

Muon-neutrino charged-current inclusive cross-sections using the NOvA near detector

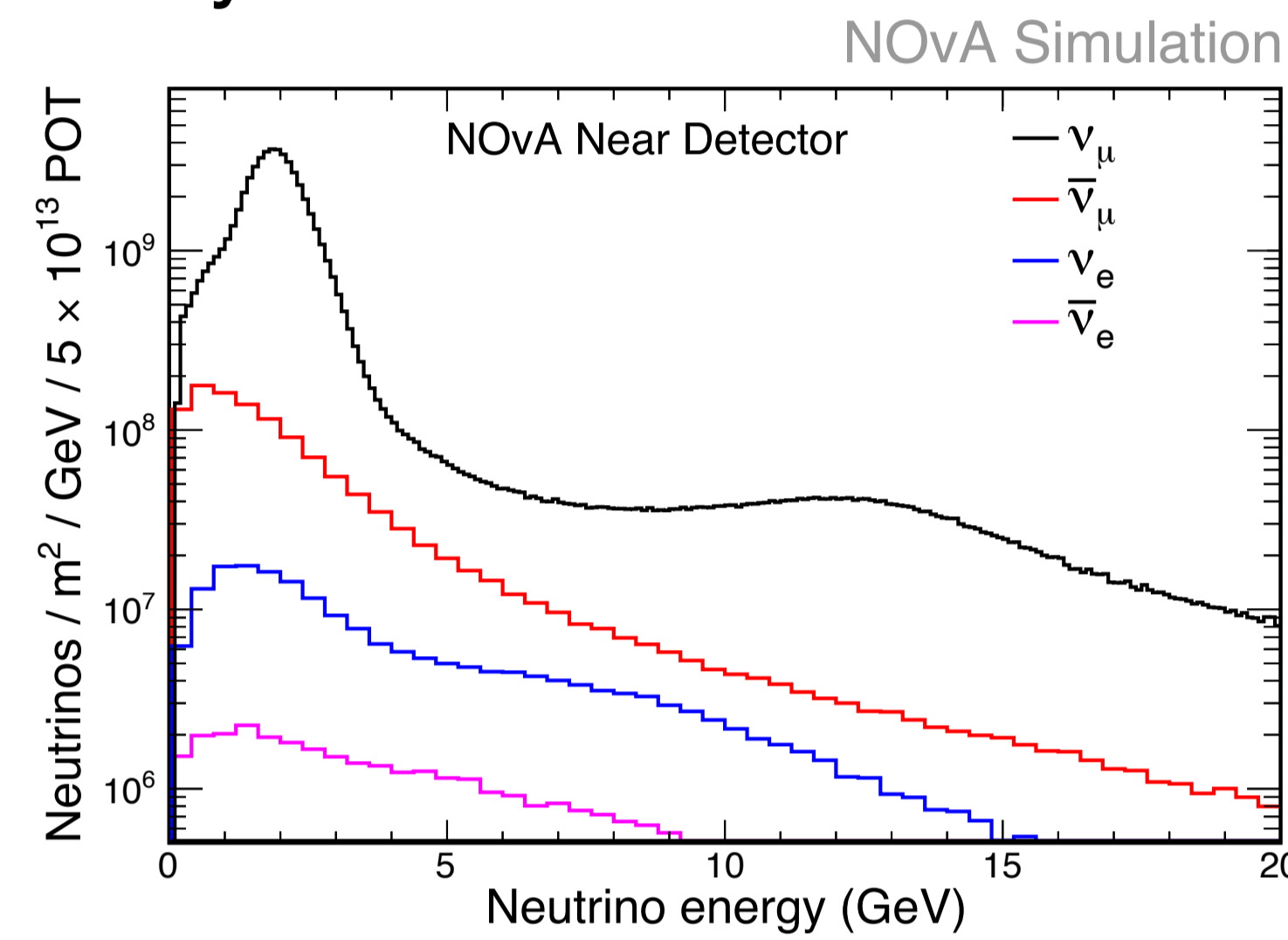


