First results on neutrinoless double beta decay of ^{82}Se with CUPID-0

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30th Rencontres de Blois

CUPID: a next generation experiment

CUPID (CUORE Upgrade with Particle IDentification)

is a proposed tonne-scale experiment based on criogenic calorimeters which aims at a sensitivity to the **Effective Majorana Mass** on the order of **10 meV**.

INCREASE THE SOURCE MASS → **ISOTOPIC ENRICHMENT**

Three candidates:
^{130}Te - ^{82}Se - ^{100}Mo

REDUCE THE BACKGROUND →

- **ALPHA REJECTION**
- **IMPROVED MATERIAL SELECTION**
- **MUON VETO**
- **BETTER ENERGY RESOLUTION**

CUPID: a next generation experiment

CUPID (CUORE Upgrade with Particle IDentification)

CUPID-0 is the first array of **enriched scintillating** cryogenic calorimeter based on **$Zn^{82}Se$ crystals**: the first demonstrator towards CUPID.

INCREASE THE SOURCE MASS → **ISOTOPIC ENRICHMENT**

Three candidates:
^{130}Te - $\boxed{^{82}Se}$ - ^{100}Mo

ALPHA REJECTION

REDUCE THE BACKGROUND →

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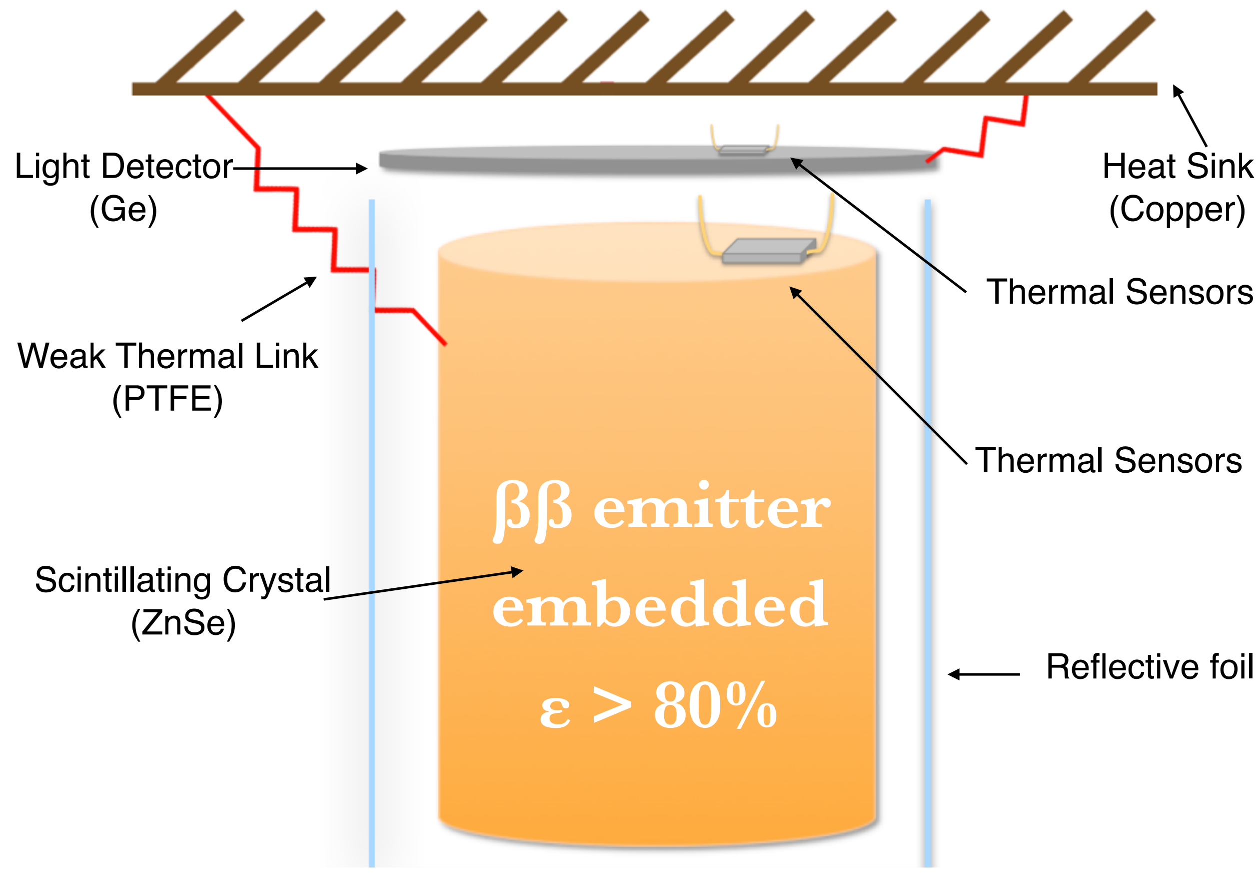
Scintillating cryogenic calorimeters

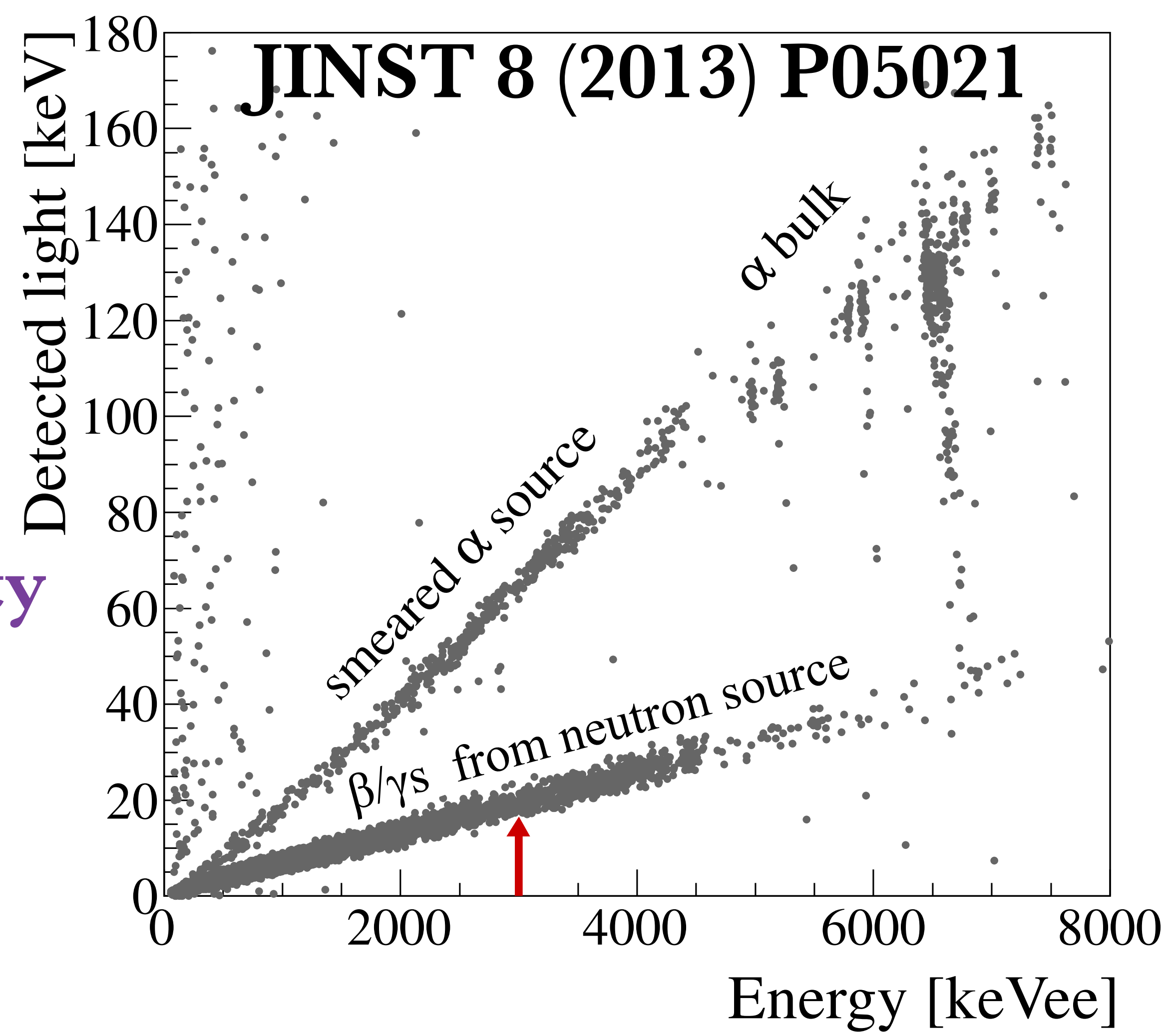


Scintillating crystals operated at **~10 mK**
Particle interaction ➜ T increasing

