Zagadnienia termiczne instrumentu naukowego STIX misji kosmicznej Solar Orbiter

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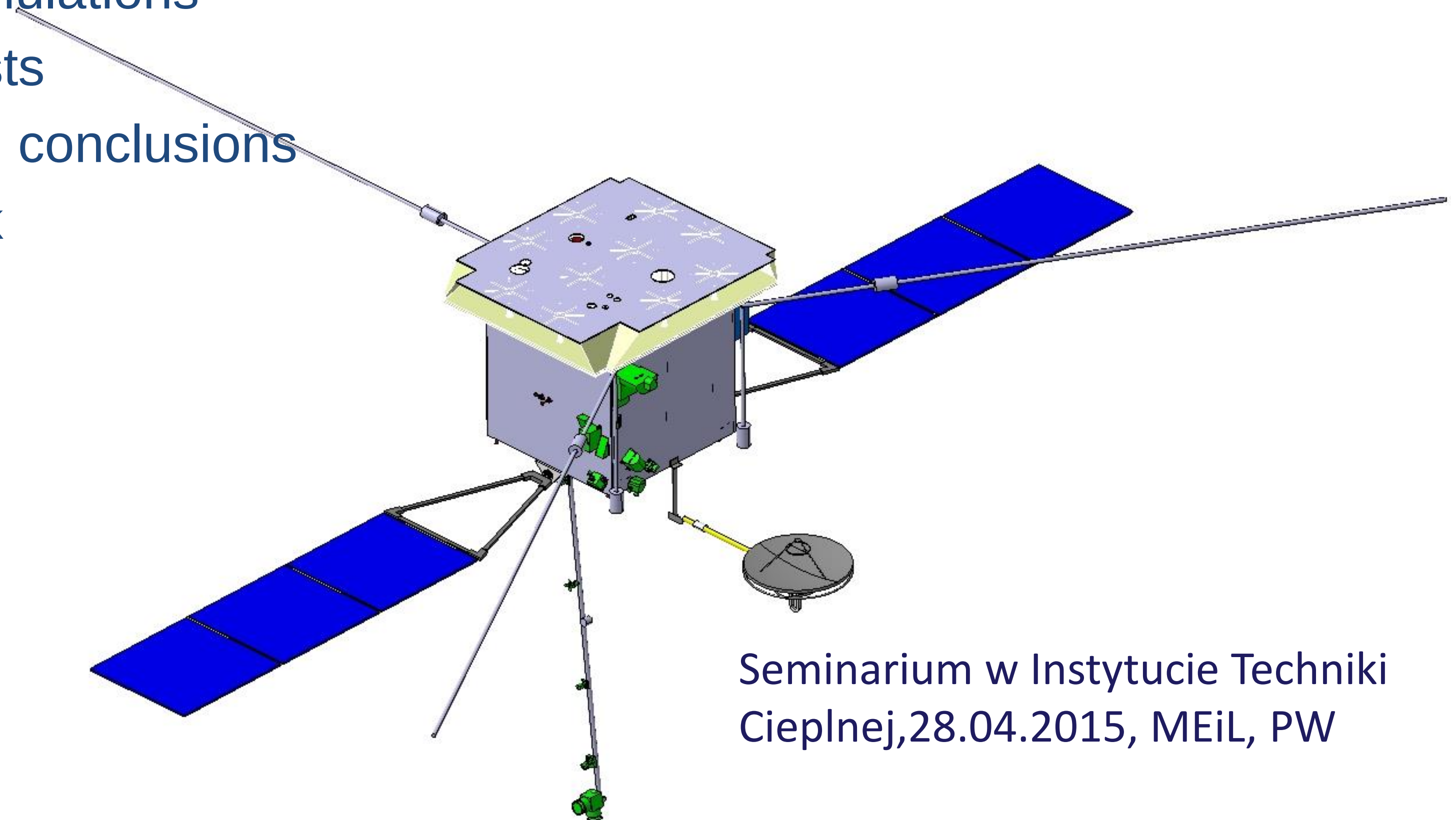
Outline

- Solar Orbiter mission
- STIX instrument and its science objectives
- STIX thermal design and thermal model description
- Thermal simulations
- Thermal tests
- Results and conclusions
- Future work



Solar Orbiter mission

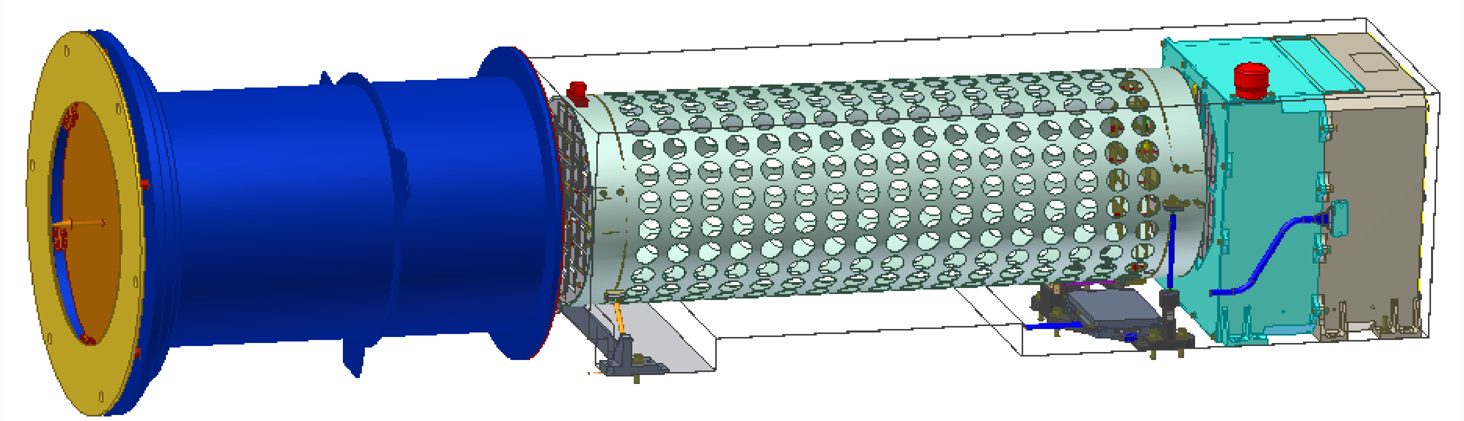
- ESA’s M-class mission
- 2018 – launching year
- Elliptical orbit around the Sun: 0.28AU (perihelion) and 0.952AU (aphelion)
- 10 different instruments on board (remote sensing instruments and in situ instruments)

Solar Orbiter mission

- Science objectives - inner heliosphere
  - How does it work?
  - How does it affect the activity of the star
- Orbit configuration allows to view both Sun's equator and its poles

STIX instrument and its science objectives

- STIX – Spectrometer/Telescope for Imaging X-rays
- One of the remote sensing instruments
- Image the solar X-rays from 4 to 150 keV
- Science objectives: to determine intensity, timing and location of accelerated electrons near the Sun



