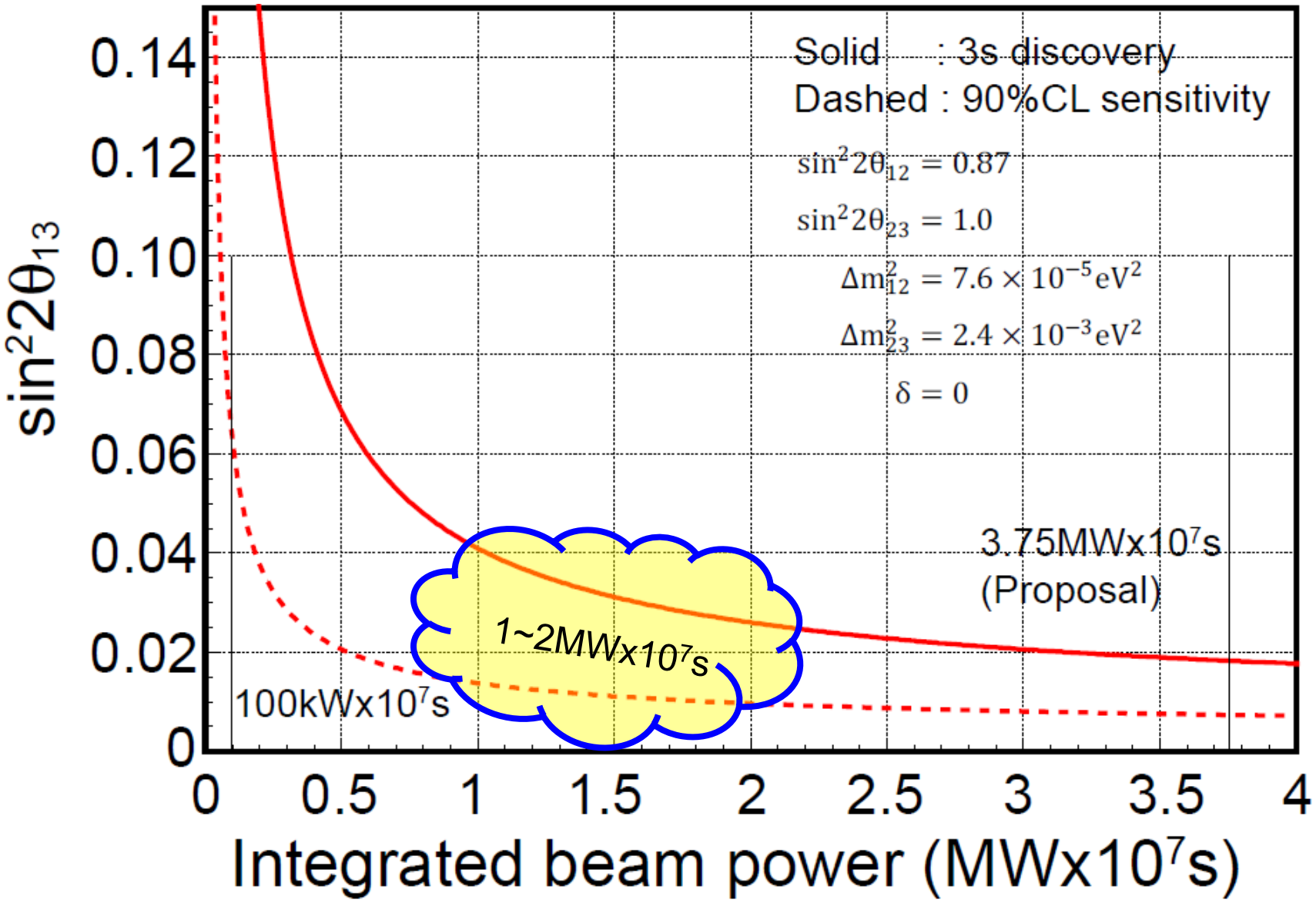
100907
NOW2010
Italy

Future Neutrino Physics Scenarios in Japan

Takashi Kobayashi

KEK

T2K θ_{13} sensitivity



Quest for the Origin of Matter Dominated Universe

One of the Main Subject of the KEK Roadmap

T2K (2009~)

Discovery of the ν_e Appearance

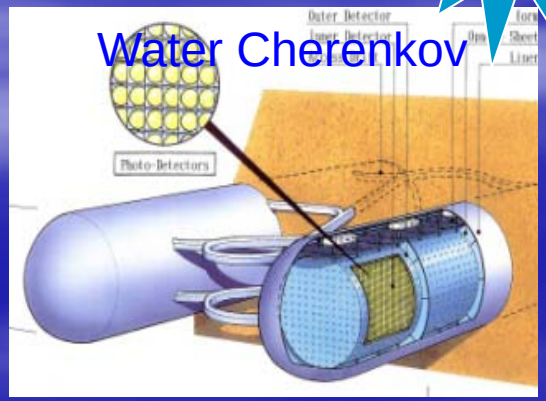
Neutrino Intensity Improvement

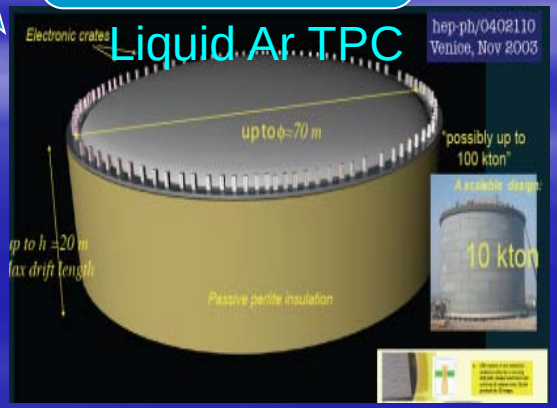
Huge Detector R&D

Establish Huge Detector Technology

Construction of Huge Detector

Discovery of Lepton CP Violation Proton Decay





Lepton Sector CP Violation

$$\begin{pmatrix} \nu_e \\ \nu_\mu \\ \nu_\tau \end{pmatrix} = \begin{pmatrix} c_{12}c_{13} & c_{13}s_{12} & e^{-i\delta}s_{13} \\ -s_{12}c_{23} - e^{-i\delta}c_{12}s_{13}s_{23} & c_{12}c_{23} - e^{i\delta}s_{12}s_{13}s_{23} & c_{13}s_{23} \\ -e^{i\delta}c_{12}s_{13}c_{23} + s_{12}s_{23} & -e^{i\delta}s_{12}s_{13}c_{23} - c_{12}s_{23} & c_{13}c_{23} \end{pmatrix} \begin{pmatrix} \nu_1 \\ \nu_2 \\ \nu_3 \end{pmatrix}$$

