

T2K/SK/HK Group Update

(All the Kamiokandes)

Liverpool HEP Christmas Eurovision Meeting

18/5/23

Sam Jenkins



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)
- ~7000 8cm PMTs (OD)
- ~1400 mPMTs

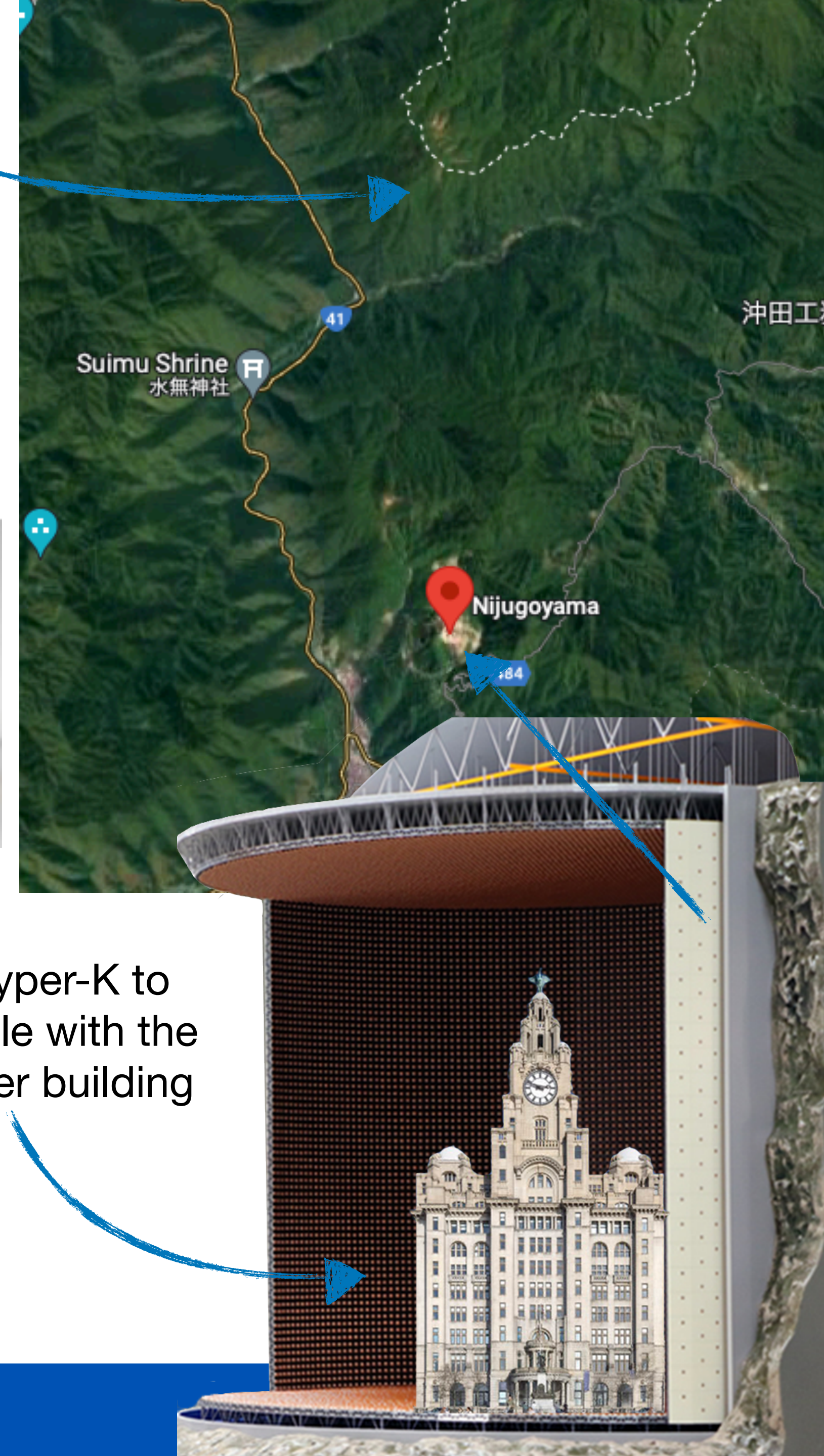
♥ UK funding has been confirmed, all Liverpool contributions going ahead



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



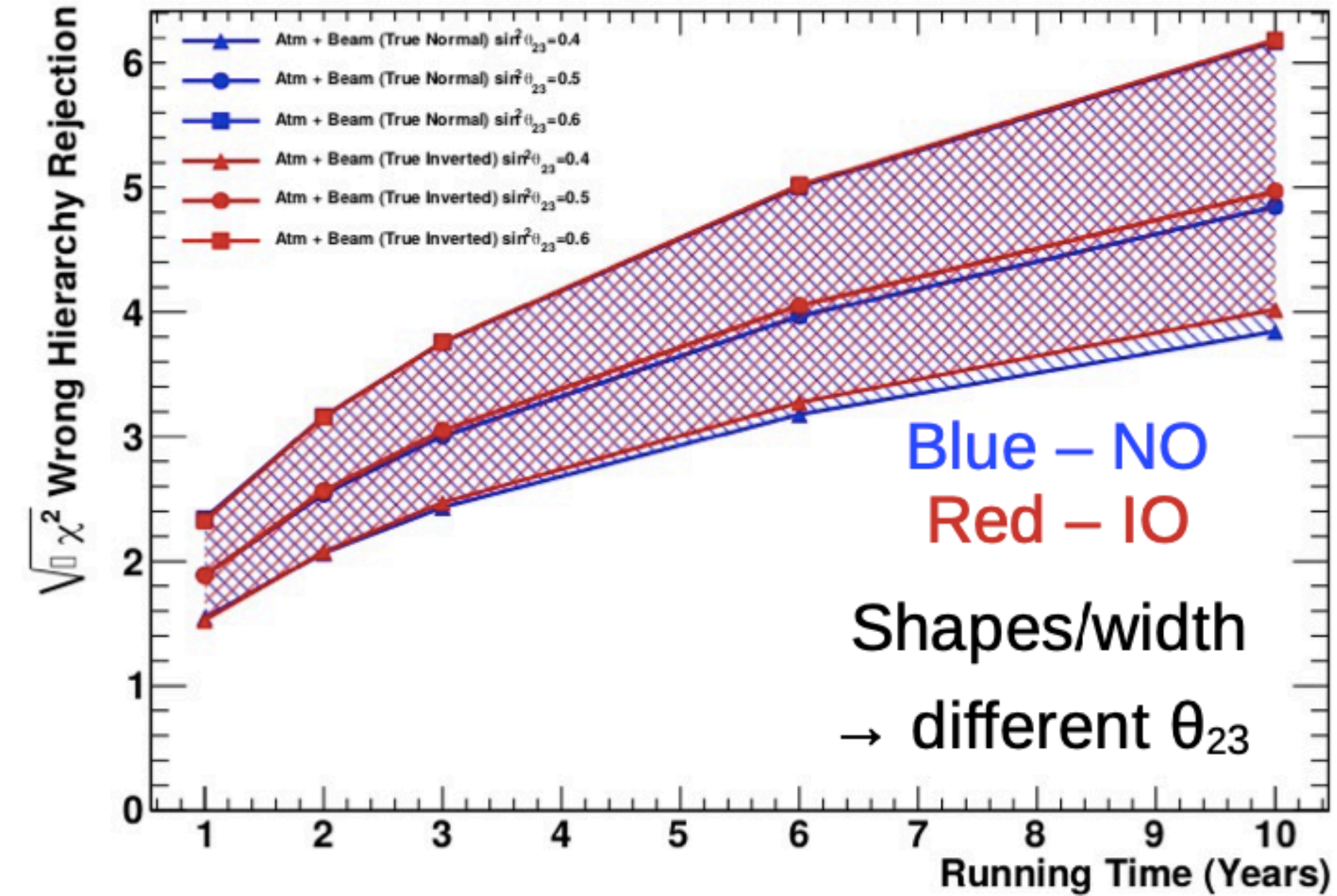
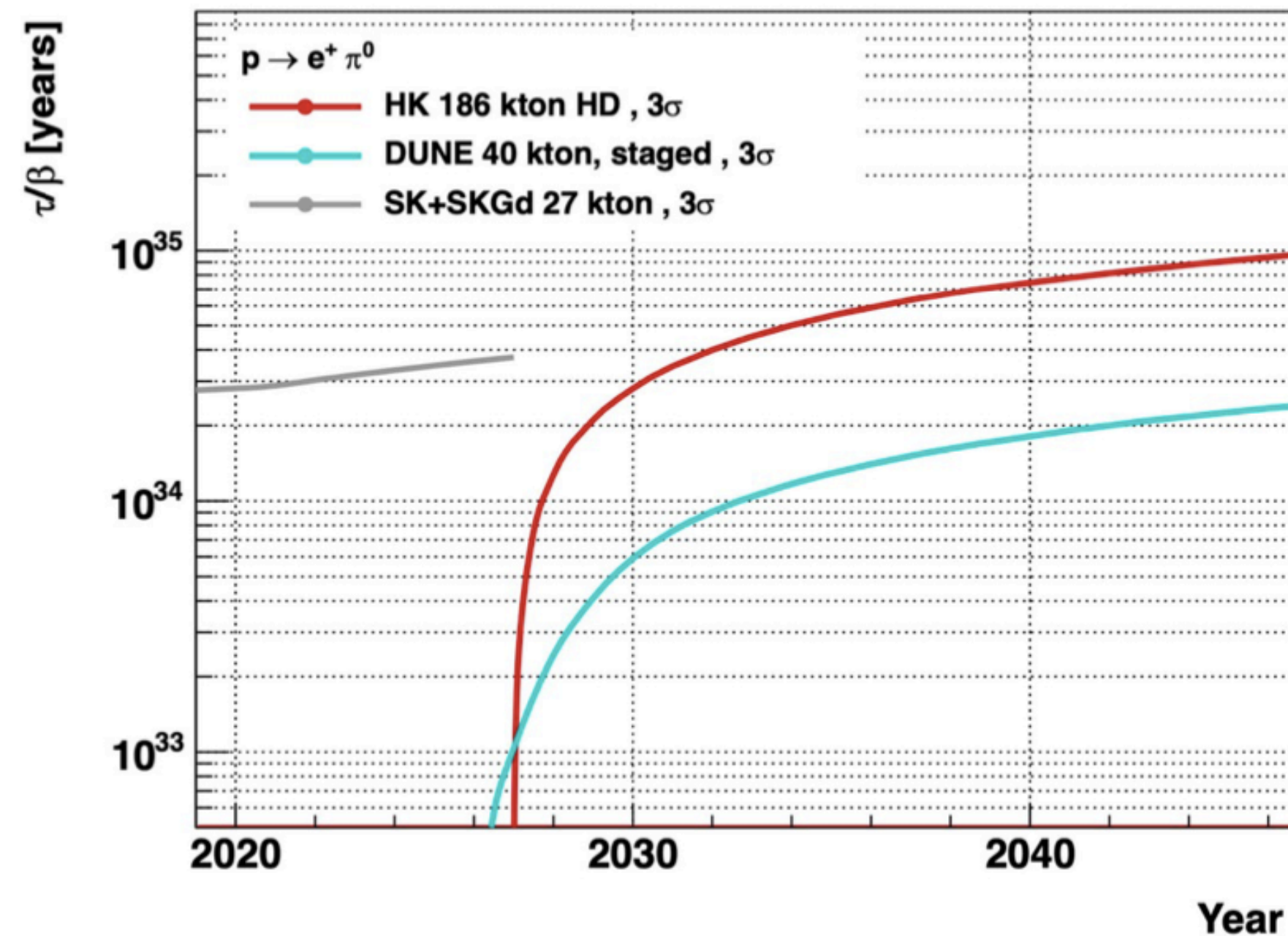
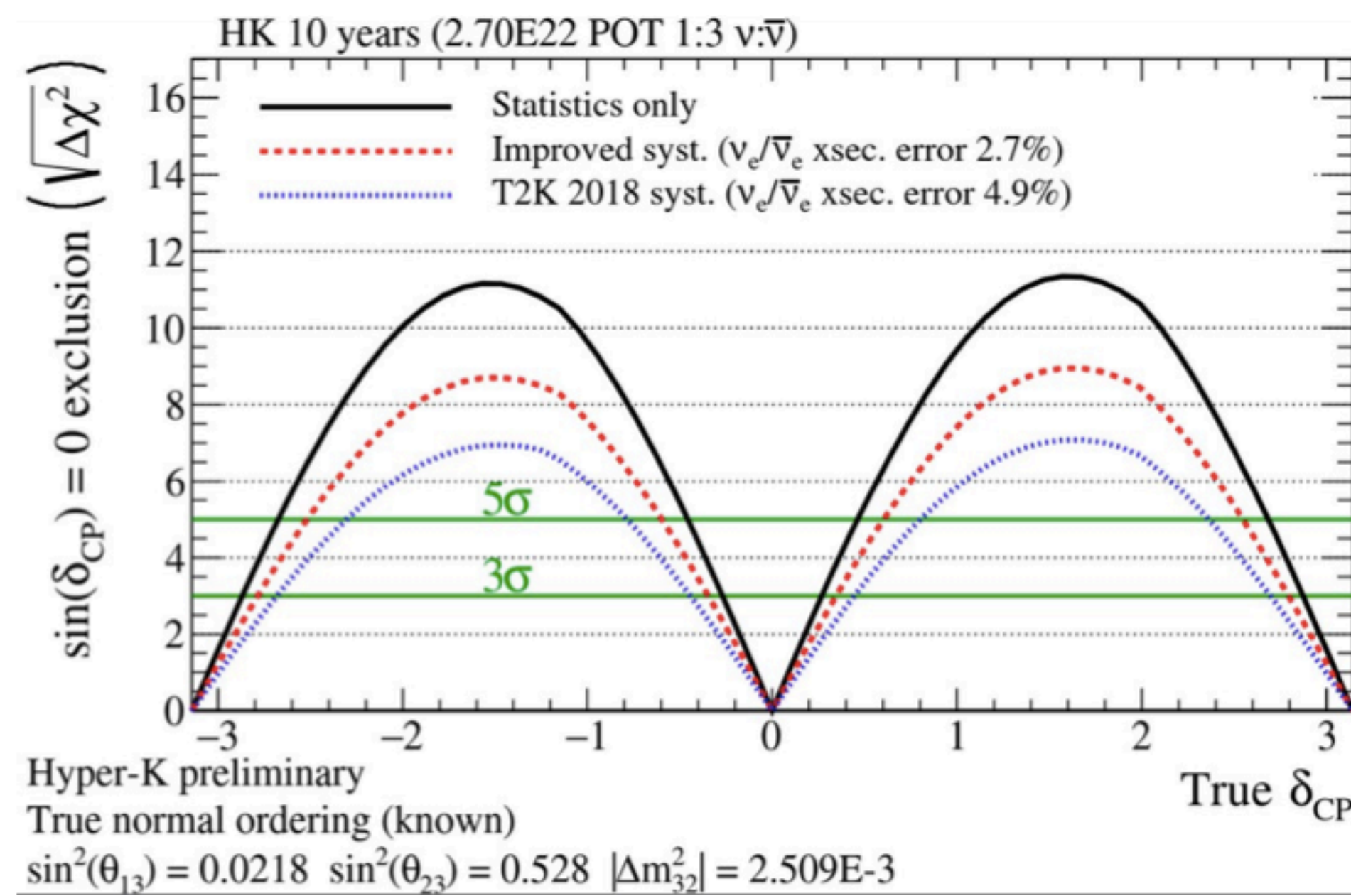
Hyper-K to scale with the Liver building



