Status of the T2K Experiment

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for the T2K collaboration

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The T2K Project

- Long baseline (L=295km) $\nu_\mu$ experiment
- Intense proton source (JPARC)
- SuperK as far detector
Off-axis beam: 2.5 degrees

Near (on and off-axis) and far detector (SuperK)
Use Charged Current Quasi Elastic (CCQE) interactions to precisely measure $E_\nu$ through kinematics ($E_l$, $q_l$):

$$\nu_l + n \rightarrow p + l^-$$

(1) Pin down $\theta_{13}$ through $\nu_\mu \rightarrow \nu_e$ appearance
   Backgrounds: $\nu_e$ beam contamination, NC- $1\pi^0$

(2) Advance $\Delta m^2_{23}$, $\theta_{23}$ (esp. pin down whether $\theta_{23}$ is maximal) through $\nu_\mu \rightarrow \nu_\mu$ disappearance
   Backgrounds: single pion production
Off-Axis Beam

- Provides (quasi) mono-energetic beam tuned to first oscillation maximum
- Increases flux at maximum
- Drastically cuts high energy tail responsible for inelastic interactions that are background to the CCQE events
- T2K beam composition: 95% $\nu_\mu$, 4% anti-$\nu_\mu$, <1% $\nu_e$
- Sensitivity on $\sin^2 2\theta_{13}$ down to $\sim 6 \times 10^{-3}$ given:
  - 5 years running at 0.75MW
  - $\Delta m^2_{23} = 2.4 \times 10^{-3}$ eV$^2$
  - 10% systematic error ($\nu_e$ and $\pi^0$ background)

- Assuming $\sin^2 2\theta_{13} = 0.1$:

  # of events in $0.35\sim0.85$ [GeV]
  - Signal $\nu_e$ BG $\ldots$ 143
  - Beam $\nu_e$ BG $\ldots$ 16
  - BG from $\nu_\mu$ $\ldots$ 10

\begin{align*}
\sin^2 2\theta_{12} &= 0.8704 \\
\sin^2 2\theta_{23} &= 1.0 \\
\Delta m^2_{12} &= 7.6 \times 10^{-5} \text{ eV}^2 \\
\delta_{CP} &= 0.
\end{align*}
T2K collaboration

- 477 members, 62 Institutes, 12 countries
April/May’09 saw successful commissioning of complete primary beam line + first horn

(for more details see talk by Takashi Kobayashi tomorrow)
Far Detector SuperK

- 50kT pure H₂O Cherenkov detector
- Excellent E-resolution and e/µ discrimination at low energy
- Synchronised to T2K beam via GPS
- Expect 10 νµ events/day at full power
- SK IV: New dead-timeless FE electronics and DAQ installed 2008 => improved decay electron tagging
- Lots of work carried out to improve recon. software performance and simulation detail
Near Detector at 280m

On-axis neutrino monitor: INGRID

Off-axis detector: ND280

Must measure all significant neutrino interactions to predict response at SuperK
Beam Monitoring: INGRID

- P-beam monitors in beamline, optical transition radiation monitor at target, muon monitors in the beam dump
- Direction of horn-focused $\nu$-beam monitored by INGRID
  - 16 modules
  - 11 layers scintillator interleaved with Fe
  - Sufficient statistics for a daily measurement
- Off-axis angle must be monitored to $<1$ mrad (i.e. 2% shift in the $\nu$ peak energy)
- Complete INGRID system was installed this Summer
Installed complete in July and commissioned in August
Reached field of 0.07T and full field 0.2T should be attained after power upgrade- ready for neutrino running
Preliminary I vs B curve agrees with the UA1 measurements to ~3%!
B-field has been precisely mapped throughout the volume on a 5cmx5cm to 1cm x 1cm grid
Photosensors: MPPC

- All detectors (except TPC's) use WLS fibres coupled to MPPC's as photo sensors
- Pixel counters in Geiger mode
- Developed jointly with Hamamatsu - largest scale implementation to date (x70K) with < 0.5% QA rejection rate
- Small, cheap and operate in B-fields
- Superb single p.e. discrimination
- Gain: $0.7 \times 10^6$ at room temp
- Dark rate: typically $< 1$ MHz at room temp
- PDE = QE x $\varepsilon$(Geiger) x $\varepsilon$(size)~25% (green)
FGD's target mass of tracker (1.3 T per module):
- alternating x-y scintillator bars (1cmx 1cm) fine enough to measure recoil protons
- 2nd module contains scintillator and water (for cross section measurements at SuperK)

