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Takaaki Kajita, ICRR, U. Tokyo

The JHF-Kamioka neutrino project

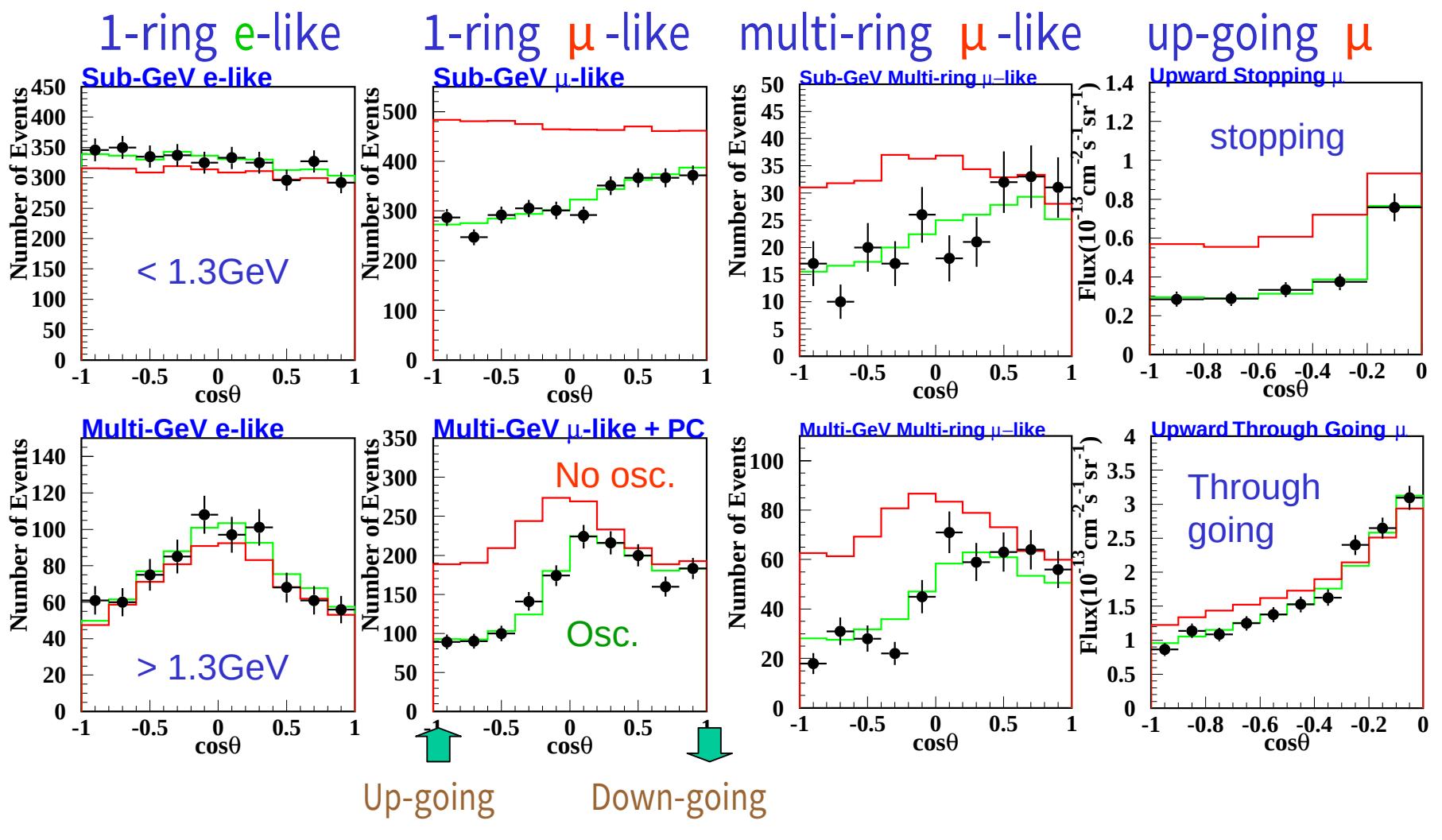
Outline

- Introduction
- JHF-Kamioka neutrino project -overview-
- Physics in phase-I
- Phase-II
- Summary

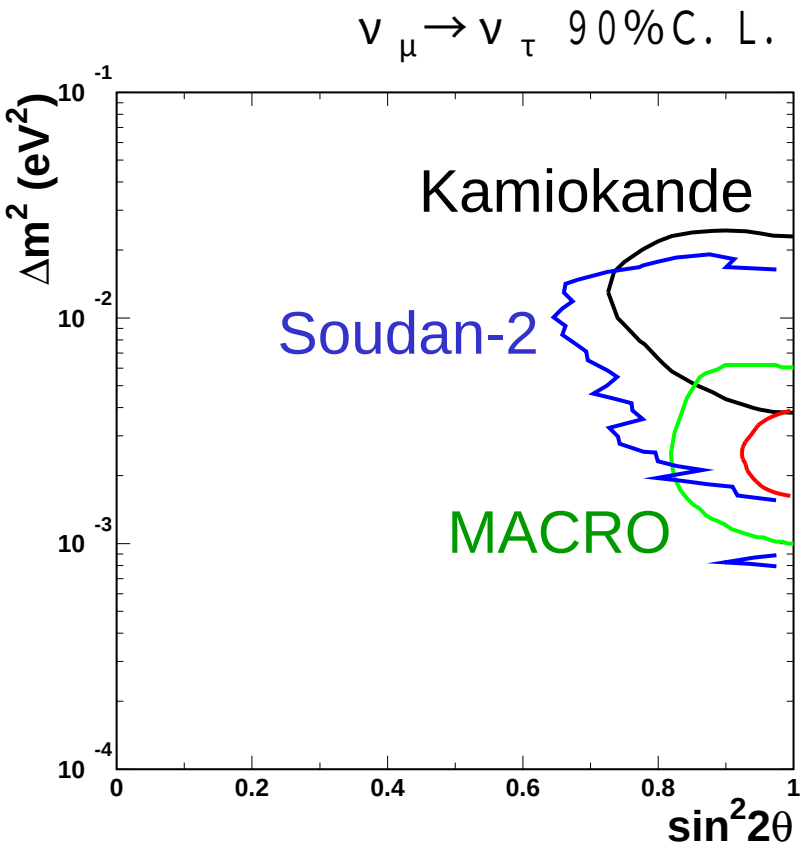
Introduction

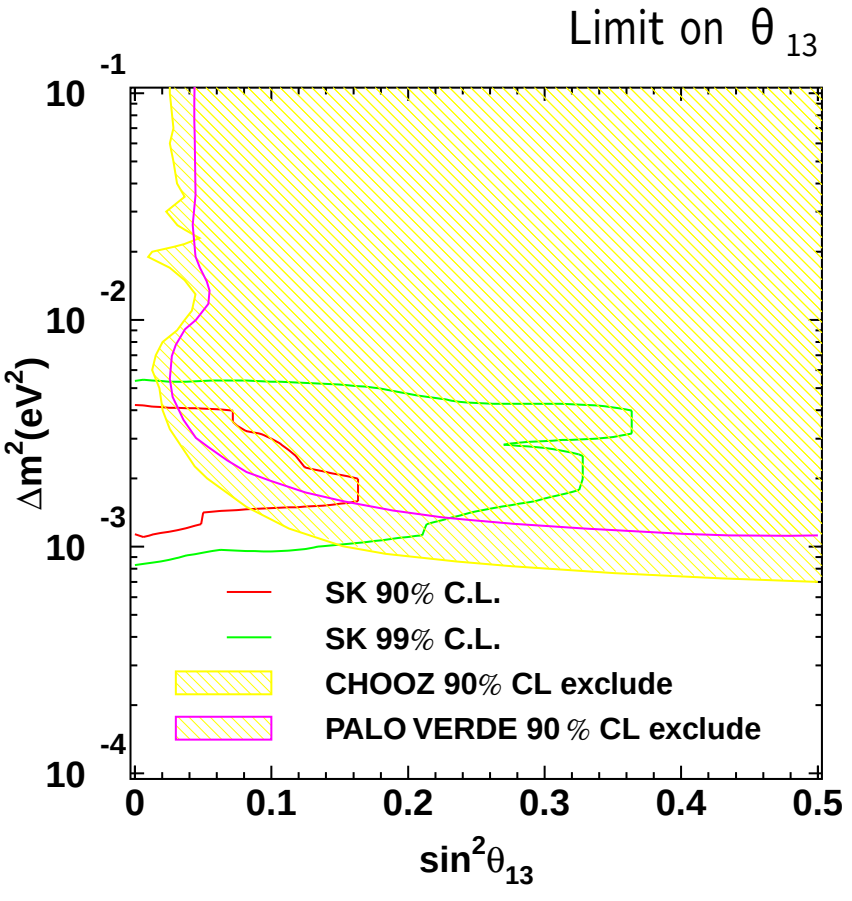
SK atmospheric neutrino data

1489day FC+PC data + 1678day upward going muon data

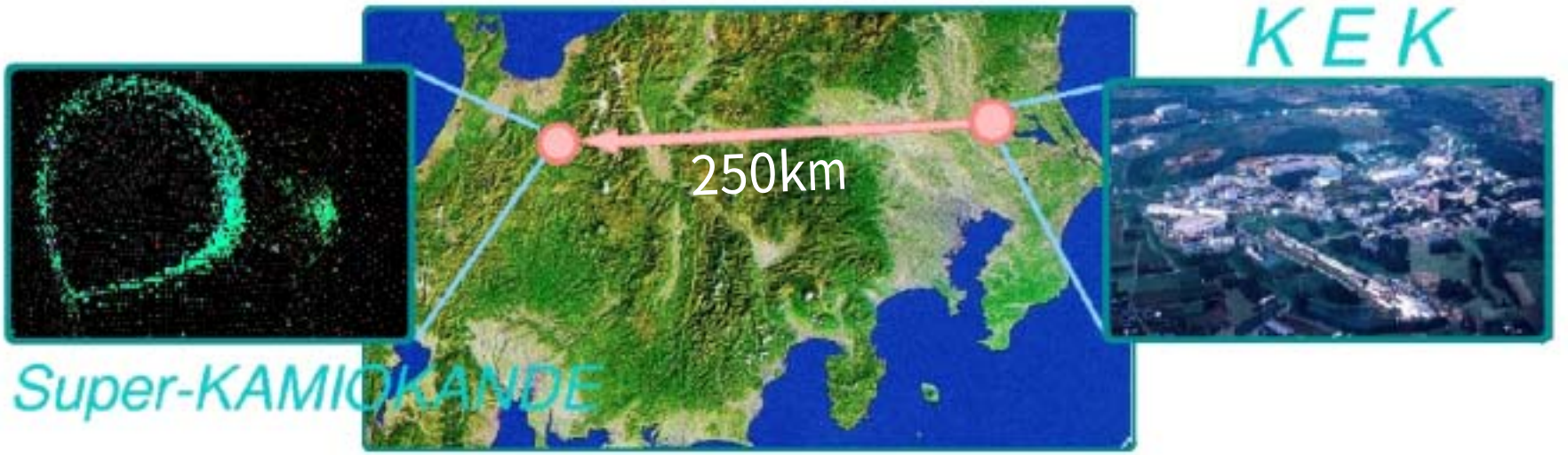


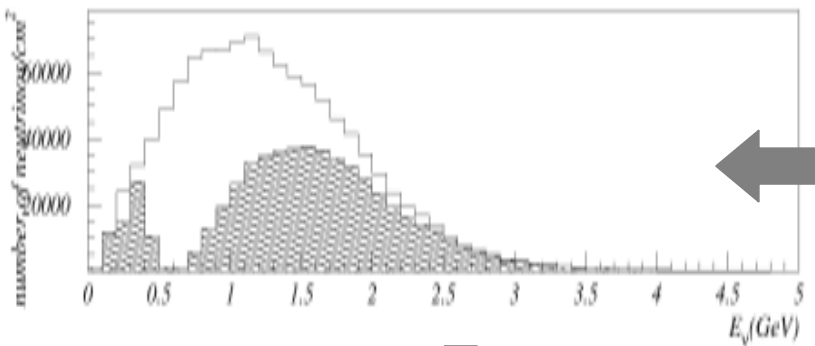
Oscillation parameters





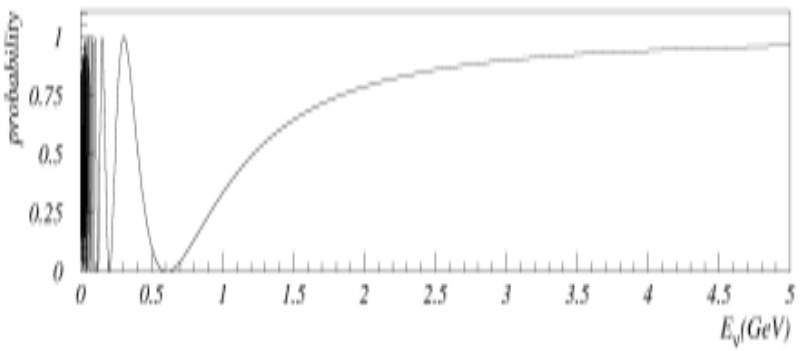
K2K





E_ν

Neutrino Oscillation (Δm^2=0.003eV^2)



E_ν

K2K data and oscillation

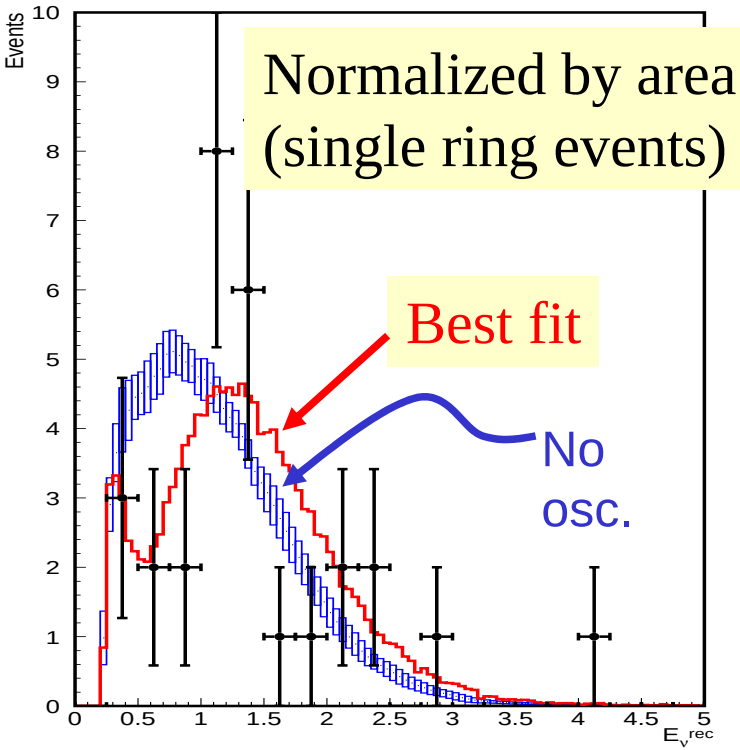
Data: 1999 – July 2001

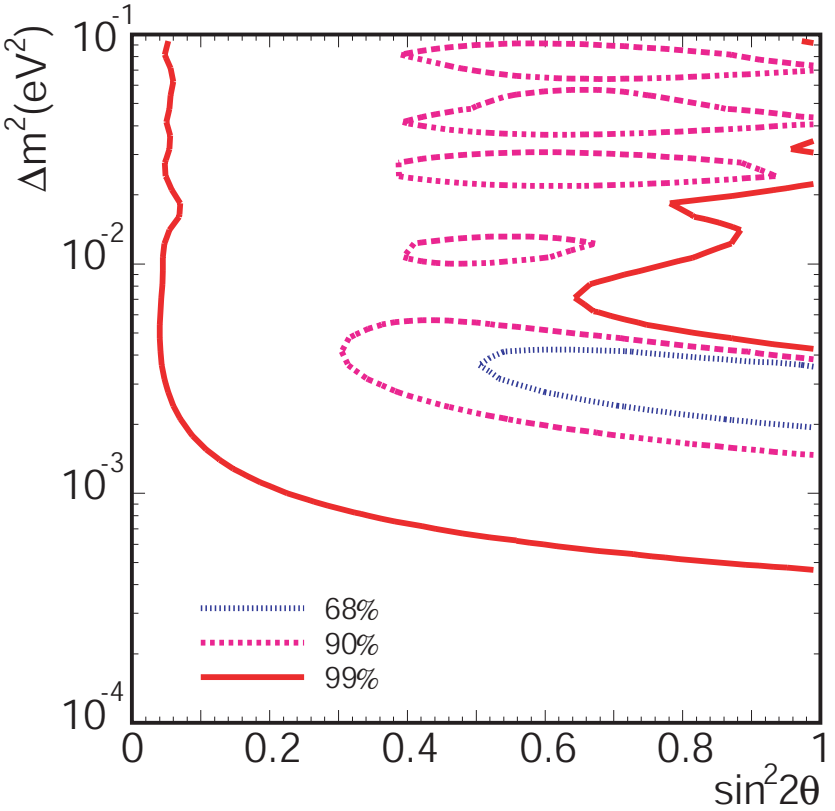
N_{SK} (# of event)

