The particle background of the X-IFU instrument onboard of ATHENA

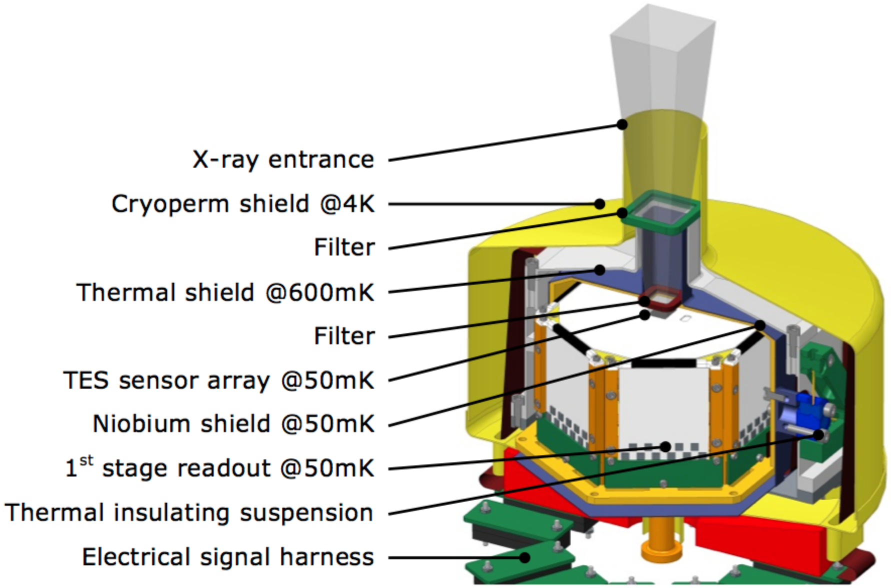
Simone Lotti[1]

Collaborators: Claudio Macculi[1], Lorenzo Natalucci[1], Emanuele Perinati[2], Luigi Piro[1]

[1]INAF-IAPS, Rome
[2]IAAT Tuebingen

X-IFU

The X-IFU is a cryogenic X-ray spectrometer, based on an array of 3840 Transition Edge Sensors (TES) of 250 µm side, 7 um thickness, offering 2.5 eV spectral resolution, with ~5''/pixel, over a field of view of 5 arc minutes in diameter.

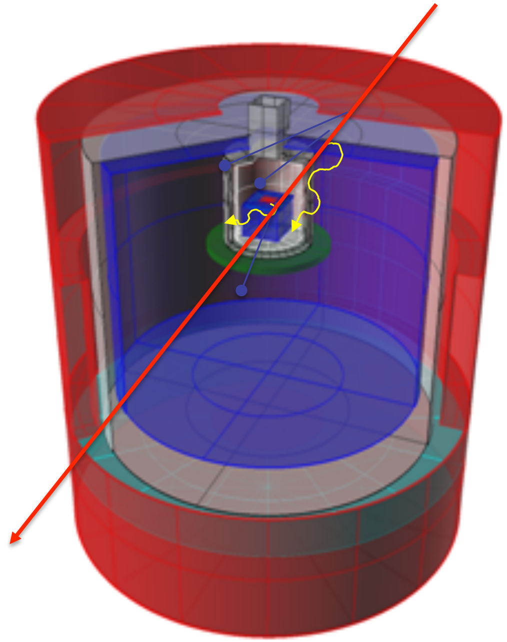


Parameter	Requirements
Energy range	0.3-12 keV
Energy resolution: E < 7 keV	2.5 eV (250 x 250 µm TES pixel)
Energy resolution: E > 7 keV	E/ΔE = 2800
Field of View	5' (diameter) (3840 TES)
Detector quantum efficiency @ 1 keV	>60%
Detector quantum efficiency @ 7 keV	>70%
Gain error (RMS)	0.4 eV
Count rate capability – faint source	1 mCrab (>80% high-resolution events)
Count rate capability – bright source	1 Crab (>30% low-resolution events)
Time resolution	10 µs
Non X-ray background	< 5 10^{-3} counts/s/cm^2/keV

Table 2: Key performance requirements for the *Athena+* X-ray Integral Field Unit

High energy particles

Above 120 MeV particles can cross the spacecraft and reach the focal plane from every direction.



