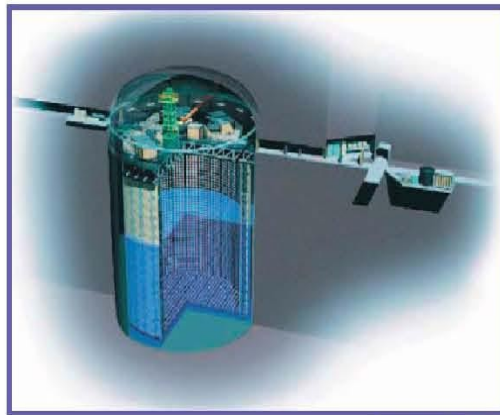


T2K Experiment 1 – The physics potential and the  
status of the neutrino beam line –

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)

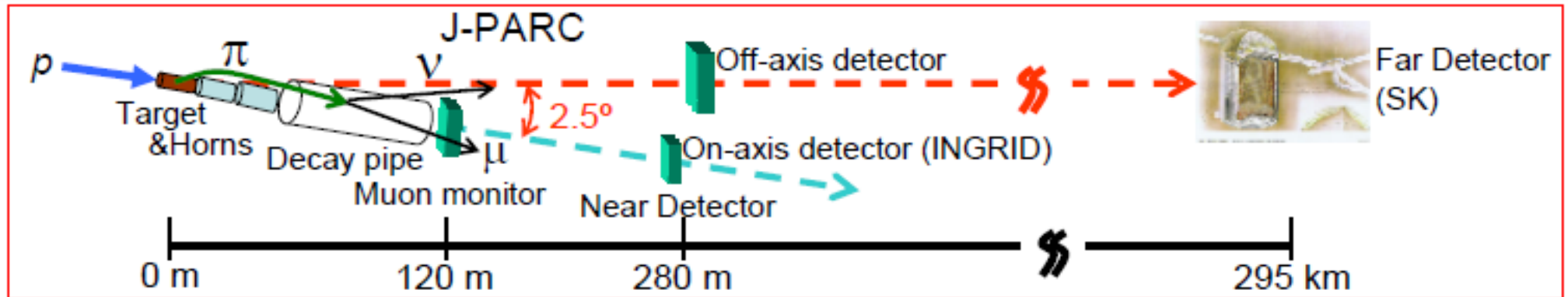
# Physics motivation

- $\nu_\mu$  disappearance
  - precise measurement of  $\theta_{23}$  and  $\Delta m_{23}^2$
  - $\theta_{23}$  is maximal mixing?
- Direct measurement of  $\nu_e$  appearance
  - discovery of finite  $\theta_{13}$
  - $\theta_{13} \neq 0 \rightarrow$  CP violation measurement in the future

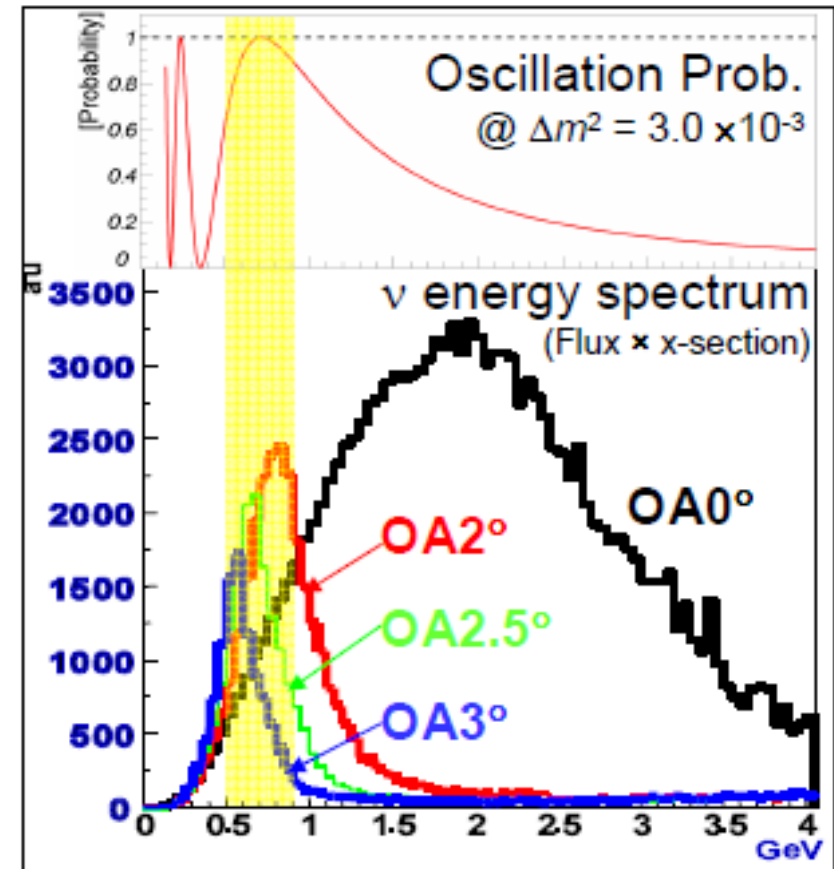
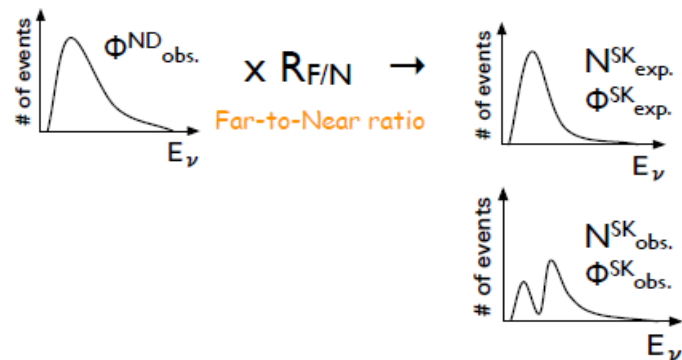
$\Rightarrow$  to conclude for neutrino flavor mixing  
to find how matter dominated universe was made

