Monte-Carlo Simulation of $CdWO_4$ Scintillator Detector

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Introduction

The positive evidence of neutrino oscillation from atmospheric, solar and reactor neutrino experiments established that neutrino has non-zero mass [1]. The investigation of neutrinoless double beta ($0\nu\beta\beta$) decay is one of the most sensitive experiments to probe the absolute value of neutrino mass and the nature of neutrino (i.e., if it is Dirac particle or Majorana particle).

^{106}Cd is one of the promising candidates for double beta decay experiment because of its high transition energy ($Q_{\beta\beta}$=2771 keV). Experimentally it is less challenging to reduce the background for double beta decay isotope with high $Q_{\beta\beta}$. Also the contribution of cosmogenic activation is less at higher energies. Recently the R&D is under progress to develop enriched ^{106}CdWO4 crystal scintillators to search for double beta decay processes in ^{106}Cd [2].

Here we present the simulation of a typical $CdWO_4$ crystal (enriched in ^{106}Cd) scintillator detector using "GEANT4" simulation toolkit and Decay0 event generator [3].

Detector Description

The detector is made of 321.5 gm of $CdWO_4$ crystal enriched in ^{106}Cd isotope to 68%. The scintillating detector is cylindrical in shape ($Ø3.6 \times 4.0cm$) and placed inside a 10 cm thick Copper (Cu) box of inner dimension $80 \times 40 \times 27$ cm with symmetry axis along z-axis of the world volume. The Cu box again is surrounded by 15 cm of lead. Two Photomultiplier Tubes (PMT) are connected to both sides of the scintillator along z-axis by 10 cm long quartz lightguides that are also taken as cylindrical shape with radius 1.8 cm for simplicity. Two $10cm \times 10cm \times 10cm$ NaI(Tl) detectors are symmetrically placed along y-axis to study the coincidences.

Results

The expected response functions of $CdWO_4$ detector for various mode of ^{106}Cd double beta decay are simulated for $0\nu\beta^+\beta^+$, $0\nu\beta^+EC$, 0νECEC, $2\nu\beta^+\beta^+$, $2\nu\beta^+EC$ and 2νECEC decays of ^{106}Cd for the transition to ground state of ^{106}Pd. The spectra of $0\nu\beta^+\beta^+$ and of $0\nu\beta^+EC$ without requiring signals in the outer NaI(Tl) detectors are presented in Fig. 1.

As a typical case, the coincidence patterns studied to search for double beta decay of ^{106}Cd for $0\nu\beta^+\beta^+(0^+ \rightarrow 0^+)$ are

case (a) the response of the CWO detector in coincidence with one of the NaI(Tl) detector(s) in the energy window : 481-541 keV($\pm1\sigma$ around 511 keV),

case (b) triple coincidence among CWO, NaI1 and NaI2 for same energy window as case (a) for NaI(Tl) detectors.

Similar studies have been done for the case of $0\nu\beta^+\beta^+(0^+ \rightarrow 2^+_1)$, $0\nu\beta^+\mathrm{EC}(0^+ \rightarrow 0^+)$ and $0\nu\beta^+\mathrm{EC}(0^+ \rightarrow 2^+)$ decay modes. The details of results shall be discussed during the presentation session.

The detection efficiencies of the $CdWO_4$ detector in double and triple coincidence with NaI(Tl) detector(s) for the case of $0\nu\beta^+\beta^+(0^+ \rightarrow 0^+)$ are reported in the Table I. The resolutions of the NaI detectors are same as in ref. [4].

Conclusions

The smallness of the detector taken for the

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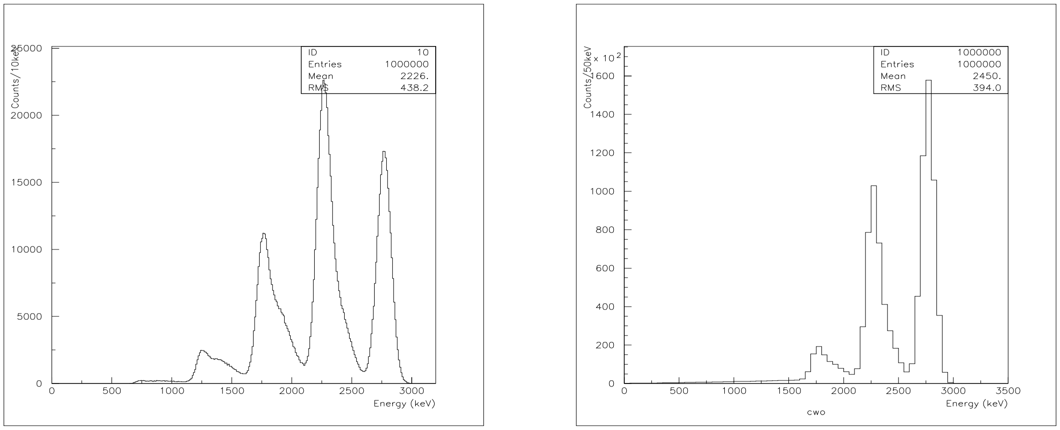

(a) $0\nu\beta^+\beta^+$ (b) $0\nu\beta^+EC$

FIG. 1: Response of the $CdWO_4$ detector for $\beta\beta$ decay of ^{106}Cd (g.s. to g.s.)

TABLE I: Efficiency of $CdWO_4$ detector in coincidence with NaI(Tl) detector(s)

Decay mode	Selection criteria	$CdWO_4$ energy window (in keV)	Efficiency (%)
$0\nu\beta^+\beta^+(0^+ \to 0^+)$	case (a)	1100-2100	9.65
	case (a)	2150-2450	7.55
	case (b)	1100-2100	1.17

simulation makes the coincidence technique a powerful tool to search double beta decay of ^{106}Cd with a low background. Two low background NaI(Tl) detectors have been placed in opposite side of central $CdWO_4$ detector to study coincidences. The detection efficiency of $CdWO_4$ in coincidence with NaI(Tl) detector(s) in the energy window 2150-2450 keV is within 7-8 % for different cases studied above. Also at this energy range the background will be comparatively lower, therefore this channel could be more promising to search for double beta decay of ^{106}Cd.

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