

TRIUMF

*Canada's National Laboratory
for Particle and Nuclear Physics*

*Laboratoire national canadien pour la recherche
en physique nucléaire et en physique des particules*

The XXIII International Conference on
Neutrino Physics and Astrophysics
(Neutrino 2008)

Christchurch, New Zealand
May 25 – 31, 2008

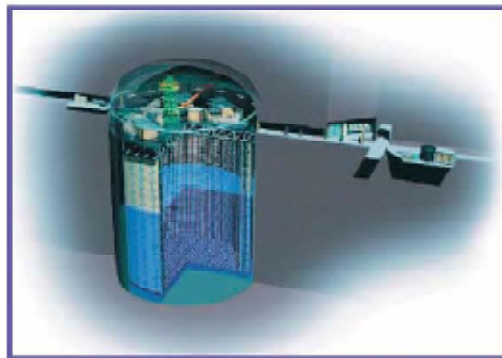
Status of the T2K experiment

Issei Kato
TRIUMF, Canada

Representing the T2K collaboration

May 27, 2008

The T2K experiment



Super-Kamiokande
(ICRR, Univ. Tokyo)



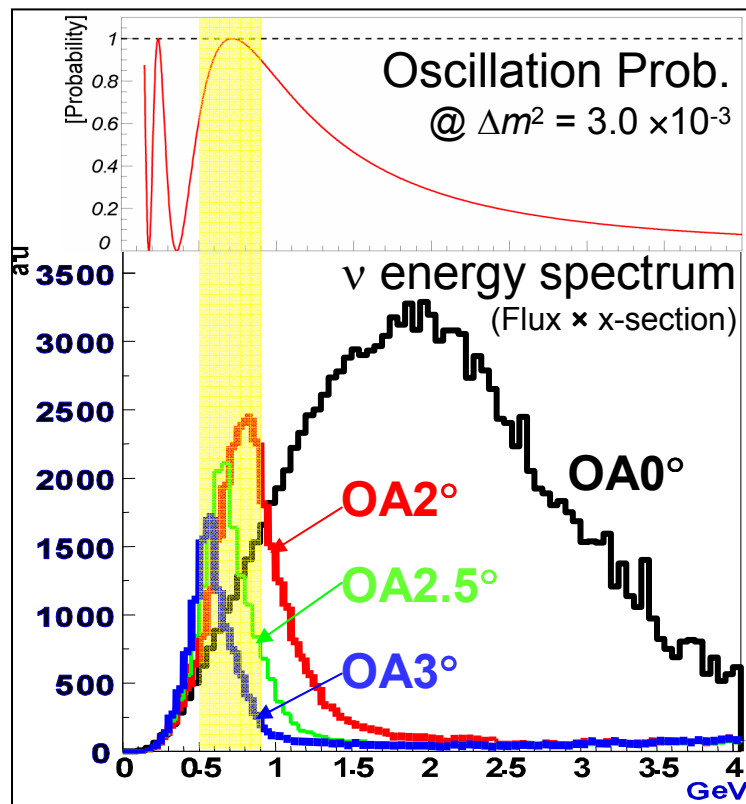
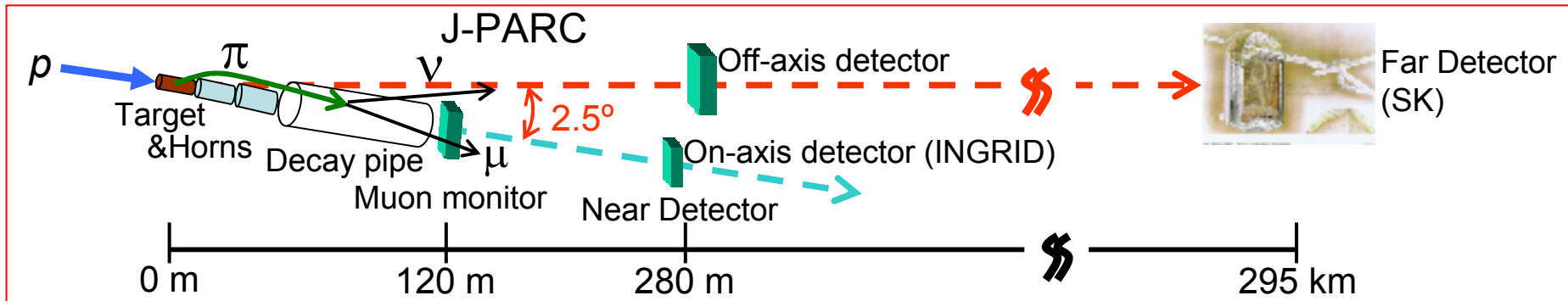
J-PARC Main Ring
(KEK-JAEA, Tokai)



Tokai-to-Kamioka neutrino oscillation experiment

- to precisely measure the ν_μ disappearance, i.e. θ_{23} and Δm^2_{23} ($\sim \Delta m^2_{13}$)
- to intensively search for $\nu_\mu \rightarrow \nu_e$ appearance, i.e. non-zero θ_{13}

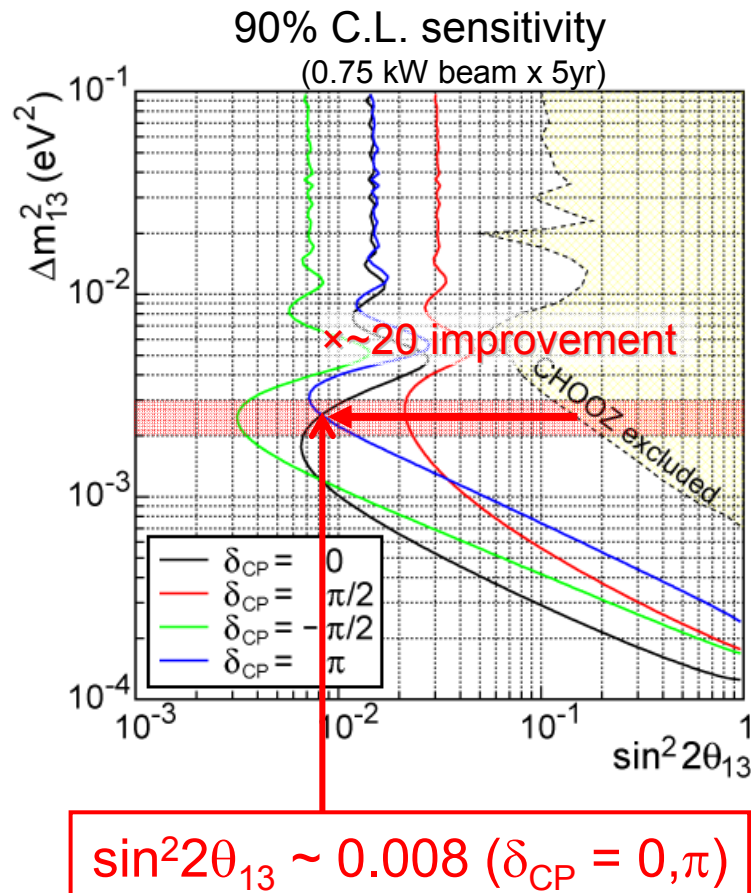
Experimental apparatus and neutrino beam



