Status of the XMASS experiment

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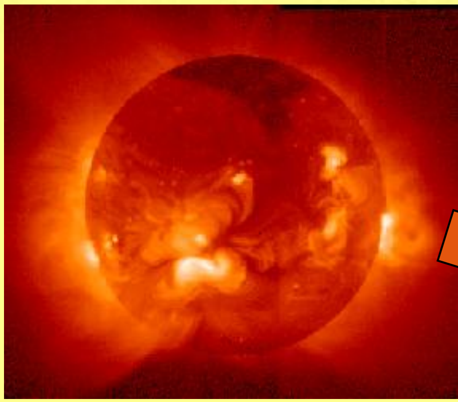
8th Patras Workshop on Axion WIMPs, and WISPs

XMASS experiment

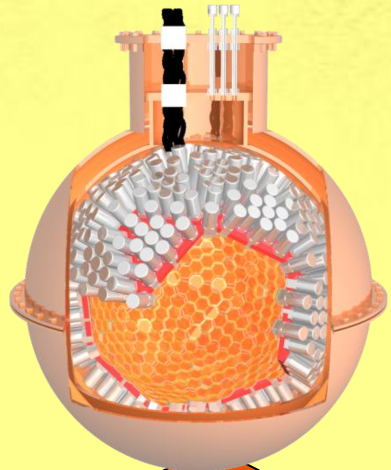
●What is XMASS?

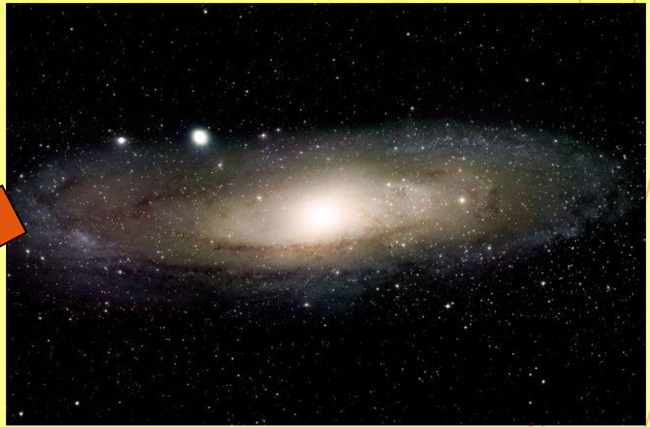
Multi purpose low-background and low-energy threshold experiment with liquid Xenon

- **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**)

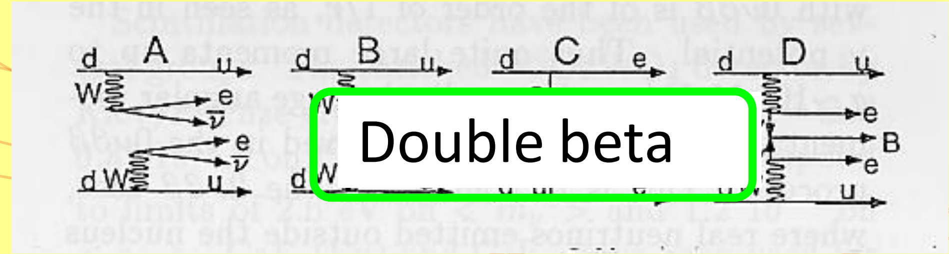


Solar neutrino



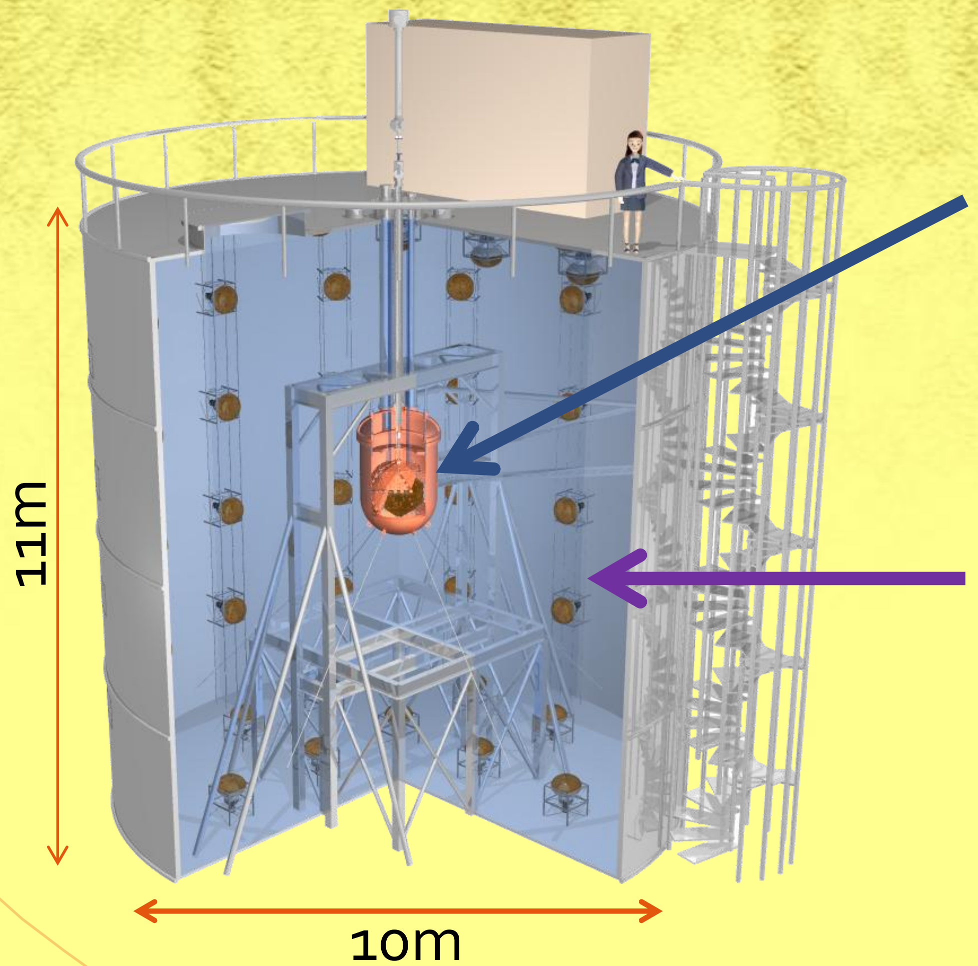


Dark matter



Double beta

The XMASS 800kg detector



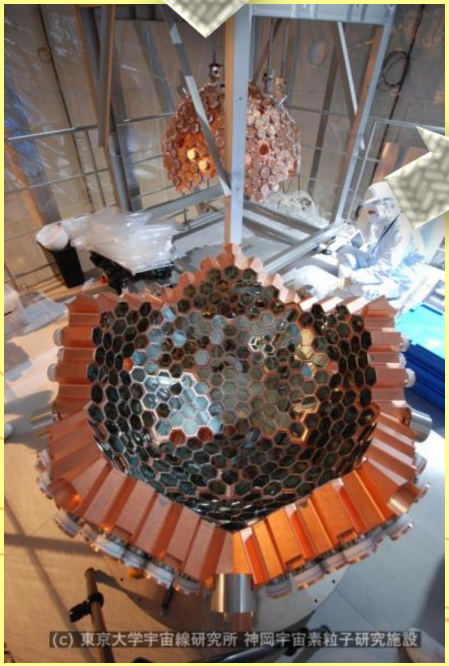
Xenon detector
- Single phase detector
- 835kg LXe (FV~100kg)
- 642 PMTs immersed in LXe

