# Protons in the NOvA Test Beam

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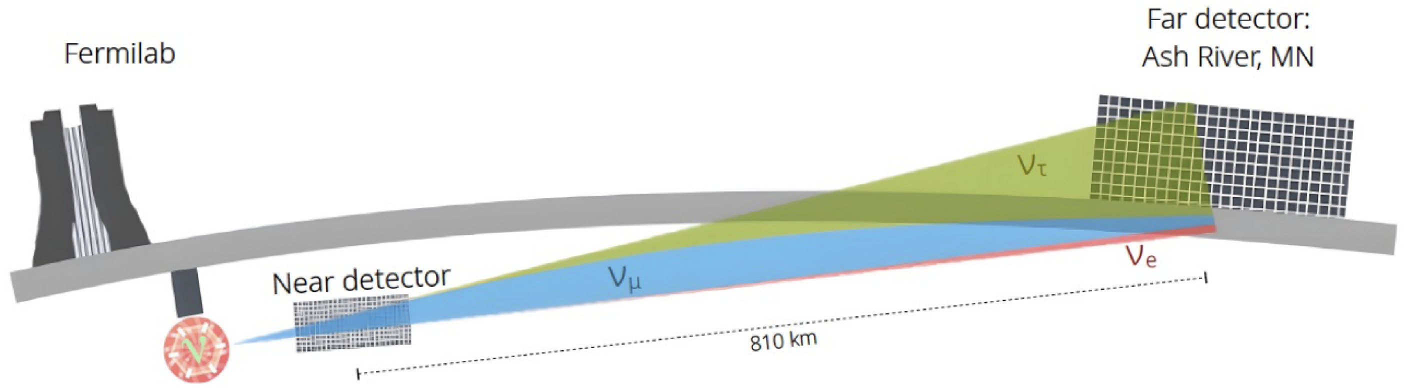
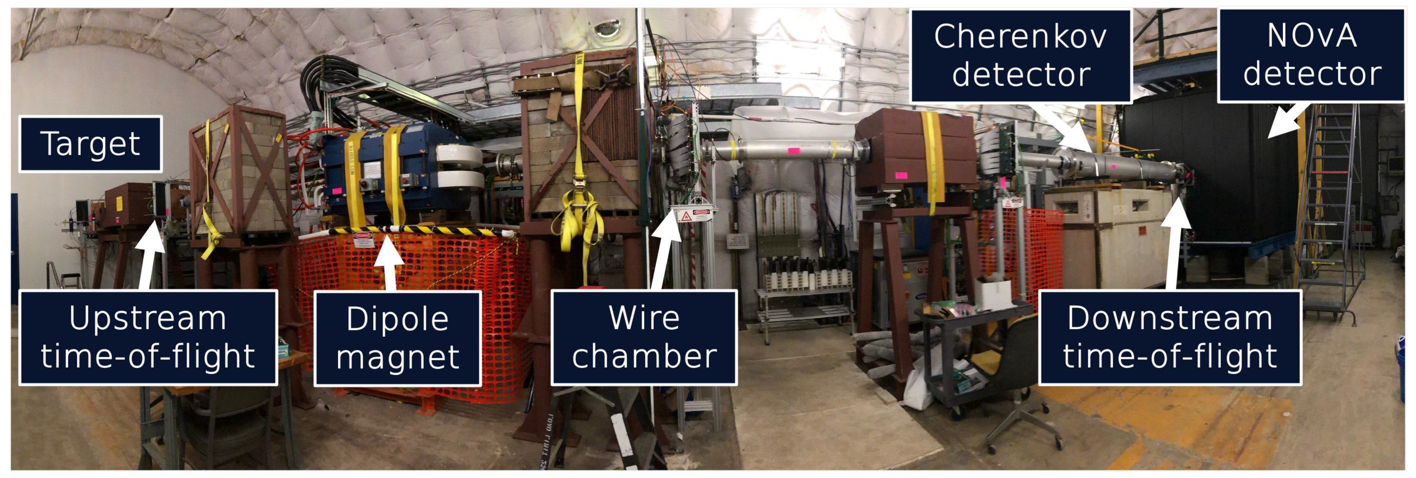
## 1 The NOvA Experiment

