# NOvA Neutrino Disappearance Results 2018

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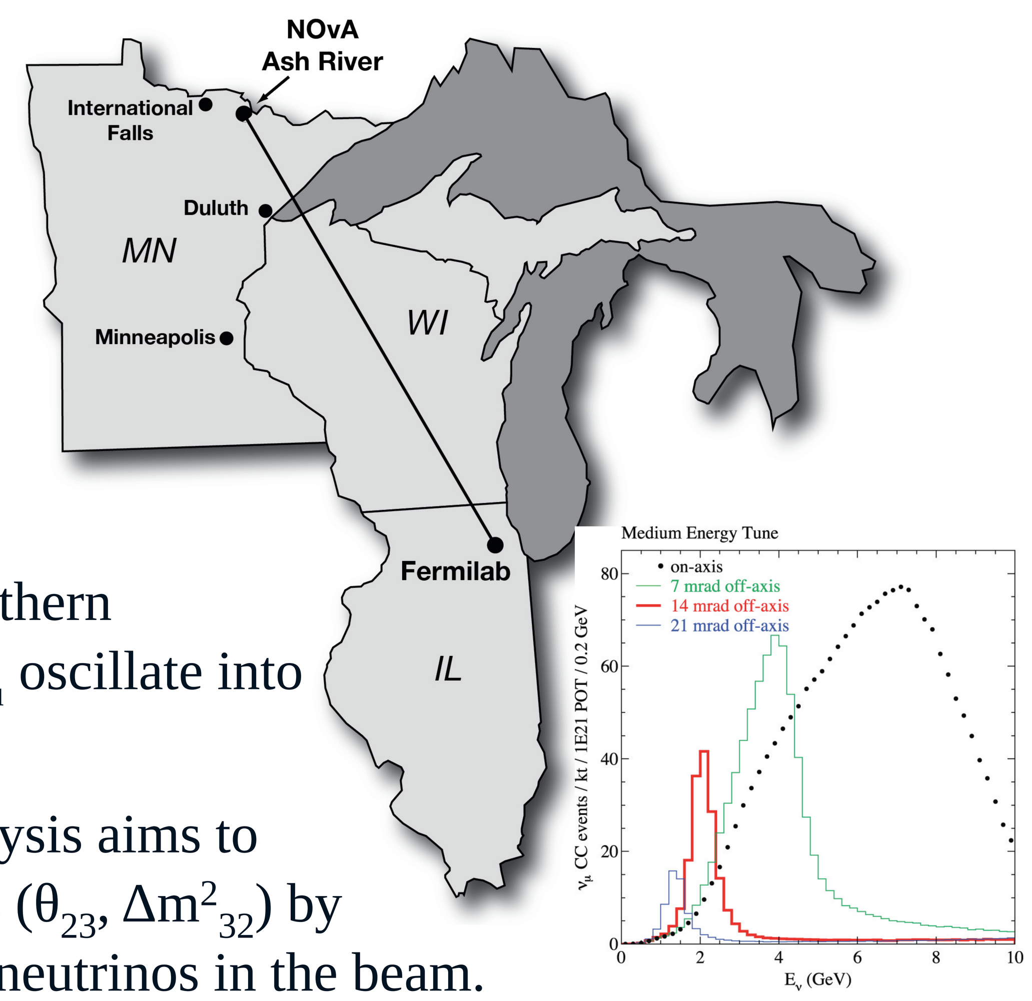
## 1 - NOvA Overview

NOvA is an accelerator based neutrino experiment designed to study $\nu_e$ appearance and $\nu_\mu$ disappearance in a muon neutrino beam.

NOvA uses the NuMI muon (anti)neutrino beam which is produced at Fermilab and directed towards northern Minnesota(14 mrad off axis).

As the beam travels from Fermilab to northern Minnesota(L=810km) some fraction of $\nu_\mu$ oscillate into $\nu_e$ and $\nu_\tau$.

NOvA muon neutrino disappearance analysis aims to determine neutrino oscillation parameters ($\theta_{23}$, $\Delta m^2_{32}$) by measuring the number of survived muon neutrinos in the beam.

