The CROSS Experiment: Rejecting Surface Events with PSD

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What are we looking for?

Neutrinoless double-beta decay: $(A, Z) \rightarrow (A, Z+2) + 2e^-$

Its discovery will

- ascertain the Majorana nature of neutrino ($\nu = \bar{\nu}$)
- Confirm lepton number violation
- measure $T^{0\nu}_{1/2}$ that will lead to $m_{\beta\beta}$ measurement

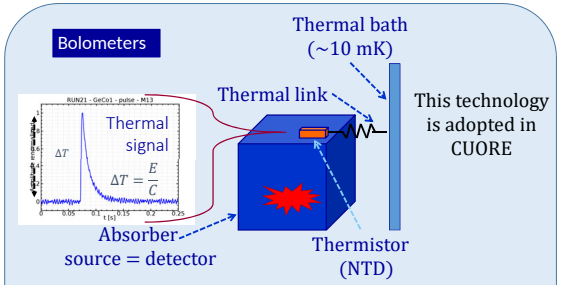
$$[T^{0\nu}_{1/2}]^{-1} = |m_{\beta\beta}|^2 \, |M^{0\nu}|^2 \, G^{0\nu}$$

- $m_{\beta\beta}$: **effective Majorana mass**
- $M^{0\nu}$: **nuclear matrix element**
- $G^{0\nu}$: **phase space factor**

- provide insight on the mass pattern problem.
- obtain constraint on the absolute scale of neutrino masses.

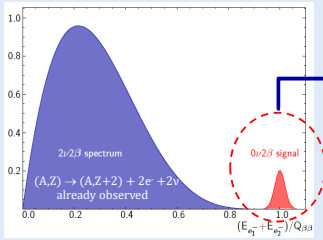
$T_{1/2} > 10^{26}$ y ⇒ experiments will face many difficulties because of the extremely low rate

How to search for it?



- high energy resolution
- full active volume (no dead layer)
- flexible material choice (Li_2MoO_4, $ZnMoO_4$, $CaMoO_4$, ZnSe, TeO_2 ...)

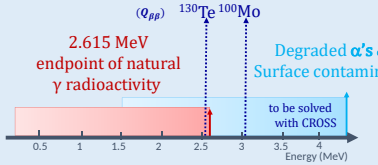
isotope	Q-value	Isotopic abundance
^{100}Mo	3034 keV	9.6 %
^{130}Te	2537 keV	34 %



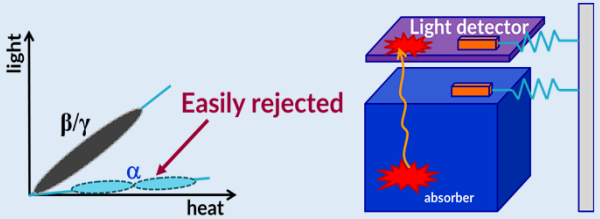
very challenging to be detected due to very low rate of the process

controlling the background in region of interest is crucial

How to suppress the background?



CUPID (CUORE Upgrade with Particle IDentification) adopts a method to reject surface α events in bolometers exploiting the scintillation ($Li_2{}^{100}MoO_4$) or Cherenkov radiation (TeO_2) emitted by the absorber, since α & β have different light yield.



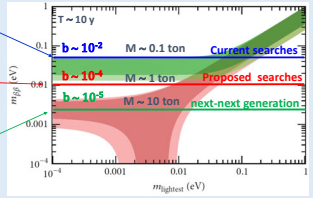
Pure bolometer: CUORE background dominated by α's

Reject α's

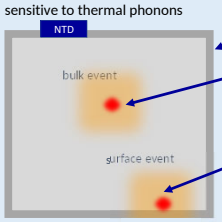
Scintillating bolometer: CUPID background still has important β component

