JHFν progress report and θ_{13} sensitivity

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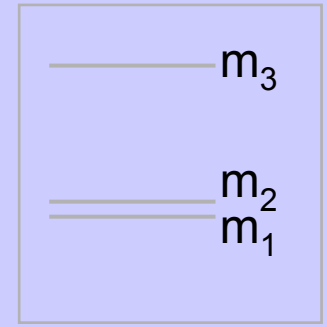
JHFν Mission

- Mission 1: (phase 1)
  - Precision measurement of $\sin^2 2\theta_{23}, \Delta m^2_{23} (\Delta m^2_{13})$
  - Find ν_e appearance if exist
  - Obtain limit of $\nu_\mu \rightarrow \nu_s$ (or find if exist)
- Mission 2: (phase 2)
  - Determine θ_{13} and δ (if ν_e appearance is found in advance)
  - Explore ν_e appearance (if mission 1 obtained only upper limit)
- Discovery of the ν_e appearance is the key of the future of neutrino oscillation world

3 flavor Oscillation

Oscillation Probabilities when



- 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

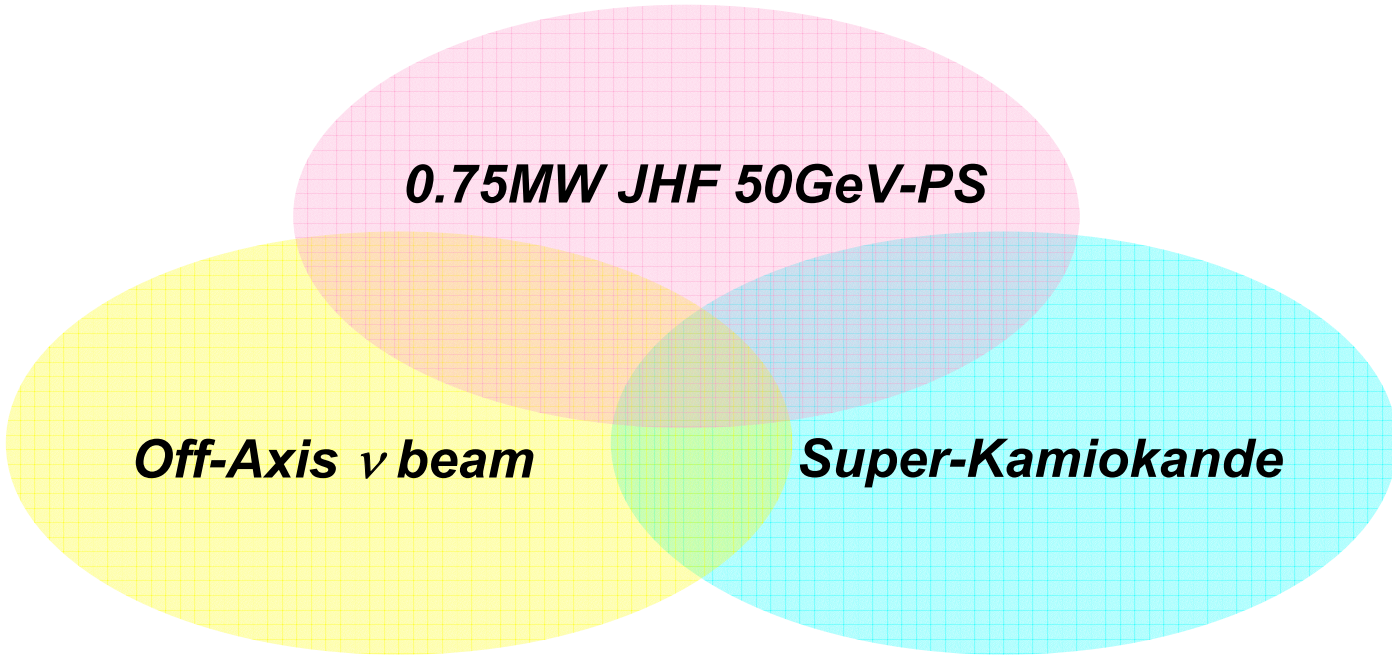
$$P_{\mu \to e} \approx \sin^2 \theta_{23} \cdot \sin^2 2\theta_{13} \cdot \sin^2 \left(1.27 \, \Delta m^2_{13} L / E_\nu\right)$$

- δ: ~~CP~~ in ν_e appearance

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

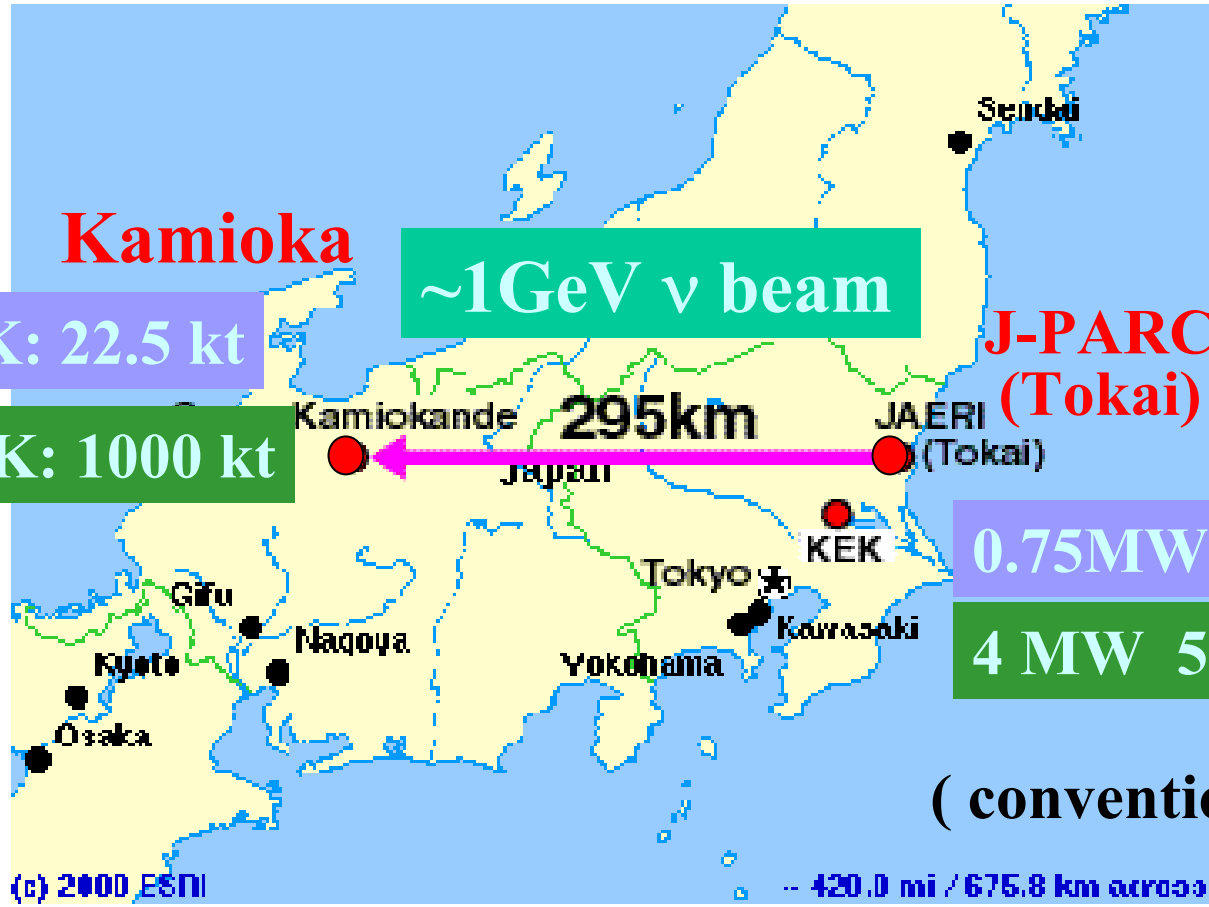
JHF Neutrino Project

- 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

Plan to start in 2007



(conventional ν beam)