Effect of CP Phase δ appear as

- ν_e Appearance Energy Spectrum Shape

  *Peak position and height for 1st, 2nd maximum and minimum

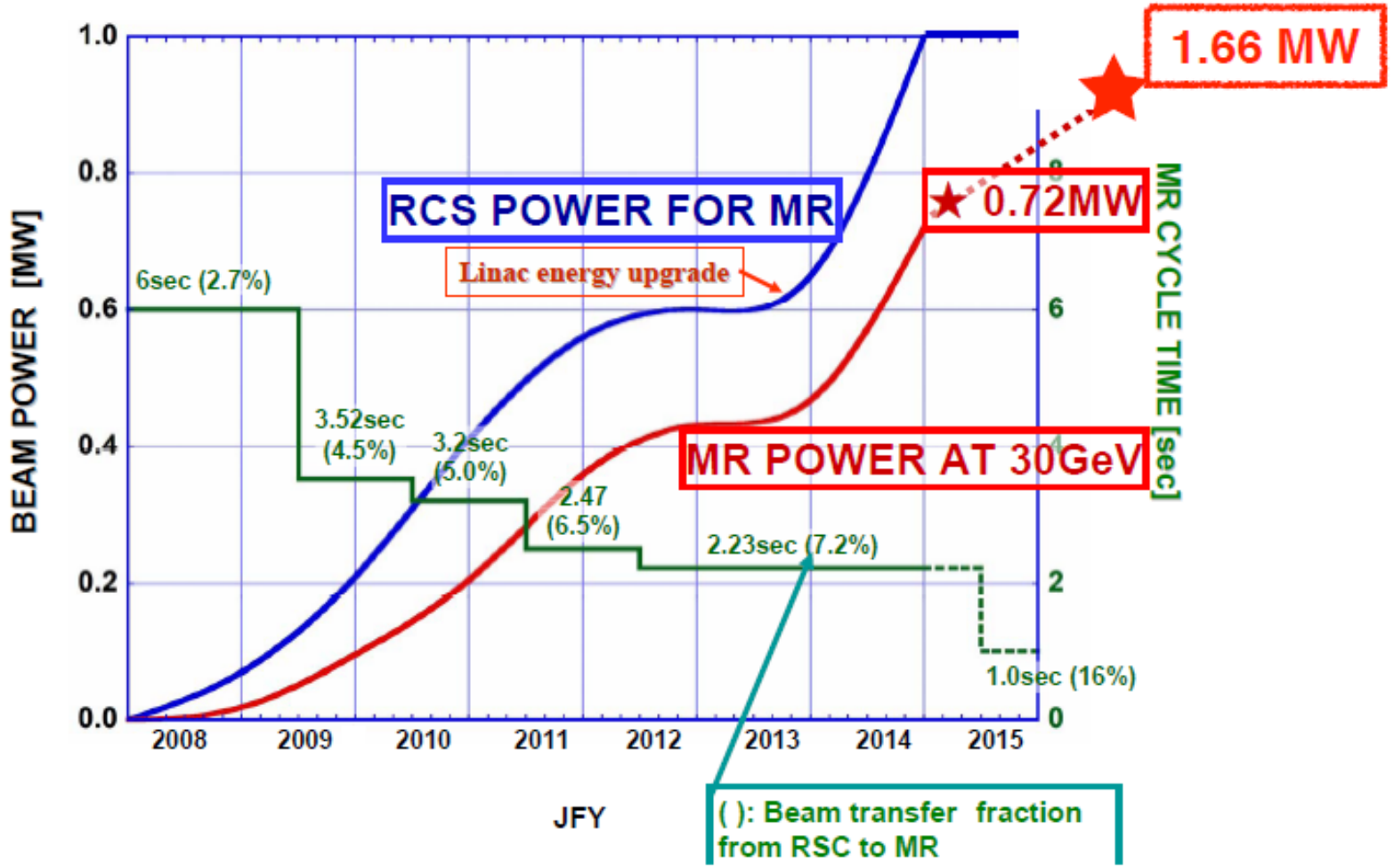
  *Sensitive to all the non-vanishing δ including 180°

  *Could investigate CP phase with ν run only

- Difference between ν_e and $\overline{\nu}_e$ Behavior
  - Sensitive to any mechanism to make asymmetry
  - Separation from possible sources of non-CPV asymmetry needed

MR Power Improvement Scenario

Increase rep. rate and/or increase # of protons
toward high power (~1.66MW)



Studies and R&D on Power supply, RF configuration, etc are being made

MR Power Improvement Scenario toward MW-class power frontier machine
— KEK Roadmap —

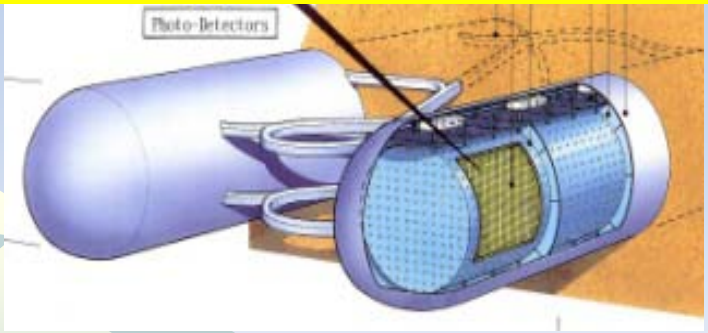
	Day1 (up to Jul.2010) Achieved !	Next Step	KEK Roadmap
Power(MW)	0.1	0.45	>1.66
Energy(GeV)	30	30	30
Rep Cycle(sec)	3.5	2.2	1.92～0.5
No. of Bunch	6	8	8
Particle/Bunch	1.2×10^{13}	2.5×10^{13}	$4.1\sim8.3\times10^{13}$
Particle/Ring	7.2×10^{13}	2.0×10^{14}	$3.3\sim6.7\times10^{14}$
LINAC(MeV)	181	181	400
RCS	h=2	h=2	h=2 or 1

Combination of **High rep. cycle** and **High beam density**

“Available” technologies for huge detector

Good at Wideband beam

Good at low E (<1GeV) narrow band beam



Liq Ar TPC

- Aim O(100kton)
- Electronic “bubble chamber”
  - Can track every charged particle
  - Down to very low energy
- Neutrino energy reconstruction by eg. total energy
  - No need to assume process type
  - Capable upto high energy
- Good PID w/ dE/dx, pi0 rejection

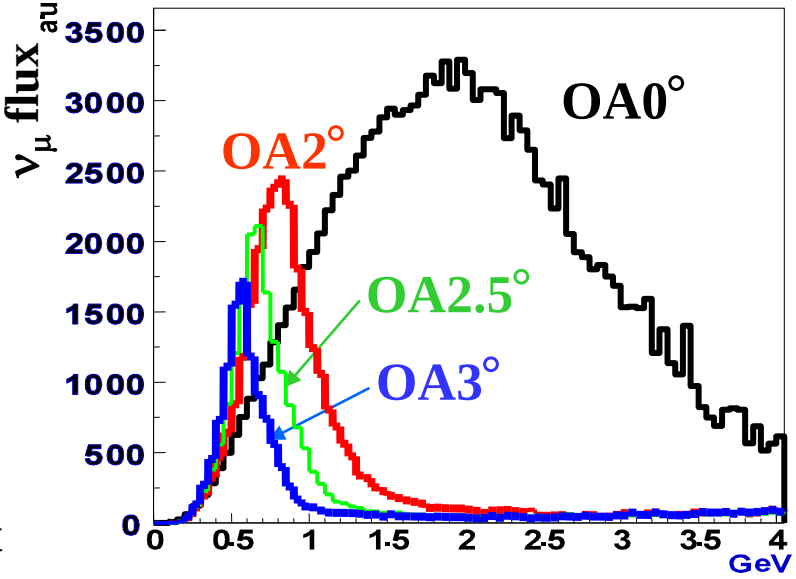
Water Cherenkov

- Aim O(1000kton)
- Energy reconstruction assuming Ccqe
  - Effective < 1GeV
- Good PID (μ/e) at low energy
- Cherenkov threshold

