Study on Background Events in the XMASS Experiment

OKA Naoya
MC1 Student at Kamioka Observatory, ICRR

1. Introduction

The XMASS Detector

XMASS Experiment aims to directly detect the cold Dark Matter using liquid Xenon. The signal of the dark matter is very rare and weak, so it is important to reduce background events.

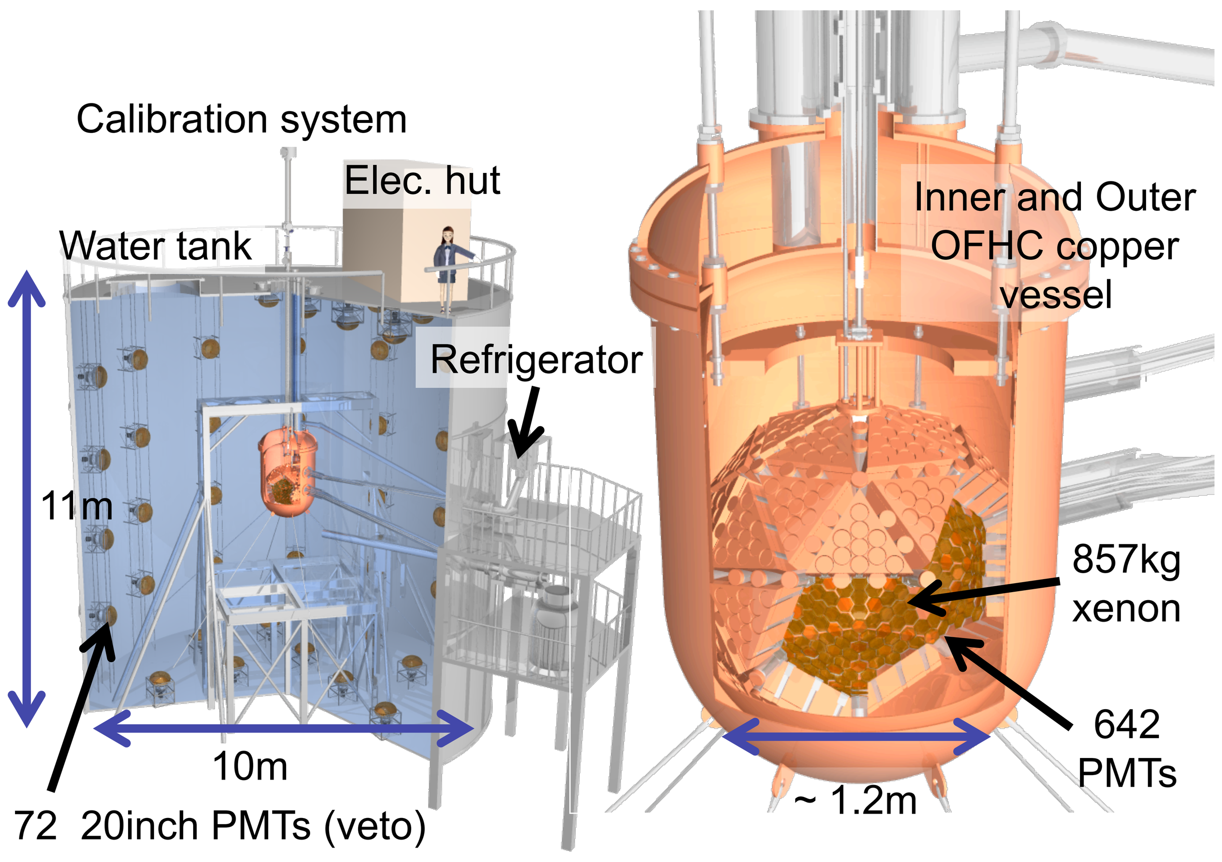

Figure 1 A schematic drawing of the XMASS Detector.

The detector system is placed in the Kamioka mine under 1000 m from the top of the mountain. This reduces cosmic-ray muon flux 10^{-5} compared to the ground. The main part of the detector is 800 kg of liquid xenon surrounded by 642 photo-multiplier tubes (PMT). This in turn is surrounded by a vacuum chamber, and the chamber is placed in a tank filled with pure water to reduce neutron-originated background. In addition, low radioactivity materials were chosen for the detector. To archive the target sensitivity, rate of the background must be under 10^{-4} events/day/kg/keV in fiducial volume.

Backgrounds in XMASS

In XMASS, commissioning runs were conducted from October 2010 to June 2012. In that period, there found unexpected backgrounds. Energy spectrum of whole volume XMASS detector is shown in Figure 2. In this figure, black line show the energy spectrum of real data, and the other spectrums show Monte Carlo (MC) simulation of backgrounds from materials of PMT. As shown in this figure, almost all backgrounds can be explained as due to radioactivities of materials used in PMT.