Collaboration

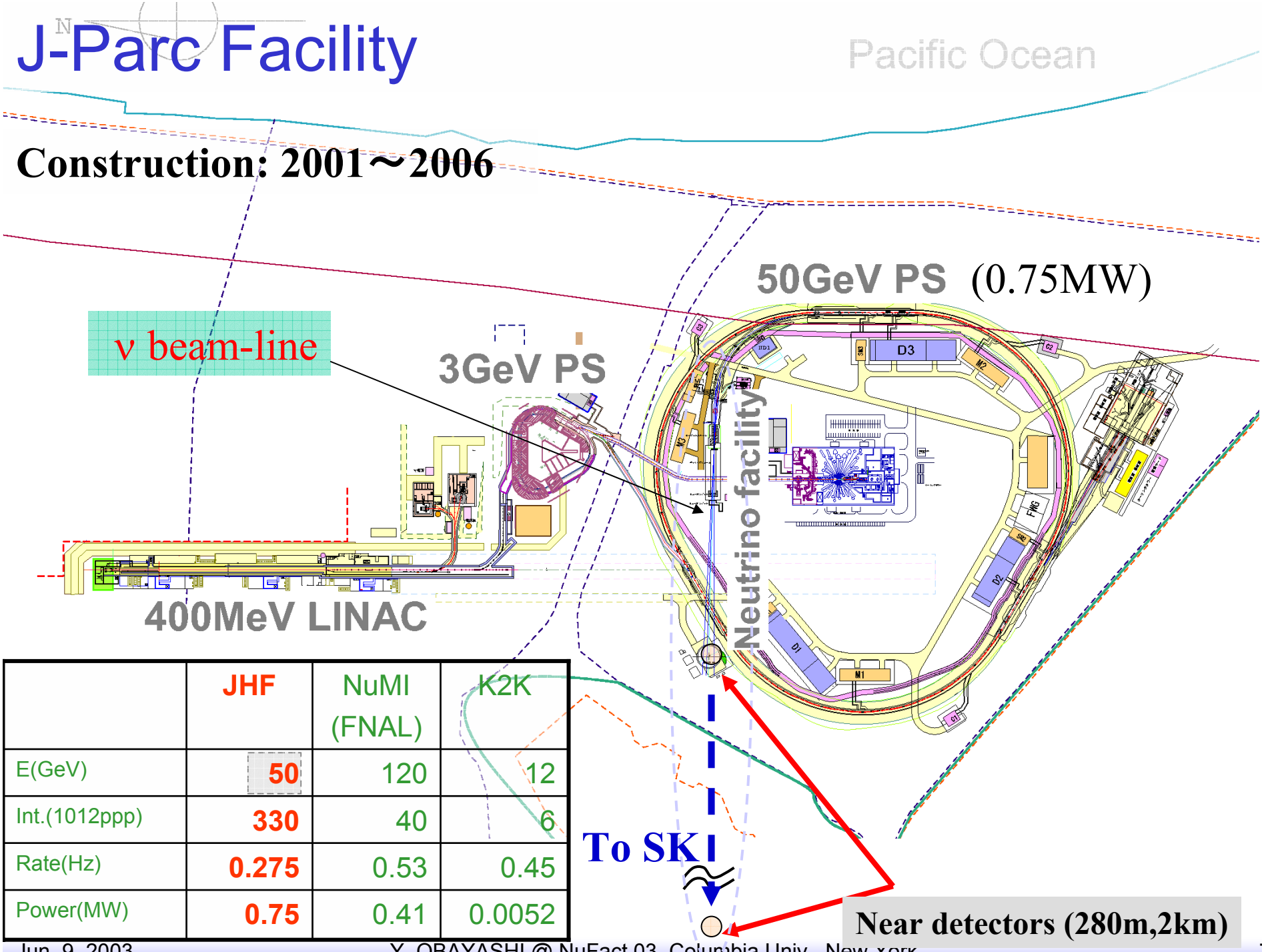
- Working Group (hep-ex/0106019)

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)

- The neutrino facility construction group was OFFICIALLY formed at KEK in 2001.
- LOI was submitted and people from Japan, Canada, France, Italy, Korea, Poland, Russia, Spain, Switzerland, UK and USA signed up in 2002
- First collaboration meeting is held on May, 2003.

J-Parc Facility

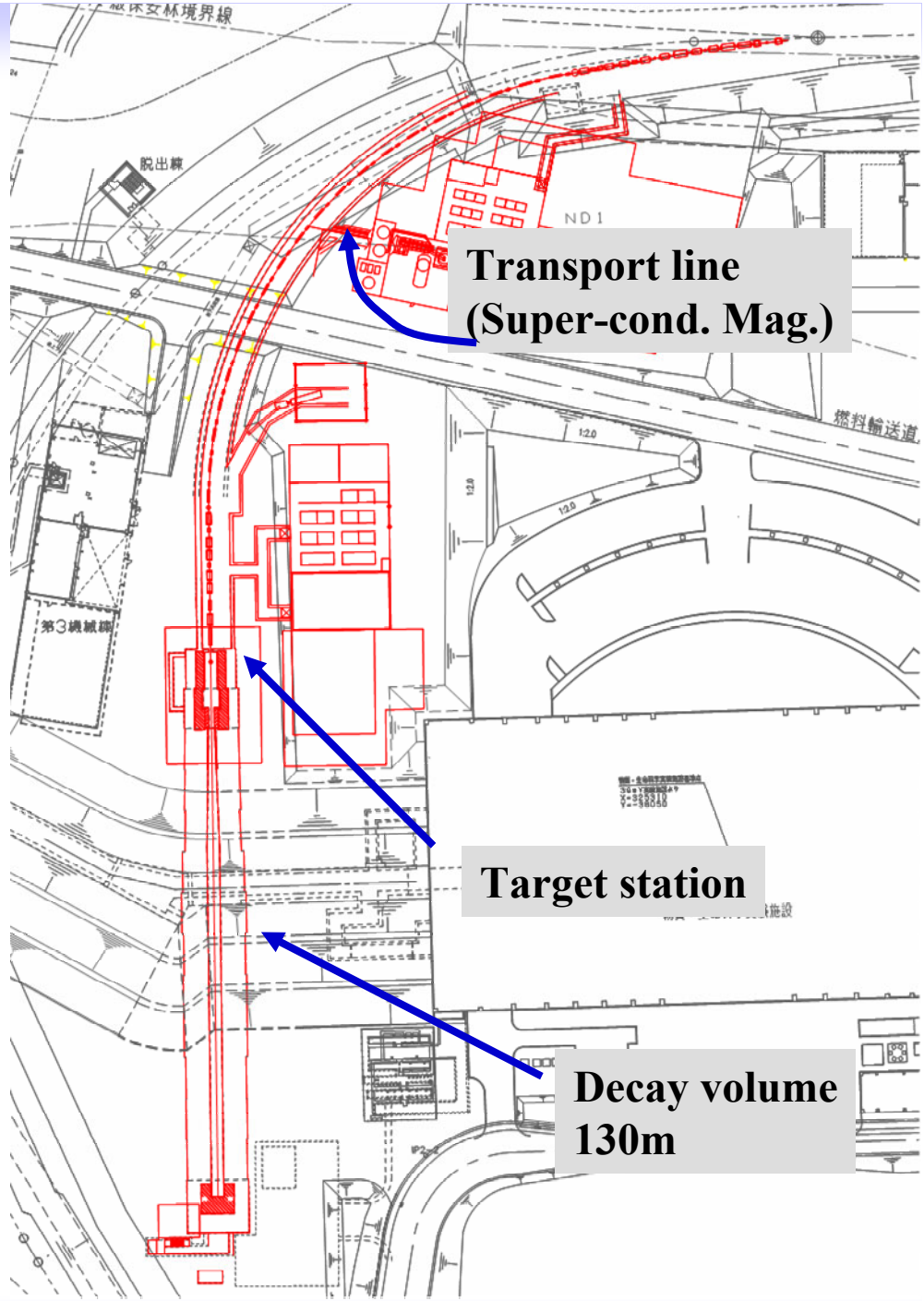
Construction: 2001～2006



	JHF	NuMI (FNAL)	K2K
E(GeV)	50	120	12
Int.(1012ppp)	330	40	6
Rate(Hz)	0.275	0.53	0.45
Power(MW)	0.75	0.41	0.0052

Neutrino Beamline

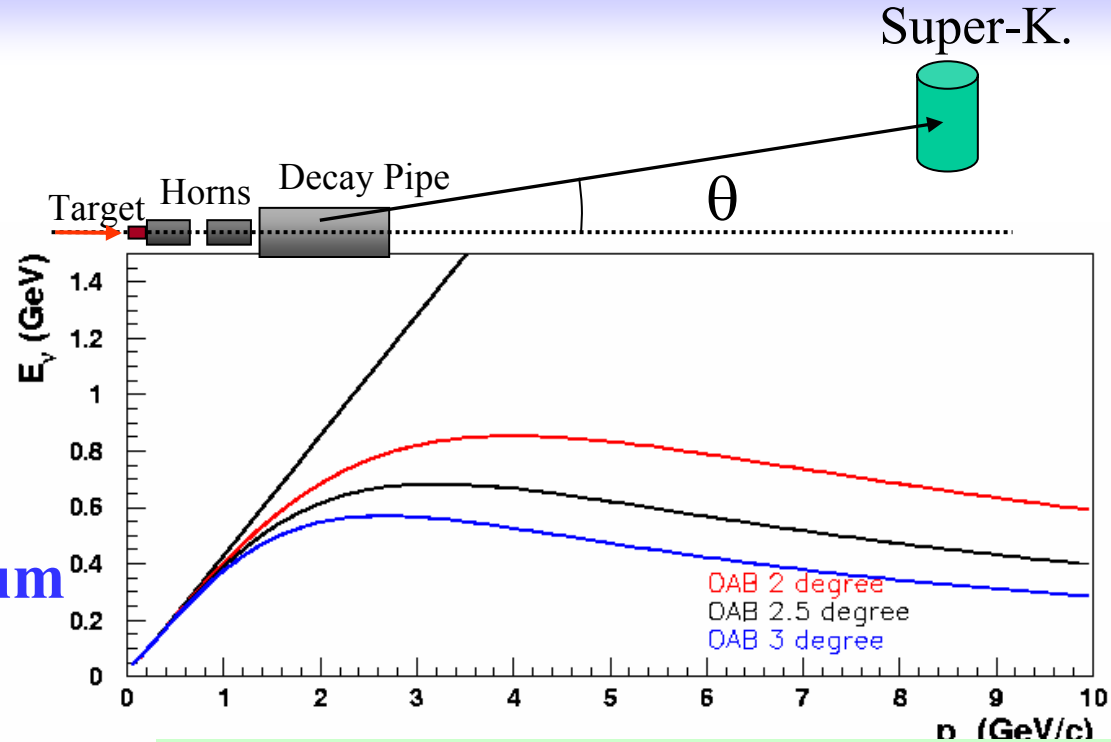
- Budget request submitted
- We expect to be approved in 2004
  - 1st priority for KEK's FY2004 budget proposal



Off Axis Beam

(ref.: BNL-E889 Proposal)

