AHEAD
Integrated Activities for the High Energy Astrophysics Domain

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AHEAD meeting at Tor Vergata (Roma)
WP7: ATHENA background simulation and scientific calibrations
(Join Research Activity 2)

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INAF/IAPS Roma

On behalf of the WP7-bkg team

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The aim

Is to improve the:

- ATHENA Instruments sensitivity
- ATHENA Instruments accuracy

For high energy detectors,

- the sensitivity is affected by
  - Particle background
- the accuracy (as for all instrumentation) on energy, gain, etc…, is related to
  - Calibration → for space instrumentations cross-calibration among different satellites

In this talk we are going to discuss only the Particle background activity, showing you skills present in the team and also results coming from other activities.

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WP7 WBS

- **AHEAD Coordination**
  INAF/IAPS
  L. Piro, L. Natalucci
  - **WP 7**
    INAF/IAPS
    C. Macculi
    Coordination
    - **WP 7.1**
      Management
      INAF/IAPS Roma
      C. Macculi
    - **WP 7.2**
      X-IFU Background
      INAF/IAPS Roma
      C. Macculi, S. Lotti, M. Laurenza
    - **WP 7.3**
      Cross-calibrations
      Univ. Leicester – INAF/IAPS Roma – Tartu Observatory
      S. Sembay, A. Read, L. Natalucci, J. Nevalainen
    - **WP 7.4**
      WFI Background/proton scattering Iridium
      Univ. Tubingen
      E. Perinati, C. Tenzer, A. Guzman
    - **WP 7.5**
      Optics protons/photon focusing
      INAF/IASF Pa
      T. Mineo

- Particle background

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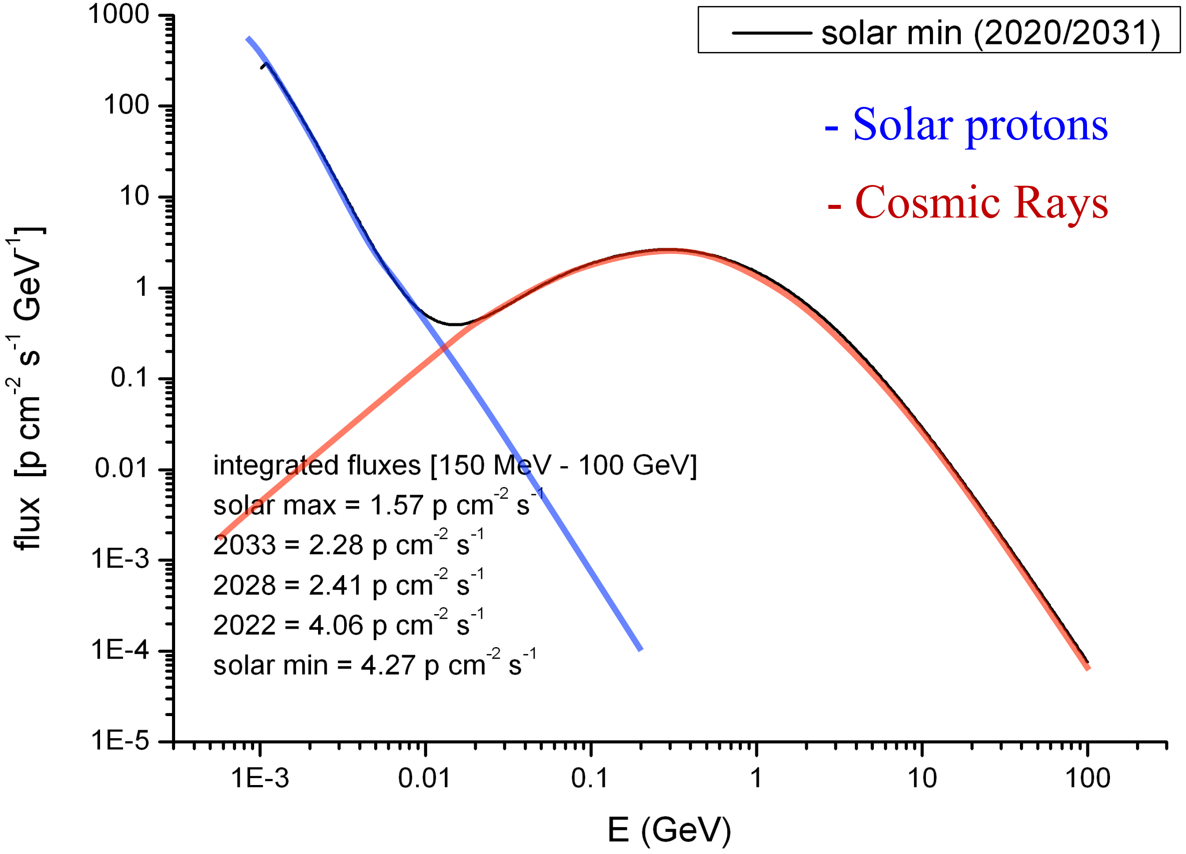
High energy particle background and context in High Energy Astrophysics



The main point is that they generates in-band detector energy signal that cannot be disentangled from the incoming scientific one so degrading the instrument performance!

$$F_{\min} = \frac{n_\sigma}{QA_s}\sqrt{\frac{\boxed{B_i A_d} + B_d Q \Omega A_s}{t \Delta E}}$$

- In order to study faint or diffuse sources it is necessary to reduce the particle bkg by a factor ~ 10^2
- → it is necessary to adopt solutions

The bkg has a crucial role!

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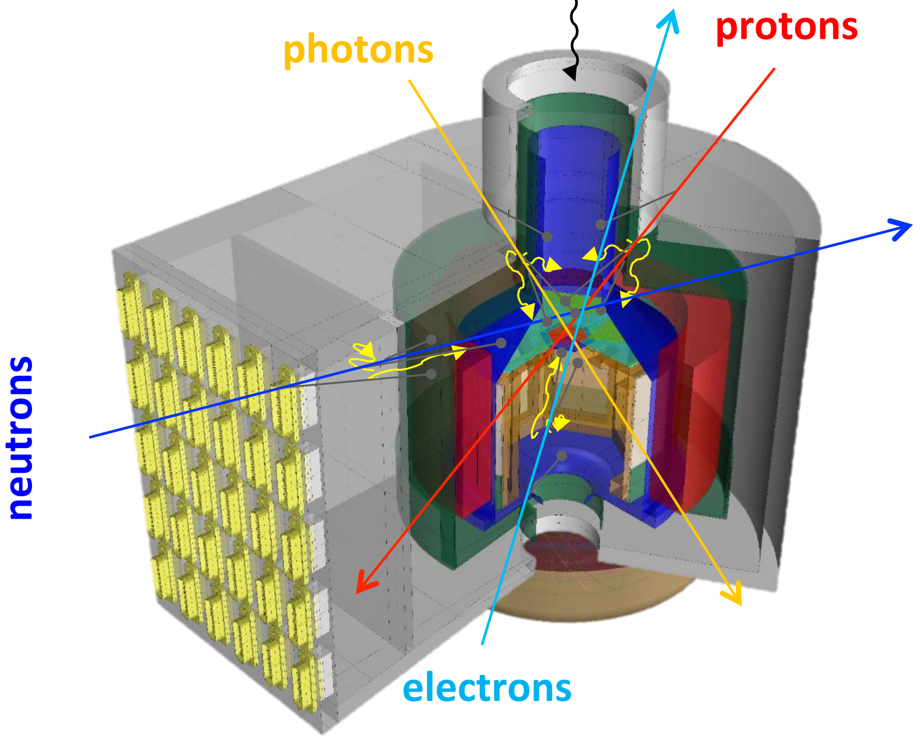
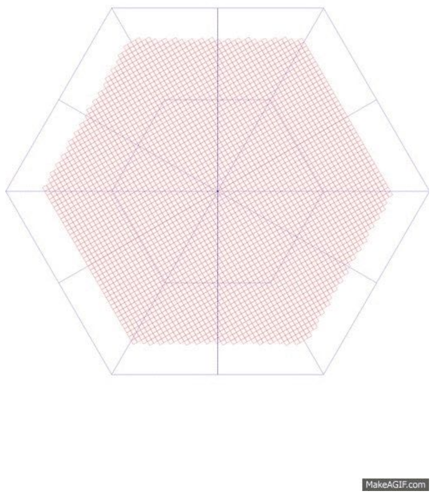
The particle background issue

