Dark matter search at XMASS

2013 Shanghai Particle Physics and Cosmology Symposium (SPCS2013)
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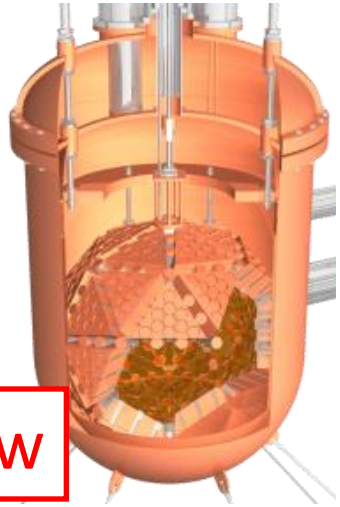
XMASS project

XMASS-I

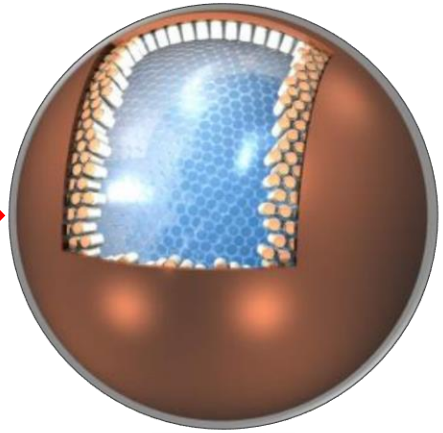


Now

835 kg,
100 kg Fiducial volume (FV)
ϕ80 cm, 642 PMTs
Since 2010 Nov.
Refurbishment work is on going

- Dark matter search

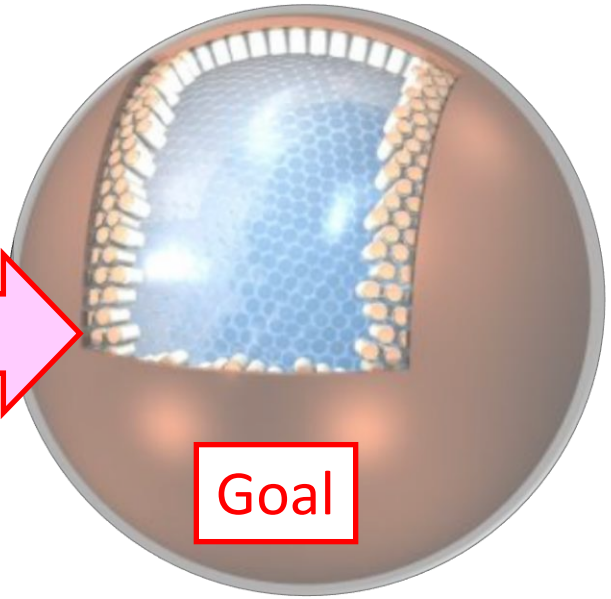
XMASS-1.5



5 ton,
1 ton FV
ϕ1.5 m, ~1000 PMTs

- Dark matter search

XMASS-II



Goal

25 ton, **10 ton FV**
ϕ2.5 m

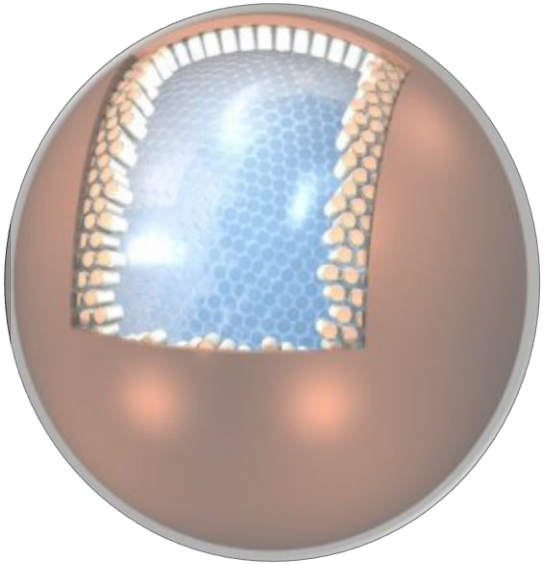
Multi purpose

- Dark matter
- pp solar neutrino
- $0\nu2\beta$ decay

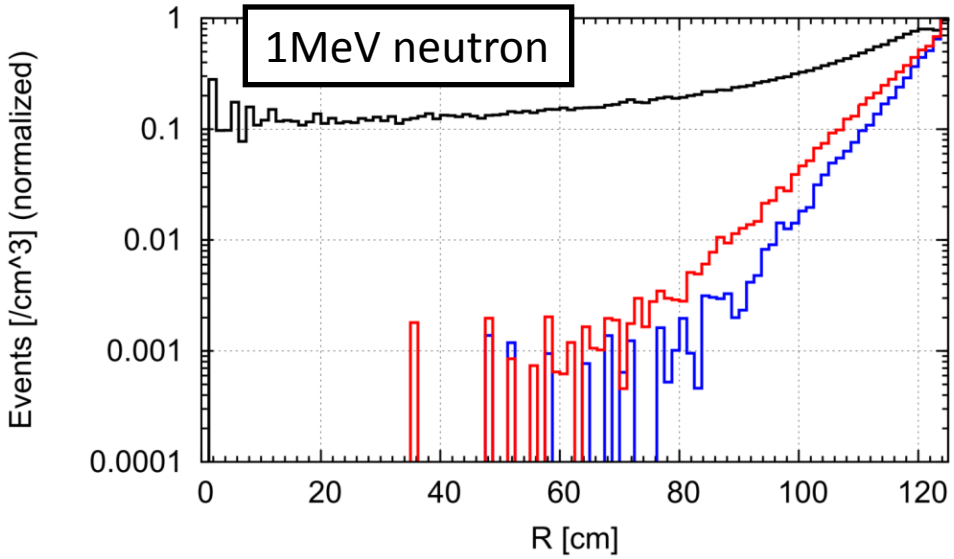
Y. Suzuki, hep-ph/0008296

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

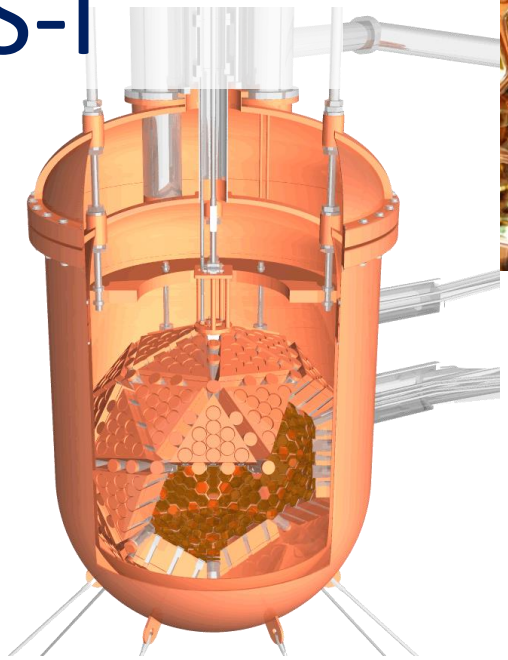


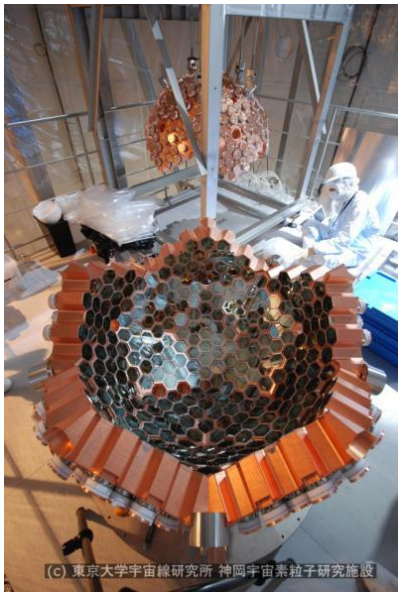
XMASS-2 (ϕ2.5m)



