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Application of $PbWO_4$ crystal scintillators in experiment to search for 2β decay of ^{116}Cd

F.A. Danevich[a,*], A.Sh. Georgadze[a], V.V. Kobychev[a], B.N. Kropivyansky[a], S.S. Nagorny[a], A.S. Nikolaiko[a], D.V. Poda[a], V.I. Tretyak[a], I.M. Vyshnevskyi[a], S.S. Yurchenko[a], B.V. Grinyov[b], L.L. Nagornaya[b], E.N. Pirogov[b], V.D. Ryzhikov[b], V.B. Brudanin[c], Ts. Vylov[c], A. Fedorov[d], M. Korzhik[d], A. Lobko[d], O. Missevitch[d]

[a] *Institute for Nuclear Research, Prospekt Nauki 47, MSP 03680 Kiev, Ukraine*
[b] *Institute for Scintillation Materials, 61001 Kharkov, Ukraine*
[c] *Joint Institute for Nuclear Research, 141980 Dubna, Russia*
[d] *Institute for Nuclear Problems, 220050 Minsk, Belarus*

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Abstract

Lead tungstate ($PbWO_4$) crystal scintillators are discussed as an active shield and light guides in ^{116}Cd double-beta decay experiment with Cadmium tungstate ($CdWO_4$) scintillators. Scintillation properties and radioactive contamination of $PbWO_4$ scintillators were investigated. Energy resolution of $CdWO_4$ detector, coupled to $PbWO_4$ light guide, was tested. Efficiency of $PbWO_4$-based active shield to suppress background from the internal contamination of $PbWO_4$ crystals, as well as possible contribution from radioactivity of copper shield and phototubes were calculated. Using of lead tungstate crystal scintillators as high-efficiency 4π active shield could allow to build sensitive 2β experiment ($T_{1/2}^{0\nu2\beta}\sim10^{26}$ yr) to search for 0ν2β decay of ^{116}Cd with $^{116}CdWO_4$ crystal scintillators.

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1. Introduction

Studies of the ^{116}Cd 2β decay with the help of cadmium tungstate ($CdWO_4$) crystal scintillators enriched in ^{116}Cd to 83% have been performed in the Solotvina Underground Laboratory [1] since 1988. The results obtained in the different phases of these researches have been published earlier [2]. Beginning from 1998, the experiment was carried out in collaboration with the group from the University and INFN Firenze, Italy [3–6].

In the apparatus, which is described in detail in Refs. [3,5], four $^{116}CdWO_4$ crystals (total mass 330 g) were exploited. They are viewed by a low background 5 in. phototube (PMT) through light guide $\varnothing$ 10 × 55 cm, which is glued of two parts: high pure quartz (25 cm) and plastic scintillator. The enriched $^{116}CdWO_4$ crystals were surrounded by an active shield made of 15 natural $CdWO_4$ crystals of large volume with total mass of 20.6 kg. These are viewed by a PMT through an active plastic light guide $\varnothing$ 17 × 49 cm. The whole $CdWO_4$ array is situated within an additional active shield made of plastic scintillator 40 × 40 × 95 cm, thus, together with both active light guides, a complete 4π active shield of the $^{116}CdWO_4$ detector was provided. Due to the active and passive shields, and as a result of the time–amplitude and pulse-shape analysis of the data, the background rate of $^{116}CdWO_4$ detector in the energy region 2.5–3.2 MeV ($Q_{2\beta}$ energy of ^{116}Cd is 2805 keV) was reduced to 0.04 counts/(yr kg keV). It is one of the lowest background

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*Corresponding author. Tel.: +380 44 525 1111; fax: +380 44 525 4463.
E-mail address: danevich@kinr.kiev.ua (F.A. Danevich).

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which has ever been reached with crystal scintillators. After 14183 h of data taking in the Solotvina Underground Laboratory the half-life limit on 0ν2β decay of ^{116}Cd was set as $T_{1/2} \geqslant 1.7 \times 10^{23}$ yr at 90% C.L., which corresponds to an upper bound on the effective Majorana neutrino mass $\langle m_\nu \rangle \leqslant 1.7$ eV [5]. This result is among the strongest world-wide restrictions (in addition to bounds obtained in experiments with ^{76}Ge [7,8], ^{82}Se and ^{100}Mo [9], ^{130}Te [10], and ^{136}Xe [11]). $CdWO_4$ crystals possess several unique properties required for a 2β decay experiment: good scintillation characteristics, low level of intrinsic radioactivity, and possibility of pulse-shape discrimination to reduce the background.

