

Dark matter search at XMASS

2013 Shanghai Particle Physics and Cosmology Symposium (SPCS2013)
Shanghai, China, June 3–5, 2013
5th of Jun. 2013

Atsushi Takeda for XMASS Collaboration

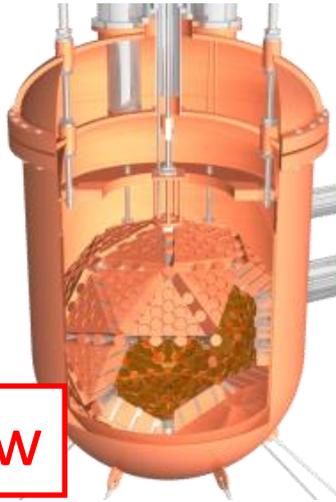


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XMASS project

XMASS-I



Now

835 kg,
100 kg Fiducial volume (FV)

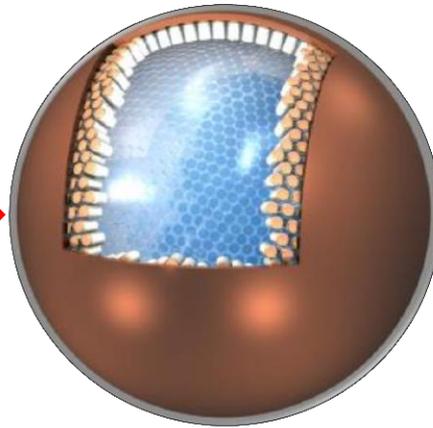
ϕ 80 cm, 642 PMTs

Since 2010 Nov.

Refurbishment work is
on going

- Dark matter search

XMASS-1.5

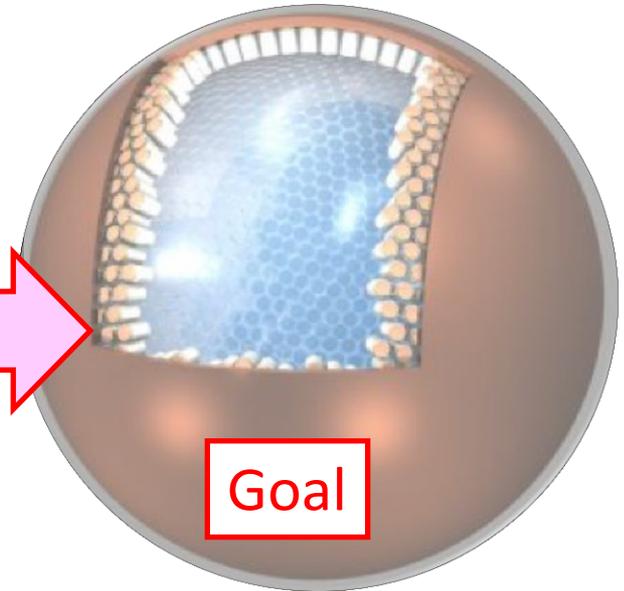


5 ton,
1 ton FV

ϕ 1.5 m, ~1000 PMTs

- Dark matter search

XMASS-II



Goal

25 ton, **10 ton FV**
 ϕ 2.5 m

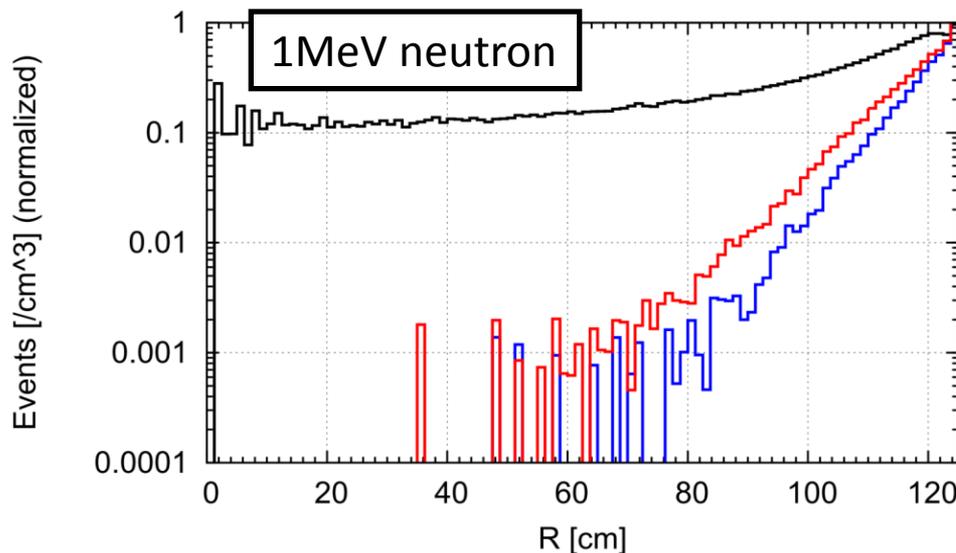
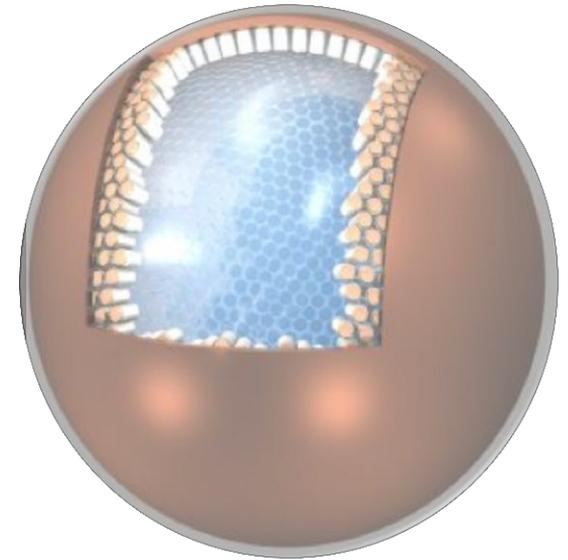
Multi purpose

- Dark matter
- pp solar neutrino
- $0\nu 2\beta$ decay

Y. Suzuki, hep-ph/0008296

XMASS detector

- Single phase detector using ultra pure liquid xenon
 - **Simple and good scalability**
 - No need for complicate structure like an HV
 - BG reduction by self-shielding
 - Effective even for neutron BG
 - High light yield & low energy threshold
 - Sensitive for e/ γ events



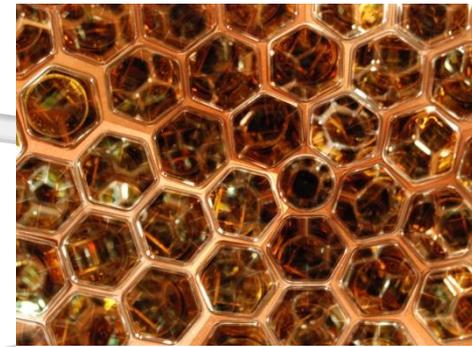
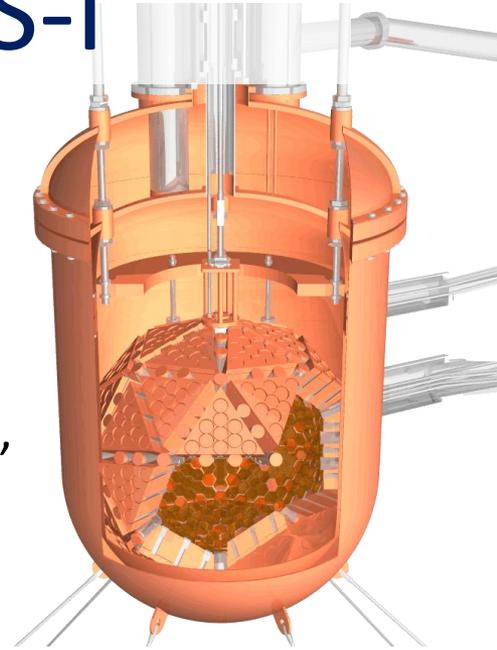
XMASS-2 ($\phi 2.5\text{m}$)

