RECENT STATUS OF THE XMASS PROJECT

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XMASS is an underground experiment aimed at searching rare phenomena under an ultra low background environment by using ultra pure liquid xenon in the Kamioka mine, Japan. The main physics targets of XMASS are cold dark matter, neutrinoless double beta decays, and low-energy solar neutrinos. So far, we have done 2 series of test experiments with a prototype liquid xenon detector. In this paper, the current status of the XMASS project, especially the first results from the second test experiment, is reported.

1 Introduction

XMASS is an underground experiment aimed at searching for rare phenomena under an ultra low background environment by using ultra pure liquid xenon in Kamioka mine, Japan. The main physics targets of XMASS are cold dark matter, neutrinoless double beta decays, and low-energy solar neutrinos.

So far, we have developed a prototype detector and done 2 series of test experiments with it. The purpose of the prototype detector is to prove the feasibilities of the next XMASS 800kg detector. In the 800kg XMASS detector, our goal will be to search for dark matter with a factor of 100 improved sensitivity.

2 Prototype detector

Figure 1 shows a schematic view of the prototype detector. The prototype detector consists of 100kg of liquid xenon and 54 low-background Photo-Multiplier Tubes(PMT). It is installed in a heavy gamma ray shield in a clean room in Kamioka Observatory, ICRR, Univ. of Tokyo in Kamioka mine (2700m water equivalent).

The low-background PMTs are Hamamatsu R8778, which were developed for this project. The quantum efficiency and collection efficiency are about 30% at 175nm and about 90%, respectively. The radioactivity of the materials were measured by HPGe detector, then low-background materials were selected to assemble R8778. The remaining radio activities of a R8778 PMT are measured as follows; U: $1.5 \pm 0.3 \times 10^{-3}$ Bq, Th: $3.2 \pm 4.6 \times 10^{-3}$ Bq, and ^{40}K: $1.7 \pm 2.9 \times 10^{-3}$ Bq. These PMTs are attached to a square-shaped 30L chamber made from OFC through 5mm thickness MgF_2 windows.

The charge information from the PMTs are read by 54 channels of charge sensitive ADCs and a common Flash ADC for summed signals. The threshold of each PMT is about 0.4 photo electron. The data acquisition trigger is applied when there are 4 multiple hits within 100ns time window. The typical trigger rate for normal runs is about 1.5Hz.

3 Results from test experiments

So far, we have done two series of test experiments with the prototype detector. The first test run was carried out in December 2003 for about 6days. We took about 2 days normal runs for external background estimation. After the first run, we purified the xenon by distillation, installed new electronics, applied longer baking time of the system, and then carried out a second test run. This was from August 3 until August 11, 2004, including 6 days normal runs. Here are the main results from these test experiments.

3.1 Vertex reconstruction

Figure 2 shows a demonstration of the reconstruction performance of the prototype detector. The collimated gamma rays are injected horizontally along the detector's Z-axis. There are 3 collimaters on the heavy shield, that is, Hole-

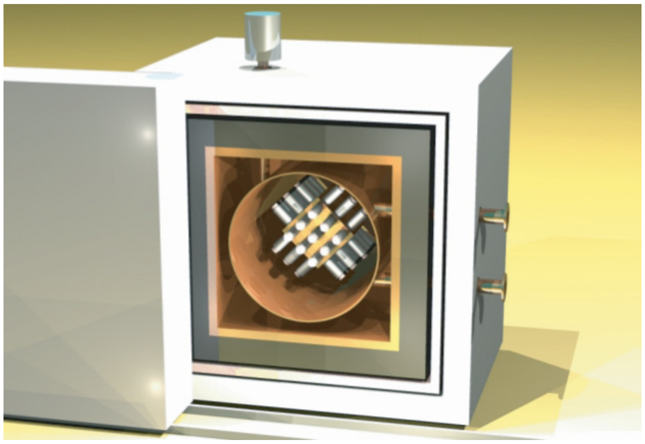

Figure 1. XMASS prototype detector. 100kg liquid xenon and 54 low-background PMTs are used. PMTs are attached to the 30L OFC chamber through 5mm thickness MgF_2 windows. They are put into a heavy shield in a clean room. The XMASS prototype detector is located in Kamioka Observatory, ICRR, Univ of Tokyo, in Kamioka mine.

