Scintillating Bolometers (for rare event physics)

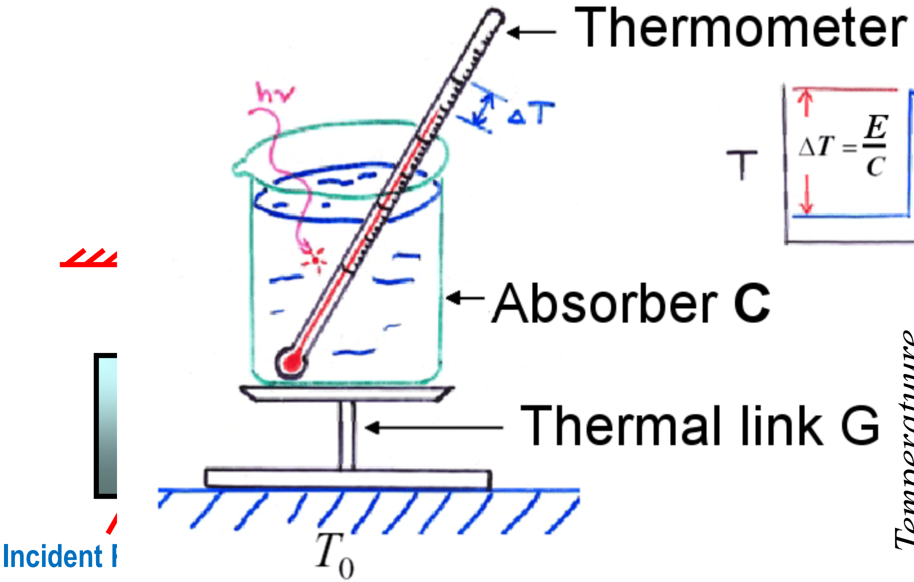
Istituto Nazionale di Fisica Nucleare

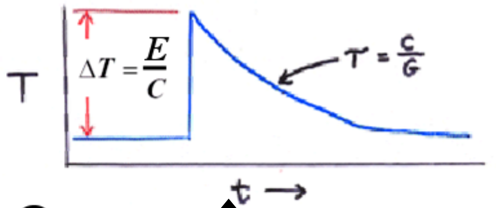
Low Temperature Detectors: instruction for use
Rare Event Physics: DDB & WIMP-DM
Scintillating Bolometers: Bolometric light detectors
Some applications in WIMP-DM
DBD: CUPID-0 CUPID-Mo & CUPID

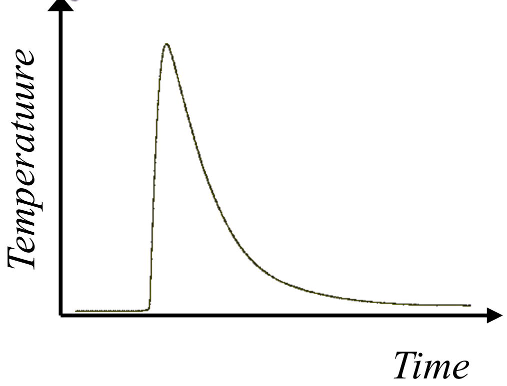
Stefano Pirro – INFN-LNGS

IBS Conference on Dark World
IBS Science Culture Center, Daejeon, Korea
November 4 Mon ~ 7 Thu, 2019

Cryogenic bolometers at "zero level"





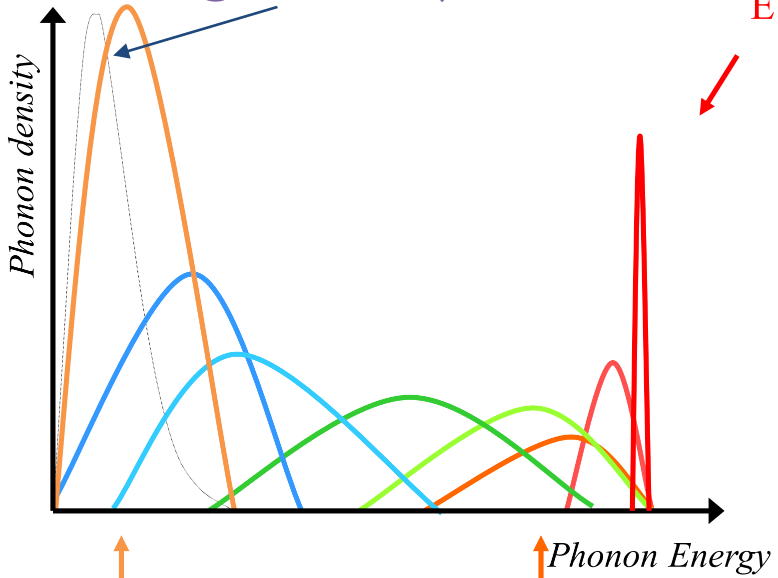


Cryogenic particle detection Springer (2005) ISBN 978-3-540-20113-7

JN Ullom DA Bennet *Supercond. Sci. Technol.* 28 (2015) 084003

SP , P Mauskopf *Annual Review of Nuclear and Particle Science* Volume 67, 2017

Ballistic and thermal phonons for massive bolometers



After few ms thermal phonons
Si and Ge Thermistors

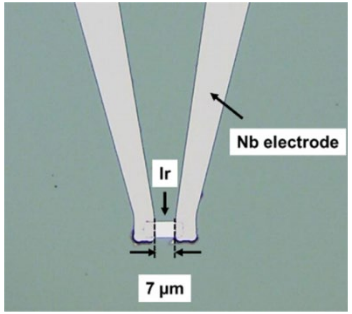
After few μs ballistic phonons (few *meV*)
TES, MMC ==> spatial resolution

ε_a ~ tens μeV – few meV

D. Twerenbold Rep. Prog. Phys. 59 (1996) 349

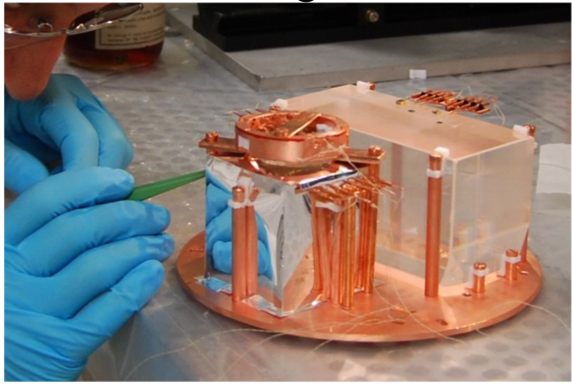
Bolometers (calorimeters)

~ 8* 10^{-15} kg



Y. Miura et al. https://doi.org/10.1016/j.nima.2019.04.074

2.1 kg



L. Cardani et al. https://doi.org/10.1088/1748-0221/7/01/P01020

photon & X-ray applications
~0 ÷ 50 μg

Rare event physics (REP)
~ > 1 g

MICRO

ΔE~ fractions of eV

MACRO

ΔE~ few keV

The nightmare of large calorimeters…..

There is a very peculiar and troublesome aspect for large calorimeters that is almost absent in microcalorimeters:

Thermal noise induced by vibration of the facility

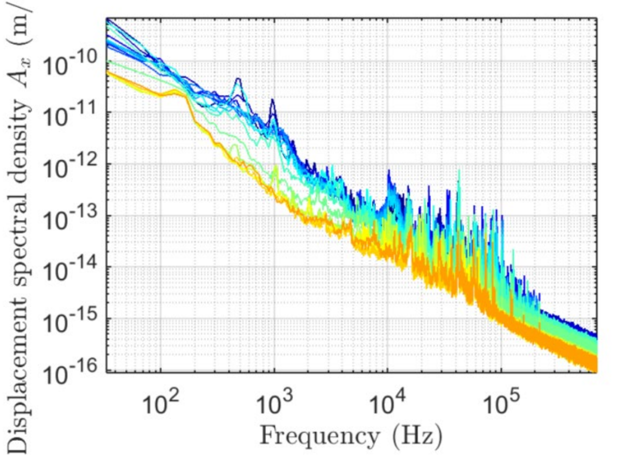
This point became much more important in the last years with the arrival of the **dry** Dilution Cryostats and was initially rather underestimated by the community.

Actually the issue of vibration was well known also with wet cryostats, being induced by the boiling off of cryogenic liquids as well as induced by the kHz-acoustic noise generated by the 1 K He pumped stage.

The issue of PT vibration is now **extensively** treated within several communities. The first works were done 15 years ago (Tomaru et al, Cryogenics **44** (2004) 309) and the first I basilar ideas of vibration mitigation were already developed in 2006 (Caparrelli et al. Rev. Sci. Instr. **77**, 095102 (2006))

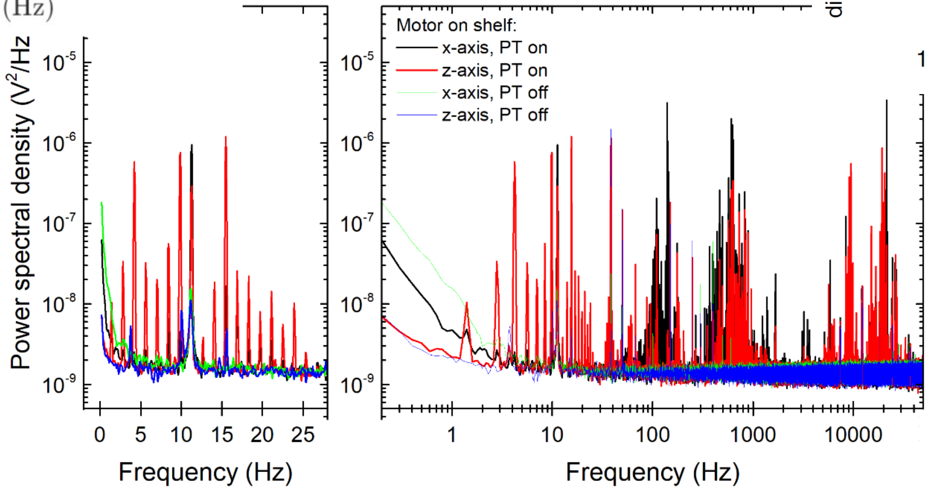
PT Vibrations

Piezospectroscopic measurement of high-frequency vibrations in a pulse-tube cryostat
Review of Scientific Instruments 90(3):034901 · March 2019
arXiv:1811.04018

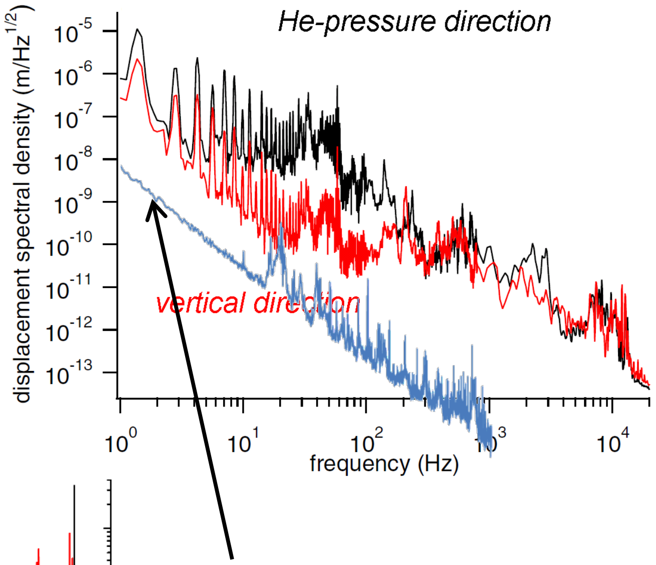


https://doi.org/10.1063/1.5080086

10.1016/j.cryogenics.2019.01.010

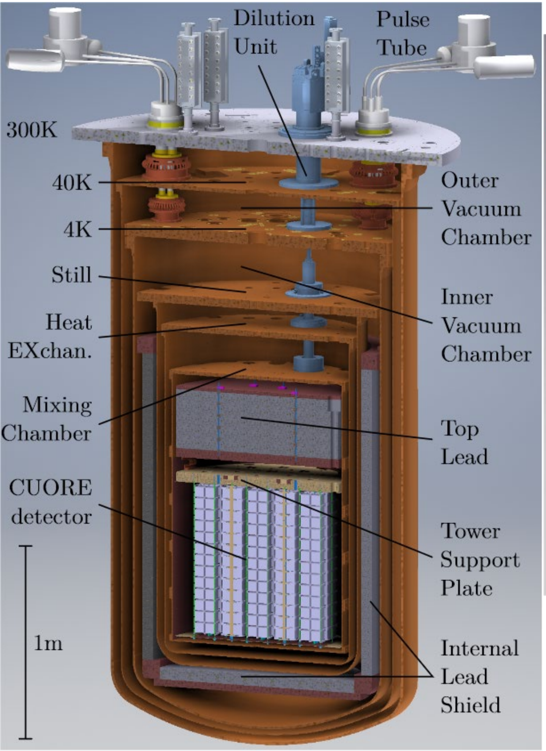


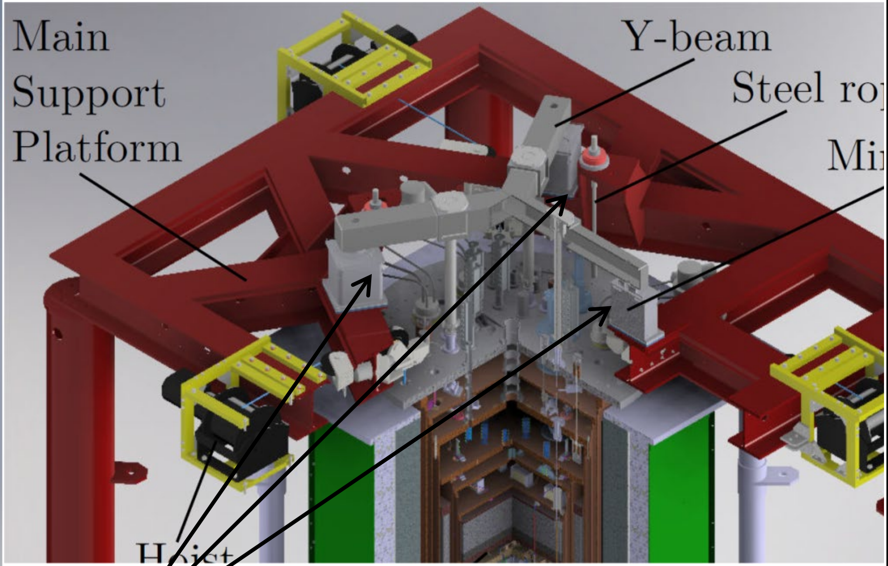
https://doi.org/10.1016/j.cryogenics.2010.01.005

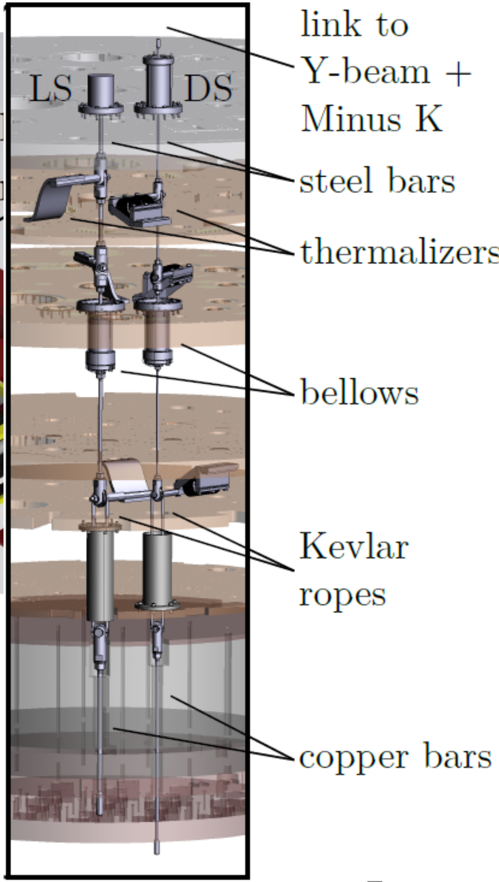


Displacement of the Top flange of CUORICINO/CUORE-0/CUPID-0 wet cryostat

Vibration damping systems – dry cryostats : CUORE



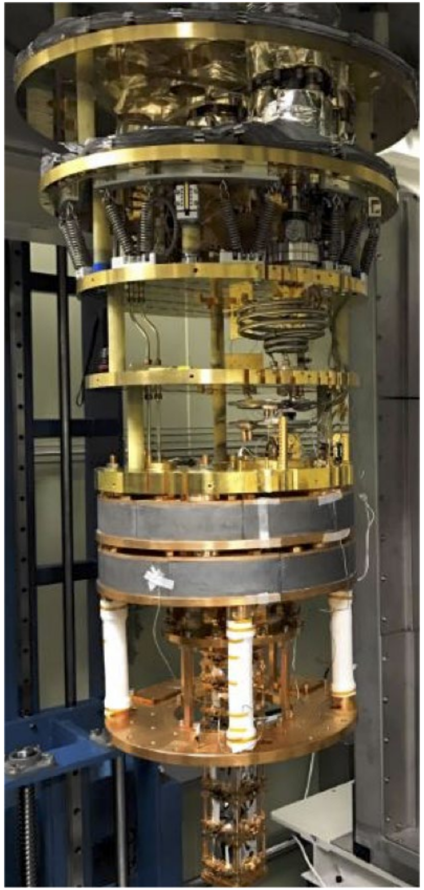


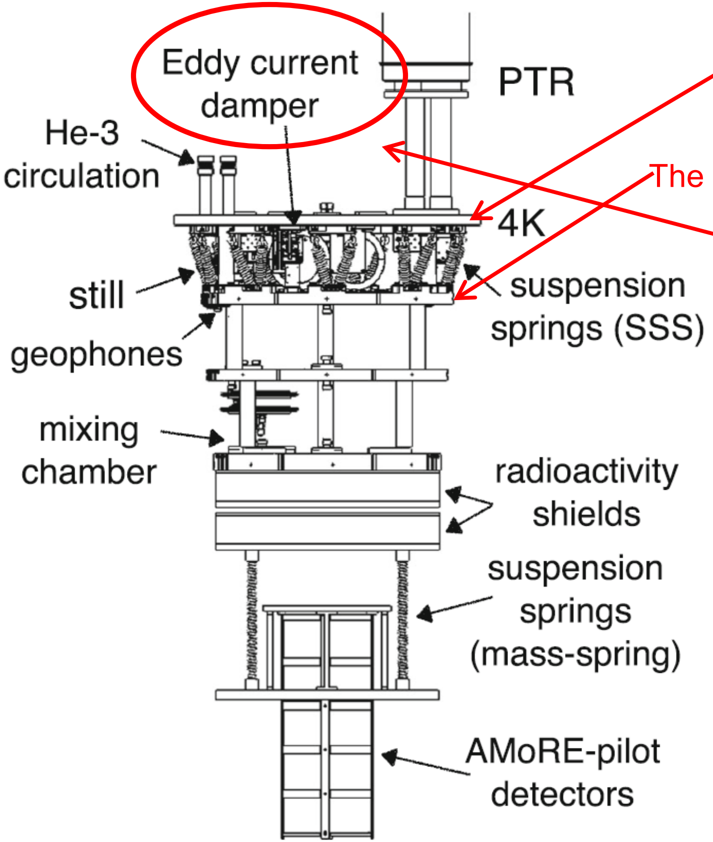


The damping system is at room temperature

C. Alduino et al.,*The CUORE cryostat: an infrastructure for rare event searches at millikelvin temperatures*
arXiv:1904.05745

