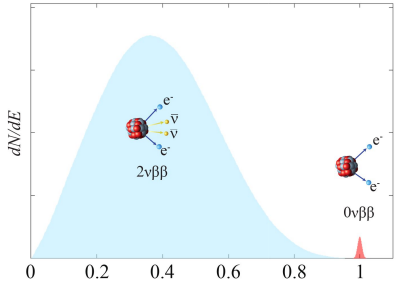
CUPID

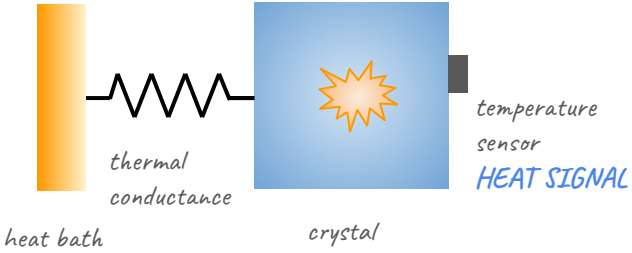
CUORE Upgrade with Particle IDentification

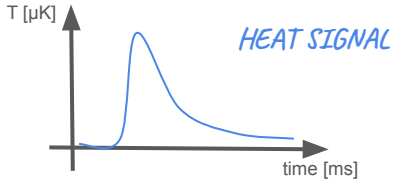
14th International Spring Seminar on Nuclear Physics, Ischia (Italy) May 2025

Maura Pavan - CUPID

Why cryogenic calorimeters for 0νββ ?



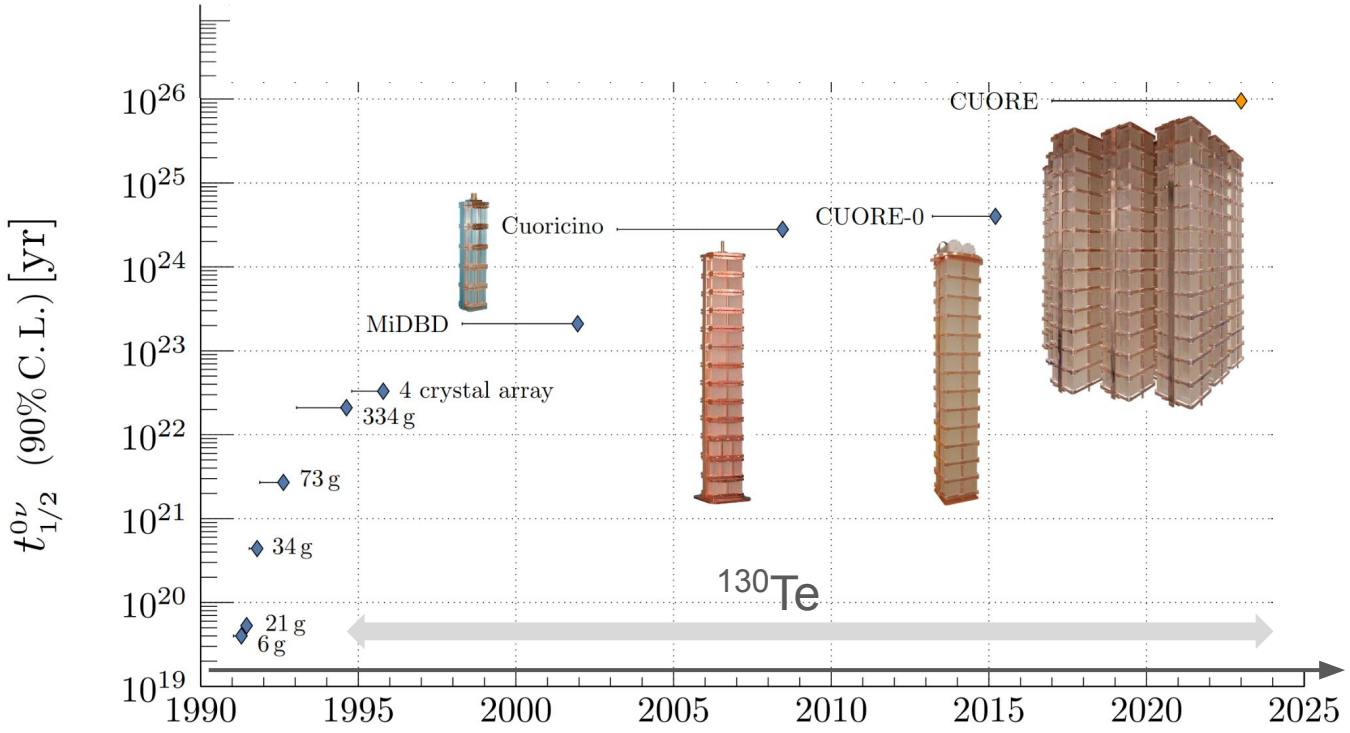




key features for 0νββ searches

- energy resolution ~0.1-0.2 % FWHM @ 3 MeV
  0νββ signal identified by E = $Q_{\beta\beta}$
- crystal embeds the ββ source
- flexibility: same technique can be used with different isotopes
  - choose the isotope according to $Q_{\beta\beta}$, NME, phase space
  - cross check a 0νββ claim on a different isotope

