XMASS experiment

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For XMASS collaboration

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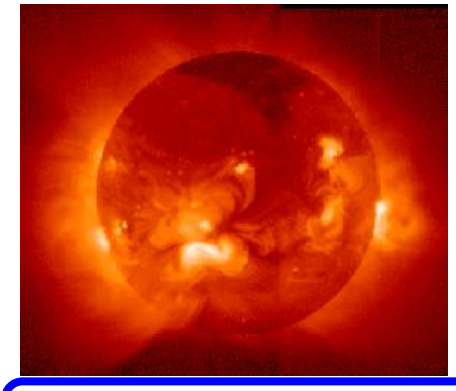
XMASS experiment

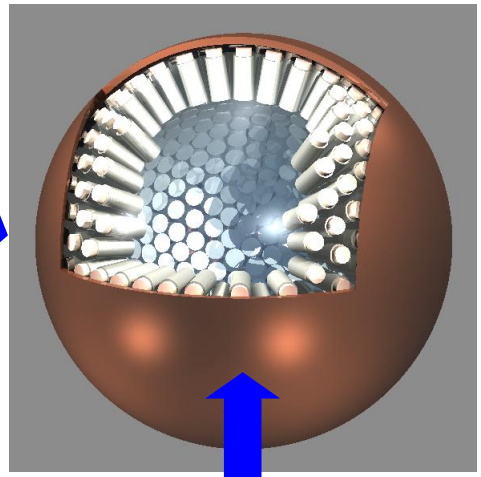
- What is XMASS?

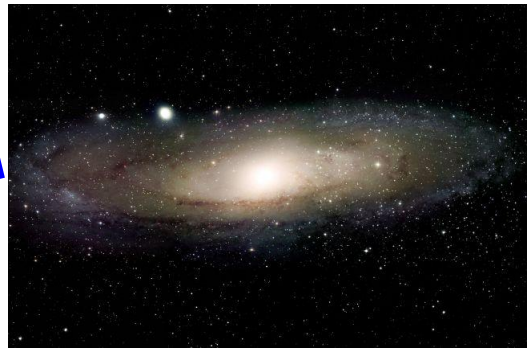
  Multi purpose low-background and low-energy threshold experiment with liquid Xenon

  - **X**enon detector for Weakly Interacting **MASS**ive Particles (**DM search**)
  - **X**enon **MASS**ive detector for solar neutrino (**pp/^{7}Be**)
  - **X**enon neutrino **MASS** detector (**ββ decay**)

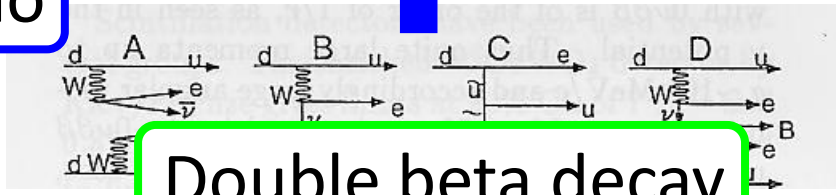


Solar neutrino





Dark Matter



Double beta decay

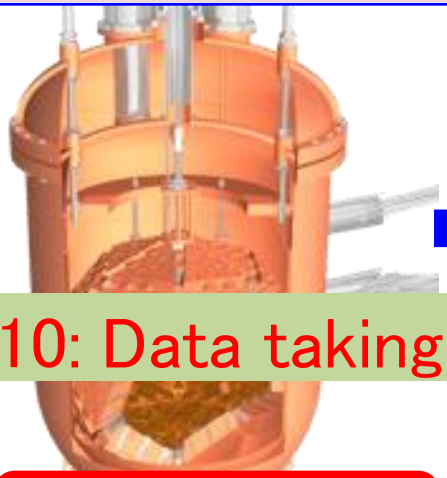
Phases of XMASS experiment

100kg Prototype
（FV:30kg, ~30cm）

800kg Detector
（FV:100kg, 80cm）

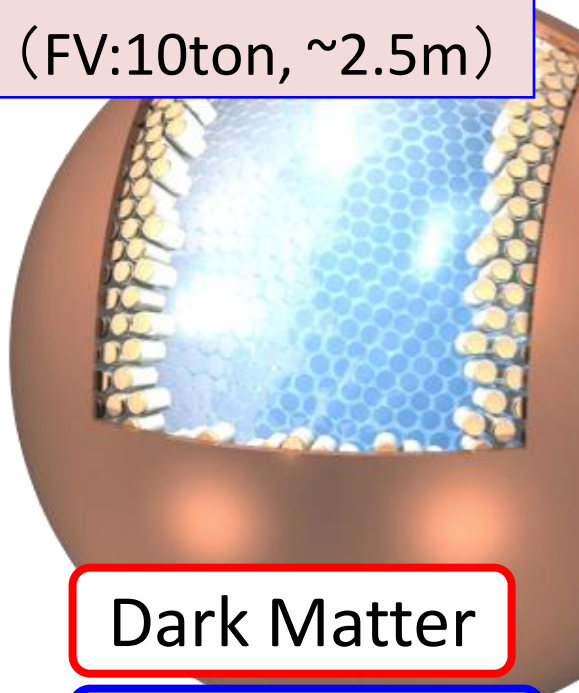
20ton Detector
（FV:10ton, ~2.5m）

Completed



2010: Data taking

Dark Matter



Dark Matter

Solar neutrino

Double beta decay

XMASS collaboration

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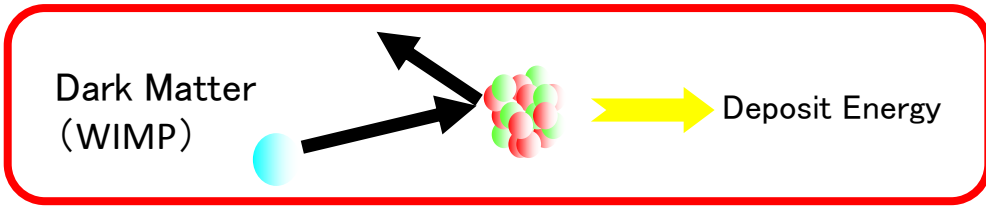
Direct Detection Principle

WIMPs elastically scatter off nuclei in targets, producing nuclear recoils.

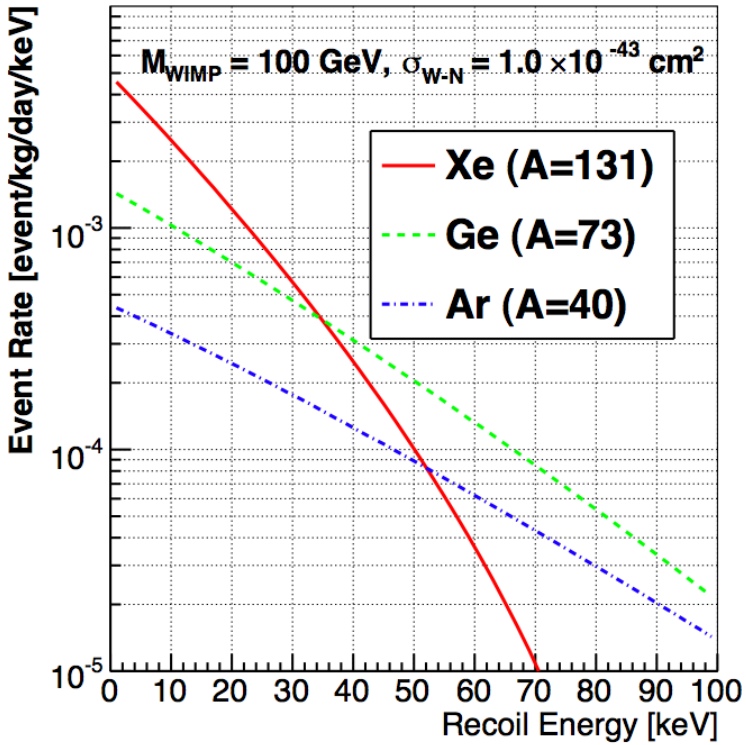
- **From the density of dark matter in the galaxy:**
- **Every liter of space: 10-100 WIMPs,**
- **moving at 1/1000 the speed of light**
- **Less than 1 WIMP/week will collide with an atom in 1kg material**



$$\frac{dR}{dE_R} = \frac{R_0 F^2(E_R)}{E_0 r} \frac{k_0}{k} \frac{1}{2\pi v_0} \int_{v_{min}}^{v_{max}} \frac{1}{v} f(\mathbf{v}, \mathbf{v_E}) d^3\mathbf{v}$$

