The current status of XMASS using 100kg detector

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ABSTRACT: XMASS is a multi-purpose underground detector using ultra pure liquid xenon whose aim is searching for dark matter, double beta decay and low energy solar neutrinos. The first physics target is the detection of dark matter and R&D studies have been performed using a 100kg detector. Here, the detector performance checks will be presented. The detector consists of a 31-cm size cubic capper chamber, 54 2-inch PMTs, and shielding to eliminate outside backgrounds such as betas, gammas and neutrons. First, since the signal of dark matter is expected at low energy region below several tens of keV, it is important to reduce backgrounds in this energy region. Therefore, the self-shielding performance of liquid xenon, which is a key idea for reduction of backgrounds, in 100kg detector is checked using a radioactive source from outside of the detector. It is consistent with expectation. Next, the source of backgrounds is studied. In order to understand backgrounds, a precise detector simulation is needed. Several parameters, e.g. light absorption and scattering in liquid xenon and reflection on the surface of copper and PMTs should be obtained for the detector simulation. Those are studied using about 4days of data. Comparing data and MC, the background level inside the fiducial volume is consistent with expectation. Each remaining backgrounds source is also estimated and will be presented.

1. INTRODUCTION

XMASS is a multi-purpose detector using large amount of ultra pure liquid xenon. The strong points of using liquid xenon are as follows; large photon yield, available for purification and compact detector size, no long life isotope, generate scintillation light (175nm), and relative high temperature (~165K), but most important point is self shielding effect. For the gamma ray below 500keV, the reduction of 6 order of magnitude can be achieved. It can be easy to reduce the main background coming from the outside.

We have three stage of the detector scale-up. The current detector is 100kg prototype. This is for R&D and a dark matter search. The second scale is planned to 800kg detector, which is possible to search dark matter [1]. The final goal of our detector is 10ton class which can detect not only dark matter, but also solar neutrino and double beta decay search.

The current status and qualities for 100kg prototype are presented in this paper.

2. DETECTOR SETUP

The schematic view of the 100kg detector is shown in Fig.1. It consists of 30litter cubic capper chamber with 100kg liquid xenon and 54 2-inch PMTs. 9 PMTs are placed in each plate through MgF2 window. The photo coverage is 16%, and it deduces the photo electron yield is 0.6p.e./keV. The detector is covered by 4π sheild, which can reduce background such as gamma and neutron from outside. The main purpose of this detector is check of the detector performance. The menu is as follows; stability check in low temperature (~165K), low background setup, vertex and energy reconstruction, demonstration of self shielding, xenon purification, particle identification, check the quality of liquid xenon such as attenuation and scattering length, and neutron background study. The data was taken in December 2003 and August 2004. The main difference of both data is purification of Kr background inside the liquid xenon using distillation method. [2]

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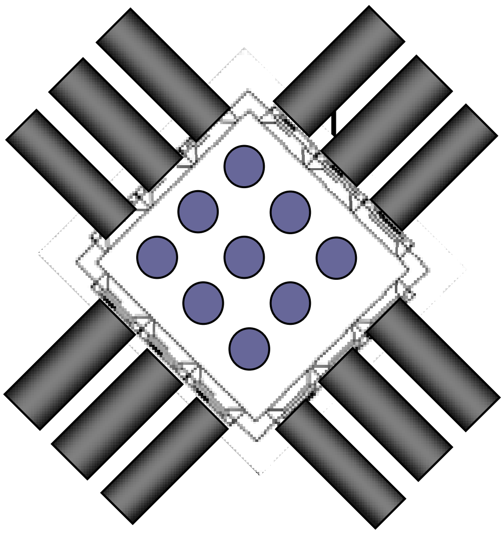

Fig. 1. The schematic view of 100kg detector.

3. DETECTOR PERFORMANCE

For the detector quality check, two kinds of data are taken. One is injection of collimated gamma ray from the outside of the detector, called 'source run'. The purposes are checking the vertex and energy reconstruction, self shielding power, and evaluate several parameters of liquid xenon. The other is background measurement inside the shield, called 'background run'.

First of all, the energy and vertex reconstruction method is presented. The maximum likelihood method from the photoelectron map made by MC is used, and the likelihood function is

$$\sum_{PMT} \log\left(\frac{\exp(-\mu)\mu^{n}}{n!}\right) \qquad (1)$$

here, μ is the function of photoelectron map with an acceptance correction and n is observed number of photo electron. The vertex distribution for source run in data and MC are shown in Fig.2. This shows the collimated gamma ray source ^{137}Cs with 662keV, and inject from three positions. The data and MC are consistent well.