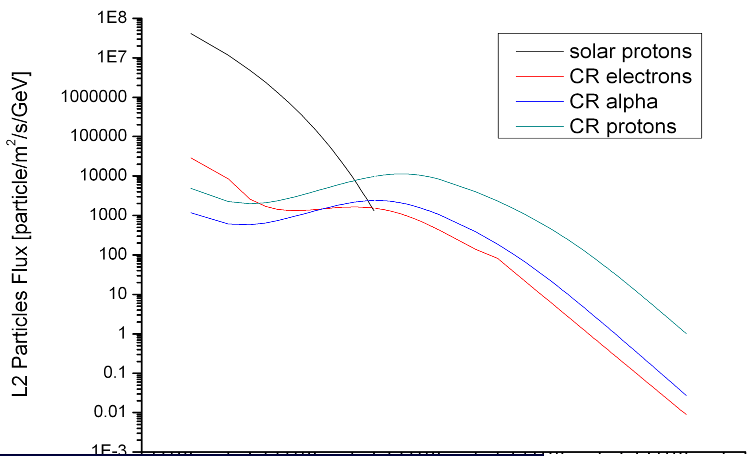
There are no data about NXB for X-ray μcal in L2 → MC Simulations (GEANT4)

Several steps:

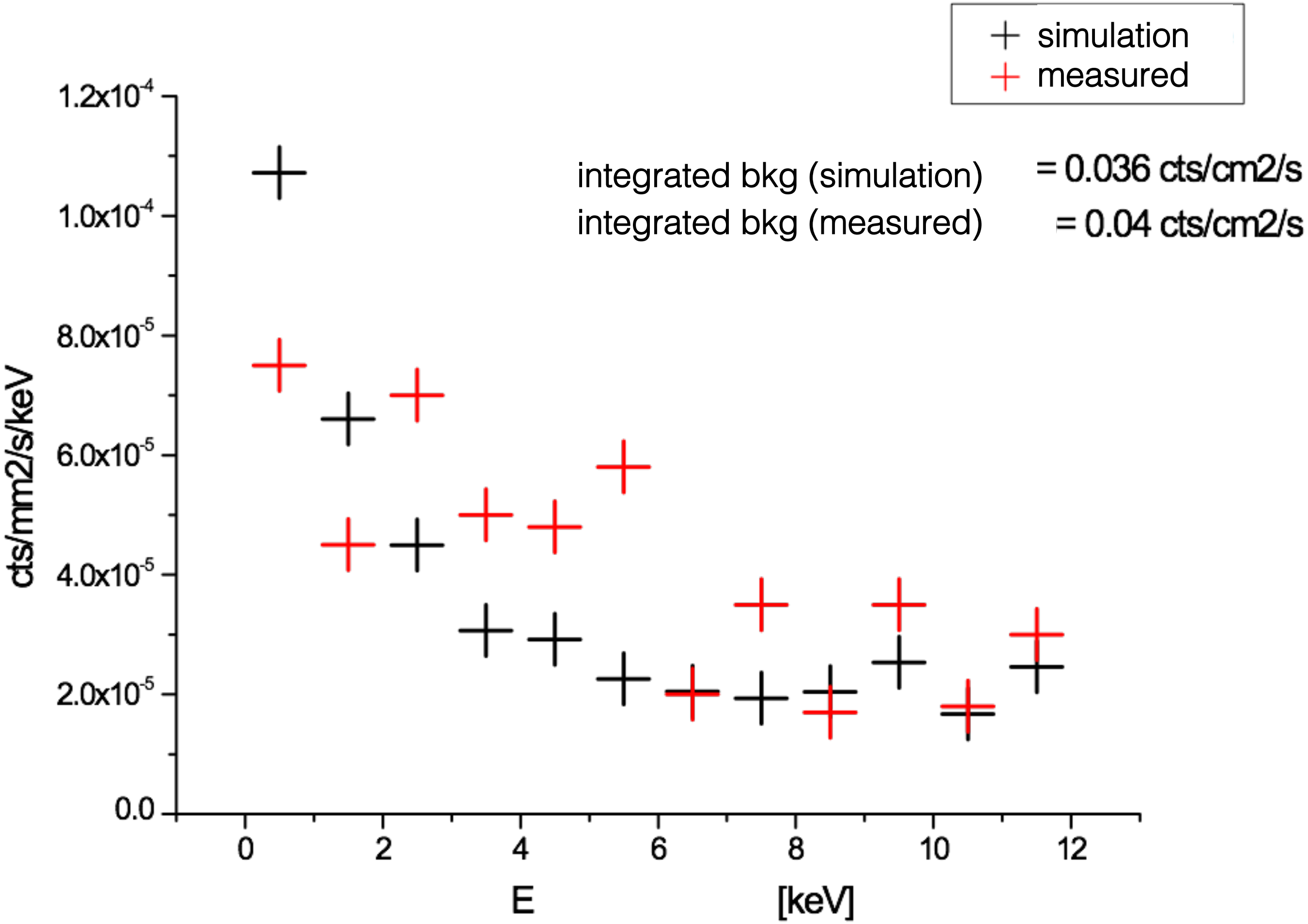
- Define mass model
- **Define radiative environment**
- **Define physics** → **EM**, **Activation**, **Set detail level**
- **Validation and data analysis**

