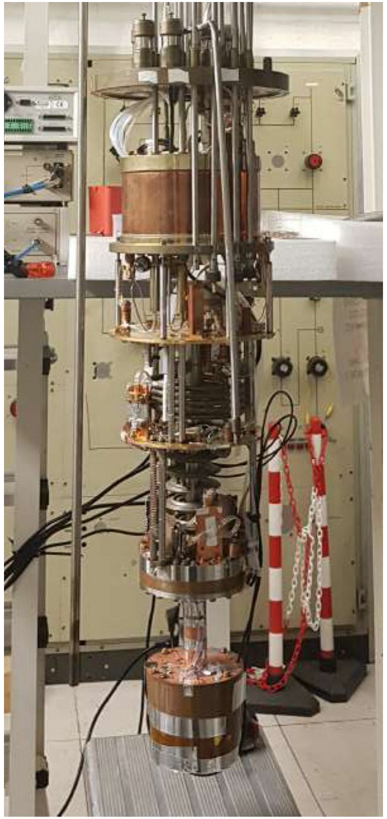
Impact of Al coating on LMO calorimeters

Studies @ Cryogenic facility in Milano-Bicocca

COLD meeting – Milano-Bicocca, 20 November 2023

Cryogenic facility @ Milano-Bicocca (aka "meno3")



Cryogenic system

- Oxford TL-200 (1987)
- wet cryostat
- no He liquefier
- above ground (-3 floor)
- ext. Pb shield
- optical fibers ongoing...

MC stage

- experim. V: 200-350 cm^3
- lowest T: ~13 mK
- Noise Thermometer

Runs

- about 2 weeks
- limited by LHe supply

Detector readout

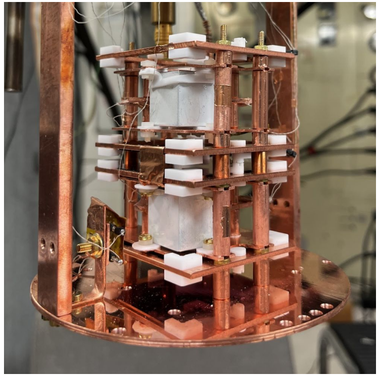
- 2 fischers (12 + 9 channels)
  - CUORE-like front-end boards (bias & ampl)
  - CUPID Bessel & DAQ boards

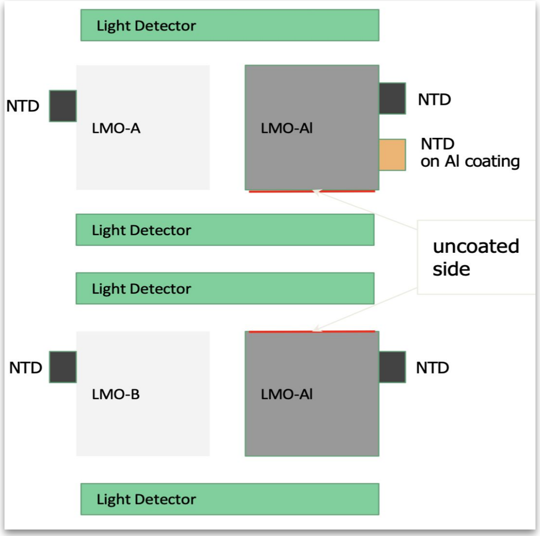
Auxiliary devices

- 1 fischer (9 channels)
  - heaters
  - diagnostic
    - NTDs (40-A, AVS bridge)
  - LEDs

Run March 2023 @ MiB

- Logistics
  - leak prevented cooldown (solved in Dec-2022)
  - LHe supply issues in Jan/Feb-2023
  - Run started at the beginning of March 2023
- Detector setup
  - LMOs + Ge LDs + other detectors
- Goals
  - CUPID
    - compare LY for LMOs w/wout coating
  - COLD
    - effect of coating on LMO
      - intrinsic gain (sensitivity)
      - pulse shape parameters
    - effect of the coating on light collection on the LD
    - general effect of coating on PS
      - basic assumptions on thermal model
      - NTD on Al coating / NTD direct contact





