ND280

The T2K near detector

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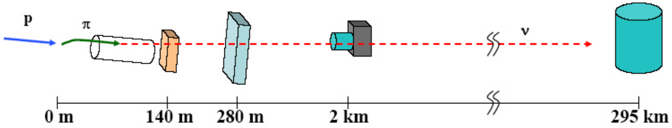
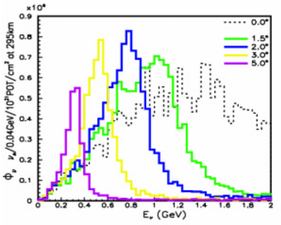
Tokai to Kamioka (T2K)



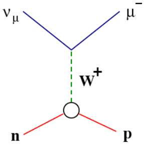


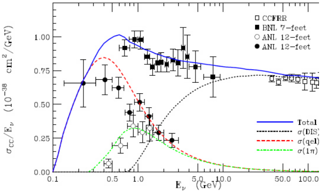
Long baseline oscillation exp.
Super beam (0.7 MW)
Off-axis (2-3 deg.)
$< E_\nu > \sim 0.7$ GeV

An appearence measurement requires:

- a good knowledge of the beam (simul + NA61 + near detector)
- a good control of the backgrounds (NC+π^0) and absolute cross-sections
- a good energy measurement

Charged Current (quasi) elastic:





(Phys. Rev. Lett. **74**, 4384 (1995))

Hence the vital necessity for a near detector: 280m

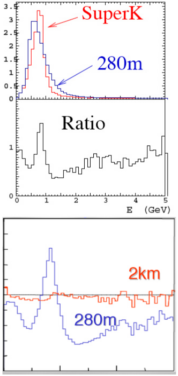
(T2K: beam=JPARC (JAEA), SK exists, 2km det. staged. → 280m)

The ND280 near detector

- measure the ν_μ spectrum before oscillating and predict the spectrum at SuperK, to measure the disappearence
- measure the background to the appearence of ν_e
- measure the beam composition (ν_μ, ν_e, $\overline{\nu_\mu}$, $\overline{\nu_e}$)

Complications:

- viewed from SK, the decay volume is a point source but not from ND280m
- SuperK is a water Č; ND280m target is mainly scintillator



The ND280 near detector physics goals

Neutrino spectrum

- energy is obtained from the CC-QE reaction (ν_μ and ν_e)
- all fluxes will be normalized to the CC-QE cross section
- measuring the high energy tail of the spectrum is also useful to understand the ν_e background (produced in Ke3 decays) (neutrino energy range from 200 MeV to > 5 GeV)
- the energy scale is required to be known to better than 2%
- the backgrounds and their energy dependance have to be understood at the near detector since this is also affecting the SK flux prediction

Backgrounds

Background prediction at SK for the ν_μ disappearence

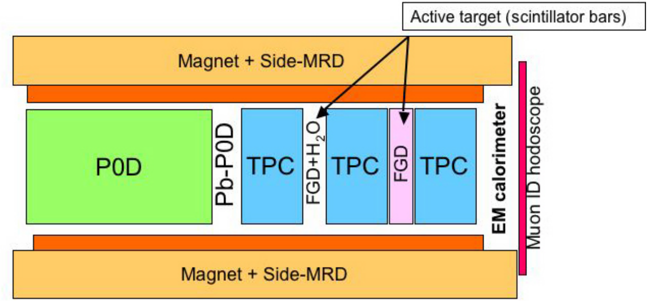
- CC-1π is the main background
- NC-Nπ where the pion appears as a single ring in SK, is an additional bckd

(both effects also depend on the nuclear reinteraction that could absorb/produce/change charge of pions. Nuclear reinteraction and pion spectrum have to be measured with precision at the near detector)

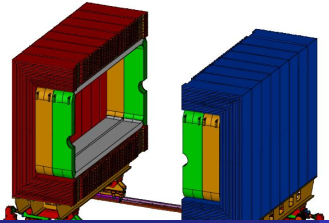
Background prediction at SK for ν_e appearence