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



Tuned at oscillation maximum

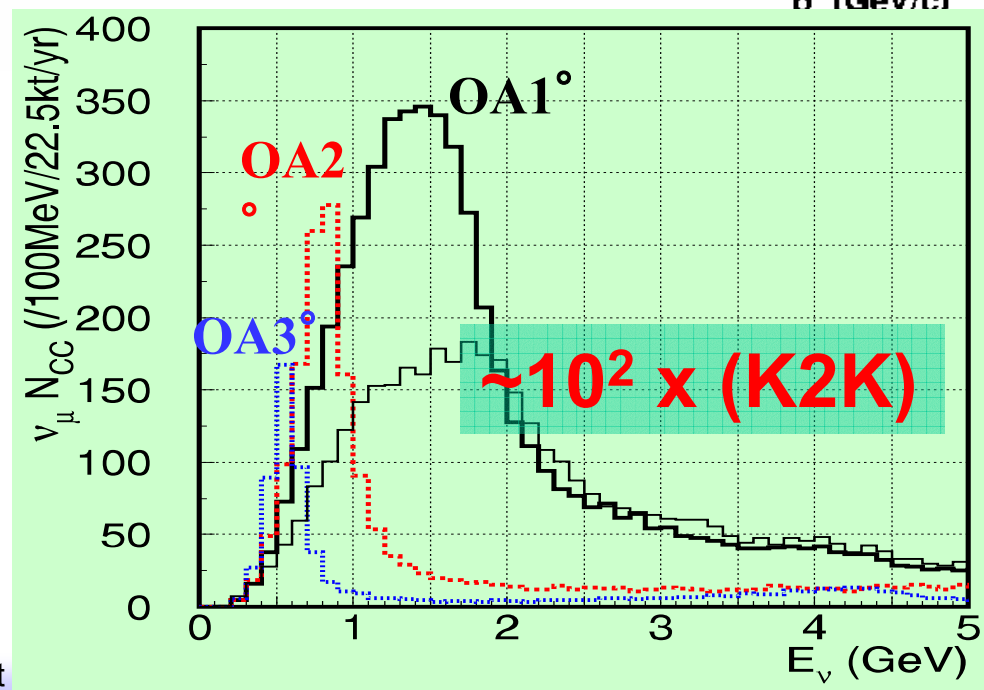
Statistics at SK

(OAB2deg,1yr,22.5kt)

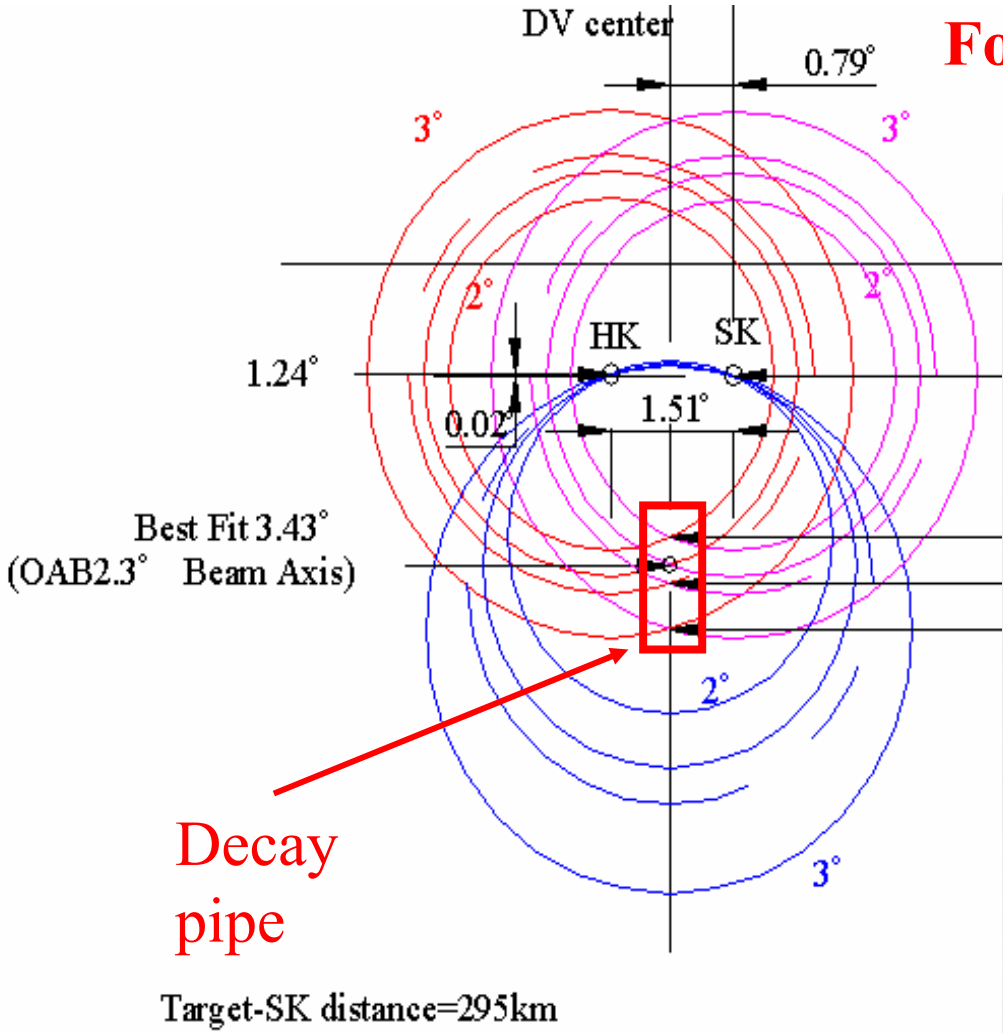
~4500 ν_μ tot

~3000 ν_μ CC

ν_e ~0.2% at ν_μ peak

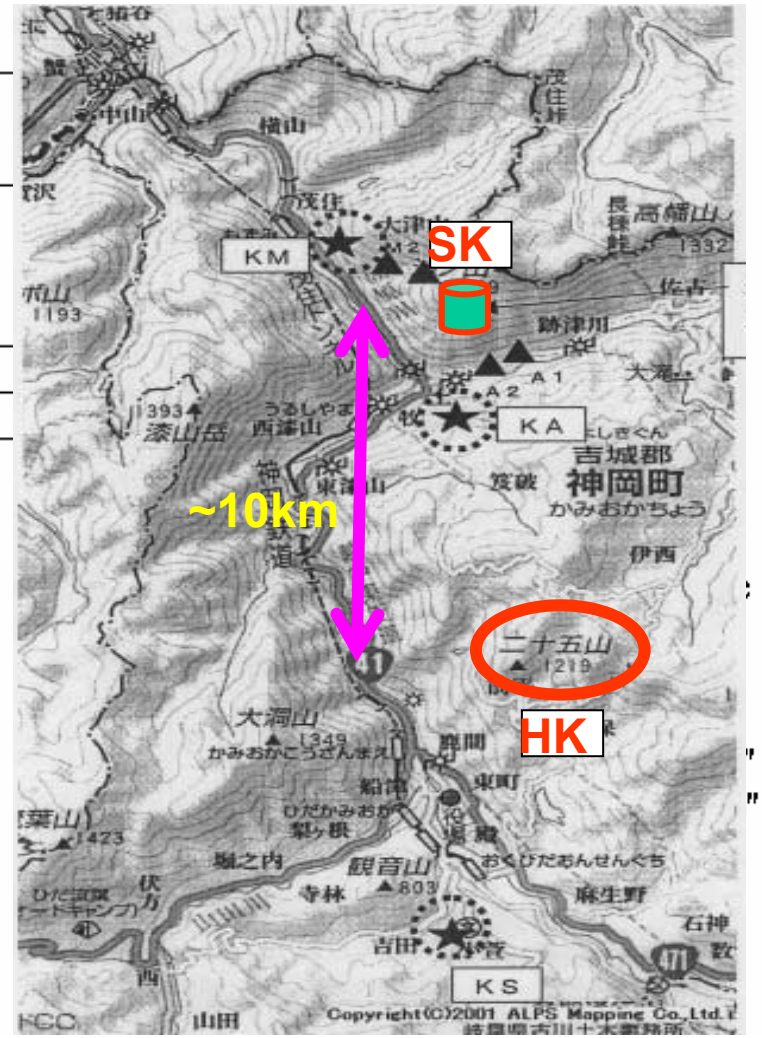


Beam Direction



For both SK and possible HK.

