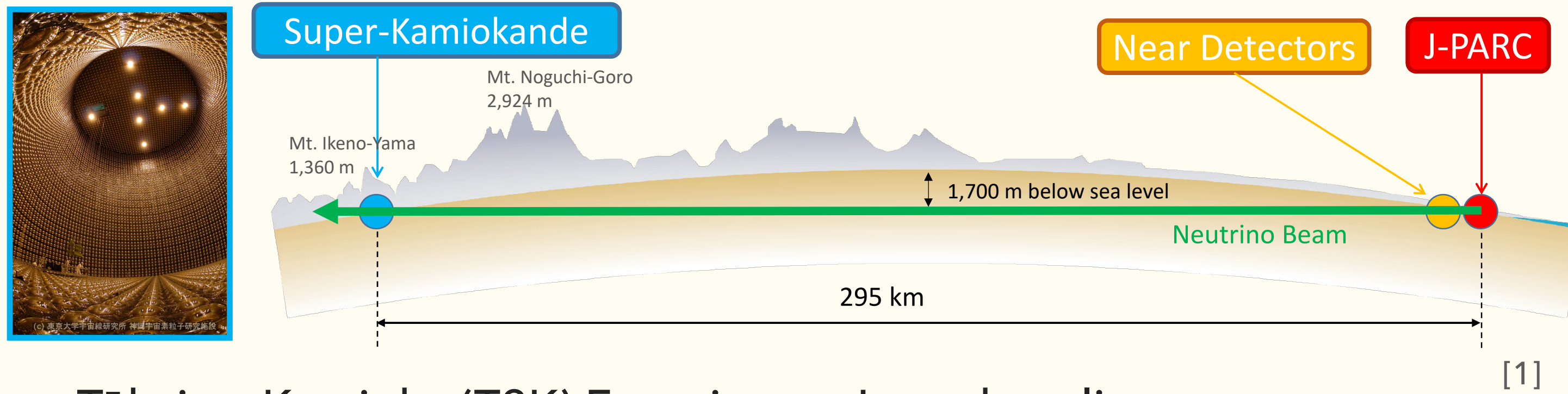


The T2K Experiment

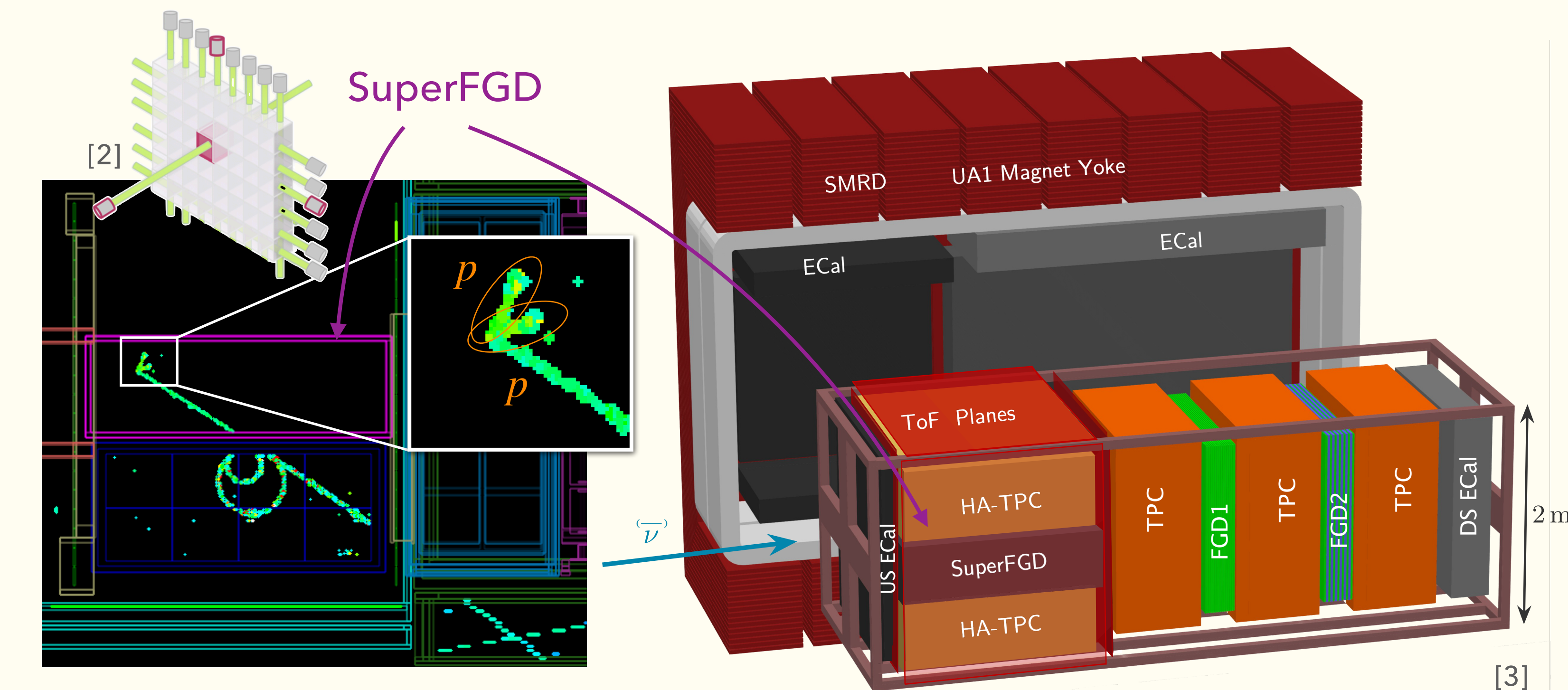


- Tōkai-to-Kamioka (T2K) Experiment: Long-baseline neutrino oscillation experiment in Japan
- Accelerator at J-PARC produces beam of ν_μ or $\bar{\nu}_\mu$ → measure $\bar{\nu}_\mu$ & $\bar{\nu}_e$ at Super-Kamiokande, 295 km away
- Sensitive to leptonic CP violation, Δm_{23}^2 , $\sin^2(\theta_{23})$

