Status of XMASS

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Abstract. The XMASS project aims to detect 7Be/pp solar neutrinos, neutrino-less double beta decay, and dark matter searches using ultra-pure liquid xenon. The first stage of XMASS project is concentrated on dark matter searches using 800 kg liquid xenon single-phase detector. The 800 kg detector construction was started in April 2007, and completed in September 2010. After distillation and purification of liquid xenon, the commissioning run has been started since October 2010. Performance of vertex reconstruction was studied using radio-active sources put inside the detector, and internal contaminations in liquid xenon were evaluated.

1. Introduction

The XMASS detector (shown in fig. 1) consists of an oxygen free high conductivity (OFHC) copper vessel with about 1.2 m diameter and 642 photomultiplier tubes (PMTs) immersed in liquid xenon. The total amount of liquid xenon for active volume is 835 kg. The 630 hexagonal and 12 round PMTs are mounted in an approximately spherical shape OFHC copper holder with an average radius of 40 cm of liquid xenon. The photo coverage of PMTs is about 64 %. The detector employs a single-phase technology and observes only scintillation lights emitted by the interaction of dark matter. Vertices of events are reconstructed using photo electron distribution observed by PMTs. The key idea of the background (BG) reduction in XMASS is “self-shielding”. The external gamma-rays can be absorbed by the outer surface of liquid xenon owing to high atomic number (Z=54). On the other hand, dark matter particles can give uniform vertex distributions over the detector. By extracting events that occur only deep inside the detector, a sensitive search for dark matter can be conducted.

Almost all the materials used for detector were selected with a high purity germanium detector and inductively coupled plasma mass spectrometry. More than 250 samples were measured. The main BG is coming from PMTs although their radio-active impurities are 2 orders of magnitude less than ordinary ones. The Monte Carlo simulation (MC) was performed to estimate the BG from PMTs, and about 0.1 counts/day/kg/keV in the whole active volume and less than 10^{-4} counts/day/kg/keV in the fiducial volume with the diameter of 20 cm (100 kg sensitive volume) were obtained.

Xenon does not have long-lived radioactive isotopes, which is one of the most important advantages for rare event search experiment like a dark matter search. However, commercial xenon contains small amount (about 0.1 ppm) of krypton which has radioactive ^{85}Kr (harf-life of 10.76 years). Our requirement for concentration of ^{85}Kr is less than 1ppt. We developed a distillation tower purification system, and achieved ^{85}Kr concentration of 3.3+/- 1.1 ppt for prototype detector [2] which was very close to goal of requirement. The new distillation tower was built with about 4 m length of the tower column and about 1.2 ton of xenon gas has been processed in September 2010 for 10 days.

