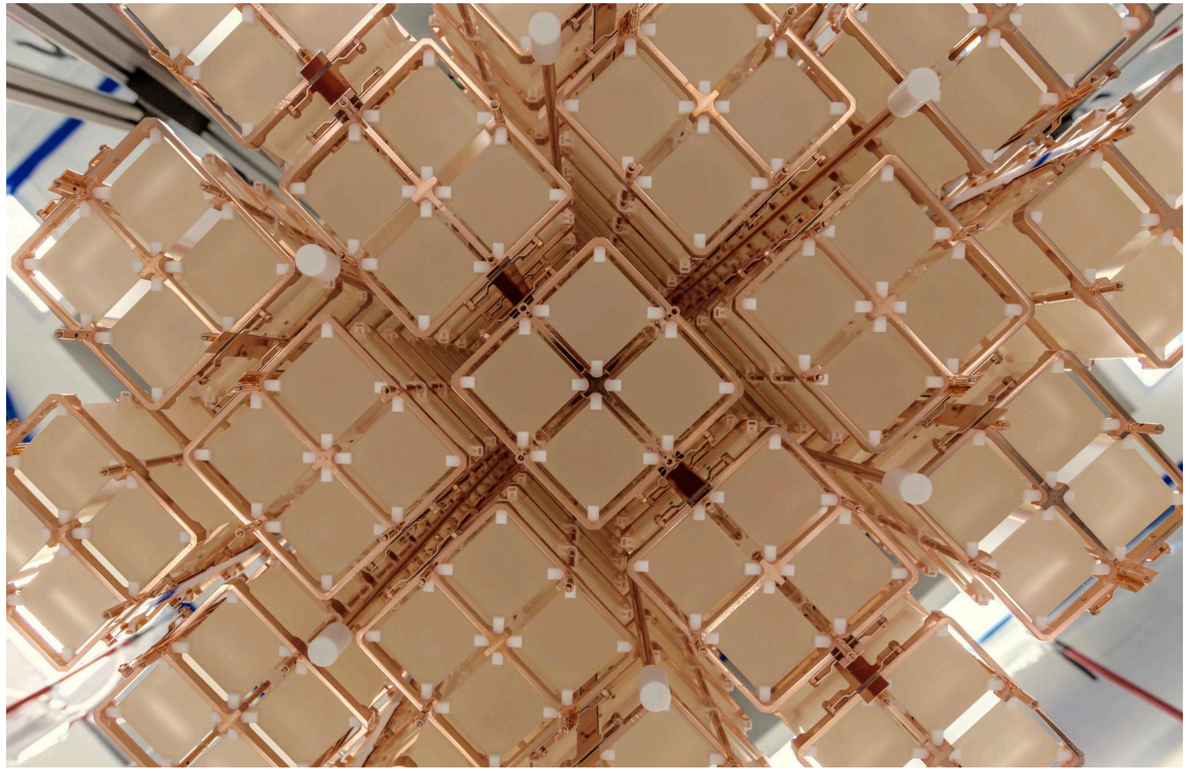


The search for $0\nu EC\beta^+$ decay of ^{120}Te with CUORE

Alice Campani for the CUORE collaboration
Università di Genova and INFN

Università di Genova

CUORE

INFN
Istituto Nazionale di Fisica Nucleare

The CUORE experiment for the search of neutrinoless double beta decay

- Allowed for even-even nuclei
- Beyond Standard Model: $\Delta L = 2$, Majorana neutrinos
- Useful information on the neutrino mass scale/hierarchy
- Matter/antimatter asymmetry via leptogenesis

- Half-life limits 10^{25} - 10^{26} y
- Several decay modes, we focus on

$(A, Z) + e^- \rightarrow (A, Z-2) + e^+ \quad (0\nu\beta^+EC)$

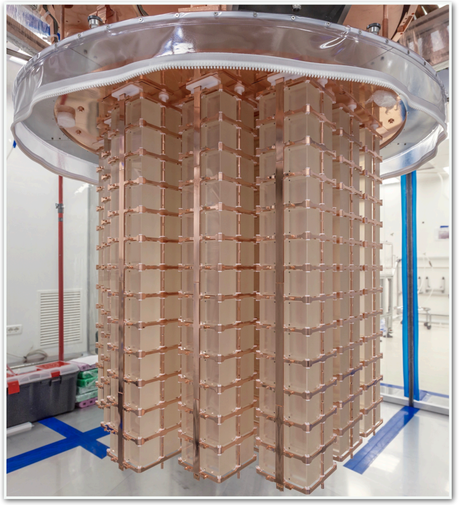
Phys. Rev. C 87 057301 (2013)

