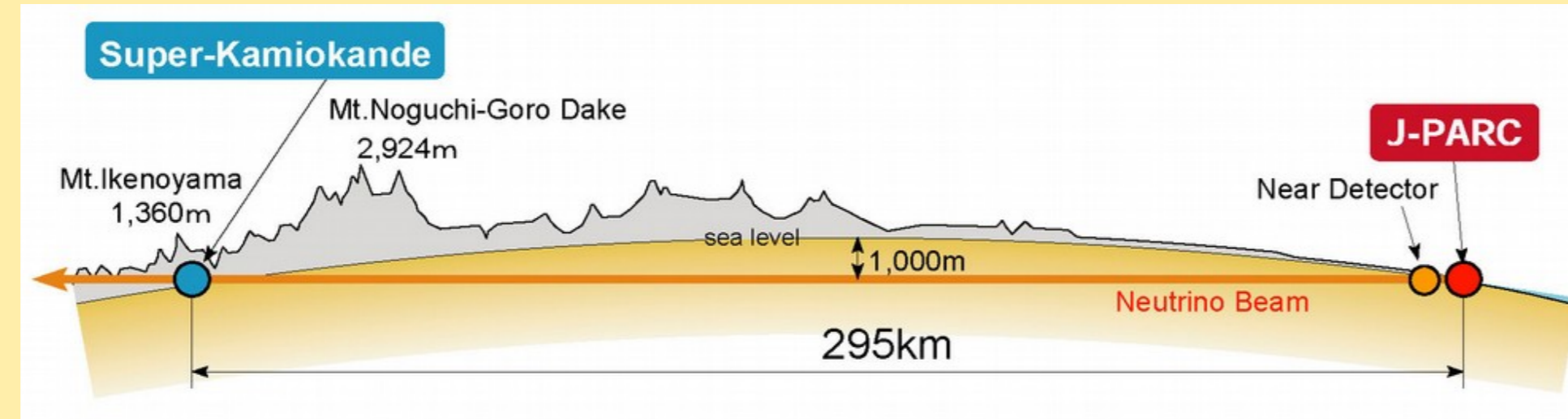


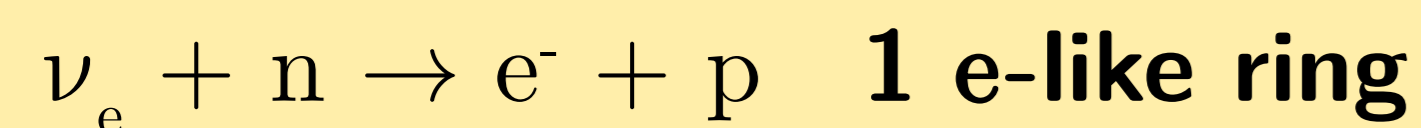
T2K measures ν_e appearance and ν_μ disappearance from a ν_μ beam using near and far detectors.



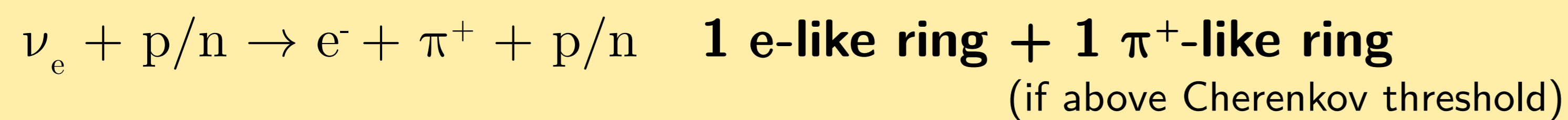
Super-Kamiokande (SK), a water Cherenkov detector, acts as the far detector. In current T2K oscillation analyses, only single-ring e-like and μ -like events at SK are used [1].