Physics Goals



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



Group Members



♥ Neil McCauley

♥ Jon Coleman

♥ Sam Jenkins

👋 ♥ Ka Ming Tsui → Ellen Sandford

♥ David Payne

♥ Balint Bogdan

♥ Ashley Greenall

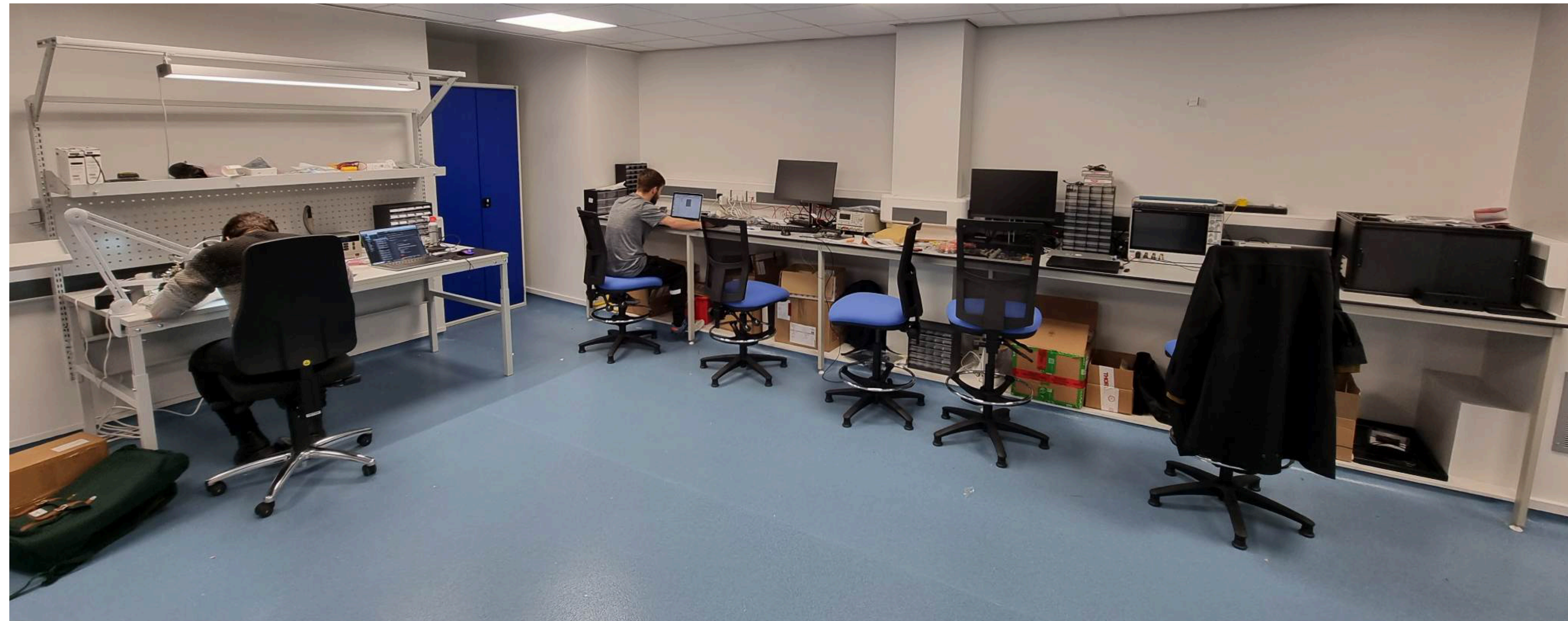
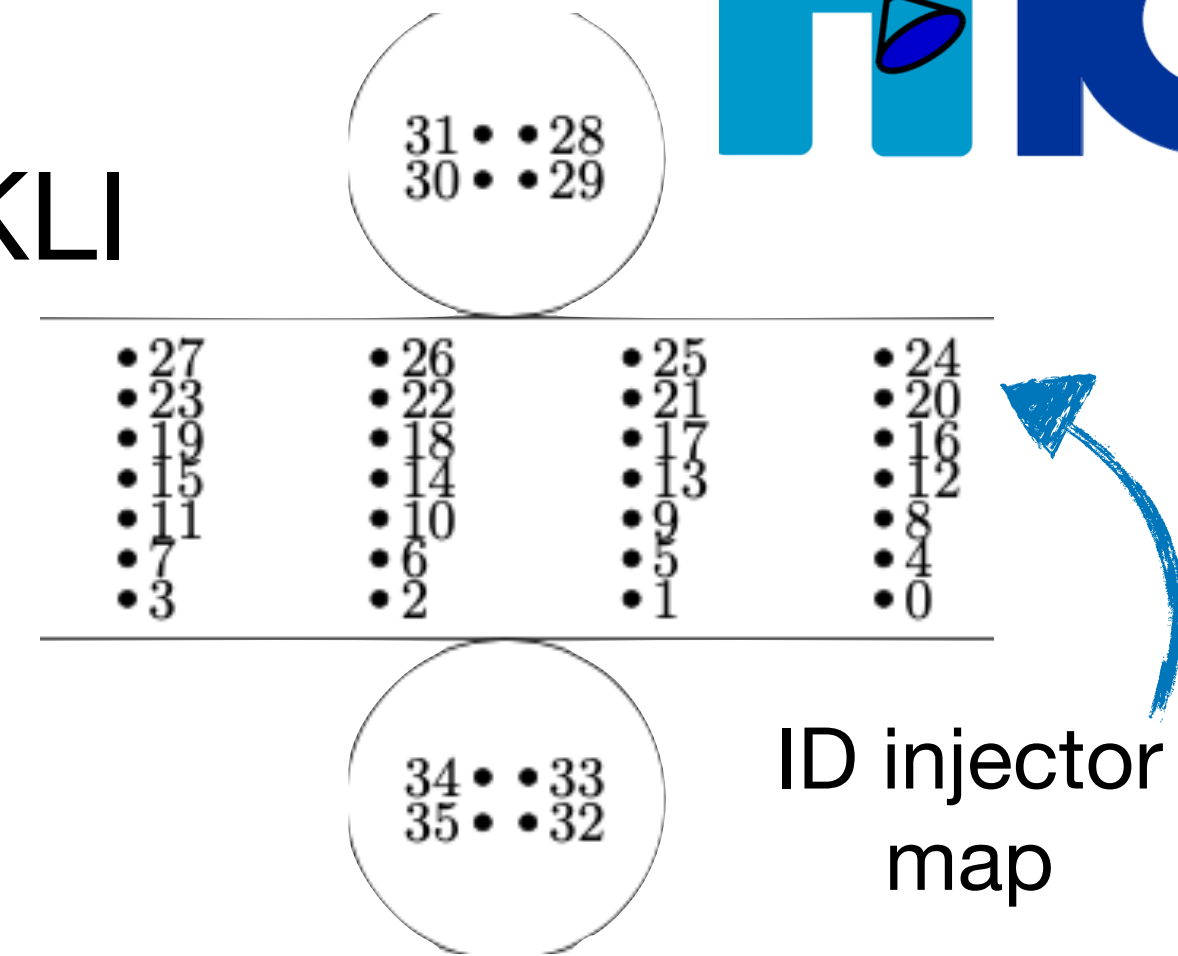
♥ Pruthvi Mehta

See Ellen's talk
later today

Optical fibre testing for light injection



- ♥ UK group developing light injection calibration system, similar to UKLI in SK
- ♥ Series of collimators and diffusers illuminated by laser (ID) and LED pulser (OD)
- ♥ Liverpool group in charge of optical fibre specification and testing
- ♥ New optics lab in chemistry building set up and equipped for this

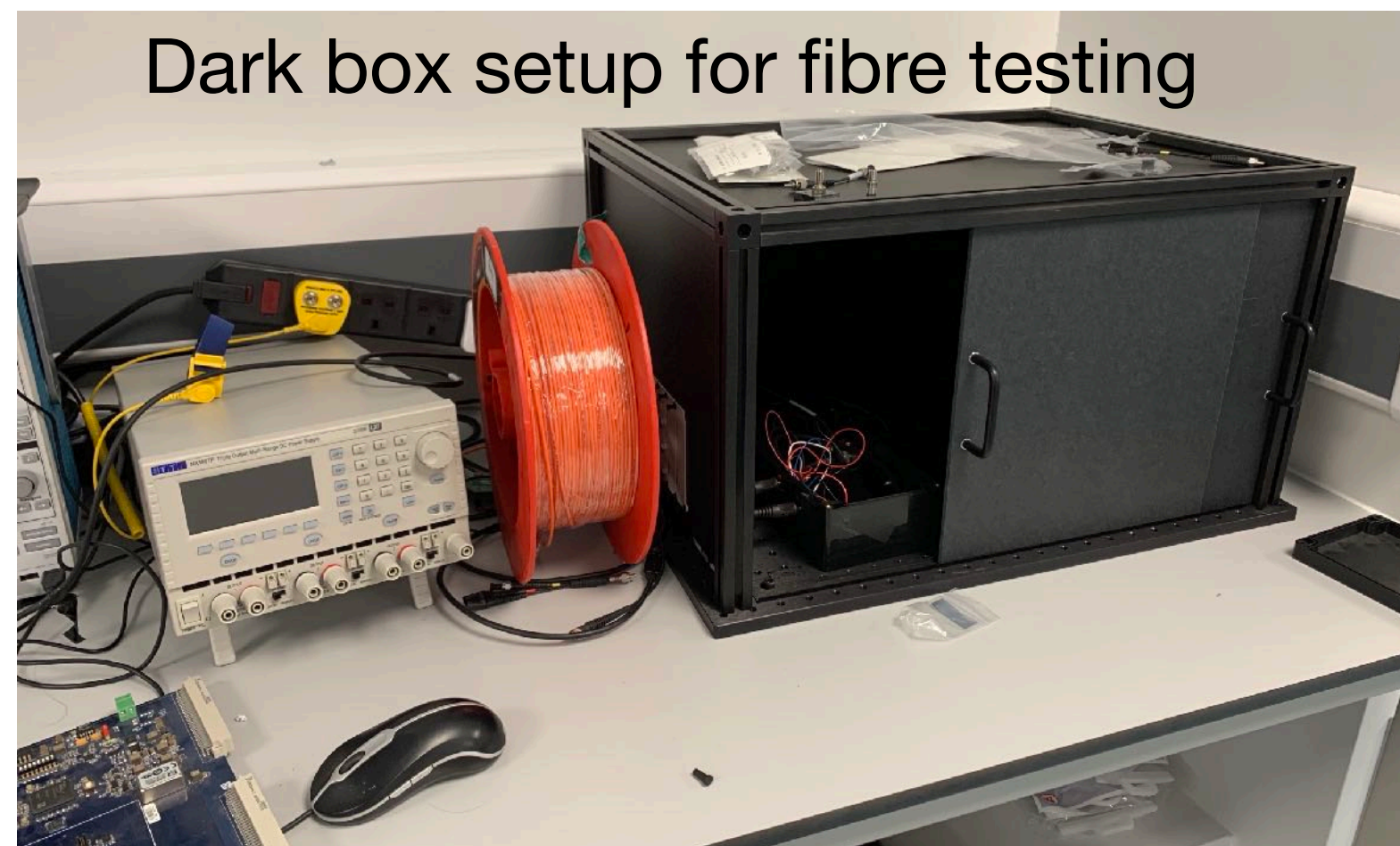


Optical fibre testing for light injection

Work by me,
Balint, Matt
Jarosiewicz (UG)



- ♥ Currently testing 6 possible fibre reels using pulsed LED sources, with help of an undergrad project student
- ♥ Aiming to start testing with laser source imminently
- ♥ Once fibre specifications are narrowed down, tests will be repeated with full 150m reels required for HK
- ♥ Neil is also working on integration plan for how we install these into Hyper-K — planning to perform installation training in the Oliver Lodge stairwell