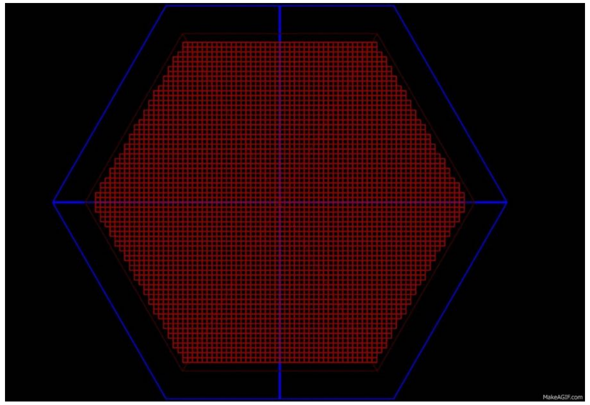
The scientific signals come from the top, focused by the Optics!!



CAD



Geant4 mass model



To increase the sensitivity it is mandatory to know:

- the particle environment in the satellite orbit (i.e., primaries)
  - ATHENA will be inserted in L2 orbit but due to lack of data we will use L1 satellites (ACE, SOHO, IMP-8 → Soft Protons and SEP) to provide info to L2. Just started in the AHEAD context.
- the so called «Mass Model» to simulate interactions among particles and solids closed to the detector (generation of primaries and secondaries) through the Geant4 toolkit (physics list).

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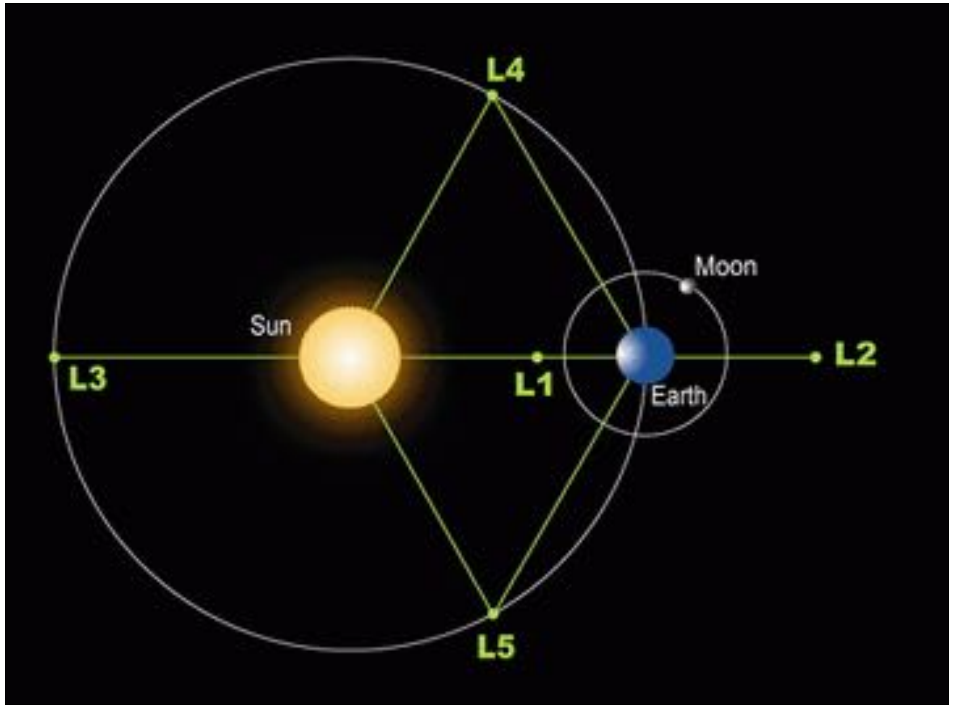
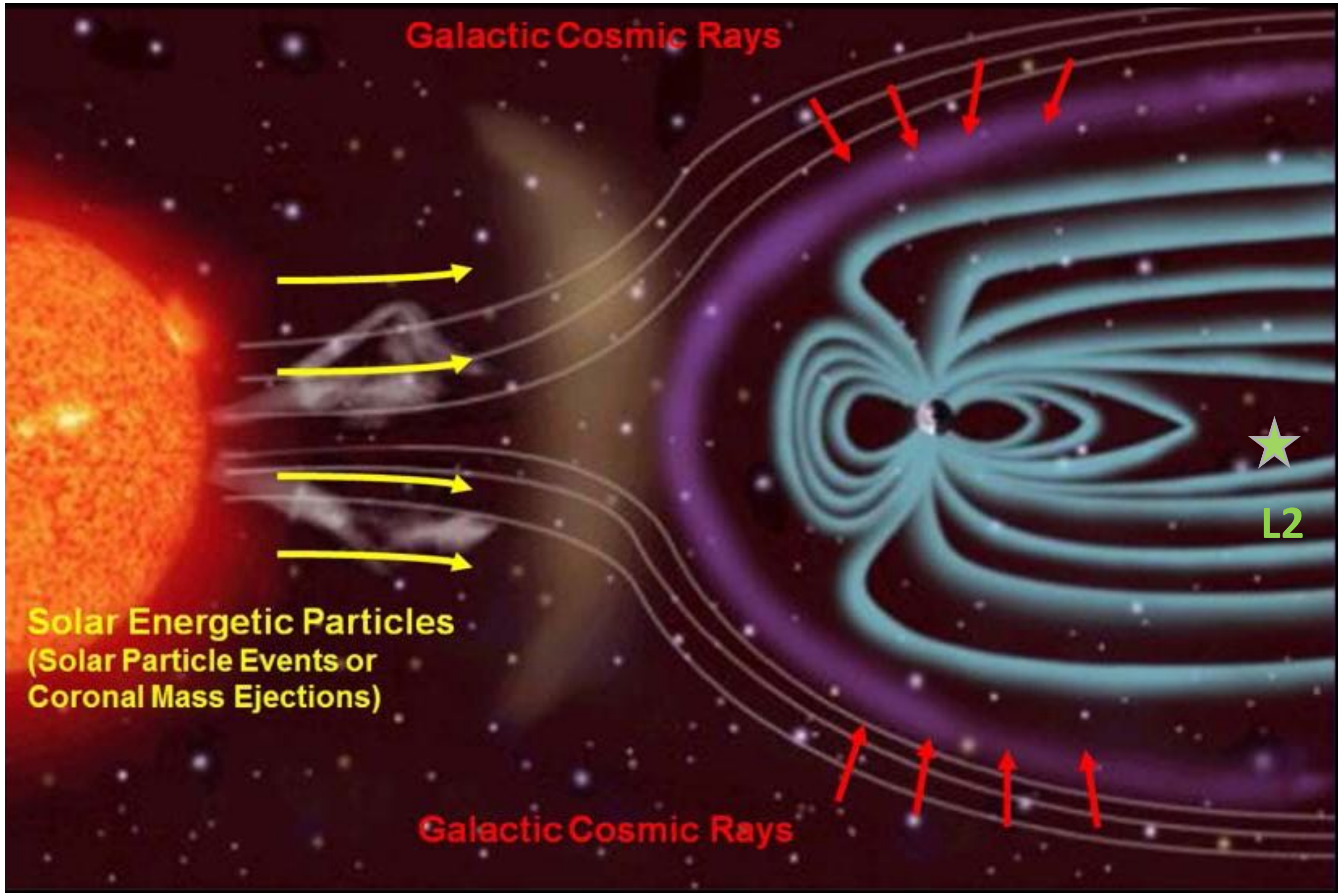
Particle background and context in High Energy Astrophysics