- π^0 reconstructed as electron in SK. (POD detector)
  the π^0 can be constrained with proper understanding of Δ resonance production in neutrino interactions and nuclear reinteractions
- intrinsic ν_e in the beam
  ν_e in the beam can be measured directly at the near detector and extrapolated to SK. It can also be constrained measuring the high energy tail of ν_μ.

sketch of the detector

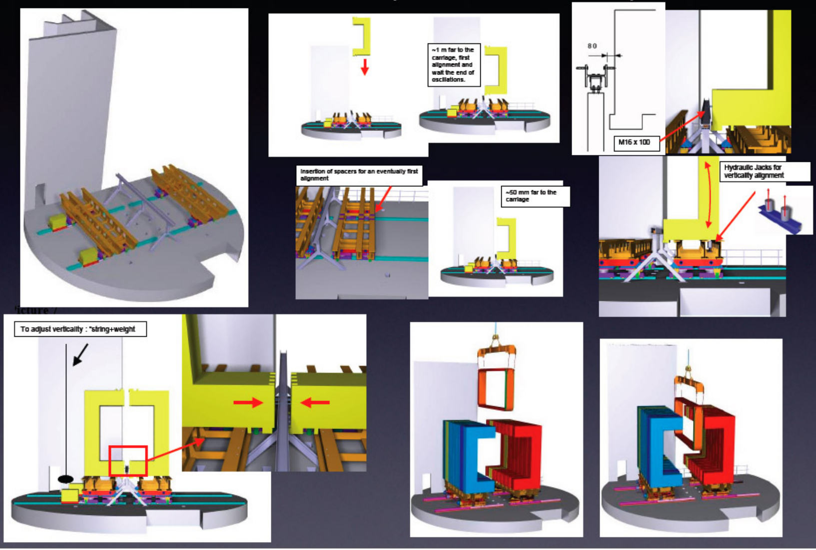


in the NOMAD magnet

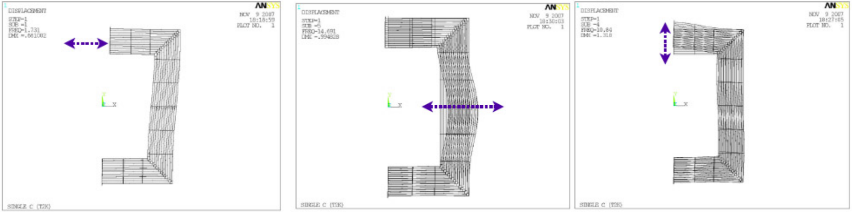


C refurbishing (spring 2007)

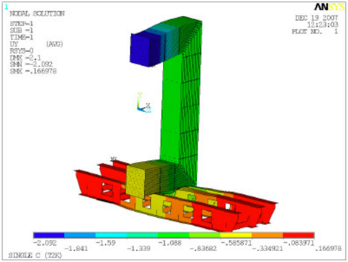
Installation (some details)



Configuration Carriage alone



Configuration Carriage+1Yoke

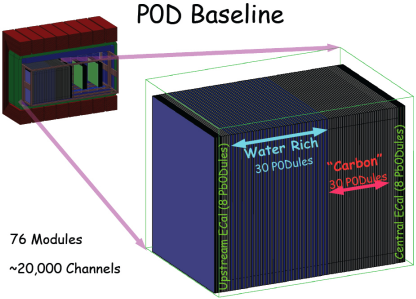


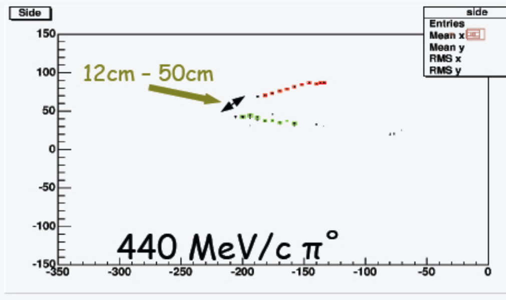
Self-Weight (without stopping system: conservative)

