Backgrounds of the CUPID experiment

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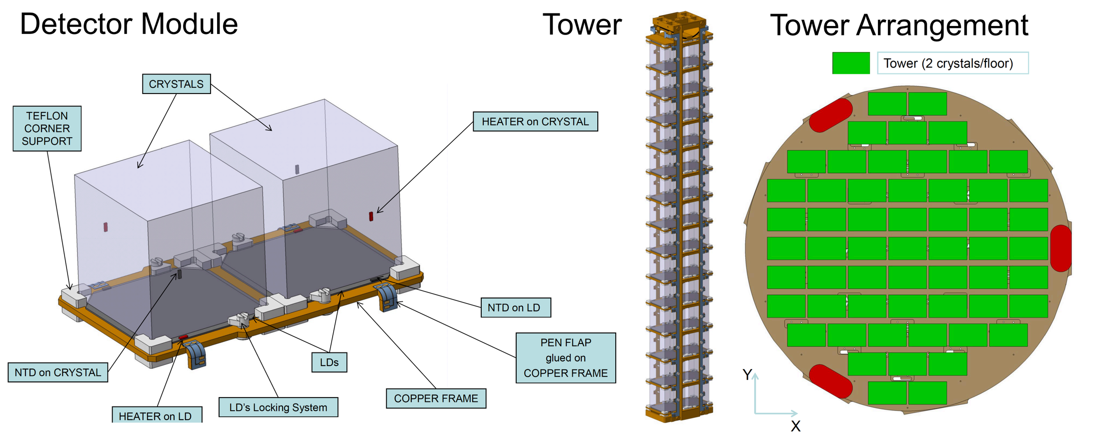
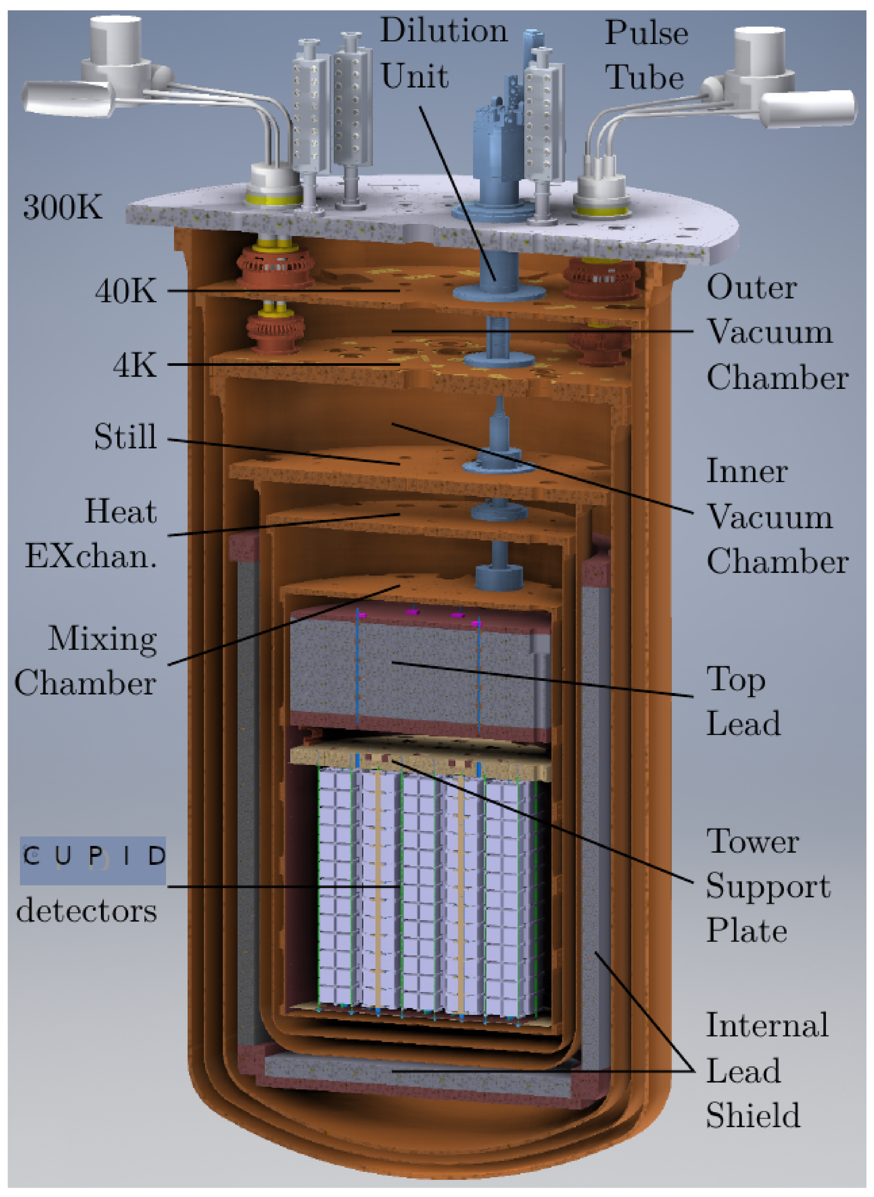
on behalf of the CUPID collaboration