⇩

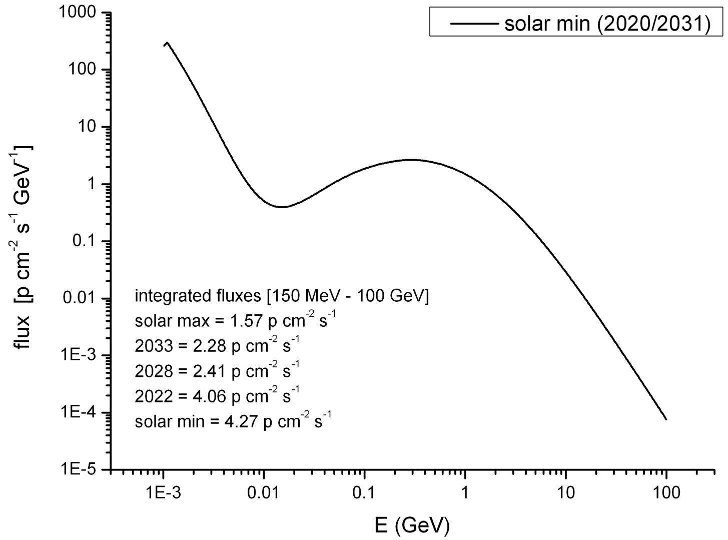
- Collaboration with software developers
- Simplified simulations to reproduce experimental data
- Reproduced Suzaku-XRS background for the first time



