The X-IFU response matrices

Prepared by	*Signature*
Barret Didier	

Accepted by	*Signature*
Barret Didier	

Concerned Models BB ☐ DM ☐ EM ☐ STM ☐ QM ☐ FM ☐ FS ☐ All ☐

Document under Configuration Control y **Approval request** ☐

Approved by	*Function*	*Date*	*Signature*
Jean-Michel Mesnager	System engineer		
Philippe Peille	Performance budget manager		

Summary	This document describes the assumptions used to create the X-IFU response matrices.
Annexes	

Keywords	

Distribution	***See Distribution list at the end of this document***

Document Change Record				
Edition	**Revision**	**Date**	**Modified pages**	**Observations**
1	0	06/10/2018		Creation
1	1	08/10/2018	4 to 10	Comments by Ph. Peille included
1	2	22/11/2018		Added comment that filters are being optimized

Applicable Documents (AD)			
AD	**Title**	**Reference**	**Version**

Reference Documents (RD)			
RD	**Title**	**Reference**	**Version**
[RD1]	X-IFU Performance requirement document	XIFU-RD-SYS-00278-CNES	2.0
[RD2]	Athena Science Requirement Document	Athena_SciRd_v2.1_20180625	2.1
[RD3]	On the Athena effective area science requirements at 7 and 10 keV	ESA-ATHENA-ESTEC-SCI-TN-0002	1.0
[RD4]	ATHENA X-IFU thermal filters and development status	Consortium Meeting #8 presentation	
[RD5]	ATHENA - Telescope Reference Design and Effective Area Estimates	ESA-ATHENA-ESTEC-PL-DD-0001	2.4

List of Abbreviations			
X-IFU	X-ray Integral Field Unit		

- Table of Contents -

1. INTRODUCTION

This document describes the assumptions used for making the X-IFU response files. These responses are to be used for scientific simulations as well as for assessing the overall count rate performance of the X-IFU. They are available through the X-IFU Consortium web site:

http://x-ifu.irap.omp.eu/resources-for-users-and-x-ifu-consortium-members/

2. ASSUMPTIONS

Here we list all the assumptions used to create the response matrices.

2.1. MIRROR EFFECTIVE AREA

The mirror effective area curves were retrieved from:

https://www.cosmos.esa.int/web/athena/resources-by-esa

so-called 15 rows, 2.3 mm rib pitch, Ir+B4C coating

- The mirror Assembly (MA) consists of 15 rows, 6 sectors and 678 mirror modules.
- The mirror aperture radius ranges from 259 to 1183 mm
- The mirror plate rib spacing (pitch) is 2.3 mm
- Ir+B4C coating on the mirror modules at all radii

The data are courtesy of Tim Oosterbroek and validated by Matteo Guainazzi against Dick Willingale ray-tracing calculations. The data provided by Tim have a higher resolution in energy and are used here.

The file containing the mirror response is area_B4C_Ir_0.0_hires_TWGcorr.dat.txt.

2.2. FILTER ATTENUATION

- 1 filter with a mesh transmission of 96.0%
- 4 filters with each a mesh transmission of 97.0%
- Each filter is made of 0.007 µm of Al_2O_3 and 0.045 µm of polyimide and 0.023 µm of Al. This means that the five filters combined have a corresponding thickness of 115 nm of Al, 225 nm of Polyimide and 35 nm of Al_2O_3.

The transmission of the filters is computed through interpolation of the Henke tables[1], downloaded with the highest possible resolution. The mesh is assumed to be opaque over the X-IFU band pass. This appears as a good approximation as it starts transmitting X-rays only above 10 keV.

2.3. TES ARRAY CONFIGURATION

- The pixel pitch is 275 µm. The gap between each pixel is 4 µm. This leads to a pixel-filling

[1] http://henke.lbl.gov/optical_constants/atten2.html

factor of 0.971 (the absorber size is 271 µm).

- The absorber is composed of 1.7 µm of Au and 4.2 µm of Bi.

The transmission of the absorbers is also computed through interpolation of the Henke tables. Note that the dead pixel fraction addressed in [RD1] is set to zero in producing the response files.

2.4. CONTAMINATION

In the baseline response file, we assume no contamination. This is an energy dependent effect that is being studied.

2.5. SYSTEM LEVEL MARGIN

We assume a constant system level margin of 2% for the quantum efficiency.

2.6. SPECTRAL RESOLUTION OVERSAMPLING

We assume an oversampling of the spectral resolution by a factor of 3 (full width at half maximum oversampling of 6) and a flat spectral resolution of 2.5 up to 7 keV and then increasing linearly above 7 keV up to 12 keV, reaching 4.8 eV.

3. X-IFU QUANTUM EFFICIENCY

Figure 1 shows the X-IFU quantum efficiency curves, together with the requirements stated in [RD1]. Note that the low-energy requirement is given at 0.35 keV to stay away from the Carbon edge.

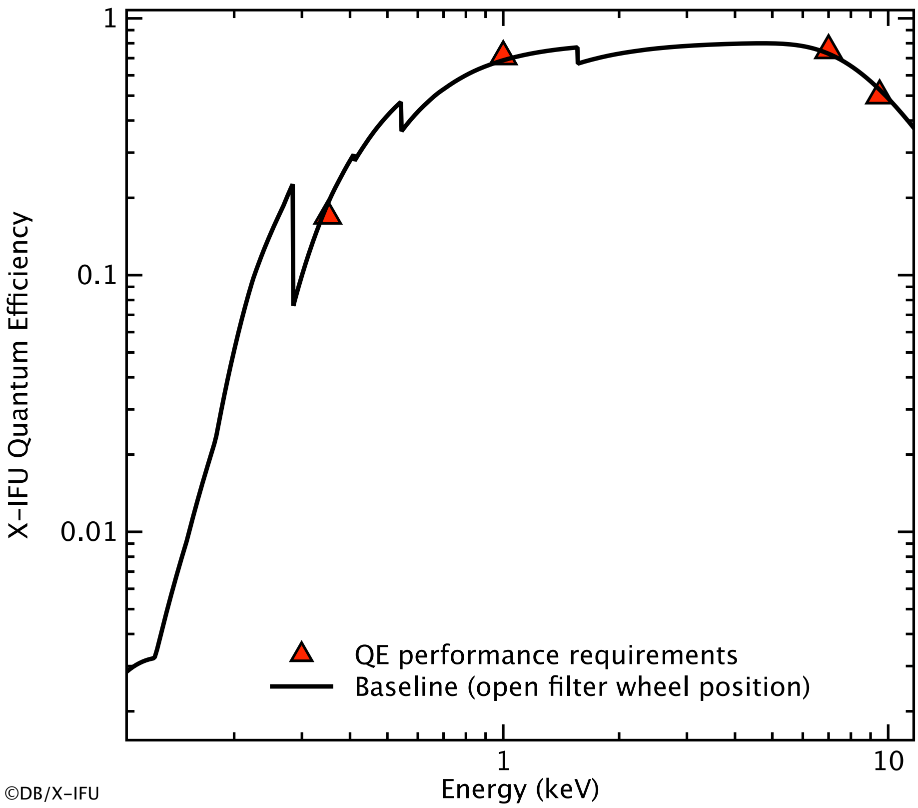

Figure 1: X-IFU quantum efficiency compared to the requirements.

4. X-IFU EFFECTIVE AREA

The X-IFU quantum efficiency can then be folded with the mirror response interpolated at the desired energies. The results are shown in Figure 2. As can be seen, thanks to the filter transmission optimization, the X-IFU effective area exceeds by about a factor of 2 the requirement stated in [RD2] at 0.35 keV, matches the requirement at 1 keV, but fails to meet the requirement at 7 keV (1300 cm^2 instead of 1600 cm^2). The non-compliance of the 7 keV requirement is being addressed separately.

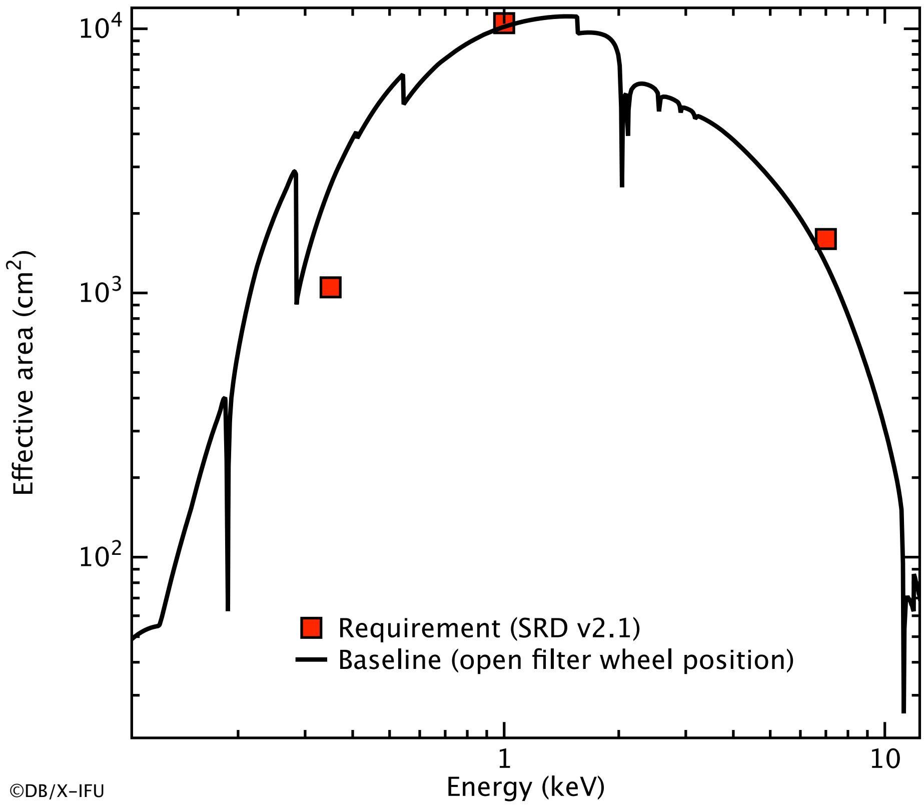

Figure 2: X-IFU effective area compared to the Science Requirements (v2.1).

5. FILTER WHEEL FILTERS

Three filters affecting the effective area are currently considered for the filter wheel. Those are still subject to optimization, awaiting inputs in particular from the XSAT on the MOCK targets to be observed by X-IFU.

5.1. THIN OPTICAL FILTER

The thin optical filter consists of 200 nm Polyimide and 40 nm Aluminum with a mesh blocking factor of 4%. No oxidation layer is included.

5.2. THICK OPTICAL FILTER

The thick optical filter consists of 200 nm Polyimide and 90 nm Aluminum with a mesh blocking factor of 4%. No oxidation layer is included.

5.3. BERYLLIUM FILTER

The thickness of the Be filter is assumed to be 100 µm, subject to further optimization.

The effective area curves corresponding to the three filter configurations considered are shown in Figure 3.

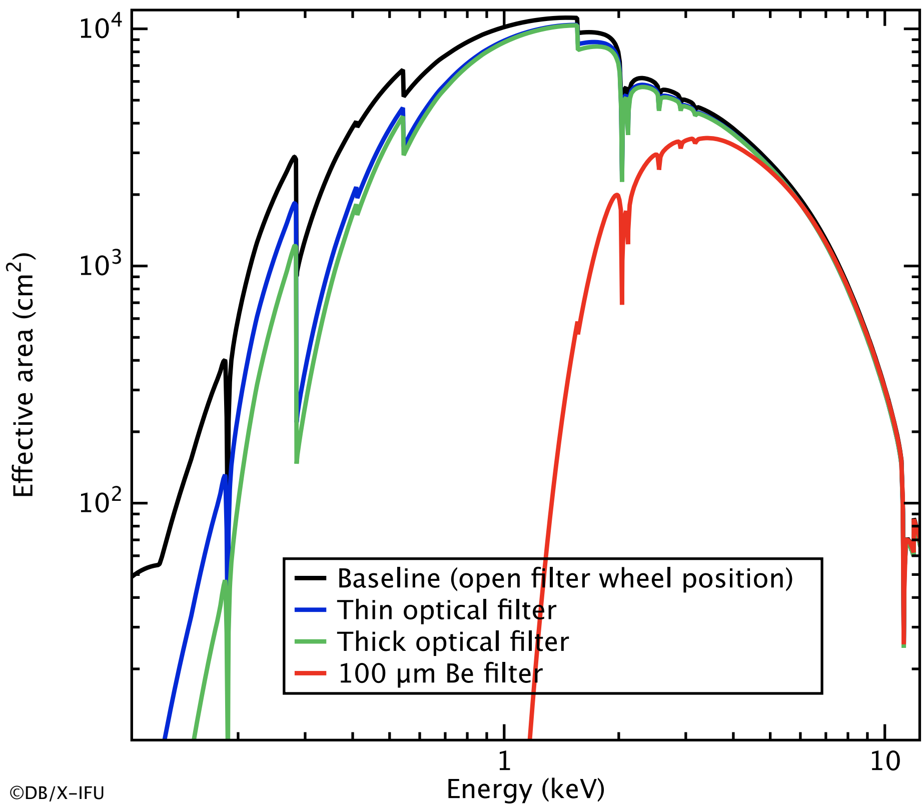

Figure 3: X-IFU effective area with the thin and thick optical filters, as well as with a 100 µm Beryllium filter.

6. FUTURE WORK

6.1. HIGH-ENERGY ATHENA X-IFU EFFECTIVE AREA REQUIREMENT

The X-IFU dos not met its effective area requirement at 7 keV: this is mostly due to the presence of filter supporting meshes, introduced in the filter design, e.g. for EMI filtering. The requirement for the EMI filtering will be consolidated.

The mirror effective area at 7 keV has also reduced. When going from the so-called as proposed mission 20 row configuration to the current 15 row baseline, it was expected that the high-energy response of the mirror would not change because the outer mirror rows contribute very little to the effective area at high energies. Unfortunately, as stated in [RD3] the new mirror configuration based on sectors, a different mirror packing within the rings led to a reduction of the effective area at 7 keV. Going from the as proposed or CDF mission configuration we went from 2100 cm^2 with no blanket factor, to 1900 cm^2 with the 0.9 blanket factor to 1800 cm^2 of area at 7 keV with the new mirror configuration and the 0.9 blanket factor (5% in total, see Figure 4).

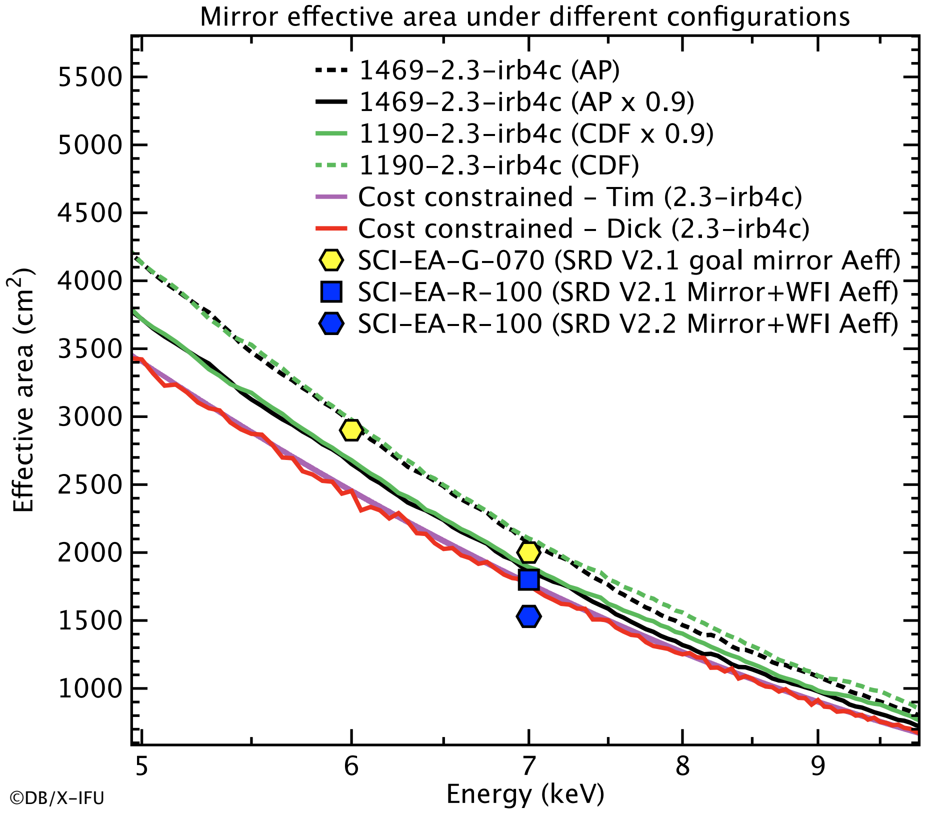

Figure 4: Comparison of the mirror effective area curves under various configurations from the As Proposed (AP) configuration, the CDF configuration and finally the Cost-Constrained (CC) configuration. The blanket factor of 0.9 was included for comparison with the latest effective area curves corresponding to the CC configuration. The goal effective area for the mirror is indicated by yellow hexagons. The requirement for the mirror and WFI effective area in SRD v2.1 is indicated by a blue square and the proposed changed requirement for the mirror and WFI effective area in SRD v2.2 is shown by a blue hexagon (reduction by 15%), most likely to match the QE of the instrument at 7 keV.

The effective area requirement at 7 keV stated in [RD2] is not met at the level of 20% (see Figure 5). All efforts should be undertaken to recover the mirror area loss (e.g. using different mirror module geometry, considering multi-layer coatings…), in addition to reducing the mesh blocking factor at the instrument level (as discussed in [RD4]). The non-compliance of the 7 keV requirement will be addressed in the subsequent revisions [RD2].

Finally, it should be noted that the rib spacing and the coating assumed for computing the mirror response used here are not the ones considered in the baseline telescope design described in [RD5]. In [RD5], the rib spacing is conservatively set to 1 mm and the coating is SiC on top of 10 nm Iridium, instead of the Ir+B4C coating not considered as a viable option anymore (as it does not survive a standard cleaning process). Going from 2.3 mm to 1 mm and from B4C to SiC coating would further decrease the mirror area at 7 keV, thus increasing further the non-compliance of the 7 keV X-IFU effective area. A high priority action must clearly be taken on the mirror side to address this issue, as it is very unlikely that the quantum efficiency of the instrument can be further increased at those energies.

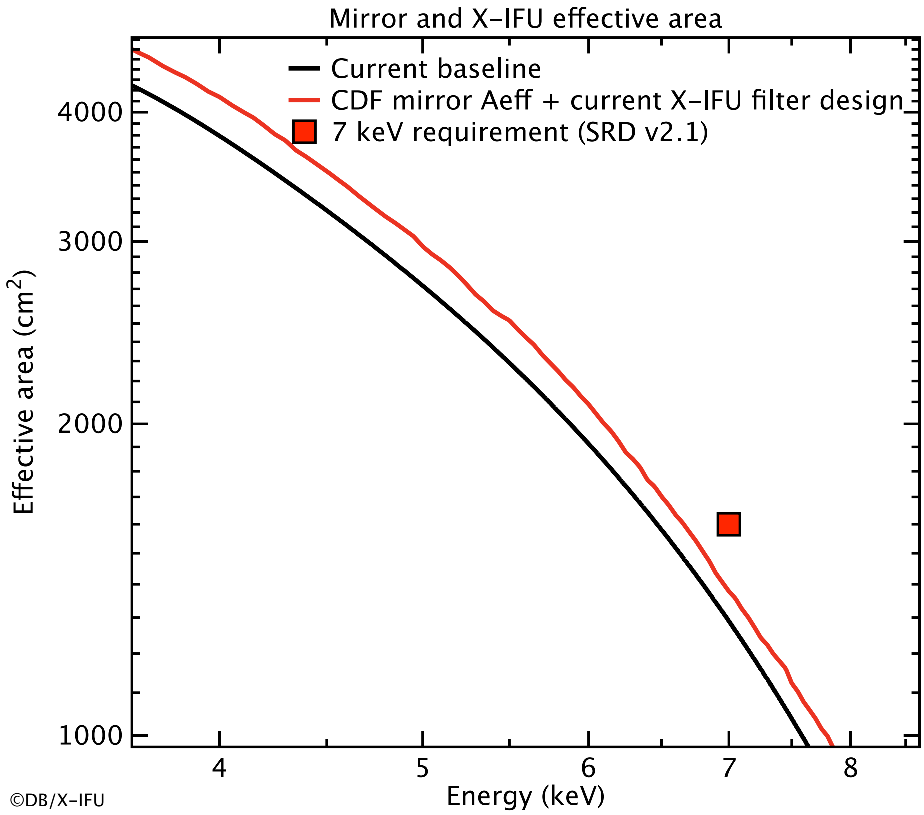

Figure 5: Comparison of the high-energy effective area of the X-IFU between the 15 row CDF configuration (the CDF mirror response included a 0.9 blanket factor and is folded with the same filter configuration as the current X-IFU baseline) and the current mirror configuration baseline, showing that the mirror effective area has dropped by about 5%. The X-IFU effective area requirement as in the SRD v2.1 document is indicated by a red square. The non-compliance between the X-IFU effective area and the requirement is at the level of ~20%.

6.2. FILTER CONFIGURATION OPTIMIZATION

The filter configuration is being optimized in view of reducing the blocking factor of the mesh down to 2%, and possibly by considering the possibility to remove one of the five filters (the one at 100 K). This would enable to increase the instrument quantum efficiency at 7 keV by up to 4-5%. This is discussed in [RD4].

6.3. SMOOTHNESS OF THE EFFECTIVE AREA CURVE

The resolution of the mirror effective area is not smooth and shows a stair like shape, as shown in Figure 6. This saw-tooth effect in the mirror response at high energy is a known effect of the reflectivity files downloaded from the CXRO web site. They are most likely due to numerical issues with the software producing the reflectivity tables for download. This will need to be fixed.

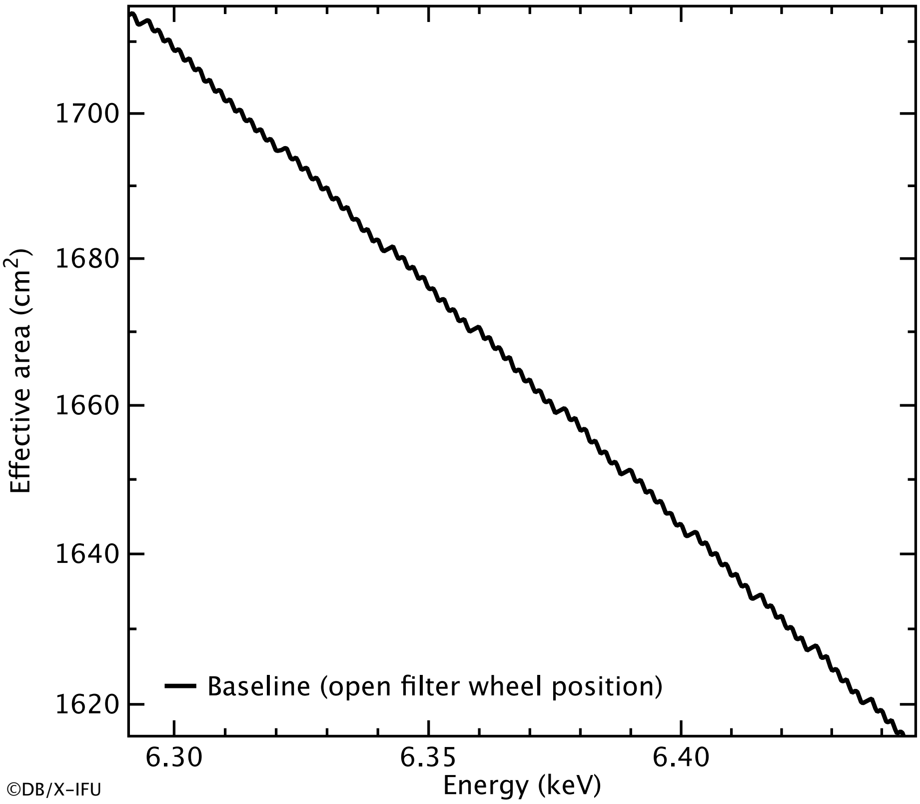

Figure 6: Stair like shape of the mirror response.

DISTRIBUTION LIST

INTERNAL Distribution (IRAP)
BARRET Didier
PAJOT François
POINTECOUTEAU Etienne
CUCCHETTI Edoardo

EXTERNAL Distribution	
Name	**Company**
MESNAGER Jean-Michel	CNES
PEILLE Philippe	CNES
CAPPI Massimo	IASF-BO
DEN HERDER Jan-Willem	SRON
GUAINAZZI Matteo	ESA
BARBERA Marco	Univ. Palermo
X-IFU Consortium	