The T2K Experiment

First LBNE experiment built for $\theta_{13}$ measurement

Accelerator complex provides a 30 GeV proton beam with a design power of 0.75 MW, currently delivering $\sim$135 kW
The T2K Experiment

ν beam energy peaked at 1st max $E \approx 600$ MeV

8 (6 in early 2010) bunches strike a $2.6 \times 91.4$ cm Helium-cooled graphite target

Spill cycle: 3.04 (3.52) s

3 Magnetic Horns at 250 kA focus positively charged hadrons

The far detector and part of the near detectors are positioned off-axis (2.5°)

$\nu$ beam energy peaked at 1st max $E \approx 600$ MeV
In principle, we want the near and far detectors to be “identical”. In practice, there are too many differences (size, event rate, geometry with respect to the beam, backgrounds,...) so we might as well make it more complex and capable with a different technology.

**What kind of Near Detector?**

- **Off-Axis (ND280)**
  - suite of fine-grained detectors/tracker in a 0.2T magnetic field (old UA1/NOMAD magnet)
  - Measurement of: CC $\nu_\mu$ events (normalisation, $E_\nu$ spectrum), NC $\pi^0$, CC $\nu_e$ events (background to $\nu_e$ appearance), neutrino cross-sections

- **On-Axis (INGRID)**
  - scintillator-iron detectors
  - Measurement of beam direction and profile
Two main target regions:
- $\pi^0$ Detector (P0D): optimized for (NC) $\pi^0$ events
- Tracker: optimized for charged particle final states
  Both regions have passive water planes

UA1 magnet (0.2T), inner volume 3.5x3.6x7m$^3$

ECals: POD, Barrel and Downstream
Measure EM showers from inner detector
($\gamma$ from NC $\pi^0$, electrons,...)
  Sand muon rejection

POD ($\pi^0$ Detector)
Scintillator planes interleaved
with water and lead/brass layers
  Optimized for $\gamma$ detection

SMRD (Side Muon Range Detector)
Scintillator planes in magnet yoke
Detects muons from inner detector
(neutrino rate, side muon veto, cosmic trigger)
  Momentum measurement

2 FGDs (Fine-Grained Detectors)
Thin scintillator planes
Provide active target mass, optimized
for p recoil detection

3 TPCs (Time Projection Chambers)
Momentum measurement of charged particles from FGD and POD
  PID via $dE/dx$ measurement

ECals: P0D, Barrel and Downstream
Measure EM showers from inner detector
($\gamma$ from NC $\pi^0$, electrons,...)
  Sand muon rejection
Main role: complement the inner detectors in full event reconstruction through the detection of photons and measurement of their energy and direction.

Detection of charged particles and the extraction of information relevant for their identification (electron-muon-pion separation).

Reconstruction of $\pi^0$'s produced in neutrino interactions inside the tracker detectors (especially important for NC1 $\pi^0$ cross-sections).

In the case of $\pi^0$ production inside the POD, the POD-ECal complements the POD reconstruction with information on escaping energy.
ND280’s ECal

The ND280 ECal is a plastic scintillator/lead sampling electromagnetic calorimeter surrounding the inner detectors (PØD, TPCs, FGDs).

It consists of 13 independent modules:

**Downstream ECal**
34 layers, each 50 scintillator bars 2.04m long and 1.75mm lead sheet: $10.6X_0$

**6 Barrel modules**
31 layers, 3.84m or 1.52 m bars and 1.75mm lead sheet: $9.7X_0$

**6 P0D ECal modules**
6 layers, 2.34m bars and 4mm lead sheet: $3.6X_0$

Scintillator bars have a $4.0\text{cm} \times 1.0\text{cm}$ section with a $1.0\text{mm} \times 2.0\text{mm}$ elliptical hole running along their full length in the middle, to allow insertion of WLS fibers.
ND280’s MPPCs

Scintillators+WLS Fibers are read out by Multi-Pixel Photon Counters (MPPC)
array of Si diodes, just above breakdown V, developed by Hamamatsu for T2K

- Number of pixels: 667
- Active area: $1.3 \times 1.3 \text{ mm}^2$
- Pixel size: $50 \times 50 \text{ mm}^2$
- Operational voltage: $68 - 71 \text{ V}$
- Gain: $\sim 10^6$
- PDE at 525 nm: $26 - 30\%$

Output is sum of charges from pixel avalanches:

- Can isolate single photoelectrons
- Low operating voltage and power consumption
- Gain similar to conventional PMTs
- Insensitive to magnetic field

Innovative readout
Quality Assurance prior of installation: excellent results

Ageing/Stability
Tested MPPCs at elevated T (≈80°C) with no obvious ill-effects. First year of operation with MPPCs has been very positive; few-to-none have failed.

High dark noise rates: ≈0.3–0.5 MHz
Cross-talk/afterpulsing effects

All quantities depend strongly on temperature and over-voltage.

need to keep T stable within a few degrees

Large variation in breakdown voltage:
Bias voltage has to be adjusted individually for each channel

The ECAL is instrumented with more than 22300 MPPCs read out by 366 front-end boards
ND280's ECal

Fiber-MPPC optical coupling:
A ferrule is glued to the fiber end and secures inside an MPPC holder

Connection to front-end electronics with micro-coaxial cables
Each module is sealed shut and light-tight, services and communication with the electronics happens via a feed-through.

Front-end Boards

Low voltage and bias voltage bus bars
The Trip-T Frontend Board

4 Trip-T chips are mounted on a TFB

Up to 16 MPPC signals (high and low gain) digitized in one Trip-T chip

Charge integrated in 23 cycles 480ns long, 100ns reset time synchronized with the beam

Timestamping accuracy: 2.5ns
**ECal Performance**

Very successful data-taking so far

DSEcal: November 2009 - March 11\textsuperscript{th} 2011
Barrel and POD ECal: November 2010 - March 11\textsuperscript{th} 2011

46 dead channels (out of 22300)

Gain stability plot from fit of MPPC spectra for each channel (2011 data)

ECal stable for the full data-taking period until March 11\textsuperscript{th}
Did not contribute significantly to ND280 down time!
ECal Performance

- We are developing a Neural Network algorithm that calculates a Track-or-shower particle identification (PID) parameter.

- Independent analysis of signal purity and reconstruction systematics.

Tagged as a track by TPCs and ECal:
- FGD2 $\nu_\mu$ candidate
- FGD1 $\nu_e$ candidate

Tagged as an electron by TPCs and ECal:
ECal Performance

Cycle: 3.52[s] 6 bunch / pulse

Cycle: 3.20[s] → 3.04[s] 8 bunch / pulse

Daily DsECal cluster rates

Normalised DsECal cluster rate

χ² / ndf = 30.21 / 20
p0 = 1.885 ± 0.016
Conclusions

13 Modules of ND280’s ECal, instrumented with more than 22300 MPPCs, have been installed at J-PARC between 2009 and 2010.

Operations have been smooth, with collection of good quality data, that are being analysed, and no significant down time – until the March 11th earthquake.

We are now in the process of fully assessing the damage to proceed with repairs, if needed.