ATHENA orbit: L2 → ~ 1.5 Mkm
Good orbit for cryogenic instrument
(far from the Earth)



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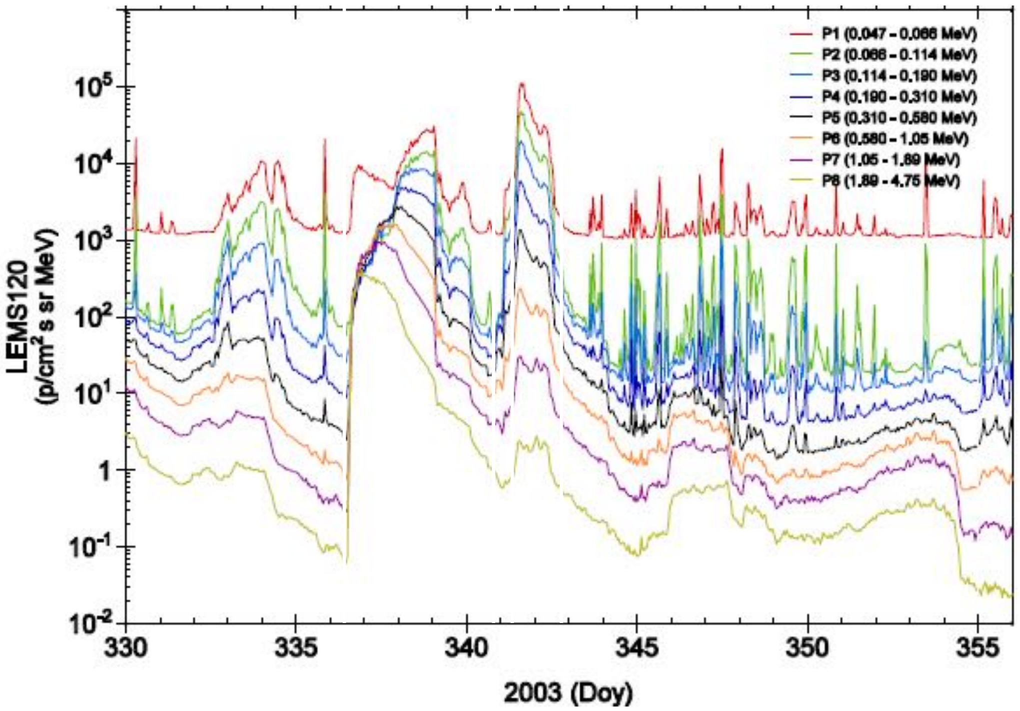
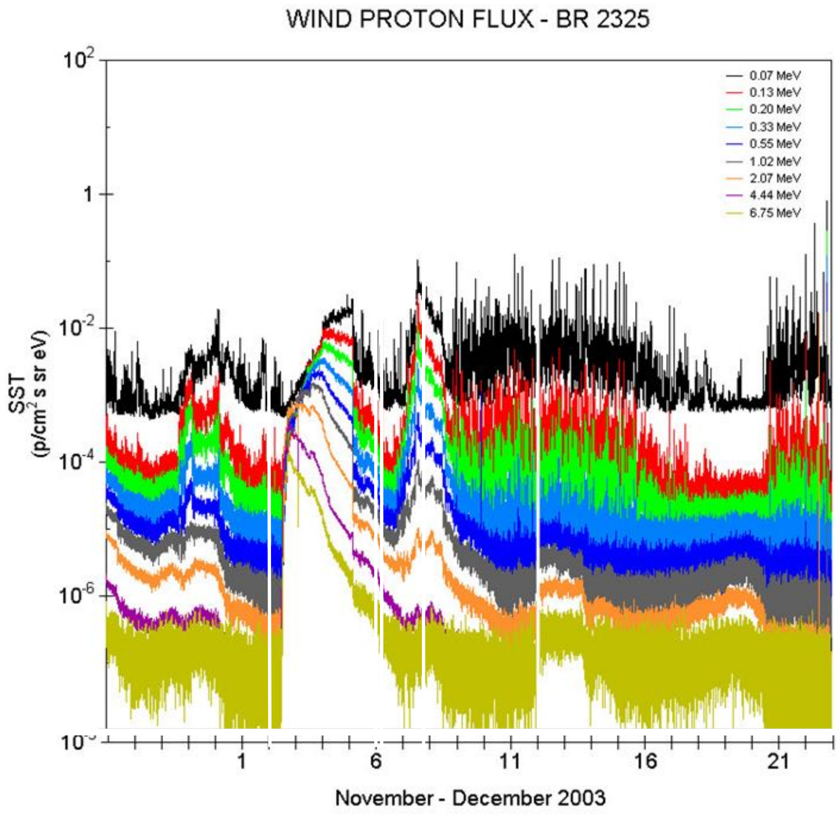
Soft protons: L1 vs L2 M. Laurenza IAPS/INAF

ACE – L1



WIND – L2



- Enhancements at L1 seen in L2 as well
- Some of flares seen in L2 are of Heliospheric origin

