Status of the CUPID-Mo bolometric experiment: searching for neutrinoless double-beta decay of ^{100}Mo

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http://cupid-mo.mit.edu

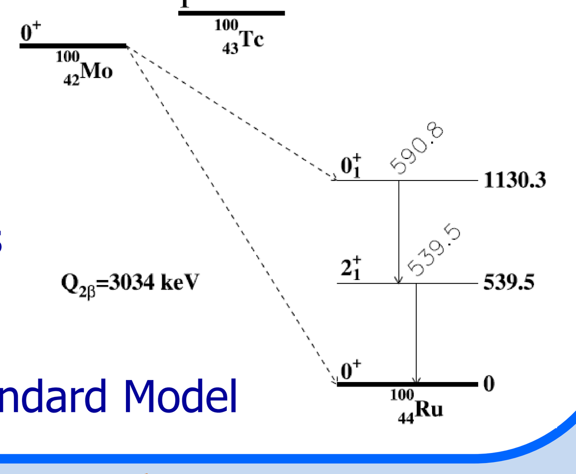
7 countries, 15 institutions, ~110 scientists

^{100}Mo double-beta decay

- **Standard Model two-neutrino decay (2νββ)**
  gs→gs: $T_{1/2}$ = (7.1±0.4) × 10^{18} yr (av. value [NPA 935 (2015) 52])
  gs→0_1: $T_{1/2}$ = $6.7^{+0.5}_{-0.4}$ × 10^{20} yr (av. value [NPA 935 (2015) 52])
- **Beyond Standard Model neutrinoless process (0νββ)**
  gs→gs: $T_{1/2}$ ≥ 1.1 × 10^{24} yr @90% CL (NEMO-3 [PRD 92 (2015) 072011])

Interest in 0νββ search

- Lepton number violation
- Majorana nature of neutrinos
- Absolute scale of ν mass
- Other effects beyond the Standard Model



Advantages of ^{100}Mo 0νββ searches

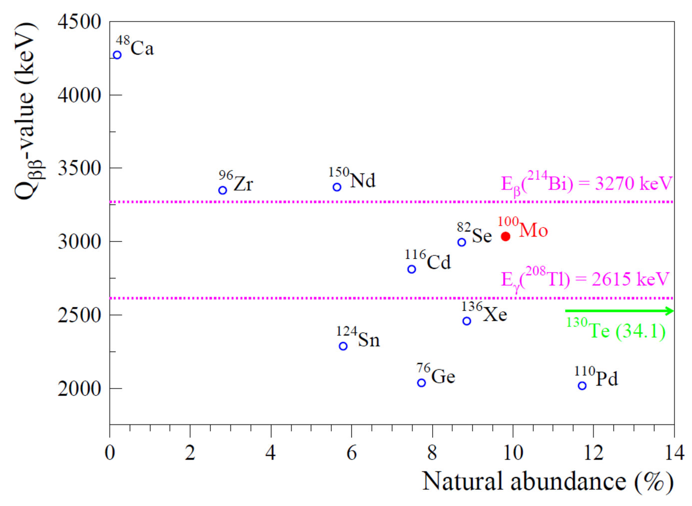
✓ **One of the highest $Q_{\beta\beta}$-values**

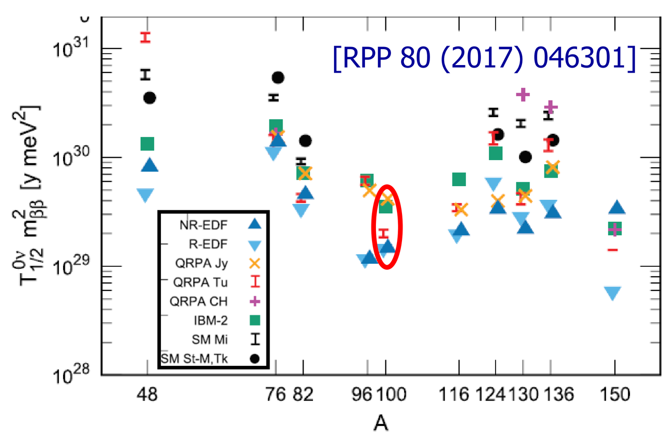
✓ **Reasonably high natural abundance and industrial enrichment to >95%**

