T2K Near Detector

Fabrice Retière for the T2K collaboration
The T2K collaboration


Spain: IFIC, Valencia, U. A. Barcelona


Japan: ICRR Kamioka, ICRR RCPN, KEK, Kobe U., Kyoto U., Miyagi U. Edu., Osaka City U., U. Tokyo

Korea: S. Korea, Chonnam, U. Dongshin, N. U. Seoul

Germany: C. H. U. Aachen, N. U. Seoul

France: IPN Lyon, LLR E. Poly., LPNHE Paris

Russia: Russia


Total: ~500 members, 59 institutes, 12 countries

Near & Far sites: KEK/JAEA, Kamioka Observatory, ICRR

06/10/2011
Tokai 2 Kamioka experiment

- Precise measurement of $\nu_\mu$ disappearance
- Search for $\nu_\mu \rightarrow \nu_\text{e}$ appearance
Neutrino beamline

Beam dump & muon monitors

Near Detector

Final Focus

Main Ring

Neutrino arc
(Super-conducting combined function magnets)

Spill cycle: 3.04 sec 8 (6 in 2010) bunches

Target and horns(3), decay volume (110m)
Characterizing the neutrino beam

- Oscillation analysis require a good understanding of the beam and $\nu$ cross-sections.

- Strategy
  - NA61 at CERN measure the hadron spectra from a target replica.
  - Measure the position of the muons at the end of the beam dump.
  - Detect a fraction of the neutrino 280 m from the target: the near detector.
T2K near detector

On-axis: INGRID
  – Measure beam flux and direction

Off-axis: ND280
  – Measure beam flux off-axis
  – Measure neutrino cross-sections
  – Allow characterizing different neutrino interactions
    • Tracking capabilities
    • Particle identification
    • Calorimetry
UA1 magnet operated at 0.2T
A common building block to all scintillator detectors

- Plastic scintillator
  - Extruded or grooved
  - 5 different kinds
- Wavelength shifting fibers
  - Kuraray Y11, 1 mm diameter
- Hamamatsu Multi-Pixel Photon Counter
  - 1.3×1.3 mm²
  - 667 pixels (50 μm pitch)
- Fiber-MPPC coupler
  - Custom designed
    - 3 different kinds
- Readout electronics
  - 2 different kinds
## Differences and similarities

<table>
<thead>
<tr>
<th></th>
<th>FGD</th>
<th>DS-ECAL</th>
<th>B-ECAL</th>
<th>INGRID</th>
<th>POD</th>
<th>SMRD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of channels</td>
<td>8,448</td>
<td>3,400</td>
<td>18,900</td>
<td>9,592</td>
<td>10,400</td>
<td>4,016</td>
</tr>
<tr>
<td>Bar length (mm)</td>
<td>1844</td>
<td>2040</td>
<td>1520, 3840</td>
<td>1119, 1203, 1299</td>
<td>2137, 2268</td>
<td>873</td>
</tr>
<tr>
<td>Bar cross-section (mm²)</td>
<td>9.6x9.6</td>
<td>40x10</td>
<td>40x10</td>
<td>50x10</td>
<td>32.5(B)x17(H)</td>
<td>170x7</td>
</tr>
<tr>
<td>Fiber diameter (mm)</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Far end</td>
<td>Mirrored</td>
<td>Readout</td>
<td>Mirrored</td>
<td>Mirrored</td>
<td>Mirrored</td>
<td>Readout</td>
</tr>
<tr>
<td>MPPC over- voltage (V)</td>
<td>0.8-1</td>
<td>1.33</td>
<td>1.33</td>
<td>1.33</td>
<td>1.33</td>
<td>~1.4</td>
</tr>
<tr>
<td>Most probable # of avalanches per MIP</td>
<td>20-35</td>
<td>20-30</td>
<td>In progress</td>
<td>10-15</td>
<td>30-60*</td>
<td>35-40</td>
</tr>
<tr>
<td>Electronics</td>
<td>Waveform</td>
<td>Q-t</td>
<td>Q-t</td>
<td>Q-t</td>
<td>Q-t</td>
<td>Q-t</td>
</tr>
</tbody>
</table>

06/10/2011
Differences

Scintillator bar

Fiber-MPPC coupler

- ECAL & POD
- SMRD

- FGD
- INGRID
Readout electronics

- Two different ASICs
  - TRIP-t: integrator + discriminator
    - ECAL, POD, SMRD
  - AFTER: Switch Capacitor Array
    - FGD
Raw data

- **TRIP-t data**
  - Integrate charge over 23 cycles (540 ns wide)
    - 100 ns reset between cycles
  - Time: discriminator fires when charge > threshold
    - 1 time per cycle