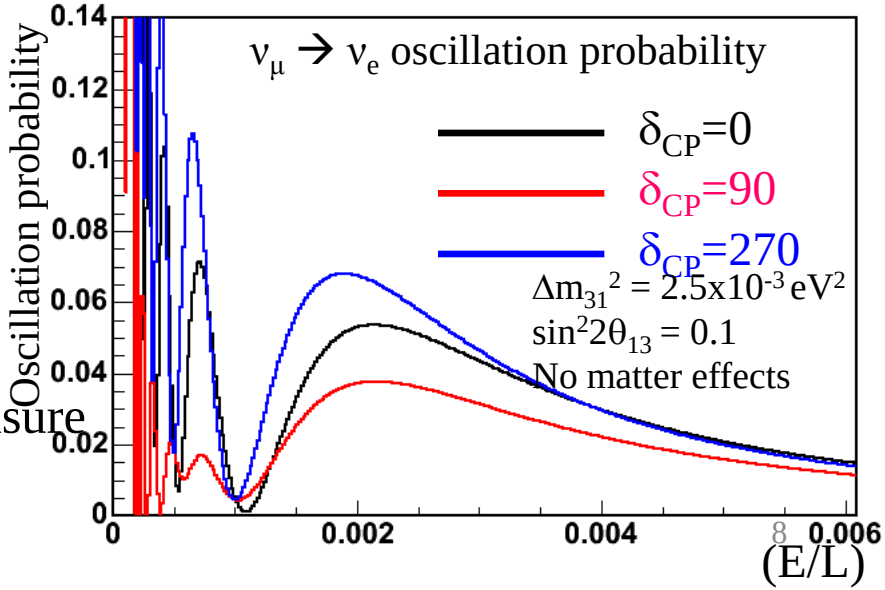
Angle and Baseline

- Off-axis angle
  - On-Axis: Wide Energy Coverage,
    - ○Energy Spectrum Measurement
    - ×Control of π^0 Background
  - Off-Axis: Narrow Energy Coverage,
    - ○Control of π^0 Background
    - ×Energy Spectrum Measurement

→ Counting Experiment



- Baseline
  - Long:
    - ○ 2nd Osc. Max. at Measurable Energy
    - × Less Statistics
    - ? Large Matter Effect
  - Short:
    - ○ High Statistics
    - × 2nd Osc.Max.Too Low Energy to Measure
    - ? Less Matter Effect



Three Possible Scenario

NP08 is **The 4th International Workshop on Nuclear and Particle Physics at J-PARC**

http://j-parc.jp/NP08

Scenario 1

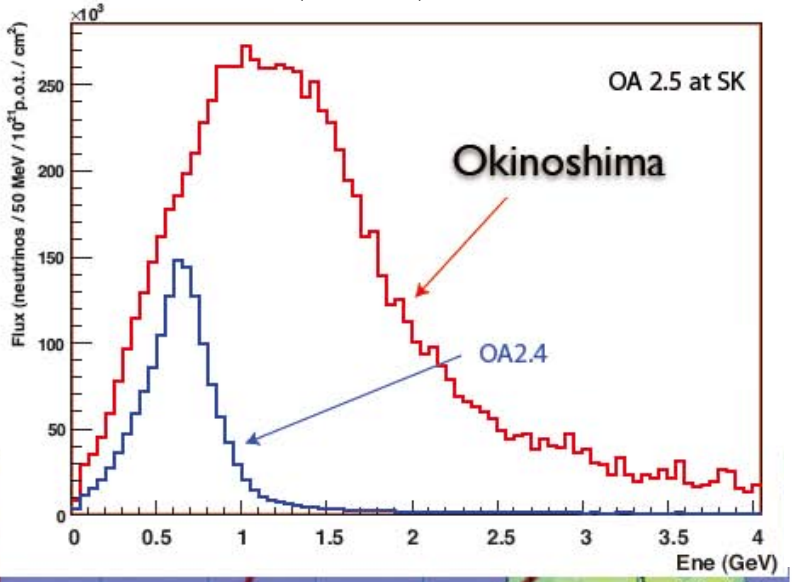
J-PARC to Okinoshima

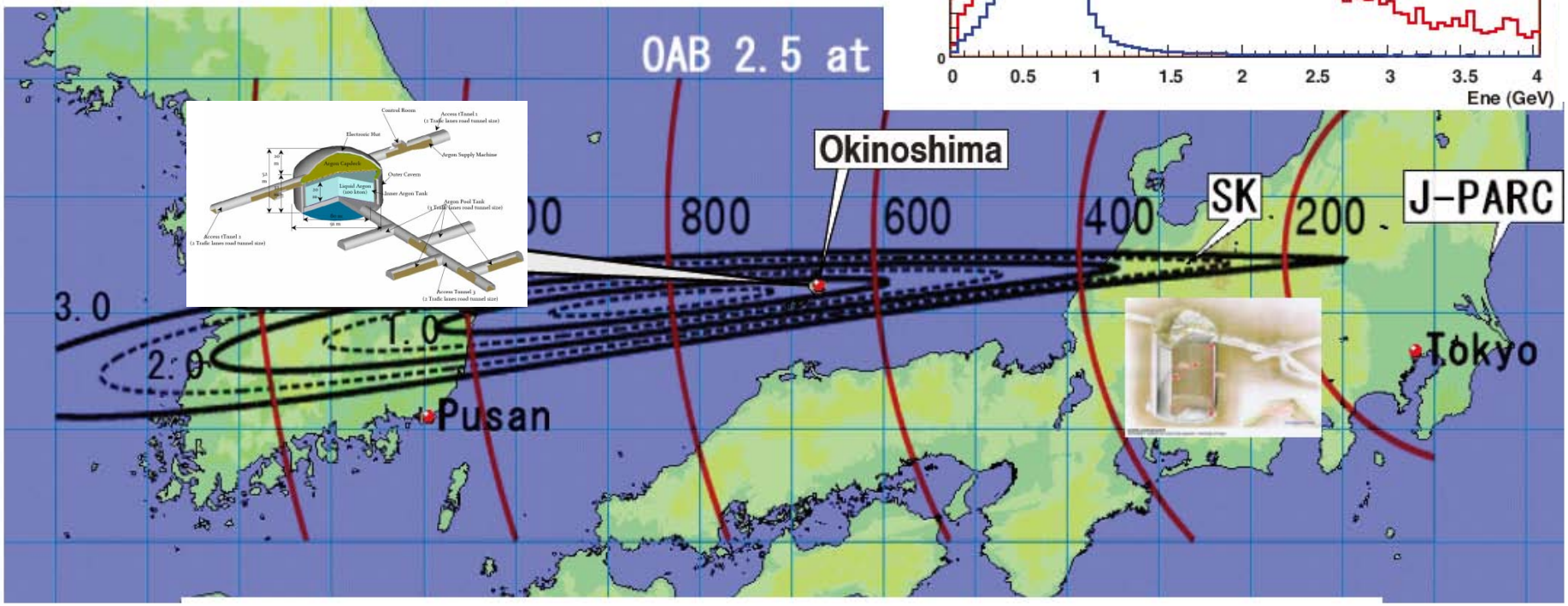
P32 proposal (Lar TPC R&D)
Recommended by J-PARC PAC
(Jan 2010), arXiv:0804.2111

