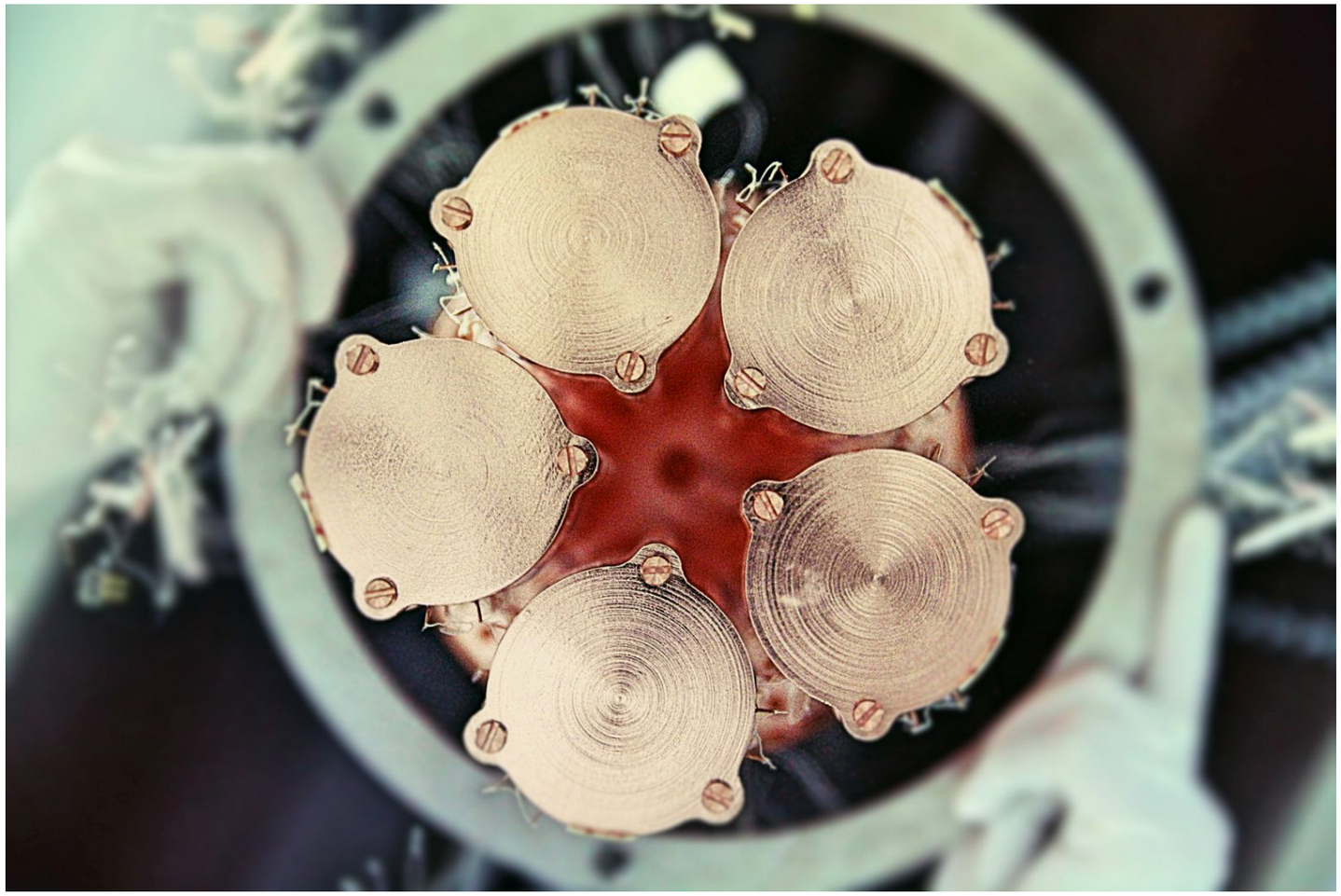
CUPID-0
a cryogenic calorimeter with particle identification for double beta decay search

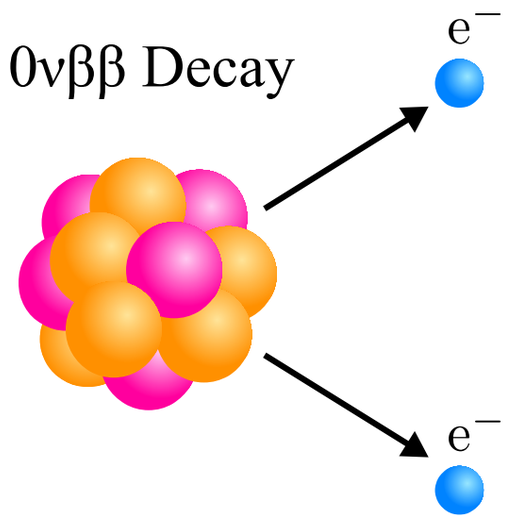


Laura Cardani
Istituto Nazionale di Fisica Nucleare - Roma
on behalf of the CUPID-0 collaboration

25 May 2017
TIPP17, Beijing, China

Neutrinoless Double Beta Decay

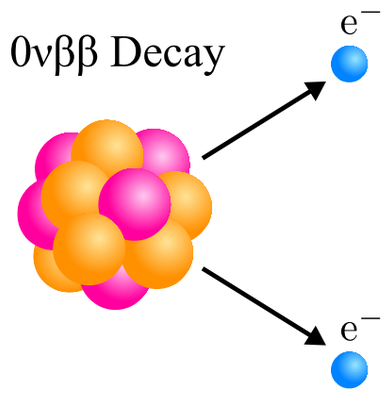
Hypothesized, **never observed**, nuclear transition



- Can occur **only if ν is a Majorana** particle
- Forbidden by SM: it **violates L** (actually B-L) conservation
- It **creates matter** (no anti-matter balancing)
- Majorana phases: **other sources of CPV**?
- If observed, insights on the **neutrino mass**

Double Beta Decay search

- Signal = 2 **electrons producing a peak at 2-3 MeV** (depends on isotope)
- Never observed and **extremely rare**: half-life larger than 10^{24} -10^{26} years
- Stringent requirements on next generation experiments



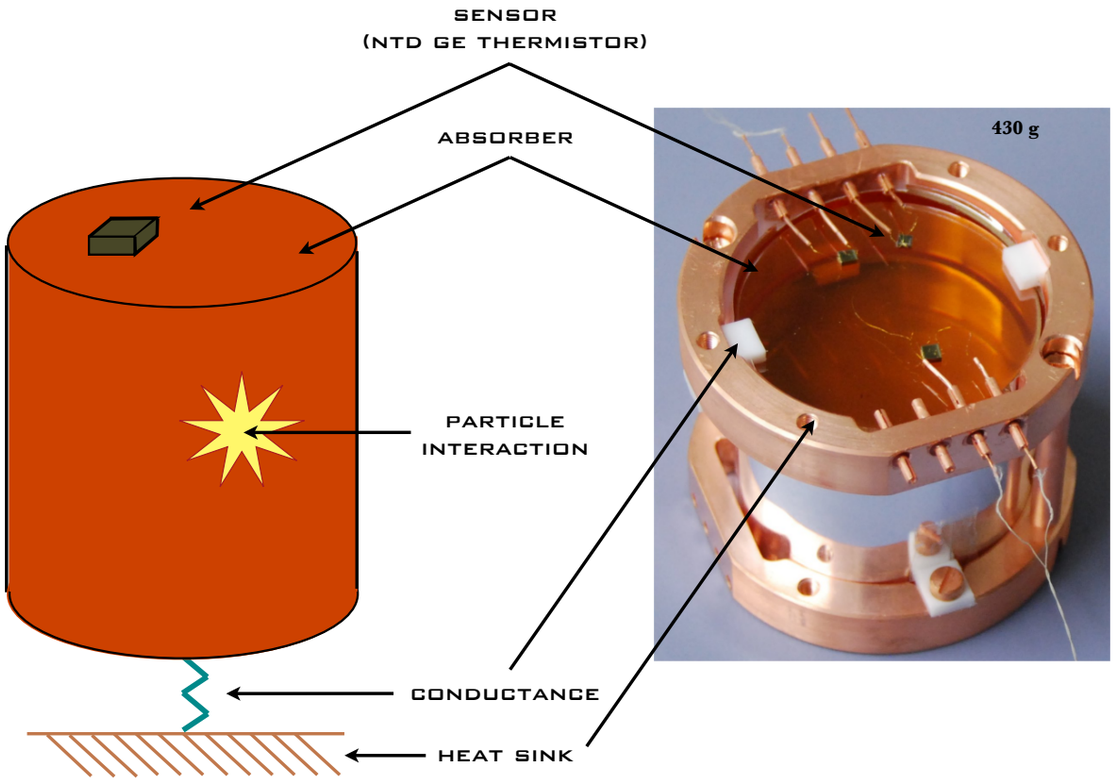
10^{27} nuclei: Hundreds of kg of source

Good Energy Resolution

Background free detectors

Many experiments in data-taking, in construction or proposed.

Cryogenic Calorimeters



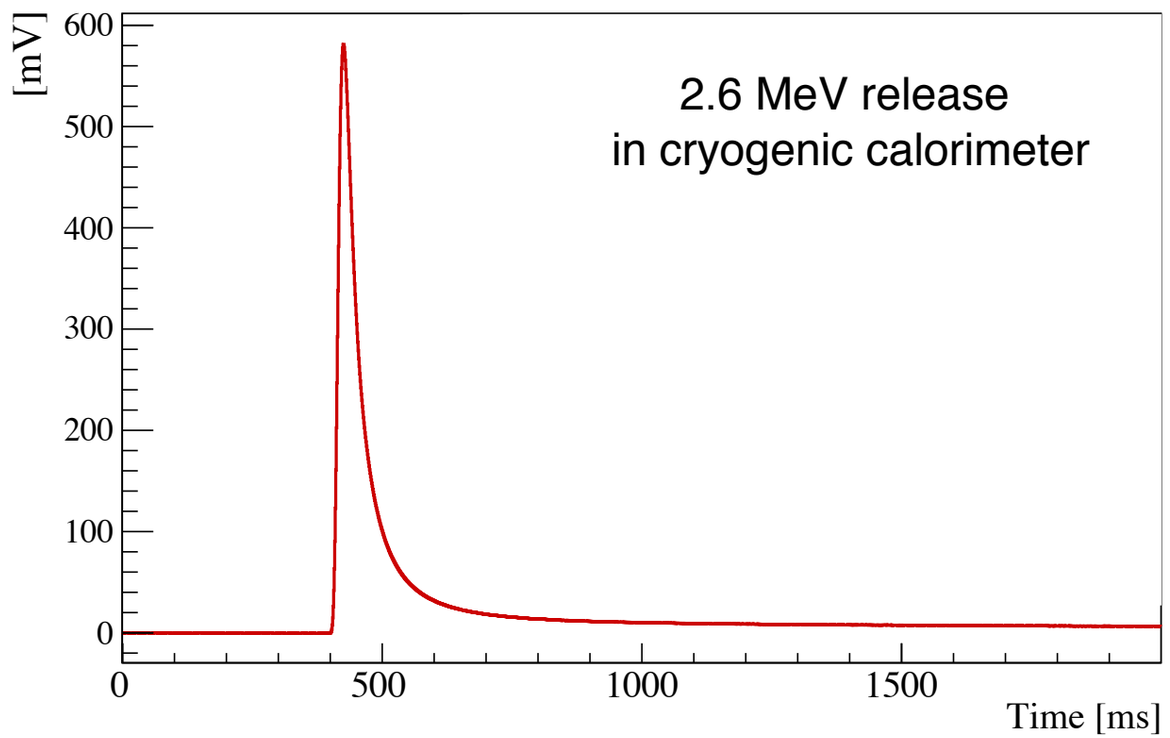
Wednesday, September 4, 13

Crystal operated as calorimeter at **~10 mK**

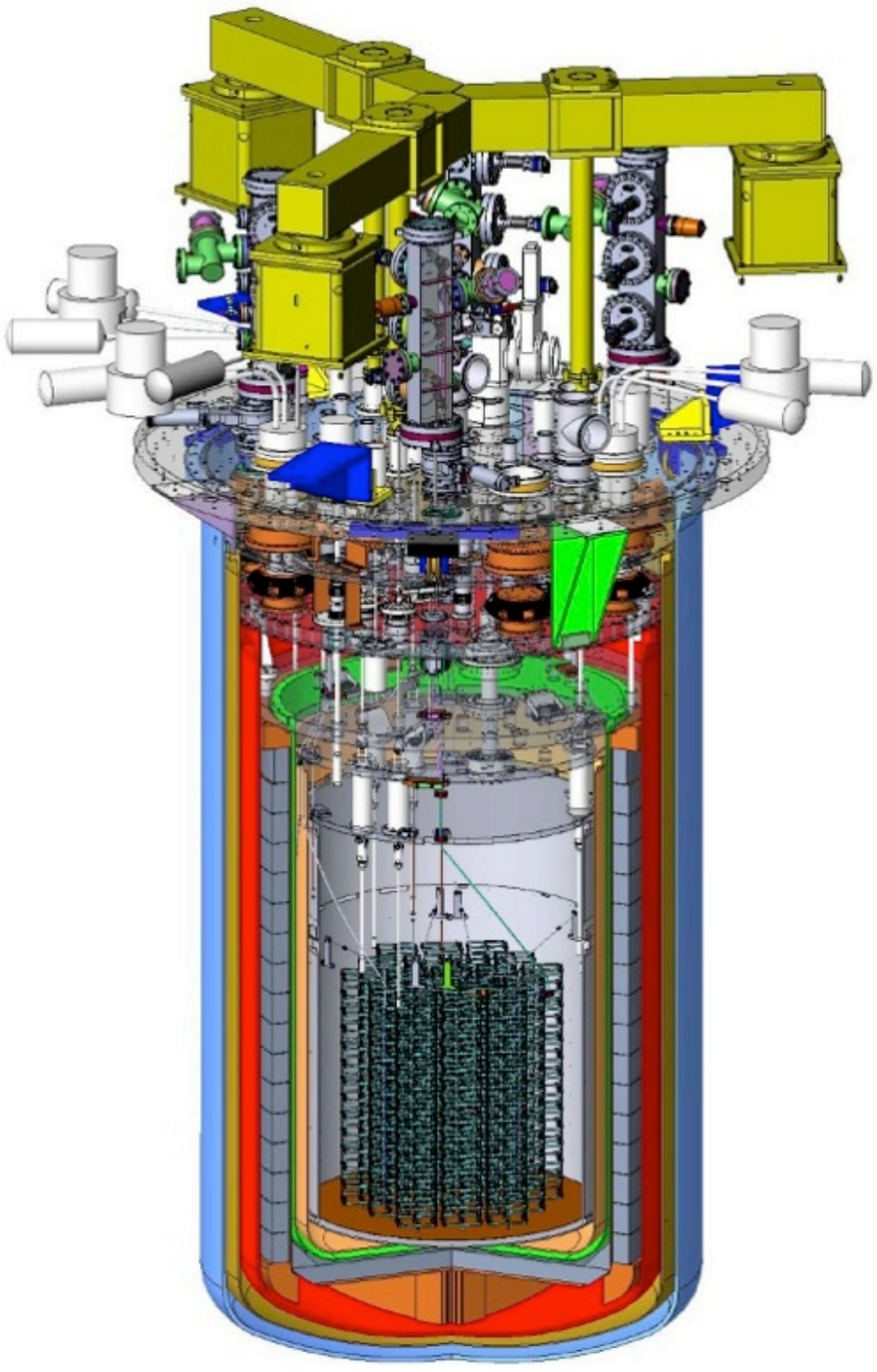
Particle interaction ➪ E deposit ➪ T increase

