



Towards a ν_μ CC exclusive cross section measurement with one proton and one muon in the final state at the NOvA near detector



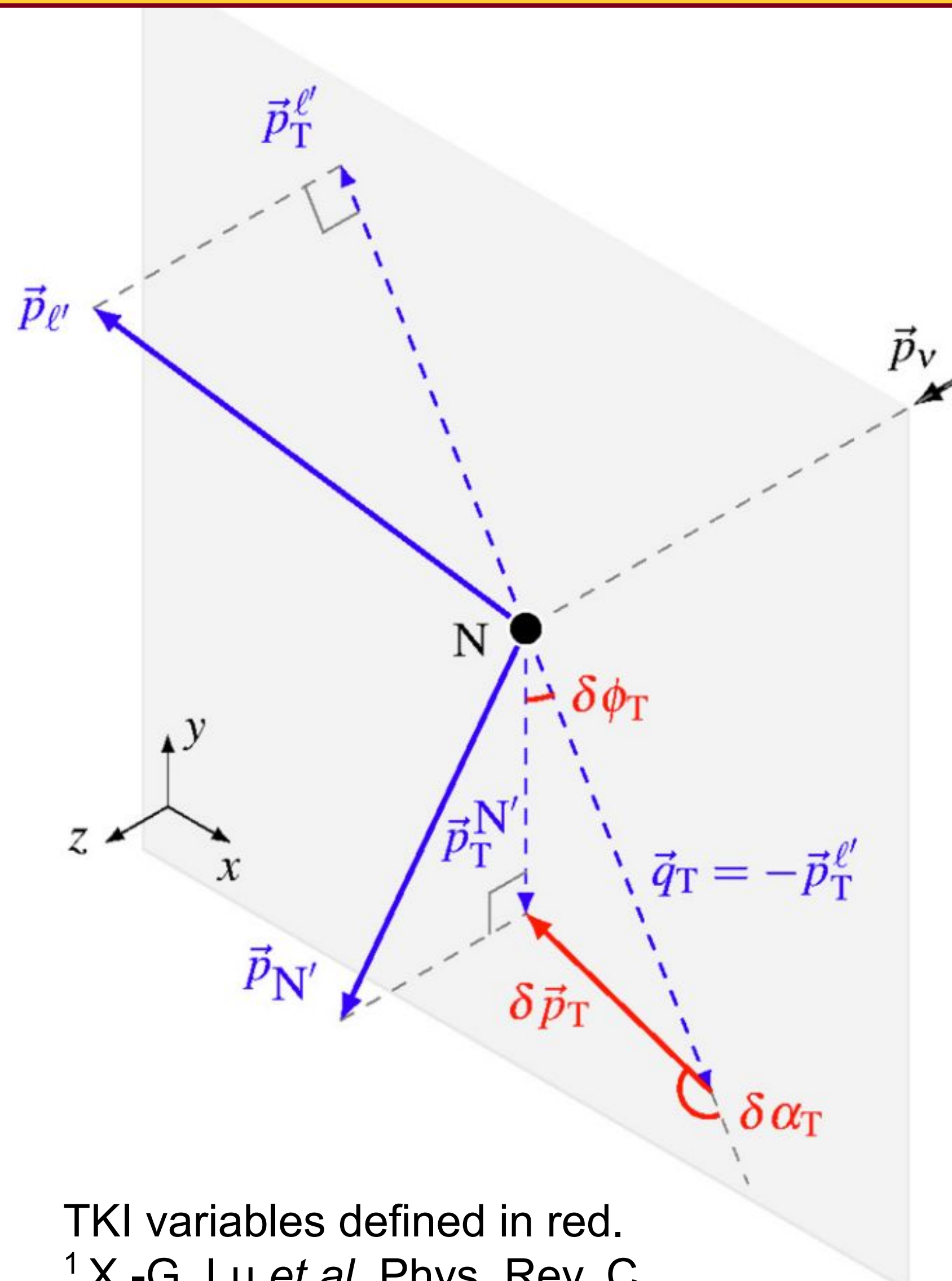
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FERMILAB-POSTER-26-0046-PPD