Validation using Suzaku XRS data



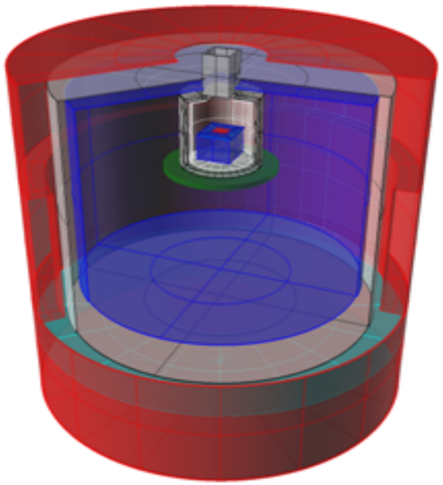
The simulations

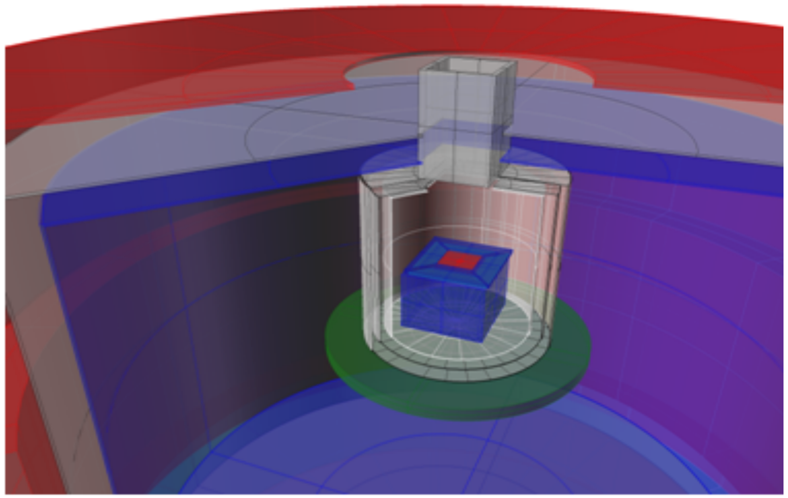


We reproduced all the components of the background expected in L2 in the worst case (solar min), with a random distribution of incoming directions over a sphere surrounding the geometrical model

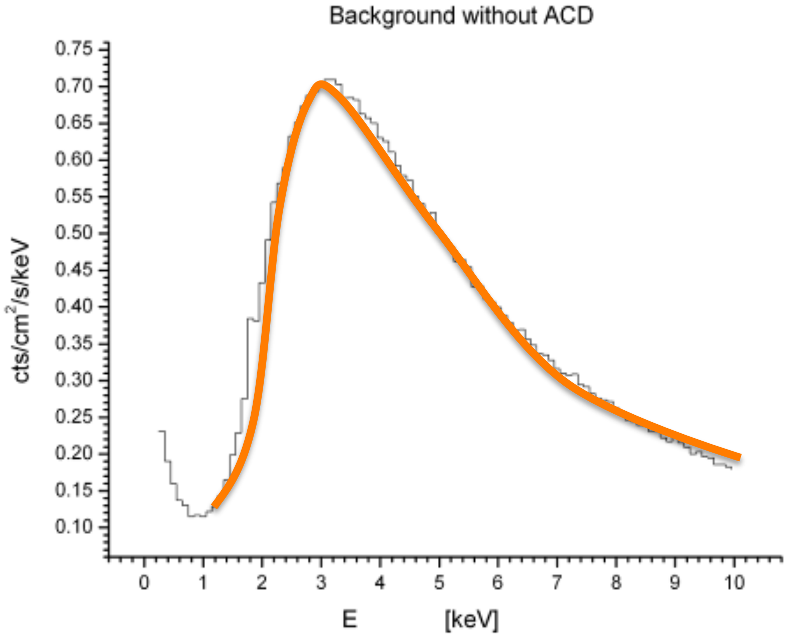
Spacecraft: aluminum sphere

Cryostat: modeled in great detail according to IXO specifics (conservative for ATHENA)





First results: without ACD



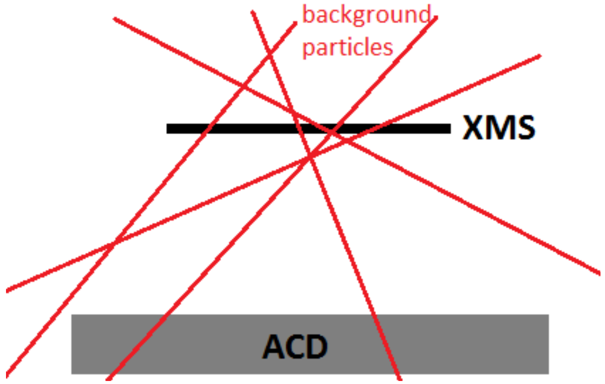
Without ACD the background can be rejected only through pattern recognition and energy selection. The residual bkg is 3.1 cts cm^{-2} s^{-1}

