Data-driven background model for the CUORE experiment and measurement of the 2νββ of ^{130}Te

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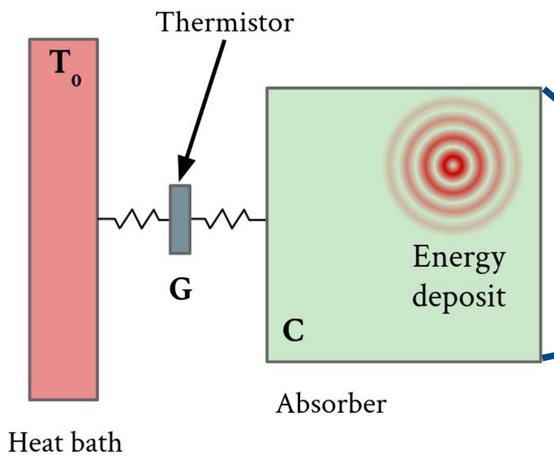
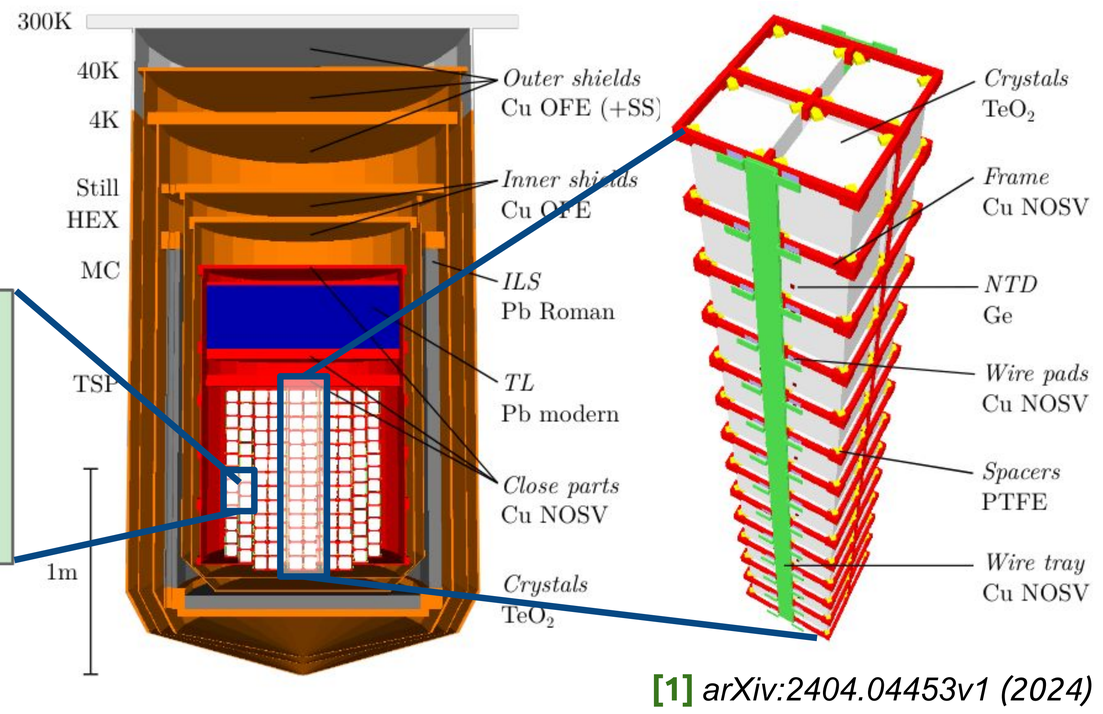
The CUORE experiment

The CUORE (Cryogenic Underground Observatory for Rare Events) searches for 0νββ in ^{130}Te (Q-value~2527 keV), a Beyond Standard Model process whose discovery would:

1. Assess the Majorana nature of neutrinos
2. Give essential information about neutrino masses
3. Provide an example of leptogenesis mechanism





The CUORE experiment

- Underground experiment at LNGS (Italy), *~1400 m under the Gran Sasso mountain*
- Searching 0νββ exploiting ***close-packed array*** of 988 TeO_2 crystals operated as ***cryogenic calorimeters*** and ***cooled down at ~15 mK***
- Stable data taking since 2019, latest limit (90% C.I.) **[1]**: $T^{0\nu}_{1/2} > 3.8 \times 10^{25}$ yr

[1] *arXiv:2404.04453v1 (2024)*

The CUORE background model fit

Rare events physics → *Low background* in the region of interest (~10^{-2} counts/keV/kg/yr)

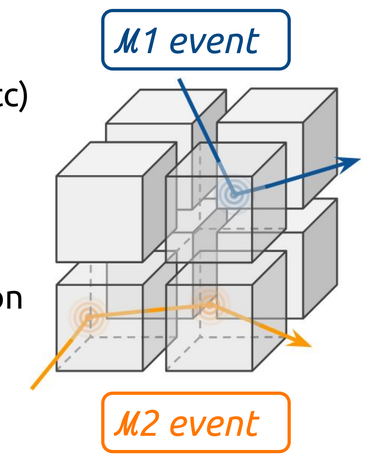
Rare events physics → Deep knowledge of current backgrounds → ***Data driven model of the backgrounds***