Black: all events
Blue: $2 < E(\text{keVee}) < 5 \text{ keV}$
Red: $2 < E(\text{keVee}) < 10 \text{ keV}$
Green: F.V. (30cm from wall)

2. Status of XMASS-I

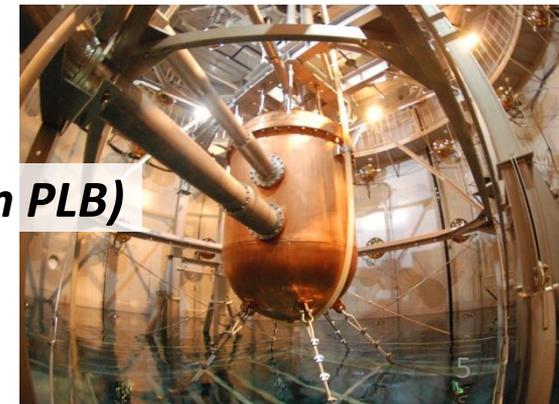
Performance

- Detail: ***NIMA 716 (2013) 78***
- Using 835 kg ultra pure liquid xenon,
 - **World largest**
 - **Lowest threshold (0.3keVee)**detector for dark matter search
- Commissioning runs were conducted (2010/10–2012/5)



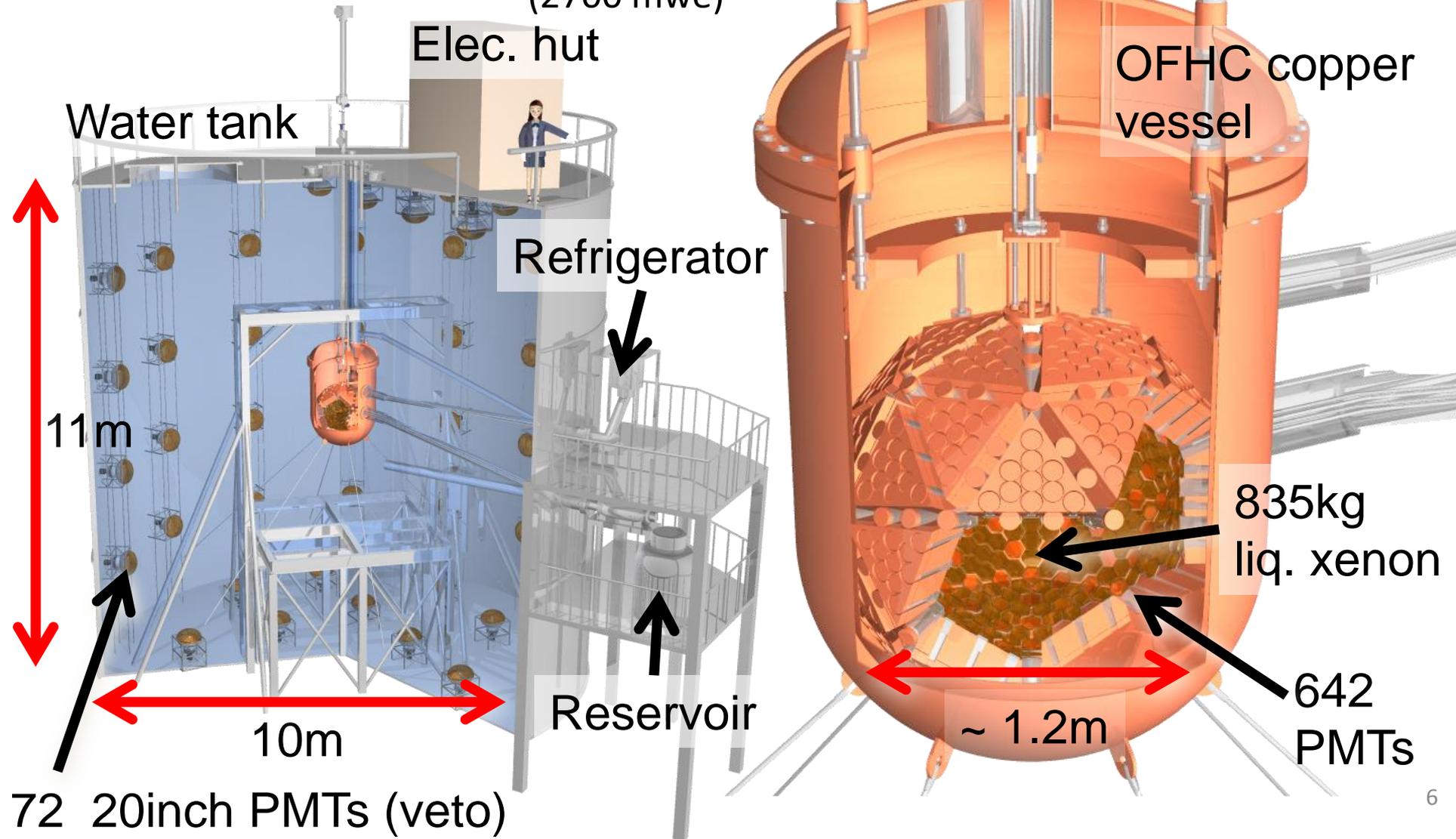
Results

- Low mass WIMPs search: ***PLB 719 (2013) 78***
- Solar Axion search: ***arXiv:1212.6153 (to be published in PLB)***
- Seasonal modulation for DM search (being analyzed)
- Inelastic scattering DM search (being analyzed)



Detector configuration

@ Laboratory C in Kamioka observatory
(2700 mwe)

