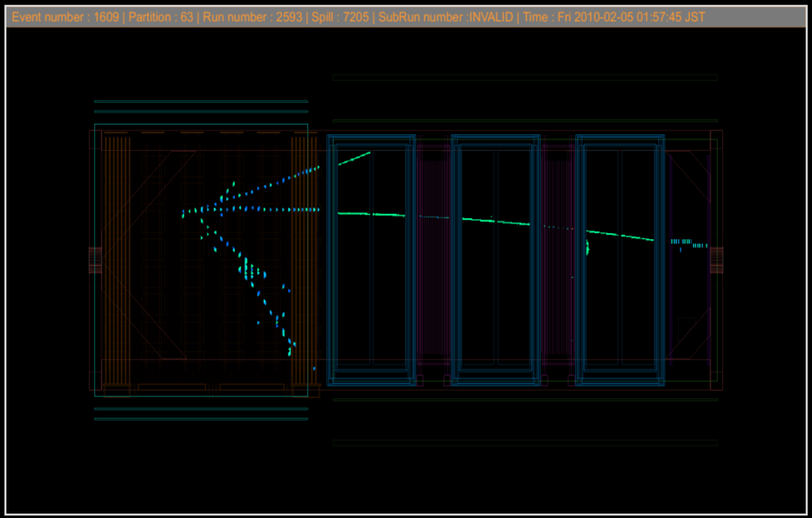
THE PIZERO DETECTOR AT T2K



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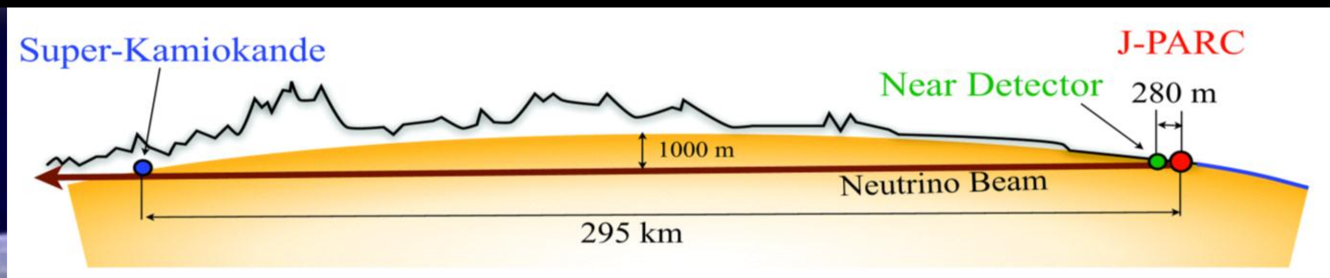
(On behalf of the T2K P0D Group)

June 9, 2010

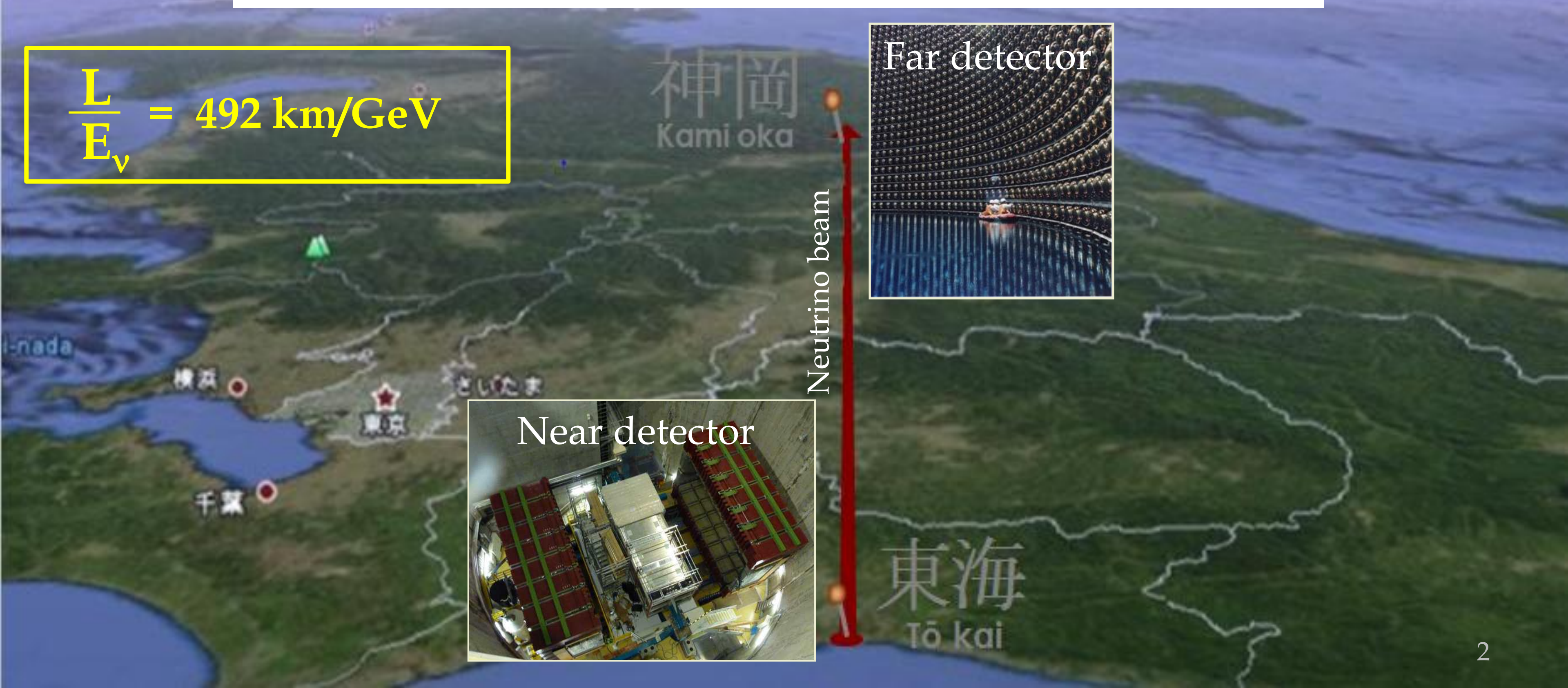
Technology and Instrumentation in Particle Physics

TIPP 2011

Tokai-to-Kamioka (T2K)



