On the mechanical design of the SCD detector for the HERD experiment

Lorenzo Mussolin - INFN/UniPG

Forum on tracking detector mechanics

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Speaker introduction

Lorenzo Mussolin

Fellow researcher at University of Perugia

Ph.D. in Physics - University of Perugia

"AMS-02 UTTPS: qualification and performance studies"

e-mail: lorenzo.mussolin@unipg.it

A.D. 1308 unipg UNIVERSITÀ DEGLI STUDI DI PERUGIA

INFN SEZIONE DI PERUGIA

Summary

- HERD experiment introduction
- Environmental design constraints for space experiments
- HERD's main components overview
- Silicon Charge Detector (SCD) mechanical design
- Next steps and conclusions

The HERD experiment

High Energy Radiation Detector (HERD)

- Part of the Chinese's “Cosmic Lighthouse Program”
- Hosted on the Chinese Space Station “Tiangong”
- Launch and installation planned for 2027
- Experiment duration > 10 years
- Project is between phase A and B

The HERD experiment

The HERD collaboration

Chinese institutions

Institute of High Energy Physics, Purple Mountain Observatory, Xi’an Institute of Optical and Precision Mechanics, University of Science and Technology of China, Nanjing University, Peking University, Yunnan University, China University of Geosciences, Ningbo University, Guangxi University

International institutions

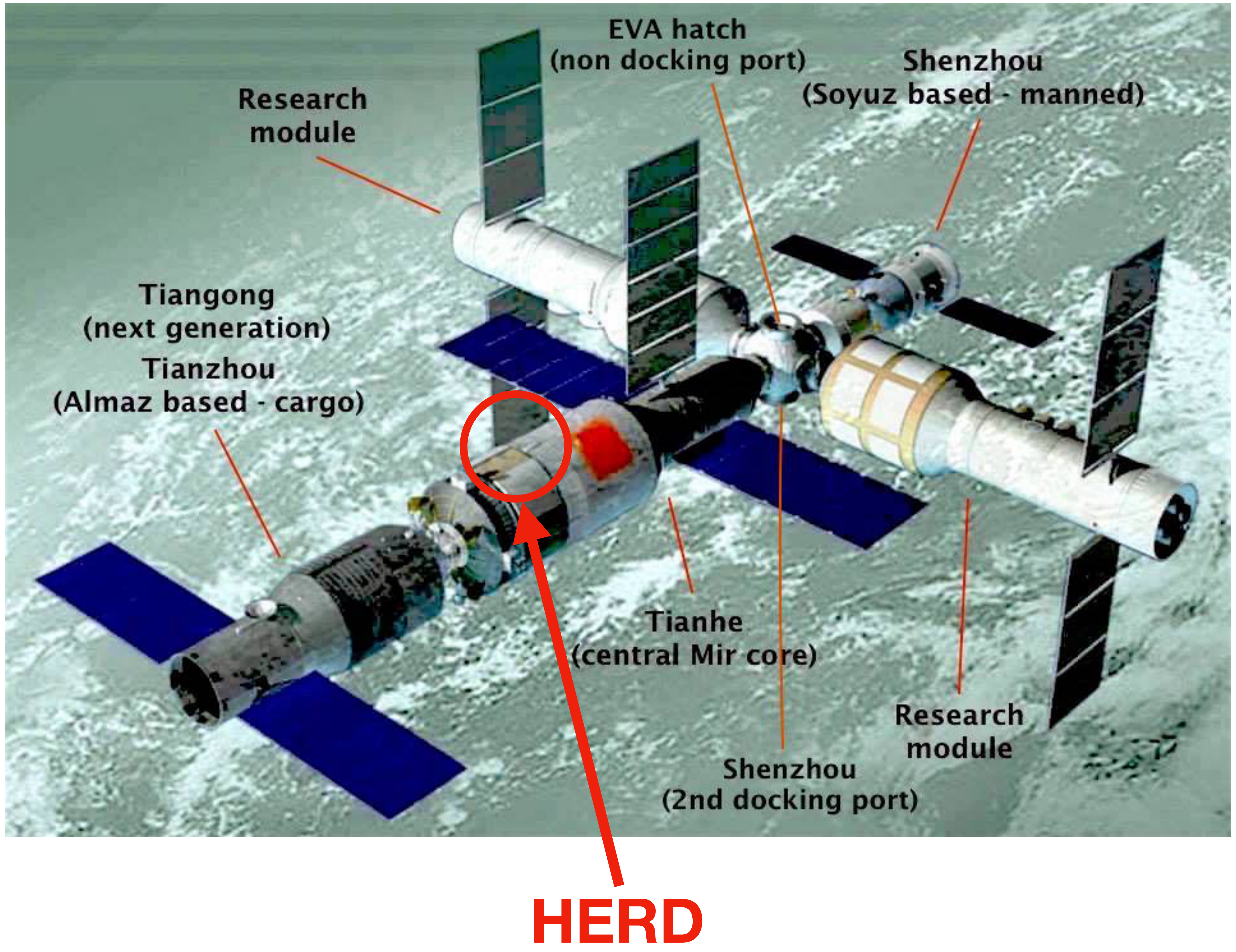
- **Italy:** Università di Pisa/INFN, University of Florence/INFN, **University of Perugia/INFN**, University of Bari/INFN, University of Salento/INFN-Lecce, University of Pavia/INFN, GSSI/INFN
- **Spain:** CIEMAT
- **Switzerland:** University of Geneva

The HERD experiment

Science Goals

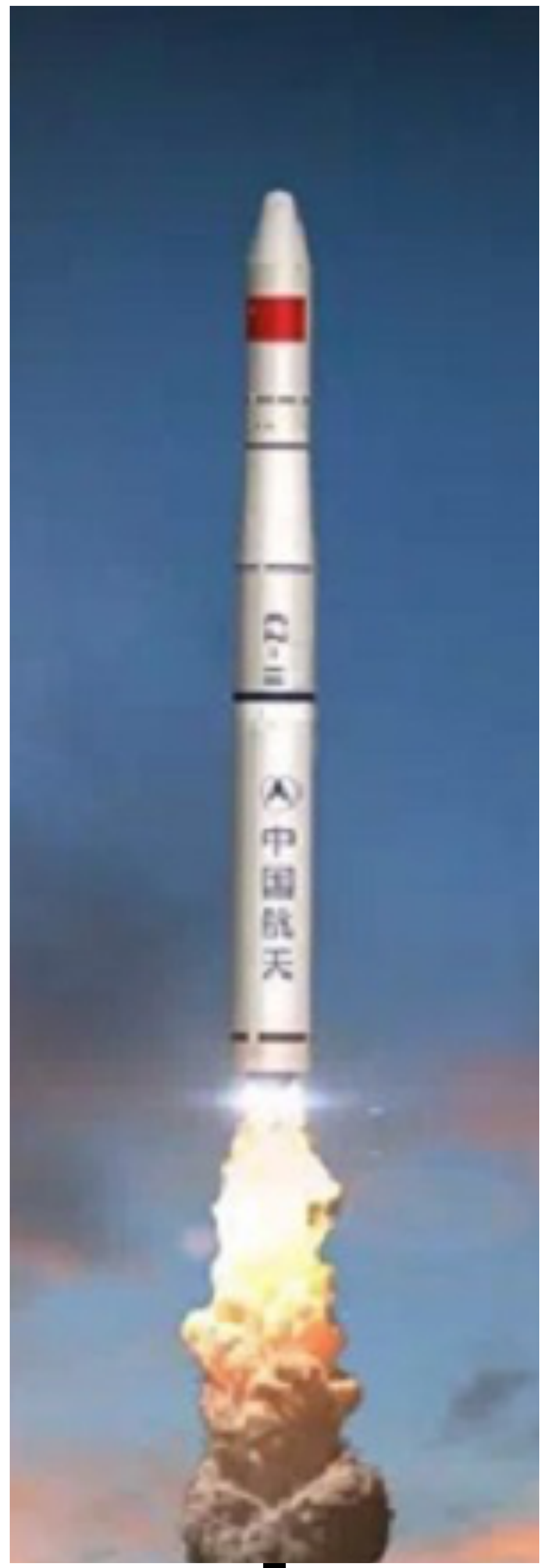
- Dark Matter: better statistical measurements of e/γ @ 0.1-10 TeV
- Origin of Galactic CRs: better spectral and composition measurements of CRs from 30 GeV to PeV with large geometrical factor
- Additional science: γ-ray astronomy, monitoring of GRBs, microquasars, Blazars and other transients, down to ~1 GeV for γ-rays