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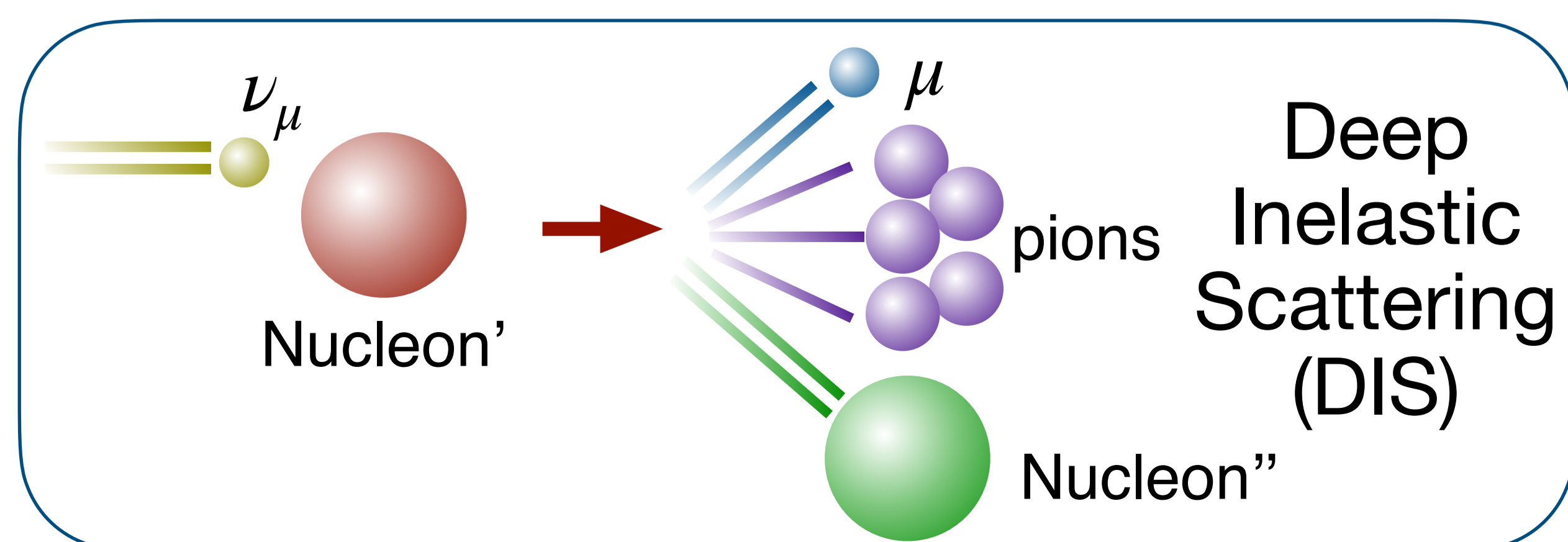
