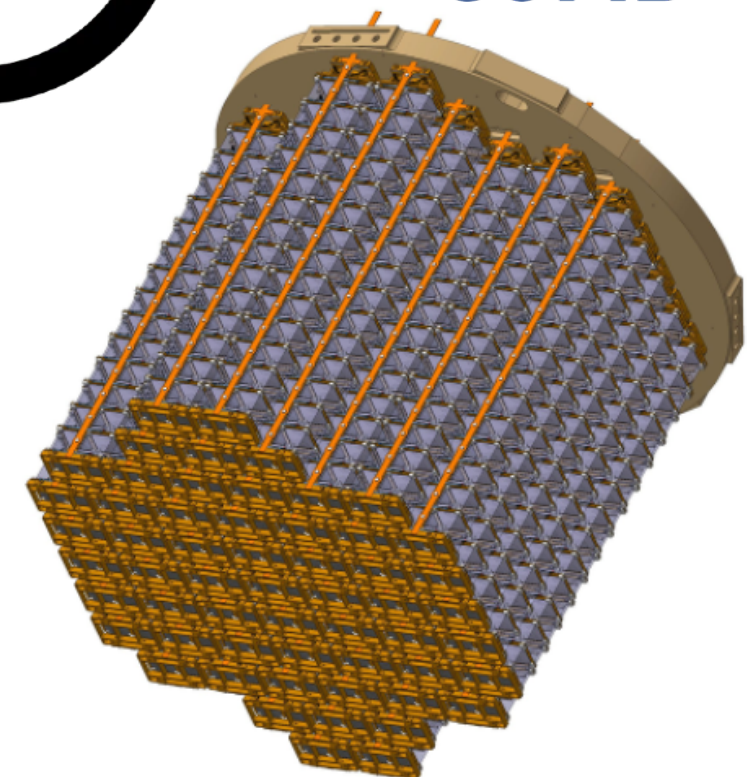
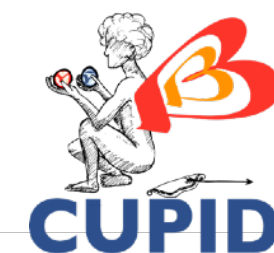
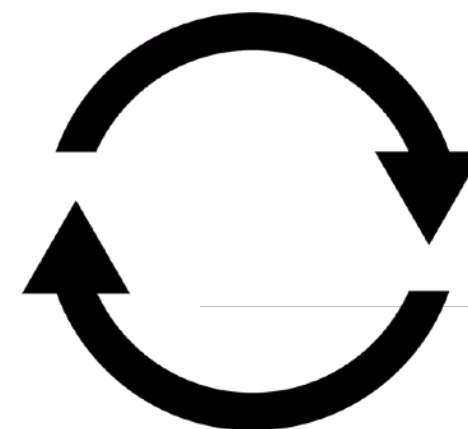
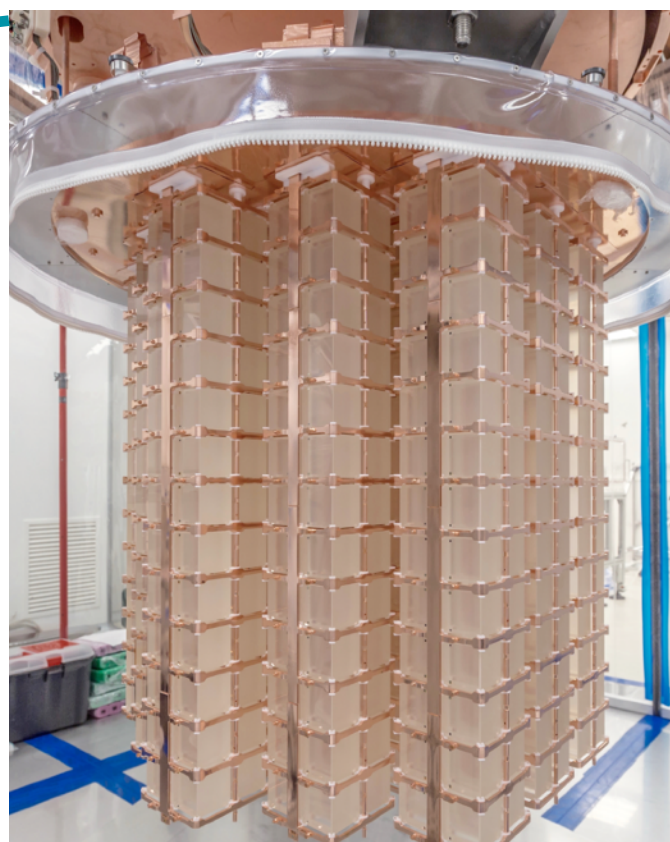
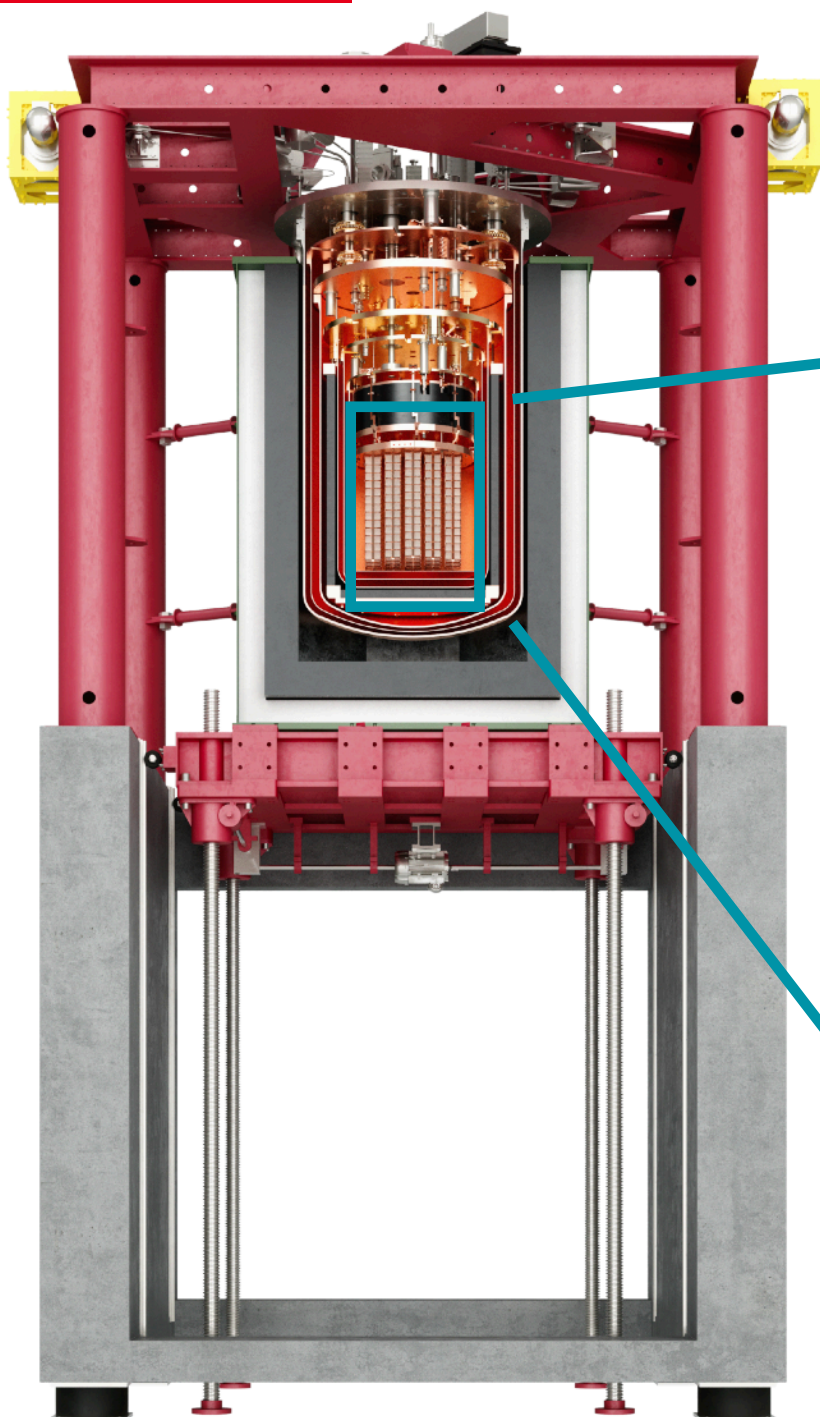


