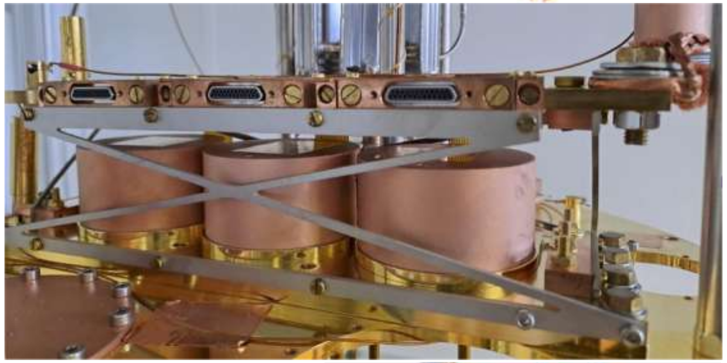
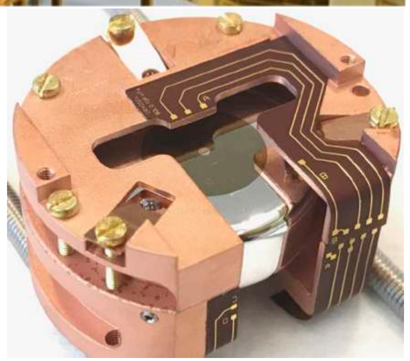
Low Energy Excess studies with CRYOSEL and RICOCHET detectors





Two discrimination techniques to reject events with no ionization

RICOCHET: charge measurement with a 1K HEMT preamplifier

EPJC 84 (2024) 186: arXiv : 2306.00166

EDELWEISS CRYOSEL: Tagging Neganov-Luke-Trofimov phonons

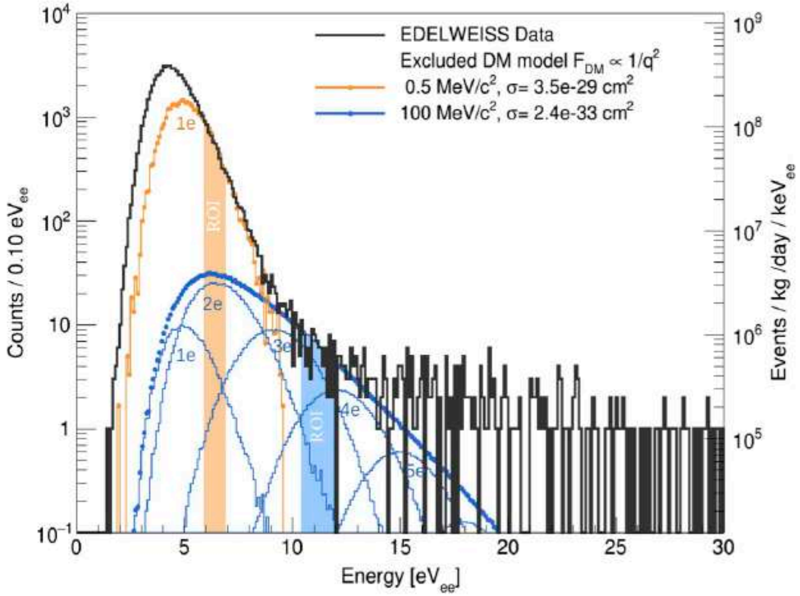
JTLP 215 (2024) 268 : arXiv:2311.01554

J. Gascon
IP2I (Lyon1 + CNRS/IN2P3)

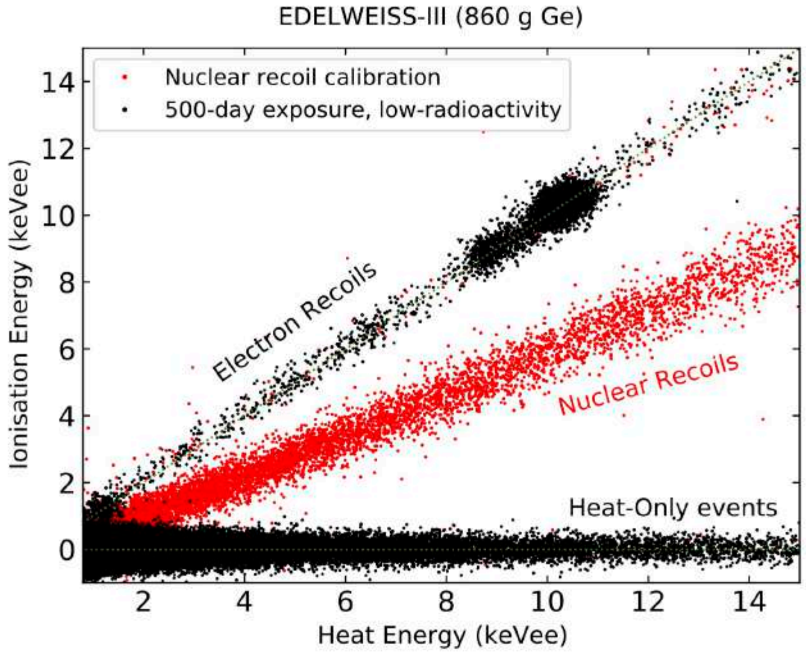
"Heat-Only" bkgs in cryogenic Ge detectors

- Main LEE in EDELWEISS 800g Ge heat-and-ionization detectors with Ge-NTD heat sensor

- Also for few-electron signal searches with 33g and 200g NTL-boosted Ge detectors



PRL 125 (2020) 141301 : arXiv:2003.01046



⟶ Charge identification essential to understand and reject LEE backgroundds

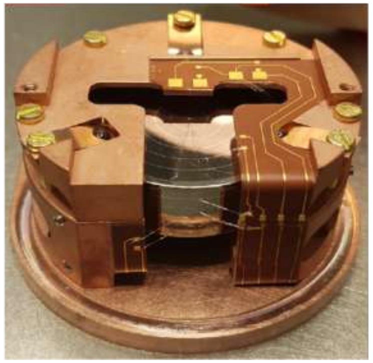
New Ge detectors for low energy searches

New detector designs evolved from EDELWEISS:

NbSi209 :