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X-IFU Geant4 mass models

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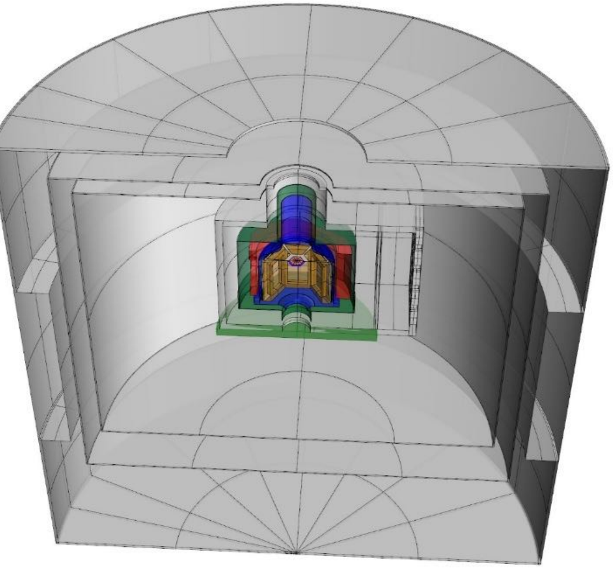
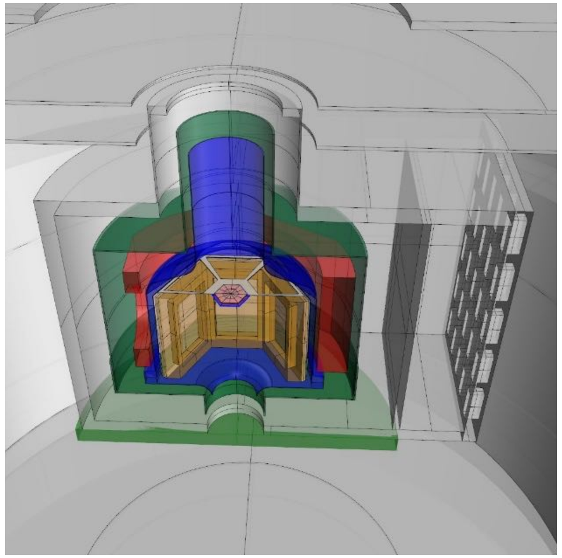
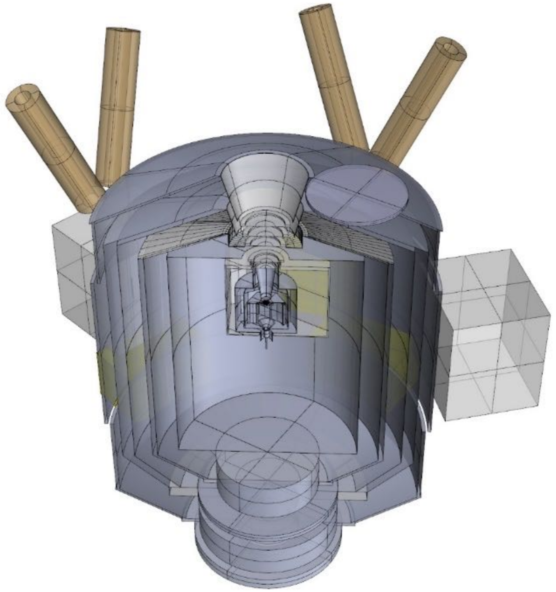
Old Cryostat



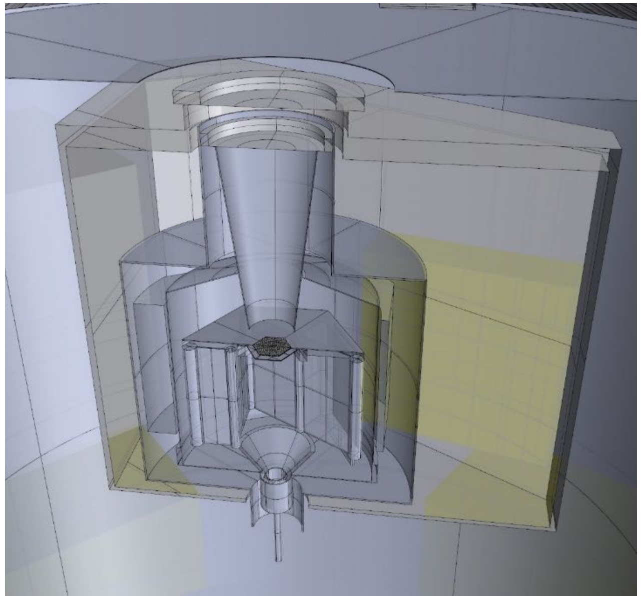
Old FPA



New Cryostat



New FPA



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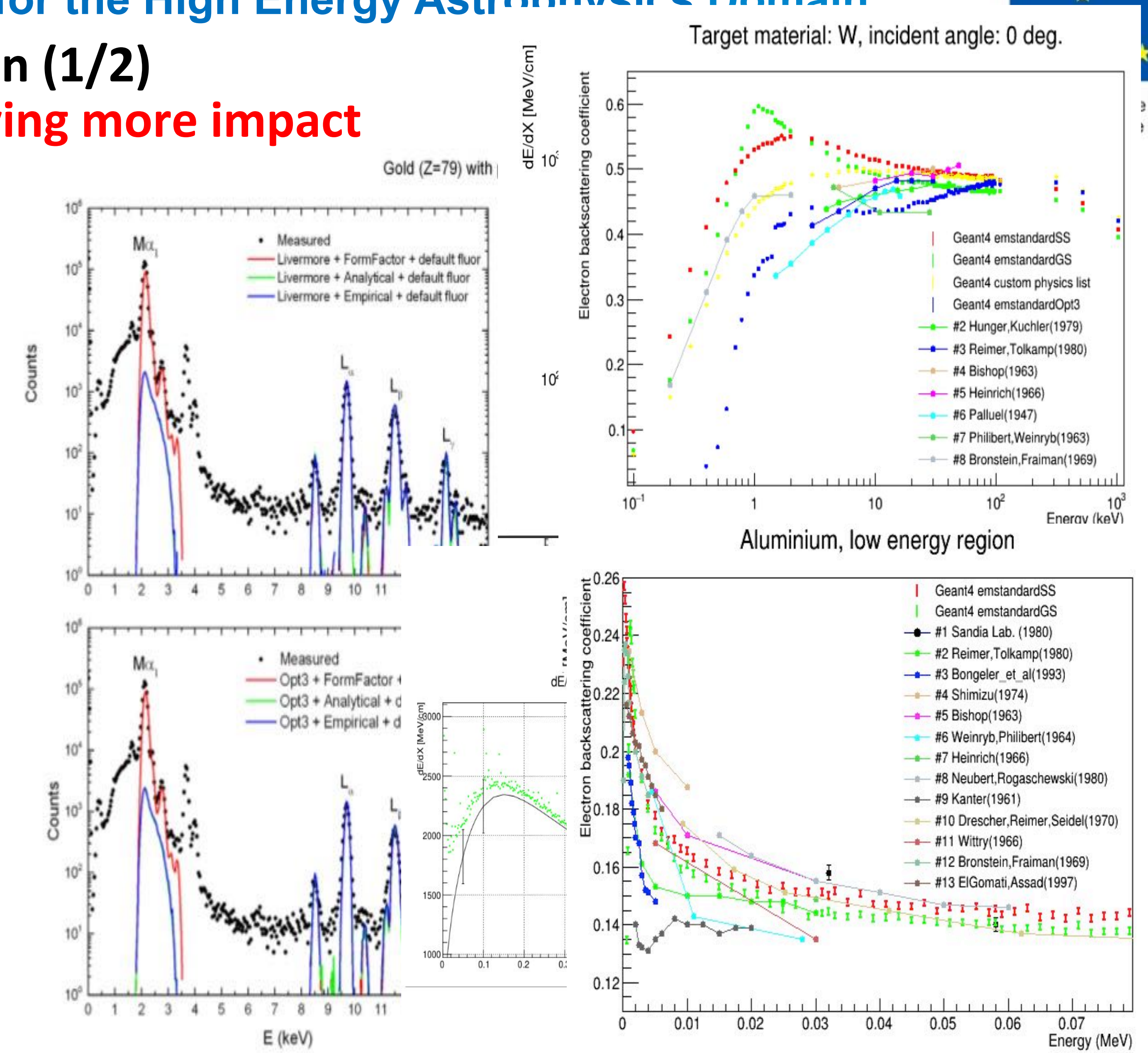
Geant 4 Physics validation (1/2)

(in red the processes having more impact on ATHENA)

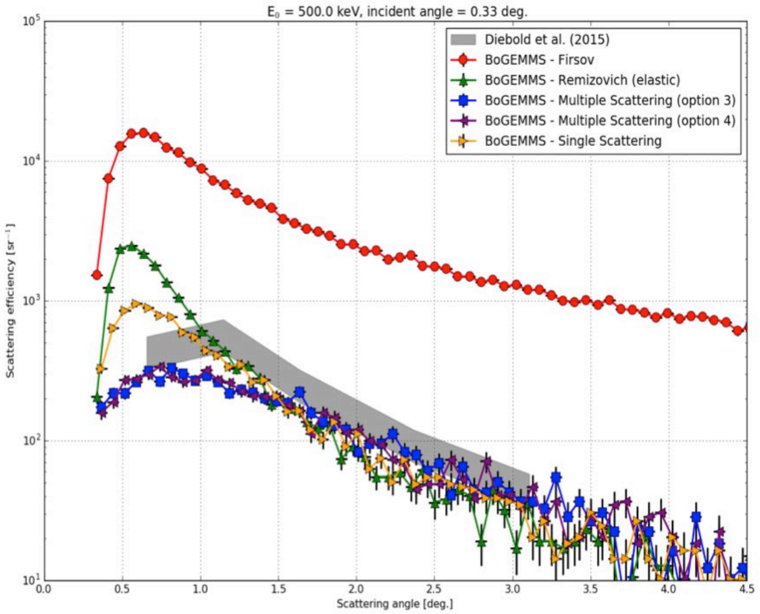
- Multiple scattering processes
- Single scattering process
- Ionization
- Bremsstrahlung
- Atomic Relaxation (fluroescences)
- Photoelectric effect
- Compton scattering
- RayleighScattering
- Radioactive Decay
- Hadron inelastic processes
- Hadron elastic processes
- Electrons backscattering

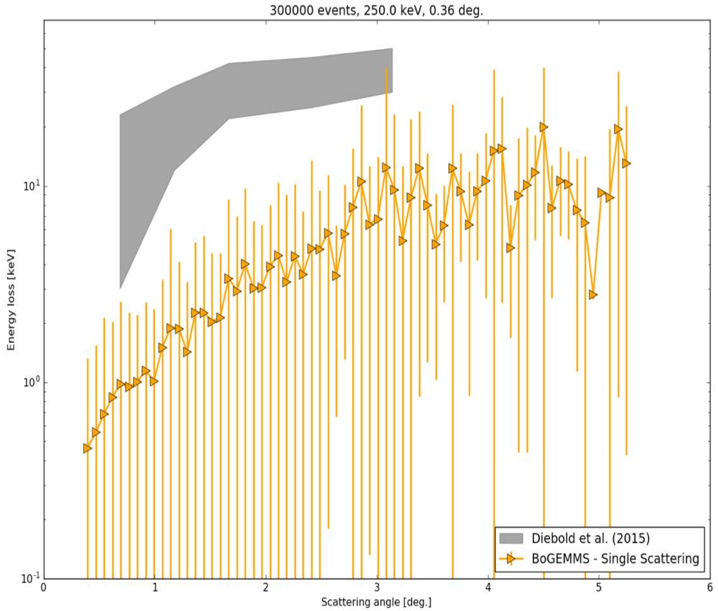


Geant4 Physics validation (2/2)
(in red the processes having more impact on ATHENA)

- Primary particles energy deposition tests
- Firsov scattering and Remizovich proton scattering model implementation on the mirror ray-tracing
- Firsov and Remizovich models implementation in Geant4
- Output of the mirror ray-tracing for the comparison with Geant4 simulations

- Tests concluded, recommended setup for Geant4 simulations in the ATHENA framework developed
- Aditional work to estimate the simulation errors, results expected by the end of the year





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The X-IFU NXB (work in progress, results not final)

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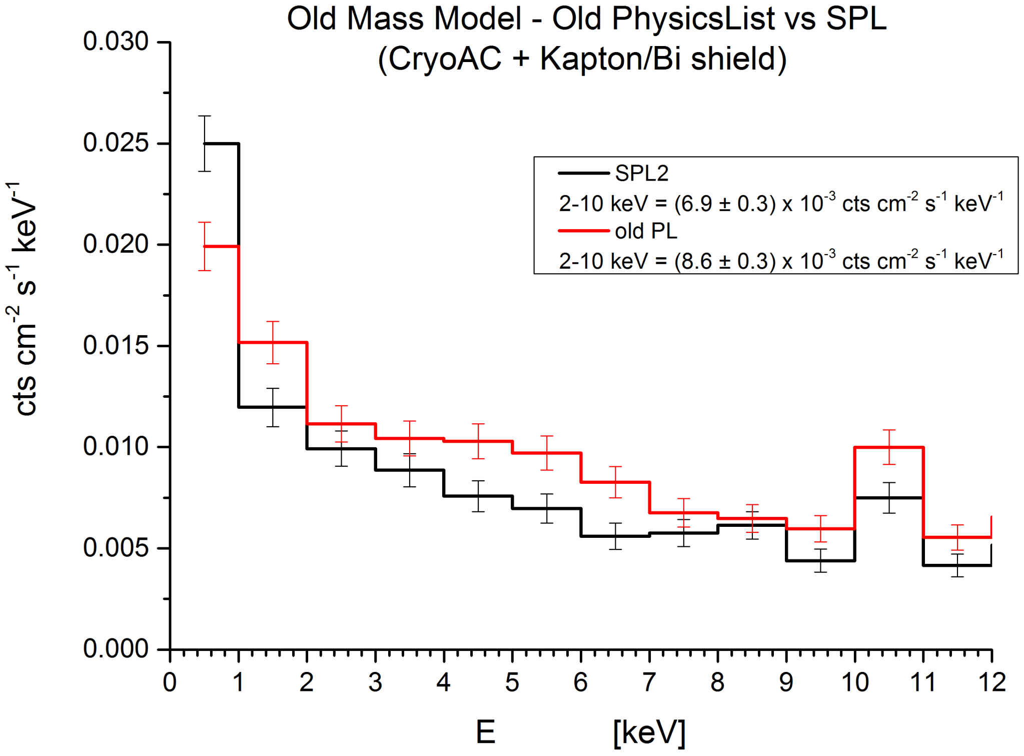
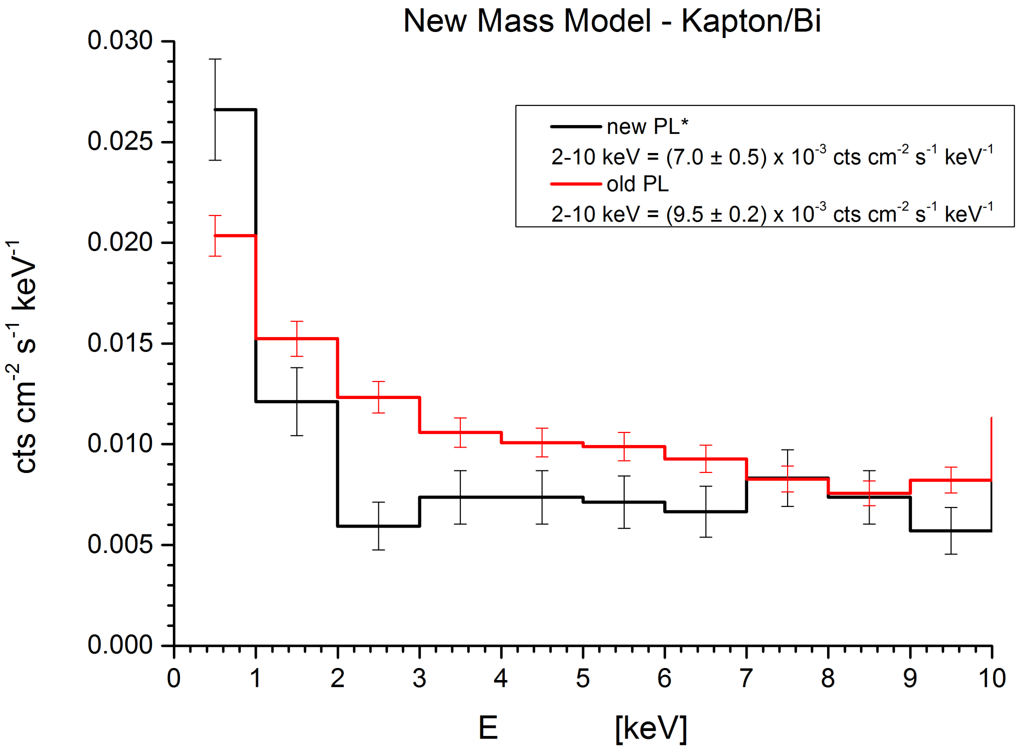


Error bars «statistics»



→ Phys. List fixed: changing the MM seems to not affect the NXB

→ The new Space Physics List wrt the previous one adopted (Opt4), provides ~ 25% decrease of the residual NXB level (to be further investigated).

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Integrated Activities for the High Energy Astrophysics Domain

Requirement: Bi = 5E-3 cts/cm^2/s/keV (in 2-10 keV bandwidth)

MIP (GeV) deposits in the TES-array ~ 5 keV → it is necessary a cryogenic anticoincidence system: the CryoAC

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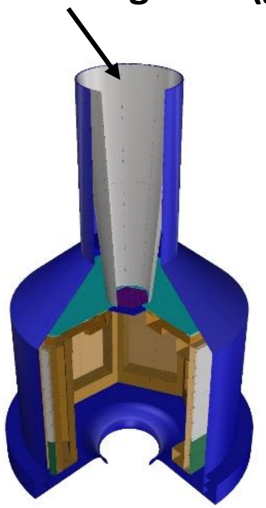
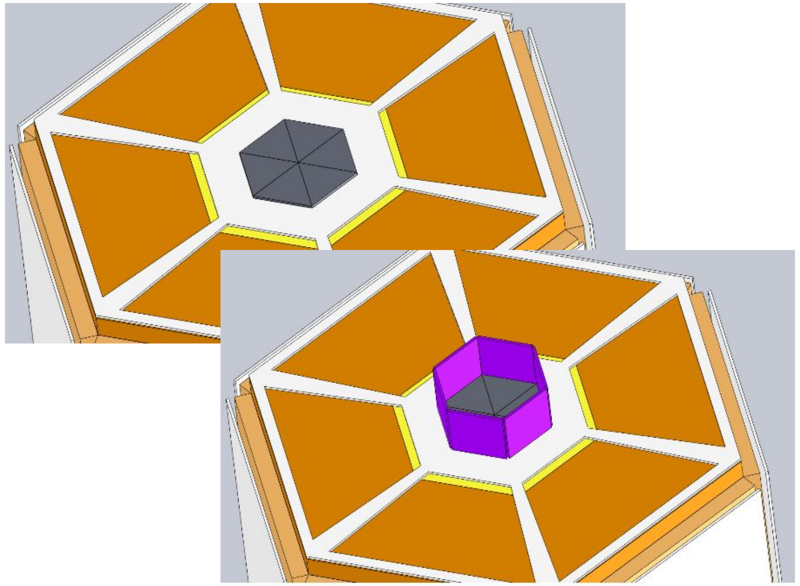
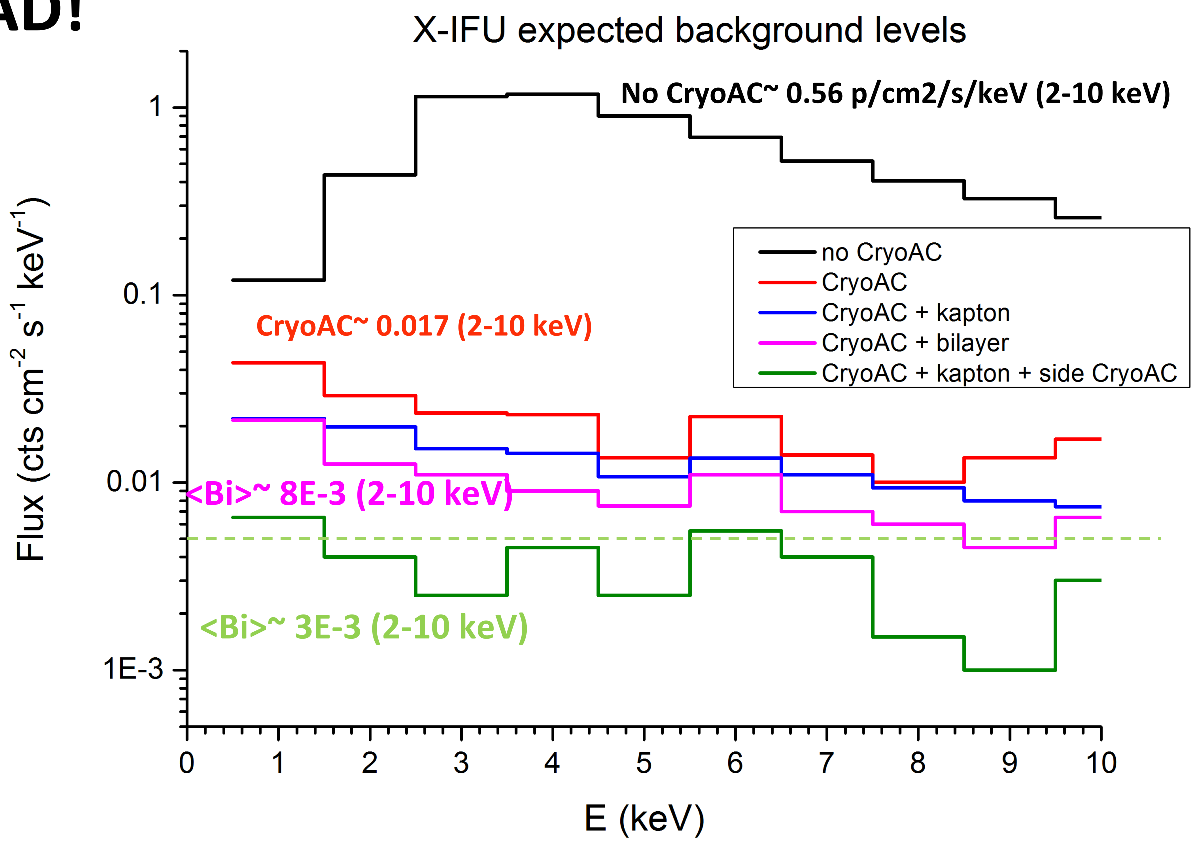
X-IFU not-in-baseline solution thanx to AHEAD!

Passive Electron shielding liner (gray)



Active Lateral coverage (CryoAC box)





Electron liner now in the X-IFU baseline. In the next phase we plan to perform the following activities:

- To update the Geant4 mass model developed for simulation of the X-IFU FPA and Cryostat
- To investigate in the X-IFU consortium, thus to optimize this possibility this use of the CryoAC as a “box”, so having an active anticoincidence detector enclosing the TES array.

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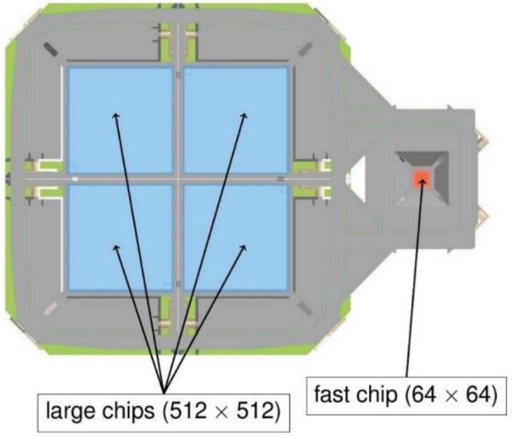
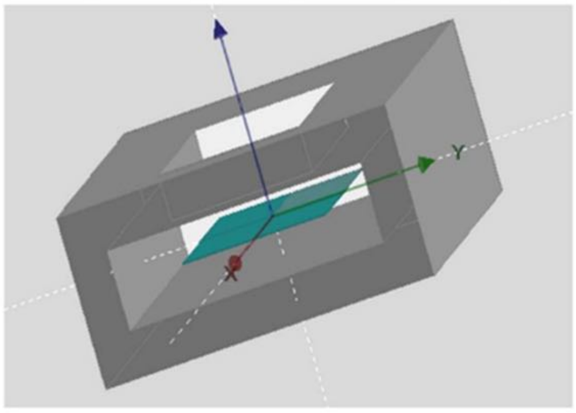
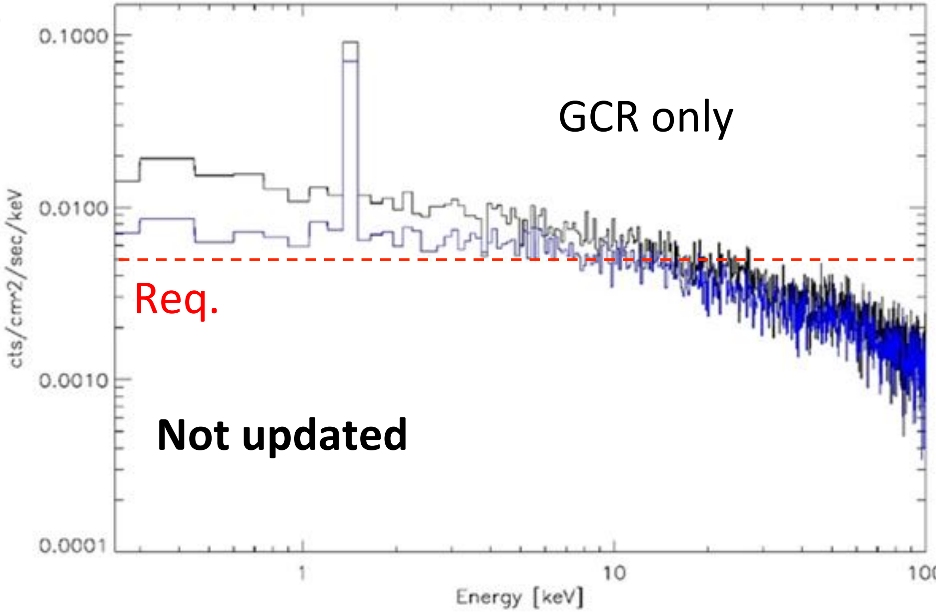
WFI (E. Perinati Tubingen Univ.)

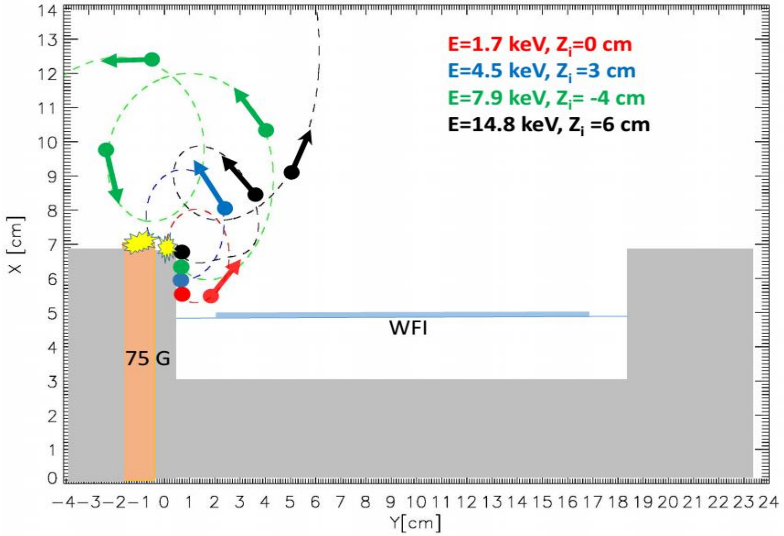
Requirement: Bi = 5E-3 cts/cm^2/s/keV (in 2-10 keV bandwidth).
On the contrary wrt X-IFU it is not necessary an active anticoincidence system: MIP deposition > 15 keV. But as X-IFU the residual bkg is due to secondaries → application of a passivation layer on the WFI non-illuminated side (3 μm C_8H_8). An Al shield 4 cm thick stop protons up to 110 MeV.







The secondary electrons are absorbed in the WFI and cannot be discriminated by pattern analysis as in most cases their mean free path is smaller than the pixel size. A relatively weak field (~100 Gauss) permits to obtain a repelling efficiency ~ 100 % for electrons < 15 keV. However, a residual magnetic field is left around the detector, possible side-effects on its functionality should be carefully assessed.



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Optics protons/photon focusing (T. Mineo IASF-Pa)

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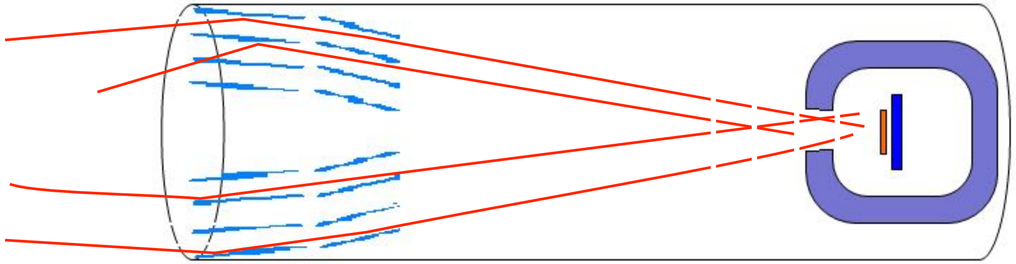
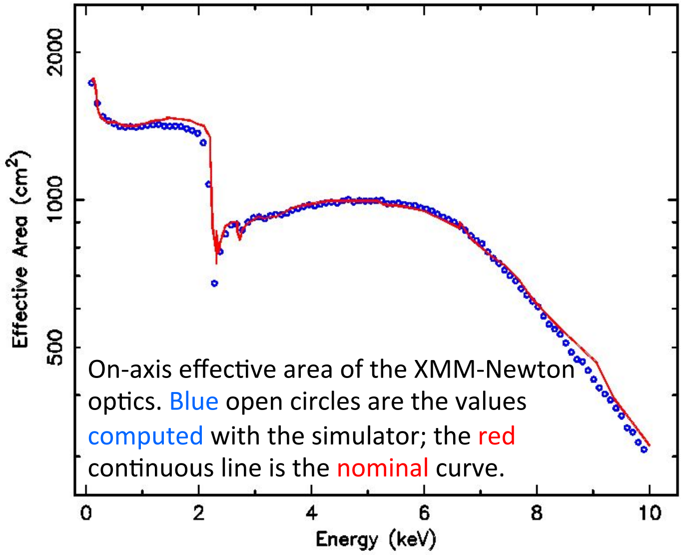
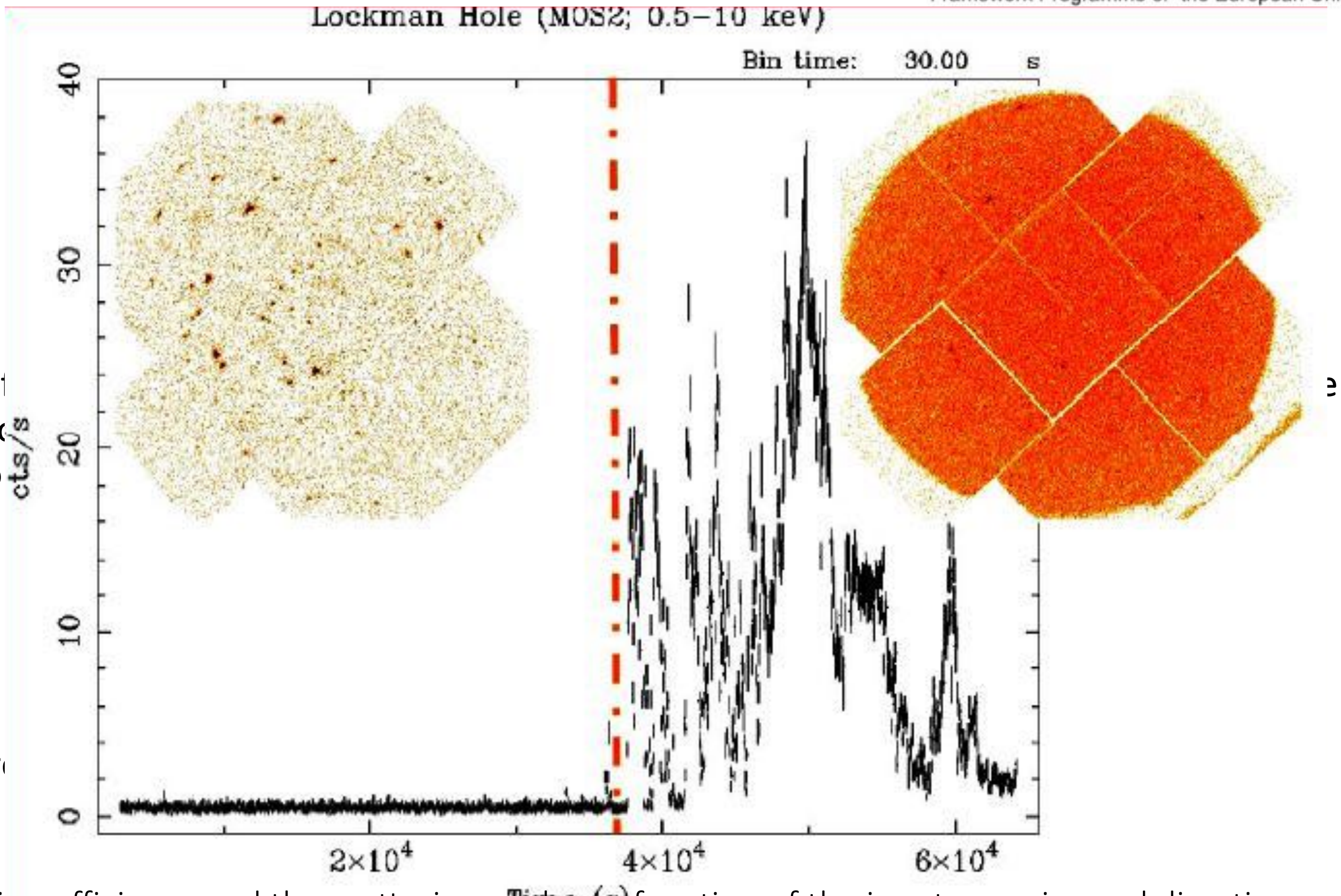




On-axis effective area of the XMM-Newton optics. Blue open circles are the values computed with the simulator; the red continuous line is the nominal curve.

The main objective of
proton transmission
- first step: productio



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- **second step**: mathematical functions to model the proton reflection efficiency and the scattering angles as function of the input energies and directions (Firsov and Remizovich model).

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Summary of exploited results.

BKG issues:

- Technical solutions, studied in the AHEAD context, now in baseline for X-IFU and WFI
- Ray tracing tool for protons validated by the XMM optics data (photons)