Dedicated sensor to convert ΔT in a voltage pulse

- Grown from 0νββ emitter ➪ **ε > 80%**
- Possibility to test **different 0νββ emitters**
- Excellent **energy resolution** (<1%)
- Scalability ➪ large **source mass**



Calorimeters for 0nDBD



CUORE

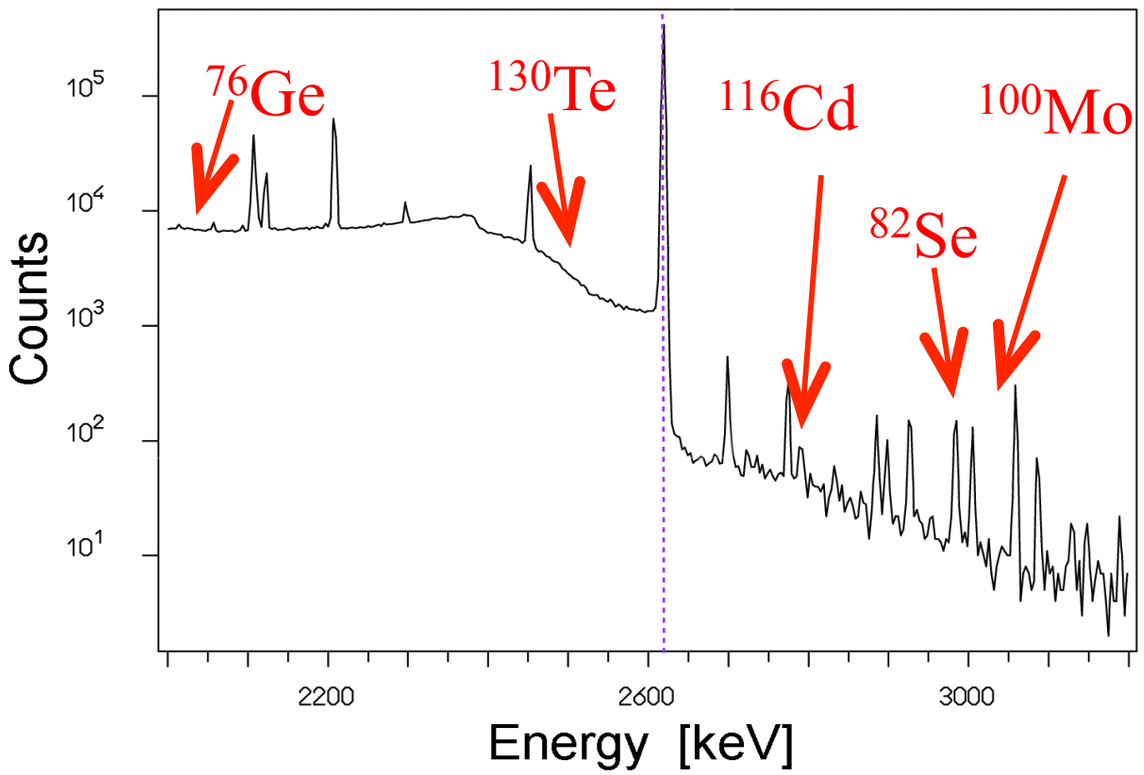
sets the standard for next generation experiments exploiting the calorimetric technique

L. Cassina's talk

- Hundreds of kg of source ➪ **Proved by CUORE**
- Good Energy Resolution ➪ **~0.1% for CUORE-like detectors**
- Background free detectors ➪ **200 events/ROI** for CUORE

Goal of CUPID-0:
prove that we can keep the advantages of calorimeters
BUT
with **zero background** in the region of interest

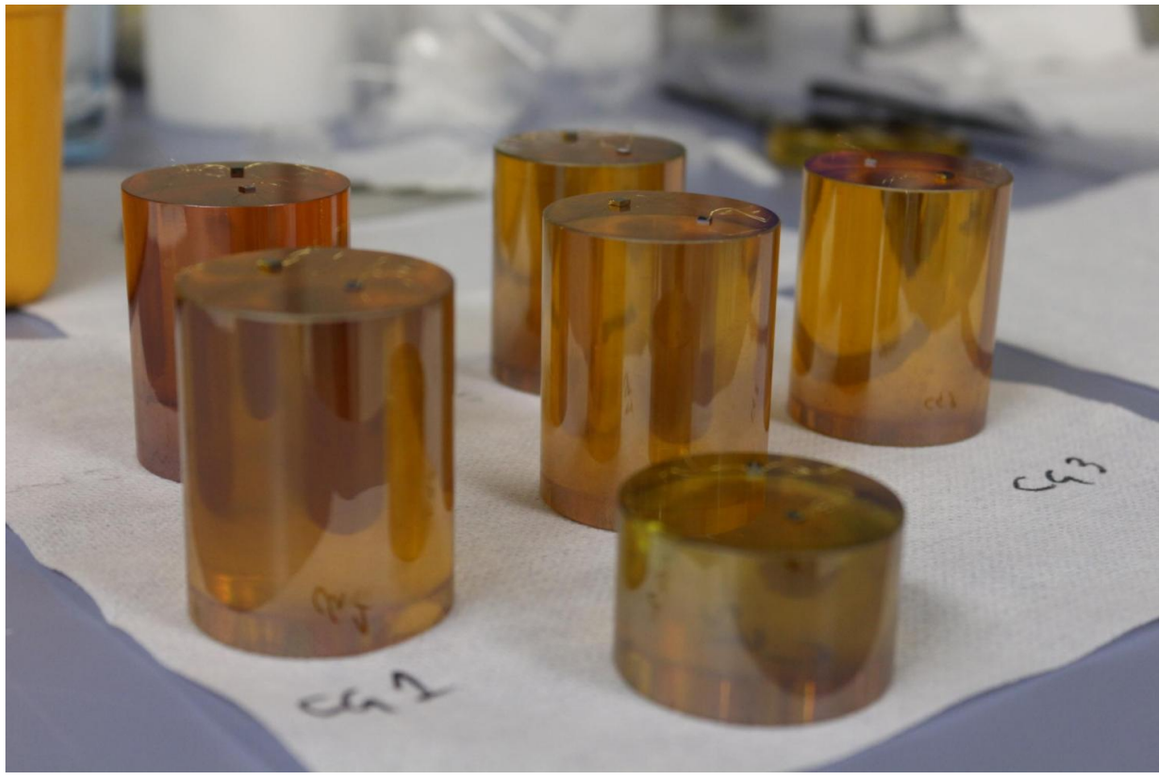
^{82}Se based calorimeters



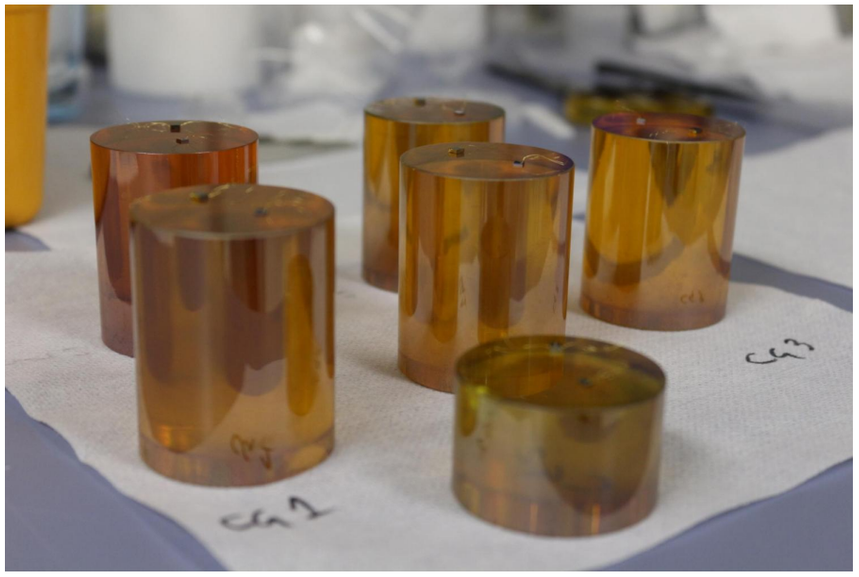
- ^{82}Se: high **Q-value ~2998 keV**
- Rather **slow 2nDBD decay**: 9.6x10^{19} years
- But: low natural isotopic abundance

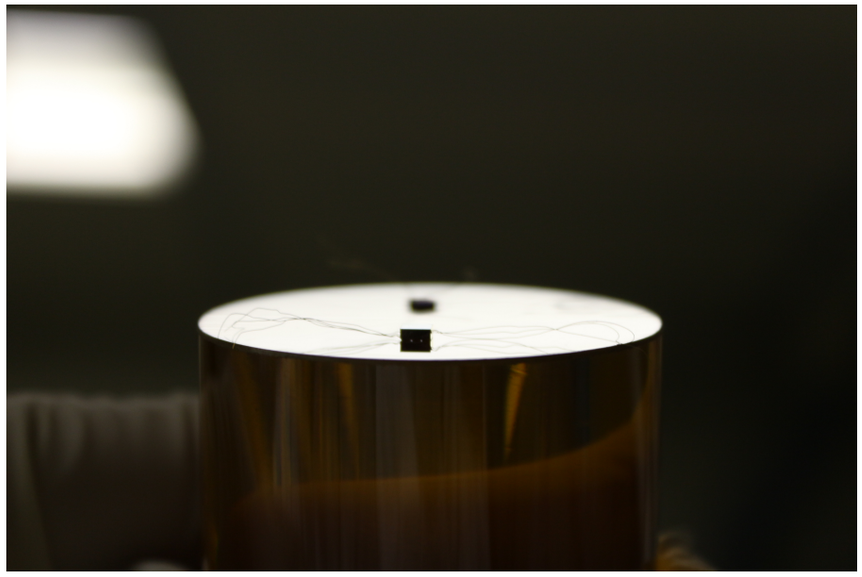
- Enrich in ^{82}Se from 8.7% to **96.3%**
  I. Dafinei et al, arXiv:1702.05877 (2017)

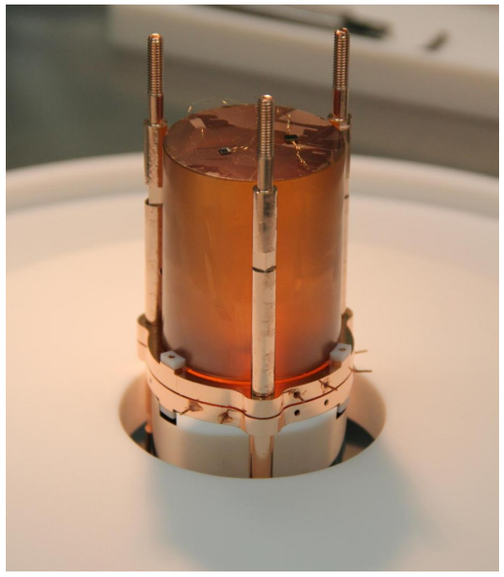
- ^{82}Se embedded in **Zn^{82}Se crystals** to be operated as **cryogenic calorimeters**



