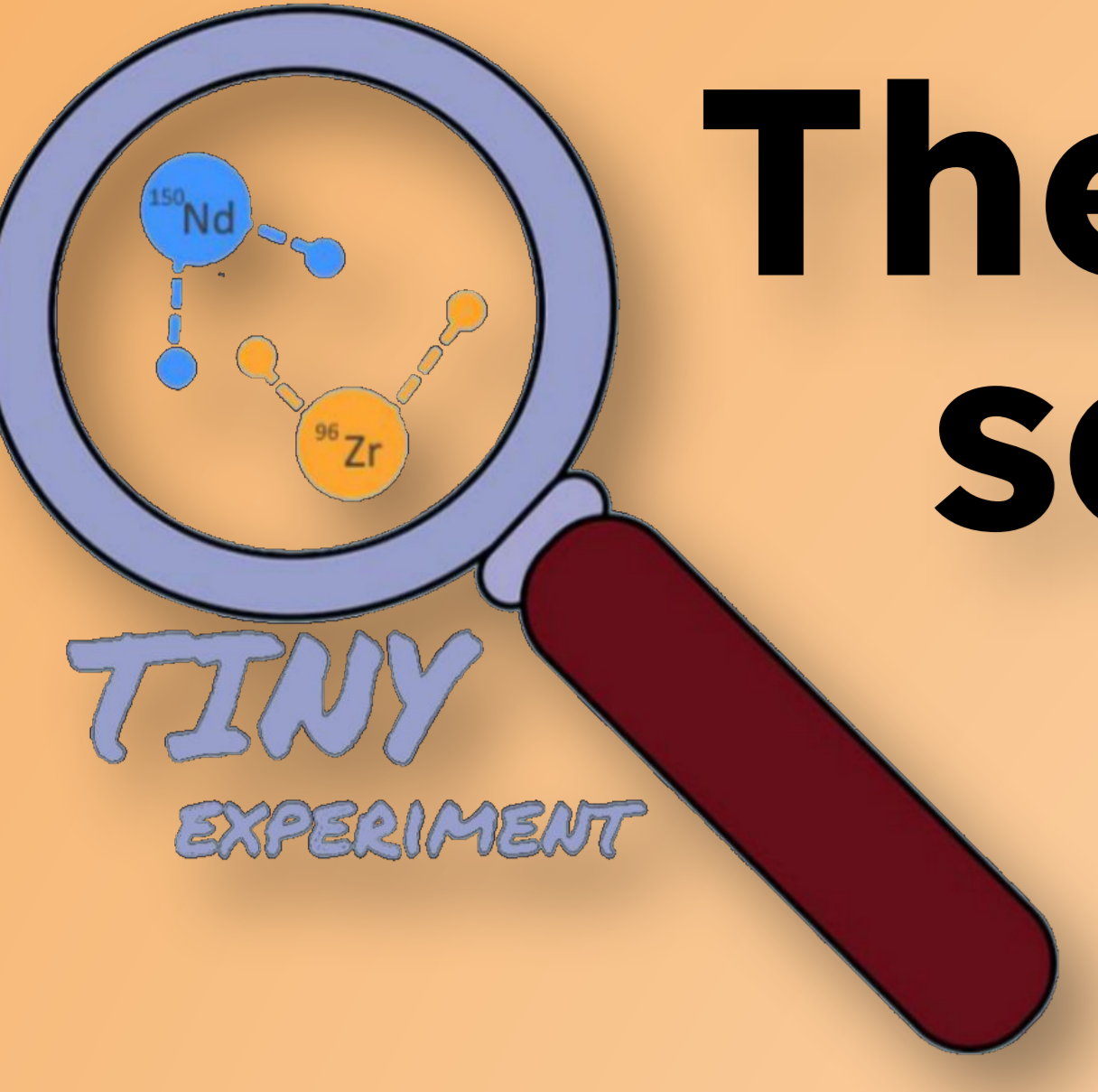


The TINY experiment: first results with Zr-based scintillating bolometer for $0\nu 2\beta$ decay search



