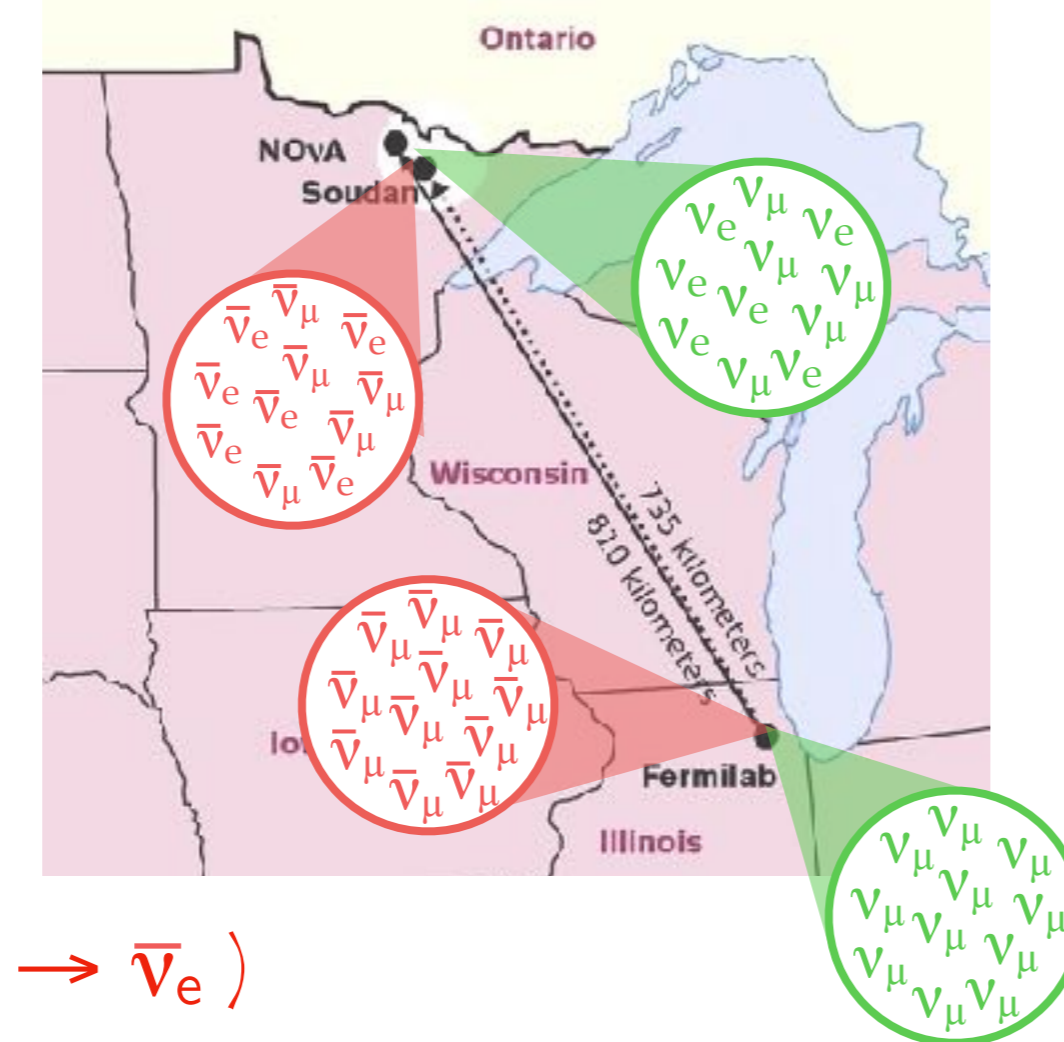


1 Neutrino oscillations and interaction model

• NOvA is a long-baseline neutrino experiment with Near Detector (ND) at Fermilab and main physics goals:

- Determine neutrino mass hierarchy
- Probe δ_{CP} violating phase
- Resolve the octant of θ_{23} mixing angle

• These parameters are extracted from the observed charged current (CC) interactions of neutrinos in the oscillation channels: $(\nu_\mu \rightarrow \nu_\mu)$, $(\nu_\mu \rightarrow \nu_e)$, $(\bar{\nu}_\mu \rightarrow \bar{\nu}_\mu)$, $(\bar{\nu}_\mu \rightarrow \bar{\nu}_e)$