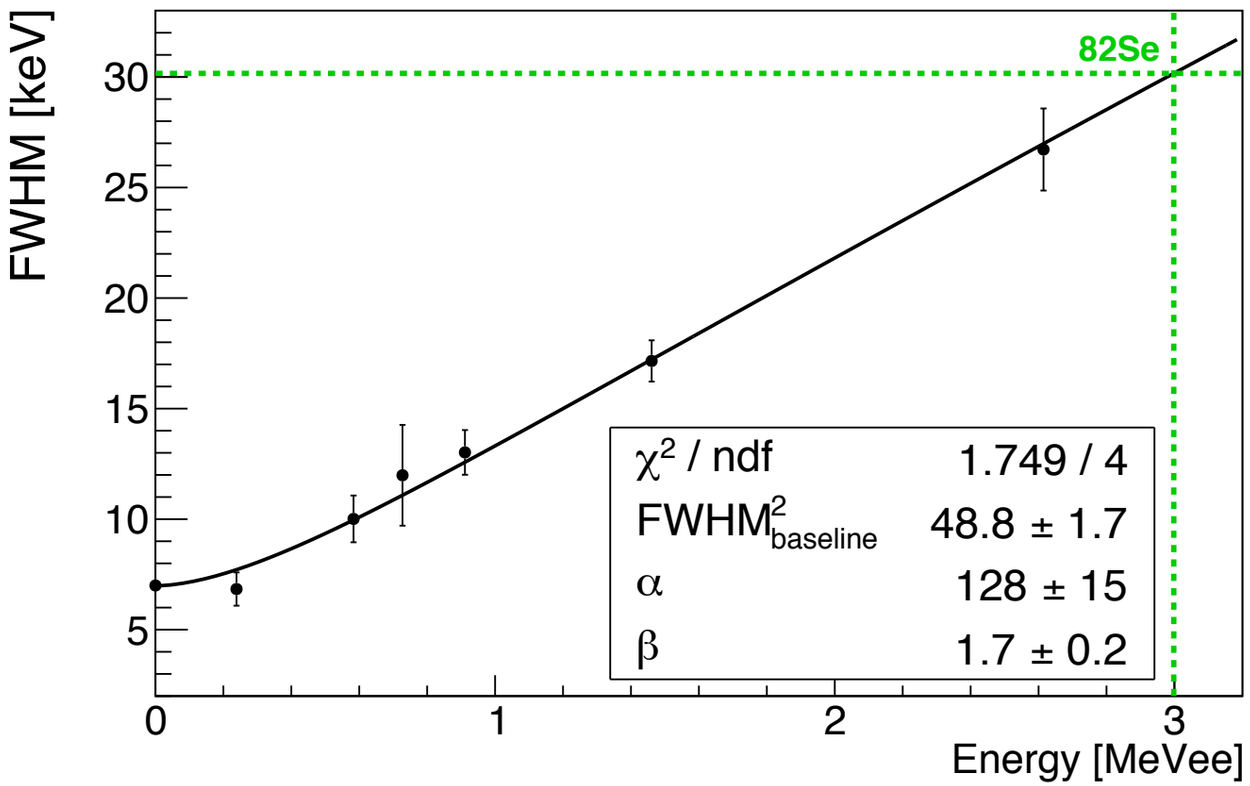
$Zn^{82}Se$ cryogenic calorimeters







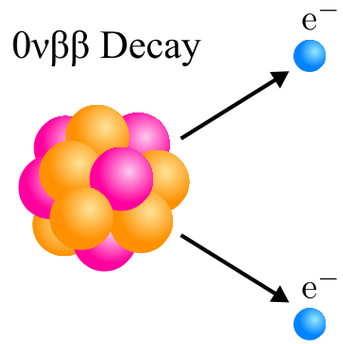
R. Artusa et al, Eur.Phys.J. C76 (2016) no.7, 364



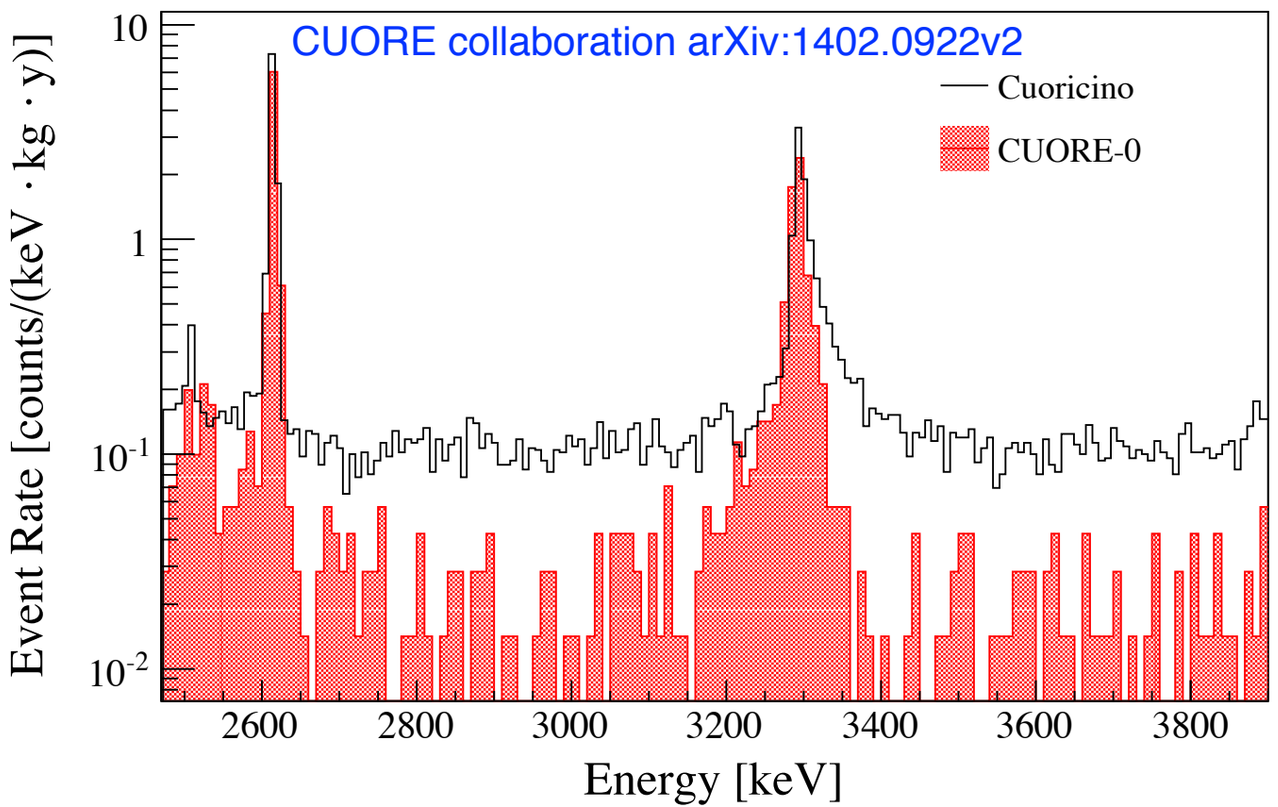
- Test with some ZnSe samples
- Containment **efficiency > 80%**
- Energy resolution **30 keV at 3 MeV** (1%)
- Reasonable **low intrinsic background**

Background Suppression

- **Target** of next generation experiments = **zero background**
- 0nDBD **signal** = 2 **electrons**
- Main background = **alpha particles (200 events in ROI)**



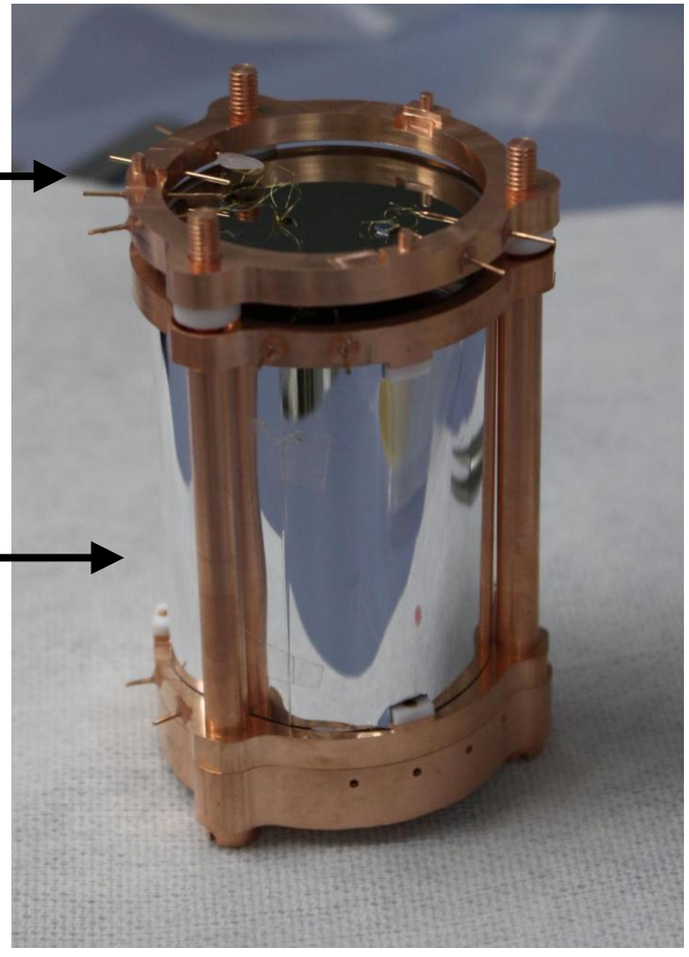
- Exploit **light output** for particle ID (alpha rejection)

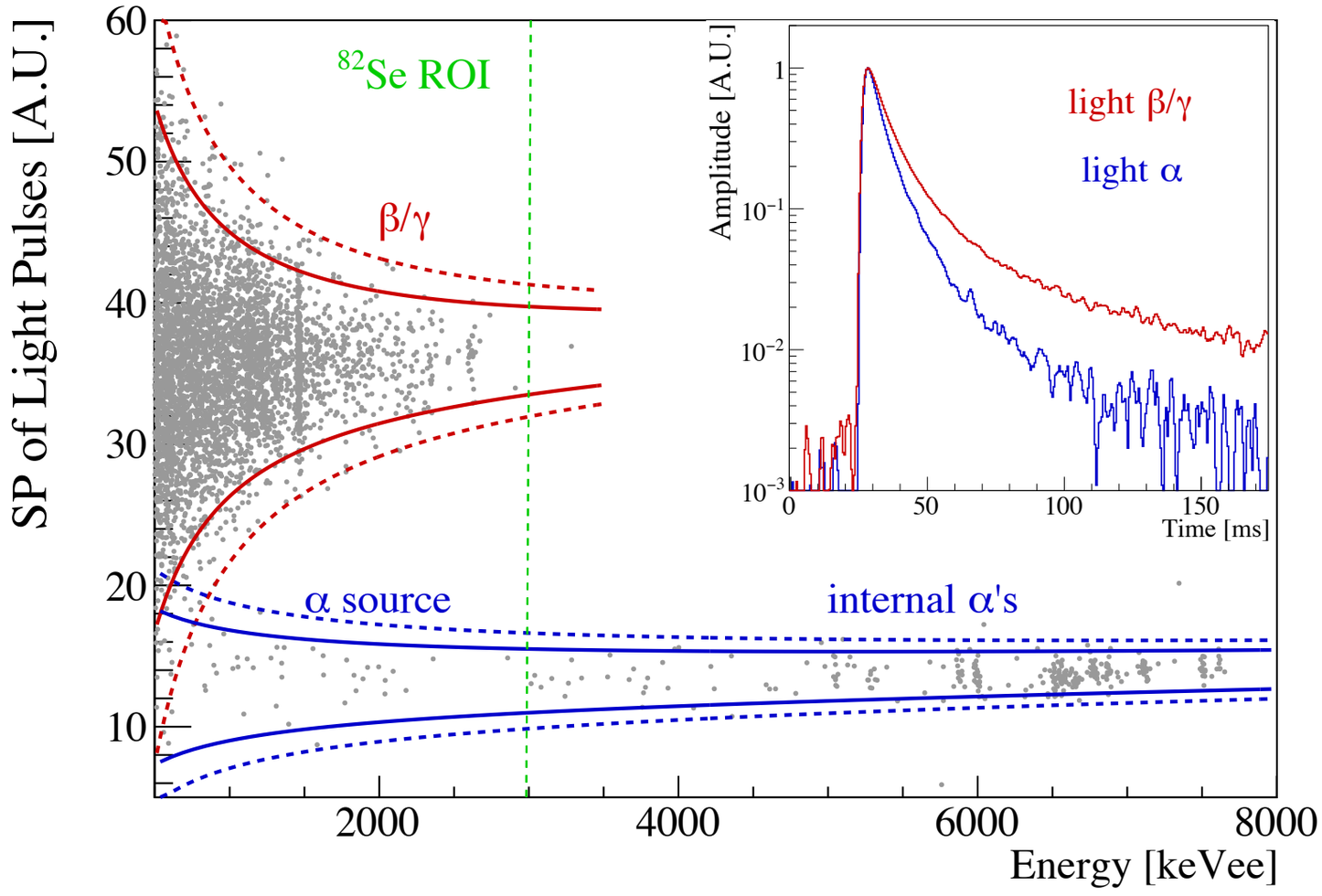


Potential of Particle ID

LD
h=150 µm
Ge coated Si

ZnSe
wrapped with
3M Vikuti™



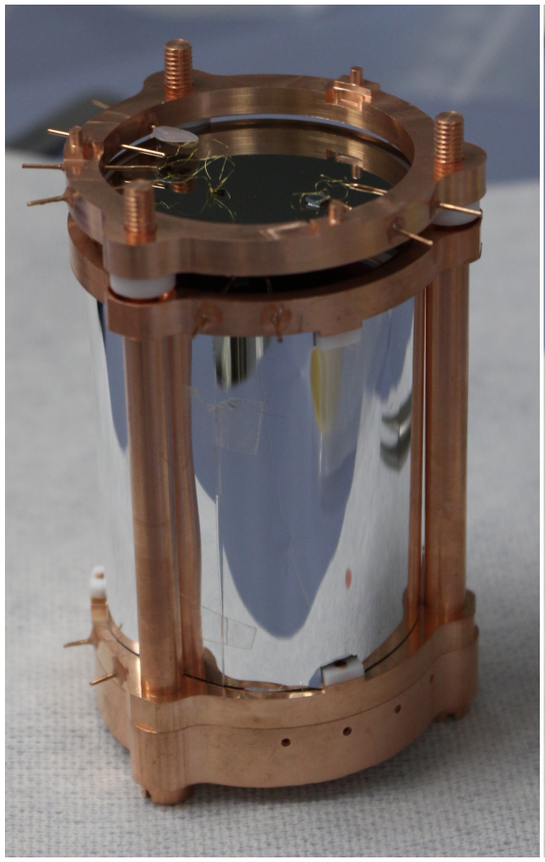
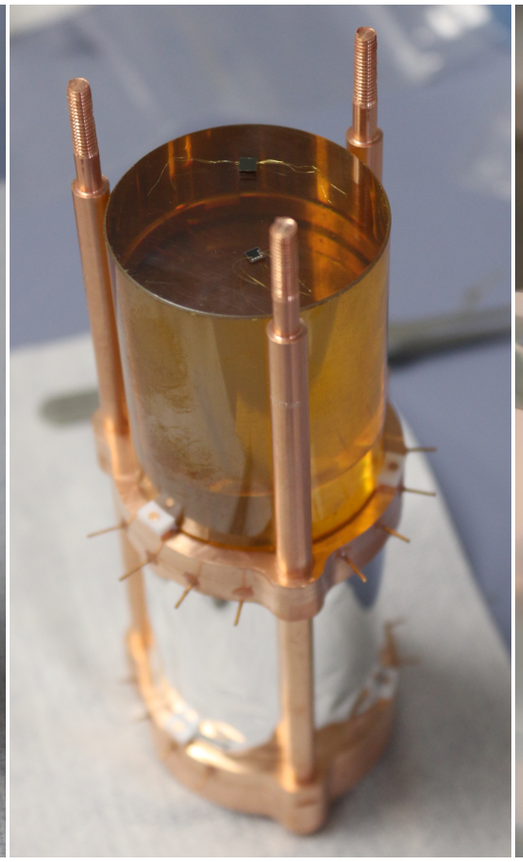
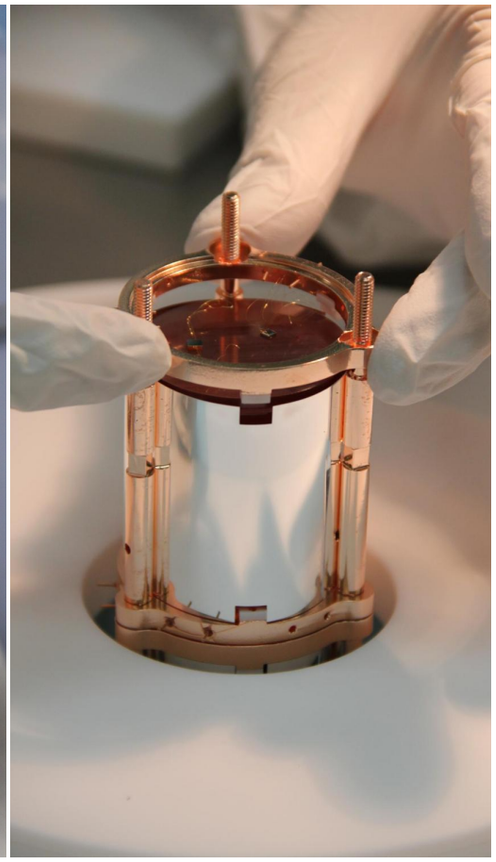