Vibration damping systems – dry cryostats :AMORE

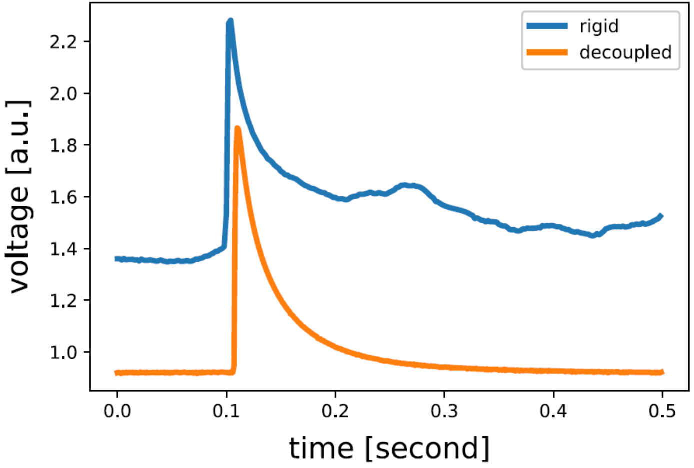




The PT is directly coupled with the 4 K stage

The Still is partially decoupled from the 4K stage

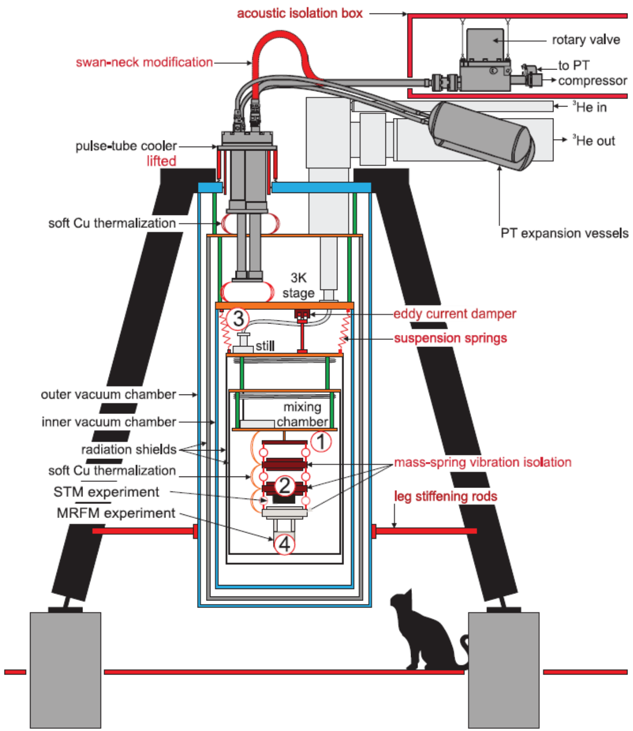
Converts the vibration directly to heat !!!



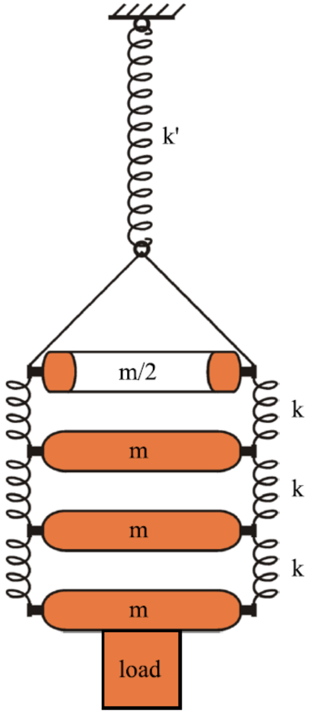
C. Lee et al., *Vibration Mitigation for a Cryogen-Free Dilution Refrigerator for the AMoRE-Pilot Experiment*, JLTP **193** (2018) 786–792

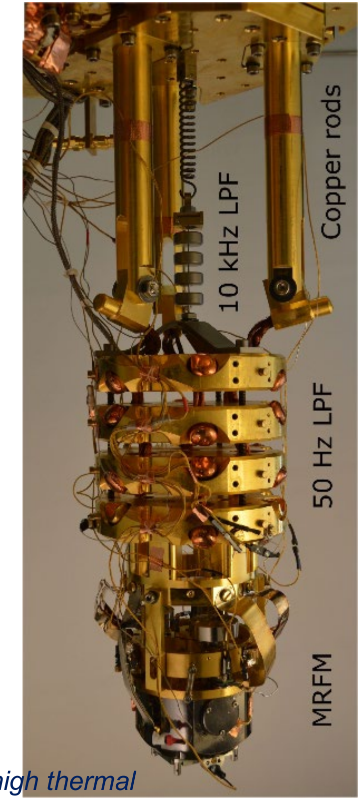
Vibration damping systems – dry cryostats: other applications

The issue of vibrations for wet cryo is well established (*<u>and almost solved</u>*) in **S**canning **T**unneling **M**icroscopes, as well as **M**agnetic **R**esonance **F**orce **M**icroscopy applications, in which the displacement resolution has to be of the order of Ångströms...



M. J. den Haan et al., *Atomic resolution scanning tunneling microscopy in a cryogen free dilution refrigerator at 15 mK* Rev. Sci. Instr. 85 035112 (2014) .





M. De Wit, et al., *Vibration isolation with high thermal conductance for a cryogen-free dilution refrigerator* Rev. Sci. Instr. **90**, 015112 (2019)

Large calorimeters…. Slow detectors……. Large Pile-up

The “natural” radioactivity environmental background is of the order of ~50÷150 Hz /Kg of absorber.
This can be reduced by something like >98% with an appropriate (~ tons) shielding around the cryostat.

But cosmic rays will anyhow release something like 5 ÷10 MeV /cm with a rate of 1 cm^{-2} min^{-1}.
For this reason why to properly test large detectors is very often mandatory to go underground.

LNGS, Italy late 80’s during excavations

Rare Event Physics: Deep Underground Labs


LNGS, Italy www.lngs.infn.it


Snolab, Canada www.snolab.ca

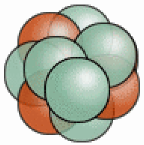
Access through Highway


Active mine, access through shaft

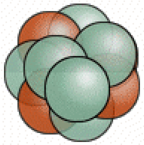
Rare Event Physics: Double Beta Decay

Two decay modes are usually discussed:

① $(A,Z) \rightarrow (A,Z+2) + 2e^- + 2\bar{\nu}_e$ ← allowed by the **Standard Model**



② $(A,Z) \rightarrow (A,Z+2) + 2e^-$ ← **never observed**

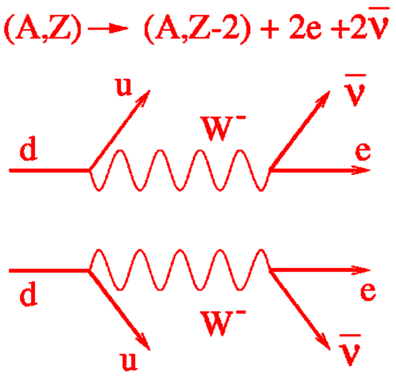


Process ② would imply new physics beyond the Standard Model

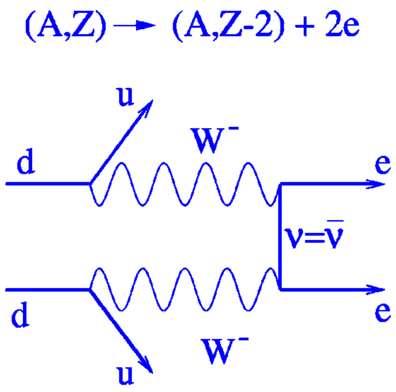
violation of lepton number conservation

This is a very sensitive test to new physics
(possibly solving neutrino mass values and helping in leptogenesis)

Double Beta Decay-expected signature



Allowed by the SM

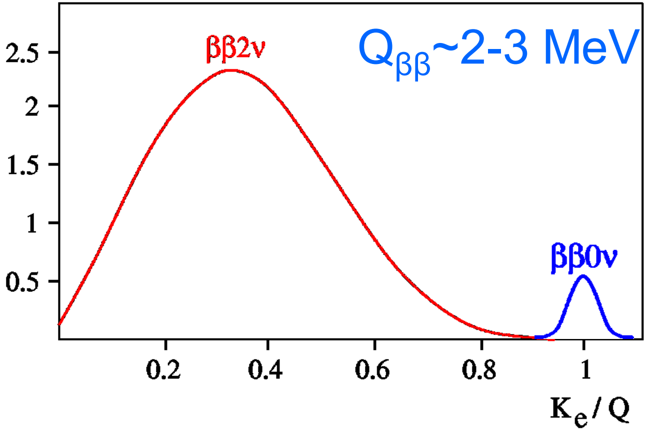


	$Q_{\beta\beta}$ [MeV]	i.a. [%]
^{48}Ca	4.27	0.19
^{76}Ge	2.04	7.8
^{82}Se	2.99	8.8
^{100}Mo	3.03	9.7
^{116}Cd	2.8	7.5
^{130}Te	2.53	34.1
^{136}Xe	2.48	8.9

Spin-Flip

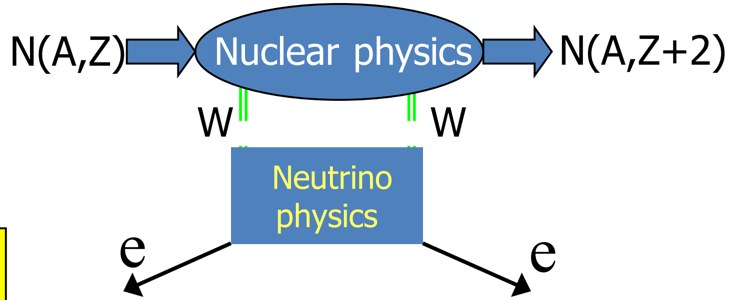
Different "nature" of the neutrino

$\nu = \nu^c \quad m_\nu \neq 0$



Nuclear physics and neutrino physics

$$(T^{0\nu}_{1/2})^{-1} = \sum_k G_k(Q,Z)\, M_k^{\,2}\, \omega_k^{\,2}$$



$$(T^{0\nu}_{1/2})^{-1} = G(Q,Z)\, M^{2} \langle m_\nu \rangle^{2}$$

Nuclear matrix element *(big uncertainties)*

Phase space $\propto$ Q^5 *(perfectly known)*

$$|\langle m_{\beta\beta} \rangle| = |\, m_1 |U_{e1}|^2 + m_2 |U_{e2}|^2 e^{i\alpha} + m_3 |U_{e3}|^2 e^{i\beta} |$$ *effective mass*

Majorana phases
(= ±1 if CP)

m_1, m_2, m_3 *Mass eigenstates*

U_{e1}, U_{e2}, U_{e3} *Matrix elements Pontecorvo Maki Nagakawa Sakata*

Predictions on the Majorana mass….

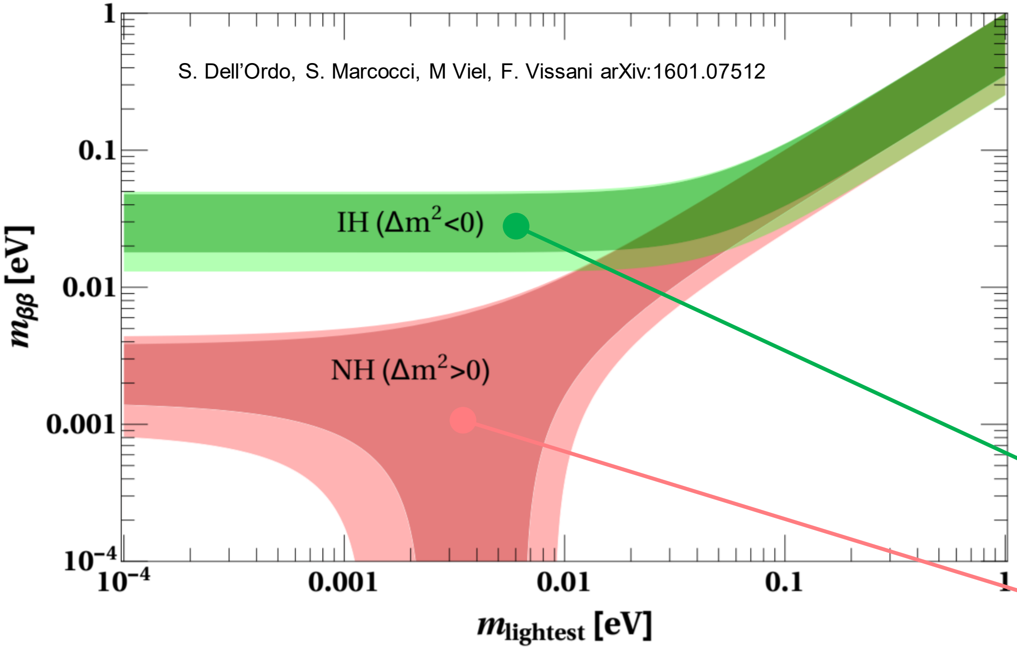
From the neutrino oscillations → U_{e1} U_{e2} U_{e3} Δm^2_{sun} Δm^2_{atm}

Parameterising

$$m_2 = \sqrt{\Delta m^2_{sun} + m_1^2}$$

$$m_3 = \sqrt{\Delta m^2_{atm} + m_1^2}$$

→ $|< m^{\nu}_{\beta\beta} >| = f(\mathrm{const}, m_1, \alpha - \beta)$



Inverted hierarchy $m_1 > m_2 > m_3$

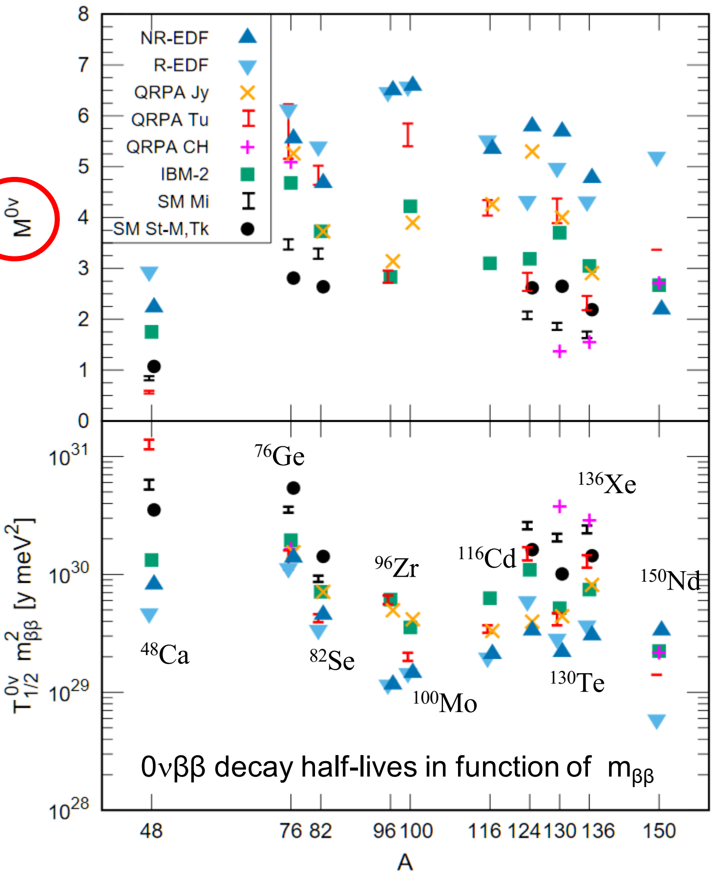
Normal hierarchy $m_1 < m_2 < m_3$

NME: Comparison of different nuclei…?

$$(T^{0\nu}_{1/2})^{-1} = G(Q,Z) M^{2} \langle m_\nu \rangle^{2}$$

!

$M^{0\nu}$

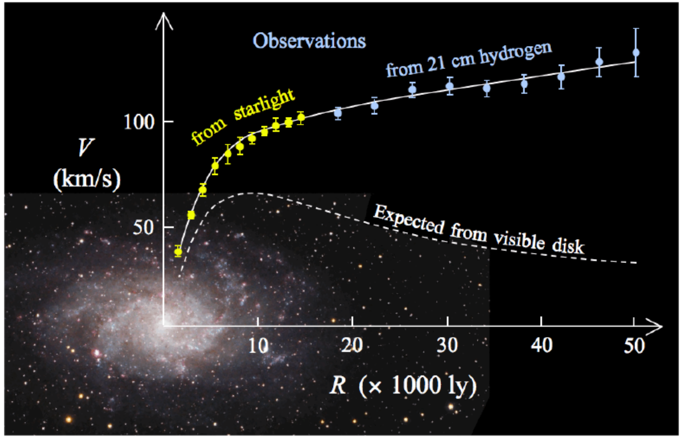


The span is not so large as a decade ago, but in 0-background mode a factor 2 in matrix element means a factor $2^2 = 4$ in mass of the (enriched) Detector (!)

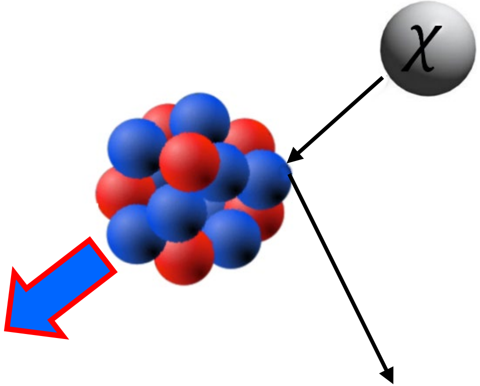
J. Engel, J Menéndez, Rep. on Prog. in Physics 80, 046301 (2017) arXiv:1610.06548

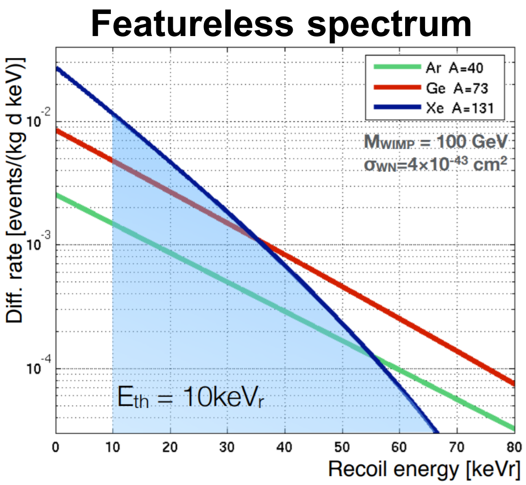
Rare Event Physics: Wimp Dark Matter

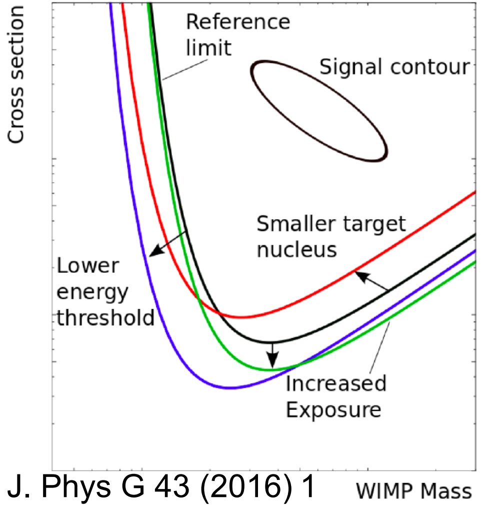
Dark Matter shows very compelling evidences at different cosmological scales.
DM interaction are searched in different ways, depending on its nature and mass.