For ν_e appearance analyses:

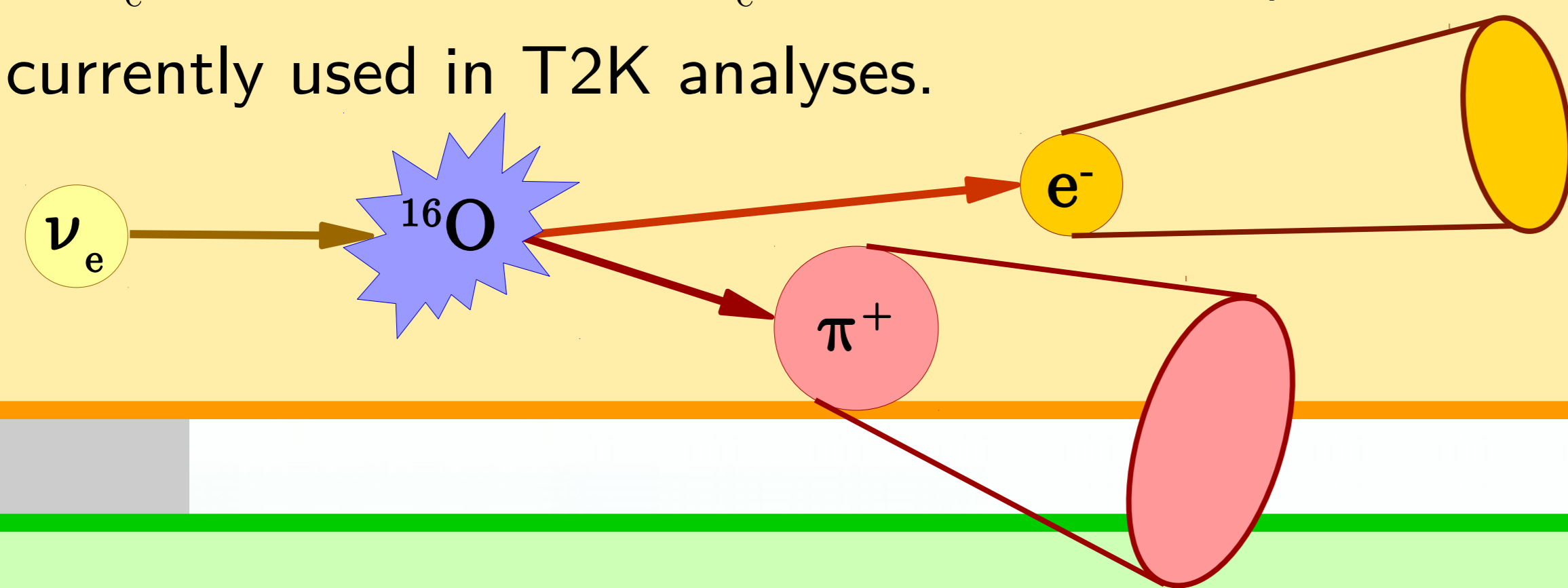
- dominant signal events: charged current quasi-elastic (CCQE)



