Status of XMASS

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DOI: http://dx.doi.org/10.3204/DESY-PROC-2011-04/kishimoto_yasuhiro

The XMASS project aims to direct ^{7}Be/$pp-$solar neutrinos, neutrino-less double beta decay, and darkmatter searches using ultra-pure liquid xenon. The first stage of the XMASS searches for darkmatter with 800 kg single-phase xenon-scintillator detector, whose construction was started in April 2007 and completed in September 2010. After installation of purified xenon, commissioning runs have been started since October 2010. Status of the current XMASS detector was reported, especially about evaluation of performance of event vertex reconstruction and amount of internal contamination in the liquid xenon.

1 Introduction

The XMASS project aims to direct ^{7}Be/$pp-$solar neutrinos, neutrino-less double beta decay, and darkmatter searches using ultra-pure liquid xenon [1]. The first stage of the XMASS project is for direct darkmatter searches. The XMASS detector with 800 kg ultra-pure liquid xenon is located in Kamioka mine(2,700 m.w.e), Japan. The liquid xenon was chosen as target material because it has large photon yield and high mass number (A=131.29). The 800 kg detector construction was started in April 2007 and it was completed in September 2010. After installation of purified xenon, commissioning run has been running since October 2010. In the commissioning run, we carried out calibration using radioactive sources to study for energy and position resolution. We put several kinds of sources inside the detector and evaluated the performance of the vertex reconstruction. We also evaluated internal contamination, such as radon (^{222}Rn and ^{220}Rn) and krypton(^{85}Kr). In this paper, the performance of the reconstruction and the evaluation of the internal contaminations will be described.

2 XMASS detector

The XMASS detector consists of 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. Ultra-low background 630 hexagonal PMTs and 12 round ones are mounted in an approximately spherical-shape holder made of OFHC copper. The photo coverage of the PMTs is about 64%. The detector employs a single-phase technology and observe only scintillation lights emitted by the interaction of darkmatter. Vertexes of events are reconstructed using photo electron distribution observed by PMTs. The key idea of the background (BG) reduction in XMASS is "self-shielding". External gamma-rays can be absorbed by the outer surface of the liquid xenon owing to the high atomic number (Z=53). On the other hand, the darkmatter particles can give uniform vertex distributions over the detector. By extracting events that occur only deep inside the detector, therefor, a sensitive search for darkmatter can be conducted.

Almost all of the material used for the detector were carefully selected with a high purity germanium detector and induced coupled plasma mass spectrometers. More than 250 samples were measured. The main BG is coming from the PMTs although their radioactive impurities are two orders magnitude less than those of ordinary ones. Monte Carlo simulations (MCs) were performed to estimate the BG form PMTs and found about 0.1 counts/day/kg/day in the whole volume and less than 10^{-4} counts/day/kg/day in the fiducial volume with 20 cm radius (100 kg sensitive volume).

Xenon does not have long-lived radioactive isotopes, which is one of the most important advantage for rare event search experiments like darkmatter search. Commercial xenon, however, contains small amount (about 0.1 ppm) of krypton which has radioactive ^{85}Kr (half-live of 10.76 years). Our requirement for contamination of ^{85}Kr is less than 2 ppt. We have developed a distillation tower purification system and achieved ^{85}Kr contamination of 3.3 ± 1.1 ppt for prototype detector [2], which was very close to the goal of our requirement. A new distillation tower was build with about 4 m length of a tower column and about 1.2 ton of xenon gas has been processed in September 2010 for 10 days.

With BG level of 10^{-4} counts/day/kg/day, expected sensitivity of WIMP-nucleon cross section for the spin independent case is presented in Fig.1 with some experimental results and one of theoretical predictions.

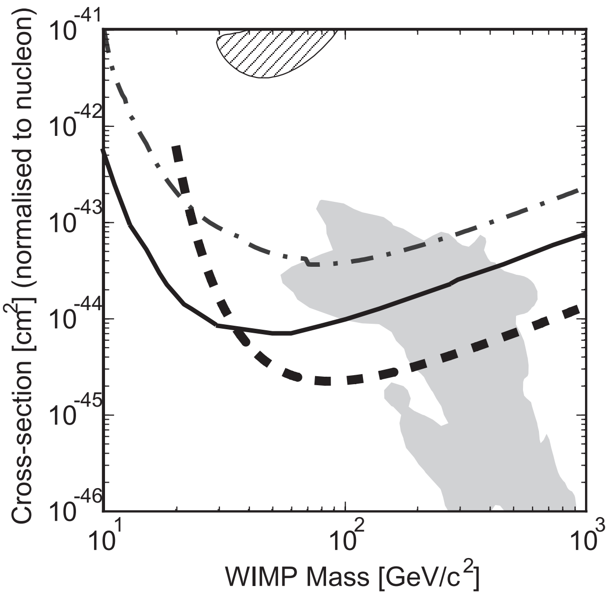

Figure 1: Measured and expected sensitivities of WIMPs-nucleon cross section as a function of WIMP mass. Hatched region is 3σ arrowed region by DAMA/LIBRA with no ion channeling[3]. Shaded region is a result of a theoretical calculation in [4]. Upper region of a solid thin line and a line-dashed lines are excluded by XENON100[5] and CDMS[6], respectively. XMASS expected sensitivity is plotted in thick dash line.

