

Status of the XMASS experiment



Katsuki Hiraide (ICRR, Univ. of Tokyo)

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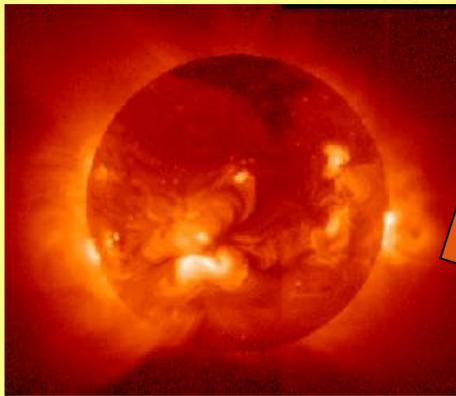
8th Patras Workshop on Axion WIMPs, and WISPs

XMASS experiment

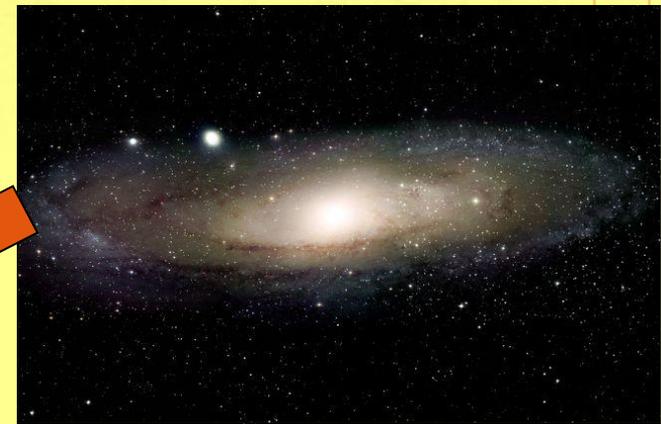
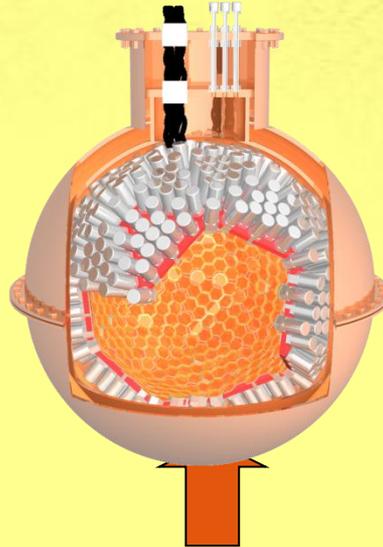
● What is XMASS?

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

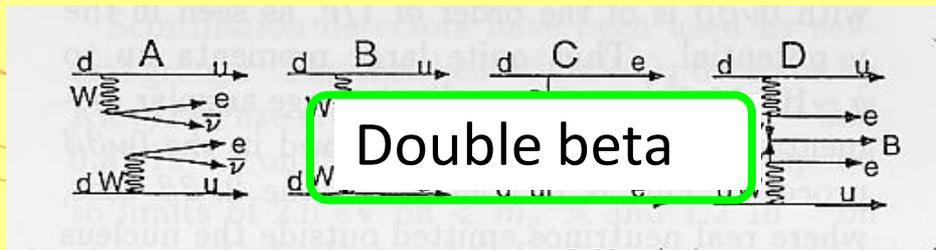
- Xenon detector for Weakly Interacting **MASS**ive Particles (DM search)
- Xenon **MASS**ive detector for solar neutrino ($pp/{}^7\text{Be}$)
- Xenon neutrino **MASS** detector ($\beta\beta$ decay)



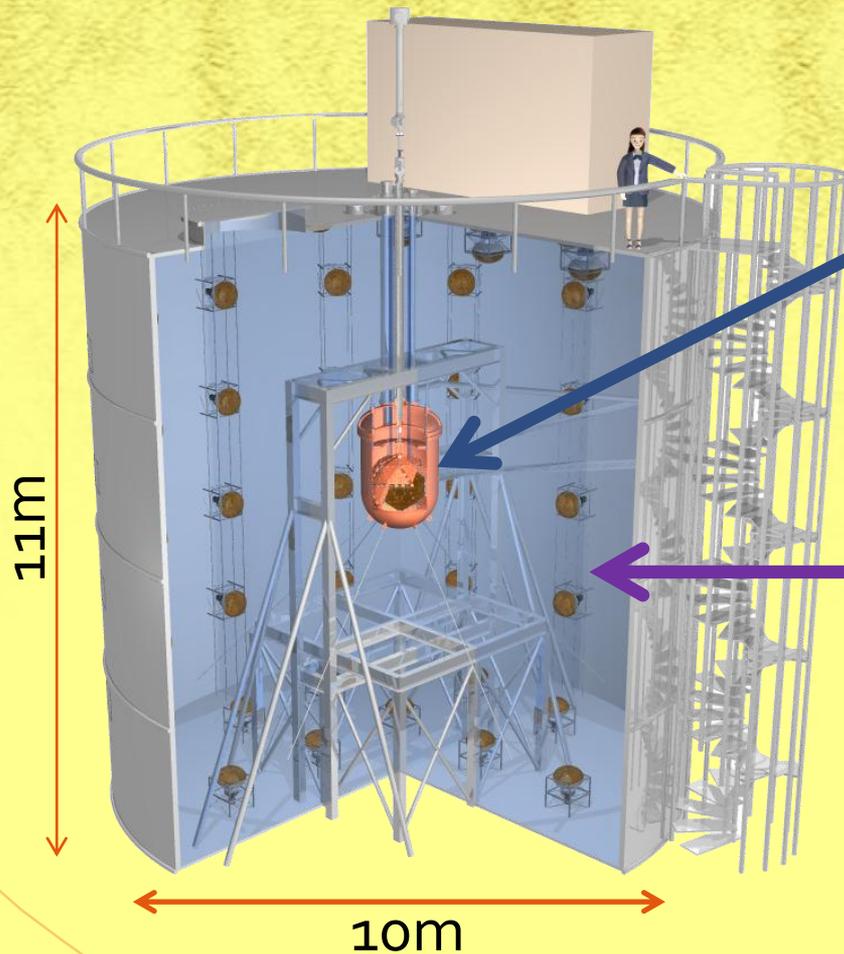
Solar neutrino



Dark matter



The XMASS 800kg detector



Xenon detector

- Single phase detector
- 835kg LXe (FV~100kg)
- 642 PMTs immersed in LXe

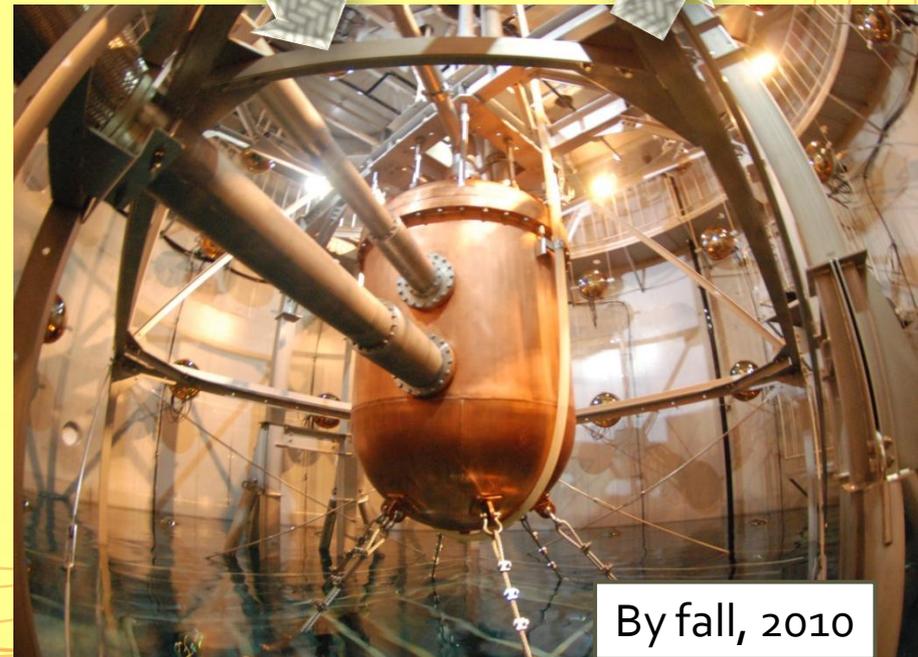
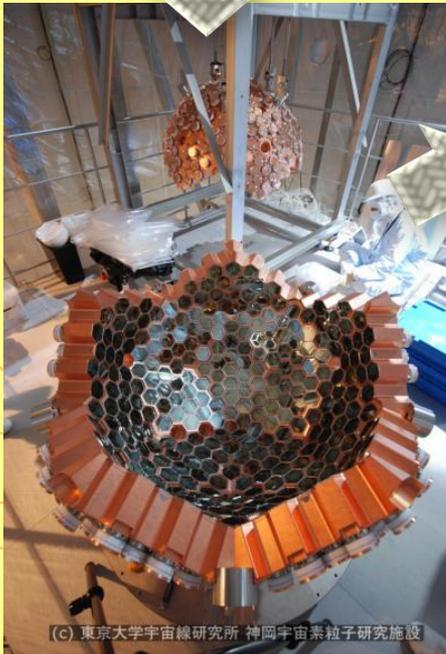
Water cherenkov detector

- shield of gamma, neutrons
- also used as cosmic-ray veto

- Construction completed and commissioning started late 2010.
- We completed commissioning data-taking and analyses are on-going.