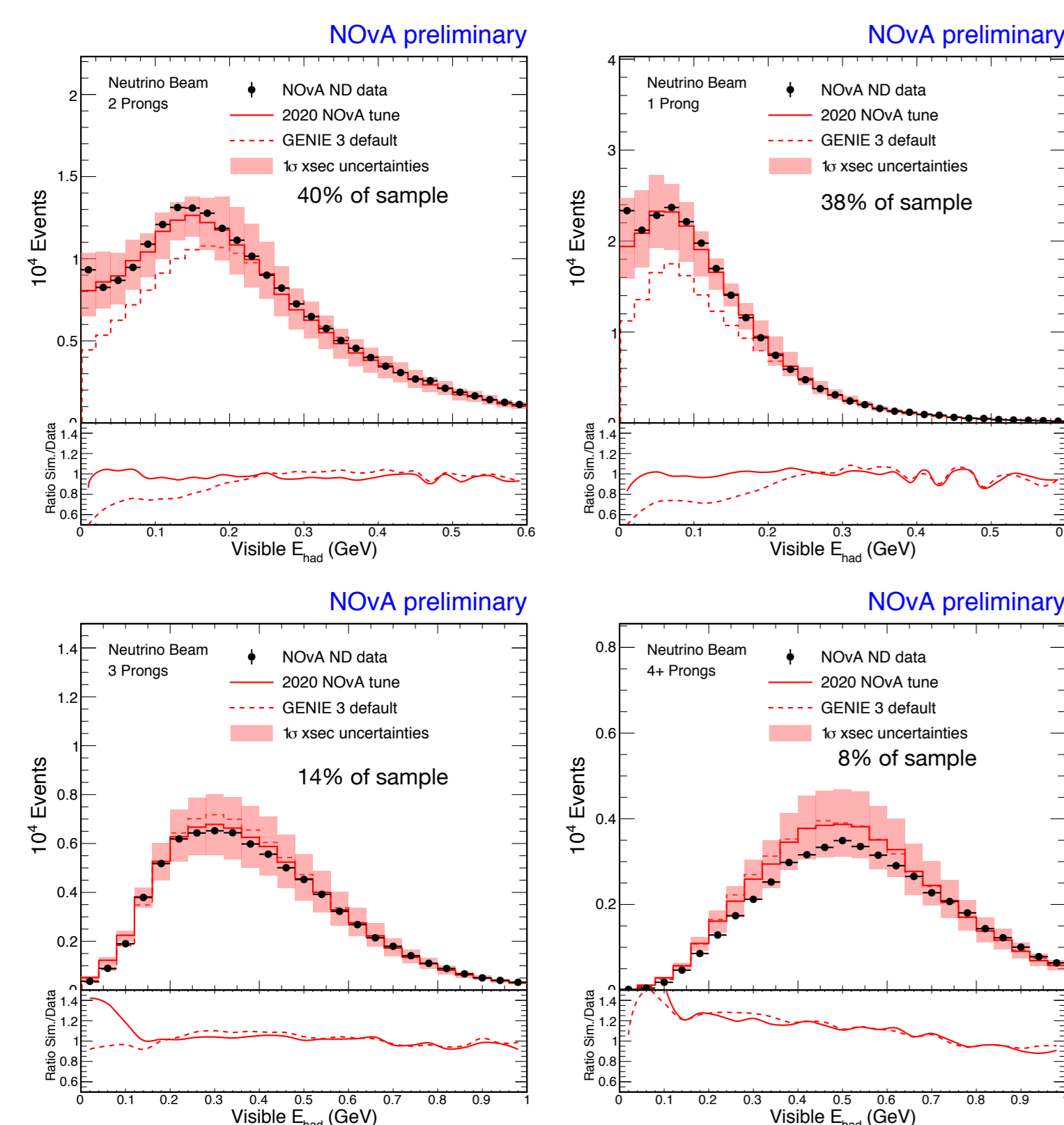
• NOvA uses simulations based on the GENIE neutrino event generator to extrapolate ND data into neutrino oscillation predictions in the Far Detector (FD).
 • Neutrino interaction model uncertainties are important for the oscillation analysis