Scatter off nucleus represents one of the most pursued search for mass ranges (hundreds) MeV ➔ TeV

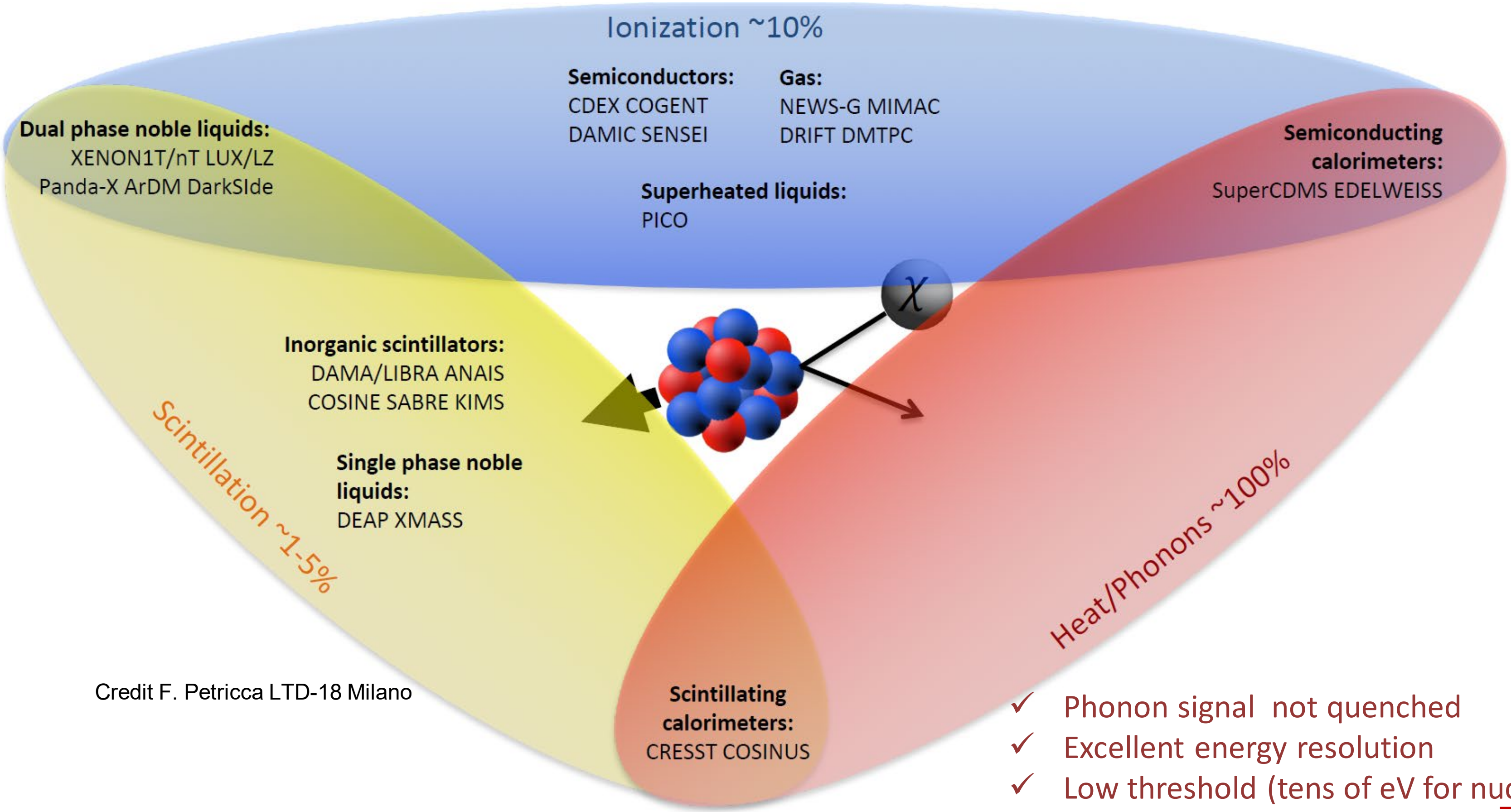






J. Phys G 43 (2016) 1

Rare Event Physics: Dark Matter

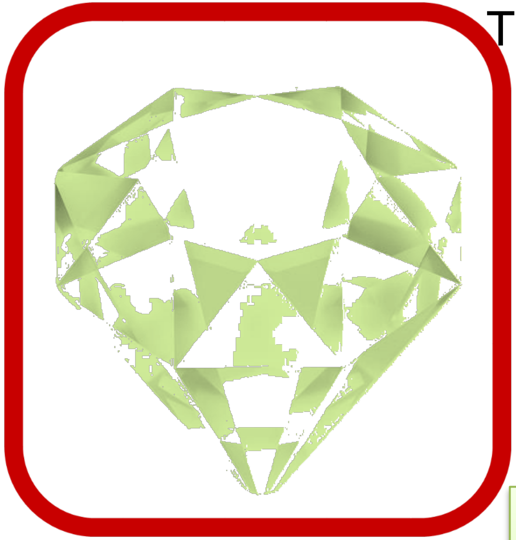


Credit F. Petricca LTD-18 Milano

- ✓ Phonon signal not quenched
- ✓ Excellent energy resolution
- ✓ Low threshold (tens of eV for nuclear recoils)
- ✓ Huge choice target materials (A, $\vec{I}$)

How to build a (large) REP calorimeter ?

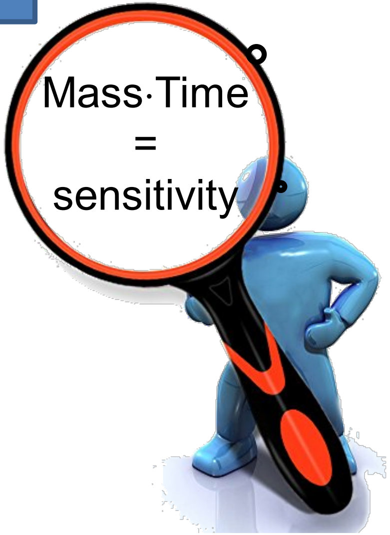
The ingredients are always the same….



The larger…. The better !!

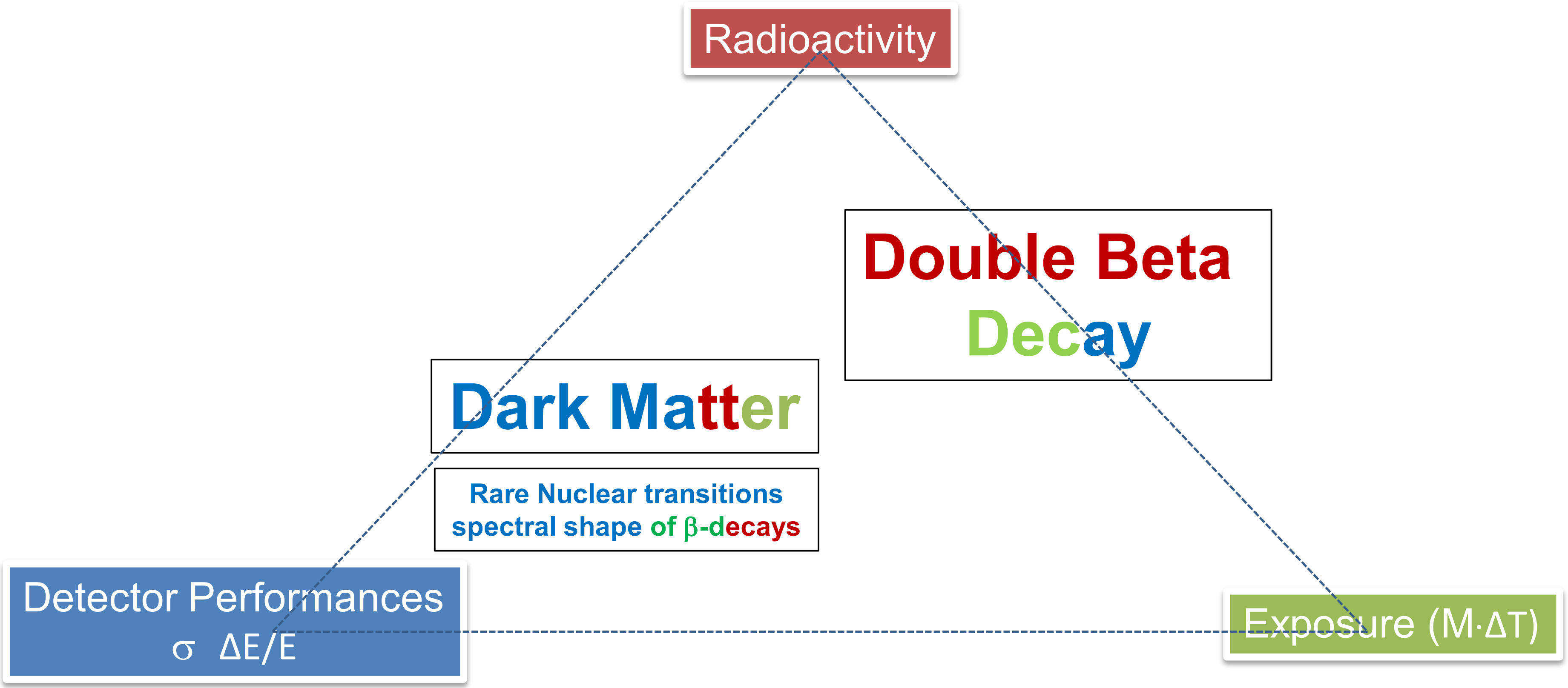
The thermometer has to match standard requirements:
- ✓ Fast response
- ✓ Sensitive
- ✓ Robust
- ✓ Easy scalable to (possible) large arrays

In REP the absorber plays a fundamental role:
- ✓ It has to be a perfect (pure) crystal
- ✓ It has to be RADIOPURE
- ✓ The larger the better (Exposure)



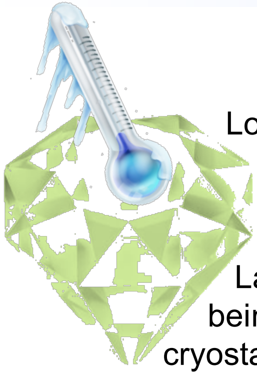
In REP the also the "environment plays a crucial role
- ✓ All the materials have to be extremely RADIOPURE
- ✓ The amount of (dead) materials have to be reduced (coincidences)
- ✓ The radiopurity of surfaces (active and dead) become crucial

Rare Event Physics… Three main challenges



DM detectors "corrected" the strategy (towards **lower thresholds** rather than **Exposure**) after the operation of Liq noble gas detectors

Large Calorimeters, some important aspects to keep in mind



Low Thermal Detectors can have superb and superior performances with respect to conventional detectors. This is particularly true for micro (mini) calorimeters that can show energy resolutions of the order of (in some cases less) than eV (*two orders of magnitude less with respect to conventional detectors*) that opened new frontiers in the X-rays spectroscopy & astrophysics field.

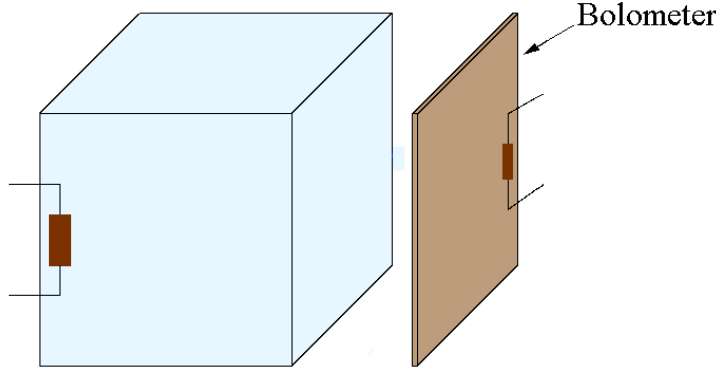
Large calorimeters, on the contrary, cannot easy compete with standard, robust and easy to use Ge diodes: being LTD, they clearly must be enclosed within a series of four to six thermal radiation shields in ^{3}He–^{4}He dilution cryostats that—in the best-case scenario—take 1 day to reach the operational temperature. Moreover, depending on the mass, operating temperature, and type of phonon sensor, the duration of a thermal pulse can last from a few milliseconds to a few seconds, which can introduce problems of pile-up.

Nevertheless, the advantages of Large LTD calorimeters over conventional detectors are evident:

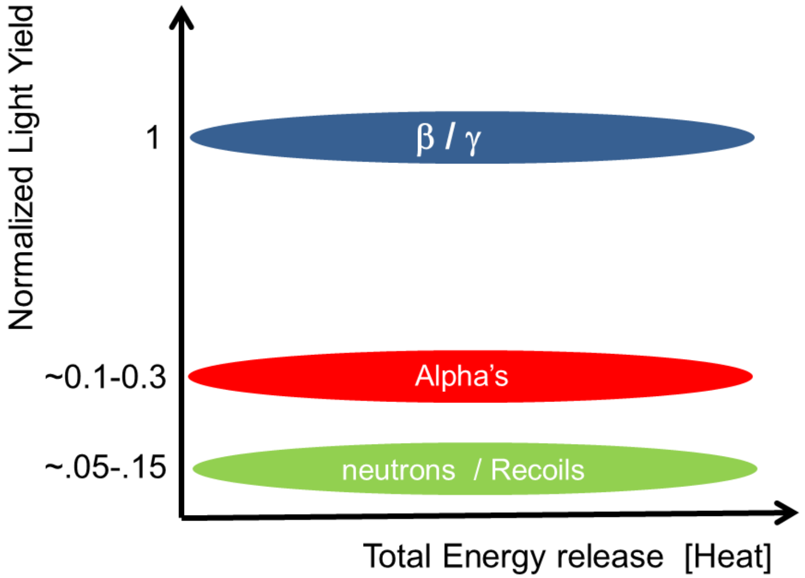
- They can be constructed from a wide variety of materials
- They can be operated with double readout to disentangle particle interactions
- They can have a low energy threshold

Scintillating Bolometers: Heat and Light

Operating Temperature for <u>*massive*</u> detectors: 10÷30 mK



Scintillating Bolometer

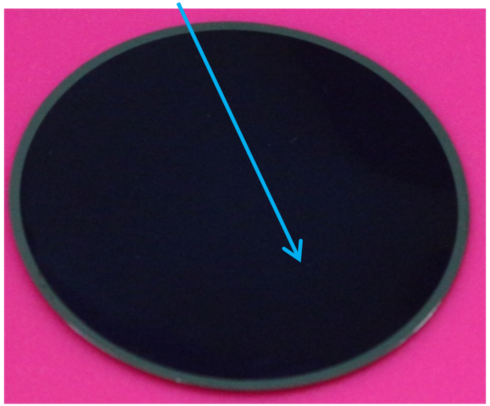


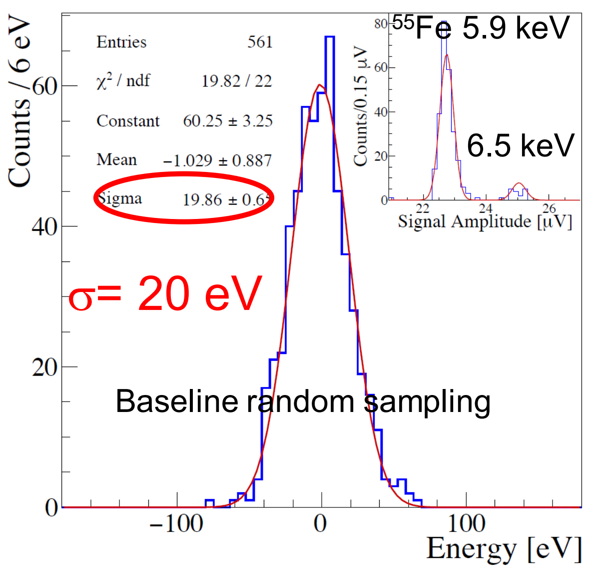
Bolometric Light Detectors I

- ✓ A Bolometric Light Detector (BLD) is fully active a particle detector
- ✓ A BLD is generally mad with a “dark” crystal (Semiconductor)
- ✓ A BLD simply measure the total energy of the absorbed light
- ✓ The performances of a BLD are normally evaluated in terms of energy resolution (^{55}Fe)

