

# Status of J-PARC Neutrino Project T2K (Tokai-to-Kamioka)

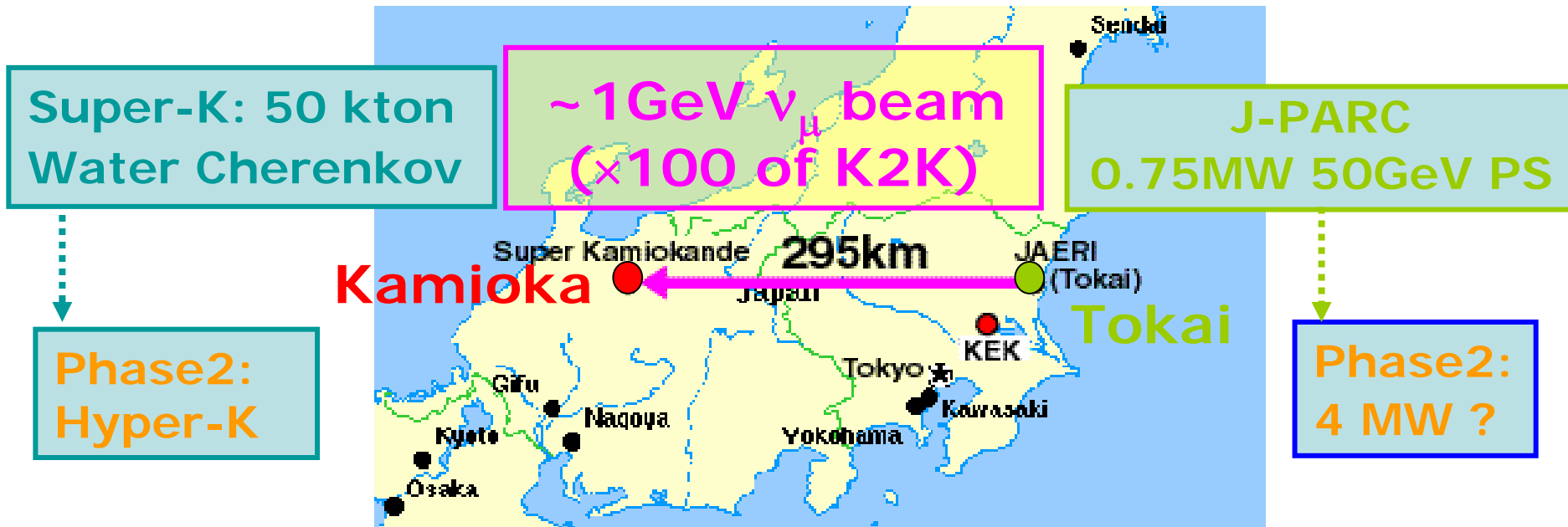
Takashi Kobayashi  
(KEK)

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1. Introduction of T2K experiment
2. Sensitivities
3. Status of Construction
4. Summary

# T2K experiment

Long baseline neutrino oscillation experiment  
from Tokai to Kamioka.



## Physics goals

- Discovery of  $\nu_{\mu} \rightarrow \nu_e$  appearance
- Precise meas. of disappearance  $\nu_{\mu} \rightarrow \nu_x$
- Discovery of CP violation (Phase 2)

# T2K collaboration



- Formed in May 2003
- 12 countries, 53 institutions  
~ 150 collaborators
- Spokesperson: K.Nishikawa

**Canada:** TRIUMF, U. Alberta, York U., U. Toronto, U. Victoria, U. Regina

**China:** IHEP (Inst. Of High Energy Phys.)

**France:** CEA Saclay

**Italy:** U. Roma, U. Bari, U. Napoli, U. Padova

**Japan:** ICRR, U. Tokyo, KEK, Tohoku U., Hiroshima U., Kyoto U., Kobe U., Osaka City U.,  
U. Tokyo, Miyagi U. of Education

**Korea:** Seoul National U., Chonnam National U., Dongshin U., Kangwon U.,  
Kyungpook National U., KyungSang National U., SungKyunKwan U., Yonsei U.

**Poland:** Warsaw U.

**Russia:** INR

**Spain:** U. Barcelona, U. Valencia

**Switzerland:** U. Geneva, ETH

**UK:** RAL, Imperial College London, Queen Mary Westfield College London, U. Liverpool

**USA:** UCI, SUNY-SB, U. Rochester, U. Pennsylvania, Boston U., CSU, Duke,  
Dominguez Hills, BNL, UCB/LBL, U. Hawaii, ANL, MIT, LSU, LANL, U. Washington

T.Kobayashi (KEK)

# MW Proton Facility : J-PARC

**Unique facility**  
**3GeV+50GeV**  
**Multi-purposes**

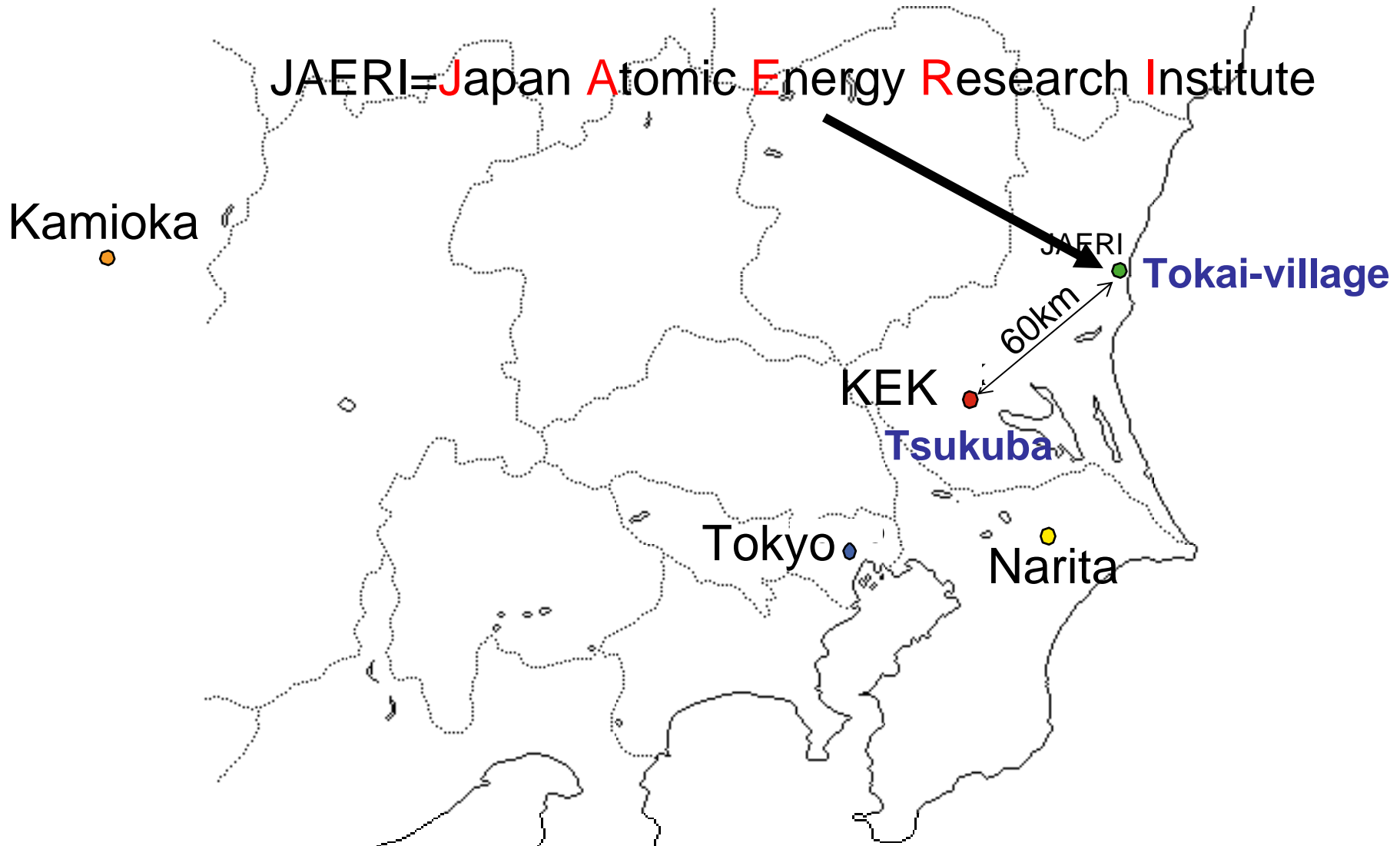
- Materials and life sci.
- Nucl. and part. phys.
- Nucl. transmutation

**Construction**  
**2001~2008**



J-PARC = Japan Proton Accelerator Research Complex

# Location of JAERI at Tokai-village



# Neutrino facility in J-PARC

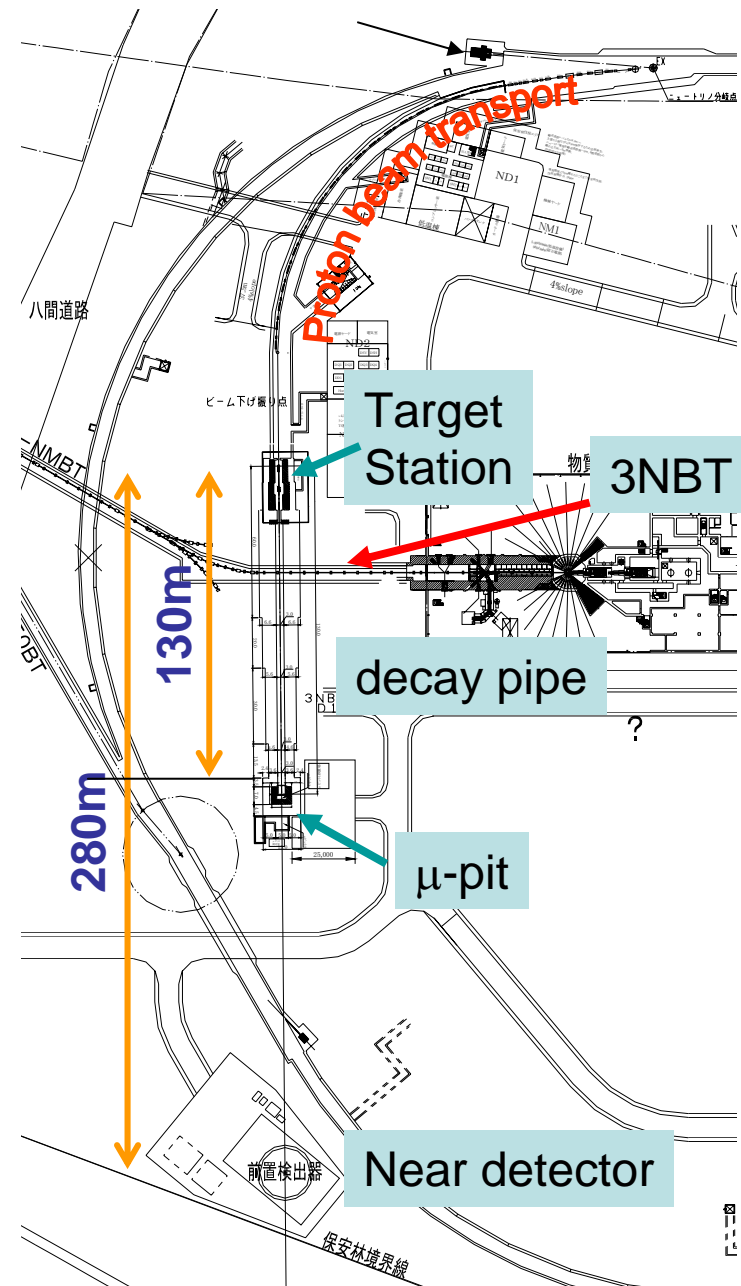
## Components

- Primary proton beam line
  - Normal conducting magnets
  - Superconducting arc
  - Proton beam monitors
- Target/Horn system
- Decay pipe (130m)
  - Cover OA angle 2~3 deg.
- Beam dump
- muon monitors
- Near neutrino detector

