

# Deep Underground Labs in Kamioka

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ASPERA Workshop, July-1-2011

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Kamioka Satellite, Institute for the Mathematics and Physics of the Universe, U of Tokyo

# Location of Kamioka Observatory



- 1000m overburden in Mt. Ikenoyama
- drive in, 24 hours, 365days
- 10 min. drive from the office buildings

## Location

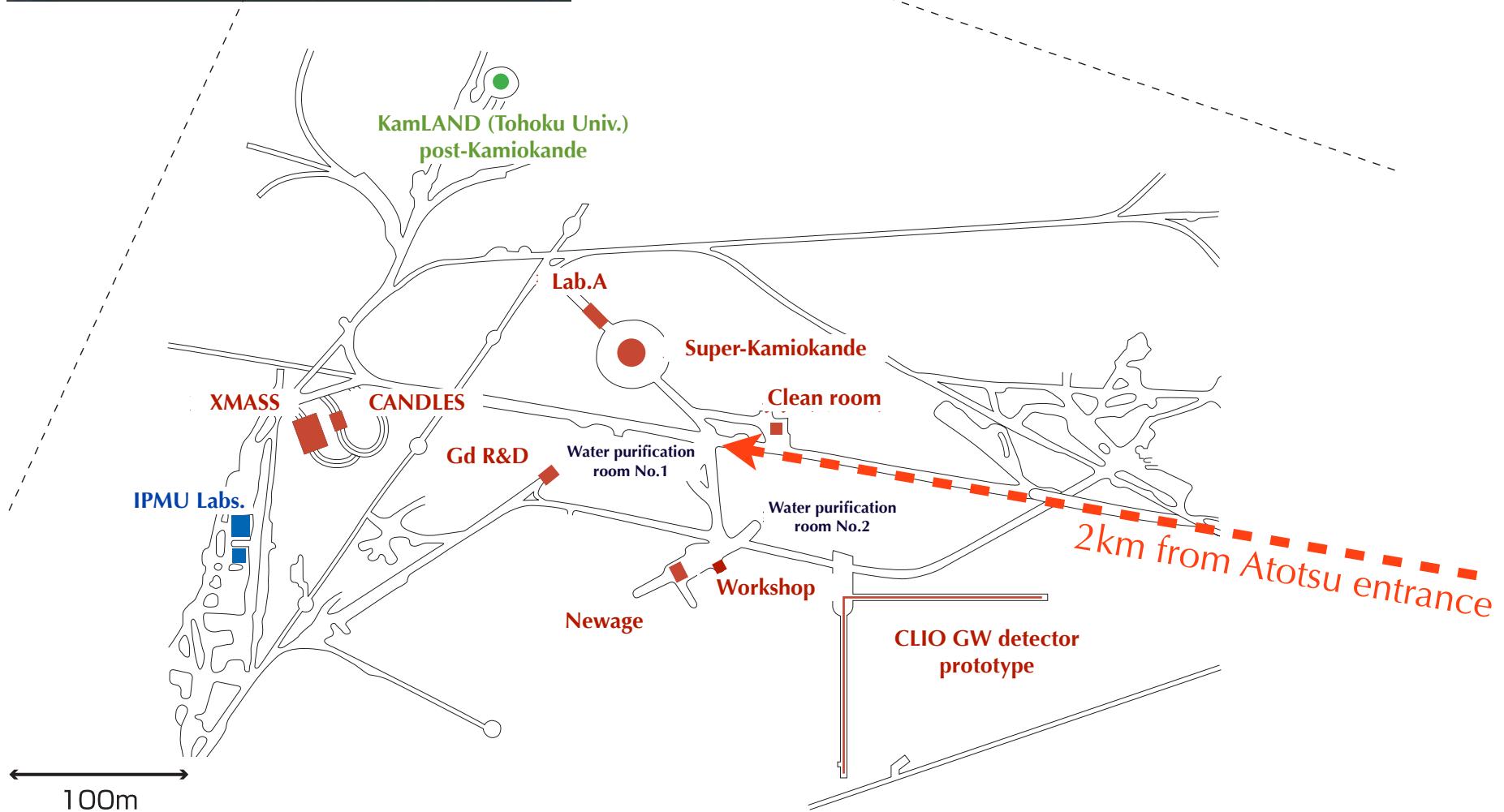
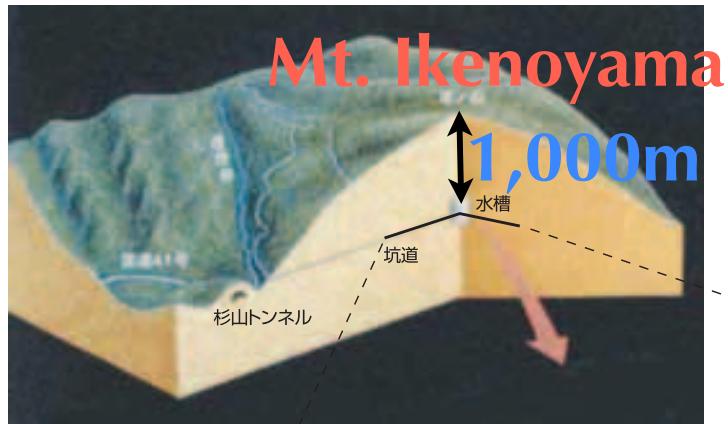
- Northern part of Gifu pref.
- one hour flight from Tokyo + 40 min. drive from Toyama airport



# Office building and dormitory (Kamioka Observatory)



- ◆ Office Building
  - ◆ Computer facility
    - ◆ ~1,000 linux CPUs
    - ◆ 750 TeraByte Hard Disk
    - ◆ 500 TeraByte Tape Library
  - ◆ Library
  - ◆ Seminar room
  - ◆ TV conf. meeting room
  - ◆ Electronics room
  - ◆ Chemicals room
  - ◆ SK remote control room
  - ◆ ~25 Office rooms
  
- ◆ Dormitory
  - ◆ ~20 guest rooms
  - ◆ Cafeteria

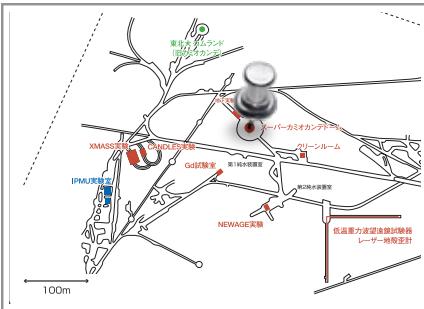


# Relevant Numbers

- ▶ Scientific Staff.: 19
  - ▶ 2 Professor
  - ▶ 5 Associate prof.
  - ▶ 12 Assistant prof.
  - ▶ (3 PostDoc)
- ▶ BG level
  - ▶ Neutron flux
    - ▶ Thermal neutron  $(8.26 \pm 0.58) \times 10^{-6} \text{ cm}^2/\text{s}$
    - ▶ Non-thermal neutron  $(1.15 \pm 0.12) \times 10^{-5} \text{ cm}^2/\text{s}$
  - ▶ Rn  $10 \sim 1000 \text{ Bq/m}^3$
- ▶ Supporting Staff.
  - ▶ 3 technical staff
  - ▶ 4 business office
- ▶ Low BG Devices
  - ▶ Ge detector  $\times 3$
  - ▶ ICP MS
  - ▶ API MS
  - ▶ Rn detectors
  - ▶ Rn-free air ( $1 \text{ mBq}$ )
  - ▶ Pure water supply
    - ▶  $\sim 18 \text{ M Ohm}$
    - ▶ For Super-K: 40ton/hour
    - ▶ For XMASS and others:  
15tons/hour



# Review of each experiments



# Super-Kamiokande

- discovery of  $\nu$  oscillation (atmospheric)  $\rightarrow \Delta m^2_{23}, \theta_{23}$
- discovery of solar  $\nu$  oscillation (w/ SNO)  $\rightarrow \Delta m^2_{12}, \theta_{12}$

1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
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SK-I

11,146 PMTs

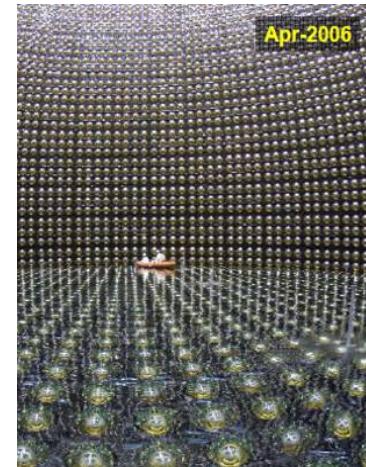
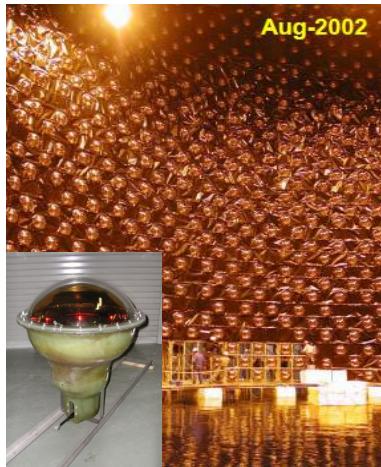
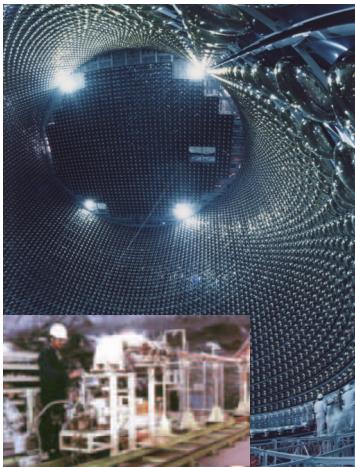
SK-II 5,182 PMTs

