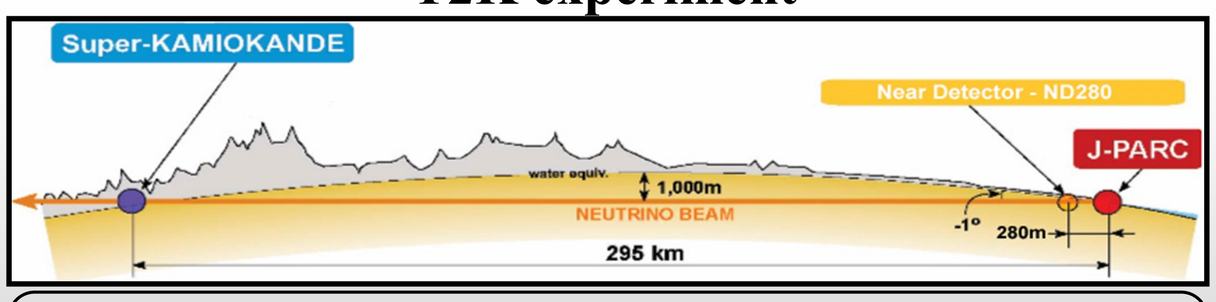
New 3D fine-grained scintillator detector for a T2K ND280 neutrino active target

S. Fedotov [1], A. Blondel [2], M. Khabibullin [1], A. Korzenev [2], Yu. Kudenko[1], A. Mefodiev [1], O. Mineev [1], E. Noah [2], S. Parsa [2], D. Sgalaberna [2], A. Smirnov [1], N. Yershov [2]

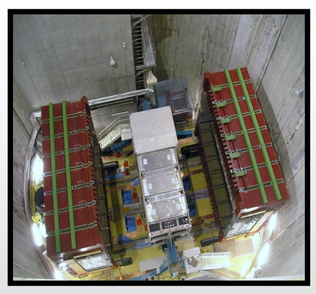
[1] Institute for Nuclear Research (INR), Russia; [2] University of Geneva, Geneva, Switzerland

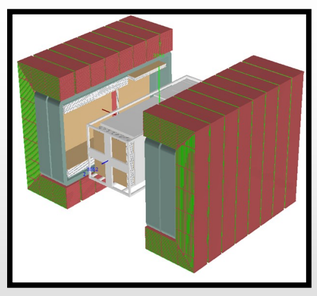
T2K experiment

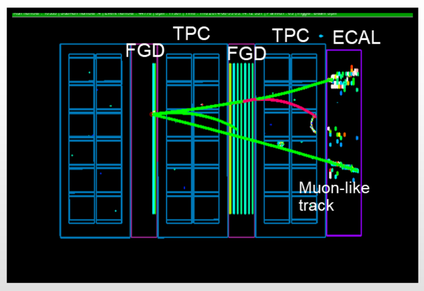


The T2K long baseline neutrino experiment has the primary goal to precisely measure neutrino oscillation parameters through measurements of ν_e appearance and ν_μ disappearance from a ν_μ beam. T2K began accumulating the data for physics analysis in January 2010. Discovery and the study of neutrino oscillations resulted in awarding of "Breakthrough Prize for Fundamental Physics" in 2016 to about 1300 scientists from the T2K and other neutrino experiments. In 2017 the T2K collaboration launched the Near Detector Upgrade project. The upgrade is targeted at reducing systematic errors in T2K's search for CP violation in the neutrino sector.

