THE INNOVATIVE SUPER-FGD FOR T2K AND ITS FRONT-END READOUT ARCHITECTURE

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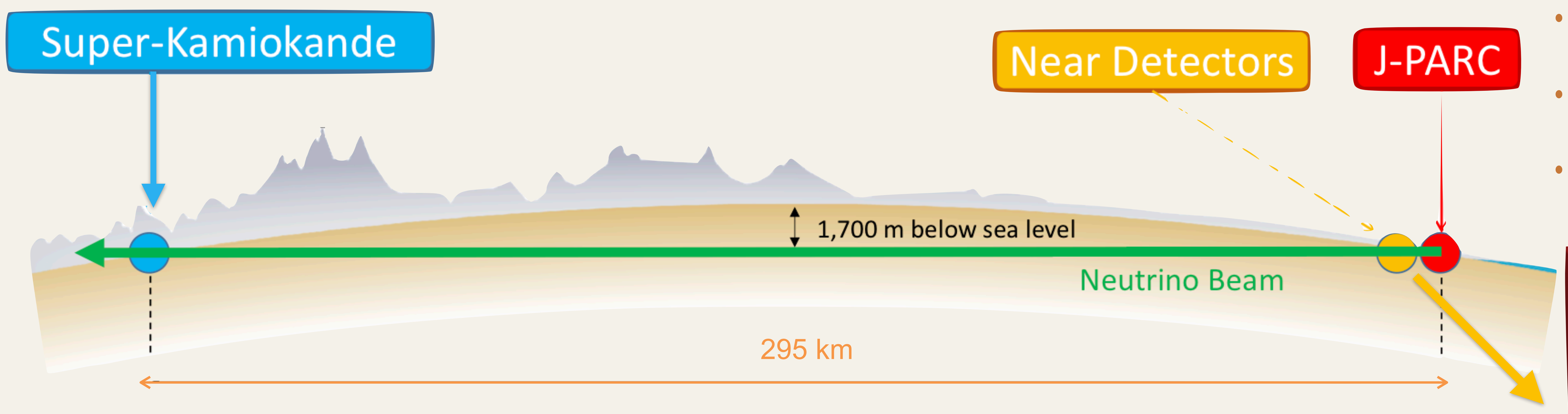
Abstract

