Low background techniques from XMASS

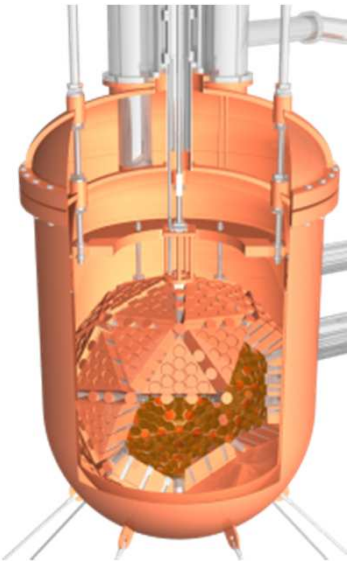
Low Radioactivity Techniques 2013
Laboratori Nazionali del Gran Sasso
Assergi (AQ), Italy, April 10-12, 2013

Dark Matter Search

Hiroshi Ogawa (ICRR, Univ. of Tokyo)
for XMASS collaboration

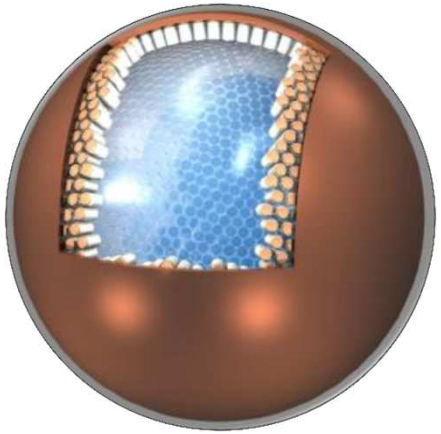
XMASS experiment

XMASS-I



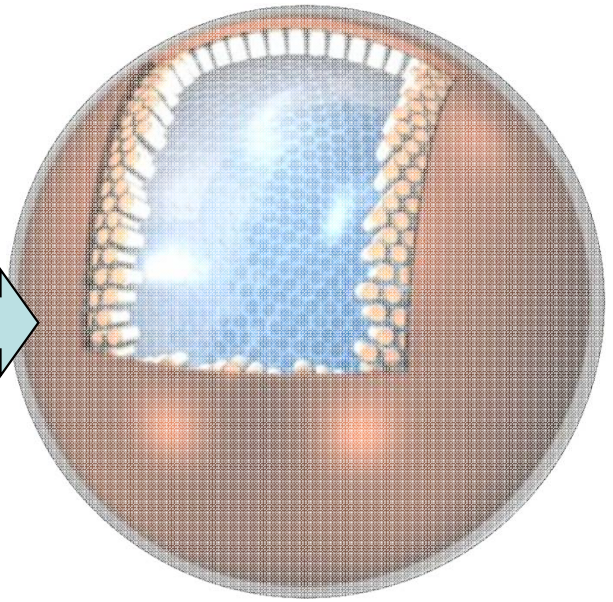
835kg,
100kg FV
80cmϕ
2010Nov
(Refurbishment work
Is progressing
DM search

XMASS-1.5



5ton,
1ton FV
(x 10 of XMASS-I)
1.5mϕ, ~1800 PMTs
DM search

XMASS-II

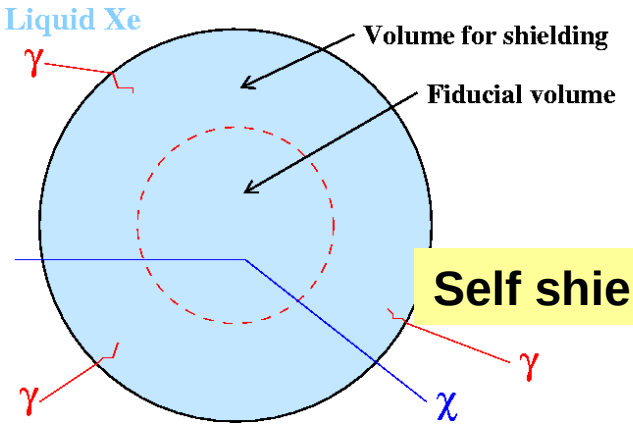


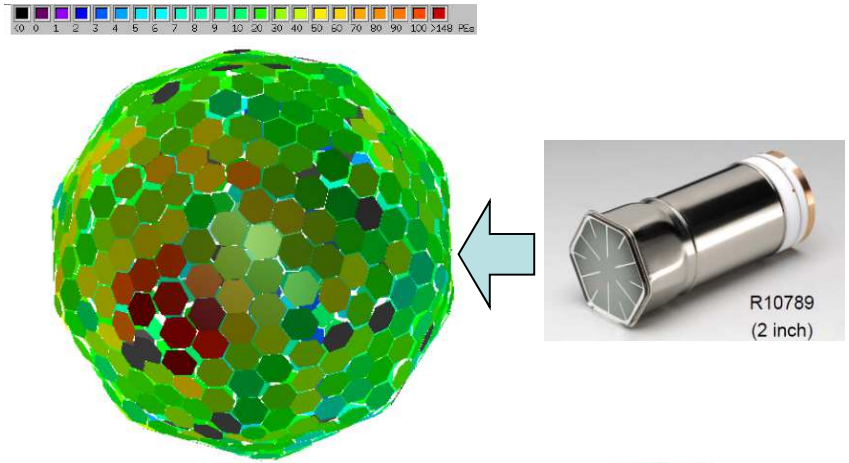
25ton, **10ton FV**
2.5mϕ
Multi purpose
DM search
pp solar neutrino
$0\nu2\beta$ decay

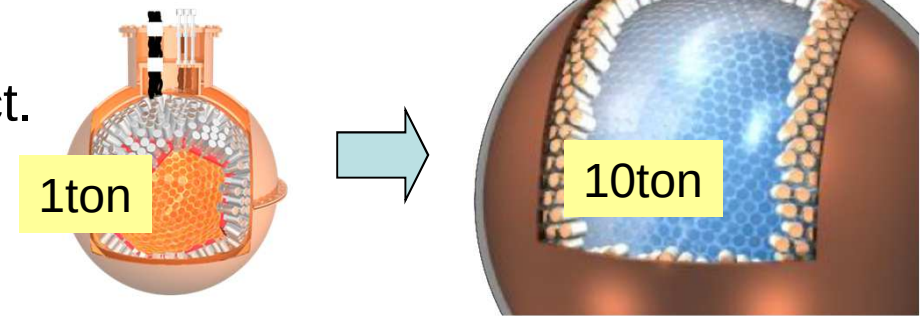
Y. Suzuki, hep-ph/0008296

Characteristics of XMASS

- XMASS : single phase detector
  - Large volume and simple structure, operation.
    - 1 ton scale xenon detector, 100kg for fiducial volume.
  - Background reduction technique :
    - Self shielding
    - Reconstruction by hit pattern of PMTs
  - High light yields & Large photon coverage (15 pe/keV)
    - Low energy threshold (< 5 keVee ~ 25 keVNR) for fiducial volume
    - Lower energy threshold: 0.3 keV for whole volume
  - Large Scalability, simple to construct.







