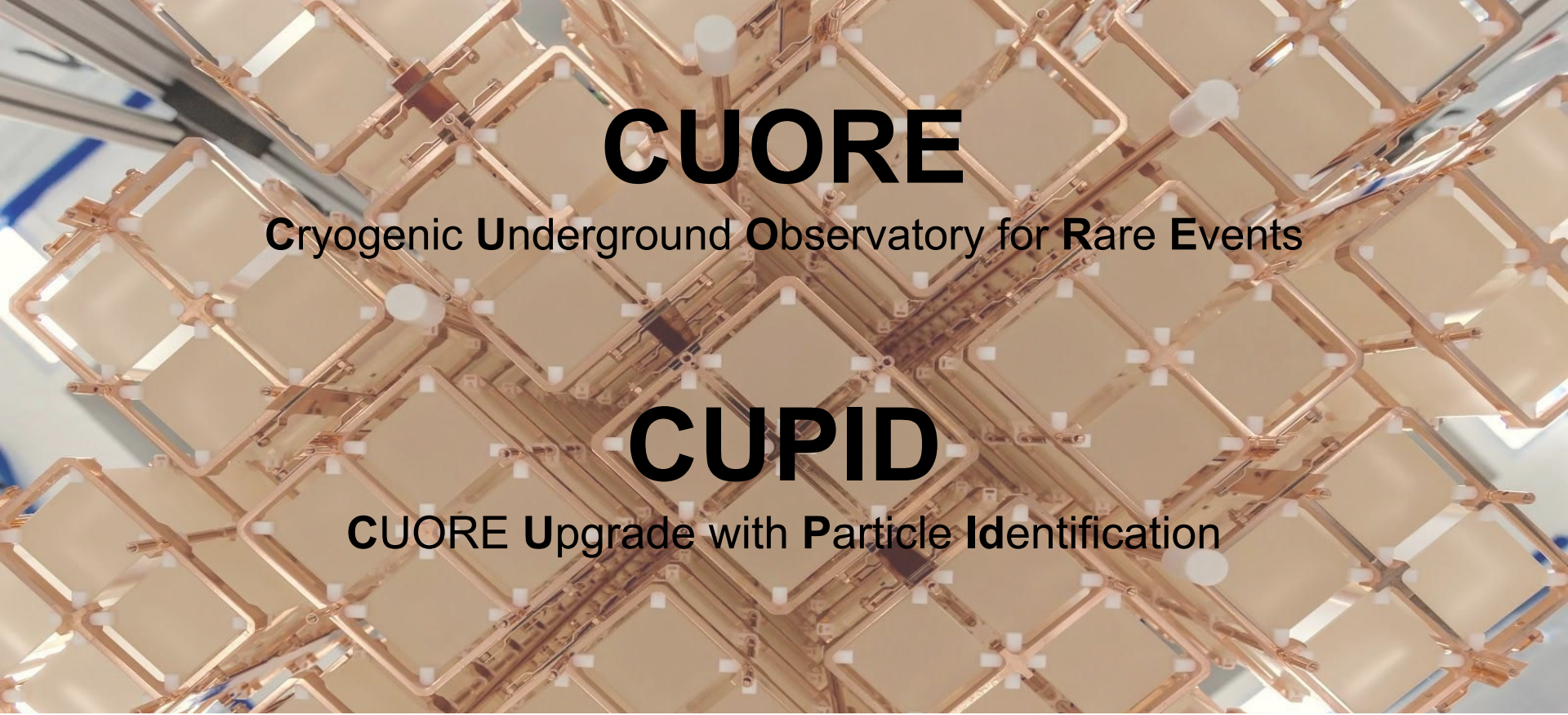


CUORE

Cryogenic **U**nderground **O**bservatory for **R**are **E**vents

CUPID

CUORE **U**pgrade with **P**article **Id**entification

Bologna - Assemblea di Sezione
Giulio Benuzzi
28/03/2022

CUORE CUPID

INFN
Istituto Nazionale di Fisica Nucleare

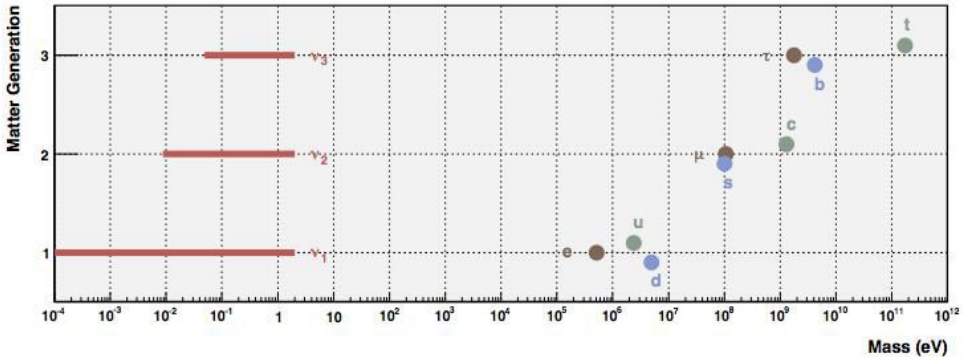
Motivazioni Teoriche

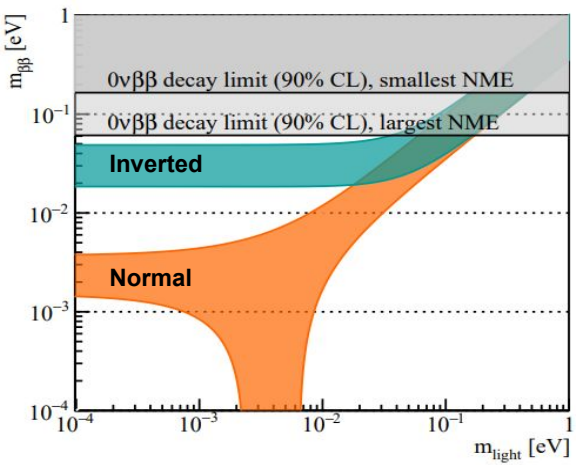
<u>Proprietà Conosciute</u>:

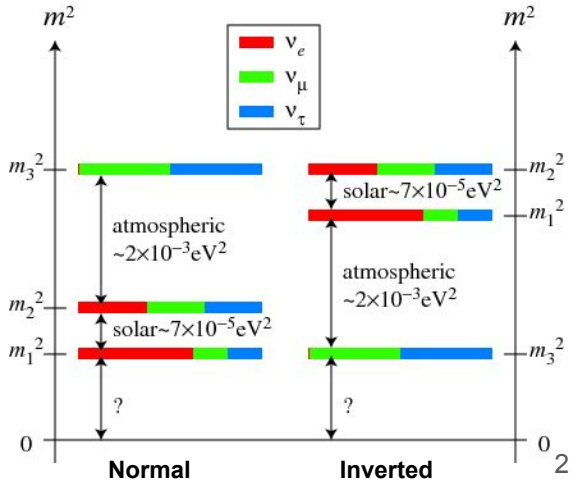
- Neutrini sono **dotati di massa**
- Possibili **oscillazioni**

<u>Domande ancora aperte</u>:

- Origine e scala assoluta della massa
- Gerarchia di massa o *mass ordering*
- Violazione CP
- Neutrini sterili
- **Natura del neutrini?**







