Event selection for the NOvA 3 flavor analysis

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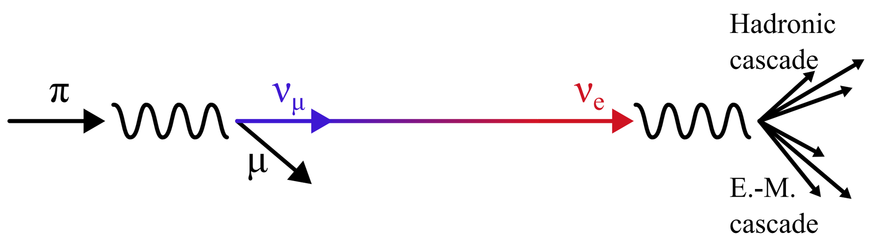
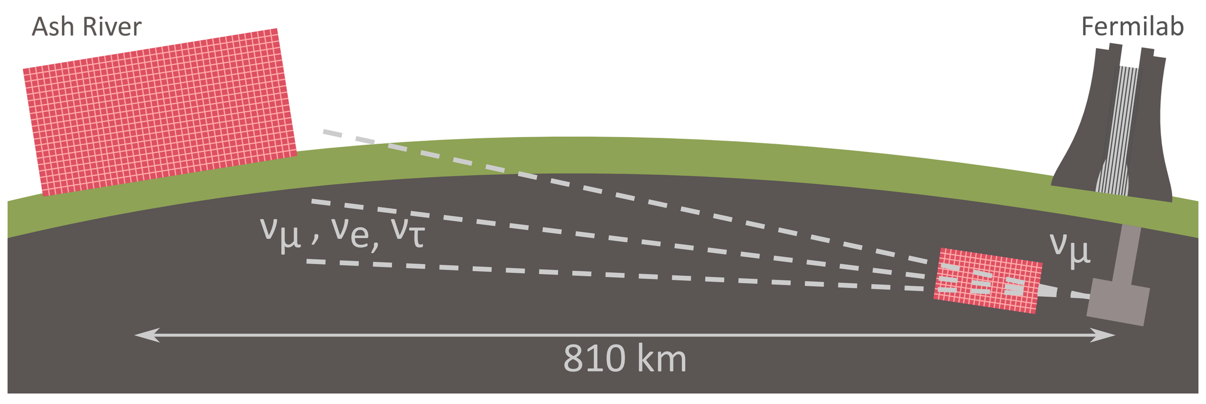
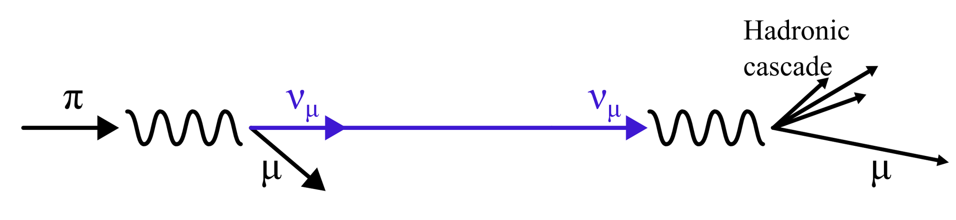
The NOvA experiment

- NOvA is a long-baseline off-axis neutrino oscillation experiment in US. Neutrino source is Fermilab's Megawatt-capable NuMI beam.
- Two functionally identical, finely granulated detectors, filled with liquid scintillator. Near detector is 297 t, Far Detector is 14 kt.
- 10 years of data collecting: 26.6 × 10^{20} proton on target (POT) with neutrino beam, 12.5 × 10^{20} POT with antineutrino beam.



