Danilo Angelone - Università degli Studi di Roma "La Sapienza"
Lex Millins - University of Birmingham and Rutherford Appleton laboratory

GRAN SASSO hands-on
PhD autumn school on experimental astroparticle physics
September 25th, 2023 – October 6th, 2023

Bolometrics

CUPID's $Li_2{}^{100}MoO_4$ crystal calibration

CUORE

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INFN Istituto Nazionale di Fisica Nucleare
LABORATORI NAZIONALI DEL GRAN SASSO
UNIVERSITÀ DEGLI STUDI DELL'AQUILA
GSSI GRAN SASSO SCIENCE INSTITUTE
SCHOOL OF ADVANCED STUDIES
Scuola Universitaria Superiore

Cryogenic Underground Observatory for Rare Events

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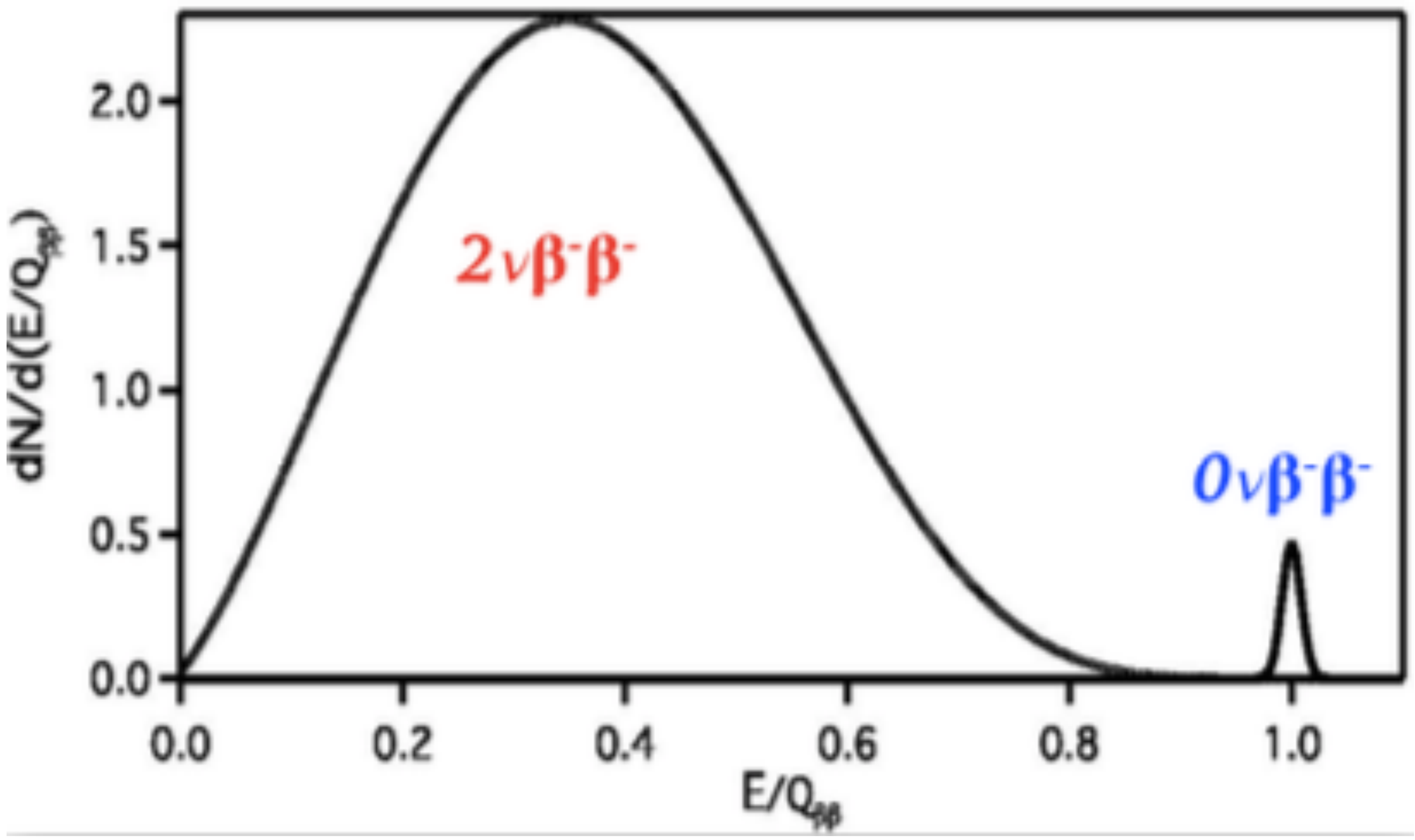
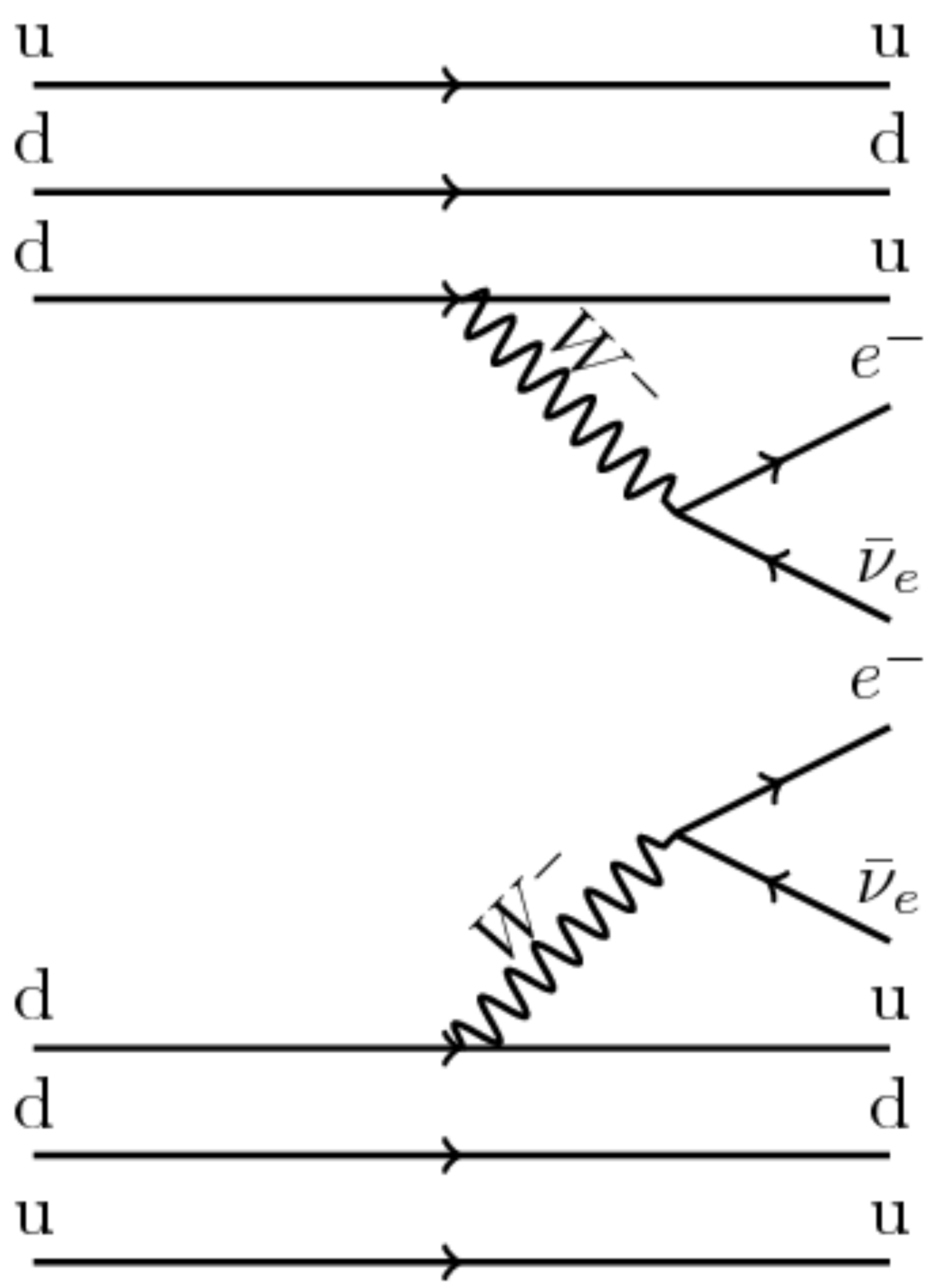
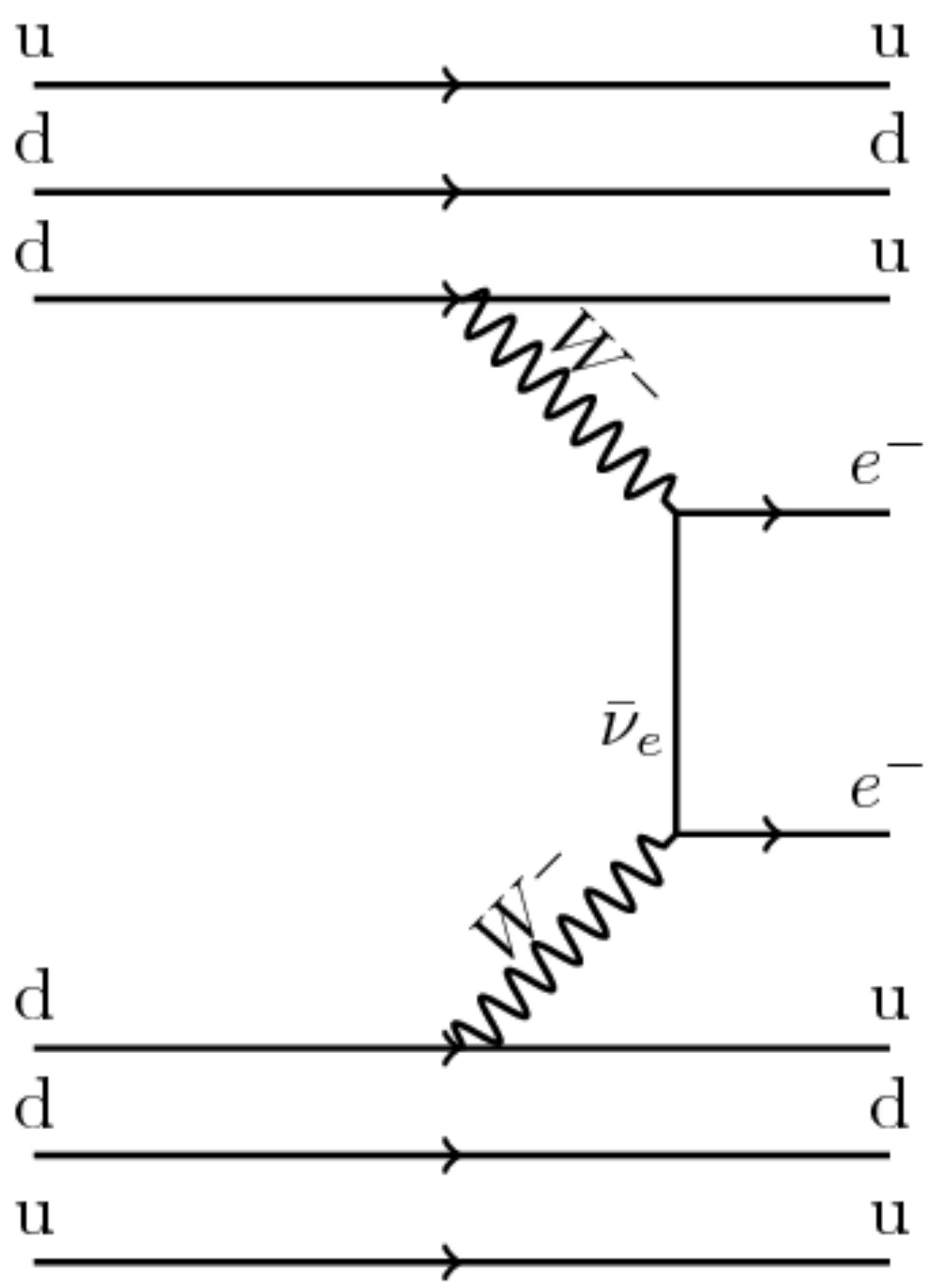
Search for **0νββ** decay of ^{130}**Te**:

- Qββ ~ **2527.52 keV**
- $T_{\frac{1}{2}} > 2.8 \cdot 10^{25}$**yr**







Cryogenic Underground Observatory for Rare Events

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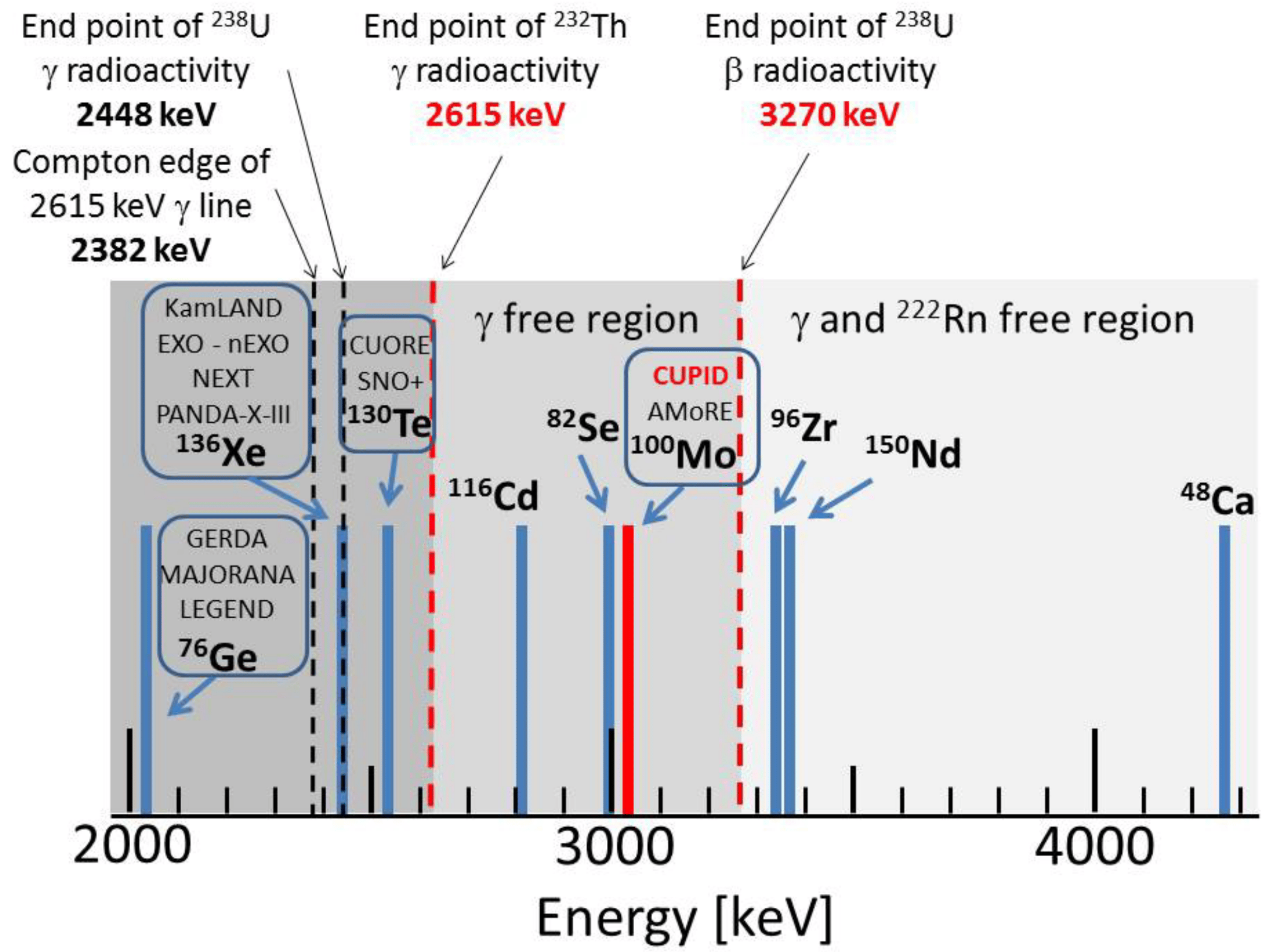
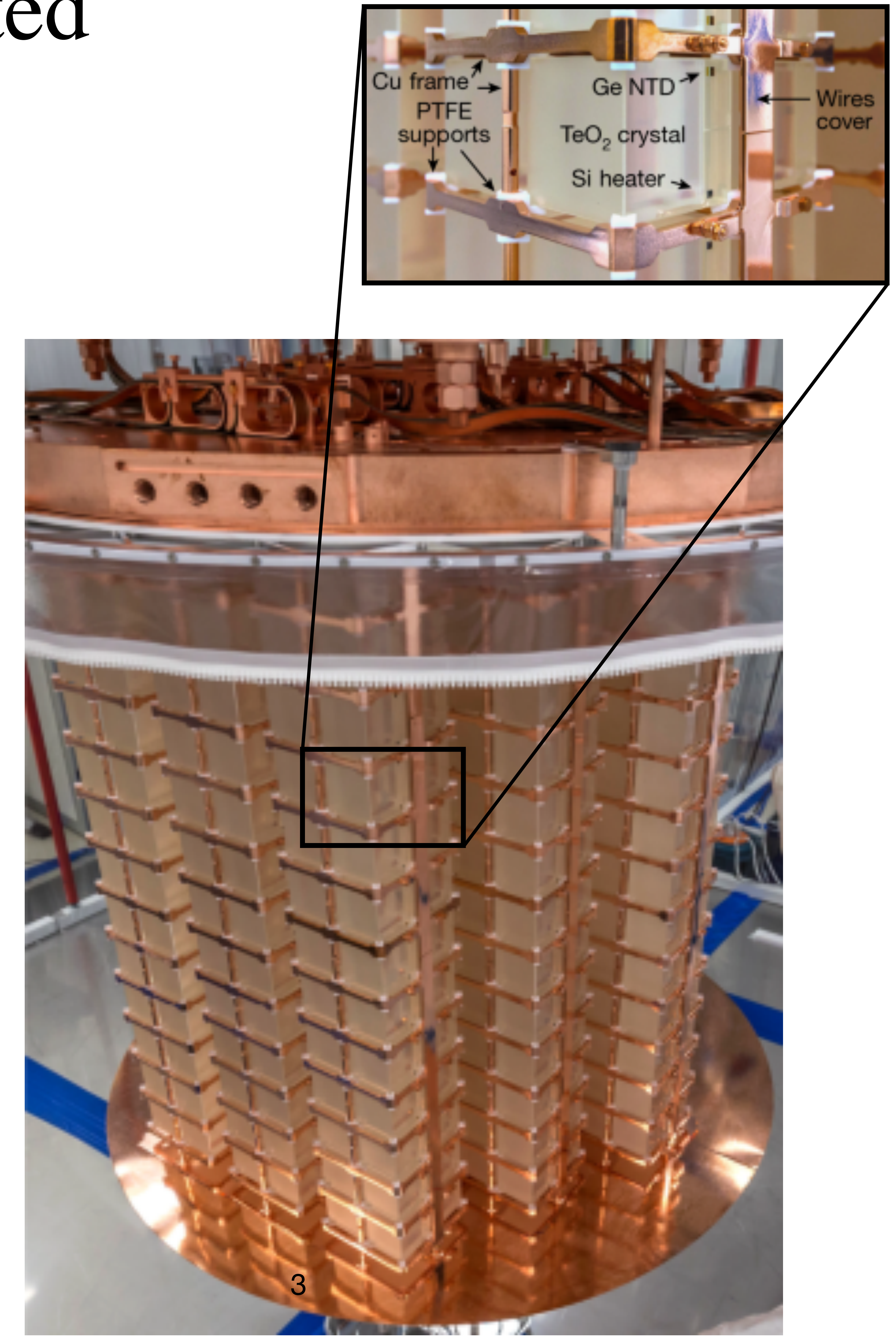
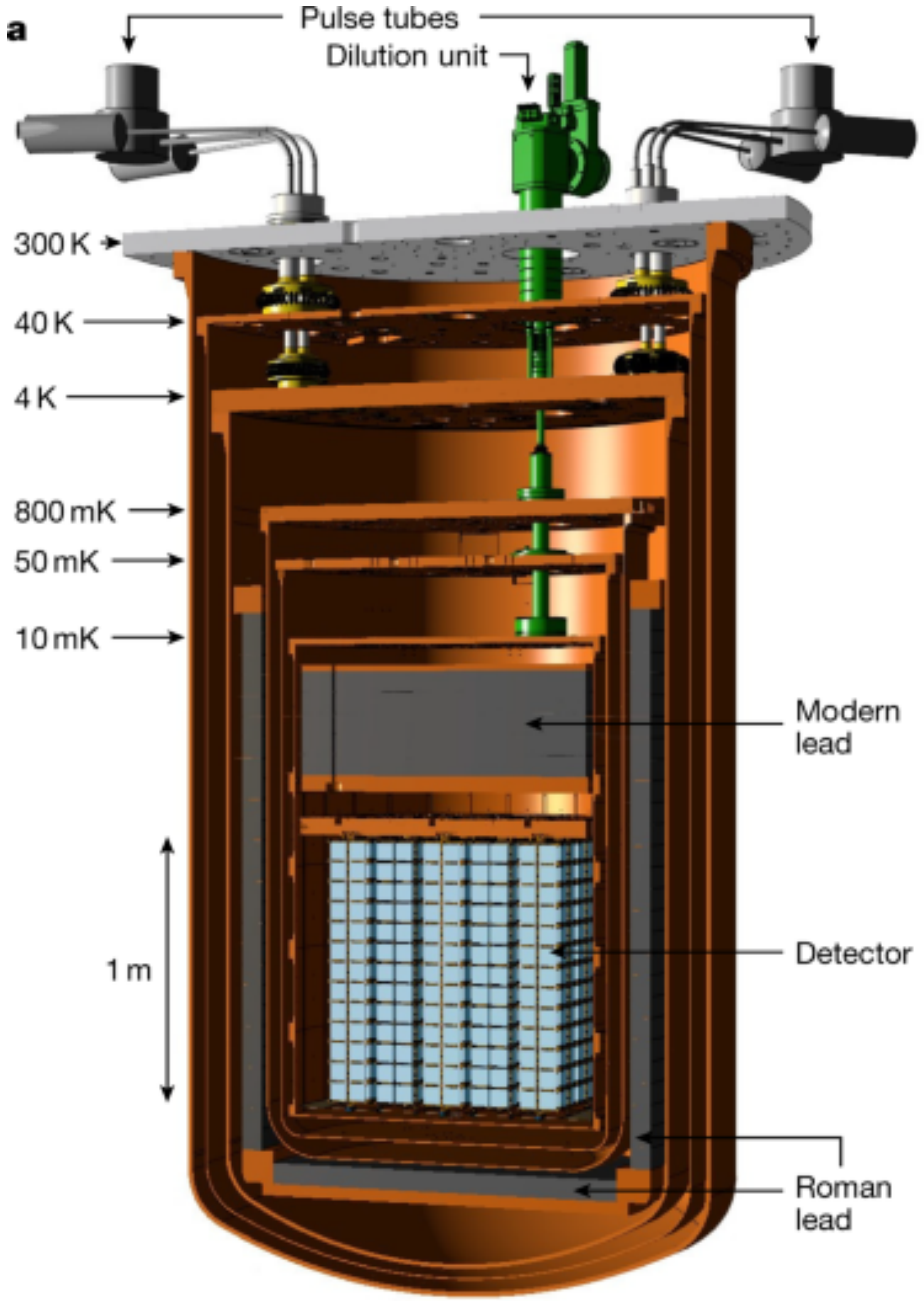
Array of **988 TeO_2** crystals operated as cryogenic bolometers:

- Total mass: **742 kg**,
- Isotopic mass: **206 kg**
- Temperature ~ **10 mK**



Isotope	I.A.
^{76}Ge	7.8%
^{136}Xe	8.9%
^{130}Te	33.8%
^{116}Cd	7.49%
^{82}Se	8.73%
^{100}Mo	9.63%
^{96}Zr	2.8%
^{150}Nd	5.64%
^{48}Ca	0.187%