56 events observed

80.1+6.2/-5.4 ev. expt'd

null oscillation prob. 1.3%



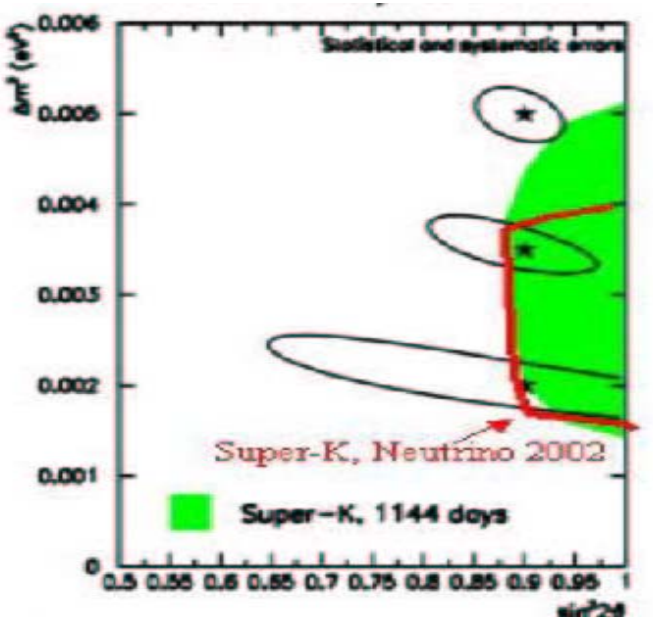


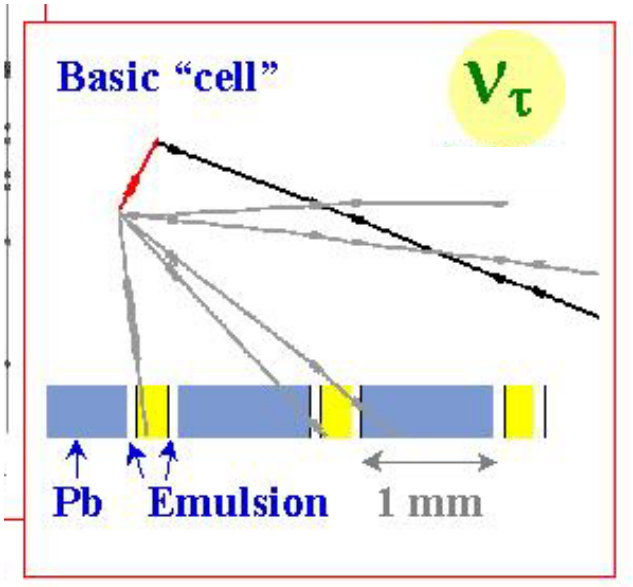
Best fit point ($\sin^2 2\theta$, Δm^2) = (1.0, $2.8 \times 10^{-3} eV^2$)

Consistent with SK atm.

Next: MINOS (end of 2004):
Detail study of oscillations.

CNGS (OPERA, ICARUS)
(2006) : τ appearance.





Next^2: JHF-Kamioka neutrino project

JHF-Kamioka neutrino project
-overview-

Main goals

Main physics goals in JHF-I neutrino exp.

★Precise determination of neutrino oscillation parameters.

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

Δm^2 ・・・・・・・・・・ a few %

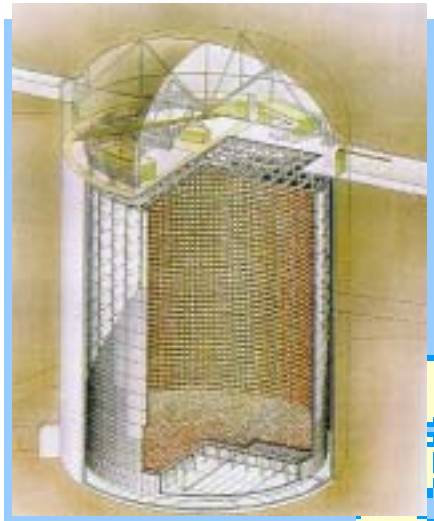
★Discovery and measurement of non-zero θ_{13}

$\sin^2 2\theta_{13}$ ・・・・・・ > 0.01

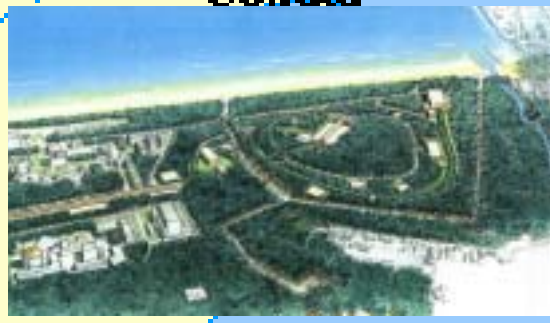
Main physics goal in JHF-II

★Discovery and measurement of non-zero CP phase

JHF-Kamioka neutrino project –overview-



< 1 GeV
ν μ beam



Super Kamiokande

295km

JAERI
(Tokai)

Japan

KEK

Tokyo

Kawasaki

Yokohama

Nagoya

Kyoto

Osaka

50 kton
Water Cherenkov

Future

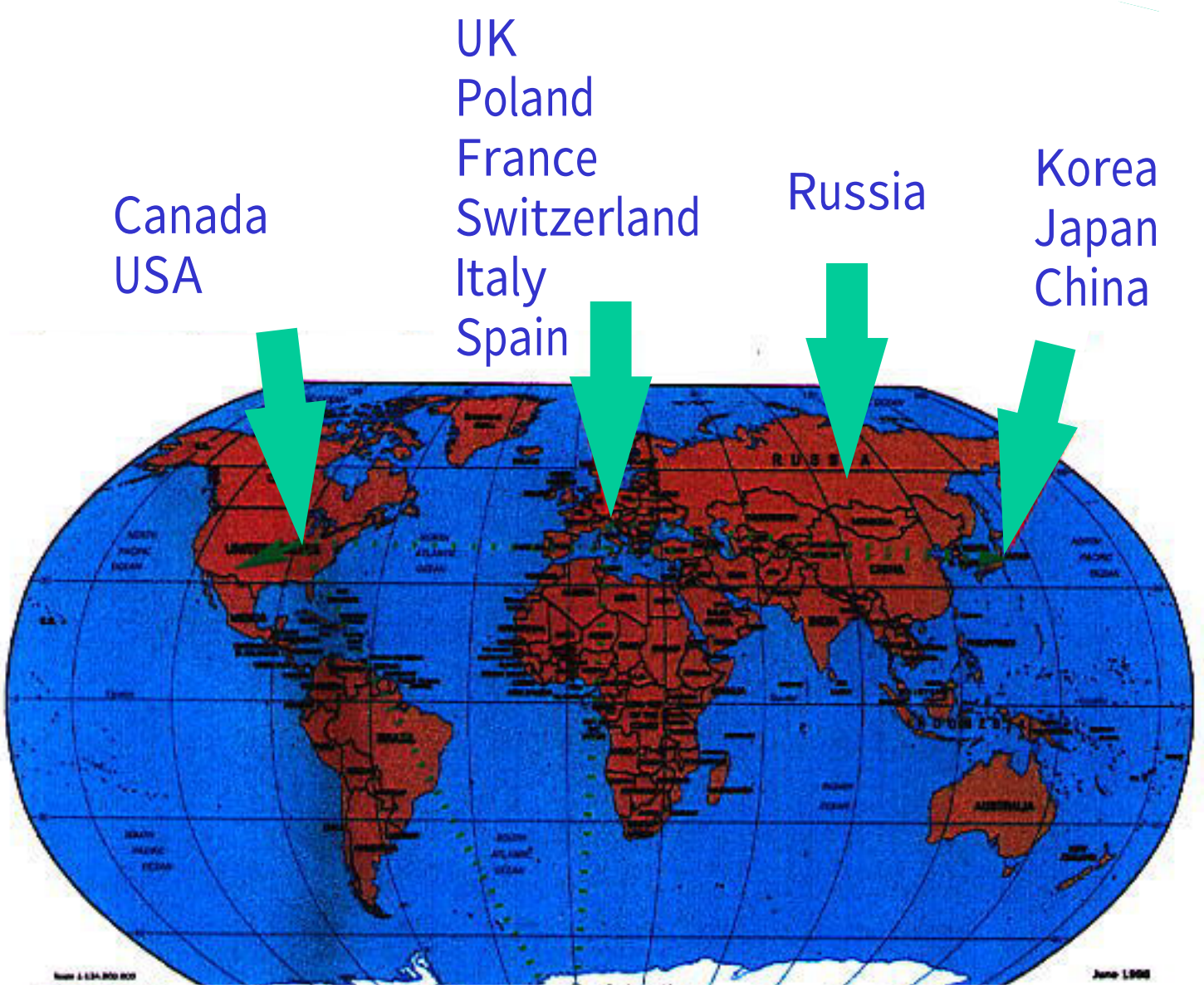
0.75 MW
50 GeV PS

Future

~1Mt "Hyper Kamiokande"

4MW 50GeV PS

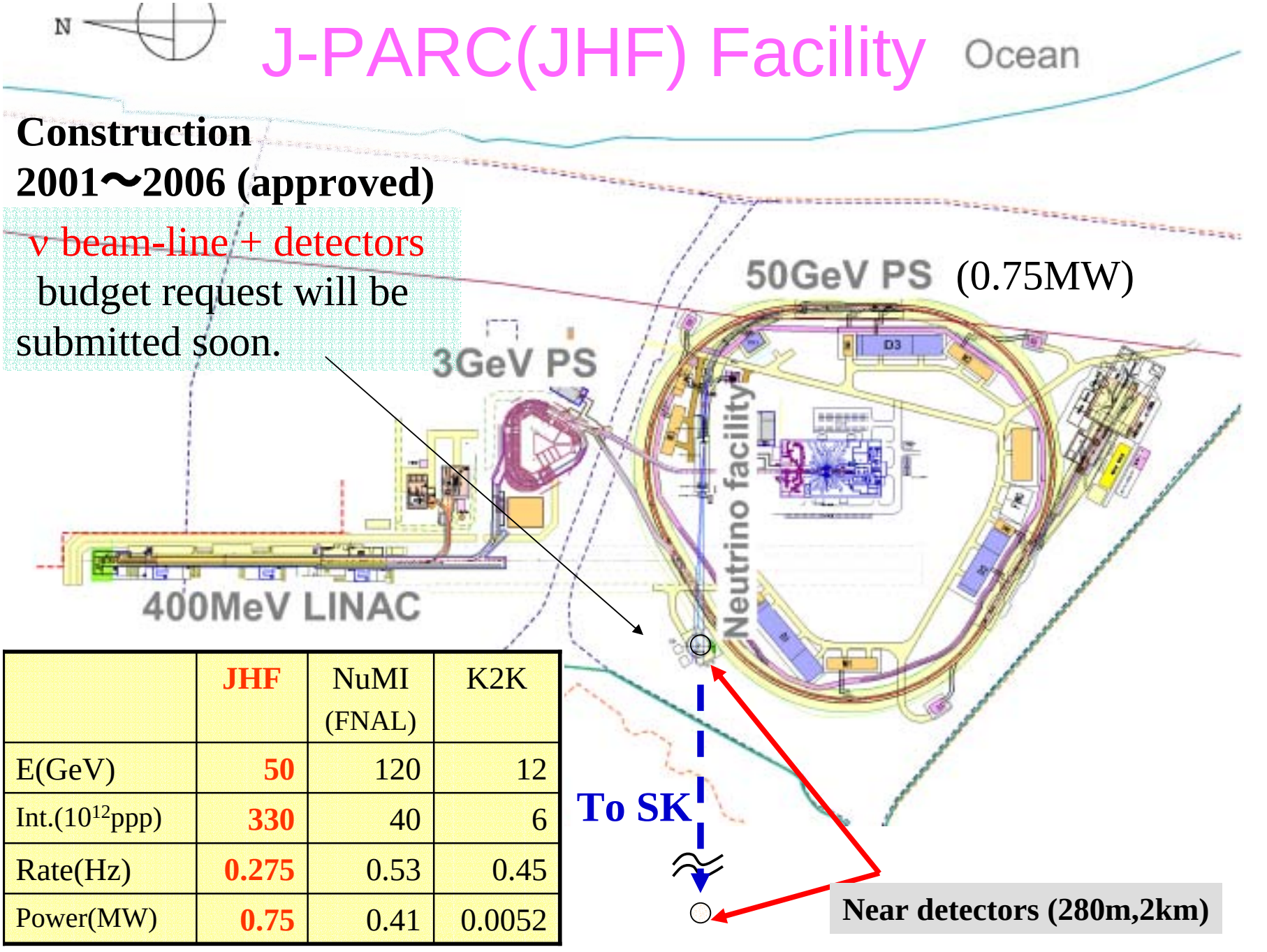
Present collaboration



J-PARC(JHF) Facility

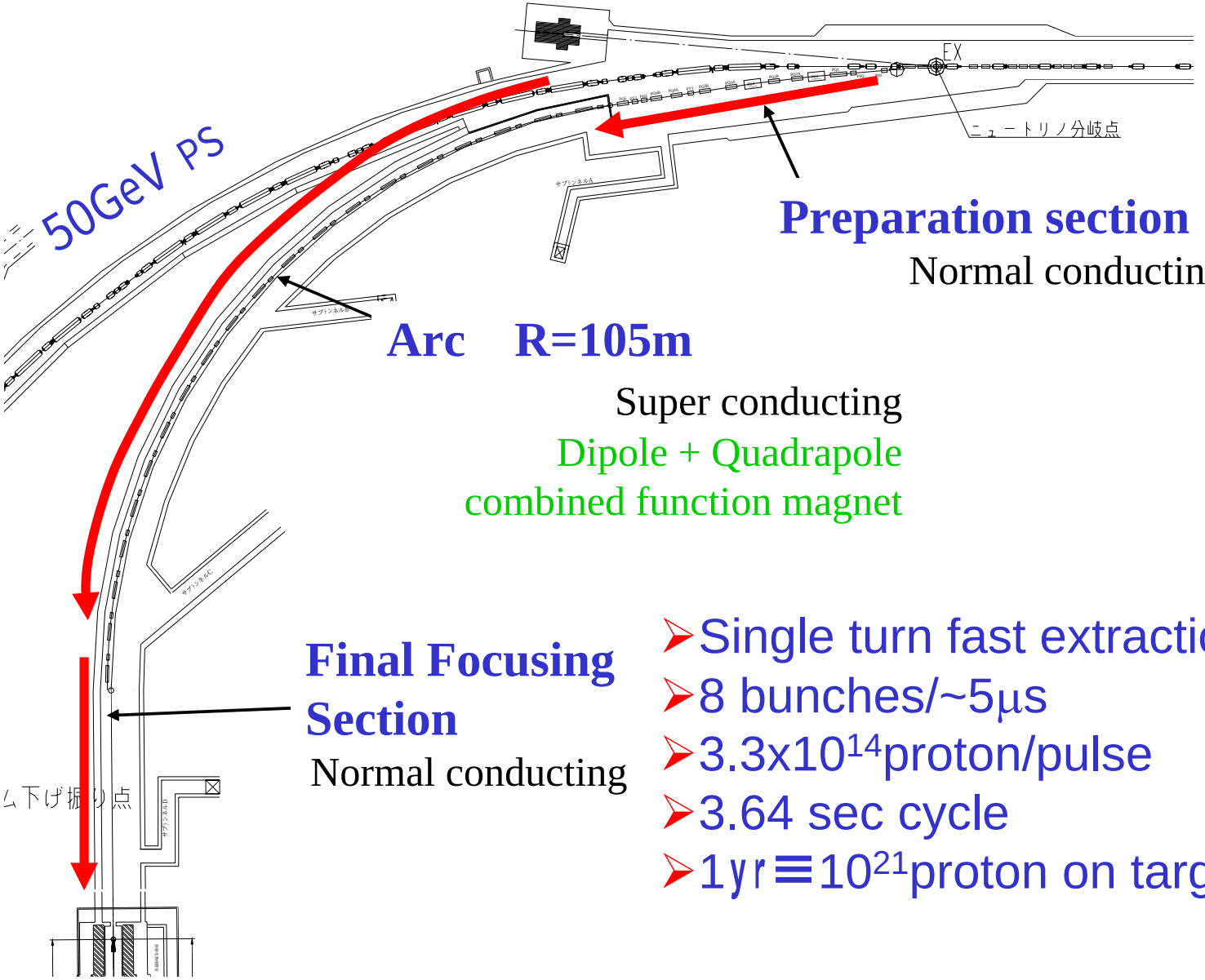
Construction
2001～2006 (approved)

ν beam-line + detectors
budget request will be submitted soon.



