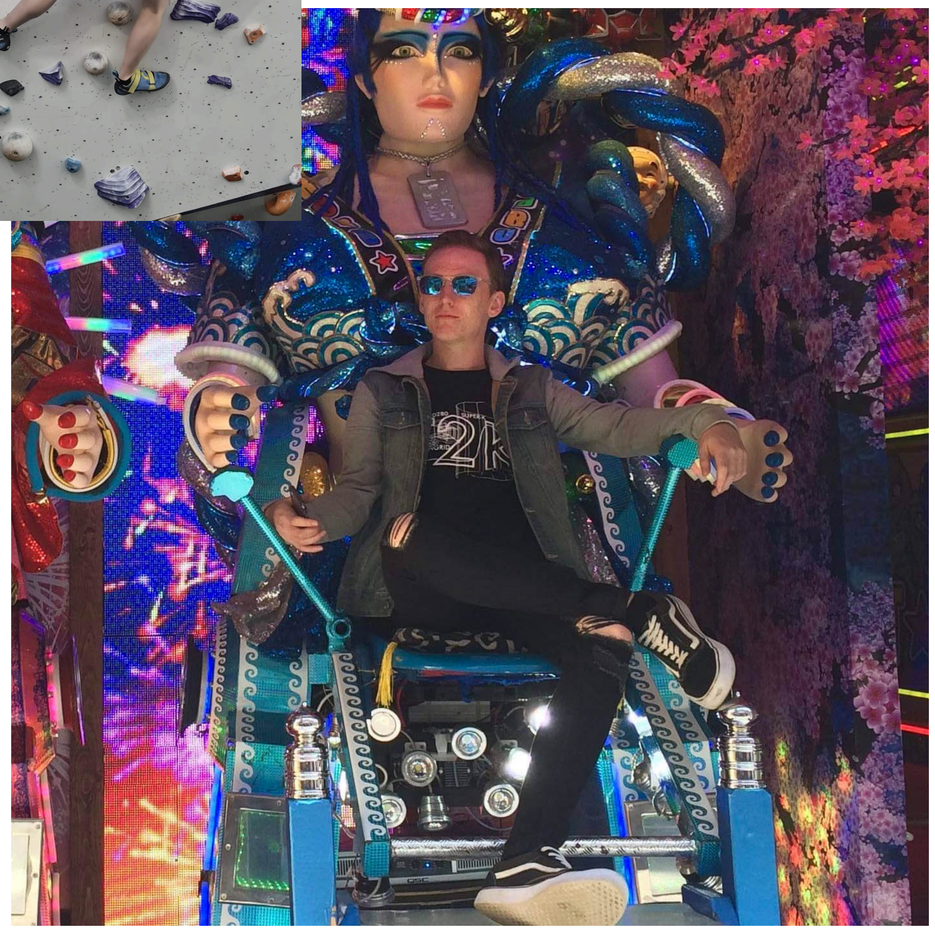
Hyper-Kamiokande Status

Particle Physics Annual Meeting

Sam Jenkins

Introduction

- Completed my PhD at University of Sheffield, neutrino cross sections in T2K
- Recently started in the department as PDRA
- Working mainly on Hyper-K calibration with Neil
- Some Super-K calibration work as part of this
- Continuing working in the cross section group in T2K
- Muon tomography side project
- Spend most of my free time climbing, baking or playing D&D

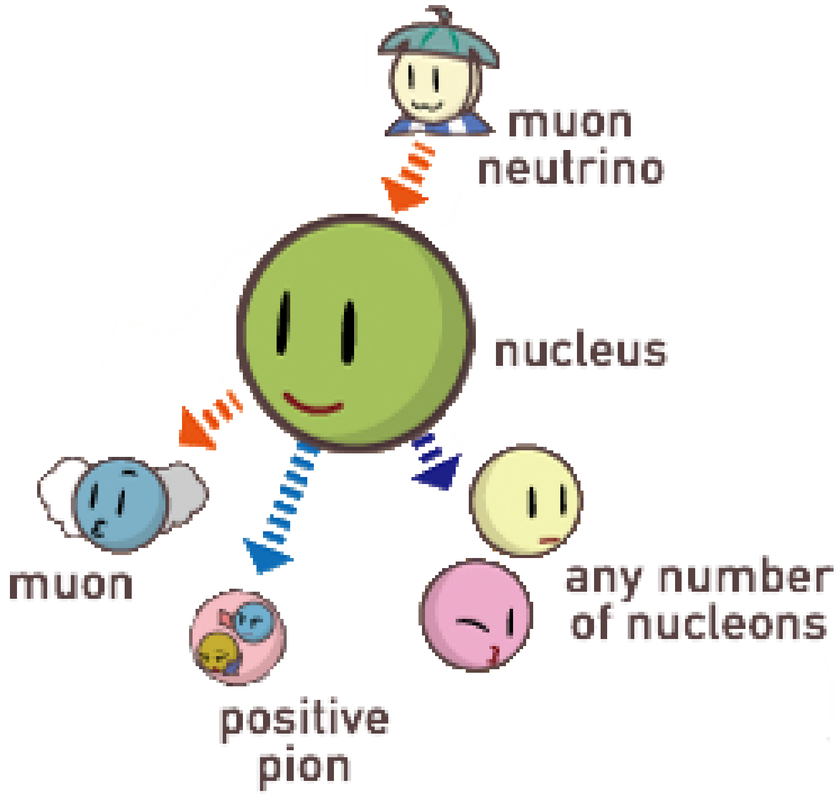


ν_μCC1π^+ Cross Section on Water and Hydrocarbon

- Signal: CC1π^+ events in ND280 FGD1 (CH) or FGD2 (layered CH/H2O)

$$\nu_\mu + N \rightarrow \mu^- + \pi^+ + X$$

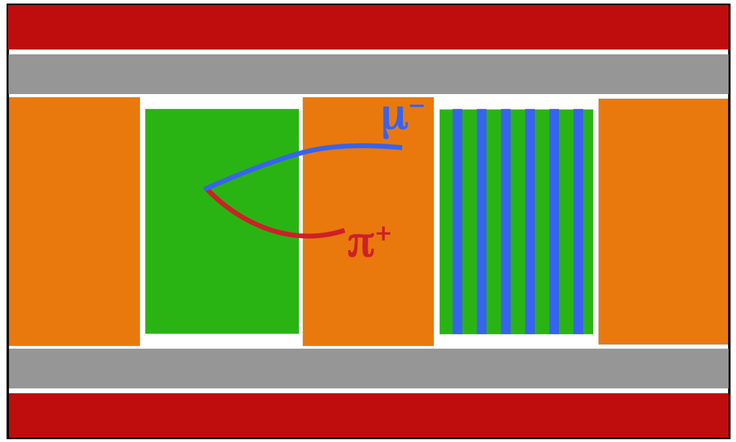
- Such resonant events are a major background to the oscillation analysis
- Kinematics of the pion of particular interest - no current differential measurements made in p_π and $\cos\theta_\pi$



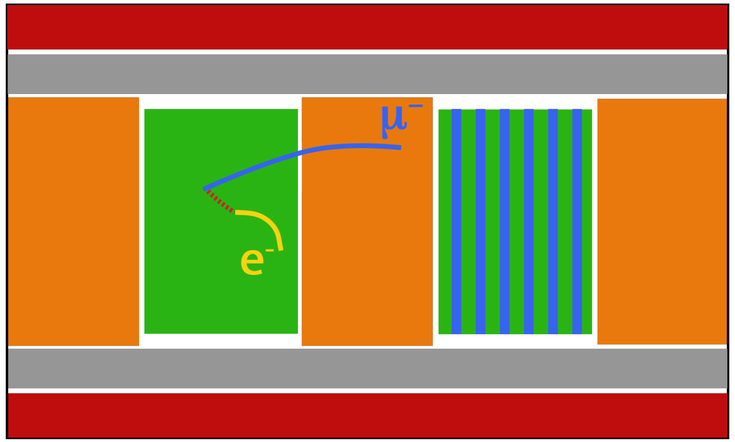
© Yuki A., HiggsTan

Selection

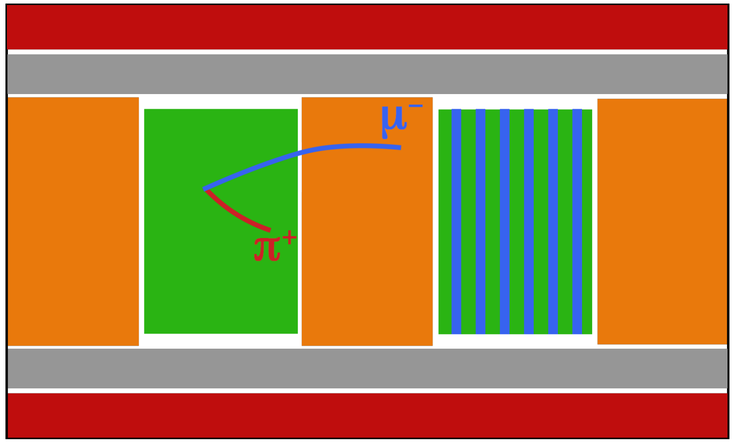
- Three signal samples based on how the pion is detected
  - Provides access to different kinematic phase spaces
- Additional control samples to constrain backgrounds
- Each sample further divided by FGD layer - most interactions on water will be reconstructed in an FGD2x layer