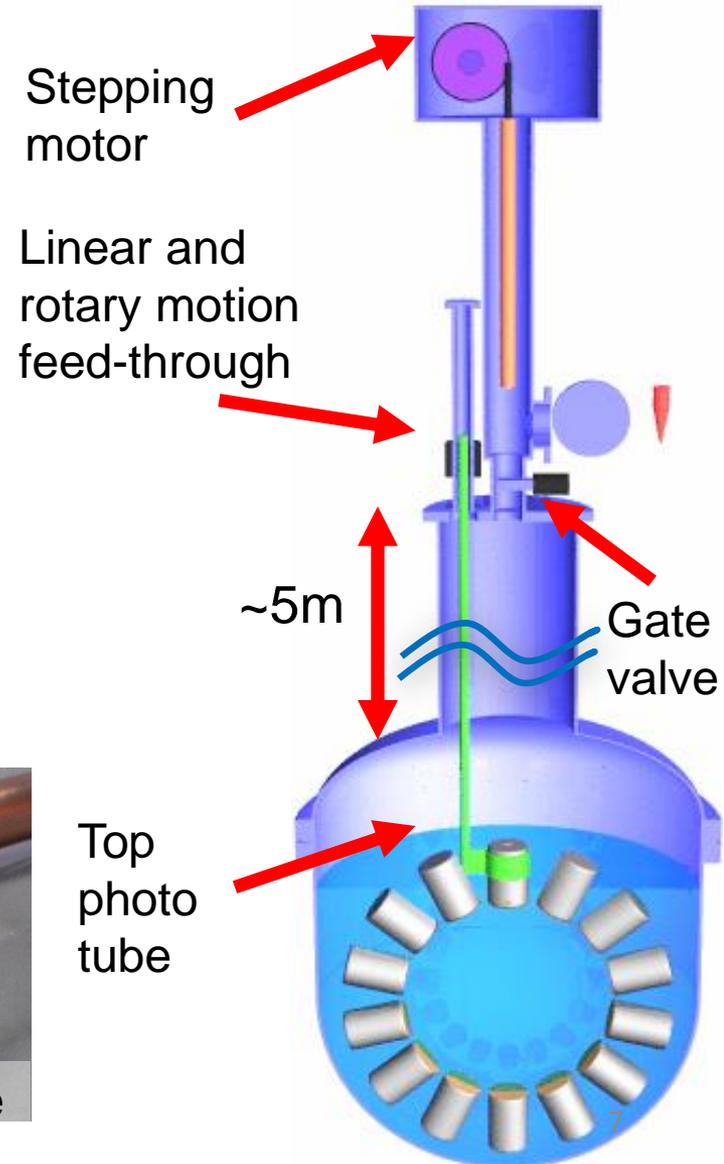


Detector calibration

RI	Energy [keV]	[Hz]	dia. [mm]
(1) Fe-55	5.9	350	5
(2) Cd-109	8(*1), 22, 25, 88	800	5
(3) Am-241	17.8, 59.5	485	0.21
(4) Co-57	59.3(*2), 122	40	0.21
(5) Cs-137	662	200	5

(*1) $K\alpha$ X-rays from the copper used for housing.

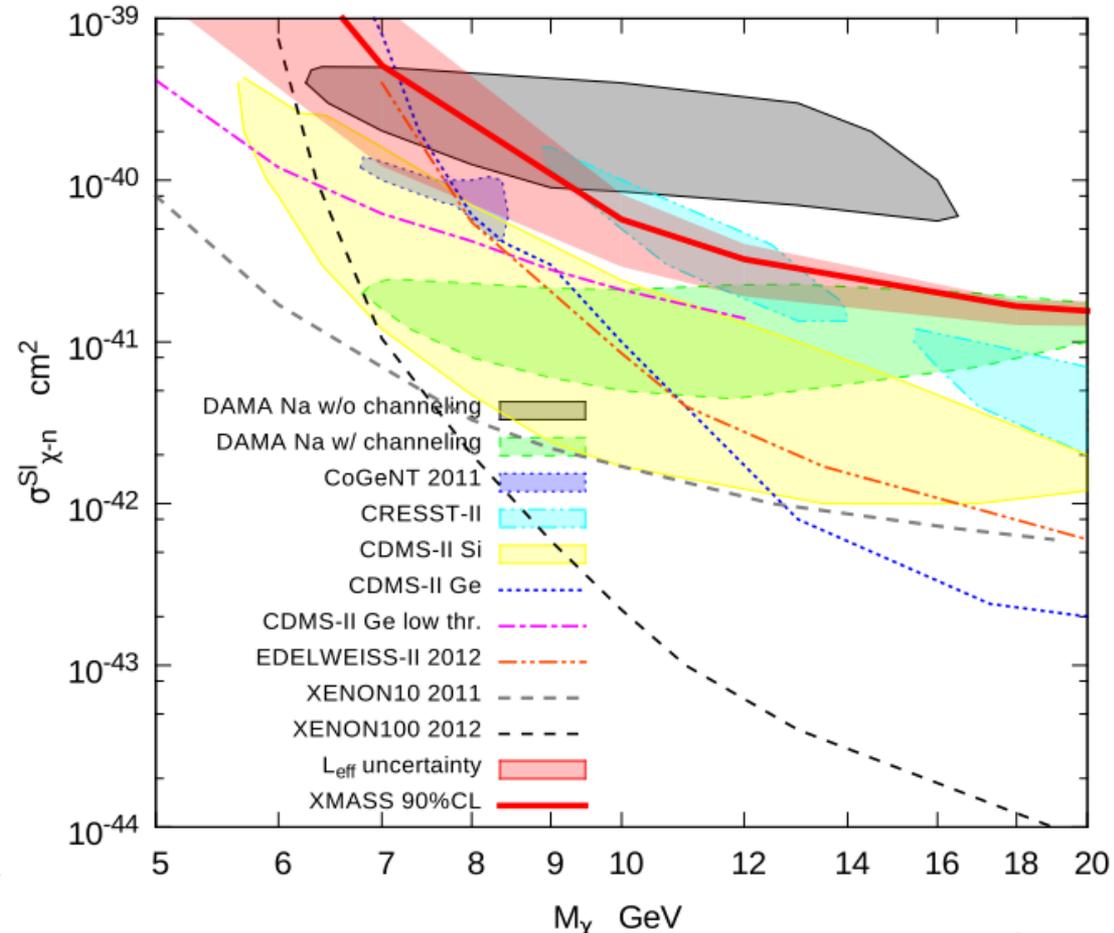
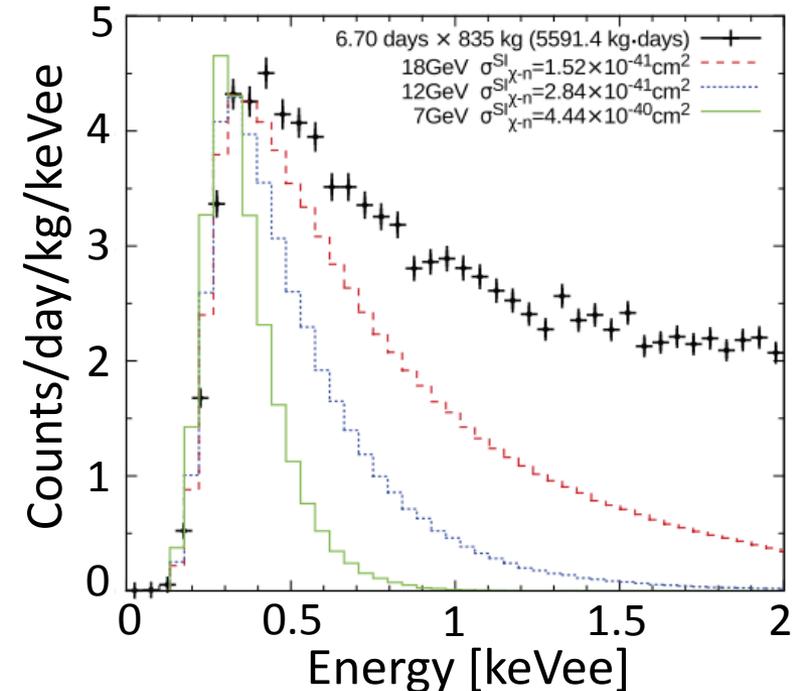
(*2) $K\alpha$ X-rays from the tungsten used for housing.