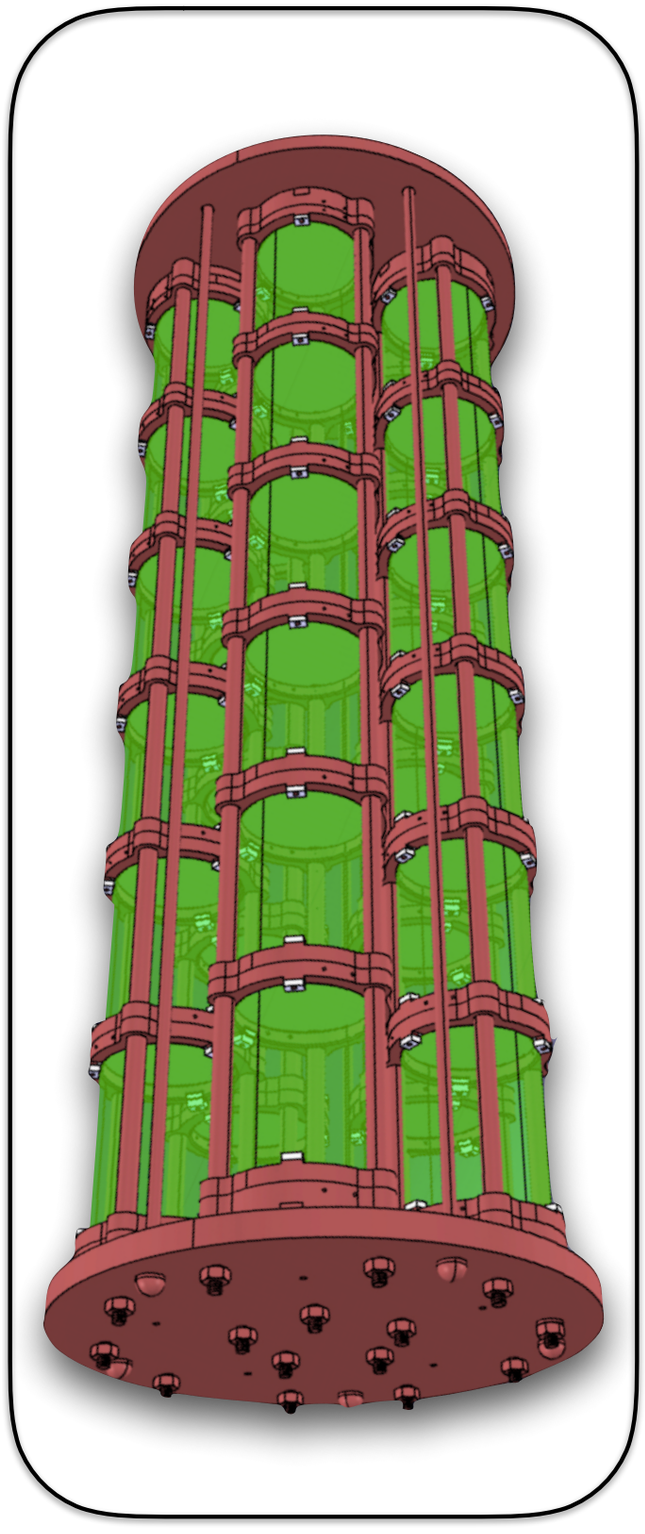
- Containment **efficiency > 80%**
- Energy resolution **30 keV at 3 MeV** (1%)
- Reasonable low intrinsic background

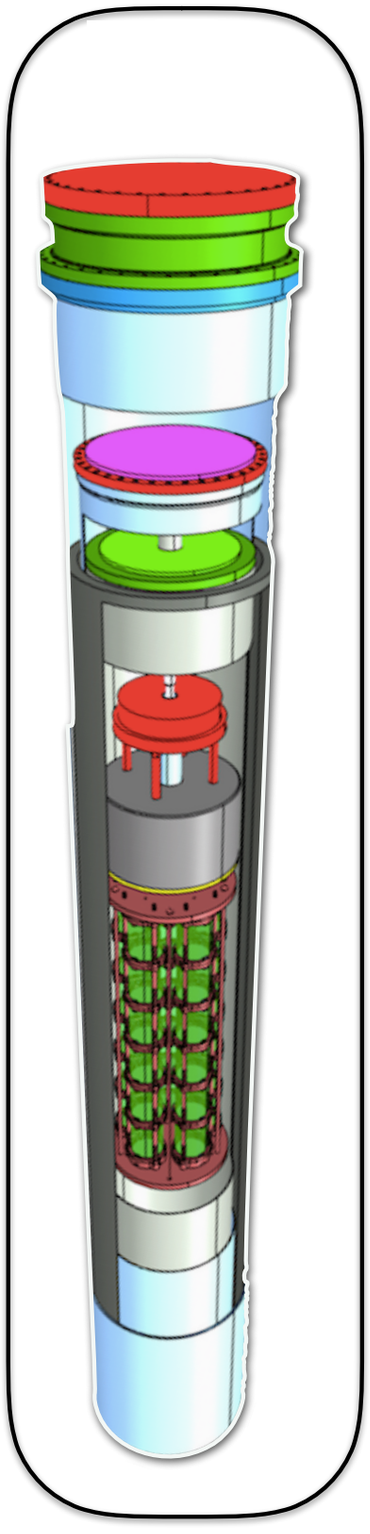
+

Complete rejection of the dominant alpha background

CUPID-0

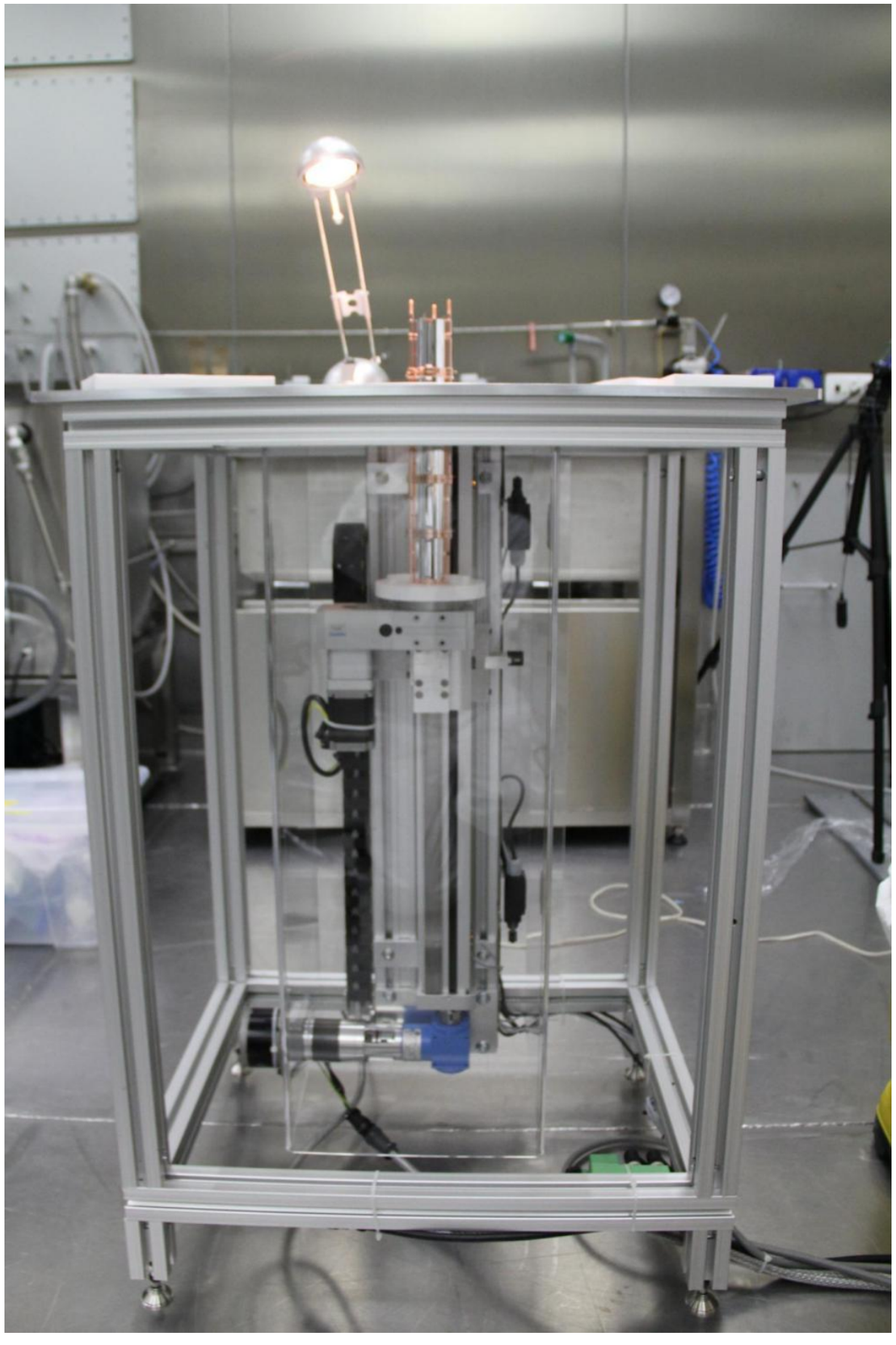






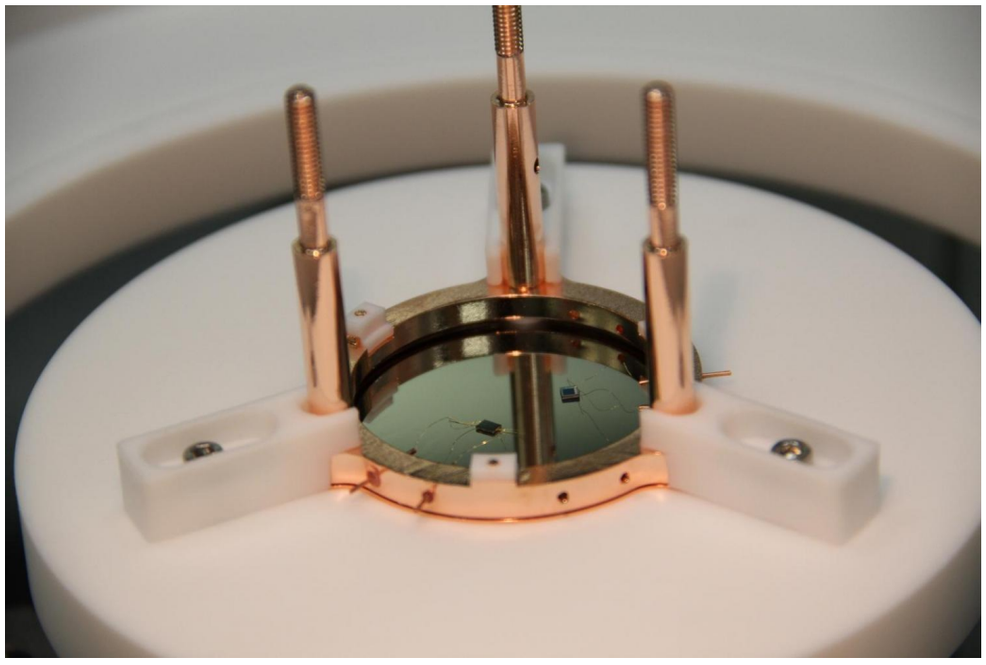


- **CUPID-0** is a modular detector **~10 kg**
- Commissioned in **early 2017**
- About 60 researchers from Italy, US and France
- Demonstrator for resolution and background