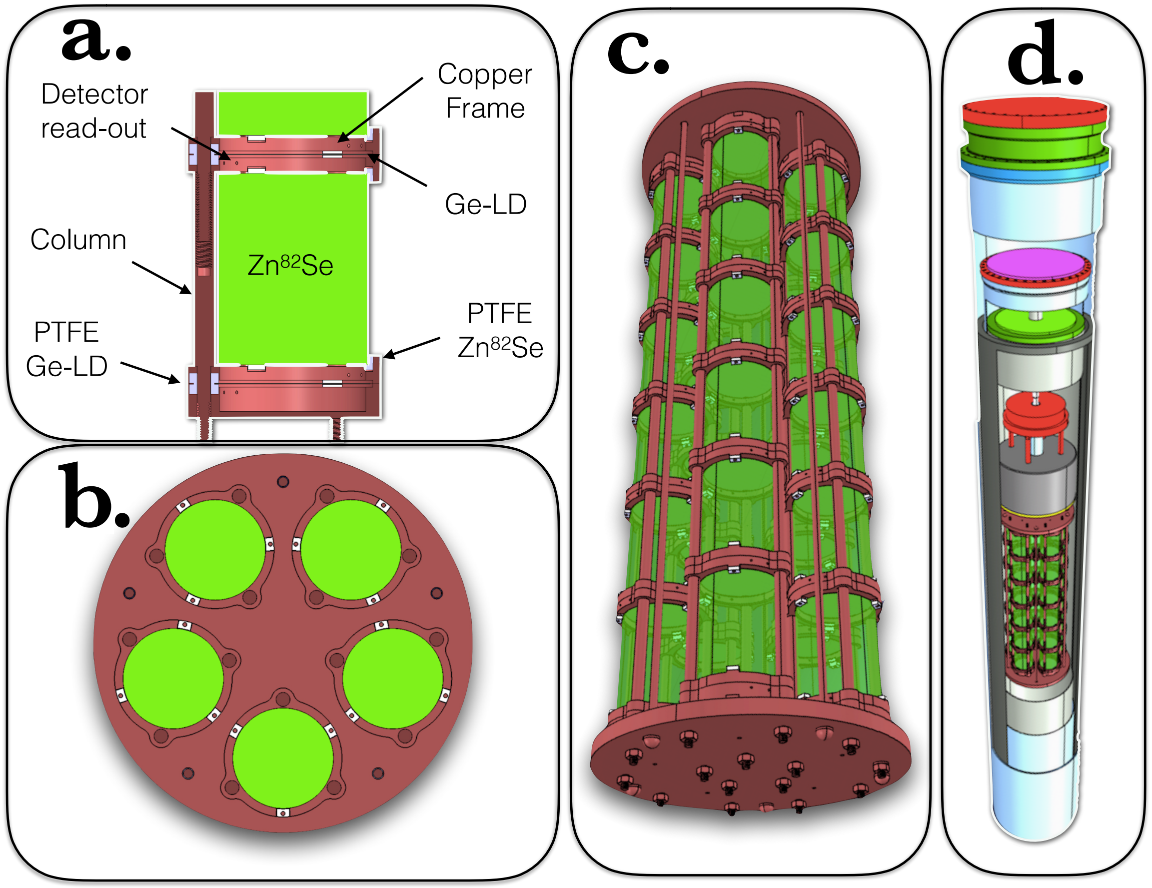
0νββ Signal: monochromatic peak at the Q-value of the reaction.

- 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



The CUPID-0 detector



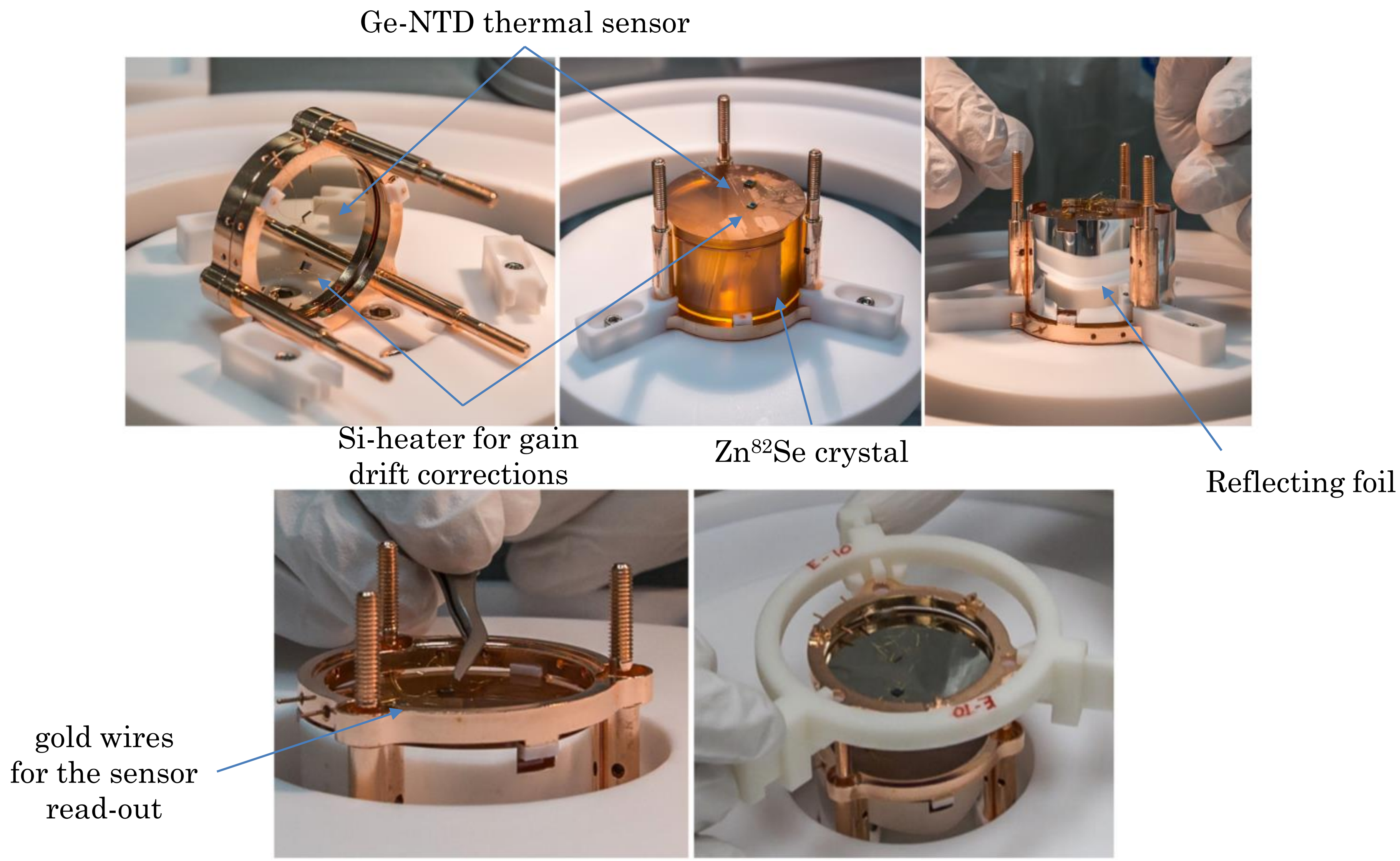
a. Single module
b. Top view
c. CUPID-0 array
d. Cryostat

- 24 **95%-enriched $Zn^{82}Se$ crystals** + 2 natural ones
- 31 Ge **light detectors**
- **Reflective** foil 3M Vikuiti™
- Total Mass: **10.5 kg (ZnSe)**
- Mass of ^{82}Se: **5.32 kg**
- Goal: background @ $Q_{\beta\beta}$ ~10^{-3} counts/(keV·kg·y)
- $Q_{\beta\beta}$ = **(2997.9 ± 0.3) keV**

The CUPID-0 assembly

- All activities were carried out in an underground Rn-suppressed clean room
- Assembly started on October, 2016
- Complex assembly: crystals have all different shapes and heights