Aims:

- Characterize the setup → *essential* for the next-gen *CUPID experiment*
- Understand the background and *extract material contamination*
- Base for *high-level analyses* (2νββ, 0νββ-$\mathcal{M}2$, etc)

How to build it:

1. Look for *signatures in the data* (peaks, continuum, etc)
2. *Geant4 Monte Carlo simulation for each background source* in each volume of the experimental setup → ~80 contributions
3. *Bayesian simultaneous fit* of $\mathcal{M}1$ (1 spectrum) and $\mathcal{M}2$ diagonal bands (39 spectra) with a linear combination of the background sources
4. Priors given by *extensive assays* and *previous experiments*



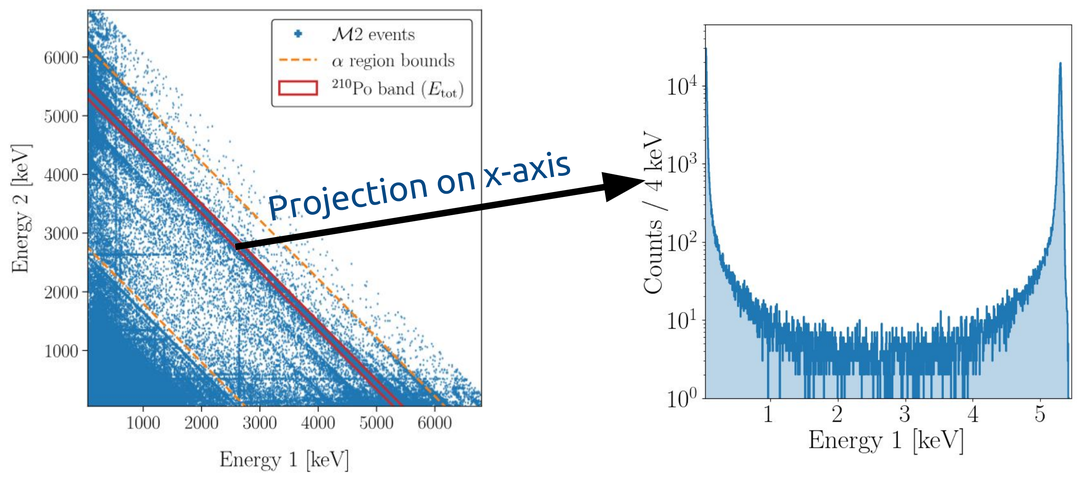
Model (bin counts)

$$\nu_{\kappa,i} = \sum_j N_j (w_{\kappa,i})_j$$

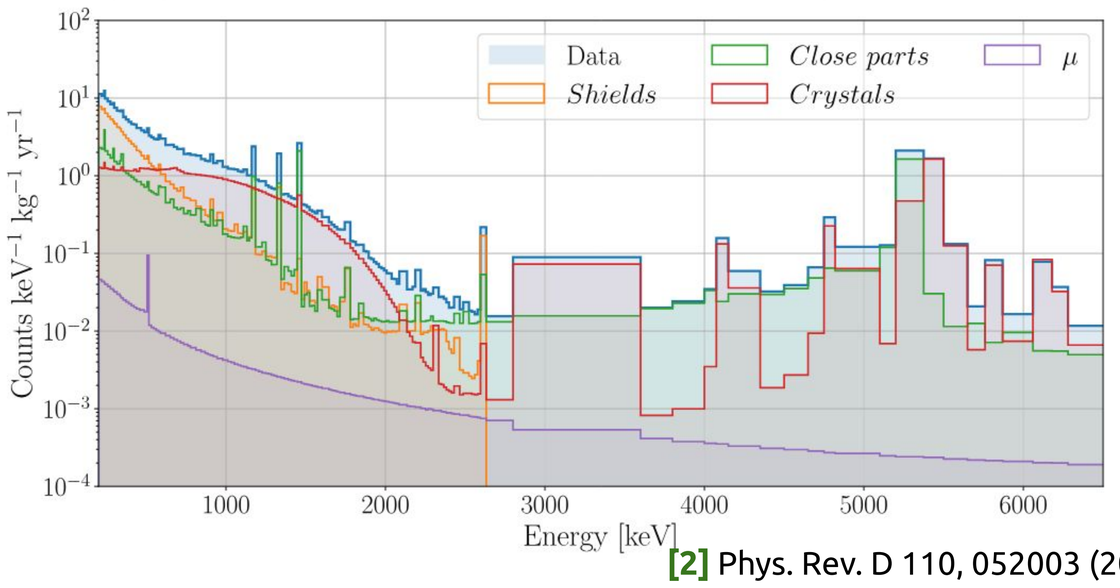
Fit Likelihood

$$\mathcal{L}(\{N_j\} \mid \text{data}) = \prod_\kappa \prod_i Pois(n_{\kappa,i}, \nu_{\kappa,i})$$