- NOvA: NuMI Off-Axis $\nu_e$ Appearance experiment
- Narrow-band neutrino beam peaked at 1.8 GeV
- Long-baseline accelerator neutrino oscillations
- Segmented liquid scintillator Near (0.3 kton) and Far (14 kt) detectors



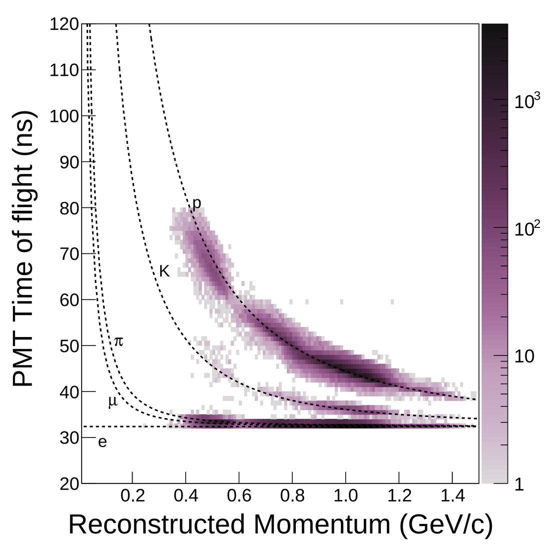

## 2 The NOvA Test Beam Experiment

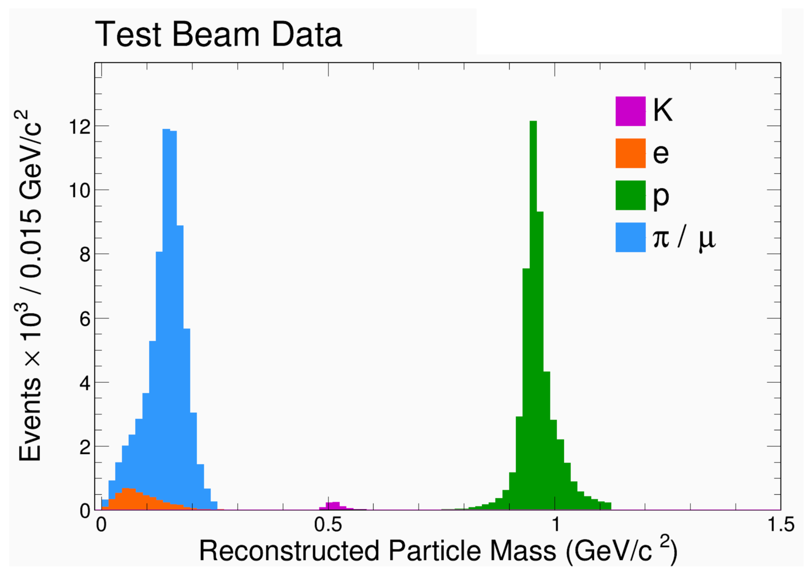
- Scaled-down NOvA detector (a tenth of Near Detector size)
- Beam composition: $e, \mu, \pi, K, p$
- Particle momentum range: 0.4–1.5 GeV/c
- NOvA test beam ran from 2019 to 2022 at Fermilab Test Beam Facility