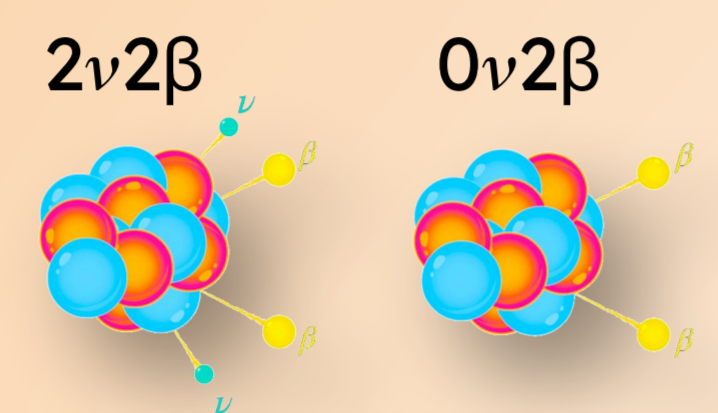
David Cintas on behalf of the TINY Collaboration
 IRFU, CEA Paris-Saclay, 91191 Gif-sur-Yvette, France
 david.cintasgonzalez@cea.fr



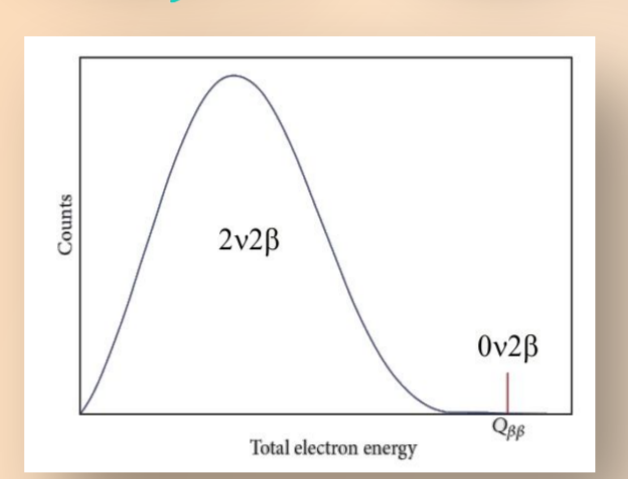
1 - Neutrinoless double beta decay ($0\nu 2\beta$)

The observation of $0\nu 2\beta$ would allow us to explore physics beyond SM:

- Neutrino nature defined (Majorana)
- Leptogenesis
- Matter-antimatter asymmetry
- Information on neutrino masses



Very rare decay ($T_{1/2} > 10^{26}$ yr)
 Few candidate isotopes promising for experiments



High sensitivity experiments require:

- High energy resolution
- High detection efficiency
- Long exposure
- **Low radioactive background**

Zero-background is essential for highly sensitive searches!

2 - The TINY project

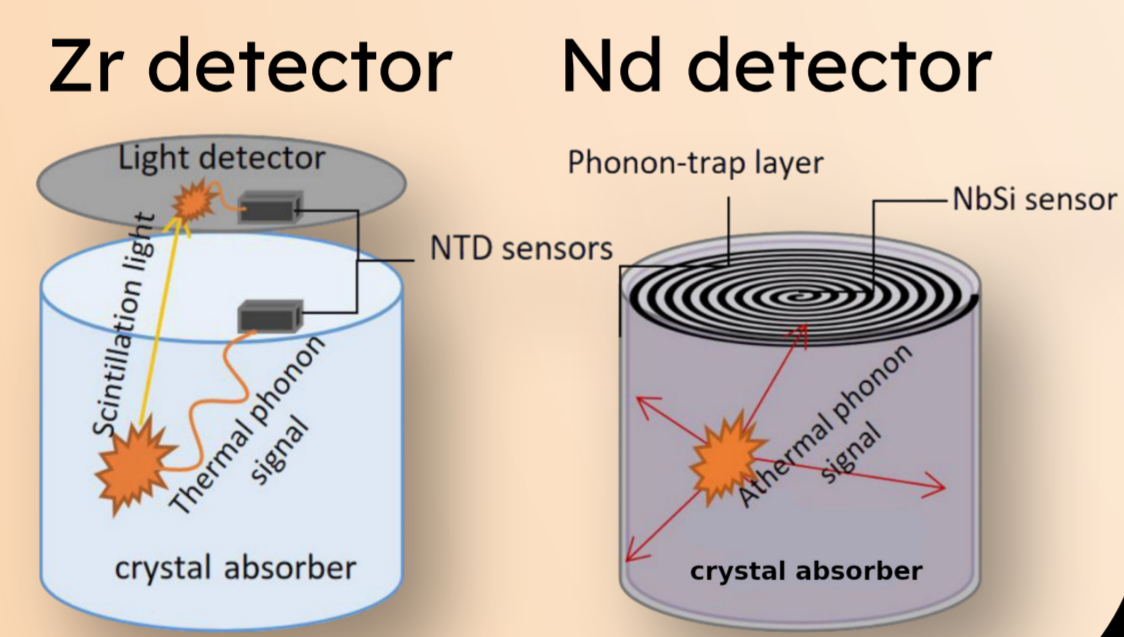
TINY (Two Isotopes for Neutrinoless double beta decaY search)¹: development of bolometric detectors, containing ^{96}Zr and ^{150}Nd isotopes for $0\nu 2\beta$ decay searches