It is composed mainly of MIP protons

Underneath the TES array, an active anticoincidence detector must be placed to screen this particle background.
The ACD is also based on TES technology (Macculi et al. 2012, 2013)

Table 1 *Particle fluxes experienced in the detector neighborhoods without the anticoincidence detector*

	Total [cts/cm^2/s]	Primaries [cts/cm^2/s]	Secondaries [cts/cm^2/s]
Total background on TES array	5.6	4.3	1.3
Total background on TES array [0.2-10 keV]	3.7	3.0	0.7
Background after autorejection	4.6	3.7	0.9
Background after autorejection [0.2-10 keV]	3.1	2.6	0.4



ACD insertion

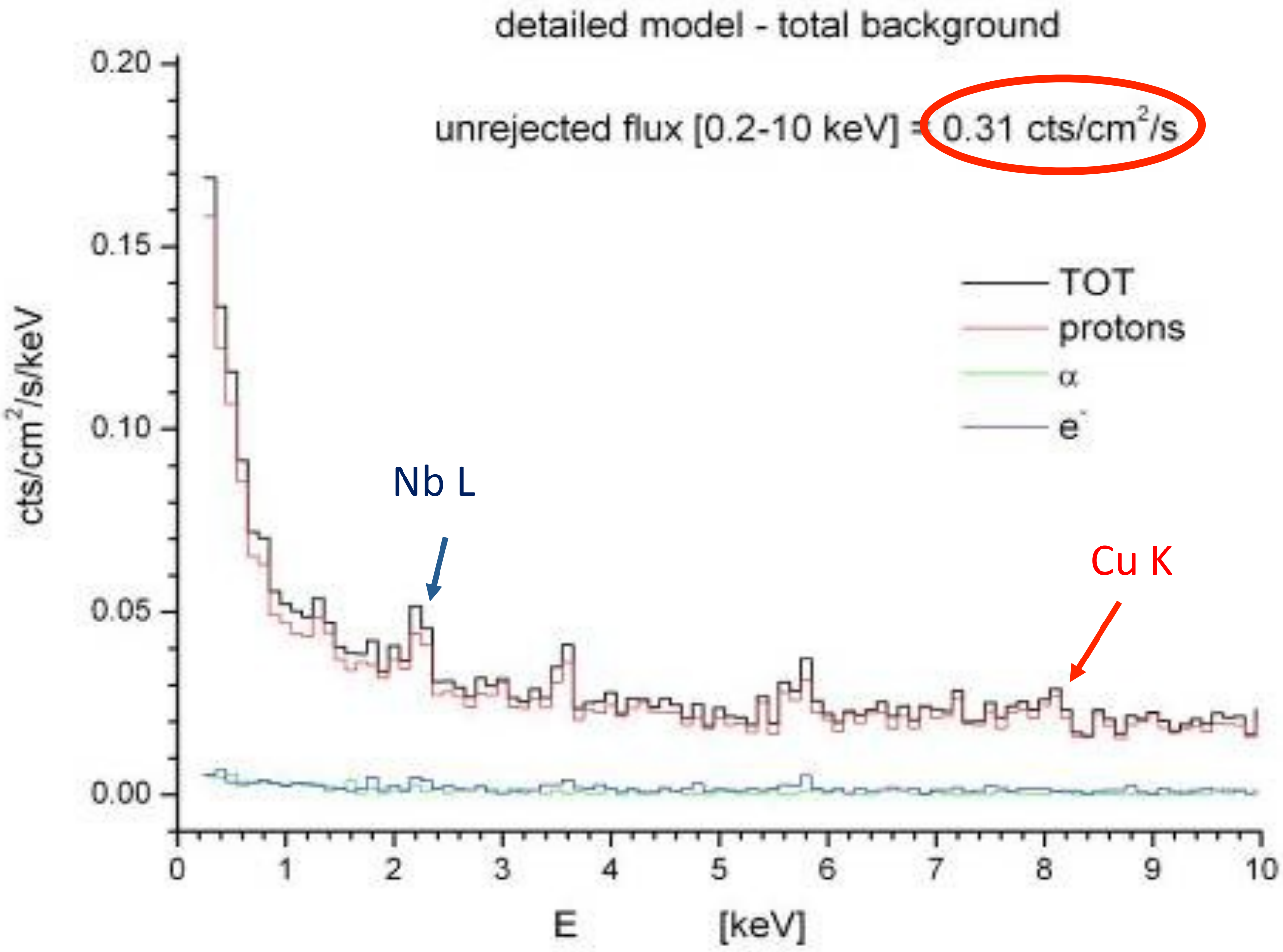
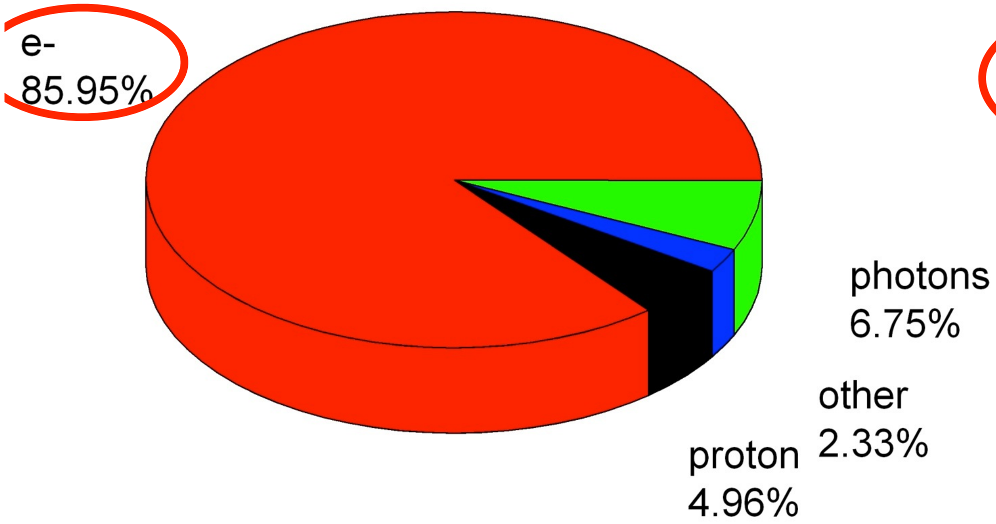