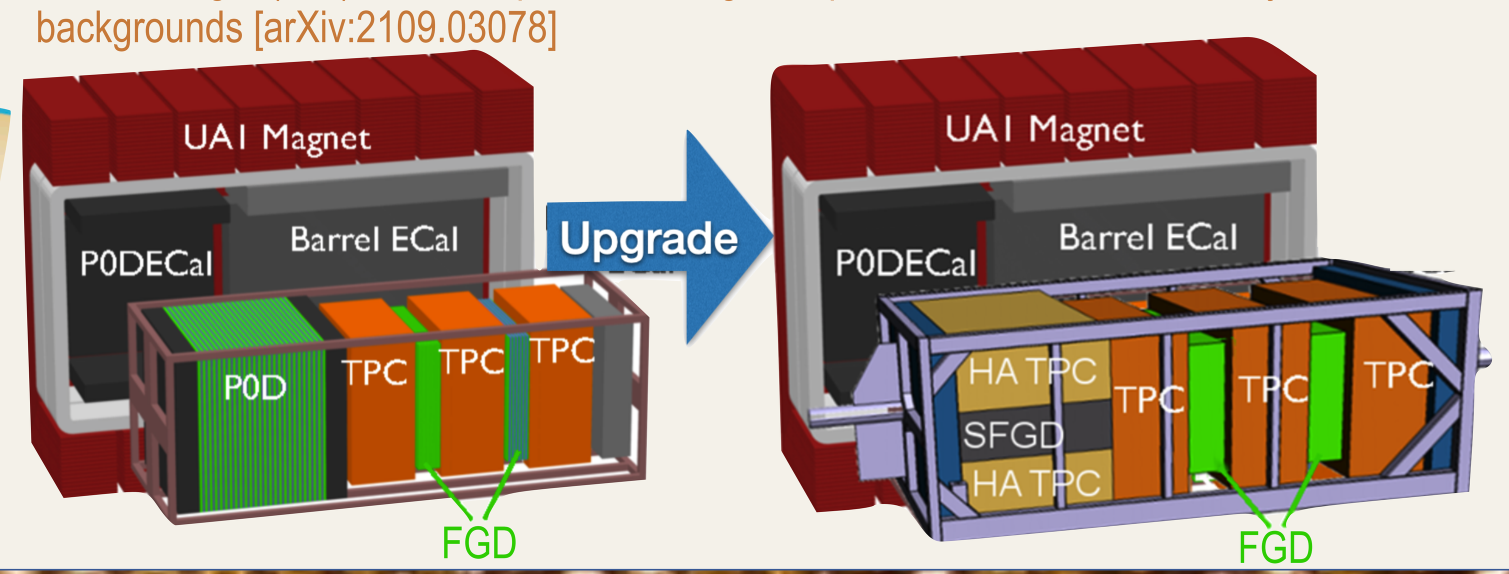
In order to be ready for the era where statistical uncertainty will not be dominant anymore, the T2K collaboration has started the second phase of T2K requiring the Near Detector (ND280) Upgrade with a significant reduction of systematic uncertainties with respect to what is currently available. One of the key sub-detectors of upgraded ND280 is the Super Fine Grained Detector (Super-FGD) which has an innovative configuration of fine-grained fully active plastic scintillator cubes totalling more than 56k channels. The features above have put many requirements for read-out electronic systems such as a large number of channels, a large dynamic range (from ~0.5 p.e up to 1500p.e), and a time resolution of sub-ns. These tasks are achievable thanks to the Front-End Board (FEB). Each FEB can read 256 channels and there is more than 200 FEB in total. In this poster, I will briefly present the Super-FGD and its expected performance then focus on characterising the architect of the FEB, together with a summary of its strict performance test series.

Introduction



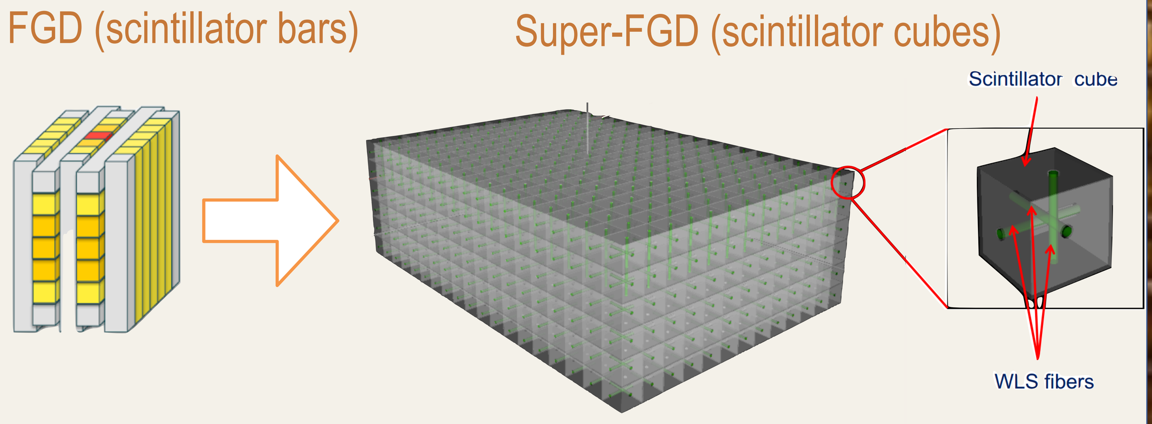
T2K (Tokai to Kamioka) is a long-baseline neutrino experiment in Japan, and is studying neutrino oscillations.
Near detector ND280 constrains the neutrino flux and neutrino interaction cross sections for oscillation analysis.
Near Detector ND280 upgrade: better constrain ν-nucleus interactions and hence improve systematic uncertainties.
=> Installation completed in May 2024