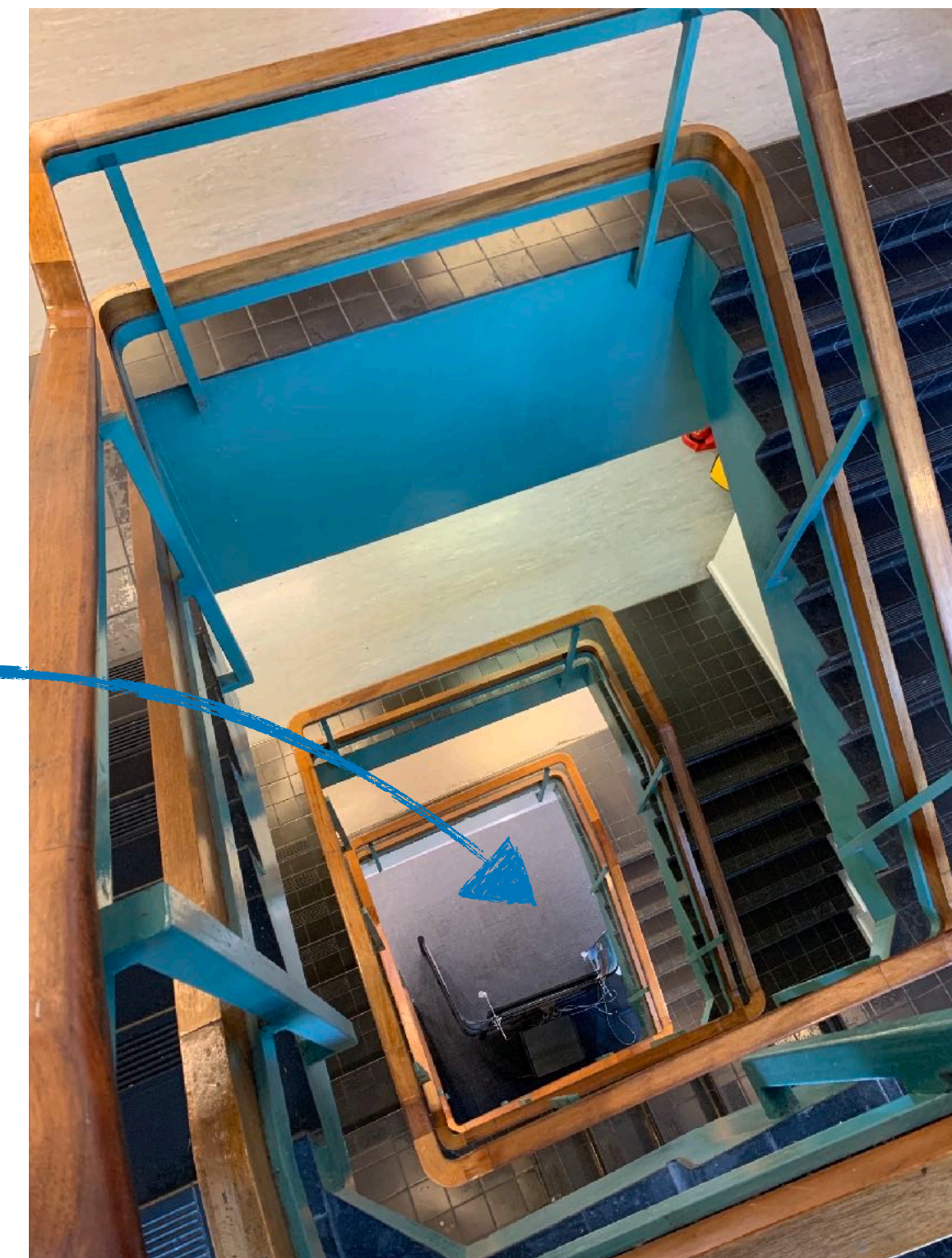


Dark box setup for fibre testing



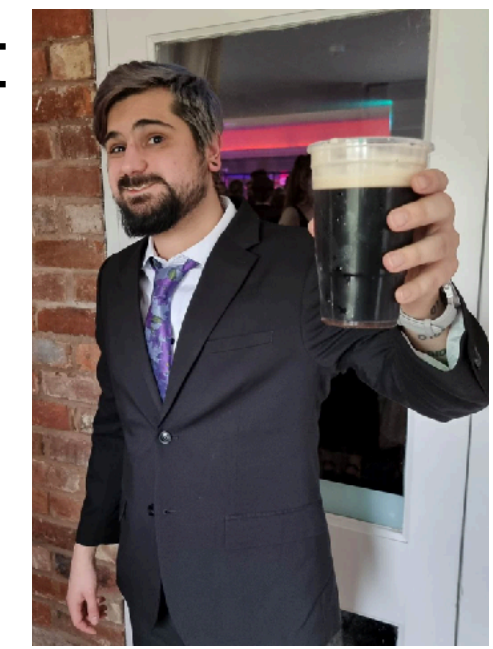
Laser source

Accurate
fibre
installation
simulation
space™



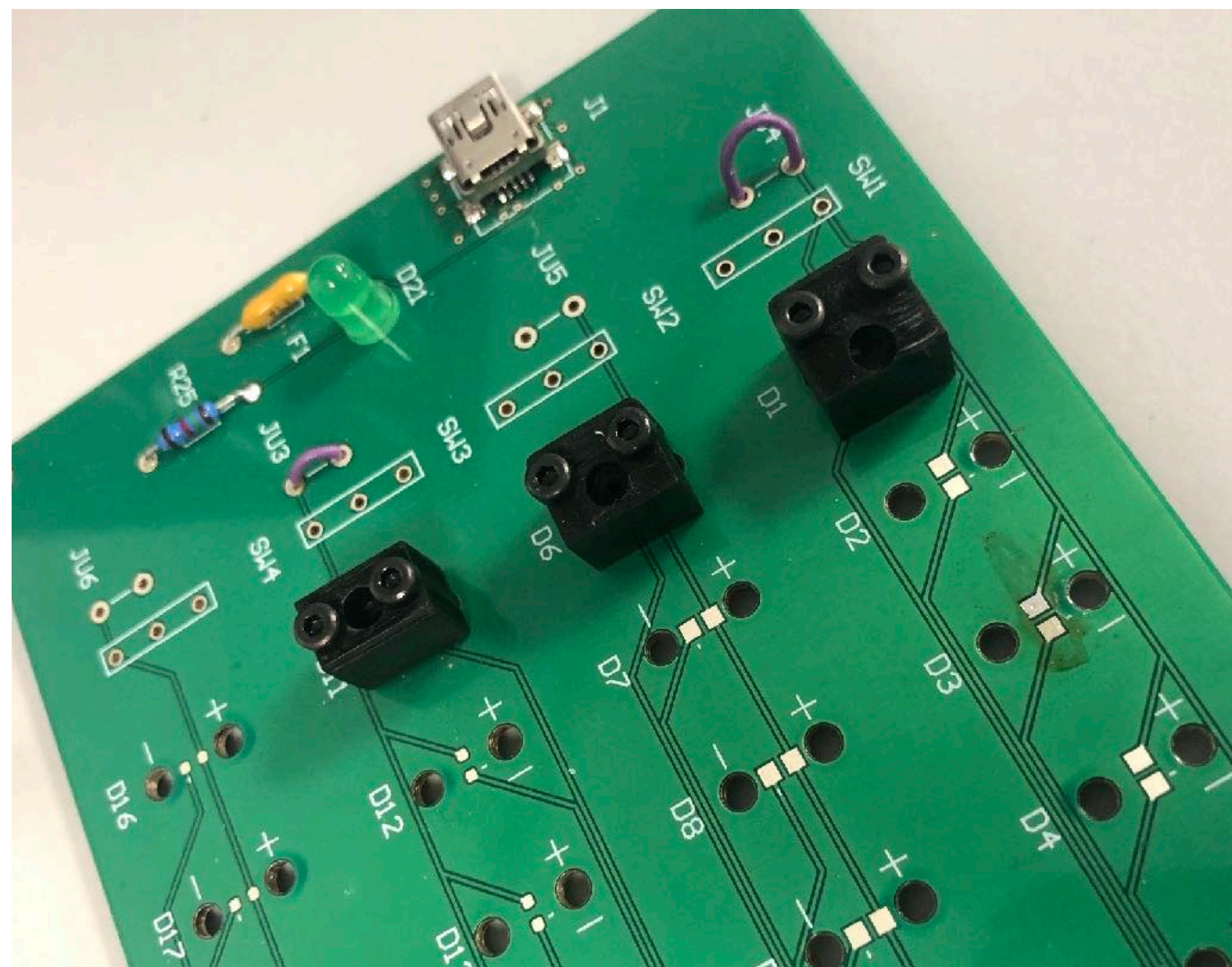
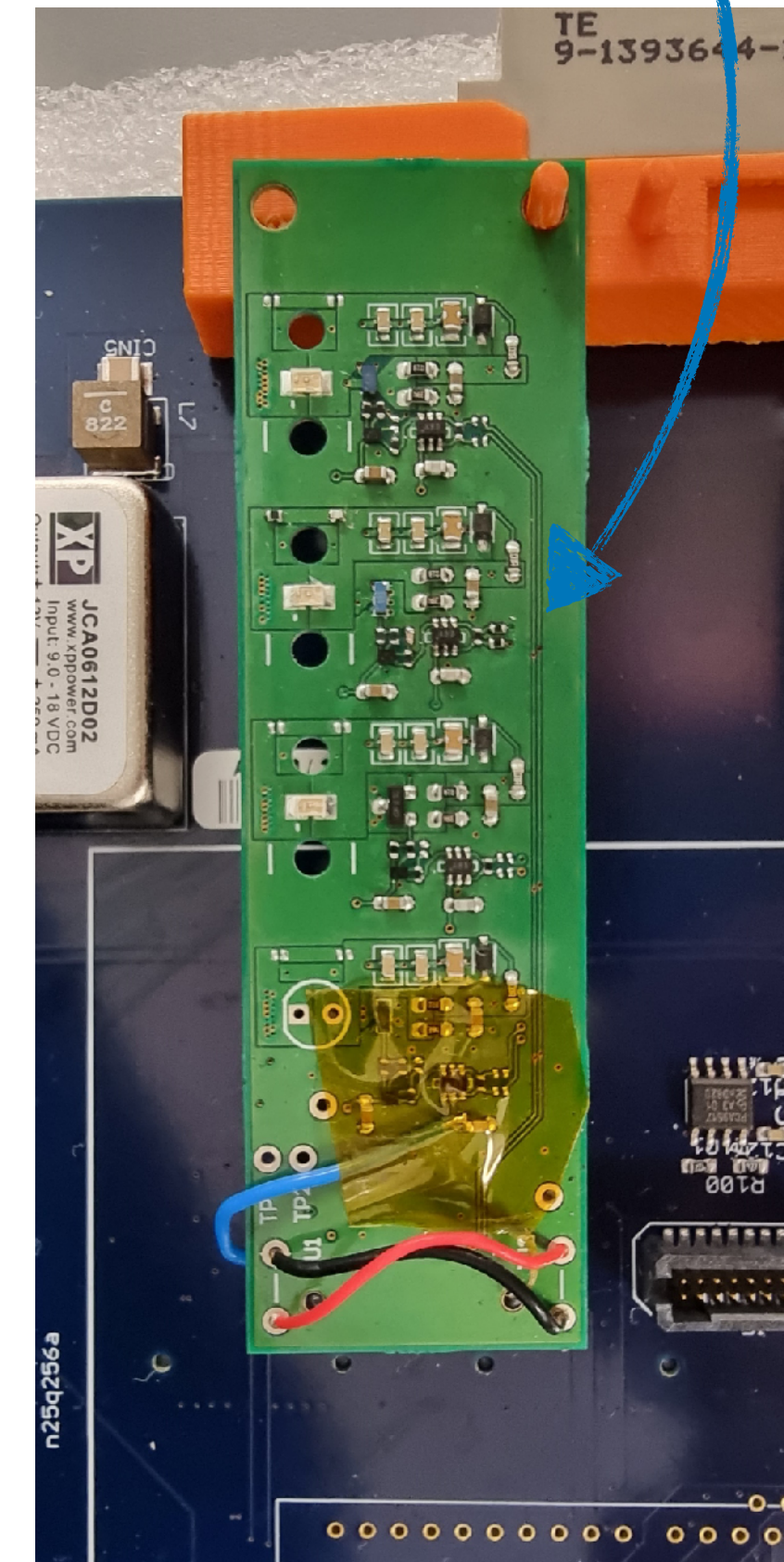
LED pulser boards

Work by Balint



- ♥ Pulser board based off original SK boards, with new design being evaluated - 3 separate switches on prototype board
- ♥ New FPGA boards for motherboard design planned
- ♥ Current pulse length down to 3ns - Balint is working to improve this further
- ♥ Surface mounted LEDs crucial for fast timing, requires new solution for LED-fibre coupling

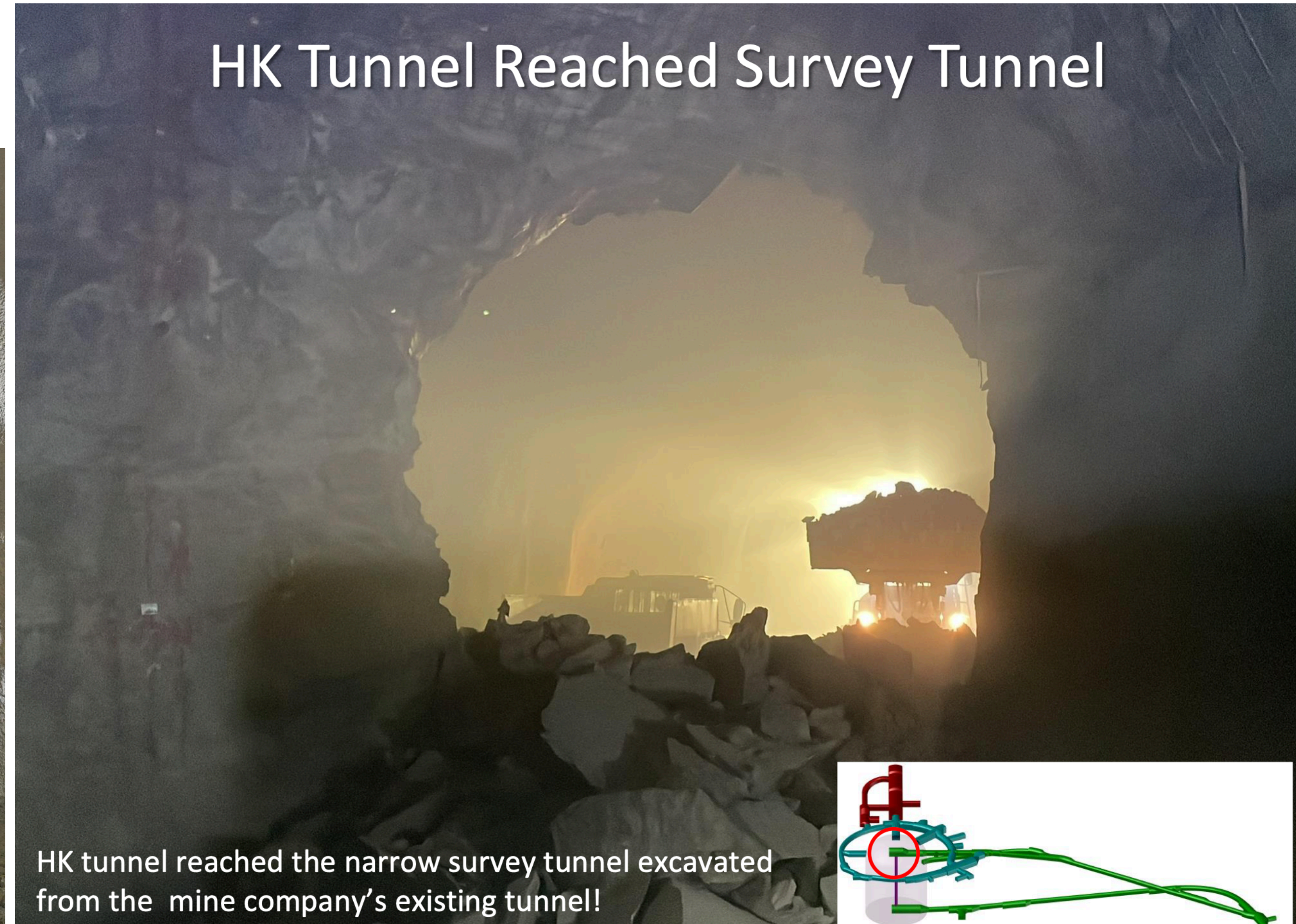
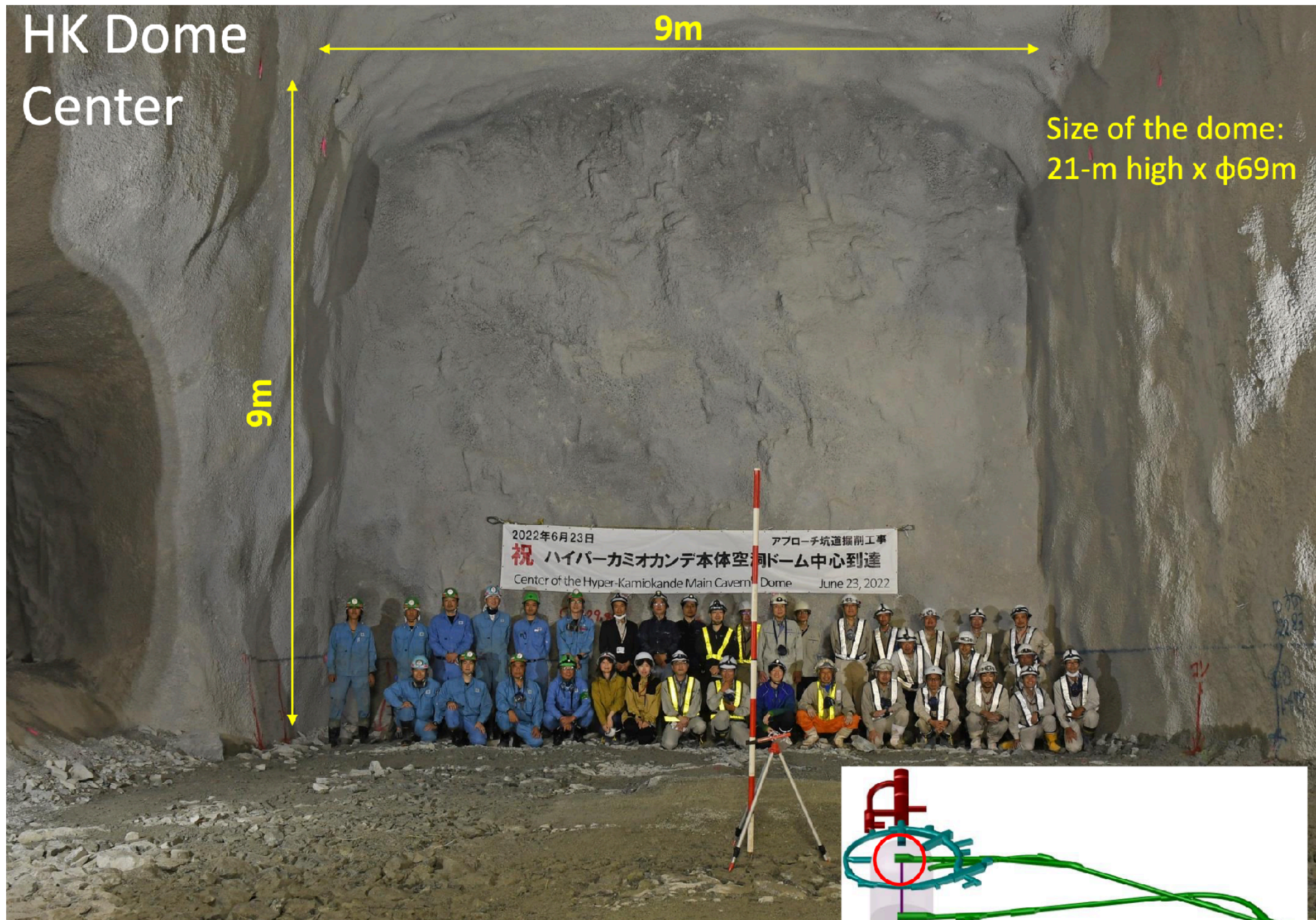
Prototype board with 3 different switch circuits



- ♥ 3D printing the connectors allows us to optimise light collection efficiency
- ♥ Screw mounted connectors perform significantly better than previous design at minimising light loss

