Characterisation of Cosmic Ray interactions with new detectors for future CMB projects

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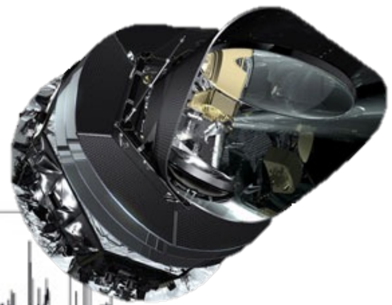
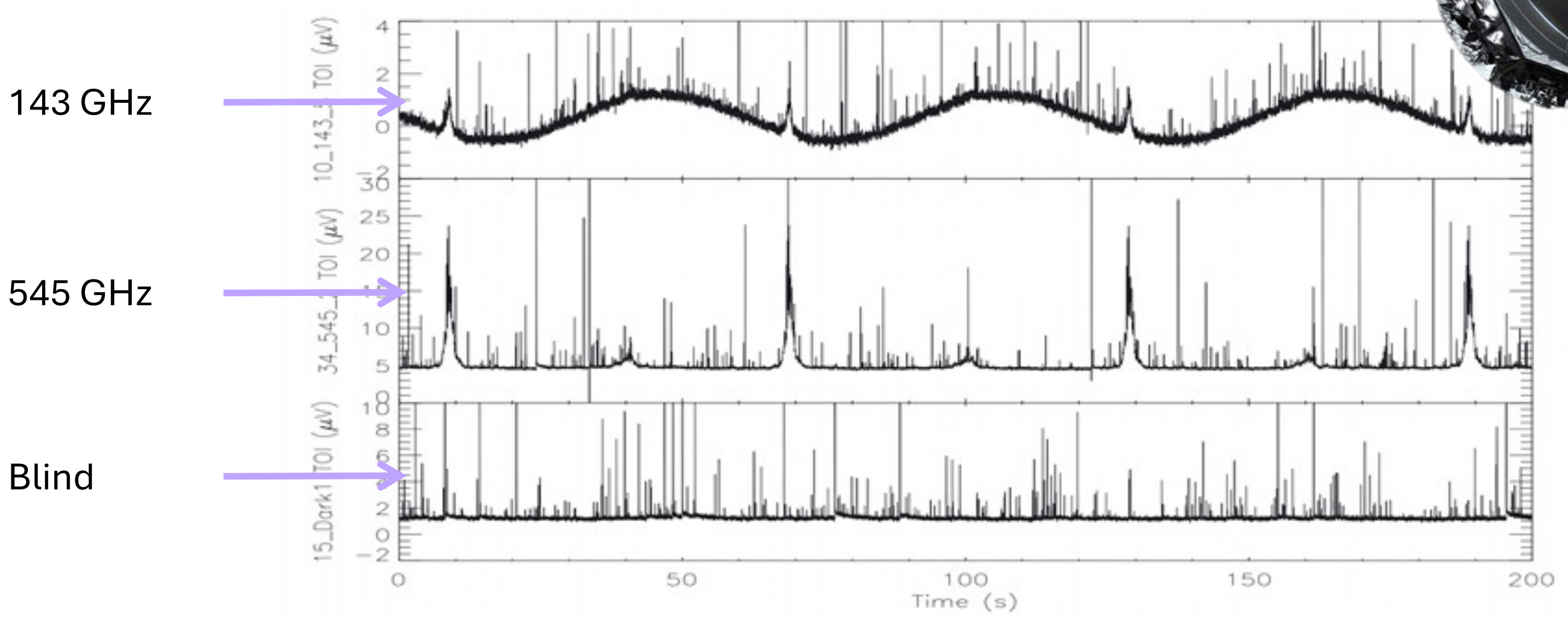
Cosmic-rays problematic in the past





Signals from Planck HFI's detectors (up : 143 GHz, middle : 545 Ghz, bottom : dark)

- Impacts of cosmic-rays (CRs) on Planck bolometers (@ 100 mK)

- Few % of the data unusable

⇢ several years of post-data treatment to clean data

« Characterization and physical explanation of energetic particles on Planck HFI instrument » A.Catalano et al. – 2013

Prepare the future

<u>After Planck ?</u>

⟹ IAS started to explore the impact of cosmic rays (SYMBOL) « Characterisation and modelling of the interaction between sub-Kelvin bolometric detectors and cosmic rays » S.L.Stever – 2019