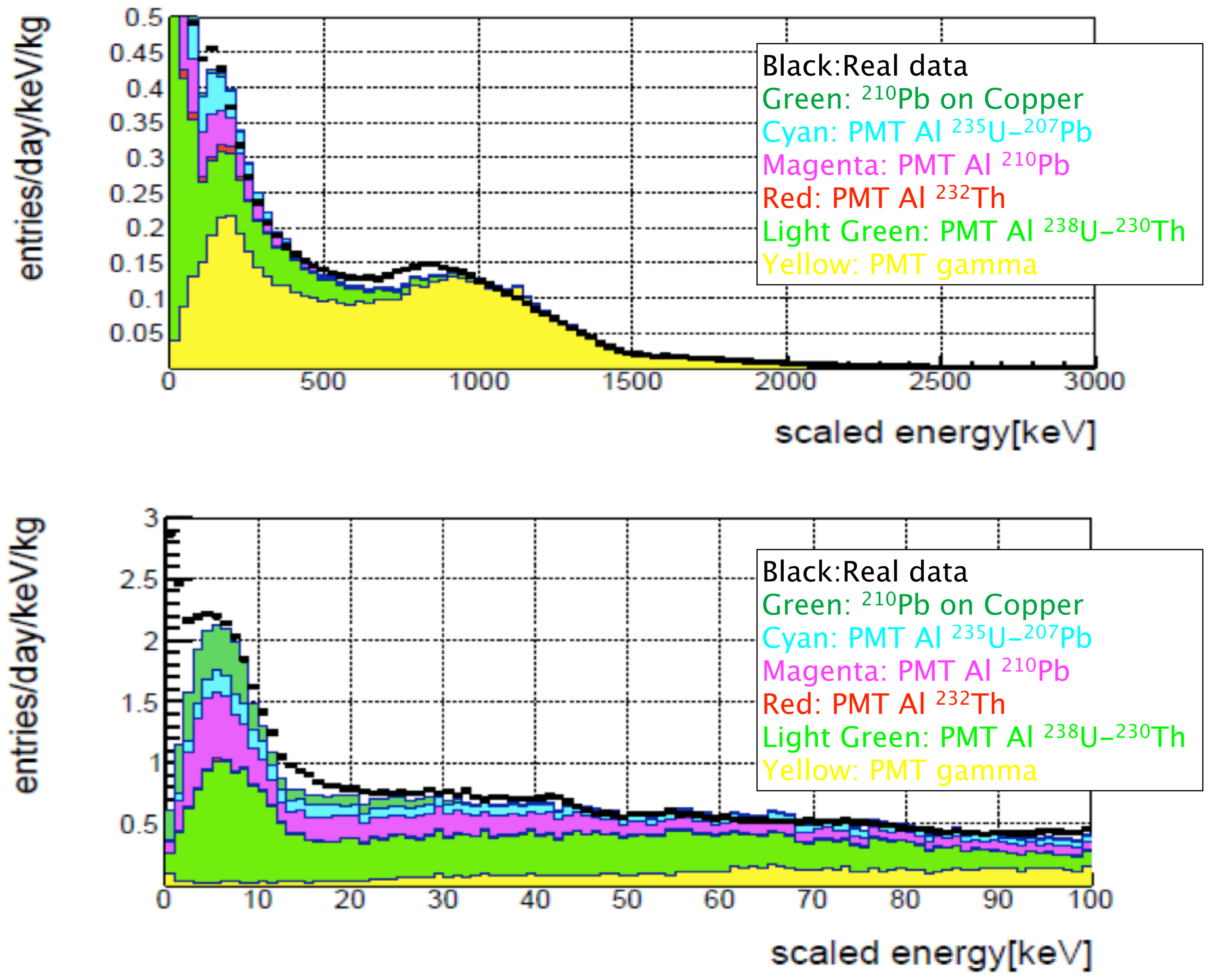

Figure 2 Energy spectrum of whole volume XMASS Detector.

2. Study of gamma ray backgrounds from materials outer than PMT

Motivation

Other than PMT materials, radioactivity of all materials used in XMASS are measured by Germanium detector before the construction of the detector[1]. As shown in Fig. 2, understanding backgrounds is not completed. One candidate for filling the gap between real data and MC is the gamma rays from the materials outer than PMT.

Method

Dominant gamma-emitting causal nuclides on these materials are ^{60}Co, ^{40}K, and the nuclides in ^{238}U and ^{234}Th series. So I estimated the background contribution of these nuclides using MC calculation based on Geant4. I simulated by MC these 4 nuclides decaying at 9 parts of the detector (3 parts of PMT holder, 3 parts of inner vacuum chamber, 2 parts of outer vacuum chamber, and the support structure of the detector system). Using radioactivity data of 86 samples by Germanium detector, MC data can be converted to the detection rate for the XMASS detector.