These isotopes have high $Q_{\beta\beta}$ values (3350 and 3371 keV, respectively), above the main environmental γ background, an advantage for:

- Background reduction in ROI
- Theoretical predictions on the half-life

Zr-containing detectors: double read-out in scintillating bolometers with thermal sensors

Nd-containing detectors: single read-out in magnetic materials with athermal sensors (proof-of-concept)



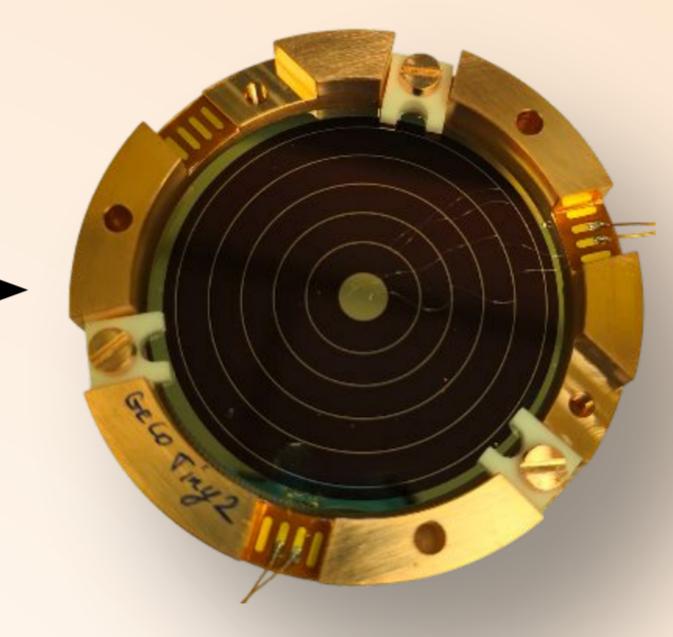
3 - Cs_2ZrCl_6 : a scintillating bolometer

First cryogenic characterization of a Cs_2ZrCl_6 (CZC) crystal

- Dimensions: $\varnothing 20 \times 20$ mm, 20.4 g
- Scintillator previously characterized at room temperature²