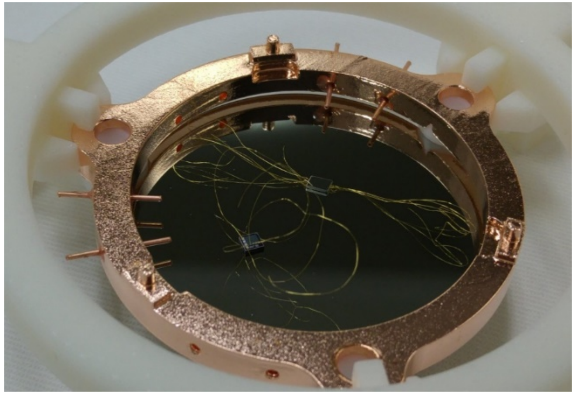
44.5 mm dia, 170 μm thick pure Ge wafer

SiO_2 coating to increase light absorption



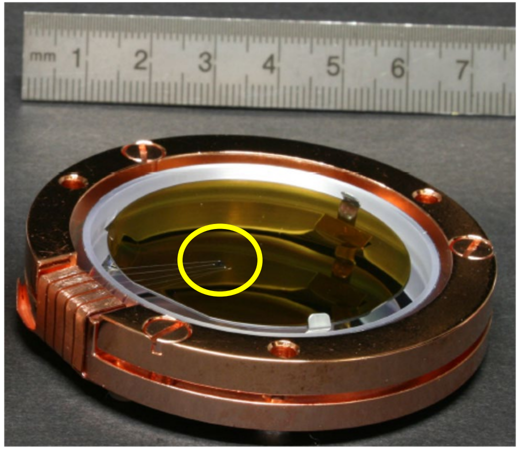


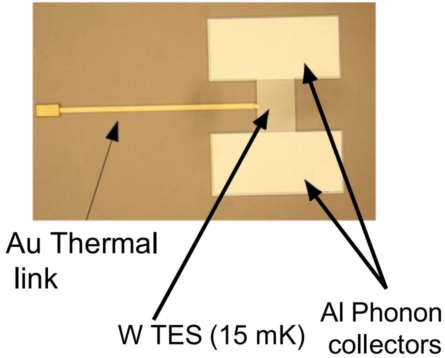
$\sigma(^{55}Fe) > \sigma_{baseline}$



Bolometric Light Detectors II

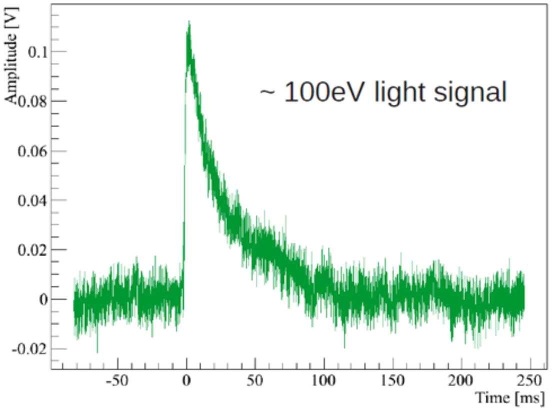
CRESST II detector



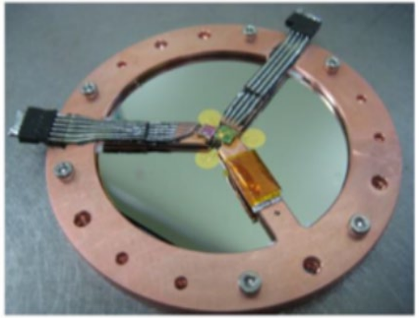


Silicon (few μm) on Al_2O_3 40 mm dia, 0.4 mm thick

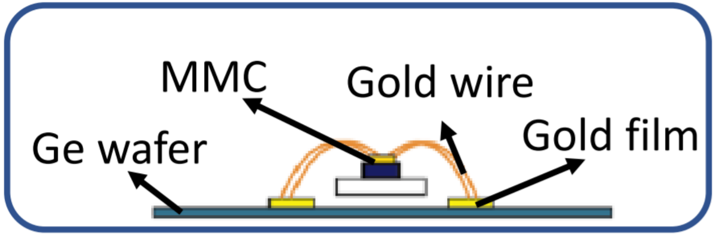
σ ~ 5 eV



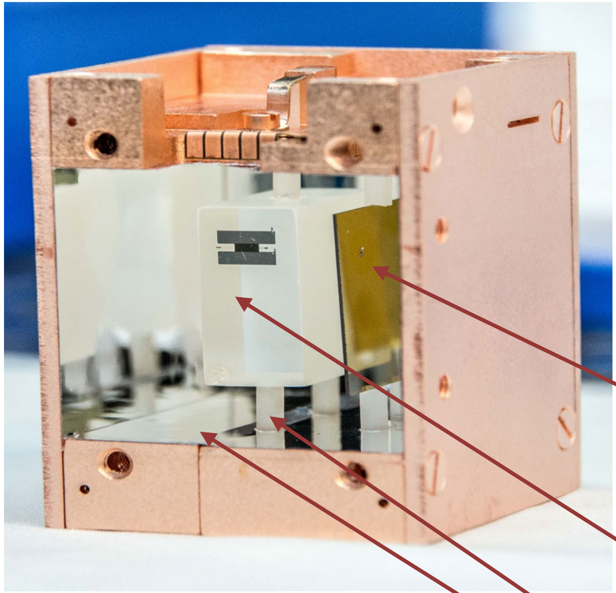
0.5mm x 2 inch Ge wafer



Amore MMC (15-35) mK



Double Readout for DM: Heat and Light (CRESST III)



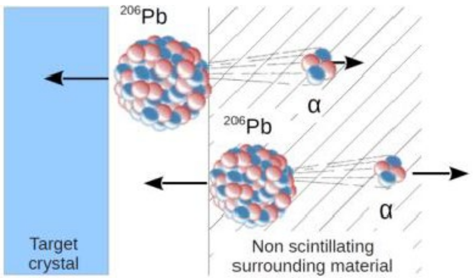
@ Laboratori Nazionali del Gran Sasso

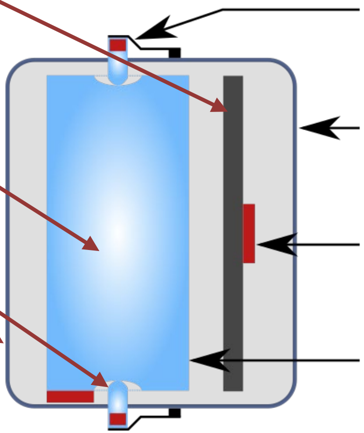
Detector layout optimized for low-mass dark matter

Radical reduction of dimension (300→25g)

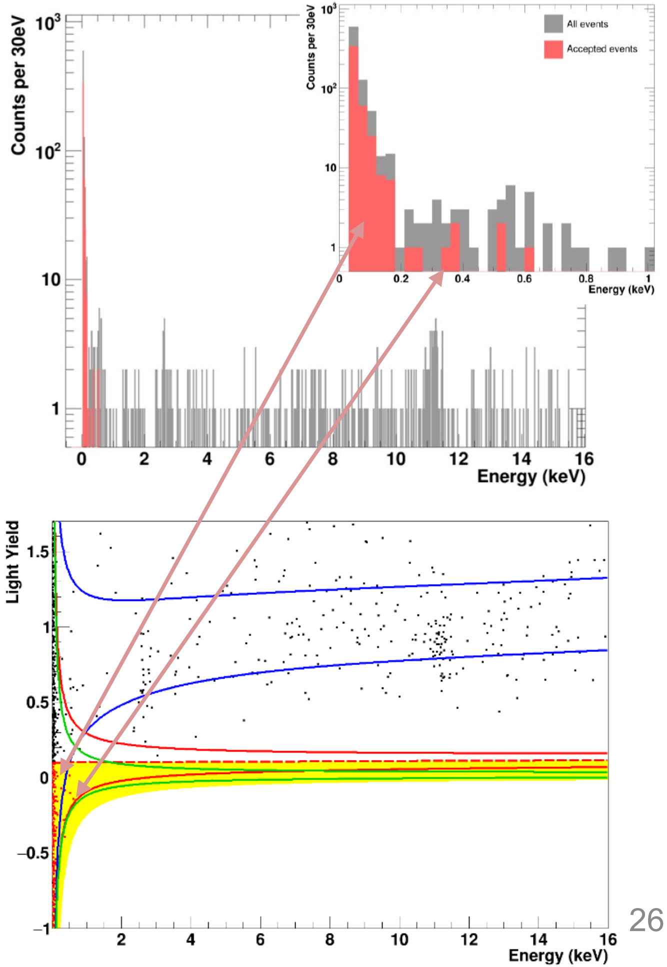
- **$CaWO_4$** crystals of $(20\times20\times10)mm^3$ (**≈24g**)
- With self grown crystals **≈4 counts/(keV kg day)**
- Threshold design goal **<100 eV threshold**
- **(best threshold 30 eV)**
- Fully scintillating housing
- Instrumented sticks

Nuclear Recoils from surface





Double Readout for DM: Heat and Light (CRESST III)



- ✓ Exponential background towards the low energy
- ✓ Particle discrimination becomes negligible below ~ 3-4 scintillation photons

A. H. Abdelhameed et al., arXiv:1904.00498

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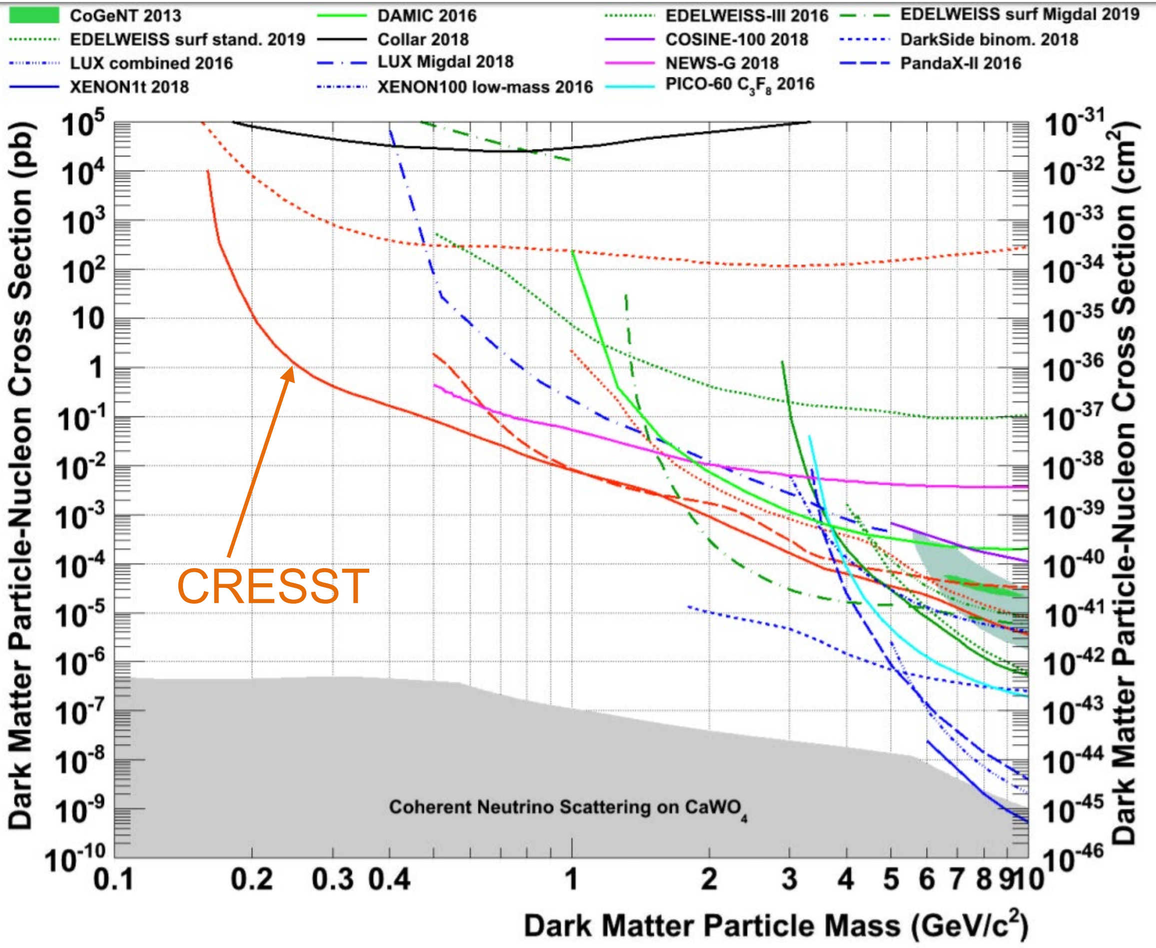
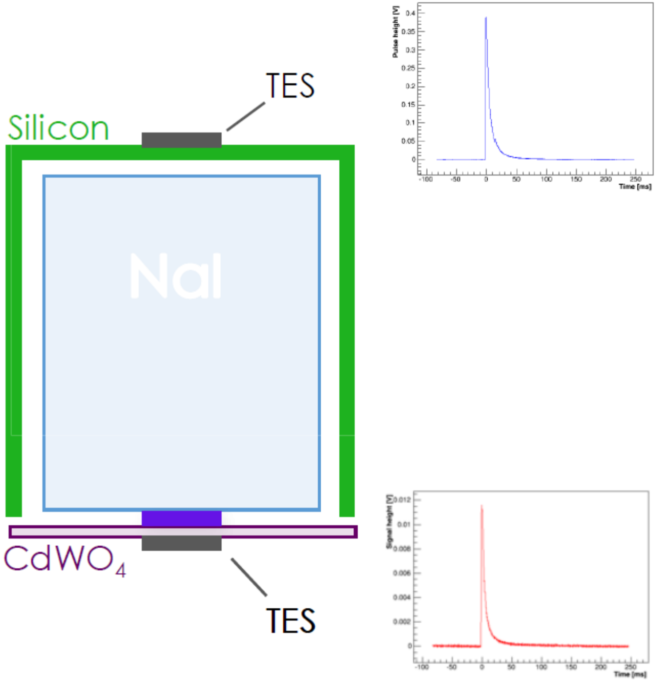


Cosinus – NaI scintillating Bolometer

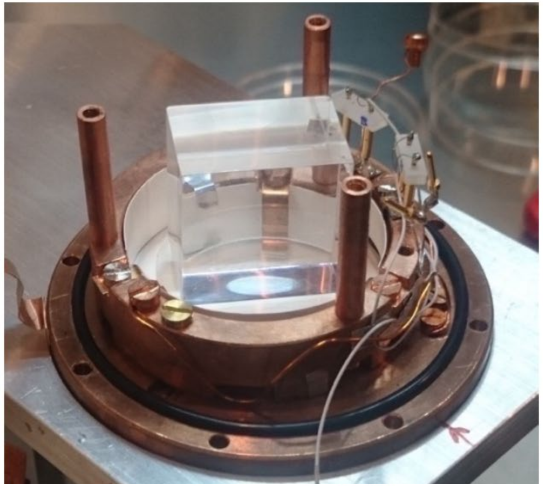
Simultaneous measurement of heat and light ➔ background (^{40}K) discrimination
Low energy threshold for nuclear recoils ➔ high sensitivity
Moderate exposure to scrutinize the nuclear recoil origin of DAMA signal

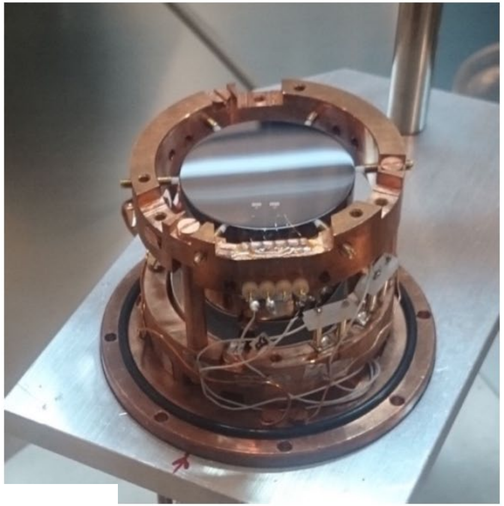


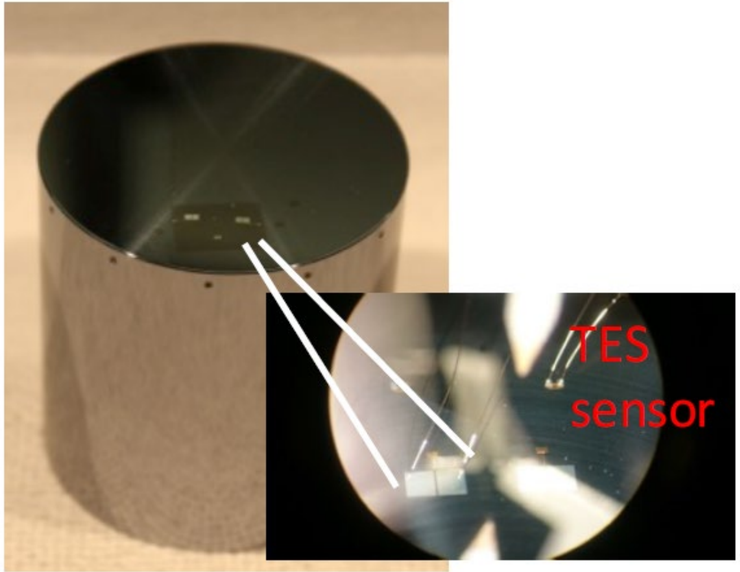
beaker-shaped HP silicon

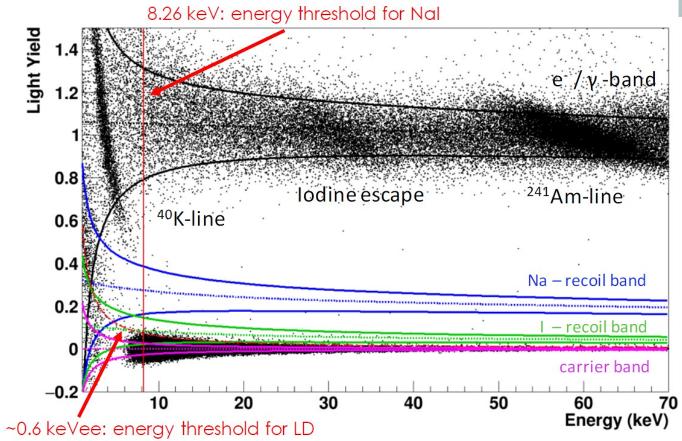
- 40 mm diameter & height
- equipped with TES optimized for light detection
- high light collection efficiency (13 %)
- fully active veto to reject surface Backgrounds (e.g. alpha-induced nuclear recoils)

