THE PIZERO DETECTOR AT T2K

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$\frac{L}{E_\nu} = 492 \text{ km/GeV}$
Background to $\nu_e$ Measurement

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

$$\nu_e + N \rightarrow \nu_e + N + \pi^0 \quad \nu_e + n \rightarrow e + p$$

Super Kamiokande Events
**Off–Axis Near Detector**

**Magnet**
UA1 magnet
Nominal B=0.2T

**Side Muon Range Detector**
Cosmic trigger and $p_\mu$ measurement

**PiZero Detector**
Optimized for $\pi^0$ rate measurement
Measure beam $v_e$

**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: \( W=2103 \text{ mm} \quad \text{H}=2239 \text{ mm} \quad \text{L}=2400 \text{ mm} \)
  - Mass: Water in \(- 16.1 \text{ tons} \quad \text{Water out } - 13.3 \text{ tons} \)
  - Components of P0D constructed at several institutions
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 TiO₂ 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

- 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

![Graph showing ADC distribution with pedestal peak and single p.e. peak](image)
POD Performance

Possible MIP tracks through layer

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

- $\nu$ interaction originating in P0D ECAL
- $\nu$ interaction originating in P0D water target

"Iso-contours" of $\theta_{OA}$ (approximate)

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

On March 11\textsuperscript{th} 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 $\pi^0$ 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**

\( \nu_\mu \) disappearance

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

How close to 45° is \( \theta_{23} \)? (measure to \( \sim 1\% \))

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

\( \nu_e \) appearance

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

Improve upper limit on \( \theta_{13} \) by \( > \) order of magnitude

Determine if \( \theta_{13} \) is large enough to measure \( \delta_{\text{CP}} \)

**MINOS & Super-K preliminary @ Nu10**

**90% CL \( \theta_{13} \) Sensitivity**

- Design goal: 3.75 MW \( \times 10^7 \) s
- Sensitivity down to 0.006 (\( \Delta m_{23}^2 = 2.4 \times 10^{-3} \text{eV}^2 \))
POD 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