R_0: Event rate
F: Form Factor should be calculated in each nuclei

Maxwellian distribution for DM velocity is assumed.
v_0:dispersion
V :velocity onto target,
V_E: Earth's motion around the Sun



$$R_0 = \frac{377}{M_\chi M_N} \left(\frac{\sigma_0}{1\text{pb}}\right) \left(\frac{\rho_D}{0.3\text{GeVc}^{-2}\text{cm}^{-3}}\right) \left(\frac{v_0}{230\text{km s}^{-1}}\right) \text{kg d}^{-1}$$

Spin independent case:

$$\sigma_0 = A^2 \frac{\mu_T^2}{\mu_p^2} \sigma_{\chi-p}$$

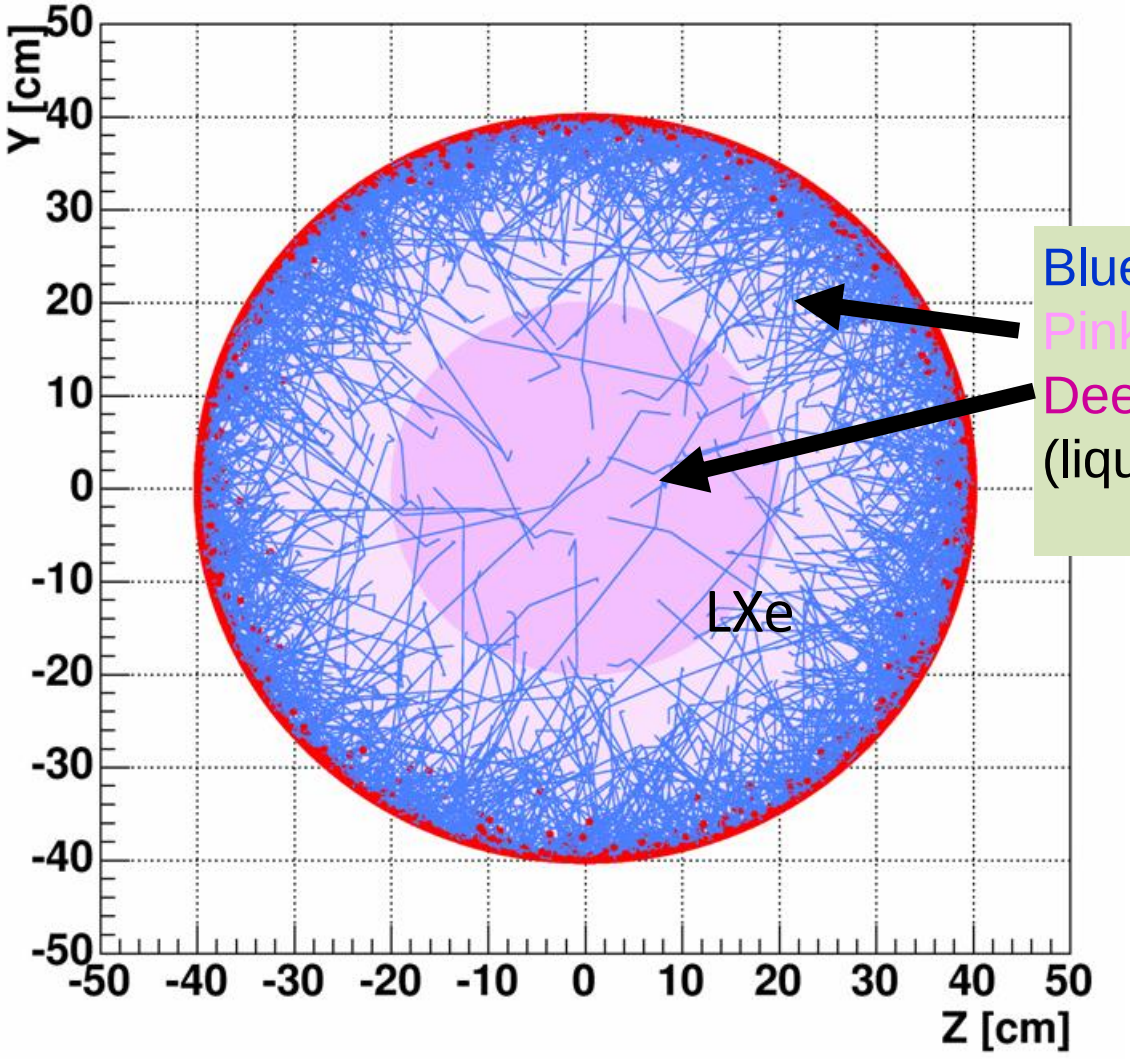
Larger A is higher event rate

Xe (A=131) is one of the best target.

Why Liquid Xenon ?

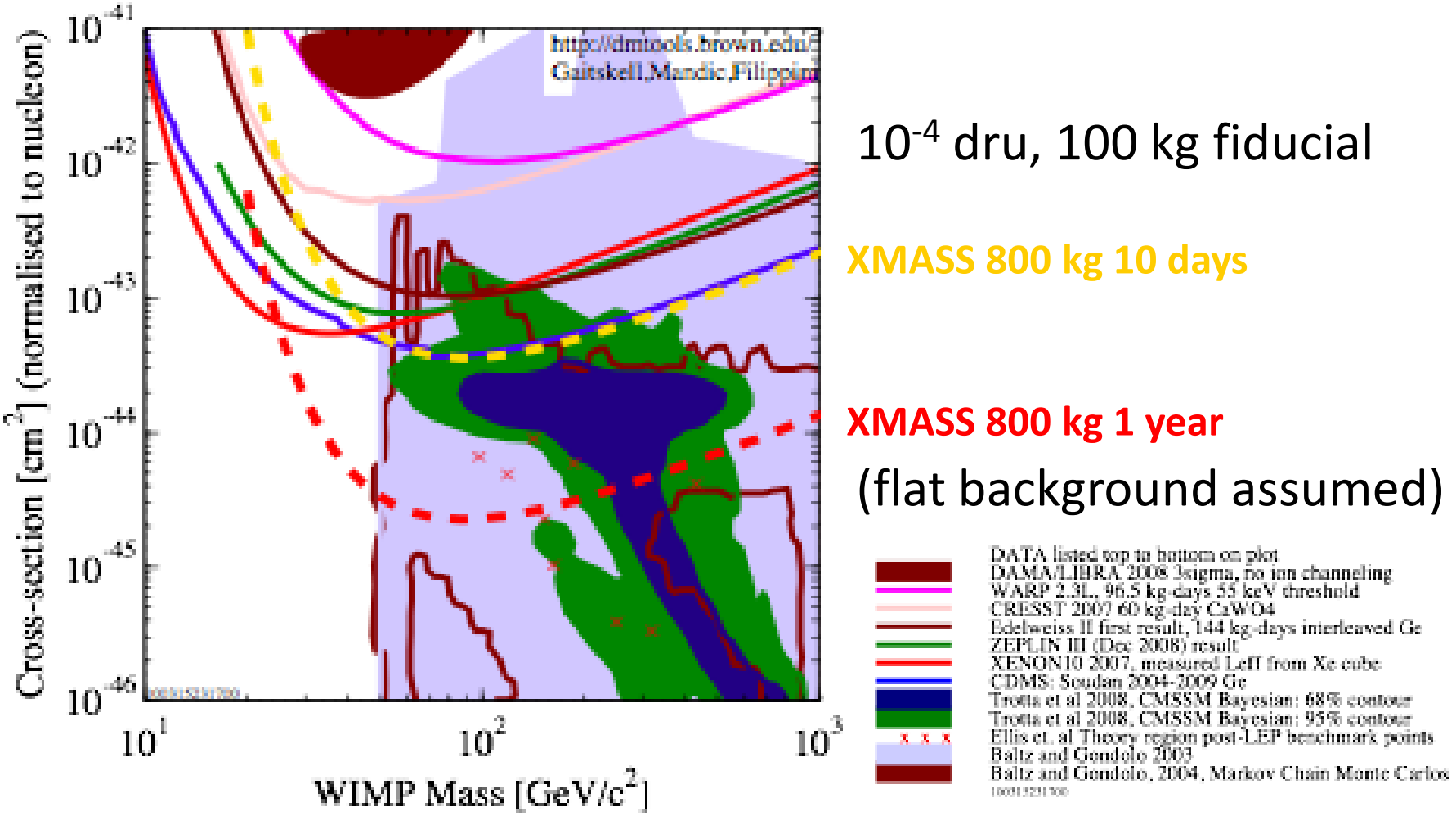
- High Atomic mass Xe (A~131)
  - good for SI case (cross section $\propto A^2$)
- Odd Isotope (Nat. abun: 48%, 129,131) with large SD enhancement factors
- High atomic number (Z=54) and density (ρ=3g/cm^3)
  - compact, flexible and large mass detector.
- High photon yield (~ 42 UV photons/keV at zero field)
- No long life radioactive isotope
- Easy to purify for both electro-negative and radioactive purity
  - by circulating Xe with getter for electro-negative
  - Distillation for Kr removal