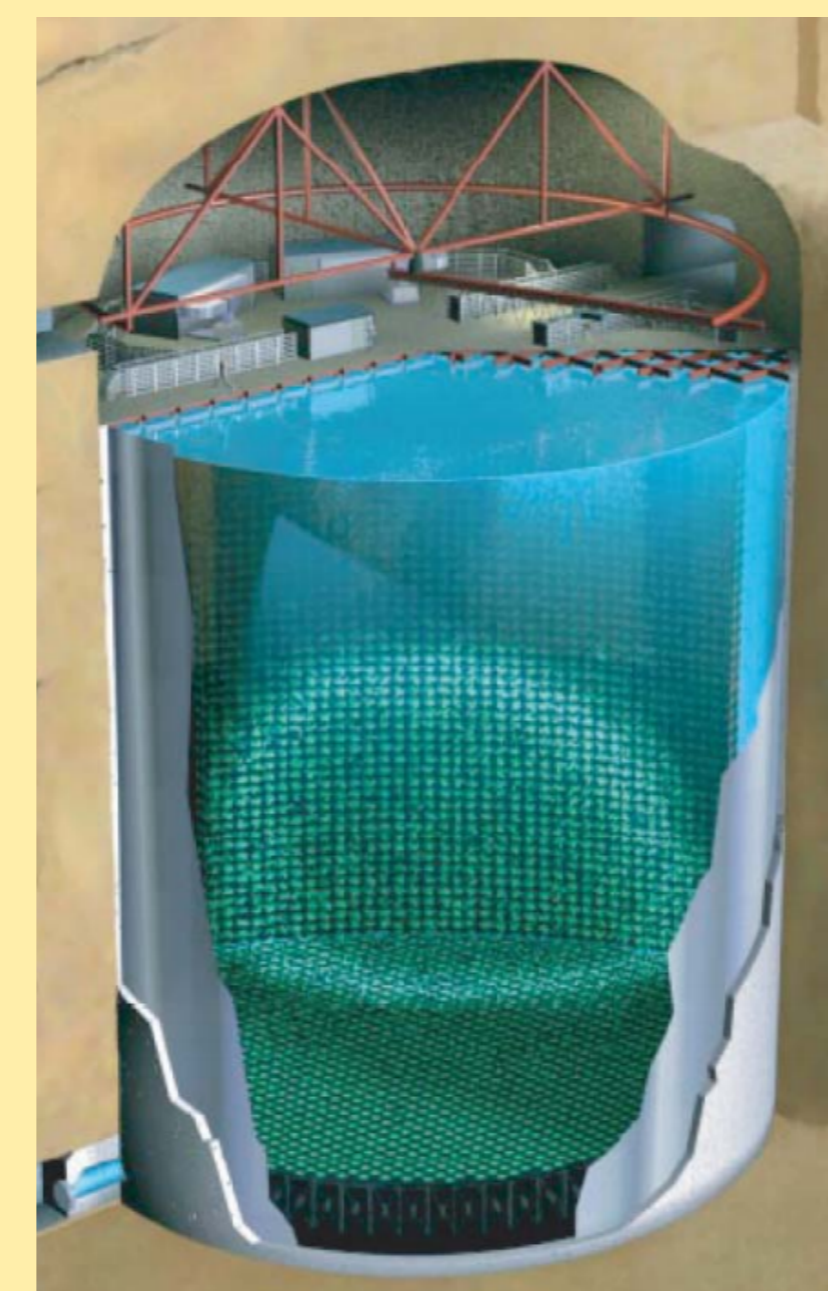
- 2nd-most-dominant signal events: charged current single π^+ (CC1 π^+) [2]



1-ring ν_e CCQE and 1-ring ν_e CC1 π^+ samples (π^+ below threshold) are currently used in T2K analyses.



