Point contact TES
Single e/h detectors for TESSERACT

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19/06/25

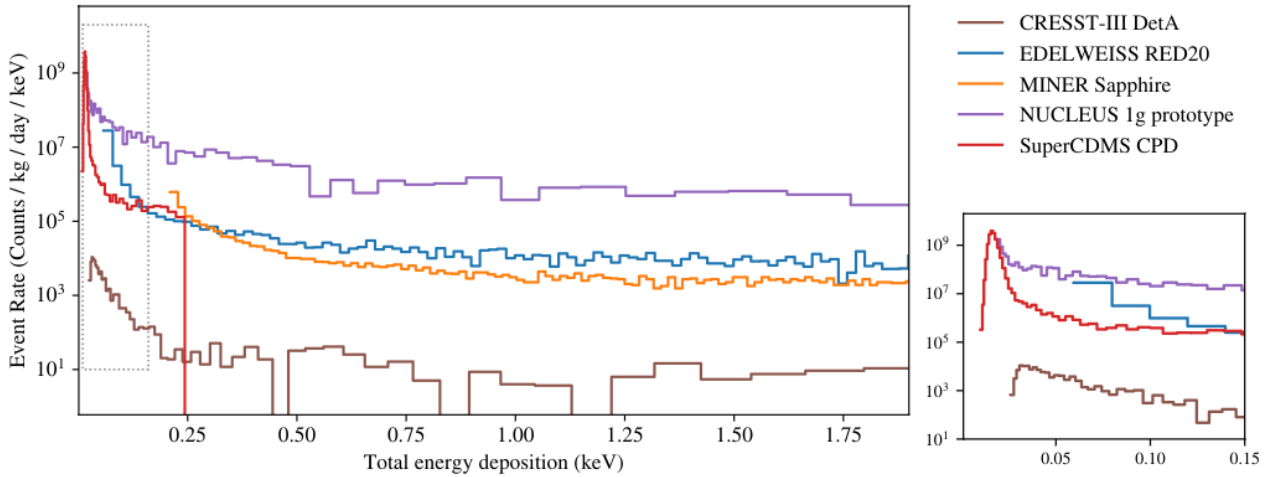
Ion Cojocari

CRYOSEL as answer to Heat Only excess

TESSERACT

Source :
2202.05097

- CRYOSEL – ANR project
- Lower the detection energy threshold
- Be « immune » to HO excess
- Novel detector design



CRYOSEL as answer to Heat Only excess

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Source :
2202.05097

- CRYOSEL – ANR project
- Lower the detection energy threshold
- Be « immune » to HO excess
- Point contact design
- High impedance sensors
- Exploit Neganov-Trofimov-Luke amplification

Neganov Trofimov Luke (NTL) amplification of the heat channel in a semiconductor:

E_{heat} = Erecoil + drifting Q dissipation
= E_{Recoil} + Q ΔV

Charge collecting voltage

NTL energy
(joule heating of the drifting electrons + holes)

- By rising ΔV we boost the heat signal: NTL amplification
- Ideally, we can achieve single electron-hole threshold

CRYOSEL as answer to Heat Only excess

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Source : 2202.05097

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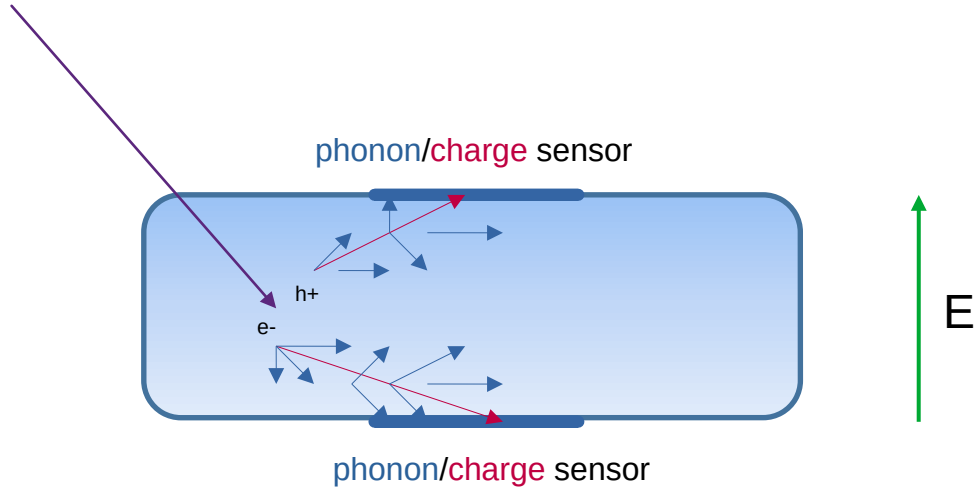
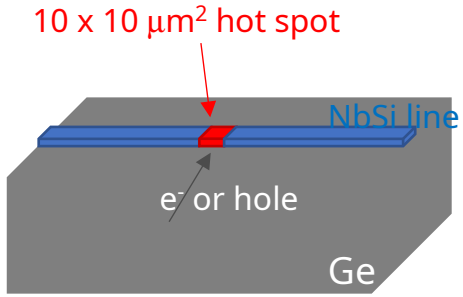
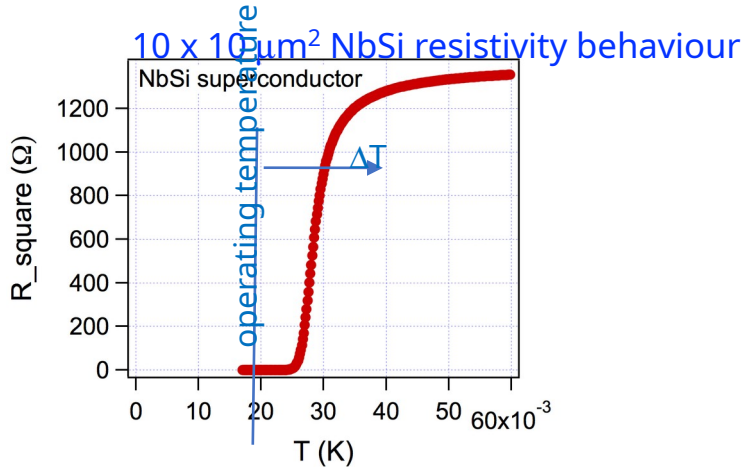


E_{heat} = Erecoil + drifting Q dissipation
= E_{Recoil} + Q ΔV

SSED – Superconducting Single Electron Device

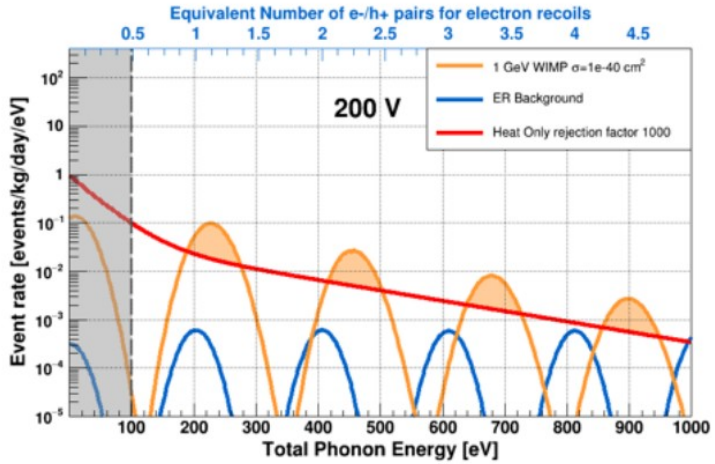
TESSERACT





NbSi film operating below Tc

- NTL phonons create a hot-spot
- Biasing under the Tc -> sensible only to NTL events
- High-impedance -> classic JFET read-out



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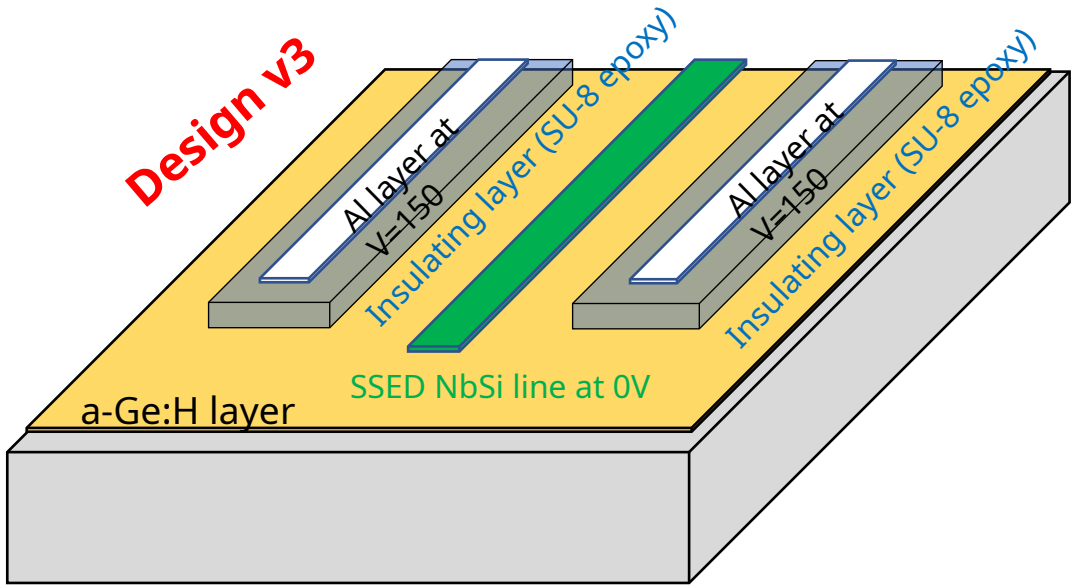

