Focal plane 50 mK anticoincidence detector for the Athena X-ray observatory

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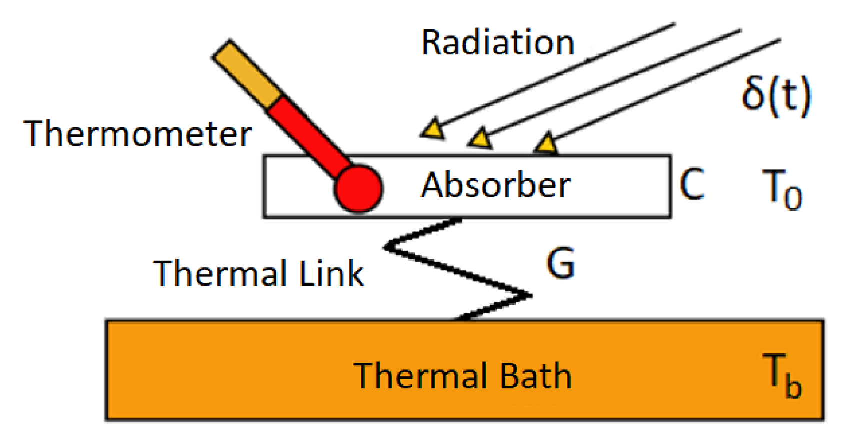
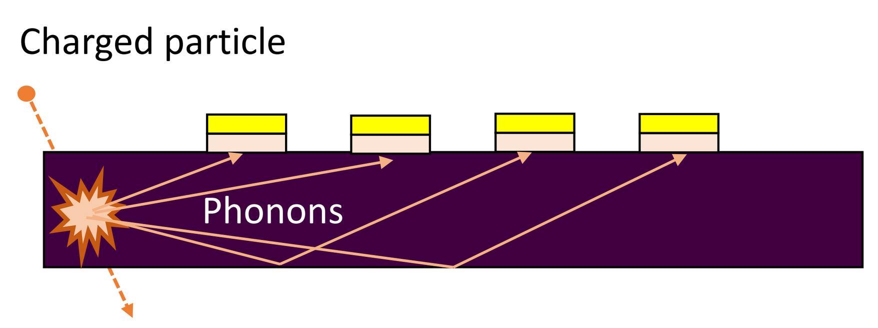
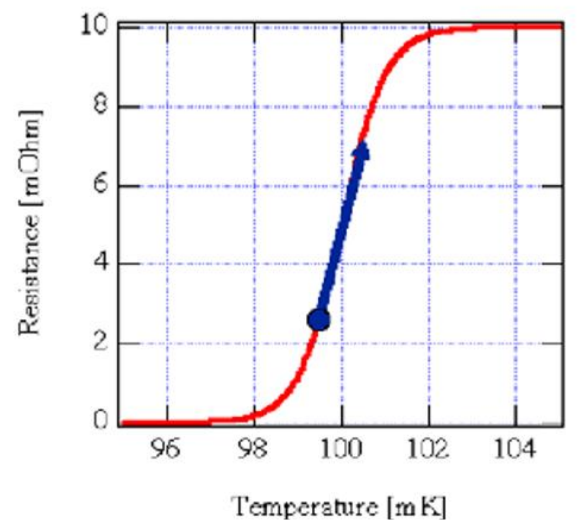
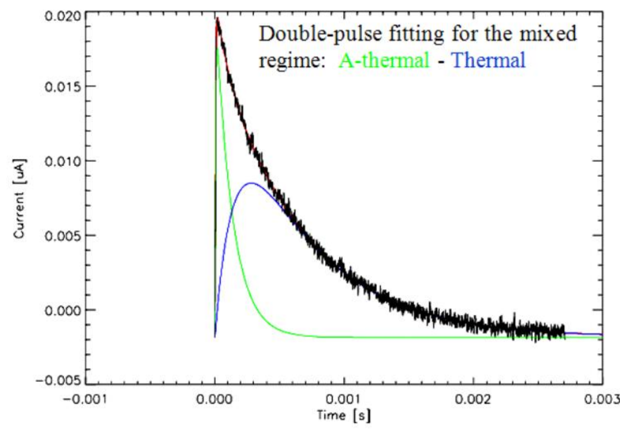
Abstract: We describe the design and fabrication of an anticoincidence detector for the focal plane of Athena space X-ray observatory. This is needed to reject the background due to cosmic charged particles, thus allowing the observations of faint and far sources, as the largescale WHIM structure of baryonic matter. Indeed, high-energy charged particles (>150 MeV) may release the same energy of the X-ray sources under observation on the instrument's X-ray microcalorimeter array detector. The prototype is based on 96 iridium TES onto a 1 cm^2 silicon absorber that is thermally and mechanically suspended with micro-machined silicon beams. The TES configuration is optimized for the detection of a-thermal phonons for achieving a faster response.