TPC



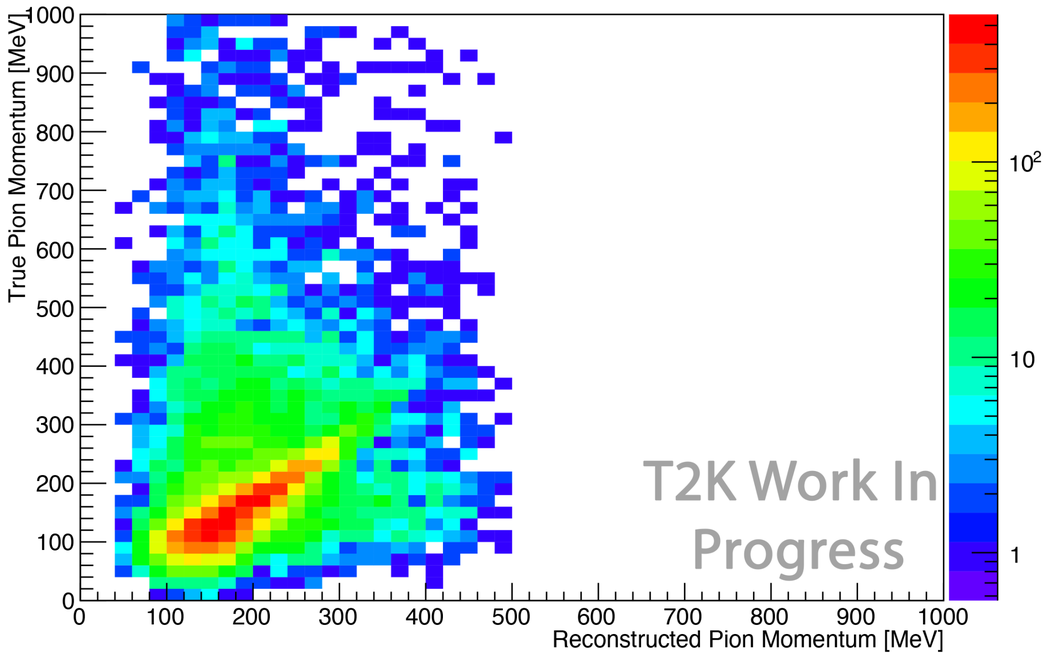
ME

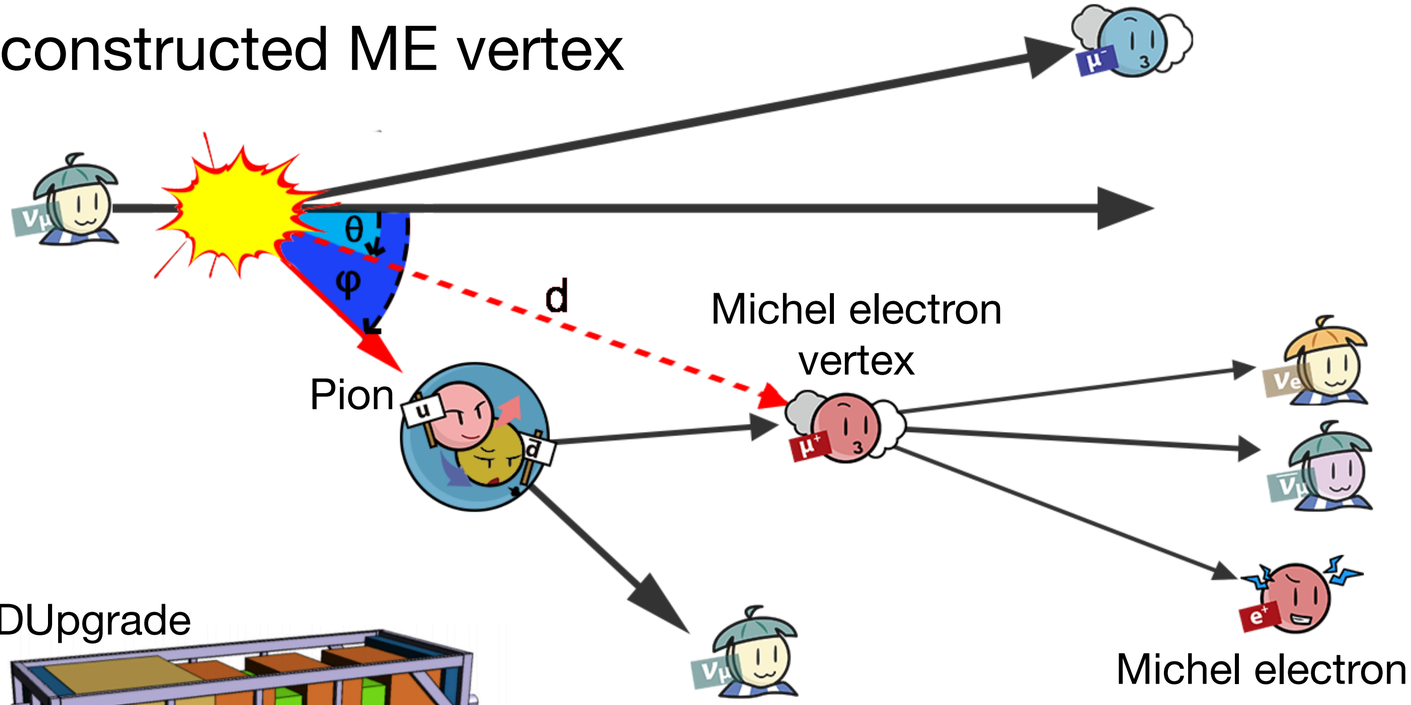


FGD

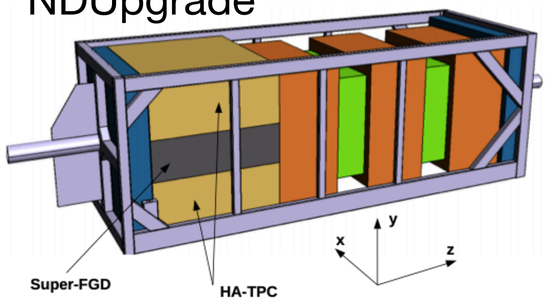
Pion reconstruction from Michel electrons

- Large number of pions unreconstructed due to decay to muons then Michel electrons - important as these pions would fall under Cherenkov threshold
- Estimate momentum using range to reconstructed ME vertex





NDUpgrade



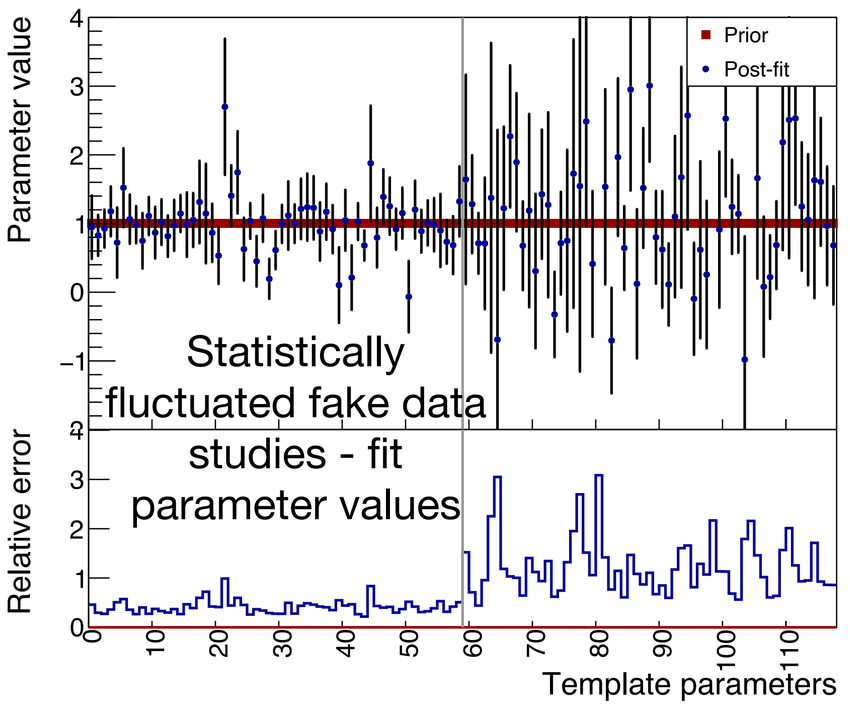
Technique will be even more effective when applied to superFGD!