CUORE CUPID

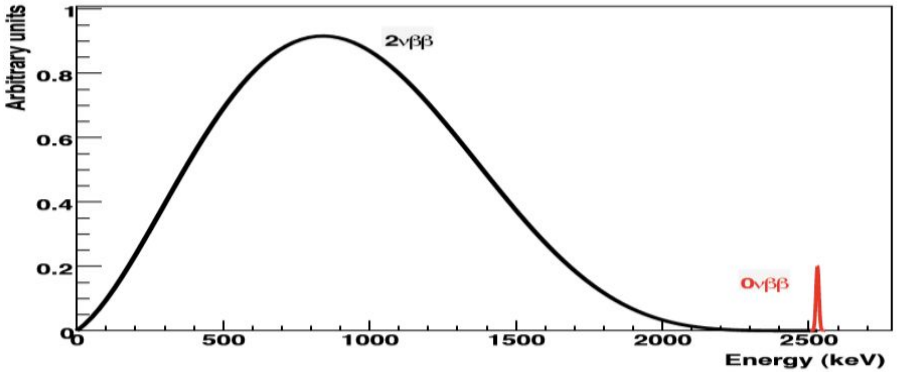
Natura dei Neutrini

- Particella di **Dirac** → Descritti teoricamente come tutti gli altri fermioni predetti dal SM
- Particella di **Majorana** → Neutrino = Anti Neutrino

Neutrini unica possibilità nel SM dato che elettricamente neutri

Doppio decadimento β senza neutrini ($0\nu\beta\beta$)

$$ {}^{A}_{Z}X \rightarrow {}^{A}_{Z+2}X + 2e^{-} $$



Esempio Spettro Energetico degli elettroni emessi per $^{130}Te \rightarrow {}^{130}Xe + 2e^{-}$

Decadimento estremamente raro

$T_{1/2} > 10^{25}$ anni

CUORE CUPID

Osservabile Sperimentale e Possibili Informazioni

NB: il $0\nu\beta\beta$ decay non è mai stato osservato sperimentalmente

<u>Se venisse osservato avremmo</u>:

- **Conferma** che Neutrino è particella di Majorana
- Primo processo con variazione del numero leptonico (non possibile nel SM)
- Info su gerarchia di massa e scala assoluta

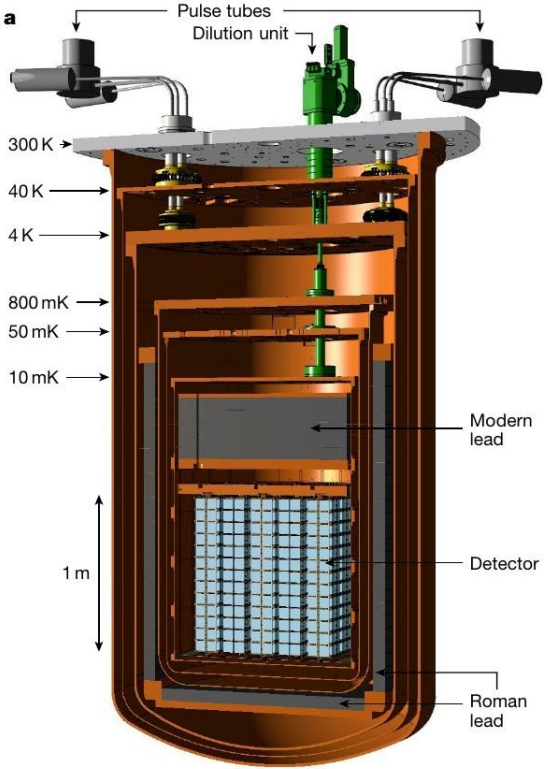
$$(T_{1/2}^{0\nu})^{-1} = G^{0\nu}(Q,Z)\,|M_{nucl}^{0\nu}|^2\,\frac{\langle m_{\beta\beta}^2 \rangle}{m_e^2}$$

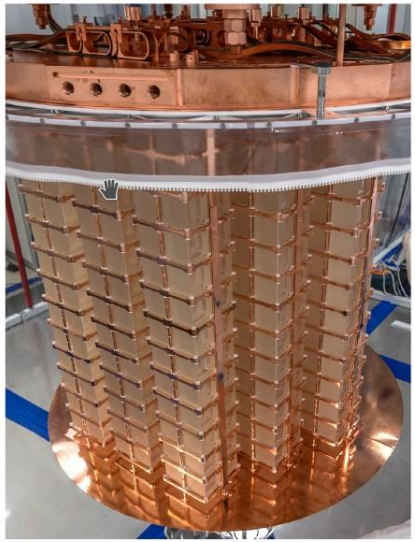
semivita — Spazio delle fasi (calcolato) — elemento di matrice nucleare (calcolato)

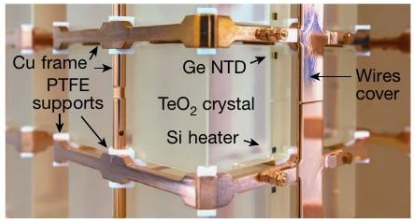
massa "effettiva" di Majorana

Dipende dalla massa dei neutrini e dal loro mixing

L'Esperimento CUORE







Article

Search for Majorana neutrinos exploiting millikelvin cryogenics with CUORE

https://doi.org/10.1038/s41586-022-04497-4
Received: 14 April 2021
Accepted: 1 February 2022
Open access
Check for updates

The CUORE Collaboration*

The possibility that neutrinos may be their own antiparticles, unique among the known fundamental particles, arises from the symmetric theory of fermions proposed by Ettore Majorana in 1937[1]. Given the profound consequences of such Majorana neutrinos, among which is a potential explanation for the matter–antimatter asymmetry of the universe via leptogenesis[2], the Majorana nature of neutrinos commands intense experimental scrutiny globally; one of the primary experimental probes is neutrinoless double beta ($0\nu\beta\beta$) decay. Here we show results from the search for $0\nu\beta\beta$ decay of ^{130}Te, using the latest advanced cryogenic calorimeters with the CUORE experiment[3]. CUORE, operating just 10 millikelvin above absolute zero, has pushed the state of the art on three frontiers: the sheer mass held at such ultralow temperatures, operational longevity, and the low levels of ionizing radiation emanating from the cryogenic infrastructure. We find no evidence for $0\nu\beta\beta$ decay and set a lower bound of the process half-life as 2.2×10^{25} years at a 90 per cent credibility interval. We discuss potential applications of the advances made with CUORE to other fields such as direct dark matter, neutrino and nuclear physics searches and large-scale quantum computing, which can benefit from sustained operation of large payloads in a low-radioactivity, ultralow-temperature cryogenic environment.

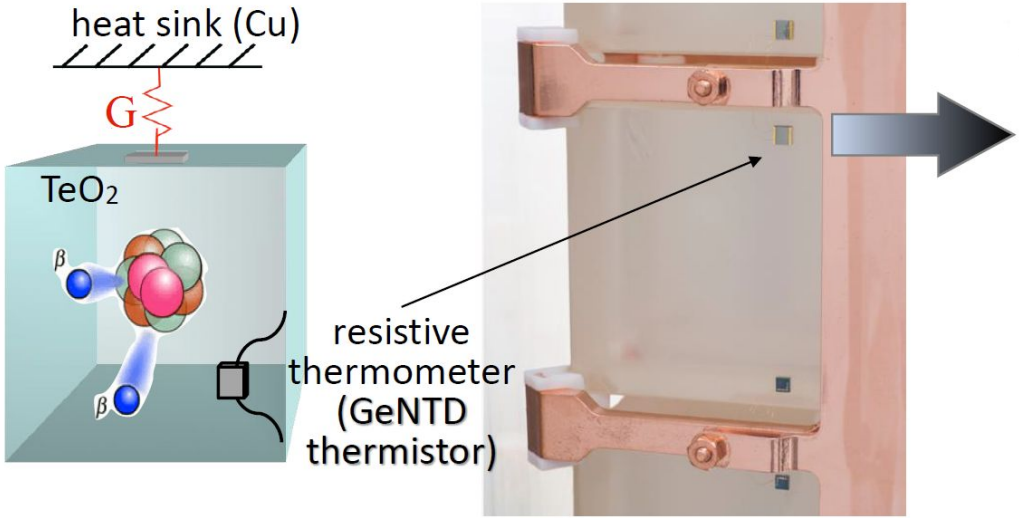
Accettato da Nature!