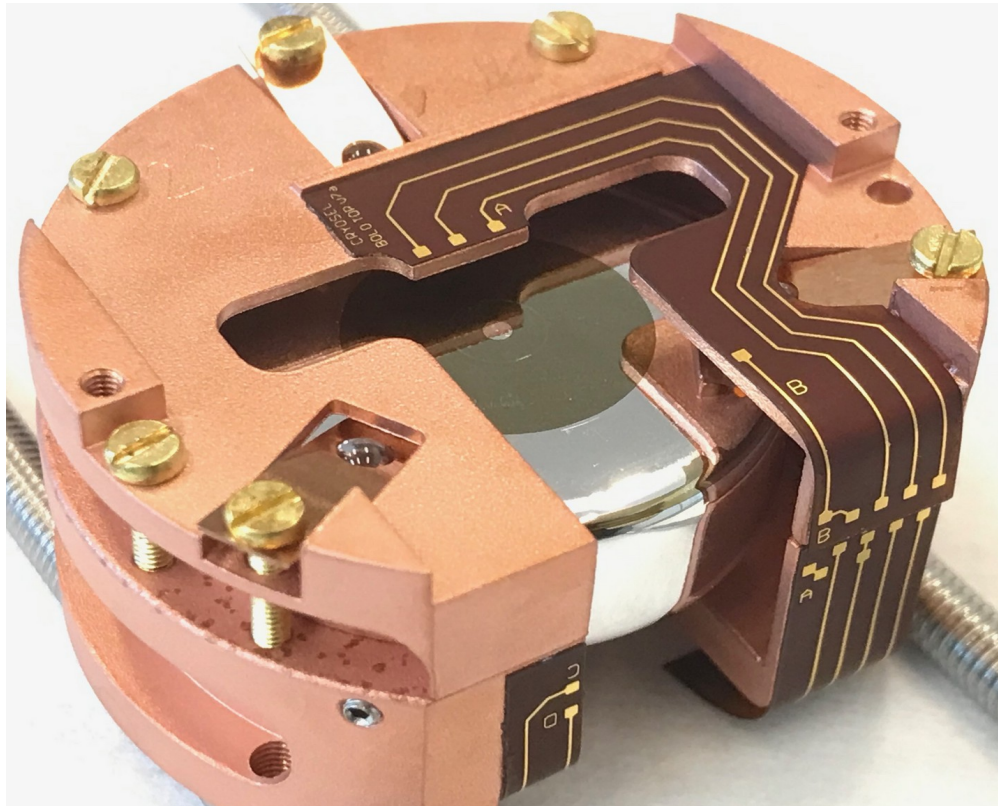

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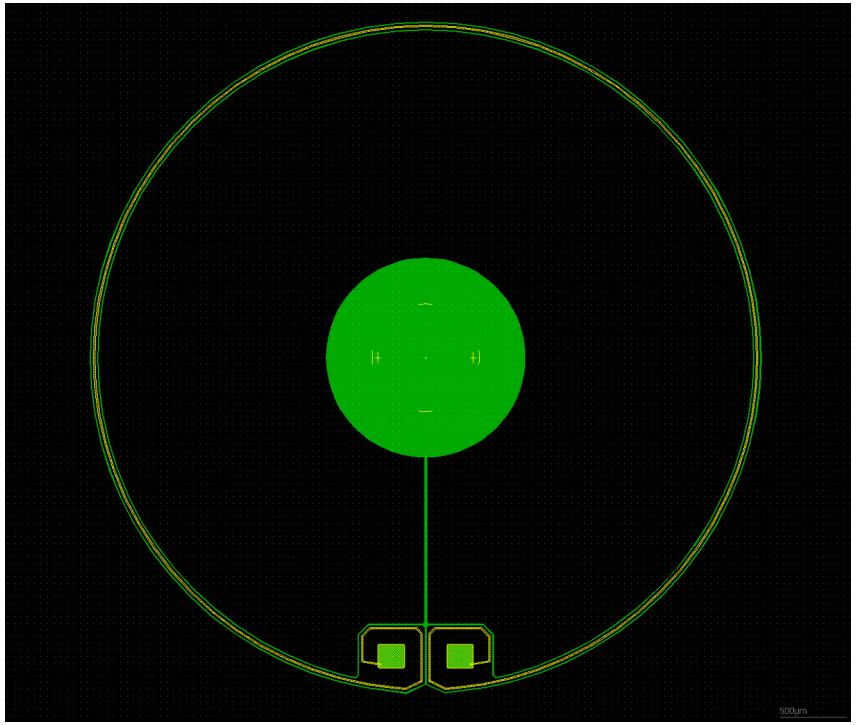
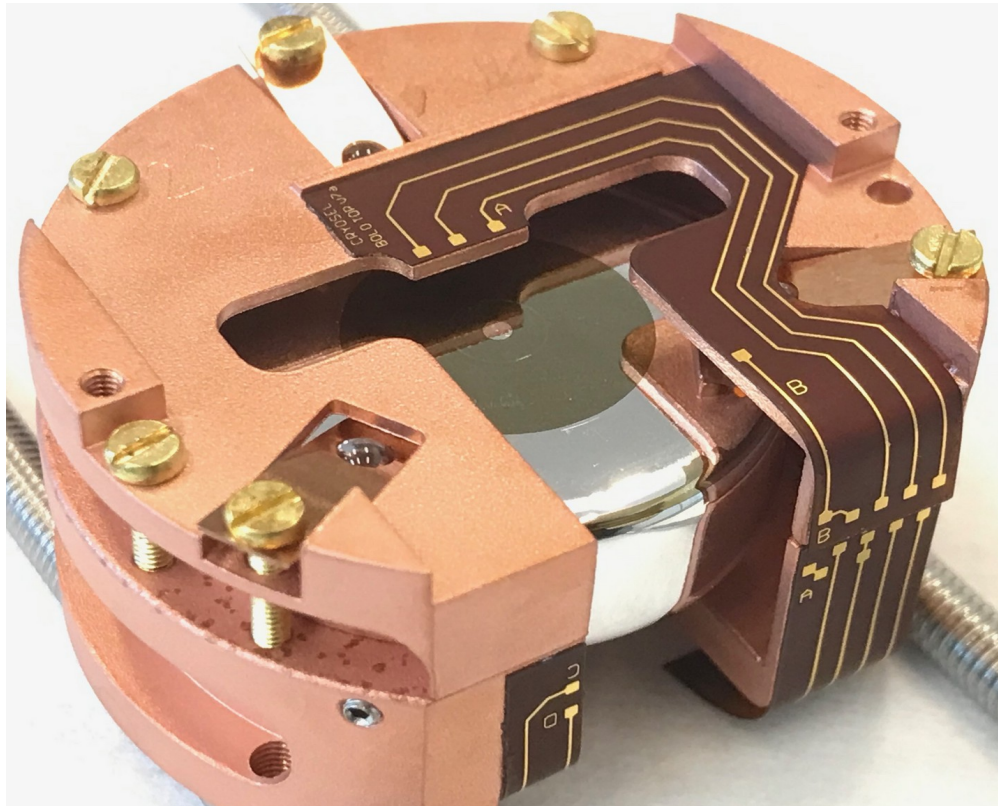
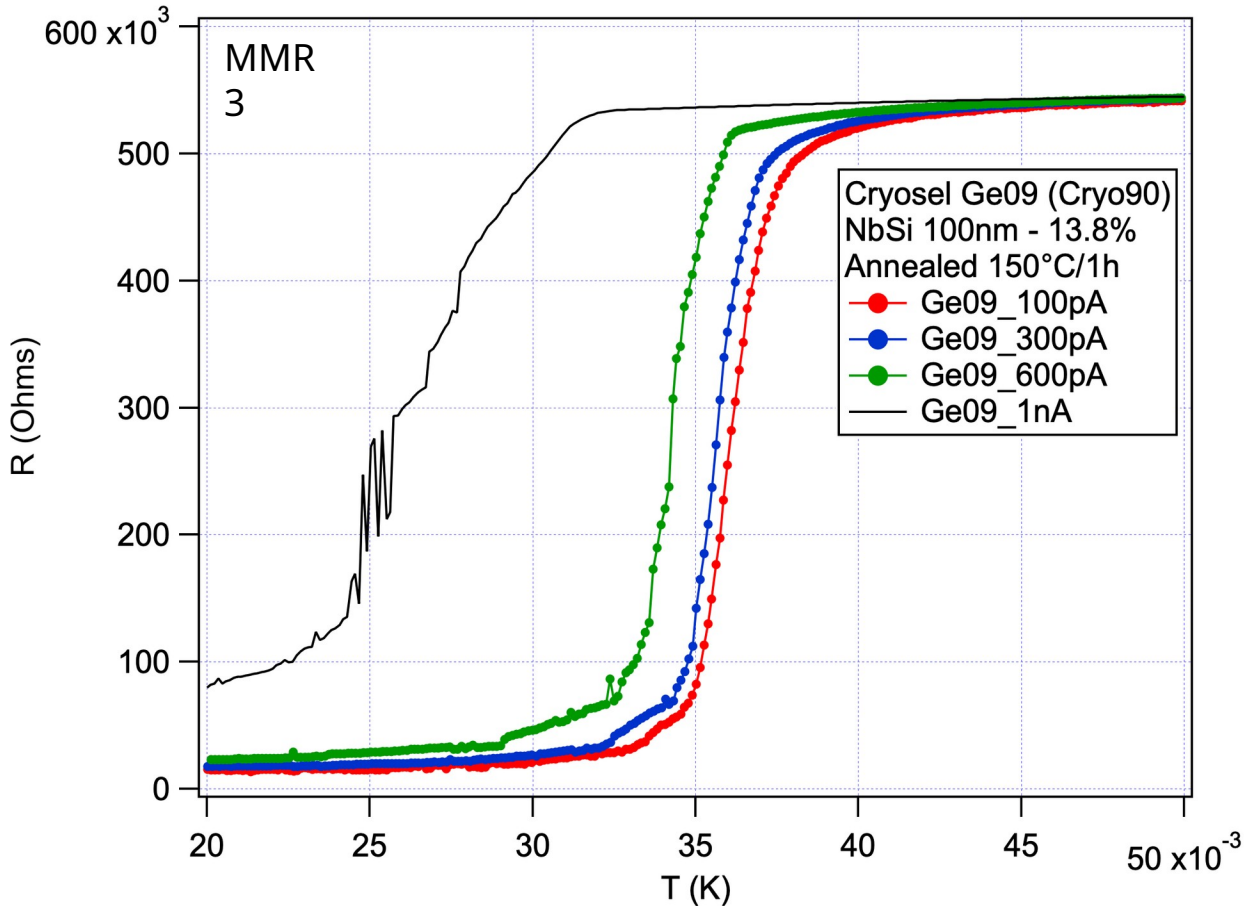




Results – Cryosel_9

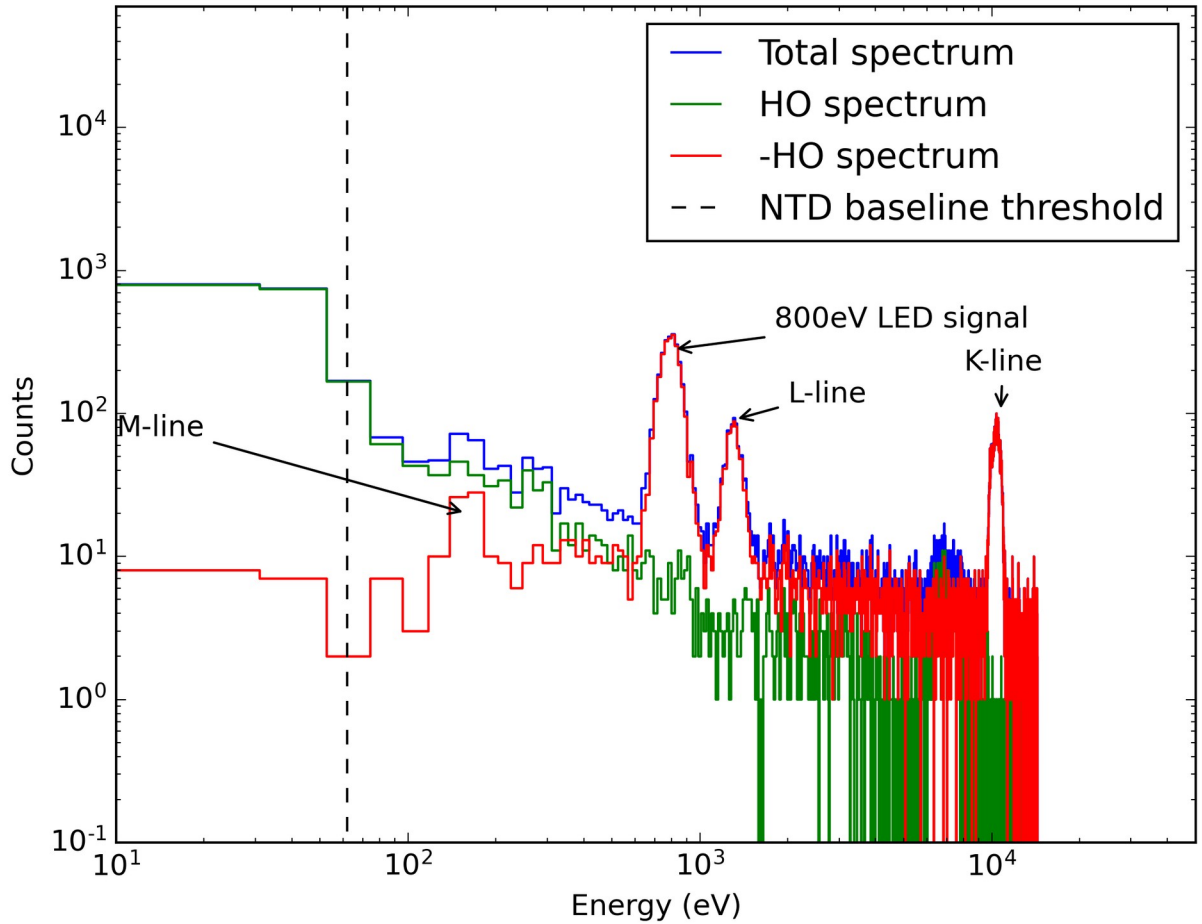
- Tc ~35mK
- Very low critical current
- Unstable behaviour at higher currents