PRD 108 (2023) 022006 : arXiv:2303.02067

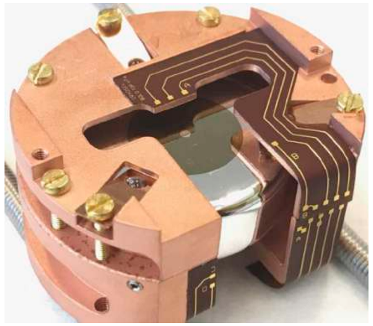
- 200g Ge + NbSi TES (instead of Ge-NTD), keeping EDELWEISS JFET ionization readout (σ ~ 200 eVee)



RICOCHET CryoCube:

EPJC 84 (2024) 186: arXiv:2306.00166

- 38g detector with Ge-NTD phonon sensor with 1-K HEMT charge readout (σ= 31 eV_{ee} achieved), for CENNS measurement



CRYOSEL

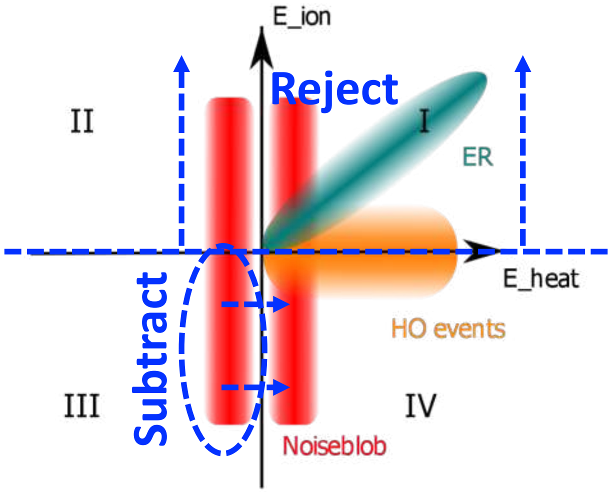
JTLP 215 (2024) 268 : arXiv:2311.01554

- 38g detector with Ge-NTD phonon sensor with NTL boost and a charge tag using NbSi film as SSED (Superconducting Single-Electron Device)

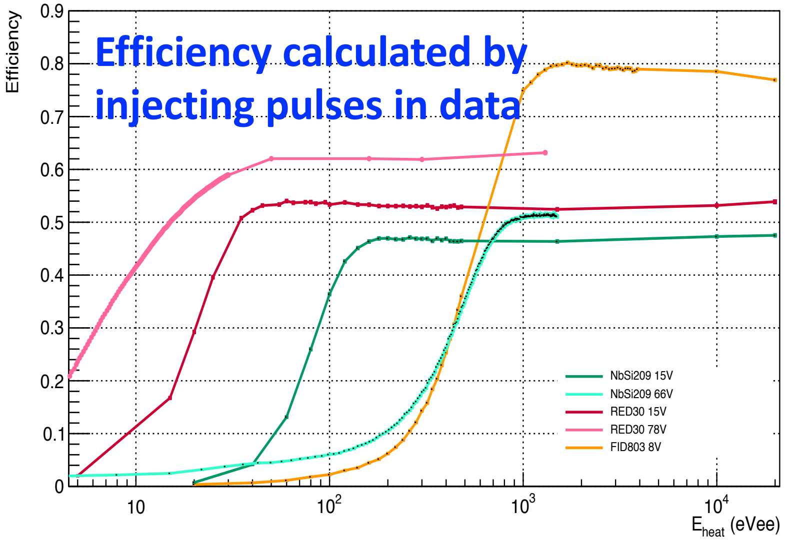
Low Energy Excess = Heat-Only?

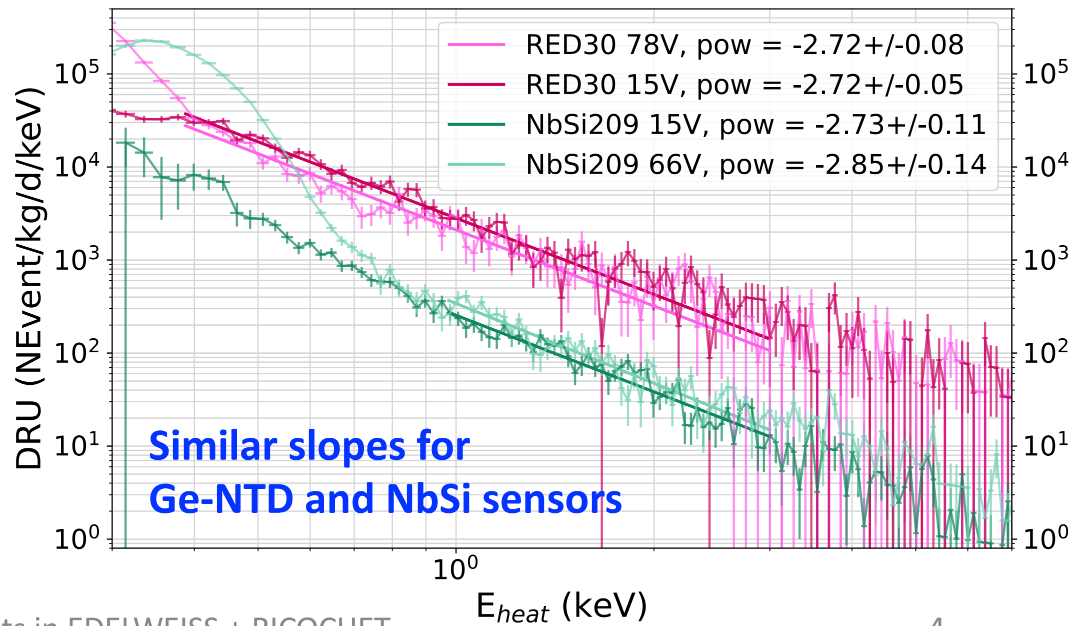
- With σ=200 eV_{ee} ionization of EDELWEISS electronics, test of "heat-only" nature of events limited to ~1 keV_{ee}
- Comparison of HV/LV spectra
- Test of HO nature down to 15 eV_{ee} in RED30 (33g, 78V) and 35 eV_{ee} in NbSi209 (200g, 66V)