3 Detector calibration

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

The left panel of Fig. 2 plots energy spectrum obtained using ^{57}Co source at the center of the detector($z = 0$ cm). The photoelectron distribution was well reproduced by a MC, and

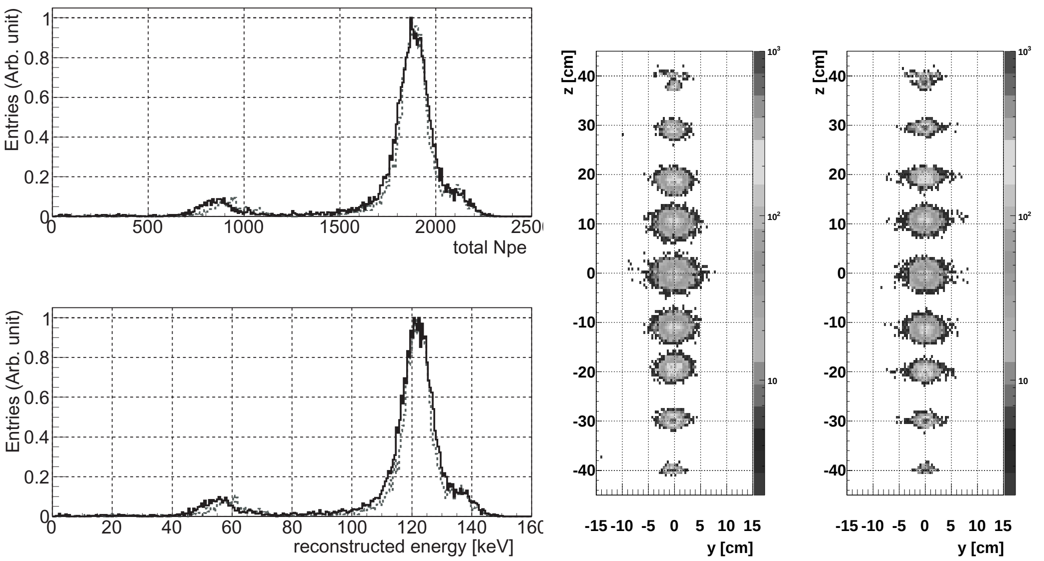

Figure 2: The left panel shows observed photoelectron(upper) and reconstructed energy(lower). Calibration data and MC results are plotted by solid line and dashed one, respectively. Reconstructed vertex distributions of calibration data(left) and MC results(right) are compared in the right panel.

high light yield which is 15.1 ± 1.2 photoelectrons/keV was obtained. The right panel of Fig. 2 shows reconstructed vertices for various position 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 resolution (RMS) are 1.4 cm at $z = 0$ cm and 1.0 cm at $z = \pm 20$ cm for 122 keV gamma-rays.

4 Evaluation of internal BG

External BGs can be effectively reduced by the "self-shielding" of liquid xenon. Internal BGs, however, 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 reaction.

- For ^{222}Rn : ^{214}Bi(β, $E_{\max} = 3.3$MeV) $\rightarrow$ ^{214}Po(α, $E = 7.7$MeV, $\tau = 164\mu$sec) $\rightarrow$ ^{210}Pb
- For ^{220}Rn : ^{220}Rn(α, $E = 6.3$MeV) $\rightarrow$ ^{216}Po(α, $E = 6.8$MeV, $\tau = 0.14$sec) $\rightarrow$ ^{212}Pb

The obtained ^{222}Rn concentration was 8.2 ± 0.5 mBq which was close to PMT's BG level. For ^{220}Rn, we did not found any candidate events. Then, we have set a limit as < 0.28 mBq(90%C.L.), which is lower than our goal (0.43 mBq).

The krypton contamination is now being evaluated with a combined system of an atmospheric pressure ionization mass spectrometer (API-MS) and a gas chromatography. Current sensitivity of the system is about 10 ppt which is very close to our target value (2 ppt). More sensitive measurement ($<$ 1 ppt) is under preparation with more proper measurement parameters and will start soon.

The krypton contamination is also evaluated from data analysis of the following delayed coincidence events:

- ^{85}Kr(β, $E_{\max} = 173$ keV) $\rightarrow$ ^{85}Rb*(γ, $E = 514$ keV, $\tau = 1.9$ μsec) $\rightarrow$ ^{85}Rb.

This analysis is being studied.

5 Conclusions

The construction of XMASS 800 kg detectors was completed inn September 2010 and commissioning run has been started since October 2010. The main component of BG of this darkmatter detector is expected to be gamma-rays coming from PMTs, and estimated BG rate is less than 10^{-4} events/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. Commissioning runs are being carried out to confirm the detector performance and low BG properties. Energy and vertex resolution were as expected. The radon BG level is close to the target values and krypton contamination will be evaluated. Physics run will be start after commissioning runs.

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