Collimator materials absorption power study

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Change history

Version	Date	Notes
1.0	Feb 7th, 2007	1st Issue

1. Absorber configurations

The following absorber configurations have been studied [1].

Case 1, XMM-like tube:

Element	Density [g/cm^3]	Thickness [mm]
Carbon fiber	1.43	0.025
Aluminium	2.7	0.02
Carbon fiber	1.62	0.5
Aluminium honeycomb(*)	0.032	12
Carbon fiber	1.62	0.5
Carbon fiber MLI (20 layers)	1.44	0.184*20
(*) This honeycomb is equivalent to 0.14mm of 2.7g/cm^3 “normal” Aluminium.		

Case 2, AAS-I structural tube with Al honeycomb density equal to 0.037g/cm^3:

Element	Density [g/cm^3]	Thickness [mm]
Carbon fiber	1.62	1.5
Aluminium honeycomb	0.037	30
Carbon fiber	1.62	1.5

Case 3, AAS-I structural tube with Al honeycomb density equal to 0.054g/cm^3:

Element	Density [g/cm^3]	Thickness [mm]
Carbon fiber	1.62	1.5
Aluminium honeycomb	0.054	30
Carbon fiber	1.62	1.5

In addition, for the configuration of Case 3, a layer of solid Aluminium (density = 2.7 g/cm^3) has been applied in order to reach, for the overall structural baffle, an absorption trasparency of:

Case 3(A) <1% at 14 keV

Case 3(B) 1/e at 28 keV

This has been calculated also in the case of no Carbon fiber skins around the Aluminum structure. The required Aluminium thicknesses required to satisfy the above 3A and 3B conditions are shown in the table below, while the transparency values at all energies are listed in the table at the end of this note:

Element (Case)	Density [g/cm^3]	Thickness [mm]	Overall (C+honeycomb+Al) column density [g/cm^2]
Aluminium (3A)	2.7	0.97	0.91
Aluminium (3A – no Carbon)	2.7	1.15	0.473
Aluminium (3B)	2.7	1.78	1.128
Aluminium (3B – no Carbon)	2.7	2.15	0.743

[1] The calculations have been performed using the online databases and tools available at the National Institute of Standards and Technology (www.nist.gov).

3.1: Case 3 plus high Z absobers

Finally, for Case 3, alternative configurations have been studied, which foresee the addition of Tungsten (W), or Tantalum (Ta), or Lead (Pb), as absorbers. These elements do have a high stopping power, and at the same time their Kα emission line energies (~59 keV for W, ~57 keV for Ta, ~73 keV for Pb) fall above the baseline upper energy threshold of HXC (40 keV). Keeping this in mind, we have calculated, for each element, the required thickness in order to satisfy the following absorption requirements:
Case 3.1(A) <1% at 14 keV
Case 3.1(B) 1/e at 28 keV
Case 3.1(C) <1% at 40 keV
Case 3.1(D) <1% at 80 keV

The results are shown in the following table:

Absorption requirement (see text above)	Case 3 plus high Z absorbers					
	W		Ta		Pb	
	Thickness [mm]	Overall (C + honeycomb + Al + W) column density [g/cm^2]	Thickness [mm]	Overall (C + honeycomb + Al + Ta) column density [g/cm^2]	Thickness [mm]	Overall (C + honeycomb + Al + Pb) column density [g/cm^2]
3.1(A) <1% at 14 keV	0.008	0.663	0.010	0.664	0.017	0.667
3.1(B) 1/e at 28 keV	0.013	0.672	0.015	0.673	0.016	0.666
3.1(C) <1% at 40 keV	0.215	1.063	0.255	1.073	0.27	0.954
3.1(D) <1% at 80 keV	0.3	1.227	0.35	1.231	1.63	2.498

The Table above shows that:
(a): the choice of the passive shield material must follow an optimization concerning the energy (range) at which the best shielding efficiency is required.
(b): the possible contamination due to Compton scattering either from the primary radiation in the shield, or from the absorber Kα emission in the detectors, must be evaluated through dedicated and detailed simulation/calibration programmes.

3.2: Case 4: Aluminium only tube, plus Carbon grading

In this case the studied shield configurations are the following:

Element	Density [g/cm^3]	Thickness [mm]
Aluminium (A)	2.7	1.75
Aluminium (B)	2.7	2.85
Aluminium (C)	2.7	30.01
Aluminium (D)	2.7	84.55
Carbon fibre	1.62	0.04

These four thickness values have been selected to reach different required transparencies at 14, 28, 40, and 80 keV, as follows:

- (A) <1% at 14 keV
- (B) 1/e at 28 keV
- (C) <1% at 40 keV
- (D) <1% at 80 keV

Carbon fibre grading thickness is selected to reach 99% absorption at the Kα fluorescence energy of Aluminium (1.49 keV).