✓ **Favorable theoretical predictions**

✓ **Developed technology (LUMINEU) of $Li_2{}^{100}MoO_4$ scintillating bolometers**

[EPJC 77 (2017) 785; AIP Conf. Proc. 1894 (2017) 020017]



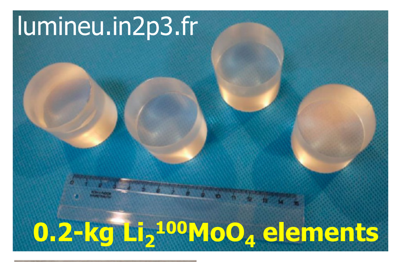


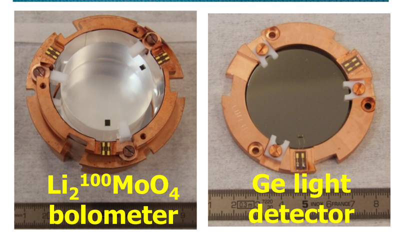
^{100}Mo-enriched crystals batch production

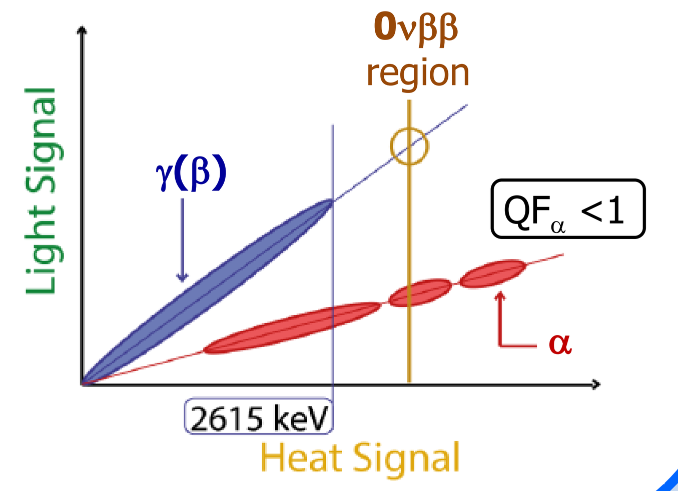
- Purified molybdenum & ultra-pure lithium carbonate
- Double crystallization using LTG Cz technique

High performance & radiopure scintillating bolometers

- Source=Detector technique: ~100% 0νββ detection efficiency
- High energy resolution: ~0.2% FWHM close to ^{100}Mo $Q_{\beta\beta}$
- Particle identification: >99.9% α bkg rejection in 0νββ ROI
- High crystal radiopurity: < 6 μBq/kg of ^{232}Th & ^{226}Ra, < 5 mBq/kg of ^{40}K