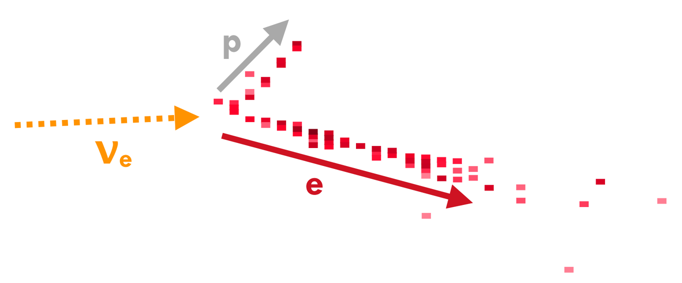
ν_e appearance
CP-violation, neutrino mass ordering, θ_{23} octant, mixing angle θ_{13}





ν_μ disappearance
mass splitting Δm^2_{32}, mixing angle θ_{23}

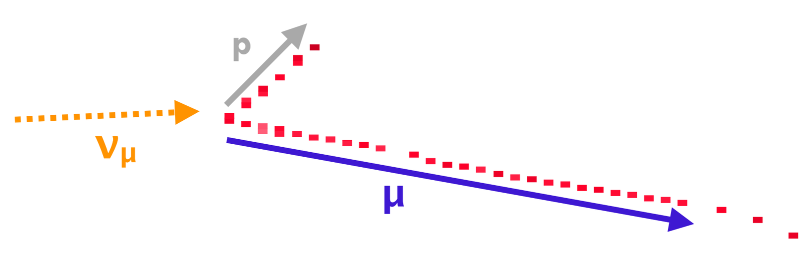
ν_e event selection



Electron neutrino signal events consist of electromagnetic and hadronic showers.

Main background channels: beam ν_e CC, NC, ν_μ CC, wrong sign ν_e CC, cosmic.

