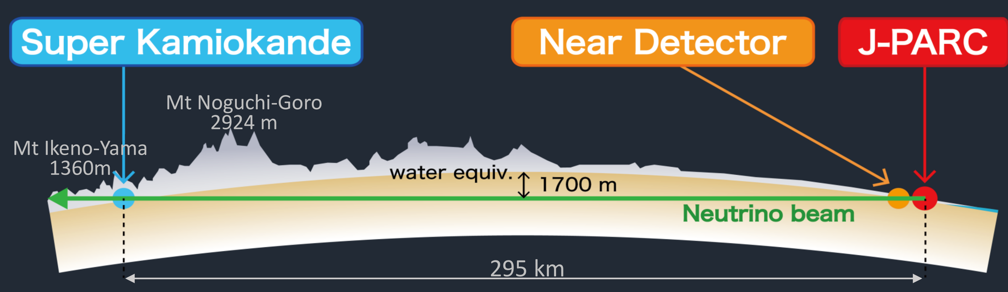
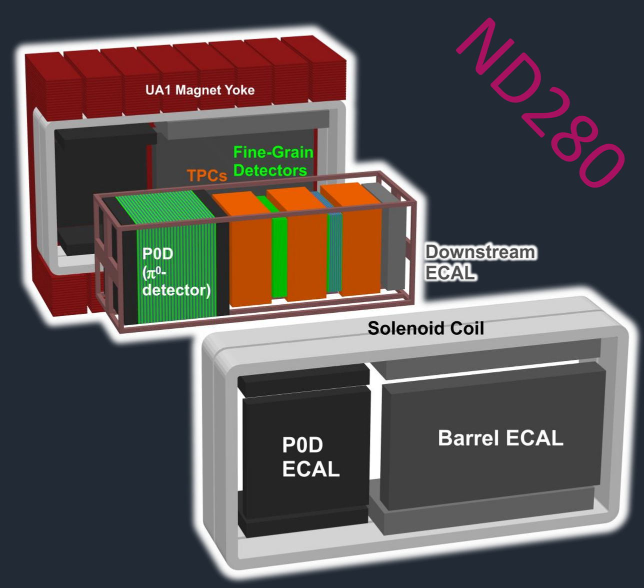
Fitting T2K Near Detector Data using Markov Chain Monte Carlo

Ewan Miller, King's College London
ewan.miller@kcl.ac.uk

1. The T2K Experiment



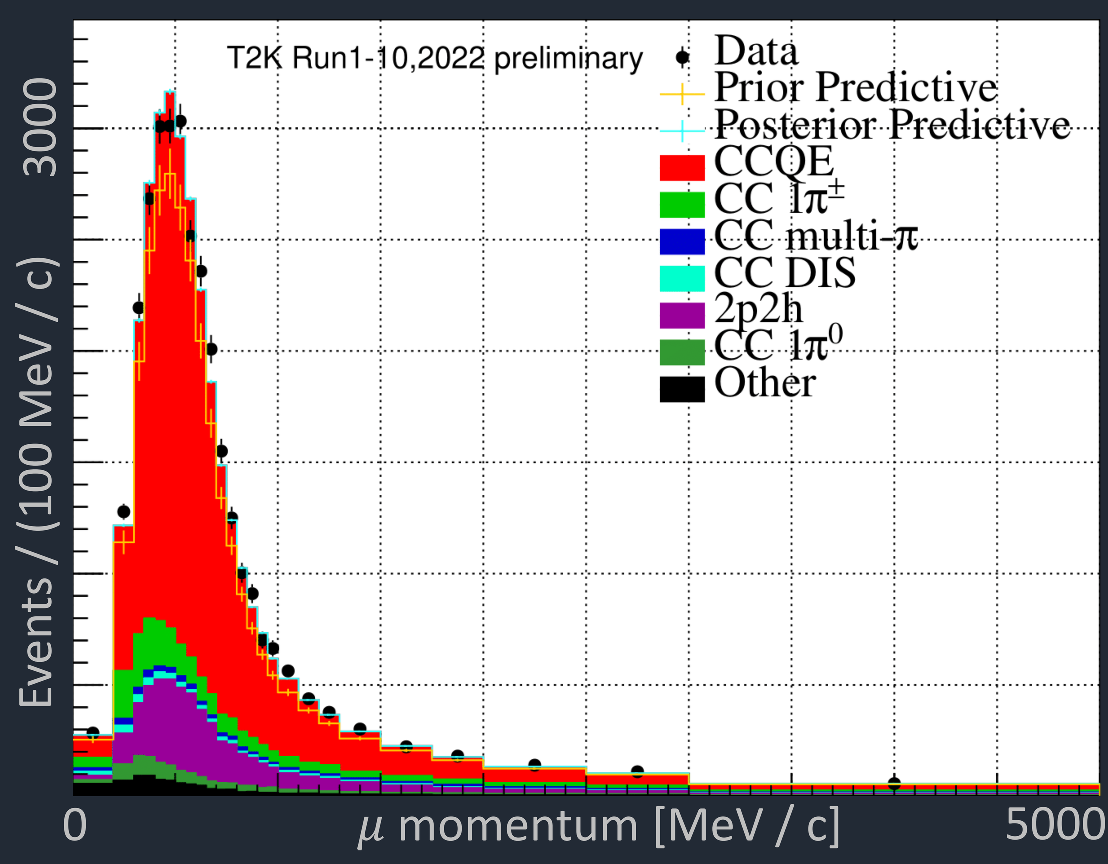
- Long baseline neutrino beam experiment in Japan
- Neutrino beam from J-PARC is characterised at the Near Detectors then measured again after travelling 295 km at the Far Detector