- Pettinacci

Magnet

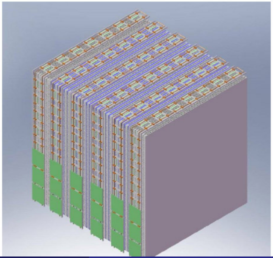
- Shipment: started!
- installation in Tokai: april-june 2008
- building construction
- commissioning: april 2009
- field measurement: june 2009 (one full month)





The PØD Design

Solidworks design assembly



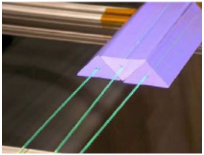
- 3 Super-PØDules
  - Upstream ECAL (3200 kg)
    - 7 PØDules
    - 7 4mm-thick lead radiators
  - Target (11000 kg)
    - 2857.3 kg water
    - 26 PØDules
    - 25 1.6mm brass radiators
    - 25 Water target layers
    - Split into 2 sub-units for pre-installation handling
  - Central ECAL (3200 kg)
    - 7 PØDules
    - 7 4mm-thick lead radiators
- Total Mass is 17600 kg

POD

US project

Measure SK ν_e appearance backgrounds

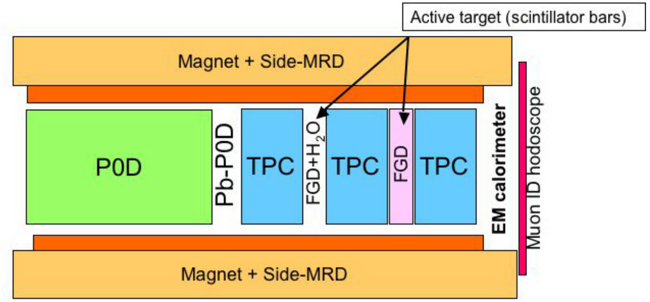
- NC π^0(40 % of bckd w/ large a priori uncertainty)
  - exclusive single π^0production (momentum and angle dist.)
  - inclusive NC and CC production
- beam ν_e interactions (57% of background)
  measure QE $\nu_e$production (complementary to tracker)

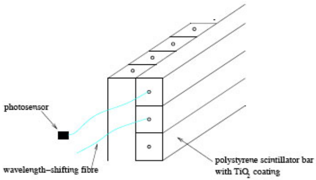


152 scintillating bars X-Y layers
3 $\times$ 1.5 cm read by 1.2 mm ws fibers
use standard ND280 photosensor (SiPM)
total mass: 20t, fid. mass: 6t, H2O fid. mass: 1.5t

- P0D design essentially complete
- On target for completion in early 2009 and in time installation

Tracker: FDG + TPC



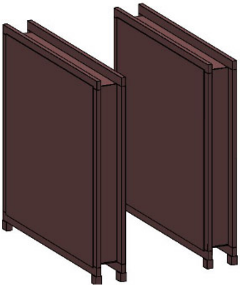


30 alternated X-Y layers of scintillating bars
1 $\times$ 1 cm read by 1.2 mm ws fibers
use standard ND280 photosensor (SiPM)
provide target mass and tracking of final state particles

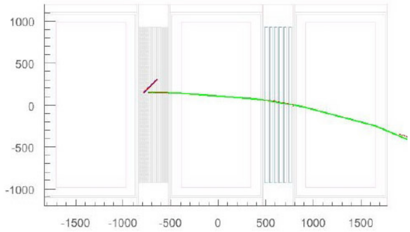
1 cm $\times$ 1 cm segmentation

FGD Detector Overview

- FGD provides target mass for tracker (2 x ~1 tonne)
- Light produced in scintillator bar is readout using a wavelength shifting (WLS) fibre coupled to a pixellated APD (ie "MPPC"). 8448 channels total.
- FGD size: ~2m x ~2m x ~30cm
- One all-plastic FGD and one plastic+water FGD.