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

# Outline of T2K experiment



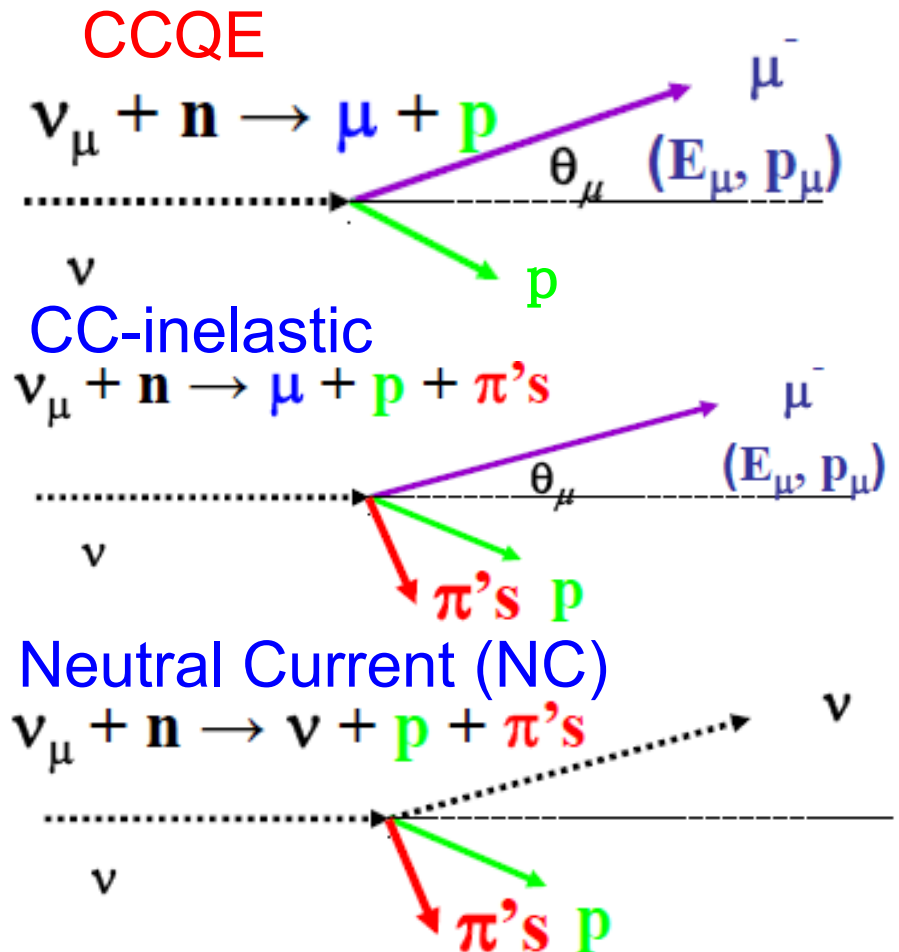
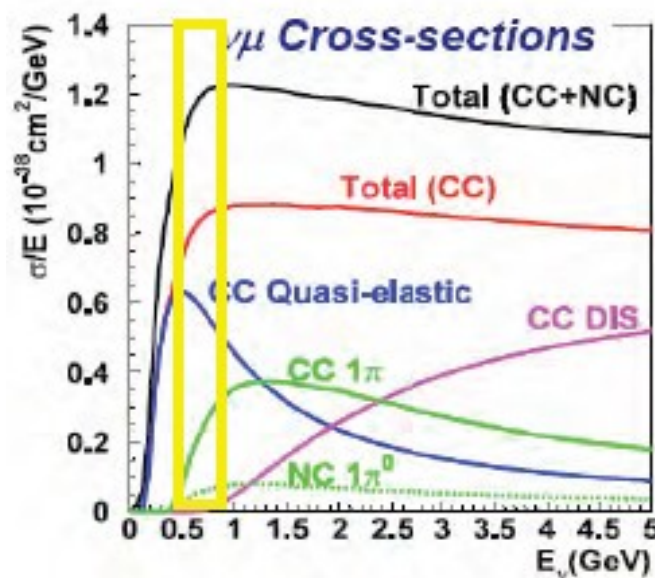
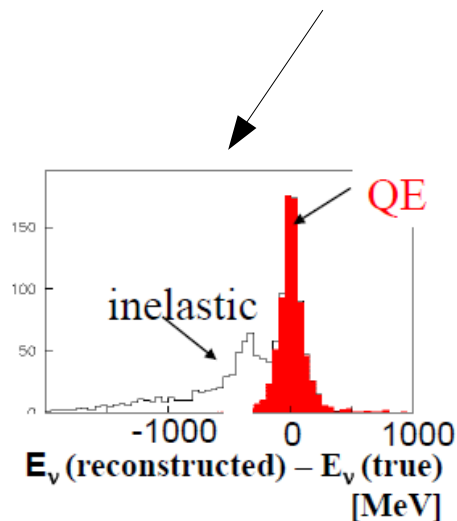
1. Produce narrow band intense  $\nu$  beam
2. Measure neutrino flux at ND ( $\Phi_{\text{obs}}^{\text{ND}}$ ) and FD ( $\Phi_{\text{obs}}^{\text{SK}}$ )
3. Estimate neutrino flux at FD ( $\Phi_{\text{exp}}^{\text{SK}}$ ) from  $\Phi_{\text{obs}}^{\text{ND}}$
4. Compare  $\Phi_{\text{exp}}^{\text{SK}}$  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)**.

