Status Of The T2K Experiment

Ryan Terri (for the T2K Collaboration)

TAU08 Conference

BINP Novosibirsk, Russia
The T2K Collaboration

<table>
<thead>
<tr>
<th>Country</th>
<th>Institutions</th>
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<tbody>
<tr>
<td>N. U. Seoul</td>
<td>U. Sungkyunkwa</td>
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<tr>
<td>Spain</td>
<td>IFIC, Valencia, U. A. Barcelona</td>
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<tr>
<td>Switzerland</td>
<td>U. Bern, U. Geneva, ETH Zurich</td>
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<td>France</td>
<td>CEA Saclay, IPN Lyon, LLR E. Poly., LPNHE Paris</td>
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<tr>
<td>Japan</td>
<td>ICRR, ICRR Kamioka, ICRR RCCN, KEK, Kyoto U., U. Kobe, U. Miyagi, U. Osaka City, U. Tokyo</td>
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<tr>
<td>Russia</td>
<td>INR</td>
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<tr>
<td>Germany</td>
<td>U. Aachen</td>
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407 members, 65 Institutes, 12 countries
The T2K Experiment

• Long baseline neutrino experiment
• Measure/set limits on neutrino oscillation parameters
  – $\nu_\mu \rightarrow \nu_\tau$
    • $\nu_\mu$ disappearance
  – $\nu_\mu \rightarrow \nu_e$
    • $\nu_e$ appearance
• Precision measurement of atmospheric neutrino parameters: $\sin^22\theta_{23}$ and $\Delta m^2_{23}$
  – Is $\sin^22\theta_{23}$ maximal?
• First measurement of $\theta_{13}$
• Possibly look for CP-violation
2 Flavor $\nu$ Oscillation Probabilities

- Atmospheric osc. parameters measured using the $\nu_\mu$ survival probability

\[
P_{\nu_\mu \rightarrow \nu_\mu} \approx 1 - \sin^2(2\theta_{23})\sin^2 \left( 1.27 \frac{\Delta m_{23}^2 L}{E} \right)
\]

- $\theta_{13}$ search involves $\nu_e$ appearance from $\nu_\mu$ oscillations
  - CP violating terms in 3 flavor osc. probs.

\[
P_{\nu_\mu \rightarrow \nu_e} \approx \sin^2(\theta_{23})\sin^2(2\theta_{13})\sin^2 \left( 1.27 \frac{\Delta m_{31}^2 L}{E} \right)
\]

\[\Delta m_{ij}^2 = m_i^2 - m_j^2\]
Main Measurements: $\nu_{\mu}$ disappearance

- **Phase 1:**
  - 5 years w/ a 0.75 MW beam
  - $5 \times 10^{21}$ POT
  - Measurement of mixing angles, $\Delta m_{23}^2$

- Use CC quasi elastic events as signal
  - Can calculate parent neutrino energy
  - Background from non-quasi elastic events

\[
E_{v}^{\text{rec}} = \frac{m_N E_\mu - \frac{1}{2} m_\mu^2}{m_N - E_\mu + p_\mu \cos \theta_\mu}
\]
Main measurement: $\nu_e$ appearance

- Search for an excess of events over expected background

- Background sources:
  - Intrinsic $\nu_e$ in beam
  - Mis-identified NC $\pi^0$ events
  - Mis-identified muons in far detector

\[ \sin^2 2\theta_{13} \sim 0.008 \ (\delta_{CP} = 0, \pi) \]
Facility at J-Parc

- J-PARC January 2008
- The ND280 Pit
- Neutrino Beamline
- Stage 1: 0.75 MW
- 181 MeV Linac
- 3 GeV RCS
- 50 GeV Proton Synchrotron
- RCS
- TAU08
Neutrino Beam Line & Beam Spectrum

Off axis beam technique:
Creates narrow band beam not pointed directly at far detector

Graphite Target in Ti-alloy capsule
Successfully installed 29-Aug-2008

Beam predictions to be tested:
• Near detectors: νs
• NA 61: Hadrons

110 m Decay Volume
J-PARC Milestones and Timeline

• The Accelerator Group at J-PARC is doing an excellent job getting beam line built in time

• Linac: **Fully Commissioned**
  • 181 MeV (day 1 beam energy) achieved Jan 2007
  • Good beam stability

• 3GeV Synchrotron (RCS): **Fully Commissioned**
  • 3 GeV acceleration and extraction Oct 2007
  • $4.4 \times 10^{12}$ particles per bunch, 25 Hz @100 kW

• Main Ring Synchrotron
  • Beam captured and circulated from RCS in May 2008
  • Acceleration to 30 GeV after the summer
  • Extraction to neutrino beamline in Apr 2009
Far Detector: Super-Kamiokande

50 kton $H_2O$ Cherenkov Detector

SK-I:
March 1996 – July 2001

SK-II:

SK-III:
Recovered from accident

SK-IV: Sept. 2008 -
Upgrade of electronics and DAQ for T2K and SK-IV; testing currently underway
T2K Near Detector Suite

