Results on double beta decay of ^{82}Se with CUPID-0 Phase I

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on behalf of the CUPID-0 collaboration

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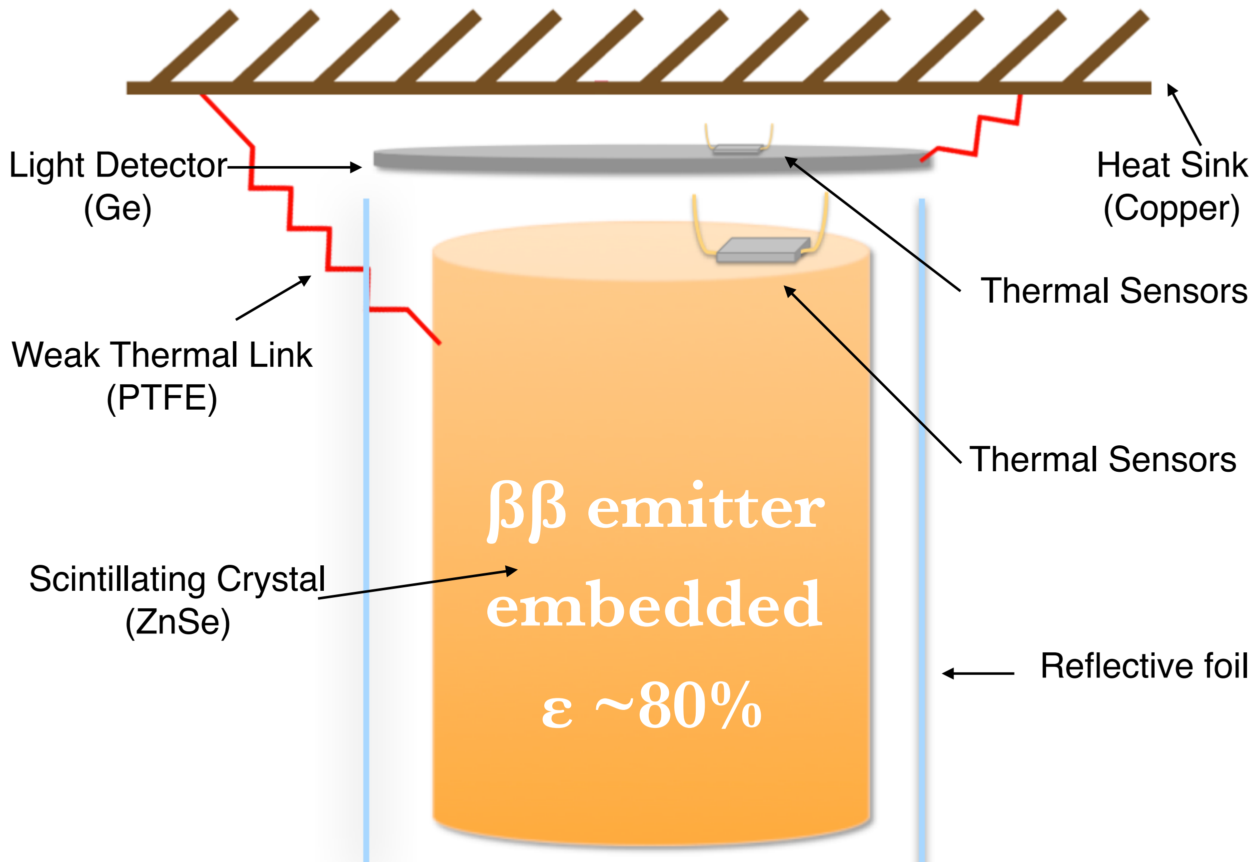
Scintillating bolometers