Table 1 *Unrejected background induced from the different primary particles: detailed model*

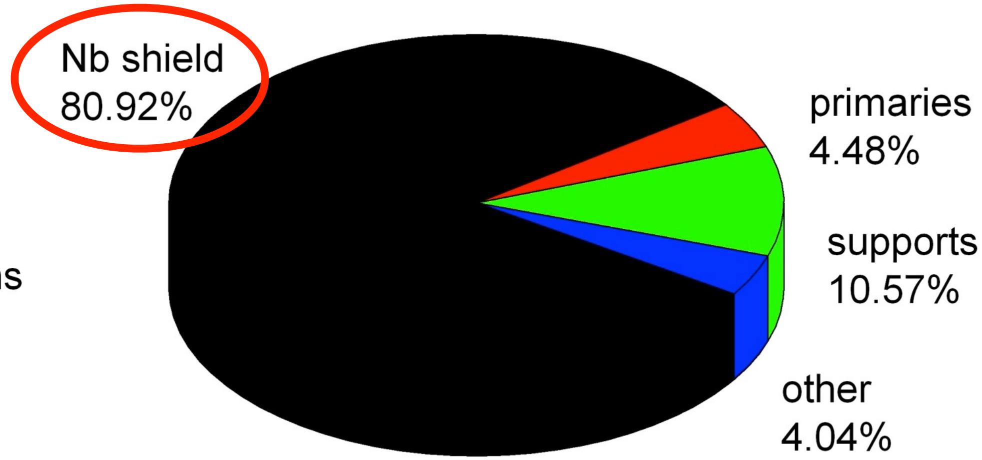
Primaries	Rate (cts cm^2 s^{-1}) d = 2 mm
Protons	0.28
Electrons	0.018
Alpha	9.8 x 10^{-3}
Total	0.31