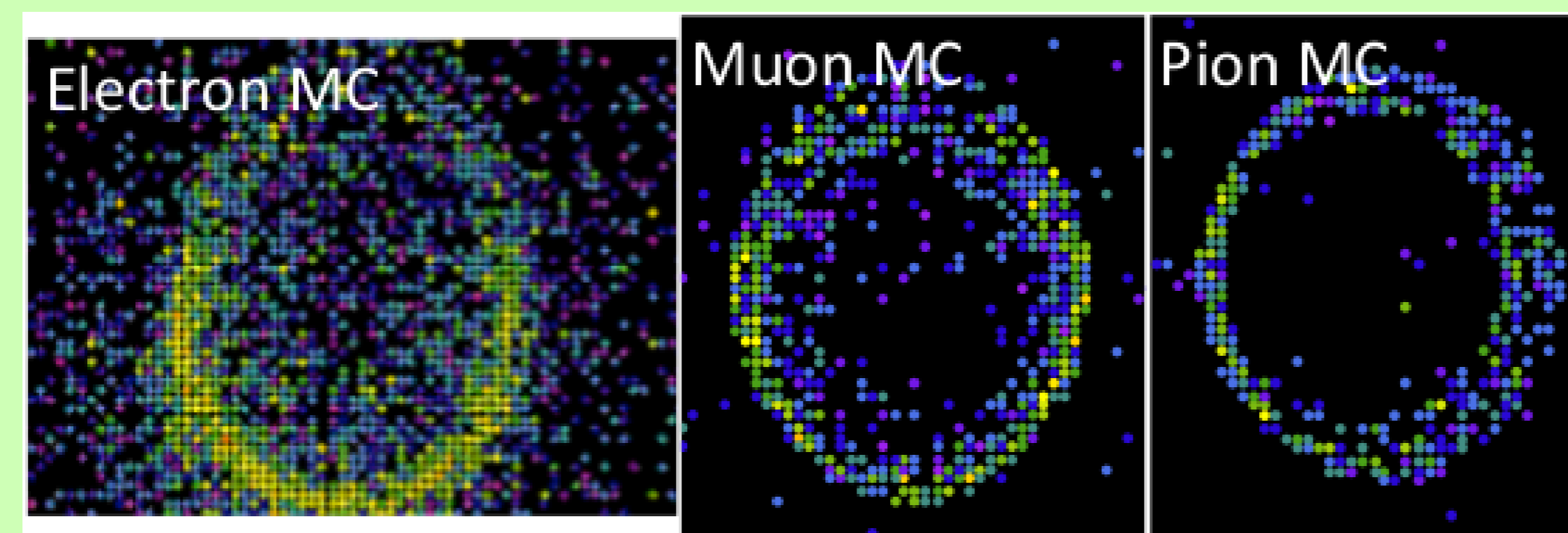
A **2-ring CC1 π^+ sample** can improve statistics at SK and improve sensitivity to δ_{CP} .



Event reconstruction in SK is performed by a maximum-likelihood algorithm called **fiTQun**.

- Different particle hypotheses (e , μ , π^+) are tested, where the likelihood depends on the charge profile.
- Various track parameters (position, time, direction, momentum, energy loss) are fit (reconstructed).