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



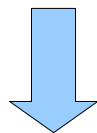
# Goal: $\nu_\mu$ disappearance

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

SK, K2K, MINOS

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

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

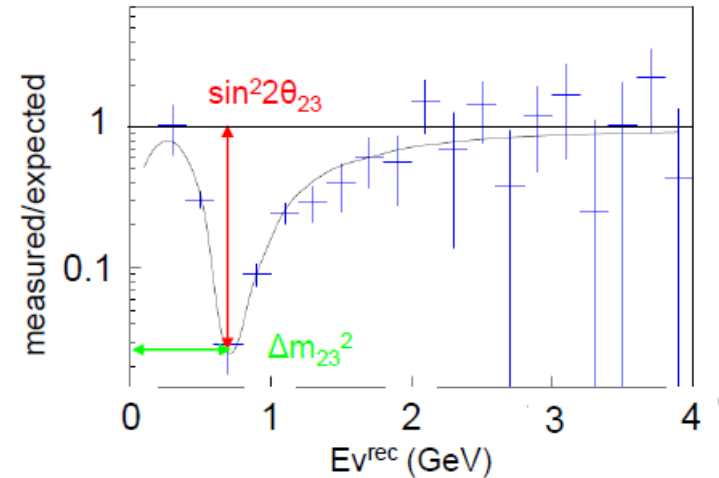


T2K goal

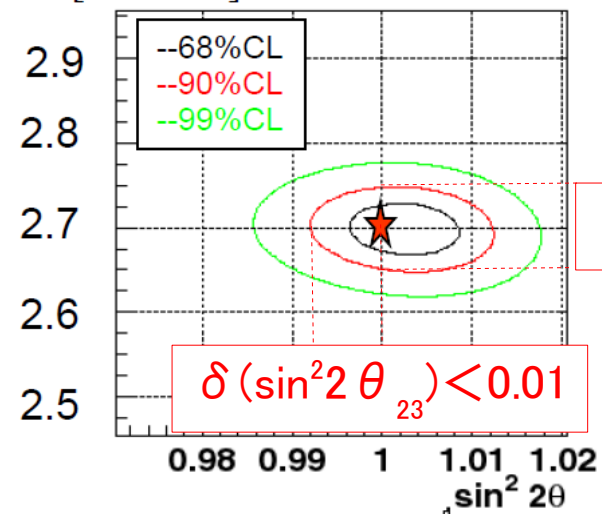
$$\delta(\sin^2 2\theta_{23}) < 0.01$$

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

@ 90% C.L.



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



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

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

(stat. error only)