Distance = 658 km

Off-axis angle = 0.76°
(2.5° @ SK)

100 kton liquid Argon





→ Extract δ_{CP} from fit of 1st & 2nd maximum

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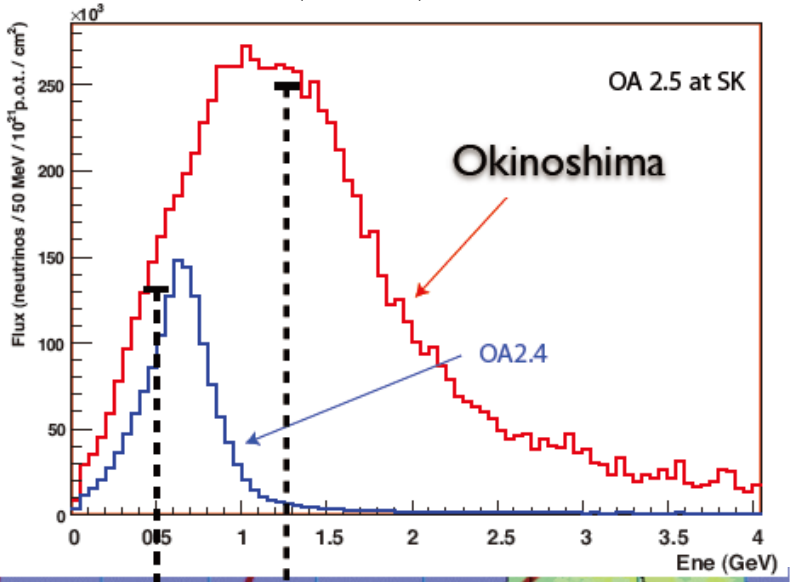
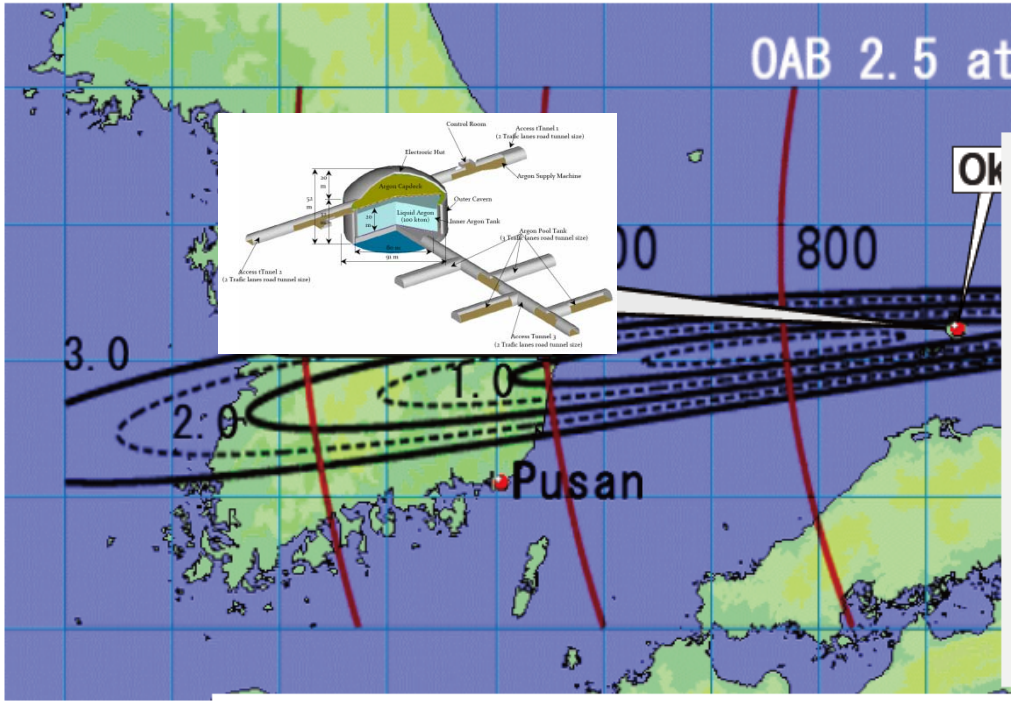
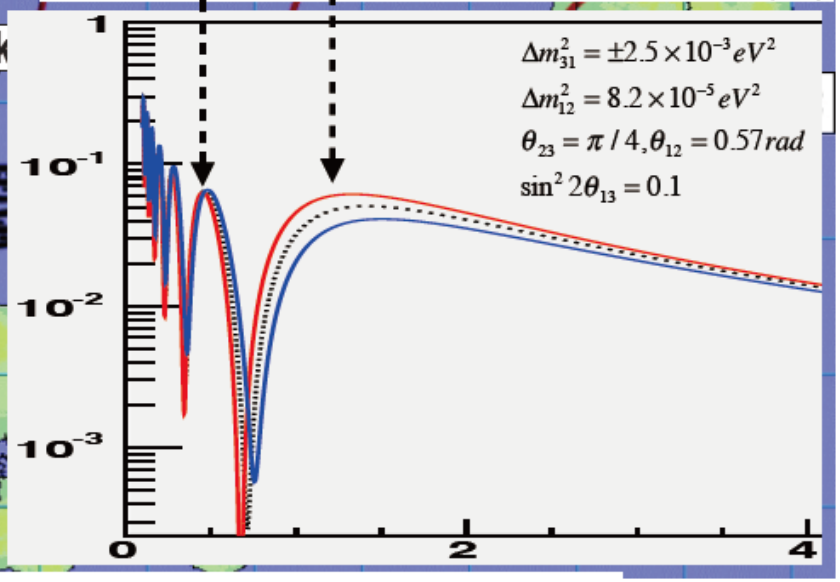




