Selection of a High Reflectivity Material for Light Collection

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The NaI(Tl)[1], CaF_2(Eu), CaF_2(pure) and CsI(Tl)[2] scintillators are under development to search for WIMPs and neutrino-less double beta decay($0\nu\beta\beta$).

WIMPs could be detected through the elastic and inelastic scattering with nucleus in the target detectors. The scattering nucleus deposit the low energy of $\sim$ 10keV with detector. Thus the measurement with the low energy threshold is required. The experimental signature of $0\nu\beta\beta$ should expect a peak at the $Q_{\beta\beta}$ in the two electron summed energy spectrum. $2\nu\beta\beta$ is a continuous spectrum with maximum energy $Q_{\beta\beta}$ and background origin for the $0\nu\beta\beta$ measurement. Thus the measurement is required the high energy resolution of a few % to reject $2\nu\beta\beta$ events within the $0\nu\beta\beta$ energy region.

In order to realize these requirements (the low energy threshold and the high energy resolution), it is important to improve the light collection efficiency. The efficiency depends strongly on the optical characteristics of the reflector covering the detector. Thus the reflector should be a high reflectivity material.

The relative reflection efficiencies were measured for several combinations of reflectors and detectors. The measured detectors are listed in Table 1. The efficiency was obtained by comparing the peak position of 662keV γ-ray from ^{137}Cs. The results are shown in Fig.1.

- CaF_2(Eu)
  The high reflectivity materials are Sample B and E. Most of scintillation photons from CaF_2(Eu) enter directly the window of photomultiplier tube because of a small size(45 $\times$45 $\times$45 mm^3) of the crystal. Thus the reflector has a small effect on the light collection efficiency.
- CaF_2(pure)
  Maximum of the emission wavelength of CaF_2(pure) is 285nm (See Table1). Reflectivity of a material vary with the emission wavelength. In general, reflectivity for a shorter wavelength($<$ 300nm) is lower than the one for a longer wavelength(300 $\sim$ 500nm) . Thus the light collection efficiency of CaF_2(pure) depends strongly on the characteristics of the reflectors at a short wavelength. The high reflectivity materials are Sample A and D.
- CsI(Tl)
  The high reflectivity materials are Sample C and F.
- NaI(Tl)
  The high reflectivity materials are Sample C. For the new NaI(Tl) detector, the combination of 3 layers of Sample C and 1 layer of Alminized myley was selected as the high reflectivity material[1].
- CaF_2(Eu)+CaF_2(pure) System
  CaF_2 scintillator modules in ELEGANT VI system consist of the combination of one CaF_2(Eu) and two CaF_2(pure) crystals[2]. CaF_2(pure) in the system acts as a light guide for CaF_2(Eu). In this measurement, the reflectivity is measured by a test system, which consists of one CaF_2(Eu) and one CaF_2(pure) crystal. The peak position of 662keV γ-rays to CaF_2(Eu) is shown in Fig.1. The high reflectivity materials is Sample D.

Introducing the best reflector for each detector, the sensitivity of the detector will be improved.

Table 1: Detector dimension and wavelength of scintillation light.

Crystal	Dimension	Wavelength of emission maximum
NaI(Tl)	30 mm ϕ × 150mm	415 nm [3]
CaF_2(Eu)	45×45×45 mm^3	435 nm [3]
CaF_2(pure)	45×45×200mm^3	285 nm [4]
CaF_2(Eu)+CaF_2(pure	CaF_2(Eu)+CaF_2(pure)	
CsI(Tl)	65×65×250mm^3	540 nm [3]

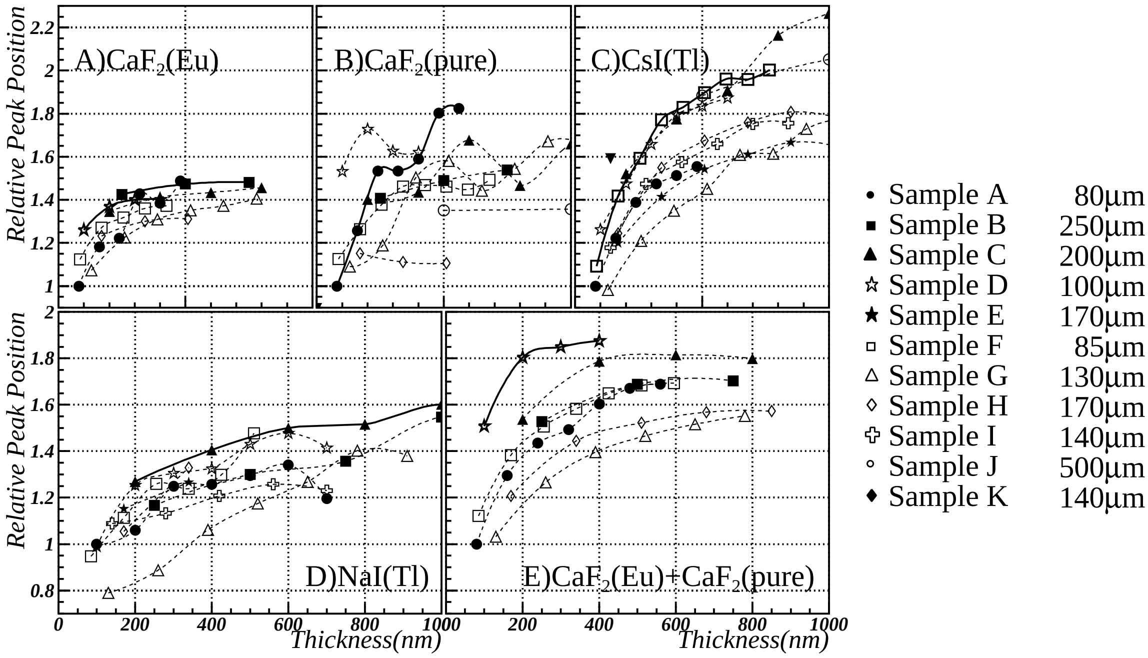

Figure 1: The peak position of 662keV γ-ray by each crystals with the reflector. The position is calibrated relative to the response of the crystal with 1 layer of Sample A(80μm). **upper:** The relative peak position of CaF_2(Eu), CaF_2(pure) and CsI(Tl). **lower:** Relative peak position of NaI(Tl) and CaF_2(Eu)+CaF_2(pure).

References

[1] S. Yoshida et al.,this volume and references therein.
[2] R. Hazama, Doctor thesis, Osaka University(1998).
[3] G.F. Knoll,Radiation Detection and Measurement, John Wiley & Sons, 1989.
[4] This measurement was supported by M. Kobayashi and performed at KEK.