JHF-Kamioka Neutrino Oscillation Experiment using JHF 50 GeV PS

- Introduction
- Facility
- Physics goal
- Summary

Y.Itow
ICRR,Univ.of Tokyo
Jul27,2002
ICHEP02 Amsterdam

Where we go ?

Cosmic ray

Discovery Phase

Atmospheric ν

$\Delta m_{23}^2 \sim 1.6 - 3.9 \times 10^{-3}$ eV^2

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

Discovery of ν_μ oscillations

Solar ν

$\Delta m_{12}^2 \sim 3 - 20 \times 10^{-5}$ eV^2

$\sin^2 2\theta_{12} \sim 0.55 - 0.95$

Large mixing in ν_e oscillations

Accelerator

Precision Study Phase

K2K

The 1st long baseline ν experiment

Precision study of 3-flavor ν mixing matrix

3 Flavor Mixing

- If neutrinos are massive particles, then it is possible that the **mass eigenstates** and the **weak eigenstates** are not the same:

$$\begin{pmatrix} \nu_e \\ \nu_\mu \\ \nu_\tau \end{pmatrix} = \begin{pmatrix} U_{e1} & U_{e2} & U_{e3} \\ U_{\mu 1} & U_{\mu 2} & U_{\mu 3} \\ U_{\tau 1} & U_{\tau 2} & U_{\tau 3} \end{pmatrix} \begin{pmatrix} \nu_1 \\ \nu_2 \\ \nu_3 \end{pmatrix}$$

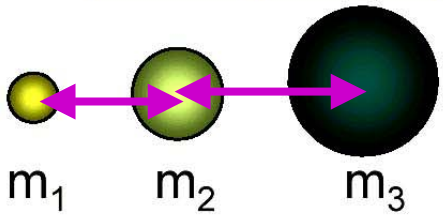
Weak eigenstates „flavor eigenstates"

3 independent parameters + 1 complex phase

$\theta_{12}, \theta_{23}, \theta_{13}$ + δ

$\Delta m^2_{12}, \Delta m^2_{23}$

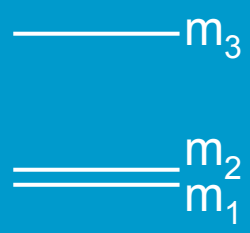
Mass eigenstates



MNS (Maki-Nakagawa-Sakata) matrix

3-flavor Oscillation

Oscillation Probabilities when $\Delta m^2_{12} << \Delta m^2_{23} \approx \Delta m^2_{13}$



- θ_{23} :ν_μ disappearance

$$P_{\mu \to x} \approx 1 - \cos^4 \theta_{13} \cdot \sin^2 2\theta_{23} \cdot \sin^2 \left(1.27 \Delta m^2_{23} L / E_\nu\right)$$

- θ_{13}:ν_e appearance

common

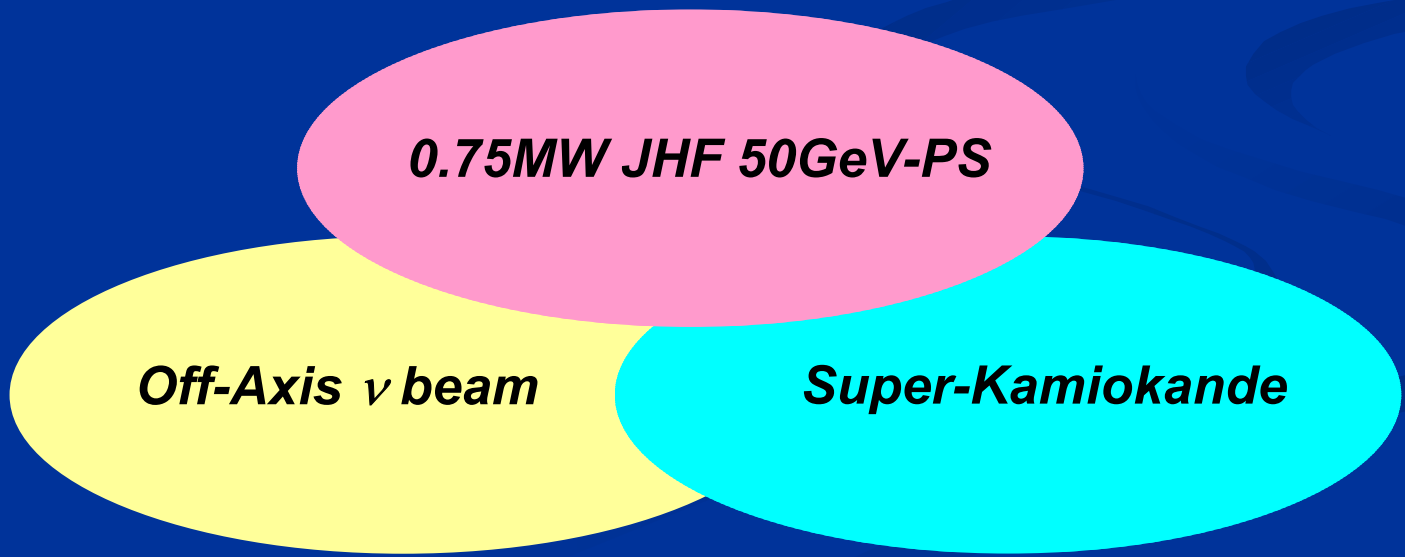
$$P_{\mu \to e} \approx \sin^2 \theta_{23} \cdot \sin^2 2\theta_{13} \cdot \sin^2 \left(1.27 \Delta m^2_{13} L / E_\nu\right)$$

- δ: ~~CP~~ in ν_e appearance

$$A_{CP} = \frac{P(\nu_\mu \to \nu_e) - P(\bar{\nu}_\mu \to \bar{\nu}_e)}{P(\nu_\mu \to \nu_e) + P(\bar{\nu}_\mu \to \bar{\nu}_e)} \approx \frac{\Delta m_{12}{}^2 L}{4E_\nu} \bullet \frac{\sin 2\theta_{12}}{\sin \theta_{13}} \bullet \sin \delta$$