Background and radio-purity control for the CUPID $0\nu\beta\beta$ experiment



Benjamin Schmidt
for the CUPID collaboration

LOW
RADIOACTIVITY
TECHNIQUES



2026
WORKSHOP X





CUPID: ~240 collaborators

<https://cupid.lngs.infn.it/>



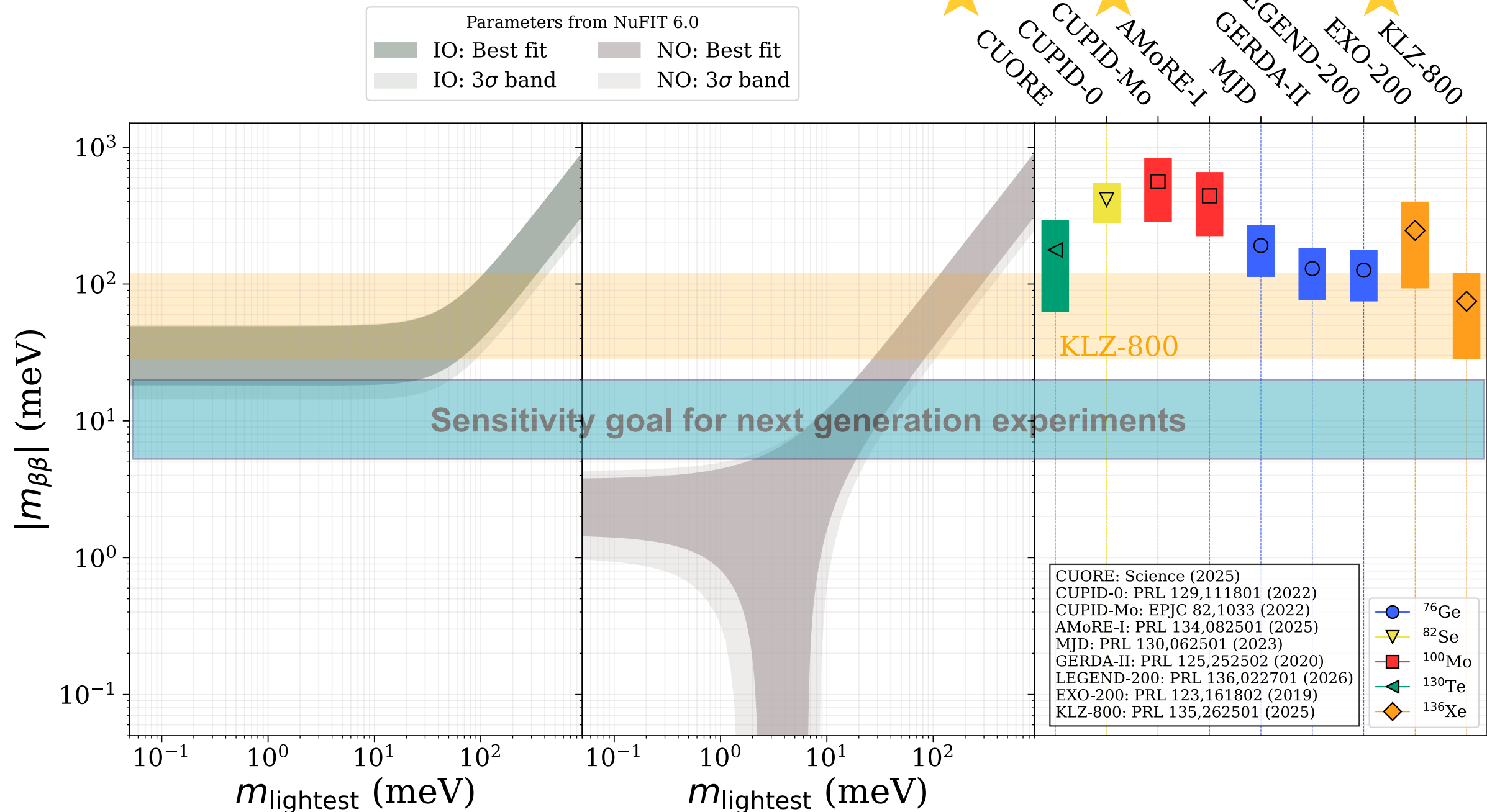
CUPID/CUORE Joint Collaboration Meeting

May 4th–8th, 2026

Laboratori Nazionali del Gran Sasso – INFN

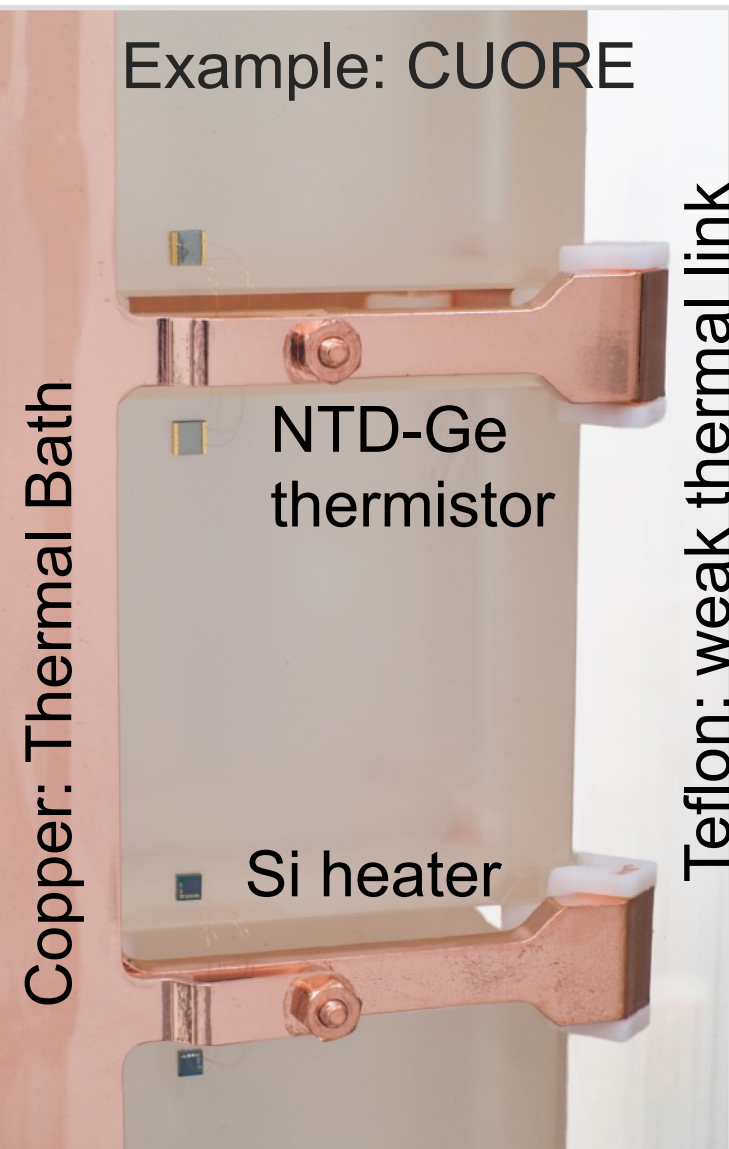
$0\nu\beta\beta$ Current status

New results in
2025/2026

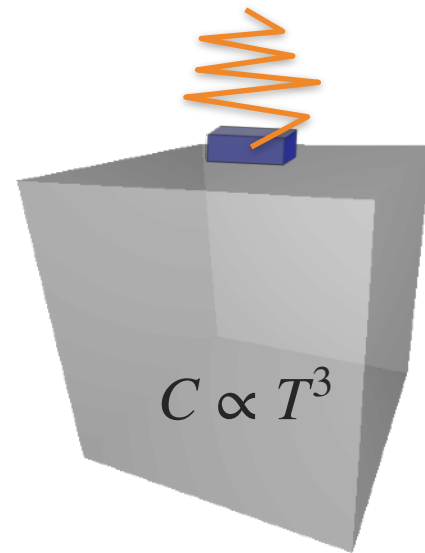


CUPID targets to achieve a discovery sensitivity of
 $|m_{\beta\beta}| < (12 - 36) \text{ meV}$ (90 % C.I.) in ^{100}Mo
—> Requires “only” a half-life sensitivity of 1×10^{27} yrs

Cryogenic calorimetric technique



Thermal bath @ 10-20 mK



NTD-Ge thermistor
as sensor

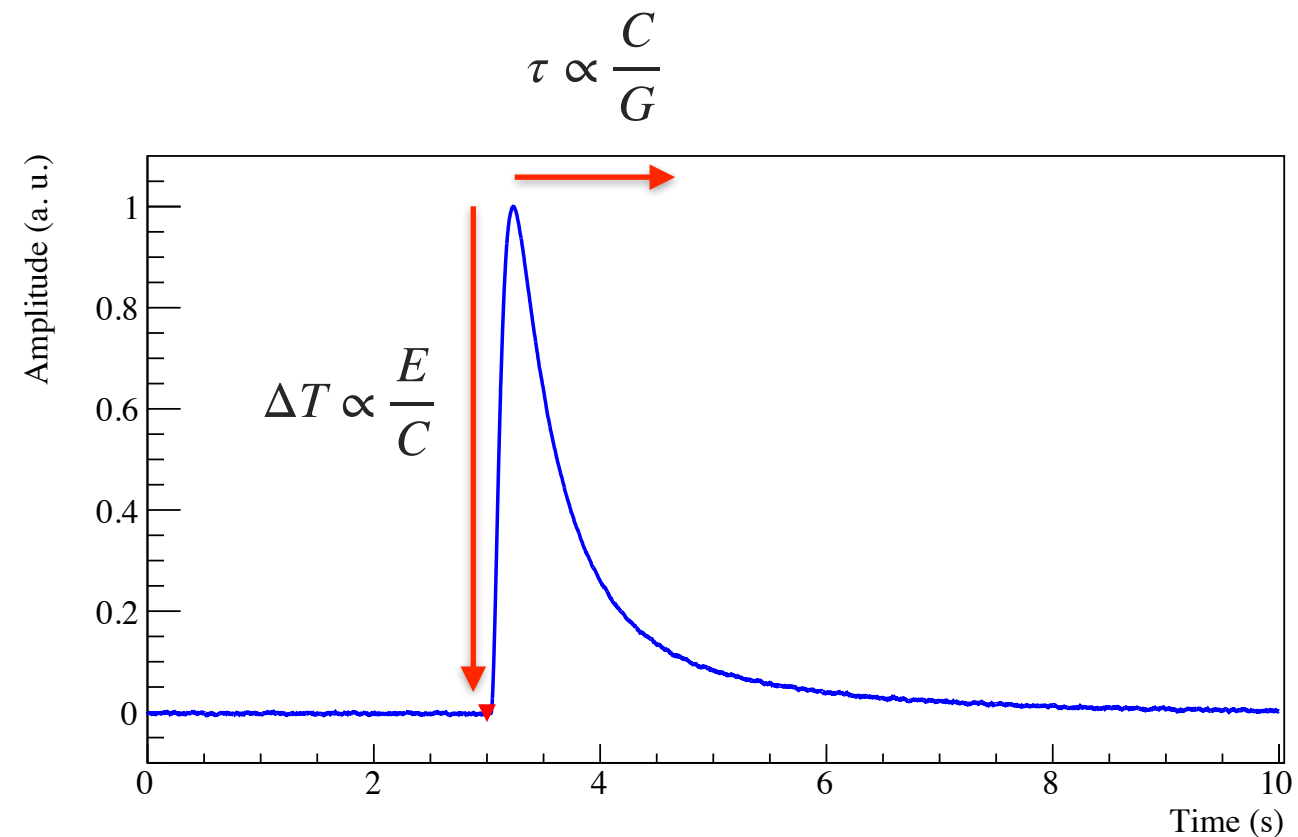
$$R(T) = R_0 \cdot e^{\sqrt{T_0/T}}$$

$$\Delta T \approx 100 \mu K / MeV$$

Isotope of interest
embedded in crystal

Many isotopes
accessible in different
crystals:

TeO_2 , Li_2MoO_4 ,
 CdWO_4 ,
 ZnSe , CaF_2 , Cs_2ZrCl_6 ,



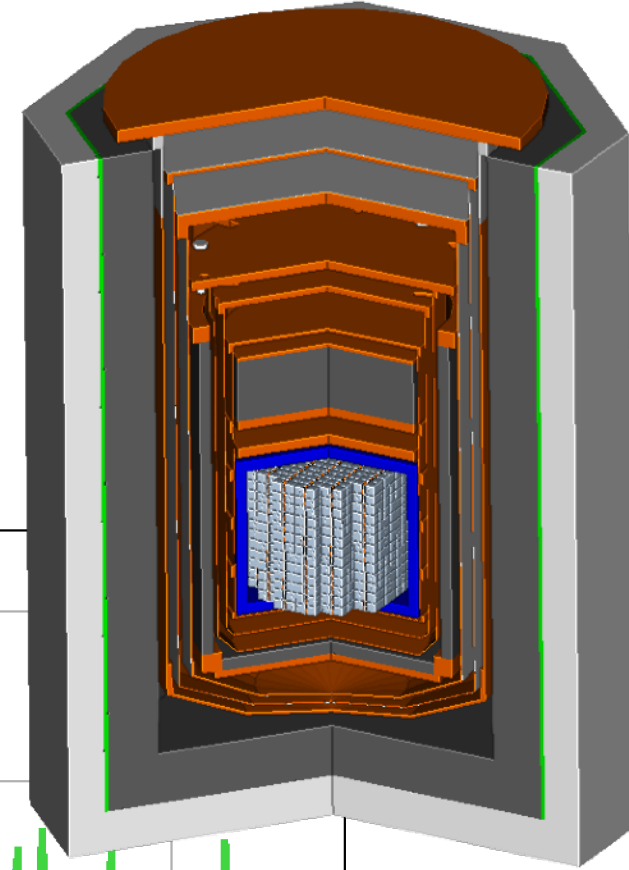
The CUORE background model

CUORE:

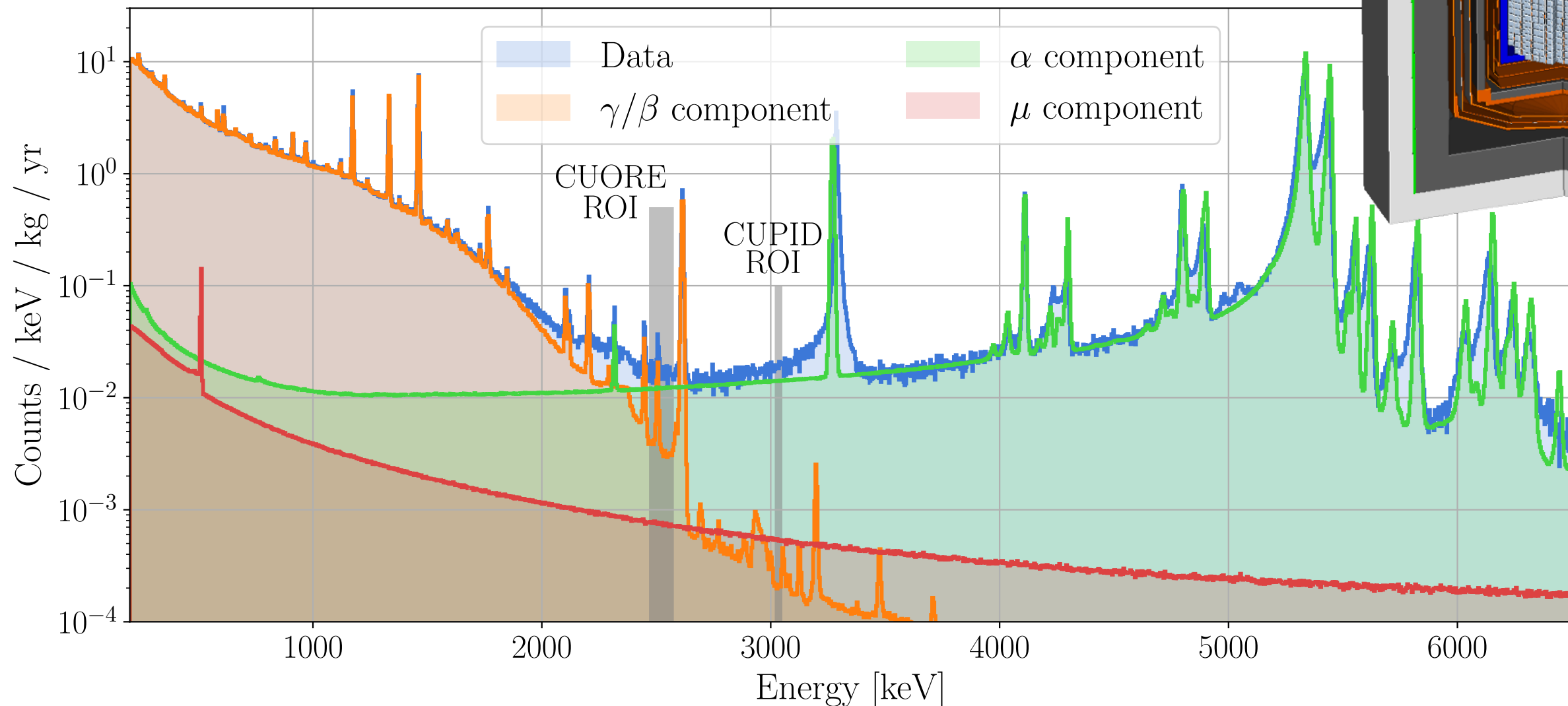
- Cryogenic Underground Observatory for Rare Events
- $0\nu\beta\beta$ search at LNGS - 742 kg TeO_2

See V. Berest
"CUORE", Sep 22, 11.30

Geant 4
rendering



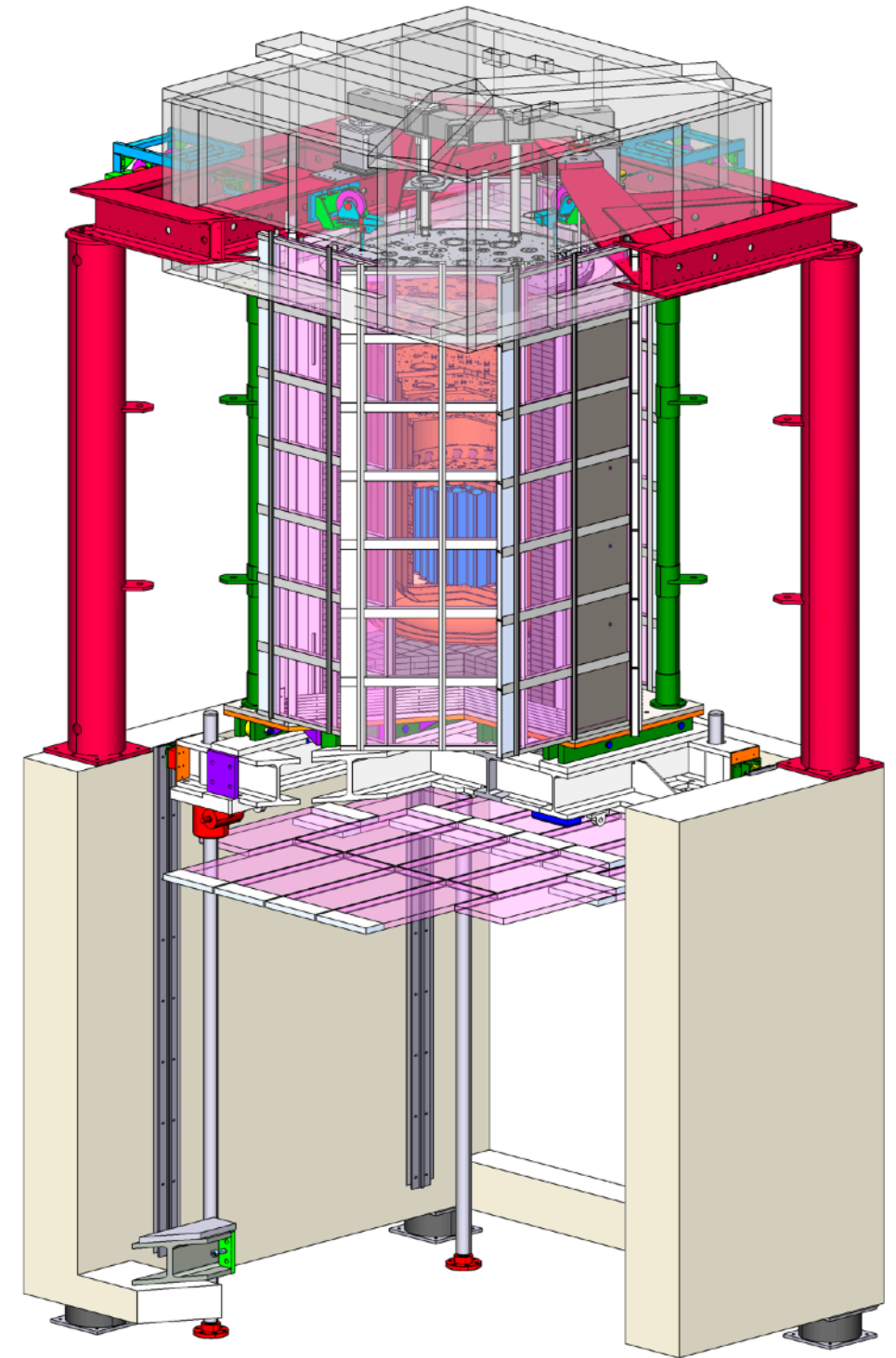
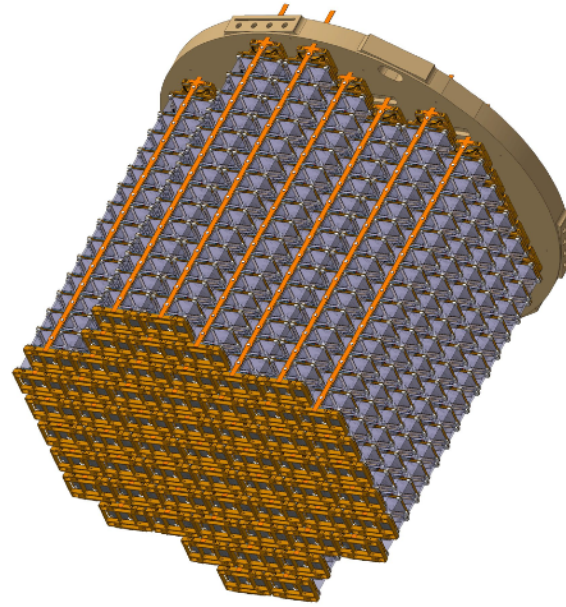
Produced from Phys. Rev. D 110, 052003 (2024) data release



From CUORE to CUPID

CUPID infrastructure

- Built on CUORE infrastructure
25 cm lead, ~20 cm PET
and CUORE background model
- New detector array:
Scintillating detector technology
240 kg of ^{100}Mo : $Q_{\beta\beta} = 3034 \text{ keV}$
- Validated in CUPID-Mo, CUPID R&D
and tower scale tests
-> detailed detector response model
- Additional muon veto system
(pink) - plastic scintillator panels
- Extra neutron shielding
20 cm thick water Cherenkov detectors
around the top (gray, transparent)

