UNIVERSITY OF TORONTO

Development of a BDT-based multi-ring sample at the T2K far detector

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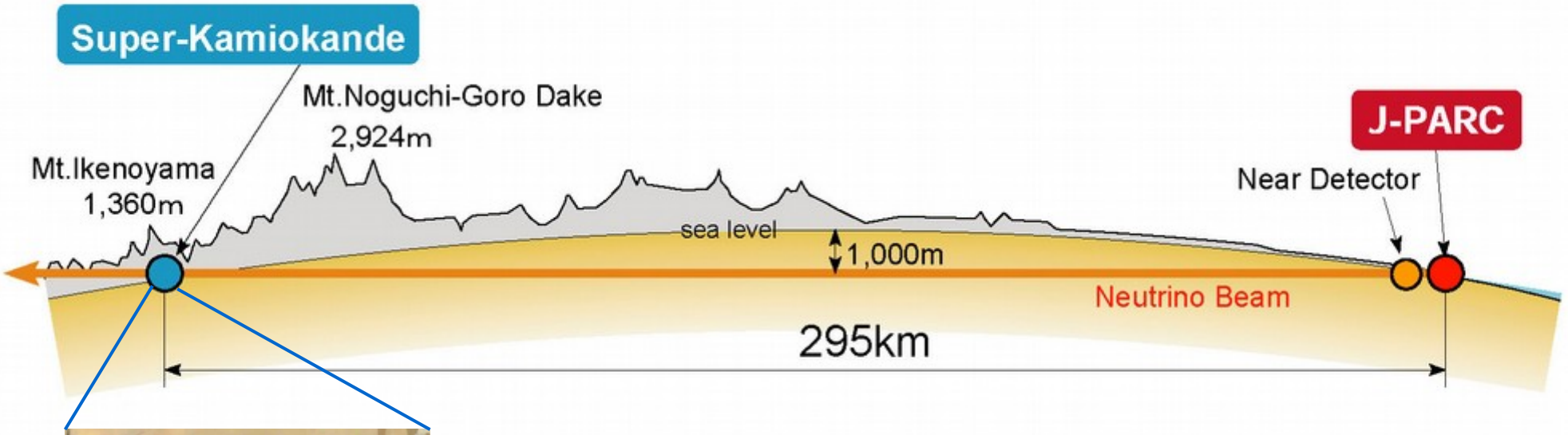
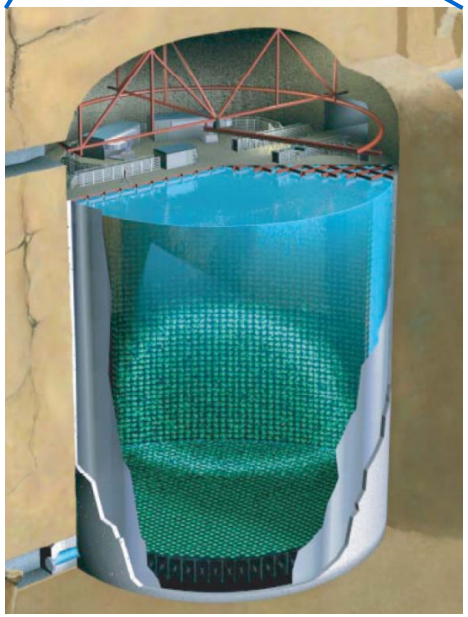
NPML Lightning Talks

June 17, 2020

The T2K Experiment





- Measure ν_e appearance and ν_μ disappearance using:
  - ν_μ beam
  - Near detector
  - Far detector (Super-Kamiokande)