Detector construction

1st application of WC tank for
WIMP search



Calibration system

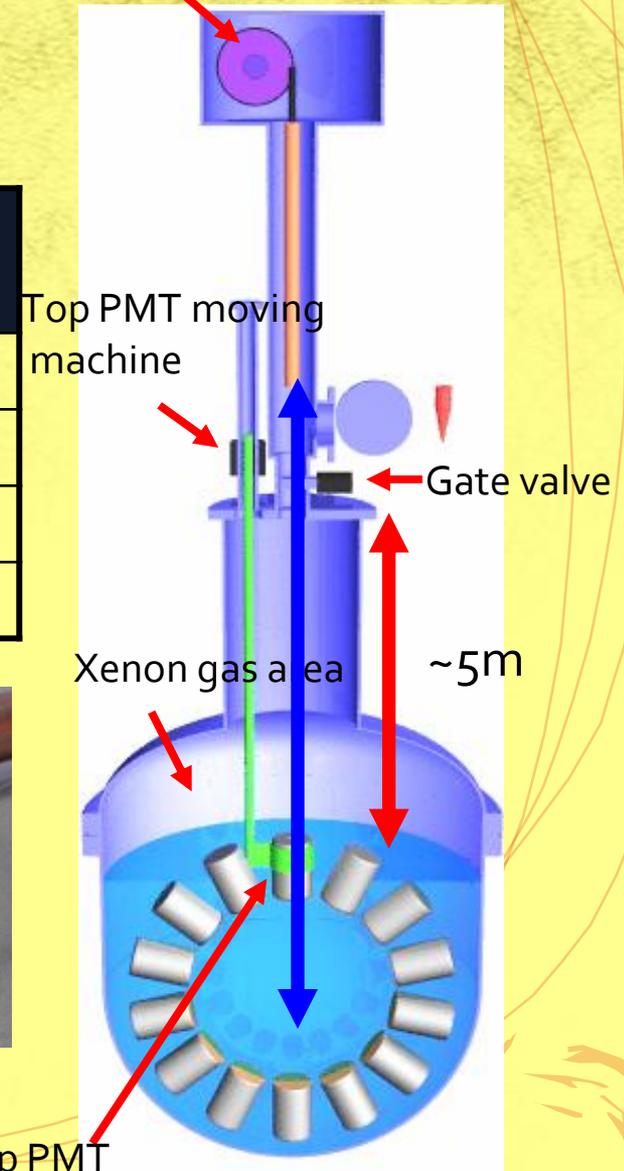
RI sources

	energy [keV]	RI [Hz]	ϕ [mm]	package
(1) Fe-55	5.9	350	5	brass
(2) Cd-109	22, 25, 88	800	5	brass
(3) Am-241	59.5	485	0.15	SUS
(4) Co-57	122	100	0.21	SUS



Source rod

Source introduce machine



Top PMT moving machine

Gate valve

Xenon gas area ~5m

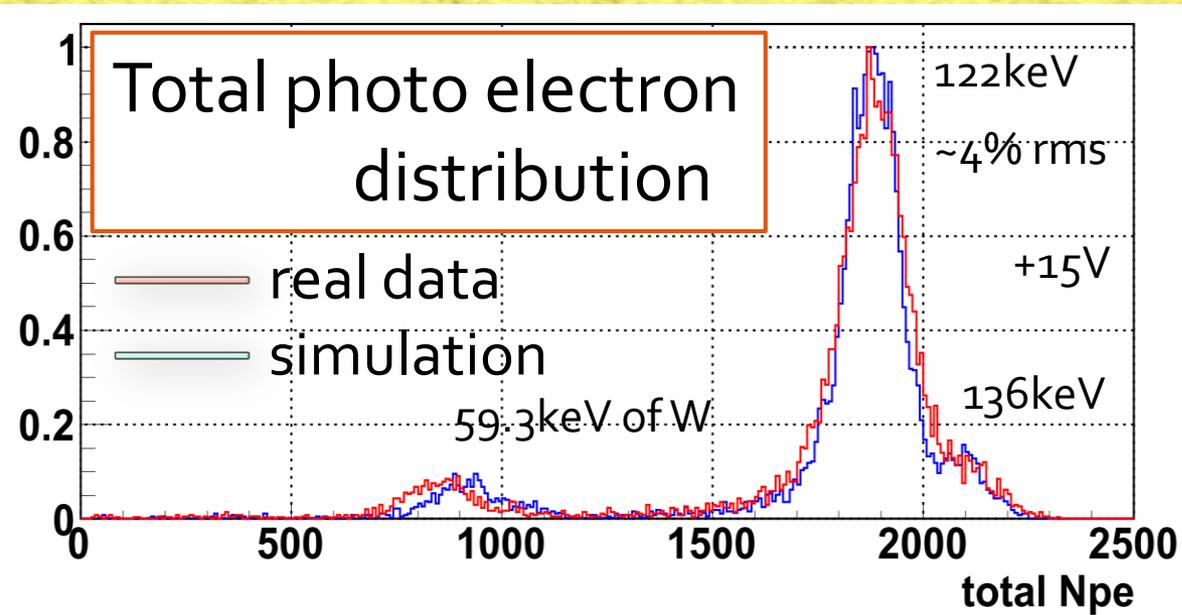
Top PMT (removed between calibration)

RI source with holder

adaptor(SUS₃₀₄)

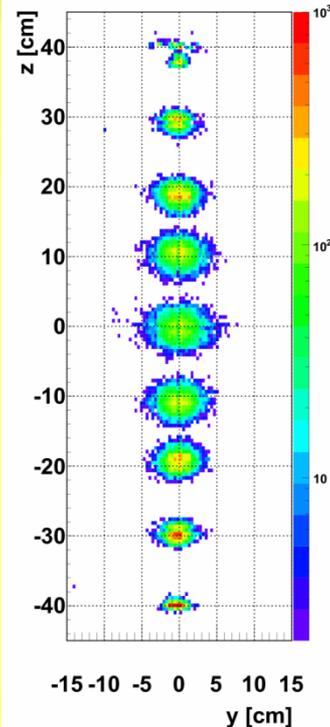
OFCu

Detector response for a point-like source (\sim WIMPs)

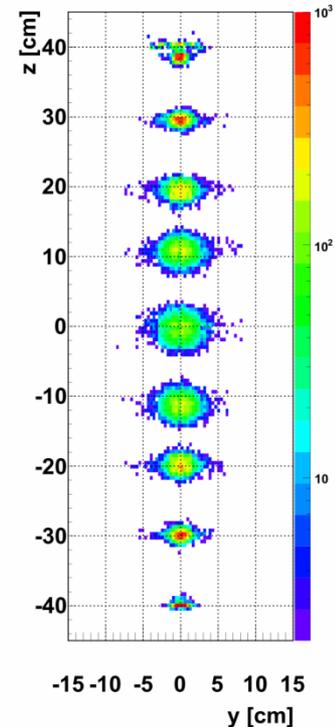


Reconstructed vertex dist.