The Near Detector Upgrade

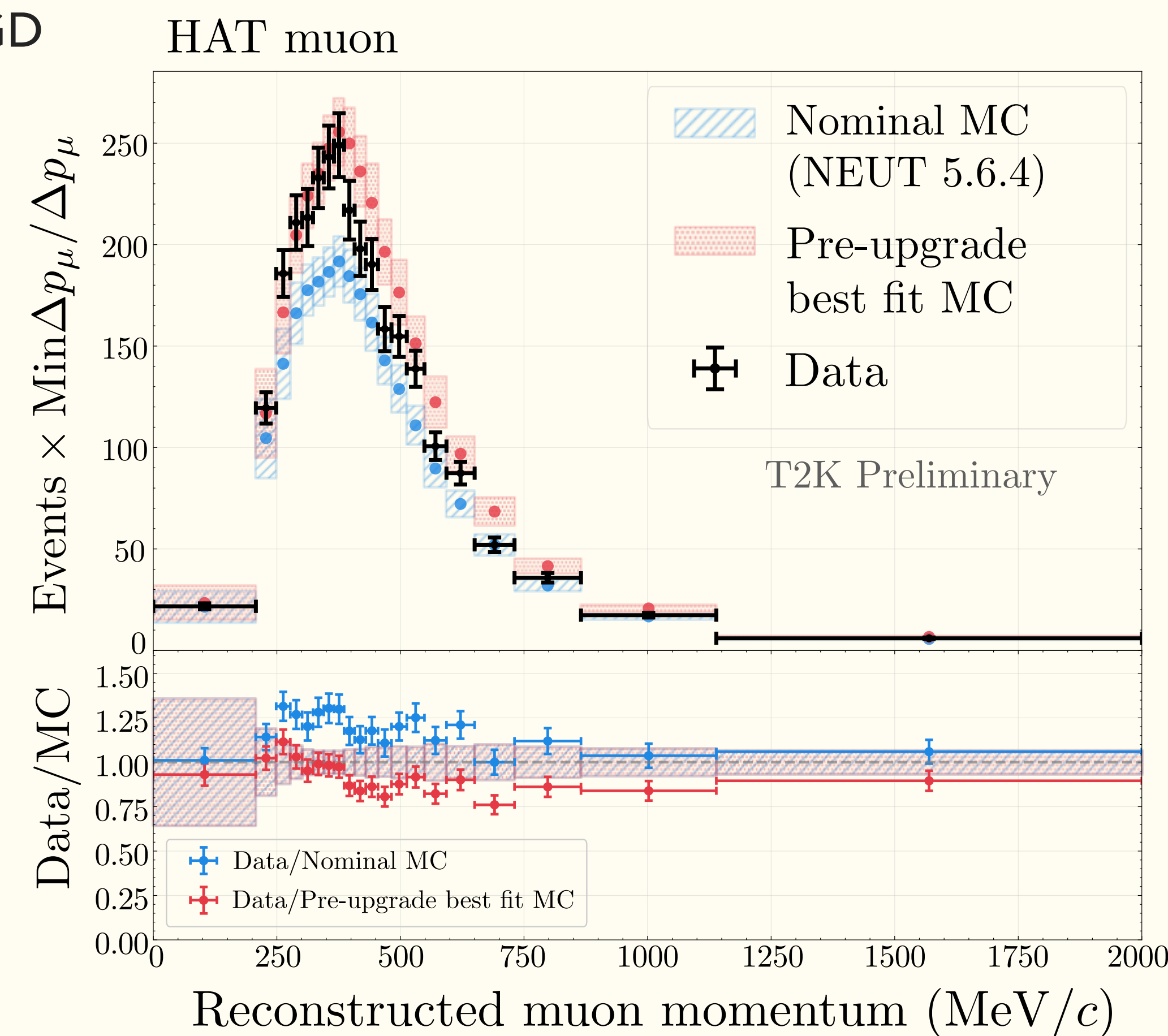
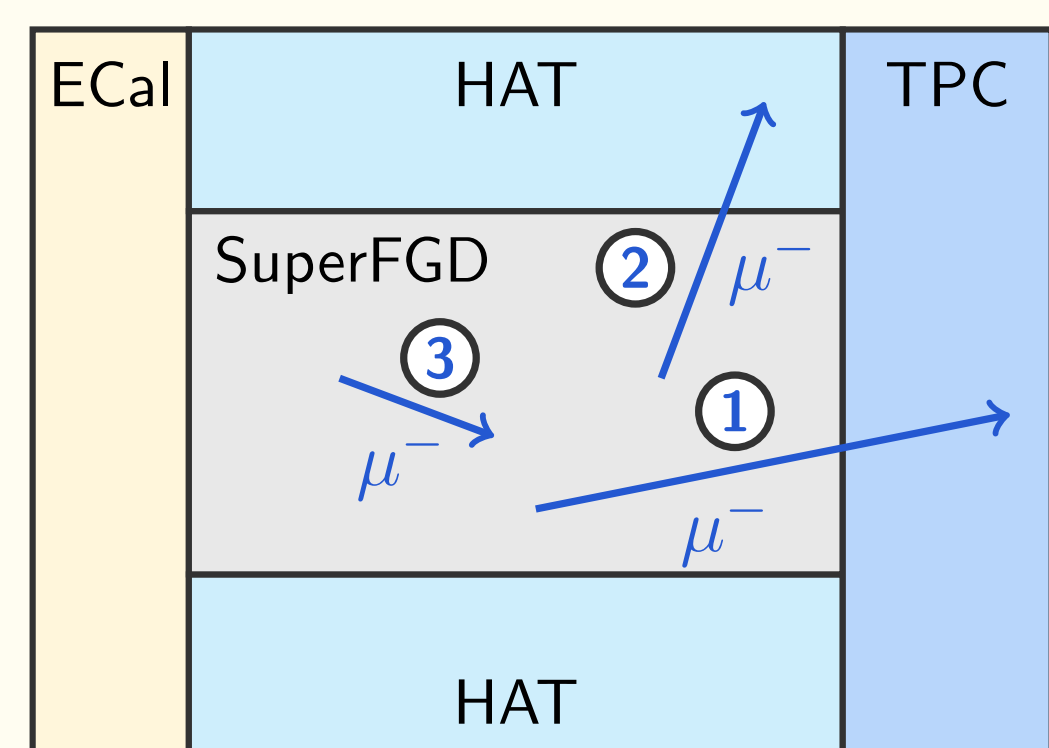
- T2K near detector (ND280): Constrains neutrino flux and interaction cross sections

$$N_e^{SK}(E_\nu) = P(\nu_\mu \rightarrow \nu_e) \sigma(E_\nu) \Phi_{\nu_\mu}(E_\nu) \varepsilon(E_\nu)$$
 - Reduces systematic uncertainties on oscillation parameters
- Upgrade completed in 2024, now taking data
 - SuperFGD: Active target made of nearly two million 1 cm³ plastic cubes with 3D readout
 - High-angle TPCs (HATs): Detect high-angle tracks for more isotropic acceptance
 - Time of Flight planes (ToF): Scintillator with ~150 ps timing resolution for track direction



