Performance of the CUPID-Mo double-beta decay bolometric experiment

Denys Poda on behalf of the CUPID-Mo Collaboration

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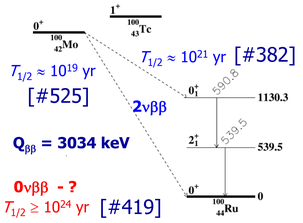
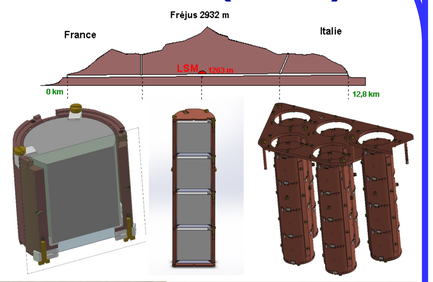
http://cupid-mo.mit.edu

7 countries, 15 institutions, ~110 collaborators

CUPID-Mo bolometric experiment:

^{100}Mo 0ν2β decay search @ LSM (France)

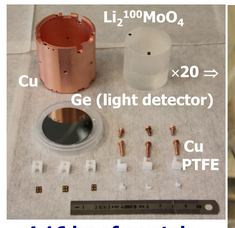




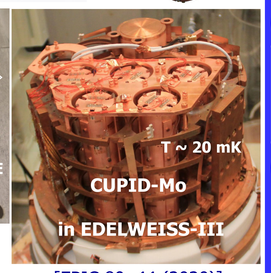
w/ 20 $Li_2{}^{100}MoO_4$ scintillating bolometers

(LUMINEU technology) [EPJC 77, 785 (2017)]

- 0.2-kg $Li_2{}^{100}MoO_4$ **crystals** (**^{100}Mo** enrichment **~ 97%**)
- ∅44×0.17-mm **Ge wafers** (w/ double-side SiO coating)
- **NTD Ge thermistors**, Si:P **heaters** (on LMOenr)
- **Cu** holders, **PTFE** supports, **reflecting film** (Vikuiti™)



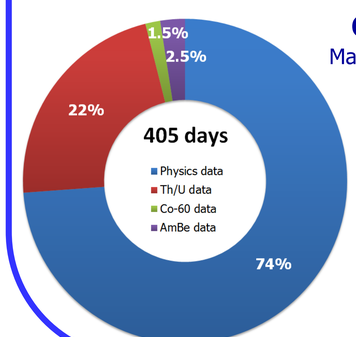
4.16 kg of crystals
2.26 kg of ^{100}Mo
(1.36×10^{25} ^{100}Mo nuclei)



[EPJC 80, 44 (2020)]
[JINST 12, P08010 (2017)]

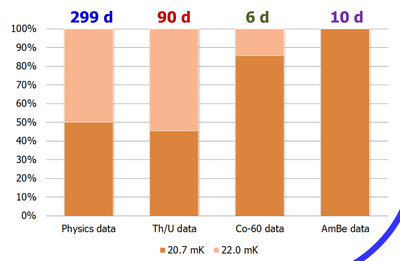
A brief history

- **Assembly @ CSNSM & LAL (IJCLab now)**: fall **2017**
- **Installation into the set-up @ LSM**: Jan. **2018**
- **Delay due to cryogenic problems**: spring **2018**
- **First commissioning at 20.5-22.0 mK**: summer **2018**
- **Serious cryostat failure**: Aug. **2018**
  Long time to fix cryogenics issues ⇒ LDs & contacts upgrade (fall 2018)
- **Second commissioning at 19.25-22.0 mK**: winter **2018/2019**
- **Physics data taking at 20.7 / 22.0 mK**: **since** Mar. / Nov. **2019**
  Notable interruptions: LHe refill and Th/U calibration (every ~10 days), neutron irradiation (Apr., Jun. 2019), partial warm-up (Mar., Oct., Dec. 2019), calibration with two ^{56}Co γ sources (120 Bq in total; June-July 2020 [#374])
- **Data blinding / unblinding**: Jun. **2019** / Jun. **2020**
  0.12 kg×yr data release (commissioning) [EPJC 80, 44 (2020)]
  0.51 kg×yr data release @ TAUP 2019 [JPCS 1468, 012129 (2020)]
  2.17 kg×yr data release @ Neutrino 2020 [#419]