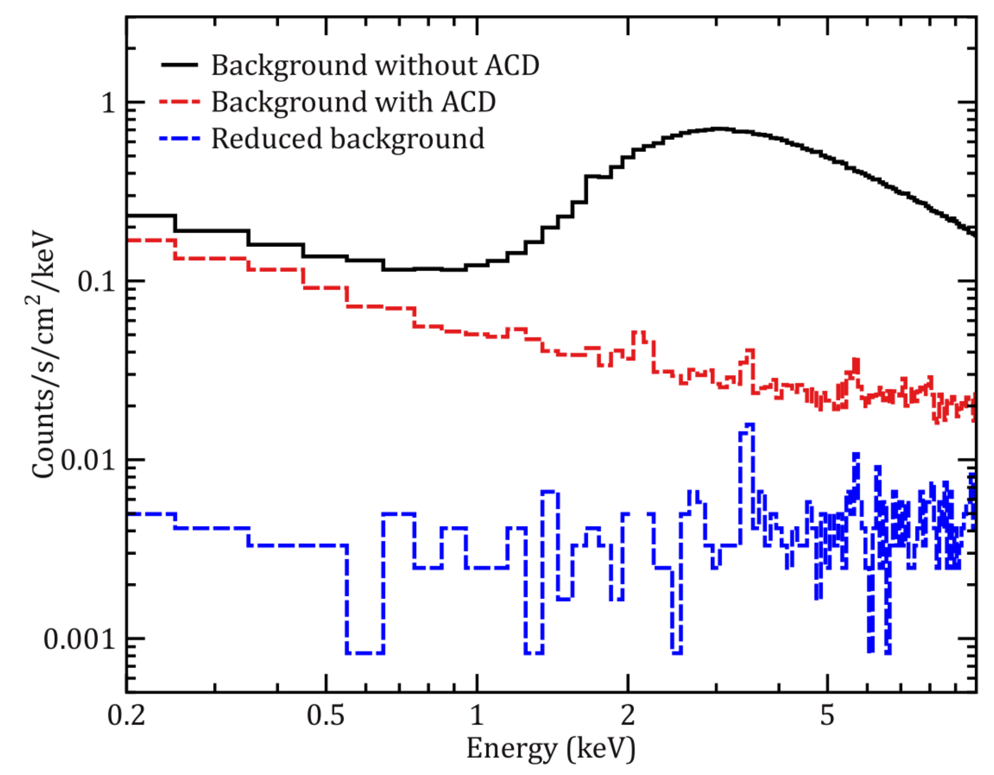






The physics behind the detector is outlined at left. The energy loss by a charged particle on the absorber heats directly the TESs array giving a signal by electron-phonon interaction.

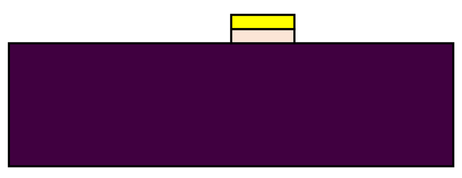
On the right is shown a simulation of the effect given by the cryogenic anticoincidence detector on the Athena mission. The background is reduced by 2 order of magnitude giving the possibility of studying far and faint objects that would have been under the background level.