External gamma-ray MC



Blue : track
Pink : self-shield (liquid xenon)
Deep pink : fiducial volume (liquid xenon)

Sensitivity for SI case



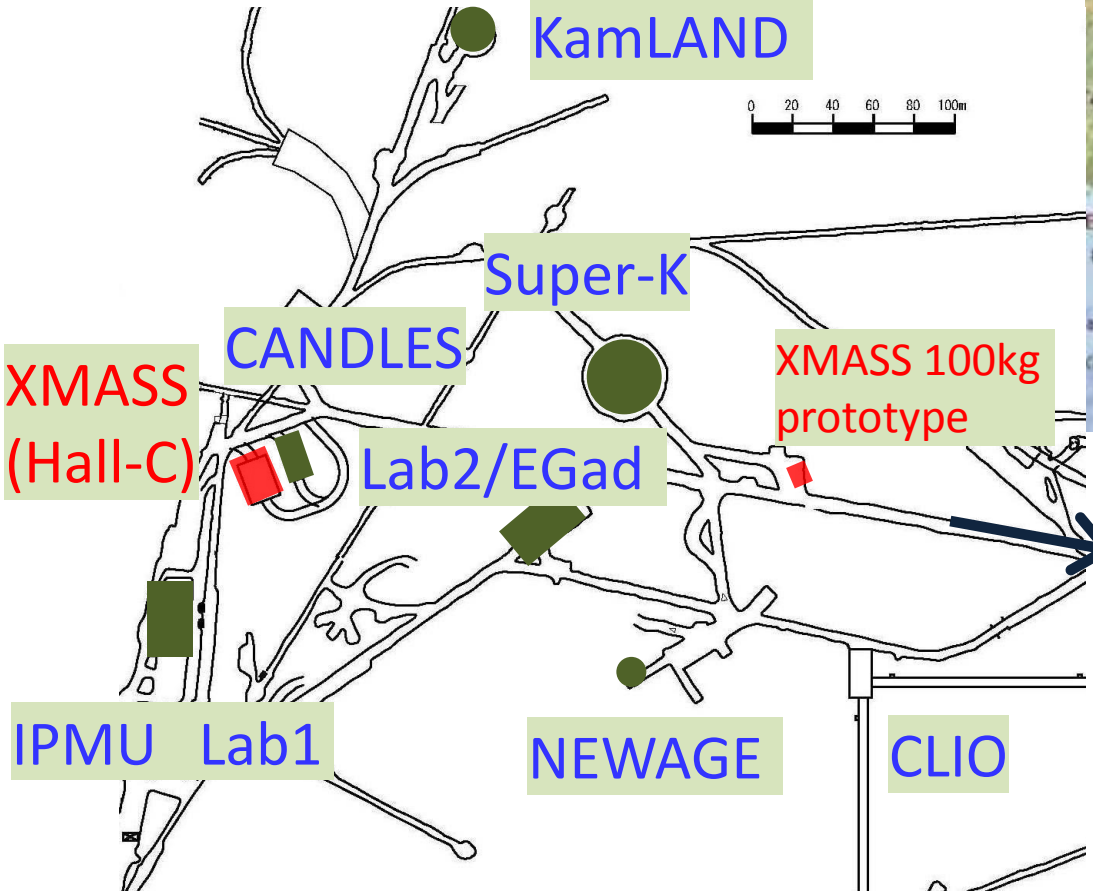
10^{-4} dru, 100 kg fiducial

XMASS 800 kg 10 days

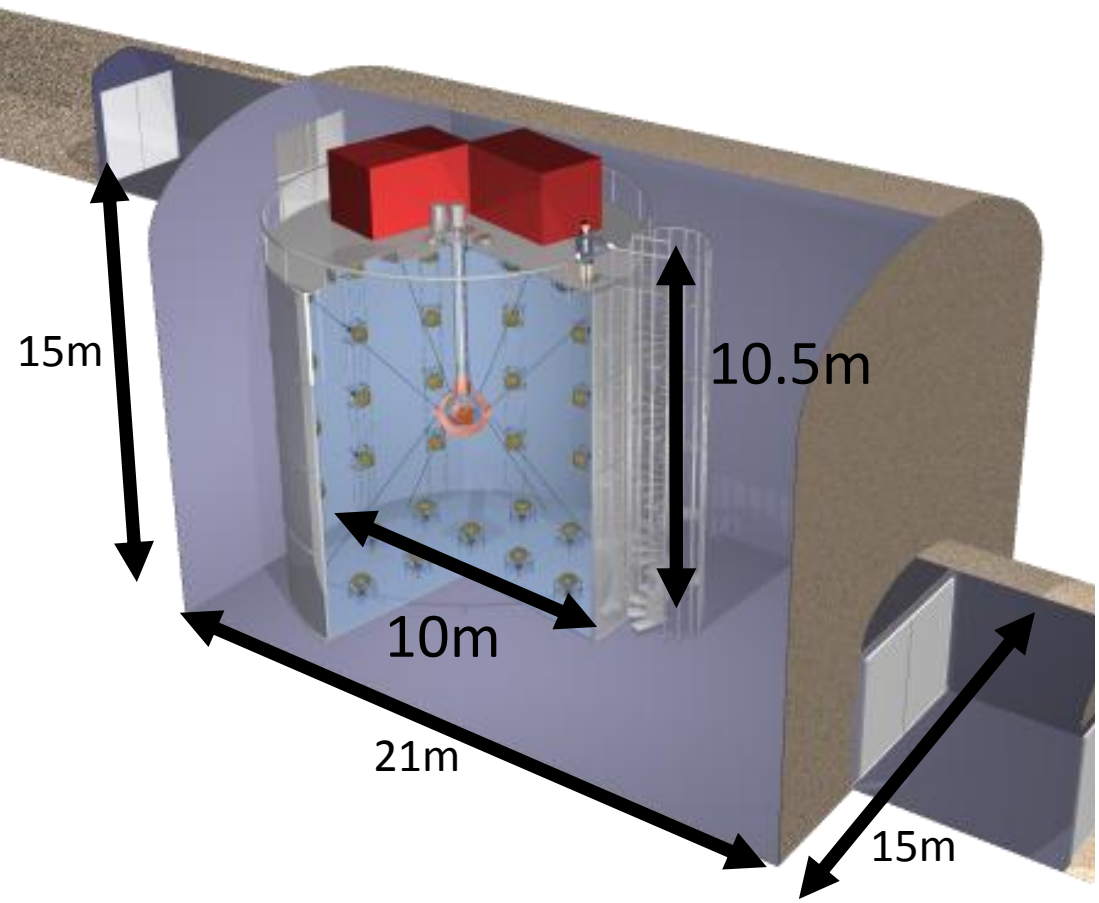
XMASS 800 kg 1 year

(flat background assumed)