Low background technique

(1) BG from detector materials

- 642 PMTs: We developed new ultra low RI PMT with Hamamatsu. (1/100 of ordinary one).

●OFHC copper: Bring in the mine < 1month after electrorefining (Mitsubishi Material Co.)

●Other materials: All the components were selected with HPGe and ICP-MS. (>250 samples were measured) The total RI level is much lower than PMT BG.

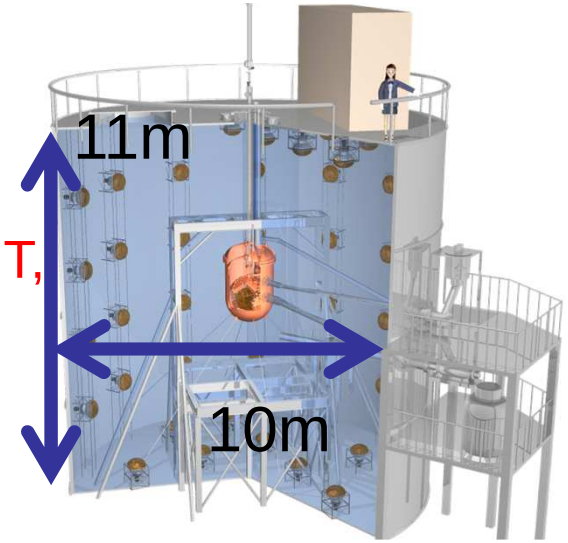
PMT HPGe meas. result

RI in PMT	Activity per 1PMT(mBq/PMT)
238U-chain	0.70+/-0.28
232Th-chain	1.51+/-0.31
40K-chain	9.10+/-2.15
60Co-chain	2.92+/-0.16

(2) External BG

● gamma and n from rock are sufficiently reduced by a >4m thickness pure water tank : $\gamma < \gamma$ from PMT, $n << 10^{-4}$ /day/kg

●72 20'' PMTs for active veto for CR μ

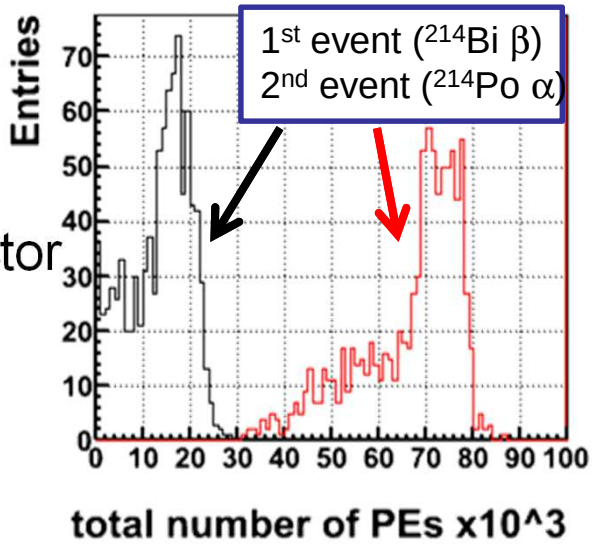


(3) Internal BG (in Xenon)

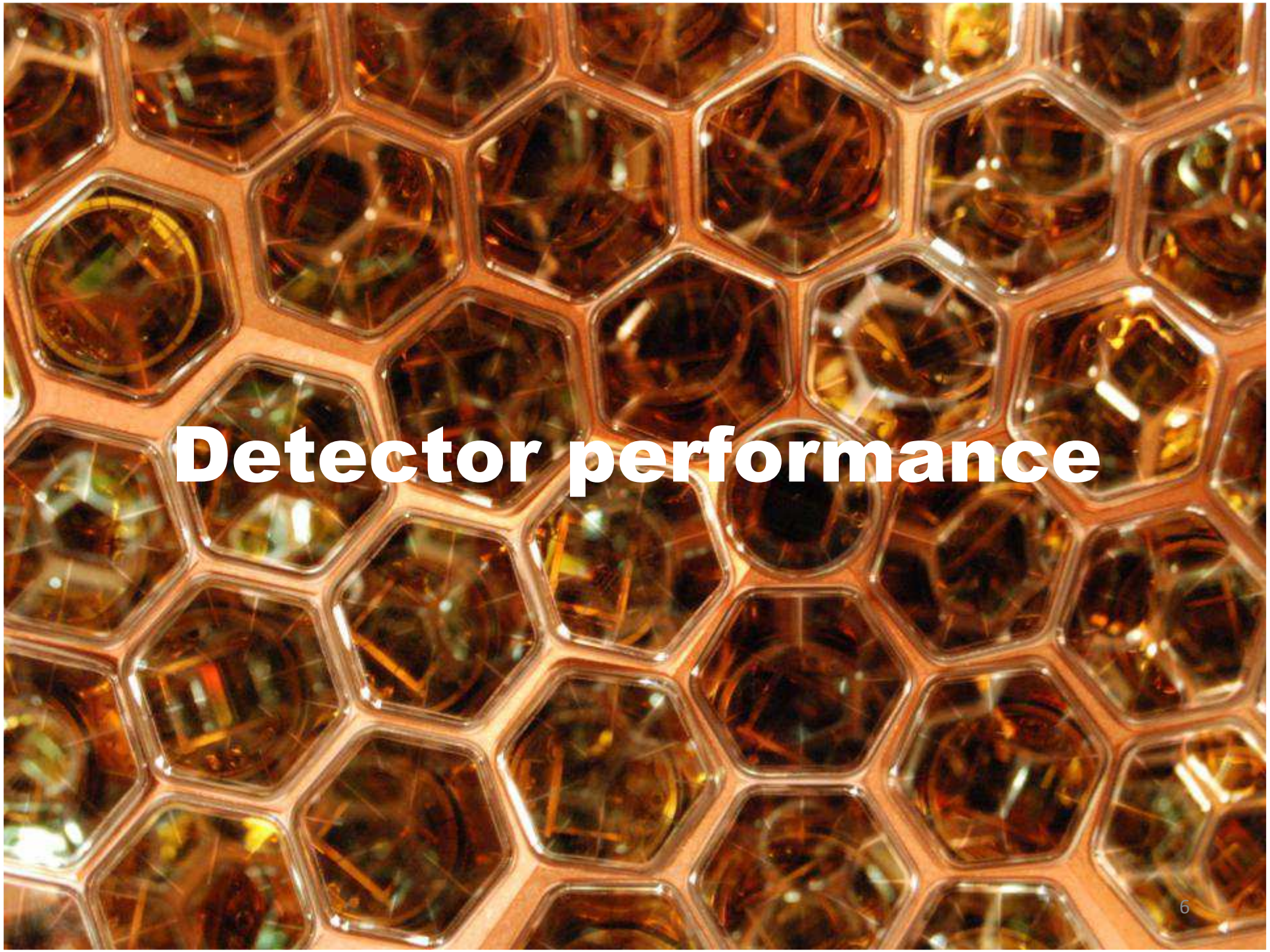
- Radon : Our goal (<10-5 /day/keV/kg)=> 222Rn < 0.6 mBq/detector
  - Radon emanation from detector material was measured with material selection. <15mBq/detector was estimated.
  - Radon concentration in XMASS by Bi-Po coincidence analysis : 8.2+/-0.5mBq.
  - The radon removal system from xenon gas are prepared.

