SPENVIS User Workshop 2013
Two cases of radiation analyses using Sector-Shielding Analysis Tool

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SPENVIS user since 2003

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   - JUDE

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EUI (Extreme UV Imager) on-board Solar Orbiter

- Solar Orbiter is a mission dedicated to solar and heliospheric physics
- EUI will provide image sequences of the solar atmospheric layers from the chromosphere into the corona
- EUI is composed of three channels
  - EUV full-sun (FSI) and high resolution (HRI_{EUV}) imagers
  - Ly-a high resolution (HRI_{Lya}) imager

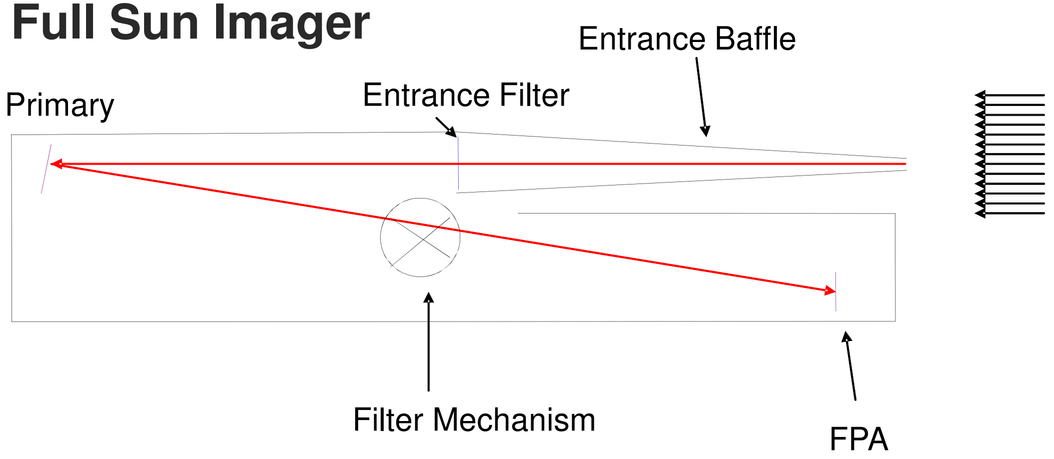
Channel	Parameter	Values
FSI	Passbands FOV Resolution (2 px) Cadence	17.4 nm & 30.4 nm 3.8 arcdeg (⇔ 2 Sun Ø) 9 arcsec (⇔ 1800 km, 3k² px) 600 s
HRI_{EUV}	Passbands FOV Resolution (2 px) Cadence	17.4 nm 0.28 arcdeg (⇔ 15% Sun Ø) 1 arcsec (⇔ 200 km, 2k² px) ≥ 1 s
HRI_{Lya}	Passband FOV Resolution (2 px) Cadence	121.6 nm 0.28 arcdeg (⇔ 15% Sun Ø) 1 arcsec (⇔ 200 km, 2k² px) ≤ 1 s