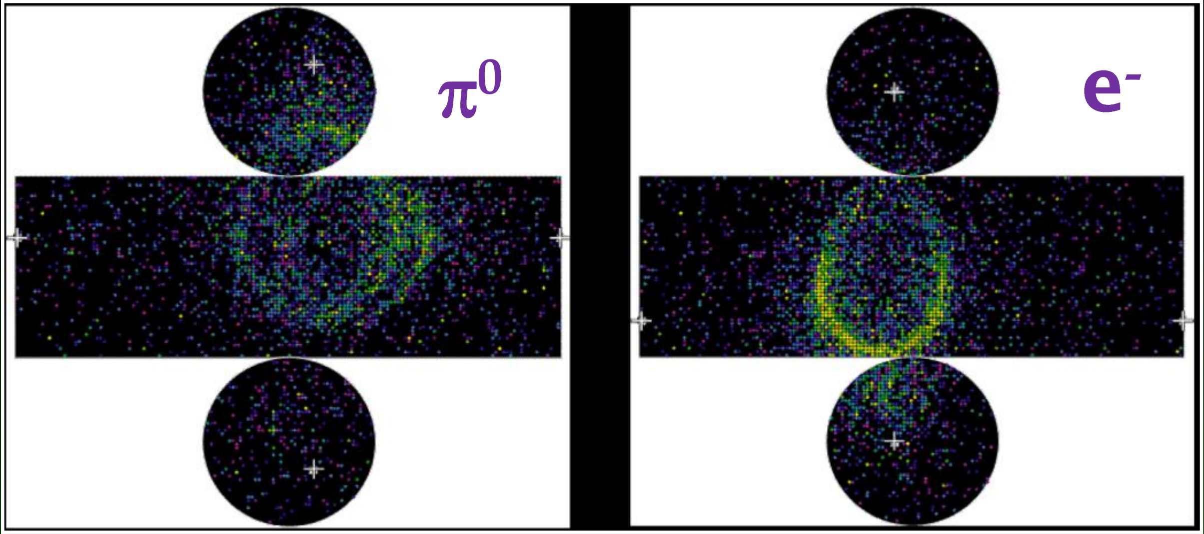
$$\frac{L}{E_\nu} = 492\ \text{km/GeV}$$



Background to ν_e Measurement

- Dominant physics background to ν_e signal is misidentified NC π^0
  - one gamma is missed and π^0 looks like electron from CCQE interaction
  - determine NC π^0 rate in near detector where rate is high and extrapolate to far detector
- Pi Zero Detector (P0D) in near detector optimized for π^0 rate measurement

$$\nu_\ell + N \longrightarrow \nu_\ell + N + \pi^0 \qquad\qquad \nu_e + n \longrightarrow e + p$$



Super Kamiokande Events

Off-Axis Near Detector

Magnet
UA1 magnet
Nominal B=0.2T

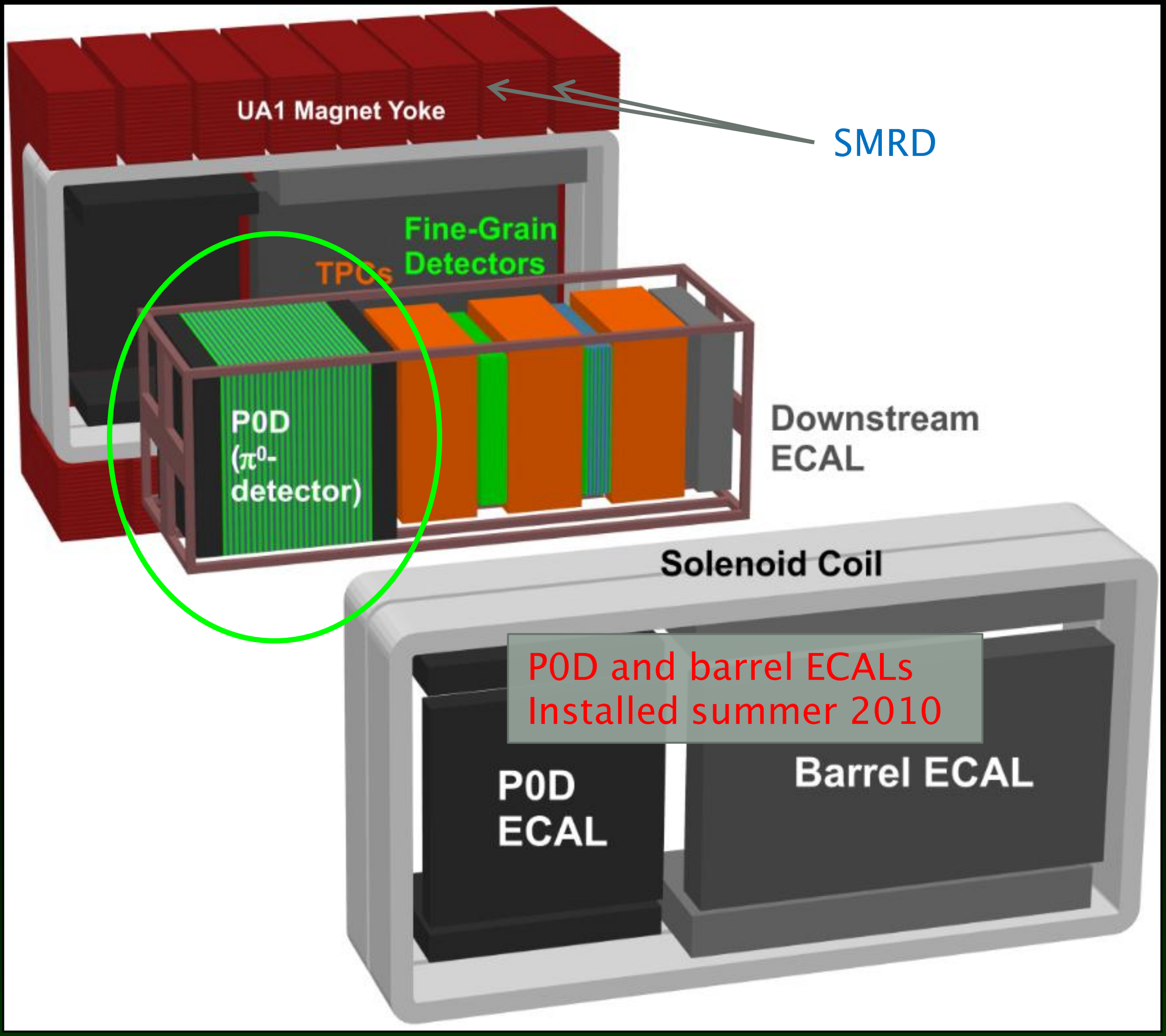
Side Muon Range Detector
Cosmic trigger and p_{μ} measurement