	JHF	NuMI (FNAL)	K2K
E(GeV)	50	120	12
Int.(10^{12}ppp)	330	40	6
Rate(Hz)	0.275	0.53	0.45
Power(MW)	0.75	0.41	0.0052

Primary proton beamline –Overview-



Preparation section

Normal conducting

Arc R=105m

Super conducting

Dipole + Quadrapole

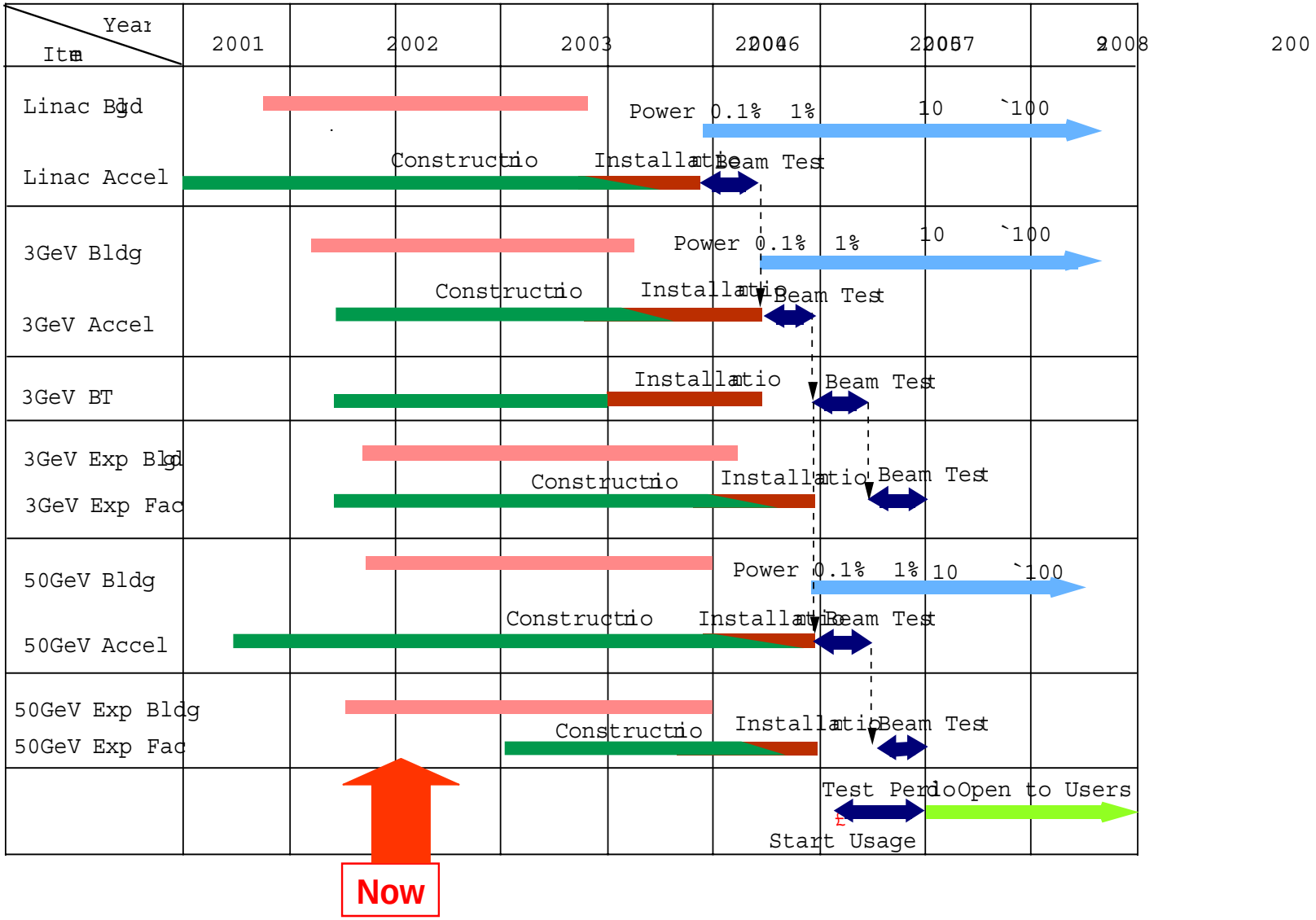
combined function magnet

Final Focusing Section

Normal conducting

- Single turn fast extraction
- 8 bunches/~5μs
- 3.3×10^{14} proton/pulse
- 3.64 sec cycle
- 1yr≡10^{21} proton on target(POT)

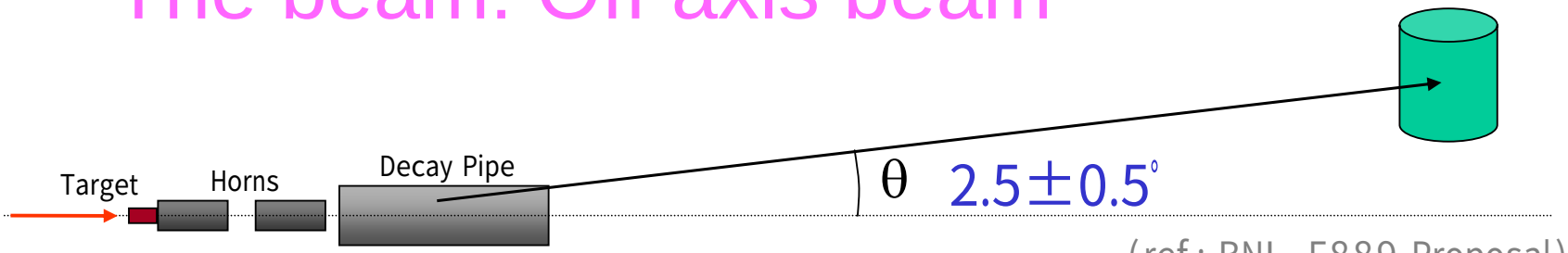
Construction Schedule & Commissioning



J-PARC construction

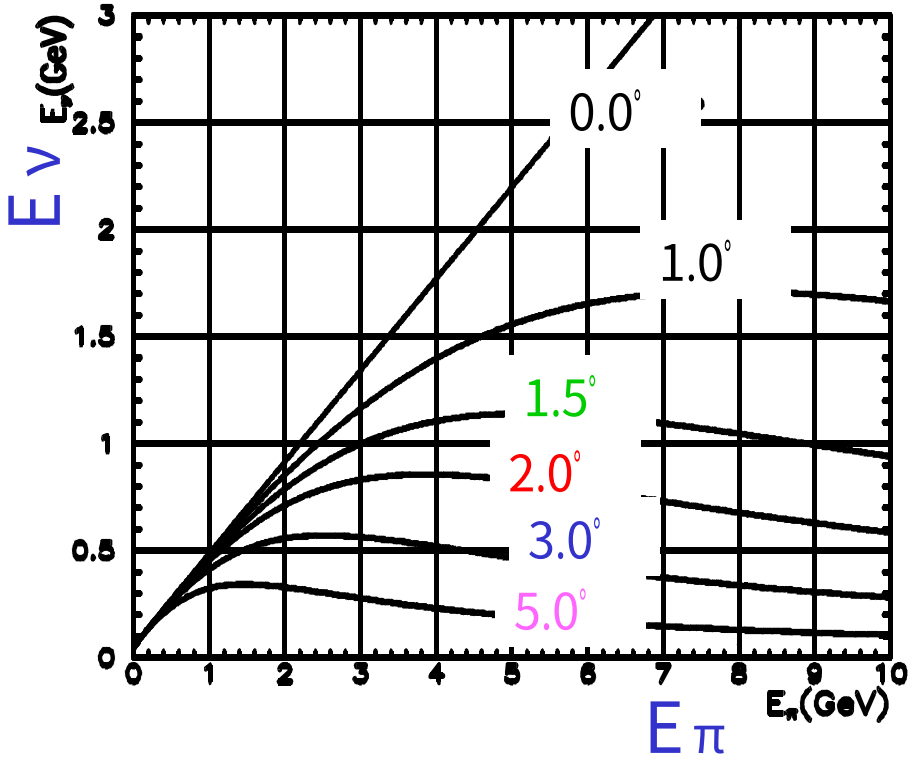
J-PARC LINAC construction (Apr.03)

The beam: Off axis beam



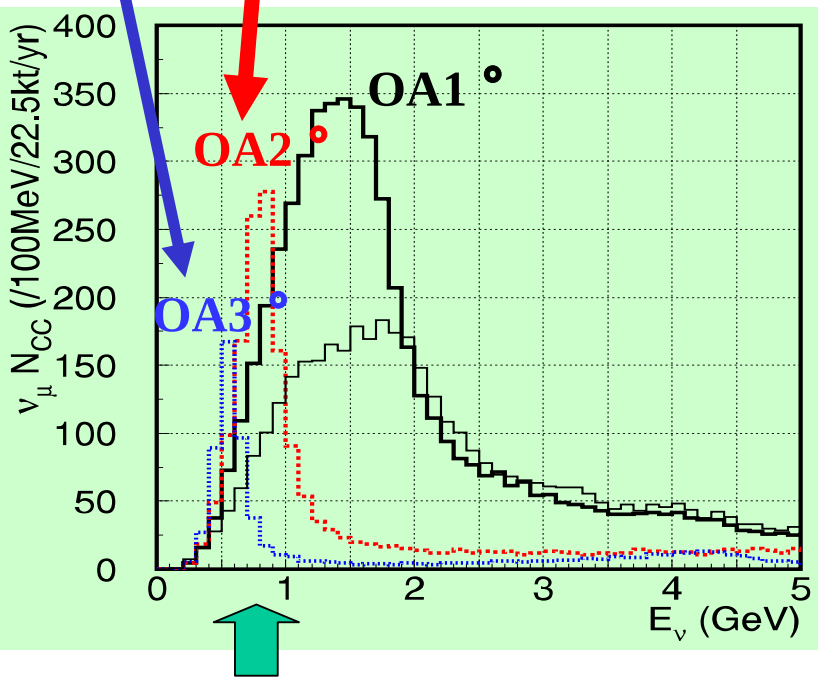
(ref.: BNL-E889 Proposal)

Eπ vs. Eν



800 CC ν_μ / year

2200 CC ν_μ / year

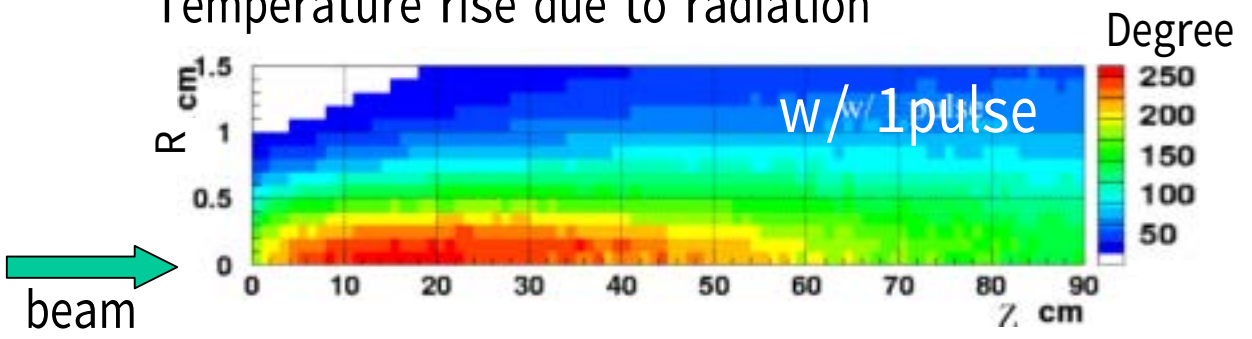


Max. osc. energy for $3\times10^{-3}eV^2$

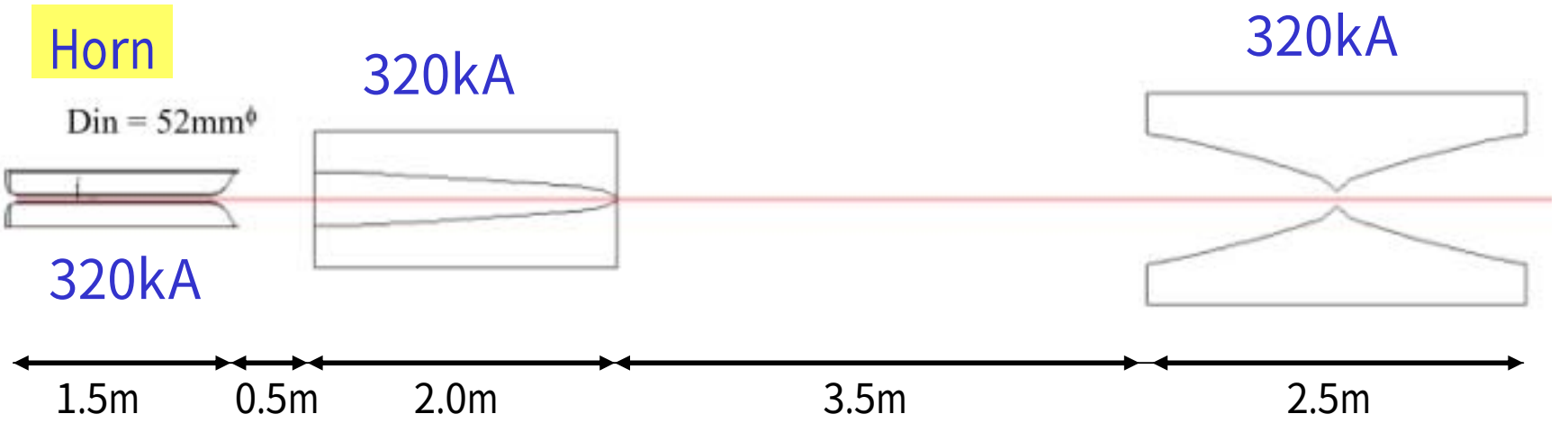
Target and horns (preliminary design)