SK-III  
11,129 PMTs

SK-IV new electronics

K2K

T2K

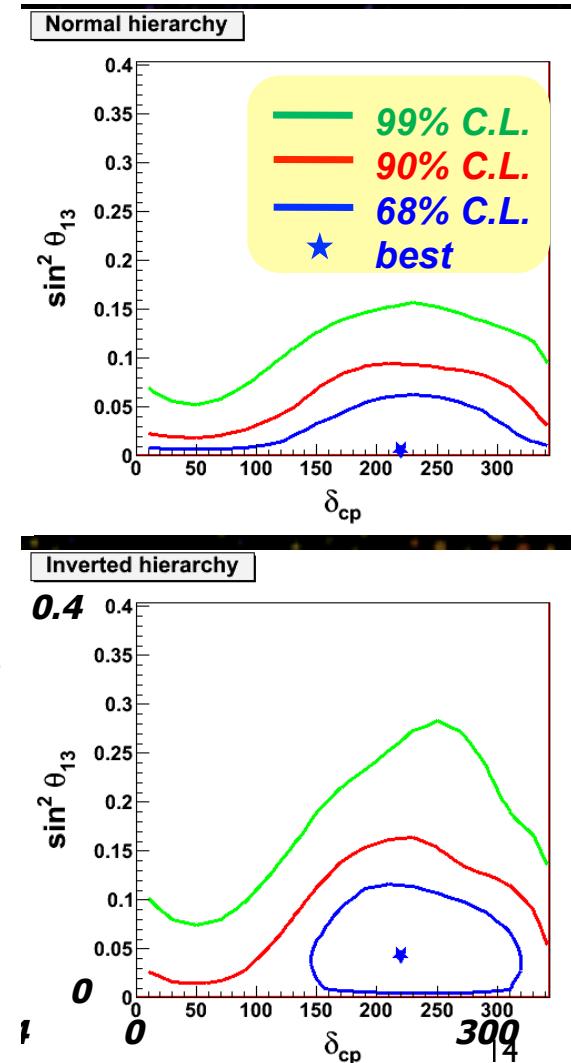
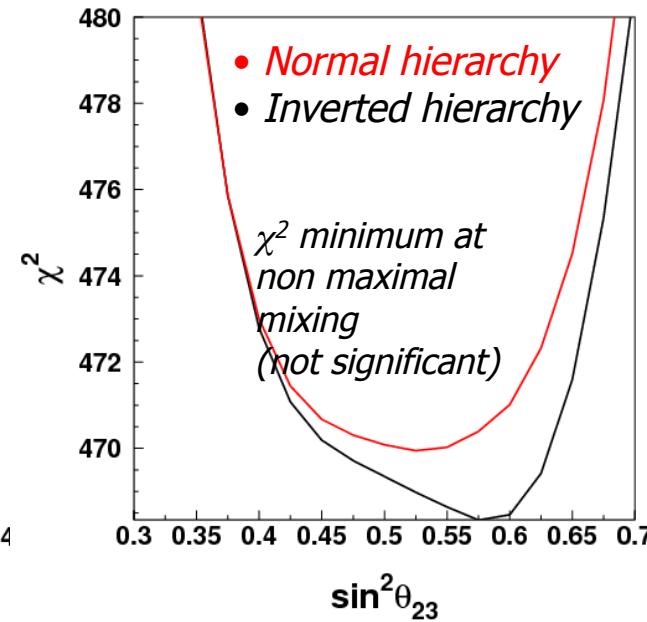
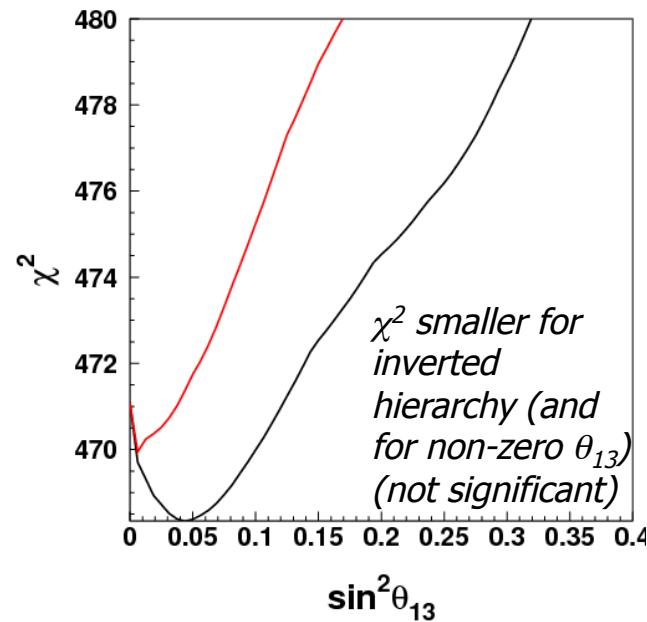


## Future

- sub-dominant effect ( $\theta_{13}$ , hierarchy,  $\delta_{CP}$ ) in atmospheric  $\nu$
- Upturn of low energy solar  $\nu$
- Past and realtime Supernova  $\nu \rightarrow$  Gadolinium doping
- Proton Decay ( $2 \sim 3 \times 10^{34}$  yrs for  $p \rightarrow e^+ + \pi^0$ )
- T2K to establish nonzero  $\theta_{13}$  and precise measurement of ( $\Delta m^2_{23}$ ,  $\theta_{23}$ )

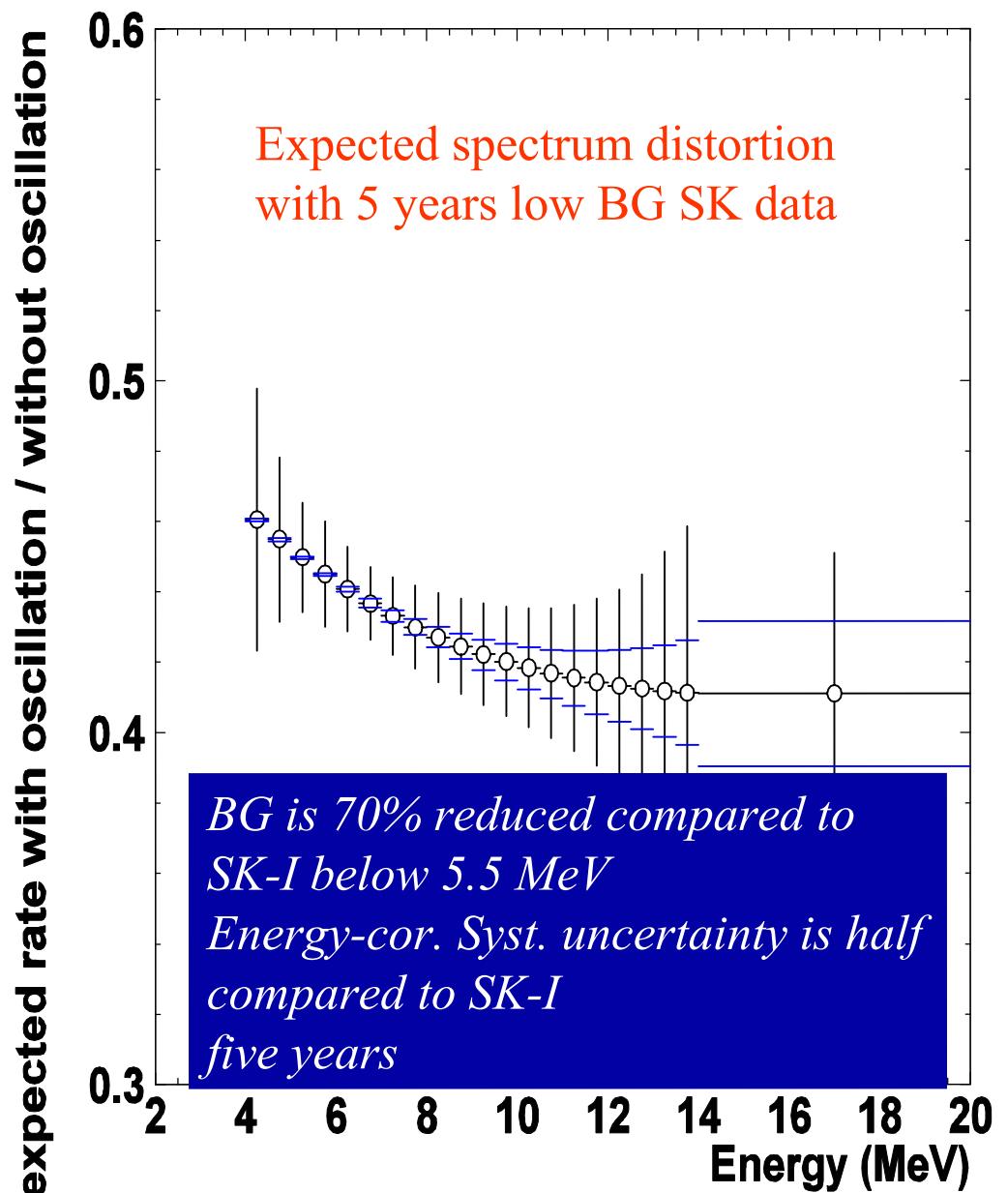
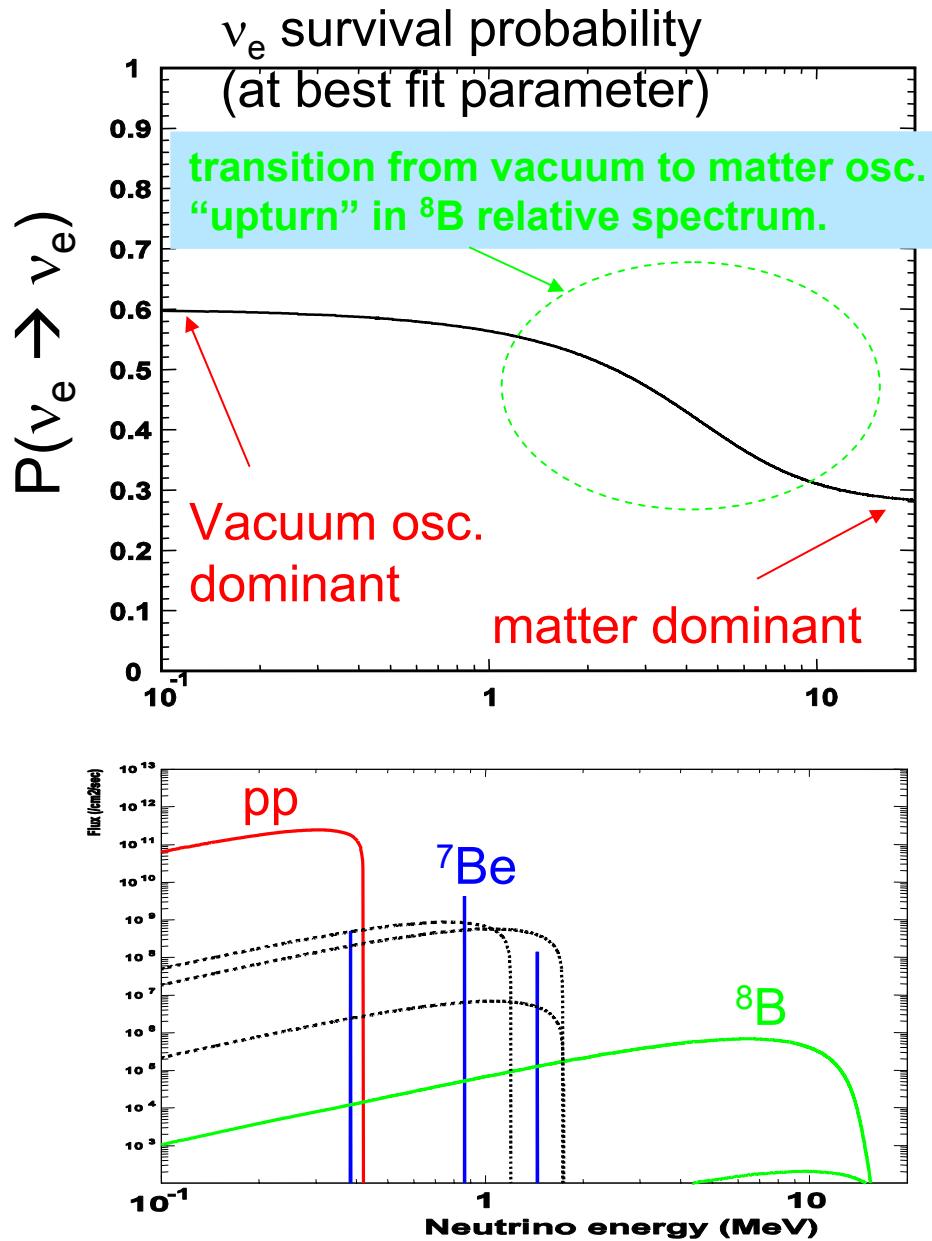
# Sub-dominant oscillation effects in atmospheric ν