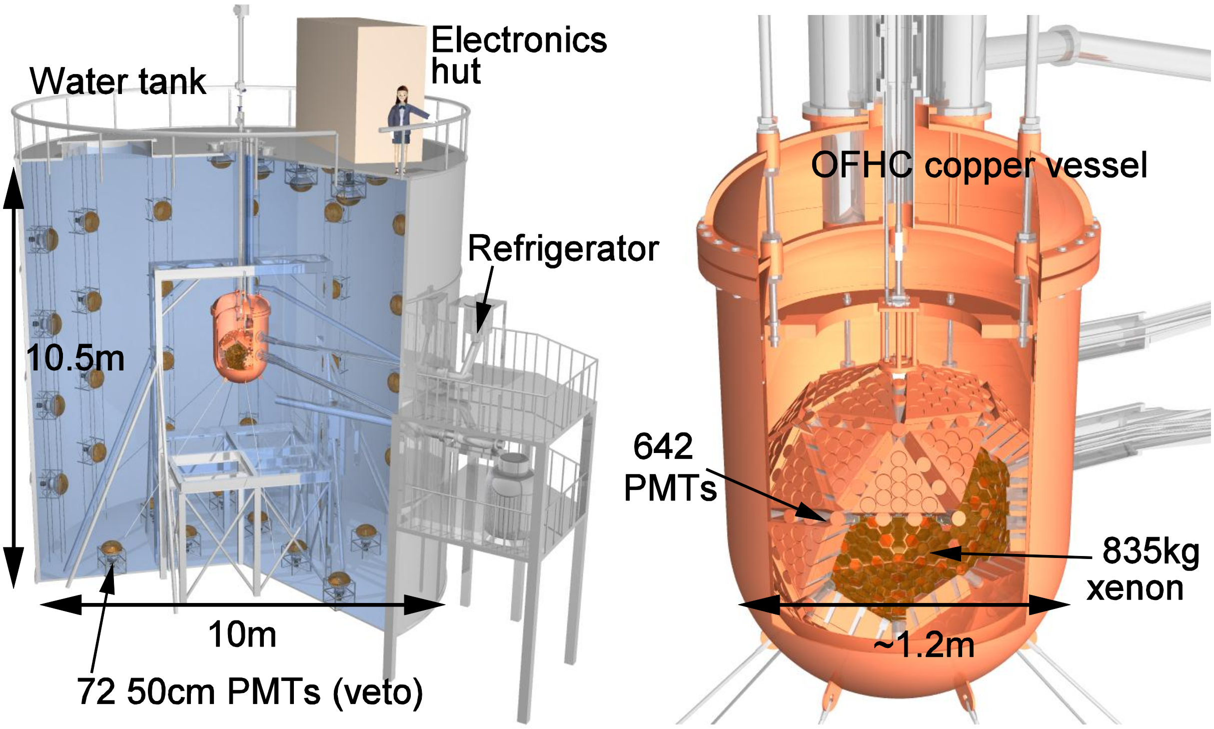

Figure 1: The schematic drawings of the XMASS 800 kg detector. The 10 m diameter and 10.5 m height water tank is used for the radiation shield, and 72 50cm PMTs on the inner surface of tank is used for the active veto for the cosmic rays. The detector was installed at the center of water tank (Left). The ultra- low BG 642 PMTs are immersed in liquid xenon. The amount of liquid xenon for active volume is 835 kg (Right).

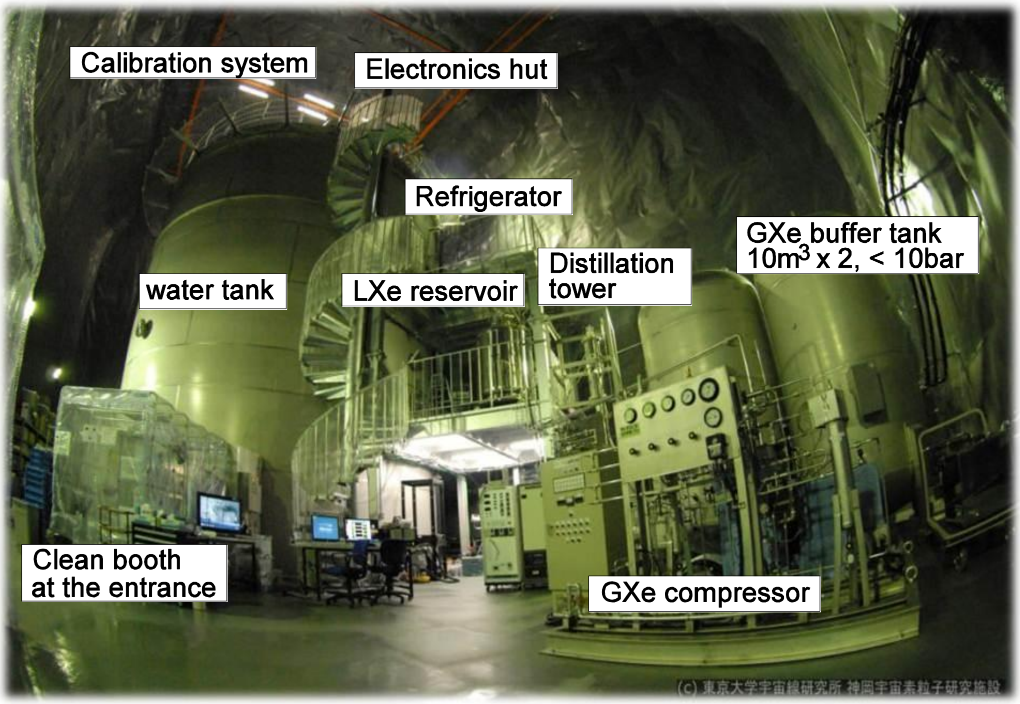

Figure 2: Photo of experimental hall in Kamioka mine. All the facilities of XMASS 800 kg detector have been completed.