New sub-detectors:
- Super-FGD: 2 million 1 cm^3 scintillator cubes with 3D readout => 2 tons of fully active target [arXiv:1707.01785]
- HA-TPC: 2 High-Angle Time Projection Chambers contain Resistive MicroMegas modules giving 3 times better spatial resolution than bulk MicroMegas [arXiv:2106.12634]
- Time-of-Flight (ToF): Ensures precise timing to improve reconstruction and reject backgrounds [arXiv:2109.03078]

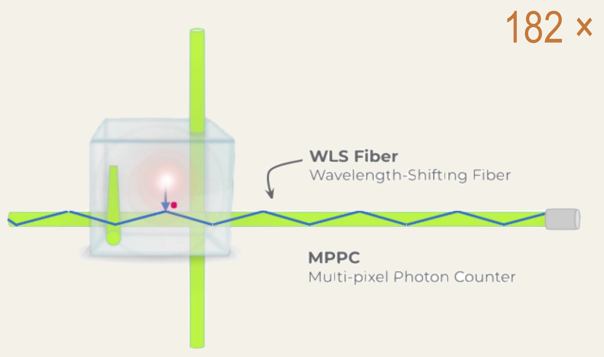


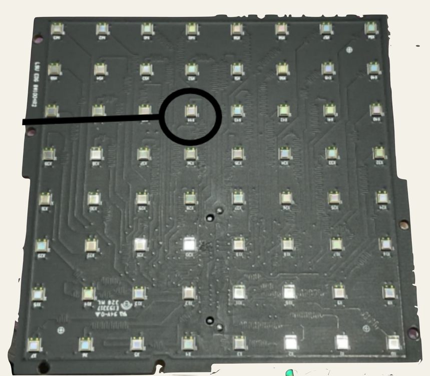
Super-FGD design and expected performance

FGD (scintillator bars) Super-FGD (scintillator cubes)

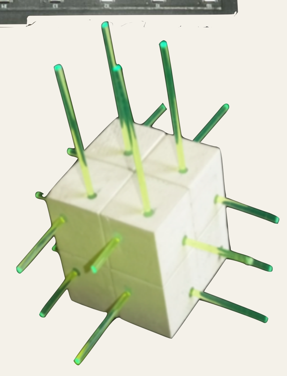


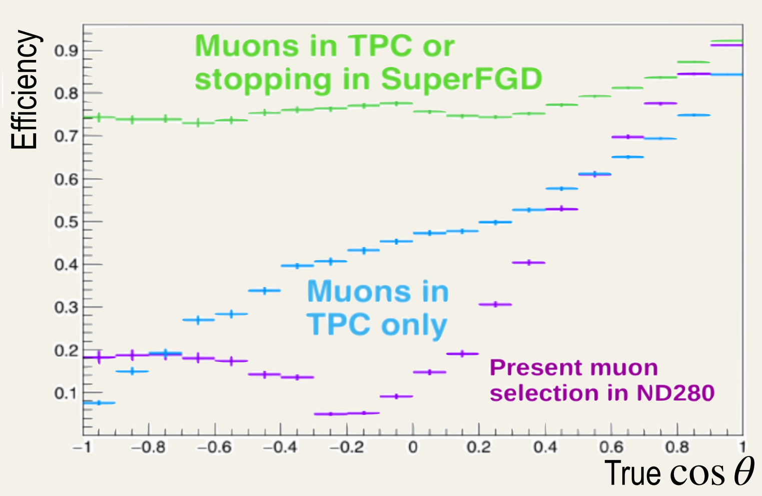
The active part of Super-FGD is 182 × 192 × 56 cubes in dimension.