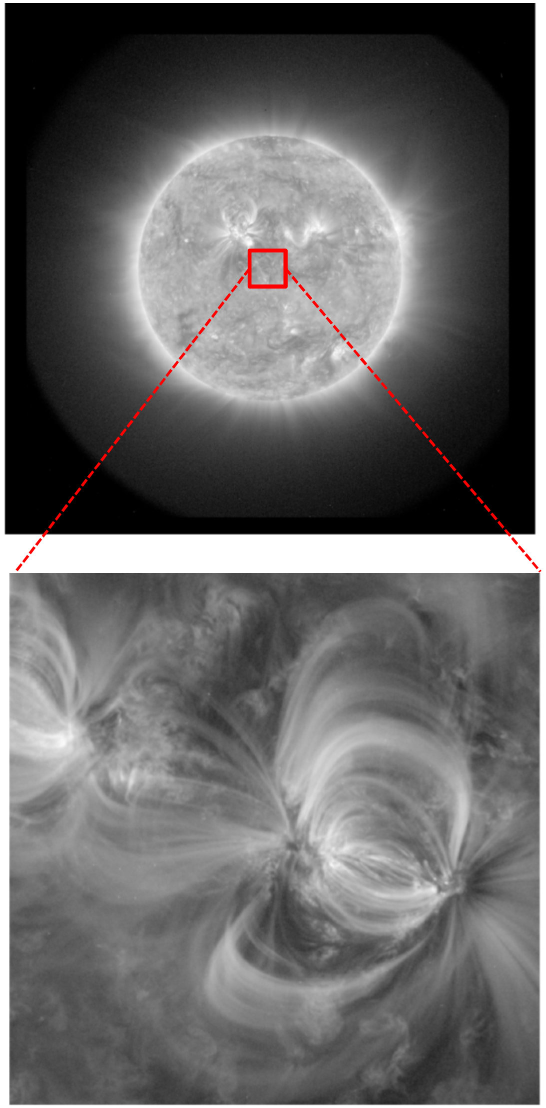
- CDR of EUI end of this year

EUI (Extreme UV Imager) on-board Solar Orbiter

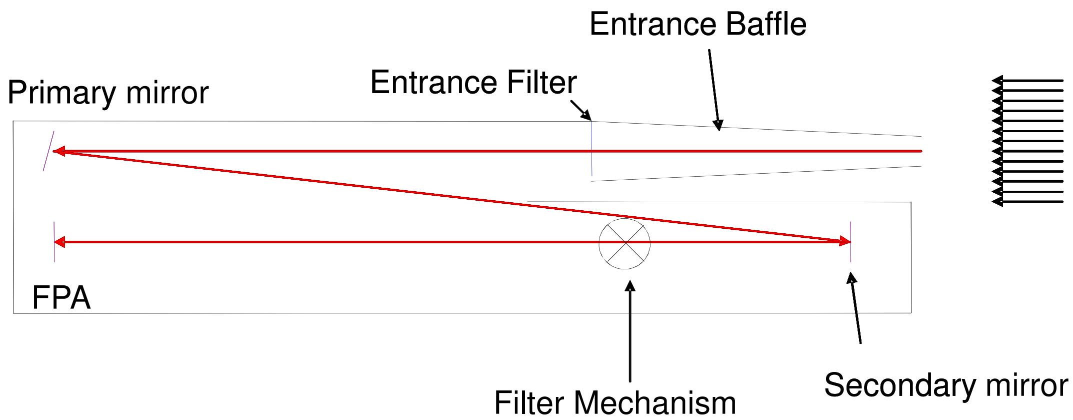
- Imaging concept

Full Sun Imager

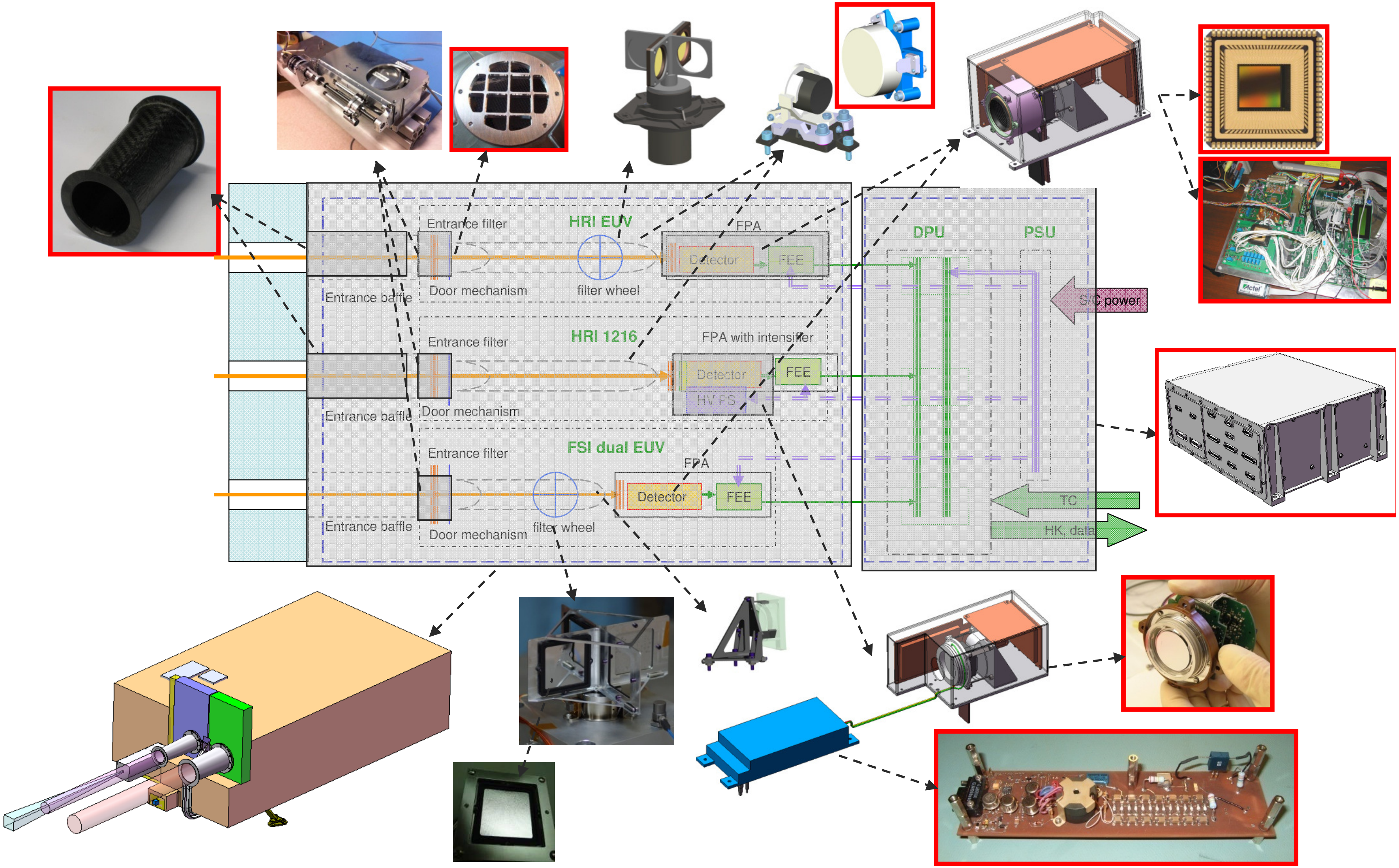




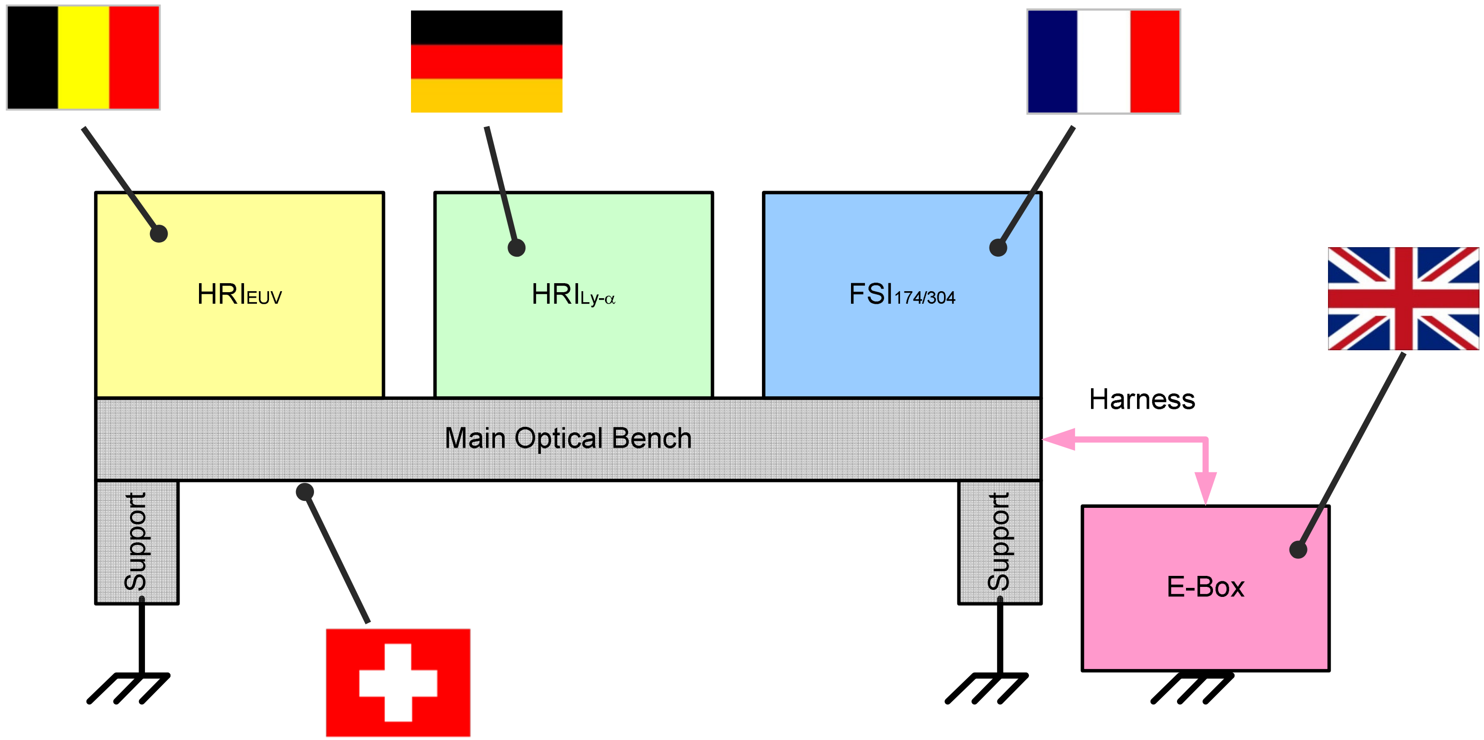
High Resolution Imager

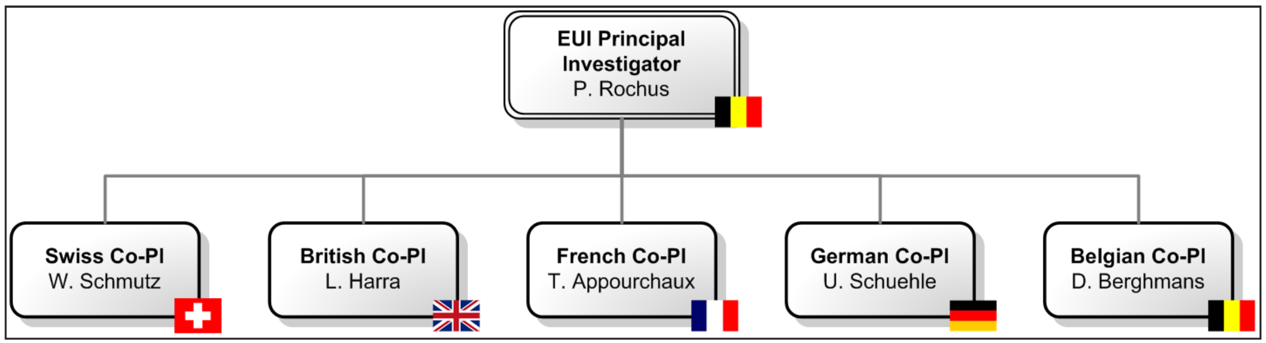


EUI overview: radiation sensitive elements

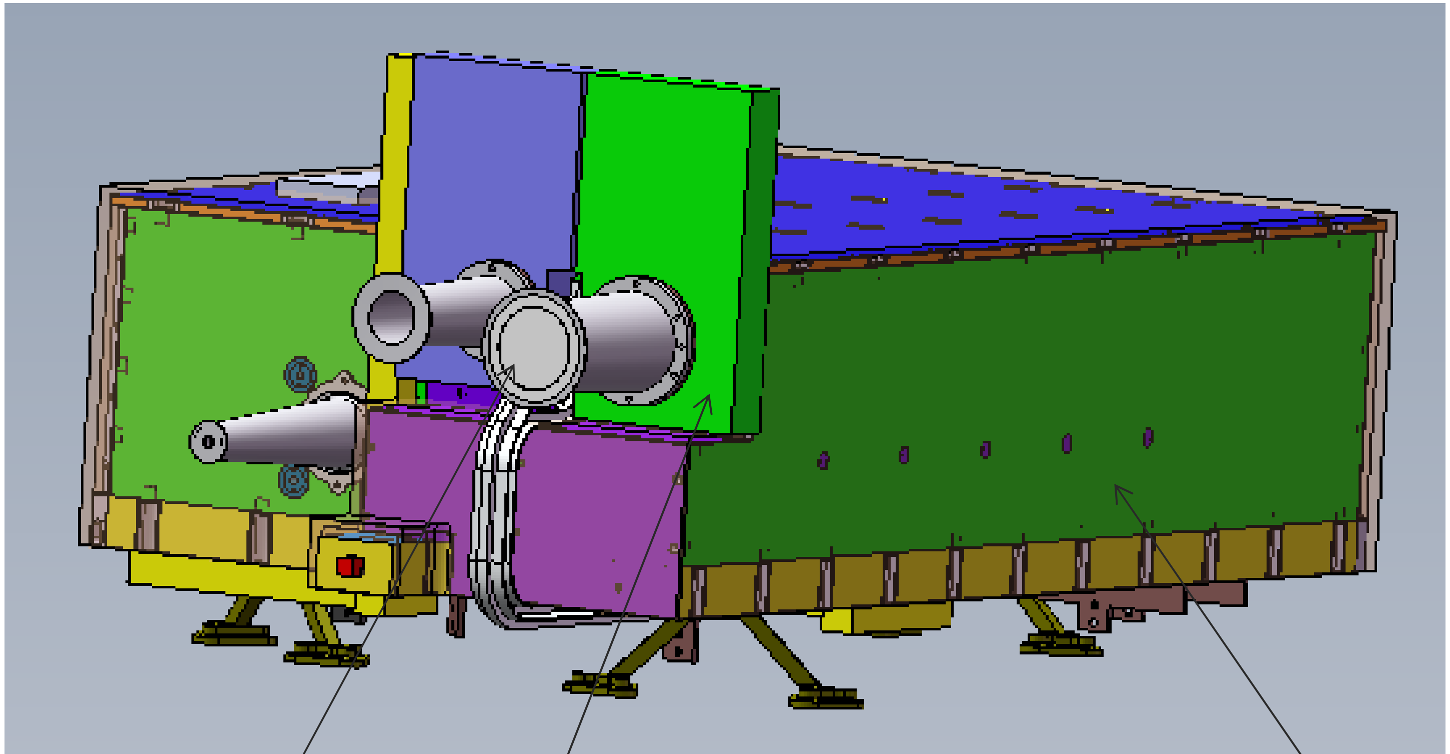


EUI Consortium overview





Optical Bench System (OBS)

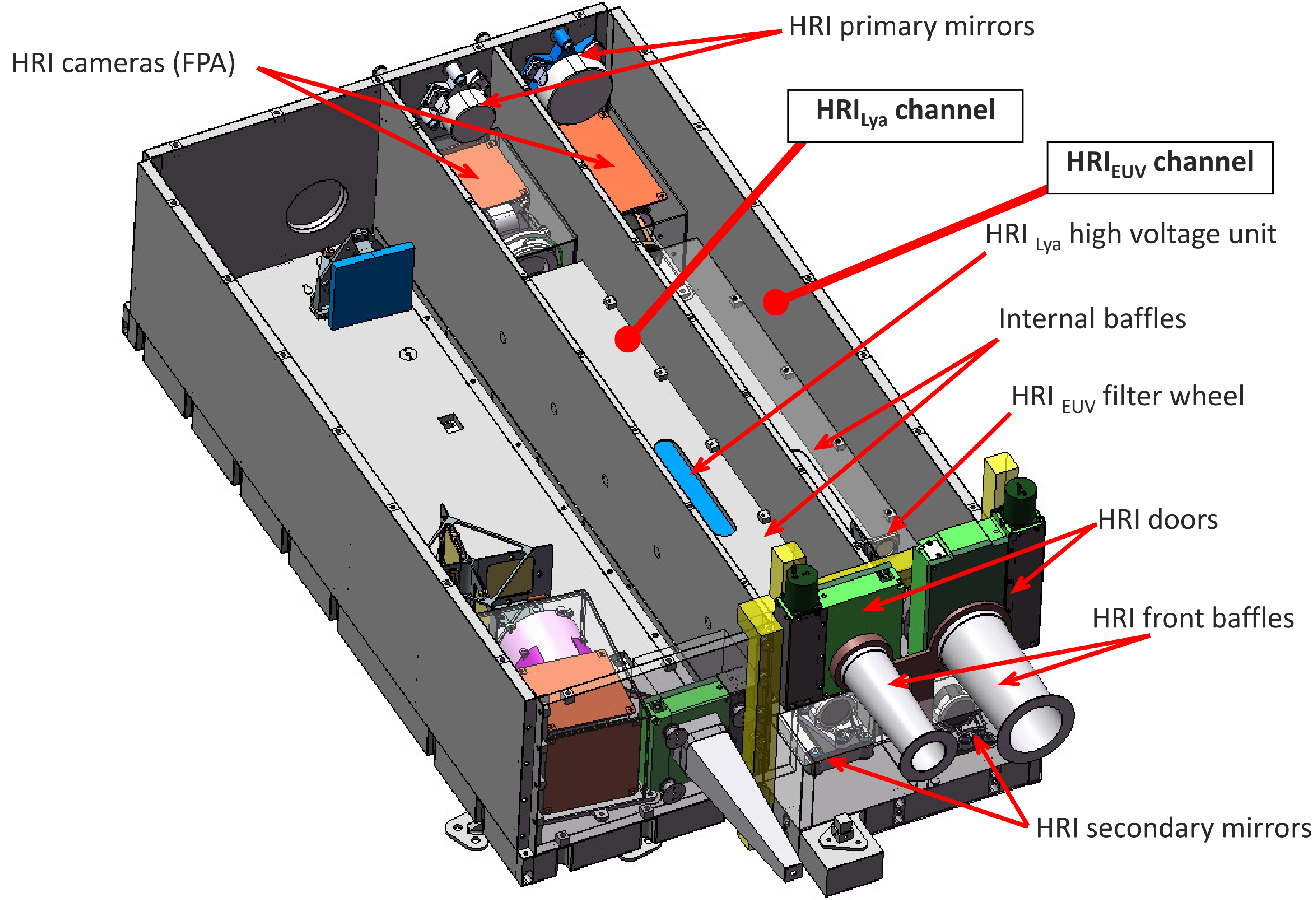


Entrance mechanisms

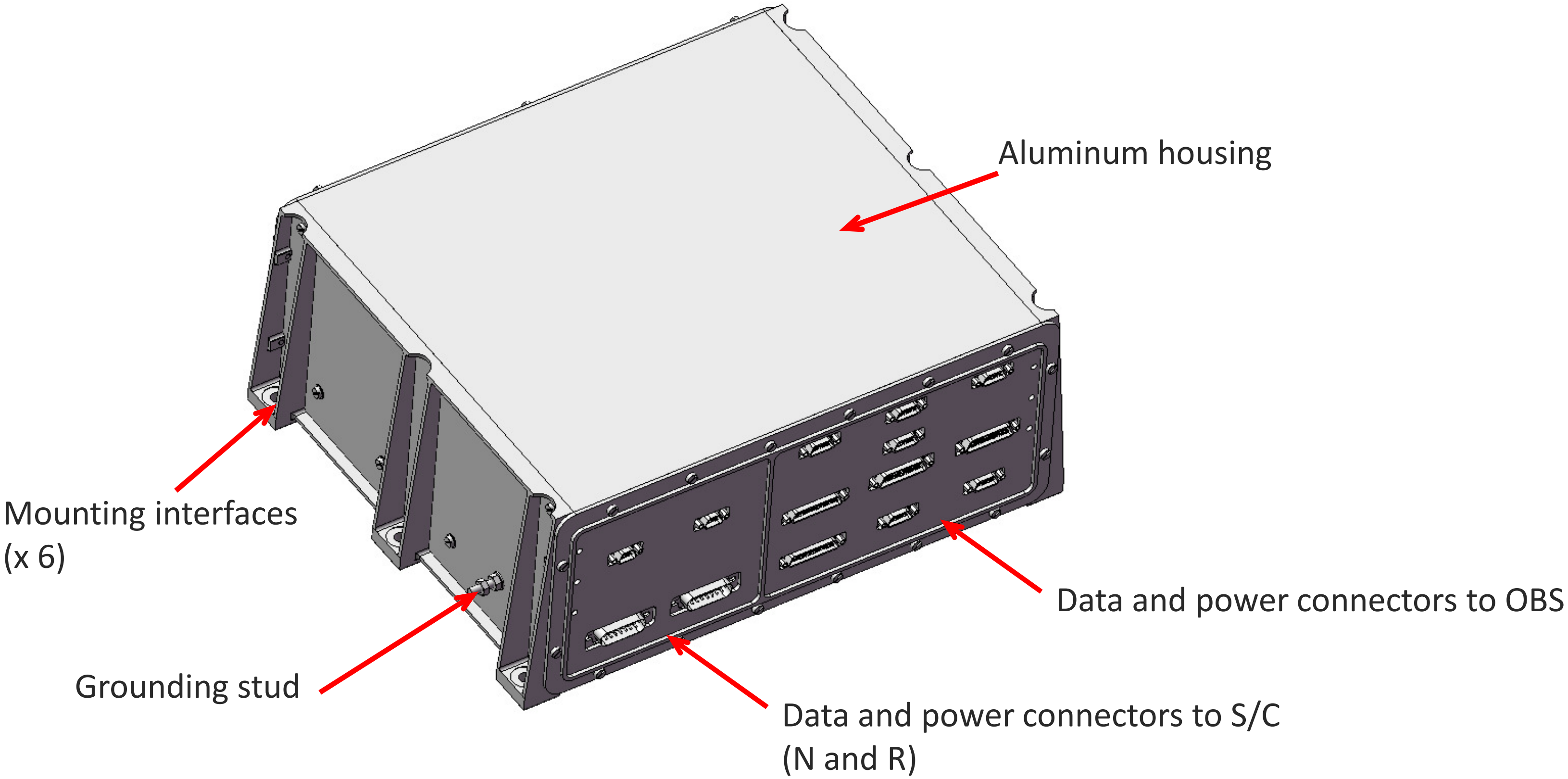
Entrance Baffles:
Inside surfaces Al coated

Sandwich (CFRP sheets + Al honeycomb)

Optical Bench System (OBS)



Common Electronic Box (CEB)