Single module assembly

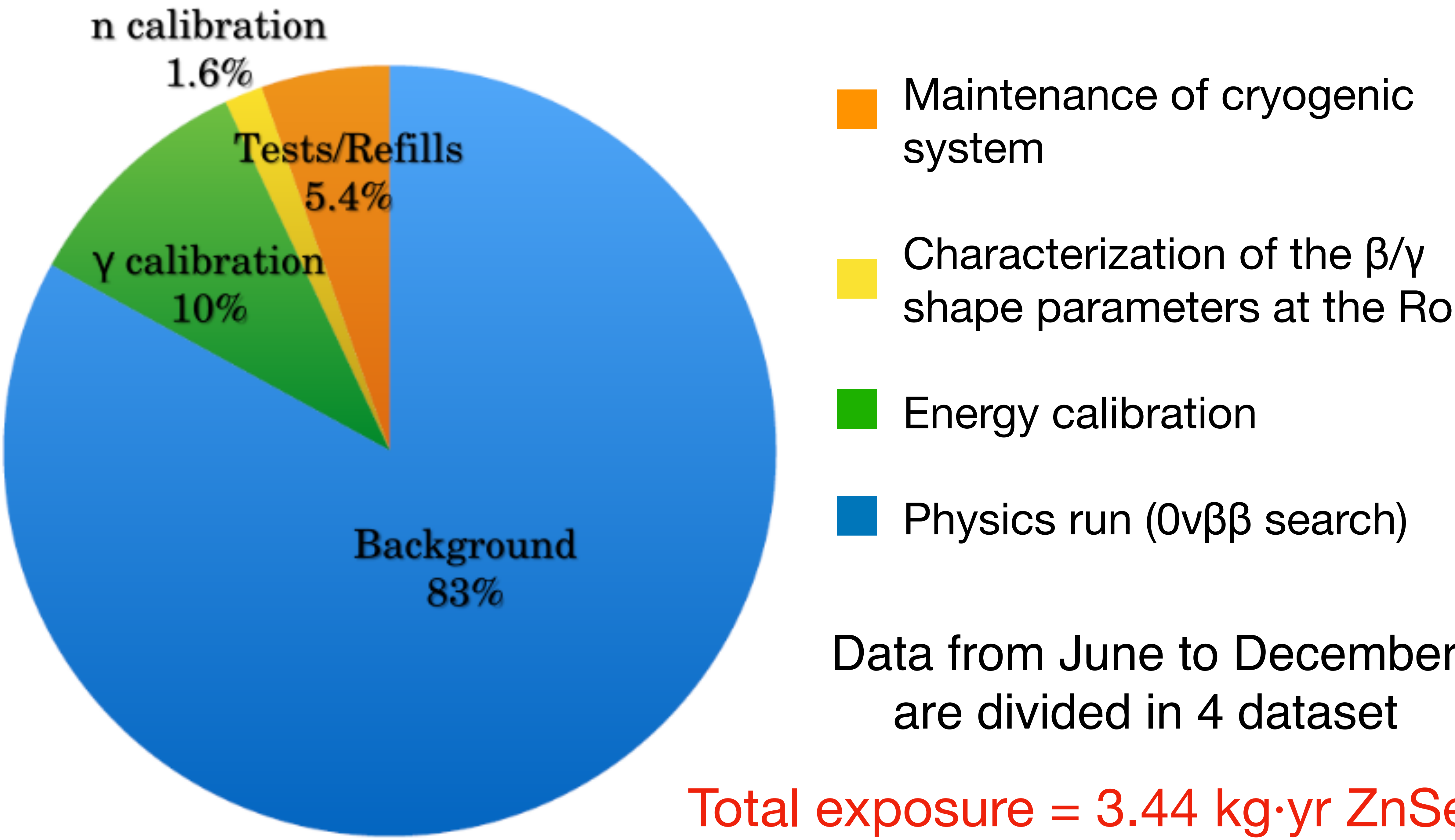


Data-taking efficiency

The data taking has started on **March 2017.**

Data collected in the first months used for system debugging and improvement

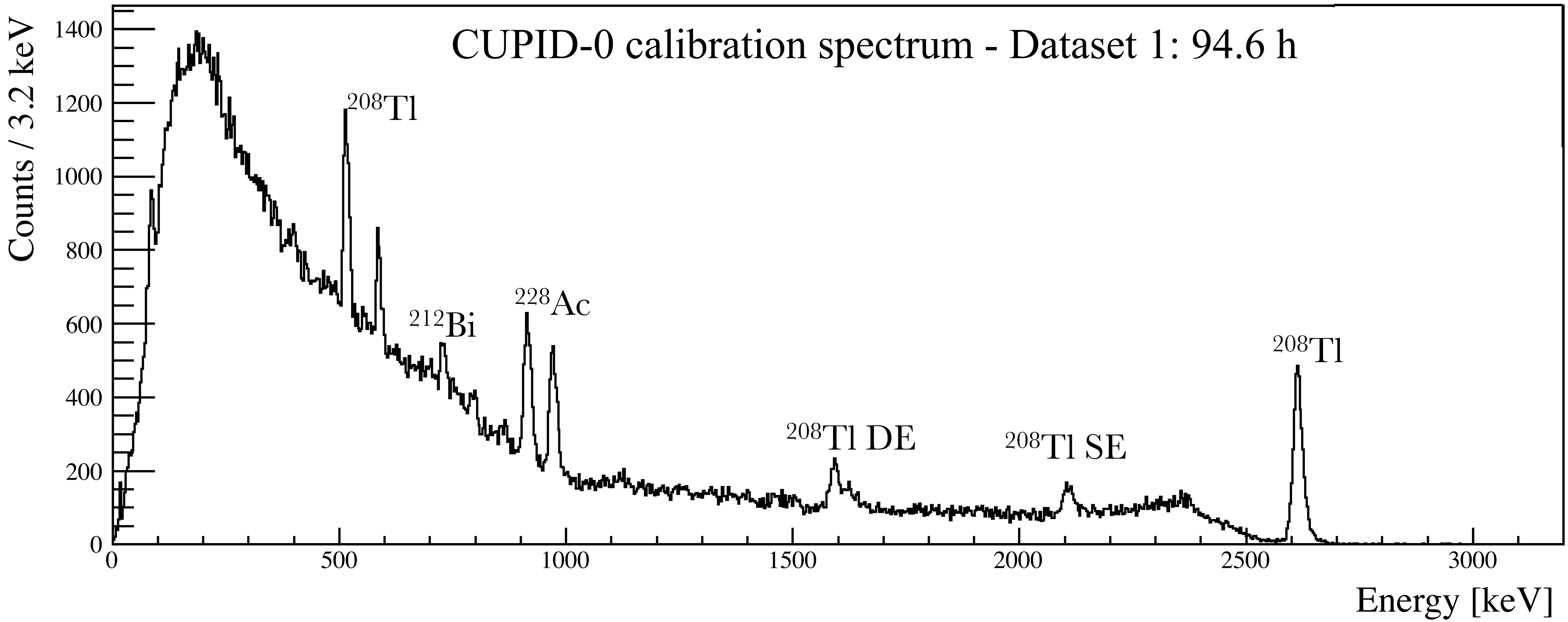
First data release: June 2017 - December 2017



Data from June to December are divided in 4 dataset

Total exposure = 3.44 kg·yr ZnSe

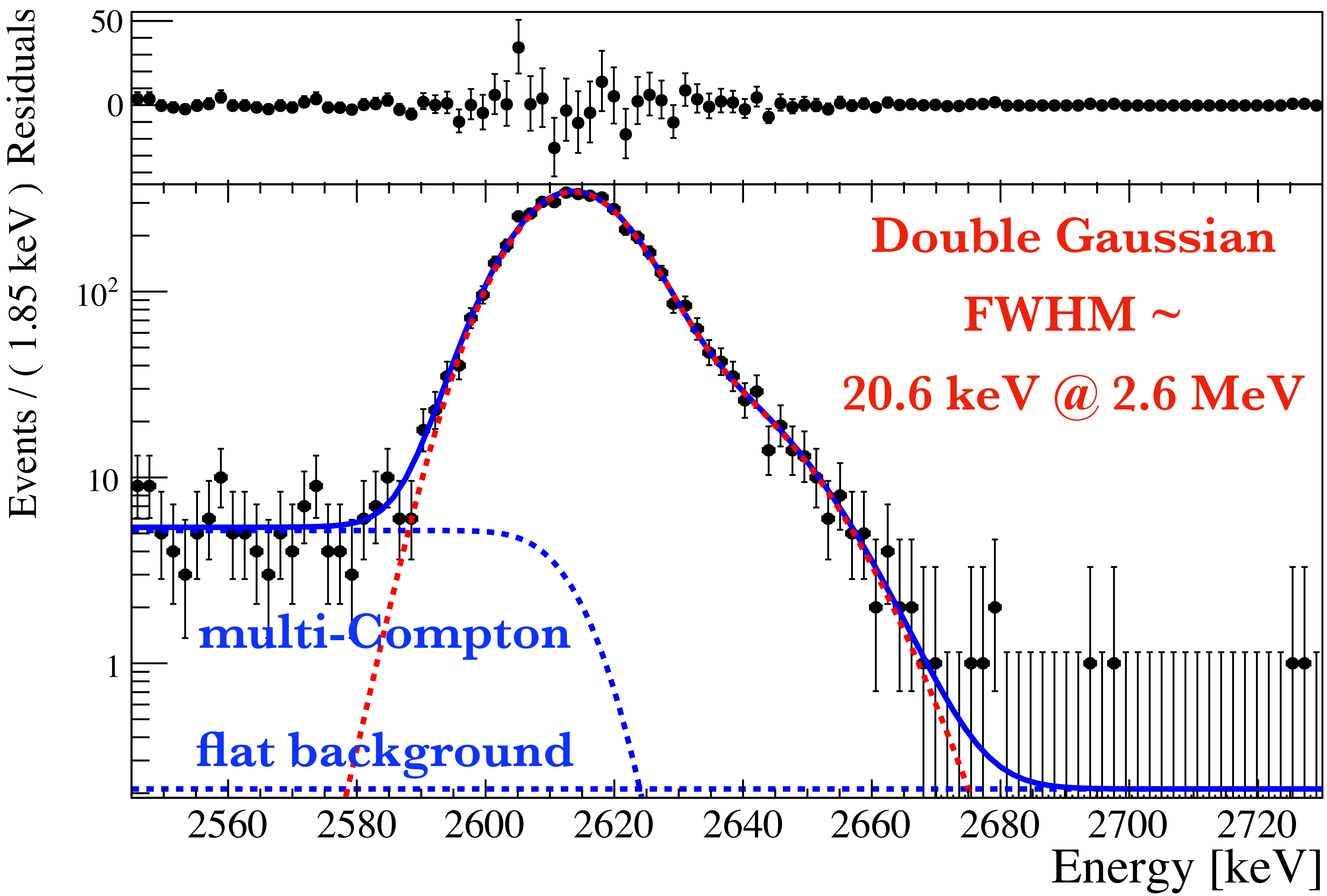
Detector performances



- **Baseline resolution**: 5 keV FWHM
- Resolution at **2.6 MeV ~ 20 keV** (deteriorated by crystals quality)
- Threshold is channel dependent and ranges between **10 and 110 keV**

Further details in Eur.Phys.J. C78 (2018) no.5, 428
CUPID-0 detector paper

Response function



Energy response of ZnSe to γs is not gaussian.

Double-Gaussian provides the best line-shape fit.

For each dataset the 2615 keV-line is used as benchmark.