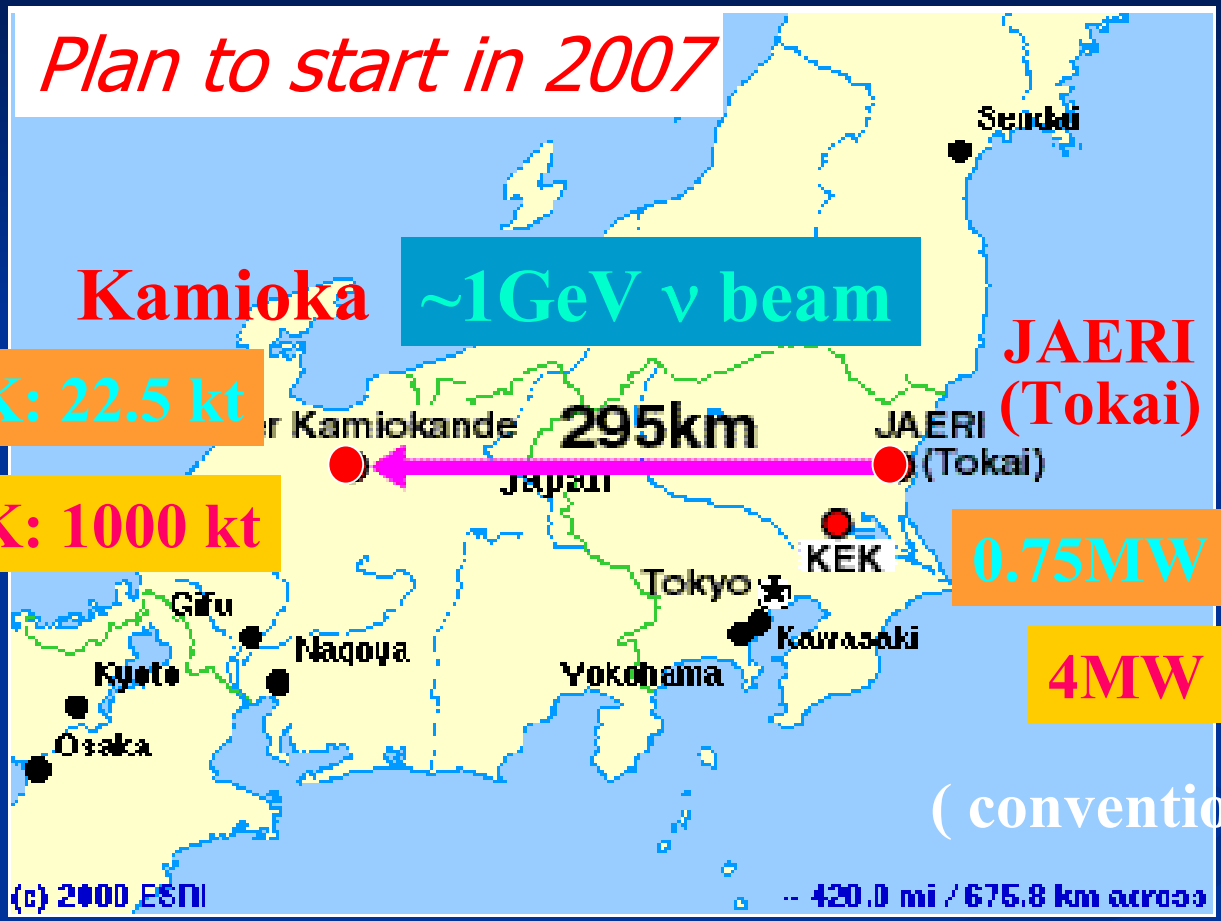
Strategy

- High statistics by high intensity ν beam
- Tune Eν at oscillation maximum
- Narrow band beam to reduce BG
- Sub-GeV ν beam for Water Cherenkov



JHF-Kamioka Neutrino Experiment

(hep-ex/0106019)



JHF 0.75MW + Super-Kamiokande

Future Super-JHF 4MW + Hyper-K ~ JHF+SK × 200

Organization

Experiment working group

- Dec.1999 : formed (ICRR/KEK/Kyoto/Kobe/Tohoku/TRIUMF)
- Jun.2001 : Letter of Intent (hep-ex/0106019)
- Mar.2002 : Meeting to discuss possibility to organize international collaboration

Facility Construction Group

- Officially formed in KEK on **April, 2001**
- The 3rd physics division, IPNS, Cryogenic facility group, Cryogenic Science Center, w/ strong support from KEK-PS beam channel group

JHF-SK Neutrino Working Group

ICRR/Tokyo-KEK-Kobe-Kyoto-Tohoku-TRIUMF

Y. Itow, T. Kajita, K. Kaneyuki, Y.Obayashi,

C.Saji, M. Shiozawa, Y. Totsuka (ICRR/Tokyo)

Y. Hayato, A.Ichikawa, T. Ishida, T. Ishii, T. Kobayashi,

T. Maruyama, K. Nakamura, Y. Oyama, M. Sakuda (KEK)

S. Aoki, T.Hara, A. Suzuki (Kobe)

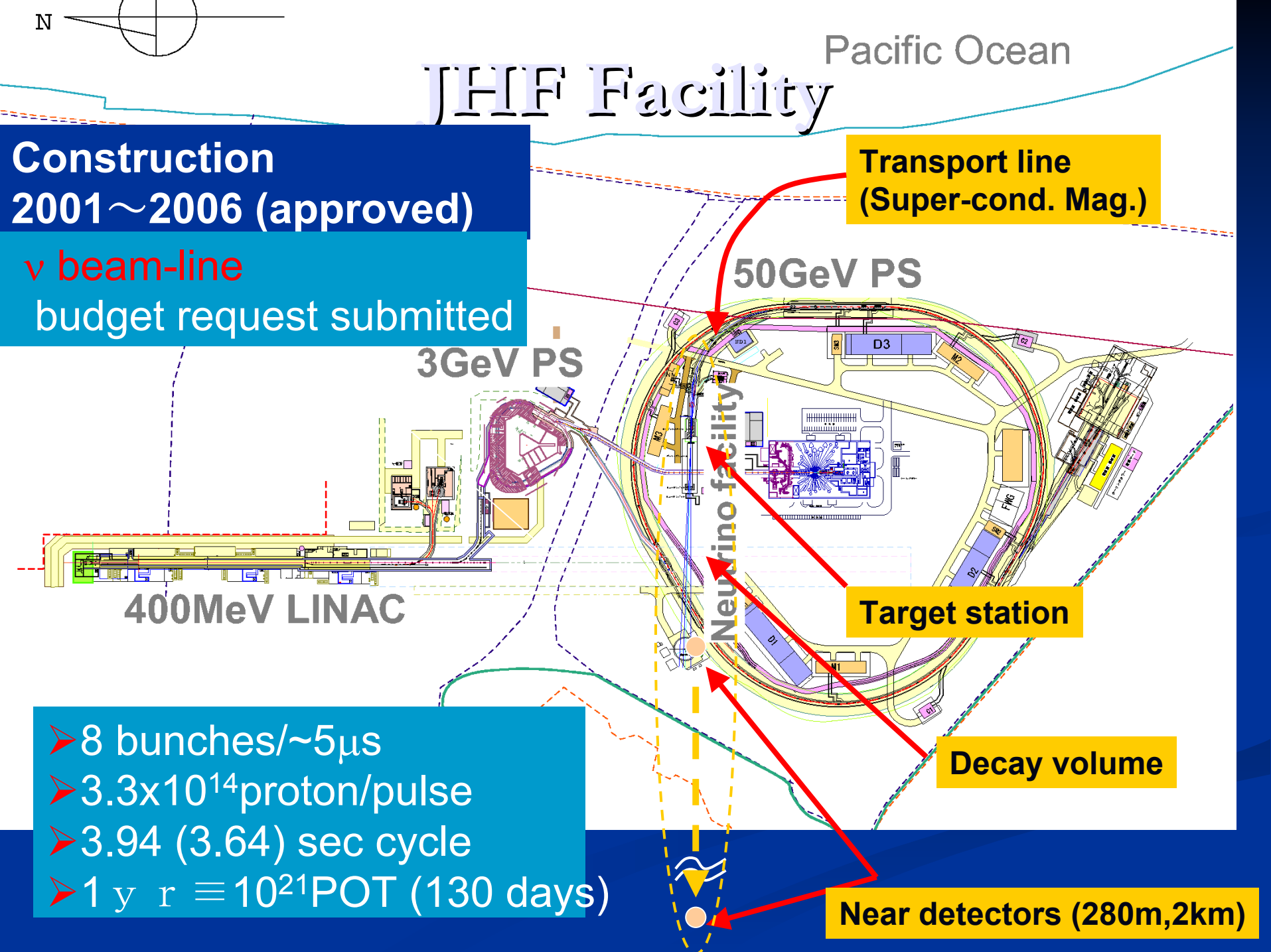
T. Nakaya, K. Nishikawa (Kyoto)

T. Hasegawa, K. Ishihara (Tohoku)

A.Konaka (TRIUMF, CANADA)

In addition to the above user group, the neutrino facility construction group is OFFICIALLY formed at KEK.