HERD operating environment



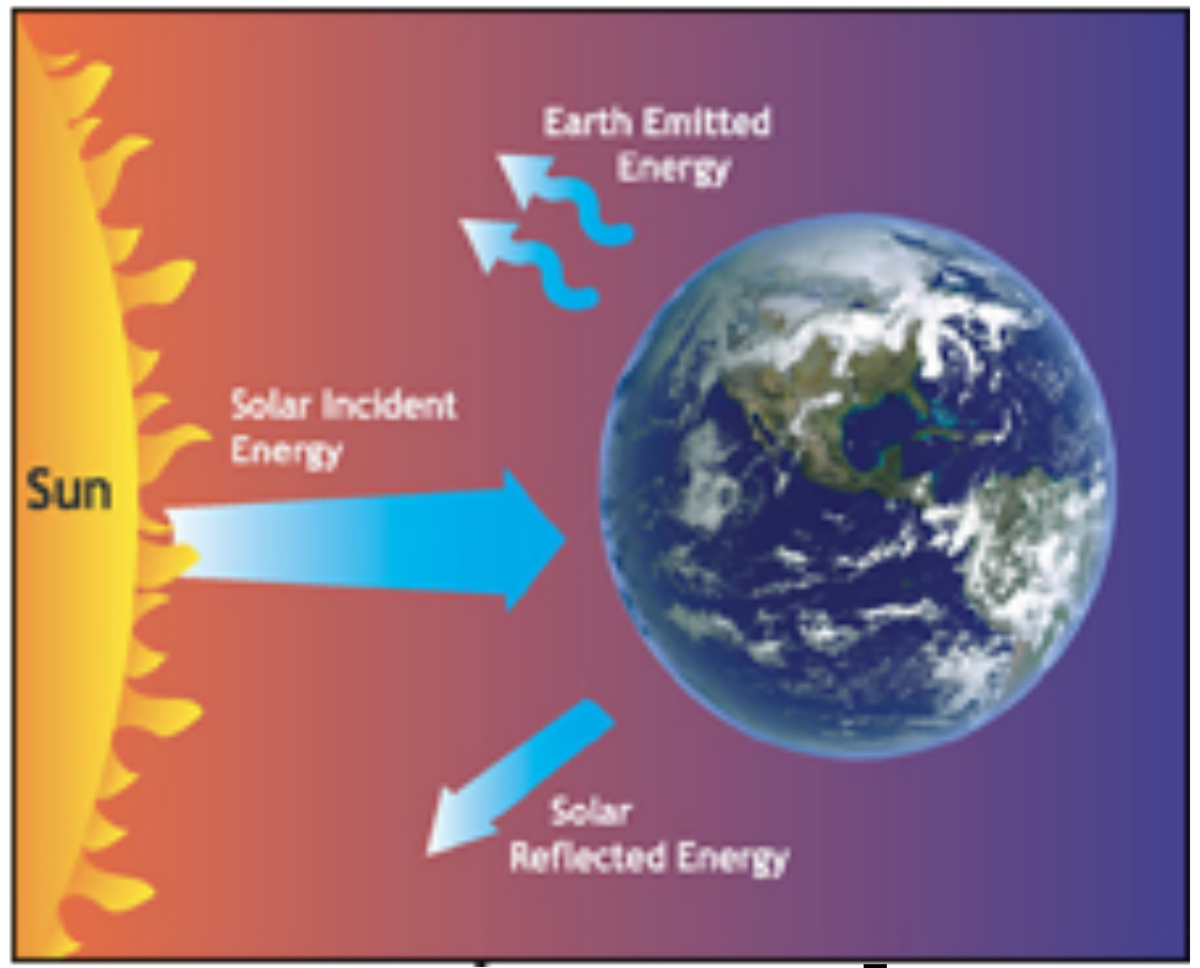
- Mission lifetime: from 2025 to 2035+
- Orbital altitude: 350 - 450 km
- Periapsis altitude: 389.5 km
- Apoapsis altitude: 395 km
- Orbital inclination: 41 - 43 deg
- Orbital period: 92.2 minutes

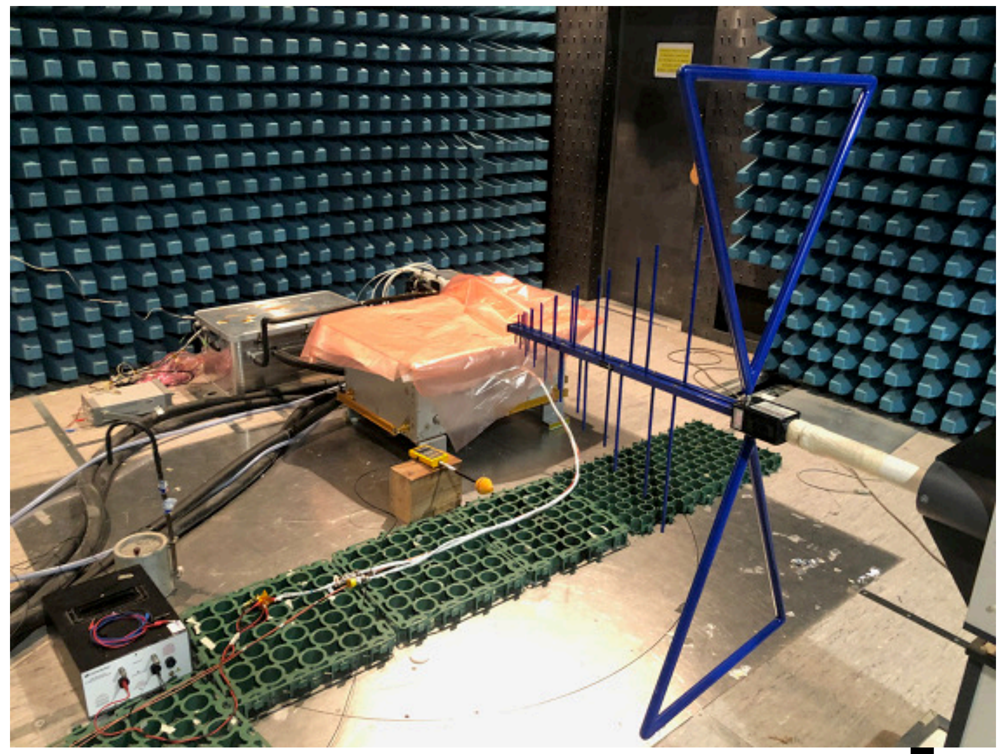
Space environment



Mechanical stresses at launch:
- Static acceleration
- Random vibration
- Sinusoidal vibration
- Shock and pyroshock

Life in space:
- Thermal stresses (seasonal, day/night effects)
- Vacuum (outgassing)
- Radiation