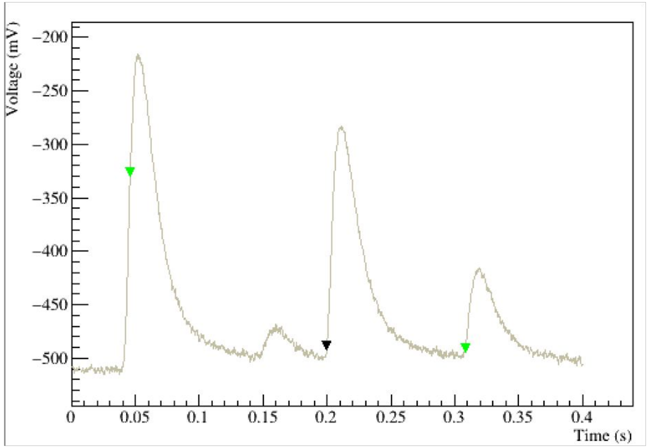
Run March 2023 @ MiB

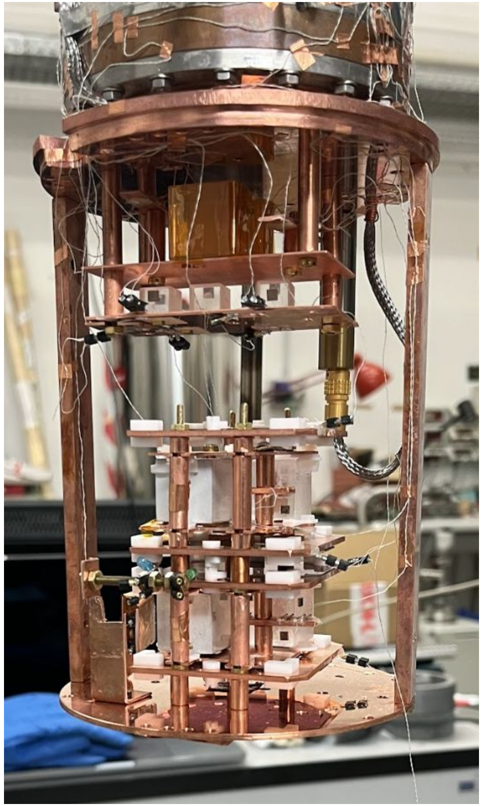
Calibration sources:

- Superficial alfa source Ra-224 (half-life 3.6d) faced to the LMOs (also used for thermal gain stabilization)
- Fe-55 facing LDs
- External Th-232 only for calibration runs

The alfa source rate was high

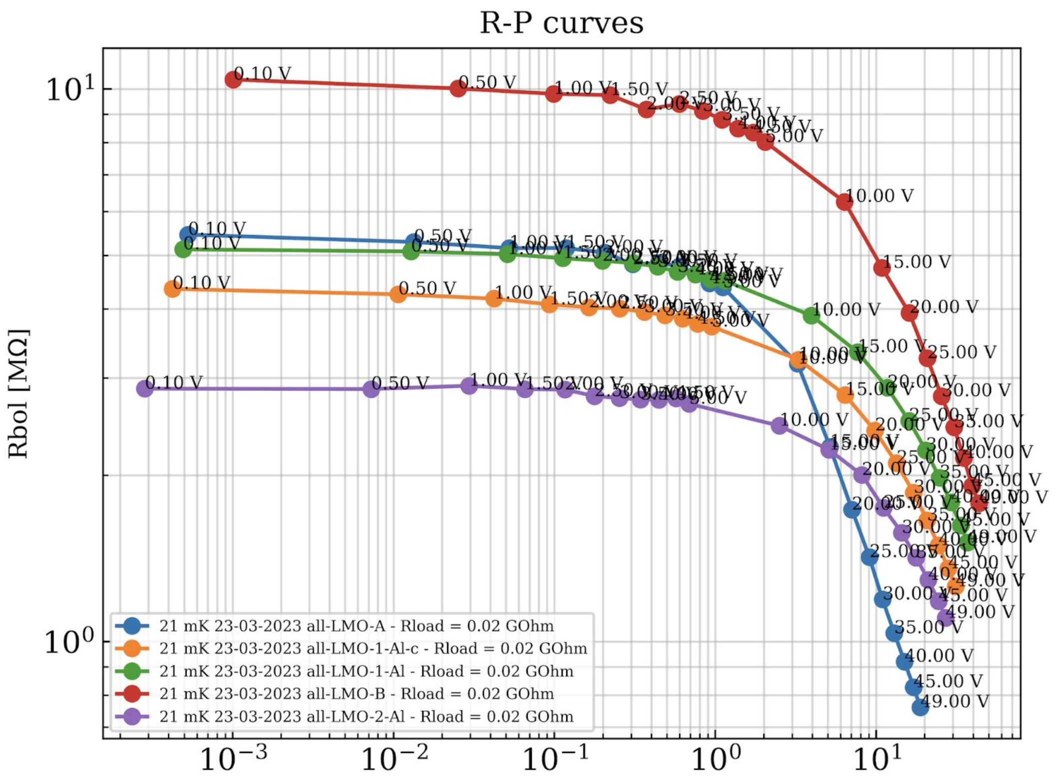
Pile-up limited the performances of the LMOs and lowered the available statistics





Light Detectors: the noise level was too high and no light signal coming from the crystals was seen. The comparison of the light collection efficiency between the bare and the Al-coated crystals was not made.