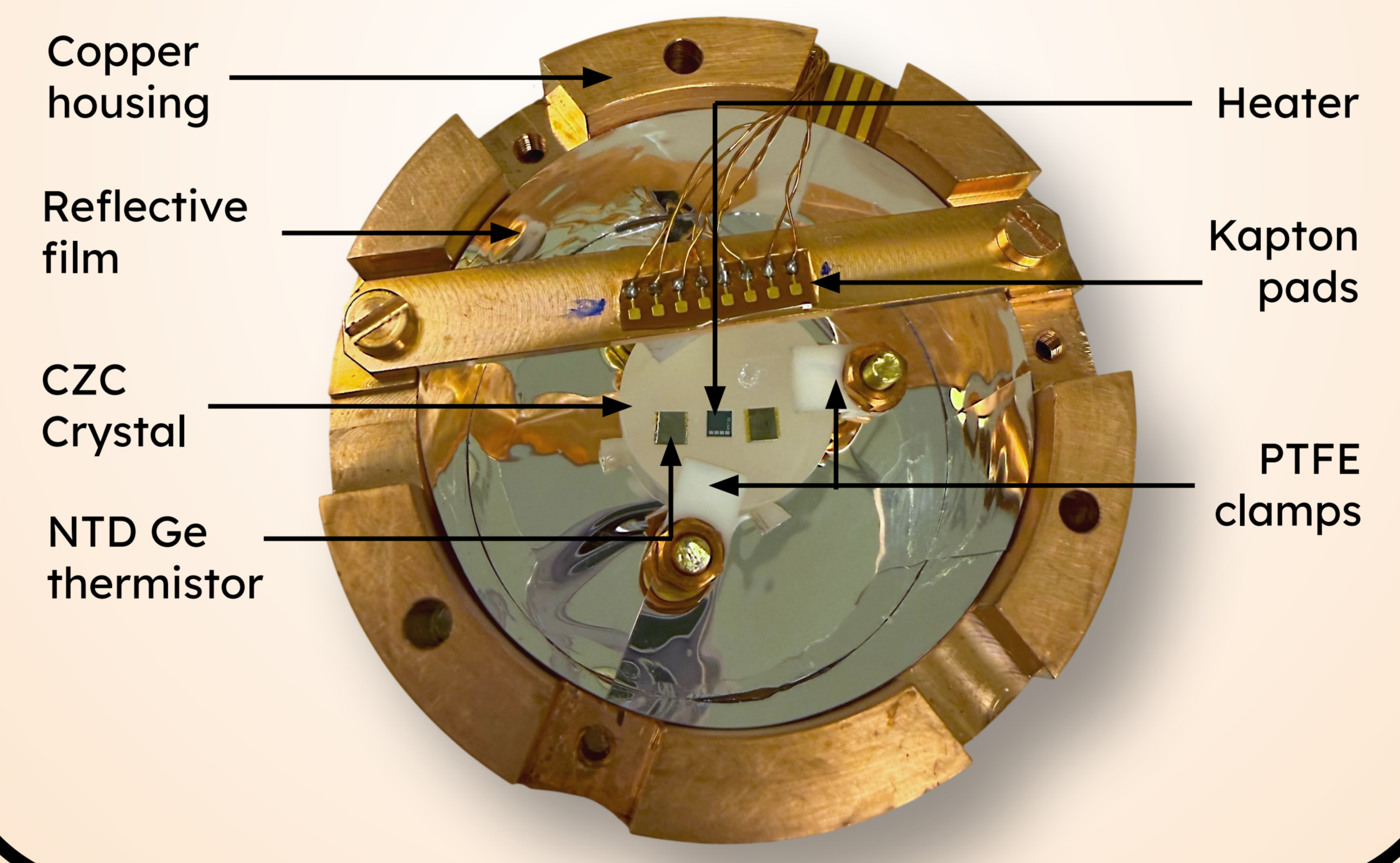
Double read out:

- Heat: Neutron Transmutation Doped (NTD) Ge thermistor
- Light: Ge wafer light detector³, placed above the crystal