CC-inclusive Interactions & Muon Selection

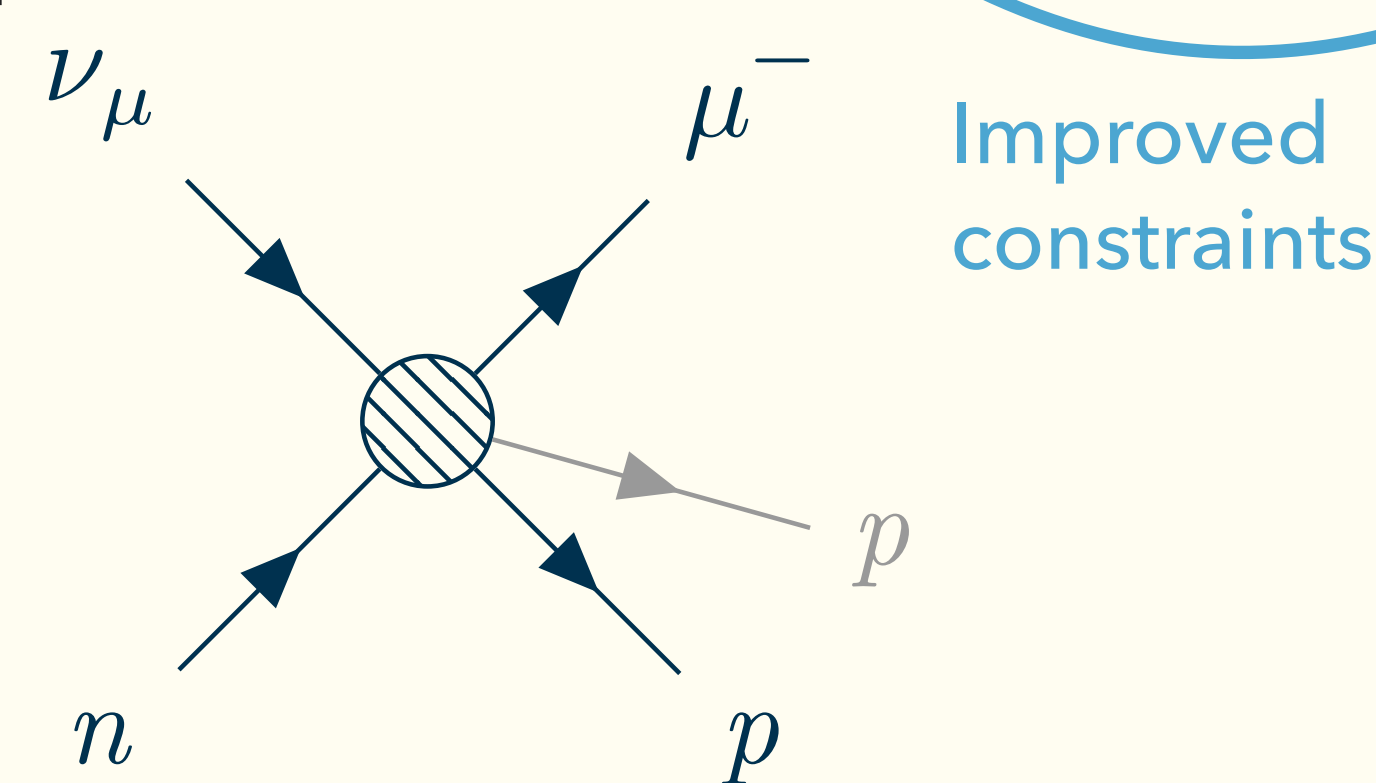
- CC-inclusive selection in ND280 Upgrade: charged-current (CC) ν_μ interactions
- Reconstruct muon escaping from SuperFGD into ① TPCs, ② HATs, or ③ Stopping within SuperFGD