## Special Features

- **Superconducting combined function magnets**
- **Off-axis beam**

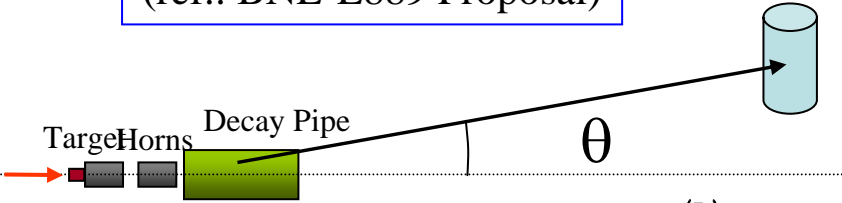
Construction: JFY2004~2008



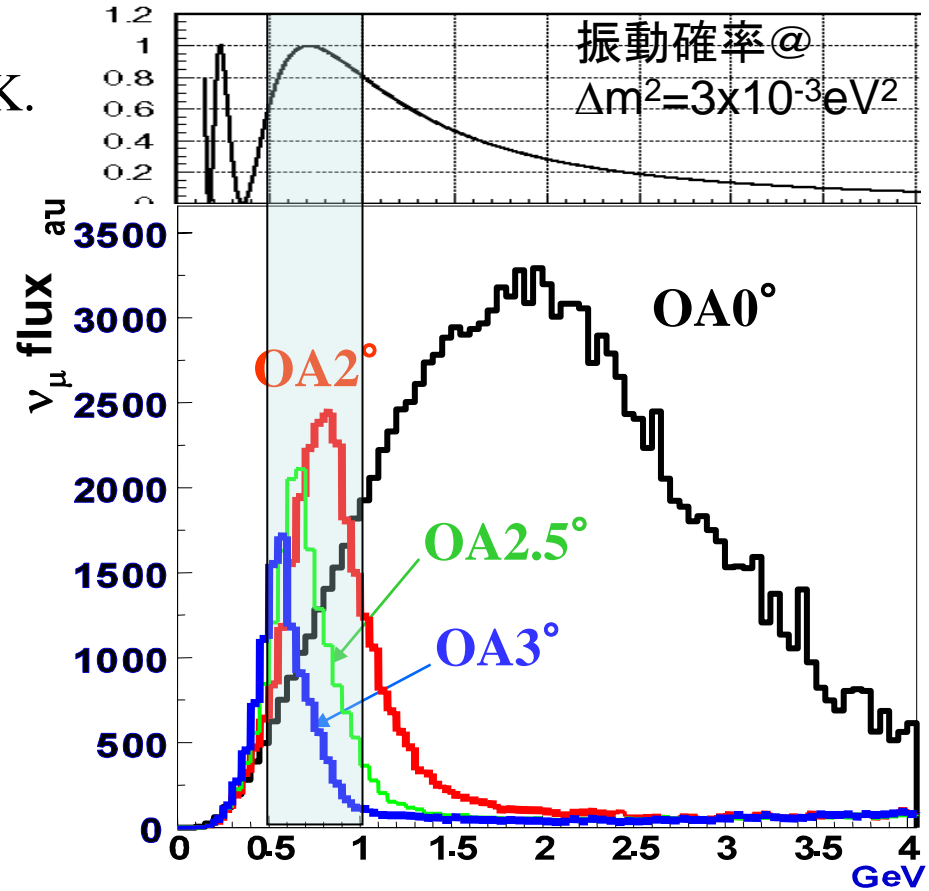
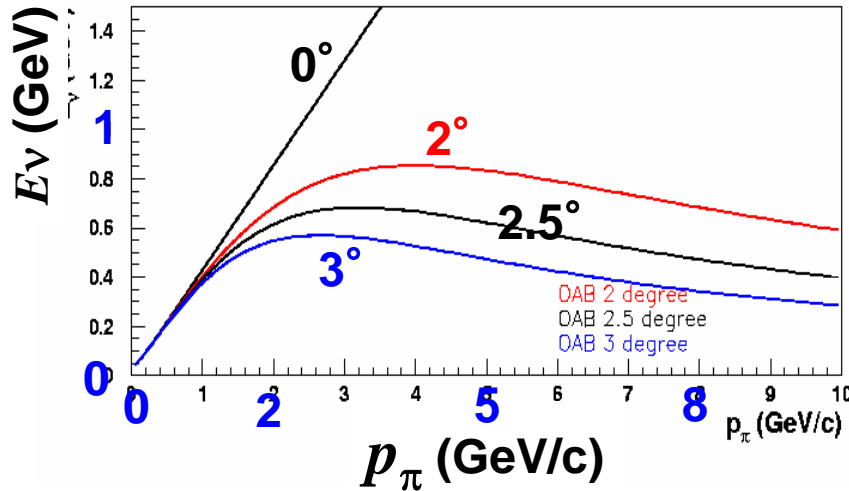
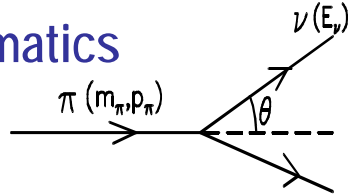
# Narrow intense beam: Off-axis beam

First Application  
(ref.: BNL-E889 Proposal)

Super-K.



$\pi$  decay Kinematics



- ◆ Quasi Monochromatic Beam
- ◆ x 2~3 intense than NBB
- ◆ Tuned at oscillation maximum

## Statistics at SK

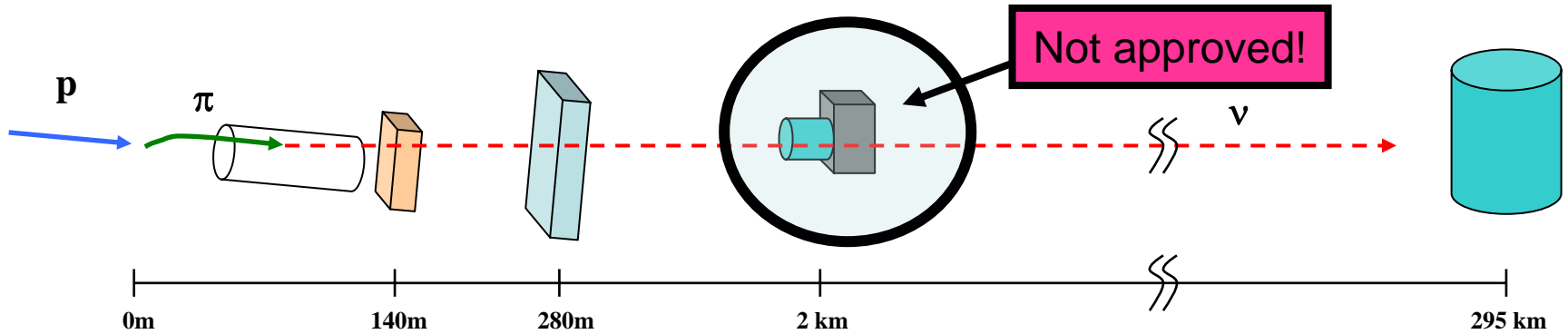
(OAB 2.5 deg, 1 yr, 22.5 kt)

~ 2200  $\nu_\mu$  tot

~ 1600  $\nu_\mu$  CC

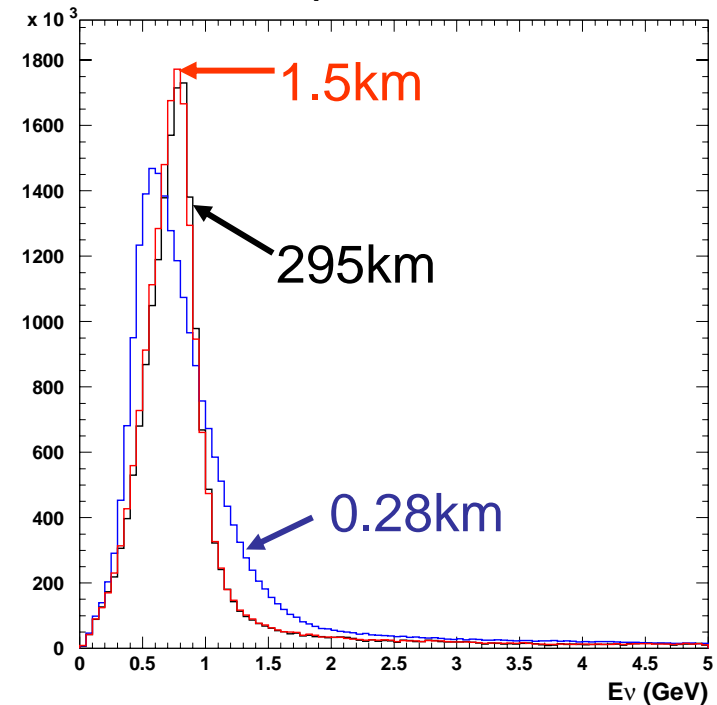
$\nu_e$  ~0.4% at  $\nu_\mu$  peak

# Detector complex



- **Muon monitors @ ~140m**
  - Fast (spill-by-spill) monitoring of beam direction/intensity
- **First near detector @280m**
  - Flux/spectrum/ $\nu_e$
  - intensity/direction
- **Second near detector @ ~2km**
  - Almost same  $E_\nu$  spectrum as for SK
  - Water Cherenkov can work
- **Far detector @ 295km**
  - Super-Kamiokande (50kt)