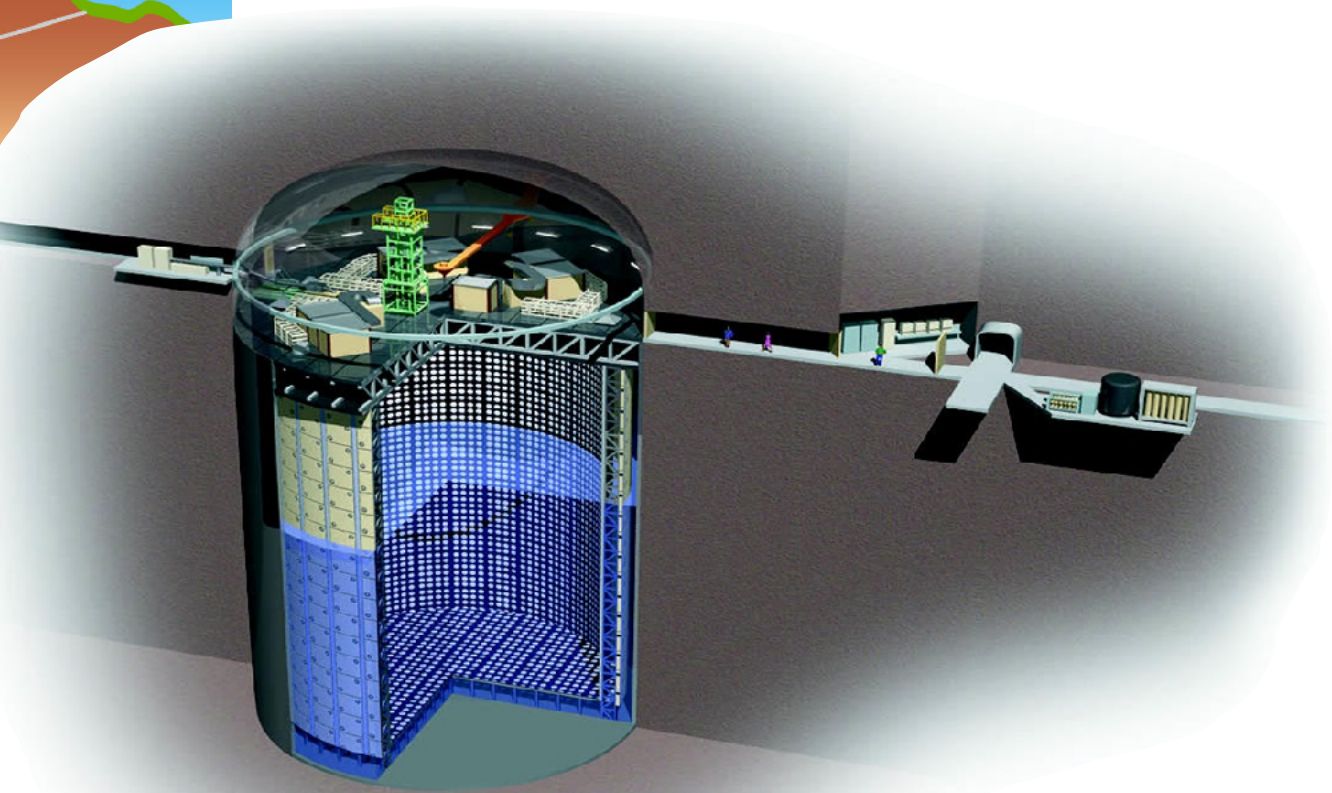
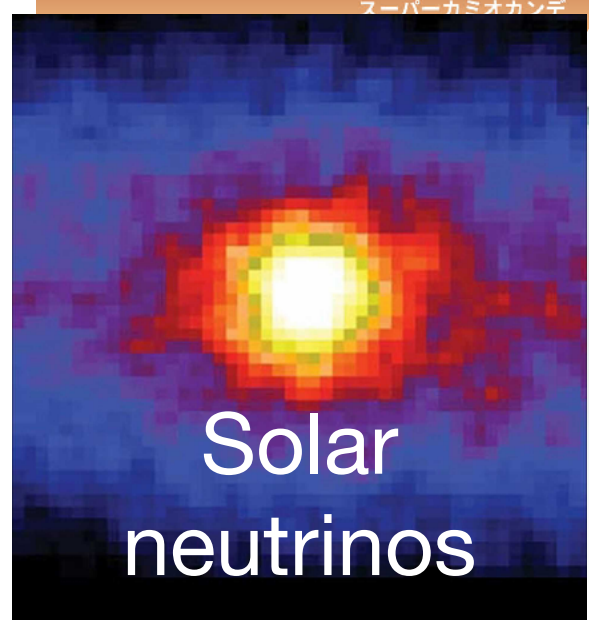
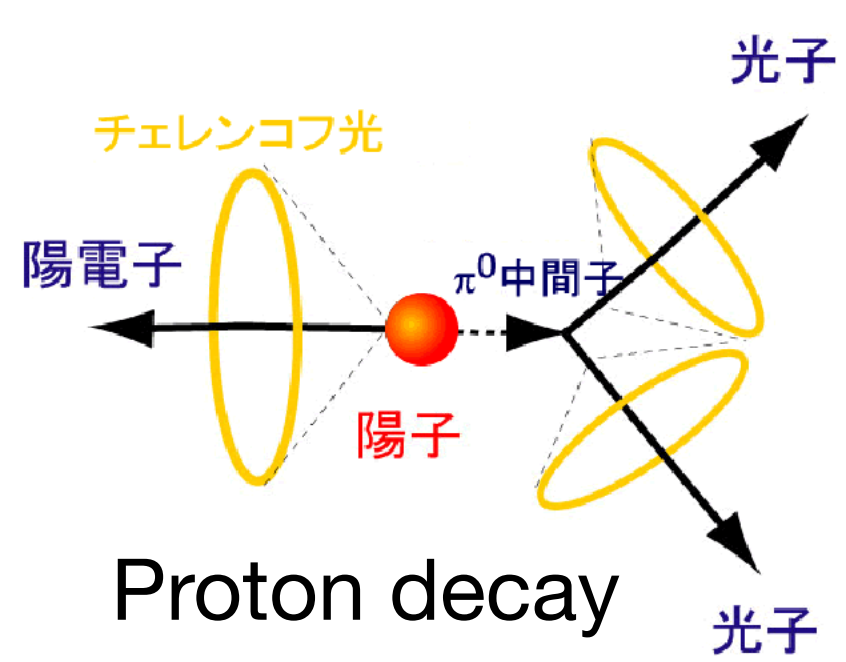
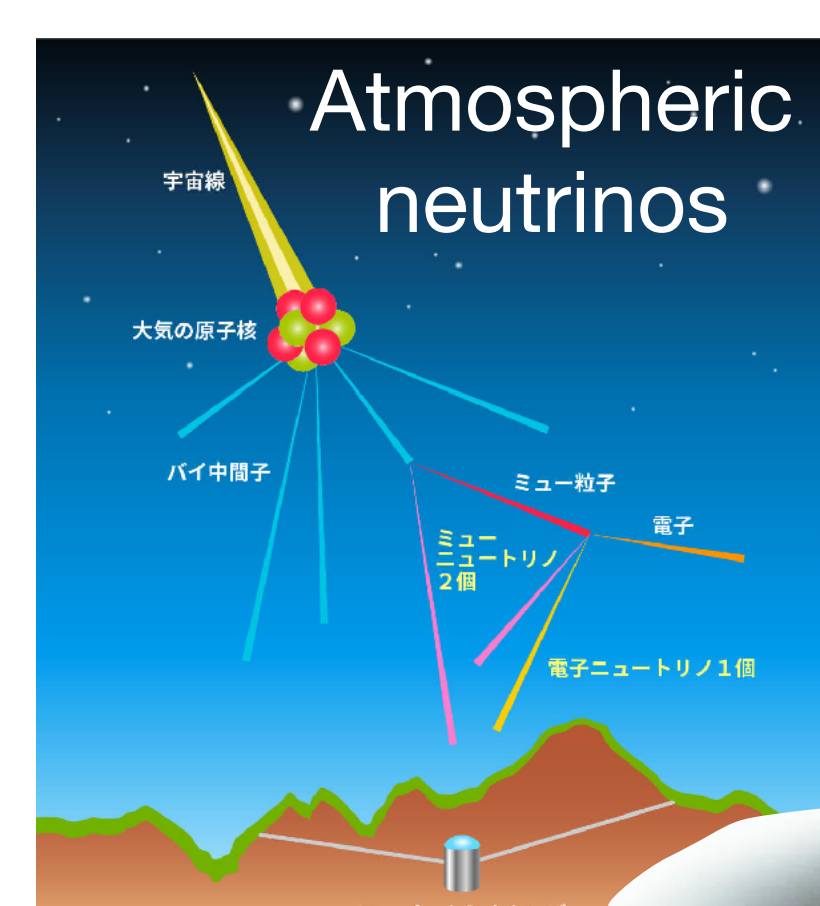
Work by Kenny Hignett (UG)

Construction Status

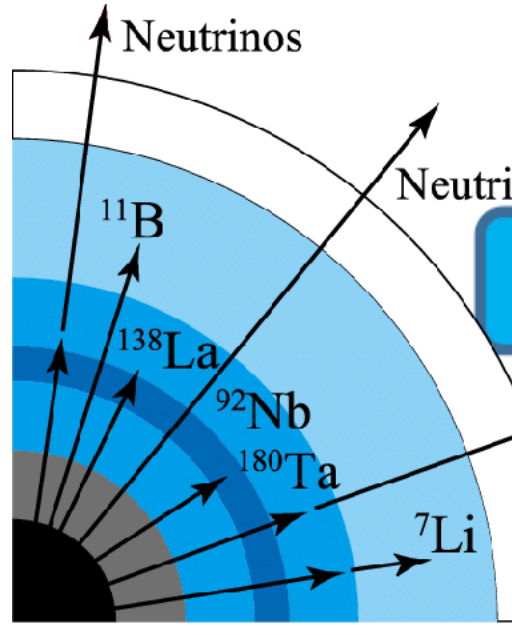
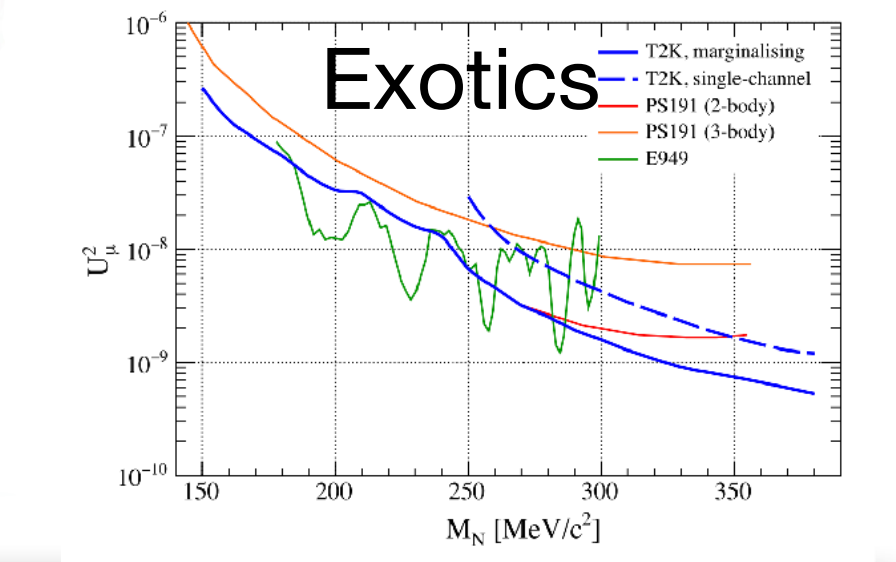
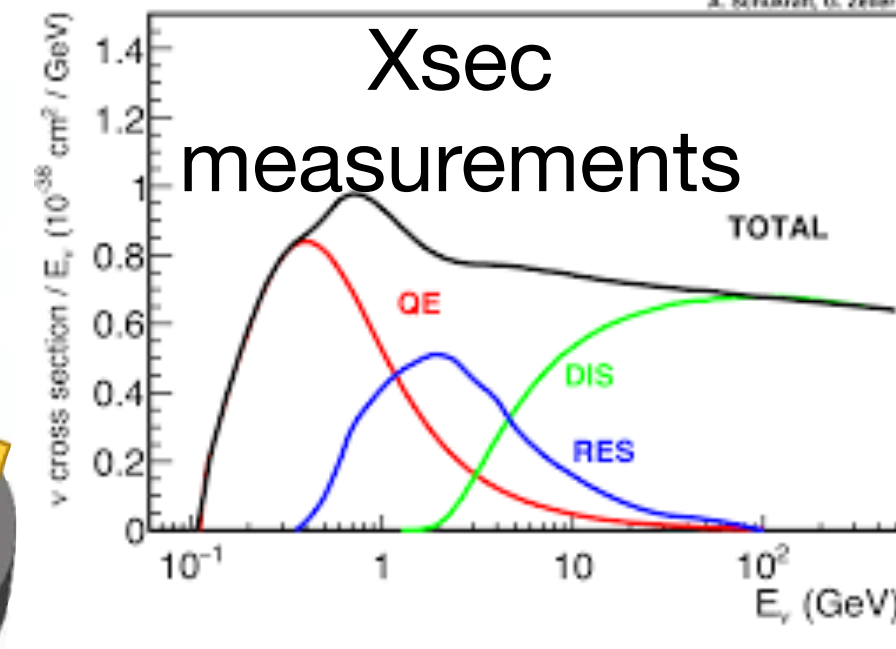
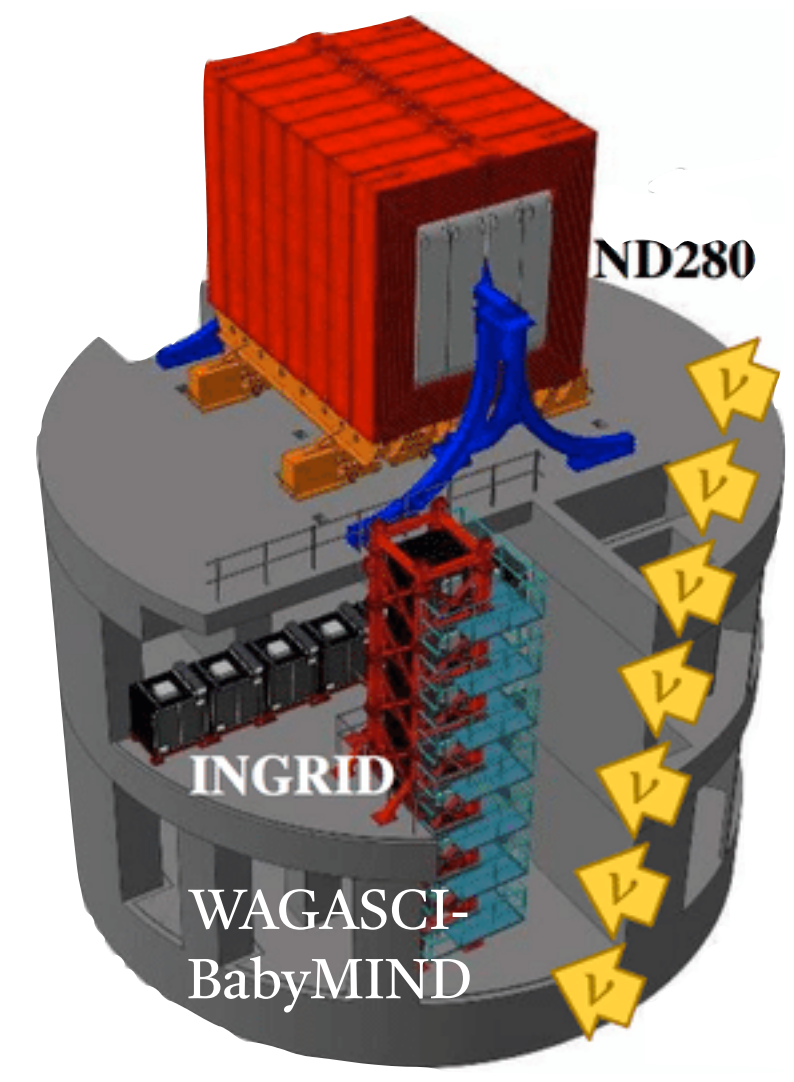
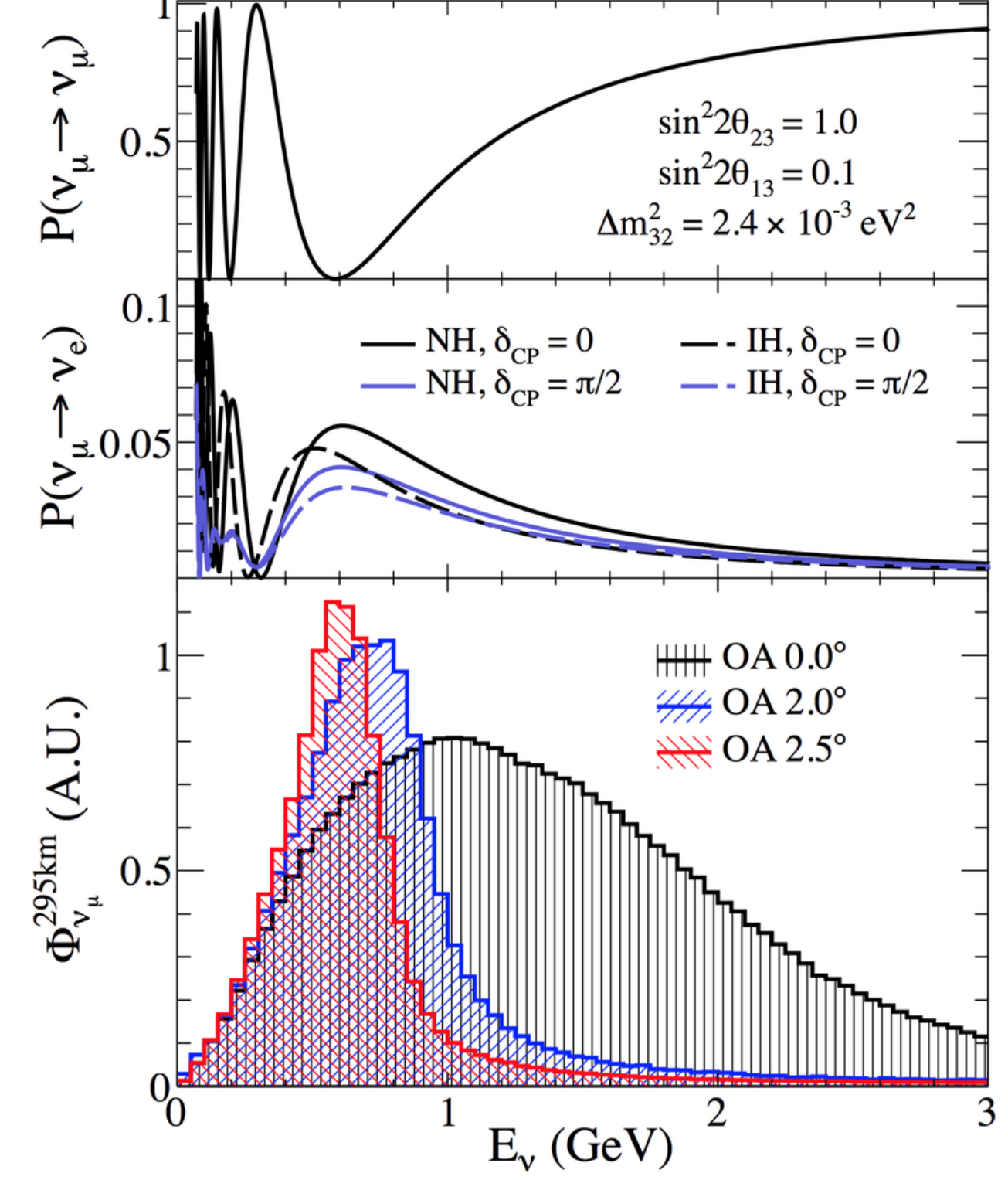