  -> Positive electrothermal feedback



Cryosel_9 – Heat only rejection

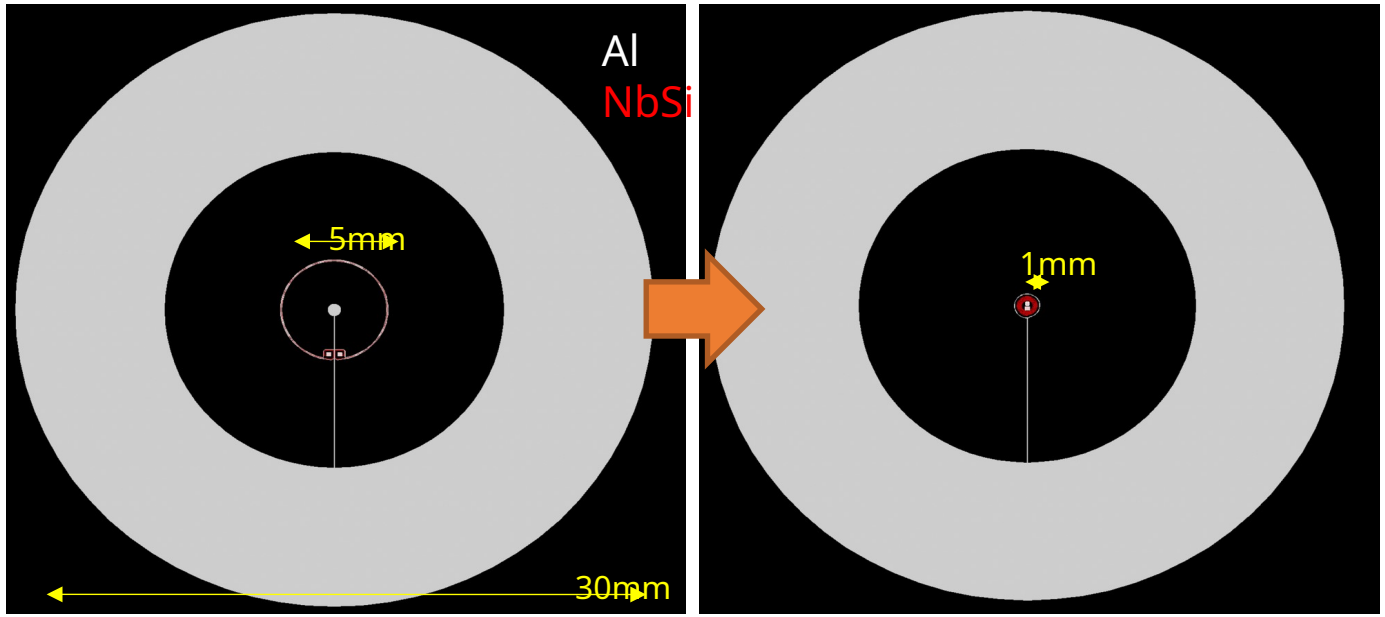
- Stable at 140V – multiple days
- Proven rejection of HO events
- ~40eV RMS
- Baseline noise 7eV RMS
- Future optimisation at a crossroad :
  - Increase NTL bias
  - Optimise resolution
  - Increase ballistic phonon absorption efficiency (3% in this design)



SSED evolution

- 2 designs to be explored:
  - High impedance
  - Low impedance

- More compact TES -> better phonon absorption



The point contact technology

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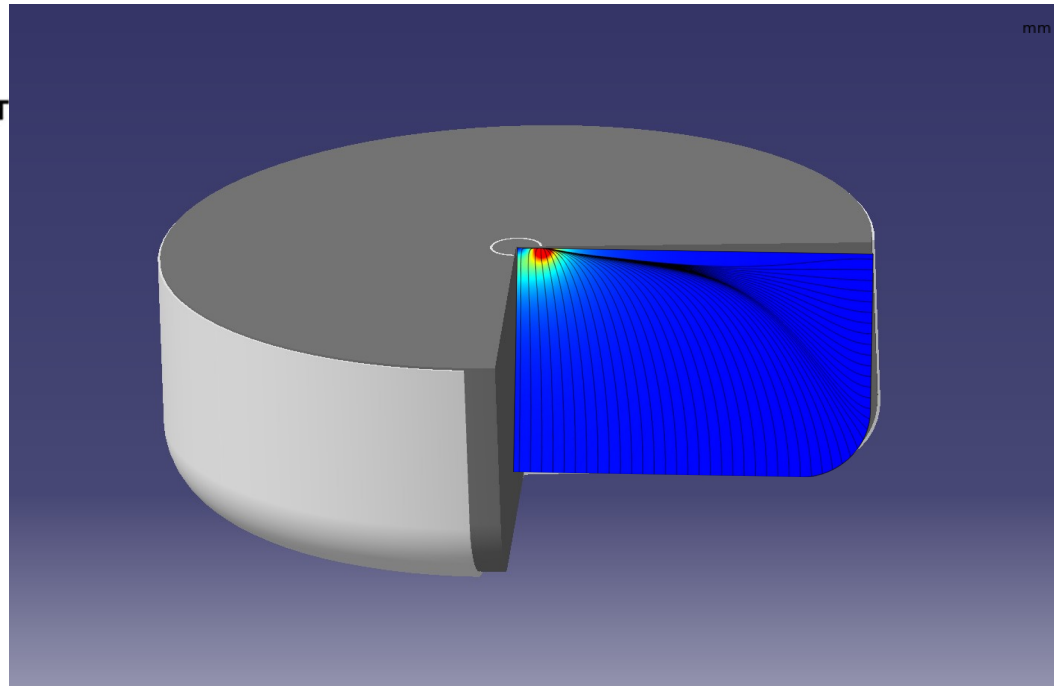

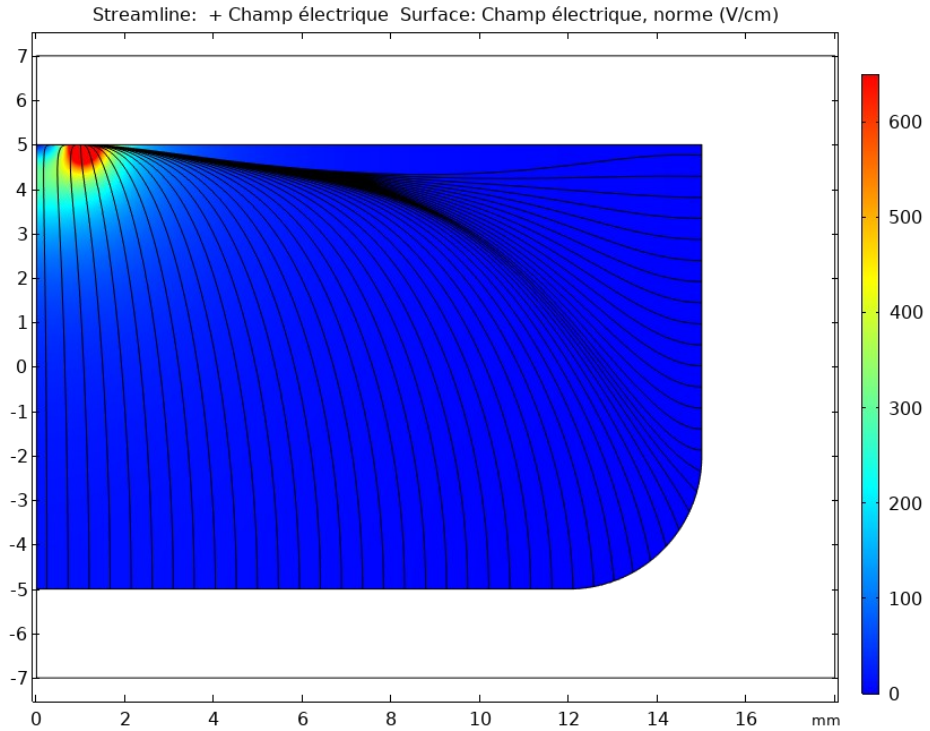

Measured PC-TES phonon-trapping efficiency **ε** to NTL-phonons **ε** = 3 %

- Suited to large mass crystals
- Negligible dependence on event localization
- Single-electron at lower V

The point contact technology

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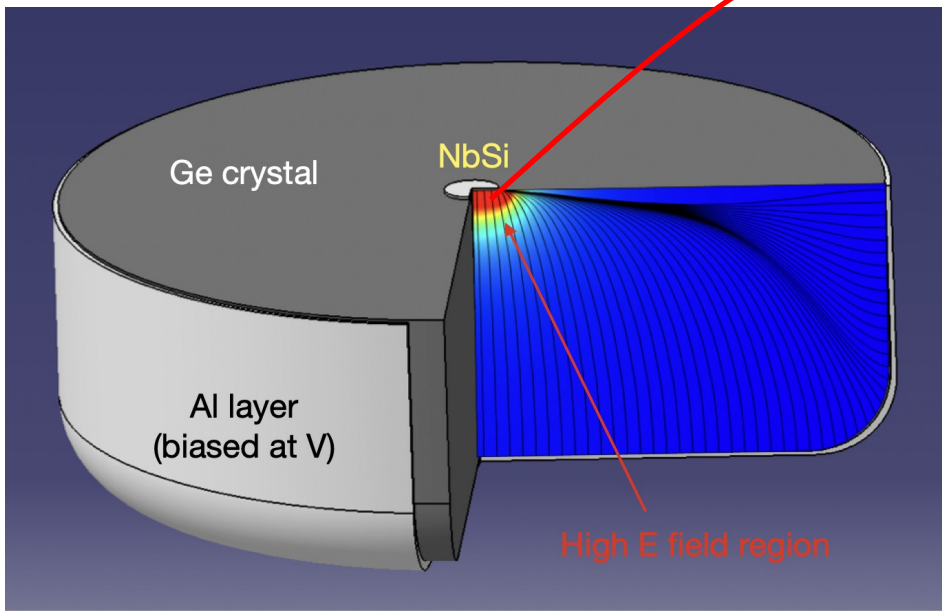
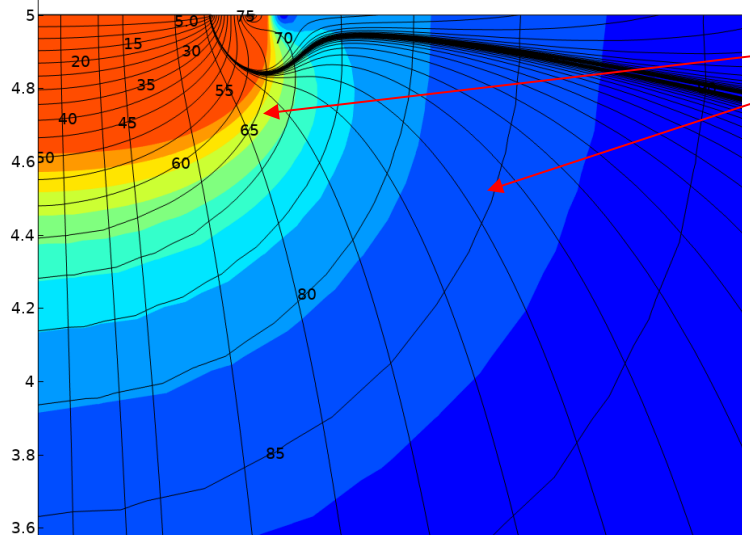
60 % of the NTL athermal phonons emitted in the red region





Measured PC-TES phonon-trapping efficiency **ε**
to NTL-phonons **ε** = 15 %
to 0 V phonons **ε** ≈ 0.2 %
Ge recoil phonons

- Suited to large mass crystals
- Negligible dependence on event localization
- Single-electron at lower V

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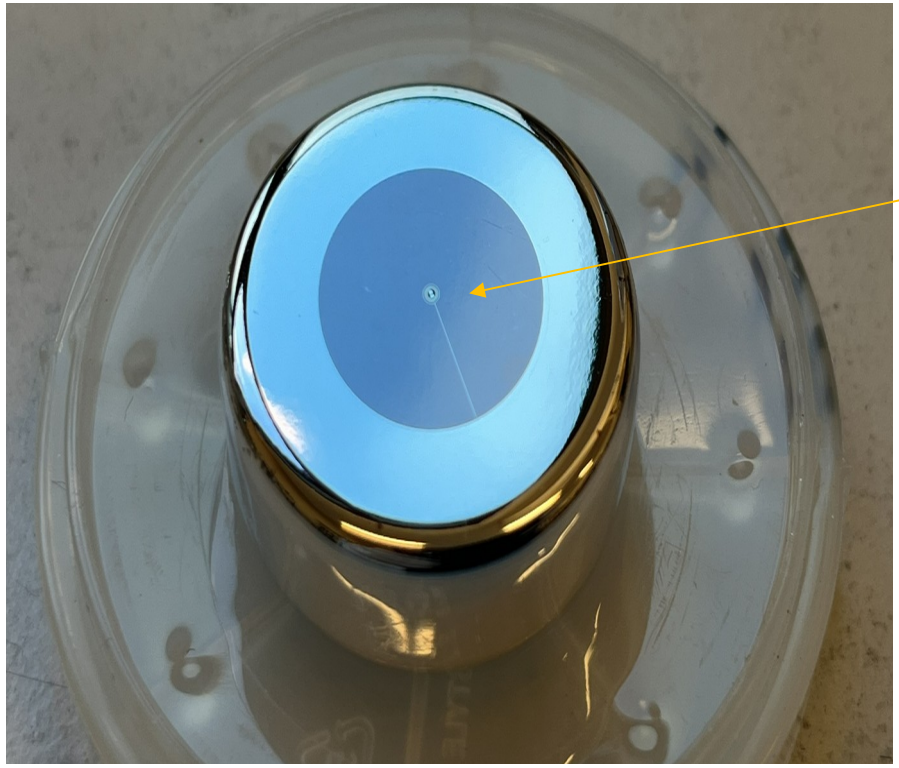
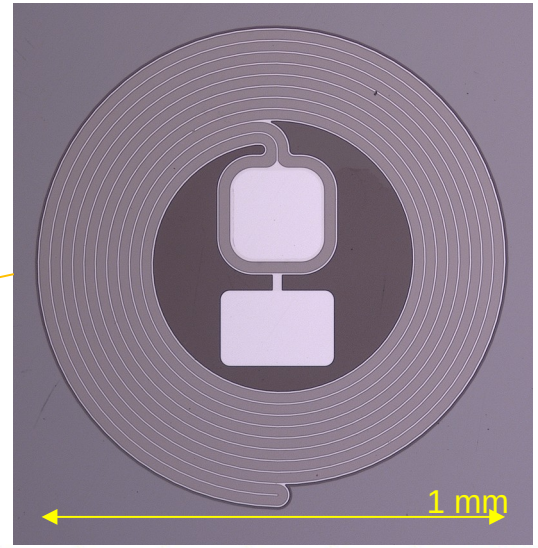
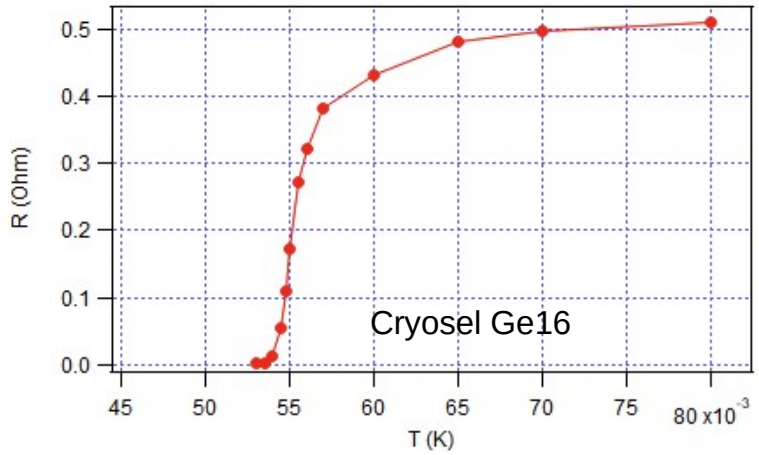
Nb_xSi_{1-x} TES design