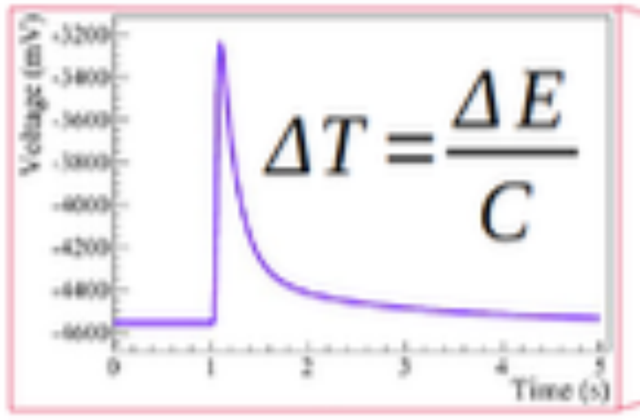


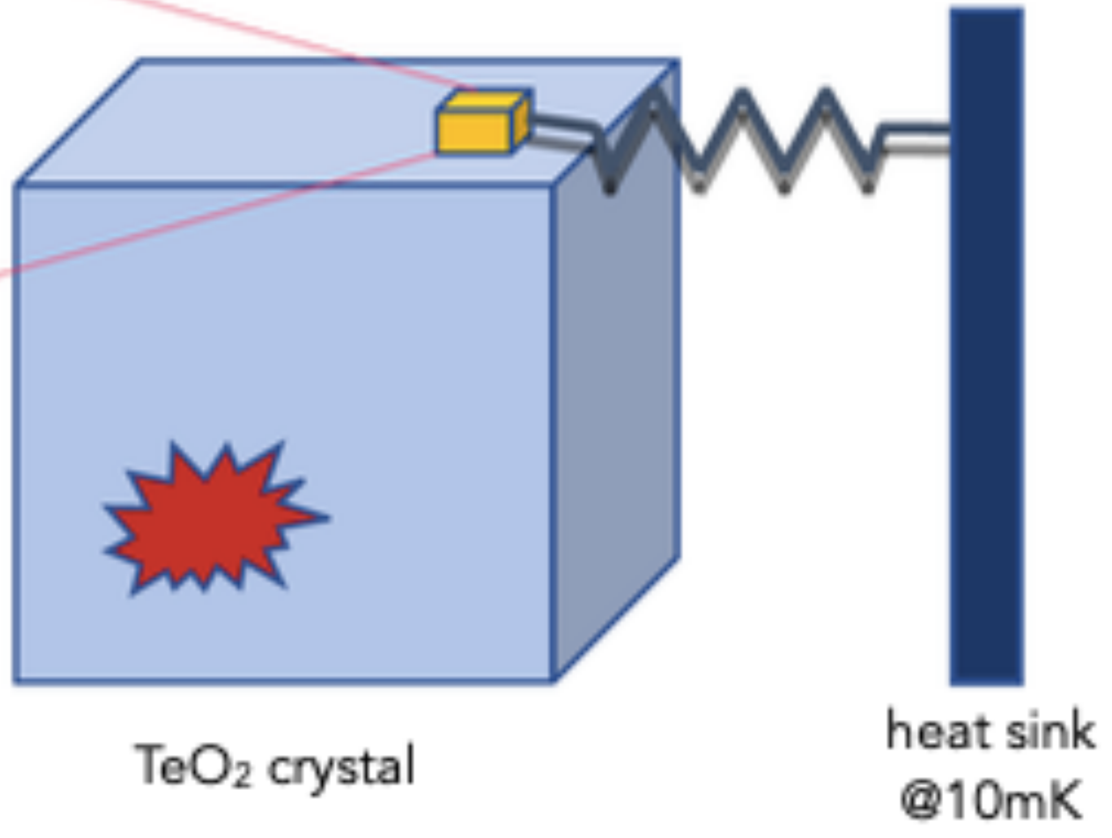
Cuore **U**pgrade with **P**article **ID**entification

- New crystals: **$Li_2^{100}MoO_4$** Instead of **$^{130}TeO_2$**
- New Total mass: **450 kg**, New isotopic mass **250 kg**

CUORE

"Bolometer" = heat signal





- Pure thermal detector
- Heat capacity C ~ T^3
- NTD-based readout
- Q-value 2527 keV

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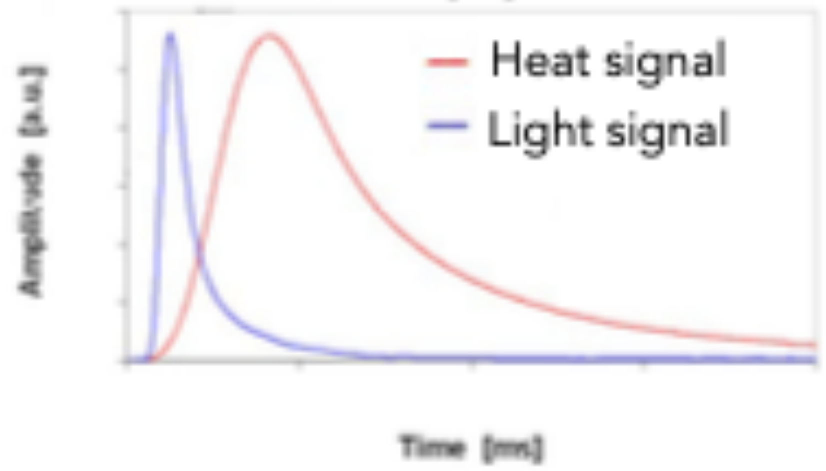
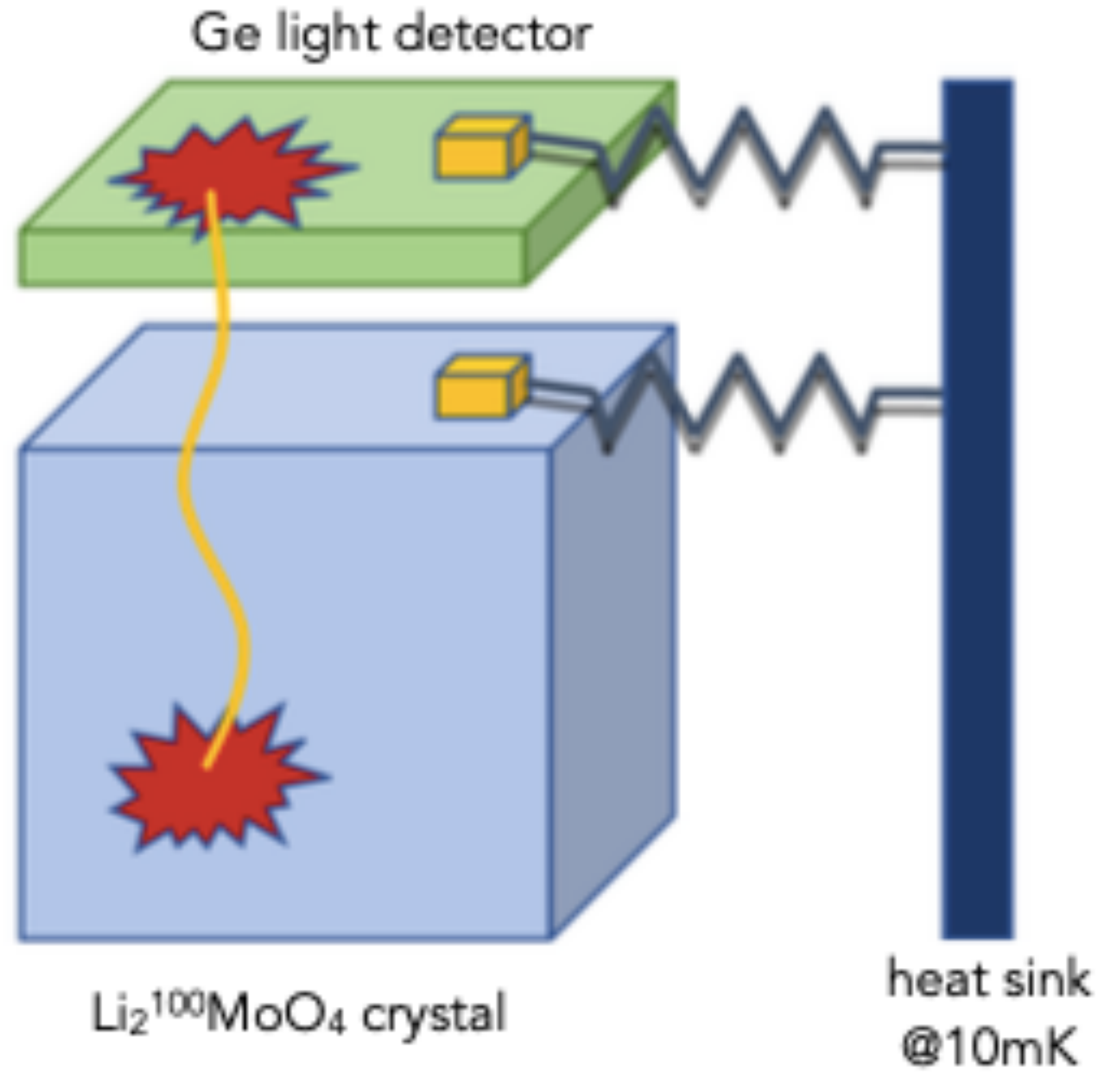
Scintillating "bolometer" = heat + light signals





- Particle Identification (PID):
  - α-discrimination
  - 2ν2β pile-up rejection
- Higher Q-value (3034 keV)

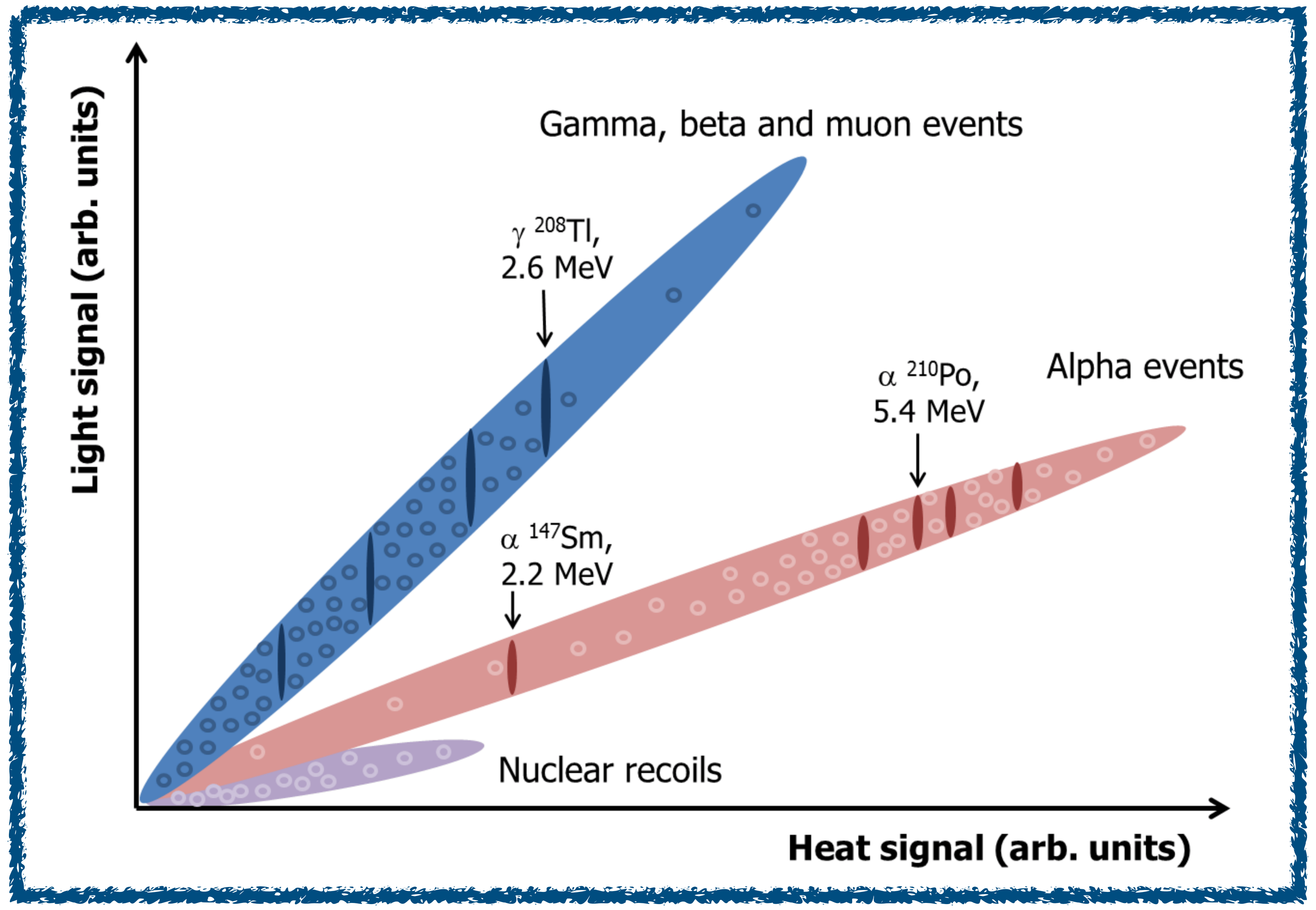
Cuore Upgrade with Particle IDentification

Sensitivity: $S_{0\nu} \propto \sqrt{\frac{M \cdot T}{B \cdot \Delta E}}$

Cryogenic detection technique (~10 mK)

