Characterising the detector response of the SuperFGD as part of the T2K near detector upgrade

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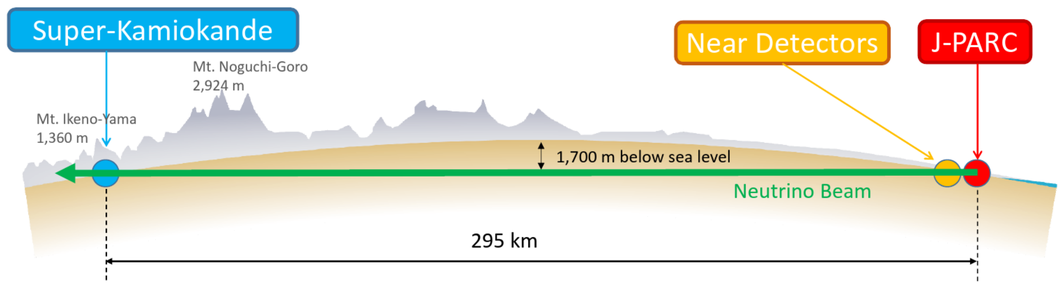
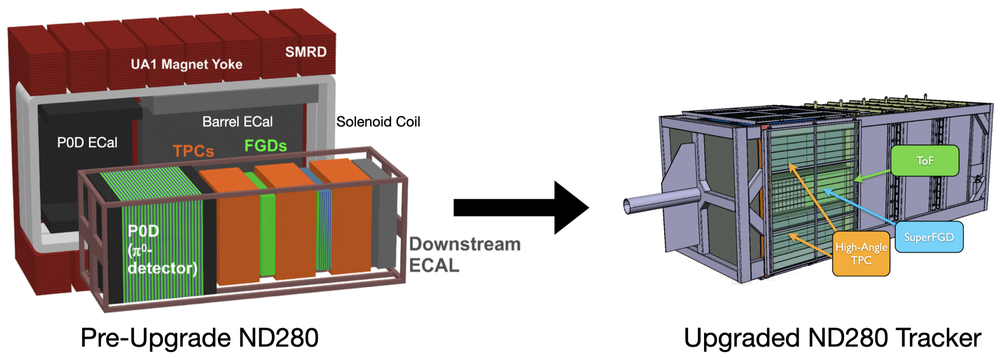
1. The T2K Experiment



- The Tokai-to-Kamioka (T2K) experiment is a long-baseline neutrino experiment based in Japan
- ν_μ ($\bar{\nu}_\mu$) beam produced at J-PARC, characterised by near detectors and detected at Super-Kamiokande
- Measures ν_μ ($\bar{\nu}_\mu$) disappearance and ν_e ($\bar{\nu}_e$) appearance

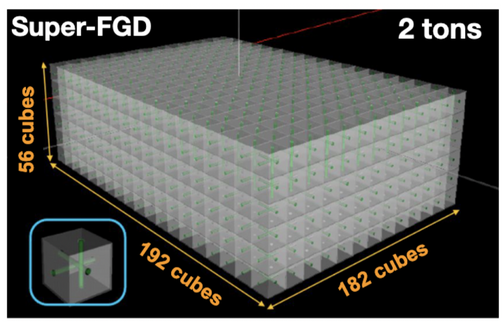
2. Near Detector (ND280) Upgrade

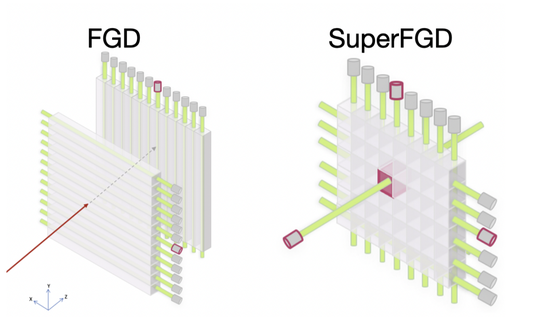


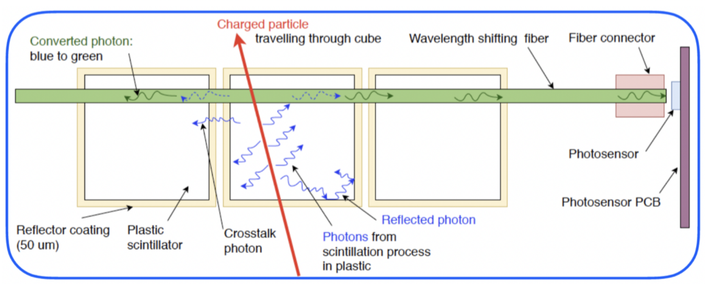
Pre-Upgrade ND280 — Upgraded ND280 Tracker