- The ND280 near detector is used to constrain ν flux and cross section uncertainties
- To do this, we also need to account for systematic uncertainties relating to the ND280 detector itself

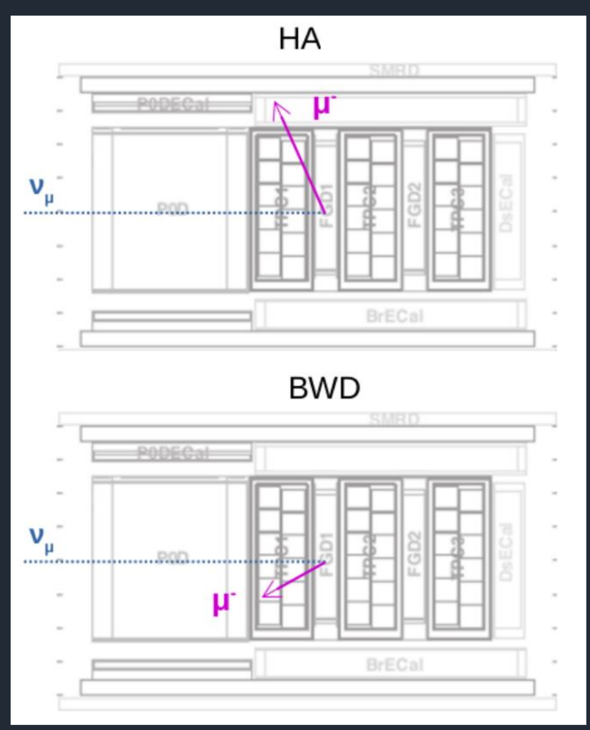
2. The ND280 Analysis

- Main goal of the ND280 fit to constrain ν flux and cross section model parameters by fitting un-oscillated MC predictions to ND280 data
- Done by tuning MC event weights to minimise a Poissonian Log Likelihood for each sample
- The fits performed for this work were done using MaCh3 fitter: Bayesian Markov Chain Monte Carlo