JHF Facility



Construction
2001～2006 (approved)

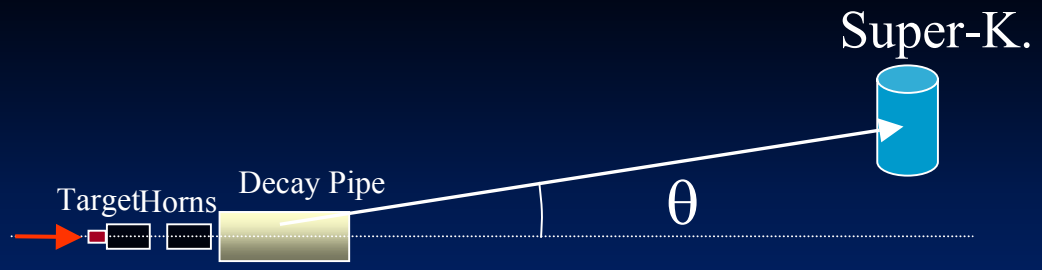
ν beam-line
budget request submitted

- 8 bunches/~5μs
- 3.3×10^{14} proton/pulse
- 3.94 (3.64) sec cycle
- 1 y r ≡ 10^{21} POT (130 days)

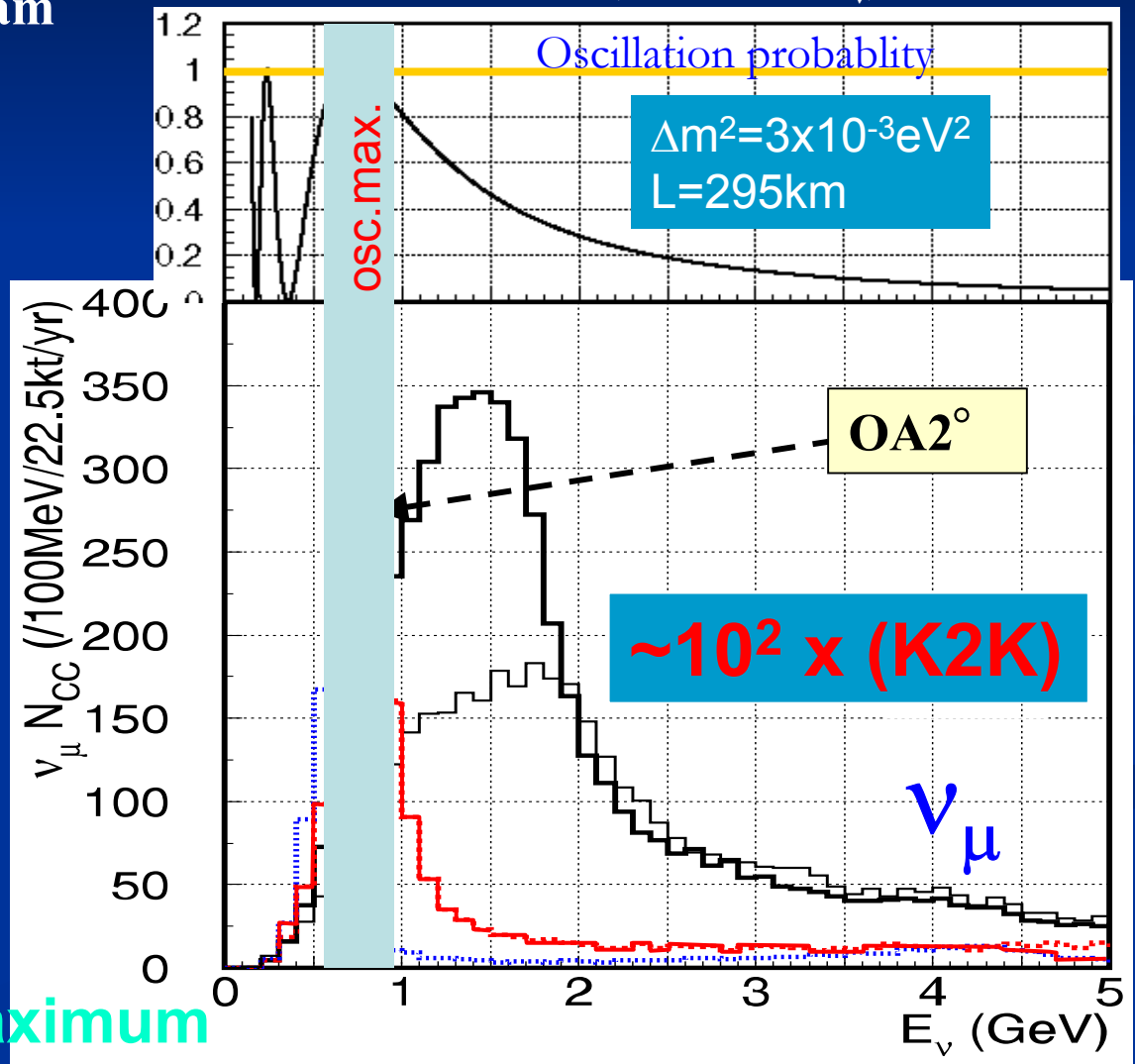
Off Axis Beam

(ref.: BNL-E889 Proposal)

- **Quasi Monochromatic Beam**
- **x2~3 intense than NBB**



Osc. Prob.=$\sin^2(1.27\Delta m^2 L/E_\nu)$



Statistics at SK

(OAB2deg,1yr,22.5kt)