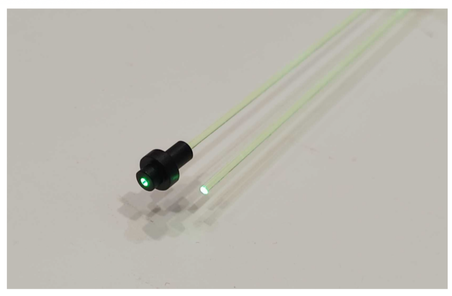
- Replace π^0 detector with three new sub-detectors:
  - → Super Fine-Grained Detector (SuperFGD): Highly segmented target material with ability to reconstruct neutrons and lower momentum protons
  - → High-Angle Time Projection Chambers (HATPCs): measure momentum, charge and particle ID with better angular acceptance than before
    - See posters by Matteo Feltre and Ulysse Virginet
  - → Time-of-Flight (ToF): Precise timing information to reject backgrounds and improve reconstruction
- See physics capabilities in posters by Liz Kneale, Katharina Lachner and Weijun Li

3. SuperFGD Concept and Construction

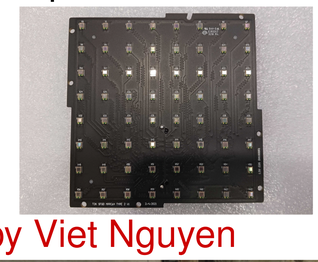


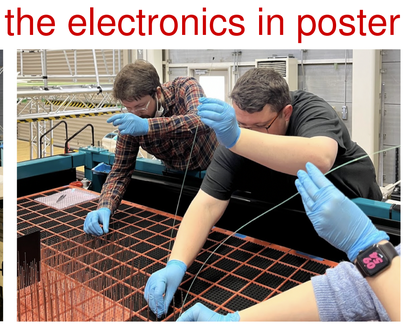


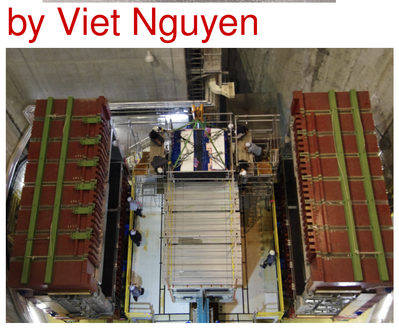




- 2 million optically isolated 1 cm^3 plastic scintillator cubes [1]
- 56,000 wavelength shifting (WLS) fibers
  - → Each coupled to a multi-pixel photon counter (MPPC)
  - → Three orthogonal fibers per cube
- Concept proven in charged particle [2] and neutron [3] beam tests
- Detector assembly at J-PARC October 2022 - April 2023:
  - → Cube layers installed with fishing lines
  - → Vertical alignment using metallic rods
  - → Fishing lines replaced with WLS fibers
  - → MPPCs and LED calibration system installed
- SuperFGD installed in October 2023
- Find description of the electronics in poster by Viet Nguyen



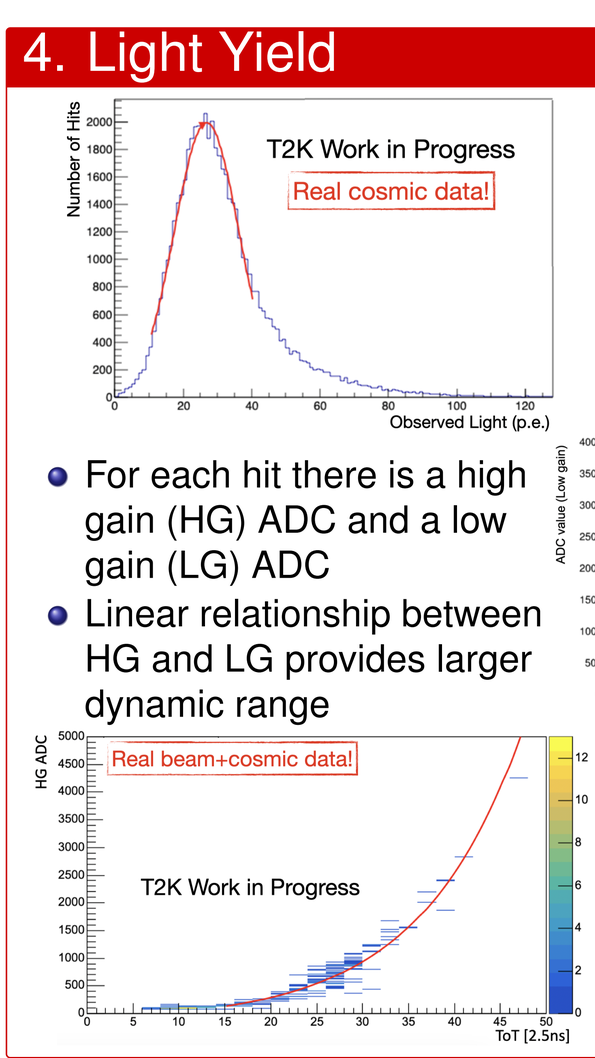




4. Light Yield

- Measure ADC counts from electronics
- Can convert ADC counts to photoelectrons (p.e.)
- See poster on calibration by Daniel Ferlewicz

