

#141: Search for sterile neutrino disappearance in the NOvA neutrino beam

Jeremy Hewes¹ and Sijith Edayath² on behalf of the NOvA collaboration

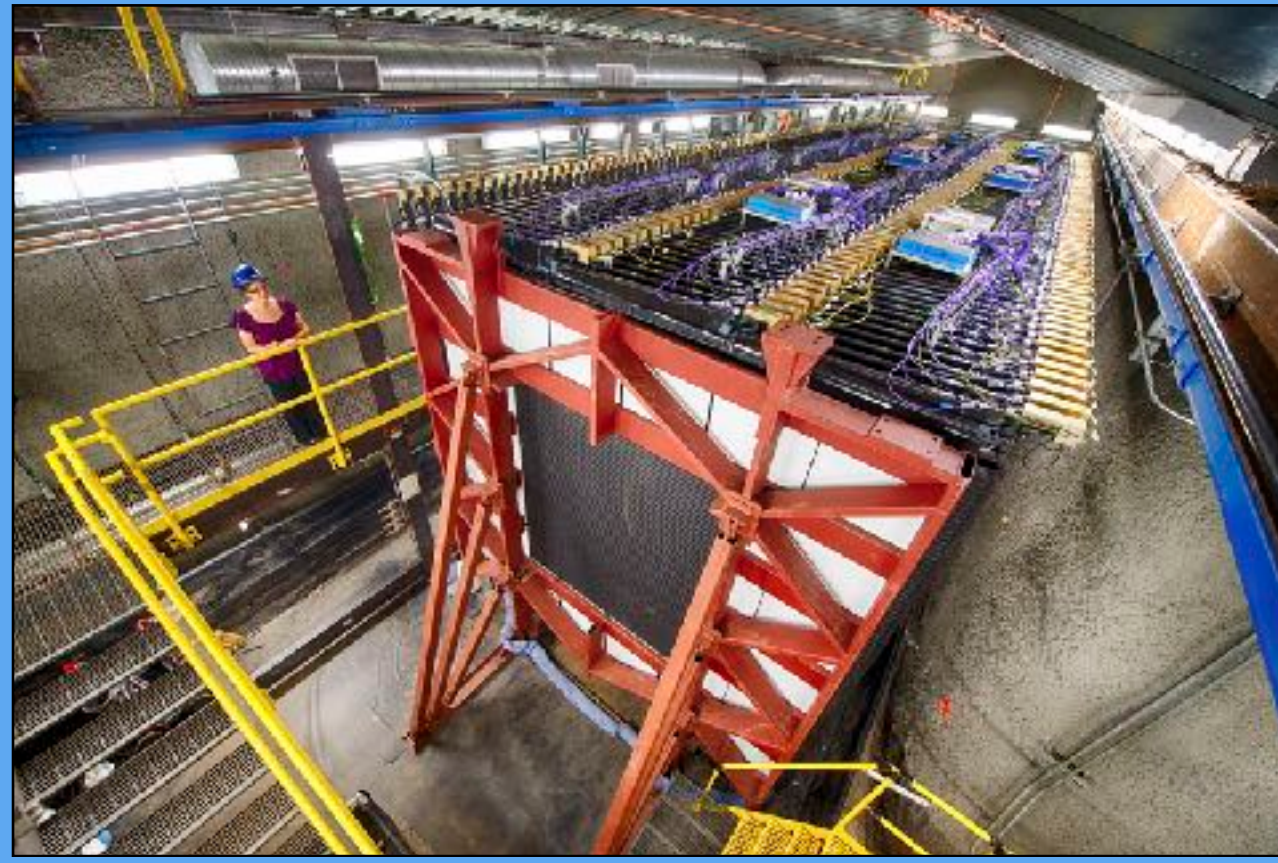


¹ University of Cincinnati
² Cochin University of Science and Technology

XXVIII International Conference on Neutrino Physics and Astrophysics
Neutrino 2018: Heidelberg, June 4-9, 2018



The NOvA Experiment



NOvA near detector.



NOvA collaboration.