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

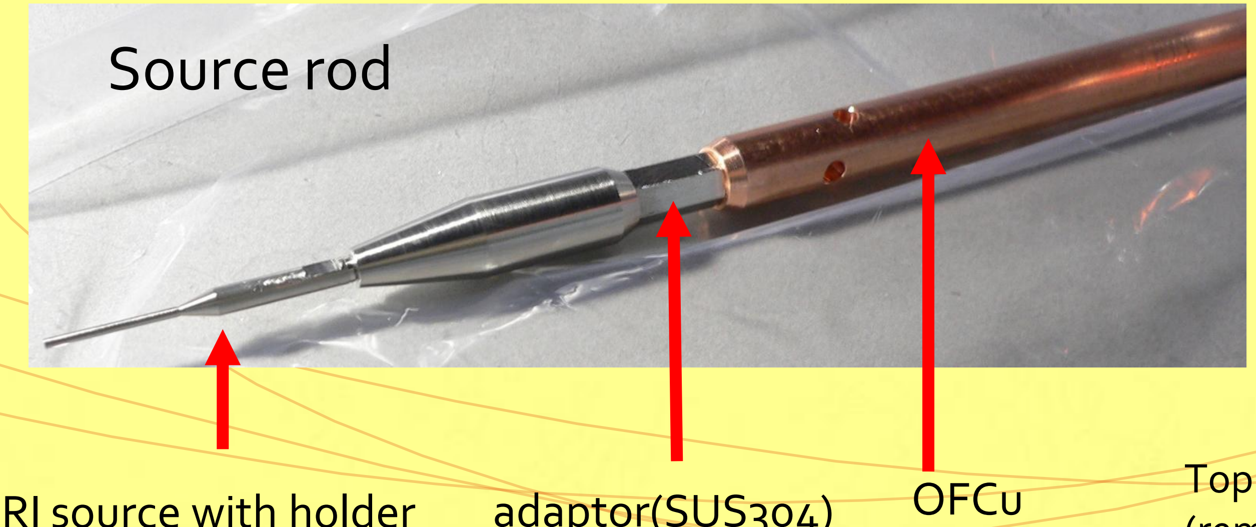


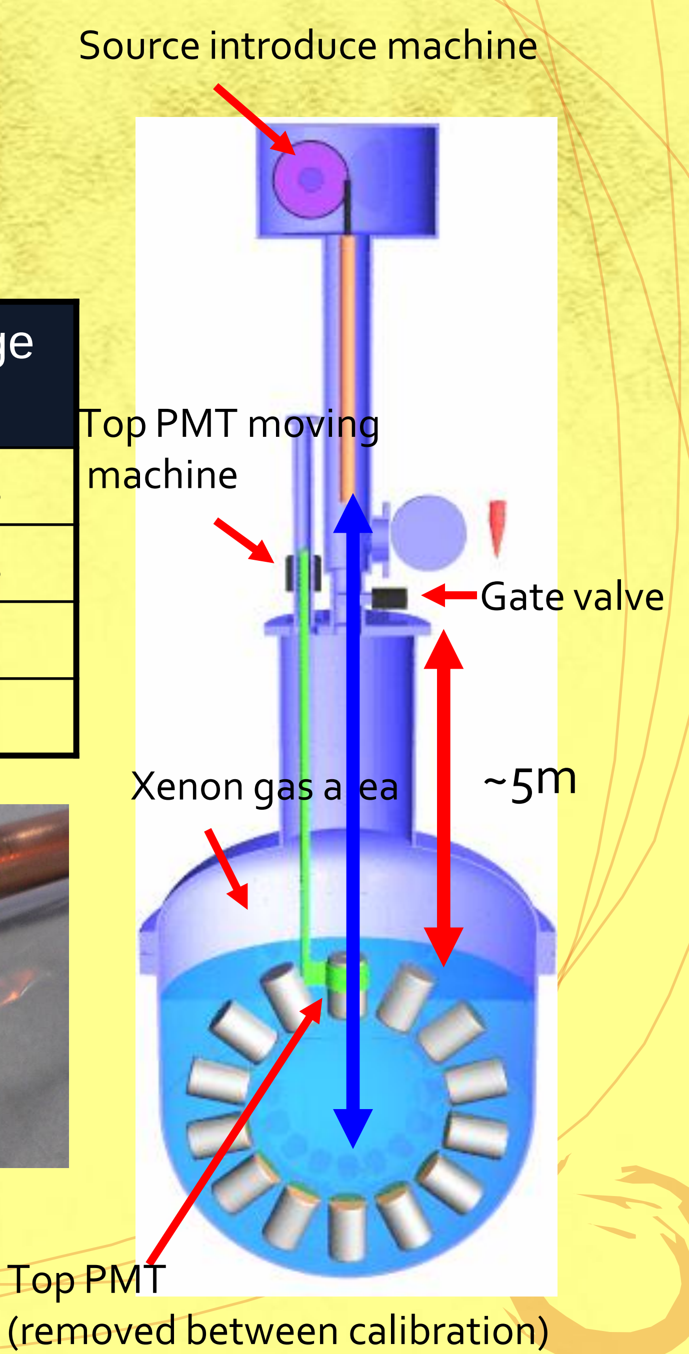
By fall, 2010

Calibration system

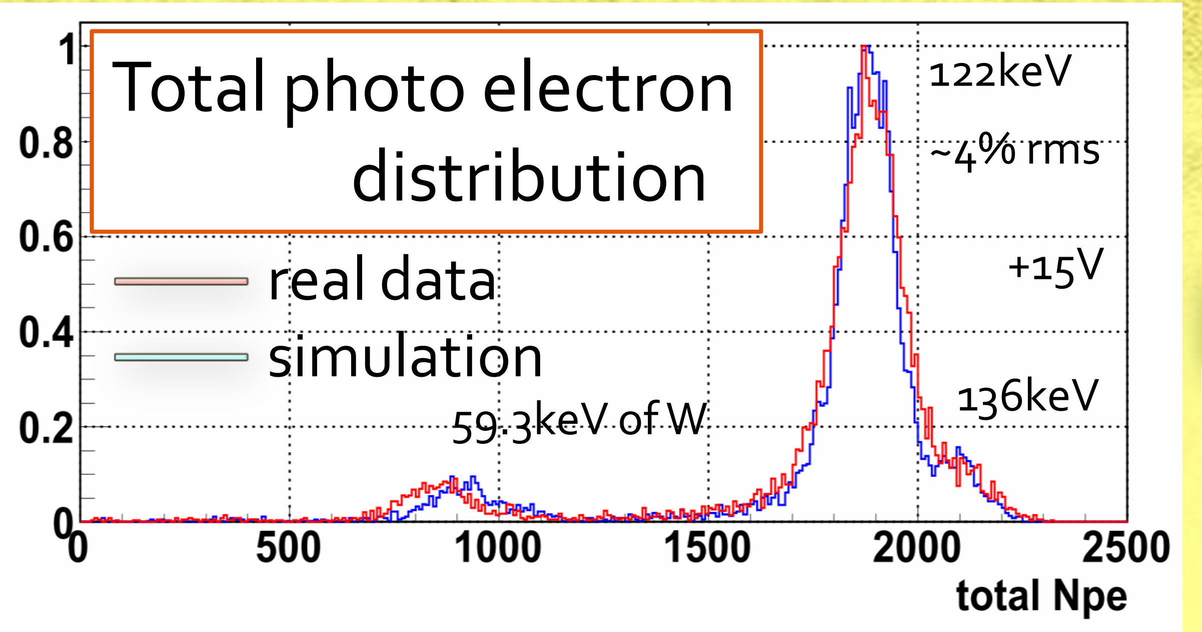
RI sources

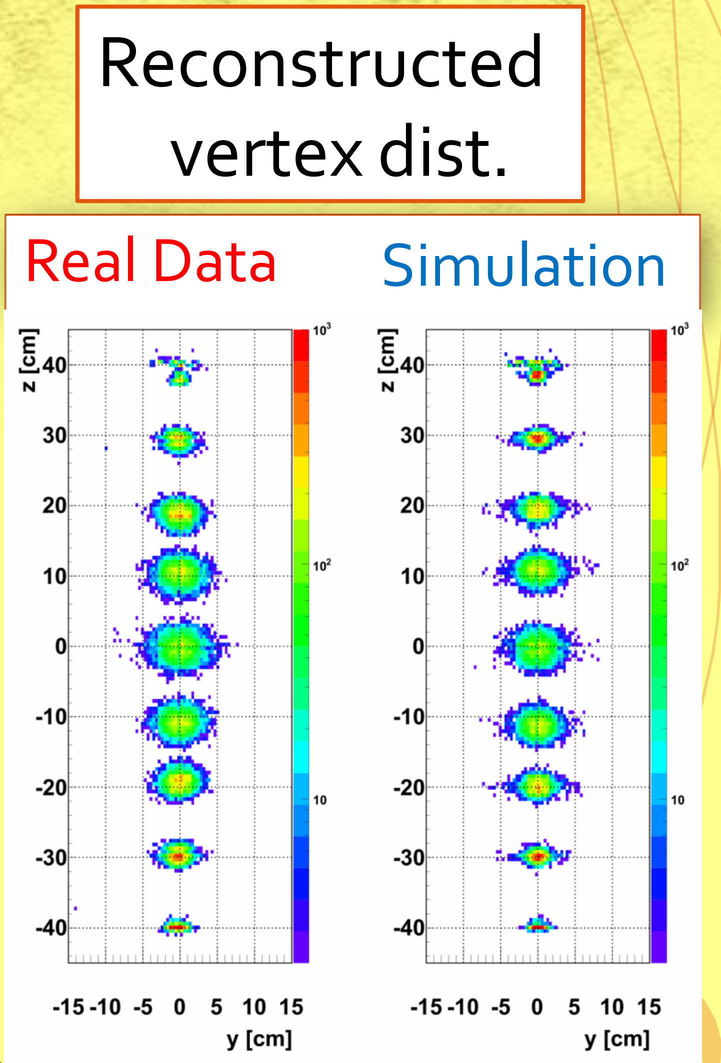
	energy [keV]	RI [Hz]	φ [mm]	package
(1) Fe-55	5.9	350	5	brass
(2) Cd-109	22, 25, 88	800	5	brass
(3) Am-241	59.5	485	0.15	SUS
(4) Co-57	122	100	0.21	SUS