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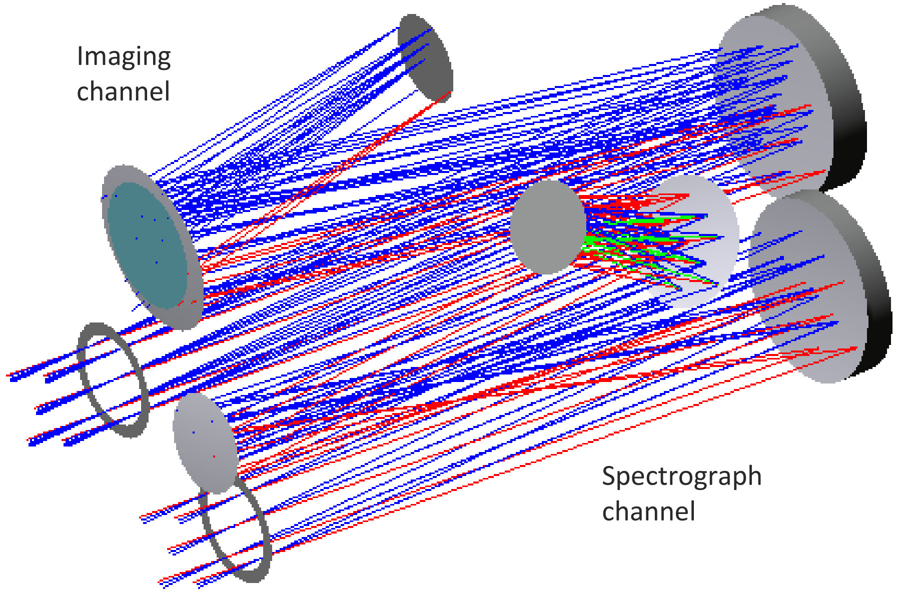
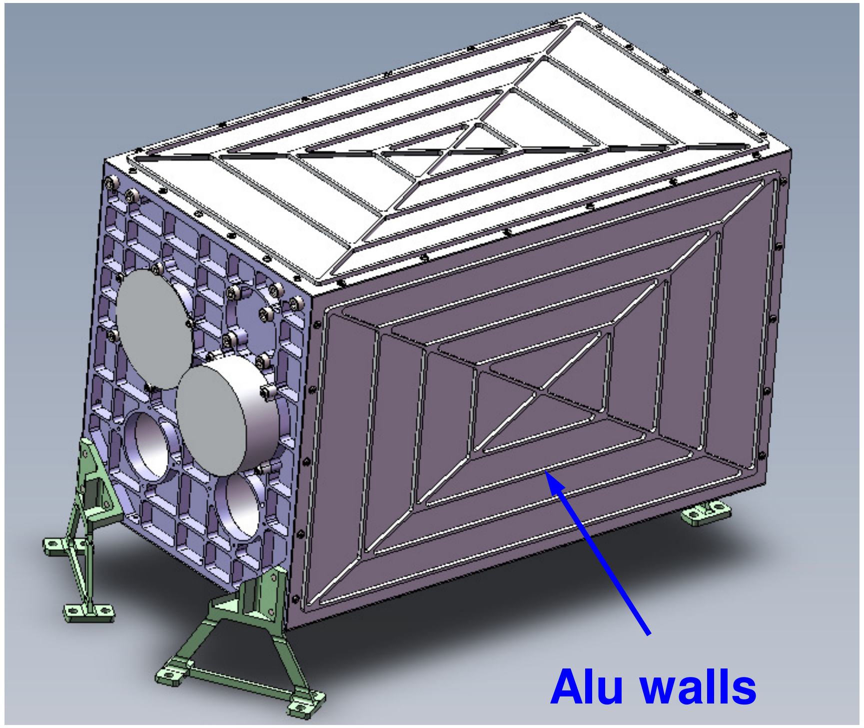
JUDE – Jupiter system Ultraviolet Dynamics Experiment





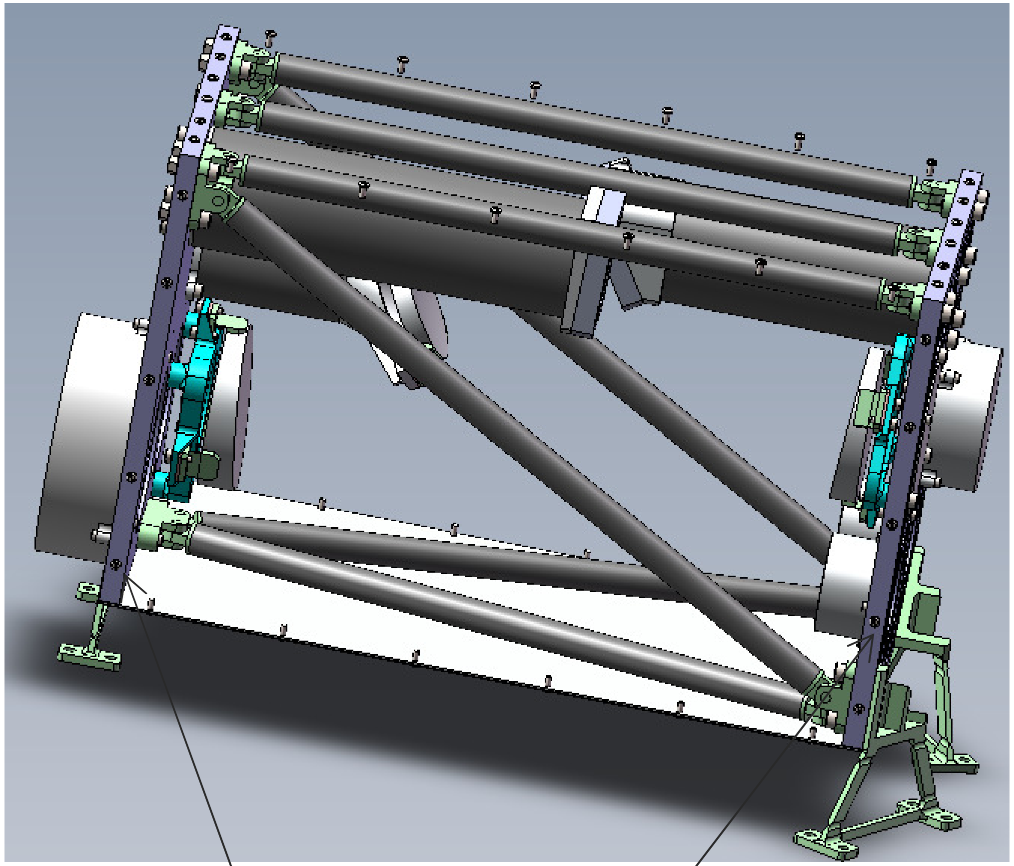
JUDE was proposed (but not selected) in October 2012 for JUICE Announcement of Opportunity by

Univ. Liege

Univ.Leicester

Boston Univ.

JUDE – Jupiter system Ultraviolet Dynamics Experiment

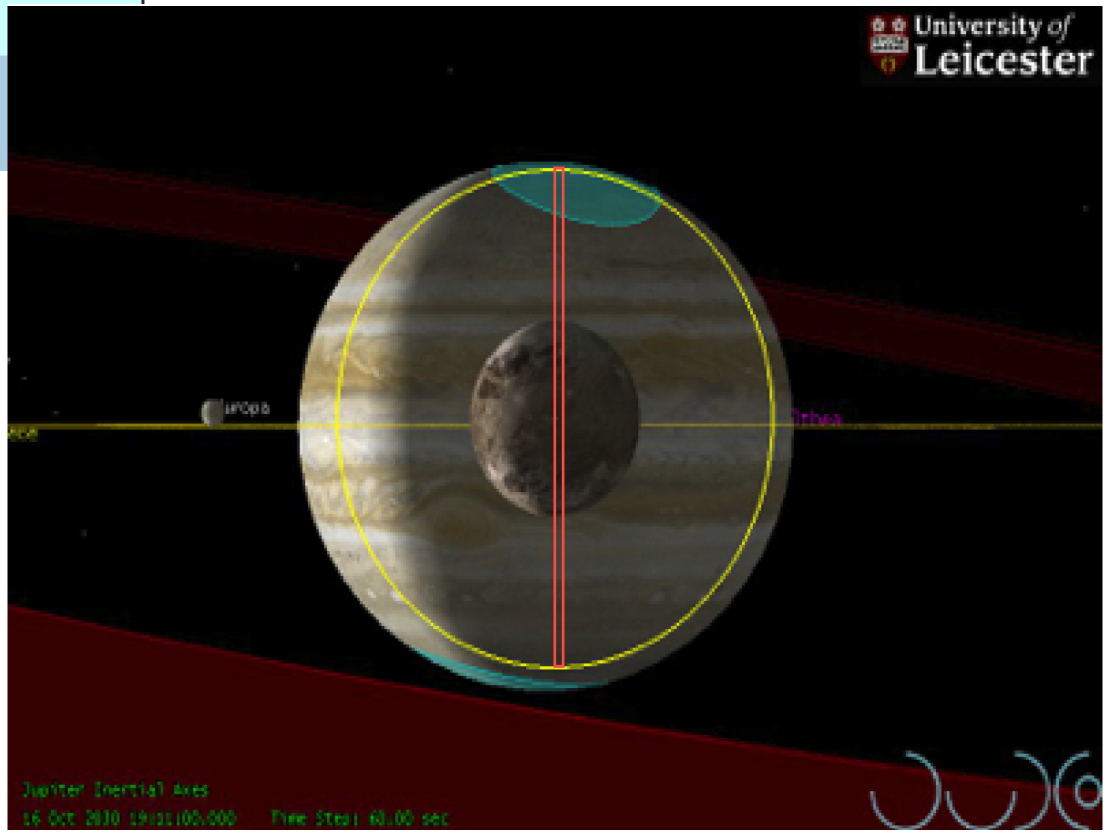


Two Alu optical benches

JUDE – Jupiter system Ultraviolet Dynamics Experiment

Channel	Parameter	Values
Imager	Passbands	130 nm => 143 nm
	FOV	6 arcdeg x 6 arcdeg
	Resolution	100 km at 15Rj
Spectrograph	Passbands	110 nm => 195 nm
	FOV	0.1 arcdeg x 6 arcdeg
	Resolution	0.5 nm

From Univ.Leicester: simulation of the JUDE imaging channel FOV (large yellow circle) and spectrometer slit (red strip) during one of the Ganymede flybys. Simultaneous within the FOV we see Jupiter's auroras (pale blue shading), Ganymede, Io, and the Io torus (red shading).



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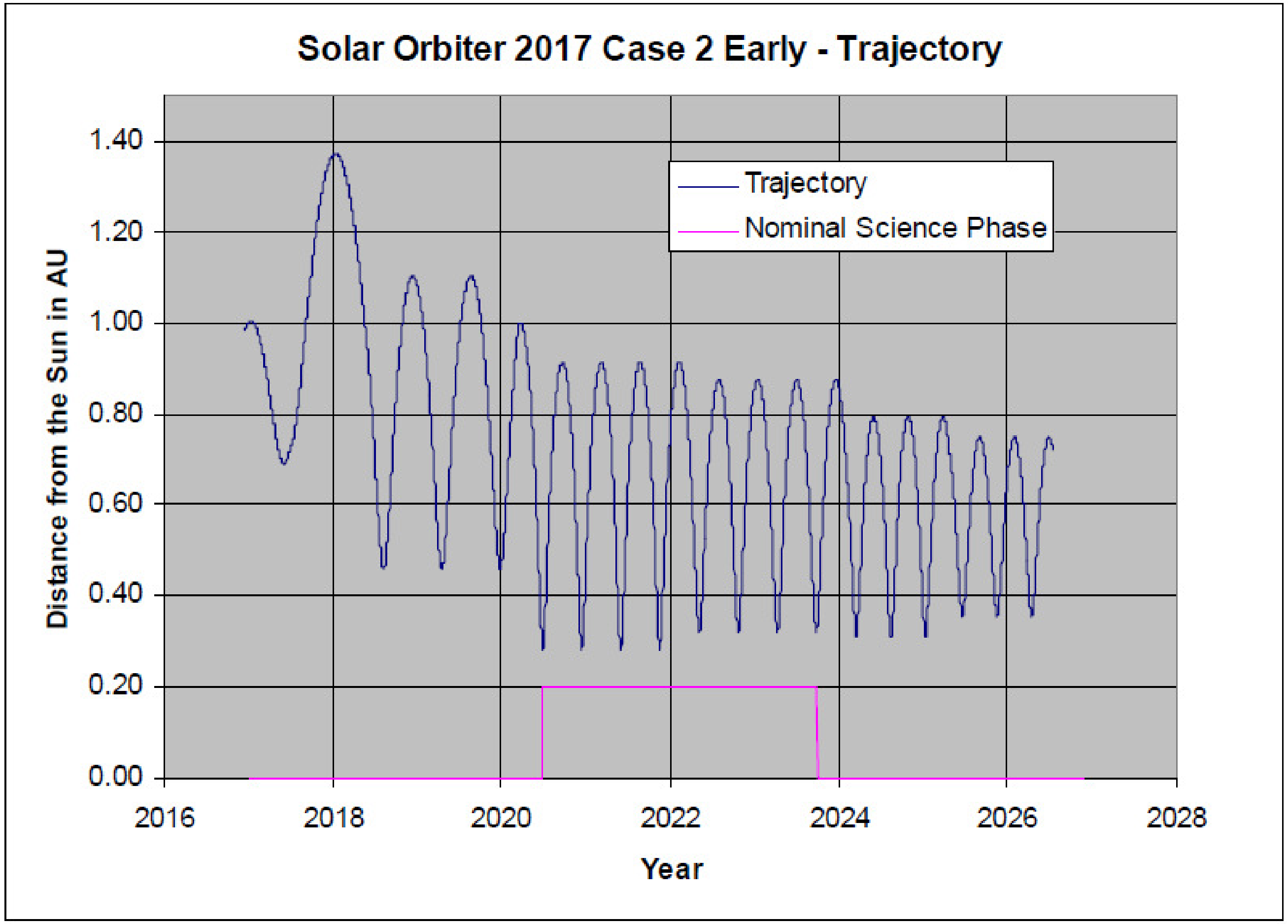
Solar Orbiter Distance from the Sun

From ESA Solar Orbiter Environment specification



Solar Orbiter environment

Solar and planetary electromagnetic radiation environment

Plasma ➔ Solar wind

Energetic particles radiation

Radiation belts => ignored because very short duration

Solar energetic particles => ESP model (1AU) was used by ESA and scaled for solar orbiter mission)