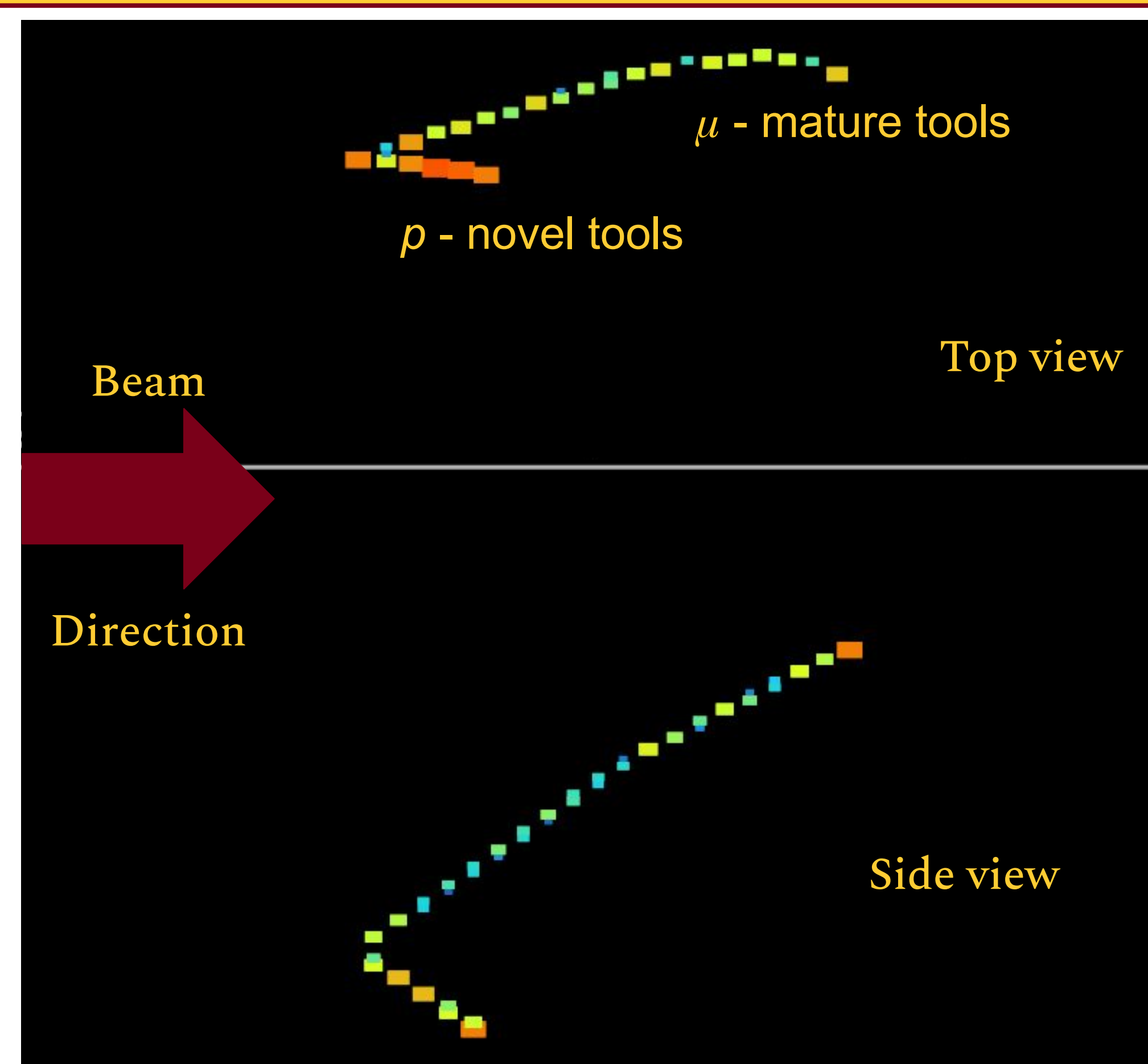
Motivation

- Upcoming long-baseline ν experiments like DUNE first to be systematics-limited
- Neutrino interaction uncertainties expected to be some of the largest contributors
- Nuclear effects especially challenging
- Transverse kinematic imbalance (TKI) variables (right) sensitive to nuclear effects¹
 - Fermi motion
 - Multinucleon effects
 - Final state interactions