    K. Abe et al. for XMASS collab., NIMA661, 50-57 (2012)
- Kr : Our goal (<10-5 /day/keV/kg)=> 1ppt
  - 5 order of magnitude reduction with 4.7kg/hr processing time was achieved by distillation system.

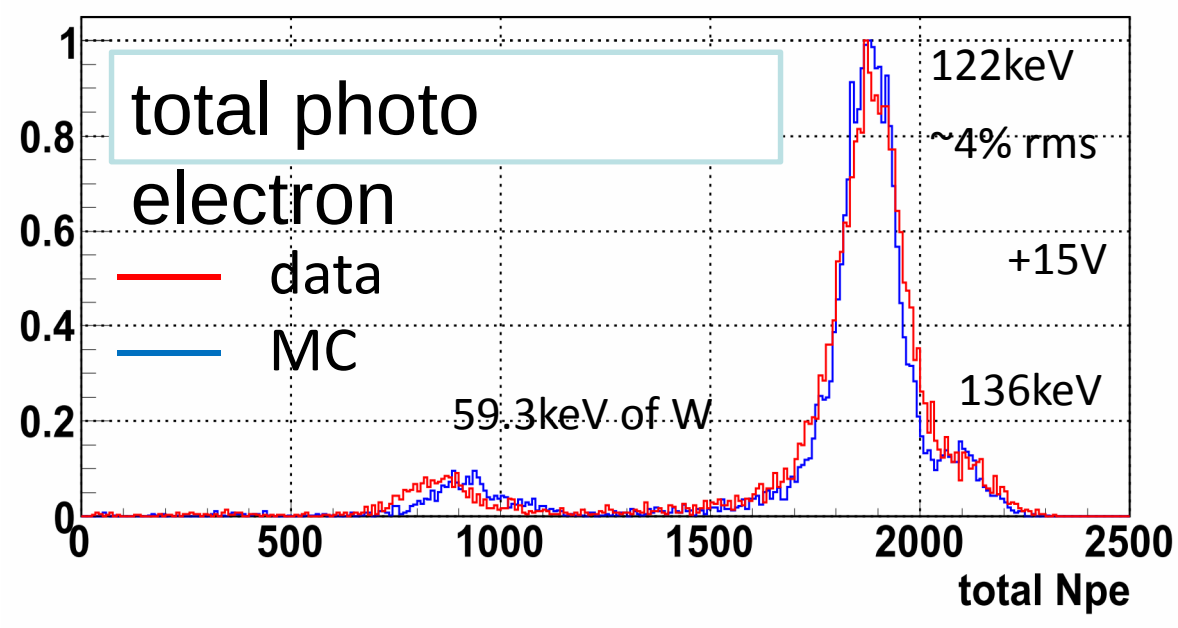
    K. Abe et al. for XMASS collab., Astropart. Phys. 31 (2009) 290
  - <2.7ppt (API-MS measurement of sample gas) was achieved.
- Water, H2, O2 etc :
  - Worse the optical property of xenon and probability of BG (3T)
  - Xenon gas was passed to hot and room temperature getter to remove these.



Distillation tower

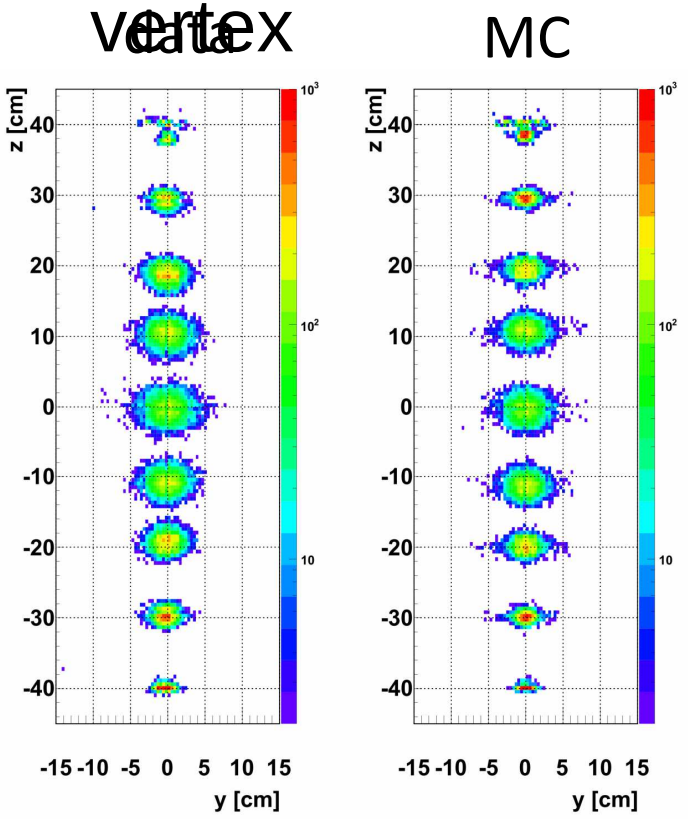

Detector performance

Detector response for a point-like source (~WIMPs)