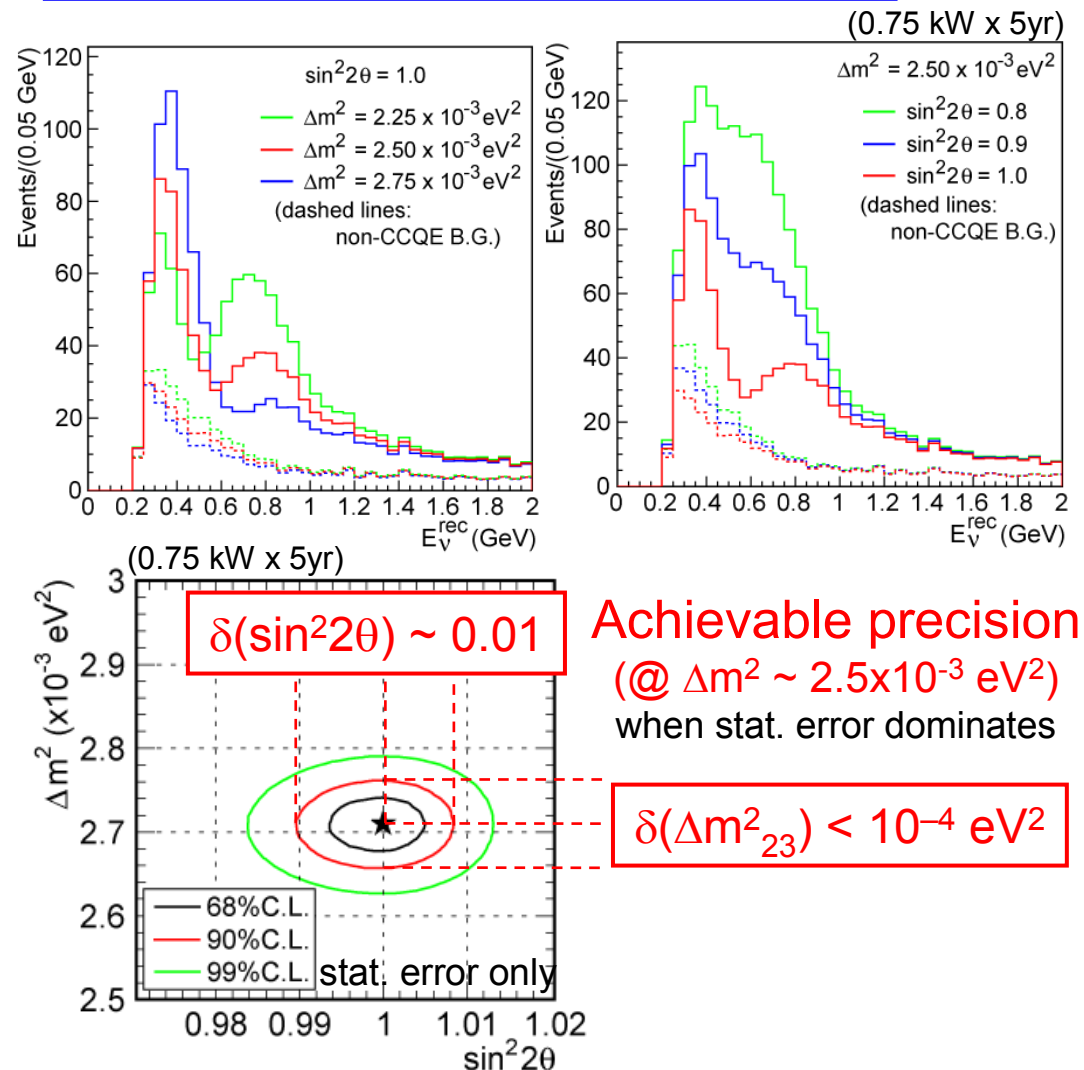
- Off-axis beam technique
 - Intense narrow band beam
- 2.5° off-axis
 - Energy peak tuned at oscillation max. ~ 0.7 GeV
- Statistics at Super-K
 - ~1600 ν_{μ} CC int./22.5kt/year (with 0.75kW beam, no oscillation case)
- Pure ν_{μ} beam
 - Beam ν_e contamination ~0.4% at ν_{μ} peak energy