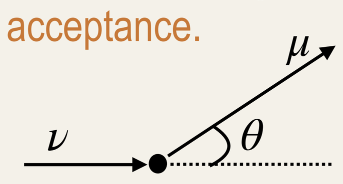


These cubes are optically independent and read out along three orthogonal directions by wavelength shifting (WLS) fibers connected with Multi-Pixel Photon Counter (MPPC).
=> 3D reconstruction

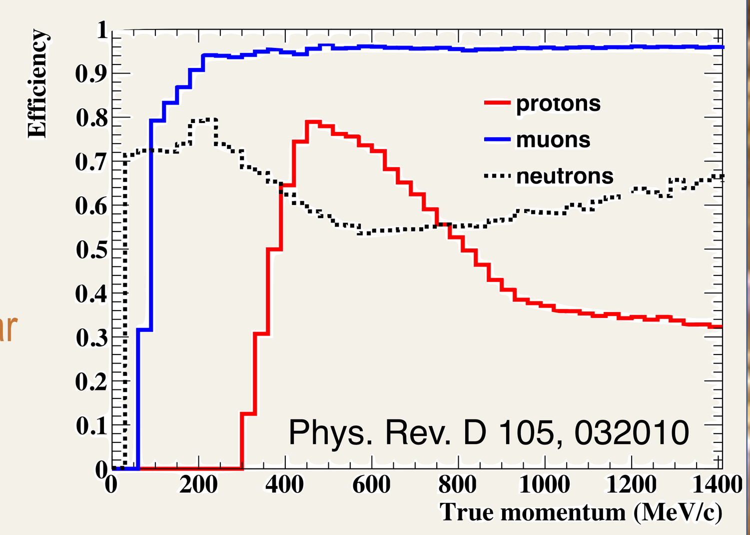




Together with High-Angle TPC, Super-FGD provides a full polar angle acceptance.



The upgraded detector has a better proton tracking threshold and access to neutron kinematics; allowing more studies on nuclear effects and better neutrino energy reconstruction.



Front-End Board (FEB)

The FEB is the heart of the electronic system:
- 1 FEB contains Cherenkov Imaging Telescope Integrated Read Out Chip (CITIROC), each CITIROC can read 32 channels => 256 channels for 1 FEB
- FEB has a large dynamic range (from ~0.5 p.e up to 1500p.e), and a time resolution of sub-ns.
- There are around 220 FEBs to be used.