2. Results (diagrams)

The figures below show, for each of the above absorber configuration, the resulting transparency as a function of energy, expressed as I/I_0, where I_0 is the incident photon flux, and I is the photon flux that leaks through the absorber.

2.1 Cases 1, 2, 3

The transparency of the shields described as Cases 1, 2, and 3, are shown in Figure 2.

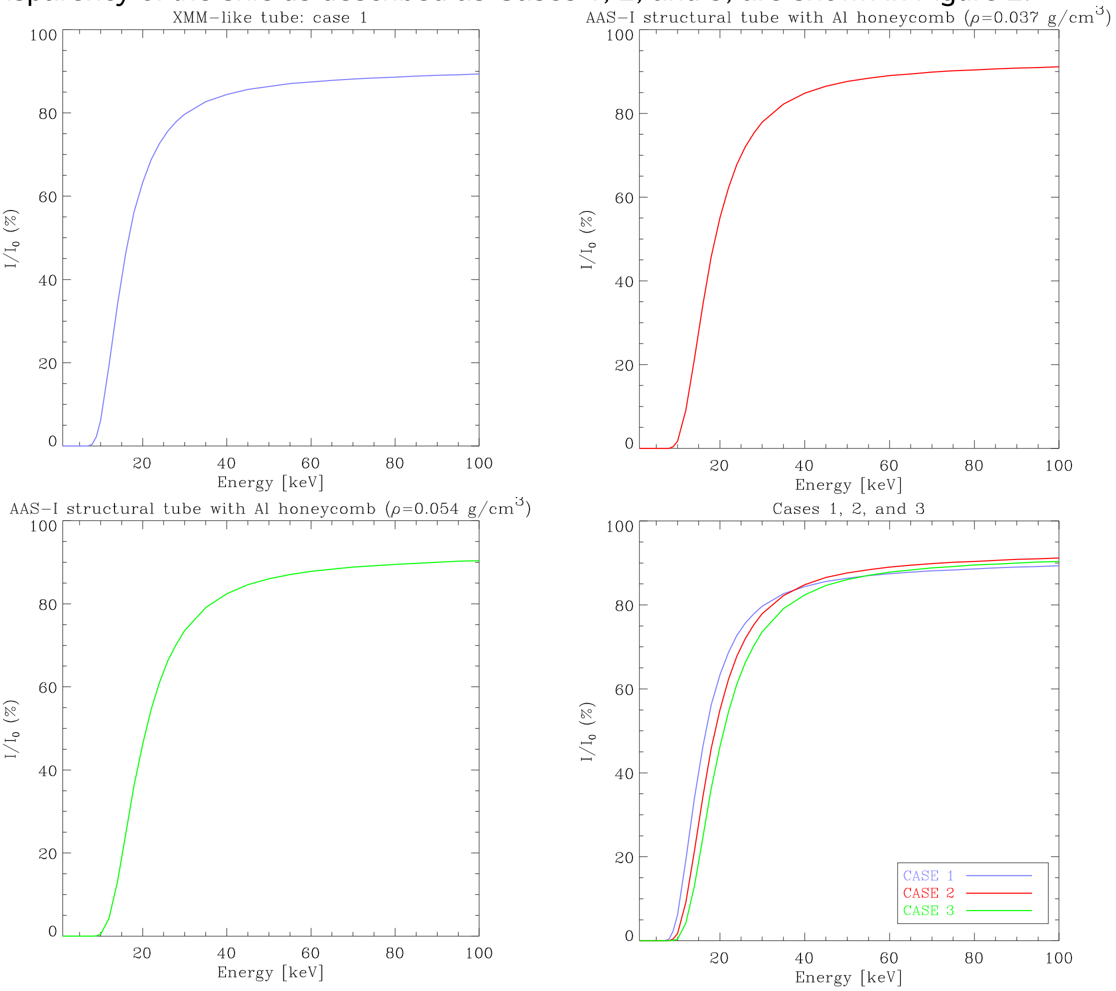
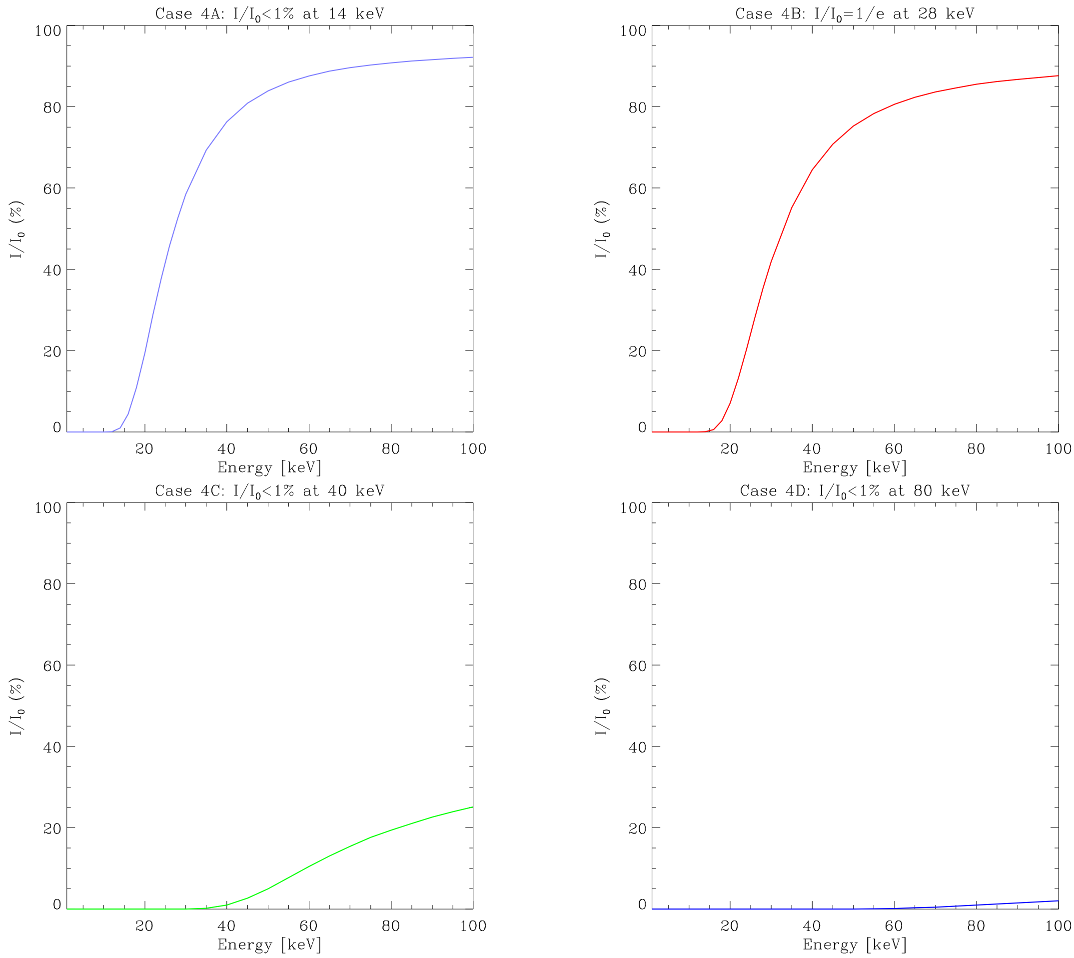


