Institute for Nuclear Research

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Commissioning of the 3D segmented neutrino detector SuperFGD

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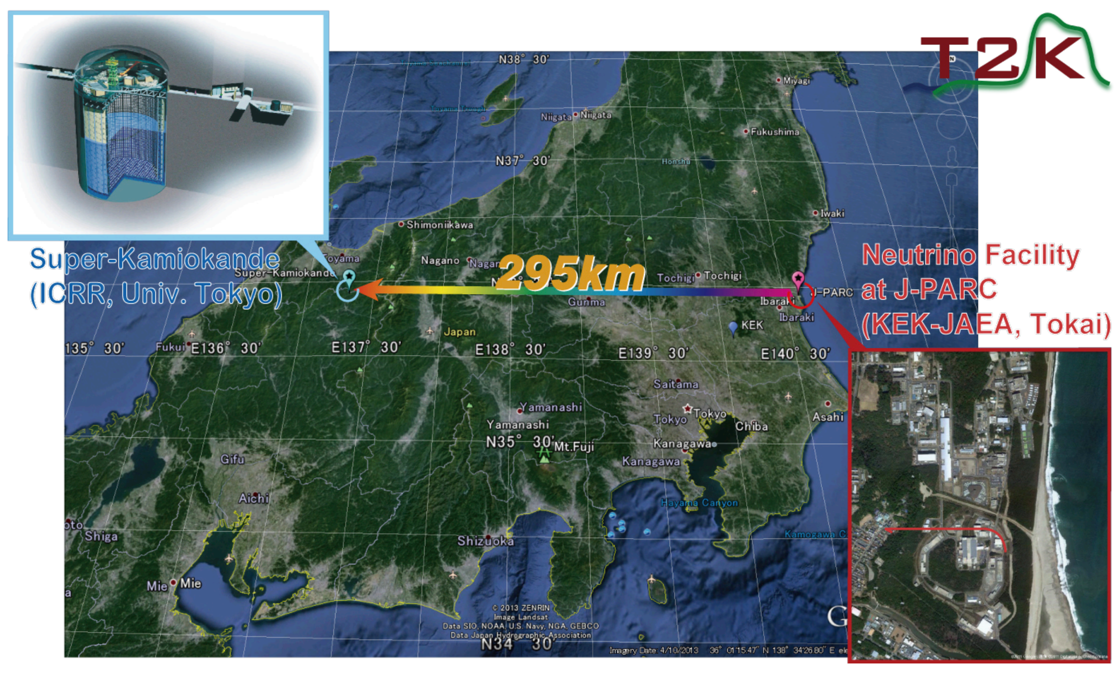
The T2K experiment