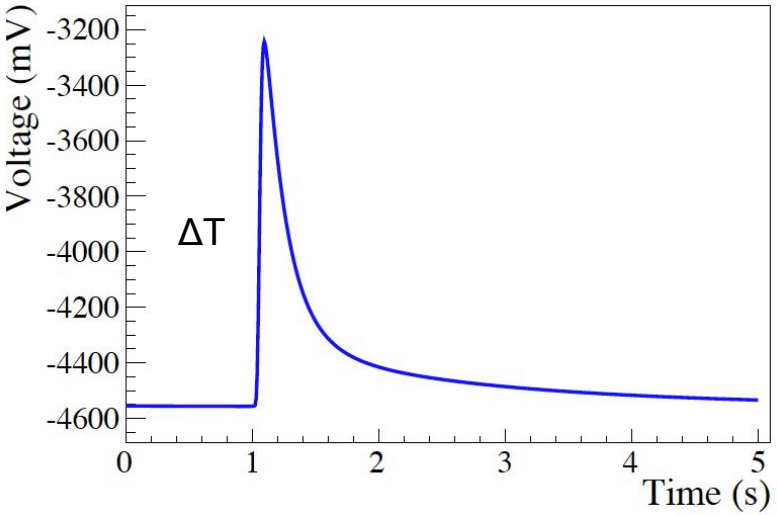
CUORE CUPID

La Tecnica Bolometrica

Il cristallo è anche il rivelatore! ⟶

- Contiene l'isotopo
- Assorbe energia
- Aumenta di temperatura



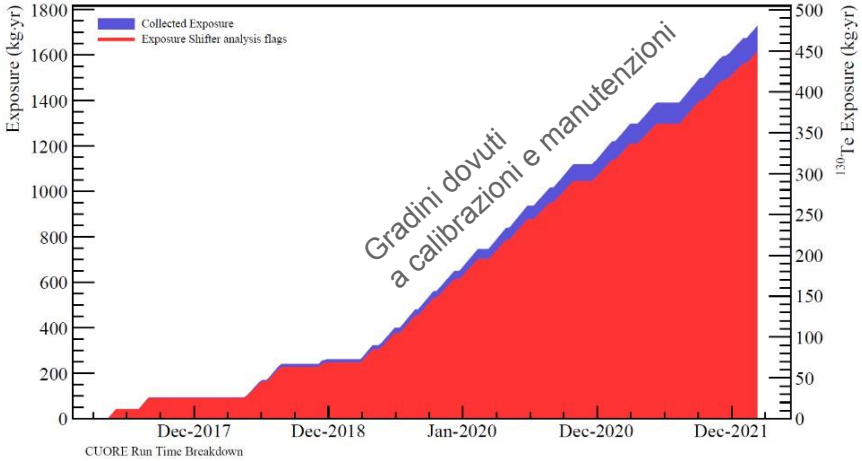


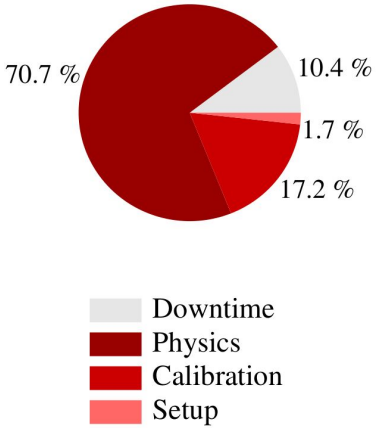
- Elevata efficienza e risoluzione in energia
- No identificazione particelle

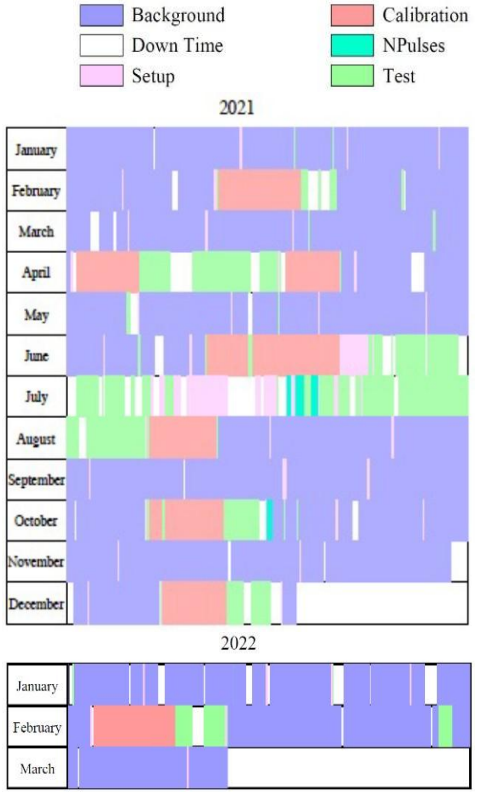
$$\Delta T \sim \frac{E}{C} e^{-t/\tau}$$

CUORE CUPID

Performance del Detector







Esposizione accumulata: 1730 kg·yr
Risoluzione @ $Q_{\beta\beta}$: ~7.8 keV FWHM
Background @ $Q_{\beta\beta}$: $1.5 \cdot 10^{-2}$ cts/keV/kg/yr

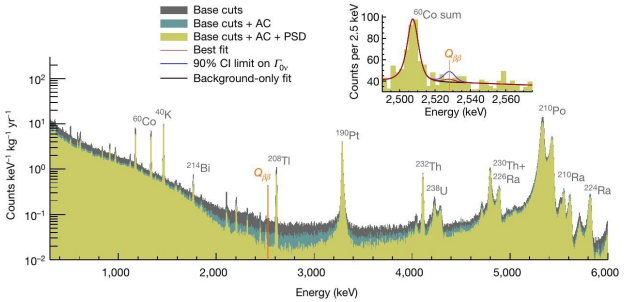
CUORE CUPID

Risultati Recenti

$T_{1/2} > 2.2 \cdot 10^{25}$ yr $\longrightarrow$ $m_{\beta\beta} < 90\text{-}305$ meV