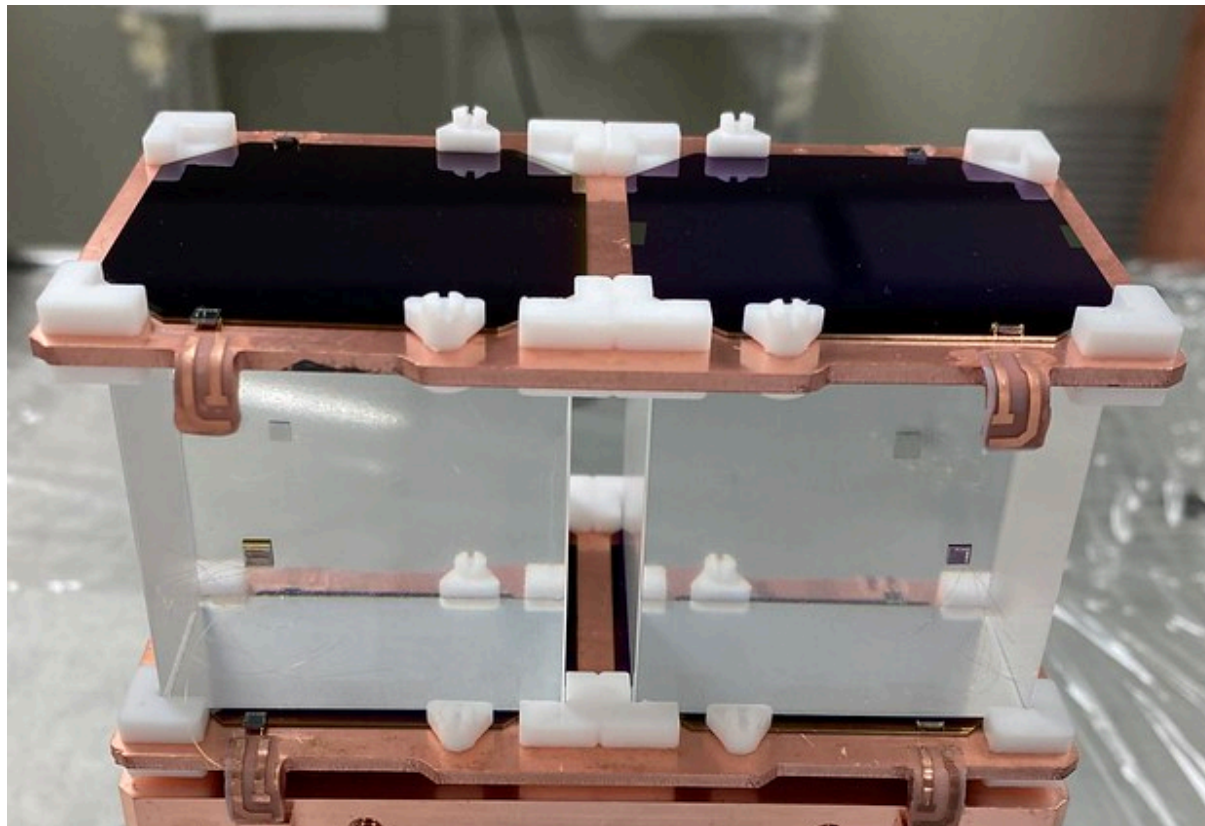


From CUORE to CUPID

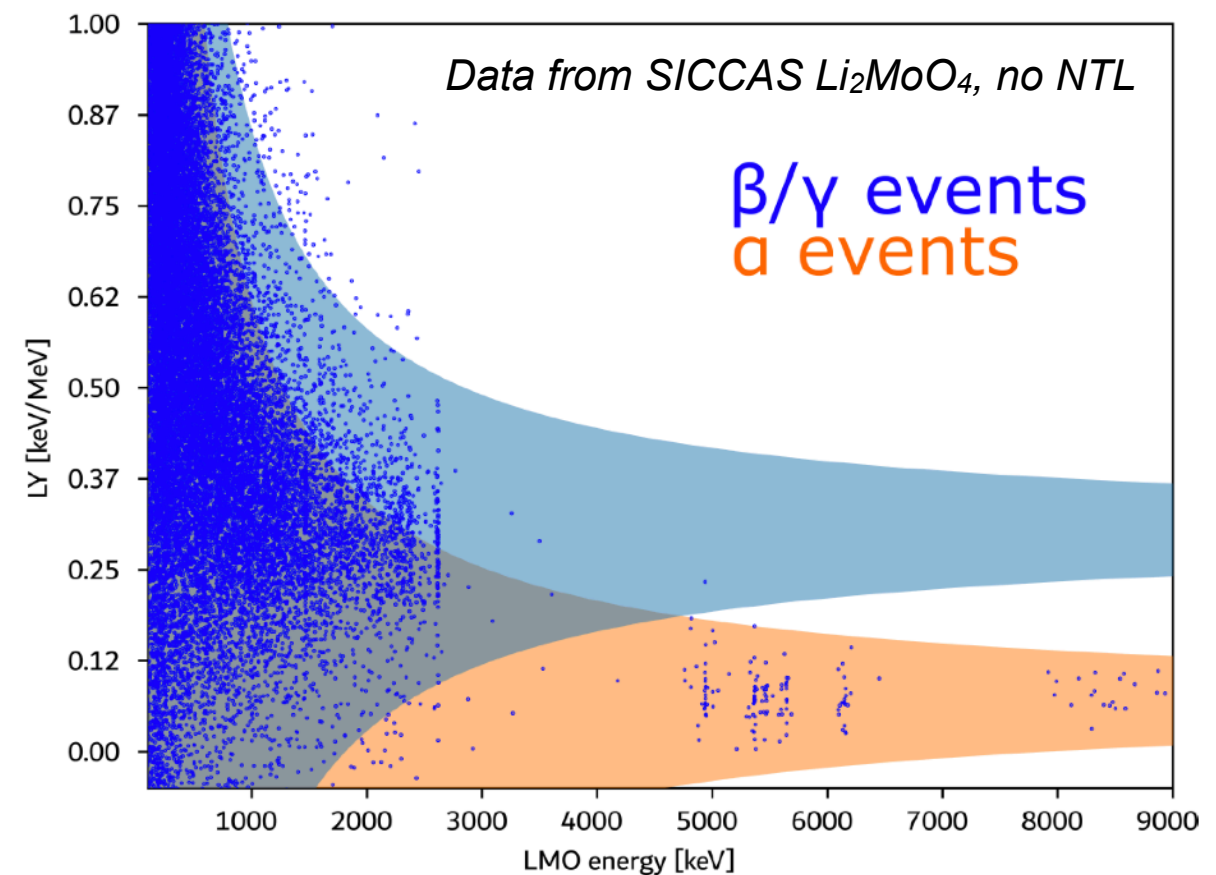
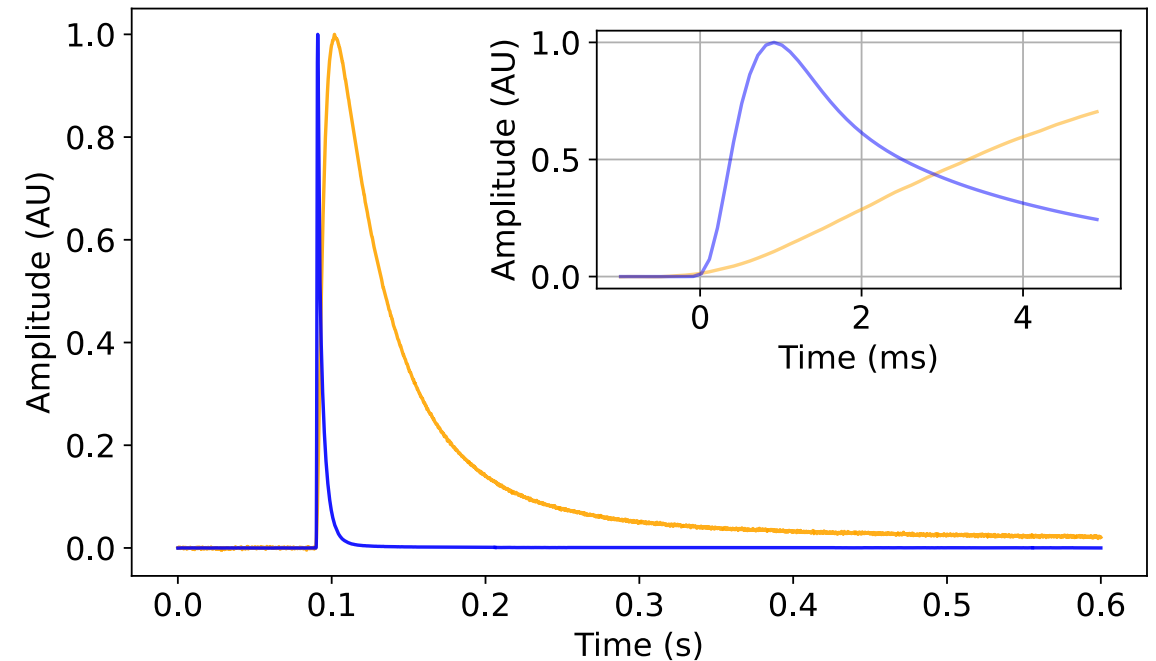
CUPID - A detector module

- 280 g Li_2MoO_4 crystals 95% enriched in ^{100}Mo with dual heat-light-readout
- Full α discrimination
>99.9%, at 90% β/γ acceptance
- Advanced Neganov-Trofimov-Luke (NTL) light detectors
- Tower scale validation program at LNGS

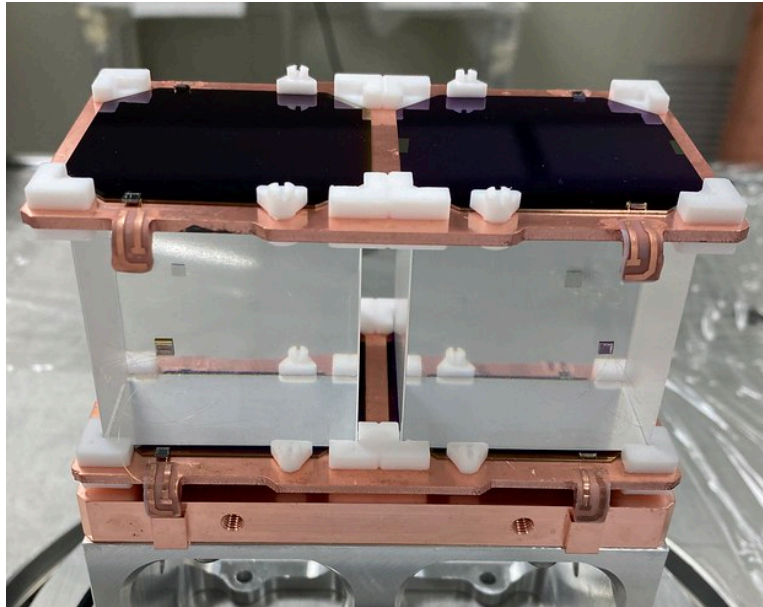
[Eur. Phys. J. C 85, 935 \(2025\)](#)



Data from [JINST 21 P01035 \(2026\)](#)

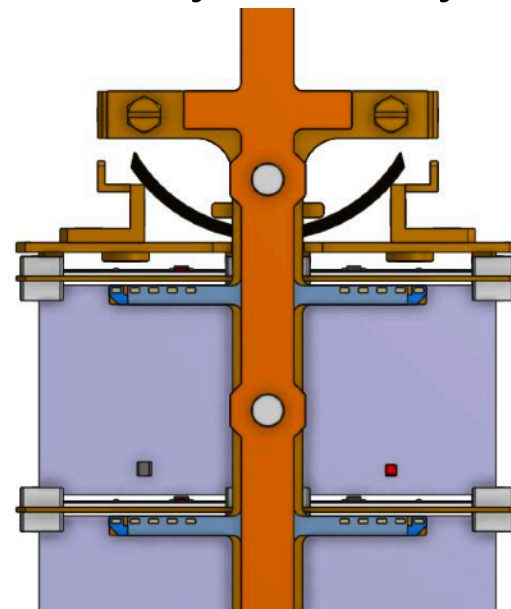
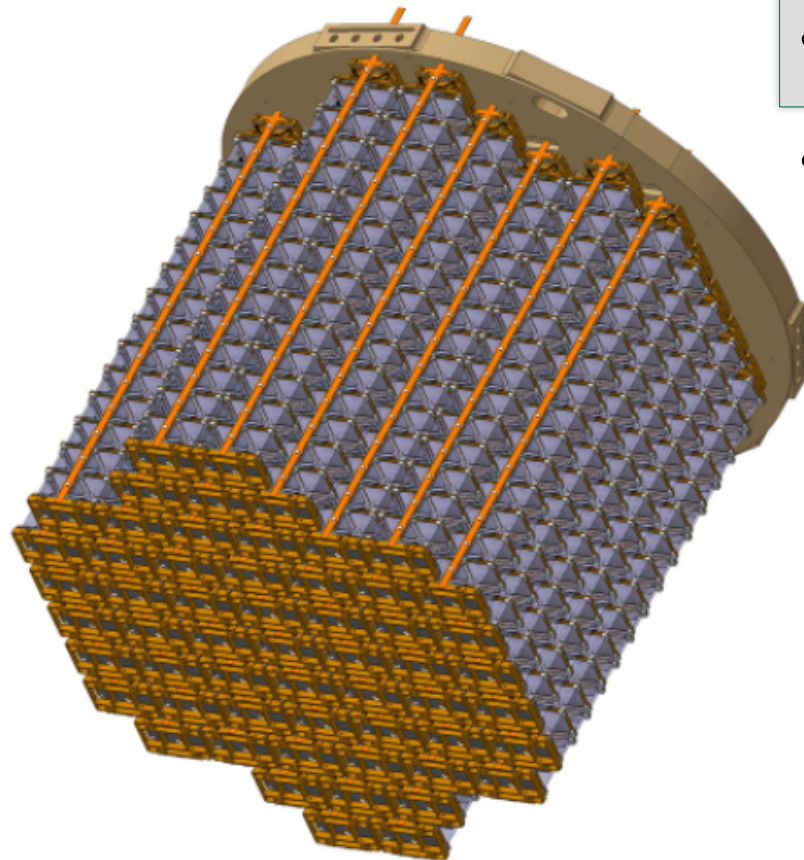


