



Contribution ID : 354

Type : Oral talk

Light yield correction in the 3D-segmented SuperFGD neutrino detector

Friday, 30 October 2026 18:20 (15)

SuperFGD [1] is a highly segmented scintillator neutrino target with a three-dimensional structure comprising nearly two million scintillator cubes, each 1 cm on a side. It is currently operating as part of the upgraded ND280 near detector [2] and is collecting data from the T2K neutrino beam [3]. Scintillation photons produced when a charged particle passes through a scintillator cube are captured by three mutually orthogonal Kuraray Y-11(200) wavelength-shifting (WLS) fibers and subsequently detected by Hamamatsu S13360-1325PE Multi-Pixel Photon Counters (MPPCs).

To ensure a uniform detector response, the signal correction must account for attenuation along the WLS fibers as a function of the distance from the scintillator cube to the MPPC, as well as for the light-yield (LY) response of individual cubes. For the horizontal X- and Z-oriented fibers, this distance dependence is determined using cosmic-muon data. Since cosmic muons predominantly traverse SuperFGD along directions close to the vertical axis, their projections onto the horizontal XZ plane are too short to provide sufficient information for calibrating the vertical Y-oriented fibers. Therefore, muons produced in interactions of T2K beam neutrinos are used for this purpose. The Y-fiber calibration sample consists predominantly of sand muons produced in neutrino interactions in the rock surrounding the detector. Muon candidates are selected using TPC and HA-TPC tracking and particle-identification information. The selection requires a high-quality track that crosses SuperFGD and originates outside the detector; the muon momentum is reconstructed using the TPC. Muons and stopping protons are also employed to estimate the linearity of the relationship between the cube LY and the track chord length within the cube.

This work is supported by Russian Science Foundation grant No. 26-72-00042.

[1] S. Abe et al. (T2K Collab.). The super fine-grained detector for the T2K neutrino oscillation experiment, Nucl. Instrum. Meth. A 1092 (2026) 171882.

[2] N. Skrobova. The Upgrade of the T2K Near Detector, Springer Proc. Phys. 425 (2025) 49-53.

[3] K. Abe et al. (T2K Collab.). Constraint on the matter-antimatter symmetry-violating phase in neutrino oscillations, Nature 580 (2020) 339–344.

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Session Classification : High energy physics: experiment

Track Classification : High energy physics: experiment