Latest results from the CUORE experiment

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On behalf of the CUORE collaboration

CUORE | Frontier Detectors for Frontier Physics

Searching for 0νββ decay

Beyond Standard Model process (ΔL = 2)

$$(A,Z) \longrightarrow (A,Z+2) + 2e^-$$

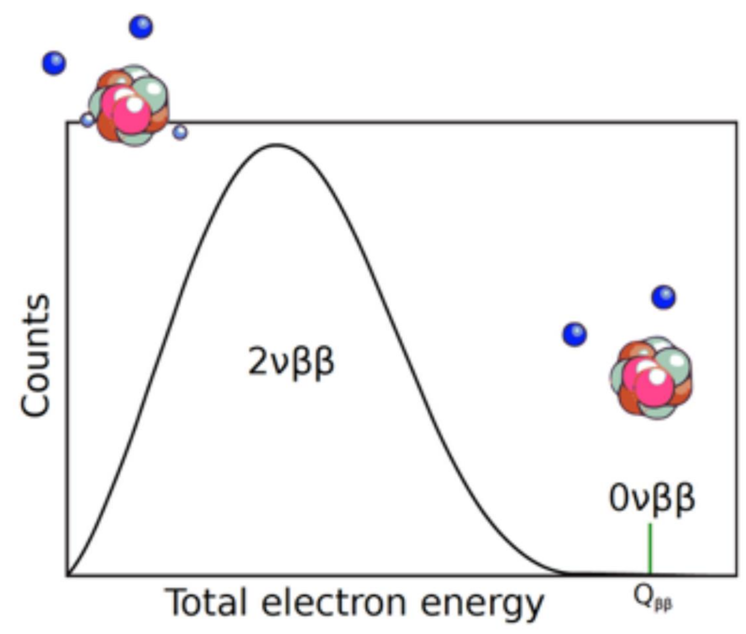
Not yet observed: $T^{1/2}_{0\nu\beta\beta} > 10^{22\text{-}26}$ yr

Impacts of a potential observation:

- Existence of Lepton Number violating processes
- Presence of a Majorana term for the neutrino mass, $m_{\beta\beta}$

→ Constraints on neutrino mass hierarchy and scale
→ Hint on origin of matter/anti-matter asymmetry (baryogenesis via leptogenesis involving Majorana neutrinos)

Broad experimental program to search for 0νββ decay with different isotopes: ^{48}Ca, ^{76}Ge, ^{82}Se, ^{100}Mo, ^{116}Cd, ^{130}Te, ^{136}Xe ...

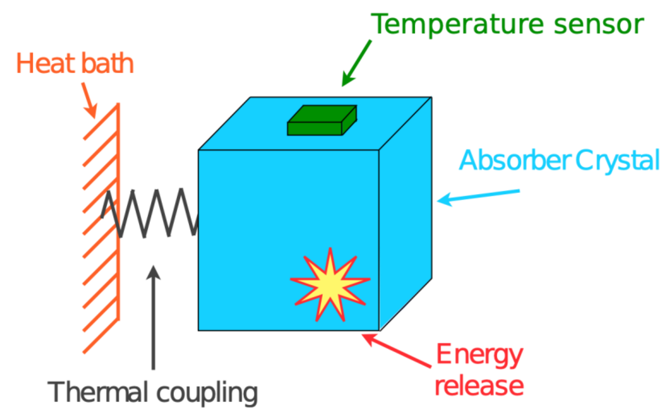


CUORE experiment

Cryogenic Underground Observatory for Rare Events

- Cryogenic experiment at tonne-scale
- utilising $^{(nat)}TeO_2$ thermal detectors operated at ~10 mK
- Located at Laboratori Nazionali del Gran Sasso (Italy)

Search for rare events and for physics beyond the SM
Search for 0νββ decay of 130Te (Qββ = 2527.5 keV)



Why thermal detectors…

- E_{dep} converted into ΔT (phonons)
- Detector = ββ source
- Large calorimeters (~kg scale)
  - Sensitive **from keV to MeV** scale
  - Optimal **E resolution** ~ **0.1%**@MeV

