2° Forum della Ricerca Sperimentale e Tecnologica INAF



# Broad energy bandwidth Ti/Au TES microcalorimeters for charged particles detection and background veto systems

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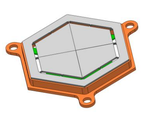
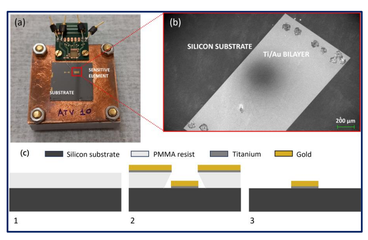
## A new production chain of TES microcalorimeters @ research Area Tor Vergata (ArToV), Roma (Italy)

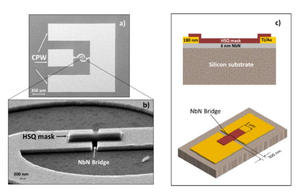
Recently, we started at Roma ARTOV research area a **new development chain of TES microcalorimeter for charged particles detection,** to be exploited as anticoincidence devices and background veto systems. The sample manufacturing is done at CNR/IFN Roma, while the detector integration and test is performed at INAF/IAPS.

Heritage in TES microcalorimeters for charged particle detection and background reduction






Heritage in HEB production (Hot Electron Bolometer) for THz applications




## Introduction and scientific motivation

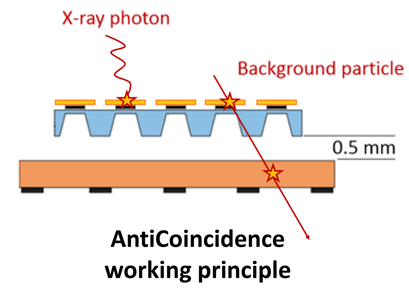
Superconducting detectors are a cutting-edge technology for many space-based observatories and ground-based experiments in the fields of astrophysics and particle physics. Beyond the increasing demand for wide collecting areas, high multiplexing factors and excellent energy resolutions, **many applications require a very low particle-background level**.

- The **future X-ray spectrometers** onboard space observatories typically require an instrument background **< ~ 5 x $10^{-3}$ cts/cm²/s/keV** (in the ~ 2-10 keV energy bandwidth)
- Ground experiments for dark matter search need even lower background levels, i.e. **< ~ $10^{-7}$ cts/cm²/s/keV for axion-search experiments** (between ~ 2 and ~ 7 keV)

Typical source of background are cosmic rays and secondary particles generated in the detector surroundings. To reduce these contributions, it is possible to develop an **active particles veto system**. This is composed by auxiliary "anticoincidence" detector, which works in combination with the main one.

To increase the geometrical rejection efficiency, the **anticoincidence** must be placed in close proximity to the main detector, thus it **needs to work at cryogenic temperature**. Furthermore, it shall ensure **high particle detection efficiency** and **low deadtime**.

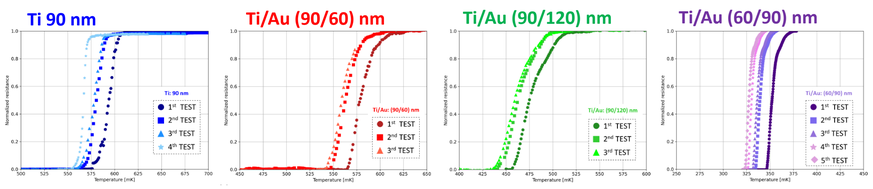
The development of cryogenic detectors optimized for this purpose is a key element in enabling future low-background experiments based on TES detectors.

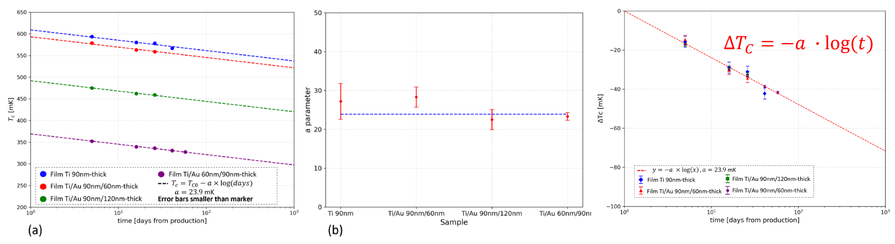



**AntiCoincidence working principle**

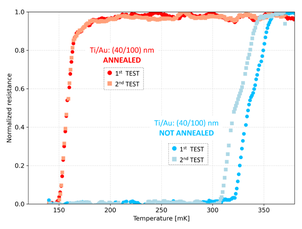
## Our first work: "Assessing the Aging Effect on Ti/Au bilayers for TES detectors" (M. Gambelli et al., MDPI, June 2024)

It is widely reported in literature that Ti/Au bilayers and Ti-only films can show a reduction of the critical temperature over time, as a result of an aging phenomena. We have reported **the characterization of this aging effect in our bilayers, through a systematic study of samples with different thicknesses**.