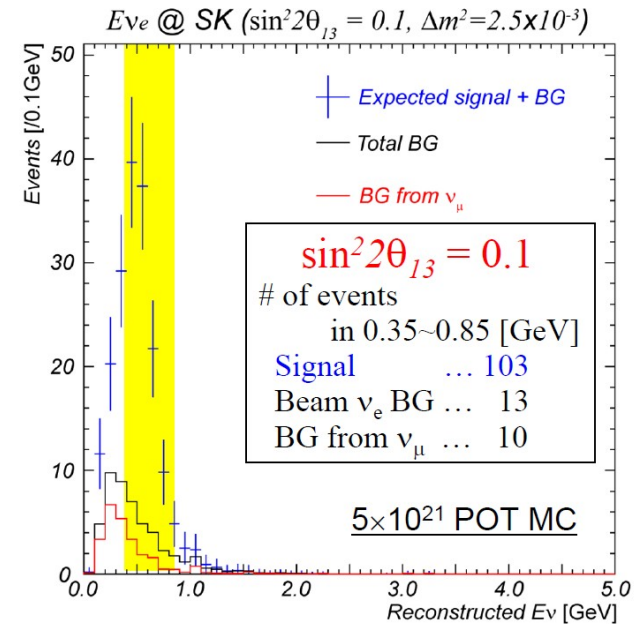
# Goal: $\nu_e$ appearance

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

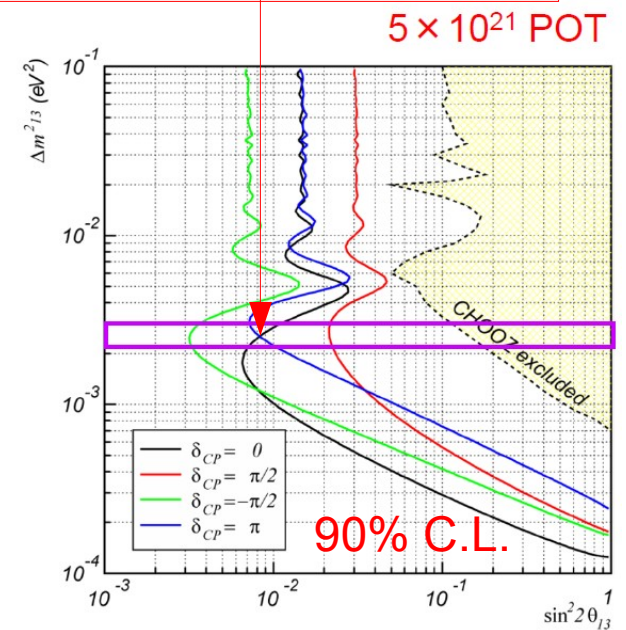
- CHOOZ  
 $\sin^2 2\theta_{13} < 0.19$
- MINOS  
 (FNAL W&C Seminar 27/Feb/2009)  
 observed: 35 events  
 expected BG:  $27 \pm 5 \pm 2$  events  
 $\sin^2 2\theta_{13} < 0.24$