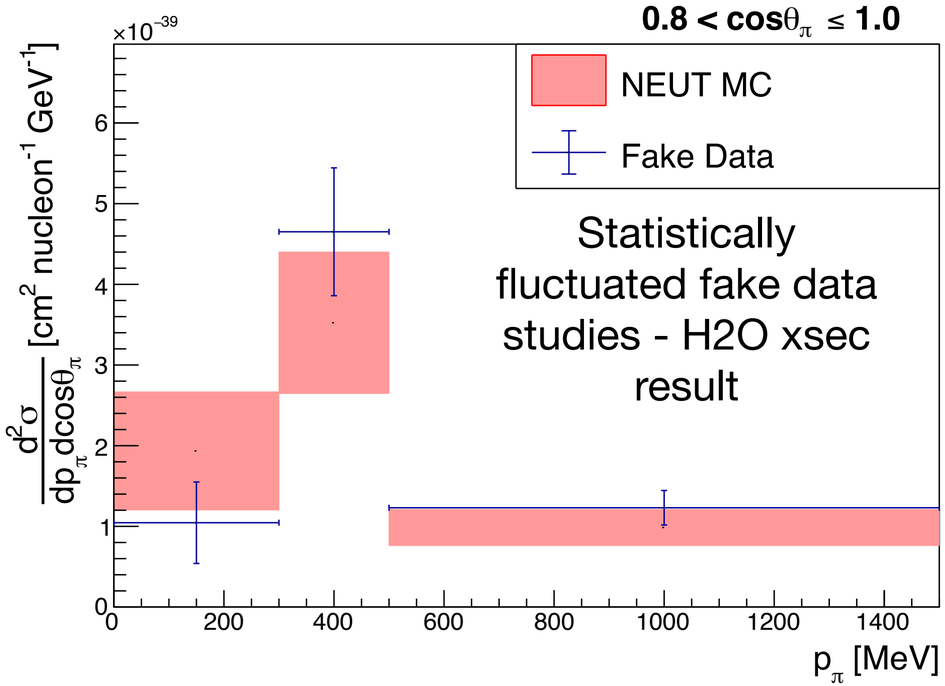
Cross Section Extraction

- Number of MC events fit to data using binned template likelihood fit
- Then calculate cross section in a given bin:

$$\left(\frac{d\sigma}{dx}\right)_i = \frac{N^{sig}_{i,true}}{\epsilon_i \phi T \Delta x_i}$$

- Report xsec measurements on hydrocarbon and water
- Start with 4D differential measurement in $(p_\mu, \cos\theta_\mu, p_\pi, \cos\theta_\pi)$, collapse to 2D in $(p_\pi, \cos\theta_\pi)$ for reduced stat. error
- Aiming for publication of xsec result soon





Hyper-Kamiokande

The Group

- Neil McCauley
- Jon Coleman

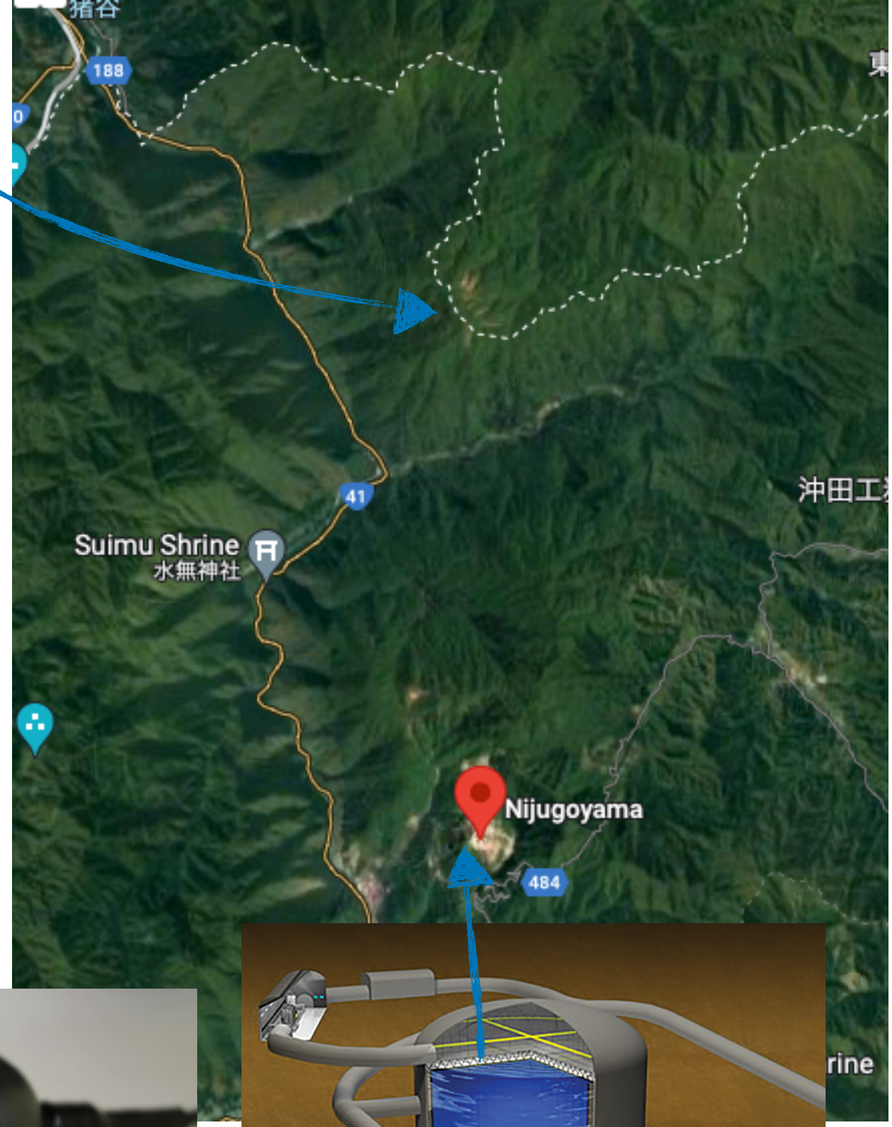
- Sam Jenkins
- Ka Ming Tsui
- David Payne

- Balint Bogdan
- Ashley Greenall

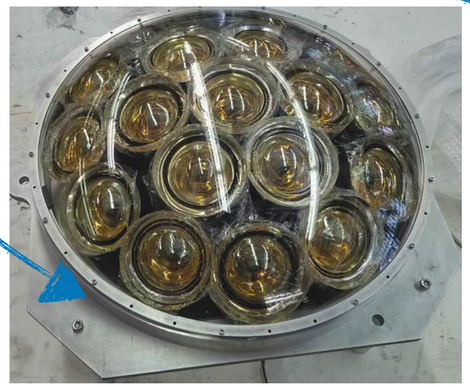
- Pruthvi Mehta
- Adam Tarrant

Hyper-Kamiokande

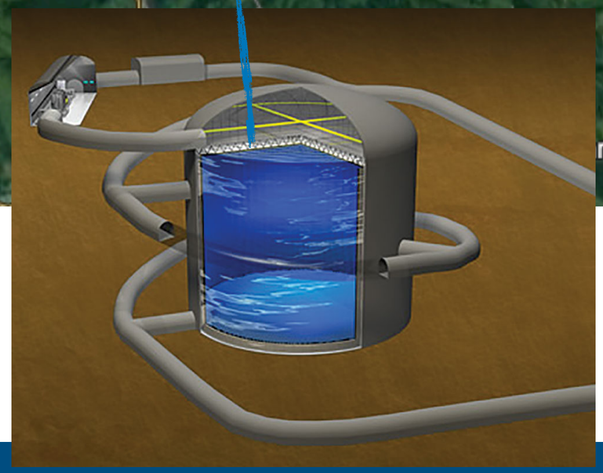
Super-Kamiokande



- 258 kton volume water Cherenkov detector
  - 216 kton inner detector (~187 kton fiducial volume)
  - 1 m thick outer detector used as a veto region
  - Optically separated using high reflectivity Tyvek sheets
- Instrumented with
  - 20000 50cm PMTs (ID)
  - ~10000 8cm PMTs (OD)
  - 1400 mPMTs