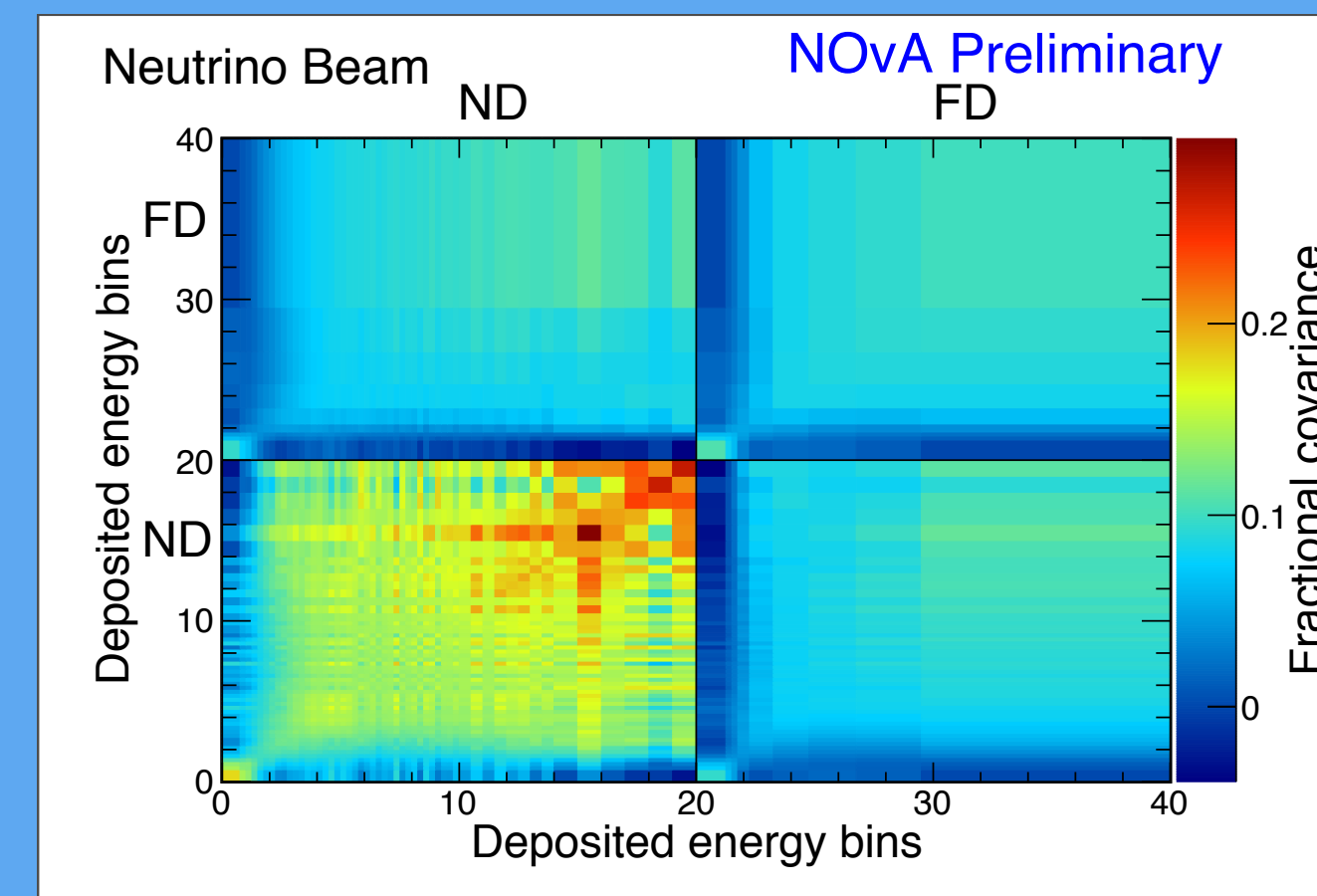


NOvA far detector.

NOvA (NuMI Off-axis ν_e Appearance) is a long-baseline neutrino experiment based at Fermilab. It consists of two functionally identical **liquid scintillator detectors**, both downstream of Fermilab's **NuMI neutrino beam**.

The near detector is a 290t detector close to the beam source at Fermilab. The far detector is a 14kt active mass detector in Ash River, MN at an **810km baseline** from the beam source, and 14.6 mrad off-axis.

Covariance matrix method



Covariance matrix encoding systematic uncertainties in near and far detectors.

On-diagonal elements in the covariance matrix correspond to the systematic **variances** in each energy bin, while the off-diagonal elements encode the **covariances** between those bins.

$$V_{ij,\text{syst}} = \frac{\sum_{n=1}^U (S_{n,i} - \mu_i)(S_{n,j} - \mu_j)}{U - 1}$$

$$\chi^2 = \sum_{i=1}^N \sum_{j=1}^N (x_i - \mu_i)[V^{-1}]_{ij}(x_j - \mu_j)$$

Use of a covariance matrix allows for **implicit cancellation of systematic uncertainties** among energy bins in both the near and far detector. While a standard near-to-far extrapolation method causes loss of sensitivity at high Δm_{41}^2 , when oscillations manifest in the near detector in addition to the far detector, the covariance method is robust against such situations, **expanding the sensitive range in Δm_{41}^2 parameter space**.