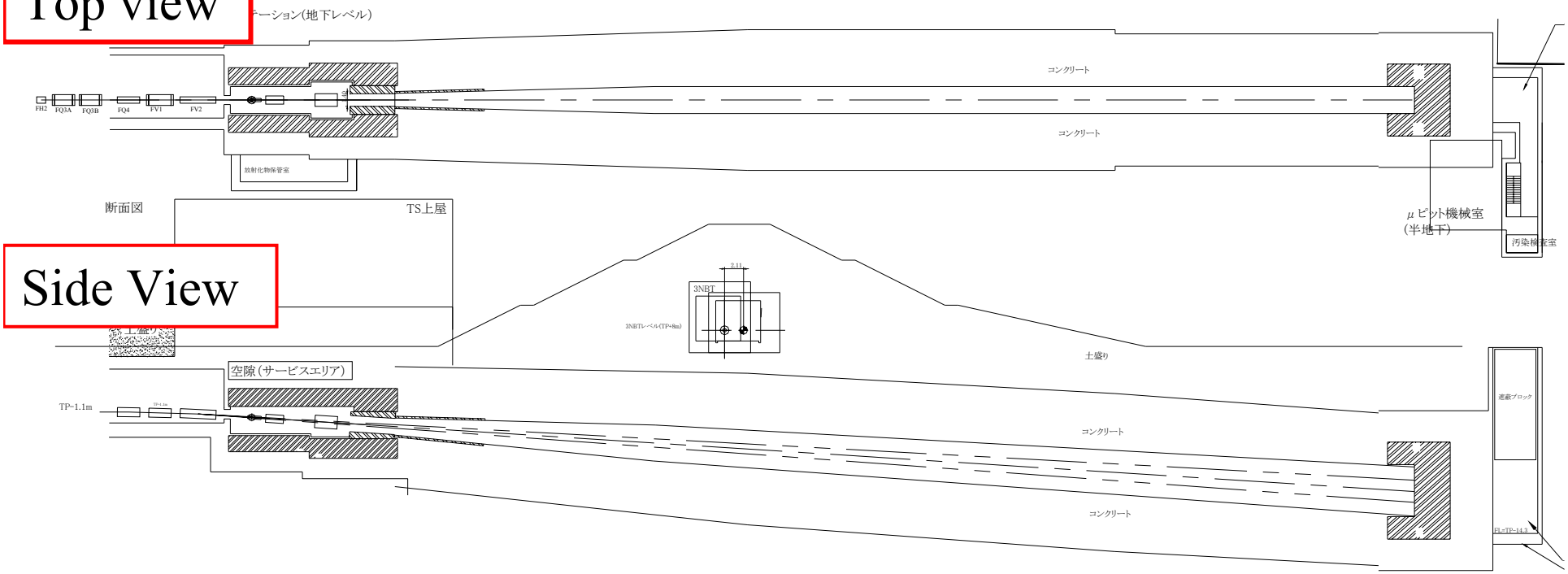
Possible site for Hyper-K



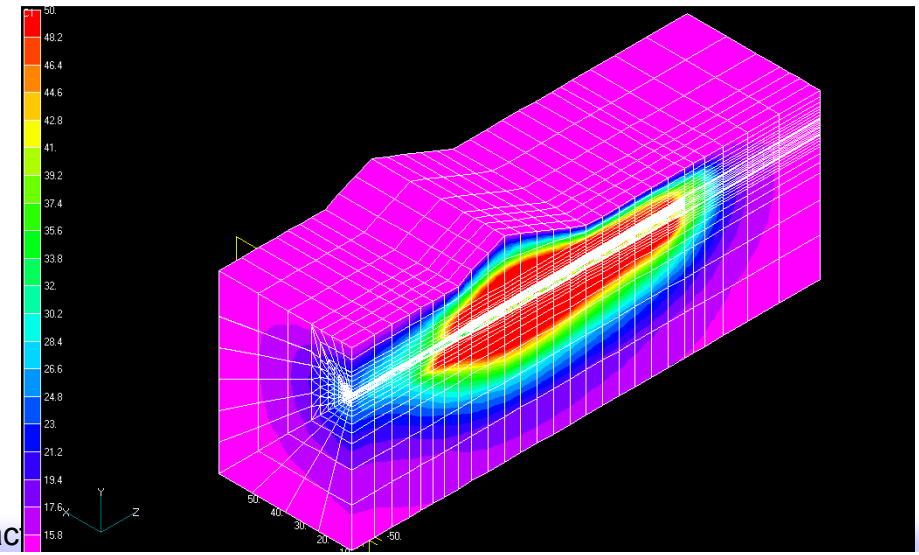
Decay Volume

Top view

Side View



4MW beam can be accepted.



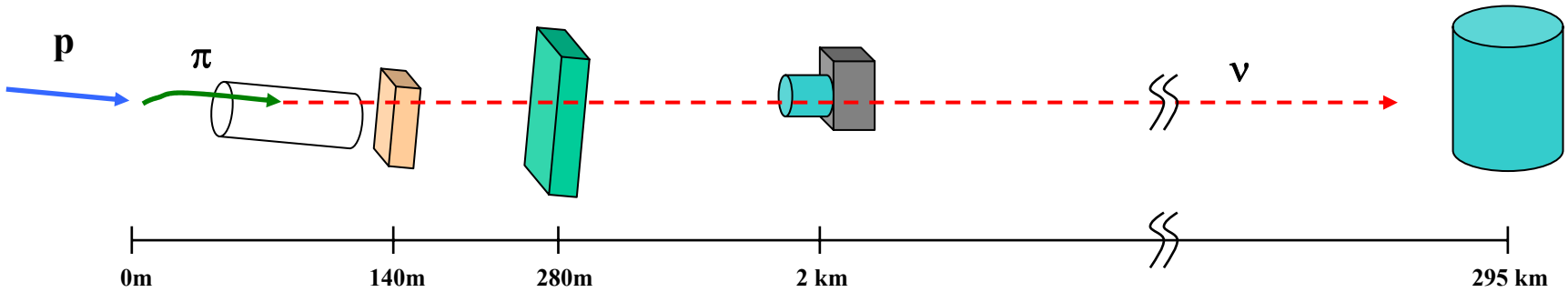
Status of the Beam line design

- Civil construction
  - Construction of Tunnel around fast ext. / preparation section started
- Superconducting arc part
  - Combined function (CF) scheme chosen
- Proton beam monitors
  - Intensive development work started (SSEC, RGBPM)
- Target Station
  - Intensive Design work started
- Strategy to change peak energy: change off axis angle
  - OA+Bending Magnet (OA+B) is studied → currently, not chosed
- Cooling design and heat simulations on decay pipe finished.
- Cooling design and heat simulations on beam dump started.
- Everything will be READY to start construction in 2004



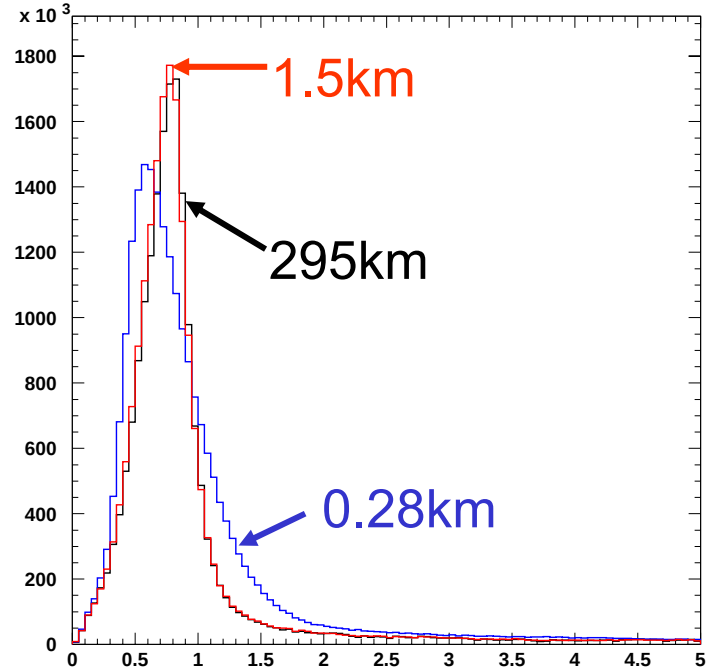



Detectors



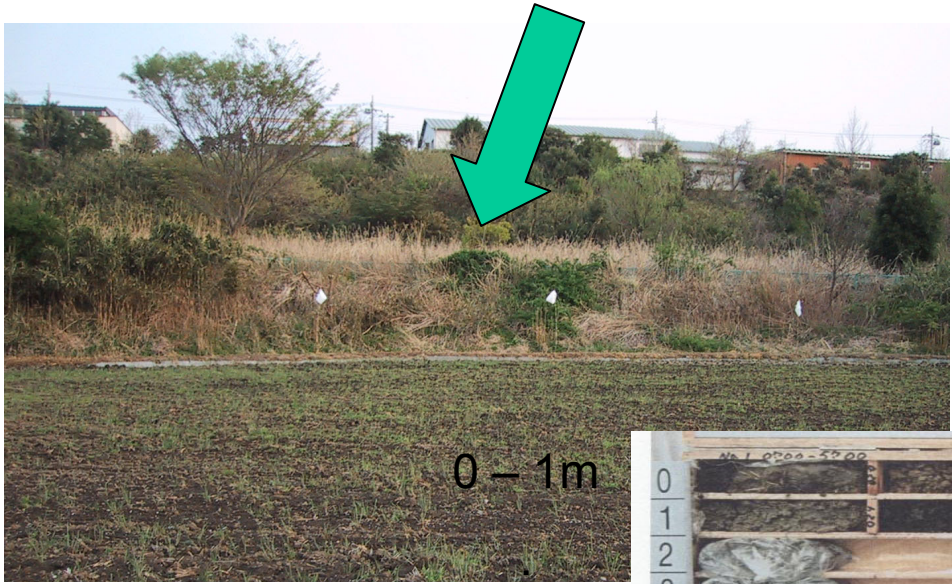
- Muon monitors @ ~140m
  - Fast (spill-by-spill) monitoring of beam direction/intensity
- First Near detector @280m
  - Neutrino intensity/spectrum/direction
- Second Near Detector @ ~2km
  - Almost same E_ν spectrum as for SK
  - Water Cherenkov can work