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

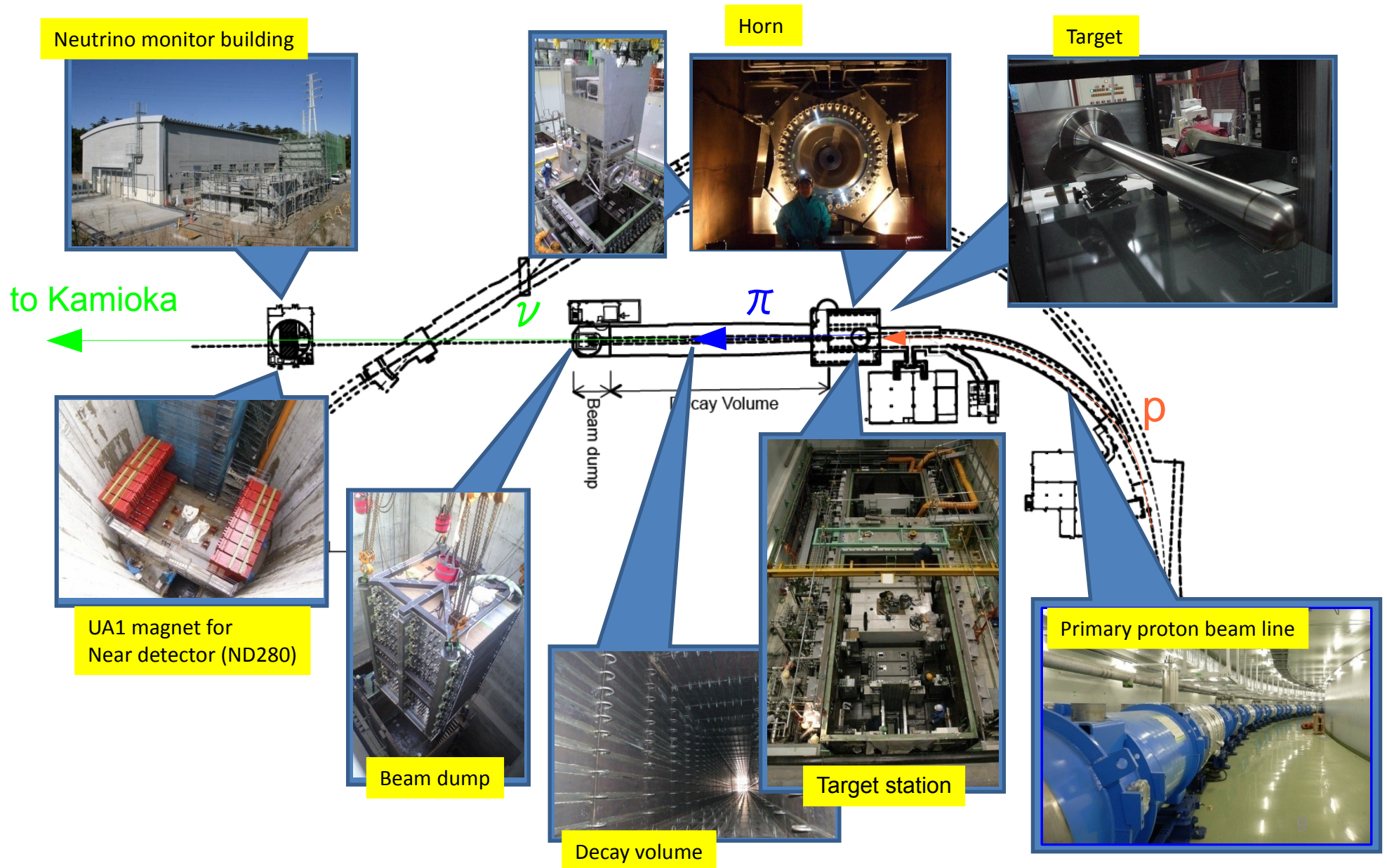


$$\sin^2 2\theta_{13} \sim 0.008 \quad (\delta = 0, \pi)$$

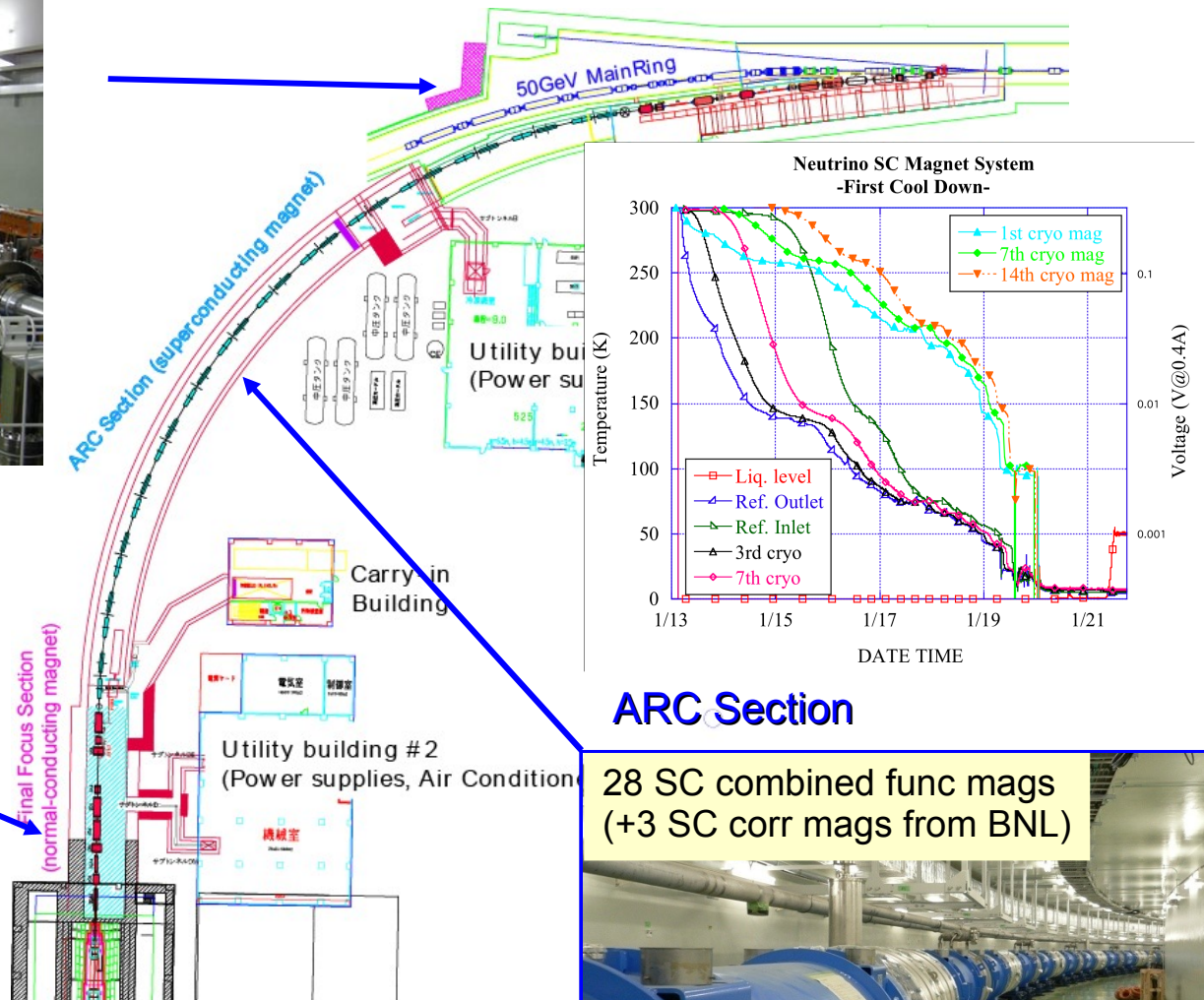


Current status of the neutrino beam line

# Outline of neutrino beam line



# Primary beam line



## ARC Section

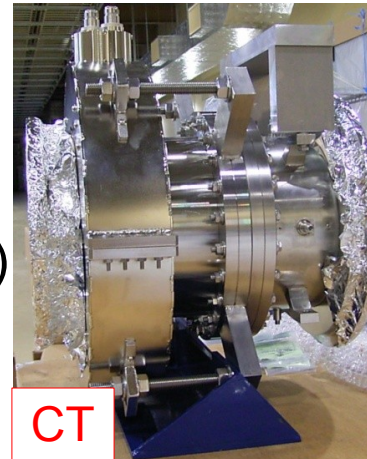
28 SC combined func mags  
(+3 SC corr mags from BNL)



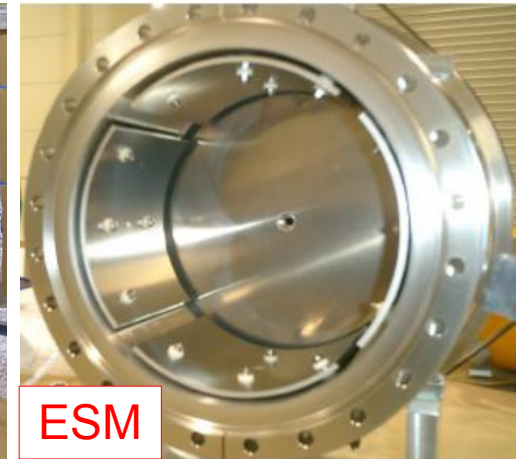
- All mags installed
- SC mags cooled down
- Successfully operated