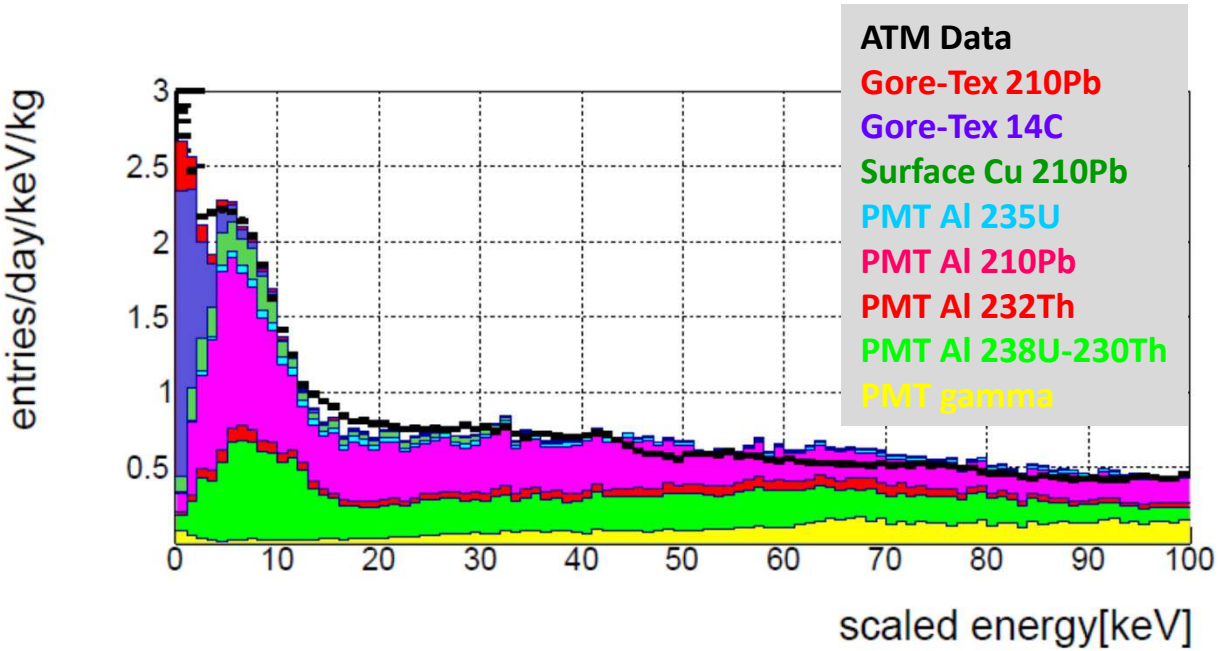
RI source with rod

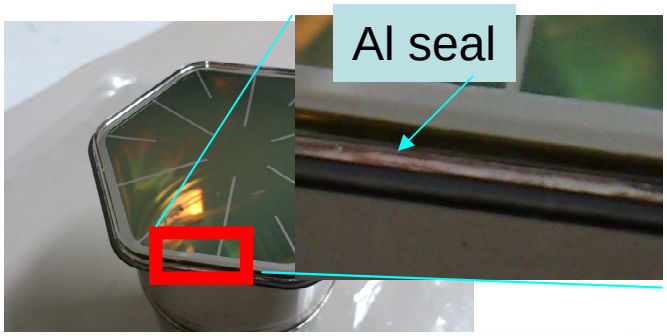
reconstructed vertex



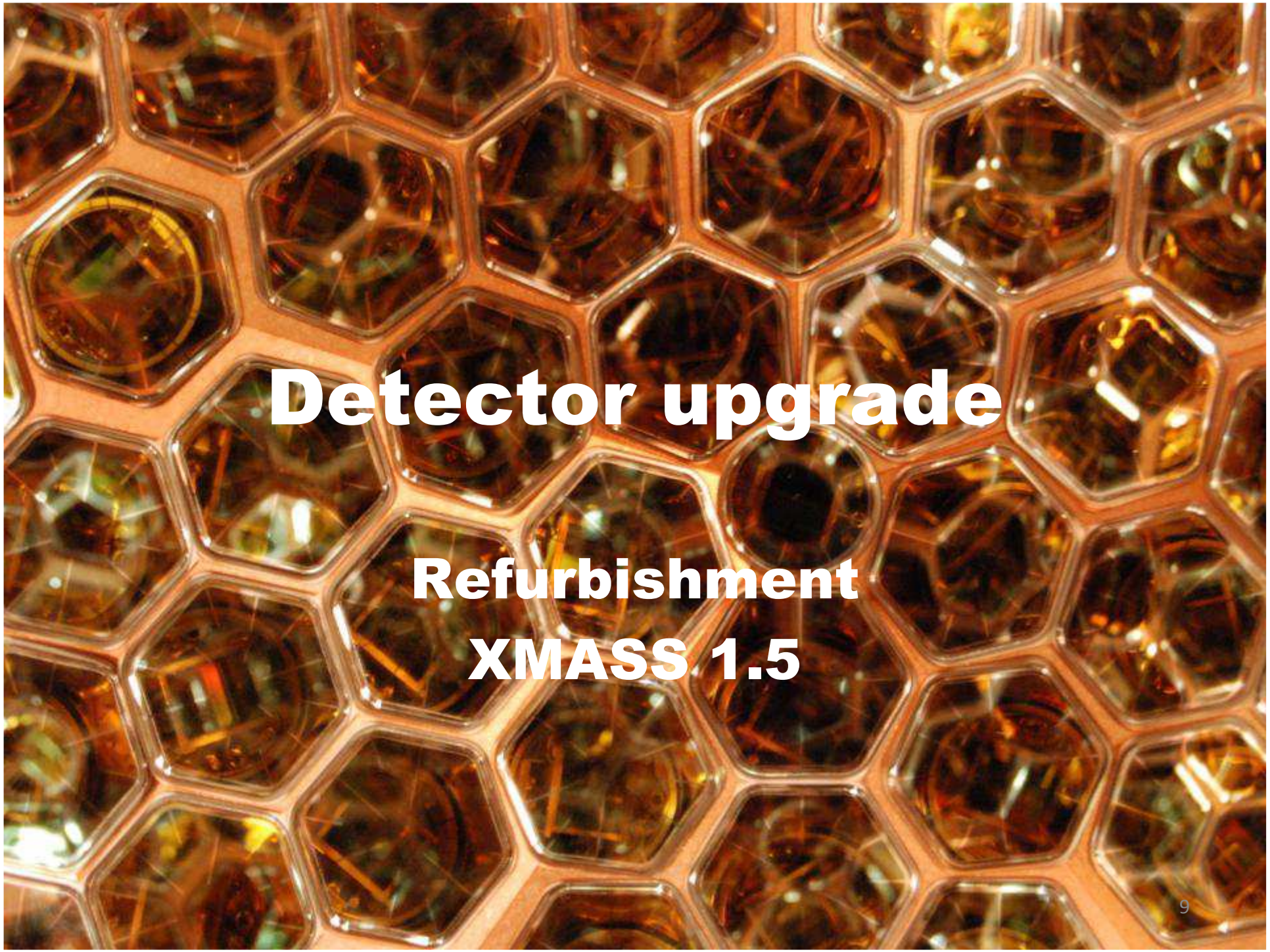
- ^{57}Co source @ center gives a typical response of the detector.
- 14.7p.e./keV$_{ee}$ (⇔ 2.2 for S1 in XENON100)
- The pe dist. well as vertex dist. were reproduced by a simulation well.
- Signals would be <150p.e. exp shape.