Normal hierarchy (NH):  $\chi^2_{\min}=469.94/416\text{dof}$   
 Inverted hierarchy (IH):  $\chi^2_{\min}=468.34/416\text{dof}$



No significant difference so far.  
 Sub-dominant effects could be seen in atmospheric ν sample in future.

# Solar Neutrino Future Prospects in SK



# Gd doping in SK (Gadzooks!)

EGADS test tank (200ton)

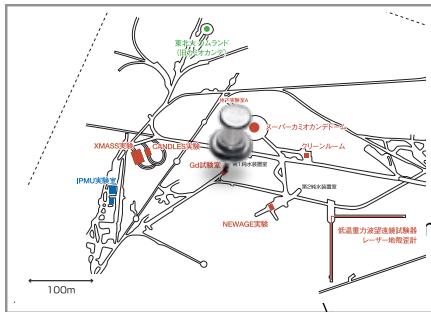
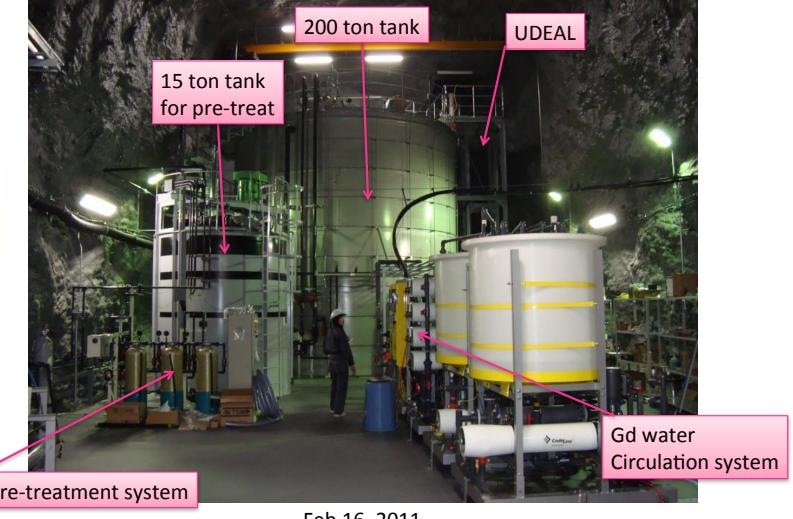
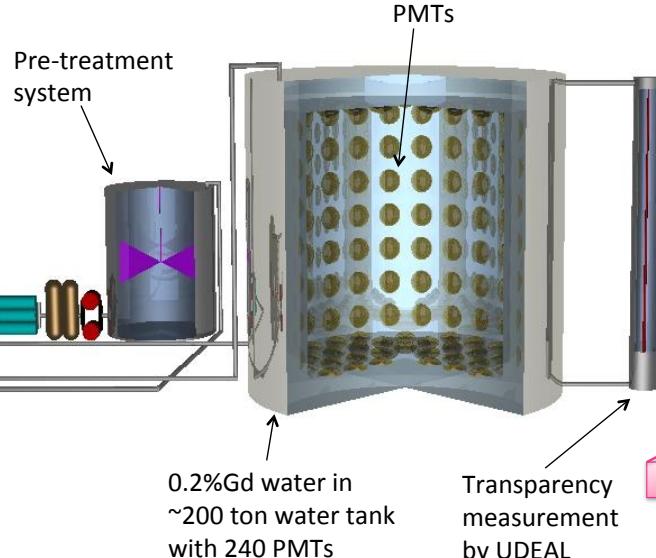


Figure by A.Kibayashi



- ◆ 0.2%w  $\text{Gd}_2(\text{SO}_4)_3$  solution
- ◆ neutron tagging for  $\bar{\nu}_e + p \rightarrow e^+ + n$
- ◆ bunch of  $\gamma$ s w/  $E_{\text{total}} = 8\text{MeV}$ ,  $\tau \sim 20\mu\text{s}$
- ◆ relic SN  $\bar{\nu}$
- ◆ high statistic reactor  $\bar{\nu}$
- ◆ BG rejection in proton decay searches