Neutrino spectra at diff. dist



dominant syst. in K2K

2km Site Candidate Place



0 – 1m

soft

Boring Core

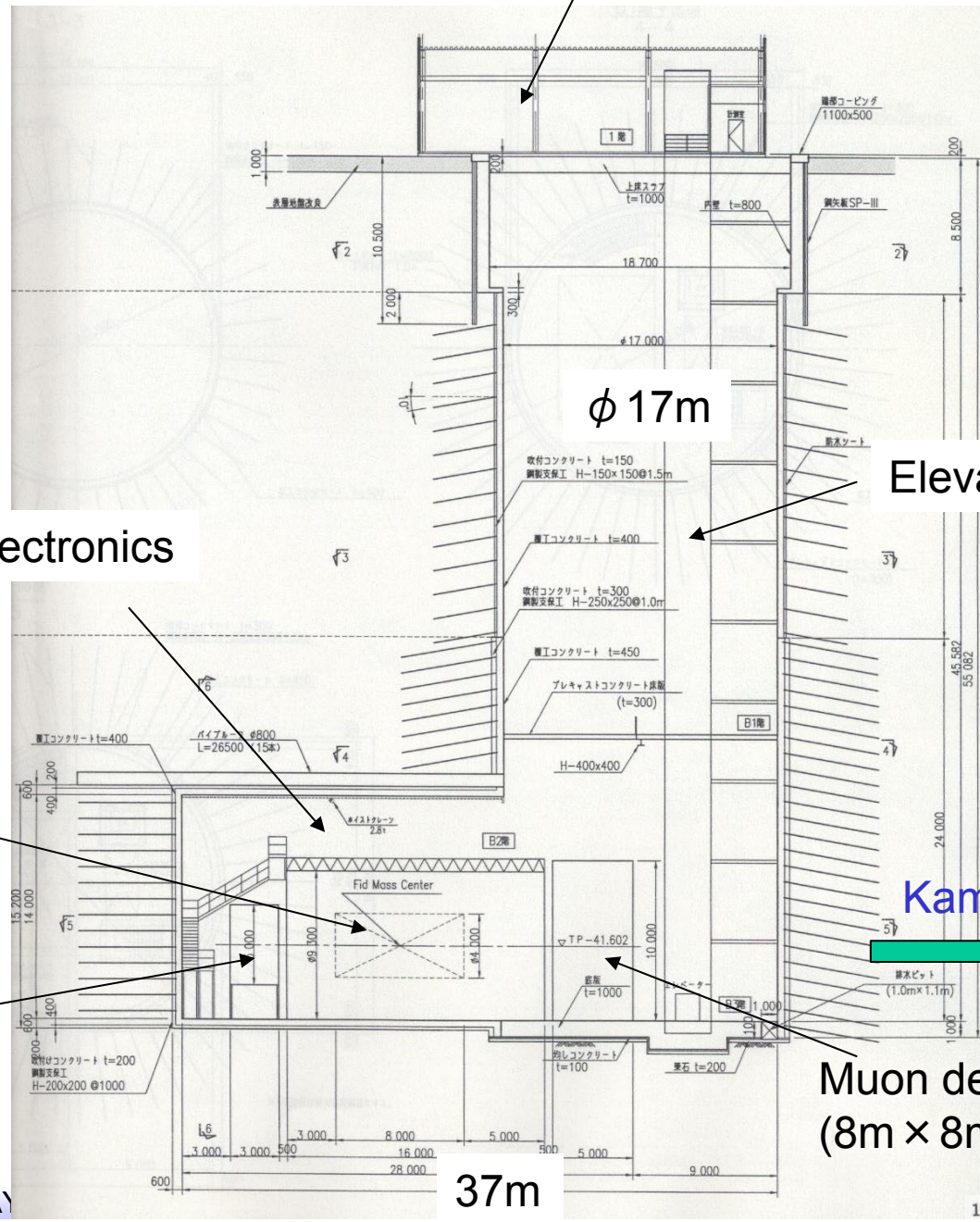
Rock !

(hard enough)

19 – 20m

Down to 65m

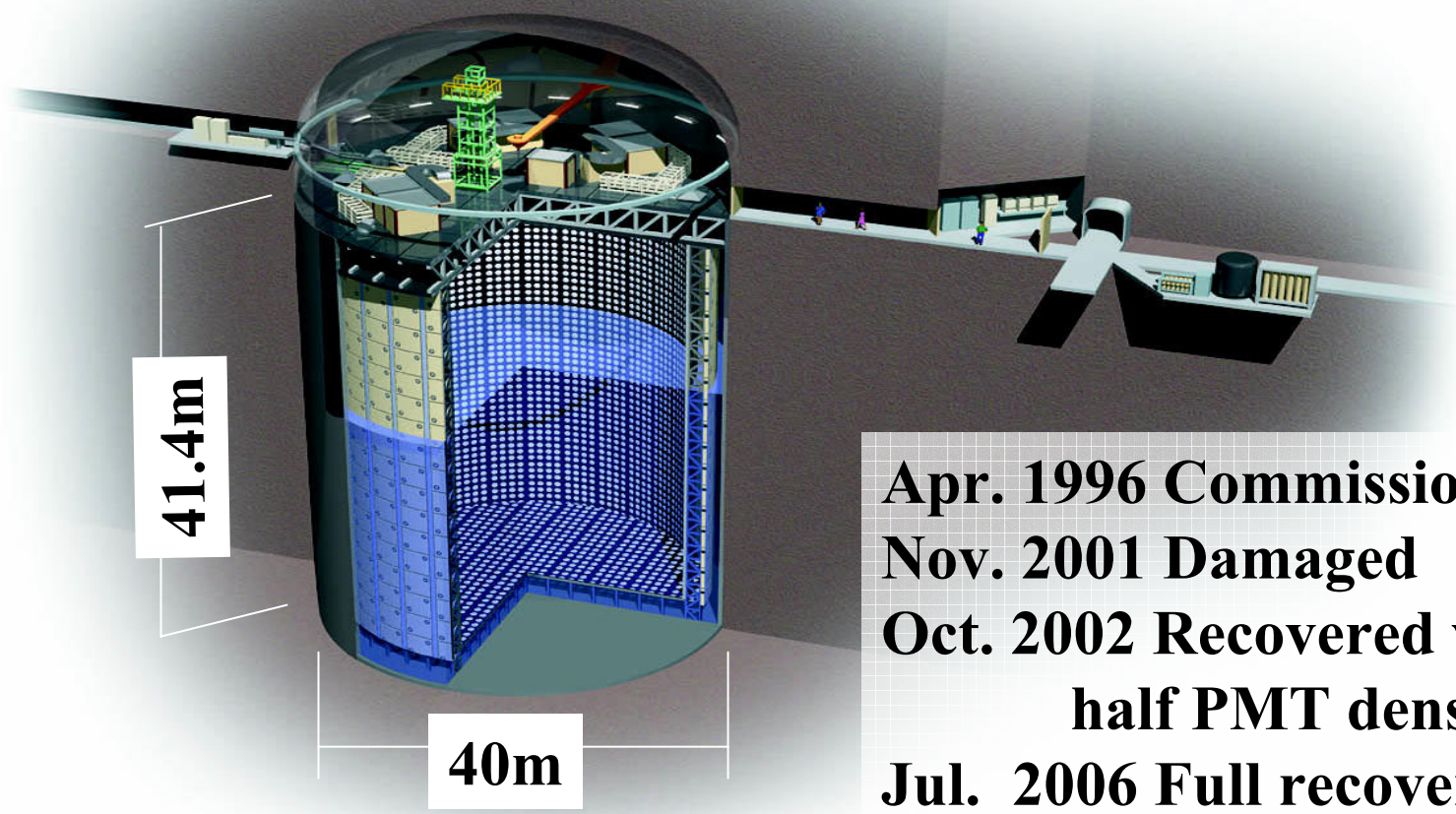
Design of the experimental hall (preliminary)



Far detector : Super-Kamiokande

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

Optically separated INNER and OUTER detector



Apr. 1996 Commissioned
Nov. 2001 Damaged
Oct. 2002 Recovered with half PMT density
Jul. 2006 Full recovery