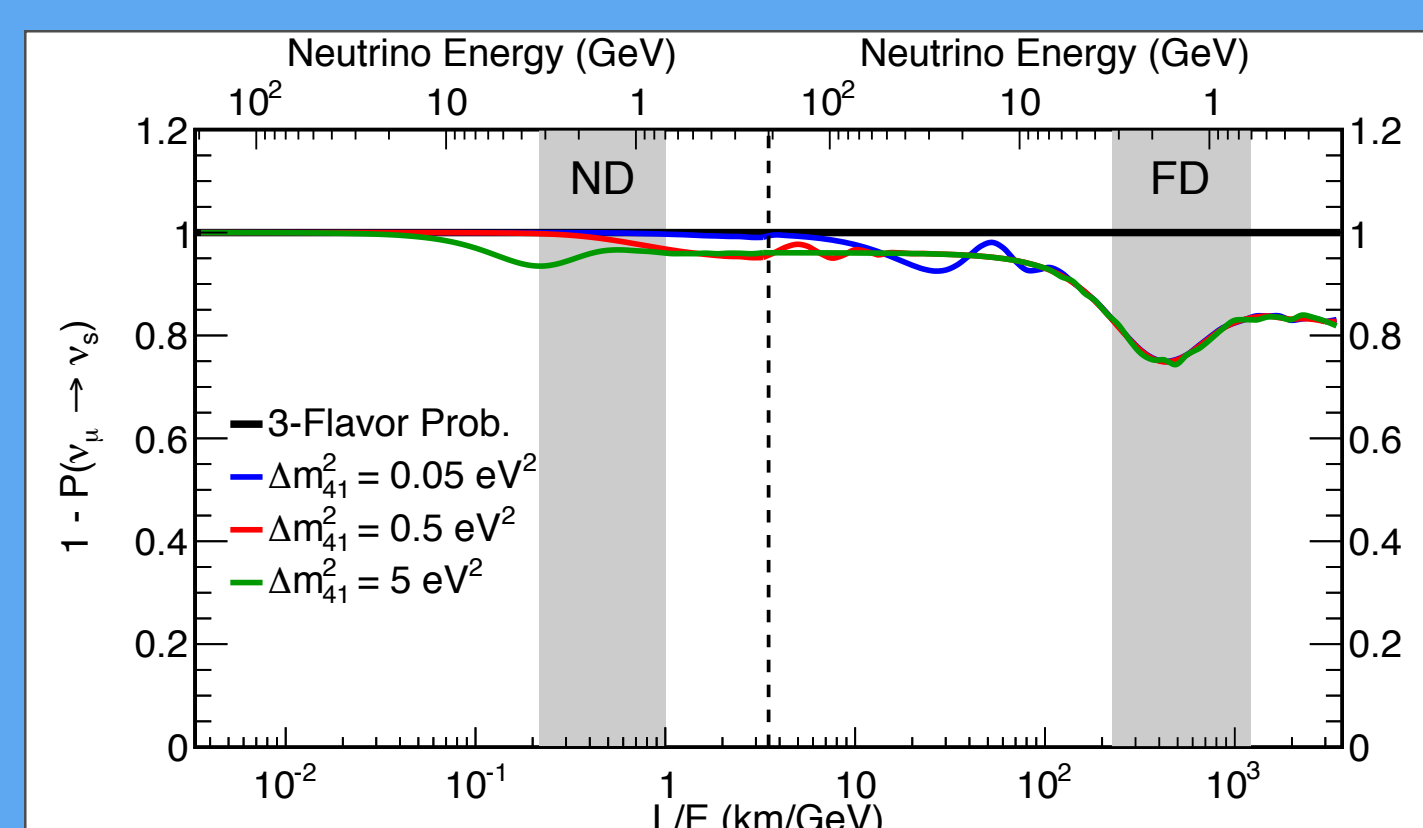
Sterile neutrinos

Use **neutral-current** (NC) events to search for active neutrino flavors **oscillating into sterile neutrinos**, as they do not undergo standard three-flavor oscillations.

Sensitive to θ_{24} and θ_{34} mixing angles, and sterile mass splitting Δm_{41}^2 .

Approximate SBL probability:

$$1 - P_{\nu_\mu \rightarrow \nu_s}^{LBL,3+1} \approx 1 - \frac{1}{2} \cos^4 \theta_{14} \cos^2 \theta_{34} \sin^2 \theta_{24} + A \sin^2 \Delta_{31} - B \sin 2\Delta_{31}$$

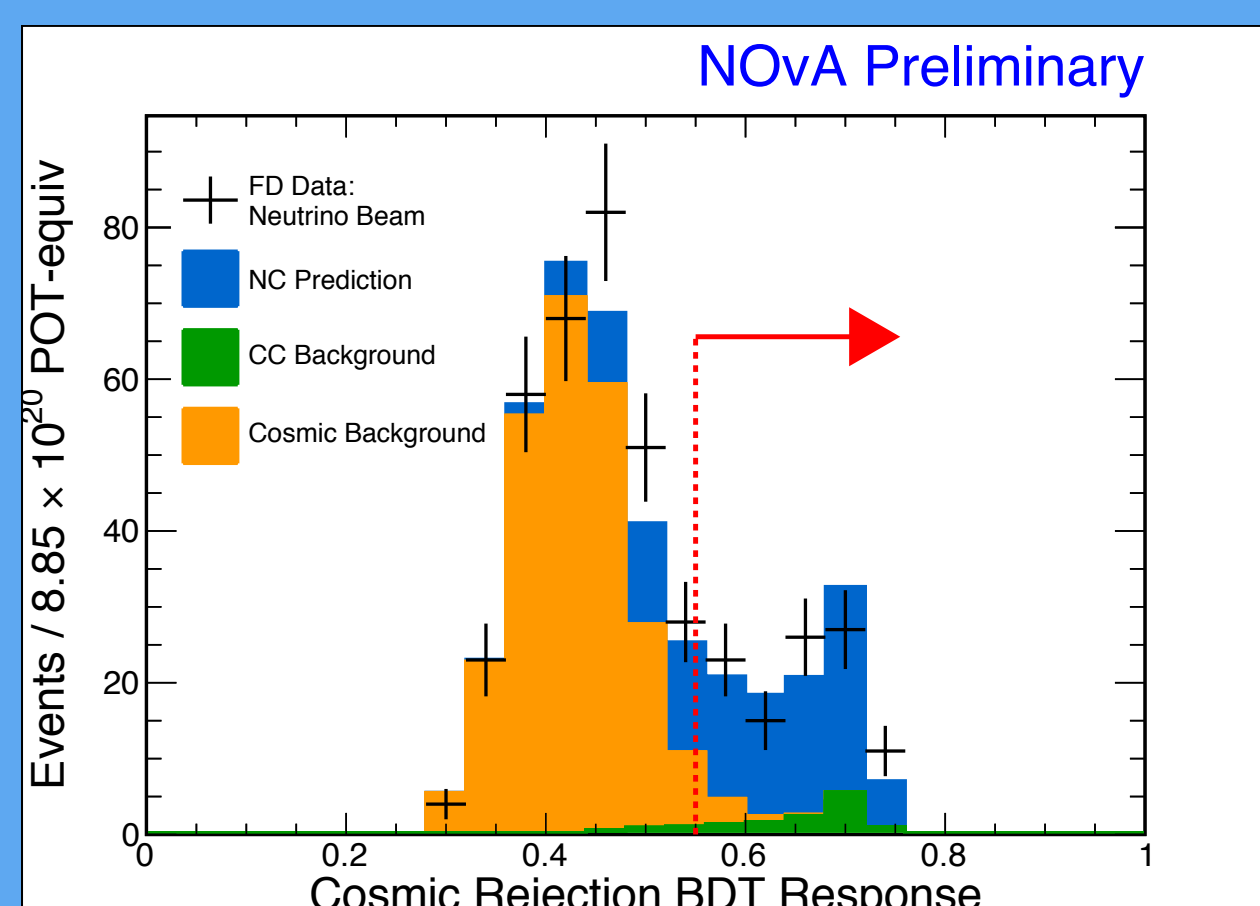


Probability of sterile neutrino disappearance in the near and far detectors as a function of Δm_{41}^2 .