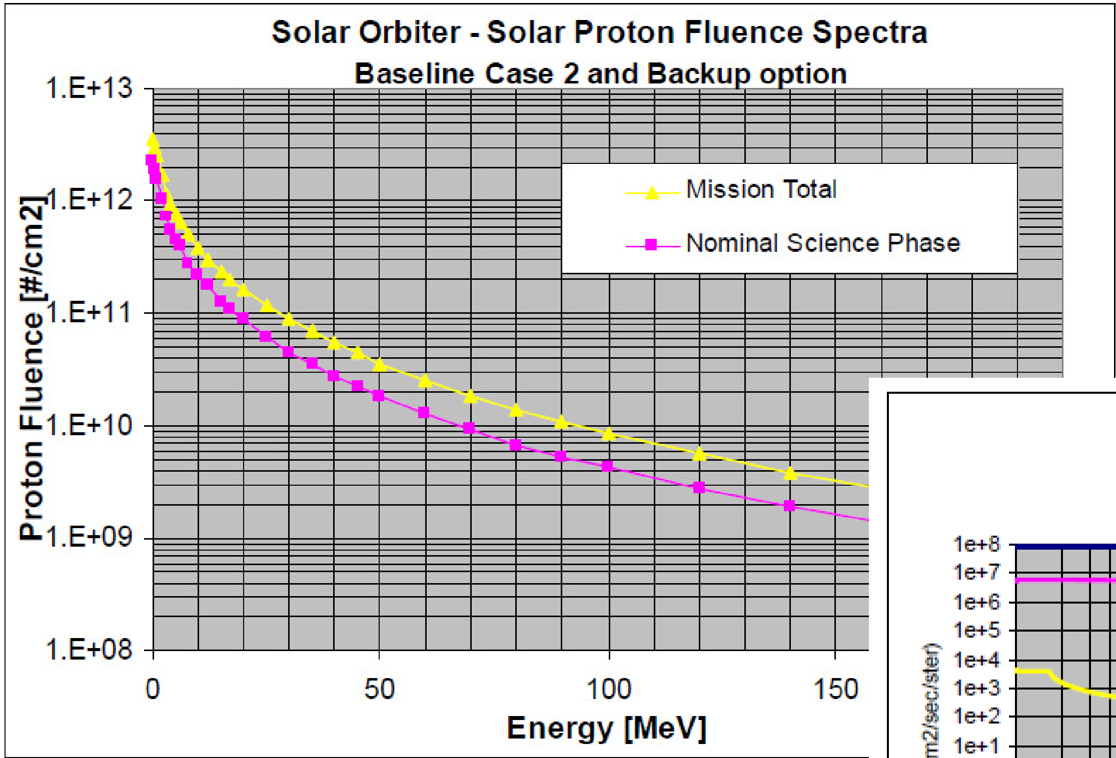
Galactic cosmis-rays: flux is low but GCR can deposit significant amount of energy in sensitive volumes (CREME model was used by ESA)

Secondary radiations

Particulates

Contamination

Solar Orbiter: solar protons fluence & GCR



From ESA Solar Orbiter Environment specification

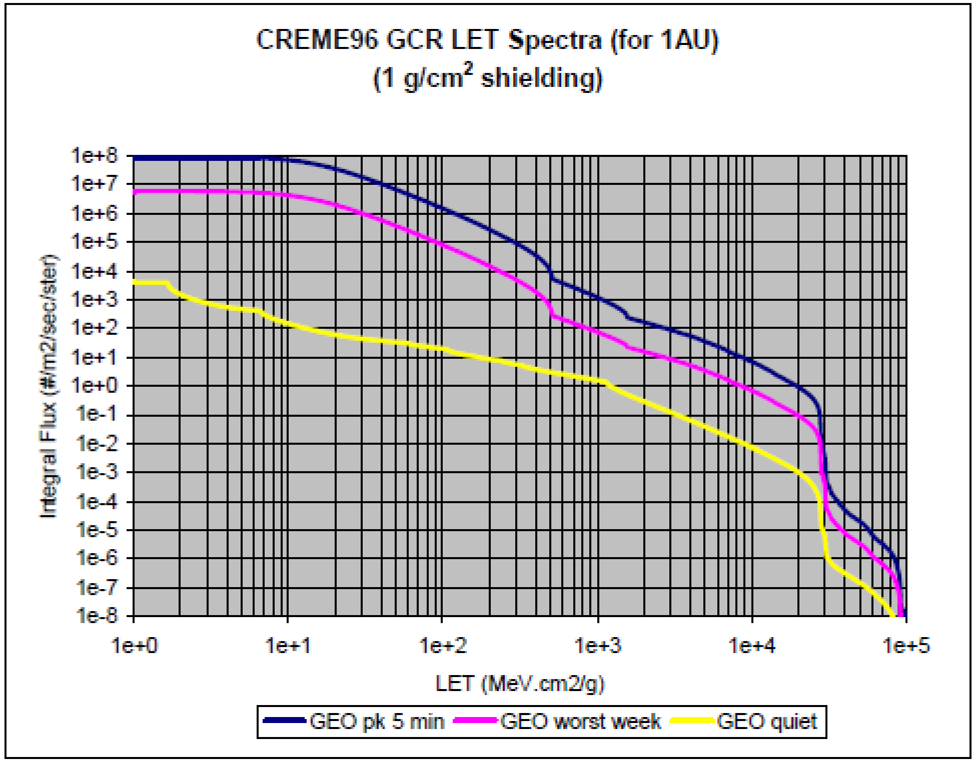
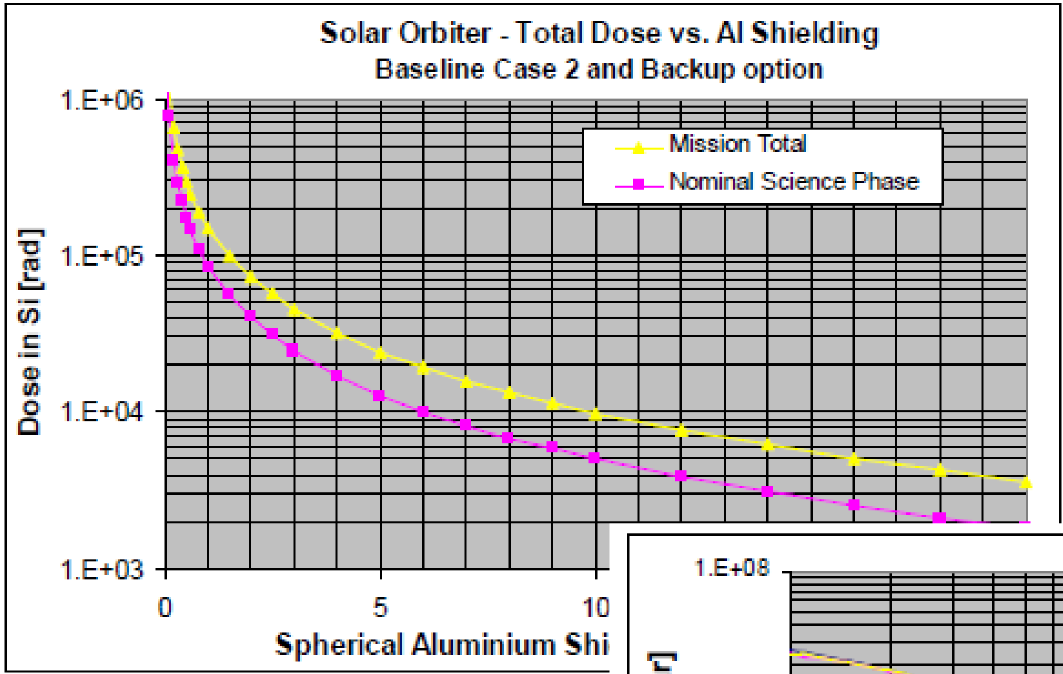
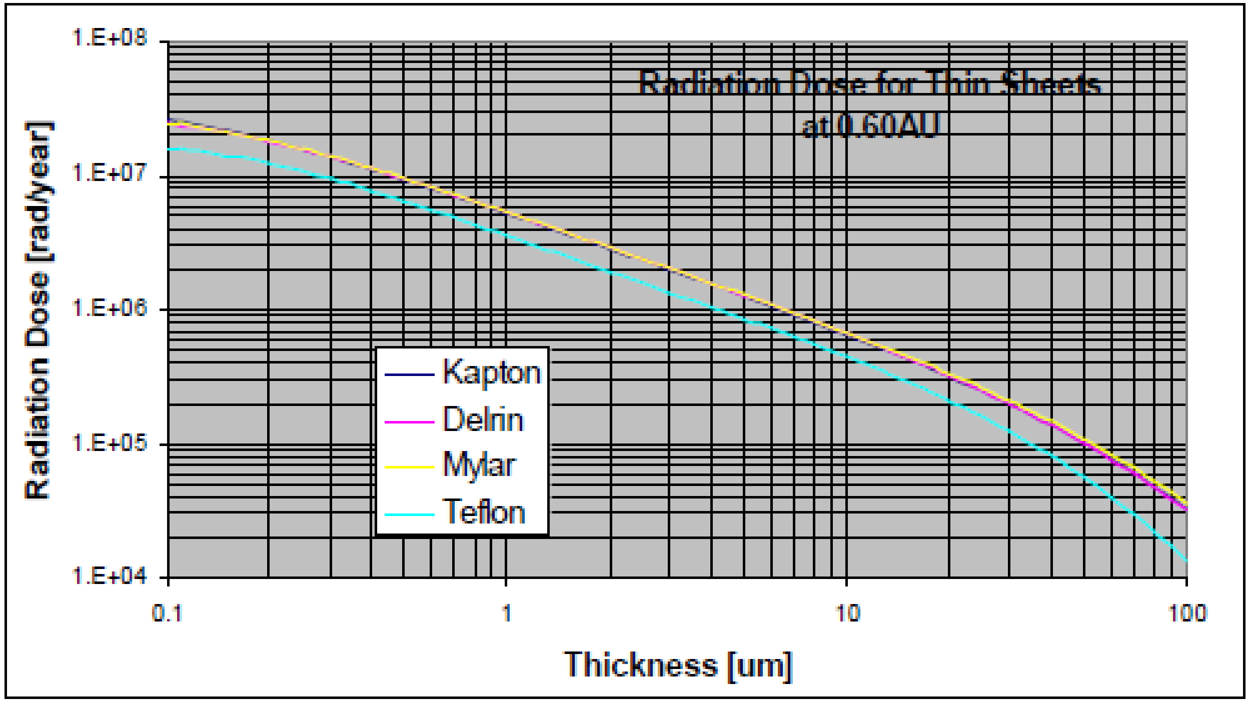


Figure 4. CREME96 Galactic Cosmic Ray LET Spectra for the three levels of activity, nominal (GEO quiet), worst week/worst case, and peak 5 minute for a component shielded by 1 g/cm². The predictions are for 1AU.

Solar Orbiter: TID and TID for thin sheets



From ESA Solar Orbiter Environment specification



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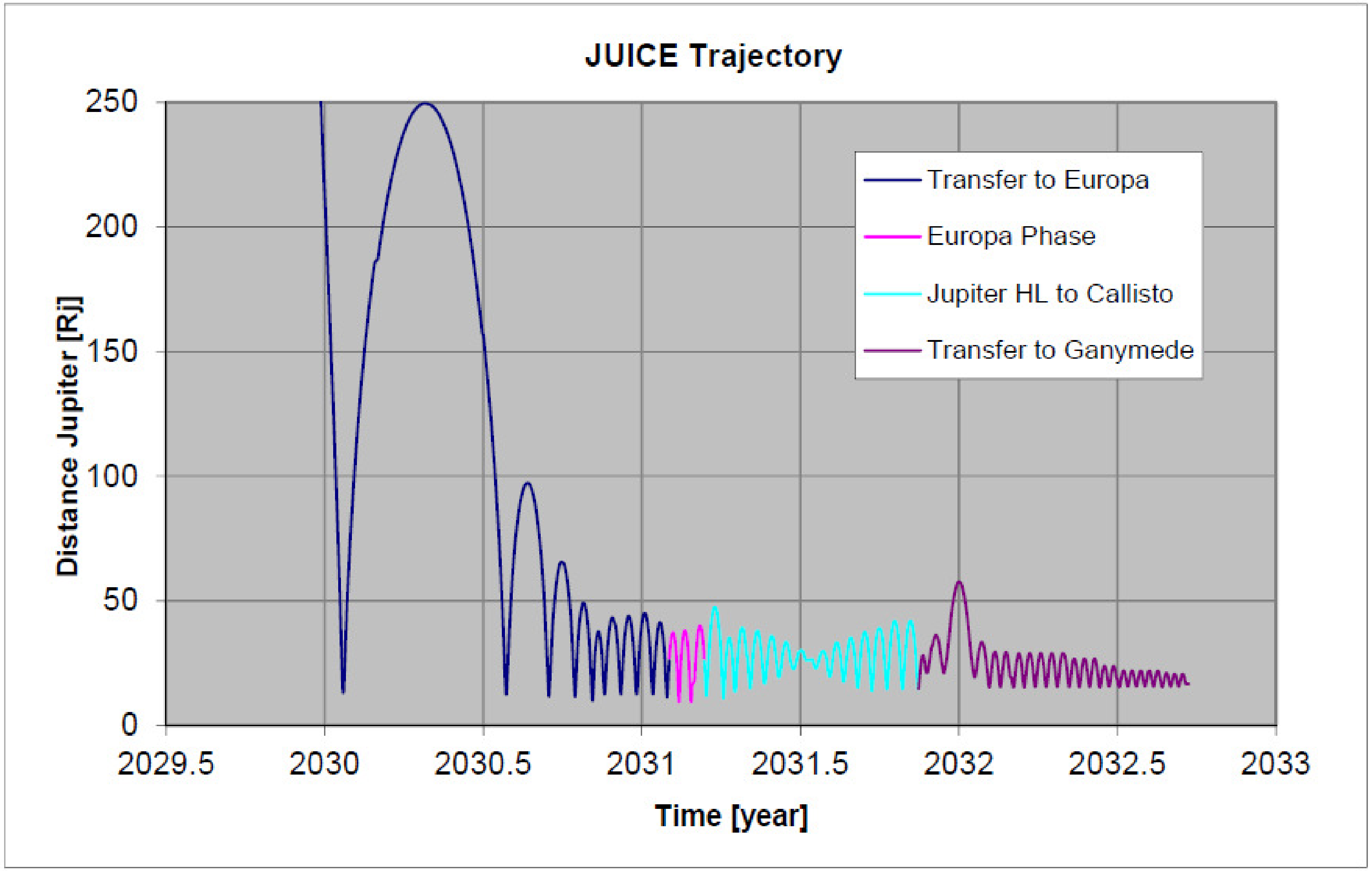
JUICE Distance from JUPITER

From ESA JUICE Environment specification (AO)