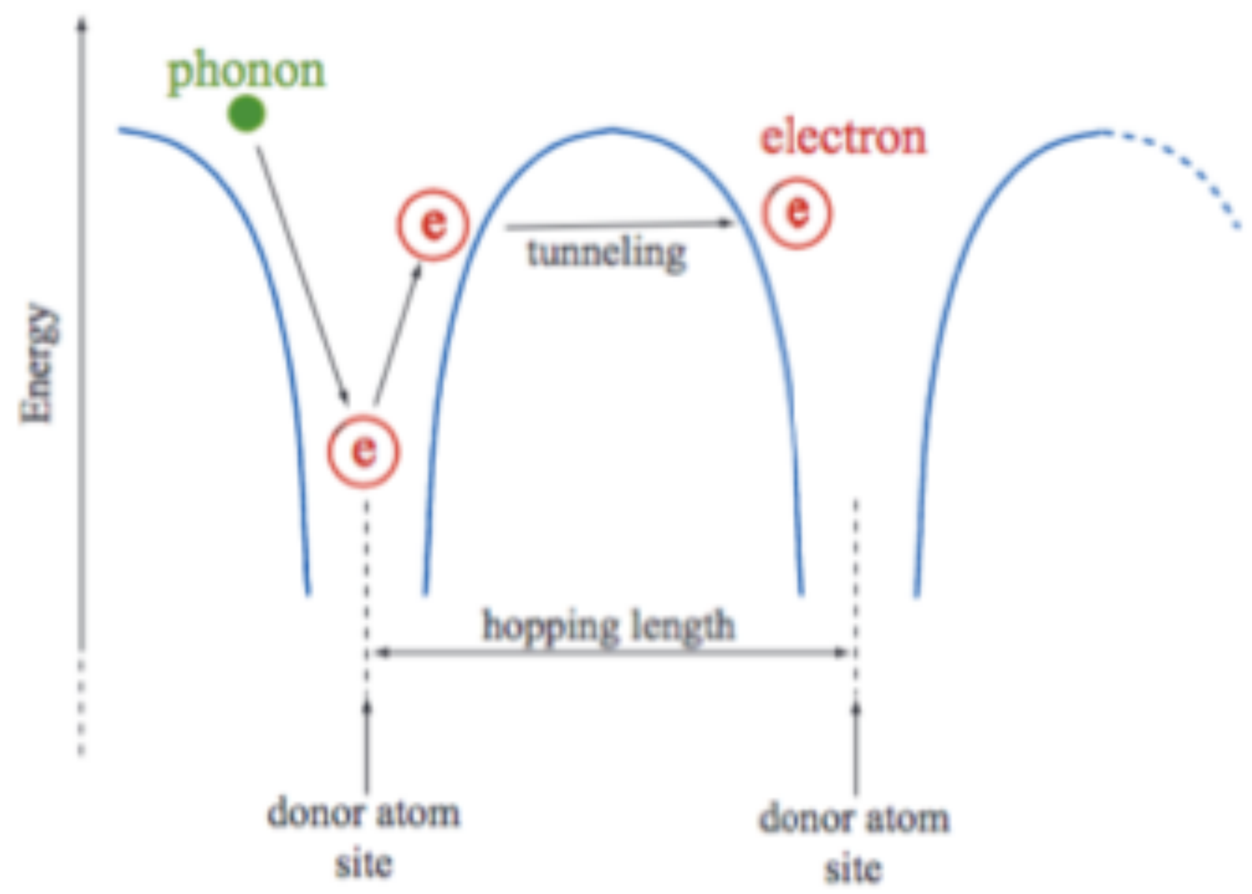
Highter isotopic mass (206 kg → 250 kg)

Alpha background rejection with light detectors



Neutron Trasmutation Doped (NTD)

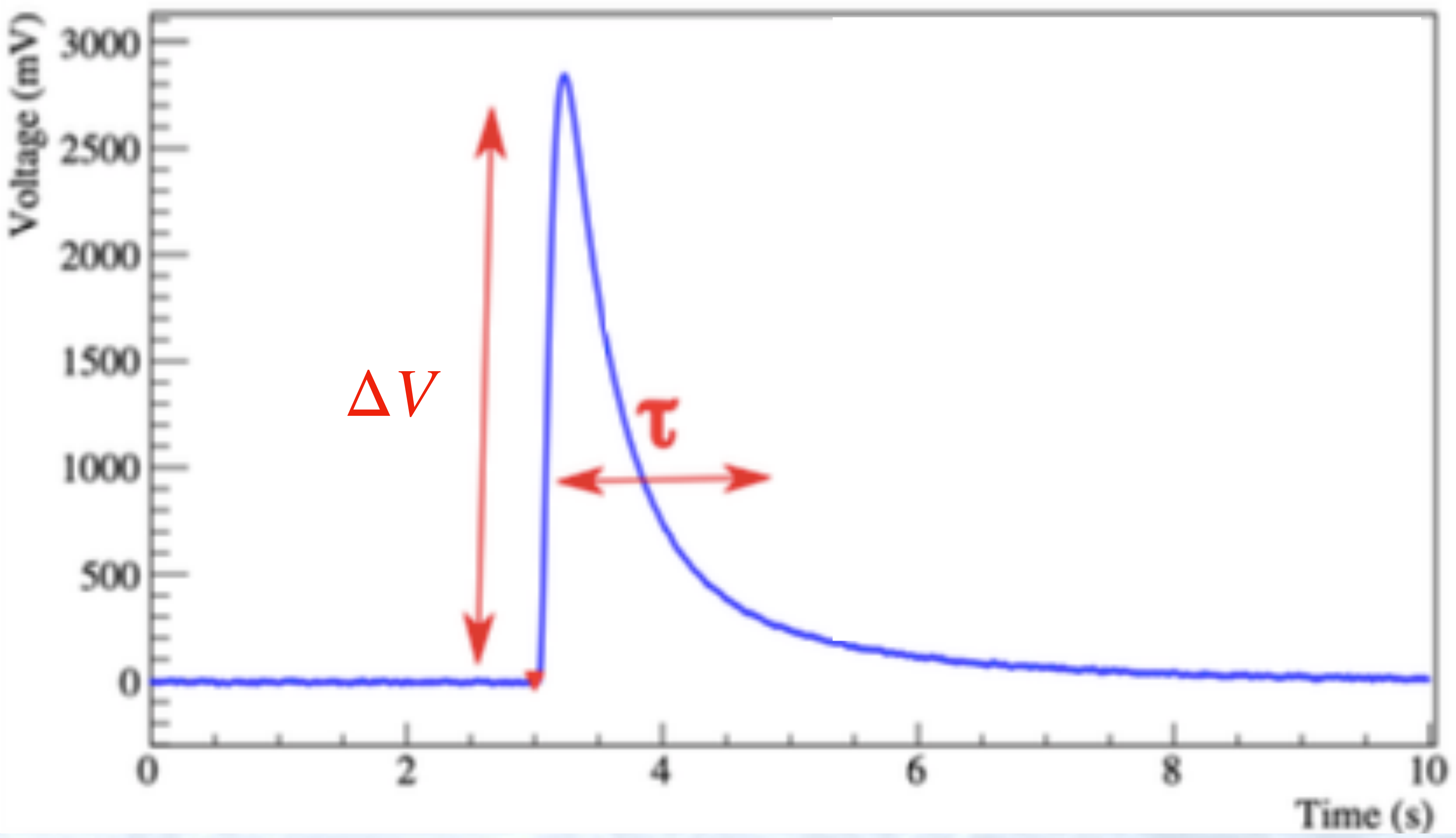
Doped semiconductors close to the Metal to Insulator Transition (MIT)



At low temperatures (< ~10 K), the resistivity is given by:

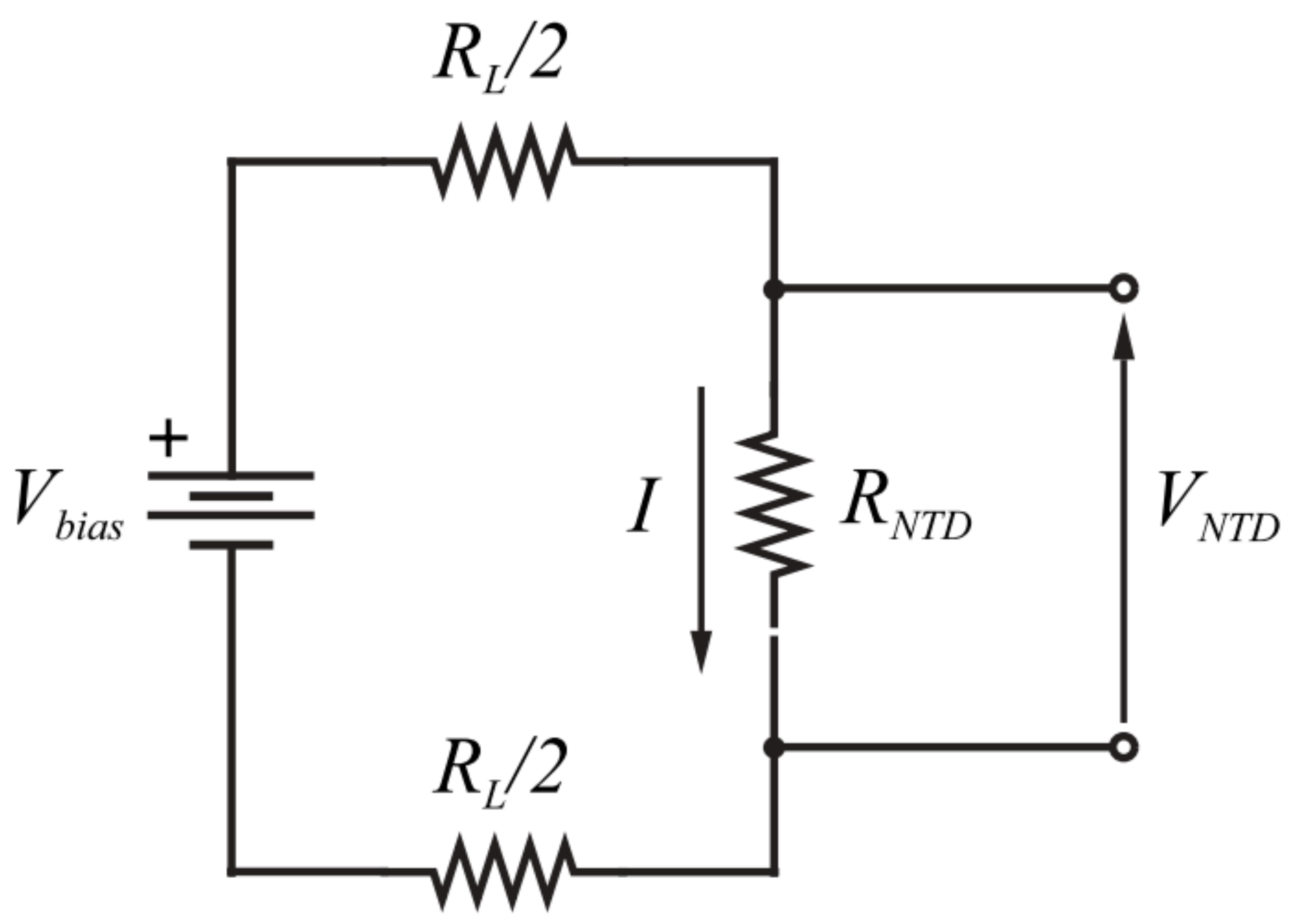
$$\rho(T) = \rho_0 exp\left(\sqrt{\frac{T_0}{T}}\right)$$

→ T_0, ρ_0 depends on the doping level.



$$\Delta V = I \cdot \Delta R \simeq I \frac{\partial R}{\partial T} \cdot \Delta T$$

Neutron Trasmutation Doped (NTD)