Real Data



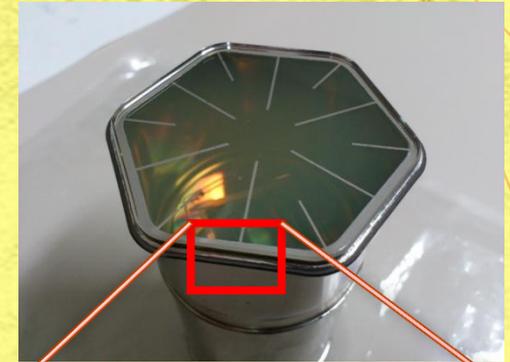
Simulation



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

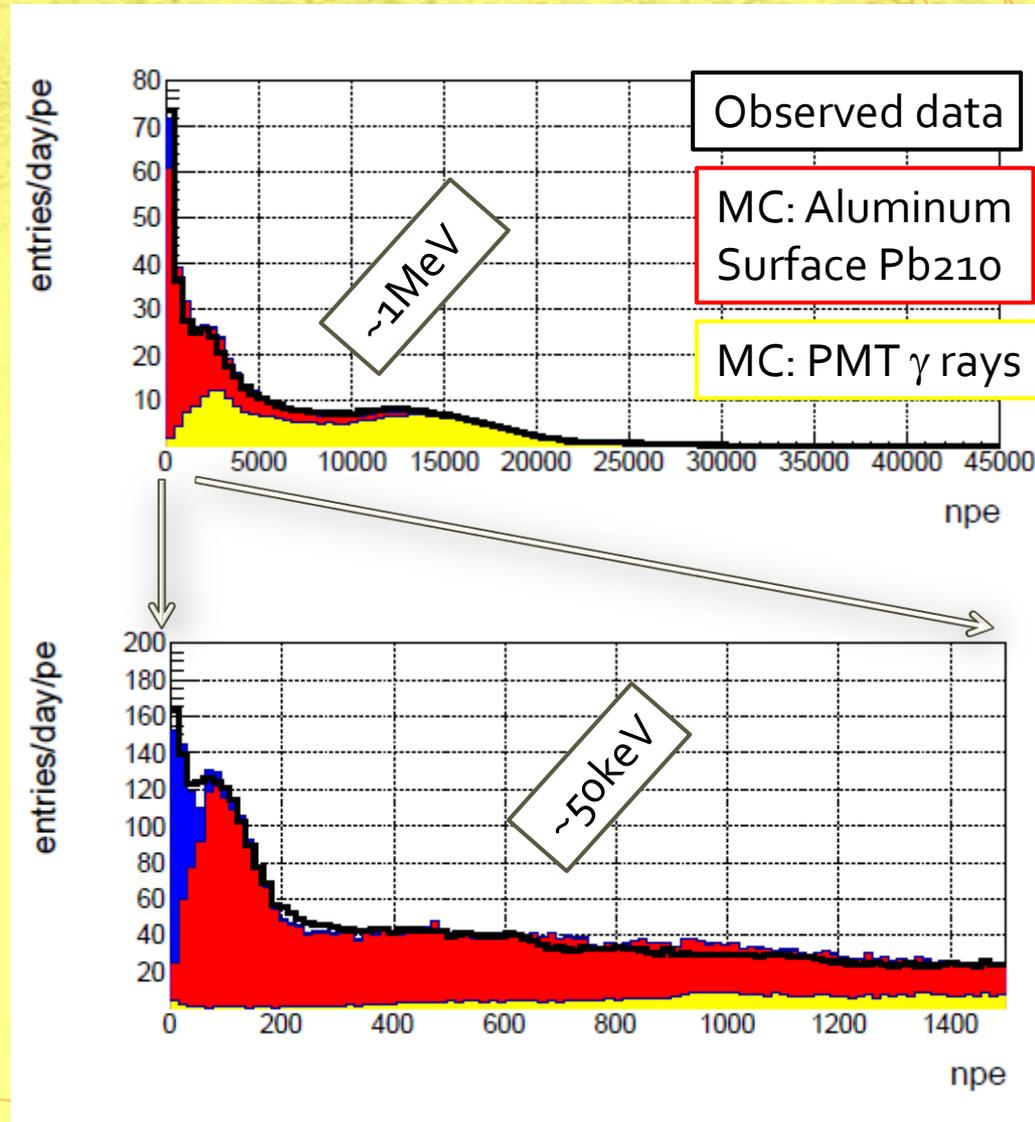
Background and its understanding

- Really important to understand BG to look for a positive evidence of signals.
- Major origin of BG was considered to be γ from PMTs. But the observed data seemed to have additional surface BG.
- Detector parts which touch liquid xenon were carefully evaluated again:
 - Aluminum sealing parts for the PMT (btw metal body and quartz glass) contains U_{238} and Pb_{210} (secular equiv. broken).
 - GORE-TEX between PMT and holder contains modern carbon (C_{14}) $0 \sim 6 \pm 3\%$.



Closer look at the observed spectrum

- Three contributions to the observed spectrum
 1. **High energy (0.1-3MeV):** **PMT γ rays:** Measured by Ge detectors and well understood.
 2. **Mid. energy (5keV-1MeV):** **Aluminum and radon daughters:** Measured by Ge det. and consistent with observed α -ray events (61/64mcps in data/MC). Rn daughters on the inner wall identified by α events.

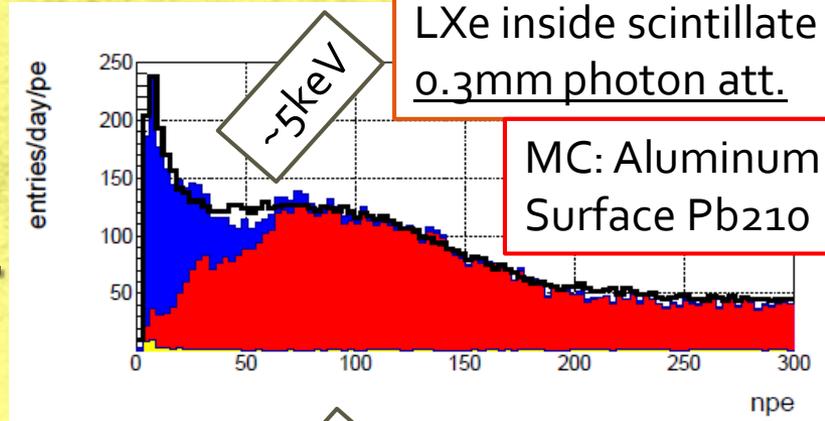


Observed data

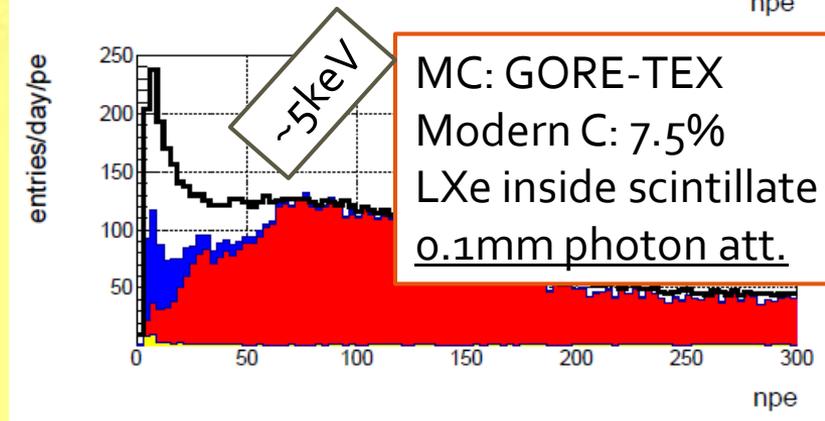
Closer look at the observed spectrum

MC: GORE-TEX
Modern C: 7.5%
LXe inside scintillate
0.3mm photon att.

MC: Aluminum
Surface Pb210

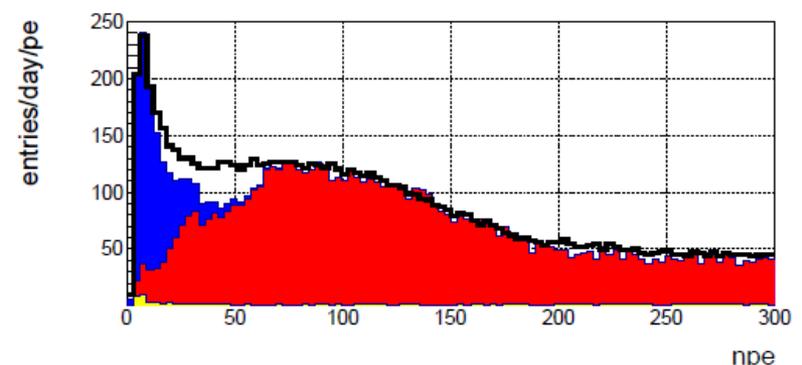


MC: GORE-TEX
Modern C: 7.5%
LXe inside scintillate
0.1mm photon att.



3. Low energy (0-5keV): Under study.

Prediction based on some assumptions on GORE-TEX gives a similar shape. But assumption dependent. Confirmation possible only by removing the GORE-TEX.