Electromagnetic compatibility:
- EM noise emission and immunity compliance

Careful design and material choice to ensure highest reliability

Space environment - Mechanical loads

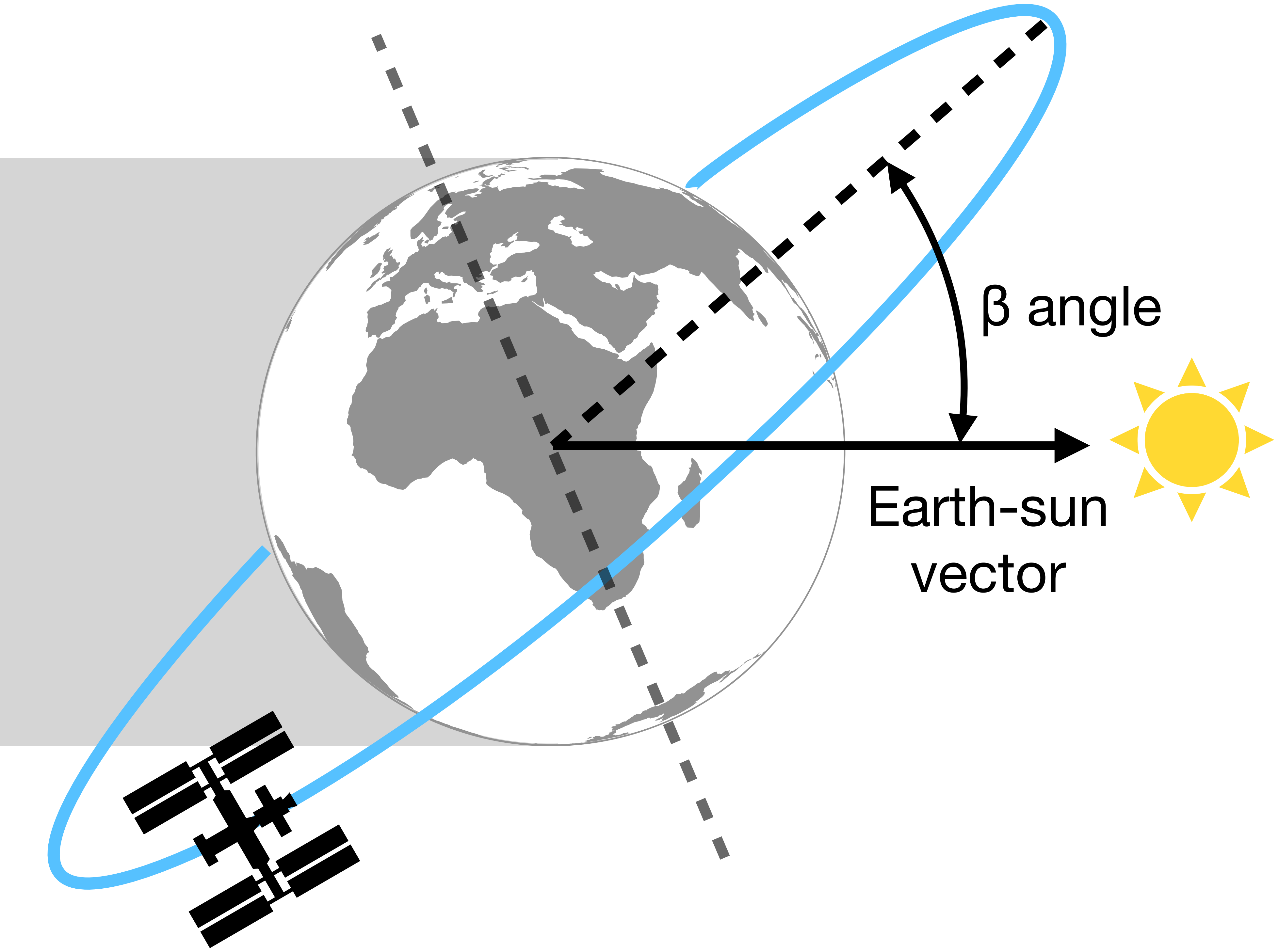
Static Loads	Value	Notes
Along axis	7.5 g	—
Lateral	3.7 g	Two perpendicular directions
Loading rate	≤ 0.5 g/s	—
Hold time	2min	Maximum overload point

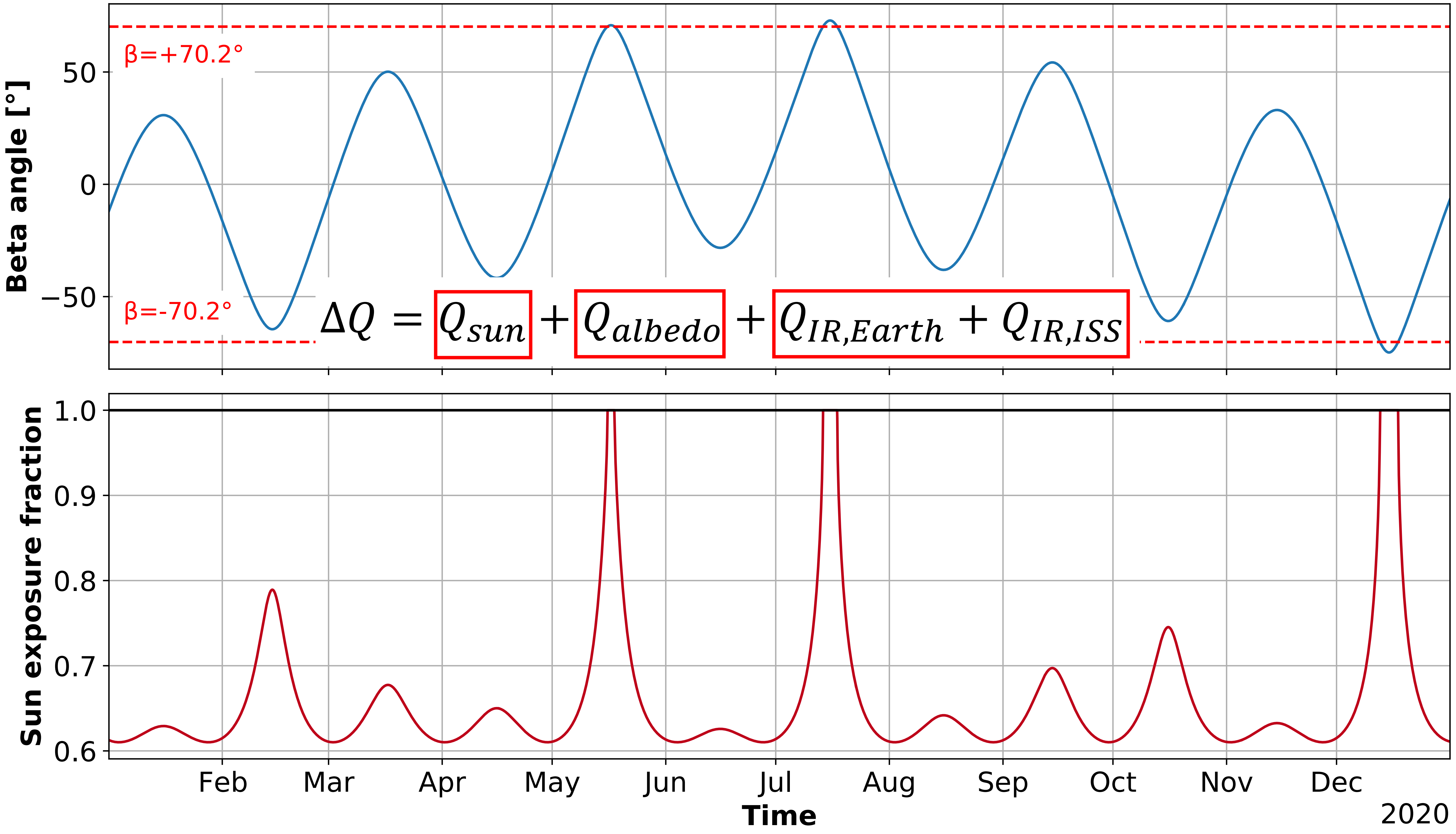
Sinusoidal vibration		Value			
		Frequency (Hz)			
		4-10	10-17	17-75	75-100
Amplitude	Qualification level	22 mm	5.4 g	19.6 g	8.4 g
	Acceptance level	14.7 mm	3.6 g	13 g	5.6 g
Load sweep rate	Qualification level	2 oct/min			
	Acceptance level	4 oct/min			
Loading direction		Three axial			