CUPID-Mo data summary

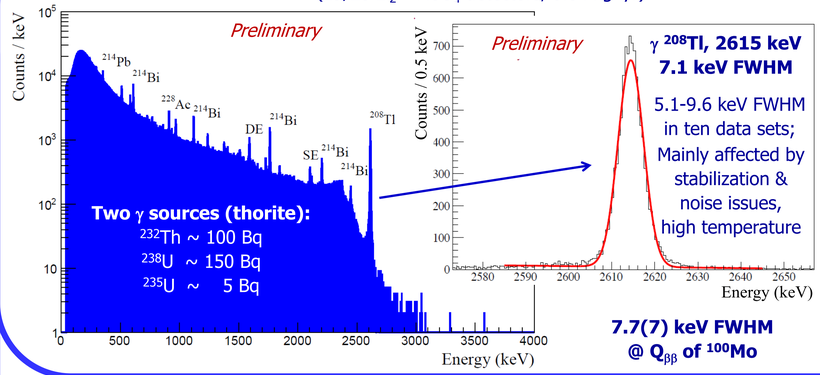
March, 2019 – June, 2020 (87% duty cycle)



Performance

γ Calibration with Th/U sources

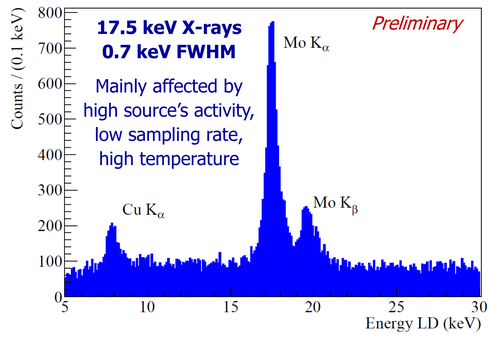
(19/20 $Li_2{}^{100}MoO_4$ detectors, 0.64 kg×yr)



7.7(7) keV FWHM @ $Q_{ββ}$ of ^{100}Mo

γ Ray induced X-ray calibration

(19/20 Ge light detectors, ^{60}Co ~100 kBq, 28 h)



Detector performance @ 20.7 mK

(similar results @ 22.0 mK)

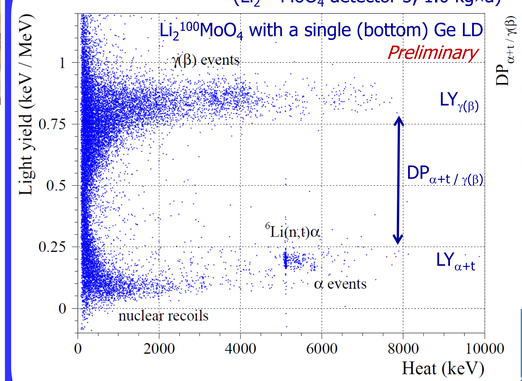
Parameter	Median value	
	20x $Li_2{}^{100}MoO_4$	19x Ge LD
R_{NTD} [MΩ]	1.4	0.8
Rise time [ms]	24	4 *
Decay time [ms]	300	9 *
$FWHM_{Noise}$ [keV]	**2.0**	**0.15**
Signal [nV/keV]	18	1100

* - affected by 500 S/s sampling rate

Particle ID

AmBe calibration [25 n/s]

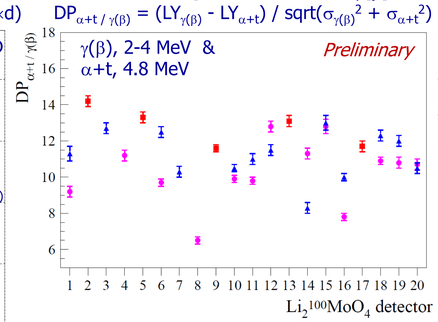
($Li_2{}^{100}MoO_4$ detector 5, 1.0 kg×d)



15 **$Li_2{}^{100}MoO_4$** are **viewed by two Ge LDs** each
⇒ **Enhanced particle ID** of surface events

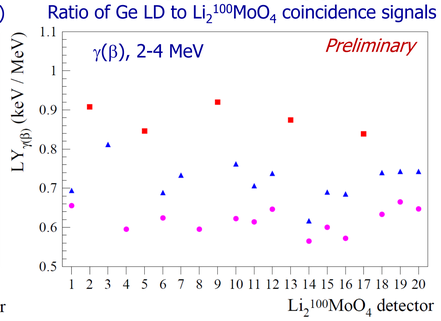
Discrimination power between γ(β) & α+t

$DP_{α+t / γ(β)} = (LY_{γ(β)} - LY_{α+t}) / sqrt(σ_{γ(β)}^2 + σ_{α+t}^2)$



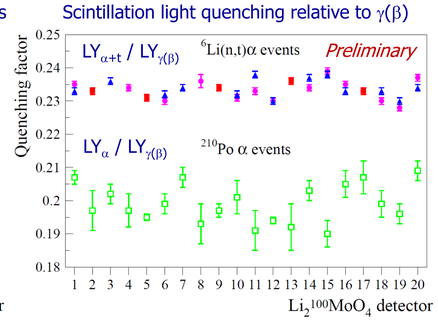
Light yield for γ(β)