Cuore challenges

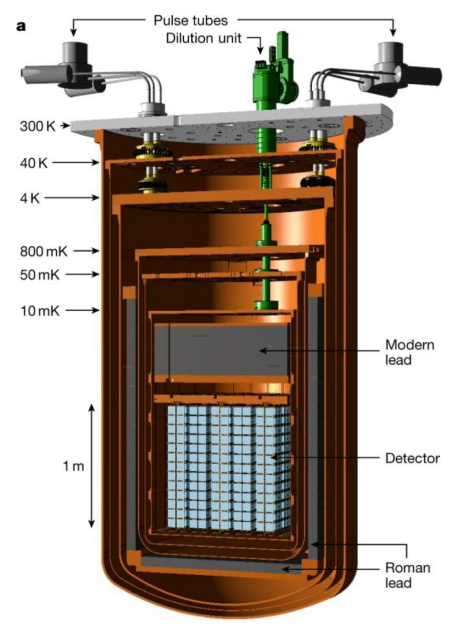
Low temperature and low vibrations

988 TeO_2 detectors at ~10 mK stable over time

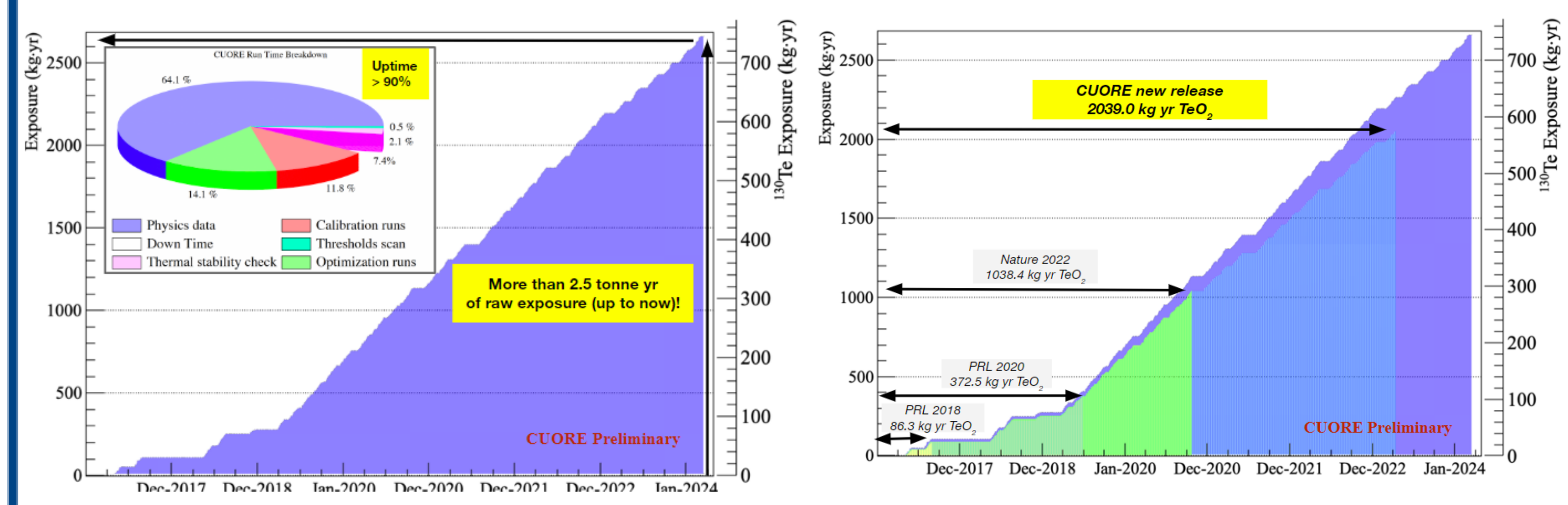
- Multistage cryogen-free cryostat
- Mechanical vibration isolation: passive and active systems

Low background

- Deep underground location
- Strict radio-purity controls on materials and assembly
- Passive shields from external and cryostat radioactivity
- Detector: high granularity and self-shielding