## 3 Proton Selection

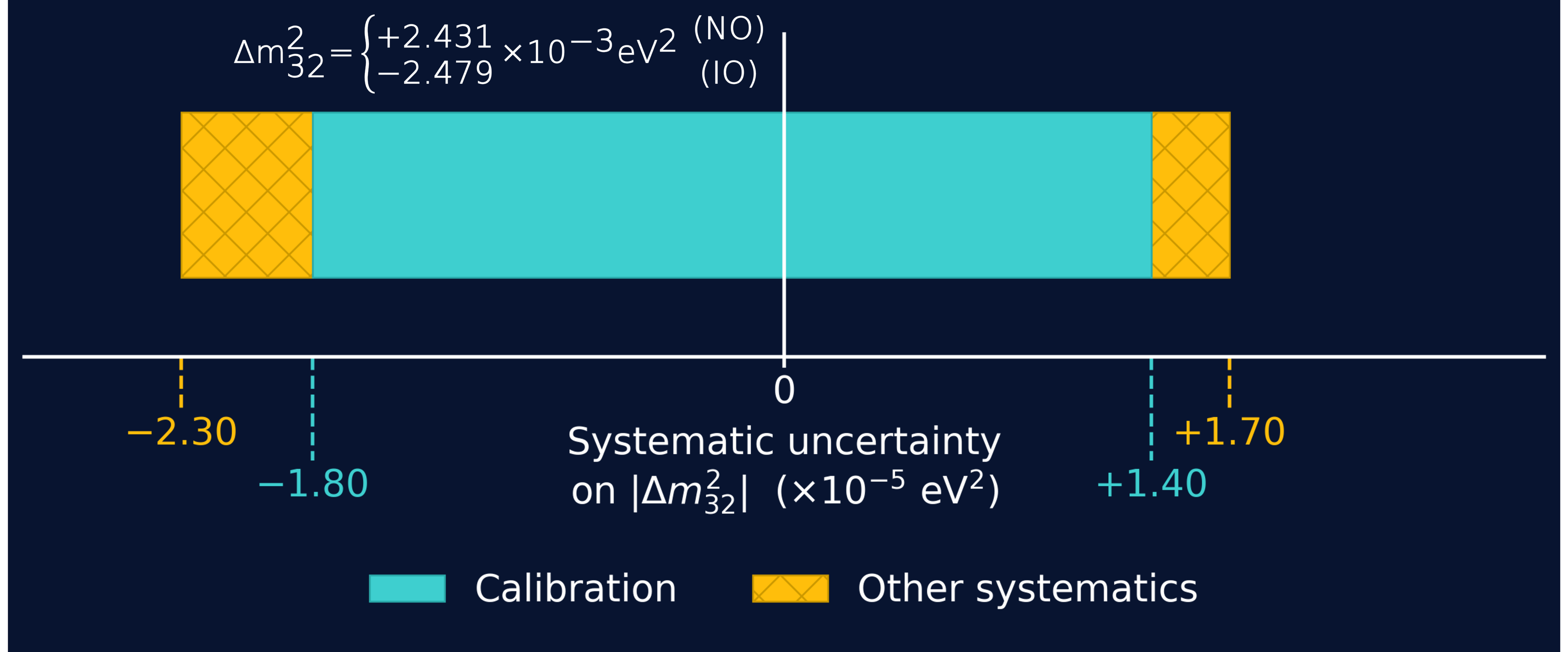
- Time-of-flight (ToF) measured by scintillator detectors
- Momentum measured by wire chambers either side of a bending magnet
- ToF vs. momentum separates protons from lighter (faster) particles
- Unique to protons: reconstructed mass from ToF and momentum