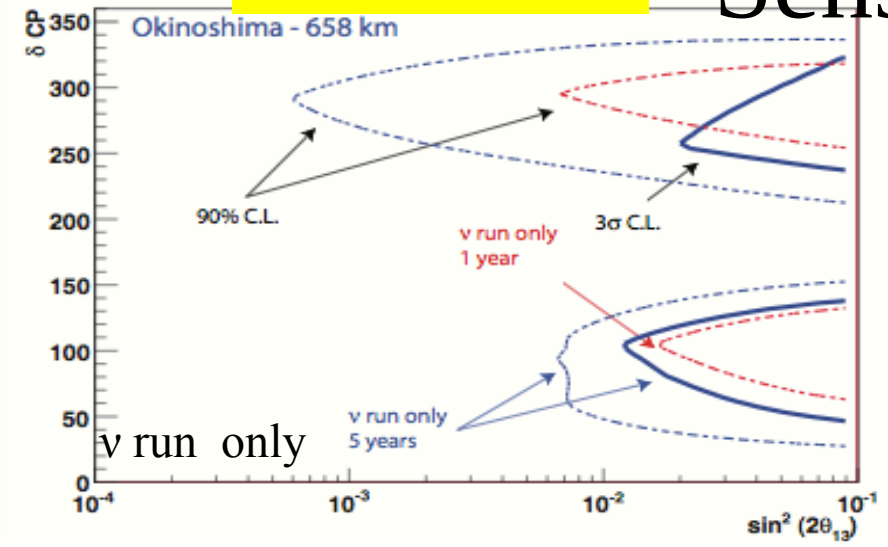


→ Extract δ_{CP} from fit of 1st & 2nd maximum

Scenario 1

J-PARC to Okinoshima: Sensitivities

CP Violation



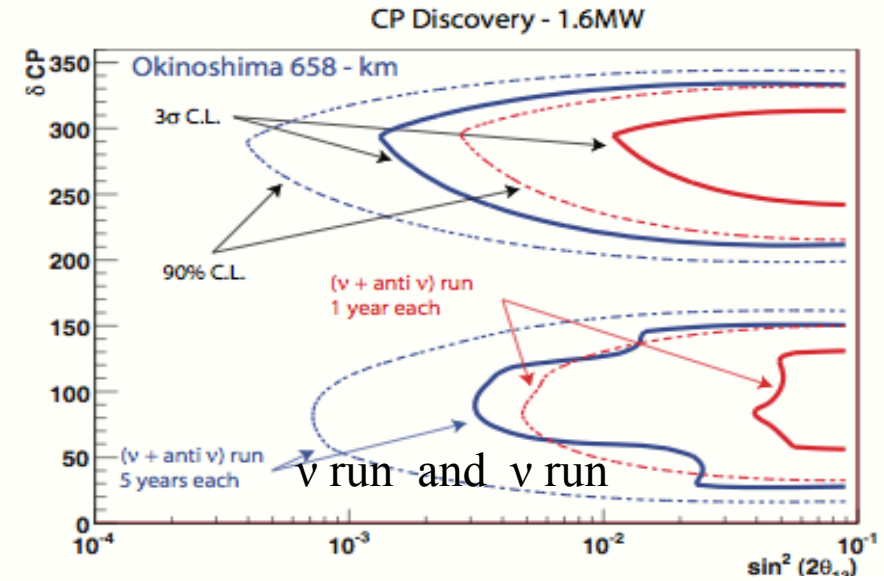


Fig. 9: Discovery potential for CP-violation at 90%C.L. and 3σ for (top) 1 resp. 5 years 1+1 resp. 5+5 years neutrino-antineutrino runs.

Hierarchy

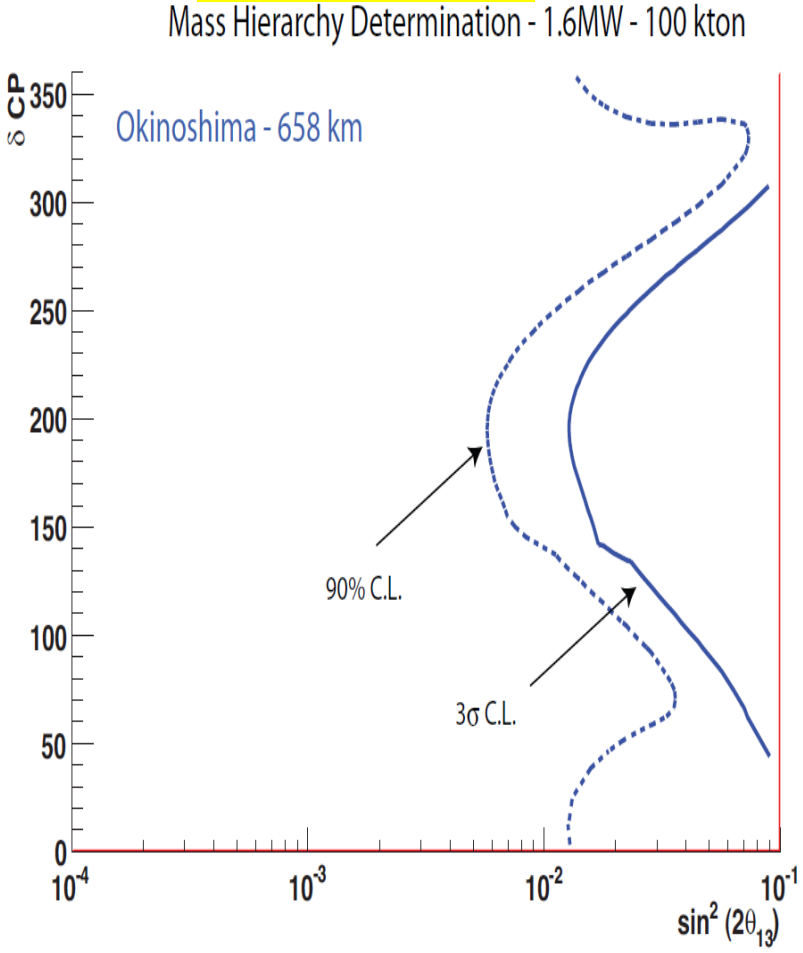


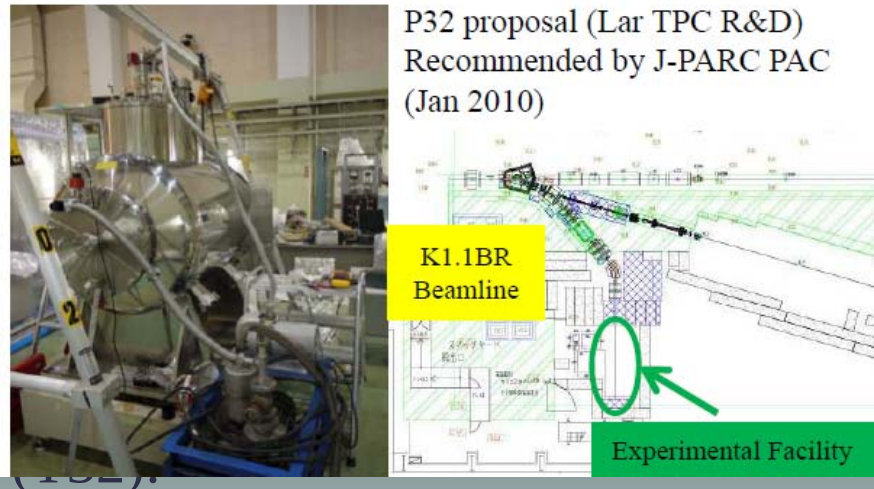
Fig. 10: Mass hierarchy discrimination at 90%C.L. and 3σ for 5+5 years neutrino-antineutrino runs.