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

2. Status of XMASS-I





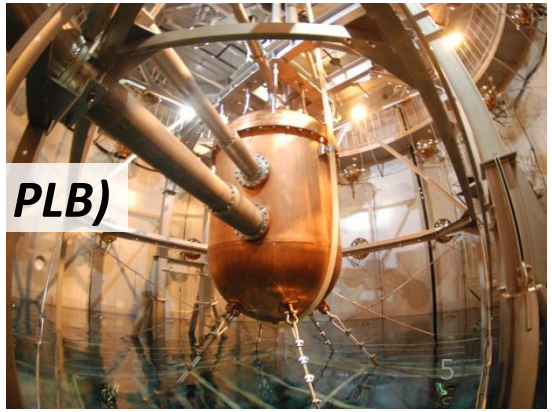
Performance

- 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)

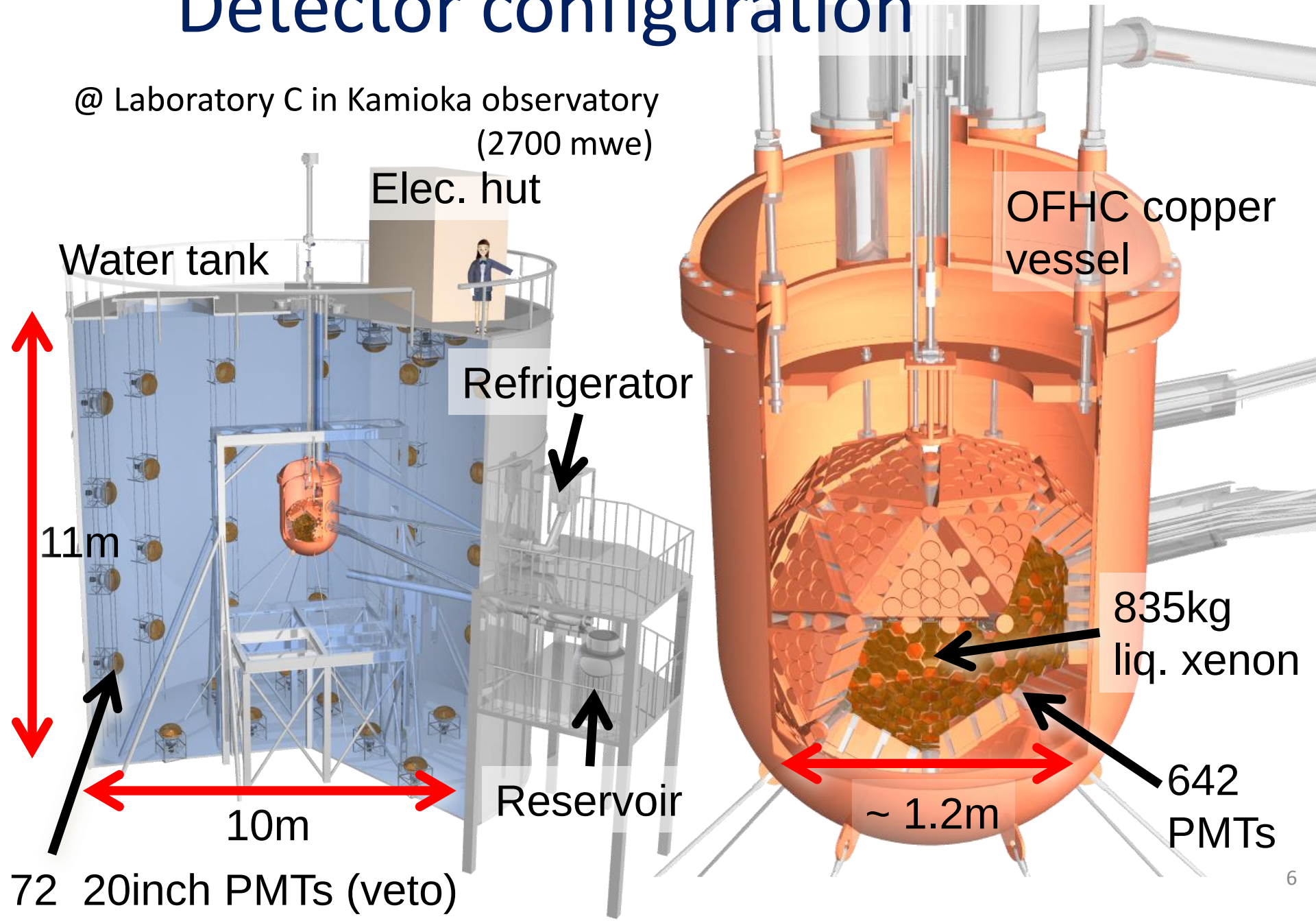
Results

- 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

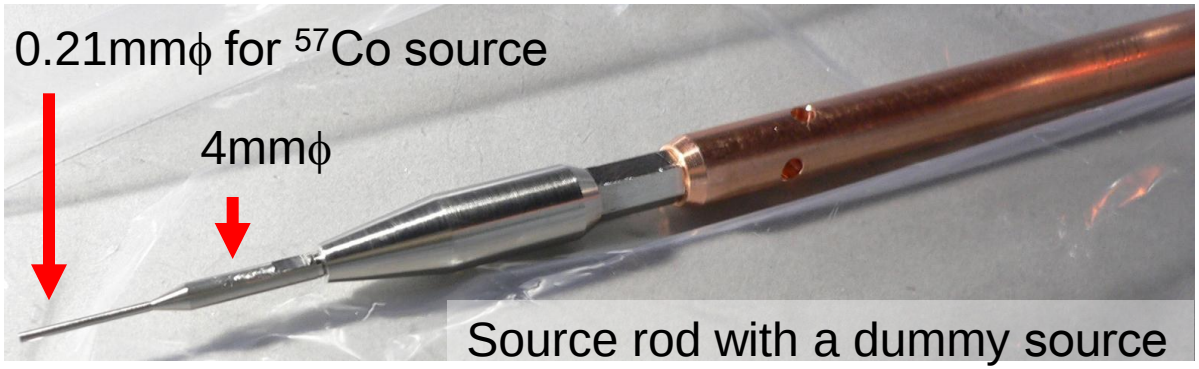
@ Laboratory C in Kamioka observatory
(2700 mwe)