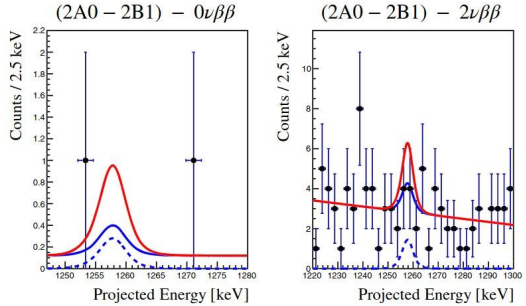
arXiv:2104.06906

Decadimento $0\nu\beta\beta$ del ^{130}Te



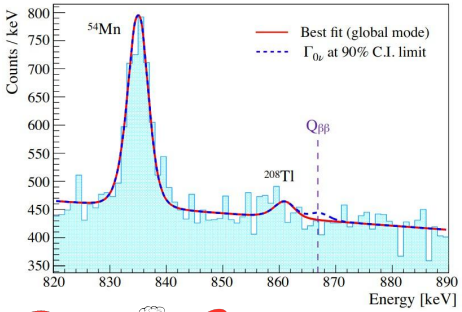
Accettato da Nature

Decadimento $0\nu\beta\beta$ e $2\nu\beta\beta$ del ^{130}Te su stati eccitati



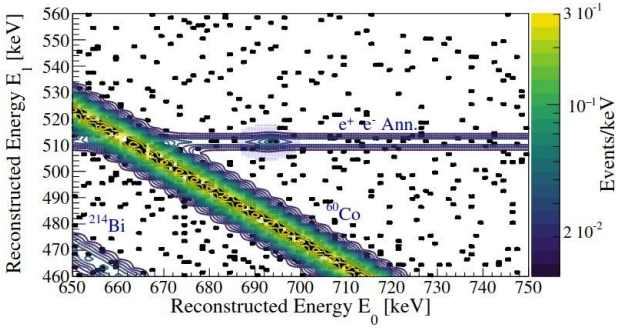
Pubblicato su EPJC (2021) 81:567

Decadimento $0\nu\beta\beta$ del ^{128}Te



Quasi pronto per la sottomissione

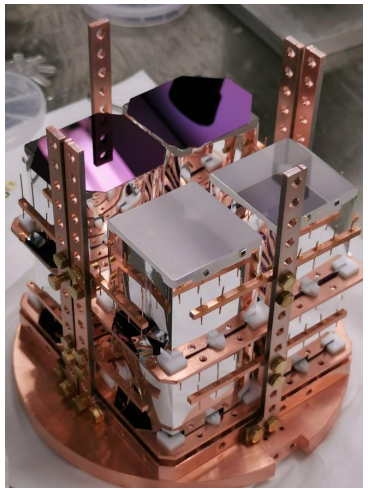
Decadimento $0\nu\beta^{+}$EC del ^{120}Te

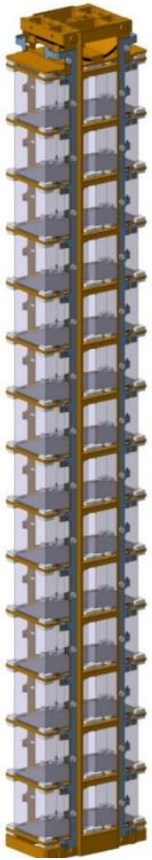


In fase di sottomissione arXiv:2203.08684

CUORE CUPID

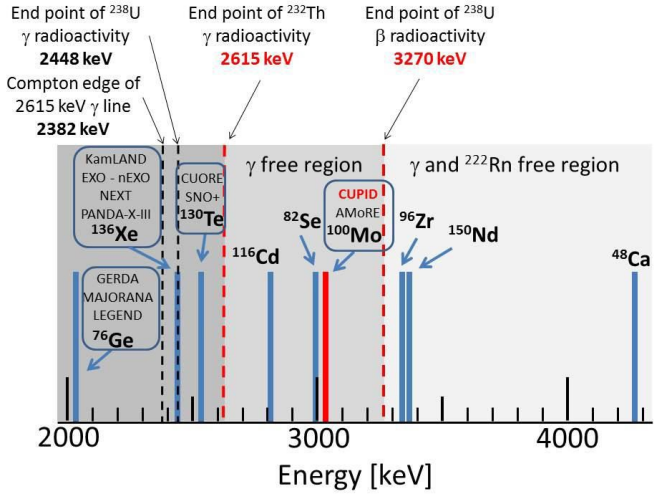
L'Esperimento CUPID

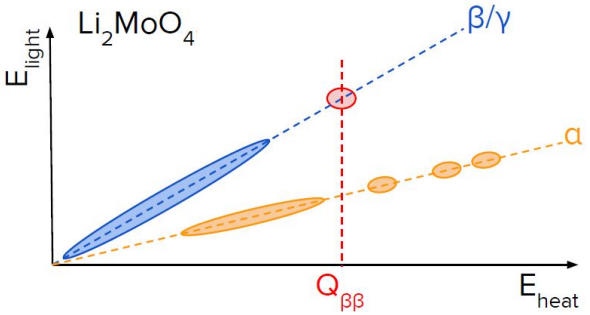




- Infrastruttura di CUORE
- Nuovo Rivelatore
- Cristalli di Molibdeno (~270 Kg)
- $Q_{\beta\beta}$ più alto (3034 keV)
- **Particle ID**

- Discriminazione α vs β/γ
- Reiezione del fondo grazie a segnali luminosi e di calore



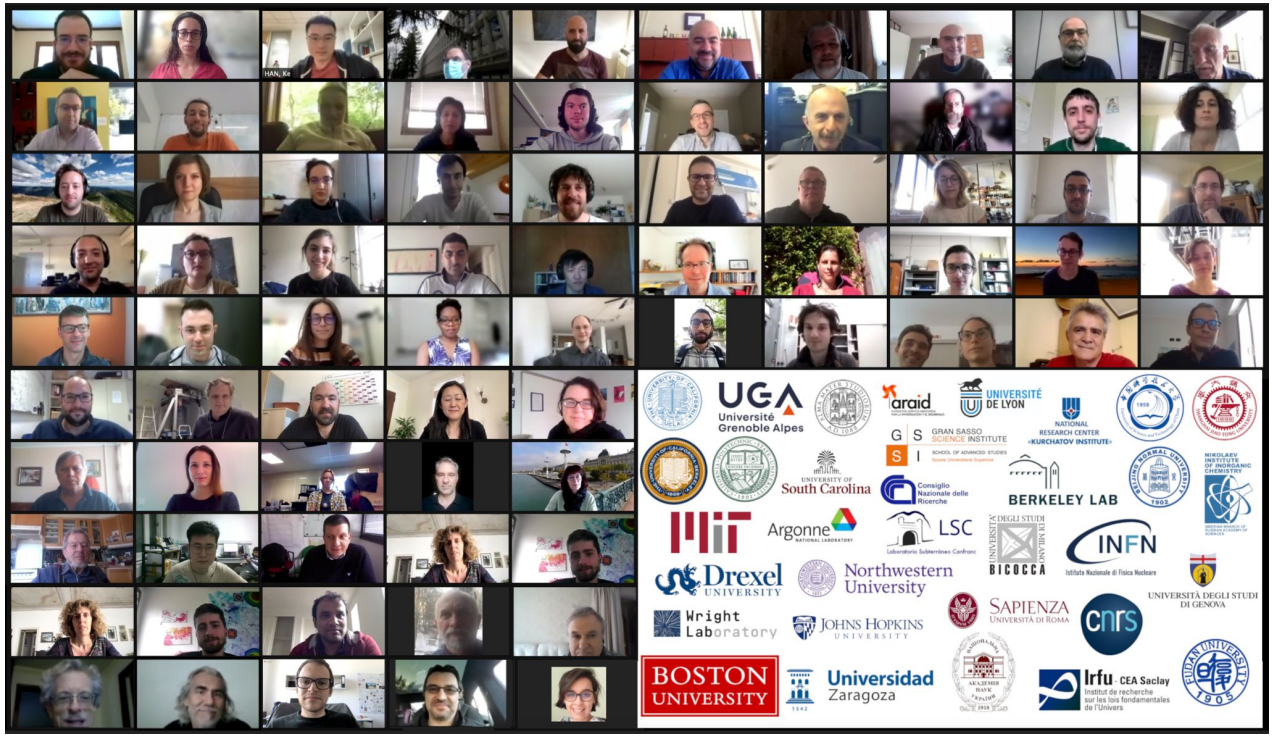


CUORE CUPID

La Collaborazione

- Più di 100 ricercatori e ricercatrici
- Da oltre 20 istituzioni

<u>Bologna</u>:
Giacomo Bari*
Giulio Benuzzi*
Antonio Chiarini
Francesca Del Corso*
Cristina Guandalini
Marco Guerzoni
Mauro Lolli
Stefano Zucchelli*