Below this: limited by noise blob from electronics



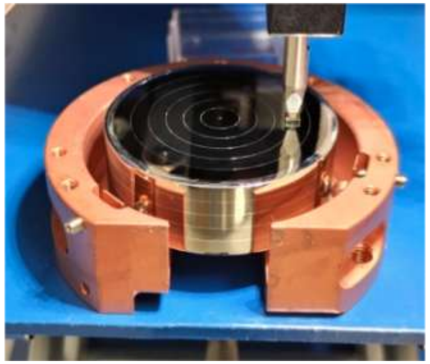
E. Guy, PhD thesis



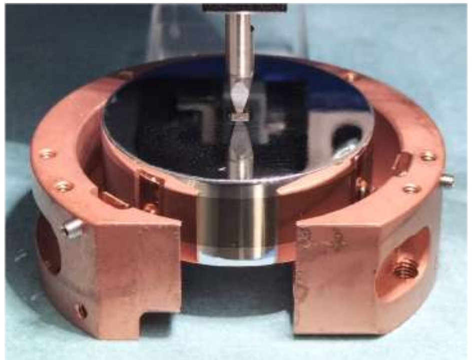


Ground-level measurements of HO in 38g Ge

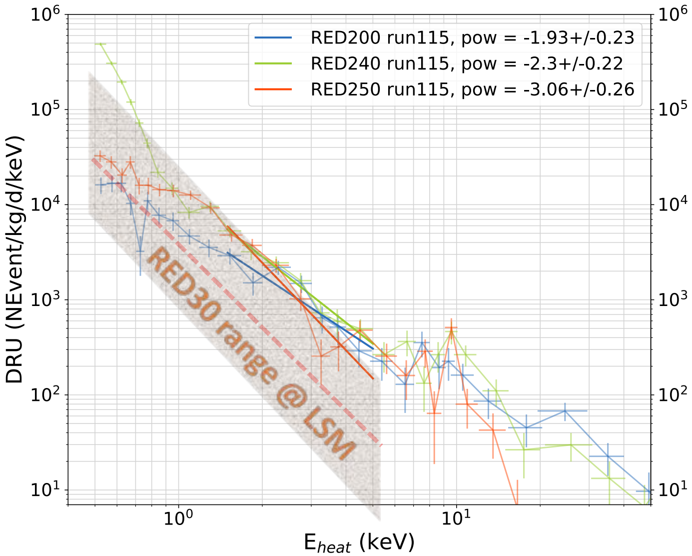
- Test of HO rate at *ground-level* (Lyon) in 38g Ge RICOCHET detectors, using EDELWEISS electronics (σ_{ion}~200 eV_{ee})
- Differences wrt LSM: reduced shielding, cosmic rays, differences in electrode schemes
- *Large variations, but overall consistent with LSM 33 g (given known time-dependence of HO rates)*



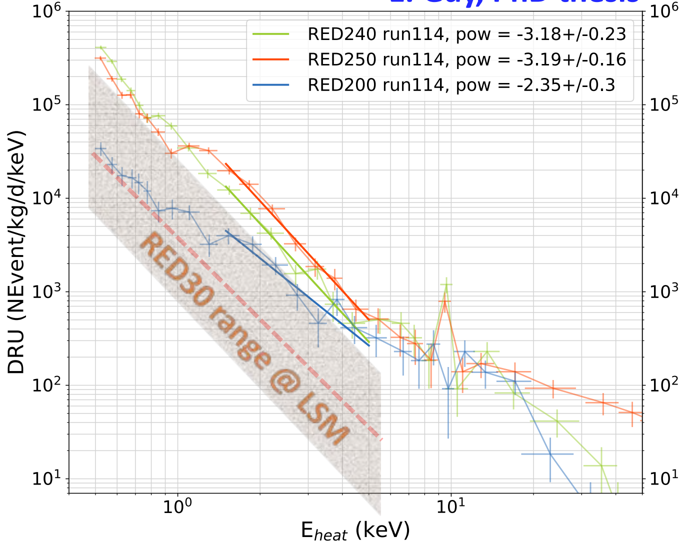
RED200: 38 g, FID electrodes



RED240 + 250: 38 g, planar electrodes



E. Guy, PhD thesis



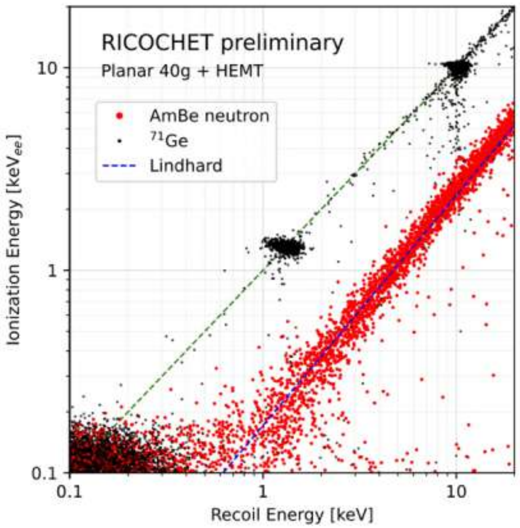
HO event rates above ground are not a show-stopper

Measurements in low-background environment of ILL and HEMT readout to come soon!