A, Hole-B, and Hole-C. Hole-A is located at the center of the detector. Hole-B and Hole-C are shifted to the left side on the plots. The upper plots are Data and lower plots are Monte Calro(MC) simulation. The agreement between Data and MC is good.

3.2 Self shielding performance

Figure 3 shows the self-shielding performance of the prototype detector. The collimated gamma rays were injected from the Z=0 side horizontally. Although the reduction factor through the prototype detector is about 1 order of magnitude for ^{60}Co, it is about 2 orders for ^{137}Cs, because ^{137}Cs has a lower mean energy. The self-shielding effect between Data and MC agrees well. This proves the self-shielding technique is working well in the prototype detector as expected.

3.3 External background measurements

Figure 4(a) shows the measured energy spectrum of the prototype detector in the heavy shield. This data was taken during the second test run in August 2003 for about 6 days. The red (green) line shows events in a 10cm (20cm) fiducial volume in which reconstructed vertex positions must be away from the detector wall by 10cm (5cm). Therefore, the 10cm (20cm) fiducial volume corresponds to a 10cm (20cm) cube and the volume inside is 1L (8L). The event rate for 200-400keV shows the self-shielding effect. The event rate increase below 100keV is artificial. It is due to detector wall effects of the prototype detector. Because there are many optically dark spots near the detector wall in the prototype detector, some high energy events occuring near the detector wall give a very low number of total photons to the PMTs. Therefore, the event reconstruction for such events tends to be pulled into the detector central region. This effect is also reproduced by the MC energy spectrum. We will eliminate this effect in the next 800kg detector.

Figure 4(b) shows the expected energy spectrum from known external background sources. The inputs are the remaining radio activities of the R8778 PMTs, ^{210}Pb in the lead shield, and external gamma rays from outside the heavy shield. Those 2 plots agree within a factor of 2. Therefore, we think we have an understanding of the major sources of the remaining external background.

There are some small differences including, for example, the shape of the peak from ^{40}K (around 1.4MeV). We are still tuning the current

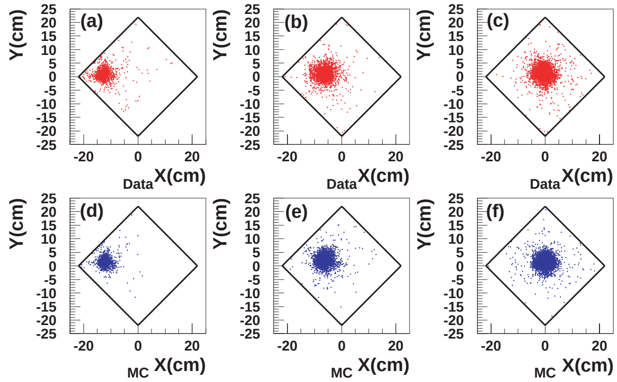

Figure 2. Vertex reconstruction performance: (a),(b),(c) Data and (d),(e),(f) MC. The reconstructed vertex positions of collimated gamma source runs are plotted. (a),(c) Hole-C (left side), (b),(e) Hole-B (left-center), and (c),(f) Hole-A (center) are used.

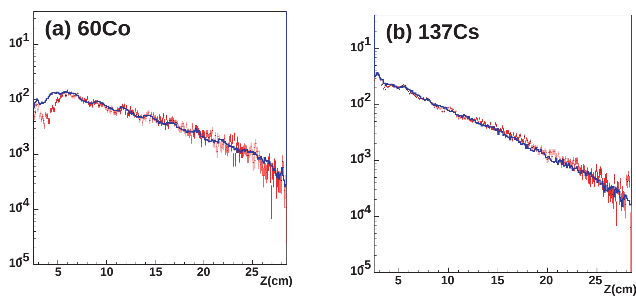

Figure 3. Self shielding performance: (a) ^{60}Co and (b) ^{137}Cs. The blue line and red plots correspond to MC and Data, respectively. The collimated gamma rays are injected horizontally from Hole-A (center) at Z=0(cm) position. The reconstructed vertex positions are plotted. The wiggles are due to grid effects of the current reconstruction tool and will be improved.