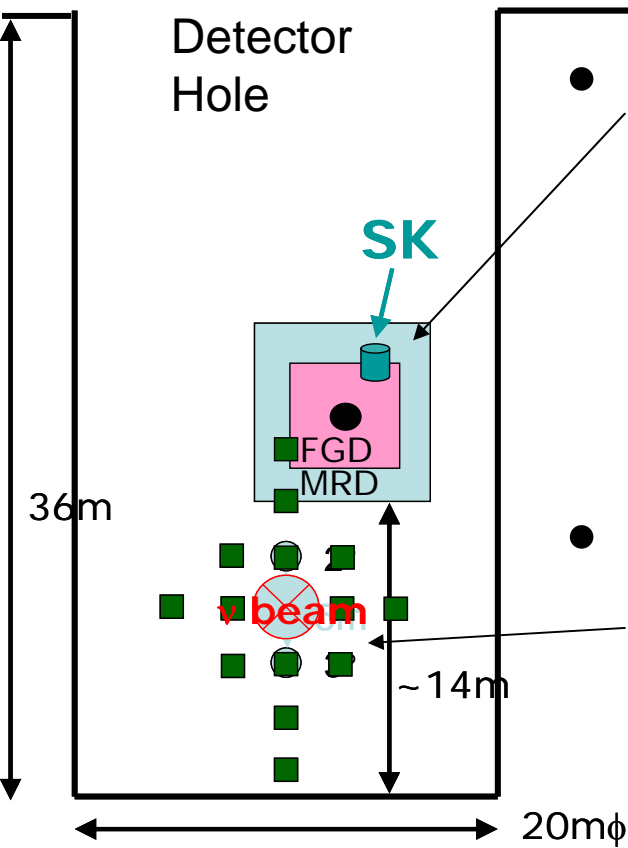
Neutrino spectra at diff. dist



dominant syst. in K2K



# Conceptual Design of Near Detector @ 280m

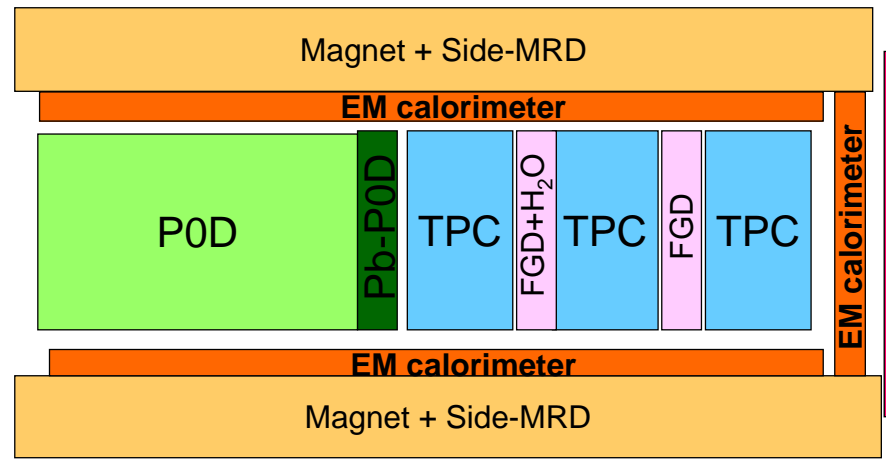
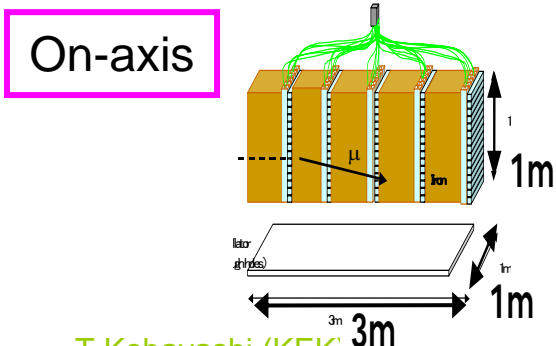
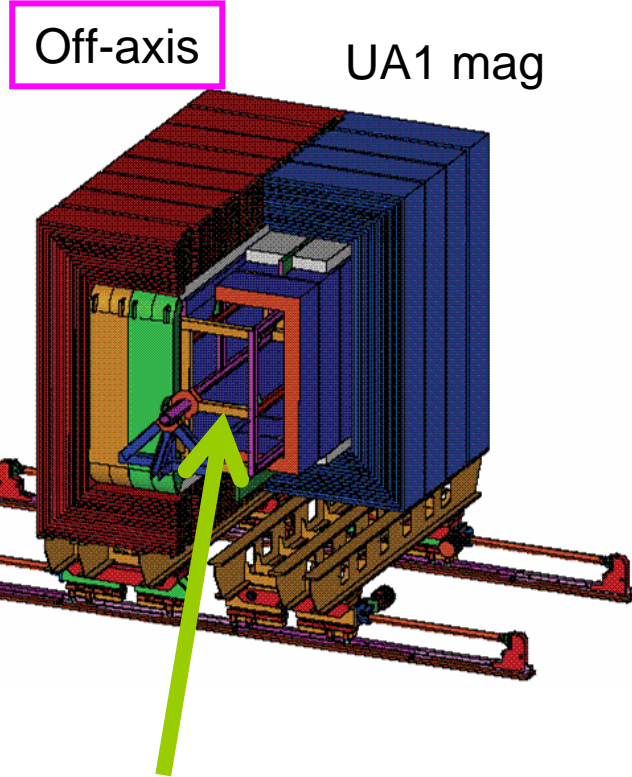


- Off-axis detector

- $\nu$  spectrum
- Cross sect.
- $\nu_e$  contami.
- UA1 mag, FGD, TPC, Ecal,...

- On axis detector

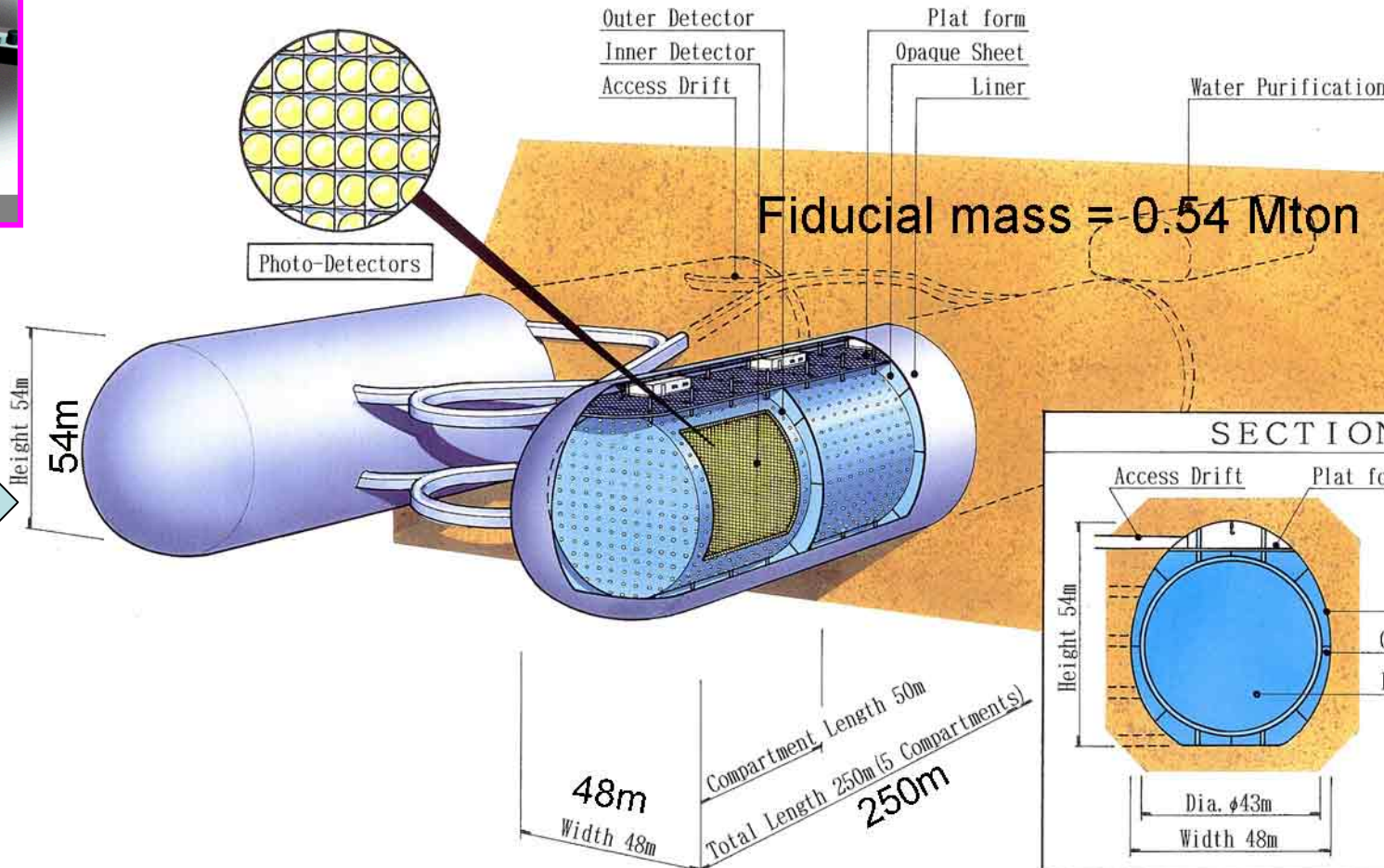
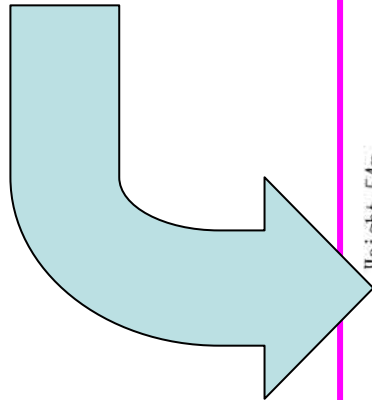
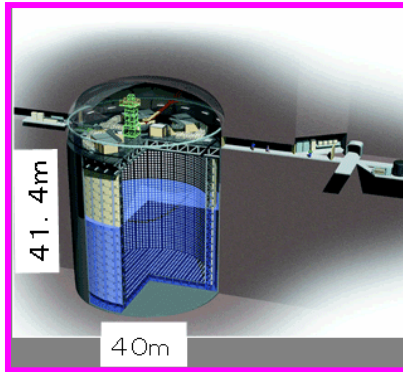
- Monitor beam dir.
- Grid layout