From CUORE to CUPID



Scaling up: [Eur. Phys. J. C 85, 737 \(2025\)](#)

- 1596 scintillating heat/light detector modules
- New low background tower design
- Staged deployment: 1/3 ~80 kg of ^{100}Mo in Stage1 -> Stage2 240 kg of ^{100}Mo
- Target energy resolution:
 $\sigma/E = 0.07\% @ Q_{\beta\beta}$ (5 keV FWHM)
- BI target: 1.0×10^{-4} counts/keV/kg/yr
- $|m_{\beta\beta}| < (9.6 - 28) \text{ meV}$ (90 % C.I.)
exclusion sensitivity with 10 yr exposure



Geant4
model



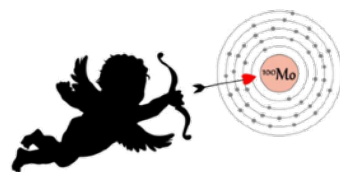
CUPID BG projection - ingredients



Cryostat and Background model
 Phys. Rev. Lett. 126, 171801 (2021)
 Phys. Rev. D 110, 052003 (2024)
 Eur. Phys. J. C 86, 749 (2026)



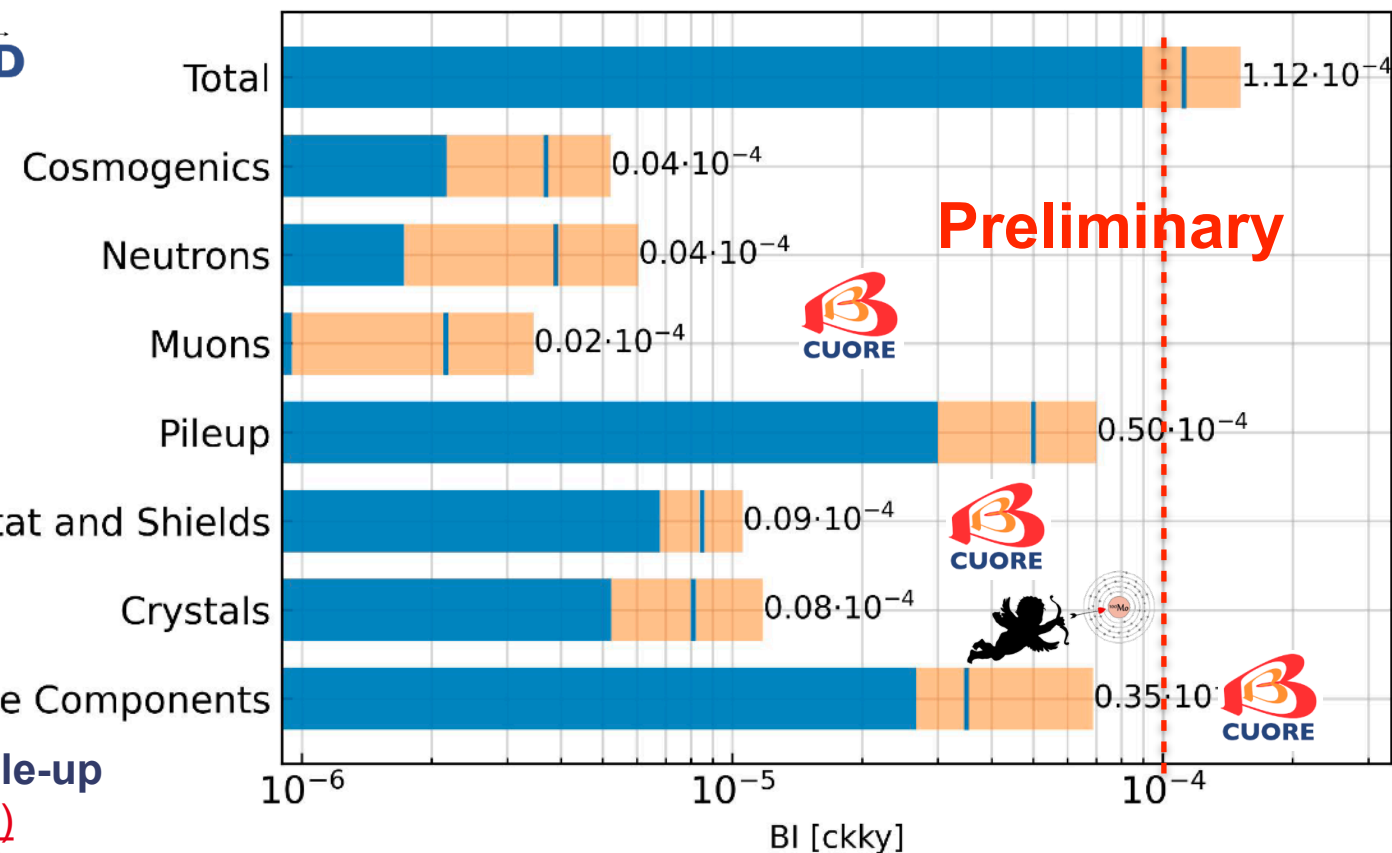
Tower design, μ and n shields
 Eur. Phys. J. C 85, 737 (2025)
 Eur. Phys. J. C 85, 935 (2025)
 JINST 20 P08020 (2025)



Li_2MoO_4 crystals & α rejection, pile-up
 Eur. Phys. J. C 82, 1033 (2022)
 Eur. Phys. J. C 83, 675 (2023)
 Phys. Rev. Lett. 131, 16250 (2023)
 JINST 21 P01035 (2026) , arXiv:2606.17948



CUPID BG simulation

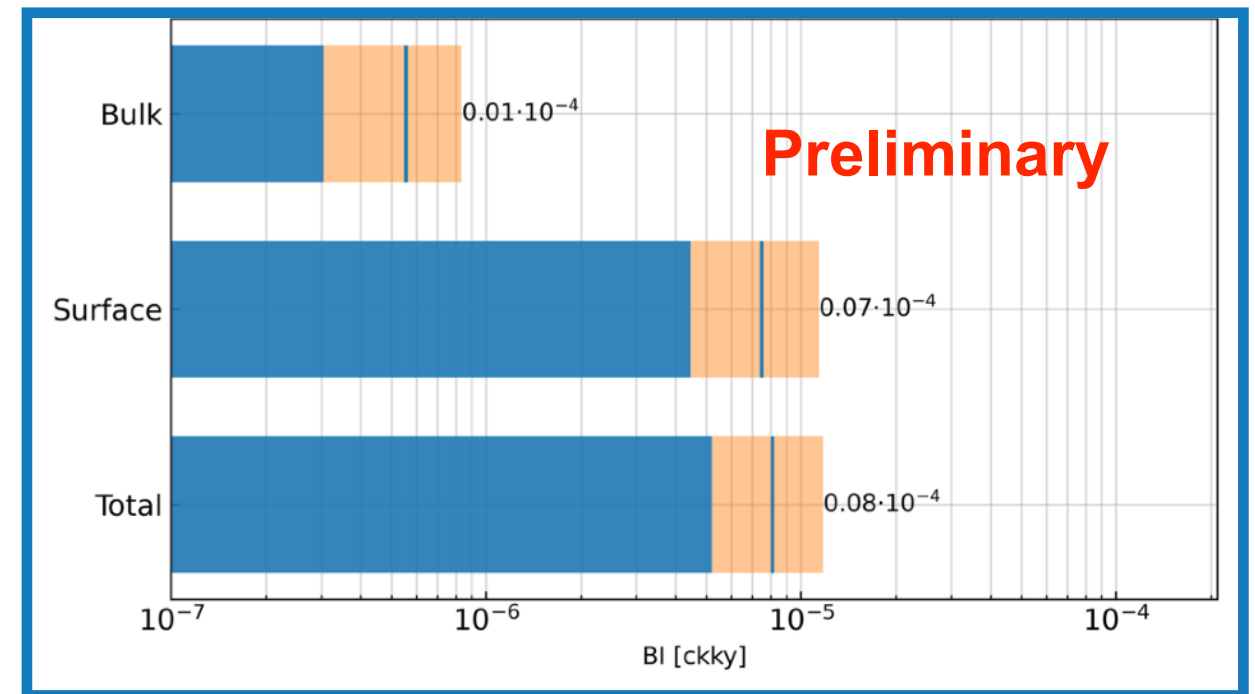


Methodology:

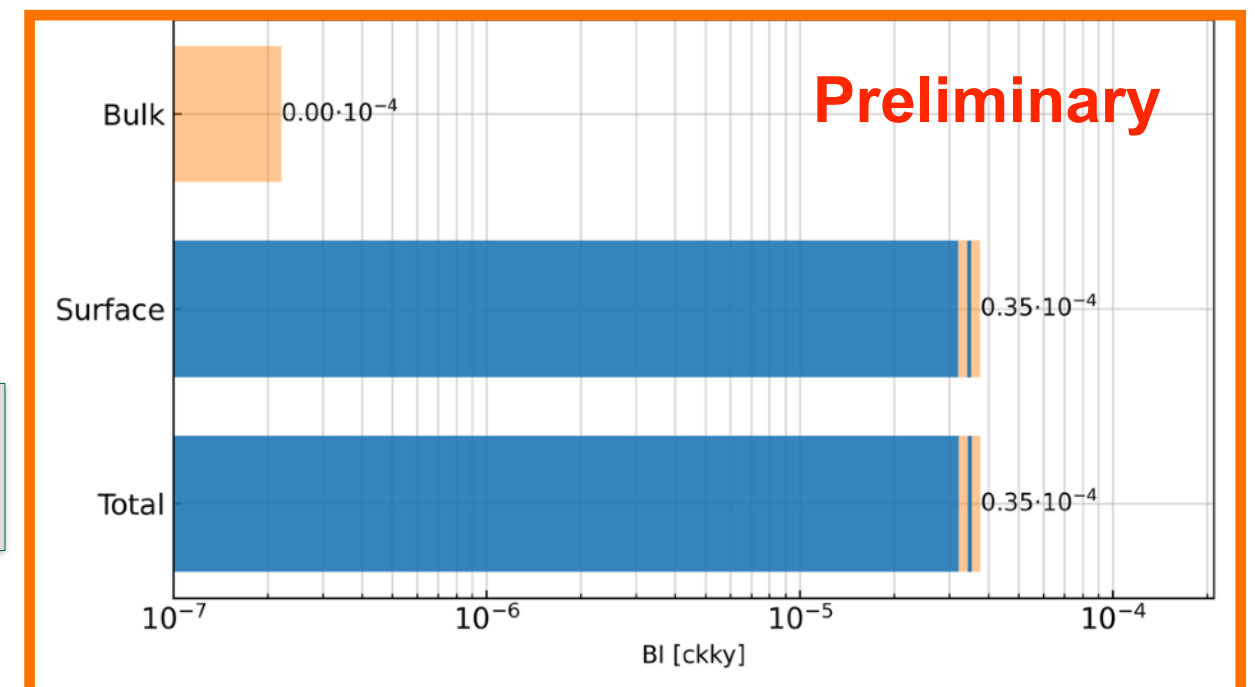
- Environmental flux (μ , γ) & contaminations from prior experiment(s) and screening (HPGe, ICPMS, NAA) -> Geant4 with detailed geometry
- MCNP for neutrons (n, γ) + prompt γ 's in Geant4 (NuDEX) + custom detector response
- Cosmogenic activation with ACTIVIA and Geant4 for Cu and Mo