Detector Assembly



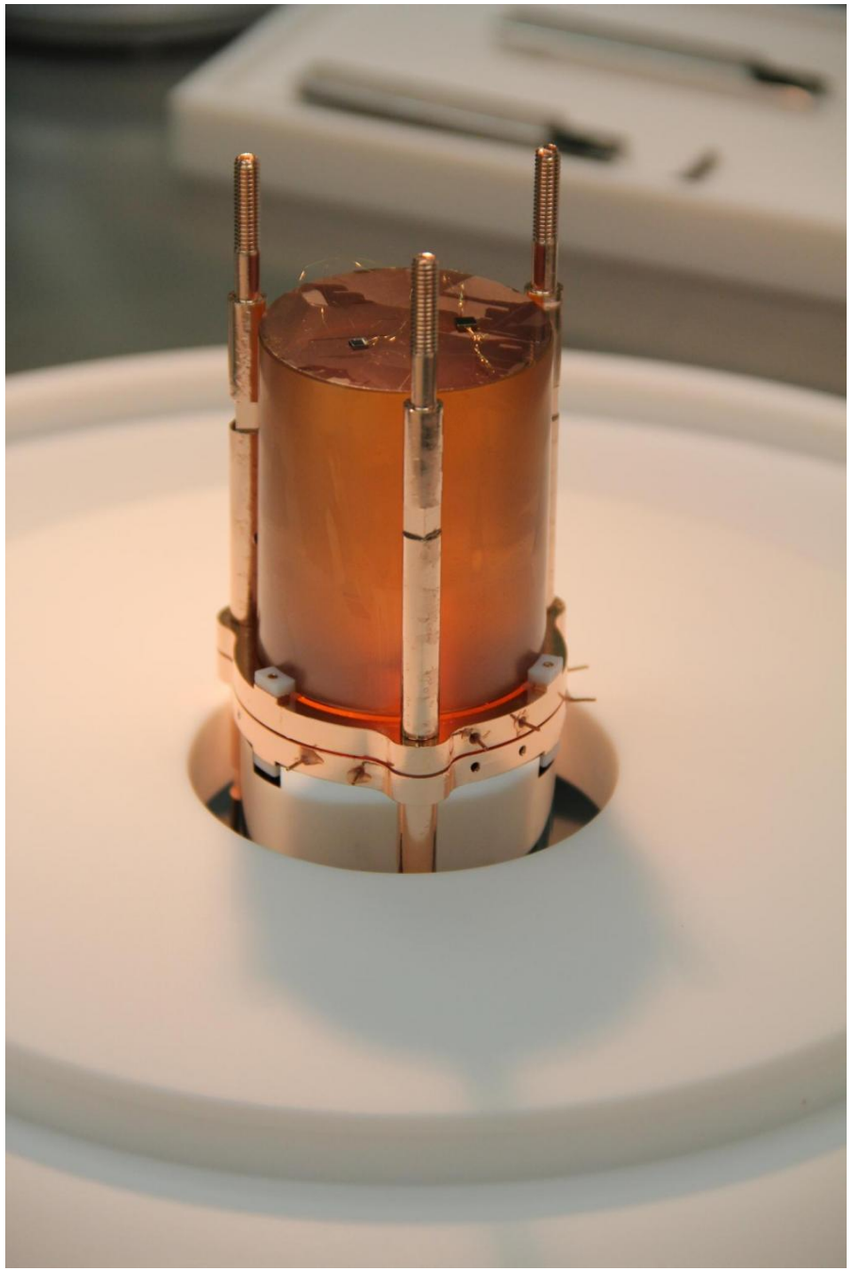
We developed many custom tools for a radio-pure detector assembly in underground clean-room

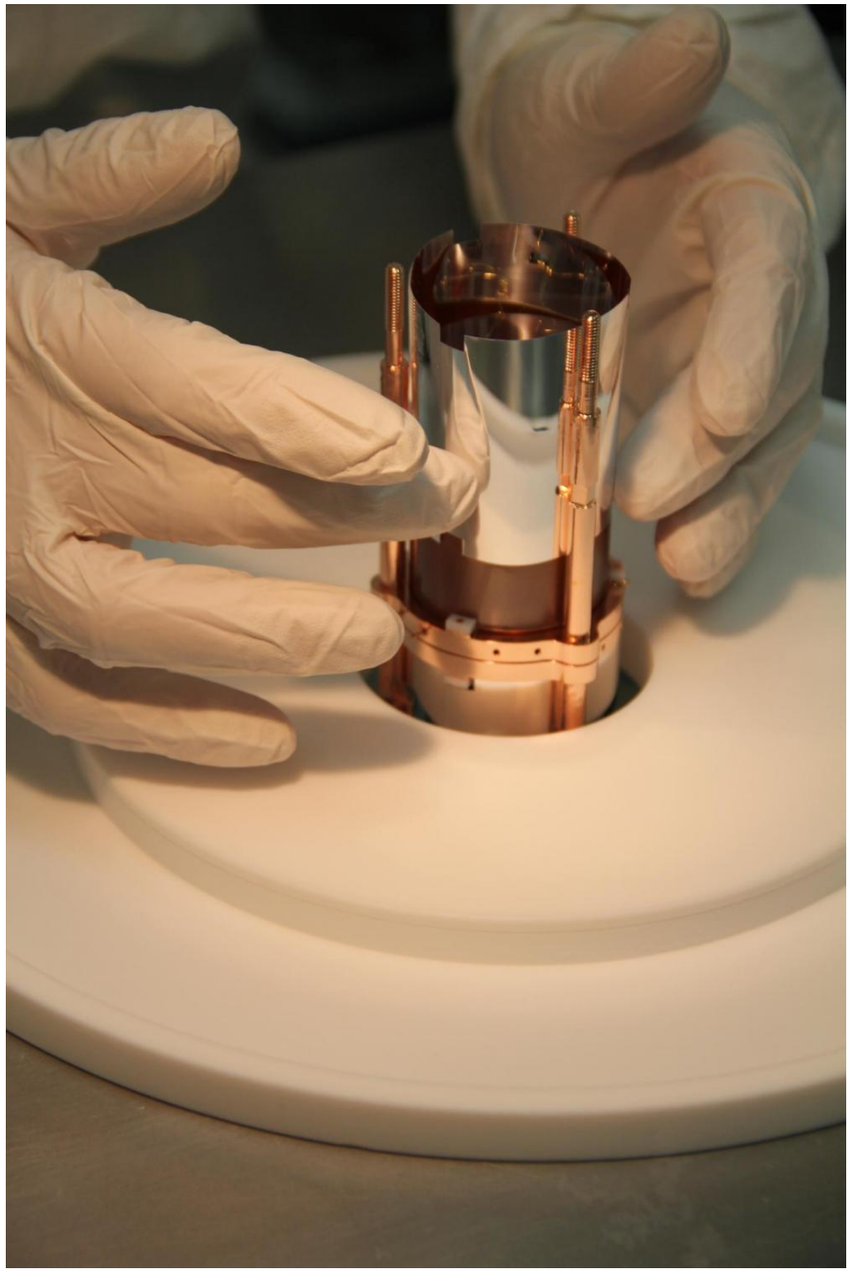


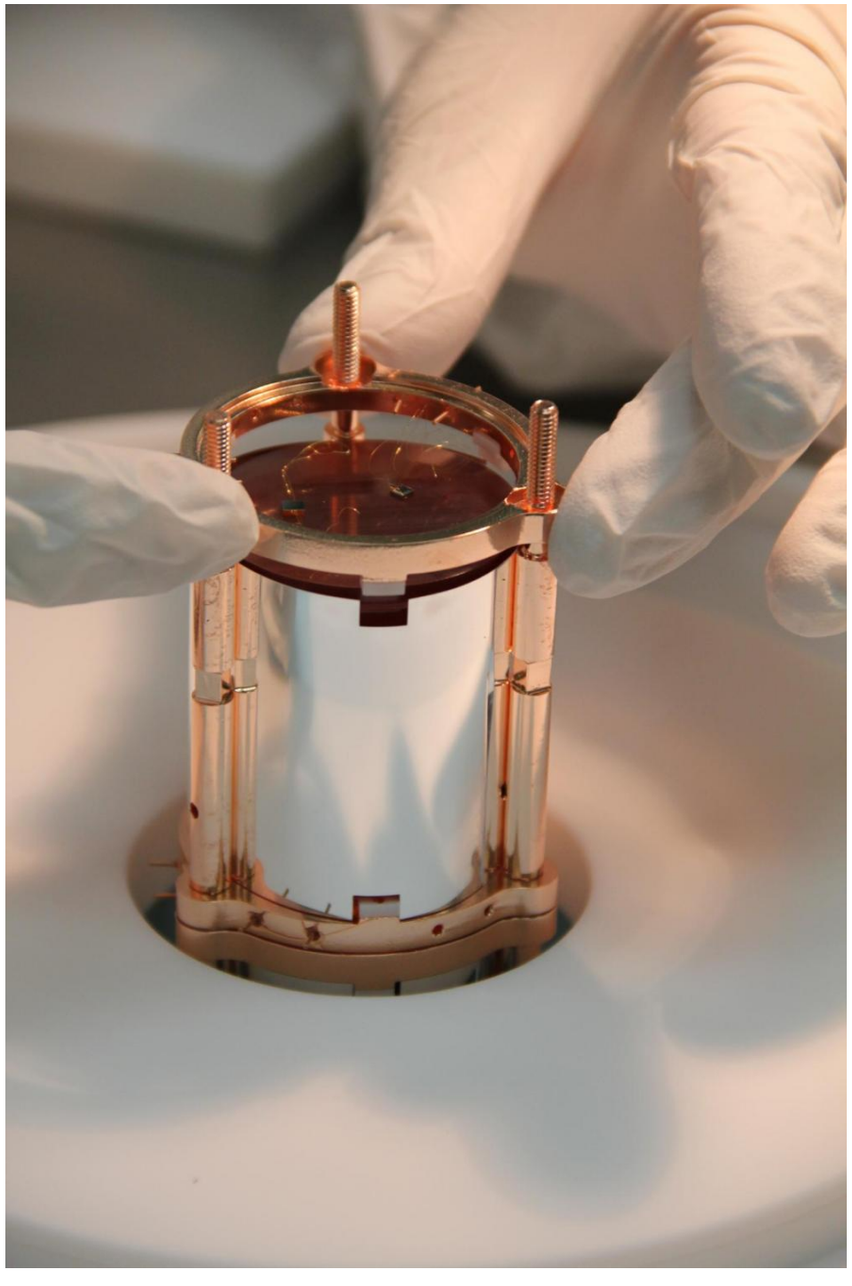
Each tower begins with a Ge light detector (previously assembled)