Energy resolution

The energy resolution at the Q-value (2998 keV) is extrapolated by linear regression of the FWHM of the calibration peaks

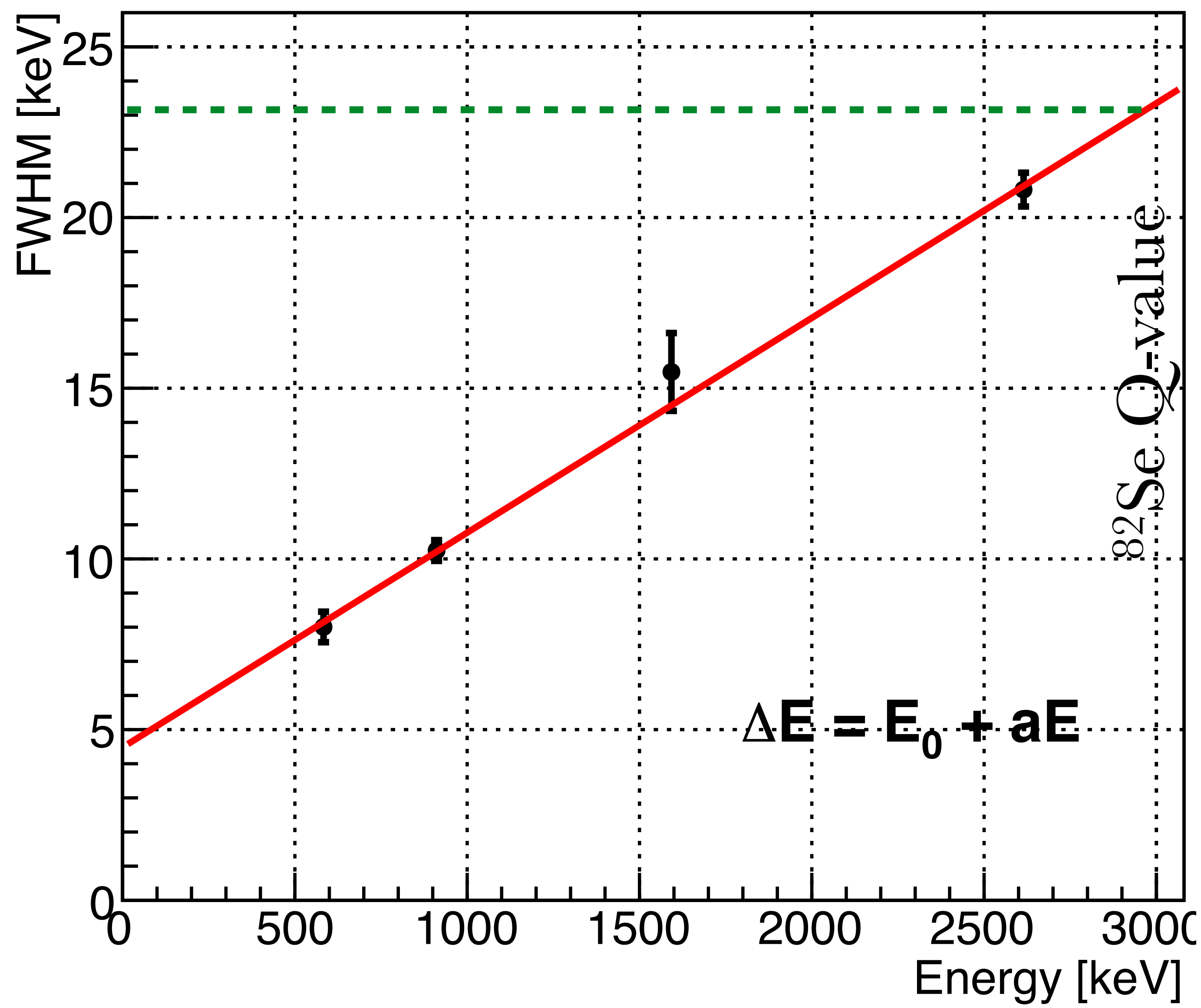
$$\Delta E = E_0 + aE$$

For each dataset the resolution at the Q-value is calculated and exposure weighted

dataset exposure

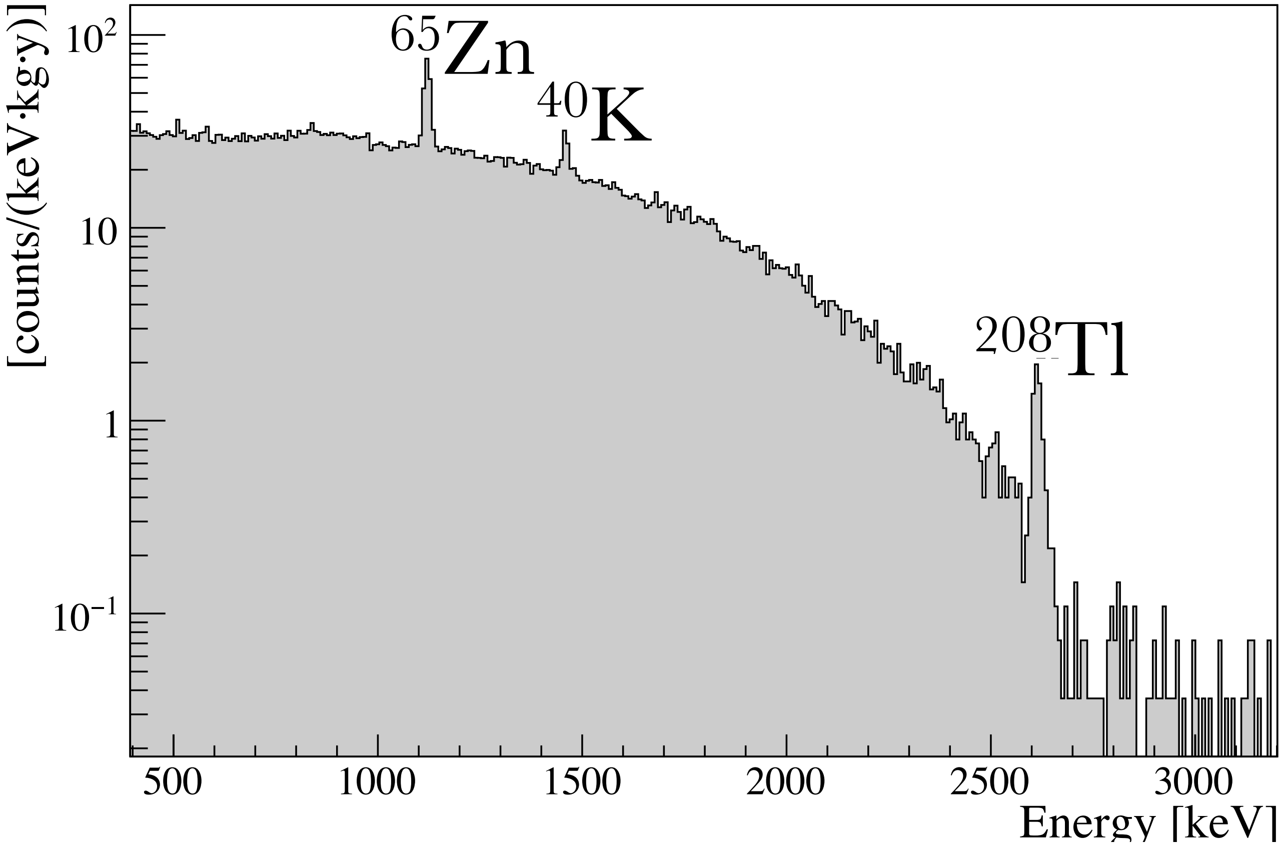
$$FWHM = \frac{\sum_i FWHM_i \cdot M_i \cdot T_i}{\sum_i M_i \cdot T_i}$$

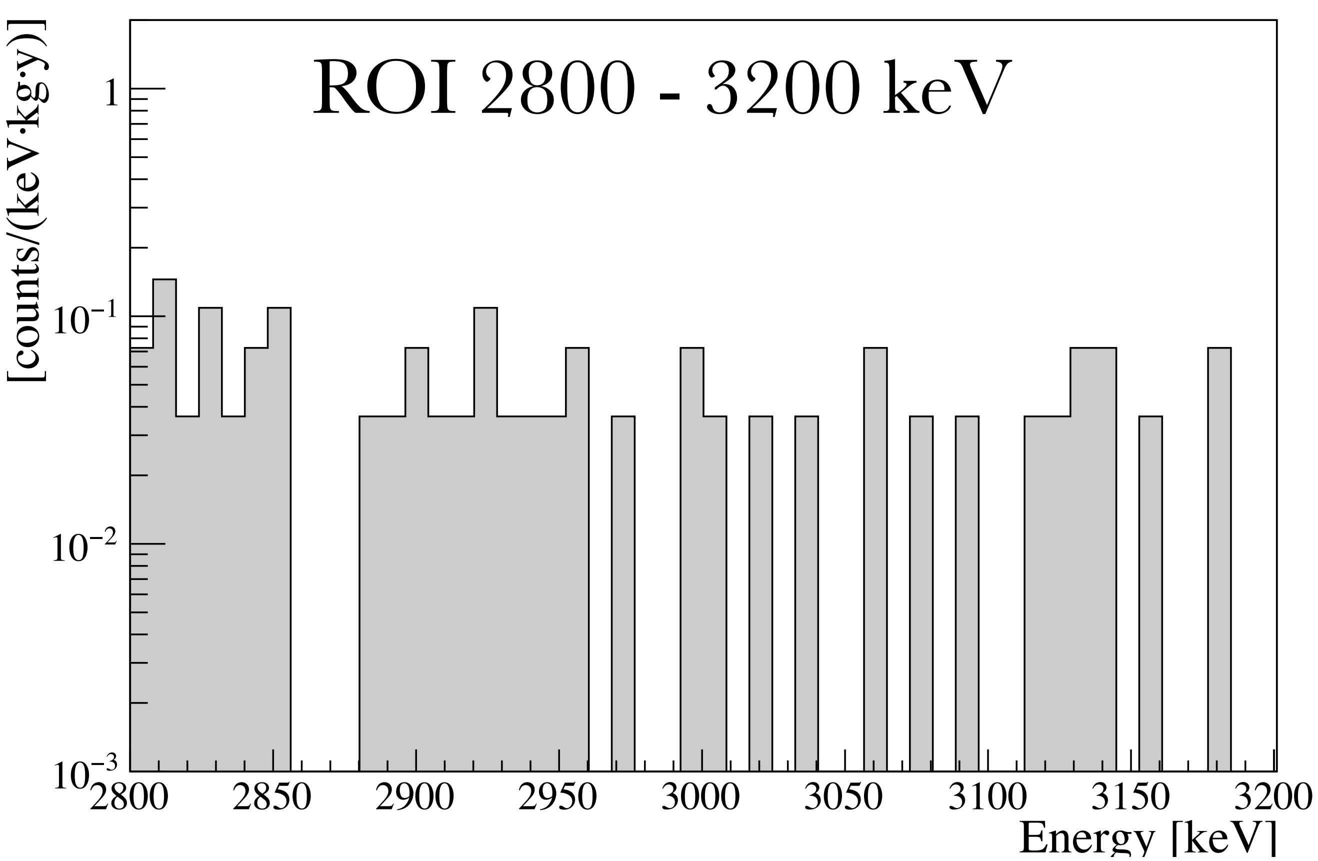
totale exposure



FWHM(Q-value) = (23.0 ± 0.6) keV [0.77 %]