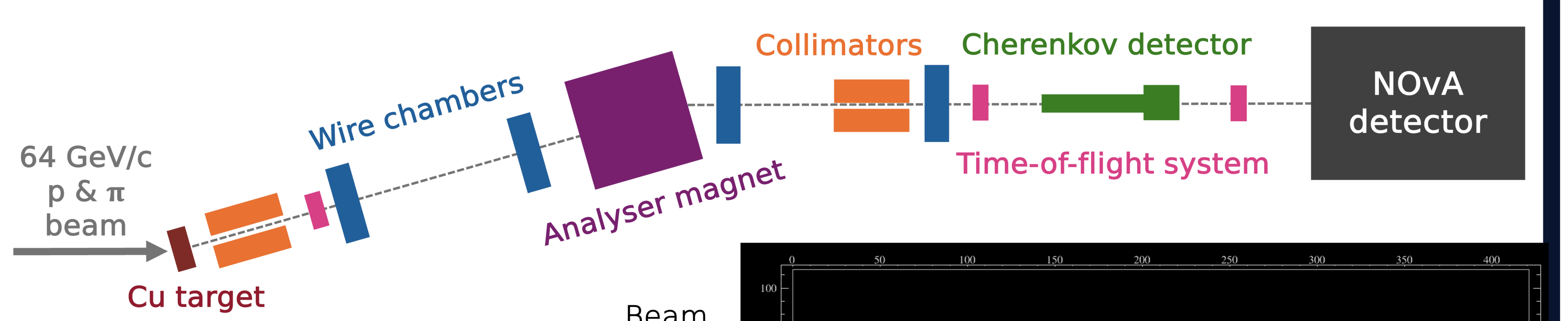

Using **protons** in the NOvA Test Beam to **reduce systematic uncertainties** in NOvA analyses.

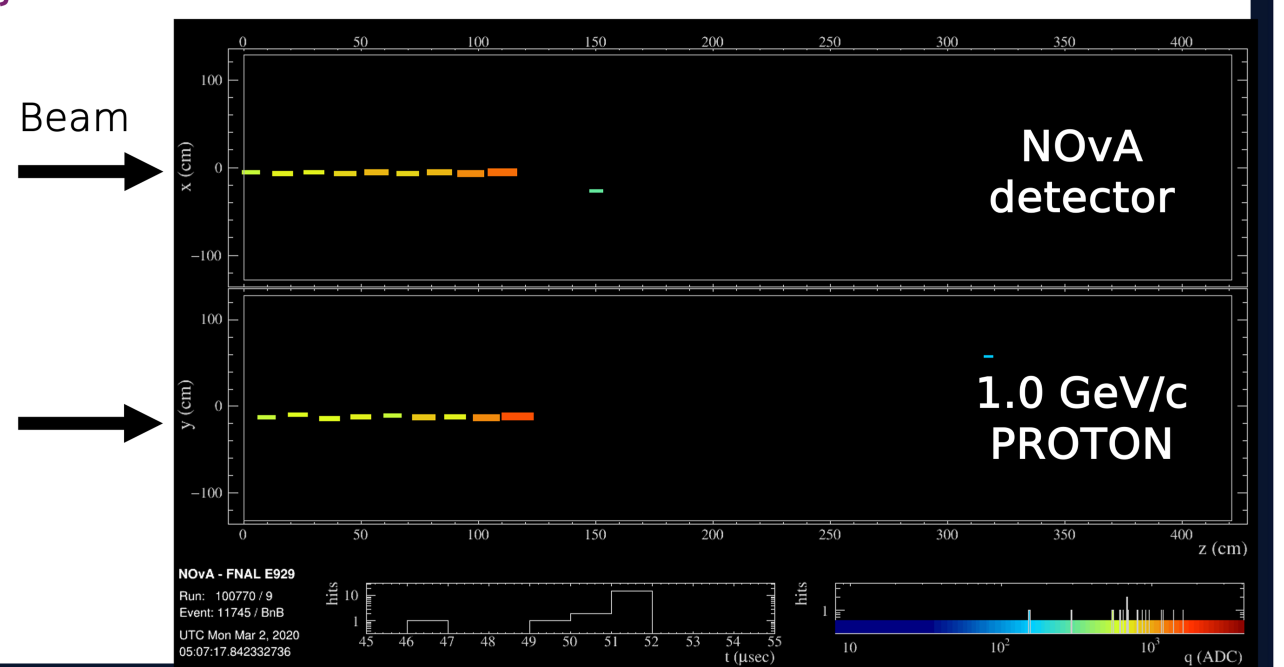
**Calibration** is the dominant systematic on $|\Delta m^2_{32}|$ — the NOvA Test Beam targets it directly.