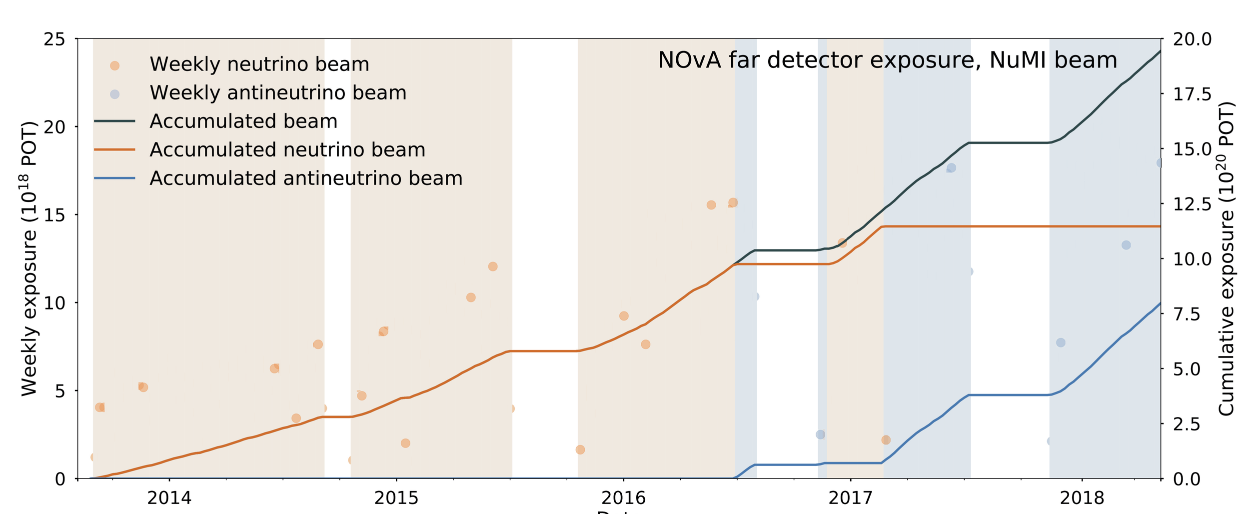



## 2 - Improvements from Previous Analysis

The NOvA experiment started taking data at 2014. Last year the beam reached 700 kW operating power.

Initially the beam was operated in muon neutrino mode. Currently we are taking data in antineutrino mode.

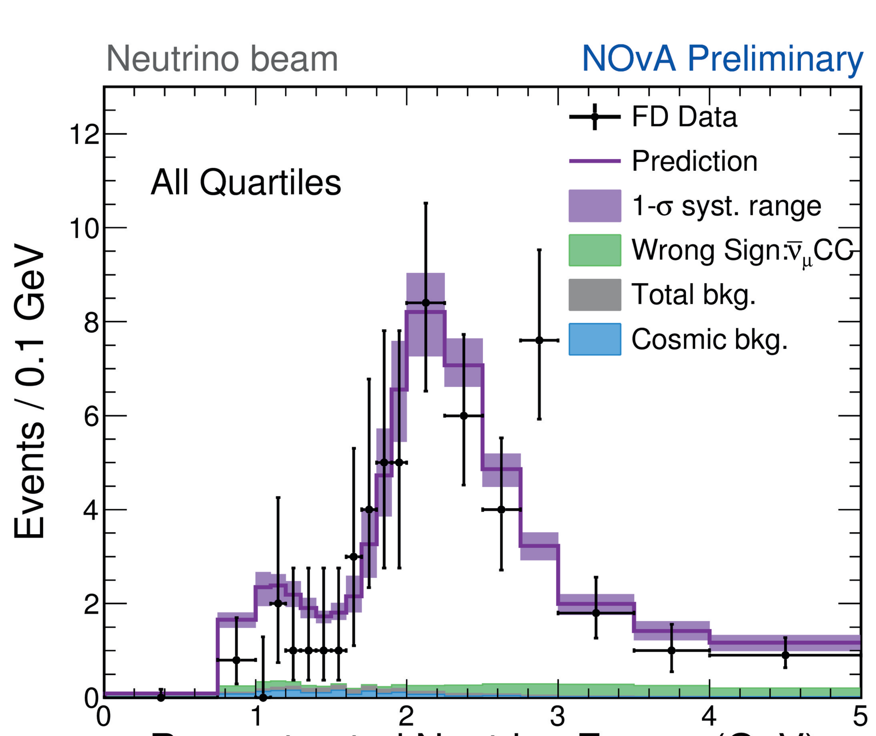
This is the first time we release data for both neutrinos and antineutrinos.