- **FGD-AFTER data**
  - Raw waveform
  - Q-t extracted in firmware
MPPC

• T2K was the first experiment to use large number of MPPCs
  – About 50,000
• Extensive quality assurance before installation
  – Less than 20 MPPCs found bad
  • Was it worth the efforts?
• No MPPC have died while in operation in ND280

• MPPC response characterization
  – Detail measurements
    • Gain variation and fluctuation
    • Photo-detection efficiency
    • Dark noise
    • After-pulsing
    • Cross-talk
    • Recovery
    • Saturation
  – Information critical for detector simulation, operation and calibration
Detector response characterization and simulation

**MPPC characterization**

- Example: photo-detection efficiency

**Fiber characterization**

- Decay time constant "speed of light"
- Mirror/MPPC reflectivity
- Light spread

**MPPC simulation**

- 1.85 Photons
- 1.32V Overvoltage

Point: data
Line: simulation

**Graphs**

- Probability / bin
- Signal / p.e.
- dN/dtime (1/ns)

- Reflected light
- Direct light

06/10/2011
16 identical modules
INGRID module

- 9 iron planes
  - $124 \times 124 \times 6.5 \text{ cm}^3$

- 11 scintillator planes
  - $24(X)+24(Y) \times 1 \times 5 \times 120.3 \text{ cm}^3$ scintillator bars
  - Y11 + Multi-Pixel Photon Counter readout
    - 8448 channels

- 4 veto detectors
  - ~Same bars + Y11 + MPPC
    - 1144 channels
INGRID performances

INGRID first neutrino event candidate

**Side view**

**Top view**

06/10/2011

Nov. 22, 2009
Side Muon Range Detector (SMRD)


- **Purpose**
  - Measure muon from neutrino interaction
  - Provide a cosmics trigger

- **Inserted in UA1 magnet**

- **Special feature**
  - “Snaking” fiber
  - Provide position resolution by reading out both ends
Pi zero detector (POD)


Purpose: Study specifically $\pi^0$ production cross-section

Check out N. Buchanan’s slides for details (yesterday’s $\nu$ session)
Electromagnetic calorimeter (ECAL)

Purpose
- Detect and measure energy of photons and electrons produced by neutrino interaction

- Sandwich of lead and scintillator bar

- Check out R. Sacco’s slides at yesterday calorimeter session
The Fine Grained Detector

- **Purpose**
  - Target for neutrino interaction
  - Track particles produced by neutrino
Time Projection Chamber

UBC, IPP, TRIUMF, U. Victoria (Canada), CEA-Saclay, in2p3-Paris (France), RWTH Aachen (Germany), INFN Bari, INFN Padova, U. Padova (Italy), IFAE Barcelona, U. Valencia (Spain), U. Geneva (Switzerland)

- **Field cage**
  - Inner box: 2.3x2.4x1m³
  - 1 m drift from central cathode
  - Cathode patterned for calibration with laser

- **Gas:** Ar:CF₄:iC₄H₁₀ (95:3:2)
TPC: readout plane and electronics

- **Bulk Micromegas**
  - 12 modules 34.2x35.9 cm$^2$
  - 7x9.8 mm$^2$ pads

- **Custom electronics**
  - ~120,000 channels
  - Based on AFTER ASIC: preamp-shaper + Switch Capacitor array
TPC: position resolution

Field distortion map (full drift)
Exaggerated 10 times
Most non-uniform TPC region

Momentum resolution driven
by this position resolution better than 10%
as specified

06/10/2011
TPC performance: $dE/dx$

**Positive tracks**

**Negative tracks**

Desired 8% resolution achieved

For more details on ND280 TPC, see B. Jamieson’s talk tomorrow in gas detector session.
Example off-axis events

Interaction in P0D: View from (north) side

Sand Muon & FGD interaction

FGD interaction with backward track

Cosmic ray muon
Number of selected events in FGD

$\text{events/(1e17 POT): (5.289 +/- 0.014)}$

Event timing in GFD
Summary

- T2K near detector fully operational since January 2010
  - Smooth operation, very good performances
  - To date, no serious damages due to earthquake identified
- High quality data being collected
  - First physics results coming out
- Detailed detector characterization work going on

Several detector papers from T2K:
- Time Projections Chambers for T2K near detectors, submitted to NIM
- Characterization and simulation of the response of MPPCs to low level, submitted to NIM, arxiv
- The T2K experiment, submitted to NIM
- The T2K Fine Grained Detector, in preparation
- Characterization of the Y11 fiber response, in preparation