Adapted from [1]

### Beamline for the NOvA Test Beam Experiment



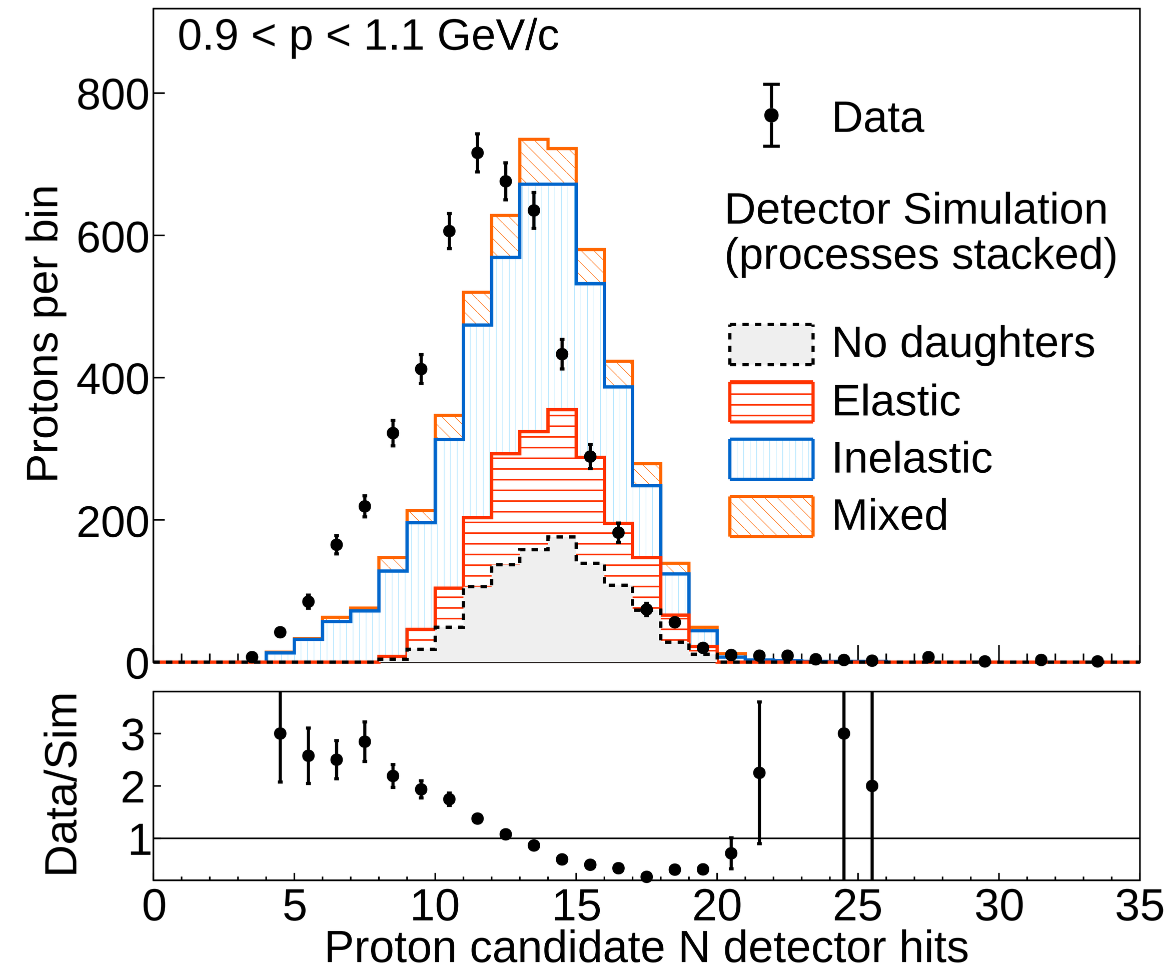




Reference

[1] Precision Measurement of Neutrino Oscillation Parameters with 10 Years of Data from the NOvA Experiment