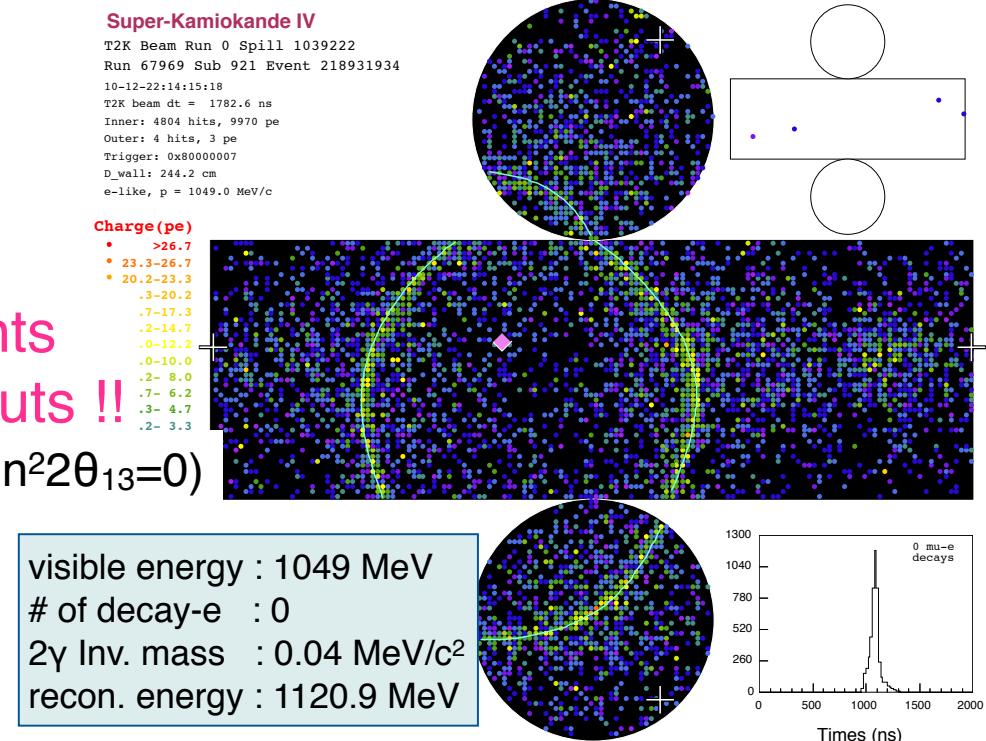
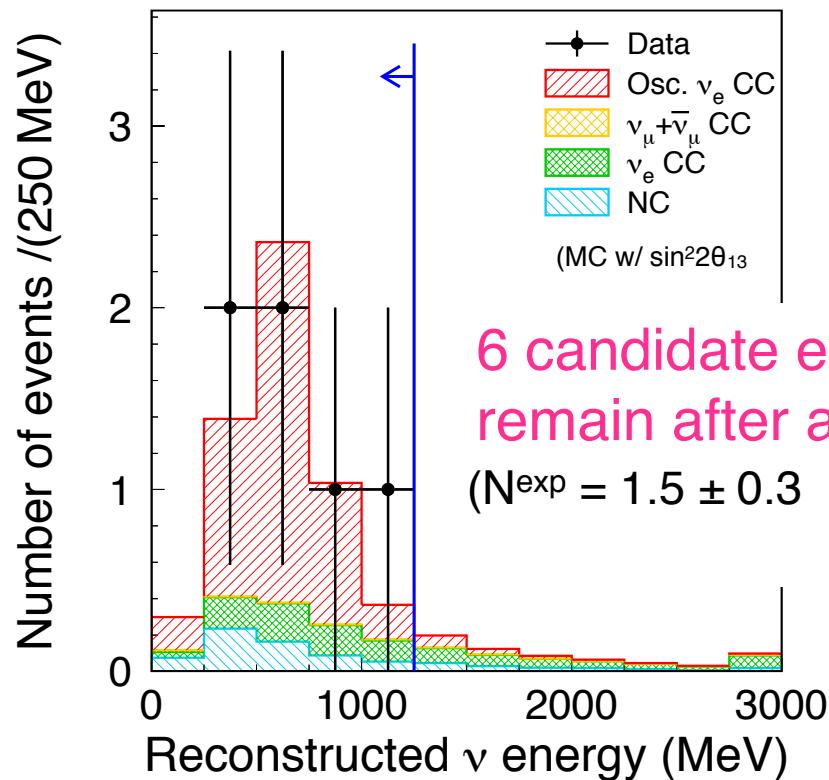
	2011												2012			
	6	7	8	9	10	11	12	1	2	3	4					
Test water system with pure water																
Gd test through 15ton tank																
Gd test through 200ton tank																
Remove Gd from 200 ton tank																
Mount 240 PMTs																
Gd test with PMTs																

- ◆ EGADS construction going on
- ◆ feasibility test in 2012
- ◆ put Gd into SK in 2013?

# T2K (JPARC ν+Super-K)



## Observed indication of $\nu_\mu \rightarrow \nu_e$



## Next step

- ◆ establish  $\nu_e$  appearance and measurement of  $\theta_{13}$
- ◆ precise measurement of  $(\Delta m^2_{23}, \theta_{23})$

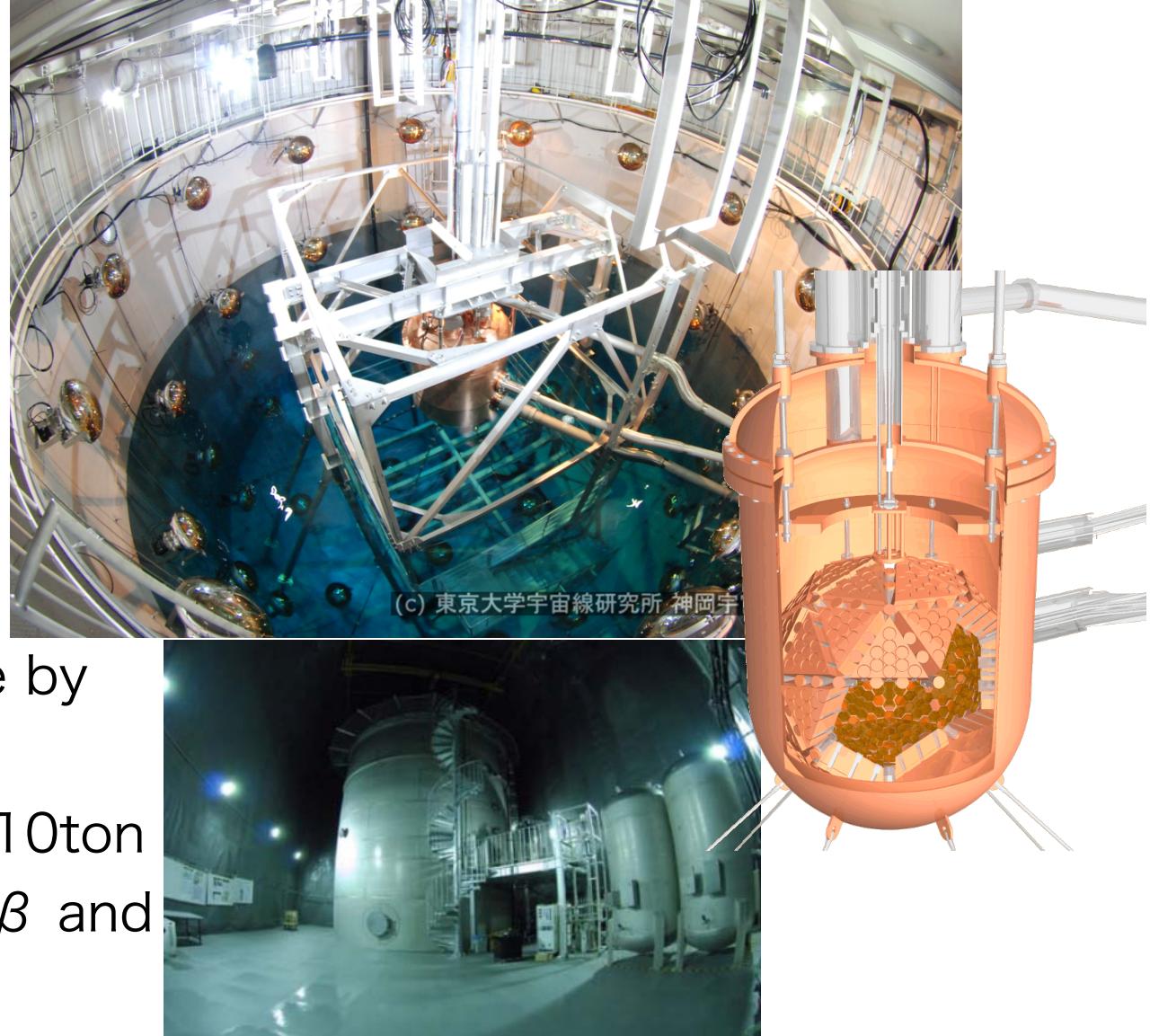
(Hesheng Chen's talk)  
(Kishimoto's talk)

# XMASS

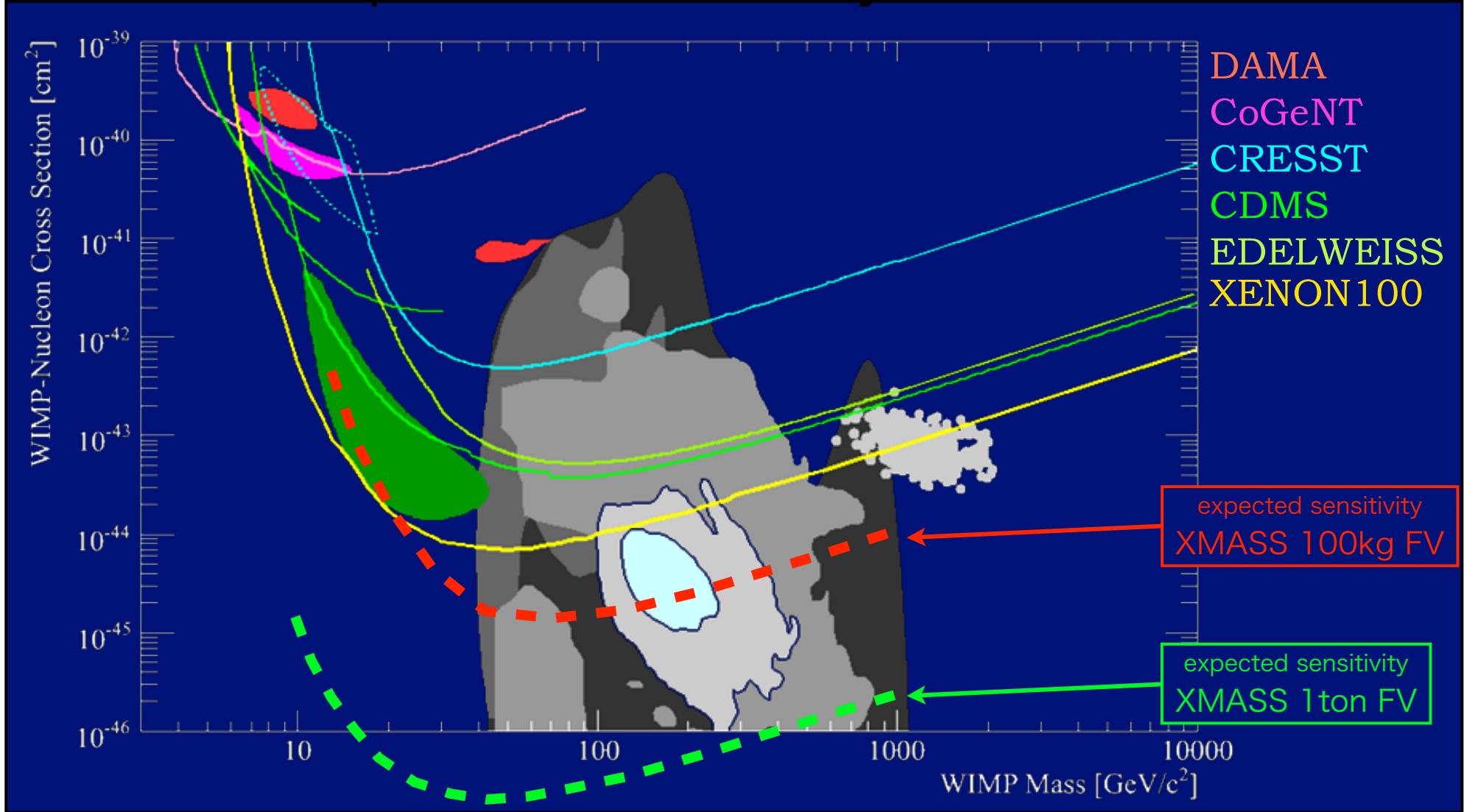
## ◆ Phase-I, 850kg(FV100kg) Liq. Xe Detector