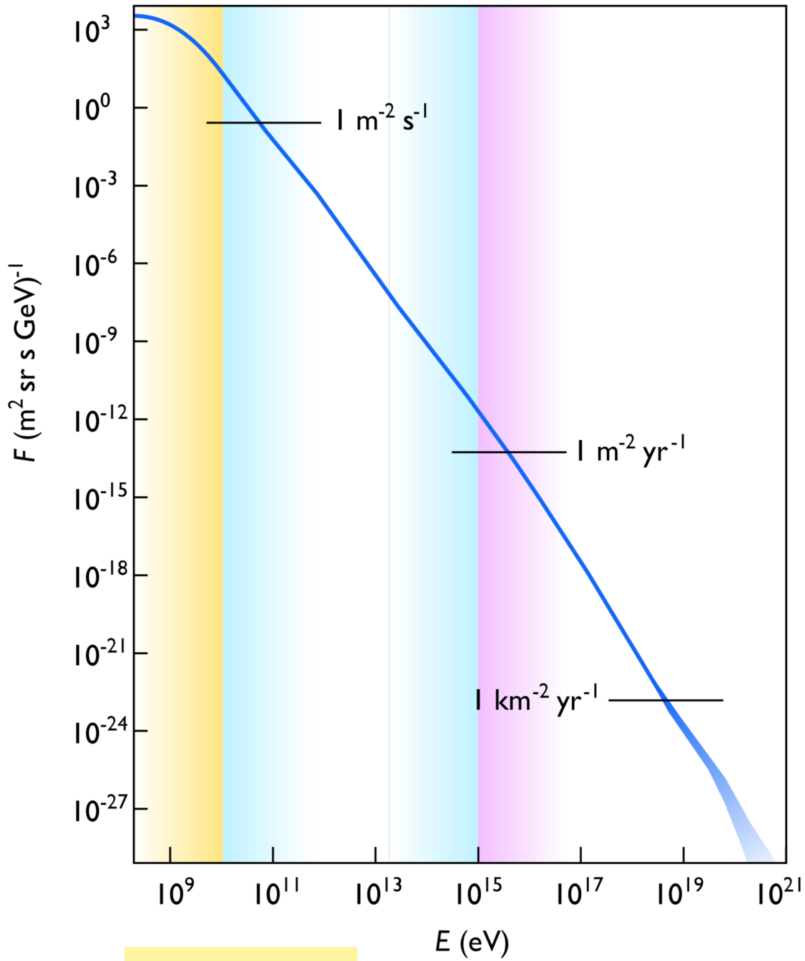
- <u>CRs at L2 :</u> mainly protons and α-particles ~ GeV
  - ⇢ Galactic origin
  - ⇢ Solar origin
- <u>Future CMB missions :</u>

❑ Higher sensitivity

❑ Higher detection surface

⟹ There is a real need to characterize the impact of the CRs on detector prototypes

CRs flux vs particle energy



Solar origin

Galactic origin

Extragalactic origin

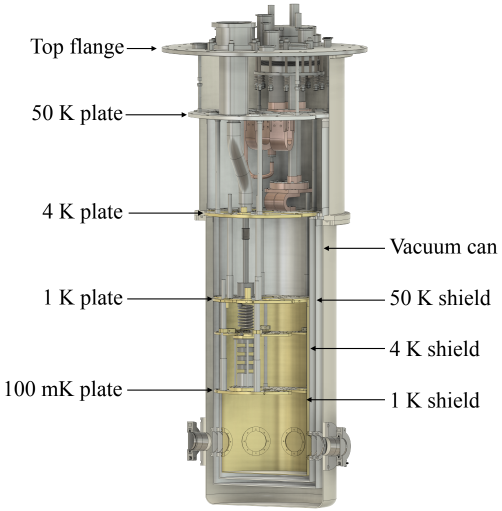
Presentation of the cryogenic test facility

1. Cryogenic facility

DRACuLA (**D**etector ir**RA**diation **C**ryogenic faci**L**ity for **A**strophysics) : developed to simulate the impact of CRs on detectors and part of focal planes

Adaptable to particle accelerators

- 500 µW @ 100 mK
- Experimental plate ϕ 25 cm
- Mobile : compact frame with wheels
- Includes micro-vibration attenuators
- 4 KF-50 ports (at 0°, 45°, 90° & 180°)
- 24 low-pass filtered lines
- Superconducting coax wires for KIDs
- SQUIDs for TESs
- 4 temperatures measurement bridges



Anatomy of DRACuLA

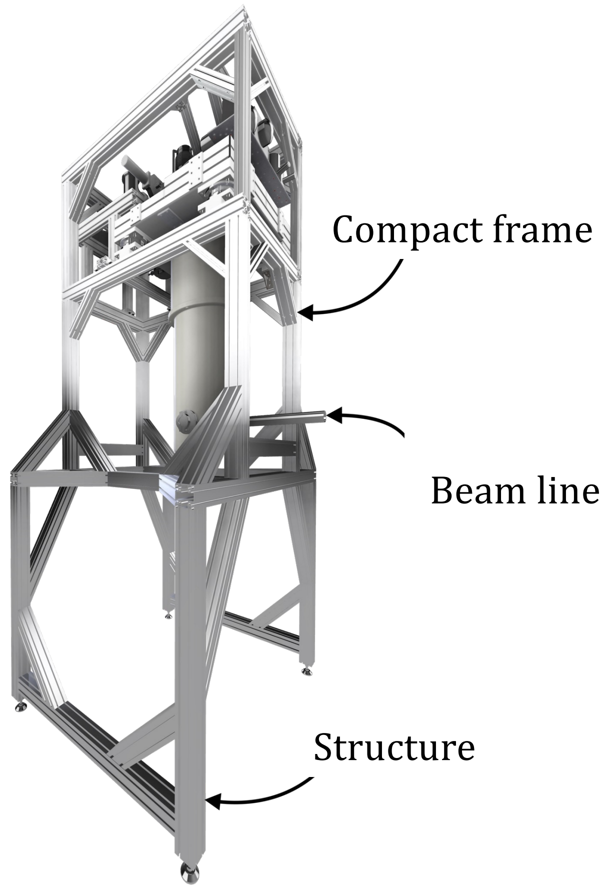
DRACuLA

More details :