$1\mu + 1p$ events in NOvA

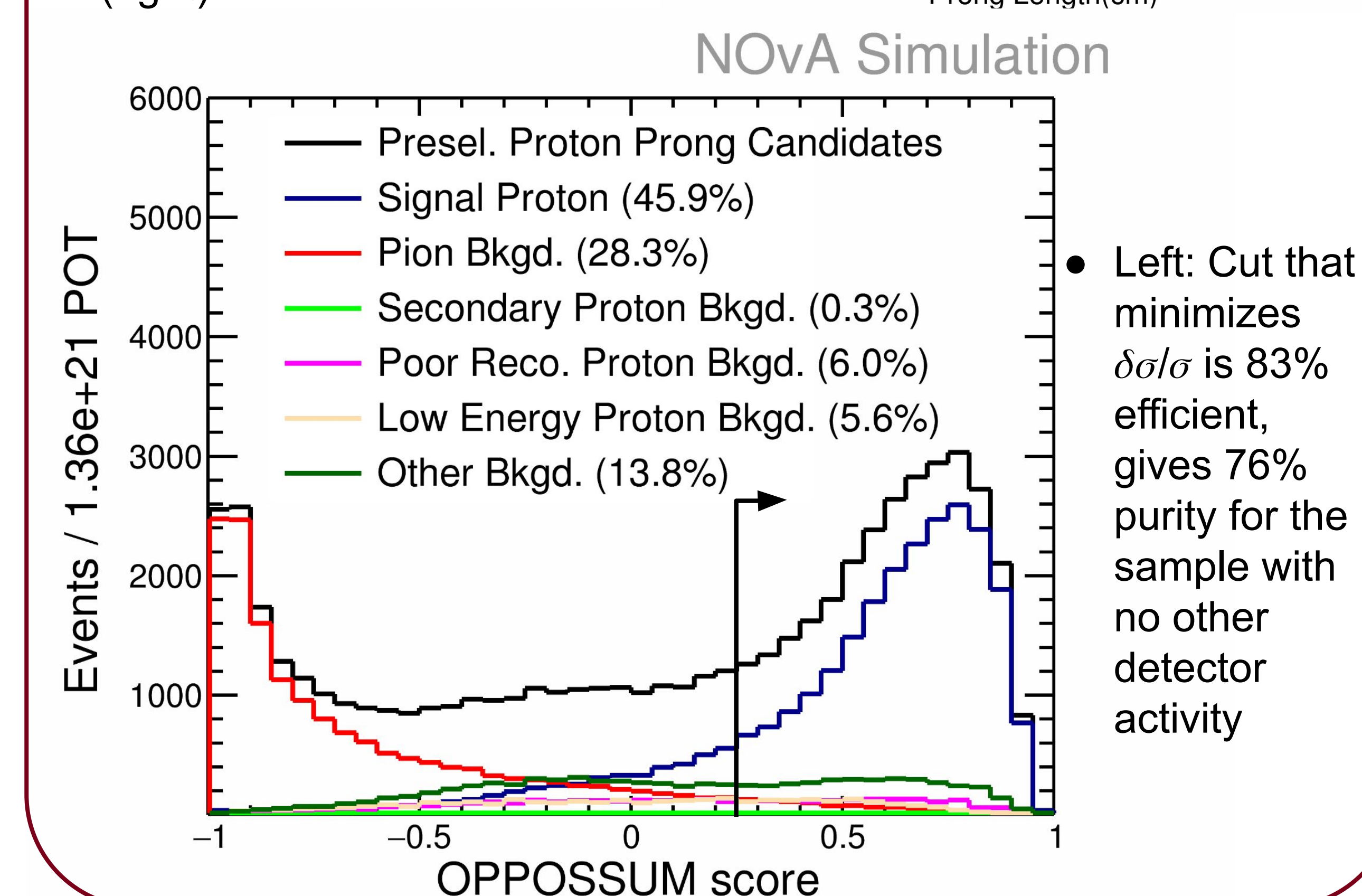
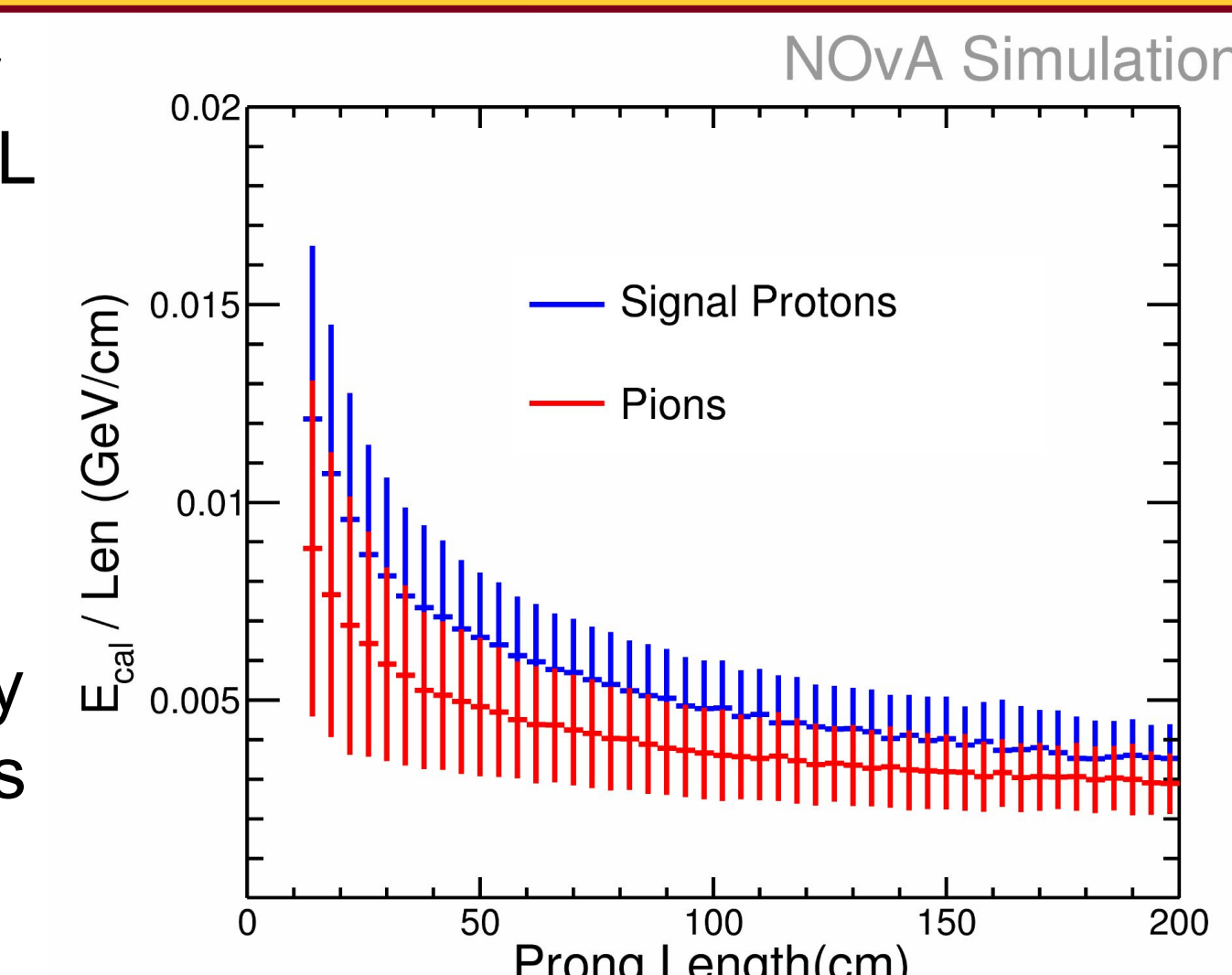
Right: NOvA event display of a simulated neutrino event with a $1\mu+1p$ exclusive final state. This measurement will be the first NOvA analysis to fully reconstruct a proton