Ratio of Ge LD to $Li_2{}^{100}MoO_4$ coincidence signals



Quenching factor: α+t vs. α

Scintillation light quenching relative to γ(β)



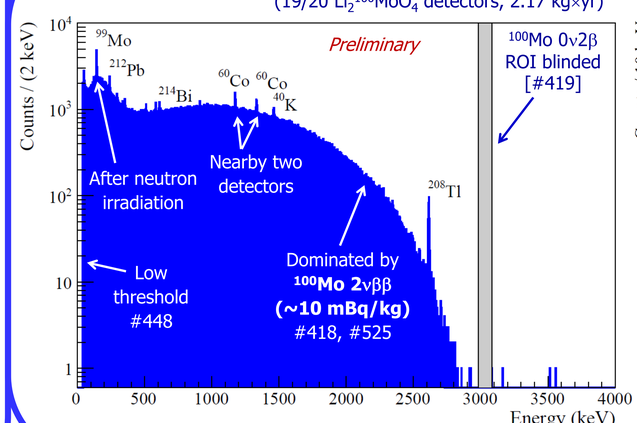
Parameter	Discrimination power $DP_{α+t/γ(β)}$			Light yield $LY_{γ(β)}$ [keV/MeV]				Quenching factor QF	
	Single LD	Top LD	Bottom LD	Single LD	Top LD	Bottom LD	2x LD	α+t (4.8 MeV)	α (5.4 MeV)
Median value	13.1	11.3	10.7	0.874	0.733	0.622	1.35	0.233	0.198

Lower $LY_{γ(β)}$ measured by bottom Ge LDs is due to a smaller ∅ entrance window (40 mm) of the Cu holder

Radiopurity

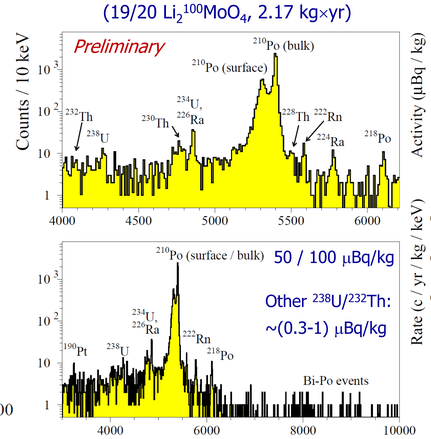
γ(β) Events

(19/20 $Li_2{}^{100}MoO_4$ detectors, 2.17 kg×yr)



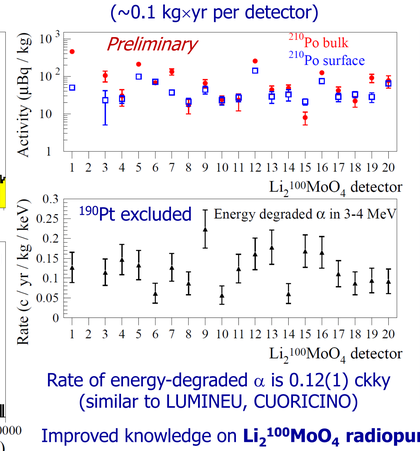
α Events

(19/20 $Li_2{}^{100}MoO_4$, 2.17 kg×yr)



^{210}Po & energy-degraded α events

(~0.1 kg×yr per detector)



Rate of energy-degraded α is 0.12(1) ckky
(similar to LUMINEU, CUORICINO)

Crystals bulk α activity

(19/20 $Li_2{}^{100}MoO_4$, 2.17 kg×yr)

Chain	Nuclide	Activity [μBq/kg]
^{232}Th	^{232}Th	0.22(9)
	^{228}Th	0.38(9)
	^{224}Ra	0.34(9)
	^{212}Bi	0.22(7)
^{238}U	^{238}U	0.35(10)
	^{234}U+^{226}Ra	1.22(17)
	^{230}Th	0.48(12)
	^{222}Rn	0.47(10)
	^{218}Po	0.35(9)
	^{210}Po	95(6)
	^{190}Pt	0.19(8)

Improved knowledge on **$Li_2{}^{100}MoO_4$ radiopurity** (U/Th, but ^{210}Po) to **sub μBq/kg**

More about CUPID-Mo posters @ Neutrino 2020

#374 (M. Zarytsky) **#382** (T. Dixon) **#418** (P. Loaiza) **#419** (B. Schmidt) **#448** (B. Welliver) **#525** (V. Singh)

Poster #404