CUPID, the next generation bolometric double beta decay search

- CUORE infrastructure
- $\sim$ 1600 $Li_2{}^{100}MoO_4$ scintillating crystals (45 x 45 x 45 mm)
- Ge bolometric light detectors
- Detection of heat and scintillation light allowing α discrimination
- ^{100}Mo, $Q_{\beta\beta}$ = 3034 keV
- Total mass = 450 kg, ^{100}Mo mass = 240 kg

CUPID discovery sensitivity:
$T_{1/2}$ (^{100}Mo $0\nu\beta\beta$)$> 10^{27}$ y
$m_{\beta\beta} < 12 - 20$ meV





Background sources

1. Radioactivity from crystals
2. Radioactivity from detector components
3. Radioactivity from infrastructure
4. $2\nu\beta\beta$ pileup
5. Muons
6. Neutrons

Background index evaluated in 3034 $\pm$ 15 keV.

1. Backgrounds from ^{238}U/^{232}Th in the bulk and surface of the crystals

- Bulk and surface contaminations from the CUPID-Mo background model [1]

^{226}Ra to ^{210}Pb	^{228}Th to ^{208}Pb	BI ^{226}Ra [ckky]	BI ^{228}Th [ckky]	BI Total [ckky]
< 0.2 μBq/kg	$0.43^{+0.16}_{-0.15}$ μBq/kg	0	$(2.7^{+1.3}_{-1.0}) \cdot 10^{-6}$	$(2.7^{+1.3}_{-1.0}) \cdot 10^{-6}$
2.0 ± 0.5 nBq/cm^2	< 2.5 nBq/cm^2	$(3.0^{+1.0}_{-0.9}) \cdot 10^{-6}$	$< 8.7 \cdot 10^{-6}$	$(6.4^{+3.4}_{-2.8}) \cdot 10^{-6}$
Total				$(9.5^{+3.1}_{-1.7}) \cdot 10^{-6}$

- **Cosmogenics:** We use ACTIVIA and assume 90 days exposure and 1 year cool-down. Potentially dangerous isotopes: ^{42}K, ^{82}Rb, ^{88}Y and ^{56}Co. Total background expected from cosmogenic activation isotopes: 2.3 $\cdot$ 10^{-6} cts/(keV$\cdot$kg$\cdot$y)

BI: (1.2 $^{+0.3}_{-0.2}$)$\cdot$ 10^{-5} cts/(keV$\cdot$kg$\cdot$y)

2. Background from detector components

- Includes copper frames, PTFE supports, cabling
- For **copper holders** we use the activities from the CUORE background model [2]
- For PTFE and cabling we use measured upper limits by ICPMS and gamma-ray spectroscopy
- Primary contribution from ^{238}U and ^{232}Th surface contamination in copper through the β decays of ^{214}Bi and ^{208}Tl