To enhance sensitivity of ^{116}Cd experiment to the level of neutrino mass 0.1–0.05 eV, one has to increase the measurement time and the mass of enriched $^{116}CdWO_4$, improve the energy resolution and reduce the background of the detector. As it was shown by Monte Carlo calculations, the required sensitivity could be achieved by using 150 kg of $^{116}CdWO_4$ crystals placed into a large volume of high-purity liquid (CAMEO project [12]). The project calls for the background reduction from the current 0.04 counts/(yr keV kg) to $10^{-3}-10^{-4}$ counts/(yr keV kg). To decrease the background, the CAMEO project intends to use ≈ 1000 t of high-purity water or liquid scintillator (≈ 10^{-15} g/g for ^{238}U and ^{232}Th) as a shield for $^{116}CdWO_4$ crystals. Due to low density of these liquids, the necessary dimensions of the shields are huge (≈ ∅ 11 × 10 m).

We propose an alternative solution for a sensitive 2β decay experiment with $^{116}CdWO_4$ by using lead tungstate ($PbWO_4$) crystal scintillators as high-efficiency 4π active shield. $PbWO_4$ crystal scintillators have been developed as heavy and fast detectors [13] for high-energy physics experiments. Scintillation characteristics of $PbWO_4$ have been intensively studied during the last decade [14–19]. High registration efficiency to γ quanta, very good transparency (a few meters in the region of $CdWO_4$ emission spectrum [20]), substantial difference of scintillation decay time in comparison with $CdWO_4$, well developed tons-scale production [21] make this material very attractive to build a relatively small yet sensitive experiment to search for 2β decay of ^{116}Cd. In this paper, we study the possibility of applying $PbWO_4$ crystals as material for light guides and active shield in a ^{116}Cd double-beta decay experiment with $CdWO_4$ scintillators.

2. Measurements and results

2.1. Scintillation properties

Table 1
Properties of $PbWO_4$ and $CdWO_4$ crystal scintillators

	$PbWO_4$	$CdWO_4$
Density (g/cm^3)	8.28	8.0
Melting point (°C)	1123	1325
Structural type	Sheelite	Wolframite
Cleavage plane	Weak (1 0 1)	Marked (0 1 0)
Hardness (Mohs)	3	4–4.5
Wavelength of emission maximum (mm)	420–440	480
Refractive index	2.2	2.2–2.3
Effective average decay time[a] (μs)	0.01	13

[a] For γ rays, at indoor temperature.

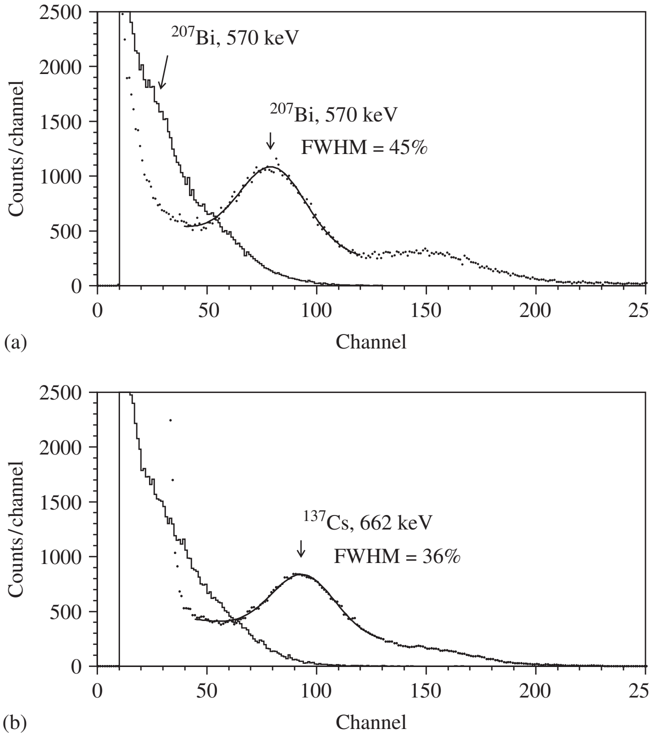

Fig. 1. Energy spectra measured by $PbWO_4$ scintillation crystal (45 × 22 × 22 mm) with (a) ^{207}Bi and (b) ^{137}Cs γ sources at two temperatures: +24 °C (solid lines) and −18 °C (points). For the spectra measured at −18 °C, the fits of the ^{207}Bi (570 keV) and ^{137}Cs (662 keV) γ peaks by Gaussian plus exponential functions are also shown.

