Study of light guide system for CANDLES

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Abstract. We are trying to observe the neutrinoless double beta decay at Osaka University with the detector system named CANDLES III that uses CaF$_2$(pure) crystals and liquid scintillator. CANDLES III has the photo-coverage of about 30% now. We will install the mirror light guide system to improve this photo-coverage. This means the improvement of the energy resolution. We will report on the result of the experiment to evaluate the performance of their light guide system.

1. Introduction
If the neutrino is Majorana particle, the neutrinoless double beta decay is predicted to happen. Then this rate is related to the mass of the neutrino.

We have tried to observe the neutrinoless double beta decay with the detector system named ELEGANT VI that has used CaF$_2$(Eu) scintillators up to now [1]. The CANDLES system that uses CaF$_2$(pure) as a new detector that replaces this is designed, and the test experiment at the sea level by the third machine tries to be conducted in Osaka University now [2].

CaF$_2$(pure) has some advantages. One is the decreasing of the background in the crystal because their densities of impurities is about one tenth lower than CaF$_2$(Eu). Another is suitable for the enlargement of the detector because CaF$_2$(pure) has the longer attenuation length than CaF$_2$(Eu). However, CaF$_2$(pure) has only the 40% amount of luminescence of CaF$_2$(Eu). Therefore, to maintain energy resolution, improvement of light collection mechanism becomes important.

It seems that we only have to bring the distance of a crystal and a photomultiplier tube (PMT) close to improve the light collection efficiency. By analyzing data taken in ELEGANT VI, however, it is understood that the gamma-rays emitted from radioactive impurities (mainly $^{40}$K) in PMT windows becomes a serious background. To veto external radiations efficiently, we want to install the liquid scintillator layer between the crystal and the PMT and to achieve $4\pi$ active shield.

The request on both sides of such the light collection efficiency improvement and the background reduction makes us need a light guide system. A light guide is able to take the distance from a PMT that is a gamma-rays source, and to lead an optical photon from a crystal to a PMT efficiently.

The loss on a reflector means that the reduction of the number of the reflection brings us to improvement of the efficiency. That is, we need decreasing the number of acute angle incidences to the light guide surface of a photon. Therefore it is necessary to make the multi-reading light guide system from a cubic crystal to shoal the angle of incidence degree [3].
2. PERFORMANCE EVALUATION EXPERIMENT OF LIGHT GUIDE

A small prototype detector with the six-reading light guide system that uses CaF\(_2\)(pure) is being produced this time (Fig.1). As a mirror-type reflector, I selected Enhanced Supecaur Reflecter(ESR)(Sumitomo 3M Co., Tokyo, Japan) that has the highest reflectivity of 98.4% in the visible light range. The light guide was composed of a square acrylic cylinder and this ESR.

With this system, I measured the light collection efficiency by using \(^{137}\)Cs gamma-ray source, and compared it with the Monte Carlo simulation result (Fig.2).

![Figure 1. The prototype six-reading mirror light guide system.](image1)

![Figure 2. The dependence of the efficiency on the light guide length in the six-reading system with ESR.](image2)

3. CONCLUSION AND FUTURE PROSPECTS

The experimental collection efficiency was about one half of the simulation result, though this is naturally better than the case without the light guide. The cause of this poor efficiency is possibly the coarse of how to paste ESR. The coarse might give ESR a bigger diffuse component. When the effective reflectivity of ESR was requested by the simulation to reproduce the experimental result, it became about 65%.

In the future, I will devise how to paste ESR, and I want to apply the effective reflectivity to the simulation of CANDLES III. And I plan to produce the light guide system for CANDLES III detector after optimization of its configuration by the simulation. Moreover, I will adjust the design of the light guide system for CANDLES III(underground) to achieve aimed energy resolution of 4% at Q value(4.27 MeV).

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References

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