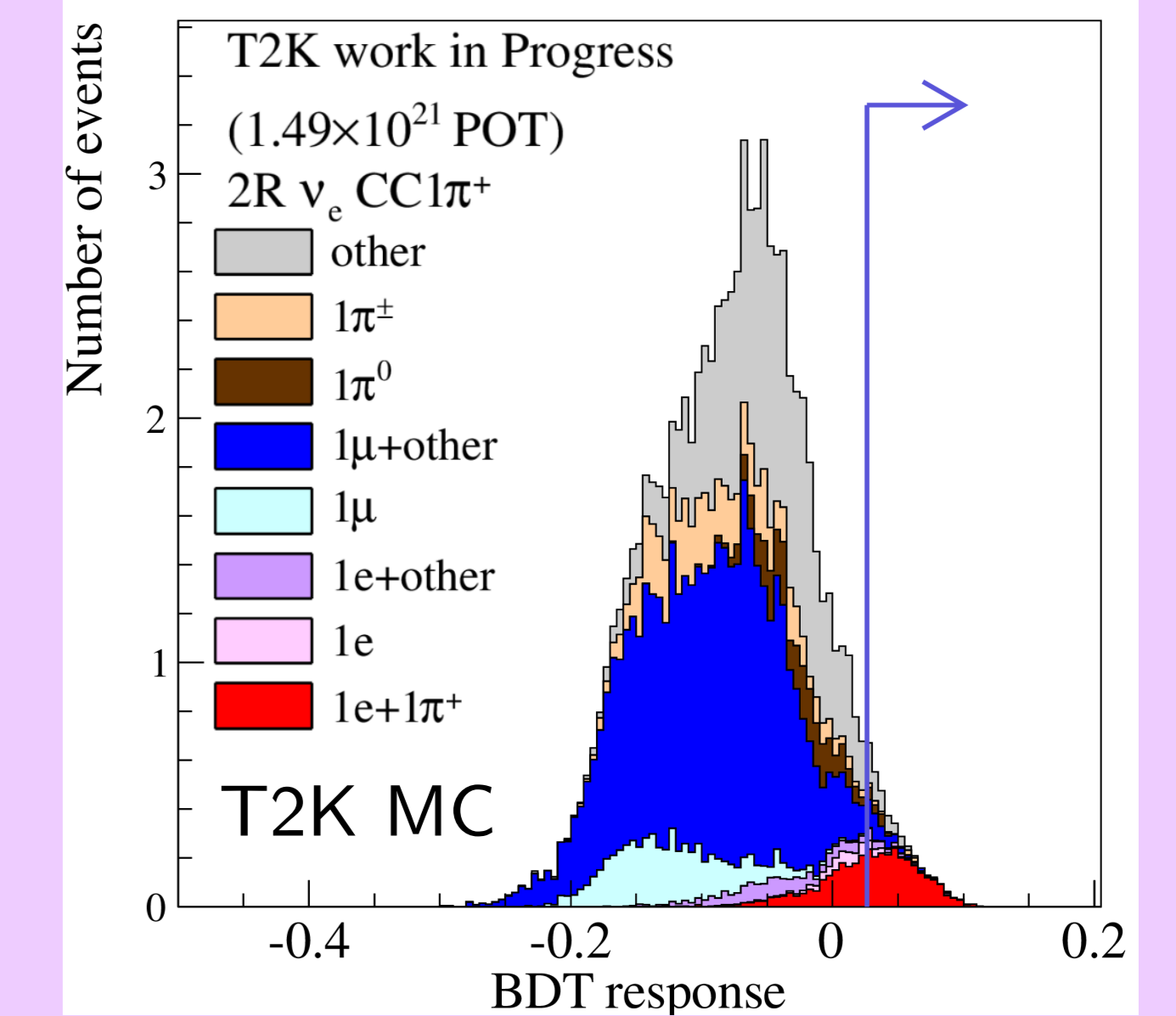
Multi-ring hypotheses are tested by sequentially adding e-like and π^+ -like rings.



Event selection involves cuts on reconstructed variables and a boosted decision tree (BDT) trained on Monte Carlo (MC) simulated events.