The main properties of $PbWO_4$ crystal scintillators are presented in Table 1 where characteristics of $CdWO_4$ are also given for comparison. Measurements were carried out with two clear, colorless, undoped $PbWO_4$ crystals grown by Czochralski method. One crystal (45 × 22 × 22 mm, 182 g of mass, referred below as PWO-1) was produced in the Institute for Scintillation Materials (Kharkov, Ukraine), and the second one (32 × 32 × 10 mm, 83 g of mass, PWO-2), produced in the Bogoroditsk Technical Chemical Plant (Russia) [21], was supplied by the Research Institute of Nuclear Problems (Minsk, Belarus).

Response of the PWO-1 scintillator to γ rays was measured with ^{137}Cs and ^{207}Bi γ sources at temperatures +24 and −18 °C. The crystal was wrapped by PTFE reflector tape and optically coupled by Dow Corning Q2-3067 couplant to PMT XP2412. The measured energy spectra are presented in Fig. 1. The energy resolution FWHM = 45% and 36% was obtained at the temperature −18 °C for 570 and 662 keV γ rays, respectively. The relative pulse amplitude has been increased in ≈ 3 times with the detector cooling from +24 to −18 °C. The temperature of the detector was stabilized and measured with an accuracy of ±0.5 °C.

2.2. α/β *ratio*

The α/β ratio was measured with the PWO-1 crystal using a collimated ^{241}Am α source and thin ($\approx 0.65\,\mathrm{mg/cm^2}$) mylar absorbers to obtain α particles in the energy range 2.1−4.6 MeV. The energies of α particles were determined with the help of a surface-barrier detector. In addition, α peak of ^{210}Po ($E_\alpha = 5.30$ MeV) from internal contamination of $PbWO_4$ crystal by ^{210}Pb (see Subsection 2.3) was used. The dependence of the α/β ratio on energy is depicted in Fig. 2 where the α spectrum measured with the ^{241}Am α source is shown too. The α/β ratio increases above 3 MeV: $\alpha/\beta = 0.08(2) + 0.025(5)E_\alpha$, while it decreases as $\alpha/\beta = 0.23(4) - 0.024(14)E_\alpha$ at lower energies, where E_α is in MeV. The same behaviour of the α/β ratio was observed for $CdWO_4$ [4], calcium tungstate ($CaWO_4$) [22], and zinc tungstate ($ZnWO_4$) [23] crystal scintillators. The energy resolution for ^{210}Po α peak was measured as 39%, which is comparable with the energy resolution obtained with γ sources.

2.3. *Radioactive contamination of* $PbWO_4$ *crystal scintillators*

To estimate radioactive contamination, the PWO-1 crystal was measured in the Solotvina Underground Laboratory built in a salt mine 430 m underground ($\simeq 1000$ m of water equivalent) [1]. The crystal was wrapped by PTFE tape and optically coupled to low radioactive PMT FEU-110. The detector was cooled to −18 °C in a temperature-controlled chamber. The temperature in the chamber was stabilized and measured with an accuracy of ±0.5 °C. The shaping time of the spectroscopy amplifier was set to 0.8 μs. Amplitude (energy) and arrival time of signals have been recorded by the event-by-event data acquisition system. The energy scale was calibrated with ^{207}Bi γ source. The energy spectrum accumulated during 2.15 h is shown in Fig. 3. The intense peak at the energy ≈ 1.2 MeV (in γ scale) can be attributed to intrinsic ^{210}Po (daughter of ^{210}Pb from the ^{238}U family) with activity of 53(1) Bq/kg. The major part of events up to the energy ≈ 1 MeV can be ascribed to β active ^{210}Bi (daughter of ^{210}Pb). The ^{210}Pb contamination of the PWO-2 crystal was measured as 79(3) Bq/kg.