# Far Detectors

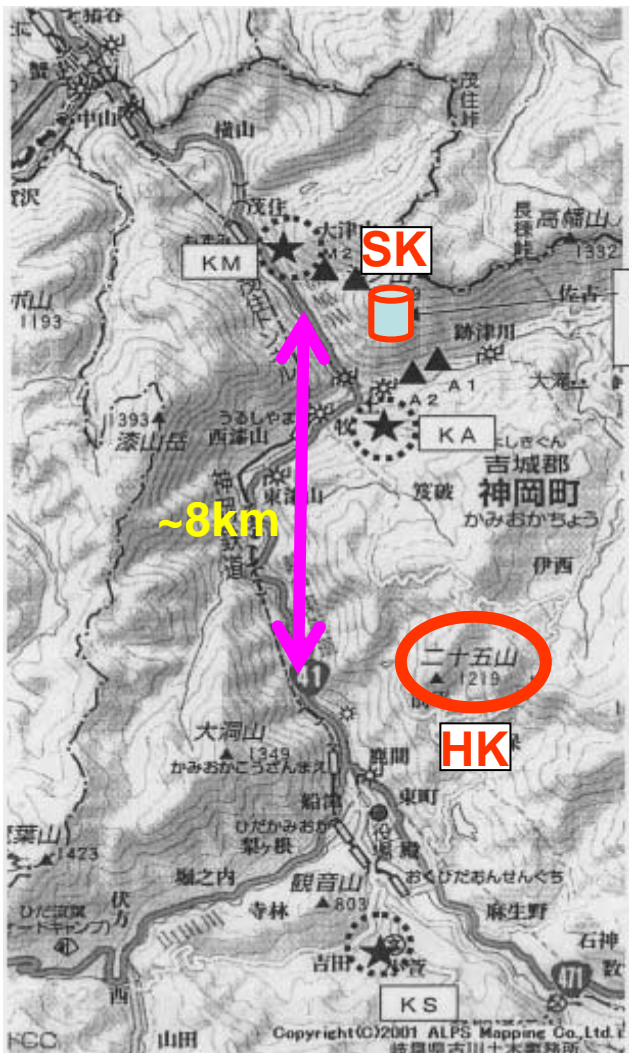
1<sup>st</sup> Phase (2009~,  $\geq 5$  yrs)  
Super-Kamiokande(22.5kt)

2<sup>nd</sup> Phase (201x~?)  
Hyper-Kamiokande(~540kt)



# Common decay pipe for SK/HK covering 2~3 deg OA angle

Candidate site for HK



Beam eye

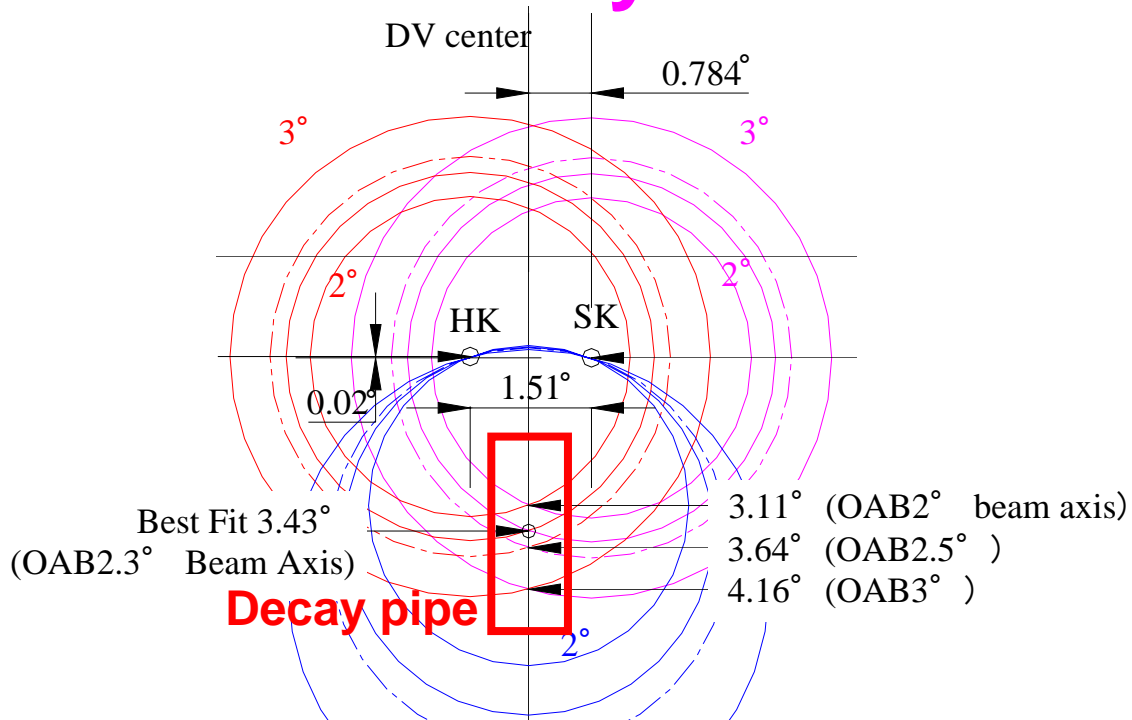
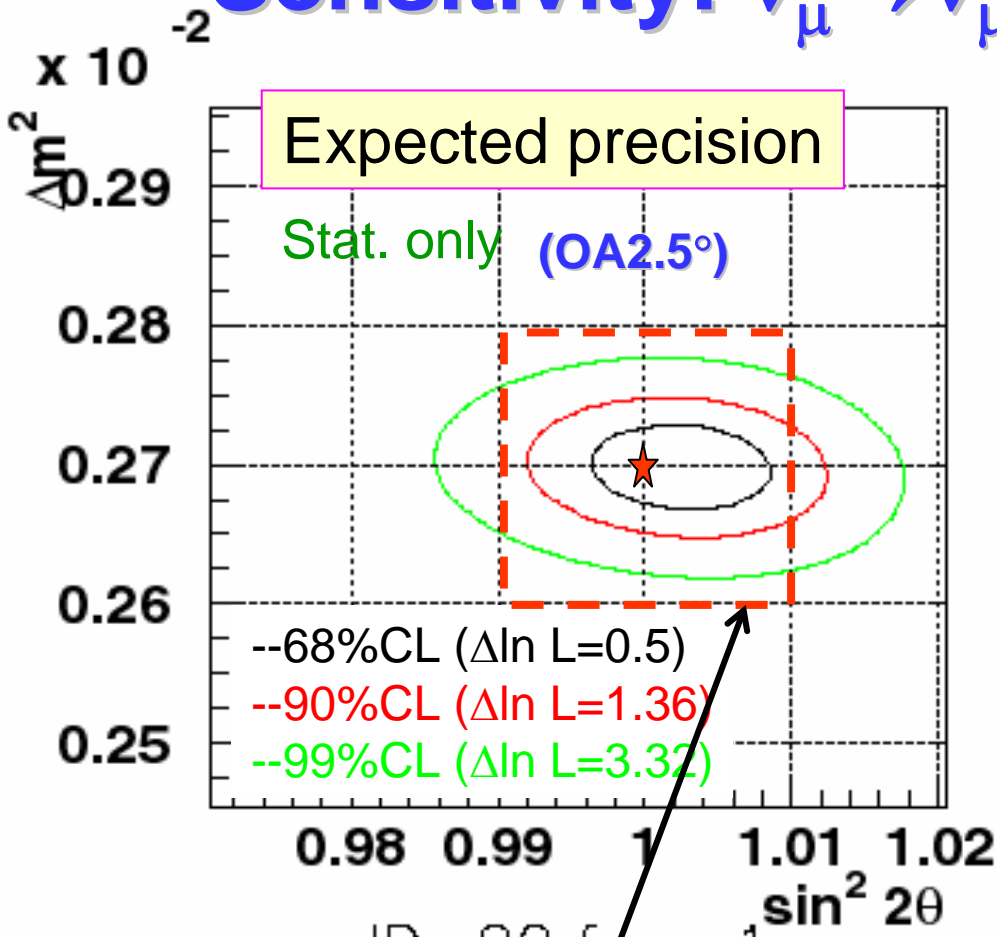


表 3.1:  $E_\nu$  at the oscillation maximum for the baseline length of 295km and corresponding off-axis angle.

$\Delta m^2$	2.04	2.18	2.75	3.17	3.28
$[10^{-3} eV^2]$	(90% A.R.)	(80% A.R.)	(best fit)	(80% A.R.)	(90% A.R.)
$E_\nu [GeV]$	0.487	0.520	0.656	0.756	0.782
OA angle [deg.]	3.1	3.0	2.4	2.1	2.0

Cover this region

# Sensitivity: $\nu_\mu \rightarrow \nu_\mu$ disappearance



Goal

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

$$\delta(\Delta m_{23}^2) \sim < 1 \times 10^{-4}$$

Stat. error

norm (+5%)

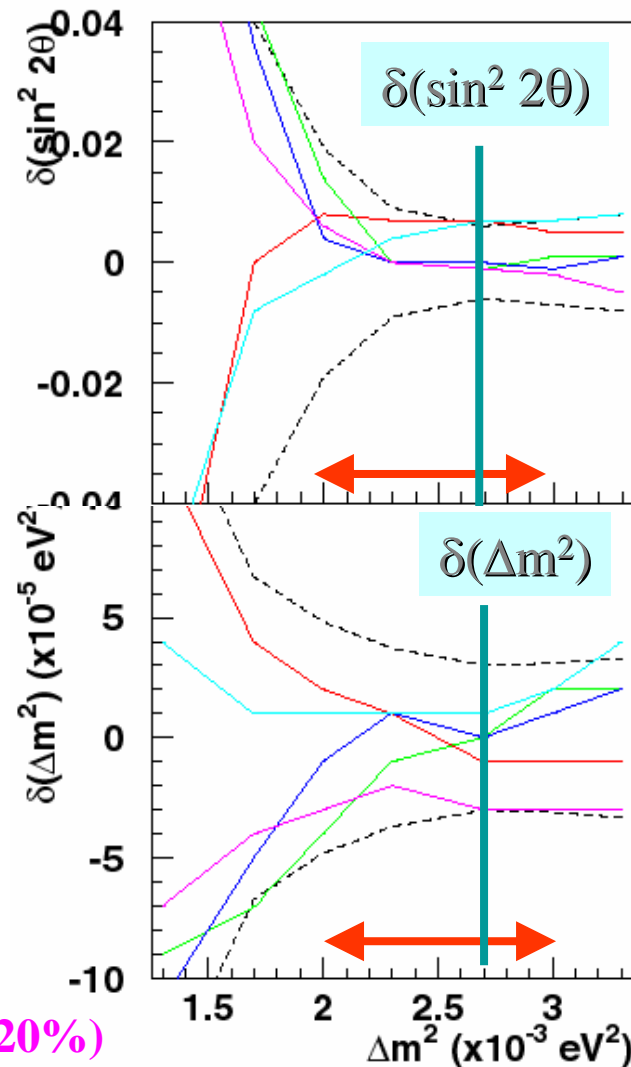
NQE (+5%)

$E_{SK}$  (+1%)

beam shape ( $\pm 20\%$ )

beam width (5%)