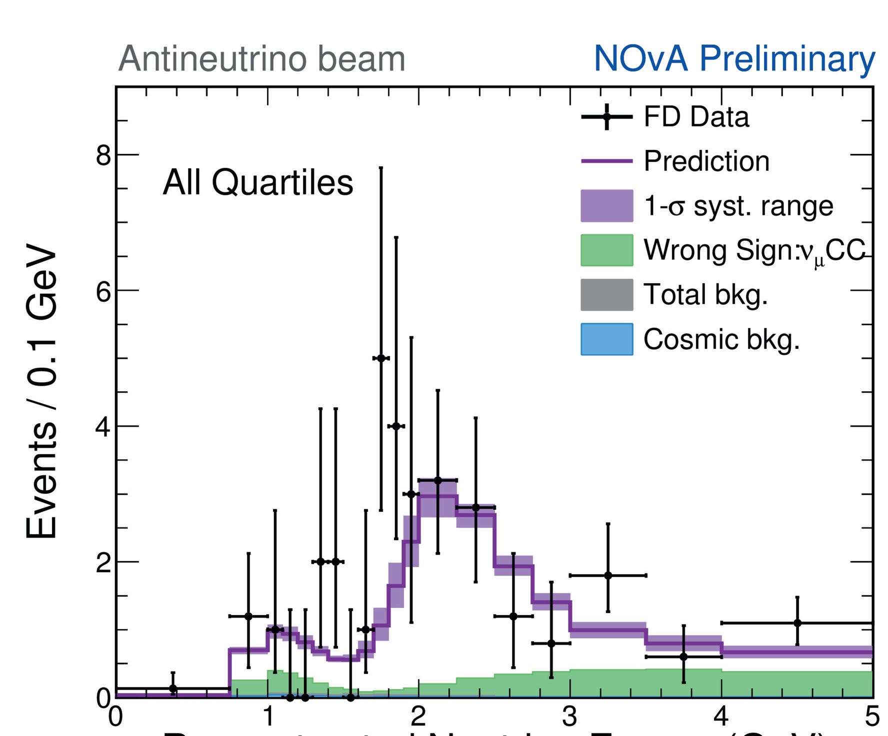



Multiple improvements have been made to the analysis techniques, including:

- Using updated simulation model
- New event selection algorithms based on Convolutional Neural Networks.
- New analysis approach, where we first separate the data into 4 classes ("quartiles") based on the fraction of hadronic energy in the event, and analyse them separately.