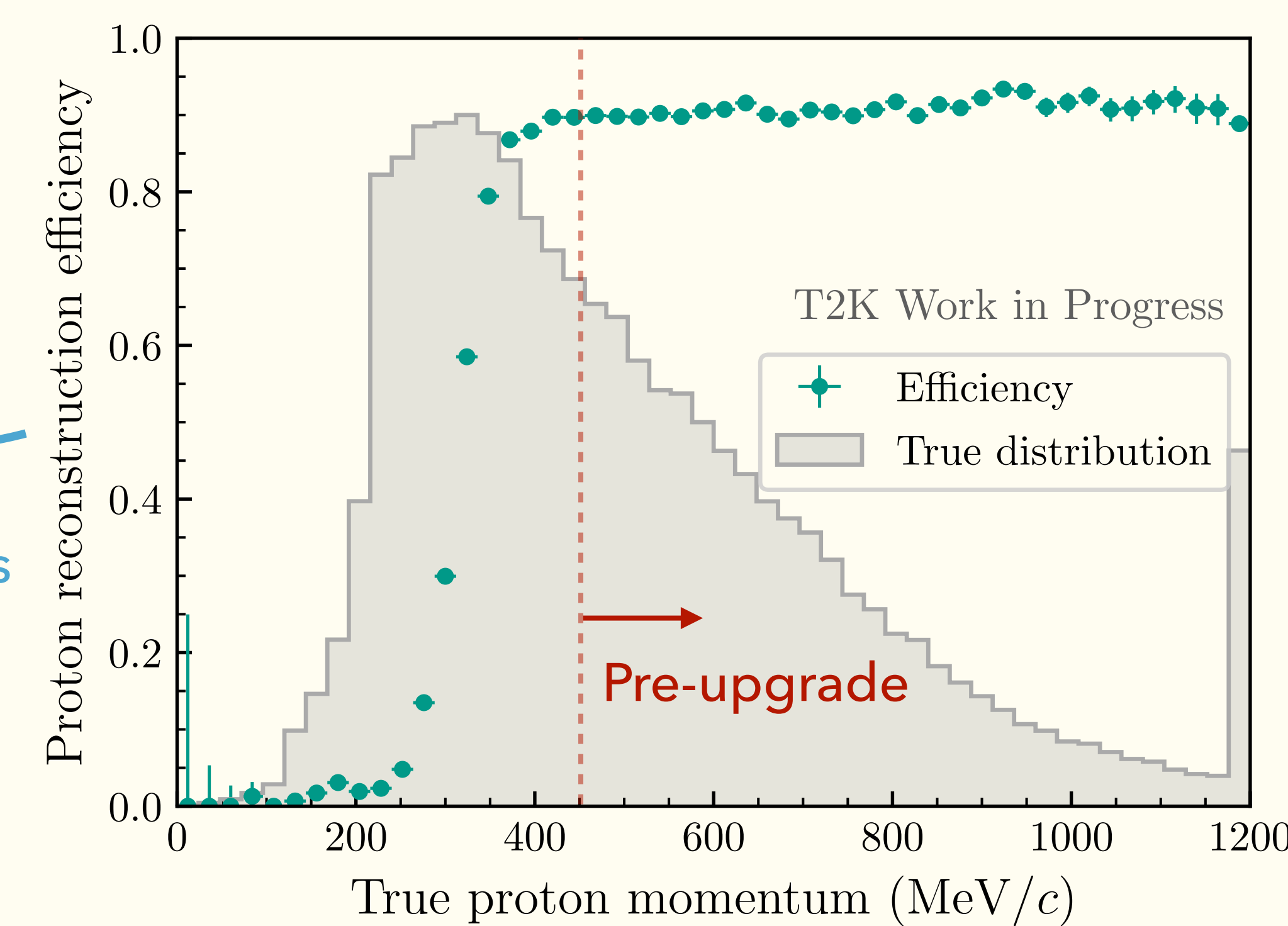
- Detector performance validated and systematic uncertainties evaluated through control samples
- First data comparison from ND280 Upgrade