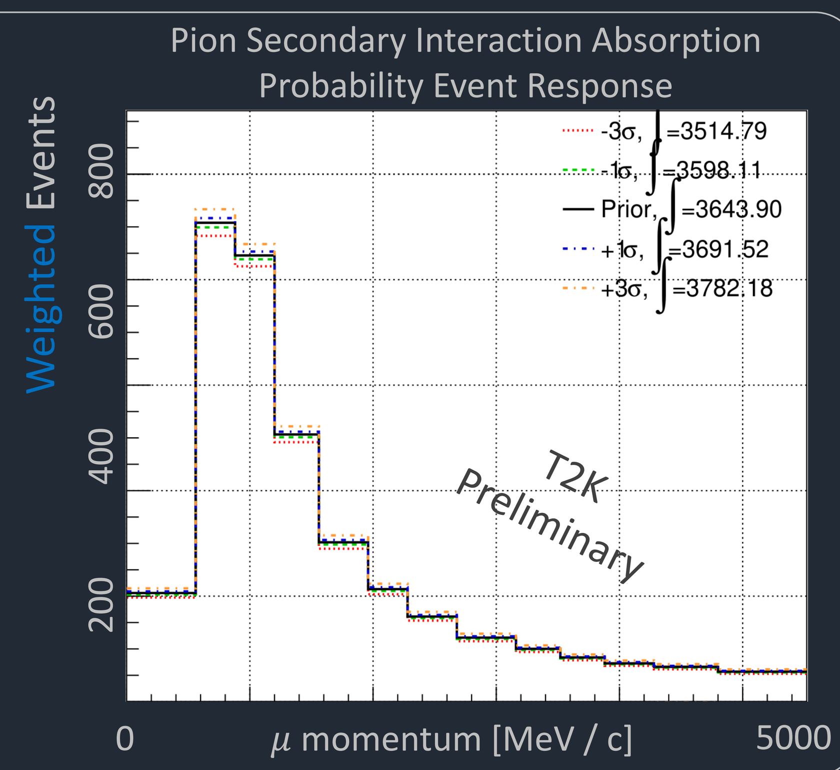


3. Improvements for 2024

- Included new high angle (HA) and backward (Bwd) going muon samples
  - Improved phase space coverage
  - Increased statistics

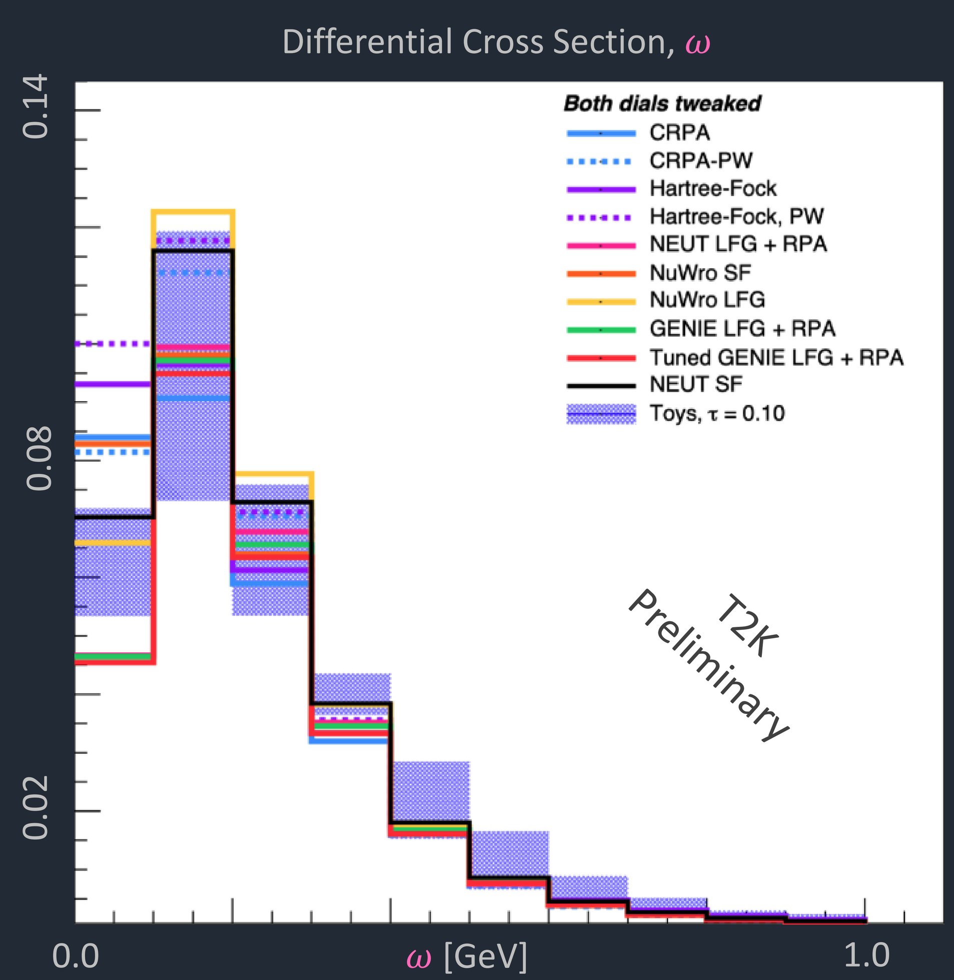


- Improved Treatment of Detector Systematics
  - Estimate event-by-event weights at fit time
  - Can directly see impact of individual detector parameters