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

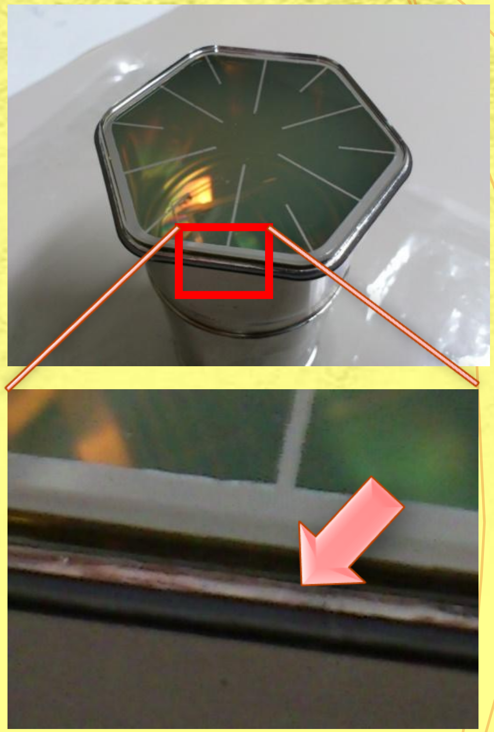




- ^{57}Co source @ center gives a typical response of the detector.
- 14.7p.e./keV$_{ee}$ (⇔ 2.2 for S1 in XENON100)
- The pe dist. well as vertex dist. were reproduced by a simulation well.
- Signals would be <150p.e. exp shape.

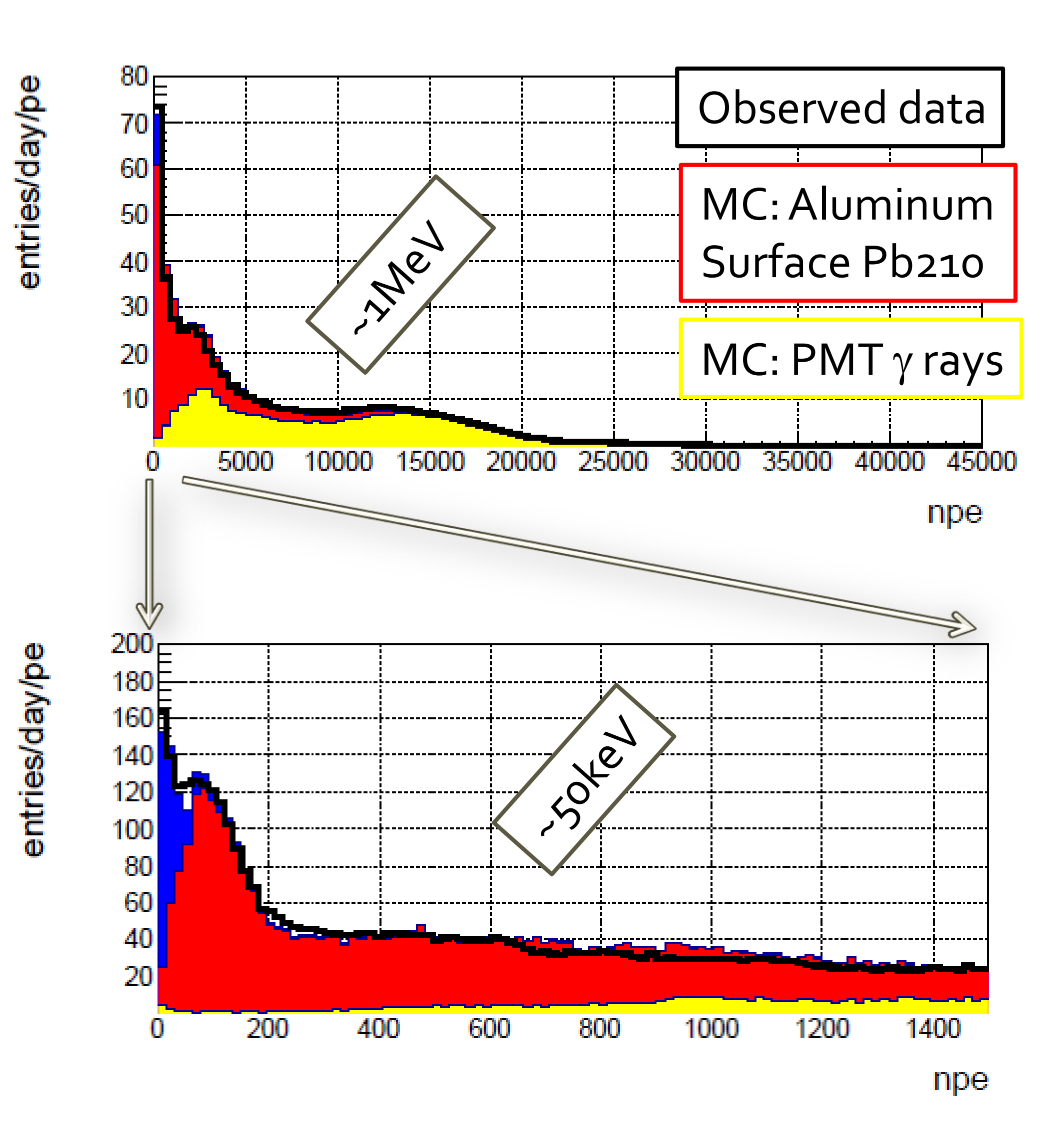
Background and its understanding

- 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 U238 and Pb210 (secular equiv. broken).
  - GORE-TEX between PMT and holder contains modern carbon (C14) 0~6+/-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.