PiZero Detector
Optimized for π^0 rate measurement
Measure beam ν_e

TPCs
Detection of charged particles
Momentum resolution < 10% (@ 1 GeV/c)

Fine Grained Detectors
Target mass for tracker
Capable of detecting recoil protons

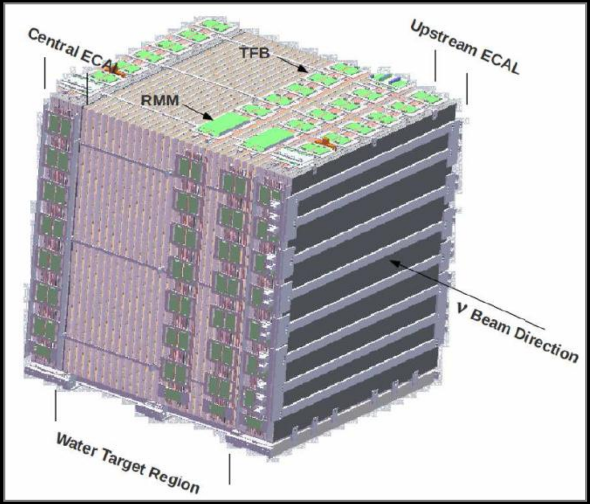
ECALs
Capture $\gamma/e/\mu$ escaping P0D and tracker
Scintillating layers and Pb absorber



See F. Retiere's talk for details of near detector Friday

The Pi Zero Detector

- Modular design
  - 40 active layers with Pb (ECAL) and Brass (WT) absorbers
  - 2 7-layer ECAL modules and 2 13-layer WT modules
  - Water target has 25 water target layers interleaved between active/absorber layers
  - Dimensions: W=2103 mm H=2239 mm L=2400 mm
  - Mass: Water in – 16.1 tons Water out – 13.3 tons
  - Components of P0D constructed at several institutions



