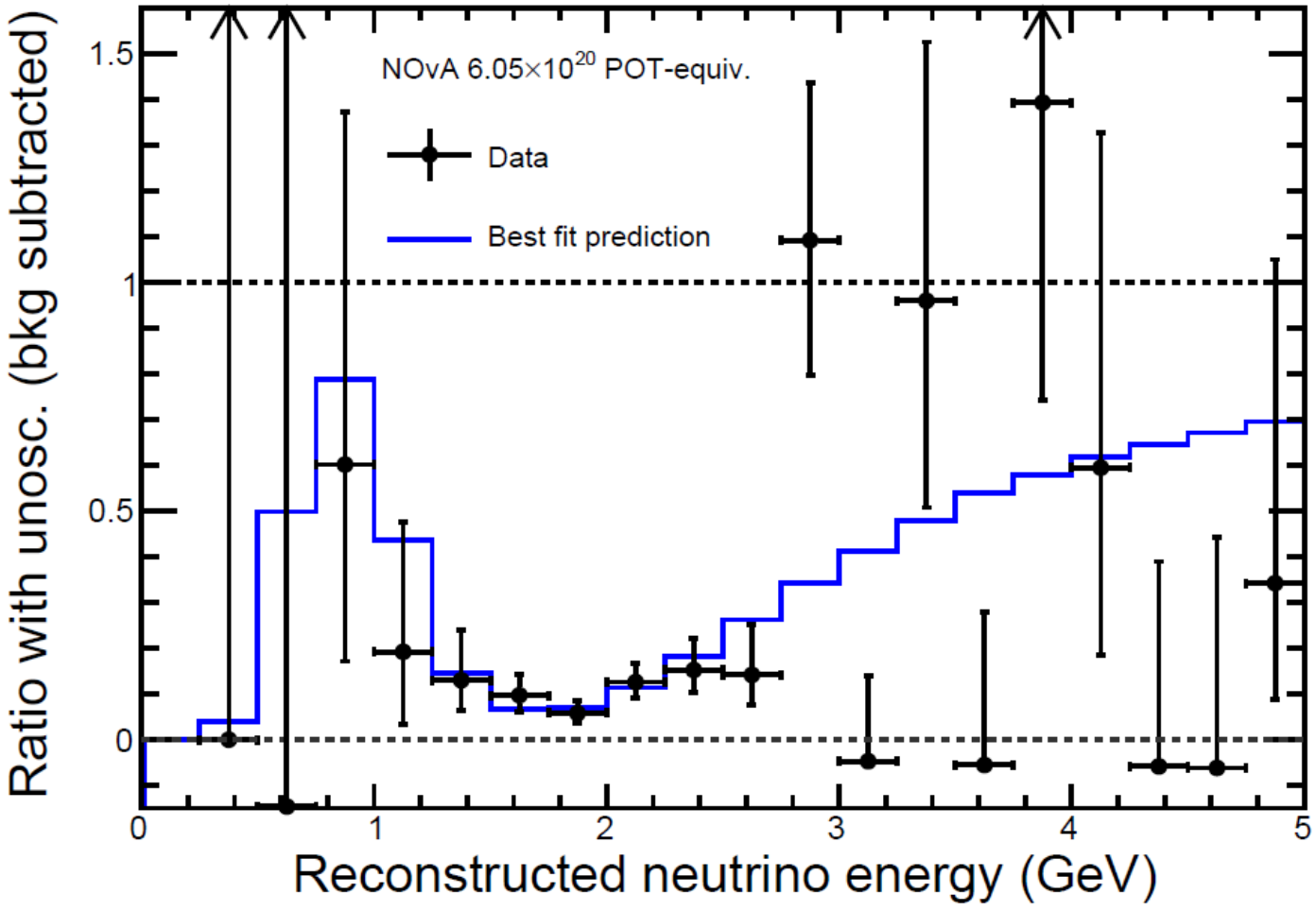
# Muon Neutrino Disappearance

- Background subtracted ratio to unoscillated prediction



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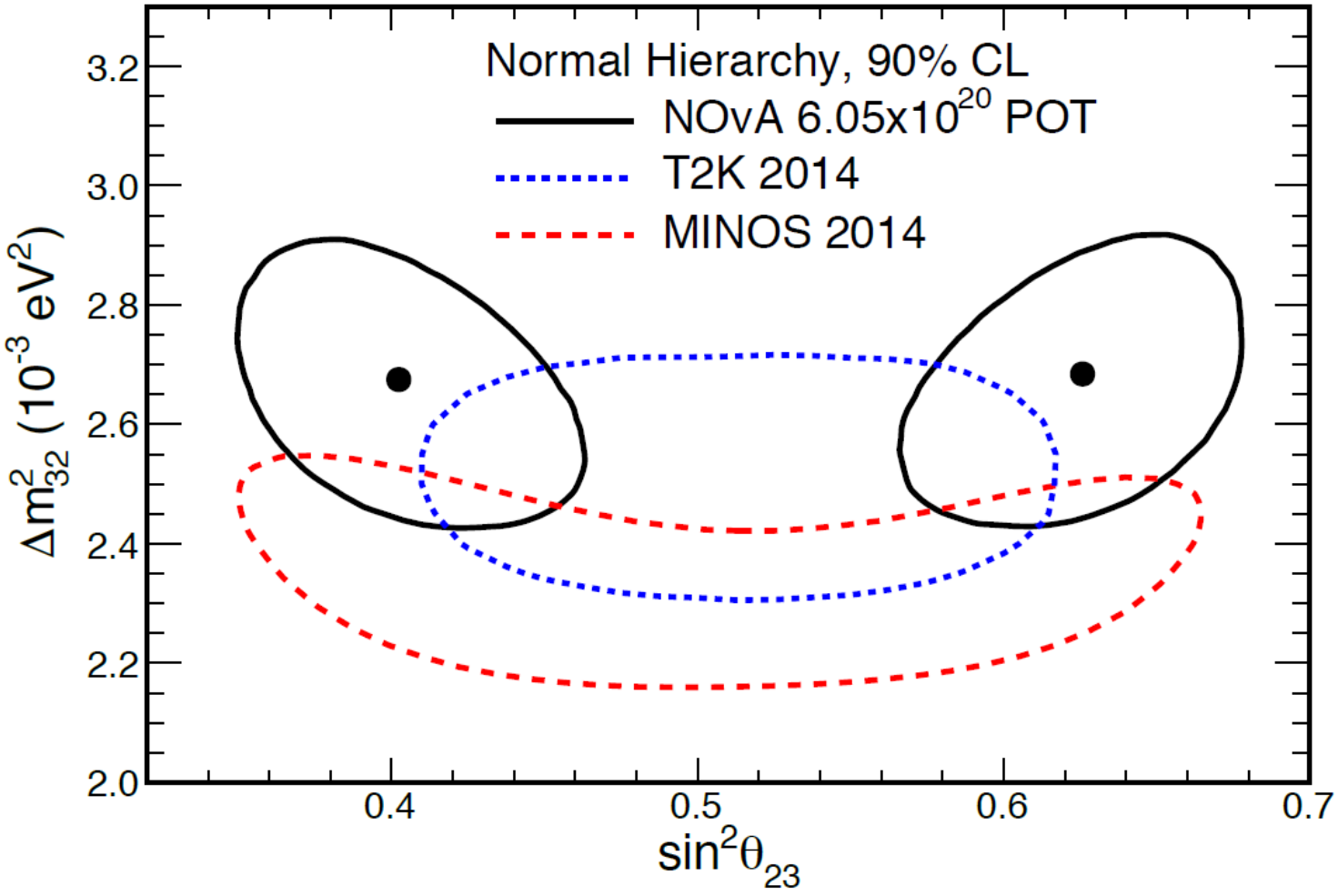
# Mixing parameter measurements

- Measurements:
- $\Delta m^2_{32} = 2.67 \pm 0.11$
- $sin^2\theta_{23} = 0.404^{+0.030}_{-0.022}(0.63^{+0.022}_{-0.030})$
- Excludes maximal mixing at 2.6σ