Past Present and Future of 0νββ with bolometers



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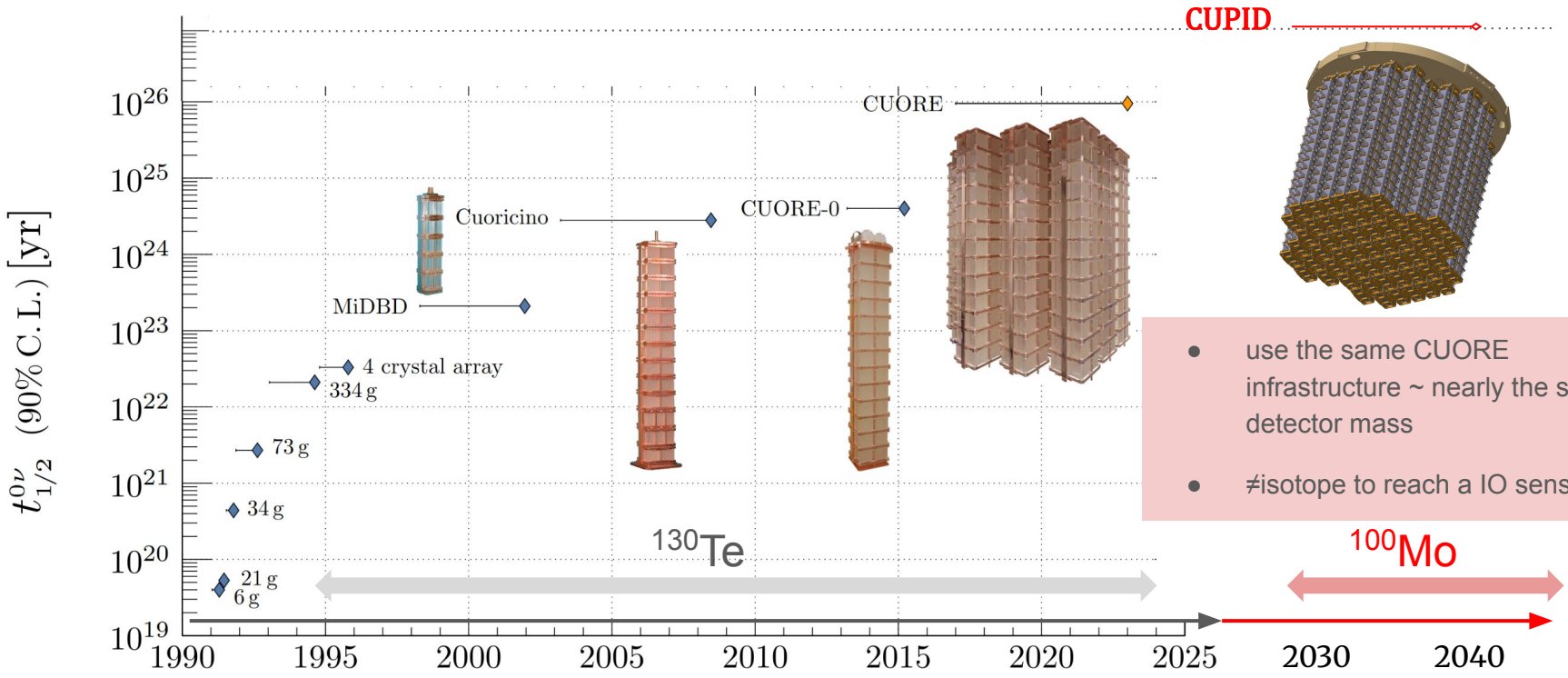


- use the same CUORE infrastructure ~ nearly the same detector mass
- ≠isotope to reach a IO sensitivity

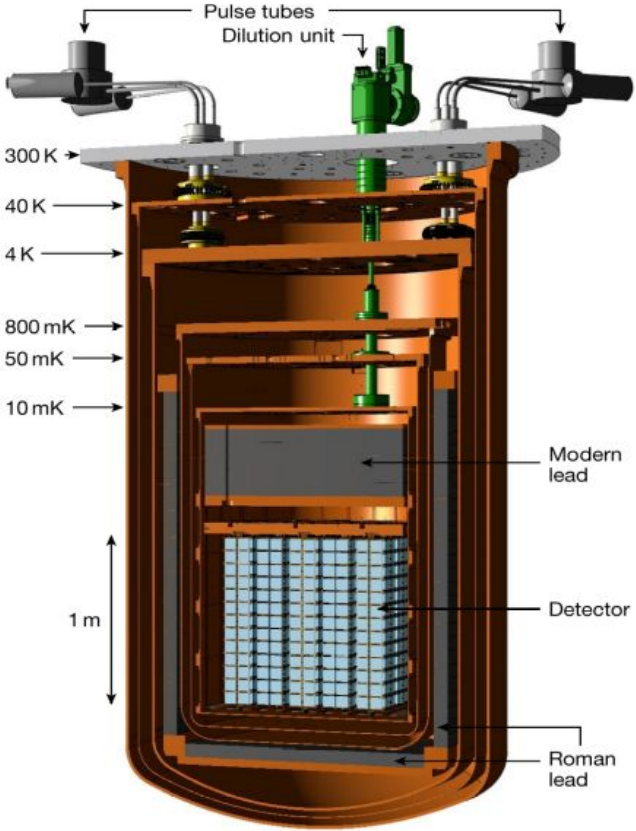
CUORE Upgrade with Particle Identification