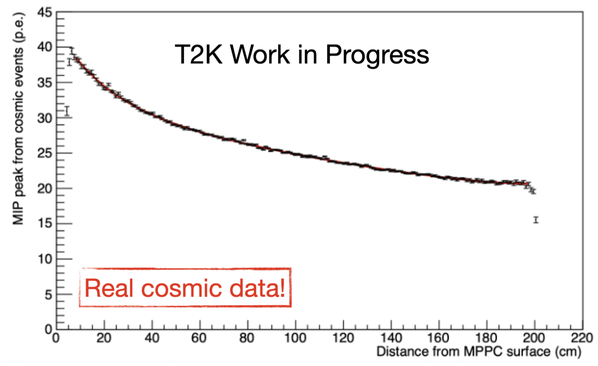
- For each hit there is a high gain (HG) ADC and a low gain (LG) ADC
- Linear relationship between HG and LG provides larger dynamic range



- Also measure time over threshold (ToT) for each hit
- Can convert ToT to HG using exponential relationship
- Provides even larger dynamic range than LG

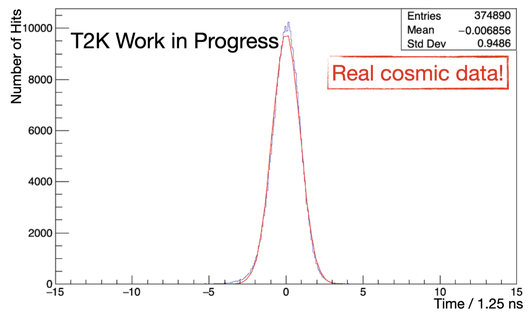
5. Attenuation Length

- Having three fibers per cube allows construction of attenuation length plot
  - → More reliable characterisation of response and calibration
- For a given distance from the MPPCs, plot observed light from hits in cosmic events



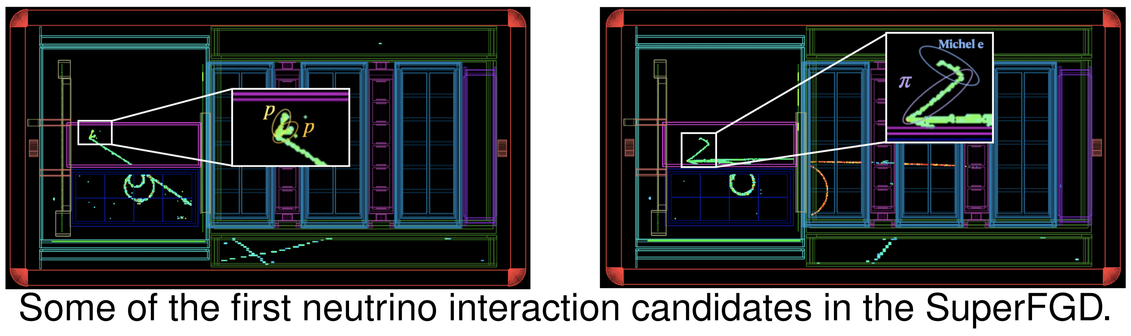
- Fit distribution as a function of distance with an exponential function to extract attenuation length
  - → Measured attenuation length consistent with specification of WLS fibers

6. Time Resolution



- Select hits $>$ 40 p.e. matched in all three dimensions
- Compare mean time of hit to mean time for event
- Gives $\sim$1.2 ns time resolution
  - → Can be improved by electronics firmware update!

7. Neutrino Interactions in the SuperFGD



Some of the first neutrino interaction candidates in the SuperFGD. Possible proton (left) and pion (right) candidates are highlighted.

7. Next Steps

- Continue tuning Monte Carlo simulation using measurements of light yield and attenuation length
- Measure dE/dx in the SuperFGD and make selection of proton candidates using Bragg peak
- Head towards first physics analyses with the SuperFGD!

References

[1] Y. Abreu *et al* 2017 JINST **12** P04024
[2] A. Blondel *et al* 2020 JINST **15** P12003
[3] A. Agarwal *et al* 2023 Phys. Lett. B **840** 137843