ND280

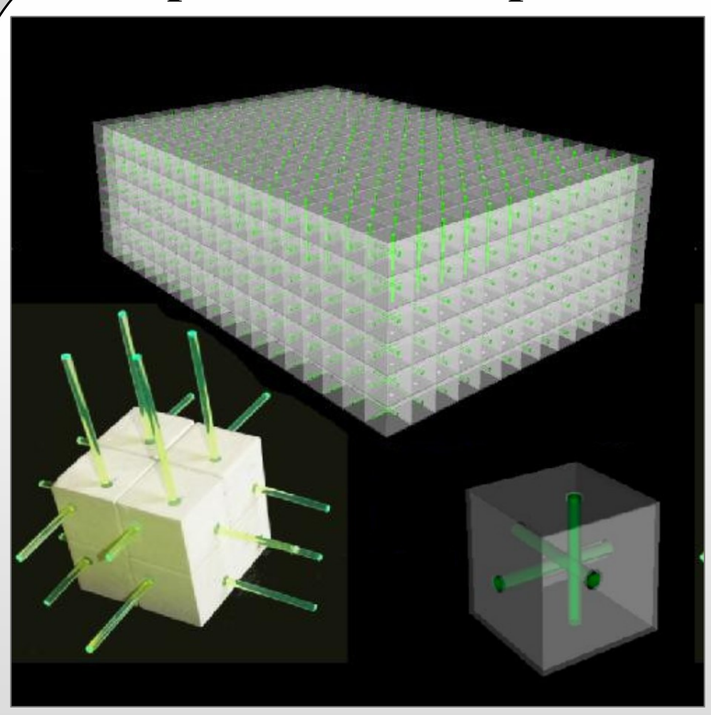


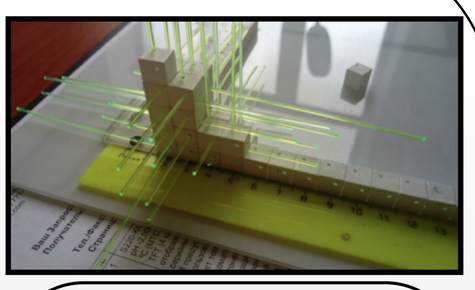




ND280 scintillator detectors (FGD) were designed as arrays of bars located perpendicular to the beam axis. Geometry is optimized to detect particles propagating in the forward direction that resulted in direction-dependence of acceptance and resolution for neutrino events. To reach more isotropic response the new scintillator detector with 3D fiber readout is proposed as the neutrino target: SuperFGD (fine-grained detector)

SuperFGD concept with 3D fiber readout





Array of 8 scintillator cubes illustrates the readout method. A single WLS fiber is going through a raw of cubes. One end of the fiber is viewed by a photosensor, another end is covered by a reflector. Each cube is viewed by 3 orthogonal fibers.

SuperFGD will be installed upstream of the beam between two TPCs (time-projection chambers) in addition to the existing FGD detectors. The size is limited by available space inside the UA1 magnet.

Detector size: 192x192x56 cm^3

Granularity: 1x1x1 cm^3 cubes

Number of cubes: >2'000'000

Number of readout channels: ~ 60'000

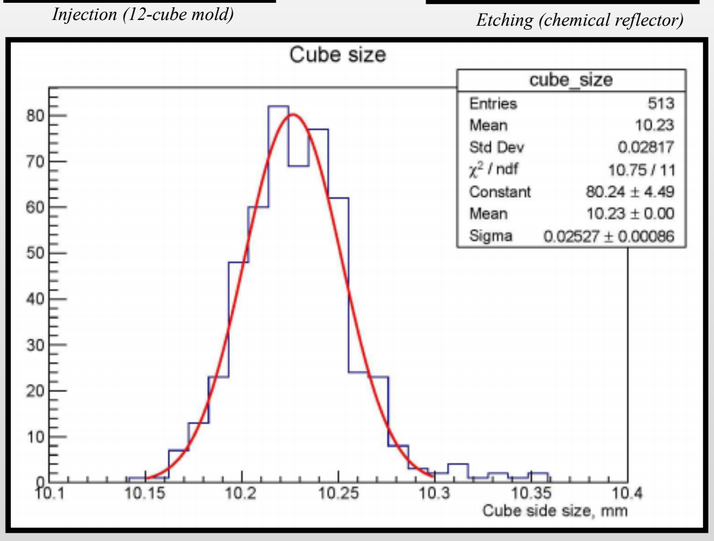
Readout: Y11 Kuraray WLS fibers of 1 mm diameter viewed at single end with surface mount Hamamatsu MPPCs.