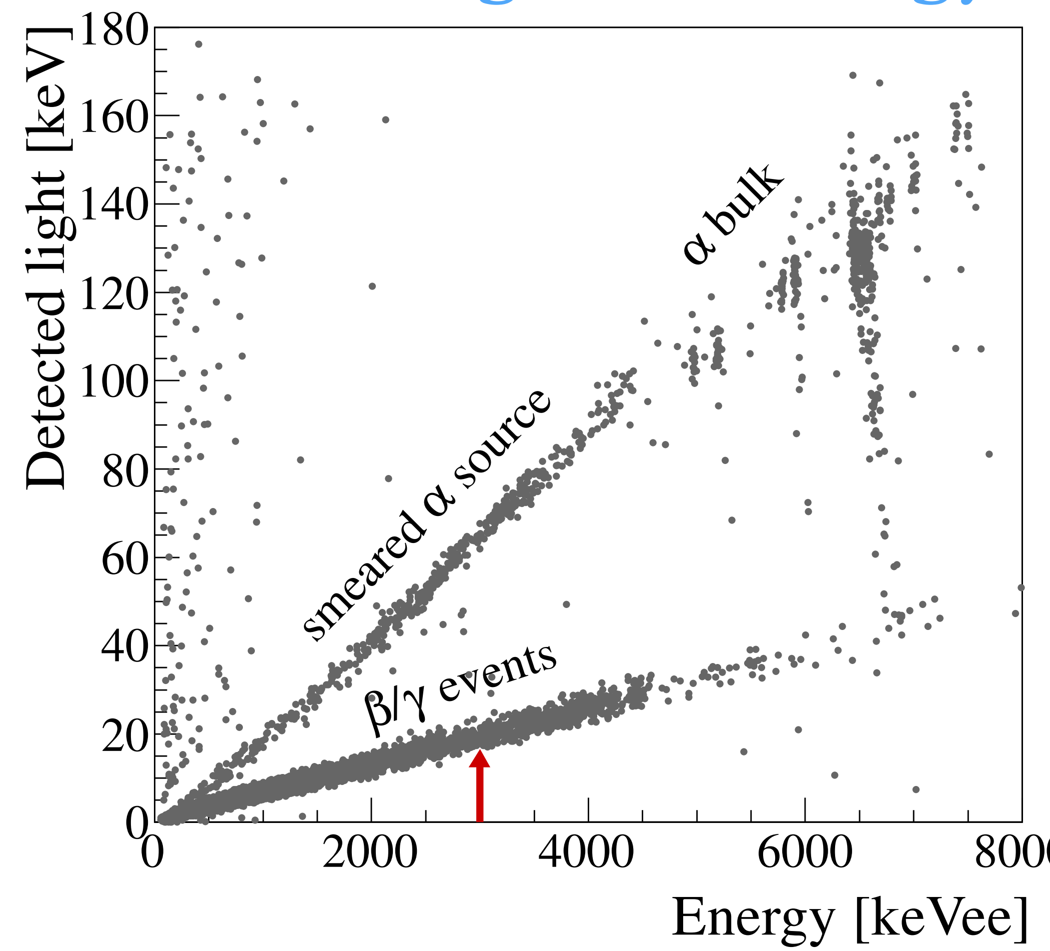


Scintillating crystals operated at **~10 mK**
Particle interaction ➜ T increasing

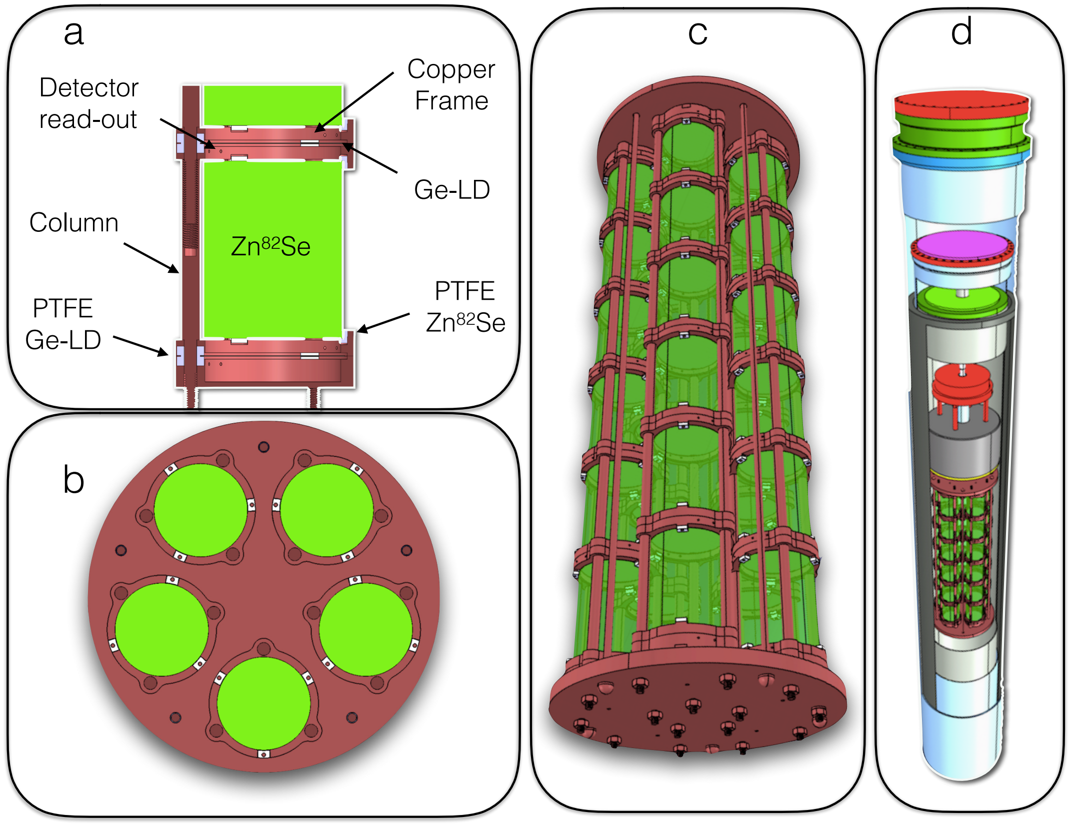
0νββ Signal: monochromatic peak at the Q-value of the reaction.