Mount copper columns

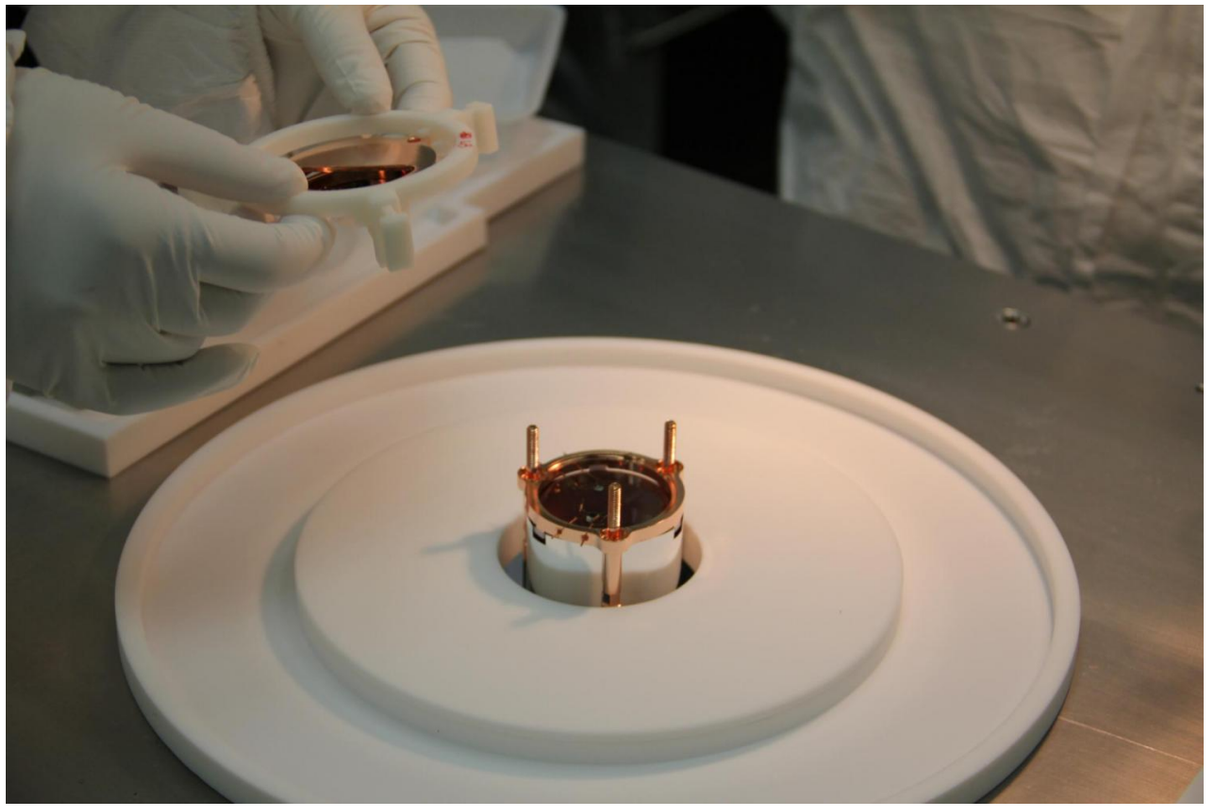
Detector Assembly

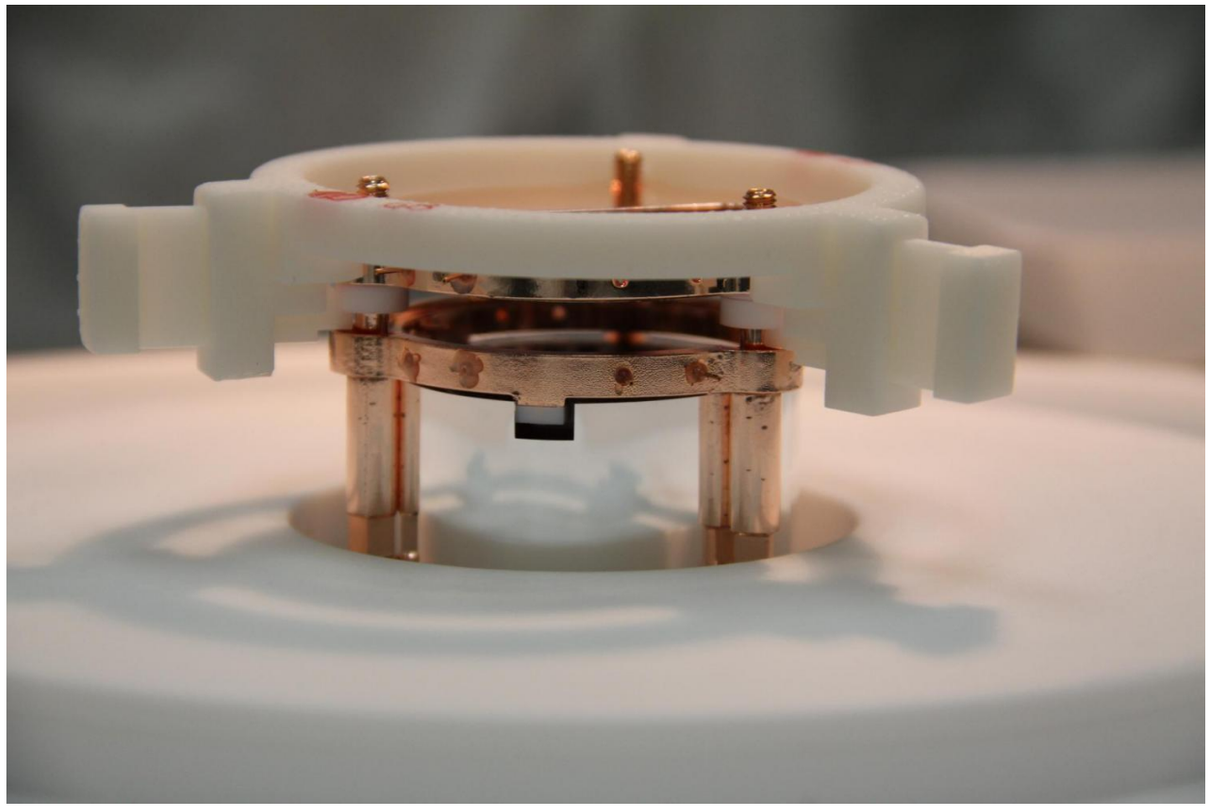


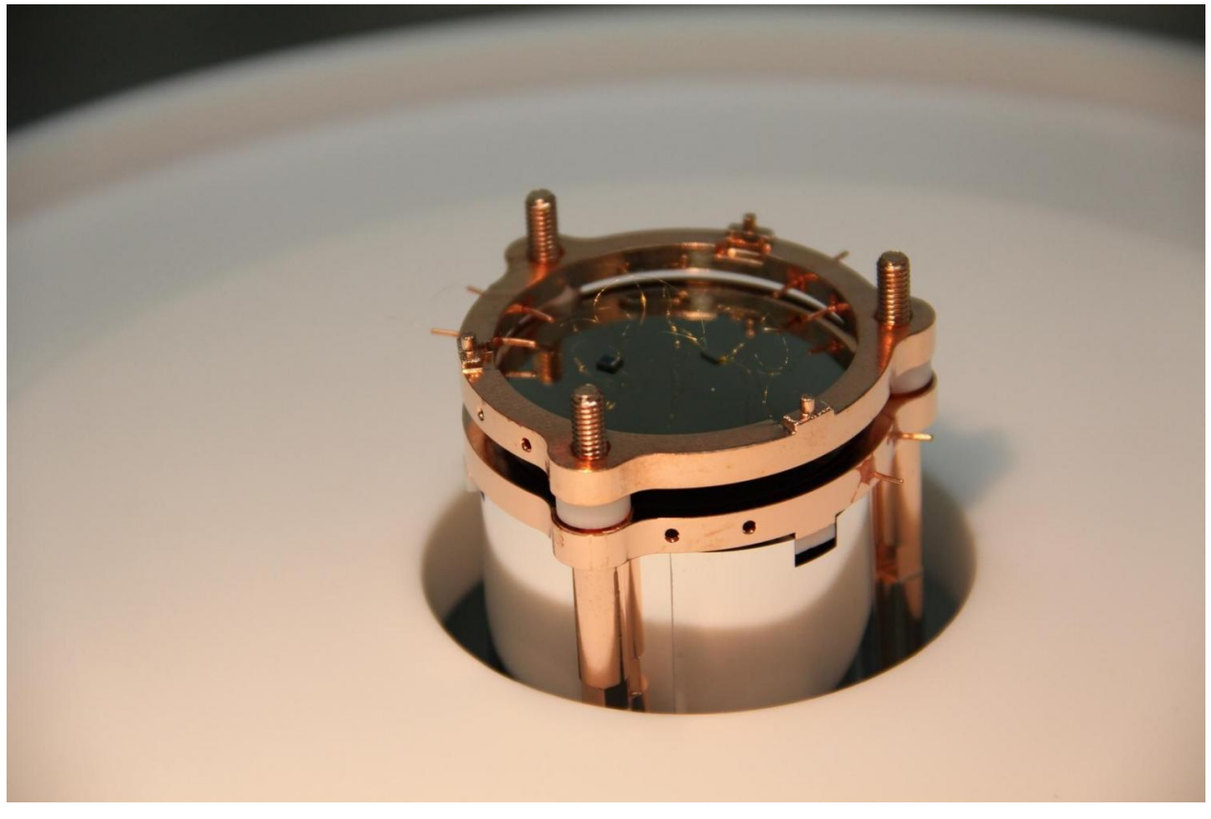




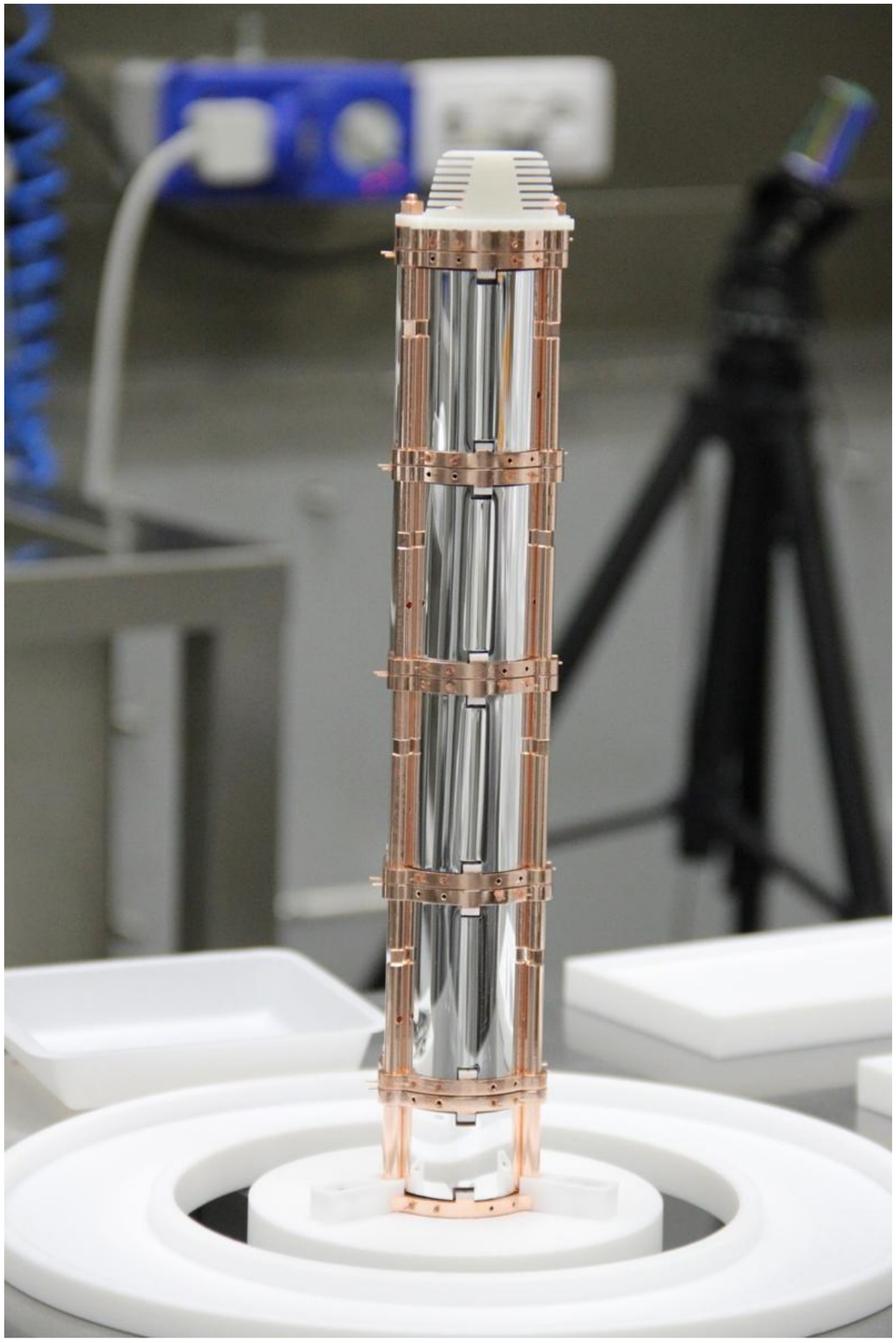
Detector Assembly

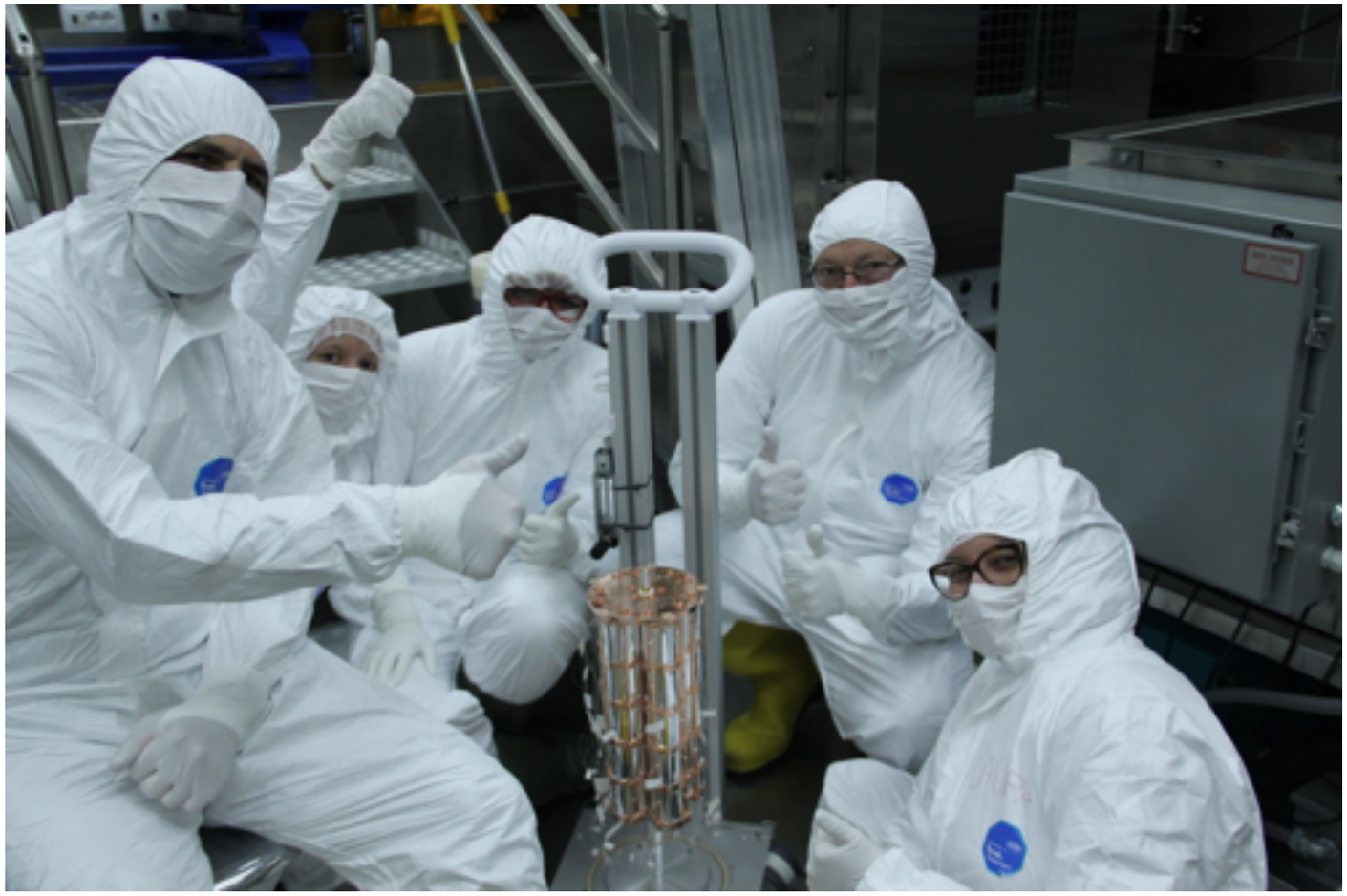






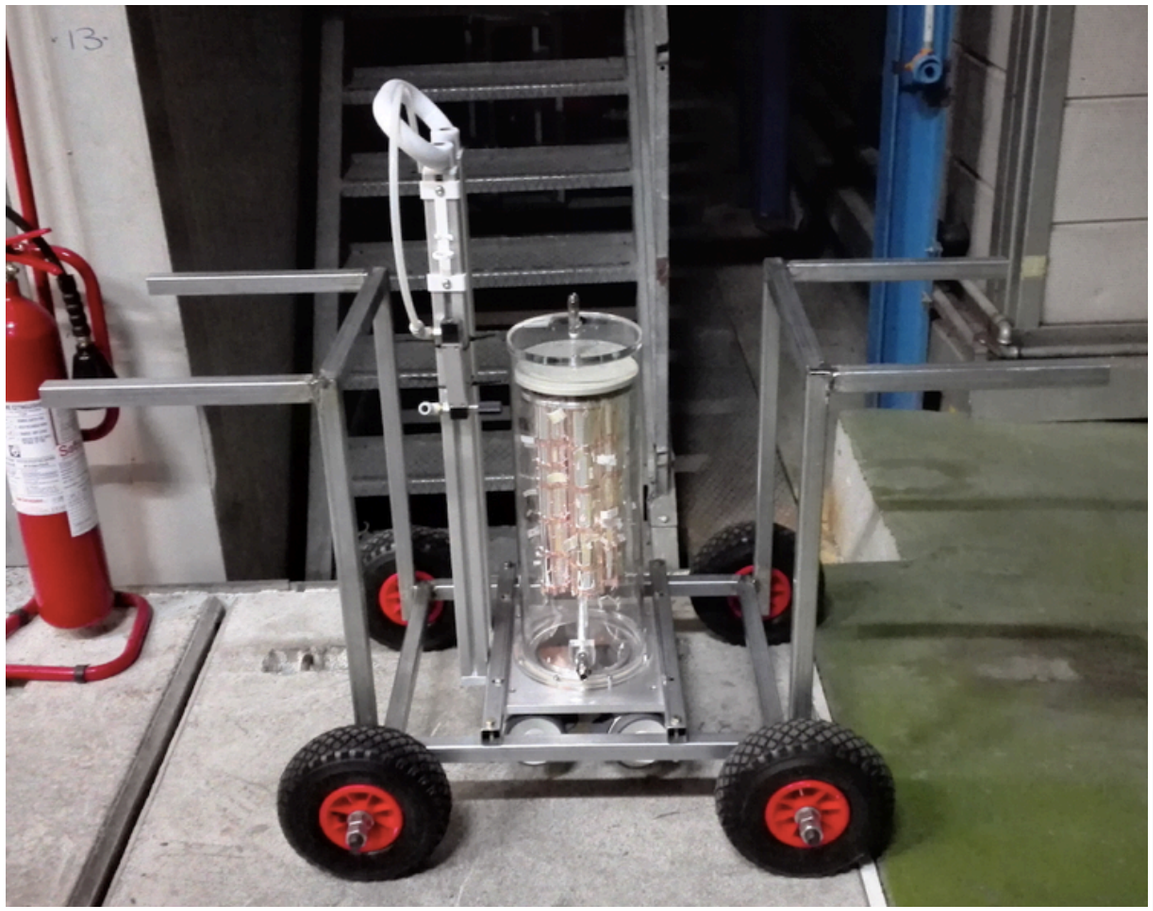
Detector Assembly





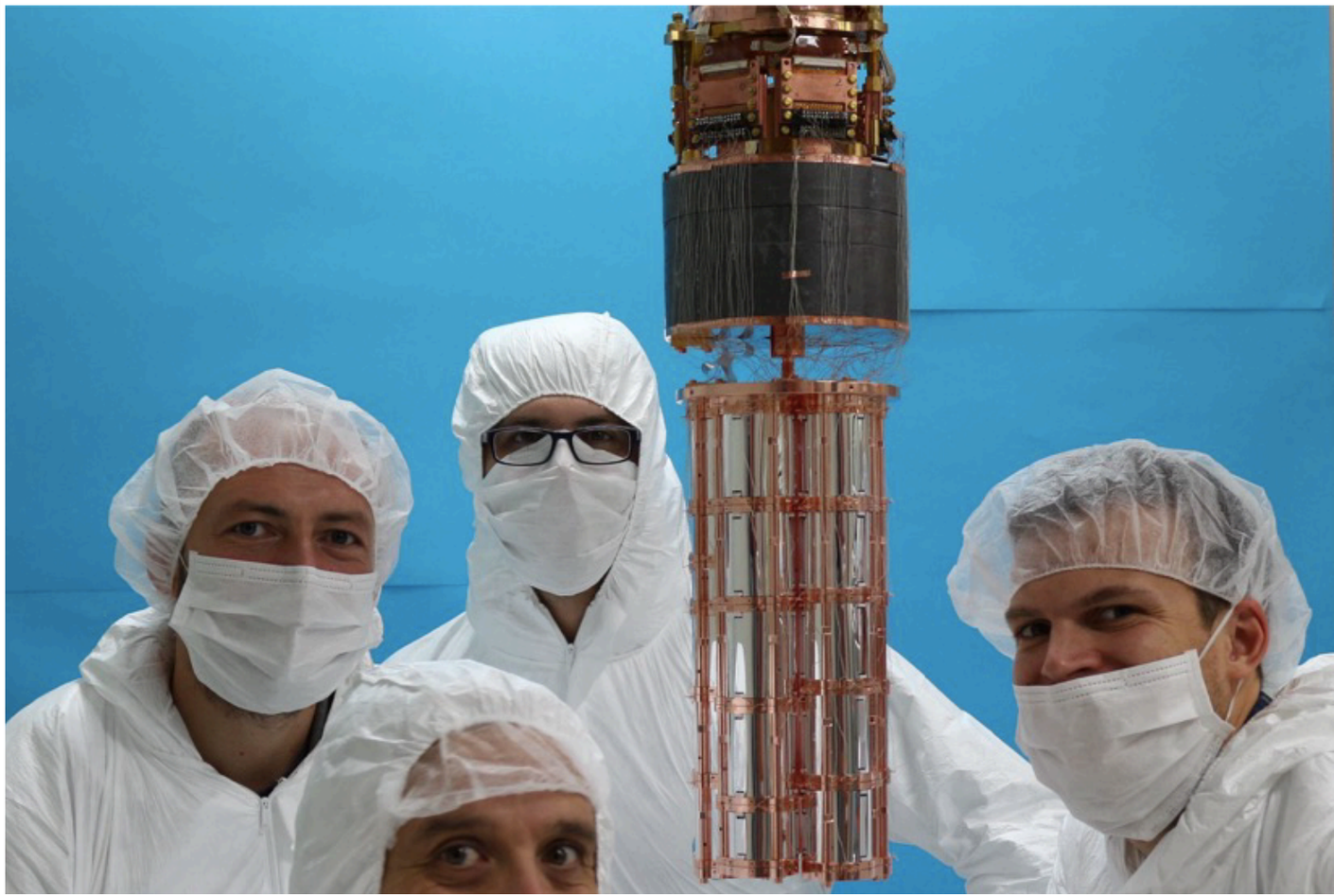
- 24 Enriched ZnSe crystals + 2 natural ZnSe