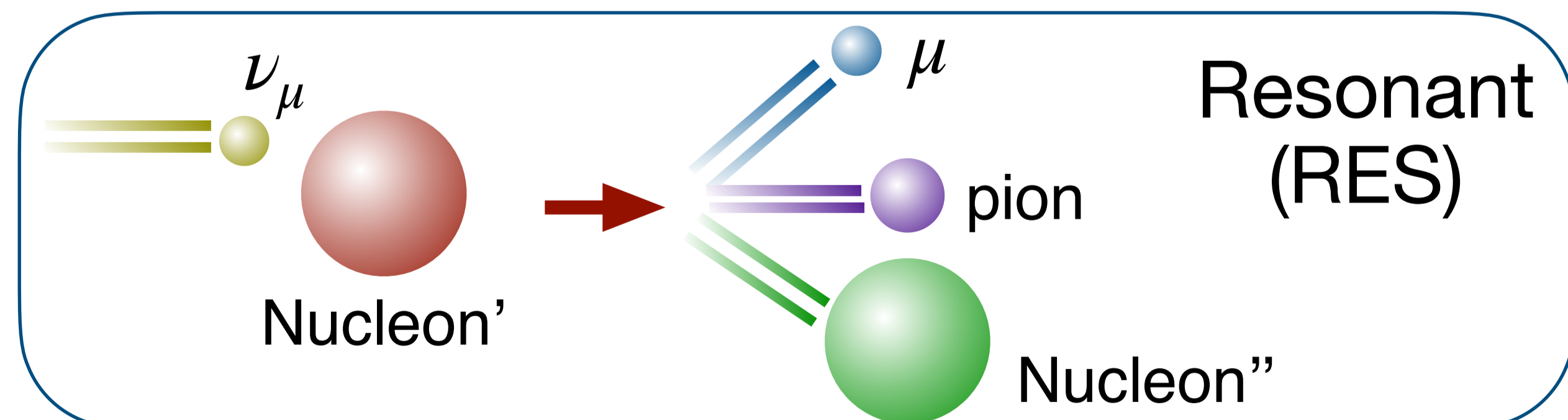
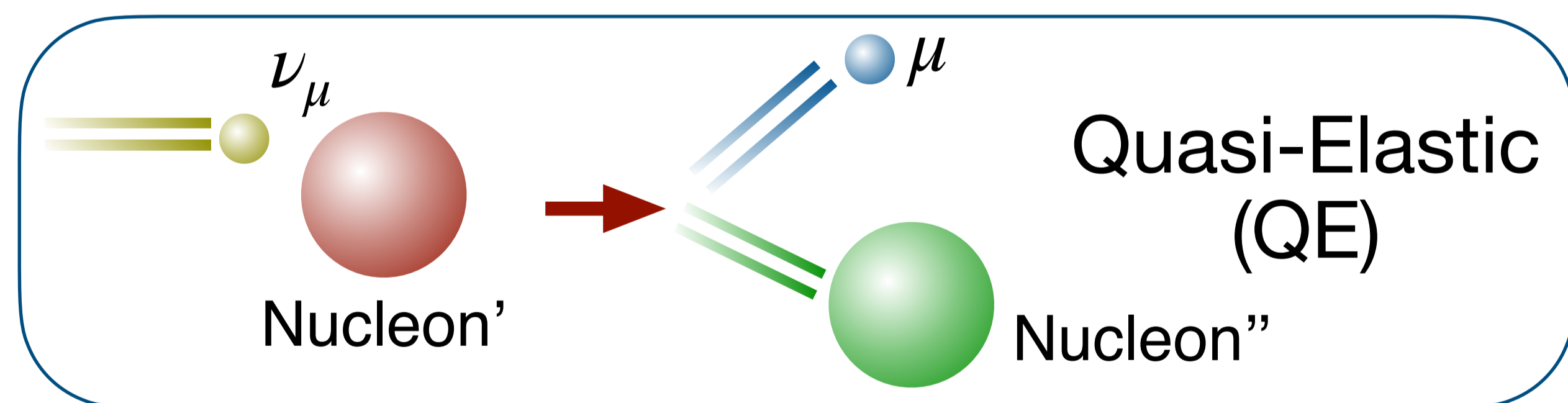
Cross-sections at NOvA