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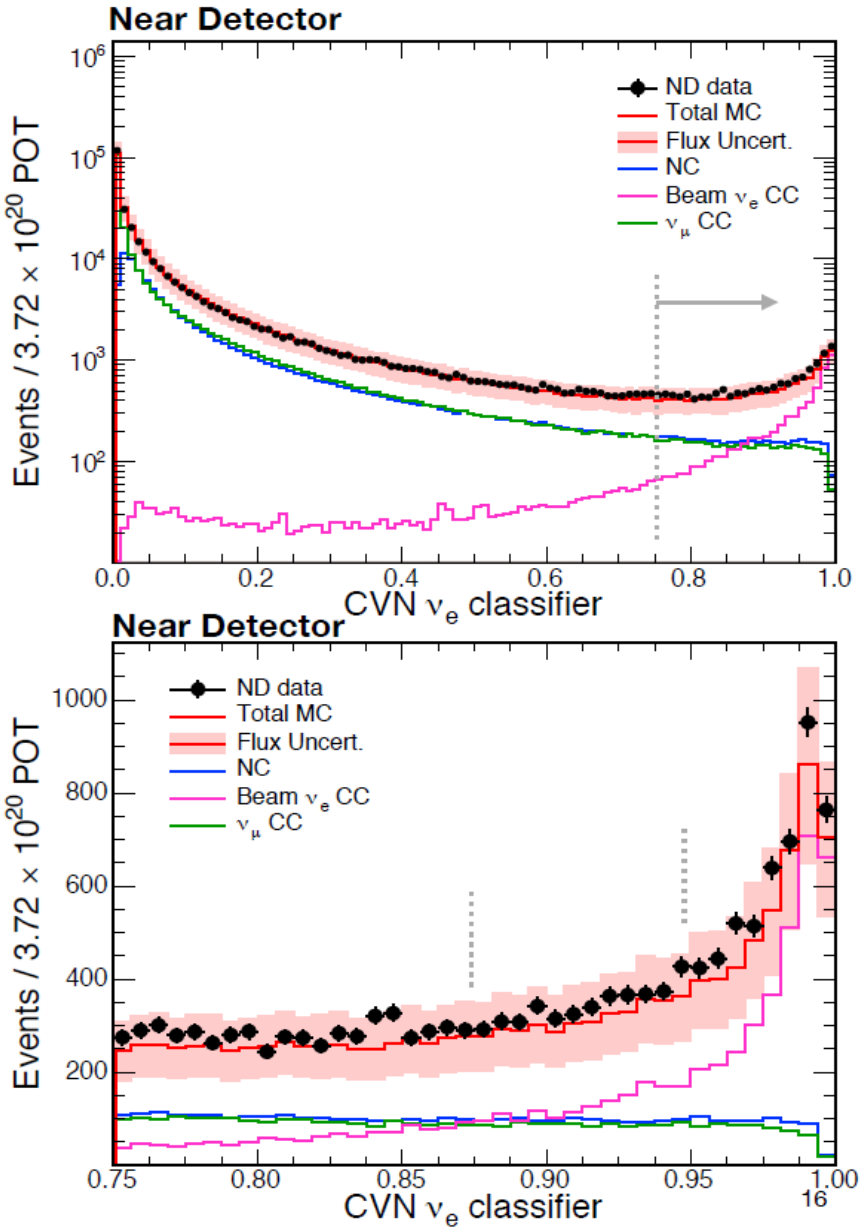
# Newly developed CVN classifier for electron neutrino events

- Machine learning technique used to select electron neutrino events and predict background
- Deeper description
  - A. Aurisano and A. Radovic and D. Rocco et al. JINST **11** P09001 (2016)
- Results arXiv:1703.03328v1

