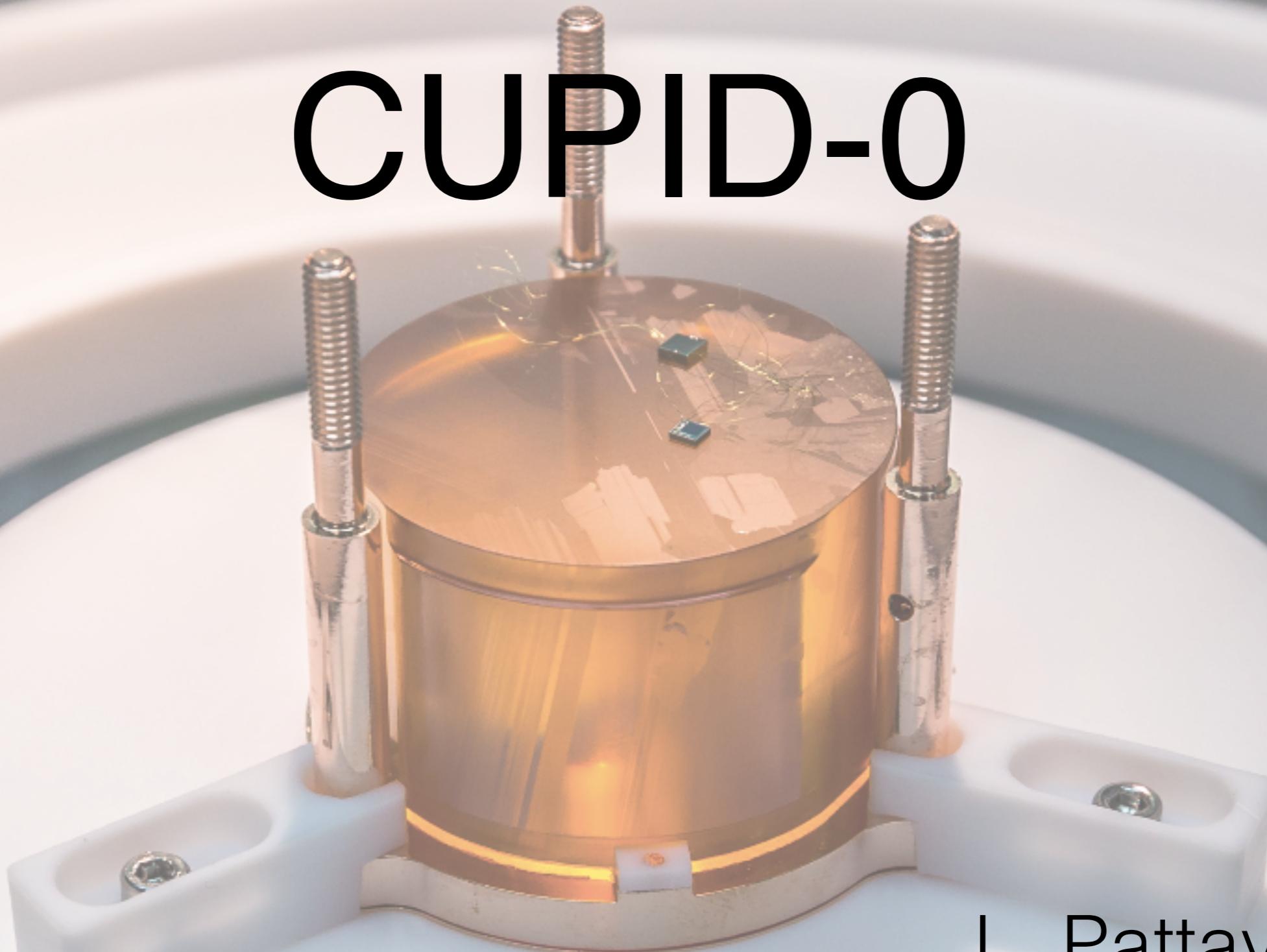


# CUPID-0



L. Pattavina  
INFN-LNGS

[luca.pattavina@lngs.infn.it](mailto:luca.pattavina@lngs.infn.it)

# OUTLINE

- CUPID project
- CUPID-0 detector
  - CUPID-0 data taking
    - Detector bolometric performance
    - Resolution and Background at RoI
- Conclusions

# CUPID-0 for CUPID

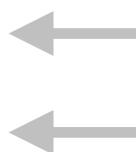
## Cuore Upgrade with Particle ID

### III. SCIENTIFIC OBJECTIVE

CUPID is a proposed bolometric  $0\nu\beta\beta$  experiment which aims at a sensitivity to the effective Majorana neutrino mass on the order of 10 meV, covering entirely the so-called inverted hierarchy region of the neutrino mass pattern. CUPID will be designed in such a way that, if the neutrino is a Majorana particle with an effective mass in or above the inverted hierarchy region ( $\sim 15 - 50$  meV), then CUPID will observe  $0\nu\beta\beta$  with a sufficiently high confidence (significance of at least  $3\sigma$ ). This level of sensitivity corresponds to a  $0\nu\beta\beta$  lifetime of  $10^{27} - 10^{28}$  years, depending on the isotope. This primary objective poses a set of technical challenges: the sensitive detector mass must be in the range of several hundred kg to a ton of the isotope, and the background must be close to zero at the ton  $\times$  year exposure scale in the ROI of a few keV around  $0\nu\beta\beta$  transition energy. <http://arxiv.org/abs/1504.03599>

Five steps beyond the present technology are required:

- Isotopic enrichment
- Active alpha rejection
- Improved material selection
- Better energy resolution
- Reduced cosmo-activation



CUPID-0 is the first, of a series, demonstrator of the new technologies that will be implemented in CUPID

# Scintillating bolometers

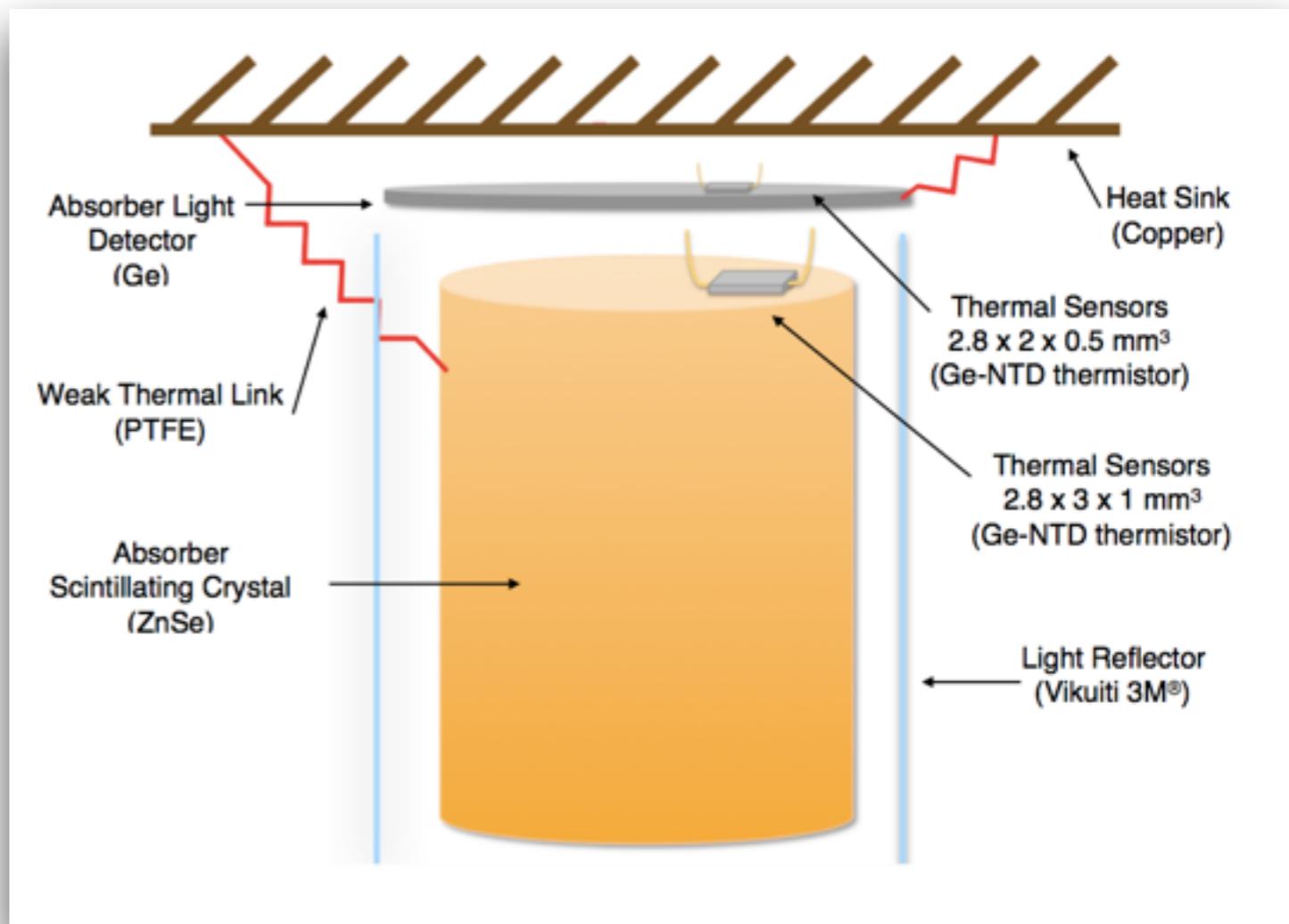
A bolometer is a highly sensitive calorimeter operated @ cryogenic temperature ( $\sim 10$  mK).

Energy deposits are measured as temperature variations of the absorber.

If the absorber is also an efficient scintillator the energy is converted into heat + light

Bolometer features:

- ▶ high energy resolution  $O(1/1000)$
- ▶ high detection efficiency (source = detector)
- ▶ scalable to large masses
- ▶ **particle ID**

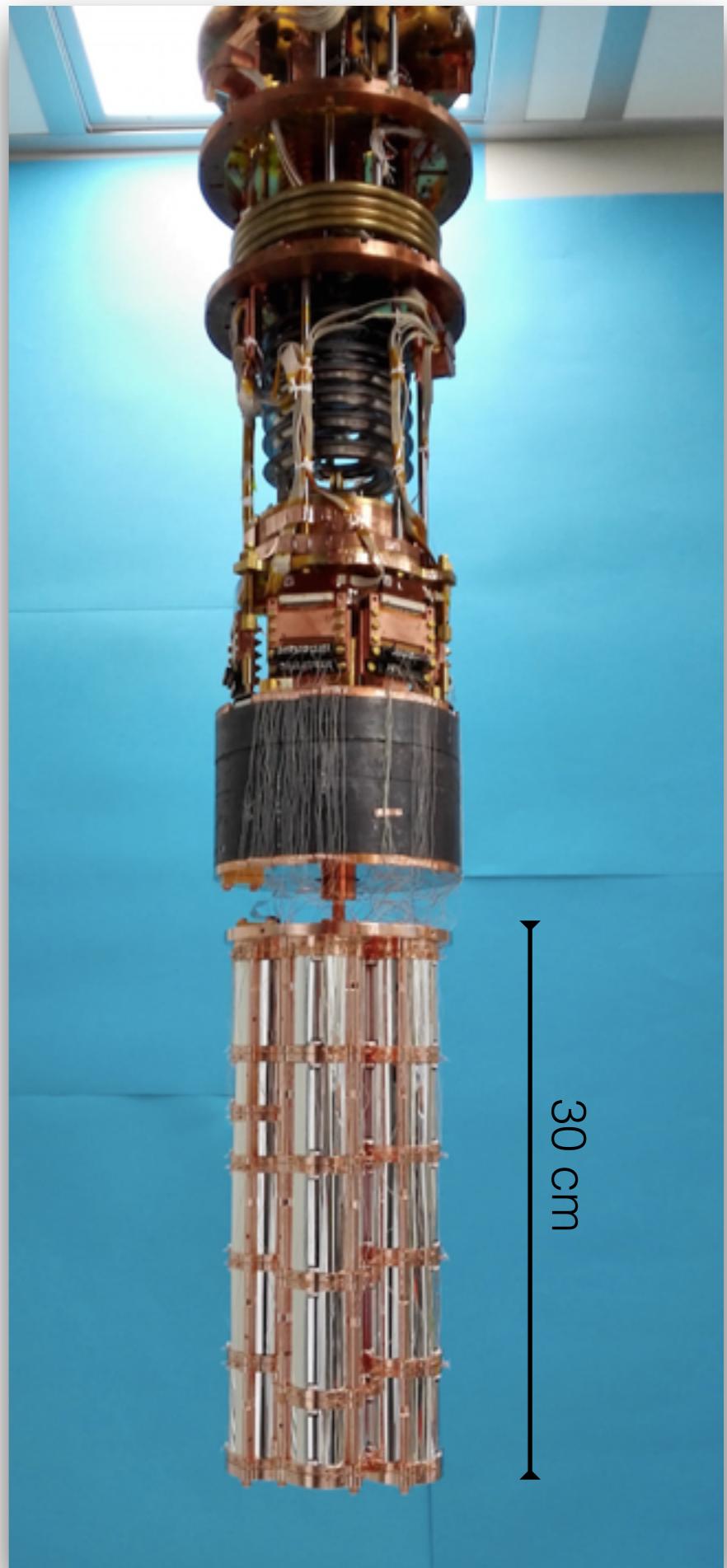


A **close-to-zero background** experiment is feasible:  
α-background: identification and rejection  
ββ-background:  $\beta\beta$  isotope with large Q-value