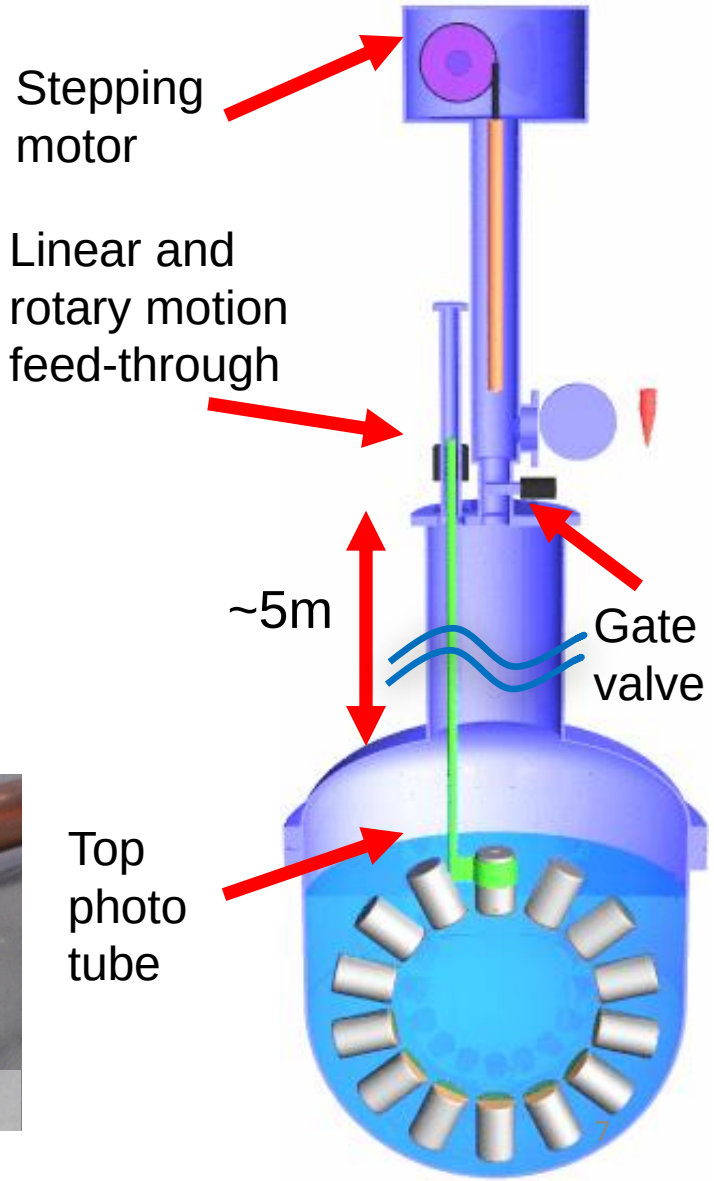
Detector calibration

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) Kα X-rays from the copper used for housing.
(*2) Kα X-rays from the tungsten used for housing.