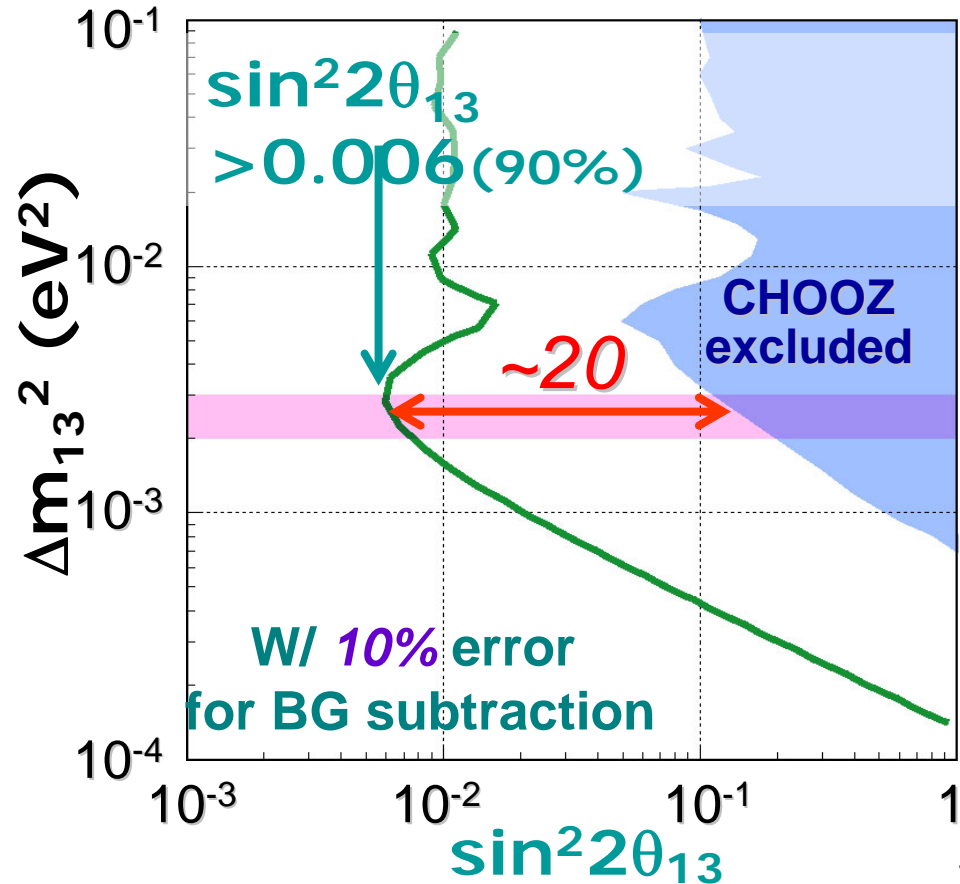
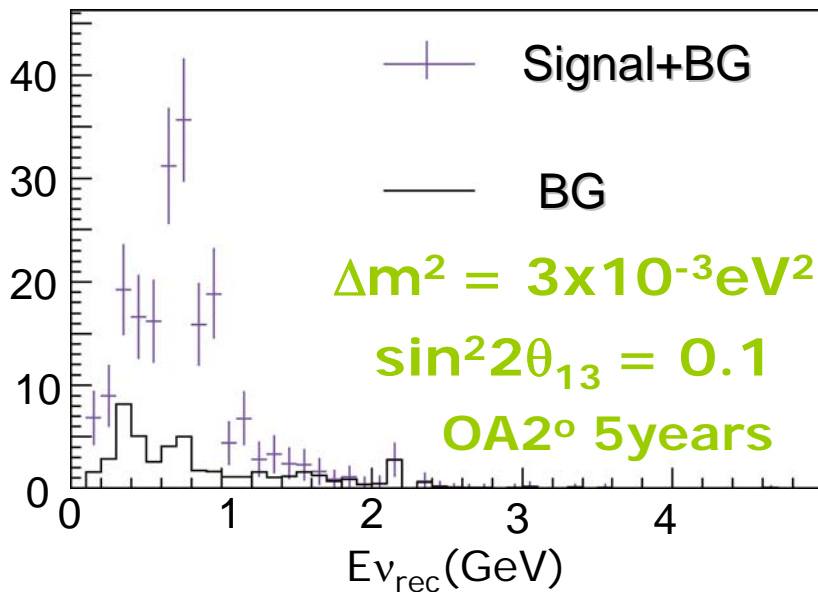
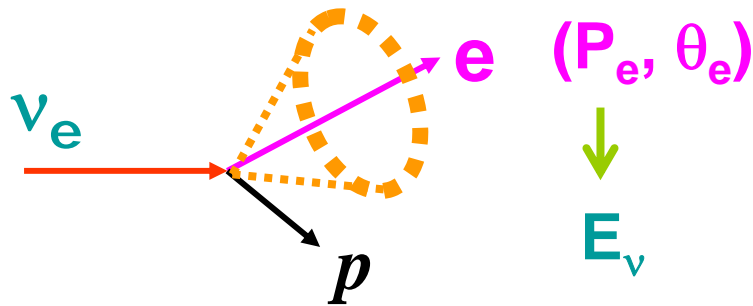
Effect of systematic error on param meas.



# Sensitivity: $\nu_e$ appearance

## Discovery of $\nu_e$ appearance ( $\theta_{13}, \Delta m_{13}$ )

$$P_{\mu \rightarrow e} \approx \sin^2 \theta_{23} \cdot \sin^2 2\theta_{13} \cdot \sin^2 \left( 1.27 \Delta m_{13}^2 L / E_\nu \right)$$



# 3 $\sigma$ Sensitivity for CPV in T2K-II

## JHF-HK CPV Sensitivity

4MW, 540kt

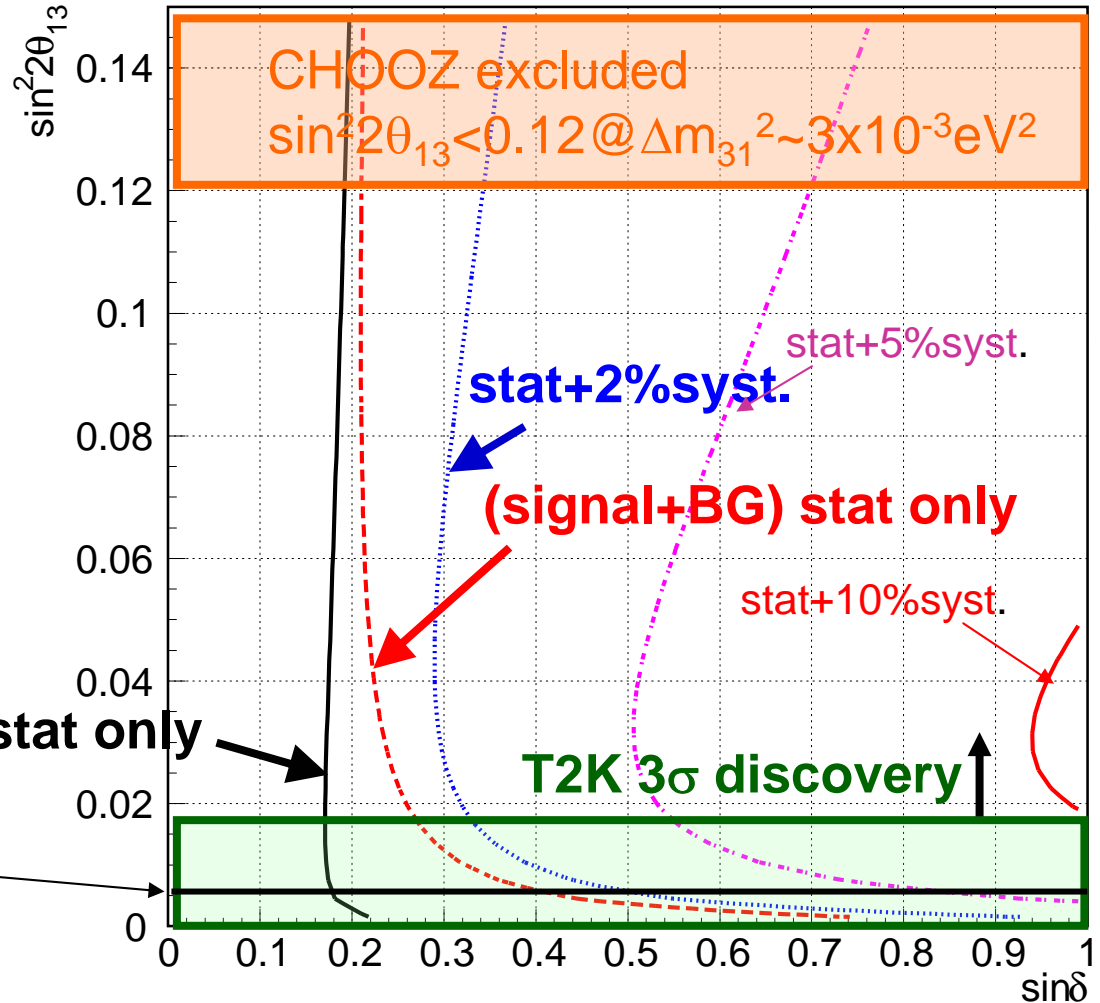
2yr for  $\nu_\mu$   
6~7yr for  $\bar{\nu}_\mu$

$\Delta m_{21}^2 = 6.9 \times 10^{-5} \text{eV}^2$   
 $\Delta m_{32}^2 = 2.8 \times 10^{-3} \text{eV}^2$   
 $\theta_{12} = 0.594$   
 $\theta_{23} = \pi/4$

$$A_{CP} \approx \frac{\Delta m_{12}^2}{4E_\nu} \cdot \frac{\sin 2\theta_{12}}{\sin \theta_{13}} \cdot \sin \delta$$

no BG  
signal stat only

T2K-I 90%



3 $\sigma$  CP sensitivity :  $|\delta| > 20^\circ$  for  $\sin^2 2\theta_{13} > 0.01$  with 2% syst.