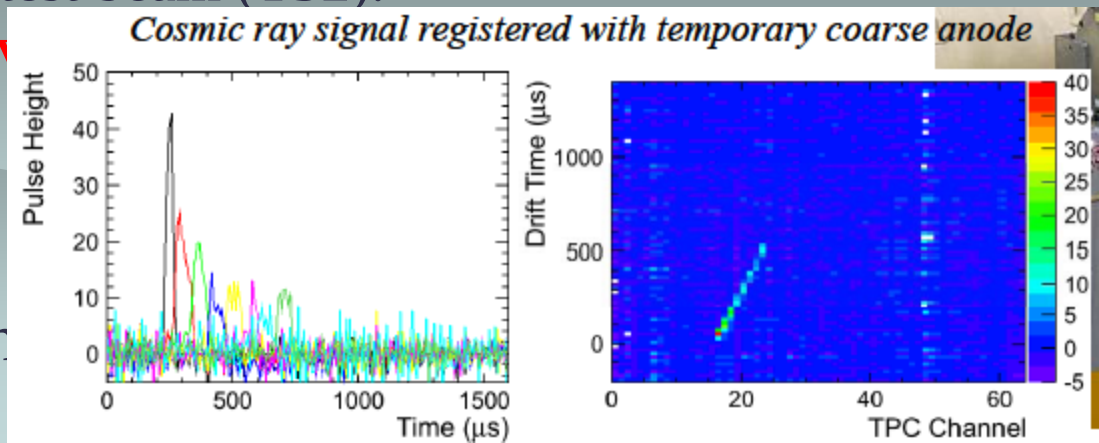
Steps towards proposal of 100 kton Giant Liquid Argon TPC

ETHZ, Iwate, KEK, Waseda,

arXiv:hep-ph/0402110

- Additional improvement of detector technology beyond ICARUS T600
  - long drift distance to reduce readout channel
    - Signal amplification, Better purity, H
    - 3L@CERN, 10L@KEK, ArDM@C
  - Acceptable purity with No-evacuati
    - 6m3@CERN
- Performance evaluation (detection suppression, etc.)
  - 250L@KEK for J-PARC test beam (T32).
    - **First cosmic track obser**
  - etc
- Final prototyping
  - Level of 1 kt prototype
- Full engineering design ar



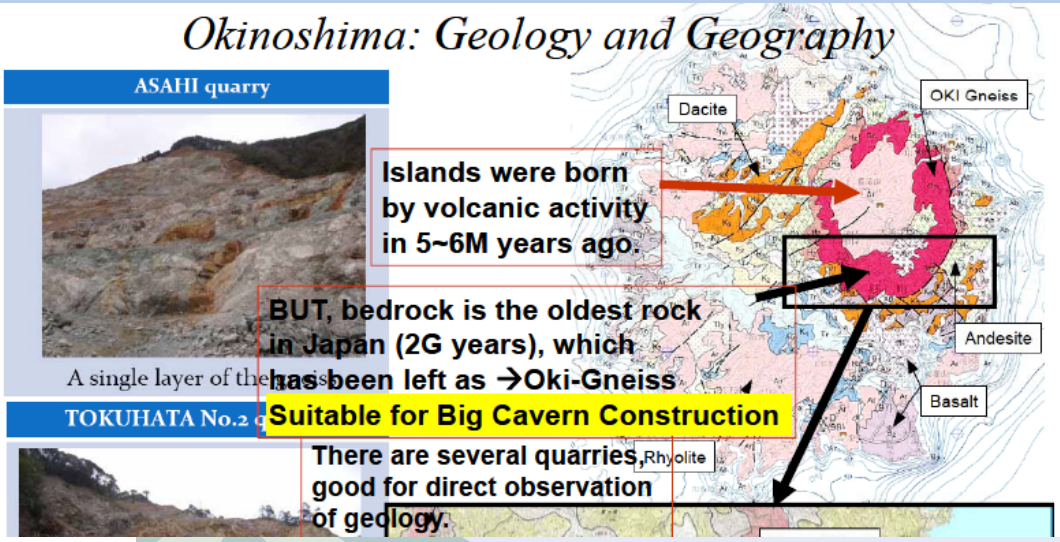


J-PARC-Okinoshima feasibility studies

(Some examples)