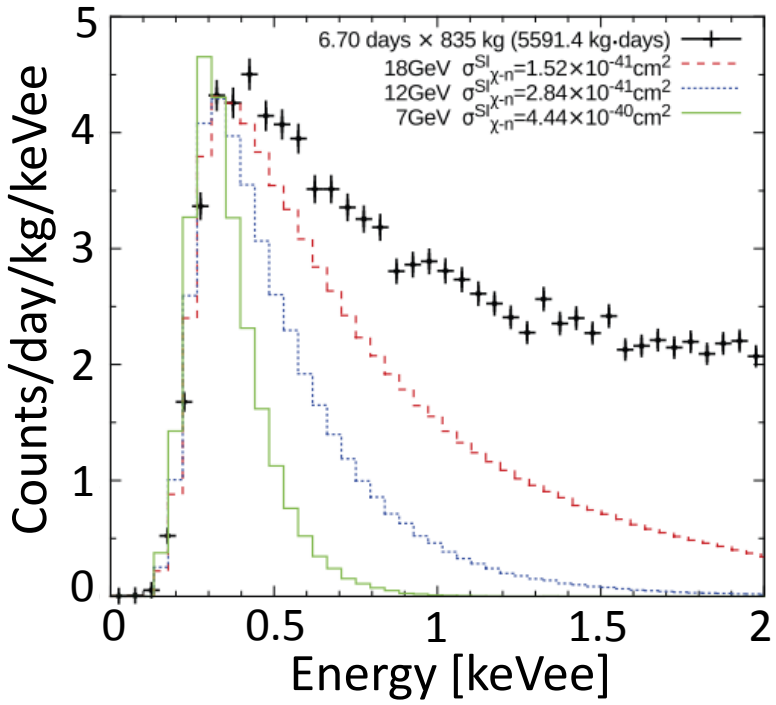
Source rod with a dummy source

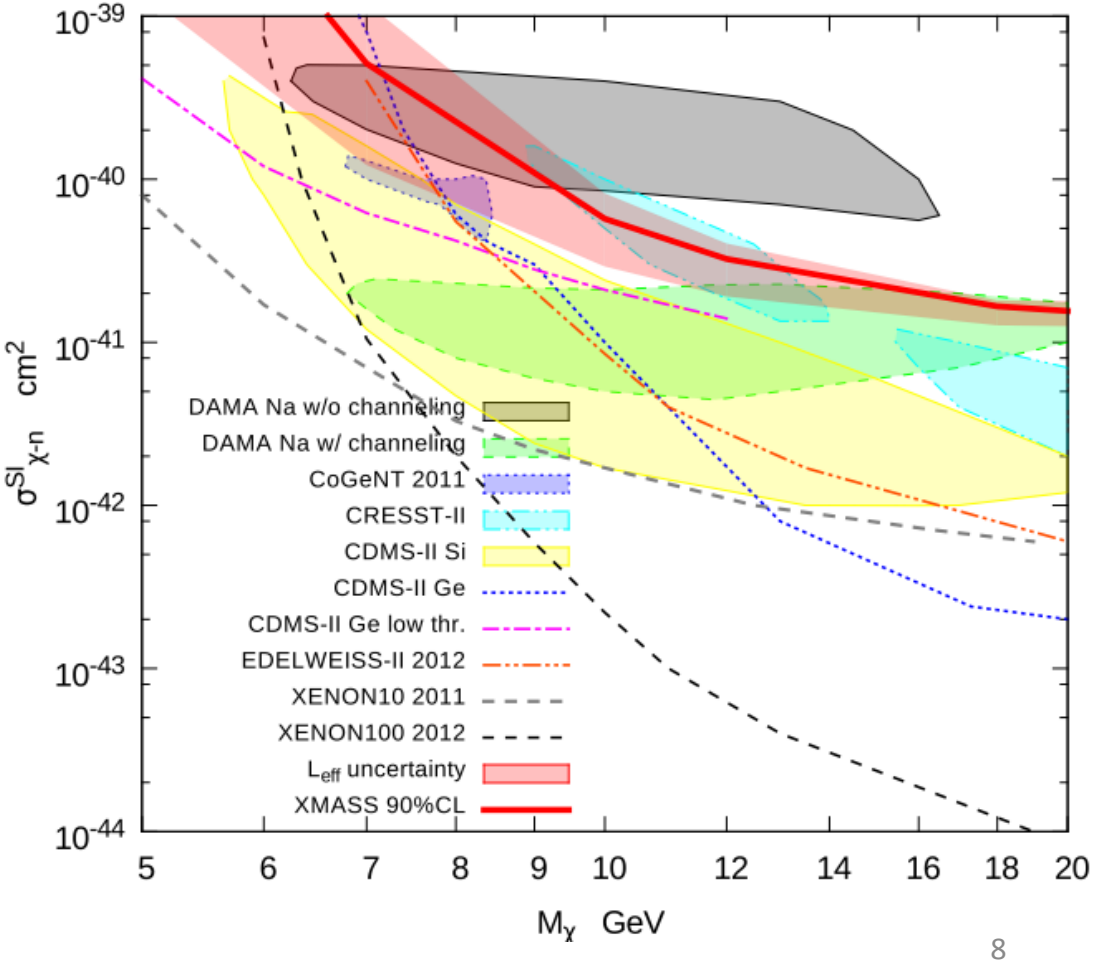


Low mass WIMPs search

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



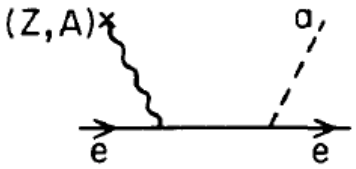


Solar Axion search

arXiv: 1212.6153, to be published in PLB

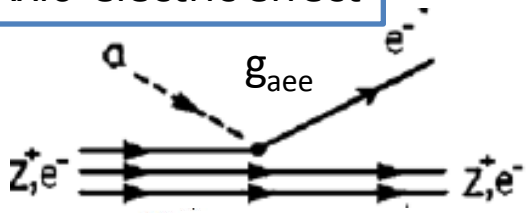
- Axion is a hypothetical particle to solve the strong CP problem
- Produced in the Sun and detected in the detector
- XMASS is suitable to search because of a large mass and low BG