Kamioka mine



XMASS milestone



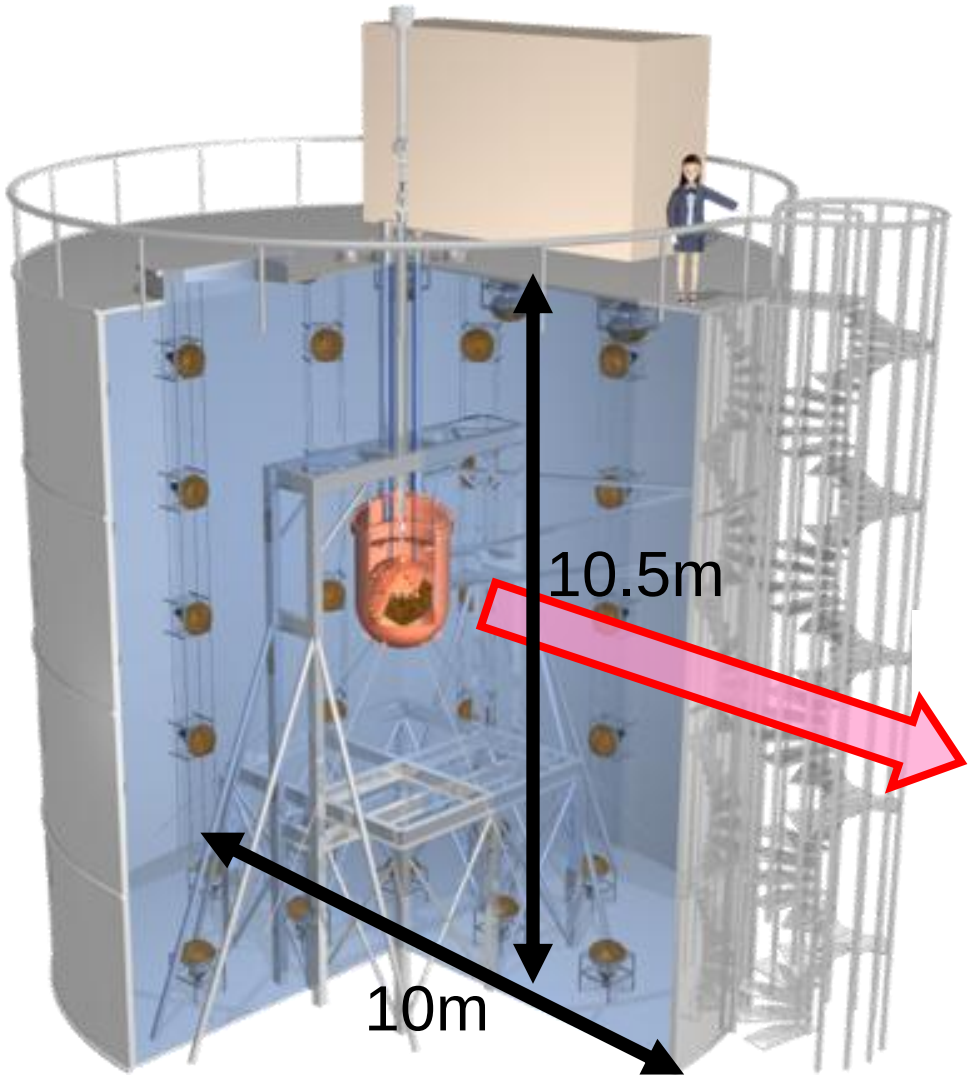
- Facility
  - Experimental Hall (1000m underground)
  - Water Tank
  - Water purification system
  - Radon free air system
- Detector
  - Liquid xenon, PMT
  - PMT Holder, Filler
  - Inner Vacuum Chamber (IVC)
  - Outer Vacuum Chamber (OVC)

Hall-C

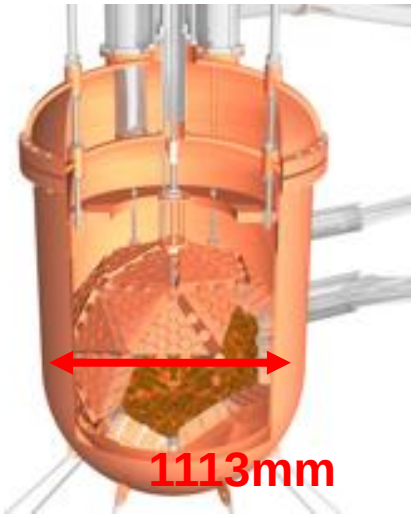
In Mar. 2008, excavation is finished.

- Hall-C facility was completed in Mar. 2009.
- urethane resin for radon shield on the wall and floor.
- air from the outside the mine (8m^3/min, ~20Bq/m^3)
- Water tank construction is completed in Mar. 2009.

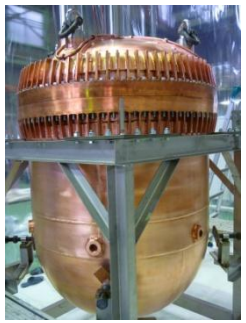
detector



•72 20-inch PMTs will be installed to veto cosmic-ray muon (<10^{-6} for thr-mu, 10^{-4} for stop-mu).
•Water is active shield for muon induced neutron and also passive shield for gamma-ray and neutron from rock/wall.
•IVC and OVC are made of OFHC (Oxygen-free high thermal conductivity) copper