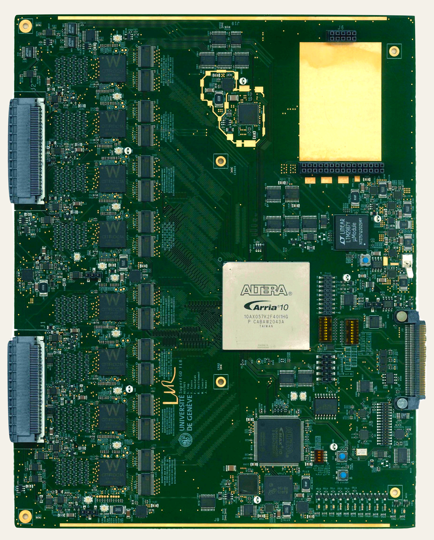
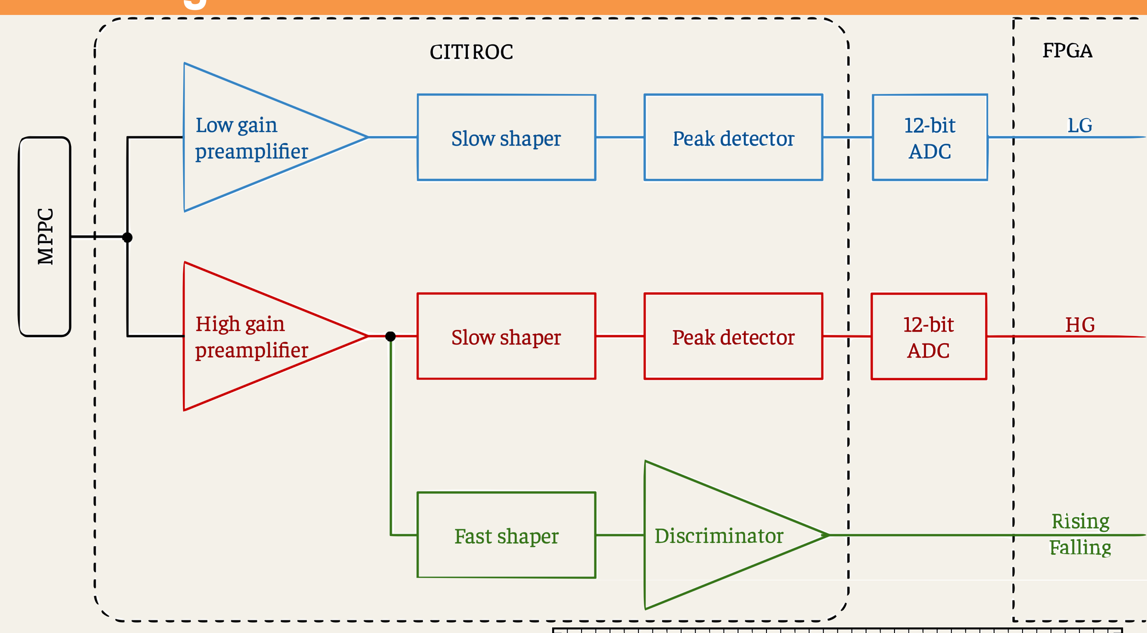
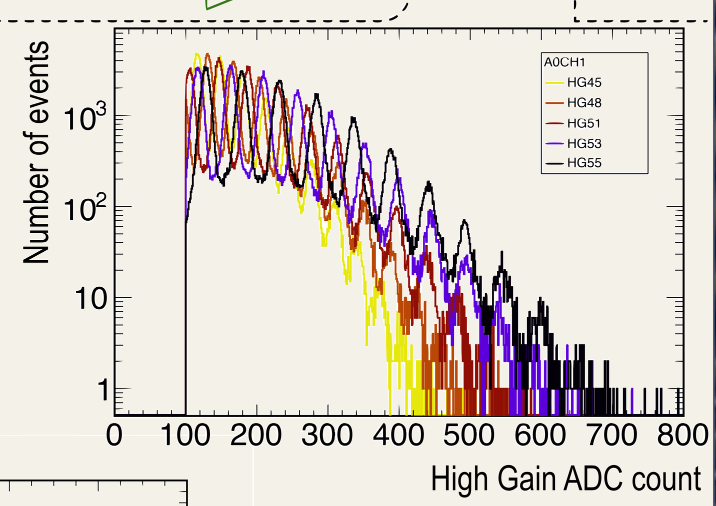
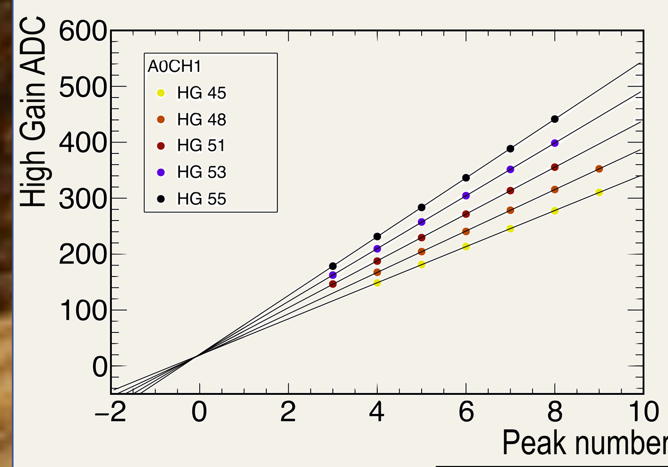