5 Performance of adjustments

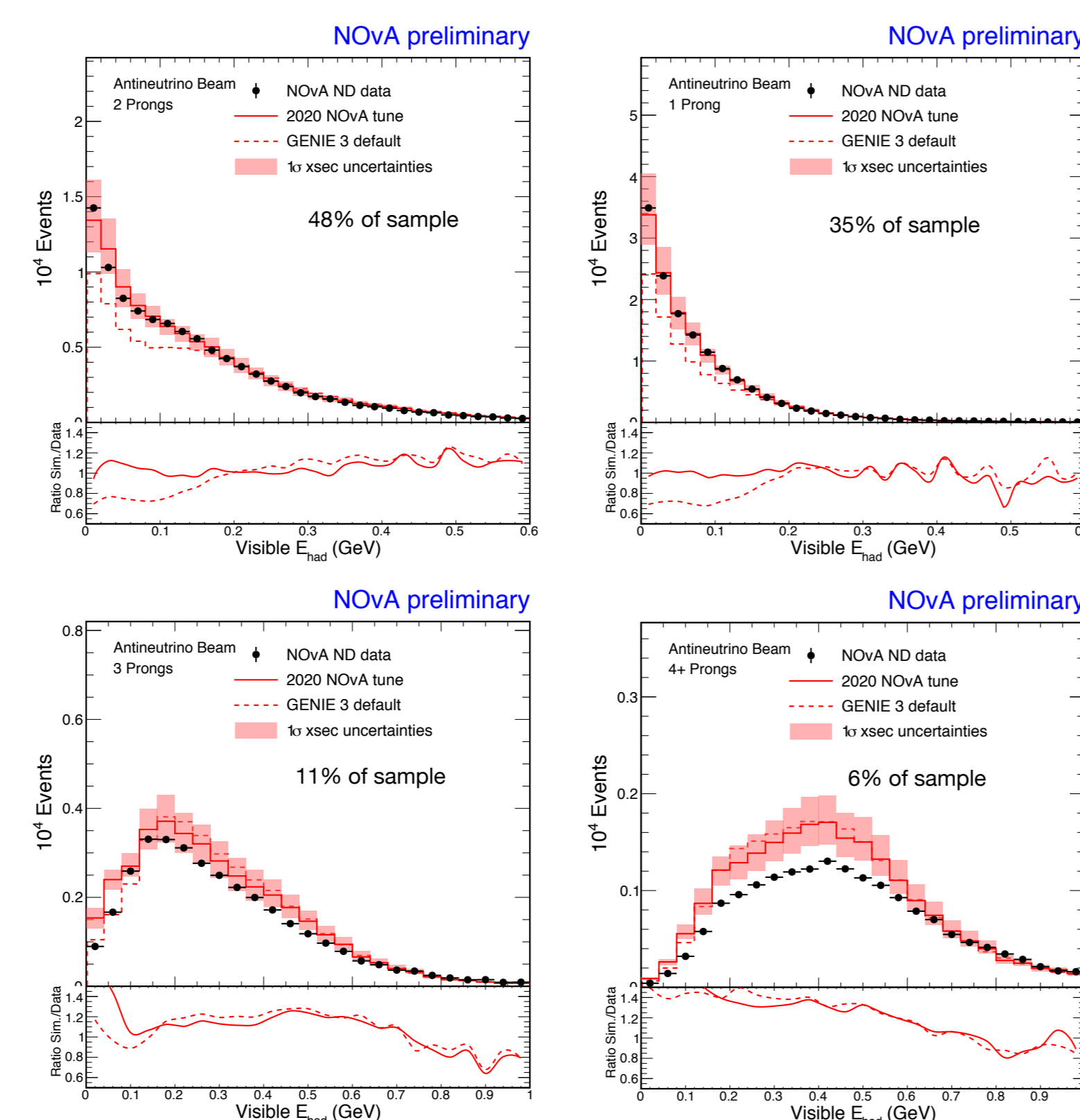
- Cross-section adjustments are based on the full neutrino beam dataset.
- Neutrino beam ND data and simulation, split into subsets of different 3D prong multiplicity, show good agreement within the cross-section uncertainty bands.

- The antineutrino beam simulation agrees with the data for low multiplicity of prongs, where most of 2p2h interactions reside.
- High prong multiplicity data lie close to cross section uncertainty bands. Less than 7% of the antineutrino data falls outside.