Production of the cubes

Injection (12-cube mold)

Etching (chemical reflector)

Drilling the holes (3 holes per a cube)



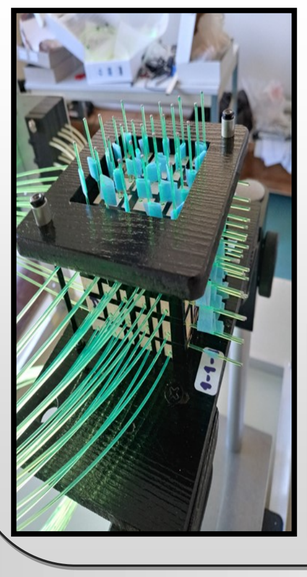
Cube size

The cubes after the mold have the precise dimensions. After etching the size of cube side is **10.26 mm ± σ=23 μm**.

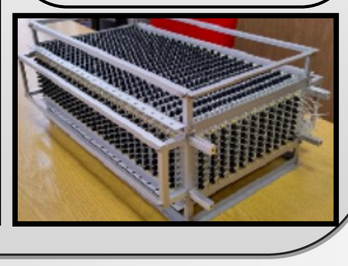
Drilling the holes

Position of the holes relative to two cube sides is currently σ=**70 μm**. We aim to reduce this value to **40-50 μm**. The potential problem is caused by some holes with positional shift beyond 3σ. Accurate quality control can not be implemented for each of 6 millions holes without consuming excessive work time.

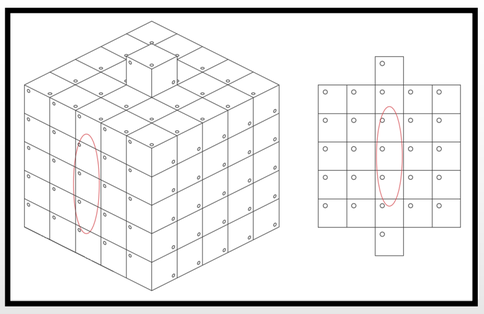
Beam tests



Two prototypes: **125** (5x5x5) cubes with **75** fibers and **9216** (48x24x8) cubes with **1728** was tested in the charge particles beam at CERN.
For 1st configuration: fiber **Kuraray Y11 1.3 m** long; MPPCs **Hamamatsu S12571-025C**. Per a single fiber:
Typical light yield ~ **42 p.e.**
Average time resolution ~**0.92 ns**

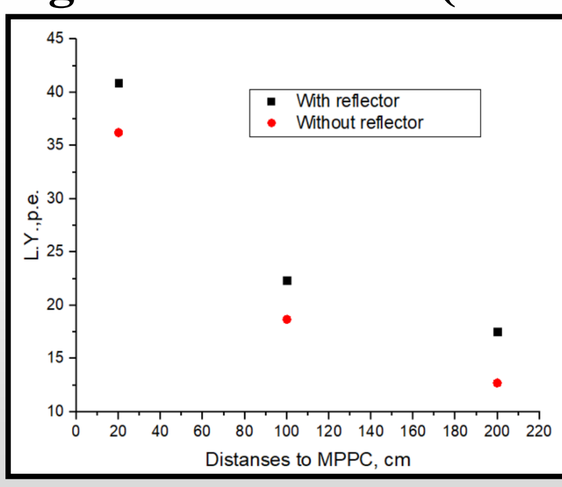


Testing of WLS-fibers (Kuraray Y11)