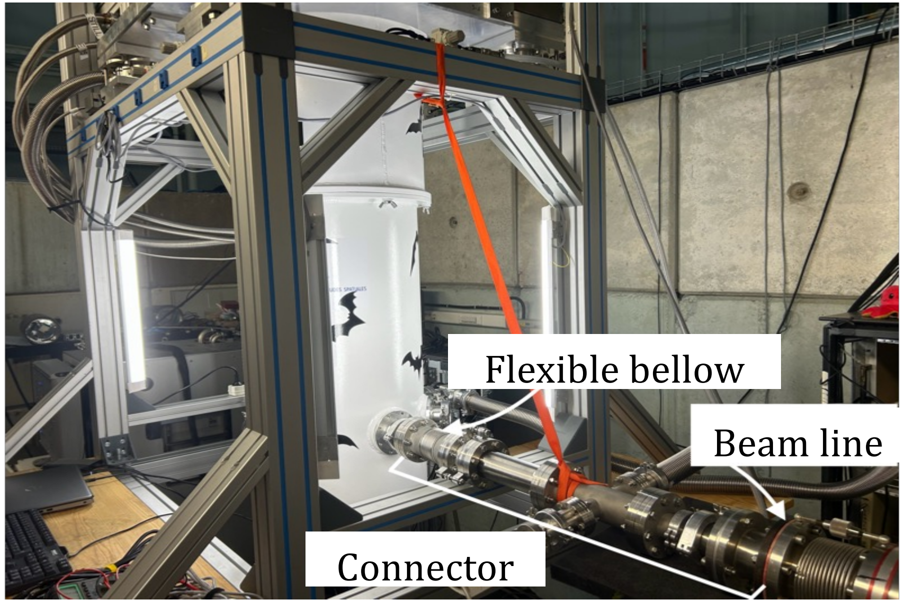
- IAS website : https://www.ias.universite-paris-saclay.fr/fr/activites-de-recherche/cosmologie/instrumentation/caracterisation_de_detecteurs_sub-K
- SPIE paper and poster : « A cryogenic facility to characterize detector-particle interactions », **A.Besnard**, V.Sauvage, S.L.Stever and B.Maffei – 2024

Presentation of the cryogenic test facility

2. Cryostat/beamline interface



Structure holding the cryostat

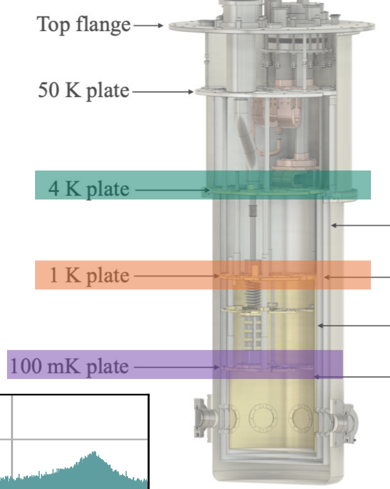


Connection between the cryostat and the beam particle

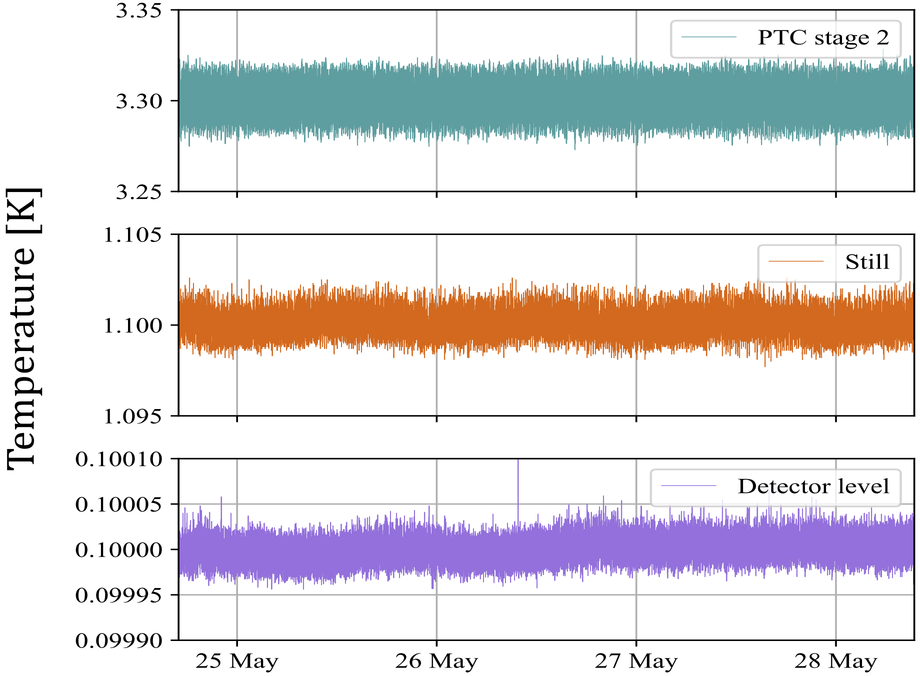
⇢ 60 μm **polypropylene window** between the vacuum can and the connector
⇢ **Mylar filters** on 4 K & 1 K shields