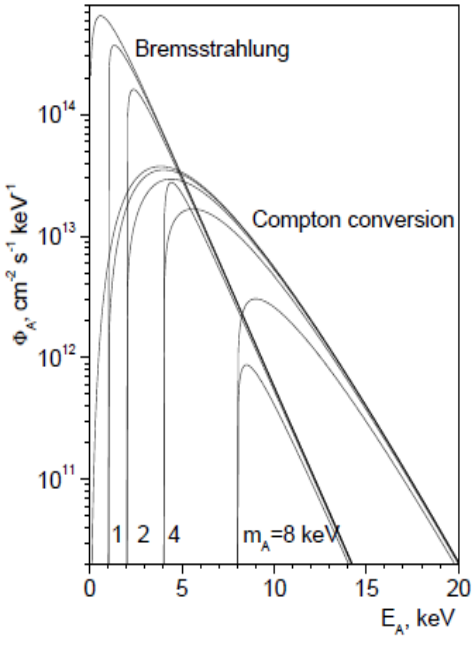
Bremsstrahlung and Compton effect

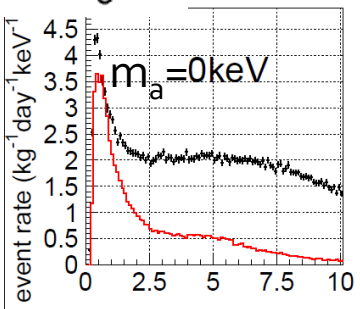


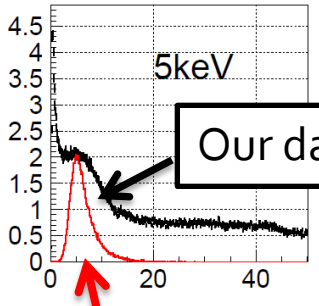
g_{aee}

Axio-electric effect

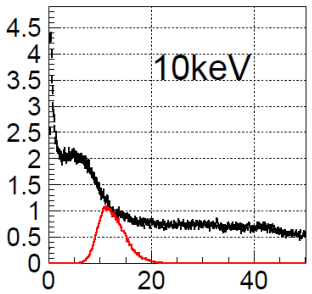




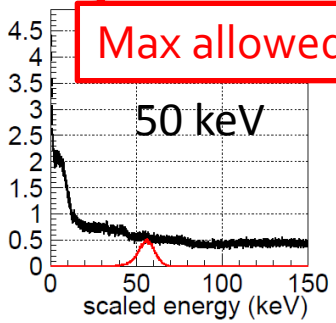


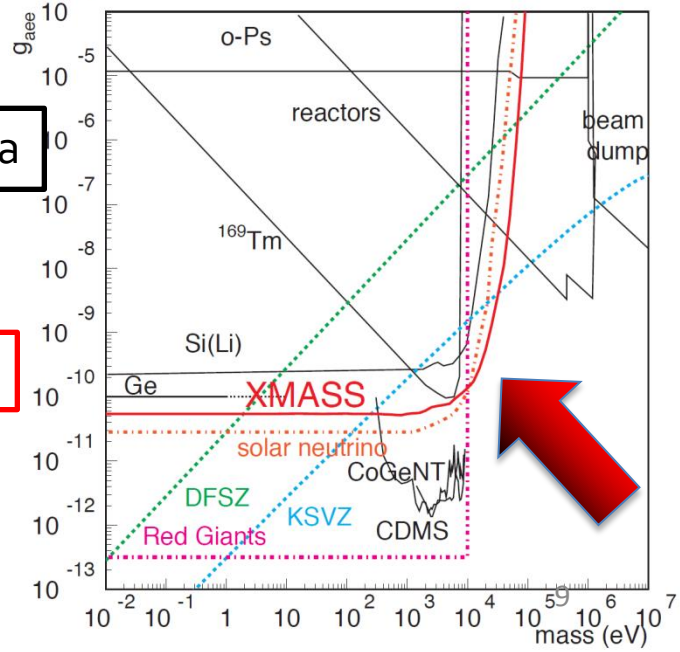


Our data



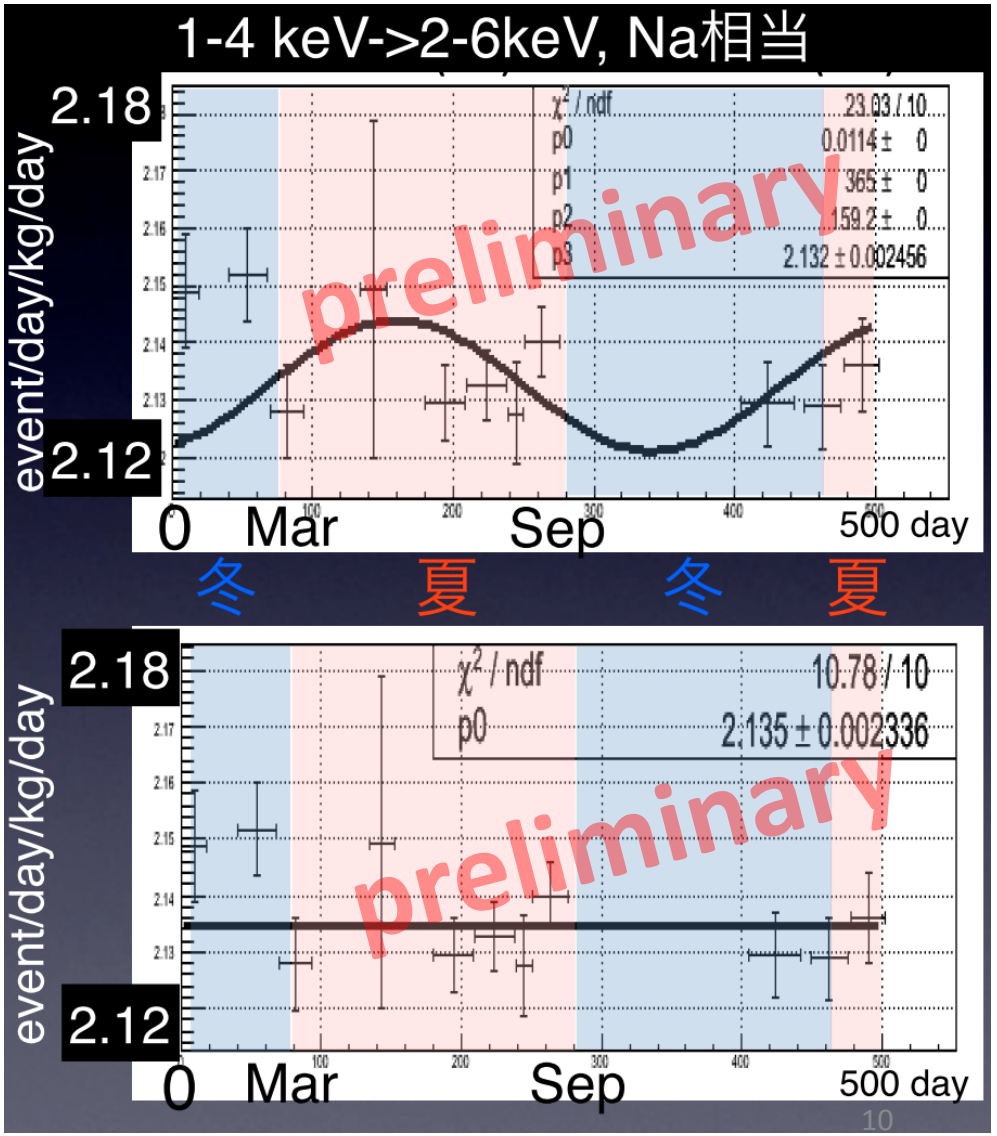
Max allowed



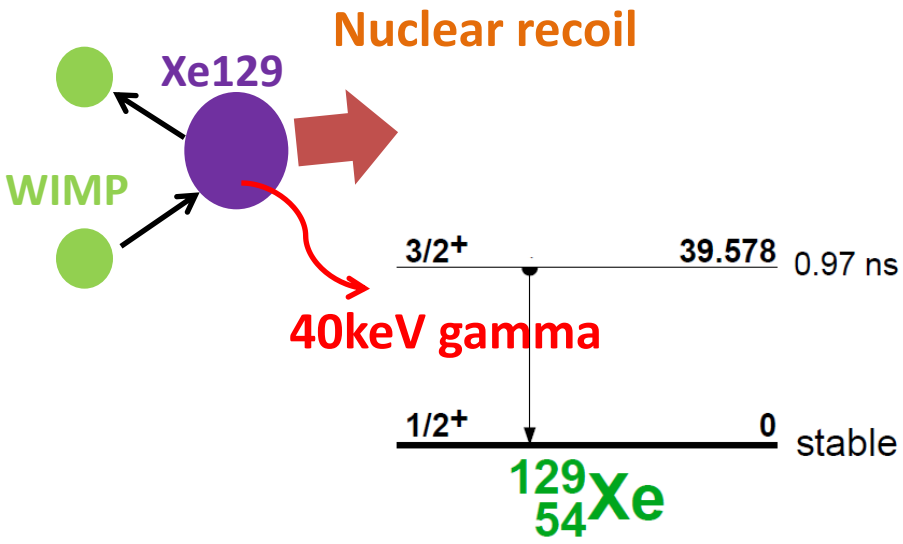


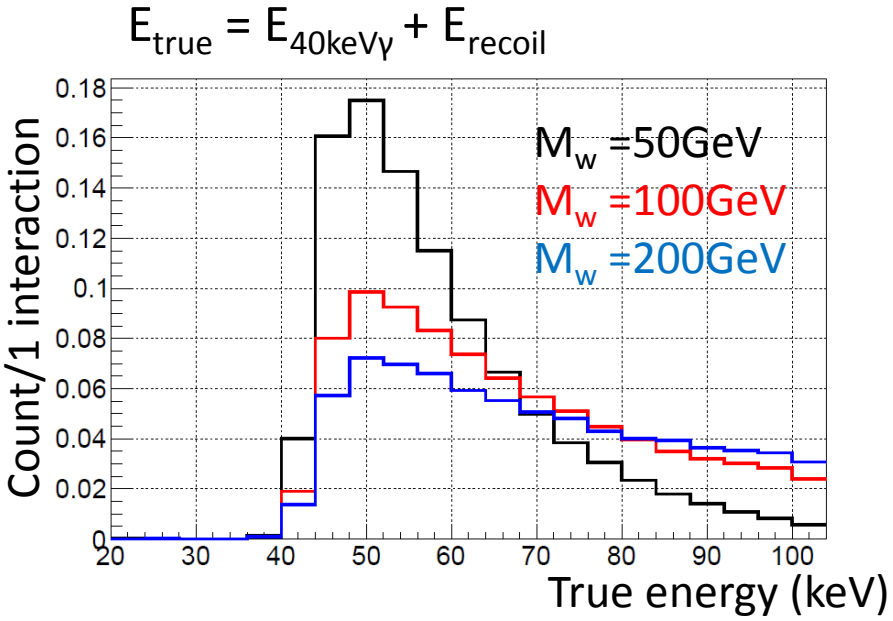
Seasonal modulation for DM search

- 160 days × 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

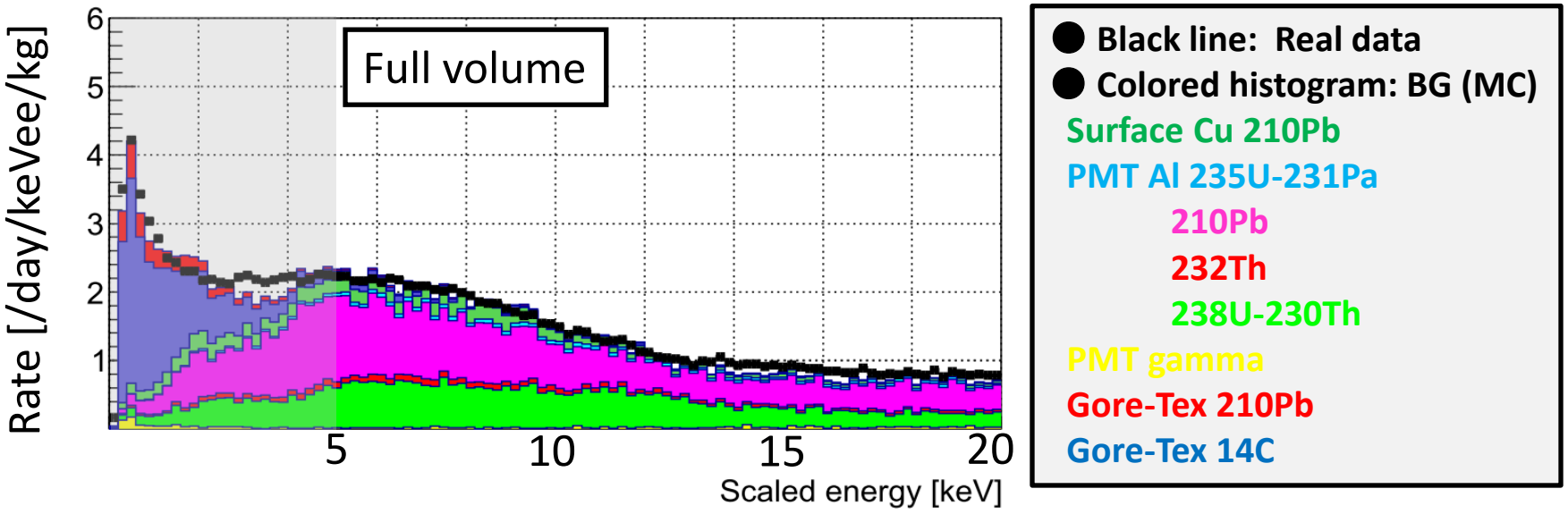