Target: Graphite (ϕ=25-30mm) w/ water cooling

Temperature rise due to radiation

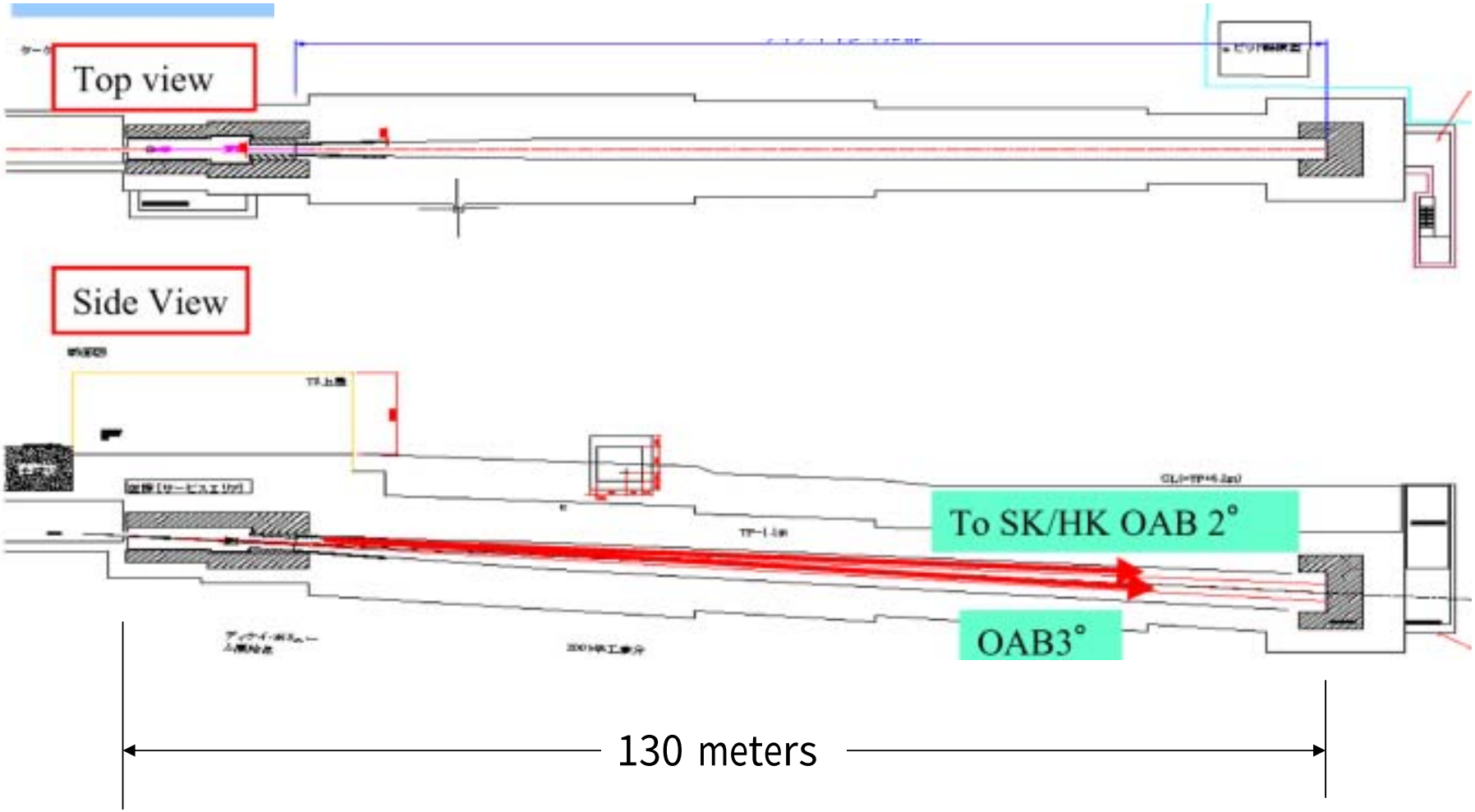


Horn

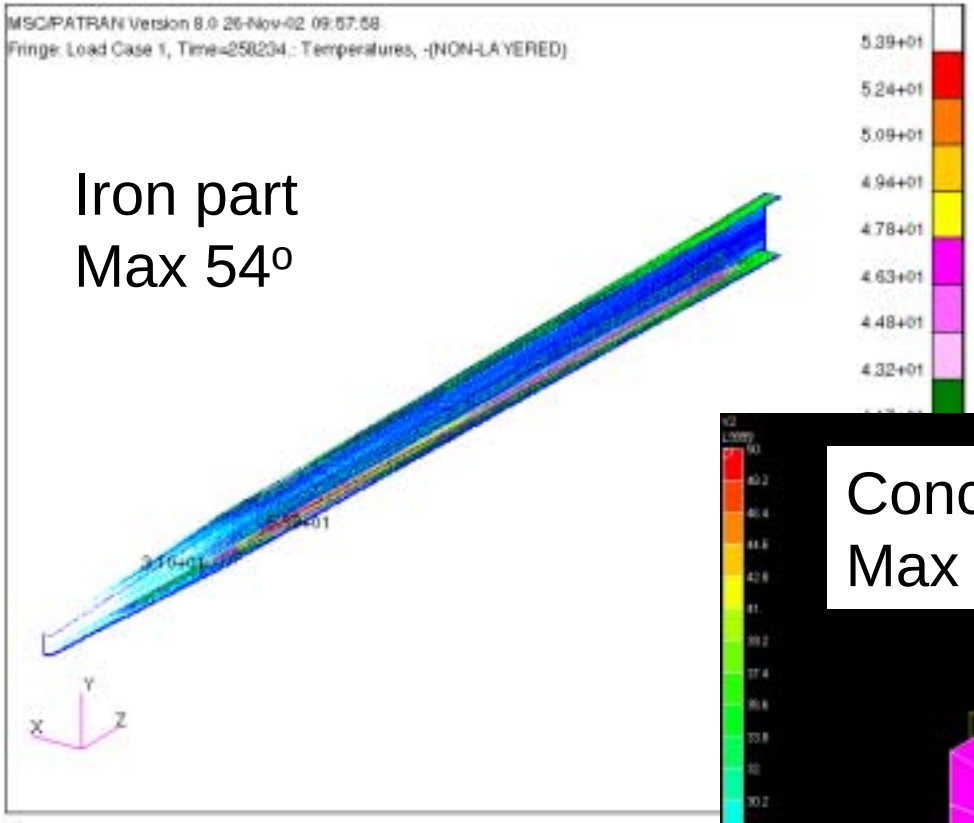


Need much more detailed studies

Decay tunnel design

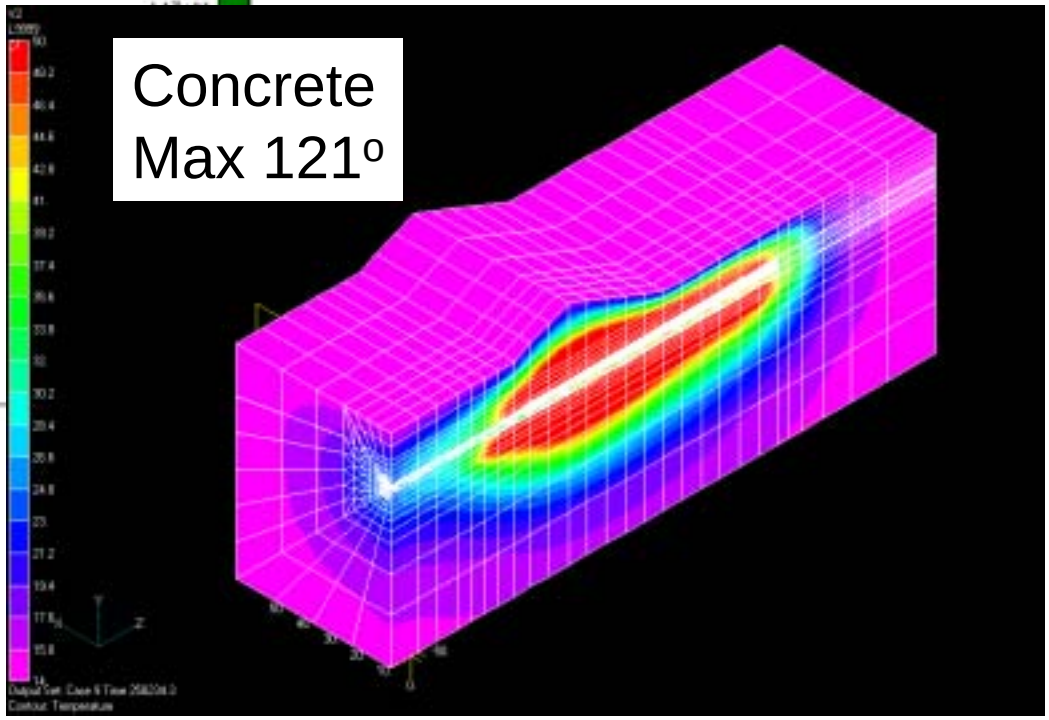


Decay pipe cooling and heat simulation



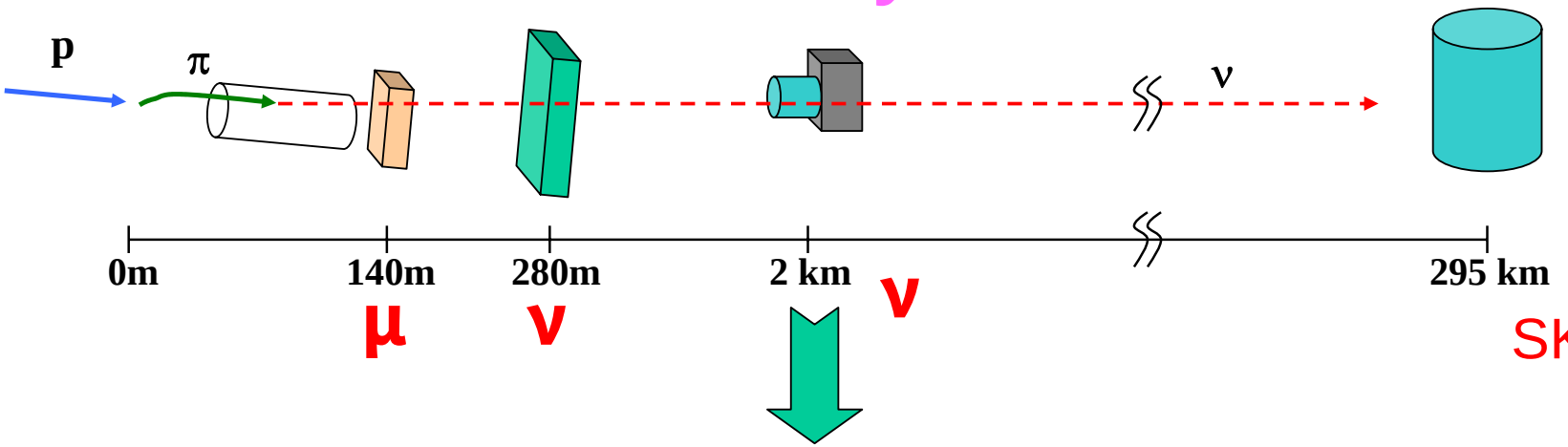
Iron part
Max 54^{o}

Non-static heat simulation
0.5yr@4MW, 0.5yr no beam
Upto 30yrs
Max @ 29.5yr

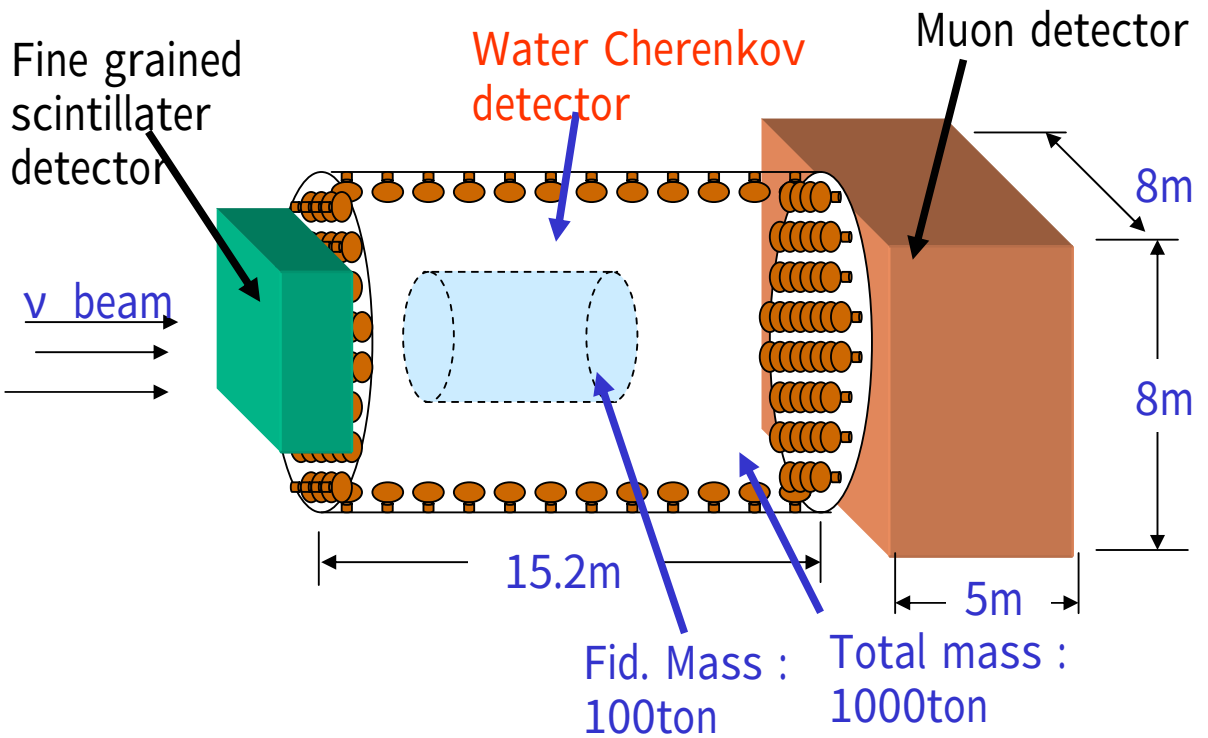


Concrete
Max 121^{o}

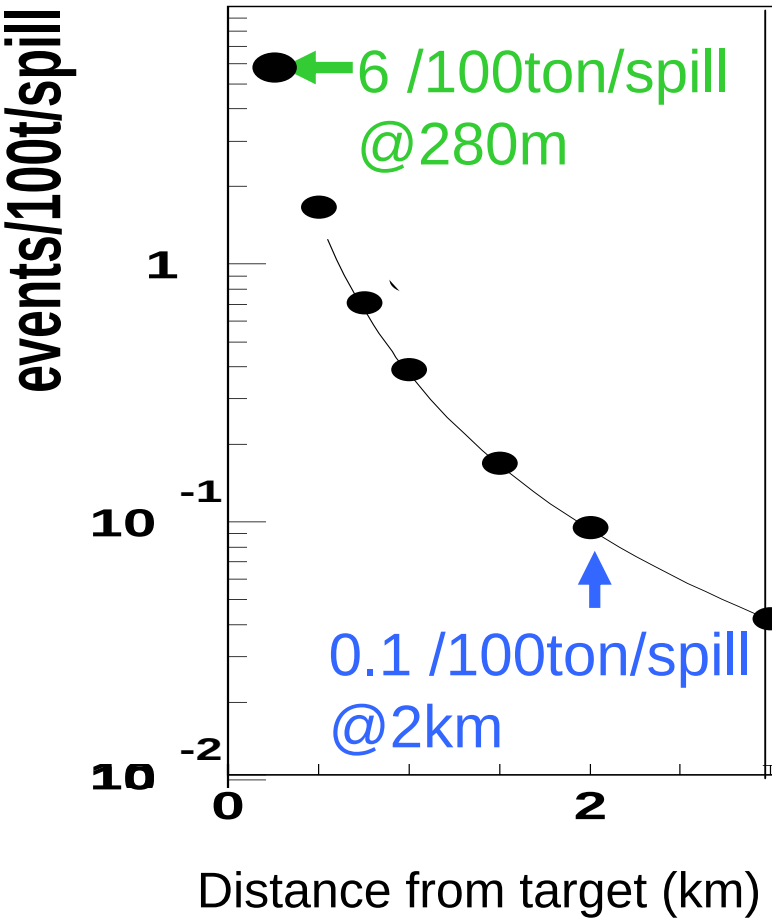
Detector system

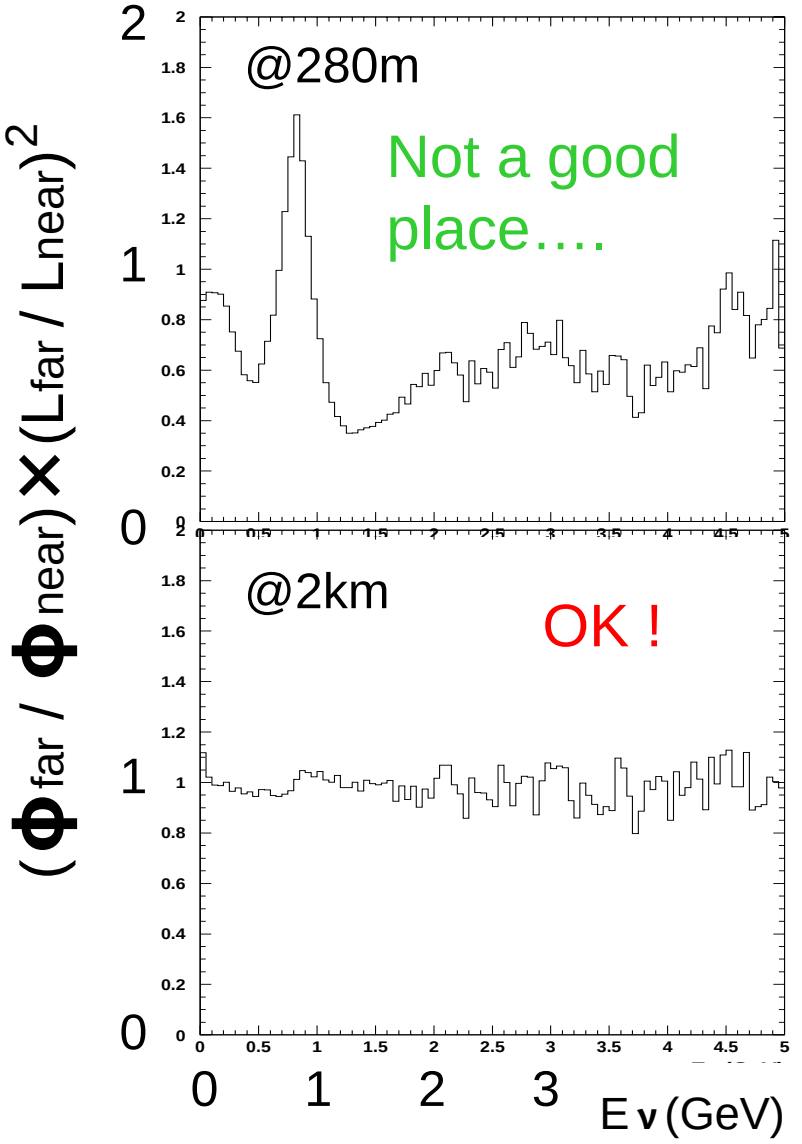


Near detector @2km (@50m underground)