~4500 ν_μ tot

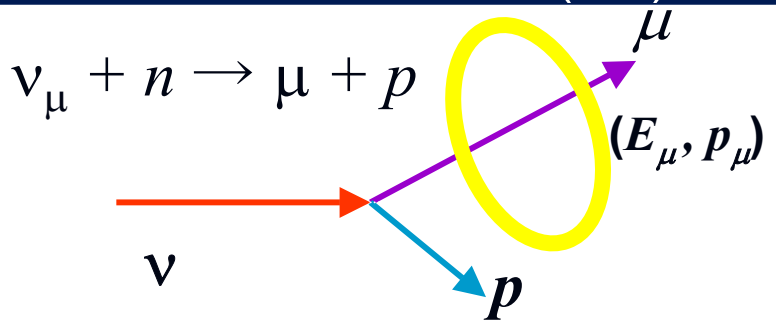
~3000 ν_μ CC

ν_e ~0.2% at ν_μ peak

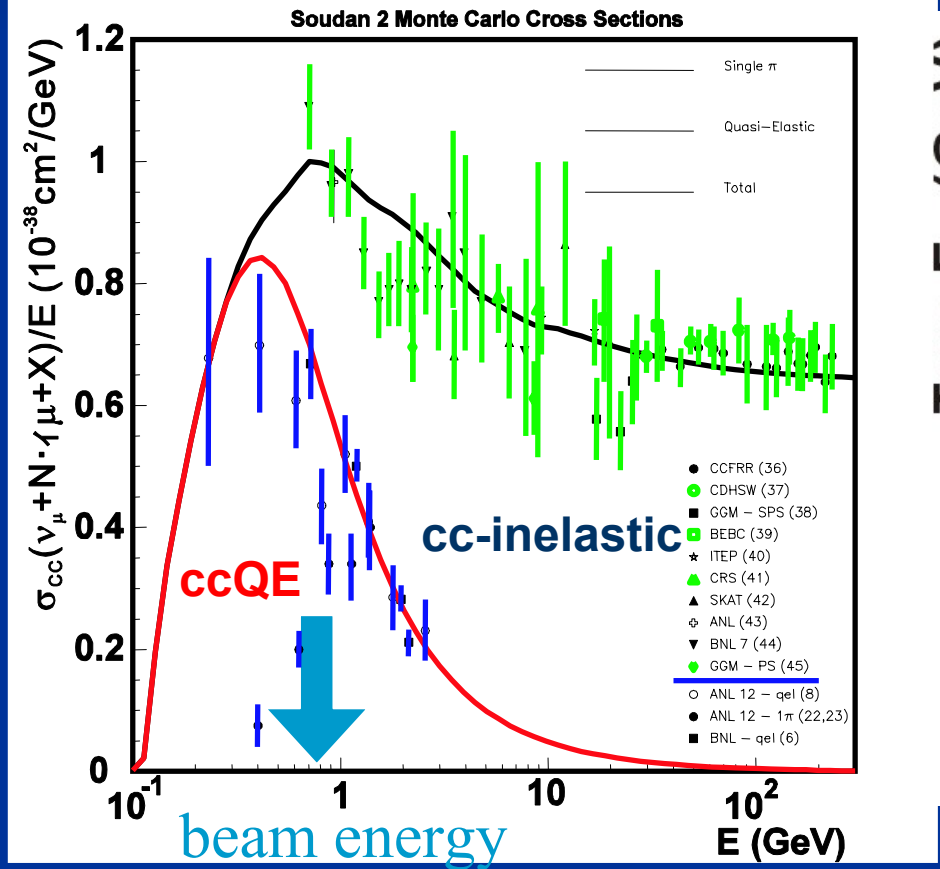
Tuned at oscillation maximum

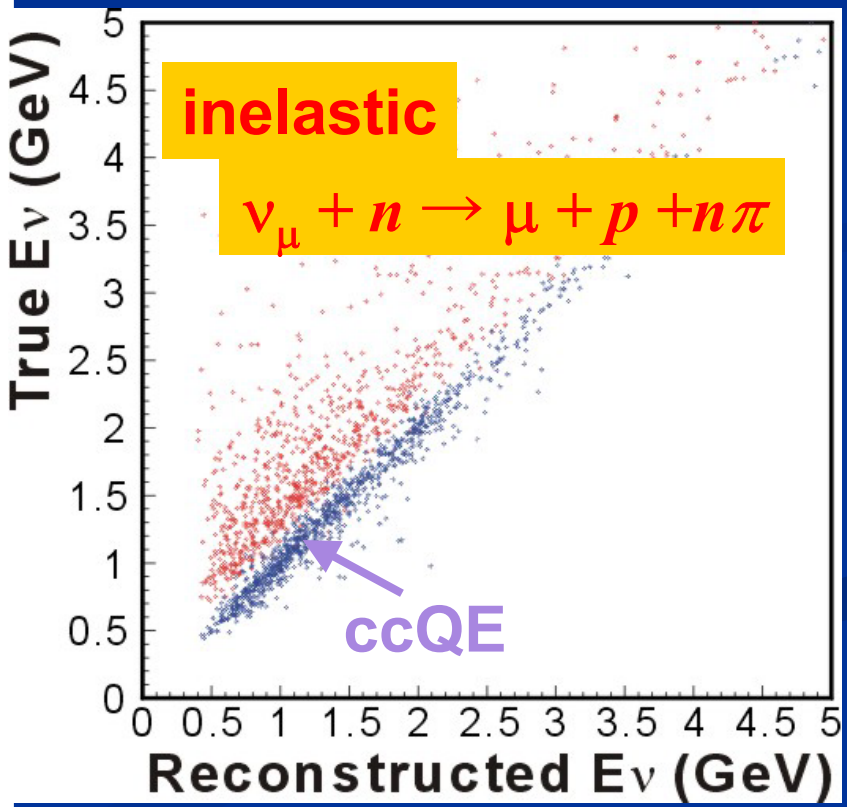
Eν reconstruction in water Cherenkov

Assume CC Quasi Elastic (QE) reaction

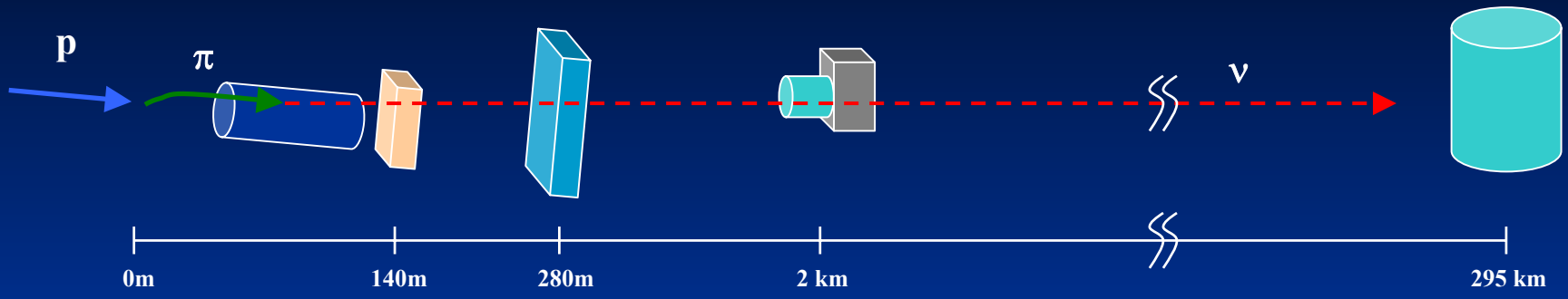


$$E_\nu = \frac{m_N E_\mu - m_\mu^2/2}{m_N - E_\mu + p_\mu \cos\theta_\mu}$$



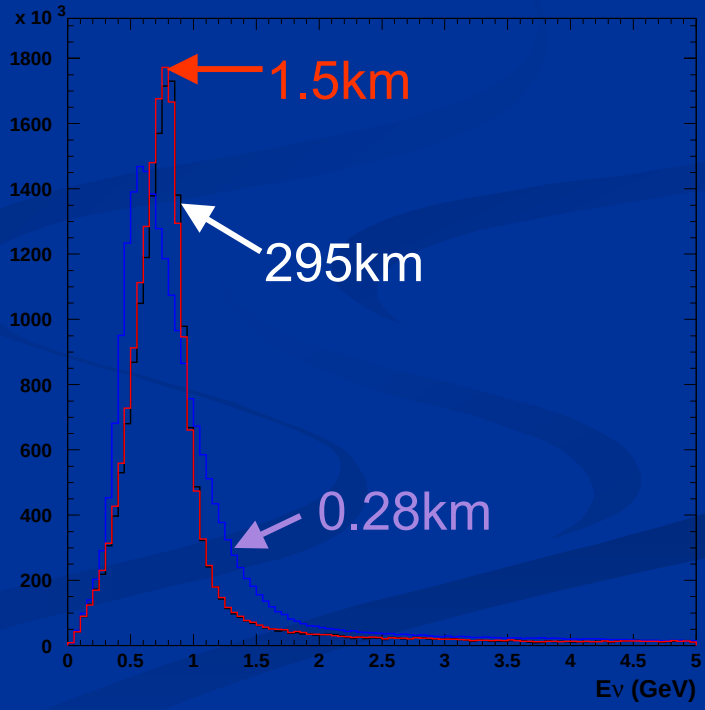


Detectors



- Muon monitors @ ~140m
  - Spill-by-spill monitoring of beam direction
- First Front detector @280m
  - Neutrino intensity/direction
- Second Front Detector @ ~2km
  - Almost same E_ν spectrum as for SK
  - Water Cherenkov can work
- Far detector @ 295km
  - Super-Kamiokande (50kt)