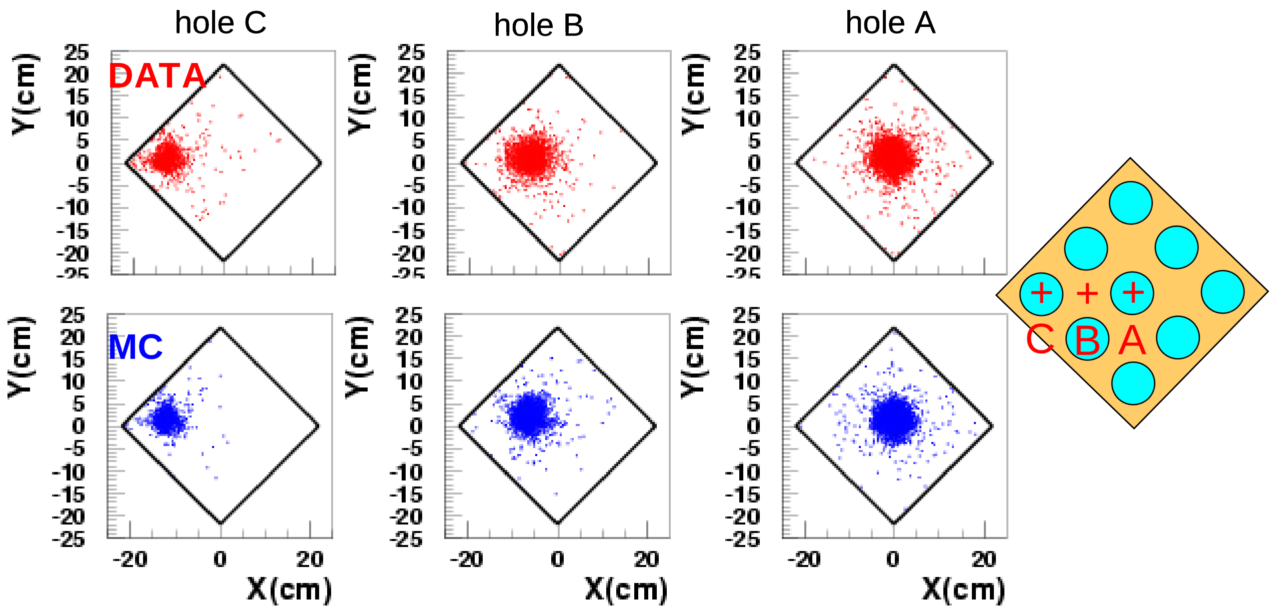

Fig.2 The vertex distribution of source run. The holes of three positions (A, B, C) are used, and upper shows the data and lower shows the MC.

The left figure in Fig.3 shows the vertex distribution from the wall for data and MC. The distribution indicates a power of self shielding. It depends on the gamma ray energy, but data and MC agree well in both sources from the figure. It concludes that the performance of the self shielding is as expected. The right figure in Fig.3 shows the reconstructed energy distribution for ^{137}Cs (662keV) source run in each fiducial volume region. The peak position in 10cm fiducial volume is 677keV and its resolution 65keV. The reconstructed energy agrees well to the expected. It means no position bias that all plots show the similar peak position.

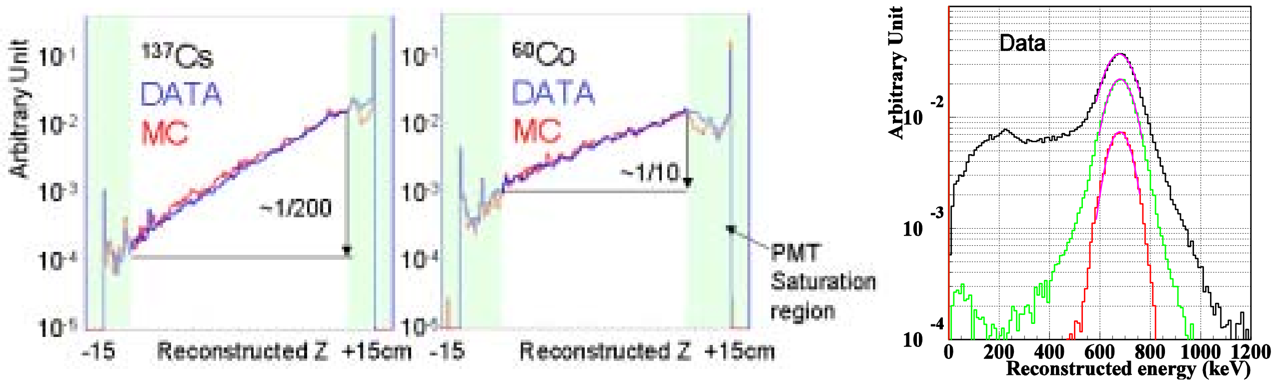

Fig.3 (left) The vertex distribution for Z position in source run. +15cm shows the wall near the source. (right) The energy distribution of Cs source run in each fiducial volume. From the outside to inside, all volume, 20cm fiducial, and 10cm fiducial volume are shown respectively.