Neutrino beam selection



Antineutrino beam selection

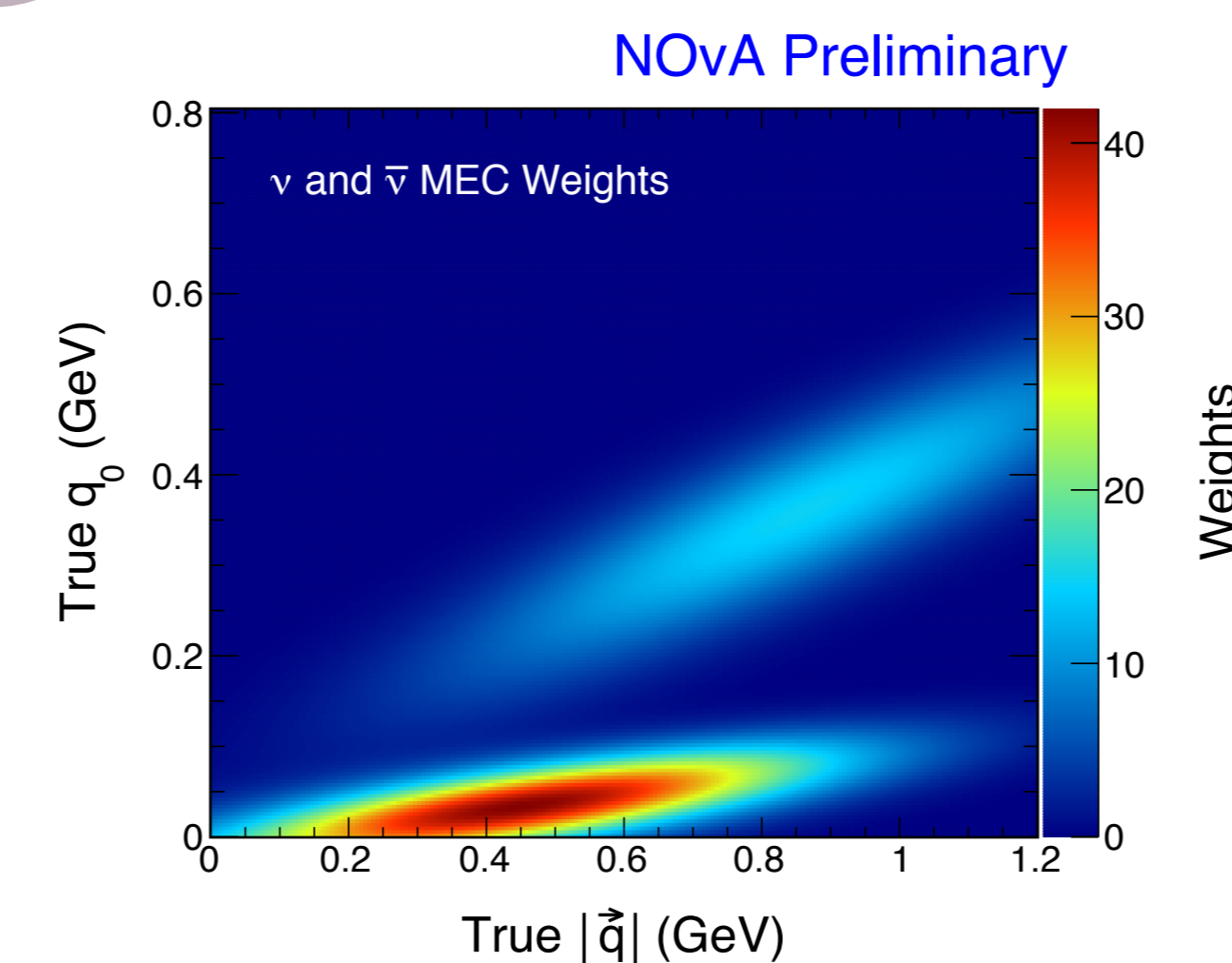


2 GENIE base model

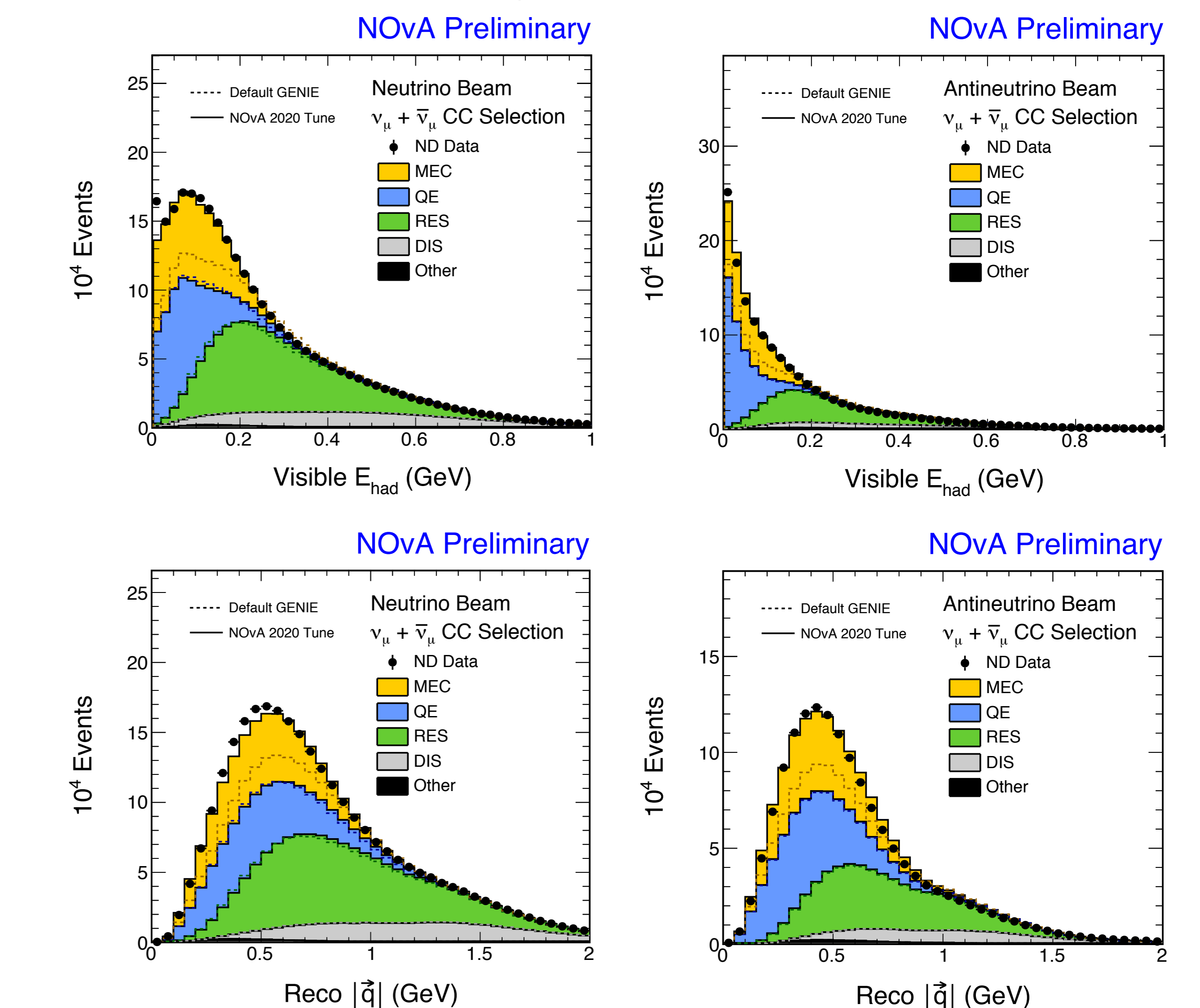
• In the past NOvA used GENIE 2.12.2 base model with several adjustments. The current analysis uses GENIE 3, with the Comprehensive Model Configuration **N1810j0211a**:

- Quasi-Elastic (QE) interactions are described by local Fermi Gas nuclear model and Z-expansion systematic uncertainties.
- Berger-Sehgal Resonance Production (RES) model tuned to data.
- Bodek-Yang Deep-Inelastic Scattering (DIS) model tuned to data.
- Meson Exchange Currents (MEC) described by Valencia model for CC 2p2h and empirical MEC for neutral current (NC) interactions, with adjusted central value and custom systematic uncertainties.
- Final State Interactions (FSI) described by the hN model with central value adjustments.