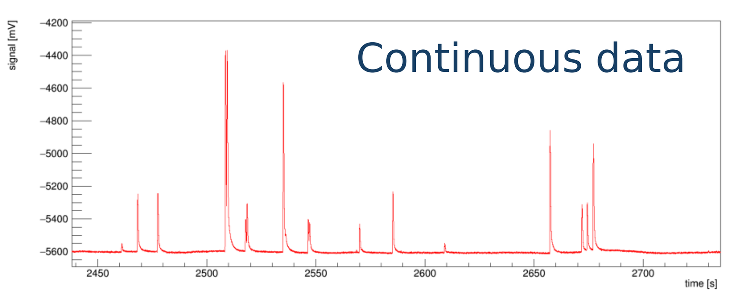


Searching for 0νββ decay



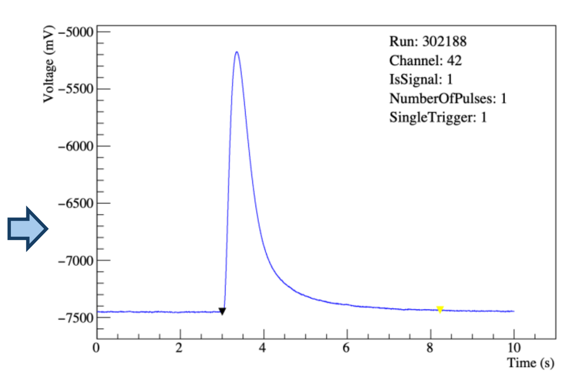
Cuore data production

From single detectors waveform data stream



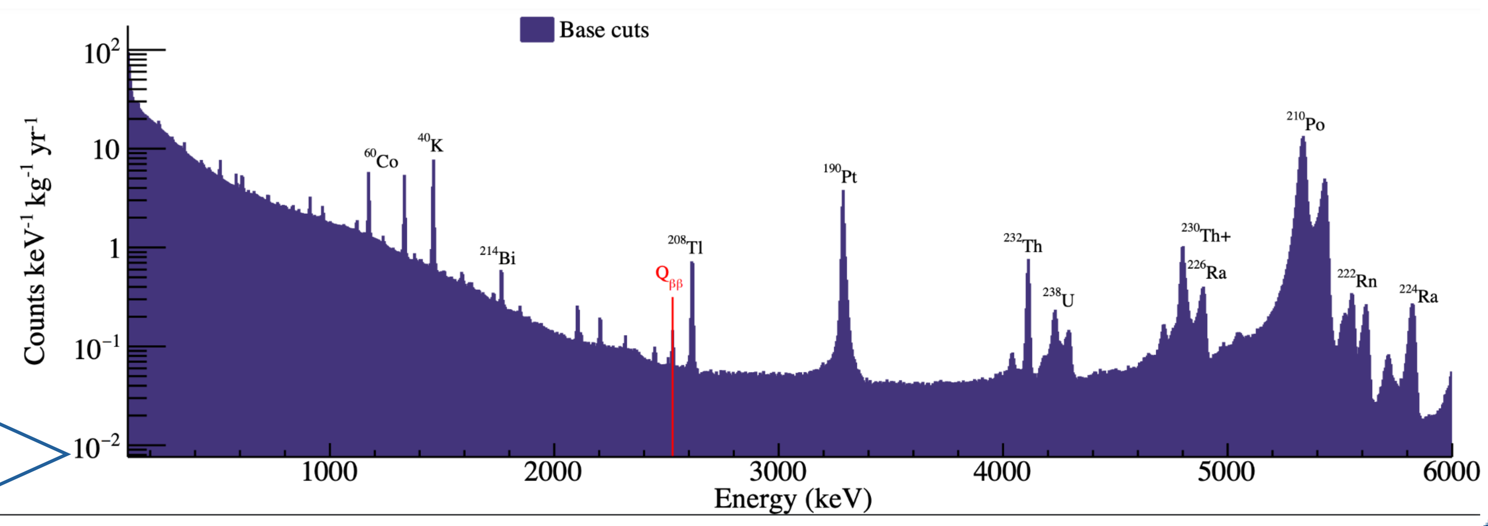
→ Denoising → Optimum trigger →

Event: physics pulse



→ Optimum Filter → Gain correction → Energy calibration → Coincidences → PCA

Cumulative energy spectrum after energy calibration →



Blinded physics spectrum (all channels)