Physics Sensitivities

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

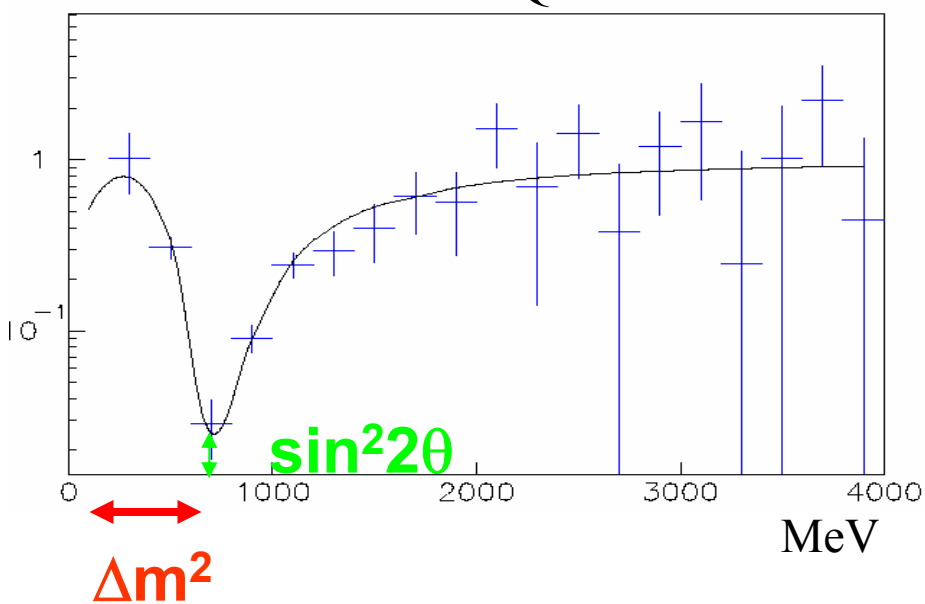
ν_μ disappearance

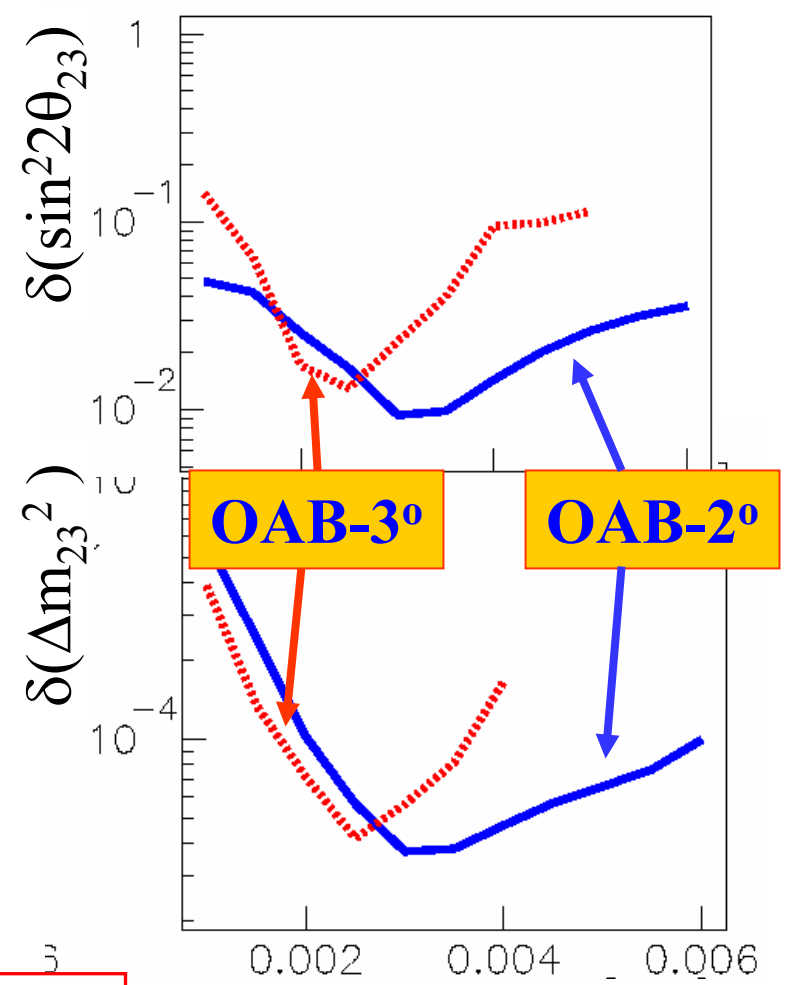
FC, 1-ring, μ-like events

Sys. error 10% for near/far

4% energy scale

20% non-QE B.G.



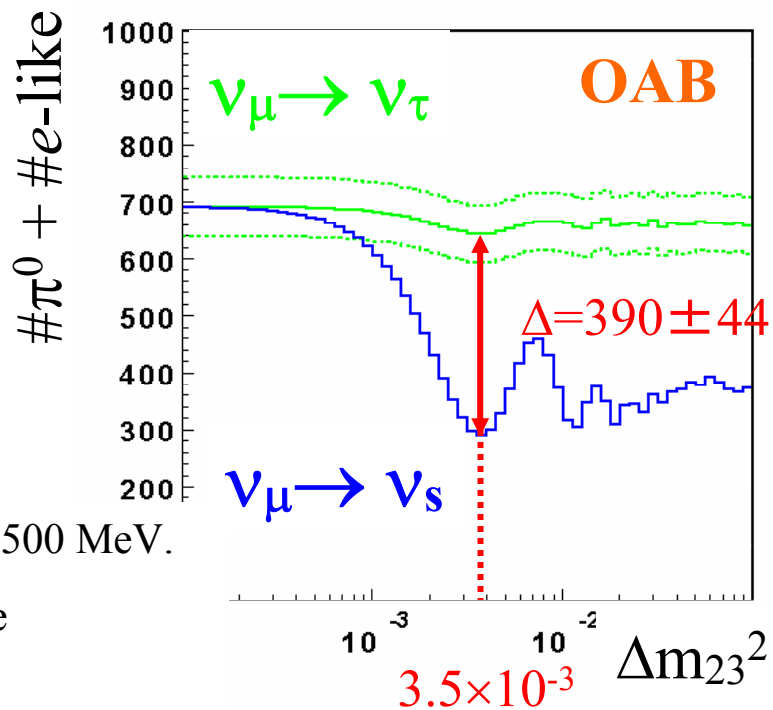


$\delta(\sin^2 2\theta) \sim 0.01$ $\quad \delta(\Delta m^2) \sim < 1 \times 10^{-4}$

Search for $\nu_\mu \rightarrow \nu_s$ oscillation w/ NC interaction

- NC π^0 interaction ($\nu + N \rightarrow \nu + N + \pi^0$)
  - $\nu_\mu \rightarrow \nu_e$ CC + NC(~0.5CC) ~0 ($\sin^2 2\theta_{\mu e} \sim 0$)
    ν_μ CC + NC(~0.5CC) ~0 (maximum oscillation)
    ν_τ **NC**

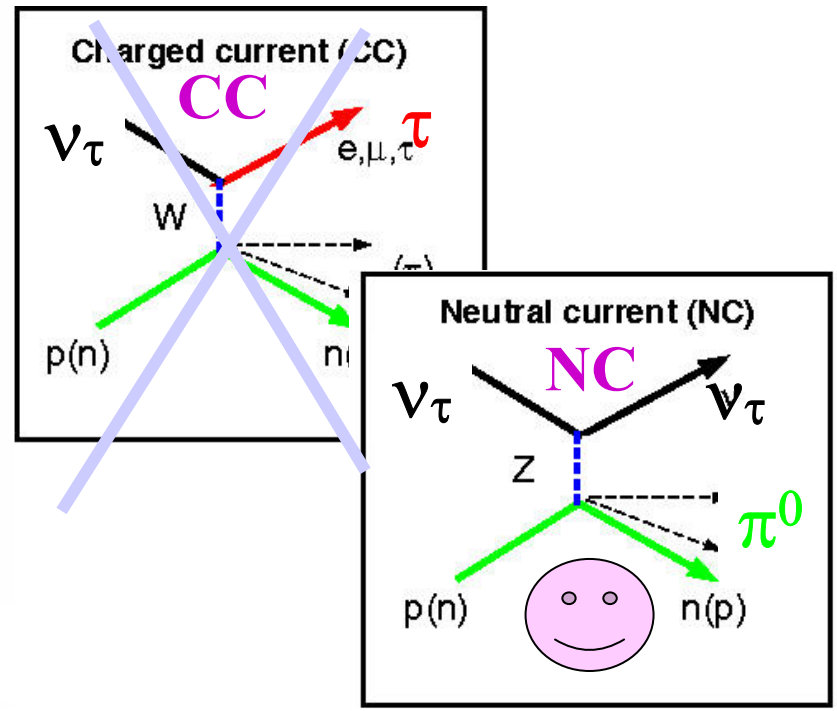
#π^0 is sensitive to ν_τ flux. **Limit on ν_s ($\delta f(\nu s) \sim 0.1$)**



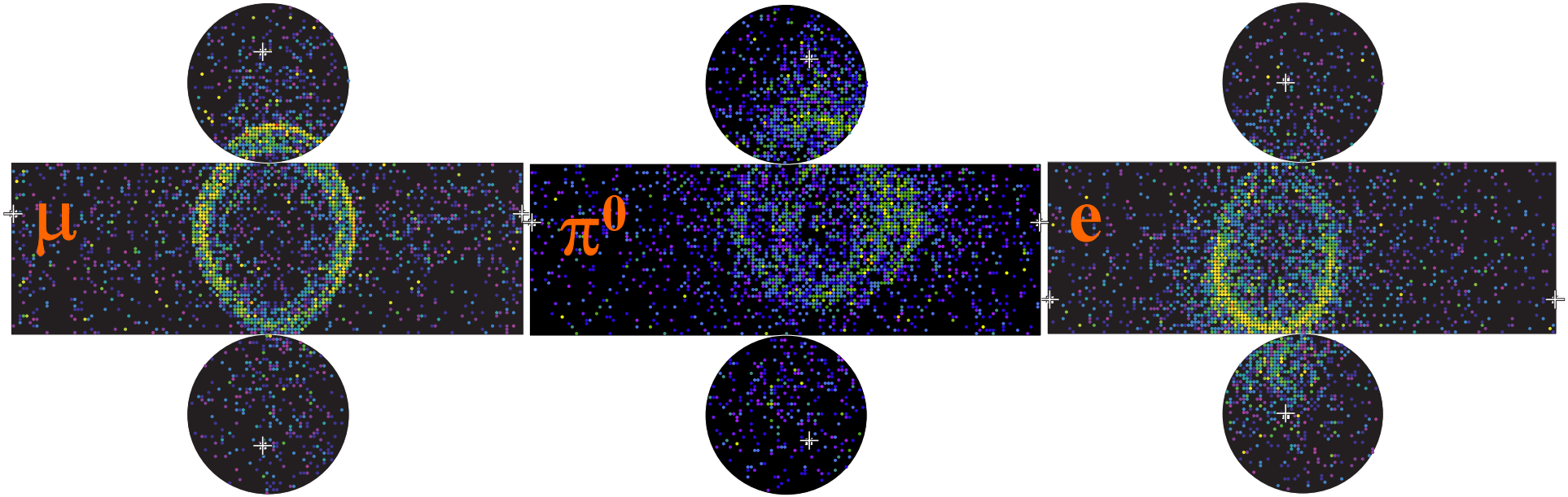
100MeV<E_{vis}<1500 MeV.