Experimental sensitivities

Search for ν_e appearance



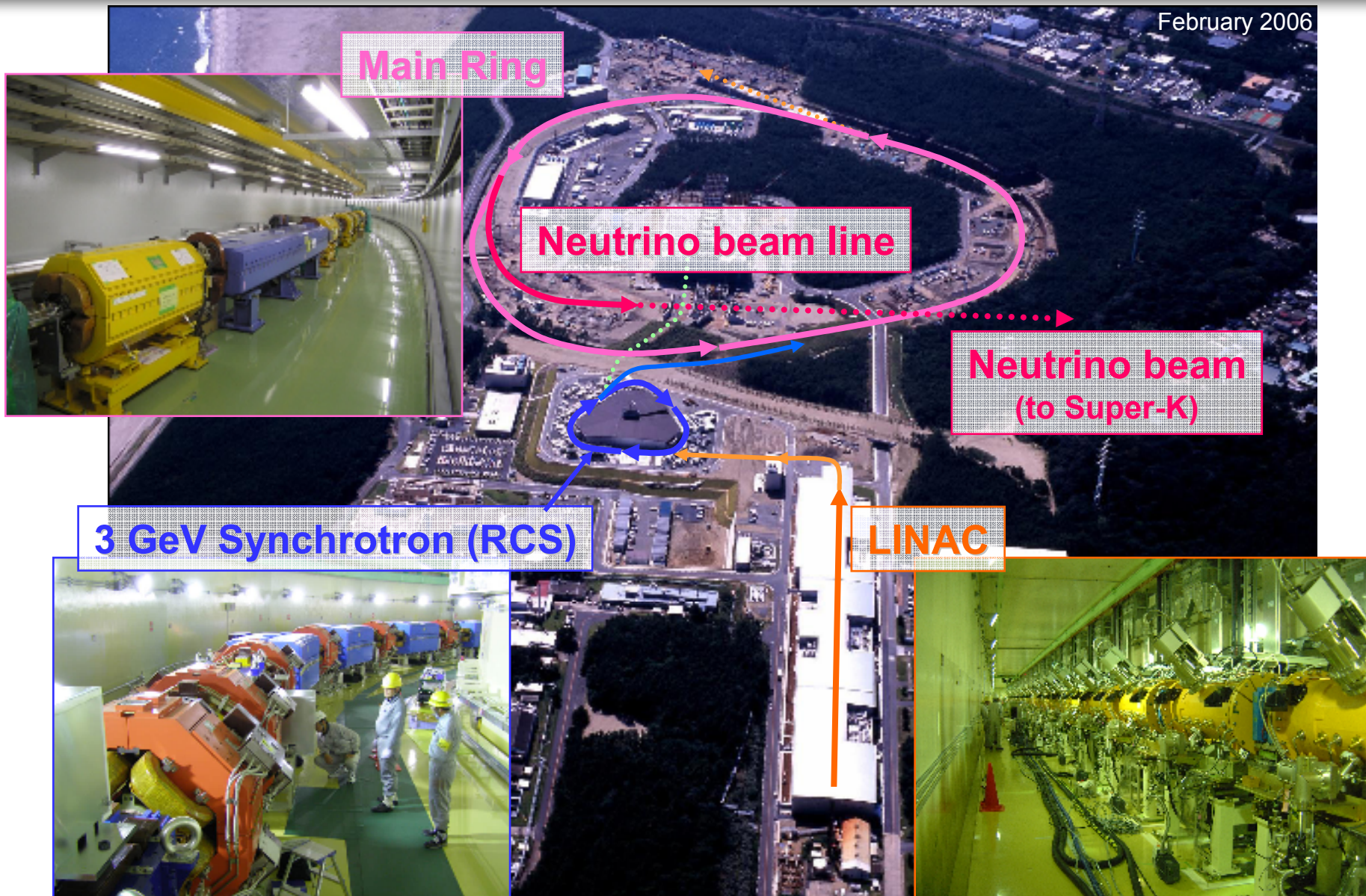
Measurement of ν_μ disappearance



**Construction status of
J-PARC accelerator and
neutrino beam line**

J-PARC accelerator status

February 2006



May 27, 2008

Status of the T2K experiment / I. Kato (TRIUMF)

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J-PARC accelerator status

February 2006

- **Accelerator group is doing quite excellent job**
 - Installation and commissioning works are going on schedule
- **LINAC:** successfully commissioned
 - 181 MeV (day-1 beam energy) acceleration achieved in Jan. 2007
 - Good beam stability
- **3 GeV Synchrotron (RCS):** successfully commissioned
 - 3 GeV acceleration and extraction achieved in Oct. 2007
 - 4.4×10^{12} particles accelerated with 25 Hz (1 bunch)
 - Corresponding to 100 kW operation in terms of particles per bunch
- **Main Ring Synchrotron:**
 - Installation of accelerator components and vacuum system completed
 - **Commissioning started last week and already succeeded a big milestone**
 - 3 GeV beam injected from RCS to MR, captured by RF, turned around MR, and extracted to the beam dump
 - Aim to accelerate to 30 GeV in Dec. 2008
 - Fast extraction to neutrino beamline in Apr. 2009

Primary proton beam line

- Primary beam line tunnel completed in Dec. 2006

Preparation section

Normal conducting magnets

- Preparation section:
All magnets installed and aligned in the beam line
- Final focus section:
Installation started in March 2008.

Superconducting magnets (doublets) in tunnel

Super-conducting magnets

- 26 (/28) magnets and 11 (/14) “doublets” completed
- 10 doublets installed in beam line
- Cryogenics installation on time
- Entire system will be completed by Dec. 2008**

to decay volume

Target and horns

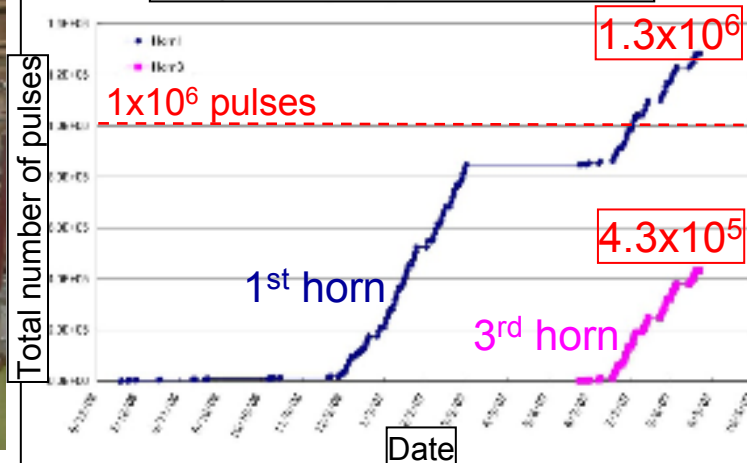


Target

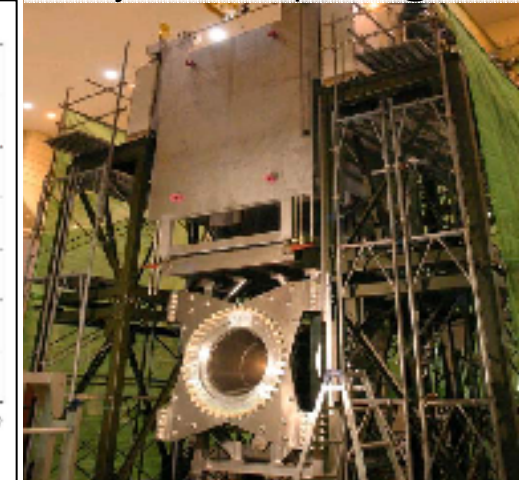
- graphite core: 26 mm (D) x 900 m (L)
- forced flow helium gas cooling in Ti-alloy capsule
- day-1 target delivered
- full-spec helium flow rate for cooling achieved