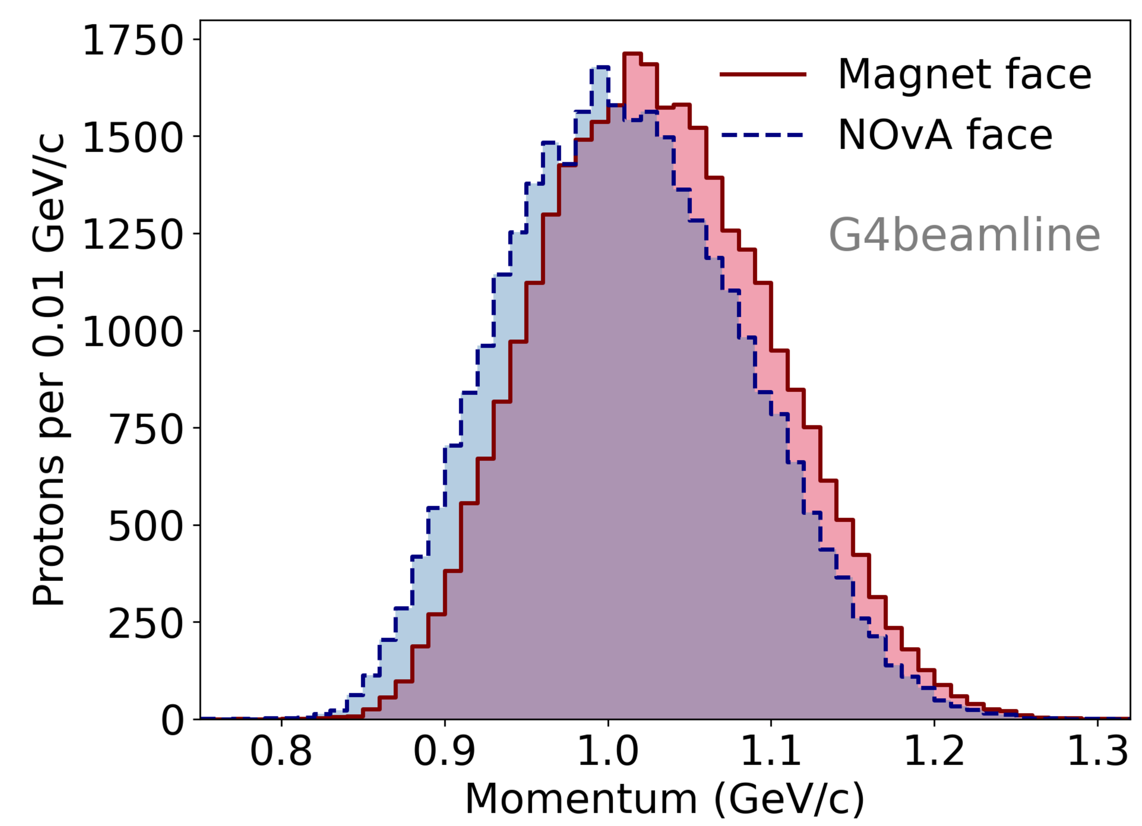
## 4 Protons in the NOvA Test Beam Detector

- Plot: number of hits in the NOvA test beam detector
- Data-sim disagreement: need a beamline energy loss correction, and light model parameter adjustment (e.g. Birks' coefficient)




## 5 Beamline Energy Loss Correction

- Momentum reconstructed from bend angle through the magnet
- Particles lose energy traversing material between the **magnet** and the **NOvA detector**
- Momentum correction function needed to account for energy losses




## 6 Ongoing work

- Apply beamline energy loss correction to proton sample
- Birks' coefficient measurement using protons that stop in the detector
- Proton energy response measurement
- **Apply proton energy scale uncertainty to NOvA analyses**

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