# Status of R&D, Design, Construction



January, 2005





3NBT

Decay Volume  
(excavated)

Jan.28, 2005

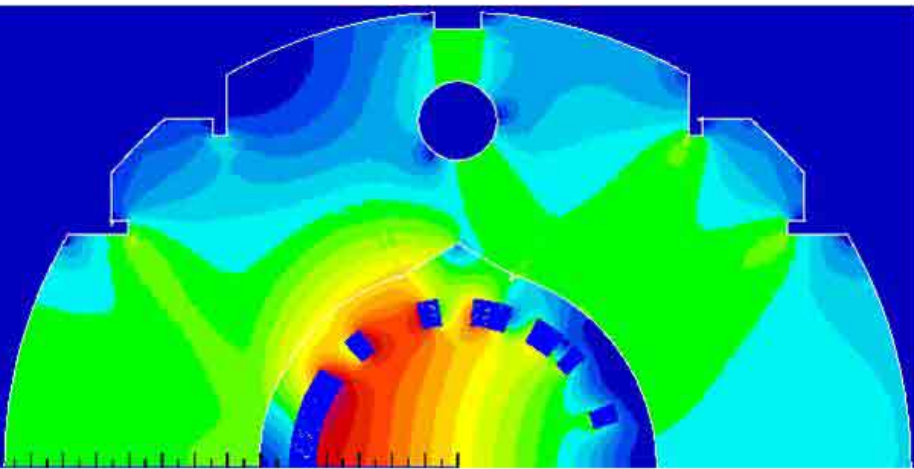
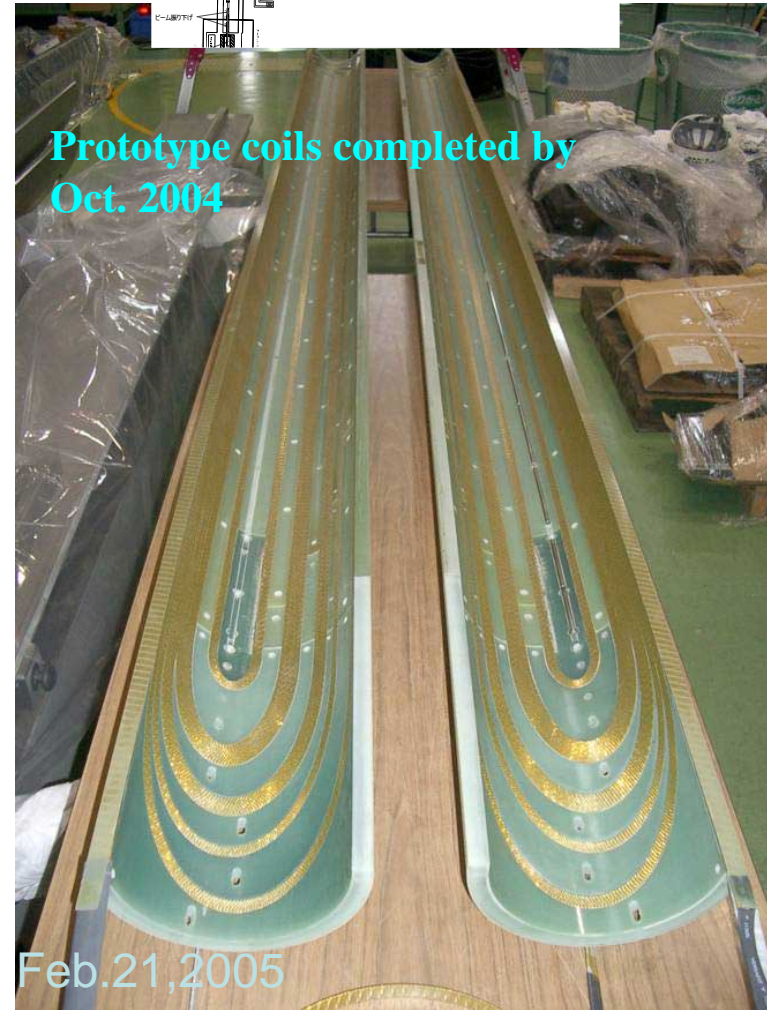
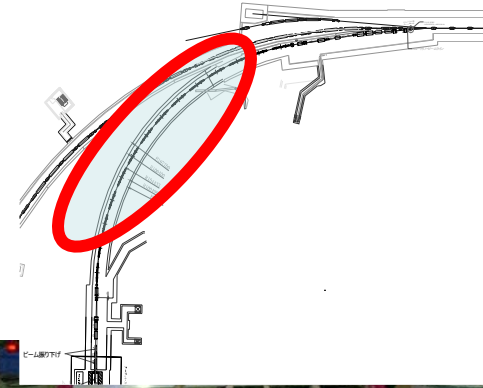


**50 GeV Synchrotron  
Construction Area B**

# Superconducting magnets

T.Ogitsu, T.Nakamoto, et.al.,  
Cryogenic Sci. Center, KEK

- 28 combined function magnets in arc part
  - Dipole Field: 2.587 T, Quad. Field: 18.62 T/m
  - Reduce cost while keeping large acceptance
  - Use common parts with LHC to reduce cost/risk
- First full size prototype completed
  - Cooled, current loaded
  - 7700A (ope. curr. @50GeV + 5%) achieved w/o any spontaneous quenching (Mar.4)
- In FY2005, mass production of magnets will start



Shell Welding Completed (Dec21,04)



Vacuum Vessel from Spain

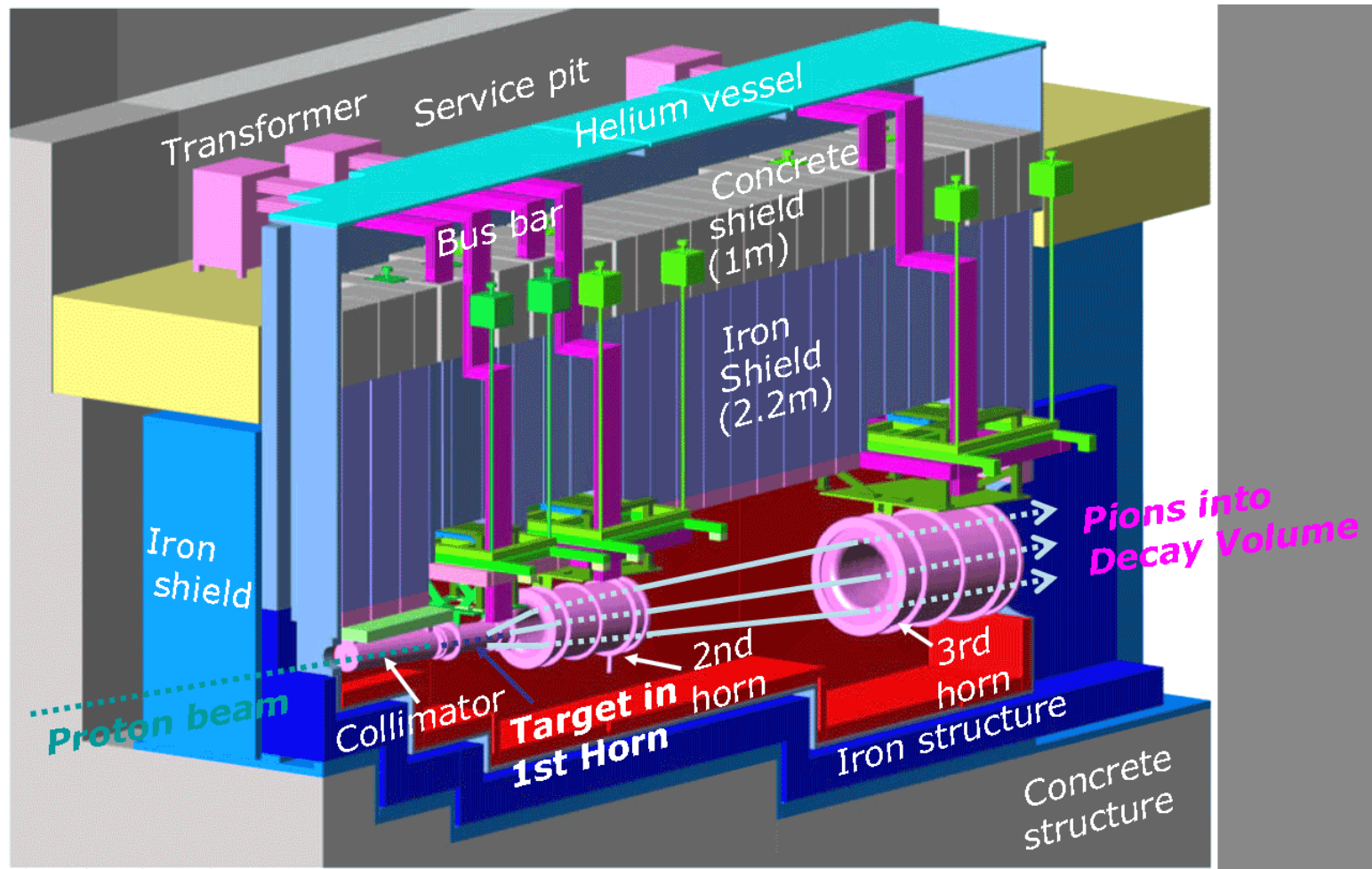
T.Kobayashi (KEK)

Put in vertical cryostat for cooling/current loading test (Feb.21,2005)



# Target Area

- Target, horns are installed. Filled with Helium gas (reduce Tritium, NOx production)
- Highly radio-activated ( $\sim 1\text{Sv/h}$ , cf  $\sim 10\text{Sv}@JCO$ , Dose meter alarm:  $0.3\text{mSv/h}$ )
  - Need remote-controlled maintenance system
- Need cooling (Helium vessel, radiation shield,..)

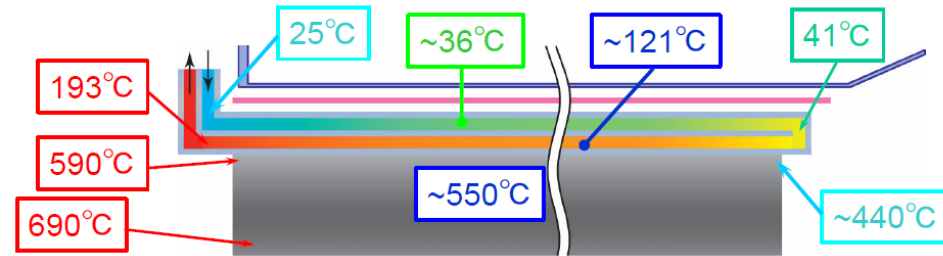


# Target

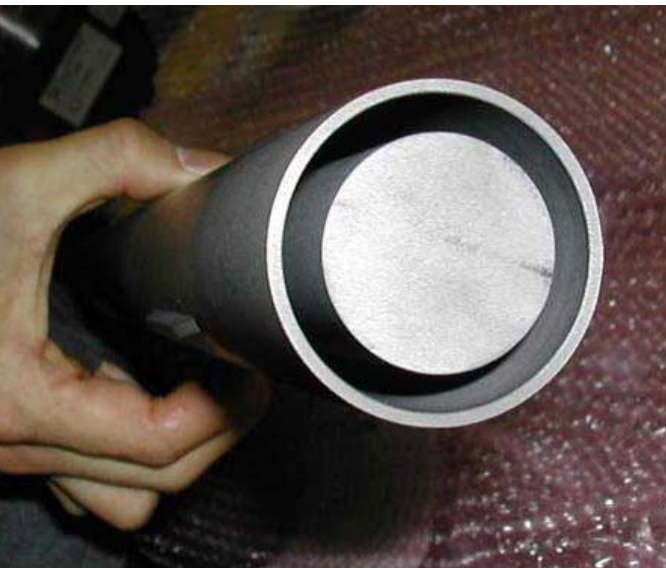
- Carbon Graphite: 30mm(D)x900mm(L), 2 interaction length (70% int.)
- Energy deposit: 58kJ/spill (~20kW)
- Equivalent stress ( $\Delta T \sim 200K$ )  $\sim 7MPa$  (<Tensile strength of 37MPa)
- Cooled at outer surface