Unexpected BG in XMASS-I:



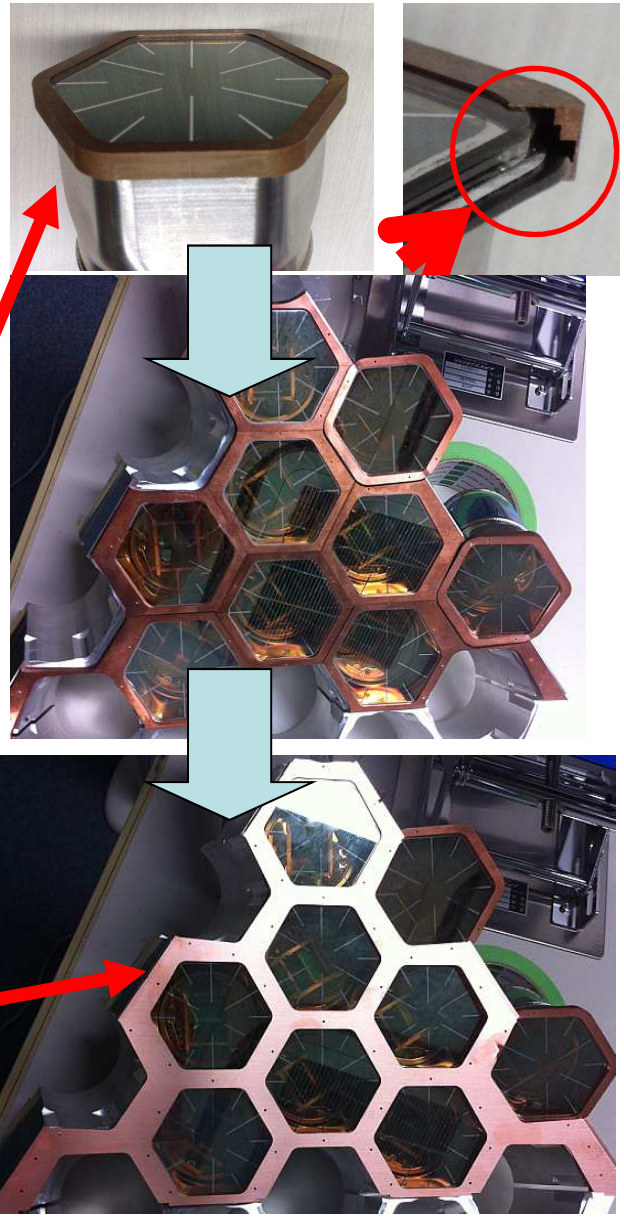


- BG was 2 order larger than PMT gamma BG which was assumed as main BG.
- BG level is nearly with DAMA and CoGent.
- The origin of BG for >5keV were confirmed. (1) BG from PMT Al seal (238U-230Th and 210Pb-206Pb). (2) 210Pb-206Pb in Copper surface.
- Also Gore-Tex (ex : 14C) is likeliest candidate for <5keV BG
- BG origin from “detector surface” is dominant. Leakage event in FV region is introduced by worse of PMT response. Need to remove these.


Detector upgrade
Refurbishment
XMASS 1.5

Background reduction : refurbishment

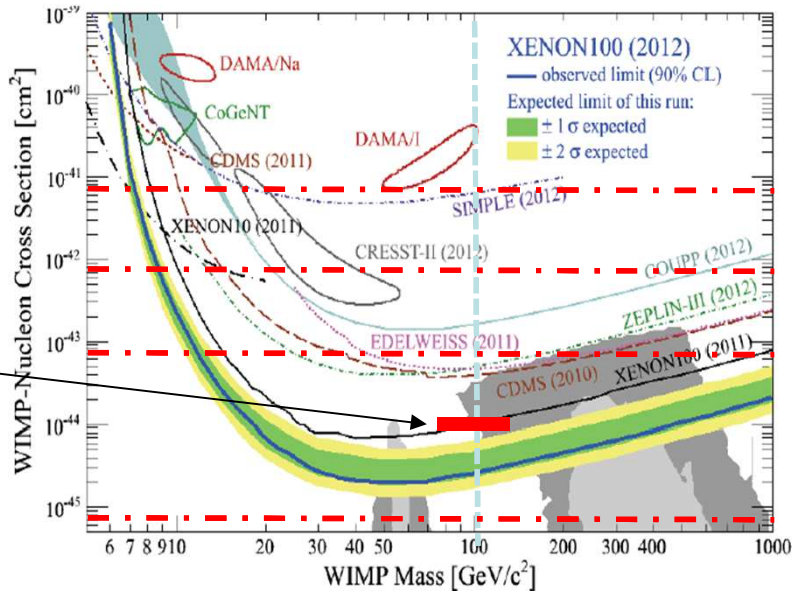
- The XMASS improvement work is progress. The detector was already disassembled.
- Most of BG is caused by α, β and γ rays from aluminum parts of PMTs.
- It will be shielded by copper covers.
  - To shield α, β and γ from Al seal, Cu ring for PMT are mounted.
  - To simplify surface and cover gap events between ring and ring to reduce the leakage events.
- Gore-Tex : removed.



Background reduction : Reduce and control of surface BG.

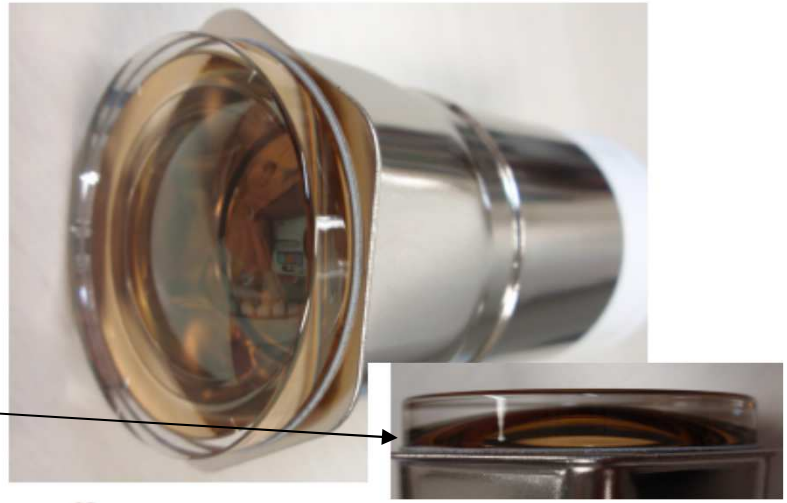
- Copper materials which used in detector will be electro polished to remove surface RI (210Pb-210Po).
- Control of surface BG :
  - keeping the assembly environment clean.
    - control of low radon level. : ~0.1Bq/m3 radon free air.
    - Reduce exposure time in room. : material will be sealed by EVOH seat.
    - Dust : keep < class 10 by HEPA filter.