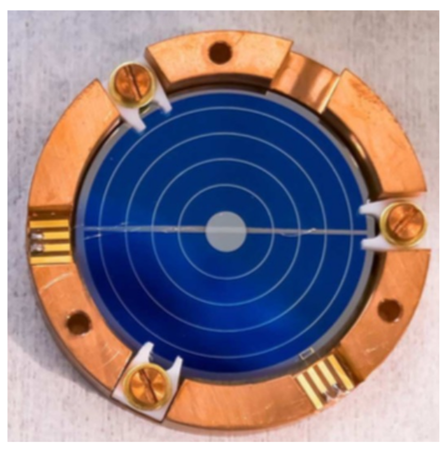
BI: (4.0 $\pm$0.4)$\cdot$ 10^{-5} cts/(keV$\cdot$kg$\cdot$y)

3. Backgrounds from infrastructure

- **Close infrastructure:** innermost thermal shield (10 mK), components and inner shielding at 10 mK. Primary contribution from ^{238}U and ^{232}Th surface contamination.
  BI: (7.1 $\pm$0.5)$\cdot$ 10^{-6} cts/(keV$\cdot$kg$\cdot$y)
- **Infrastructure:** 50 mK, 600 mK, 4 K, 40 K and 300 K thermal shield, internal lead shielding on sides and top. Background from ^{238}U and ^{232}Th bulk radioactivity.
  BI: (3.0 $^{+1.3}_{-0.8}$))$\cdot$ 10^{-6} cts/(keV$\cdot$kg$\cdot$y)
- We use the activities from the CUORE background model [2]

4. $2\nu\beta\beta$ Pile-up

- Two events occurring close enough in time that are not resolved, but reconstructed as a single event at their summed energy
- To a first approximation, the parameters that determine the ability to identify pile-up events are the detector **rise time** and the **signal-to-noise ratio**
- CUPID baseline: Light Detector instrumented with Neganov-Trofimov-Luke, NTL, amplification



- R&D results of NTL performances combined with a phenomenological law are used for background estimate

5. Neutrons

- Neutron shielding to be expanded to mitigate (n,γ) reactions in Mo and Cu
- With additional 10 cm of polyethylene on the top and at sides, neutron backgrounds suppressed to $\sim$2 $\cdot$ 10^{-6} cts/(keV$\cdot$kg$\cdot$y)

6. Muons

- Additional muon veto. Construction ongoing
- From simulations, muon rejection efficiency $\sim$98.9 % of single-site muon induced events, leads to (1.3 $\cdot$ 10^{-6} cts/(keV$\cdot$kg$\cdot$y)