Cosinus – NaI scintillating Bolometer

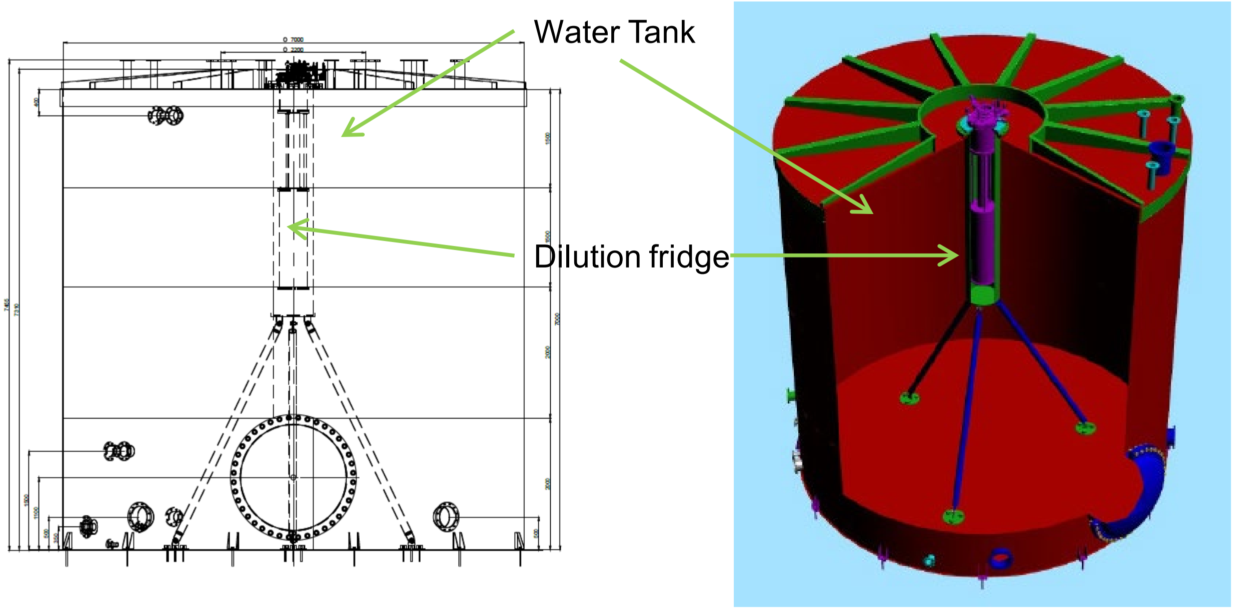








COSINUS officially funded



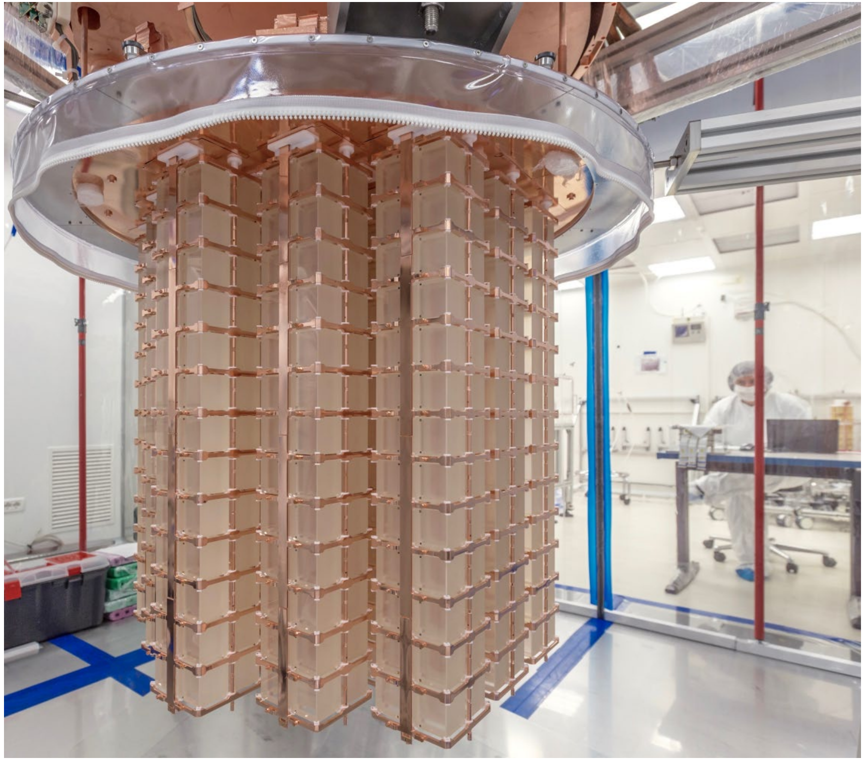
- **Funding granted:**

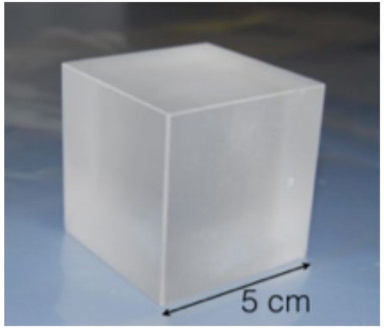
MPRG grant, MPP:	3.115 Mio. Eur
HEPHY, Vienna:	100k Eur
INFN – CSN5 (2019):	28k Eur

M(NaI) > 50 g
E_{th}= 1 keV
20 detectors

Cosinus 1-π : Clarication of a nuclear recoil origin of the DAMA signal

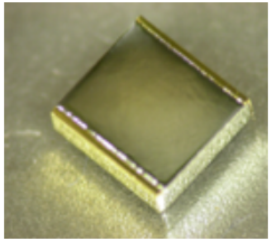
Double Beta Decay (CUORE)





$^{(nat)}TeO_2$ crystal

Absorber = $0\nu\beta\beta$ source
$5.0 \times 5.0 \times 5.0$ cm^3
750 g mass
$C(T) \sim 2.3 \times 10^{-9}$ J/K (@ 10 mK)
$\Delta T_{crystal} \sim 100$ μK/MeV
$\tau \sim 0.1 - 1$ s

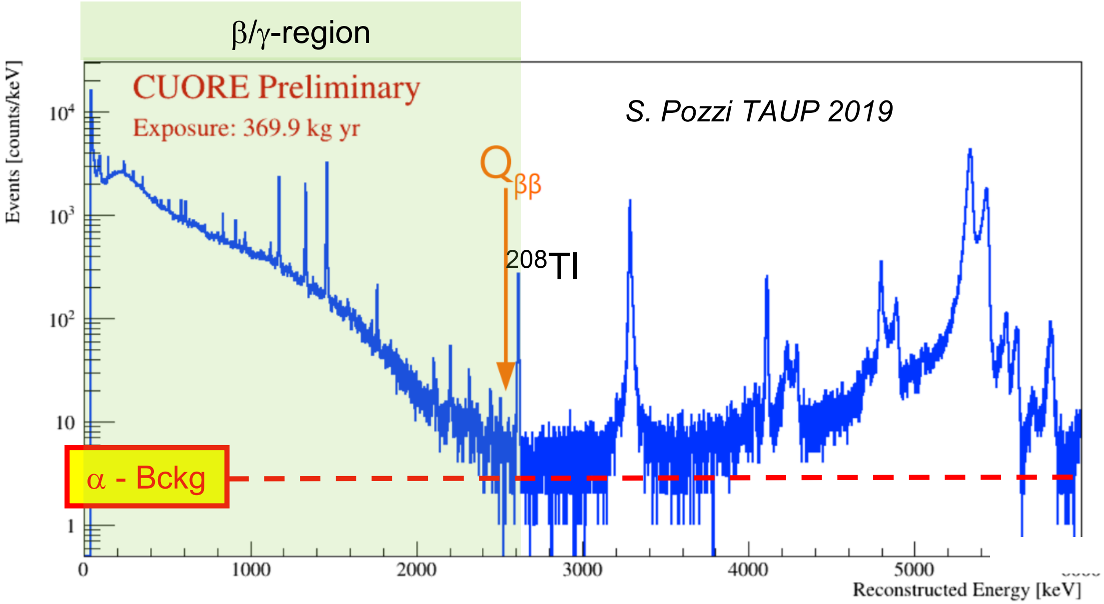


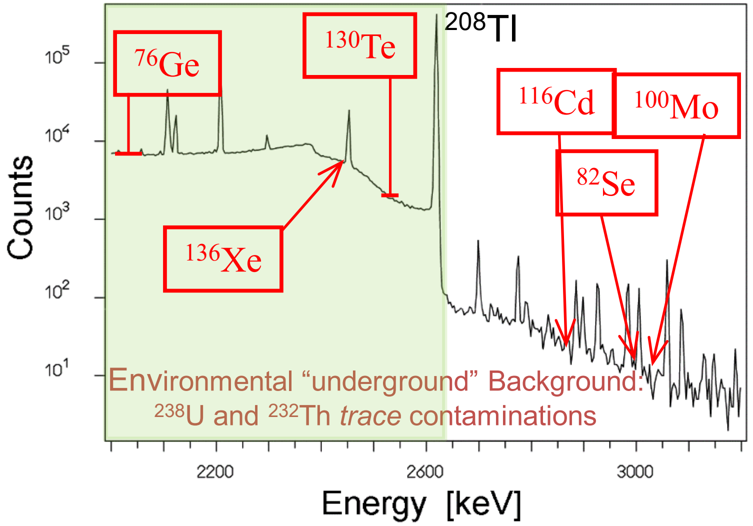
Ge-NTD thermistor

$3.0 \times 2.9 \times 0.9$ mm^3
Working impedance of the thermistors:
$R_{wp} \sim 100$ MΩ -1 GΩ
$\Delta V_{NTD} \sim 400$ μV/MeV (@10 mK)

Phys. Rev. Lett. 120, 132501 (2018)

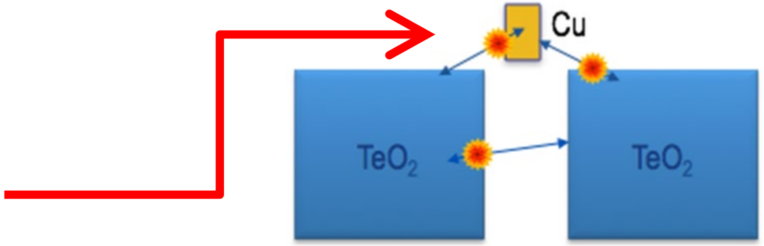
α-background: the bottleneck for DBD with bolometers





Bolomers are **fully sensitive** detectors, no dead layers

Dominant Background :
energy-degraded α's from surfaces



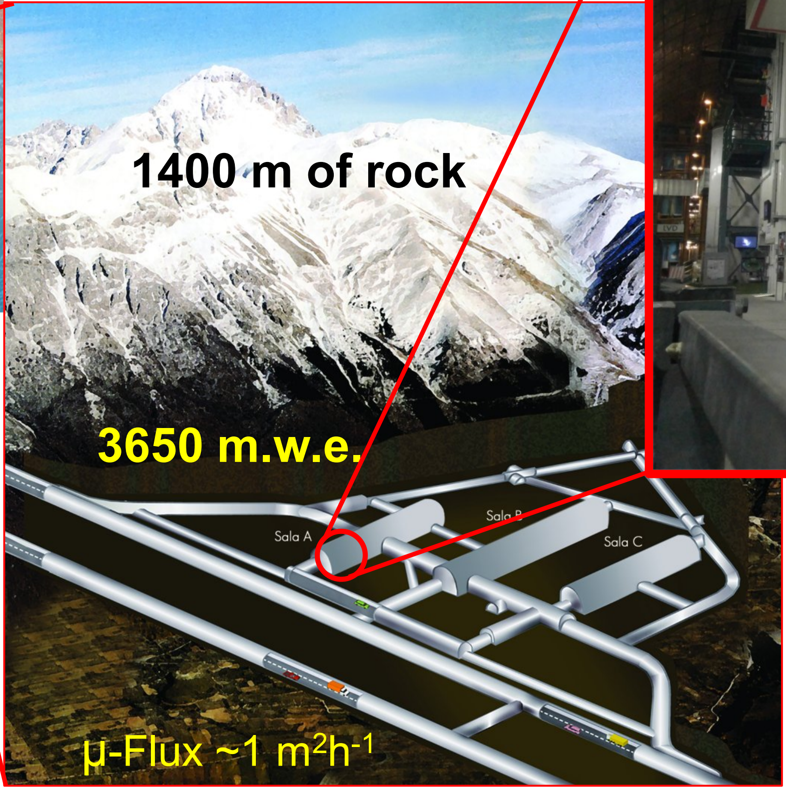
Solution: α-Tagging
$Q_{\beta\beta}$> 2615 keV

CUPID @ LNGS

100 km east from Rome

Easy access from
Highway tunnel

3 main halls 100x20x18 m^3

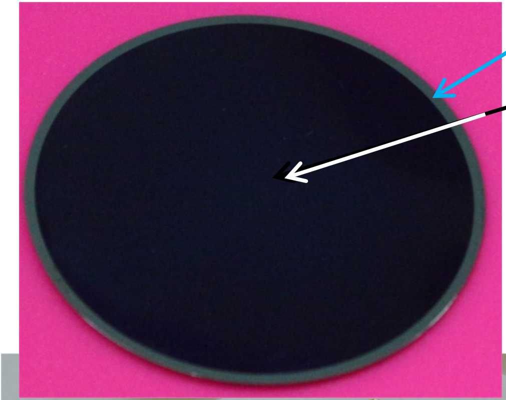


24 **$Zn^{82}Se$** crystals total mass ≈ **5.1 kg of ^{82}Se**
Light detectors: Ge wafers
Thermal sensors: NTD thermistors
Detector assembled in 5 towers

Total active **mass of the detector ~10.5 kg**

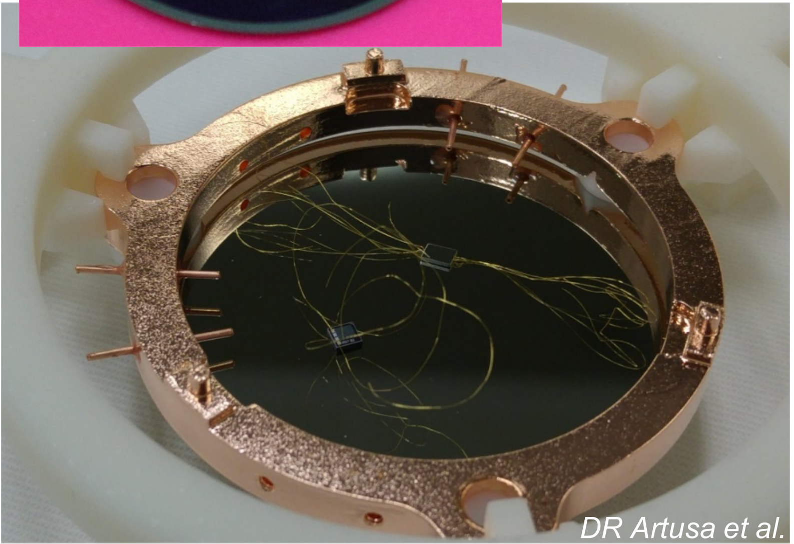
The light detectors (bolometers)

Light detectors are the fundamental part of the experiment since they permit the alpha background discrimination

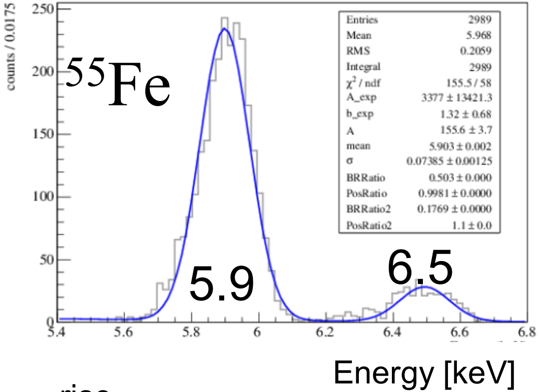


44.5 mm dia, 170 μm thick pure Ge wafer

SiO_2 coating to increase light absorption



Performance evaluated with ^{55}Fe source



$\tau^{rise}{}_{(10\text{-}90)}$~1.8 ms

$\tau^{decay}{}_{(90\text{-}30)}$~ 6 ms

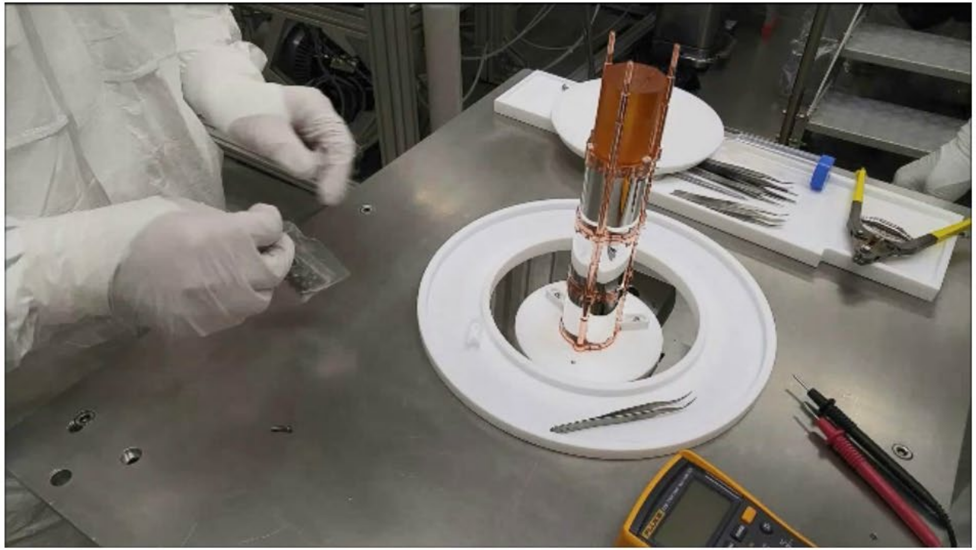
σ~ 50 eV

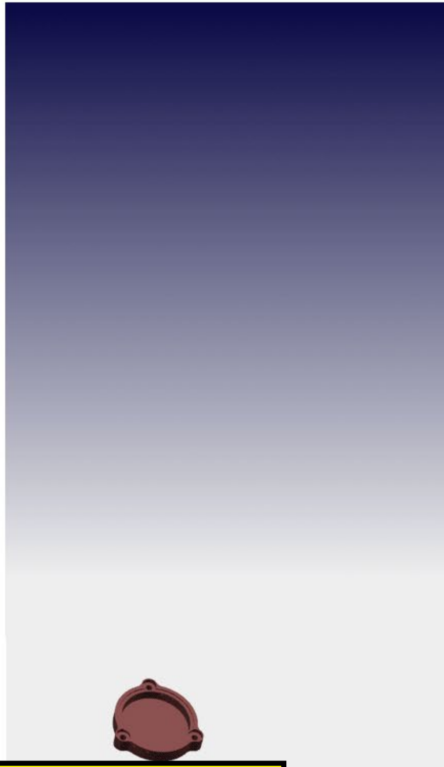
DR Artusa et al. Eur. Phys. J. C (2016) 76

The CUPID-0 tower

26 ZnSe Crystal 24 enriched 2 natural : *Driving Idea: minimize frame mass, type of pieces, use **only** certified (large bar) copper*

