Low background techniques in XMASS

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Abstract. The XMASS project aims to detect pp and ^{7}Be 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 detector which requires low background and low threshold. Several techniques applied to XMASS detector for low background will be presented.

Keywords: Dark matter; liquid xenon; low background

INTRODUCTION

The XMASS detector with 800 kg ultra-pure liquid xenon is located in Kamioka mine (2,700 m.w.e.), Japan. It requires a low background (BG) in the fiducial volume of the detector. Almost all the components used for the detector were selected with a high purity germanium (HPGe) detector and inductively coupled plasma mass spectrometry (ICP-MS). In particular, we have developed ultra-low BG photomultiplier tubes (PMTs) with 2 orders of magnitude less radio activity than ordinary one. The PMT holder and vessel are made from oxygen free high thermal conductivity (OFHC) copper brought into the underground one month after electrorefining avoid to radioactivation by cosmic rays. The known component of internal BG of xenon is krypton (^{85}Kr). We achieved 5 orders of magnitude reduction of krypton with 4.7 kg/hour processing time. Whole the vessel is located at the center of water tank with a diameter of 10 m and height of 11 m as a passive shield against external gamma-rays and neutrons. The main BG source is thought to be gamma-rays from radioactive impurities (RIs) in PMTs. The estimated BG level from PMTs is less than 10^{-4} counts/day/kg/keV around threshold energy of 5 keV after fiducial volume cut. With this BG level, the 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.

XMASS DETECTOR

The XMASS detector (shown in fig. 1) consists of an outer and inner OFHC copper vessel with respective 1280 mm and 1120 mm diameters and total 642 PMTs immersed in liquid xenon. The total amount of liquid xenon for active volume is about 850 kg. The inner vessel holds liquid xenon and PMTs, and outer vessel is used for vacuum insulation. The 630 hexagonal and 12 round PMTs are mounted in an approximately spherical shape holder with an average radius of 40 cm of xenon. The photo coverage of PMTs is about 64.4 %. The actual shape of holder is called Pentakis-dodecahedron which consists of 12 pentagonal pyramids and each pyramid is made by 5 triangles. The detector employs a single phase technology and observes only scintillation lights emitted by the interaction of dark matter.

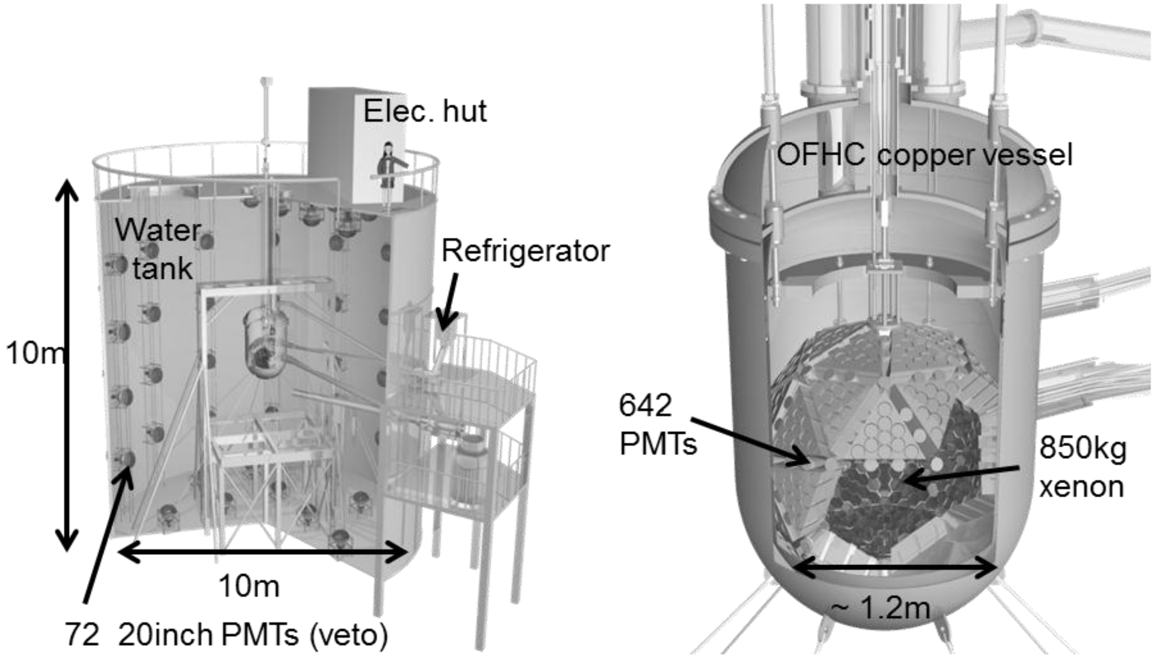

FIGURE 1: The schematic drawings of the XMASS 800 kg detector. The 10 m diameter and 10 m height water tank is used for the radiation shield, and 72 20'' PMTs on the inner surface of tank is used for the active veto for the cosmic rays. The detector was installed at the center of water tank (Left). The ultra- low BG 642 PMTs immersed in the 850 kg liquid xenon. The double wall vessel made from the OFHC copper holds liquid xenon with the vacuum insulation. The average radius of liquid xenon is about 40 cm (Right).

BACKGROUND REDUCTION

BG from detector materials

Almost all the materials used for detector were selected with an HPGe detector and ICP-MS. More than 250 samples were measured. Total amount of RIs from detector materials excluding PMTs is much lower than that of PMTs. The main BG is coming from PMTs although their RIs are 2 orders of magnitude less than ordinary ones. The table 1 is summary of RIs in PMTs including the base measured with the HPGe detector. 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.

TABLE 1. The measured RIs of PMTs including the base. ^{40}K is lower than the detection limit.

Radio isotope	RIs/PMT [mBq]
U chain	0.70 +/- 0.28
Th chain	1.51 +/- 0.31
^{40}K	< 5.10
^{60}Co	2.92 +/- 0.16

External BG from rock

External gamma-rays and neutrons coming from rock are sufficiently reduced by 2 m thick pure water. According to our MC study, 2 m is thick enough to reduce BG caused by gamma-rays and neutrons to lower level than PMT BG and 10^{-4} counts/day/kg, respectively. The actual size of water tank is 10 m diameter and 10 m height for future extensions. Seventy two 20 inch PMTs are mounted inner surface of water tank for active veto against cosmic-rays.

Internal BG (1): Kr

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 [2] which is very near the goal of requirement. The new distillation tower was built with about 4m length of the tower column to achieve < 1 ppt ^{85}Kr and about 1.2 ton of xenon gas has been processed in September 2010 for 10 days.

Internal BG (2): Rn

Another internal BG source is radon emanated from the detector component. We measured the radon emanation rate from the detector materials using radon detector with electrostatic collection, and obtained value is less than 15 mBq. On the other hand, our requirement value is less than 0.6 mBq. The purification system for removing radon by the filter is under studying.

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 $2x10^{-45}$ cm^2 at 100 GeV/c^2 WIMP mass. The construction of XMASS 800 kg detector was completed fall, 2010.After commissioning run, the data taking will be started in late 2010.

ACKNOWLEDGMENTS

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REFERENCES

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[2] K. Abe , *et al., Astroparticle Phyics* **31** (2009) 290.