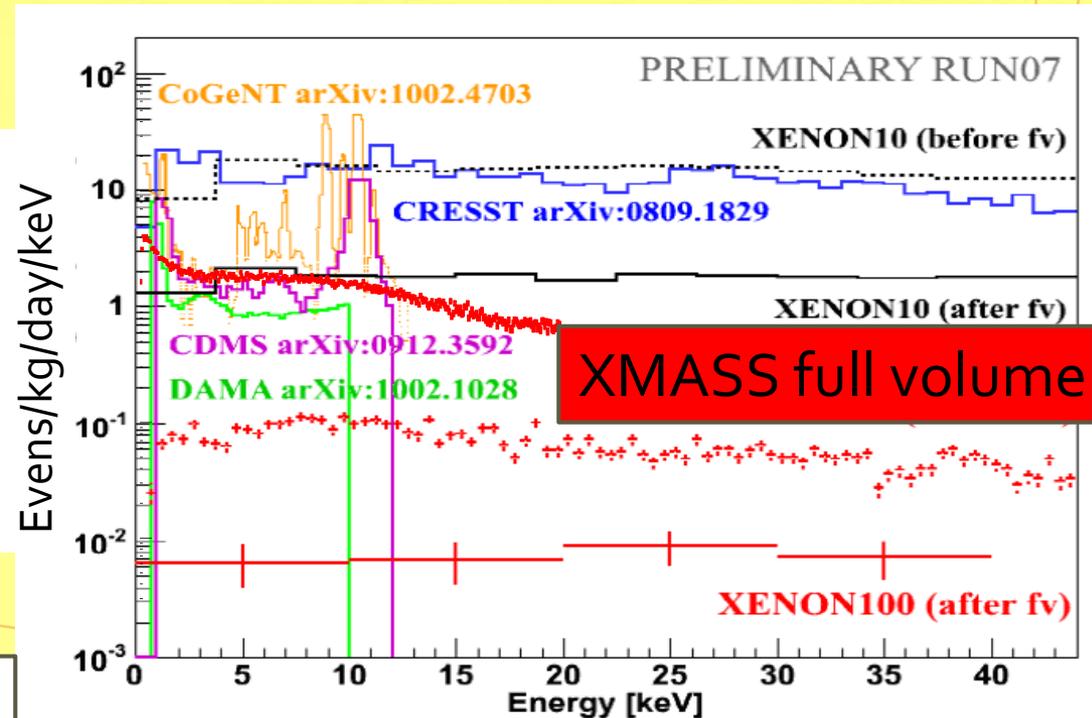


BG >5keV (the design energy threshold) is well understood!

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.

- Today, our sensitivity for the low mass WIMP signals at low energy without reconstruction will be shown.

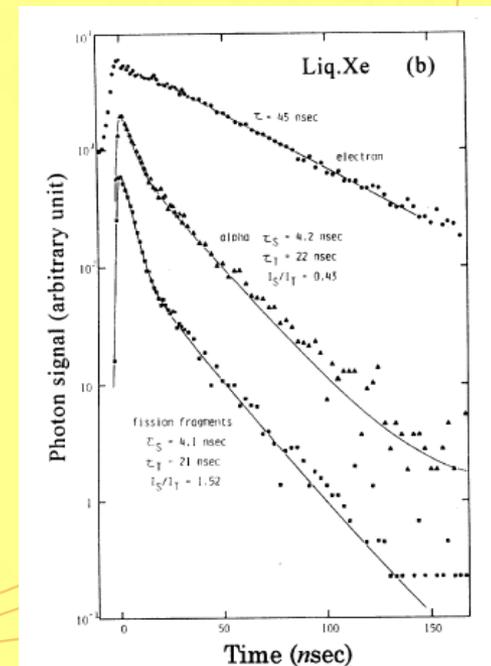
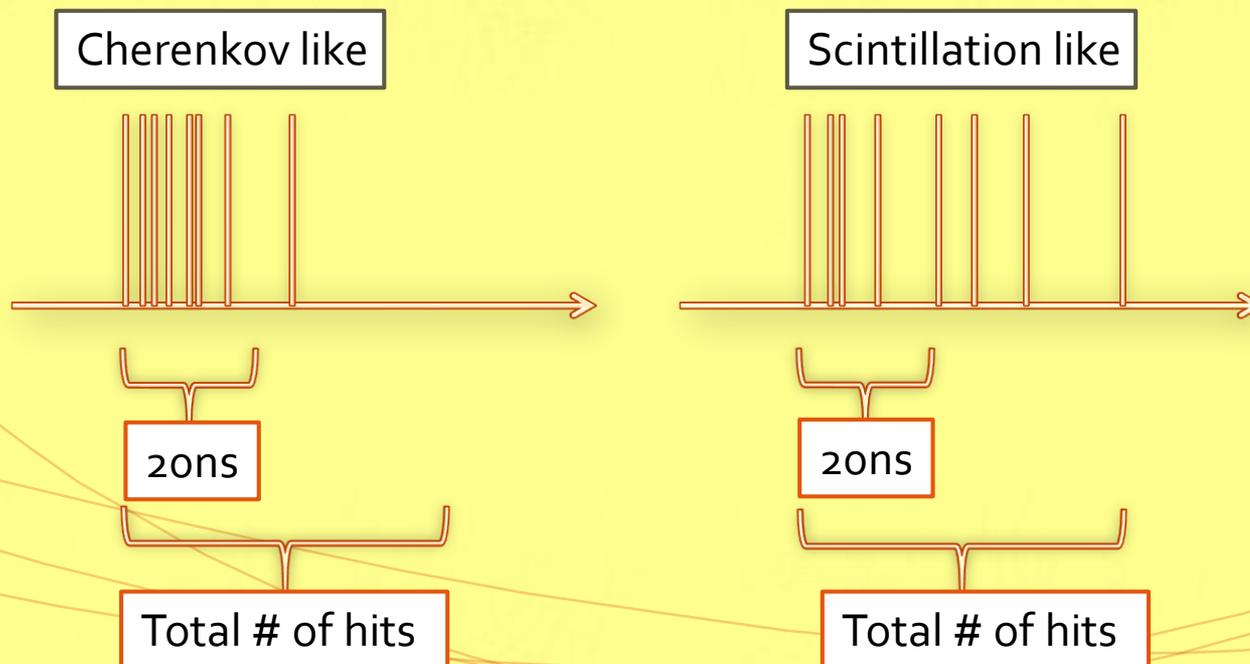


Low energy, full volume analysis for low mass WIMPs

- The dark matter signal rapidly increase toward low energy end. The large p.e. yield enables us to see light WIMPs.
Try to set absolute maxima of the cross section (predicted spectrum must not exceed the observed spectrum).
- The largest BG at the low energy end is the Cherenkov emission from ^4K in the photo cathodes.
- Selection criteria
 - Triggered by the inner detector only (no water tank trigger)
 - Time difference to the previous event $>10\text{ms}$
 - RMS of hit timing $<100\text{ns}$ (rejection of after pulses of PMTs)
 - Cherenkov rejection

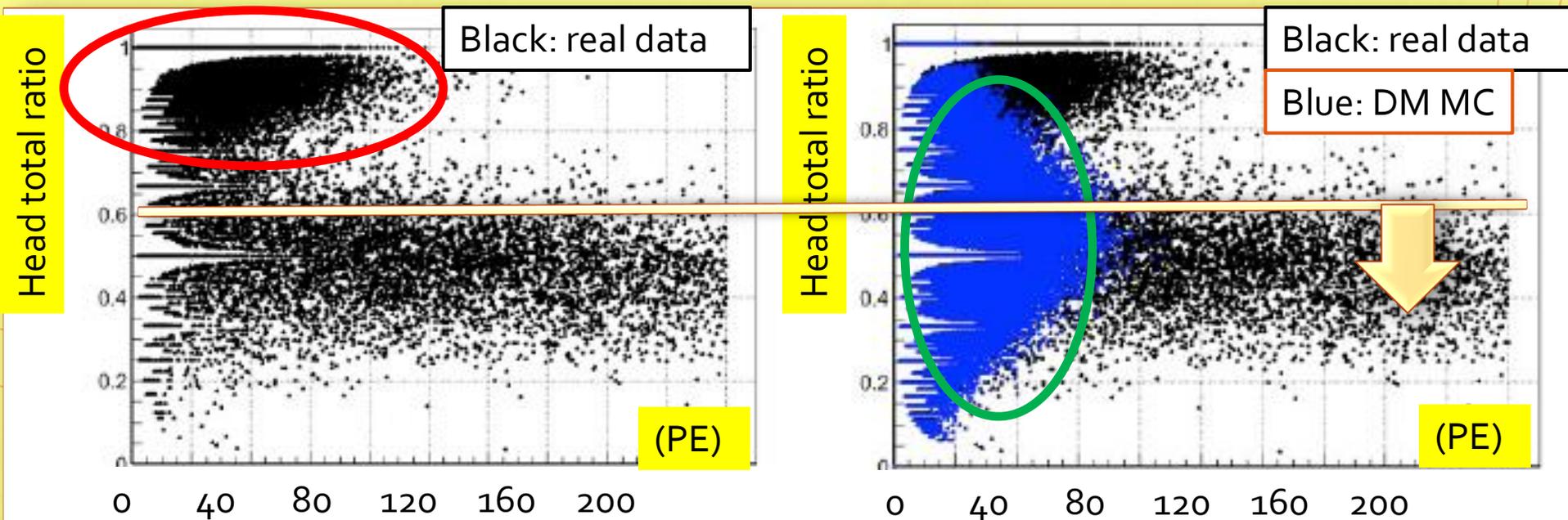
Detail of the Cherenkov rejection

- Basically, separation between scintillation lights and Cherenkov lights can be done using timing profile.
- $(\# \text{ of hits in } 20\text{ns window}) / (\text{total } \# \text{ of hits}) = \text{"head total ratio"}$ is a good parameter for the separation.