- Grown from **different ββ emitters**
- Excellent **energy resolution** (<1%)
- Modular design allows for large **scalability**
- **Q-value > 2.6 MeV**
- **$LY_{\alpha} \neq LY_{\beta/\gamma}$ ➜ Particle ID**

ZnSe: Light Vs Energy



CUPID-0 detector



a. Single module
b. Top view
c. CUPID-0 array
d. Cryostat

- 24 **95%-enriched $Zn^{82}Se$ crystals** + 2 natural ones
- 31 Ge **light detectors**
- **Reflective** foil Vikuiti™ to increase the light collection
- Total Mass: **10.5 kg (ZnSe) - 5.17 kg (^{82}Se)**
- $Q_{\beta\beta}$ = **(2997.9 ± 0.3) keV**
- Hosted in the CUORE-0 **Cryostat (LNGS, Italy)**

☞ Eur. Phys. J. C (2018) 78:428 (Detector Paper)

CUPID-0 livetime

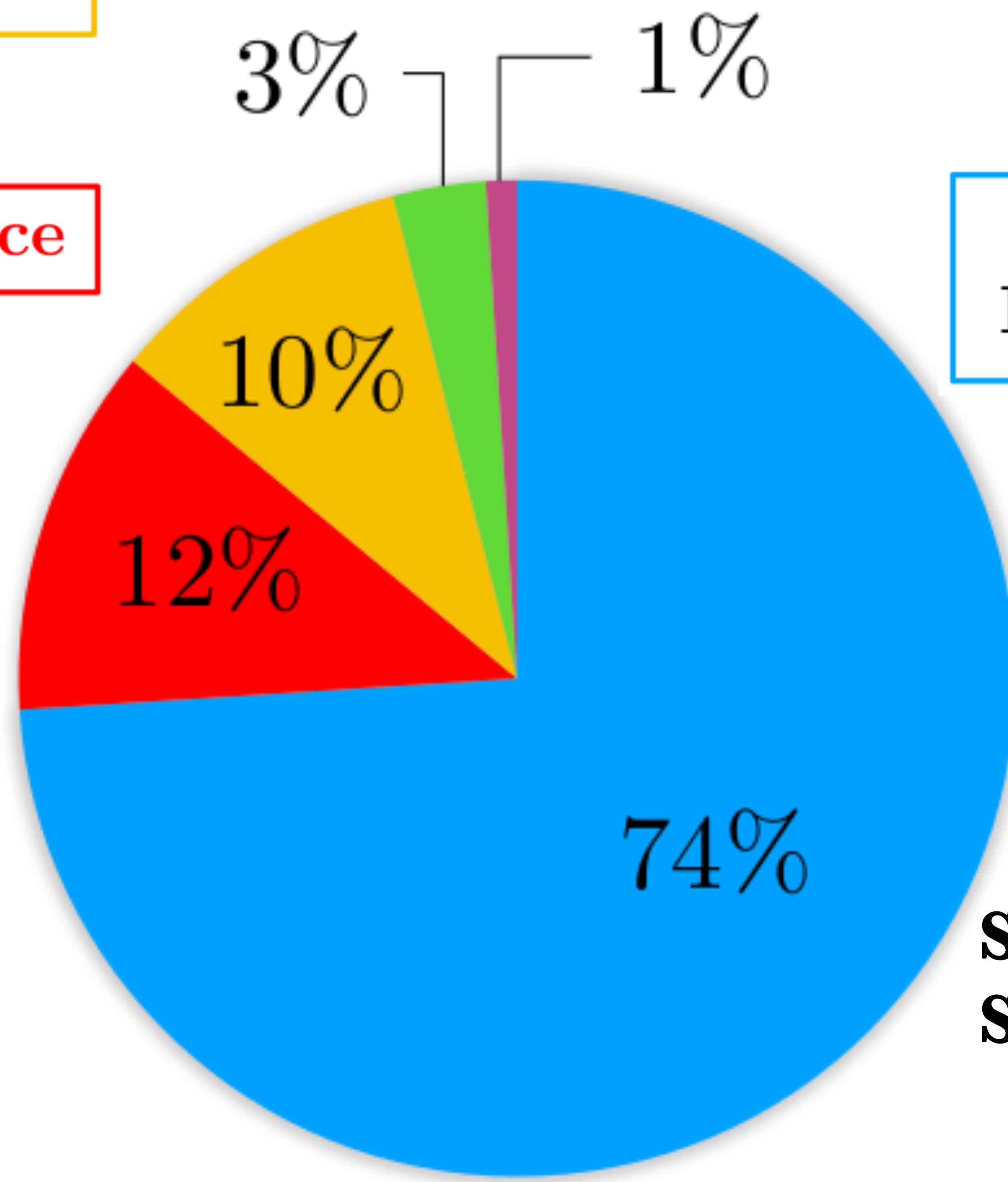
^{56}Co Energy Calibration

^{232}Th Energy Calibration

System manteinance

AmBe source
$\beta\gamma$ Shape Characterization in the ROI

$\beta\beta$ physics
Exposure: 9.95 kg·y

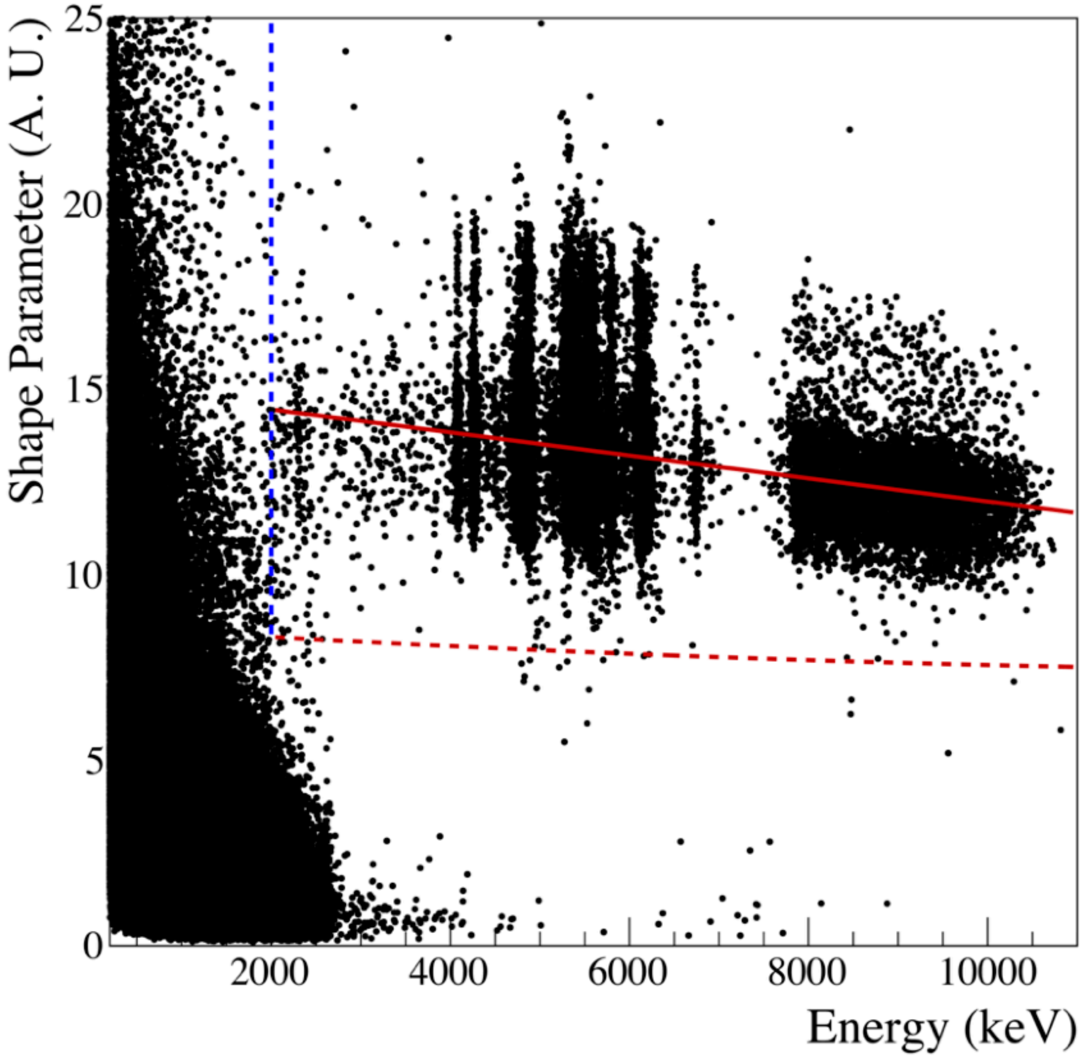


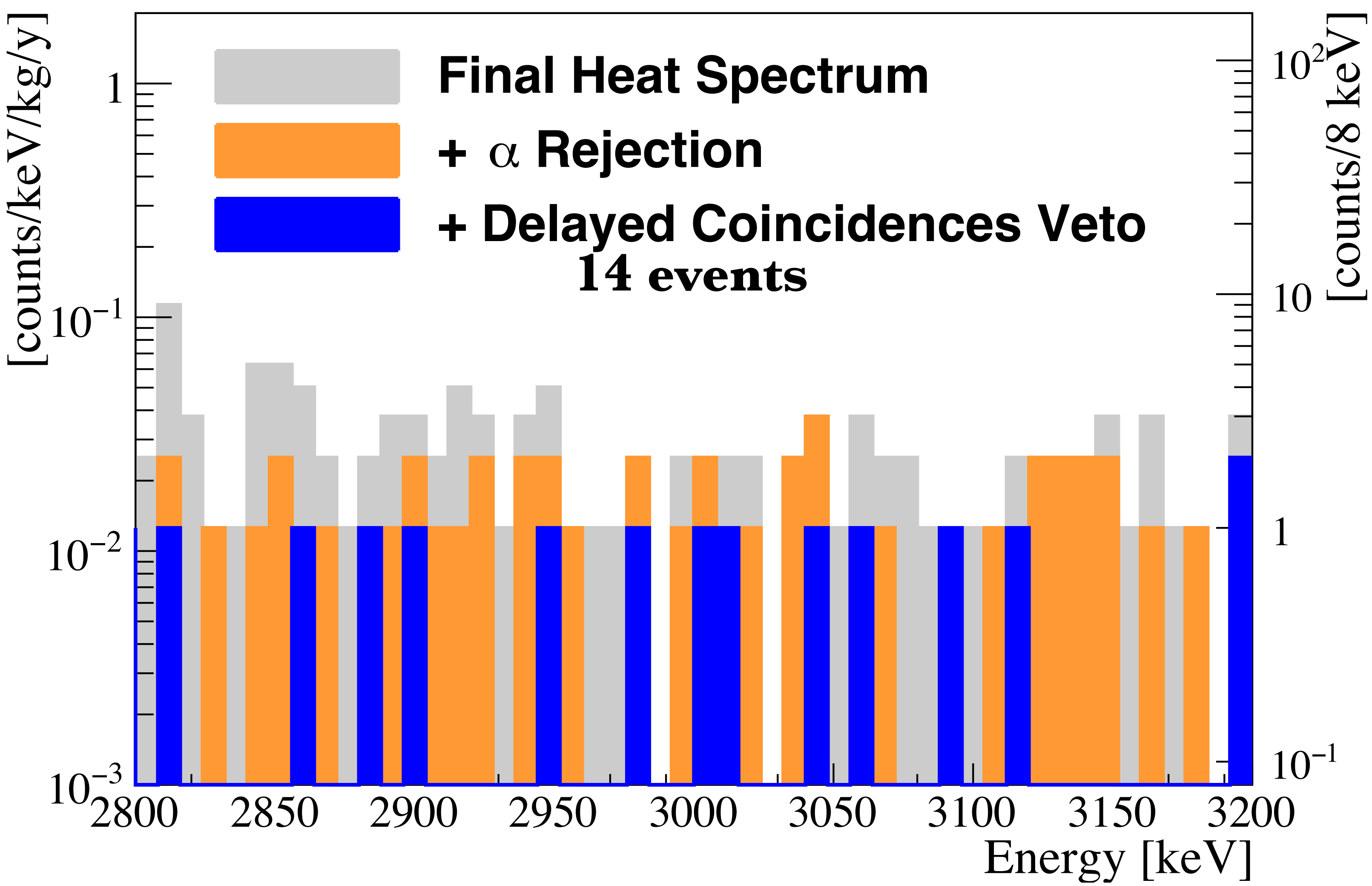
Start: March 2017
Stop: December 2018

Performances and results

- Final Exposure (Physics Runs): **9.95 kg × y (22 Zn^{82}Se)**
- **^{82}Se atoms: (3.41 ± 0.03) 10^{25}**
- Resolution at $Q_{\beta\beta}$: **(20.05 ± 0.34) keV**
- Background: **$3.5^{-0.9}_{+1.0}$ × 10^{-3} counts/(keV × kg × y)**
- $T_{1/2}$ ($0\nu\beta\beta$ ^{82}Se) > **3.5 × 10^{24} y (90% C.I. Limit)**
  5.0 × 10^{24} y (Median Sensitivity)
- $m_{\beta\beta}$ < **(311 - 638) eV**

New Release





Background model overview

In order to measure the **2νββ activity** and **identify the background sources**, we perform a **Bayesian fit** to the experimental data with a linear combination of simulated spectra.

