Rejection of surface background in thermal detectors: the ABSuRD project

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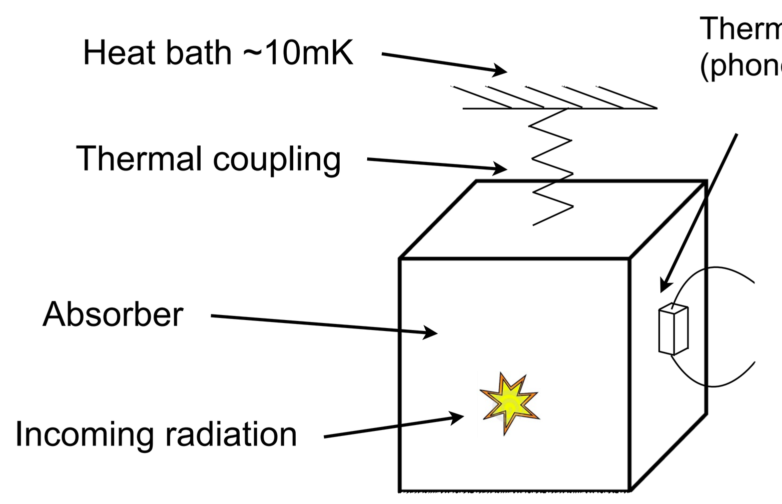
Thermal detectors have recently achieved a leading role in the fields of Neutrinoless Double Beta Decay and Dark Matter searches thanks to their excellent energy resolution and to the wide choice of absorber materials. In these fields the background coming from surface contaminations is frequently dominant. ABSuRD (**A B**ackground **Su**rface **R**ejection **D**etector) is a scintillation-based approach for tagging this type of background and we discuss the innovative application of this technique in non-scintillating bolometric detectors which will allow a more favorable signal to background ratio.

Thermal detectors

A *bolometer* is a particle detector that measures the energy deposited by incident radiation based on the temperature change of the detector.
Bolometers are Phonon-Mediated particle detectors and they provide very good energy resolution (~few per mil).

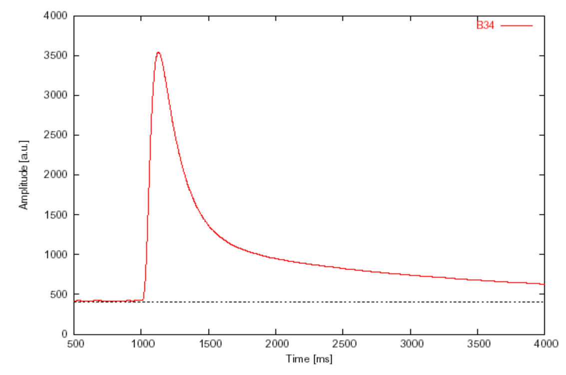


Signal amplitude: $\Delta T = E/C$

Relaxation time: $\tau = C/G$

The only relevant parameter for the energy absorber is the heat capacity C

$$C \propto (T/\Theta_D)^3 \text{ (Debye Law)}$$

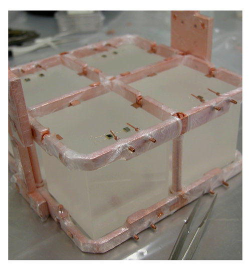


Example: properties of a TeO_2 absorber crystal

- M = 750 g
- C = 2x10-9 J/K
- ΔT = 0.1 mK/MeV
- τ ~1 sec

Bolometers features


CRESST


CUORE

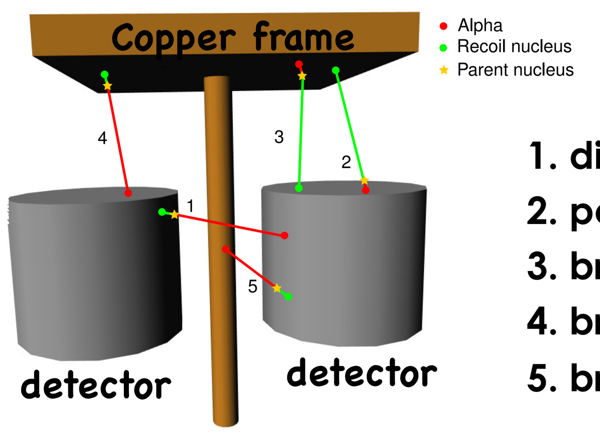

CDMS

Advantages
- good energy resolution (~0.1%)
- wide choice of detectors materials
- true calorimeters

Disadvantages
- speed: the response is very slow (decay time ~sec)
- need to work at very low temperature

Bolometers are ideal detectors for many rare events physics applications, such as Neutrinoless Double Beta Decay (0vDBD) and dark matter searches, for which the slowness of the detector response is not a problem.