ν_μ event selection

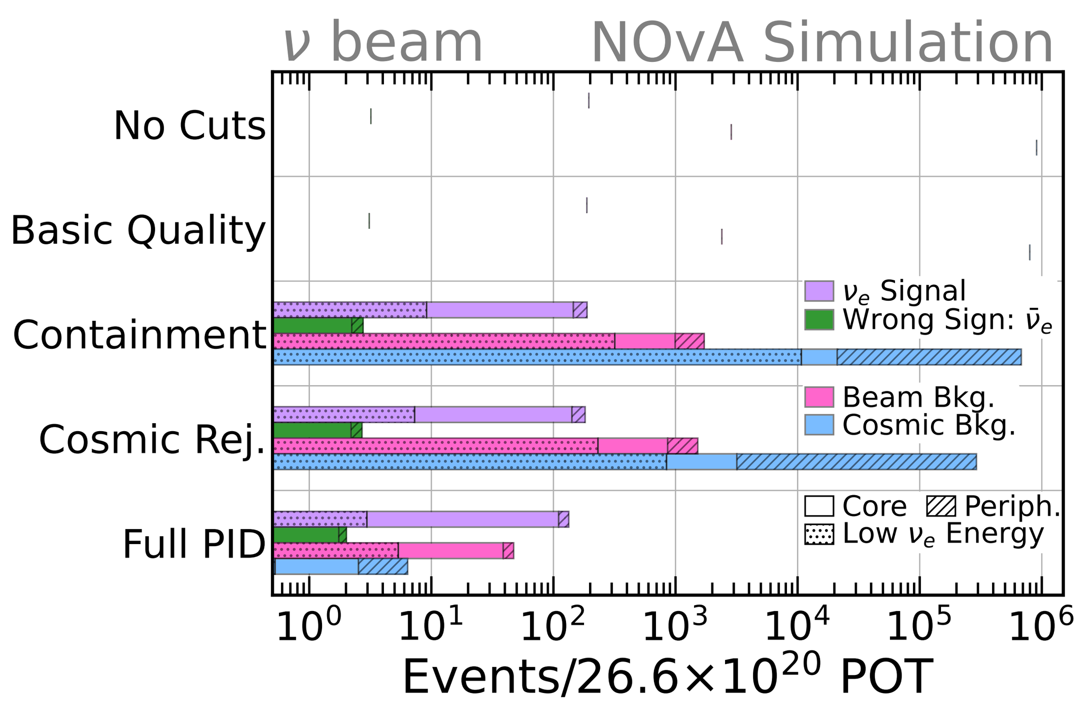


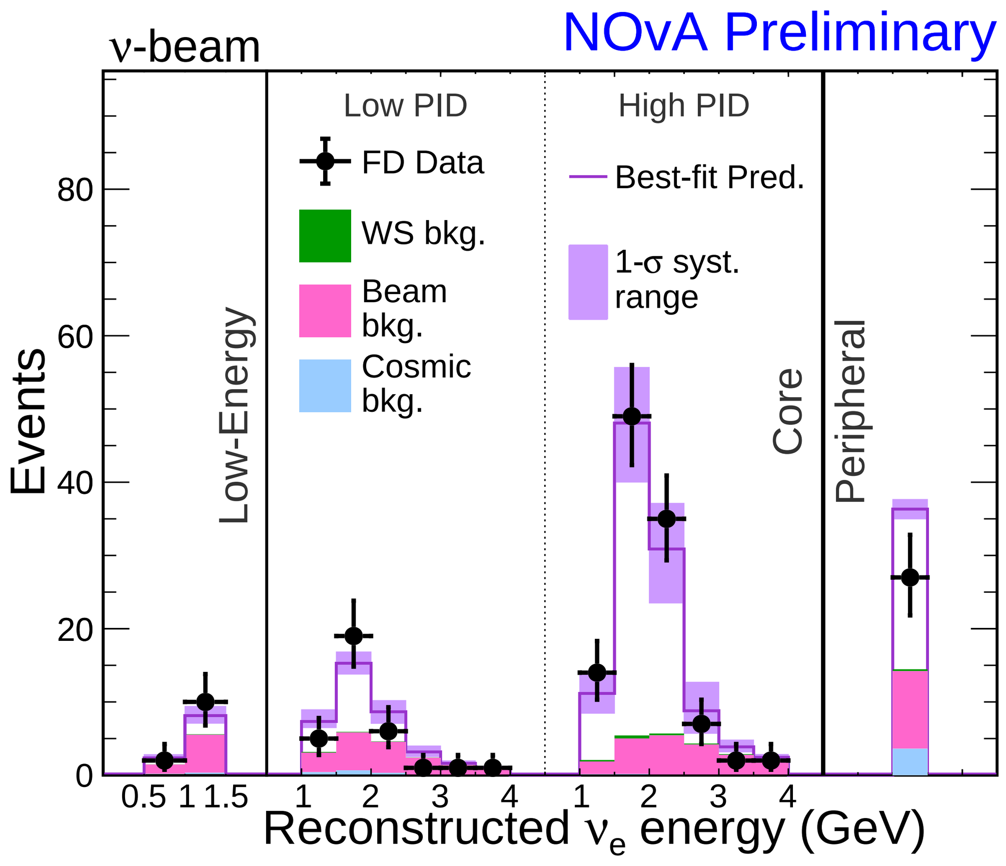
Muon neutrino signal events consist of a long muon track and hadronic activity.

Main background channels: NC, cosmic, wrong signal ν_μ CC.

Basic quality → Containment → Preselection → Cosmic rejection → Particle identification

Efficiency	Purity
ν_μ : 33%	ν_μ : 91%
ν_e : 69%	ν_e : 71%





3 flavor analysis selection flow

Basic quality cut removes events which are pathologically bad.

Containment cut ensures that the deposited neutrino energy lies entirely within the detector.
However, events occurring outside the fiducial volume can be included in the $\nu_e(\bar{\nu}_e)$ peripheral sample [1].