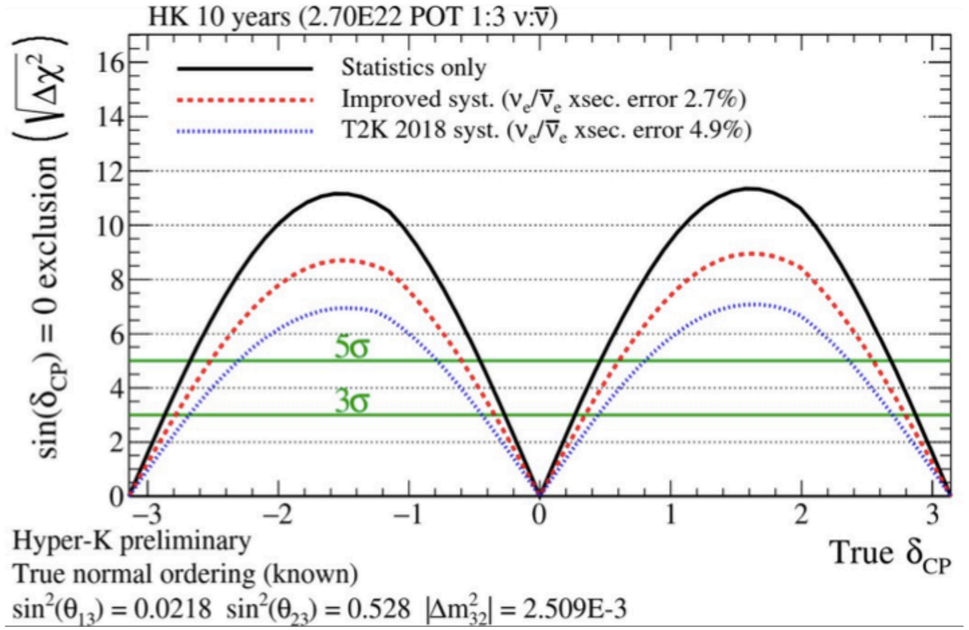


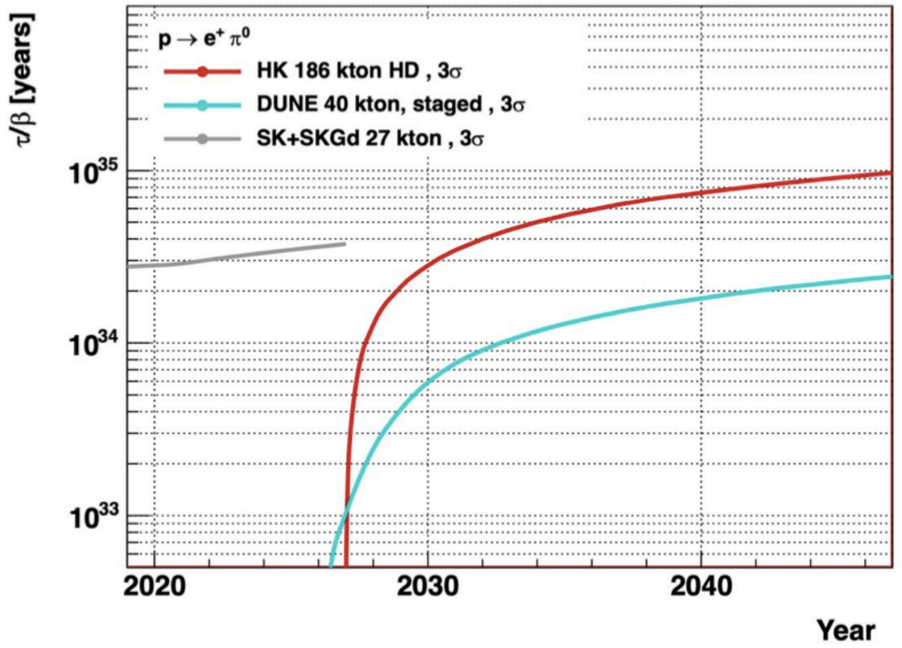
mPMTs provide improved timing and spatial resolutions - Neil chairing mPMT review

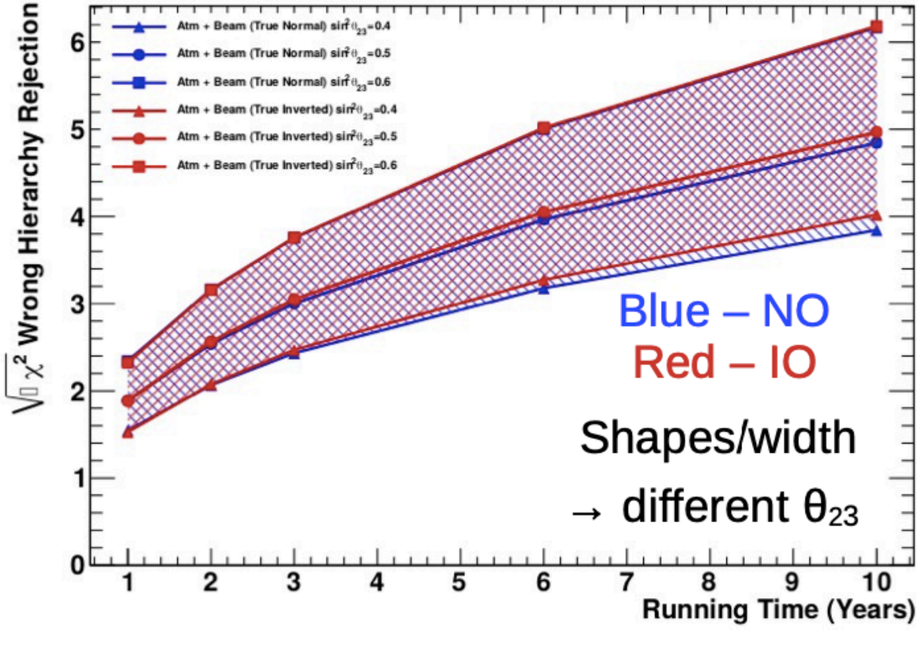


Physics Goals

- Aiming to start data taking in 2027
- Wide programme of physics goals
- Neutrino oscillations
  - CP violation
  - Mass ordering
  - θ_{23} octant
- Proton decay
- Supernovae alarm
- SN relic neutrinos