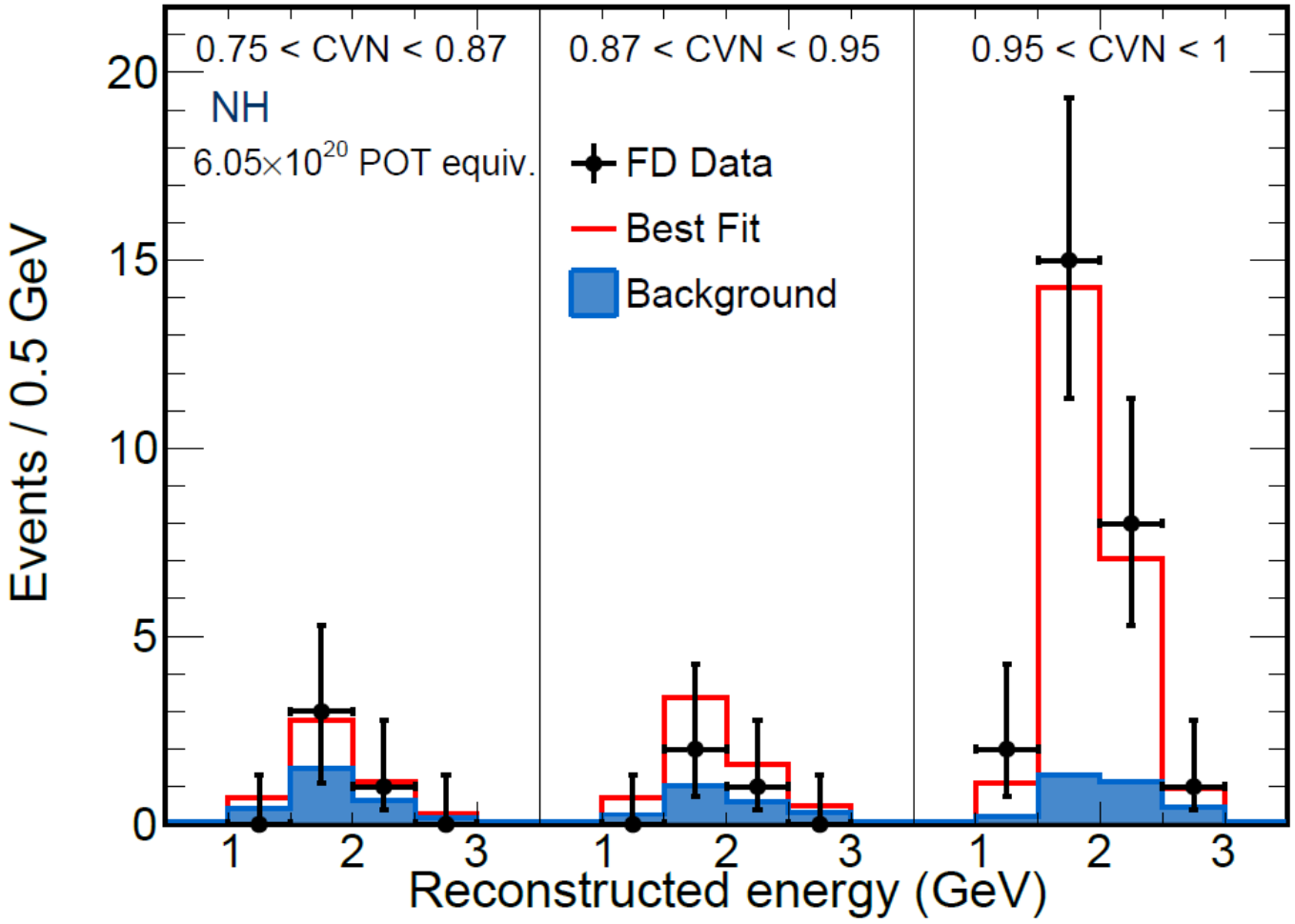
# CVN Classifier

- Use CVN classifier with near detector data to measure and extrapolate backgrounds expected at the far detector.
- Also use to predict oscillated electron neutrino signal
- Increases sensitivity compared to previous selection techniques