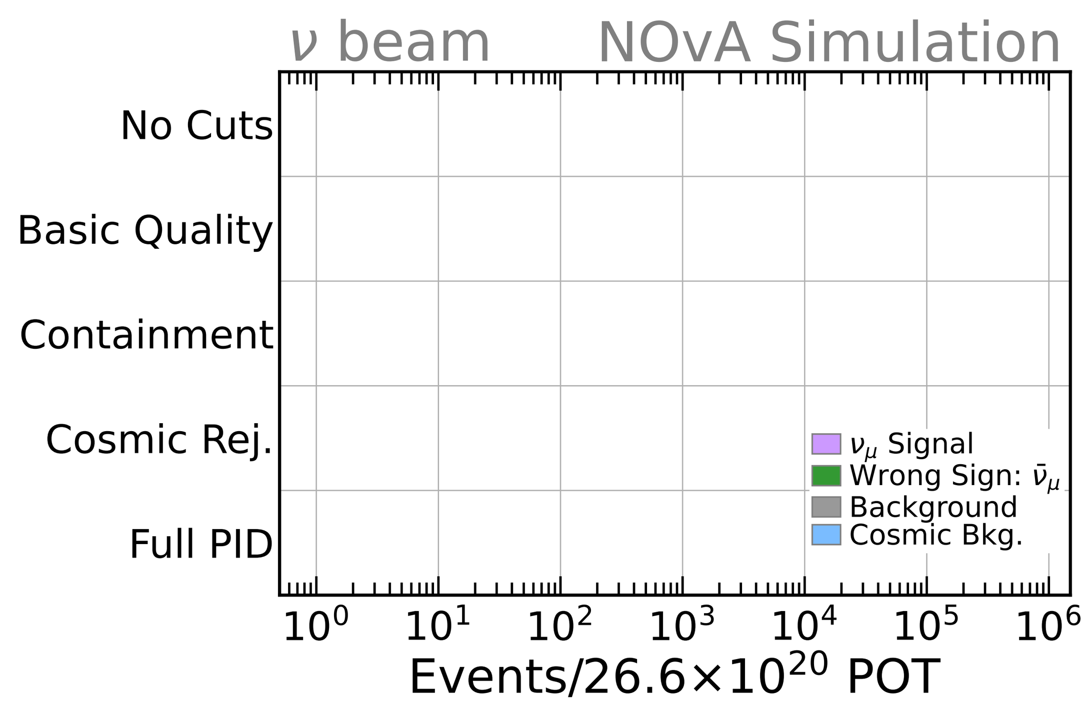
Preselection cut establishes the neutrino energy estimation function and defines the energy range.

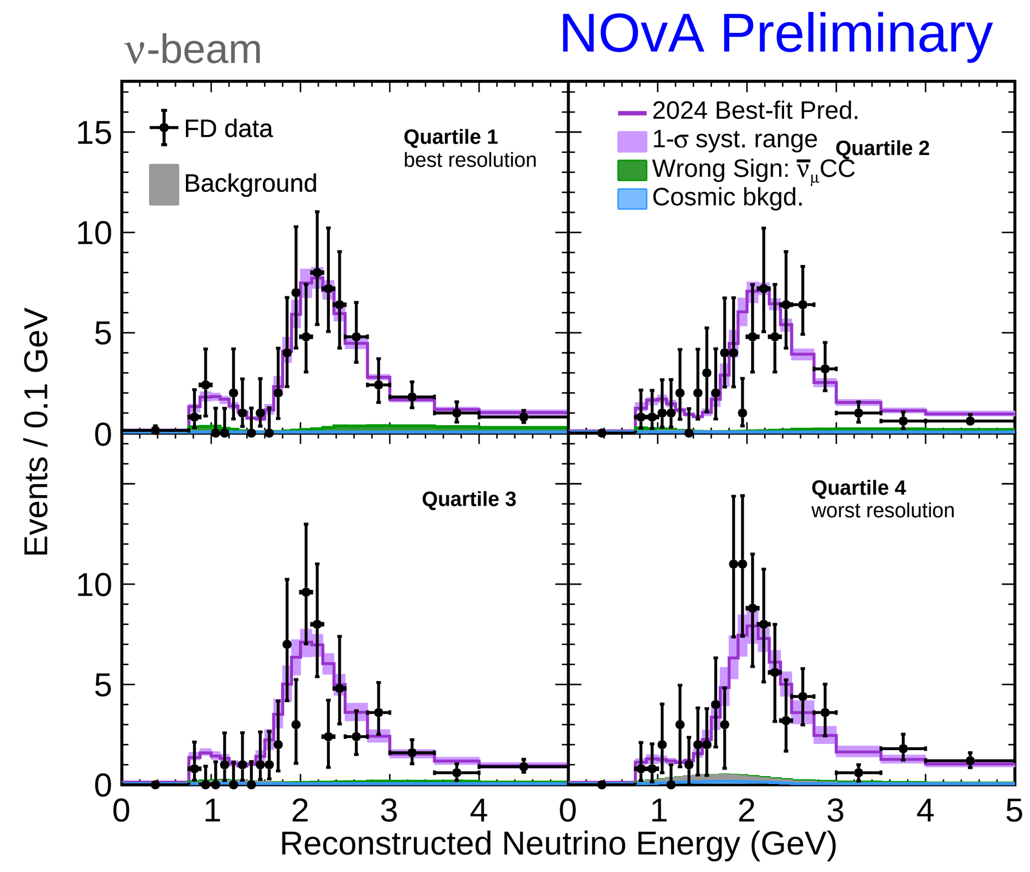
Boosted decision trees are used to reject **cosmic** backgrounds.