Total spectrum

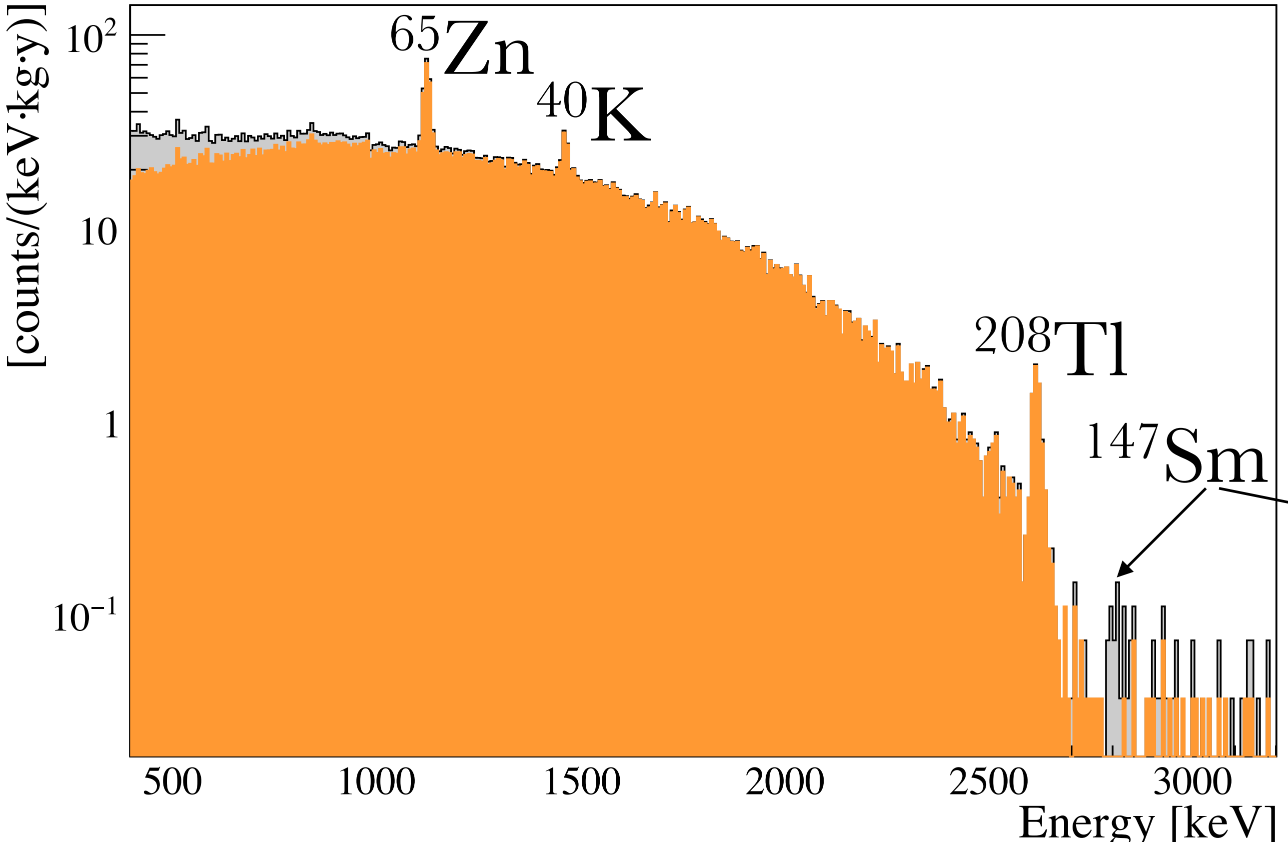


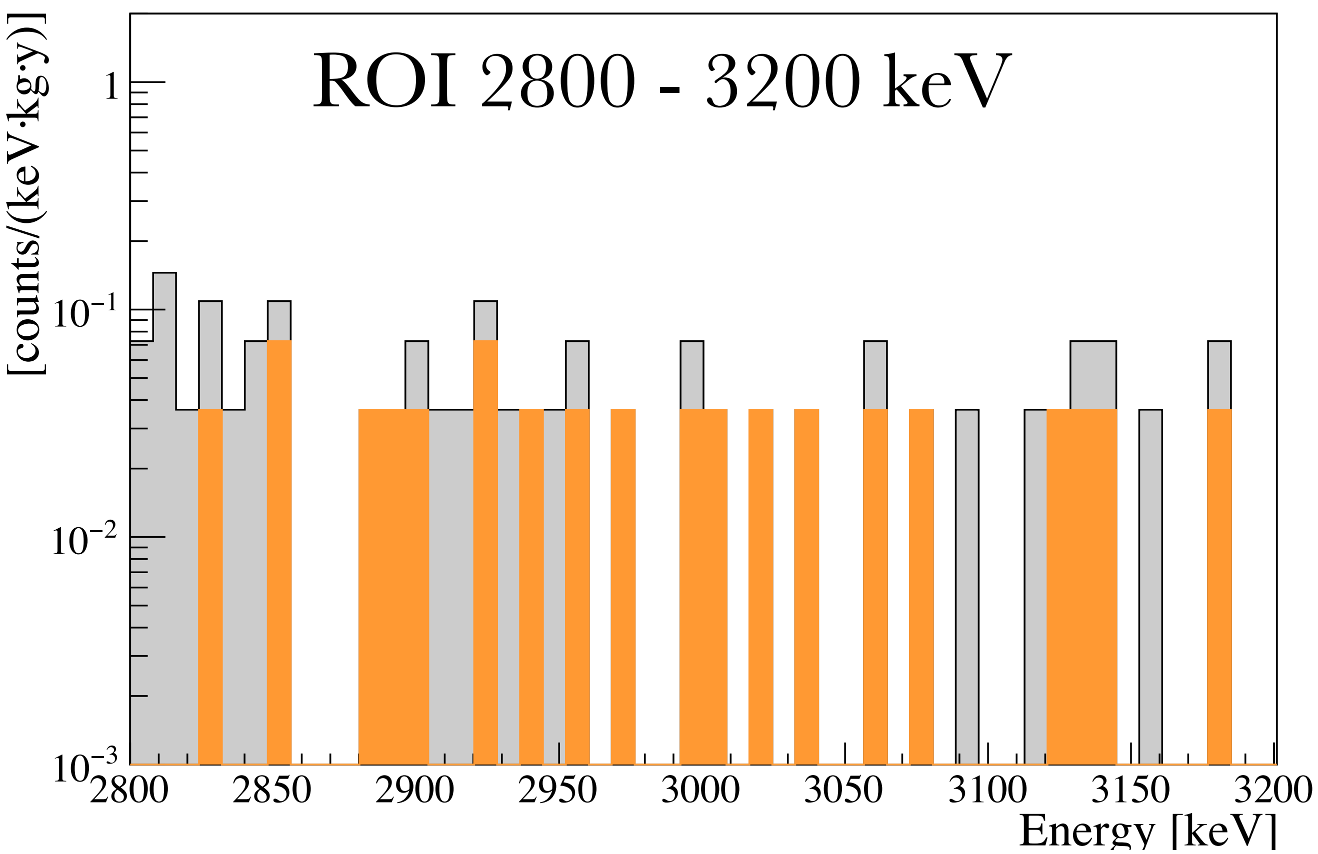


- **Non-particle events** are rejected by Pulse Shape Analysis on Heat pulses (ZnSe)
- Anti-coincidence cut ($\Delta t = 20$ ms) removes a large fraction of the events due to **multi-Compton** and **muon showers**.

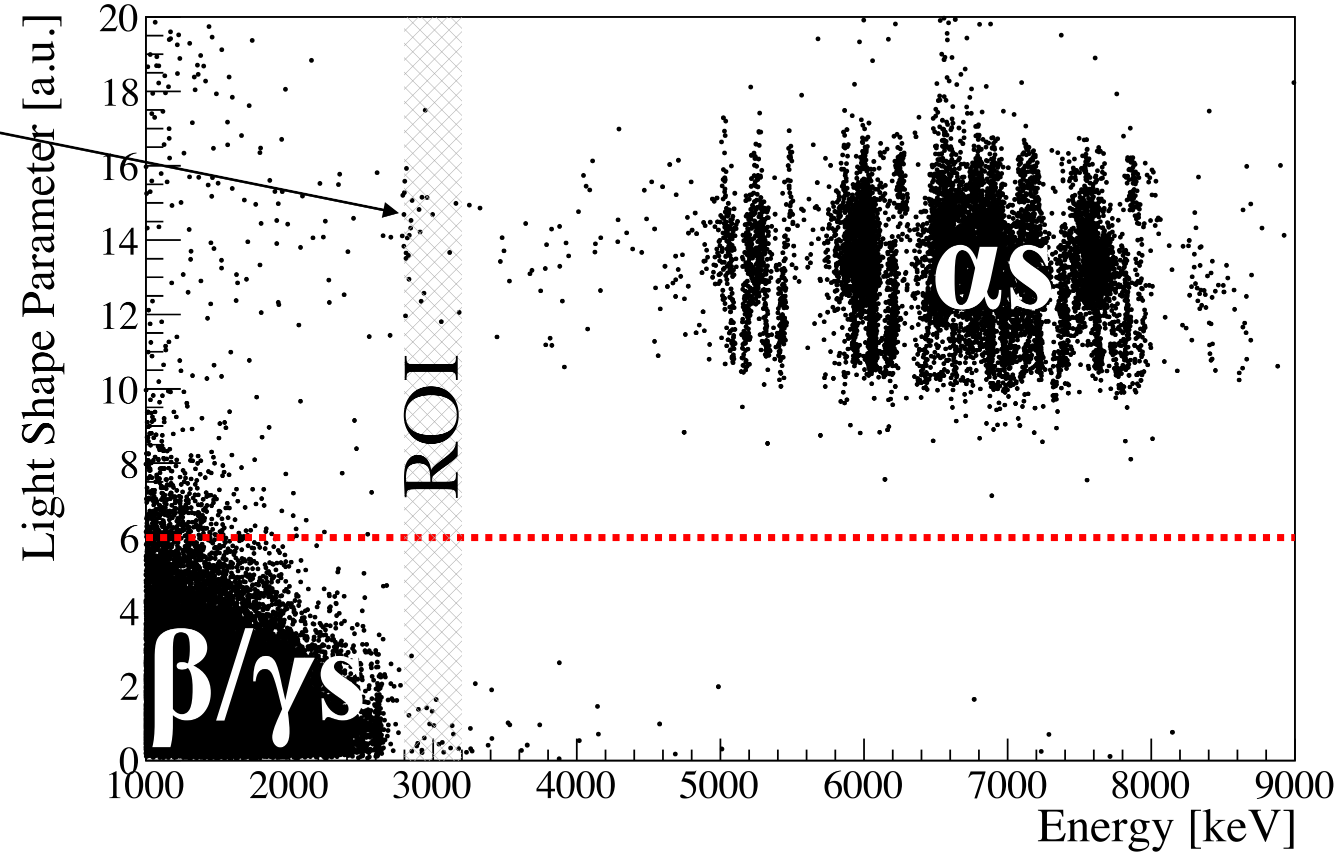
Counting rate ~10^{-2} counts/(keV kg y) is dominated by **α-particles** and γs form **^{208}Tl decays**.