# 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

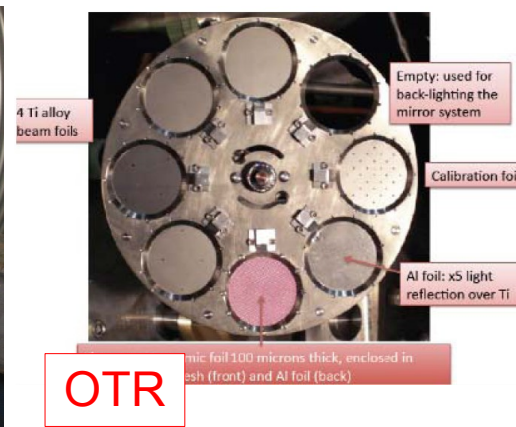


ESM

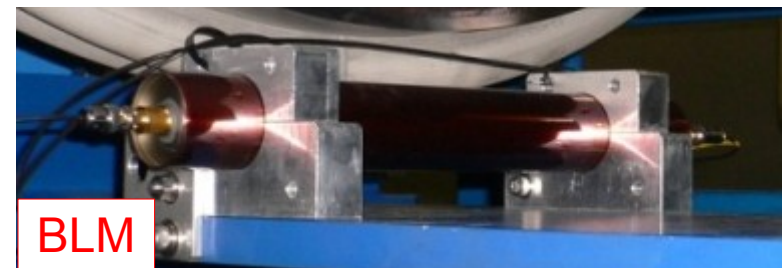
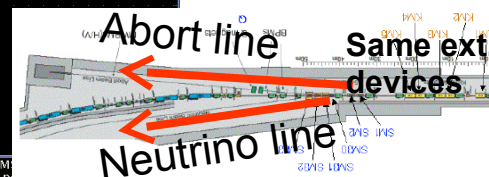
- All monitors (except few) were installed.
- Operation test was done during MR commissioning. (except OTR)
- First signal was measured by BLM.