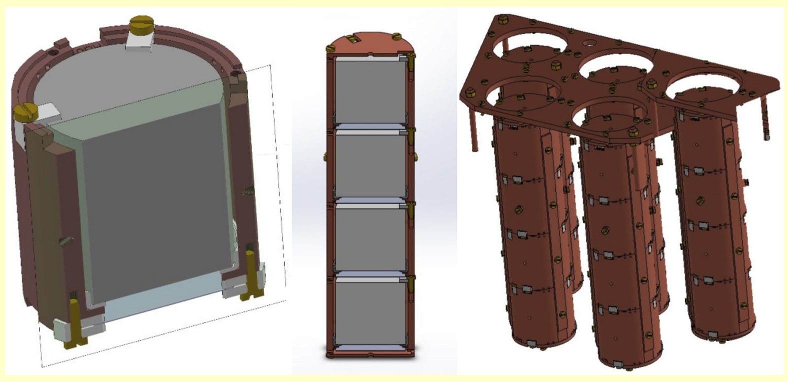




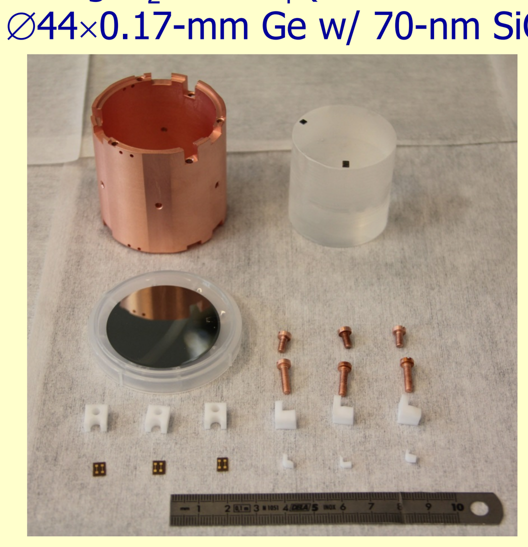


CUPID-Mo

20 $Li_2{}^{100}MoO_4$ scintillating bolometers



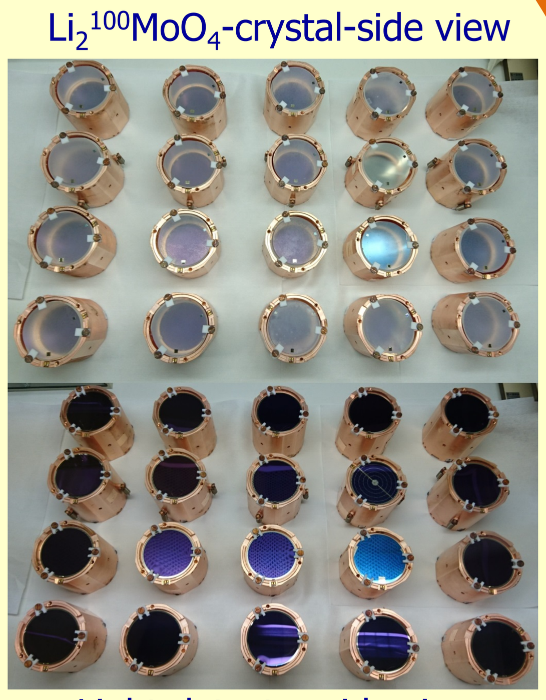
Single module
0.2-kg $Li_2{}^{100}MoO_4$ (^{100}Mo ~ 97%)
∅44×0.17-mm Ge w/ 70-nm SiO



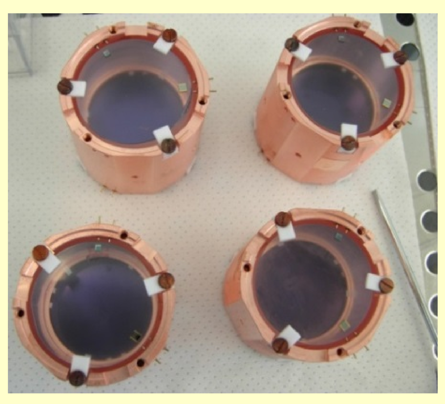
(+ 3M Vikuiti™ reflecting film)

x 20

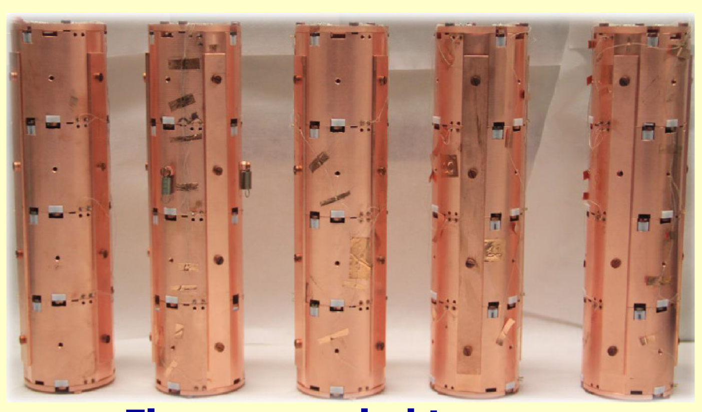
$Li_2{}^{100}MoO_4$-crystal-side view



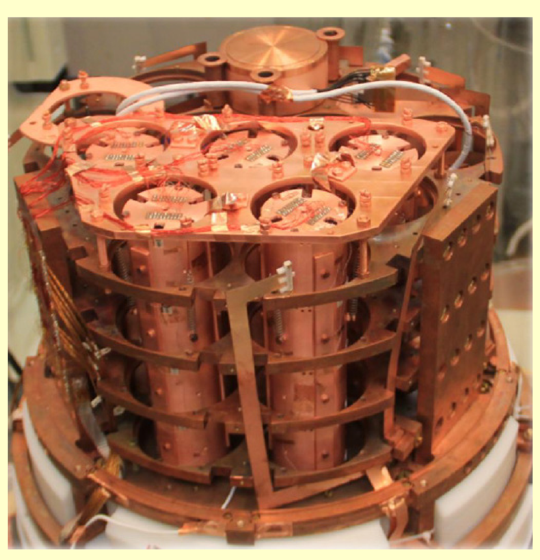
Light-detector-side view



Four modules per tower



Five suspended towers
4.16 kg crystals ⇒ 2.26 kg ^{100}Mo
(1.365×10^{25} ^{100}Mo nuclei)