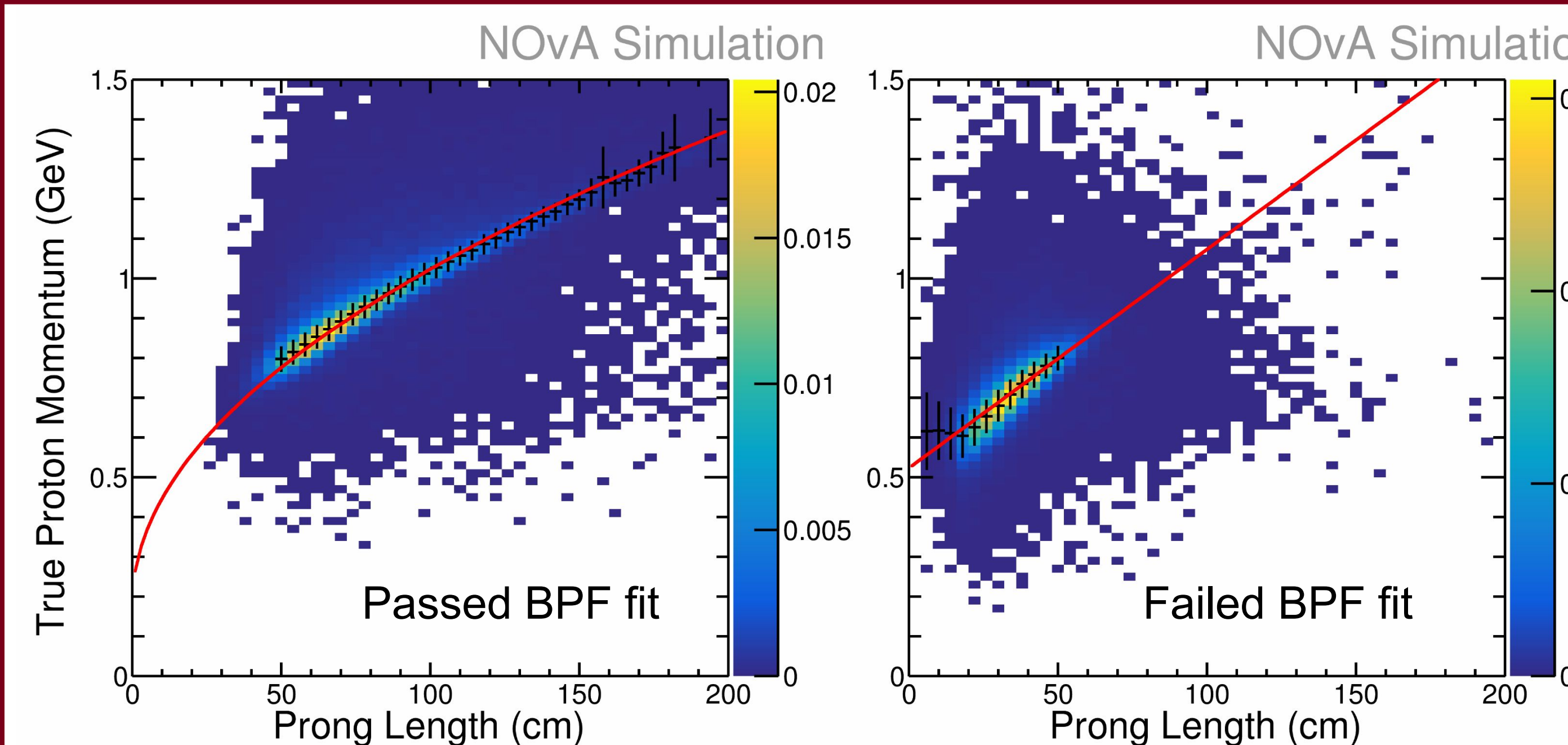
- Full kinematic reconstruction required for TKI variables
- Two particle final states are cleanest
- Requires new reconstruction and particle ID tools
- Expected proton track: > 4 hits, 20-50cm