- ◆ WIMP DM search
- ◆ 642 low BG PMTs
- ◆ ~20cm selfshield
- ◆ water shield
- ◆ 5keV threshold
- ◆ Commissioning

- ◆ Scalability
- ◆ 20ton is acceptable by the water tank
- ◆ FV100kg → 1ton → 10ton
- ◆ DM as well as  $0\nu 2\beta$  and solar pp  $\nu$



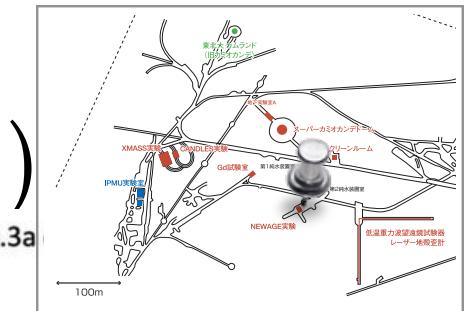
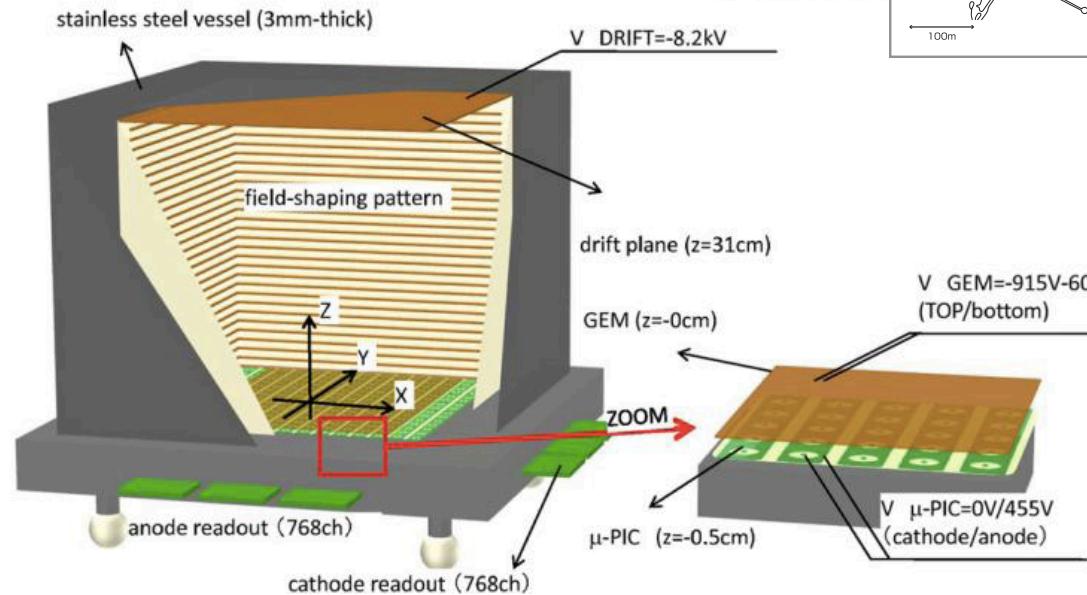
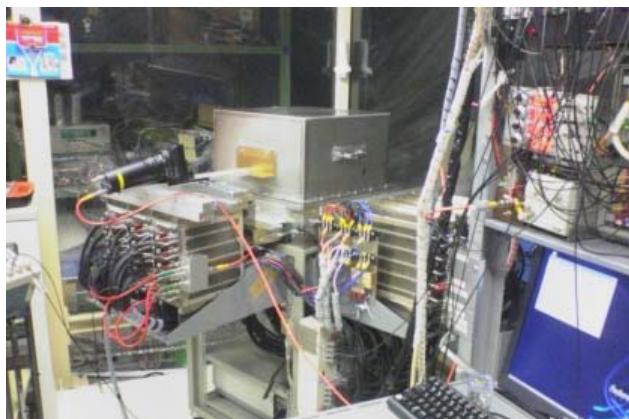
# XMASS expected sensitivity



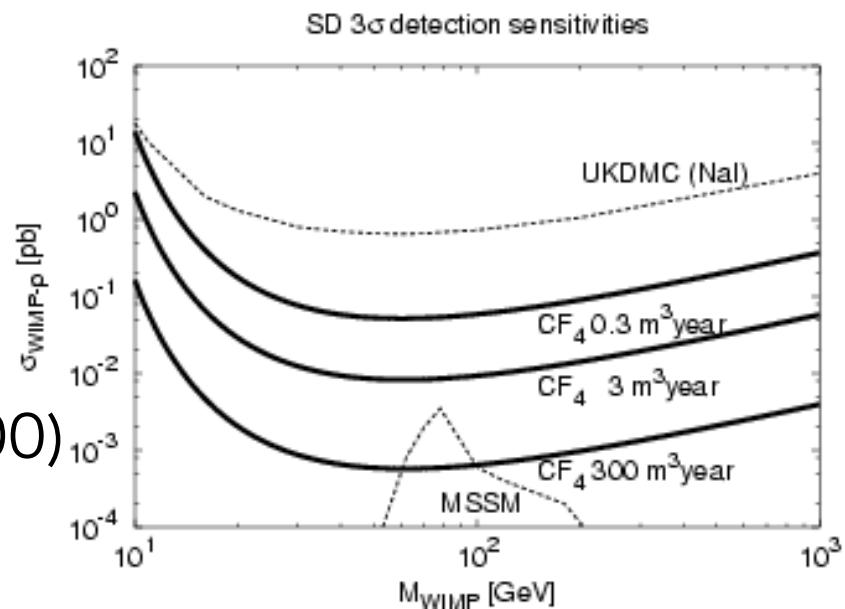
phase-I:  $10^{-45} \text{ cm}^2$  (@50GeV) → phase-II:  $10^{-47} \text{ cm}^2$  (@50GeV)

If DM is observed in the phase-I, phase-II aims to observe seasonal variation and spectrum

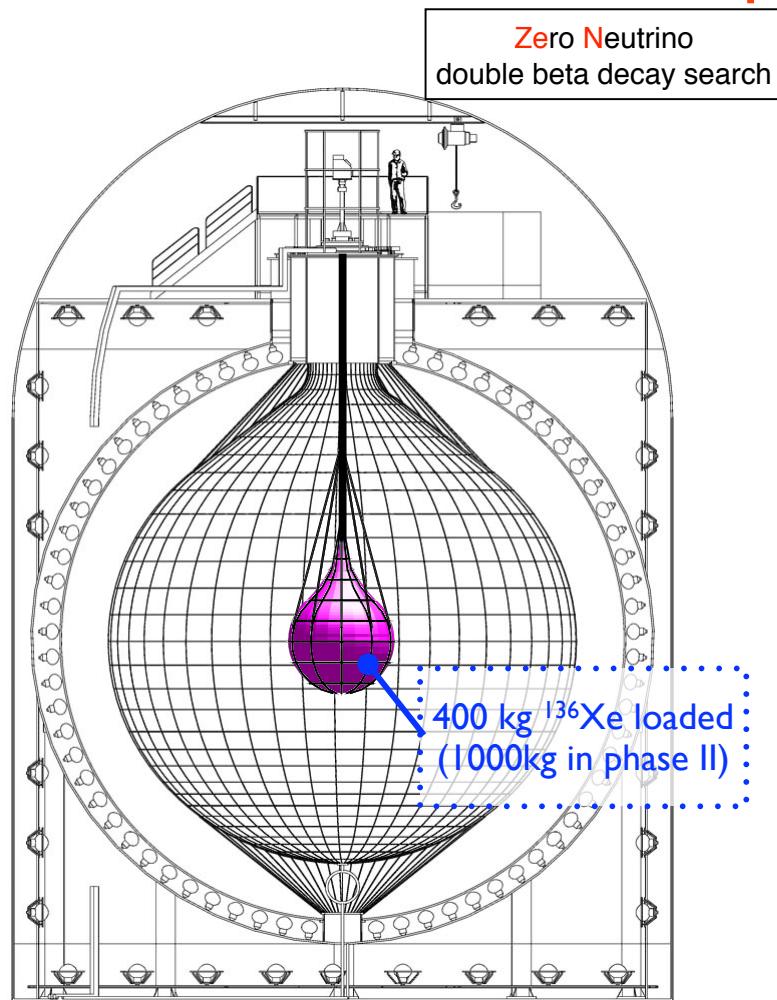
# NewAGE (Kyoto Univ.)



