The reduction techniques of the particle background for the ATHENA X-IFU instrument at L2 orbit: Geant4 and the CryoAC.

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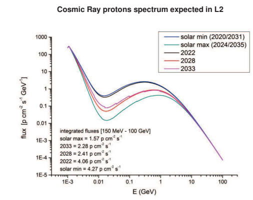
We present the particle background reduction techniques aimed to increase the X-IFU sensitivity, which is reduced by primary protons of both solar and Cosmic Rays origin, and secondary electrons. The adopted solutions involve Monte Carlo simulation by both Geant4 toolkit related to the "expected" background at L2 orbit through the payload mass model and the ray tracing technique to evaluate the soft protons components focused by the optics to the main detector, and the development of an active Cryogenic AntiCoincidence detector and a passive electron shielding to meet the scientific requirements.

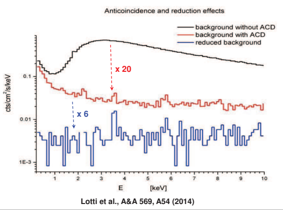
The Geant4 simulation

Parameter	Value	What it defines	Main science drivers
Background level	$<5\times10^{-3}$ cts/s/cm²/keV	Defines the anti coincidence performance and the passive shielding of the detector	Matter assembly in clusters - Metal production and dispersal - **low surface brightness objects**

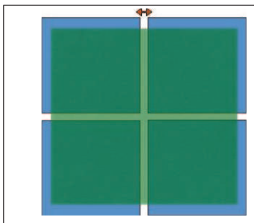
Minimum detectable flux

$$F_{min} = \frac{n_\sigma}{QA_S}\sqrt{\frac{B_iA_b + Q\Omega j_d A_S}{t\Delta E}}$$

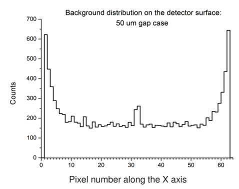




To achieve the ATHENA scientific objectives a particle background level $B_i<5\times10^{-3}$ cts/s/cm²/keV is required. Since there are no data from X-ray instruments in L2 we estimate and improve this value with Geant4 Monte Carlo simulations.



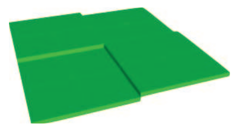
Main detector (green) and cryoAC (blue), as seen from above



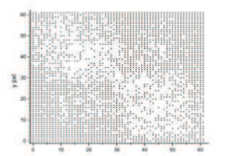
Impact to CryoAC design (1)

We exploited Geant4 simulations to investigate the impact of the detectors design on the particle background.

One of the first problems regarding the old baseline design we addressed was the presence of a gap among the cryoAC pixels. This induced a increase of the background in the pixels placed among the gap. We estimated that for a 50 μm gap this would be noticeable in a 60 ks obeservation.



An alternative cryoAC configuration (above), and the background distribution it produces on the main detector surface (below)



A solution was proposed to eliminate the gap with 4 pixel on two different planes and slightly overlapping, but this turned out to be worse, since we created 4 different background zones involving the entire detector instead of a tiny strip, so we decided to reduce this gap as much as possible instead.

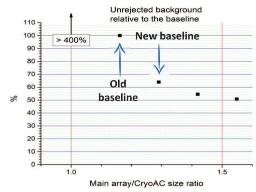
Impact to CryoAC design (2)

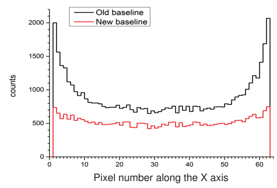
Another issue regarding the old baseline was the presence of an increased background level at the edges of the main detector.

This was caused by high energy particles with very skew trajectories that the CryoAC could not intercept.

To address this problem we studied the impact of the CryoAC size on the background level, and decided to increase the CryoAC size by 40%.

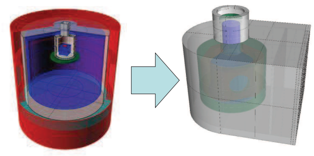
This allowed to obtain a more homogeneous background level along the whole detector surface.