Low mass WIMPs search

PLB 719 (2013) 78-82

- Full volume (835 kg) analysis
- 6.80 days in 2012 Feb.
- 5591.4 kg day exposure
- 0.3 keVee threshold

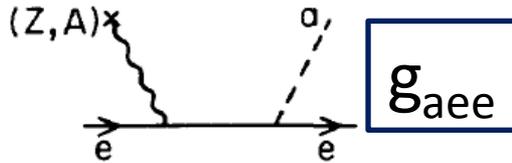


Solar Axion search

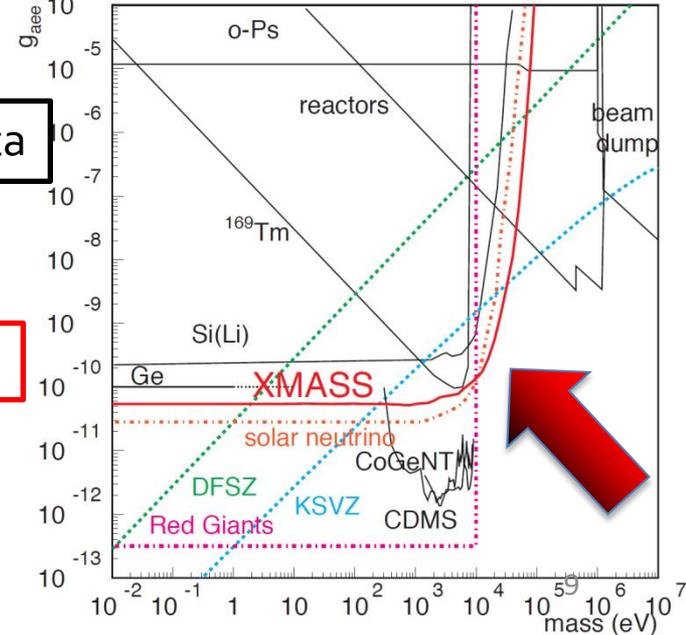
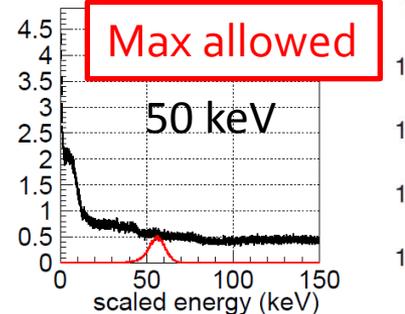
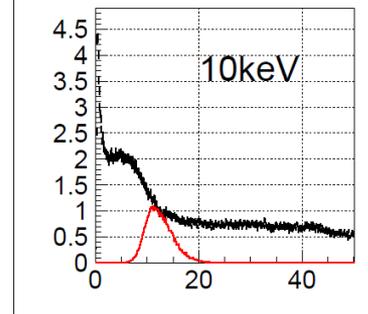
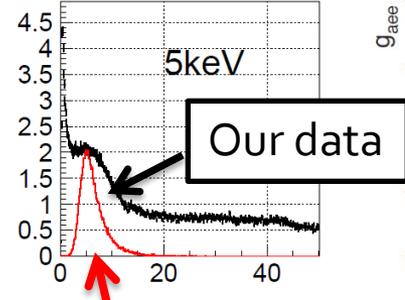
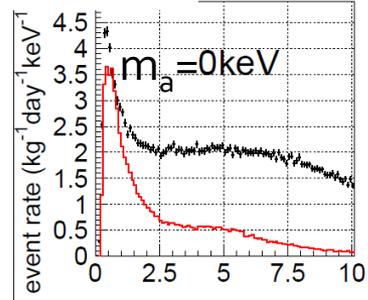
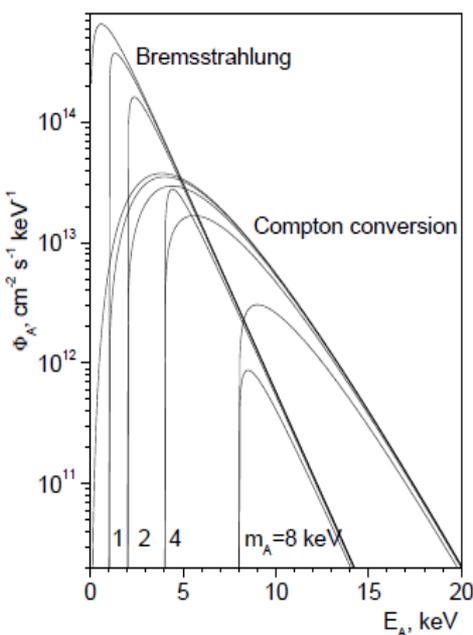
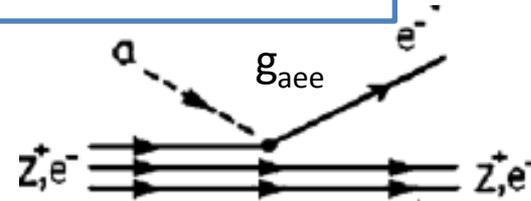
arXiv: 1212.6153, to be published in PLB

- Axion is a hypothetical particle to solve the strong CP problem
- Produced in the Sun and detected in the detector
- XMASS is suitable to search because of a large mass and low BG