Neutrino spectra at diff. dist

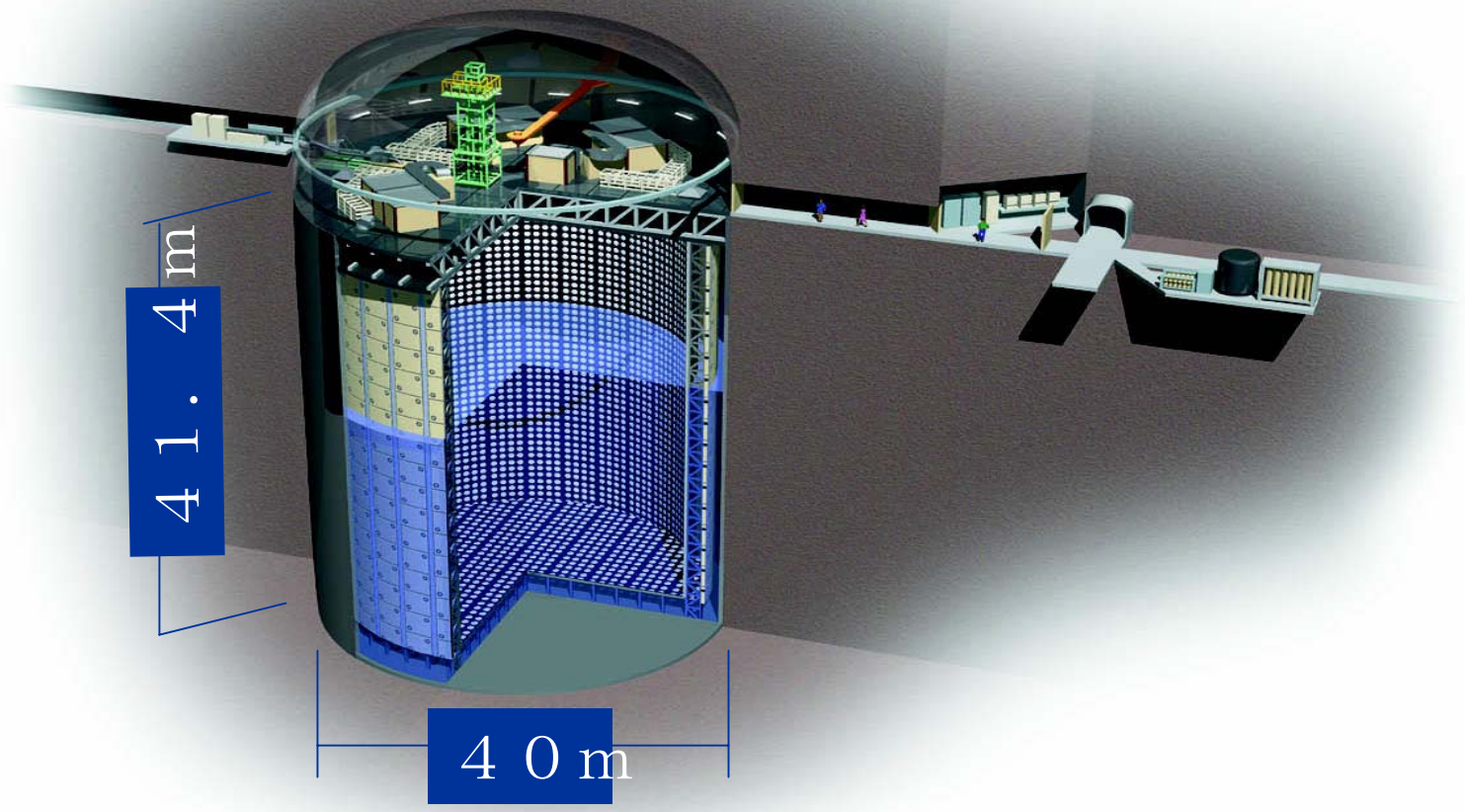


dominant syst. in K2K

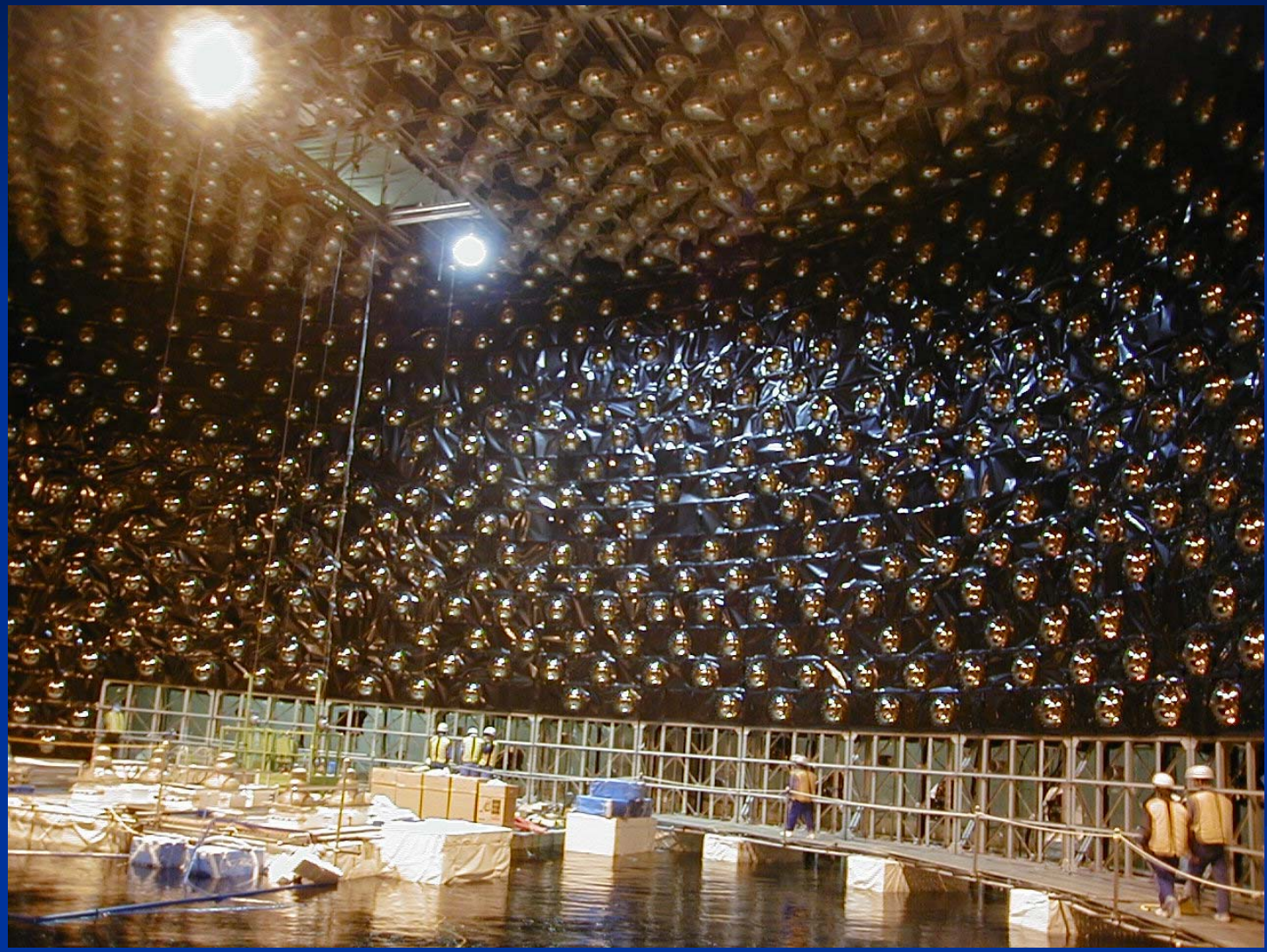
Far detector
Super-Kamiokande

(since Apr 1996)

50,000 ton water Cherenkov detector
(22.5 kton fiducial volume)



Re-Construction of Super-K (Jul 2002)



Physics Goal

★Precise measurement of neutrino mixing matrix

Accuracy: $\sin^2 2\theta_{23}$ ・・・・・・・ 1%

Δm^2_{23} ・・・・・・・・・・・ a few %

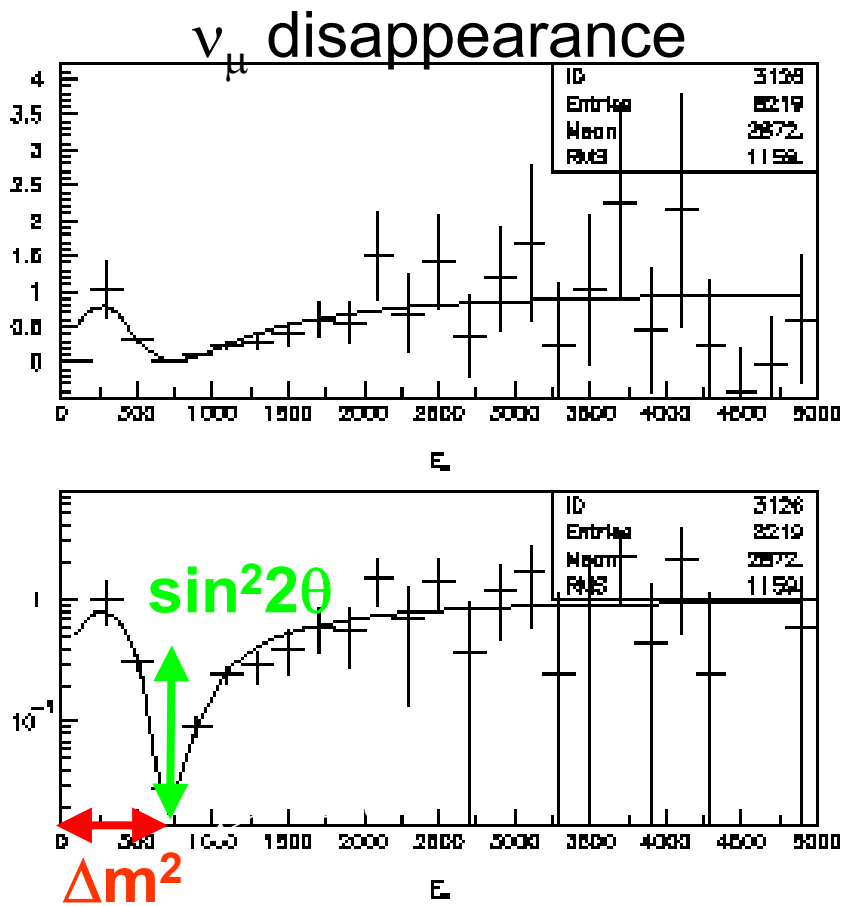
★Discovery and measurement of non-zero θ_{13}