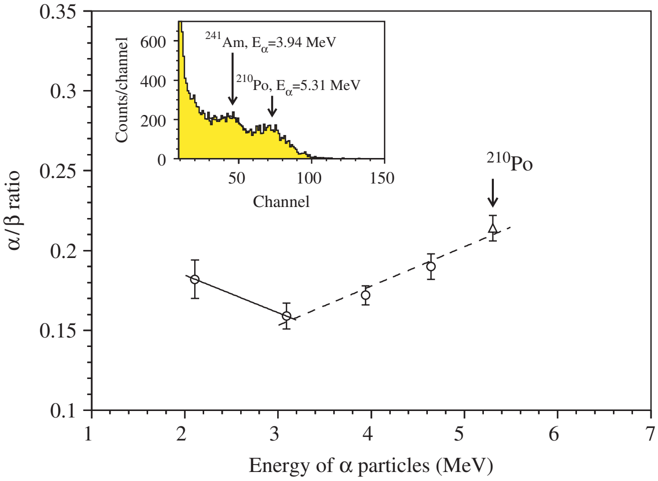

Fig. 2. Dependence of the α/β ratio on energy measured with the $PbWO_4$ scintillator 45 × 22 × 22 mm. The crystal was irradiated by α particles from ^{241}Am source through absorbers to obtain energies in 2.1–4.6 MeV range (circles). Triangle corresponds to α particles of ^{210}Po. (Inset) The α spectrum of ^{241}Am source measured with mylar absorber to obtain energy 3.94 MeV. Second peak at ≈ 73 channel is caused by α decay of ^{210}Po (daughter of ^{210}Pb) inside the scintillator.

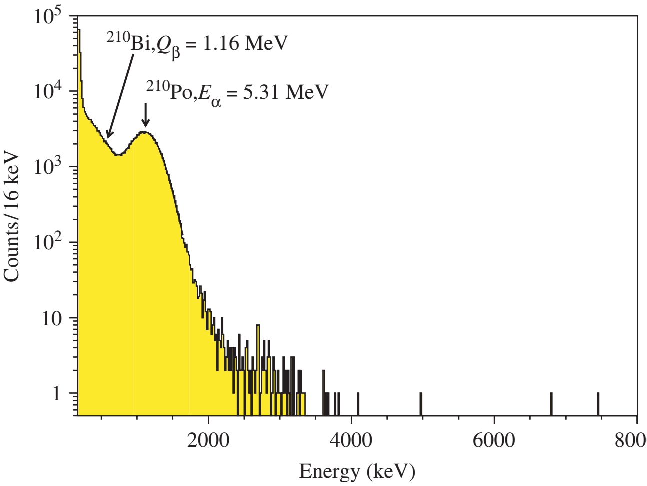

Fig. 3. Energy spectrum of $PbWO_4$ scintillation crystal (PWO-1) measured in the Solotvina Underground Laboratory at the temperature −18 °C during 2.15 h. Peak at the energy ≈ 1.2 MeV (in γ scale) can be attributed to α decay of ^{210}Po from internal contamination of the crystal by ^{210}Pb. Broad distribution up to ≈ 1 MeV corresponds to β spectrum of ^{210}Bi ($Q_\beta = 1.16$ MeV).

Besides, the raw background data accumulated with the PWO-1 were analyzed by the time–amplitude method (described in detail in Ref. [24]), when the energy and arrival time of each event were used for find the fast sequence of β and α decays: $^{214}\mathrm{Bi}$ ($Q_\beta = 3.27$ MeV) $\rightarrow$ ^{214}Po ($E_\alpha = 7.69$ MeV, $T_{1/2} = 164\,\mu s$) $\rightarrow$ ^{210}Pb (^{238}U family). To select the β decays of ^{214}Bi, the energy threshold was set at 0.3 MeV (interval from 0.3 MeV to the end of the ^{214}Bi β spectrum contains 76% of the ^{214}Bi β events). For the α decay of ^{214}Po, the energy window 1.6−2.6 MeV (94% of α events) and time interval of 90–1000 μs (67% of ^{214}Po decays) were chosen. There are no peculiarities in the obtained spectra which could be attributed to the sequence of decays searched for. The limit on the activity of ^{226}Ra in the $PbWO_4$ crystal $\leqslant 10$ mBq/kg was set. Comparing this value with the ^{210}Po activity, we can conclude that equilibrium of the uranium chain in the crystal is strongly broken.