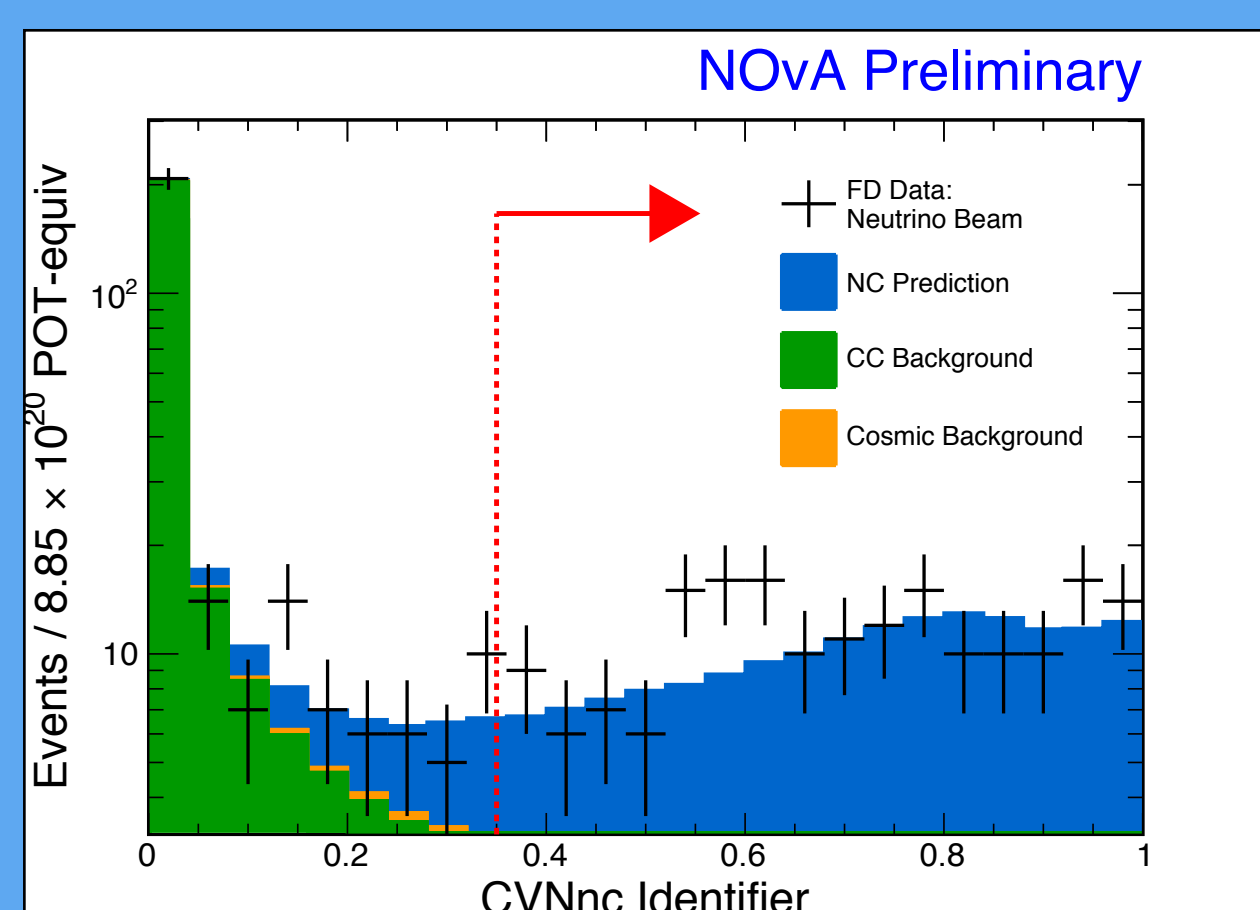
Approximate LBL probability:

$$P_{\nu_\mu \rightarrow \nu_s}^{SBL,3+1} = 1 - 4|U_{\mu 4}|^2(1 - |U_{\mu 4}|^2) \sin^2 \Delta_{41} = 1 - \cos^2 \theta_{14} \sin^2 \theta_{24} \sin^2 \Delta_{41}$$

Event selection



Boosted decision tree used for rejection of cosmic interactions.

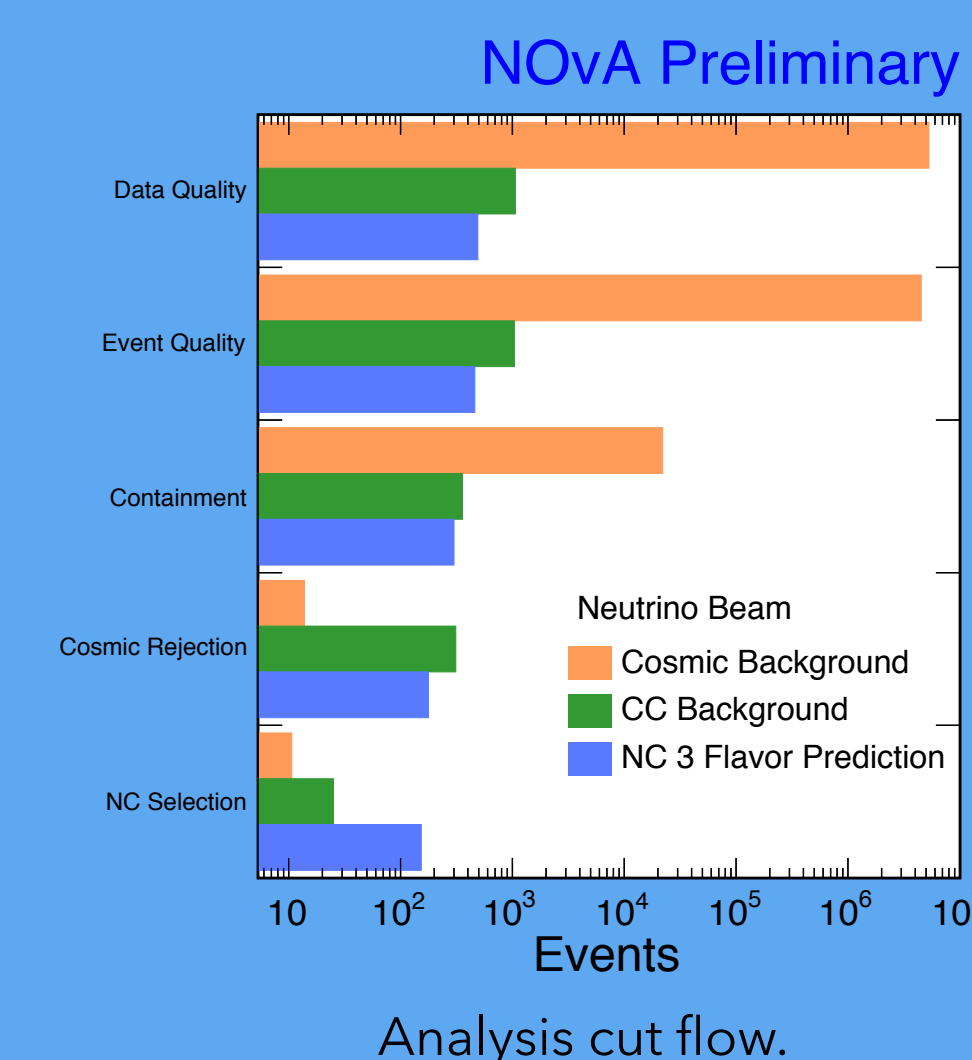


Neutral current identification using NOvA's Convolutional Visual Network.

