The Shielding Effect of Honeycomb Sandwich Panels and a Method for Consideration in Radiation Analysis for Space

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I. INTRODUCTION

Honeycomb sandwich panels are common in spacecraft structures. Due to the complexity of these structures, it was an usual, conservative approach to neglect the mass of the honeycomb cores. The extreme number of volumes would make an exact replication of the original hardly impossible to model. On the other hand, this shielding effect could be relevant in terms of mass saving - especially on challenging missions like in Jupiter's radiation belt. The goal of this work was, to find an easy and practical method to consider the shielding effect of these structure in radiation analysis for space.

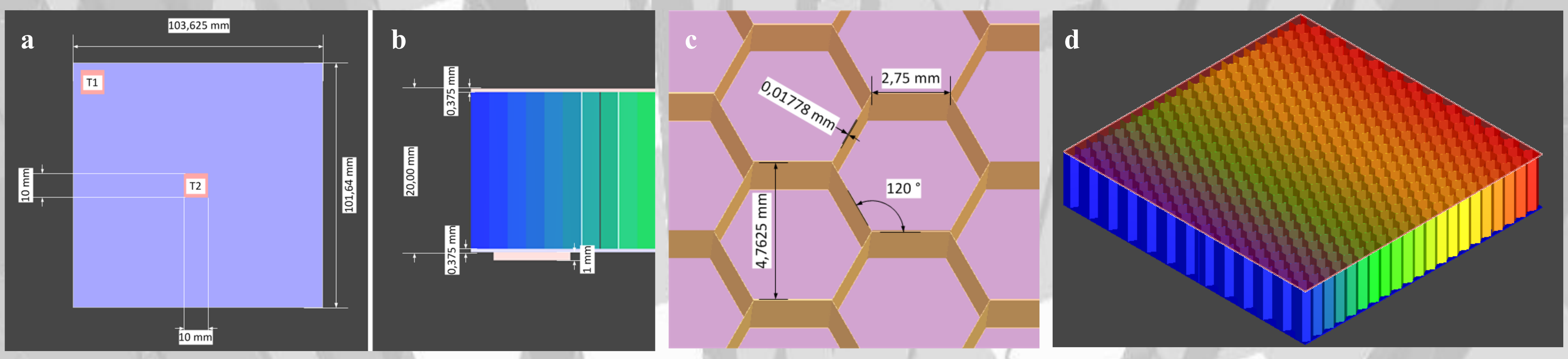

Figure 1: a,b) Measures of the analysed panel including the two silicon targets, c) the honeycomb structure and d) a view on the complete model.

II. GEOMETRIC DESIGN

The analysed honeycomb sandwich panel has typical measures in cell size (see figure 1) and material properties. The model was designed with ESABASE2 [1] and then transformed into the GDML [2] format. It contains 2100 cuboids which form hexagonal cells. The face sheets are made of carbon fibre (CFRP) and the core of the aluminium alloy 5056.

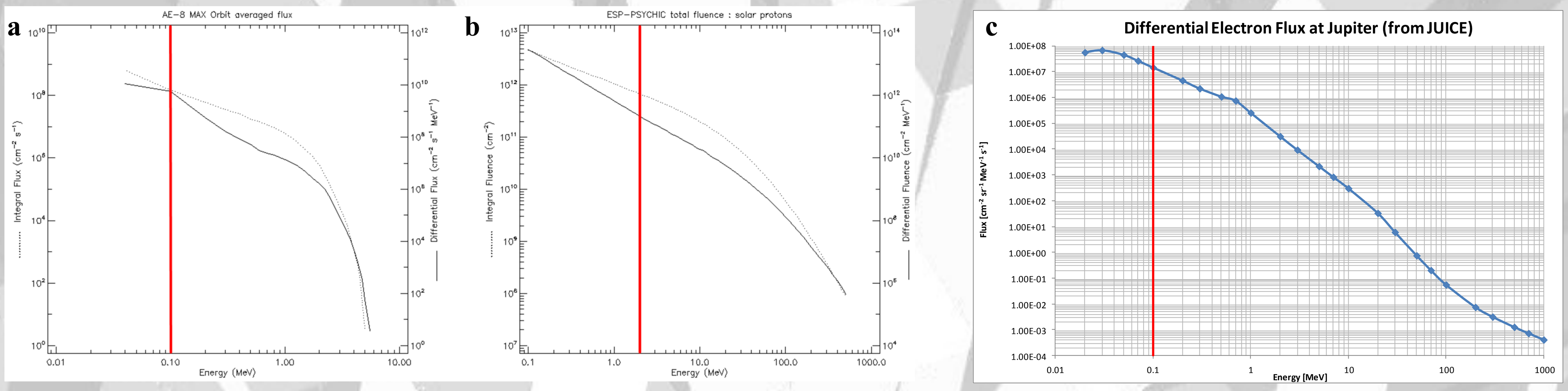

Figure 2: The spectra which were used in the simulation: a) trapped electrons (AE-8 MAX [3] in SPENVIS [4]) and b) solar protons (ESP [5] in SPENVIS [4]) in GEO and c) Jovian electrons (from JUICE Environment Specification [6]). The low energy parts of the spectra were cut for the simulation at the red line.