CUORE is a closely packed array TeO_2 crystals working @ 10 mK as bolometers, in operation since 2016 @ LNGS (L'Aquila Italy)

- 988 TeO_2 crystals
- 206 kg of ^{130}Te
- $Q_{\beta\beta}$ = 2528 keV
- FWHM = 7.320 ± 0.024 keV
- BI = (1.42 ± 0.02) x 10^{-2} cts/(keV kg yr)

LABORATORI NAZIONALI DEL GRAN SASSO

INFN



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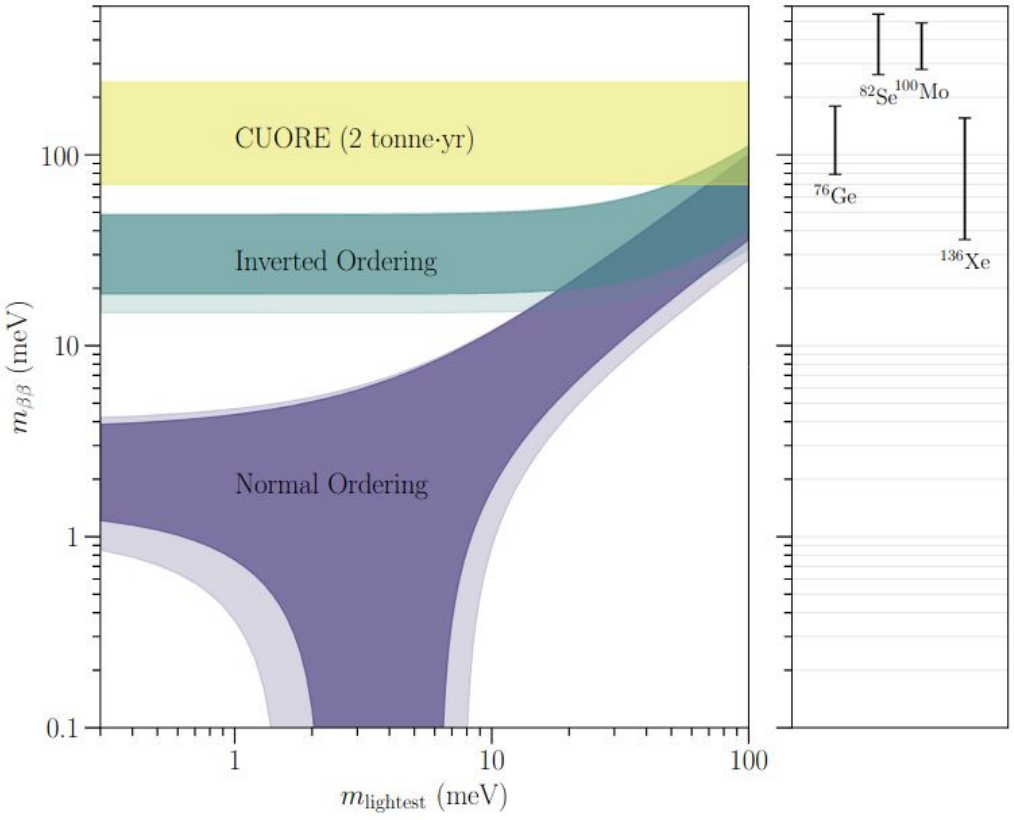

