The Pizero Detector at T2K

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

\[ \nu_e + N \rightarrow \nu_e + N + \pi^0 \]

\[ \nu_e + n \rightarrow e + p \]
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
  - 27-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
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$_2$ coating)
- 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)
- Water bladders reside between WT P0Dules
  - Each water layer contains 2 bladders that can be filled and drained on demand using a remote controlled pump array
  - Level and depth sensors are used to provide monitoring of water bladders during fill/drain procedures and normal operation

10,400 total active channels

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

2 TFBs mounted on ECAL super-P0Dule
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 2 400 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
**POD Performance**

Possible MIP tracks through layer

Percentage of 1 and 2 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 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 $\pi^0$ 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**

**νμ disappearance**

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

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

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

**νe appearance**

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

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

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

**Sensitivity**

Sensitivity down to 0.006 (\( \Delta m_{23}^2 = 2.4 \times 10^{-3} \text{eV}^2 \))

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