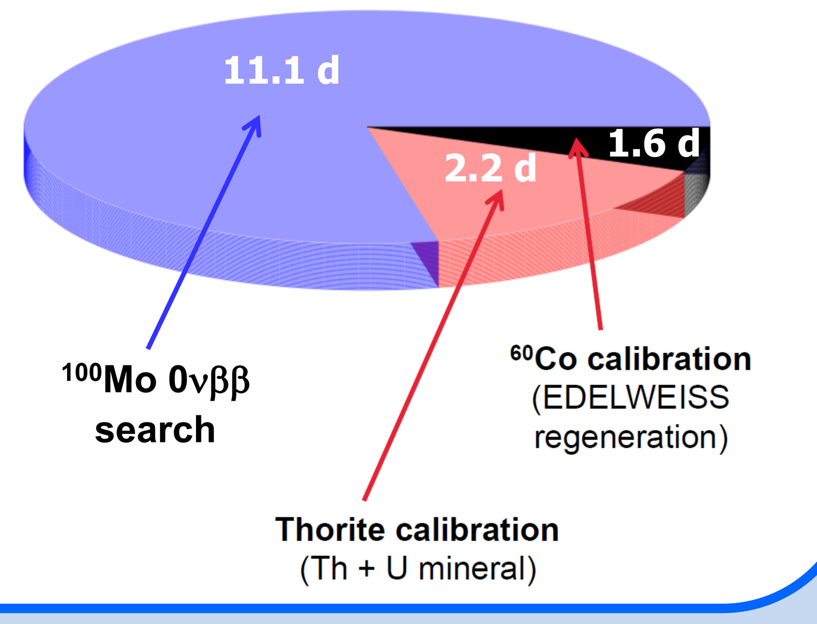


CUPID-Mo experiment in EDELWEISS-III set-up
Modane underground laboratory (France)