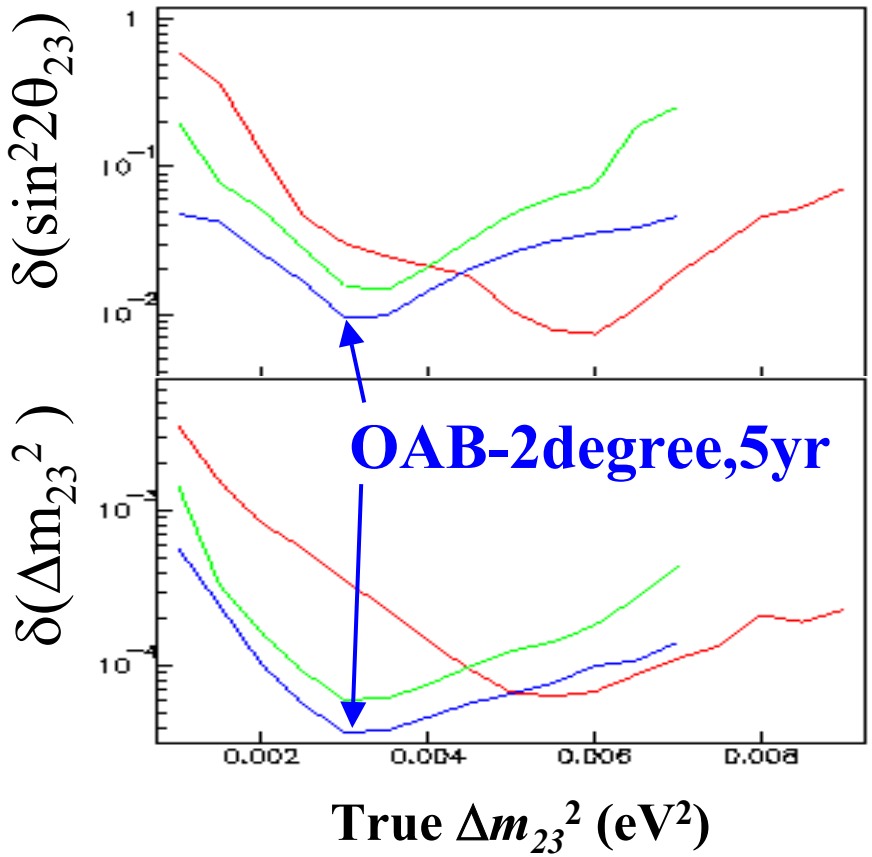
$\sin^2 2\theta_{13}$ ・・・・・・・ > 0.006

1st Evidence of 3-flavor mixing !