Long-term operation at 320 kA



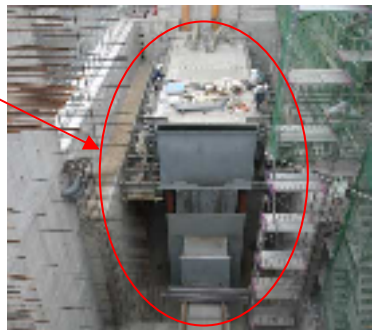
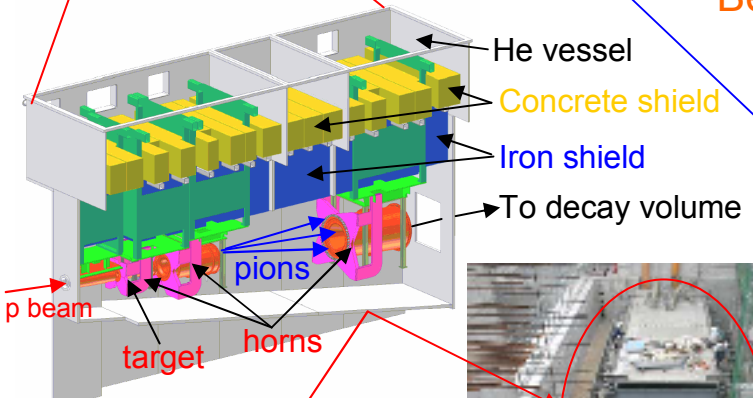
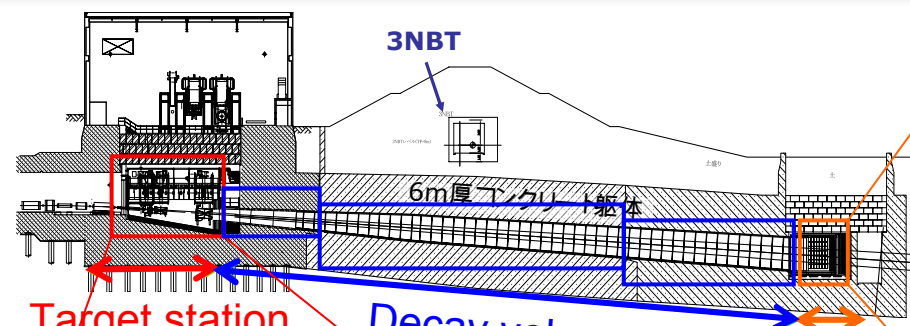
Full system setup test @ KEK



Electromagnetic horns

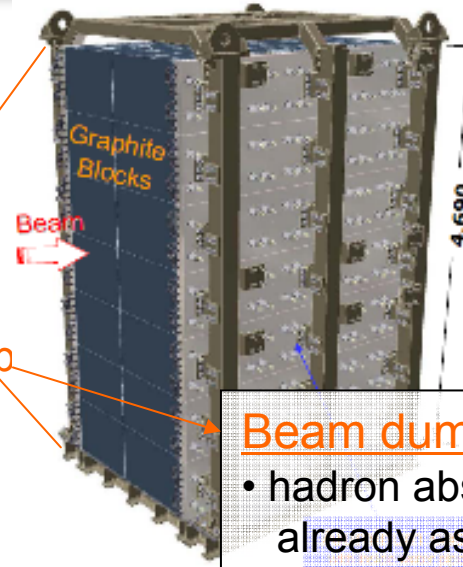
- long term test with 320 kA
 - for 1st and 3rd horns successfully performed
- 1st and 3rd horns for Day-1 delivered
- 2nd horn to be delivered from the US in Jun/Jul
- full system setup at KEK
 - remote maintenance demonstrated
 - 320 kA operation succeeded
 - assembly/installation will start in Aug. 2008

Target station and secondary beam line



Target station

- helium vessel installed
- passed vacuum test in Nov. 2007
- surface building being constructed



Beam dump

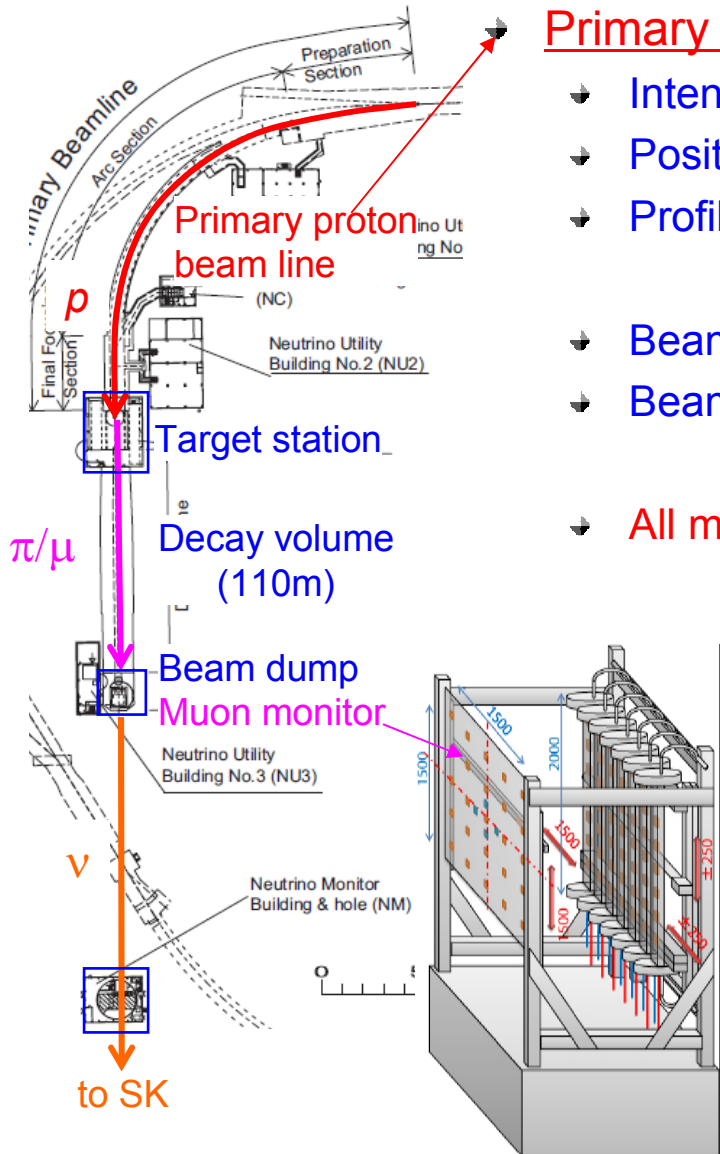
- hadron absorber modules (graphite) already assembled
- to be installed in place in Oct. 2008

Decay volume

- upstream 2/3 part completed
- downstream part civil construction to be finished by Aug. 2008