- Understand the neutrino beam before oscillations occur
- On – Axis Detector
  - Monitor beam direction
  - Monitor beam intensity
- Off – Axis Detector
  - Beam flux
  - Beam $\nu_e$ contamination
  - Cross sections
On Axis – The INGRID Detector

• Modular Detector
  – 16 Modules

• Each Module
  – 10 Scintillator Bar Layers, 9 Fe Layers
  – Surrounding Veto Planes
  – Wavelength Shifting Fiber → Hamamatsu MPPCs

• Construction and installation begins this month

INGRID Module Construction
Multi-Pixel Photon Counters: MPPCs

- Used in all scintillator detectors
  - Need ~50,000
- Array of silicon photodiodes operating just above avalanche breakdown voltage
- Similar to PMTs, but cheaper, smaller, and insensitive to magnetic fields

Characterization
- Dark noise ~ 0.5MHz
- Cross-talk/after-pulsing
- Recovery effects
- ~70 V operation voltage
- Strong temperature and over-voltage dependence

Simulation
- Developing simulation for all characteristics
- Incorporated into ND280 electronics simulation

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The Off-Axis Detector

- UA1 Magnet 0.2T field
- Includes a water target in P0D and Tracker
  - Understand interactions at SK
- Tracker Region
  - Fine Grained Detectors (FGDs) & TPCs
  - Particle Tracking
- P0D
  - Measure NC $\pi^0$ rate
- ECAL
  - Surrounds tracker and P0D
  - Capture EM energy
- SMRD
  - Muon ranging instrumentation in the magnet yoke
ND280 Magnet and Basket

Installation of the coils

The Magnet at JPARC

The Magnet Moving System in the Pit

Delivery of the basket for testing
Constructing the ND280: Tracking region TPCs and FGDs

• Measure CCQE events ($\nu_e$ & $\nu_\mu$ flux, E-spectrum)
• Measure $\nu$ cross-sections and kinematics
• Measure nuclear recoil
• PID

Currently in test beam at TRIUMF
Constructing the ND280: P0D, ECal, SMRD

P0D or $\pi^0$ Detector
- Measure $\nu_e$-appearance backgrounds, especially $\pi^0$ production rates, kinematics
- Water-in vs. water-out subtraction for cross-sections

ECal
- Surrounds P0D and trackers to capture EM energy
- $\pi^0$ reconstruction and PID

SMRD
- Muon-ranging instrumentation in magnet yoke
Some Predicted Performances of the Off-Axis Detector

TPC & FGD

Protons

Pions

P0D NC $\pi^0$ Reconstruction $\varepsilon$

Water

No Water

TPC

$\Delta p/p$

ECAL Energy Resolution

Electrons

Photons

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ND280 event

- As ND280 is being virtually integrated
- Software team is working on matching sub-detector information at boundaries
- A “Physics Book” is being created for upcoming analyses

Reconstructed tracks overlay the MC “truth” tracks
The T2K Timeline

- 2000: Ideas for T2K first discussed
- Jan 2007 – Dec 2008: JPARC accelerator commissioning
- Apr-Jun 2008: Installation of the magnet in the Pit
- Jun 2008: T2K funding fully approved in all contributing countries
- Sep 2008 – Mar 2009: Construction and installation of the INGRID Detector
- Sep 2008: FGD, TPC beam tests at TRIUMF
- Apr 2009: First T2K neutrinos
- May 2009: ECAL test beam at CERN
- Summer, Fall 2009: Installation of ND280 off axis Detector
- Winter 2009: Start of full T2K running
- 2010: First T2K Results!
Conclusions

- T2K is on target to start collecting neutrinos next April
  - J-PARC facility on schedule
  - Super-Kamiokande upgrade complete
  - Construction of ND280 detectors on schedule

- T2K will address open questions in the neutrino sector
  - How small is $\theta_{13}$?
    - Can we search for CP violation?
  - How close is $\theta_{23}$ to maximal?

- Presenting first results in 2010
Back Ups
Other $\theta_{13}$ Experiment Sensitivities vs. T2K

- **Double CHOOZ**
  - Sensitivity for $\theta_{13}$ is at $\sin^2 2\theta_{13} < 0.02$ (@ 90% C.L.)
  - hep-ex 0704.0498

- **Daya Bay**
  - Sensitivity for $\theta_{13}$ is at $\sin^2 2\theta_{13} < \sim 0.01$ (@ 90% C.L.) for 3 years running
  - hep-ex 0701029

- **Note:** T2K is competitive with Daya Bay in $\theta_{13}$ sensitivity

From slide 6:

- Search for $\nu_e$ appearance

- $\sin^2 2\theta_{13} \sim 0.008$ ($\delta_{CP} = 0, \pi$)
Possible Tau Appearance Search

- Small flux of neutrinos with $E_\nu > m_\tau$
- Tau appearance search would probably need similar selection to SK analysis (PRL 97 171801 (2008)) for beam events:
  - Inside SK’s 22.5 kton fiducial volume
  - Visible $E > 1.33$ GeV
  - Most energetic ring electron-like
- Initially, use counting experiment

From slide 8:

![Neutrino Flux at SK](image)

$\nu_\mu, \bar{\nu}_\mu, \nu_e, \bar{\nu}_e$