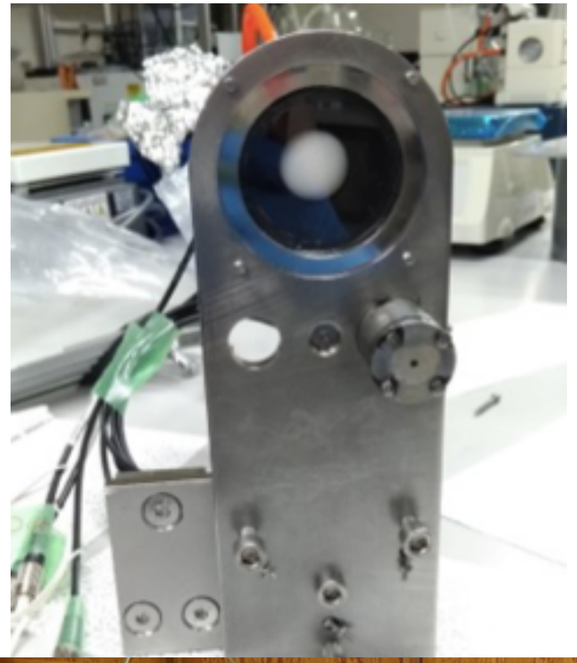






Detector Calibration

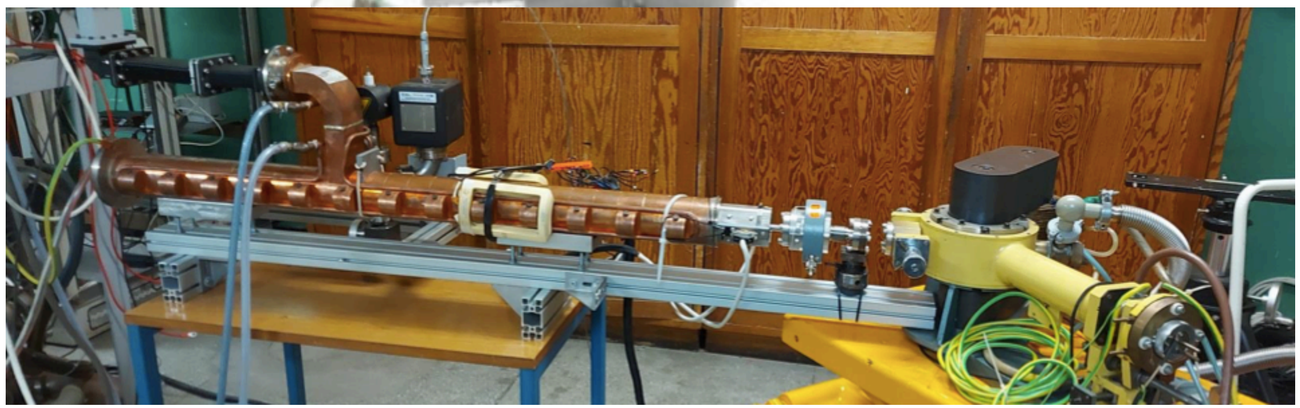
- Important to fully understand detector systematics - ~1% uncertainty needed
- Wide array of detector calibrations:
  - Light injection system
  - PMT precalibration
  - DT generator
  - NiCf gamma source
  - AmBe source
  - Electron LINAC
- Neil is leading integration



LI system injector housing

SK nickel source

LINAC test setup



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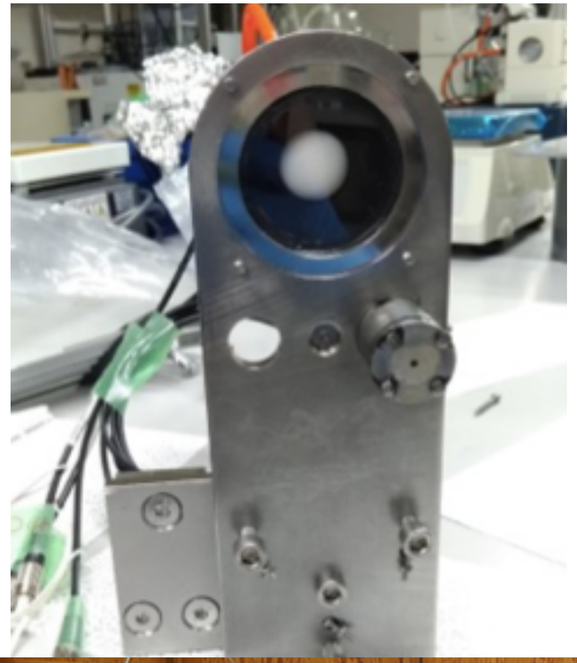

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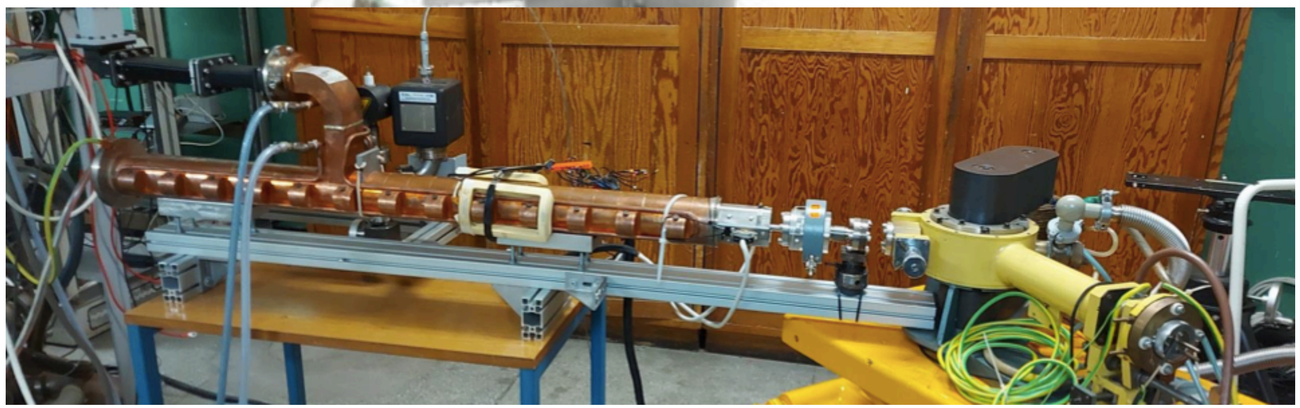
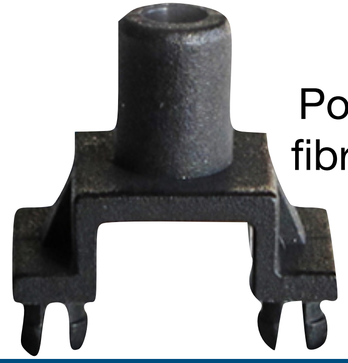
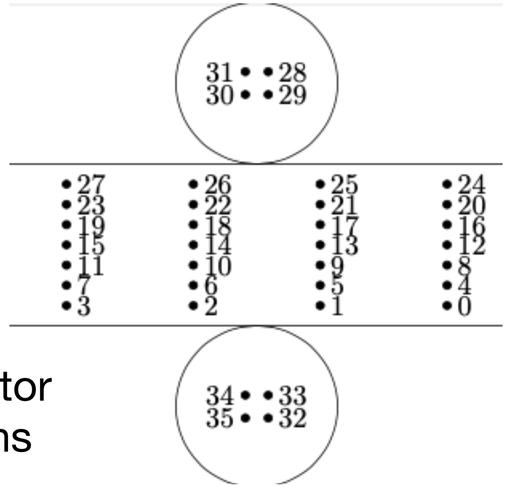


Calibration System Prototyping

- 36 injector positions, with collimated and diffuse light sources
- Liverpool group focussing on LED pulser board R&D
  - Need fast (<5 ns) timing
  - Balint working on new prototype boards - good progress but chip shortages are a problem!
  - I will be investigating surface mounted LEDs, and testing/ printing possible fibre connectors
  - Fibre test stand in new lab coming soon!