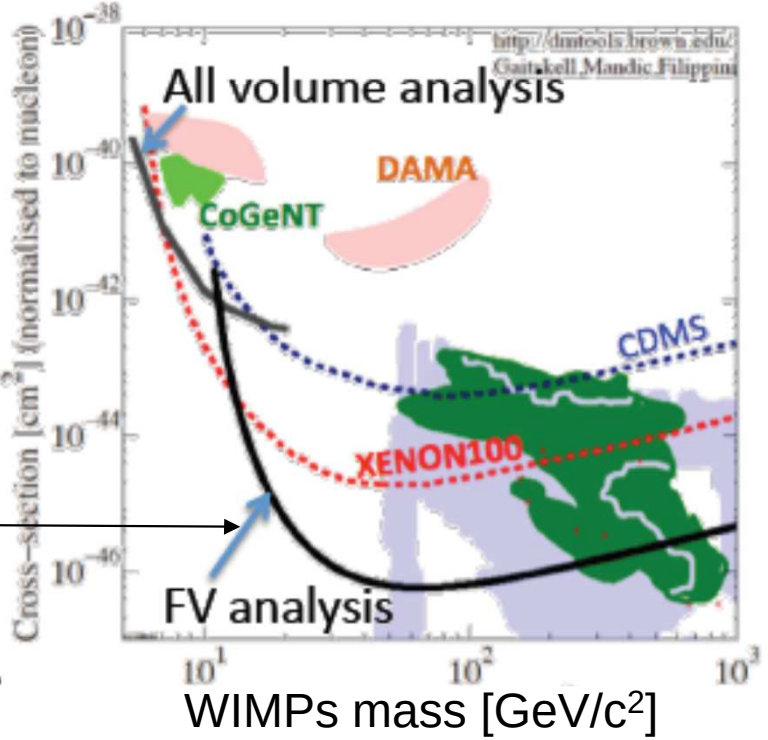
•BG and leakage events after fiducialization should be re-evaluated and controlled.
•For 100GeV WIMP, we toward to reach ~10-44 with fiducialization.
•Experiment will resume in first of Autumn 2013

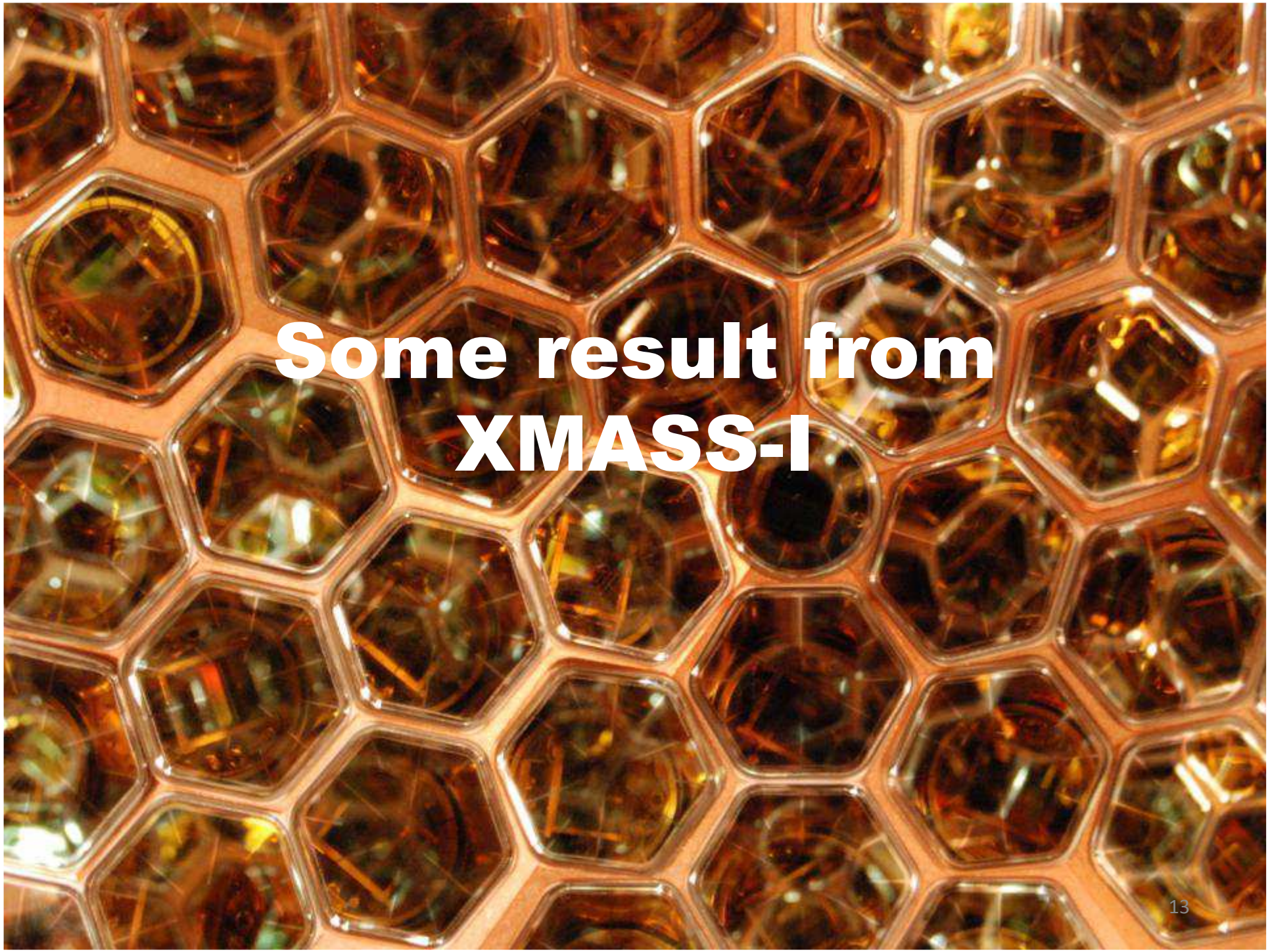


XMASS-1.5

- Full : 5ton, FV 1ton xenon
- New PMT :
  - More clean material (include Al seal) will be selected.
  - New PMTs being developed help to identify surface events.
- BG will be controlled by techniques of Refurbishment .
- Plan : start construction in 2014
- Sensitivity for DM search :
  - $\sigma_{SI}<10^{-46}$cm2(>5keV) for fiducialization.