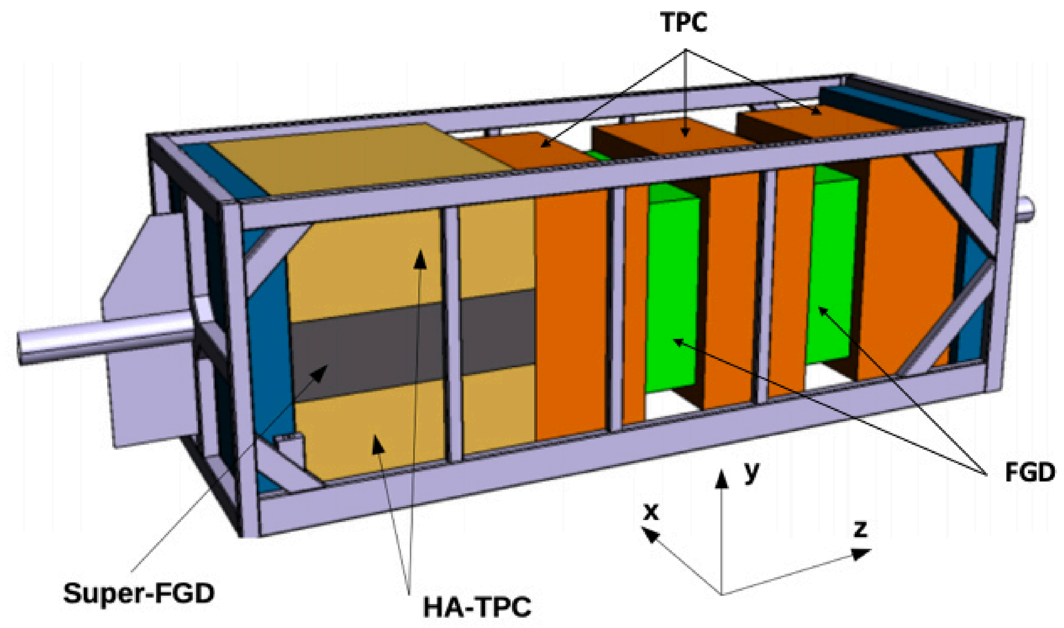


The T2K (Tokai-to-Kamioka) experiment is a long baseline neutrino oscillation experiment designed to probe the mixing of the muon neutrino (antineutrino) with other species and shed light on the neutrino mass scale. reconstruct the energy of the neutrino or antineutrino based on measurements of the resultant visible particles from the neutrino interaction.

Physics goals:

Measurement of the neutrino oscillation parameters with precision of $\delta(\Delta m^2_{23}) \sim 10^{-4}\text{eV}^2$ and $\delta(\sin^2 2\theta_{23}) \sim 0.01$ via ν_μ disappearance studies.
Search for CP violation in the lepton sector.

The Near Detector upgrade

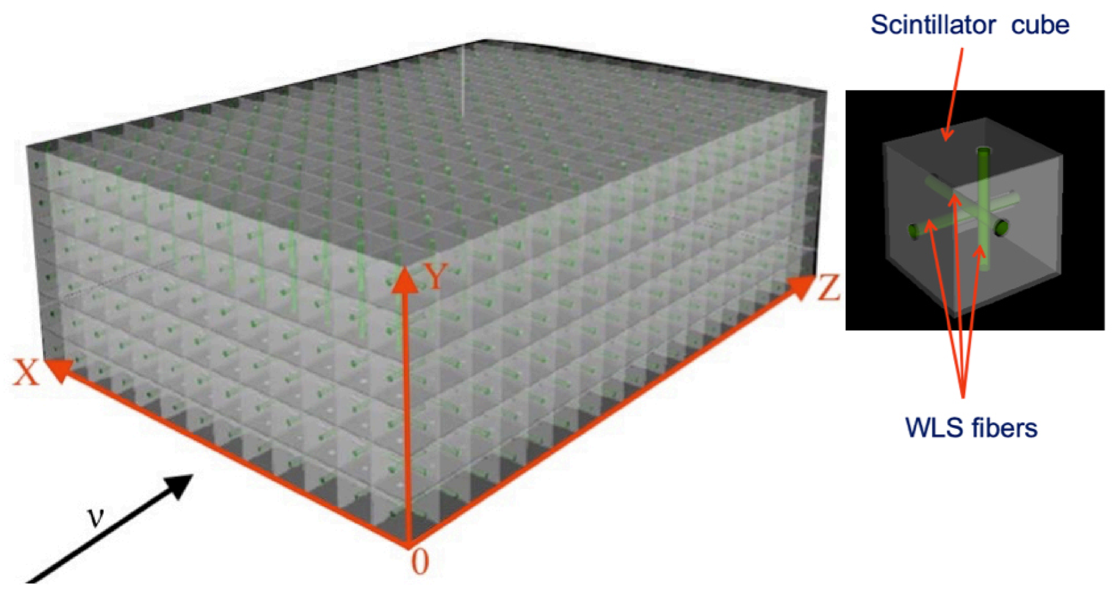


CAD 3D Model of the ND280 upgrade detector. In the upstream part (on the left in the drawing) two High-Angle TPCs (brown) with the scintillator detector Super-FGD (gray) in the middle.

The upgraded ND280 detector will be able to perform a full exclusive reconstruction of the final state from neutrino-nucleus interactions.

