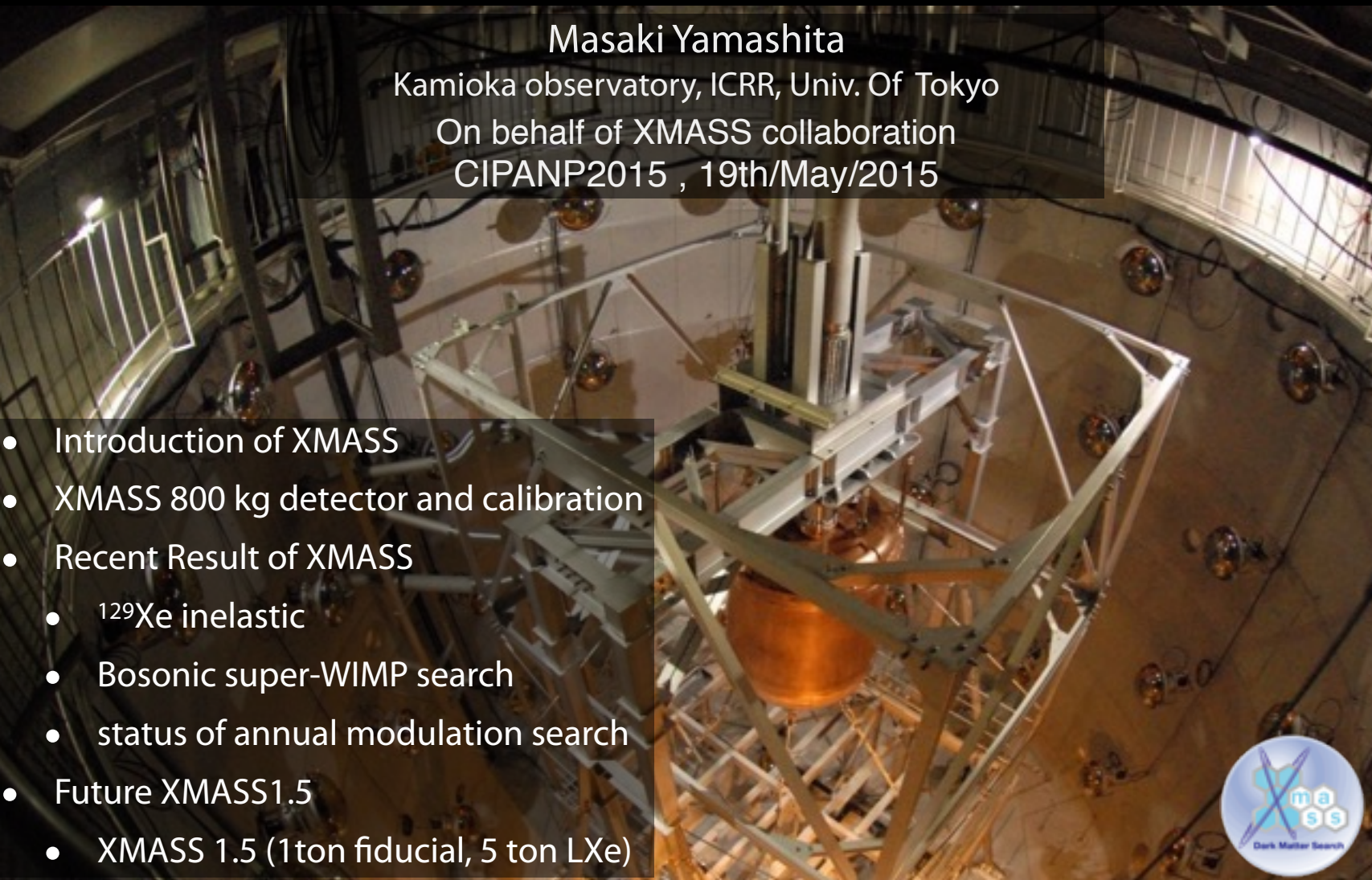
XMASS experiment

Masaki Yamashita
Kamioka observatory, ICRR, Univ. Of Tokyo
On behalf of XMASS collaboration
CIPANP2015 , 19th/May/2015



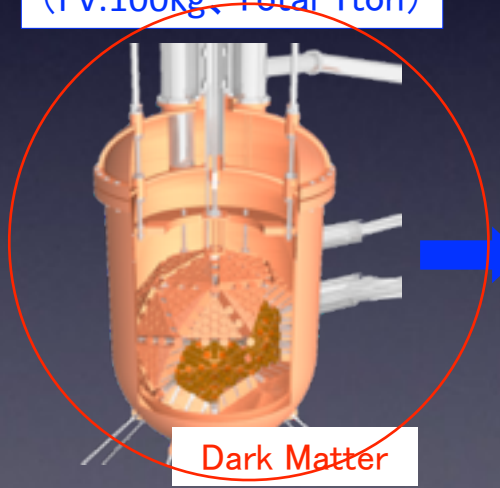
- Introduction of XMASS
- XMASS 800 kg detector and calibration
- Recent Result of XMASS
  - ^{129}Xe inelastic
  - Bosonic super-WIMP search
  - status of annual modulation search
- Future XMASS1.5
  - XMASS 1.5 (1ton fiducial, 5 ton LXe)

XMASS Experiment

Multi purpose low-background experiment with LXe.

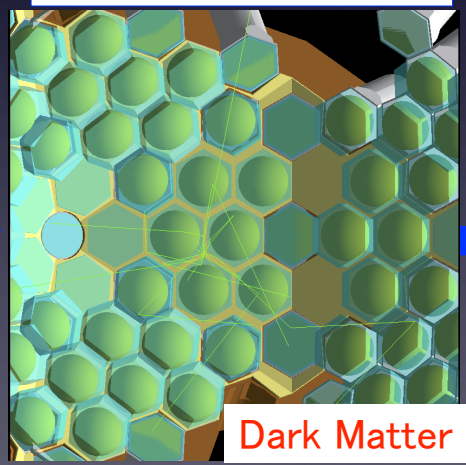
- Xenon MASSive detector for Solar neutrino (pp/^{7}Be)
- Xenon neutrino MASS detector (double beta decay)
- Xenon detector for Weakly Interacting MASSive Particles (DM)