Proton identification methods

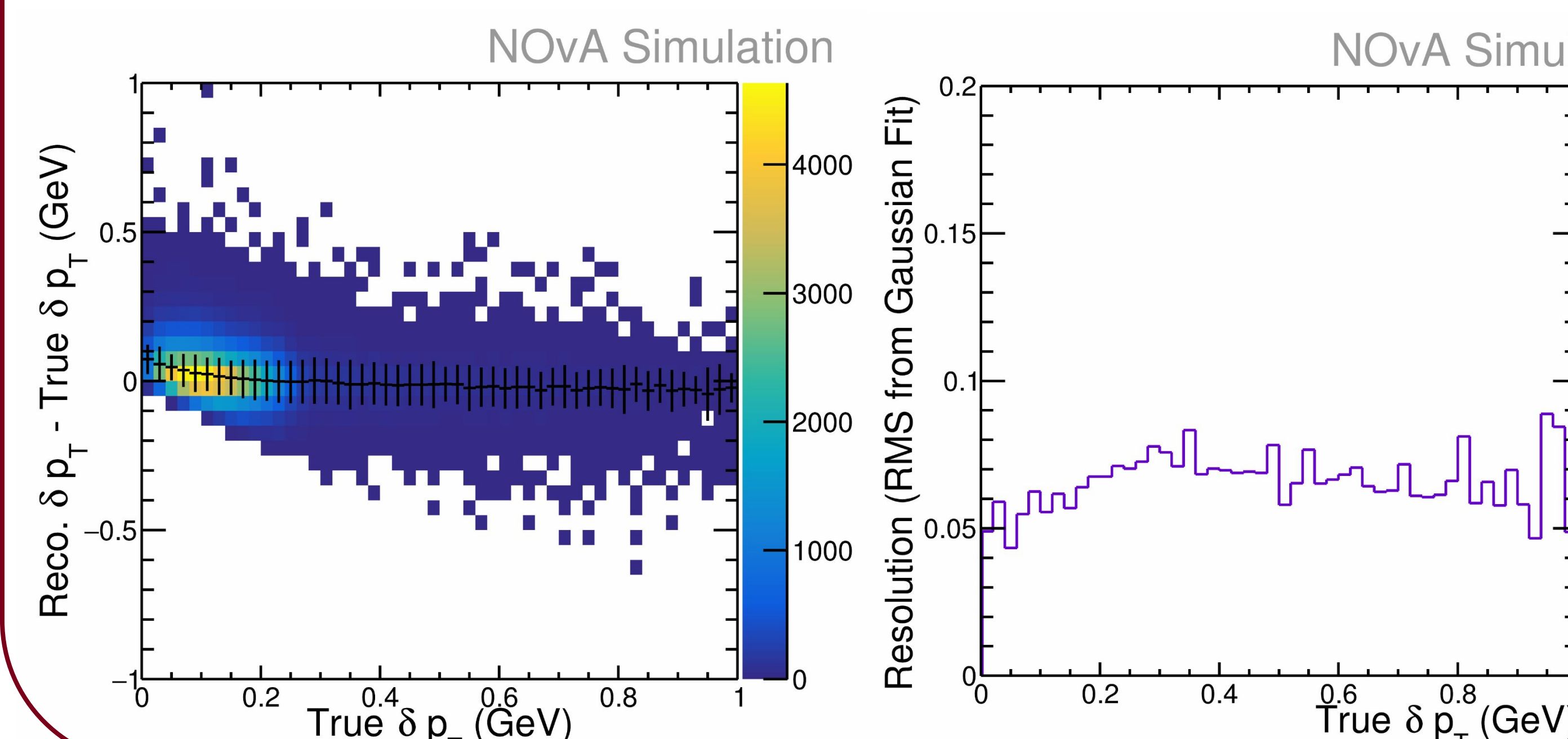
- One Proton Prong Optimizer for Selecting Signal Using ML (OPPOSSUM) is a BDT trained on single particle ID CVN scores and dE/dX variables for tracks from preselected events
- Includes metrics that quantify how similar a track's dE/dX is to that expected for a proton (right)



