Kamioka Mine Safety Training

Kamioka Observatory
ICRR, the University of Tokyo

Safety related

- Underground Labs are inside a mine and can be a hazardous environment.
- So, this training is required for all the visitors.

Behavior inside the mine

- Follow a designated guide at all times inside the mine. Do not stray from the designated path decided by your guide.
- Do not touch any machines or tools.
- Do not be under the influence of alcohol or drugs. (Including at least 6 hours before entering mine)
- Smoking is not permitted.
- In the occasion of an emergency like on earthquake or fire, follow the guide's instructions.

Clothes and shoes

- Wear a helmet at all times inside the mine. We will provide you with one.
- You may feel cold inside the mine(13~15 ^{o}C), we recommend you have a jacket
- Inside the mine, there are steep slopes and uneven floors, so wear comfortable work shoes and clothes. Sandals and slippers are not permitted. Also, there is no running inside the mine. Please mind your step for some slope bases can be slippery.

Others

- Please go to the lavatory before you enter.
  - There are toilets in the mine, but…
- It is your responsibility to remain safe at all times. University of Tokyo is not liable for any accidents that might occur.
  - This time, our (CYGNUS2013) insurance covers up to 200,000Euro (26,000,000Yen)

If you agree

- Please sign on the paper.

- The bus will depart at 11:00!
- Don’t be late!

DM Oriented Introduction of Kamioka Observatory

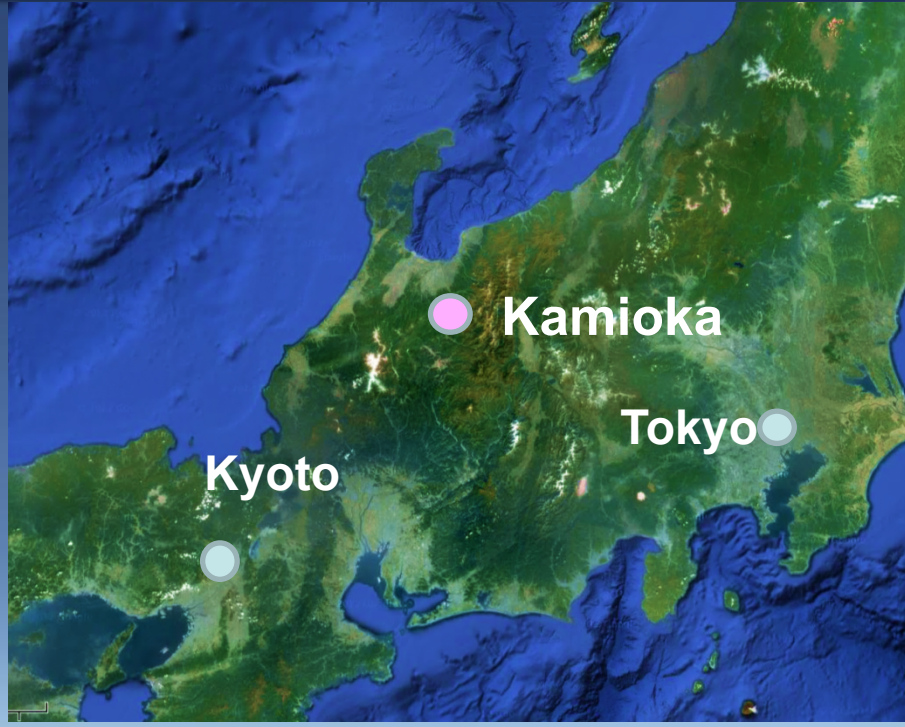
Hiroyuki Sekiya
ICRR & Kavli-IPMU(WPI), University of Tokyo

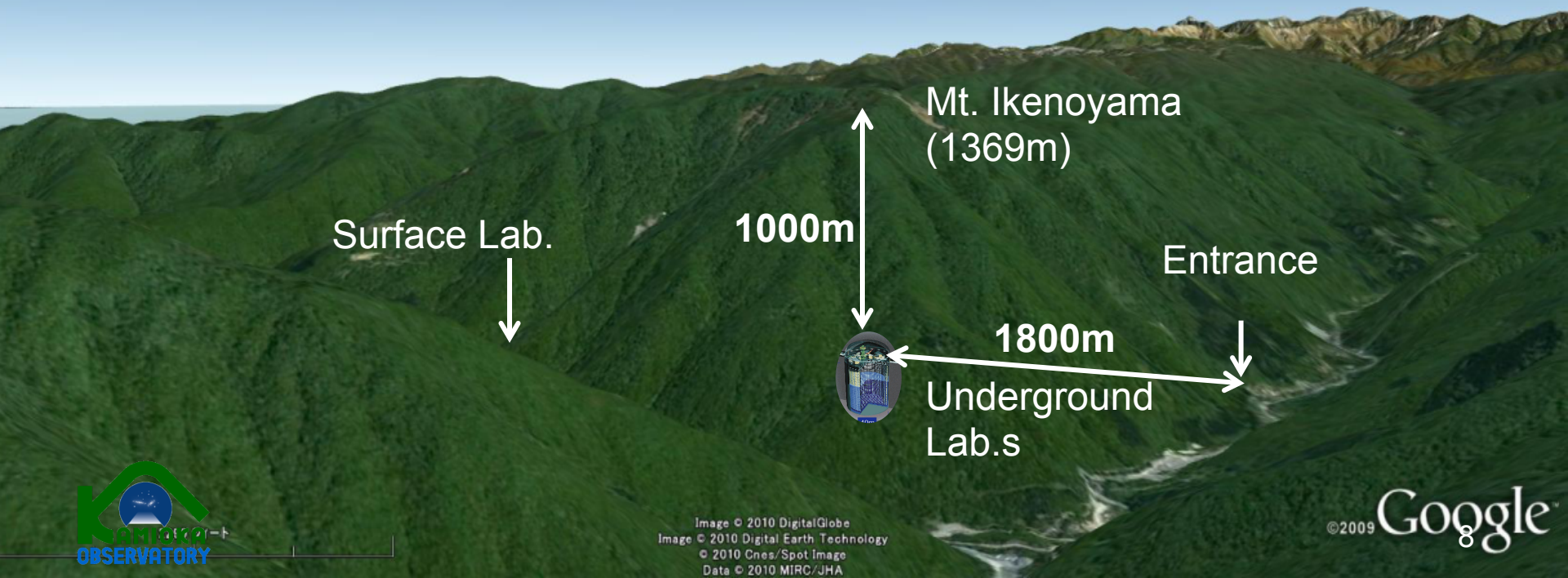
June. 12 2013

CYGNUS2013 TOYAMA

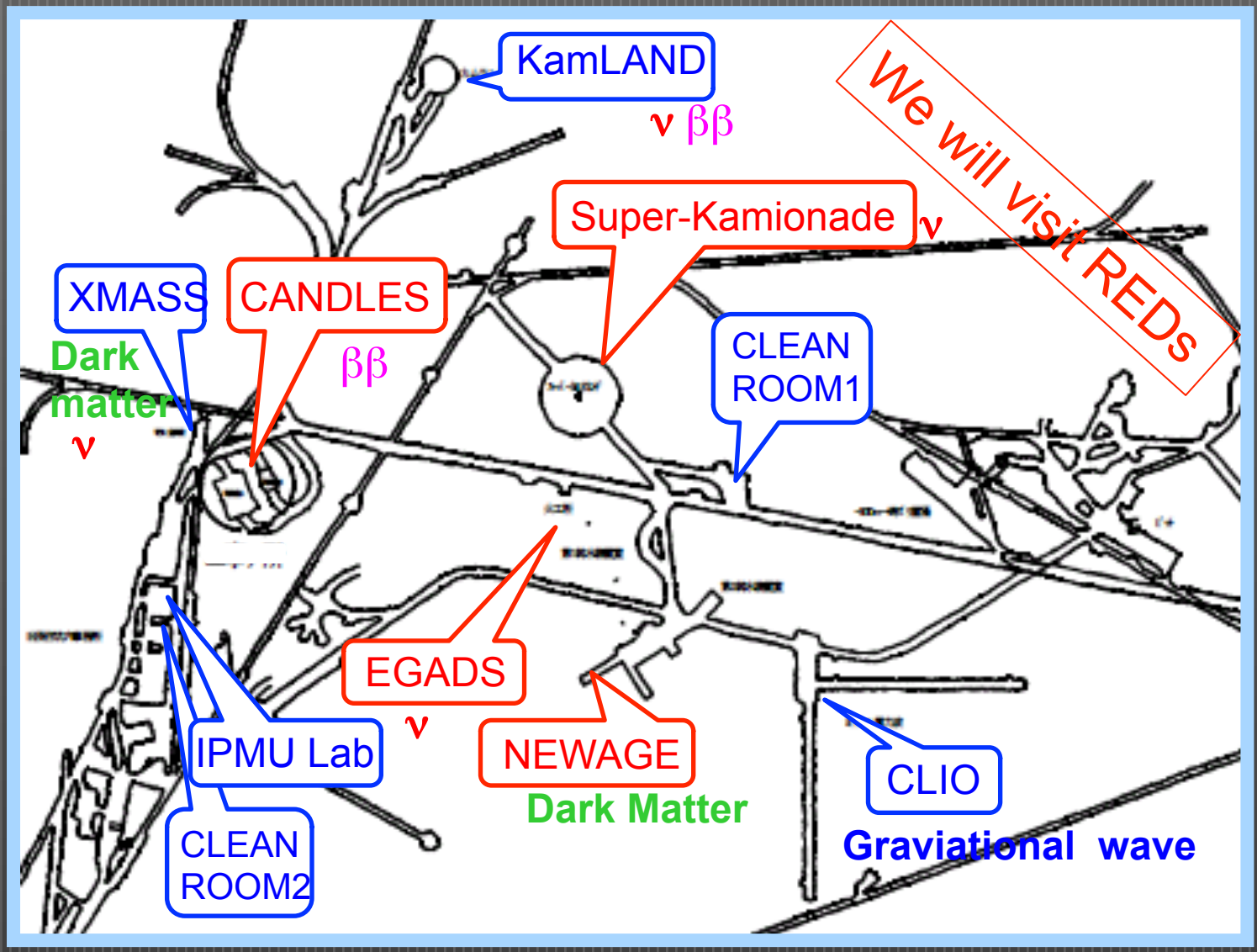
Kamioka Observatory

- Located underground in Mozumi zinc mine at a 2700 m.w.e. depth.
- 2km horizontal access by cars





Kamioka Underground Map 2013



List of experiments
Historical order of “Kamiokande”

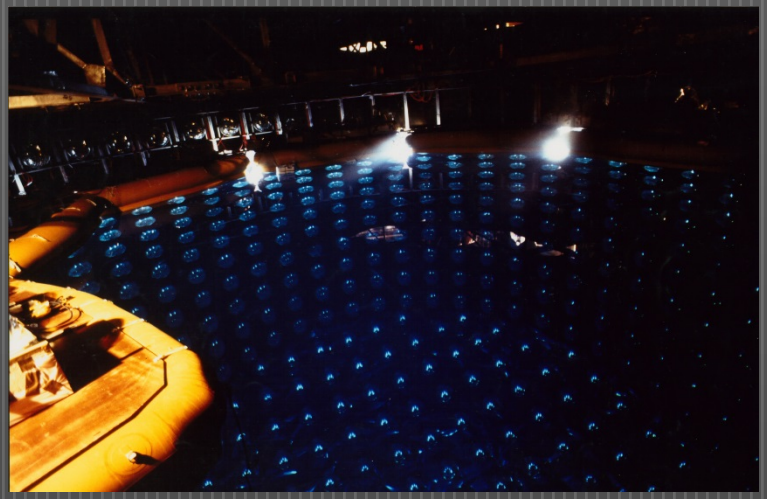
- KAMIOKANDE(1983-)
  - ELEGANT(DM, double beta)
- Super-Kamiokande-I(1996-)
  - LISM(GW 20m)
  - Tokyo DM searches
    - bolometer/stilbene/CaF2
  - K2K
- Super-Kamiokande-II(2002-)
  - XMASS 100kg, XMASS-II(2-phase)
  - KamLAND
- Super-Kamiokande-III/IV(2006-)
  - CLIO(GW100m)
  - XMASS
  - NEWAGE
  - CANDLES
  - KamLAND-Zen
  - T2K
  - EGADS
  - KAGRA(GW)
- Hyper-Kamiokande(201?-)

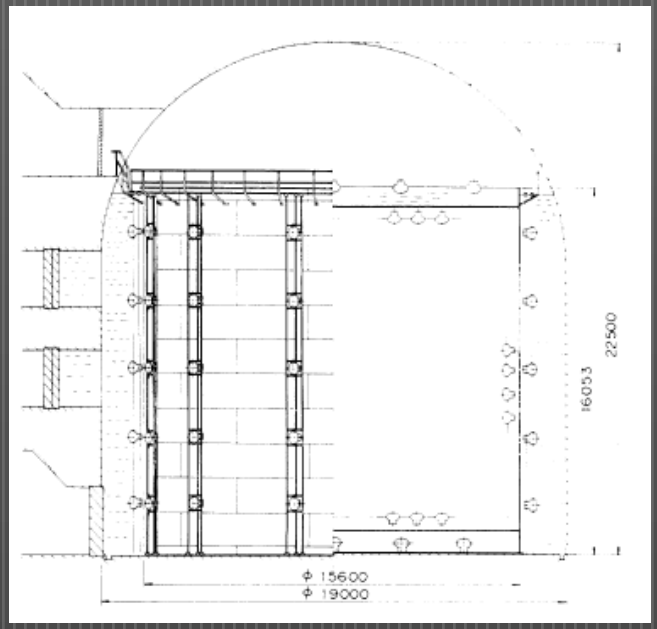
PAST

Kamioka Underground in 1980's

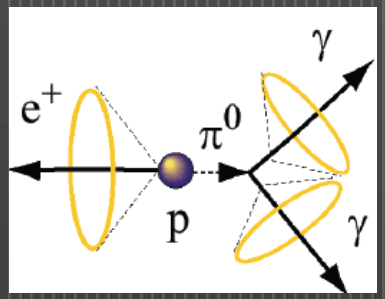
KAMIOKANDE

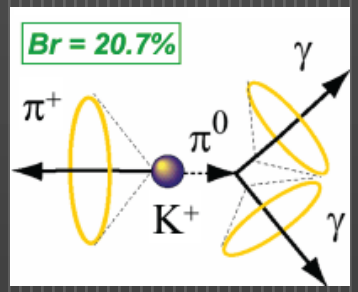
- 1983- 3000t Water Čerenkov Detector

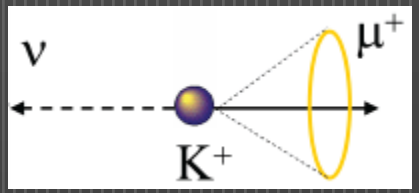




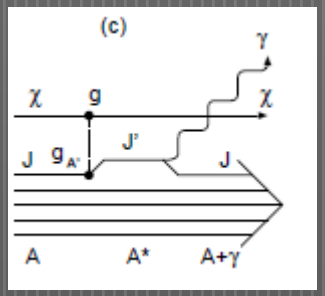
– For proton decay seacrch







ELEGANT V (Osaka Group)



- Rare event search detector complex
  - NaI dark matter search (Inelastic, ^{127}I:57.6keV)
  - ^{100}Mo double beta decay

NIM 302(1991) 304

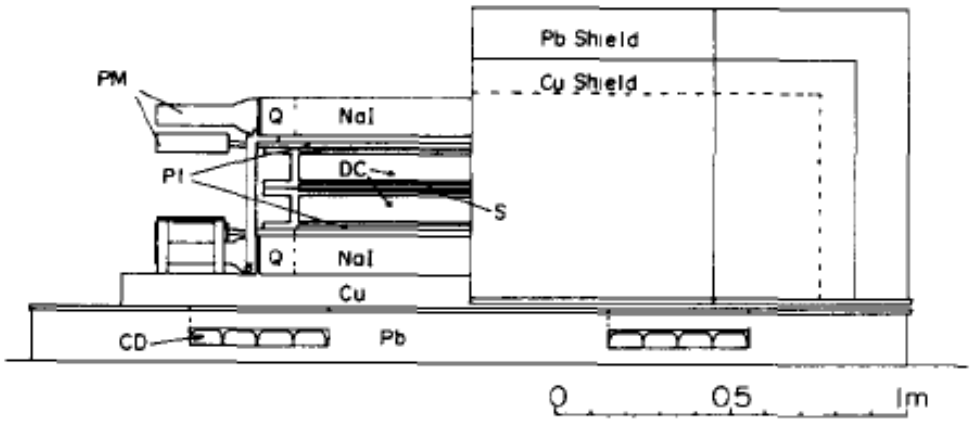


Fig. 1. Schematic view of ELEGANTS V. Top: a top view. Bottom: a side view. S: source films (sheets). DC: drift chamber, NaI: NaI(Tl) crystal, Q: quartz light guide, PL: plastic scintillator, PM: photomultiplier, Cu: OFHC copper bricks, Pb: lead bricks, CD: cable duct.