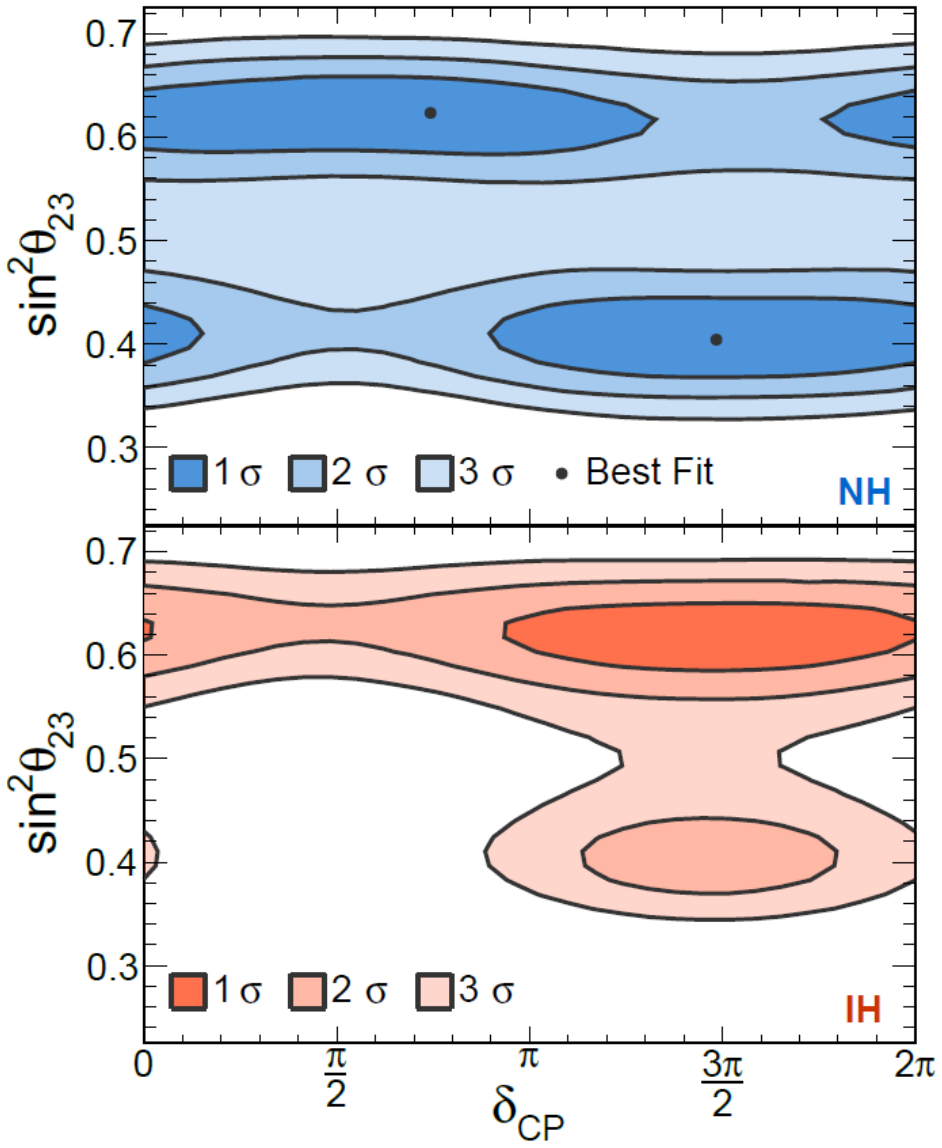
# Electron Neutrino Appearance

- New Results using CVN technique found 33 events in 6.05E20 Protons on Target in the NuMI beamline
- Background of 8.2+-0.8



# Combined fit results

- Combined fit with muon disappearance measurements disfavoring inverted mass ordering



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# Conclusions

- Detectors are running well
- Data taking very efficient, 99%+ typical beam weeks
- Beam running well, hitting new records
  - Routinely over 700kW to NOvA
- New results have been interesting
- Anti-Neutrino data coming in now until the Summer Shutdown
  - Ready for this after 1 month of Anti-Neutrino running in FY16
- Additional analyses and improvements are actively being developed for the interesting times ahead