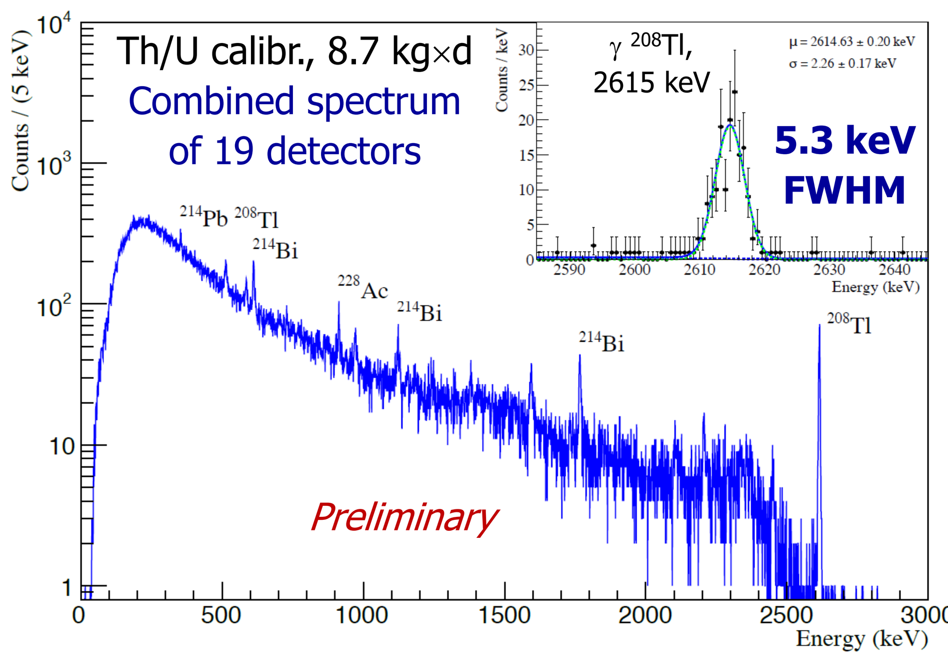
CUPID-Mo installation & operation

- **Assembly @CSNSM & @LAL**: Autumn 2018
- **Installation into the set-up @LSM**: January 2018
- **Delay due to cryogenic problems**: Spring 2018
- **First commissioning**: Summer 2018
- **Serious cryostat failure**: August 2018
  - long time to fix cryogenics issues
  - take advantage to improve LDs performance
- **Second commissioning**: Winter 2019
- **Continuous data taking at 20.7 mK**: since Spring 2019