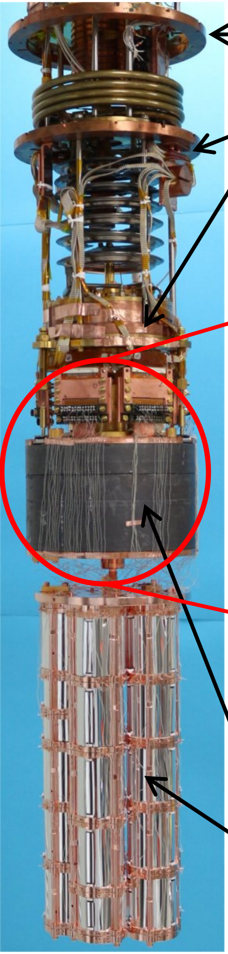
https://cupid.lngs.infn.it





ZnSe 78 % Cu 22% PTFE 0.1% 0.14 % VIKUTI™ reflector

The overall detector



← 600 mK

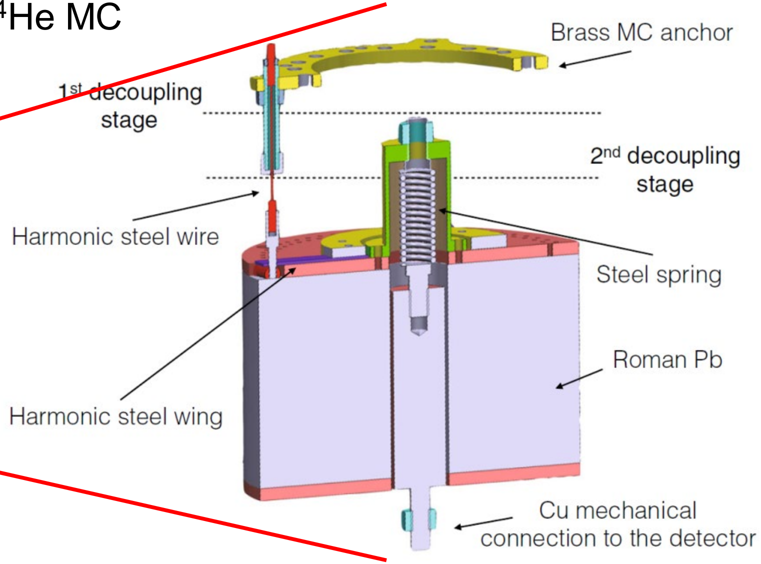
50 mK

^{3}He - ^{4}He MC

Roman Lead 10 cm

CUPID-0

5 tower, 26 ZnSe

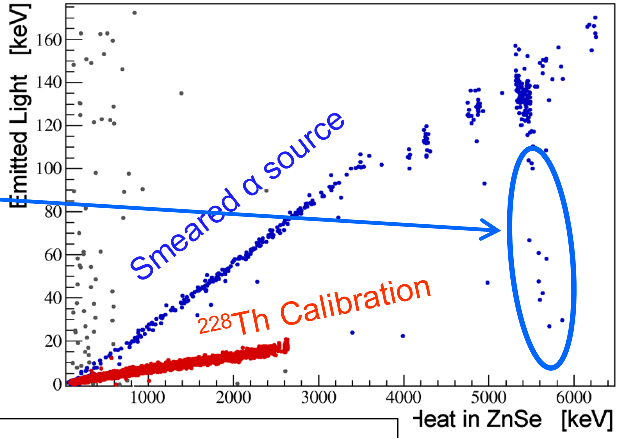


More videos @ https://cupid-0.lngs.infn.it

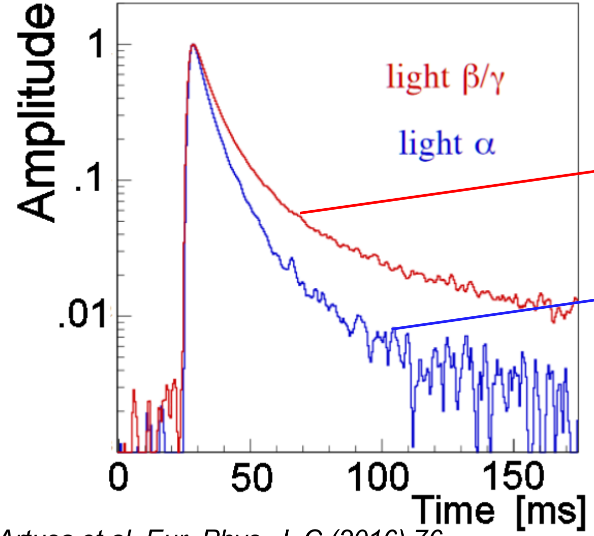
[*CUPID-0: the first array of enriched scintillating bolometers for 0νββ decay investigations*](#)
[A. Azzolini et al. , Eur. Phys. J. C (2018) 78:428](#) *(https://arxiv.org/abs/1802.06562)*

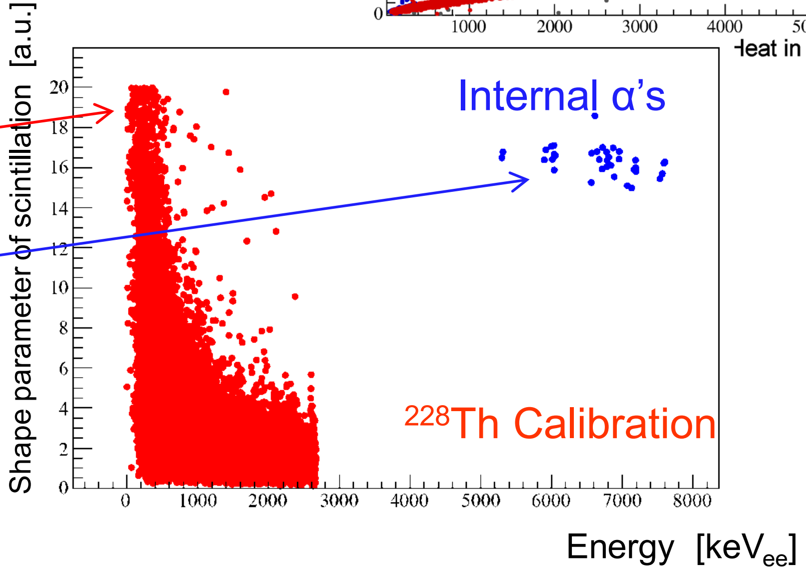
Light detectors for alpha discrimination

The particle discrimination is based on the shape of the light instead of the amount due to possible leakage problems



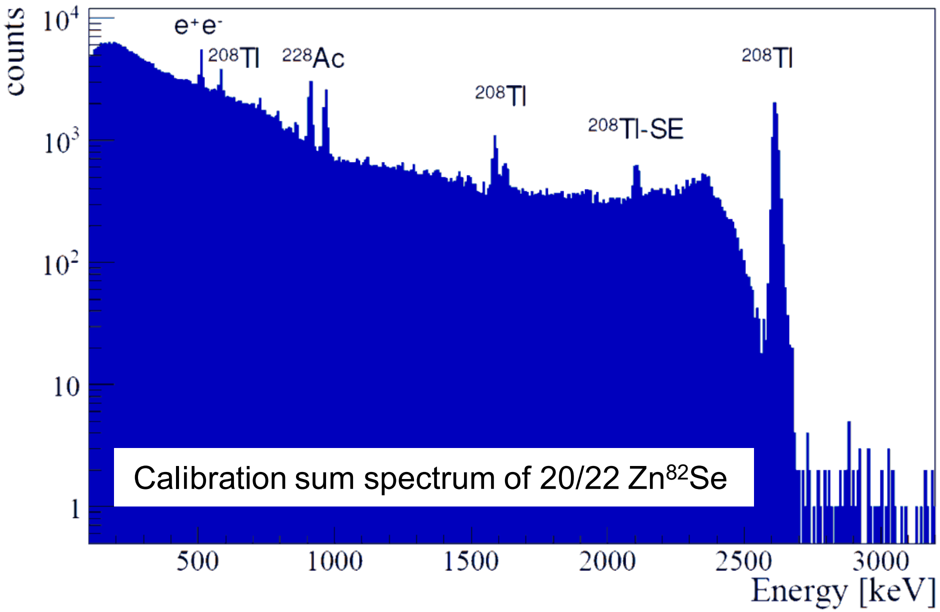
Different Scintillation signal for α and β/γ

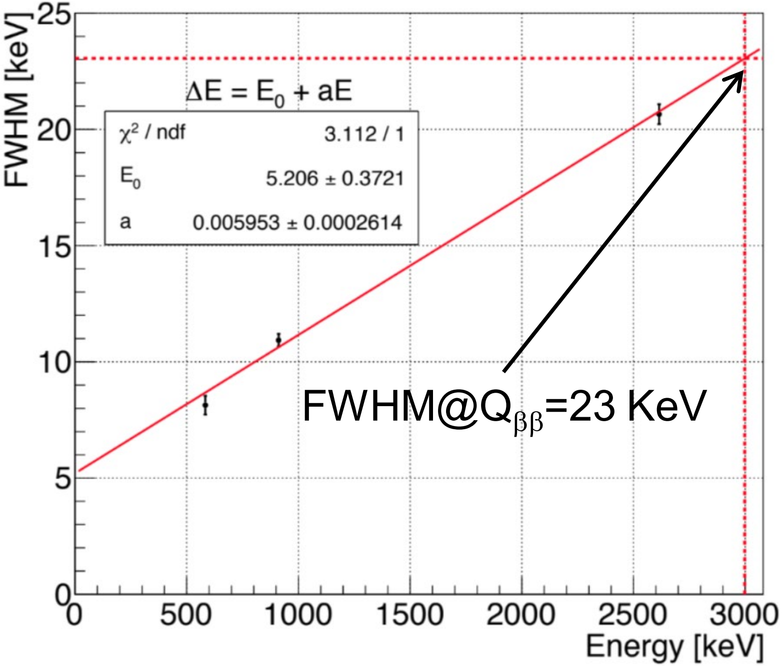




DR Artusa et al. Eur. Phys. J. C (2016) 76

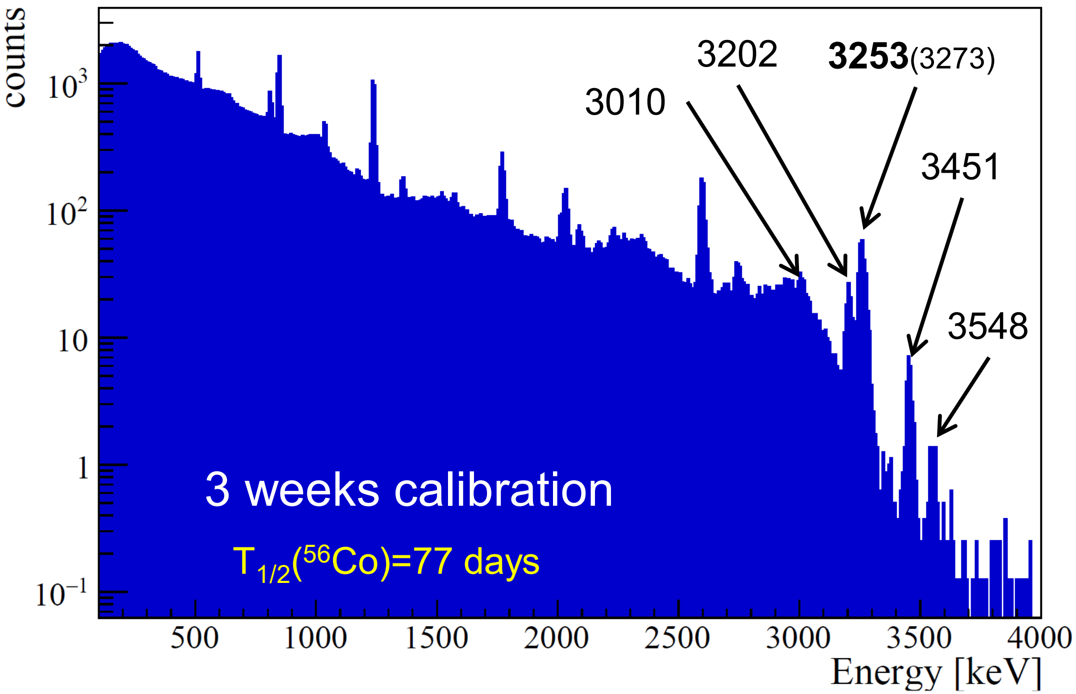
Energy calibration – Extrapolation

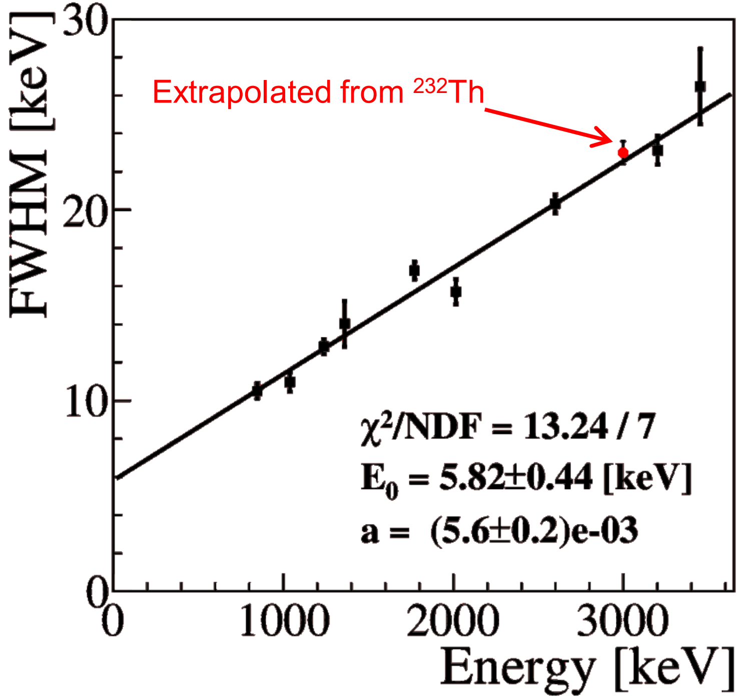




The mean baseline energy resolution of the detector is 3.8 keV. This indicates that the actual energy resolution is dominated by the poor crystalline structure of the crystals (position effects).

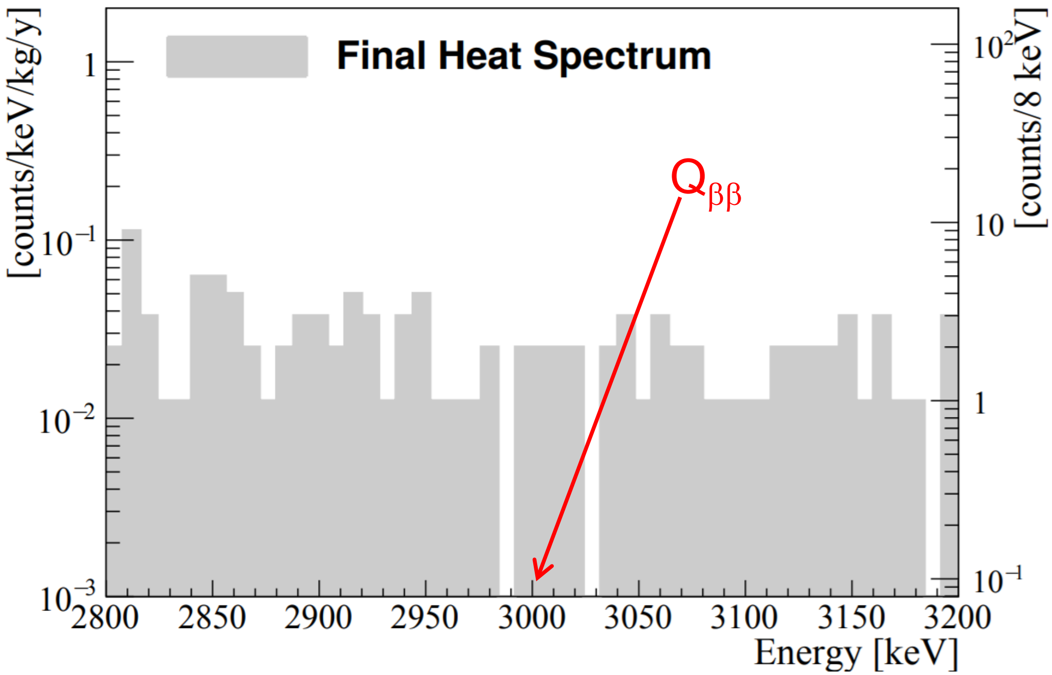
Energy calibration @ $Q_{\beta\beta}$ - ^{56}Co





Energy resolution in ROI = (22.5 ± 1.2) keV FWHM, consistent with (23.0 ± 0.6) keV extracted from ^{232}Th calibration, used or PRL analysis. Residuals @ $Q_{\beta\beta}$< 3 keV

Background in the RoI

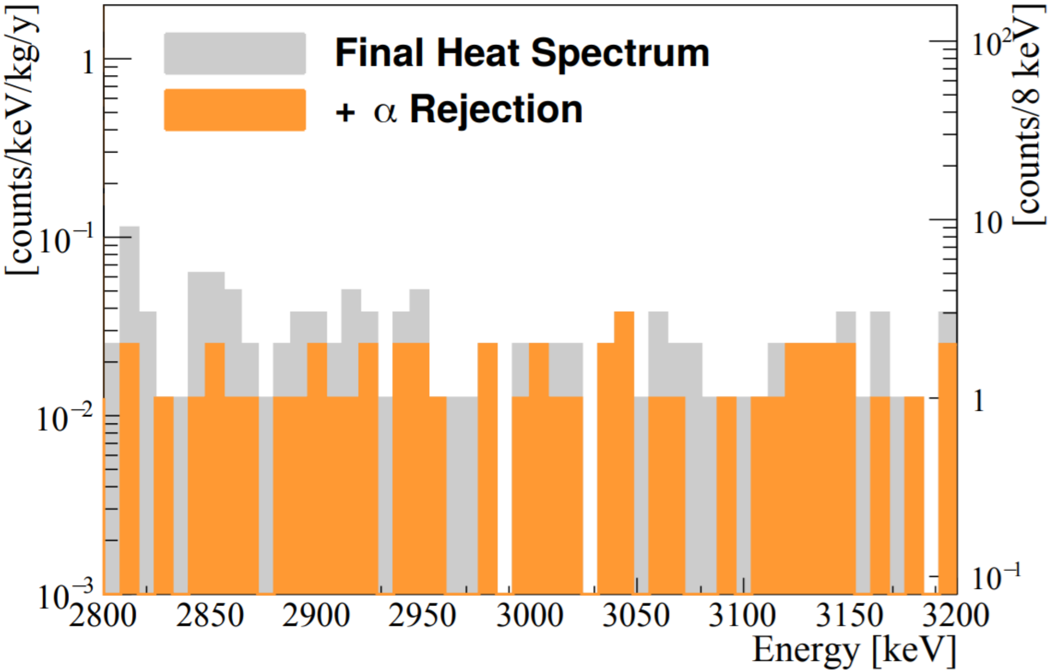


BKG = 3.2 x 10-2 counts/(keV kg yr)

We have chosen a symmetric window (± 200 keV) across $Q_{\beta\beta}$

- ✓ Rejection of "non particle-like" events through pulse shape on thermal pulses.
- ✓ Anti-coincidence between ZnSe crystals

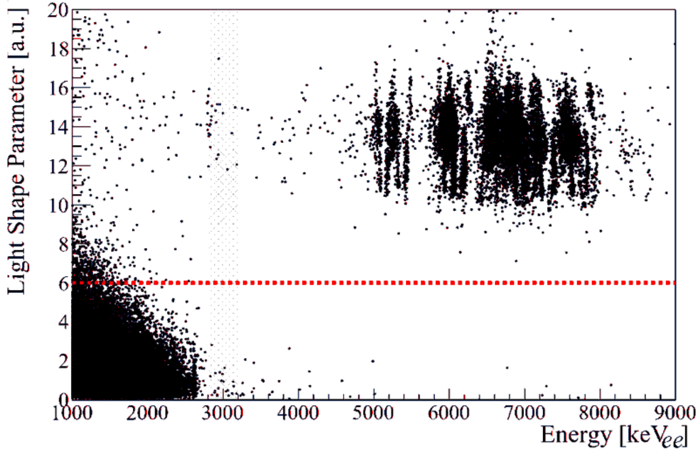
Background in the RoI (2): PSA



BKG = 3.2 x 10^{-2} counts/(keV kg yr)

BKG = 1.3 x 10^{-2} counts/(keV kg yr)