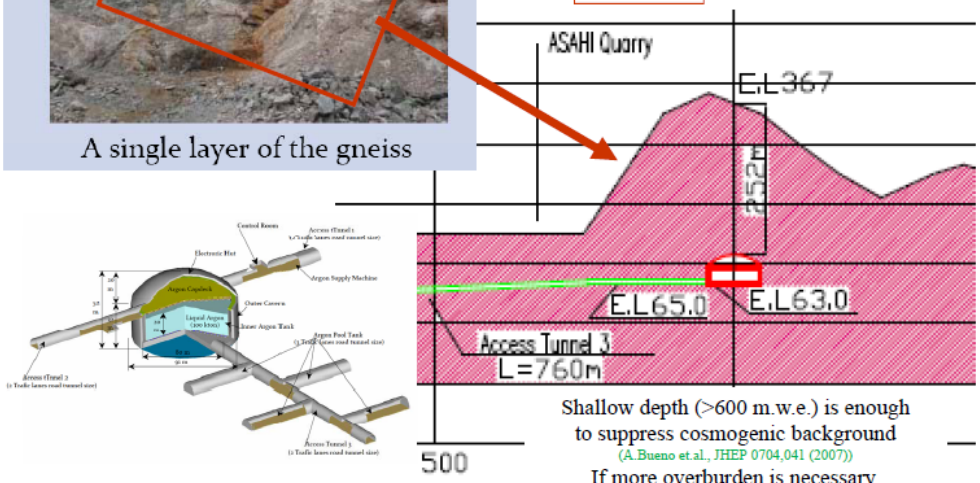
Site visit

Okinoshima: Geology and Geography



Okinoshima. Geology and Geography

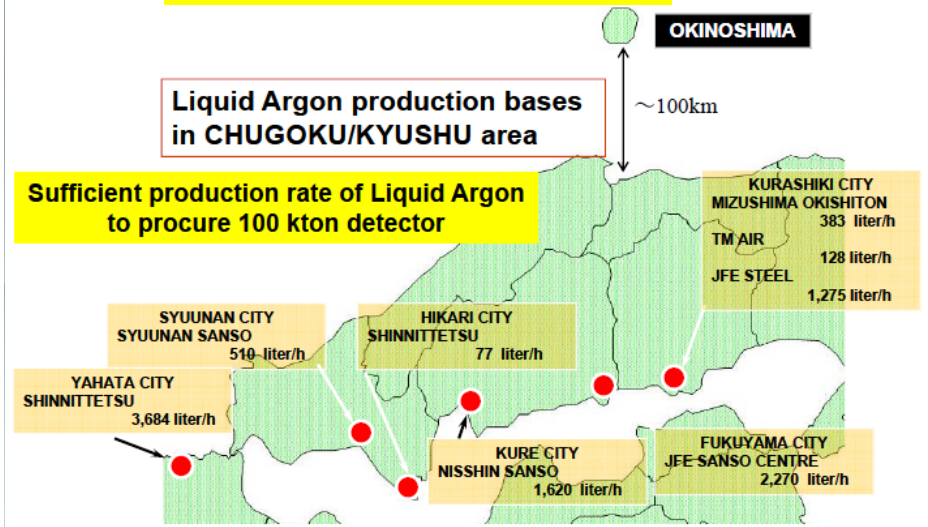
A conceptual design



Shallow depth (>600 m.w.e.) is enough to suppress cosmogenic background
(A.Bueno et.al., JHEP 0704,041 (2007))
If more overburden is necessary, inclined access tunnel is also possible

PENTA-OCEAN construction co., Ltd.,

Potential LiqAr supply

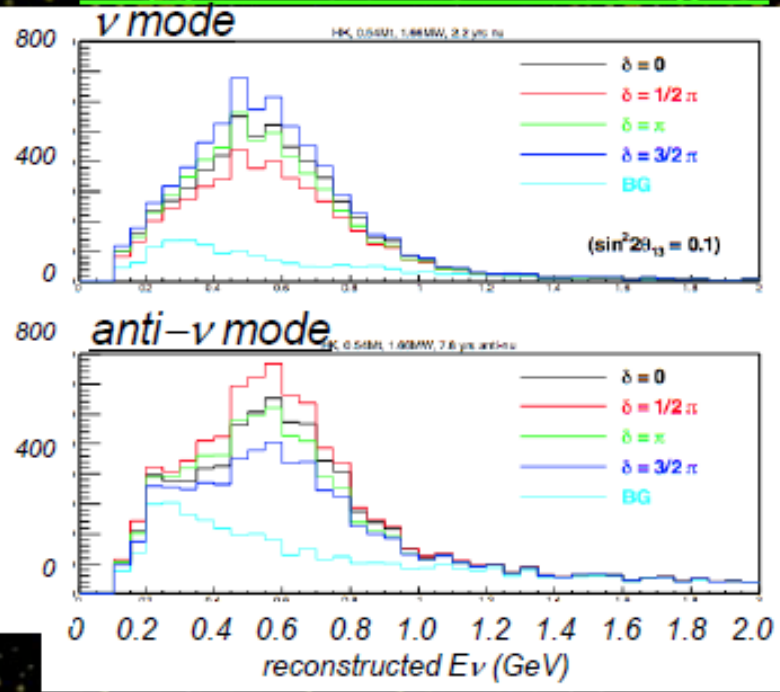


Scenario 2: J-PARC-HyperK @ Kamioka

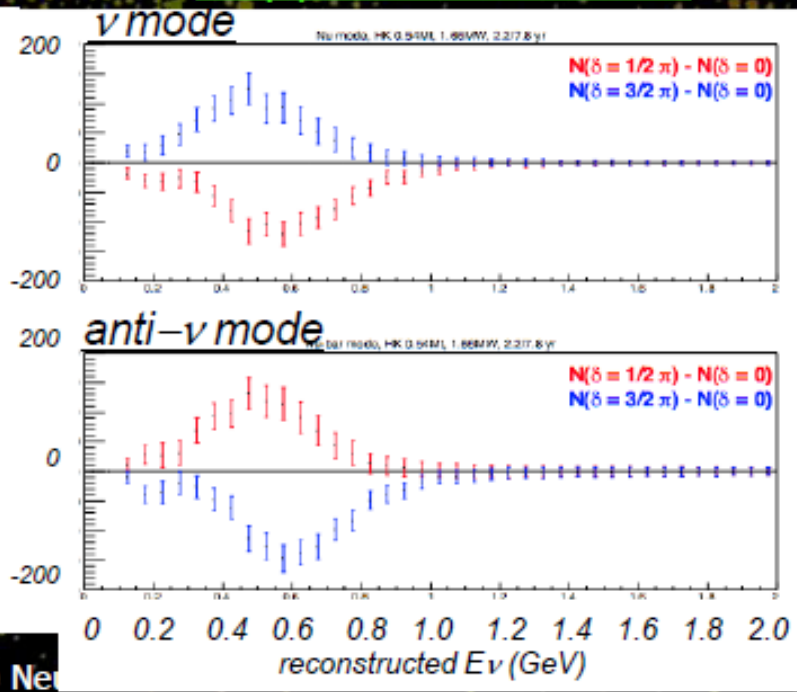
Shiozawa, Nu2010

item	parameters
ν beam	Quasi-monochromatic beam (off-axis 2.5 degree, Eν=~0.6GeV) Upgraded to 1.66MW
Far ν detector	0.54Megaton
Data taking period	5 yrs (1.1 yrs ν mode + 3.9 yrs anti-ν mode) – 10yrs *1 yrs = 10^7 sec
Electron selection	Single-Ring, Pe>100MeV/c, no decay-e, Mπ0<100MeV/c^2, $\cos\theta_\mu < 0.9$
systematic errors (reference)	5% for νe signal, NC BG, beam νe (anti-νe), ν mode/anti-ν mode normalization
ν parameters	$\sin^2\theta_{23}=0.5$, $\Delta m^2_{23}=2.4\times10^{-3}$eV^2(normal hierarchy), $\sin^2\theta_{12}=0.32$, $\Delta m^2_{12}=7.6\times10^{-5}$ eV^2

Ne(δ) = selected electron signal



Ne(δ) (Ne(δ=0) subtracted)