CUORE: **C**ryogenic **U**nderground **O**bservatory for **R**are **E**vents

- **Main scientific goal** search for $0\nu\beta\beta$ decay of ^{130}Te (isotopic abundance ~34%, $Q_{\beta\beta} \simeq 2527$ keV)
- **Bolometric technique** 988 TeO_2 crystals grouped in 19 towers, Adv. in High En. Phys. 2015 (2015), 879871
- **Tonne-scale detector** 742 kg of TeO_2, 206 kg of ^{130}Te
- **Effective energy resolution** (7.0 ± 0.4) keV FWHM at $Q_{\beta\beta}$
- **Background index** $(1.38 \pm 0.07) \cdot 10^{-2} \ \frac{\text{counts}}{\text{keV} \cdot \text{kg} \cdot \text{yr}}$ at $Q_{\beta\beta}$
- **Located underground at LNGS in Italy:**
  3600 m we rock, muon flux is $\sim 10^{-6}\ \Phi_\mu$ at sea level
- **Half-life sensititivity** (5y livetime): $S^{0\nu}_{T_{1/2}} = 9 \cdot 10^{25}$ y (90% C.L.), Eur. Phys. J C77 (2017), 532

Latest results on $0\nu\beta\beta$ of ^{130}Te:
Phys. Rev. Lett. 124, 122501 (2020)

See the talk from **Guido Fantini**
"The latest results from the CUORE experiment"
[presentation material]

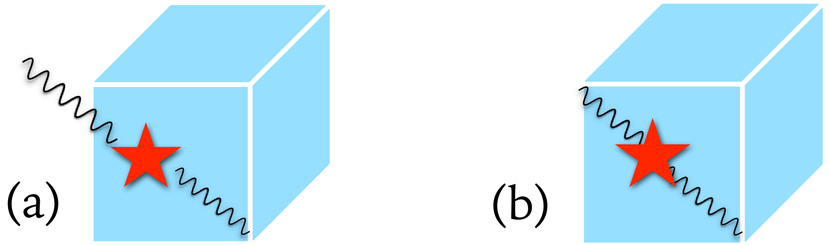


Neutrinoless positron emitting electron capture ($0\nu EC\beta^+$) decay of ^{120}Te in CUORE

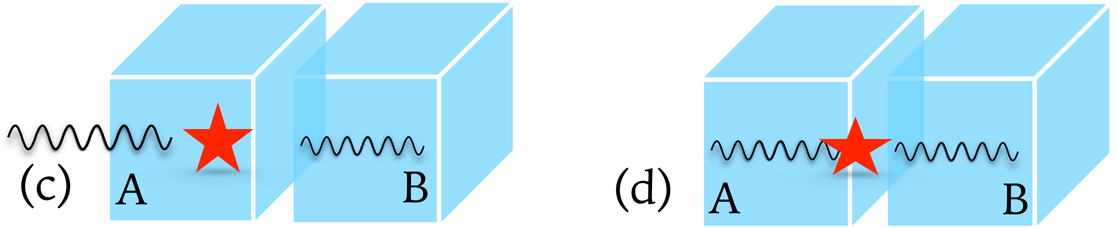
$$^{120}\mathrm{Te} + e_b^- \rightarrow {}^{120}\mathrm{Sn} + \beta^+ + X$$
$$\rightarrow {}^{120}\mathrm{Sn} + 2\gamma_{511} + X$$

Kinematics

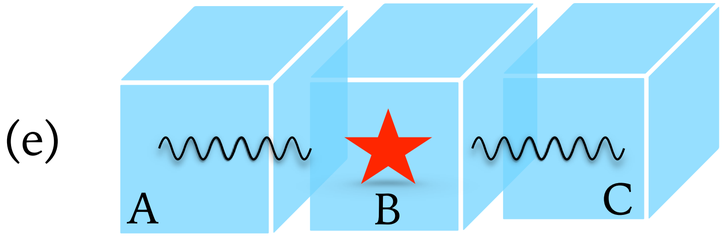
- ^{120}Sn de-excites via X-ray/Auger e^- emission
- $Q = 1714.8$ keV
  $K_{\beta^+} + E_b = Q - 2m_e = 692.8$ keV
- Several decay signatures within CUORE detector
  depending on where particles are absorbed:
  - the positron β^+ ⟷ ★
  - the 511 keV γs ⟷ 〰