CUPID BG projection - radiogenics

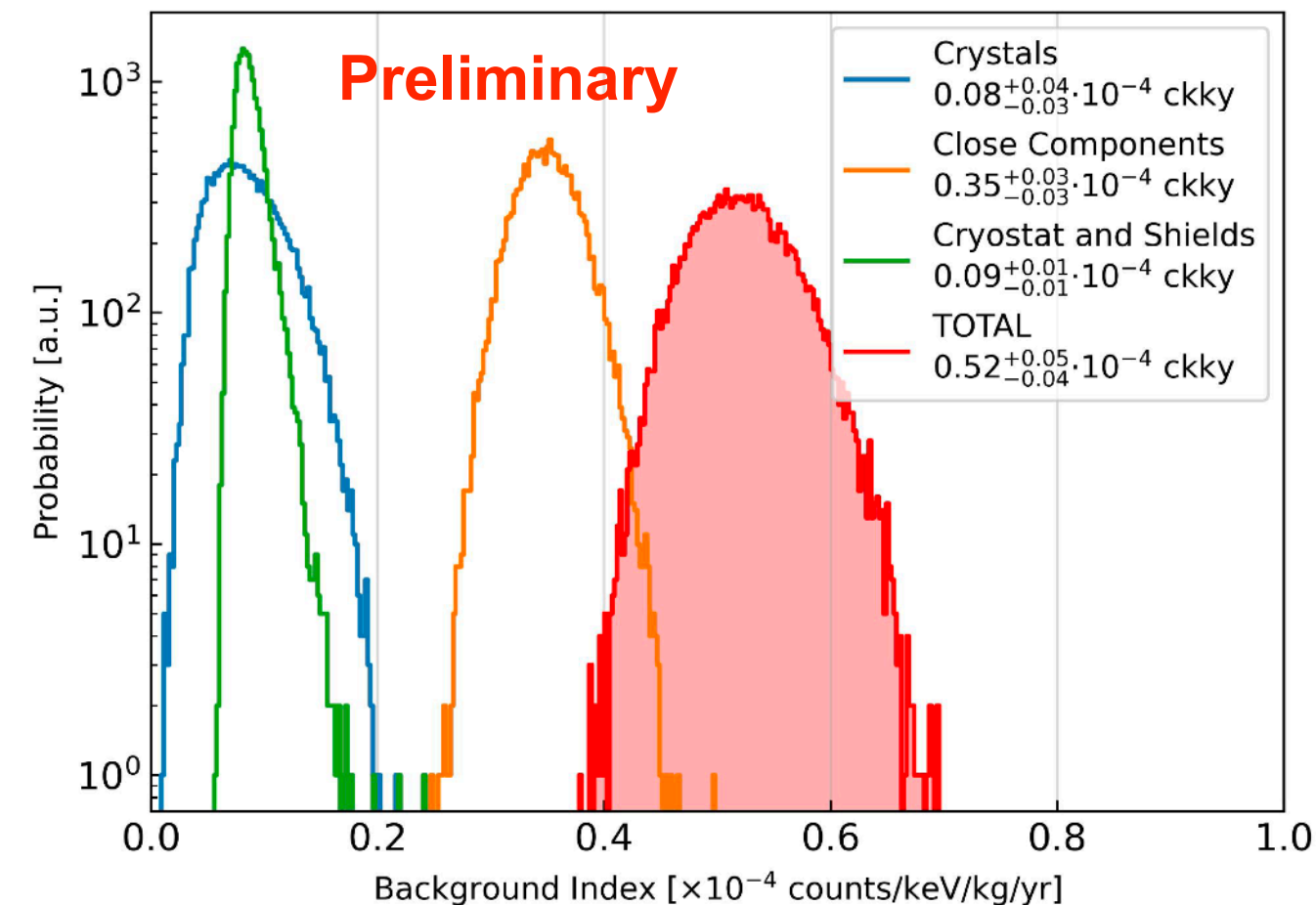
Li₂MoO₄ crystals



Close components



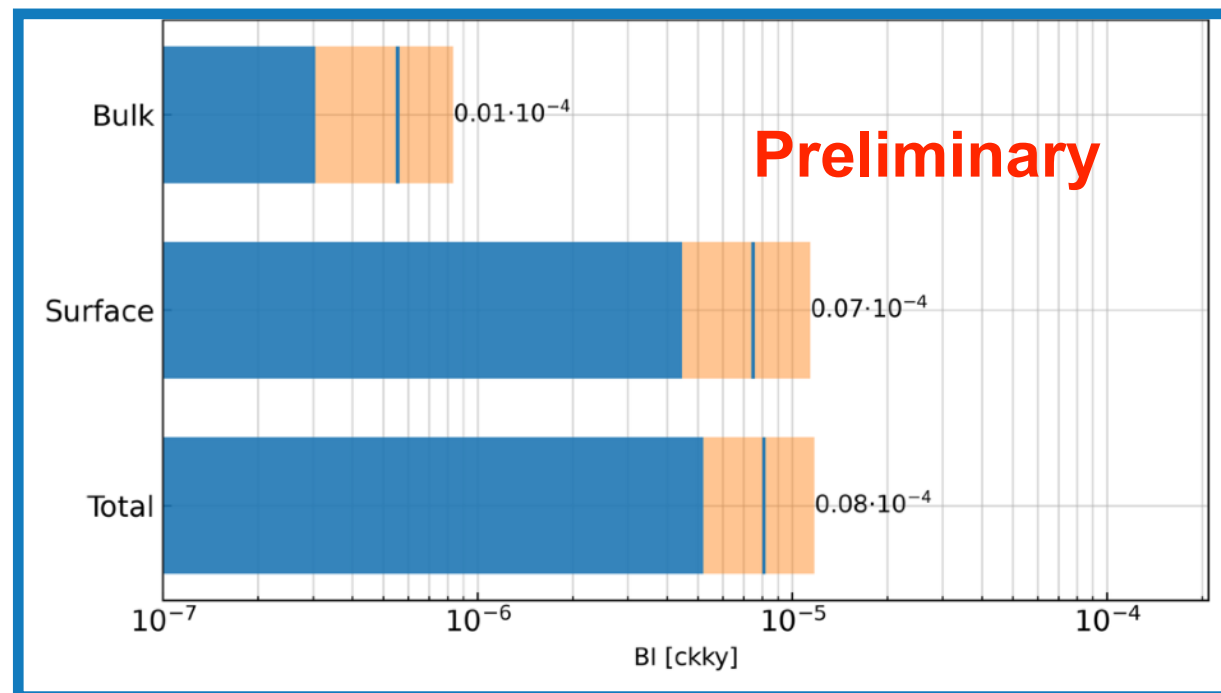
BI in CUPID ROI - Baseline



**For CUPID: After surface α rejection:
Surface contaminations remain crucial!**

CUPID BG projection - crystals

Li₂MoO₄ crystals



**For CUPID: After surface α rejection:
Surface contaminations remain crucial!**

CUPID crystal contamination requirements (based on CUPID-Mo)

Bulk:

$$< 0.2 \mu\text{Bq/kg}$$

²²⁶Ra

$$0.4 \pm 0.2 \mu\text{Bq/kg}$$

²²⁸Th

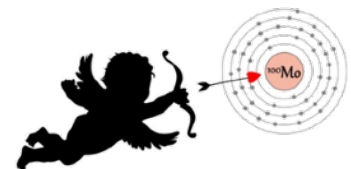
Surface:

$$2 \pm 0.5 \text{ nBq/cm}^2$$

²²⁶Ra

$$< 2.5 \text{ nBq/cm}^2$$

²²⁸Th

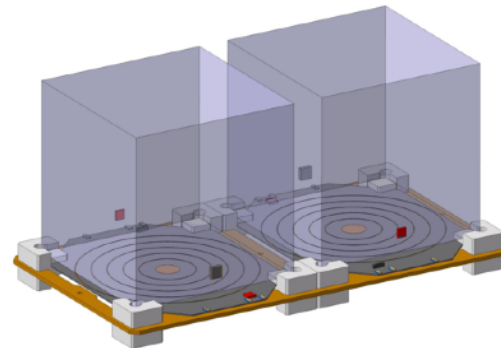
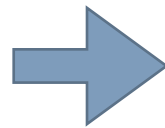
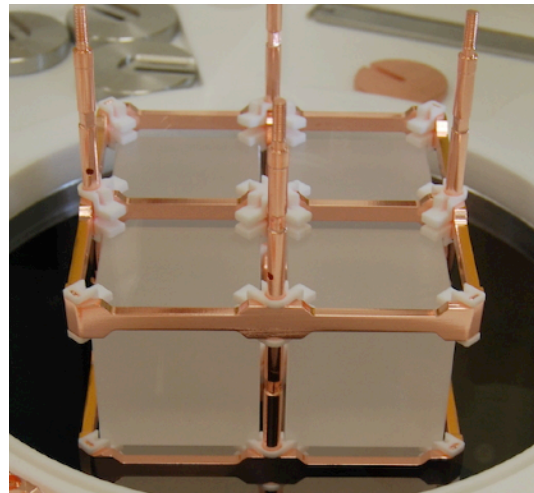


See T. Bradanini "CUPID Crystal Validation Run", Sep 24, 9.30

SICCAS is being validated for the procurement of the ~1600 Li₂MoO₄ crystals for CUPID:

- SICCAS produced the 988 CUORE TeO₂ crystals, meeting surface requirements
- More vigorous surface / radioactivity protection protocols with respect to CUPID-Mo
- CUPID Crystal Validation Runs will sample and validate maintained radio purity throughout crystal production