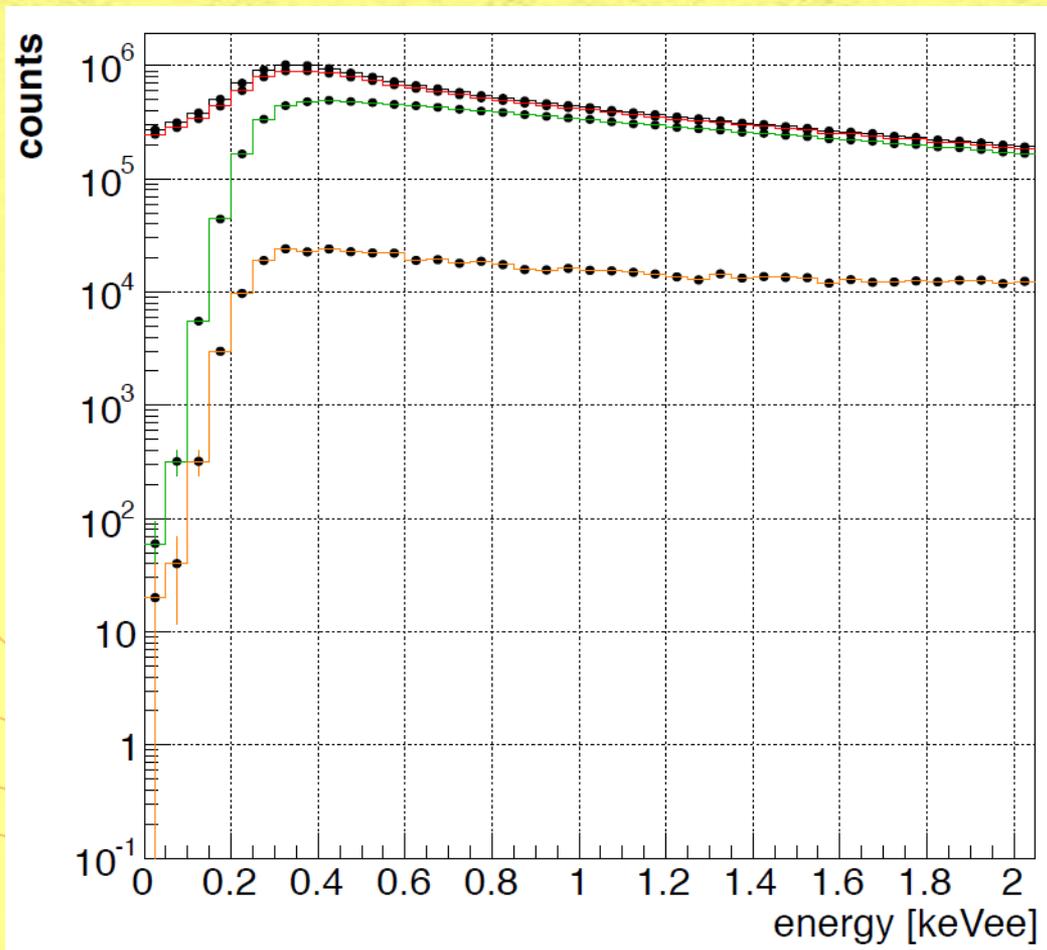
“head total ratio” distribution

- Cherenkov events peaks around 1 \leftrightarrow scintillation \sim 0.5
- Low energy events observed in Fe55 calibration source as well as DM simulation (t=25ns) show similar distributions.
- Efficiency ranges from 40% to 70% depending on the p.e. range.



Energy spectrum after each cut

- 6.64 days x 835kg data
- The Cherenkov events are efficiently reduced by the cut.

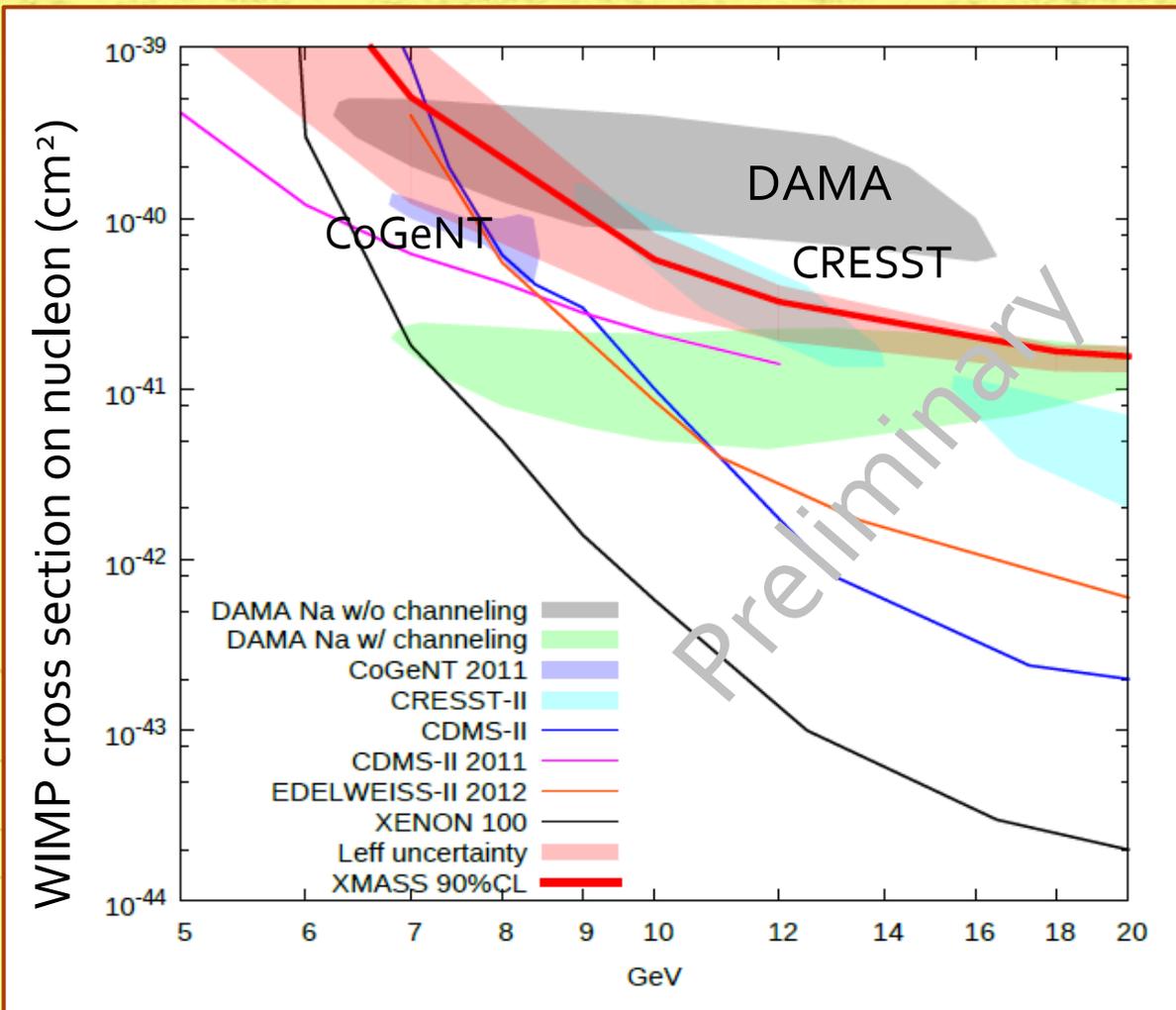


- Events @ each reduction step

cut0: <code>triglId == 1</code>	:932863
cut1: <code>+ dT_Pre(10msec)</code>	:866343
cut2: <code>+tdcRMS < 100</code>	:570025
cut3: <code>+Chrenkov</code>	:28863

Exclusion limit

- Sensitive to the allowed region of DAMA/CoGeNT/CRESST.
- Some part of the allowed regions are excluded.
- Annual modulation study using our ~160 days data is also on going.