- ELAGANT VI CaF_2 →CANDLES
- PICO-LON NaI → KamLAND-PICO

Kamioka Underground 90's-2001

Prof. Totsuka

Super-Kamionade ν

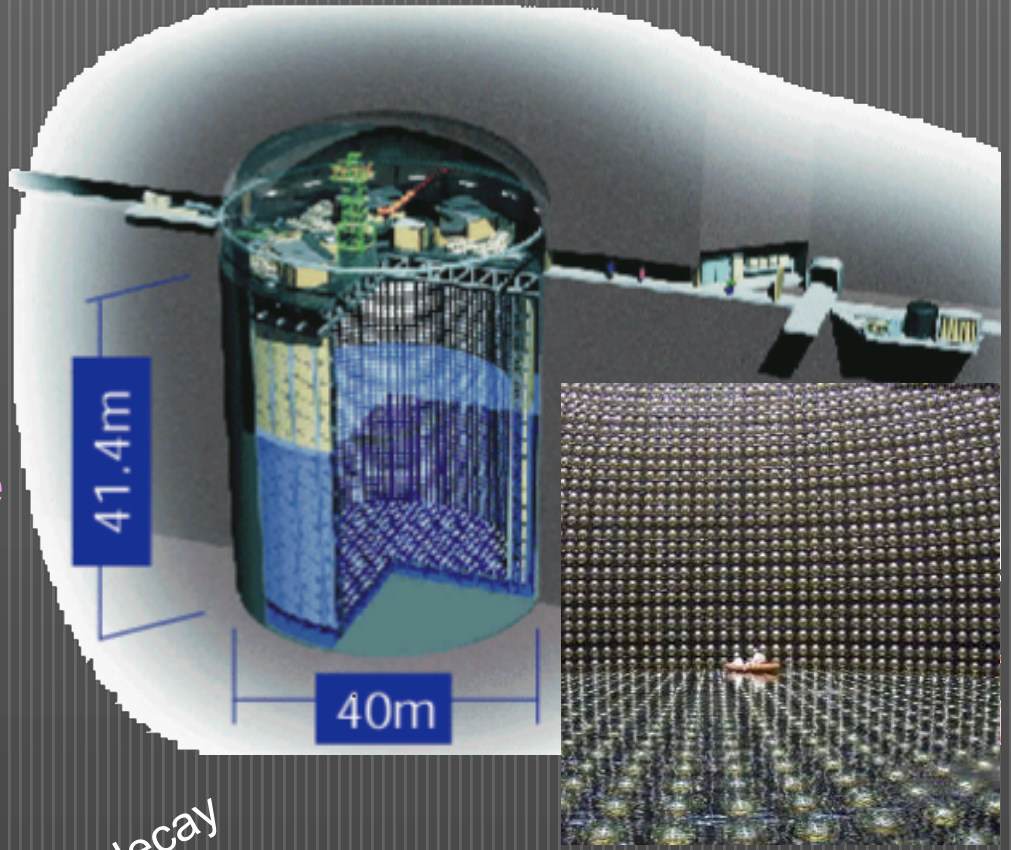
Storage

20m GW

Tokyo

Super-Kamiokande I

- 50kton pure water Cherenkov detector
- 11146 50cm PMTs in Inner Detector
- Great direction-sensitive detector!



Physics targets

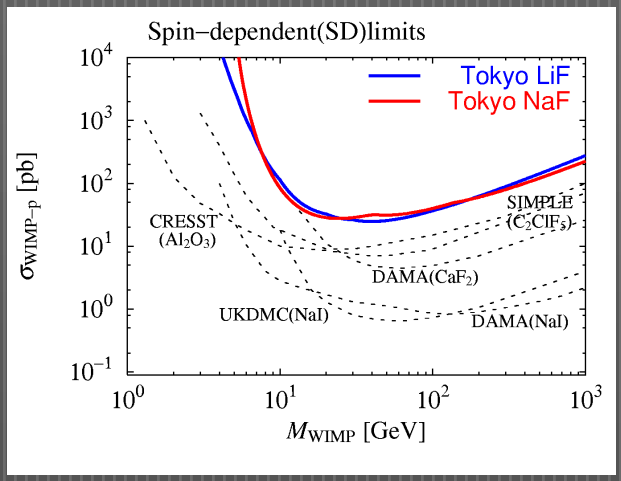
Solar ν
Relic SN ν
Proton decay
WIMPs
Atmospheric ν

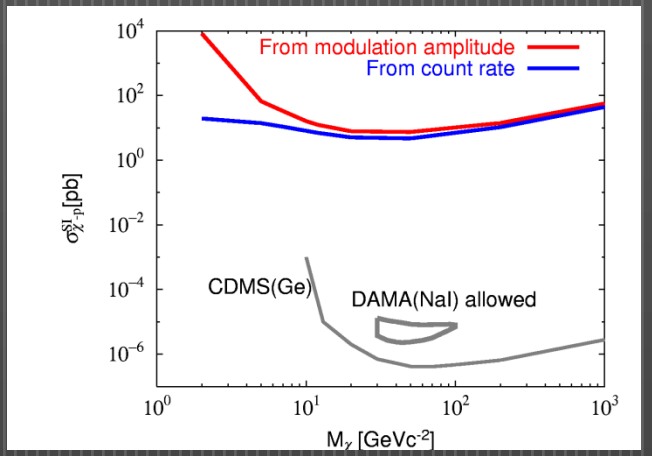
3.5 MeV ~20 ~100 ~1 GeV TeV

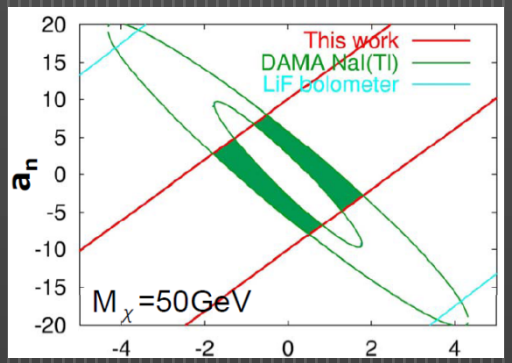
Low energy

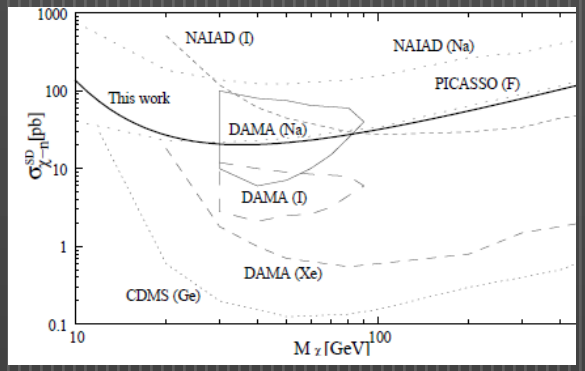
Tokyo Group DM searches

- 1999-2003
  - LiF/NaF bolometer
- 2003
  - Stilbene scintillator
- 2004-2005
  - $CaF_2(Eu)$ scintillator

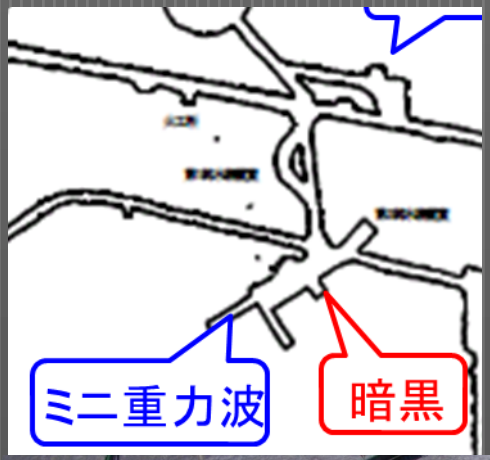


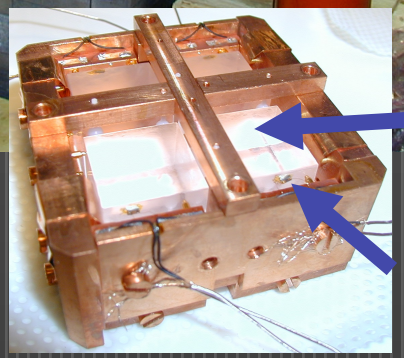






Fluoride Crystal Bolometer





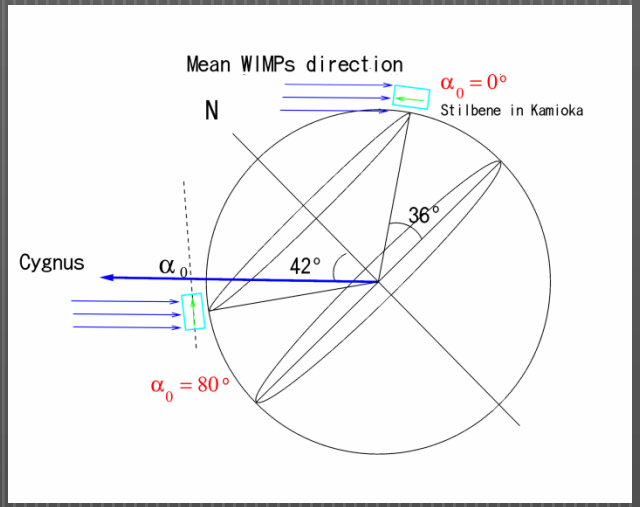
NaF Crystal

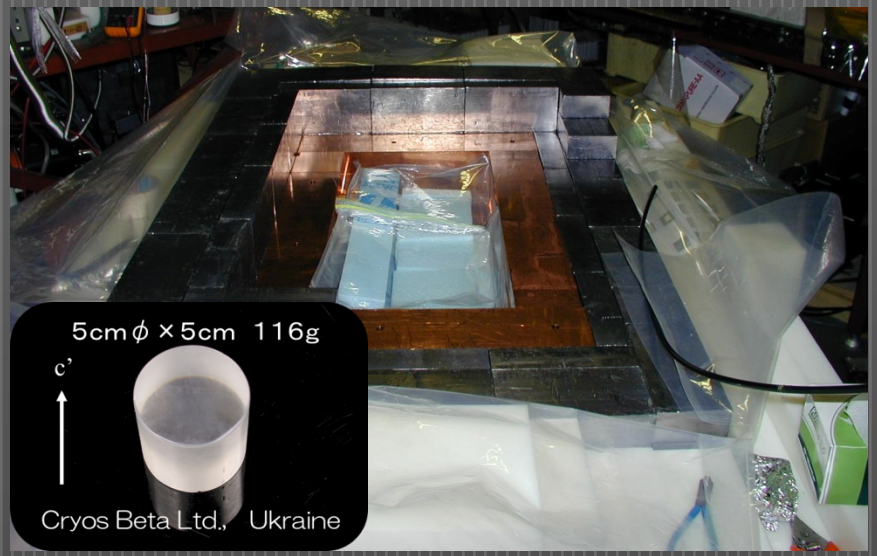
NTD thermistor

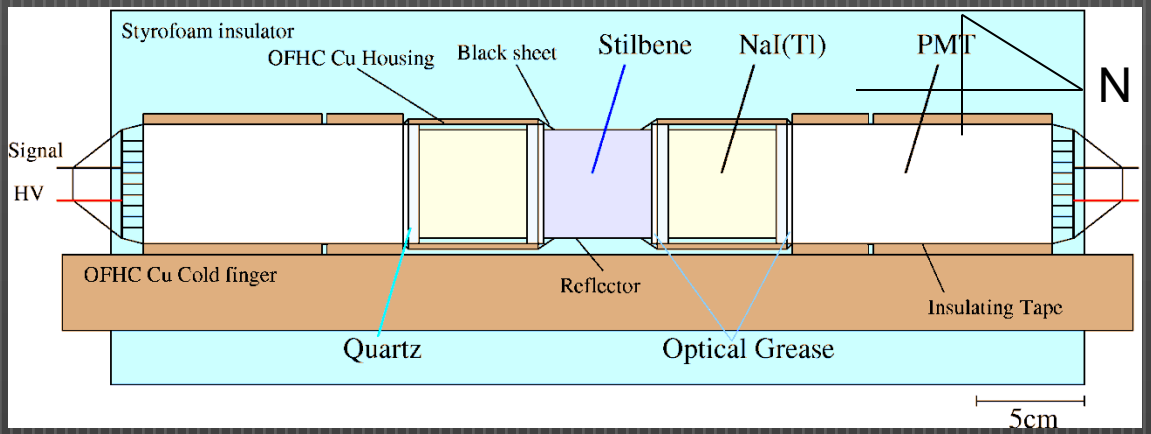
- Installation started in Nov. 1999
- LiF run: 22 Nov. 2001- 12 Jan. 2002
- NaF run: 23 Dec. 2002 – 24 Jan. 2003

Direction sensitive scintillator

80° rotation at Kamioka







Shields of Bolometer

PMTs of XMASS

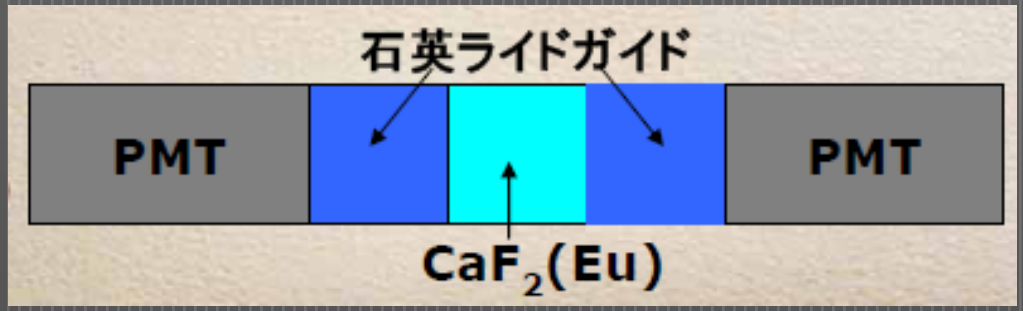
(Hamamatsu R8778)

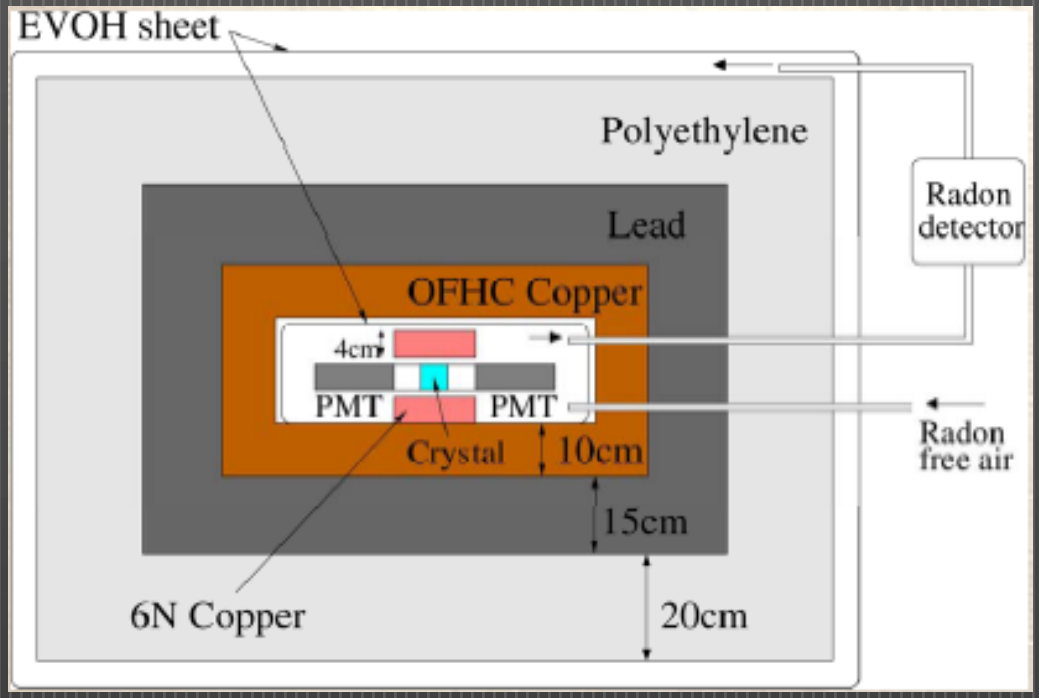
NaI of ELEGANT

(Horiba Ltd.)