# CUPID-0

CUPID-0 is the first array of scintillating bolometers for the investigation of  ${}^{82}\text{Se}$   $0\nu\beta\beta$

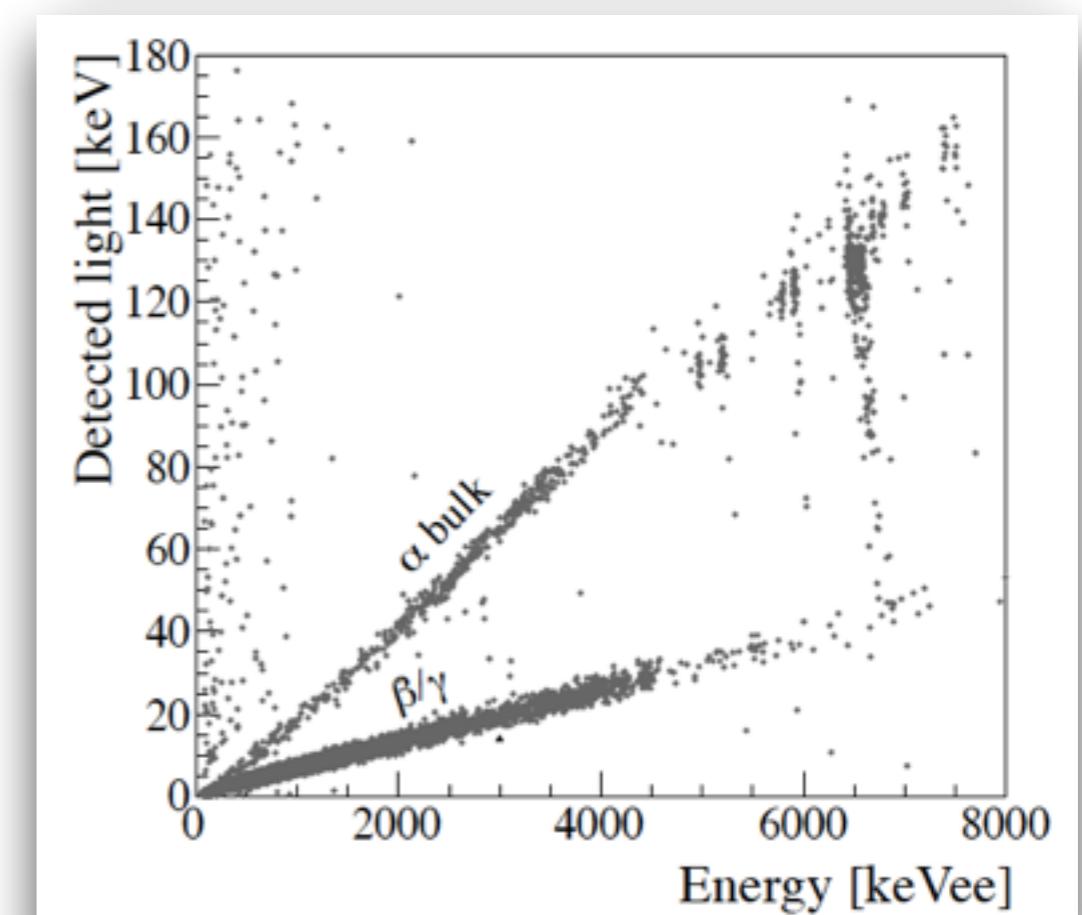
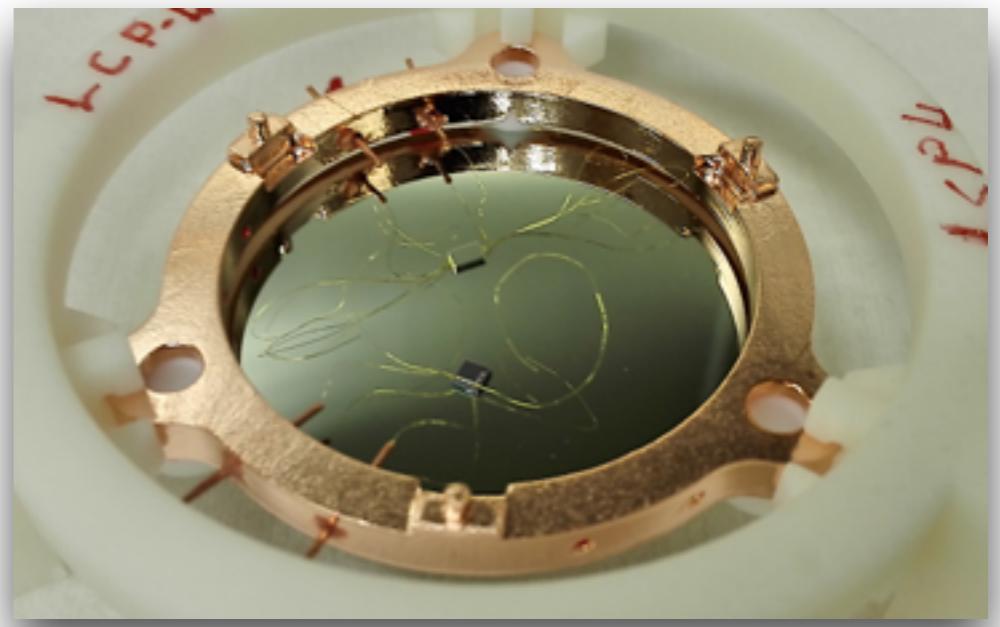
- ${}^{82}\text{Se}$  Q-value 2998 keV
- 96% enriched Zn ${}^{82}\text{Se}$  bolometers
- 26 ZnSe (24 enr + 2 nat) & 31 LDs arranged in 5 towers
  - 10.5 kg of ZnSe
  - 5.17 kg of  ${}^{82}\text{Se}$   $\rightarrow 3.8 \times 10^{25} \beta\beta$  nuclei
- Background goal at the level of  $10^{-3} \text{ c/keV/kg/y}$
- Simplest modular detector:
  - Copper structure (ElectroToughPitch)
  - PTFE holders
  - Reflecting foil (VIKUITI 3M)



# LD for a background rejection

- Well established technology for bolometric LDs
  - Ge disk 44.5 x 0.17 mm
  - Ge-NTD thermal sensor 2x1.5x3 mm<sup>3</sup>
  - Si-heater for gain drift corrections
- One face coated with 60 nm SiO
  - Light collection enhancement ~50%
- LD performance are crucial for background suppression
  - Light vs Heat: possible a leakage in  $\beta/\gamma$  ROI
  - PSA of Light: highly efficient particle-ID

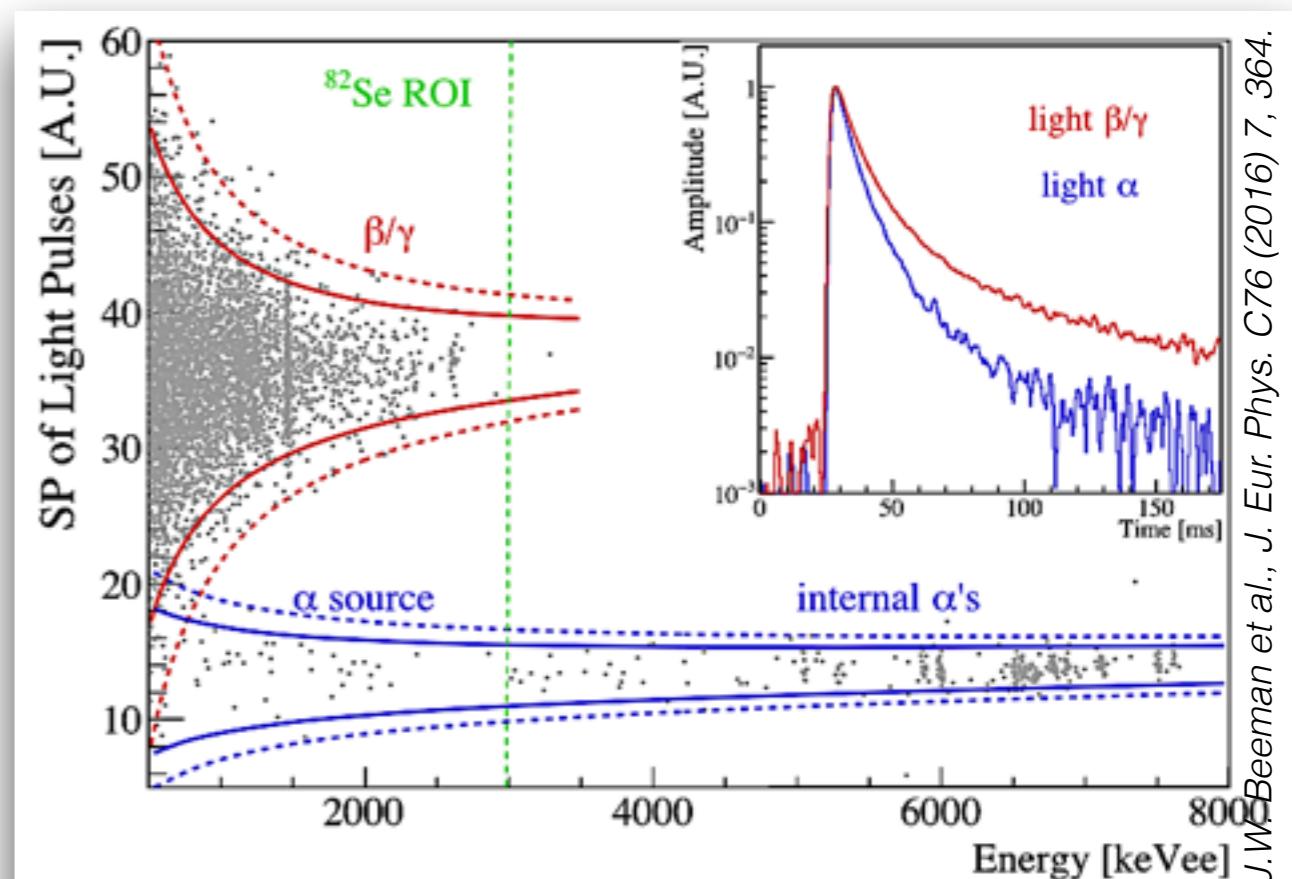
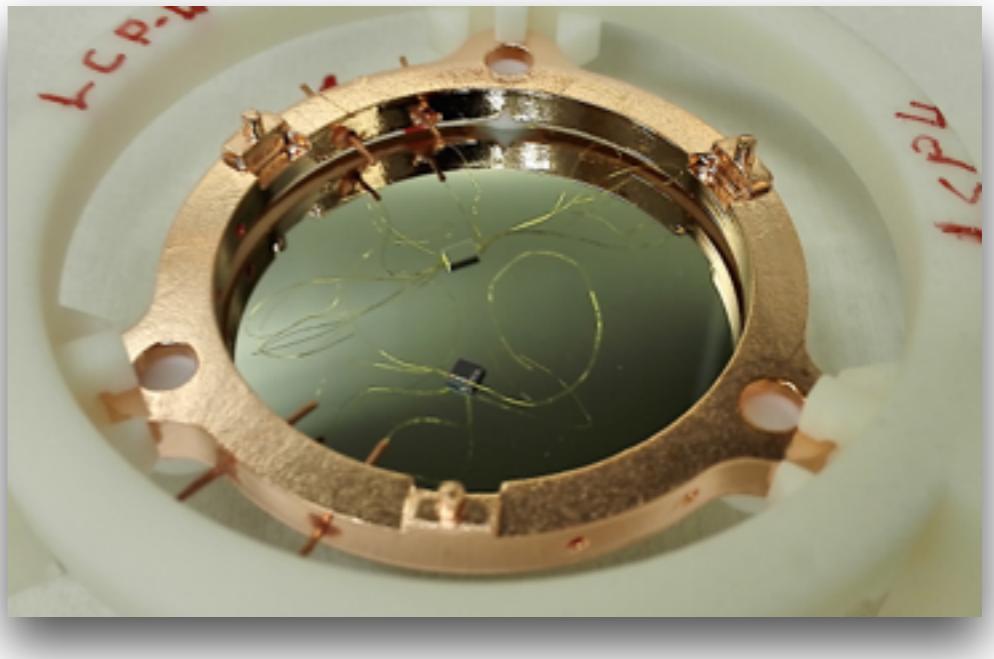
CUPID-0 operates 31 LDs