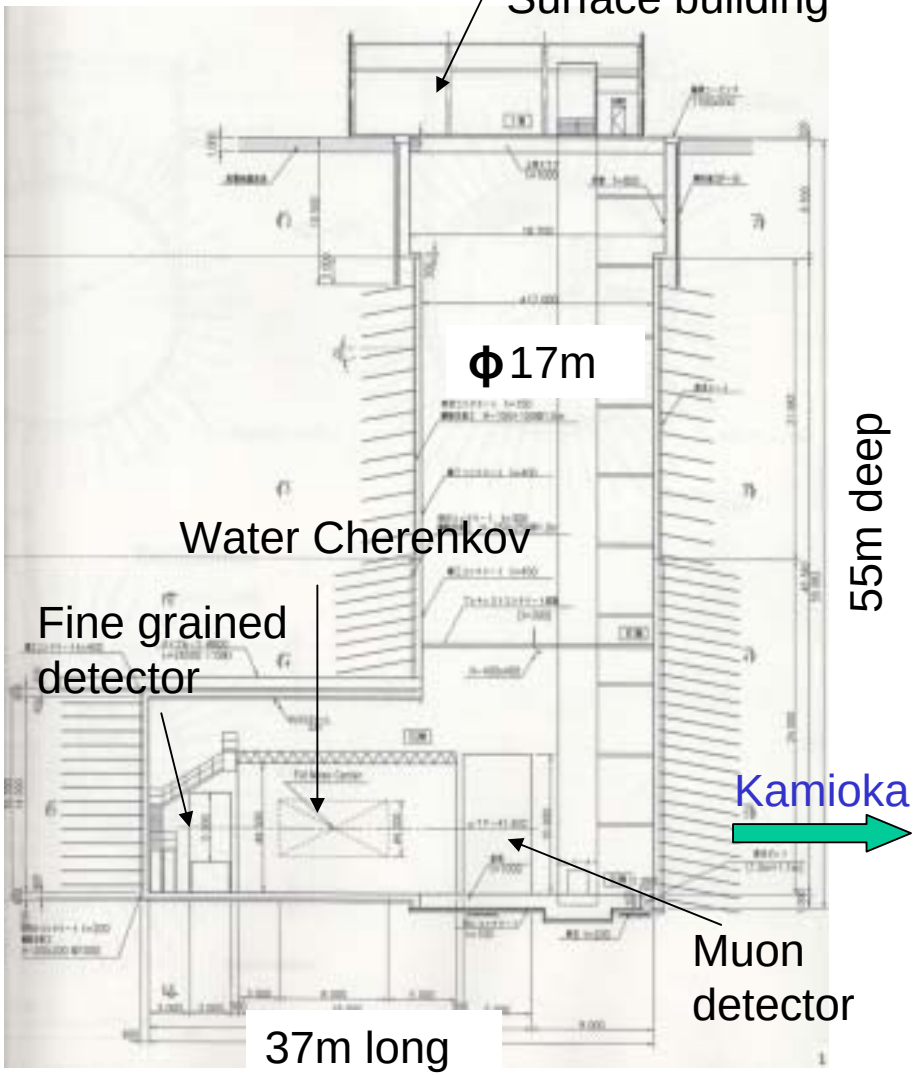
Event rate & Far/near ratio





Water Cherenkov :
Impossible @280m
(Total mass > 100 tons)

Near detector @1.84km

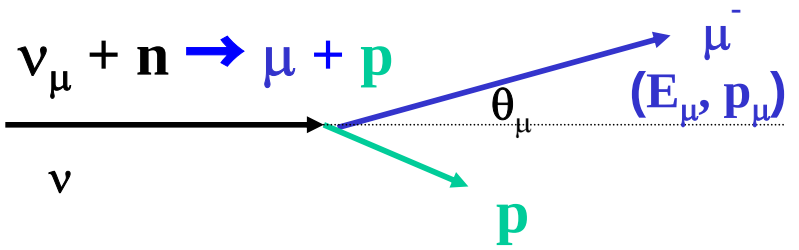


Physics in Phase-I

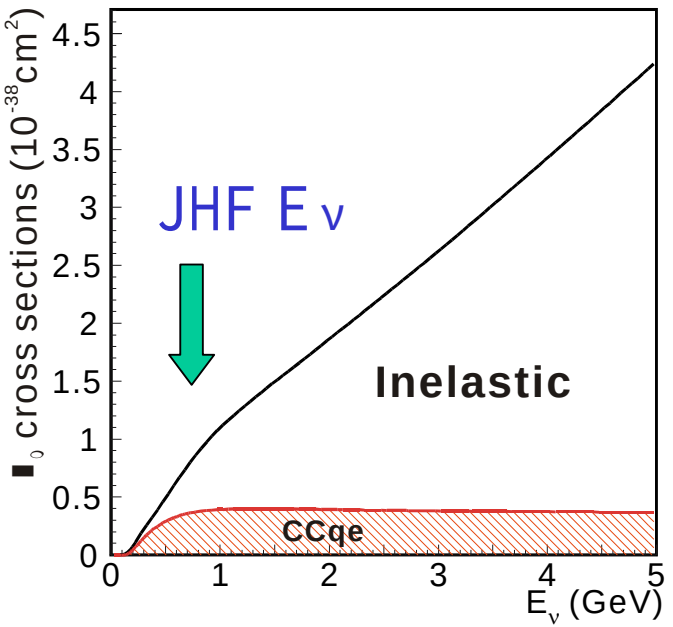
Reconstruction of E ν

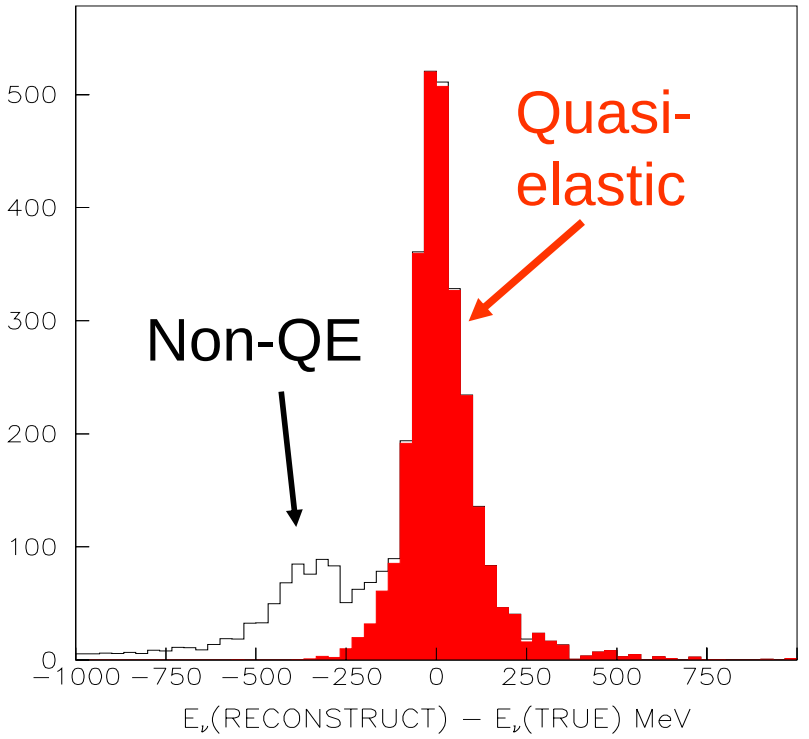
For single Ch ring events:

E_μ, θ_μ ➡ E_ν

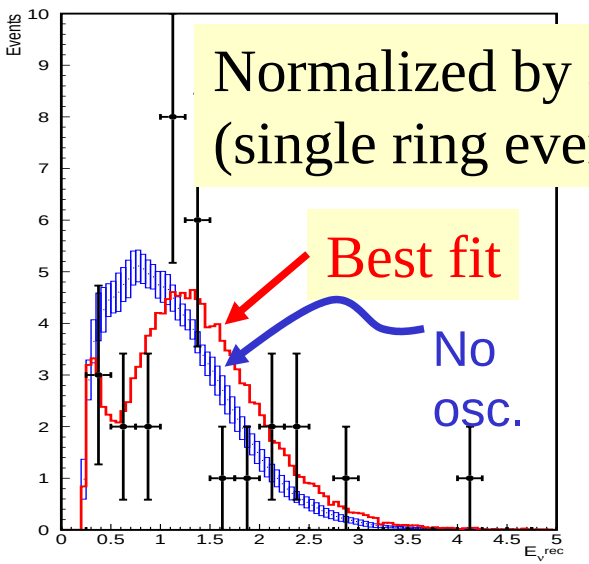


Super-K w/ JHF beam





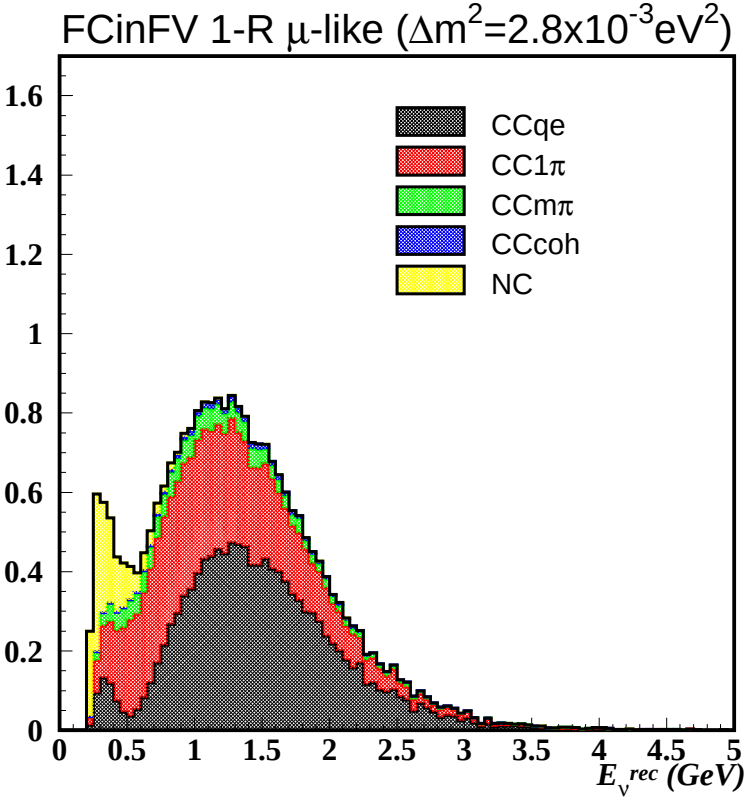
Quasi-elastic and other interactions



Normalized by area (single ring events)

Best fit

No osc.

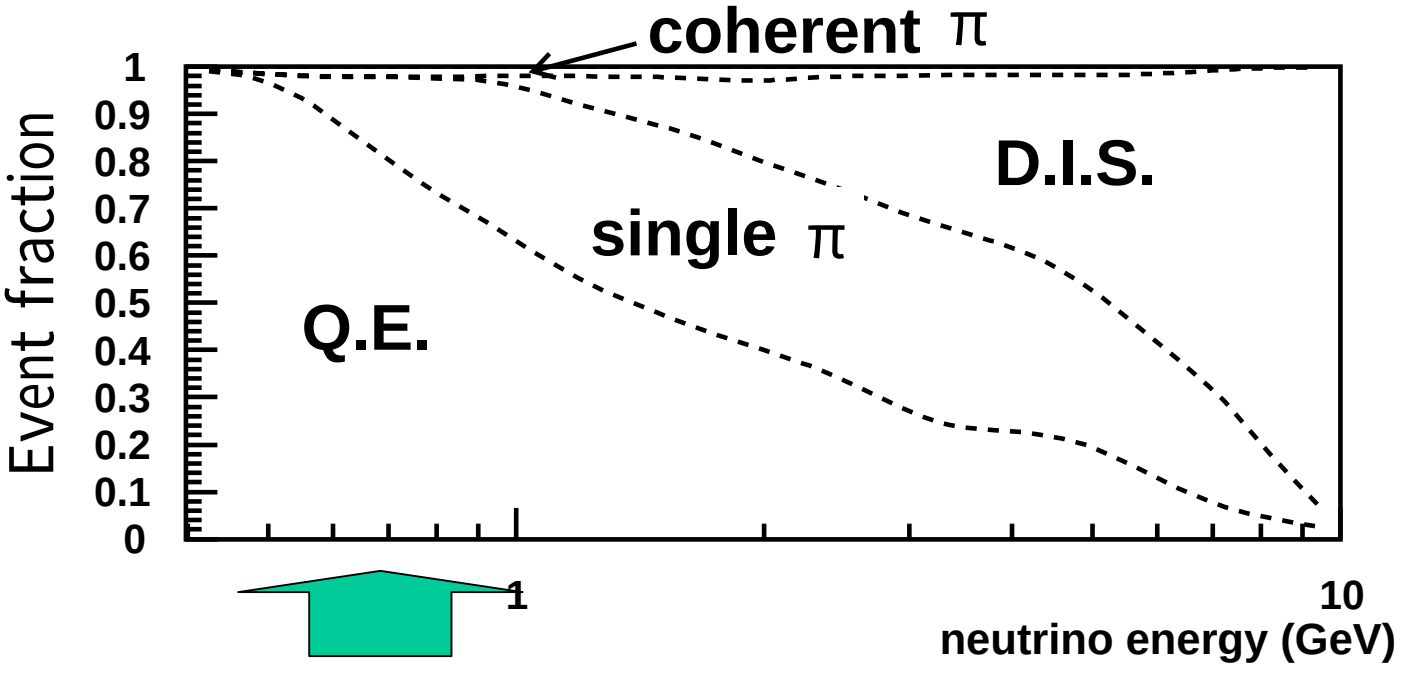


High E_ν non-quasi-elastic interactions cause problems.

Minimize the high energy (above the max. osc. energy) neutrino flux.

Single ring (muon-like) in Super-K

Data sample: SK Monte Carlo, Fully-contained single-ring, muon-like events.

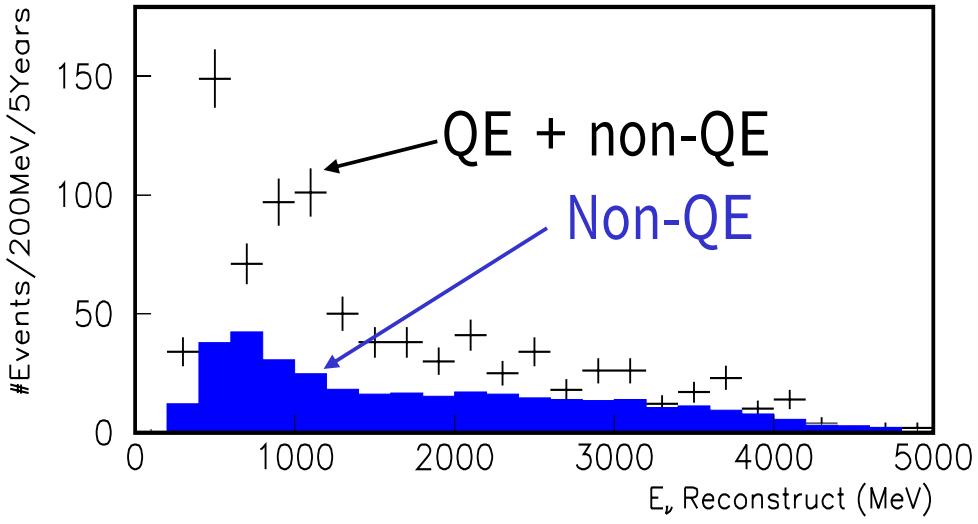


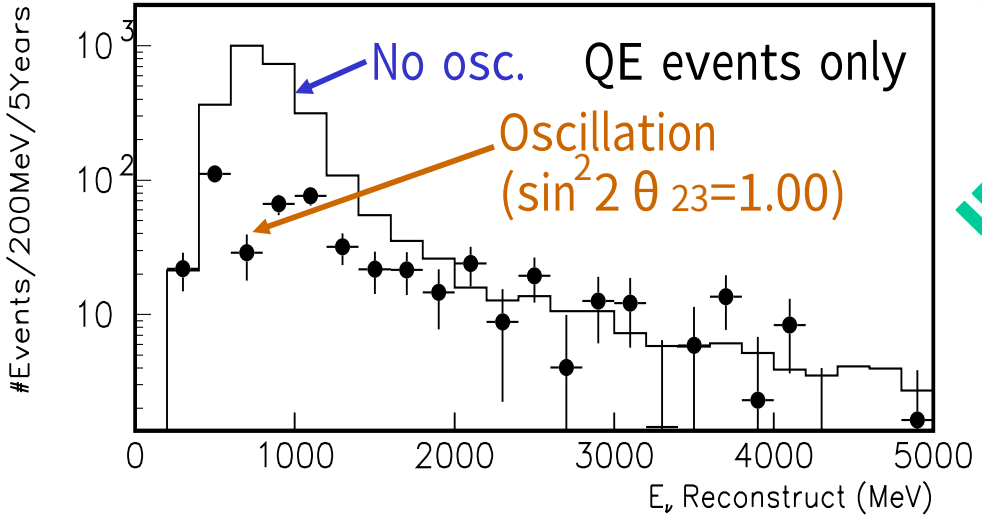
Typical JHF neutrino energy

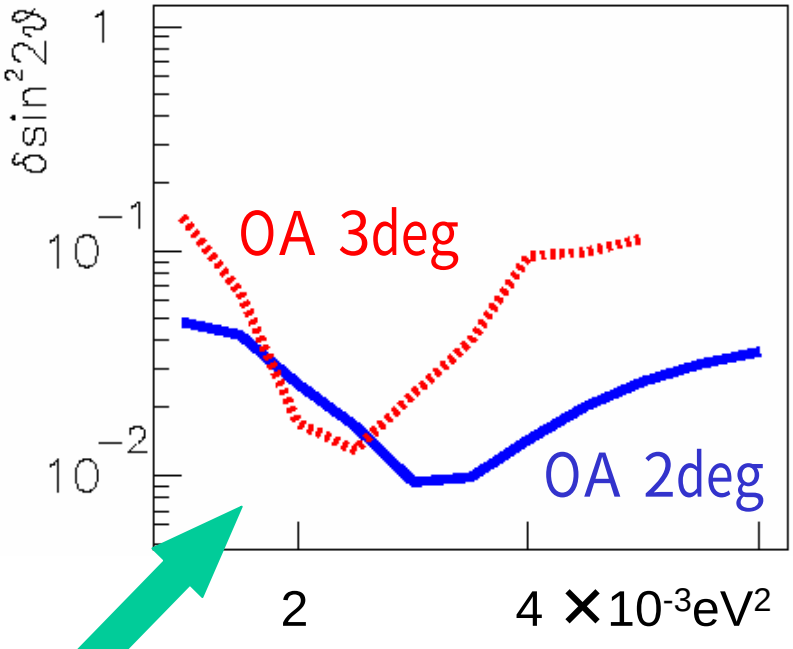
Important to run the experiment with low energy beam.