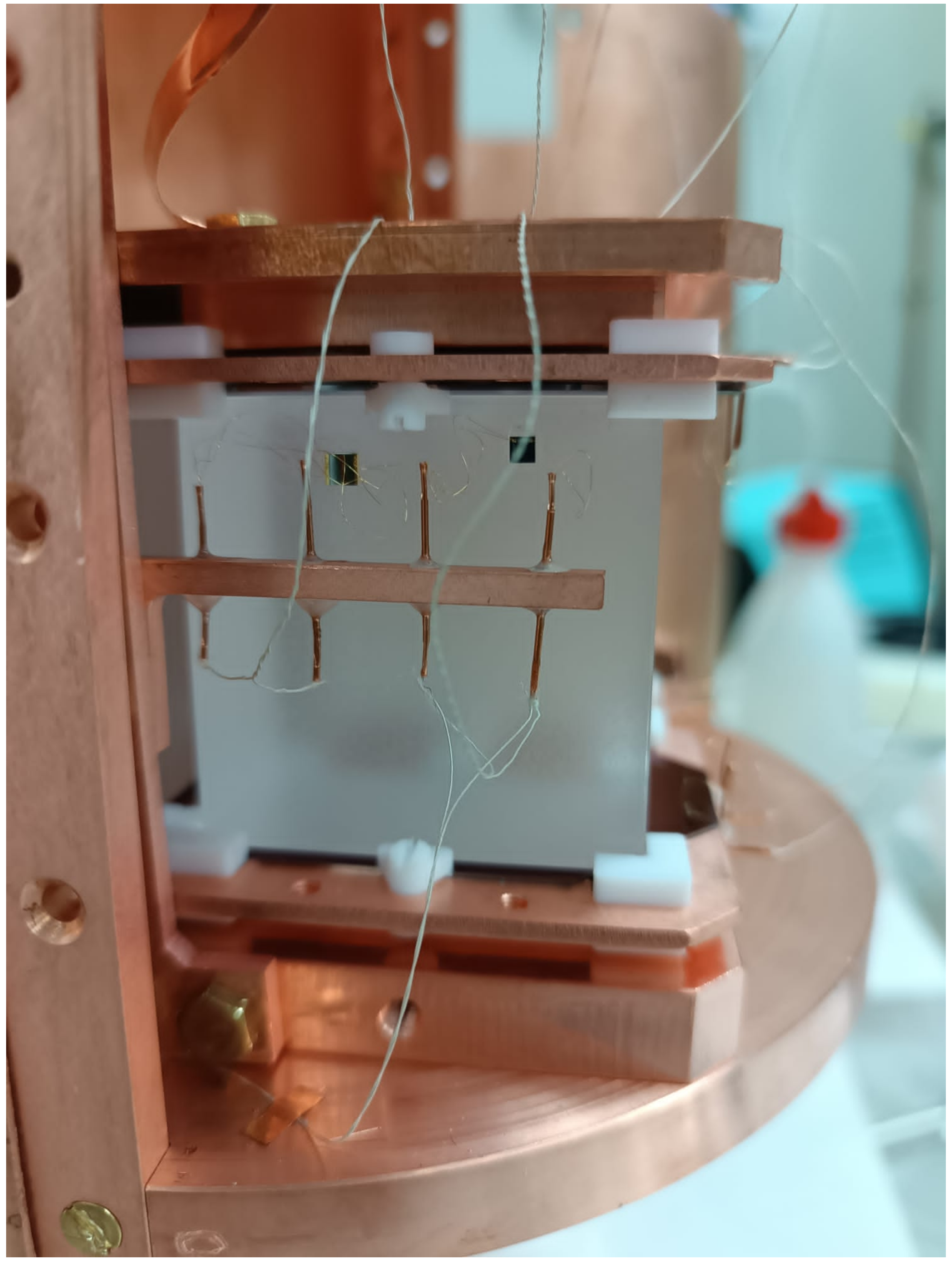


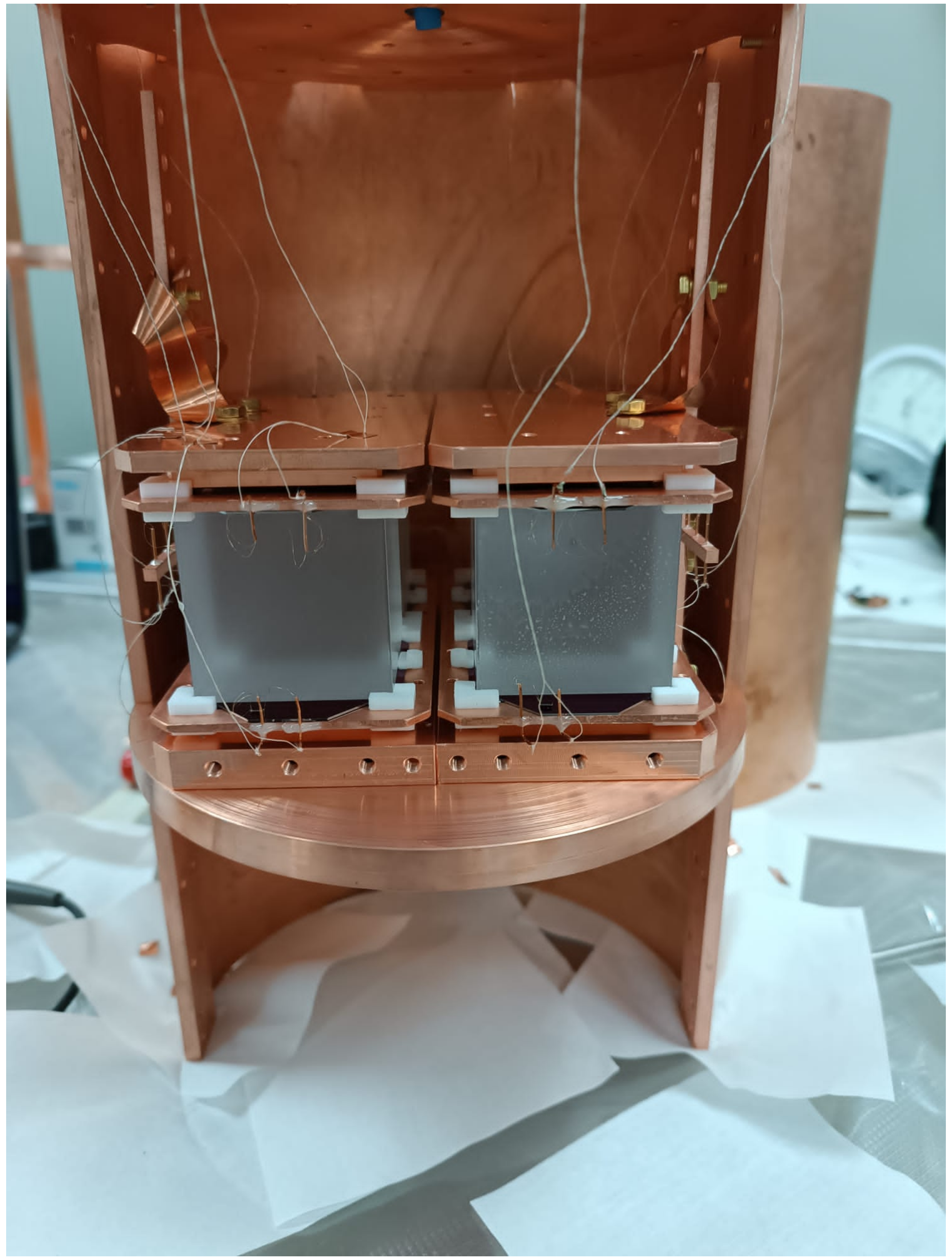
$$V_{NTD} = \frac{V_{bsl}^{+} - V_{bsl}^{-}}{2 \cdot G}$$

$$I = \frac{V_{bias} - V_{NTD}}{2 \cdot R_L}$$

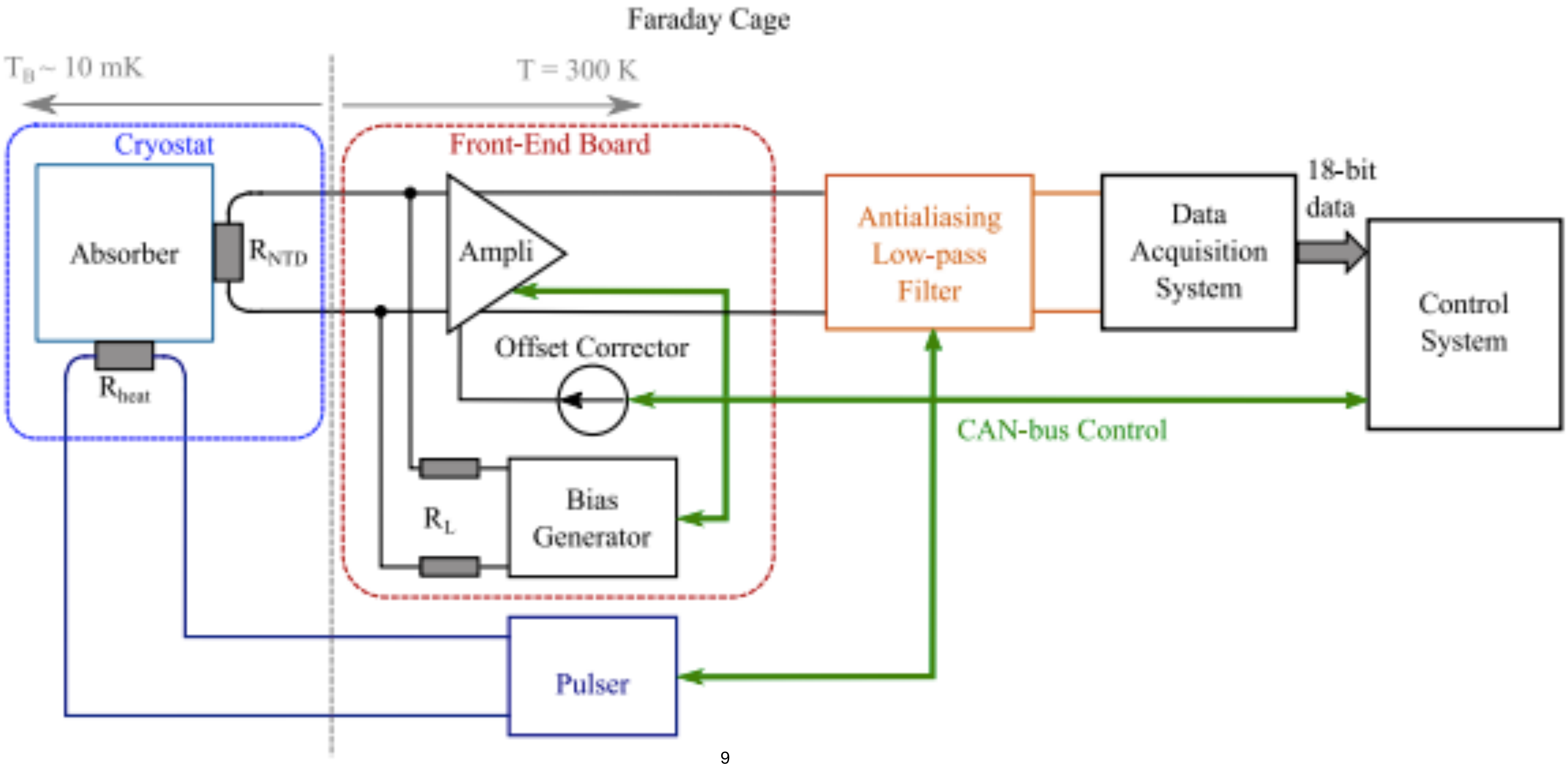
$$A \propto \frac{\Delta T}{T} \cdot V_{NTD}$$