Load curves @ Noise Therm temp 21 mK



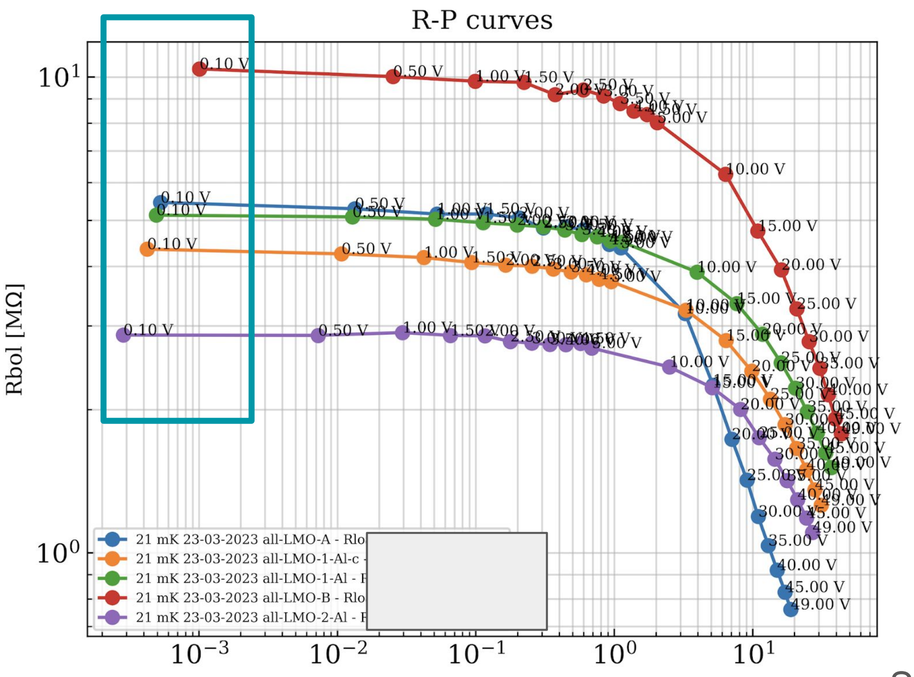
LMO A
LMO B

LMO-1-Al
LMO-1-Al-c
LMO-2-Al

From the slope of the LC at higher power the conductance to the bath of the uncoated xtals seem to be different from the bare one

Data taking for characterization and Working Point

Ohmic working point to avoid non-linear effects in the response



5 kHz sampling frequency

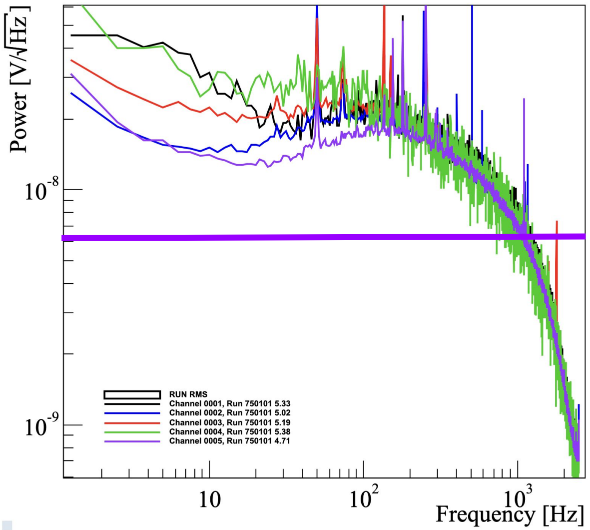
1 kHz bessel cut-off

LMO	Bias [V]	R Load [GOhm]	Gain	Base R [MOhm]
A (bare)	0.1	10	10300	5.3
B (bare)	0.1	10	10300	10
Al-1	0.1	10	10300	5
Al-1-c	0.1	10	10300	4
Al-2	0.1	10	10300	3