Measurement of $\sin^2 2\theta_{23}$

For $\sin^2 2\theta_{23}=1.00$ (OA 2deg)

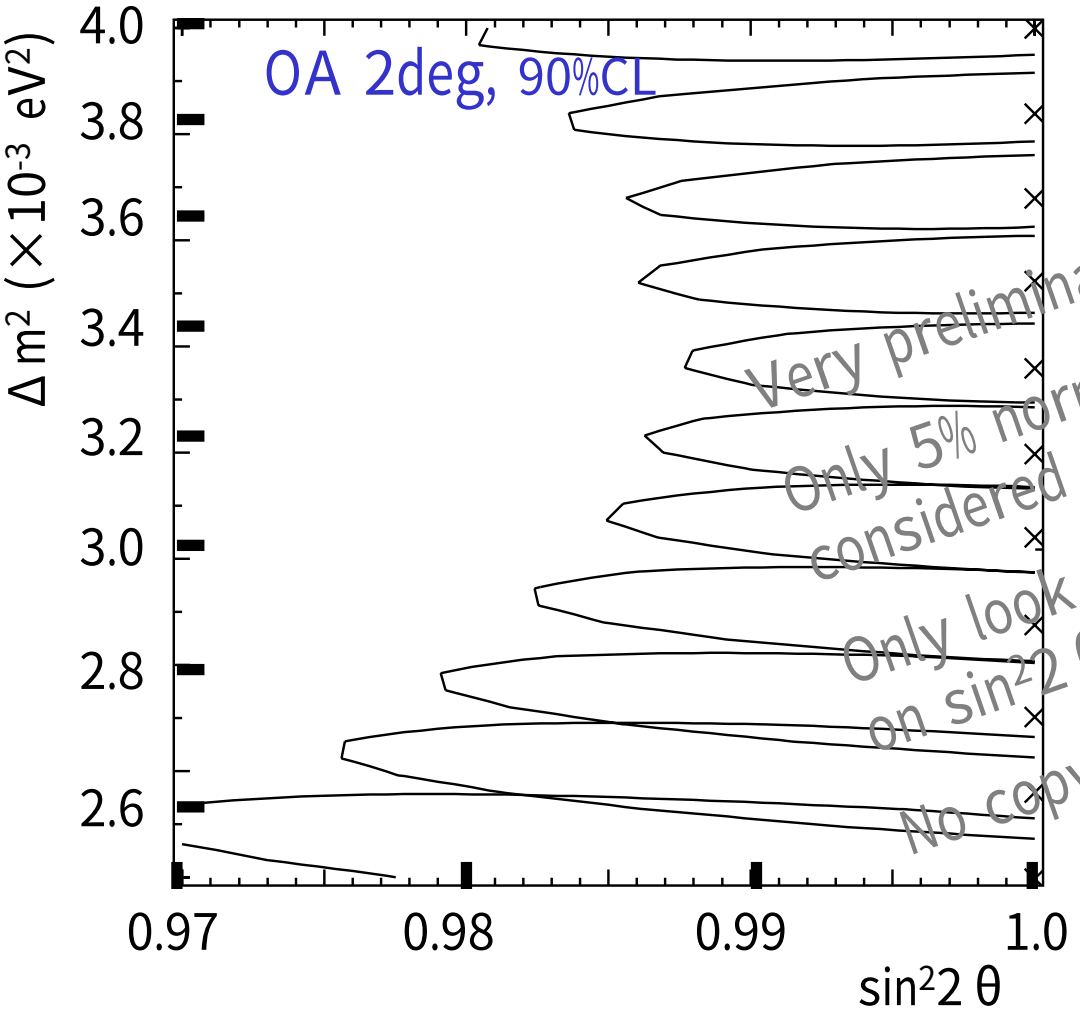






$$\begin{cases} \delta(\sin^2 2\theta_{23}) = 1\% \\ \delta(\Delta m^2) = 1\times 10^{-4}\,\mathrm{eV}^2 \end{cases}$$

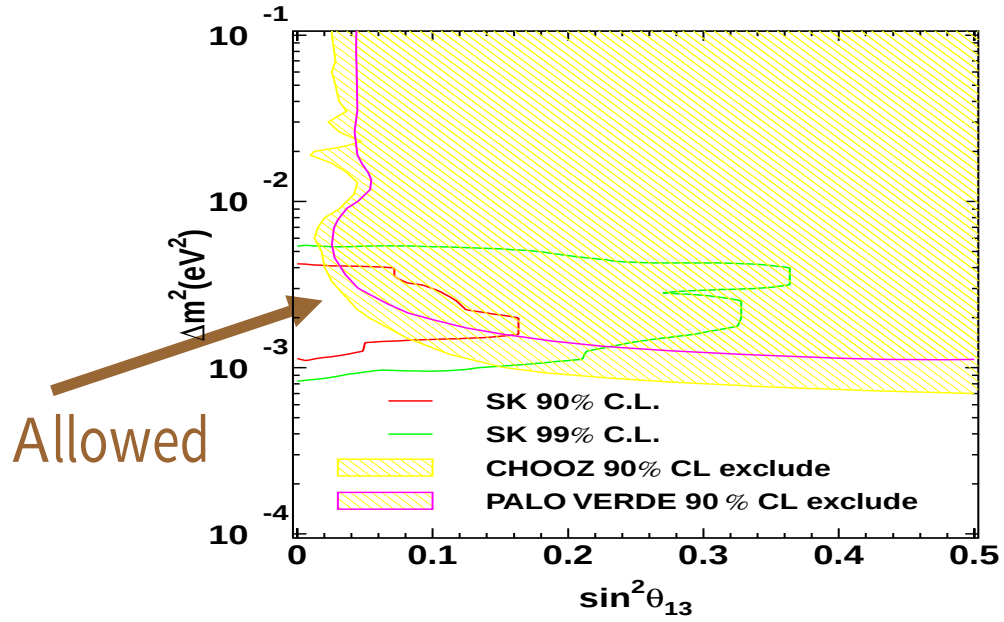
Δm^2 dependence of the sensitivity



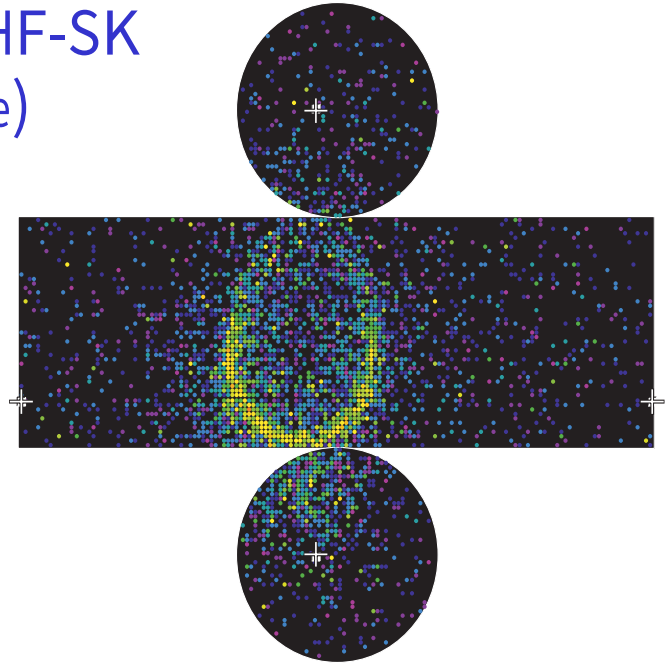
➡ Off-axis angle should be adjusted to about 0.1 deg.

θ_{13}

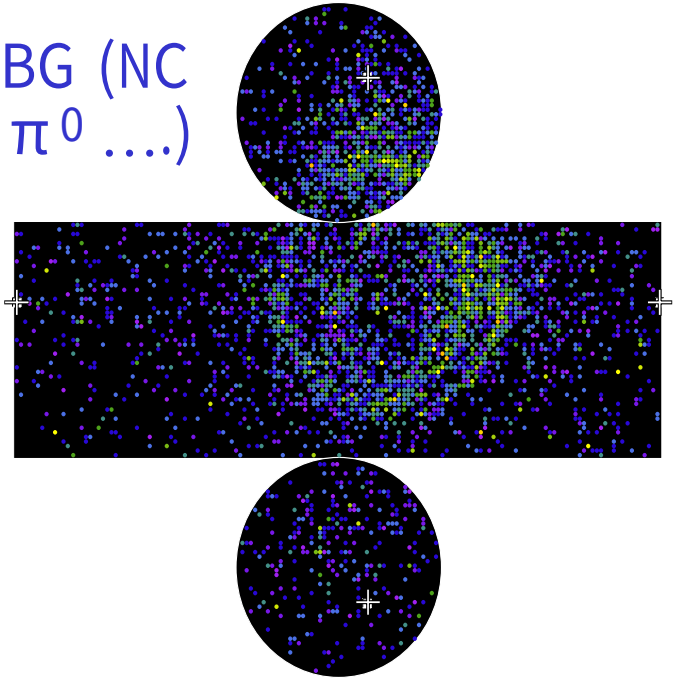
Present status:



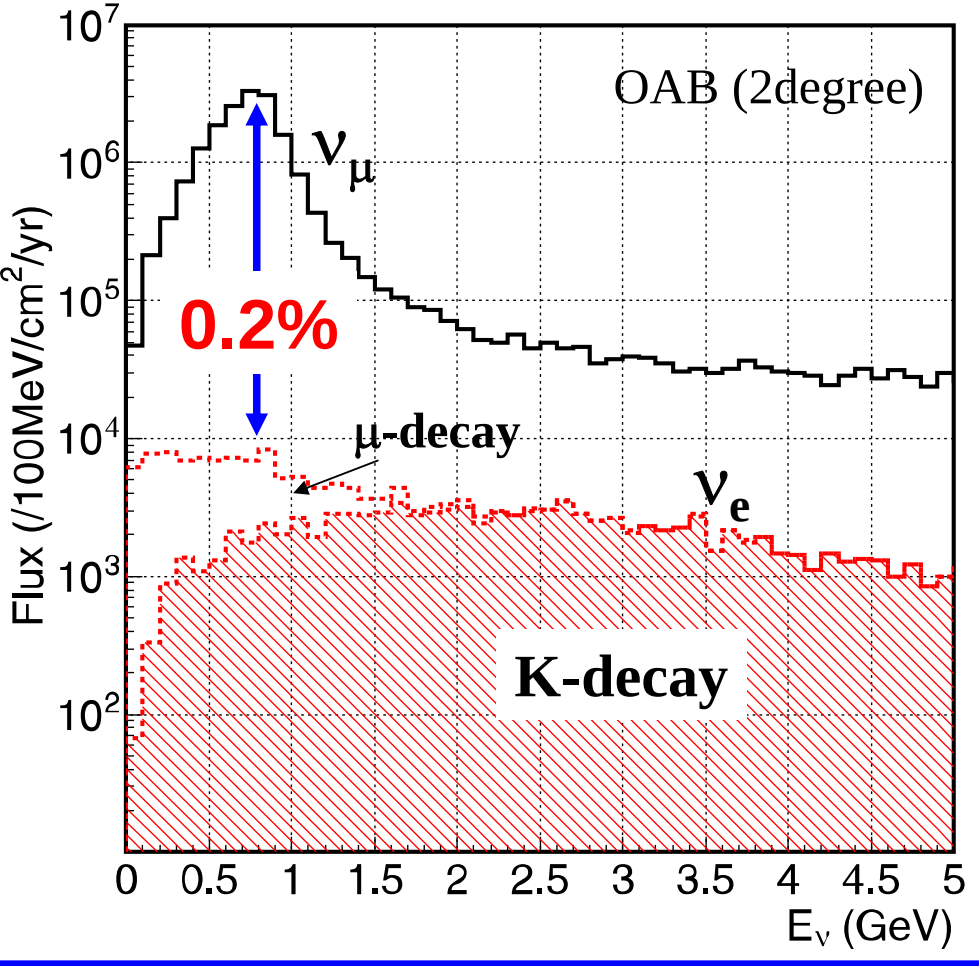
Signal for non-zero θ_{13} in JHF-SK ($\nu_\mu \rightarrow \nu_e$)



BG (NC π^0 ....)



ν_e beam contamination



ν_e/ ν_μ ratio=0.2% at the spectrum peak.

Number of signal events and BG

$\Delta m^2=3\times10^{-3}eV^2$,
$\sin^2 2\theta_{13}=0.1$

OAB 2deg., 5yrs

	ν_μC.C.	ν_μN.C.	Beam ν_e	Osc'd ν_e
Generated	10713.6	4080.3	292.1	301.6
1ring e-like	14.3	247.1	68.4	203.7
red. eff.	0.1%	6.1%	23.4%	67.5%
e/π^0 sep.	3.5	23.0	21.9	152.2
red.eff.	0.03%	0.6%	7.5%	50.4%
.4<Eν<1.2	1.8	9.3	11.1	123.2
red.eff.	0.02%	0.2%	3.8%	40.8%

e/π^0 separation

- Shower direction w.r.t. beam

  (1) $\cos\theta_{ve}$: π^0 tend to have a forward peak

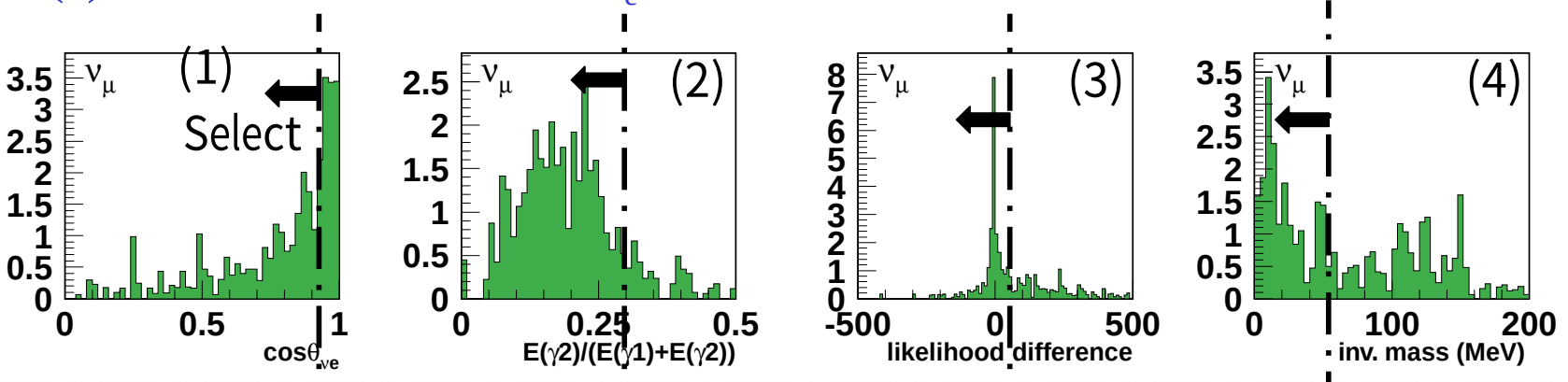
- Force to find 2nd ring and…

  (2) $E(\gamma_2)/E(\gamma_1+\gamma_2)$: Large for BG

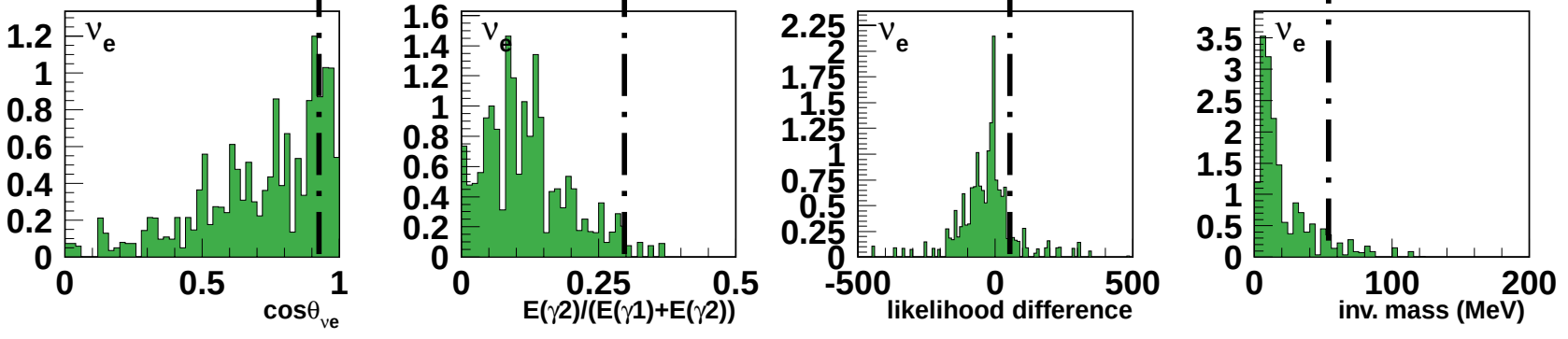
  (3) Likelihood diff. between 1 and 2-ring assumptions