Feedthrough with top cover and the X-ray windows

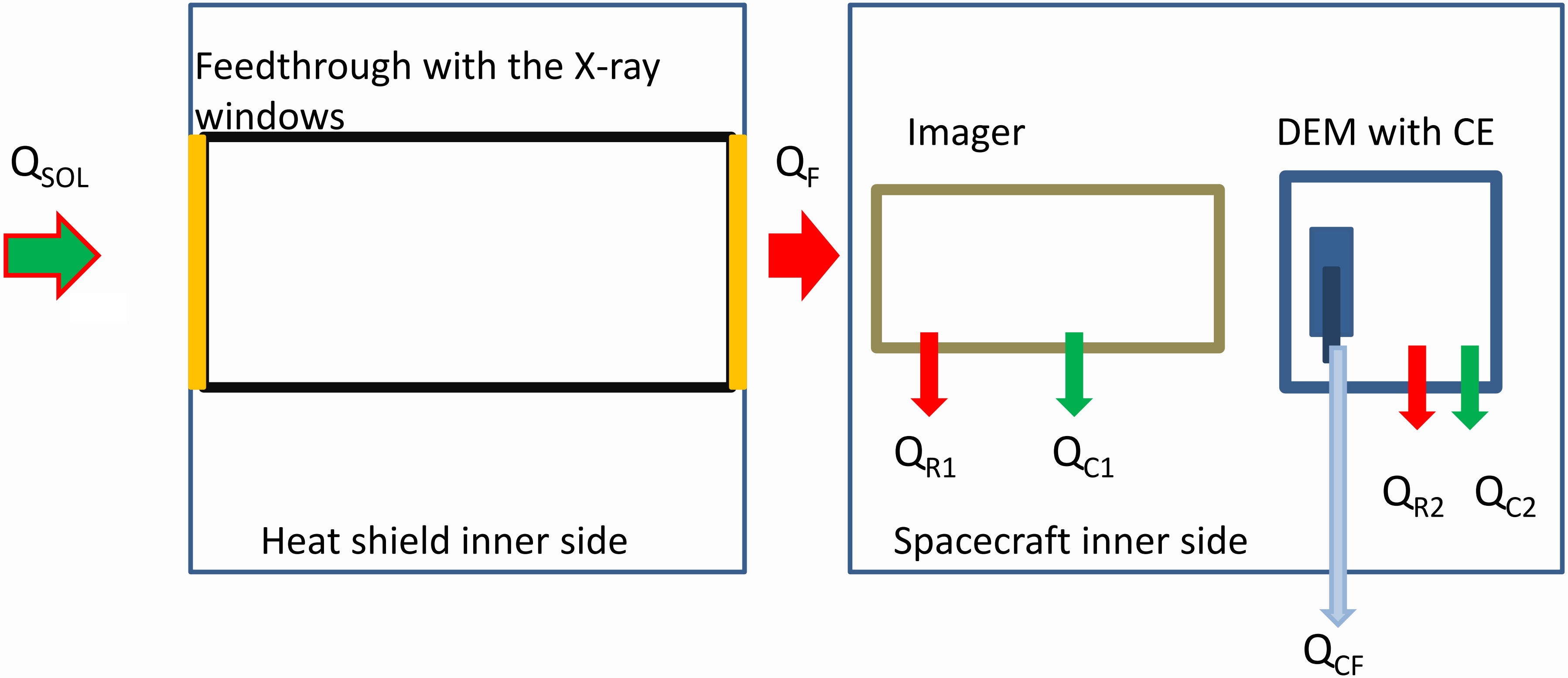
Imager with grids and aspect system

Detectors and electronics module

STIX instrument and its thermal design requirements

- The ratio of the incoming solar flux which reaches the parts of the instrument located in the spacecraft should be minimized, but at the same time the most of the X-rays from 4 to 150keV should reach the detectors.
- The heat exchange between the STIX instrument and the spacecraft and its deep space radiator should be minimized.
- The detectors should be kept at temperature below -20°C, because of their working temperature range from -50 to -20°C.