## R&D and Design Status

- Helium cooling method designed
- Prototype of Graphite target made
  - Feasibility of machining proved
- Radiation damage of Graphite tested



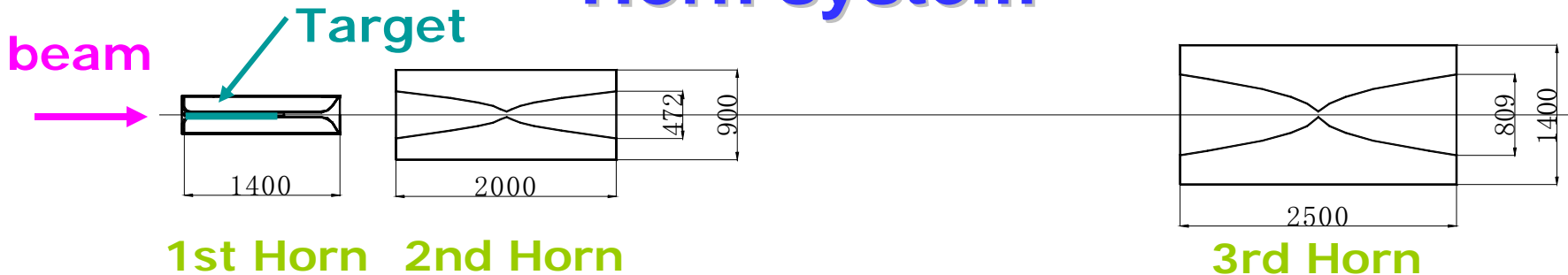
## Prototype production



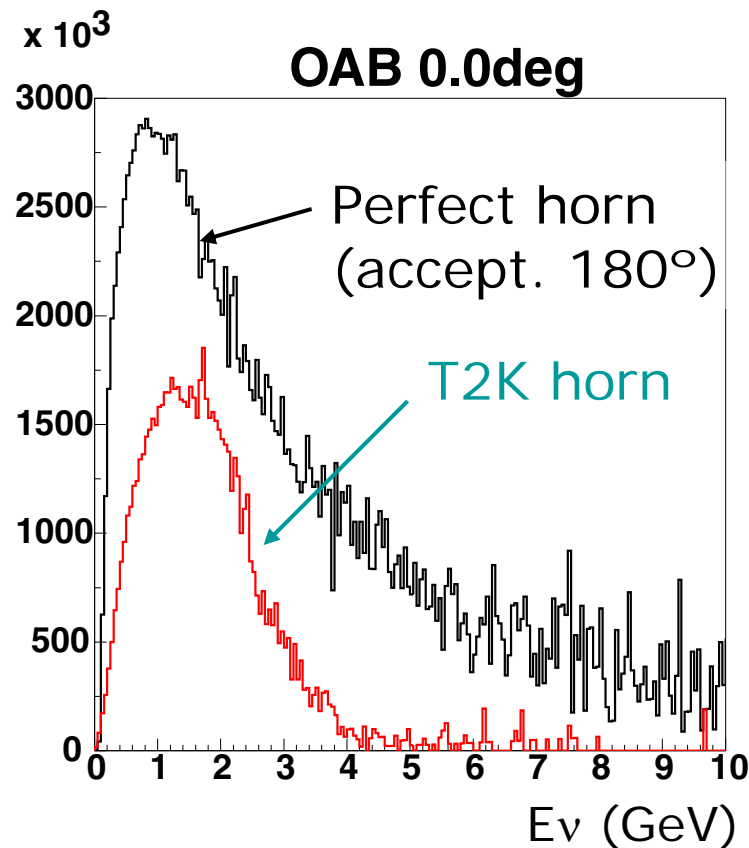
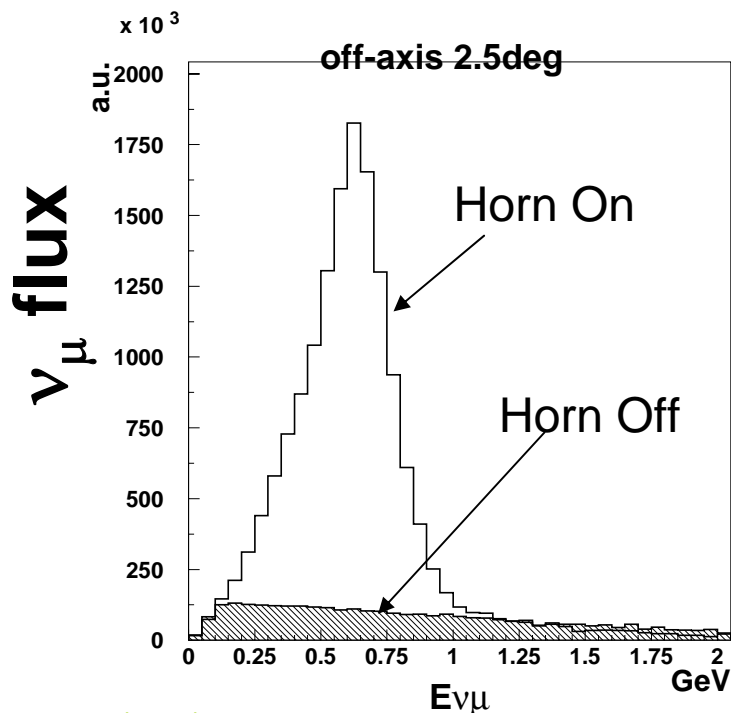
- Feasibility of machining Graphite tested
  - Thin (2mm) inner cooling pipe
- Will be used for Helium flow test



# Horn system

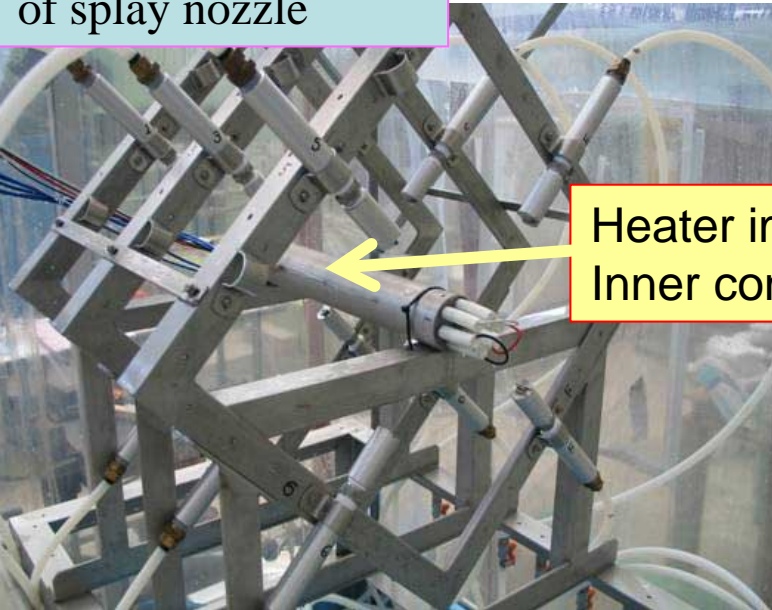


- Focus secondary pions into decay volume
- Field shape optimization completed
- 320kA pulse current synchronized w/ beam
- Made of Aluminum alloy (A6061)