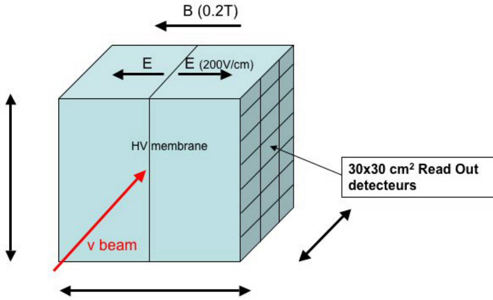
Simulated CCQE interaction



TPC

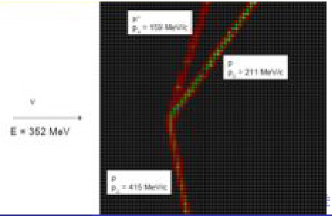
Sketch of the TPC

- 3 TPC modules
- E-field: 200 V/cm
- pads: 8x8 mm^2
- $\sim$ 100000 channels

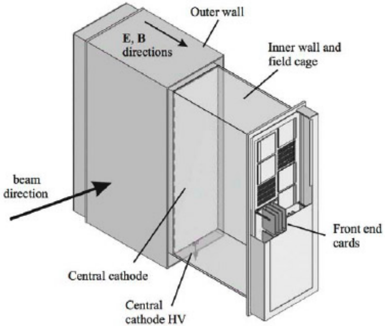


why a TPC?

- good spatial resolution
- good track reconstruction
- little matter across track trajectories
- identify e, μ, p through dE/dx



- Micromegas
- Mechanical
- Gas system
- Module 0 test plans
- Front end electronics
  - details in Alfon's talk
- Schedule

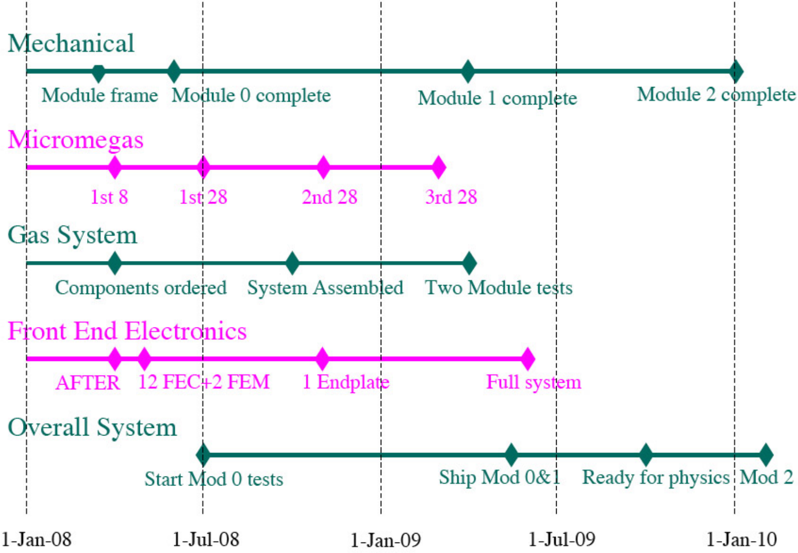


Module 0 Tests at TRIUMF

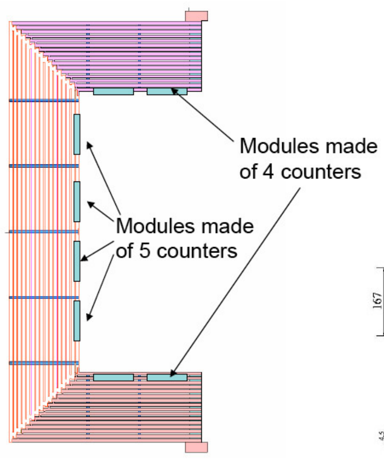
- Planning is underway for beam/cosmic tests of Mod 0 starting July 2008.
  - » system test
  - » performance tests
  - » operational experience
- 2 instrumented MM initially; full endplate by end of year.
- $e/\mu/\pi$ ~250 MeV/c, 1% $\Delta p/p$