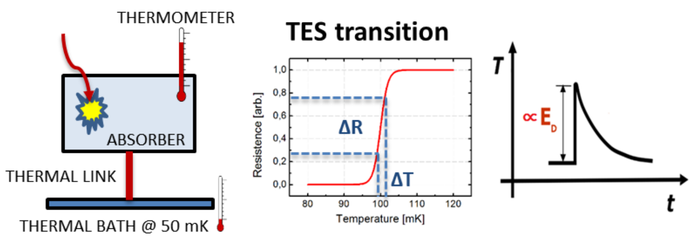

**Ti/Au films aging – Annealing "solution"**
150 °C - 24 hr - Air environment

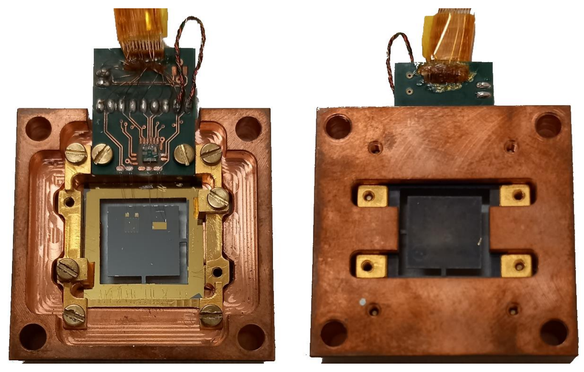



Our data reproduce well the logarithmic law proposed by Zhang+ 2023. Furthermore, we show that there is **no dependence of the «a» decay index on the bilayer thickness ratio**. Finally, as reported by other groups, exposing samples to an annealing treatment assures the reduction and stabilization of the critical temperature over time.

## A first working prototype showing the feasibility of the project (mini-grant feseability study closure)

**TES (Transition Edge Sensor) microcalorimeter schematics**

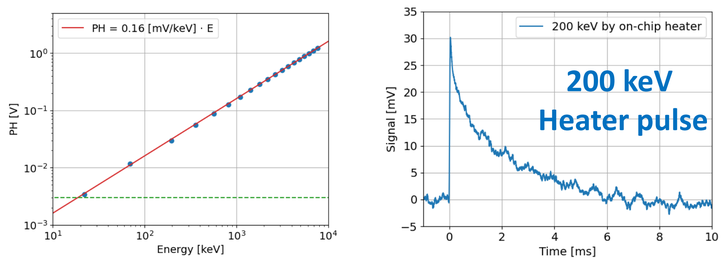


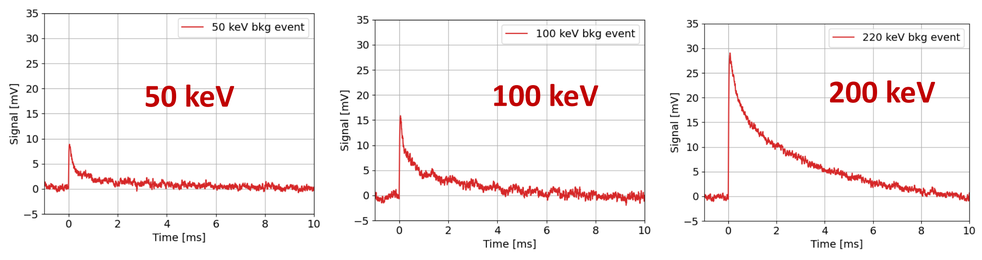
$T_C$ ~ 250 mK, **Power Dissipation @ 50 mK** ~ 40 nW

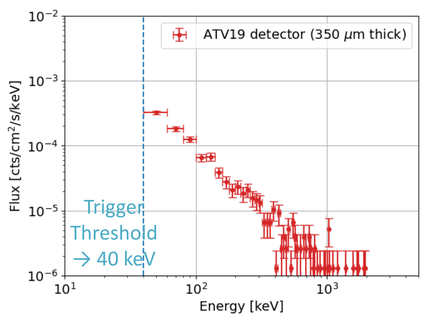
- **Si absorber**, 1 cm² (350 µm thick), 10 kΩ/cm wafer
  Suspended structure by 2 x Si beam (600 µm width)
- **TES Ti/Au** (100nm/75 nm), 150 °C - 24 hr annealing
- **Heater Ti/Au** (30nm/100nm), 1000□ → R = 150 Ω at 50 mK for calibration and diagnostic
- **Gold plated rim** for proper chip thermalization (via Au bonding wires)

**Broad-band energy scale calibration by on-chip heater**




**LAB background acquisition (38 ks) : cosmic mouns, γ radiation and secondary particles**




## Conclusions and next steps

- We are setting-up a new development chain of Ti/Au TES microcalorimeters for background reduction purposes (i.e. anticoincidence veto systems)
- We have characterized the Ti/Au bilayers produced in our facility, establishing the groundwork for this new TES production line.
- We are now defining and optimizing the procedures to develop a full detector in collaboration with INAF Product Assurance (PA) experts.
- Meanwhile, we have produced a first working prototype (ATV19) having promising performance, demonstrating the feasibility of the project.
- **We are looking for collaborations in future projects!**
- **We will submit a proposal in the new Large Grant / Techno Grant INAF call. Possible collaborations with SRON (Netherlands) & JAXA (Japan) for TES Array + AntiCoincidence systems for Axions detection**