CC0π Interactions & Proton Selection

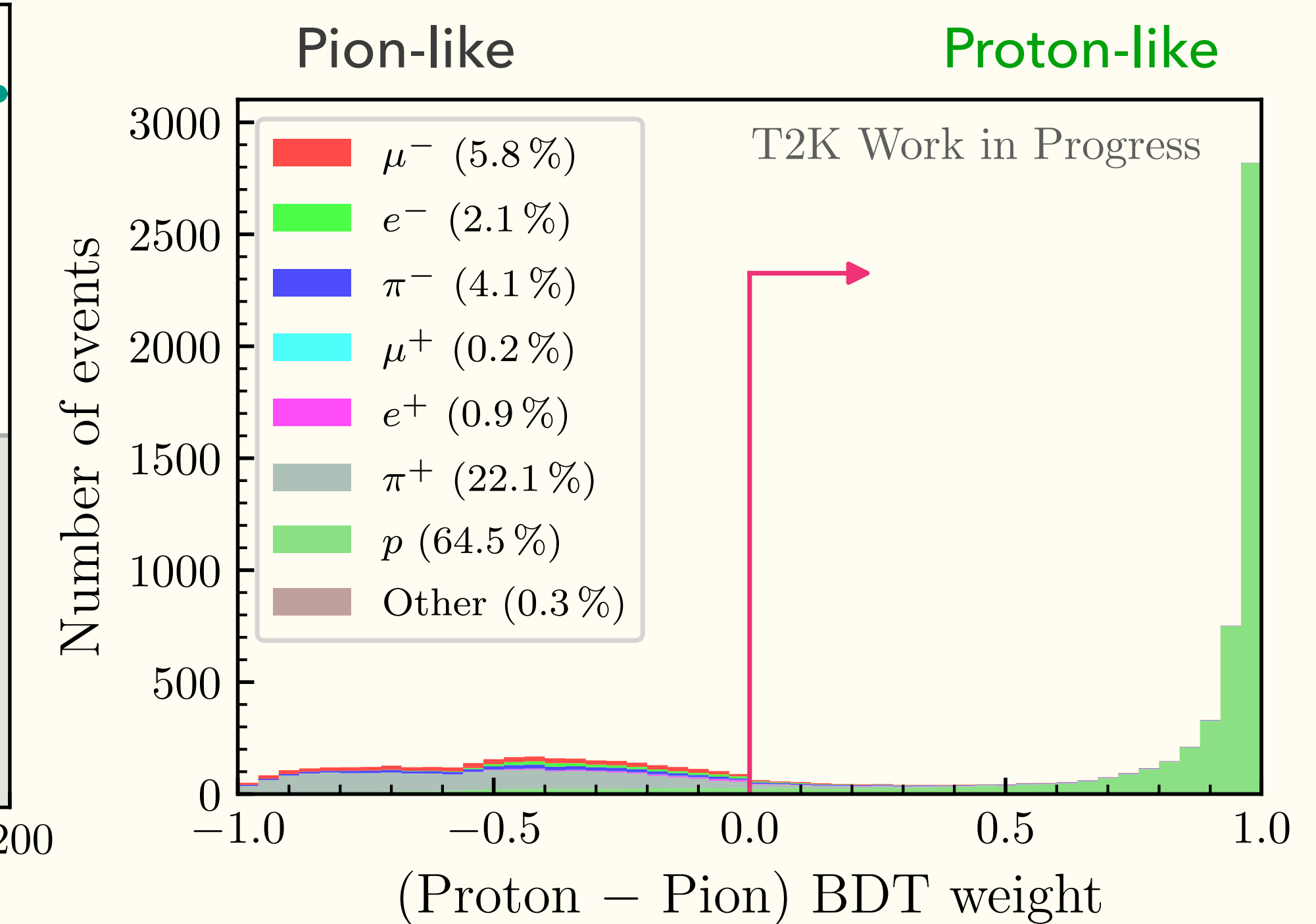
- CC0π interactions: pion-less charged-current interactions
- Select CC0πNp with ≥1 protons
 - CC0π1p: Dominant topology at T2K neutrino energies
- Nuclear effects bias oscillation parameters



Protons: SuperFGD granularity gives reconstruction threshold at 350 MeV/c



For SuperFGD-contained protons, particle identification is performed with a BDT, using the energy loss profile (dE/dx) in SuperFGD