1-crystal scenarios: either 1 γ escape (a), or full containment (b)

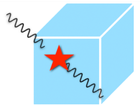
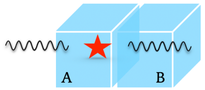
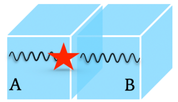
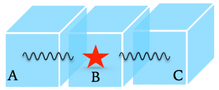


2-crystals scenarios:
A sees β^+ & B sees a γ (c), A detects $\beta^+ + \gamma$ & B sees other γ (d)



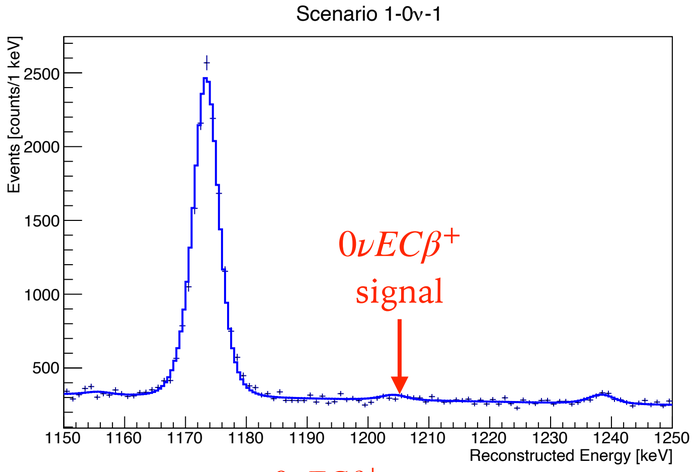
3-crystals scenario: full decay event containment
each particle is absorbed by a different channel

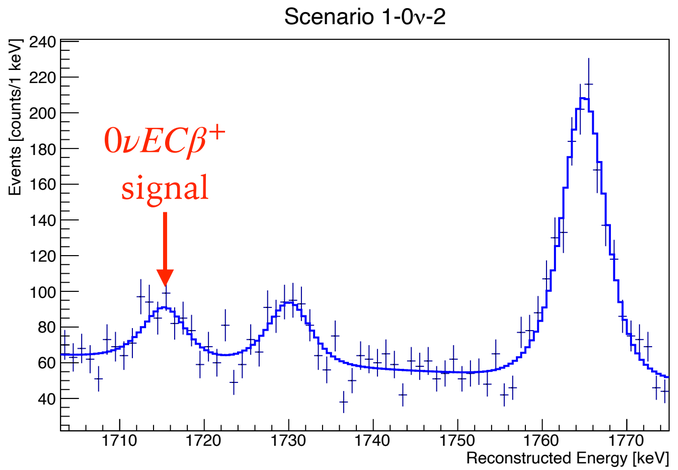
The search for $0\nu EC\beta^+$ decay of ^{120}Te with CUORE: Method

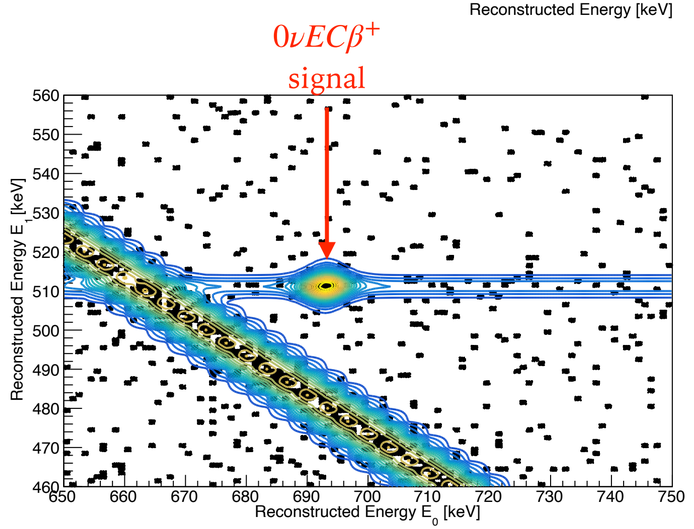
Scenario	Particles detected	**#crystals involved**	**Energy ranges** $\Delta E_0 \dots \Delta E_{n-1}$ **[keV]**	**Containment efficiency** [ε]	$\frac{\varepsilon}{\sqrt{BI}}$ $\left(\text{BI} = \left[\frac{1}{\text{keV kg yr}}\right]\right)$
	$\beta^+ + \gamma$	**1**	[1150,1250]	**12.86%**	**0.14**
	$\beta^+ + \gamma_1 + \gamma_2$	**1**	[1703,1775]	**13.10%**	**0.33**
	β^+ on xtal A γ on xtal B	**2**	[650,750], [460,560]	**3.90%**	**0.33**
	$\beta^+ + \gamma_1$ on xtal A γ_2 on xtal B	**2**	[1150,1250], [460,560]	**13.54%**	**3.39**
	γ_1 on xtal A β^+ on xtal B γ_2 on xtal C	**3**	[650,750],[460,560], [460,560]	**2.06%**	**1.96**