# LD for a background rejection

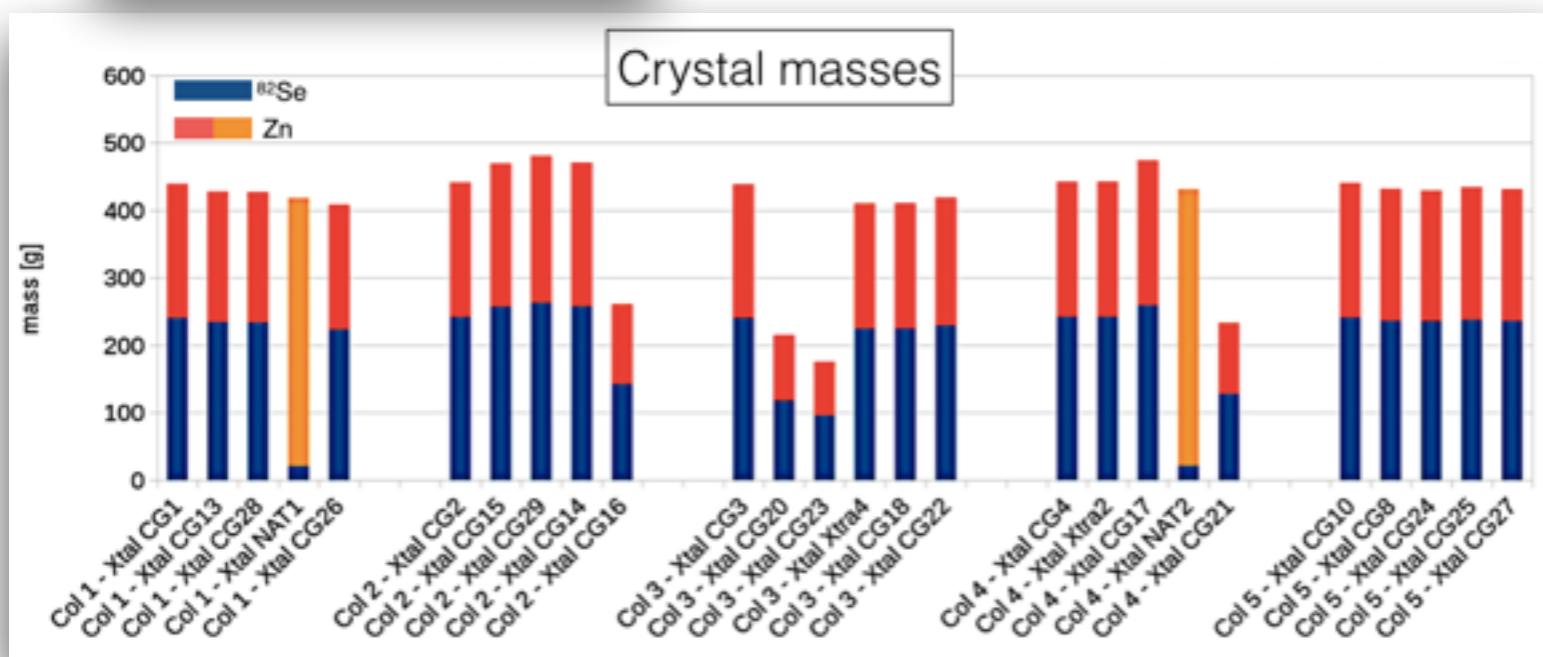
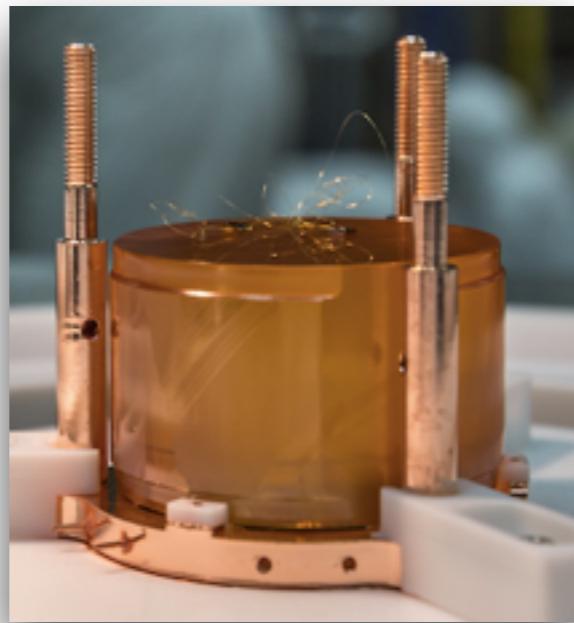
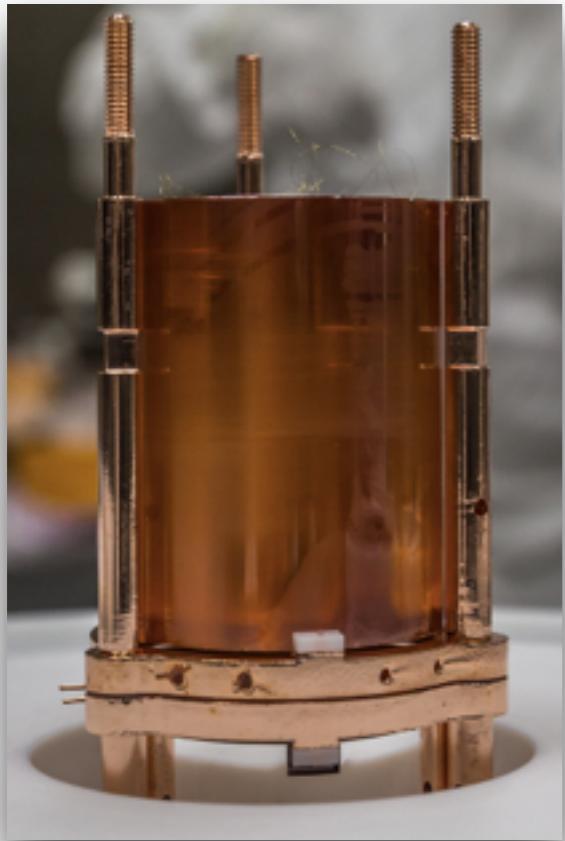
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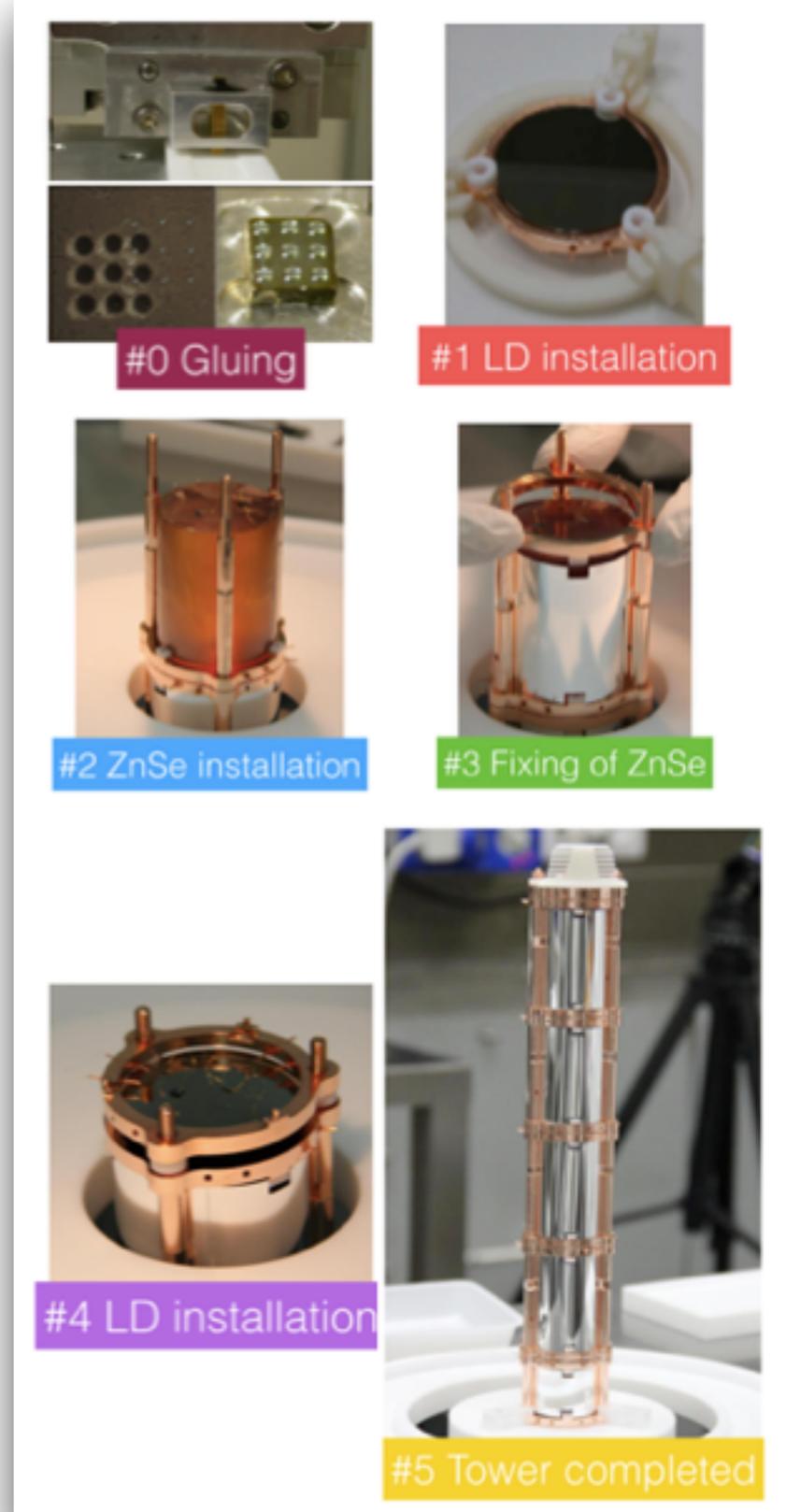


# CUPID-0 assembly

Complex detector design: CUPID-0 crystals have all different shapes and heights ranging from 21 mm to 58 mm.