  (4) Invariant mass: Small for ν_e

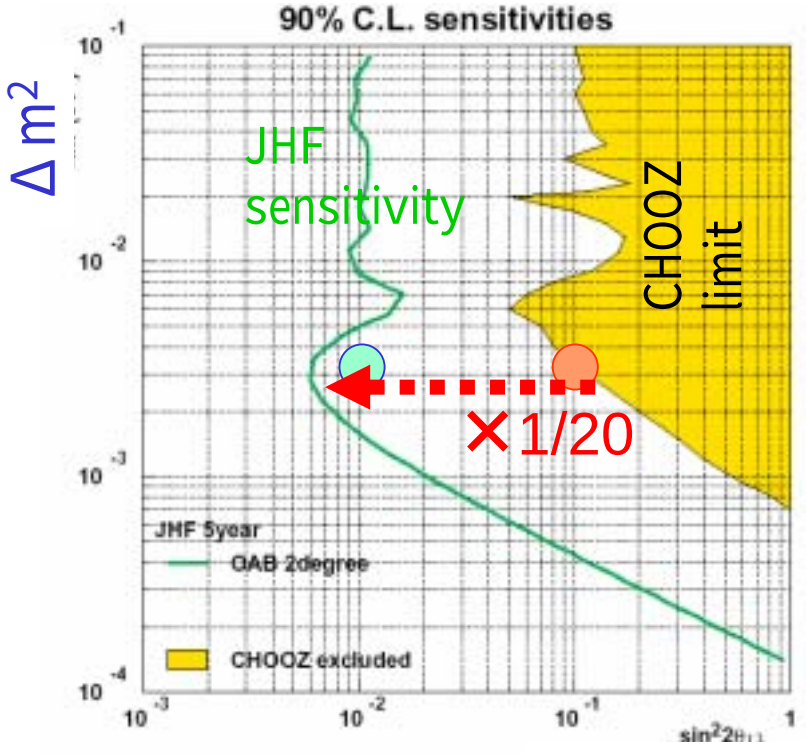
BG



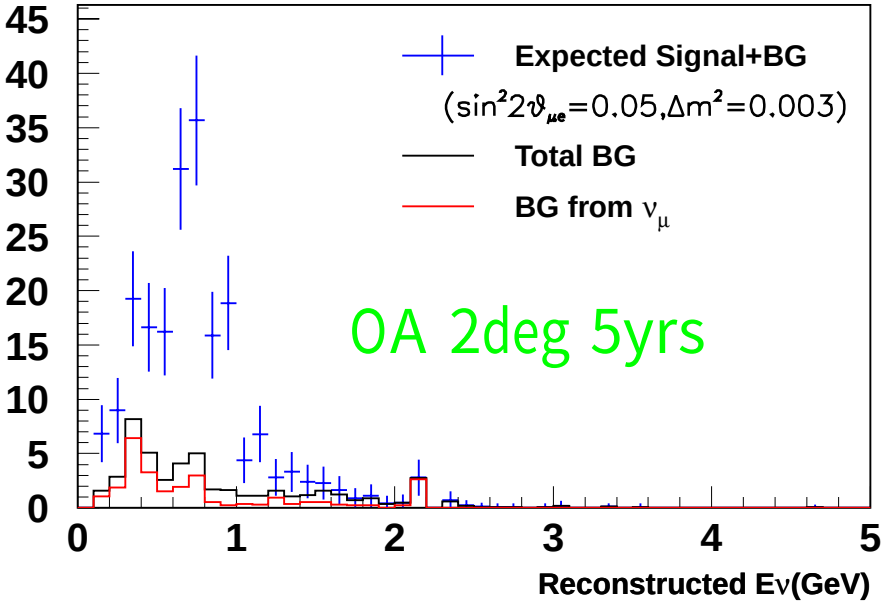
ν_e



Measurement of $\sin^2 2\theta_{13}$



Expected signal for ●



$\sin^2 2\theta_{13}$	ν_μ (CC+NC)	Bean ν_e	Osc'd ν_e	Signal+BG
0.1	11.1	11.1	123.2	145.5
0.01	11.1	11.1	12.3	34.5

Phase–II

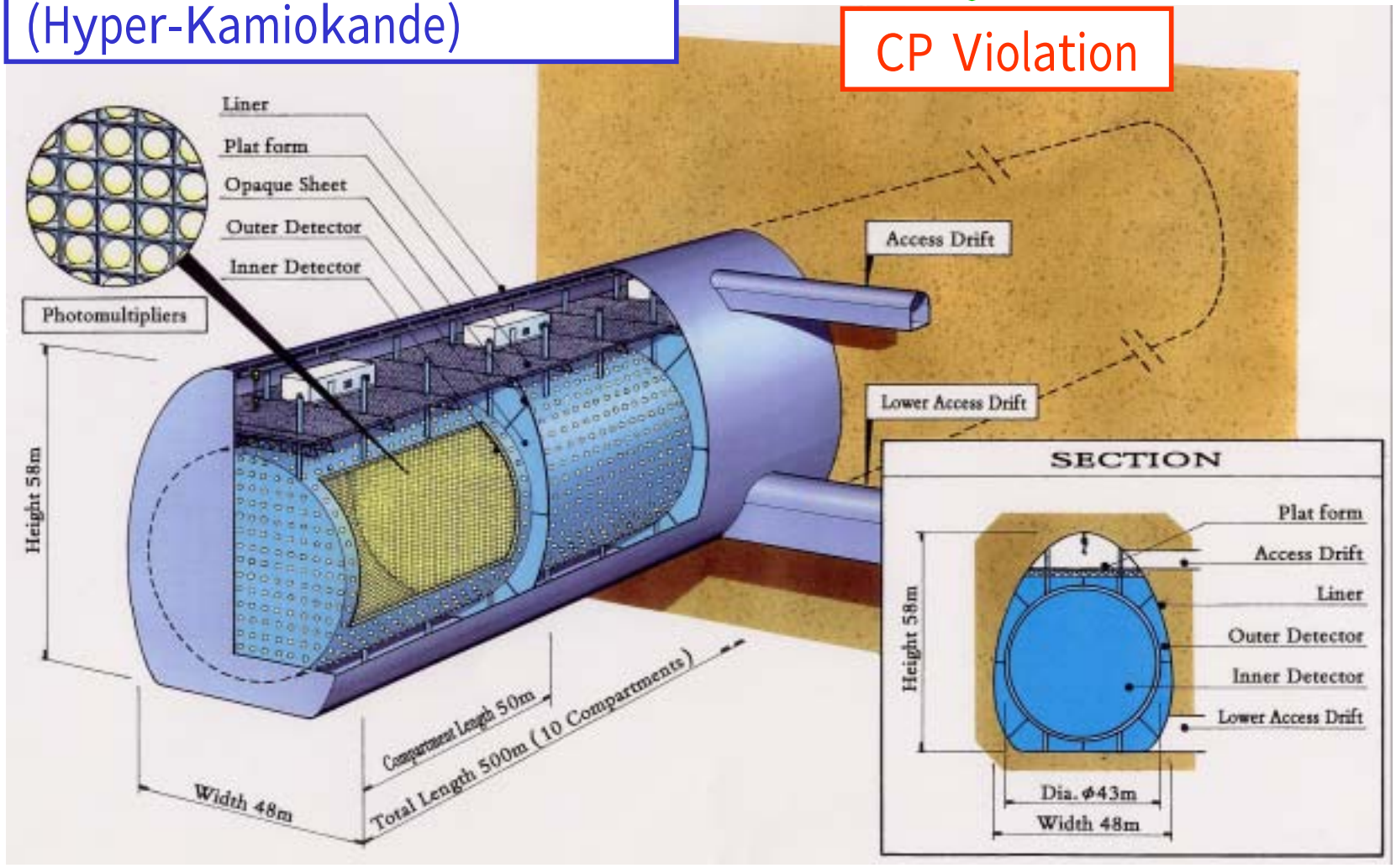
JHF Phase-II

★0.77 → 4 MW beam power

★∼1 Mton detector
(Hyper-Kamiokande)

→ 10^6 events

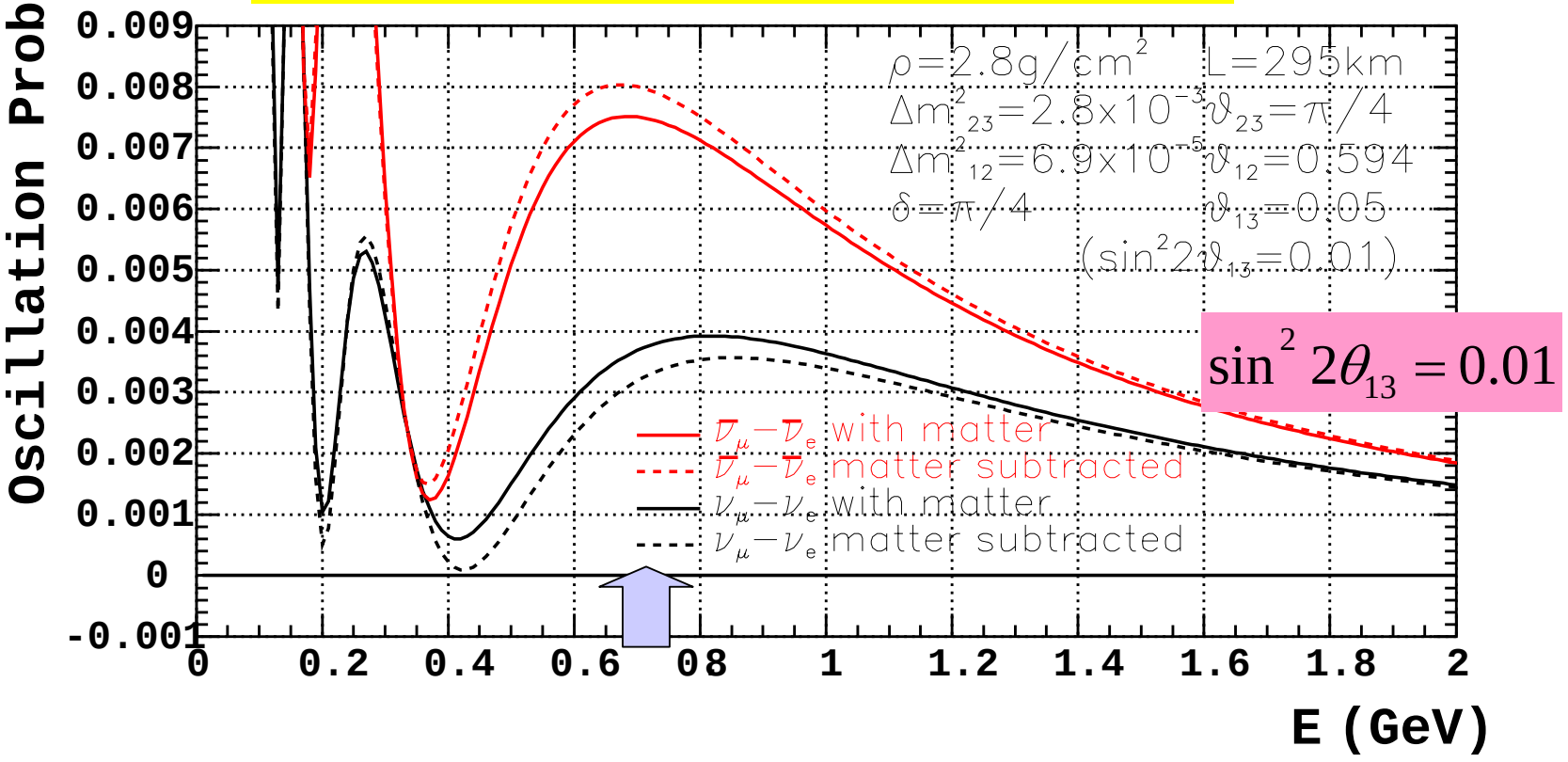
→ CP Violation



Assumptions

$$\theta_{23} = 45°, \quad \Delta m^2_{23} = 2.8\times10^{-3}\,eV^2$$
$$\theta_{12} = 34°, \quad \Delta m^2_{12} = 6.9\times10^{-5}\,eV^2$$

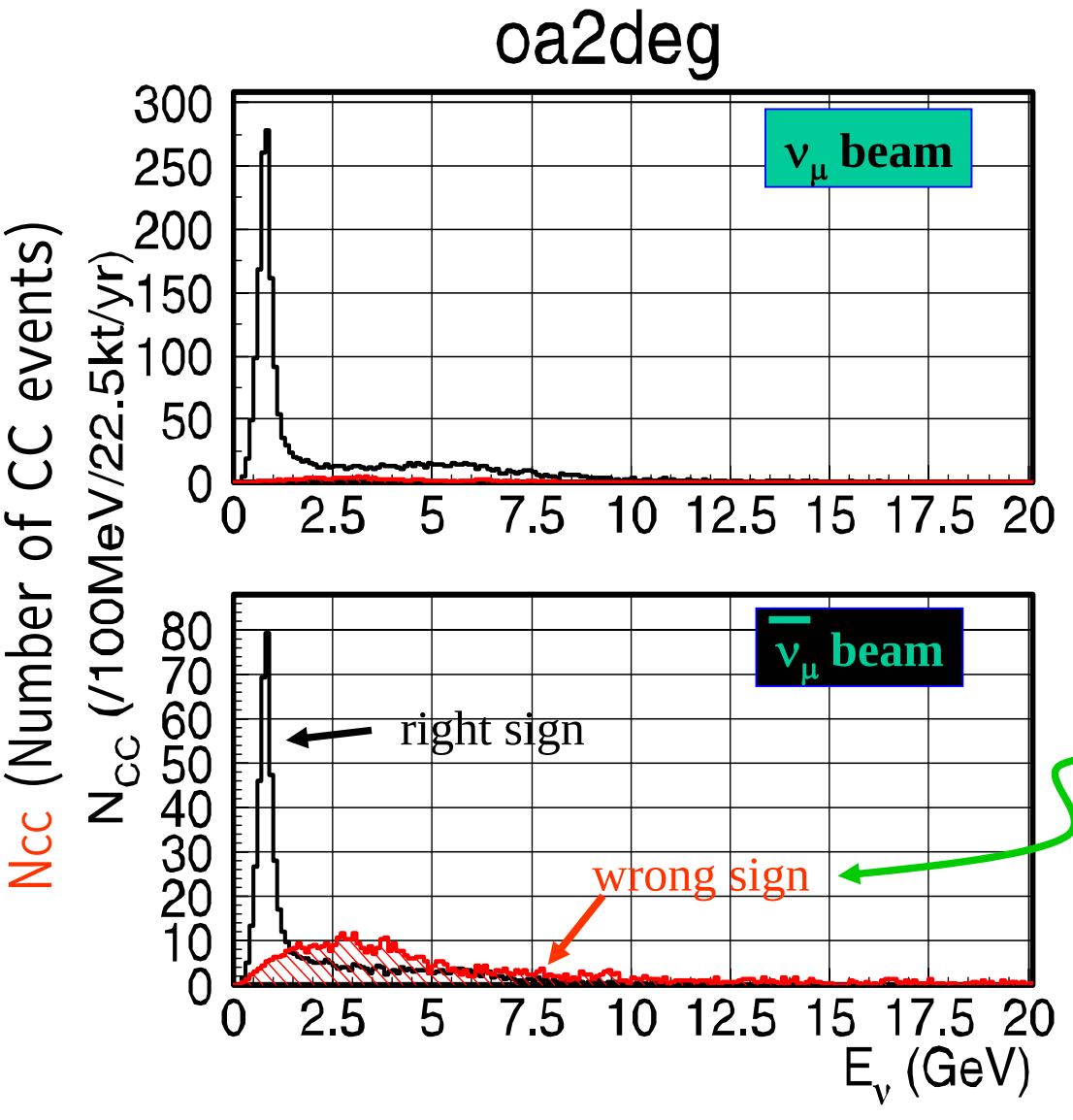
(unless otherwise stated)