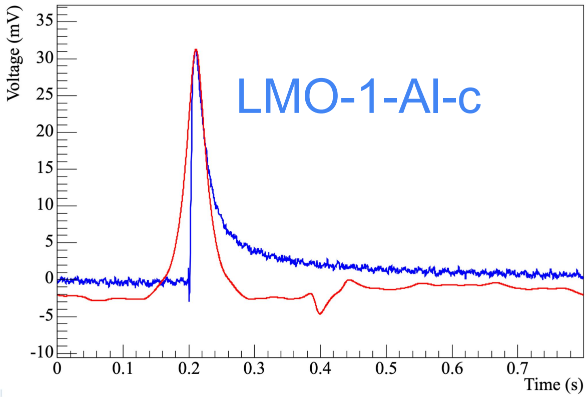
Study the ‘ideal’ pulse shape, despite a reduced sensitivity

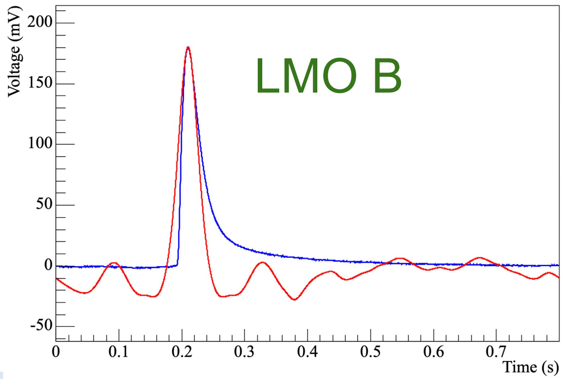
Optimum Filter

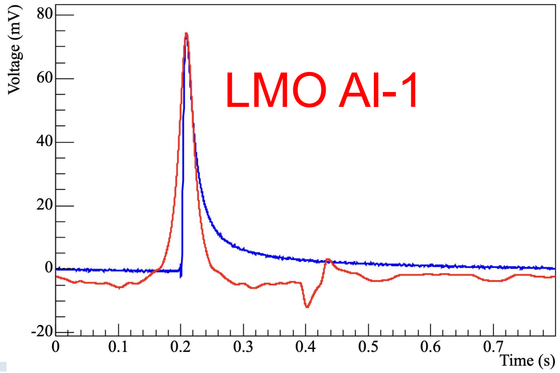
Similar noise level for all the LMOs



LMO A
LMO-1-Al-c
LMO Al-1
LMO B
LMO Al-2







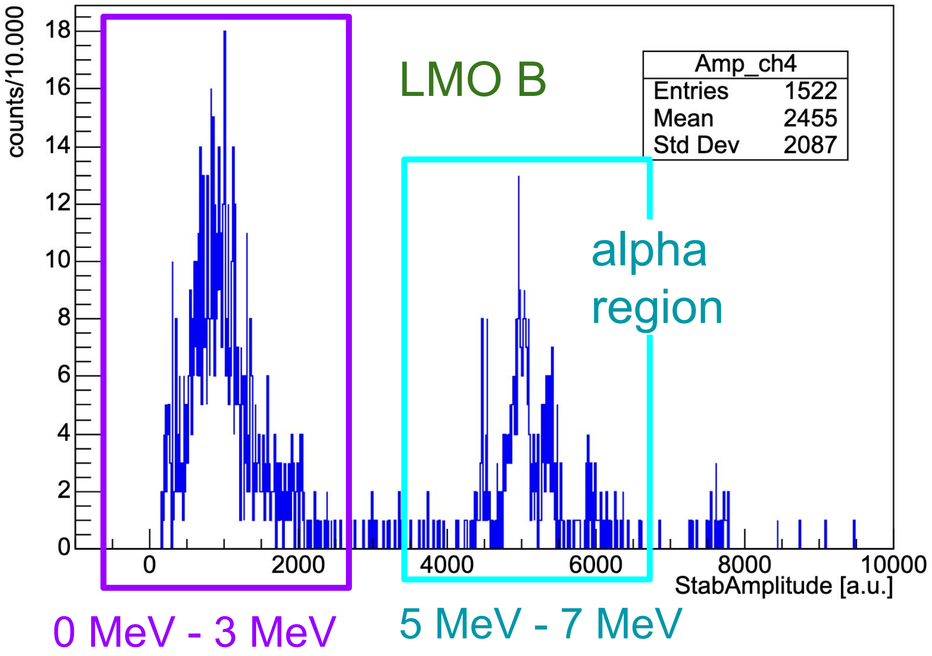
Stabilized spectra bare vs Al coated