$\mathcal{M}2$ diagonal bands "technique" (example with ^{210}Po peak) **[2]**



Satisfying data reconstruction in all the detector range [200,7000] keV **[2]**

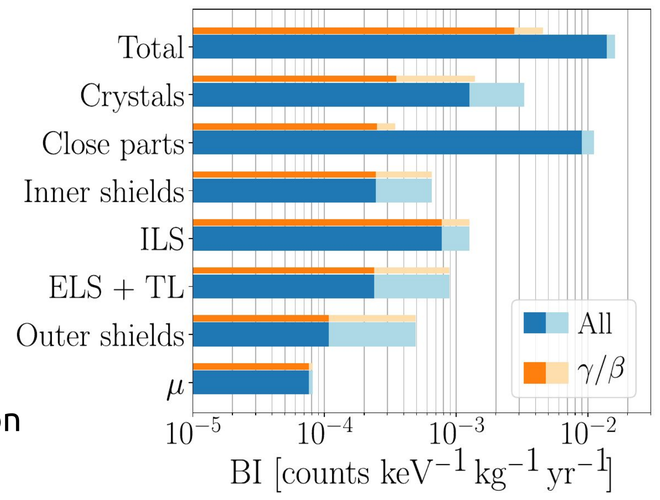


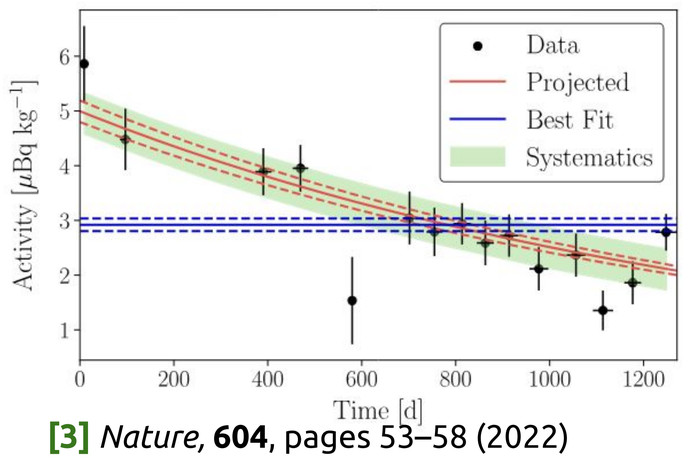
[2] Phys. Rev. D 110, 052003 (2024)

Further results

Studies of the 0νββ region of interest [2465, 2575] keV **[3]**:

- ✔ *Measurement of the background index (BI) in the ROI* **[2]**
- ✔ Precise determination of each background component
- ✔ *Check and validations* of CUORE background *projections* **[4]**
- ✔ Analysis of recontaminations happened during the construction





Several studies on the single background sources **[2]**:

- ✔ Time-development of activation isotopes (example of ^{125}Sb in TeO_2)
- ✔ Localization of non-uniform contaminations
- ✔ LNGS muon flux measurement

[3] *Nature*, **604**, pages 53–58 (2022)

[4] *Eur. Phys. J. C* **77,** 543 (2017)

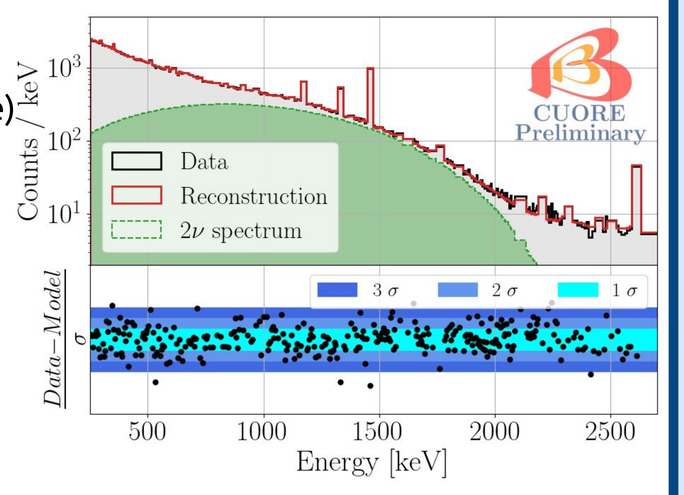
Measurement of 2νββ half-life of ^{130}Te

Studies of the 2νββ half-life and spectral shape with the single state dominance model (1 ton·yr exposure)

Fit optimization

- Fitting range
- Thinner binning to highlight spectral shapes
- Detector selection (only innermost towers)

Most precise measurement of the 2νββ decay half-life for ^{130}Te to date



$$T_{1/2}(^{130}\text{Te}) = 9.323^{+0.052}_{-0.037}\ (\text{stat}) \times 10^{20}\ \text{y}$$

Systematics (~1%) under finalization

PRELIMINARY RESULT

Near future:

Performed fits with the improved formalism, of primary importance for nuclear models. ***Soon out!!***

- Systematics not dominant, (to be added)
- Studies of the "Taylor expanded" shape for this decay
- Effective axial coupling g_A^{eff} measurement

LOW RADIOACTIVITY TECHNIQUES 2024 WORKSHOP IX