STIX instrument thermal design

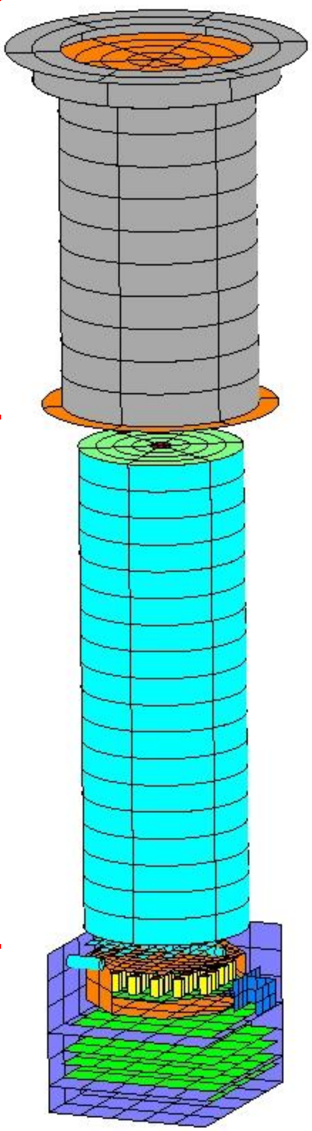


STIX thermal design

Feedthrough and the X-ray windows

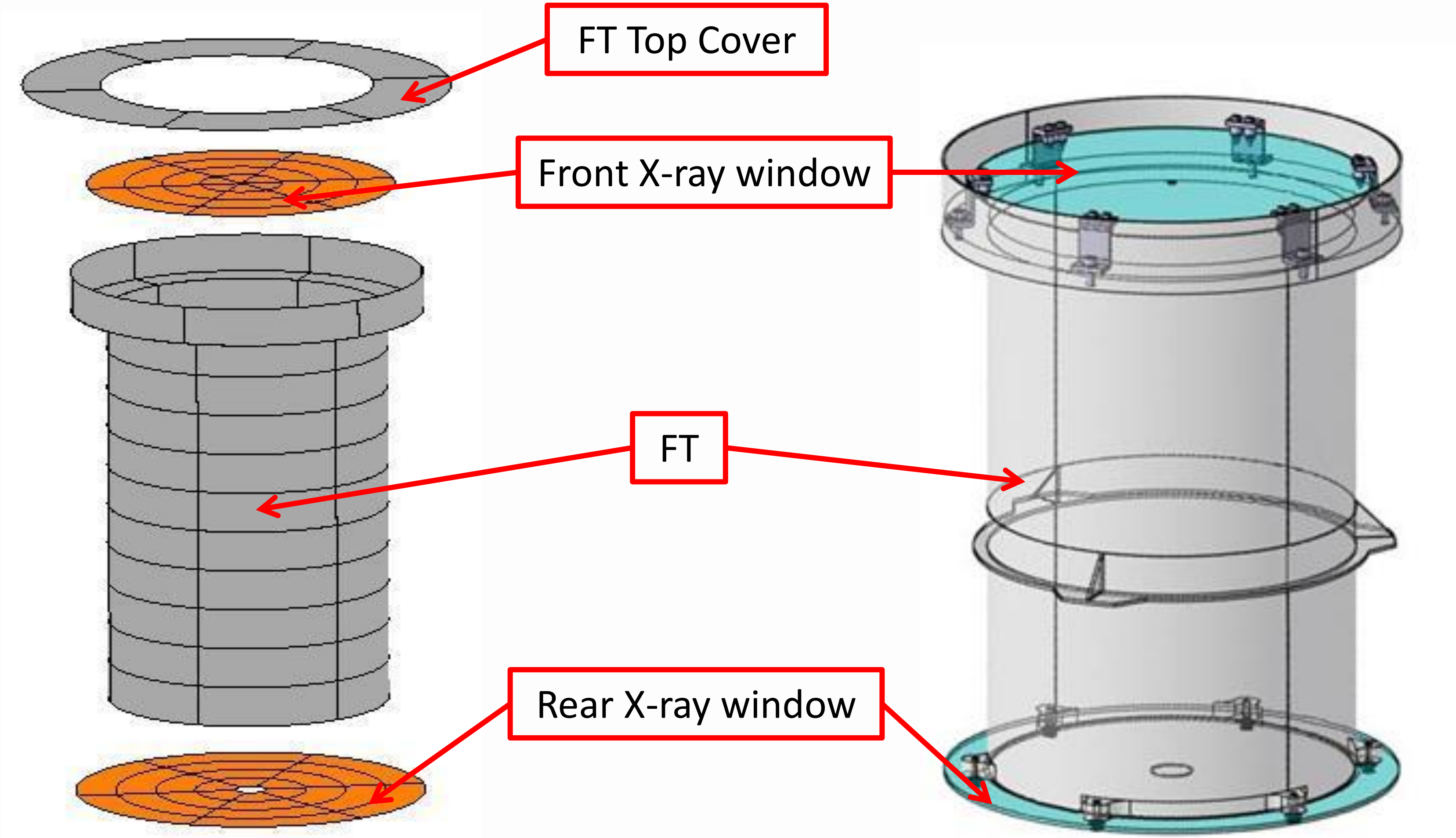
Imager, grids and aspect system

Detector – Electronics Module



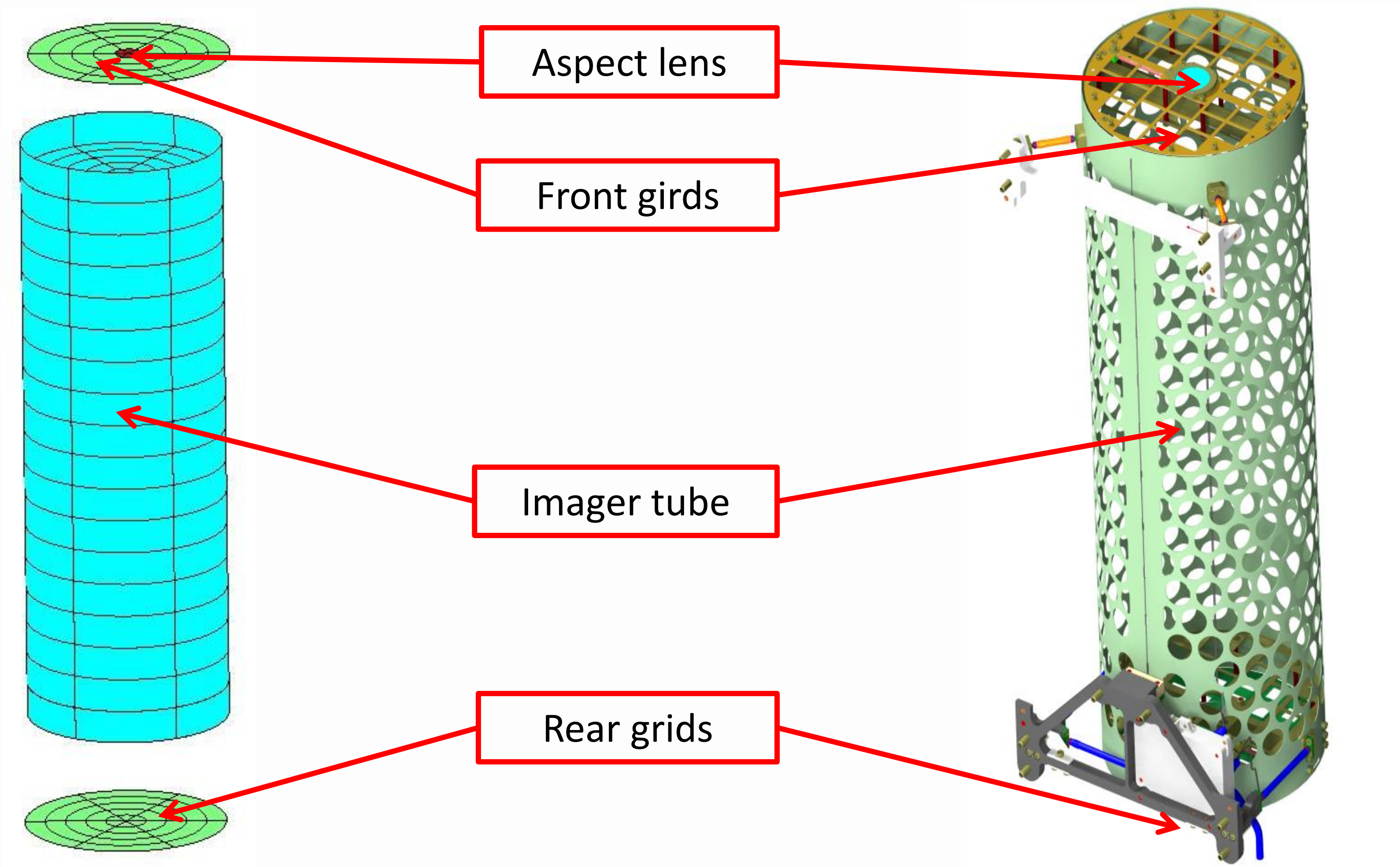
STIX thermal design

X-ray windows and Feedthrough LP model



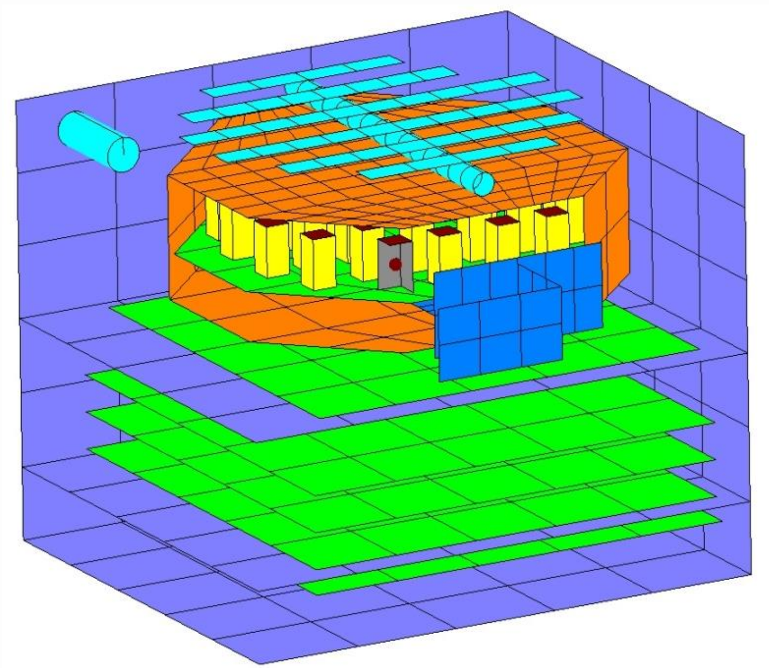
STIX thermal design

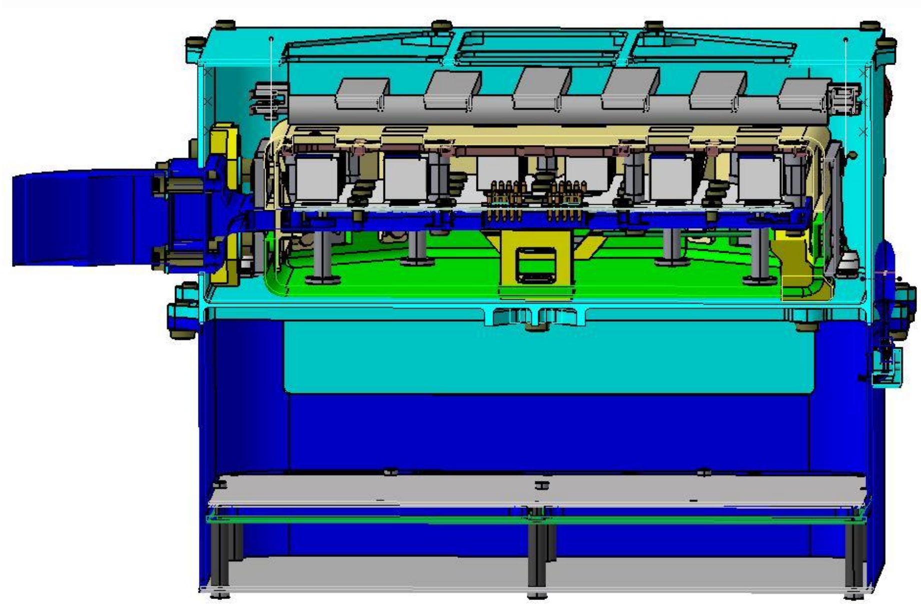
Imager, grids and aspect system LP model