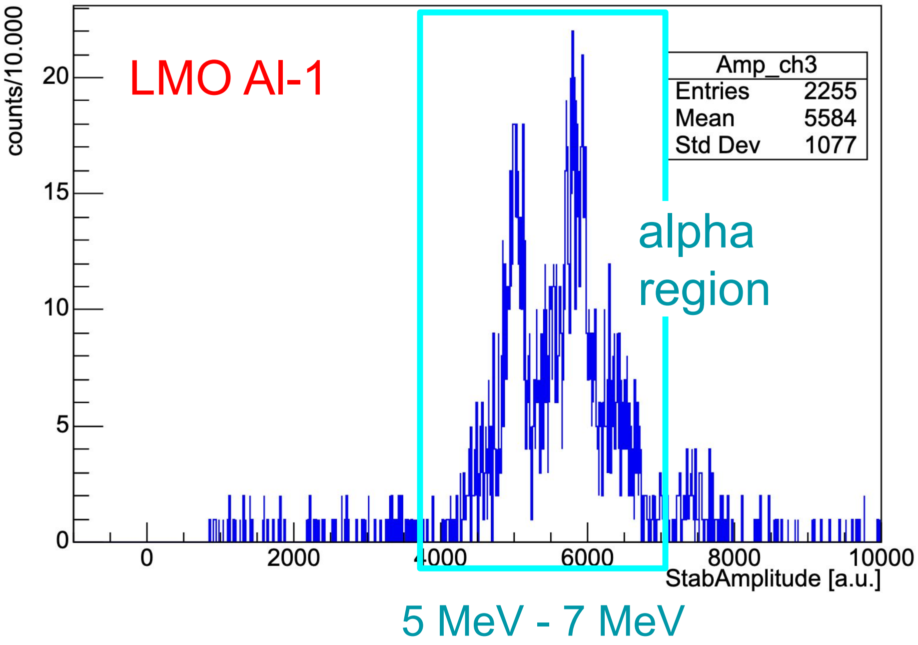
the resolution is worsened by pileup

the statistics is low due to pileup

beta/gamma region under threshold

overall worse resolution

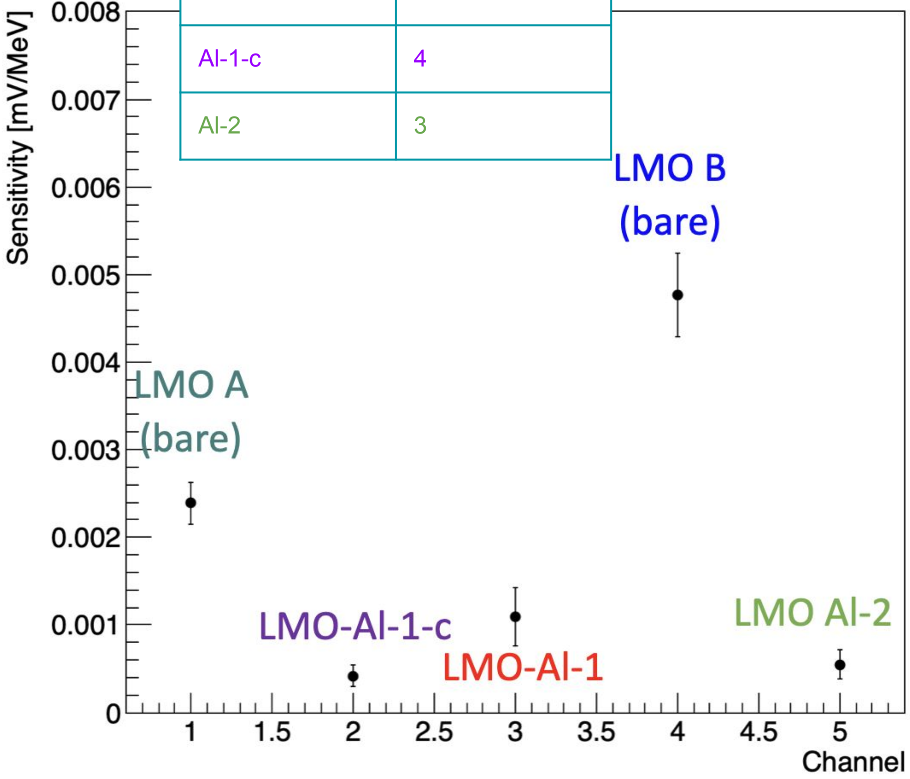




Sensitivity

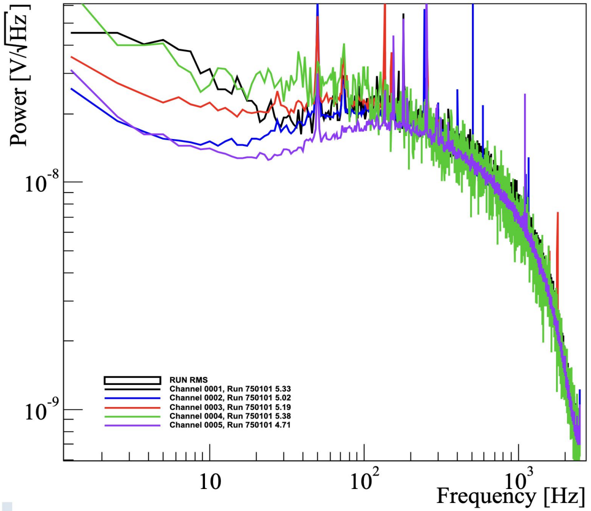
- estimated on alpha region (same type of particle, similar energy range)
- normalized by FE gain