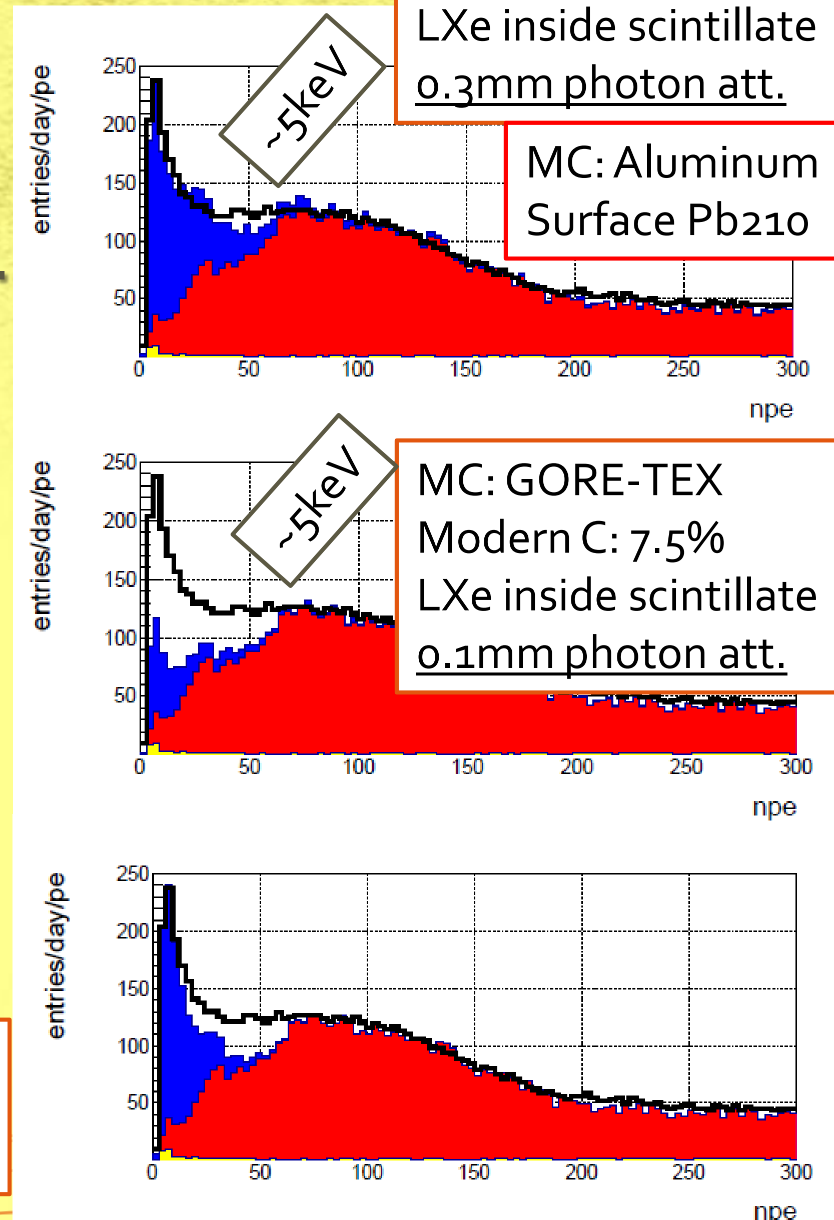


Closer look at the observed spectrum

- Three contributions to the observed spectrum

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

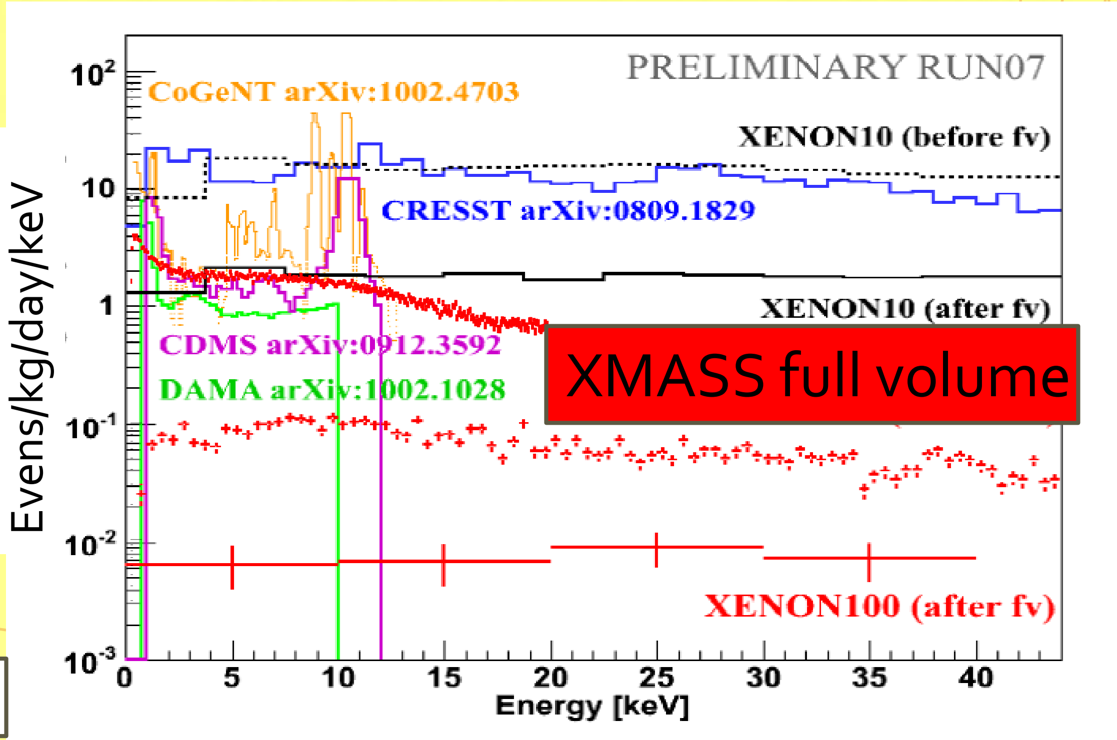
Prediction based on some assumptions on GORE-TEX gives a similar shape. But assumption dependent. Confirmation possible only by removing the GORE-TEX.



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.



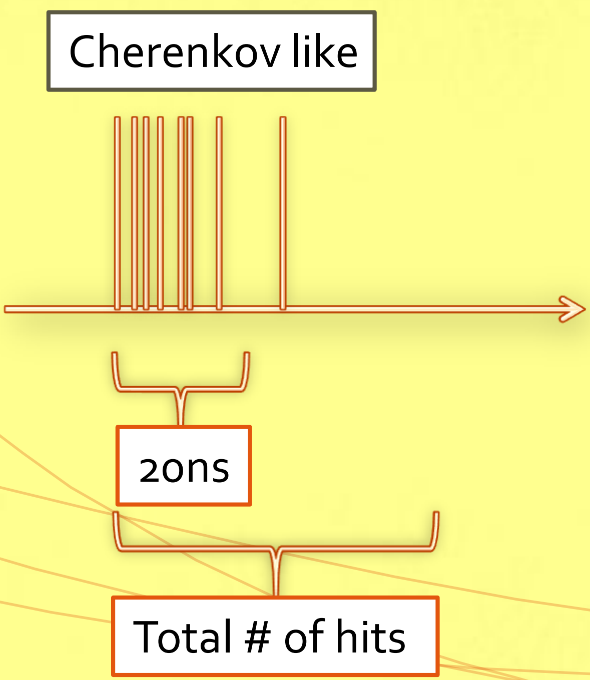
E. Aprile, 2010 Princeton

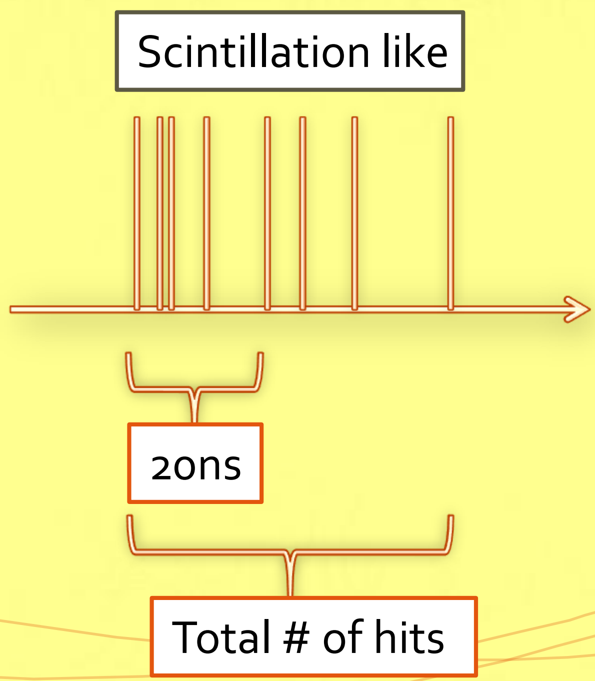
Low energy, full volume analysis for low mass WIMPs

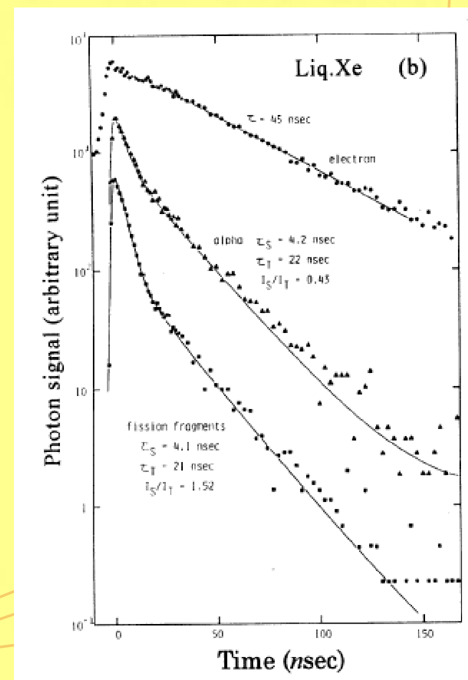
- The dark matter signal rapidly increase toward low energy end. <u>The large p.e. yield enables us to see light WIMPs.</u> Try to set absolute maxima of the cross section (predicted spectrum must not exceed the observed spectrum).
- The largest BG at the low energy end is the Cherekov emission from ^{40}K in the photo cathodes.
- Selection criteria
  - Triggered by the inner detector only (no water tank trigger)
  - Time difference to the previous event >10ms
  - RMS of hit timing <100ns (rejection of after pulses of PMTs)
  - Cherenkov rejection