20

Schedule


Mechanical
Module frame
Module 0 complete
Module 1 complete
Module 2 complete
Micromegas
1st 8
1st 28
2nd 28
3rd 28
Gas System
Components ordered
System Assembled
Two Module tests
Front End Electronics
AFTER
12 FEC+2 FEM
1 Endplate
Full system
Overall System
Start Mod 0 tests
Ship Mod 0&1
Ready for physics
Mod 2
1-Jan-08
1-Jul-08
1-Jan-09
1-Jul-09
1-Jan-10

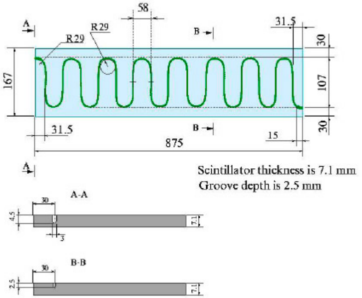
Magnet instrumentation



Total horizontal counters: 768
Dimensions: **870 x167 x 7 mm3**

Total vertical counters: 1060
Dimensions: **870 x175 x 7 mm3**

Total counters: ~2000
(including spares)



Scintillator Production Status

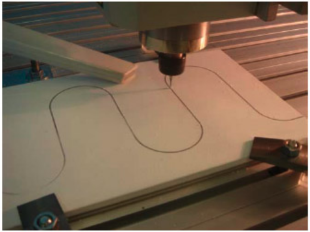
Mass production started in November 2007

Extrusion of first batch of scintillators complete: (Vladimir)

~1000 slabs (800 x 167 mm wide;
200 x 175 mm wide)

Processing: (INR Moscow)

- cut and covered by reflector ~250
- Machining of S-grooves 110
- assembly 2 (without a stainless cover)



S-groove depth	2.6-2.8 mm
Total time per slab	~25 min

SMRD Schedule + Plans

before start of mass assembly:

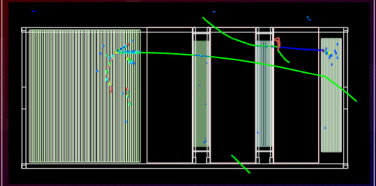
test/glue front panels and steel cover
light protection
fiber polishing and optical connector test

Begin mass assembly	Jan-Feb 2008
Completion and test of ~1000 counters	late May 2008
Extrusion of another 1000 slabs (mainly 175 mm)	Oct 2008
Assembly/test all SMRD counters	May 2009
Large scale photosensor QA	start March 2008
Detector shipment (batch 1)	summer 2008
Final detector QA in Tokai	summer/fall 2008
Start of installation (batch 1)	March - April 2009
Detector shipment (batch 2)	early 2009
Final detector QA in Tokai	spring 2009
Start of installation (batch 2)	*July – Sept. 2009* (now under revision)

Software

Simulation

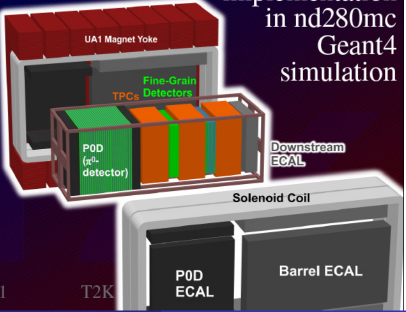
Software Status



A CC1π interaction in the P0D, with full-bunch background

- Geant4-based simulation
- Simulates full-spill interactions, and additional planted interactions for signal studies