Bremsstrahlung and Compton effect

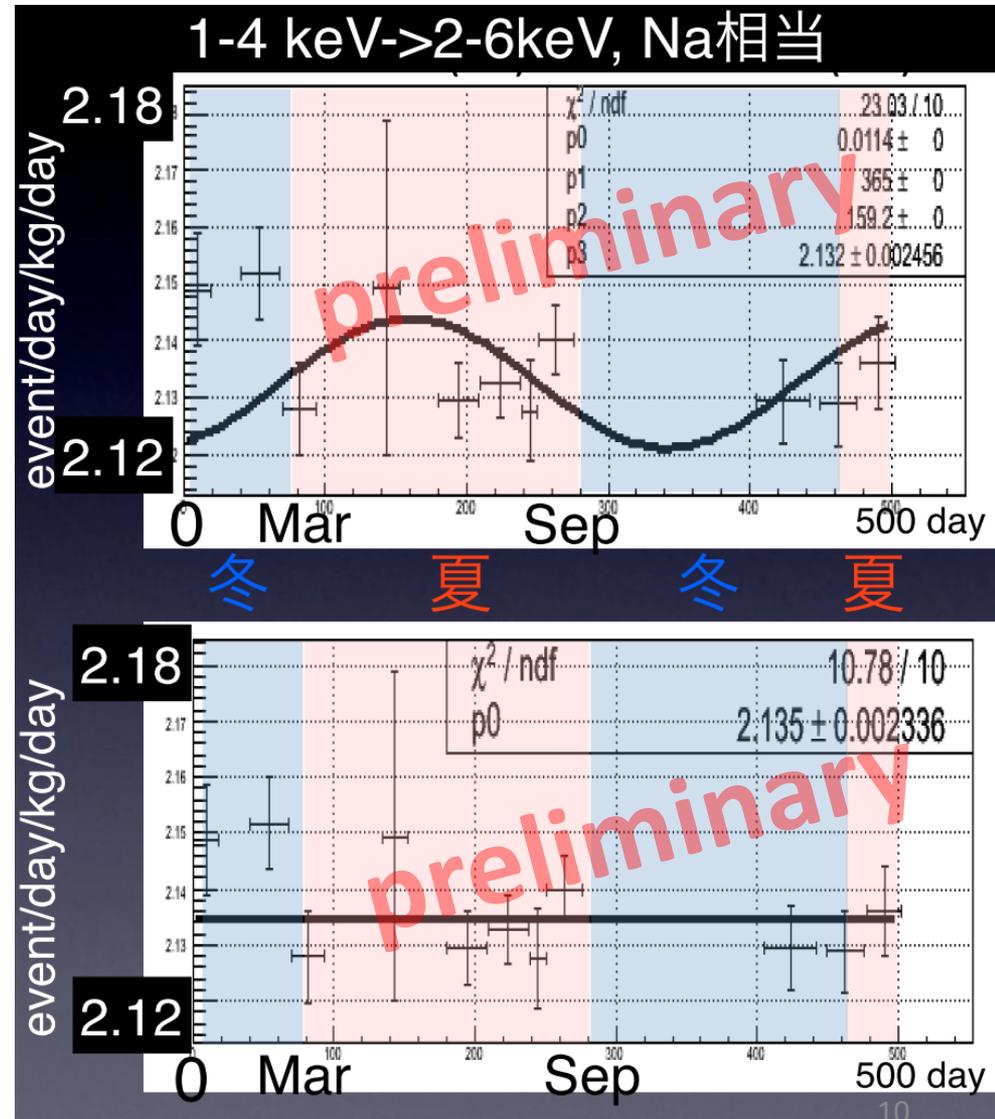


Axio-electric effect

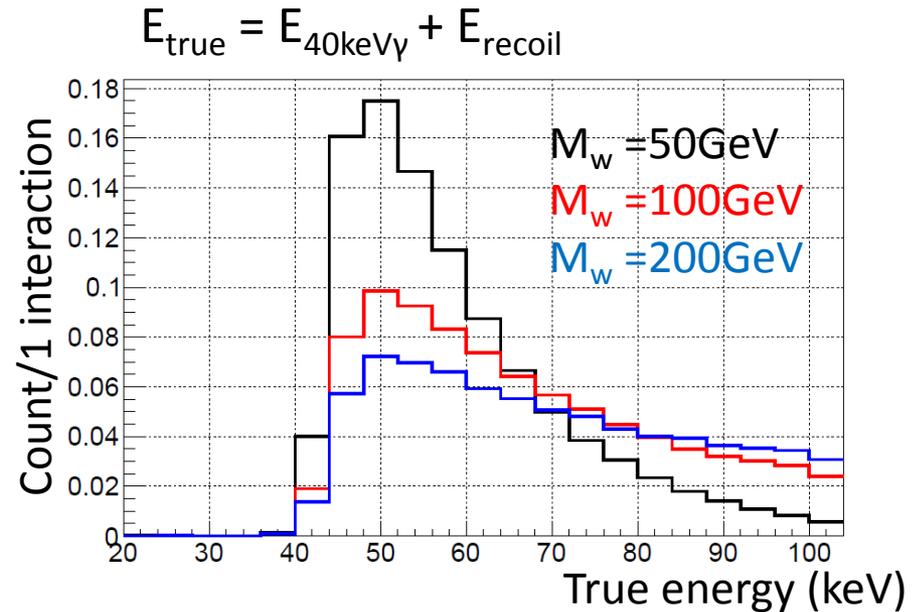
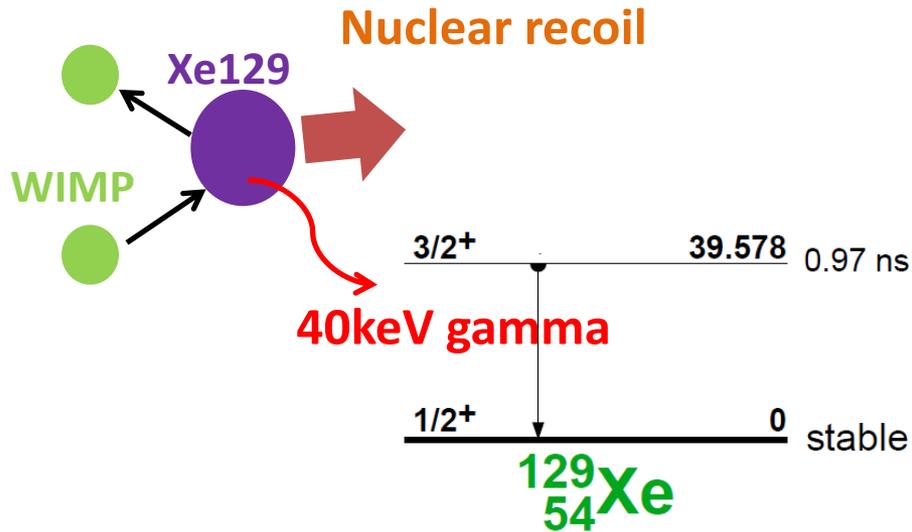


Seasonal modulation for DM search

- 160 days \times 835 kg exposure (Preliminary)
- In commissioning run, several kind of data with different conditions were taken to understand the detector response. Currently, data with same condition were used for analysis.
- χ^2 : 23.03 DAMA modulation (A=0.014, T=365, Phase=159.2)
- χ^2 : 10.8 for flat



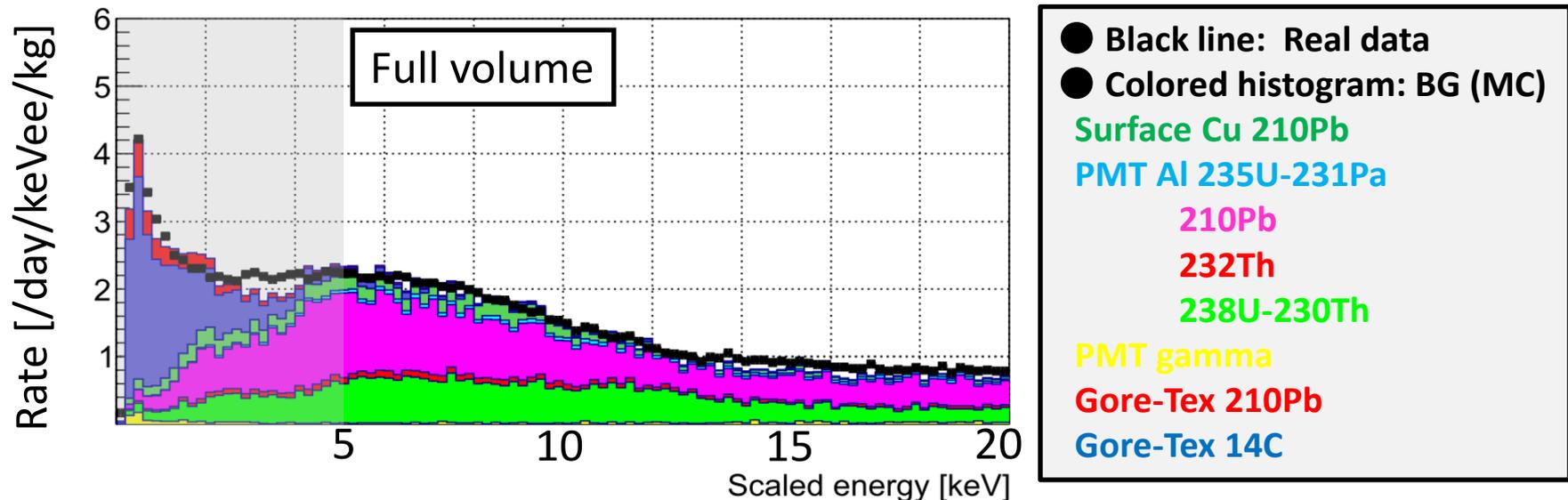
Inelastic scattering DM search



- Sensitivity is as good as the DAMA's world best limit
(*NJP vol.2, 15 (2000), R. Bernabei, et al*) even before optimization of BG reduction.
- Now, optimization of reduction and evaluation of systematic error are on-going. The result will be shown soon.