#ring<3 & e-like

No decay-e

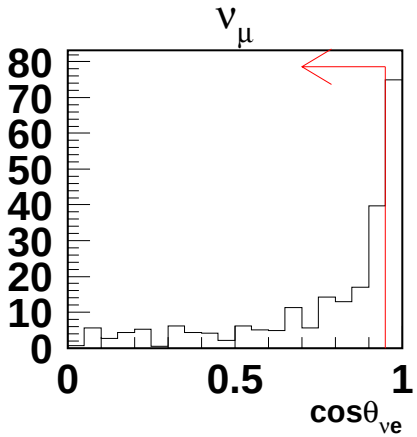


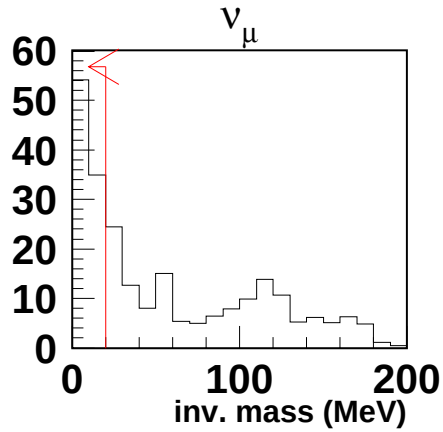
θ_{13} Search (ν_e appearance search)

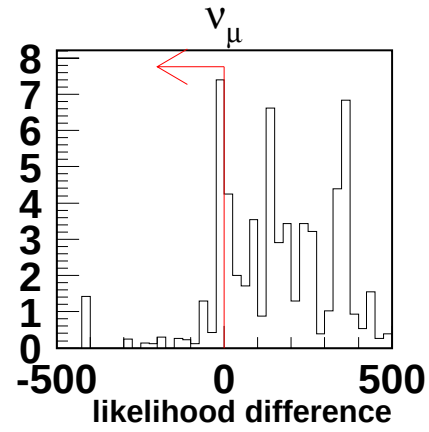


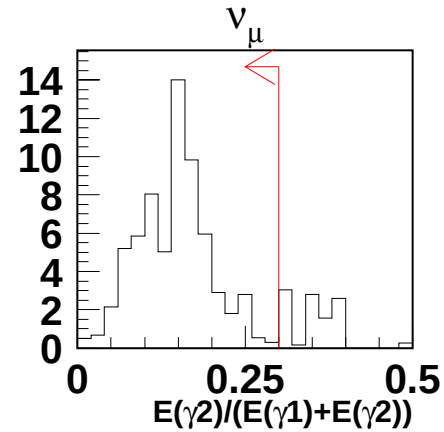
- ν_e appearance probability
  - $P_{\mu\to e} \approx \sin^2\theta_{23} \cdot \sin^2 2\theta_{13} \cdot \sin^2\left(1.27\Delta m^2_{13} L / E_\nu\right)$,$\sin^2\theta_{23}\times\sin^2 2\theta_{13}$~0.05 @CHOOZ limit, 0.005@JHFν aiming
- Back ground for ν_e appearance search
  - Intrinsic ν_e component in initial beam
  - Merged or missed π^0 ring from ν_μ (NC) interactions
  - Miss ID of muon from ν_μ CC interactions

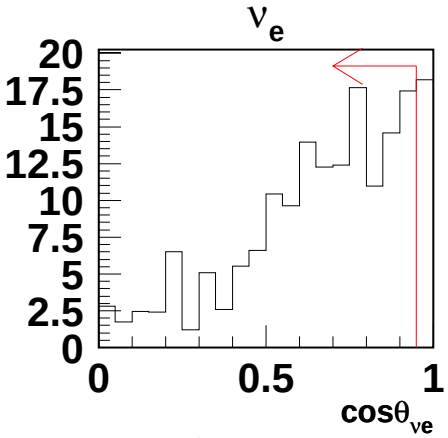
π^0 rejection after 1-ring e-like selection



