The CROSS Experiment: Unveiling Neutrino’s Mysteries with Superconductivity Methods

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Neutrinoless double beta decay (0νββ) is a hypothetical rare nuclear transition (T1/2 > 10^24 y). Its observation would provide important information about the nature of neutrinos (Dirac or Majorana particles) demonstrating that the lepton number is not conserved. This decay can be investigated with bolometers embedding the double beta decay isotope 136Xe, 130Te, 136Cd, 138Te, which, perform as low temperature calorimeters (-10 mK) detecting particle interactions via a small temperature rise read out by a dedicated thermometer. CROSS (Cryogenic Rare-event Observatory with Surface Sensitivity) aims at the development of bolometric detectors (Li2MoO4 and TeO2) capable of discriminating surface α and β by exploiting superconducting properties of Al film deposited on the crystal surface. We report in this paper the results of tests on prototypes performed at CSNSM (Orsay, France) that showed the capability of a few-μ thick superconducting Al film deposited on crystal surface to discriminate surface α from bulk events, thus providing the detector with the required surface sensitivity capability. The CROSS technology would further improve the background suppression and simplify the detector construction with a view to future competitive double beta decay searches.

Abstract

CROSS proposes a technique to mitigate surface contamination via providing bolometers with surface sensitivity, no light detector is needed.

The superconductor Al film acts as a pulse shape modifier for surface events

Proof of concept was achieved in a test on TeO2 with a fast sensor (NbSi) and 10 μm Al film in 2010 (CSNSM, Orsay), J. Low Temp. Phys. 167 (2012) 1029

The background problem

controlling the background is crucial:

• high energy resolution
• full active volume (no dead layer)
• flexible material choice

CUPID (CUORE Upgrade with Particle IDentification) adopts a method to reject surface α events in bolometers exploiting the scintillation (Li2MoO4) or Cherenkov radiation (TeO2) emitted by the absorber, since α & β have different light yield.

CROSS assembly & results

Pulse shape parameter used is the rise-time of the pulse (time from 10% to 90% of the pulse maximum amplitude) (for a more efficient parameter can be found here: arXiv:1906.10233)

NO impact of Al film on bolometric performance (energy resolution, sensitivity)

Near future goals:
• fully coat the crystals with Al film
• test of another coating material
• underground tests (LSC, Spain)

Far future goals:
• CUPID demo with 90-crystal array
• Of enriched Li2MoO4 & 136TeO2 bolometers

What is a neutrino?

neutral elementary particles

oscillate

neutrinoless double beta decay (0νββ): (A, Z) → (A, Z+2) + 2e

evidence will determine some of the unknown properties of ν

• Mββ: effective Majorana mass
• Mν: nuclear matrix element
• gν: phase space factor

• confirm the Majorana nature (v ≠ ¥)
• measure T1/2 Measurement
• provide insight on the mass pattern problem
• obtains constraint on the absolute scale of neutrino masses

T1/2 > 10^24 y very long half-life experiments will face many difficulties

CROSS technology

Cryogenic Rare-event Observatory with Surface Sensitivity

experiment will face many difficulties by using bolometers

<table>
<thead>
<tr>
<th>Isotope</th>
<th>Q-value</th>
<th>Isotopic abundance</th>
</tr>
</thead>
<tbody>
<tr>
<td>136Xe</td>
<td></td>
<td></td>
</tr>
<tr>
<td>130Te</td>
<td></td>
<td></td>
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<tr>
<td>136Cd</td>
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<tr>
<td>138Te</td>
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