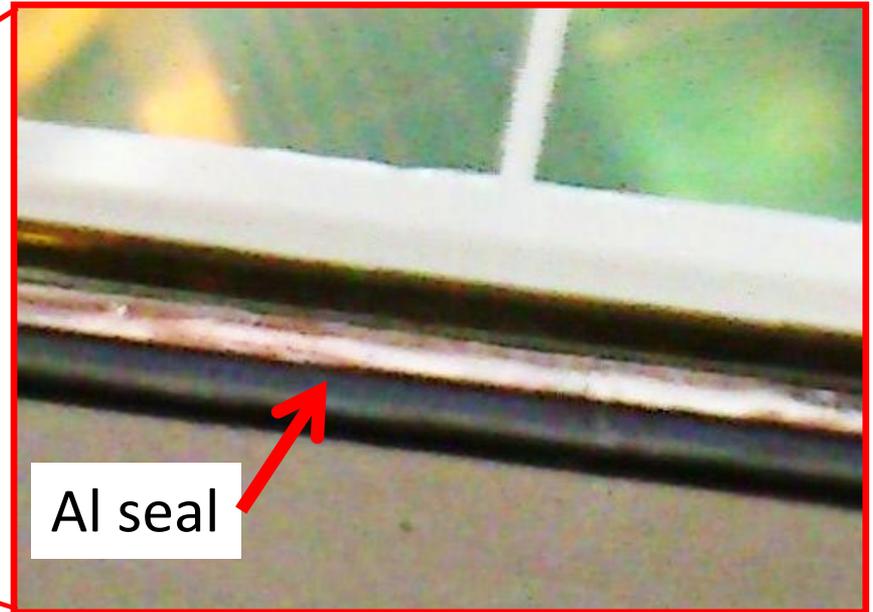
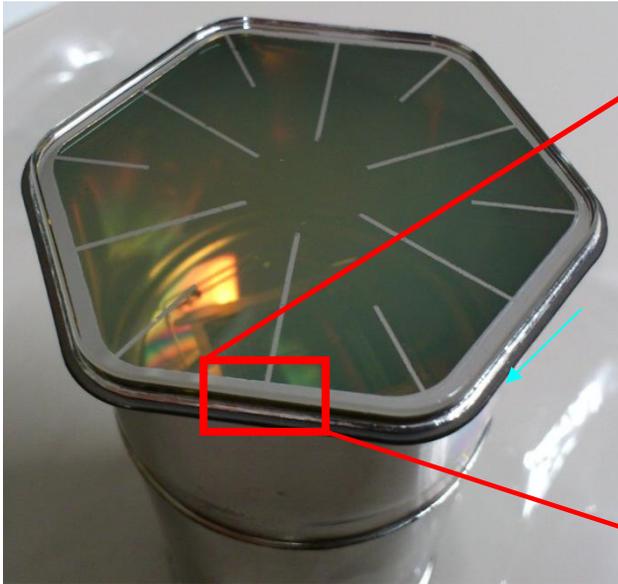
Remaining background in XMASS-I

- BG level was 2 order of magnitude larger than expectation
- It was same level with DAMA and CoGeNT
- The origin of BG for ≥ 5 keV were **confirmed** (lower figure)
- Also for < 5 keV, likeliest candidate (Gore-Tex) was identified
- “**Surface events**” are dominant in both energy regions
- To reduce these surface events, refurbishment is in progress.



Origin of BG in XMASS-I

- Main BG source ($\geq 5\text{keV}$)



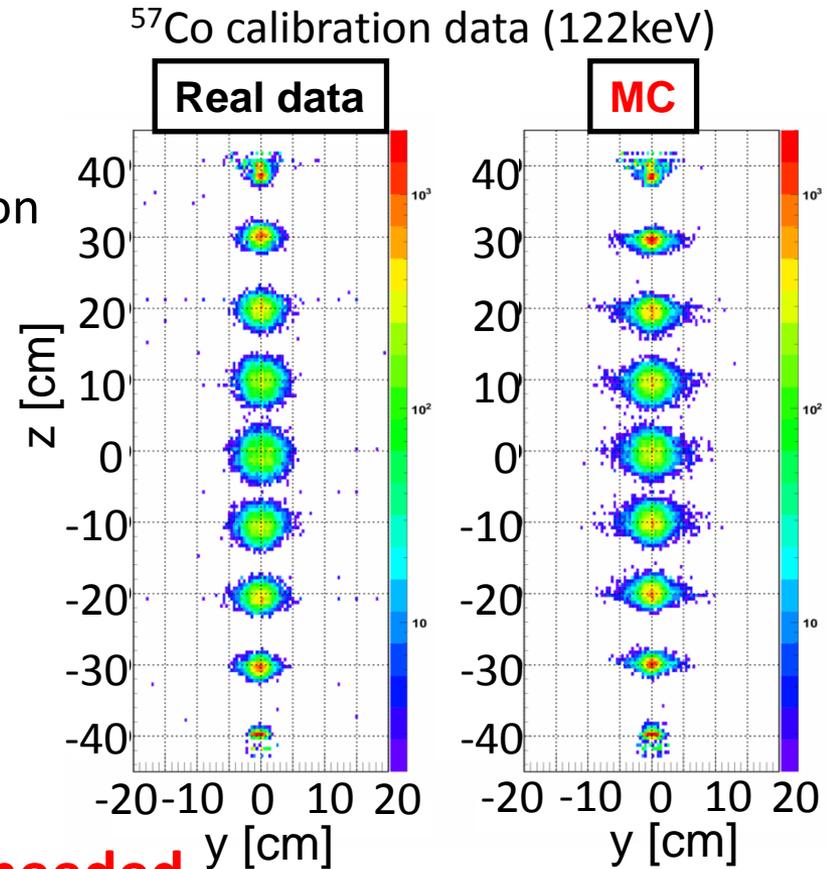
- BG candidate ($< 5\text{keV}$)



- In refurbishment, Al seal will be covered by copper rings and GORE-TEX will be removed
- In XMASS-1.5, Al seal will be replaced with ultra pure one

Fiducial volume analysis in XMASS-I

- BG reduction by fiducial volume cut using position reconstruction.
- It was confirmed that position reconstruction worked well using calibration data.
- “Leakage events” that “surface events” were miss-reconstructed into the fiducial volume are serious problem.
→ **“Surface events” itself should be reduced.**
- Structure around PMT also resulted in “leakage events.”
→ **Refurbishment of structure is also needed.**

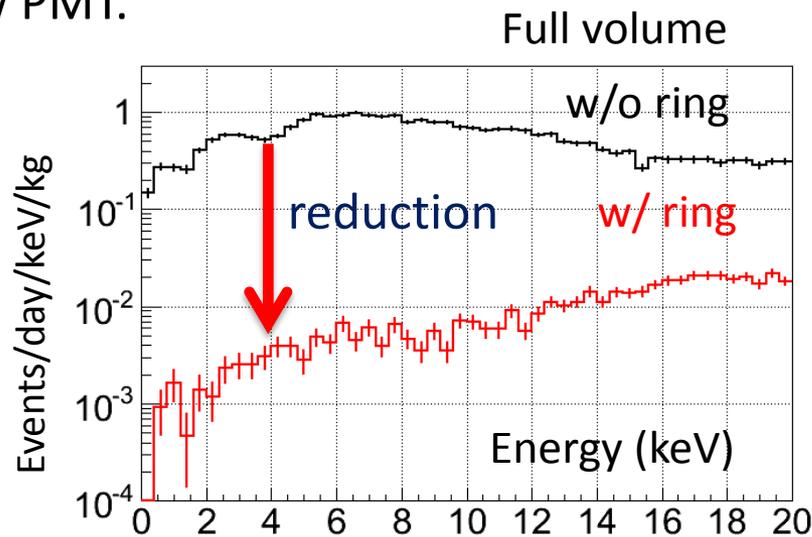


For fiducial volume analysis, refurbishment work is needed.