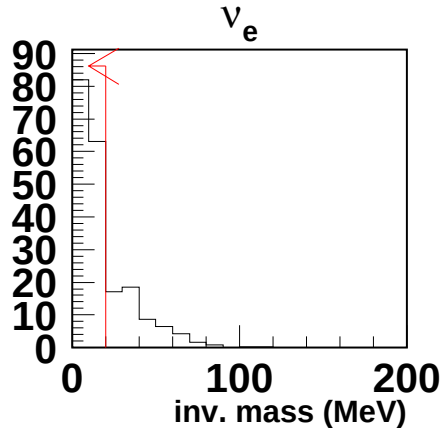




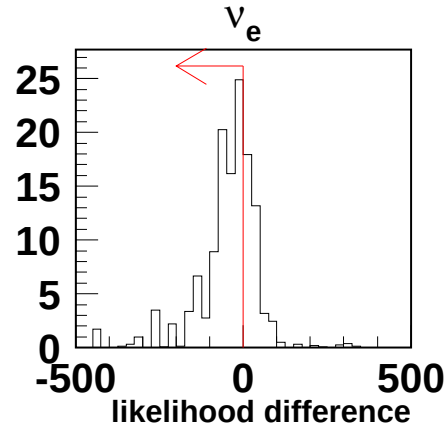




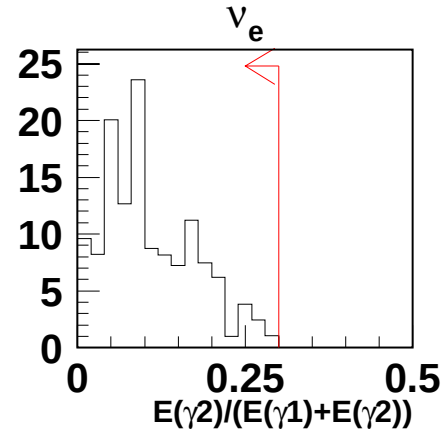
reduce coherent π^0



inv. mass of 2γ

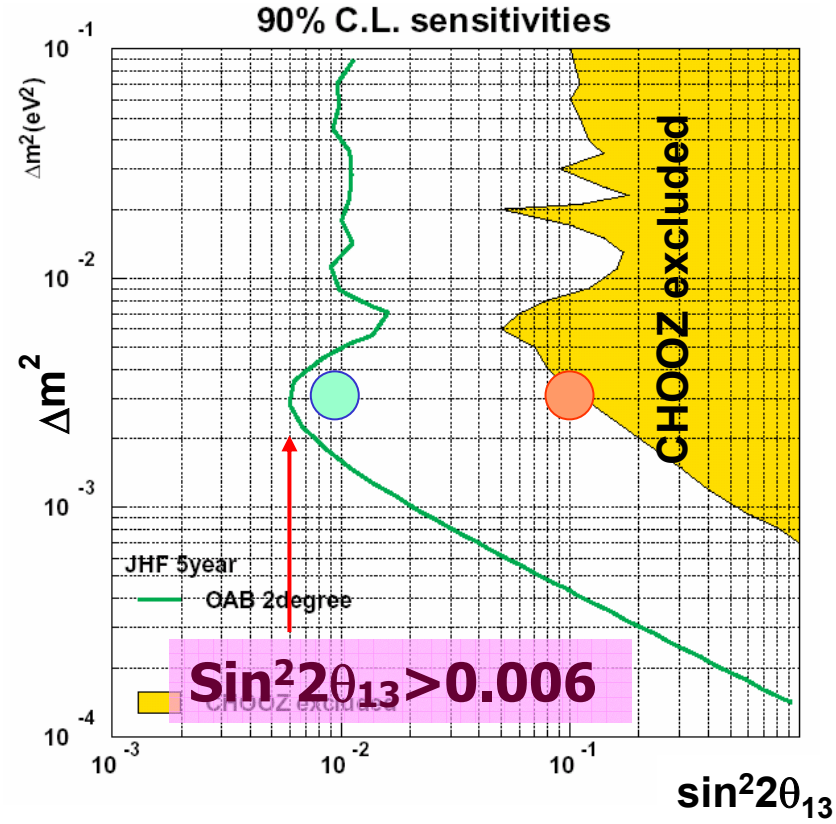


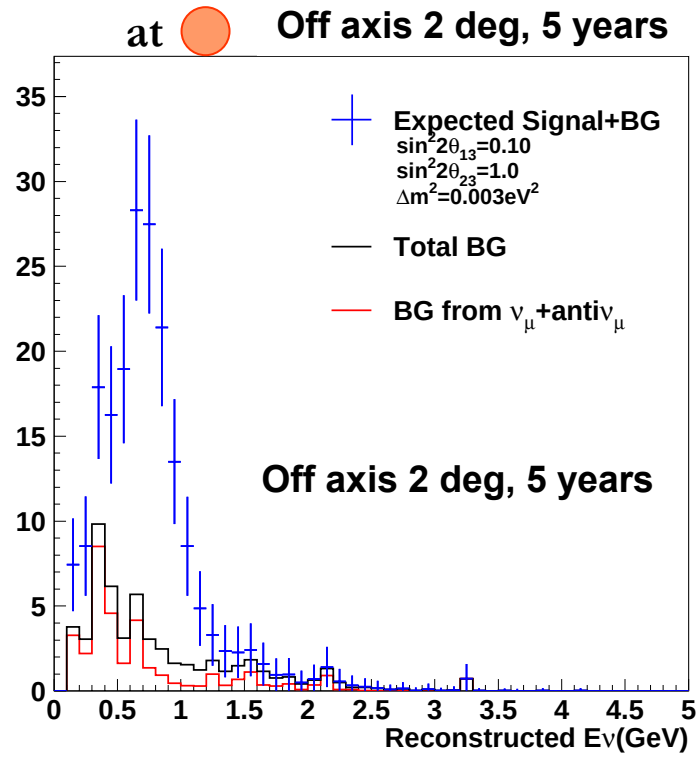
1-ring /2-ring



energy of 2nd γ candidate

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



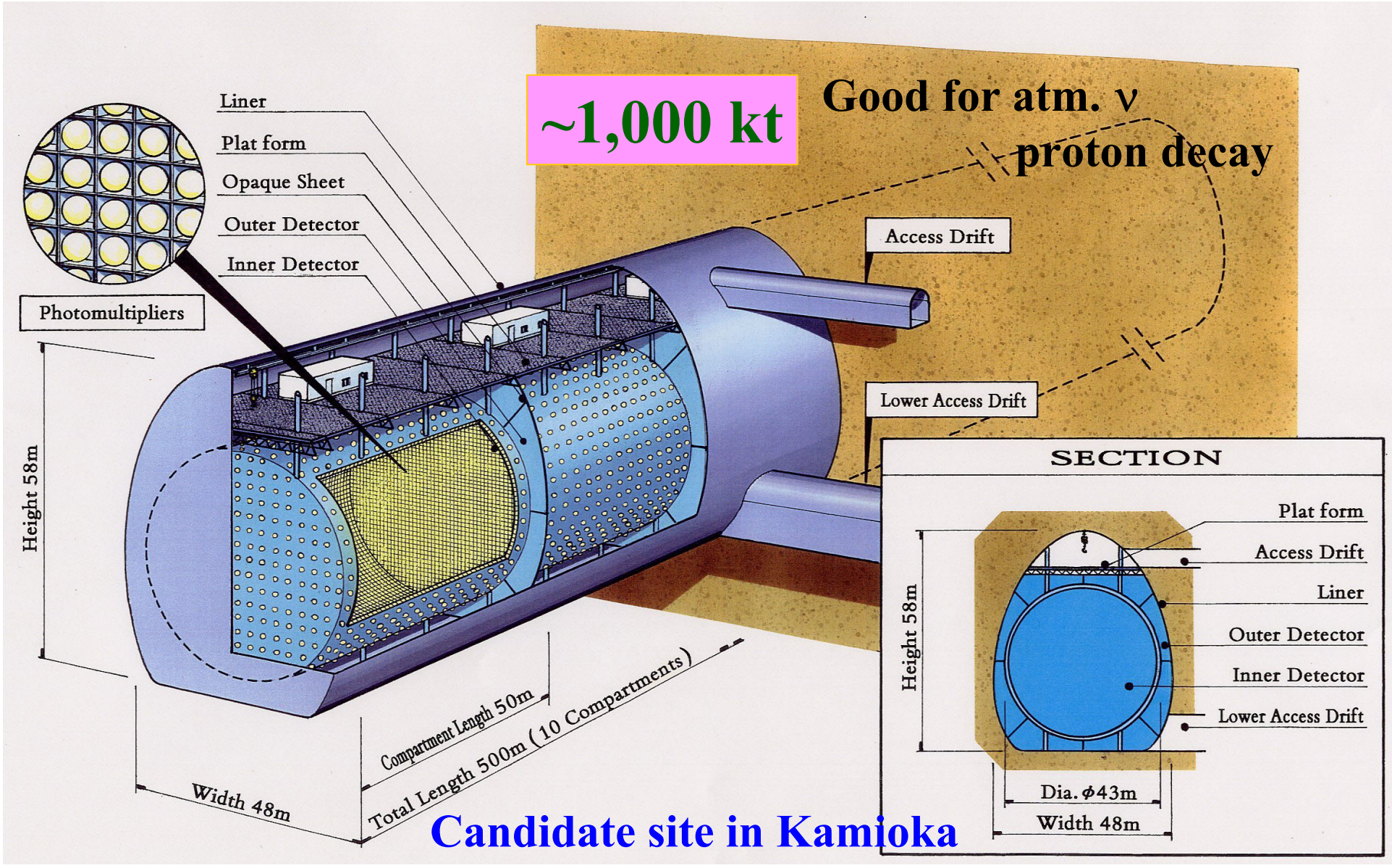


$\sin^2 2\theta_{13}$	Background in Super-K					Signal	Signal + BG
	ν_μ	ν_e	$\bar{\nu}_\mu$	$\bar{\nu}_e$	total		
0.1	12.0	10.7	1.7	0.5	24.9	114.6	139.5
0.01	12.0	10.7	1.7	0.5	24.9	11.5	36.4

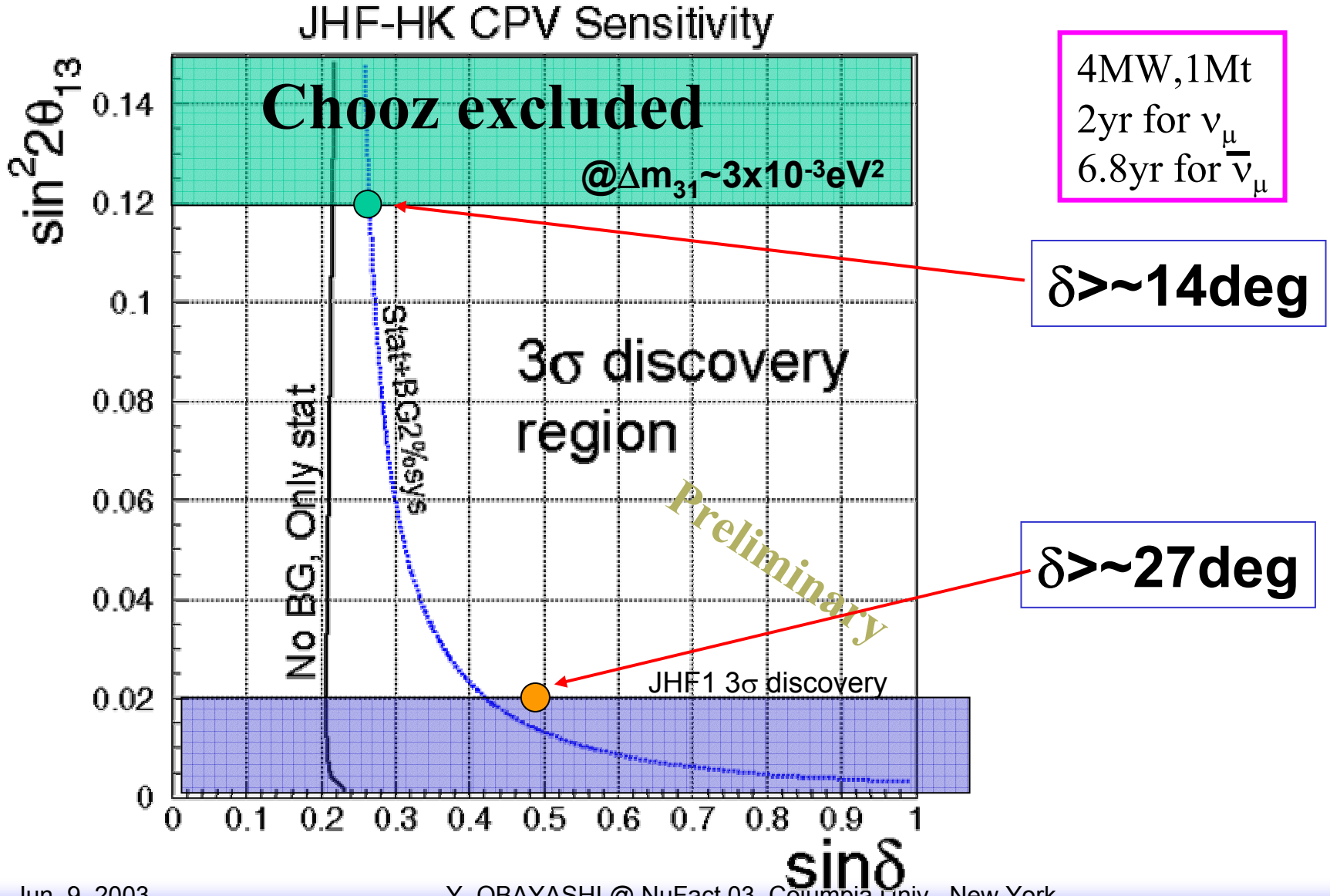
CP measurement

Future upgrade

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



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



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

δ>~14deg

δ>~27deg

Recent Status in Sensitivity Study

Physics Working Groups are formed

- First Collaboration Meeting is held on May 6-7, 2003 @KEK
- Spokes person, Project coordinators, Working group conveners are chose, Interim Board of Representative (IBR) is formed
- Working Groups:
  - Beam line (normal magnets, installations, maintenance scheme etc.)
  - Proton beam monitors
  - Target and Horn
  - Beam line control/electronics
  - Muon monitor, 280 m detectors
  - 2km detectors
- Each Group start to have meeting regularly

Detailed Physics Studies Started

- Design of beam line components are close to the final
  - Realistic beam MC is ready
- SK rebuilding finished, SK/K2K data taking restarted (Shiozawa's talk)
- Now, It is the time to start detailed studies on physics sensitivities
  - Organized MC samples are under production, just now.
  - Re-tune BG rejection which is currently not tuned well
    - Maybe from starting point
  - We currently assuming δBG~10%, but not guaranteed yet
    - List up source of systematic errors and try to find the way to minimize them one by one
      - Absolute flux, Spectrum, Cross sections, BG from HE tail, Reconstruction related, ...
  - Demonstrate the performance of tight BG (π^0) rejection
    - K2K 1kt WC data is available
      - π^0 fitter is already installed in 1kt detector analysis
- First Goal: Decide strategy of front detectors

Summary

- JHF-Kamioka neutrino experiment (2007~)
  - JHF 0.75MW 50GeV PS + OAB + Super-K
  - Construction of accelerator has been started and named “J-PARC”
  - Neutrino beamline: Budget request is submitted, Design is close to “ready–to-construct”
  - Sensitivity for θ_{13} : sin $^2 2\theta_{13} > 0.006$,90%CL
  - 1st Collaboration meeting was held, Working groups are formed
    - Detailed sensitivity study is started
    - Front detector strategy will be fixed soon
  - Schedule