XMASS I
（FV:100kg、Total 1ton）



2007: Project was funded.
2013～: Data taking

XMASS 1.5
（FV:1ton、Total 5ton）



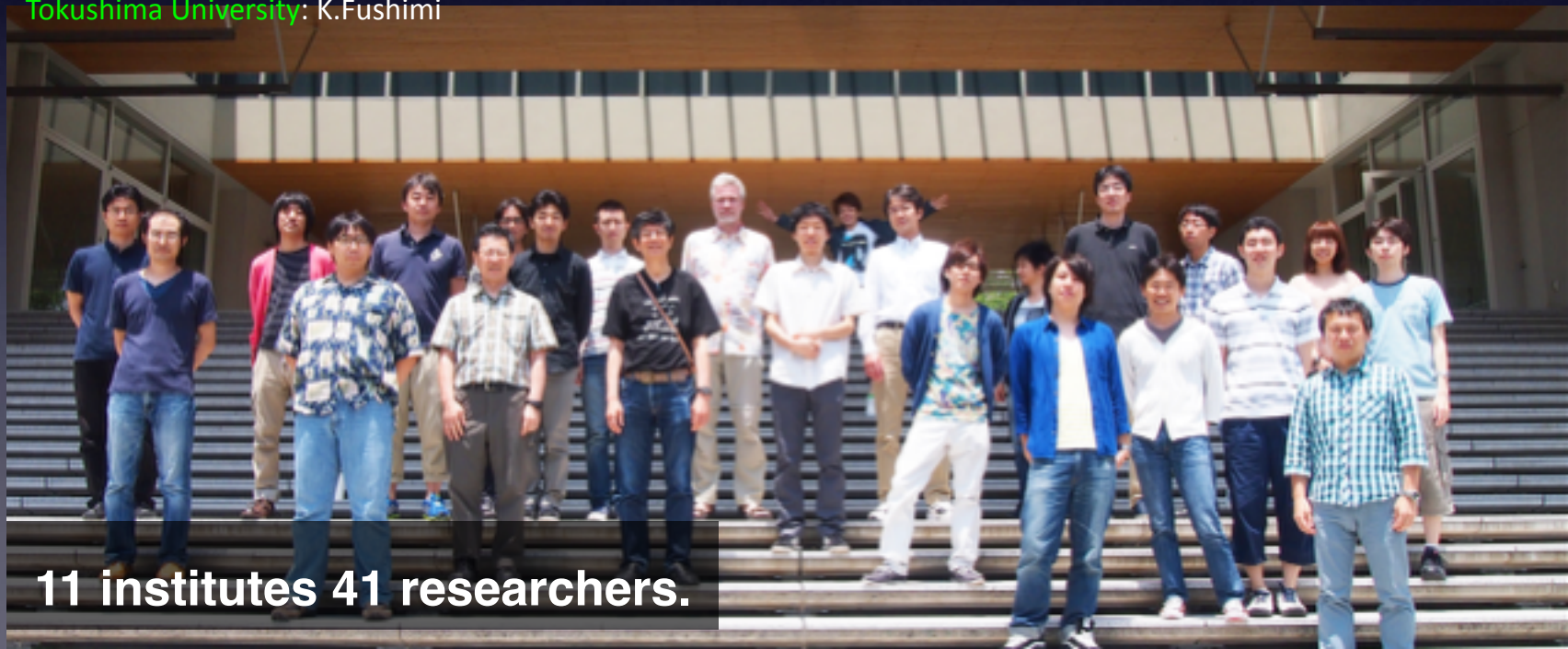
3inch dome shape PMT

XMASS II
（FV:10ton、24Ton）

Solar Neutrino
Dark Matter
DBB

The XMASS collaboration:

Kamioka Observatory, ICRR, the University of Tokyo: K. Abe, K. Hiraide, K. Ichimura, Y. Kishimoto, K. Kobayashi, M. Kobayashi, S. Moriyama, M. Nakahata, T. Norita, H. Ogawa, H. Sekiya, O. Takachio, A. Takeda, M. Yamashita, B. Yang
Kavli IPMU, the University of Tokyo: J.Liu, K.Martens, Y. Suzuki, X. Benda
Kobe University: R. Fujita, K. Hosokawa, K. Miuchi, Y. Ohnishi, N. Oka, Y. Takeuchi
Tokai University: K. Nishijima
Gifu University: S. Tasaka
Yokohama National University: S. Nakamura
Miyagi University of Education: Y. Fukuda
STEL, Nagoya University: Y. Itow, R. Kegasa, K. Kobayashi, K. Masuda, H. Takiya
Sejong University: N. Y. Kim, Y. D. Kim
KRISS: Y. H. Kim, M. K. Lee, K. B. Lee, J. S. Lee
Tokushima University: K.Fushimi



11 institutes 41 researchers.

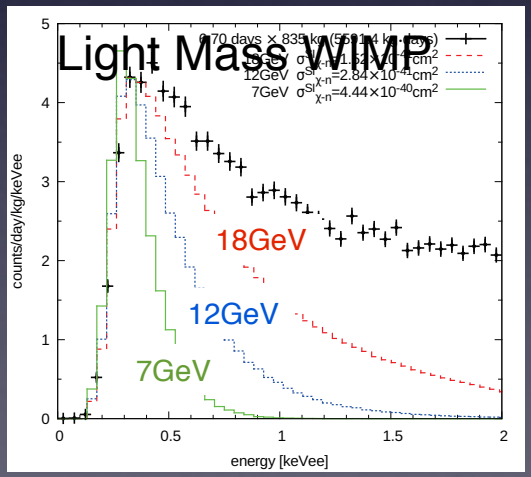
Physics results of XMASS-I

Published

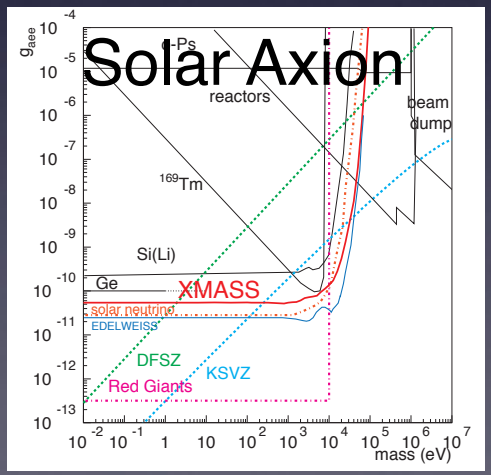
- Light WIMP search, ***Phys. Lett. B 719 (2013) 78***
- Solar axion search, ***Phys. Lett. B 724 (2013) 46***
- Bosonic Super-WIMPs, ***Phys. Rev. Lett. 113 (2014) 121301***
- Inelastic scattering on ^{129}Xe, ***PTEP 2014, 063C01***

coming soon

- Double electron capture of ^{124}Xe
- Seasonal modulation with full volume of LXe
- Fiducial volume analysis for heavy WIMPs

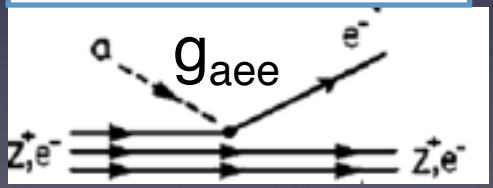


Physics Letters B 719 (2013) 78-82



Physics Letters B 724 (2013) 46

Axio-electric effect



Masaki Yamashita

- 1000m under a mountain = 2700m water equiv.
- 360m above the sea
- Horizontal access
- Experiment
  - Super-K
  - KamLAND (Tohoku U.)
  - KAGURA for interferometer
  - NEWAGE