Signal is **neutral-current** neutrino interactions, with primary background **cosmic interactions** and **charged-current** (CC) neutrino interactions.

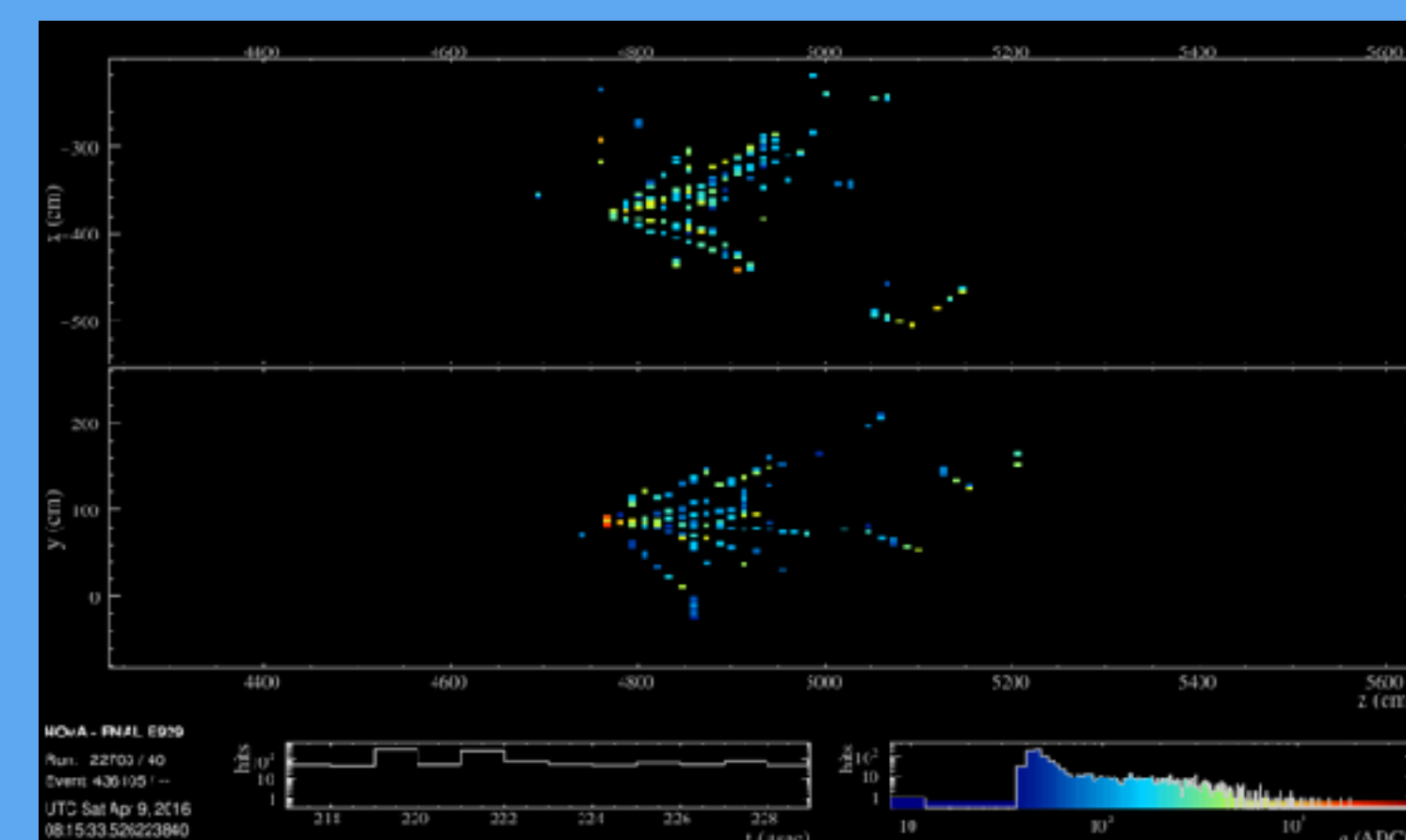
Cosmic rejection cuts applied in the far detector include transverse momentum and prong direction, in addition to a **boosted decision tree** trained on shower variables.

NC events are identified and **selected** with NOvA's **Convolutional Visual Network** (CVN), a convolutional neural network-based image processing technique.