$CaF_2(Eu)$

- EuF_3 was doped into CaF_2 of CANDLES

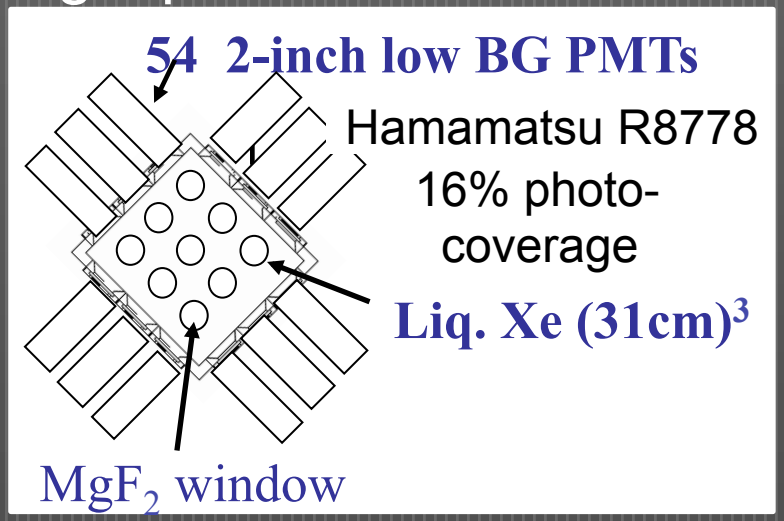


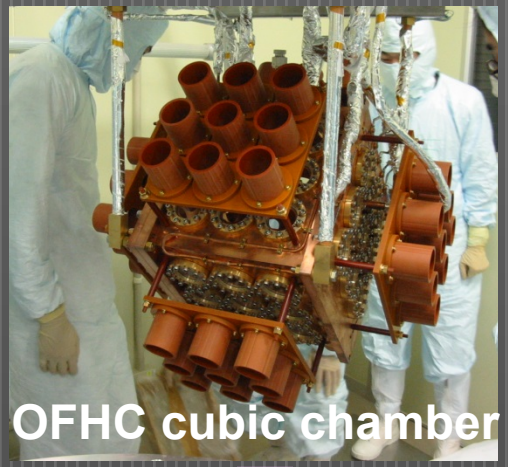


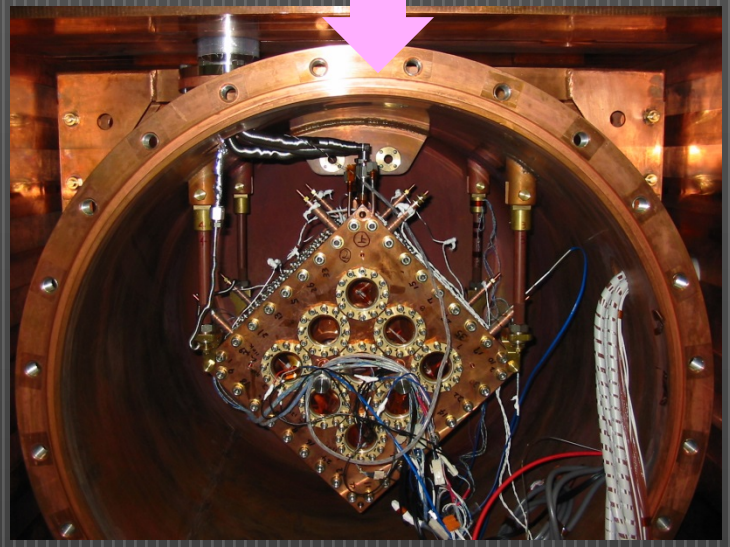
Expanding underground! since 2002

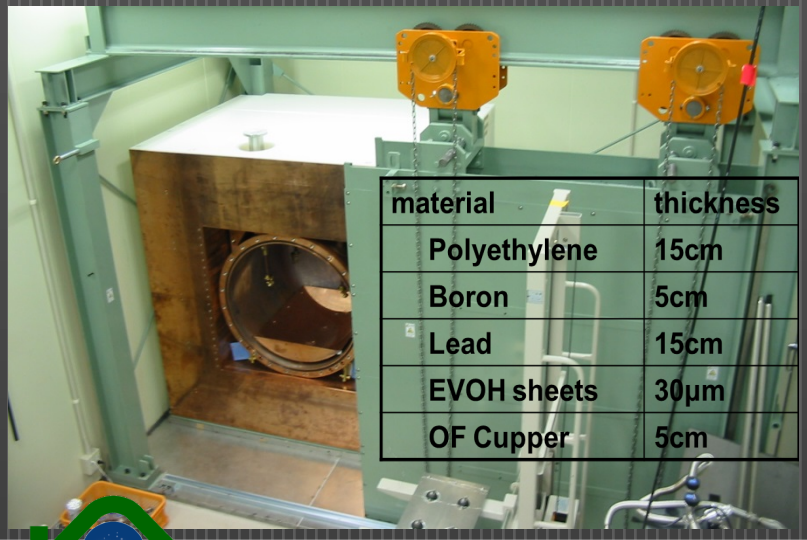
XMASS 100kg Prototype

- Single phase LXe scintillator







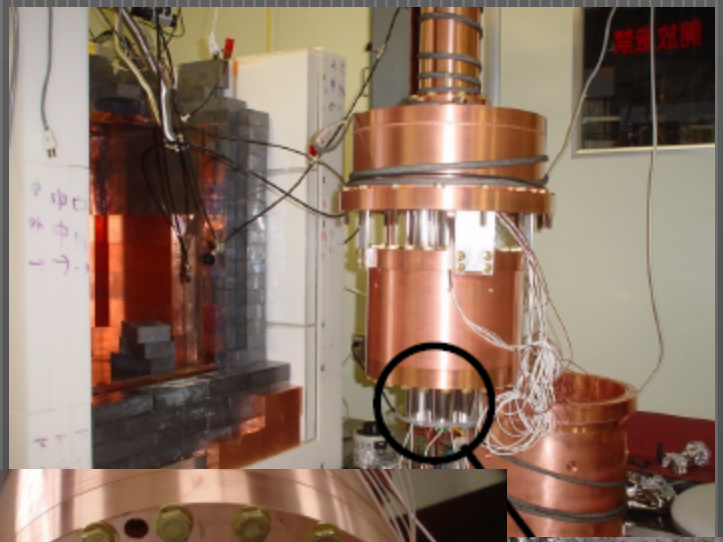


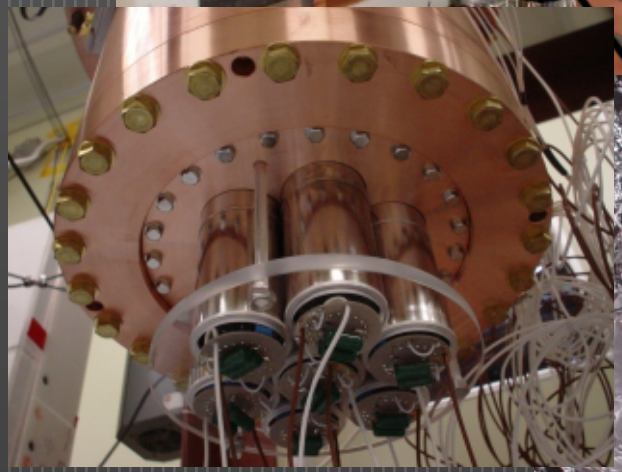
material	thickness
Polyethylene	15cm
Boron	5cm
Lead	15cm
EVOH sheets	30μm
OF Cupper	5cm

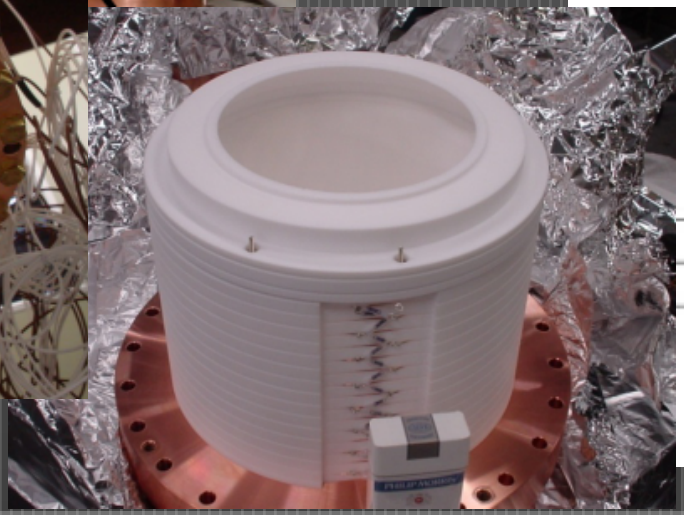
“XMASS-II” by S.Suzuki

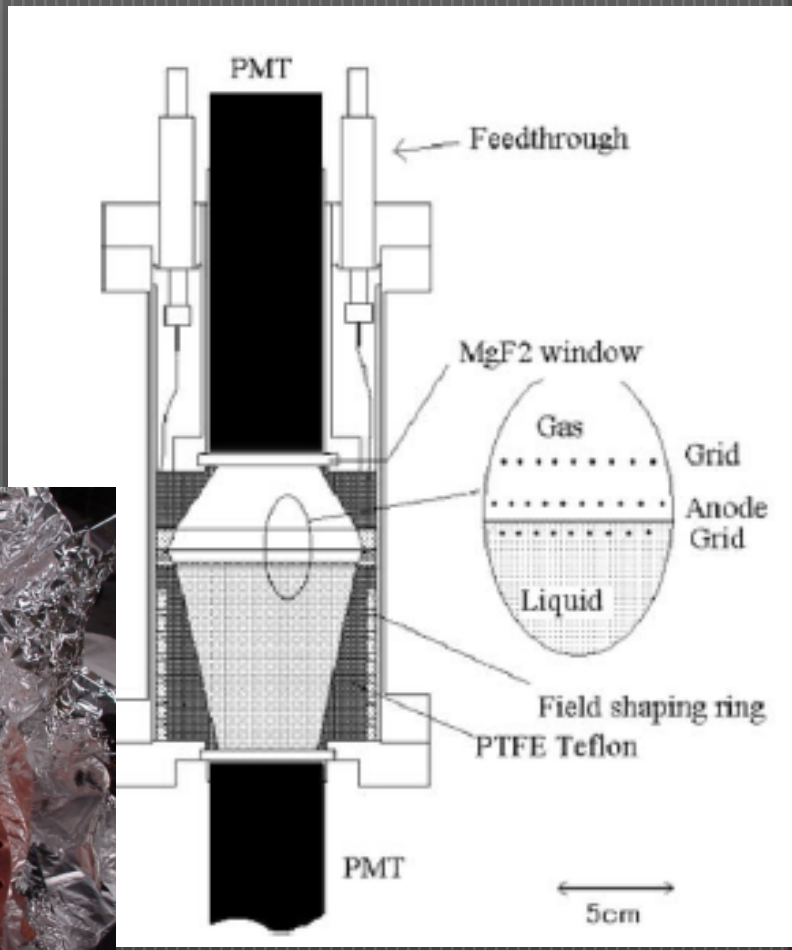
- 2 phase detector (15kg Xe)

Astropart. Phys. 20(2003) 79



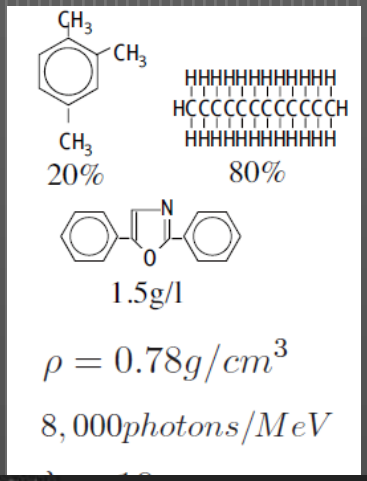


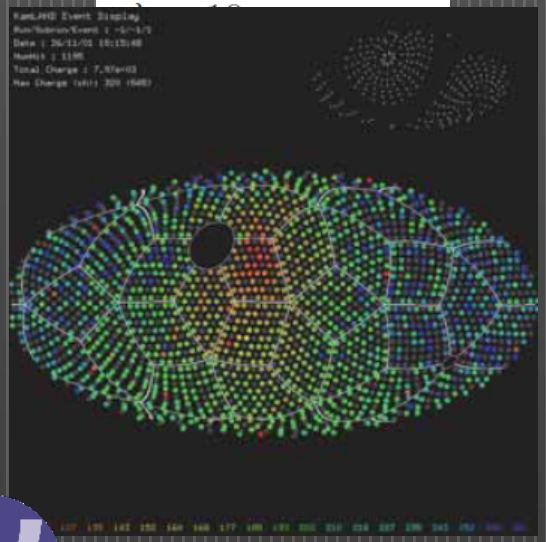


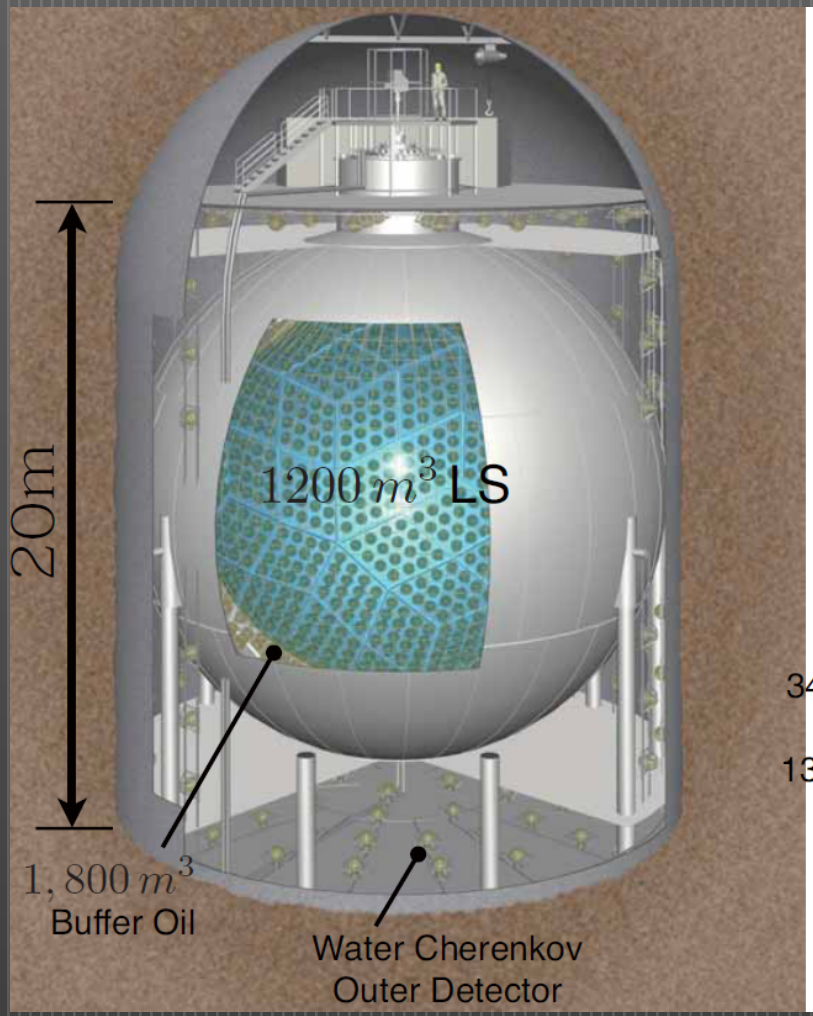


KamLAND (2002-)