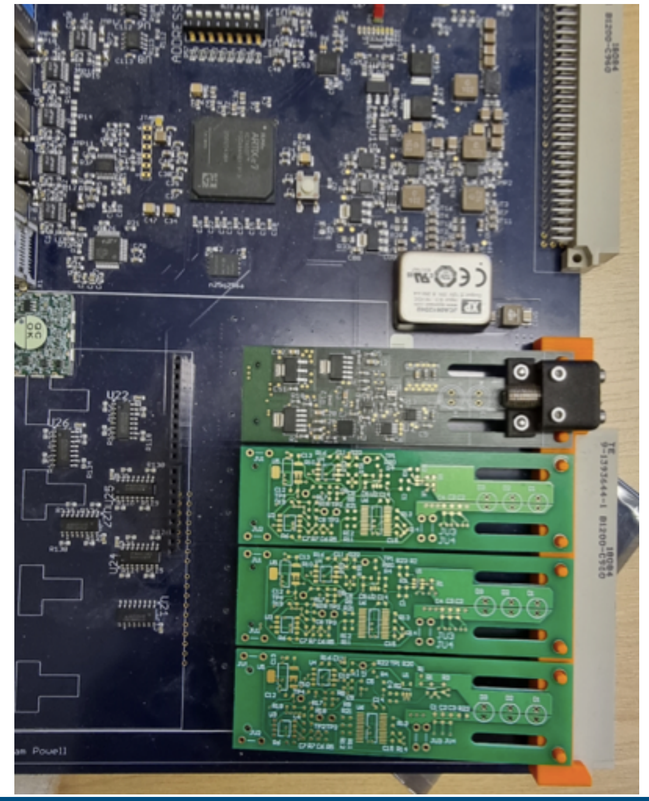


Potential SMD fibre connector



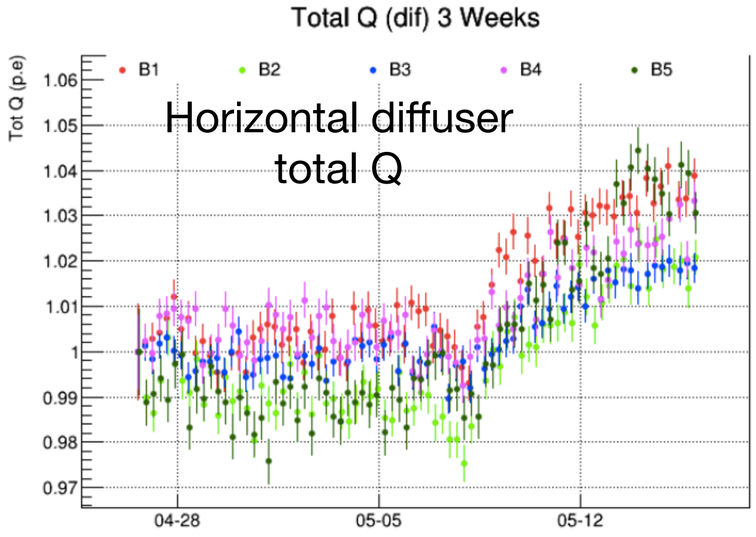
HK injector positions

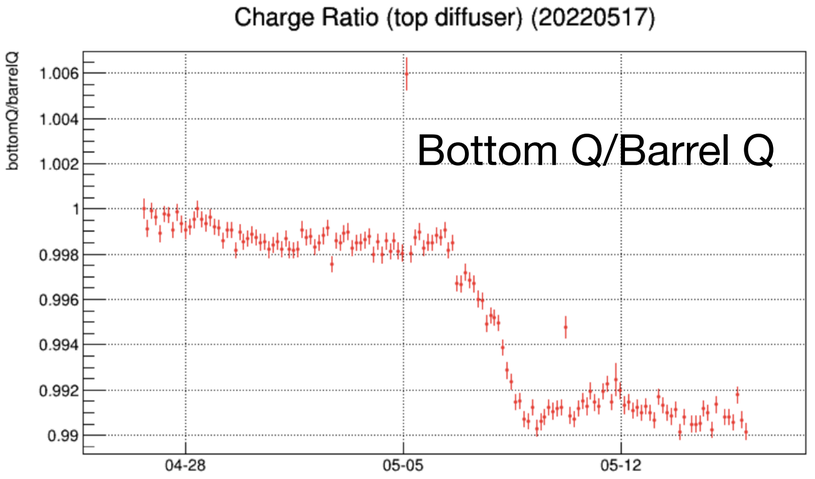
Balint's prototype boards



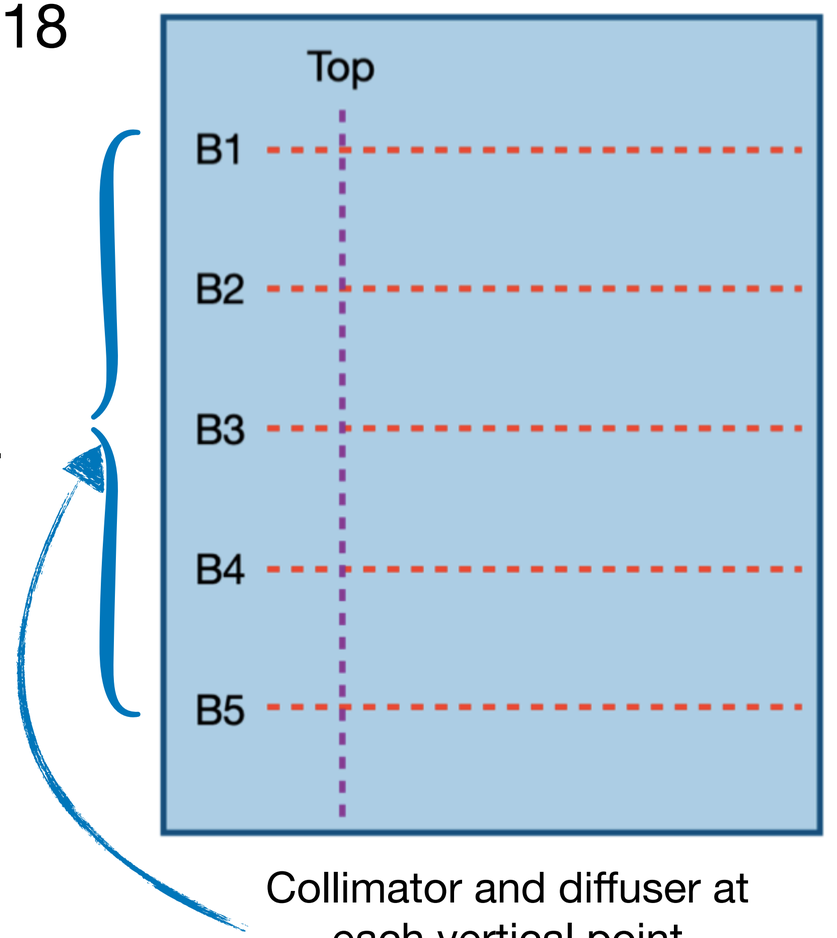
UKLI prototype system in Super-K

- Diffuser and collimator injector system installed in SK in 2018
  - New top diffuser laser source at a more sensitive wavelength
- Now used for water quality monitoring - clear sensitivity to current water convection
- I'm currently updating this to move to realtime monitoring - important for upcoming Gd loading