- NOvA is a long-baseline neutrino oscillation experiment
 - Studies 3-flavor ν oscillation, measures mixing, mass splitting, CP-Violation
- Cross-section measurements at NOvA
 - Major systematic uncertainty in oscillation measurements
 - Helps improve models
 - Near detector: high neutrino flux, functionally identical to far detector



Muon-neutrino charged-current inclusive

- ν_μ CC Inclusive - interacts with nucleus to produce a μ
 - Differentiate by the outgoing μ track
- Inclusive: all CC interaction modes / outgoing particles

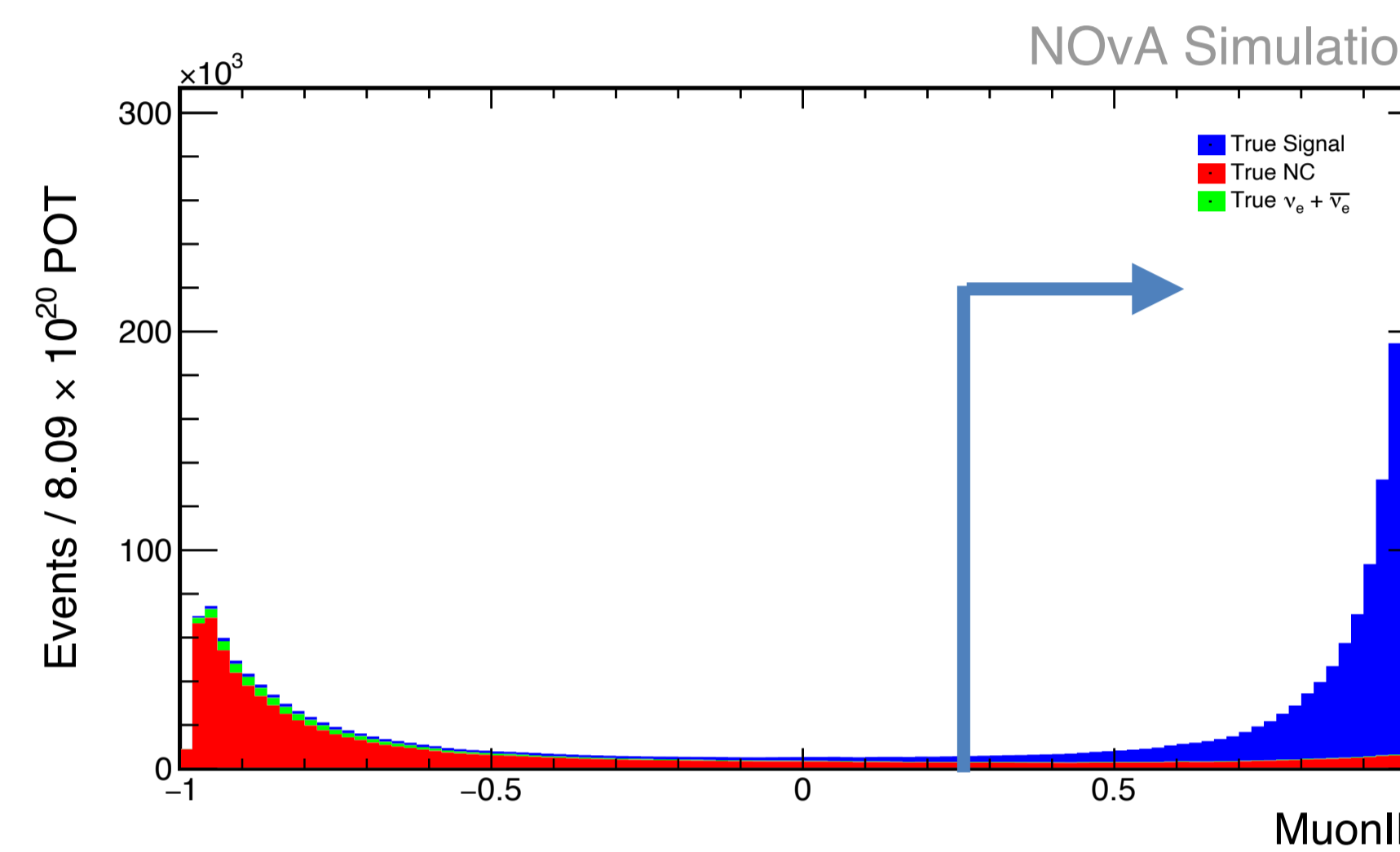


Muon Identification

- Muon tracks can be distinguished after reconstruction
- Select using boosted decision tree trained on:
 - The $\frac{dE}{dx}$ log likelihood, scattering log likelihood, $\frac{dE}{dx}$ in the last 10cm of track, and last 40cm of track
- Strong signal and background separation

Muon BDT ("MuoniD") trained on statistically independent Monte Carlo simulation

- ν_μ CC interactions (blue)
- ν_μ Neutral-current (red)
- $\nu_e/\bar{\nu}_e$ interactions (green)



Selection and measurement

- Pick out interactions with:
 - Reconstructed particle track with high MuoniD (> 0.24)
 - Vertex inside an optimized fiducial volume
 - All particles contained within the detector