CUORE performances

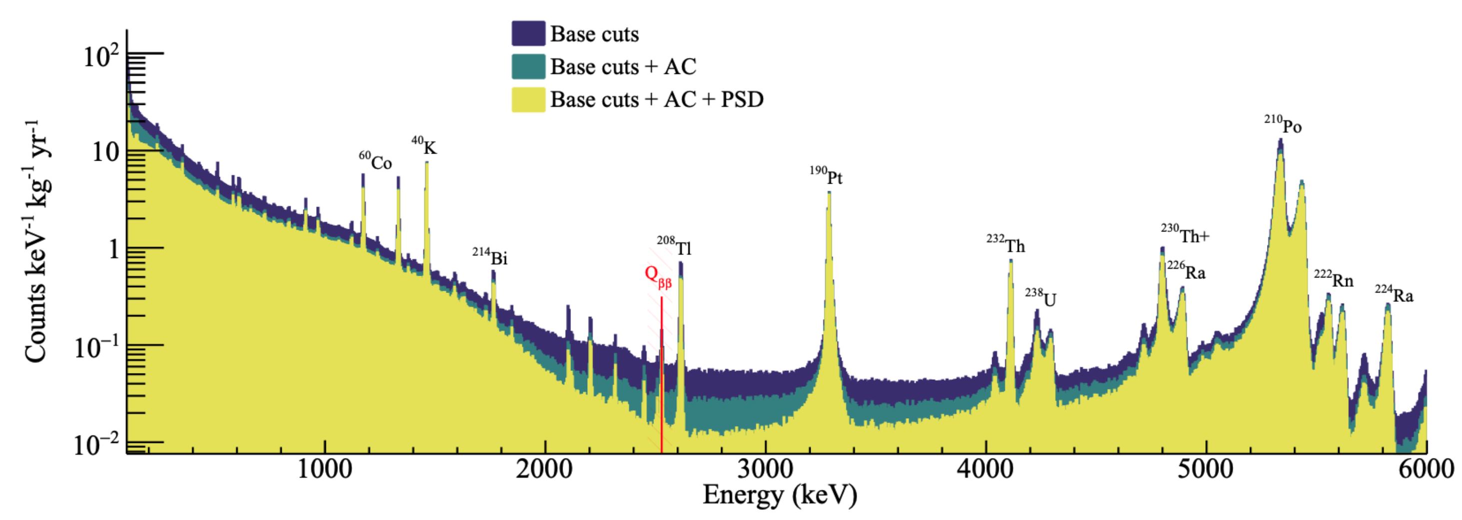
CUORE 2 TonneYr release (this result)

28 datasets analyzed: May '17 - April '23

Number of detectors surviving the data production chain: ~914 (avg) per dataset

Total exposure for 0νββ decay search
2039.0 kg yr TeO_2,
567.0 kg yr ^{130}Te

Base cuts + AC + PSD/PCA: Total efficiency 93.4(2)%
Choose M1 events for main 0νββ search
Energy resolution at 2615 keV FWHM = 7.540(24) keV

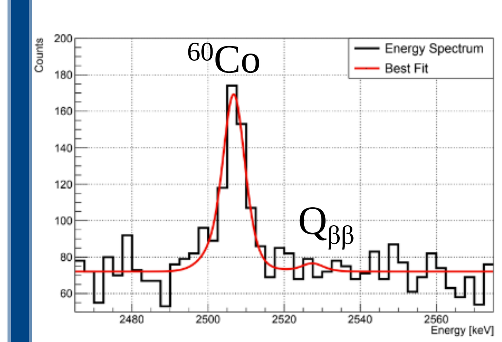


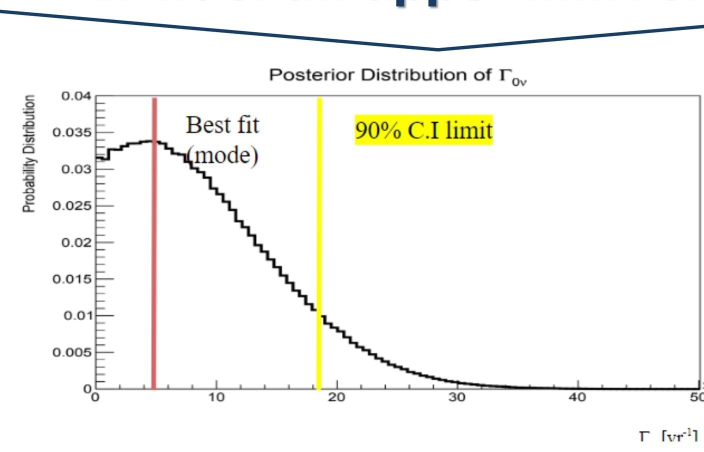
^{130}Te 0νββ decay search

0νββ peak search on unblinded data:

- Fit of the unblinded data
- Systematics: include nuisance parameters (efficiencies, energy bias …)

No evidence of signal at Qββ in ROI. Posterior of Γ0ν
→ Extract an upper limit on Γ0ν