Kamioka mine

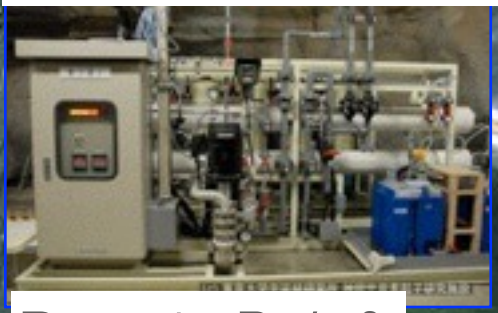
Gifu, Hida city, Ikenoyama

Kamland

super Kamiokande

Experimental Hall

water purification system



Rn: ~ 1mBq/m^3
5ton/hour

Distillation Tower

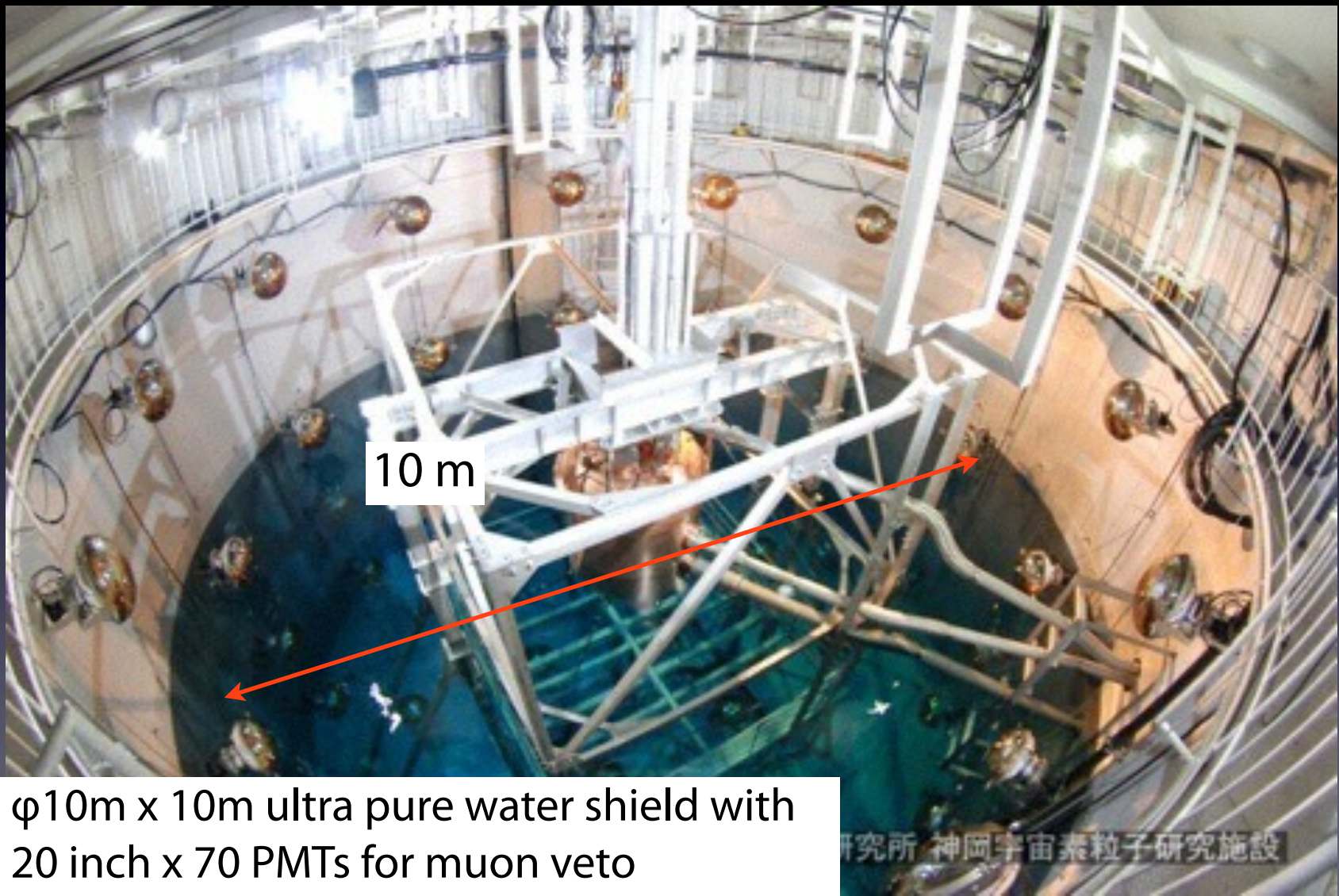
LXe Tank

Water Tank

Xenon Buffer Tank

entrance (clean room)

Water Shield



- φ10m x 10m ultra pure water shield with 20 inch x 70 PMTs for muon veto

XMASS Detector

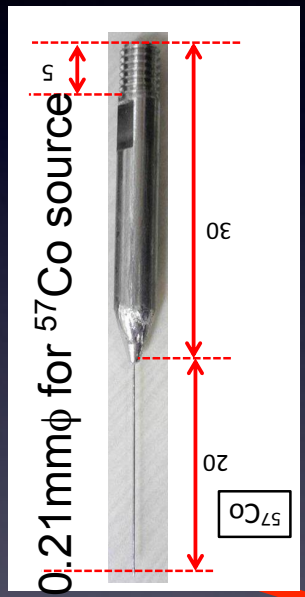
R10789

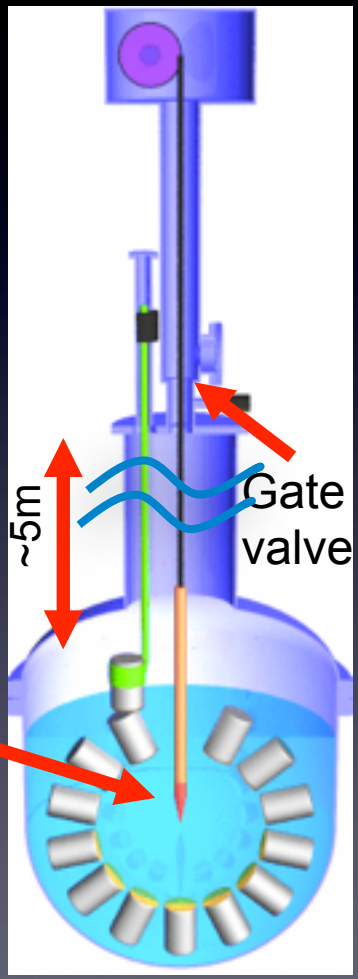
RI in PMT	Activity per 1PMT(mBq/
238U-chain	0.70+/-0.28
232Th-chain	1.51+/-0.31
40K	<5.1
60Co	2.92+/-0.16

- 642 ultra low background 2 inch PMTs
- Largest detector: 832 kg of LXe for sensitive volume.

Detector calibration

-Inner calibration is for energy calibration.



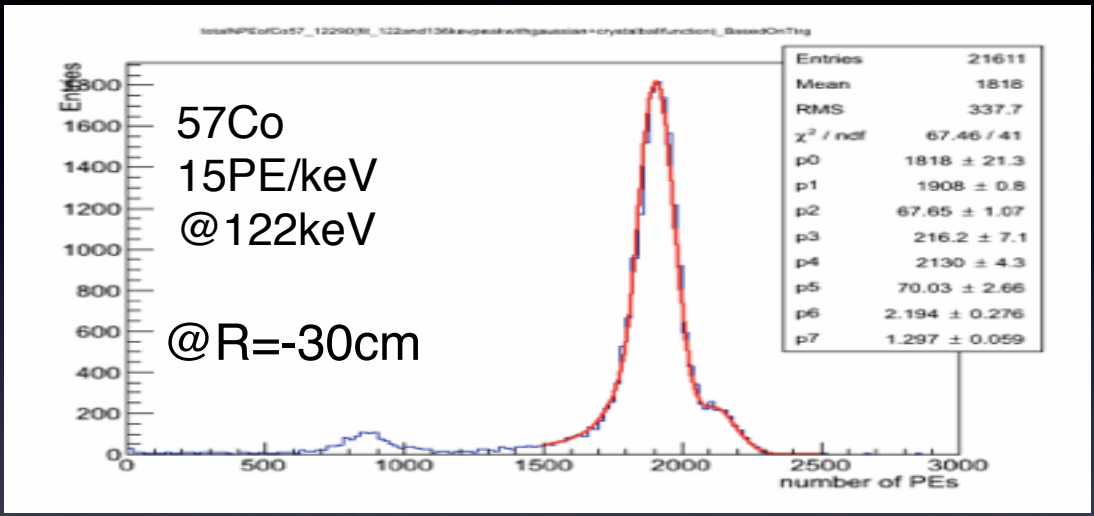


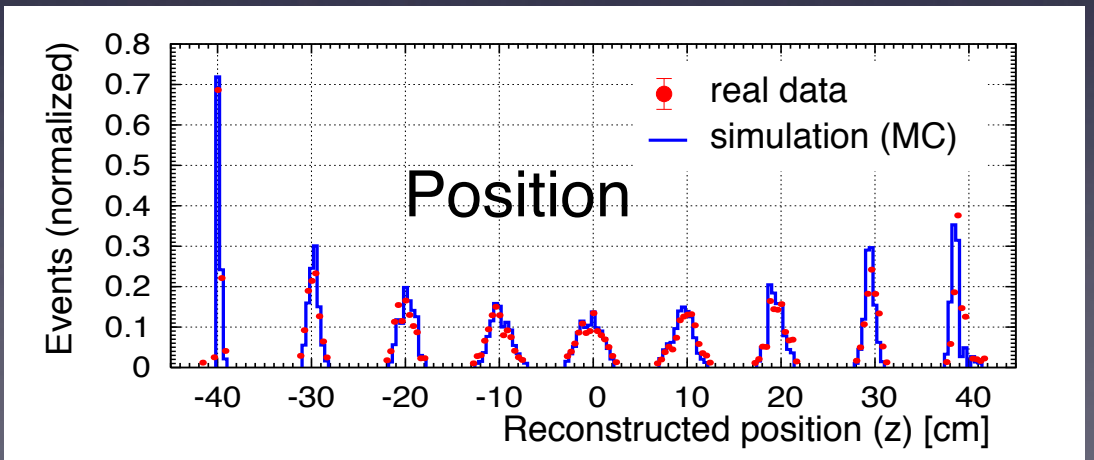
Isotopes	Energy [keV]	Shape
^{55}Fe	5.9	cylinder
^{109}Cd	8(*1), 22, 58, 88	cylinder
^{241}Am	17.8, 59.5	thin cylinder
^{57}Co	59.3(*2), 122	thin cylinder
^{137}Cs	662	cylinder