Assembly started in Oct-2016



# Data taking

Data taking started on March 17<sup>th</sup>

Collected exposure divided in 4 Science Runs (SR)

2.4 kg x y of ZnSe

1.2 kg x y  $^{82}\text{Se}$

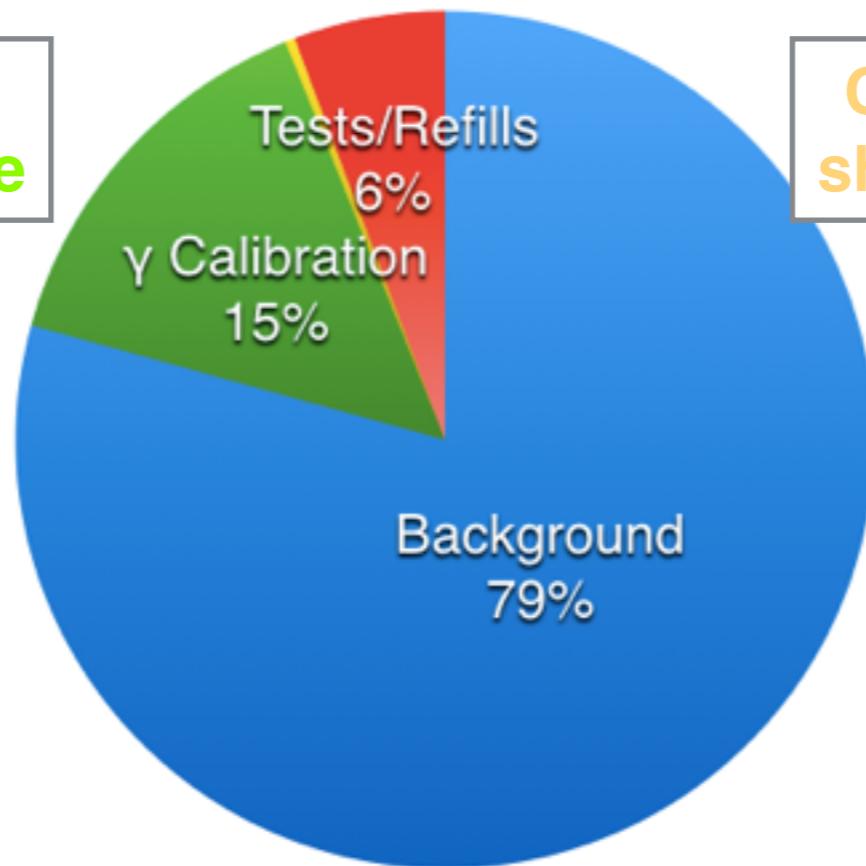
- Background
- $\gamma$  Calibration
- n Calibration
- Tests/Refills

Energy calibration  
Detector performance

Characterization of  $\beta/\gamma$   
shape parameters at RoI

$0\nu\beta\beta$  Physics

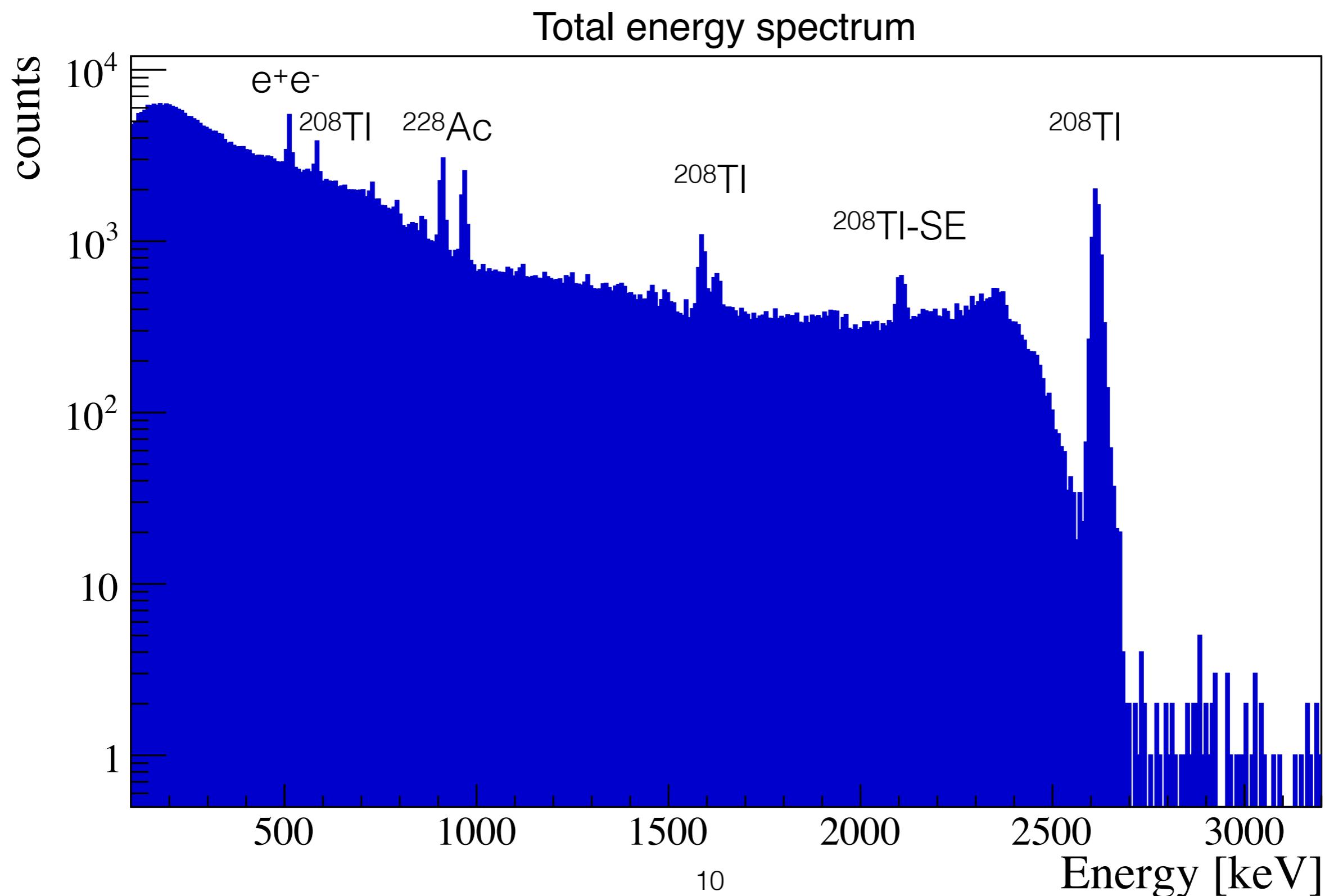
Maintenance  
cryogenic system



In this talk preliminary results on the first 2 SR: 1.5 kg x y ZnSe

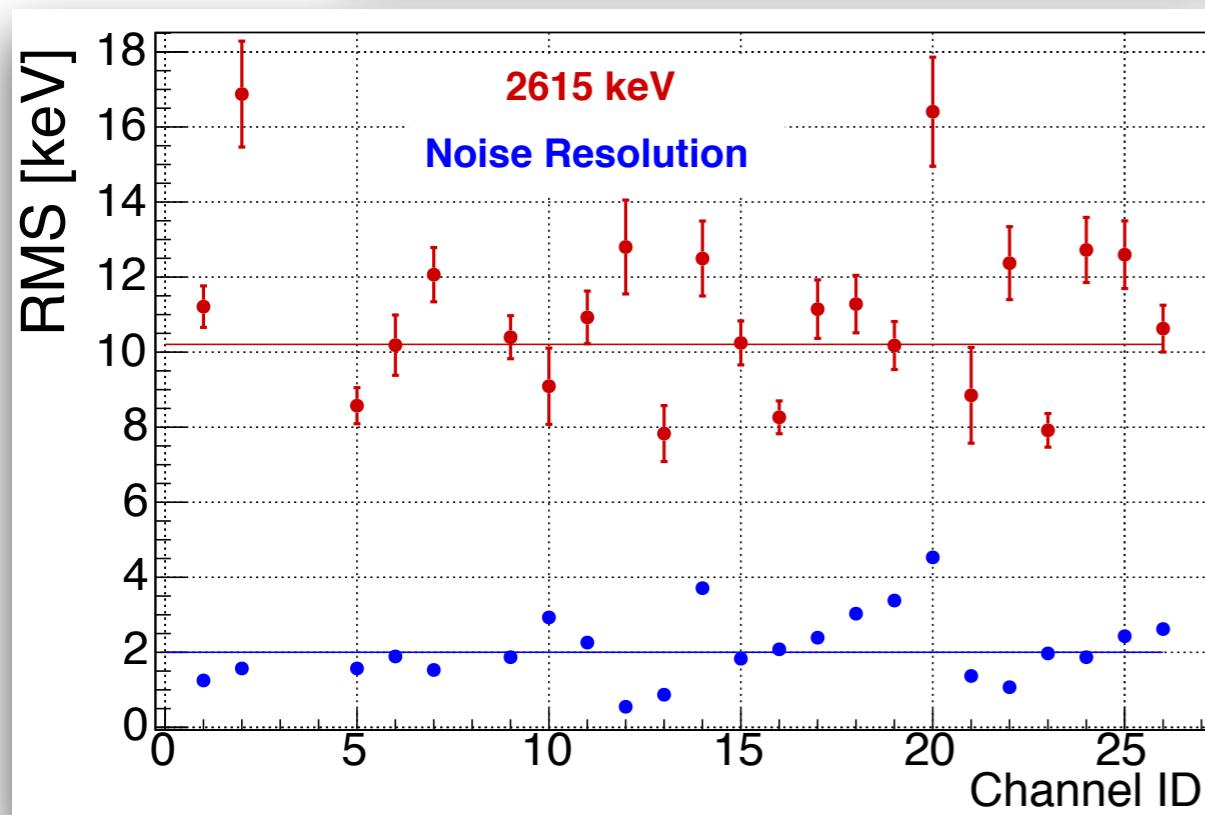
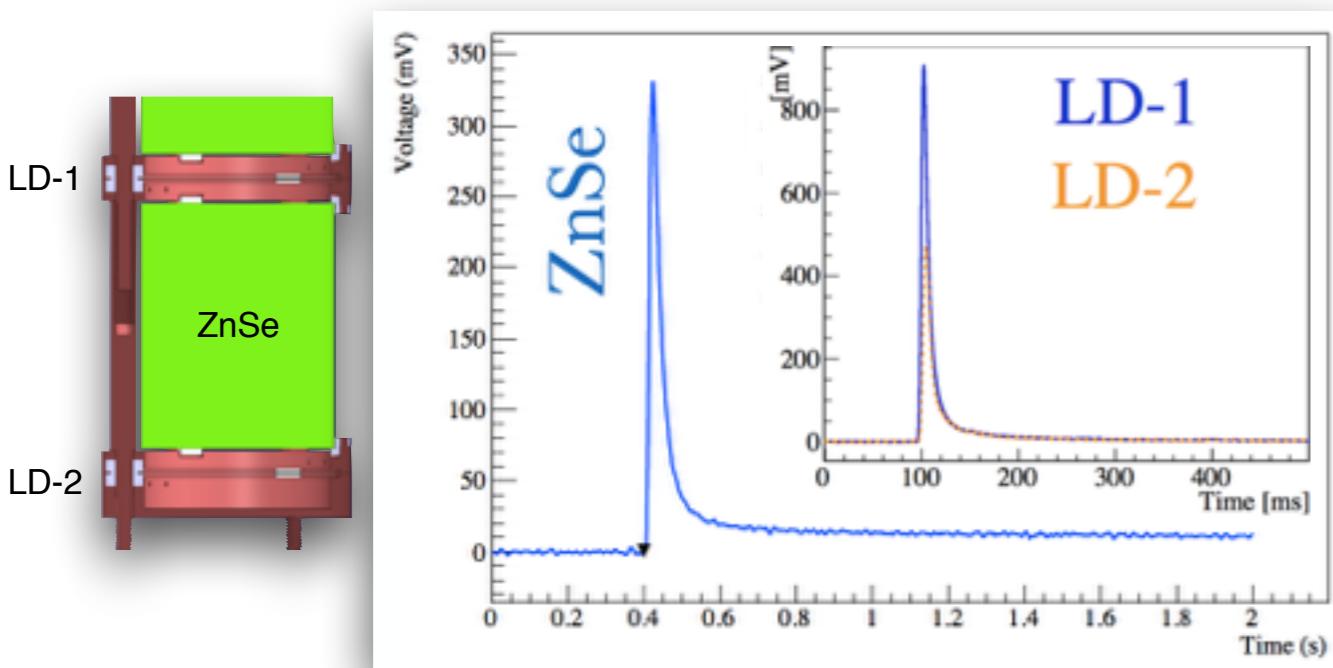
# Detector performance