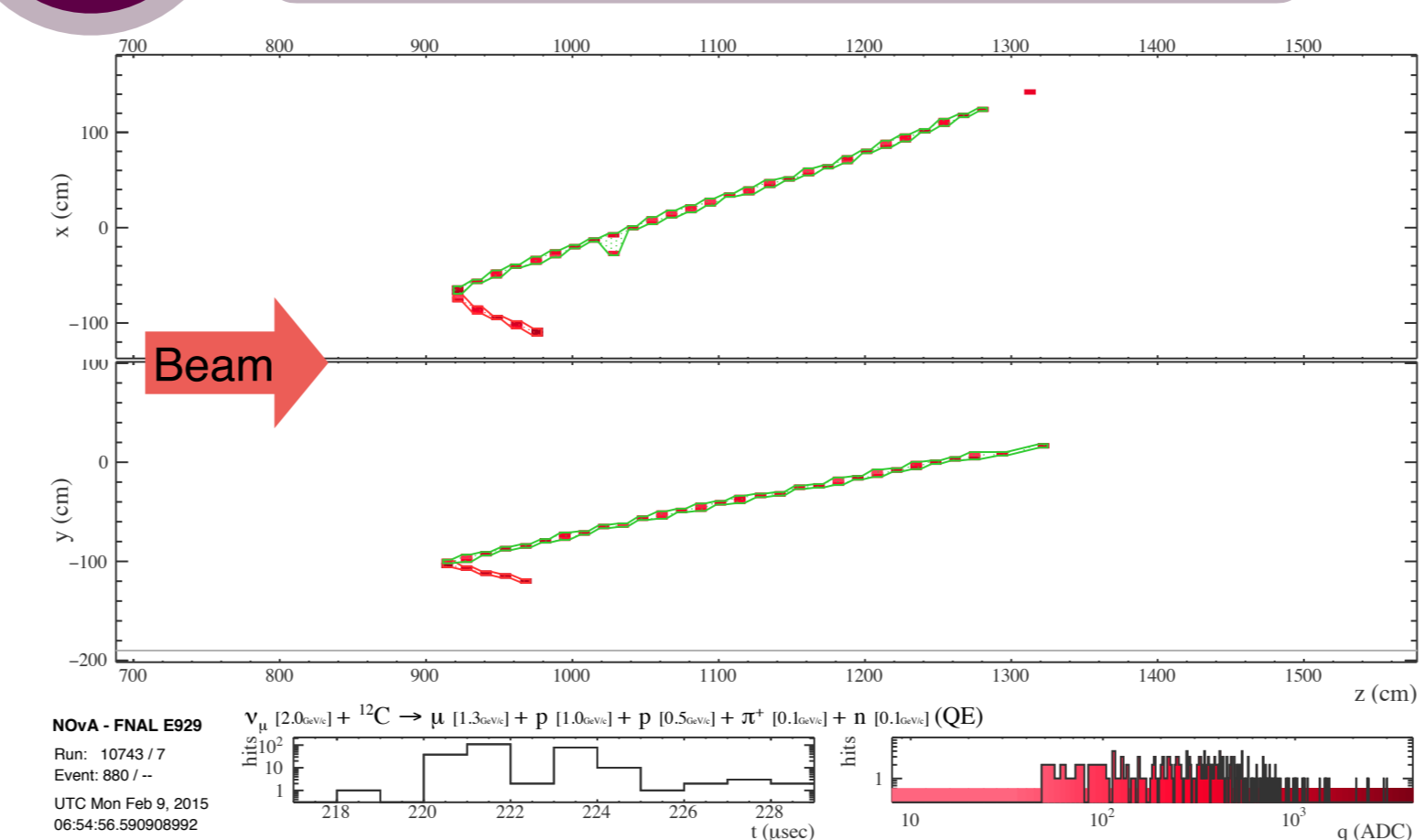
3 Adjustments to 2p2h model



- Multi-nucleon emission processes such as nucleon pair knockout via Meson Exchange Current are simulated using the Valencia MEC Model, for CC interactions.
- This is adjusted to match neutrino beam ND data in the true three-momentum transfer and energy transfer $(|q|, q_0)$ space by optimizing for the agreement of data and simulation in the 2D space of reconstructed visible hadronic energy and three momentum transfer.
- Weights are parametrized as two 2D gaussians and normalization of the base model
- 13 parameters fitted
- The same weights are used for neutrino and antineutrino beam simulation resulting in good agreement with data for both.



4 3D prongs



A simulated interaction in the ND with two 3D prongs: The 2D clusters of hits with the same color are matched between the two views to define a 3D prong.