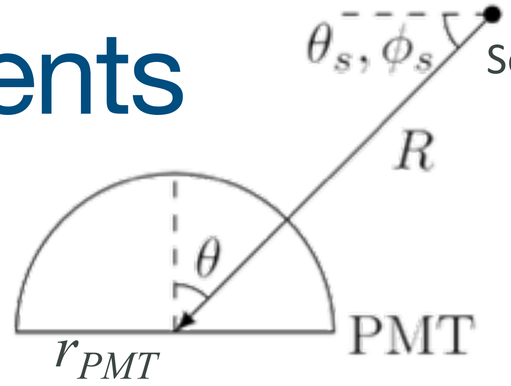


Additional top diffuser to illuminate bottom region

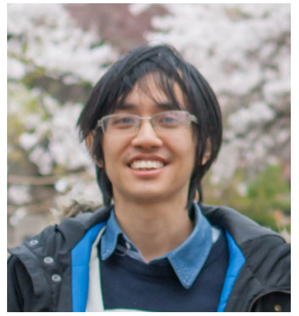


Collimator and diffuser at each vertical point

Light Attenuation Measurements

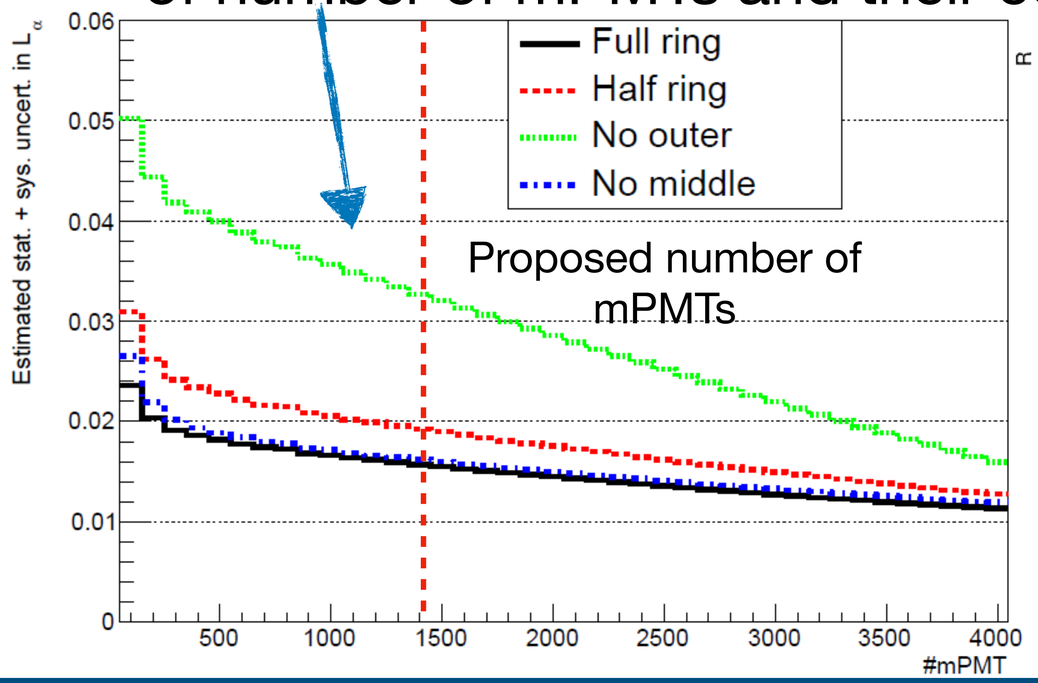


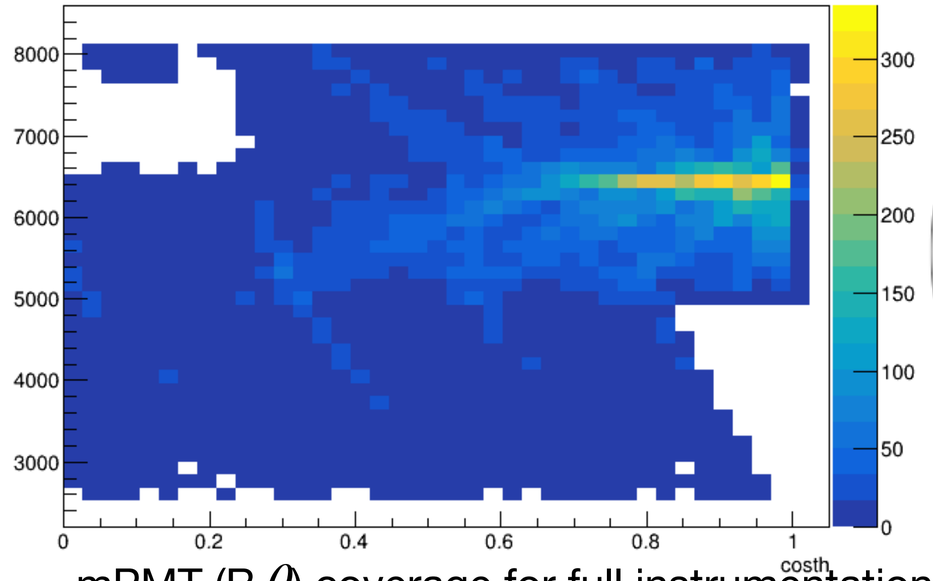
$$\Omega(R) \approx \frac{\pi r_{PMT}^2}{R^2}$$



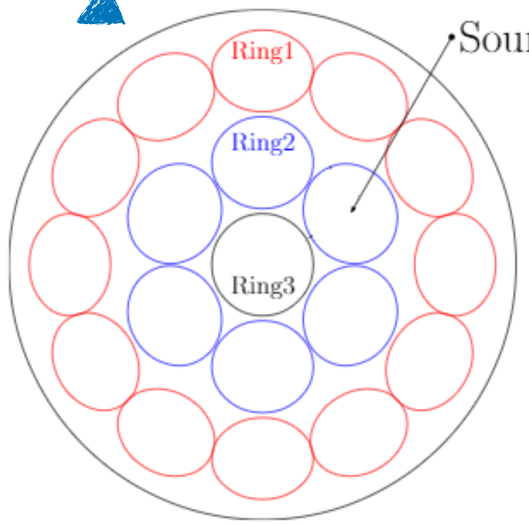
$$PE = I_s(\theta_s, \phi_s) e^{-R/L_\alpha} A(\theta) \Omega(R)$$

- Ka Ming has been working on a maximum likelihood fit framework for water quality measurements and PMT response
- Performance of fit enhanced with mPMTs
  - Provides estimation of uncertainties as a function of number of mPMTs and their configuration

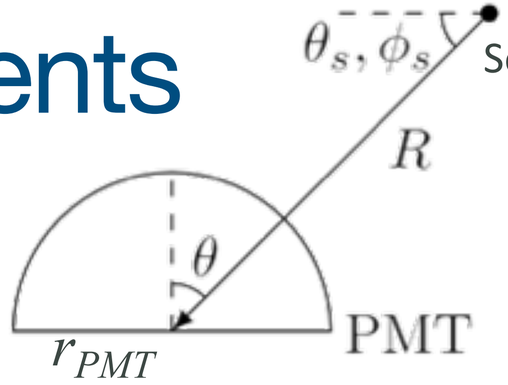




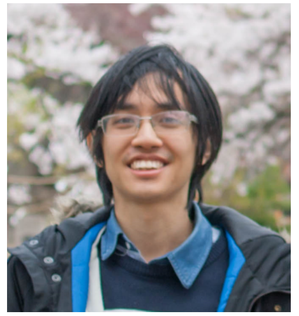
mPMT (R,θ) coverage for full instrumentation



Light Attenuation Measurements

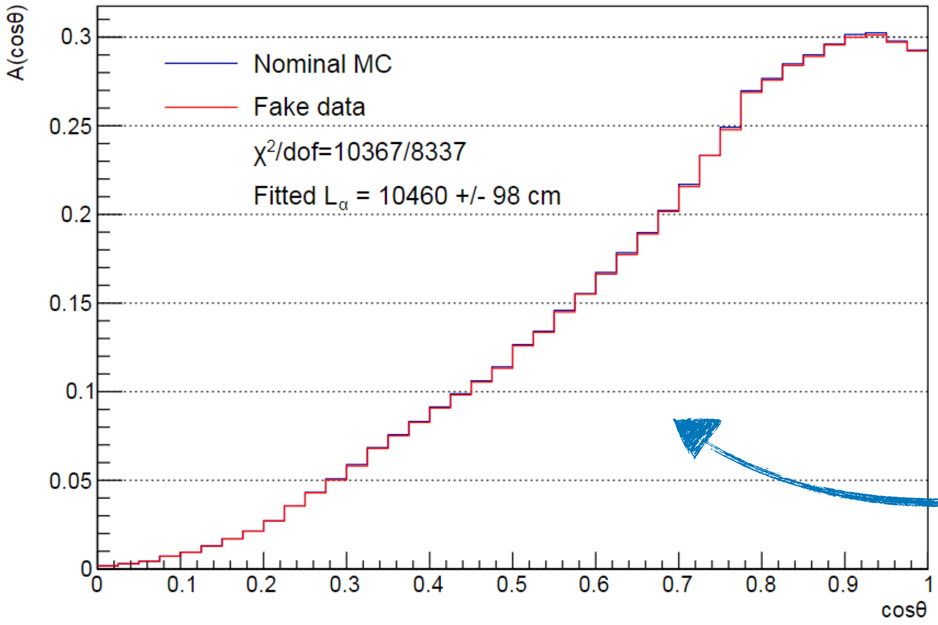


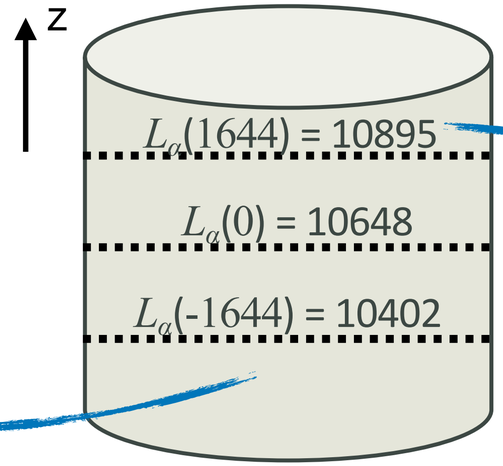
$$\Omega(R) \approx \frac{\pi r_{PMT}^2}{R^2}$$

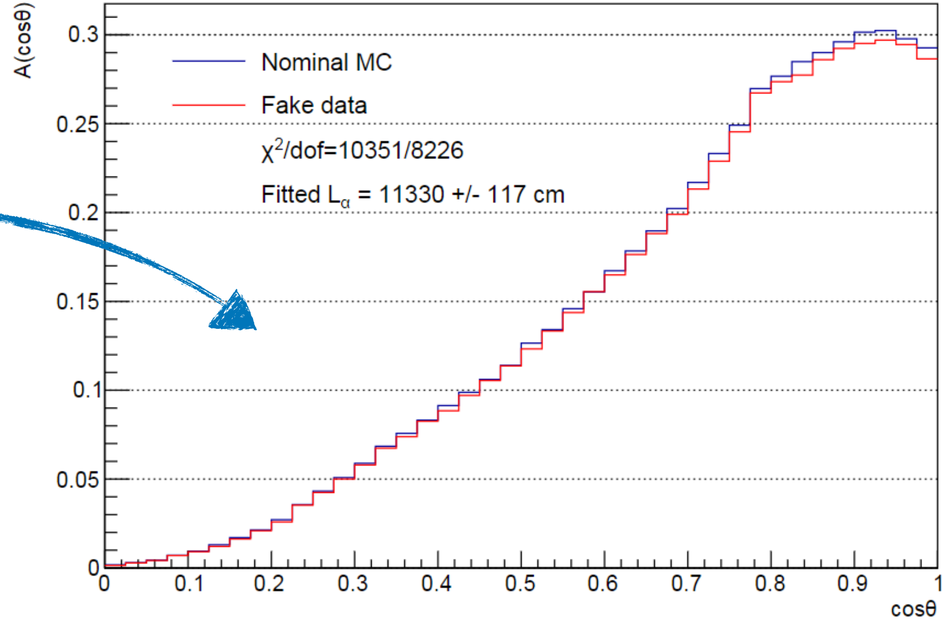


- Ka Ming has been working on a maximum likelihood fit framework for water quality measurements and PMT response
- Also has applications for top-bottom asymmetry (TBA) analysis
- Assume attenuation length linearly dependent on z