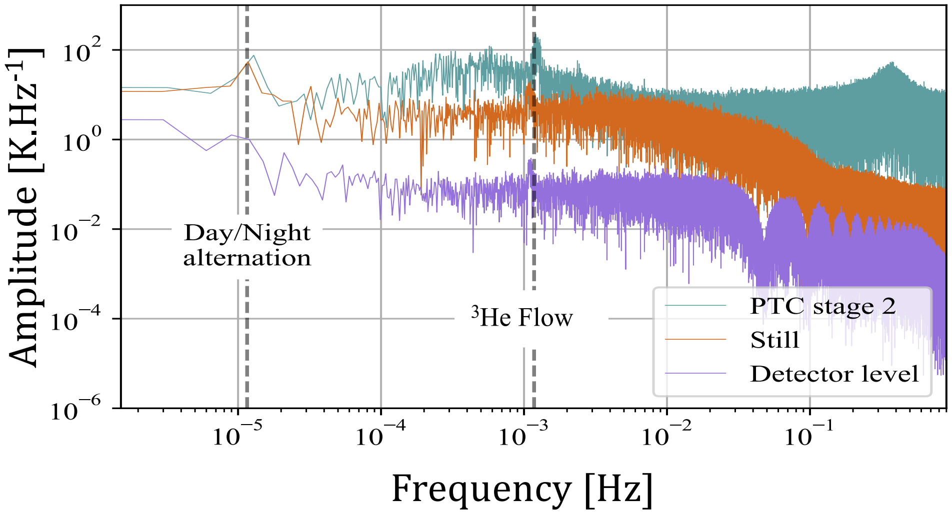
- 1st campaign at ALTO (Orsay) in 2021 to test the facility with a bolometer

Presentation of the cryogenic test facility



3. Thermal stability





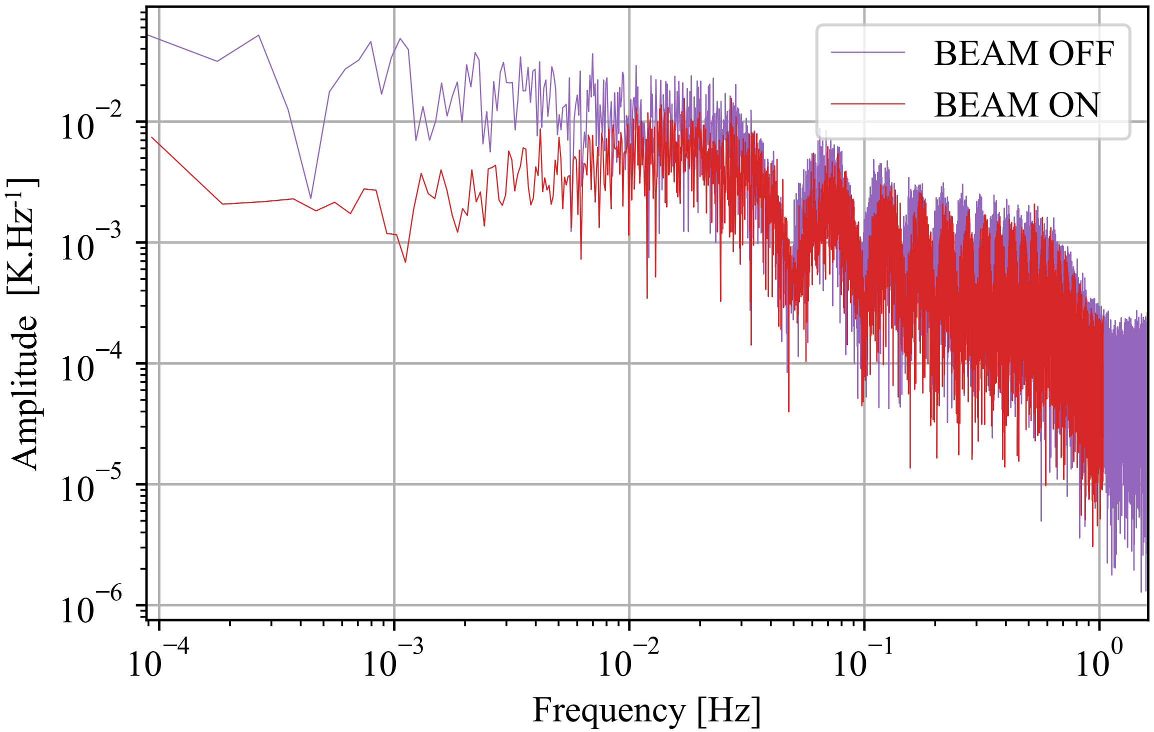
Thermal variations and their FFT for each thermal stages in the cryostat, beam off