1st step to $\not{CP}$ measurement

Measurement of $\sin^2 2\theta_{23}$, Δm^2_{23}

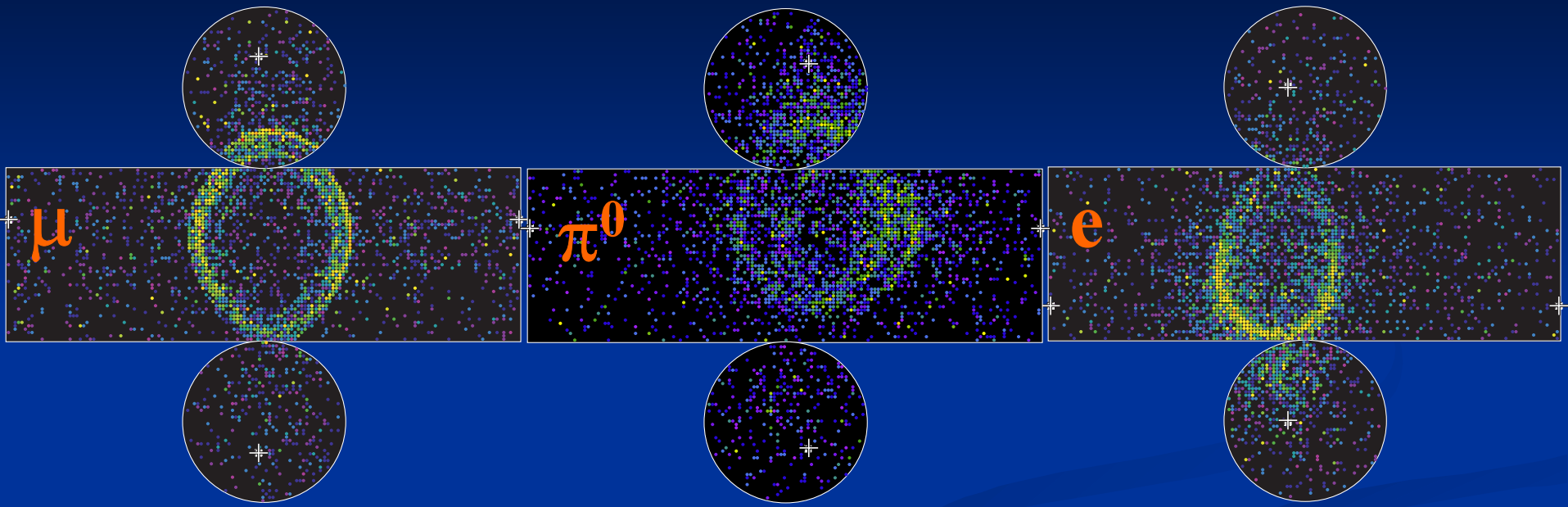




$\delta(\sin^2 2\theta) \sim 0.01$

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

ν_e appearance in JHF-Kamioka



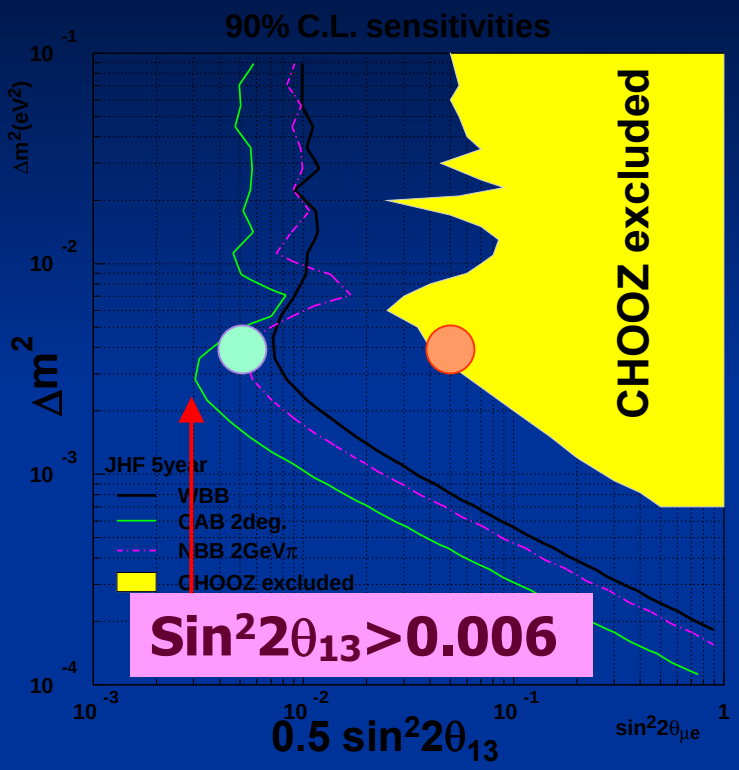
Back ground for ν_e appearance search

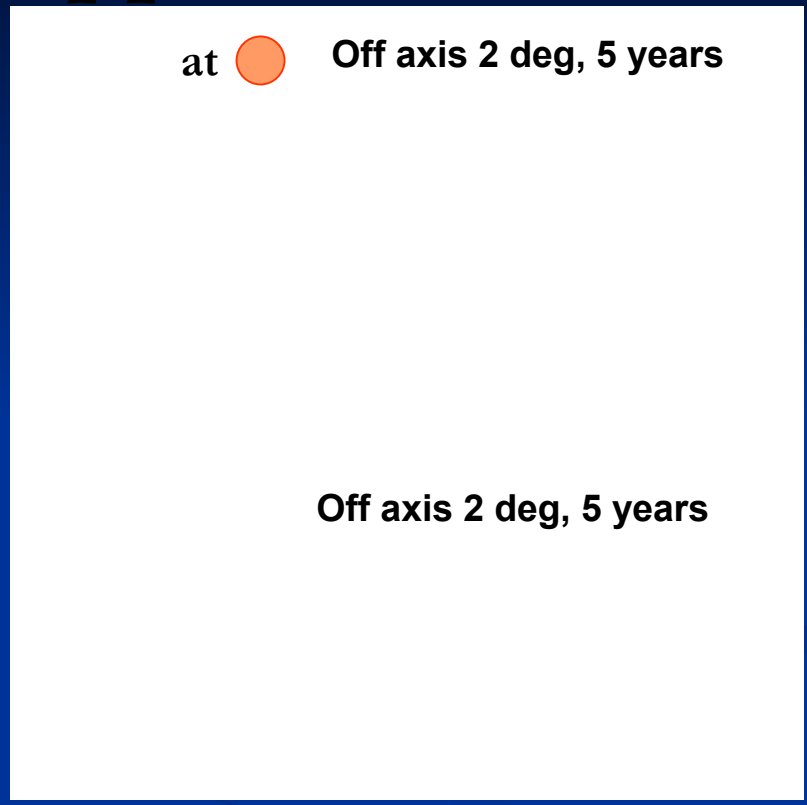
- Intrinsic ν_e component in initial beam
- Merged π^0 ring from ν_μ interactions

10% uncertainty for BG estimation

The 1kt π^0 data will be studied for exercise

$\sin^2 2\theta_{13}$ from ν_e appearance

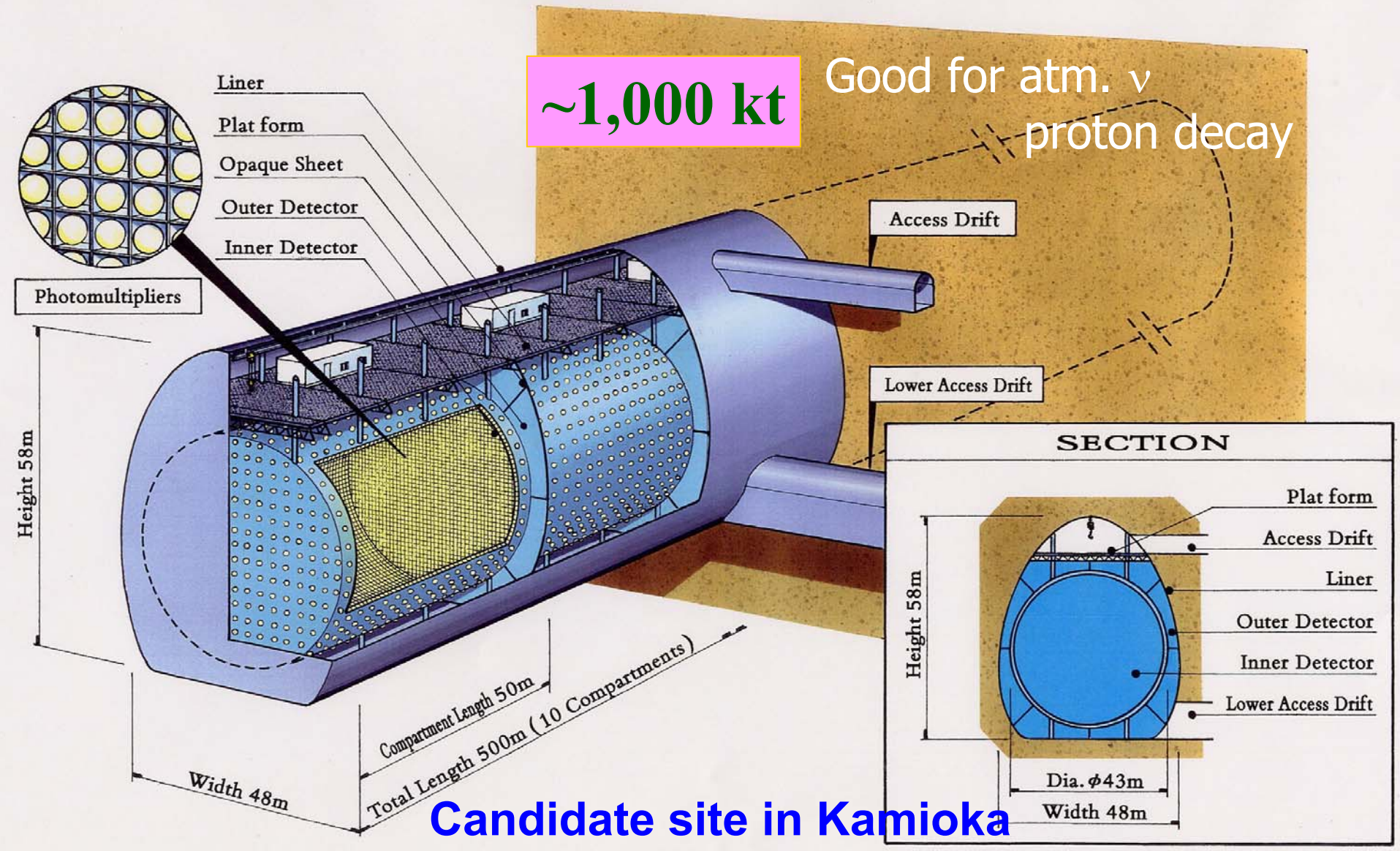




$\sin^2 2\theta_{13}$	Background in Super-K (as of Oct 25, 2001)					Signal	Signal + BG
	ν_μ	ν_e	$\bar{\nu}_\mu$	$\bar{\nu}_e$	total		
0.1	12.0	10.7	1.7	0.5	24.9	114.6	139.5
0.01	12.0	10.7	1.7	0.5	24.9	11.5	36.4