- Measurements of low momentum protons and pions and for the first time, event-by event measurements of neutron kinematics
- 4π acceptance for muons
- Decrease systematic uncertainties to 3-4% (from current 6-7%)
- Separation of electrons and gamma radiation

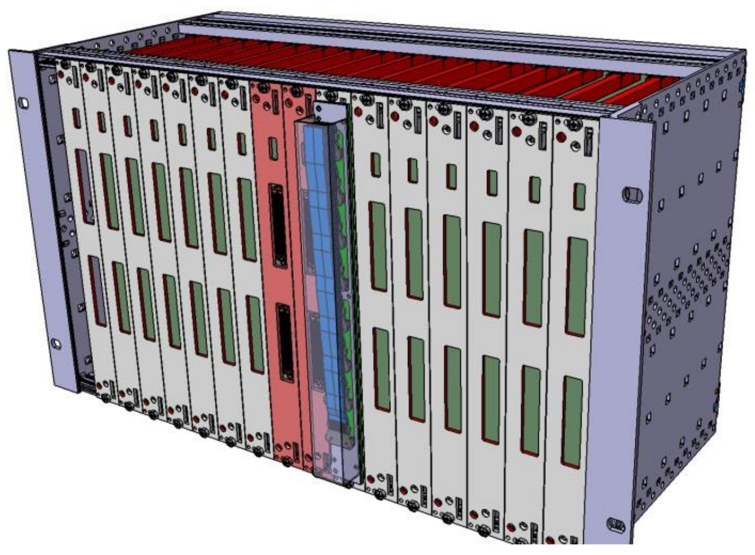
The SuperFGD detector

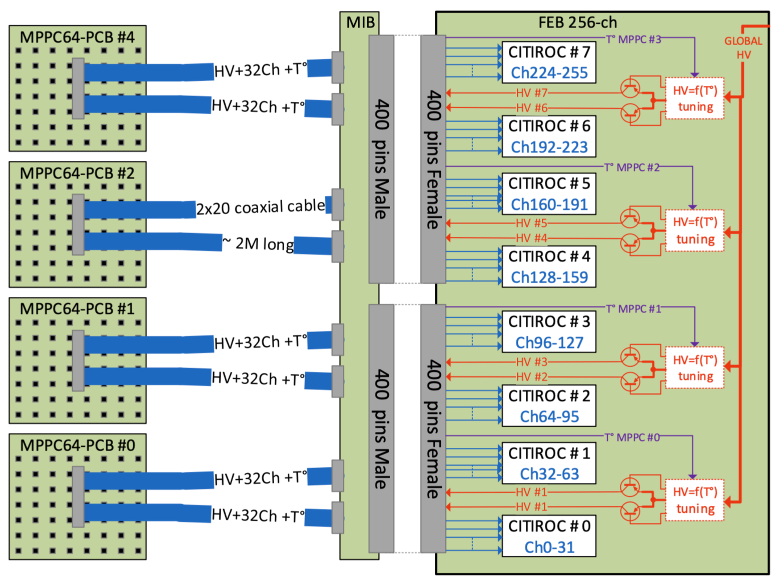


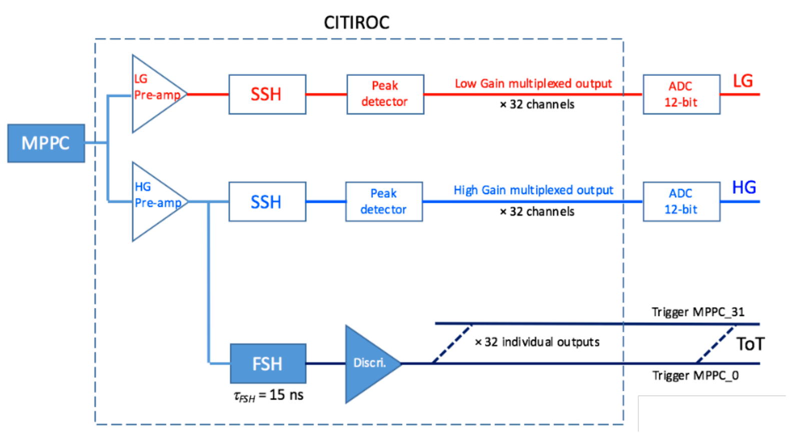
The SuperFGD detector will be an important part of the ND280 near detector upgrade for both the T2K and Hyper-Kamiokande projects.