Thermal stabilities obtained beam off during five days :

- 100 mK stage : **100 mK ± 11 μK**
- 1 K stage : **1.1 K ± 665 μK**
- 4 K stage : **3.3 K ± 11 mK**

Presentation of the cryogenic test facility

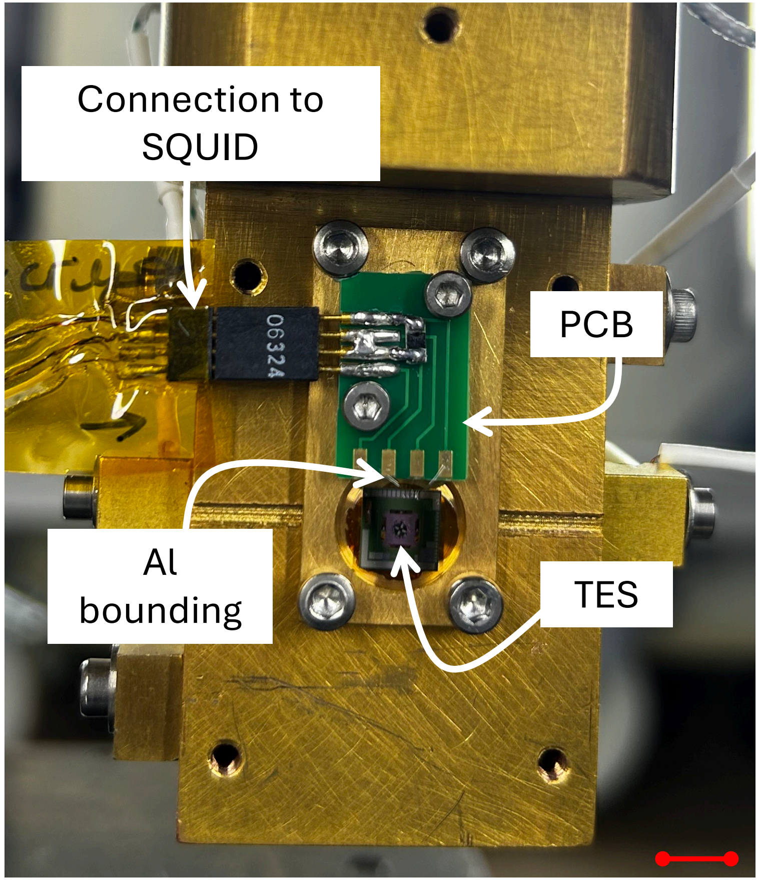
3. Thermal stability



Excellent thermal stability beam off **and beam on**

Preparation of the campaign

1. Transition Edge Sensor (TES)



TES installed in DRACuLA Scale = 5 mm

For a ΔT change : $\Delta R = \alpha R \Delta T$

Detector with a sharp transition phase between a superconducting state and a normal state

⇢ TES from NIST

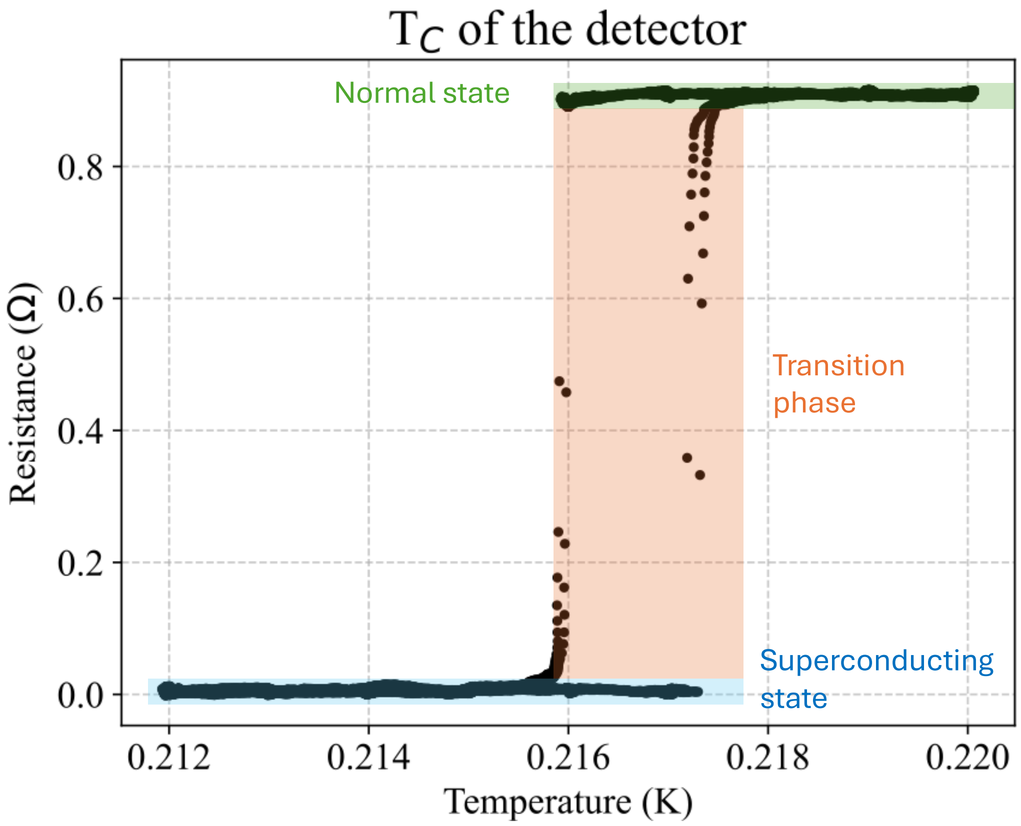
« Thermal Design and Characterization of Transition-Edge Sensor (TES) Bolometers for Frequency-Domain Multiplexing », **M.Lueker et al.**