JUICE environment

Gravitational fields

Magnetic fields

Solar and planetary electromagnetic radiation

Atmospheres/exospheres

Plasmas

<u>Energetic particles radiation</u>

Particulates

Contamination

JUICE : Fluences using JOSE

ESA oem orbit files

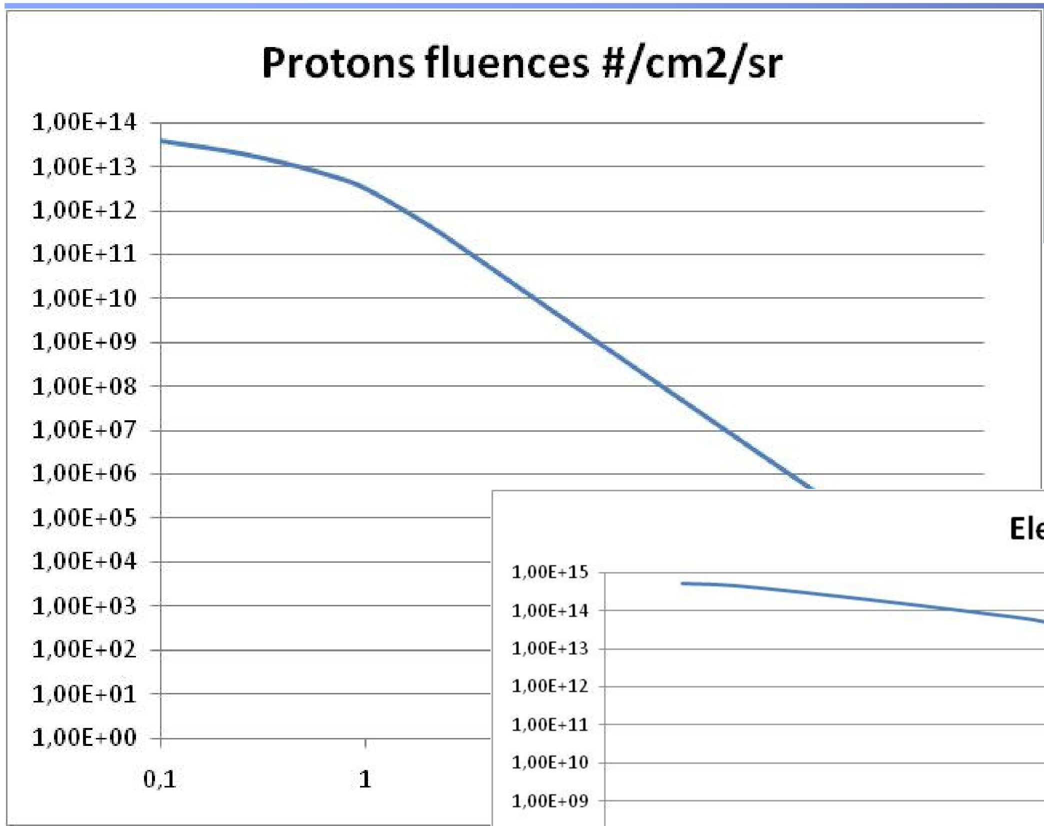
Univ. of Leicester IDL script ➔ Orbit files compatible with SPENVIS format

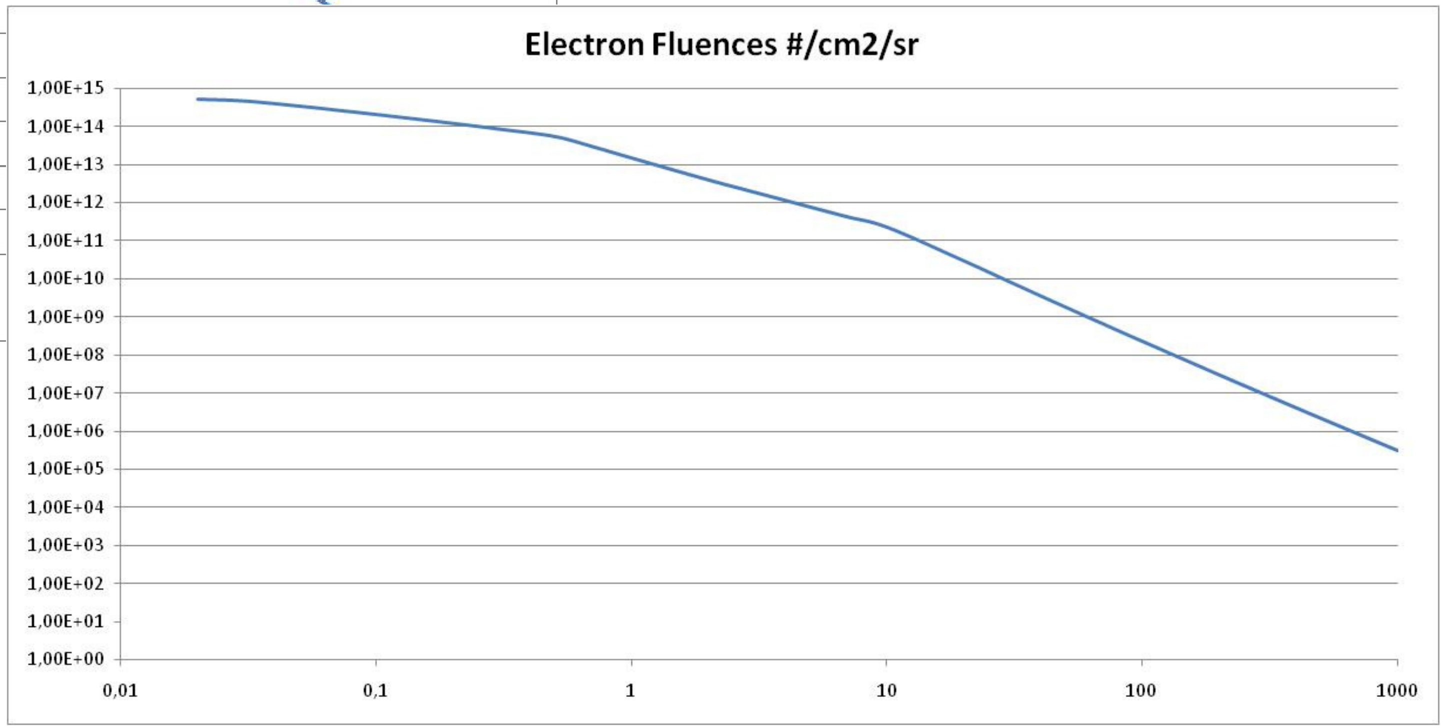
This script allowed generating 16 trajectory files - 352 kB => size compatible with SPENVIS orbit generator - from 22 January 2030 to 27 January 2033 corresponding to the period of the ESA oem trajectory file.

JOSE (Jovian Specification Environment model) is run for each part of the spacecraft trajectory to obtain energetic particles environment.

Energy	total mission fluence (#/cm2/sr)	22jan2030-31mar2030	1jun2030-1aou2030	5aou2030-1oct2030	2oct2030-25oct2030	26oct2030-1dec2030
		fluence (#/cm2/sr)	fluence (#/cm2/sr)	fluence (#/cm2/sr)	fluence (#/cm2/sr)	fluence (#/cm2/sr)
0.1	**4.93E+13**	2.2687E+11	3.2179E+11	7.739E+11	8.83E+11	1.01E+12
0.2	**3.00E+13**	1.3975E+11	1.996E+11	4.9114E+11	5.69E+11	6.62E+11
0.3	**2.05E+13**	97038000000	1.3946E+11	3.4927E+11	4.09E+11	4.80E+11
0.4	**1.49E+13**	71693000000	1.0387E+11	2.6455E+11	3.14E+11	3.72E+11
0.5	**1.14E+13**	54986000000	80202000000	2.076E+11	2.49E+11	2.97E+11
0.7	**7.13E+12**	34812000000	51016000000	1.3525E+11	1.65E+11	2.01E+11
1	**3.68E+12**	18990000000	28372000000	78600000000	9.83E+10	1.22E+11
2	**5.33E+11**	3116300000	5351700000	18395000000	2.61E+10	3.63E+10
3	**1.47E+11**	837600000	1452100000	5264500000	8.04E+09	1.22E+10
4	**5.77E+10**	328220000	569710000	2069300000	3.17E+09	4.83E+09
5	**2.77E+10**	158340000	275320000	1001800000	1.53E+09	2.34E+09
7	**9.22E+09**	52264000	91260000	333670000	5.13E+08	7.84E+08
10	**2.90E+09**	16408000	28388000	103030000	1.59E+08	2.44E+08
20	**3.10E+08**	1757400	3040500	10987000	1.68E+07	2.55E+07
30	**8.39E+07**	475710	823040	2974100	4.54E+06	6.91E+06
40	**3.32E+07**	188220	325650	1176700	1.80E+06	2.73E+06
50	**1.62E+07**	91694	158640	573260	8.75E+05	1.33E+06
70	**5.47E+06**	31002	53637	193820	2.96E+05	4.50E+05
100	**1.73E+06**	9820.9	16991	61399	9.37E+04	1.43E+05
200	**1.86E+05**	1051.9	1819.9	6576.1	1.00E+04	1.53E+04
300	**5.02E+04**	284.73	492.62	1780.1	2.72E+03	4.13E+03
400	**1.86E+04**	104.34	182.59	677.23	1.05E+03	1.60E+03
500	**7.91E+03**	48.118	85.591	322.66	5.02E+02	7.76E+02
700	**8.04E+02**	8.4667	22.138	98.189	1.60E+02	2.53E+02
1000	**1.31E+02**	0	0	8.8133	3.15E+01	6.75E+01

JUICE : Fluences using JOSE





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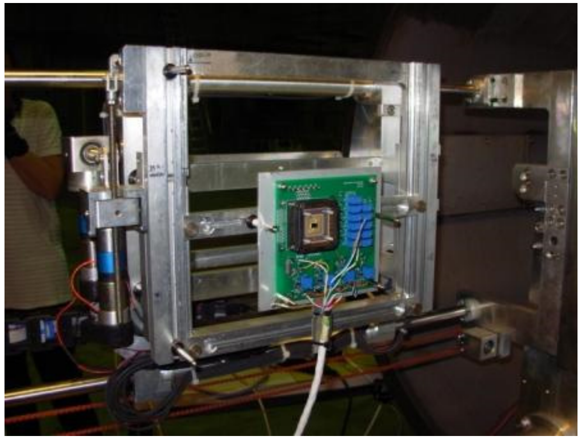
3) The challenges for both instruments

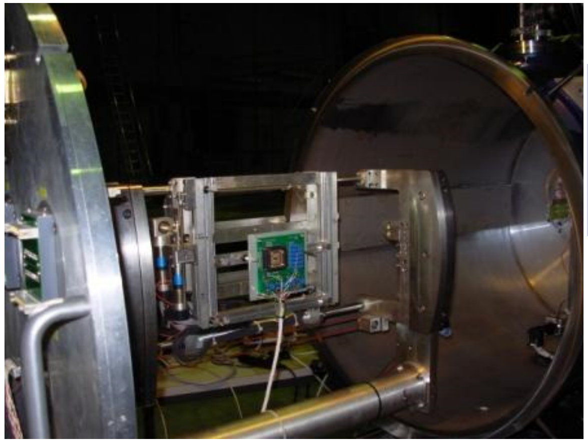
Components selection shall be done for PDR so pre-qualification was done (radiation tests) especially for the detector of EUI.
For the EUI entrance baffles coating (Al coating with a protective layer) a pre-radiation test is also foreseen to select the protective layer.

Spot shielding design: the mass constraint is very critical for both instruments; CFRP (+Al honeycomb) is selected for the housing of EUI => shielding is not guaranteed => spot shielding will be necessary for the detector proximity electronic.

3) Challenge: component design optimisation for radiations

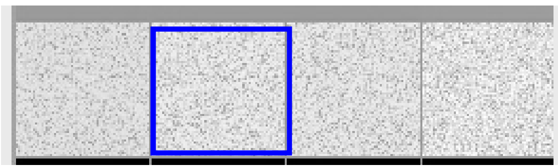
Design optimisation of the detector for Solar Orbiter EUI (partnership CSL / ROB / CMOSIS):
Heavy ions (N & Xe) required by ESA; TID tests up to 160 krad with 600 krad protons; DDD tests with10MeV and 20MeV protons @ four fluences.
The best candidate for the pixel design was selected.



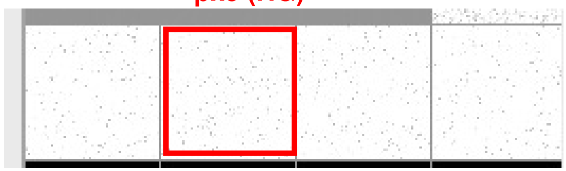


HI facility at Univ.Catholique de Louvain

px9 (LG)



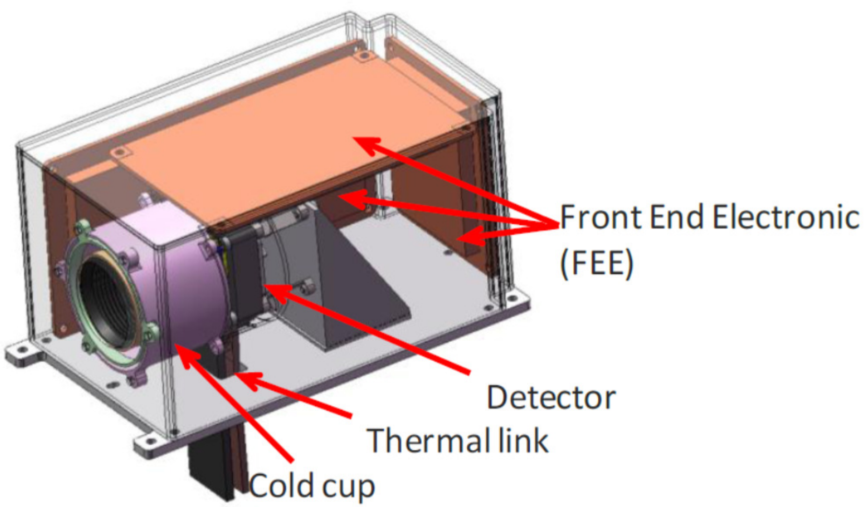
px9 (HG)