Result

Total background contribution of gamma ray from materials outer than PMT is shown in Figure 3. In this energy spectrum for whole volume XMASS detector, the blue line shows the center value, and the red band shows the error (1σ) from Germanium measurement.

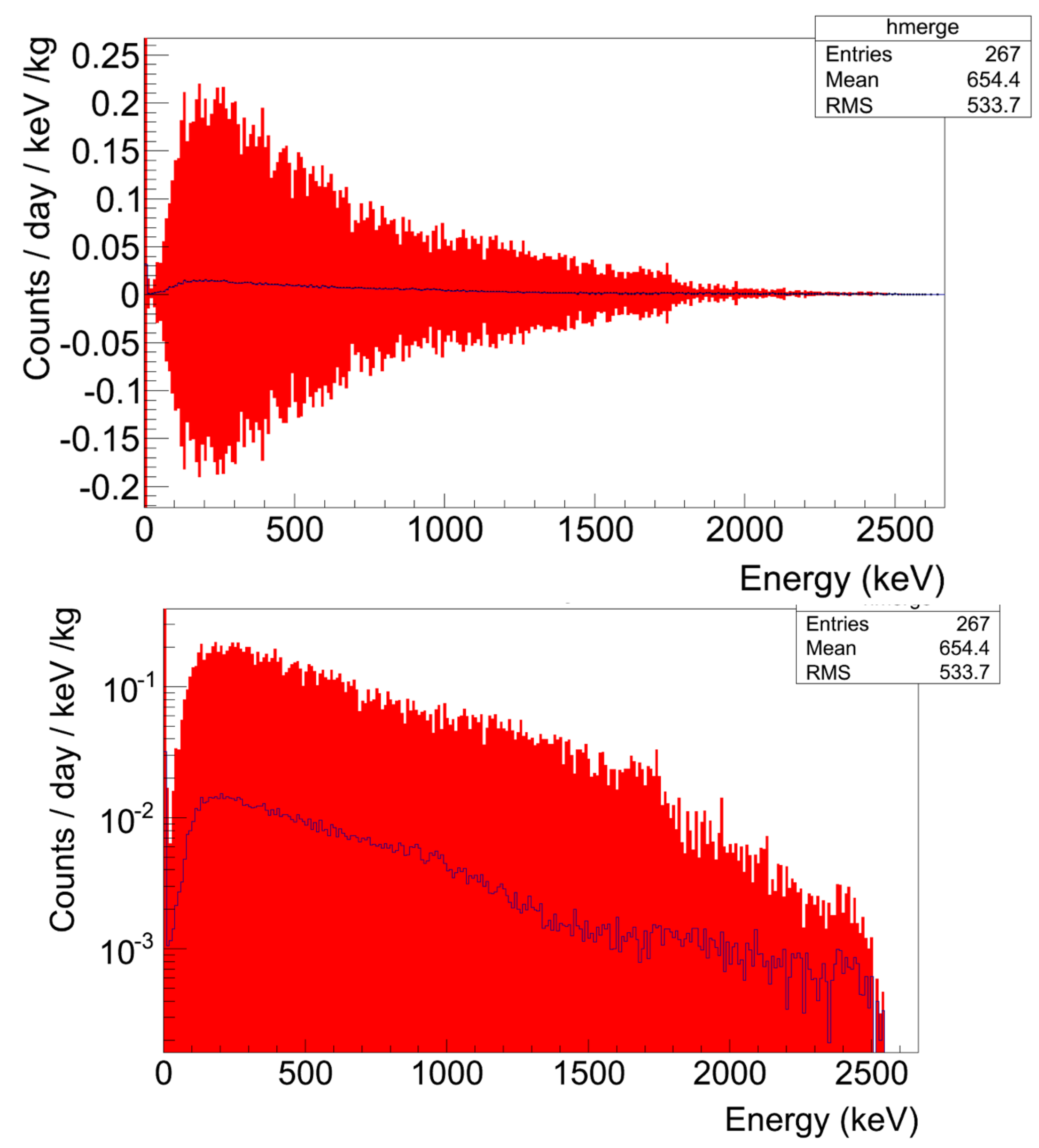

Figure 3 Energy spectrum of gamma ray from outer source.

3. Conclusion

Background contribution from these components were estimated as

$$1.2 \times 10^5 \text{ counts/day/detector } (1\sigma \text{ C.L. upper limit})$$

for full energy range (total backgrounds were 8.7×10^5 counts/day). Especially in low energy region (<100 keV) which is important in dark matter search, it was much lower than PMT background.

4. Reference

[1] 篠崎晃宏，XMASS実験用検出器材料の放射能不純物測定とガンマ線バックグラウンドの見積もり（2010年度東京大学理学研究科物理学専攻修士論文）