Experimental setup

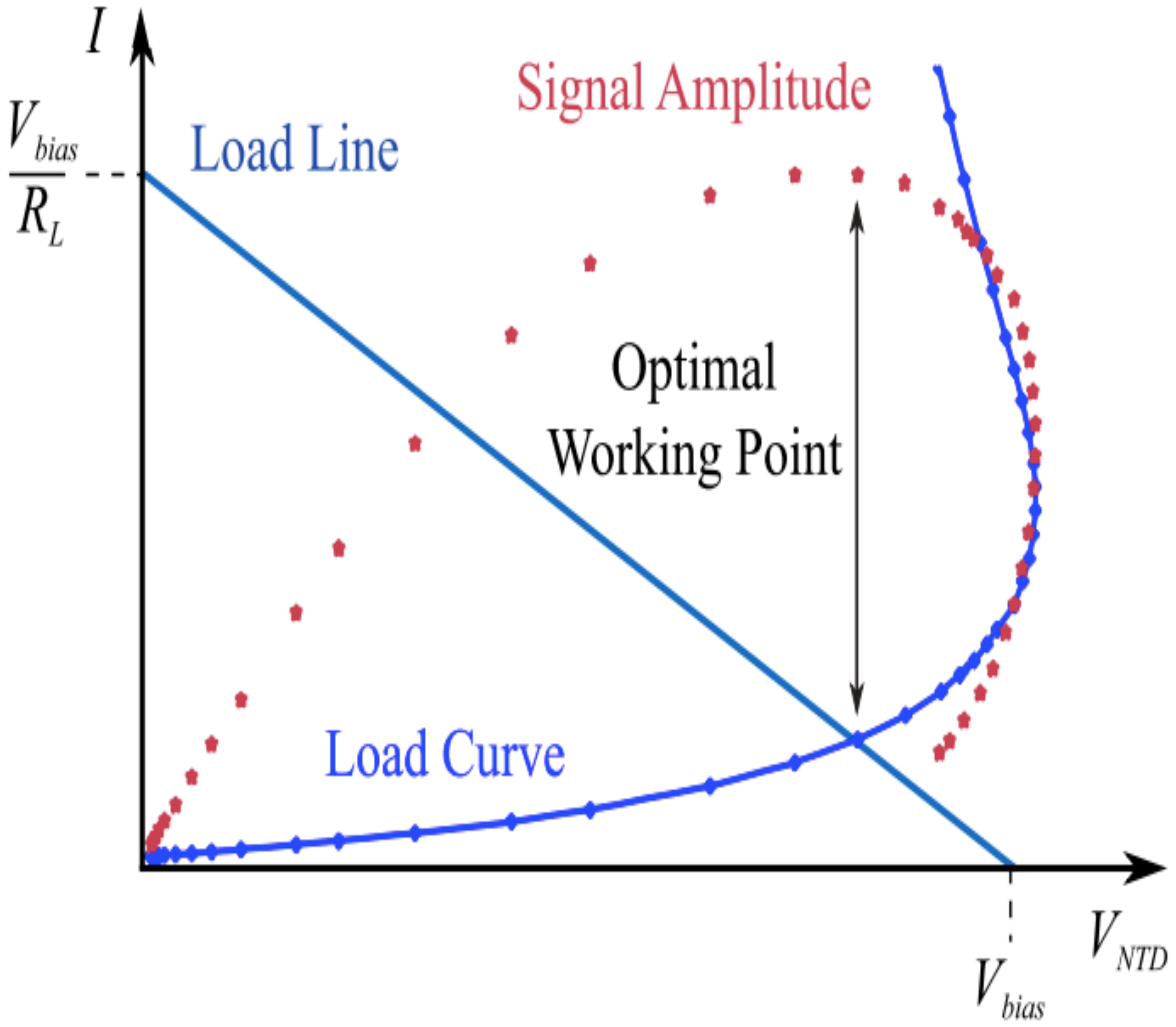


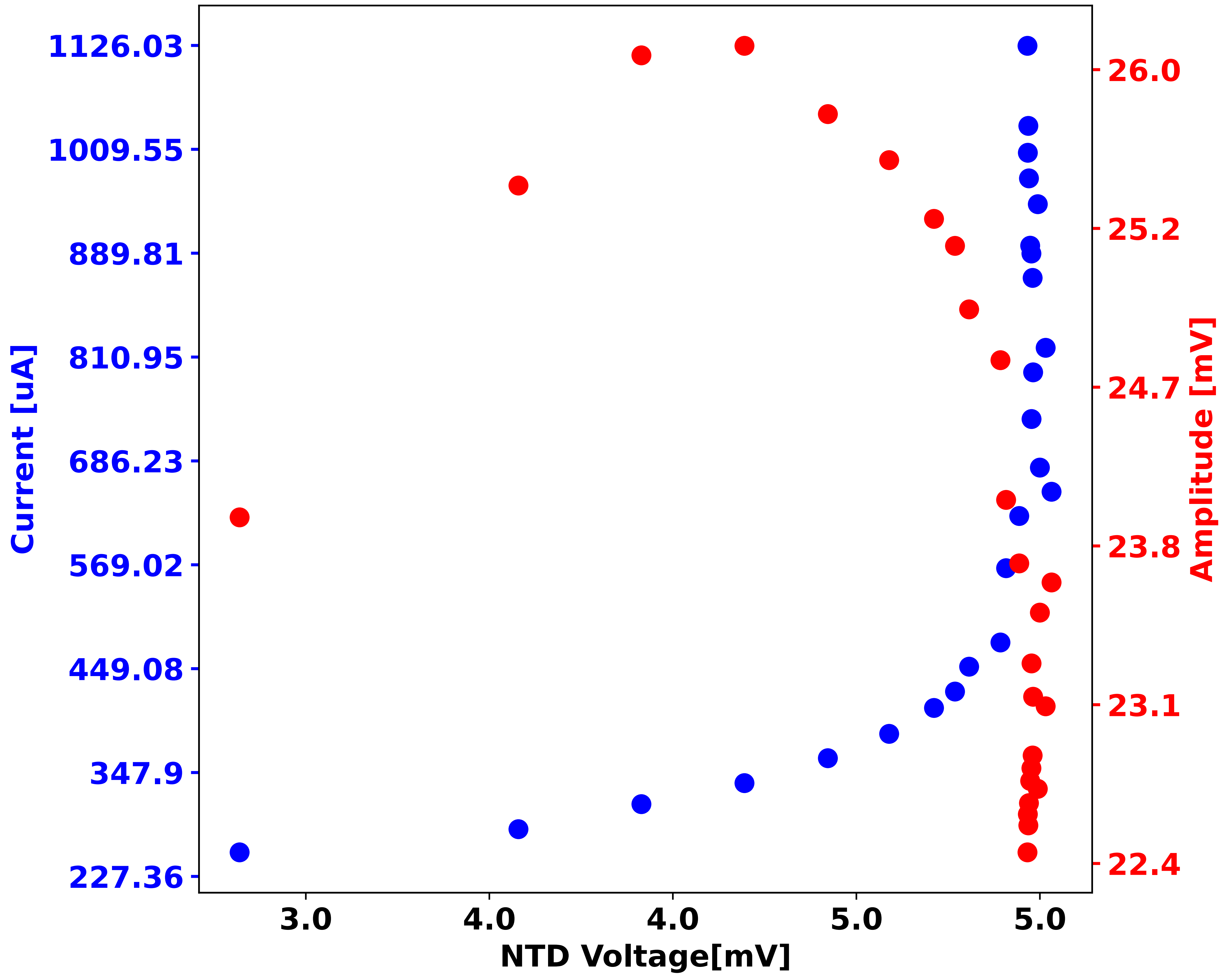


Experimental setup



$Li_2^{100}MoO_4$ Load Curve





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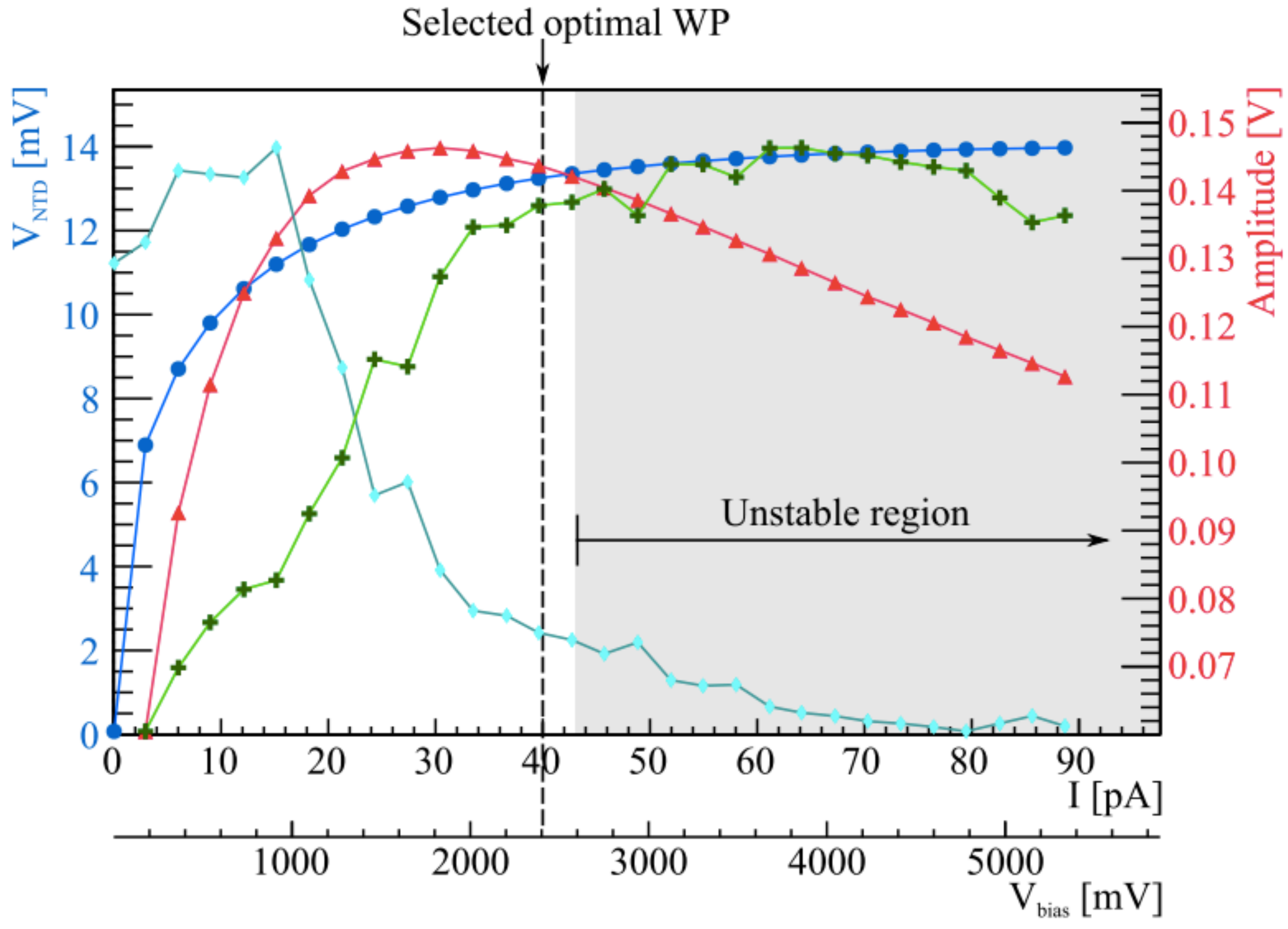

