Scintillating $\text{Li}_2\text{MoO}_4$ Bolometers for neutrinoless double beta decay search

XIX International Workshop on Neutrino Telescopes
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on behalf of CUPID collaboration
CUORE and CUPID

CUORE:

Searching for $^{130}\text{Te } 0\nu\beta\beta$ decay with $\text{TeO}_2$ bolometers at 10 mK

- First ton-scale bolometric experiment
- Reached 1 ton $\times$ year exposure
- $\sim 0.2\%$ energy resolution at $^{130}\text{Te}$ Q-value ($Q_{\beta\beta} \approx 2527$ keV)
- $^{130}\text{Te } 0\nu\beta\beta$: limit on $t_{1/2} > 10^{25}$ y

$\rightarrow$ Background level dominated by $\alpha$ particles from surface contamination: $10^{-2}$ counts/(keV kg y) $\rightarrow$ 50 counts/y in the ROI

See G. Fantini's Talk
https://agenda.infn.it/export/event/24250.ics
CUORE and CUPID

CUPID:
Next generation experiment searching for $^{100}\text{Mo} \, 0\nu\beta\beta$ with **Scintillating Bolometers** using CUORE infrastructure:
- **Reject α particles** background with scintillation light detection
- **$^{100}\text{Mo isotope}$**: higher $Q_{\beta\beta}$ (3034 keV) to reduce natural radioactivity background in the ROI

→ “Background-free” condition
→ $10^{27}$ y sensitivity on the $^{100}\text{Mo} \, 0\nu\beta\beta$ half-life

See A. Giuliani’s Talk
https://agenda.infn.it/export/event/24250.ics
CUPID R&D Activities

R&D tests ongoing at LNGS to define the final CUPID design.

- 8 enriched Li$_2$MoO$_4$ cubic crystals (LMO)
- 12 Light Detectors (LD) on top and bottom faces
- 4 crystals are covered with Reflecting Foil (RF)
- Heater: inject fixed energy purely thermal pulses

Light detected with small bolometers

- Ge disk coated with SiO and equipped with thermistors
CUPID R&D Activities

Targets:

1. Test **Energy Resolution**
   → cubic Li$_2$MoO$_4$ studied for the first time

2. Analyse **Light Detectors Performances** and Noise Level

3. Study the **Particle Identification** capabilities and Light Collection
   → with/without RF to study the final CUPID configuration
Energy Resolution

Energy spectrum: peaks from $^{232}$Th source
FWHM ($\Delta E$) vs Energy
fitted using ($p_0+p_1E$)

Extrapolate $\Delta E$ at the $^{100}$Mo Q-value (3034 keV)

$\Rightarrow (6.7 \pm 0.6)$ keV
$\Rightarrow 0.22\%$

Despite not optimal cryogenics conditions, the result approaches the CUPID goal of 5 keV FWHM.
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Light Detectors Performances

Light Detectors calibrated with X-rays hitting directly the Ge disk from $^{55}$Fe sources

Noise RMS results in the range 25-40 eV for each LD

Reproducible result which satisfy the request for CUPID
CUPID R&D Activities

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Particle Identification

**Light Yield** at a fixed Energy on heat channel is quenched for $\alpha$ particles. **Heat** and **Light** simultaneous read-out allows Particle Identification.

Reject $\alpha$ from surfaces contamination: it is the dominant background at the $\beta\beta$ Q-value in CUORE.

**Discrimination Power:**

$$DP \equiv \frac{|LY_{\beta/\gamma} - LY_{\alpha}|}{\sqrt{\sigma_{\beta/\gamma}^2 + \sigma_{\alpha}^2}}$$
Particle Identification

**Light Yield** at a fixed Energy on heat channel is quenched for α particles. **Heat** and **Light** simultaneous read-out allows Particle Identification.

Study of the **Light Yield** with/without Reflecting Foil (RF) using 2 LD:

- **Blue**: crystals with RF \( \rightarrow (1.10\pm0.05) \text{ keV/MeV} \)
- **Red**: bare crystals \( \rightarrow (0.50\pm0.05) \text{ keV/MeV} \)

\( \rightarrow \) the RF increases the light collection by a factor > 2

Particle Identification

Study of α particles events discrimination with different configurations:

Signal acceptance: 99.7% → cut at $LY_{\beta/\gamma} - 3\sigma_{\beta/\gamma}$

- **Complete Rejection** (DP > 8) using 2 LDs & crystal with RF
- **Good Results with**
  - 1 LD & RF (DP > 7)
  - no RF but 2 LDs (DP > 4)
- **Inefficient with** 1 LD and no RF (DP < 4)
Summary

Targets:
1. **Energy Resolution** of Li$_2$MoO$_4$ cubic crystals:
   \[ (6.7 \pm 0.6) \text{ keV FWHM} \]: Close to CUPID goal

2. **Light Detectors Performances** and Noise Level:
   \[ 25-40 \text{ eV RMS} \]: reproducible results

3. **Particle Identification** and Light Collection:
   \[ \text{RF increases LY by a factor } > 2 \]
   \[ \text{Complete } \alpha \text{ rejection} \] with different light collection configurations
Future Prospects

New R&D run is ongoing at LNGS Hall C:

- Foreseen better experimental conditions. **Noise and cryogenics can be improved**. Operating the detector at 10 mK, instead of 20 mK, the energy resolution is expected to improve.

- Light collection will be improved using **square, instead of circular, Light Detectors** which will be also placed closer to the crystals

THANKS FOR YOUR ATTENTION!