- Ultra lowBG Liquid scintillator for anti-neutrino detector







BO

50% dodecane
50% isoparaffin

$\frac{\rho_{LS}}{\rho_{BO}} = 1.0004$

34% photo-coverage with 1325 17" and 554 20" photo-tubes

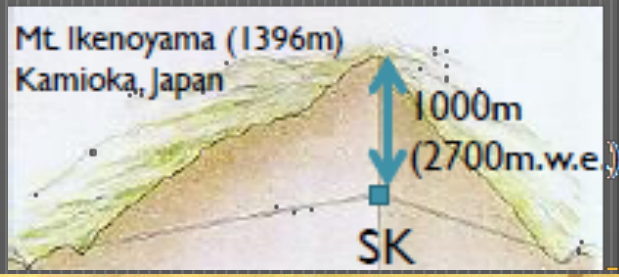
~500p.e./MeV

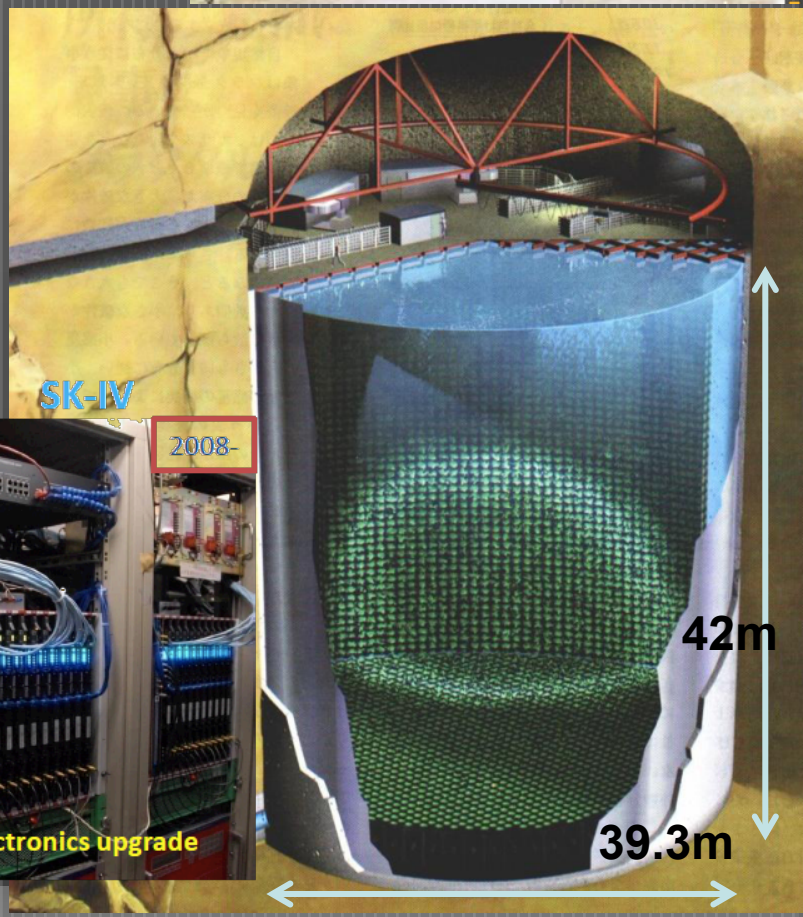
NOW

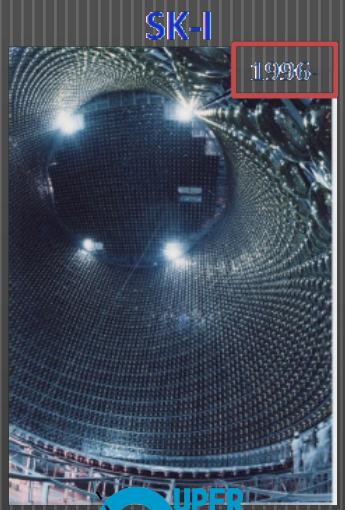
SK IV Detector

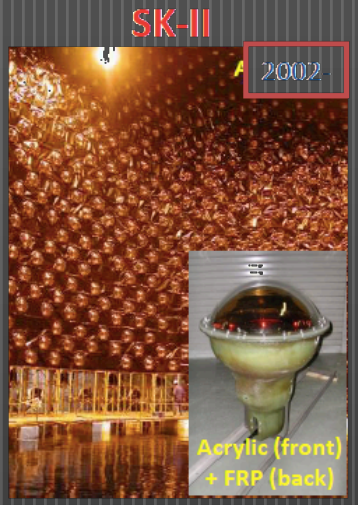
A direction-sensitive detector!

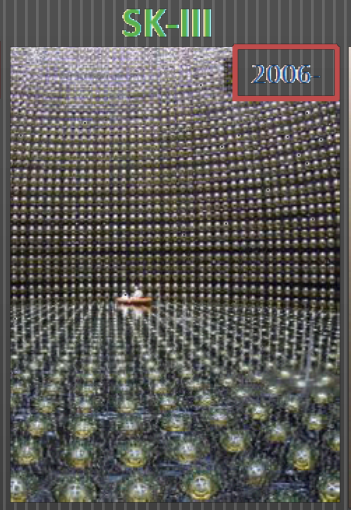
- SK-IV: since 2008 Oct.
  - 20'' PMTs x 11129 for ID
  - 8'' PMTs x 1885 for OD
  - New electronics
    - software trigger (dead time free)
    - HV replacement in this summer





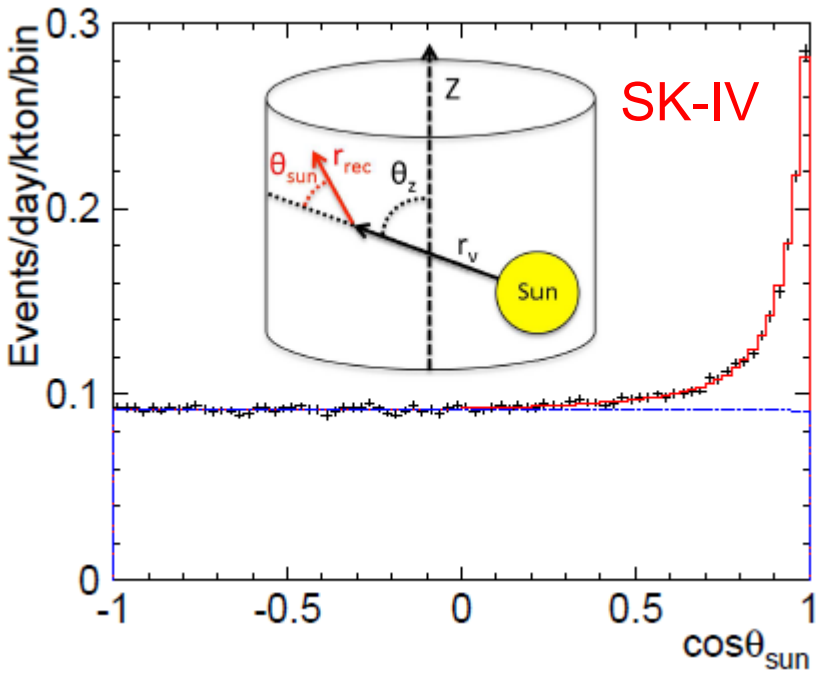




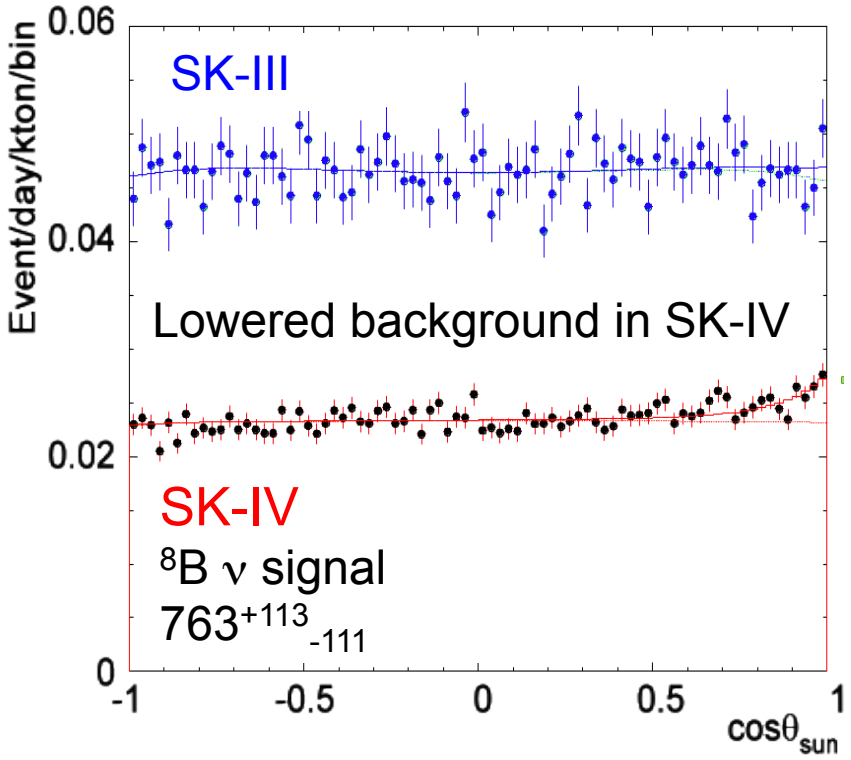


Solar neutrino

SK-IV solar angle distribution
(4-19.5MeV)



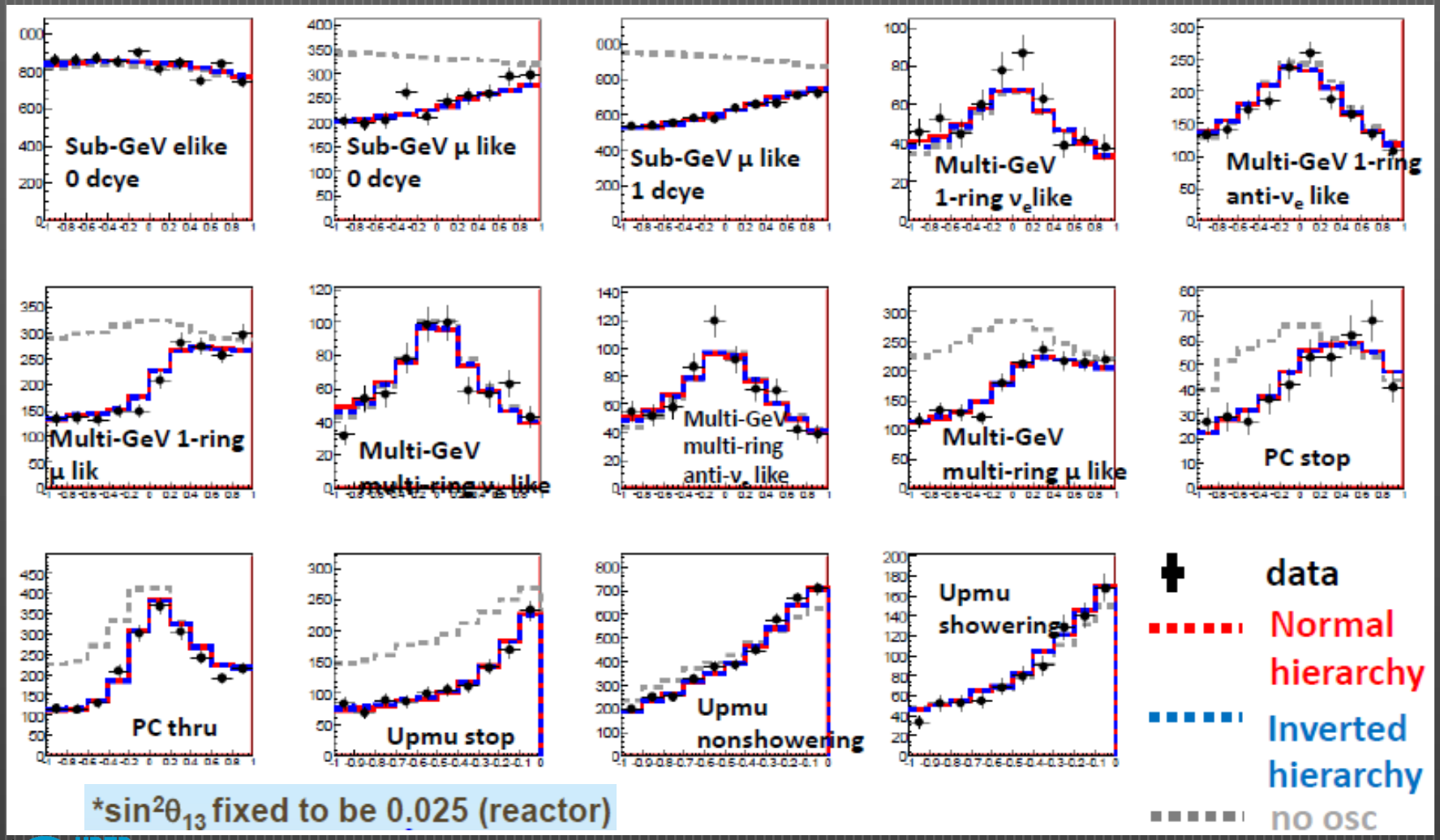
Lower energy distribution
3.5~4.0MeV



Clear Solar peak ~7σ level
3.5MeV threshold is achieved!

Atmospheric neutrino

- Zenith angle distributions



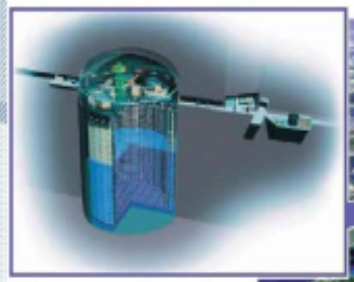
*$\sin^2\theta_{13}$ fixed to be 0.025 (reactor)

T2K

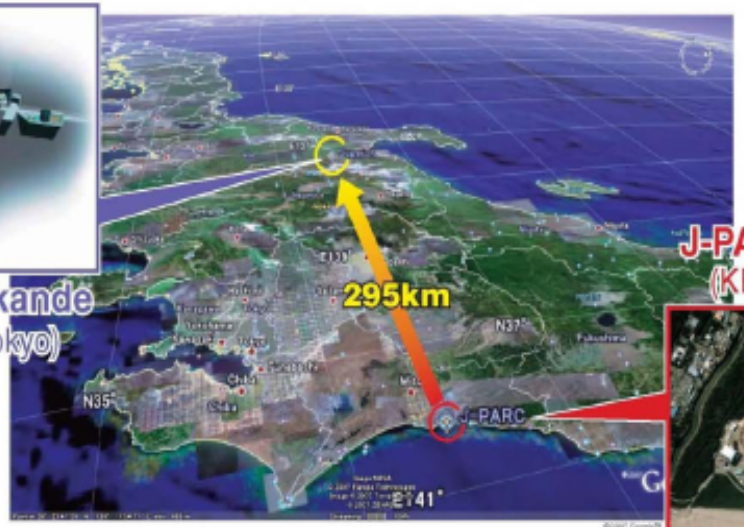
~0.6 GeV ν_μ over 295km

信号

- ν_e appearance → θ_{13}
  - e-like ring, π0 mass cut etc.
- ν_μ disappearance → θ_{23}
  - μ-like ring etc.