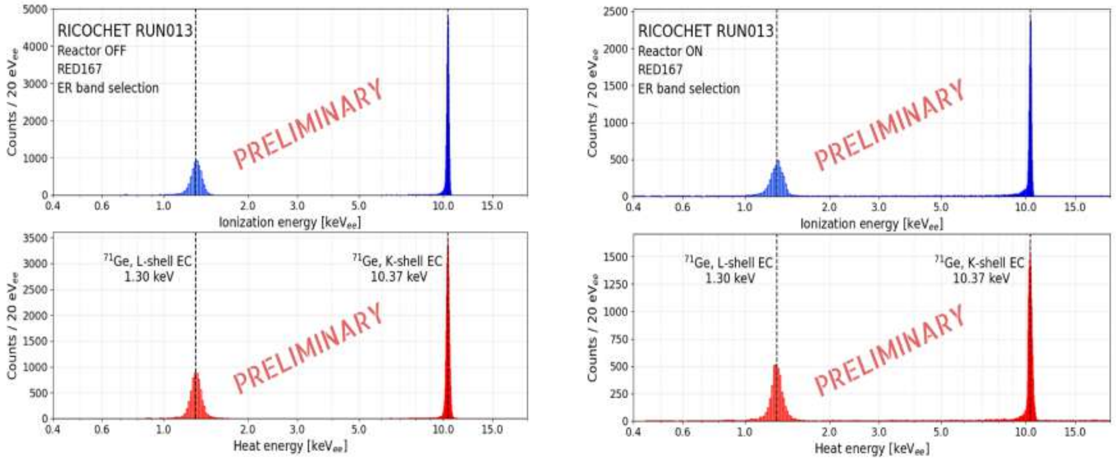
RICOCHET Commissioning

V. Novati, Neutrino 2024
N. Martini, Magnificent CENNS 2024

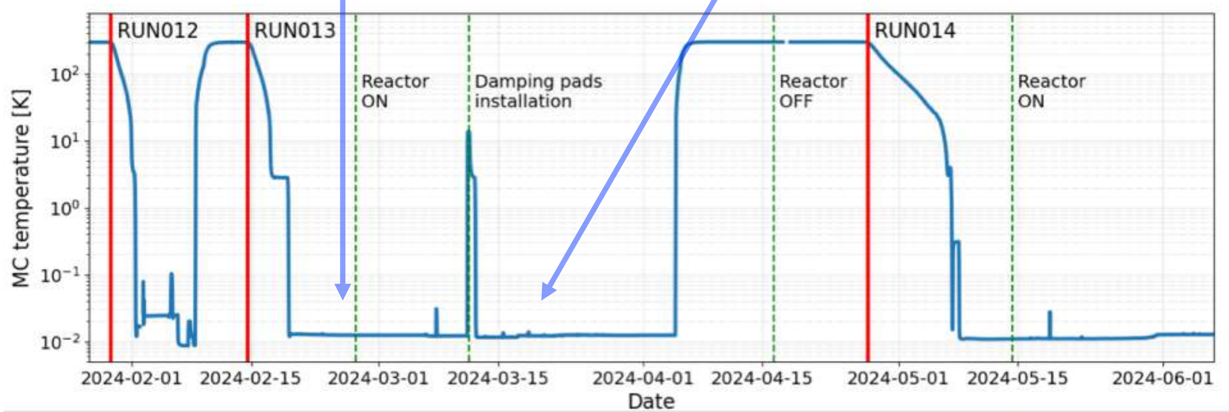
2023-07: cryostat and HEMT commissioning @Lyon



2024: Commissioning @ ILL started!



^{71}Ge Calibration reactor OFF **^{71}Ge Calibration reactor ON**



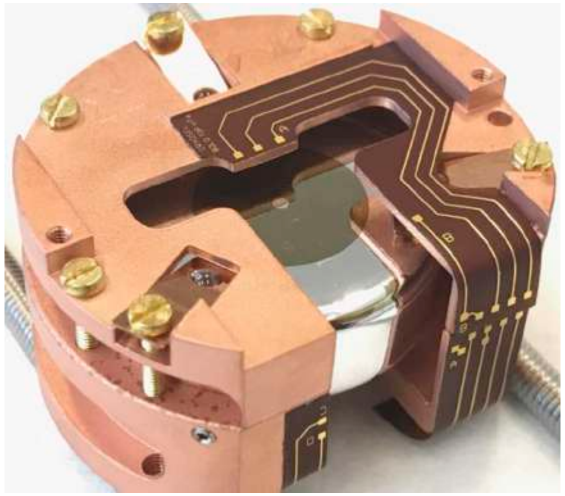
RUN012: Validation of cryogenics (8.6 mK)

RUN013: Detector performance assessment (ON/OFF) and vibration mitigation

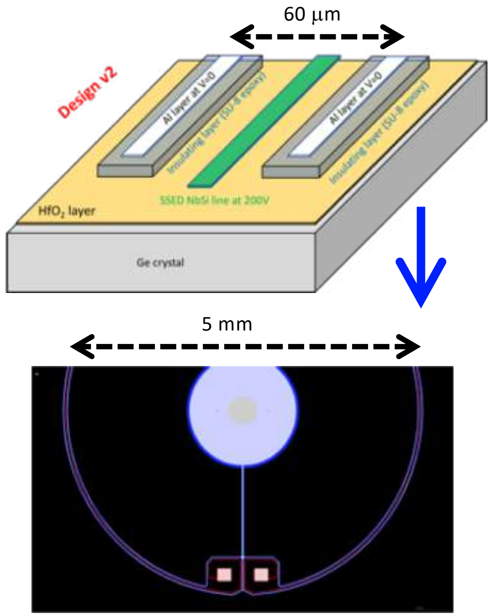
RUN014: Background characterization with full shielding

CRYOSEL concept : thermal + athermal

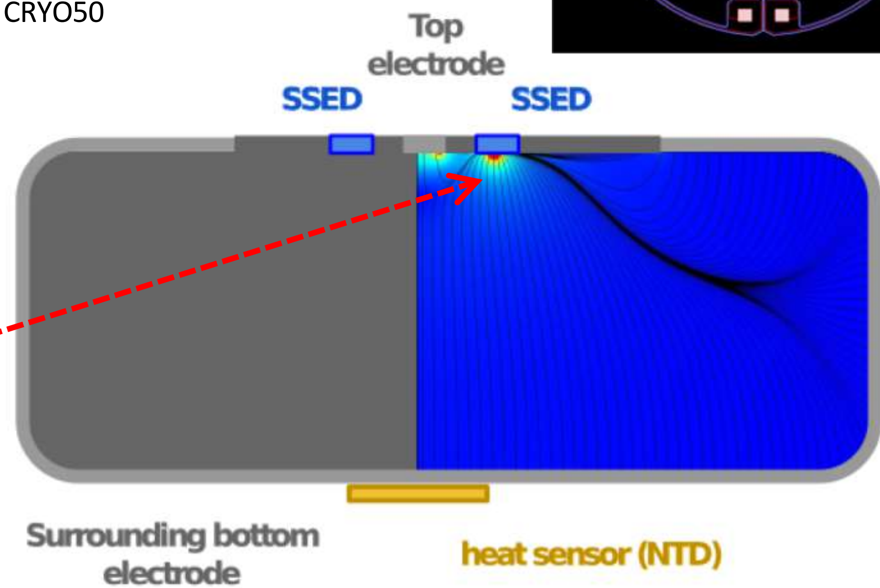
- 40 g Ge crystal
- Phonon sensor = single NbSi strip (10 μm wide) forming a 5 mm-wide circle
- Use this small film as Point-Contact-like electrode of HV detector
- NTD glued on large enveloping electrode (high-resolution NTL-amplified heat measurement)
- NbSi operated as SSED (Superconducting Single-Electron Detector)
- *Detector kept well below T_c : SSED only triggered by large bursts of primary NTL phonons from high-field region just in front of it*
- *Most HO will not trigger SSED*