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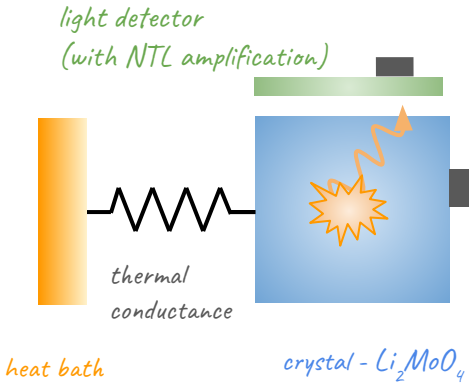
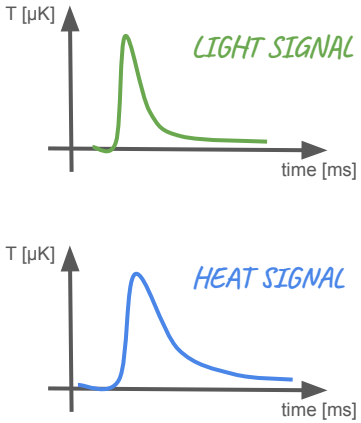
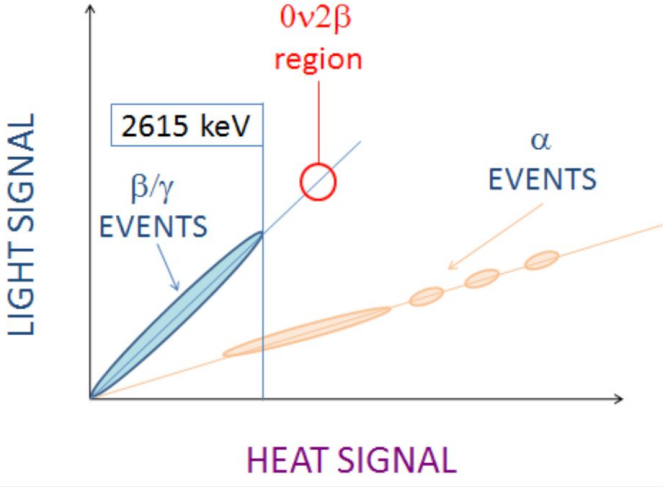
CUPID will be a closely packed array Li_2MoO_4 crystals working @ 10 mK as scintillating bolometers calorimeters, in operation starting from 2030 @ LNGS (L'Aquila Italy)

- 1592 $Li_2{}^{100}MoO_4$ enriched crystals
- 240 kg of ^{100}Mo
- $Q_{\beta\beta}$ = 3034 keV
- FWHM = 5 keV
- BI = 1 x 10^{-4} cts/(keV kg yr) with α rejection

Detector

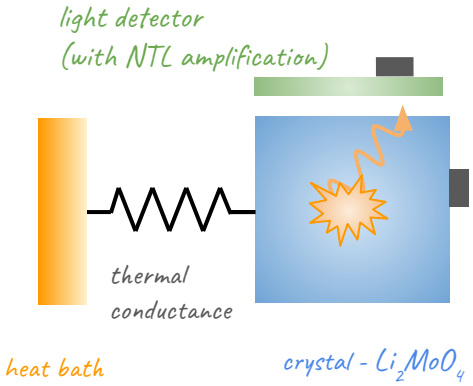


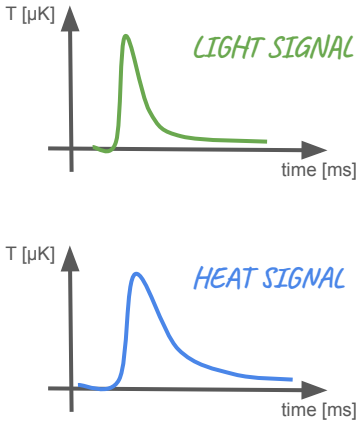


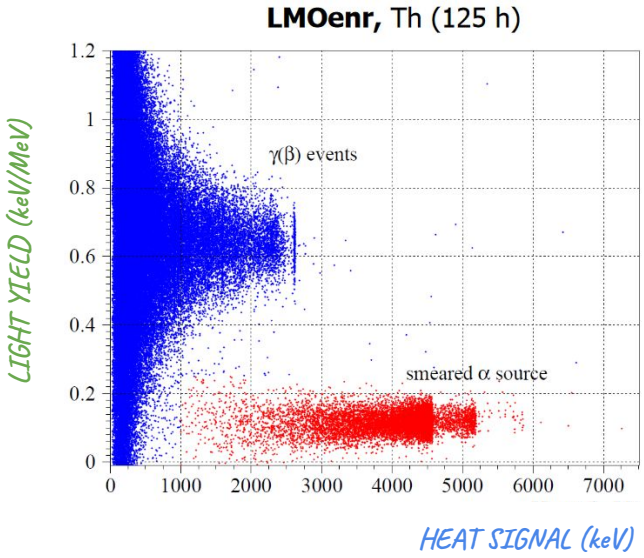


- HEAT→ energy resolution ~5 keV FWHM @ $Q_{\beta\beta}$
- HEAT+LIGHT → α particle rejection > 99.7%
- LIGHT → ^{100}Mo 2νββ pile-up rejection

Detector







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Main systems involved in the upgrade

1) **detector** is the only major change:

- enriched LMO crystals
- light detectors
- mechanical assembly

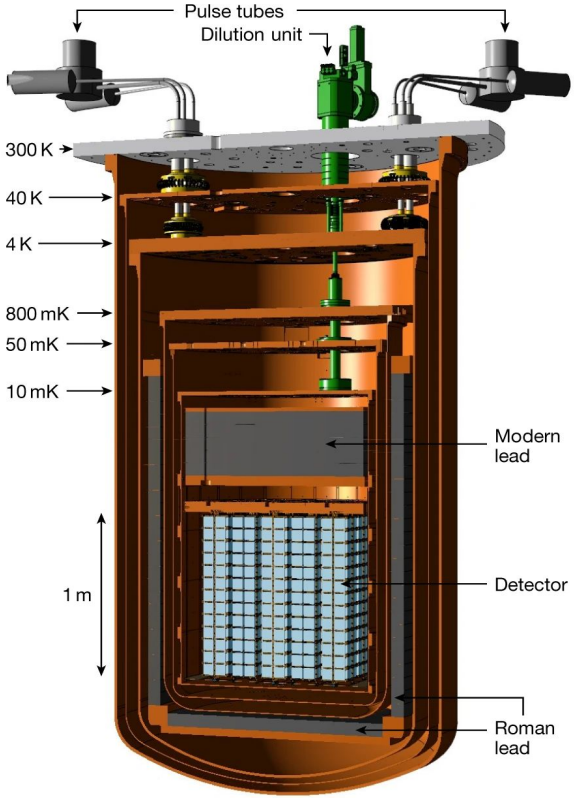
2) **read-out & bias systems**: to meet the needs of higher number of channels

3) **cryostat**: maintenance and upgrade to improve performances, new wiring and new PTs

4) **external shields**:

- muon veto (not existing in CUORE)
- neutron shield (increase thickness)

work in progress on all of them (construction already started)



Work in-progress: enriched crystals

isotope (IPCE China) →**4 kg produced** in 2024 meet our requirements

few grams screened by ICP-MS

- enrichment >98% @LNGS
- U/Th and K @China, LNGS, USA meet requirements

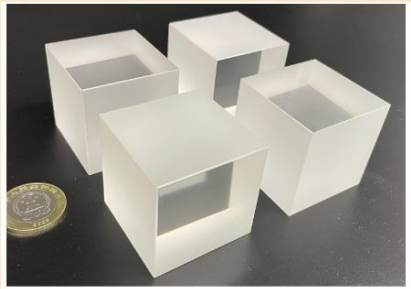
$^{100}MoO_3$ powder requirements

Element	Requirement
^{232}Th	< 0.8 mBq/kg
^{238}U	< 2.5 mBq/kg
^{40}K	< 50 mBq/kg

crystals (SICCAS China) → **pre-production on-going**

goal is to identify a procedure that meets

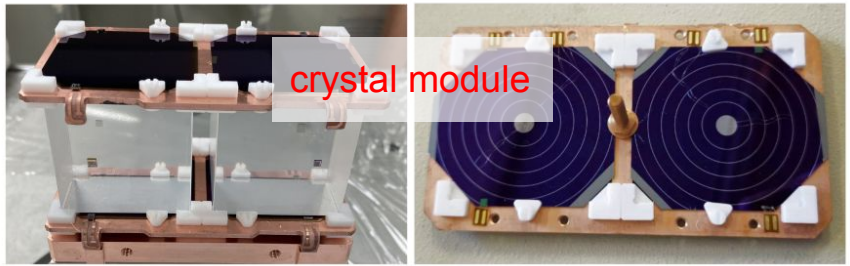
- radiopurity requirements
- low material (isotope) loss during production (< 10%)

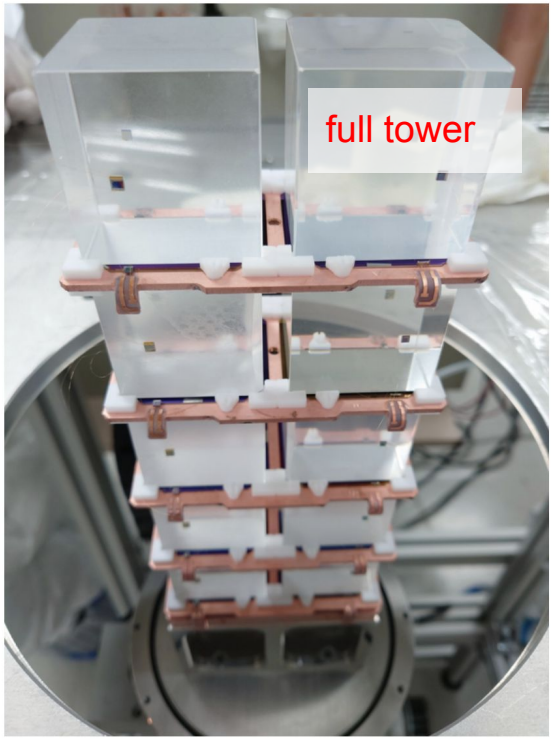


Work in-progress: a single-tower test-bench

1 - first test of a CUPID-like single tower prototype (BDTP) conceptual test of the new mechanical assembly✅