$$\sin^2 2\theta_{13} = 0.01$$

Solid line: w/ matter
Dashed line: w/o matter

Neutrino and anti-neutrino runs

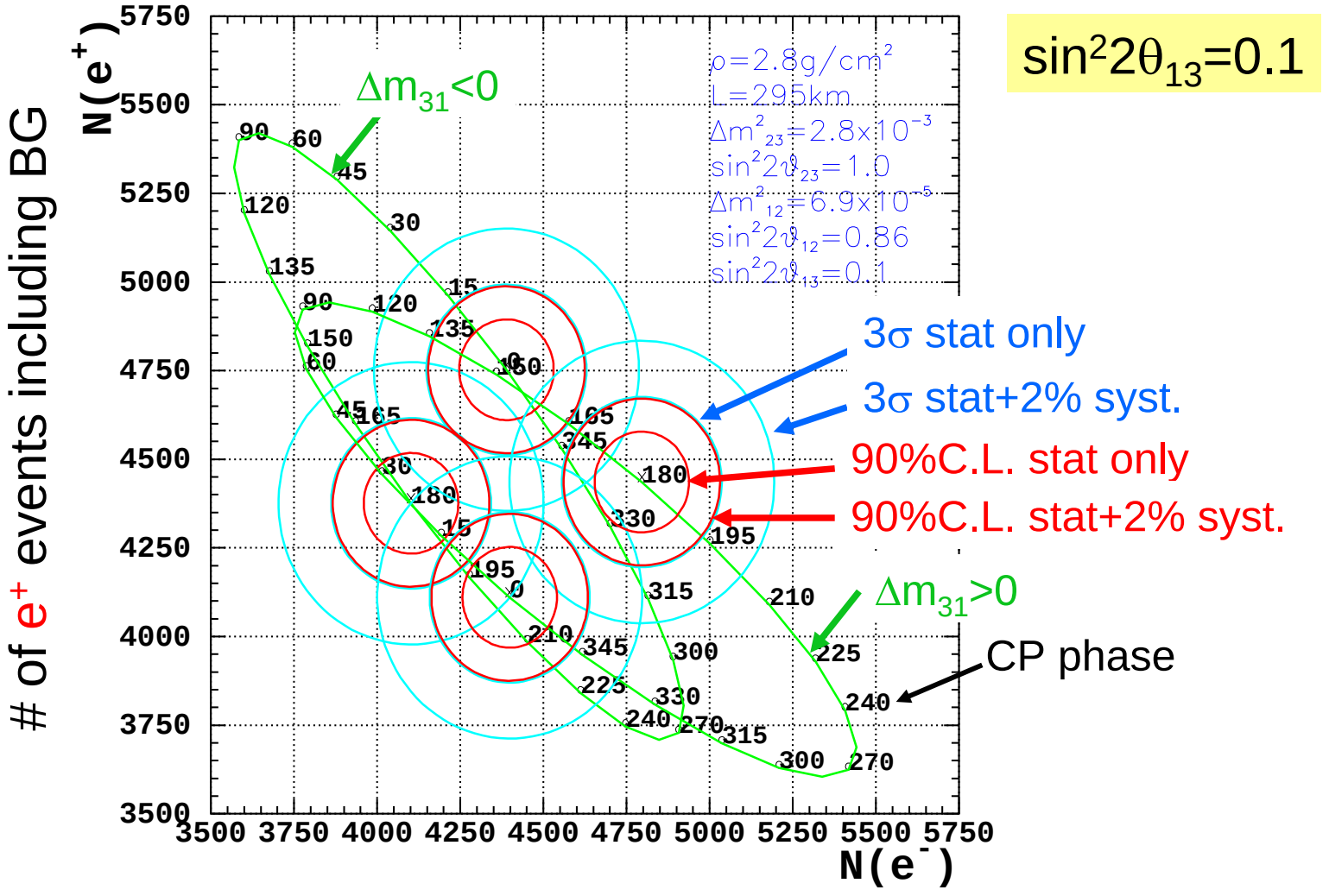


3.4yr $\bar{\nu}_\mu$

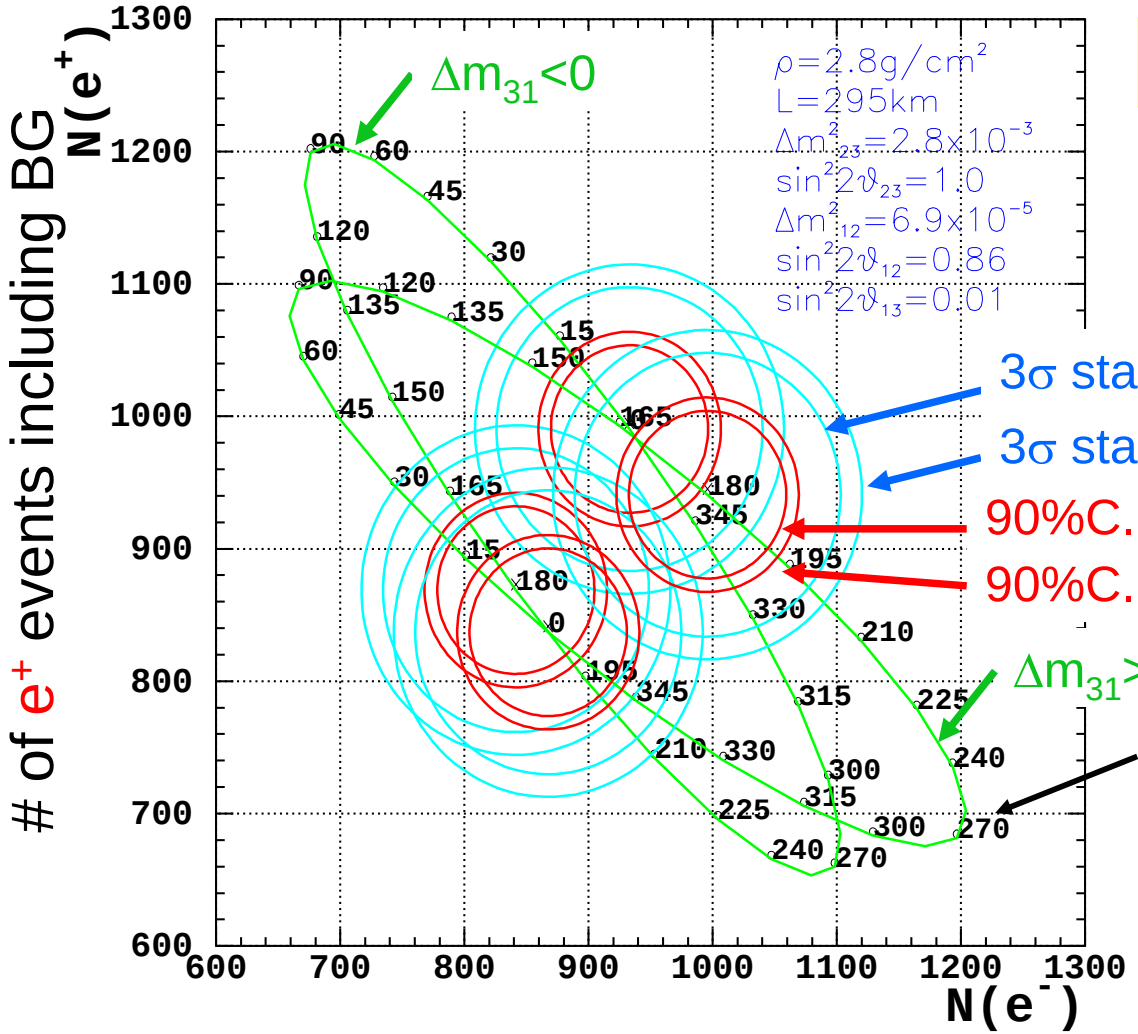
= 1yr ν_μ

Important to understand the wrong sign contamination

Expected CP violation signal(1)

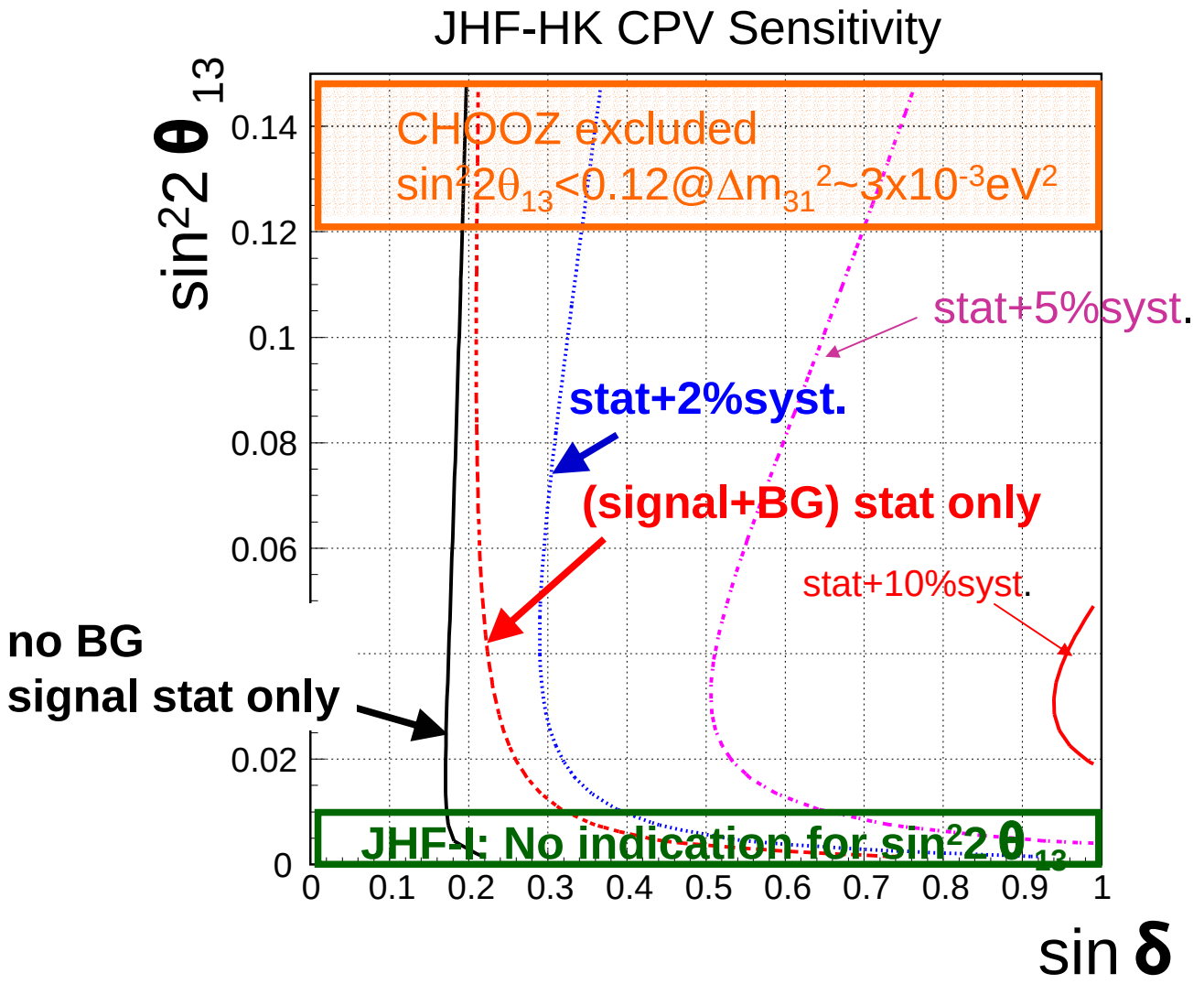


Expected CP violation signal (2)



$\sin^2 2\theta_{13}=0.01$

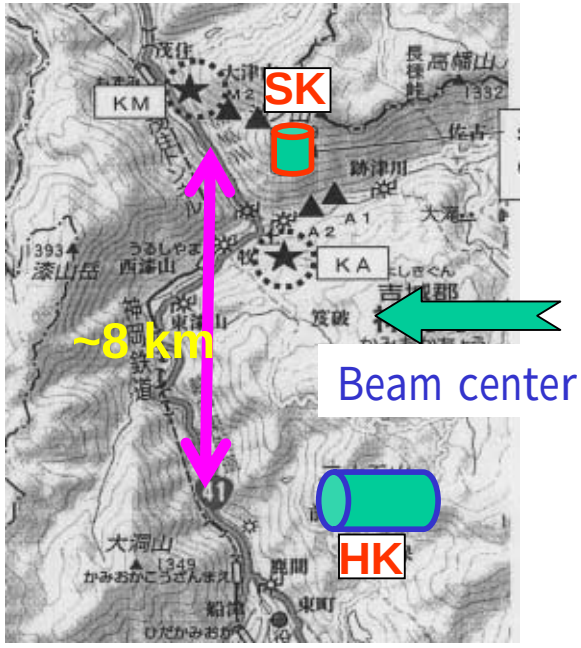
3σ CP sensitivity

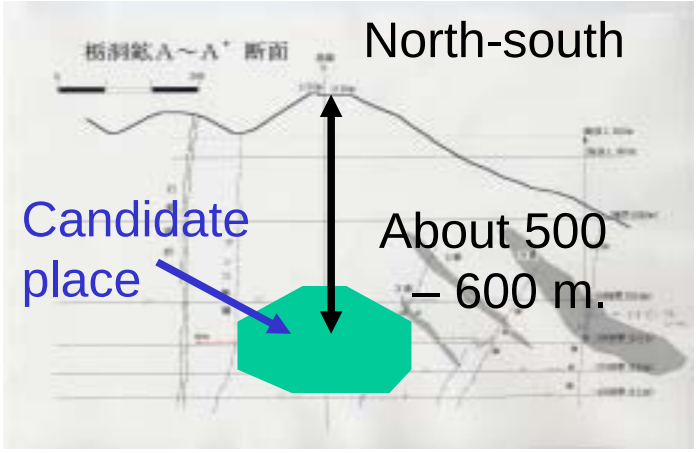


3σ CP sensitivity : $|\delta|>20^o$ for $\sin^2 2\theta_{13}>0.01$ with 2% syst.

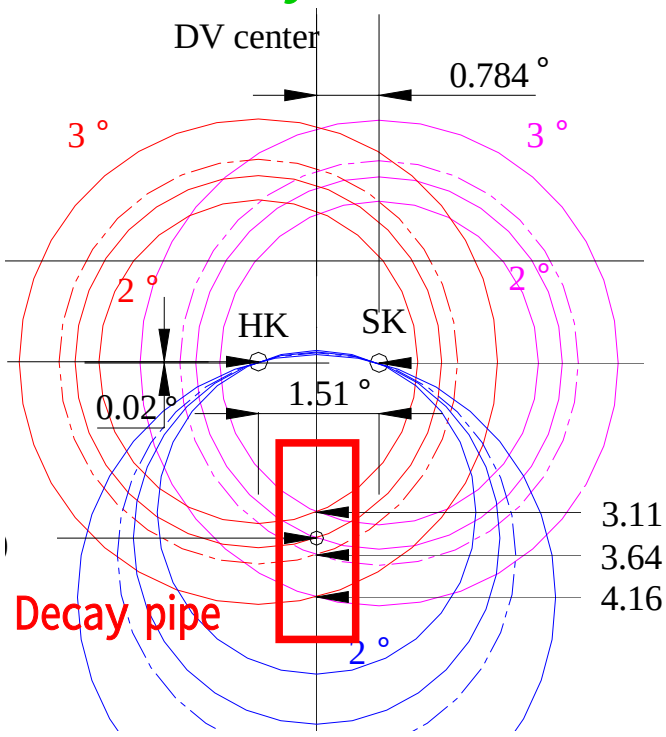
Decay Pipe Common for SK/HK

Possible site for Hyper-K





Beam eye



Common off-axis angle (2-3 degrees) for both Super-K and Hyper-K

Summary

- Main goals of JHF-Kamioka neutrino project (Phase-I)
  - ★Precise determination of neutrino oscillation parameters.
    Accuracy: $\sin^2 2\theta_{23}$ ····· 1%
    Δm^2 ····· a few %
  - ★Discovery and measurement of non-zero θ_{13}
    $\sin^2 2\theta_{13}$ ····· > 0.01

- Main goals of JHF-Kamioka neutrino project (Phase-II)
  - ★Discovery and measurement of non-zero CP phase

- Design works are in progress hoping to start the experiment by (the end of 2007 or) early 2008.