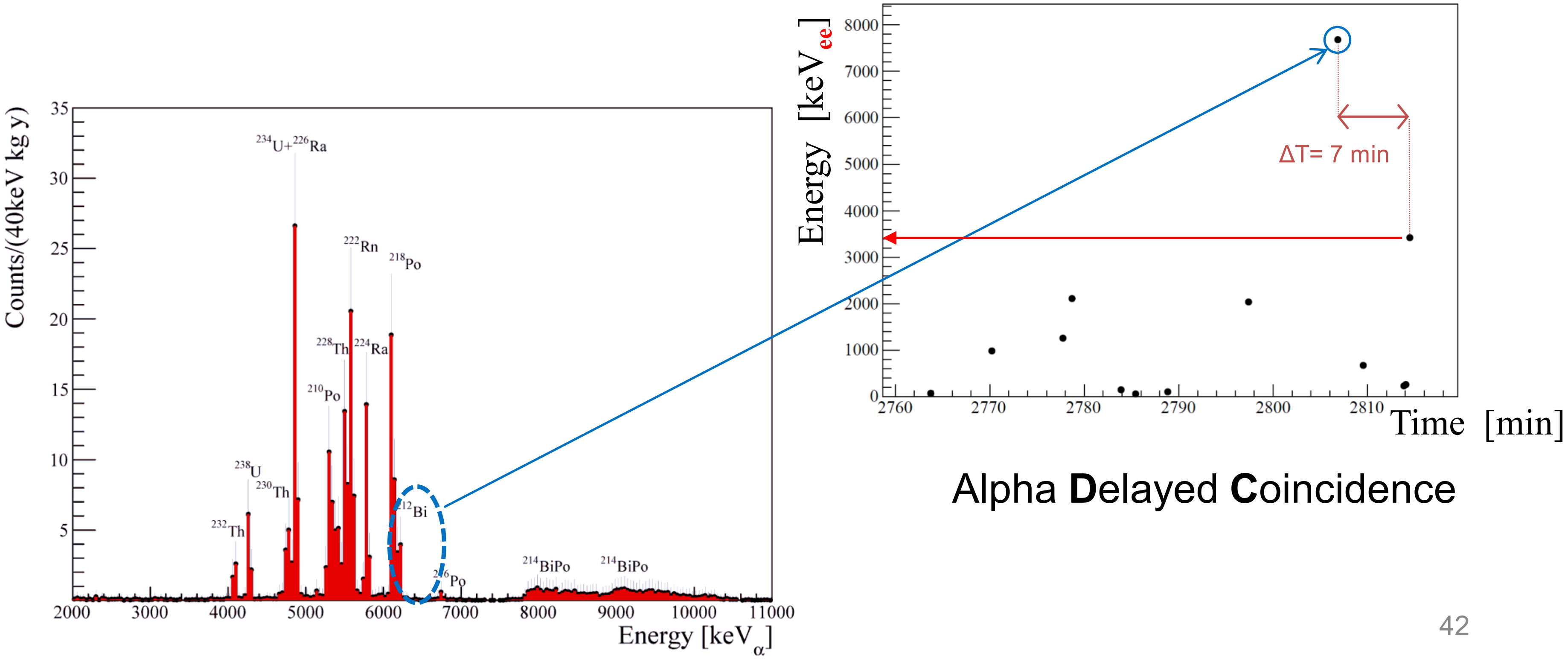
The alpha are recognized thanks to the Light shape



- ✓ Rejection of "nonparticle-like" events through pulse shape on thermal pulses.
- ✓ Anti-coincidence between ZnSe crystals
- ✓ Alpha rejection

Internal background rejection

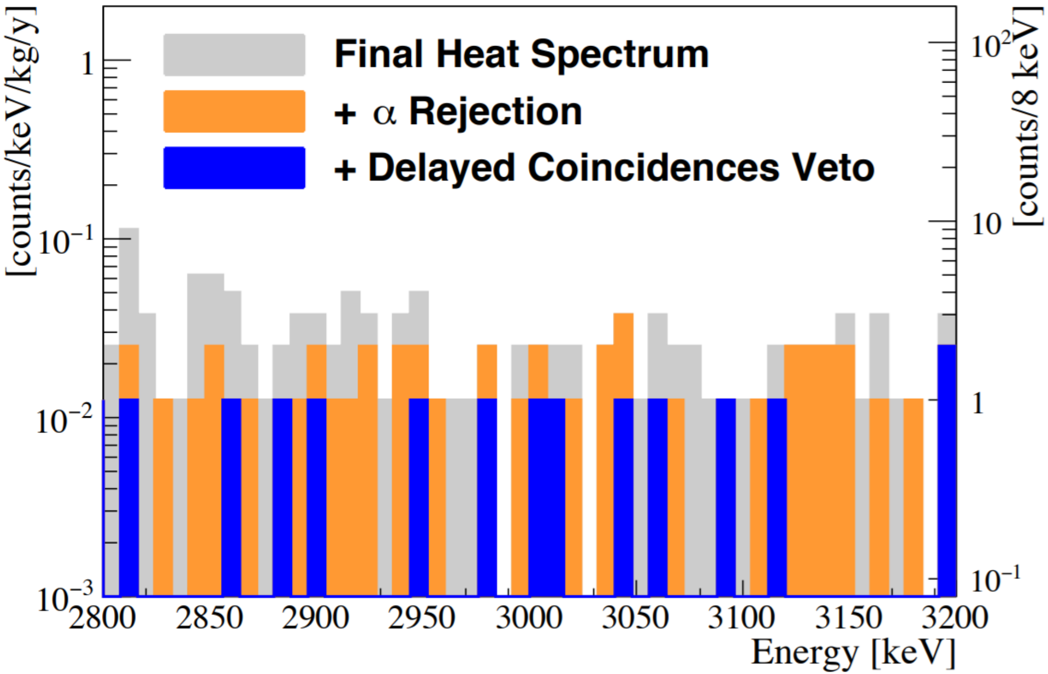
A not negligible background is induced by internal contamination belonging to the ^{232}Th chain, through the decay of ^{208}Tl with Q-Value of 5 MeV. The decay is preceded ($T_{1/2} \cong 3$ min) by the α-decay of ^{212}Bi, Q-value 6.2 MeV.



Alpha **D**elayed **C**oincidence

Background in the RoI (3)

O. Azzolini et al. Phys. Rev. Lett. ***123****, 032501 15 July 2019*

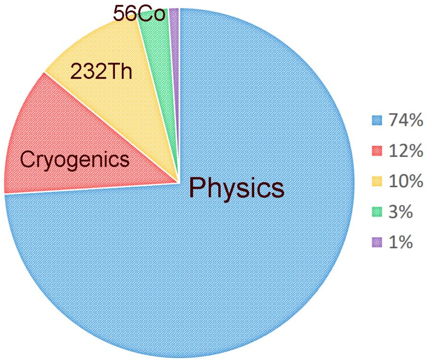


BKG = 3.2 x 10^{-2} counts/(keV kg yr)

BKG = 1.3 x 10^{-2} counts/(keV kg yr)

BKG = 3.5 x 10^{-3} counts/(keV kg yr)

- **Total exposure:**
  - **9.95 (kg x yr) of $Zn^{82}Se$**
  - **3.88x10^{25} (emitters x yr) of ^{82}Se**
- **Final efficiency: (70 ± 1) %**
  - **All cuts efficiency (86 ± 1)%**
  - **Probability of 0νββ electrons containment (81.0 ± 0.2) %**
- **Energy resolution in ROI: (20.05 ± 0.34) keV**



Jun 2016

Dec 2018

Bayesian Lower Limit

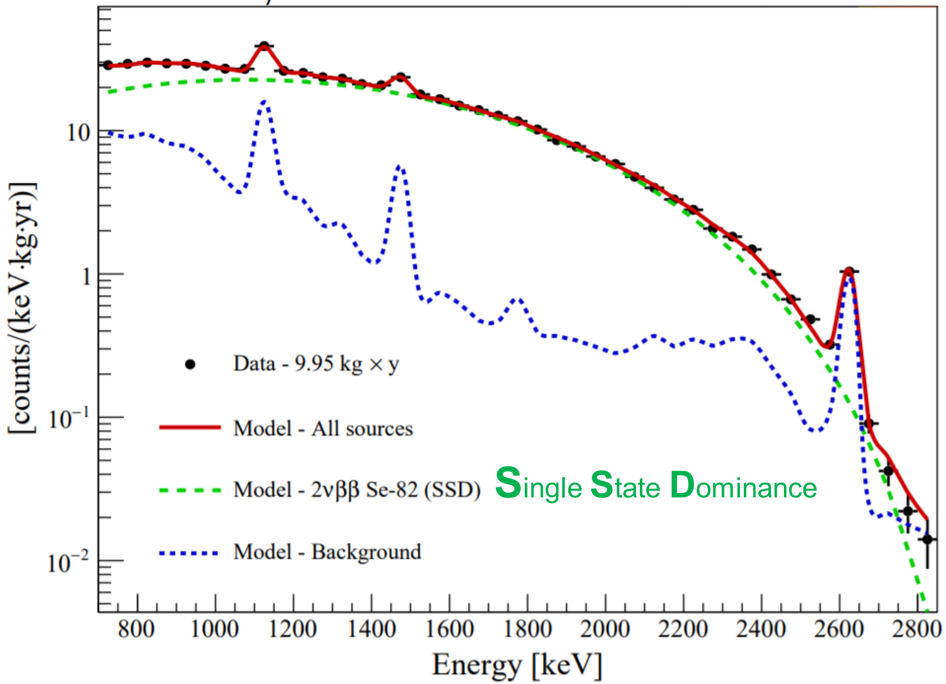
$T_{1/2}$ > 3.5x10^{24} yr (90% C.I.)

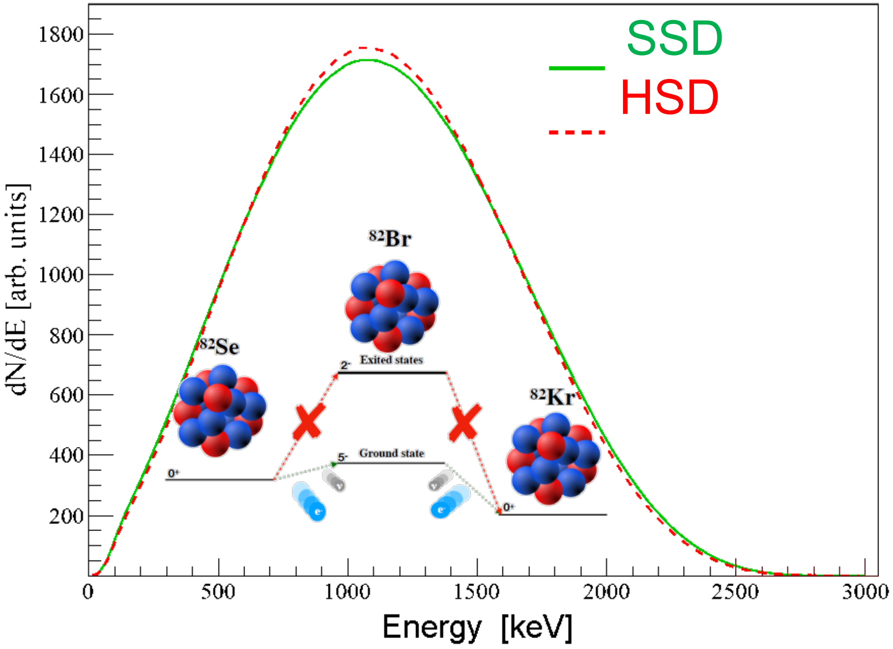
Median Sensitivity $T_{1/2}$ > 5.0x10^{24} yr (90% C.I.)

Precise 2ν measurement

CUPID-0 measured with an unprecedented precision level the 2νββ decay time of ^{82}Se. Such precision level is the best ever obtained among the 2νββ measurements. We identify the single state dominance as the underlying mechanism of 2νββ decay.

$$T^{2\nu}_{1/2} = [8.60 \pm 0.03(\text{stat.})\ ^{+0.18}_{-0.12}(\text{syst.})] \times 10^{19}\ \text{yr}$$



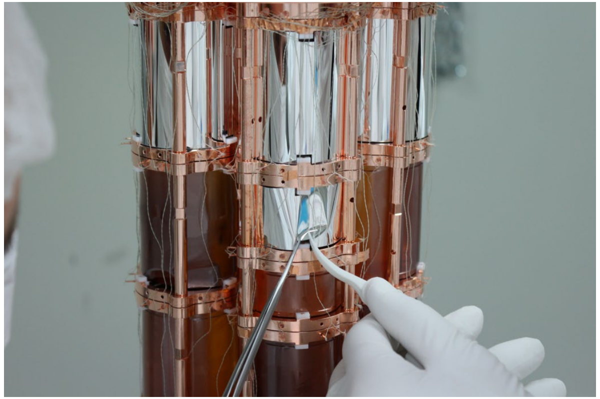


https://arxiv.org/pdf/1909.03397 Submitted to PRL

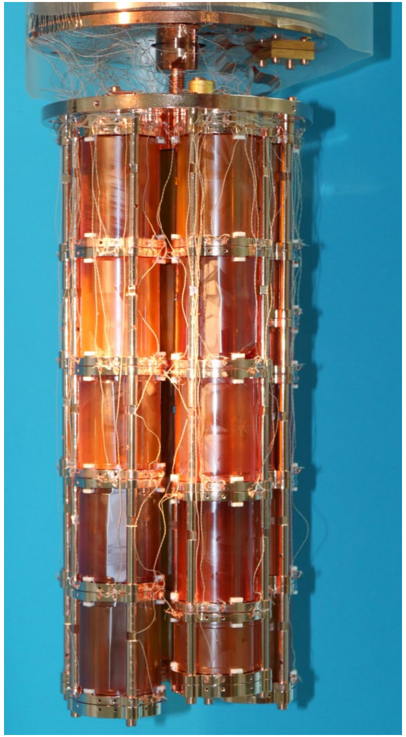
CUPID-0 Phase II

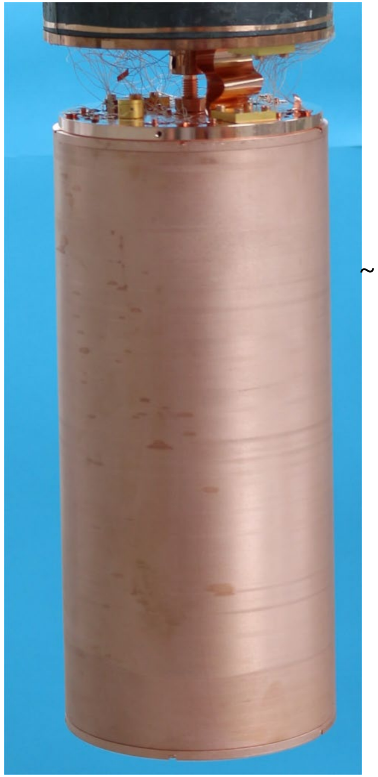
The second Phase is the dedicated to background assessment. This is fundamental for a background model aiming to describe surface and bulk contaminations down to 10^{-3} c/keV/kg/y level an lower (CUPID).

- **~44% muons**
- **~33% contaminations ZnSe crystals**
- **~17% cryostat**
- **~6% reflecting foil and holders**

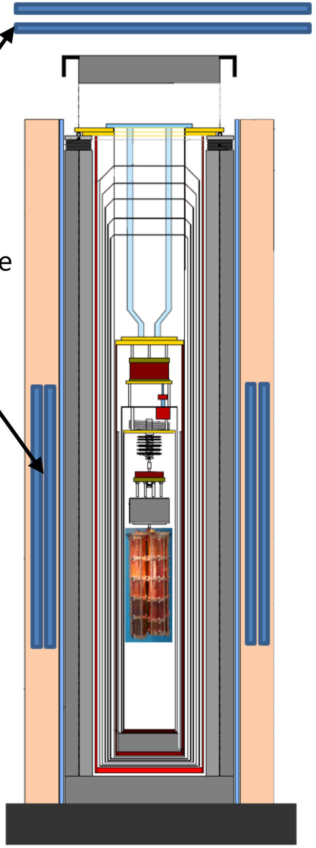


Remove the reflective foils
Install a new clean copper shield
Install a muon veto
Phase2 data taking started in June 2019



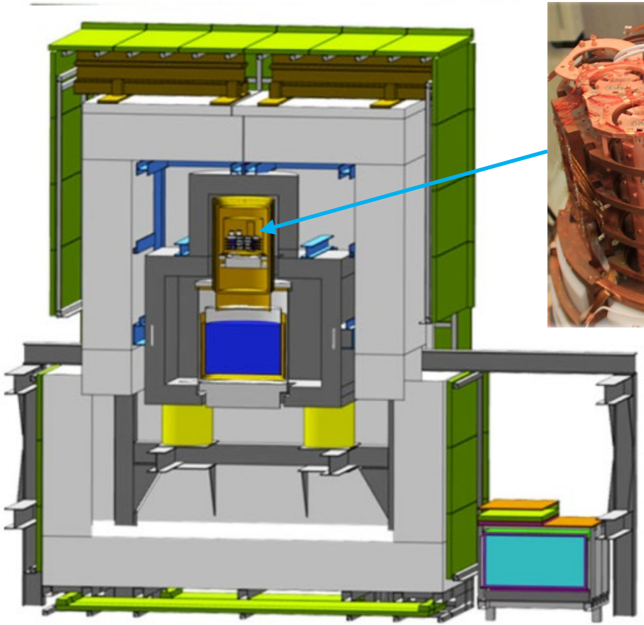


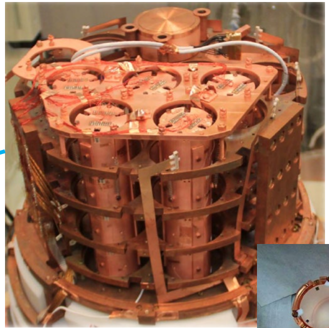
μ-Veto
~ 40 % coverage



CUPID-Mo ^{100}Mo with Li_2MoO_4

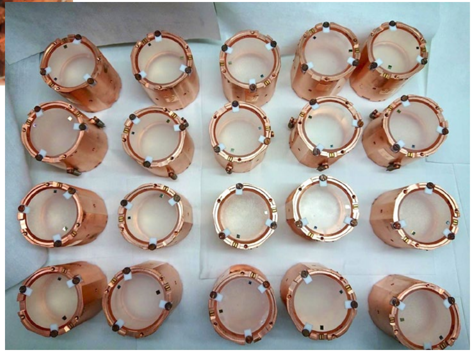
CUPID-Mo is the pilot experiment of CUPID using ^{100}Mo. The experiments uses 20 enriched Li_2MoO_4 crystal arranged in five Towers, in the same setup hosting the Edelweiss experiment.
From a long path (Lumineu) of tests on ^{100}Mo based compounds (Eur. Phys. J. C 77 (2017) 785)