The detector performance were investigated using a  $^{232}\text{Th}$  source



# Detector performance

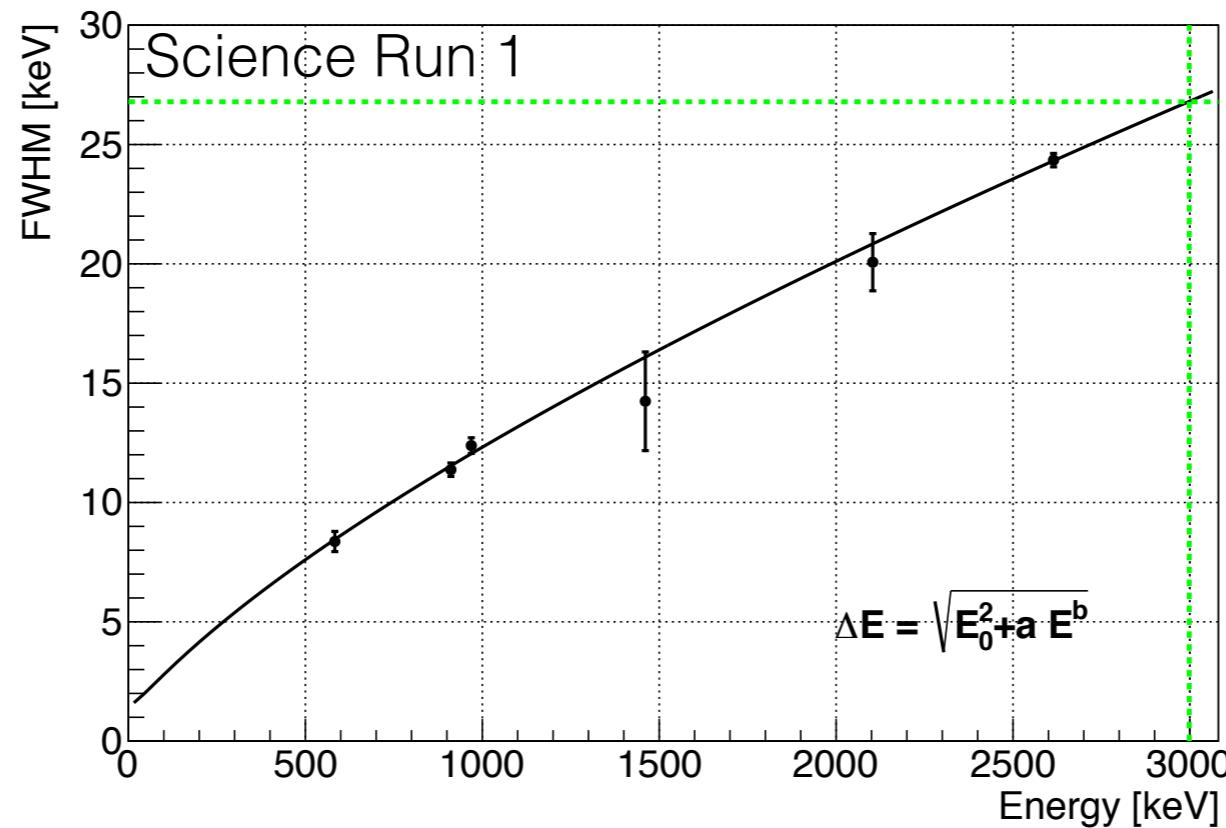
The detector performance were investigated using a  $^{232}\text{Th}$  source



- Excellent scintillating performance
- The heat channel is within the expectation
  - average FWHM @2615keV=  $\sim 25$  keV
- Major contribution to the energy resolution is the crystal quality
  - average FWHM @0keV=  $\sim 4$  keV
  - Still room for improvements

# Detector performance @ ROI

The detector performance were investigated using a  $^{232}\text{Th}$  source



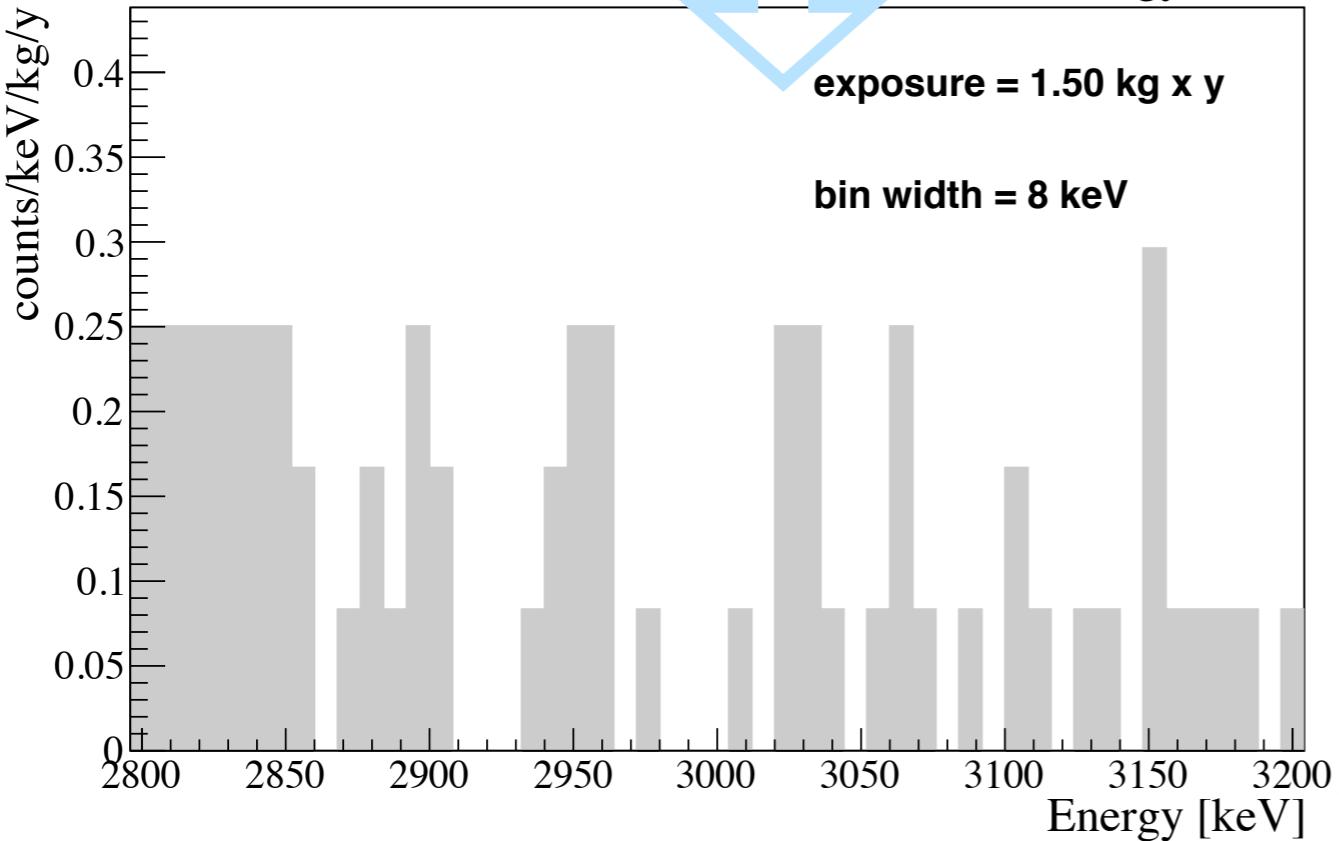
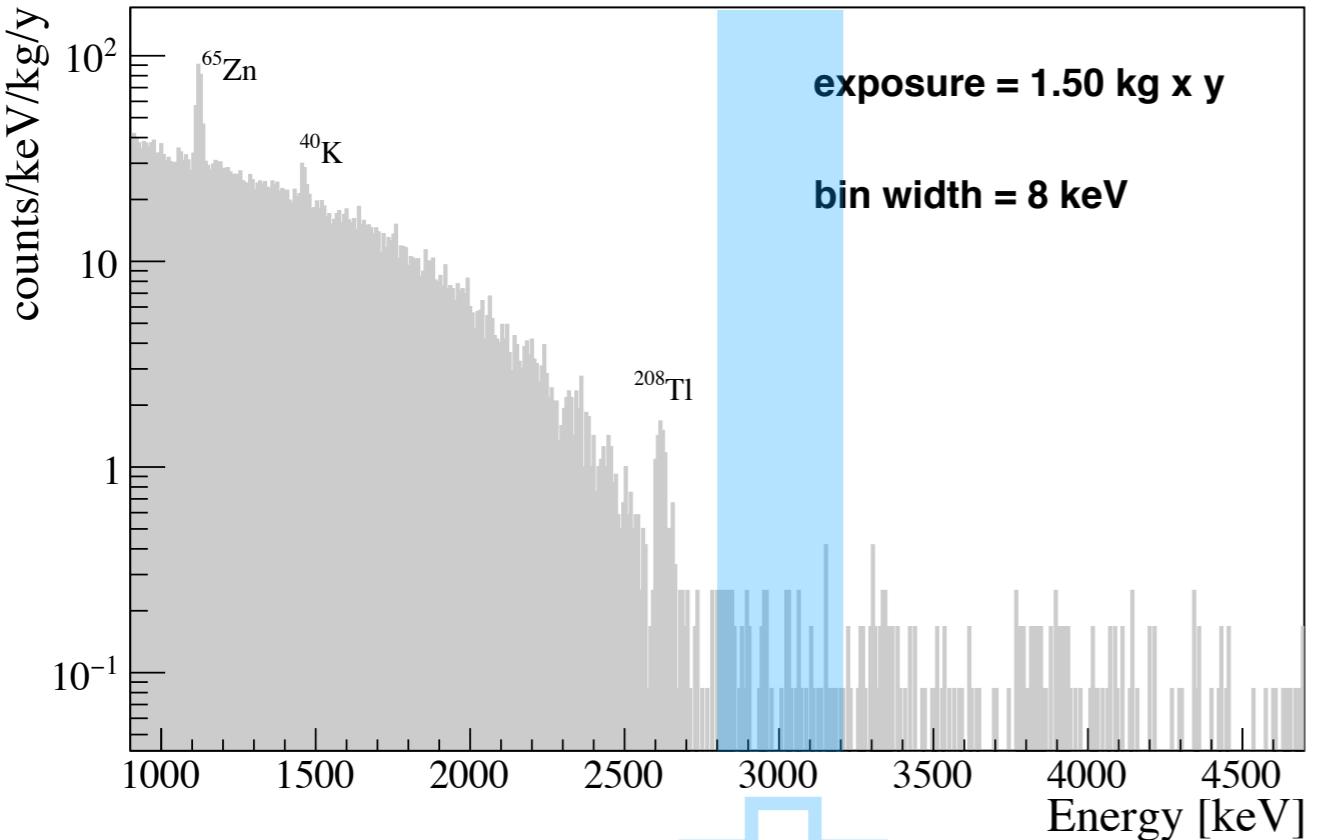
Fit model:  $\Delta E^2 = E_0^2 + a E^b$