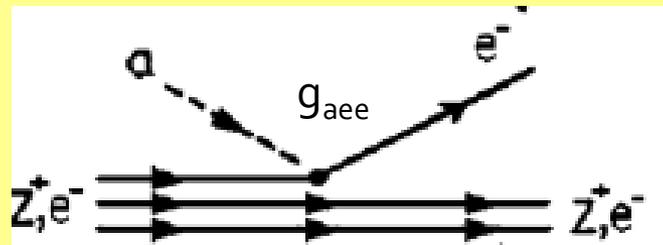


XMASS 90%CL

- The XMASS 90%CL limit includes systematic errors except for L_{eff} uncertainty.
- L_{eff} band is shown separately.

Dark matter axion search in XMASS

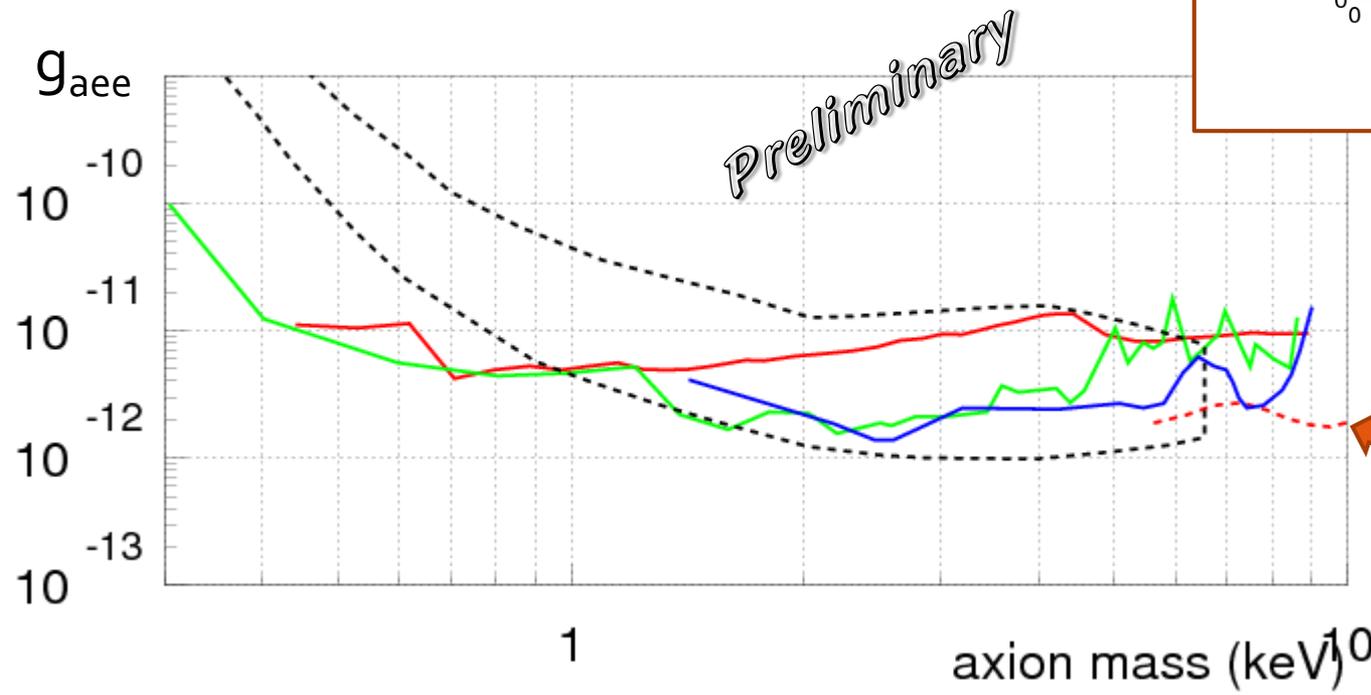
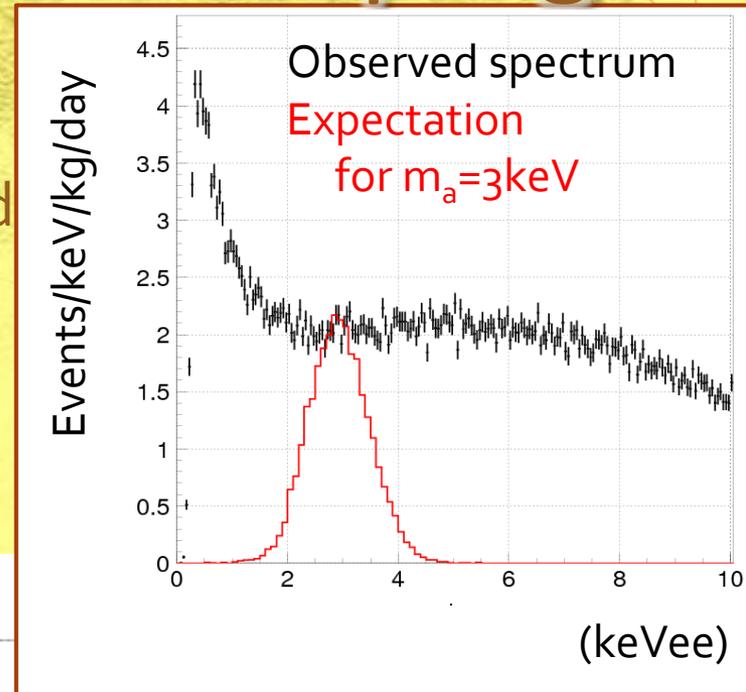
- The DAMA signal may be due to electromagnetic interaction of WIMPs to the NaI detectors by such as a non-relativistic axion dark matter. See J. Collar, arXiv: 0903.5068
- XMASS can search for dark matter axion by detection through axio-electric effect.



- We show a preliminary result based on 6.64 days x 835kg data.

Limit on the axio-electric coupling

- We obtained a limit on the axio-electric coupling (g_{aee}) by comparing the observed spectrum and the expectation.
- The result can be further improved above 5keV by fitting spectrum.



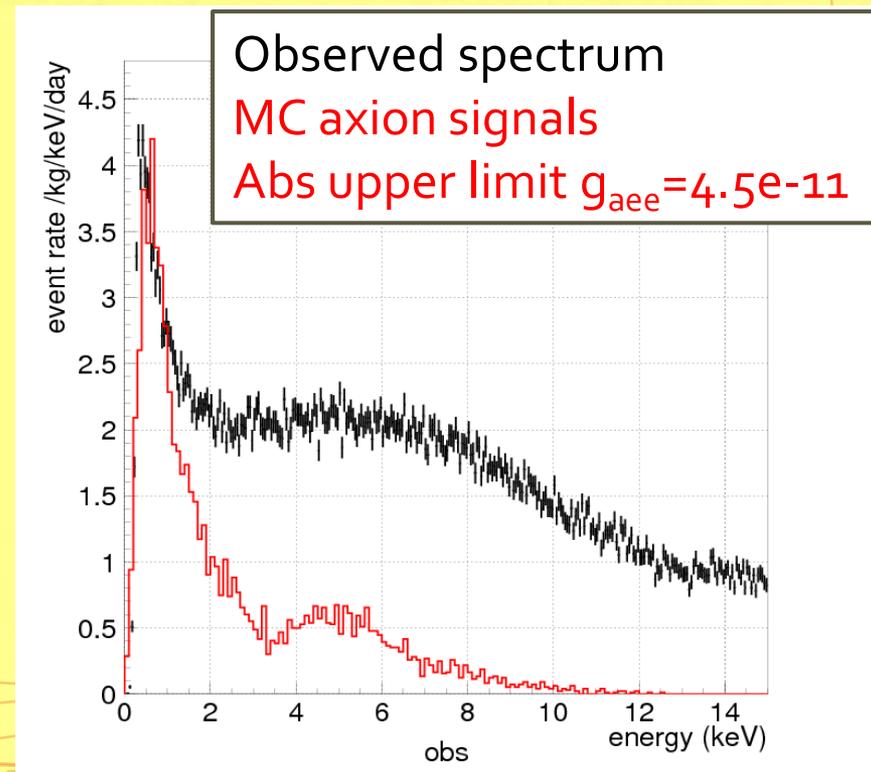
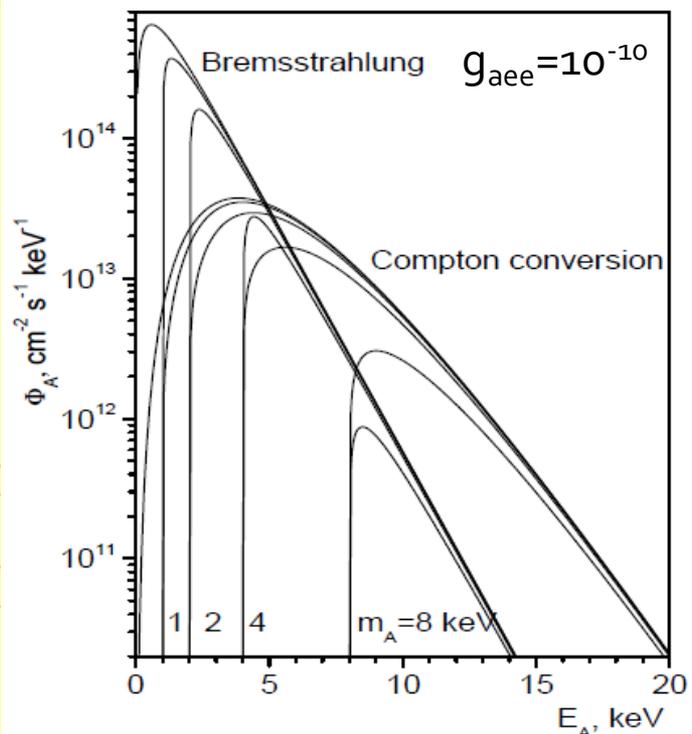
DAMA allowed
CoGeNT
CDMS
XMASS