- The dimension of the active part of SuperFGD is 192 × 56 × 182 cm3, ~56000 of readout channels.
- The scintillator cubes are produced at UNIPLAST Co. (Vladimir, Russia), comsist of polystyrene doped with 1.5% of paraterphenyl (PTP) and 0.01% of POPOP. Size: 1.0× 1.0× 1.0 cm3
- WLS fibers are commonly used to collect light from large area of scintillators, produced by Kuraray Co Y-11, shape type fiber with 1.0 mm diameter

SFGD electronics





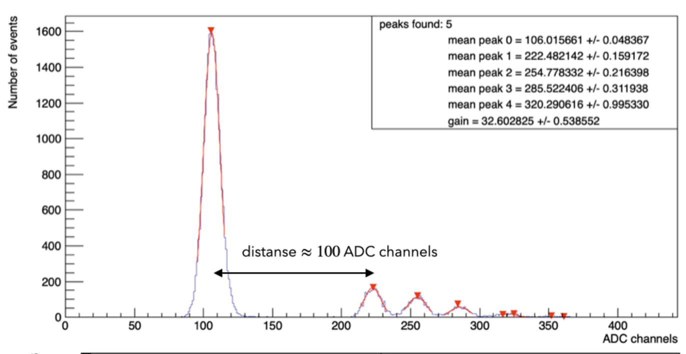


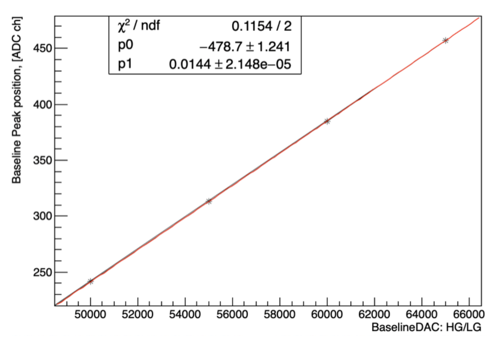
The SuperFGD electronics consist of 16 crates. One crate is an Optical Concentrator Board (OCB) in the middle of the crate section for initial data aggregation, Backplane, 14 Front End Boards (FEB) for analog processing, ADC, bias voltage to the MPPCs. Each crate is connected to the Master Clock Board (MCB), which provides a common clock signal and synchronization.

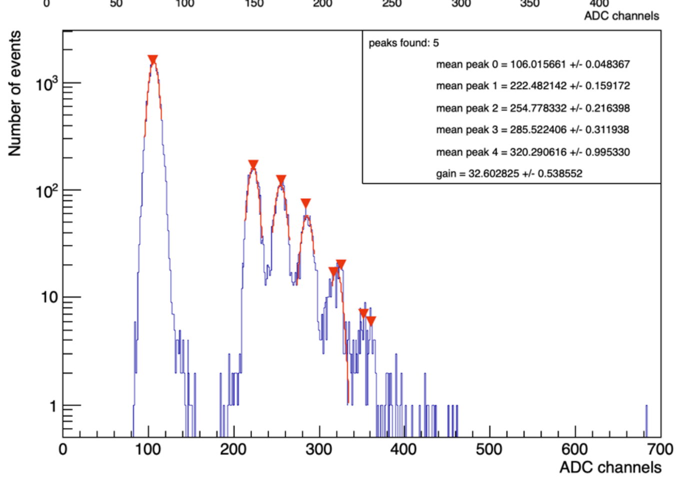
The FEB architecture is based on 8 CITIROC chips that can each read signals from 32 MPPCs, one FPGA Altera Aria X to control, and manage the timing and data flow from the CITIROCs, one 8-channel ADC for the digitization of the CITIROC analog output.

The signal from MPPC goes to CITIROC, which provides a measurement of amplitude, the HG and LG signal paths, whose output from the CITIROC is digitized by a 12-bit ADC and the Time over Threshold (ToT) obtained by sampling the rising and falling edges of the CITIROC trigger lines at 400 MHz by the FPGA on the FEB.