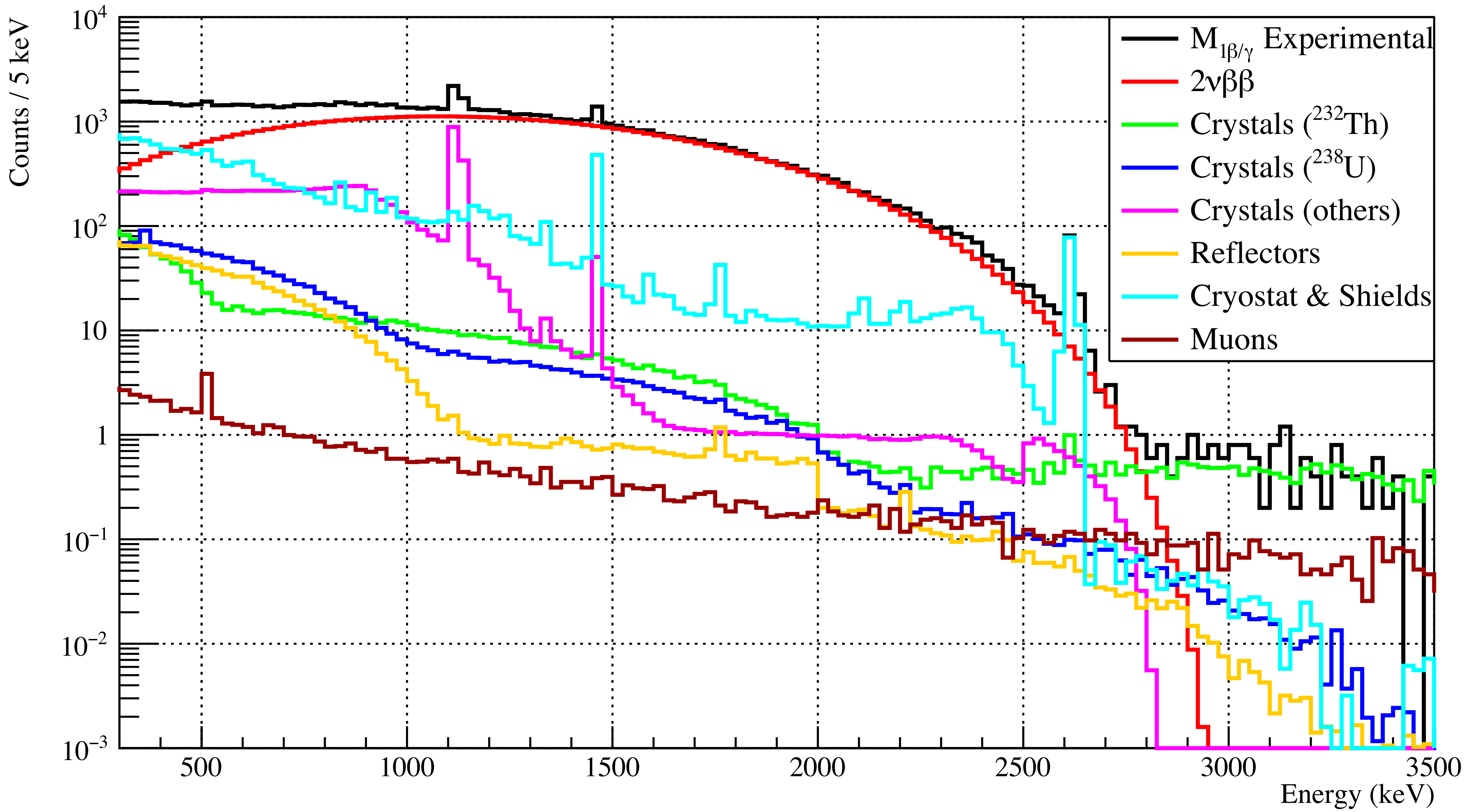
33 BACKGROUND SOURCES

- ZnSe crystals **bulk** / **surf_O(10μm)** / **surf_O(10nm)** contaminations
- Reflective foil **surf_O(10nm)**
- Cryostat (bulk only):
  - Internal shields (Holder + 600 mK + 50 mK)
  - Roman Lead
  - External shields (IVC + OVC)
  - External Lead
- Muons (normalized to high multiplicity events M>3)

Thickness of VM foils: 70 μm
Range of a particles ~50 μm

☞ **arXiv:1904.10397v1 (Background Model)**

Background Components (β/γ)



2νββ is the dominant contribution!
Caveat: Delayed coincidence cut is not applied in this plot.