Shock		Value	
		Frequency (Hz)	
		100-650	650-3000
Acceleration	Qualification level	8 dB/oct	800g
	Acceptance level	8 dB/oct	400g
	Test direction	Three axial	
	Hold time	No more than 20ms	
Number of tests	Qualification level	Three times per axis	
	Acceptance level	Once per axis	

Random Vibration		Value		
		Frequency (Hz)		
		10-250	250-800	800-2000
Power spectral density	Qualification level	6 dB/oct	0.4 g^2/Hz	-9 dB/oct
	Acceptance level	6 dB/oct	0.16 g^2/Hz	-9 dB/oct
Total RMS acceleration	Qualification level	19.6 grms		
	Acceptance level	12.4 grms		
Hold time of every direction	Qualification level	180 s		
	Acceptance level	60 s		
Loading direction		Three axial		

Space environment - Thermal loads





- β angle
- Space station flight attitude
- Surface optical properties (α/ε)
- Surface orientation
- Shadowing (temporary or planned)
- Unexpected scenarios (i.e. power cut)

SERMS Laboratory

University of Perugia / INFN Perugia / University Spin-off

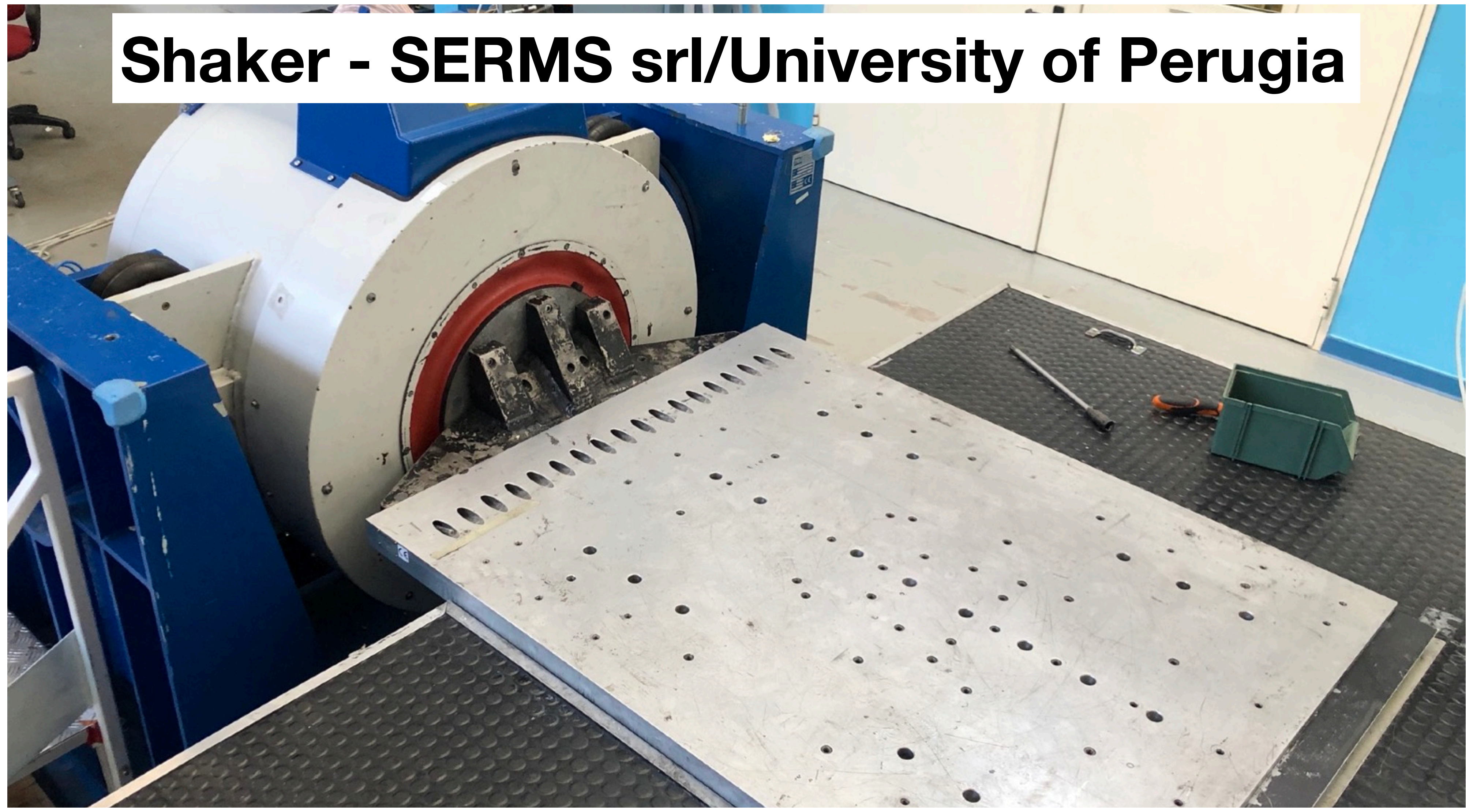
Space environment - Mechanical loads

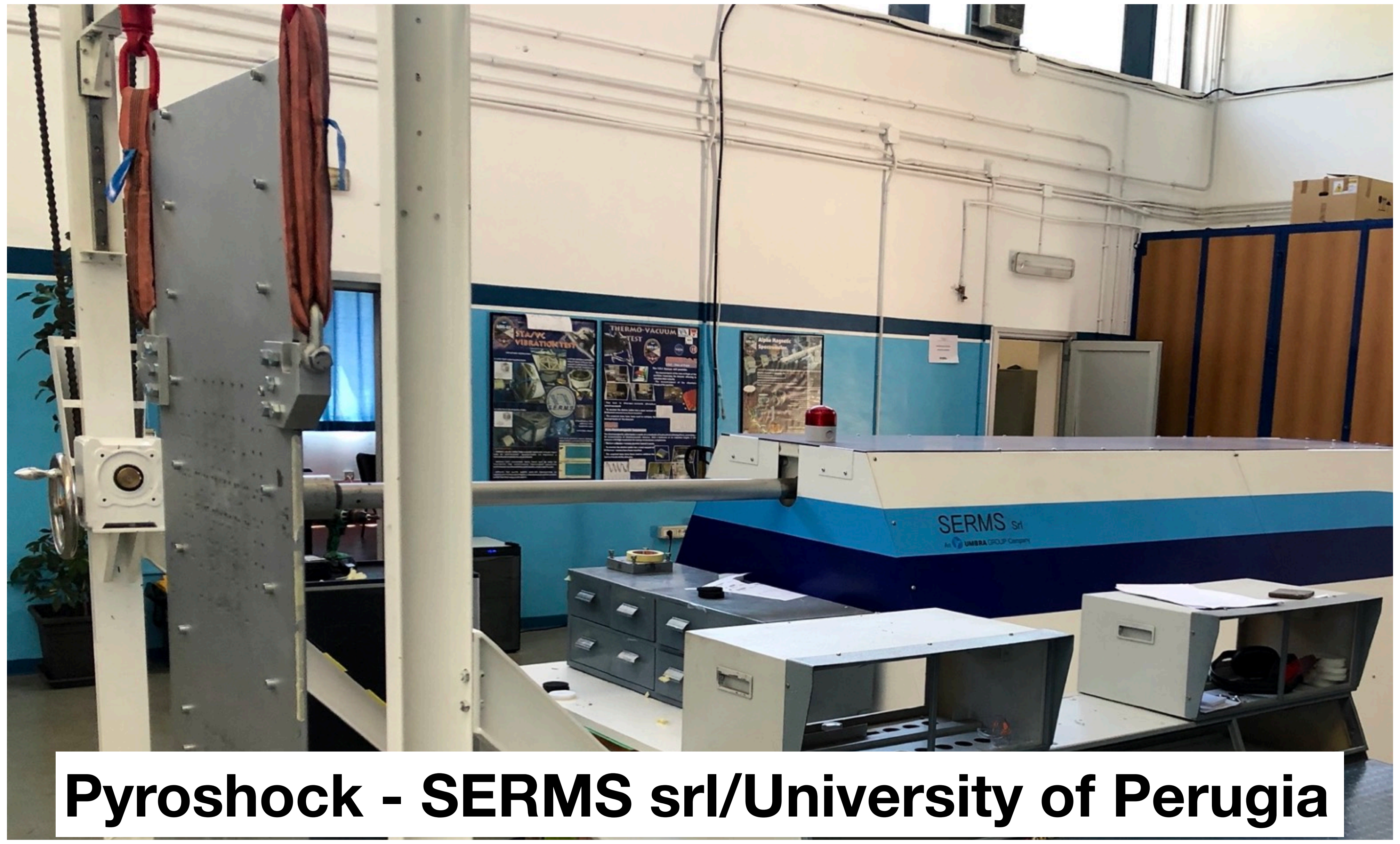
Electrodynamic shaker

- Frequency range: 5 - 3000 Hz
- Force: 49.5 kN
- Max acceleration: 100 g
- Max velocity: 2 m/s
- Max displacement: 54 mm_{p-p}

Pyroshock simulator

- Frequency range: 0.1 - 10 kHz typ.
- Max SRS acceleration: 12000 g


Shaker - SERMS srl/University of Perugia



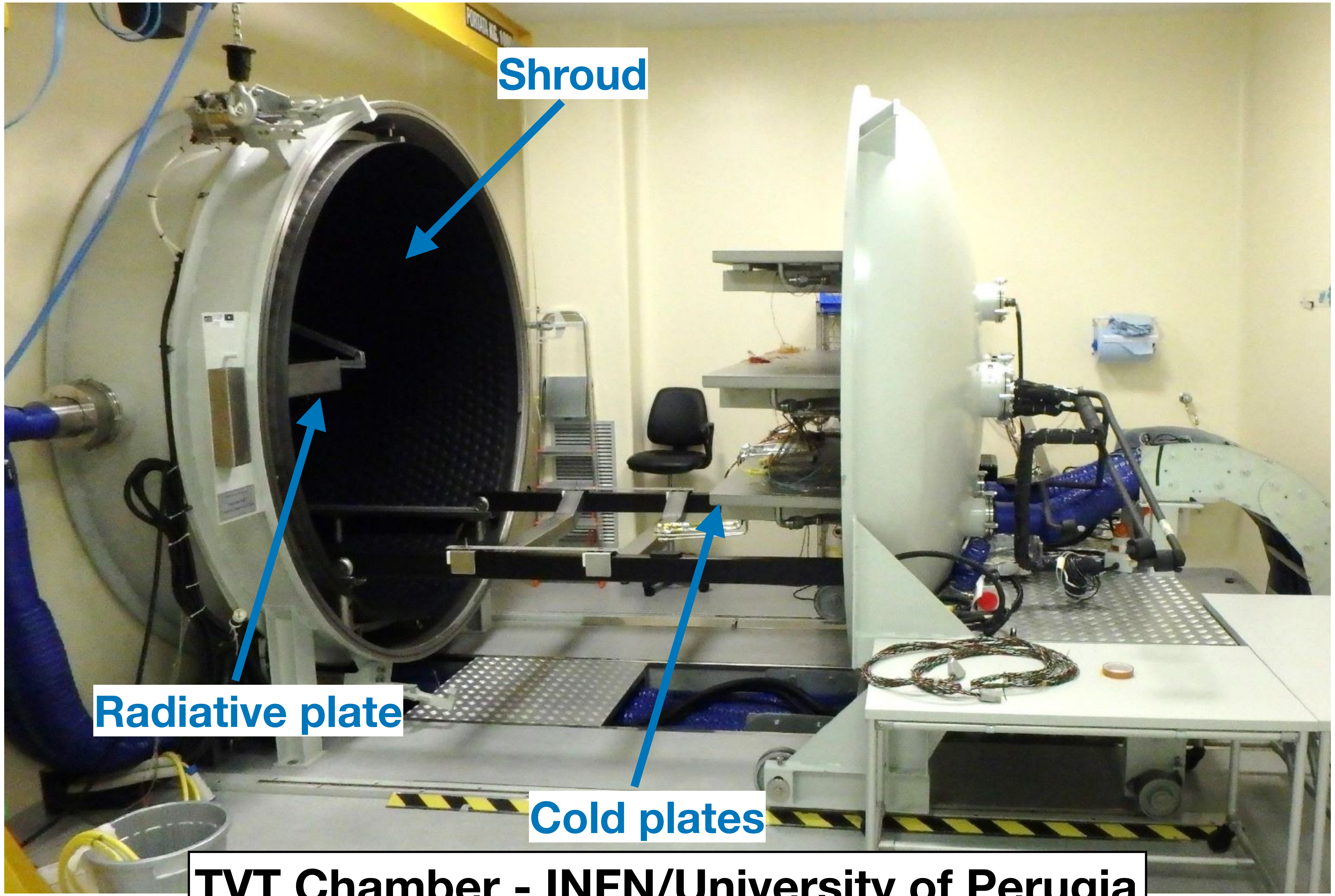
Pyroshock - SERMS srl/University of Perugia

Space environment - Thermal loads

Thermal vacuum chamber

- Dimensions: 2.1 x 2.1 m^2 (Lxϕ)
- P < 10-5 mbar
- -70 °C < T < 125 °C
- Thermal fluxes recreated via radiation or conduction