Because the shaping time of the spectroscopy amplifier (0.8 μs) exceeds the half-life of ^{212}Po, and taking into

Table 2
Radioactive contaminations in $PbWO_4$ and $CdWO_4$ crystal scintillators

Chain	Source	Activity (mBq/kg)	
		$PbWO_4$	$CdWO_4$ [25–27,5]
^{232}Th	^{228}Th	$\leqslant 13$	$\leqslant 0.004-0.039(2)$
^{238}U	^{226}Ra	$\leqslant 10$	$\leqslant 0.004$
	^{210}Pb	$(53-79)\times 10^3$	$\leqslant 0.4$

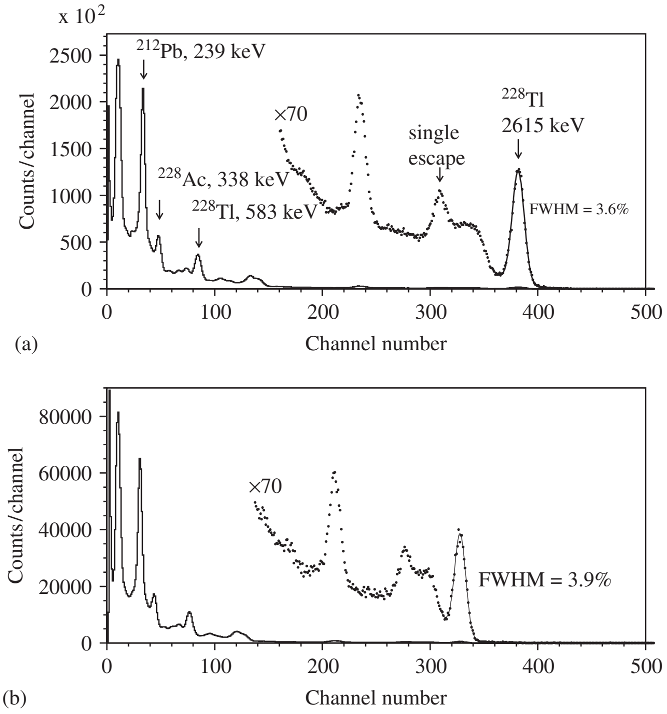

Fig. 4. Energy spectra measured by $CdWO_4$ scintillation crystal ($10\times 10\times 10$ mm) with ^{232}Th γ source in two detector arrangements: (a) the crystal wrapped by PTFE reflector tape optically coupled to PMT; (b) the $CdWO_4$ crystal viewed by the PMT through the $PbWO_4$ crystal $45\times 22\times 22$ mm as light guide.

account the α/β ratio, events from the fast sequence of ^{212}Bi β decay ($Q_\beta = 2.25$ MeV) and ^{212}Po α decay ($E_\alpha = 8.78$ MeV, $T_{1/2} = 0.3\,\mu$s) can result in one event registered in the detector with energy from 2.5 to 5 MeV. In the energy region 3.4–5 MeV (where $\approx 60\%$ of events from the sequence are expected), there are 7 events, which gives the limit on the activity of ^{228}Th (^{232}Th family) in the PWO-1 crystal $\leqslant 13$ mBq/kg.

The summary of the measured radioactive contamination of the $PbWO_4$ crystal scintillators (or limits on their activities) is given in Table 2 in comparison with $CdWO_4$ scintillators.

2.4. *$PbWO_4$ crystal as light-guide for $CdWO_4$ scintillator*

A possibility to use $PbWO_4$ crystal as a light guide for $CdWO_4$ scintillation detector has been tested in measurements. With this aim, the energy resolution and relative pulse amplitude were measured with a $CdWO_4$ crystal in two conditions. First, the $CdWO_4$ crystal ($10\times 10\times 10$ mm, produced in the Institute for Scintillation Materials, Kharkov), wrapped by PTFE reflector tape, was optically coupled to PMT XP2412. The shaping time of the spectroscopy amplifier was set to 16 μs. The energy resolution was measured with ^{137}Cs, ^{207}Bi, and ^{232}Th γ sources. In particular, the energy resolution (FWHM) 7.1%, 5.8% and 3.6% were obtained for 662, 1064 and 2615 keV γ lines, respectively. It should be stressed that the energy resolution of 3.6% at the energy 2615 keV was never reported for $CdWO_4$ scintillator. The energy spectrum measured with ^{232}Th γ source is presented in Fig. 4(a). Then, the $CdWO_4$ crystal was viewed by the PMT through the $PbWO_4$ crystal PWO-1 (wrapped by mylar). The crystals and the PMT were optically coupled by Dow Corning Q2-3067 couplant. The energy resolution of 3.9% (for 2615 keV γ line of ^{232}Th) and 86% of relative pulse amplitude were obtained (see Fig. 4(b)).