Detail of the Cherenkov rejection

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



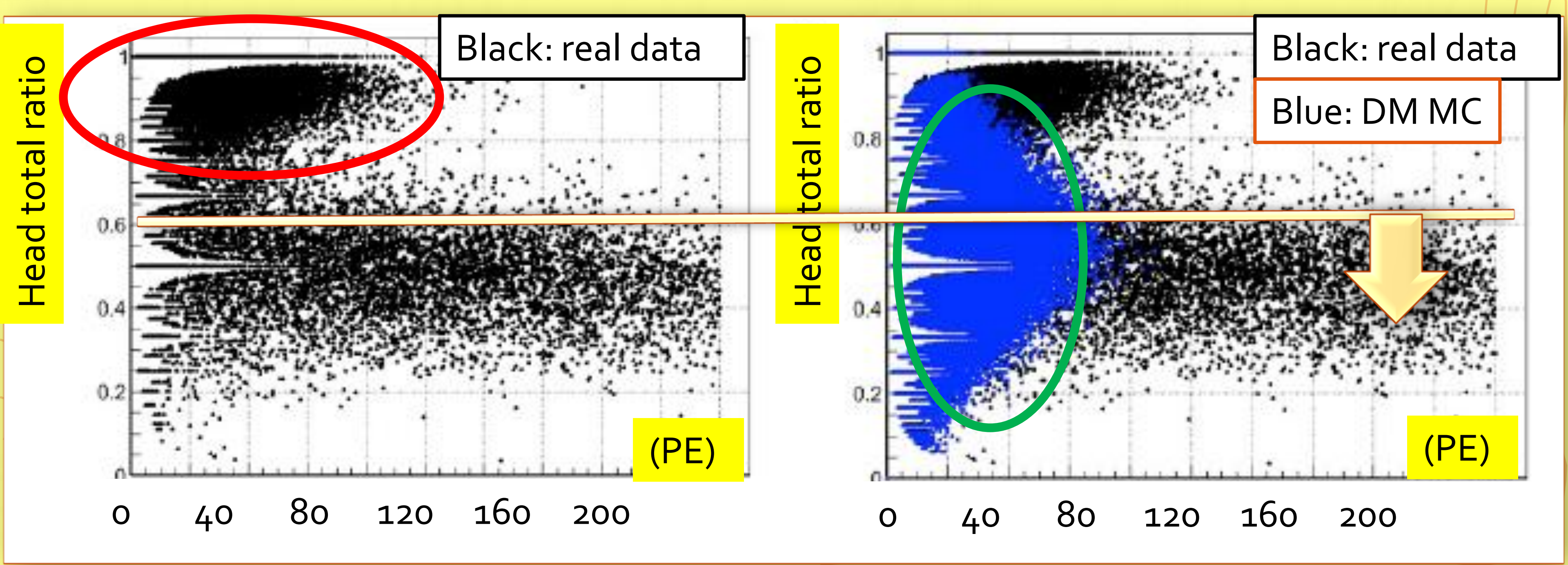




A. Hitachi et al., Phys. Rev. B 27 (1983) 5279.

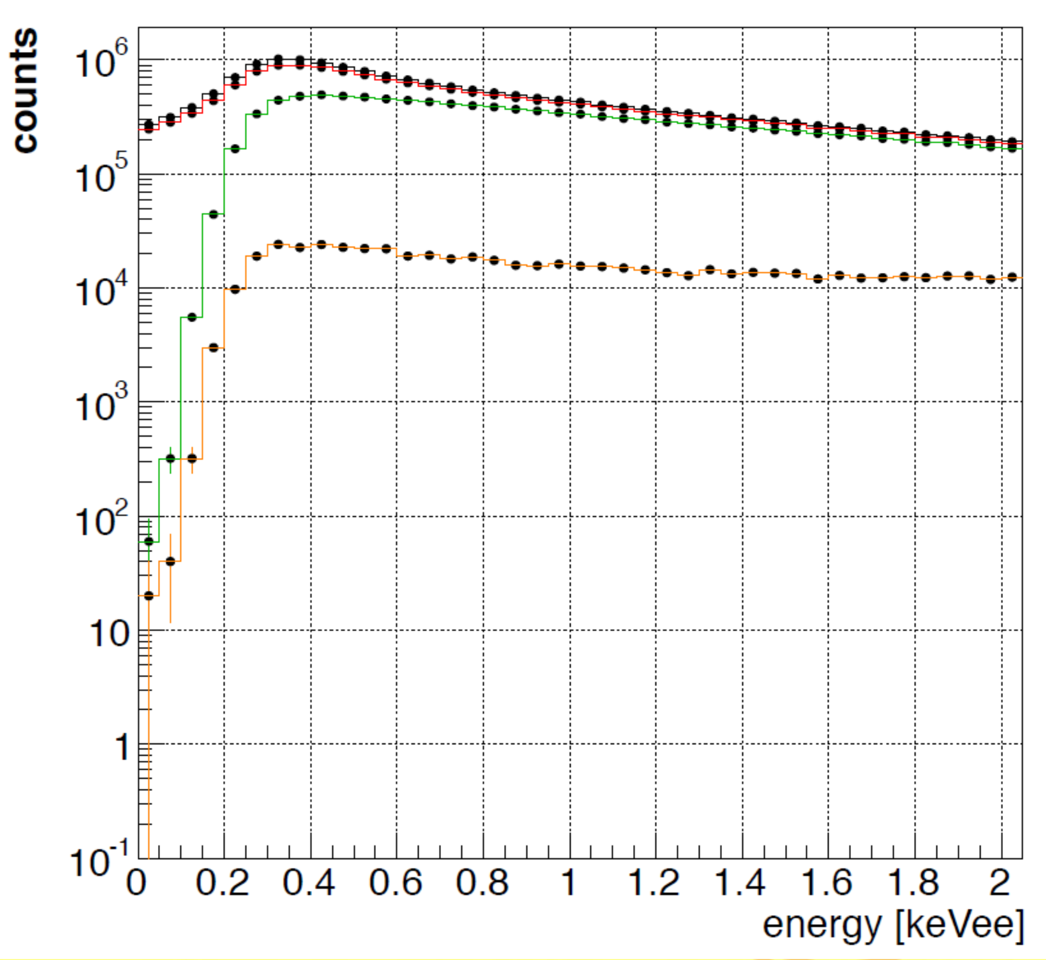
"head total ratio" distribution

- Cherenkov events peaks around 1 ⇔ scintillation ~ 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.