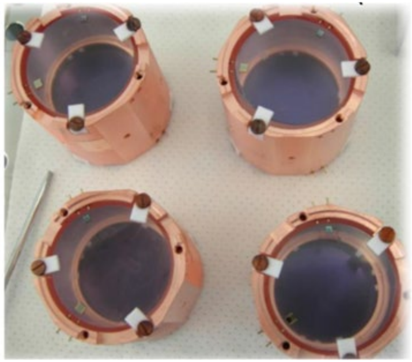




20 x ~210 g cylindrical Li_2MoO_4 crystals enriched to ~97% in ^{100}Mo, dimensions: ø 44 mm x 45 mm
Ge wafer with SiO anti-reflective coating as light detector
Ge-NTD (on both Li_2MoO_4 and Ge light detector)

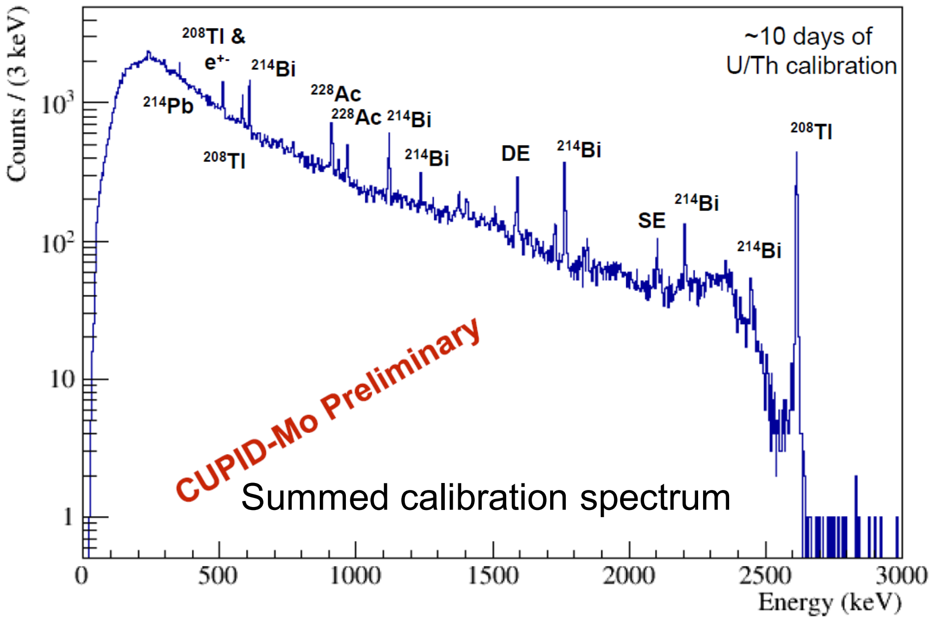
https://arxiv.org/abs/1909.02994



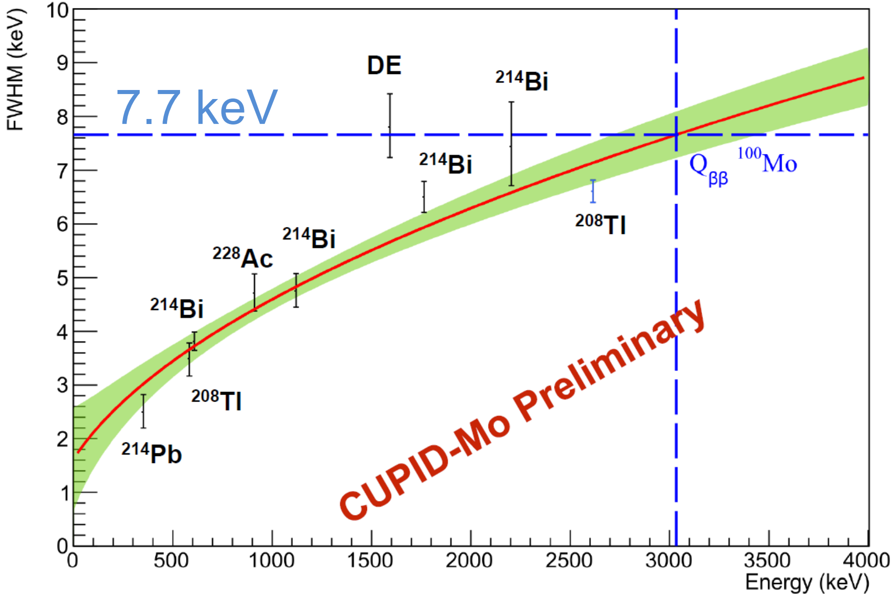


CUPID-Mo ^{100}Mo

Excellent Performance uniformity
Energy resolution (@2615) 4-7 keV for all crystals

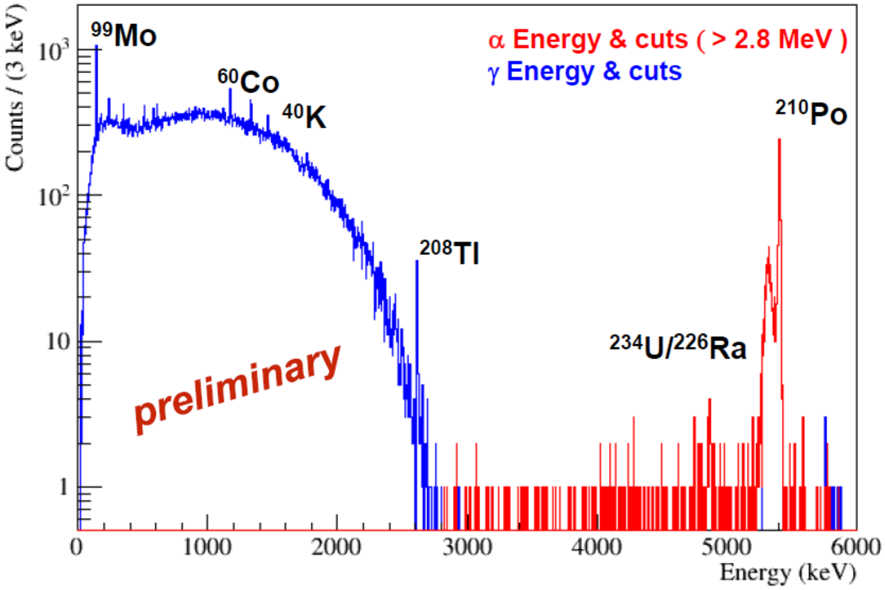


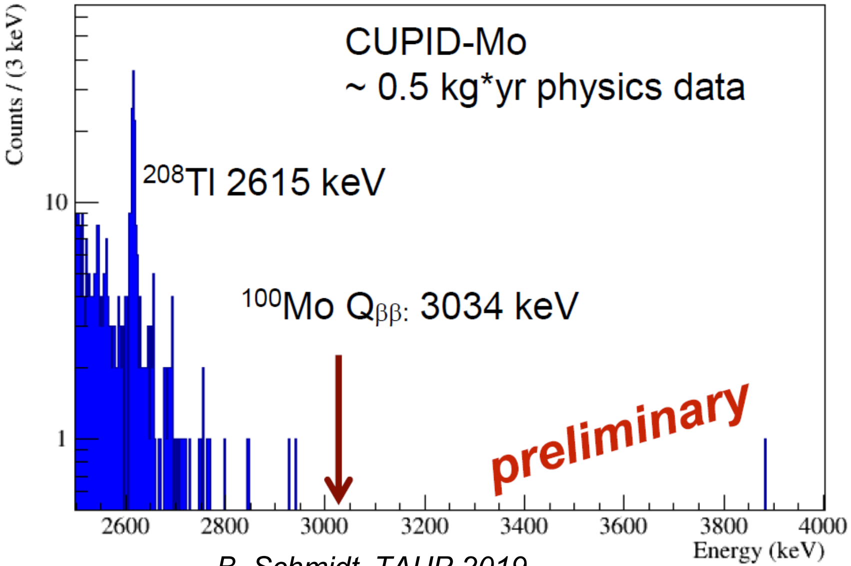
Energy resolution @ ROI



B. Schmidt, TAUP 2019

CUPID-Mo ^{100}Mo





B. Schmidt, TAUP 2019

Extremely radiopure crystals:

^{238}U ~ 0.5 μBq/kg ^{232}Th ~ 0.3 μBq/kg

^{210}Po (^{210}Pb) ~ 158(3) mBq/kg

\+ Energy resolution

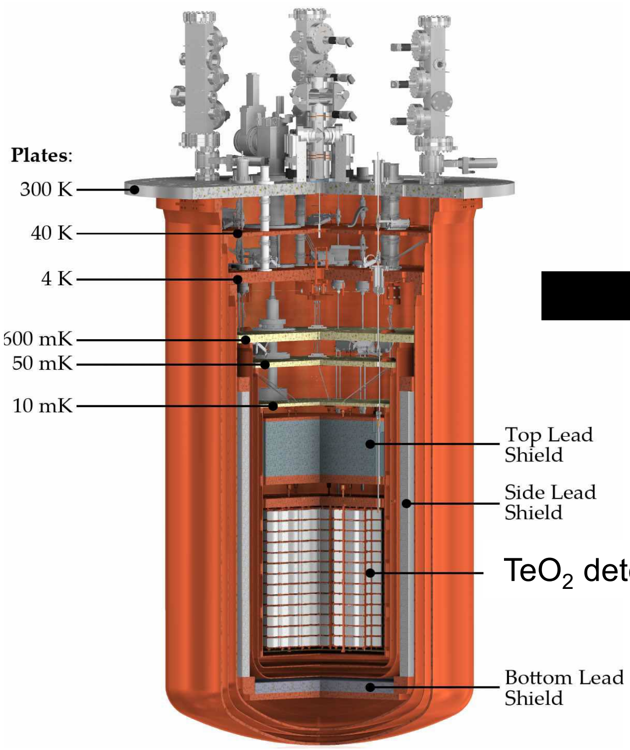
α discrimination

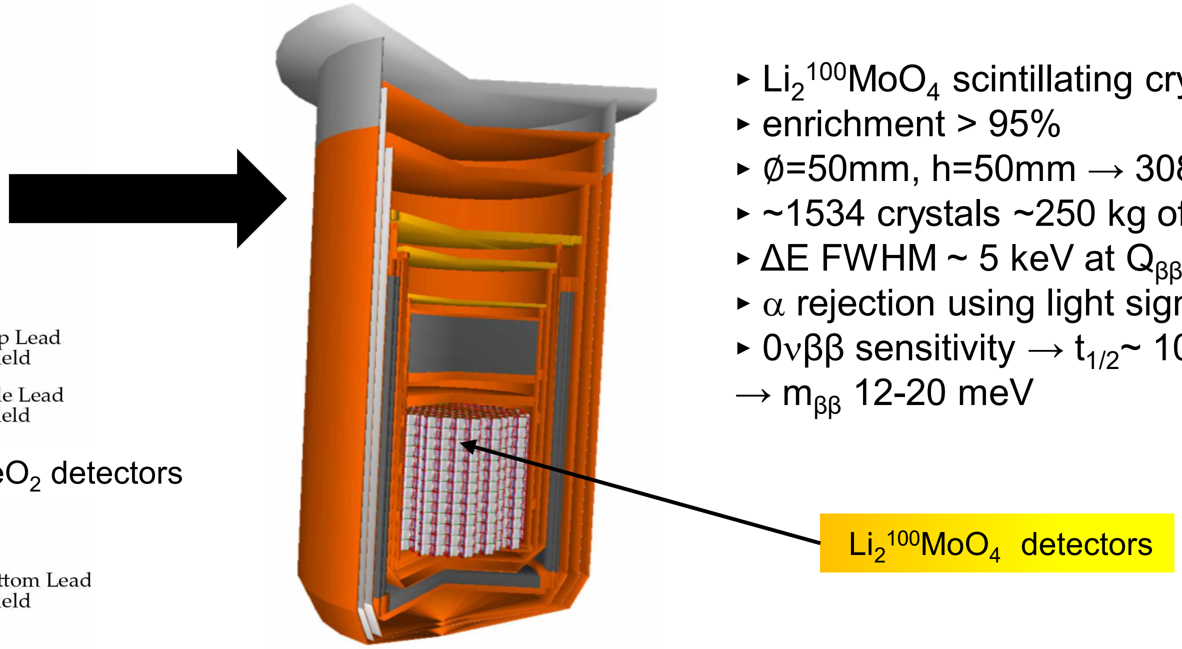
⇒ ….CUPID

New precise evaluation of the 2ν decay time to be submitted within December

Cuore Upgrade with Particle IDentification

CUORE successfully proved the possibility to operate 1K bolometers at ~10 mK





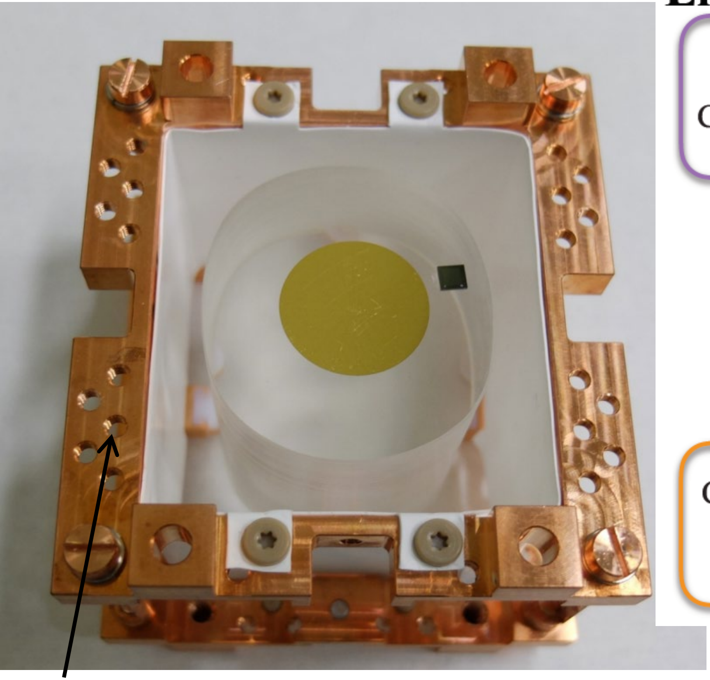
CUPID *arXiv:1907.09376*

- $Li_2{}^{100}MoO_4$ scintillating crystals
- enrichment > 95%
- Ø=50mm, h=50mm → 308 g
- ~1534 crystals ~250 kg of ^{100}Mo
- ΔE FWHM ~ 5 keV at $Q_{\beta\beta}$ ~3034 keV
- α rejection using light signal
- $0\nu\beta\beta$ sensitivity → $t_{1/2}$~ 10^{27} y

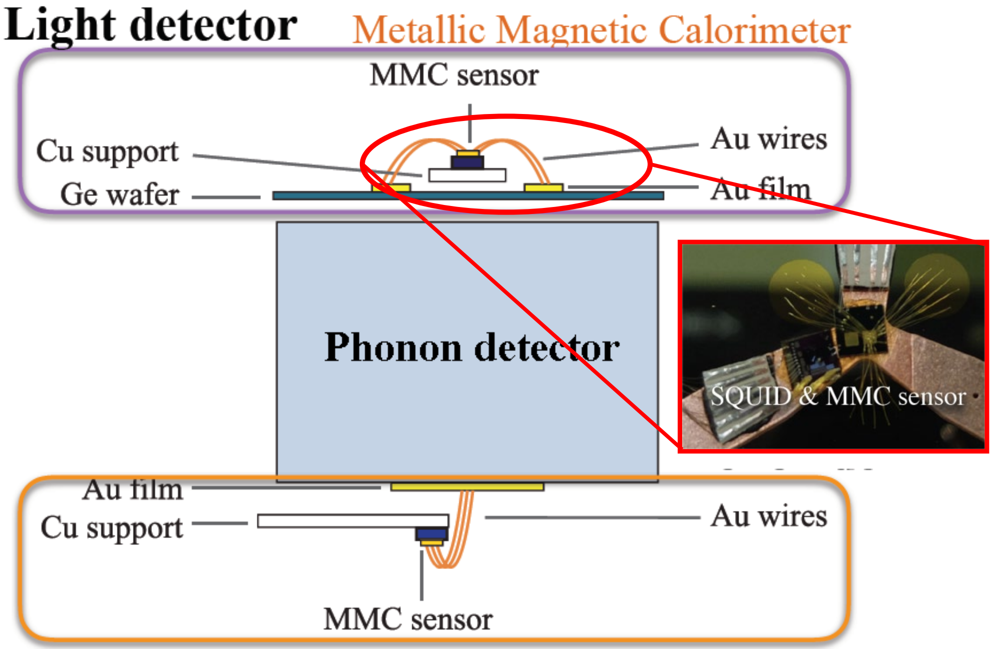
→ $m_{\beta\beta}$ 12-20 meV

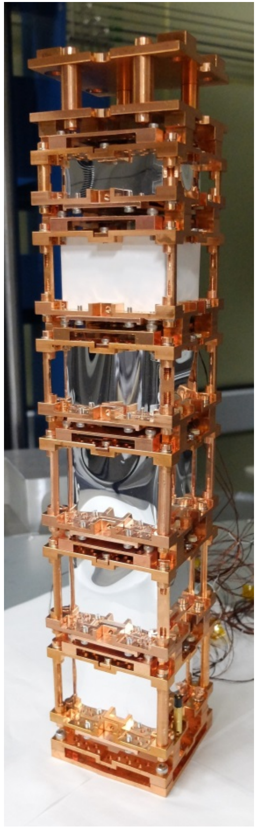
Scintillating Bolometers: AMORE ^{100}Mo

Micro Magnetic Calorimeter detectors, Heat & Ligth detector



$X^{100}MoO4$ crystal





The collaboration is deciding which type of crystal Li_2MoO4 $CaMoO_4$ $PbMoO_4$ ….

See Yeongduk Kim Talk tomorrow !!!

Last but not least: nuclear physics

The possibility to have a high efficiency + high resolution detector that can be constituted of almost all of the elements of the periodic table is extremely important in nuclear physics, since this permits to measure with high accuracy alpha, beta and especially Double Beta Decays.

Experimental detection of α-particles from the radioactive decay of natural Bismuth
P. de Marcillac et al., Nature 422 (2003) 876

46 g BGO crystal

Detection of the natural α decay of -Tungsten
C. Cozzini et al., Phys. Rev. C 70 (2004) 064606

300 g $CaWO_4$

Discovery of the ^{151}Eu α decay
N. Casali, et al. J. Phys. G: Nucl. Part. Phys.41(2014) 075101

6 g $Li_6Eu(BO_3)_3$

Eur. Phys. J. C (2014) 74:3035
DOI 10.1140/epjc/s10052-014-3035-8

THE EUROPEAN PHYSICAL JOURNAL C

Regular Article - Experimental Physics

Search for axioelectric effect of solar axions using BGO scintillating bolometer

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Conclusions

- ✓ Large LT scintillating (and also not…) bolometers have the chance to play a fundamental role in REP
- ✓ But their successful operation needs huge care in the whole setup, from cryogenics to (especially) radiopurity issues.
- ✓ In the last years DM searches drove to the enhancement of the energy threshold that was successfully reached by most of the detectors.
- ✓ Double Beta Detectors, on the contrary, already meet good performances. They also show a kind of fearsome Dark Side, not due to operation or performances but for radioactivity and background assessments.
- ✓ Bolometers have a *Scintillating* future !