# Horn design & test status

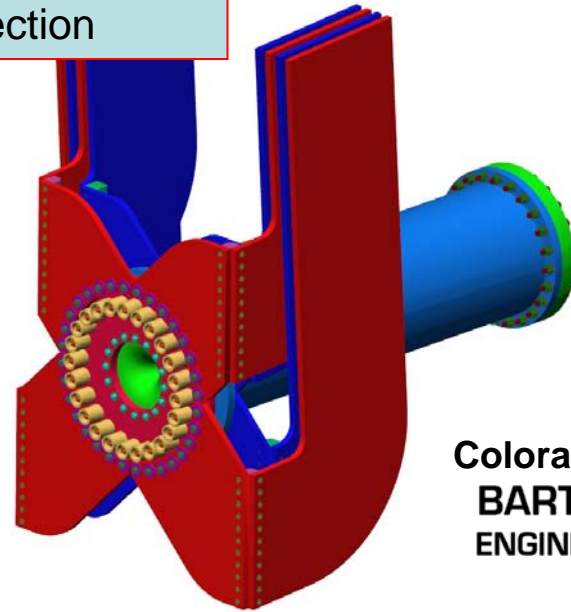
Cooling power test of splay nozzle



Heater imitating Inner conductor



One of the designs of Stripline connection



Colorado U w/  
BARTOSZEK  
ENGINEERING

Inner conductor of the 1<sup>st</sup> horn

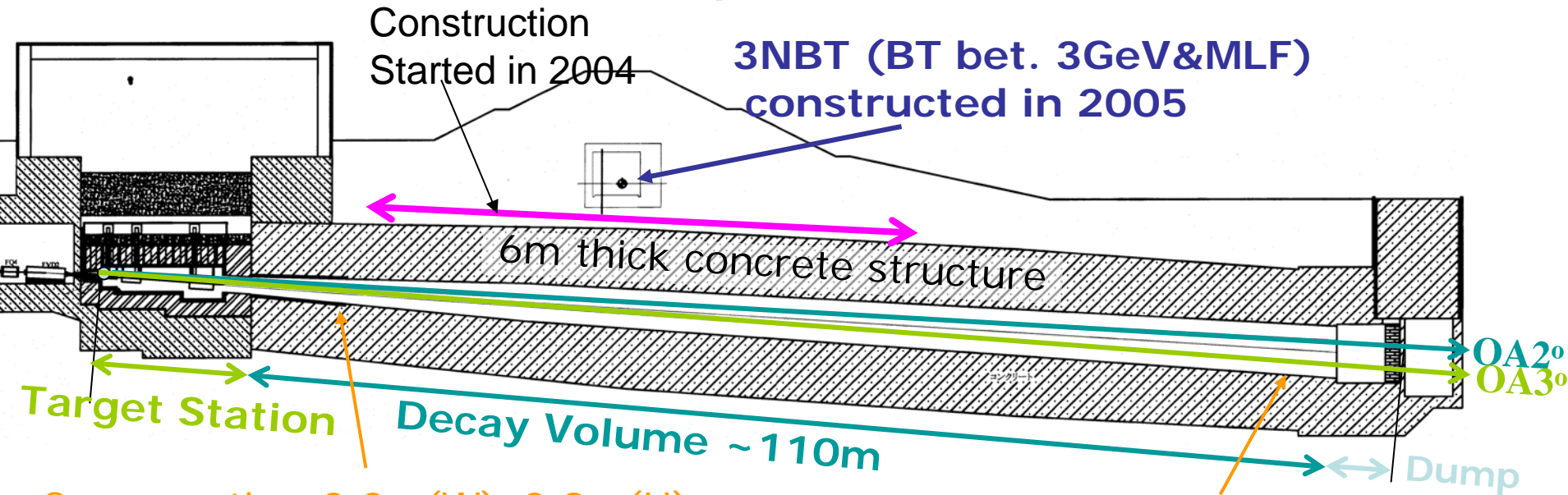


Outer conductor of the 1<sup>st</sup> horn





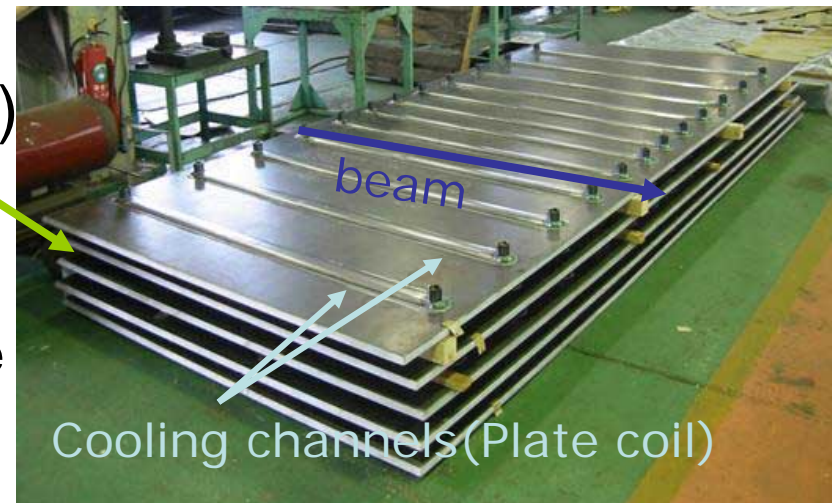
# Decay Volume



Cross section: 2.2m(W)x2.8m(H)

- Cover Off Axis angle :  $2^\circ \sim 3^\circ$
- Square box shape made with water cooled iron plates ( $T < 60^\circ\text{C}$ )
- Filled by 1atm Helium gas
- Construction started
  - Crossing 50m part w/ 3NBT by June 15, 2005
- Remaining part in 2007&2008

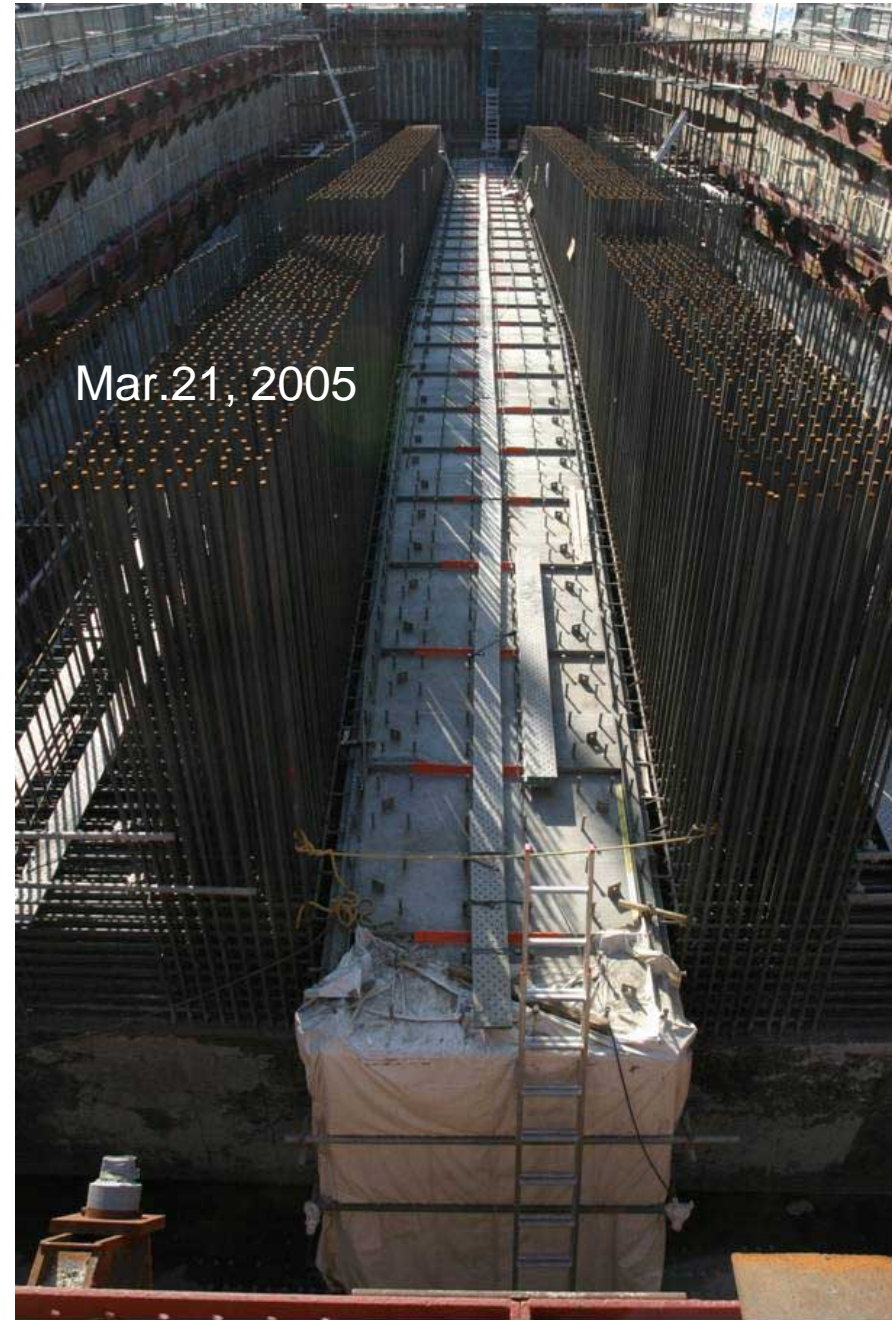
3.0m(W)x4.6m(H)



# Decay pipe construction



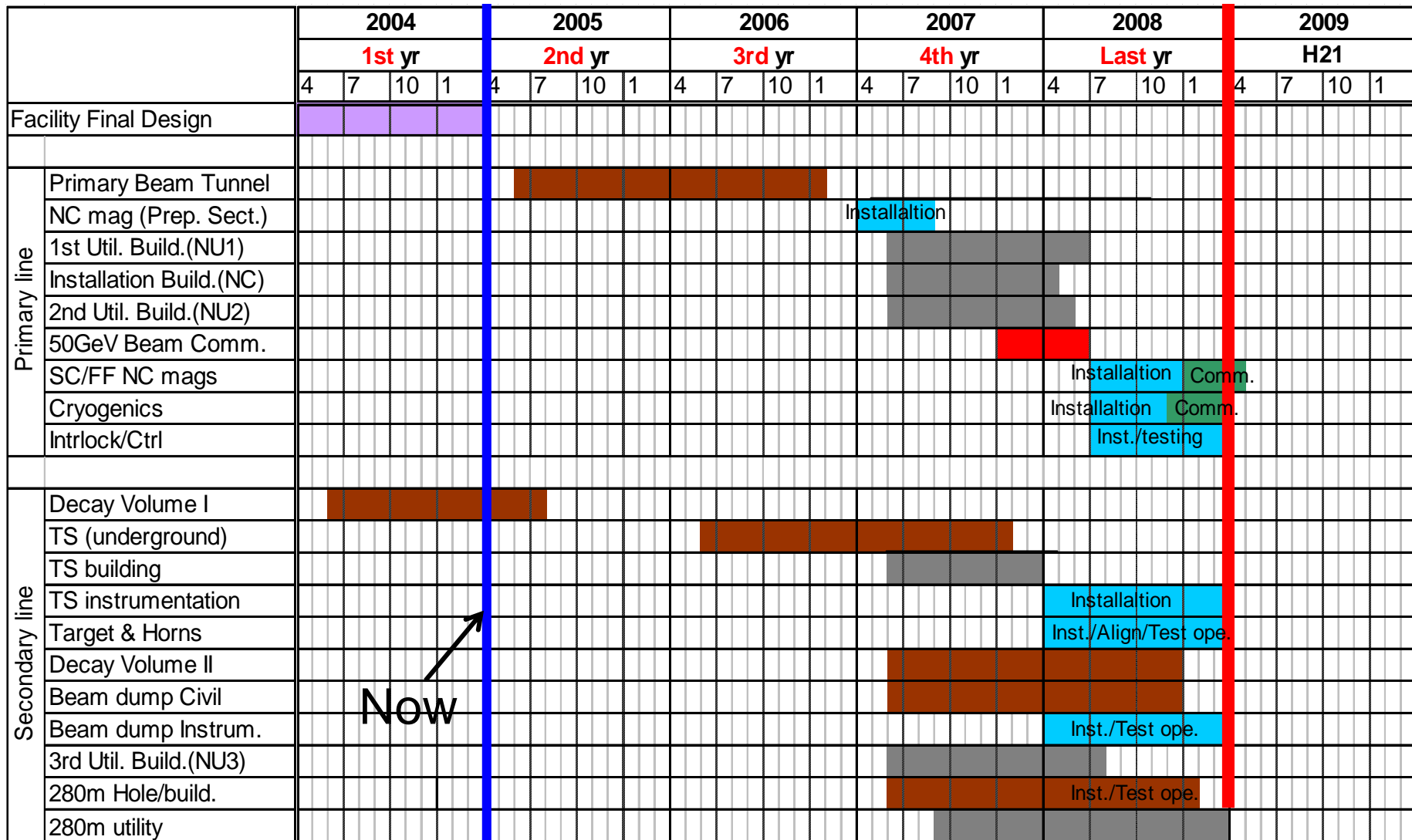
Feb. 9, 2005



# Decay volume Apr. 5



# Schedule



- Construction takes 5 yrs (2004~2008JFY)
- Experiment start in 2009JFY

# Summary

- T2K Experiment
  - High sensitivity superbeam experiment
  - Narrow, intense beam with Off-axis technique
  - Physics goals
    - $\nu_e$  appearance:  $\sin^2 2\theta_{13} > 0.006$  (90%CL)
    - $\nu_\mu$  disappearance:  $\delta(\Delta m_{23}^2) \sim 10^{-4} \text{eV}^2$ ,  $\delta(\sin^2 2\theta_{23}) \sim 1\%$ 
      - Search for CPV(phase 2):  $\delta > \sim 20 \text{deg}$
- Neutrino beam line construction started
- Intensive R&D and design work of beam line components
- Start experiment in 2009