Detector calibration

-High Photoelectron Yield ~15 PE/keV

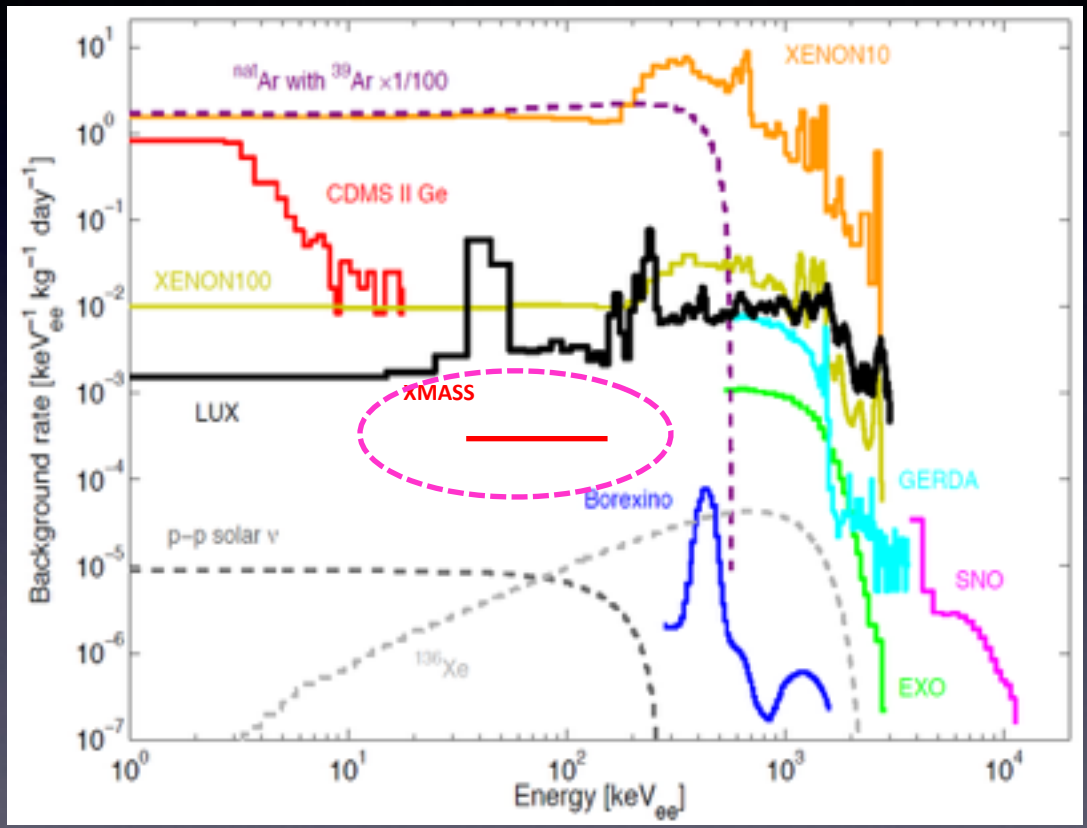
-Good agreement between data and.





Comparison of background rate

- Background rate in the fiducial volume before separation of nuclear recoils from e/γ
- XMASS achieved O(10^{-4}) event/day/kg/keVee at a few 10's keV.

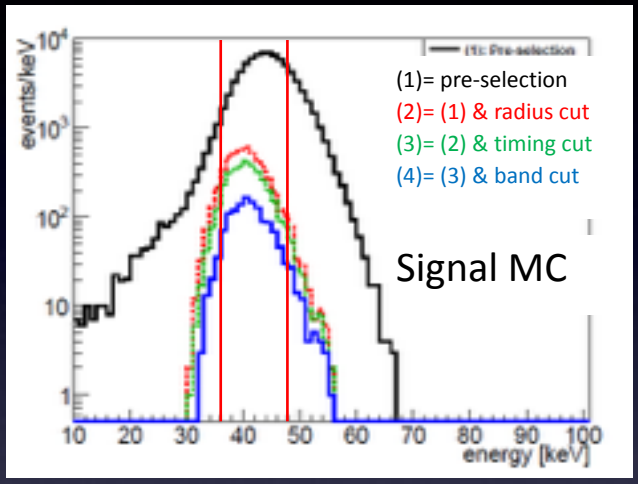


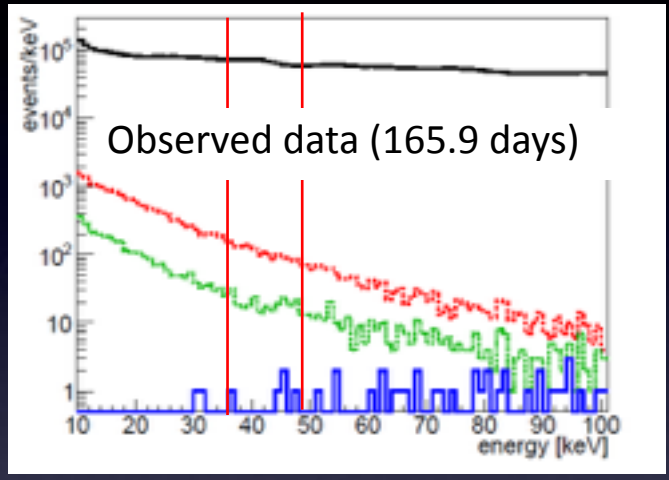
Added to D.C.Malling thesis (2014) Fig.1.5

Search for ^{129}Xe Inelastic scattering by WIMP

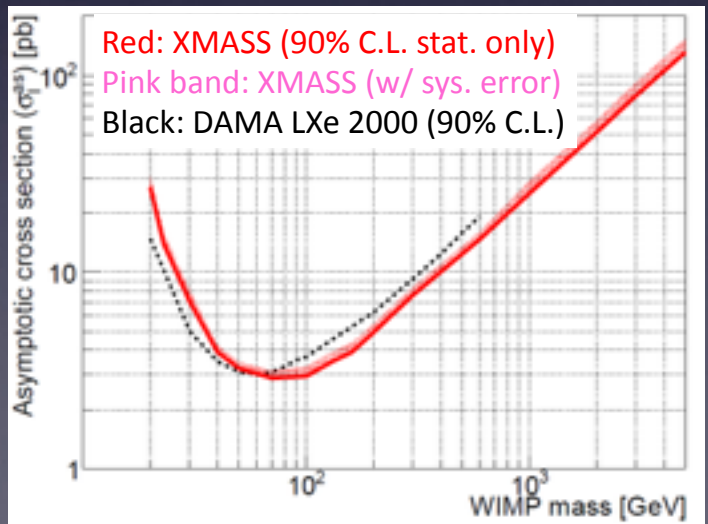
- $\chi + {}^{129}Xe \rightarrow \chi + {}^{129}Xe^*$
  ${}^{129}Xe^* \rightarrow {}^{129}Xe + \gamma$ (39.6keV)
- Natural abundance of ^{129}Xe: 26.4%

not
X+N -> X* + N





- ✓ 40 keV+ nuclear recoil signal ~40keV mono-energetic peak
- ✓ 41 kg の fiducial volume cut , 2010/12/24-2013/05/10 165.9 days data.
- ✓ position information by PE and timing.
- ✓ 3pb at 100 GeV.(most stringent limit>80GeV)