- Sensitivity is as good as the DAMA's world best limit *(NJP vol.2, 15 (2000), R. Bernabei, et al)* even before optimization of BG reduction.
- Now, optimization of reduction and evaluation of systematic error are on-going. The result will be shown soon.

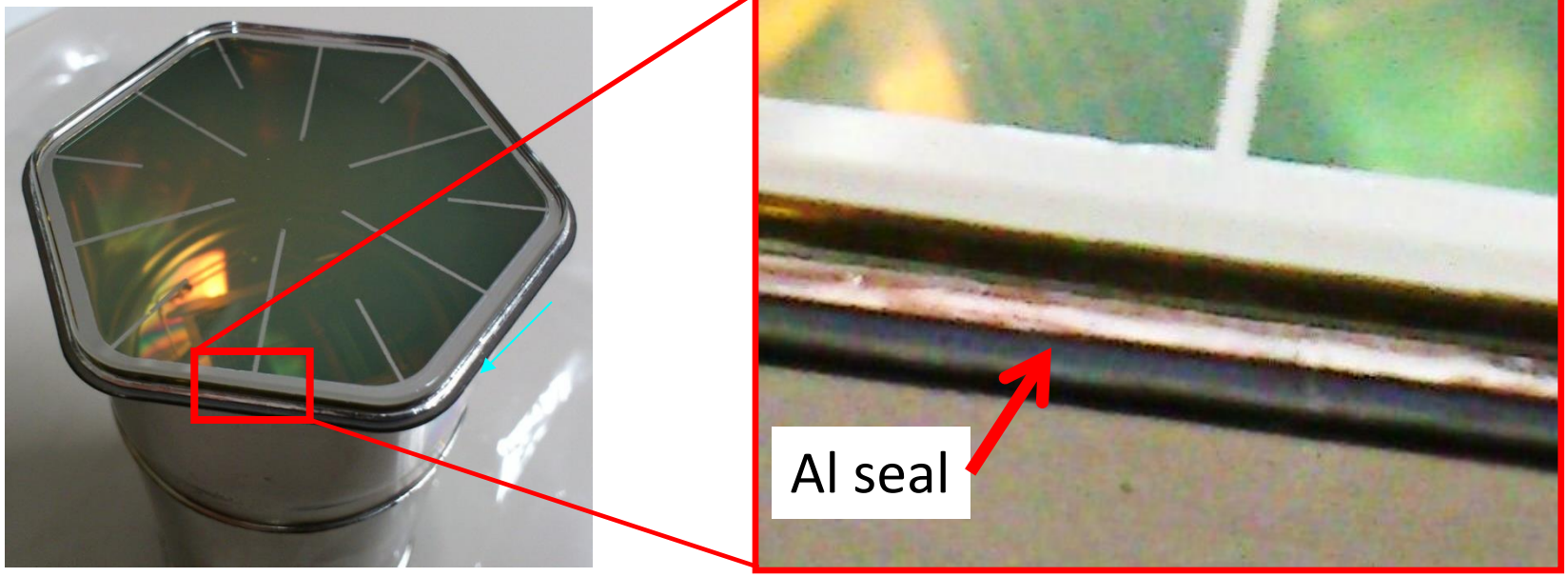
Remaining background in XMASS-I

- 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 (≧5keV)



- BG candidate (< 5keV)

- 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

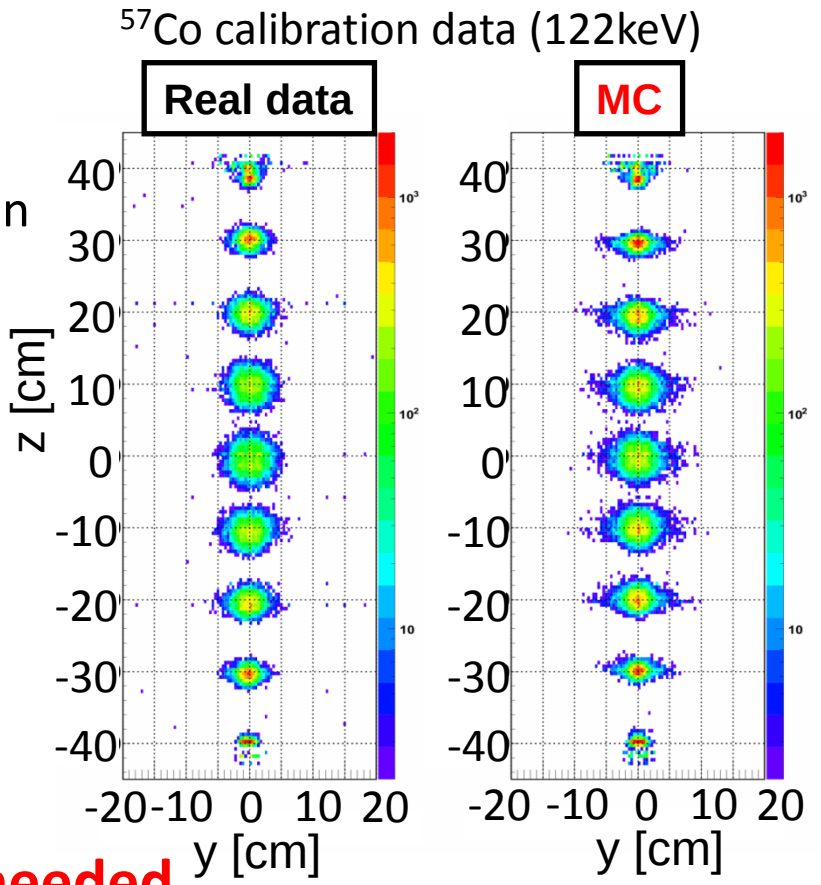
- BG reduction by fiducial volume cut using position reconstruction.
- It was confirmed that position reconstruction worked well using calibration data.