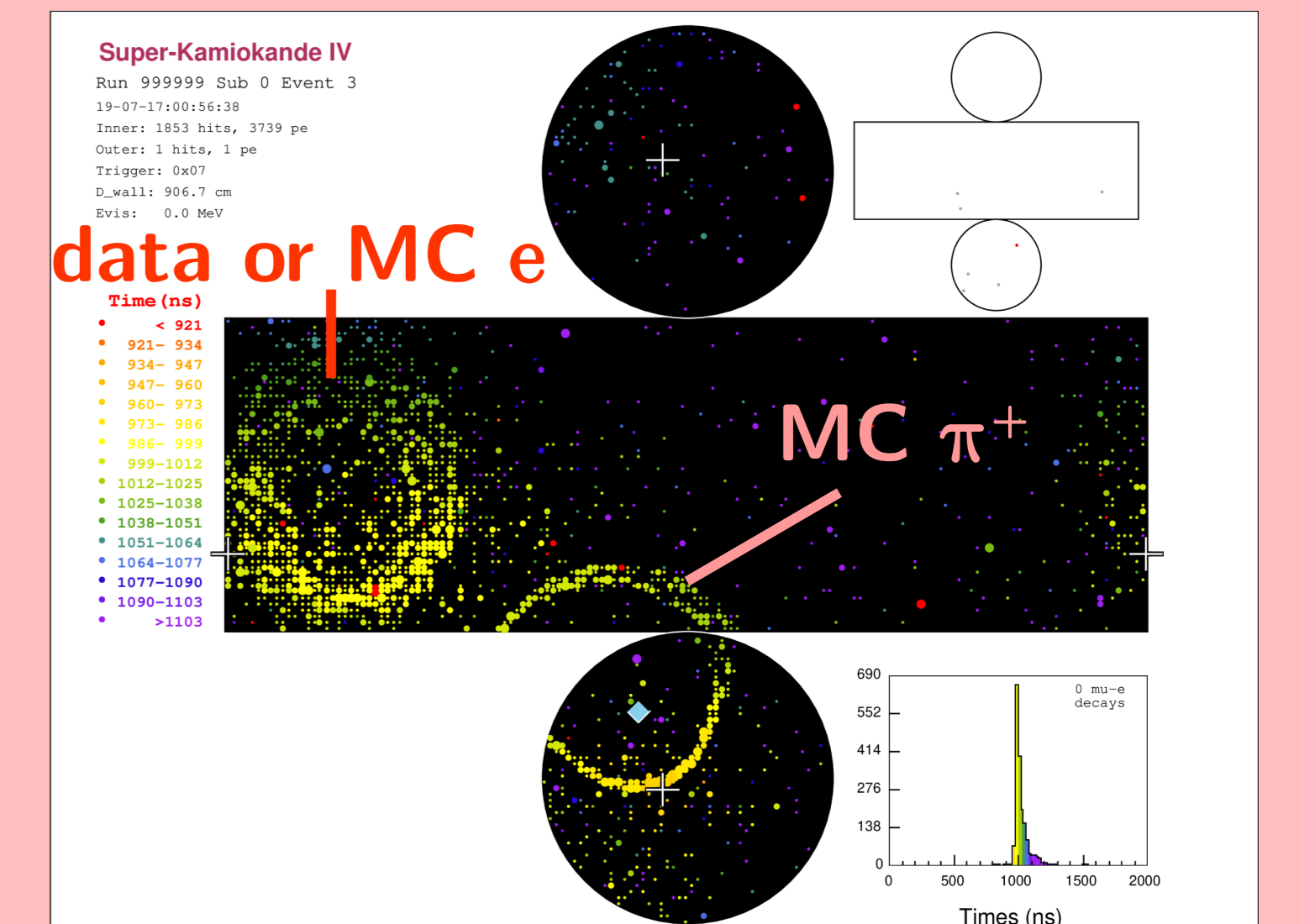
Pre-BDT cuts select events within the fiducial volume of SK and require 1 decay electron (from $\pi^+ \rightarrow \mu^+ \rightarrow e^+$). Events with reconstructed ν energy less than 1.5 GeV are selected.

The BDT uses likelihood ratios and reconstructed kinematics from various fits to select for the final sample. A 12% increase in ν_e signal statistics is predicted.