- 10.5 kg ZnSe (5.17 kg of ^{82}Se)
- CUPID-0 is a demonstrator, still it features **3.8×10^{25} 0nDBD emitters**

Detector Cool Down



- October 2016: end of the assembly
- November/December 2016: cool-down [addressing of minor cryogenic problems]
- January 2017: solved all cryogenic problems

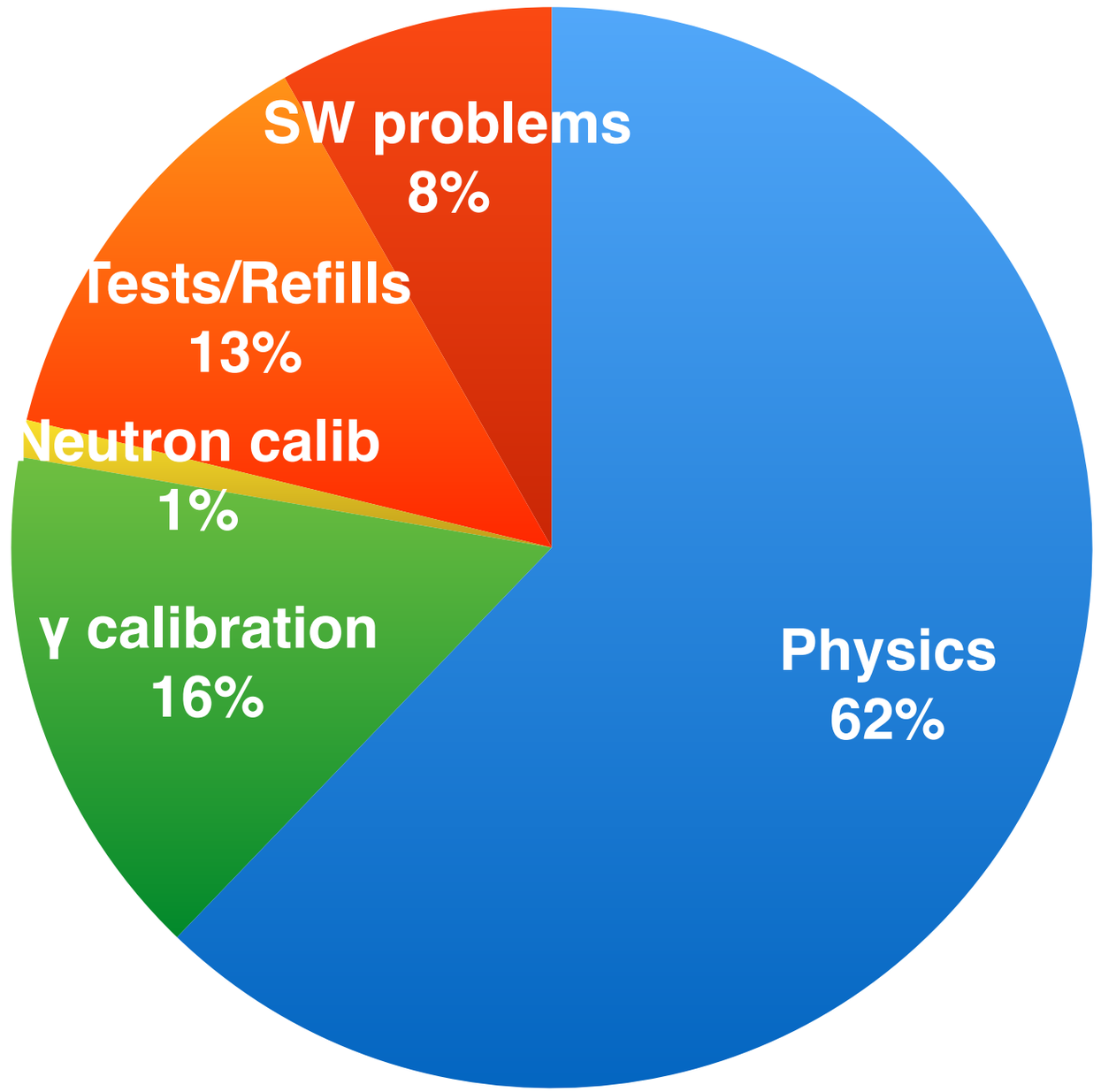
- January 2017: other technical problems (snow + earthquake)
- February 2017: start commissioning