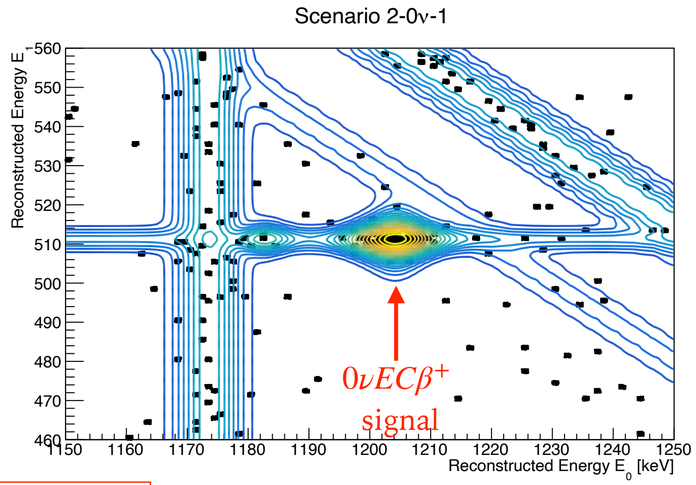
- **MC simulations** to evaluate containment efficiency
- **Bkg identification** and spectra modeling based on **blinded data** and CUORE background model [arXiv:2012.11749]
- **Simultaneous spectral fit** of the 5 scenarios - **Bayesian** analysis developed with BAT
- Fit algorithm defined and intensively tested on **blinded data**

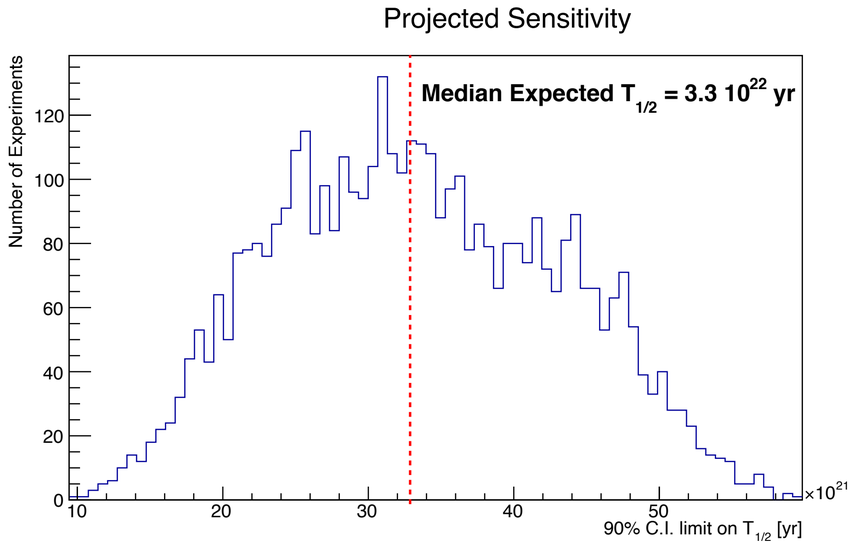
The search for $0\nu EC\beta^+$ decay of ^{120}Te with CUORE: Results











Major improvement in the
median exclusion sensitivity

$$S^{0\nu}_{T_{1/2}} = 3.3 \cdot 10^{22}\ \mathrm{y}$$

a factor ~10 increase compared to CUORE-0 result
[Phys. Rev. C 97, 055502 (2018)]

Next steps:

Blinded fits

- Evaluation of the systematic effects (11% uncertainty on the ^{120}Te isotopic abundance) and data unblinding!