Exploded view of ND280 Geometry implementation in nd280mc Geant4 simulation



- Interfaces with all widely-used neutrino interaction generators
- Custom detector response (Scintillator detectors and TPC) and electronics (Trip-t and AFTER) simulations

Yoshi.Uchida@imperial.ac.uk

Software

Global Reconstruction

Anselmo Cervera

RecPack

- Setup-independent reconstruction tool-kit
  - Track and vertex fitting
  - Geometry representation
  - Track propagation
  - Toy simulation for debugging
  - Object matching

- Initially developed for HARP
- Is now used by other experiments:
  - MICE, MIPP, Muscat, interest from MINERvA and NOvA

- Developments are being done mainly for T2K

Status of Global Recon

- The tracker (TPC+FGD) is using the RecPack functionality to merge objects in both detectors
- P0D and ECAL will start using it shortly:
  - Examples exist
  - Ongoing discussions with Ian and Trung
- SMRD geometry is being implemented. Once smrdRecon is committed, matching should be trivial
- The idea is to have a fully connected nd280 for the next collaboration meeting.

Anselmo Cervera

Neutrino Interaction Generators

- nd280 software designed to be generator-agnostic
- NUANCE, NEUT, GENIE (NEUGEN) all used extensively in past
- Discussions ongoing on more tightly bound interfaces with generators

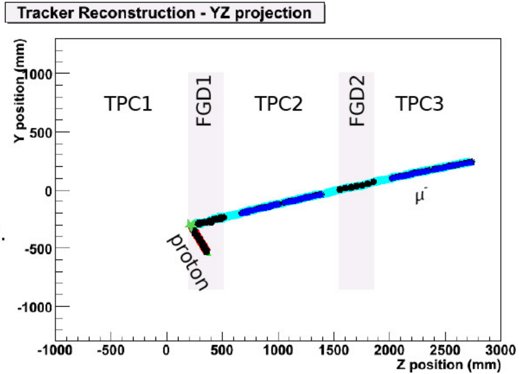
  multiple nuclei types, geometry aware generation, generator comparisons, model constraints and uncertainty estimates from data etc

- Close cooperation between software group and generator authors / experts

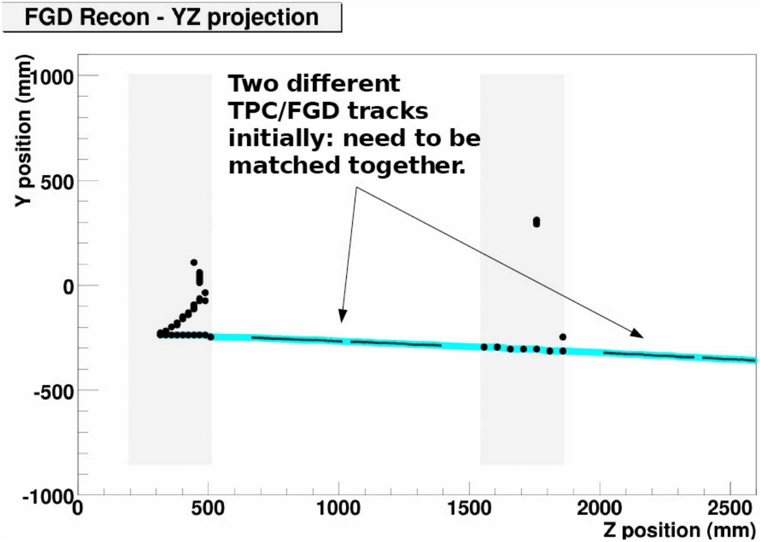
Tracker Reconstruction

1) TPC reconstruction is done first.
2) TPC tracks are projected/matched to FGD hits.
3) Remaining FGD hits are reconstructed into tracks.

Example of successfully reconstructed CCQE interaction.