Background composition

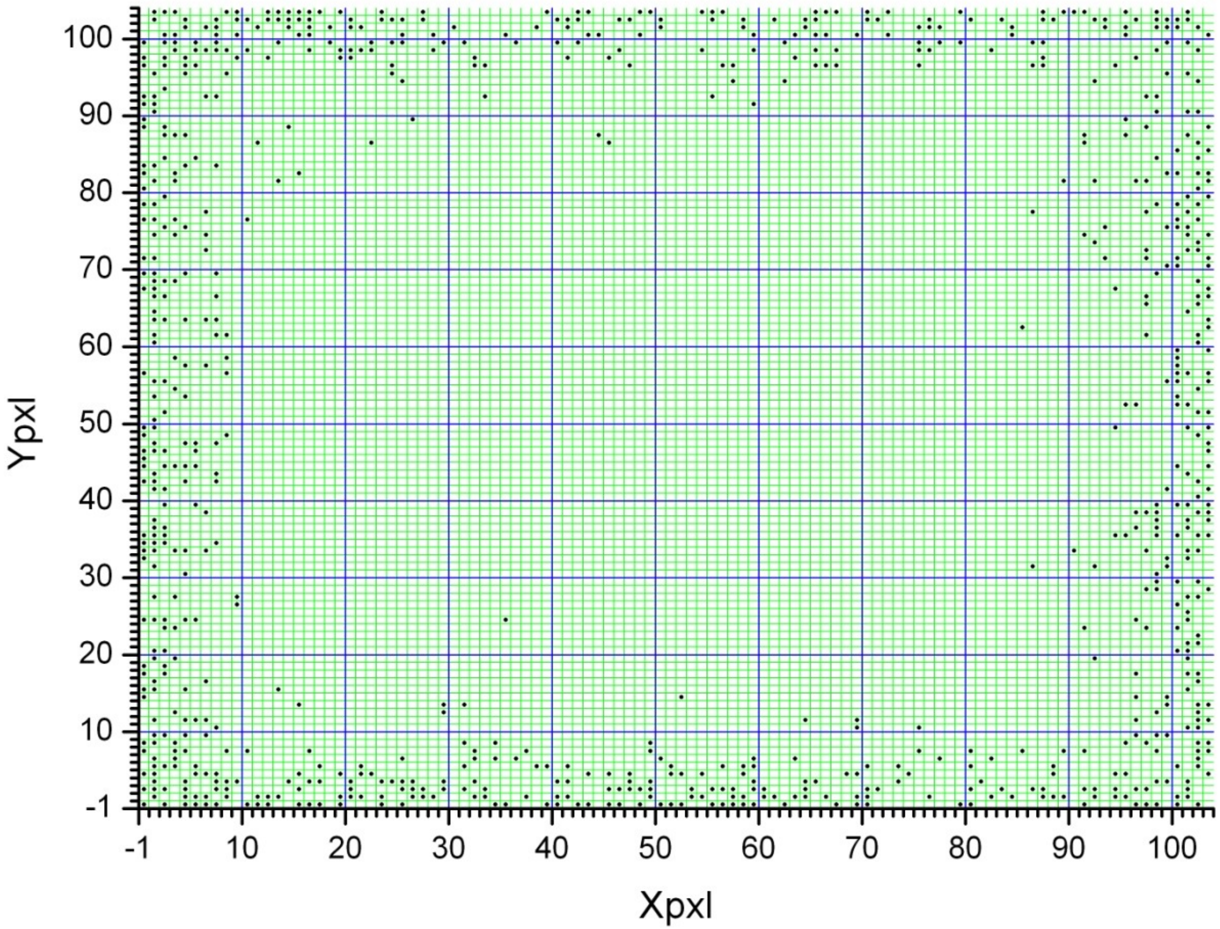
unrejected background composition



unrejected background geometrical origin



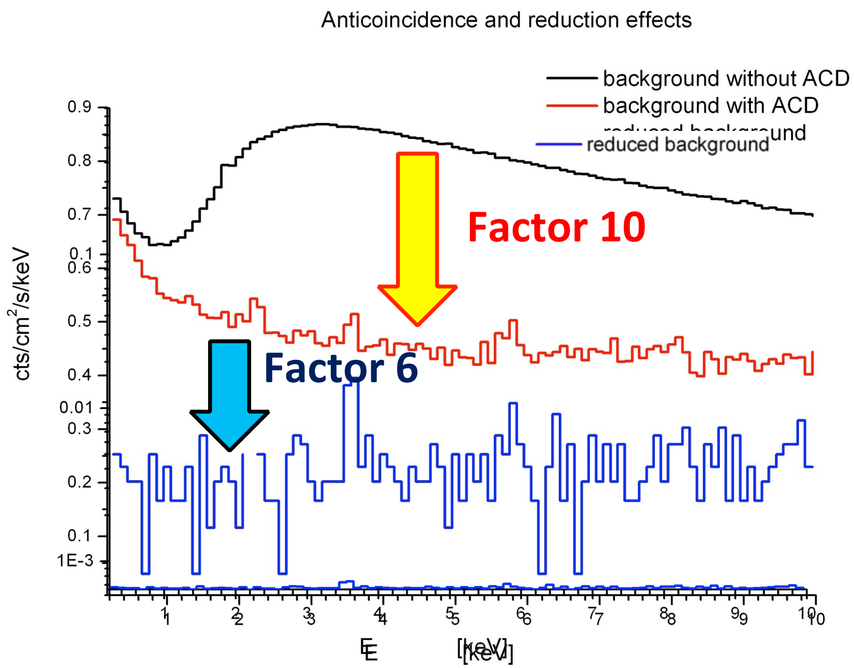
Unrejected primary protons geometrical distribution



Background reduction

The bkg main components are secondary electrons and primary protons due to the ACD low efficiency in the outer zones. We then improve the geometrical efficiency of the ACD and exploit materials with low electron production yield

- Reduce the distance between the TES array and the ACD from 2 mm to 1 mm:
  19% reduction
- Kapton layer inside the Nb shield:
  70% reduction
- Kapton filter very close to the detector:
  17% reduction



Putting everything together we achieve a further bkg reduction of a factor 6, and reach the background level of **0.05 cts cm^{-2} s^{-1}**

Summary

- The main component of the particle bkg is MIP protons. However this component is easily discriminated in every detector through energy/pattern selection analysis

- Once MIP are removed secondary low E electrons become the main problem. They can be restrained exploiting materials with low electron production yield (low Z) and clever FPA design (see Lotti et al. 2013, 2014.).

- In FI CCDs there is a non-sensitive layer that absorbs these low E electrons, acting as our kapton layer. Thus FI cameras exhibits a background significantly lower than BI devices.

References

S. Lotti, et al., 2012. “Estimate of the impact of background particles on the X-ray Microcalorimeter Spectrometer on IXO”, [NIMA, Volume 686], http://dx.doi.org/10.1016/j.nima.2012.05.055

S. Lotti et al., 2013. - An efficient method for reducing the background of microcalorimeters applied to ATHENA-XMS - Proc. SPIE 8443, Space Telescopes and Instrumentation 2012: Ultraviolet to Gamma Ray, 84435H (17 September 2012); doi: 10.1117/12.925443

S. Lotti et al. 2014. - The in-orbit background of X-ray microcalorimeters and its effects on the observations - AA/2013/23307 (under review)

Macculi C. et al., 2012, Proc. of SPIE 8443 84435G-1, (2012).

Macculi C. et al., 2013, Proc. of LTD15, to be submitted to JLTP (2013)