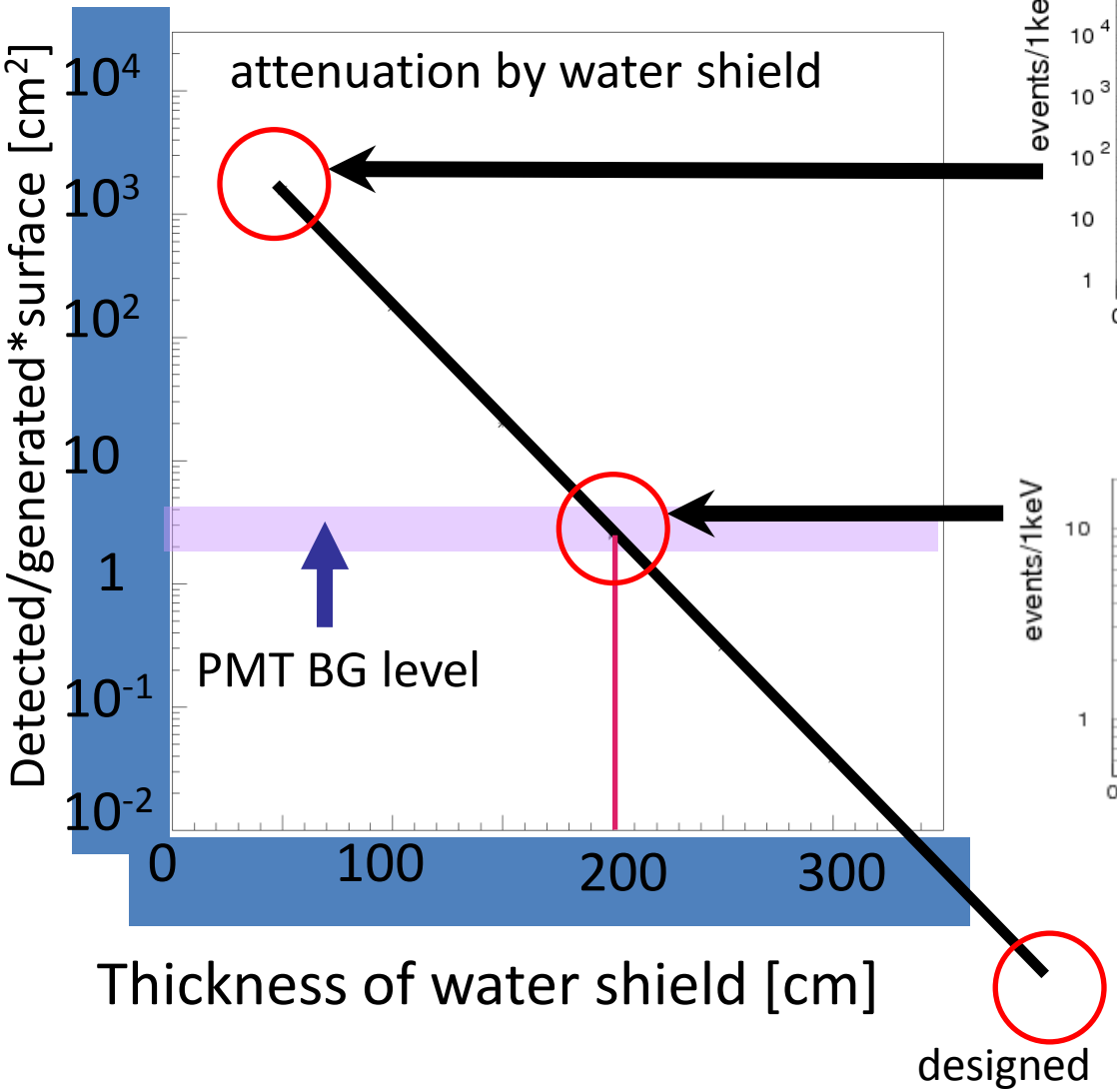


OVC

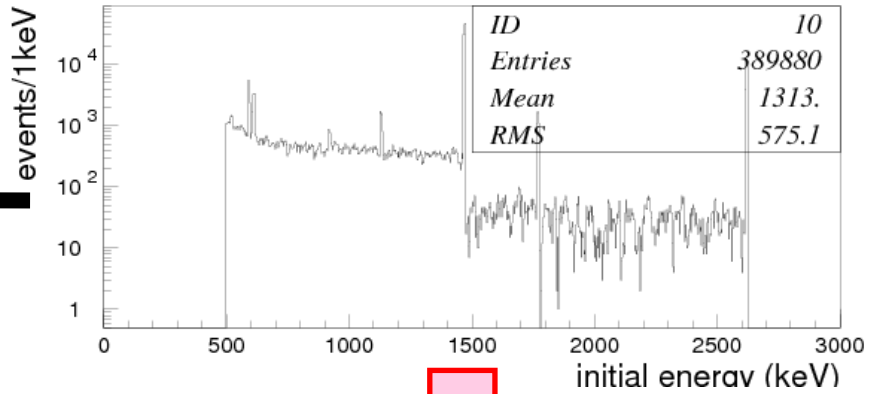


IVC

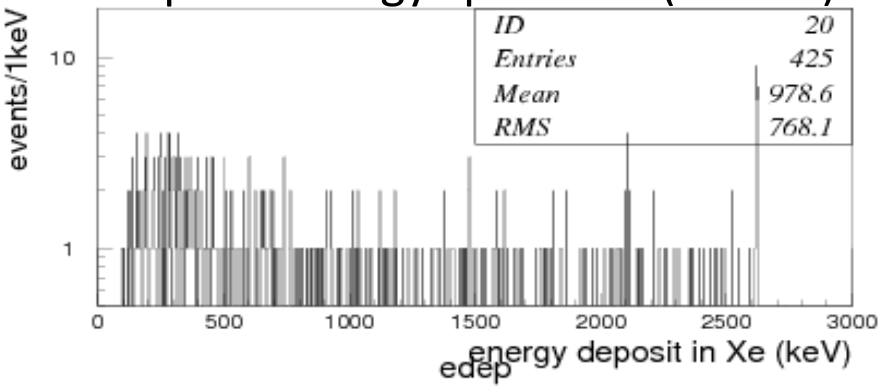
Water shield for gamma-ray background



Initial energy spectrum from the rock



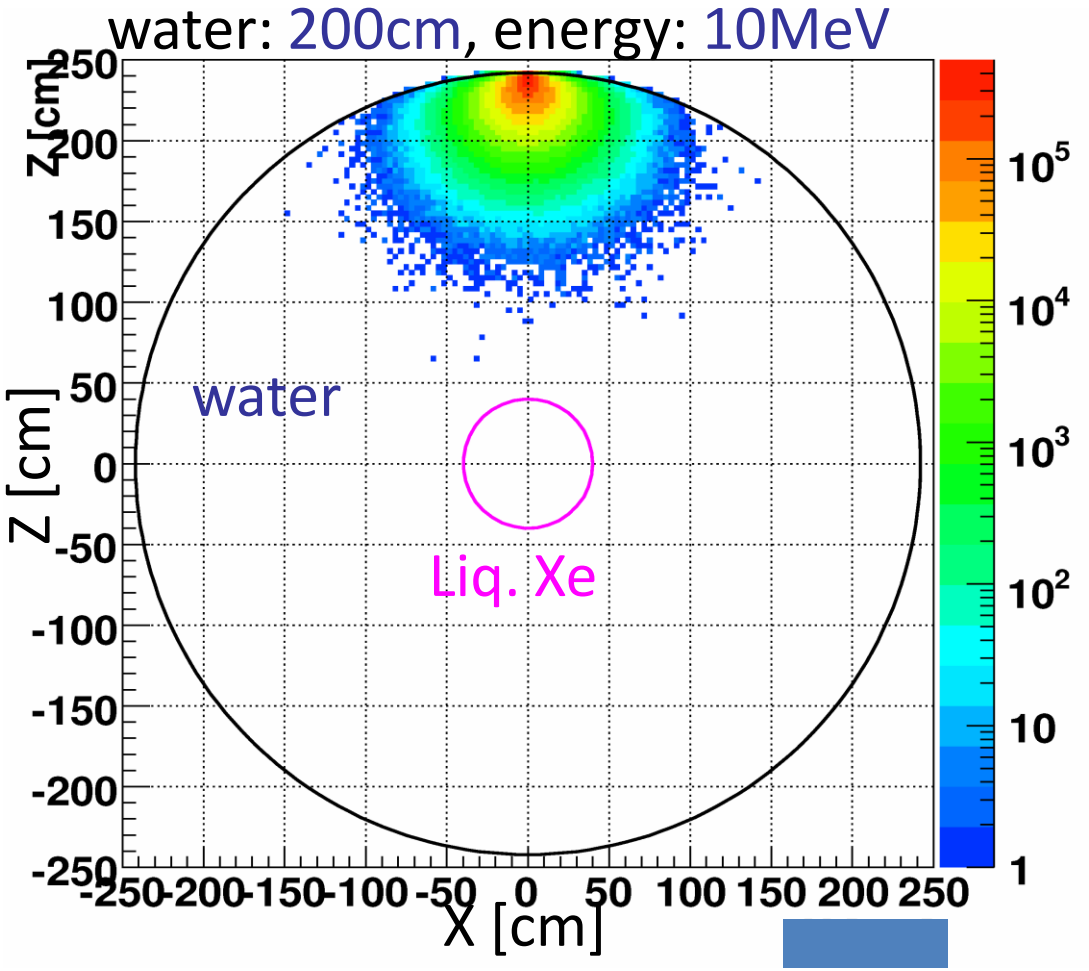
Deposit energy spectrum (200cm)