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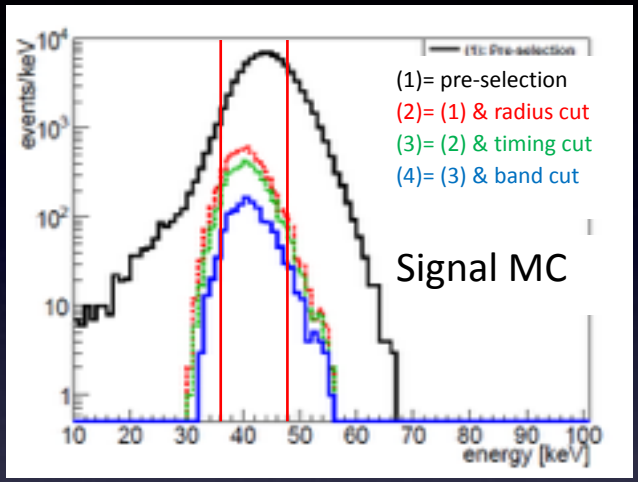

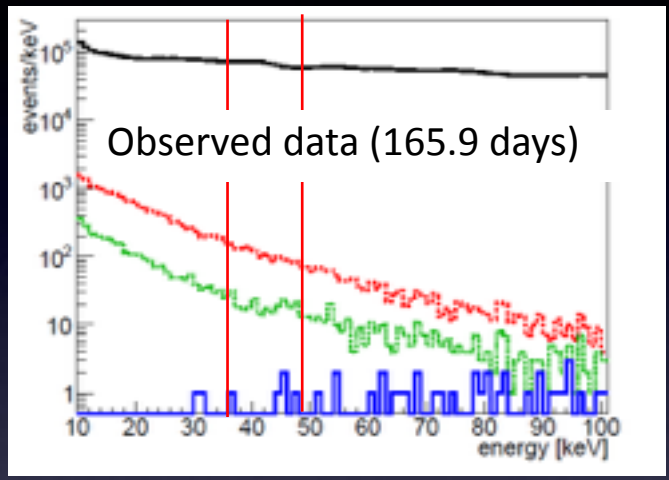

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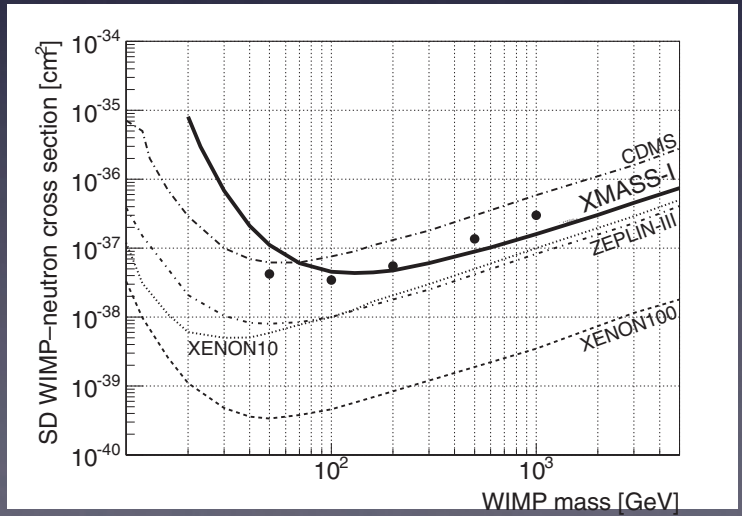
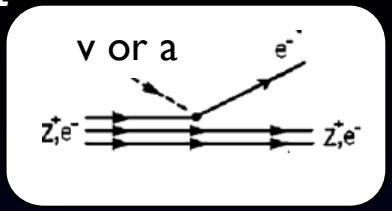
- ✓ Form Factro(L.Baudis et al., PRD88,115014,2013)
  (V.D.Vergados et al., NPB 877,36(2013)



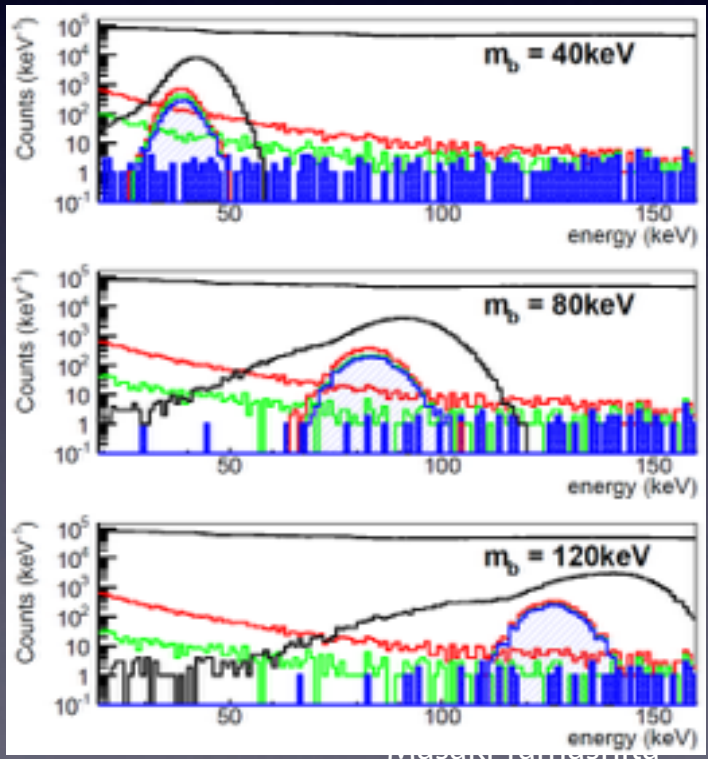
Search for Bosonic super-WIMPs

Phys. Rev. Lett. 113 (2014) 121301



- Candidate Warm Dark Matter
  - sterile neutrino, gravitino …
- NO SUSY so far.
- Lighter and more weekly interacting than WIMPs
- It can be pseudoscaler or vector boson and in this case, it can be detected by absorption of the particle,
  which is similar to the photoelectric effect.
- Search for mono-energetic peak at the mass of the particle
- same data set as inelastic scattering
  41 kg fiducial volume cut ,
  2010/12/24-2013/05/10 165.9 days data.

Observed data + signal(MC)



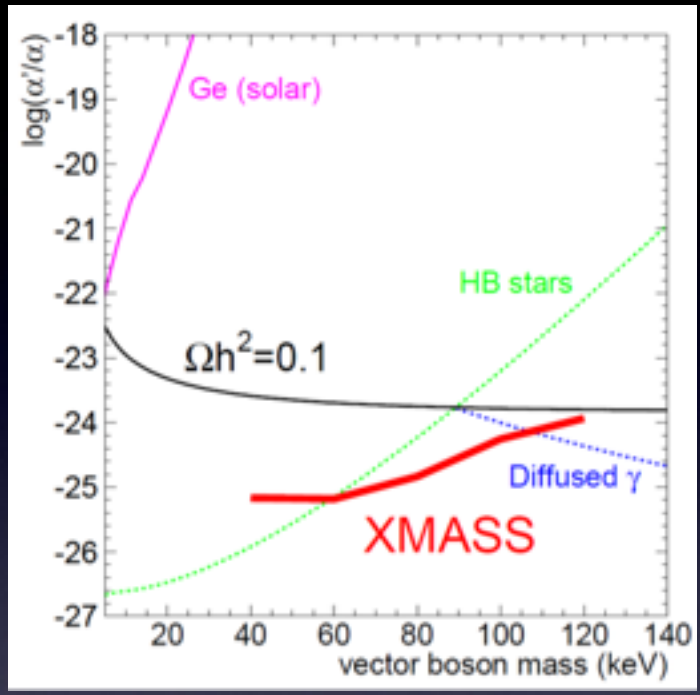
Bosonic super-WIMPs Search Results

- For vector boson case

vector boson case

$$S_v \approx \frac{4\times10^{23}}{A}\frac{\alpha'}{\alpha}\left(\frac{\mathrm{keV}}{m_V}\right)\left(\frac{\sigma_{\mathrm{photo}}}{\mathrm{barn}}\right)\ \mathrm{kg}^{-1}\,\mathrm{day}^{-1},$$

- the first direct search in the 40–120 keV range.
- The limit excludes the possibility that such particles constitute all of dark matter.