Diagram of a CITIROC channel inside FEB



The finger plot (individual P.E. distribution): Distribution of High-Gain ADC count for different gain values

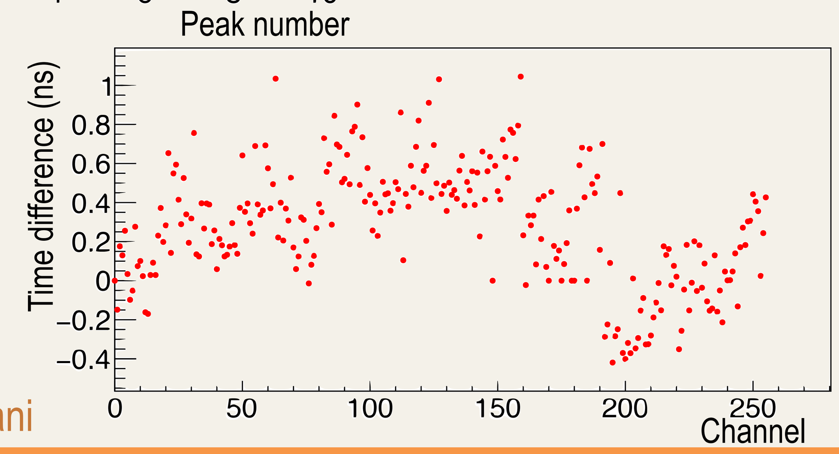




Finding pedestals

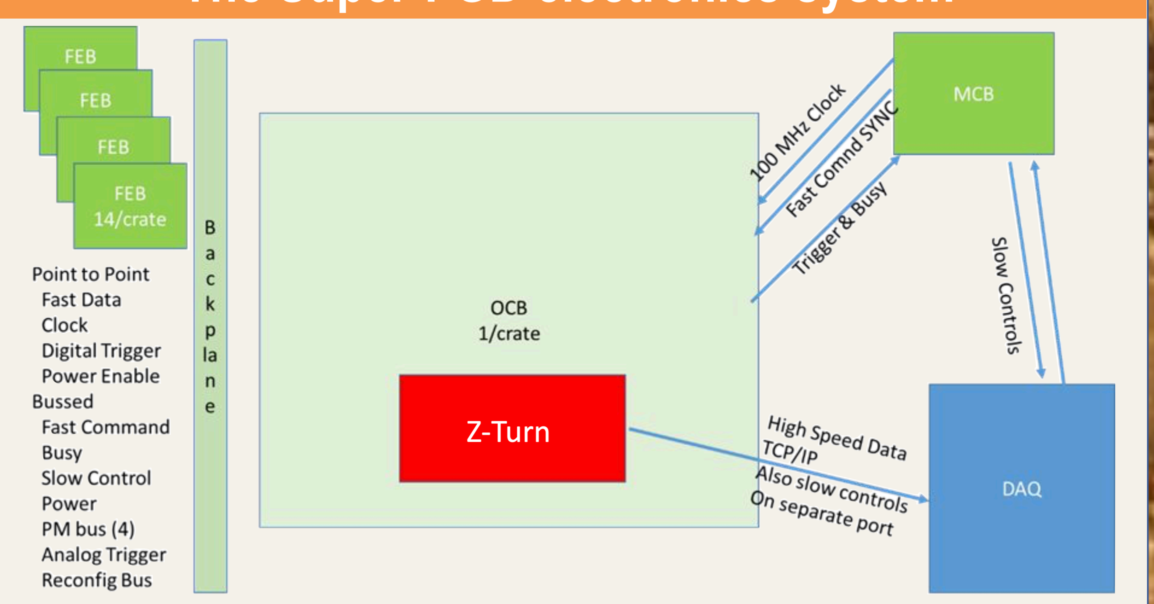
See Tristan Doyle's and Daniel Ferlewicz's posters for more about performance and calibration.