Installation :

- SQUID readout system (lent by INFN Pisa)
- Designed PCB to connect with SQUID @1K and bounded to TES with 25 µm Al wires (Stefanos Marnieros from IJCLab)
- Blind detector (TES 2) not facing the beam

Preparation of the campaign

1. Transition Edge Sensor (TES)



First tests with an internal α-source ~5.4 MeV ✅

2nd campaign with TES

Determination of the T_C :

- 1st detector : ~212 mK
- 2nd detector : ~217 mK

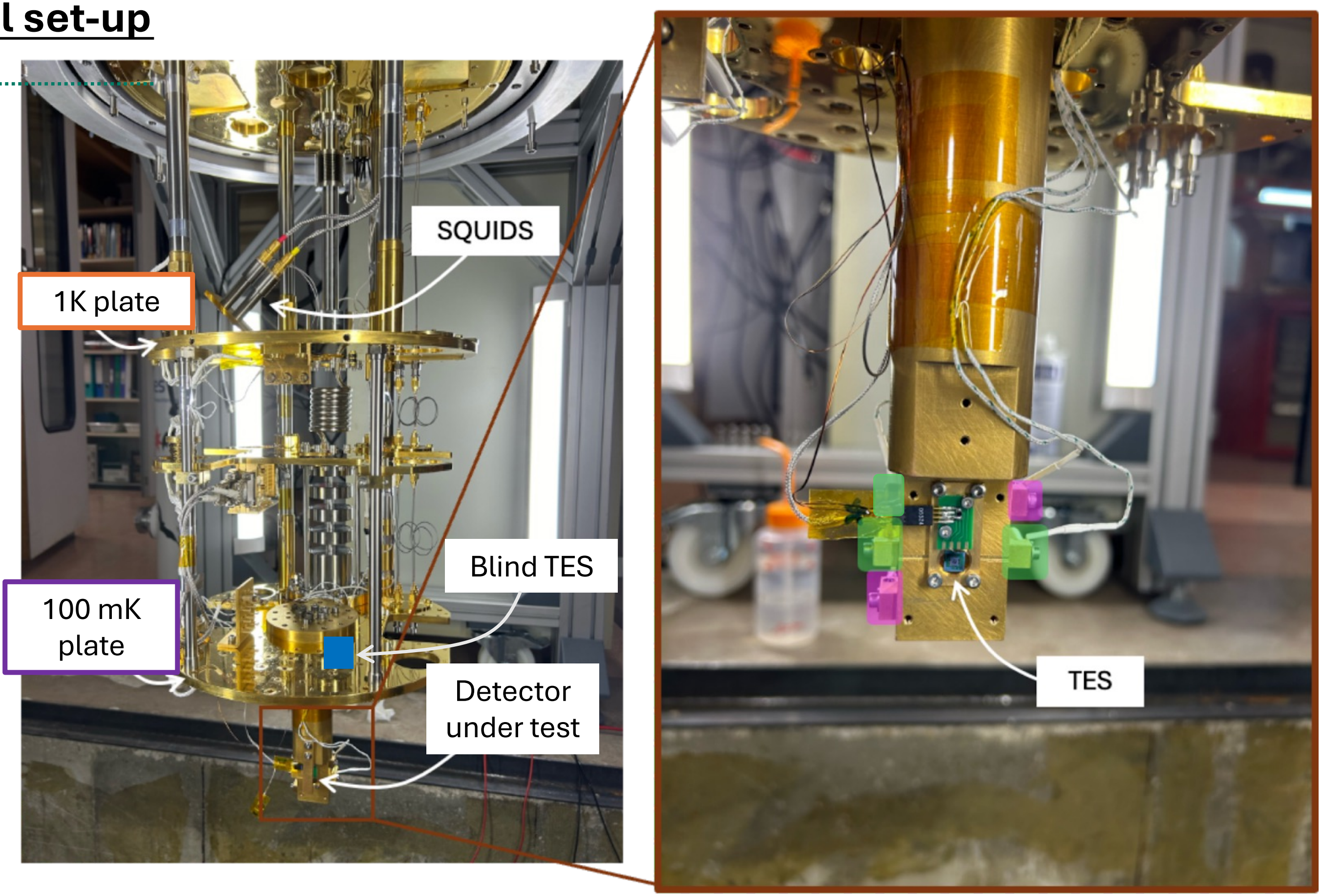
Preparation of the campaign

2. Experimental set-up

PTC 2 stage

Still stage

Experimental stage



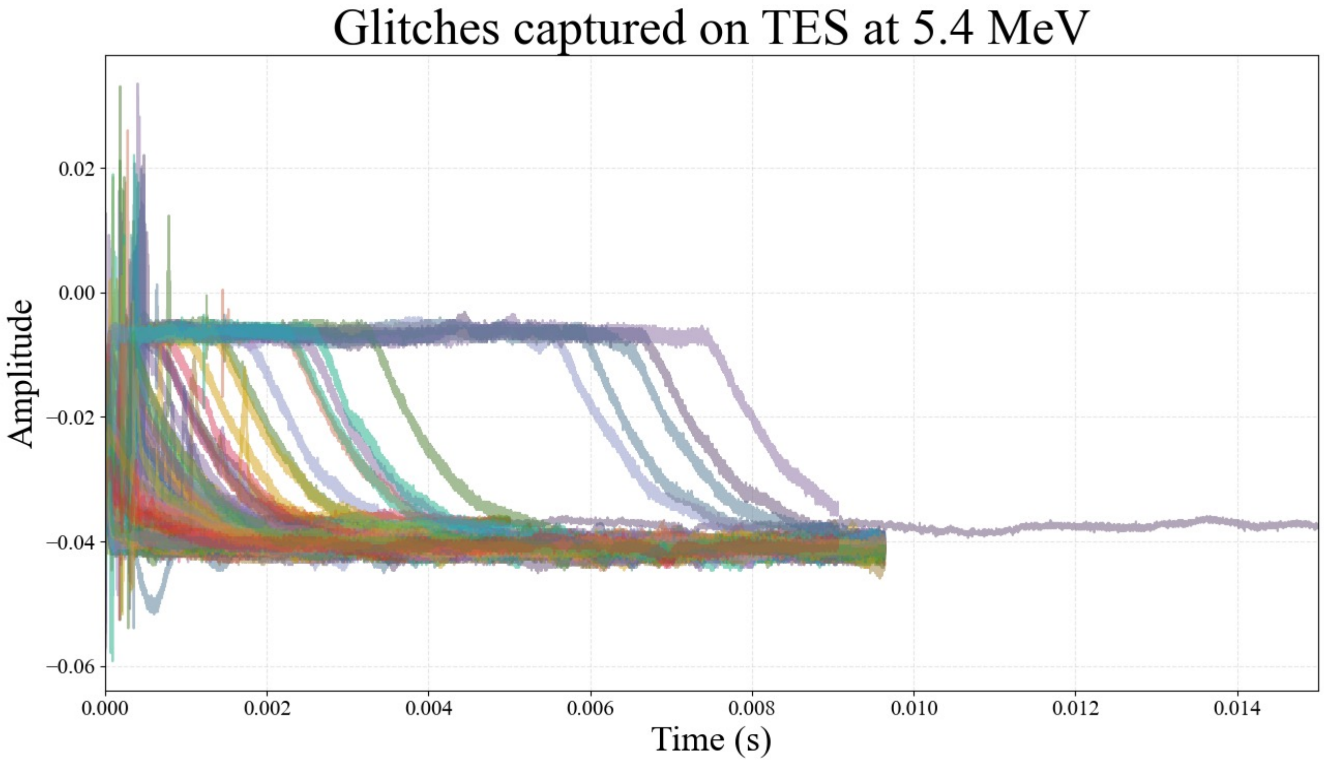
Heaters

Thermometers

Raw data

Alpha source :

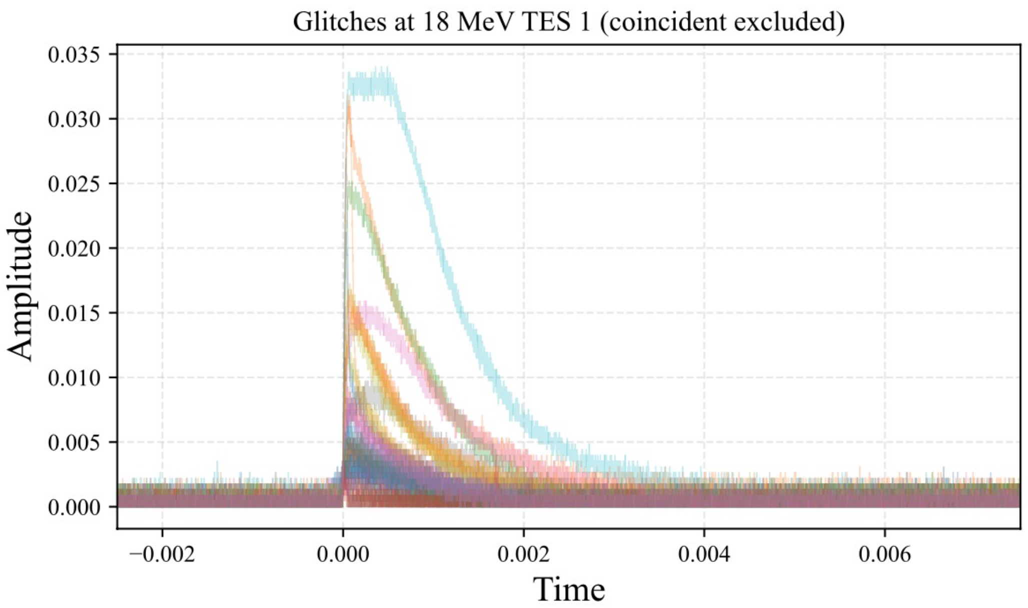
- @ 5.4 MeV : 149 events
- Measurements done in the lab to ensure TESs are functionnal + T_C