Baseline scan



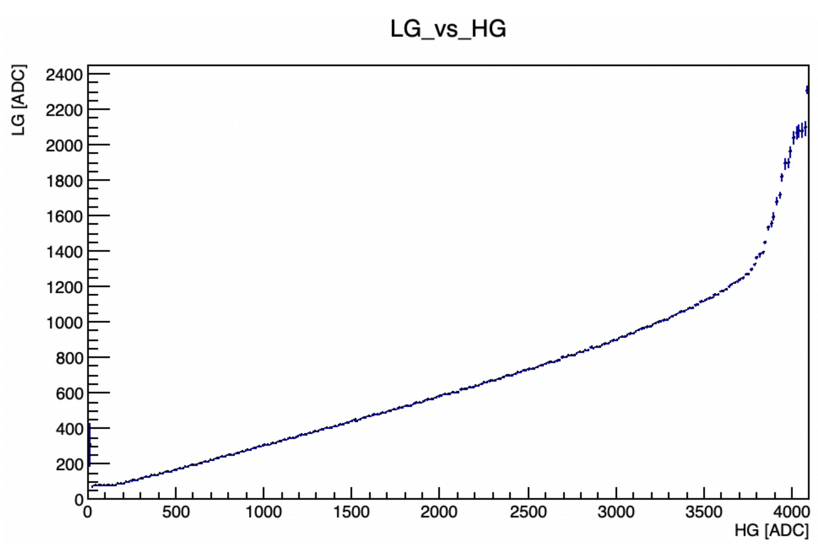




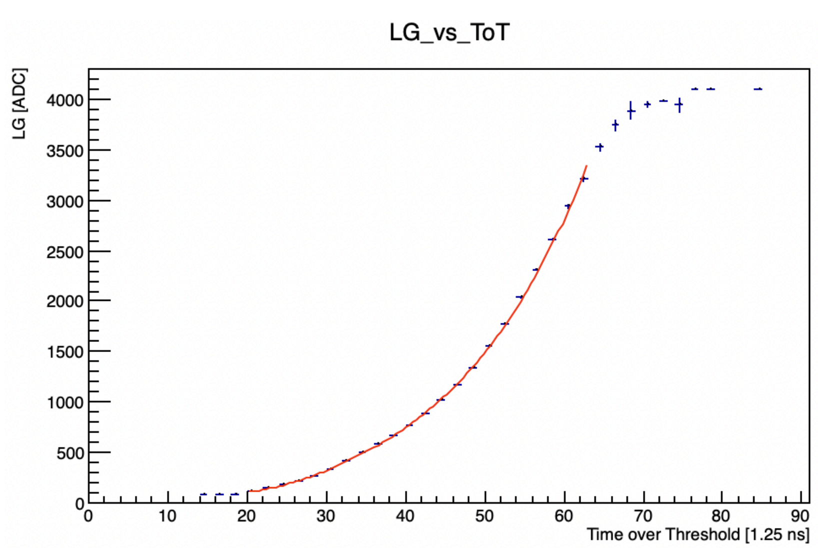
Choose baseline position by setting it in range from -10 to 0 ADC channels for each channel in one ASIC. This will reduce data size without cutting off the p.e. peaks.

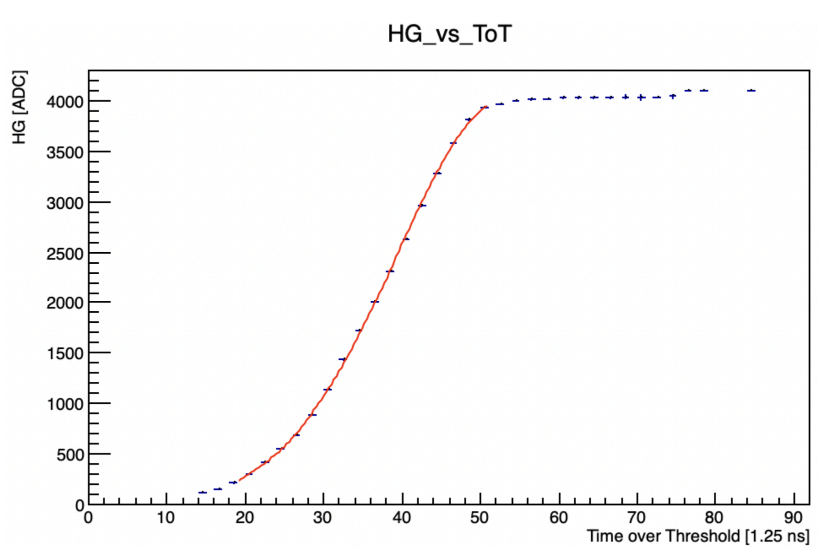
HG/LG vs ToT calibration

The separation of the signal into HG and LG allows to generate a signal amplitude with a large dynamic range and small accuracy or with high accuracy and a small dynamic range.