3. XMASS Refurbishment work

- Purpose of Refurbishment:
 - Confirmation of BG reduction by shielding of scintillation light originated from PMT Al
 - Also reducing ^{210}Pb (2nd largest component in BG) with electro-polishing and special clean environment.
- Expected BG level:
Al and surface BG are reduced to same level as PMT gamma BG. ($\sim 10^{-44} \text{ cm}^2$ for 100 GeV WIMP with fiducialization)
- In next step (XMASS-1.5), it will be replaced with new PMT.

Before installation of ring



After installation of ring

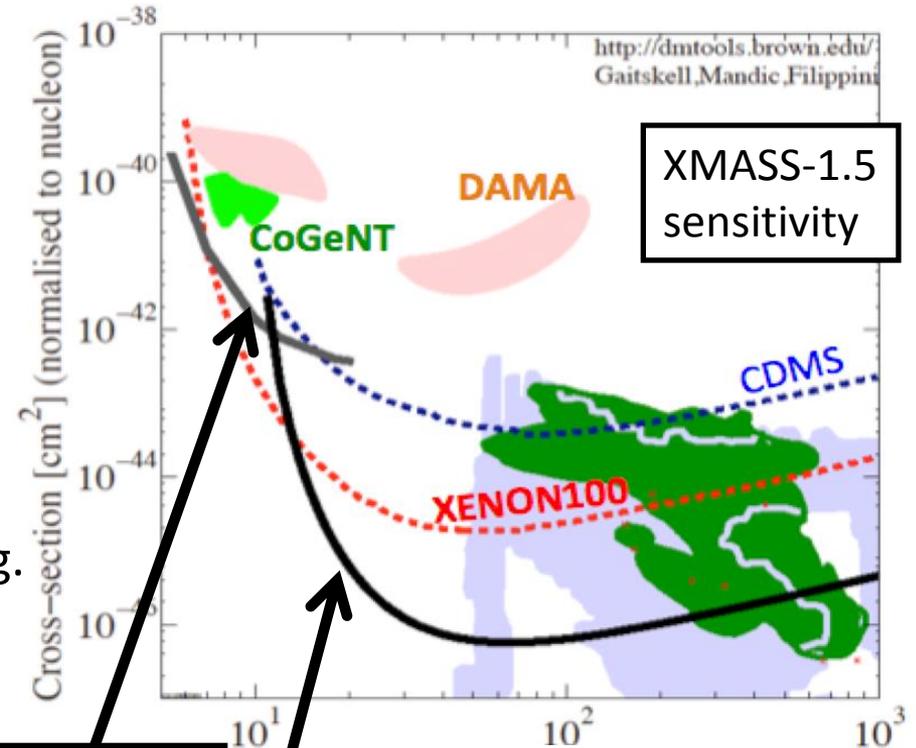


XMASS-1.5

- Total 5 ton (FV 1 ton)
- BG reduction:
 - No dirty aluminum
 - No GORETEX
 - Less surface ^{210}Pb ($< 1/100$)
- New PMT with round shape window to identify surface event is being developed. MC study for evaluation of miss-reconstruction rate is on-going.

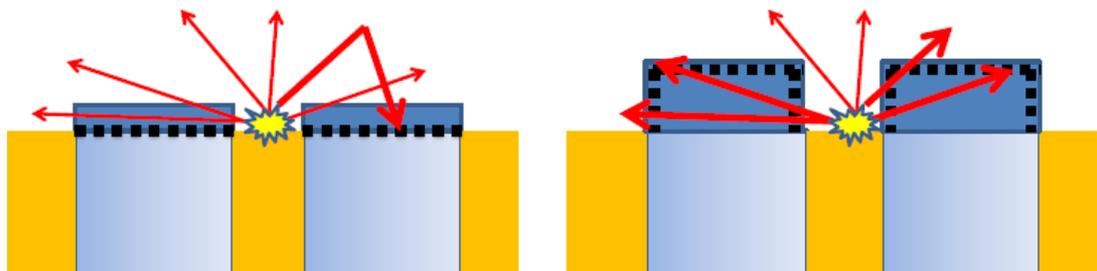


Round shape window



XMASS-1.5 full volume

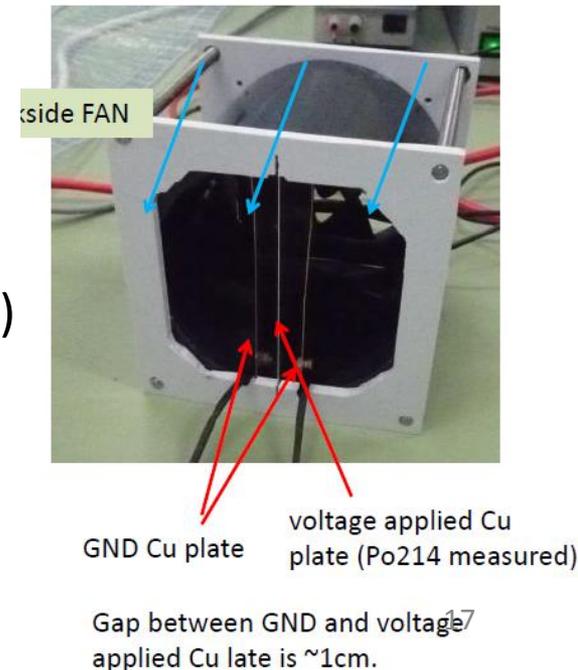
XMASS-1.5, 2keV threshold, 1yr



Less surface ^{210}Pb (<1/100)

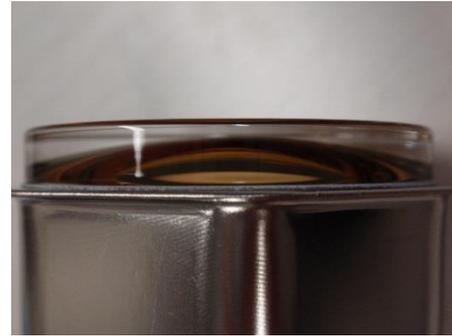
- Environment controlling during machining of detector
 - (1) All the works should be done under Rn free air with Rn concentration of $\sim 10\text{mBq}/\text{m}^3$ (usually $20\text{Bq}/\text{m}^3$)
 - (2) All the surfaces should be cleaned by electro-polishing (EP)