Proton reconstruction methods

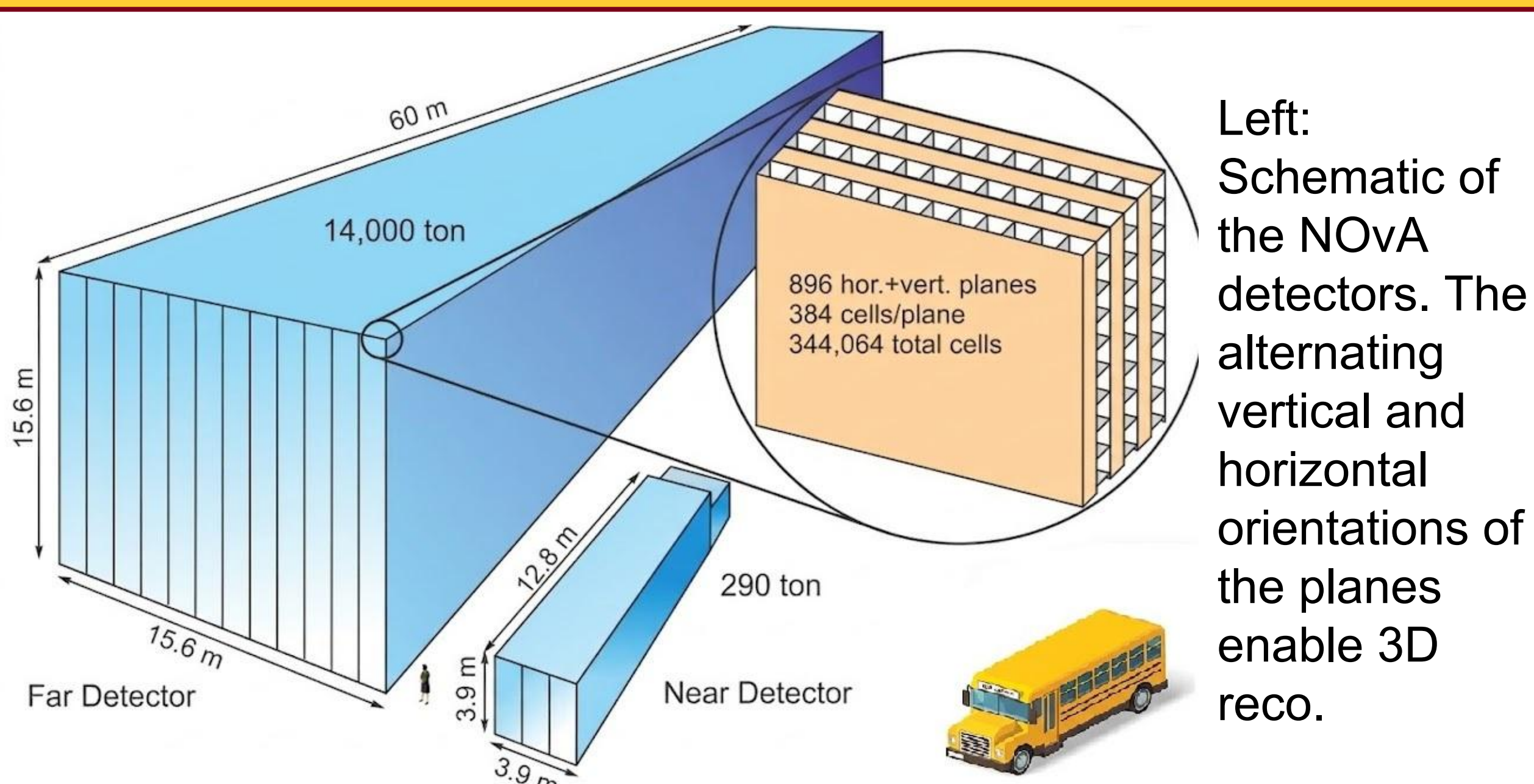


- Proton 3-momentum never measured before in NOvA
- Left: Two samples are distinguished by success or failure in BPF (multiple Coulomb scatter) fit
- Shorter tracks more likely to fail



- Left: Combined with mature muon reconstruction methods, the proton estimator enables δp_T measurement to 50-80 MeV precision

The NOvA Experiment



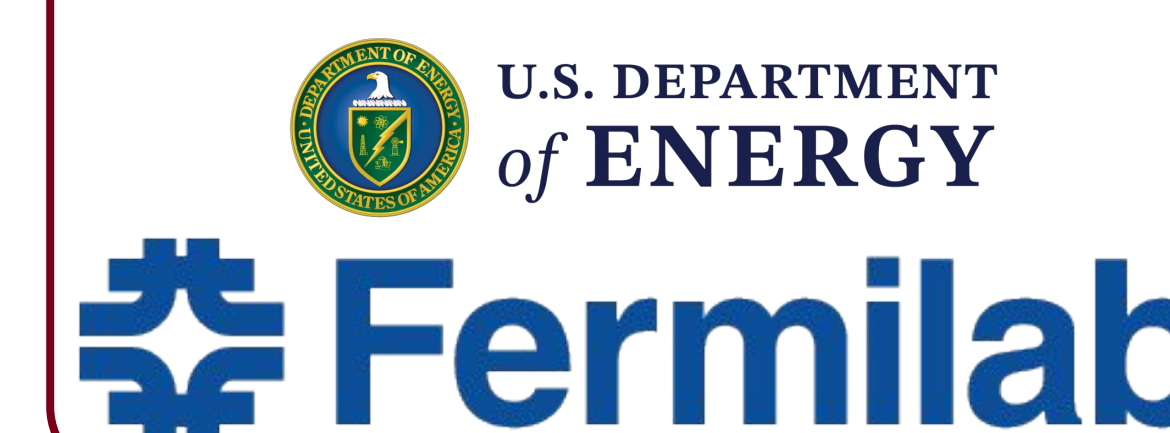
Left: Schematic of the NOvA detectors. The alternating vertical and horizontal orientations of the planes enable 3D reco.

- Long-baseline neutrino experiment at Fermilab that studies neutrino oscillations via electron neutrino appearance and muon neutrino disappearance
- Measures NuMI beam neutrinos using a near detector ~ 1 km from the beam target, and a far detector 810 km in Ash River, MN
- Two functionally identical segmented liquid scintillator detectors (above) enable full 3D kinematic reconstruction
- ND dataset includes ~ 6.5 million ν_μ CC events with $\langle E_\nu \rangle = 2$ GeV

Summary and future work

- NOvA is capable of making cross section measurements of ~ 2 GeV neutrinos due to its proximity to the NuMI target (~ 6.5 million ν_μ CC events) and its segmented liquid scintillator detector.
- Cross sections in TKI variables are sensitive to nuclear effects. NOvA can probe these via the $1\mu + 1p$ exclusive final state.
- Proton reconstruction in NOvA has recently been made possible thanks to a new proton momentum estimator and proton ID BDT.
- Currently exploring viability of semi-exclusive sideband for a data-driven background estimate.

Acknowledgement



This document was prepared by NOvA using the resources of the Fermi National Accelerator Laboratory (Fermilab), a U.S. Department of Energy, Office of Science, Office of High Energy Physics HEP User Facility. Fermilab is managed by Fermi Forward Discovery Group, LLC, acting under Contract No. 89243024CSC000002.