In the ROI [2998 keV] extracted from the fit:  **$29.2 \pm 2.0 \text{ keV}$**  FWHM in SR1  
In the ROI [2998 keV] extracted from the fit:  **$27.0 \pm 1.0 \text{ keV}$**  FWHM in SR2

Still room for improvements

# Background: data selection

Total energy spectrum



No cuts

ROI [2800,3200] keV  
counts/kg/y

$47.4 \pm 5.6$

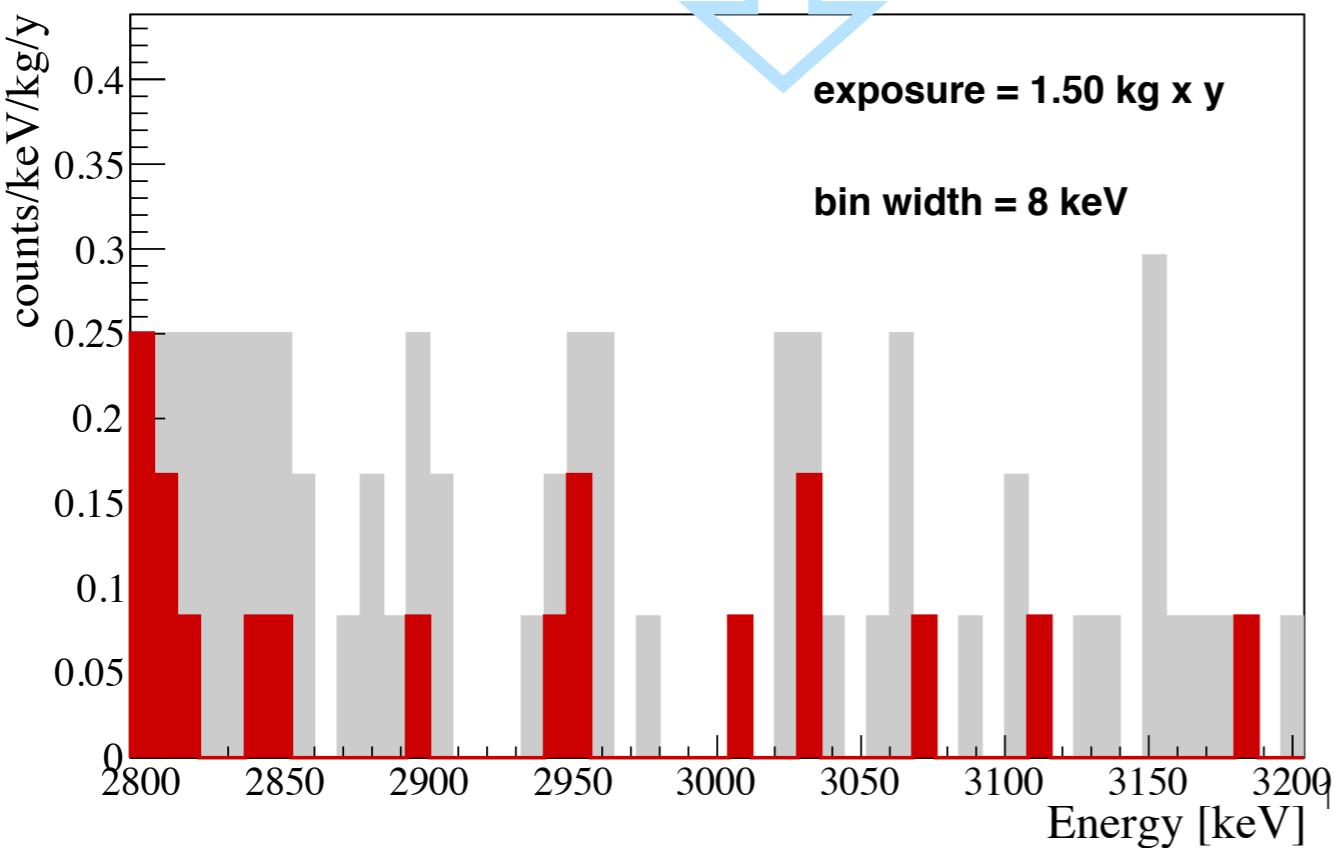
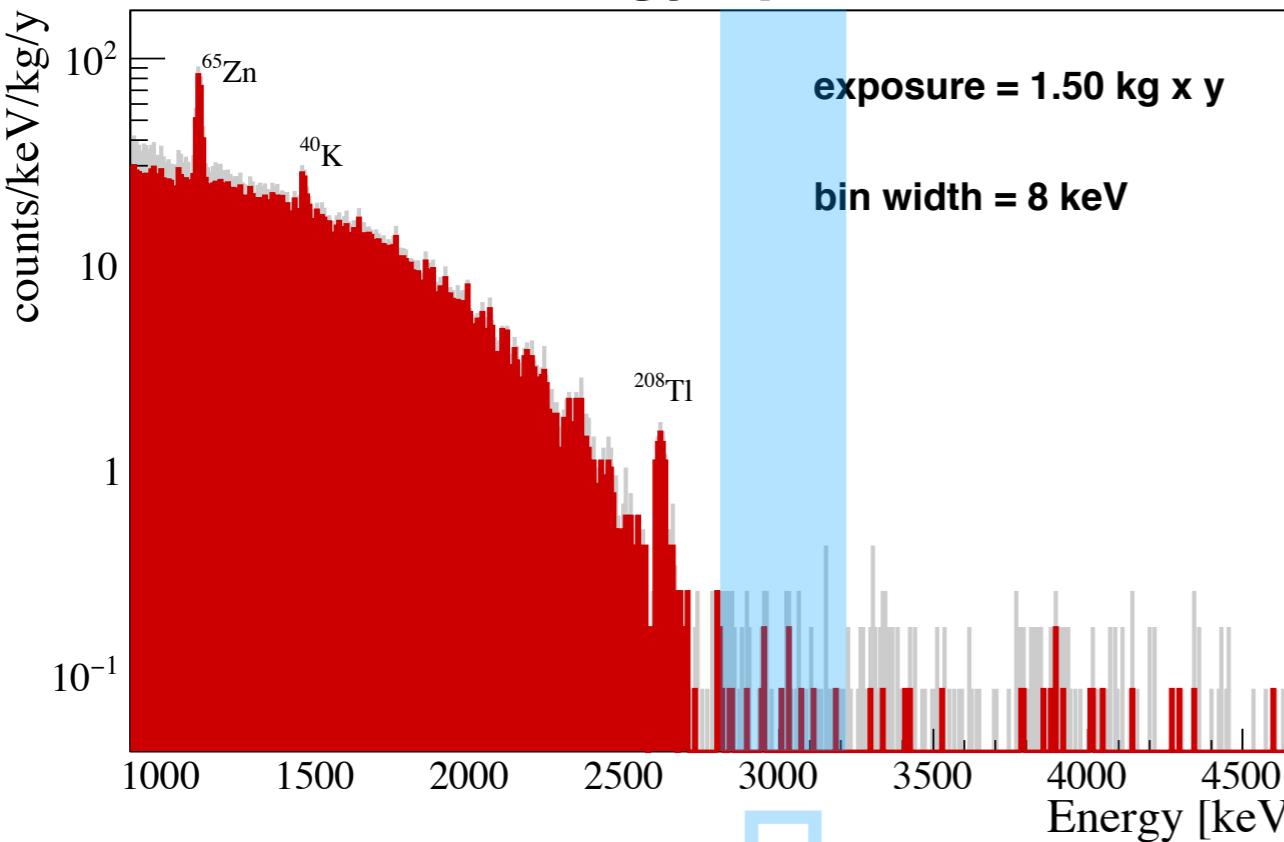
All events after first level data analysis:

- Optimum filtering
- Gain stability corrections
- Energy calibration
- Synchronization Heat-Light

ROI is [2800,3200] keV is large enough (conservative) to be able to evaluate most relevant background contributions:  $^{214}\text{Bi}$

# Background: data selection

Total energy spectrum



ROI [2800,3200] keV  
counts/kg/y

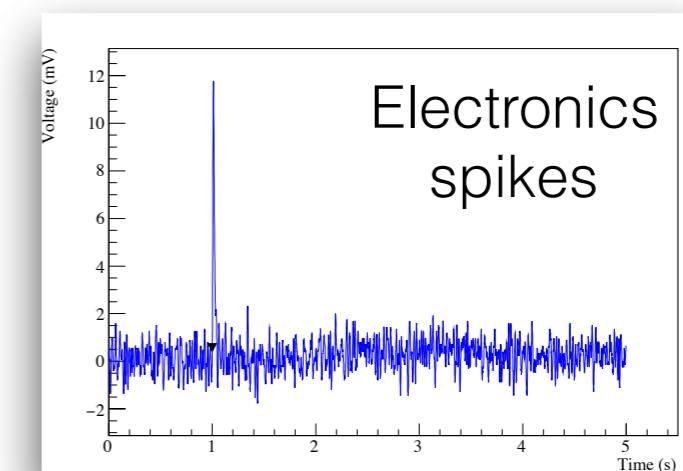
No cuts

$47.4 \pm 5.6$

Particle Selection  
(basic cuts on heat + M1)