Data selection: β/γ





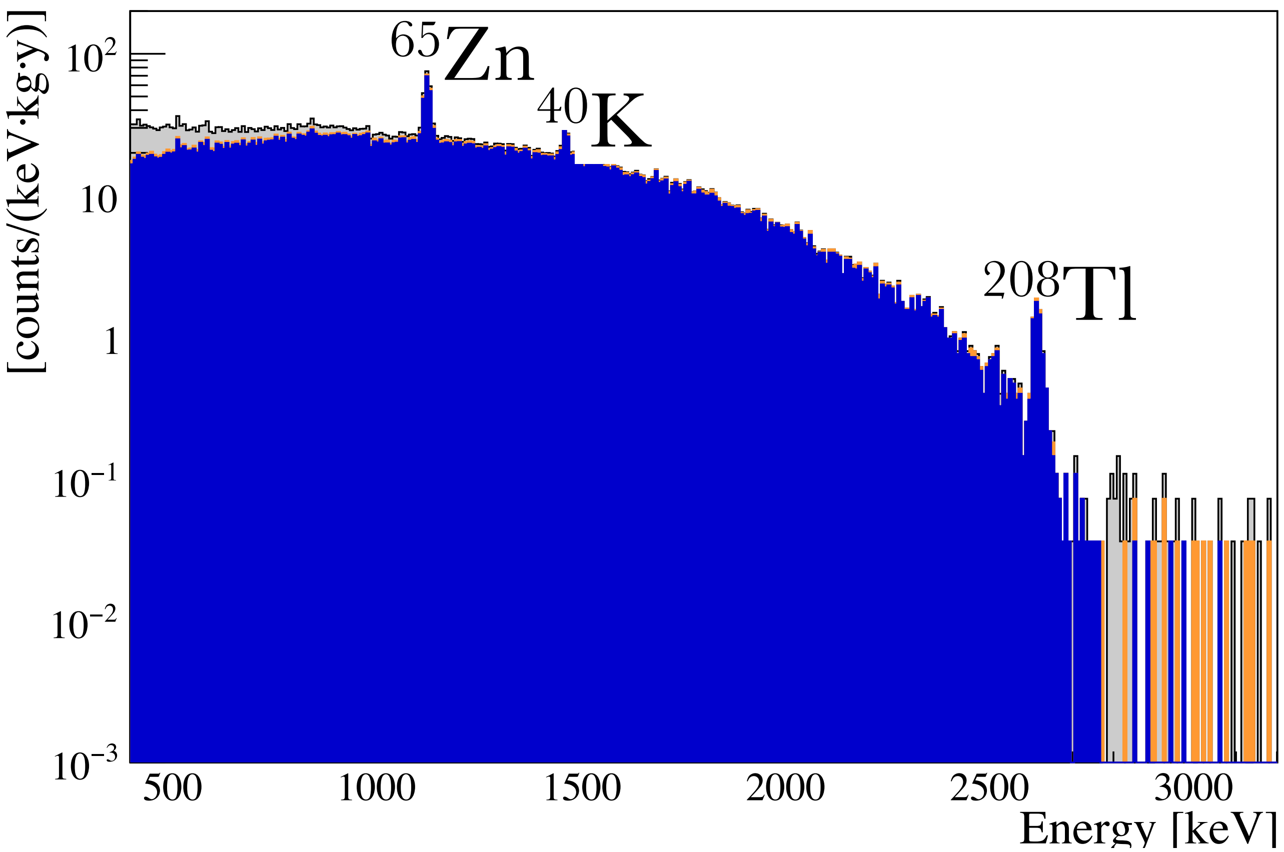
α-particles are removed exploiting the different **pulse shape** of the light signal