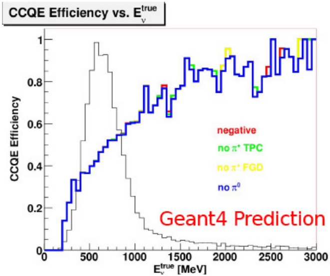


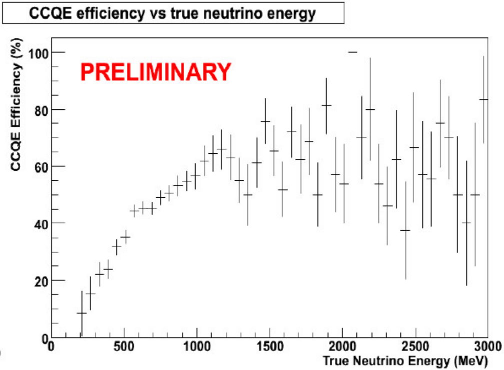
TPC/FGD Matching



CCQE Efficiency vs True Neutrino Energy

- Higher energy neutrinos -> more forward-going -> more likely to cross TPC -> more likely to pass selection cuts.





PØD π^0 Selection

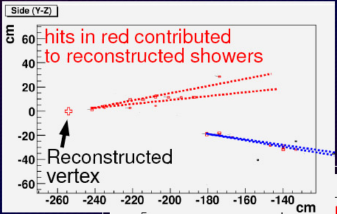
Preliminary Reconstruction
Software Demonstration

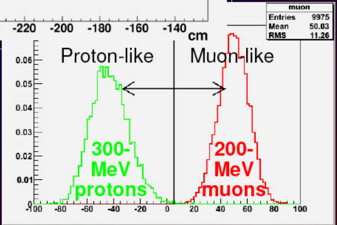
- Reconstructed vertex in fiducial volume
- No μ-like tracks
- 2 or 3 candidate showers
- At least one shower $>$ 10 cm from vertex
- No μ decay candidates
- Event topology consistent with π^0

Ongoing Work

- Charged track and shower selection
- Shower vertex reconstruction
- 3D shower matching

A successfully reconstructed π^0 in the P0D





Muon and Proton PID likelihood distributions

List of Software Tasks for 2008

ND280Control

- Lead by N. McCauley
- Jobs
  - Expand the available dictionary
    - Interfaces to NEUT and GENIE
    - Simplify interface for user prograr
  - Stress testing

elecSim

- Lead by A. Vacheret
- Jobs
  - SMRD scintillator model
  - Refinement of ECal/P0D/FGD scintillator models
  - Refine Trip-T electronics simulation
  - Parameter tuning

Database

- Lead by I. Bertram
- Jobs
  - File Catalogue
    - Assemble requirements list
    - Database table design
    - Interface to nd280Control
    - Database implementation
    - Database entry tools
    - Database query tools
    - Documentation
  - Calibration Database
    - Specify sub-detector tables
    - Access routines
    - Design backup and replication
  - More... Speak to Iain Bertram

Detector Simulation

- Lead by C. McGrew
- Jobs
  - Improve model of the ND280 Hall (Hole?)
  - Improve model of the off-axis basket
  - Introduce model of the inactive material in front of the PØDECal and TrackerECal
  - Introduce the improved model of the magnetic field
    - The magnetic field in the Yokes is very poorly approximated
  - Verify the G4 physics lists
    - Validate the chosen hadronic models
    - Verify the chosen ionization models
      - Properly chosen cut values could dramatically speed up the full-spill simulation
  - Improve simulation of SMRD geometry
  - Interface to generators
    - For NEUT (only) need to combine files generated for different nuclei with proper weighting to preserve spectrum &c

Reconstruction

- Lead by F. Sanchez (and each Sub-Detector)
- Jobs
  - Myriads
    - Conversion to new recon objects
    - Algorithm tuning
    - Algorithm development
    - Full bunch and full spill tests

Calibration Framework

- Lead by Anselmo
- Jobs
  - Creation of the calibration framework
  - Start calibration libraries for each sub-detector
  - Start interfacing with DAQ group and defining/understanding "Raw" data formats