$12.0 \pm 2.8$

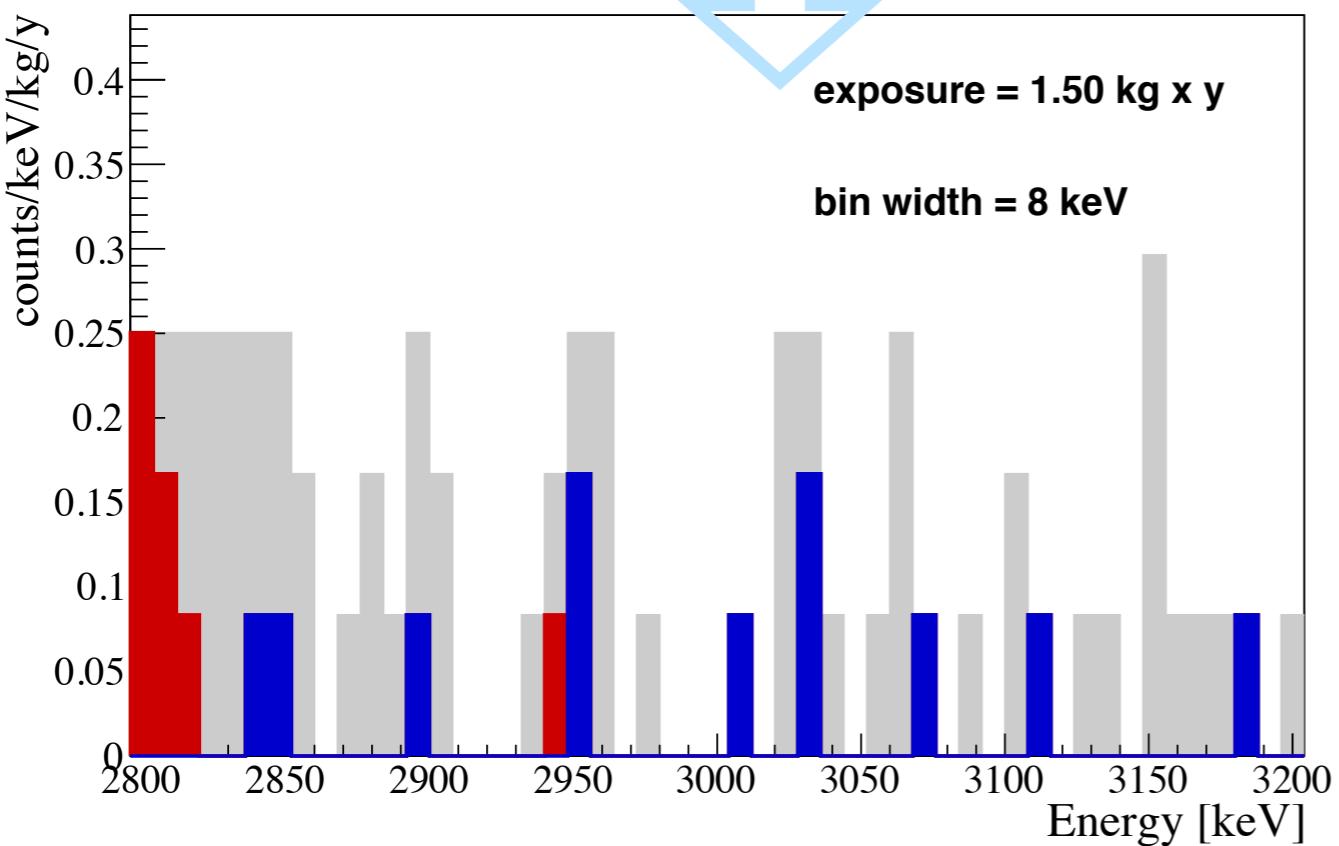
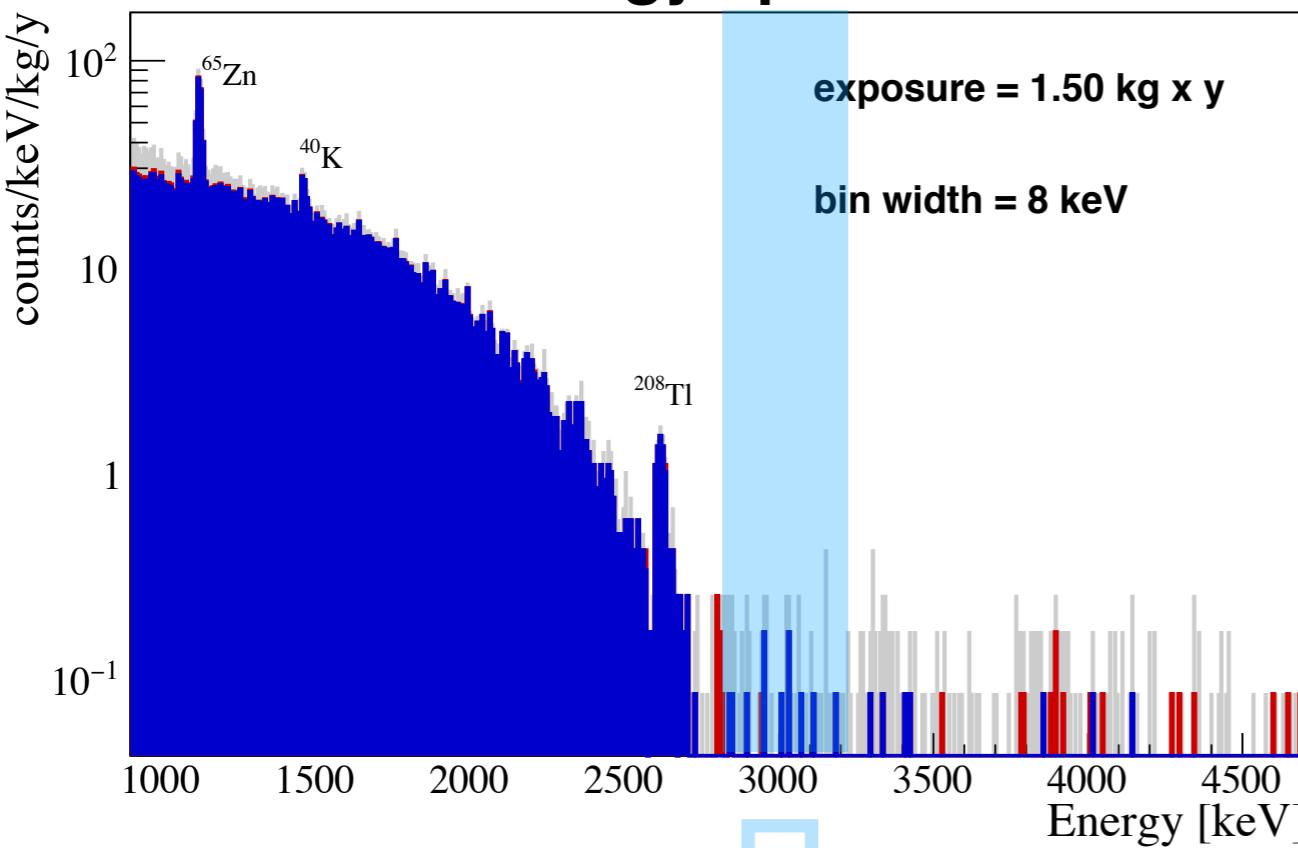
- Rejection of “non-particle-like” events:



- M1: Anti-Coincidence time window = 20 ms

# Background: data selection

Total energy spectrum



ROI [2800,3200] keV  
counts/kg/y

No cuts

$47.4 \pm 5.6$

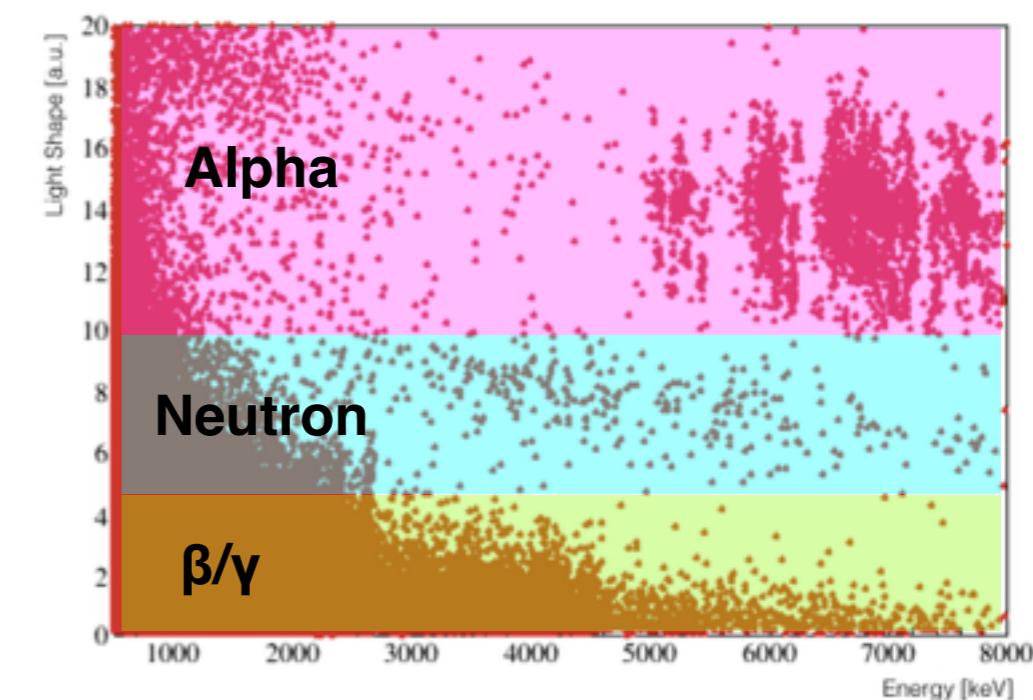
Particle Selection  
(basic cuts on heat + M1)

$12.0 \pm 2.8$

Particle Selection  
+ reject  $\alpha$

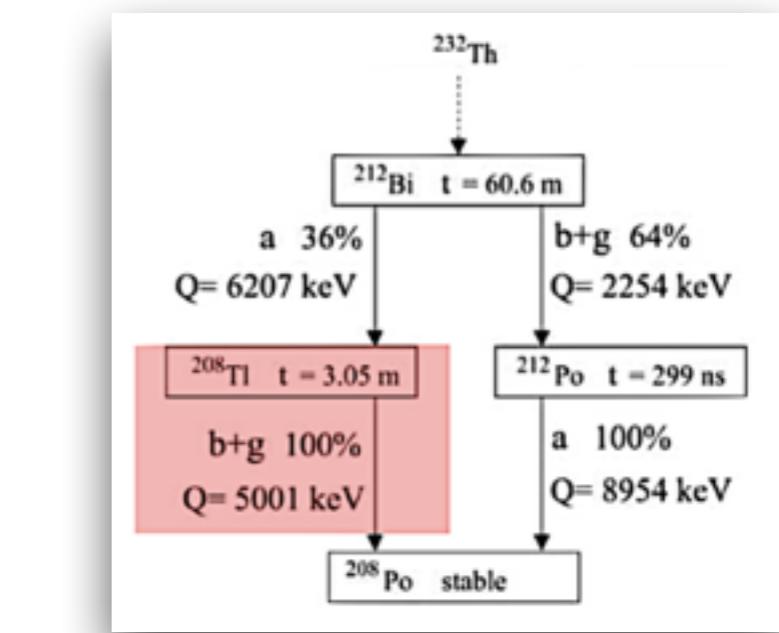
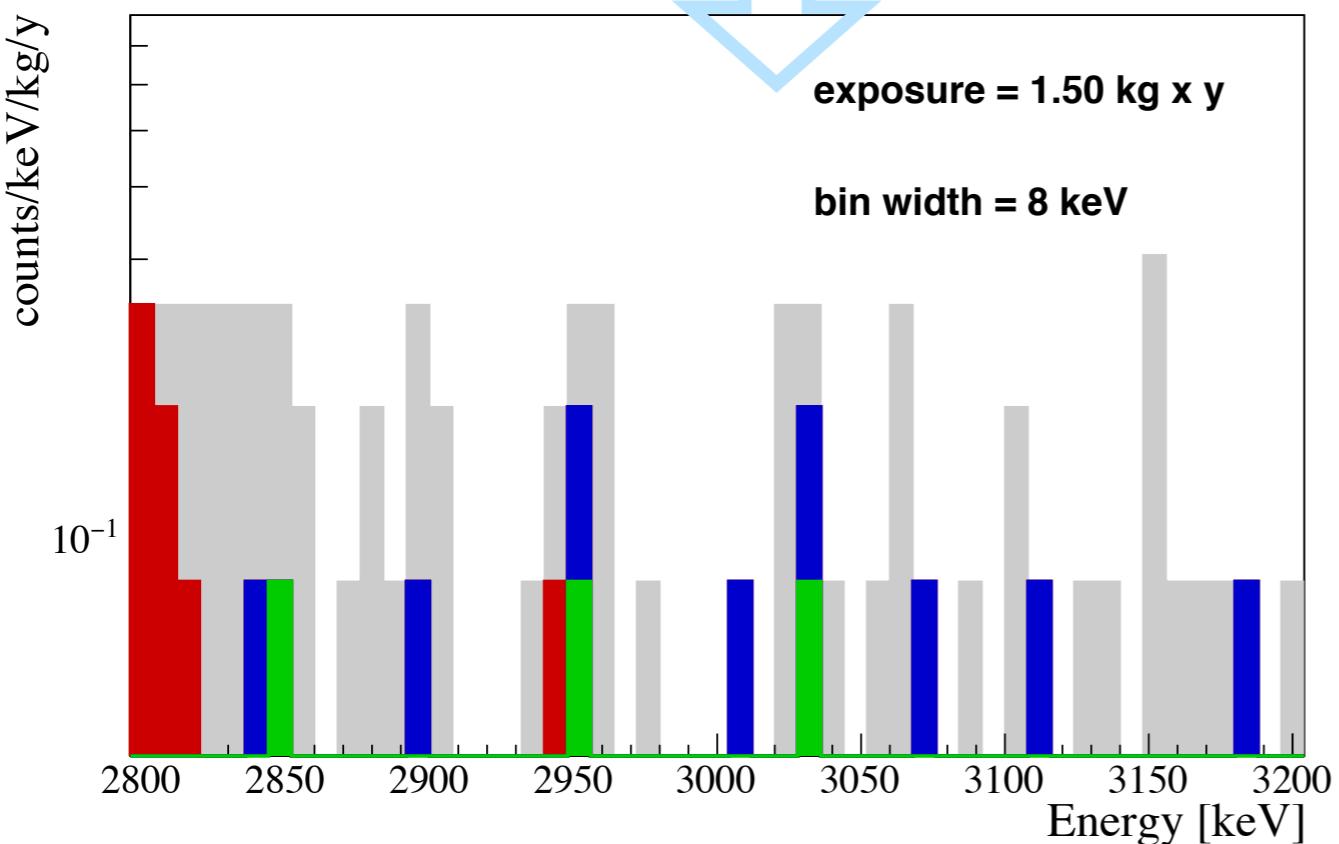
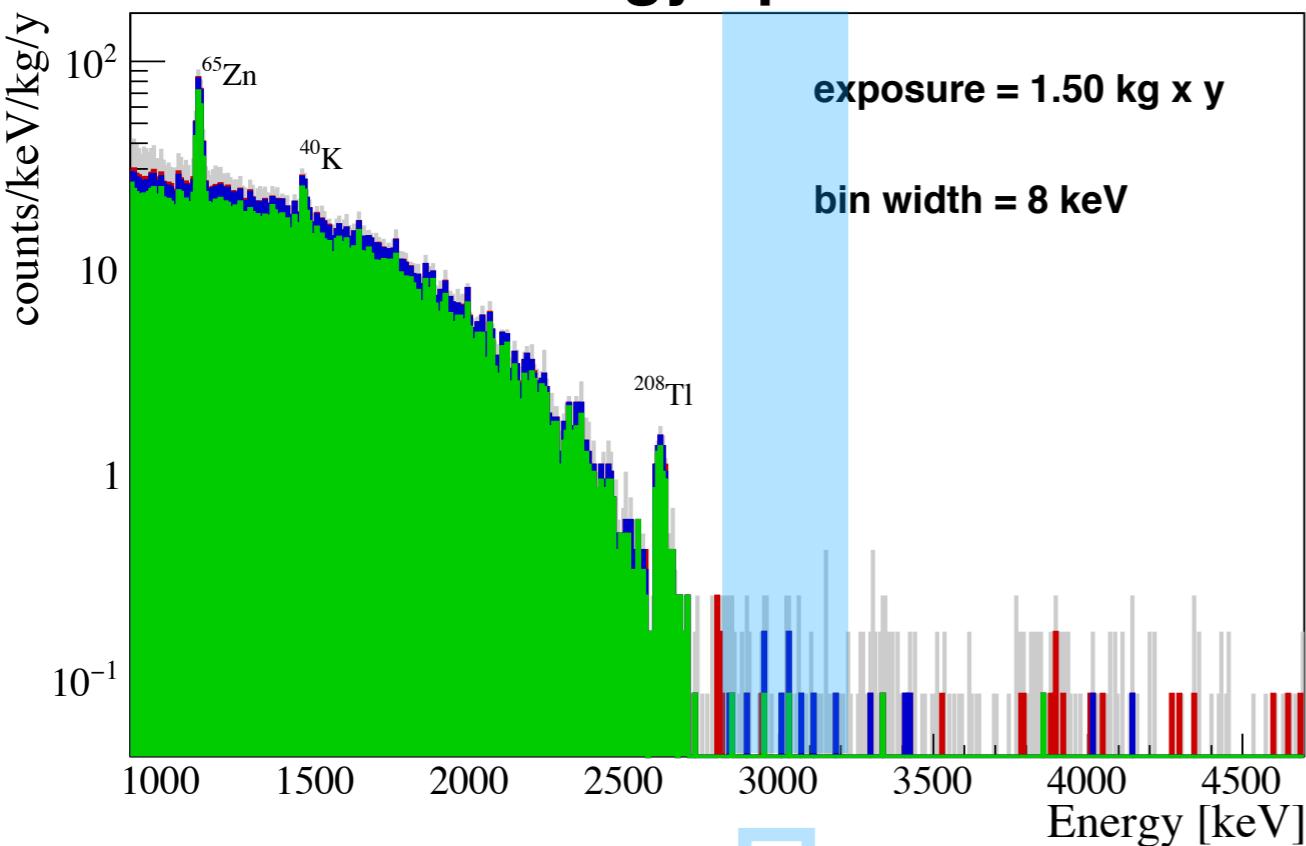
$7.3 \pm 2.2$