- ♥ Dome centre excavation completed last year
- ♥ Third of six stages of full dome excavation was underway as of March





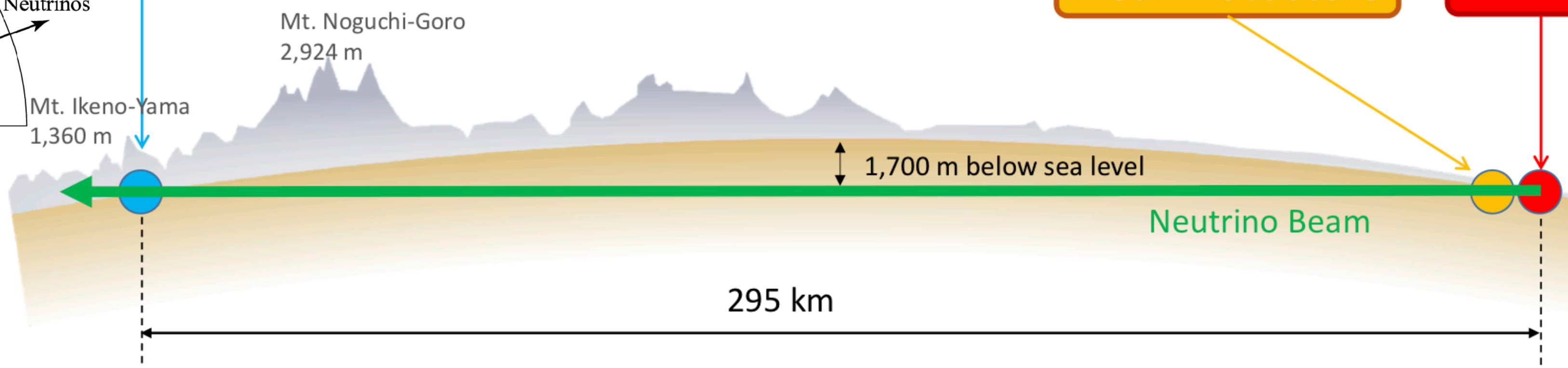
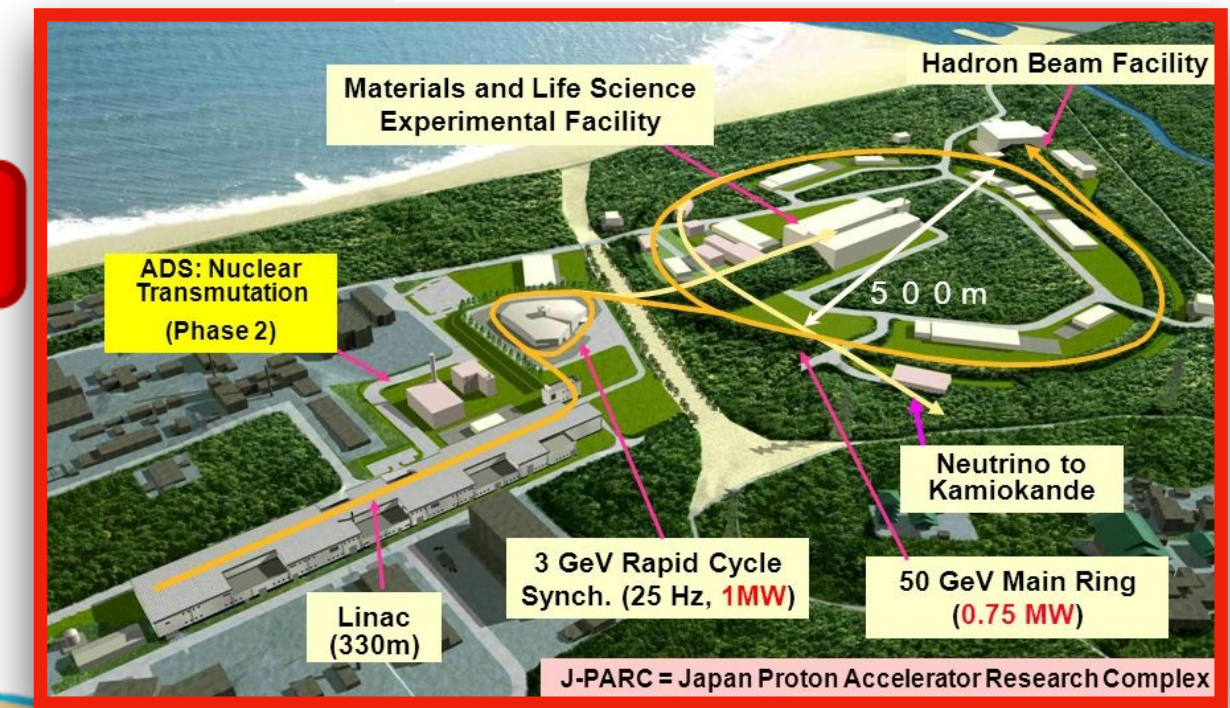
Oscillation parameters



Super-Kamiokande

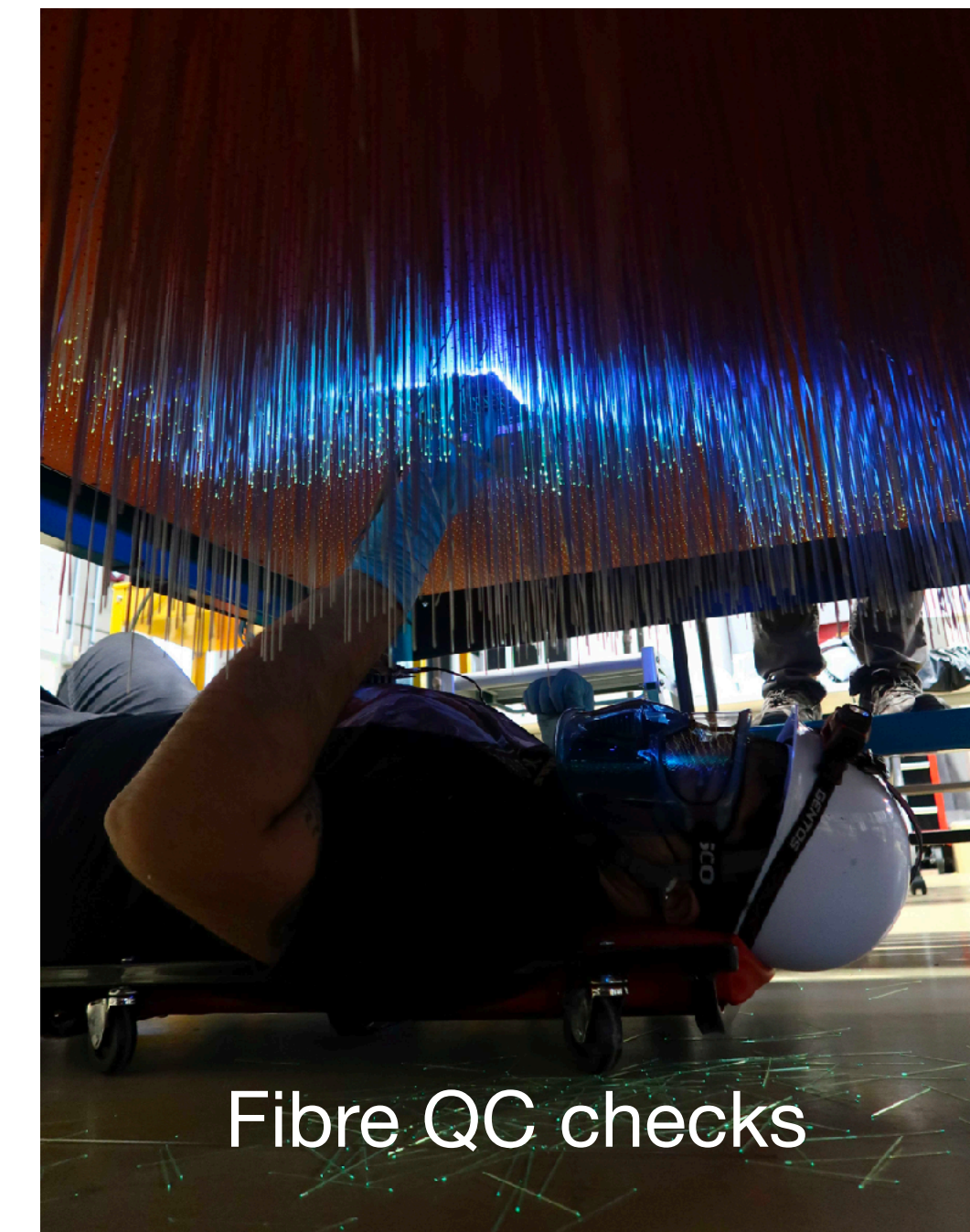
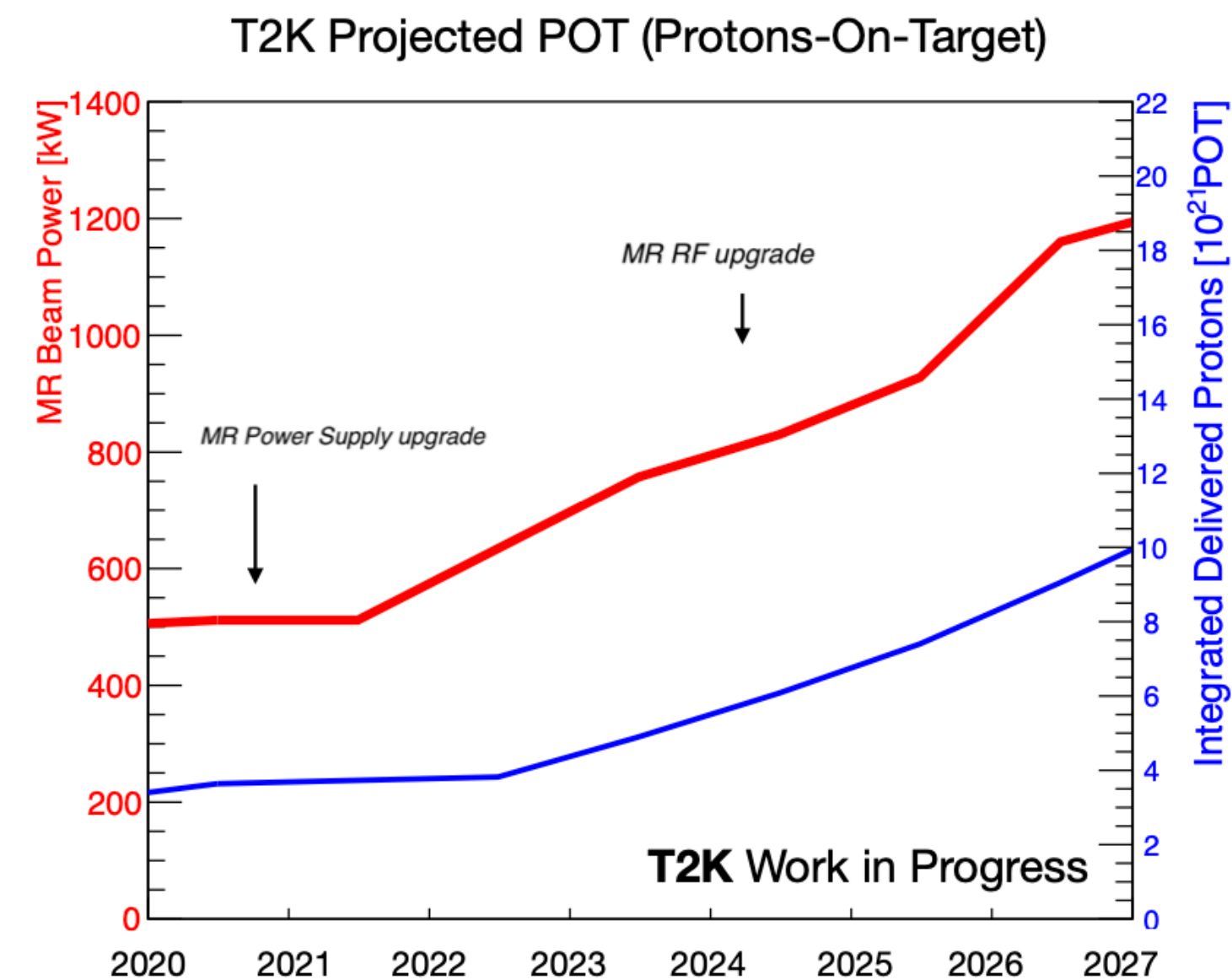
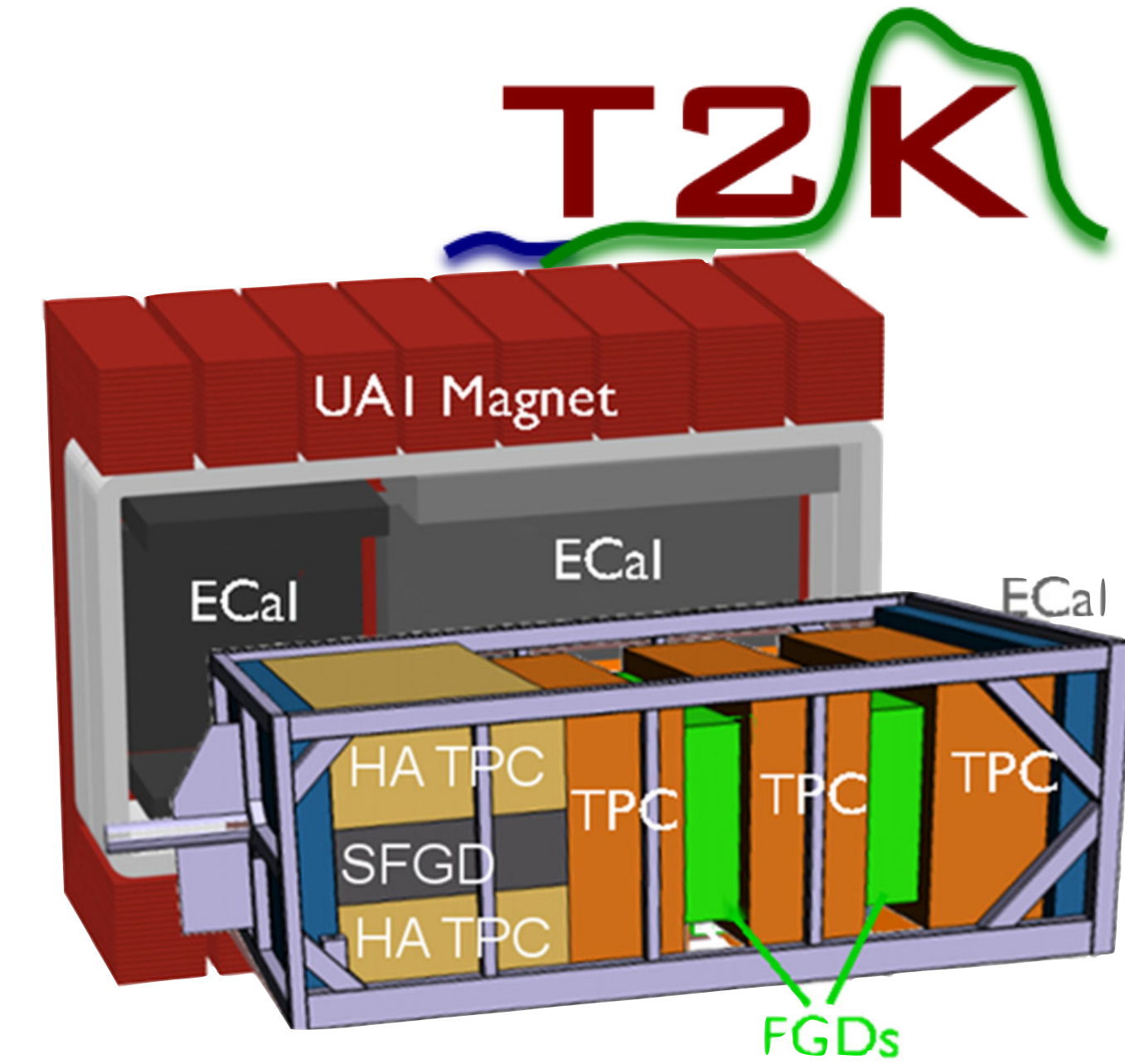
Near Detectors