Simulation of orbital extreme condition and particular operative conditions

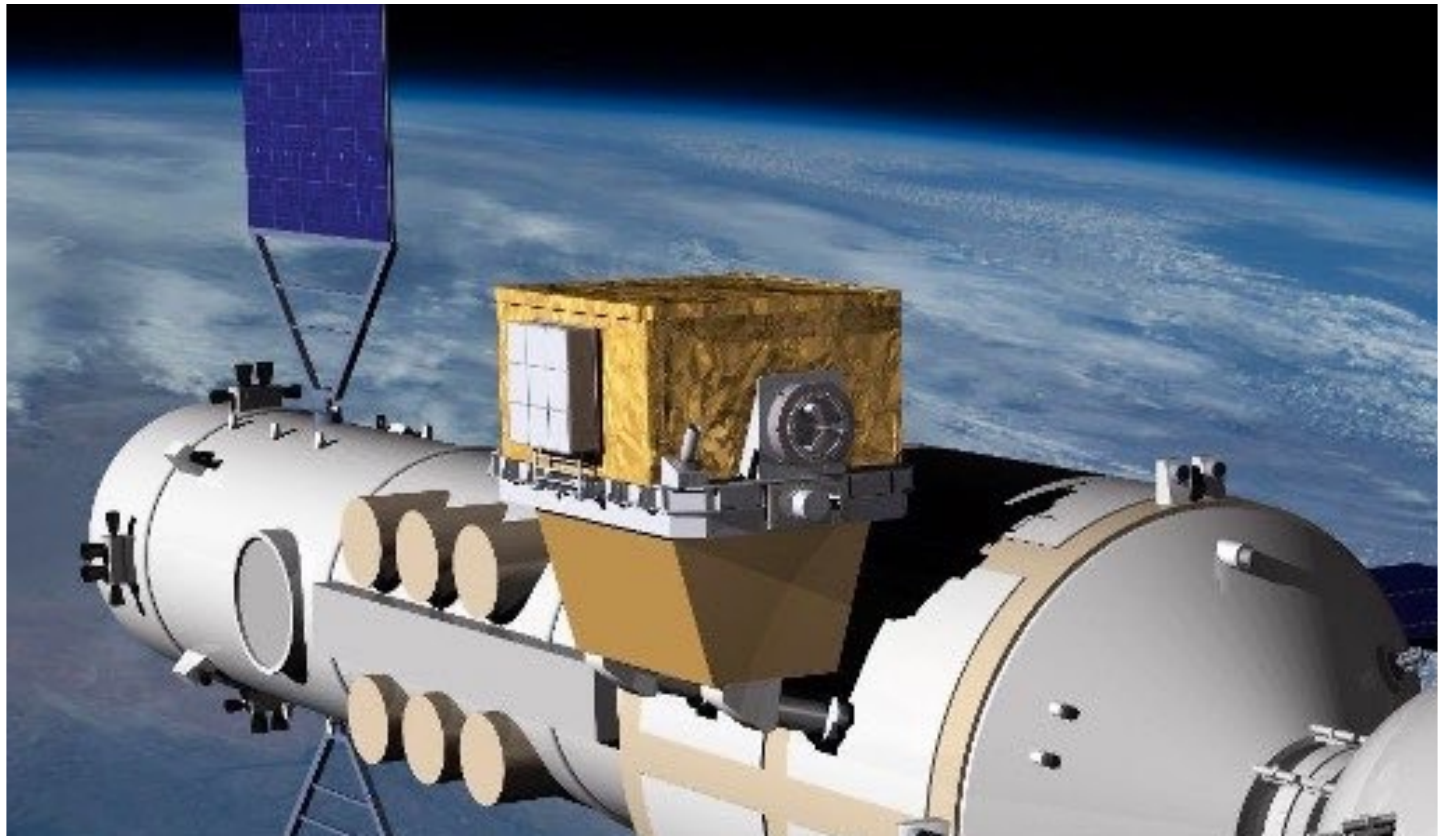


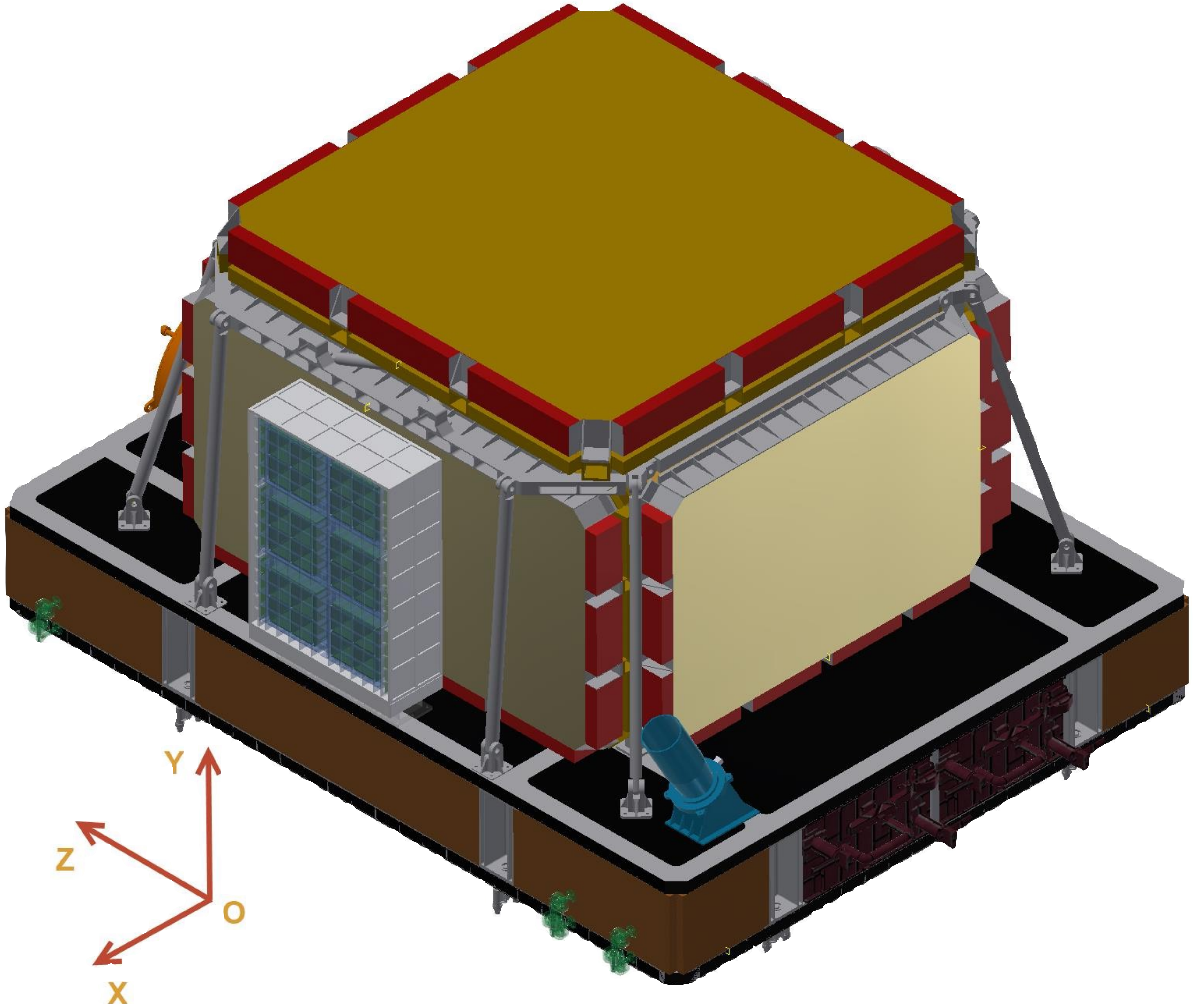
TVT Chamber - INFN/University of Perugia

The HERD experiment

HERD in numbers:

- Overall weight: 3.2 tons
- Overall dimensions: 3 x 2.3 x 1.5 m^3
- Energy range (CRs): 30 GeV - 3 PeV
- FoV: +/- 70°
- Lifetime: ~ 10 years