Timing differences between channels in one FEB

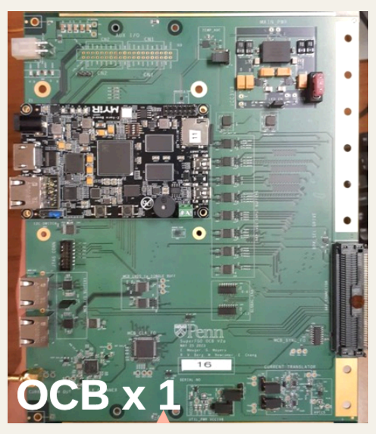


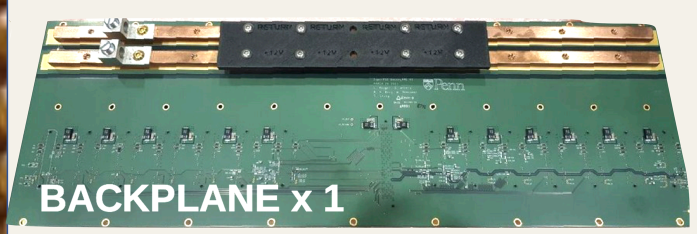
Set up by J.Chakrani

The Super-FGD electronics system



- The primary function of the Optical Concentrator Board (OCB) is to move and organise digital data and commands.
- The DAQ and slow control systems are connected to 14 FEBs in a Super-FGD crate via the OCB.
- Additionally, the OCB serves as a bridge between the Master Clock Board (MCB) and 14 FEBs.

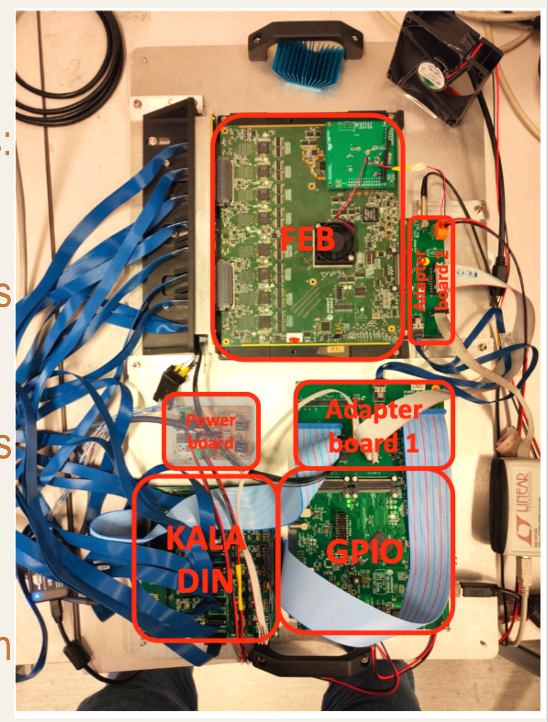




Backplane: Point-to-point and multi-drop signals that transit via the backplane make up the FEB - OCB communication.

FEB Functional test (QC Test Bench)

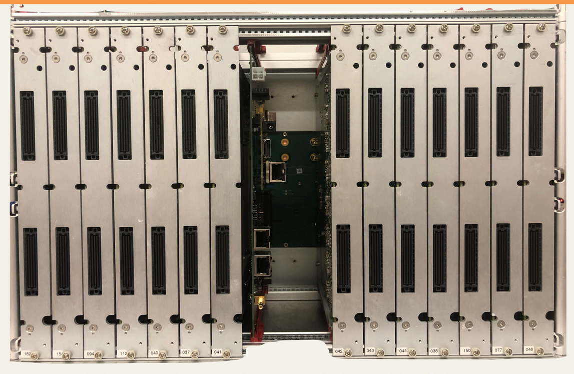
Functional test includes:
- Housekeeping and loopback
  - Test all the backplane lines: SYNC, trigger, busy
  - Test debug connector lines
  - Housekeeping (HK) values (currents, temperature, voltage)
- Calibration
  - Produce calibration parameters to be passed to DAQ
- All 256-channel test
  - Short test of each channel
  - Check ADC distribution in each channel
  - Citiroc triggers, baseline, noise.