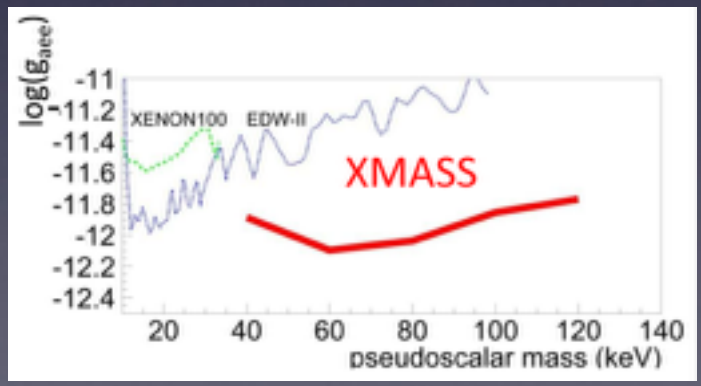


- For pseudoscaler case

pseudoscaler case

$$S_a \approx \frac{1.2\times10^{19}}{A} g_{aee}^2\left(\frac{m_a}{\mathrm{keV}}\right)\left(\frac{\sigma_{\mathrm{photo}}}{\mathrm{barn}}\right)\ \mathrm{kg}^{-1}\,\mathrm{day}^{-1}.$$

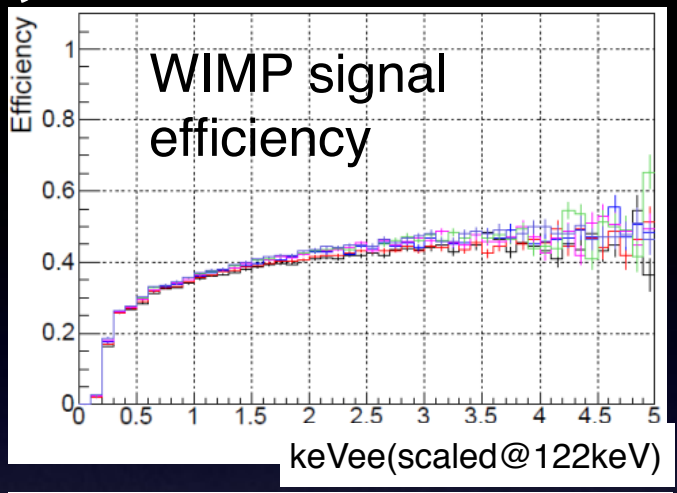
- The most stringent direct constraint on gaee.

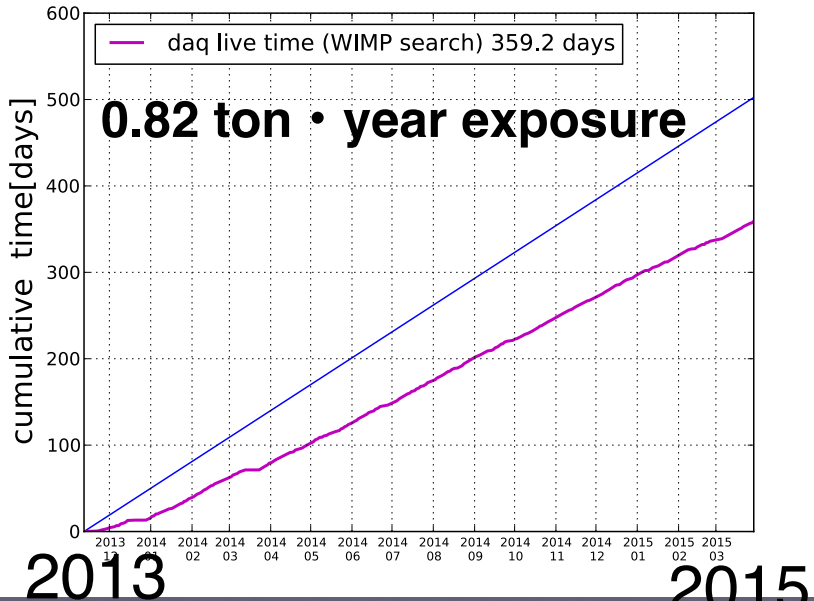


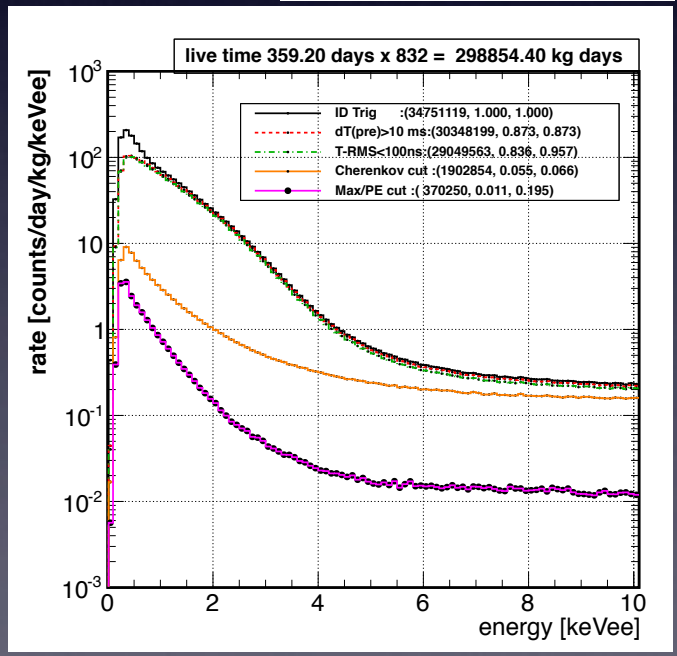
Modulation analysis data set

ID Trig : Nhit>= 4, ID only
dT(pre)>10ms: veto 10ms after the event
T-RMS : timing RMS of event (<100ns)
Cherenkov cut: nhit in first 20nsec < 60%
Max/PE cut : maxpt/total pe cut

NO PARTICLE ID
(both nuclear/electronic recoil)