CRYO50



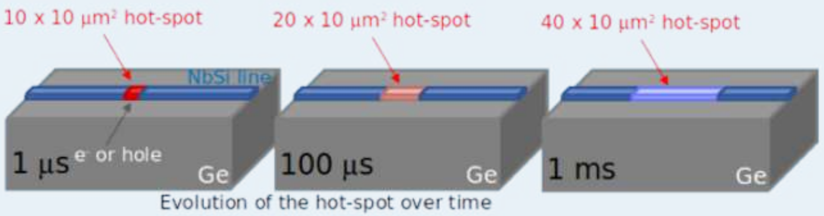
SSED



SSED pulse shape

- CRYO50 prototype, T_c = 46 mK
- 60V, T=15 mK (well below T_c)
- Pulses selected from NTD signal for 59.5 keV ^{241}Am γ
- Slow thermal response of NTD
- Faster transition in part of SSED, followed by quick (<1ms) disappearance of this hot spot

SSED pulse amplitude in kΩ
→ R_{SSED} ∝ portion of NbSi film that transitions



(from S. Marnieros)

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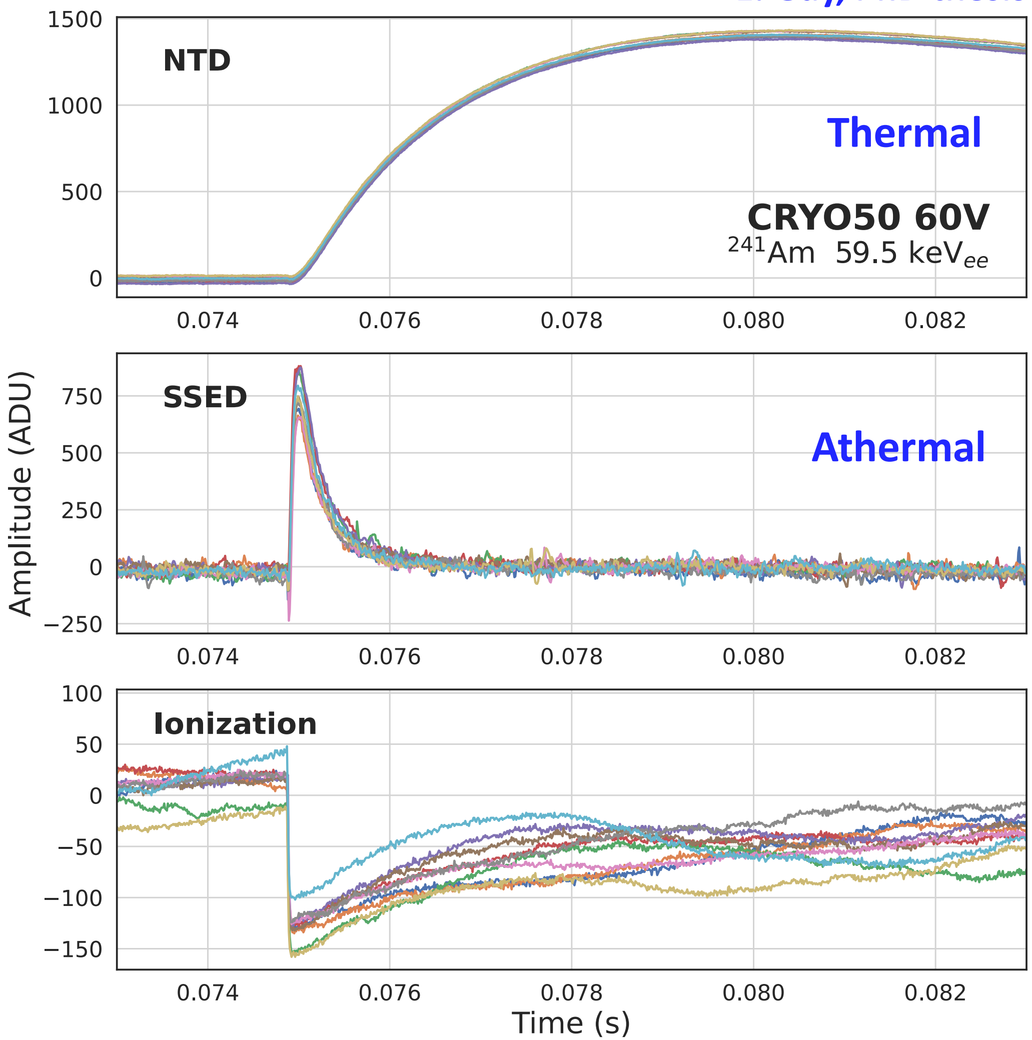

SSED response to various excitations

- 1650 nm IR laser or LED pulses (~diffuse bulk excitation), 1 to 300 keV
- ^{71}Ge EC lines (point-like events in bulk, 1.3 and 10.37 keV)
- ^{241}Am collimated γ, 59.5 keV (surface)