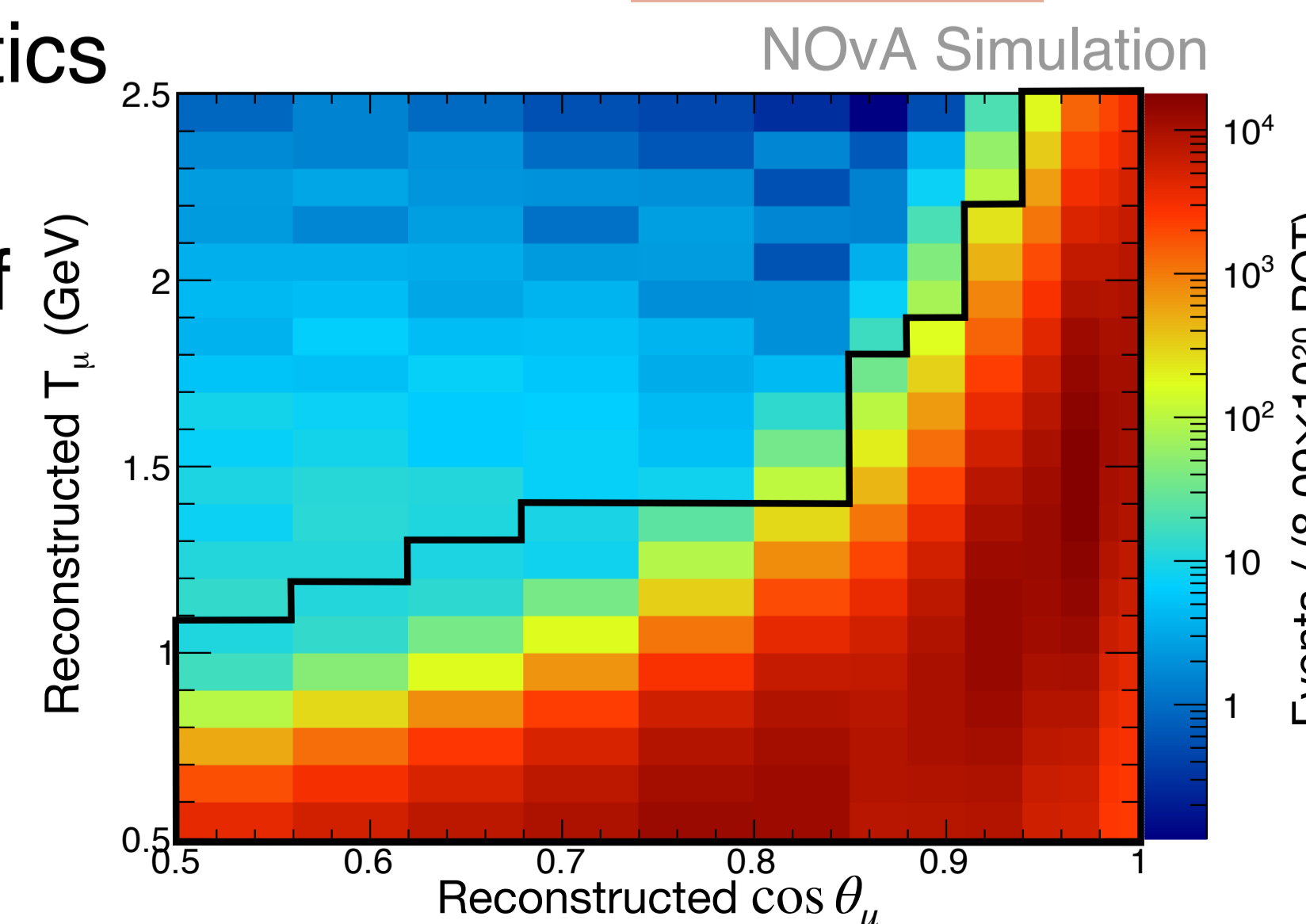
Cross-section Calculations

$$\left(\frac{d^2\sigma}{d\cos\theta_\mu dT_\mu}\right)_i = \sum_k \left(\frac{\sum_j U_{ijk}^{-1} (N_{ijk}^{\text{sel}}(\cos\theta_\mu, T_\mu, E_{\text{avail}})_j P(\cos\theta_\mu, T_\mu, E_{\text{avail}})_j)}{N_t \Phi \epsilon(\cos\theta_\mu, T_\mu, E_{\text{avail}})_{ik} \Delta\cos\theta_{\mu_i} \Delta T_{\mu_i}} \right)$$