ν_e Charged Current Samples

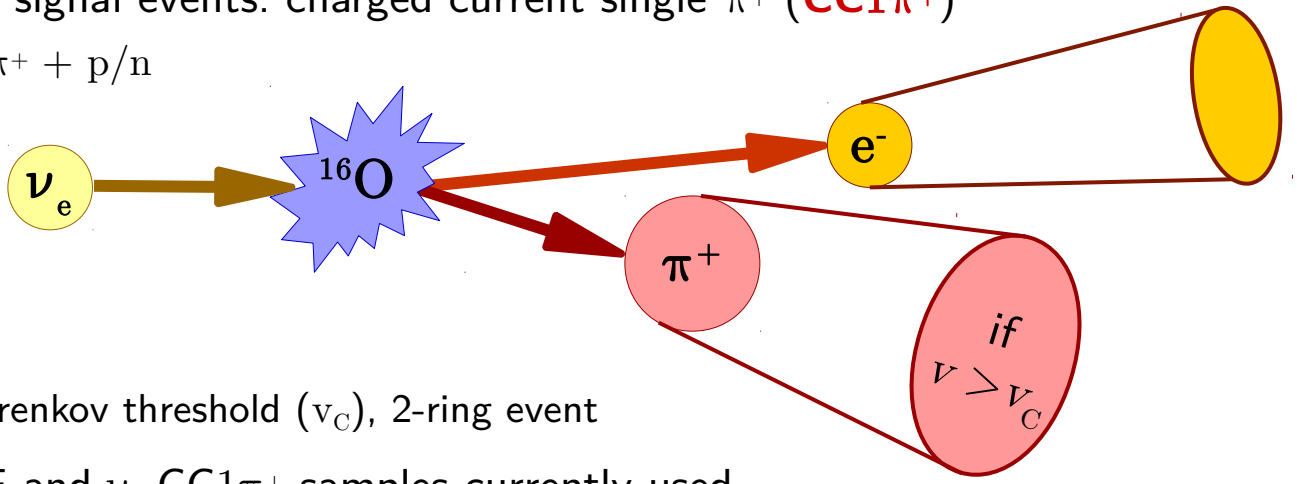
For ν_e appearance analyses:

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

  $\nu_e + n \rightarrow e^- + p$

- 2nd-most-dominant signal events: charged current single π^+ (**CC1π^+**)

  $\nu_e + p/n \rightarrow e^- + \pi^+ + p/n$



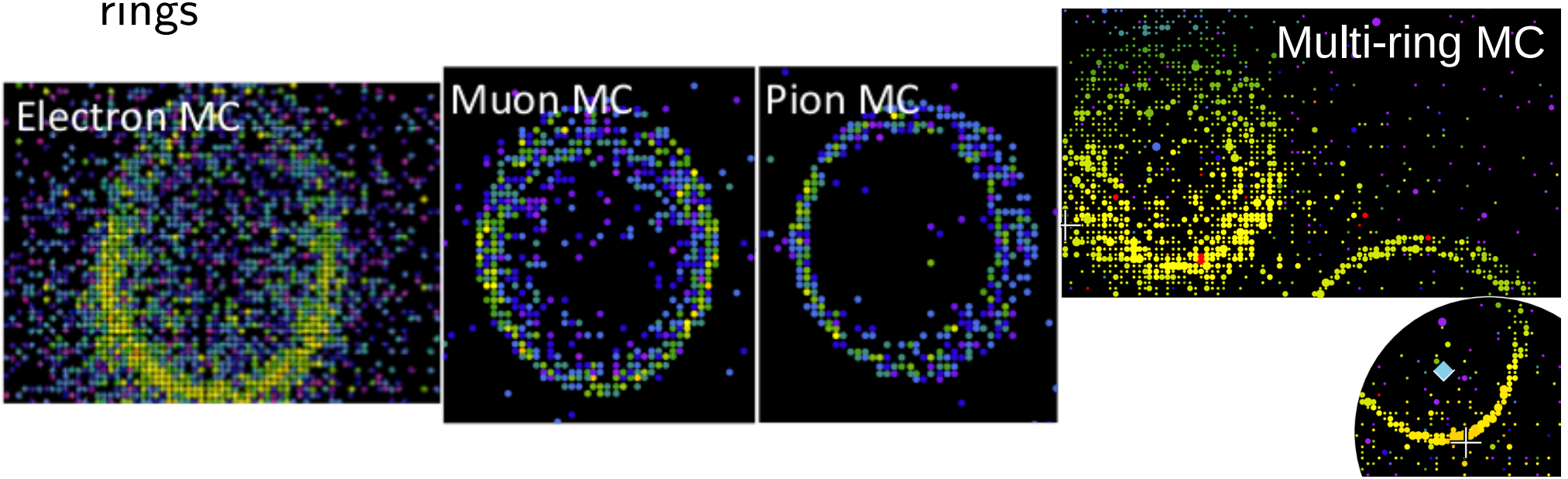
  - If π^+ is above Cherenkov threshold (v_C), 2-ring event