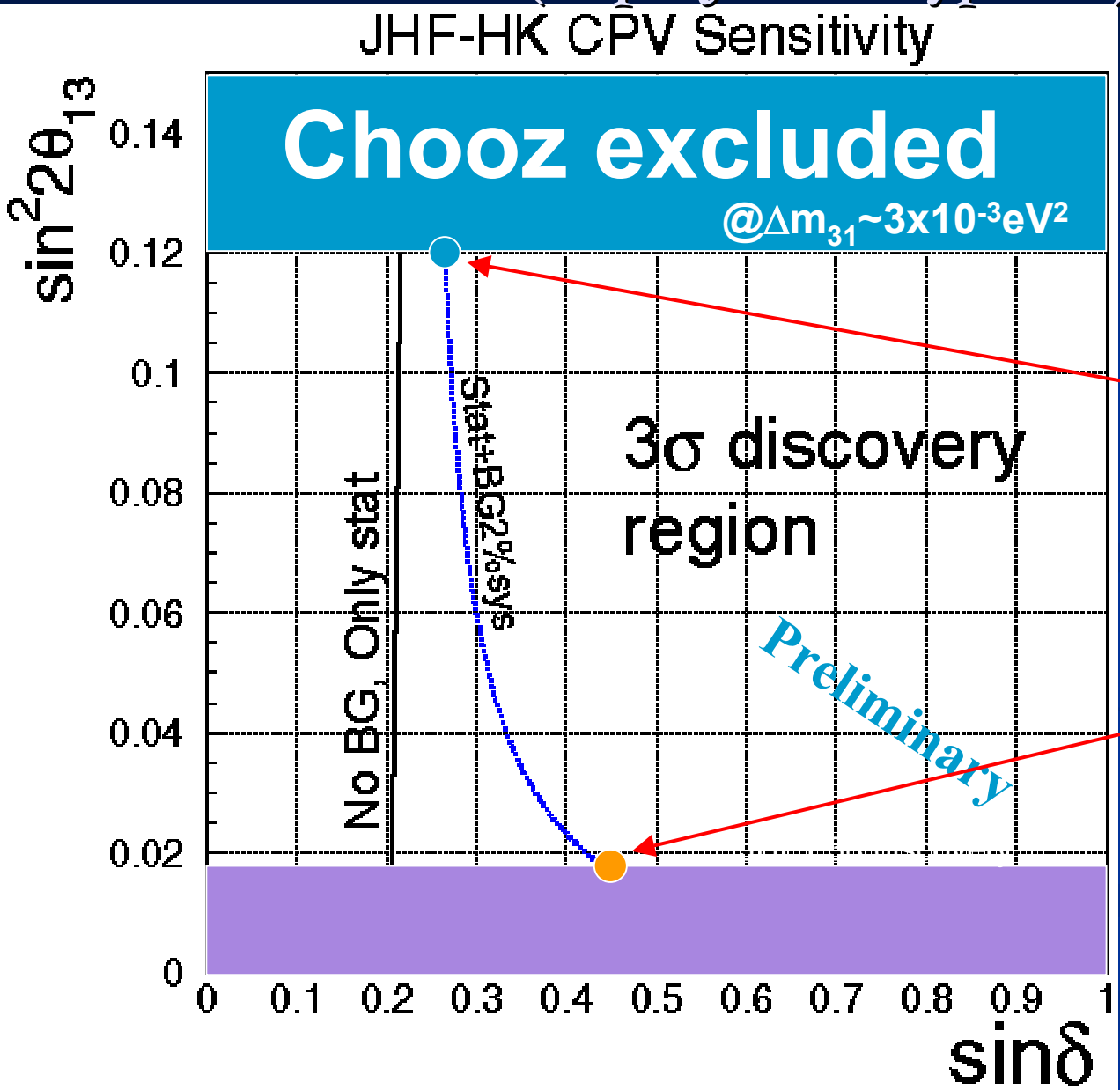
Future upgrade

Super-JHF(4MW)+Hyper-K(1Mt)



Candidate site in Kamioka

Sensitivity(3σ) to CP violation (SuperJHF+Hyper-K)

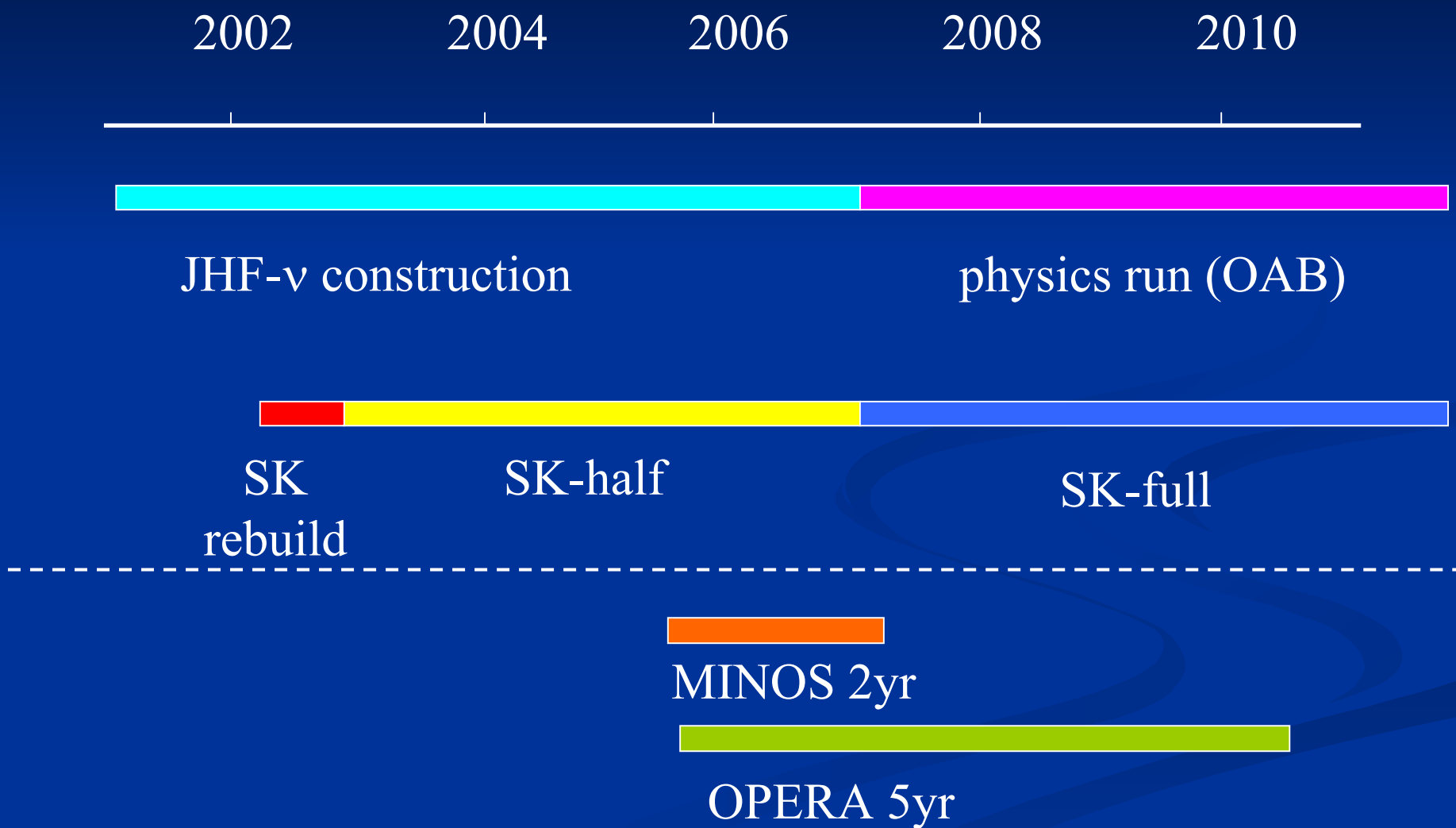


4MW,1Mt
2yr for ν_μ
6.8yr for $\bar{\nu}_\mu$

δ>~14deg

δ>~27deg

Global Schedule



Summary

- Precision study of neutrino mixing matrix
  - Next step after the discovery
  - We may find a hint for next break-through
- JHF-Kamioka neutrino experiment (2007~)
  - JHF 0.75MW 50GeV-PS+Off Axis beam+Super-K
  - Narrow band beam at oscillation maximum (~ 1GeV)
  - ν_e appearance, discovery of θ_{13} ($\sin \theta_{13} > 0.006$, 90%CL)
  - Budget request submitted, R&D started
- Possible upgrade in future
  - 4MW Super-JHF + Hyper-K (1Mt water Cherenkov)
  - CP violation in lepton sector
  - Bonus ! (Proton Decay !)