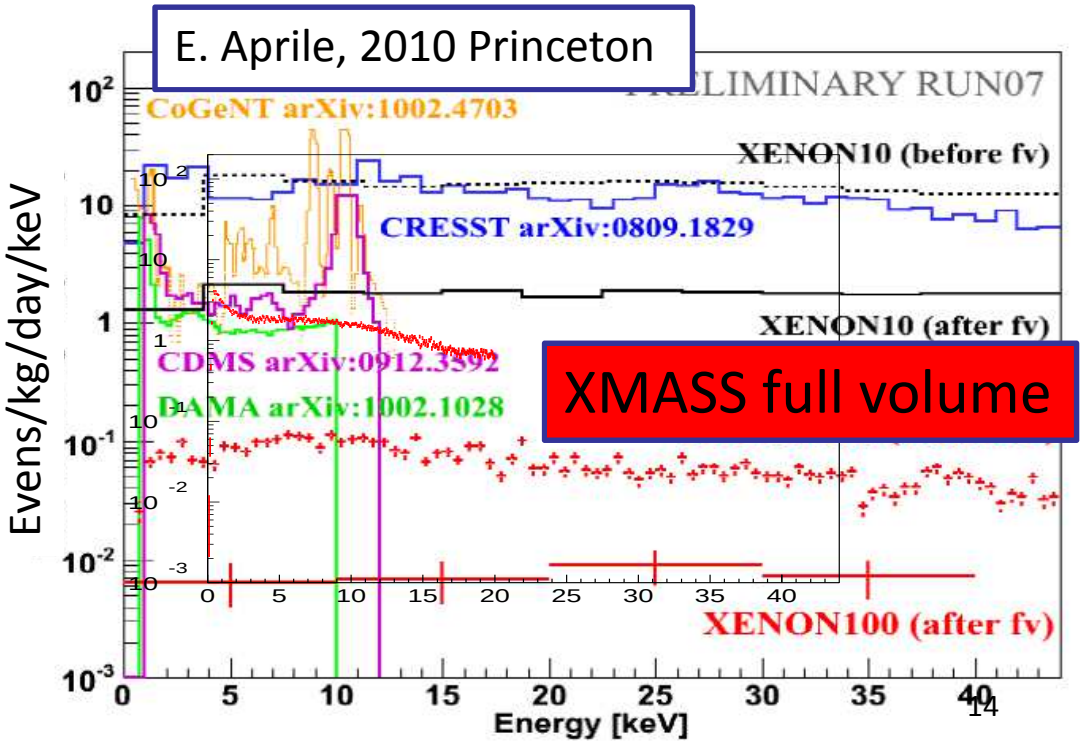





Some result from
XMASS-I

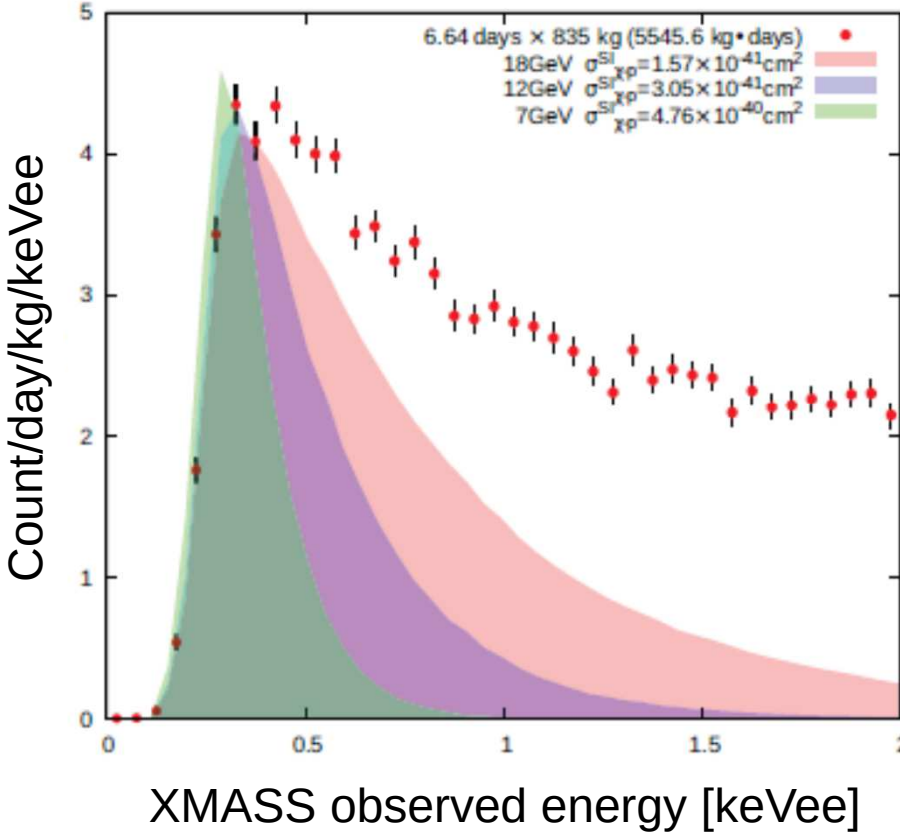
Low background even with the surface BG

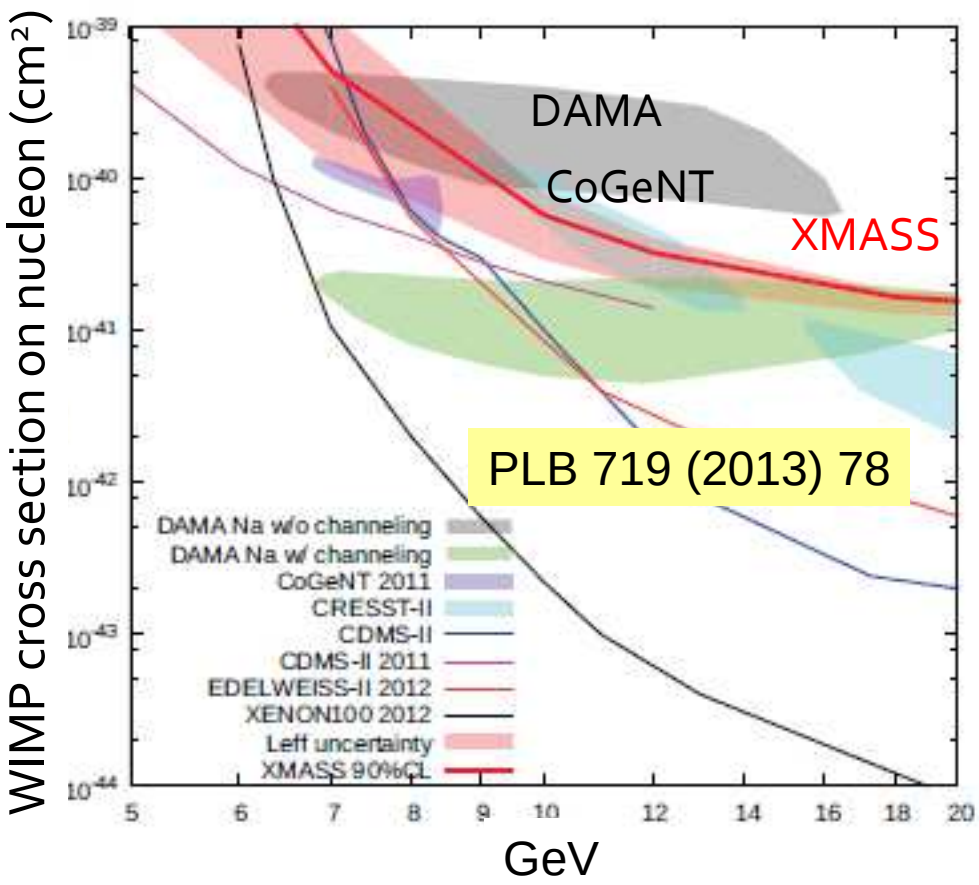
- Our BG is still quite low, even with the extra surface BG!
- In principle, the surface BG can be eliminated by vertex reconstruction. Optimization of the reconstruction program is on going to minimize a possible leakage to the inner volume.
- Our sensitivity for the low mass WIMP signals at low energy without reconstruction will be shown.
- Low mass WIMPs search
- Solar Axion search



Low mass WIMPs search

- Threshold is 0.3keV and Full volume analysis.
- Spectrum shows that observed data and MC WIMPs signal with best fit per WIMPs mass.
- Some part of the allowed regions of DAMA/CoGeNT can be excluded.
- After refurbishment, sensitivity will be improved ~ 2 order.