STIX thermal design

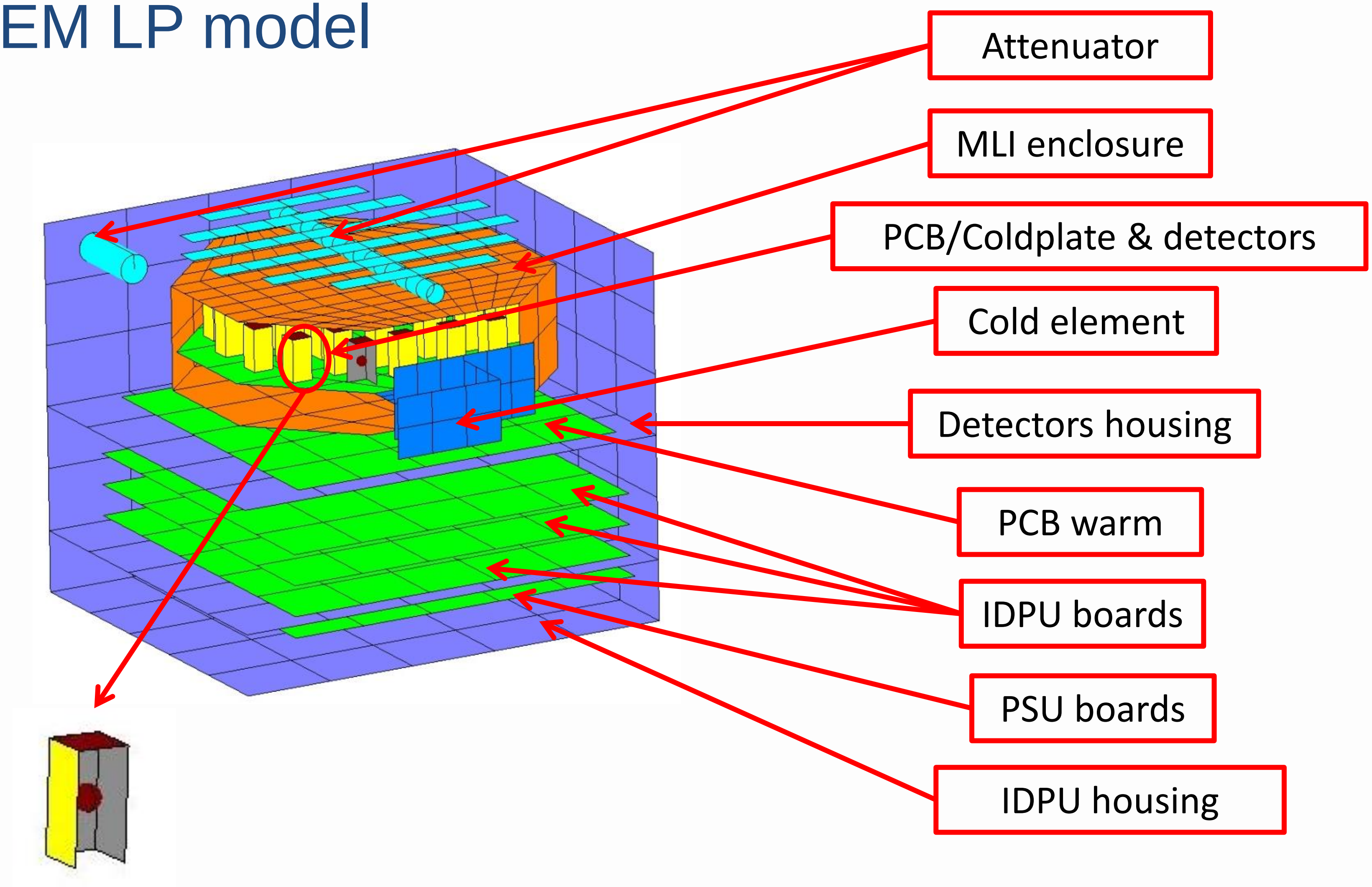
DEM LP model



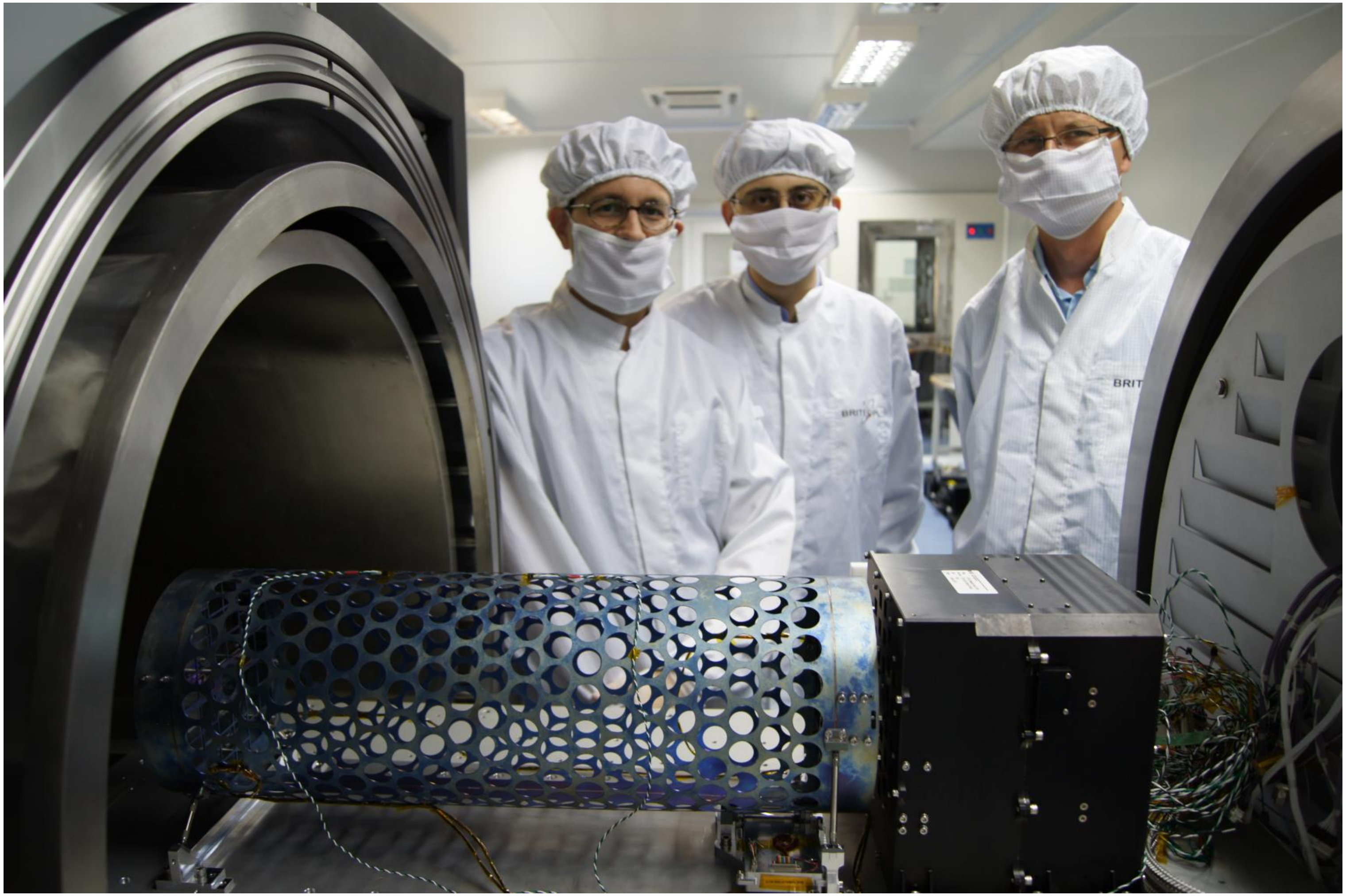


STIX thermal design

DEM LP model



STIX thermal design



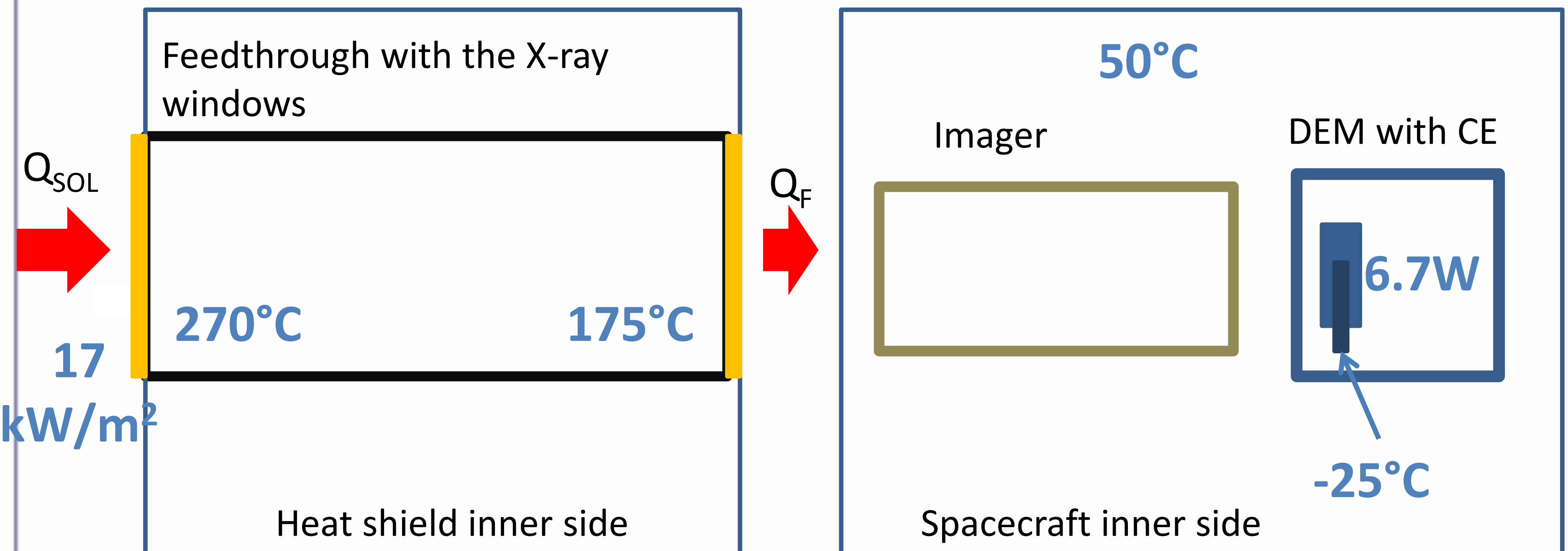
STIX thermal design

Radiative couplings

- All surfaces are radiatively active, except the inner sides of the Caliste-SO Units.
- transmissivity coefficient (τ) defined for the imager tube and the grids in order to simulate the holes.
- The net radiation (view factors) are calculated using Monte Carlo simulations.