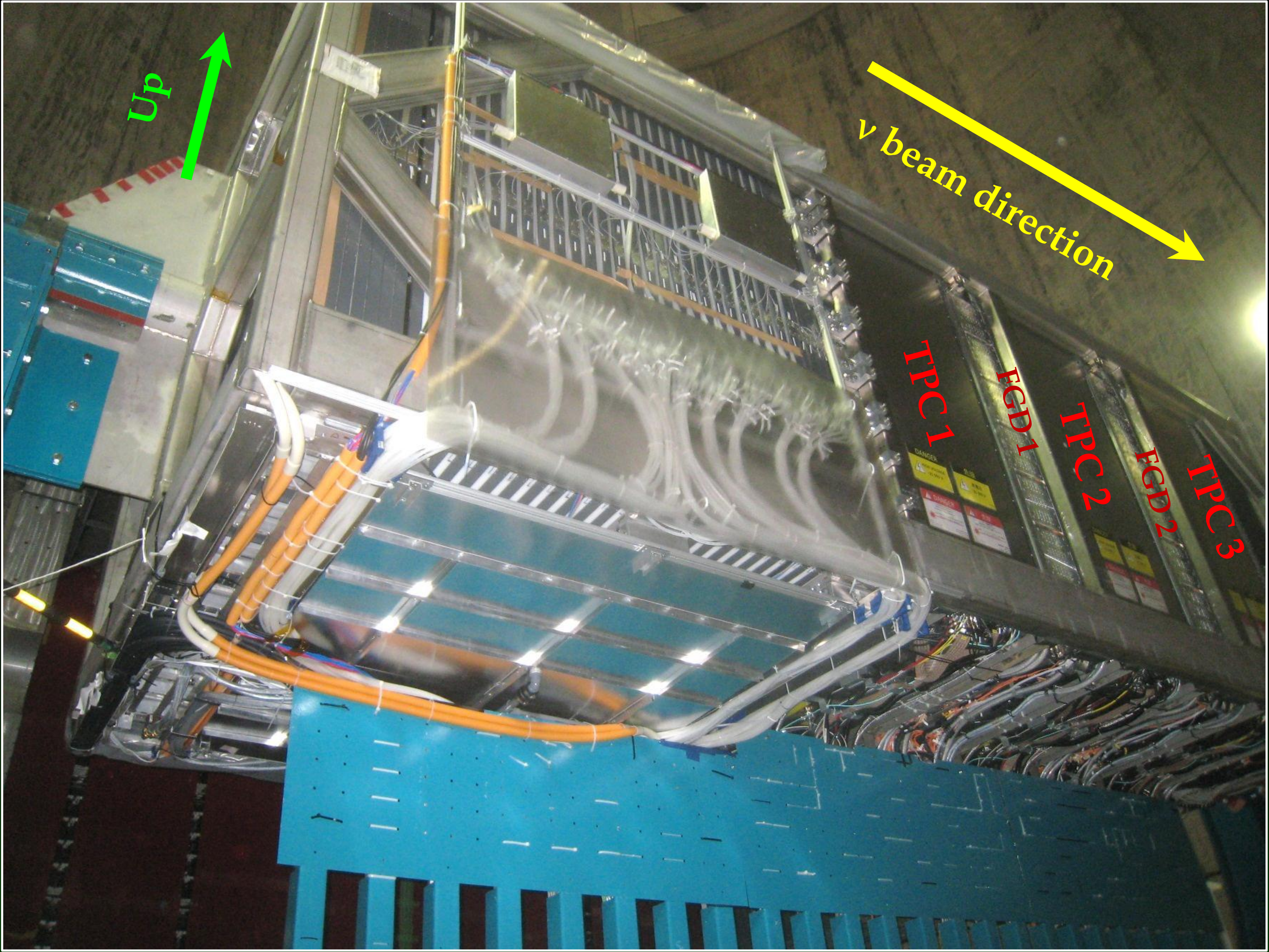
Central ECAL

Central WT

Upstream WT

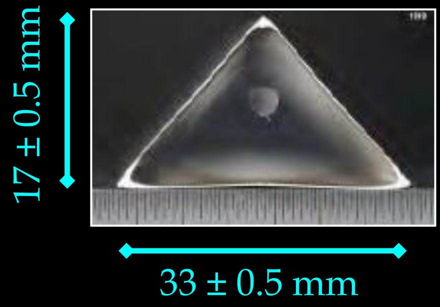
Upstream ECAL

P0D Installed in ND280



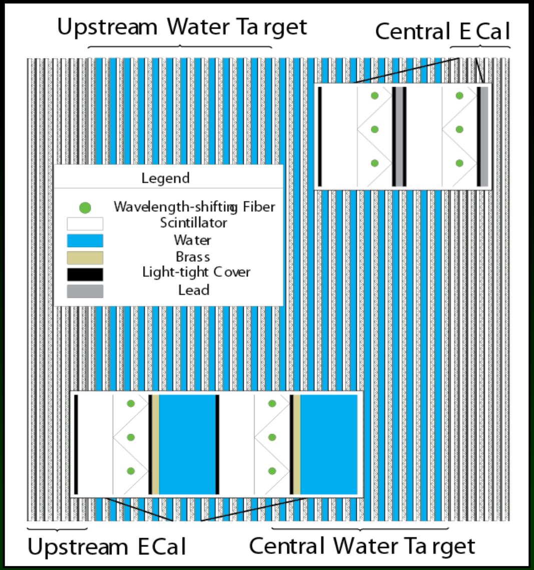
Detection Layers (P0Dules)

- Each P0Dule contains an X and a Y plane of triangular scintillating bars
  - 134 bars make up an X plane and 124 bars make up a Y plane
  - Bars extruded at FNAL extrusion facility: consist of 1%PPO and 0.03% POPOP in a styrene base (with a reflective TiO_2 outer layer)



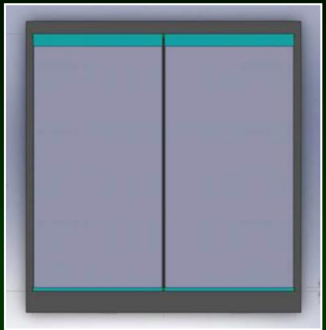
- An optical fiber installed in the center of each bar
  - Multi-clad WLS fiber (doped with Y11 at 175 ppm)
  - Fibers mirrored on one end and read out from the opposite end by Hamamatsu multi-pixel photon counters (MPPCs)

10,400 total active channels



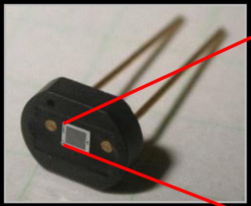
- Water bladders reside between WT P0Dules
  - Each water layer contains 2 bladders that can be filled and drained on demand using a pump array located near the detector
  - Level and depth sensors are used to provide monitoring of water bladders during fill/drain procedures and normal operation

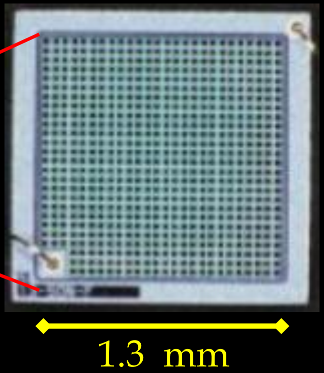
Schematic of 2 bladders in a water layer (x-y view)

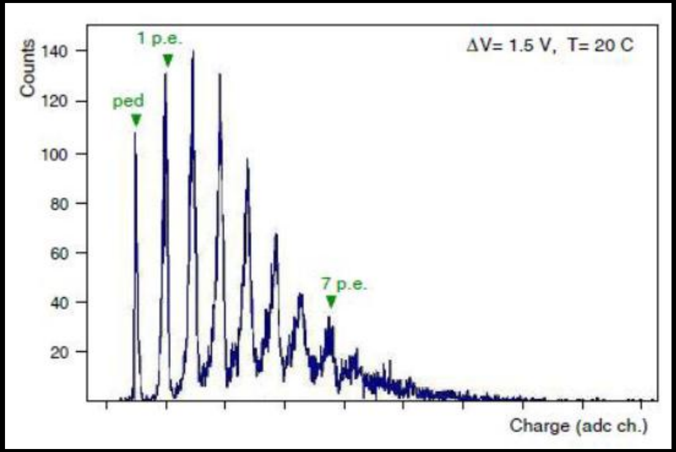


Detector Readout

- Multiple-pixel photon counters (MPPCs)
  - Each fiber is coupled to a 667 pixel Hamamatsu MPPC
  - # of pixels illuminated proportional to # photons





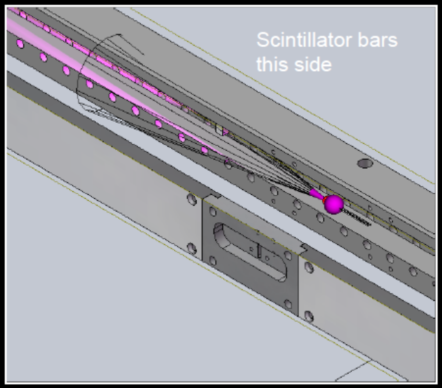


2 TFBs mounted on ECAL super-P0Dule

- Readout electronics
  - 32-channel Trip-t ASICs read out MPPCs (4 ASICs per trip-t front-end board (TFB)
  - Low gain and high (10x) gain channels cover dynamic range of 1 – 500 p.e. (~10 ADC/p.e. resolution for high gain channel)
  - Trip-t's integrate charge over 23 integration cycles sync'd to beam timing
  - Timing, control, and trigger signals are handled by separate boards servicing large # of channels

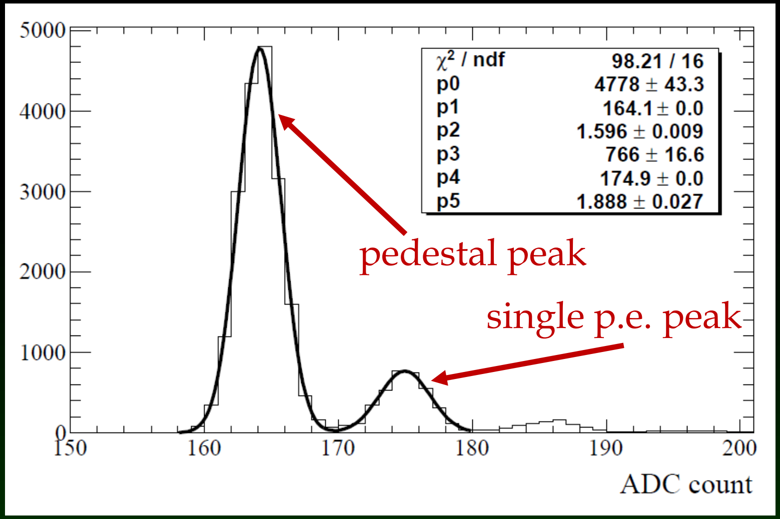
- Data Acquisition
  - Global ND280 DAQ utilizes MIDAS framework running on a farm of Linux nodes
  - Global slow controls system uses same MIDAS framework