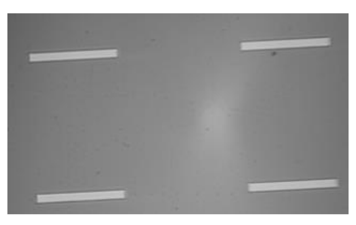
Lotti S. et al. *«Updates on the background estimates for the X-IFU instrument onboard of the Athena mission»*, SPIE,2016.

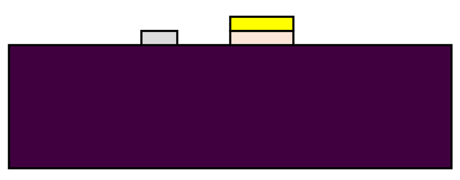
Here is outlined the fabrication process performed in Genoa:

The detectors are produced from intrinsic silicon wafer (ρ>10 kΩ·cm).

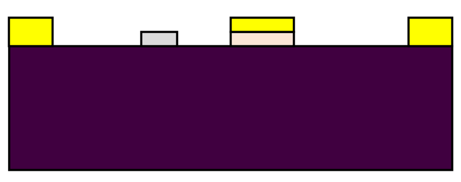


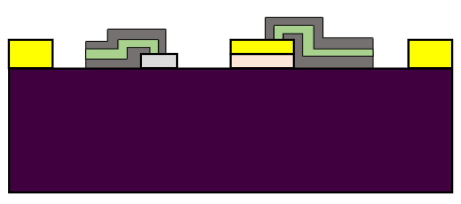
A bilayer Ir/Au is patterned using positive photolithography and dry etching. Iridium is grown by PLD at P < 5·10^{-9} mbar. The gold layer by e-beam evaporation

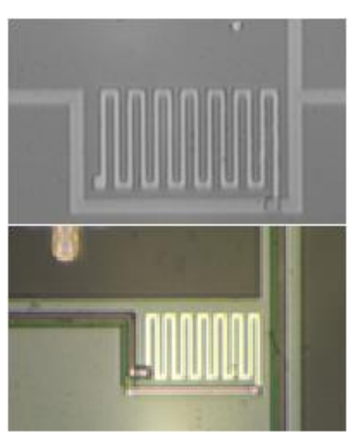




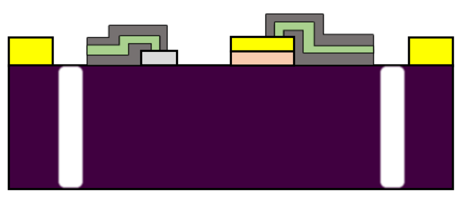
All the other patterning are made by negative photolithography and lift-off. The platinum heaters and gold on rim were deposited by evaporation.





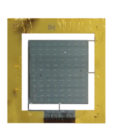


The wiring was fabricated with three different depositions and patterning: niobium, silicon monoxide, and niobium. Both niobium layers were grown by RF-sputtering, whereas silicon oxide was thermally evaporated.