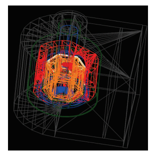
Ongoing activities:

- Satellite, cryostat and FPA mass models update
- Relevant physics models validation/update
- Inclusion of the ray-tracing code in Geant4 to estimate the low energy particles contributions to the particle background
- FPA improvement and L2 environment models improvement
- CryoAC performances improvement



Preliminary cryostat mass model

New FPA mass model (CAD) *Credits: Henk van Weers (SRON)*



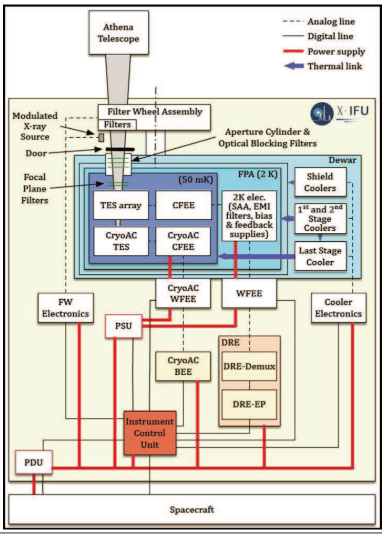
New FPA mass model (Geant4)

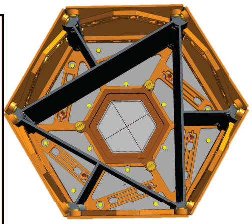
The CryoAC: an instrument inside another instrument.

CryoAC Specifications

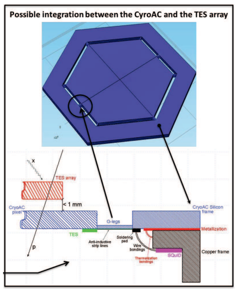
Size:	5.2 cm² (in 4 pixel, each ~ 1.3 cm²), no Multiplexing
Thickness:	500 µm
Distance from X-IFU:	< 1 mm
Rise Time constant:	< 30 µs
Time constant Decay:	< 300 µs (Goal)
Bandpass:	20 keV – 0.5 MeV

- **4 pixels** made of Silicon absorber sensed by Ir TES. Tbath = 50 mK
- **CFEE**: SQuID + RF filtering
  - **SQuID** (from VTT): We adopt a single stage SQuID, Series Array, at 50 mK
  - **RF filtering** at 2K to reduce EMI towards the FPA
- **WFEE (1 board-for-4 pixels)** it biases the CryoAC pxl and the SQuIDs; standard FLL
- **WBEE (2 boards: N + R)** will process the analog pulses from the WFEE, and HK to the ICU;
  → No VETO onboard. It manages the WFEE in diagnostic mode (FLL, V-PHI, test pulses...).





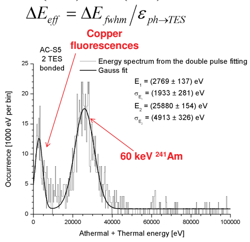
Credits: Henk van Weers (SRON)

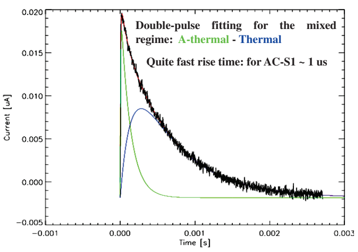


Possible integration between the CyroAC and the TES array

$$E_{measured} = \left(\frac{L}{L+1}\right)\cdot E_d = \left(\frac{L}{L+1}\right)\cdot \varepsilon_{ph\to TES}\cdot E_\gamma$$

$$\Delta E_{eff} = \Delta E_{fwhm}/\varepsilon_{ph\to TES}$$

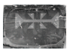




The past samples

AC-S1

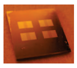
Area [mm²]	Collecting area (%)
16.5	11



Ir TES Area [mm²]	Abs Thickness
3.7	300 um

AC-S2

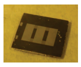
Area [mm²]	Collecting area (%)
100	9



Ir TES + Al Area [mm²]	Abs Thickness
1.5x4-1.5x8	380 um

AC-S3,4

Area [mm²]	Collecting area (%)
100	~ 20



Ir TES + Al Area [mm²]	Abs Thickness
1.5x4-10x3	380 um

AC-S5

Area [mm²]	Collecting area (%)
42	~ 24

Ir TES Area [mm²]	Abs Thickness
2x10	300 um

Last sample - 2015 - produced: AC-S7 and AC-S8: 1cm2 area