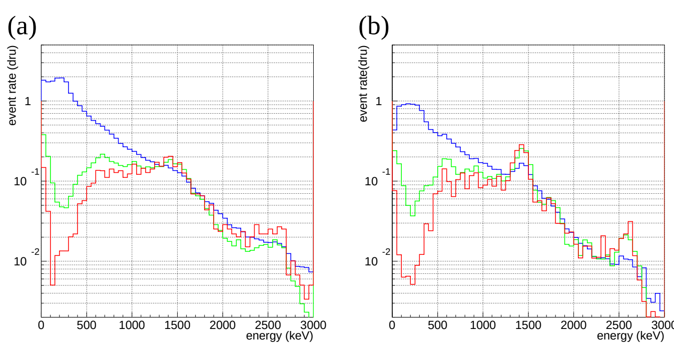

Figure 4. Energy spectrum of normal run: (a) Data and (b) MC. The blue, green, and red lines correspond to full volume, 20cm fiducial volume, and 10cm fiducial volume, respectively. The event rate increase at the lowest energy region of red and green lines are due to the detector wall effects (see text).

Table 1. Summary of the current estimation for internal background sources. The current goal is for the XMASS 800kg detector.

Source	Estimation	Goal
^{238}U	$(33\pm7)\times10^{-14}$ g/g	1×10^{-14}
^{232}Th	$<23\times10^{-14}$ g/g	2×10^{-14}
^{85}Kr	(3.3 ± 1.1) ppt	1 ppt

MC to improve these points.

3.4 Internal background measurements

We have estimated major internal background sources of the prototype detector. For radon in the Uranium and Thorium series, the time coincidence between Bi and Po decay chains was used. For ^{222}Rn in the Uranium chain, we have found 67 coincidence events during 1.8-day measurements. Actually, we took two separate runs; 0.8-day on Aug. 4 and 1.0-day on Aug. 10, 2004. The estimated Uranium contaminations from these 2 runs were ^{238}U = $(72\pm11)\times10^{-14}$ g(U)/g(Xe) for Aug. 4 and ^{238}U = $(33\pm7)\times10^{-14}$ g(U)/g(Xe) for Aug. 10. This decrease is consistent with the expected radon decay (half life = 3.8days). Therefore, most of the ^{222}Rn might come from outside the detector from storage tanks, piping, etc.

For the ^{220}Rn in the Thorium chain, we have searched for possible peaks from Bi and Po decay chains in FADC signal. We found no coincidence during 3.2 days FADC data. This corresponds to ^{232}Th $<23\times10^{-14}$ g(Th)/g(Xe) (90% C.L.).

Another major internal background would be ^{85}Kr. In the December 2003 run, there was a 3 ppb Kr level in xenon (measured value). We have purified 100kg of xenon by a distillation method in March 2003, then measured Kr contamination in xenon again. Then, the measured Kr contamination decreased to (3.3 ± 1.1) ppt.

Table 1 shows a summary of the current estimation of the internal background sources.

4 Conclusion

We have confirmed the followings: (1) The event reconstruction method works well. (2) The self-shielding against external events works well as expected. (3) The measured external background level of the prototype detector is consistent with expectations within a factor of 2 or less. Therefore, the remaining main source of external background events would be coming from the PMTs. For the PMTs, our current goal is another factor of 10 reduction. (4) The estimation of internal background levels of U, Th, and ^{85}Kr is done. Another factor $10\sim30$ reduction is needed for the current goal of the 800kg XMASS detector.

These results demonstrated the most important features of the XMASS detector and the feasibility of the dark matter search planned in the next 800kg detector.

Acknowledgments

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