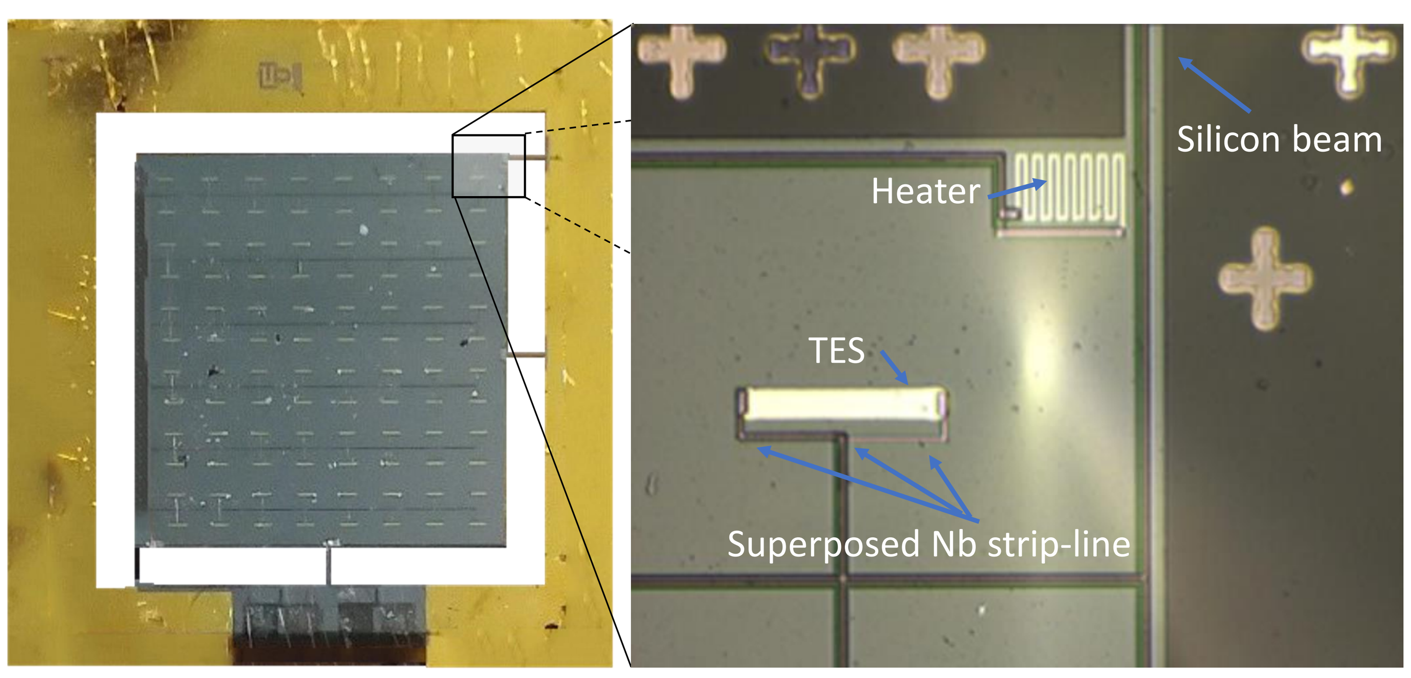


Finally the silicon is etched to obtain the four beams and to free-stand the structure.

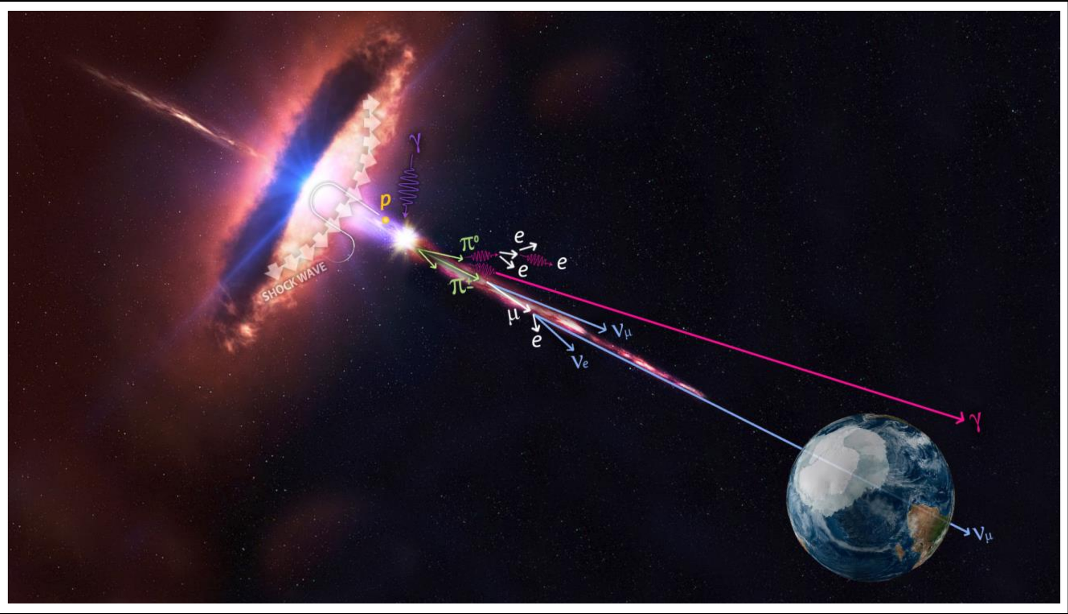
The final aspect of the Cryo-AC demonstration model:

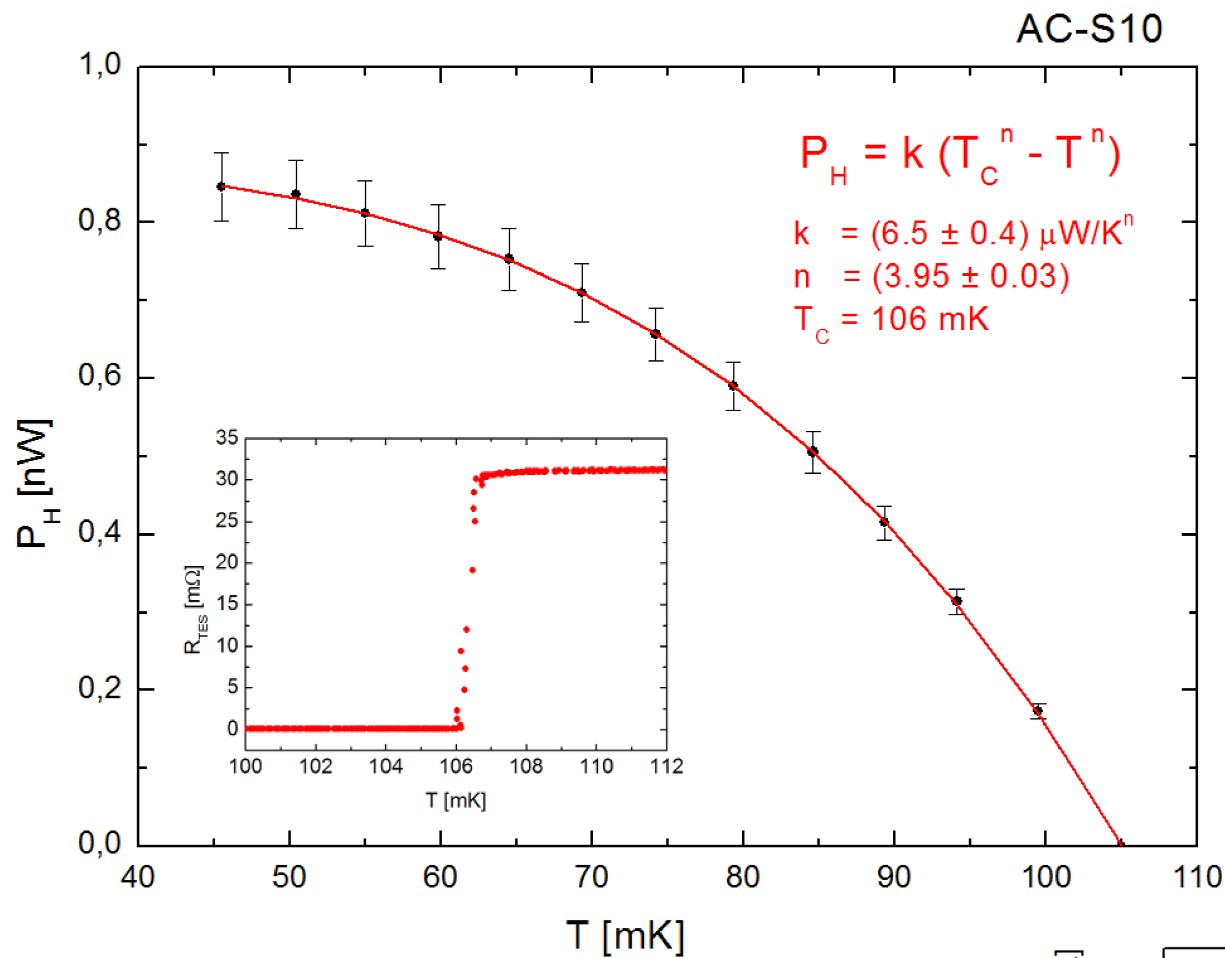


Are shown a life-sized picture of the detector and two zoom to appreciate the design and the micro-structures on the pixel.