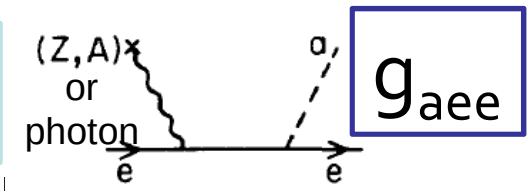


Solar axion search in XMASS

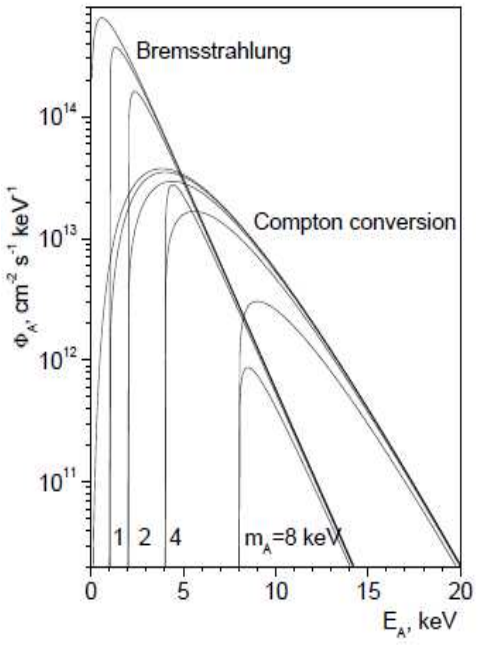
- Axion is a hypothetical particle to solve the strong *CP* problem.
- Produced in the Sun and detected in our detector. (like photo-electric effect)
- Our detector is suitable to see its signal, especially because of a large mass and low background.

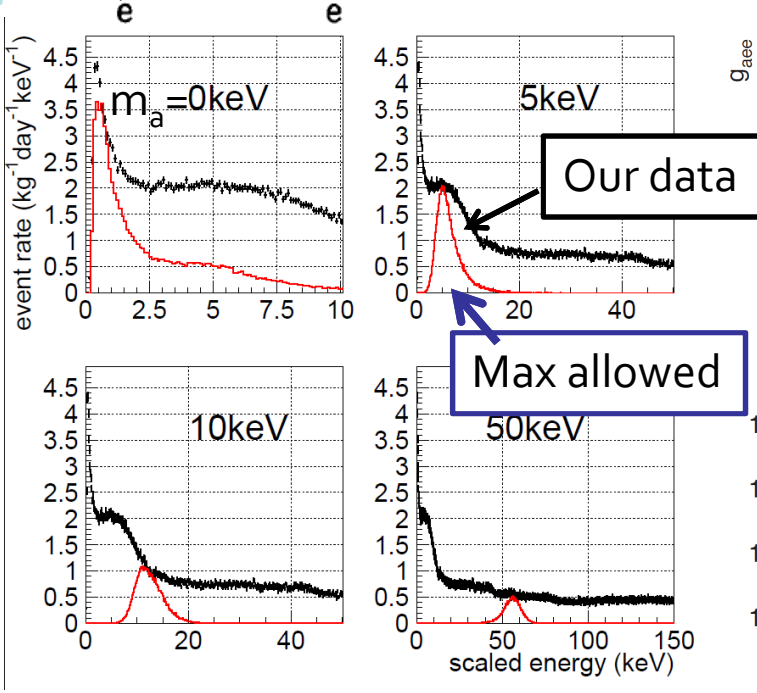
- Analyzed data ;
  - No indication of signals. Bound in g_{aee} vs. mass.
  - Better than any constraint in 10-40keV.
  - Better than any experimental constraint <1keV

Bremsstrahlung and Compton effect

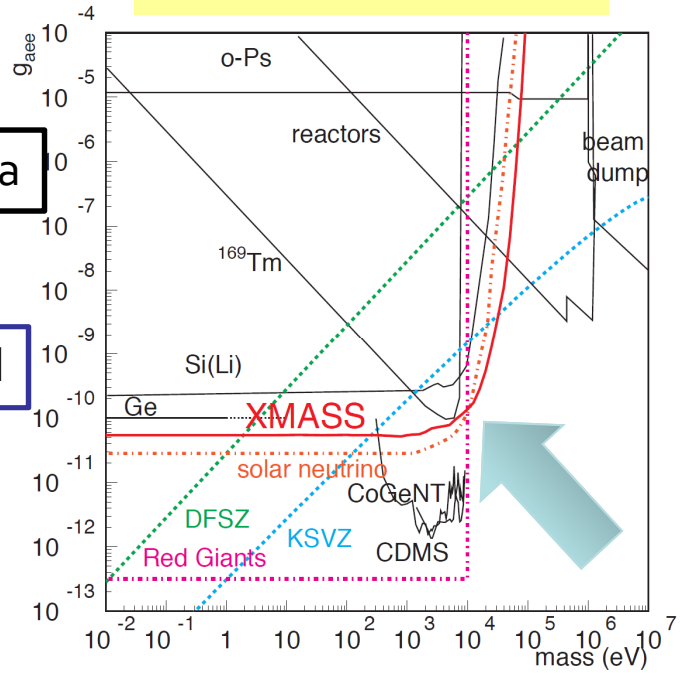


g_{aee}





arXiv: 1212.6153



Summary

- The XMASS-I was constructed and started commissioning late 2010.
- We completed commissioning data-taking and physics analyses are on-going.
- BG level is not as low as originally expected, but now the composition is well understood above 5keV.
- The refurbishment of XMASS-I is on-going. Experiment will resume in first of Autumn 2013.
- Also XMASS-1.5 is planning.
- Some preliminary results on dark matter and axion searches are shown. More results will come later.

XMASS collaboration

ICRR, University of Tokyo	K. Abe, K. Hieda, K. Hiraide, Y. Kishimoto, K. Kobayashi, Y. Koshio, S. Moriyama, M. Nakahata, H. Ogawa, H. Sekiya, A. Shinozaki, Y. Suzuki, O. Takachio, A. Takeda, D. Umemoto, M. Yamashita, B. Yang
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