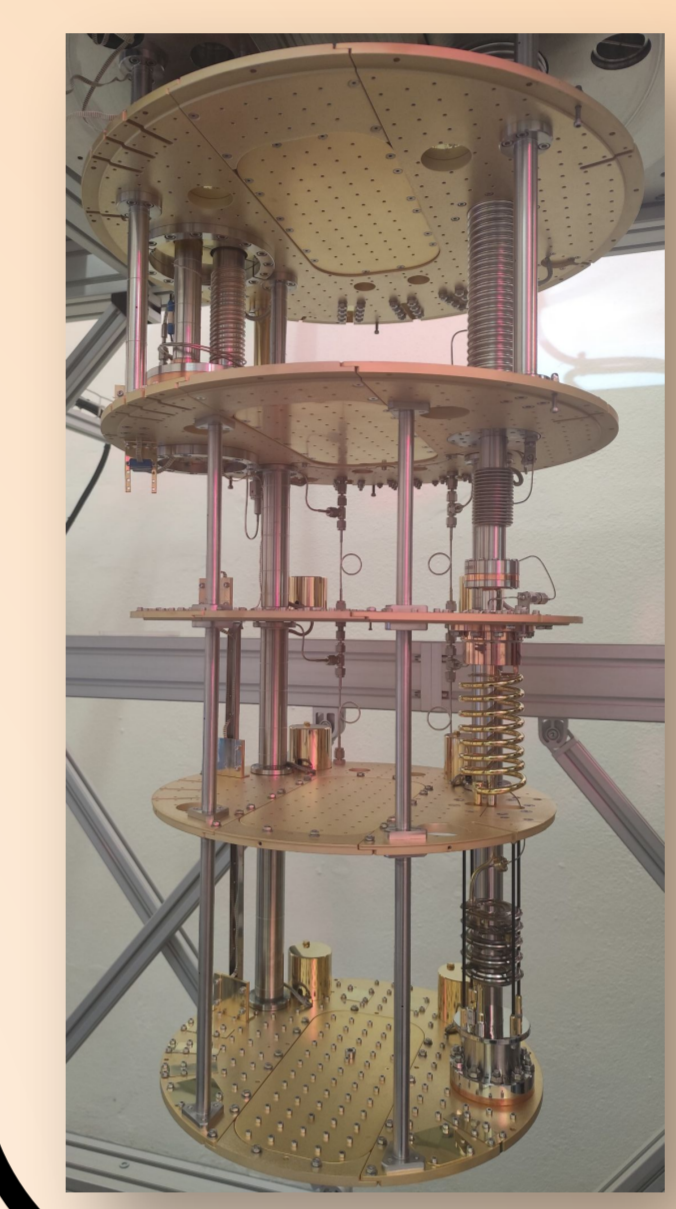


$^{238}\text{U}/^{234}\text{U}$ α source placed inside the detector housing

Cavity covered with a reflective film to improve light collection efficiency

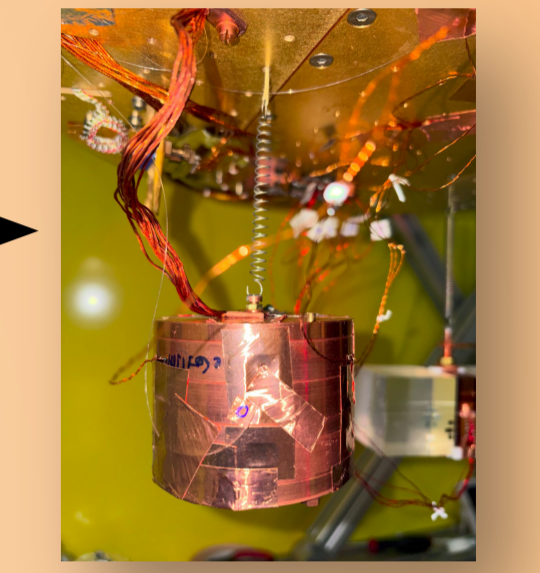


4 - Cryogenic setup and data taking



Setup:

- Proteo MX (Quantum Design) $^3\text{He}/^4\text{He}$ dilution refrigerator, commissioned in April 2025
- Shallow site at CEA - Paris Saclay (muon flux reduction from surface $\sim 30\%$)
- 5 cm of Pb shielding
- Spring suspension from mixing chamber plate



Data taking:

- Operating temperature = 15 mK
- 67 h ^{152}Eu calibration + 302 h background
- Two working points: maximum sensitivity and best resolution