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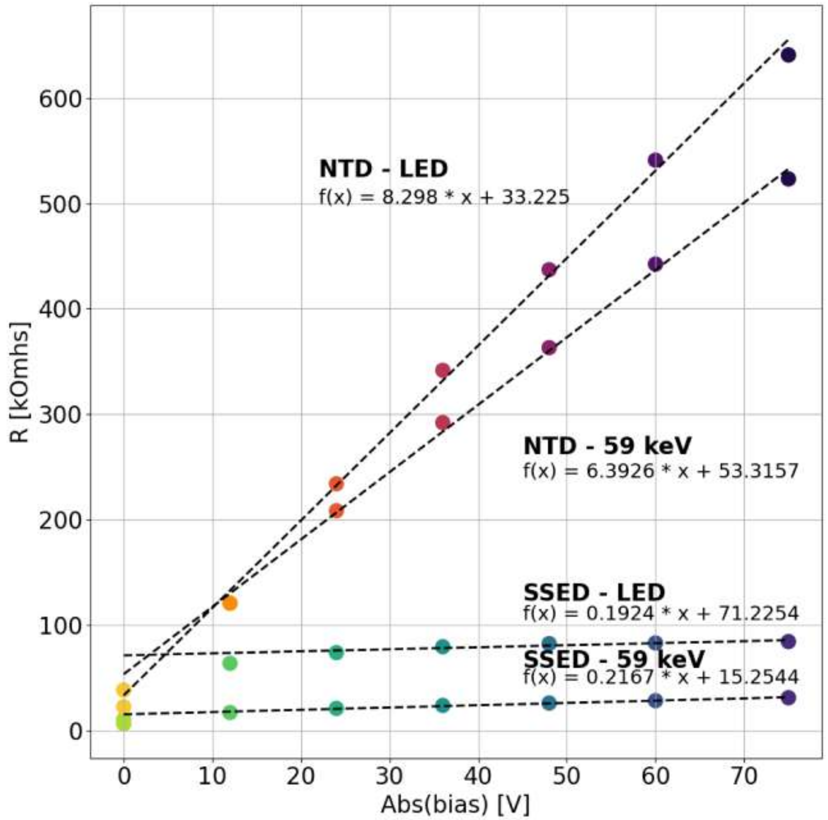
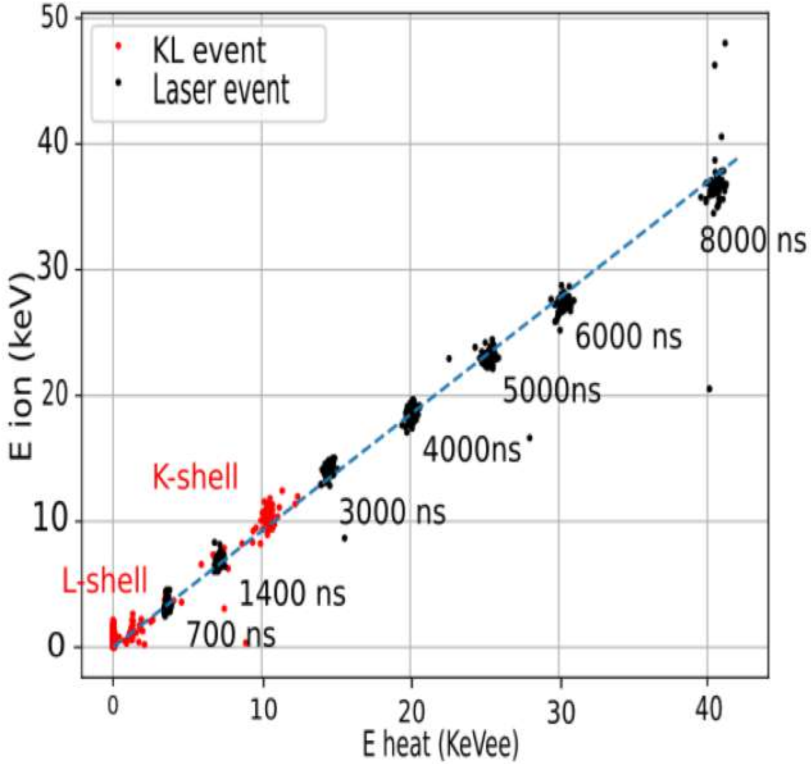
- Fixed LED energy and ^{241}Am γ, variation of applied bias
- NTD signal increases with applied bias, as expected by NTL boost
- SSED signal ~saturates at a fraction of the total film resistance (1 MΩ)



Peak energy resolution

- Despite huge variation of electric field inside the detector, the NTL boost is uniform for bulk events ➞ good peak resolution

JTLP 215 (2024) 268 : arXiv:2311.01554



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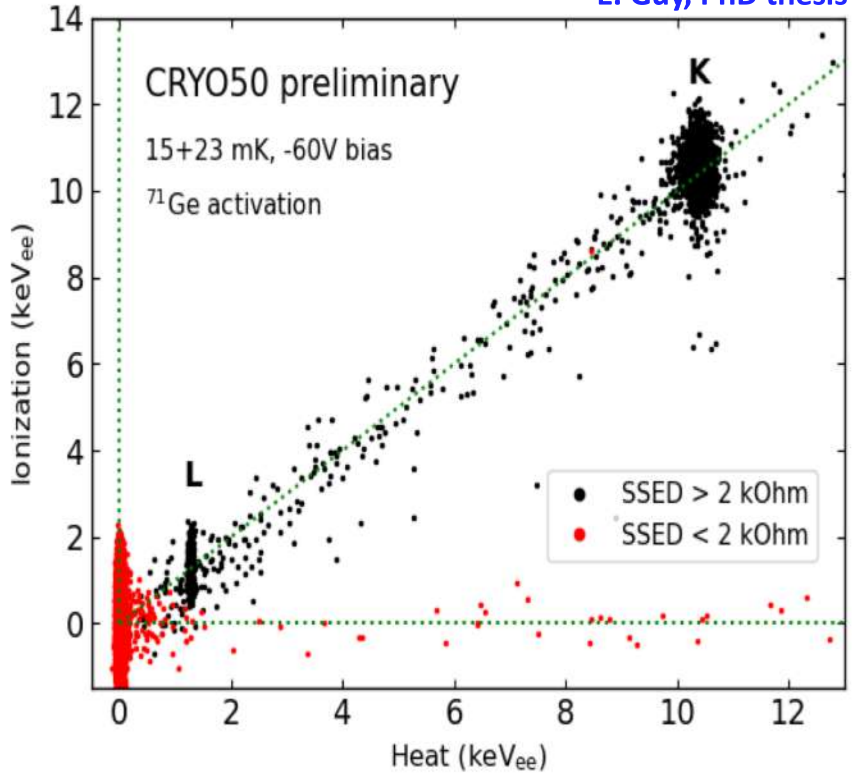
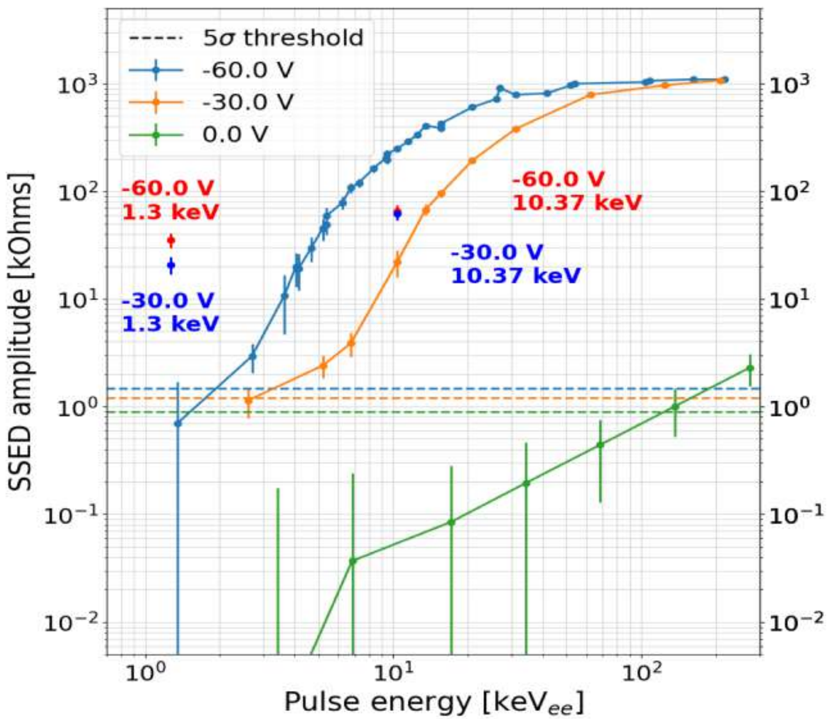