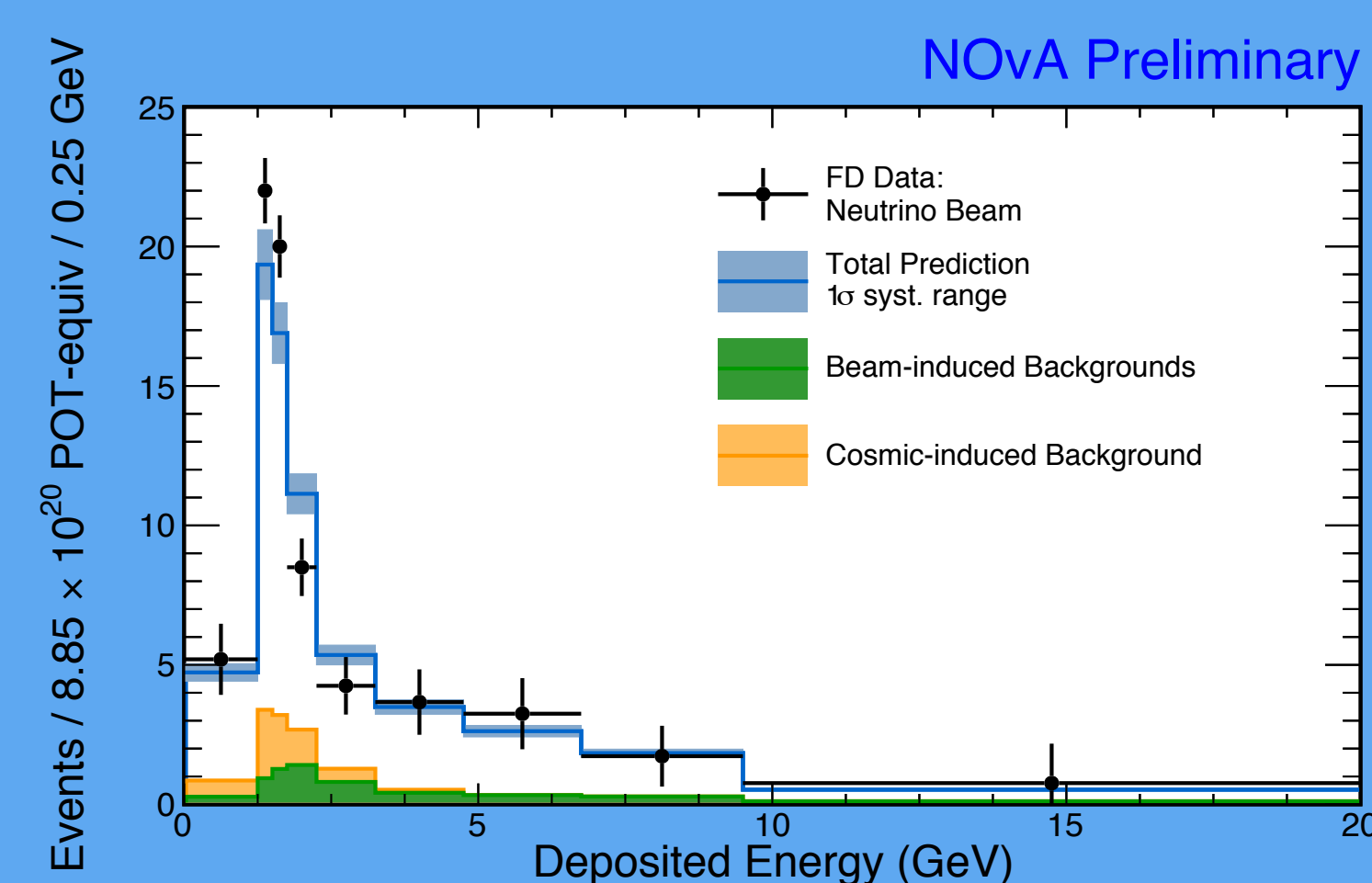
Analysis cut flow.

Results

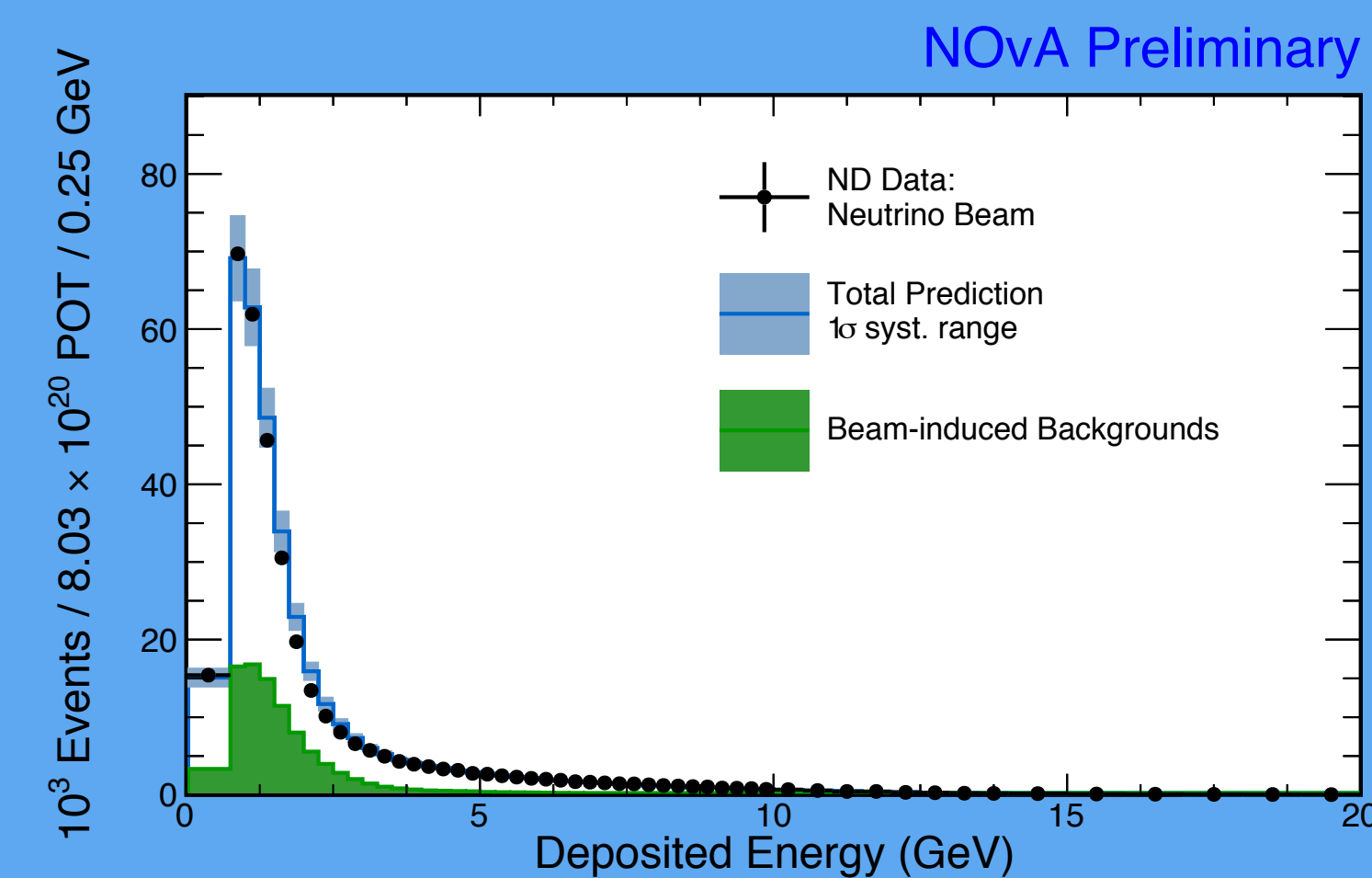


Neutral current event candidate in NOvA.