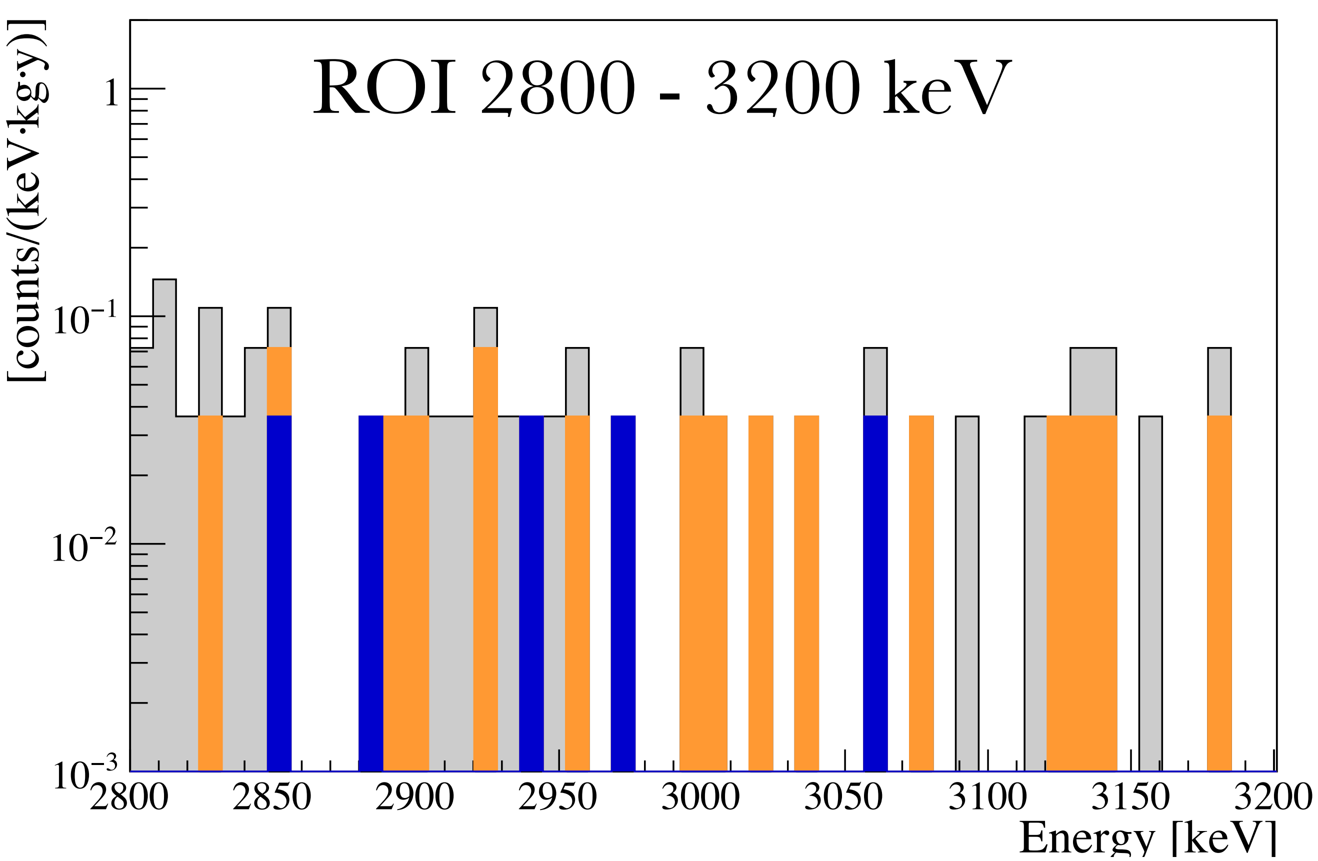


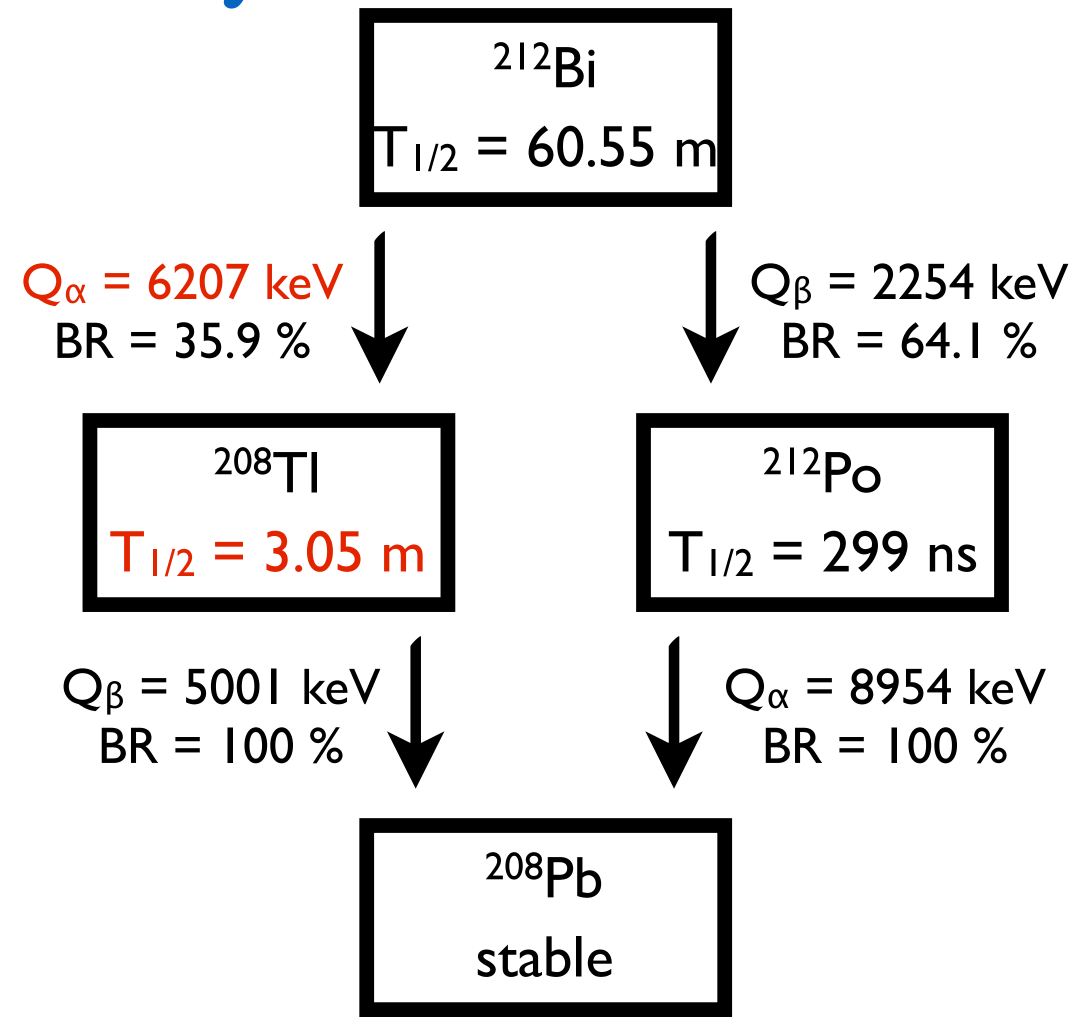
Acceptance threshold optimized on multisite events due to muon induced showers (i.e. pure sample of β/γs).

P(Light Shape$_\alpha$ < 6) = 5 · 10^{-8}

Data selection: delayed veto



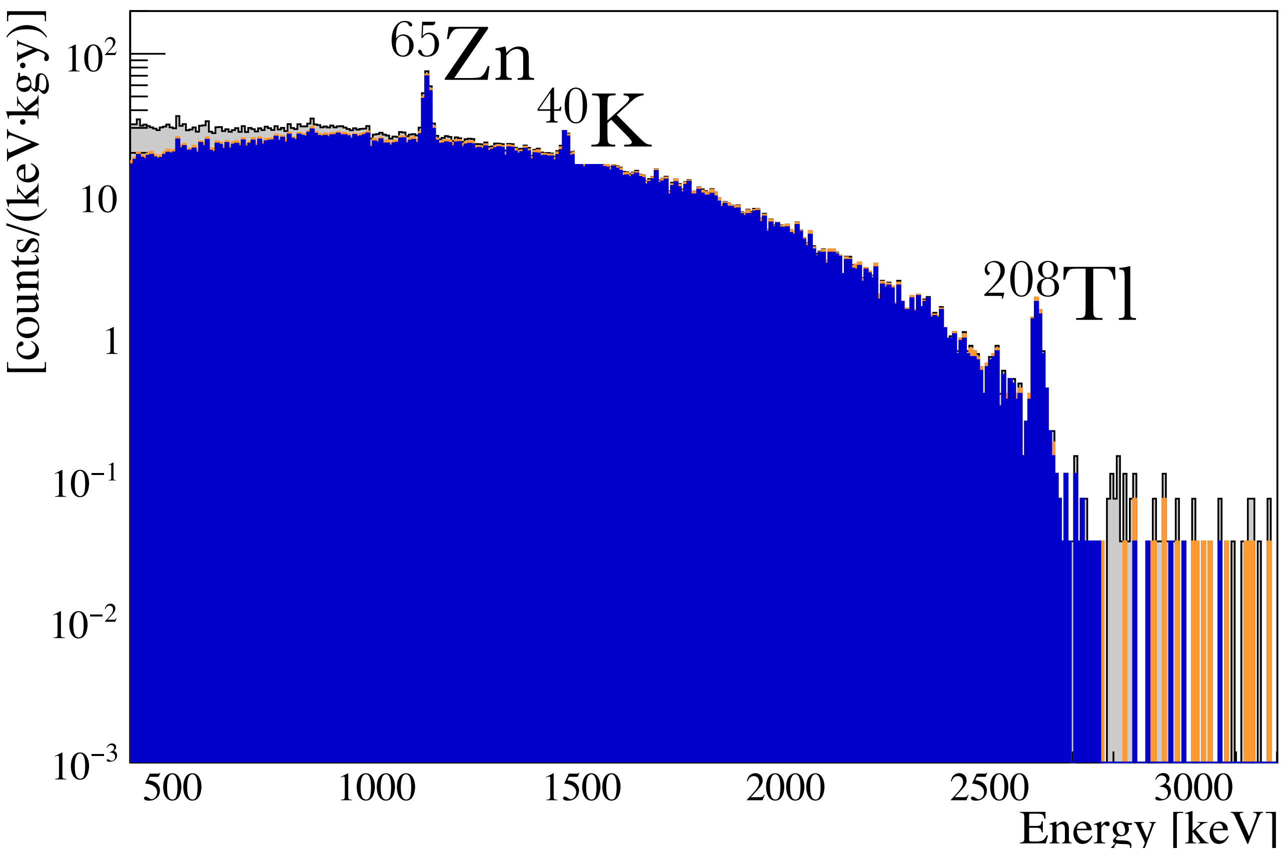


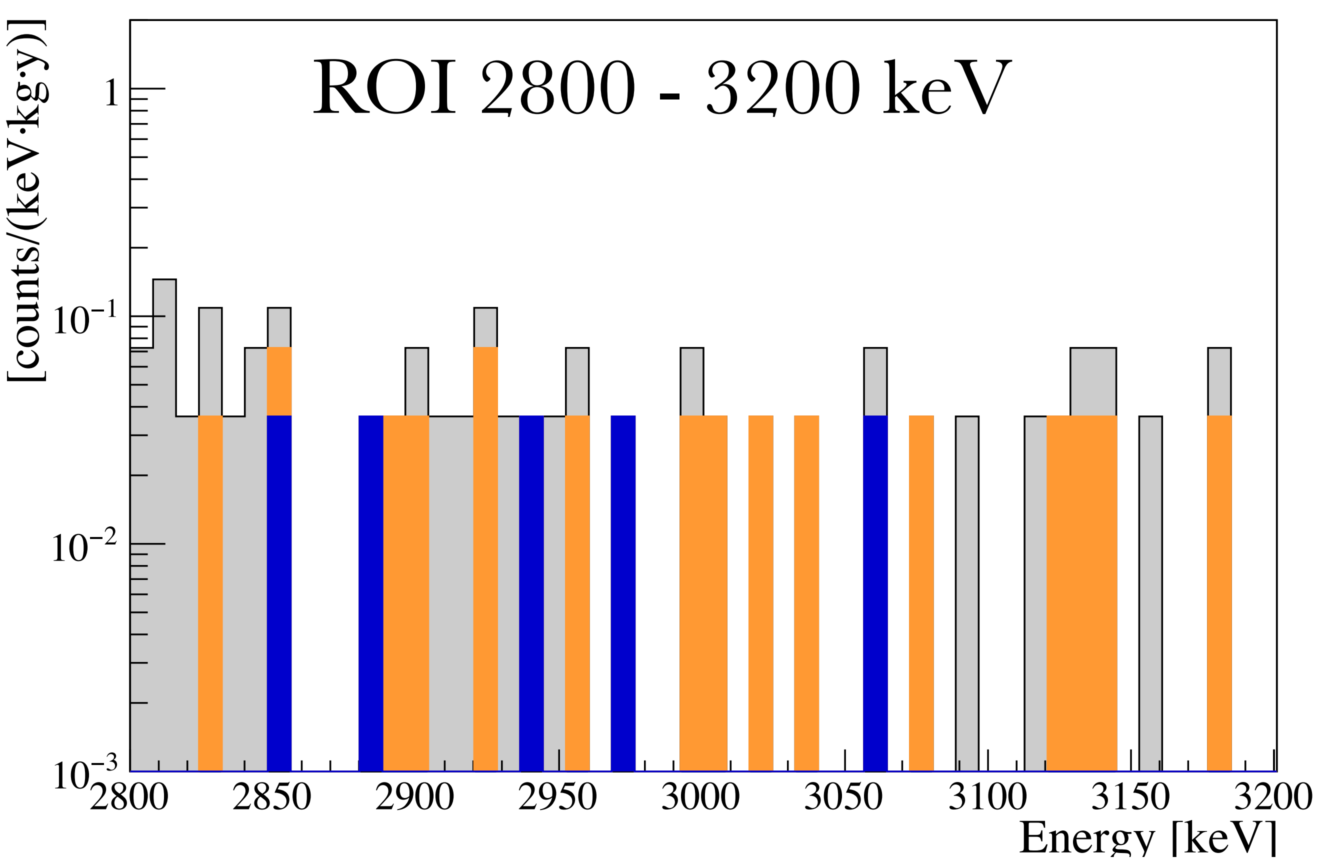


^{212}Bi α-events are selected in the energy range **(2 - 6.5) MeV** to include also surface contaminations.

