T2K- ND280 upgrade test results

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ND280 upgrade

Upgrade the T2K Near Detector ND280 to reduce systematics to $\leq 4\%$ level
Needed for T2K-II and Hyper-K

New upstream tracker:
- Two Horizontal TPCs
- One 3D fine-grained scintillator target SuperFGD
- TOF system around new tracker

- Fully active detector
- $4\pi$ acceptance for charged particles
- Detection of low energy protons and pions
- Electron/gamma separation
- Electron neutrino studies

arXiv:1609.04111

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SuperFGD

- Volume 200 x 200 x 60 cm³
- $2 \times 10^6$ scintillator cubes, 1 x 1 x 1 cm³
- Each cube has orthogonal 3 holes, diameter 1.5 mm
- 3D (x,y,z) WLS readout
- About 60000 readout WLS/MPPC channels
- Total active weight about 2 t

Fully active, highly granular, $4\pi$ scintillator neutrino detector with 3D WLS/MPPC readout

MC simulations

- Efficiency
- Electron
- Protons
- Photon
Technology

Cubes are manufactured at Uniplast, Vladimir, Russia

Injection molding technique

Press form with 4 chambers

Precision: each side $\leq 30 \, \mu m$
Beam tests at CERN

T9 channel at CERN: muons, pions, protons, electrons 0.5 – 5.0 GeV

-First small prototype:
- 125 cubes, 75 readout channels
- Beam test October 2017

Large prototype
Length 48 cm
Width 24 cm
Height 8 cm
9216 cubes, each 1x1x1 cm³
1728 Y11 WLS fibers, 1 mm diameter
Readout: 1728 MPPC’s

2 beam tests:
June-July 2018
August-September 2018
Beam events

Top views

Positron, 1 GeV, B = 0.2 T

Muon, 5 GeV, 45 deg

Stopped proton, 0.5 GeV, 45 deg
Performance

Light yield of a MIP: 1 cube/1 fiber

Time resolution of a MIP: 1 cube/1 fiber

Light yield of 1 cube/1 fiber \(\sim 40\) p.e./MIP
Light yield of 1 cube/2 fibers \(\sim 80\) p.e./MIP

Time resolution \((\sigma)\)
- 1 fiber: 0.92 ns
- 1 cube/2 fibers: 0.68 ns
- 2 cubes/4 fibers: 0.48 ns
- 3 cubes/6 fibers: 0.39 ns
Horizontal TPC

Micromegas MM-0 mounted on the ex-HARP field cage at T9

Drift distance 1.5 m
MM with resistive foil
Horiz x Vert = 36 x 48 pads
1728 pads in total
Each pad 0.98 x 0.7 cm²
Nominal MM voltage 340 V
Sampling time 80 ns
Nominal peaking time 600 ns

Beam test at CERN in August-September 2018
Beam: muons, pions, electrons, protons
momentum 0.5, ±0.8, 1, 2 GeV/c
TPC performance

Beam events

dE/dx, 2 GeV/c muons

Truncated mean energy deposit

<table>
<thead>
<tr>
<th>cluster_norm_charge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entries</td>
</tr>
<tr>
<td>Mean 236.8 ± 0.4342</td>
</tr>
<tr>
<td>Std Dev 41.91 ± 0.307</td>
</tr>
<tr>
<td>(\chi^2 / \text{ndf} ) 412.8 / 88</td>
</tr>
<tr>
<td>Const 899.1 ± 12.7</td>
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<tr>
<td>Mean 234.2 ± 0.3</td>
</tr>
<tr>
<td>Left sigma 26.63 ± 0.25</td>
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</tbody>
</table>

\(\sigma \sim 12\%\)

Muons track

before cluster selection

after cluster selection

2 tracks detected

dE/dx, electrons

Truncated mean energy deposit

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<tr>
<th>cluster_norm_charge</th>
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<tbody>
<tr>
<td>Entries 16654</td>
</tr>
<tr>
<td>Mean 432.1 ± 0.7902</td>
</tr>
<tr>
<td>Std Dev 101.8 ± 0.5587</td>
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<tr>
<td>(\chi^2 / \text{ndf} ) 2041 / 145</td>
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<tr>
<td>Constant 919.9 ± 10.1</td>
</tr>
<tr>
<td>Mean 414.6 ± 0.4</td>
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<tr>
<td>Sigma 42.21 ± 0.31</td>
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\(\sigma \sim 11\%\)

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TOF system

Time-of-Flight detector surrounds the new tracker (Super FGD + Horizontal TPCs) for better rejection of incoming background.

TOF bar: cast scintillator EJ-200, 1.68 m x 6 cm x 1 cm readout by 8 arrays of 6x6 mm² of Hamamatsu MPPC’s

P = 0.8 GeV/c, L = 10 m

Achieved time resolution σ~70 ps

Testbeam Aug 15 – Sep 19, East hall T10 of CERN PS
Upgrade of the T2K near detector ND280 is in progress

Beam tests at CERN → good performance of TPC, SuperFGD, TOF

Innovative technology works well

Production all detector components - 2019-2020

Assembly, installation and commissioning at J-PARC - 2021