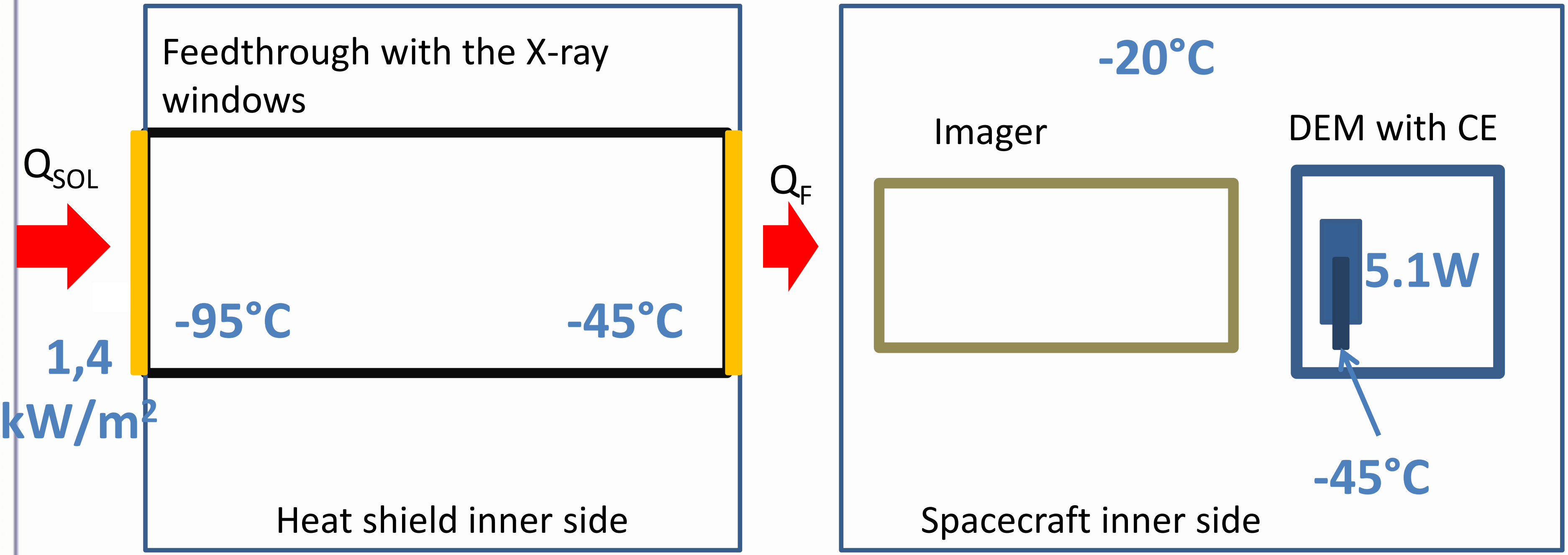
Boundary conditions

Hot operational case



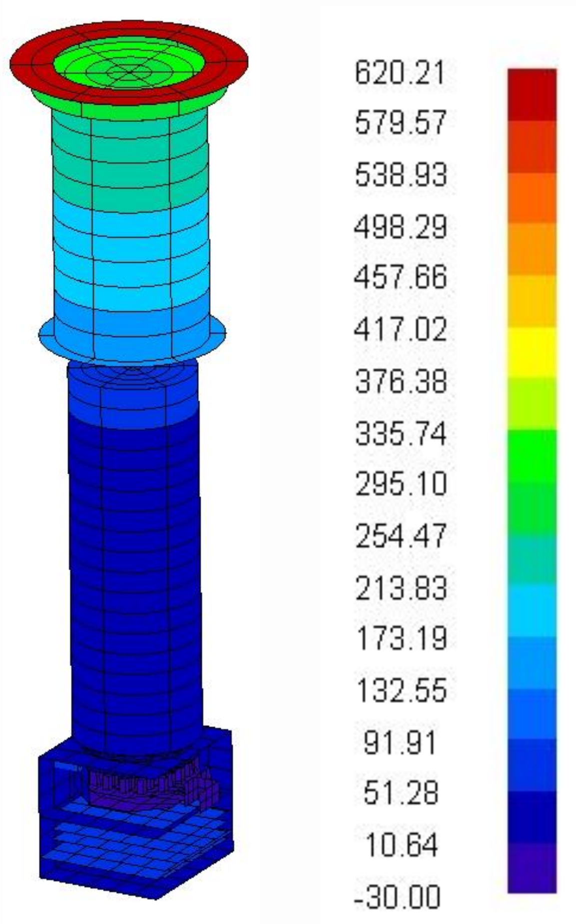
Boundary conditions

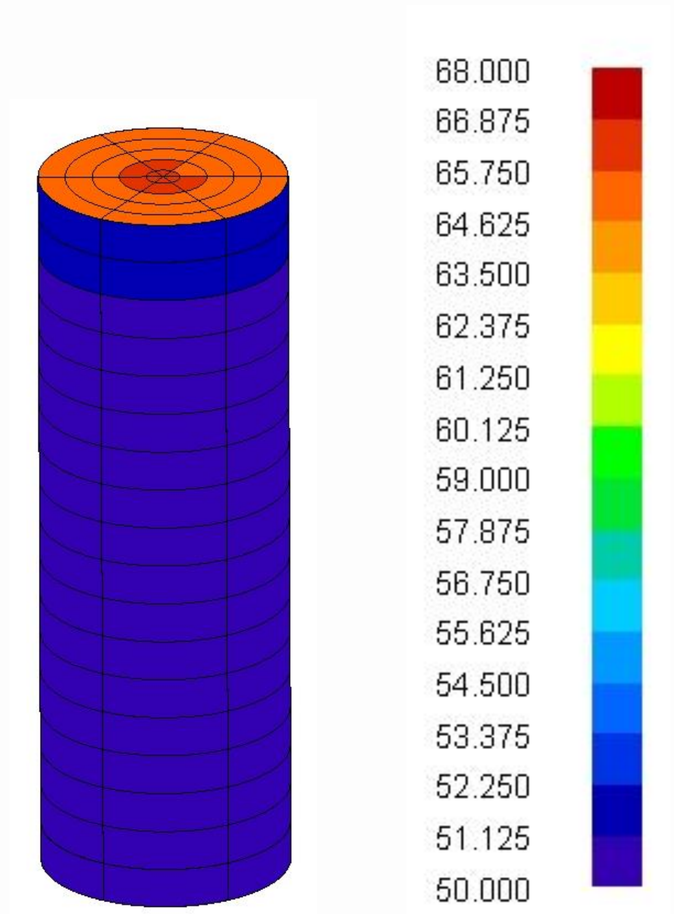
Cold operational case



Results

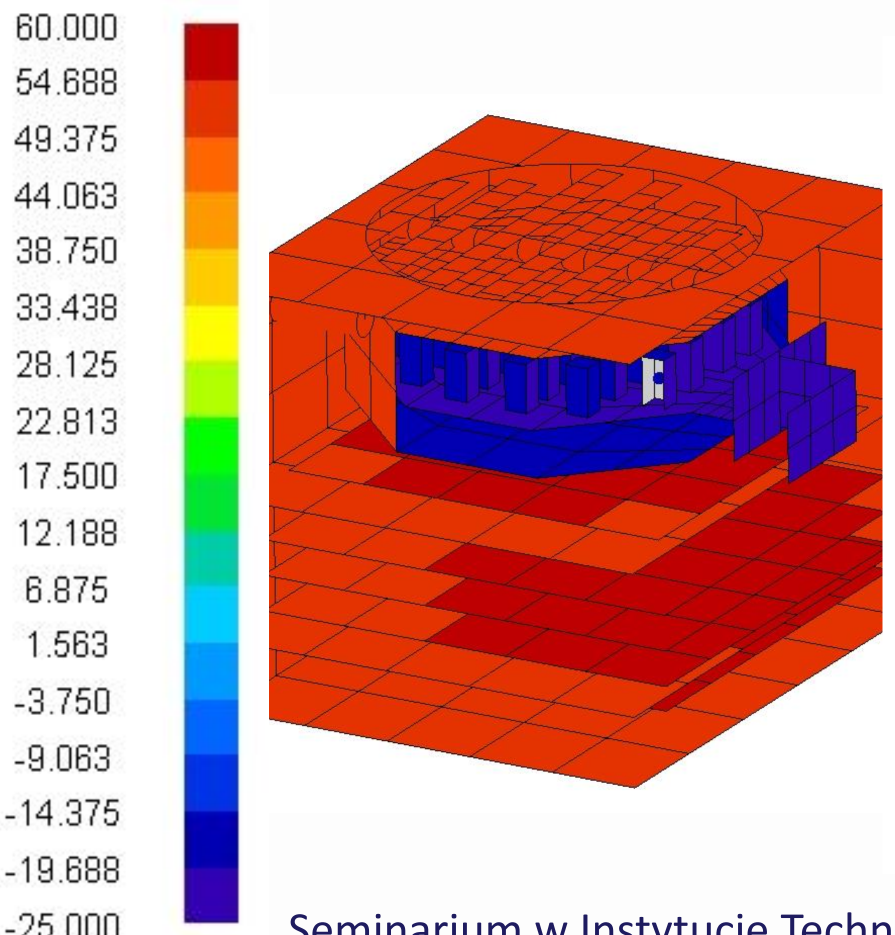
Hot operational case – temperatures

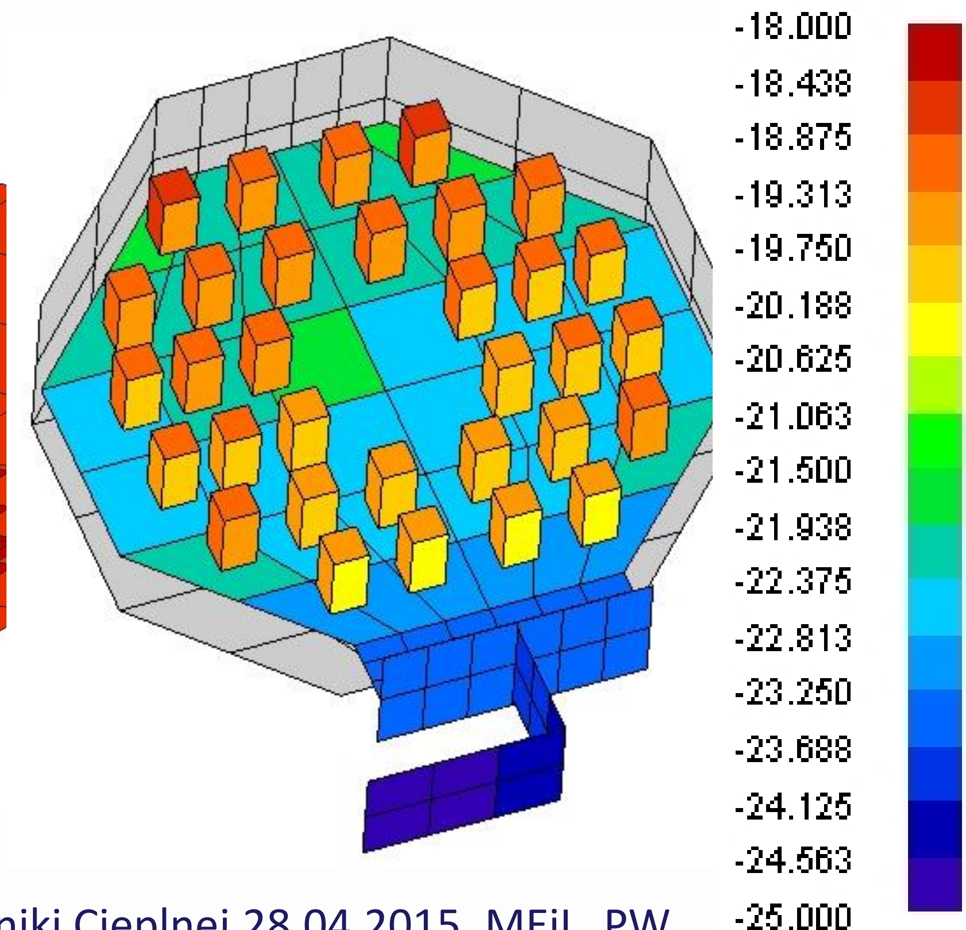




Results

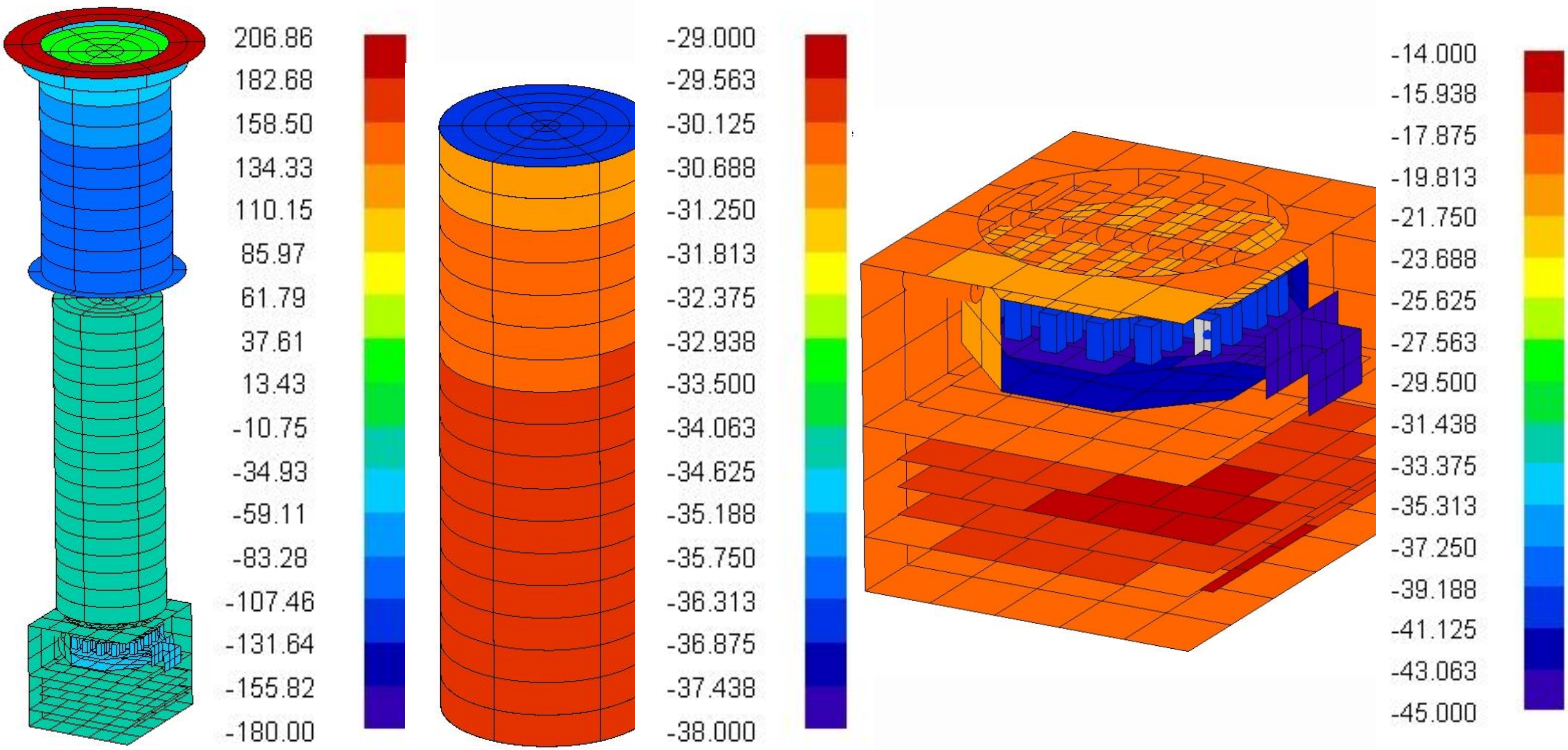
Hot operational case – temperatures





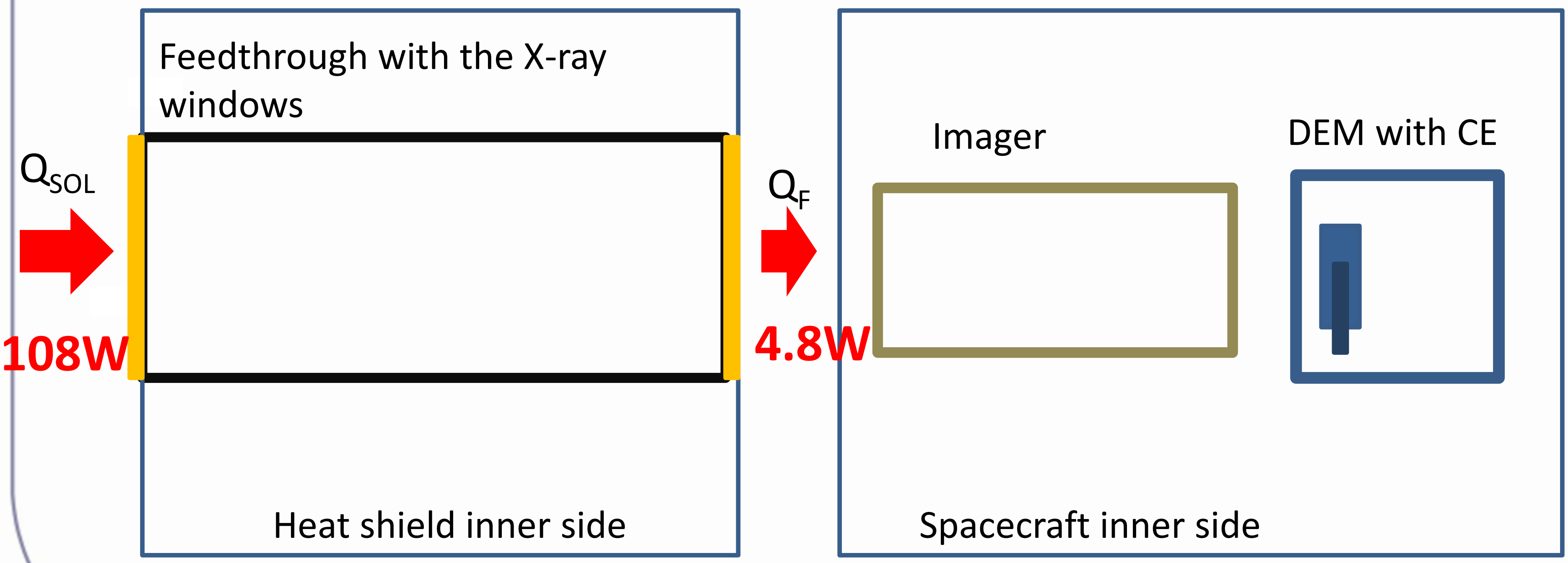
Results