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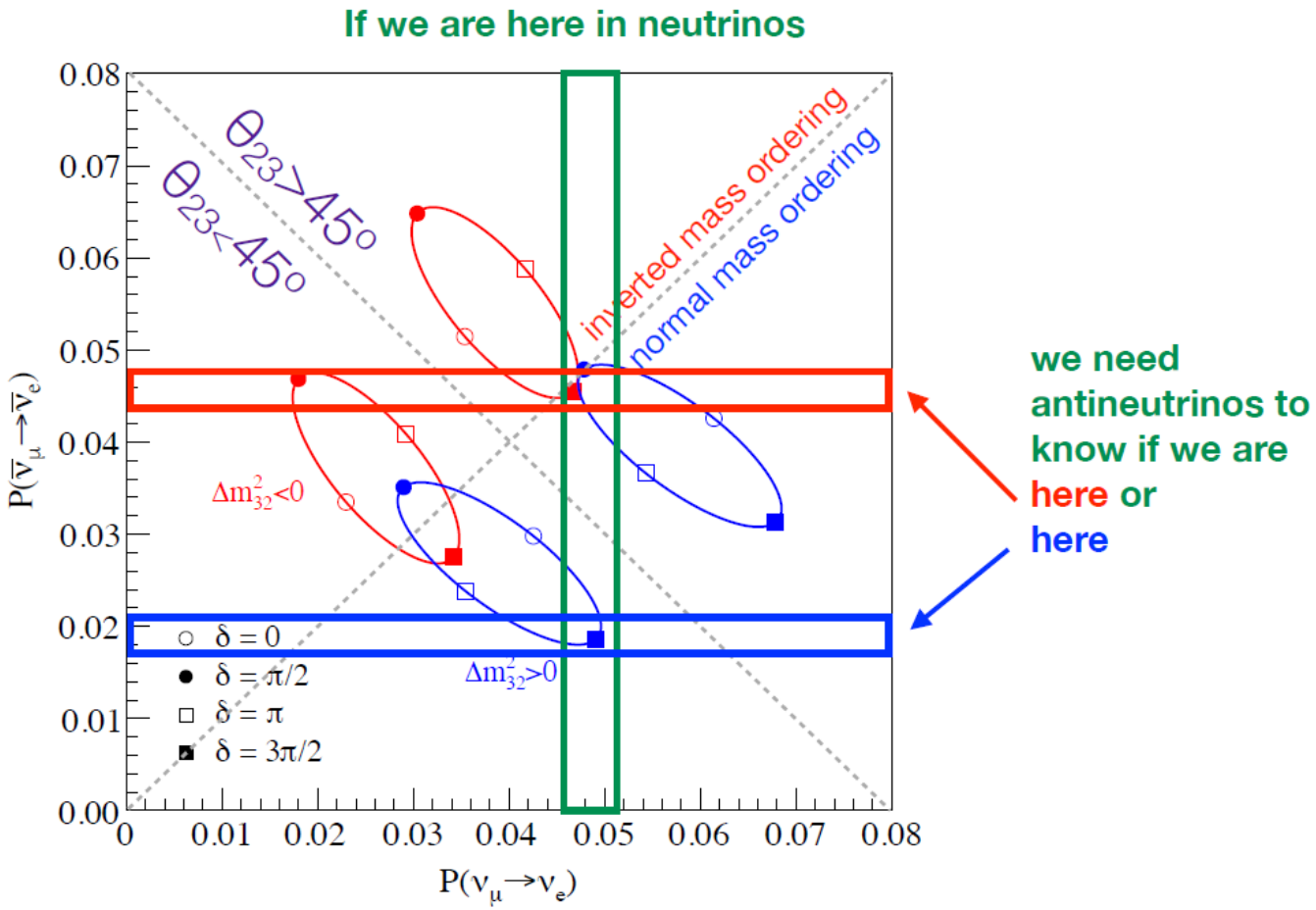
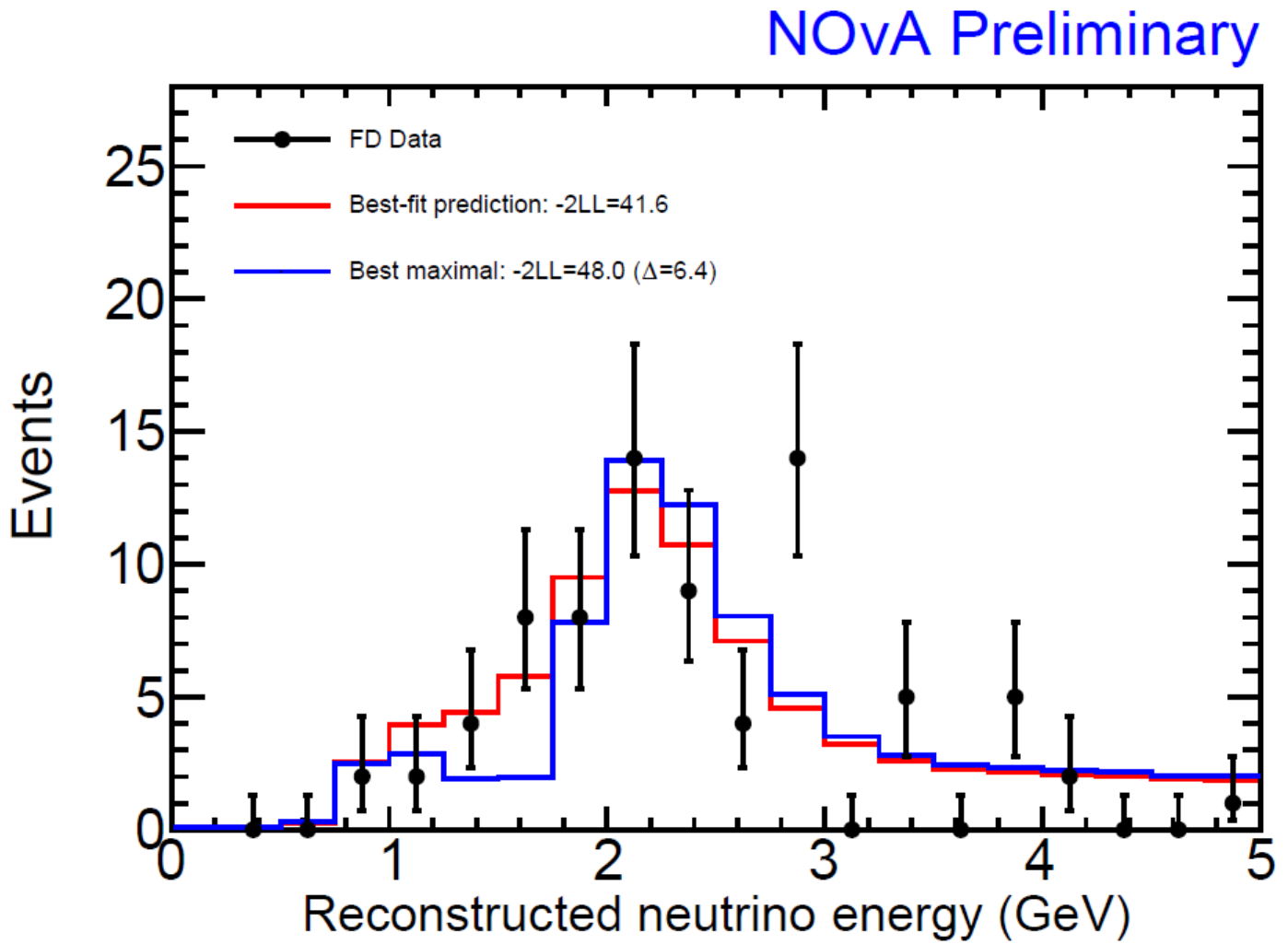
## Need for antineutrinos:

**If we are in lower octant, normal hierarchy, antineutrinos are required.**



# Backup: Max mixing comparison



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