- estimated by using centroid of the unstabilized alpha peaks in the filtered pulse amplitude vs baseline plot
- the comparison is more meaningful for the detectors with similar base resistance

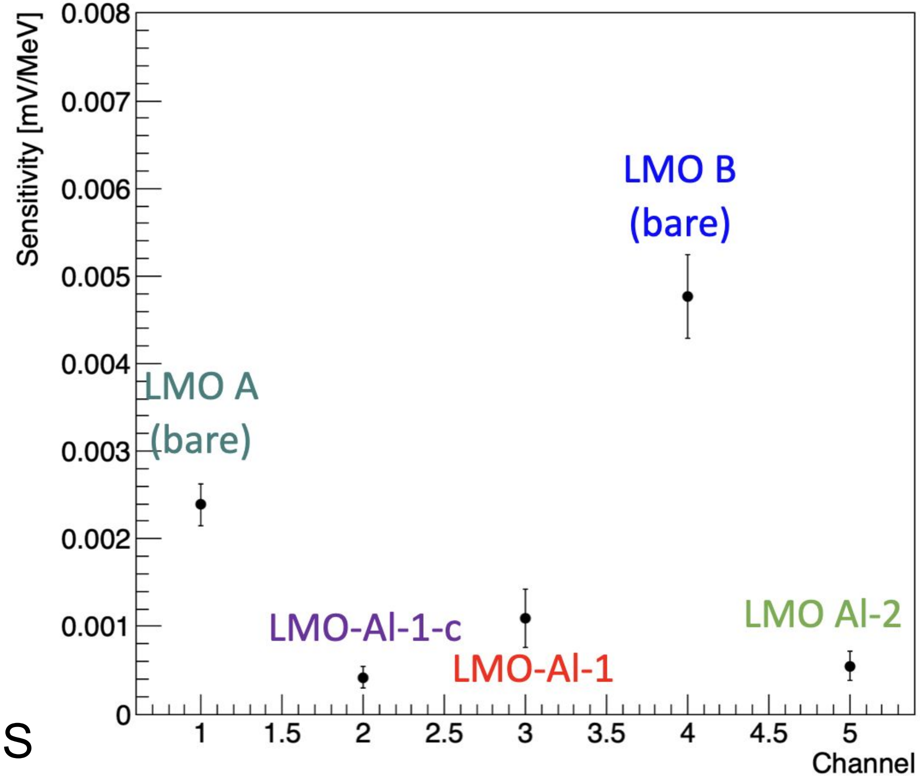
LMO	Base R [MOhm]
A (bare)	5.3
B (bare)	10
Al-1	5
Al-1-c	4
Al-2	3



The Al-coated crystals show overall lower sensitivity than bare crystals.