2. Detector calibration

Radio-active sources are introduced into the active volume using an XMASS calibration system. The XMASS calibration system consists of several kinds of sources (^{57}Co, ^{241}Am, ^{55}Fe, ^{109}Cd, and ^{137}Cs), OFHC copper rod, thin stainless wire, and stepping motor. One of the radio-active sources is put on the edge of copper rod. The rod is hung with thin stainless wire and lifted up and down from outside the detector with motion feed-through and stepping motor located on the top of water tank. The source position can be controlled along z axis of active volume inside the detector with ±1mm accuracy. The radio-active source can be exchanged without any influences on the detector owing to gate valve for isolation.

The left panel of figure 3 shows energy spectrum obtained using 57Co source at the center of detector (z = 0 cm). The photo electron distribution was well reproduced by MC, and high light yield which is 15.1±1.2 photo-electrons/keV was obtained.

The right panel of figure 4 shows reconstructed vertices for various positioning of the ^{57}Co source. The position and energy are reconstructed from PMT charge patterns which are function of position and energy in the detector by using a likelihood method. Obtained position resolutions (rms.) are 1.4 cm at z = 0 cm and 1.0 cm at z = ±20 cm for 122 keV gamma-rays.

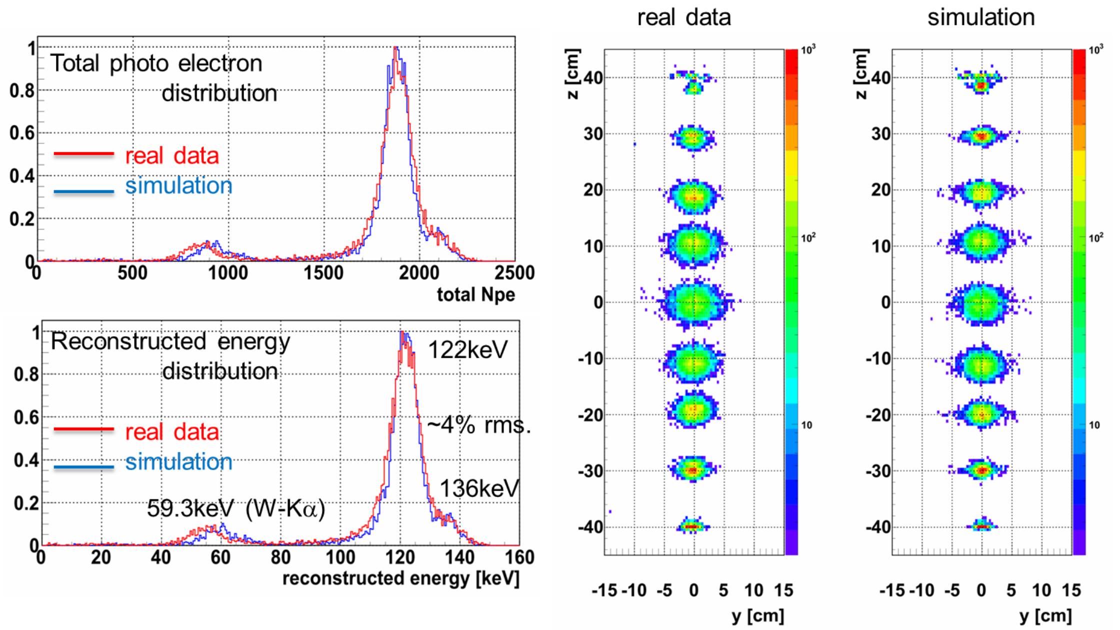

Figure 3: The observed photo electron and reconstructed energy spectra (left) and reconstructed vertex distribution (right) from ^{57}Co.