4. Cross Section Model Improvements

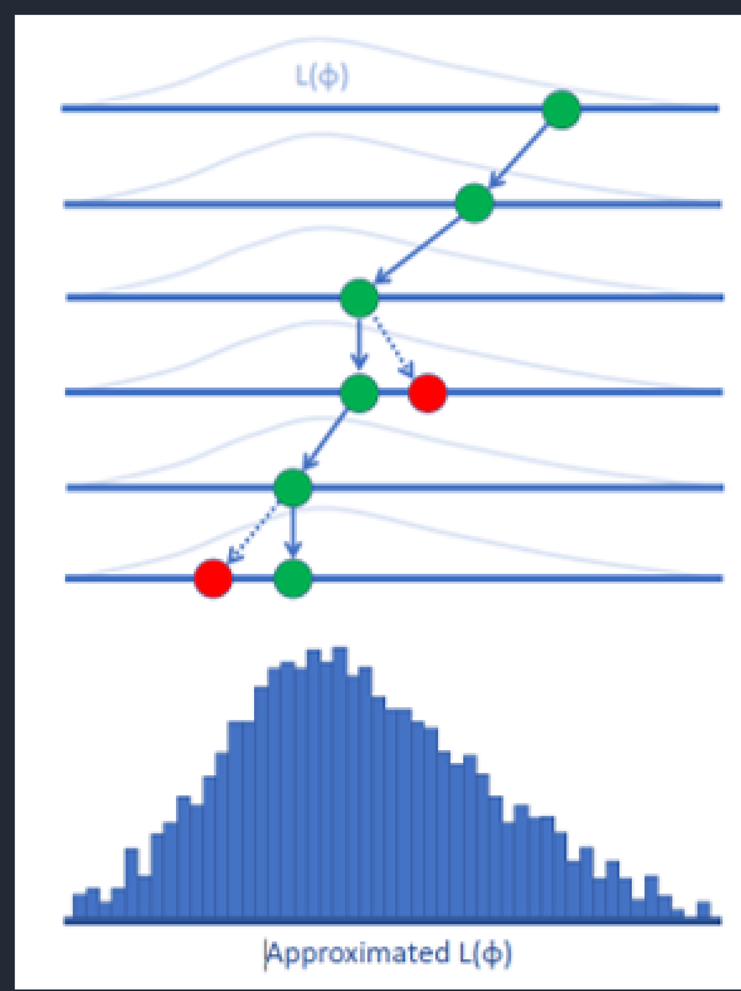
- Massively expanded parameterisation of the neutrino cross section model
- New parameters to cover modelling of low energy transfer (ω) events
- Many, many more!



5. Markov Chain Monte Carlo (MCMC)

- MCMC performs a directed random walk around parameter space
- Efficiently samples posterior likelihood $L(\Phi)$
- "Accepts" proposed steps Φ' with probability

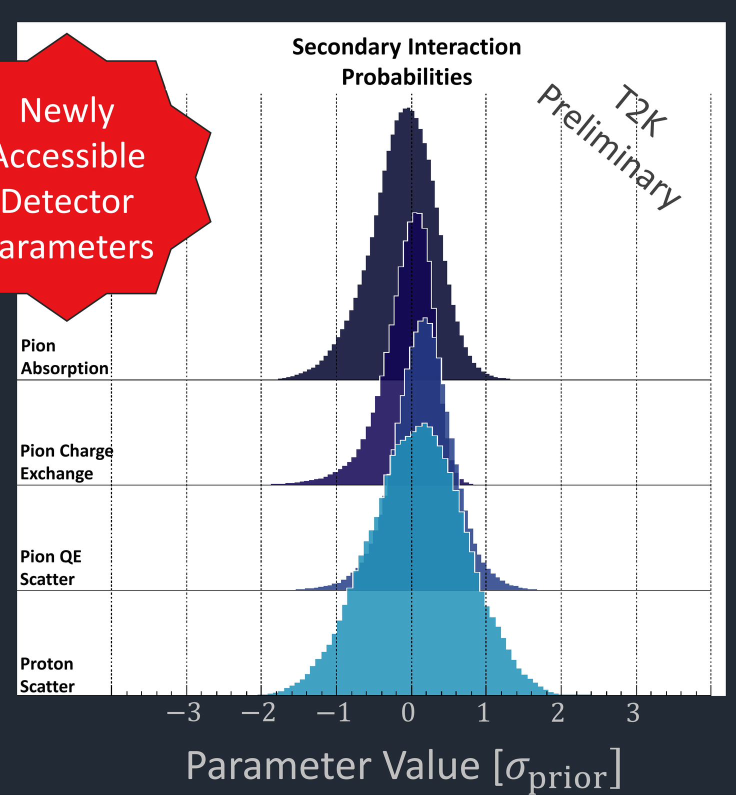
$$\alpha = \min\left[1, \frac{L(\Phi')}{L(\Phi)}\right]$$