Cryosel_Ge16: Tc = 55mK







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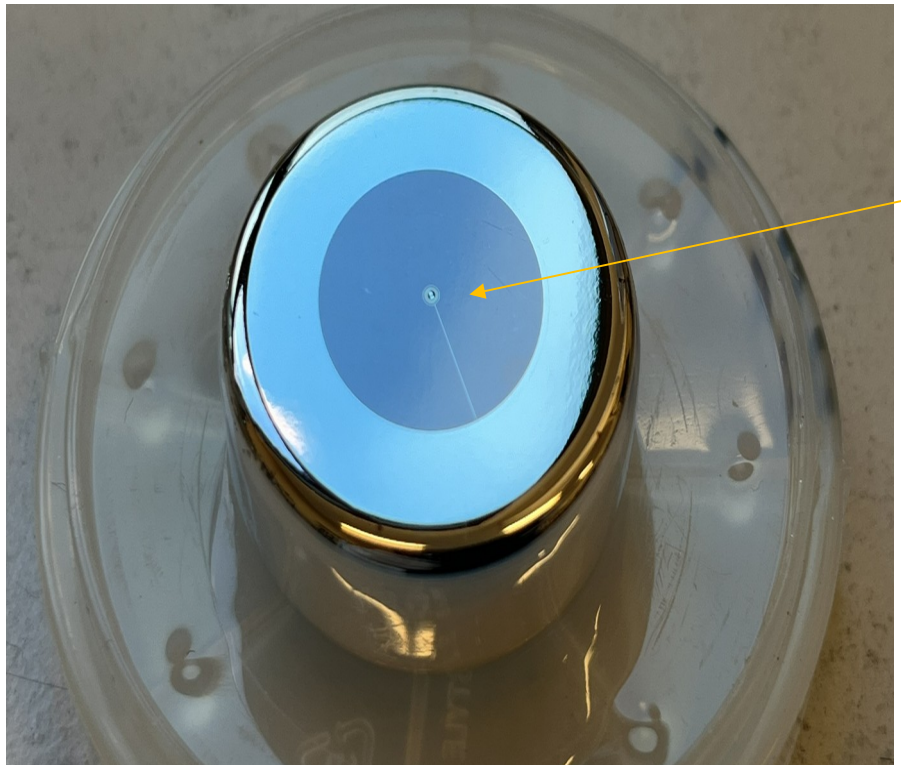

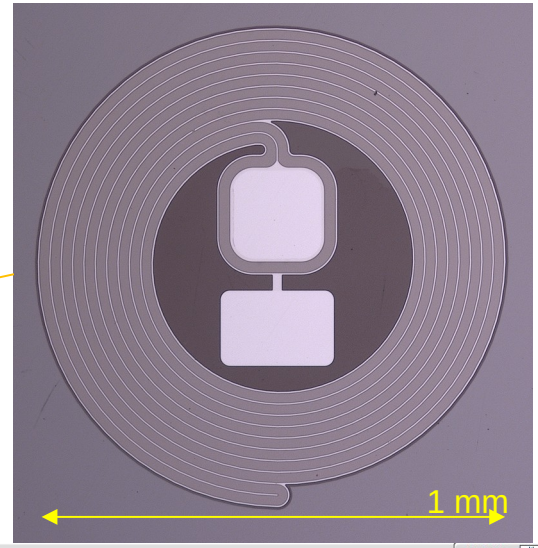

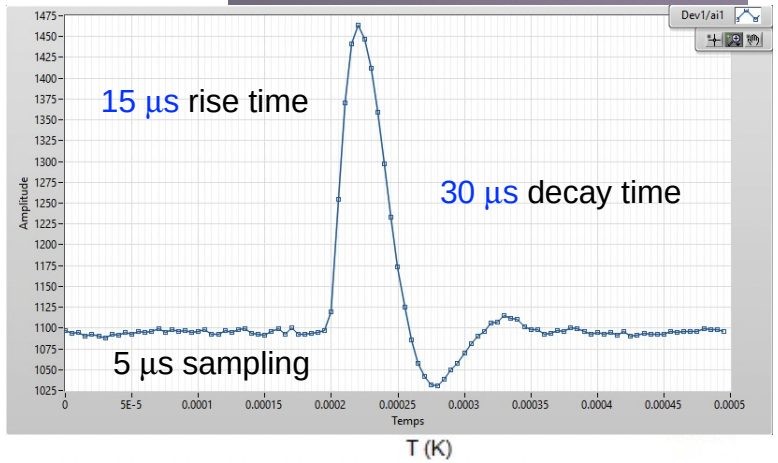

PC-TES single electron threshold

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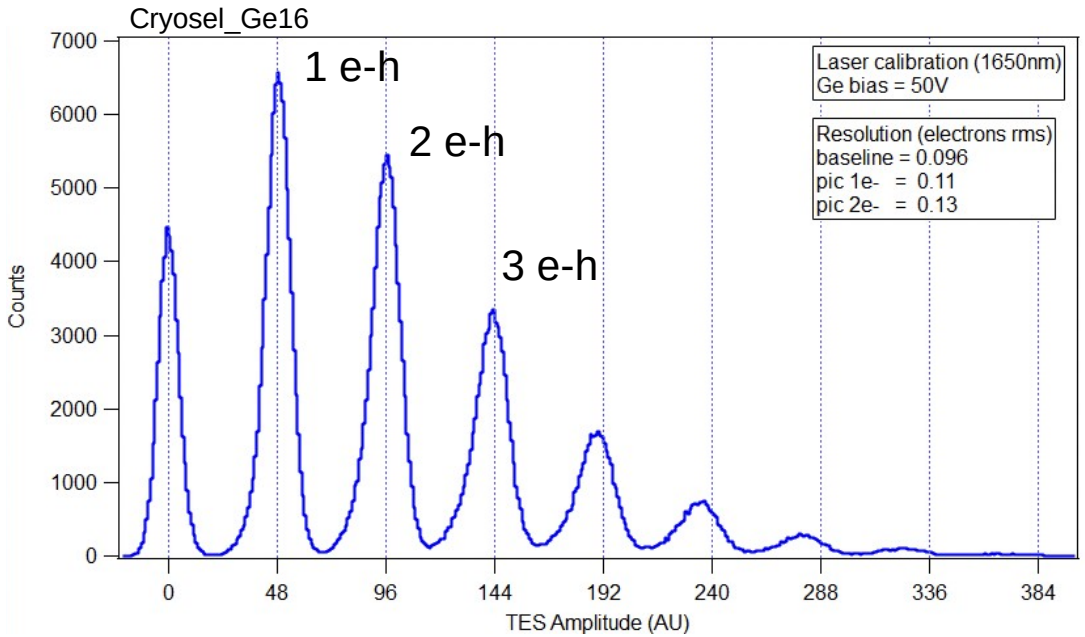

- Single e-h threshold for Ge voltage biasing above 30 V
- Baseline resolution at 50 V : 0.1 e-h RMS
- Achieved with just 1 SQUID or SQUID + SQUID Array system (more stable)

PC-TES dynamic range

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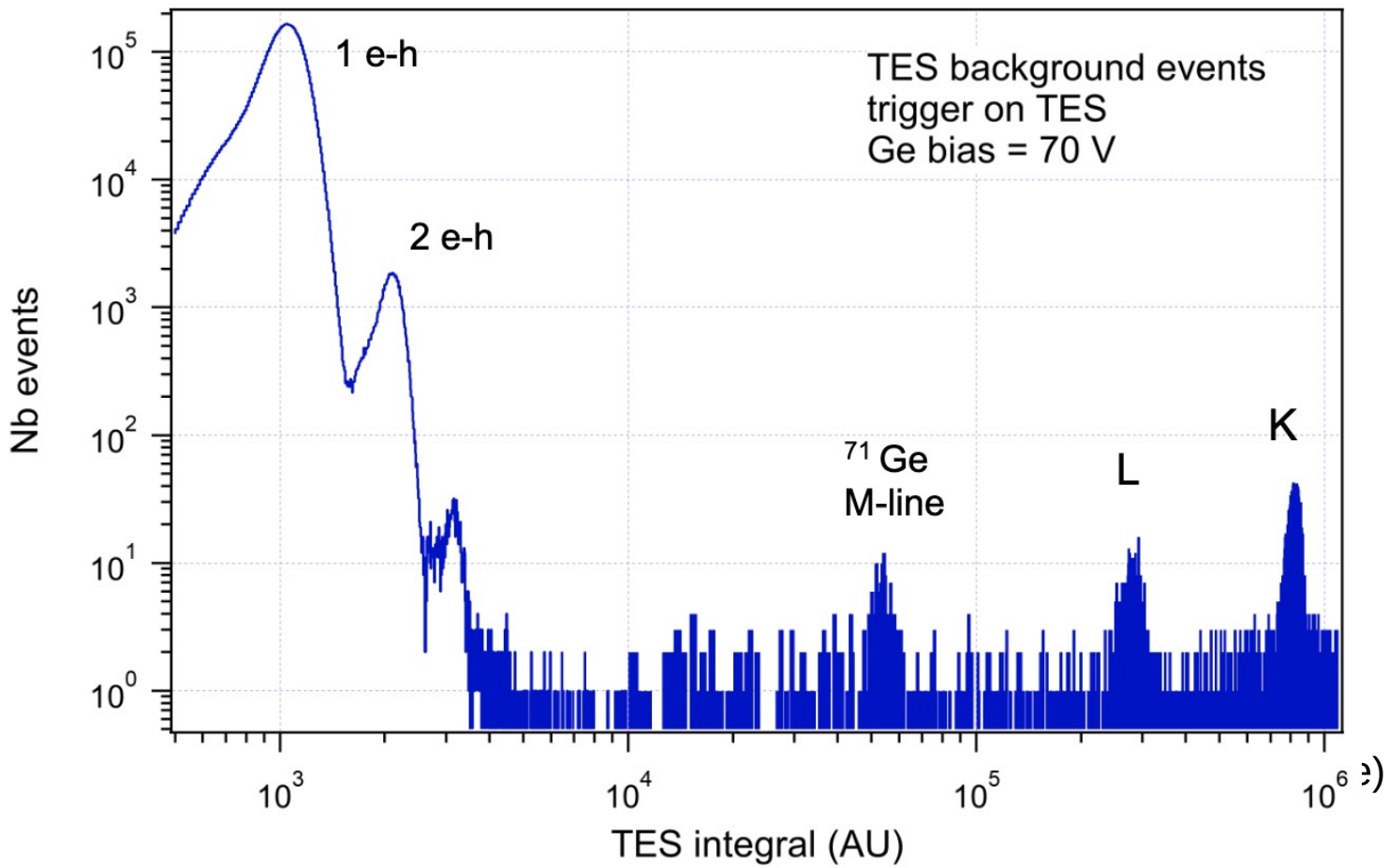
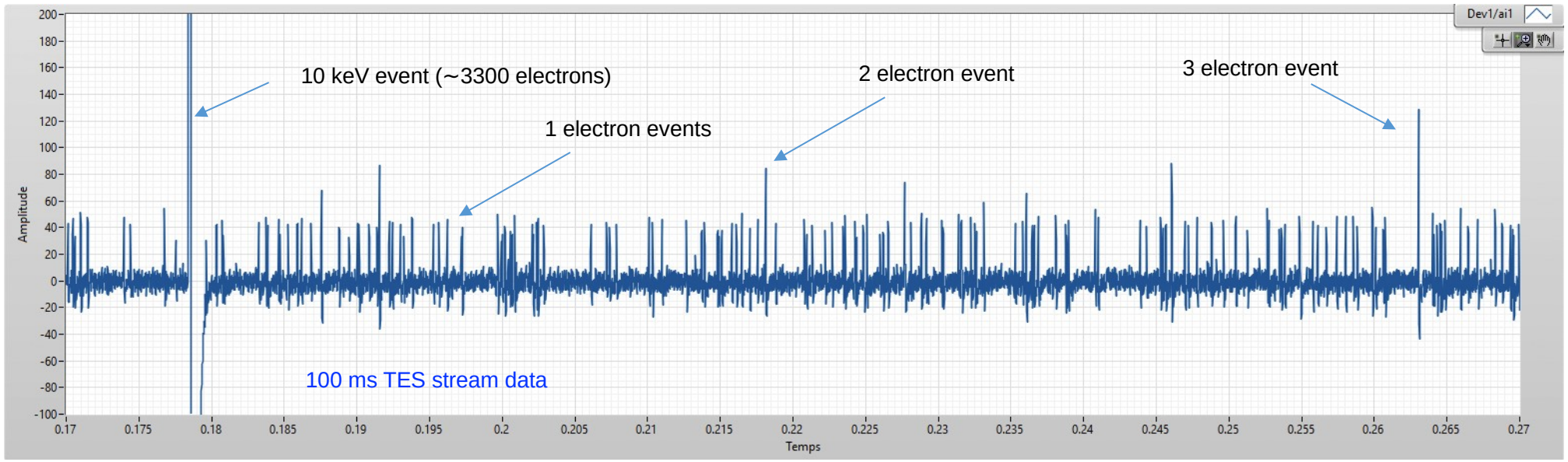