Super-Kamiokande
(ICRR, Univ. Tokyo)

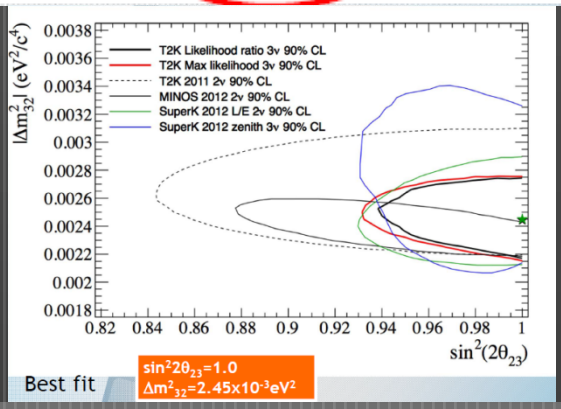


J-PARC Main Ring
(KEK-JAEA, Tokai)

$$P_{\mu\to e} \approx \sin^2\theta_{23}\,\sin^2 2\theta_{13}\cdot\sin^2\left(1.27\,\Delta m^2_{31} L/E_\nu\right)$$

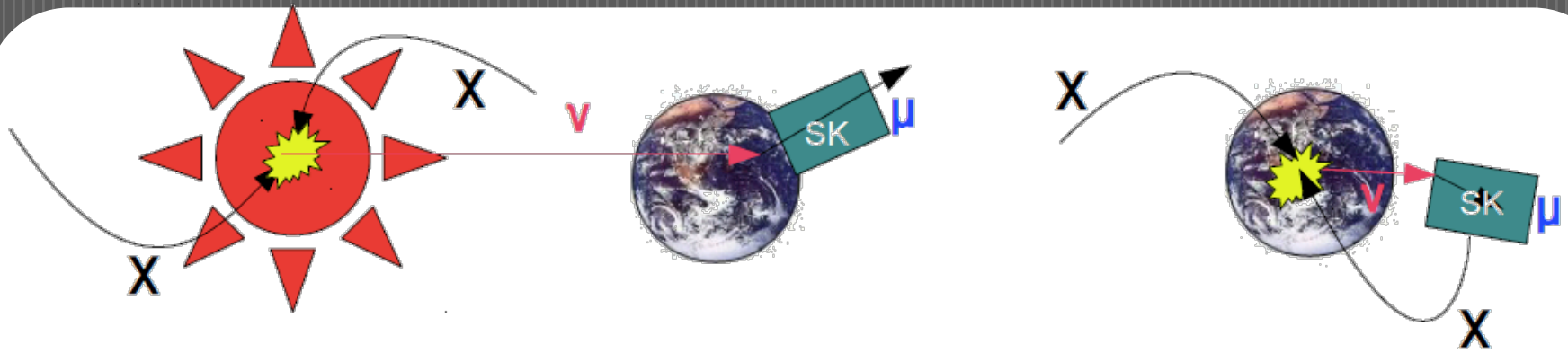
$$P_{\mu\to x} \approx 1-\cos^4\theta_{13}\cdot\sin^2 2\theta_{23}\cdot\sin^2\left(1.27\,\Delta m^2_{32} L/E_\nu\right)$$

Direction<GPS timing



Direction sensitive indirect DM search

- Neutrino as χ self-annihilation product
  - From Solar and Earth



Accumulated by mainly SD scattering in Sun, and by mainly SI scattering in Earth → Limit on $\sigma_{\chi-p}$

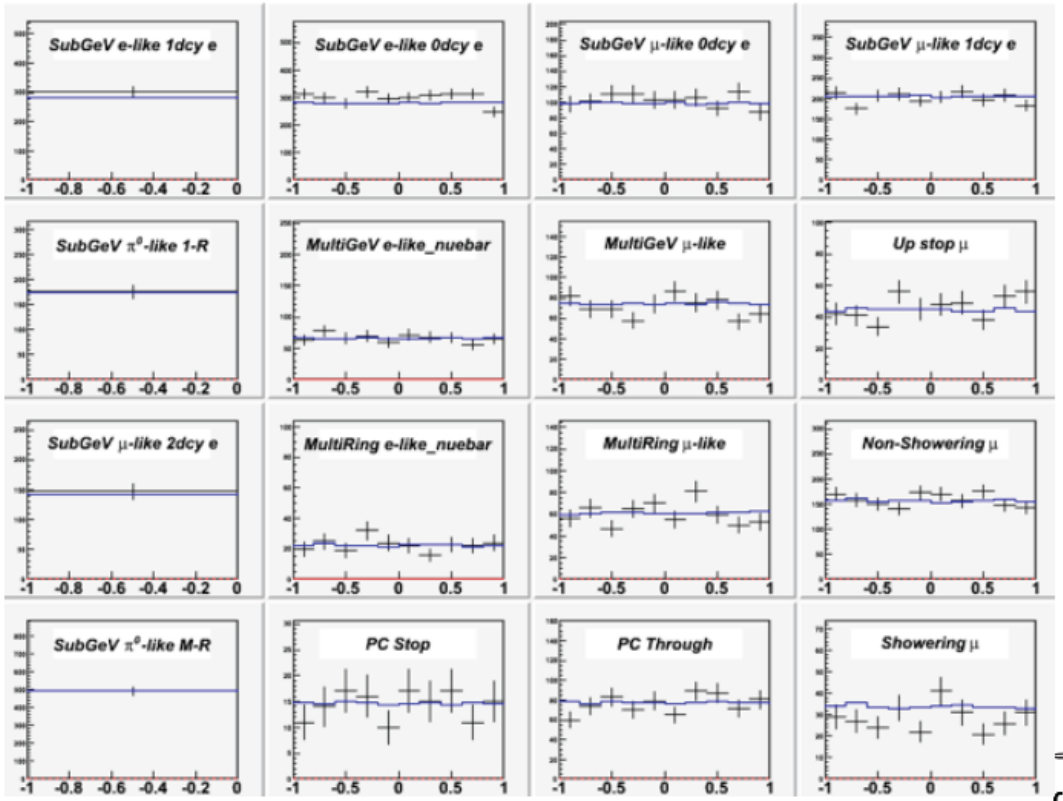
  - From galactic center

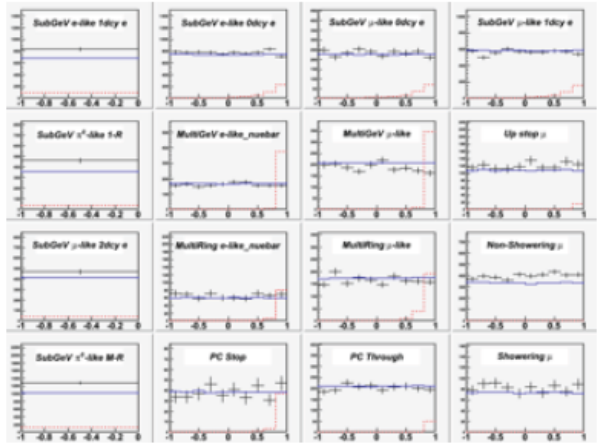
direct detection $\chi + \chi \rightarrow \nu + \bar{\nu}$ from dark halo

→ Limit on flux = $<\sigma_A v>$

From Sun

Reconstructed angle(to the Sun)





☝ arbitrary normalized

signal(10bb,tautau)

☜best fit : not visible

contribution

☜cossun=1

:from the sun

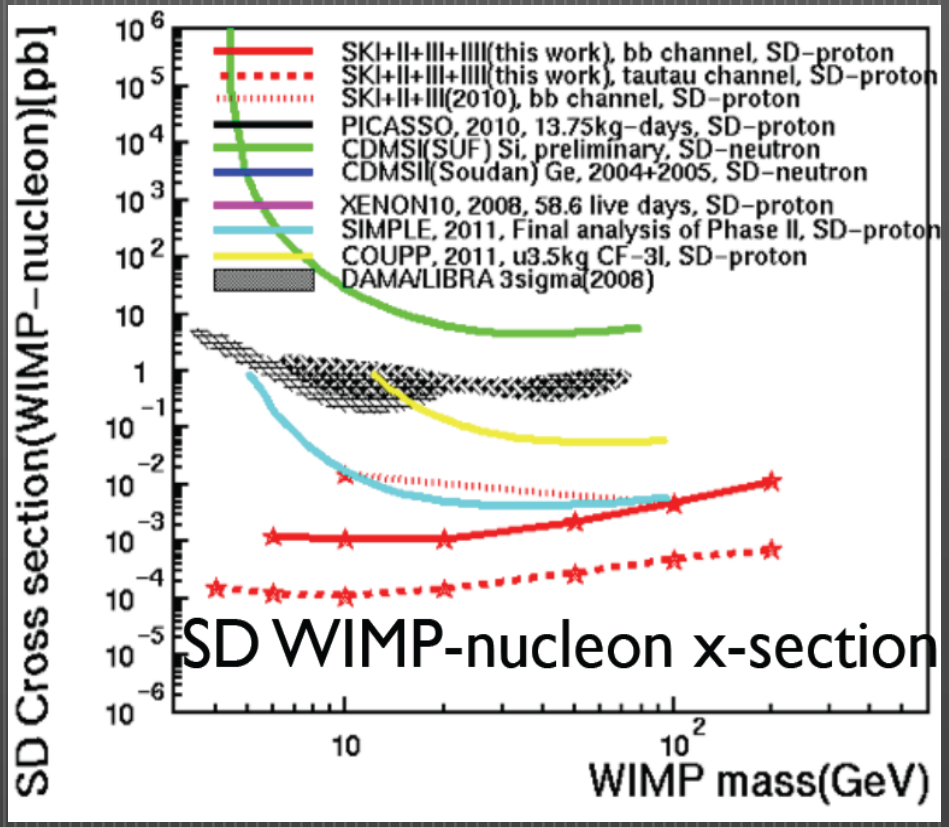
Black cross: SK I- IV Data

Blue solid : atmospheric MC(oct11 500yrs, normalized by livetime, tau MC included)

Red dashed : WIMP induced events for 4GeV, tautau

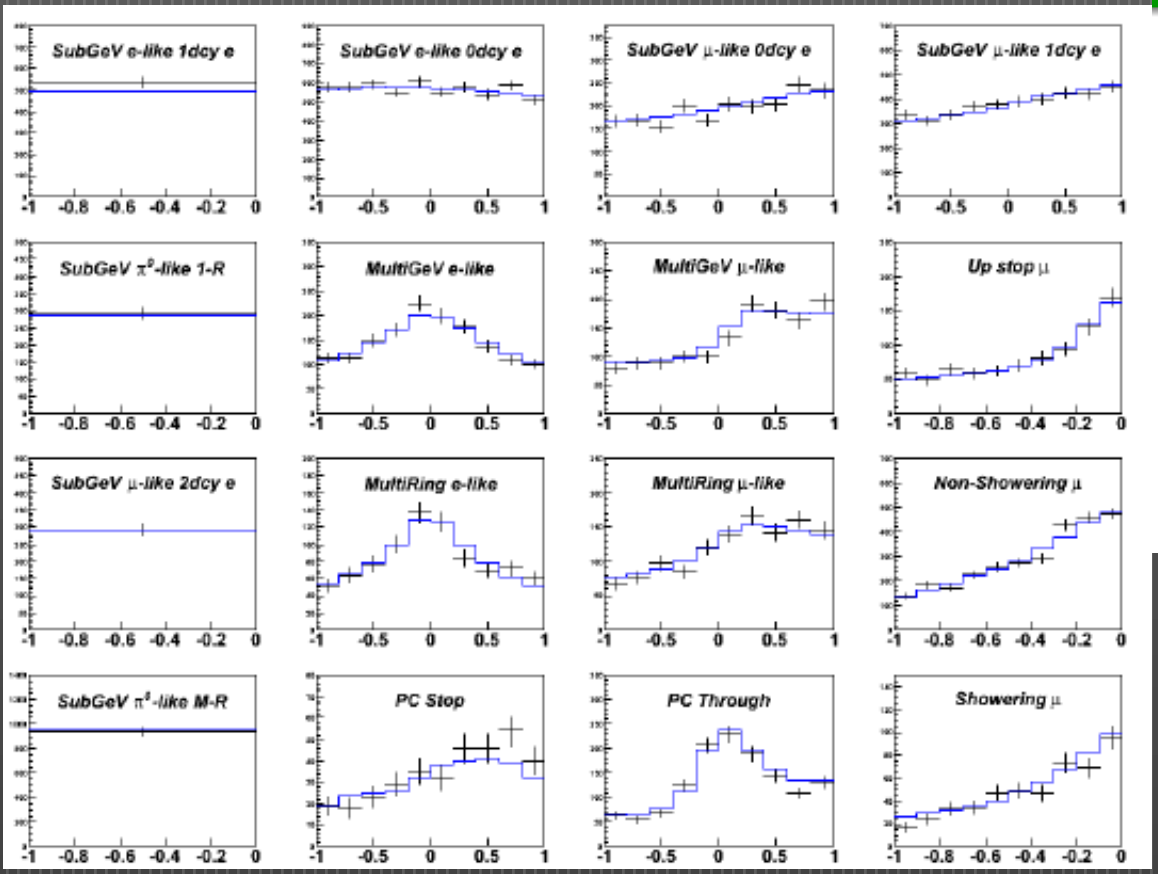
SK Solar (SD) WIMP Search Results

- Better than IceCUBE in Low mass region
- Better than direct searches

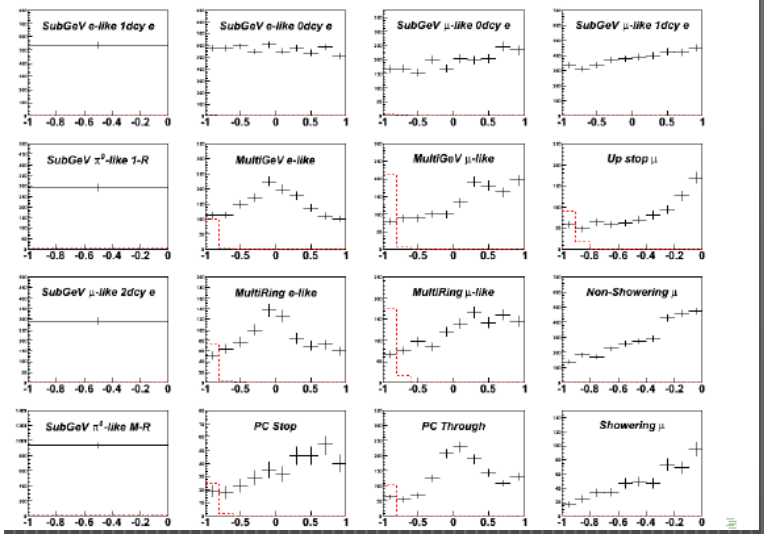


From Earth

- Zenith angle (same as Atm ν)