Alpha background in rare events searches

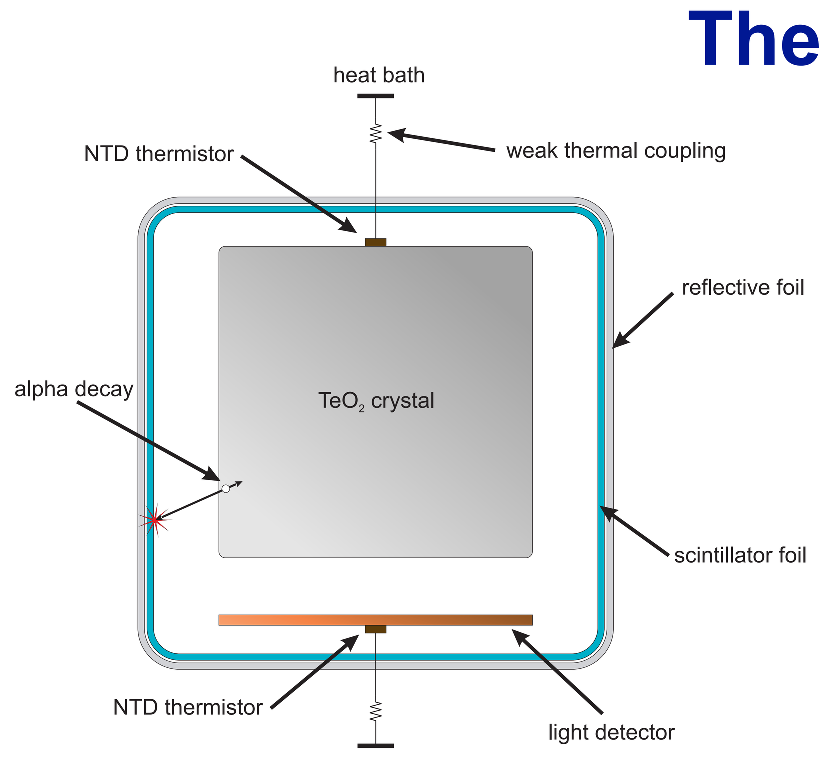


$E_\alpha \approx$ 5 MeV
$E_{recoil} \approx$ 100 keV

1. discarded by coincidence cut
2. peak with tail at E_α
3. broad distribution up to E_{recoil}
4. broad distribution up to E_α
5. broad peak at E_{recoil}

An α particle generated near the surface of a detector component releases only a part of its energy before escaping from the material ("degraded α").
In bolometers, that are fully active detectors, the pure thermal signal does not carry any information about the radiation type, preventing α/β discrimination. An alternative strategy to reject this kind of background is to tag surface events. **The goal is to find a way to tag α surface events that can induce a background in the ROI.**

The ABSuRD detector



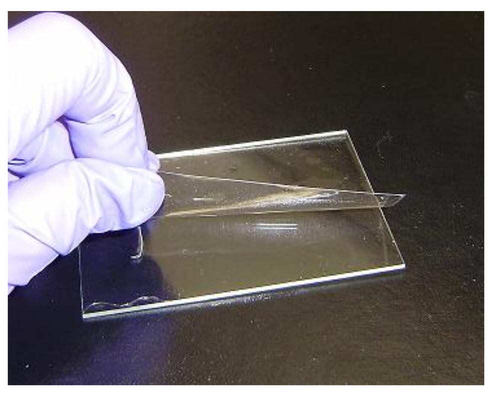
To tag the events coming from surface contaminations the thermal detector can be encapsulated in a scintillating foil. Adding a bolometric light detector, should make possible to detect the light produced by the interaction of degraded α particles with the scintillating foil.

Low energy threshold are needed for bolometric light detector (<1 keV), in order to be able to detect small light signals produced by degraded α. An α of 5.3 MeV (^{210}Pb) produces about 10 keV of photons (commercial scintillating foil at room temperature)

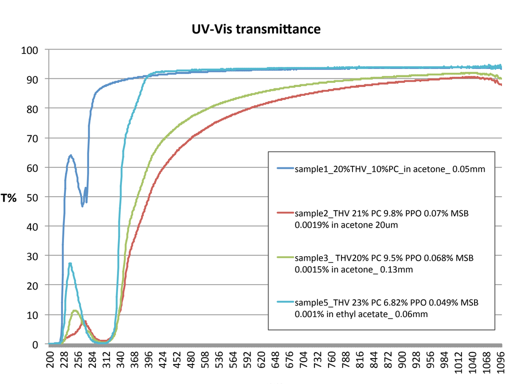
For 0vDBD with TeO_2, we need to tag α releasing 2.5 MeV on the crystal. Because of the α decay with lower energy belonging to natural chains is the ^{232}Th (Q-value of 4.01 MeV), we need to detect α down to 1.5 MeV.
Unfortunately, plastic scintillators have an extremely non-linear response to alpha particles and the light produced by an α particle of 1.5 MeV is about an order of magnitude smaller than at 5.3 MeV.