CUPID BG projection - tower design



CUPID close components assume same contamination (posteriors) from CUORE

Copper bulk:

$$< 0.5 \mu\text{Bq/kg}$$

^{226}Ra

$$< 0.4 \mu\text{Bq/kg}$$

^{228}Th

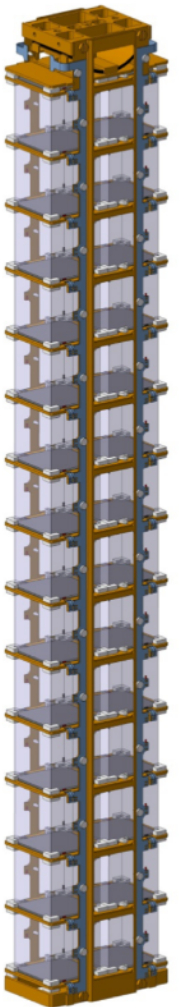
Copper surface:

$$8.4 \pm 0.7 \text{ nBq/cm}^2$$

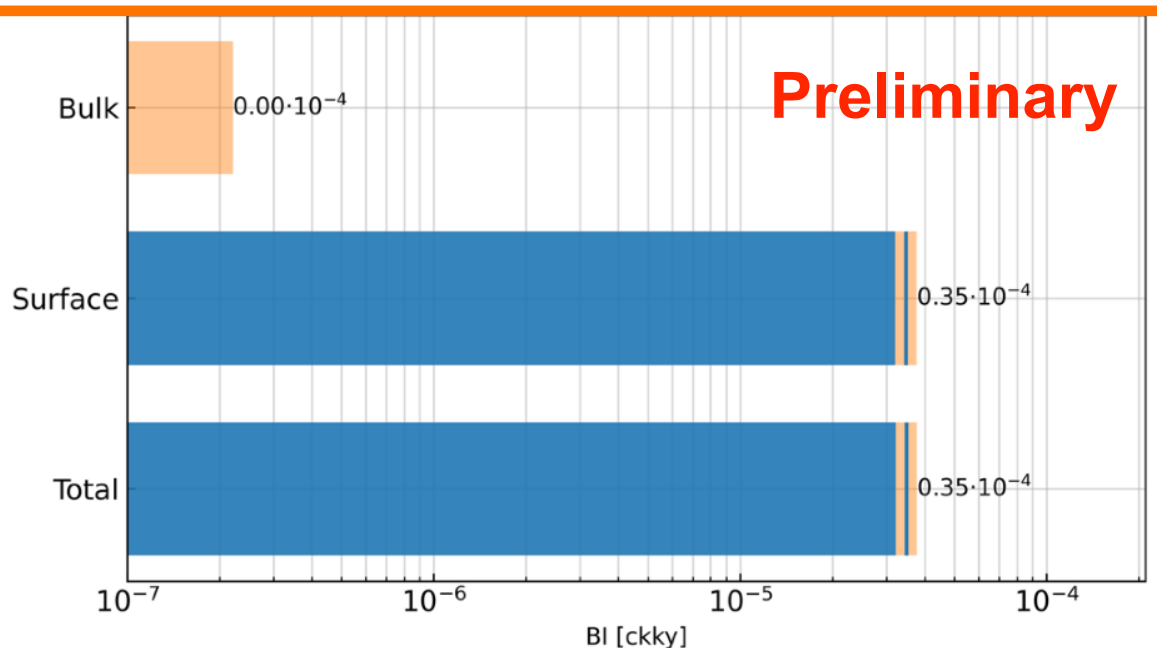
^{226}Ra

$$11.5 \pm 0.5 \text{ nBq/cm}^2$$

^{228}Th



Close components



Improvements to be evaluated (not included in projections):

- New simplified mechanical tower design: less machining & handling

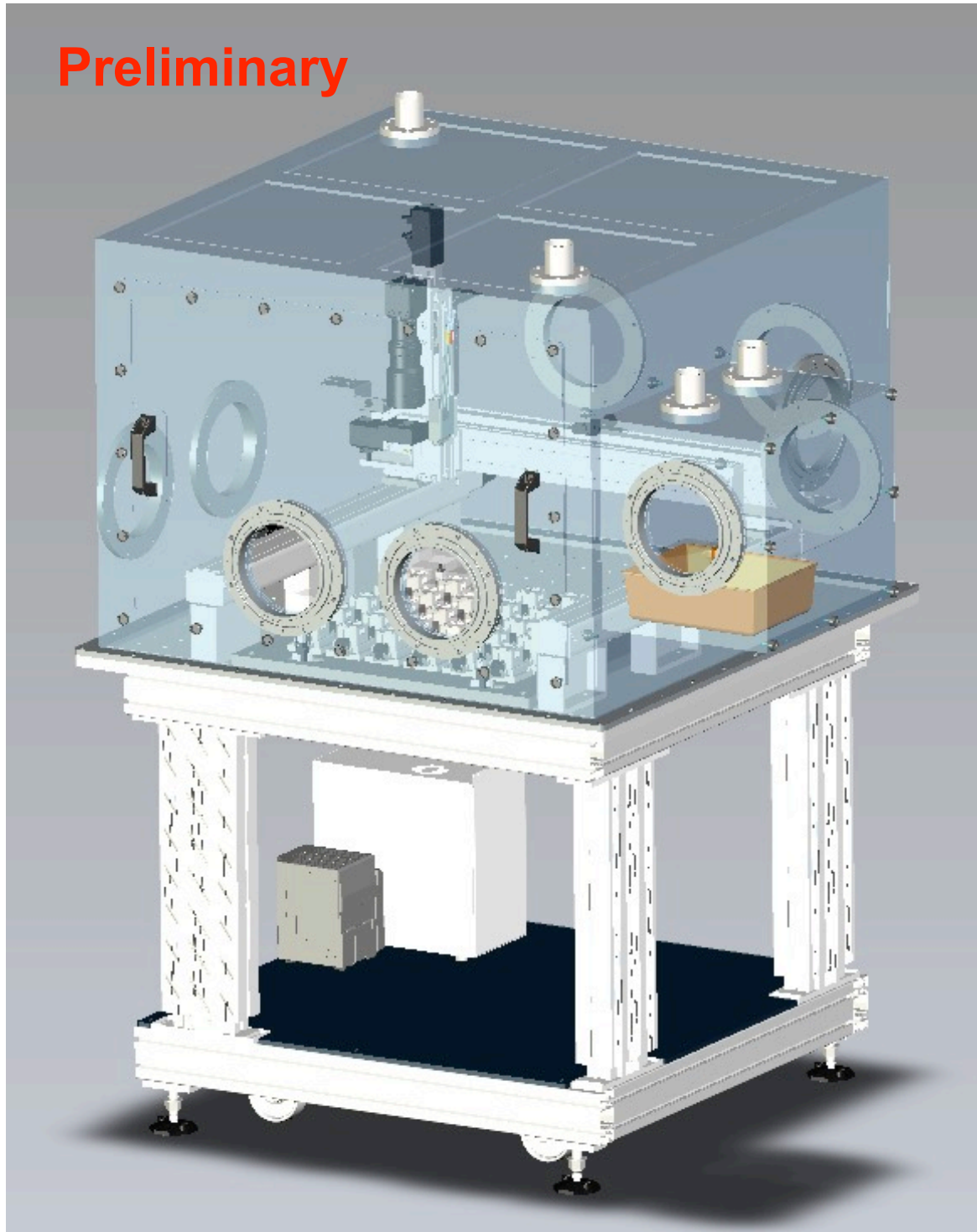


- Lamination + contact-less production with laser cutting
- No shadowing during etching/plasma cleaning procedure

HPGe screening campaigns to qualify surface backgrounds of machined pieces of CuPEN/PTFE/Copper ongoing

CUPID assembly - Maintain surface radio purity!

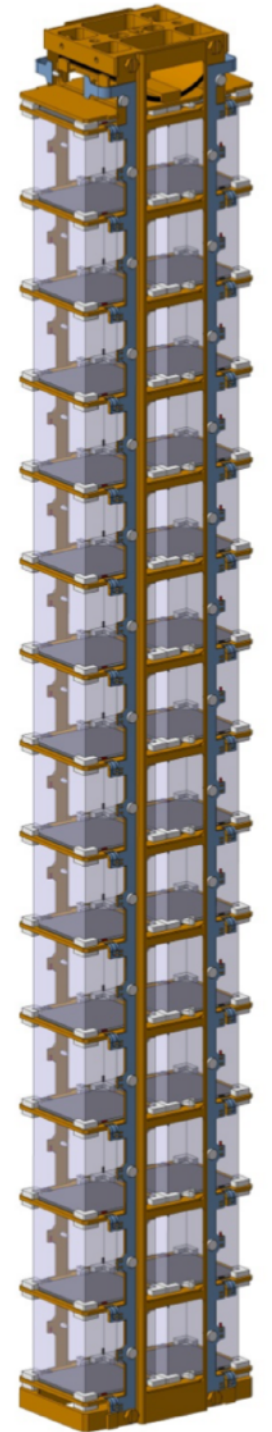
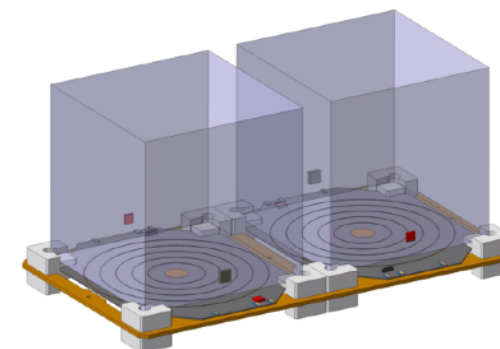
Preliminary



Sensor instrumentation station design

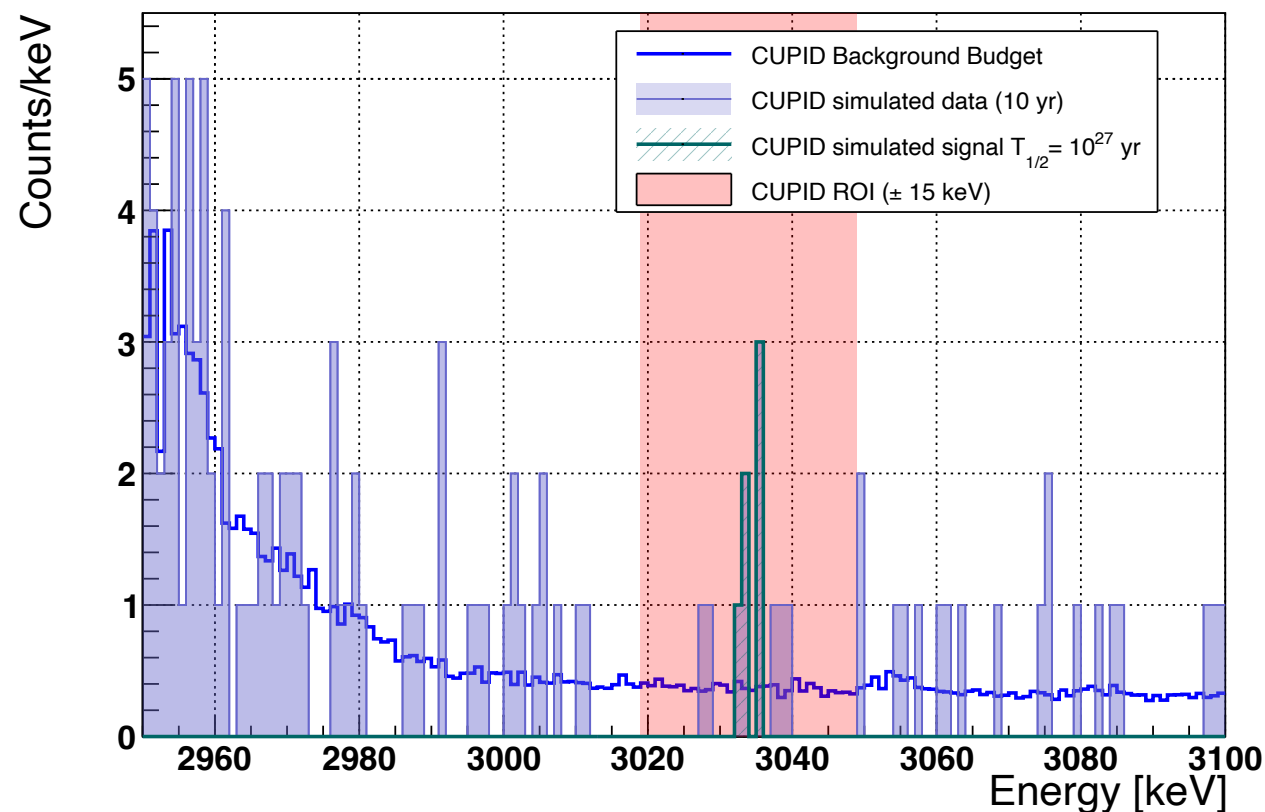
Production & assembly steps in controlled clean room environment