Particle identification (PID) is based on convolutional network [2], classifying neutrino event candidates into ν_e CC, ν_μ CC, NC, or cosmogenic background.

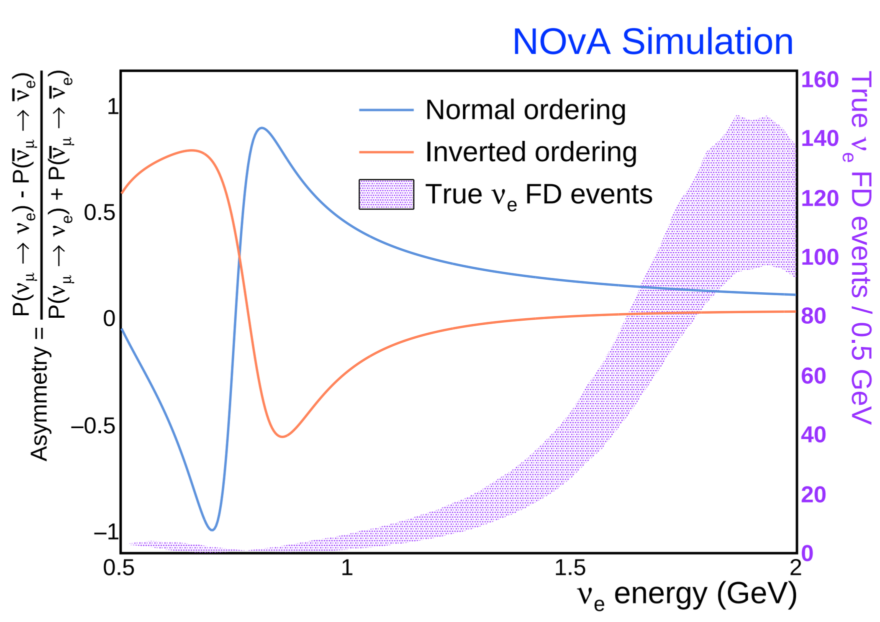
Far detector observations

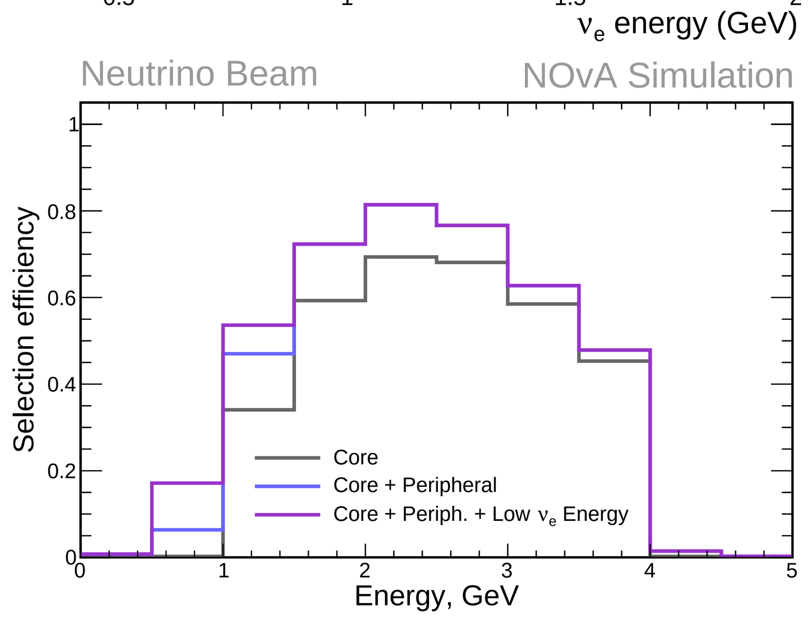
Channel	Observed	Best-fit Pred.	Total bkg.
$\nu_\mu \to \nu_\mu$	384	407.6	11.0
$\bar{\nu}_\mu \to \bar{\nu}_\mu$	106	97.5	1.7
$\nu_\mu \to \nu_e$	181	189.1	62.5
$\bar{\nu}_\mu \to \bar{\nu}_e$	32	30.6	12.2