SSEM

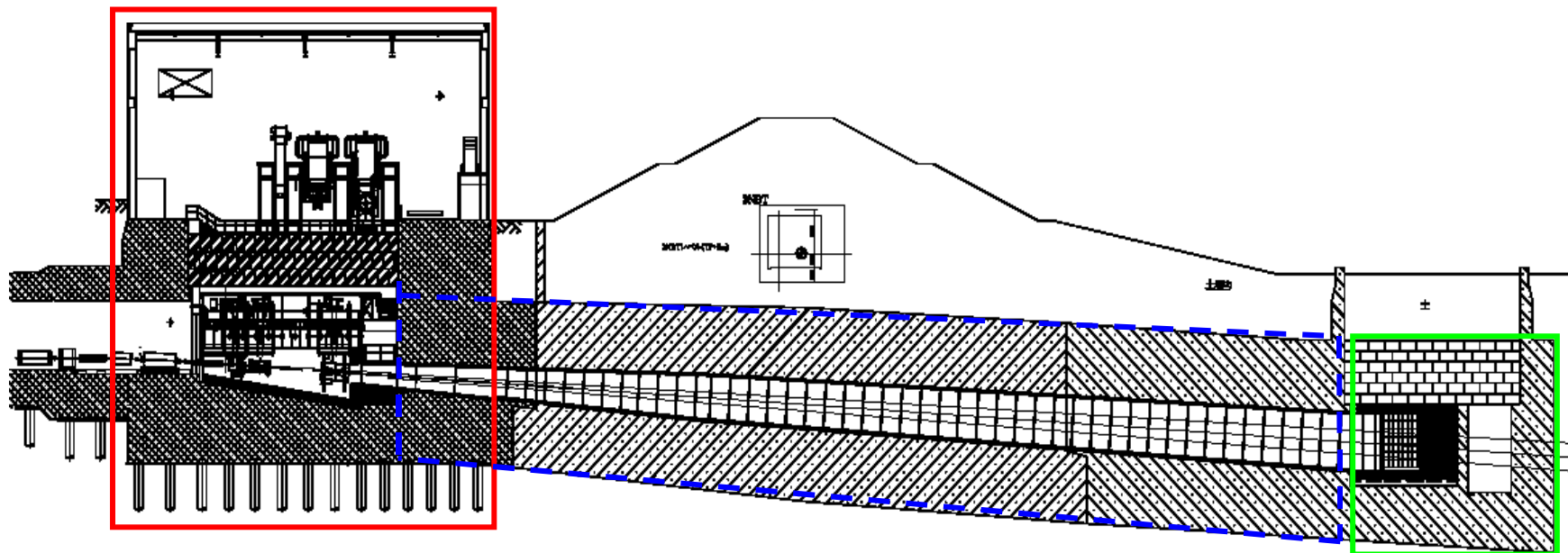


OTR



BLM

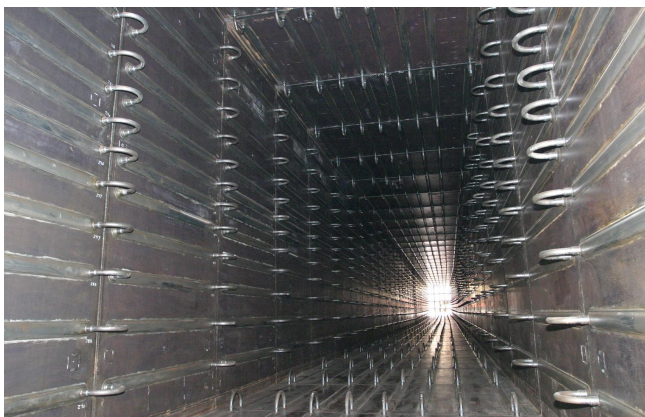
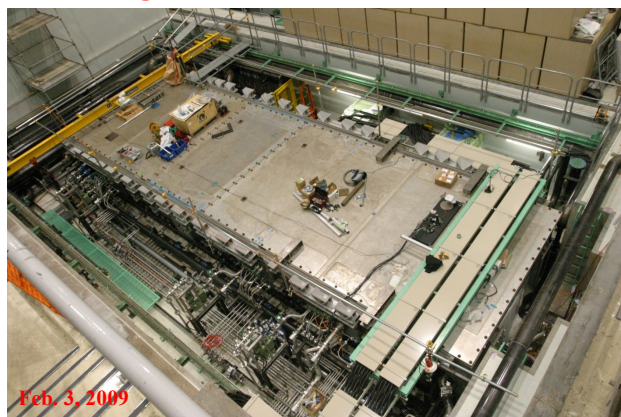
# Secondary beam line



Target station (TS)

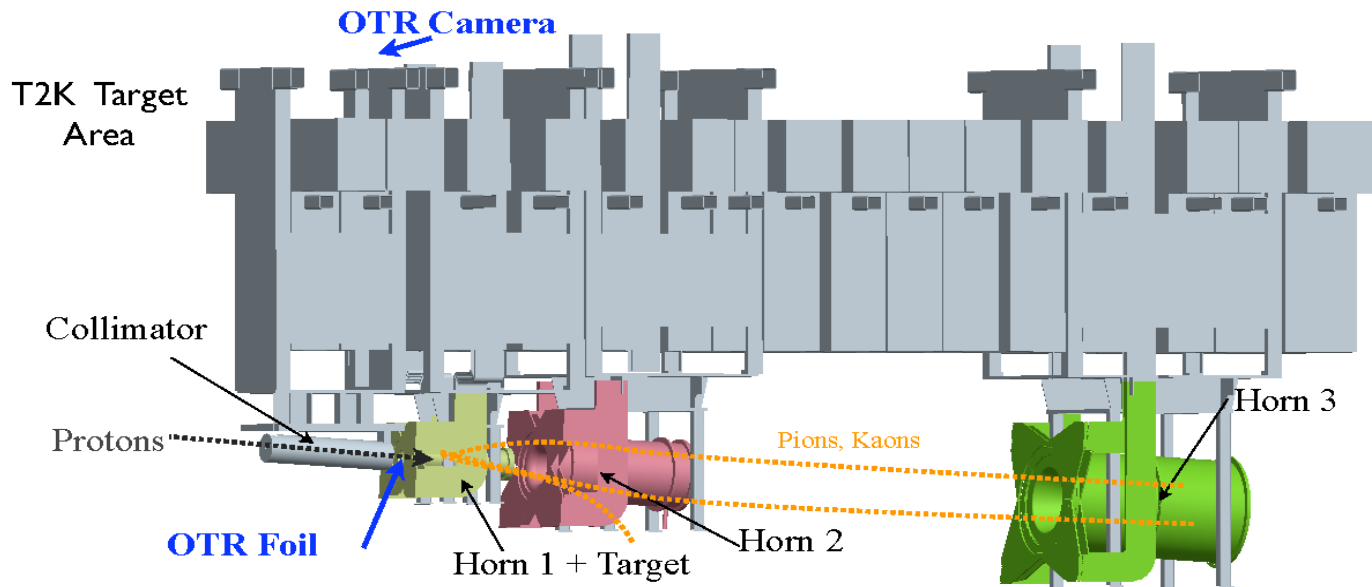
Decay volume (DV)

Beam dump (BD)

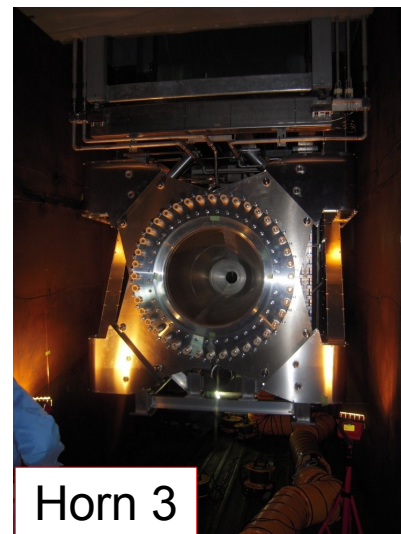
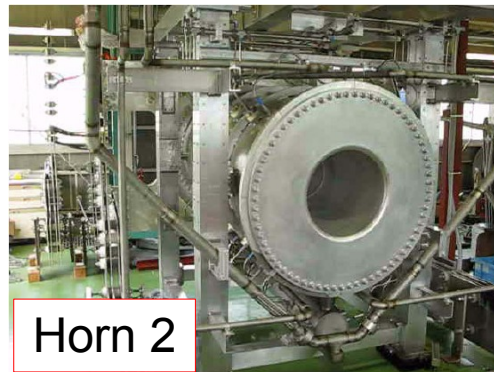
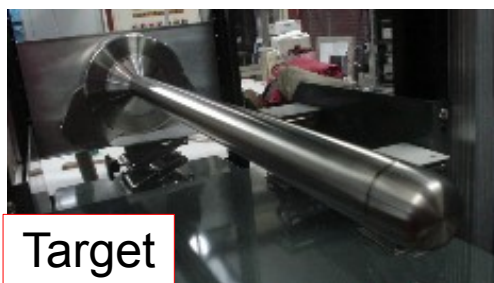
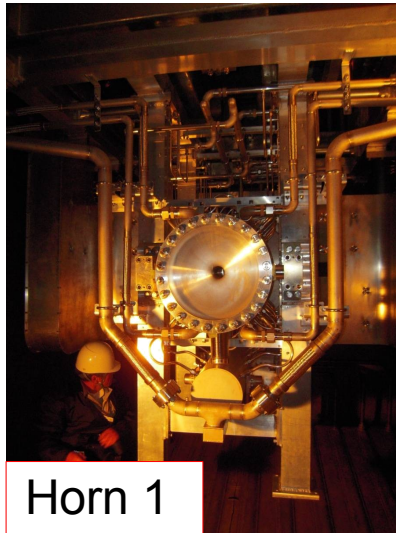