More than 200cm water is needed to reduce the BG to the PMT BG level

Water Shield for fast neutron background

- Fast n flux @Kamioka mine:
  $(1.15\pm0.12) \times 10^{-5}$ /cm^2/sec



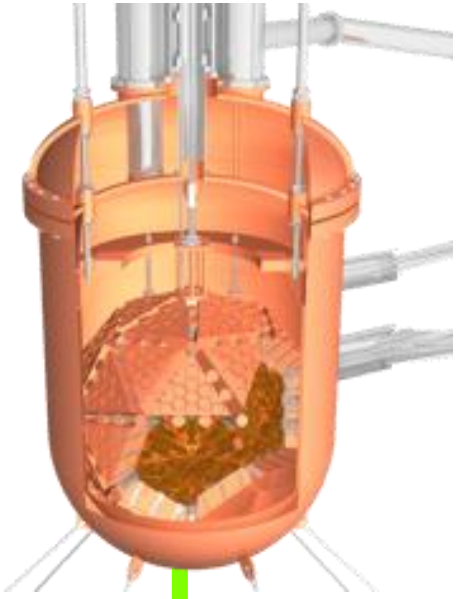
- Assuming all neutron's energies are 10 MeV very conservatively

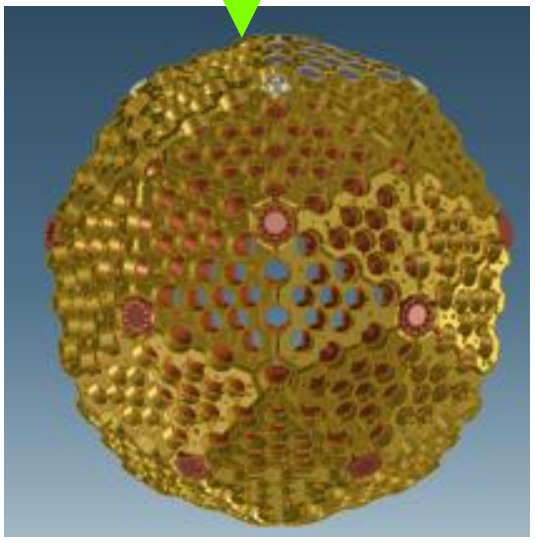
Generat:10^7 MC events, no event in Liquid Xe volume

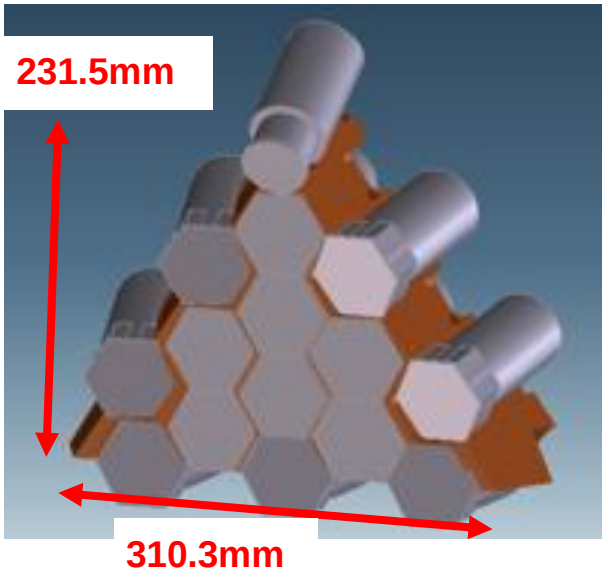
$< 2 \times 10^{-4}$ counts/day/kg

200cm of water is enough to reduce the fast neutron

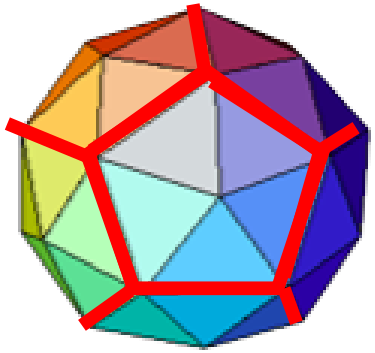
Detector design detail







pentakisdodecahedron



Hexagonal PMT
Hamamatsu R10789

- 60 triangles
- Total: 642PMTs
- Photo coverage: 62%
- Diameter: ~800mm

PMT

XMASS PMT HISTORY



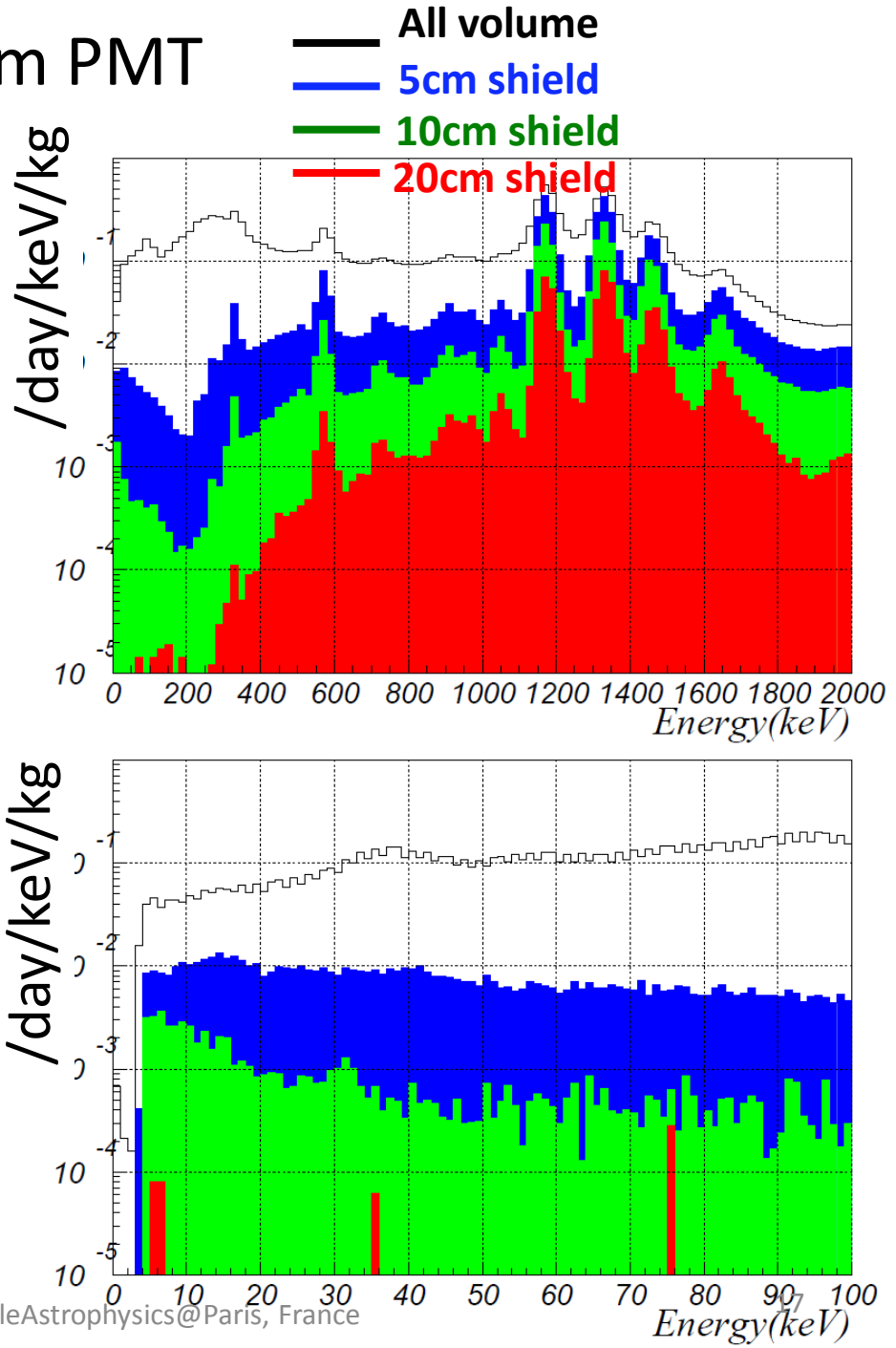
YEAR	2000	2002	2009
Model	Prototype	R8778	R10789
Material:Body	glass	Kovar	Kovar
QE	25%	25%	27-39%
RI:			
U [mBq/PMT]	*50*	*18±2*	*0.7 ± 0.28*
Th [mBq/PMT]	*13*	*6.9±1.3*	*1.5 ± 0.31*
^{40}K [mBq/PMT]	*610*	*140±20*	*<5.1*
^{60}Co [mBq/PMT]	*<1.8*	*5.5±0.9*	*2.9 ± 0.16*