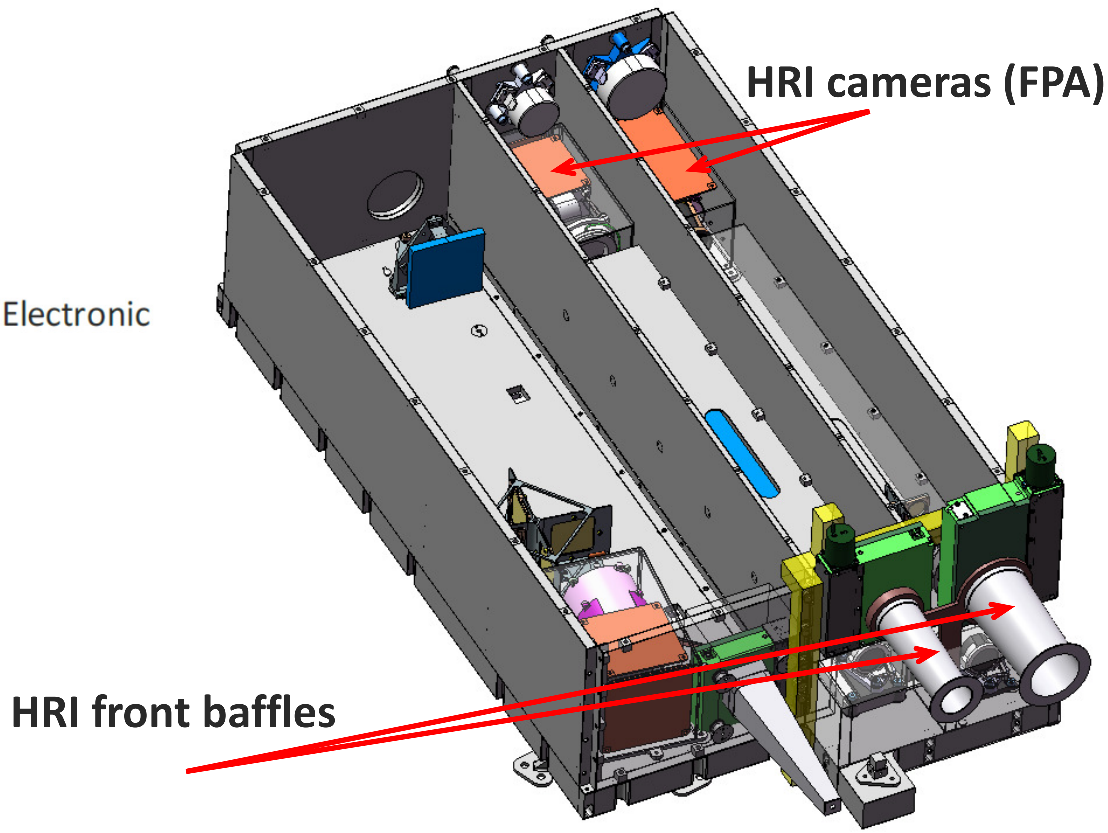
Visual degradation after HI

3) Challenges: shielding & coating design optimisation

Shielding design of Solar Orbiter EUI cameras:



Design optimisation of the entrance baffle coating



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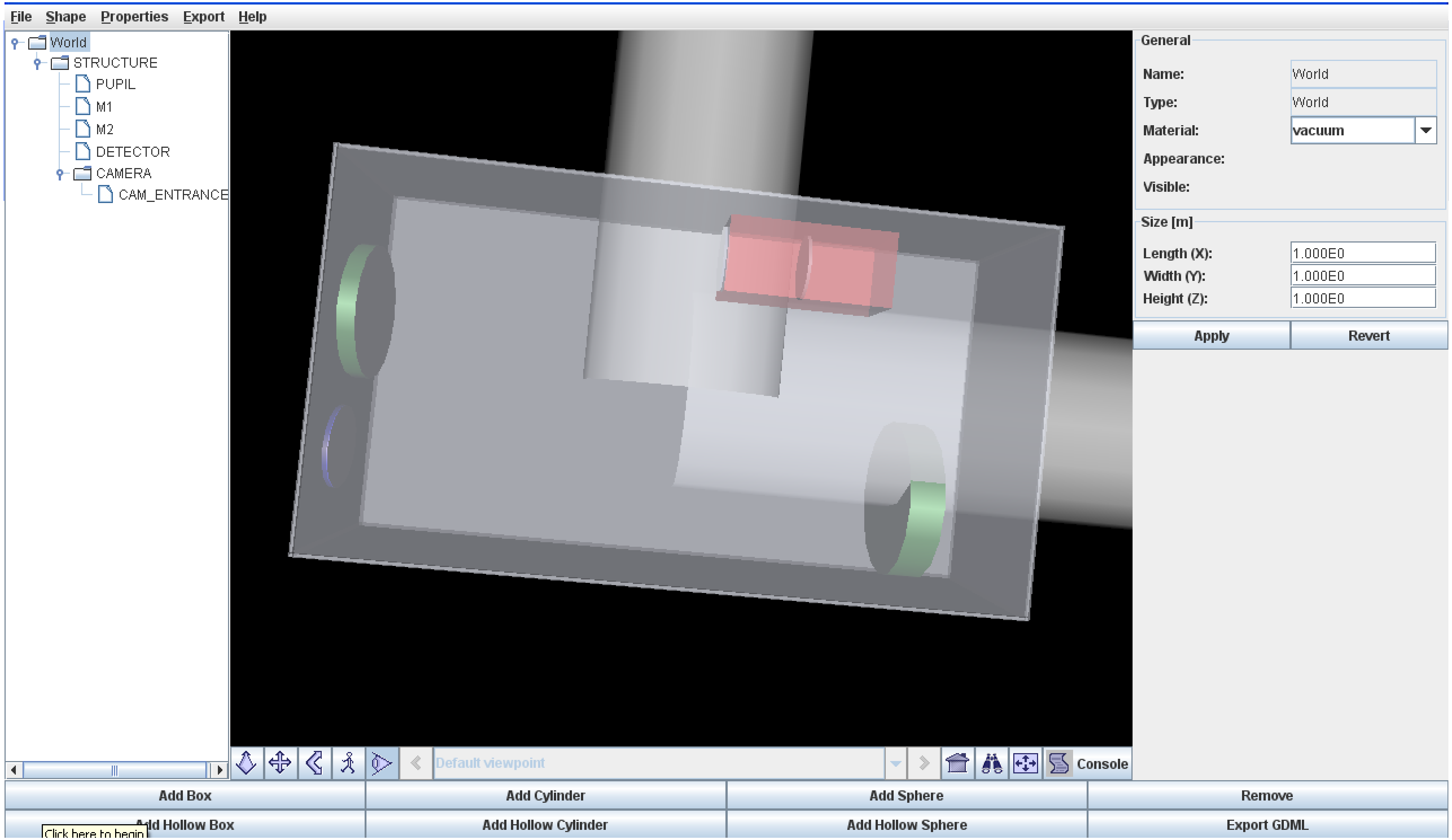
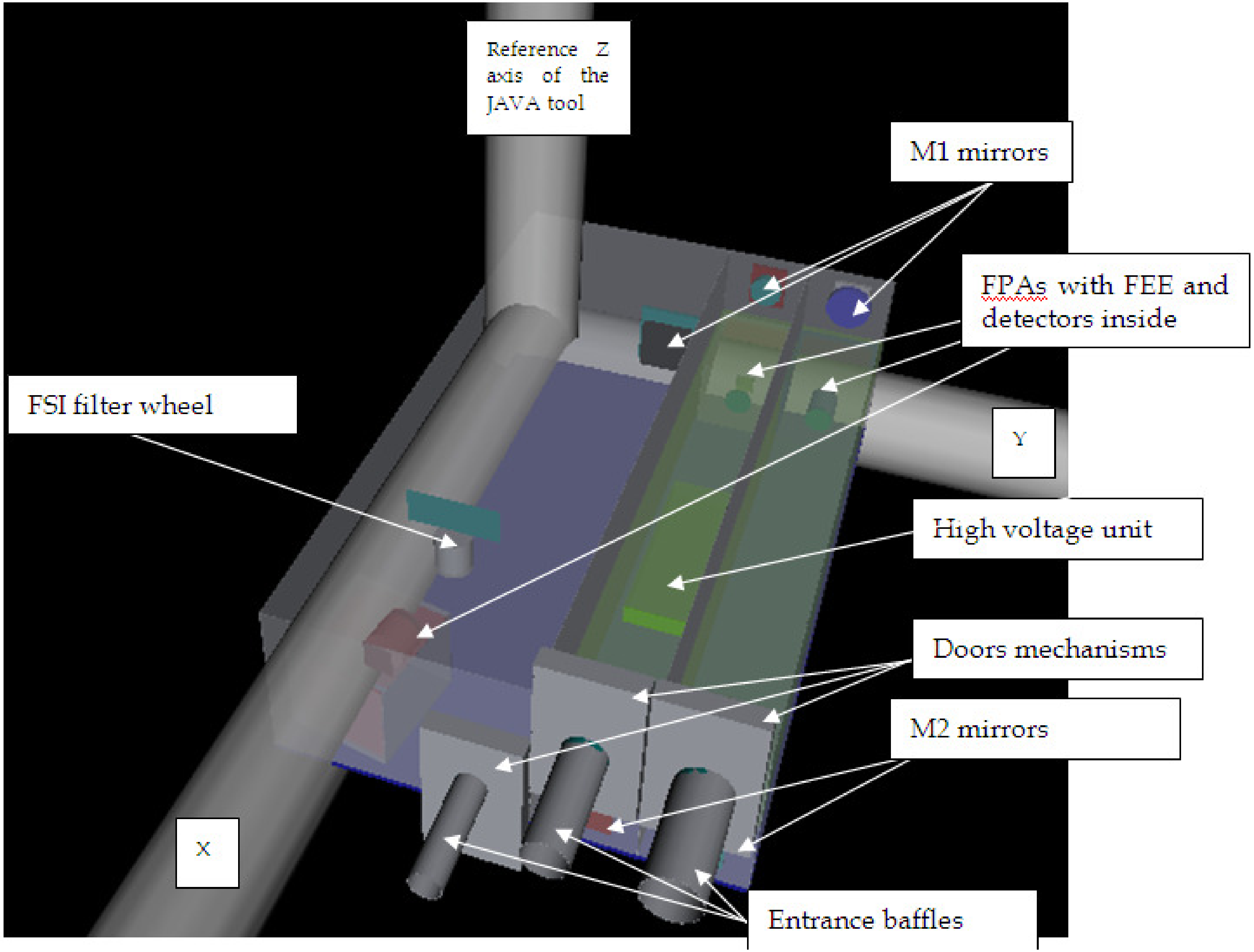
Geometries of JUDE built with SPENVIS JAVA Tool



Geometries of EUI built with SPENVIS JAVA Tool



SPENVIS JAVA Tool: where I had some problems:

Parent-child relations

All geometry objects are part of a tree which is shown in the tree panel. This is due to the structure of GDML. T
When creating a structure one can place a child outside its parent. This can be the user's intention or an error.

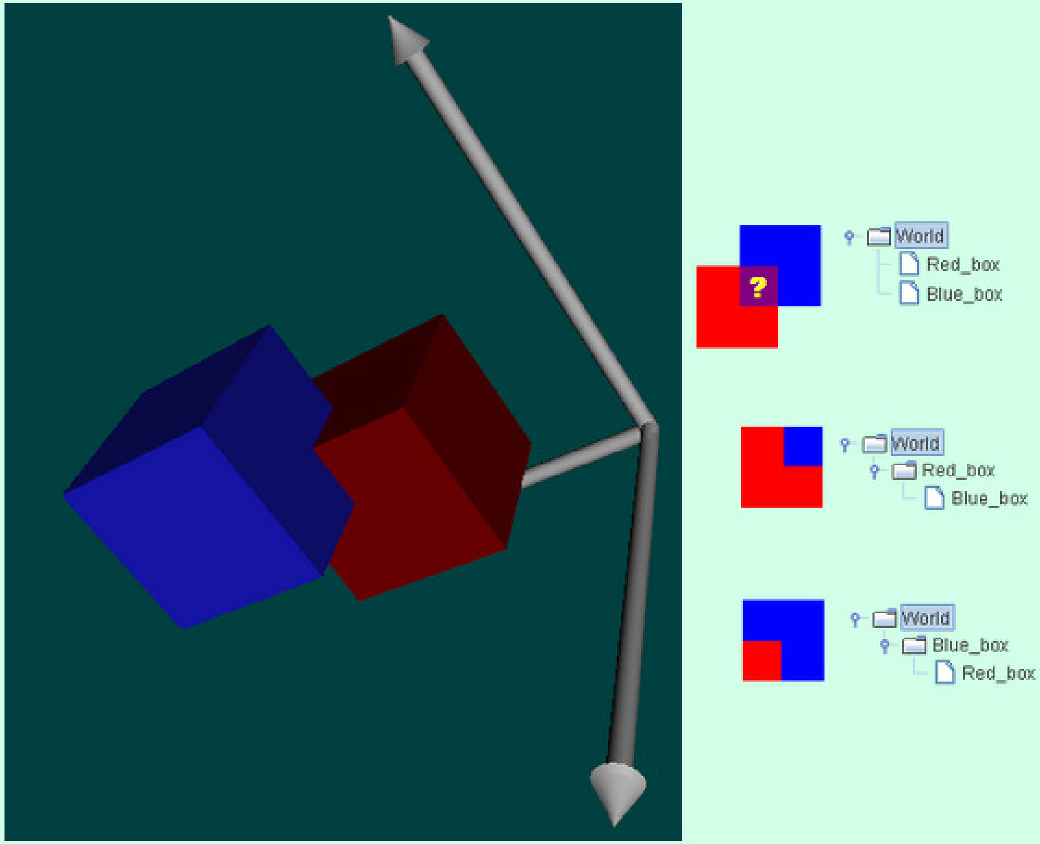


Figure-2: Two boxes with different parent-child relations

Advice:
Excepting if there are overlaps (as shown on the picture) to be defined, it's easier and less risk if there is no parent-child relation.