Sensitivity - impact on the energy resolution





Worse resolution → Lower S/N

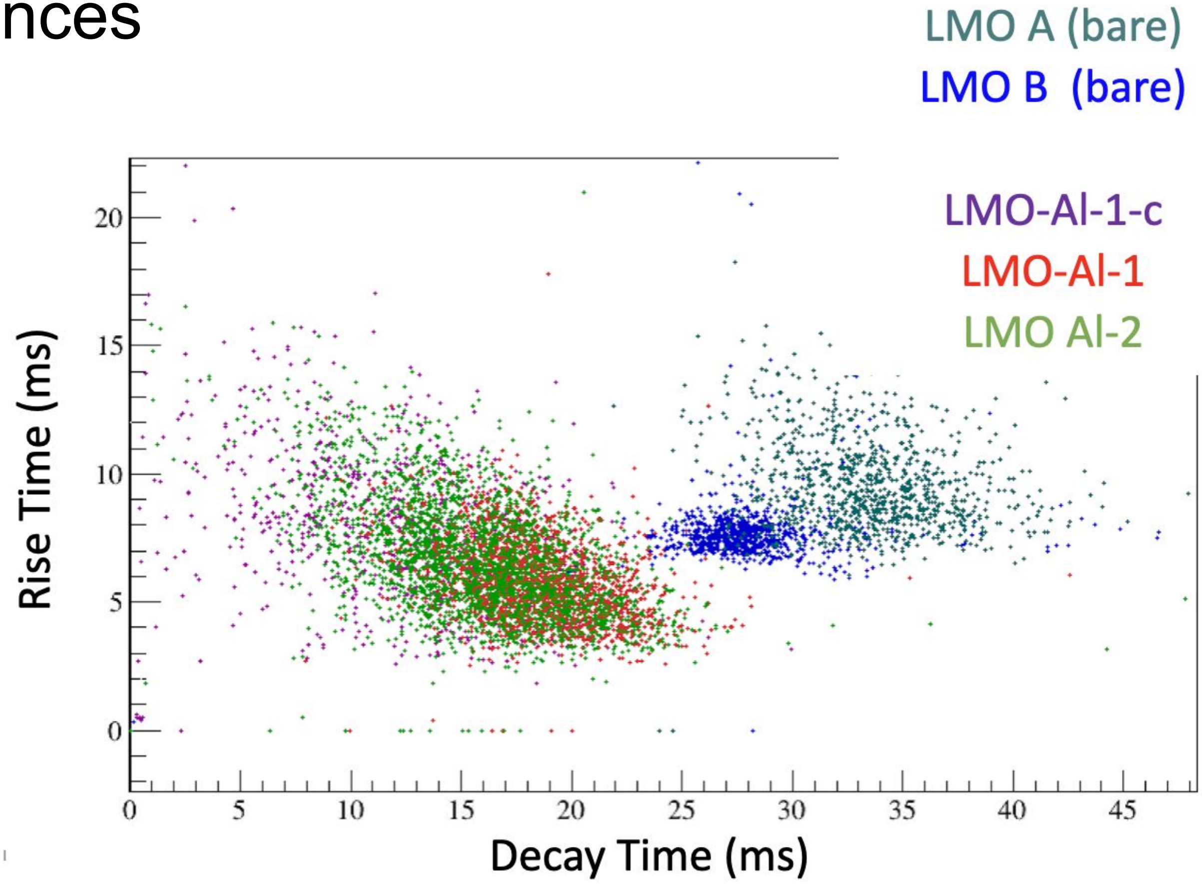
↓

Similar N → Lower S

Pulse shape differences

The **Al-coated crystals** show an overall **shorter decay-time** than the bare crystals

The **rise time is similar** between the two



Conclusions and results of the analysis

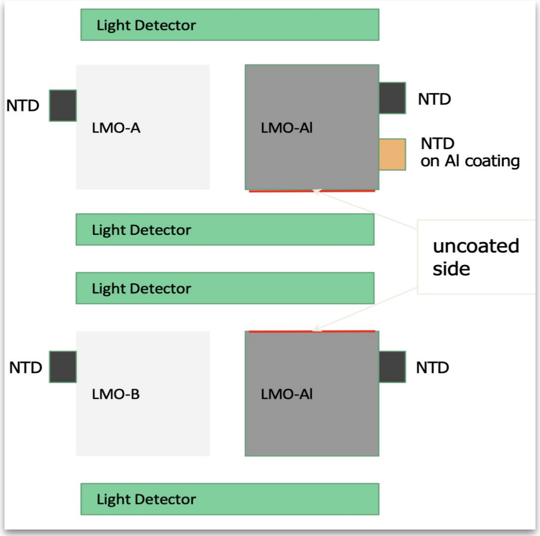
- Comparison between light collection efficiency on the LD is still an open point

- The overall performances of the Al-coated crystals is worse
  - Worse energy resolution (lower S/N)
  - Lower intrinsic gain (sensitivity)

- There are evident pulse shape differences
  - Al-coated crystals have lower decay time

Next run @ MiB

Run March 2023



Next run (Jan 2024?)

- Each LMO has 2 NTDs
- 2 LD
- 1 coated LMOs (NTDs 39-D) [4 total channels]:
  - 1 NTD on Al coating
  - 1 NTD directly on crystal
- 1 coated LMOs (NTDs 39-D) [4 total channels]:
  - 2 NTD on Al coating
- 2 uncoated LMOs:
  - 2 NTD glued with Araldite

Discussion:
open points and possible interpretations

How to treat the Al coating?