- Controlling of Rn exposure after EP
 - (1) Minimization during machining:
Optimization of all process
 - (2) Minimization during storage:
Packed with Rn barrier sheet (EVOH) and conductive bag.
 - (3) Less Rn environment during assembling ($<10\text{mBq}/\text{m}^3$)
Rn removing device with electro-static collection is being developed.
(Rn decay products (especially, ^{218}Po) tend to have positive charge and collected with high voltage)

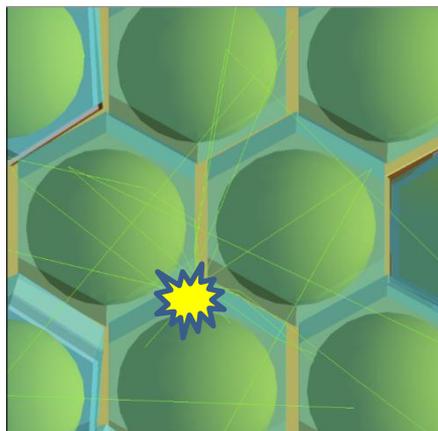


PMT with round shape window

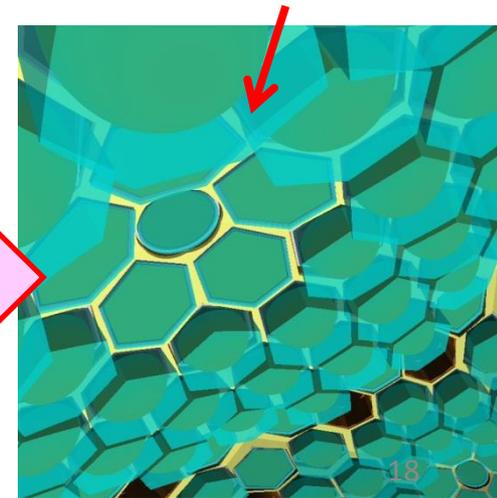
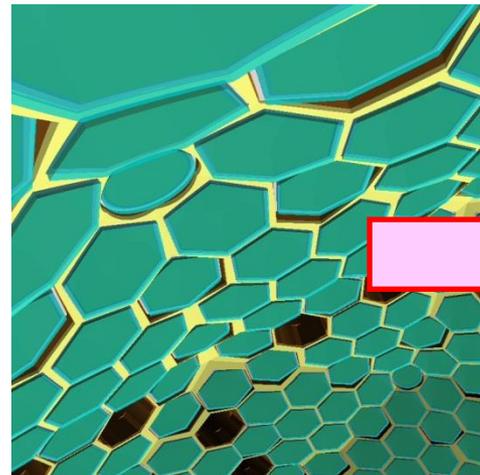
- Mass-production is OK
- Optimization of shape and cost-cutting are being concerned
- Less radio-active impurities
- MC study of miss-reconstruction rate is being evaluated:
Reduction rate of $< 10^{-5}$ at 2.5keV was obtained for events occurred in the side of window.



Round shape window

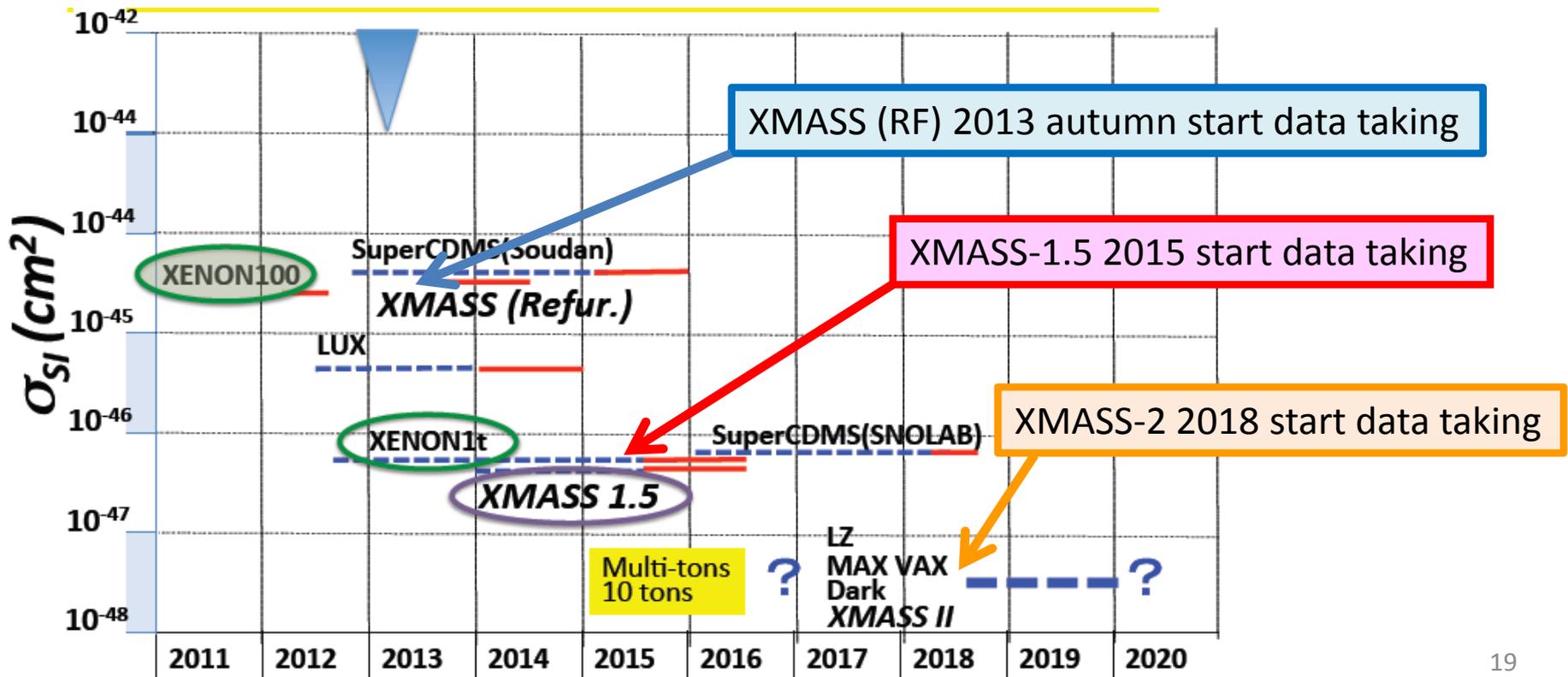


- 3 PMTs around event vertex detect 48% of pe.
- Cut criteria:
Fraction of pe in 3 PMTs $> 10\%$



Schedule

- 2013 autumn: Complete XMASS Refurbishment and start data taking
- 2014: Start XMASS-1.5 construction
- 2015: Complete XMASS-1.5 construction and start commissioning run
- 2016–2018: XMASS-1.5 physics run
- 2018: Complete XMASS-2 construction and start commissioning run



Summary

- XMASS-I is the world largest (835kg) and lowest threshold (0.3keVee) detector for dark matter search.
 - Low mass WIMP search (PLB 719(2013)78)
 - Solar Axion search (to be published in PLB)
 - Seasonal modulation for DM search
 - Inelastic scattering DM search
- BG level in XMASS-I is not as low as original expectation. However, origins of BG are mostly identified and possible to be reduced.
- The refurbishment of XMASS-I is on-going.
Data taking will resume in first of autumn 2013
- XMASS-1.5 is also planned.