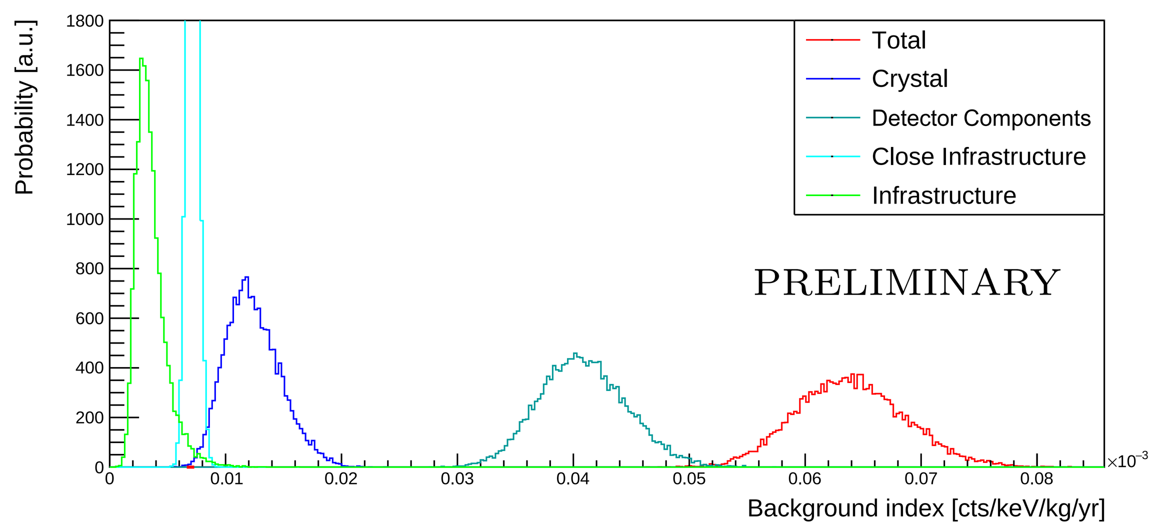
References

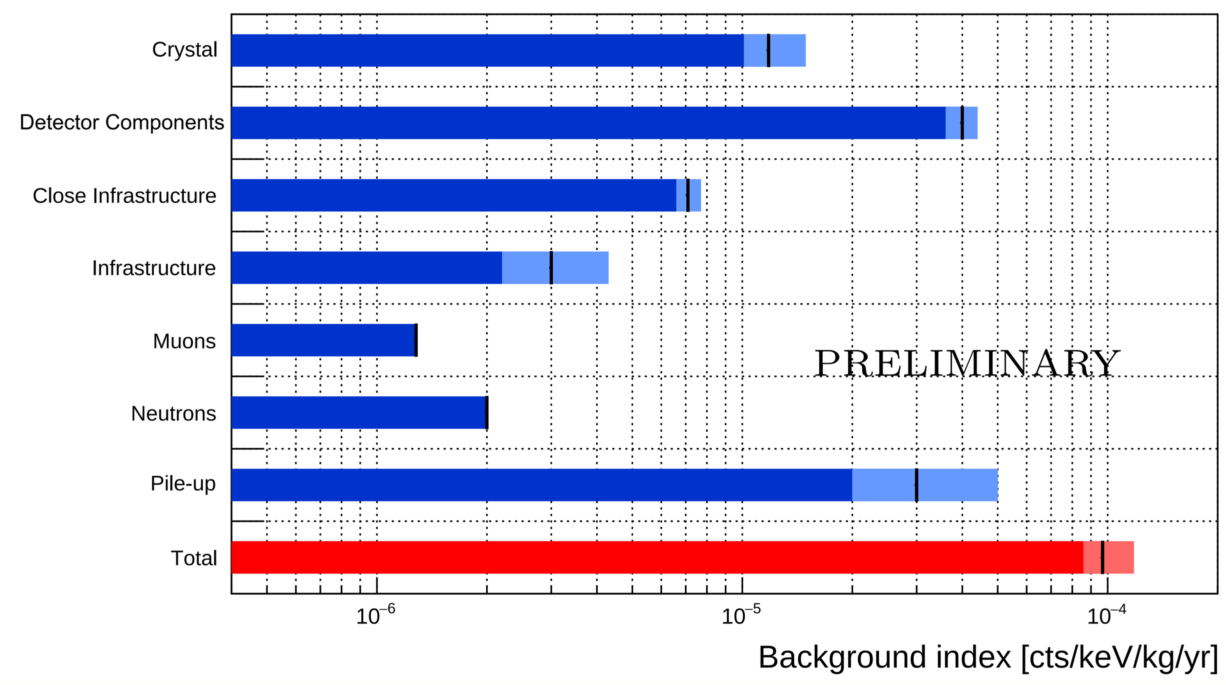
[1] Eur. Phys. J. C 83(7):675, 2023.

[2] arXiv:2405.17937 [nucl-ex].

Total predicted background

Probability density distributions of the background index from the radioactive contaminations in materials:





CUPID background predictions based on results from precursor experiments (CUORE and CUPID-Mo) and on improved new design.

The black lines show the mode of the expected distribution and the light band the $\pm 1\sigma$ uncertainty