- ◆ gas micro-TPC
- ◆ CF<sub>4</sub>, Xe, Ar etc
- ◆ directional sensitivity
- ◆ DM-wind detection
- ◆ R&D Phase
- ◆ CF<sub>4</sub> 0.2atm, (30cm)<sup>3</sup>
- ◆ Goal: CF<sub>4</sub> 0.05atm, 1m<sup>3</sup> x O(100)

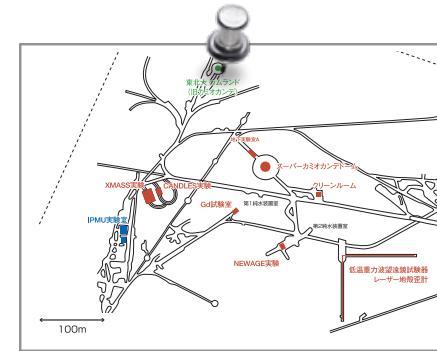


# KamLAND-Zen $0\nu 2\beta$ (Kishimoto's talk)

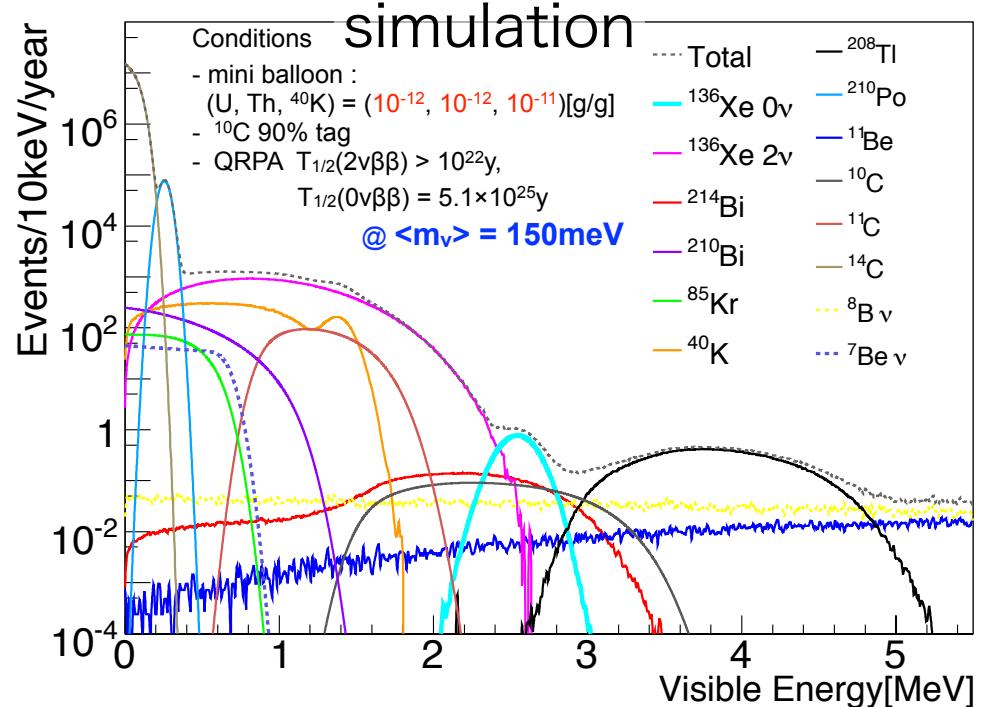


## Merit of using Xe

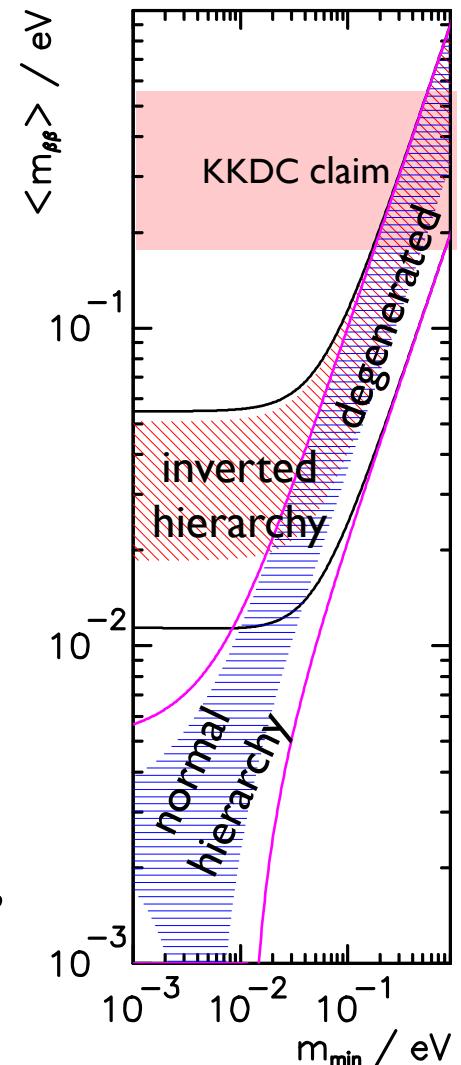
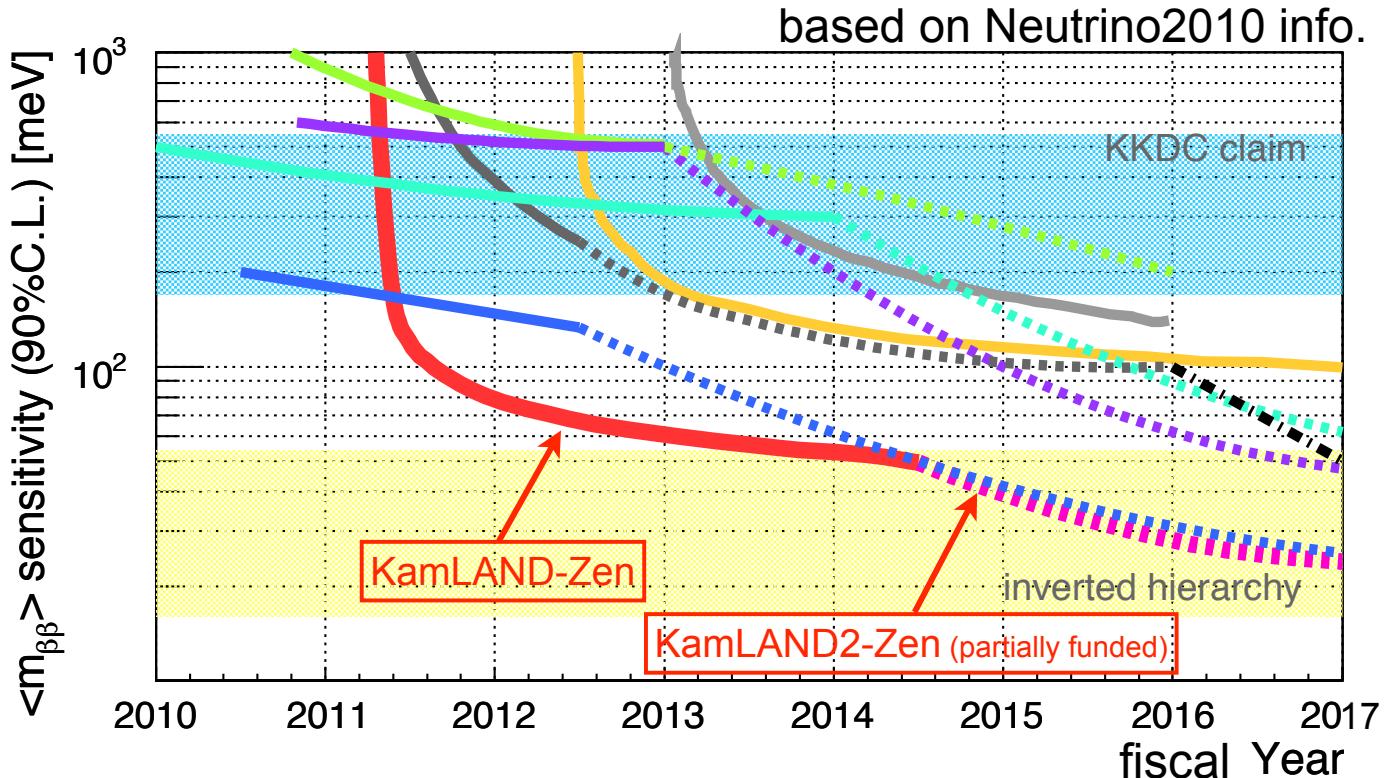
- isotopic enrichment, purification established
- soluble to LS more than 3 wt%, easily extracted
- slow  $2\nu 2\beta$  ( $T_{1/2} > 10^{22}$  years) requires modest energy resolution



- 1st phase  
400kg  $^{136}\text{Xe}$  ~60 meV in 2 years
- high scalability (2nd phase)  
1000 kg  $^{136}\text{Xe}$ , improvement of energy resolution with light concentrators and brighter LS, maybe higher concentration with pressurized Xenon  
~20 meV in 5 years