Only 1-ring ν_e CCQE and ν_e CC1π^+ samples currently used

- **Increase sensitivity to δ_{CP} by adding 2-ring CC1π^+ sample**

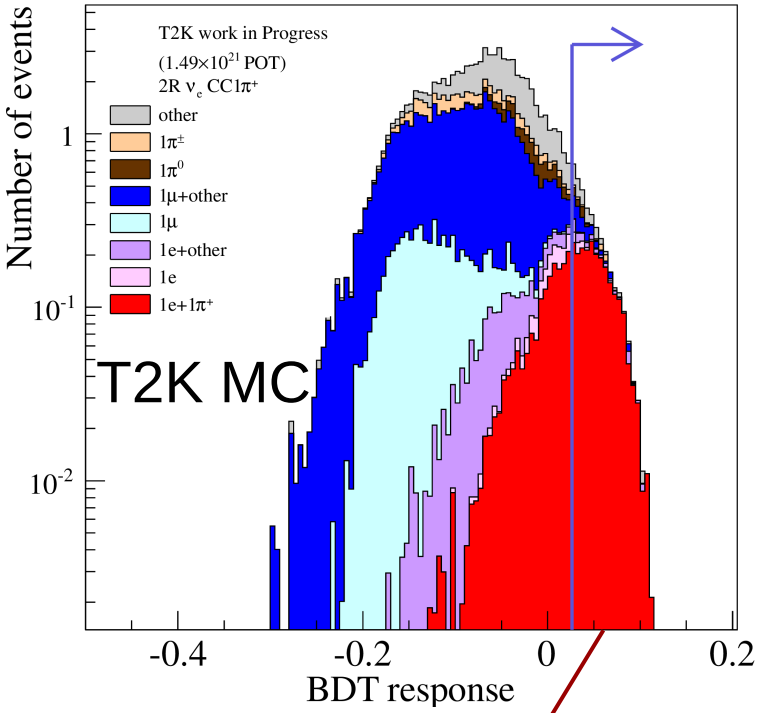
Event Reconstruction

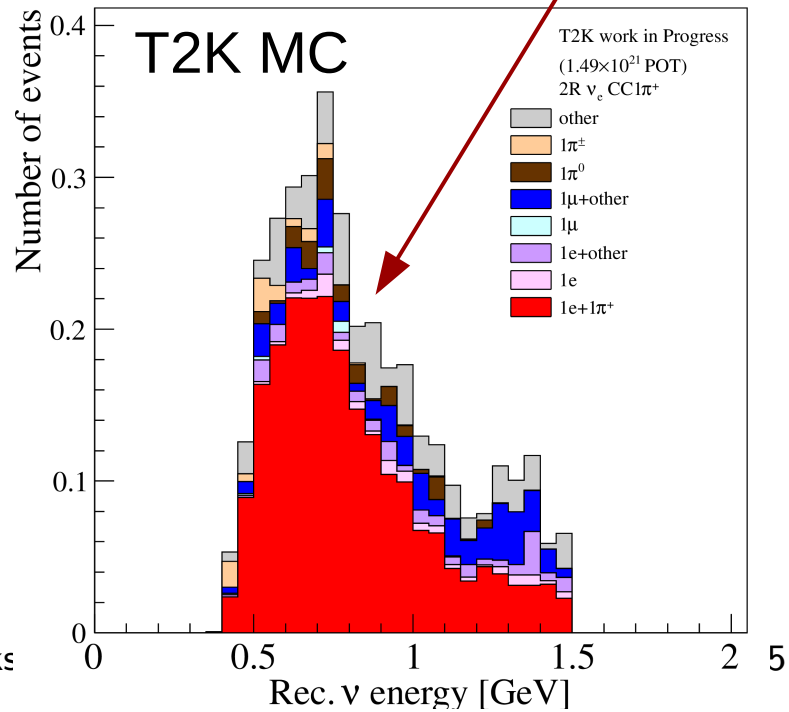
- Maximum-likelihood algorithm called **fiTQun**
  - Test e, μ, and π^+ hypotheses (charge profiles)
  - Fit/reconstruct track parameters (vertex, direction, momentum, etc.)
- Multi-ring hypotheses tested by sequentially adding e-like or π^+-like rings