2 - full integrated test (VSTT) of assembly + assembly line + NTL light detectors + electronics + …





CUPID goal

3 σ - discovery sensitivity

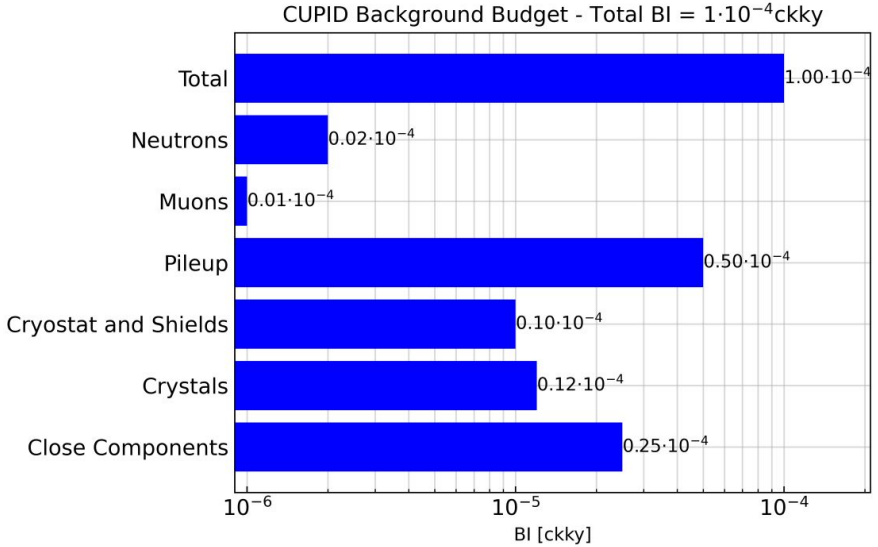
(240 kg ^{100}Mo + 5 kev FWHM)

$T^{0\nu}_{1/2} = 1 \times 10^{27}$ yr

$m_{\beta\beta} = (12\text{-}21)$ meV

Background Index (BI) goal for the counting rate in 0νββ ROI

< **1 x 10^{-4} ckky***



** ckky = counts/(keV kg yr)*

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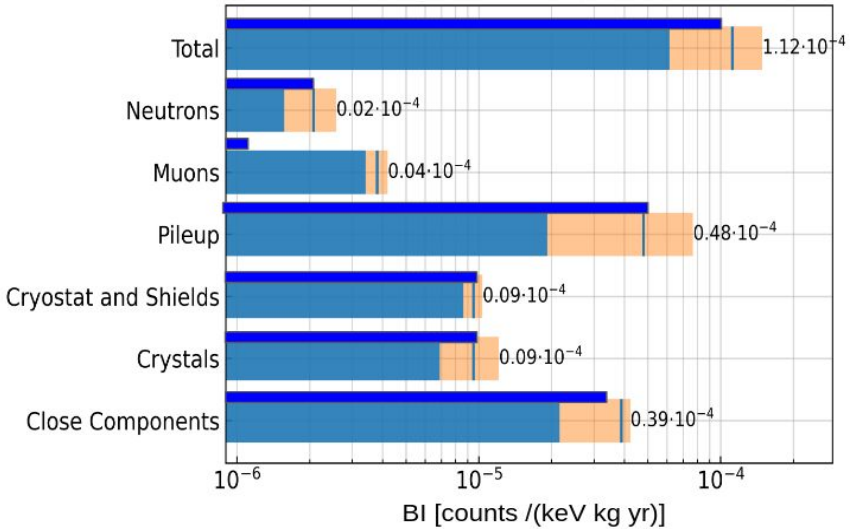
Background projections where we, are based on currently available data (with the support of MC simulations):

= **1.12 x 10^{-4} ckky***

68% interval = (0.61, 1.48) x 10^{-4} ckky



* *ckky = counts/(keV kg yr)*

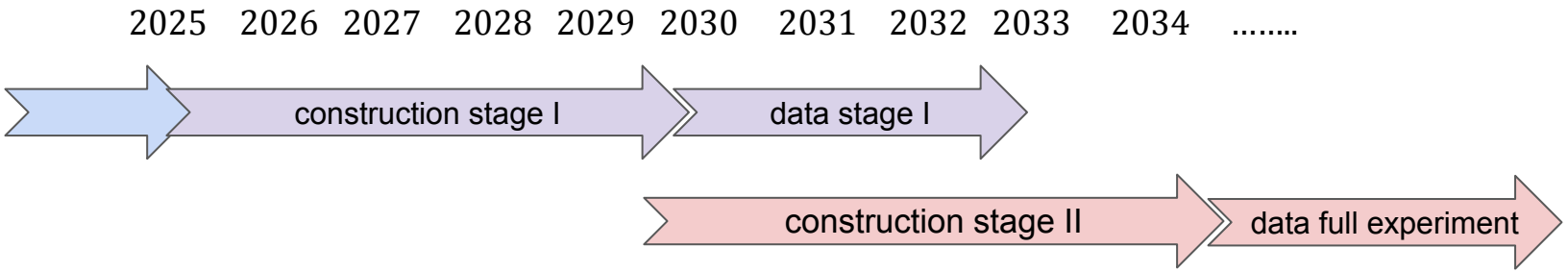
Timeline: from CUORE upgrade to CUPID and beyond