6. 2024 Sensitivities

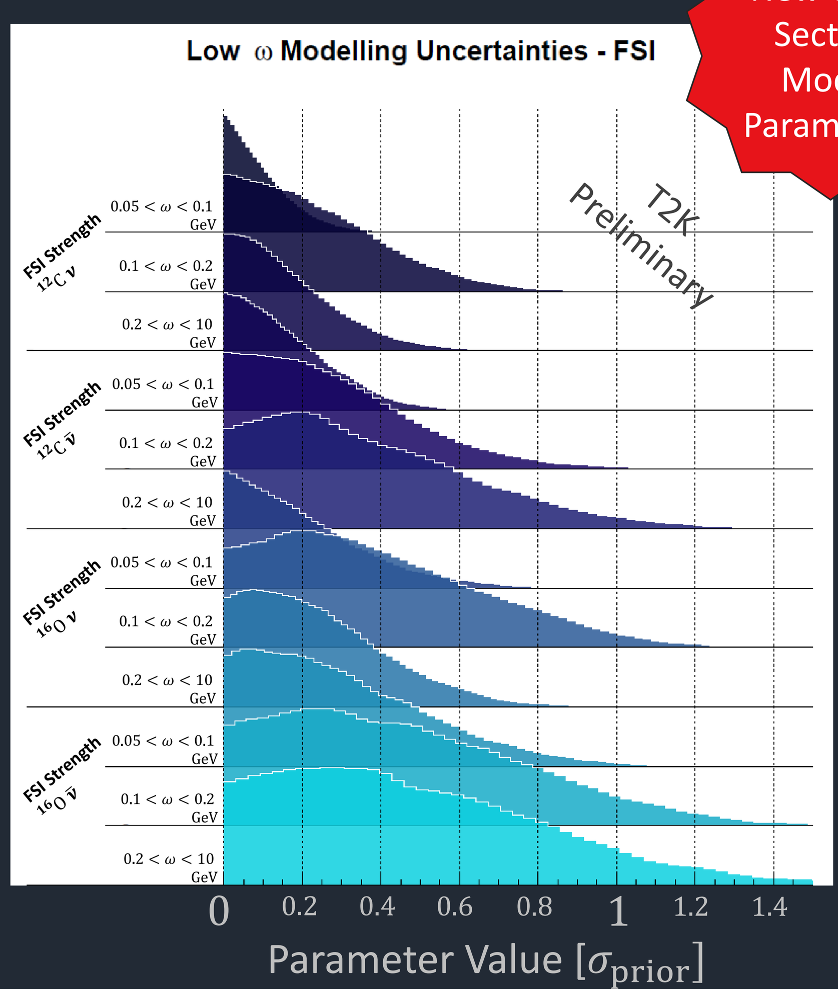
- Fits to fake ND280 data done d with new model

Newly Accessible Detector Parameters



- With MCMC, can see full posterior distributions:

New Cross Section Model Parameters



- We can see the constraining power of the ND280 fit by propagating model to far detector and looking at errors on predicted event rates:

Sample	Prior Error	Post ND Error
ν-Mode 1 μ Ring	15.8%	2.6%
ν-Mode 1 e Ring	20.8%	4.0%
ν-Mode 1e Ring + Decay Electron	12.1%	2.8%
ν-Mode Multi-Ring	13.8%	4.7%
$\bar{\nu}$-Mode 1 μ Ring	15.3%	2.7%
$\bar{\nu}$-Mode 1 e Ring	15.5%	3.5%