## 3 - Far Detector Events



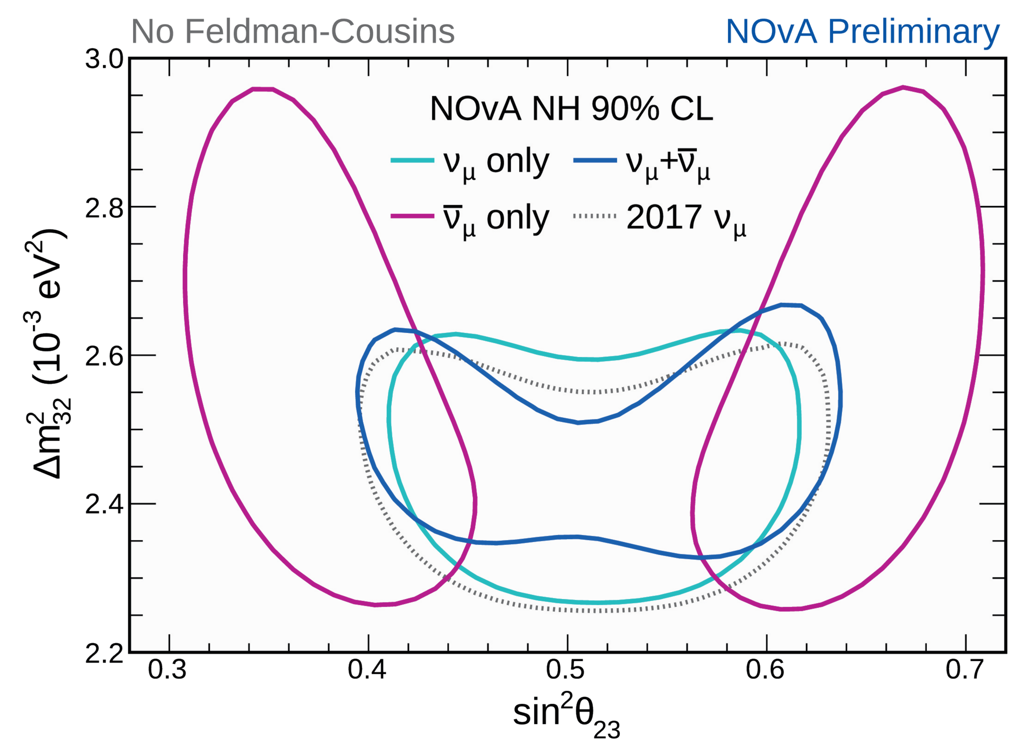




Here we can see the comparison of the Far Detector data and prediction, obtained from the Near Detector data for both muon neutrinos and antineutrinos.

The dip between 1-2 GeV is produced by neutrino oscillations.

| | Neutrino Mode $\nu_\mu$ | Neutrino Mode $\bar{\nu}_\mu$ |
|---|---|---|
| Total Observed | 113 | 65 |
| Best fit prediction | 121 | 50 |
| Cosmic Bkgd. | 2.1 | 0.5 |
| Beam Bkgd. | 1.2 | 0.6 |
| Unoscillated | 730 | 266 |

## 4 - NOvA Confidence Contours




The plot to the left shows NOvA 90% confidence contours in the ($\sin^2\theta_{23}$, $\Delta m^2_{32}$) plane for the normal hierarchy.

Muon neutrino disappearance results only.

The neutrino data is consistent with the maximal mixing($\sin^2\theta_{23}$ = 0.5).

The antineutrino data prefers non-maximal value of $\theta_{23}$.

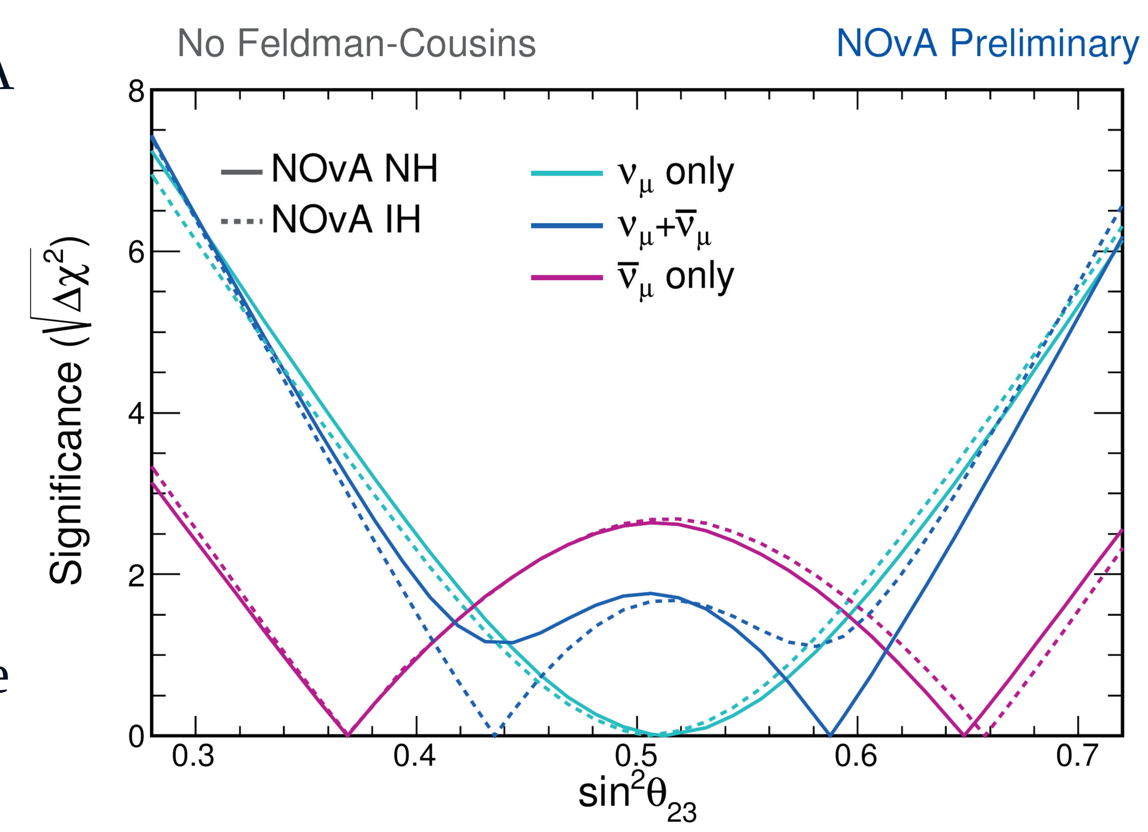
Consistency with the combined fit oscillation parameters for the neutrino and antineutrino datasets is better than 4%.