Detecting such a small amount of light represents a serious challenge for most of the currently used light detectors at mK temperature.

Low temperature plastic scintillator characterization



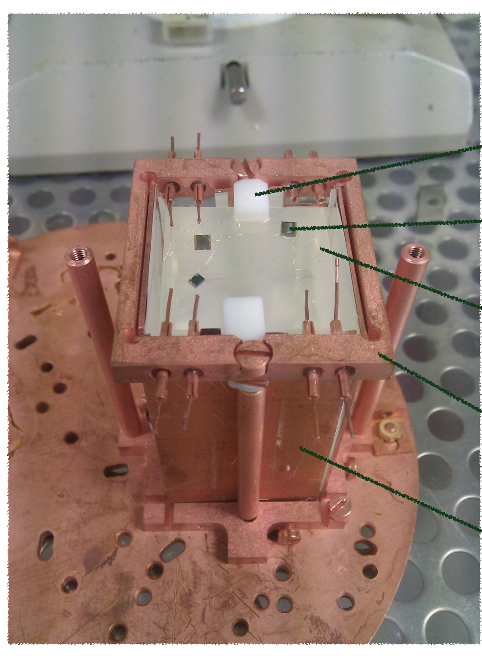
In order to be able to identify degraded α events, plastic scintillator with large light yield are needed as well as low energy threshold of the bolometric light detector.
The response of these samples to α and β interactions at low T has never been measured.

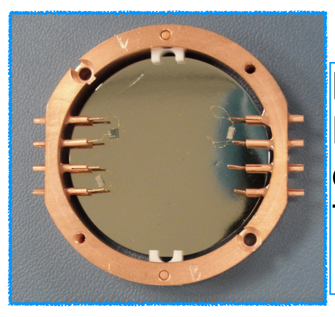


We are developing different kind of scintillating foils in collaboration with Brookhaven National Laboratory and their light and transmittance have been measured at room temperature.
A fast and flexible **low temperature test facility** has been assembled at the Gran Sasso National Laboratory. The use of a Gifford-McMahon cold head and of SiPM light sensor make this facility very appealing for multiple test and temperature characterization.

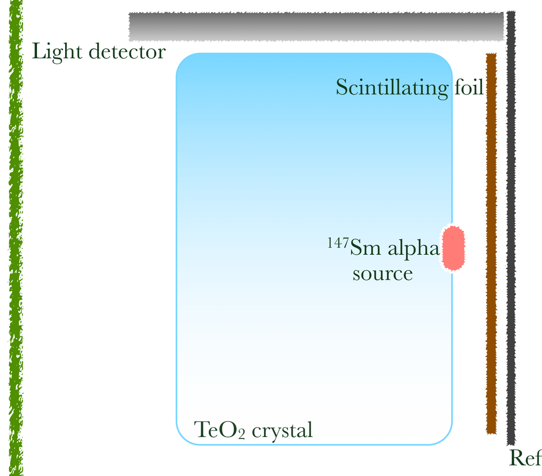
The low temperature characterization is in progress

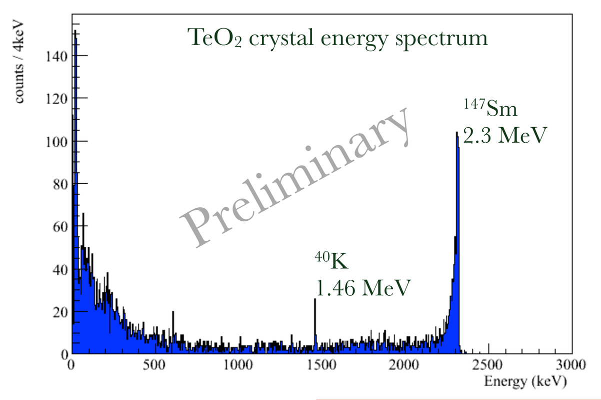
First bolometric test with commercial plastic scintillator

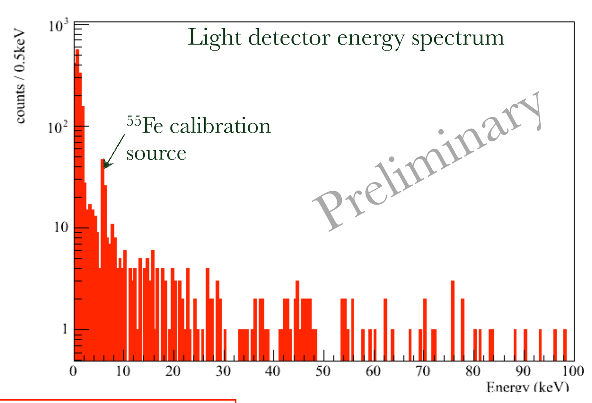




Bolometric Light Detector: HPGe on the top of the TeO_2 crystal







The analysis is in progress

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