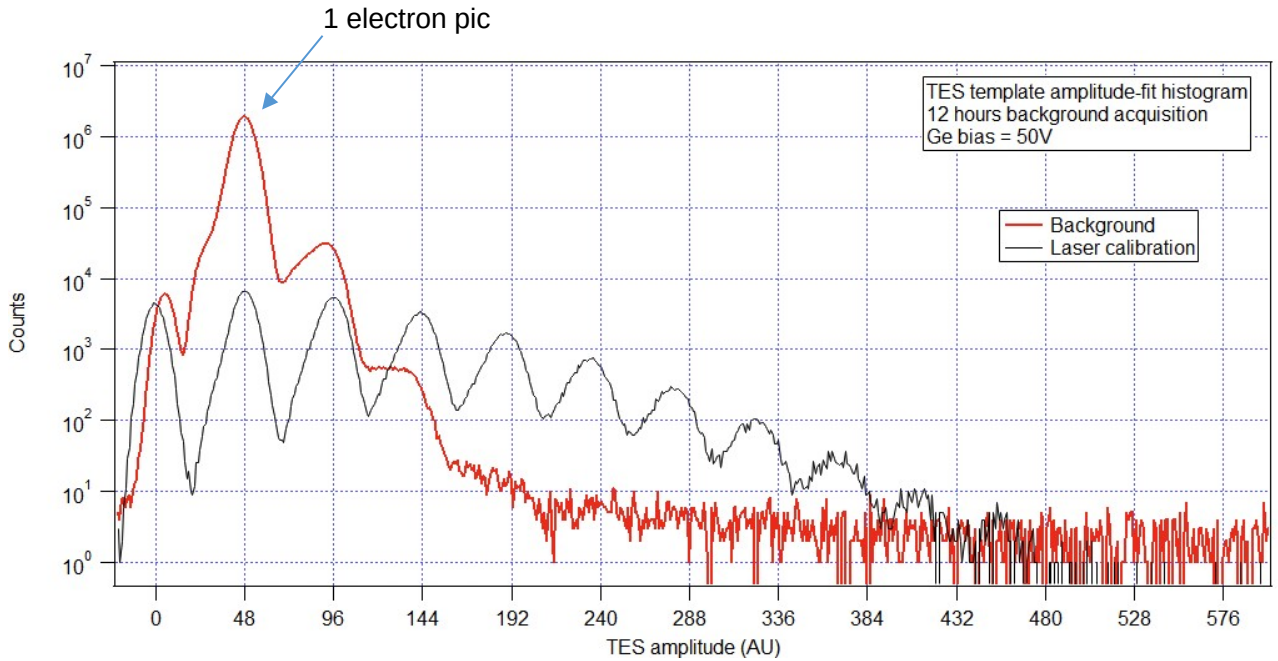
Background events



We observe a high rate of 1 electron events : approximately 500 to 1000 Hz.

This background is currently under study

Low energy background



Background rising below approx. 5 e-h (15 eV_{ee} ionization) :

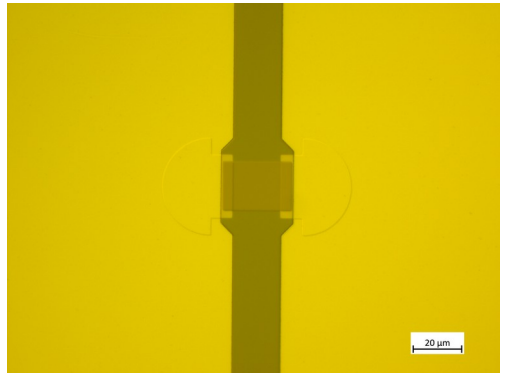
Next steps

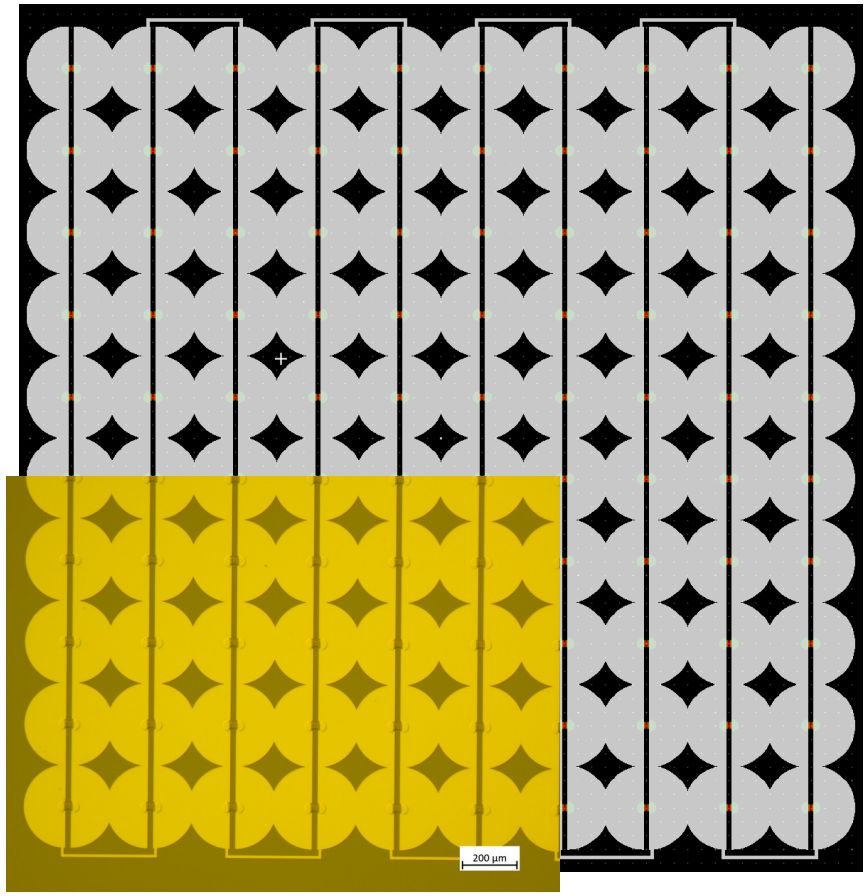
- Implement a low threshold phonon-TES
  goal: phonon energy resolution $\lesssim$ 10 eV

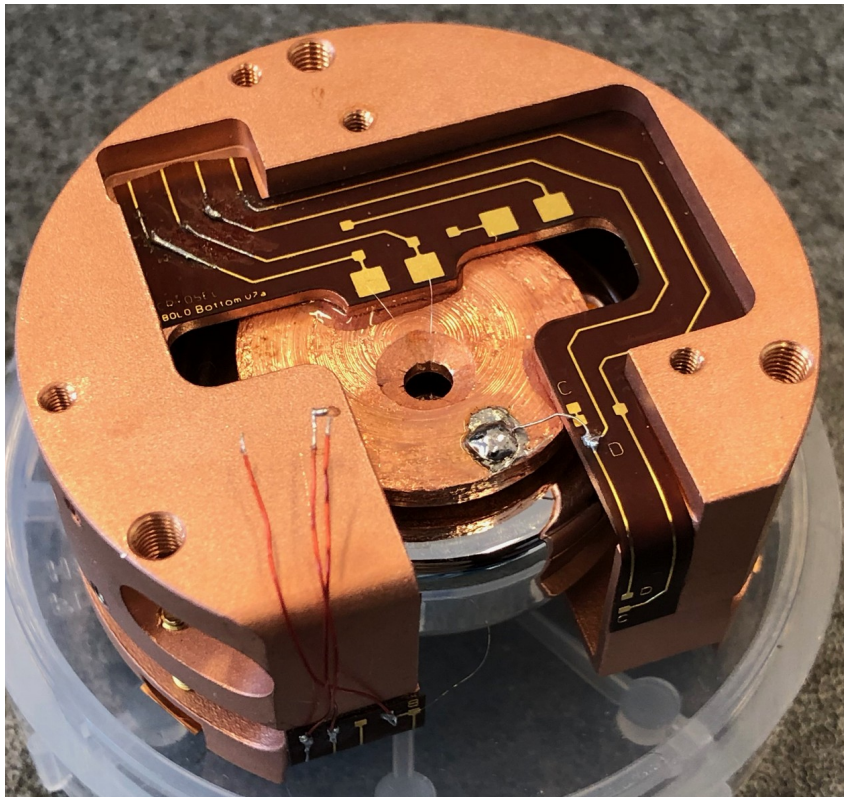
- Minimize backgrounds & optimize rejection efficiency
  - Fully understand and mitigate background below 5 e-h
  - LEE discrimination (already demonstrated at high energies with an NTD-Ge thermistor)

Large area TES detectors

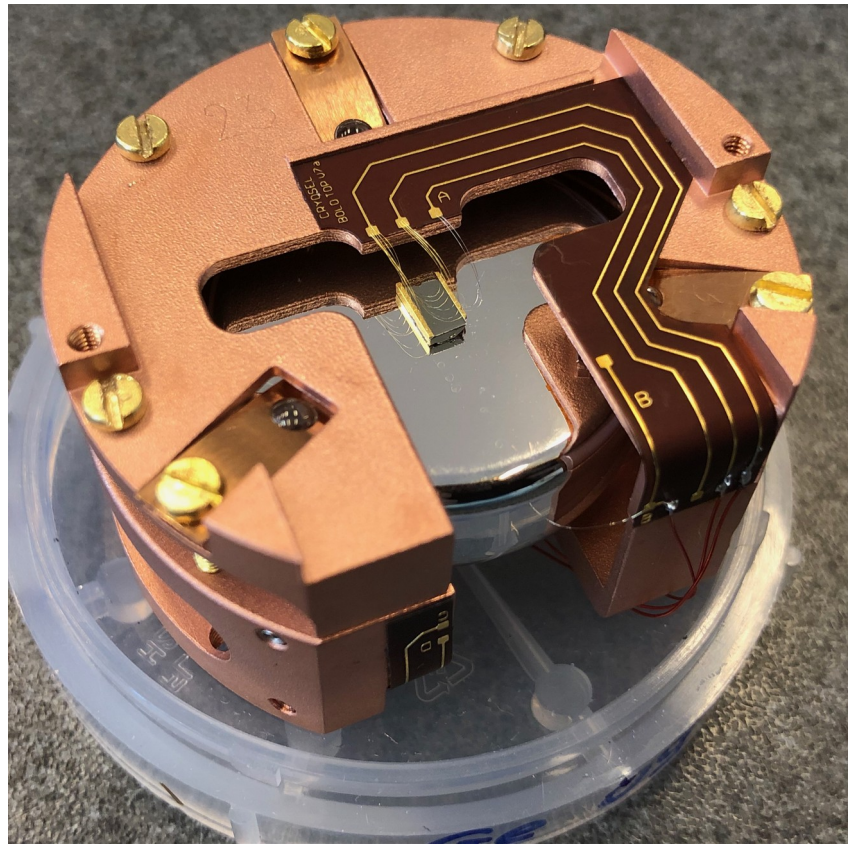
- Implement a low threshold phonon-TES
  goal: phonon energy resolution ≲ 10 eV
- Square matrix – parallelized NbSi sensors + Al fins
- Multiple designs under study
  - NbSi + Al fins
  - NbSi + Ir(Ti) + Al fins
- Laser lithography for quick turn-around during design phase