J-PARC



T2K Status

- ♥ ND280 undergoing major upgrade - PØD to be replaced with SuperFGD, high-angle TPCs and TOF detectors
- ♥ PØD already removed, SFGD fibre threading and cabling recently finished
- ♥ Final HA-TPC configuration undergoing cosmic test currently
- ♥ TOF shipping CERN → JPARC next month for installation in ~July
- ♥ Due to start taking data with full upgrade configuration next year
- ♥ Significant upgrade of the Main Ring over the next few years to bring the beam power up to 1.3 MW
- ♥ Ongoing joint analysis between T2K and NOvA



Group Members



♥ Neil McCauley

♥ Christos Touramanis

♥ Costas Andreopoulos

♥ Kostas Mavrokoridis

♥ Jon Coleman

♥ Sam Jenkins

👋 ♥ Ka Ming Tsui → Ellen Sandford

♥ David Payne

See Ellen's talk
later today

♥ Balint Bogdan

♥ Ashley Greenall

♥ Carl Metelko

🎓 ♥ Gabriel Penn

📖 ♥ Pruthvi Mehta

♥ Jaiden Parlone

♥ Adam Tarrant

♥ Patrick Bates

Oscillation analysis

OA2021
POT

Run	POT 1-10b:	POT 1-11:
ν mode	19.664e+20	21.428e+20
$\bar{\nu}$ mode	16.346e+20	16.346e+20

OA2023
POT



Two current ongoing oscillation analyses: OA2021 and OA2023

OA2021 has several new additions:

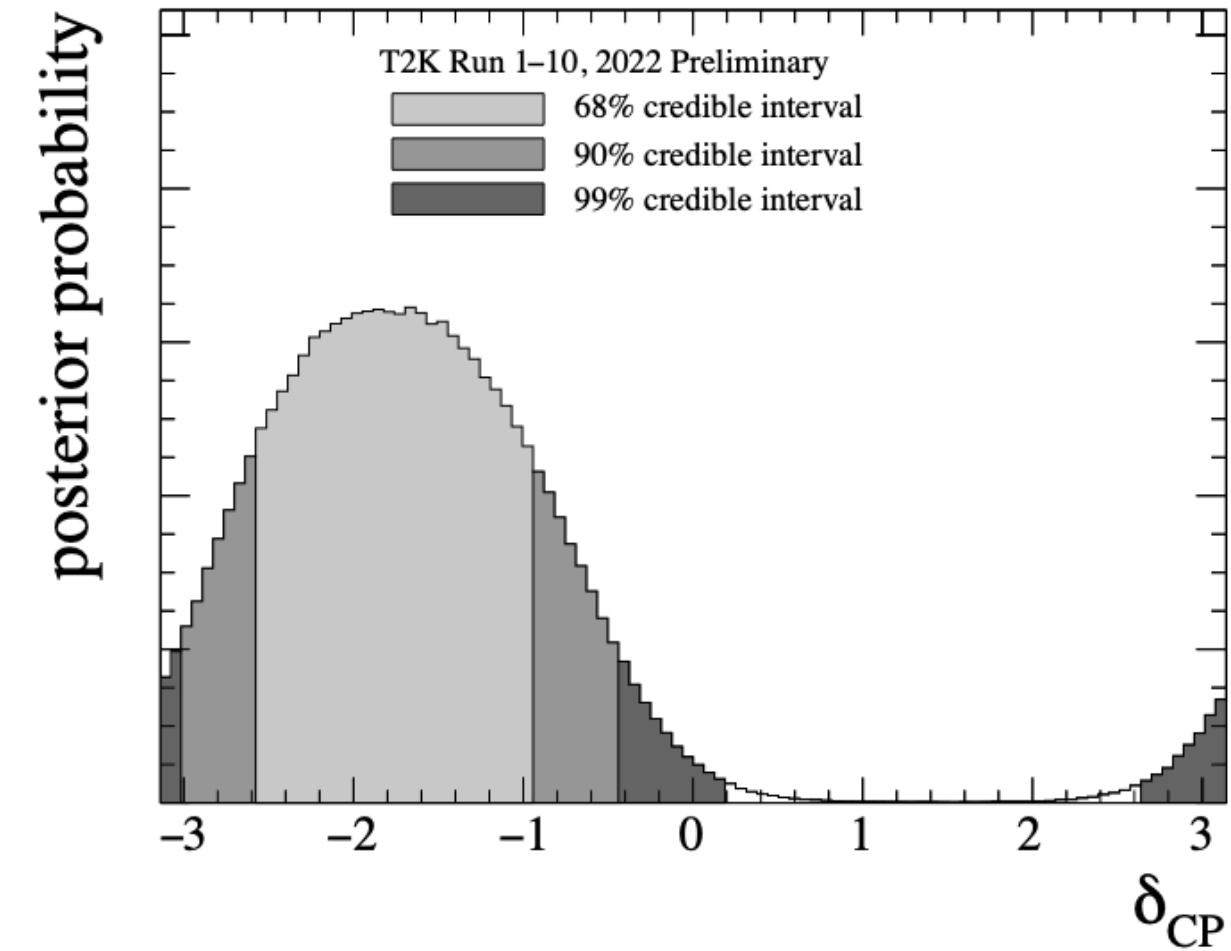
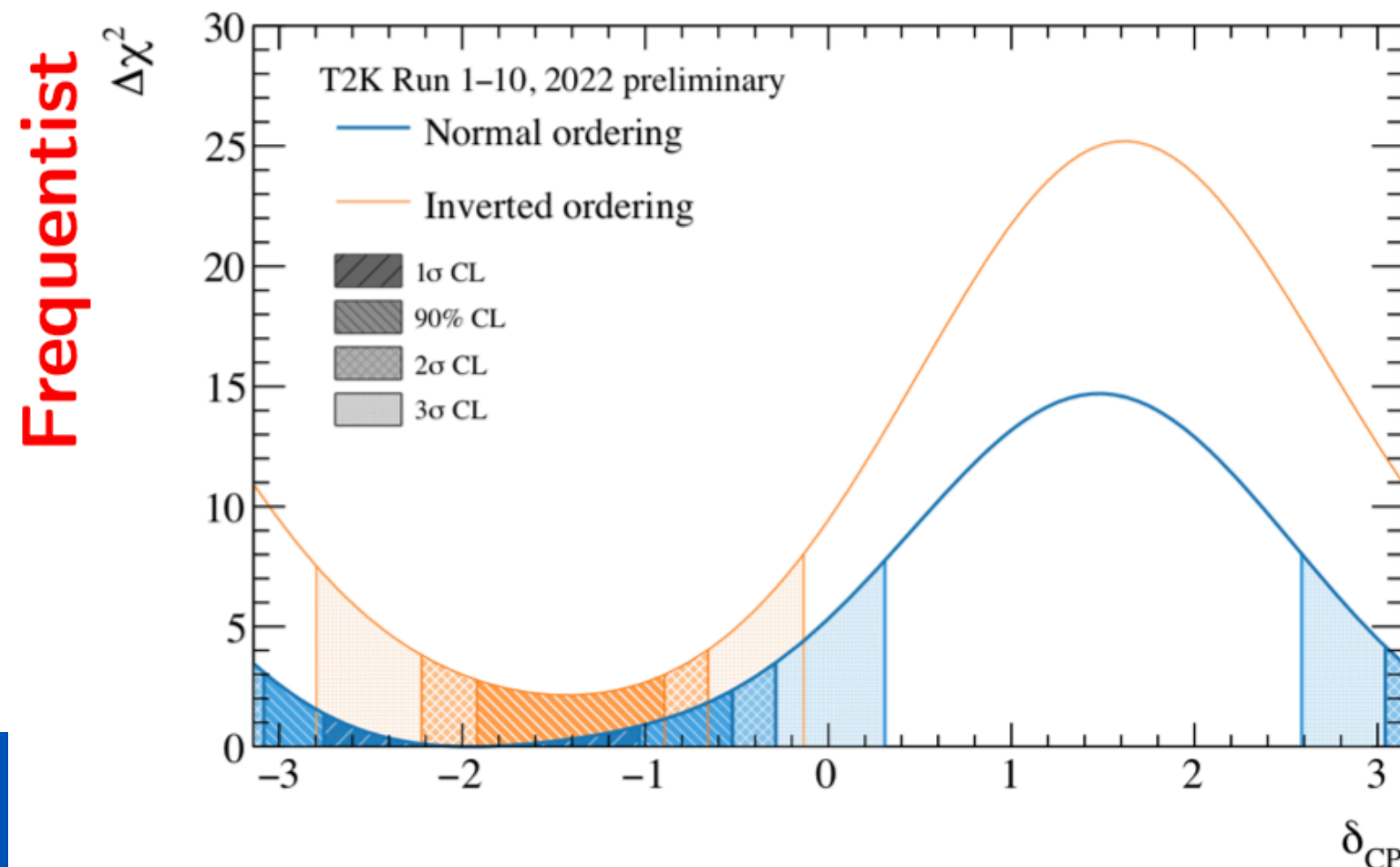
- Non-CCQE focused sample ($\nu_{\mu} CC1\pi^+$) providing 40% increase to muon-like events in ν -mode
- Number of neutrino interaction model parameters increased from 47 to 75, covering previous deficiencies
- Updated flux tuning from replica target data

OA2023 is mostly a stats update, with increase protons on target for ν -mode

Jaiden uses the VALOR fit framework to cross check results



Work by Jaiden



Bayesian δ_{CP} best fit at $-2.18 (-0.694\pi)$, CP conserving values 0 and π are outside of 90% CL intervals

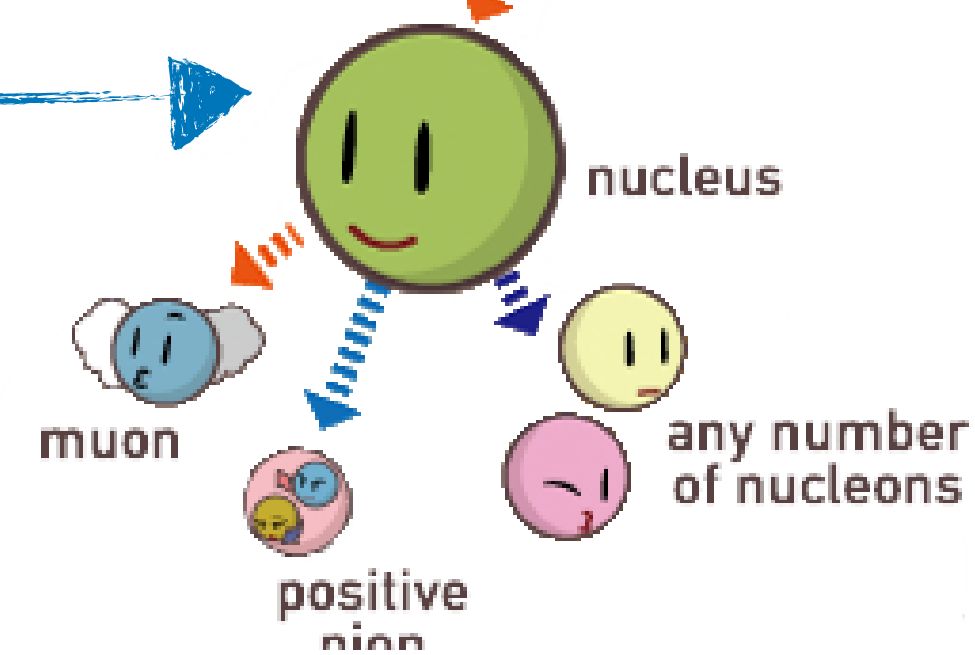
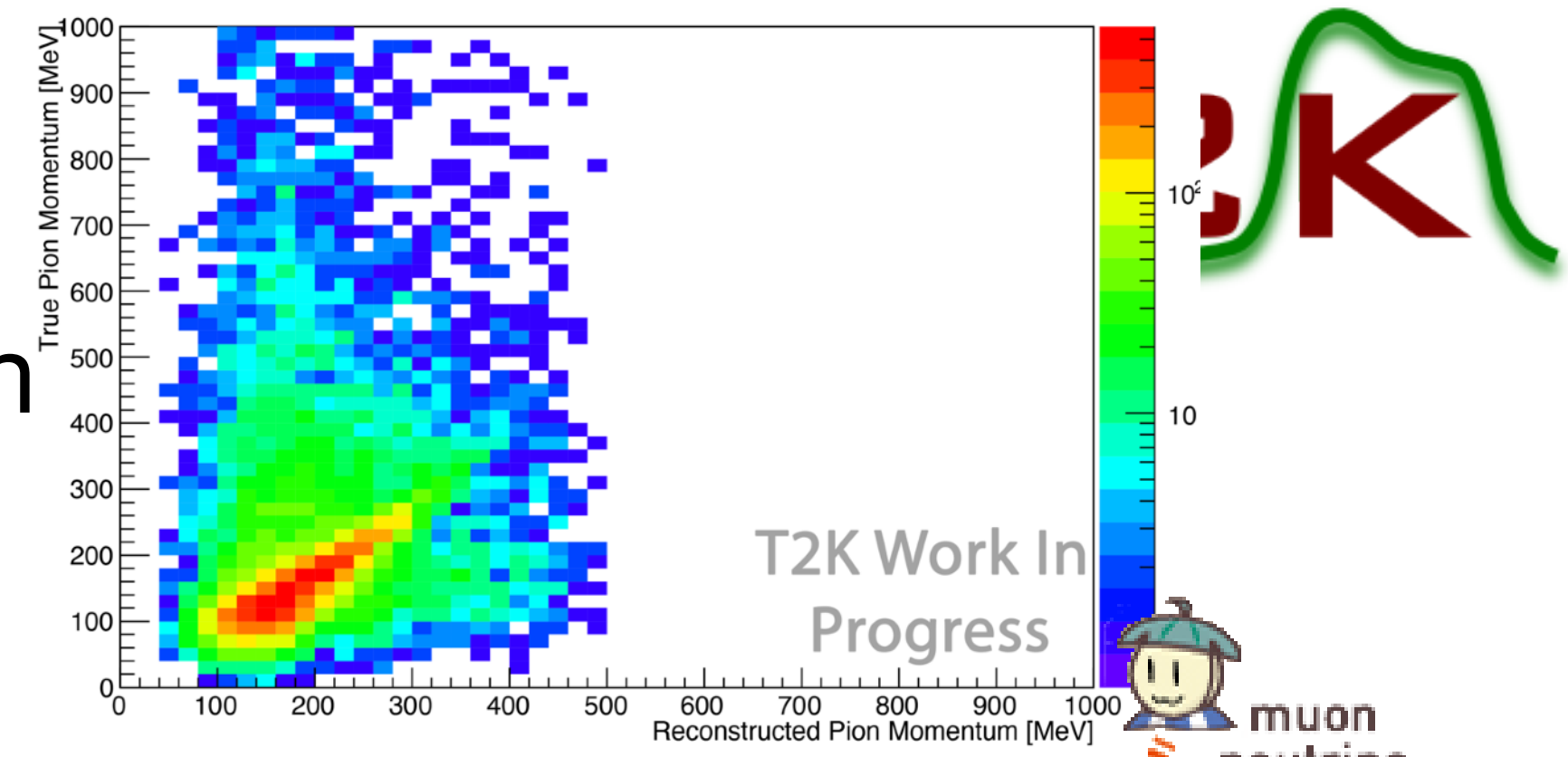
See Jaiden's poster for more info!