With base

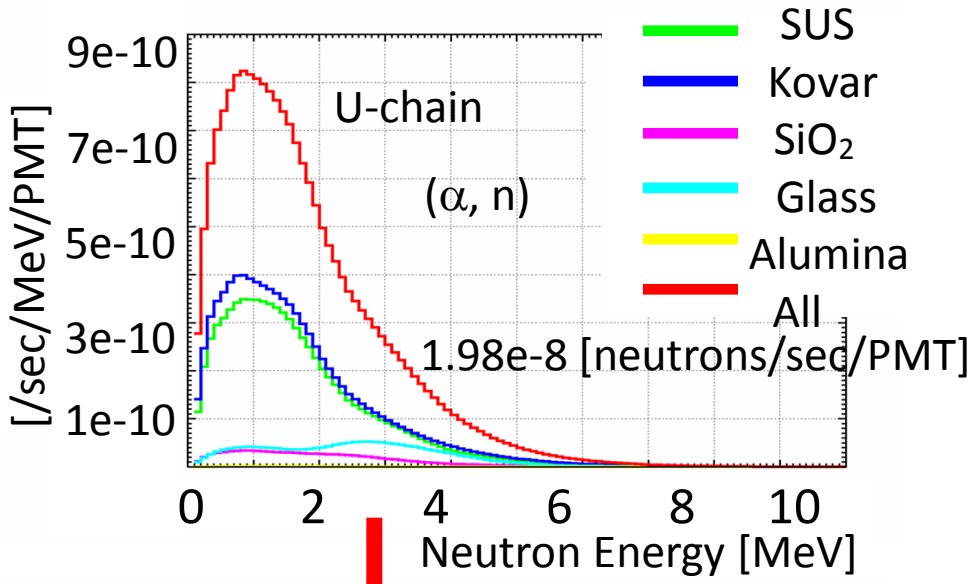
- Developed with Hamamatsu Photonics K.K.
- Mass production of the PMTs was completed in Oct. 2009.

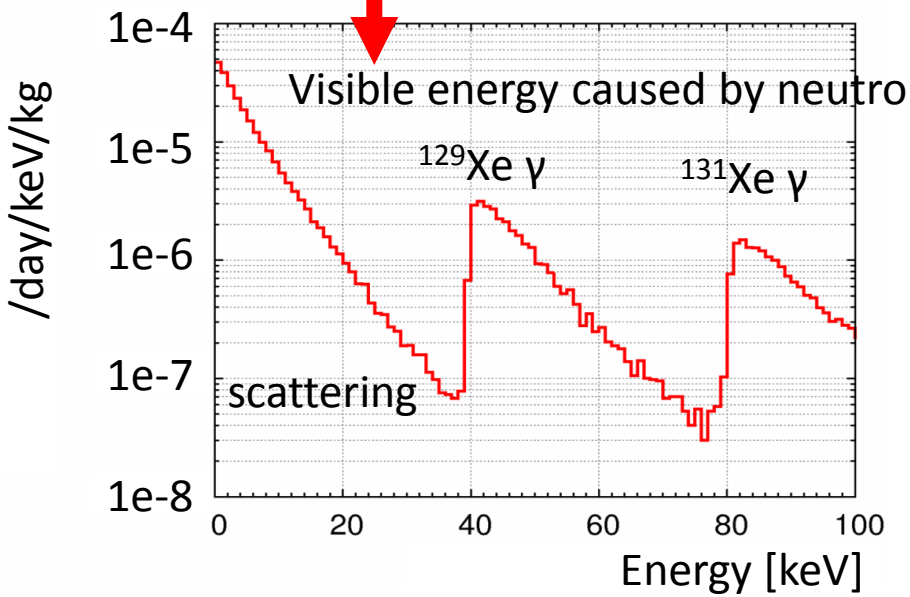
gamma-ray background from PMT

- Activity of PMT
  - **^{238}U chain 1.8x10^{-3} Bq/PMT**
  - **^{232}Th chain 6.9x10^{-4} Bq/PMT**
  - **^{60}Co 5.5x10^{-3} Bq/PMT**
  - **^{40}K 1.4x10^{-2} Bq/PMT**
- Below 300 keV,
  - number of events in the 20cm fiducial volume decreases.
  - <10^{-4}dru background level.