Light Injection and Calibration

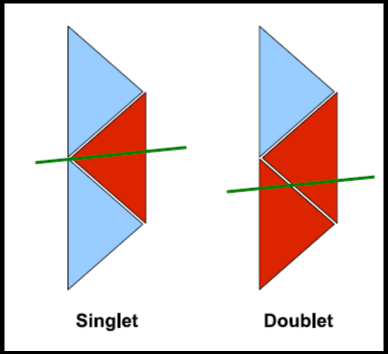


- UV LED-driven light injection system
  - Designed to monitor gross channel issues and temporal changes
  - Each X and Y layer contains two 400 nm LEDs (back to back)
  - LEDs aim along channel at opposite end to MPPCs
  - Covers dynamic range of 1 – 100s of photons
  - Amplitude and pulse length adjustable via current pulse variation

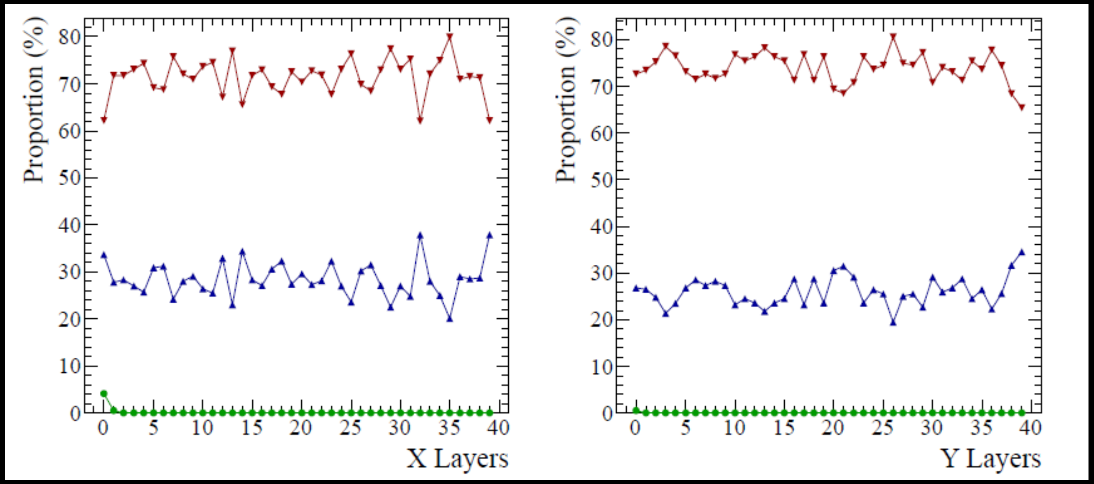
- Calibration
  - Dark noise spectrum used to determine pedestal and photo-electron unit in terms of ADC values
  - An internal TFB charge injection circuit is used to determine any non-linearity in the electronics
  - MIP light yield was determined for tracks passing through the individual super-P0Dules and then for the entire P0D once it was installed