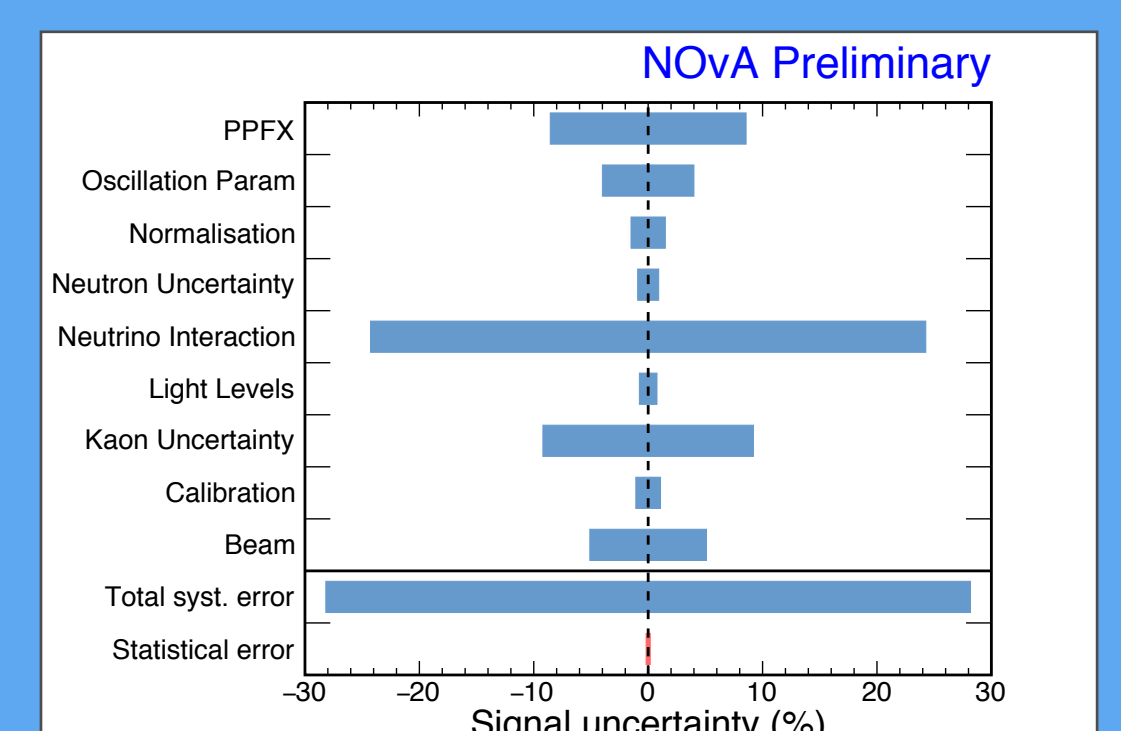
A total of **201 data** events were selected in the far detector, compared to **188** from MC prediction, consistent with **no sterile neutrinos**.



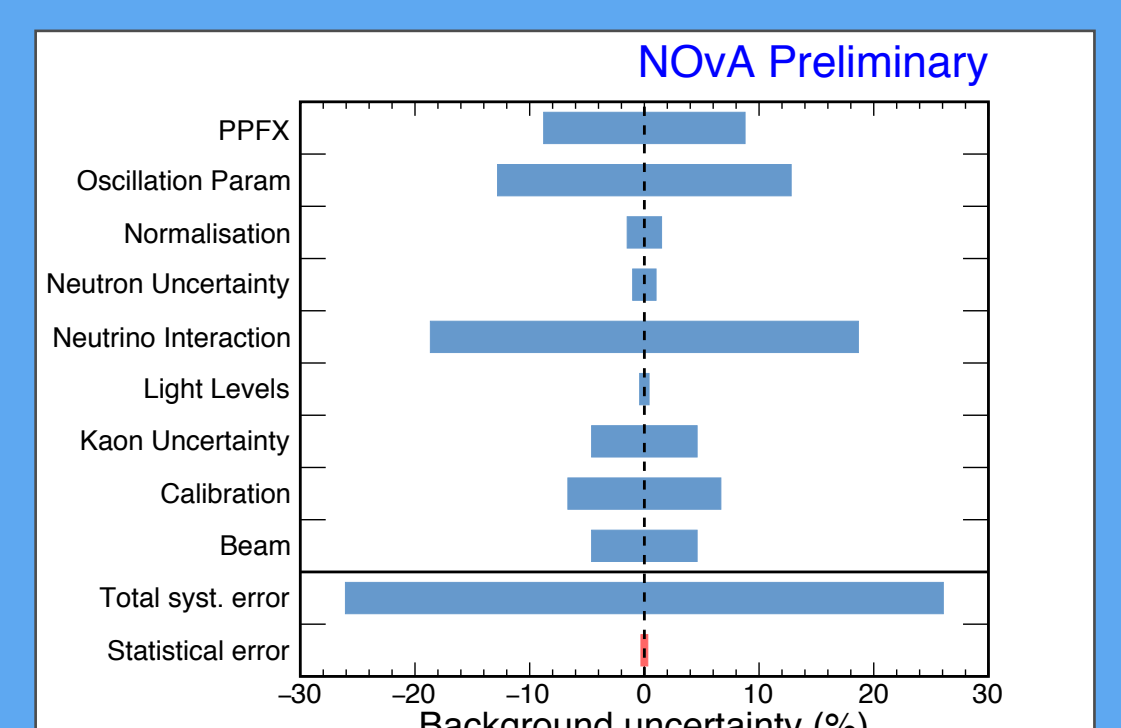
Far detector data spectrum.