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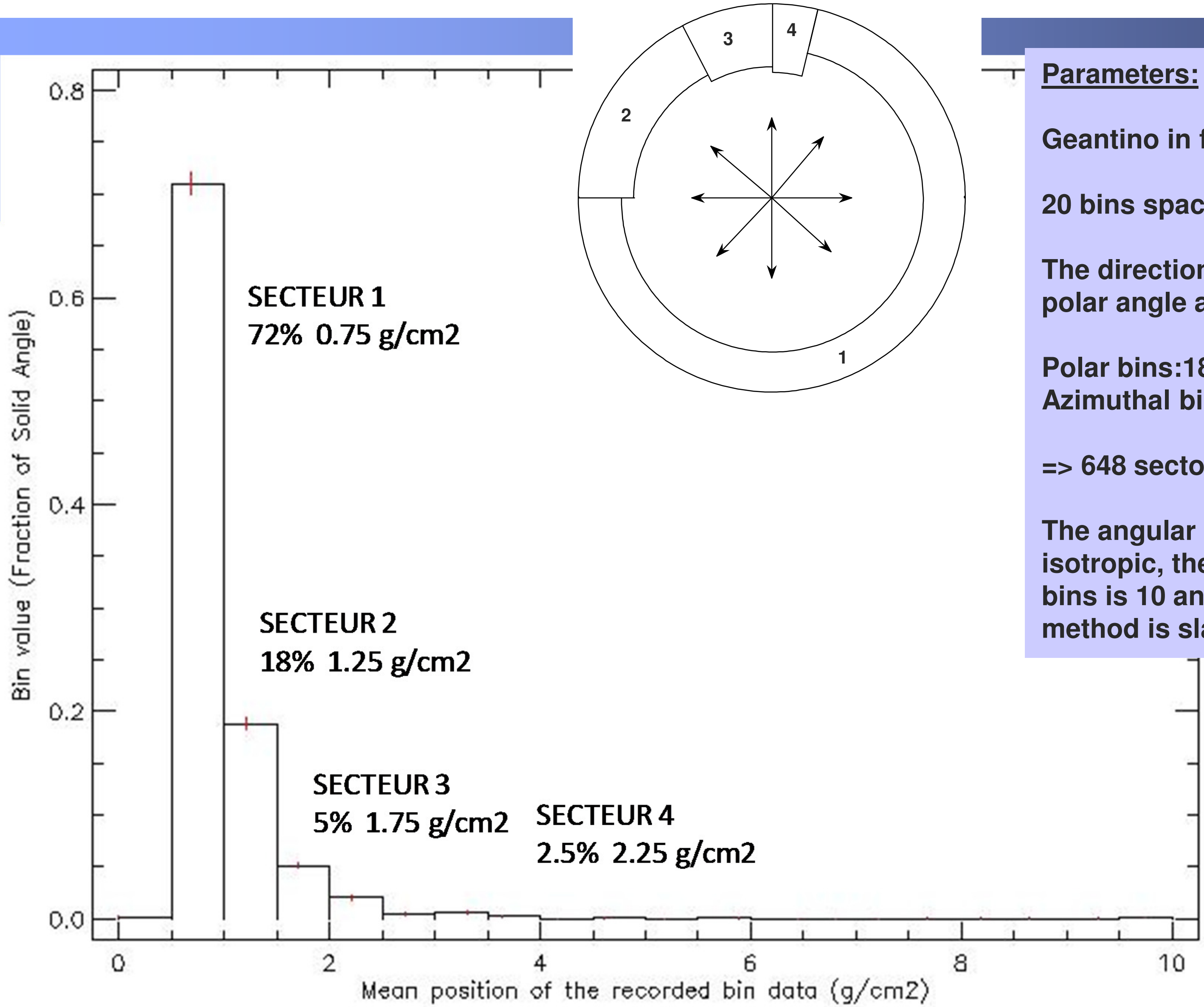
SSAT results for JUDE detector



<u>Parameters:</u>

Geantino in front of the element.

20 bins spaced equidistantly

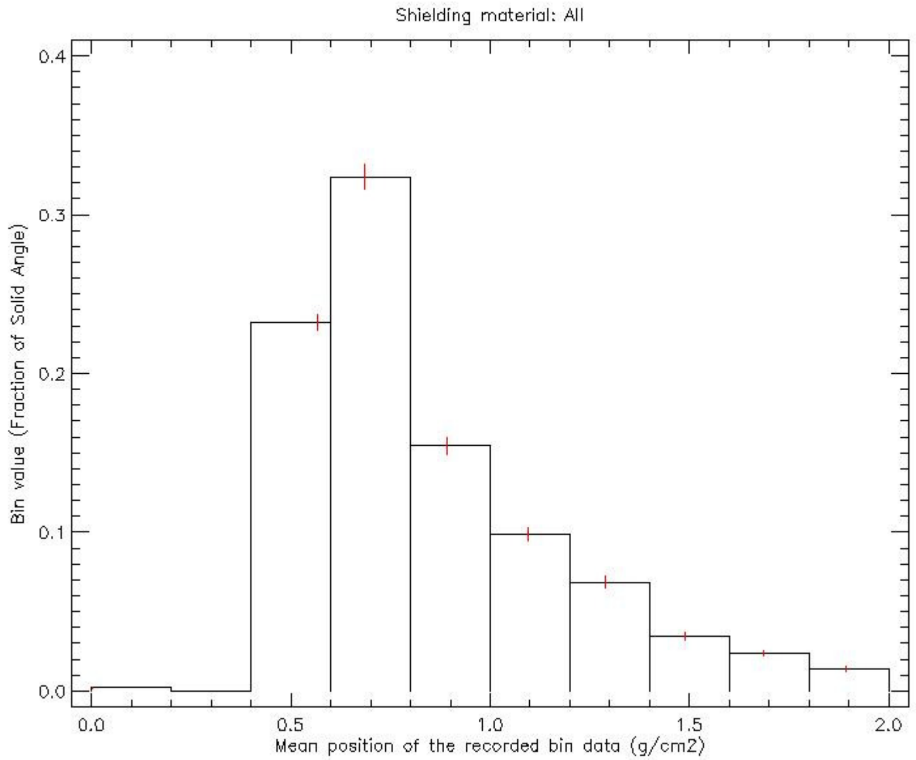
The direction window from 0 to 180° for polar angle and from 0 to 360° for azimuth.

Polar bins:18
Azimuthal bins: 36

=> 648 sectors.

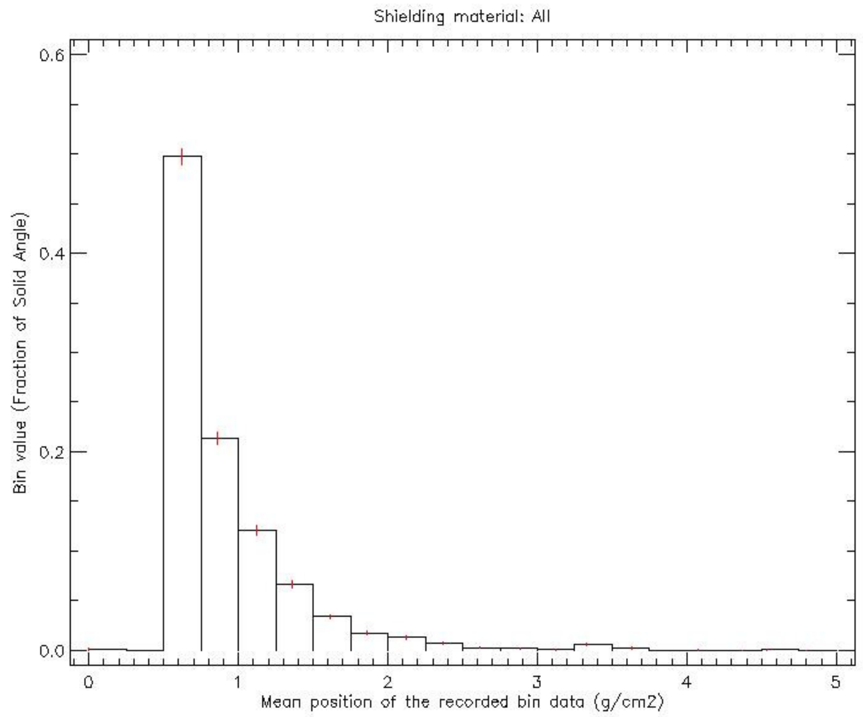
The angular sampling distribution is isotropic, the number of rays per angular bins is 10 and the path length calculation method is slant.

SSAT results for JUDE detector

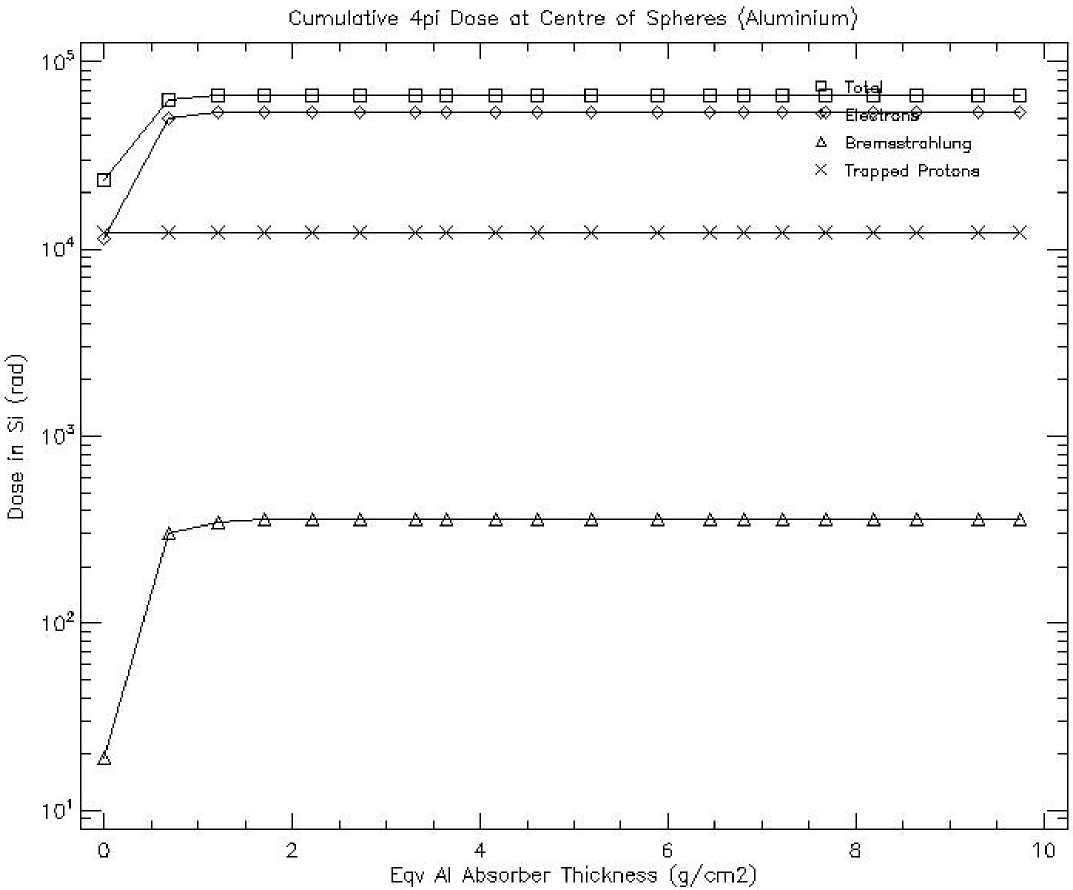


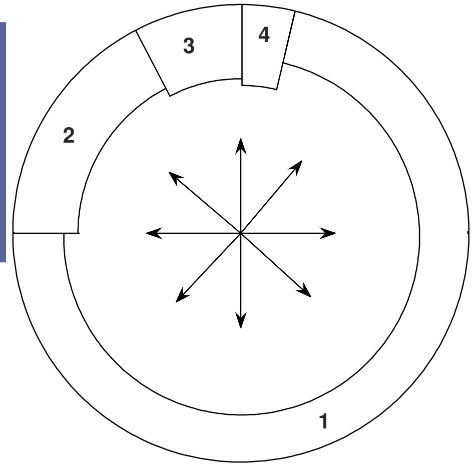
Advice:
In the SHIELDOSE model, I took into account the shielding distribution which provides an assymptotic cumulative dose.