$$PE = I_s(\theta_s, \phi_s) e^{-R/L_\alpha} A(\theta) \Omega(R)$$



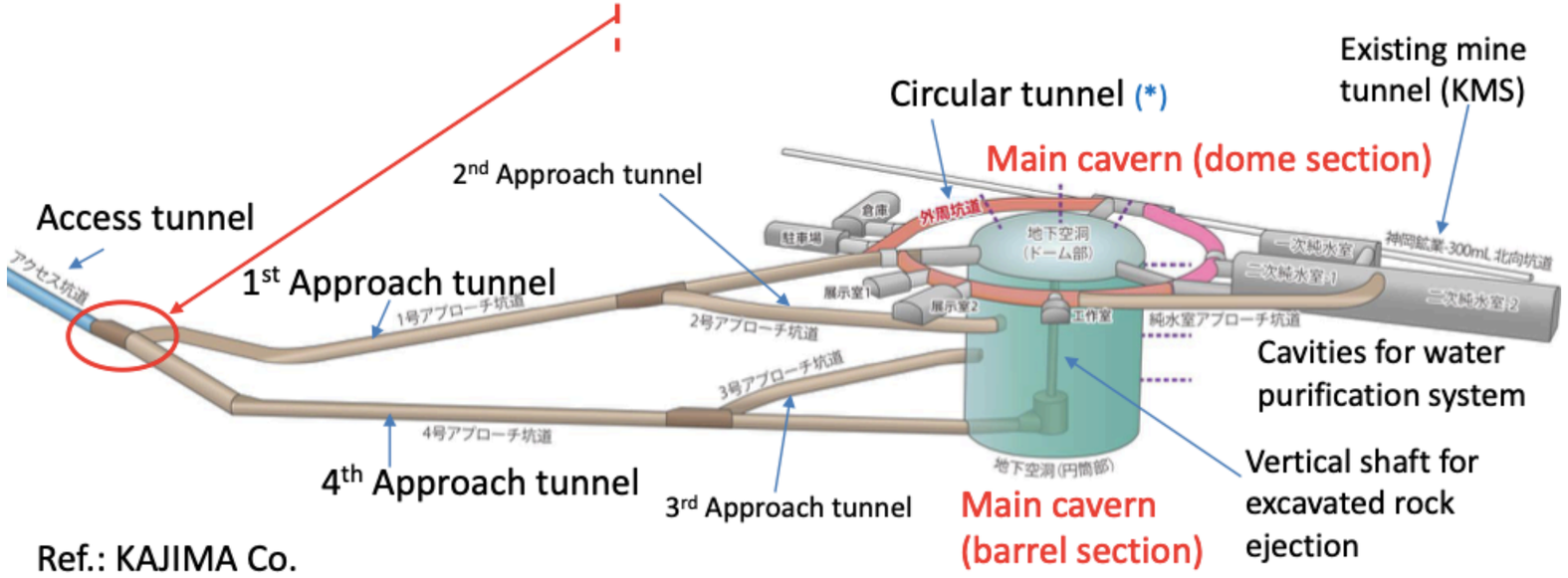




Excavation Status

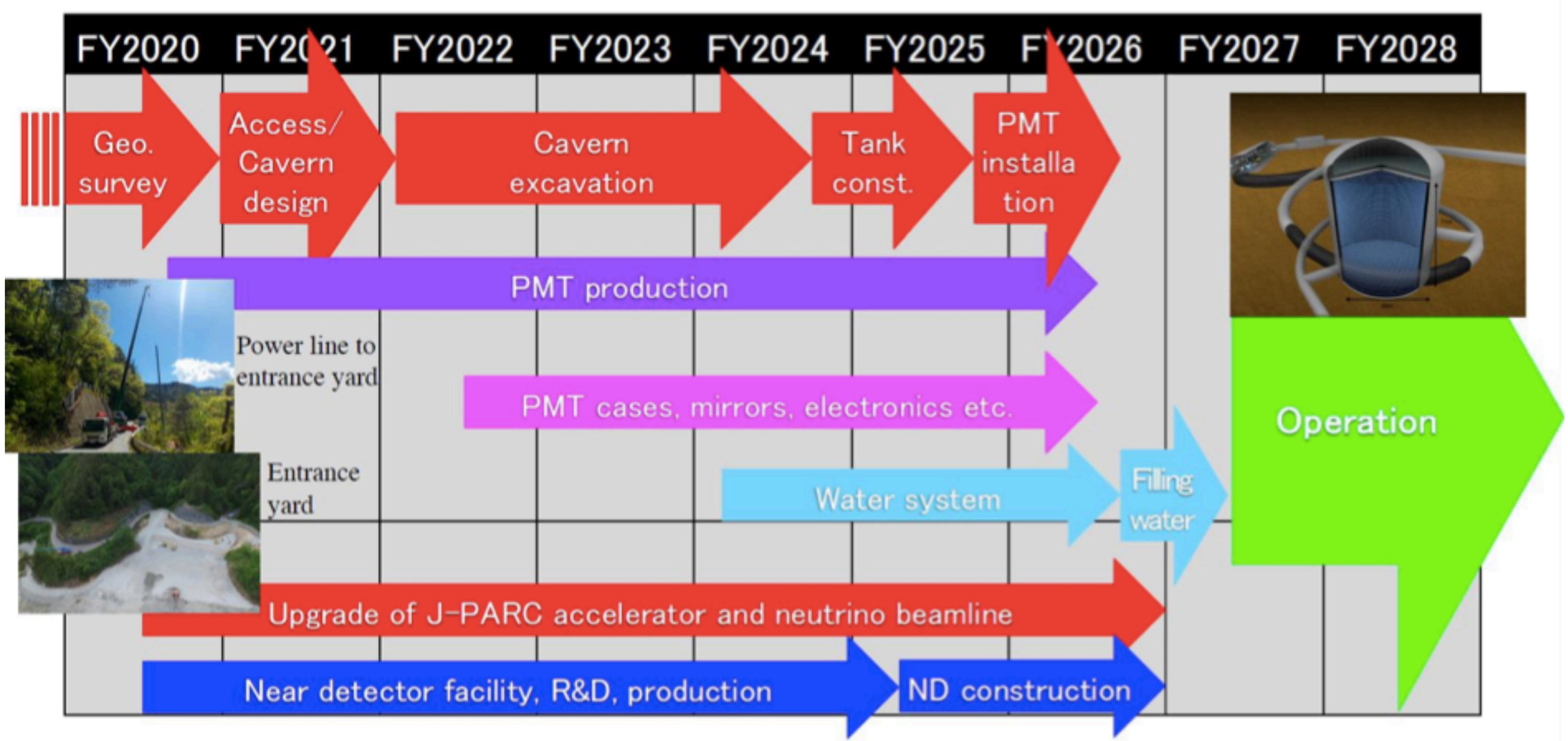
Access tunnel excavation completed. Approach tunnel excavation starting

	FY2020	FY2021	FY2022	FY2023	FY2024	FY2025	FY2026
Cavern excavation	Entrance yard	Access tunnel	Approach tunnels	Circular tunnel & satellite cavities	Vertical shaft for rock ejection		
	Design	Design	Design	Dome section	Barrel section		
	Geo-survey						



Ref.: KAJIMA Co.

Timeline


FY2020
FY2021
FY2022
FY2023
FY2024
FY2025
FY2026
FY2027
FY2028
Geo. survey
Access/ Cavern design
Cavern excavation
Tank const.
PMT installation
PMT production
Power line to entrance yard
PMT cases, mirrors, electronics etc.
Entrance yard
Water system
Filling water
Operation
Upgrade of J-PARC accelerator and neutrino beamline
Near detector facility, R&D, production
ND construction

Overview

- Hyper-K construction ongoing, aiming to begin data taking in 2027
- Liverpool playing a key role in the calibration system and mPMT physics potential