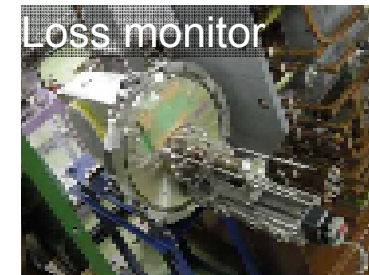
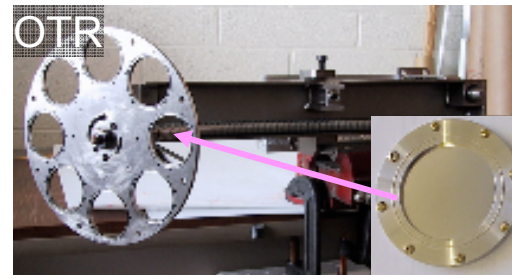
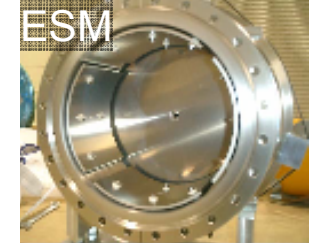
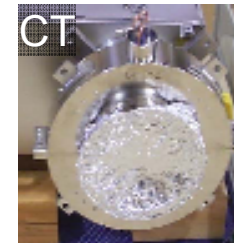


Beam monitors



Primary proton beam monitors

- **Intensity:** current transformer (CT)
- **Position:** electro-static monitor (ESM)
- **Profile:** segmented secondary emission monitor (SSEM)
- **Beam loss:** Ionization chamber
- **Beam profile in front of target:** optical transition radiation (OTR)
- **All monitors to be installed by Oct.2008**



Secondary beam monitors

- Muon profile center after beam dump
- muon monitor:** Ionization chamber
Si PIN/Diamond
- **To be installed in fall-winter 2008**



Design and status of near detector

Search for $\nu_\mu \rightarrow \nu_e$ appearance

- Look for excess events in 1-ring e-like sample at SK

Expected number of events at SK (0.75kW beam x 5yr)

$\sin^2 2\theta_{13}$	Backgrounds			Signal
	ν_μ induced	Beam ν_e	Total	
0.1	10	13	23	103
0.01				10

- Dominant background sources:

- **Beam ν_e contamination**

- Irreducible, but different energy spectrum from oscillated ν_e

- **ν -induced $\text{NC}1\pi^0$ events**

- one of 2γ from π^0 is missed

- Reducible, needs knowledge of **$\text{NC}1\pi^0$ interaction**

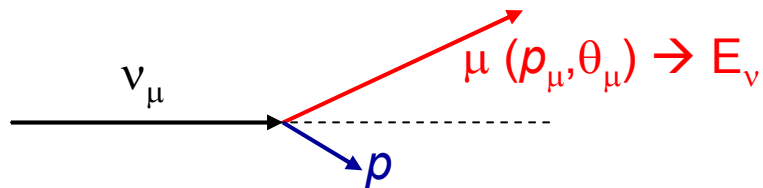
→ **To be studied/estimated at near detector**

Measurement of ν_μ disappearance

- Measure the oscillation pattern in the neutrino energy spectrum
 - Compare expectation v.s. observation
 - needs well-understood expected neutrino energy spectrum

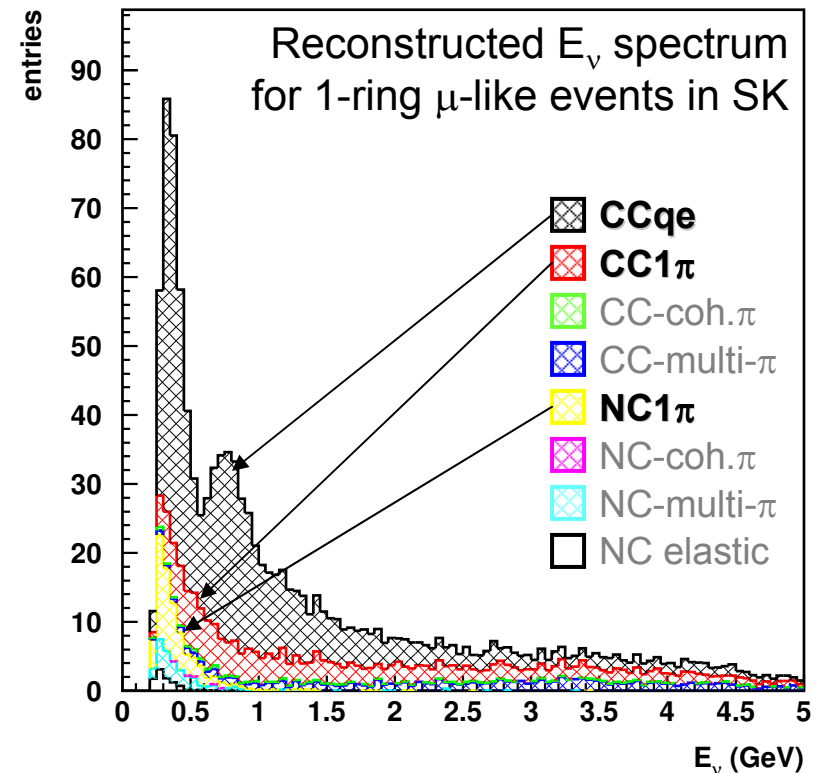
- Neutrino energy reconstruction
 - use kinematics of CCQE

→ CCQE: $\nu_\mu + n \rightarrow \mu^- + p$

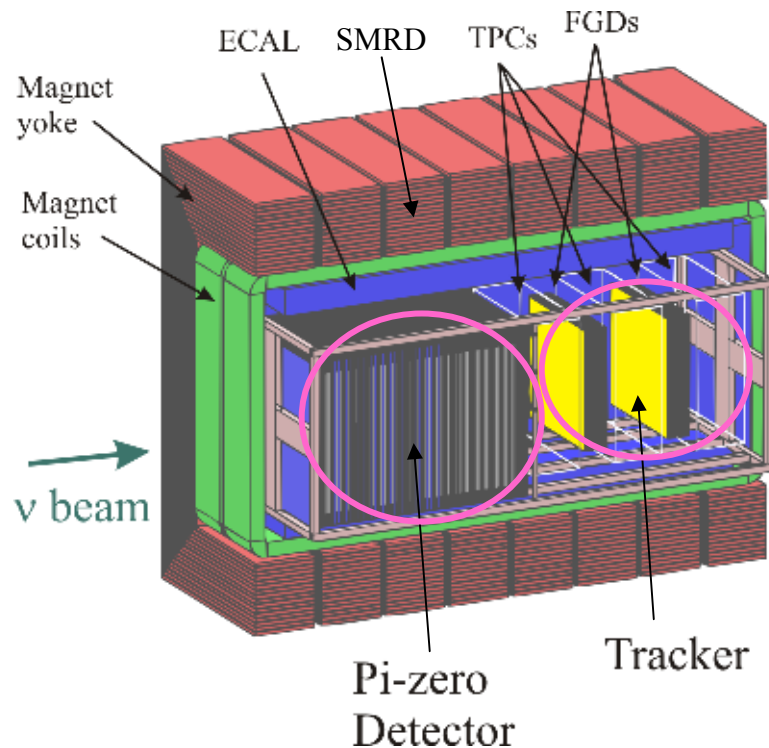
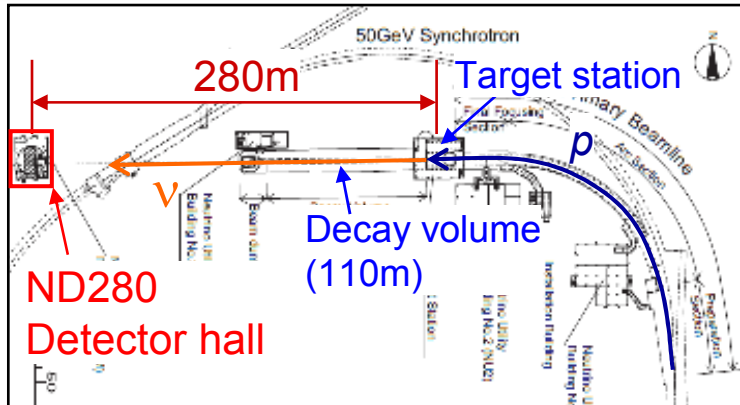


- CCQE candidates: 1-ring μ -like events
- Backgrounds: non-CCQE events
 - $\text{CC1}\pi^+$ and $\text{NC1}\pi^\pm$ are dominant (π^\pm below/above Cherenkov threshold)

→ To be estimated at near detector



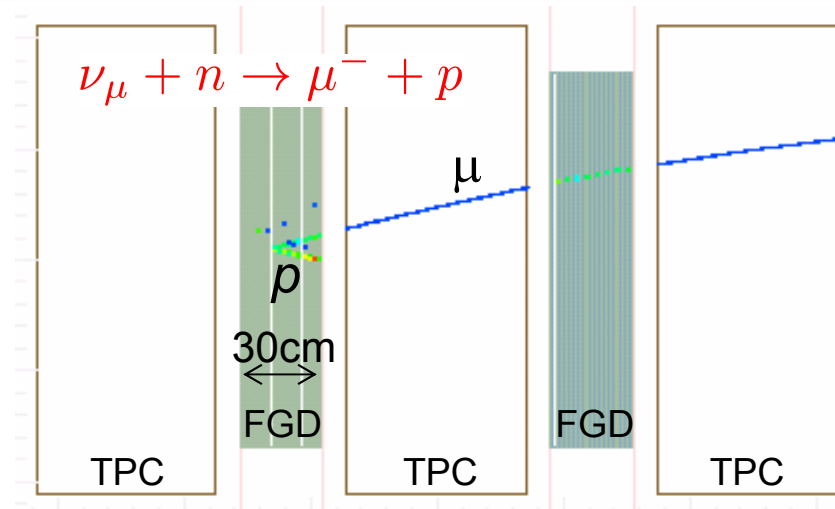
Near off-axis detectors



- Near off-axis detector located at 280 m downstream of the target
- Consists of 5 subdetectors:
 - Pi-zero detector (PØD)
 - measures $NC\pi^0$ interactions
 - Tracker: fine-grained detector (FGD) and time projection chambers (TPC)
 - measures CC interactions
 - Electromagnetic calorimeter (ECAL)
 - detects EM activities coming from PØD/Tracker
 - Side muon range detector (SMRD)
 - measures side-going muon energy
- All detectors housed in UA1/NOMAD magnet: B-field = 0.2 T
- $0.8M \nu_\mu$ and $16k \nu_e$ interactions per ton after $0.75kW \times 5yr$ accumulation

Main features of ND280 off-axis detector

- Key for good E_ν spectrum and background estimations
 - CCQE / non-CCQE separations
 - Neutrino interaction models
 - Cross sections
 - Fermi motion
 - Nuclear effects ...



- Finely segmented (1cm x 1cm) FGD with 10 μ s time window
 - short 2nd (and more) tracks' activities
 - $\pi \rightarrow \mu \rightarrow e$ decays from non-CCQE
 - TPC following the FGD
 - particles' charge: μ^- / π^+ separation
 - momentum of π from non-CCQE as well as μ
 - ECAL surrounding the Tracker
 - detects γ 's from π^0 from non-CCQE
- Two independent CCQE / non-CCQE separation in a single detector:
 - Final state particles
 - Kinematics of 2nd track
 - Kinematics of final state particles:
 - Fermi motions, nuclear effects, ...
- intensive study of the neutrino interactions

Other features of ND280 off-axis detector

- Background studies for ν_e appearance
 - beam ν_e estimation: μ/e separation
 - dE/dx in TPC plus EM activity in following ECAL
 - PØD: fine-segmented scintillator tracker with lead EM converters, provides complementary measurement
 - NC $1\pi^0$ estimation
 - PØD is optimized for NC π^0 measurements
 - Tracker + ECAL system also provides complementary measurement
- PØD and 2nd FGD have water target
 - same as SK
 - study neutrino interactions on water

Construction status of ND280 detector hall and UA1 magnet



- ND280 detector pit excavated
- UA1/NOMAD magnet refurbished and shipped from CERN arrived at J-PARC in March
- Magnet carriage installed in the pit in April
- Magnet assembly and installation in progress, to be completed by June
- ND280 infrastructure and surface building to be completed by the end of this year