Event Selection

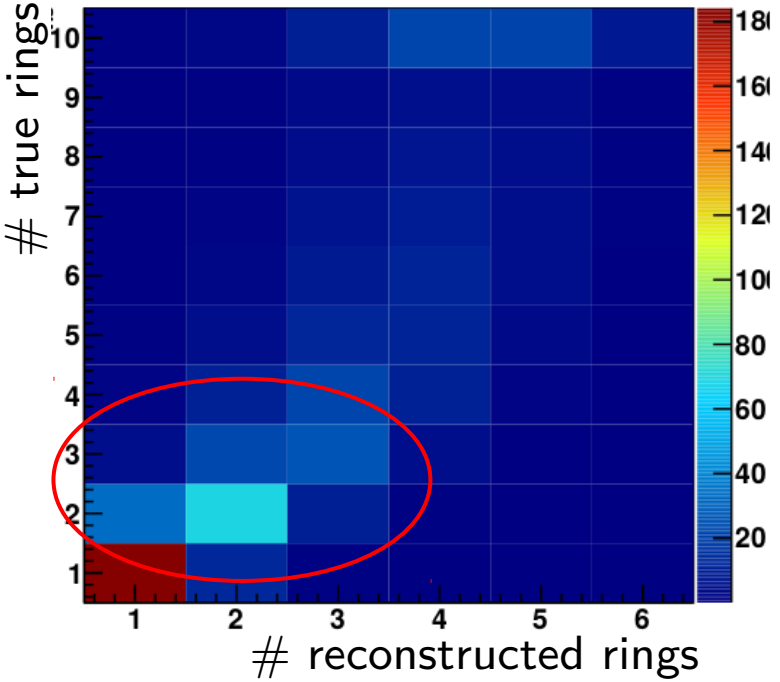
- Pre-BDT cuts
  - Within fiducial volume
  - 1 decay electron (from $\pi^+ \rightarrow \mu^+ \rightarrow e^+$)
  - Reconstructed ν energy $<$1.5 GeV
- Apply BDT
  - Trained on fiTQun likelihood ratios and reconstructed kinematics
- Final Sample:
  - ~60% $1e1\pi^+$ final state purity
  - ~12% increase in ν_e CC statistics
- Systematic error studies ongoing