3. Evaluation of internal background

External BGs can be effectively reduced by the "self-shielding" of liquid xenon. However, internal BGs need to be reduced by other means. Possible internal BG sources are radon (^{222}Rn and ^{220}Rn) and krypton (^{85}Kr).

The evaluation of radon was done through the following coincidence reactions.

For ^{222}Rn: ^{214}Bi (β, E_{max} =3.3 MeV) → ^{214}Po (α, 7.7MeV, τ=164 μsec) → ^{210}Pb

For ^{220}Rn: ^{220}Rn (β, 6.3 MeV) → ^{216}Po (α, 6.8MeV, τ=0.14 sec) → ^{212}Pb

Figure 4 shows the observed photo electron distribution of 1st and 2nd events from ^{222}Rn, and distribution of time difference between 1st and 2nd events. The obtained ^{222}Rn concentration was 8.2±0.5 mBq which was close to PMT BG level. For ^{220}Rn, we did not find any candidate events. Then we have set a limit as < 0.28 mBq (90%C.L.) which was lower than our goal (0.43 mBq).

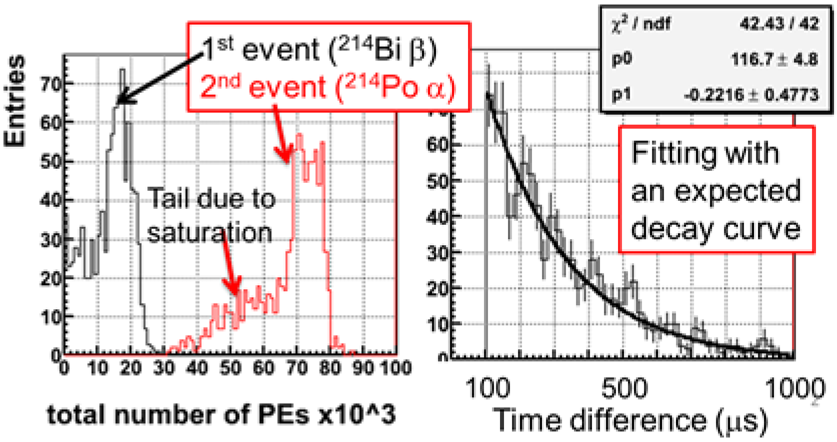

Figure 4: The observed photo electron distribution of 1st and 2nd events from ^{222}Rn (left) and distribution of time difference between 1st and 2nd events (right).

The krypton contamination is evaluated with an atmospheric pressure ionization mass spectrometer (API-MS) and a gas chromatography (GC) system. Current sensitivity of our API-MS and GC system is 10 ppt which is very close to target value (2 ppt). More sensitive measurement (< 1 ppt) using a cold trap is under preparation and will start to measure soon.

The krypton contamination is also evaluated from data analysis of 800 kg detector using the following delayed coincidence events.

^{85}Kr (β, E_{max} =173 keV) $\rightarrow$ ^{85}Rb* (γ, 514keV, τ=1.0 μsec) $\rightarrow$ ^{85}Rb.

This analysis is being studied.

4. Conclusion

The main component of BG is expected to be gamma-rays coming from PMTs, and estimated BG rate is less than 10^{-4} counts/day/kg/keV. The corresponding sensitivity of WIMP-nucleon cross section for the spin independent case will be 2×10^{-45} cm^2 at 100 GeV/c^2 WIMP mass. The construction of XMASS 800 kg detector was completed in September 2010 and commissioning run has been started since October 2010. Commissioning runs are being carried out to confirm the detector performance and low BG properties. High light yield (15.1±1.2 photoelectrons/keV) was obtained, and energy and vertex resolution were as expected. The radon BGs are close to the target values and krypton contamination will be evaluated. Physics run will start after commissioning runs.

Acknowledgements

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References

[1] Y. Suzuki, *et al.*, [hep-ph/0008296]
[2] K. Abe, *et al.*, *Astroparticle Phyics* 31 (2009) 290.