Analysis Framework

- Lead by Y. Uchida
- Jobs
  - Provide modules for
    - FGD
    - TPC
    - Global Fitting
    - Others
  - Improve control of active modules
  - Improve readout modules

Will be presented to the collaboration alongside the user release

Global Analysis

The T2K Global ANalysis Group (GANG)

Membership of Physics conveners group:

Beam line group	Takashi Kobayashi, Sandro Bravar
ND280 group	Tsuyoshi Nakaya, Kevin McFarland
2km	Takaaki Kajita, Chris Walter
SuperK-T2K	Kenji Kaneyuki, Chris Walter, Akira Konaka
Global Analysis	Alain Blondel (convener) Christos Touramanis, Eric Zimmerman

Alain.blondel@cern.ch

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Global Analysis

Physics goals
(by estimated eventual importance)

1. Discover ν_μ --> ν_e appearance
2. Precise meast of ν_μ --> ν_e oscillation probabilities
3. ν_μ disappearance (atmo parameters)
4. ν_μ cross-sections (and anti-neutrinos)
5. ν_e cross-sections (and anti-neutrinos)
6. completely new searches

Physics goals
(by chronology?)

1. ν_μ cross-sections (and anti-neutrinos)
2. ν_μ disappearance (atmo parameters)
3. completely new searches
4. ν_μ --> ν_e appearance
5. ν_e cross-sections (and anti-neutrinos)
6. Precise meast of ν_μ --> ν_e oscillation probabilities

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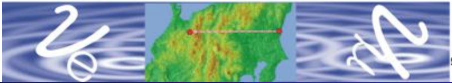
Global Analysis

'burning issues'

Monte carlos: how will they be used? Specification? baseline
Blind analysis
Interfaces between tasks



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Global Analysis

Monte-Carlo Policy:

-- Monte Carlo for ND280 and SK *must* be identical and controllably so.

-- issue of ND280 vs SK material difference and nuclear re-interactions
multiple materials present in ND280 (Scintillator, G10, water, Al, Ar, iron, pb, …)

-- practical proposal: common baseline generator be NEUT
decision for Monte-Carlo productions until further decision
may evolve in the future

-- SK group will make source code available to T2K collaborators
Much tuning will come from the ND280 data in the future
Questions remaining: Tunability, Re-weightability (syst.errors estimates, data fits)

-- Availability of other physics generator (e.g. GENIE, NUANCE) is highly encouraged to check robustness of system.
Same requirements as for baseline Monte Carlo.

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Global Analysis

Blind analysis

This should be understood as ‘unbiased’ analysis procedure

-- cuts and procedures should not be optimized or otherwise influenced by their effect on the actual physics result.

-- several techniques:

-- “blind box”-type analysis (à la MiniBooNE)

-- cut or likelihood based analysis with optimization based a-priori on Monte Carlo

-- in any case e.g. optimal cuts are statistics-dependent so
<u>accumulated statistics or closing date for publication data set defined ahead of time.</u>

-- BUT: Monte-Carlo must be cross-checked or tuned on data to be reliable so one must have access to data somehow. Analysis must be “blind but not stupid”

-- preliminary bias: no need for blind analysis in disappearance analysis.

-- $\nu_\mu \rightarrow \nu_e$ analysis is the most likely candidate -- How?

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Summary

- T2K is a very ambitious project with a major scientific goal θ_{13}
- this is actually the start of a precision measurement round on the MNSP matrix
- the JPARC accelerator is progressing in time first neutrinos expected 1st of april 2009: commissioning done with on-axis detector: INGRID
- the ND280m off-axis detector: installation in magnet during summer 2009 (shutdown of the accelerator)
- first physics events in - almost complete (except for ECAL) - ND280 by the end of 2009
- Schedule is tight and all efforts and contributions are important (beam, NA61, INGRID, ND280, SK)