Reject surface α's & β's

Surface sensitive bolometer: CROSS



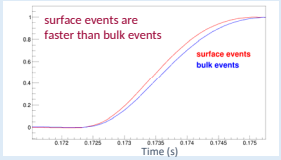
CROSS proposes a technique to mitigate surface contamination via providing bolometers with surface sensitivity ⇒ no light detector is needed



few μm superconducting Al film

athermal phonons slowly converted to thermal phonons by energy down conversion

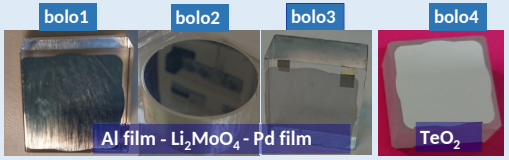
athermal phonons quickly converted to thermal phonons thanks to superconducting Al film



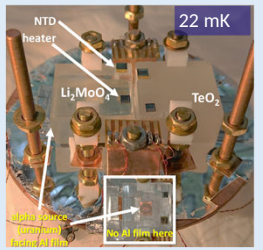
Palladium coating:

- Normal metal thermalizes better athermal phonons than superconductor but with the drawback of a much higher specific heat

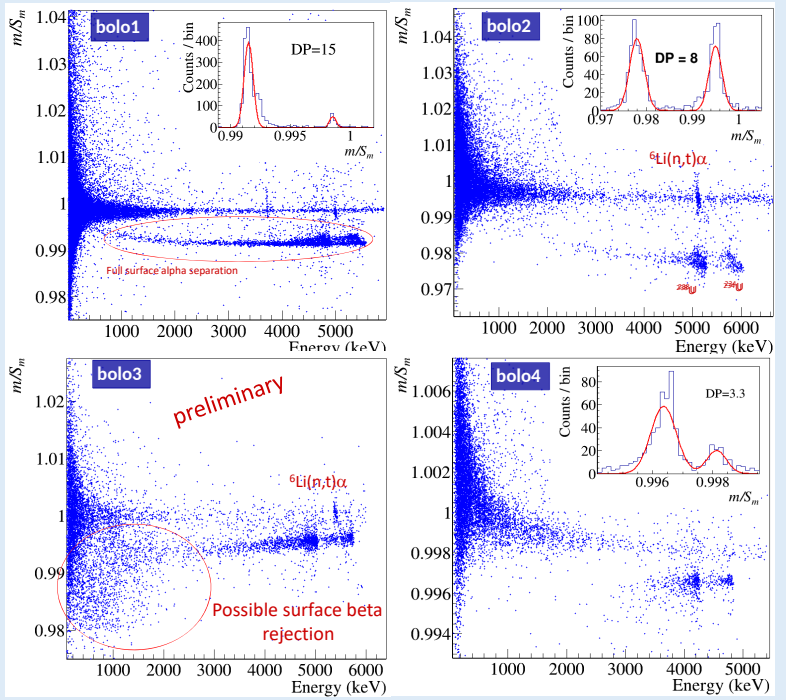
Results



2×2×1 cm³	Ø4×2 cm³	2×2×1 cm³	2×2×1 cm³
12 g	67 g	12 g	25 g
10 μm Al	10 μm Al	10 nm Pd	1 μm Al
53 nV/keV	37 nV/keV	23 nV/keV	44 nV/keV



Discrimination power: $DP = \frac{|\mu_{bulk} - \mu_{surface}|}{\sqrt{\sigma^2_{bulk} + \sigma^2_{surface}}}$



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

Conclusion

- The CROSS technology showed the feasibility to reject surface alphas and betas exploiting Al/Pd film coating on the surface of the crystal.
- Mid-scale demonstrator to be installed soon underground to test the CROSS technology on large crystals and medium-scale arrays.

Bandac, I.C. *et al.* The 0ν2β-decay CROSS experiment: preliminary results and prospects. *J. High Energ. Phys.* **2020,** 18 (2020).
Khalife, H. *et al.* The CROSS Experiment: Rejecting Surface Events by PSD Induced by Superconducting Films. *J Low Temp Phys* **199,** 19–26 (2020).

CROSS posters: **The new CROSS cryogenic Underground facility: an overview (ID: 246)**
First results of CROSS underground measurements with massive bolometers (ID: 303)