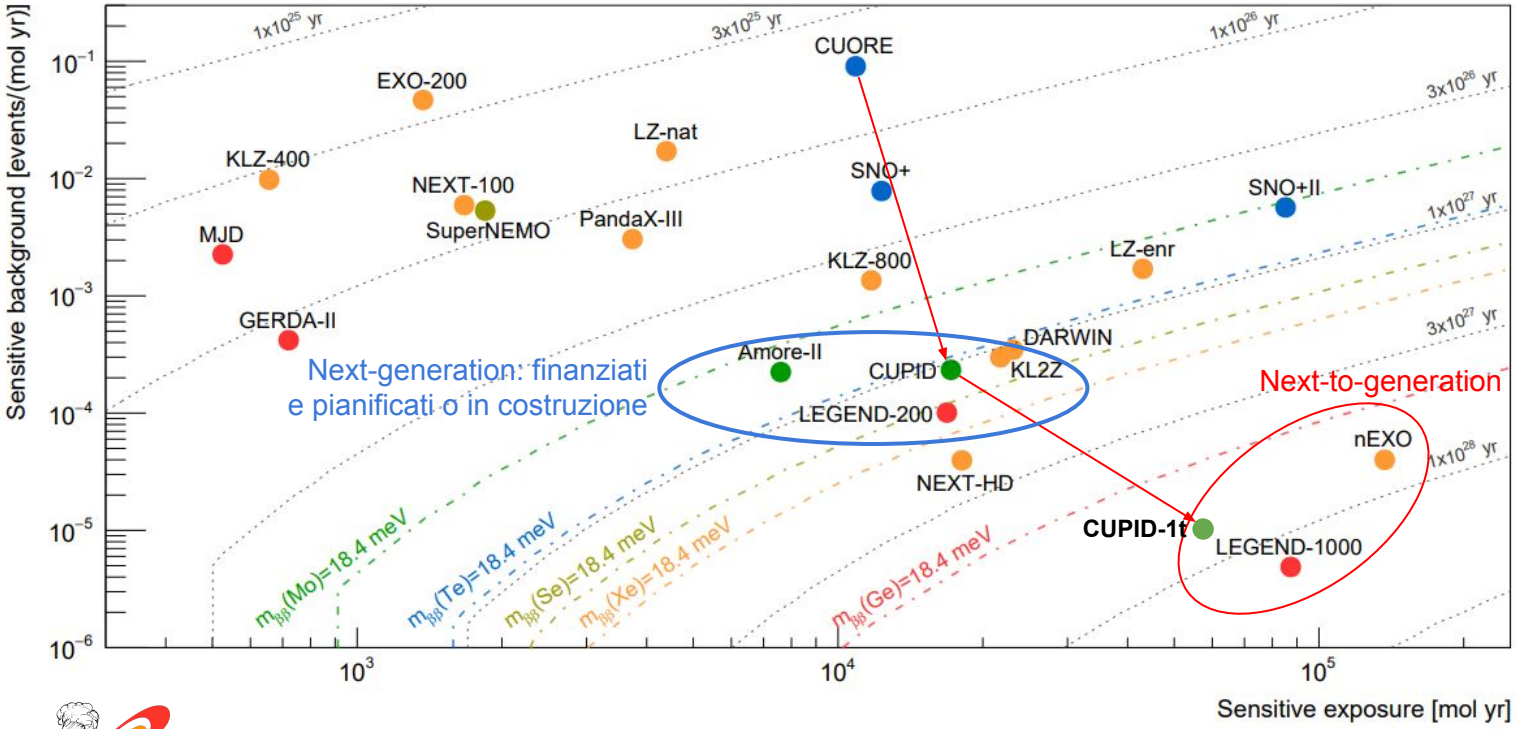


Collaboration Meeting, Maggio 2021.

*: firmatari

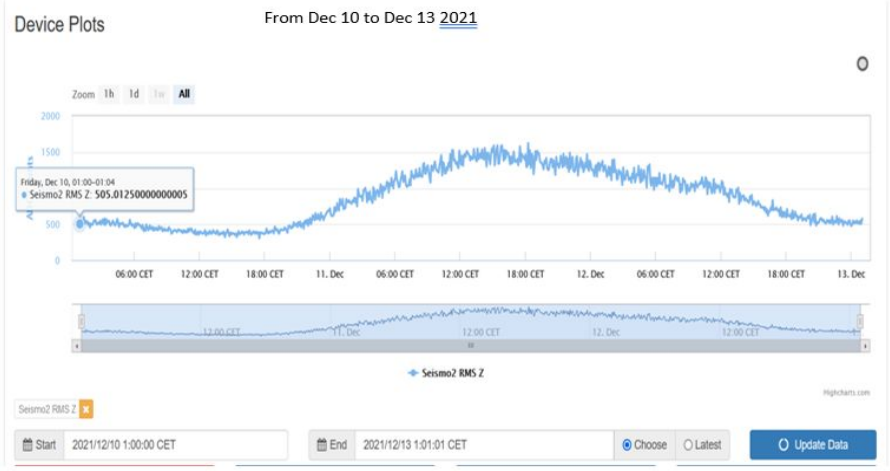
Risultati e Update

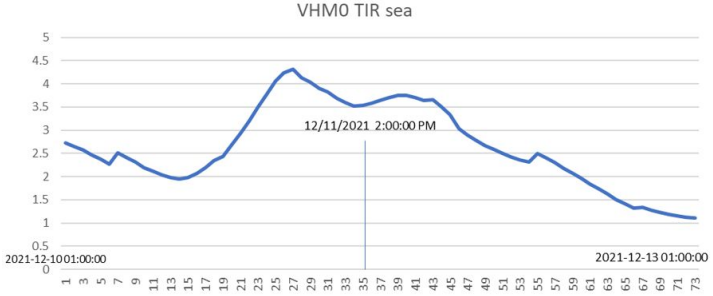
https://arxiv.org/abs/2202.01787

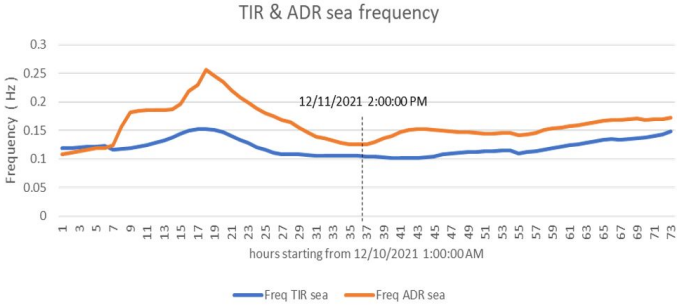


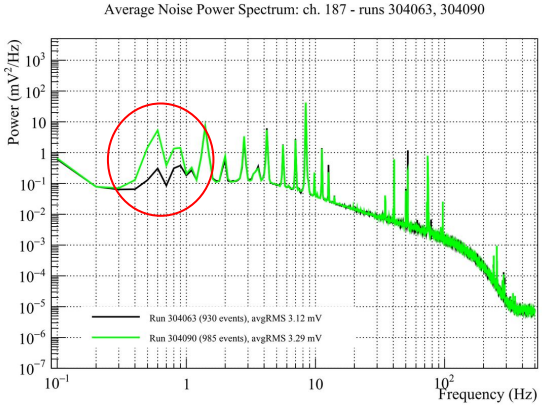
- Abbassamento del fondo di 3 ordini di grandezza