☞ **arXiv:1904.10397v1 (Background Model)**

Region Of Interest

Background rate in the ROI (2.8 - 3.2 MeV) after the **delayed coincidences** cut.

Source	Rate (counts/(keV·kg·y))	Systematics
$2\nu\beta\beta$	$(6.0 \pm 0.3) \times 10^{-4}$	
Crystals bulk – ^{232}Th	$(3.4 \pm 0.6) \times 10^{-4}$	
Crystals surf – ^{232}Th	$(3.4 \pm 0.5) \times 10^{-4}$	$[2.2 - 4.7] \times 10^{-4}$
Crystals surf – ^{238}U	$(5.3 \pm 0.4) \times 10^{-4}$	$[5 - 7] \times 10^{-4}$
Reflectors – ^{232}Th	$< 7 \times 10^{-5}$	
Reflectors – ^{238}U	$(1.8 \pm 0.3) \times 10^{-4}$	$[1 - 3] \times 10^{-4}$
Cryostat & Shields – ^{232}Th	$(4.0 \pm 1.3) \times 10^{-4}$	$[0.7 - 11] \times 10^{-4}$
Cryostat & Shields – ^{238}U	$(2.2 \pm 0.4) \times 10^{-4}$	$[1.5 - 2.6] \times 10^{-4}$
Muons	$(1.53 \pm 0.13) \times 10^{-3}$	$[1.3 - 1.8] \times 10^{-3}$
Total	$(4.2 \pm 0.2) \times 10^{-3}$	$[4.1 - 4.8] \times 10^{-3}$

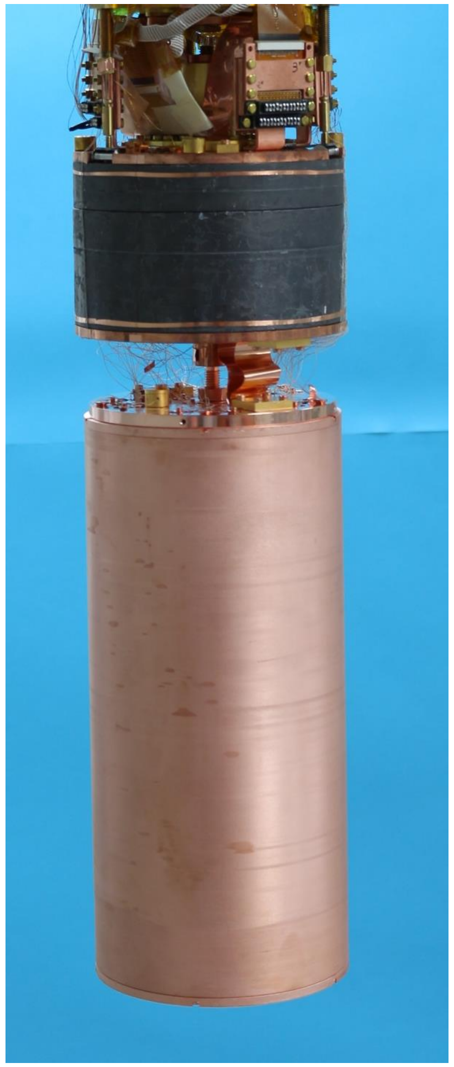
We can improve understanding of our background thanks to CUPID-0 Phase II