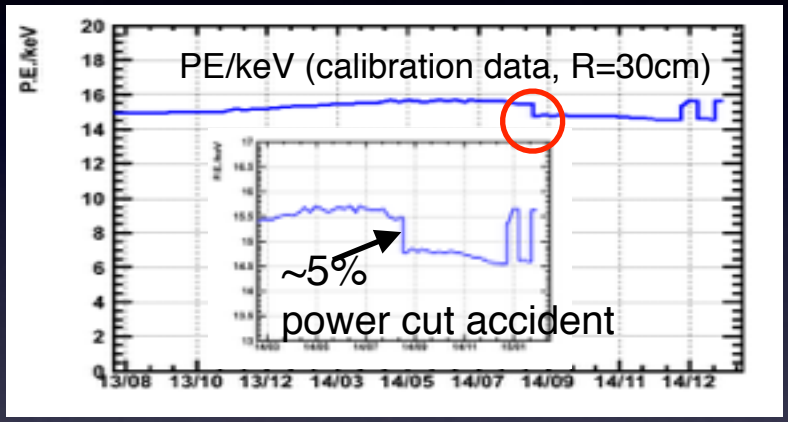


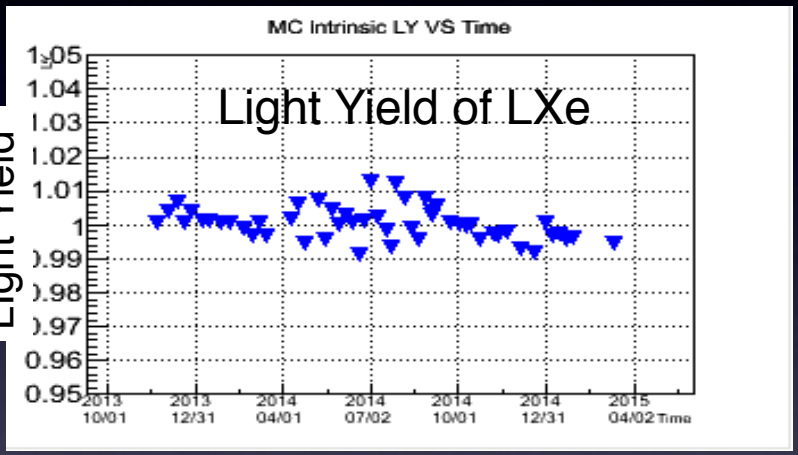


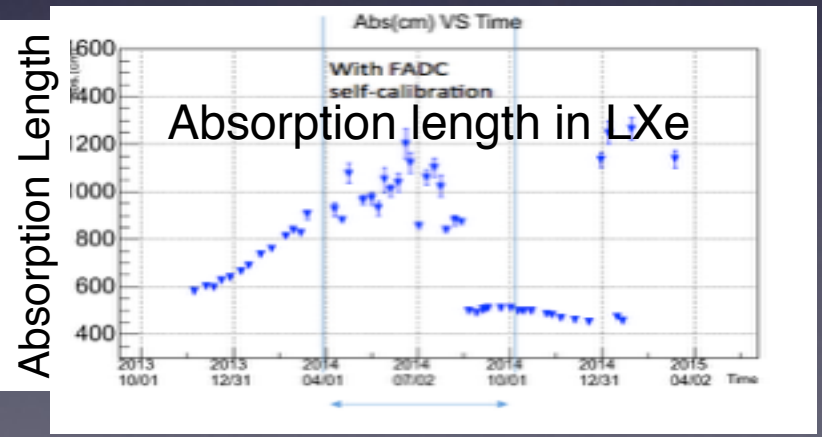
Masaki Yamashita

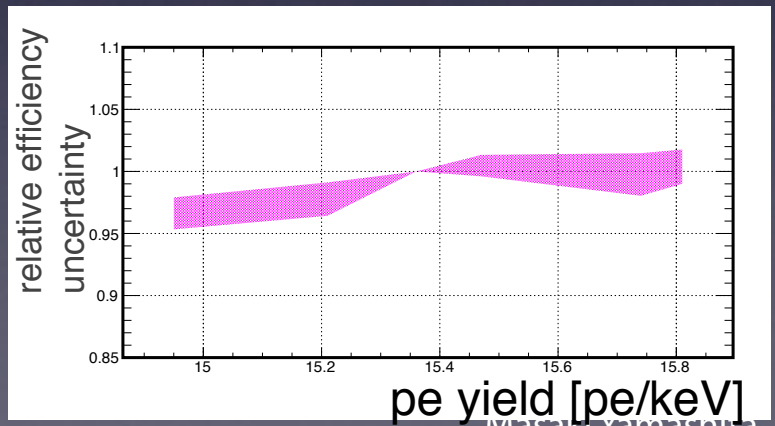
Detector Performance

Energy Calibration and its physical parameters.
After power cut at 2014/8, the PE yield dropped ~5%.
This change effect on the efficiency for the cuts due to the position dependency in whole detector.
Those uncertainty of detector response is taken into account as systematic error by Monte Carlo.

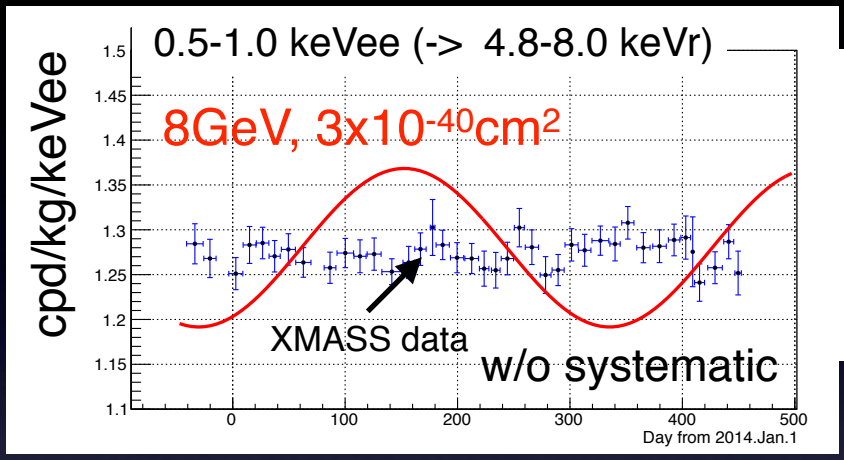


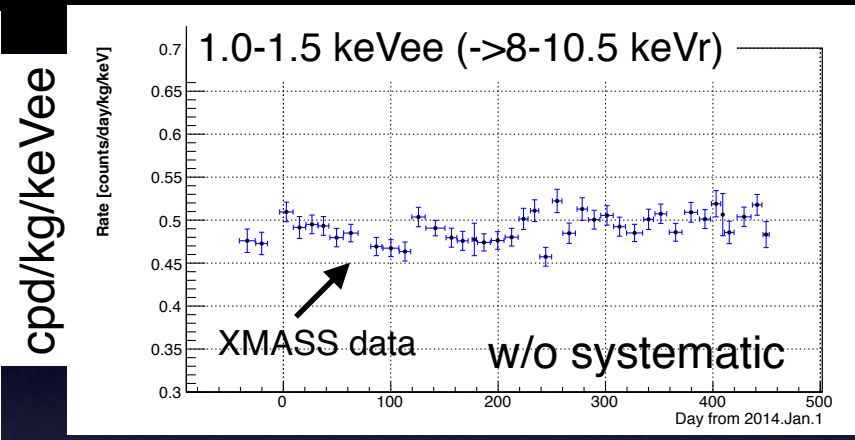






Annual modulation analysis





-World's largest mass

1 year data of XMASS (0.82 ton*year) vs. 14 years data of DAMA/LIBRA (1.33 ton*year)

→ Current statistics is already half of DAMA/LIBRA data.

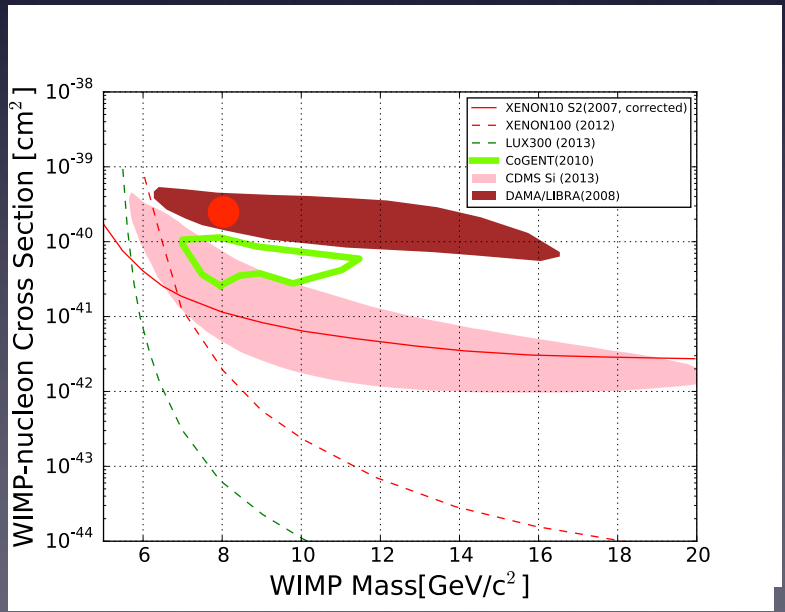
-Low energy threshold: 0.5 keVee by 122keV

(-> s4.8keVr, 1keVee true energy)

-Achieving without particle ID (DM, axion like particle, mirror dm etc).

This threshold will be lower down to 3keVr in the future.

The results for 1 year data will come soon.