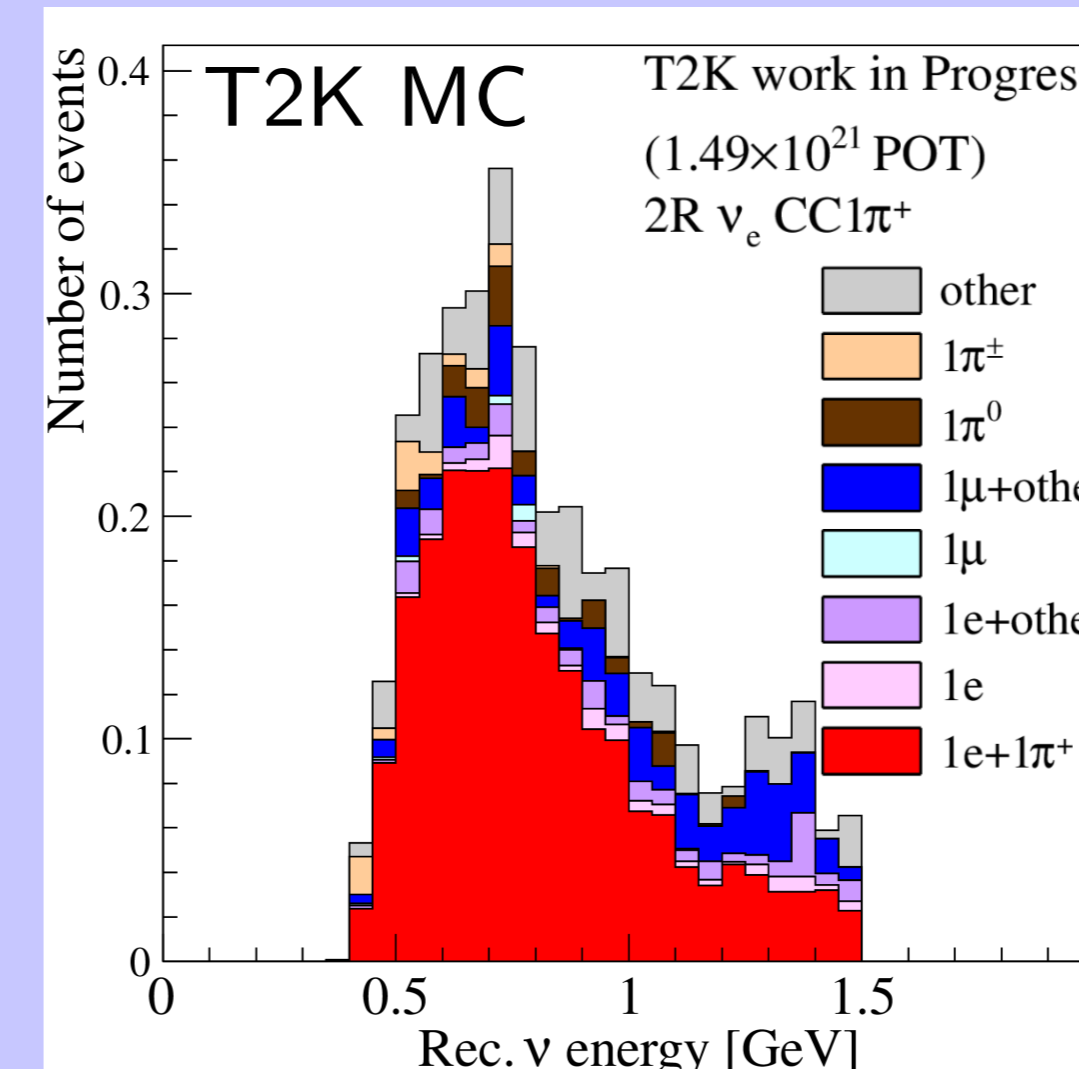


Systematic uncertainties in the neutrino beam flux, neutrino interaction model, π^+ final state and secondary interactions, and SK detector model must be considered.

Hybrid $e\pi^+$ samples were produced. These merge an MC-generated π^+ with an atmospheric data or MC e using true ν_e CC1 π^+ MC kinematics. Comparisons between these hybrid samples can constrain detector systematic uncertainties for $e\pi^+$ -like events.



Estimation of all other systematic uncertainties is underway.



Conclusions: A 2-ring ν_e CC1 π^+ sample at the T2K far detector is being developed, with preliminary results suggesting a **12% increase in ν_e signal statistics**. Studies to estimate systematic uncertainties of this sample are underway. Inclusion of this sample into the T2K oscillation analysis can improve sensitivity to δ_{CP} .

References:

- [1] K. Abe *et al.* *Nature* **580**, 339–344 (2020).
- [2] J. A. Formaggio and G. P. Zeller, *Rev. Mod. Phys.* **84**, 1307 (2012).