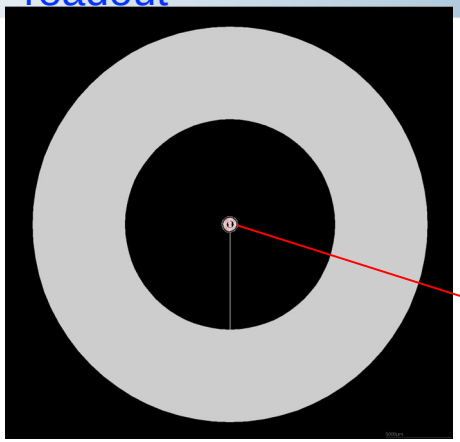


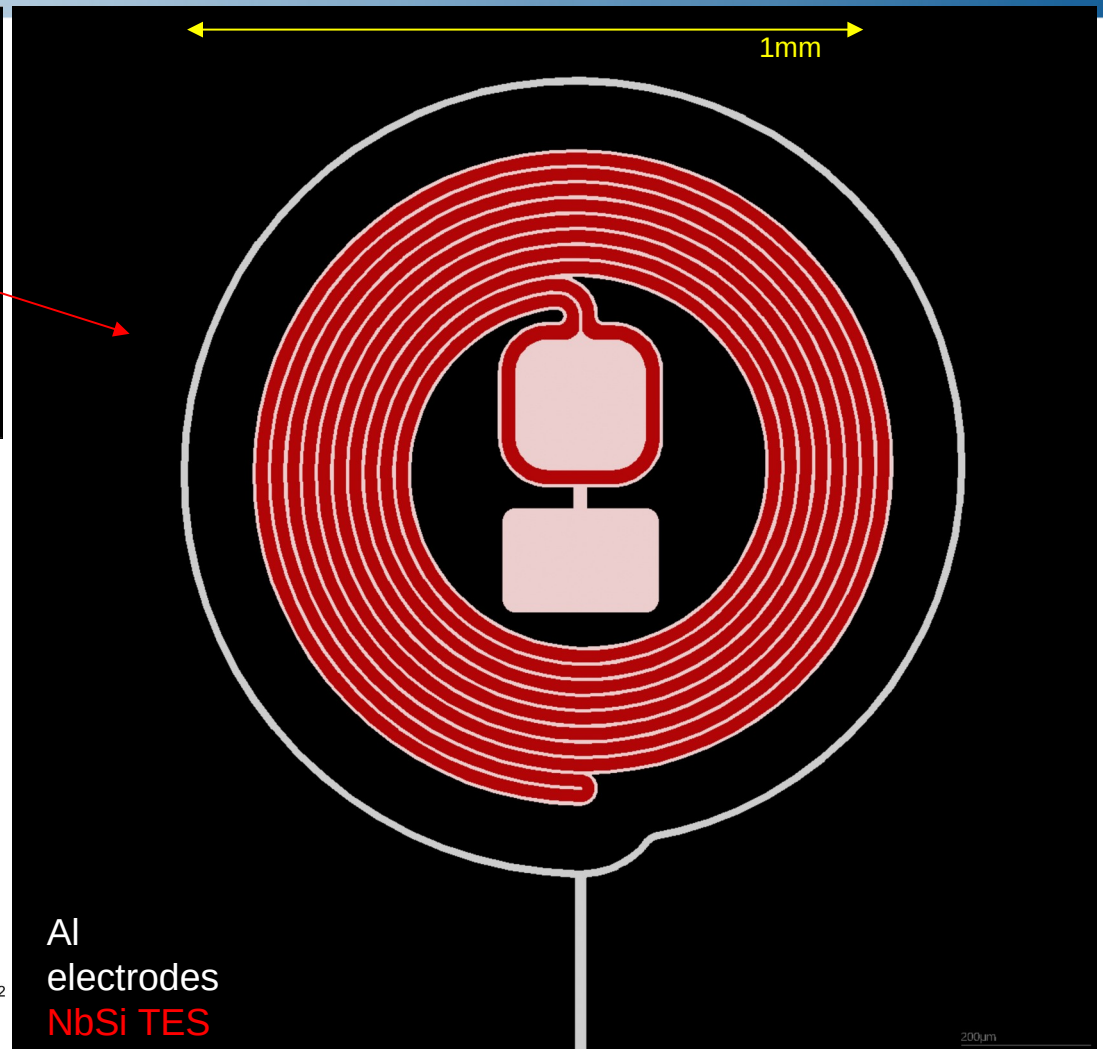


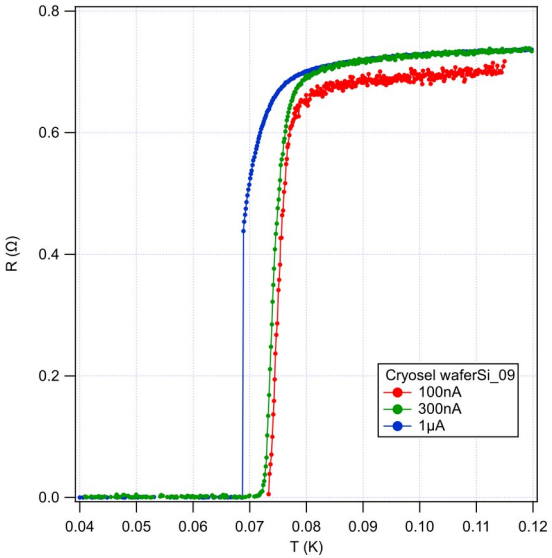
Thanks!



Low impedance TES design, optimized for SQUID readout







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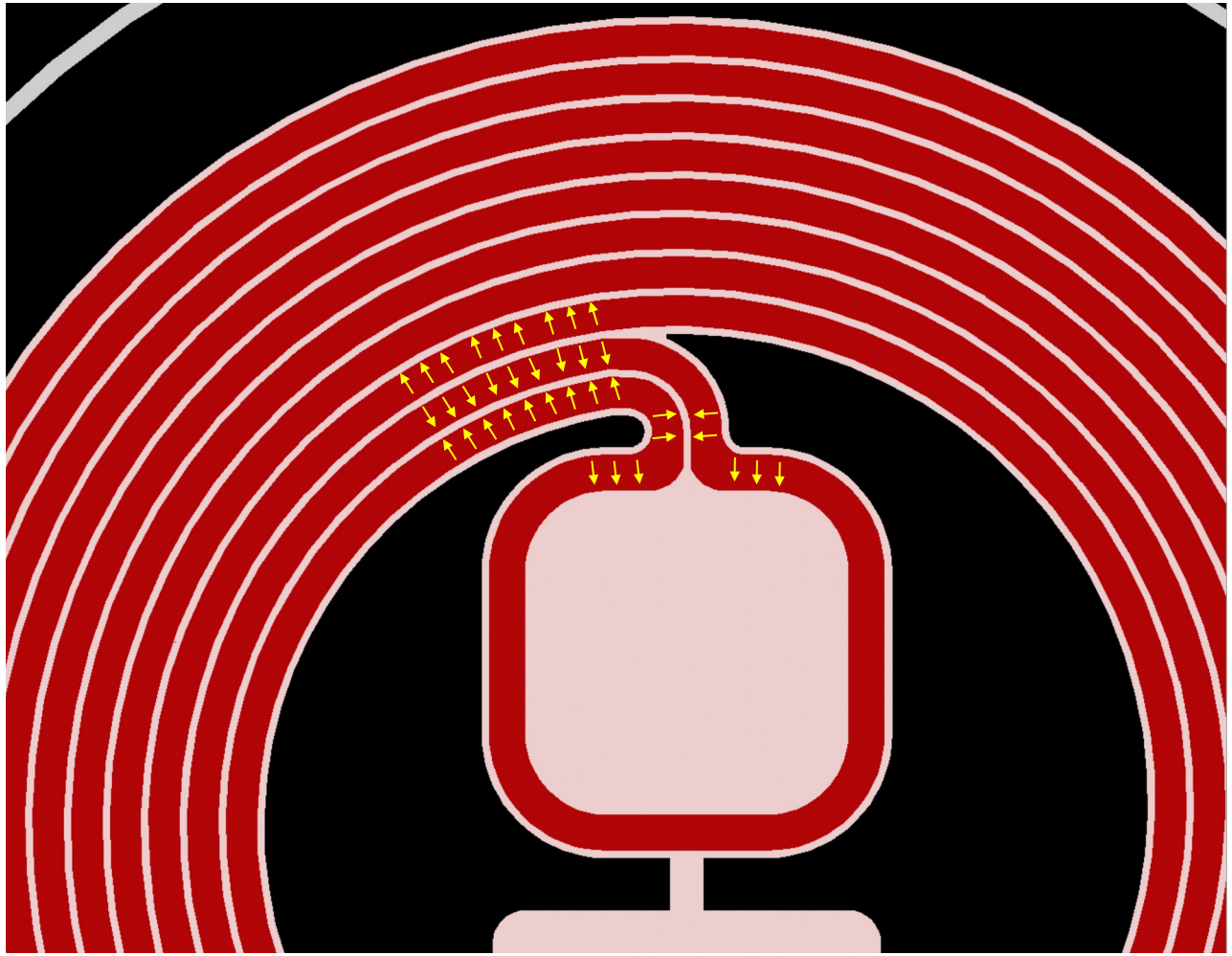
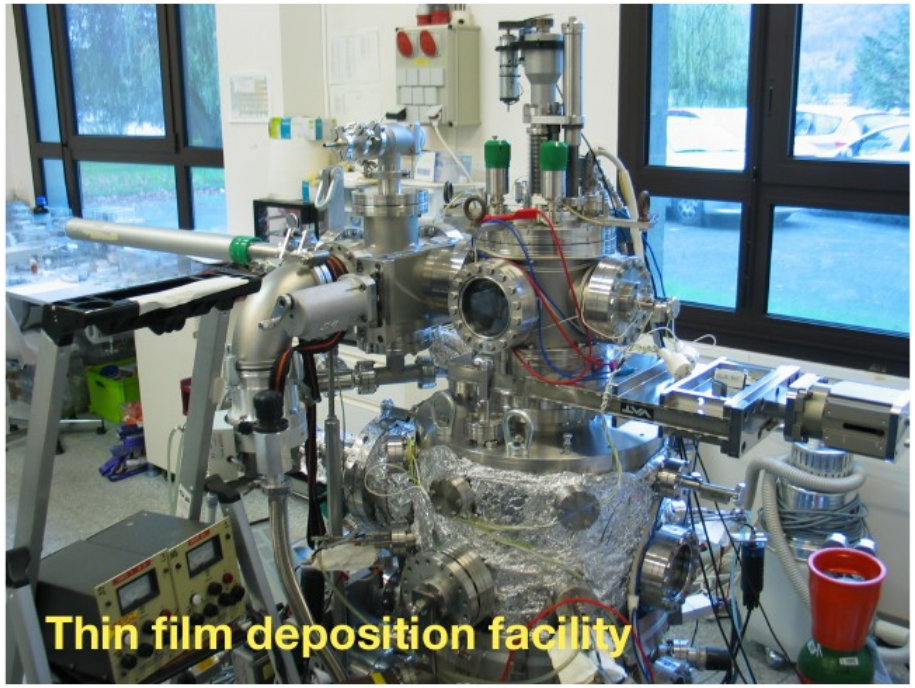