First physics data set
from March 24th to April 6th, 2019

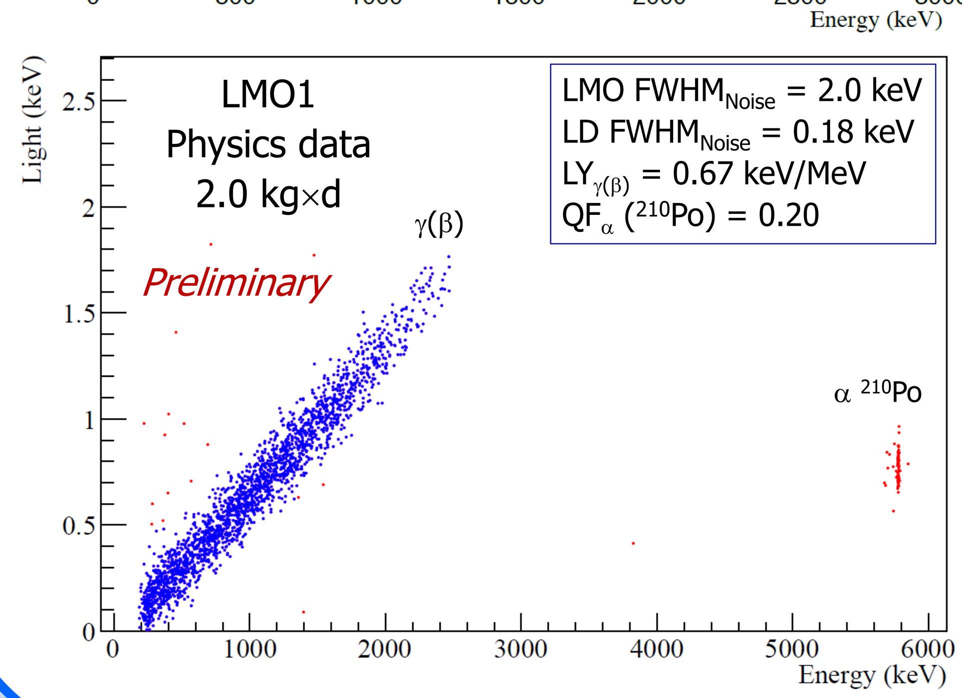


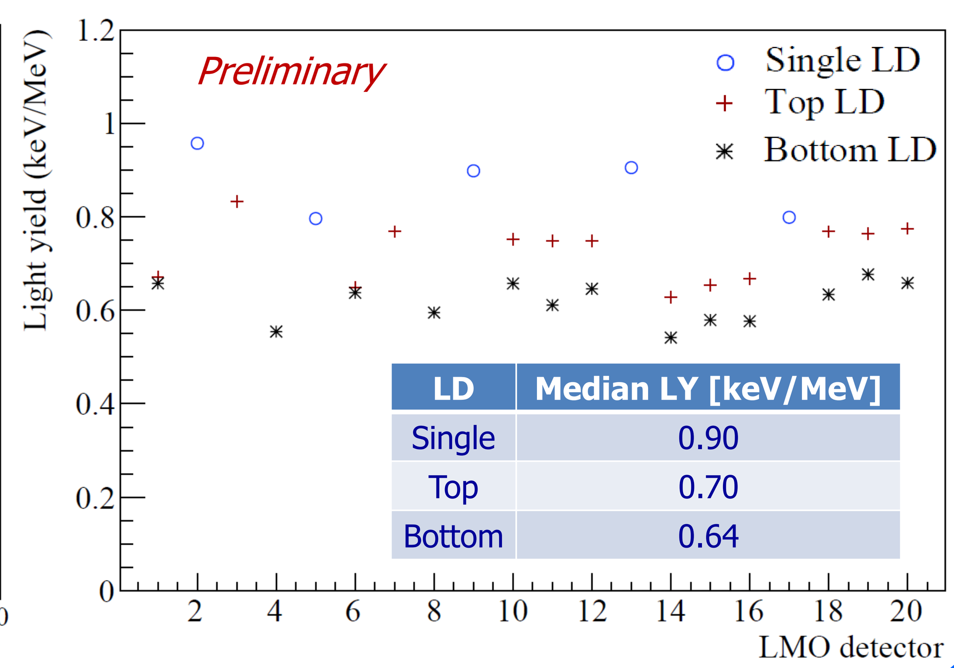
CUPID-Mo detector performance



Median parameters	20x LMO	19x LD
R_{NTD} [MΩ]	1.37	0.77
Rise time [ms]	24	4.2*
Decay time [ms]	297	9.2*
$FWHM_{Noise}$ [keV]	**1.97**	**0.15**
Signal [nV/keV]	17.5	1.1×10^3
$LY_{\gamma(\beta)}$ [keV/MeV]	**0.75**	
QF_α (^{210}Po)	0.20	
α/γ(β) separation around ^{100}Mo $Q_{\beta\beta}$	**15σ**	