## 5 - NOvA Octant Hierarchy Sensitivity

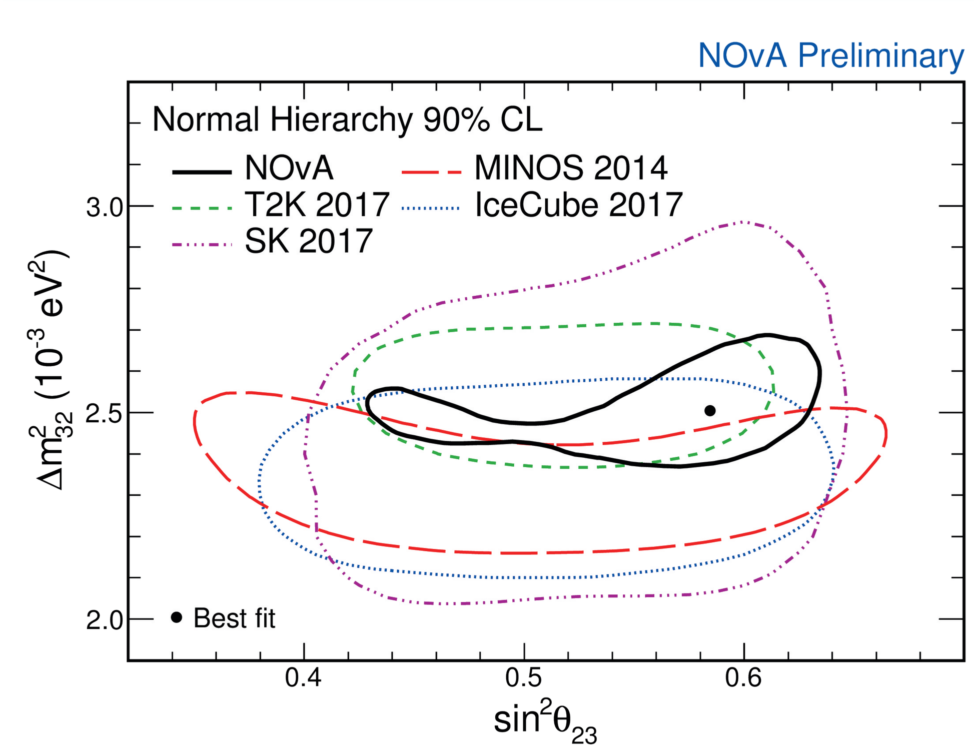
The plot to the right shows NOvA profiles for $\theta_{23}$ for both normal and inverted hierarchies.

Muon neutrino disappearance results only.

The combined neutrino/ antineutrino fit prefers upper octant value for the normal hierarchy and lower octant for the inverted hierarchy.




## 6 - Comparison with other experiments




The plot here shows NOvA 90% confidence joint(numu disappearance + nue appearance) contours in the ($\sin^2\theta_{23}$, $\Delta m^2_{32}$) and their comparison with contours from other experiments.

NOvA has good $\Delta m^2_{32}$ resolution.

Our best fit values are:

$\sin^2\theta_{23} = 0.58^{+0.03}_{-0.03}$

$\Delta m^2_{32} = 2.51^{+0.12}_{-0.08} \cdot 10^{-3}$ eV$^2$

## 7 - Conclusions and Outlook

The beam has reached its designed power. We obtained our first results with both neutrino and antineutrino data.

Our first joint neutrino-antineutrino results are very promising. Currently, NOvA has measurements of $\theta_{23}$ and $\Delta m^2_{32}$ that are competitive with other experiments(c.f. poster on the measurement of oscillation parameters in NOvA).

Looking forward, the beam will be run half of the time in neutrino mode and half of the time in antineutrino mode.

This will allow us to further improve the precision of measurement of the oscillation parameters, which is crucial for improving our sensitivity to the mass hierarchy, octant and CP violation.