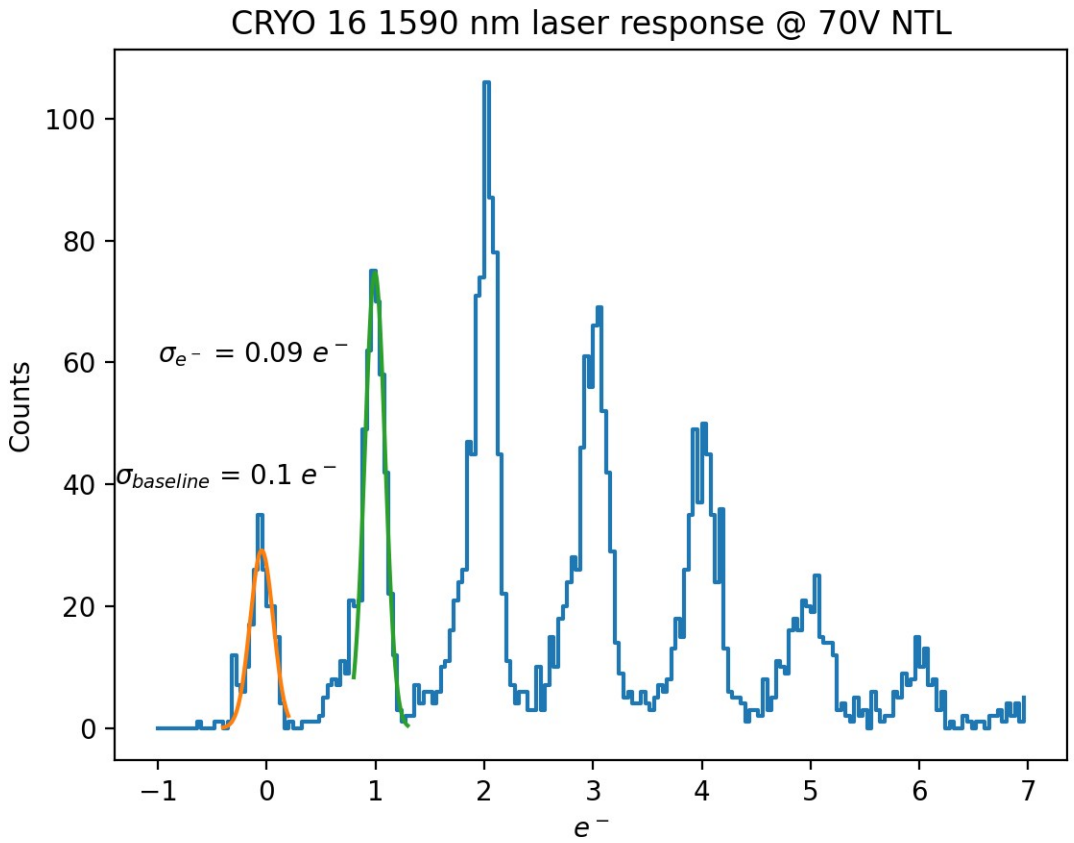
A IJCLab

- Design et fabrication des détecteurs
- Déposition de couches minces de NbSi
- Tests et caractérisation→ cryostat à dilution 10mK

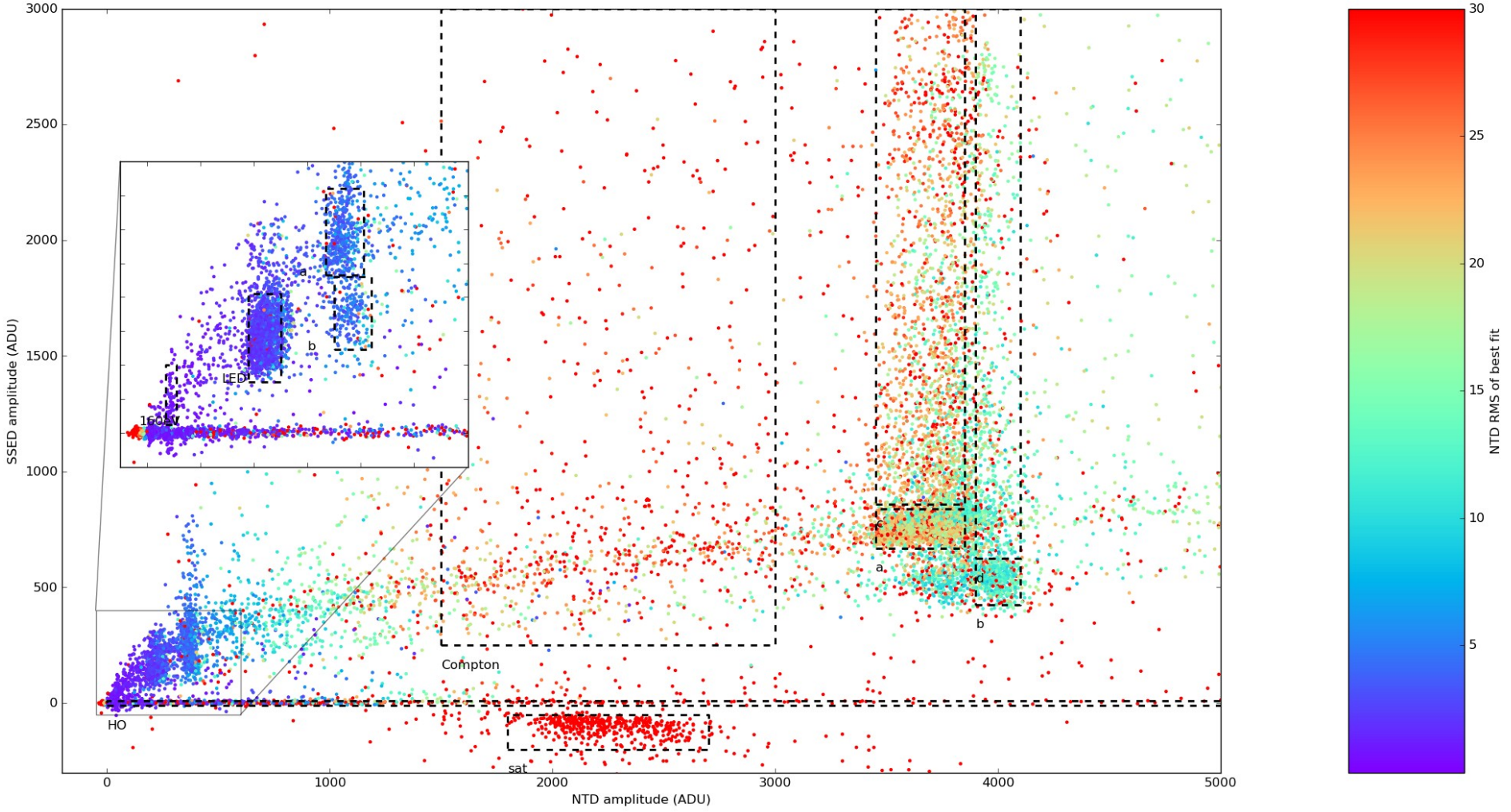


Cryosel_16 – TES basse impédance

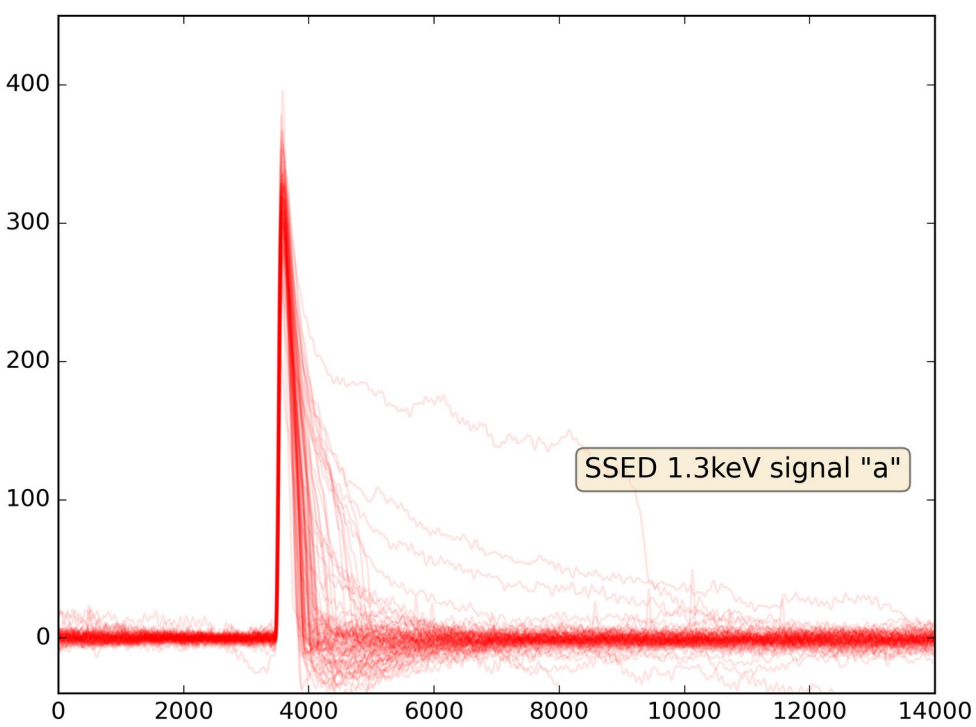
- Actuellement sous étude – TES basse impédance (500mOhm)
- Lecture SQUID
- Détection de l'électron unique
- Bruit RMS < 0,1e-