Tracker Optimised to measure momenta and to provide PID of charged particles especially muons and pions

TPC high resolution tracking
- charge/momentum measurement: $\sigma_p/p \sim 10\%$
- $5\sigma$ e/$\mu$ discrimination
Status: Fine-grained Detectors

- Both modules have travelled well: commissioned on surface with cosmics and less than 0.1% dead channels
- Installation of both modules was completed this week
- Currently integrating readout with T2K DAQ

~25 p.e per m.i.p. (low tail due to clipping)
Status: Time Projection Chambers

- First large-scale implementation of bulk micromegas (32 modules, 124K channels)
- TPC0 and TPC1 extensively tested with cosmic and particle-beam running at TRIUMF
- Uniform/low-noise channel performance confirmed in Tokai recently

- TPC0 and TPC1 are ready for installation this week
- Majority of cabling, gas systems and laser calibration complete
POD detector

- 40 x-y brass+scintillator tracking planes interspersed with water volumes (Carbon:Oxyg. 1.8ton:0.9ton)
- 5.7 $X_0$ upstream/downstream $\gamma$-stops
- WLS fibre readout
- All 4 POD modules now installed, utilities installation and commissioning is underway
- Surrounded by a coarse Pb/scintillator calorimeter (PODECAL) (5 $X_0$ thick) to collect escaping $\gamma$/mip's

ND280: $\pi^0$ Measurement
ND280: ECAL+SMRD

- Detectors surround entire inner region to catch high angle $e, \mu, \gamma$
  - boost CCQE efficiency and $E_\nu$ resolution
  - veto for cosmic, magnet or cavern wall interactions

### ECAL
- Scint.+Pb sampling calorimeter (Tracker+POD)
- Downstream module installed this week
- 5/12 modules installed by Dec.’09-Jan’10

### SMRD
- Scint. planes in UA1 calorimeter gaps in yolk
- All installed, commissioning underway
Cross-Section Measurements

- Cross section measurements in ND280 needed to measure backgrounds at SuperK i.e.
  
  - NC-1π, CC-1π for $\nu_\mu$ disappearance
  
  - NC-1π$^0$ for $\nu_e$ appearance

- To achieve design precision on $\theta_{23}, \Delta m_{23}$ demands: non-QE/QE ratio known to < 10%

  e.g. From 5 years running (5x10$^{21}$ POT) expect following numbers of NC-1π$^0$ events in POD:
  
  C/Pb/brass=20k, water=8k ( $\varepsilon(\pi^0)$=55%, purity=60% )

- ND280 will provide the most extensive measurements of sub-GeV neutrino cross-sections on oxygen to date
**T2K: Schedule**

**Beamline**
- Beam commissioning to recommence from mid October:
  - Full horn system in place
  - Increased intensity (with up to 6 bunches)
- Plan is for physics running to start from December collecting $100\text{kW} \times 10^7\text{s} \, (2 \times 10^{20} \text{ POT})$ in the first year
- Subsequent power increases will come from increasing the rep. rate at $E=30\text{GeV}$ and LINAC energy upgrade from $181\text{MeV}$ to $400\text{MeV}$

**ND280**
- FGD1 + FGD2, DSECAL were installed this week
- TPC0+TPC1 to be installed in next days
- What remains: TPC2 installed December/Jan.'10, remainder of ECAL in place by Summer 2010

*View down ND280 pit yesterday*
T2K experiment close to being ready for first physics
- All beamline elements installed and are currently being commissioned
- SuperK improved and ready to run
- Almost all ND280 components are ready and currently being installed/commissioned
- First neutrino data beginning in 2010 aiming for 100kWx10^7 sec in first year:
  - expect 1-sigma sensitivities:
    \[ \delta (\sin^2 2\theta_{23}) = 0.03, \quad \delta (\Delta m^2_{23}) = 1.6 \times 10^{-4} \] (statistics limited)
  - begin extending the Chooz \( \theta_{13} \) limit
Extra slides
T2K Discovery Potential on $\nu_\mu \rightarrow \nu_e$ as a Function of Integrated Power

- Excluded by CHOOZ
- Line: 3$\sigma$ Discovery
- Dot: 90% C.L. Upper Bound

- 2009?: MINOS
- 2010?: D.CHOOZ (disappearance)
- 2013?: OPERA
- 2012?: NOvA
- 2012?: D.CHOOZ (disappearance)
- 2012?: Daya Bay (disappearance)

Integrated Power ($10^7$MW·sec: ~1MW×Effective 1 Year Experimental Period)

T2K
Full Proposal