- Unfold from detector observation into true variables
 - Iterative unfolding in 3D (Bayesian): $\cos\theta_\mu, T_\mu, \text{Available Energy (hadrons)}$
 - Perform purity, efficiency corrections (also in 3D)
 - Project to μ kinematics
- Final cross-section from ν flux, number of target nucleons in fiducial volume

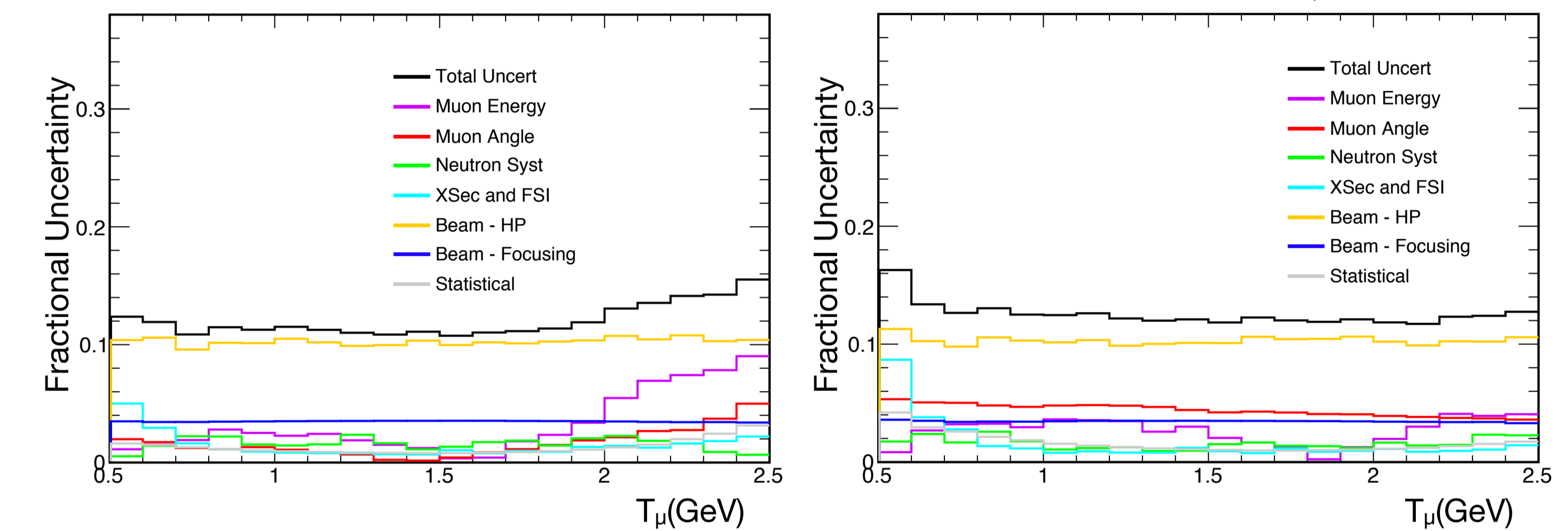
Shown is a projection of event count from 3D into μ kinematics