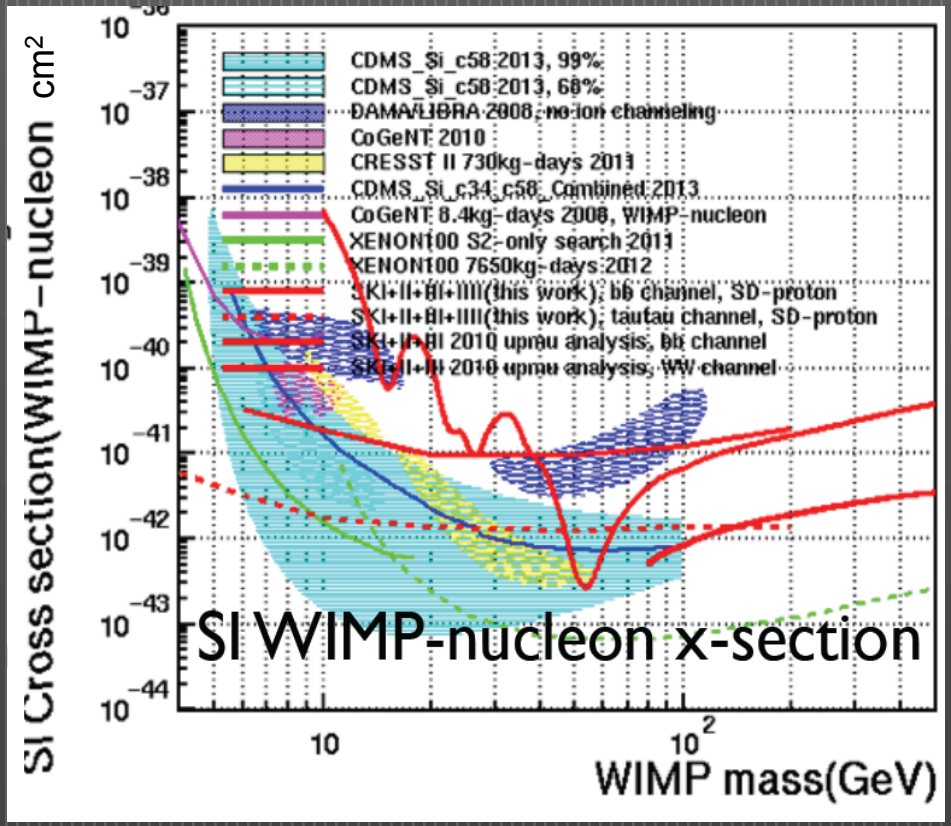
Results: $3.9GeV < E_\nu < 4.1GeV$, $-1 < \cos(\theta) < -0.9$



arbitrary normalized

SK Earth (SI) WIMP search result

- Competitive results with direct searches

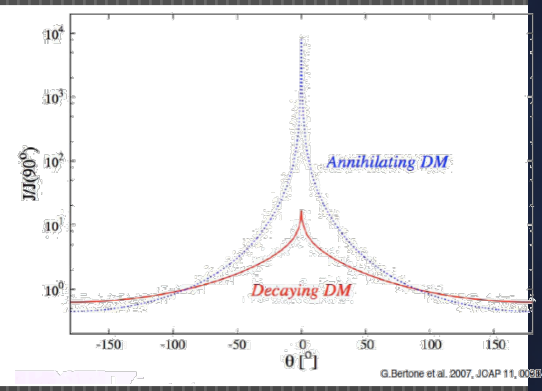


Galactic WIMP search

- HOT TOPICS: positron excess by AMS/PAMELA/FERMI

Ex) NFW Halo model

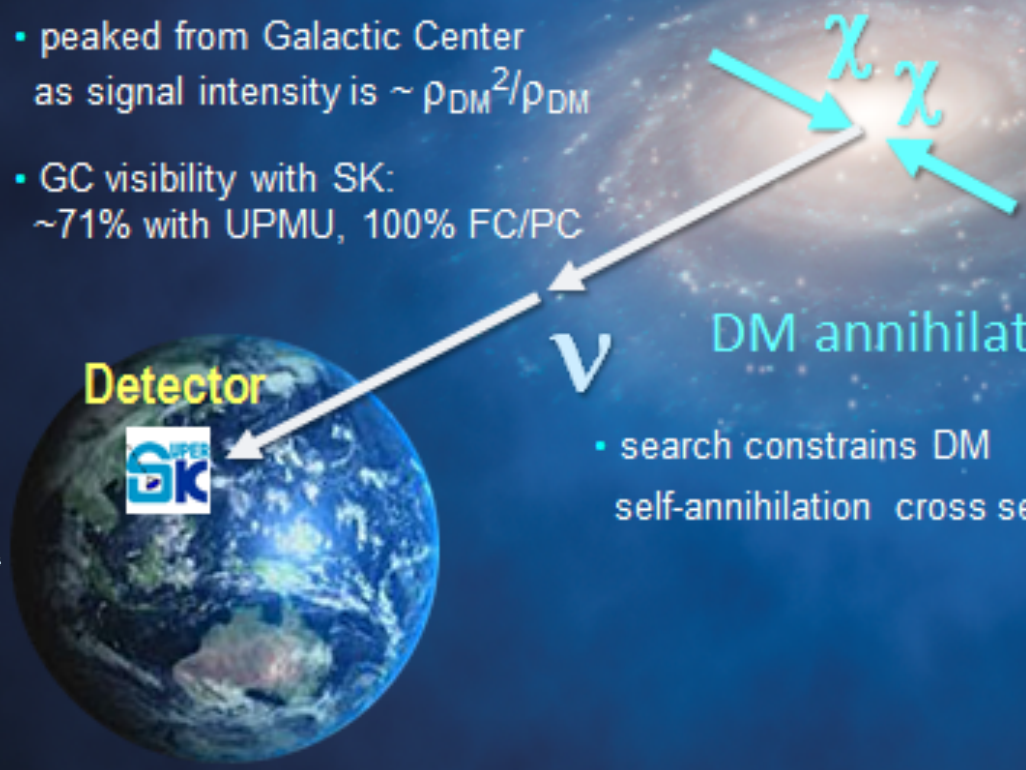
$$\rho_{\rm DM}(r) = \frac{\delta_c \rho_{\rm crit}}{(r/r_{\rm s})(1+r/r_{\rm s})^2}$$



Peaked in G.G

$$\chi\chi \rightarrow \nu\bar{\nu}, W^+W^-, b\bar{b}, \mu^+\mu^- \rightarrow ... \nu_{e/\mu/\tau}$$

- peaked from Galactic Center as signal intensity is ~ ρ_{DM}^2/ρ_{DM}
- GC visibility with SK: ~71% with UPMU, 100% FC/PC

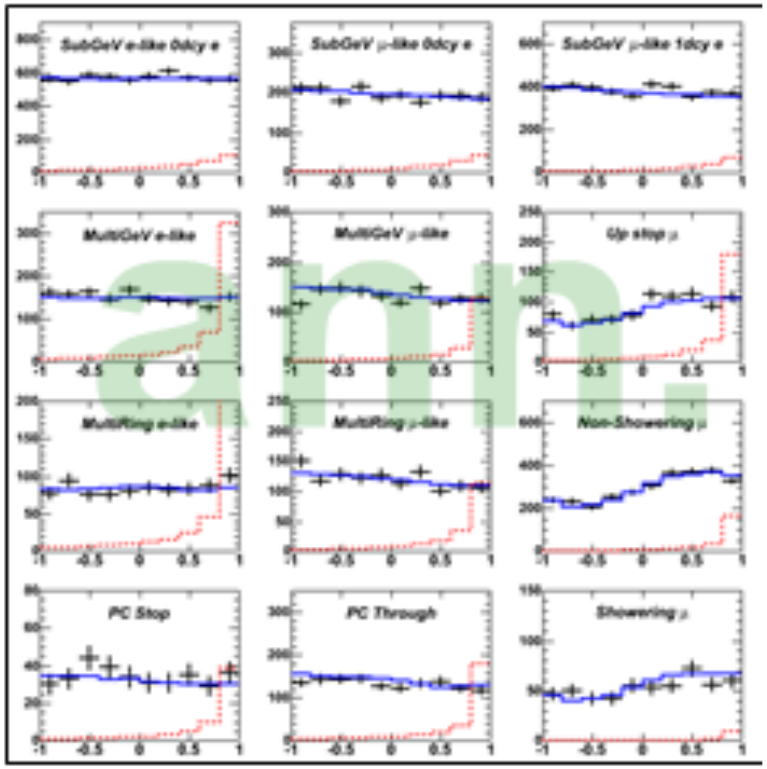


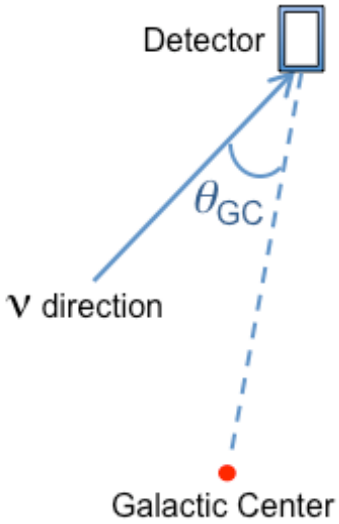
From G.C.

M_χ = 100 GeV

DM signal illustration before fit

energy spectra of neutrinos are the same on both plots





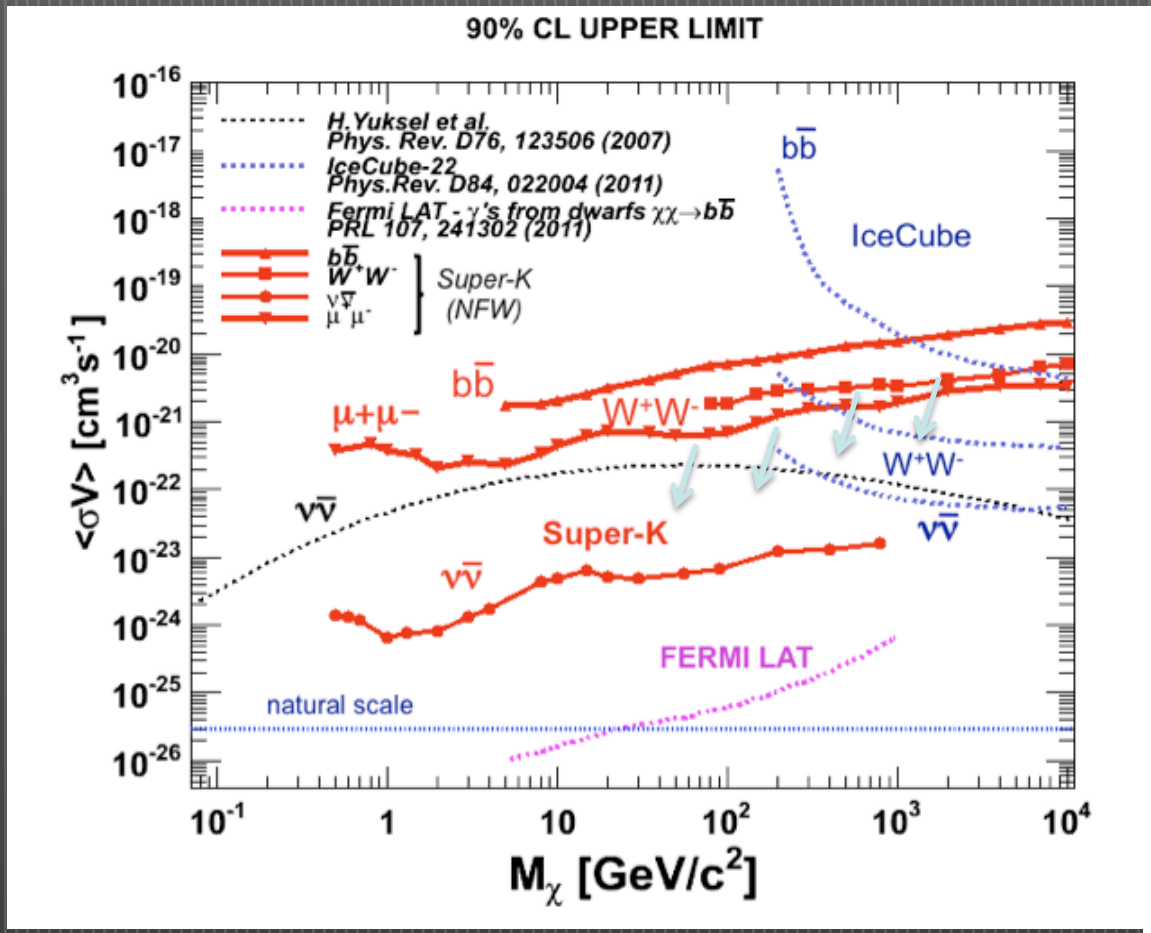
$\cos\theta_{GC}$

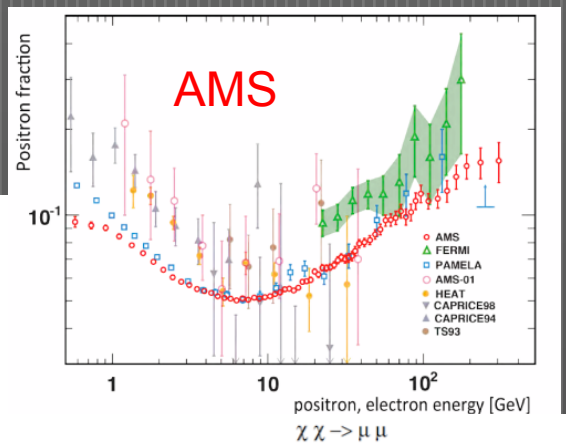
DATA SK1,2,3 — ATM MC with oscillations — DM signal shape enhanced for illustration

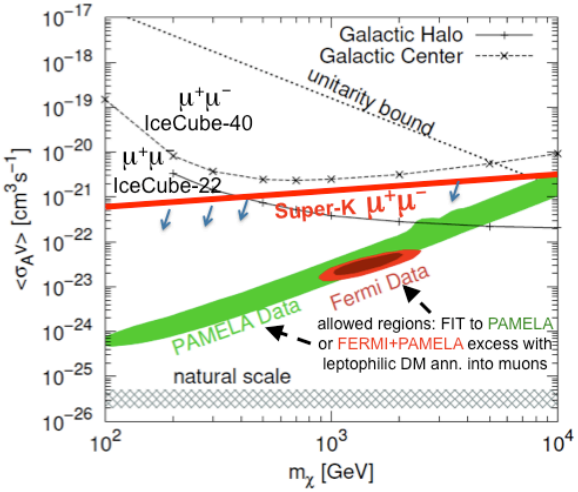
5

SK Galactic WIMP search results

- Best in Low mass region







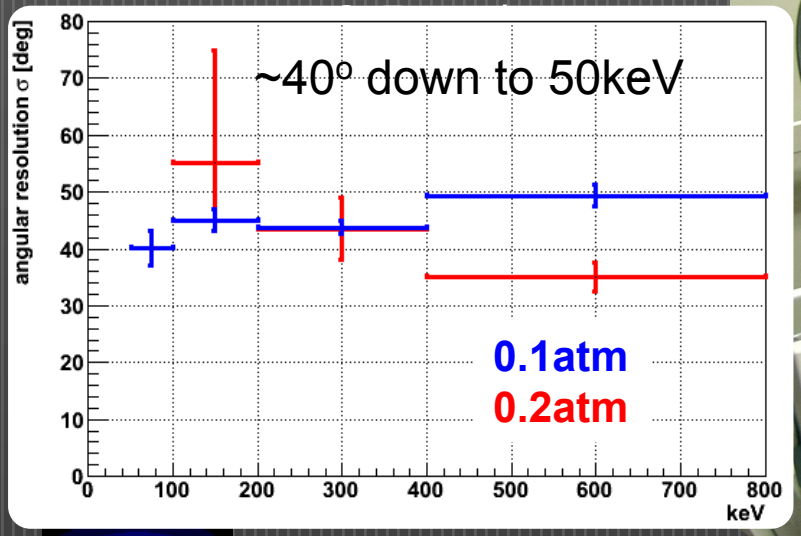
$$\frac{d\phi_{\Delta\Omega}}{dE} = \frac{\langle \sigma_A \cdot V \rangle}{2} J_{\Delta\Omega} \frac{R_{sc}\rho_{sc}^2}{4\pi \cdot m_\chi^2} \frac{dN}{dE}$$