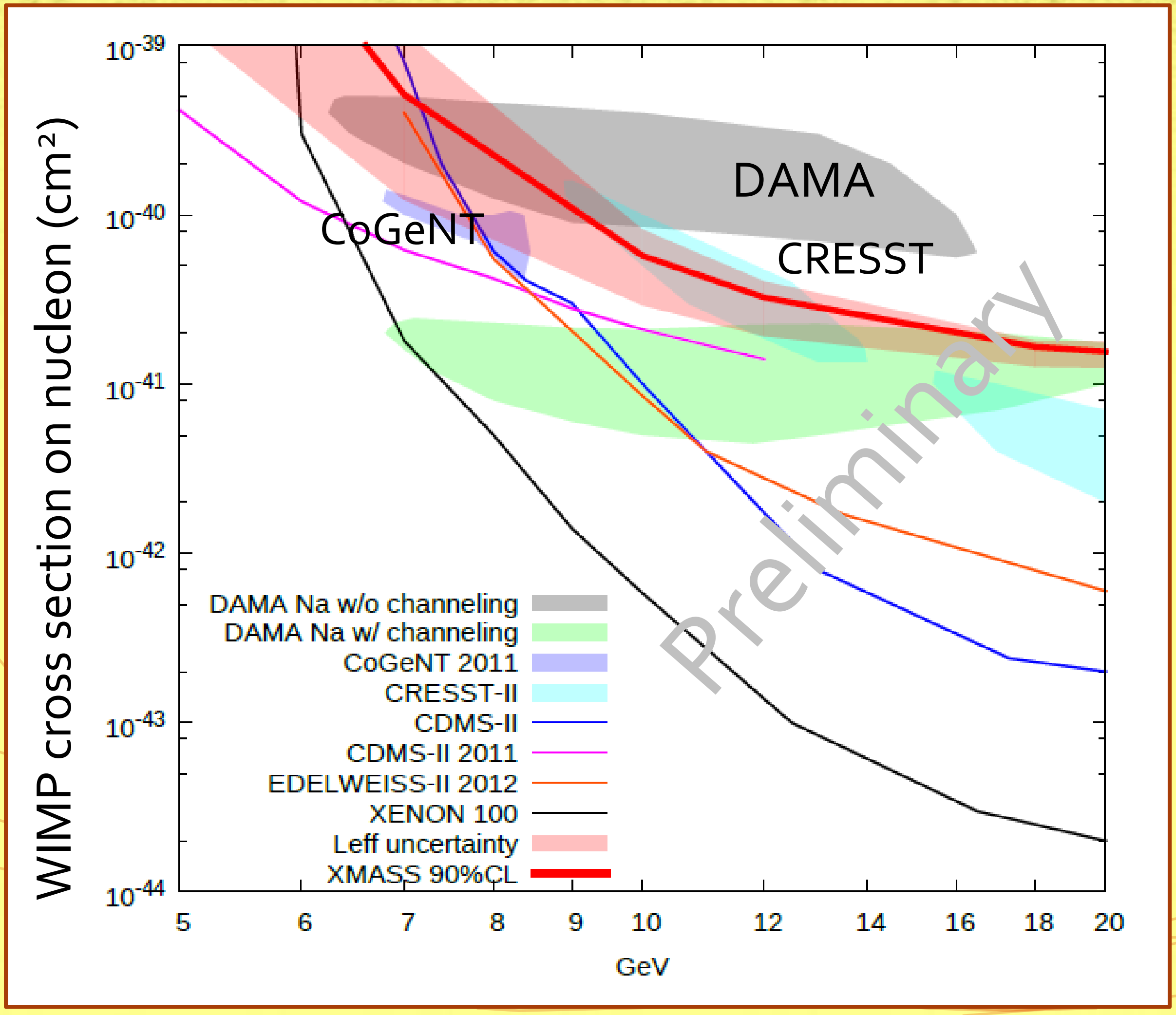


- Events @ each reduction step

cut0: trigId == 1	:932863
cut1: + dT_Pre(10msec)	:866343
cut2: +tdcRMS<100	:570025
cut3: +Chrenkov	: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.



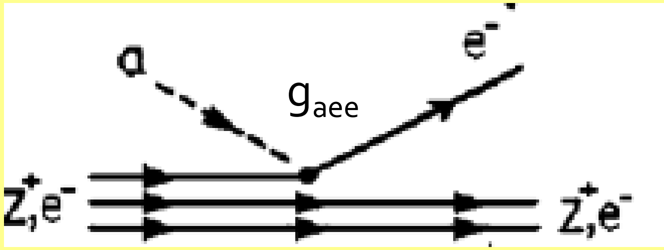
XMASS 90%CL

- The XMASS 90%CL limit includes systematic errors except for Leff uncertainty .
- Leff 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

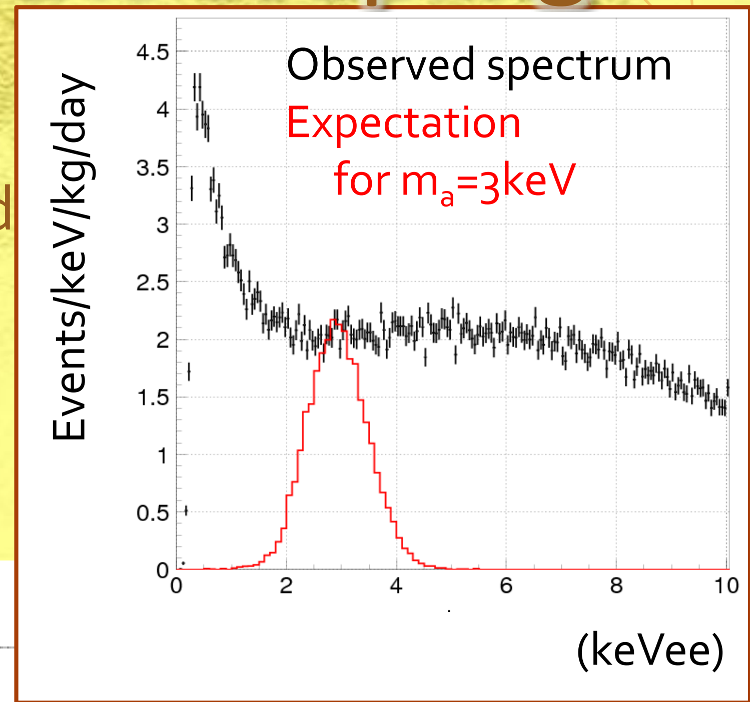
- XMASS can search for dark matter axion by detection through axio-electric effect.

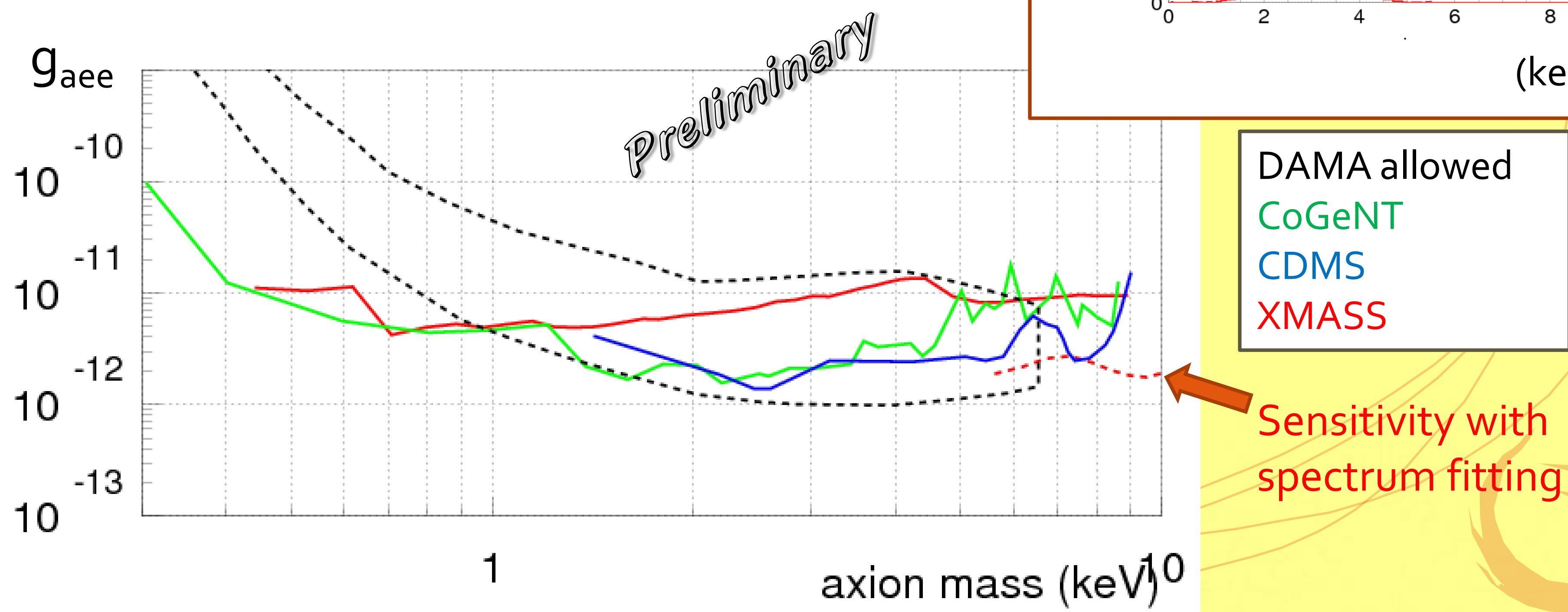


- We show a preliminary result based on 6.64 days x 835kg data.

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.