- "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.**



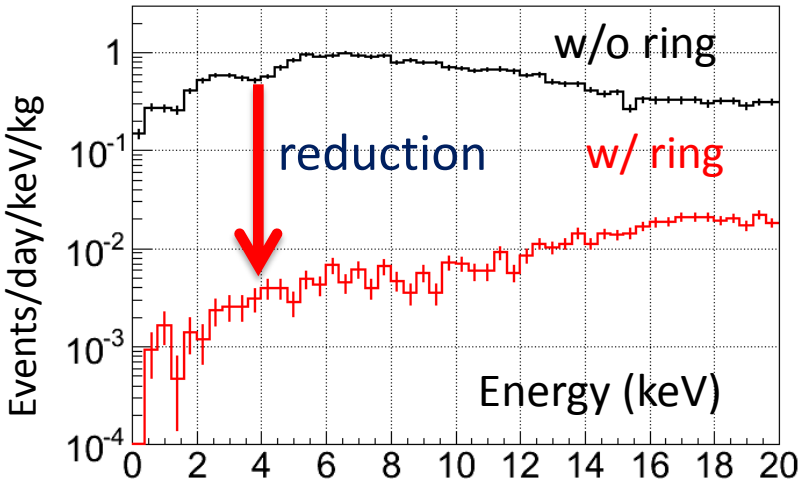
For fiducial volume analysis, refurbishment work is needed.

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. (~10^{-44} 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

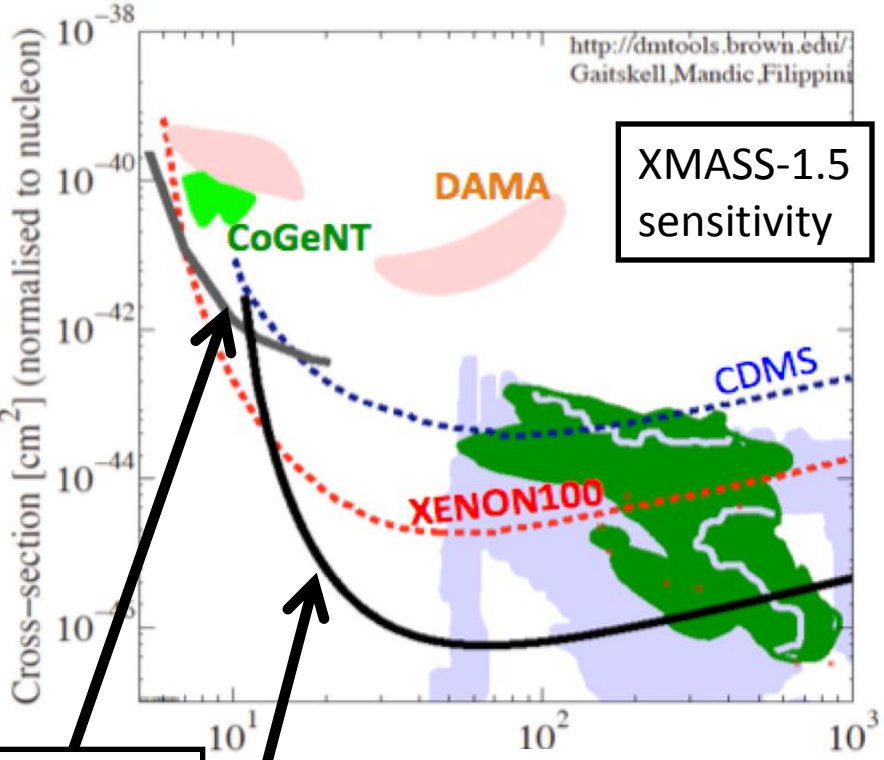
Full volume



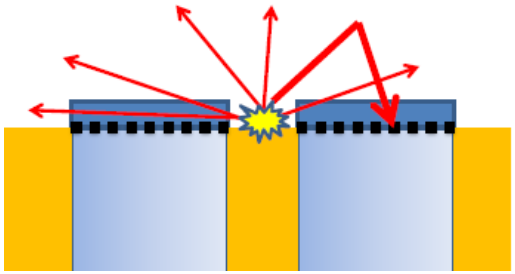
After installation of ring

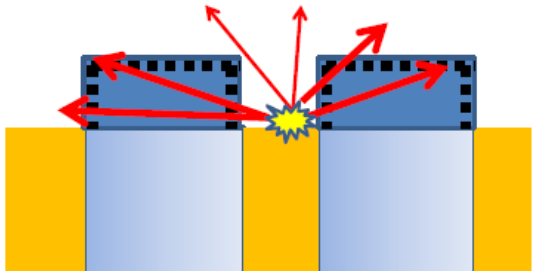
XMASS-1.5

- 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.

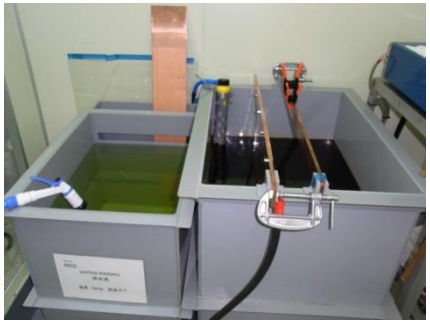


Round shape window



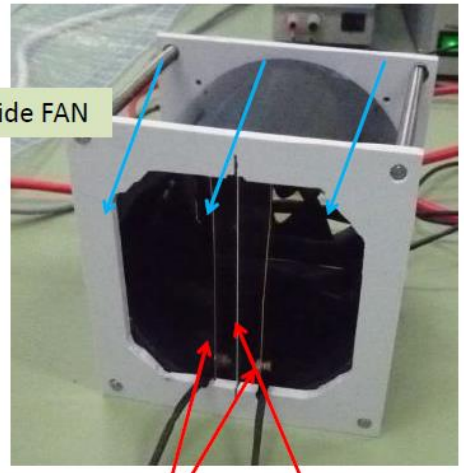


Less surface ^{210}Pb (<1/100)