Figure 2: Absorber transparency, expressed as the ratio I/I_0 (in %) between undetected and incident radiation as a function of photon energy, calculated for the shield compositions of Cases 1, 2, 3, described in Section 1:
Case 1 (top left),
Case 2 (top right),
Case 3 (bottom left),
Case 1, 2, 3 synopsis (bottom right).

2.2 Case 4:

The Aluminium thickness values calculated for the required absorption efficiencies described in Section 1 as subcases A, B, C, and D, of Case 4, are as follows:
4A (I/I_0<1% at 14 keV): 0.17cm (0.46 g/cm^2)
4B (I/I_0=1/e at 28 keV): 0.29cm (0.77 g/cm^2)
4C (I/I_0<1% at 40 keV): 3.00cm (8.10 g/cm^2)
4D (I/I_0<1% at 80 keV): 8.46cm (22.82 g/cm^2)
The resulting transparency profiles are shown in Figure 3.



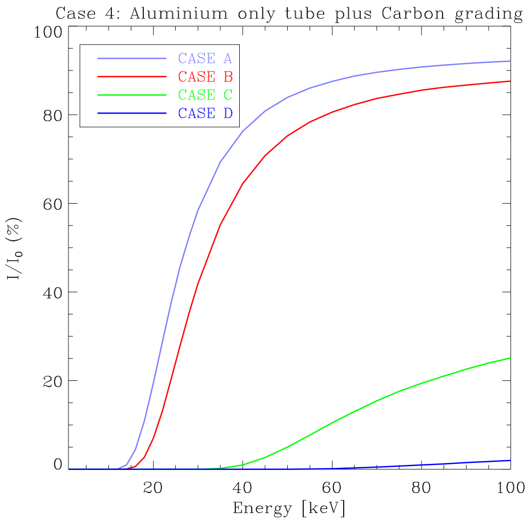


Figure 3: Absorber transparency, expressed as the ratio I/I_0 (in %) between undetected and incident radiation as a function of photon energy, calculated for the shield compositions of Cases 4A, 4B, 4C, 4D, described in Section 1:

- Case 4A (top left):

[Absorption efficiency =99% at 14 keV.]