III. PARTICLE SPECTRA

To get representative results three different spectra was used: trapped electrons and solar protons in an geostationary orbit over ten years and the trapped electron spectra from the Jovian mission JUICE. The electron spectra were both cut at 0.10 MeV and the proton spectrum at 2 MeV, because the low energy part don't contribute to radiation exposure behind the panel. Furthermore, this reduces runtime and improves statistics.

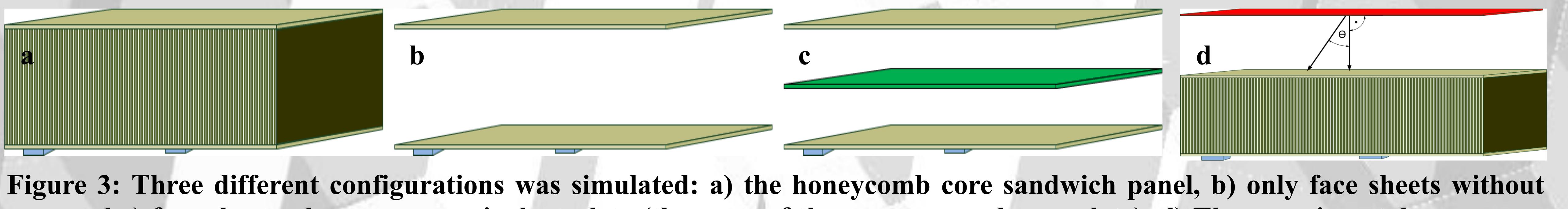

Figure 3: Three different configurations was simulated: a) the honeycomb core sandwich panel, b) only face sheets without core and c) face sheets plus a mass equivalent plate (the mass of the core smeared on a plate). d) The experimental array consists of a plane source with the dimensions of the panel and two silicon targets on the other side.

IV. EXPERIMENTAL SETUP

The whole simulation was done with GRAS [7], a Geant4-based radiation analysis tool working with Monte Carlo method provided by ESA. Three configurations were irradiated from a plane source directly above the panel (see figure 3d). On the backside of the panel two silicon targets (see figure 1a) were placed for dose measuring or for fluence measurements, a surface where the passing particles were counted.

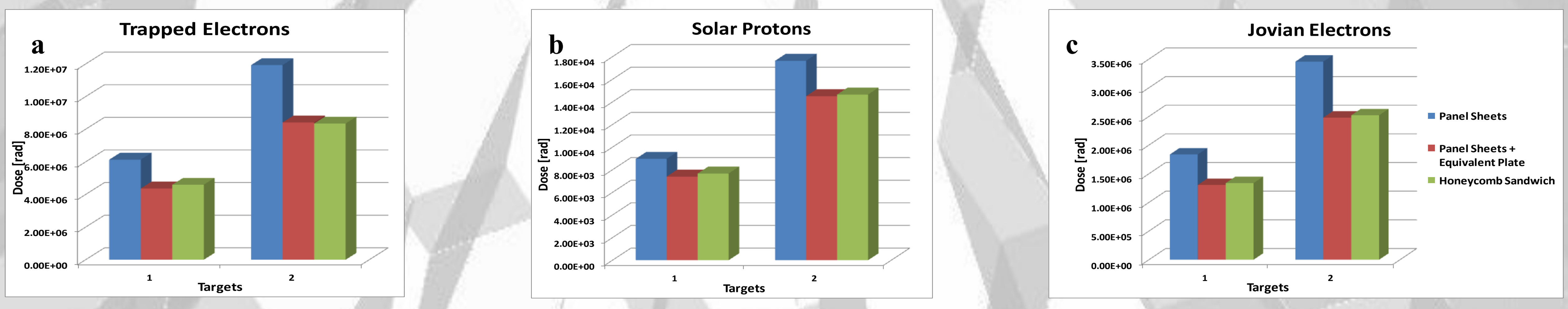

Figure 4: The doses for a) trapped electrons, b) solar protons and c) Jovian electrons for the three configurations.