3. Background simulation

The different sources of background in the 2β experiment with $^{116}CdWO_4$ crystal scintillators were considered in Ref. [12]. Here we focus our attention on radioactive contamination of $PbWO_4$ crystals, photomultipliers and copper shield by ^{232}Th and ^{238}U. In addition, we consider background due to cosmogenic activation of $PbWO_4$. Processes with β, α particles and γ rays were simulated with the help of the GEANT4 package [28] and the event generator DECAY0 [29].

3.1. *Radioactive contamination of $PbWO_4$*

The following conditions were accepted for the calculations: the $CdWO_4$ crystal (∅ 5×5 cm) with the energy resolution (FWHM) 4% at 2.8 MeV is placed in the center of $PbWO_4$ scintillation detector (∅ 45×45 cm), contaminated by ^{232}Th and ^{238}U at the level of 10^{-12} g/g. 7.61×10^6 decays of ^{208}Tl inside the $PbWO_4$ detector were simulated. It corresponds to exposure of ≈ 250 kg × yr with the $CdWO_4$ detector. The calculated energy spectrum of the $CdWO_4$ detector, if no coincidence would be taken into account ($PbWO_4$ works as a passive shield), is shown in Fig. 5(a). The anticoincidence energy spectrum (the energy threshold of $PbWO_4$ detector was taken to be equal 0.5 MeV) is presented in Fig. 5(b). There are only two events in the energy interval of 0ν2β peak of ^{116}Cd (2.7–2.9 MeV), which corresponds to the background counting rate 4×10^{-5}counts/(yr keV kg) from the ^{232}Th contamination in $PbWO_4$.

The contamination of $PbWO_4$ crystals by ^{226}Ra is even less dangerous. The Monte Carlo calculations show that no events above the energy of 2 MeV will be registered in the $CdWO_4$ detector during ≈ 250 kg × yr of exposure.

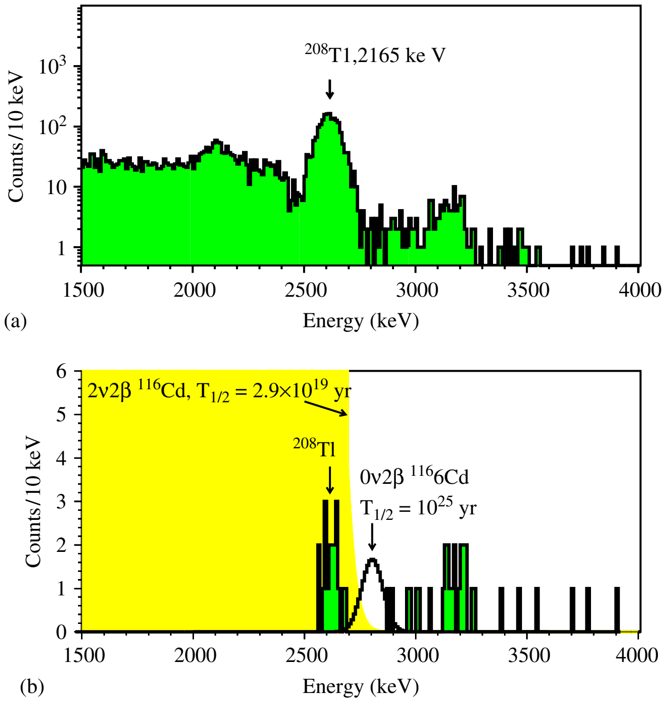

Fig. 5. The Monte Carlo simulated (a) response function of ^{116}CdWO$_4$ detector (250 kg × yr of exposure) to decays of ^{208}Tl inside shielding PbWO$_4$ crystals (see text). (b) The same as (a) but in anticoincidence with the PbWO$_4$ detector. Also the 0ν2β peak of ^{116}Cd with $T_{1/2} = 10^{25}$ yr, and two neutrino 2β distribution ($T_{1/2} = 2.9 \times 10^{19}$ yr) are shown.