The other purpose of source run is that MC tunable parameters are determined. Among them, photon yield, QE and collection efficiency of PMT, and refractive index of liquid xenon are known or measured. While the absorption and scattering of liquid xenon, and the reflection on the surface of cupper is not yet measured, and may change as the detector situation. Therefore, those parameters are fine tuned using the hit pattern in source run. A χ^2 method using hit pattern distribution in each source run is used. Though the tentative values are determined that 60cm for absorption, 55cm for scattering, and 20% for reflection, the uncertainty estimation has not been done yet, and they may change in near future. [2]

Finally, the remaining background evaluation is discussed. Fig. 4 shows the spectrum of background run in data and MC. The background sources are thought to be internal and external. The internal background is discussed in [1]. Among external backgrounds, gamma ray from the outside of the shield, radio active in PMTs, and ^{210}Pb in the lead shield are considerable. The figure of MC in Fig.4 includes those kinds of background events. From the figures, data and MC agree well, and its background level is quite low at the level of 10^{-2}/kg/day/keV with 100-300 keV energy region. In the energy region below 100keV, a lot of background evens are still remained both in data and MC. Looking at those kinds of events, the vertex of them are mostly reconstructed to very near the wall even though fiducial volume cut is applied. This is caused from a misfit of vertex because of the dead angle of incident light for PMT even though photons are generated in very near the PMT. This phenomena comes from the shape of detector, here, it is cubic. Therefore we plan to use spherical shape in the next 800kg detector. [1] And we will reduce such light as has dead angle to PMTs also in the 100kg detector, attaching the light guide inside the chamber. The background in the detector with light guide is estimated to the 10^{-2}/kg/day/keV in the energy region below 100keV. If it is achieved, we can start dark matter search. The expected sensitive area is covered all of the so-called DAMA region in 10weeks of data taking at three sigma level.

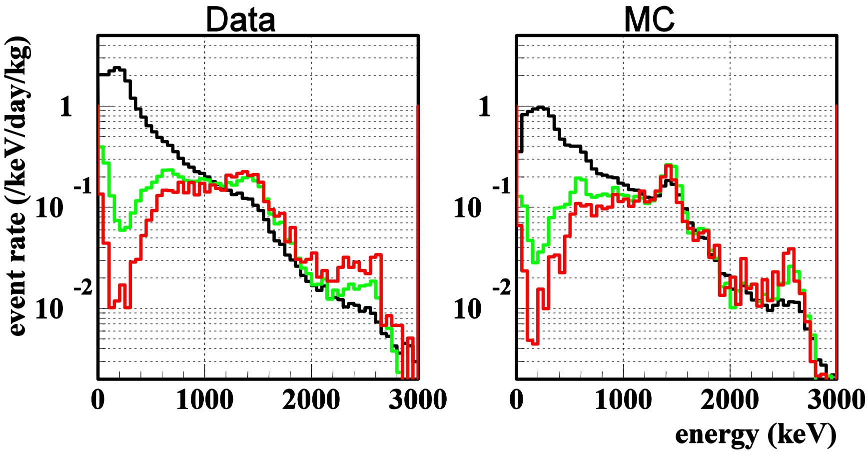

Fig.4 The spectrum of background run in each fiducial volume. From the upper to lower in low energy region shows, all volume, 20cm fiducial, and 10cm fiducial volume are shown respectively.

4. SUMMARY

The performance of XMASS 100kg detector is described. Its key technology is self shielding and the performance is shown as expected. The other performances such as vertex and energy reconstruction, and the spectrum shape of remaining background are also consistent with the expected. The parameters for liquid xenon are also estimated. The next step of 100kg detector is that the light guide is attached in order to reduce the remaining backgrounds in lower energy region. The succeed in R&D phase of 100kg liquid xenon detector can lead the dark matter search in the next 800kg detector.

REFERENCES

[1] Y.Takeuchi, the proceeding of this conference.
[2] J.Hosaka, master thesis in Univ. of Tokyo (2004)