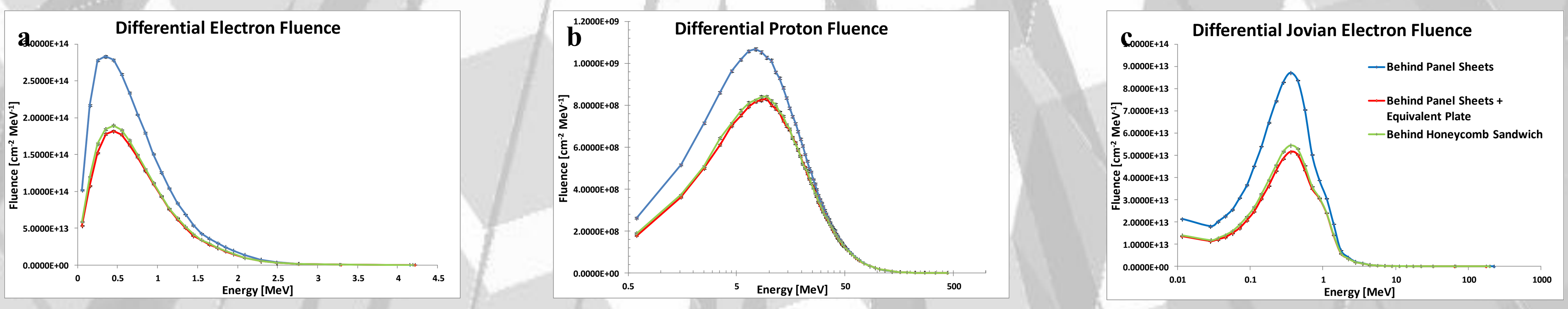

Figure 5: The fluences for a) trapped electrons, b) solar protons and c) Jovian electrons behind the three configurations.

V. RESULTS AND CONCLUSION

As it could be seen in figure 4, neglecting the honeycomb core leads to significant higher doses, while the additional plates with equivalent masses reproduce nearly the real situation. The fluence analysis (figure 5) gives the same result: fluences can be reproduced by adding an equivalent plate. A closer look on the comparison of the results from the honeycomb panel to the equivalent plate panel shows, that this approach is slightly underestimating radiation exposure (see table 1).

Table 1: The results of the different measurements and the deviation from honeycomb panel to equivalent plate.

Spectrum	Measurement	Result Equivalent Plate	Stat. Error	Error in %	Result Honeycomb Panel	Stat. Error	Error in %	Deviation	Uncertainty of Deviation
Solar Protons (GEO)	Dose Target 1 [rad]	7.3958E+03	1.0546E+02	1.43%	7.6680E+03	1.0849E+02	1.41%	3.55%	1.94%
	Dose Target 2 [rad]	1.4506E+04	1.5018E+02	1.04%	1.4651E+04	1.4975E+02	1.02%	0.99%	1.44%
	Integrated Proton Fluence [cm^{-2}]	2.6639E+12	3.5933E+10	1.35%	2.6914E+12	3.6012E+10	1.34%	1.02%	1.88%
Trapped Electrons (GEO)	Dose Target 1 [rad]	4.3700E+06	6.3259E+04	1.45%	4.5988E+06	6.3667E+04	1.38%	4.97%	1.90%
	Dose Target 2 [rad]	8.4165E+06	8.7863E+04	1.04%	8.3492E+06	8.7196E+04	1.04%	-0.81%	1.49%
	Integrated Elektron Fluence [cm^{-2}]	1.9767E+16	1.6478E+14	0.83%	2.0542E+16	1.6774E+14	0.82%	3.77%	1.12%
	Integrated Gamma Fluence [cm^{-2}]	2.0691E+15	3.6280E+13	1.75%	2.0752E+15	3.6503E+13	1.76%	0.29%	2.48%
Jovian Electrons (JUICE)	Dose Target 1 [rad]	1.3044E+06	1.3280E+04	1.02%	1.3361E+06	1.3344E+04	1.00%	2.37%	1.39%
	Dose Target 2 [rad]	2.4792E+06	1.8354E+04	0.74%	2.5193E+06	1.8527E+04	0.74%	1.59%	1.03%
	Integrated Elektron Fluence [cm^{-2}]	5.9123E+15	1.8402E+13	0.31%	6.1207E+15	1.8723E+13	0.31%	3.41%	0.42%
	Integrated Gamma Fluence [cm^{-2}]	3.7564E+14	4.7913E+12	1.28%	3.7198E+14	4.7780E+12	1.28%	-0.99%	1.83%

The deviation is calculated with the formula $\text{Deviation}[\%]=\left(1-\frac{\text{Value}_{\text{Equivalent Plate}}}{\text{Value}_{\text{Honeycomb Panel}}}\right)\cdot 100\%$.It shows, that especially the exposure of target 1 lies a few percent higher than that of the construction with the equivalent plate. Finally, the deviation is for no measurement greater than 5%, so the conservative conclusion is, that 95% of the whole mass including face sheets could be used. Therefore the following formula could be used, where d stands for the area densities: $d_{\text{Substitute Plate}}=0,95\cdot d_{\text{Equivalent Plate}}-0,1\cdot d_{\text{Face Sheet}}$. In the studied case, that meant that 82% of the thickness of the original equivalent plate could be used as shielding. The validation of this approach showed that all estimated doses were a few percent higher than those of the detailed model, which confirms the applicability of this approach.

References

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