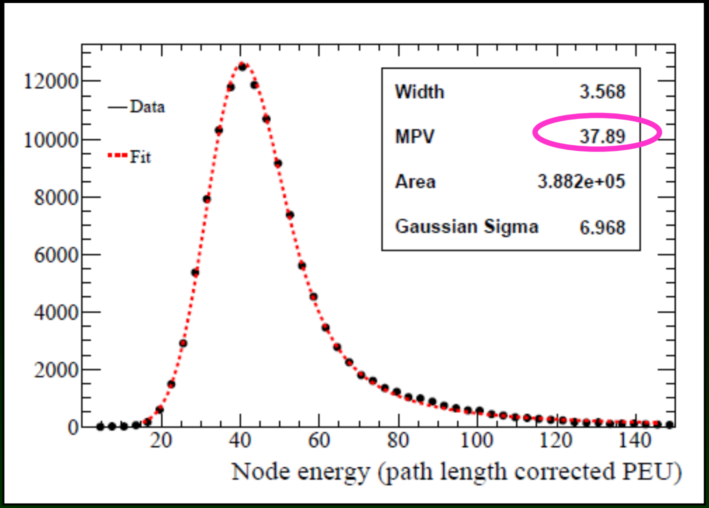
P0D Performance



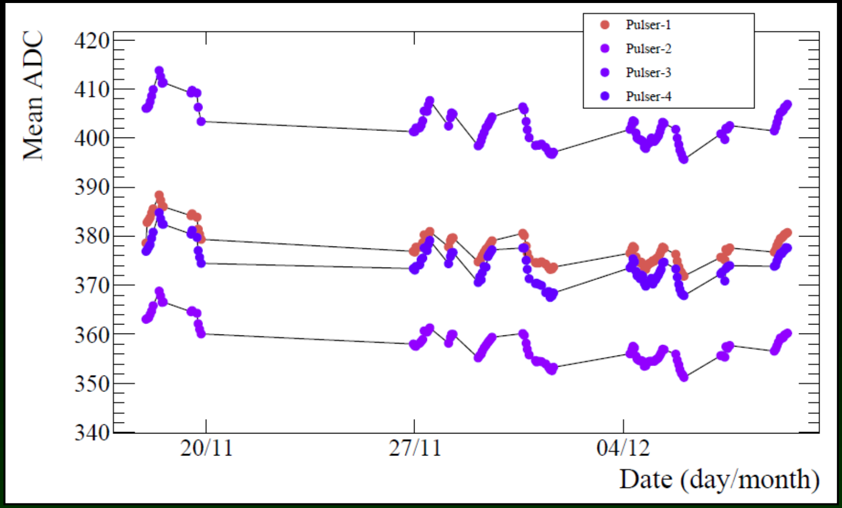
Possible MIP tracks through layer



Percentage of 2, 1, and 0 hit MIP tracks for each X and Y P0D layer

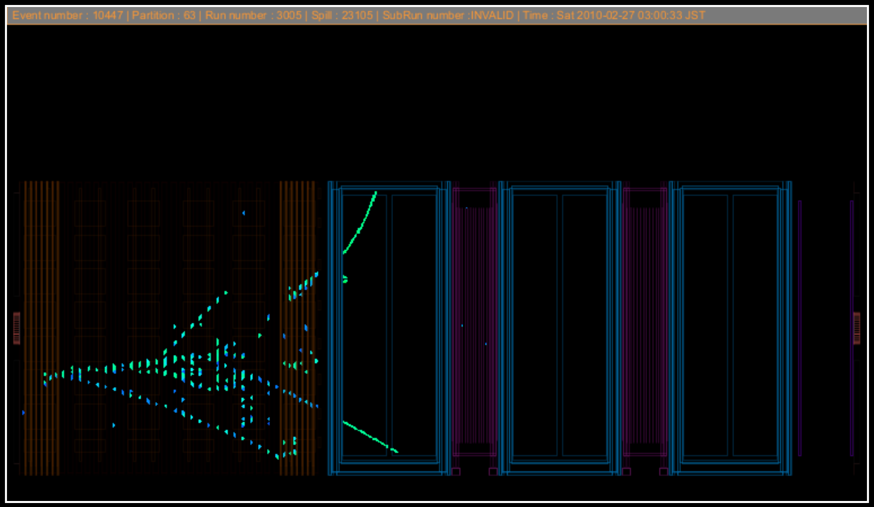


Calibrated and path-length corrected MIP charge deposits in PEU

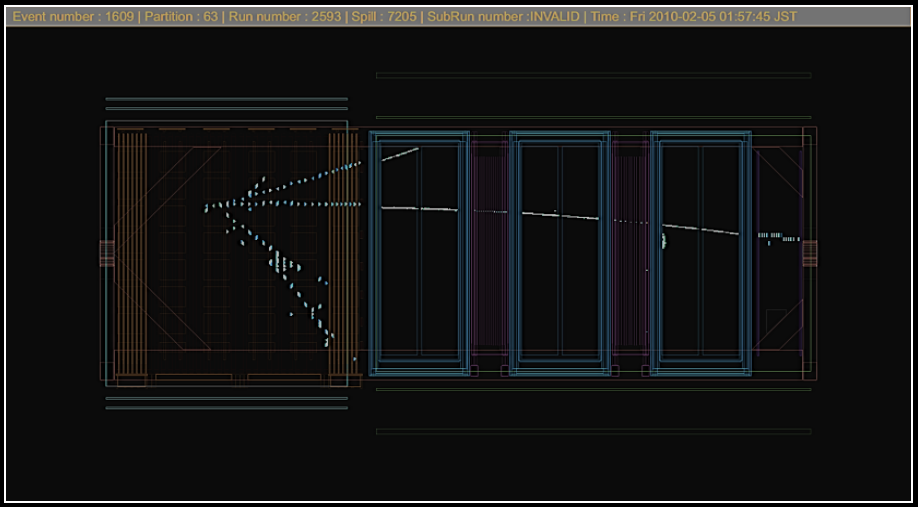


Light injection output over 3 week period (short term variations come from MPPC gain)

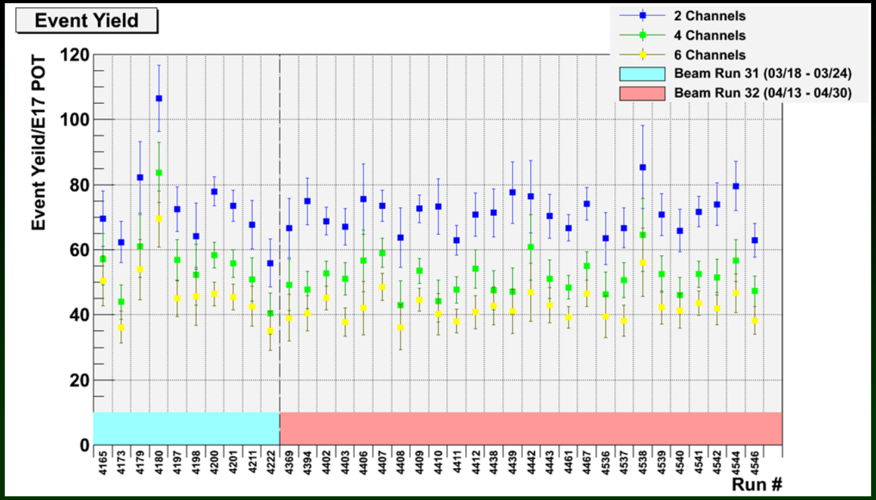
P0D Performance

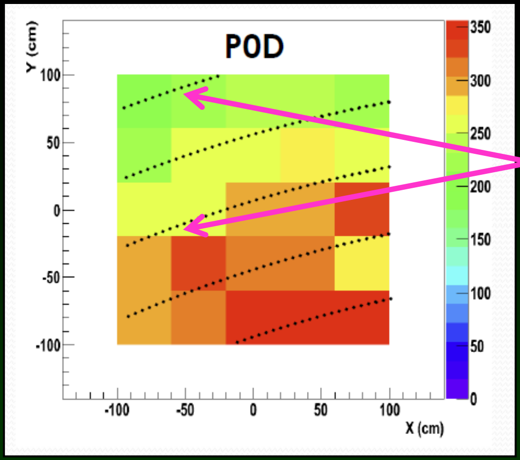


ν interaction originating in P0D ECAL



ν interaction originating in P0D water target





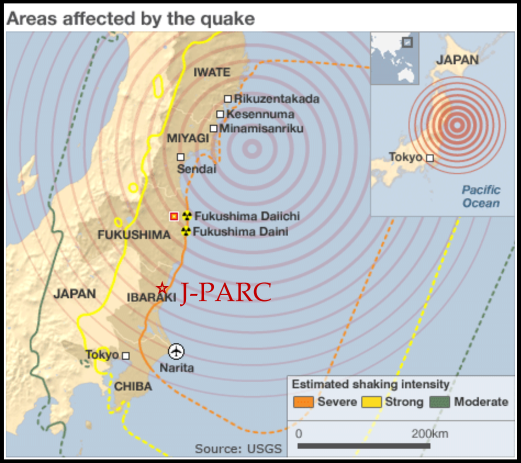
"Iso-contours" of θ_{OA}

(approximate)

Outer corner of P0D about 20% more off-axis than inner corner

Earthquake

On March 11th the largest (9.0 magnitude) earthquake in recorded history to strike Japan hit off the east coast of Honshu near Sendai.