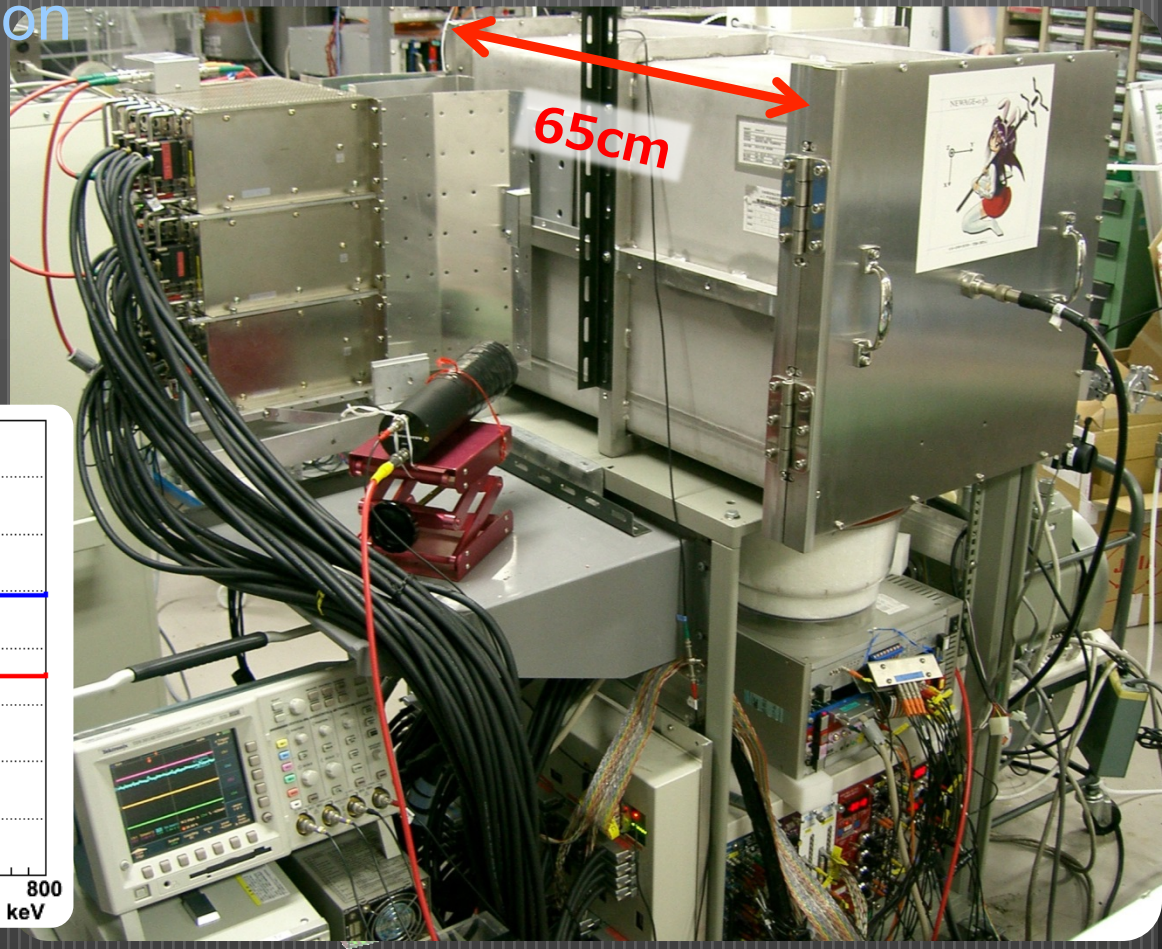
$J_{\Delta\Omega}$ *integrated intensity over all sky related to DM halo density profile*

NEWAGE –The direction sensitive DM search-

New general WIMP search with an Advanced Gaseous tracker Experiment

- NEWAGE-0.3b detector @ Kamioka
  - CF_4 0.1atm operation
  - 60cm drift
    - drift field :
      625 V/cm/atm
    - drift velocity :

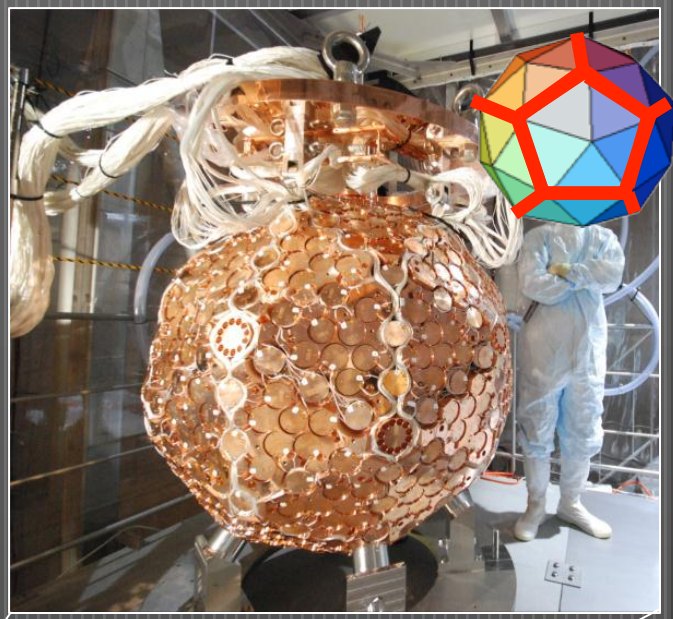


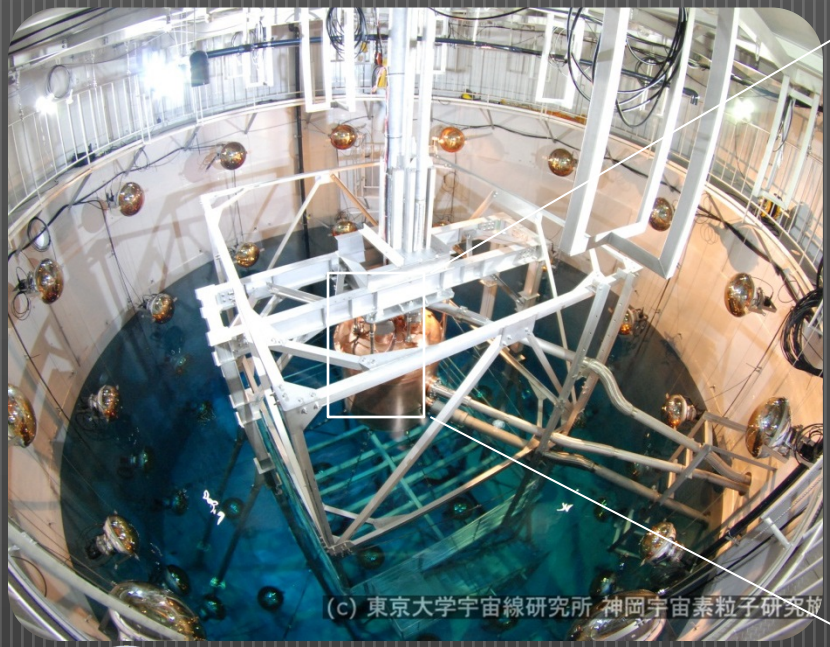


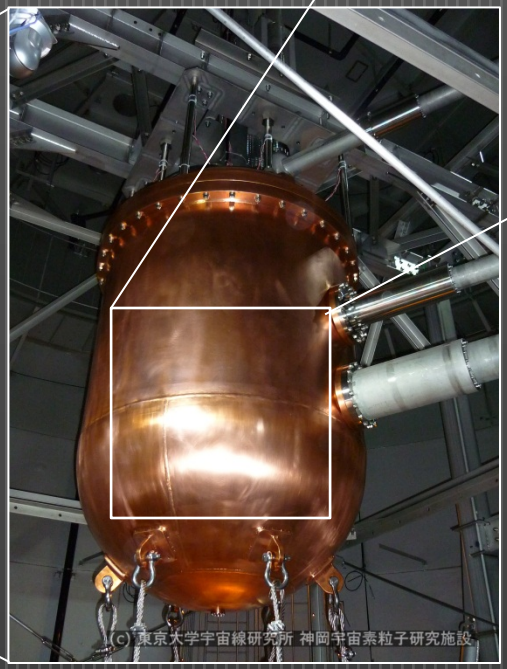
XMASS

Xenon detector for Weakly interacting MASSive Particles

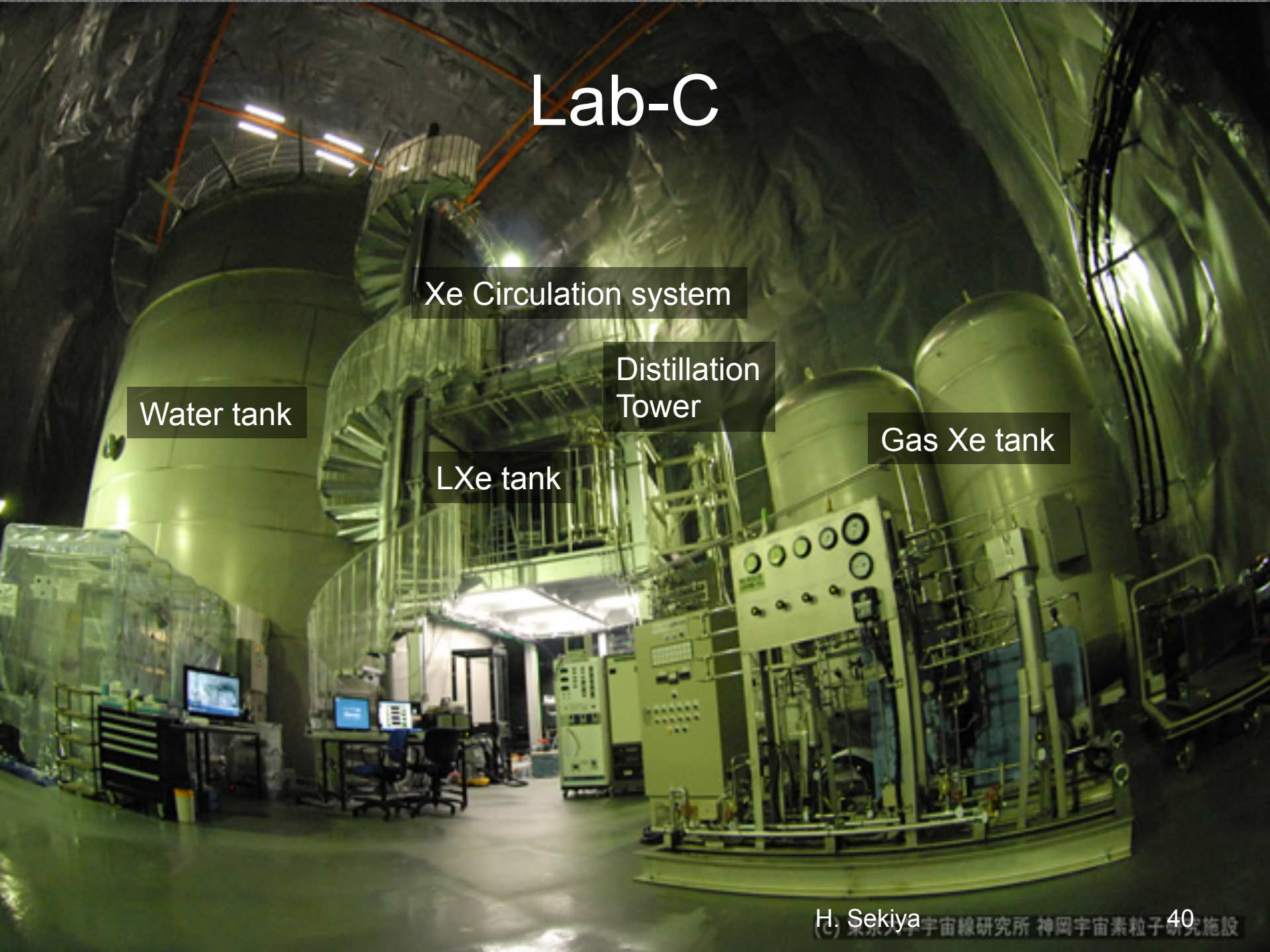
- 10m x ϕ10m water shield for external BG
- 857 kg Liquid Xe within PMT holder.
  - Largest mass among DM detectors
- 642 hexagonal PMTs on
  80cm pentakisdodecahedron





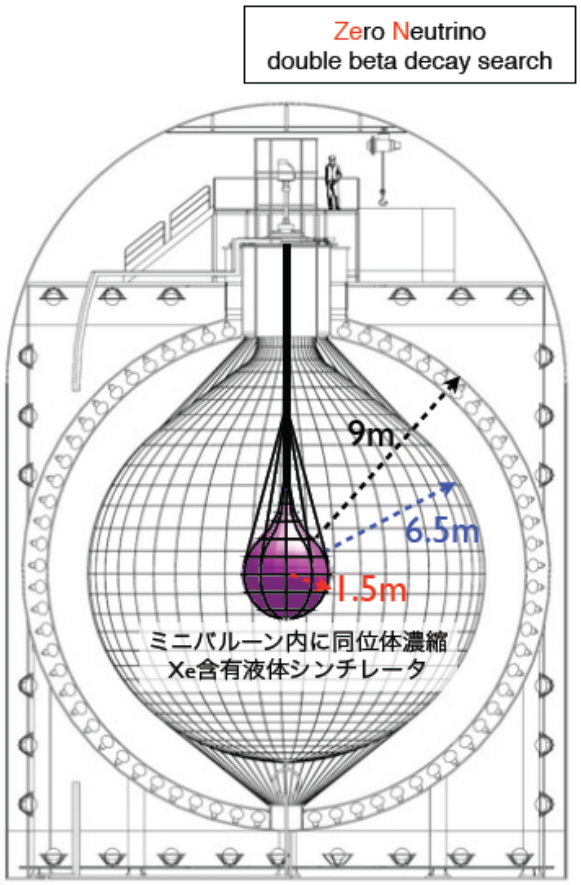


Construction was completed in Oct 2010


Lab-C
Xe Circulation system
Distillation Tower
Water tank
Gas Xe tank
LXe tank

KamLAND-Zen(^{136}Xe double beta decay)

- ^{136}Xe320kg in central balloon



~320kg 90% 同位体濃縮 ^{136}Xe を導入

将来800kg~1000kgに拡張

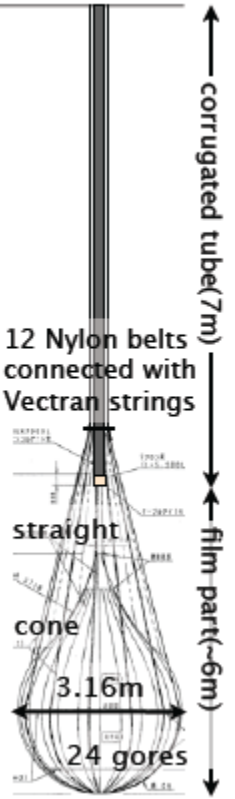
mini balloon fabrication

produced in a class 1 super-clean-room
(class 1 = less than 1 0.5-micron-particle in cubic feet)

less material → 25 μm Nylon6
- transparency 99.4% @400nm
- strength 19.4 N/cm
- Xe barrier < 220 g/year

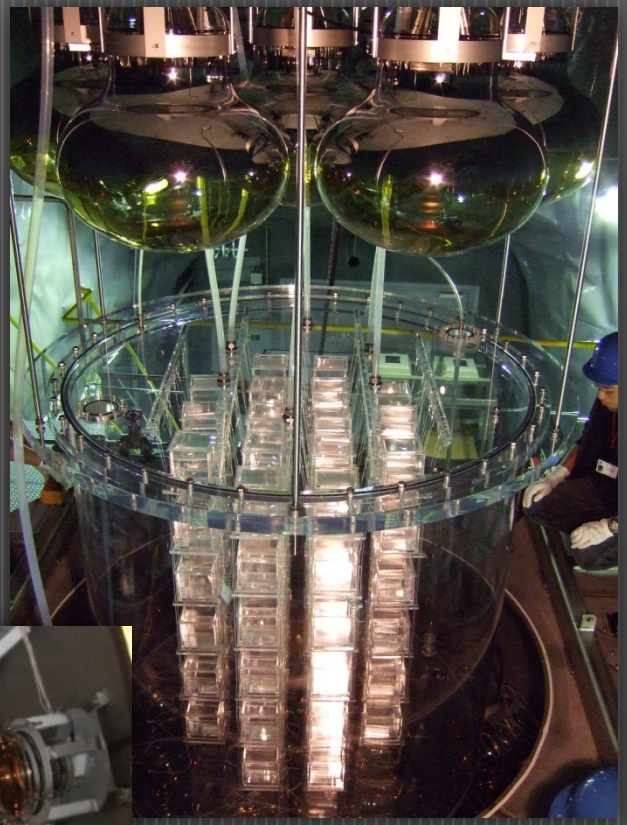
low radioactivity
→ specially made no filler film

U	: 150 →	2×10^{-12}g/g
Th	: 59 →	3×10^{-12}g/g
^{40}K	: 140 →	2×10^{-12}g/g



CANDLESIII (^{48}Ca double beta decay)

- Pros:
  - Largest Q value (4.27 MeV)
    - large phase space factor
    - almost background free
      (γ: 2.6 MeV, β: 3.3 MeV)
- Cons:
  - Low Natural abundance (0.187%)
    - large detector
    - Enrichment