Staged detector deployment

- stage I = first ⅓
- stage II = remaining ⅔

parallelized approach for the construction and commissioning of the experiment

early data taking while the remaining crystal are produced



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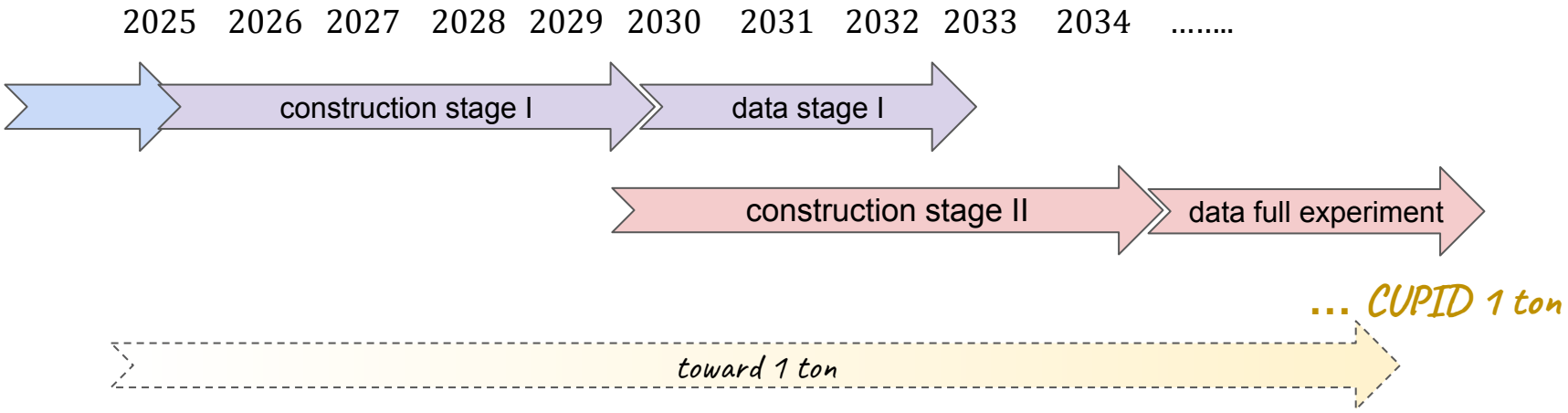

CUPID 0νββ sensitivity in the more general scenario of ν physics

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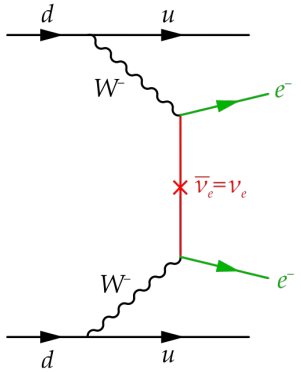
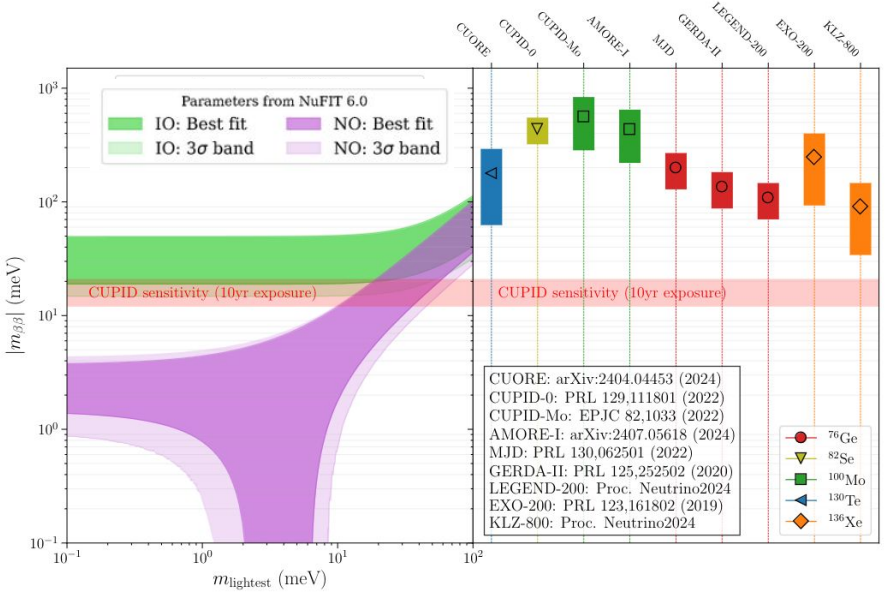
0νββ decay w/t mass mechanism →$m_{\beta\beta}$ $m_{ee} = \left| \sum_{i=1,2,3} U_{ei}^2 m_i \right|$