- 25,000 people killed or missing
- >100,000 homeless
- Many towns and villages up the eastern coast destroyed
- Fukushima nuclear power plant severely damaged

J-PARC suffered moderate damage but was spared the wrath of the resulting tsunami

- Some road damage around site
- Near detector, including magnet, seem to be in excellent shape after the earthquake
- Visual inspection of P0D made with a remote camera on the end of a long flexible neck - OK
- Cooling system checked out and again operational
- No obvious damage to P0D electronics – no power to ground shorts observed
- Planning on full P0D power up in coming weeks

Summary

- PiZero Detector optimized to measure π^0 rate in ND280
- Installed in 2009 – taking data since Jan 2010
- Performance has been excellent
- No obvious signs of damage from March 11 earthquake
- Full power-up will happen soon

THANK YOU!

Supplementary Material

T2K Goals and Sensitivity

ν_μ disappearance

$$P(\nu_\mu \rightarrow \nu_\mu) \approx 1 - \sin^2(2\theta_{23})\sin^2(1.27\Delta m_{23}^2 L/E)$$

How close to 45° is θ_{23}? (measure to ~1%)

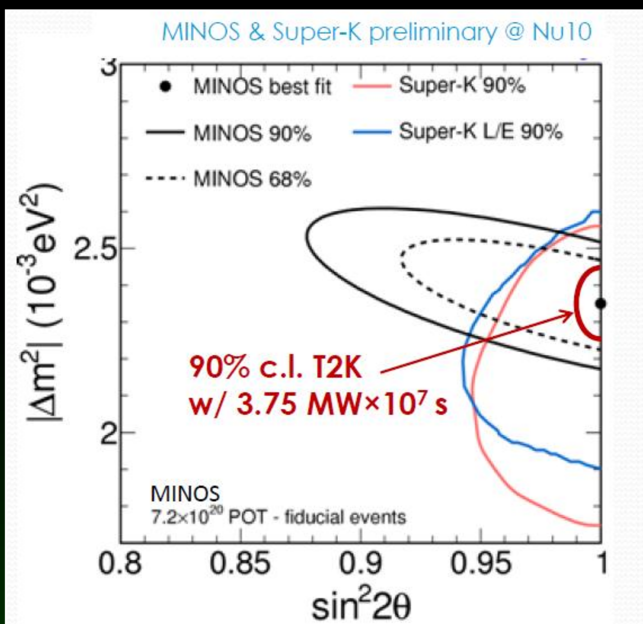
Measure Δm_{23}^2 to higher precision ($< 1\times10^{-4}$)

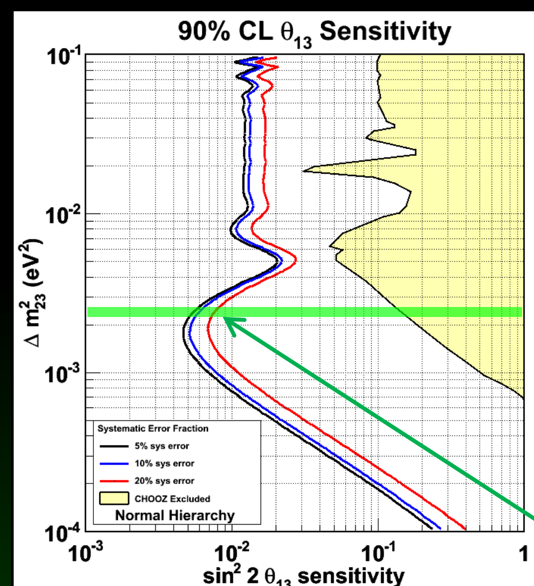
ν_e appearance

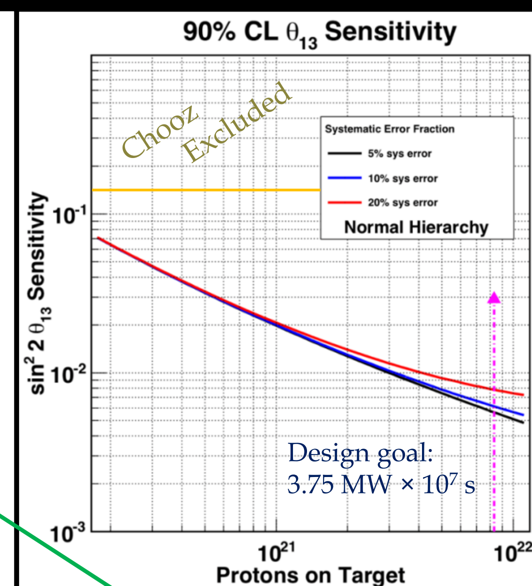
$$P(\nu_\mu \rightarrow \nu_e) \approx \sin^2(\theta_{23})\sin^2(2\theta_{13})\sin^2(1.27\Delta m_{13}^2 L/E)$$