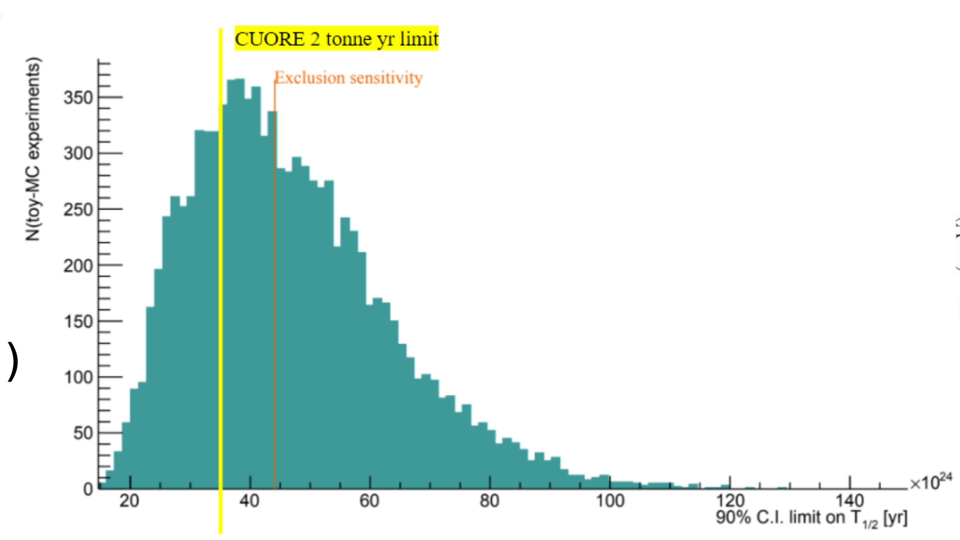
$T_{0\nu}^{1/2}$ (^{130}Te) > 3.8x10^{25} yr
(90%C.I. including syst.)
(new most stringent limit for ^{130}Te)

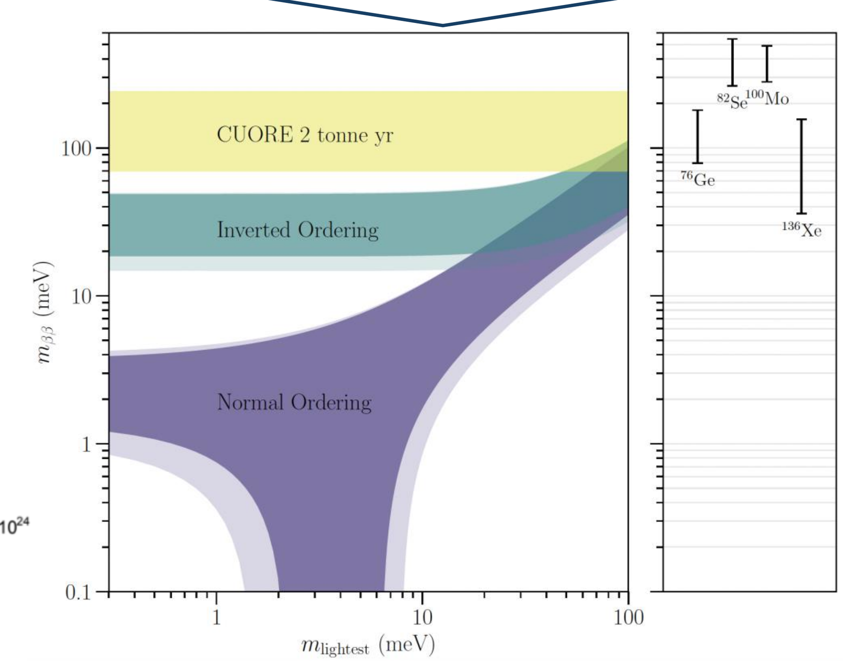
Frequentist limit:
$T_{1/2}$ > 3.7x10^{25} yr (90% C.L.)

New CUORE 0νββ ^{130}Te decay $T_{1/2}$ limit with 2 tonne year exposure

Compare with 2 tonne yr sensitivity: $S_{0\nu}^{1/2}$ (^{130}Te) = 4.4 × 10^{25} yr (90%CI);
Probability to get a more stringent limit given the current sensitivity: 67%

Limit on the effective Majorana mass, assuming light Majorana neutrino-exchange: $m_{\beta\beta}$ < 70-240 meV





Evaluating the background index in ROI

Fit ROI of unblinded data with bkg-only hypothesis
BI ~ (1.42 ± 0.02) x 10^{-2}cts/(keV kg yr) [*avg, exposure weighted*]

References

- Adams D. et al. (CUORE collaboration), *Nature* 604 (2022) 7904, 53-58, https://www.nature.com/articles/s41586-022-04497-4
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