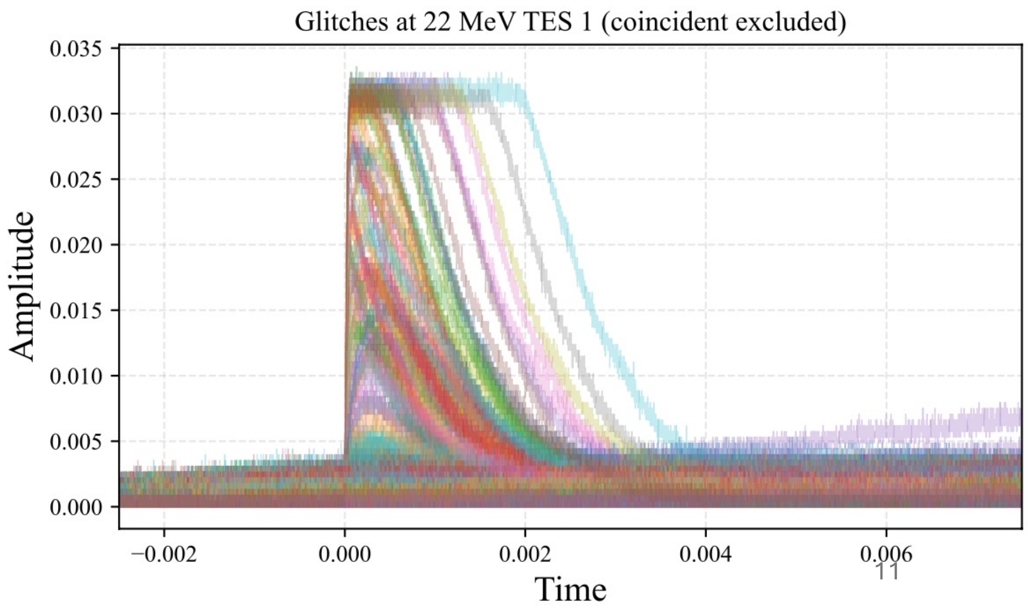


Raw data

2nd campaign in May 2024 :

- 2x8 hours of irradiation
- @ 18 MeV : 51 events
- @ 22 MeV : 2885 events





To conclude

- The tests at 18 and 22 MeV were succesfully carried out
- Data treatment on the glitches and post-irradiation tests in progress

Future

- Confirmation of the COMSOL models
- Previsions on the future observations
- Go higher energies and continue the tests on TES

⟹ Tests adaptable to any kind of detector for anykind of missions

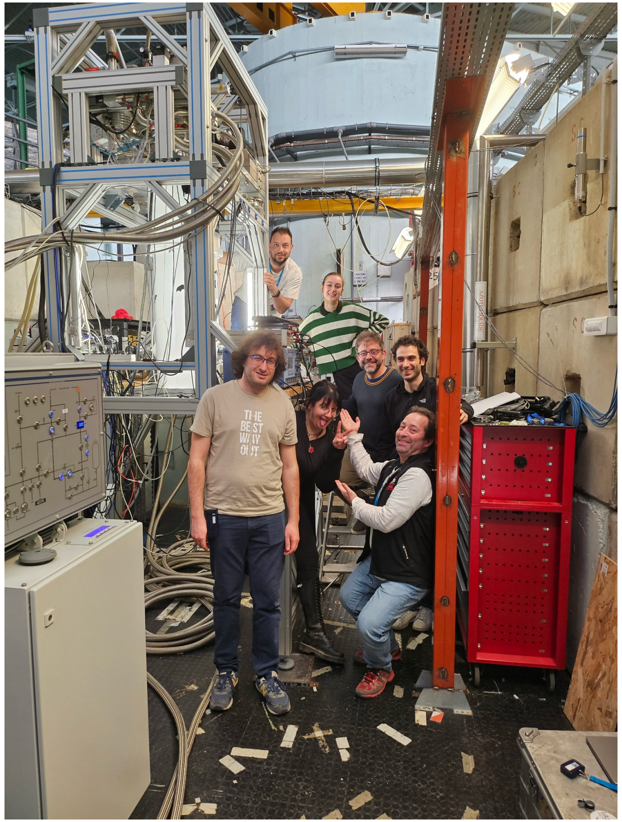


Photo of the team : thank you to Paolo, Tommaso and Andrea from the INFN