For each ^{212}Bi candidate, the crystal where the the decay occurred is disabled for **9.15 minutes** (=3 $t_{1/2}$).

Data selection





Background index in the ROI, after all the selection criteria are applied is **$(3.6^{+1.9}_{-1.4})\cdot 10^{-3}$ counts/(keV · kg · y).**

An unprecedented level for a detector based on cryogenic calorimeter.

This result is due to the excellent **α-rejection** achieved by the scintillating calorimeter technique.

CUPID-0 results: $T_{1/2}$ and $m_{\beta\beta}$

No signal evidence in 3.44 kg · y of exposure (ZnSe) was found, being able to set the following lower limit on the **half-life of ^{82}Se 0νββ decay**:

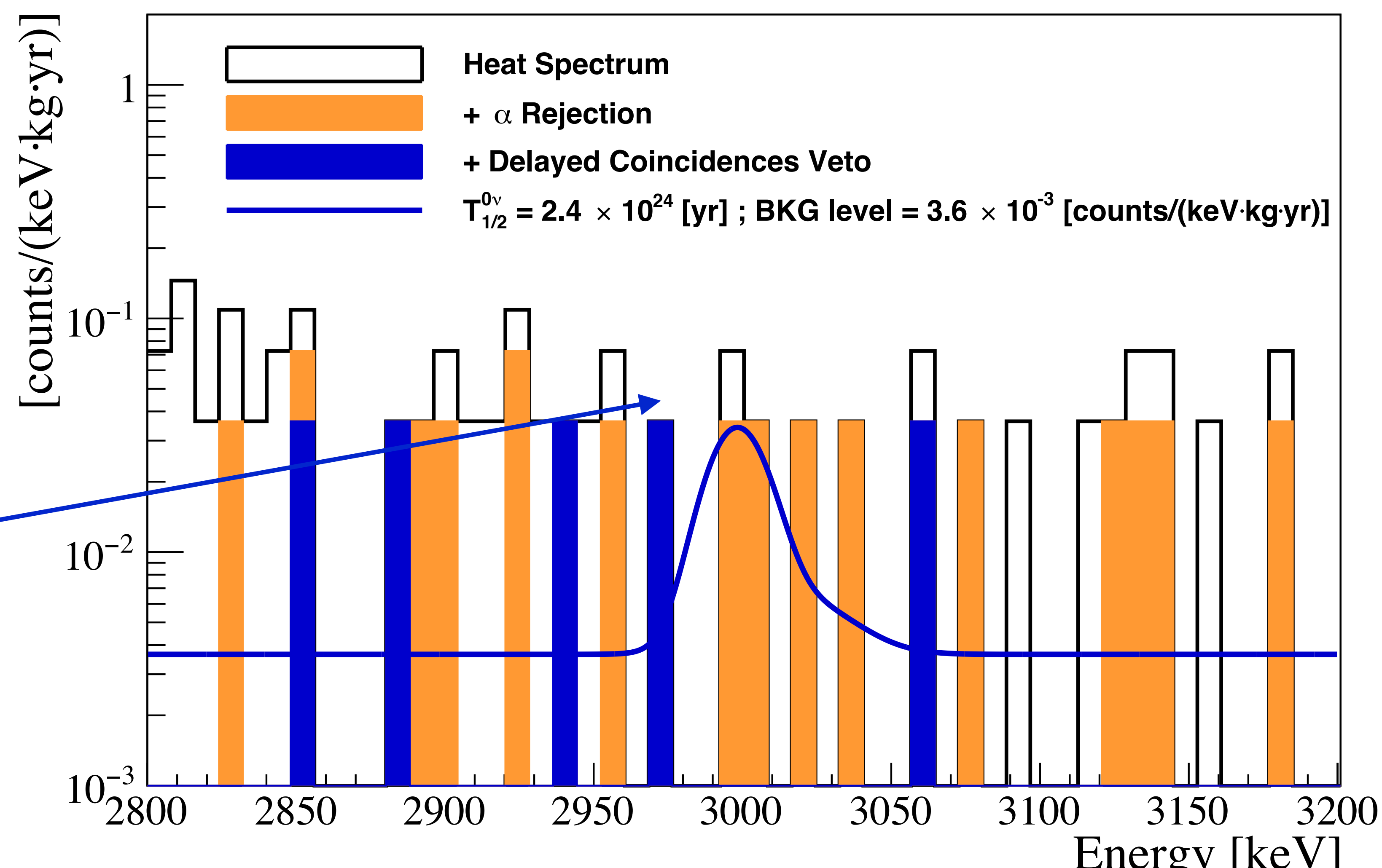
$$T^{0\nu} > 2.4 \cdot 10^{24}\ \text{y (90\% C.I.)}$$

which corresponds to an upper bound to **Effective Majorana Mass** of

$$m_{\beta\beta} < 376 - 770\ \text{meV}$$

Result published today in Phys. Rev. Lett. 120, 232502 (2018)

Flat background
+
Hypothetical 0νββ signal
corresponding to an half-life
of $2.4 \cdot 10^{24}$ y



Conclusions

1) CUPID-0 is the first array of **enriched scintillating** calorimeters.
2) Data taking is stably ongoing since March 2017.
3) **α-background rejection** was fully demonstrated, reaching for a bolometric experiment an unprecedented background level of

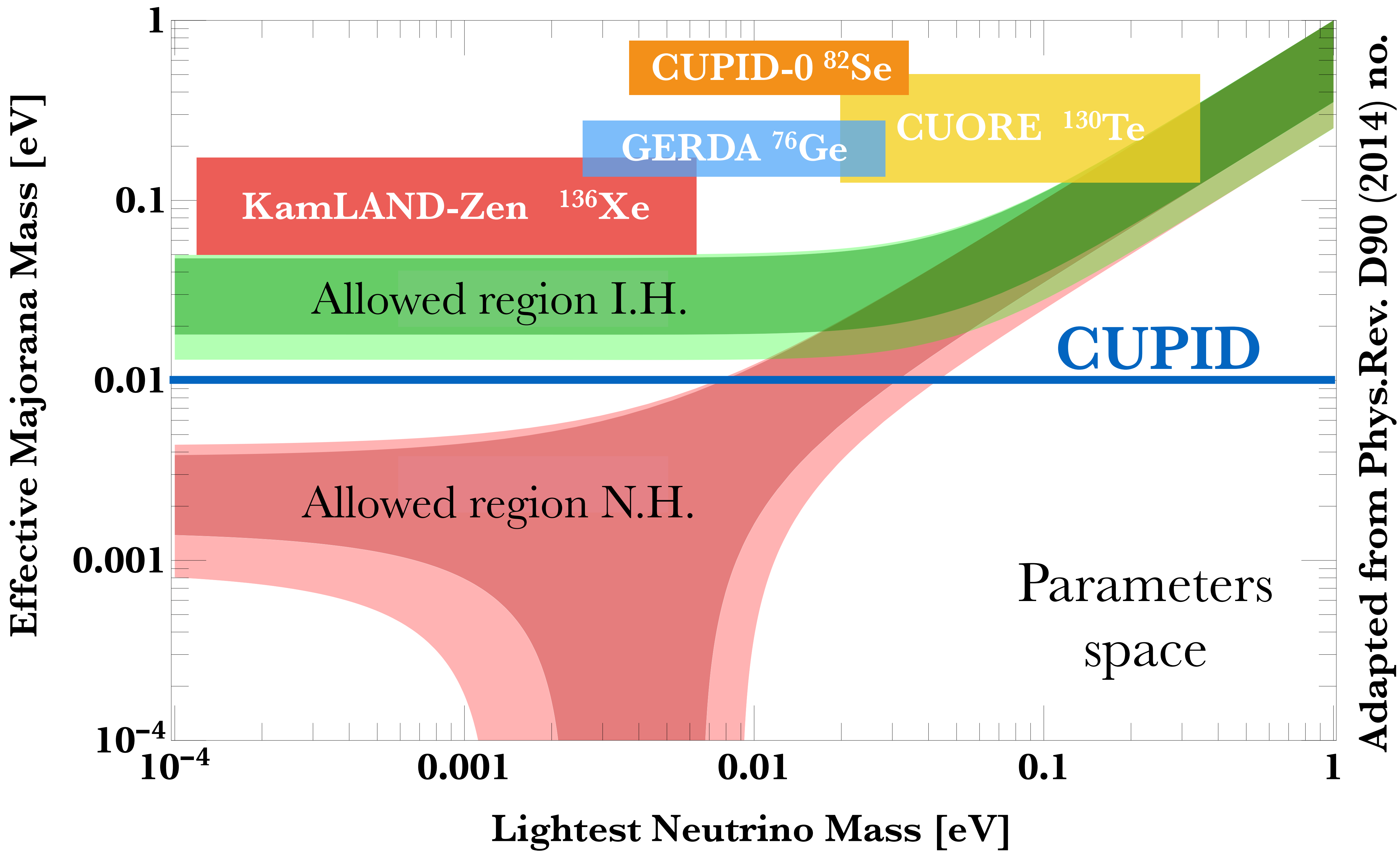
$$\mathbf{BI = (3.6\,^{+1.9}_{-1.4}) \cdot 10^{-3}\ counts/(keV \cdot kg \cdot y)}$$

4) The analysis of the first data released allows to set the best limit on **^{82}Se 0νββ half-life** (paper published **Phys. Rev. Lett. 120, 232502 (2018)**)

$$\mathbf{T^{0\nu} > 2.4 \cdot 10^{24}\ y\ (90\%\ C.I.)}$$

5) We plan to reach an exposure of 10 kg · y of ZnSe, collecting enough data to obtain a reliable **background model** in for CUPID.

Conclusions



CUPID-0 collaboration

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