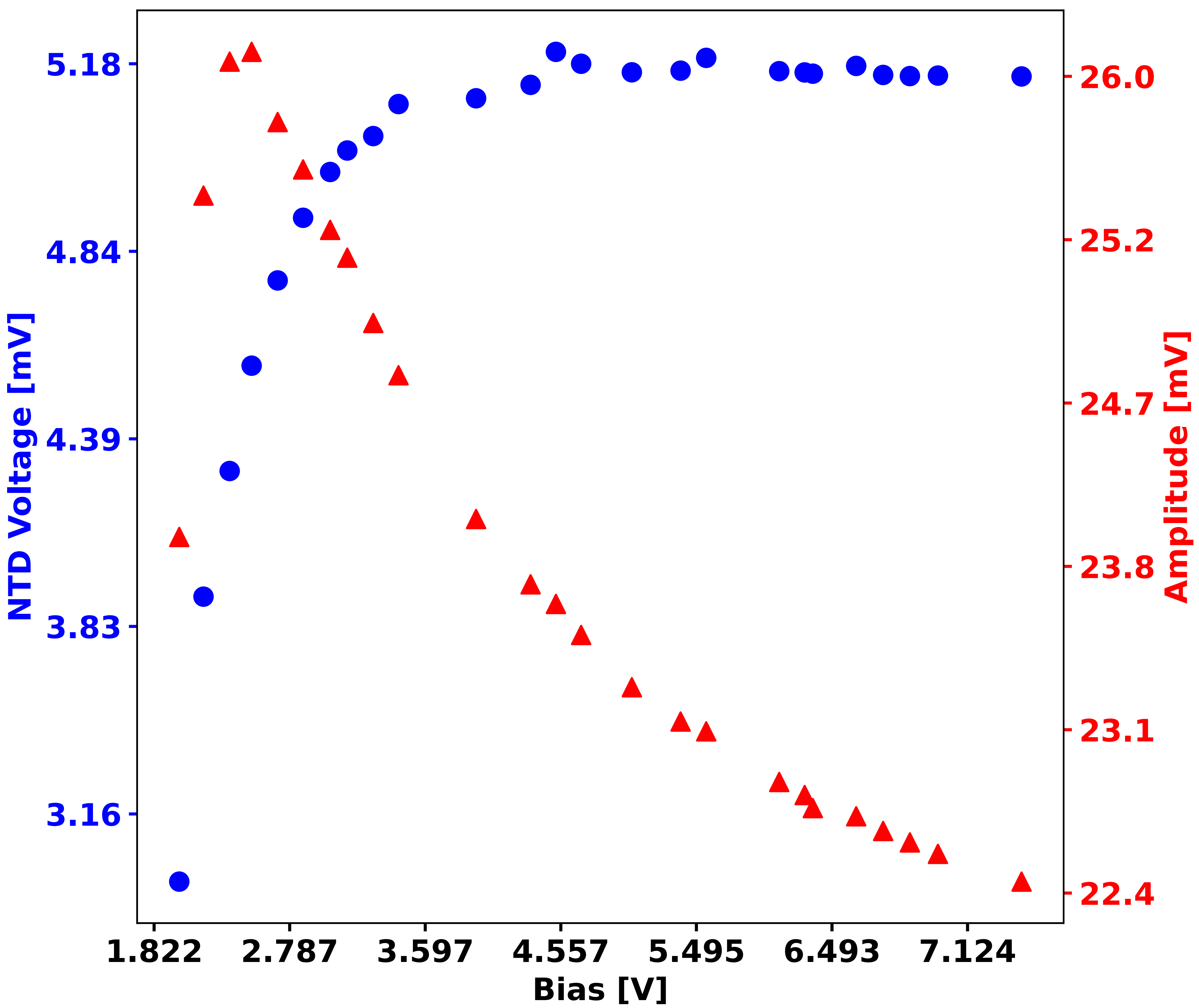

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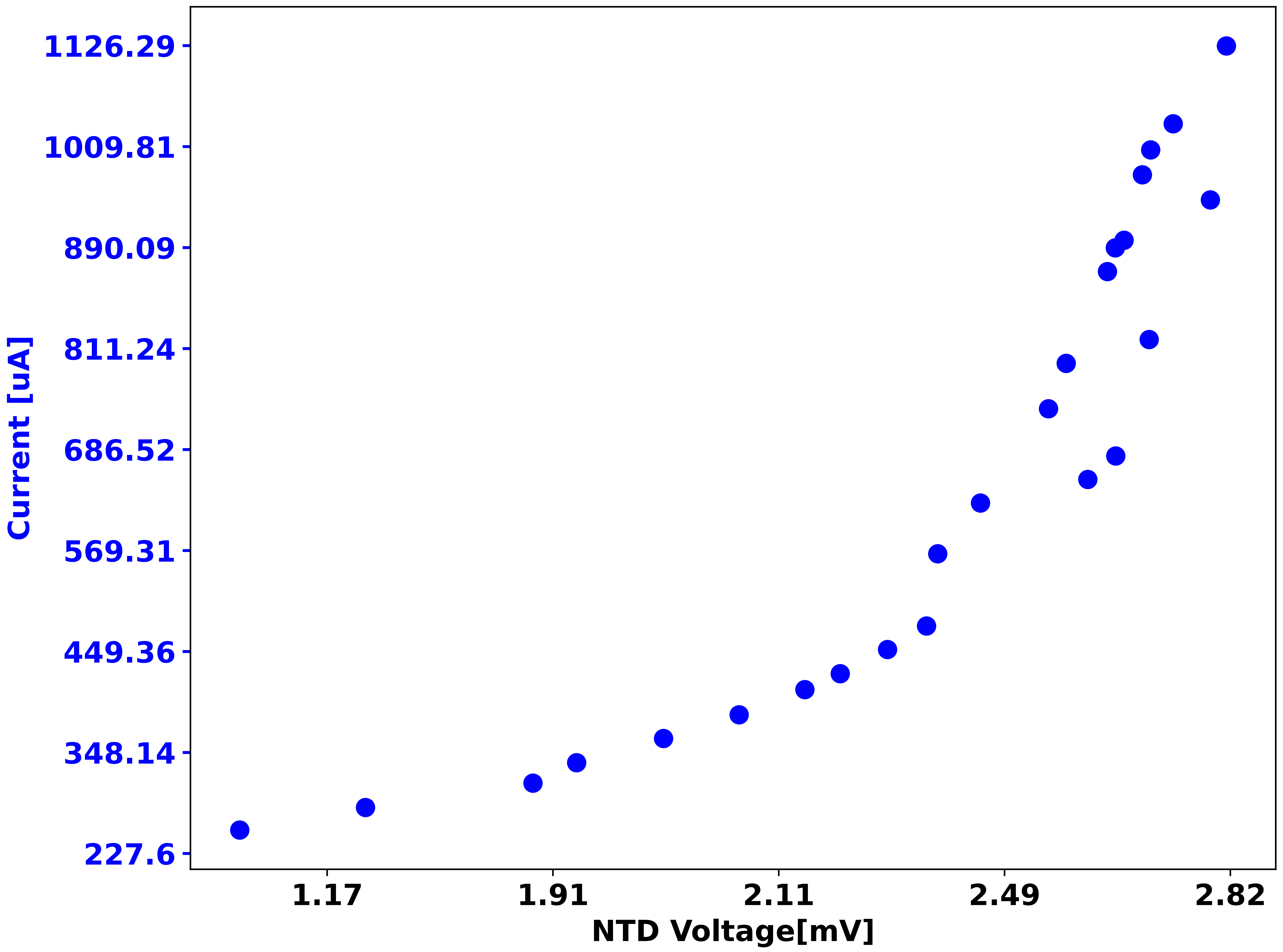
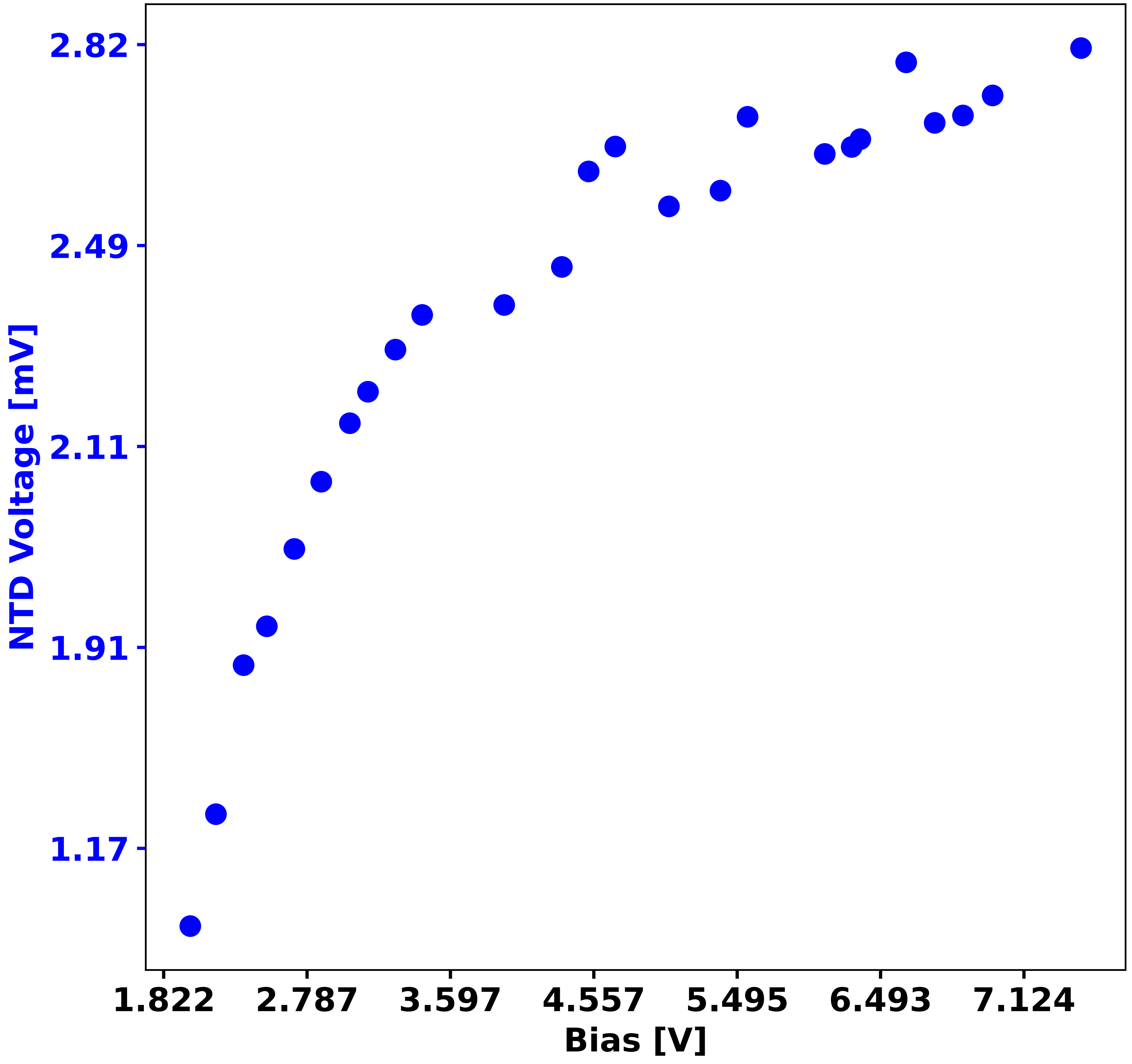
Ge Light Detector Load Curve



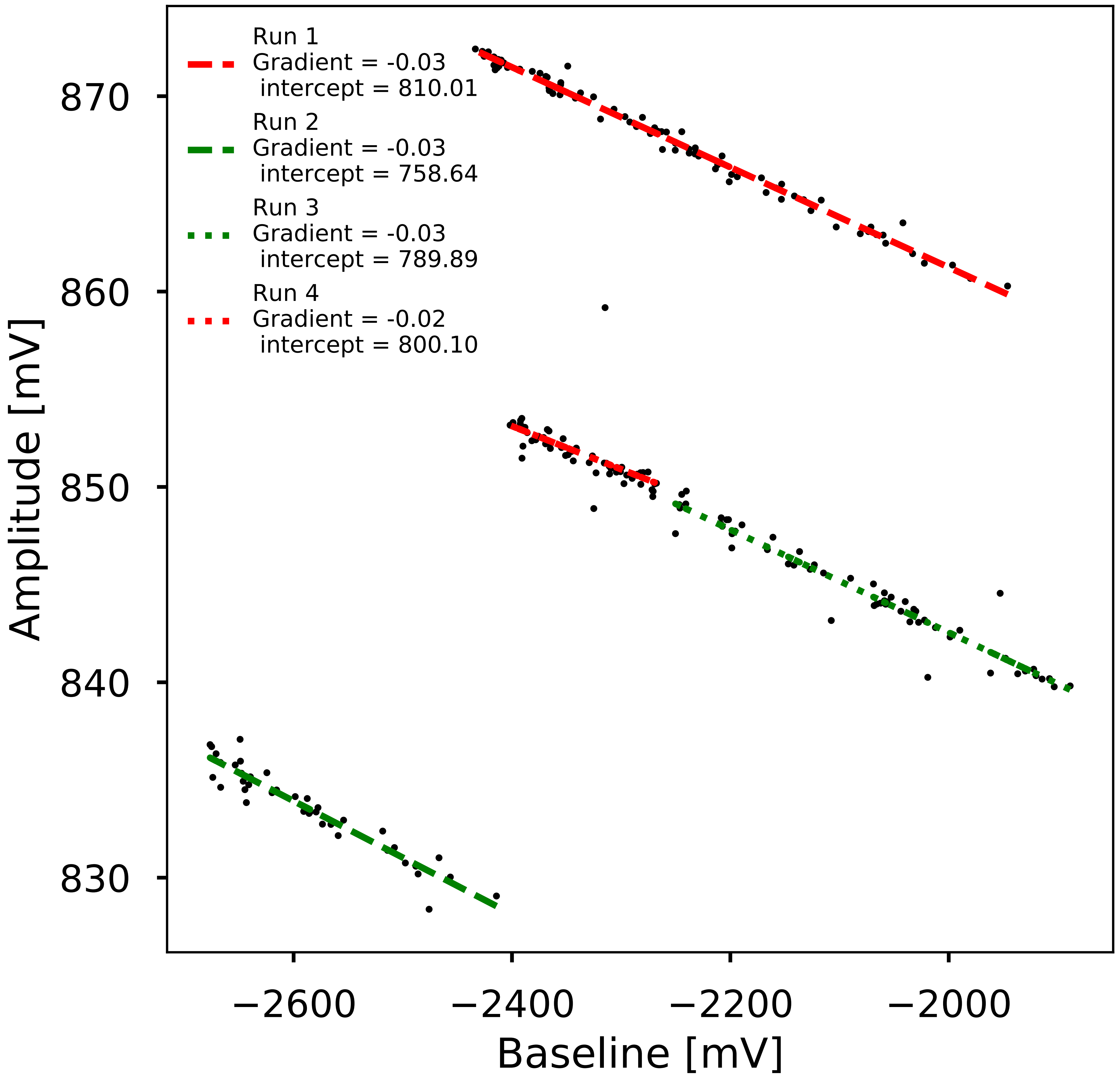


Calibration process: stabilisation

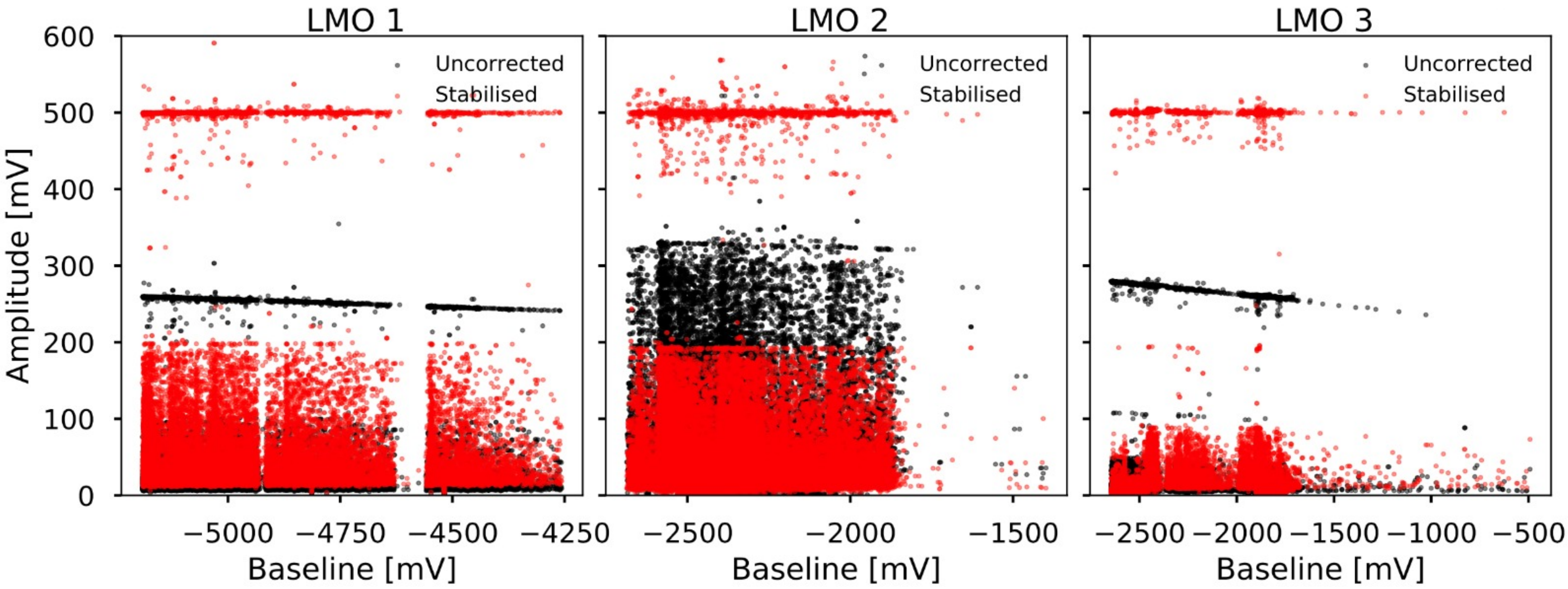
- **4 runs** of approximately 24h were taken
- **Pulses** are made applying 3.5 V across a resistor