3.2. External γ rays from copper and PMTs

Only ^{232}Th contaminations in copper shield and PMT's were taken into account (the contribution from ^{238}U was found to be negligible) to estimate background in the vicinity of an expected ^{116}Cd 2β decay peak. The following conditions were taken for the calculations: 32 CdWO$_4$ crystals (∅ 5 × 5 cm) are surrounded by PbWO$_4$ scintillators (70 × 70 × 70 cm). A copper shield of 5 cm thick surrounds the PWO assembly. The copper is contaminated by ^{232}Th at the level of 10^{-11} g/g. It should be noted such a level of radiopurity was reported in Ref. [30]. The CdWO$_4$ crystals are viewed through PbWO$_4$ light guides of 33 cm length by PMT with thorium contamination at the level of 2.5×10^{-7} g/g (PMT made of low background glass, see Ref. [31]), which corresponds to ^{232}Th activity ≈ 0.2 Bq/PMT. The Monte Carlo simulation by GEANT4 gives 13 counts in the 2615 keV peak from copper and 3 from PMT during ≈ 10 yr of experiment. It results in ≈ 0.5 counts in the expected peak (2.7–2.9 MeV) from 0ν2β decay of ^{116}Cd.

3.3. Cosmogenic activation of PbWO$_4$ crystals

The cosmogenic activation of lead tungstate was calculated with the help of the COSMO code [32]. PbWO$_4$ crystals was supposed to be produced during 30 days on the ground level and stored underground during 1 yr. Isotopes were selected from the full list of 175 radionuclides by their decay rate after cooling (more than 10^{-3} decays/day/kg) and by their energy release (near 3 MeV). The most dangerous cosmogenic isotopes are listed in Table 3.

The background of CdWO$_4$ detector caused by cosmogenic activation of PbWO$_4$ crystals was calculated with the help of the GEANT4 code. We suppose 0.5 MeV energy threshold of PbWO$_4$ active shield, like for estimation of thorium- and uranium-induced background. It gives ≈ 0.16 counts from ^{68}Ga, ≈ 0.5 from ^{88}Y and ^{88}Zr, ≈ 0.26 from ^{106m}Ag in 25 kg CdWO$_4$ detector during ≈ 10 yr of measurements in the energy region of interest (2.7–2.9 MeV). The contribution from ^{106}Ru is less than 0.06 counts. Total cosmogenic background from PbWO$_4$ is expected to be only ≈ 0.9 counts in the energy interval of ^{116}Cd 0ν2β decay peak.

4. Discussion

The response functions of a detector with enriched ^{116}CdWO$_4$ crystals (≈ 250 kg × yr of exposure) for two neutrino ($T_{1/2} = 2.9 \times 10^{19}$ yr [5]) and neutrinoless 2β decay of ^{116}Cd with half-life 10^{25} yr are presented in Fig. 5(b). Sensitivity of the experiment to neutrinoless 2β decay of ^{116}Cd is at the level of lim $T_{1/2} \approx 10^{26}$ yr (which corresponds to the limit on neutrino mass of ≈ 0.07 eV [33]). It is evident that the 0ν2β decay with $T_{1/2} \approx 10^{25}$ yr (neutrino mass ≈ 0.2 eV) would be certainly observed at this level of sensitivity.

The size of PbWO$_4$ active shield[1] in a setup could be equal approximately to 70 × 70 × 70 cm. Thirty two enriched ^{116}CdWO$_4$ crystals ∅ 5 × 5 cm are viewed by 3 in. PMT through logarithmic-spiral PbWO$_4$ crystals of 33 cm length. PbWO$_4$ as light guide has an advantage in comparison with plastic or quartz. Because of the high index of refraction (2.2), a logarithmic-spiral-type light guide can be made ≈ 60 mm in diameter, that allows to use 3 in. PMT (which typically have lower mass, better energy resolution and lower noise) instead of 5 in. PMT. Assuming ≈ 5 cm of passive copper, ≈ 50 cm of lead, and ≈ 50 cm polyethylene shield, dimensions of the setup are much more compact (2.8 × 2.8 × 3.1 m) if to compare with "water shield" apparatus (≈ ∅ 11 × 10 m) proposed in Ref. [12].