Attività di Bologna - Sismometria





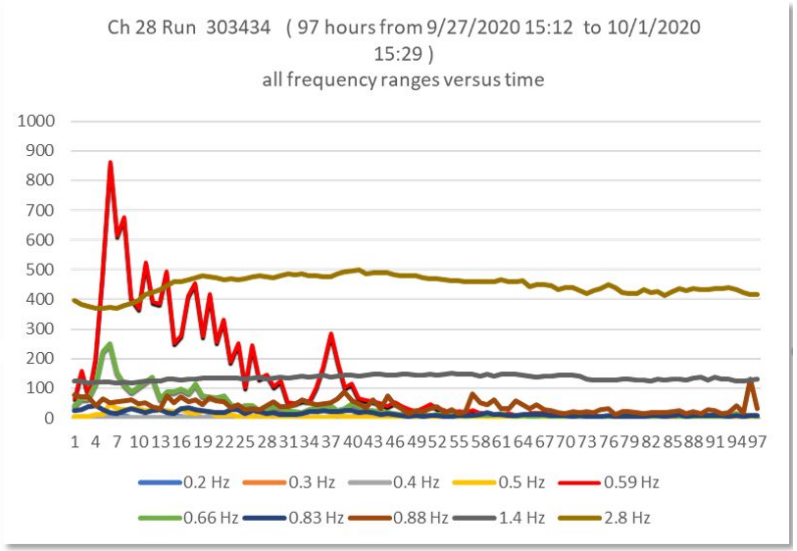


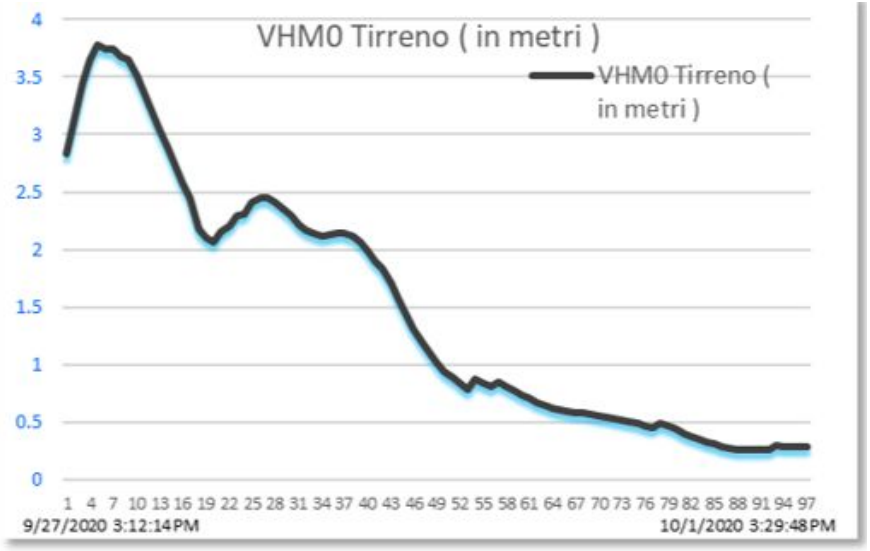


- Nero: Avg noise PSD con mare calmo
- Verde: Avg noise PSD con mare mosso

Attività di Bologna - Sismometria

Work in Progress

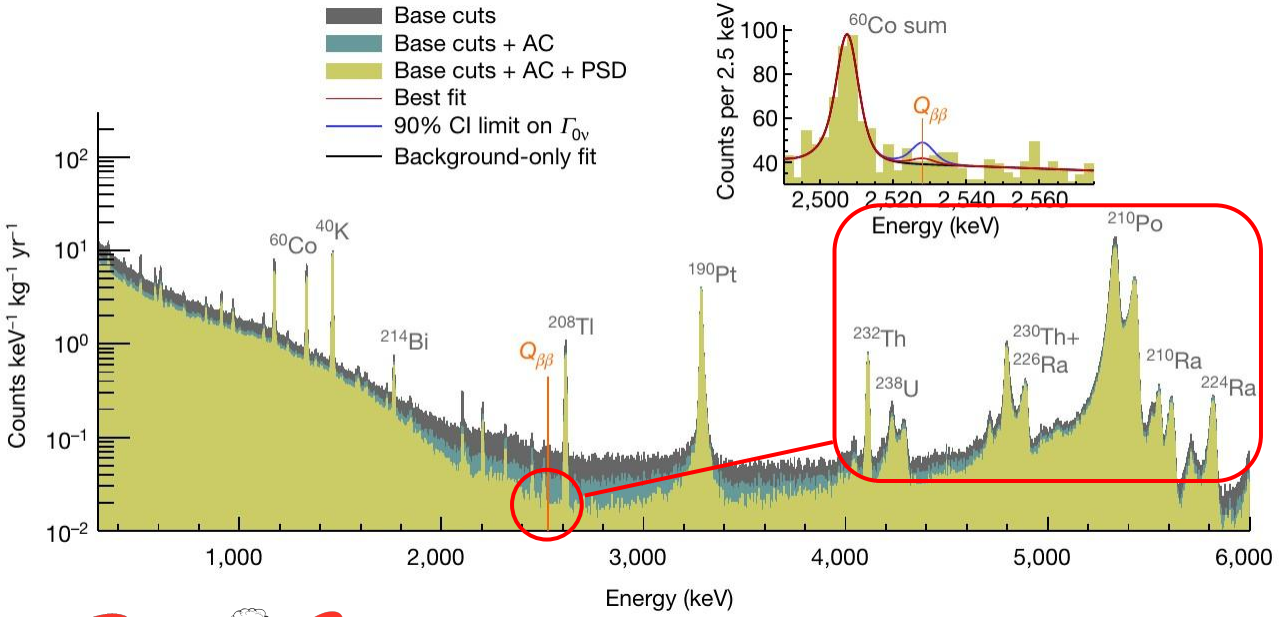


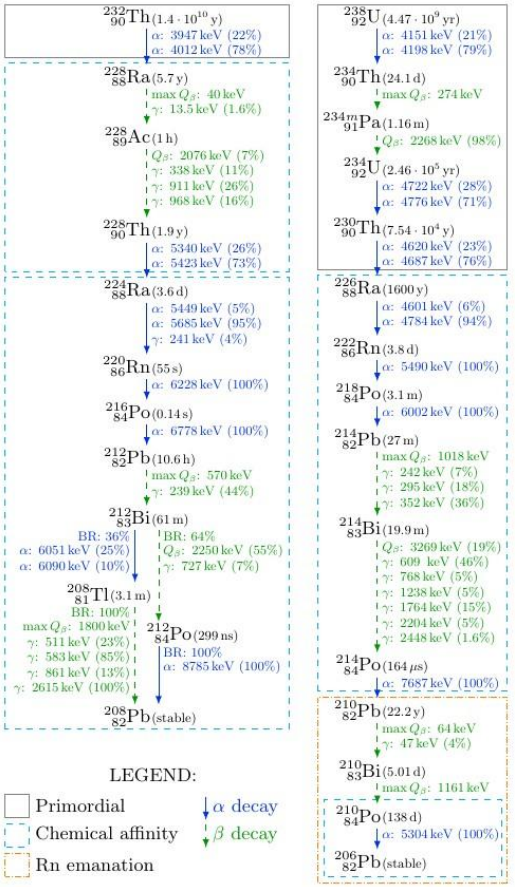


- Fondo dipendente dal tempo.
- Possibile miglioramento della risoluzione in energia del 5-10%.
- Importante per CUPID e per altre ricerche a basse energie (e.g. DM).