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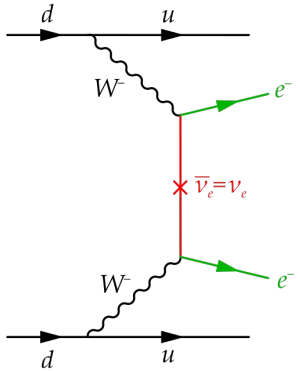
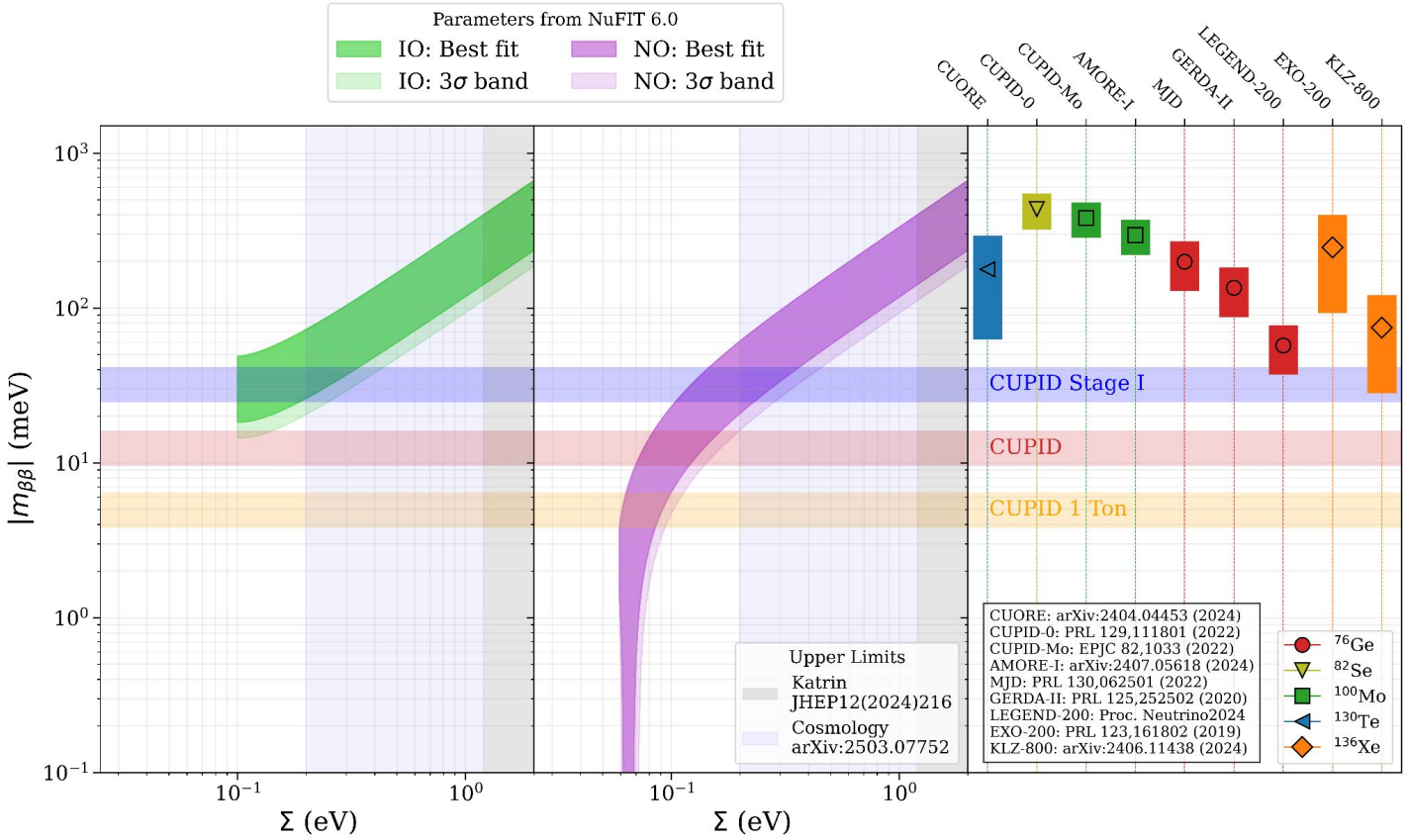


other inputs from the community

- measurement of neutrino mass from kinematics $m_{\nu_e} = \sqrt{\sum_{i=1,2,3} |U_{ei}|^2 \cdot m_i^2}$
- indication on neutrino mass from cosmology $\Sigma = m_1 + m_2 + m_3$
- mass ordering from oscillations

Exclusion Sensitivities compared with pub-results



Thanks for your attention !