Test developed by L.Giannessi

Vertical Slide Test (VST)

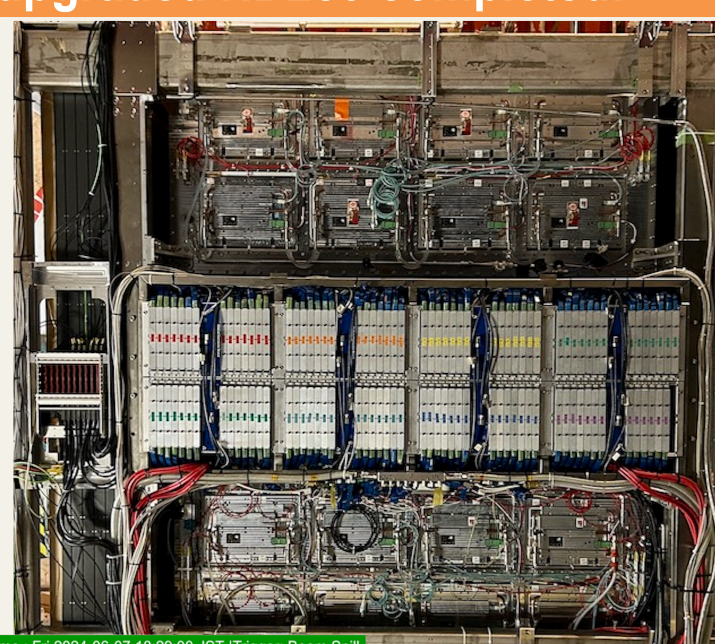
This was the final test with the real configuration of the electronic system in 1 crate:
- Full crate slow control test
- Test all the communication lines between OCB and 14FEBs
- Housekeeping test for all FEBs

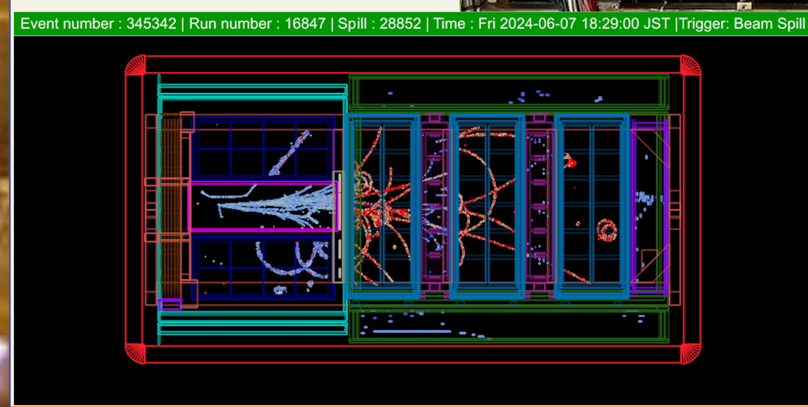


Test developed by P.Chong

SuperFGD and upgraded ND280 completed!

The Super-FGD was installed in October 2023.
The upgraded ND280 was fully installed last month (May 2024).





First neutrino events from an upgraded beam and upgraded detector

Outlook

- Super-FGD has been successfully installed and is currently under an active period of calibration, reconstruction and analysis development.
- Thanks to the upgraded detector and beam, we expect to reach 99% C.L on CP conservation exclusion by 2027. => Stay tuned!!

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