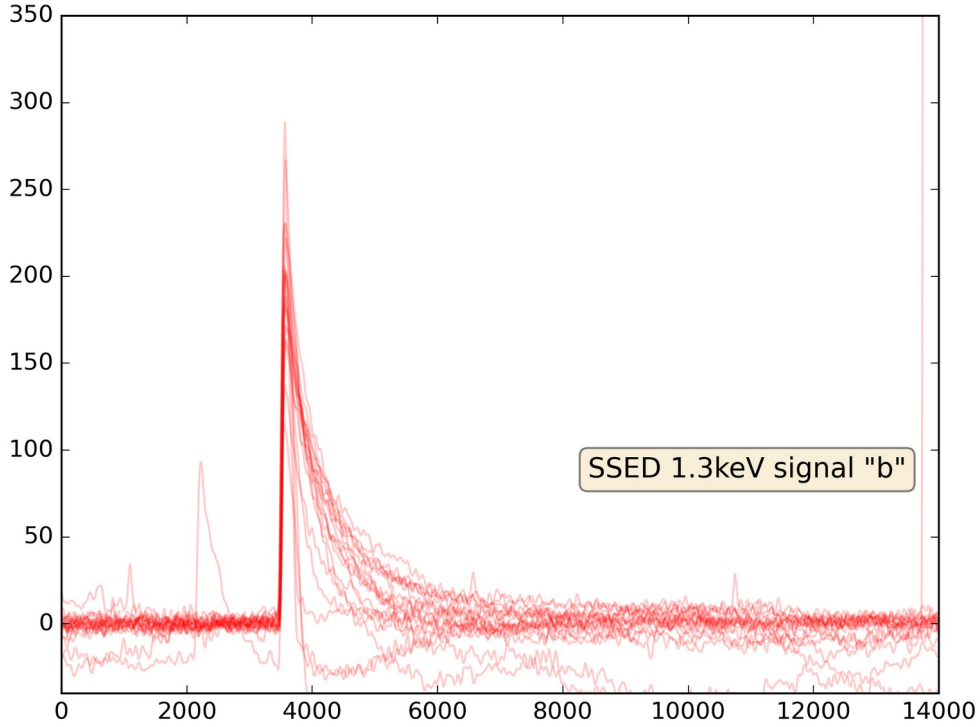


Signal shape zoology



Short vs Long events

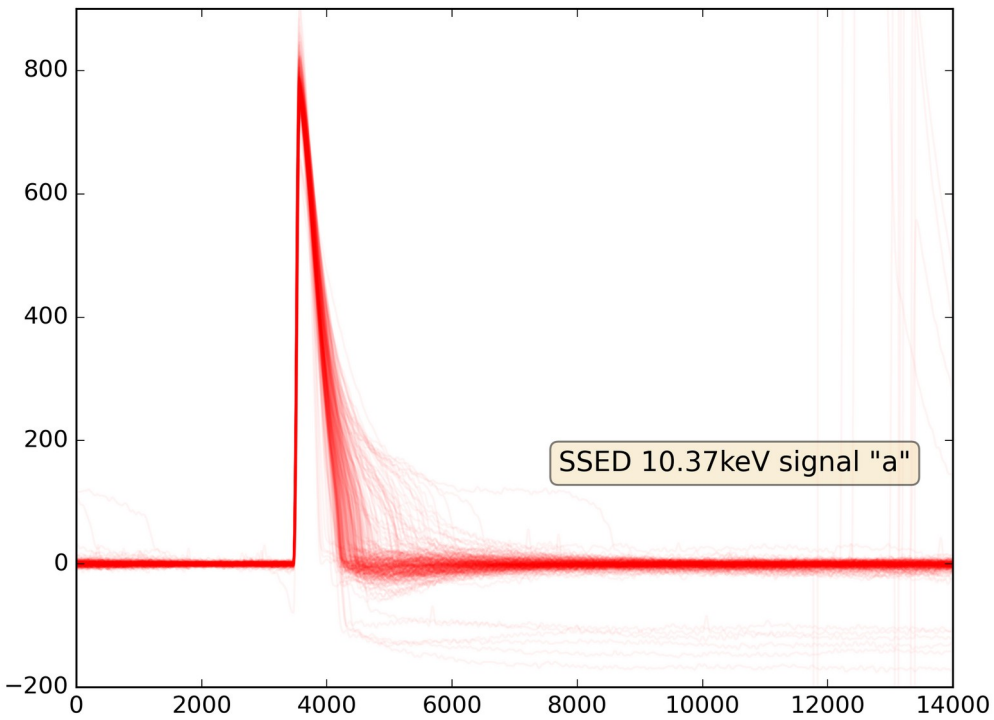


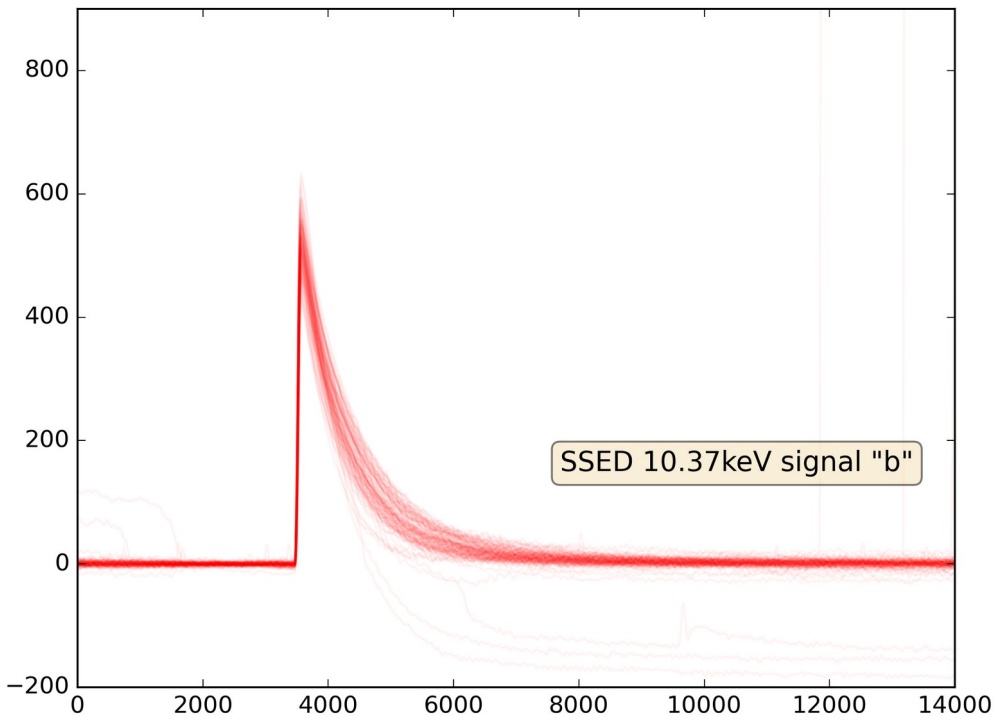


- X-axis : 0 → 140ms
- Long event → 30% of total events
- Long event → ~ 22% of total events at 10.37 keV

NTD signal shape does not exhibit the same variability

Short vs Long events





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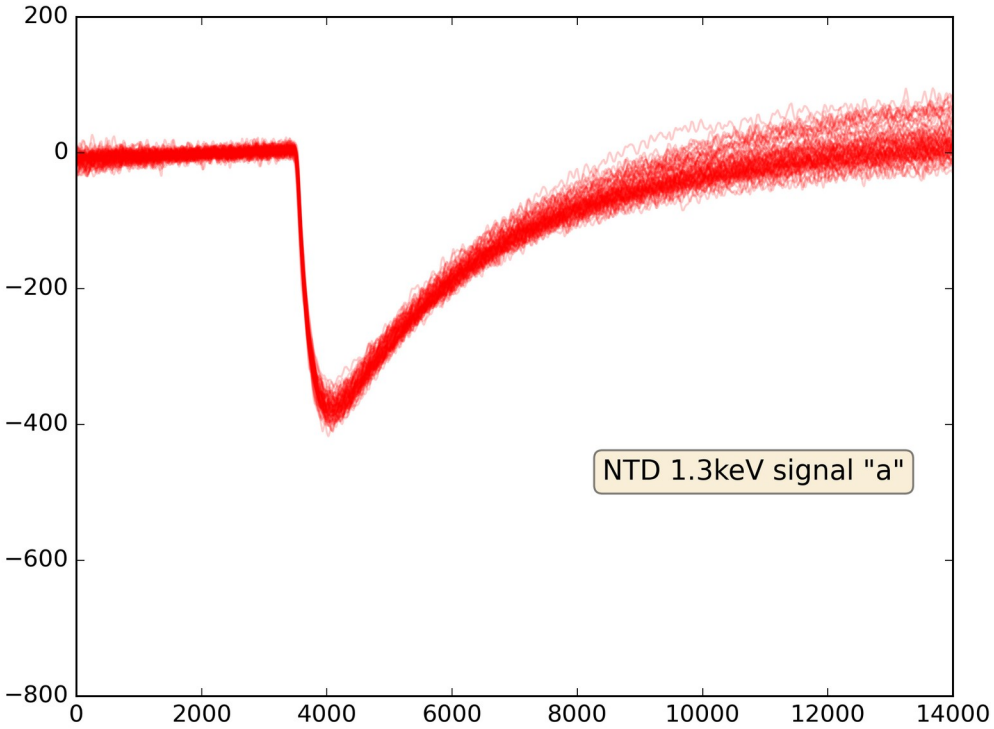

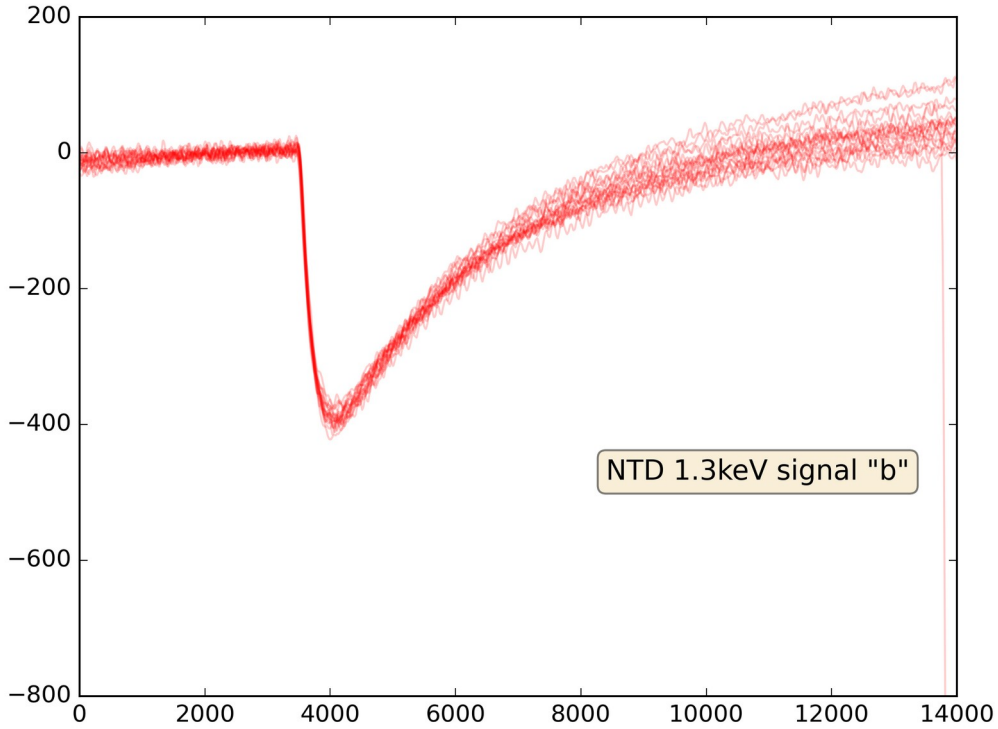

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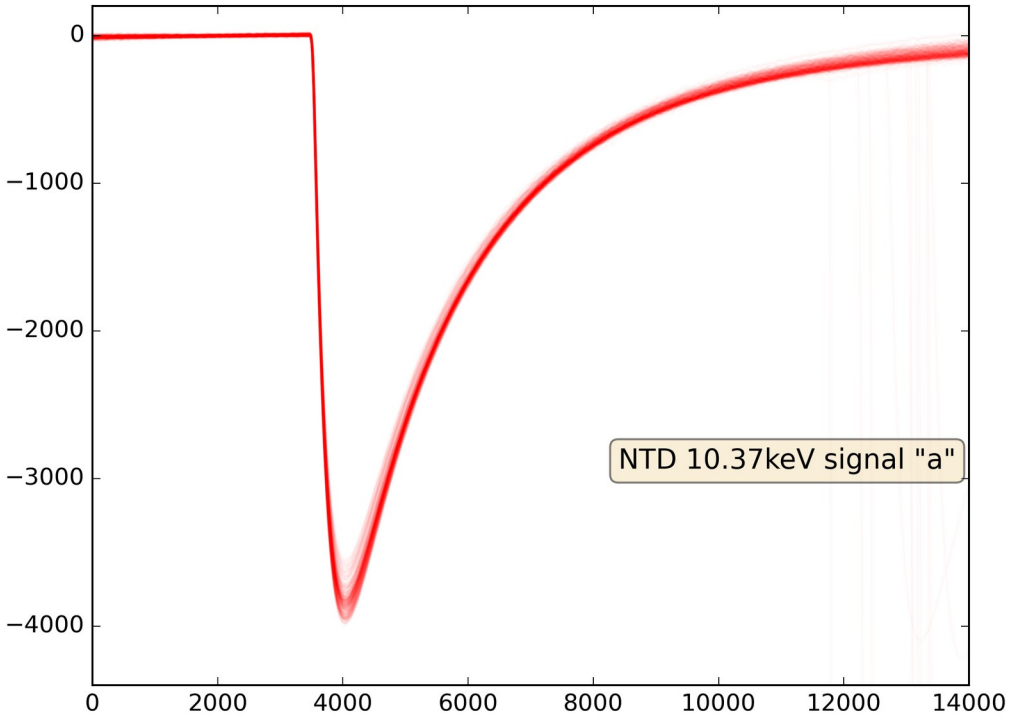

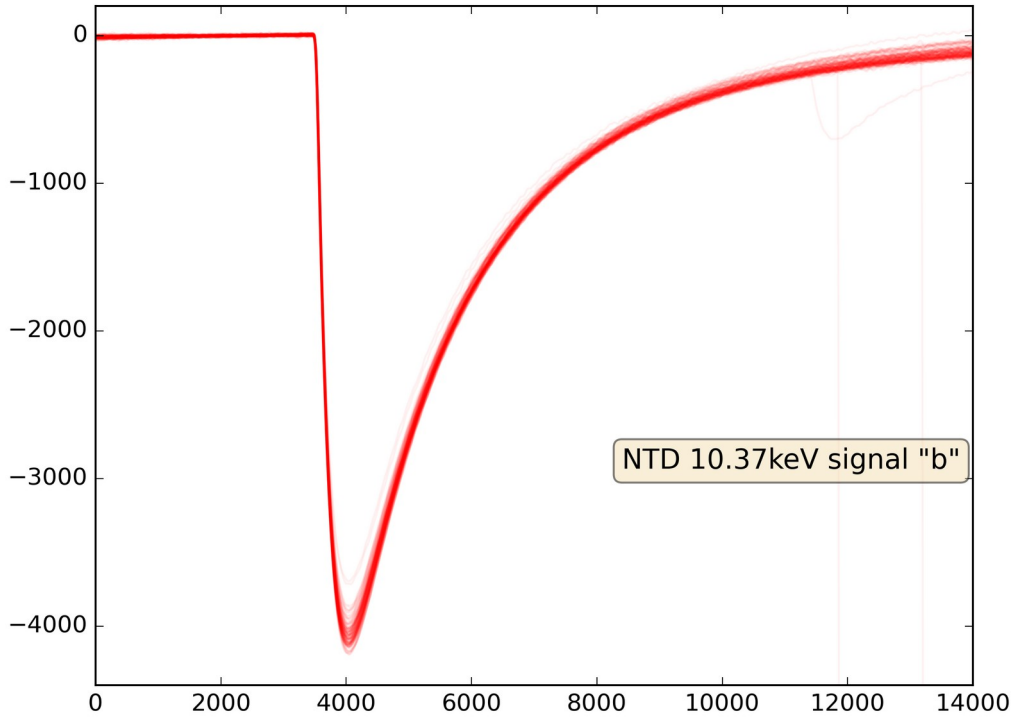

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