Cold operational case – temperatures



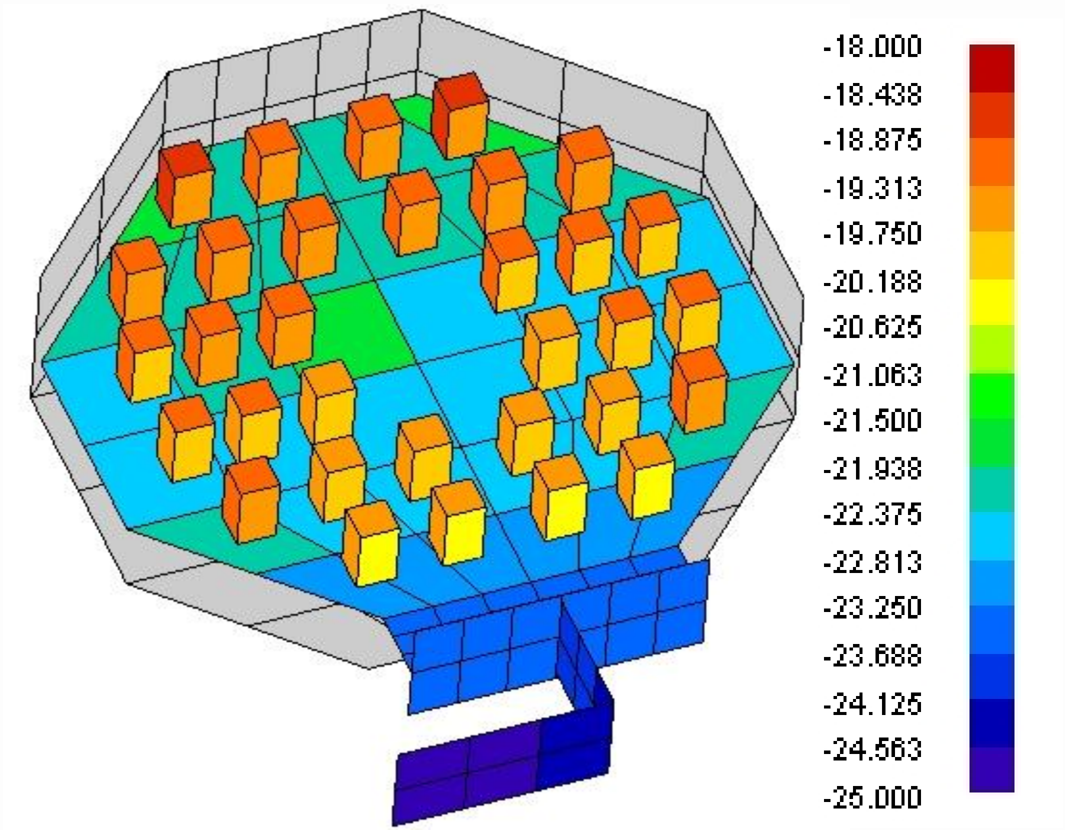
Final results from simulations

1. The Solar heat flux reaching the instrument was minimized by Beryllium X-ray windows with high emissive coating.



Final results from simulations

2. The maximal temperature of Caliste-SO units is -18.8°C in hot operational case.



Final results from simulations

3. The heat flow through the cold element is 2.2W and exceeds the limit of 2W in the hot operational case.
4. The conductive heat flow from DEM to S/C is 3.8W in hot operational case, and 2.5W in cold operational case, and exceeds the limit of 2W.
5. The DEM dissipates 80% of heat conductively through the baseplate; 20% is radiated. The heat flow through CE was not considered here.

Thermal tests - objectives

- Cross check the DEM thermal design, especially heat flux through Cold Element, the performance of x-ray windows, functionallity of STIX instruments in worst case scenarios

The following were done to fulfill these objectives:

A1. Design manufacturing and integration of the DEM STM2.0 based on ICDR model

A2. Tests execution in 20 cases

A3. Model correlation

A4 Flight model predictions

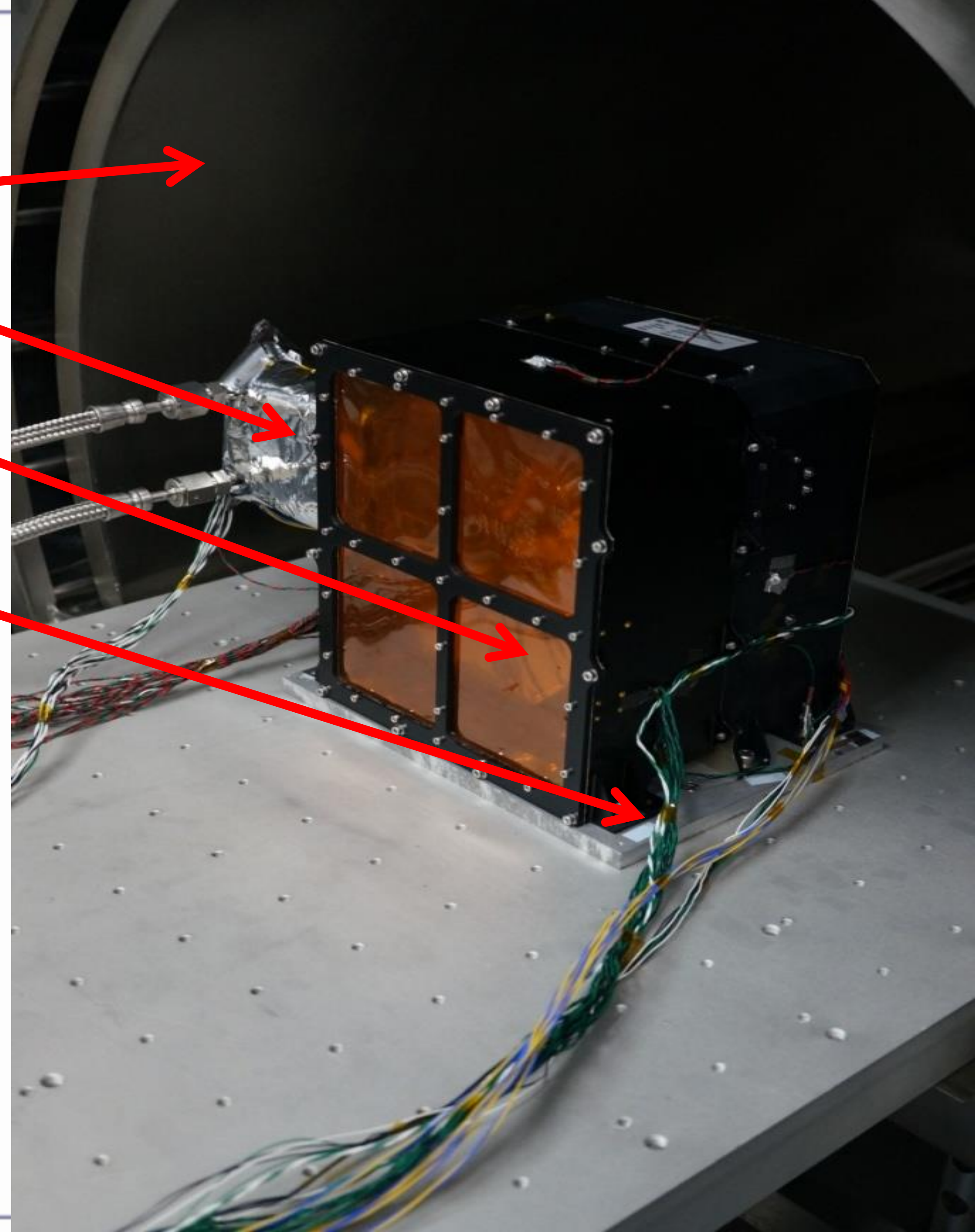
A5 Report preparation

S/C enviroment

CE interface

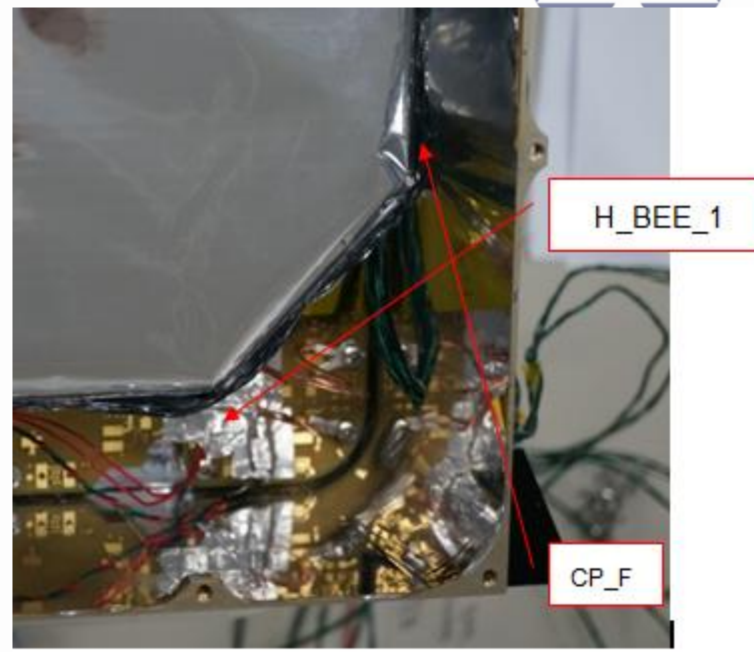
DEM STM 2.0
(Imager side)

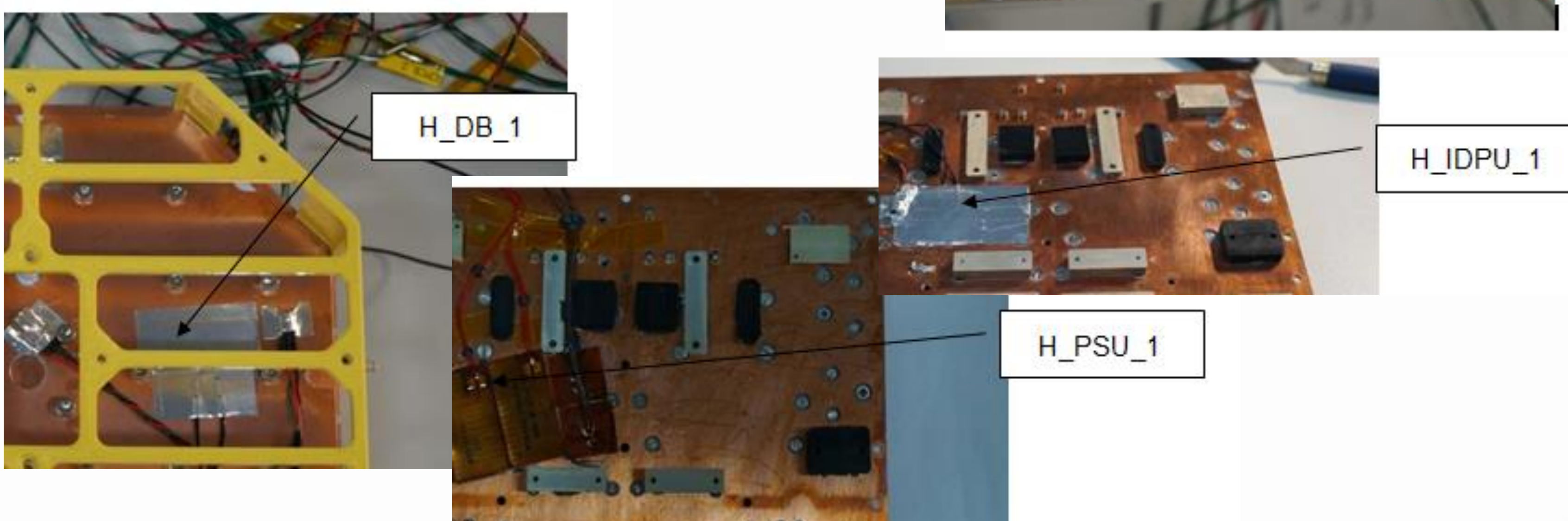
S/C interface



Heat dissipation

HEATER CODE	Power hot case [W]	Power cold case [W]
H_IDPU_1	2.066	1.680
H_PSU_1	1.77	0.48
H_DB_1	1.15	0
H_PCB_warm	1.596	0





Test results

(all of them are in the report)

Test number	Heat dissip.	CE temp.	Heat flux through CE	URP temp.	Detector – cold PCB temp.	PSU temp.	IDPU temp.
H1.1	1.15W	-5C	2.6W	50C	-3C	48.5C	48C
H2.1	1.15W	-15C	2.8W	50C	-12.5C	48.5C	48C
H5.1	6.6W	-20C	3.17W	51.5C	-17C	63.5C	71C
H8.1	6.6W	-25C	3.2W	51.5C	-21.5C	63.5C	70.5C
C2	2.16W	-45C	0.4W	-18C	-43C	-11C	1.5C

The heat flux through the CE is significantly higher then expected (2.2W)

Finall results of the test

- Confirmation of the thermal design
- The consolidated results of simulation and test was the base to request increasing the Spacecraft radiator size dedicated for STIX. Currently the STIX can transmit 3.2W with guaranted -25C at interface

Conclusions

- During the x-ray window tests the problems with coating appeared. The beryllium coating is an open issue,
- There is a important manufacturing and assembly issue related to MLI. Depending on the procedure the impact of ~0.6W can be reached
- The materials with temperature dependent thermo optical properties would be interesting for future investigations

Thank you!