Cross-section measurement

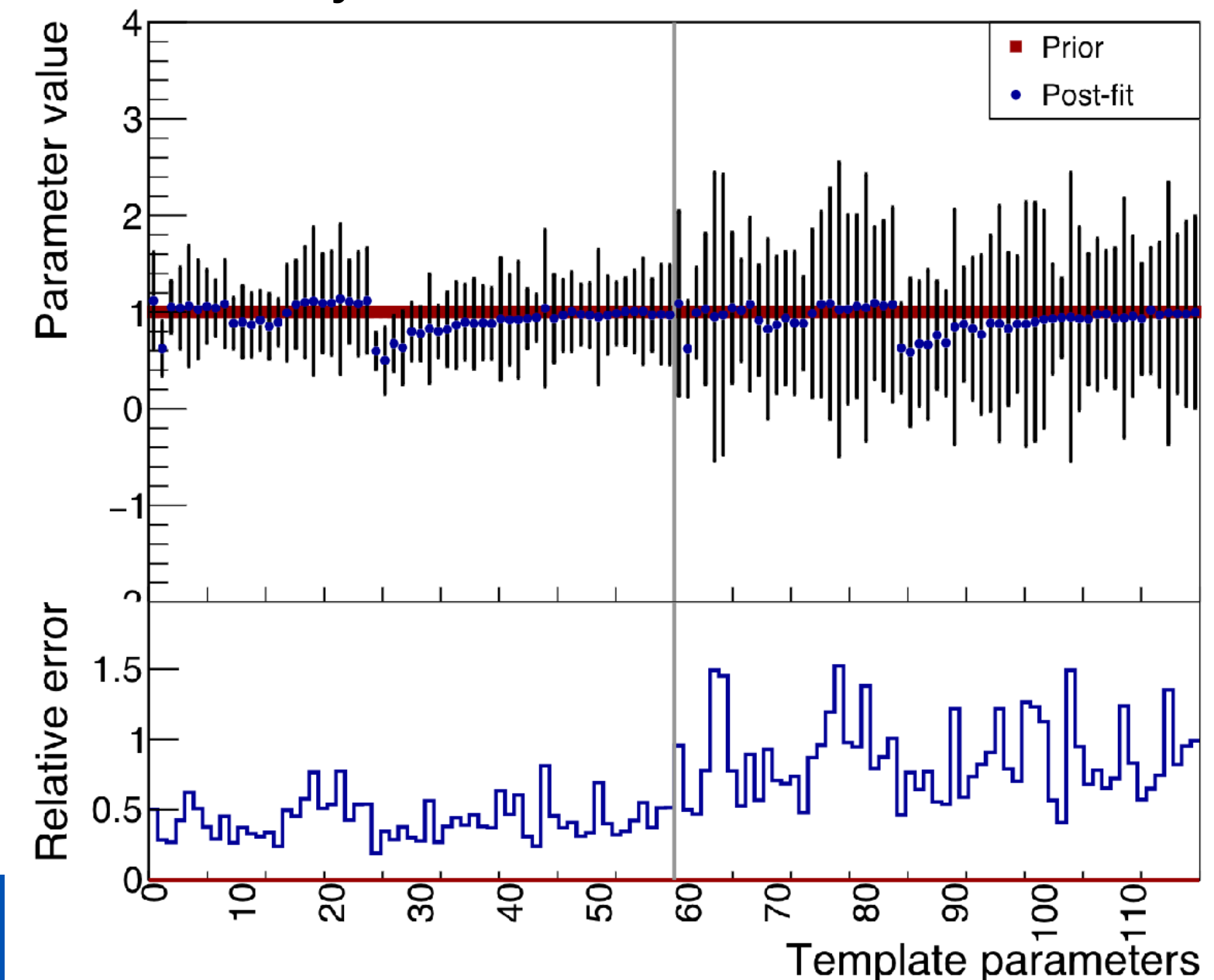
- ♥ I'm working on measurement of the single pion production cross section on water and hydrocarbon
- ♥ Resonant events such as these are a significant background to the CCQE dominated OA
- ♥ Technique developed to reconstruct short-range pion momentum from range of Michel electrons produced - first use of this in T2K
- ♥ Fit MC to data using binned template likelihood fit, then calculate xsec per kinematic bin as

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

- ♥ Currently performing physically motivated fake data studies to test fitter robustness and error coverage, before unblinding to data



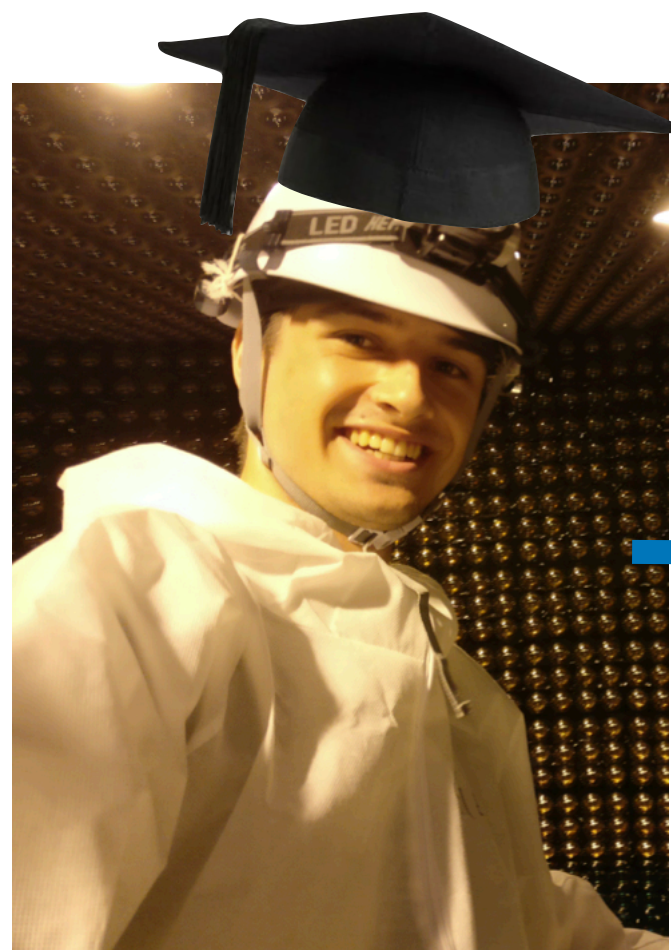
Work by me



Global PID tools

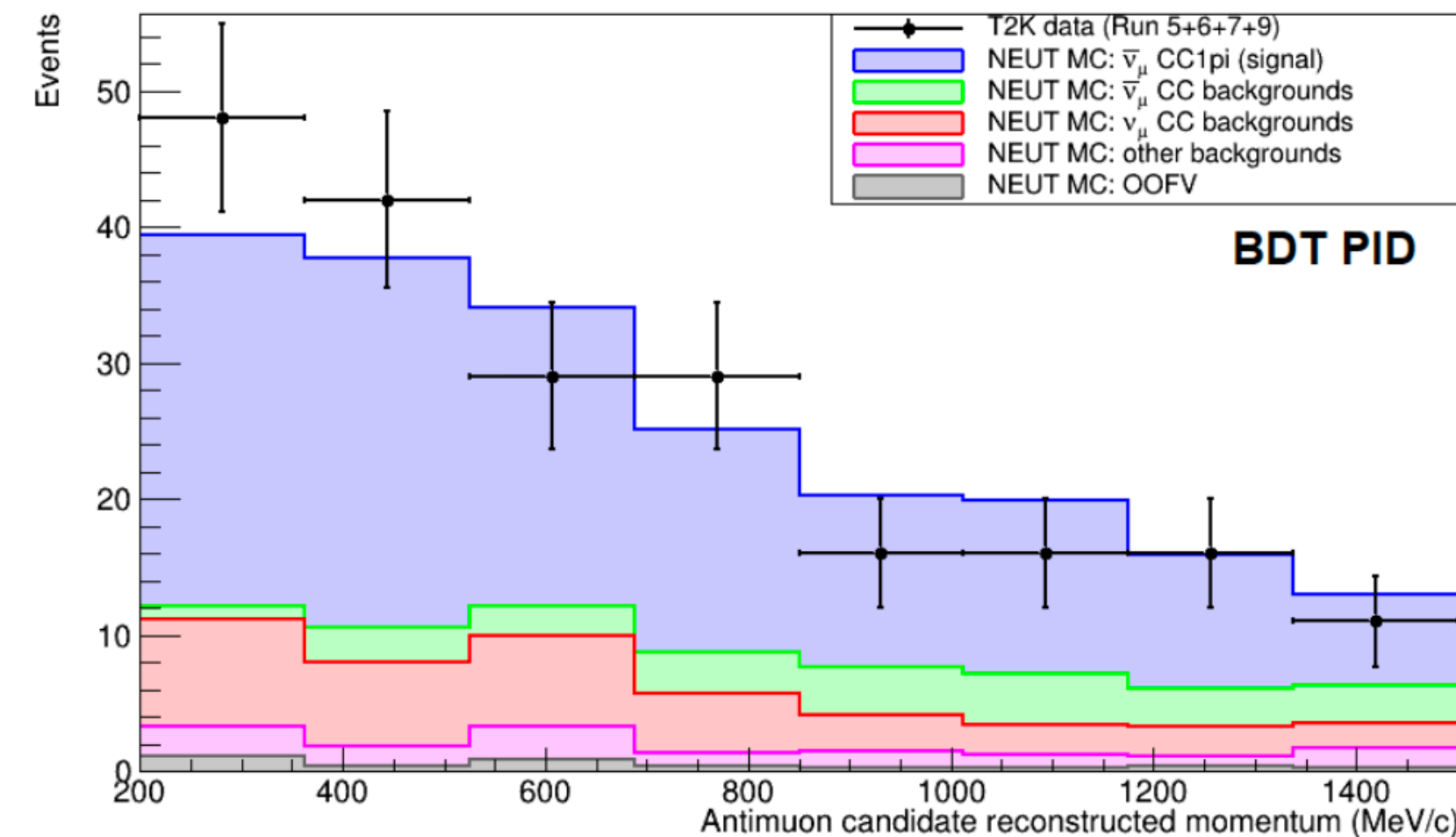
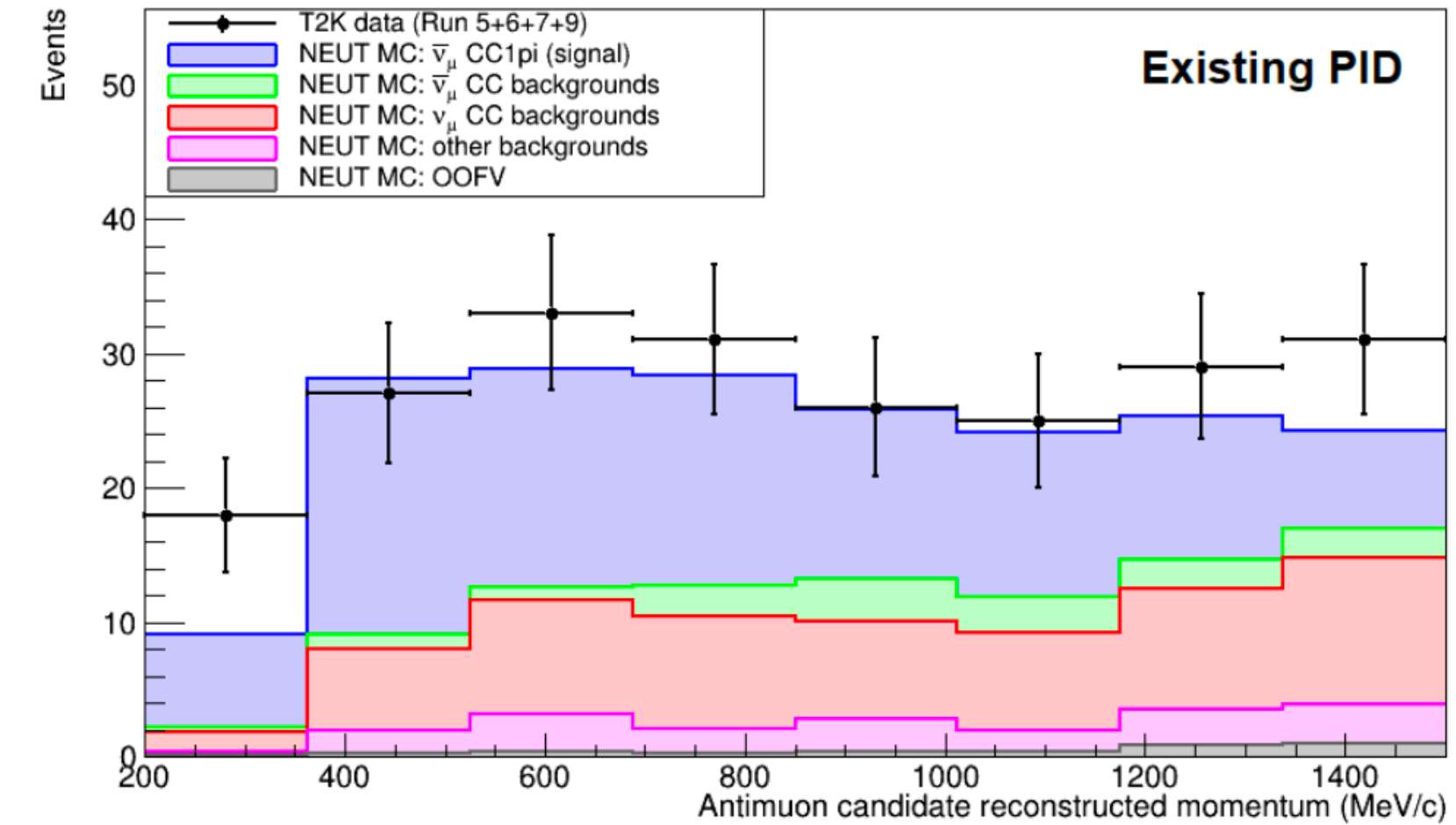
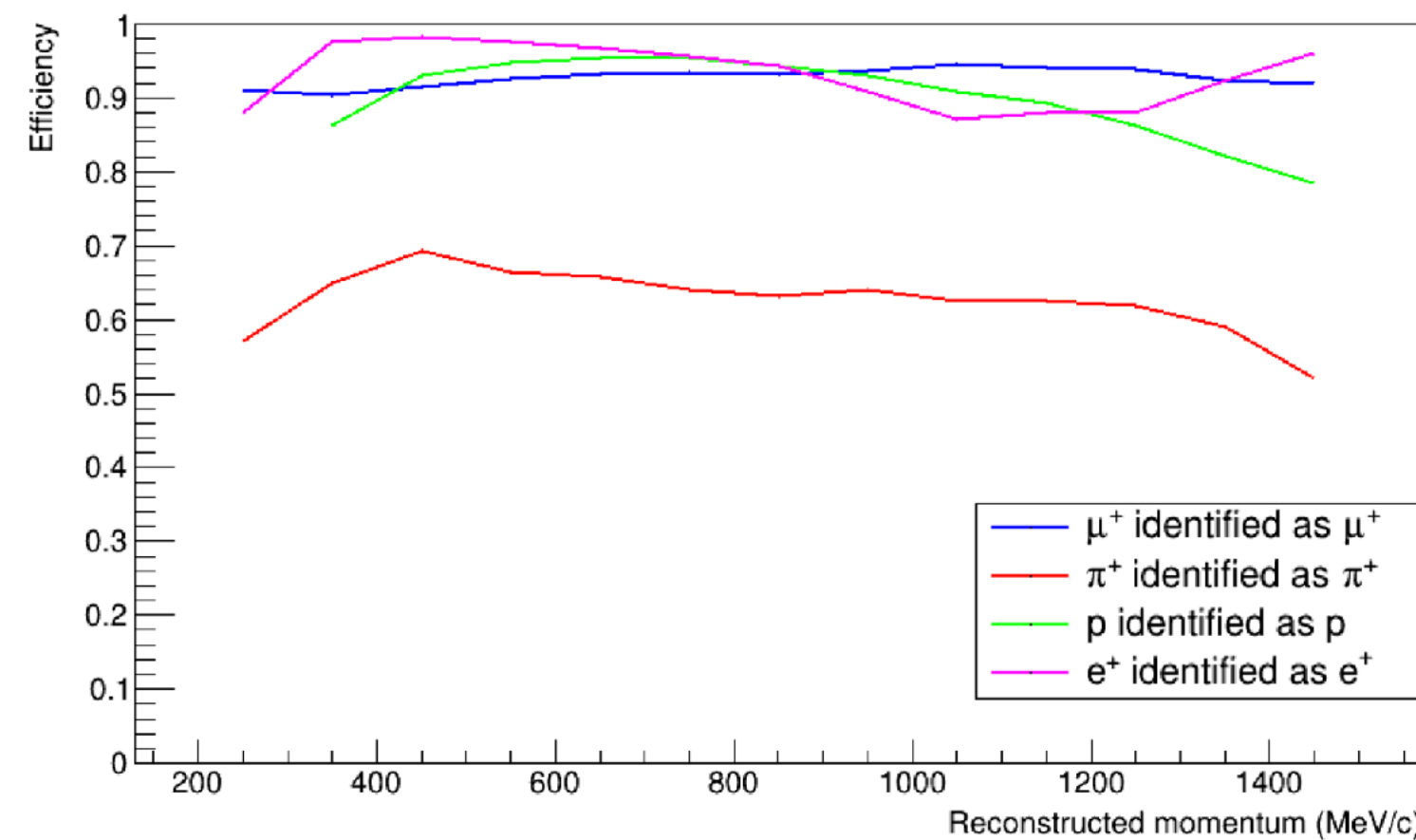


- ♥ ND280 composed of multiple sub-detectors, giving several PID related quantities
- ♥ Rather than rectangular cuts, use a multi-variate approach
- ♥ High efficiency BDT-based selection, which significantly outperforms standard PID method
- ♥ Patrick is taking this over, extending to full ND280 coverage and applying it to ND280 Upgrade