First Data

preliminary

0.89 kg x y of exposure of ZnSe
0.47 kg x y exposure of **^{82}Se**



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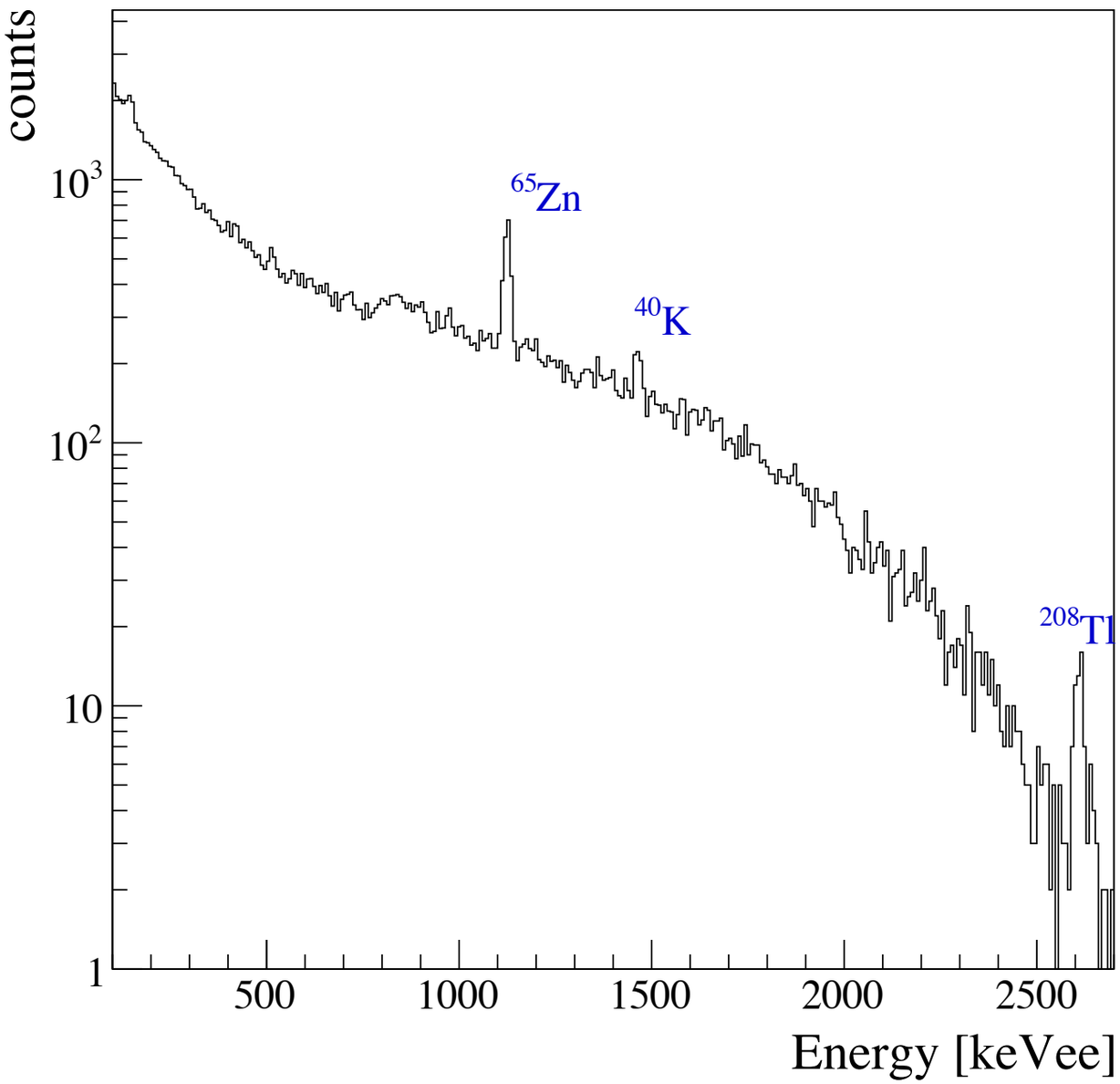
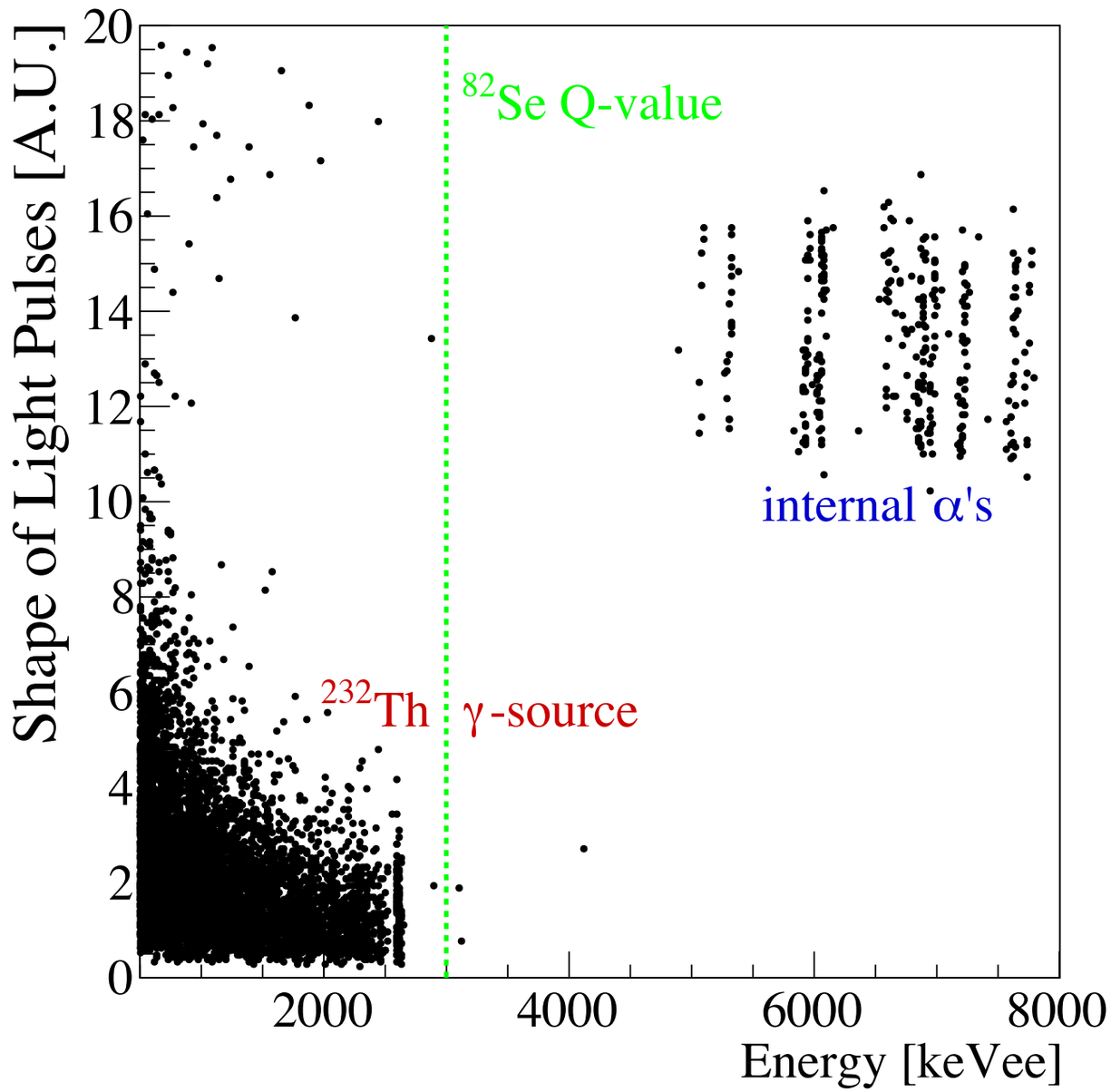
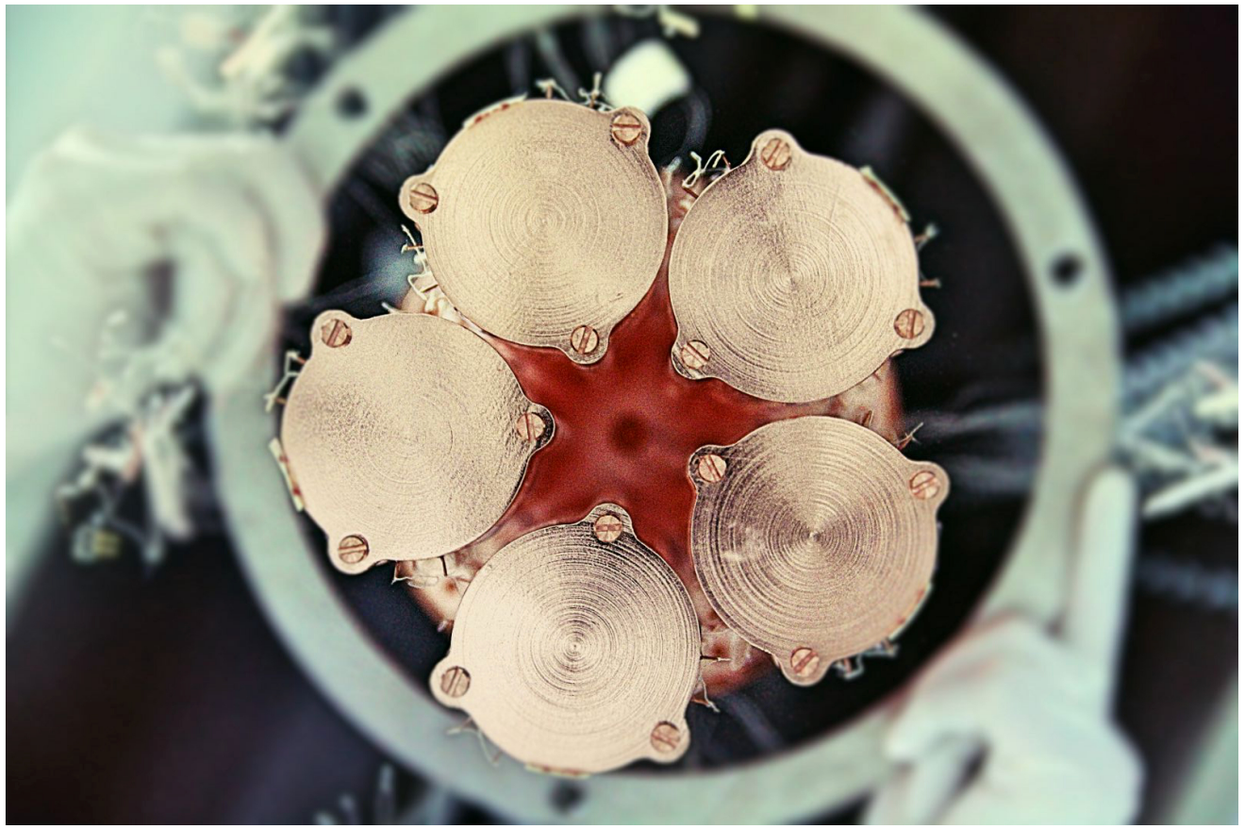




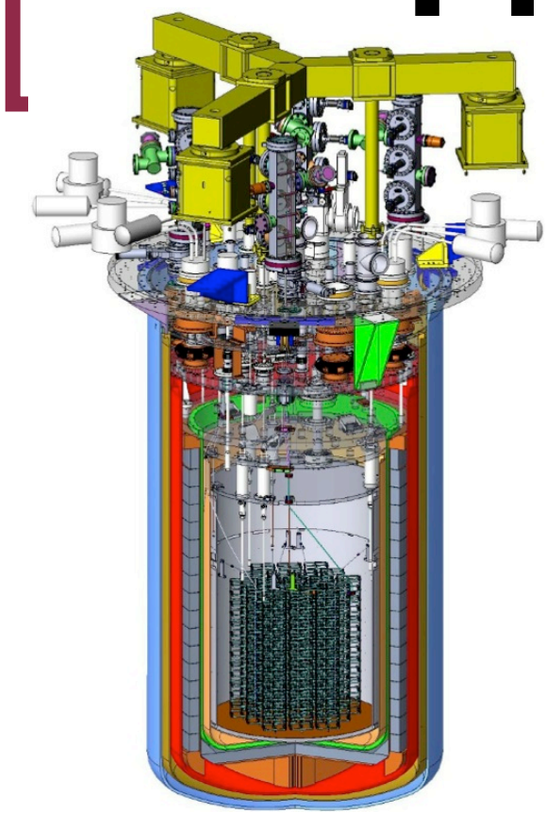
What's next

- Physics runs ongoing to increase statistics
- Compute and improve energy resolution
- Prove that we can reach **zero background in the ROI**



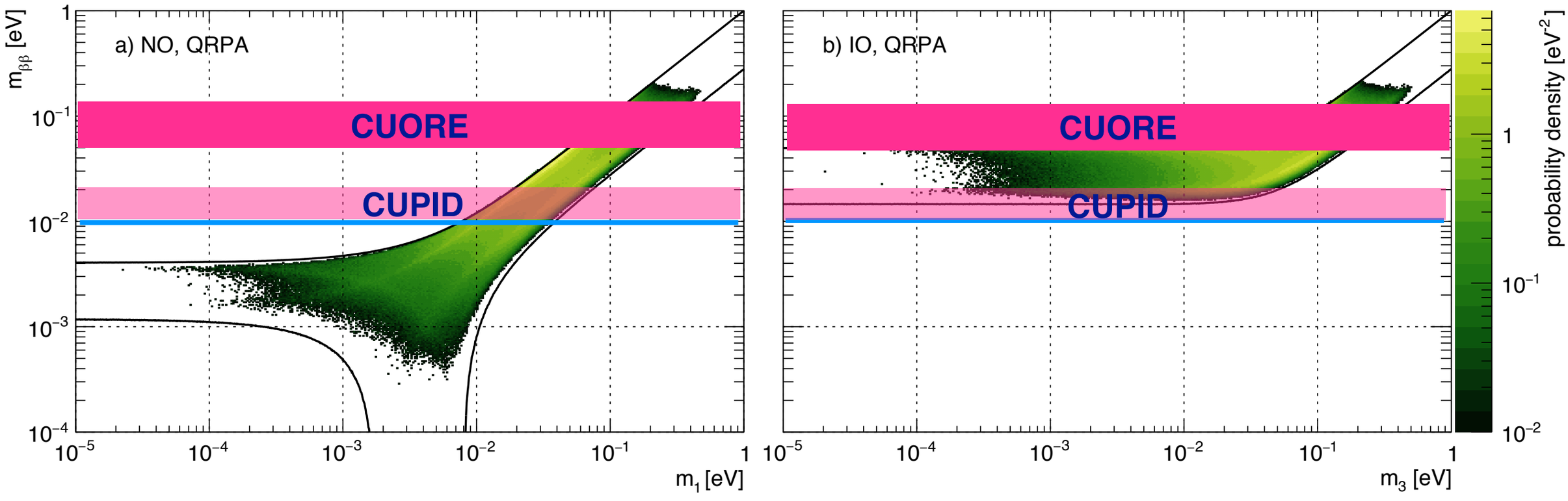
Thanks for the attention!

From CUORE to CUPID



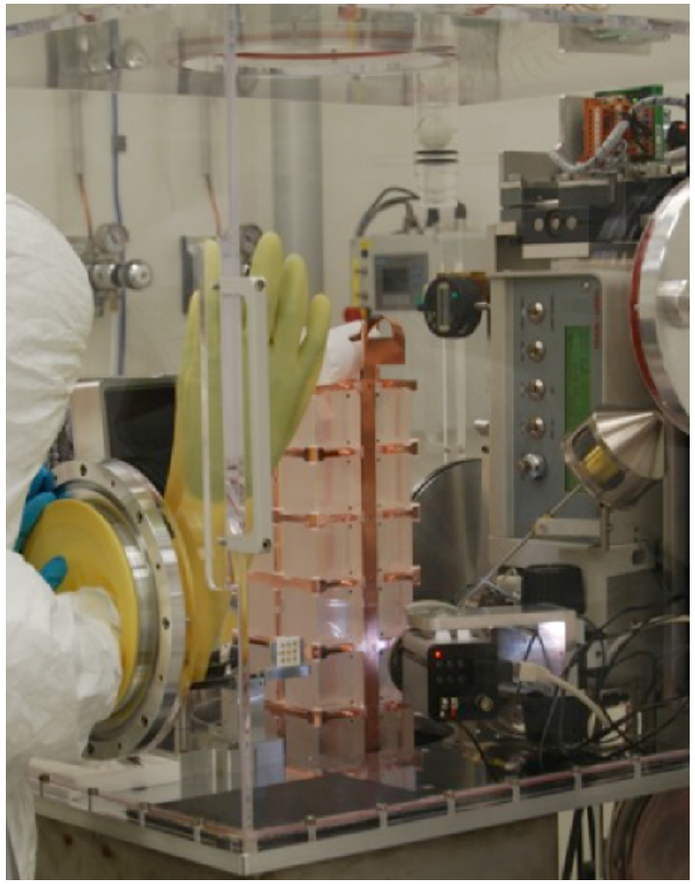
CUPID: **C**uore **U**pgrade with **P**article **ID**entification

- **CUORE cryostat** ➪ useful also for CUPID (ultimate limit in mass)
- Calorimeters: **energy resolution 0.1%** ➪ suitable for CUPID
- <u>But</u> expected **background** of **~200 events** in the ROI ➪ **<u>~0 in CUPID!</u>**



Background Study: CUORE-0

During CUORE construction, we run a CUORE-like tower: CUORE-0



Result of an R&D activity of several years to **suppress the background**

Proved that CUORE can reach the background and resolution target

But still far from the zero background: **200 counts/ROI** expected