Black outline shows accepted region for this analysis



Uncertainties

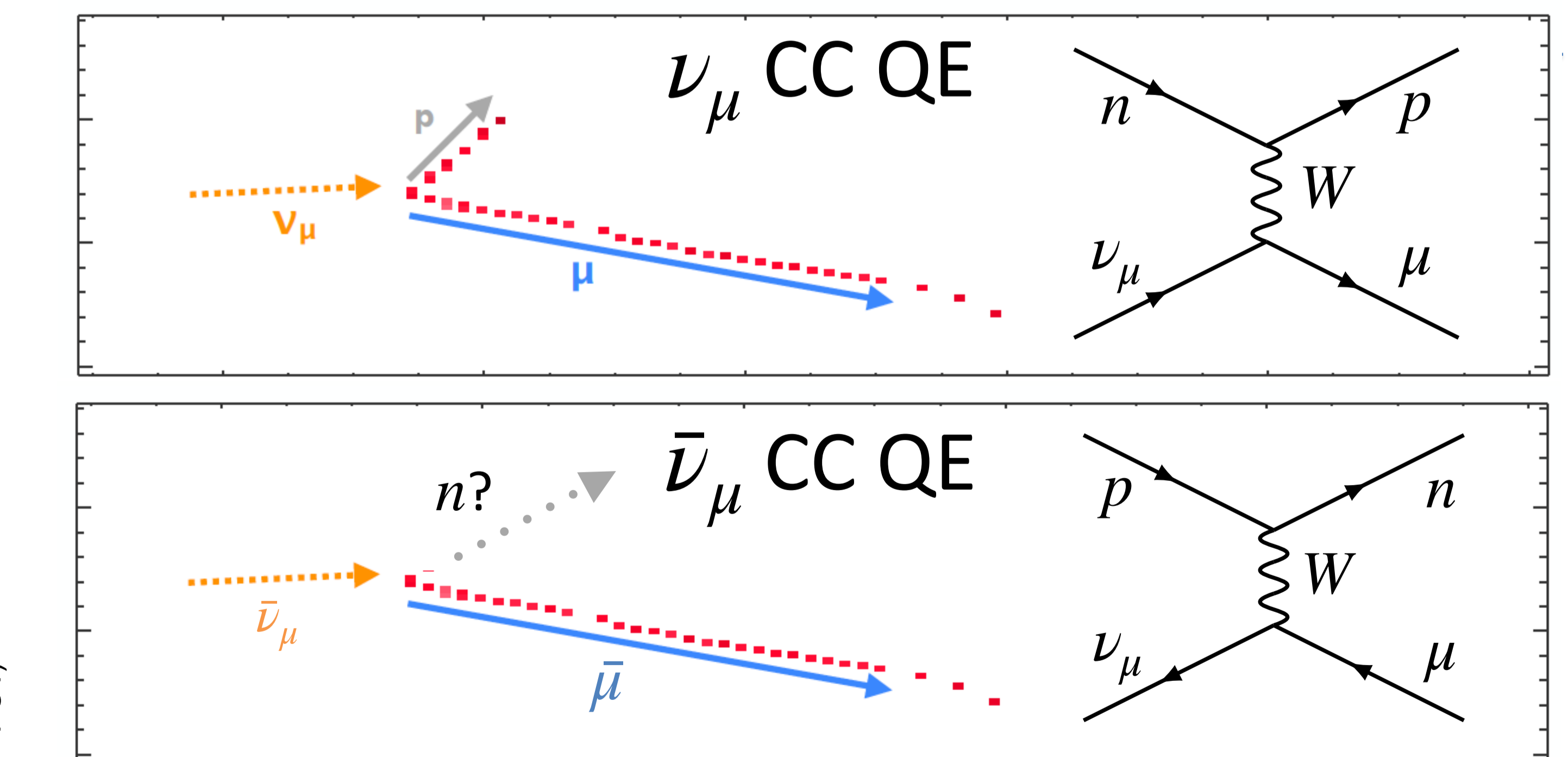
- Measurement is systematics-limited
- Systematically shifted samples undergo complete cross-section calculation and unfolding
 - Construct full bin-to-bin covariance matrix
- Leading uncertainties from beam
 - $0.96 < \cos(\theta_\mu) < 0.98$
 - $0.99 < \cos(\theta_\mu) < 1.00$



Cross-section Results

- Full results are presented by Linda Cremonesi **Cross-section measurements with NOvA** (Neutrino Interactions II Session 6/23/2020)
- Data results are compared against major neutrino generators: GENIE, GiBUU, NEUT, and NuWro

Anti-muon-neutrino CC Inclusive



- Next up: anti-muon-neutrino CC Inclusive cross-section measurement, $\nu_\mu/\bar{\nu}_\mu$ CC Inclusive ratio
- Energy hard to reconstruct for quasi-elastic
- High ν_μ contamination when beam is in $\bar{\nu}$ mode