Response vs energy

- ~100 keV laser pulses can trigger transition in entire film (1 MΩ)
- Response ∝ total (init+NTL) phonon energy (not equivalent-electron): phonon detector!
- K + L lines saturate around ~70 kΩ : point-like excitations → limited film section
- ***At low energy, point-like excitation trigger more efficiently than diffuse IR flux***



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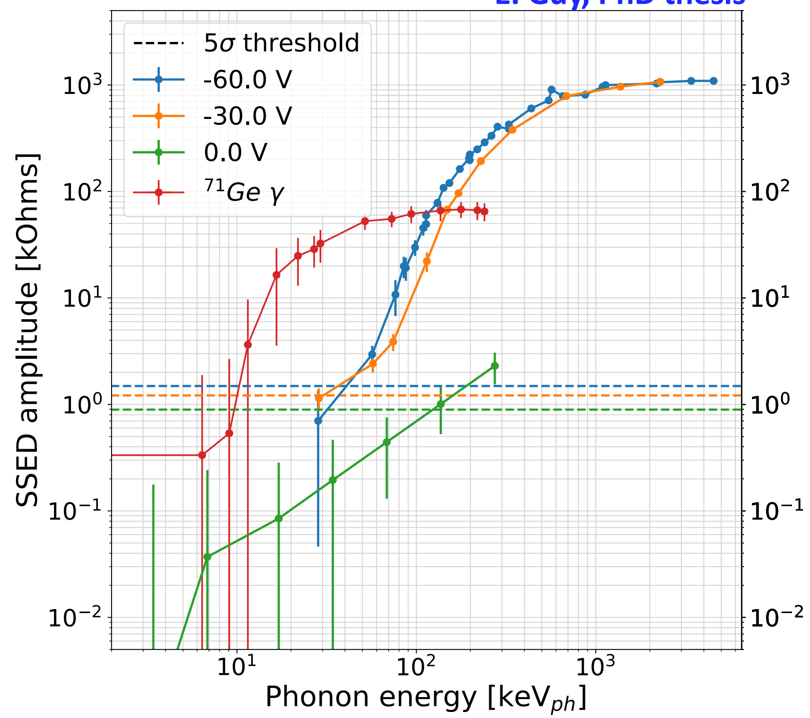
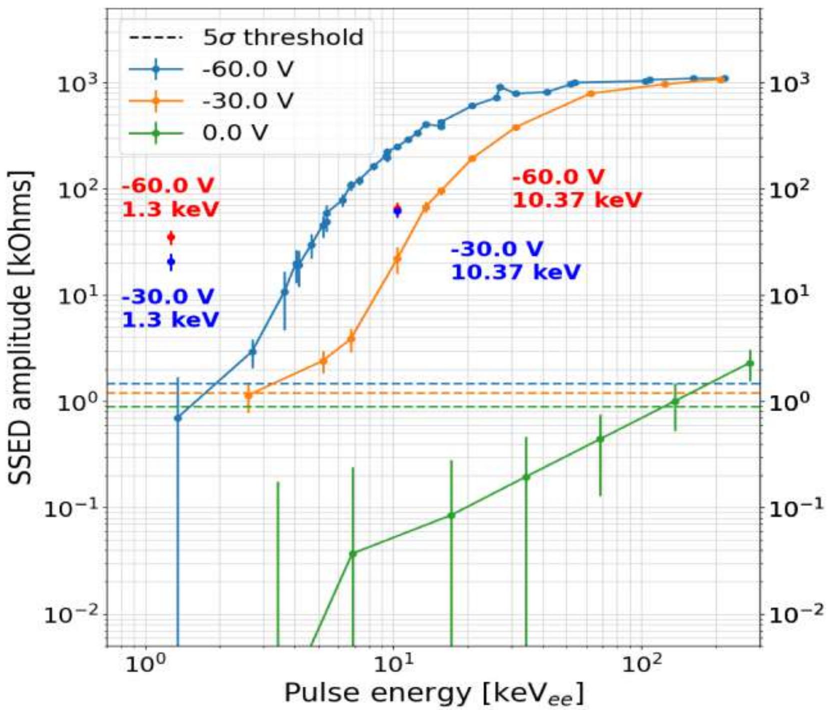


Response vs (T_c-$T_{operation}$)

- Annealing of NbSi film allow a reduction of Tc.
- Not done here on this first prototype: allow to study wide range of T_c-$T_{operation}$
- **Threshold can be lowered by reducing T_c-$T_{operation}$**