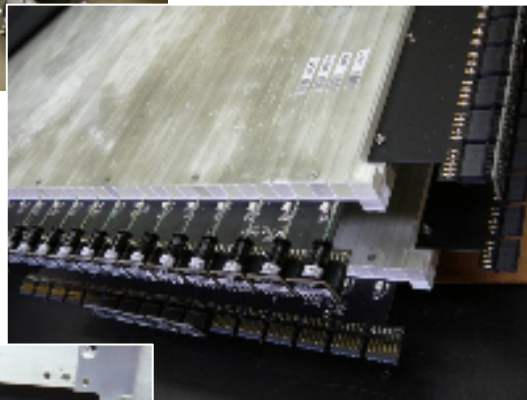
ND280 detector construction status

– Tracker –

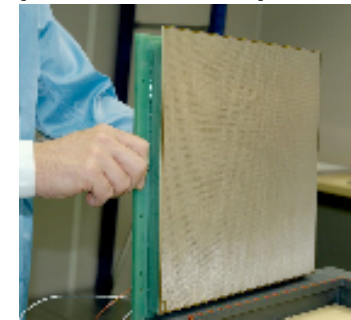


FGD: all layers completed

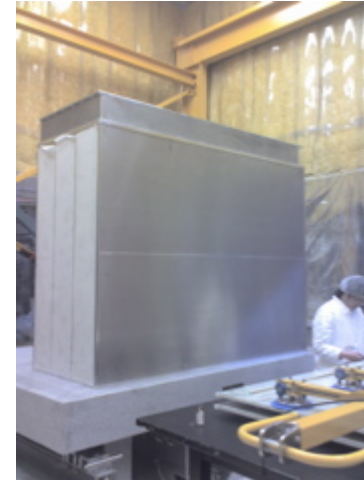
Assembly work in progress



MicroMegas module in production phase



FGD electronics: Prototype tests in progress
Final production, soon

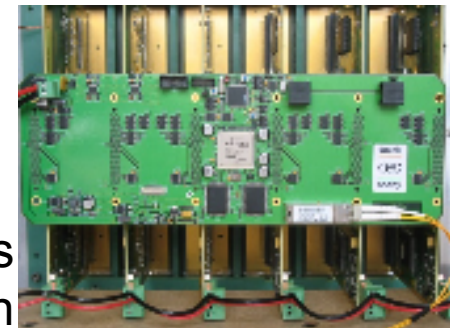


TPC box construction on-going



final gas system assembly will start soon

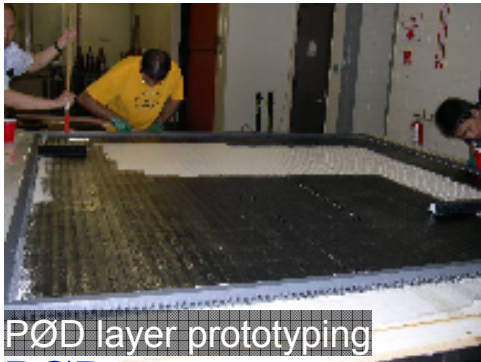
TPC electronics close to final production



➔ 1st module of both FGD and TPC will be completed in July

ND280 detector construction status

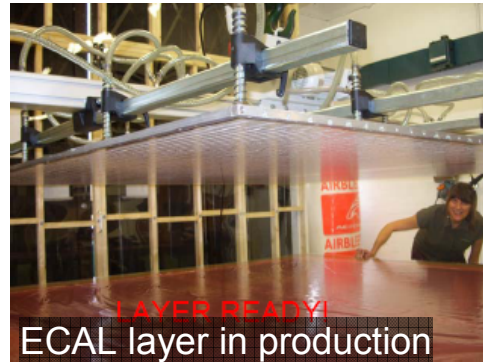
– PØD, ECAL, SMRD, On-axis monitor –



PØD layer prototyping

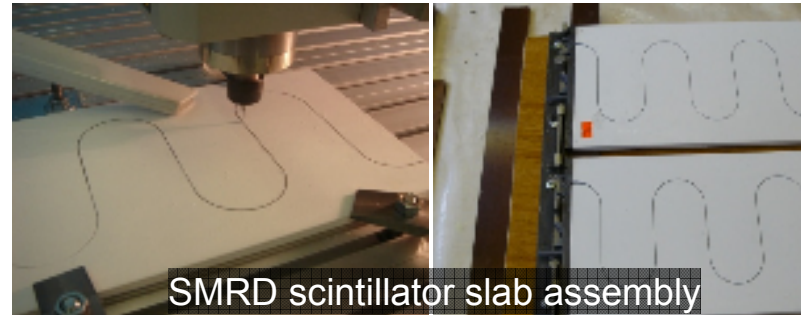
PØD:

preparing for production
expect to be completed
by Jan. 2009



LAYER READY!
ECAL layer in production

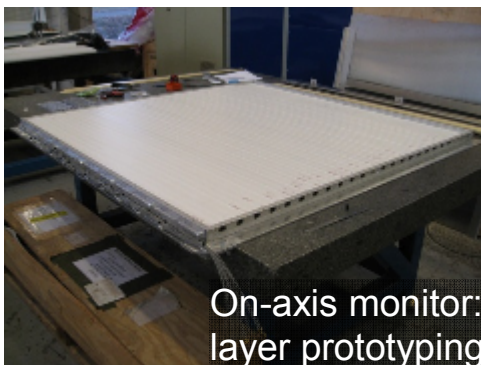
Downstream ECAL:
to be completed by
Nov. 2008



SMRD scintillator slab assembly

SMRD:

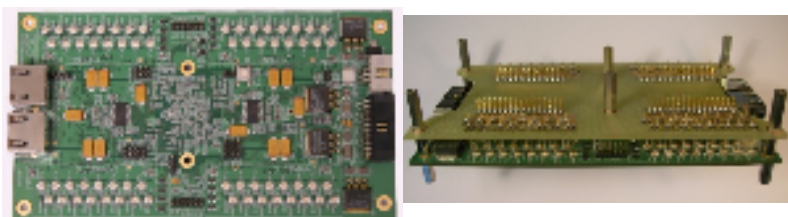
Scintillator slabs being assembled
50% by Oct.2008, the rest by Mar.2009



On-axis monitor:
layer prototyping

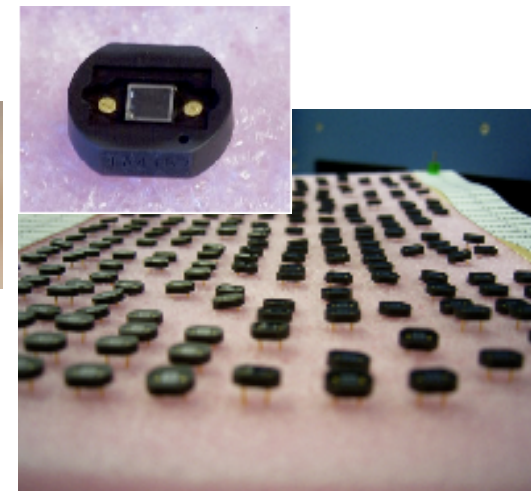
On-axis v monitor:

Start assembly work
in this summer



**Electronics for PØD, ECAL, SMRD
and on-axis monitors:**

Testing pre-production board
Will start final production soon



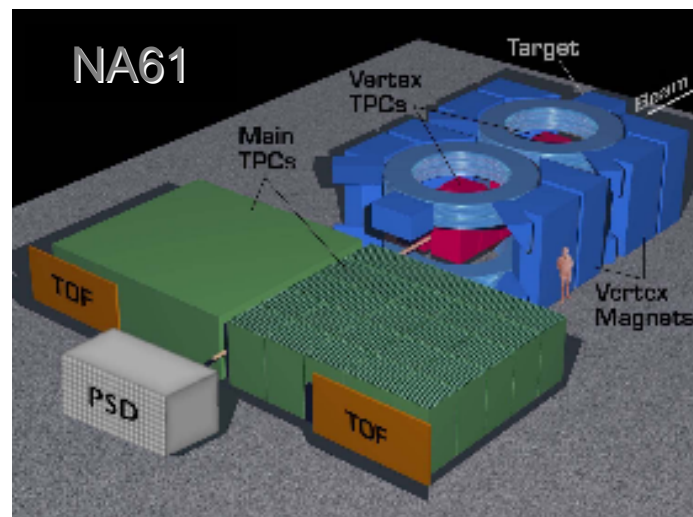
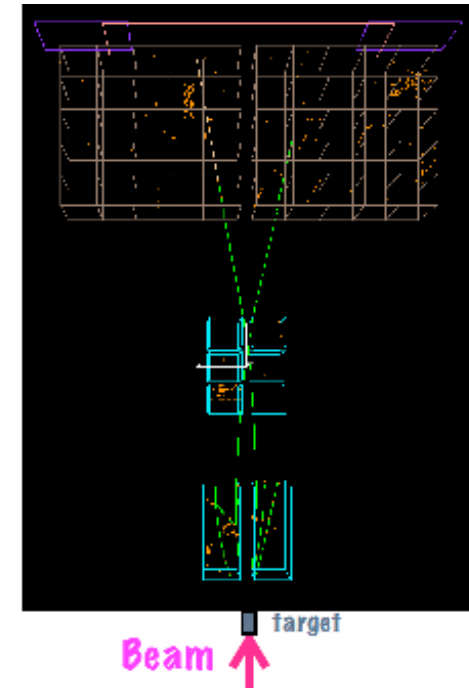
**Photo-sensors for
scintillator detectors
in mass production**

ND280 detector construction status

- All detectors are in production (except for barrel ECAL)
- Overall integration issues being considered
- Installation work will start early in 2009
 - On-axis neutrino monitor (INGRID) will be completed by April 2009, to be ready for ν beam
 - Off-axis detector will be completed by fall 2009 to start data taking in the end of 2009

CERN-SPS NA61: SHINE experiment

- Another effort to constrain the neutrino flux
 - Hadron production measurement (π^\pm , K^\pm)
 - π , K kinematics \rightarrow daughter ν kinematics
 - π/K ratio \rightarrow beam ν_e contamination
- Experimental setup/acceptance:
 - same proton energy (30 GeV) as T2K
 - same target (graphite) as T2K
 - 0.5 – 5 GeV/c, 0 – 250 mrad, relevant to T2K

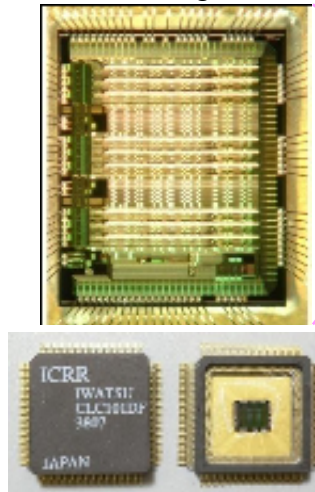


- First data taking in Oct. 2007 (1 month)
 - Thin target (2cm thick, 4% λ): \sim 500k int.
 - Replica target (90cm, 80% λ): \sim 180 k int.
- Data analysis in progress
- Further data taking planned in 2008

Super-Kamiokande upgrade

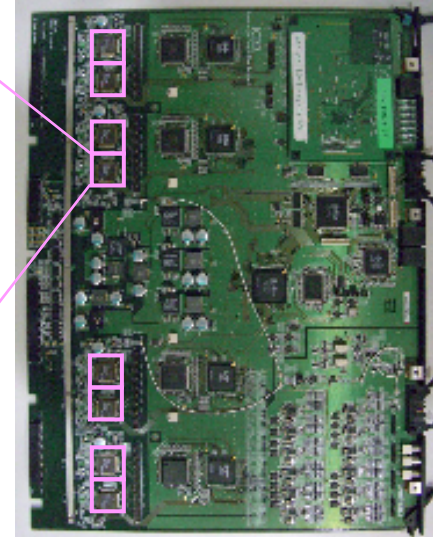


Custom ASIC QTC
3ch x 3 gains



QBEE board:

QTC-based electronics w/ ethernet



- SK fully reconstructed in 2006, 'SK-III' taking data
- Electronics & online DAQ full-upgrade in preparation
 - for high-speed & dead-time-less DAQ, for wider dynamic range
 - electronics (QTC and QBEE) development and production done, being delivered
 - installation in Aug./Sep. 2008
 - will start 'SK-IV' data taking in fall 2008

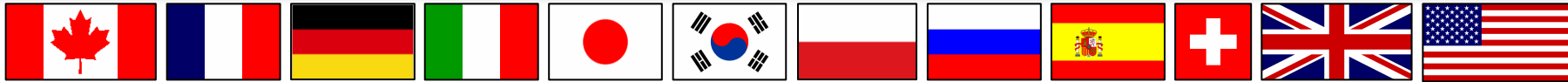
Summary

- The T2K experiment will
 - intensively search for ν_e appearance
 - $\sin^2 2\theta_{13}$ down to ~ 0.008 (90% C.L.)
 - precisely measure ν_μ disappearance
 - $\delta(\sin^2 2\theta_{23}) \sim 0.01$, $\delta(\Delta m^2_{23}) < 10^{-4} \text{ eV}^2$
after 0.75kW x 5yr accumulation
- J-PARC accelerator is now being commissioned
 - LINAC and 3 GeV RCS successfully commissioned
 - Main Ring commissioning started, succeeded to turn beam in MR
 - On schedule
- Construction / preparation / installation works for neutrino beam line are in progress
- ND280 detector aims to address
 - energy spectrum, backgrounds, neutrino interactions
- Detector construction are also in progress

T2K start-up schedule

- Neutrino beam will start in Apr. 2009
- ND280 on-axis detector will be ready for data taking when ν beam starts
- ND280 off-axis detector will be installed by fall 2009 to be ready for data taking

The T2K collaboration



Canada

TRIUMF
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U. British Columbia
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U. Toronto
U. Victoria
York U.

France

CEA Saclay
IPN Lyon
LLR E. Poly
LPNHE Paris

Germany

U. Aachen

Italy

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INFN, U. Napoli
INFN, U. Padova
INFN, U. Bari

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ICRR Kashiwa
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Kyoto U.
Miyagi U.
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