➔ An iterative process was done



SSAT results for JUDE detector

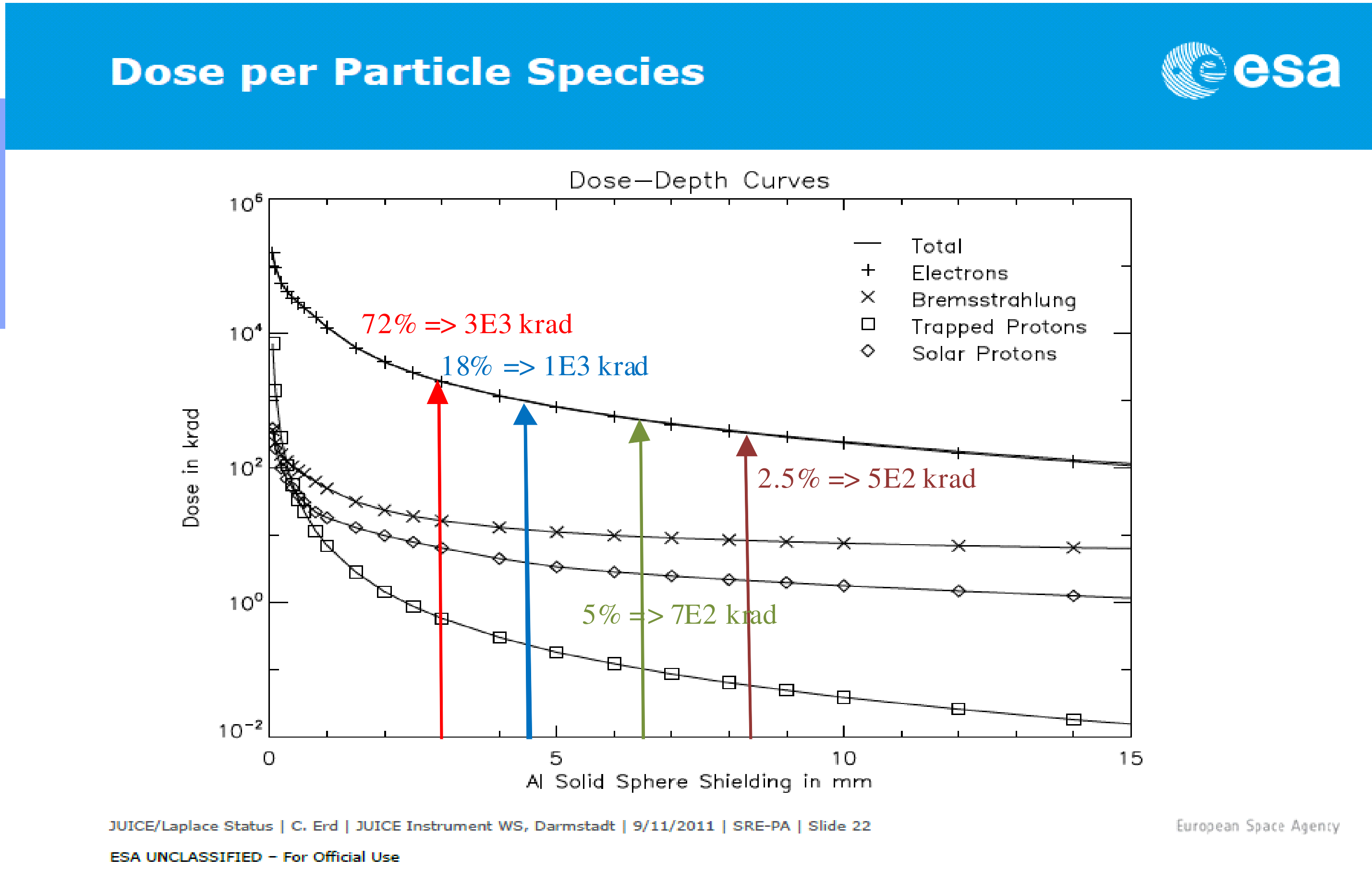




For each phase of the mission, SHIELDOSE was run with the SSAT shield distribution, and each cumulative dose was added to obtain the total dose on the target:

Runing SHIELDOSE with this shield distribution gives 3.73 Mrad(Si) for the detector.

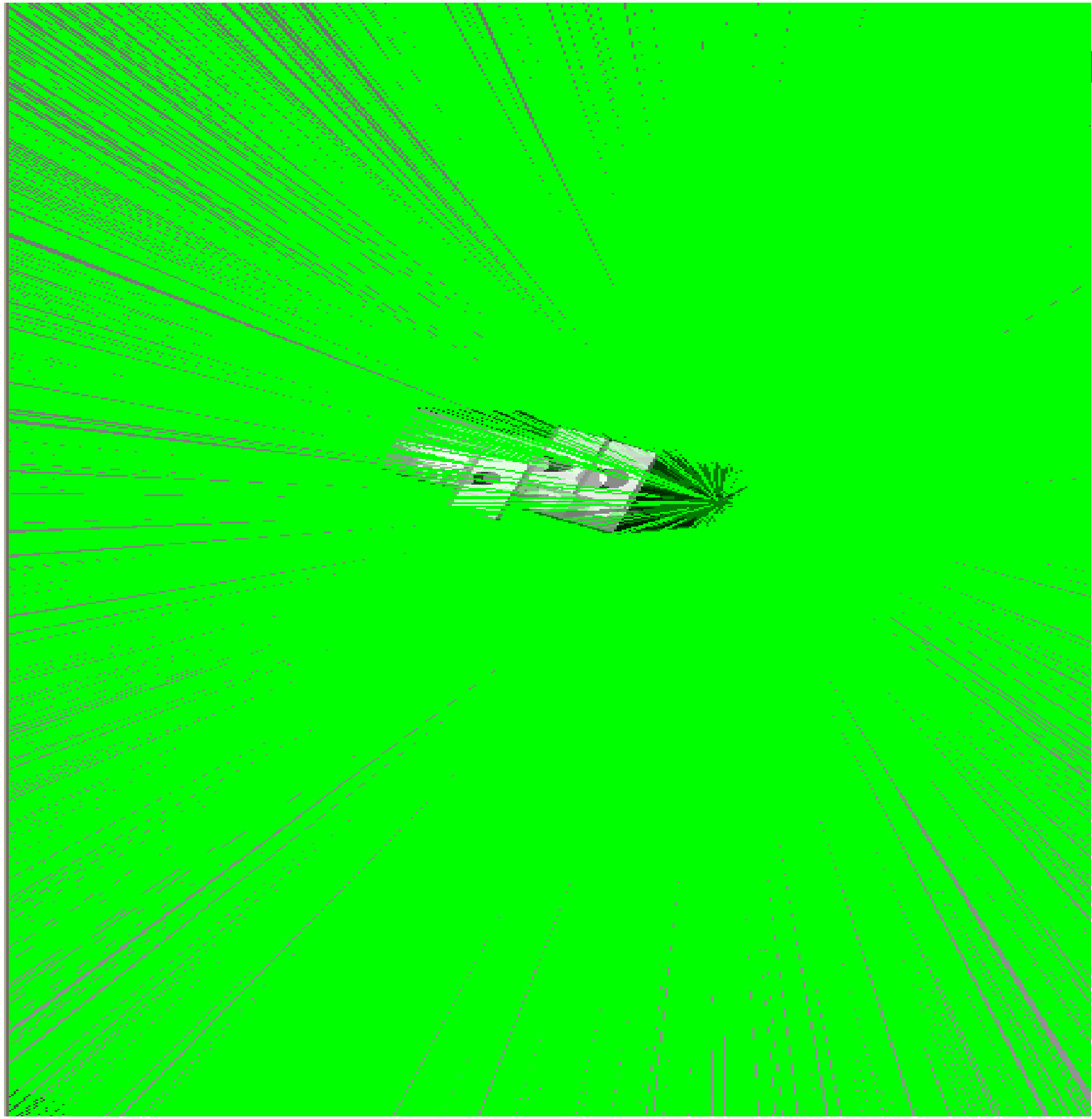
JUICE : Total ionising dose using ESA environmental specification



This graph – ESA JUICE environment specification was used to correlate the results with ESA results.

TOTAL TID = 72 % * 3E3 + 18% * 1E3 + 5% * 7E2+ 2.5% * 5E2 = 2.38 Mrad

SSAT results for EUI detector



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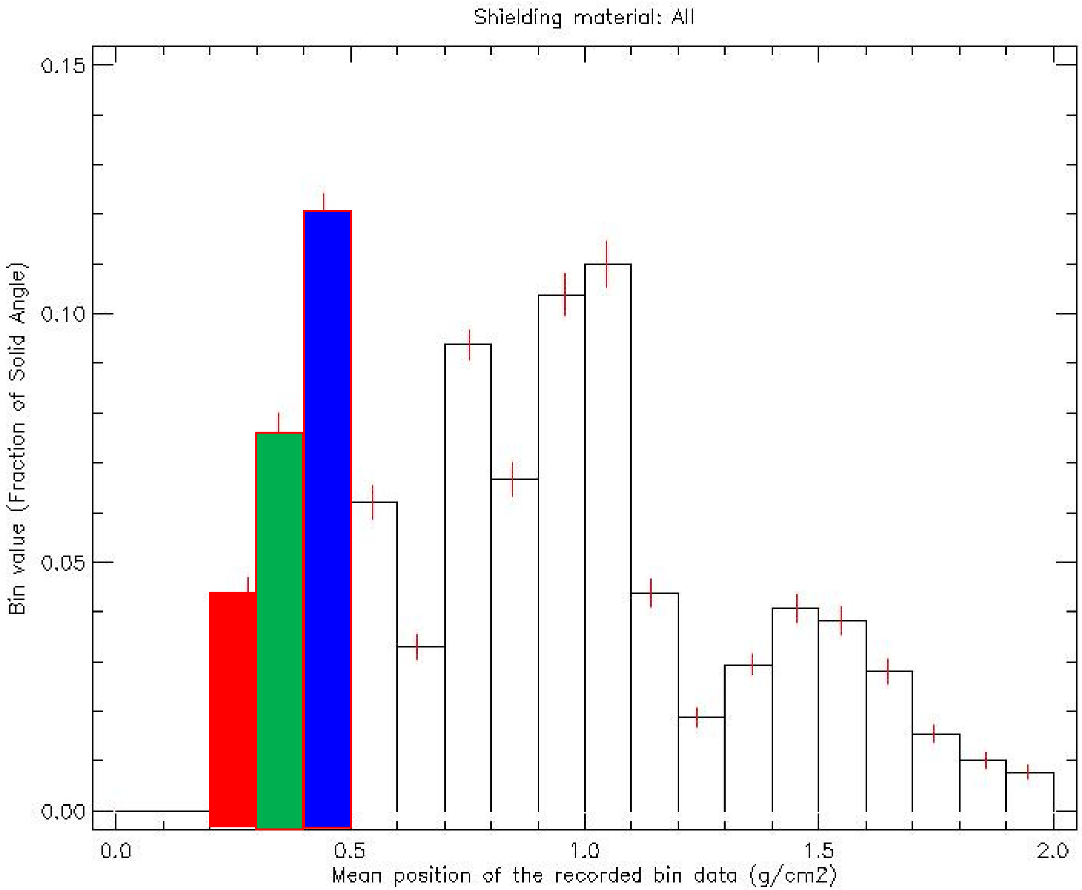
SSAT results for EUI detector



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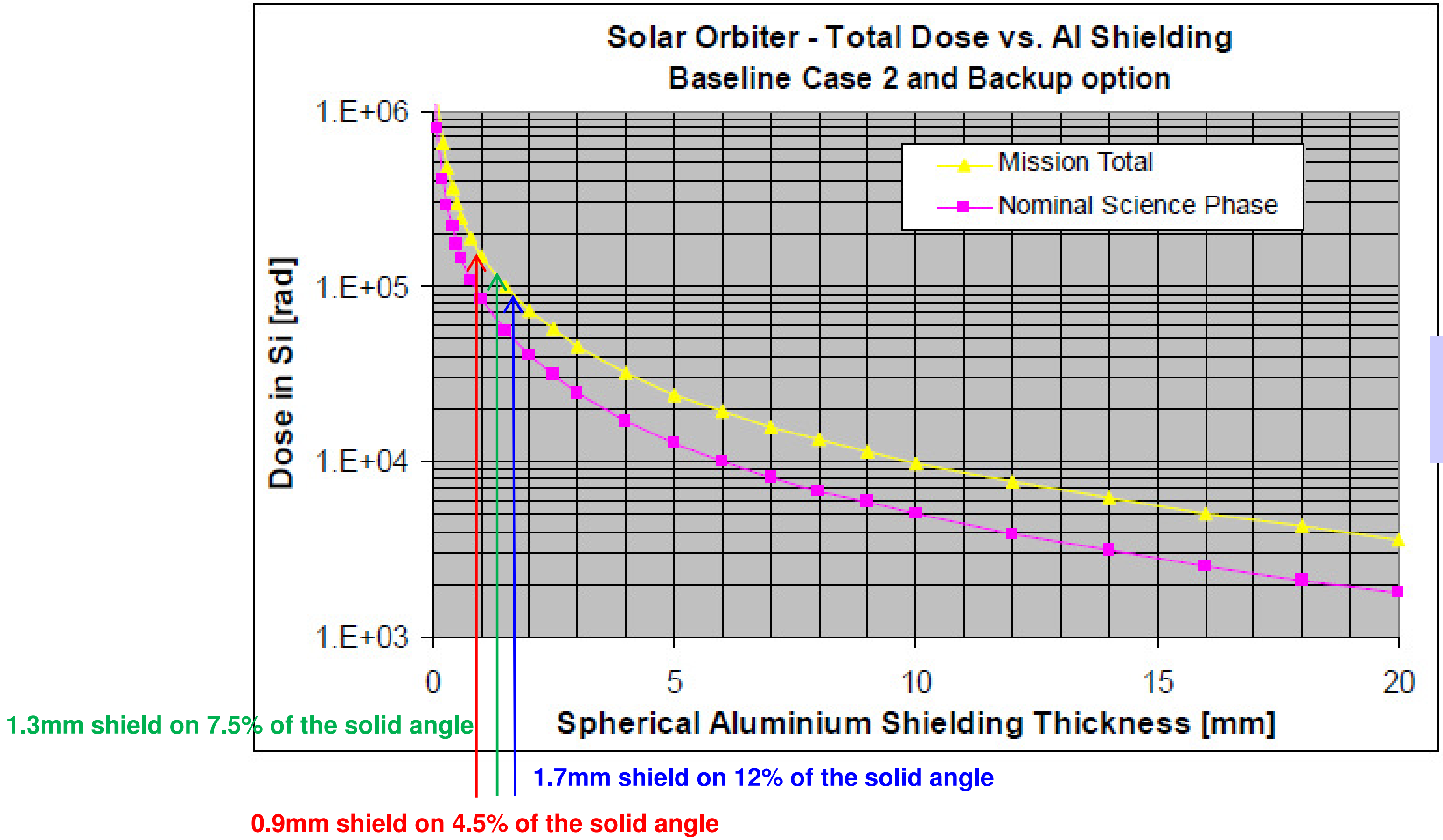
TID results for EUI detector

For Solar Orbiter, the TID and NIEL curves were given in the ESA environmental specification
➔ The TID for each specific element was calculated manually taking into account the shield distribution and ESA specifications



TID = 36.36 krad (Si)
NIEL = 8.96 10^{10} p/cm^2

Conclusion

For JUDE instrument on-board JUICE, the analyses were in line with ESA results.
The complete analysis (excepting the generation of the orbit files) was performed.
I had trouble when generating the orbit around Jupiter, because the max size of the files is only ~350 kB => for each phase (21 phases from 2030 to 2032) the whole process shall be done (SSAT + SHIELDOSE).
But results were very satisfactory when compared with ESA results.

For EUI instrument on-board Solar Orbiter, the doses (DD and TI) computed by ESA were used; the fraction of the solid angle with a shield thickness t was taken into account and weighted the TID figure for that thickness t.
This analysis will continue in the frame of the CDR preparation and GRAS model will be used as the next step with a more accurate spacecraft shield information provided by the platform.