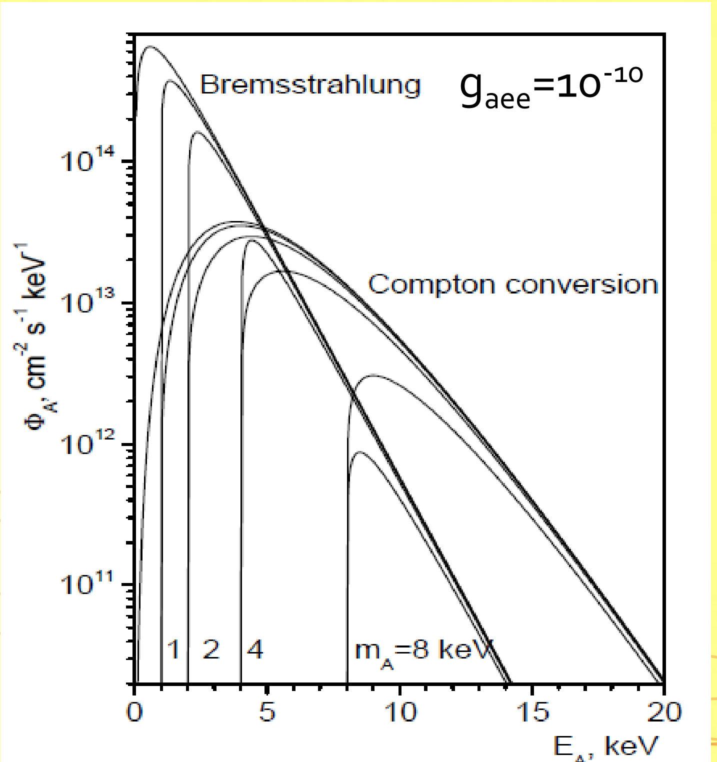


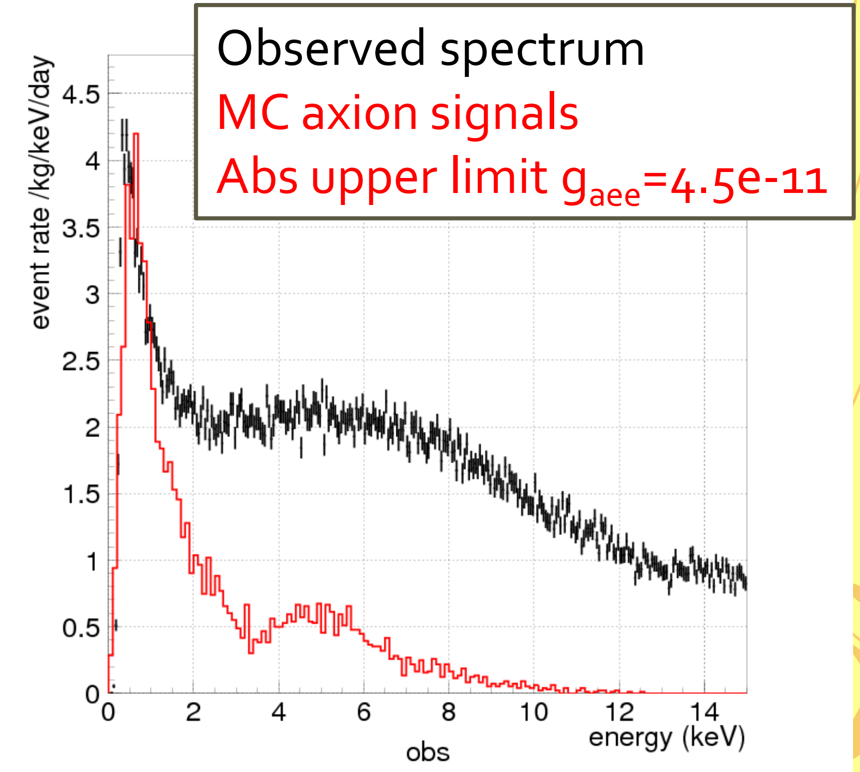


Solar axion search in XMASS

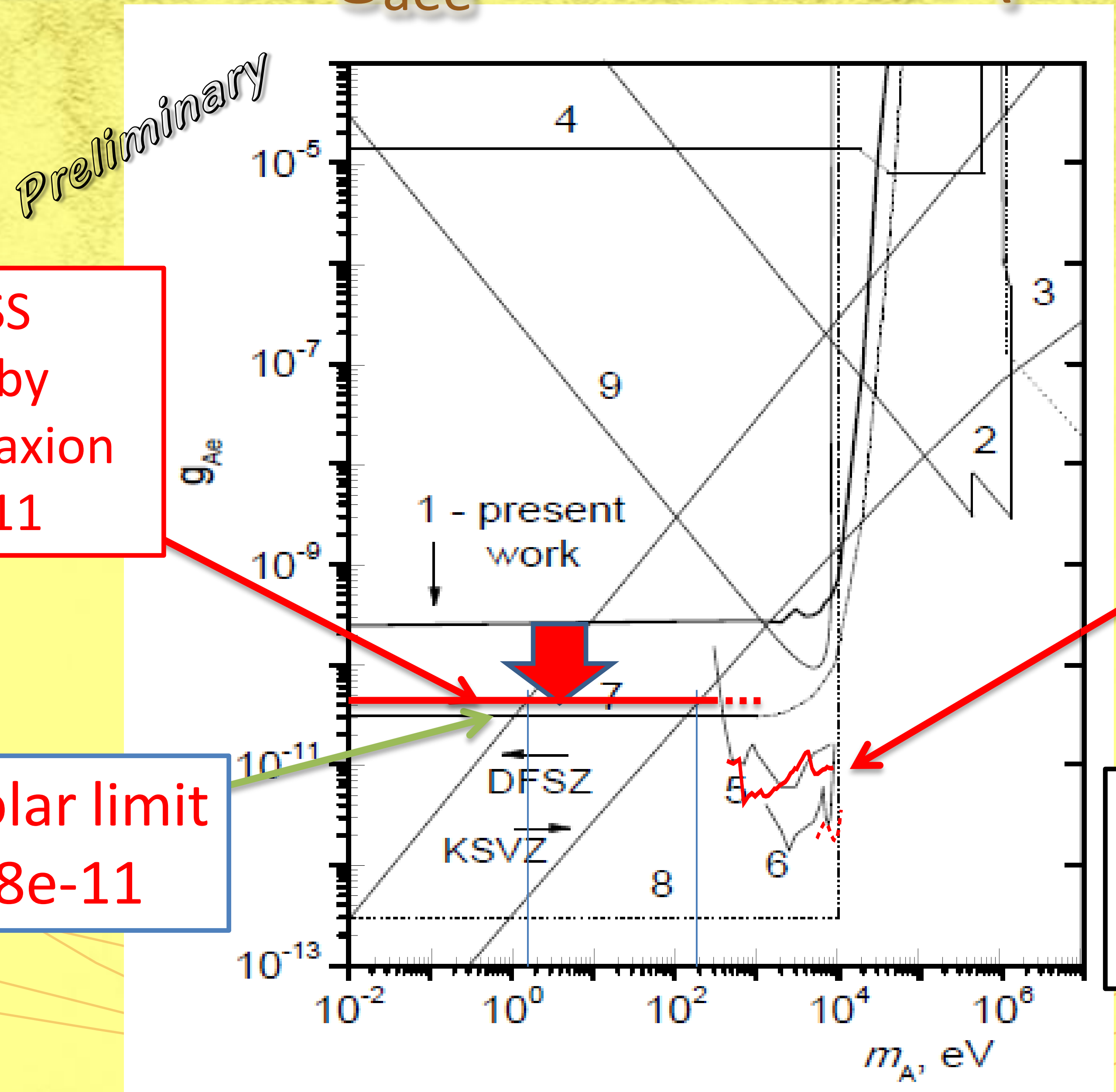
- XMASS can also search for solar axion emitted owing to Bremsstrahlung and Compton processes in the Sun, by detection through axio-electric effect.
- We obtained a limit on axio-electric coupling (g_{aee})

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





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



Original figure from Derbin et al., 1206.4142

XMASS Limit by solar axion 4.5e-11

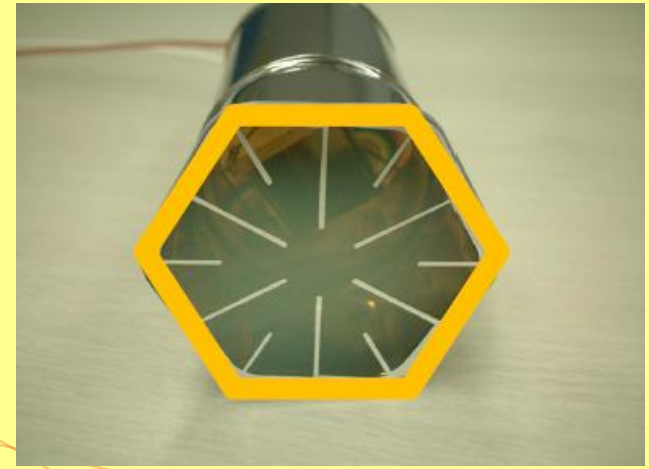
XMASS Limit by DM

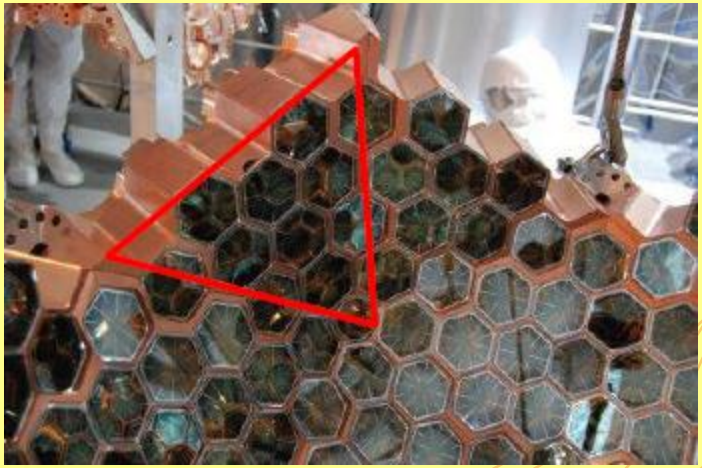
Solar limit 2.8e-11

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:

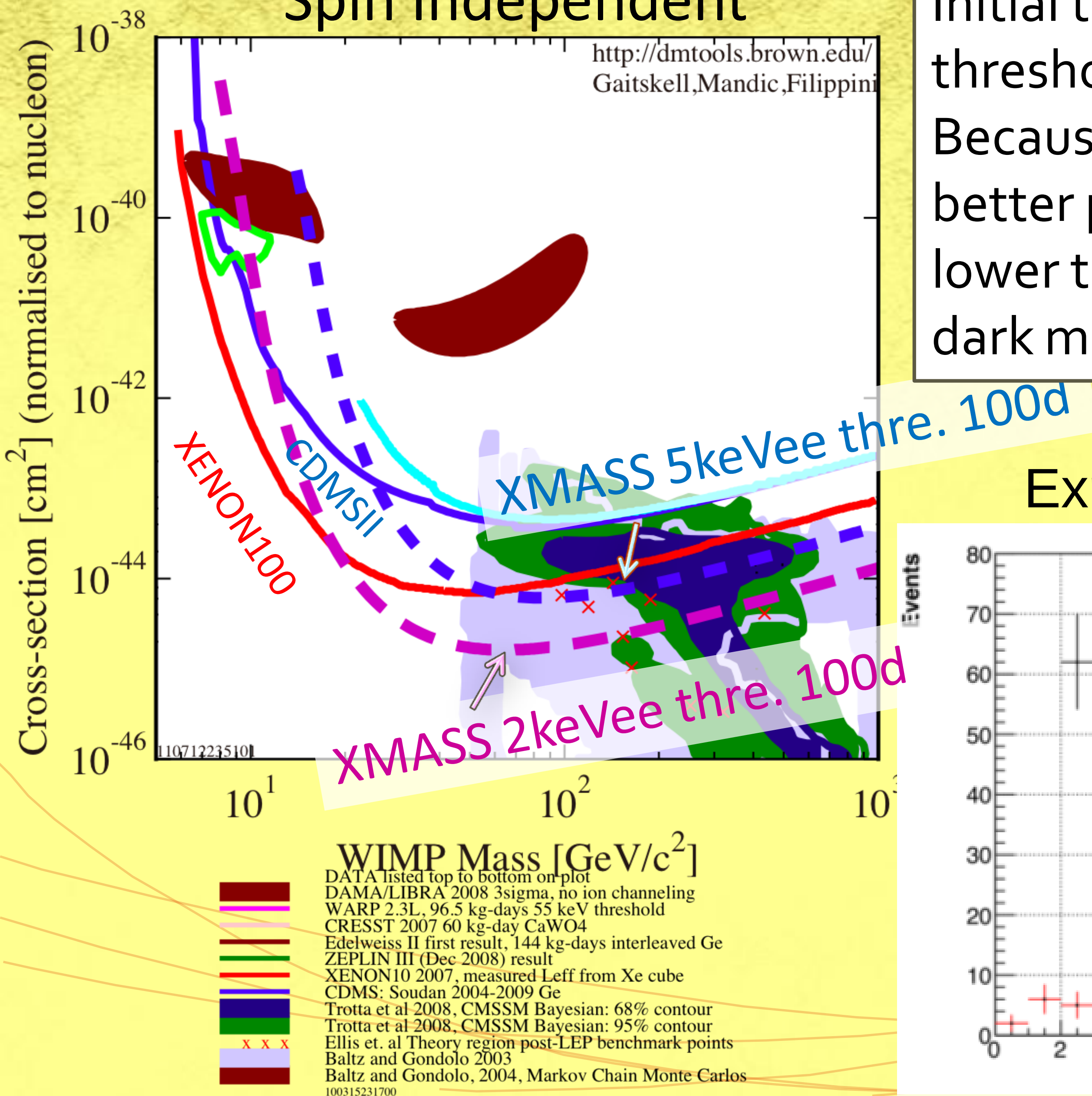




- This work will be done latter half of this year.

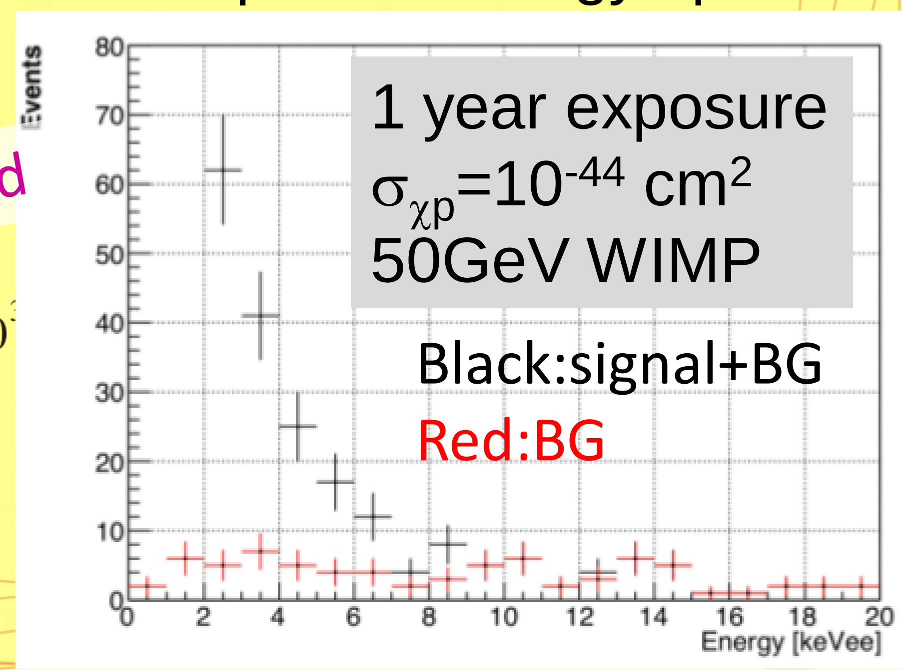
Expected sensitivity with fiducialization

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.



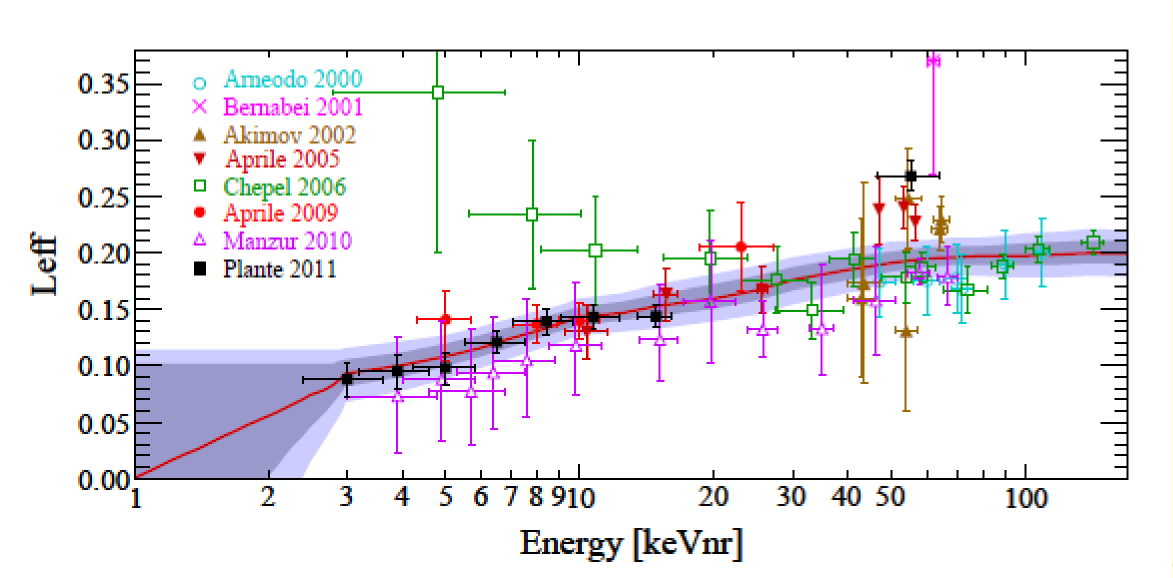
Summary

- 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