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

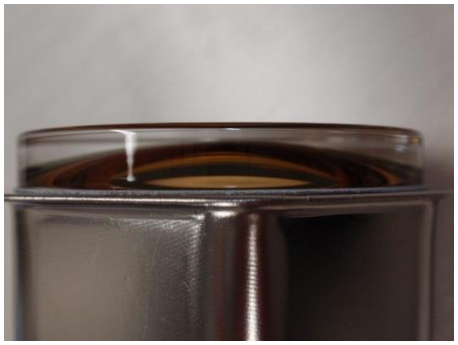
- Controlling of Rn exposure after EP
  (1) Minimization during machining:
  Optimization of all process
  (2) Minimization during storage:
  Packed with Rn barrier sheet (EVOH) and
  conductive bag.
  (3) Less Rn environment during assembling (<10mBq/m^3)
  Rn removing device with electro-static collection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



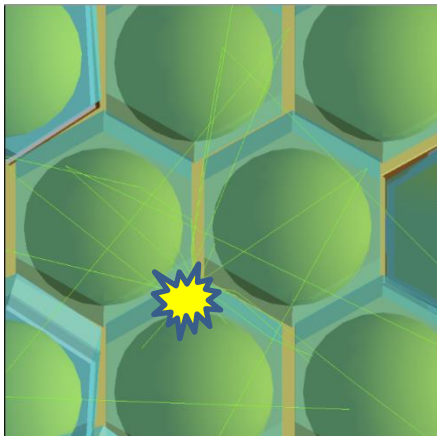
Gap between GND and voltage applied Cu late is ~1cm.

PMT with round shape window

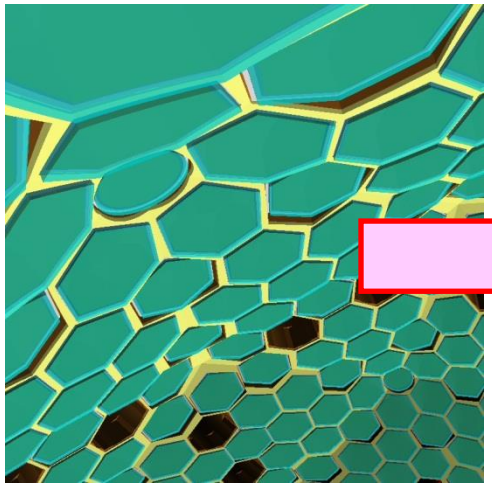
- Mass-production is OK
- Optimization of shape and cost-cutting are being concerned
- Less radio-active impurities
- MC study of miss-reconstruction rate is being evaluated:
  Reduction rate of $< 10^{-5}$ at 2.5keV was obtained for events occurred in the side of window.

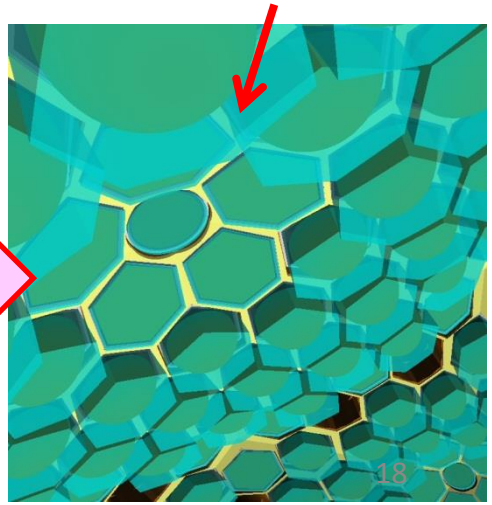


Round shape window



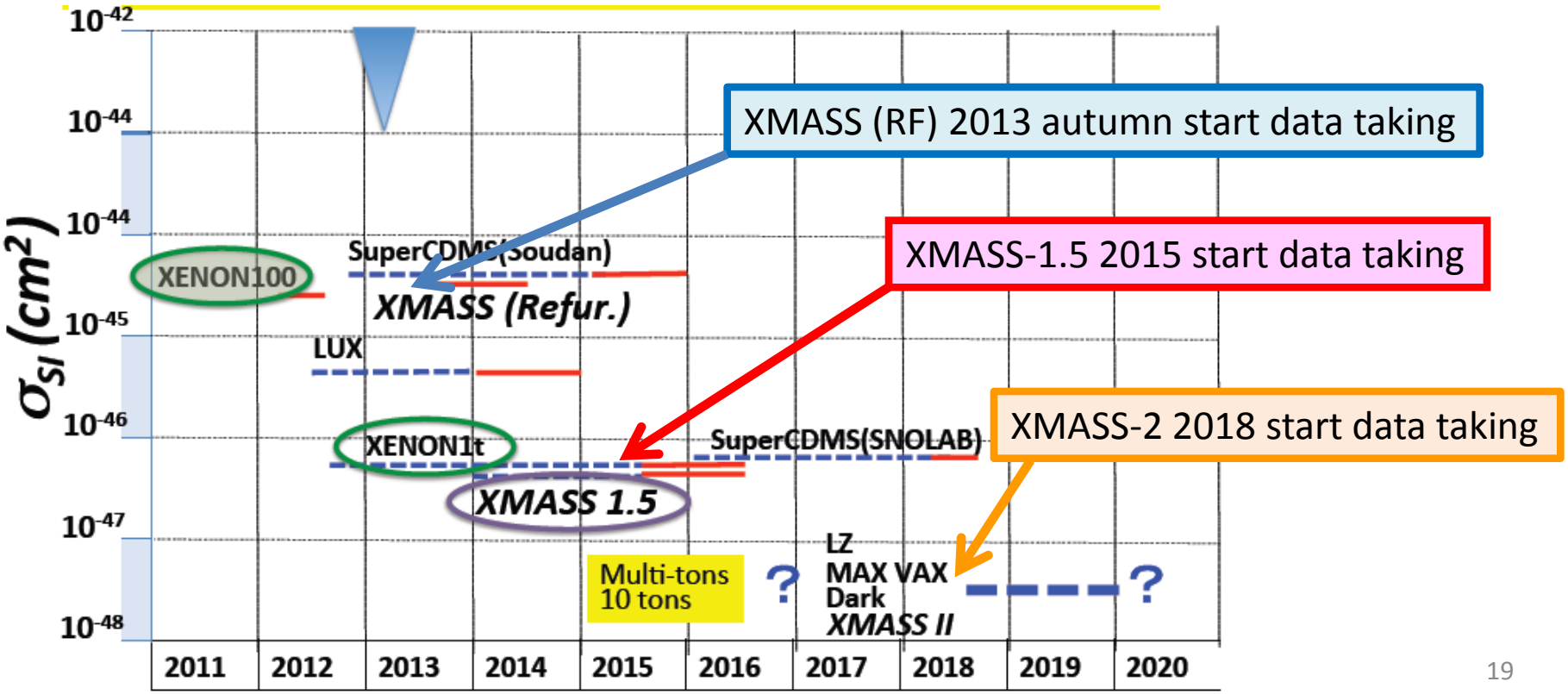
- 3 PMTs around event vertex detect 48% of pe.
- Cut criteria: Fraction of pe in 3 PMTs > 10%





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.