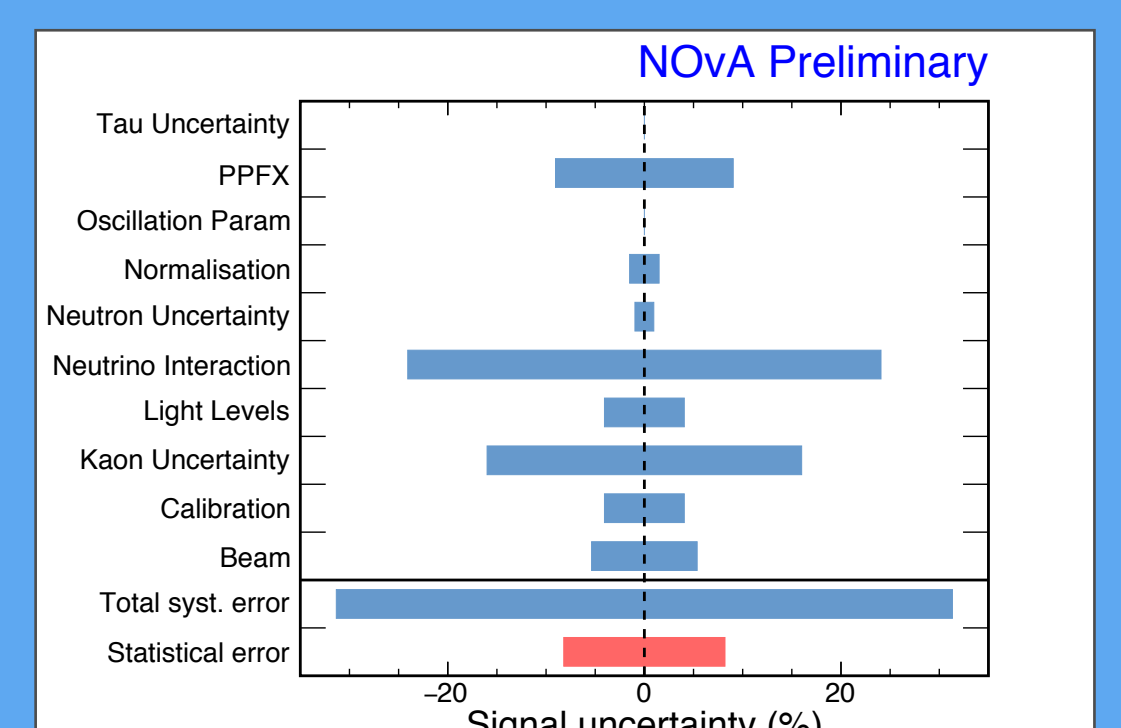
Near detector data spectrum.



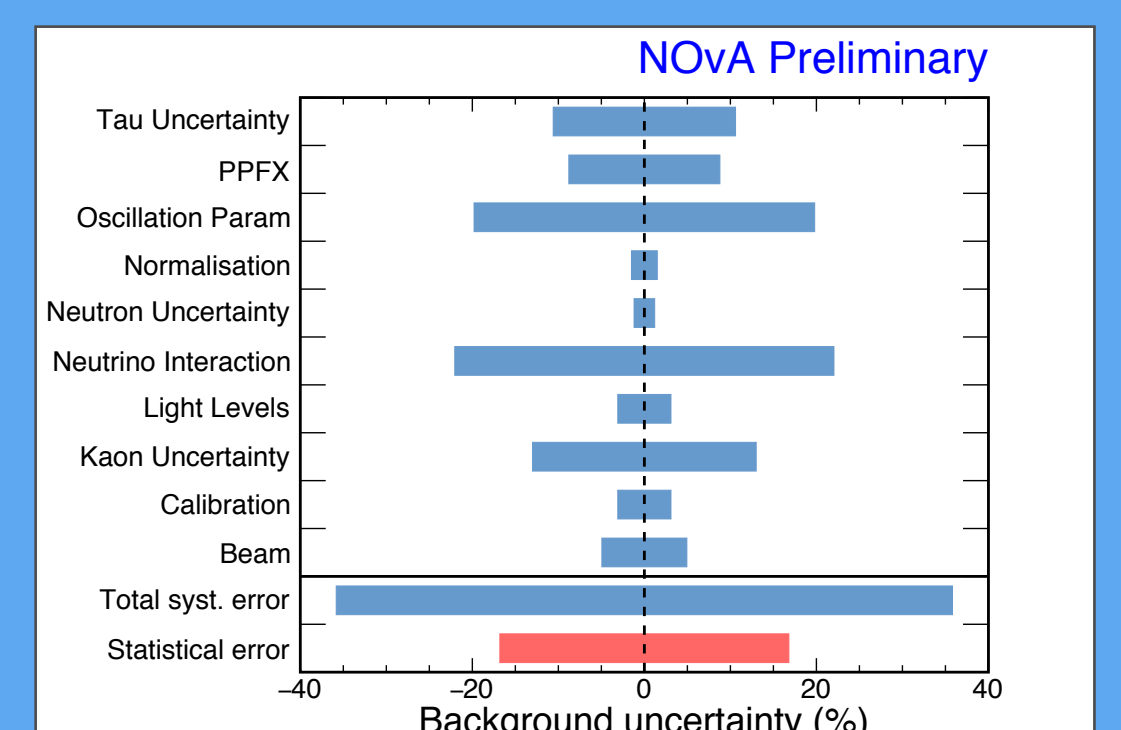
ND signal uncertainties.



ND background uncertainties.



FD signal uncertainties.



FD background uncertainties.

This poster describes the development of a novel new analysis technique which greatly increases reach in sterile mixing parameter space. This method will allow fits to be carried out in θ_{24} vs θ_{34} , θ_{24} vs Δm_{41}^2 and θ_{34} vs Δm_{41}^2 parameter space, extending into the sterile mass splitting range where 3+1 flavour disappearance begins to manifest in the near detector.

See also:

NOvA short-baseline oscillation poster (#142, G. Davies)

NOvA deep learning poster (#79, F. Psihas)

NOvA antineutrino beam NC sterile poster (# 132, M. Wallbank)