Future Work

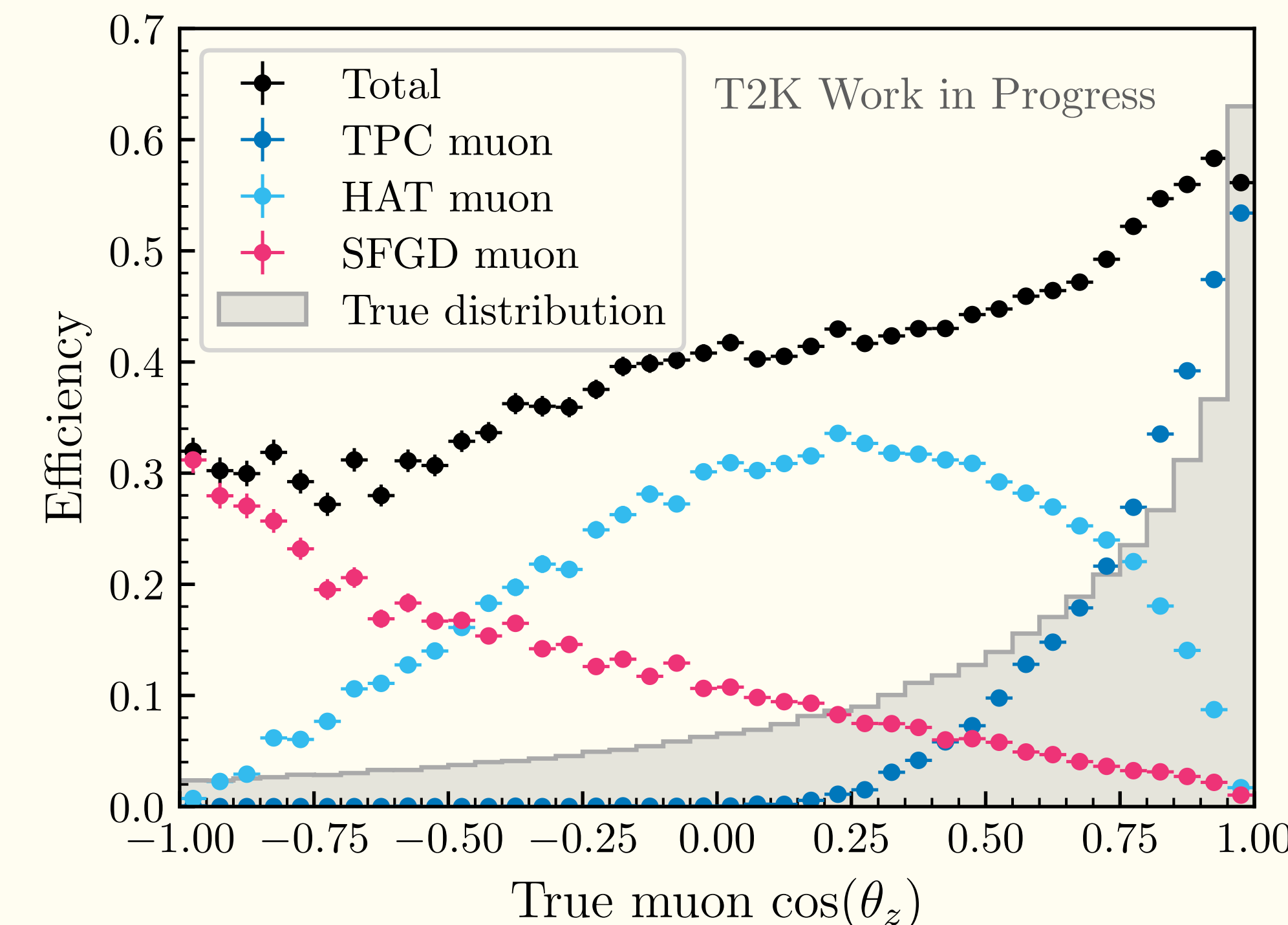
- Evaluate remaining detector systematic uncertainties for exclusive selections
- Perform neutrino interaction model comparisons with CC0π data
- Include ND280 Upgrade samples in the oscillation analysis → Improved constraints, particularly important for Hyper-Kamiokande, which will use ND280 as its near detector

References

- [1] Abe, K. et al. The T2K experiment. Nucl. Instrum. Meth. A **659**, 106–135 (2011).
- [2] Douqa, D. The SuperFGD for the T2K near detector upgrade. J. Phys.: Conf. Ser. **1690**, 012070 (2020).
- [3] Lachner, K. Simulation and reconstruction of neutrino interactions in the upgraded T2K ND280 detector, NuFact. 2023.

CC0π Selection Performance

Overall CC0π efficiency: relatively flat in muon angle → Improved overlap with Super-Kamiokande



- Reject CCNπ⁰ events from electron tracks and showers in electromagnetic calorimeters
- Final samples: High purity of CC0π interactions

Example sub-sample