FUTURE

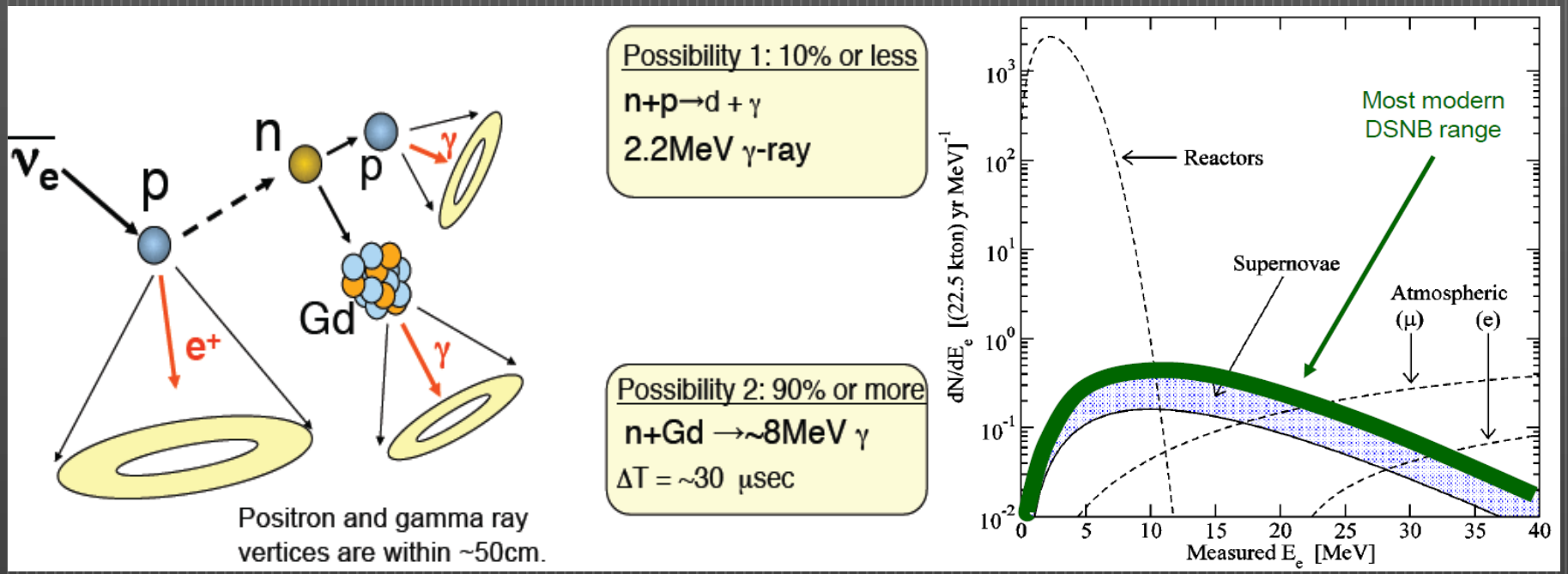
Beacom and Vagins, PRL, 93:171101, 2004

GADZOOKS! Project

Gadolinium
Antineutrino Detector
Zealously
Outperforming
Old
Kamiokande,
Super!

- 0.2% Gadolinium sulfate in SK for supernova relic neutrino search.

➡ Neutron tag (signal) efficiency : 90%
Background reduction : 2×10^{-4}



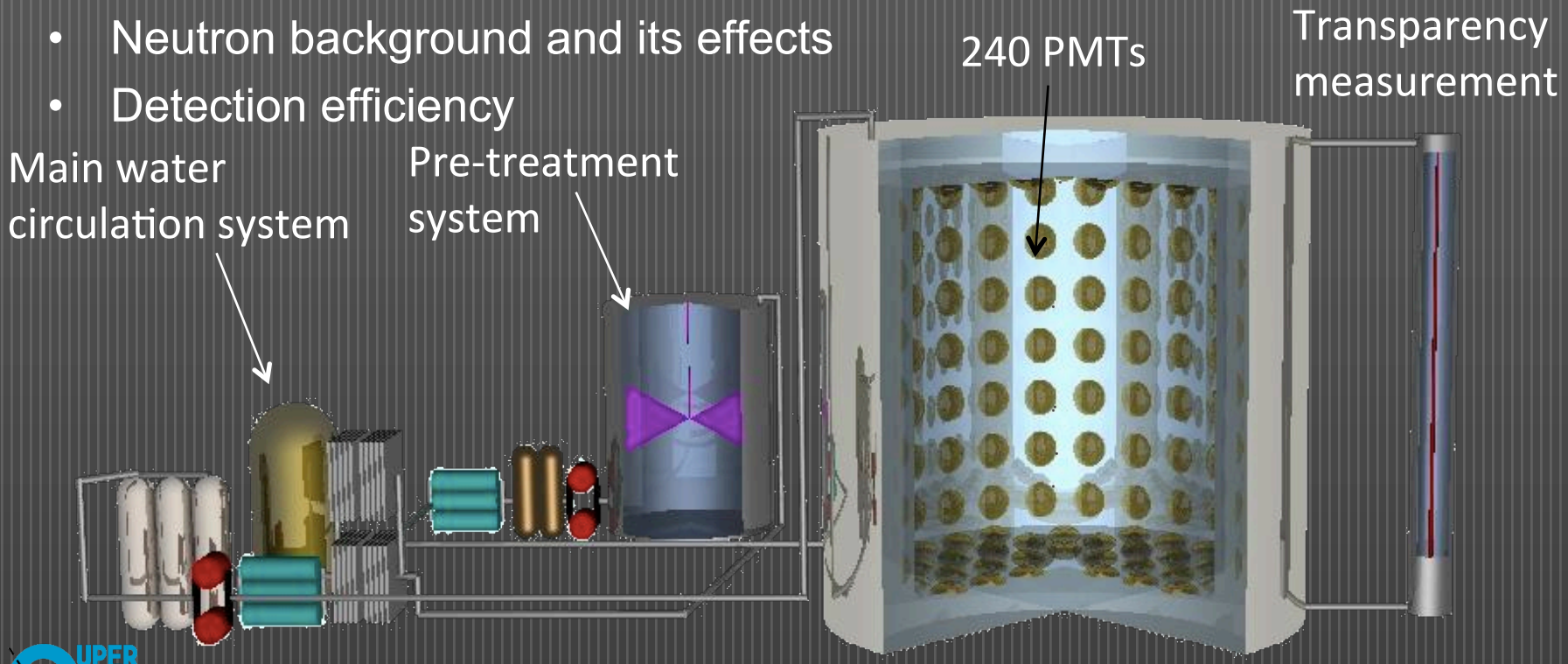
$\bar{\nu}_e$ can be identified by the delayed coincidence technique

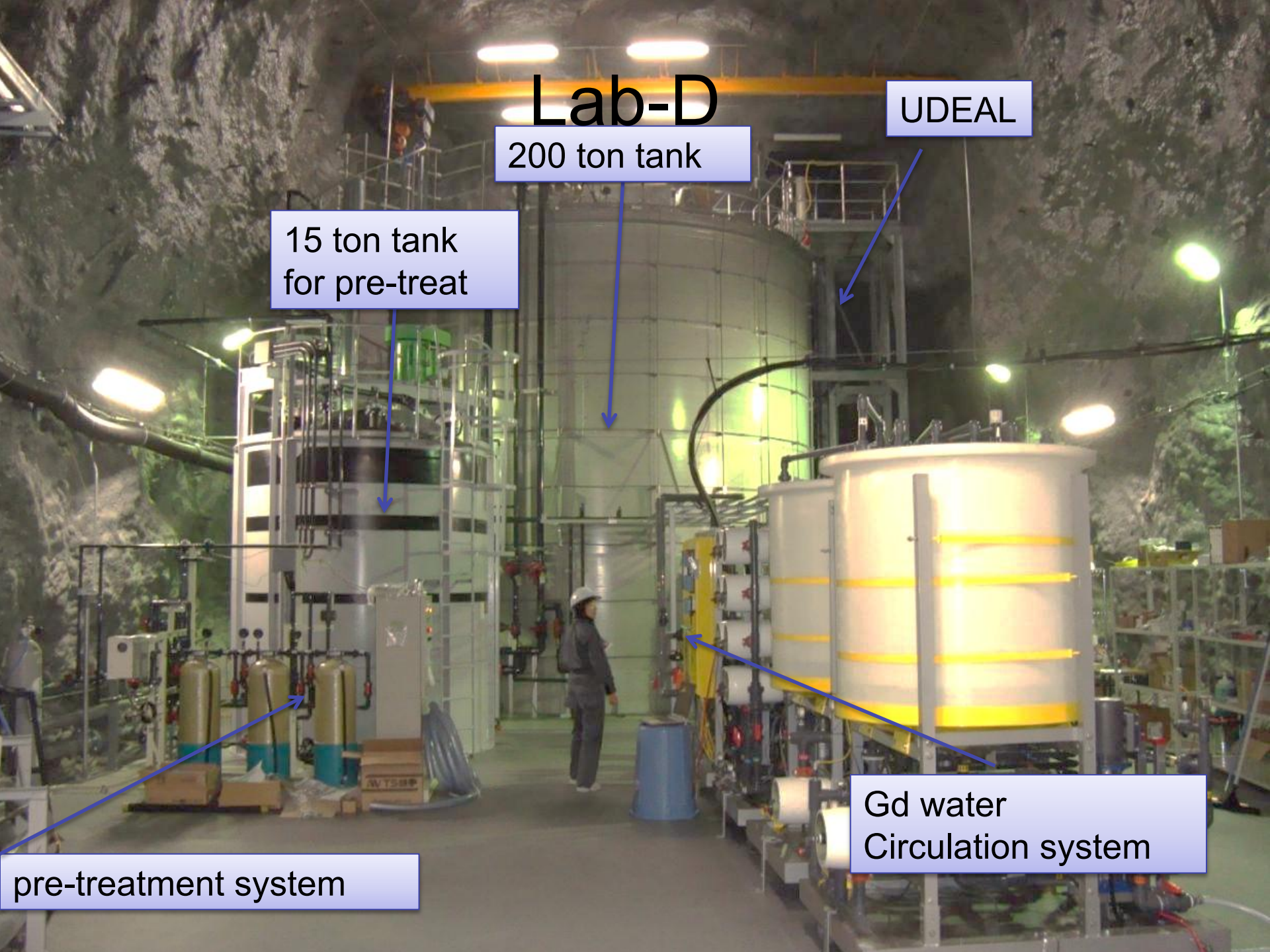
EGADS

Evaluating Gadolinium's Action on Detector Systems

R&D items

- ✓ Water purification with gadolinium sulfate
- ✓ Keep water transparency with gadolinium sulfate
- • Effects on Super-K components/materials
- • Neutron background and its effects
- • Detection efficiency

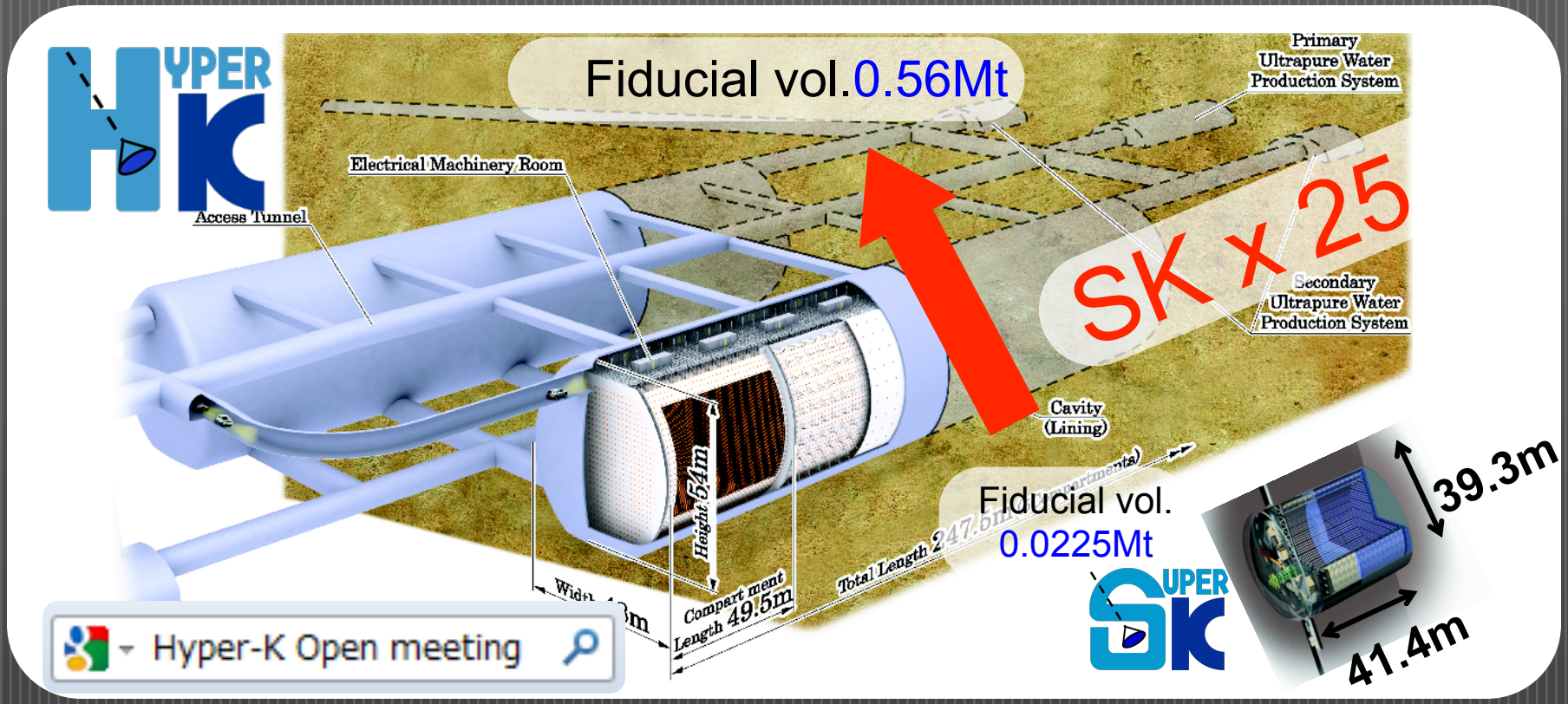



Lab-D
200 ton tank
UDEAL
15 ton tank
for pre-treat
pre-treatment system
Gd water
Circulation system

Hyper-Kamiokande

The next decade's flagship experiment

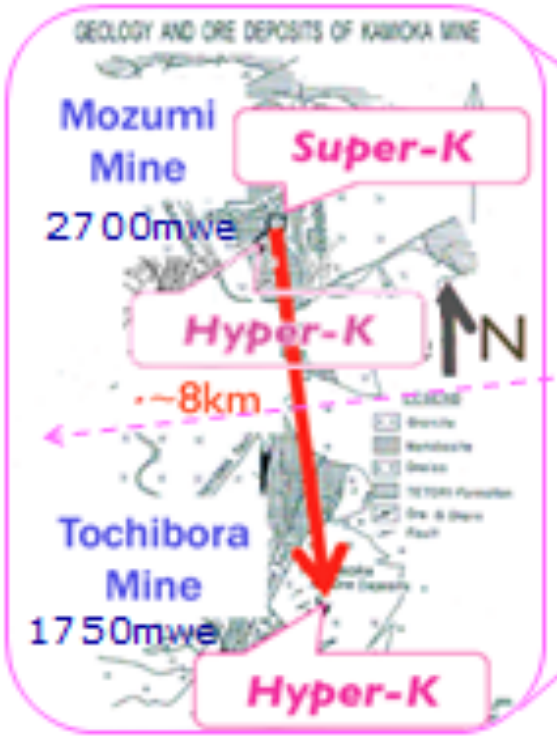
- Open HK meetings are held twice a year.



All those interested are welcome to join!

HK candidate cite

- 2.5° off-axis high intensity ν beam
- HK cite candidates in Kamioka



- J-PARC 30GeV proton beam power will be upgrade to 0.75MW

My DREAM

TPC in Super-K Cavity