BDT Benefits and Limitations

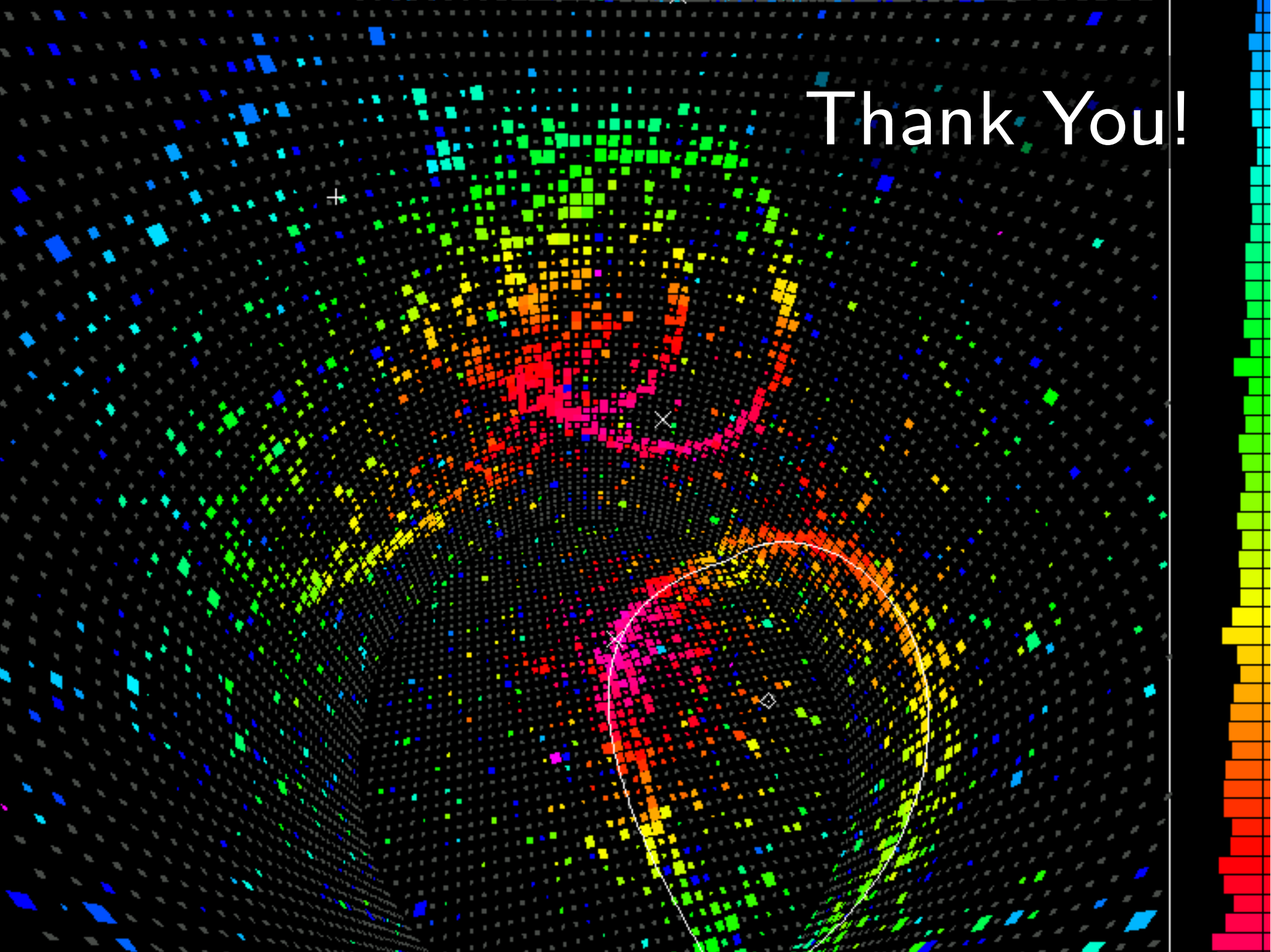
- Better performance than cuts-based selection
  - Previously struggled to get purity >40%
- However, still limited to reconstruction performance of fiTQun
  - Fit designed primarily for single-ring events
    - Not optimised for multi-ring events, especially considering large number of possible topologies



- As the push to improve systematic errors and expand multi-ring samples for future water Cherenkov experiments continues, reconstruction may become more of a limiting factor in improving sensitivity

Future of ML for Multi-Ring Samples

- Particle ID is a "visual" classification problem
  - Natural to assume CNNs would be beneficial
    - PID of multi-ring topologies, rather than a 1-ring fitter generalised to multiple rings
- Improve kinematic reconstruction
  - Semantic segmentation $\rightarrow$ better reconstruction?
- Lots of interesting work ongoing by others (ML Water Cherenkov group)


Thank You!