Sensitivity with
spectrum fitting

Solar axion search in XMASS

- XMASS can also search for solar axion emitted owing to Bremsstrahlung and Compton processes in the Sun, by detection through axio-electric effect.
- We obtained a limit on axio-electric coupling (g_{aee})

Solar axion flux (Derbin et al., arXiv:1206.4142)



Limits on g_{aee} from XMASS (DM+solar)

Preliminary

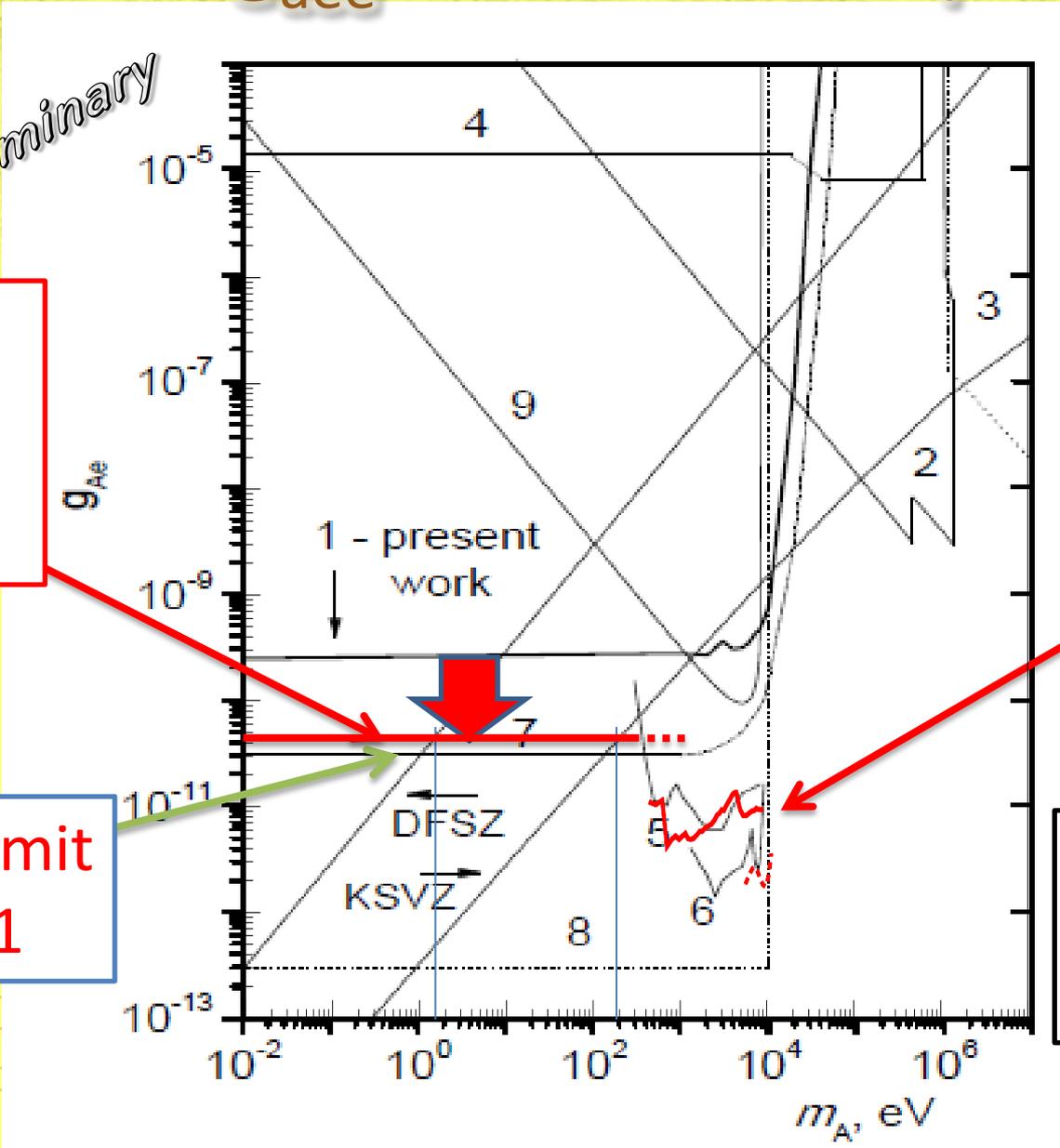
XMASS
Limit by
solar axion
 $4.5e-11$

Original
figure from
Derbin et al.,
1206.4142

XMASS
Limit by DM

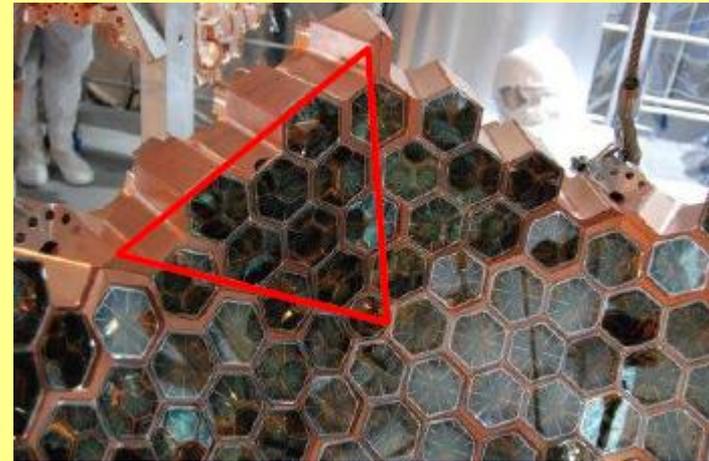
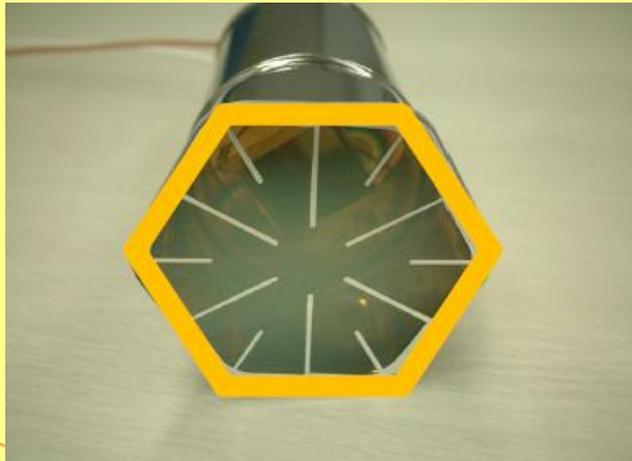
Solar limit
 $2.8e-11$