Improve upper limit on θ_{13} by > order of magnitude

Determine if θ_{13} is large enough to measure δ_{CP}



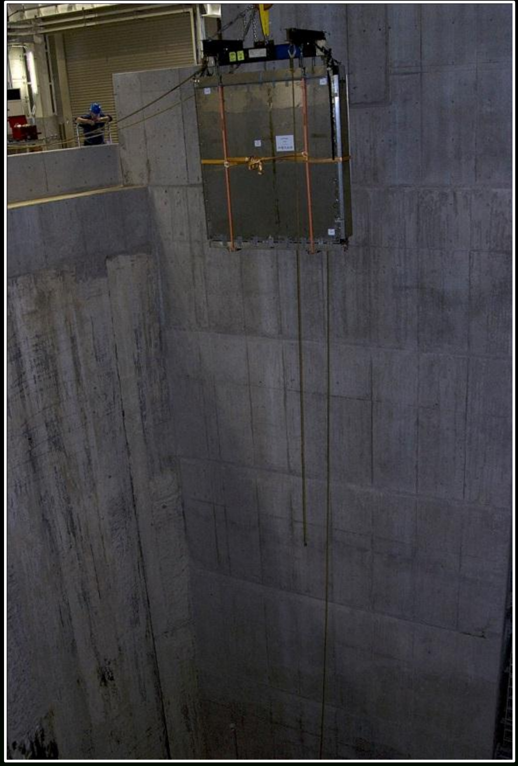


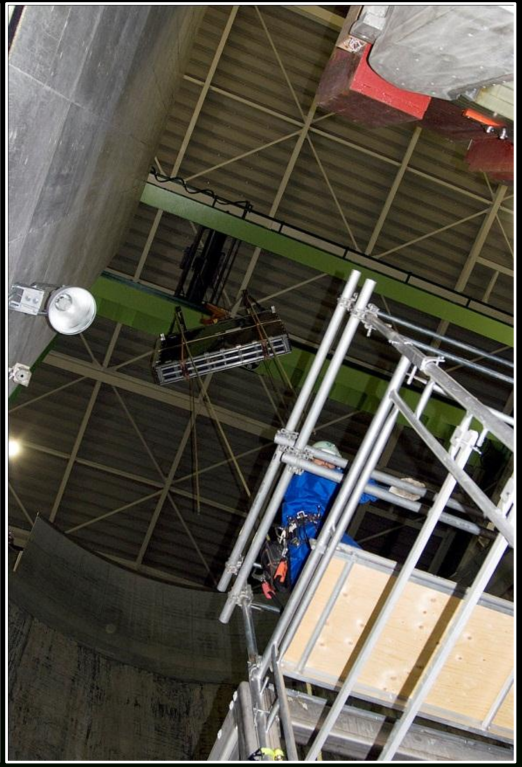


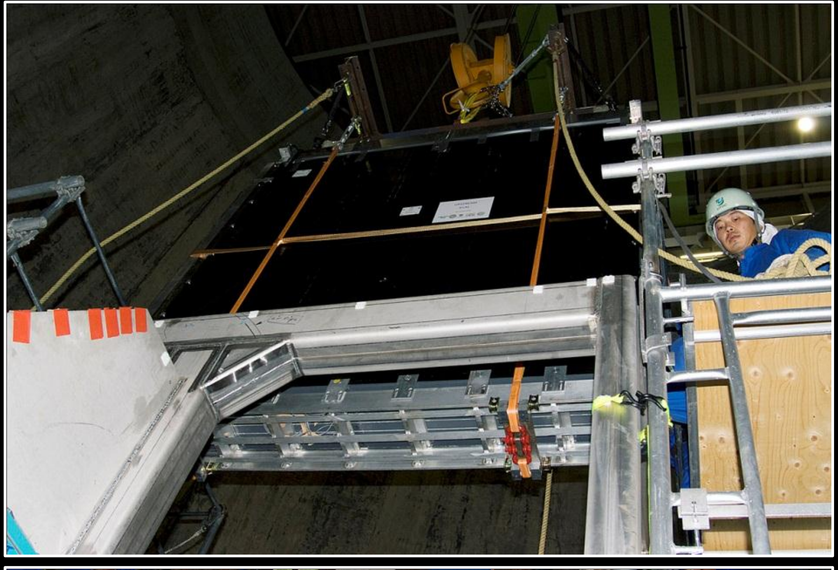
Sensitivity down to 0.006 ($\Delta m^2_{23} = 2.4 \times 10^{-3}\, eV^2$)

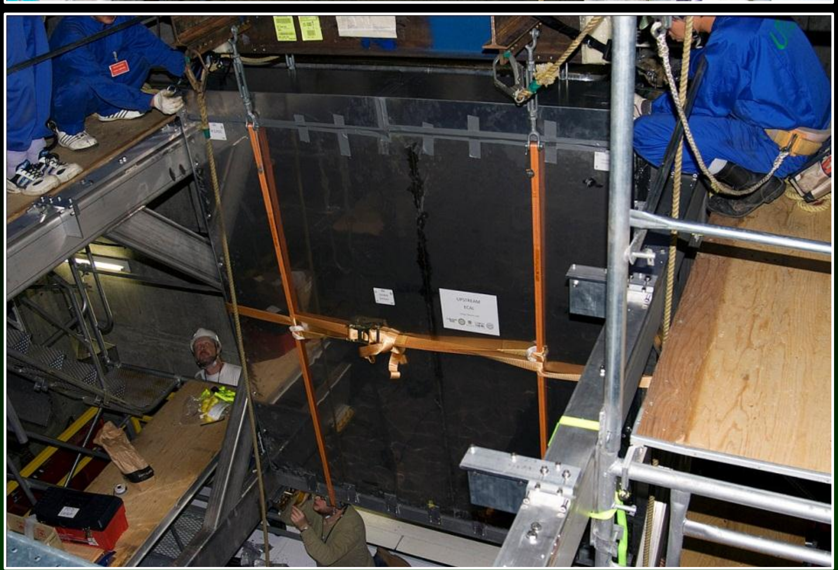
90% C.L.

P0D Installation



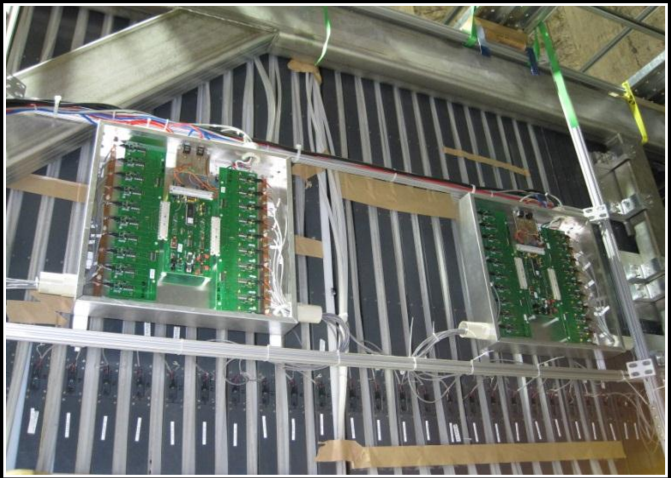






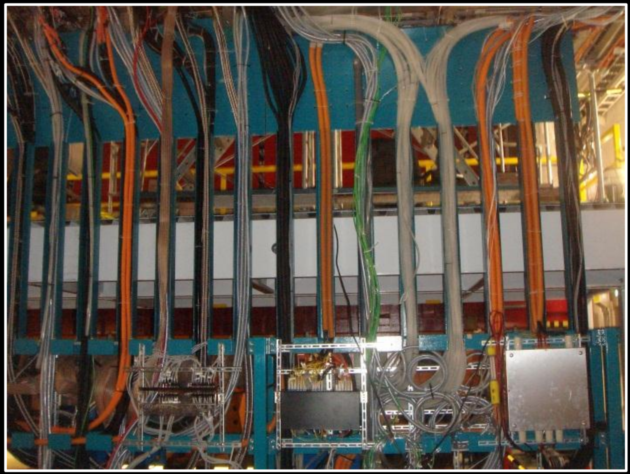
Lowering ECAL into basket

P0D Installation



Light injection system hardware installed

Bracing on downstream ECAL



Utilities Curtain

P0D readout and water system electronics

Power distribution

Mounting cover panels