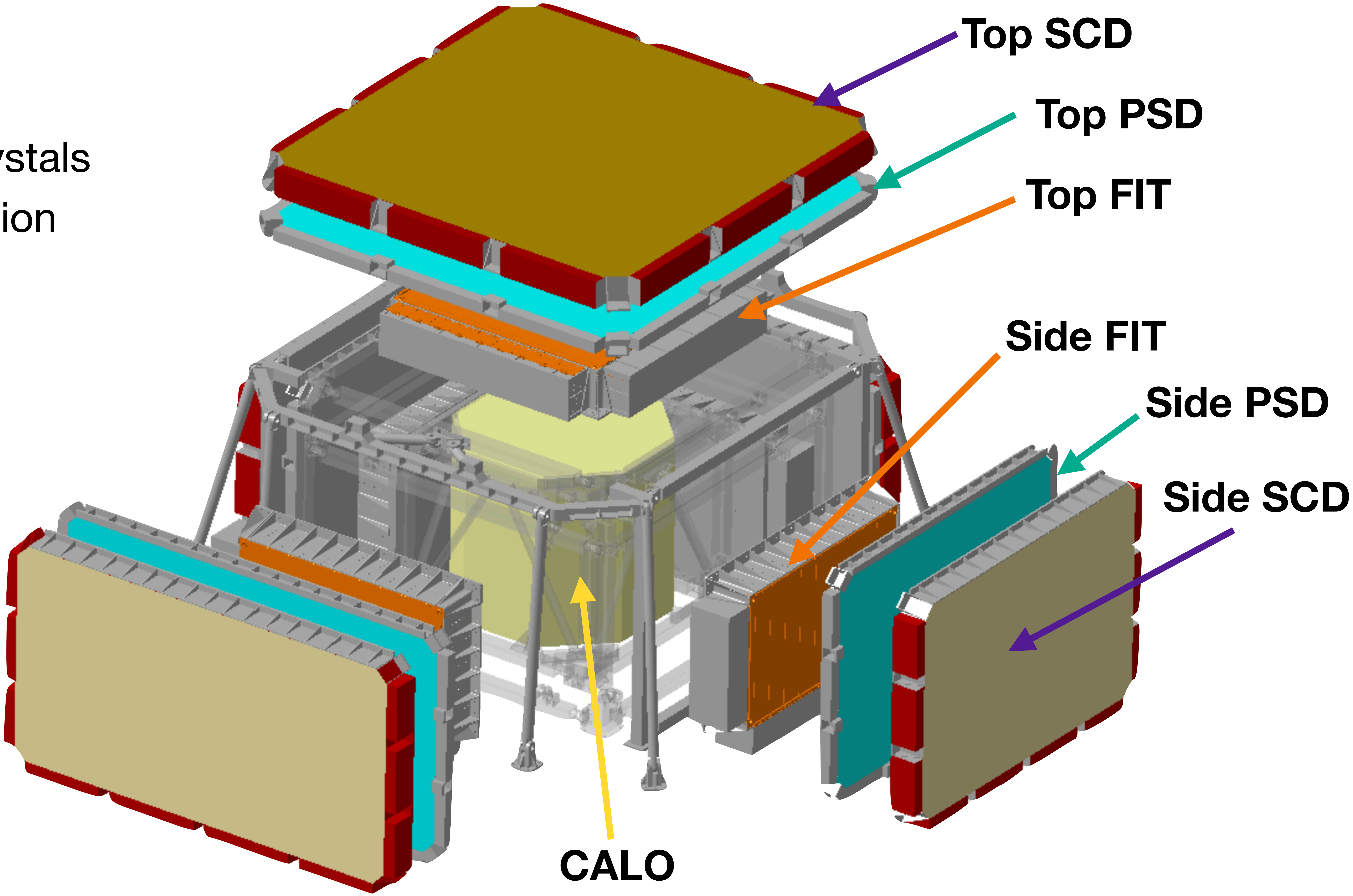
The HERD detectors

Calorimeter (CALO)
- Octogonal prism made of LYSO crystals
- Energy measurement + e/p separation

FIber Tracker (FIT)
- Track reconstruction

Plastic Scintillator Detector (PSD)
- Charged particles + gamma trigger
- Charge measurement

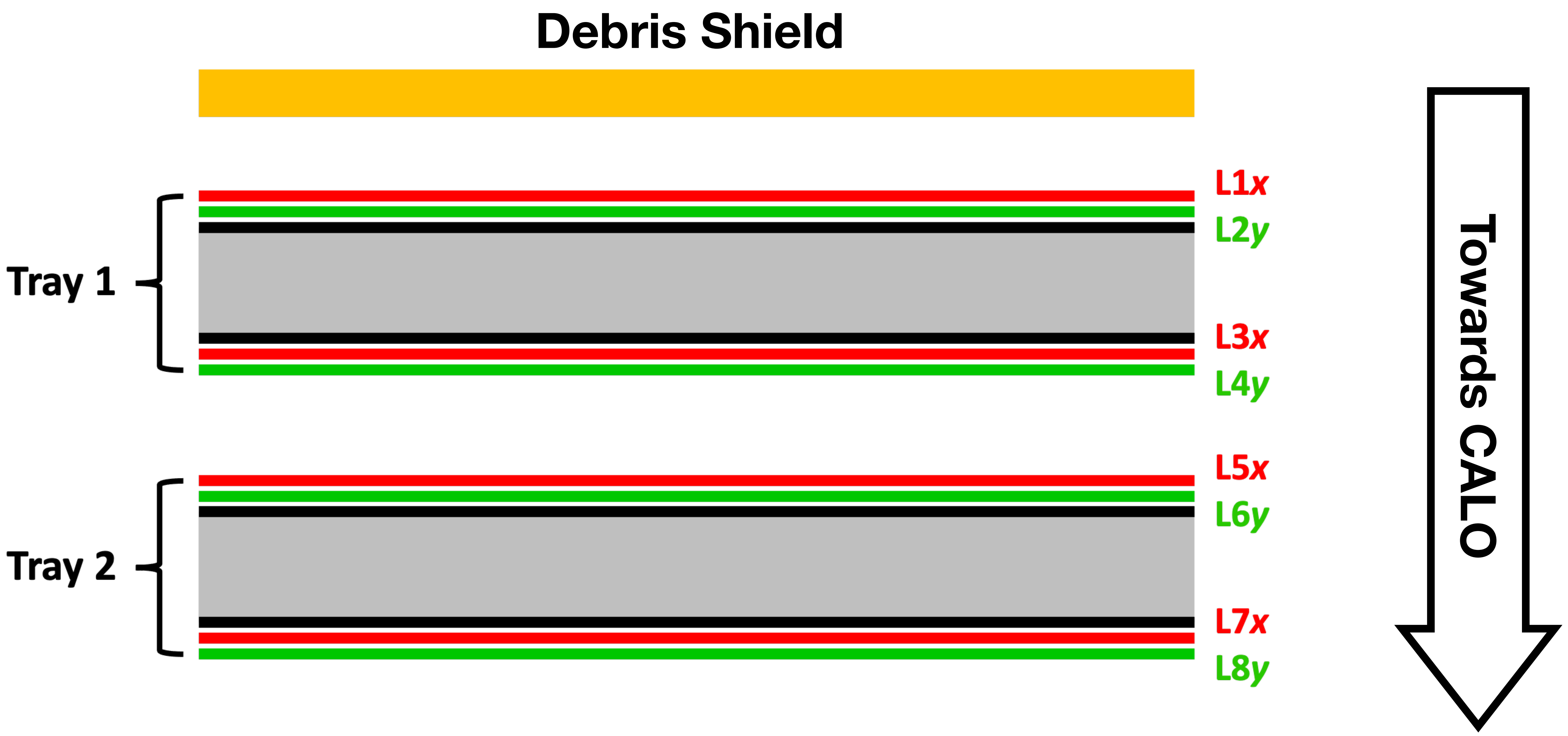
Silicon Charge Detector (SCD)
- Single sided Silicon Strip Detectors
- Charge measurement



Silicon Charge Detector (SCD)