Alpha rejection with Light-shape variable.  
Neutron calibration:

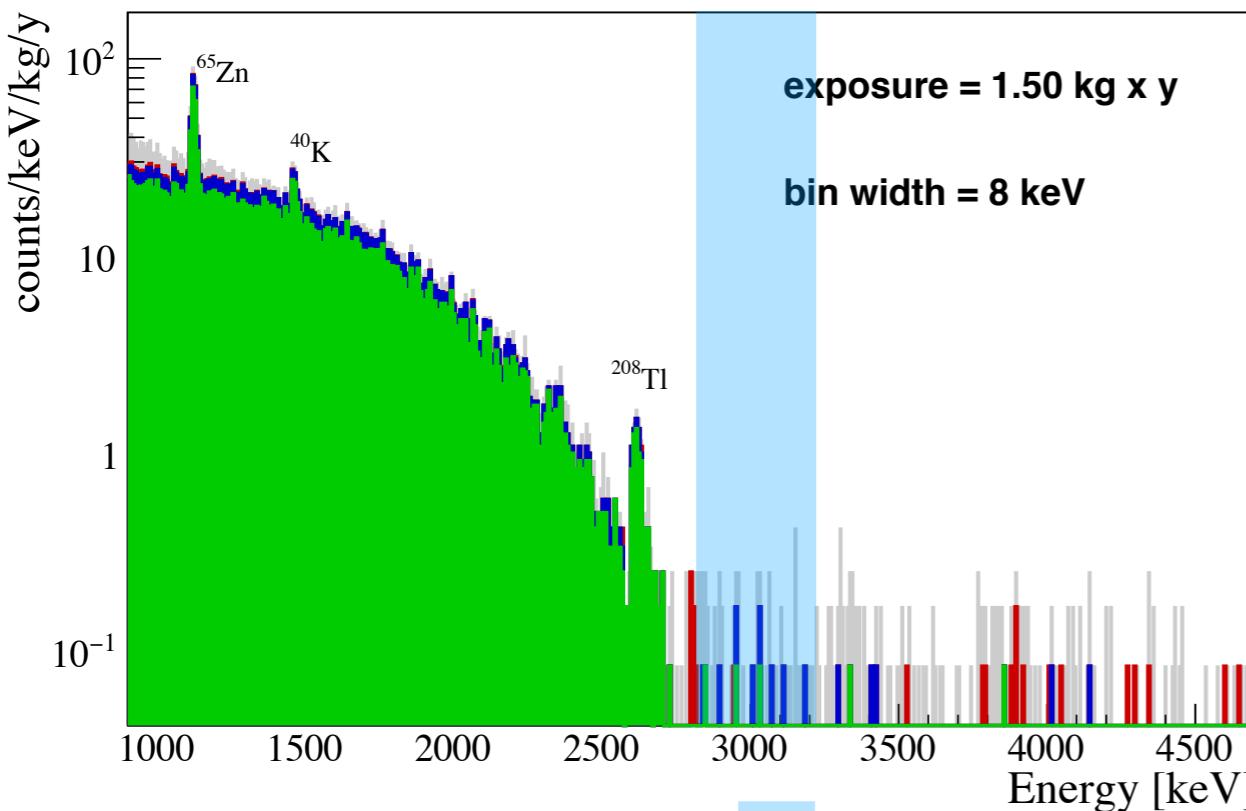


# Background: data selection

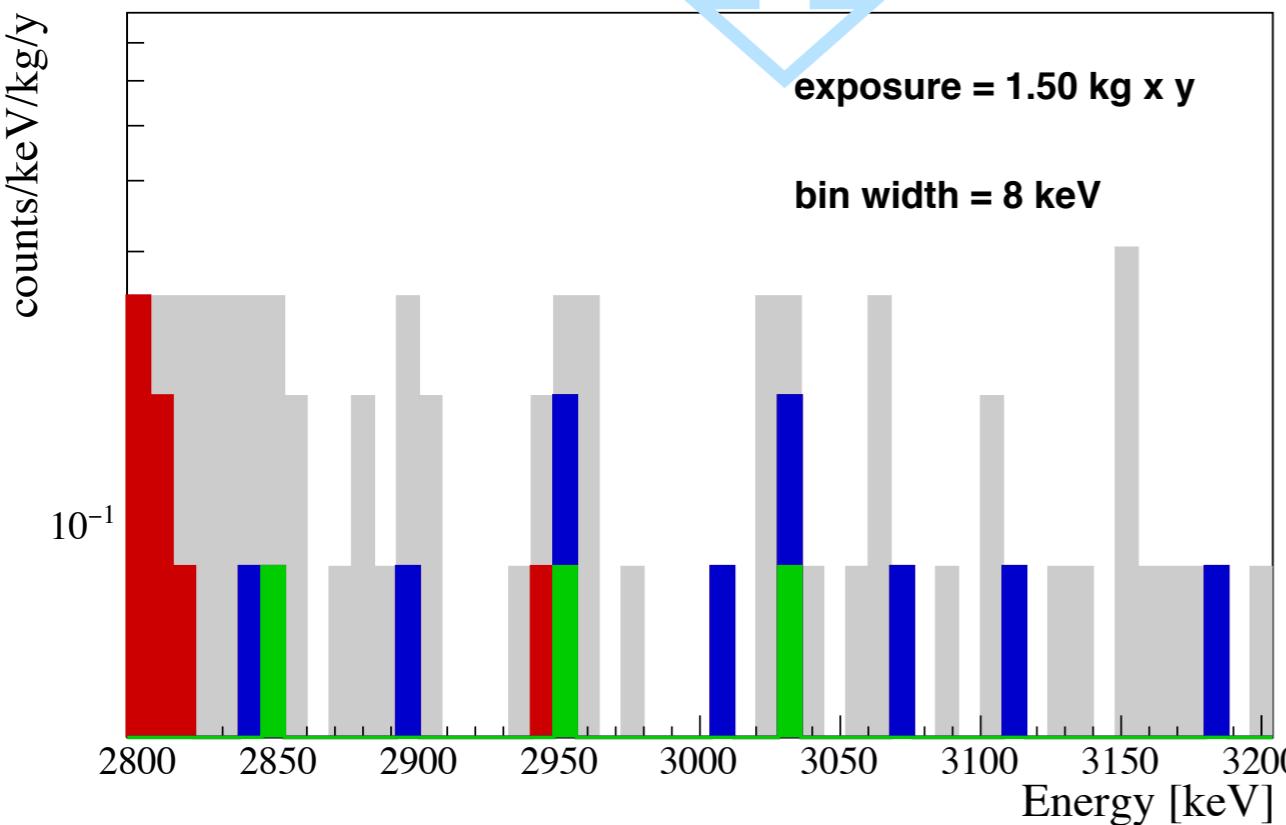
Total energy spectrum



# Background: data selection



	Exp [kg x y]	Events R <sub>0.1</sub>	$\epsilon_{\text{cuts}}$ [%]	FWHM @ R <sub>0.1</sub> [keV]
<b>SR1</b>	0.9	3	>85%	29
<b>SR2</b>	0.6	0	>85%	27



Bkg index in R<sub>0.1</sub>:  
 $(2.2-8.6) \times 10^{-3} \text{ c/keV/kg/y}$

0νββ half-life limit soon published

# Conclusion

- CUPID-0 is the first large array of enriched scintillating bolometers
- Data taking is smoothly going on since March 2017
- Acquired data are already enough to establish the world best half-life limit on  $^{82}\text{Se}$   $0\nu\beta\beta$
- Background index in the R<sub>0</sub>I looks promising
  - Background model is in progress (higher statistics is needed)
- Goal: run until 10 kg x y of Zn<sup>82</sup>Se exposure