neutron background from PMT

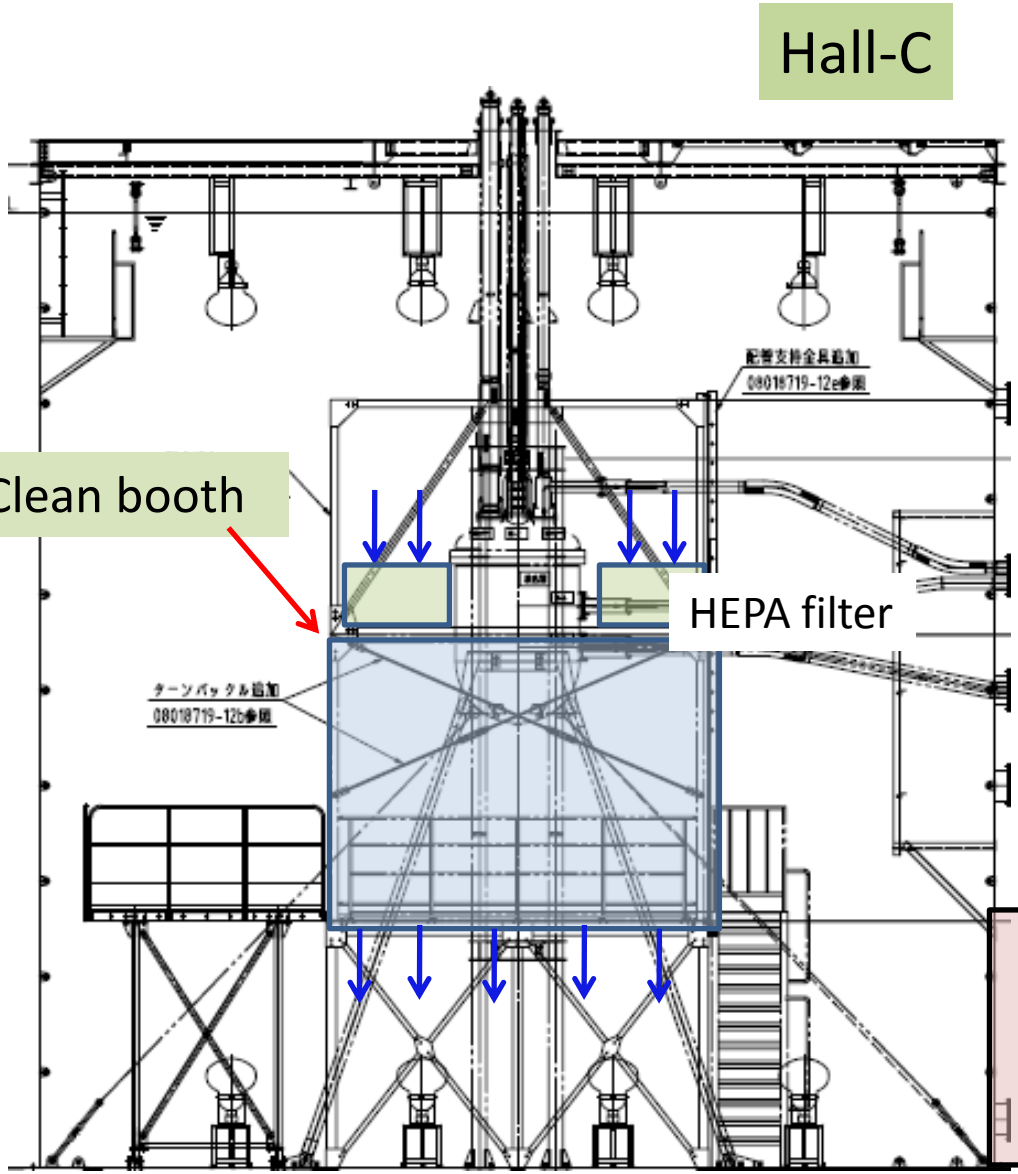




Estimate the generation rate of (α, n) neutron and SF neutron, originated from the U/Th of R10789 using SOURCES*.

* V. Tomasello et.al. NIM A 595 (2008) 431‧438

PMT, holder, and filler installation



- Dust and radon in the air could be background source.
- Dust from mine is shielded by two shutters.
- Water tank is closed and is filled with radon-free air.
- Clean booth is made in the water tank for the installation.
- During the installation, radon concentration is ~200mBq/m^3.
- Dust level is <1000/ft^3.

Clean booth in the water tank

- **No smoking two hours before the work**
- **No beard**
- **No make up**

Base with clean booth
For the detector assembly

PMT/holder installation

PMT installation was done from Dec. 2009 to Feb. 2010.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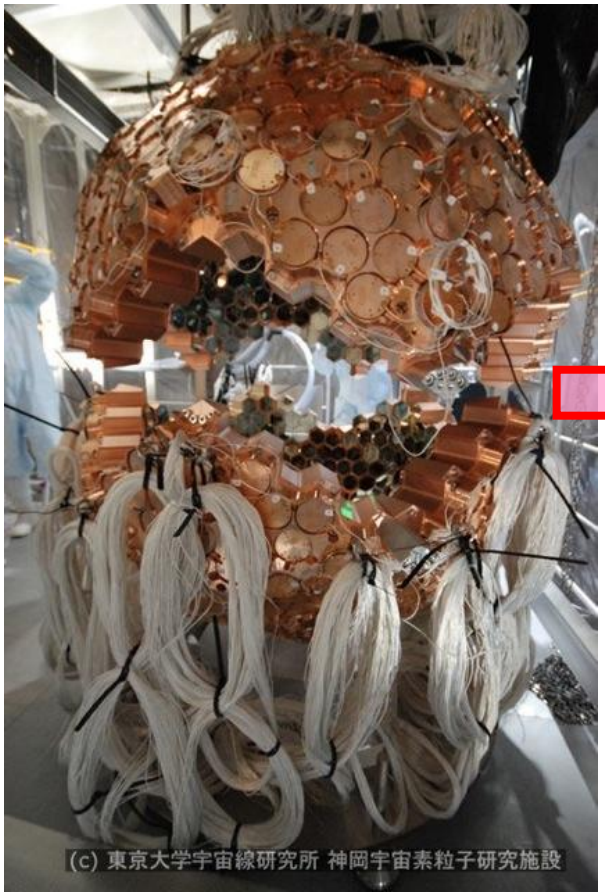
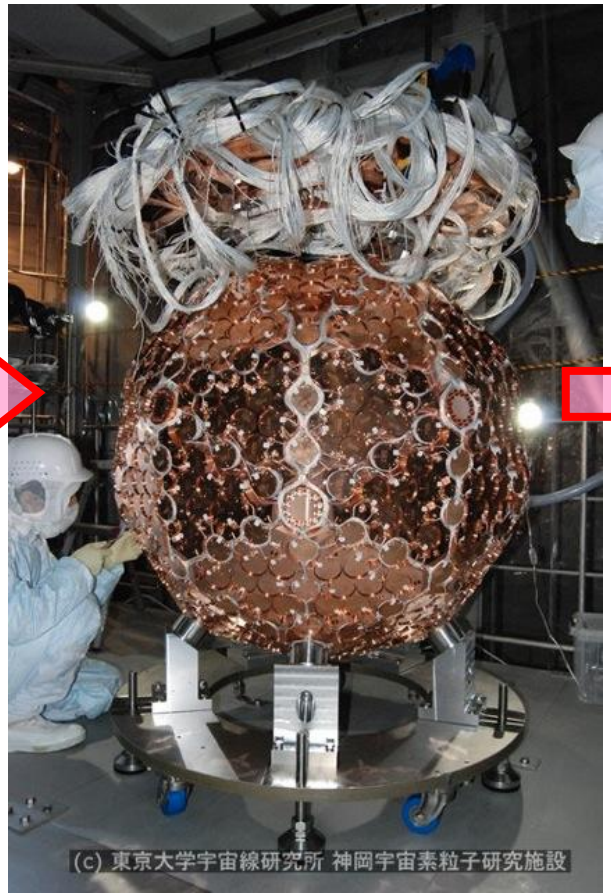
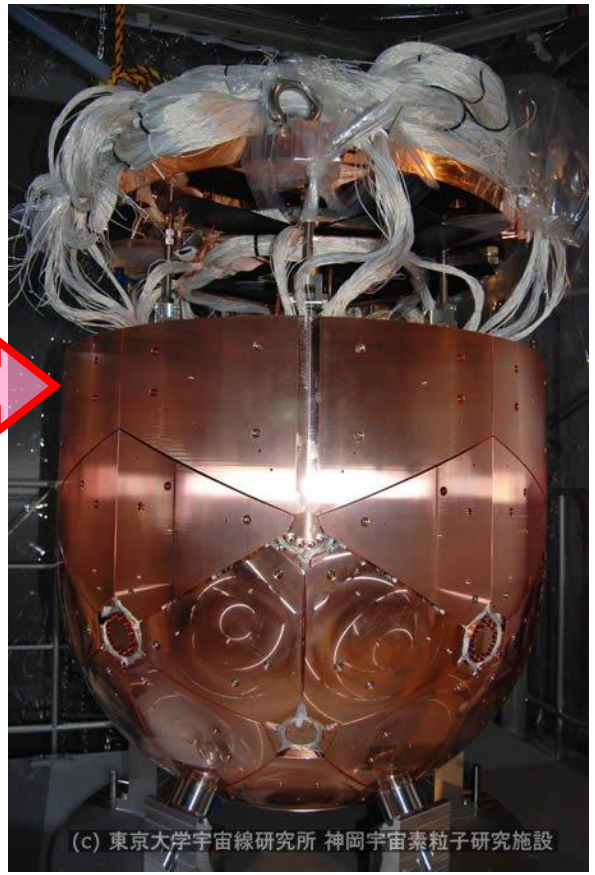
PMT holder







OFHC Filler to reduce the amount of liquid xenon

Summary

- XMASS 800kg detector construction is ongoing
  - PMT, holder, and Filler installation was completed.
  - IVC/OVC is coming soon. Then chamber and pipes will be installed.
- WIMP search run will start after the commissioning.