The Athena mission will greatly improve the possibilities of X-Astrophysics. Furthermore will be even more important in multimessenger observation of the Universe. For example the study of pulsar coalescence where are produced gravitational waves, photons and neutrinos or Blazars emissions like in the illustration on the right.





Here are shown the measurements made at INAF in Rome.

In particular is possible to observe: the 0.5 mK narrow superconducting transition at 106 mK and the power that must be dissipated on the heaters to reach the transition; the average pulse given by the detector where are evident both the a-thermal and thermal pulse.

The a-thermal pulse, faster, is given by the interaction of quasi-balistic phonons and the thermal one, slower, is given by thermalization of the absorber.

In the end, a spectrum measurement of the emission by a ^{55}Fe x-ray source together with thermal pulses given through the heater on the absorber and a table with the device parameters.

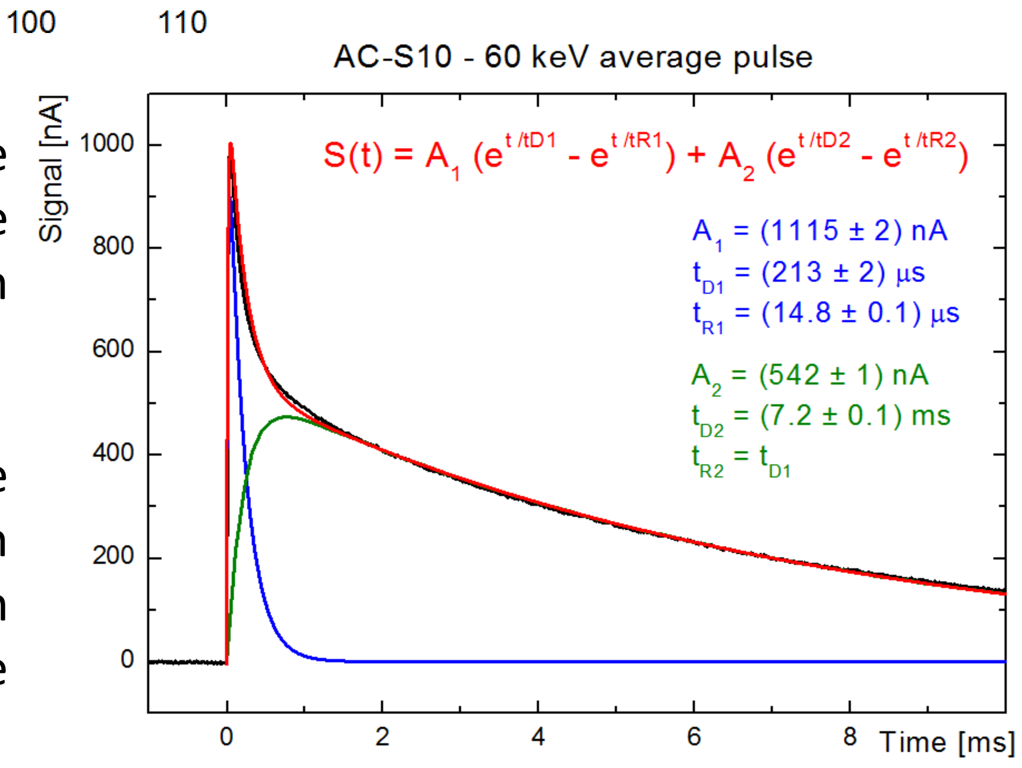


TABLE I
PARAMETERS OF THE DEVICE

Parameter	Value
Total silicon chip area	16.6 x 16.6 mm^2
Silicon chip thickness	525 μm
Silicon beam length	1000 μm
Silicon beam width	100 μm
Silicon absorber area	10 x 10 mm^2
TES (x96) area	50 x 500 μm^2
TESs (Ir/Au) thickness	320 nm
Iridium thickness	240 nm
Gold thickness	80 nm
Critical temperature	106 mK
Device normal resistance	31 mΩ
Thermal conductance @ 106 mK	34 nW/K
Power to drive device in transition from bath @ 50 mK	0.86 nW