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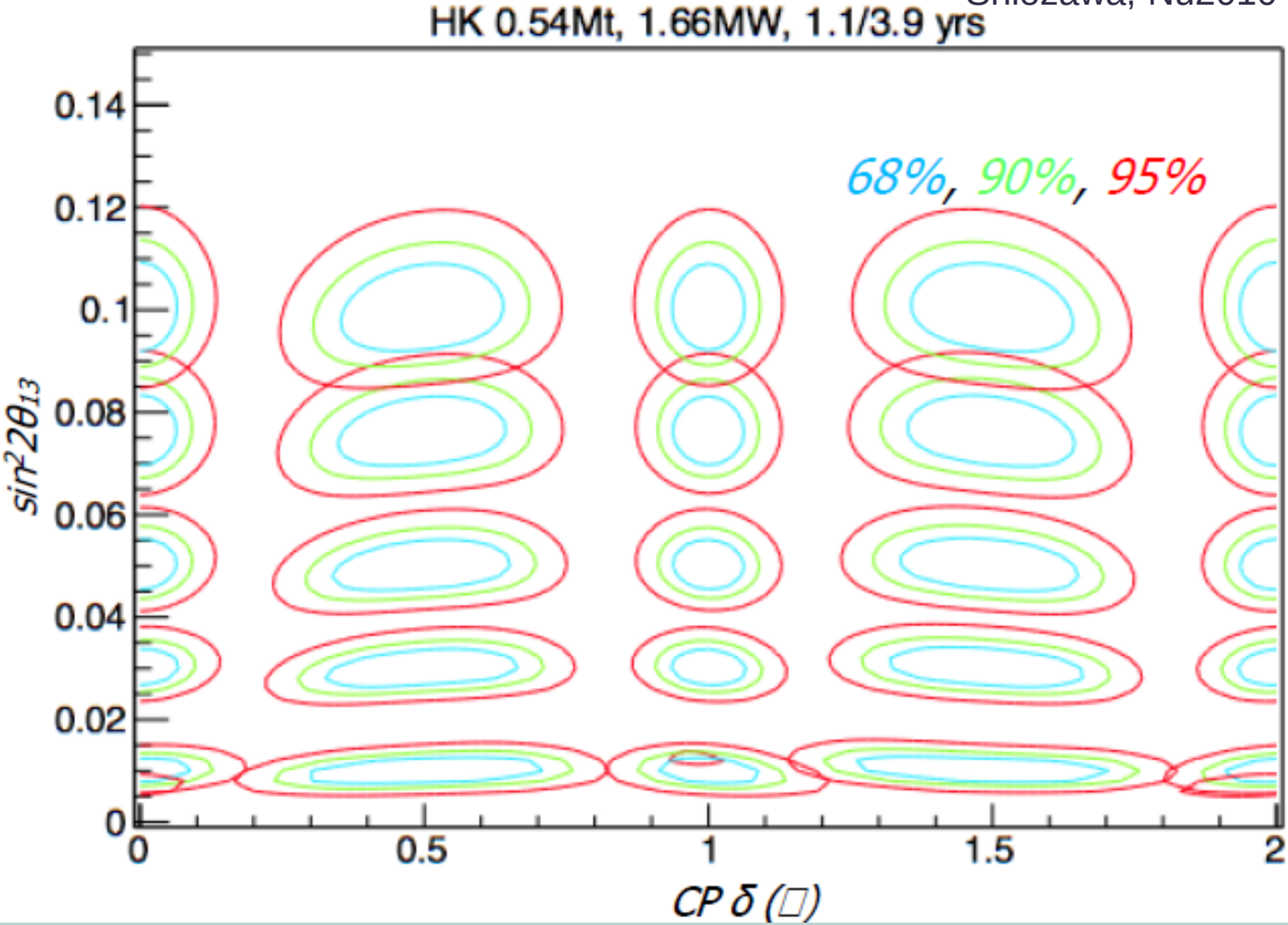
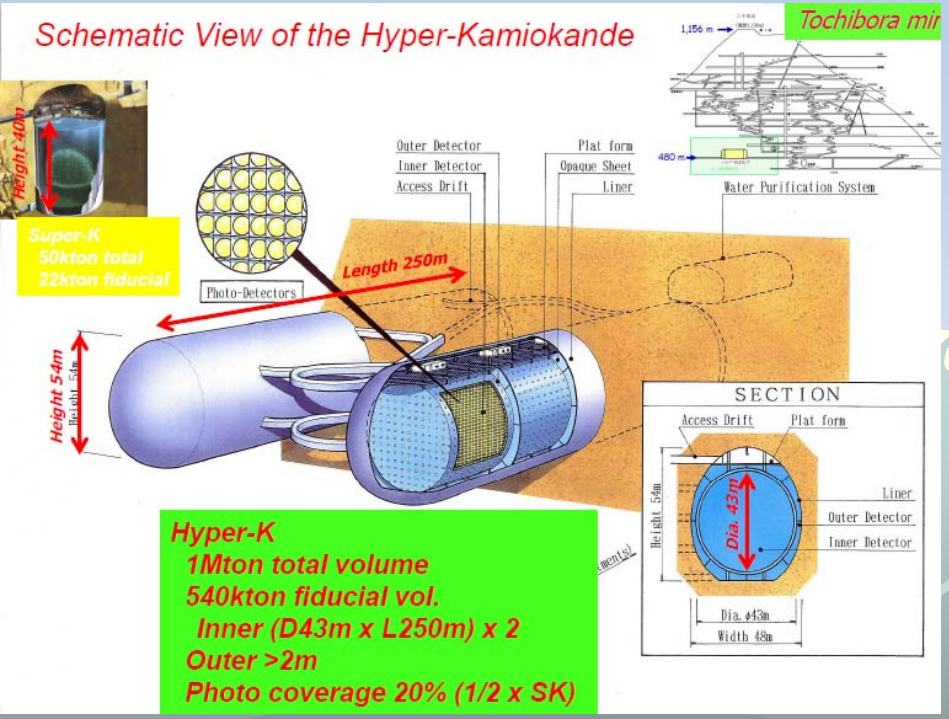


Hyper-K feasibility studies

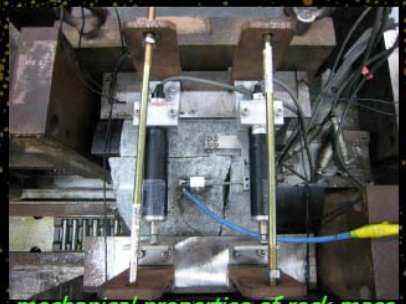
Shiozawa, Nu2010



Site studies so far

- ✓ site selection (Tochibora mine, +480-550m s.l.)
- ✓ geological sketching – very sound intact mass in excellent condition
- ✓ core boring – geological map, joint orientation survey
- ✓ rock sampling – mechanical property of rock mass and joint
- ✓ initial state of stress in the rock mass
- ✓ conceptual design of cavern and layout (two 250m tunnels with 100m spacing)
- ✓ FEM analysis of the cavern
- ✓ clean natural water supply

Initial state of stress in the rock mass (important for cavern design)



mechanical properties of rock mass as well as joint measurements

Summary

- **Aim to realize an experiment to discover CPV in neutrino and Proton decay with**
  - Upgraded J-PARC 0.75MW ➔ 1.66MW (➔??MW)
  - Huge, high sensitivity detector
- Possible options
  - 100kton LiqAr @ Okinoshima: CPV (,hierarchy)
  - ~Mton Hyper-K @ Kamioka: CPV
  - Half Mton WCh @Kam&Korea
- Intensive studies and R&D on going
  - Physics potential
  - Detector
    - LiqAr (ETHZ/KEK/Waseda/Iwate)
    - Water Cherenkov: Photo detector, site study, etc
- Within few years when T2K acquire ~1MW.107s, hope (need) to decide next direction