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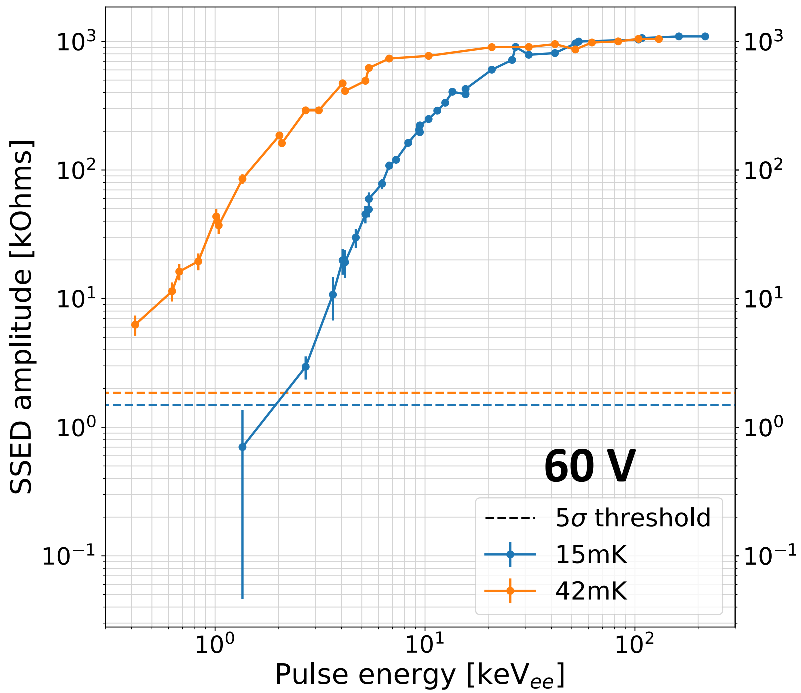

HO rejection

Cut on RSSED > 2 kΩ:

Rejection of all 58 heat-only events above 3 keV

>25 rejection @ 90%CL

The principle of identifying bulk ionizing events in a NTL-boosted detector using only NTL phonons works!

Next steps: higher bias, lower T_c, improve resolution

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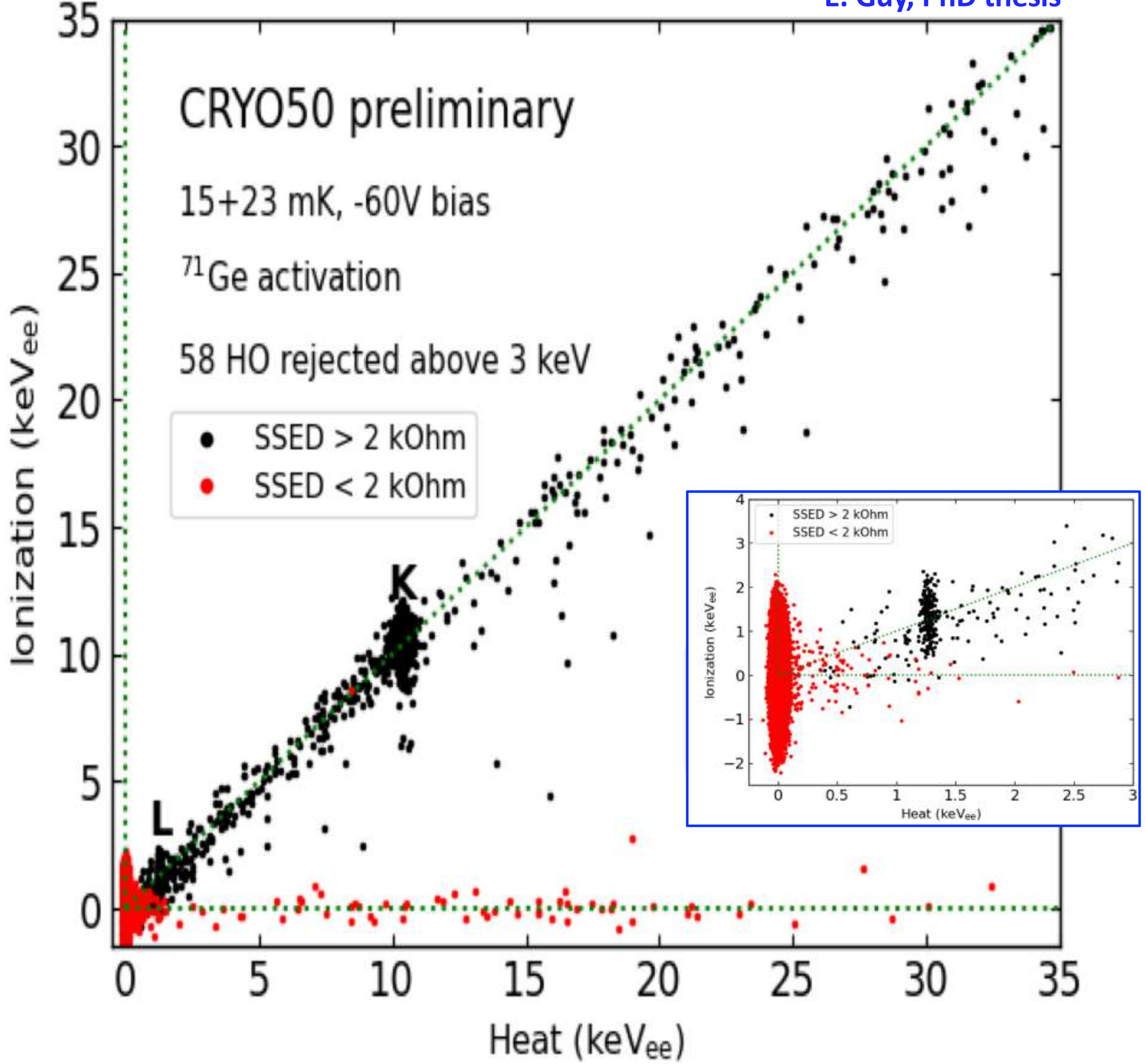

Conclusions

RICOCHET: Ionization readout with 1K HEMT preamplifier

- Ionization readout with 1K HEMT preamplifier
- Ongoing commissioning at ILL reactor
- Preliminary HO rate measurements in Lyon (noisier above-ground environment) consistent with previous measurements

CRYOSEL: Tagging NTL phonons with SSED:

- Superconducting NbSi strip sensitive to NTL phonons produced exclusively in nearby very-high field zone
- Principe of HO rejection confirmed
- *Development for TESSERACT@LSM*