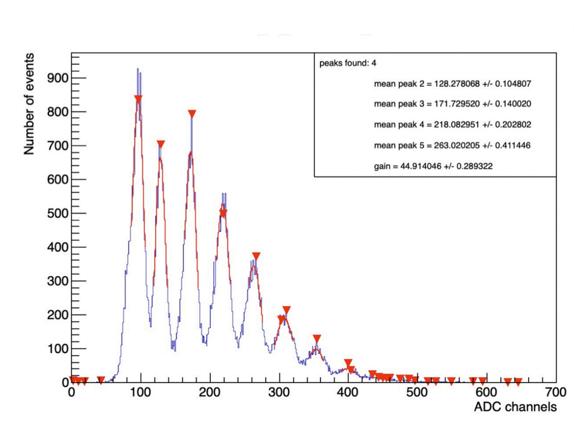


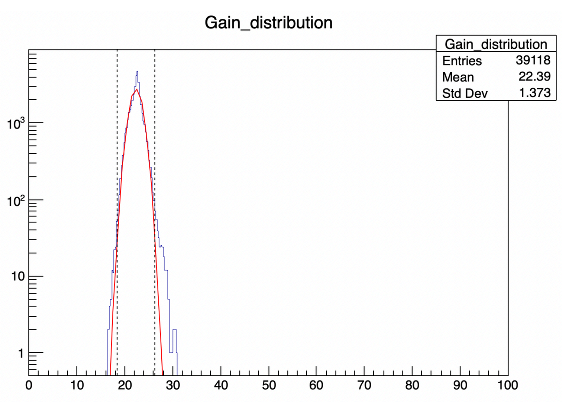
The time difference between rising and falling of the signal gives ToT (Time-Over-Threshold) value. To recover events that have occurred in the dead time, it is necessary to investigate the data of the ASICs CITIROC and SiPM. For this purpose, ToT vs HG/LG calibration was done.



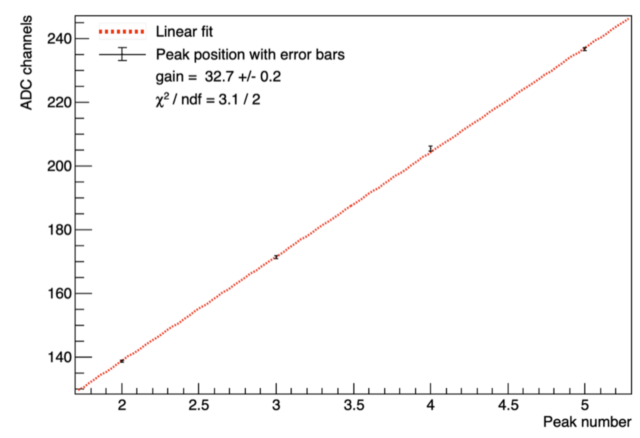


HG calibration



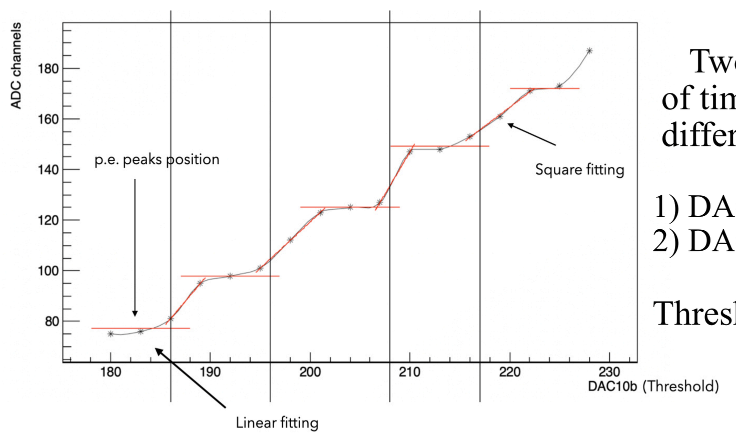


Calibrated: 39118 / 39142 channels



Extract HG calibration ratio ADC/p.e. from MPPC fingerplots. ROOT library TSpectrum was used to find p.e. peaks, mean distance between peaks: gain value, first peak is not taken into account as it might be cut off by threshold.

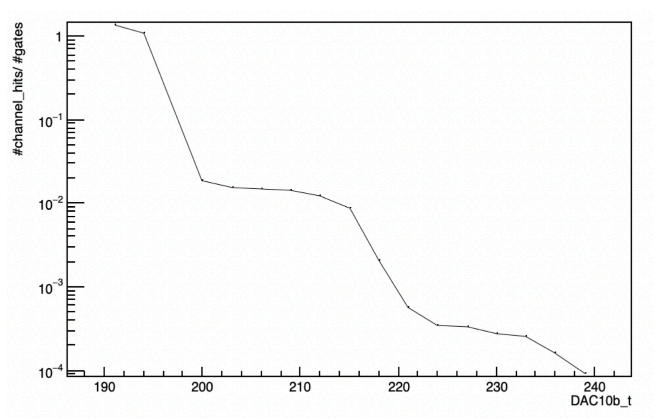
Threshold study



Two separate lines of measurements of time and amplitude provides two different thresholds:

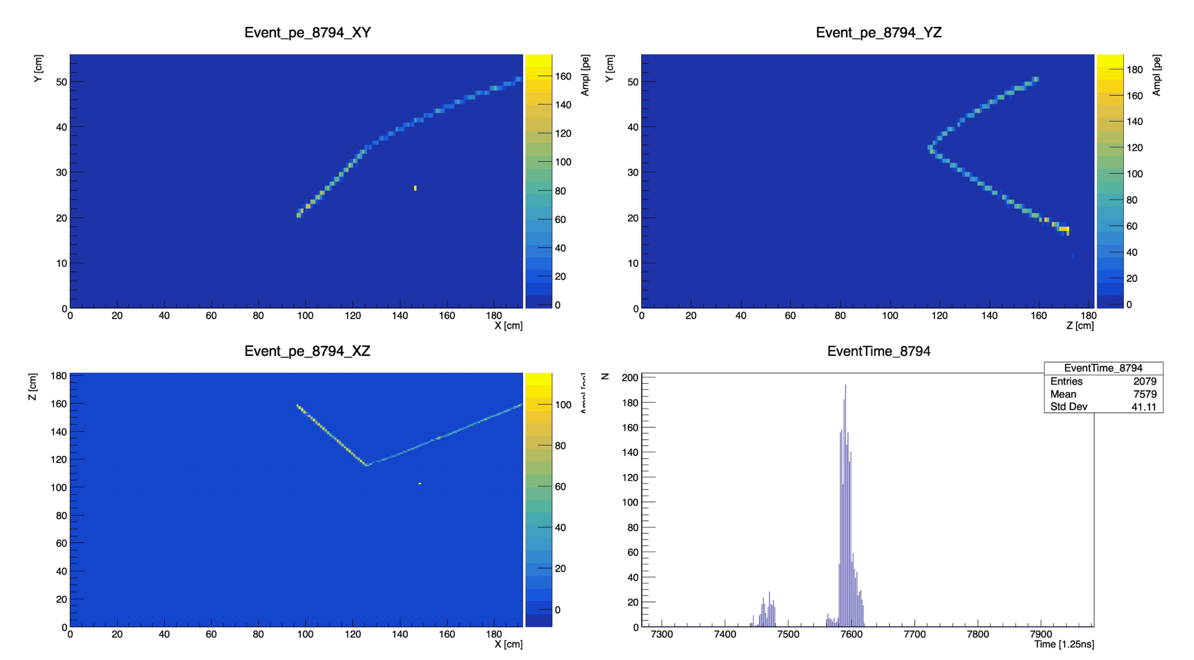
1) DAC10b for amplitude measurement
2) DAC10b_t for time measurements

Thresholds were calibrated separately.



It is supposed that the threshold value is the same for each channel in one ASIC. The value corresponding to 1.25 p.e. were set for each ASIC.

First neutrino CCQE event



Abe K. et al. T2K ND280 Upgrade--Technical Design Report //arXiv preprint arXiv:1901.03750.