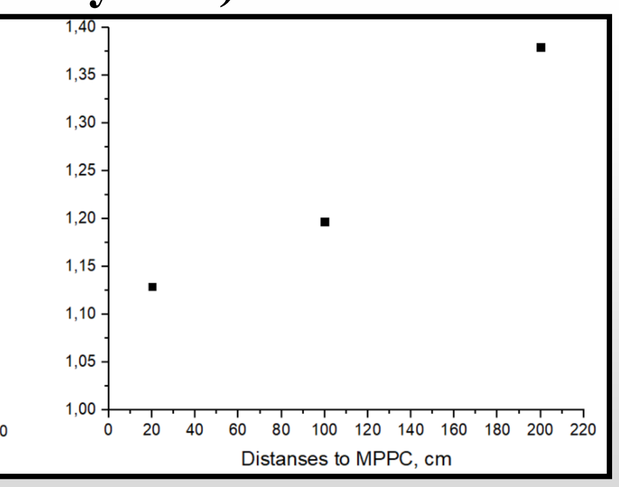


Experimental setup

Testing with cosmic muons
Trigger – 2 cubes 1x1x1 cm
Testing 3 fiber (on the red ellipse)
T ~ 22°C
>100 events on the trigger
MPPC **Hamamatsu S13081-050CS**

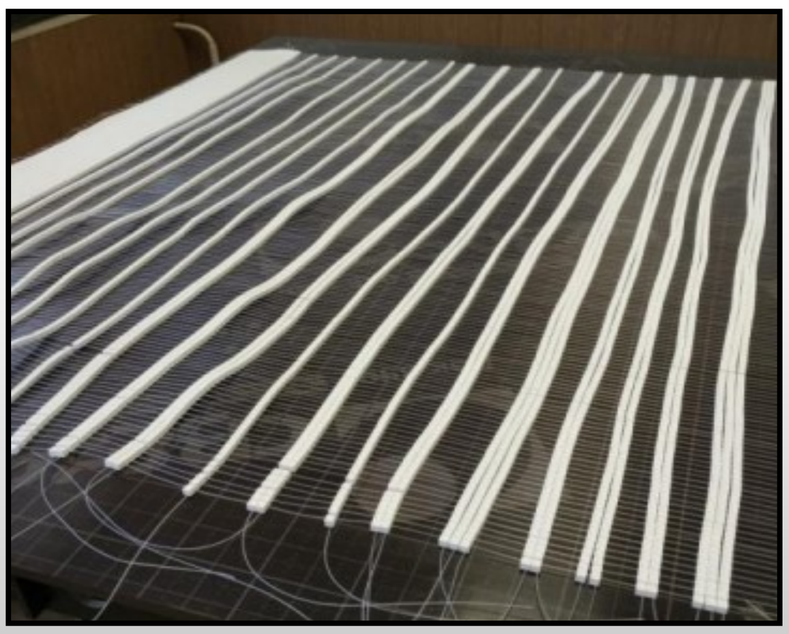


Average L.Y. for 3 fibers vs distances to MPPC for WLS-fibers with/without reflector



The effect of reflector (average L.Y. for 3 fibers with reflector) / (average L.Y. for 3 fibers without reflector)

Assembly



Steps of assembly

- First step is to select **192 cubes** for a string. Fastest way is to weigh up the quantity. The error is +/- 1 cube, and easy corrected during assembling the sheet.
- Making the cube beads (strings). **192 cubes** are threaded on a fishing line of **1.3 mm** diameter. Actual diameter was measured to be **1.35 mm**
- Cube strings are connected in a **192x192** cube sheet.

SuperFGD should be installation into the magnet at October 2021

References

- *O. Mineev,.. et al. Beam test results of 3D fine-grained scintillator detector prototype for a T2K ND280 neutrino active target // **arXiv:1808.08829** accepted for publication in NIM*
- *Blondel,.. et al. A fully-active fine-grained detector with three readout views JINST February 2018 13(02):P02006-P02006*