CUORE CUPID

Misurazione Contaminazioni con Coincidenze Ritardate



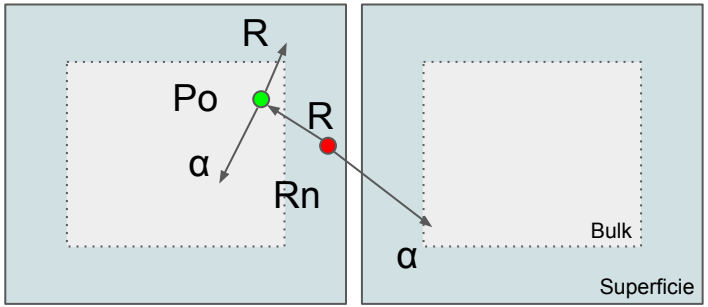


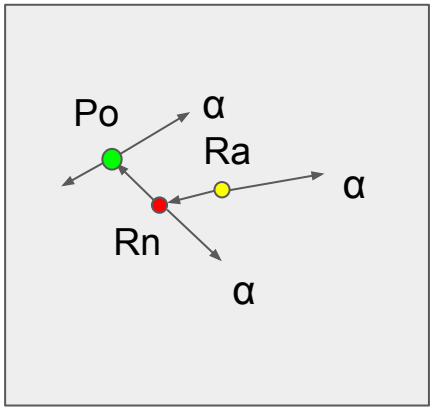
CUORE CUPID

Misurazione Contaminazioni con Coincidenze Ritardate

Contaminazioni di Torio e Uranio

M2 ^{222}Rn
M1 ^{218}Po



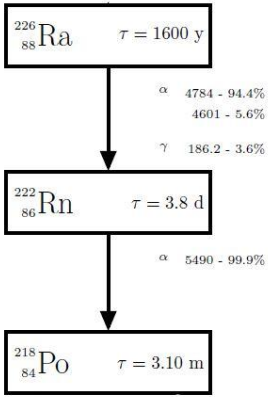


Tripletto M1

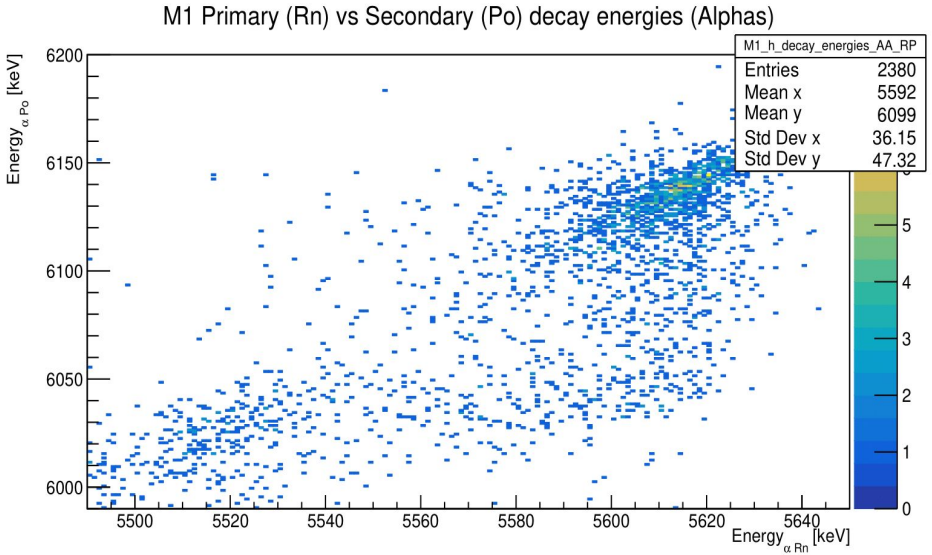
<u>Motivazioni</u>

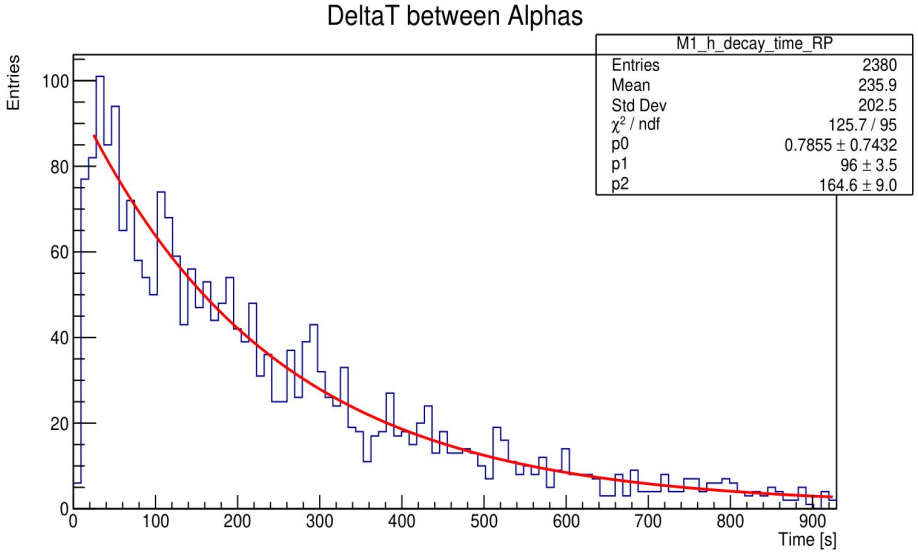
- Informazioni per il Background Model
- Miglioramento della precisione delle proiezioni per CUPID

Parte della catena di decadimento ^{238}U



Misurazione Contaminazioni con Coincidenze Ritardate





$$A = s/(\varepsilon_{MC} \cdot \varepsilon_{analysis} \cdot area \cdot t)$$

Misurazione Contaminazioni con Coincidenze Ritardate

In collaborazione con Toby Dixon (Paris-Saclay)

Coincidenze Ritardate per stima riduzione del fondo

<u>To Do List</u>:

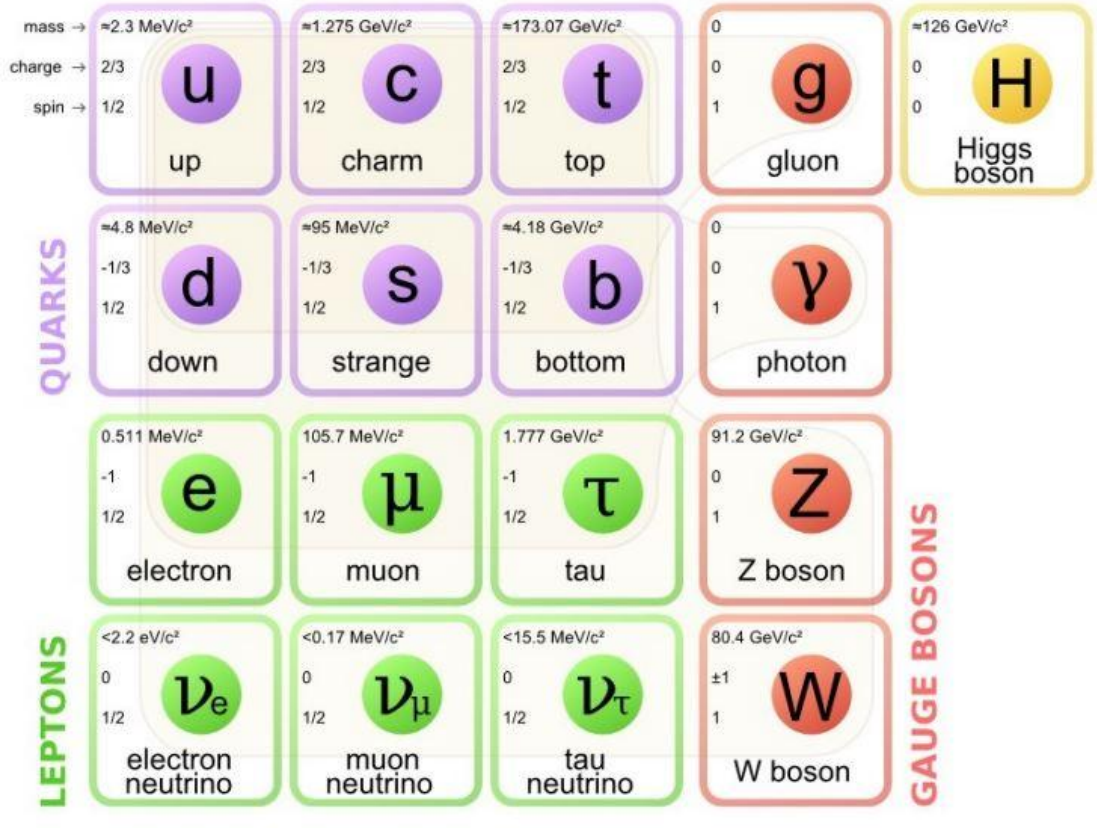
- Proseguire la mia analisi di coincidenze anche più complesse da ricostruire e appartenenti a diverse catene di decadimento (^{232}Th, ^{235}U).
- Estrarre le contaminazioni.

<u>Possibilità Future</u>:

- Continuare questa analisi durante il dottorato.
- Applicare quanto imparato da CUORE a CUPID per contribuire attivamente alla ricerca.

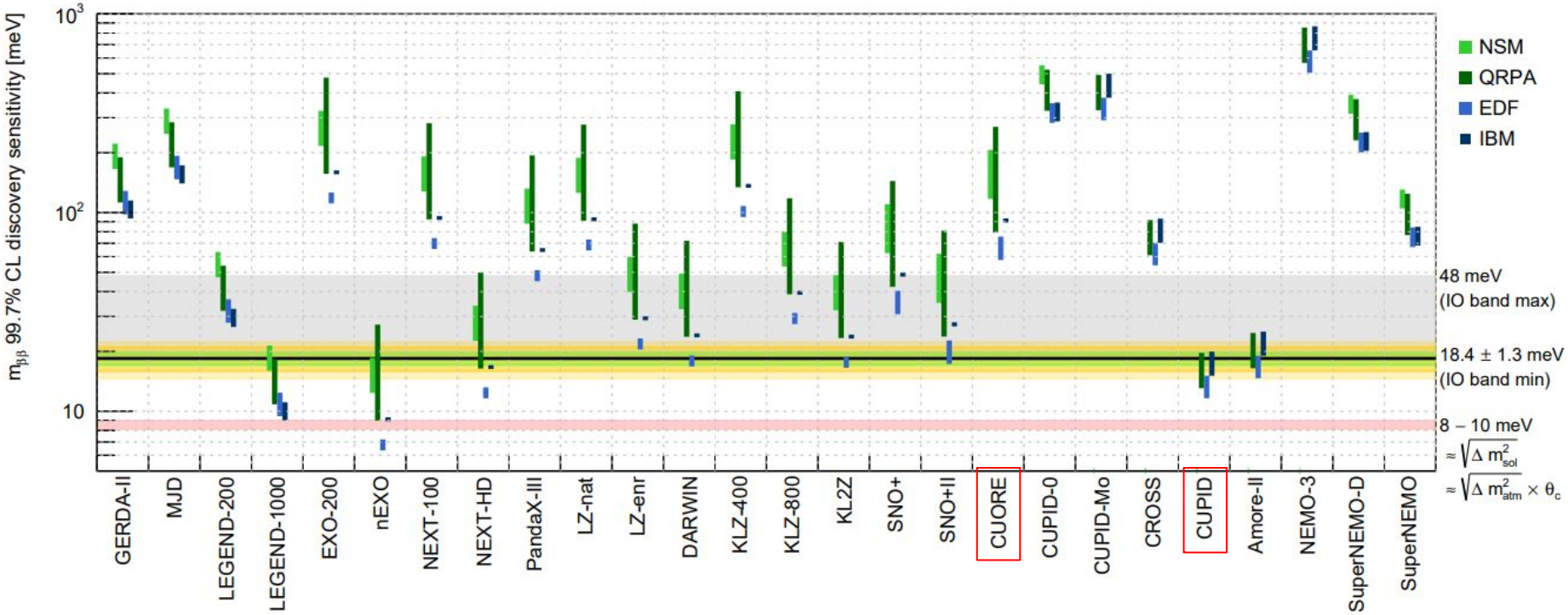
Contatti: giulio.benuzzi@studio.unibo.it o giulio.benuzzi@bo.infn.it

BACKUP - Standard Model

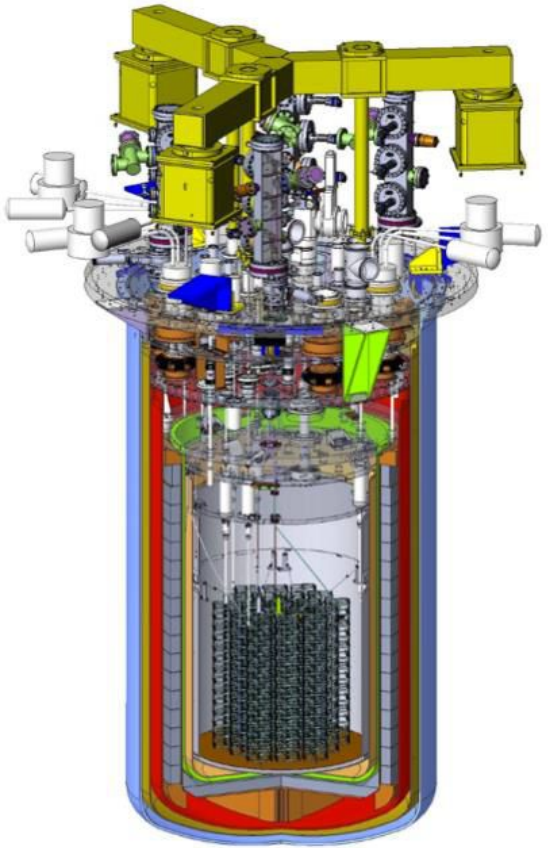


BACKUP - Discovery Sensitivity

https://arxiv.org/abs/2202.01787



BACKUP - CUPID



BACKUP - La Collaborazione

Collaboration Meeting, Sestri Levante, Maggio 2019.