Dark matter search and measurement of double beta decay by ELEGANT VI

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Search for WIMPs (Weakly Interacting Massive Particles) as dark matter (DM) and search for double beta decay are the challenging issues in particle physics and cosmology. We constructed CaF_2 scintillation detector system [1][2], so called ELEGANT VI, to study for above two subjects. We chose fluorine for the dark matter search because of its best figure of merit represented by the product of the cross section and natural abundance (100% ^{19}F). The nuclear recoil energy is expected as 0–100 keV. For $\beta\beta$ decay study, we chose ^{48}Ca as target nuclei. Since its Q-value of the decay (4.27 MeV) is largest among other potential $\beta\beta$ decay nuclei, good signal-to-noise ratio can be expected.

A schematic diagram of the ELEGANT VI is shown in figure 1. The detector system consists of 25 modules of $4.5 \times 4.5 \times 4.5$ cm^3 CaF_2(Eu) crystals surrounded by active and passive shields. Total weight of ^{48}Ca is 6.7 g. In order to find the rare signal, background reduction is essential. Segmentation of the CaF_2(Eu) crystal into 25 parts is an effective way to reduce the background because the true events are localized in space but the almost backgrounds are not. As active shields against photomultiplier direction, $4.5 \times 4.5 \times 7.5$ cm^3 light-guides made of pure CaF_2 are attached to both sides of CaF_2(Eu) crystal. Signals coming from the CaF_2(Eu) crystals are identified by measuring the roll-off ratio of the left and right output signals. The CaF_2 crystal array is covered by 40 CsI scintillators. The CsI scintillators and the pure CaF_2 crystals constutute a 4π active shield. The scintillator system is put into an airtight box inside of which is purged by N_2 gas to be free from radioactive Rn gas. Materials used in the scintillator system are carefully selected by checking the radioactive contaminations [3]. Outside of the airtight box, there are two passive shielding systems. Conventional 5 cm layer of OFHC copper inside a 10 cm layer of low activity lead are employed for external radioactivities. The shield for the neutrons consists of a 15 mm layer of paraffin loaded with LiH inside the layer of OFHC copper and a Cd sheet with 0.6 mm thick. The whole system is surrounded by 17 cm water (with boric acid) tank moderator.

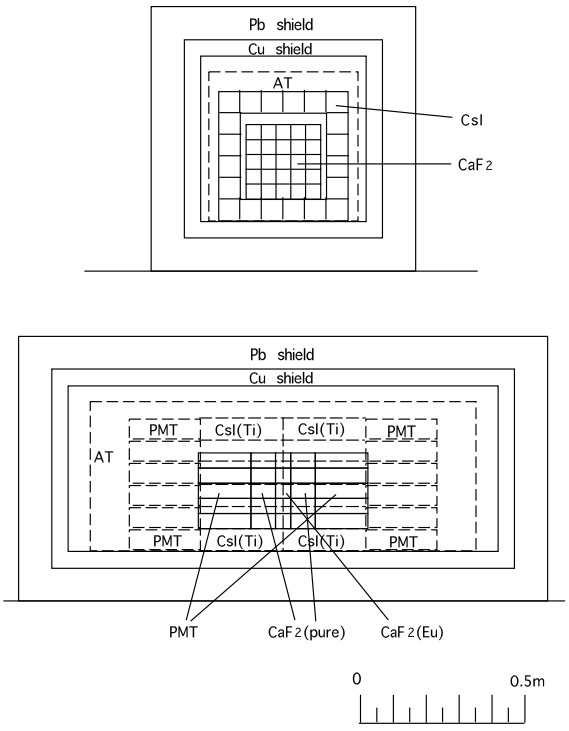

Figure 1: A Schematic drawing of ELEGANT VI. Front view (top) and side view (bottom).

For the calibration in the energy range of $\beta\beta$ decay, we used pair production decay from the first 0^+ state (3.35 MeV) in ^{40}Ca excited by $^{40}\mathrm{Ca}(n, n')$ reaction. The energy resolution is also given as a function of energy [4]. In order to derive the exclusion plot for DM one has to know so-called f value which is the response of the detector to a nuclear recoil. We measured it by using the $^{19}\mathrm{F}(n, n')$ reaction. The obtained f value is a little larger especially at low energy region than that has been measured for other detectors [5] which makes total detection efficiency large.

A run was carried out at the overground laboratory (Osaka University). The exclusion plot for the spin coupled dark matter by this measurement is shown in figure 2 (cited from [6]). It indicates that at almost sea level our system already has similar precision as DAMA Collaboration [8]. The observed spectrum in $\beta\beta$ decay energy range is shown in figure 3. We think the remaining background signals in the high energy region are caused by the cosmic ray muon from horizontal direction.

We expect much better results when the detector is fully operational at the underground laboratory. Recently, we moved whole system to the new underground laboratory "Oto Cosmo Observatory" (1200 m water equivalent depth) at Yoshino, Nara. Background rates are very small, 4×10^{-7} cm^{-2}sec^{-1} for cosmic muons, 4×10^{-5} cm^{-2}sec^{-1} for neutrons, and 10 Bq/m^3 for Rn. We are planning to start the full operational run in summer, 1998.

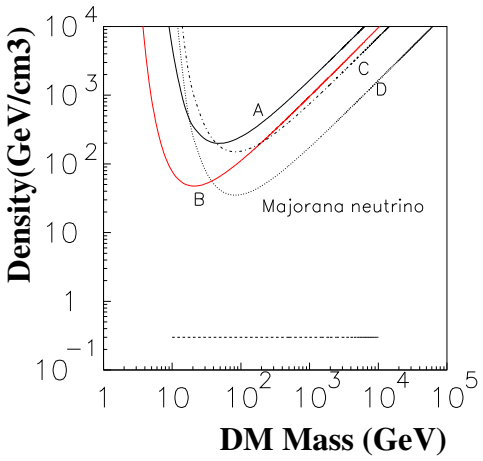

Figure 2: Exclusion plot obtained in the overground run for Majorana neutrino. Upper regions from lines are excluded. A:test run using only 8 CaF_2 modules [1]. B:present result of ELEGANT VI at Osaka. C:BPRS Collaboration [7]. D:DAMA Collaboration [8]. The horizontal line indicates the critical density of 0.3 GeV/cm^3.

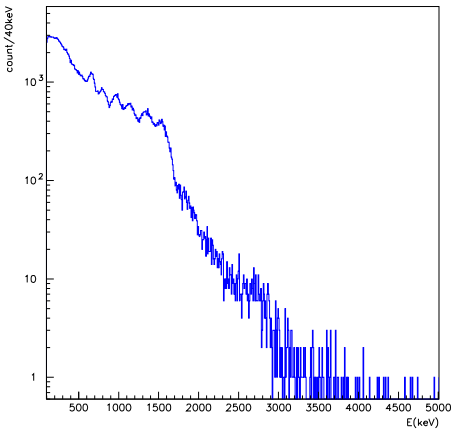

Figure 3: Background spectrum obtained in the overground run. The Q-value of the $\beta\beta$ decay for ^{48}Ca is 4.27 MeV. A few events are remaining in this region (refer to the text).

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