

T2K Experiment 1 – The physics potential and the status of the neutrino beam line –

Masahiro Shibata (KEK) for T2K collaboration

Tokai to Kamioka (T2K) experiment



Super-Kamiokande
(ICRR, Univ. Tokyo)



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



- Long base line (295 km) neutrino oscillation experiment with
 - high intensity proton beam (750 kW) of J-PARC main ring
 - world largest water Cherenkov neutrino detector (Super-Kamiokande)

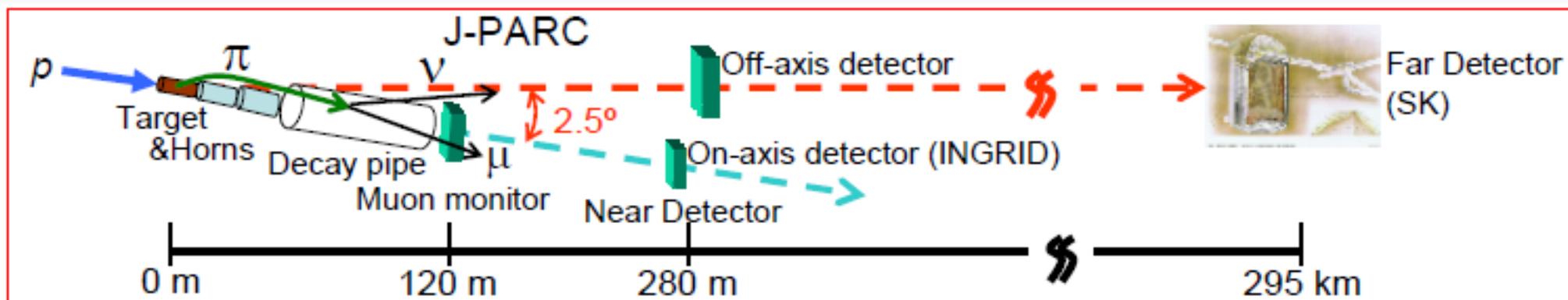
Physics motivation

- ν_μ disappearance
 - precise measurement of θ_{23} and Δm_{23}^2
 - θ_{23} is maximal mixing?
- Direct measurement of ν_e appearance
 - discovery of finite θ_{13}
 - $\theta_{13} \neq 0 \rightarrow$ CP violation measurement in the future

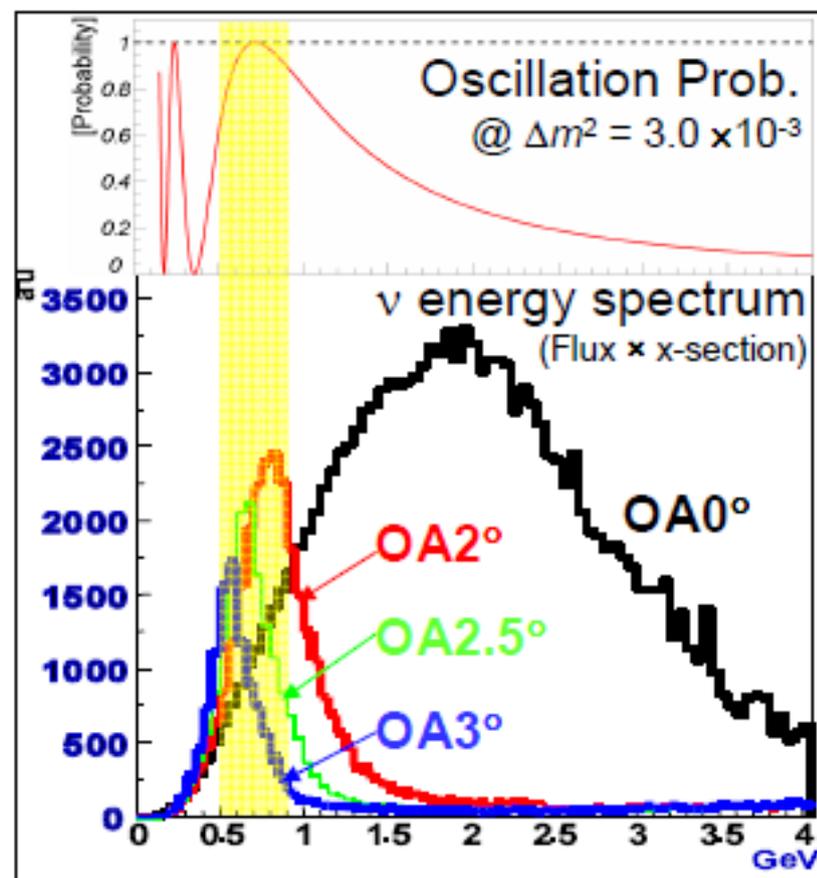
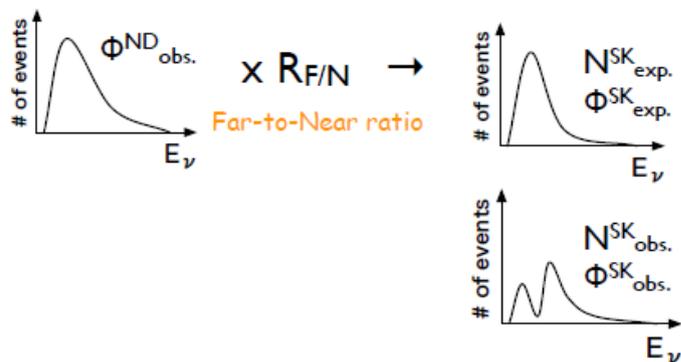
\Rightarrow to conclude for neutrino flavor mixing
to find how matter dominated universe was made

$$\begin{pmatrix} \nu_e \\ \nu_\mu \\ \nu_\tau \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos\theta_{23} & \sin\theta_{23} \\ 0 & -\sin\theta_{23} & \cos\theta_{23} \end{pmatrix} \begin{pmatrix} \cos\theta_{13} & 0 & \sin\theta_{13}e^{-i\delta} \\ 0 & 1 & 0 \\ -\sin\theta_{13}e^{-i\delta} & 0 & \cos\theta_{13} \end{pmatrix} \begin{pmatrix} \cos\theta_{12} & \sin\theta_{12} & 0 \\ -\sin\theta_{12} & \cos\theta_{12} & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} \nu_1 \\ \nu_2 \\ \nu_3 \end{pmatrix}$$

Outline of T2K experiment



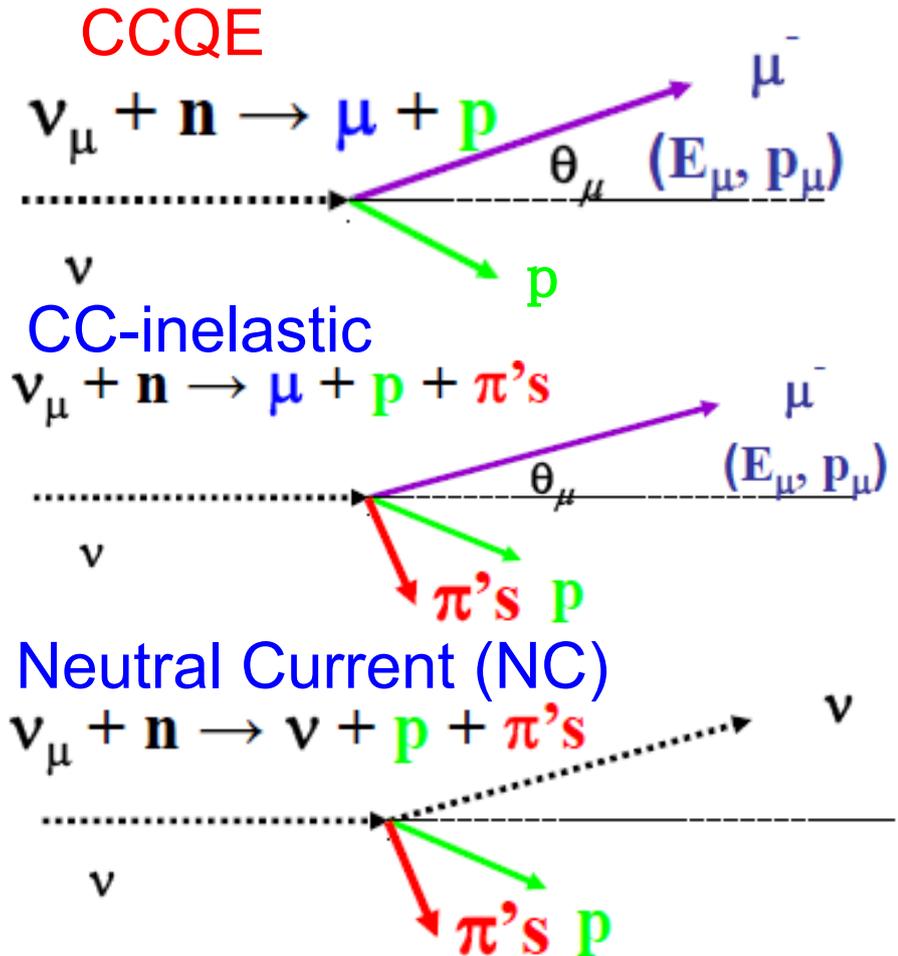
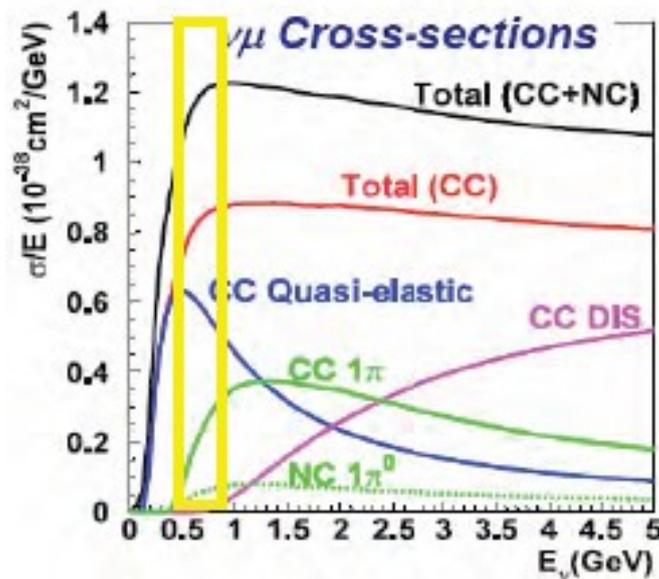
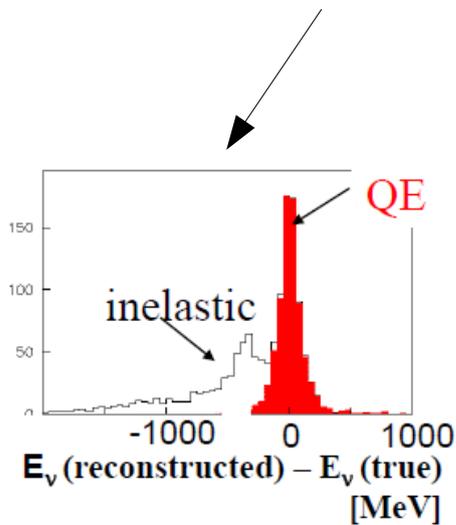
1. Produce narrow band intense ν beam
2. Measure neutrino flux at ND ($\Phi_{\text{obs}}^{\text{ND}}$) and FD ($\Phi_{\text{obs}}^{\text{SK}}$)
3. Estimate neutrino flux at FD ($\Phi_{\text{exp}}^{\text{SK}}$) from $\Phi_{\text{obs}}^{\text{ND}}$
4. Compare $\Phi_{\text{exp}}^{\text{SK}}$ and $\Phi_{\text{obs}}^{\text{SK}}$
 \Rightarrow derive oscillation parameters ($\theta, \Delta m^2$)



Neutrino energy reconstruction

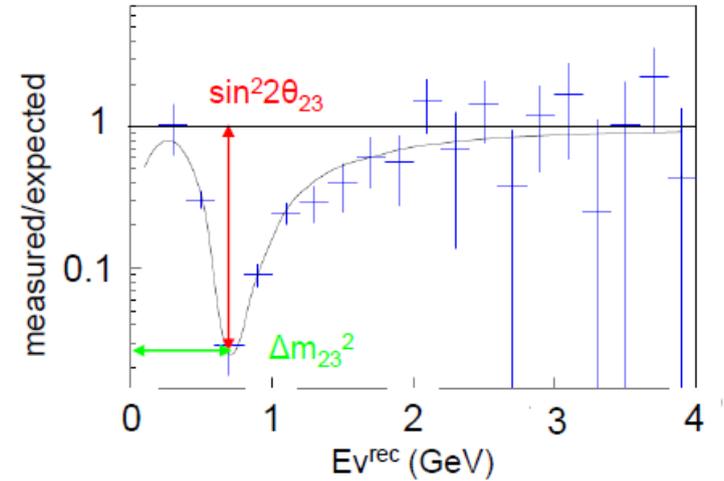
- Interaction with nucleon in detector material is utilized.
- Neutrino energy is derived from **Charge Current Quasi Elastic scattering (CCQE)**.

$$E_{\nu}^{\text{rec}} = \frac{m_N E_{\mu} - m_{\mu}^2 / 2}{m_N - E_{\mu} + p_{\mu} \cos \theta_{\mu}}$$



Goal: ν_μ disappearance

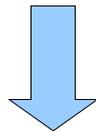
$$P(\nu_\mu \rightarrow \nu_\tau) \approx \sin^2\left(\frac{1.27 L}{E}\right)$$



SK, K2K, MINOS

$$\sin^2 2\theta_{23} > 0.92$$

$$|\Delta m^2_{23}| = 2.3 \sim 3.0 \times 10^{-3} \text{ eV}^2$$



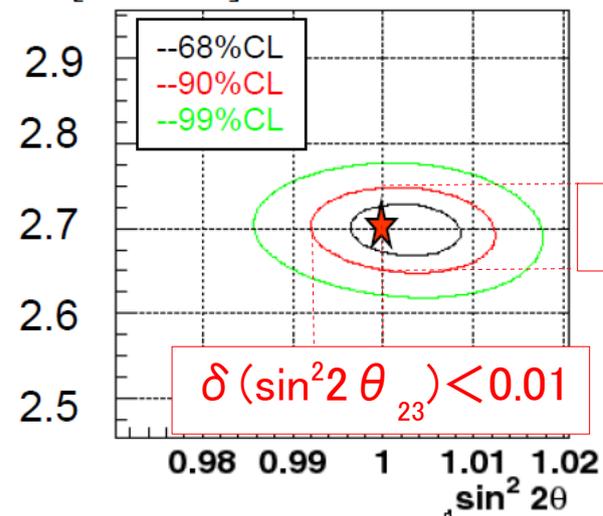
T2K goal

$$\delta(\sin^2 2\theta_{23}) < 0.01$$

$$\delta(\Delta m^2_{23}) < 10^{-4} \text{ eV}^2$$

@ 90% C.L.

$\Delta m^2 [10^{-3} \text{ eV}^2]$ $5 \times 10^{21} \text{ POT}$



$$\delta(\Delta m^2_{23}) < 10^{-4} \text{ eV}^2$$

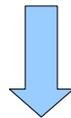
$$\delta(\sin^2 2\theta_{23}) < 0.01$$

(stat. error only)

Goal: ν_e appearance

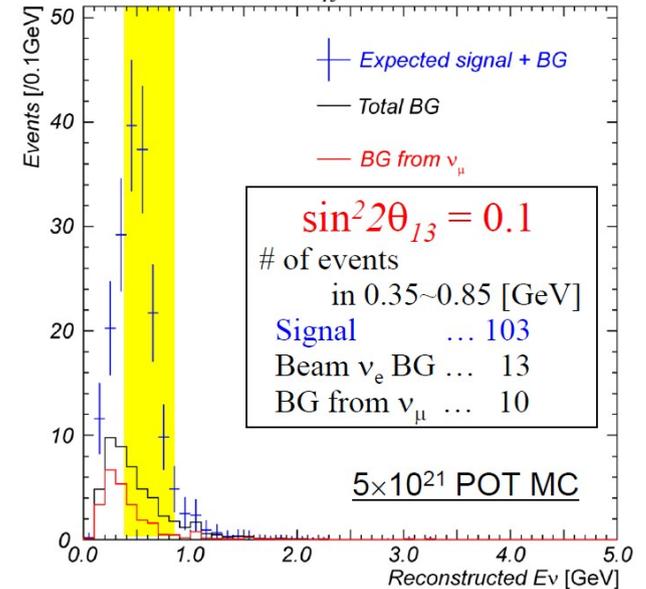
$$P(\nu_\mu \rightarrow \nu_e) \approx \sin^2 2\theta_{23} \sin^2 \left(\frac{1.27 \Delta m_{31}^2 L}{E} \right)$$

- CHOOZ
 $\sin^2 2\theta_{13} < 0.19$
- MINOS
 (FNAL W&C Seminar 27/Feb/2009)
 observed: 35 events
 expected BG: $27 \pm 5 \pm 2$ events
 $\sin^2 2\theta_{13} < 0.24$

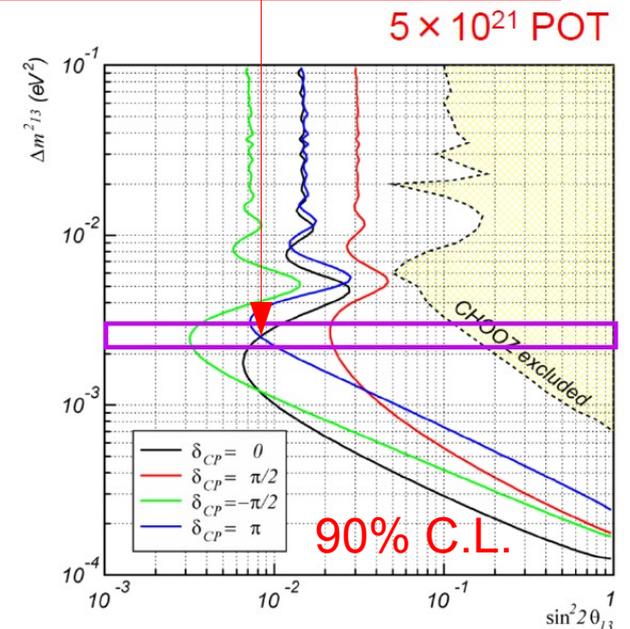


T2K goal
 $\sin^2 2\theta_{13} \sim 0.008$ ($\delta = 0, \pi$)
 @ 90% C.L.

ν_e @ SK ($\sin^2 2\theta_{13} = 0.1, \Delta m^2 = 2.5 \times 10^{-3}$)

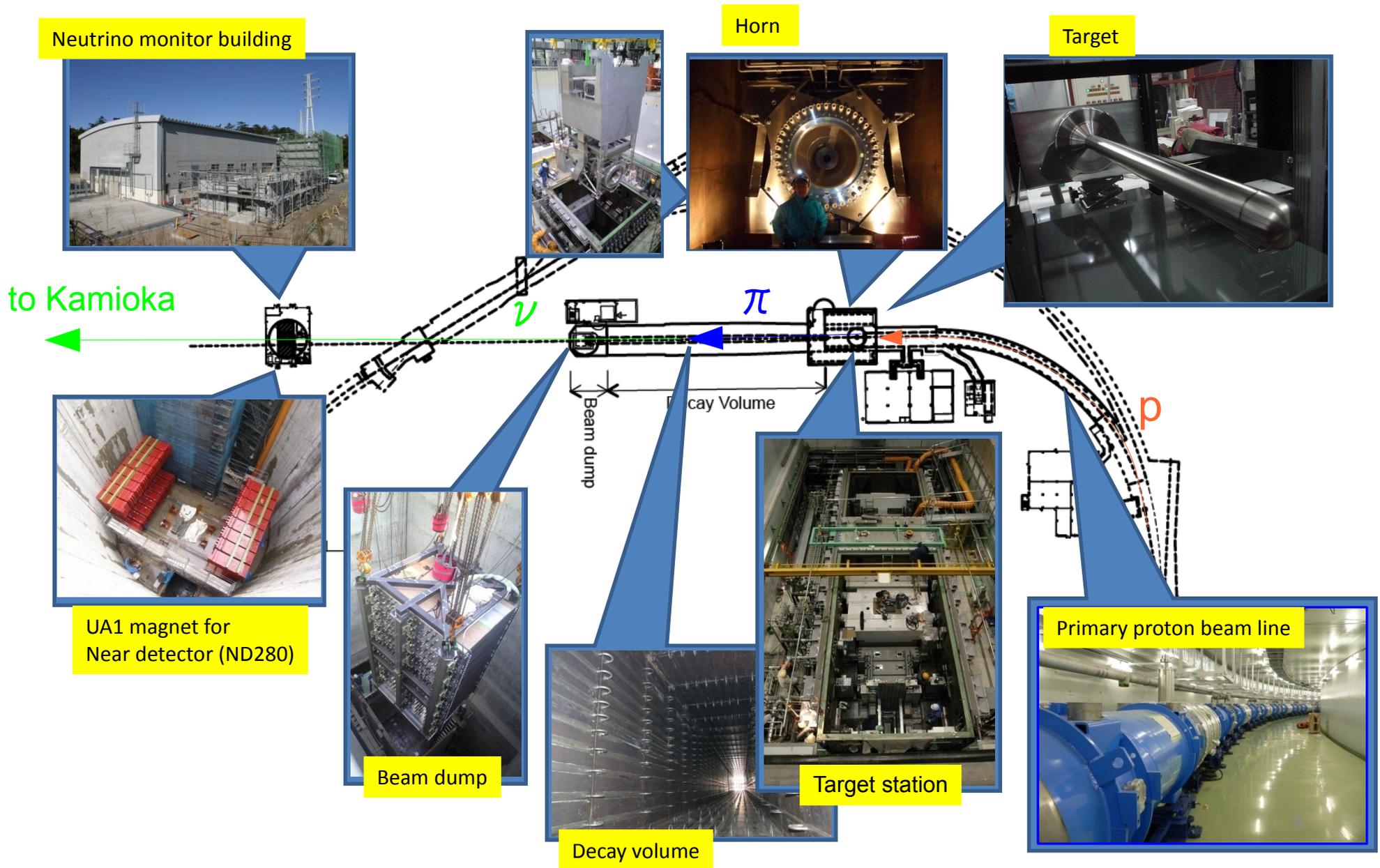


$\sin^2 2\theta_{13} \sim 0.008$ ($\delta = 0, \pi$)

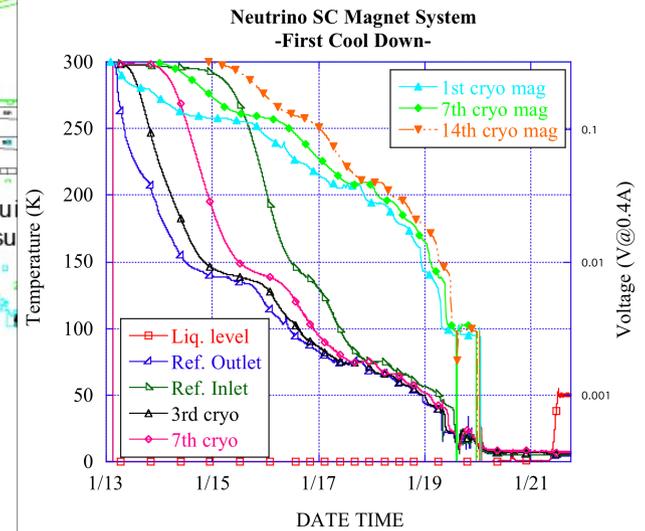
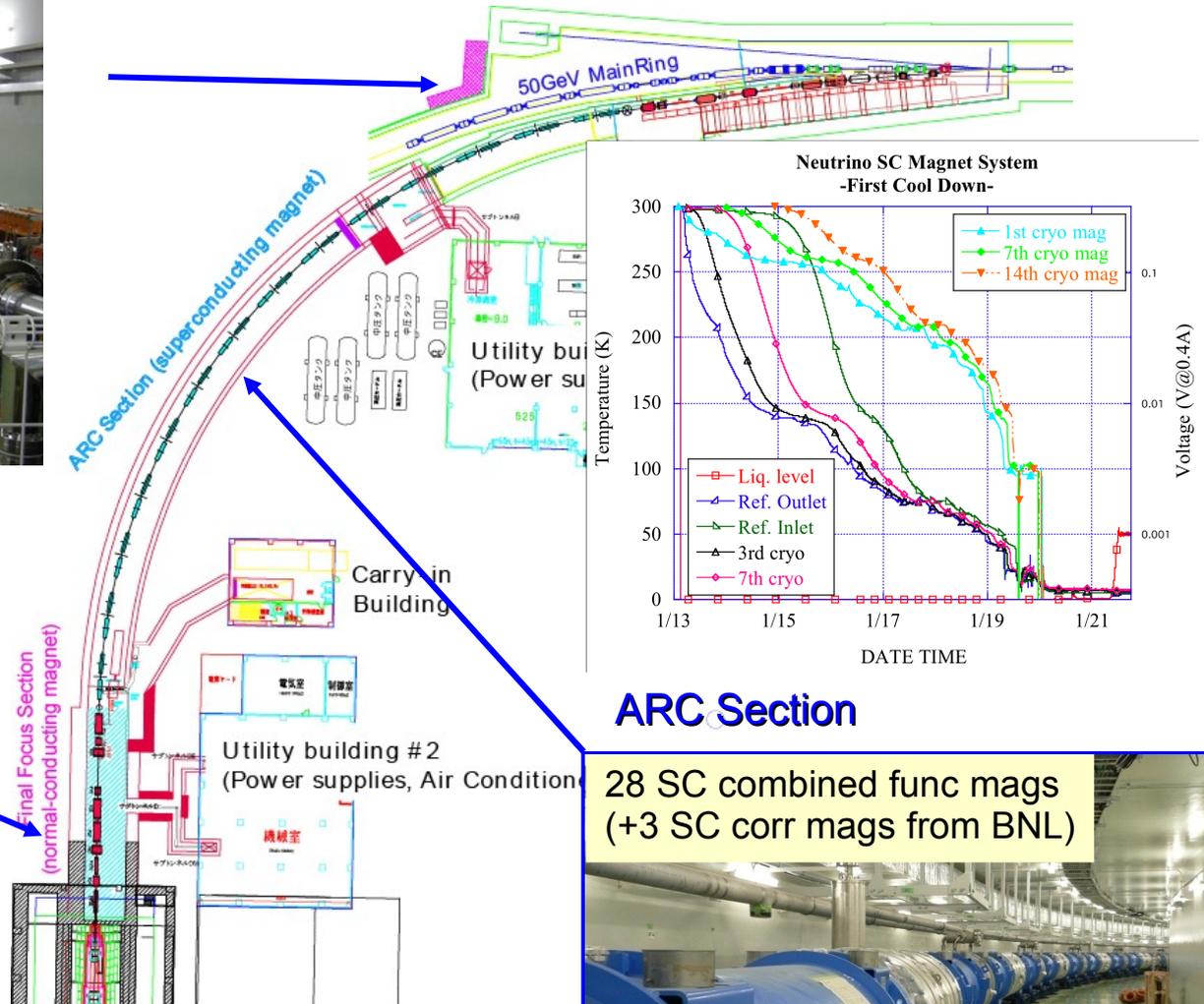


Current status of the neutrino beam line

Outline of neutrino beam line



Primary beam line



ARC Section



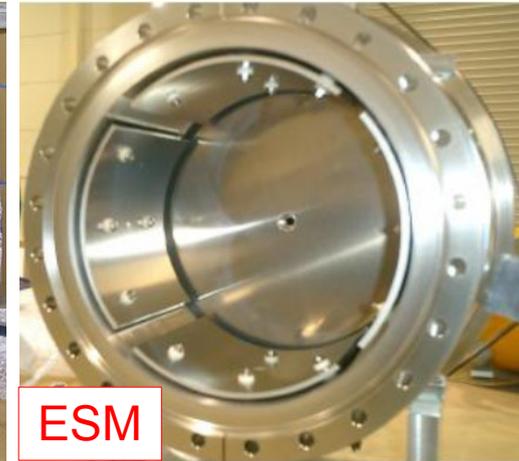
- All mags installed
- SC mags cooled down
- Successfully operated

Proton beam monitors

- Intensity monitor: current transformer (CT)
- Position monitor: electro static monitor (ESM)
- Profile monitor:
segmented secondary emission monitor (SSEM)
optical transition radiation monitor (OTR)
- Beam loss monitor (BLM): ionization chamber



CT

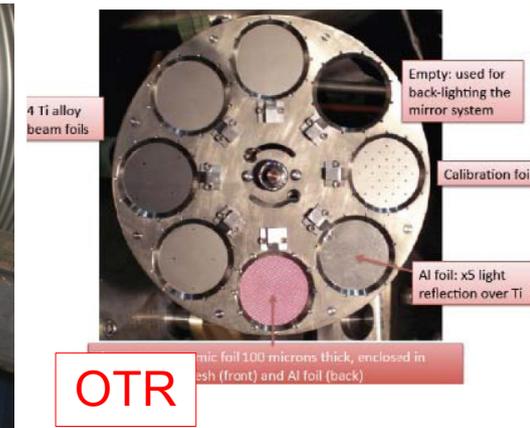


ESM

- All monitors (except few) were installed.
- Operation test was done during MR commissioning. (except OTR)
- First signal was measured by BLM.

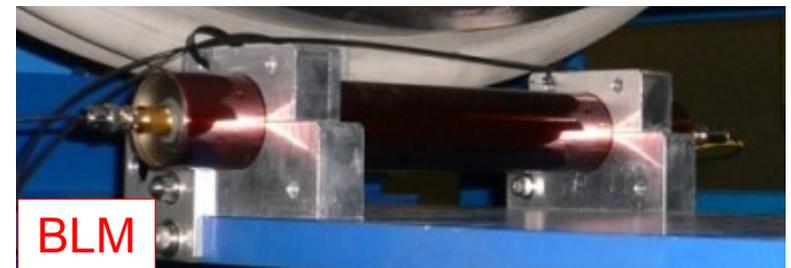
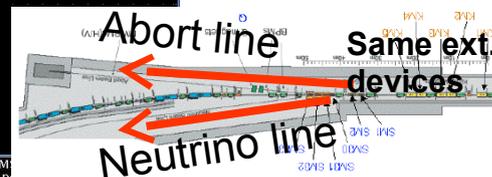


SSEM



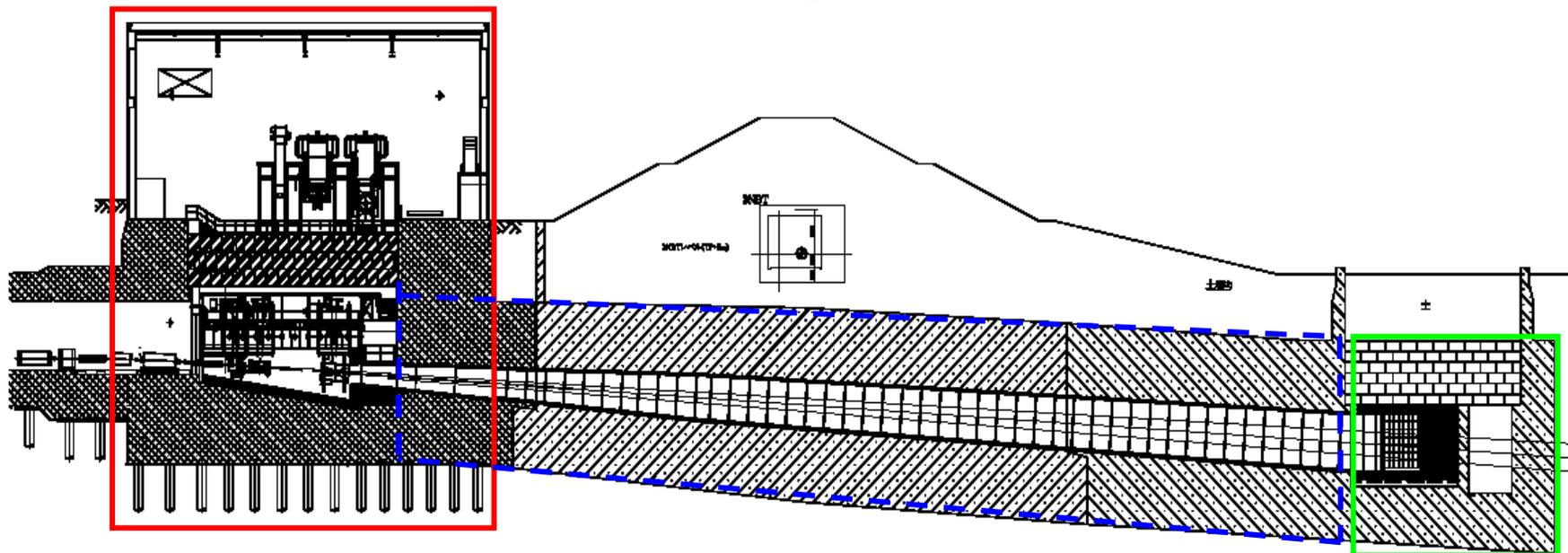
OTR

4 Ti alloy beam foils
Empty: used for back-lighting the mirror system
Calibration foil
Al foil: x5 light reflection over Ti
mic foil 100 microns thick, enclosed in mesh (front) and Al foil (back)



BLM

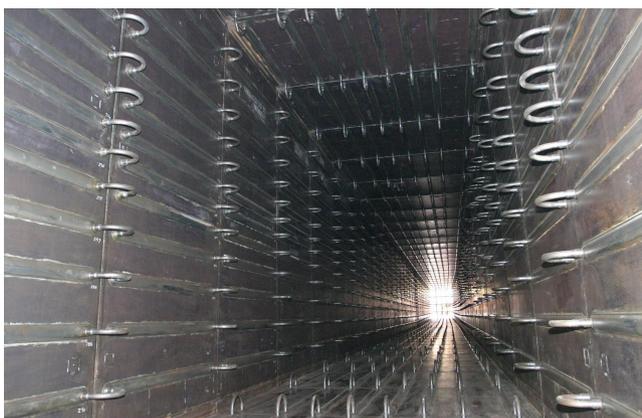
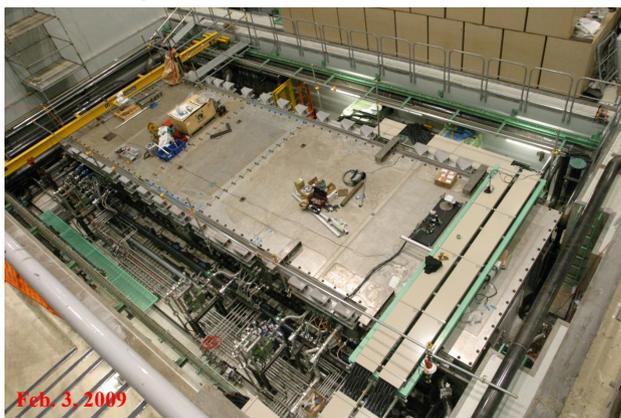
Secondary beam line



Target station (TS)

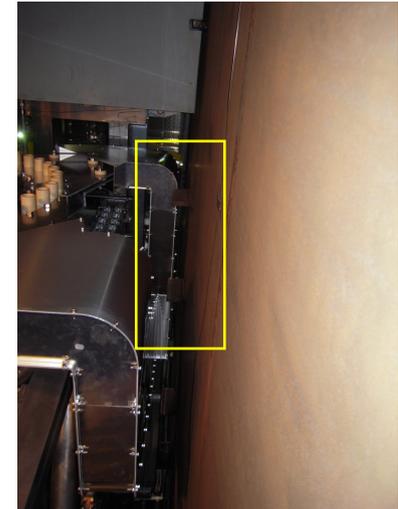
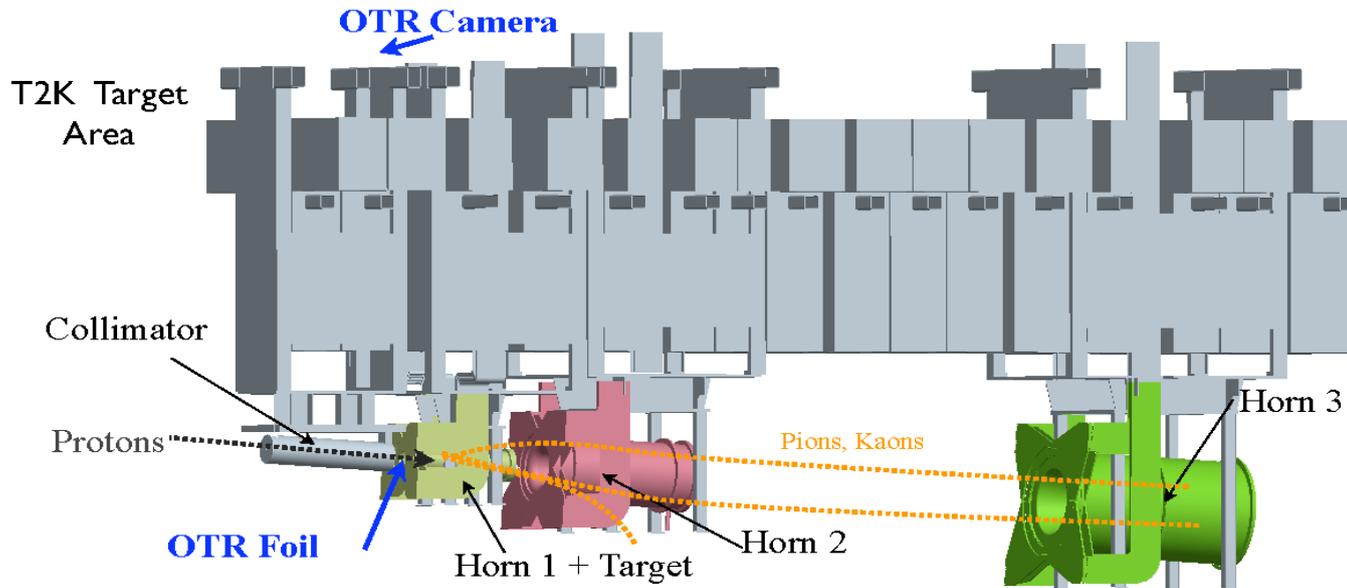
Decay volume (DV)

Beam dump (BD)

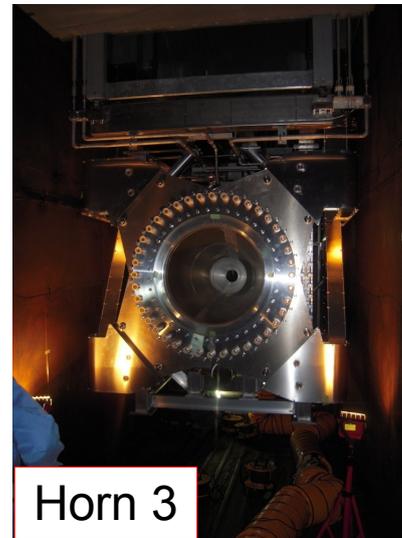
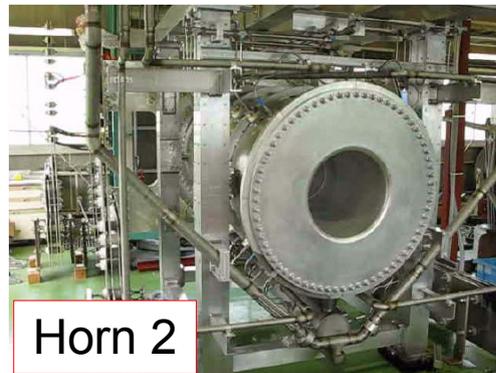
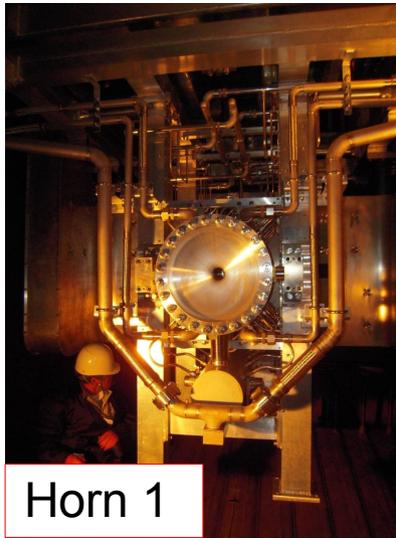


- Most components have been installed. (except horn2,3)
- Vacuum test of the He chamber was successfully finished.
- Installation of ceiling concrete blocks on TS & BD is on going.

Target and horns



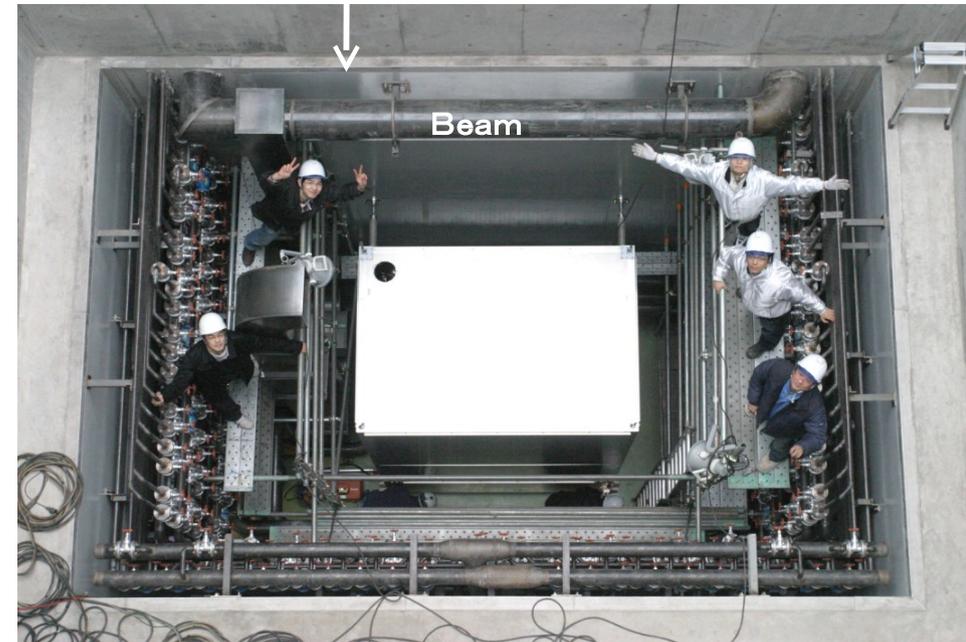
- Target & Horn 1 were installed.
- Interference between Horn 2,3 & He chamber was found.
- **2 months delay was foreseen for modification.**
- **decide operation with target & Horn 1 only from Apr.**
- Horn 2, 3 will be installed during summer shutdown.
- **No actual impact on overall T2K schedule.**



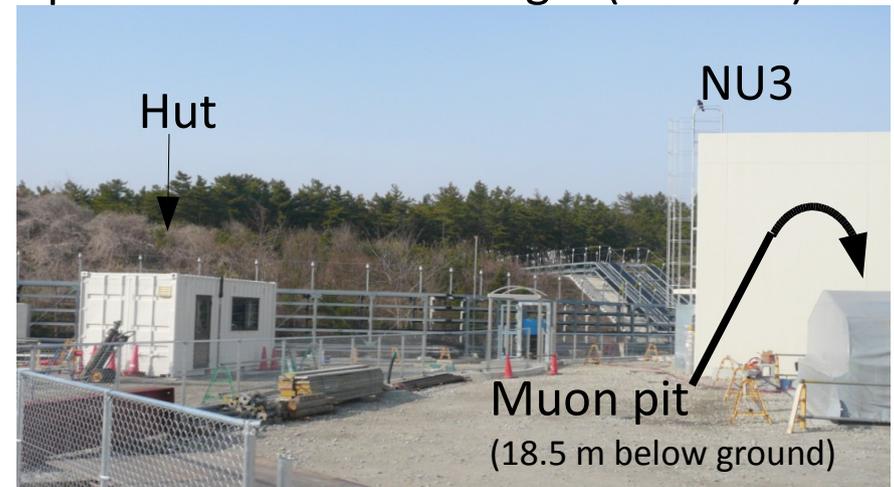
Muon monitor

Installed the support structure into the muon pit. (2/13)

Installed all 7 ionization chambers and 49 silicon PIN photodiodes.



- Readout electronics is installed in Hut.
- Cabling / gas-piping is also finished.
- Measured noise-level during MR operation is small enough. ($\pm 0.5\text{mV}$)



Chamber



Silicon

Achieved alignment precision of 1 mm.

Schedule

Apr. ~ May 2009

- First beam commissioning with target and Horn 1
- 0.1 % beam intensity (4×10^{11} p/pulse, single shot operation)
- Extract and transport the proton beam to the target
- Observe muon monitor signal to confirm neutrino production and focusing to Kamioka direction

June ~ Sept. 2009

- Install Horn 2 and Horn 3

Oct. ~ Nov. 2009

- Beam commissioning with full setup

Dec. 2009 ~ June 2010

- After 100kW stable operation of accelerator is achieved
- Physics run $100\text{kW} \times 10^7\text{s} \sim 10^{20}$ POT
- **First physics result in 2010**

Summary

- T2K experiment
 - Long base line (295km) neutrino oscillation observation
 - Narrow band high intensity neutrino beam from J-PARC
- Physics goal (with 5×10^{21} POT)
 - ν_{μ} disappearance: $\delta(\sin^2 \theta_{23}) < 0.01$, $\delta(\Delta m_{23}^2) < 10^{-4} \text{ eV}^2$
 - ν_e appearance: $\sin^2 \theta_{13} \sim 0.008$
- Beam line status
 - Beam line construction is almost completed.
 - First commissioning will start from April with target & Horn 1 configuration.
 - Horn 2 & Horn 3 will be installed during summer shutdown.
 - Full setup commissioning will start in October 2009.
 - **First physics result in 2010.**