# Expected sensitivity of KamLAND-Zen



- ✓ Xenon loaded LS with the same density, luminosity, transparency
- ✓ 3.16 m  $\phi$  Mini-balloon (target: thin, 25 $\mu\text{m}$ , and low radioactivity,  $10^{-12} \text{ g/g U/Th}$ )
- ✓ Xenon handling system (mixing, extraction) etc
- ✓ Cosmogenic background rejection with dead-time free electronics

KamLAND-Zen plans to start in August

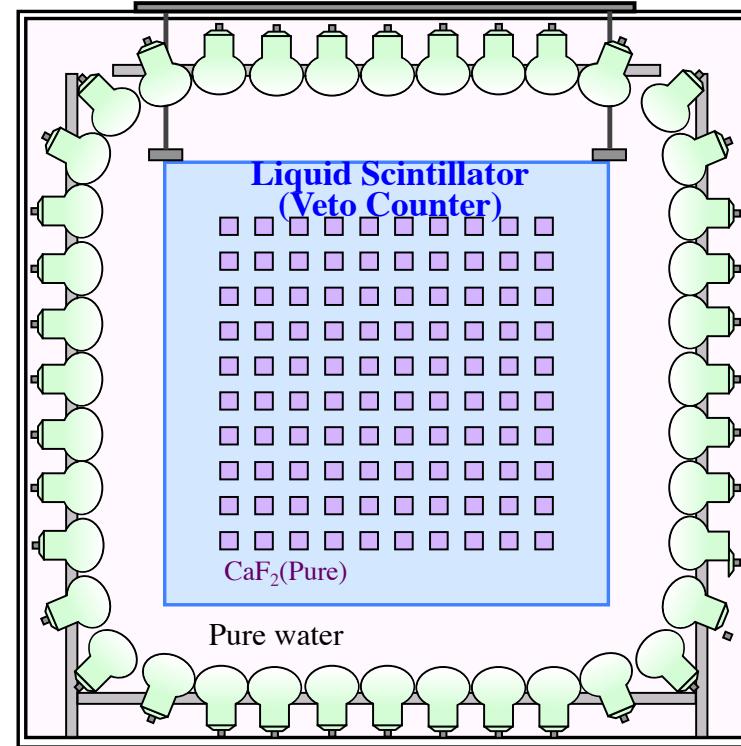
(Kishimoto's talk)

# CANDLES (Osaka Univ.)

Phase-III commissioning started



- ◆ 0ν2β search w/ CaF<sub>2</sub> crystal
- ◆ <sup>48</sup>Ca, Q=4.27MeV
- ◆ low BG
  - ◆ water and LS shields
  - ◆ pulse shape discrimination
- ◆ phase-III (305kg) running
- ◆ m<sub>ββ</sub>~0.5eV
- ◆ IV (3.4t→3.3kg<sup>48</sup>Ca), →V(10t 1%)  
→ 30t 5%), goal m<sub>ββ</sub>~10mV



<sup>48</sup>Ca: 0.2% natural abundance  
could be enriched by crown ether



# GW experiments

## CLIO (prototype) and LCGT

CLIO (ICRR, Kamioka) 100m

2003-2006 Construction

2008 Best sensitivity at room temperature

2010 Cryogenic mirrors

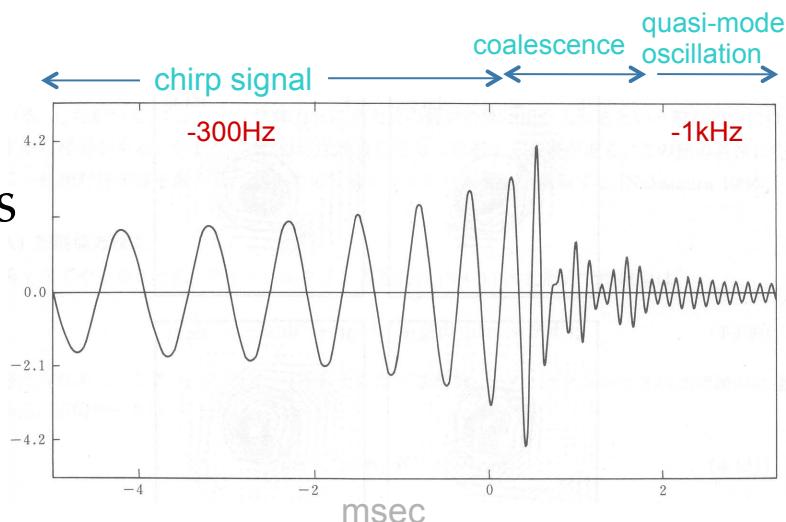
Low frequency sensitivity  
Demonstration of Cryogenic system



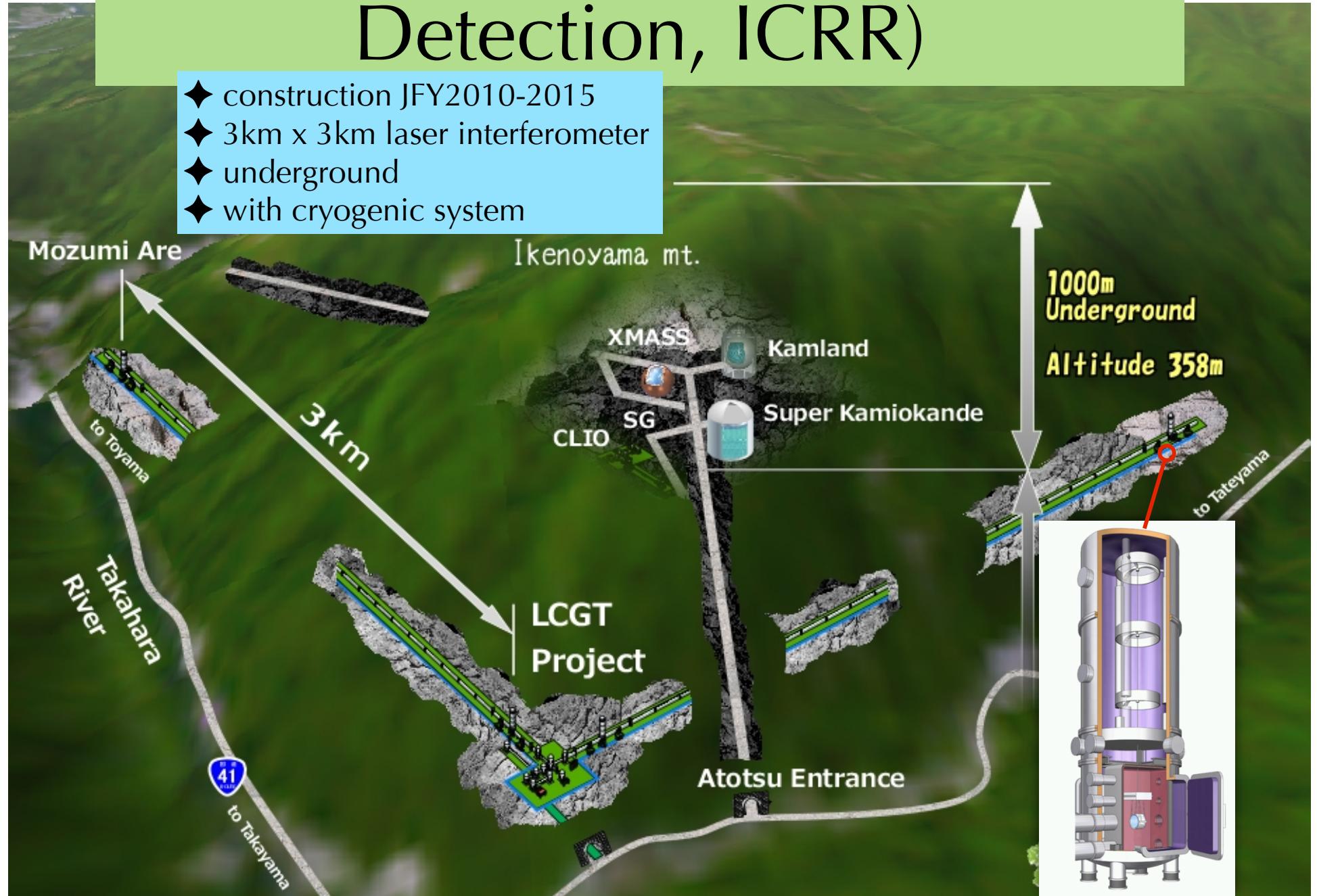
The world's first demonstration of cryogenic system for interferometer

### Target GW sources of LCGT

- Coalescence of neutron start binaries
- Coalescence of black hole binaries
- Core collapse of massive stars
- else