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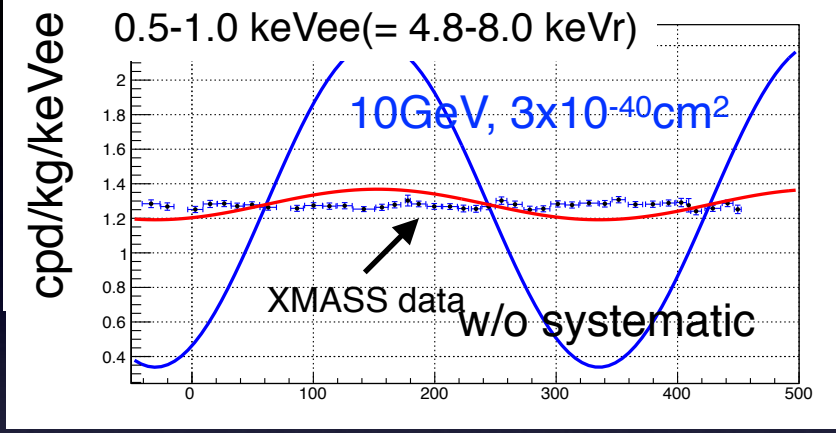

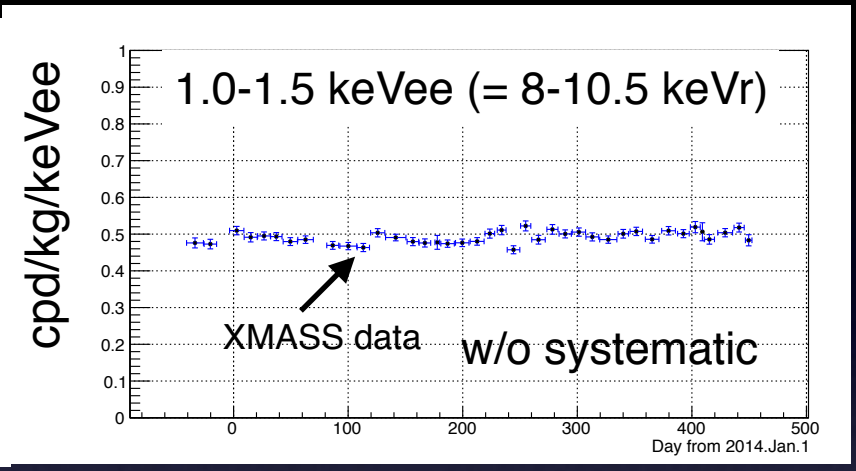

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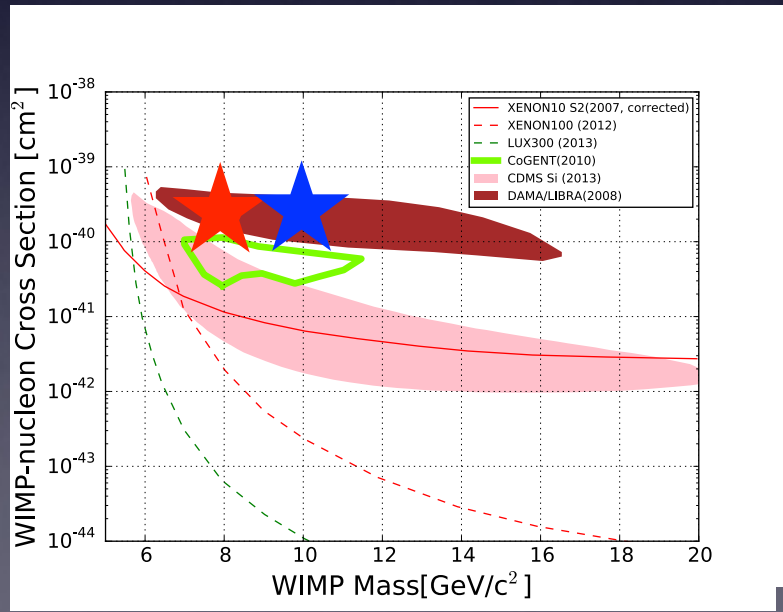
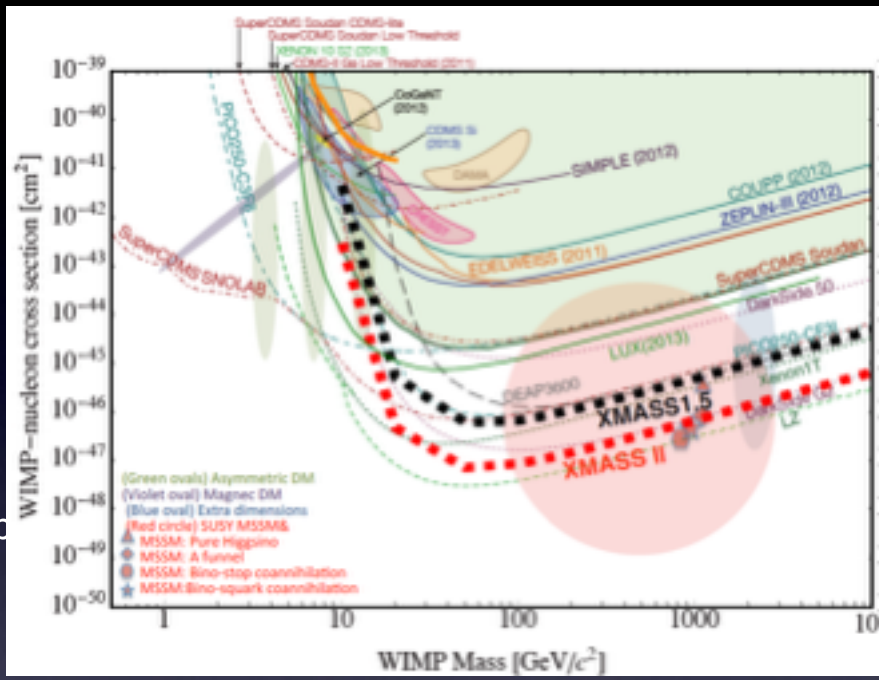


Next phase: XMASS 1.5



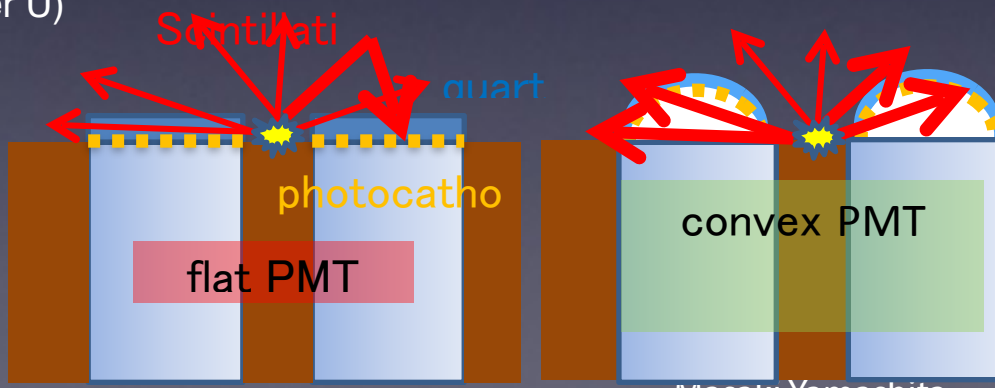
- to improve sensitivity for next phase, dome shap
PMT has been developed to solve
the problem of surface events.
- 180° field view
- pure Al seal (> 3 order magnitude lower U)
- R10789 5.6nsec →R13111 <3.5nsec
- goal is 1/10 of R10789 radioactivity
- Test in LXe is going on.

-1ton fiducial, 5 ton total

- $<10^{-46}$cm^2 at 100 GeV.

-Inherit current water shield

-XMASS 1.5 design study is on going.



Summary

- Recent Result from XMASS
  - Inelastic 129Xe
    - 3pb at 100 GeV.(>80GeV, most stringent limit)
  - bosonic Super WIMP
    - vector-boson warm dark matter was ruled out in the 40-80 keV.
  - status Annual modulation
  - final result coming soon
- XMASS1.5 design is on going.
  - 3inch dome shape PMT