Allowed mass
< 200eV for KSVZ
< 2eV for DFSZ



Refurbishment work

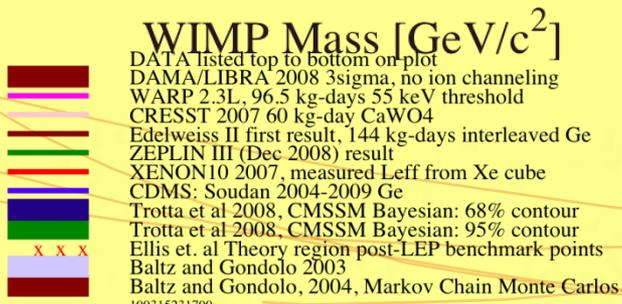
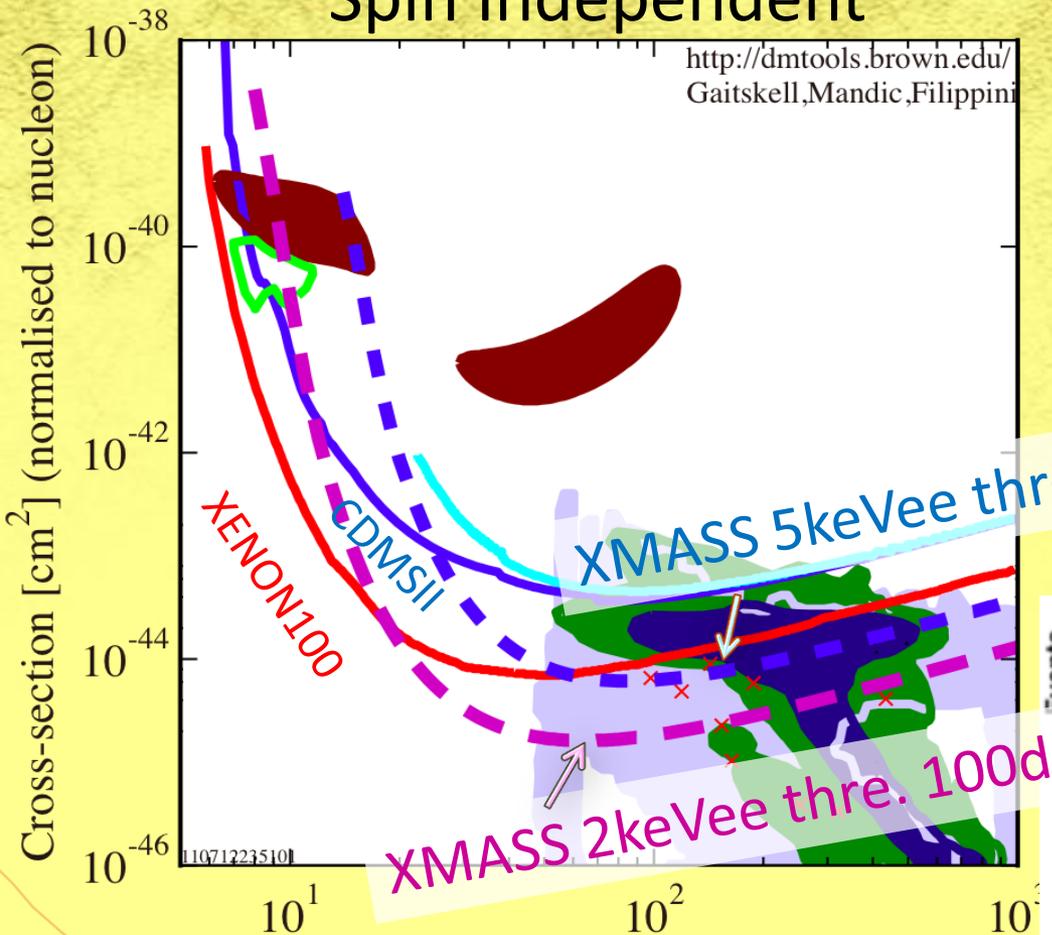
- Tuning of reconstruction/reduction is on-going.
- However, removing the origins of BG must be done for better sensitivity.
- To reduce the BG caused by Aluminum, we are planning to cover the part and surfaces by copper rings and plates:



- This work will be done latter half of this year.

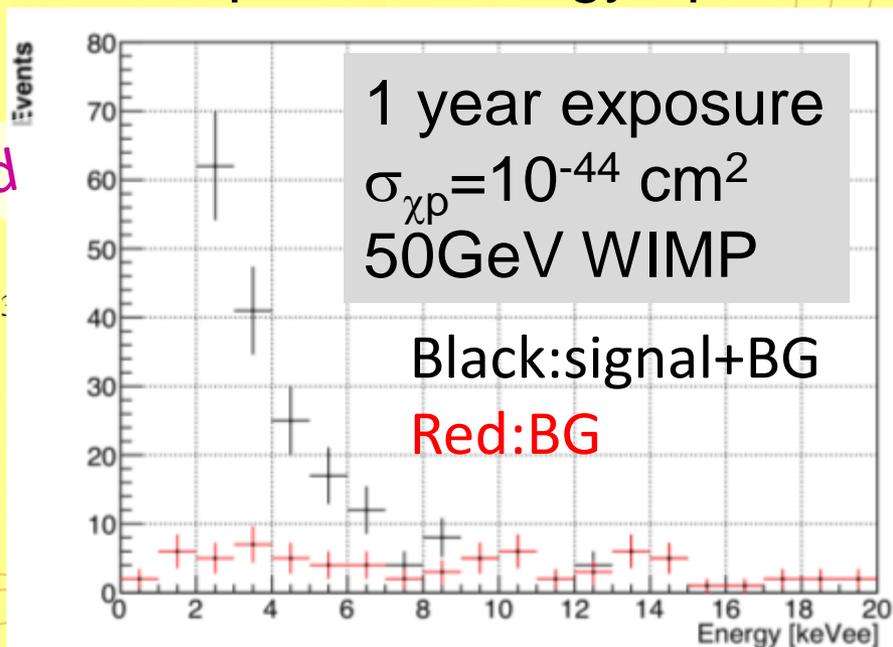
Expected sensitivity with fiducialization

Spin Independent



Initial target of the energy threshold was ~5keVee. Because we have factor ~3 better photoelectron yield, lower threshold = smaller mass dark matter may be looked for.

Expected energy spec.



Summary

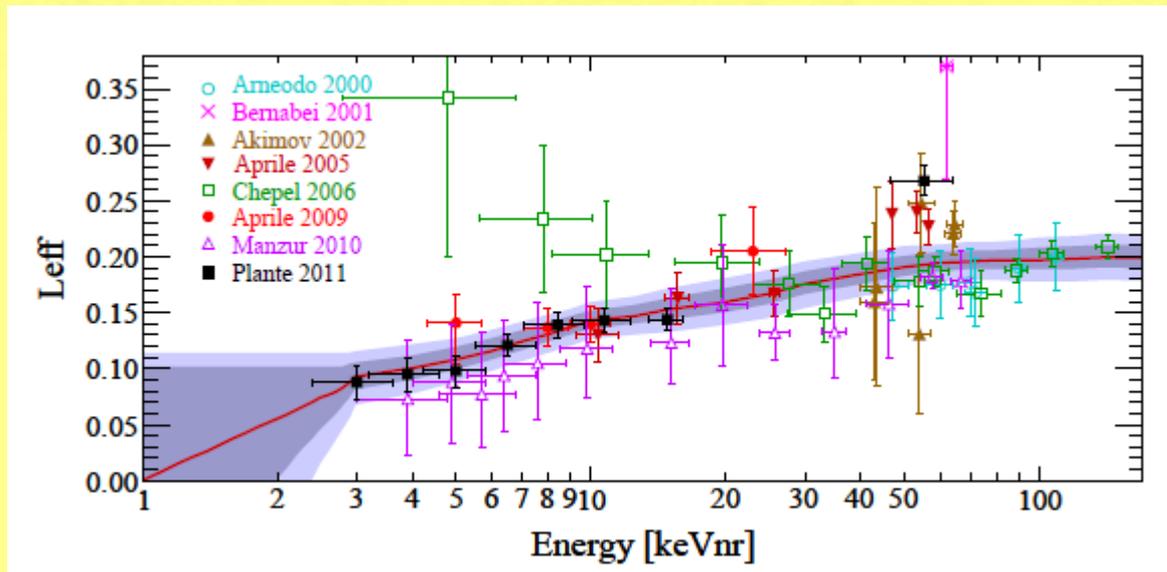
- The XMASS 800kg detector was constructed and started commissioning late 2010.
- We completed commissioning data-taking and physics analyses are on-going.
- BG level is not as low as originally expected, but now the composition is well understood above 5keV.
- Some preliminary results on dark matter and axion searches are shown. More results will come later.
- By improving software (reconstruction/BG reduction) and hardware refurbishment, we aim at the dark matter search with the original sensitivity.

Backup slides



Uncertainties

- Major uncertainty is the scintillation efficiency of nuclear recoil in liquid xenon.
- Uncertainties of the trigger thre. (hard trig. 4hits), cut eff., and energy scale are also properly taken into account.



Scintillation efficiency as a function of energy
 E. Aprile et al., PRL 105, 131302 (2010)

Note: our "energy"
 = keVnr * Leff