Low ν_e energy sample

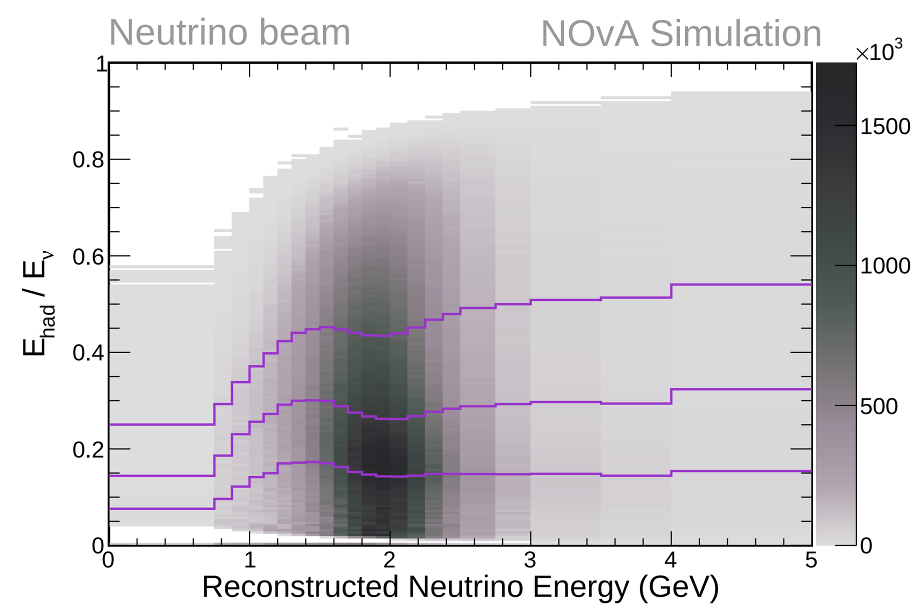




- The sensitivity in appearance channels depends primarily on separating signal from background.
- The oscillation asymmetry function exhibits significantly different behavior at low energy, depending on whether the neutrino mass ordering is normal or inverted.
- A brand new, independent sample has been designed to "reclaim" low energy events and slightly improve the mass ordering sensitivity.
- A new low energy classifier based on a boosted decision tree was developed.
- 12 ν_e additional candidates were observed, with expected background 7.1.

ν_μ hadronic energy quartiles

- The sensitivity in disappearance channels depends primarily on the shape of the energy spectrum.
- The ν_μ sample is subdivided into four bins of hadronic energy fraction.
- The first quartile demonstrates the best energy resolution, $\sim 6.5\%$, whereas the fourth quartile has the worst energy resolution, $\sim 12.5\%$.



Enhanced neutrino beam exposure and re-tuned event selection algorithms have contributed to new NOvA results [3]. In the 2024 analysis, the sensitivity to Δm^2_{32} was improved to 1.5% uncertainty, which is the most precise single-experiment measurement.

References

[1] Phys. Rev. **D** 106, 032004, (2022), 10.1103/PhysRevD.106.032004.
[2] Phys. Rev. **D** 100, 073005, (2019), 10.1103/PhysRevD.100.073005.
[3] Neutrino 2024, (2024), FERMILAB-SLIDES-24-0130-PPD.