- Case 4B (top right):

[Absorption efficiency =1-1/e at 28 keV.]

- Case 4C (middle left):

[Absorption efficiency =99% at 40 keV.]

- Case 4D (middle right):

[Absorption efficiency =99% at 80 keV.]

- Case 4A, 4B, 4C, 4D, synopsis (bottom left).

3. Results (tables)

The following table shows the transparency values (in %) as a function of energy for the different cases studied (for details concerning the absorber configurations in tha various cases 1, 2, 3a-b-c, 4, please refer to Section 1 of this note)..

	I/I_0 (%)										
E [keV]	**CASE 1**	**CASE 2**	**CASE 3**					**CASE 4**			
			Baseline	(A)	(A) no Carbon	(B)	(B) no Carbon	(A)	(B)	(C)	(D)
1	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0
3	8e-41	0	0	0	0	0	0	0	0	0	0
4	7e-17	4e-24	7e-32	0	0	0	0	0	0	0	0
5	4e-8	5e-12	2e-16	3e-38	2e-38	0	0	2e-38	0	0	0
6	4e-4	1e-6	4e-9	3e-22	2e-22	4e-33	8e-36	2e-22	3e-37	0	0
7	0.04	9e-4	2e-5	8e-14	6e-14	8e-21	1e-22	6e-14	2e-23	0	0
8	0.48	0.04	3e-3	6e-9	5e-9	1e-13	6e-15	4e-9	1e-15	0	0
9	2.28	0.40	0.07	5e-6	5e-6	2e-9	3e-10	5e-6	1e-10	0	0
10	6.19	1.72	0.46	5e-4	4e-4	2e-6	4e-7	4e-4	2e-7	0	0
12	19.21	9.13	4.20	0.08	0.07	3e-3	1e-3	0.07	7e-4	0	0
14	33.95	21.31	13.04	1.01	0.99	0.12	0.07	0.99	0.06	5e-33	0
16	46.33	34.35	24.57	4.36	4.44	1.04	0.76	4.42	0.63	7e-22	0
18	56.15	45.75	36.22	10.65	10.96	3.85	3.12	10.94	2.74	4e-15	0
20	63.40	55.05	46.32	18.73	19.62	8.87	7.77	19.55	7.06	8e-11	8e-33
22	68.72	62.25	54.51	27.45	28.92	15.4	14.29	28.85	13.26	6e-8	1e-24
24	72.70	67.76	61.09	35.75	37.88	22.85	21.82	37.74	20.49	6e-6	5e-19
26	75.66	72.01	66.28	42.96	45.78	29.95	29.36	45.73	27.96	2e-4	4e-15
28	77.93	75.31	70.34	49.34	52.77	36.76	36.69	53.56	35.30	2e-3	4e-12
30	79.68	77.92	73.60	54.68	58.57	42.80	43.21	58.41	41.88	0.01	6e-10
35	82.68	82.27	79.13	64.66	69.45	54.66	56.45	69.37	55.23	0.20	2e-6
40	84.41	84.86	82.47	71.01	76.42	62.79	65.58	76.32	64.46	0.99	2e-4
45	85.61	86.55	84.63	75.21	80.93	68.25	71.75	80.85	70.82	2.68	4e-3
50	86.37	87.64	86.07	78.14	84.01	72.12	76.09	83.89	75.24	5.05	0.02
55	87.01	88.43	87.07	80.15	86.14	74.86	79.14	86.05	78.35	7.76	0.08
60	87.47	89.06	87.81	81.63	87.67	76.82	81.35	87.59	80.63	10.48	0.17
65	87.79	89.49	88.38	82.75	88.79	78.40	82.99	88.74	82.34	13.05	0.32
70	88.12	89.87	88.84	83.58	89.68	79.55	84.30	89.59	83.70	15.47	0.52
75	88.38	90.19	89.18	84.35	90.36	80.45	85.31	90.24	84.68	17.62	0.75
80	88.64	90.40	89.53	84.88	90.88	81.27	86.07	90.80	85.54	19.42	0.99
85	88.84	90.62	89.76	85.35	91.31	81.92	86.71	91.24	86.21	21.06	1.25
90	89.03	90.84	89.99	85.74	91.70	82.38	87.29	91.59	86.74	22.65	1.53
95	89.17	91.00	90.23	86.13	92.01	82.85	87.75	91.90	87.22	23.98	1.80
100	89.36	91.16	90.40	86.45	92.27	83.31	88.14	92.16	87.62	25.17	2.06