To get such an impressive result, the problem of low-radioactive PbWO$_4$ crystals production should be solved. In particular, content of ^{210}Pb has to be decreased: high counting rate (and, thus, big number of random coincidences) in ^{210}Pb–^{210}Bi–^{210}Po decays, observed in the current measurements, creates a problem for performing the time–amplitude analysis of events to search for the specific decay chains. It is well known that the freshly smelted lead is contaminated by ^{210}Pb at the level of hundreds Bq/kg [34], while its contamination by uranium and thorium is substantially less [35]. As the first step, we

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[1] It should be stressed that CdWO$_4$ crystals, successfully applied in the Solotvina experiment [5], can be also used as active shield detector.

Table 3
Cosmogenic activity in $PbWO_4$ scintillators calculated with the help of the COSMO code (see text)

Initial isotope and reaction	$T_{1/2}$	Energy release (keV)	Initial decay rate after 1 yr storing underground (decays/day/kg)	Number of decays during next 1 yr (decays/yr/kg)
$^{68}Ge \to {}^{68}Ga \to {}^{68}Zn$	271 d/68 m	106/2921	1.7×10^{-3}	0.4
$^{88}Y \to {}^{88}Sr$	107 d	3623	5.4×10^{-3}	0.76
$^{88}Zr \to {}^{88}Y \to {}^{88}Sr$	83 d/107 d	673/3623	2×10^{-3}	0.23
$^{106}Ru \to {}^{106}Rh \to {}^{106}Pd$	374 d/30 s	39/3541	4.7×10^{-3}	1.2
$^{110m}Ag \to {}^{110}Cd$	250 d	2892	1.6×10^{-2}	3.7

intend to grow $PbWO_4$ crystals from archaeological lead aiming to obtain $PbWO_4$ crystals less contaminated by ^{210}Pb.[2] As the next step, we foresee to estimate radioactive contamination of $PbWO_4$ crystals in low-background measurements by using the time–amplitude and pulse-shape (to select fast sequence of β and α decays from the ^{212}Bi–^{212}Po chain) analyses. As it was demonstrated in the experiments with $CdWO_4$ scintillators, the sensitivities are at the level of a few μBq/kg for ^{228}Th, ^{226}Ra, and ^{227}Ac [5].

The energy threshold of the shielding $PbWO_4$ detector of 0.5 MeV can be achieved even with undoped scintillators at room temperature (see Fig. 1). However, as it was shown in Refs. [15,19], dopants like molybdenum and terbium can improve light yield of this scintillator, that allows to decrease the energy threshold of $PbWO_4$-based active shield.

5. Conclusions

Scintillation properties of $PbWO_4$ crystal scintillators were studied. The energy resolution FWHM = 36% was obtained for the 662 keV γ line of ^{137}Cs at $-18\,^{\circ}C$. The α/β ratio was measured in the energy interval 2–5.3 MeV. The dependence of the α/β ratio on energy of α particles was observed. Radioactive contamination of two $PbWO_4$ crystals was measured in the Solotvina Underground Laboratory. Both crystals are considerably polluted by ^{210}Po at the level of 50–80 Bq/kg. For ^{228}Th (^{232}Th family) and ^{226}Ra (^{238}U) activities only upper limits were set at the level of 13 and 10 mBq/kg, respectively.

The excellent energy resolution of FWHM = 3.6% was obtained for 2615 keV γ line of ^{208}Tl with high-quality $CdWO_4$ crystal scintillator 10 × 10 × 10 mm. The energy resolution of 3.9% (2615 keV γ line) and 86% of relative pulse amplitude was obtained for $CdWO_4$ scintillator viewed through $PbWO_4$ crystal as light guide. We expect an improvement of the light collection and the energy resolution of $CdWO_4$ detector by using the logarithmic-spiral $PbWO_4$ light guide.

Monte Carlo simulation and measurements demonstrate good abilities of $PbWO_4$ crystals to build 4π active shield for a sensitive ^{116}Cd double-beta decay experiment with $CdWO_4$ scintillators. Furthermore, $PbWO_4$ crystals, if their radiopurity will be proved, can be used as light guide and active shield in low counting experiments with scintillation, cryogenic and semiconductor detectors.

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