- Class 1000 (ISO 6) clean-room at LNGS surface building
- Use dedicated N₂ flushed assembly stations
 - Support/Packaging station
 - Sensor instrumentation
 - Tower assembly
 - Wire bonding
 - Tower & element storage underground
- Optimised procedure ~ 1 week aboveground

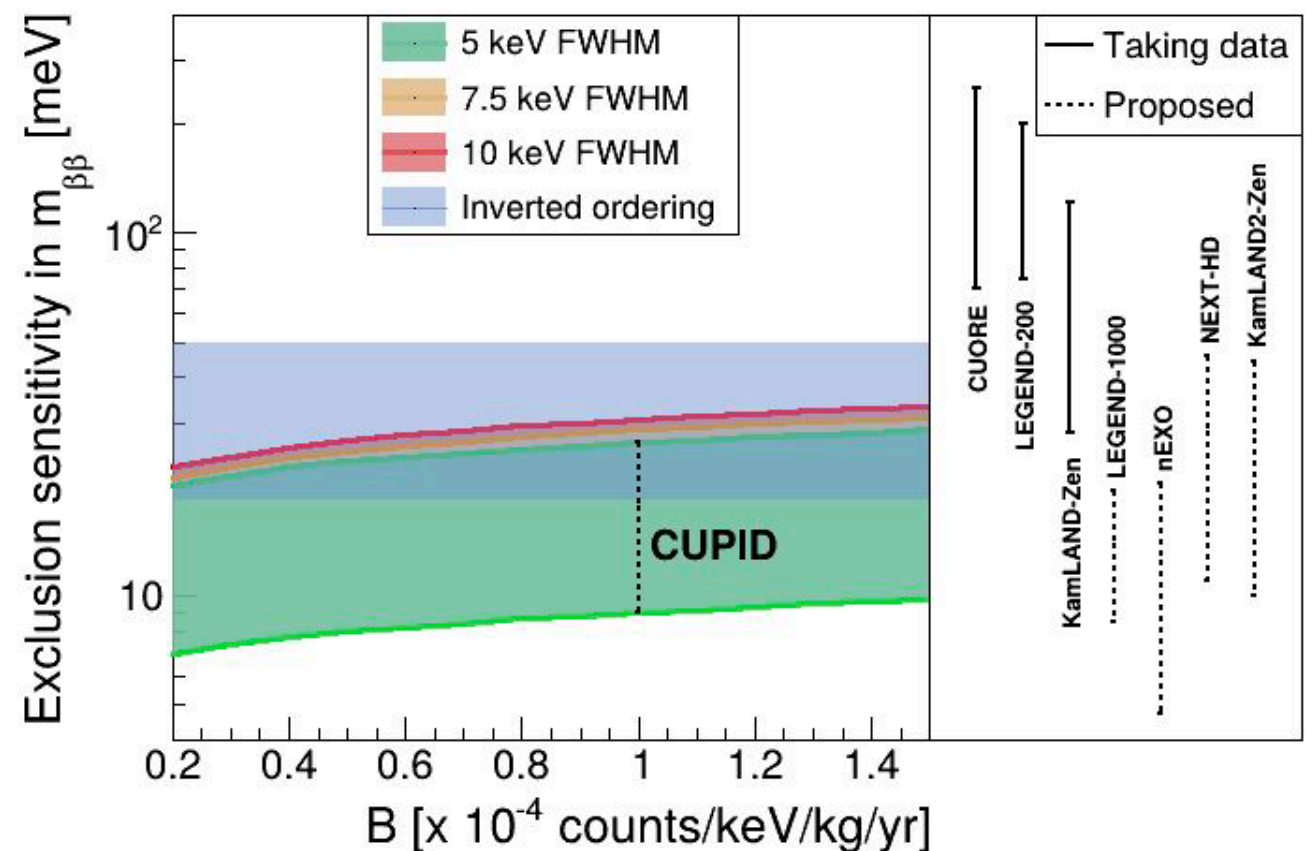


CUPID with 10 yr exposure

Simulated signal



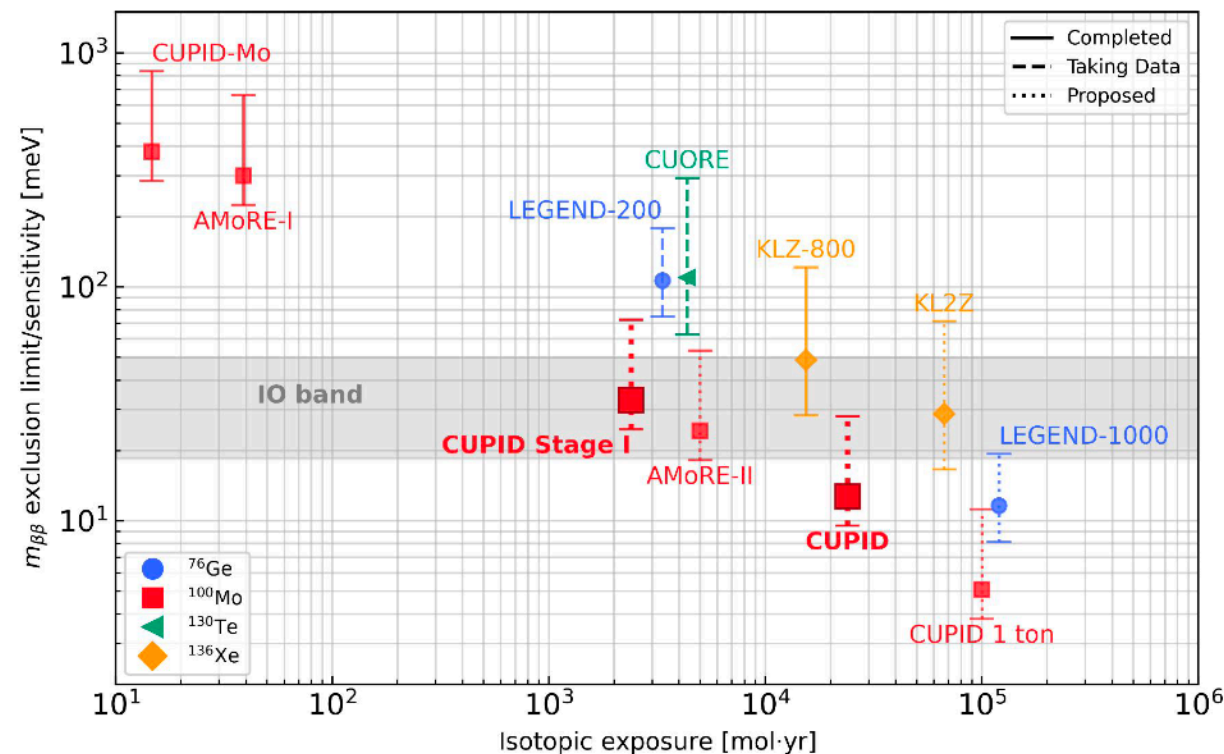
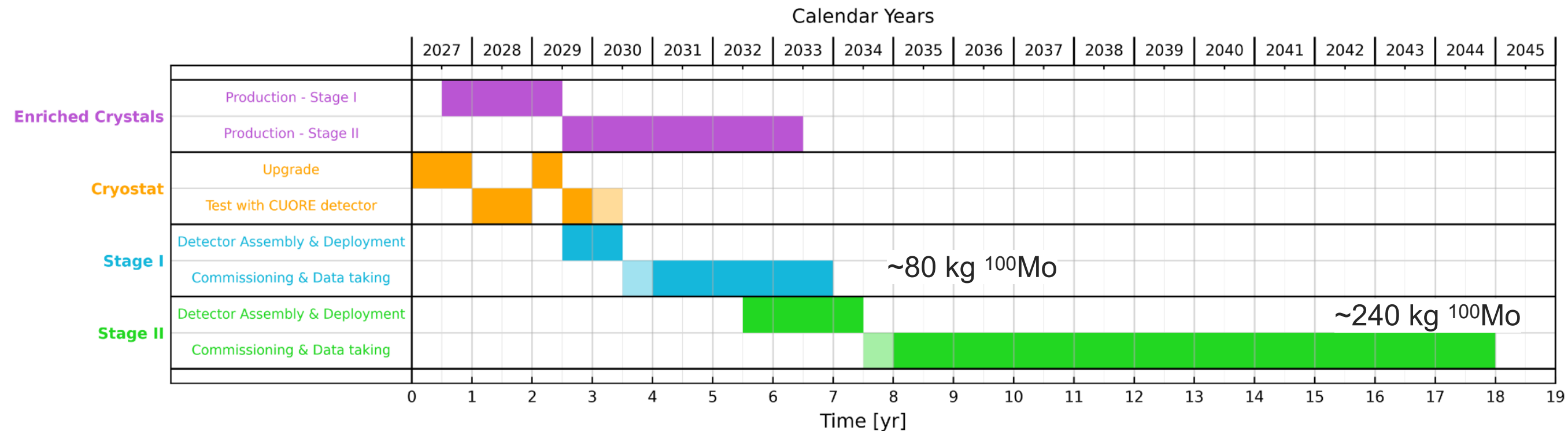
[Eur. Phys. J. C 86, 633 \(2026\)](#)



**CUPID is a discovery experiment with a clear peak signature over a flat background
median 3σ discovery sensitivity of 10^{27} yr**

Bonus: $2\nu\beta\beta$ dataset with $O(10^9)$ events:
Excellent potential for nuclear physics and precision studies

CUPID Outlook



CUPID's technology is mature & ready for construction

First data expected by 2030/2031

CUPID will be one of the leading experiments

Exciting prospects for a ton-scale experiment beyond CUPID with ^{100}Mo !

See also C. Nones
"BINGO", Sep 24, 13.20;
and many other developments
(TES, MMC)

Thank you