5 - Energy response

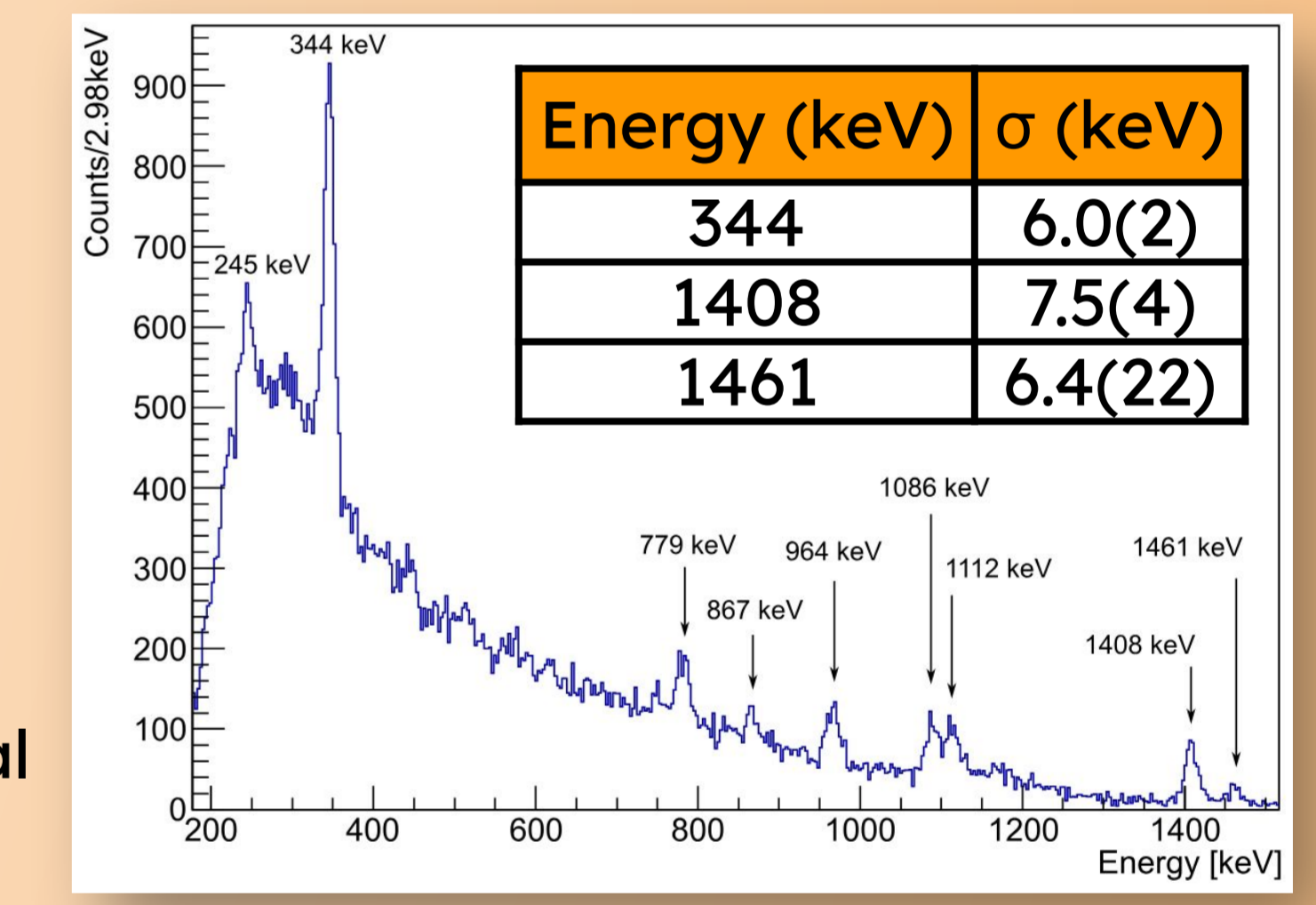
Calibration heat: ^{152}Eu source
 Calibration light: muon distribution

Main results:

- Best sensitivity = 92 nV/keV
- Baseline resolution = 6–8 keV
- Rise time = 3.9 ms
- Decay time = 18.0 ms
- Linear calibration response

Resolution limited by environmental noise, not by intrinsic properties of the CZC crystal