Coating: a new ingredient in the thermal model

If the coating can be treated as a superconductor (expected behavior for Al):

1. T_{critic}(Al) = 1.2 K → specific heat @ 10 mK **dominated by lattice term**
   - small impact on total C of Al coating (negligible mass)
2. If coated side connected to support frame → affect link to the thermal bath
   - (superconducting) Al @ $T<T_{critic}/10$ ~ **thermal insulator**

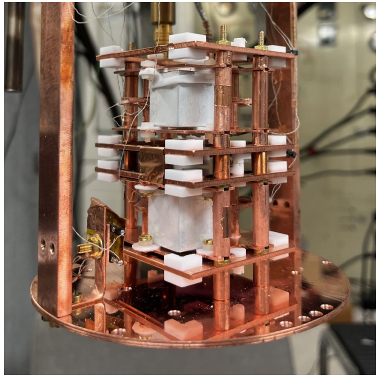
=> Al coating should not have evident effect on system's thermal response
… *however*, contributions from 1. + 2. difficult to formulate

- new thermal nodes could impact signal shape (total C → pulse height / C/G → t_{decay})
- impact on the sensitivity if the signal is not integrated purely on the NTD:
  - Al could absorb some of the phonons which goes into loger state excitations
  - Al could provide a secondary (dead) channel to integrate the signal amplitude

Moreover:

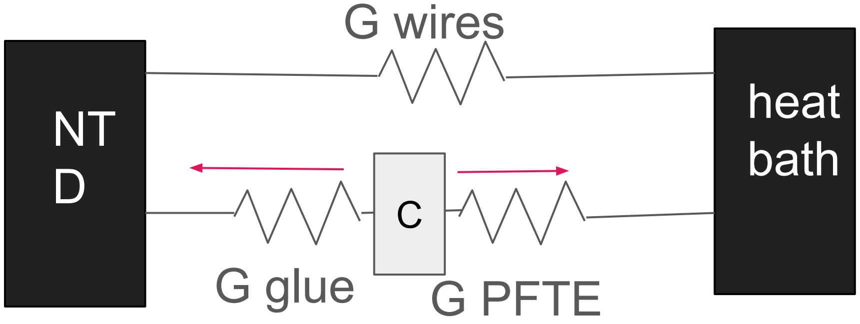
- Phonons can be absorbed breaking cooper pairs in the superconducting Al layer lowering the signal amplitude

How the coating could impact the pulse shape?

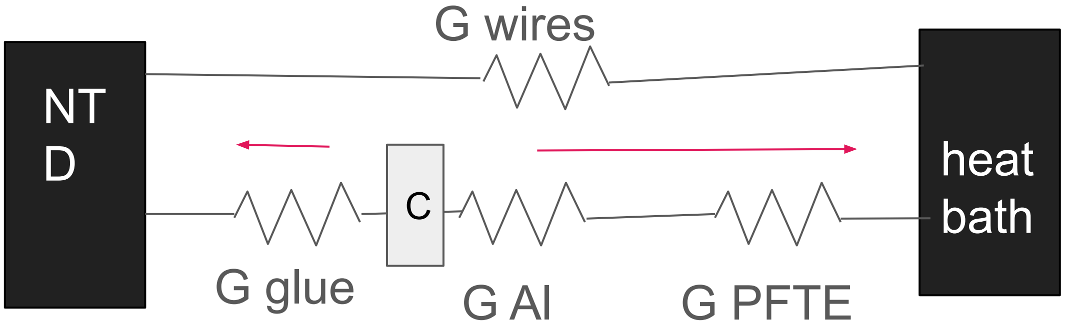


From the NTD point of view:

without coating:



with coating and NTD on crystal:



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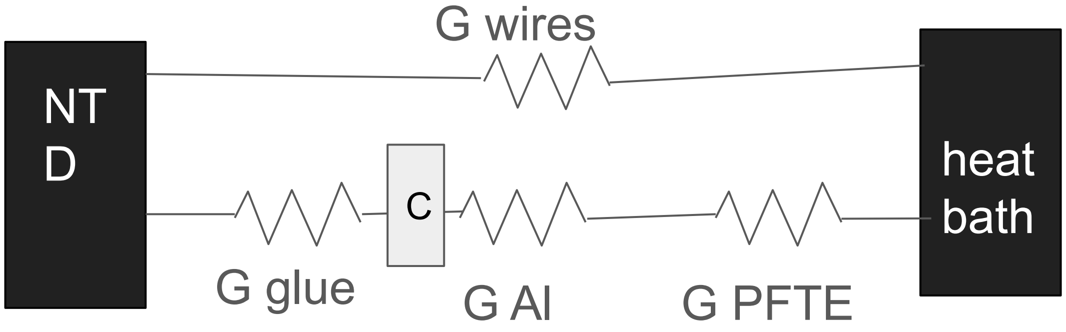

with coating and NTD on crystal: