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First test of a $Li_2WO_4(Mo)$ bolometric detector for the measurement of coherent neutrino-nucleus scattering

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Abstract

The first observation of coherent elastic neutrino-nucleus scattering (CE ν NS), reported by the COHERENT Collaboration in 2017, paved the way for a new generation of experiments using reactor $\bar{\nu}_{e}$ and aiming at precisely measuring this process. In this context, the BASKET (Bolometers At Sub-KeV Energy Thresholds) R&D project investigates the use of cryogenic detectors for a reactor CE ν NS experiment. This article reports on the first test of a Mo-doped lithium tungstate scintillating bolometer ($\otimes 18 \times 7$ mm, 8 g), performed in an aboveground laboratory at CSNSM, Orsay (France). The detector bolometric performance (energy and time response, particle identification capabilities) and radiopurity have been studied and confirm the promising potential of lithium tungstate-based bolometric detectors for the measurement of CE ν NS at reactors.

Keywords: Neutrino Physics, Coherent Elastic Neutrino-Nucleus Scattering, Low temperature detectors, Scintillating bolometers, Cryogenics

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1. Introduction

The first observation of coherent elastic neutrino-nucleus scattering (CE ν NS) [1], reported in 2017 by the COHERENT Collaboration [2, 3], has recently renewed a great interest in precisely measuring this process [4] as it offers a new way to probe physics beyond the standard model [5, 6, 7] and nuclear structure [8]. This process, where a neutrino coherently scatters off all the nucleons within a target nucleus at low momentum transfers, can exhibit a cross section up to two orders of magnitude higher than the standard neutrino detection channels such as the inverse beta decay reaction or $\bar{\nu}_e e^- \rightarrow \bar{\nu}_e e^-$ scattering, making it possible to perform precision physics experiments with kg-scale detectors rather than the ton- or kiloton-scale detectors used nowadays.

The ongoing experimental efforts and proposals mostly focus on studying this process at nuclear reactors [9, 10, 11, 12, 13], which deliver copious amounts of $\bar{\nu}_{e}$ with energies in the MeV range. The nuclear recoils signing CE ν NS events are

then expected to have energies in the 0.01–1 keV range, depending on the target nucleus. Accessing such a very low energy deposition regime with detection techniques relying on scintillation or ionization signals seems quite difficult, and a promising alternative is the use of bolometric detectors which have the potential to reach the lowest energies and fully exploit a $CE\nu NS$ signal [10, 11,

13, 14]. Nuclear power plant environments usually offer experimental sites with shallow overburdens, implying the use of fast detectors with high background rejection capabilities. For instance, neutrons originating from the interactions of atmospheric muons in materials surrounding the detection setup can be of particular importance because they produce nuclear recoils identical to those coming from CEνNS.

With this in mind, a new R&D program called BASKET (Bolometers At Sub-KeV Energy Thresholds) [15] has started in 2017 and aims at the development of cryogenic detectors suited to the study of $CE\nu NS$ in above-ground conditions. A key idea of the project is the use of scintillating crystals containing

- ³⁰ a heavy element to enhance the CE ν NS rate¹ and lithium (natural, with ~8% of ⁶Li [16], or enriched in ⁶Li, e.g. see [17]) to study and mitigate the neutron backgrounds exploiting the ⁶Li(n,t) α reaction². As demonstrated in several past studies [19, 20, 21, 22, 23, 24, 25, 26, 27], such Li-containing bolometers can exhibit excellent particle identification capabilities and can be well-suited
- for the spectroscopy of neutrons. A low energy threshold Li-containing bolometric detector could thus offer several advantages in a detection setup dedicated to the study of CEνNS at reactors, such as being used as a CEνNS event detector, as a neutron flux monitoring device and/or even as an active veto (see e.g. [13, 14]) possibly acting as a neutron-absorption "skin" for another cryogenic detector.

This article reports on the first test of a cryogenic detector using a Mo-doped lithium tungstate crystal ($\text{Li}_2\text{WO}_4(\text{Mo})$) as an absorber material. The choice of lithium tungstate comes from the fact that tungsten is the heaviest element suitable for scintillator production and does not contain long-lived radioisotopes

- harmful for the study of CEνNS³. Also, knowing about the chemical affinity between Mo and W, previous studies performed on lithium molybdate (Li₂MoO₄) crystals further motivated this choice as they demonstrated excellent bolometric performances as well as low levels of radioactive impurities [23, 24, 25]. Finally, successful attempts to grow Li₂WO₄(Mo) crystals were already reported in the
- ⁵⁰ literature [28]. Growth of lithium tungstate crystals requires doping by molybdenum at the few % mass fraction level [28]. However, such a molybdenum doping is expected to have a negligible impact on the $\text{Li}_2\text{WO}_4(\text{Mo})$ crystal bolometric performances, firstly because of the above-mentioned chemical affinity between Mo and W, and secondly because of the results about investigations
- ⁵⁵ on the tungsten doping of zinc molybdate crystals [29].

¹The CE ν NS cross section roughly scales with N², N being the number of neutrons in the target nucleus.

²In particular, the cross section for thermal neutron capture is ~ 1 kb [18].

 $^{^3 \}rm{Indeed,}$ radio isotopes of $^{210}\rm{Pb}$ and $^{207}\rm{Bi}$ disfavour the choice of lead and bis muth respectively.

The article is structured as follows. The detector assembly and operation are presented in Section 2. Section 3 describes the results of the cryogenic test, focusing on the bolometric performance characterization of $\text{Li}_2\text{WO}_4(\text{Mo})$, on the particle identification capabilities of the detector and on the crystal radiopurity. Finally, Section 4 is devoted to the conclusion and perspectives.

2. Detector assembly and operation

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A picture of the tested Li₂WO₄(Mo) crystal is shown on the left panel of Fig. 1. The cylindrical element is colorless and has a mass of 8 g. It was cut from a Li₂Mo_{0.08}W_{0.92}O₄ crystal boule (with a size of ⊘25×100 mm) grown
⁶⁵ in a platinum crucible along the main crystallographic axis by the Czochralski technique with a pulling rate of 4 mm/h and a rotating rate of 10 rpm from a stoichiometric mixture of Li₂CO₃ (99.99 wt%), 5 mol. % MoO₃ (99.98 wt%) and 95 mol. % WO₃ (99.98 wt%) [28].



Figure 1: The Li₂WO₄(Mo) crystal sample with a size of $\otimes 18 \times 7$ mm before (left) and after (center) its assembly used for the cryogenic test. The Cu holder was shared with another crystal (colored). A $\otimes 44 \times 0.175$ mm Ge light detector (right), assisted with a Neganov-Trofimov-Luke signal amplification, was installed on the Cu housing top lid and faced the Li₂WO₄(Mo) bolometric detector to collect scintillation light.

The bolometric detector is shown on the middle panel of Fig. 1. A neutron transmutation doped (NTD) germanium thermistor [30] was used as a thermal sensor. It was directly glued on the crystal surface with a two-component epoxy glue (Araldite® Rapid). A P-doped silicon heater [31] was also glued on the same surface to inject periodically a constant power for an off-line stabilization of the detector thermal response fluctuations [32]. The crystal was mounted and

- fixed to a copper holder using PTFE supporting elements. Ultrasonic bondings were used to connect the golden pads of the NTD to the gold-plated-on-Kapton contacts glued on the holder with two Au wires ($\otimes 25 \ \mu m$), providing both thermal and electrical links, while the heater was bonded with two Al wires ($\otimes 25 \ \mu m$). The Li₂WO₄(Mo) absorber was also equipped with a bolometric
- ²⁰ light detector (LD) in order to measure emitted scintillation light and to study particle identification using a dual readout technique (e.g., see [33] and references therein). As shown by the right panel of Fig. 1, the LD consists of a thin germanium slab (\oslash 44×0.175 mm) with Al concentric electrodes deposited on the surface. By applying an electric field, the bolometric signal originating from
- the creation of electron-hole pairs can be amplified thanks to the Neganov-Trofimov-Luke effect (see details in [34]). Finally, the internal bottom part of the Cu housing was covered by a reflecting film (Enhanced Specular Reflector, 3M VikuitiTM) to improve the light collection.
- The cryogenic test of the $Li_2WO_4(Mo)$ crystal was performed above ground at the CSNSM laboratory (Orsay, France) using a pulse-tube cryostat [35] shielded by a lateral lead wall with 10-cm minimum thickness. A smeared ²¹⁰Po alpha source (made by ²¹⁸Po implantation into a copper substrate) was used and placed on the copper holder approximately 1 cm away from the crystal lateral surface. The crystal holder temperature was stabilized at 20 mK. The
- ⁹⁵ NTD of the $Li_2WO_4(Mo)$ detector was biased with a 6.25 nA current resulting in a 0.6 M Ω working resistance; the operational point was chosen to get the best signal-to-noise ratio. A room temperature DC-polarized electronics, developed for the CUORICINO experiment [36], was placed inside a Faraday cage and used for the readout of the channels. An active low-pass Bessel filter with a 675
- Hz cut-off frequency was also used in the electronics chain. The LD electrode bias was set either to 0 V or 23 V. The data, acquired in a stream mode, were recorded by a 16-bit ADC (National Instruments NI USB-6218 BNC) with a 5 kHz sampling rate. Reference signals were injected by a pulse generator through the heater every minute. The data were processed using an optimum filter tech-

¹⁰⁵ nique [37]. The results of the data analysis are presented and discussed in the next section.

3. Results of the low-temperature test

The goal of the low temperature test of the $Li_2WO_4(Mo)$ detector was to study its bolometric response, the energy resolution, the particle identification capabilities and the radioactive contamination. Such information helps to evaluate the potential of this material to be used in a cryogenic CE ν NS experiment. The achieved results are detailed and discussed below.

3.1. Bolometric performances

The time profiles of the Li₂WO₄(Mo) and Ge LD signals are compared in Fig. 2. The rising edge of the Li₂WO₄(Mo) pulse (from 10% to 90% of the signal maximum) is 3.4 ms, while the decaying part (from 90% to 30% of the signal maximum) is 19 ms. These time constants are typical for NTD-Ge-instrumented macro-bolometers (e.g. comparable results for similar-size bolometers [38, 27]). As illustrated in Fig. 2, the Ge LD exhibits a shorter pulse profile thanks to the smaller heat capacity of both the absorber and the sensor as compared to Li₂WO₄(Mo) detector (e.g. see in [24]). However, the Ge LD time response is also limited by the slow response of the NTD Ge thermistor used to read out the heat signal. In spite of that, the observed time profile of the Li₂WO₄(Mo) scintillating bolometer signals and the measured counting rate (0.27 counts/s)

are compatible with a reasonably low probability of pile-ups ($\sim 5\%$) in a time window (0.2 s) covering a pre-trigger, i.e. a baseline, and a signal.

The sensitivity of the $Li_2WO_4(Mo)$ detector, defined as the average pulse height for a 1 keV energy deposit, was measured to be 91.5 nV/keV, in agreement with what is usually observed for such kind of detectors (in particular, for

similar-size bolometers tested in the same set-up [38, 27]). By applying a 23 V bias to the electrodes, the LD signal amplitude was amplified to 3.2 μ V/keV, which is a factor of 7 larger than the signals read out without an electric field



Figure 2: An example of a heat signal from the 8-g $Li_2WO_4(Mo)$ bolometer and a corresponding light signal detected by the 1.4-g Ge cryogenic light detector. Both pulses are normalized with respect to their amplitude maximum.

applied on the electrodes. It is worth to be noted that the sensitivity of both detectors (and thus the signal-to-noise ratio) can also be enhanced by optimizing the thermal sensor design, e.g. as it was done for Ge bolometers [39, 40].

3.2. Energy response

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The Li₂WO₄(Mo) detector energy response was calibrated and studied in a 113-h long background measurement at 20 mK, using the environmental γ radioactivity (mainly originating from ²²⁶Ra and its daughters, ²¹⁴Pb and ²¹⁴Bi) ¹⁴⁰ inside the Pb-shielded cryostat. As illustrated by the left panel of Fig. 3, the acquired background energy spectrum shows several peaks below 700 keV and clearly demonstrates that the Li₂WO₄(Mo) cryogenic detector provides excellent energy resolution. In particular, the energy resolution of the different γ peaks varies from 2.5(2) keV FWHM at 186 keV (γ following the α decay of ²²⁶Ra) to

- ¹⁴⁵ 3.7(1) keV FWHM at 609 keV (γ following the β decay of ²¹⁴Bi). The baseline noise energy resolution was measured to 1.1(1) keV FWHM. The small difference between the quoted energy resolution and the baseline noise fluctuations indicates a low thermalization noise, already observed for similar detector materials such as lithium molybdate [24] and lithium magnesium molybdate [26].
- Thus, the present high spectrometric performance of the $Li_2WO_4(Mo)$ bolometric detector can even be improved by operating the detector in conditions

characterized by a lower noise and/or lower counting rate (improved shielding or underground operation).



Figure 3: The background energy spectrum accumulated over 113 h with the 8-g Li₂WO₄(Mo) bolometric detector operated at 20 mK, and shown over two energy regions. (Left) The low energy part of the $\gamma(\beta)$ distribution up to 700 keV. (Right) The high energy region where decays of α -active radionuclides from U/Th chain are expected to contribute. Alpha particles from the ²¹⁰Po source and α + triton events from ambient neutron capture on ⁶Li are also visible. The events selection was done using the scintillation light assisted particle identification capability of the Li₂WO₄(Mo) bolometric detector (see Sec.3.3 for further details).

The small detector size and the relatively short exposure prevent a detailed ¹⁵⁵ investigation of the detector energy resolution with γ quanta populating the MeV energy range. The two prominent populations around 4.8 and 5.3 MeV⁴, visible in the right panel of Fig. 3 in the α event region, provide only a provisional estimate of the detector energy resolution in this energy interval. Indeed, the energy of the α particles emitted by the external ²¹⁰Po source is smeared, giving rise to an exponential tail of events along the left side of the distribution, enlarging its FWHM to 23(1) keV. As opposed to the ²¹⁰Po α events, the energy resolution of the alpha+triton events coming from the ⁶Li(n, t) α reaction on ambient neutrons is 17(1) keV FWHM since such events take place directly

⁴In the energy scale calibrated with γ quanta, these peaks are shifted by ~3.5% with respect to a nominal energy of the reaction (4784 keV for ⁶Li(n,t) α and 5304 keV for ²¹⁰Po α decay). This effect corresponds to the so-called thermal quenching and it is typical for scintillator-based bolometers on the level of few-ten percent (e.g. see [41, 24]).

within the detector medium. However, the width of the alpha+triton event distribution is affected by surface escapes of the produced particles resulting thus in a partial energy deposition, and hence an underestimate of the detector energy resolution (e.g. as it is illustrated in [26]).

3.3. Particle identification capability

Scintillation light assisted particle identification is one of the most important features of scintillating bolometers as it allows an active background rejection [33]. In addition, selecting α particles from $\gamma(\beta)$ events with high efficiency is also important in view of the possibility to tag and reconstruct neutron events coming from the ⁶Li(n, t) α reaction. This feature would especially be useful when running a CE ν NS bolometric detector in aboveground conditions, where the muon-induced neutron background is expected to play a decisive role. Such type of particle identification relies on the fact that the amount of scintillation light produced by a highly ionizing particle is lower (quenched) than the scintillation light produced by an electron of the same energy (see e.g. [42]). In particular, the quenching factor for alpha particles is observed to be at the

level of 0.1–0.2 for different crystal scintillators [42, 43, 33]. Thus, a commonly used parameter, which characterize the ability of a scintillating bolometer for particle identification, is the scintillation light yield $LY_{\gamma/(\beta)}$, which is defined as the ratio of the light signal to the heat signal, both originating from the energy deposition of a γ/β particle. The scintillation light yield is typically ex-

¹⁸⁵ pressed in keV/MeV, and it depends on the combination of several experimental parameters such as the crystal optical properties (i.e scintillation efficiency at low temperatures, light transparency, shape and surface treatment) and the performance of a photodetector in terms of light collection and detection. For example, the baseline noise fluctuations of a bolometric photodetector can play a crucial role for particle identification (see, e.g., in [33]).

The left panel of Fig. 4 depicts the light yield distribution of events acquired during the 113-h background run. The measured light yield is 0.17(1) keV/MeV and is rather low in comparison to other Li-, Mo-, or W-containing scintillating



Figure 4: (Left) Light yield versus heat energy scatter plot measured with the 8-g Li₂WO₄(Mo) bolometric detector. A 23 V bias was applied on the Ge LD electrodes. (Right) Distribution of the light yield parameter for events with energies between 4.5 and 5.5 MeV: the solid histogram shows α events, which are well separated from the γ/β event distribution represented by the dashed histogram. The achieved discrimination power amounts to 4.87(4) (see text for further details).

bolometers [33], in particular with respect to the (0.7-1.0) keV/MeV measured

- ¹⁹⁵ light yield for Li₂MoO₄ bolometers. However, the scintillation light collection was not optimized, especially because neither reflecting materials on the internal lateral side of the Cu holder [25] nor antireflecting SiO coating of the LD used from the batch of such devices [34] were used in the tested setup. Thus, the light yield of the material is rather expected to be at the level of 0.4 keV/MeV
- or more⁵, which is well-enough for a highly efficient $\alpha/\gamma(\beta)$ separation using scintillating crystal equipped with NTD-instrumented Ge LD [25]. As demonstrated in earlier studies, the use of the Neganov-Trofimov-Luke amplification can further enhance the particle identification power of such a setup [34, 33]. Indeed, having a $LY_{\gamma(\beta)}$ equal to 0.17(1) keV/MeV and the LD baseline noise of
- ²⁰⁵ 0.3 keV at 0 V electrode bias, a partial $\alpha/\gamma(\beta)$ separation with a discrimination power⁶ (DP) of 1.3 was achieved. It was evaluated from the distribution of

⁵For instance, the light yield ~0.6 keV/MeV has been recently measured with another Li₂WO₄(Mo) bolometer (based on $@25 \times 25$ mm crystal produced at NIIC, Novosibirsk) in a low temperature test at CSNSM.

 $^{^{6}}$ The discrimination power between two Gaussian distributions is calculated as the differ-

 $^{210}\mathrm{Po}~\alpha$ events and from muon-induced events with similar energies. As shown by the right panel of Fig. 4, applying a 23 V bias on the Neganov-Trofimov-Luke light detector electrodes notably amplifies the scintillation signal, resulting in a

²¹⁰ DP of 4.87(4) or around 5σ (see [24] for further details). A Gaussian fit to the α and the γ/β light yield distributions gives a quenching factor of 0.282(2) for α particles.



Figure 5: A two-dimensional histogram showing the energy dependence of the PSD parameter (left) and its projected distribution (right) in the 4.5–5.5 MeV energy region, for events detected by the 8-g Li₂WO₄(Mo) scintillating bolometer in the 113-h background run. The band of β -, γ - and μ -induced events is clearly separated from the population of alpha+triton events coming from thermal neutron capture on ⁶Li (Q ~ 4.8 MeV) and from α particles emitted by the ²¹⁰Po source (Q ~ 5.3 MeV). The achieved $\alpha/\gamma(\beta)$ separation, expressed as a discrimination power, is DP = 4.11(5).

An efficient $\alpha/\gamma(\beta)$ separation can also be achieved with a pulse-shape analysis using only the Li₂WO₄(Mo) bolometric signals, as illustrated in Fig. 5. In this particular case, a pulse-shape discrimination (PSD) parameter is defined as the slope of a linear fit to a vector which matches an analyzed heat signal and an average pulse (used in the optimum filter) scaled to the signal maximum height [44]. This PSD parameter allows to achieve a slightly better separation power than e.g. using another simple PSD parameter as the rise and decay times, demonstrating that a more complex PSD parameter can even improve

ence between their mean values scaled by the square root of the sum of squared standard deviations.

the particle identification capability of the Li₂WO₄(Mo) bolometric detector. With the present level of the PSD-based $\alpha/\gamma(\beta)$ discrimination power, DP = 4.11(5), more than 99.9% of $\gamma(\beta)$ events can be rejected from the region of interest, which is definitely a very useful ability for performing neutron tagging and spectroscopy exploiting the pulse-shape analysis.

3.4. Crystal radiopurity

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Ensuring low levels of radioactive contaminants can be of paramount importance when using a Li₂WO₄(Mo)-based bolometric device both for the CE ν NS detection at reactors and for the spectroscopy of neutrons. The expected CE ν NS recoil signal from reactor $\bar{\nu}_{e}$ in Li₂WO₄(Mo) is expected to be below 1 keV, hence requiring a detailed understanding and a tight control of the backgrounds in this region. As concerns the neutron spectroscopy application, (α +t) events lie at 4.8 MeV (thermal neutrons) and above (fast neutrons), which should hence not be polluted by α energy deposits coming from the U and Th decay chains. Finally, applying high radiopurity standards for the fabrication of Li₂WO₄(Mo) crystals could also help in reducing the total counting rate, which is important when running cryogenic detectors in aboveground conditions since they are known to be slow devices.

The elemental composition of the $Li_2WO_4(Mo)$ material does not contain ra-

dioactive nuclides⁷. Therefore, the radioactive impurity content of the Li₂WO₄(Mo) crystal should mostly be driven by the purity of the initial materials and by the cleanliness of the equipment used to fabricate the crystal. The chemical affinity between lithium and potassium can lead to a ⁴⁰K activity in Li-containing materials at the level of ~0.1 Bq/kg. It can be mitigated by the selection of radiopure

Li-containing powder and/or by applying additional purification processes [24]. This contamination is also expected to be present in the studied Li₂WO₄(Mo)

⁷The activity of ¹⁸⁰W alpha decay and ¹⁰⁰Mo double-beta decay, present in tungsten and molybdenum isotopic composition respectively, is negligible because of their low amount in the studied material and extremely long half-lives ($\sim 10^{18}$ yr).

crystal. However, in our test the determination of ⁴⁰K activity at the level of hundreds of mBq/kg or lower is impossible in an aboveground bolometric test. For example, aboveground [23] and underground [24] measurements of the same

- ²⁵⁰ Li₂MoO₄ bolometric detector resulted in very different sensitivities to its radiopurity level. The Li₂WO₄(Mo) contamination by radioactive nuclides from the U/Th chains can be investigated in the present data thanks to the achieved efficient $\alpha/\gamma(\beta)$ separation, allowing to select α particles with energies in the 4 to 7 MeV range, as expected from the α decays of ²³⁸U/²³²Th and their daugh-
- ters. The energy spectrum of α particles, shown in the right panel of Fig. 3, does not contain any other peculiarities except those caused by thermal neutron capture on ⁶Li and by the ²¹⁰Po source, as well as a hint on a bulk ²¹⁰Po contamination (a peak-like structure around 5.4 MeV with an activity 4.2(12) mBq/kg). Using the approach described in details in [45], upper limits at the
- ²⁶⁰ 90% confidence level on the bulk contamination of the Li₂WO₄(Mo) crystal can be estimated: $\leq 0.8 \text{ mBq/kg}$ of ²³²Th, $\leq 1.0 \text{ mBq/kg}$ of ²²⁸Th, $\leq 3.4 \text{ mBq/kg}$ of ²³⁸U and $\leq 2.1 \text{ mBq/kg}$ of ²²⁶Ra. These results indicate a low U/Th content, and can be considerably improved by increasing the measurement exposure. If necessary, μ Bq/kg-level sensitivities in U/Th content of Li₂WO₄(Mo) crystals
- could also be achieved benefiting from the recent progress in the development

of lithium molybdate crystals [24, 46, 25].

4. Conclusions and perspectives

In the perspective of a precise measurement of CE ν NS close to a reactor facility, this article reports on the first test of a lithium tungstate cryogenic detector developed in the framework of the BASKET R&D program. The choice of lithium tungstate as an absorber material was driven by two main reasons: the presence of a heavy element to enhance the CE ν NS rate and the presence of ⁶Li to leverage the ⁶Li(n, t) α reaction for neutron background identification and/or mitigation. In this context, a Mo-doped lithium tungstate crystal (Li₂Mo_{0.08}W_{0.92}O₄) with a size of $\oslash 18 \times 7$ mm and a mass of 8 g was investigated for the first time as a low temperature detector.

The $Li_2WO_4(Mo)$ scintillating bolometer was operated at a 20 mK (sample holder) temperature in a pulse-tube-based ${}^{3}\text{He}/{}^{4}\text{He}$ dilution refrigerator running in an aboveground laboratory at CSNSM (Orsay, France). The time constants of the bolometric signals (respectively rise and decay time parameters) were 280 measured to be in the 1–10 ms range, and are in agreement with what is usually observed for the NTD Ge thermistor technology. The obtained baseline noise (1.1 keV FWHM) is similar to values reported for other macro bolometers tested in the same set-up. The $Li_2WO_4(Mo)$ detector baseline noise was not meant to be optimized, and can be further improved by operating the detector 285 in low noise conditions and/or by adjusting the temperature sensor to enhance the bolometer sensitivity. The tested $Li_2WO_4(Mo)$ bolometric detector showed an excellent energy resolution (e.g. 3.7 keV FWHM at 609 keV γ quanta). It also exhibited a low light yield value of 0.17 keV/MeV, which is a factor 3-4smaller than that usually observed for example in Li_2MoO_4 cryogenic detec-290 tors. The poor light collection did not prevent to investigate the scintillation light assisted particle identification capibility of $Li_2WO_4(Mo)$. Exploiting a thin Ge ($\oslash 44 \times 0.175$ mm) bolometer with the Neganov-Trofimov-Luke signal amplification, a 5 σ separation of $\beta/\gamma/\mu$ both from neutron-induced events ($\alpha+t$) and from α particles of a ²¹⁰Po source was demonstrated. Similar particle separation 295 (4σ) was achieved by using a pulse-shape analysis on the Li₂WO₄(Mo) bolometric signals. Finally, the energy spectrum of α particles did not show any hint on a bulk contamination from U/Th α -active radionuclides (except ²¹⁰Po with a 4.2(12) mBq/kg activity), thus resulting to upper limits on their activity at the

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level of (0.8-3.4) mBq/kg. More precise investigations of the crystal radiopurity require an underground operation.

All these results confirm the promising potential of lithium tungstate-based bolometric detectors for the study of $CE\nu NS$ in nearly aboveground conditions, such as those met at a reactor facility. Thanks to their neutron tagging capabilities and their heavy element content, $Li_2WO_4(Mo)$ cryogenic detectors could either be used as a neutron flux monitoring system, a $CE\nu NS$ event detector and/or an active neutron-absorbing veto. The next steps of the BASKET R&D project therefore consist in testing of $\text{Li}_2\text{WO}_4(\text{Mo})$ materials obtained with different production processes (different compound synthesis, advanced crystal

- growth method) together with the use of different phonon sensor technologies (e.g. metallic magnetic calorimeters or high impedance NbSi transition-edge sensors) targeting for a detector prototype with a fast time response, O(100 μ s rise time), and a very low energy threshold (≤ 50 eV). Moreover, the development of a ⁶Li-enriched Li₂WO₄(Mo) crystal is in progress. The use of
- 315 ⁶Li-enriched crystals will significantly enhance the probability of a neutron capture inside the material, and will then improve the neutron identification and spectroscopy capabilities of Li₂WO₄(Mo)-based bolometric detectors, which is rather important in context of its application for the CE ν NS detection.

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