CZC works as a cryogenic calorimeter with keV-scale energy resolution



6 - Particle identification

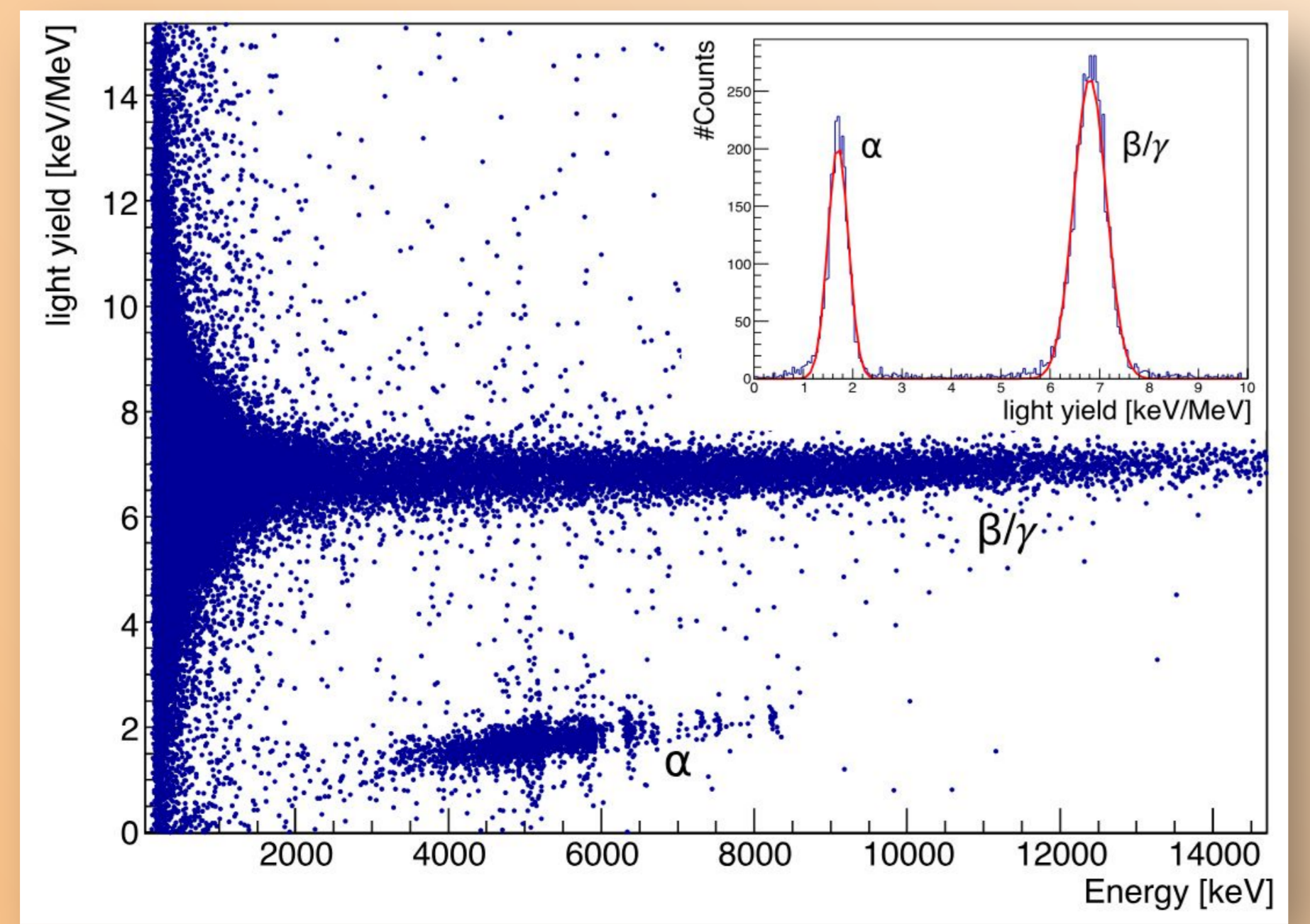
Simultaneous heat-light readout enables event-by-event particle identification

Measured light yield:

- $\gamma(\beta)$ band: ~ 7 keV
- α band ~ 1.7 keV

Discrimination power ≈ 14

Excellent α rejection enables strong background suppression in the ROI

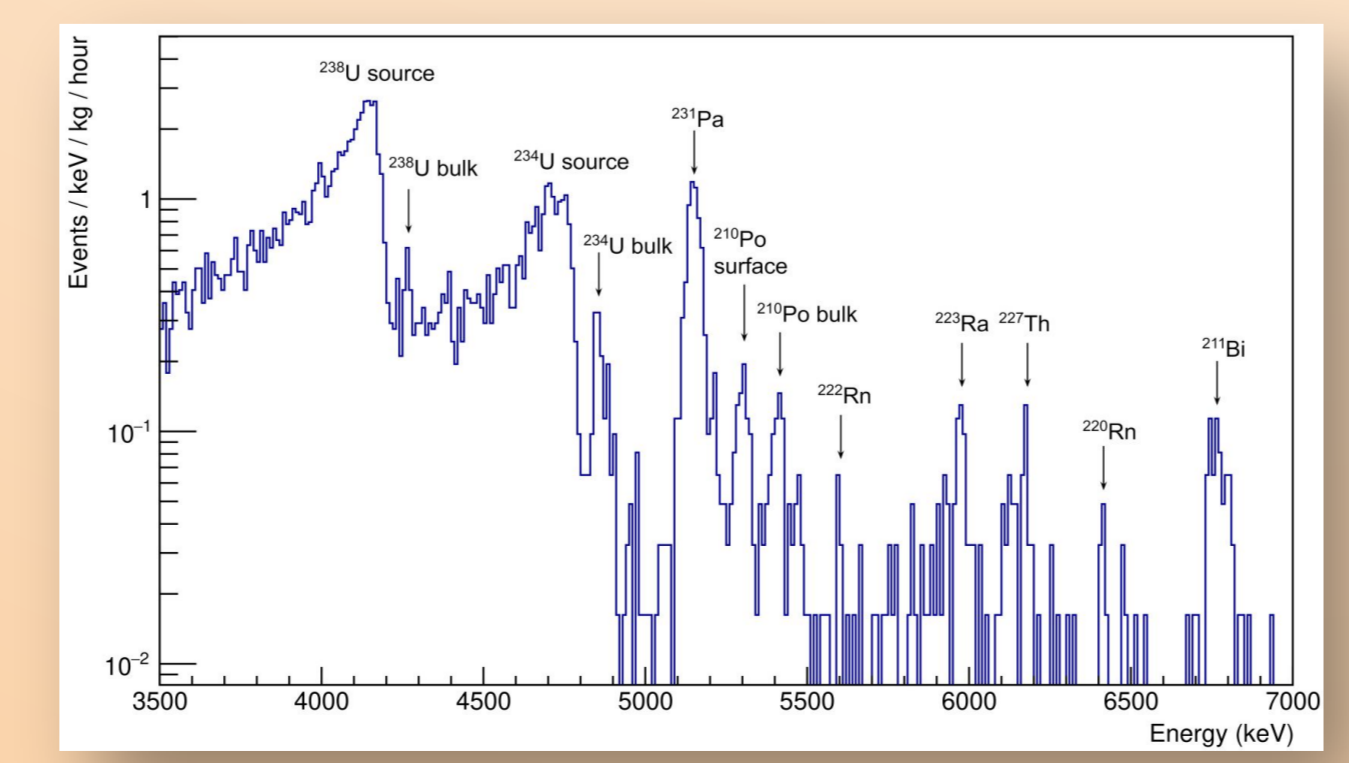


7 - Internal radiopurity

Internal radioactive contamination evaluated using α events identified via LY from the 302 h background run

Dominant contaminant: ^{231}Pa

Bolometric α spectroscopy resolves internal contaminants and provides a direct radiopurity assessment



Isotope	Activity*
^{238}U	1.7(6)
^{234}U	3.2(8)
^{210}Po bulk	1.8(8)
^{210}Po surf.	1.4(5)
^{231}Pa	17.7(15)
^{227}Ac	1.2(2)
^{226}Ra	< 0.3
^{228}Th	< 0.4

* units in mBq/kg

8 - Conclusion and prospects

First cryogenic operation of a Cs_2ZrCl_6 scintillating bolometer within the TINY project

Cs_2ZrCl_6 is a promising Zr-based scintillating bolometer for future double beta decay studies thanks to particle identification and good energy resolution

Development of larger, high-radiopurity crystals is currently ongoing

The final TINY experiment will perform underground measurements to demonstrate the scalability of this technology toward ton-scale rare-event searches

¹ Poster in Neutrino 2024 (11nq.com/tinyexperiment)

² JINST 19 (2024) P05037

³ NIMA 940 (2019) 320

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