Detector upgrade

- μ are the main residual background
  - Installation of μ-veto

No reflective foil
- Sensitivity to M2 α events

New clear Cu Shield
- Thermalization
- Additional shielding



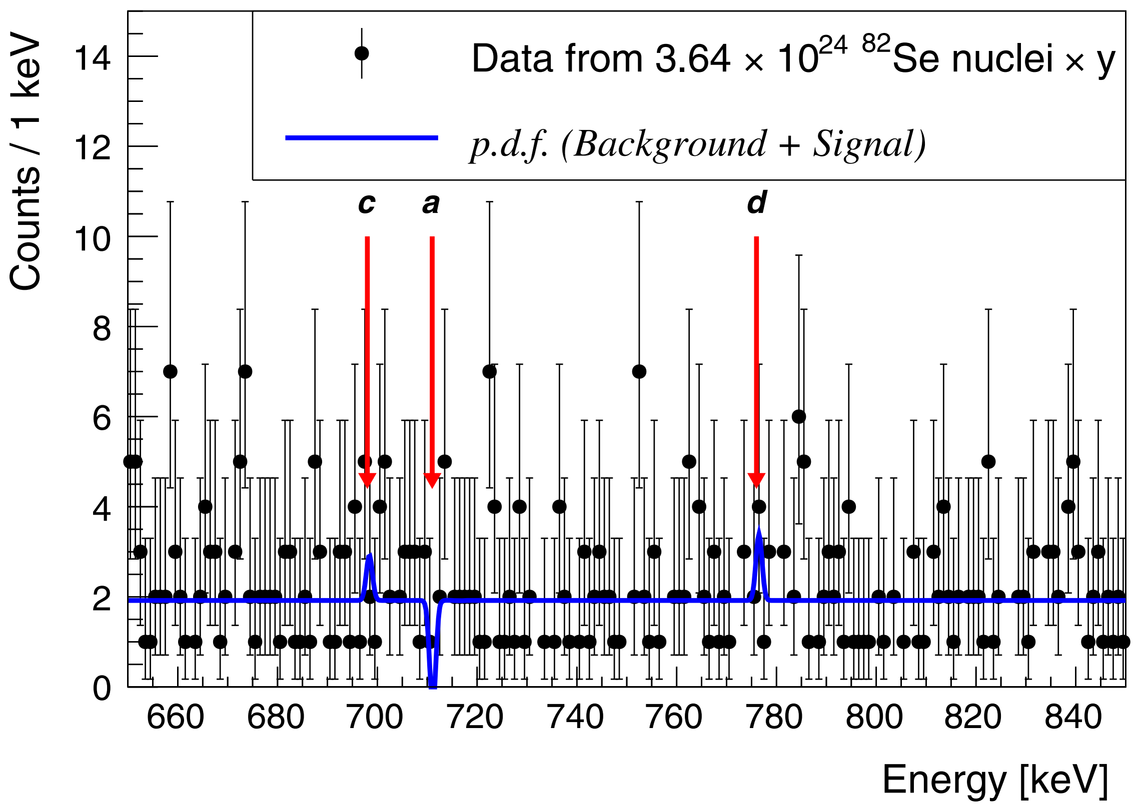
CUPID-0 PhaseII data-taking is going to start!

Double β-decay into the excited states of ^{82}Kr

HPGe measurement with 2.5 kg of enriched ^{82}Se (2νββ + 0νββ)

☞ Eur. Phys. J. C (2015) 75:591

$$T_{1/2}^{\beta\beta}(^{82}\mathrm{Se} \to {}^{82}\mathrm{Kr}_{0_1^+}) > 3.4 \times 10^{22}\ \mathrm{y}$$
$$T_{1/2}^{\beta\beta}(^{82}\mathrm{Se} \to {}^{82}\mathrm{Kr}_{2_1^+}) > 1.3 \times 10^{22}\ \mathrm{y}$$
$$T_{1/2}^{\beta\beta}(^{82}\mathrm{Se} \to {}^{82}\mathrm{Kr}_{2_2^+}) > 1.0 \times 10^{22}\ \mathrm{y}$$



CUPID- 0 measurement of 0νββ

☞ Eur. Phys. J. C (2018) 78:888

$$T_{1/2}^{\beta\beta}(^{82}\mathrm{Se} \to {}^{82}\mathrm{Kr}_{0_1^+}) > 8.11 \times 10^{22}\ \mathrm{y}$$
$$T_{1/2}^{\beta\beta}(^{82}\mathrm{Se} \to {}^{82}\mathrm{Kr}_{2_1^+}) > 1.11 \times 10^{23}\ \mathrm{y}$$
$$T_{1/2}^{\beta\beta}(^{82}\mathrm{Se} \to {}^{82}\mathrm{Kr}_{2_2^+}) > 8.40 \times 10^{22}\ \mathrm{y}$$

Soon also 2νββ on exited states from CUPID-0

Conclusions

- CUPID-0 is the first experiment for ββ-decay based on **highly enriched scintillating calorimeter**
- An **excellent Alpha rejection** has been demonstrated
- **Lower background** cryogenic calorimeters
- Best limit on ^{82}Se **0νββ**
- Best measurement of ^{82}Se **2νββ**
- **Single State Dominance** proved
- CUPID-0, together with CUORE and CUPID-Mo, is laying the foundation for the next generation CUPID experiment.