* - affected by 0.5 kS/s sampling

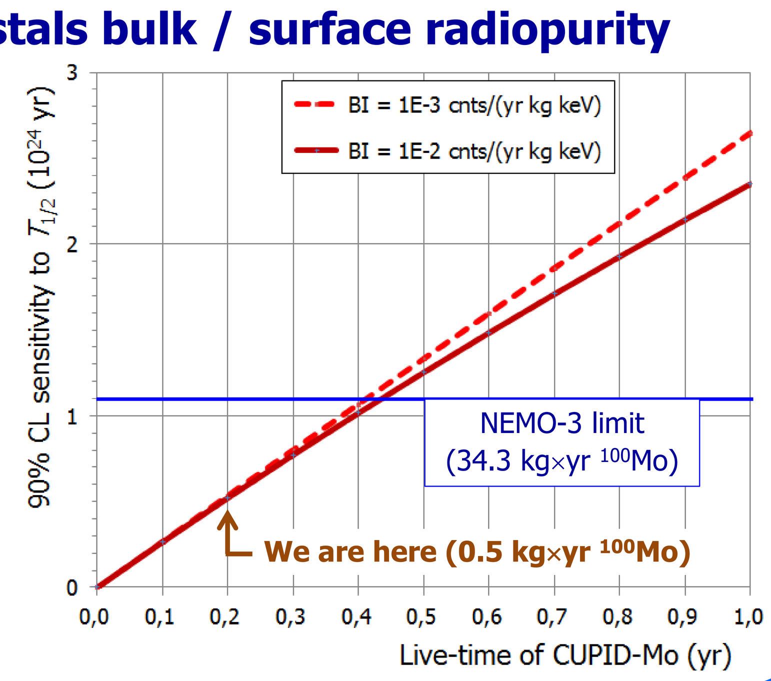




LD	Median LY [keV/MeV]
Single	0.90
Top	0.70
Bottom	0.64

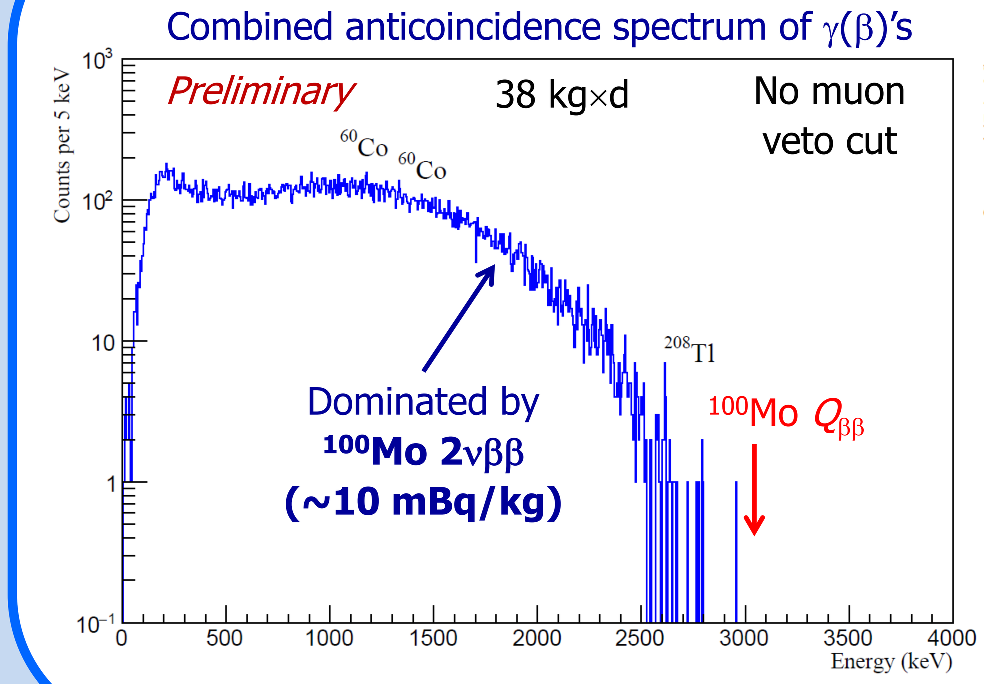
CUPID-Mo goals & prospects

- **At least six-months-long live-time measurements @LSM**
- **Investigation of $Li_2{}^{100}MoO_4$ crystals bulk / surface radiopurity**
- **New ^{100}Mo 0νββ half-life limit & improved 2νββ study**
- **Extension @LNGS or/& @LSC** (+new 26x 0.28-kg $Li_2{}^{100}MoO_4$)
- **Extensive demonstration of the $Li_2{}^{100}MoO_4$ scintillating bolometer technology, selected for CUPID project** (CUORE follow-up; a ton-scale 0νββ bolometric experiment)

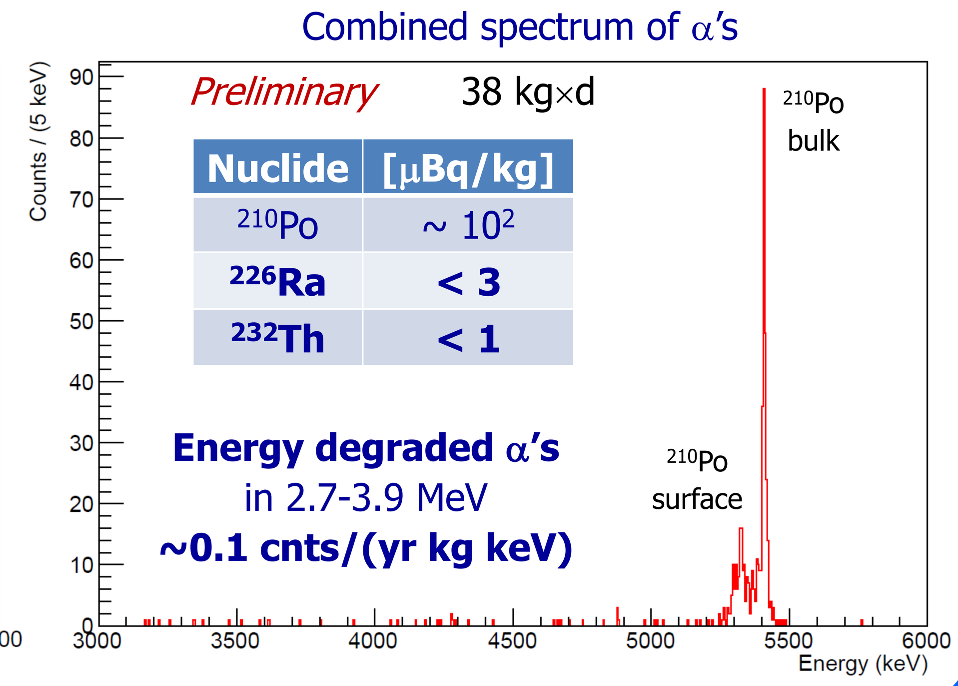


CUPID-Mo background

Combined anticoincidence spectrum of γ(β)'s



Combined spectrum of α's



Nuclide	[μBq/kg]
^{210}Po	~ 10^2
^{226}Ra	< 3
^{232}Th	< 1