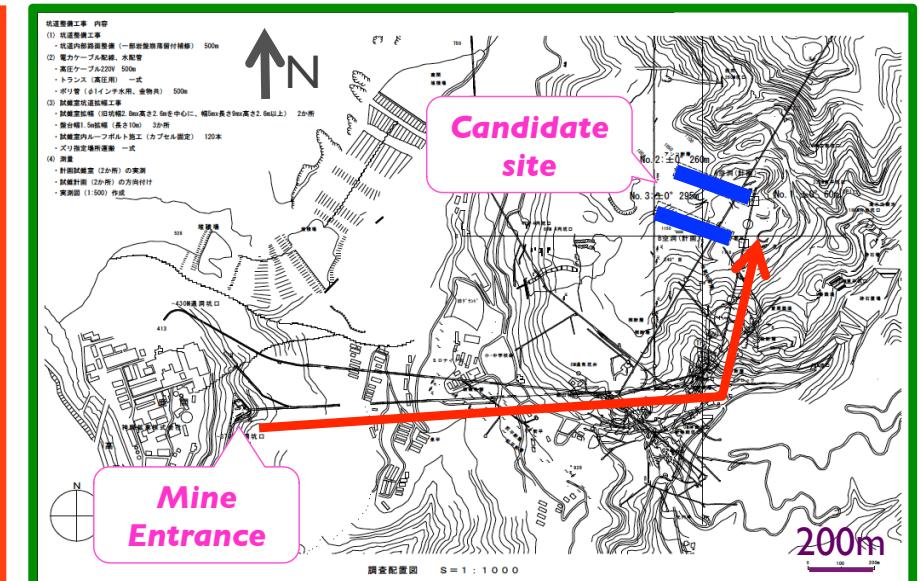
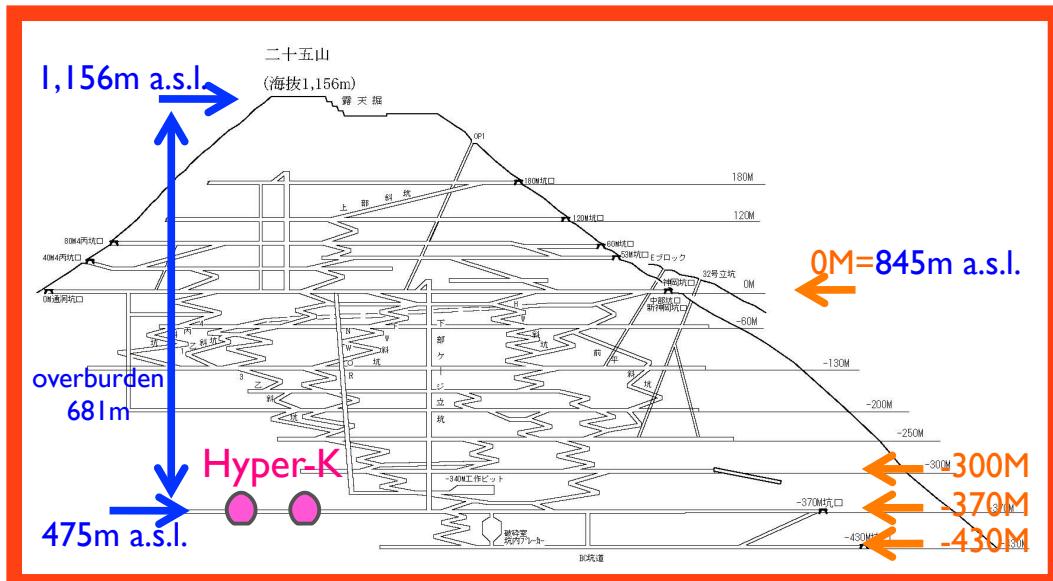
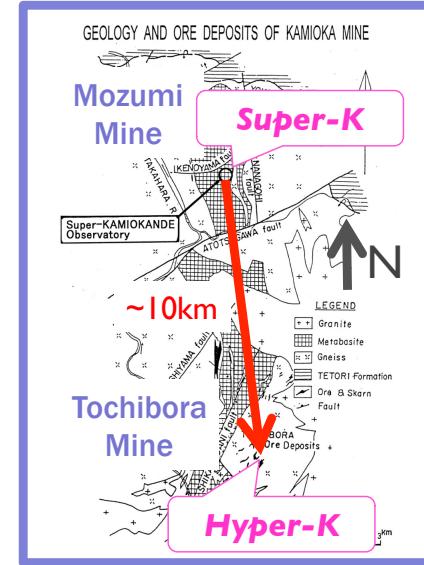


# LCGT (Gravitational Wave Detection, ICRR)

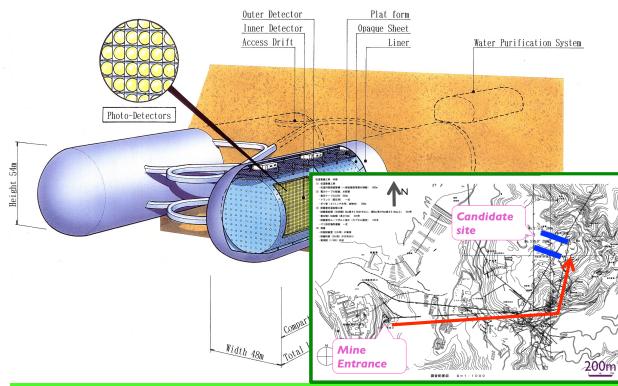


# Hyper-Kamiokande candidate site

- ◆ 8km south from Super-K
- ◆ same T2K beam off-axis angle
- ◆ 2.6km horizontal drive from entrance
- ◆ under the peak of Nijuugo-yama
  - ◆ 648m of rock or 1,750 m.w.e. overburden
  - ◆ 508m above sea level
- ◆ dominated by Hornblende Biotite Gneiss and Migmatite
- ◆ 2.3km from waste rock disposal place
- ◆ 13,000 m<sup>3</sup>/day or 1megaton/80days natural water



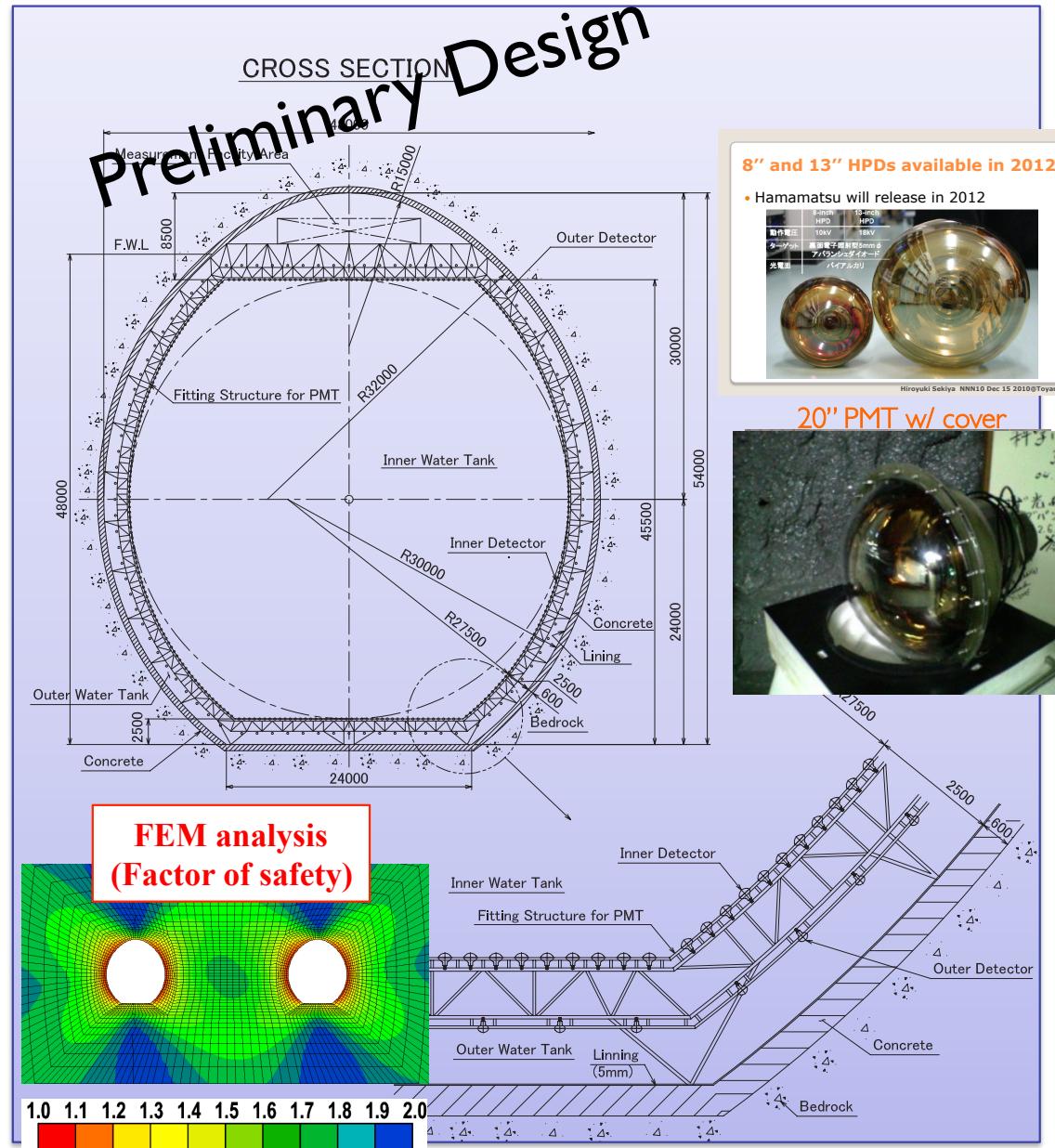
# Hyper-Kamiokande R&D



## Hyper-K Base-Design

- 1Mton total volume, twin cavity
- 0.54Mton fiducial volume
- Inner (D43m x L250m) x 2
- Outer Detector >2m
- Photo coverage 20% (1/2 x SK)

- Base-design to be optimized
- Geological survey of the site is going on
- Qualitative studies on physics potential



# Summary

- ▶ Scientific activity in Kamioka is rapidly growing
  - ▶ Nucleon Decay and  $\nu$  oscillation exp. in progress
  - ▶ multiple DM detection experiments are starting
  - ▶ multiple  $\beta\beta$  experiments are starting
  - ▶ Gravitational Wave Antenna will start in ~5 years
- ▶ We expect physics outputs in a few years
- ▶ Many extensions are under discussion, R&D is going on