

XMASS Experiment

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Abstract

The final goal of XMASS experiment aims at the direct dark matter, the solar neutrinos from pp and ^{7}Be and neutrino less double beta decay with ton scale fiducial volume of liquid xenon detector. In the current stage, we focus on the the direct detection of dark matter in the form of WIMPs (Weakly Interacting Massive Particles) via their elastic scattering off Xenon nuclei with 800 kg detector at Kamioka in Japan. XMASS 800 kg detector will achieve a sensitivity more than two order of magnitude beyond current limits of WIMP-nucleus cross section to reach 10^{-45} cm^2 for the spin independent case. The status of experiment will be review and discussed here.

1 Introduction

XMASS is a multi-purpose of ultra pure liquid xenon detector for the underground physics. Its targets are dark matter search, low energy solar neutrinos and neutrinoless double beta decay with ton scale fiducial volume [1]. The project was funded for the 800 kg detector mainly for the dark matter search prior to the final stage. Based on the results and experiences which will be obtained by this 800 kg detector, the final detector will be employed for the study of low energy solar neutrinos and the further investigation of dark matter. WIMPs populating the halo of our galaxy can be detected directly via their interactions with nuclei in terrestrial detectors. XMASS is a dark matter detector, with the aim of observing the small energy (~ 10 keV) released after a WIMP scatters off a Xe nucleus. Liquid xenon has a large scintillation photon yield of 42,000 photons/MeV, which is as good as NaI(Tl) scintillator. This enables us to achieve the detection of small energy signals like dark matter recoil. The Key idea of the background reduction in XMASS is self-shielding, to use detector liquid xenon itself as shield to reduce gamma ray background. Due to its high atomic number ($Z=54$) and high density of liquid xenon (3g/cm^3), the compact detector with relatively small size can be constructed. Using the outer region of liquid xenon as shield for gamma rays, extremely low background environment can be achieved in the detector center region for the purpose of detecting rare events from WIMPs or neutrinos.

2 XMASS 800 kg Detector

The XMASS 800 kg detector will be installed in the new experimental hall at Kamioka in Japan. This experimental hall, 15 m wide and 21m deep and 15m height, was completed in February, 2008. Fig.1 shows and the installation of the water tank, $\phi 10\text{ m} \times 10\text{m}$, which was completed in March, 2009. The spherical liquid xenon detector will be installed in the water tank in fall, 2009. The detector employs a single phase technology and observes only scintillation lights emitted by the interaction of dark matter. The total amount of liquid xenon for active volume is about 800 kg. The 642 hexagonal photomultiplier tubes (PMTs), R10789 Hamamatsu, will be mounted in an approximately spherical shape with an average radius of 40 cm of xenon as shown in Fig. 1. PMTs photo-cathode give about 64% coverage of the inner surface of the detector. The actual shape of the structure holding PMTs is called Pentakis-dodecahedron which consists of 12 pentagonal pyramids and each pyramid is made by 5 triangles.

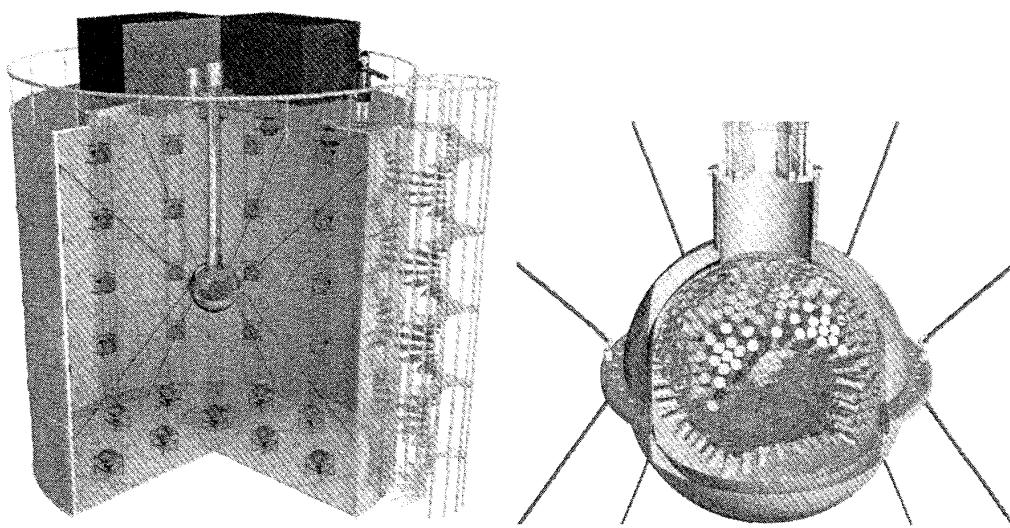


Figure 1: The water tank will be used for the radiation shield (Left). The size of the tank is $\phi 10$ mm $\times 10$ m, the detector will be installed in the center of it and 20 inch PMTs in the water will be used for the active veto for the cosmic ray events. 800 kg of liquid xenon will be surrounded by 642 ultra low radioactive PMTs. (Right) The double wall detector vessel is about 1.2 m in inner diameter to hold liquid xenon with the vacuum insulation. The average radius of liquid xenon is about 40 cm.

3 Background and Sensitivity

The key technology to reduce the radioactive background at low energy for XMASS experiment is to use "self-shield" as mentioned above. The clean core of liquid xenon volume will be used as sensitive volume by eliminating the volume near the wall which is suffered from the gamma rays background from the outside. The main component of radioactive background is expected to come from the PMTs. The activity level of PMT is designed to be 1/10 of R8778, giving 1.8 mBq/PMT for uranium-chain, 0.69 mBq/PMT for thorium-chain, 14 mBq/PMT for 40K, and 5.5 mBq/PMT for ^{60}Co . The Monte Carlo simulation was performed to estimate the background from PMTs and its rate is about 0.1 count/day/kg/keV in the active volume and less than 10^{-4} count/day/kg/keV will be achieved by 20 cm fiducial volume cut from the PMT windows.

Requirements for the internal background are $^{238}\text{U} < 10^{-14}\text{g/g}$, $^{232}\text{Th} < 2 \times 10^{-14}\text{g/g}$ and $^{85}\text{Kr} < 1$ ppt in liquid xenon. Their contribution to the background is negligible compared with that from PMTs. ^{238}U and ^{232}Th daughters in liquid xenon are measured using the Bi-Po coincidence method by the prototype detector. Assuming radioactive equilibrium, ^{238}U is $(9 \pm 6)10^{-14}\text{g/g}$ and ^{232}Th is less than $23 \times 10^{-14}\text{g/g}$. As for ^{85}Kr , 3.3 ± 1.1 ppt was achieved by a distillation tower purification system which was developed by XMASS. These radioactive contaminations are near the goal of requirements, within factor 10. The purification system for the 800 kg detector will be installed for removing radon by the filter which is under studying. The distillation tower for Kr was built to achieve < 1 ppt with about 4m length of the tower column. It is estimated to perform in one week to purify 1000 kg xenon by this tower.

With 10^{-4} count/day/kg/keV background level, the sensitivity of WIMP-nucleon cross section for the spin independent case will be 10^{-45} cm^2 at $100\text{ GeV}/c^2$ WIMP mass (Fig. 2). This sensitivity is two order of magnitude lower than the current best limit by CDMSII and XENON10 as shown in Fig. 2.

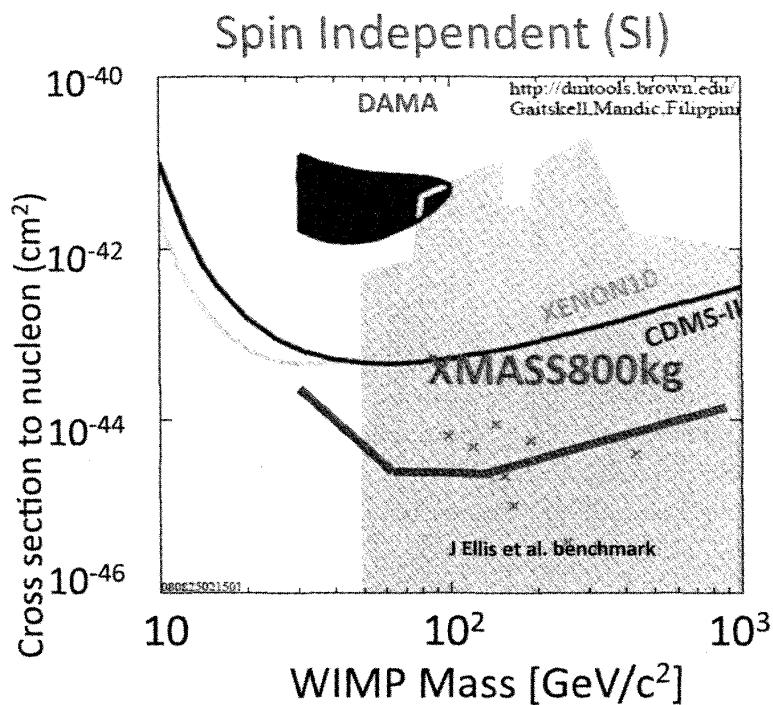


Figure 2: Spin-independent WIMP-nucleon cross-section upper limits (90% C.L.) versus WIMP mass. Curves are shown for the previous best published limit [2](blue) and [3](green). XMASS 800 kg will be sensitive down to 10^{-45} cm²

4 Conclusion and Summary

The XMASS 800 kg will be constructed in fall, 2009 and after the commissioning run, the data taking will be started late 2009. The goal of XMASS 800 kg is 10^{-45} cm² WIMP-nucleon cross section for the spin independent case.

References

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- [2] Z. Ahmed *et al.*, [astro-ph/0802.3530]
- [3] J. Angle *et al.* (XENON Collaboration), *Phys. Rev. Lett.* **100**, 021303 (2008)