Work by Gabriel

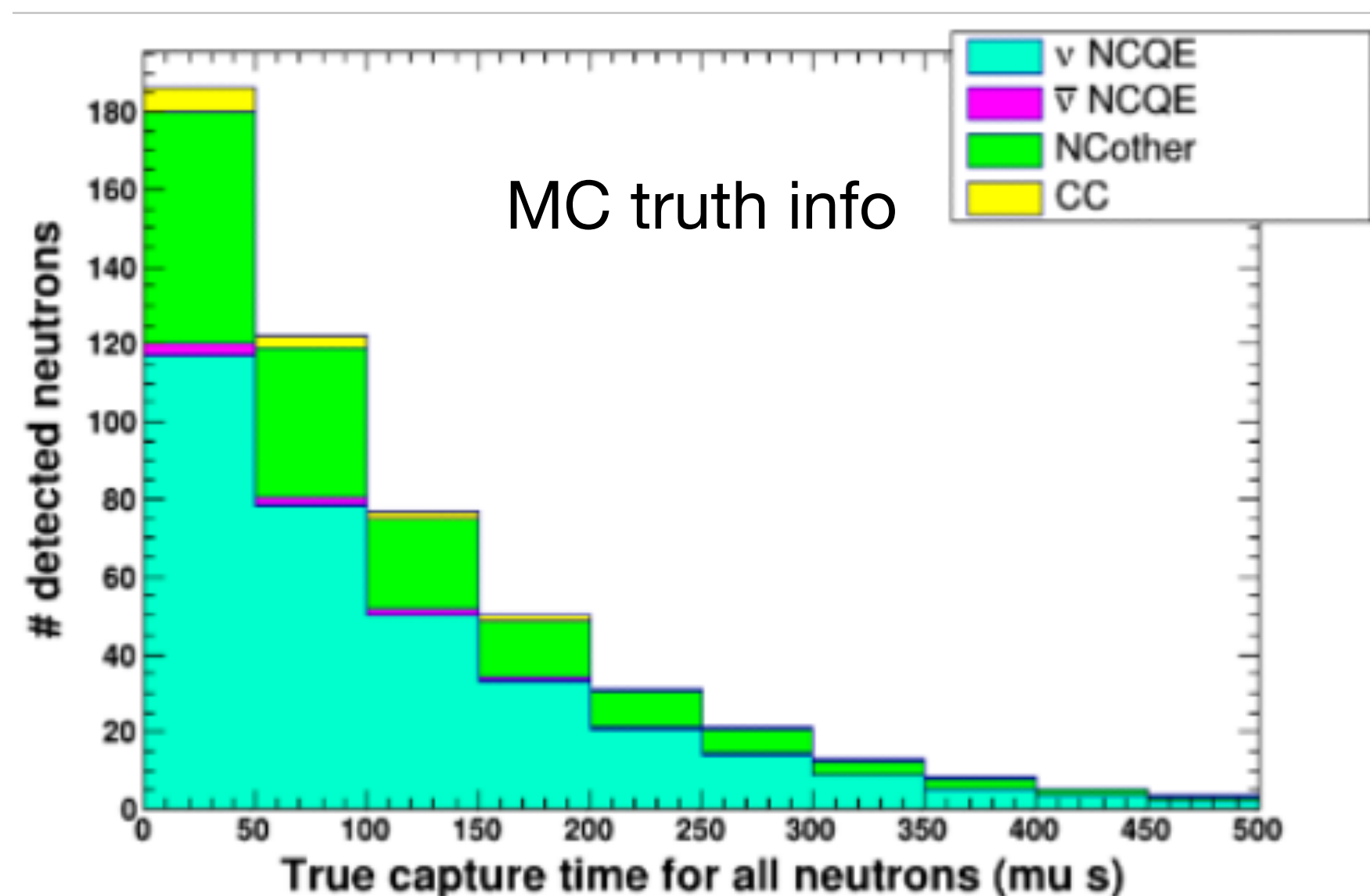
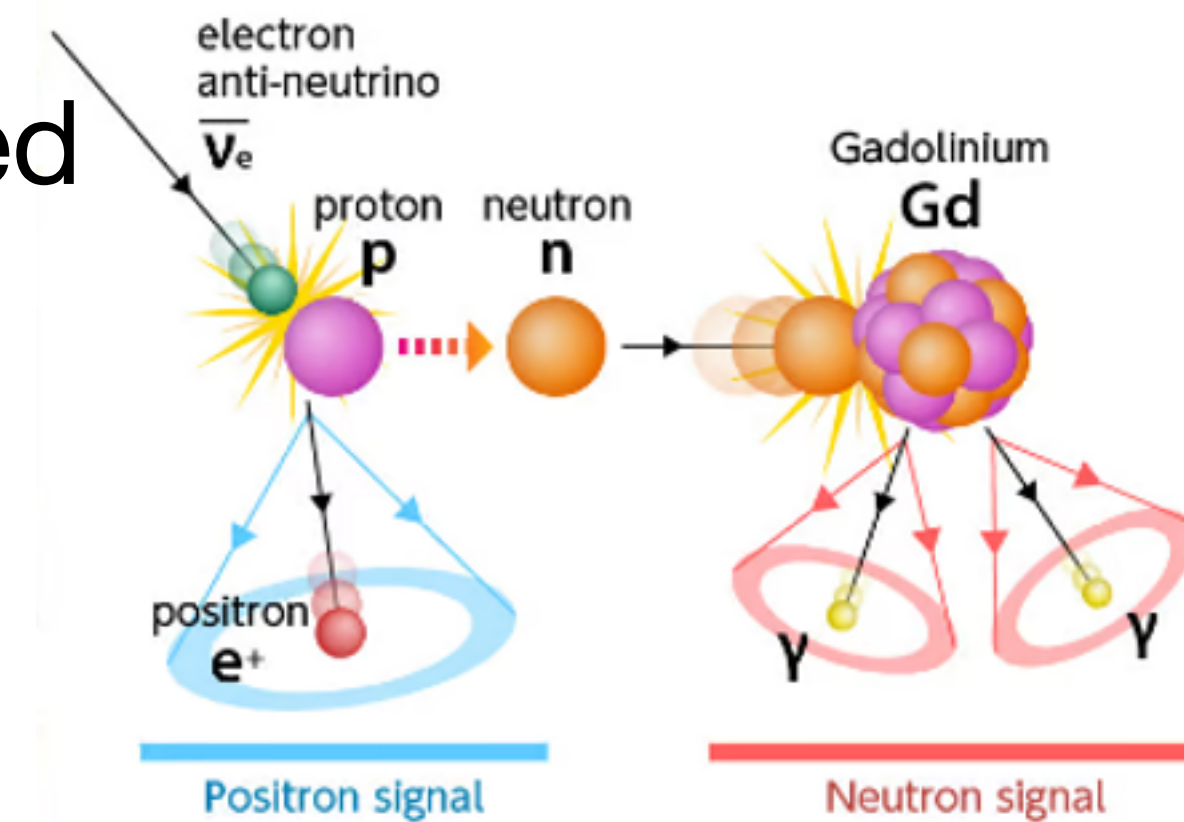
Patrick taking over



NCQE neutron tagging

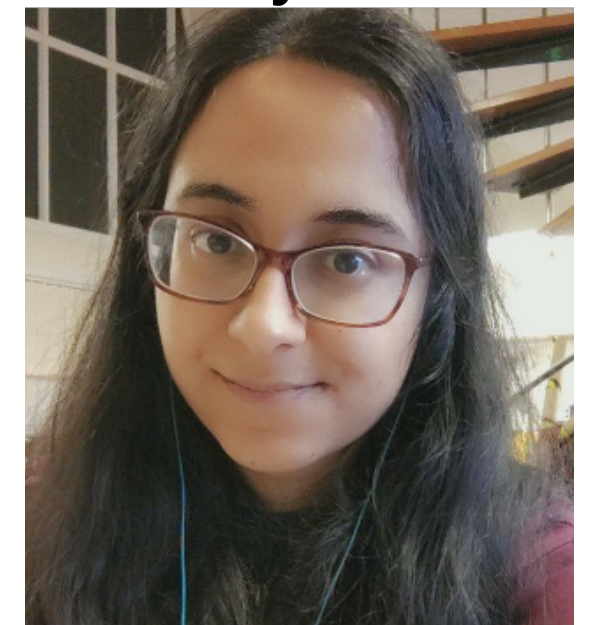


- ♥ NCQE interactions at SK are a significant background to the signal used to detect supernova relic neutrinos and DSNB
- ♥ Gd-loading improves neutron tagging ability through higher capture xsec and higher energy gamma cascade
- ♥ Developed new NTag algorithm for SK-Gd, efficiencies recalculated after applying NN to enhance signal and reduce background



- ♥ Efficiency from MC compared and validated against data from the AmBe calibration source
- ♥ Performed estimation of the error on the DSNB NCQE background

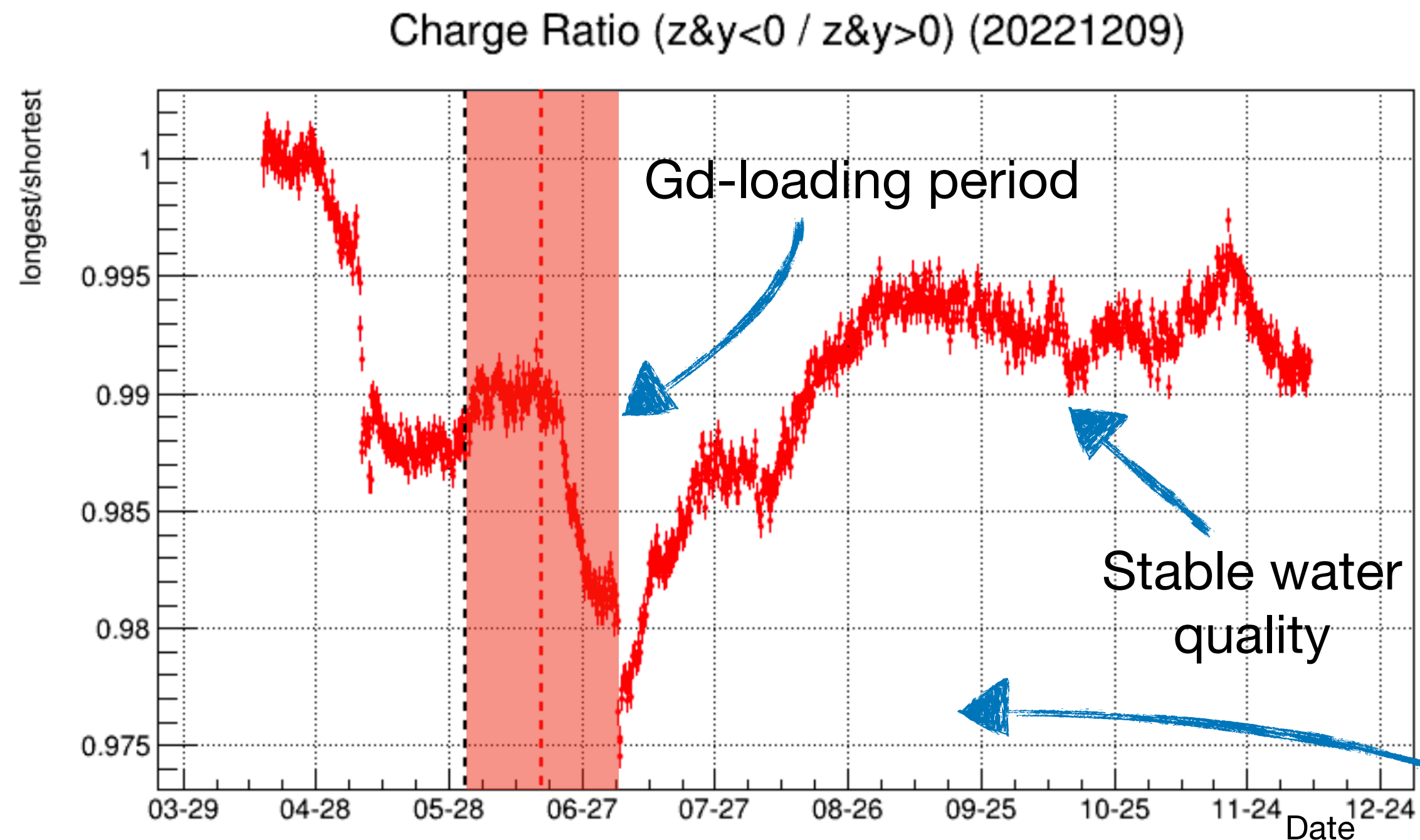
Work by Pruthvi



Super-K Monitoring




- ♥ Second phase of Gd-loading completed in July last year, bringing SK to 0.03% concentration Gd and marking beginning of SK-VII run
- ♥ UKLI system integral part of water quality monitoring during the loading period, now used for weekly monitoring purposes
- ♥ Top diffuser is particularly sensitive to changes in water quality
- ♥ Adam is working on an attenuation measurement likelihood fit - see his talk
- ♥ First visit since COVID by SK-UK members (inc. Neil and Balint) in Sep 22 - system working well
- ♥ Liverpool members taking part in upcoming calibration campaign in July, will also be replace monitor PMT in UKLI system



私たちは日本へ帰った！



Obligatory trip to the Pokémon centre



21st International Workshop on Next Generation Nucleon Decay and Neutrino Detectors
September 28-30, 2022 Hida-city, Gifu, Japan

Example: water absorption

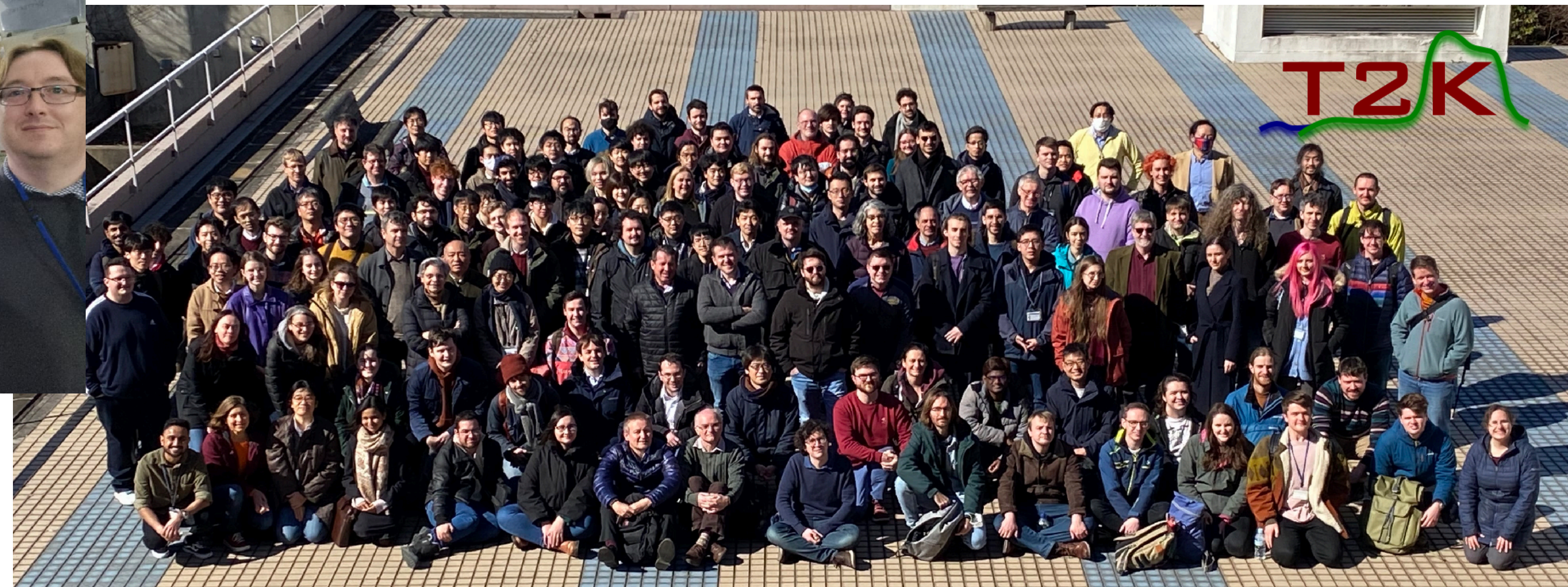

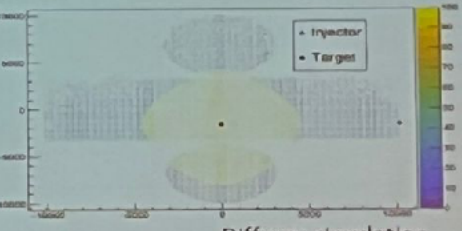
Water absorption will be measured using the light injection system

- Diffusers provide wide angle uniform beam to illuminate many PMTs
- Large variation in path length

Collected charge depends on

- Solid angle
- Diffuser Profile
- Absorption length
- PMT angular response

Absorption length and angular response measurements correlated



Neil giving Hyper-K plenary at NNN22