

1ST year Ph.D. report - Lorenzo Ferrari Barusso

Ph.D. supervisor: prof. Flavio Gatti.

Research activity:

During this year my research work was part of the Athena project. Athena (Advanced Telescope for High Energy Astrophysics) is an ESA project to investigate the universe in the X-ray band. Measurements will examine the baryonic matter evolution in large scale structures, warm-hot intergalactic medium, as well as in energetic compact objects like Black holes, Gamma ray burst. In order to better comprehend our Universe.

Because most of the baryonic component of the Universe is locked up in hot gas at temperatures of around a million degrees, and because of the extreme energetics of the processes close to the event horizon of black holes, understanding the Hot and Energetic Universe requires space-based observations in the X-ray band. Specifically, the theme calls for spatially-resolved X-ray spectroscopy and deep wide-field X-ray spectral imaging with performance greatly exceeding that offered by current observatories like XMM-Newton and Chandra.

ATHENA consists of an X-ray telescope with a fixed 12 m focal length. The telescope focuses X-ray photons onto two instruments, the innovative X-ray Integral Field Unit (X-IFU), based on cryogenic detectors; and the Wide Field Imager (WFI), a Silicon-based DEpleted P-channel Field Effect Transistors (DEPFET) detector. These two instruments combine the high spectral resolution of X-IFU and the high spatial resolution of WFI to provide the scientific goals, with a measurement spectrum from 0.5 to 10 KeV.

X-IFU is based on 50 mK cooled Transition Edge Sensors (TES), films working around the metal-superconductor transition. These can deliver the necessary energy resolution, while providing exceptional efficiency compared to the dispersive spectrometers flown on the current generation of X-ray observatories. The TES technology has already demonstrated the required spectral resolution (2 eV FWHM), but needs to be developed further to provide this over a large field of view (5' diameter).

My research work is focused on X-IFU, in particular the anticoincidence detector, that is one of the core parts of the instrument. Its scope is the reduction of the signal background of about 2 orders of magnitude. Without it, it shouldn't be possible to disentangle signals from background on the X-ray main detectors. It will be positioned beside the detector just 1 mm apart.

During this year I've managed to perform characterization tests over new demonstration model prototypes for the Athena CryoAC detector. This in order to improve the device. After several studies and processes adjustment we managed to improve the general cleanliness of our samples, the control over parameters and the comprehension of how our production steps, such as film growth, take place. This is fundamental to reach the TRL5 (Technology Readiness Level) and fulfil Space missions requests. Regarding this I've investigated: our Nb sputtering deposition, characterized the films and their critical current density and started the improvement of material density, RRR and T_c; and oxides deposition such as Silicon Dioxide to switch to Silicon Oxide that is stronger for our applications. That because we observed some crypticity of these process for the thermal, mechanical and electrical stability of our detector. The work is not finished and I'm investigating on film step coverages to reduce film stress that can cause crack in the wiring of the device. In the end I've started the processes for the mechanical model prototype of the final detector. Focusing on the Silicon deep etching with Bosch process. This step is not trivial as perform a straight wall etching over 500 um requires the comprehension of how the physical parameters during the process changes and what this will affect the process itself. The first demonstration model was also delivered to SRON and now is integrated with the X-IFU sensor. Preliminary measurements of the whole system show as the two detectors work together and coincidence signals are well visible.

Courses and exams:

I have attended the following courses:

- Introduction to High Energy Astrophysics
- Elettronica e Acquisizione Dati
- Criogenia Applicata
- Progettazione di Magneti Superconduttori
- Tecnologia dei fili, nastri e cavi Superconduttori

I have already taken the exams for the course Tecnologia dei fili, nastri e cavi Superconduttori and I've already been in touch with the professor of Elettronica e Acquisizione Dati to take the exam by the end of October.

I also attended the school EASITrain 3, Superconductivity and its applications (<https://indico.cern.ch/event/883251/>)

Papers:

- G. Addamo et al. [LSPE collaboration] "The large scale polarization explorer (LSPE) for CMB measurements: performance forecast" (<https://arxiv.org/abs/2008.11049>, submitted to JCAP)
- M. Biasotti, C. Boragno, L. Ferrari Barusso, F. Gatti, D. Grosso, M. Rigano, B. Siri, C. Macculi, M. D'Andrea & L. Piro, *The Phonon-Mediated TES Cosmic Ray Detector for Focal Plane of ATHENA X-Ray Telescope*, Journal of Low Temperature Physics **199**, 225–230 (2020) DOI: [10.1007/s10909-020-02348-y](https://doi.org/10.1007/s10909-020-02348-y)
- C. Macculi, A. Argan, D. Brienza, M. D'Andrea, S. Lotti, G. Minervini, L. Piro, M. Biasotti, L. Ferrari Barusso, F. Gatti et al., *The Cryogenic AntiCoincidence Detector for ATHENA X-IFU: The Project Status*, Journal of Low Temperature Physics **199**, 416–424 (2020) DOI: [10.1007/s10909-019-02314-3](https://doi.org/10.1007/s10909-019-02314-3)
- M. D'Andrea, C. Macculi, G. Torrioli, A. Argan, D. Brienza, S. Lotti, G. Minervini, L. Piro, M. Biasotti, L. Ferrari Barusso et al., *The Demonstration Model of the ATHENA X-IFU Cryogenic AntiCoincidence Detector*, Journal of Low Temperature Physics **199**, 65–72 (2020) DOI: [10.1007/s10909-019-02300-9](https://doi.org/10.1007/s10909-019-02300-9)

Conferences:

At the end of October, I will attend the following conference:

- Applied Superconductivity Conference ASC20 (<https://ascinc.org/>)

and I participated to the following contribution:

- L. Ferrari Barusso "Cryogenic AntiCoincidence detector for ATHENA X-IFU"- talk at the EASITrain 3 School, Superconductivity and its applications (<https://indico.cern.ch/event/883251/>), presented by me.