Baseline increase → Lower amplitude

In order to **Calibrate** the amplitude need to be **stabilised**

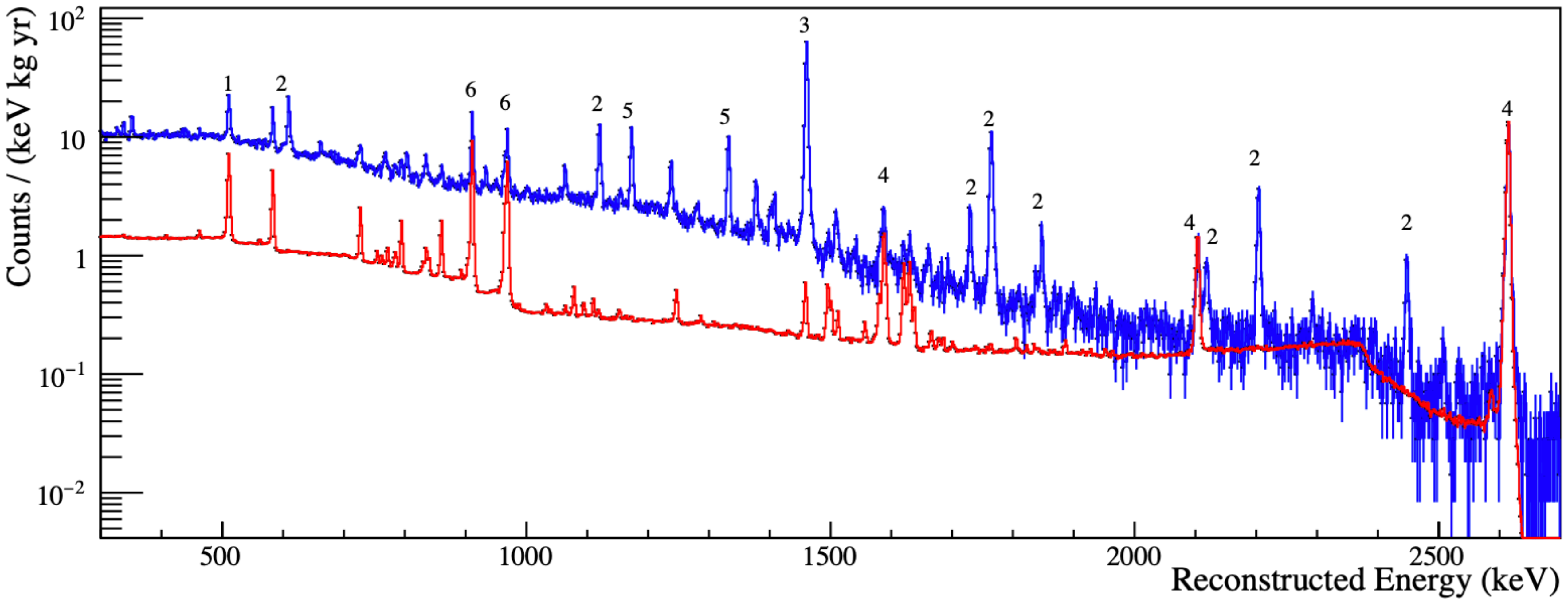


Calibration process: **stabilisation**



Calibration process: calibration

- Known radioactive decays from a ^{232}Th source are used to calibrate the energy response of the detector
- A linear energy calibration is performed using the 2615 keV peak from ^{208}Tl
- The spectrum is cleaned using data quality cuts requiring no pile up, a cut on rise time and decay time of the pulse



Isotope/source	Energy [keV]	
e^+e^- annihilation	511.0	1
^{208}Tl	510.8	
^{228}Ac	911.2	6
^{228}Ac	968.9	
Double escape 2614.5	1592.5	
Single escape 2614.5	2103.5	
^{208}Tl	2614.5	4

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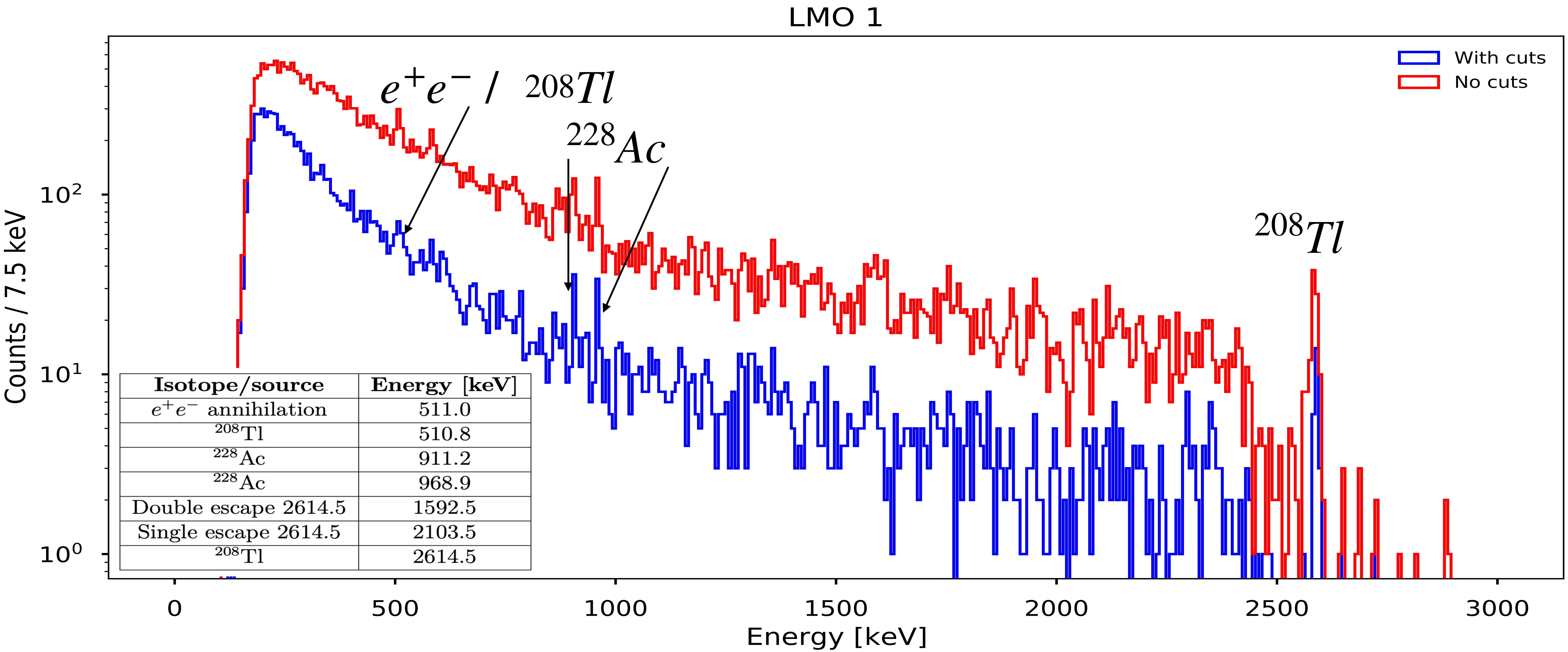
Calibration process: calibration



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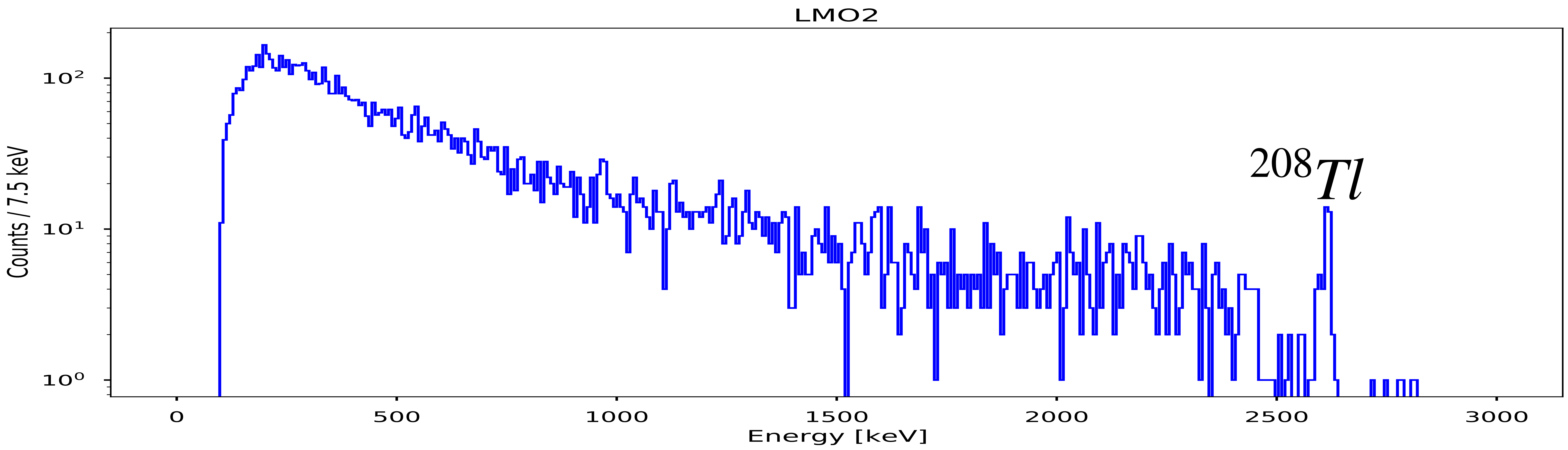
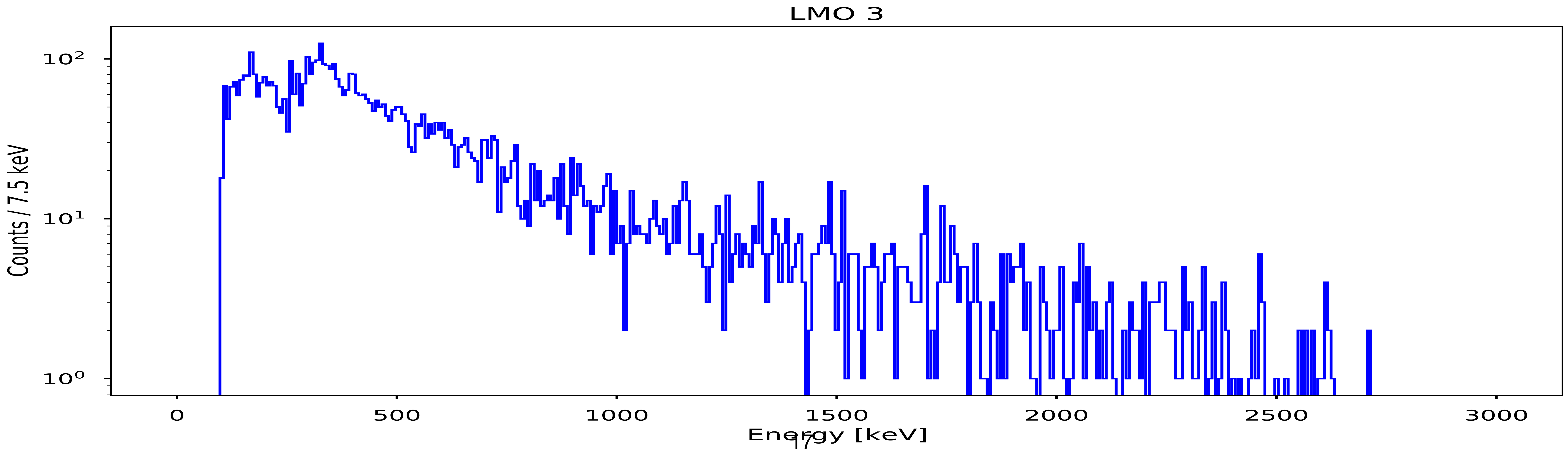
Calibration process: calibration





Summary

- We have found the **optimum working point** for an LMO crystal and light detector
- We have **stabilised the amplitude** of the signal to correct for variations in temperature over the course of a run
- We have performed a successful **calibration**, using the 2615 keV Tl-208 peak in the Th-232 decay chain and resolved multiple peaks in the spectrum

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Thank you for your attention

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Stay tuned
Wine so serious?

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