- Most components have been installed. (except horn2,3)
- Vacuum test of the He chamber was successfully finished.
- Installation of ceiling concrete blocks on TS & BD is on going.

# Target and horns



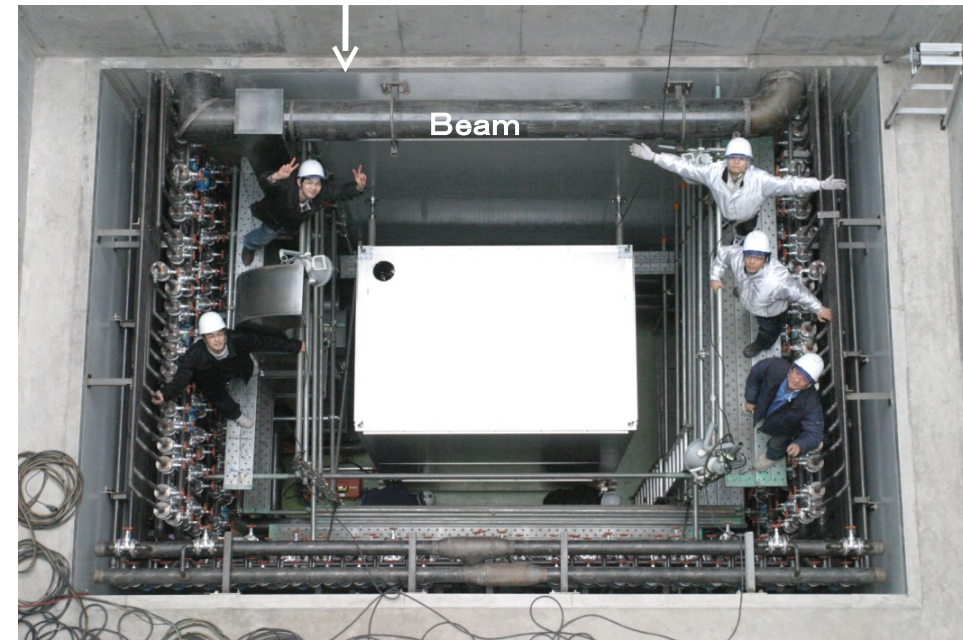
- Target & Horn 1 were installed.
- Interference between Horn 2,3 & He chamber was found.
- 2 months delay was foreseen for modification.
- decide operation with target & Horn 1 only from Apr.
- Horn 2, 3 will be installed during summer shutdown.
- No actual impact on overall T2K schedule.



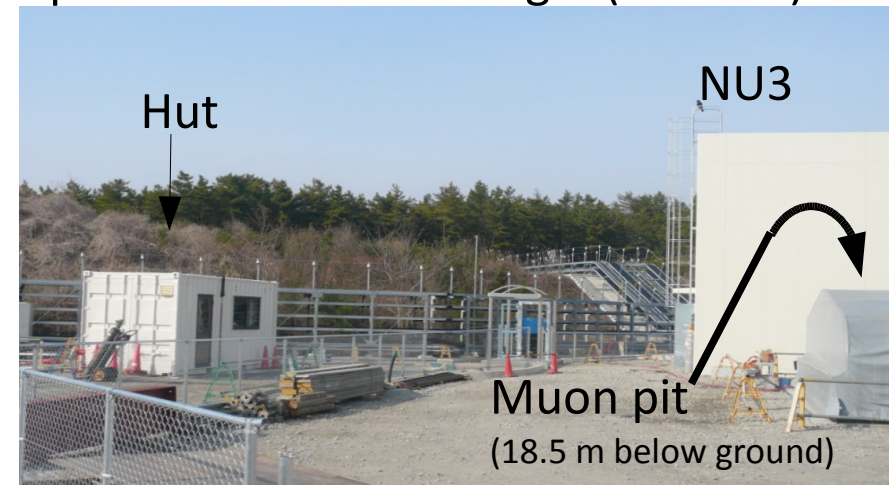
# Muon monitor

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 ( $4 \times 10^{11}$  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  $5 \times 10^{21}$  POT)
  - $\nu_{\mu}$  disappearance:  $\delta(\sin^2 \theta_{23}) < 0.01, \delta(\Delta m_{23}^2) < 10^{-4} \text{ eV}^2$
  - $\nu_e$  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.**