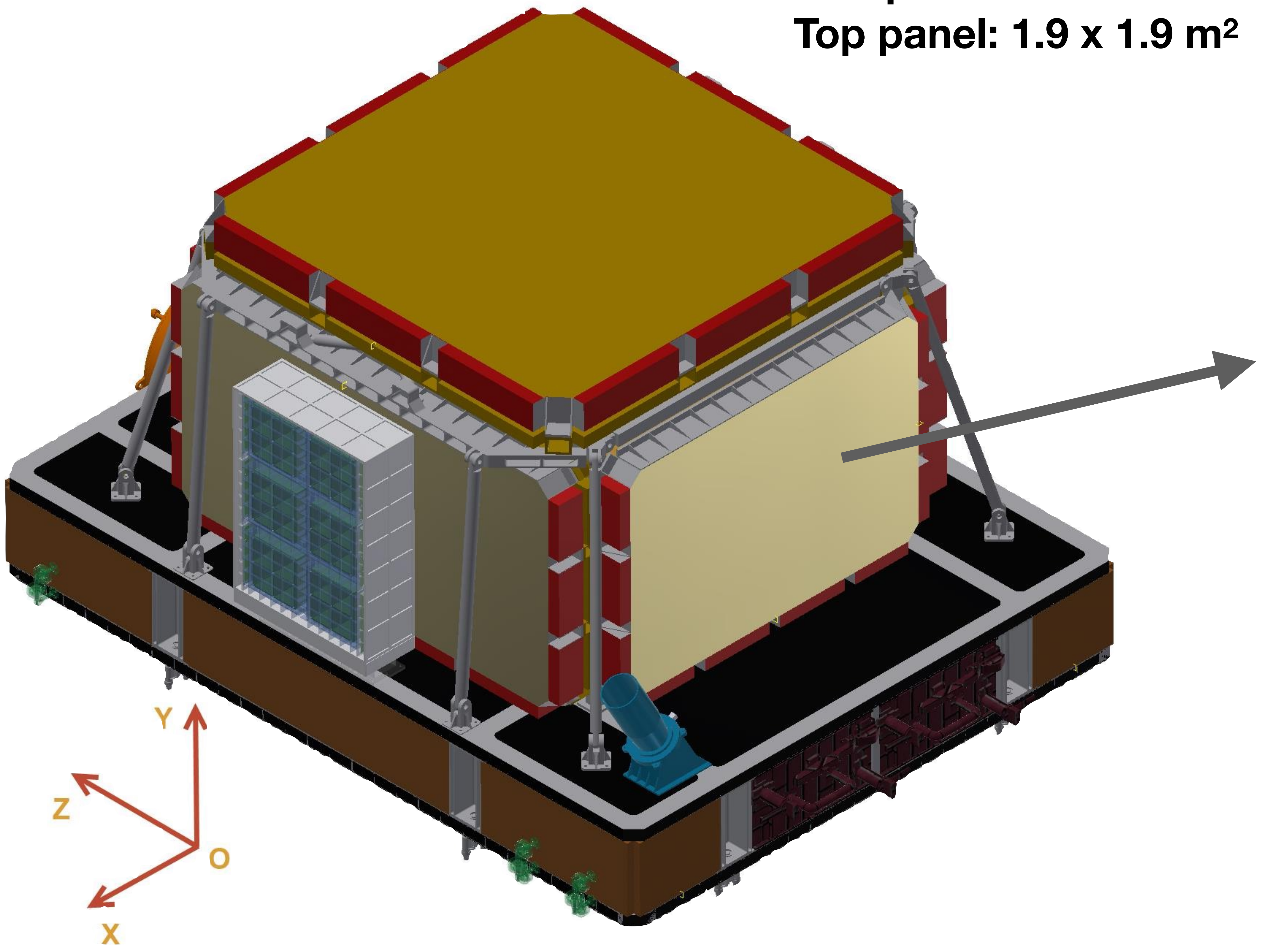
Preliminary design:

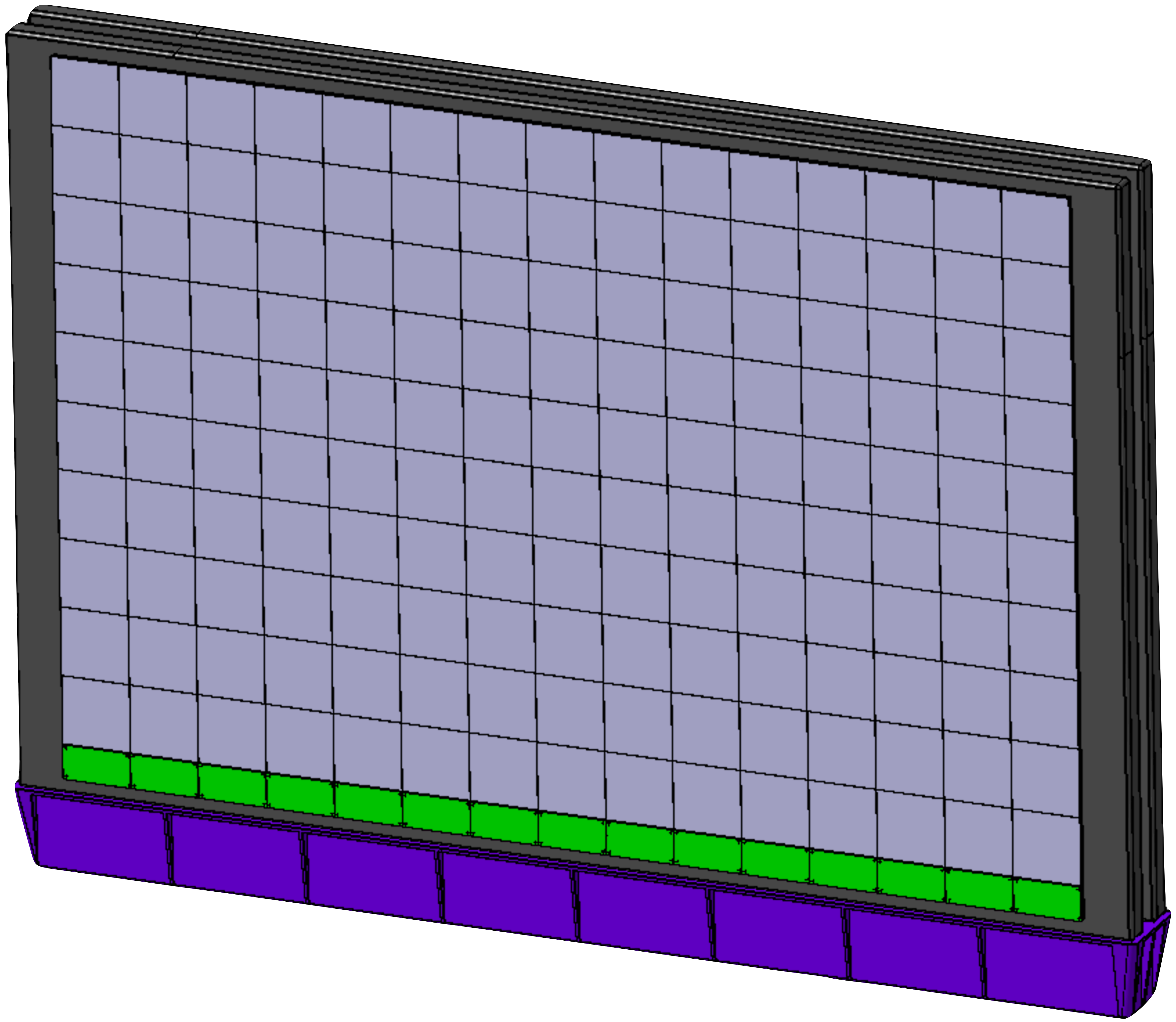
- Single sided silicon strip detector (SSD)
- Two mechanical planes per SCD
- Four silicon layers per mechanical plane
- 15x10 silicons per layer on side SCD
  18x18 silicons per layer on top SCD
- Total of 1200 silicon per side SCD
  Total of 2592 silicons on top SCD
- Grand total of 3792 silicons



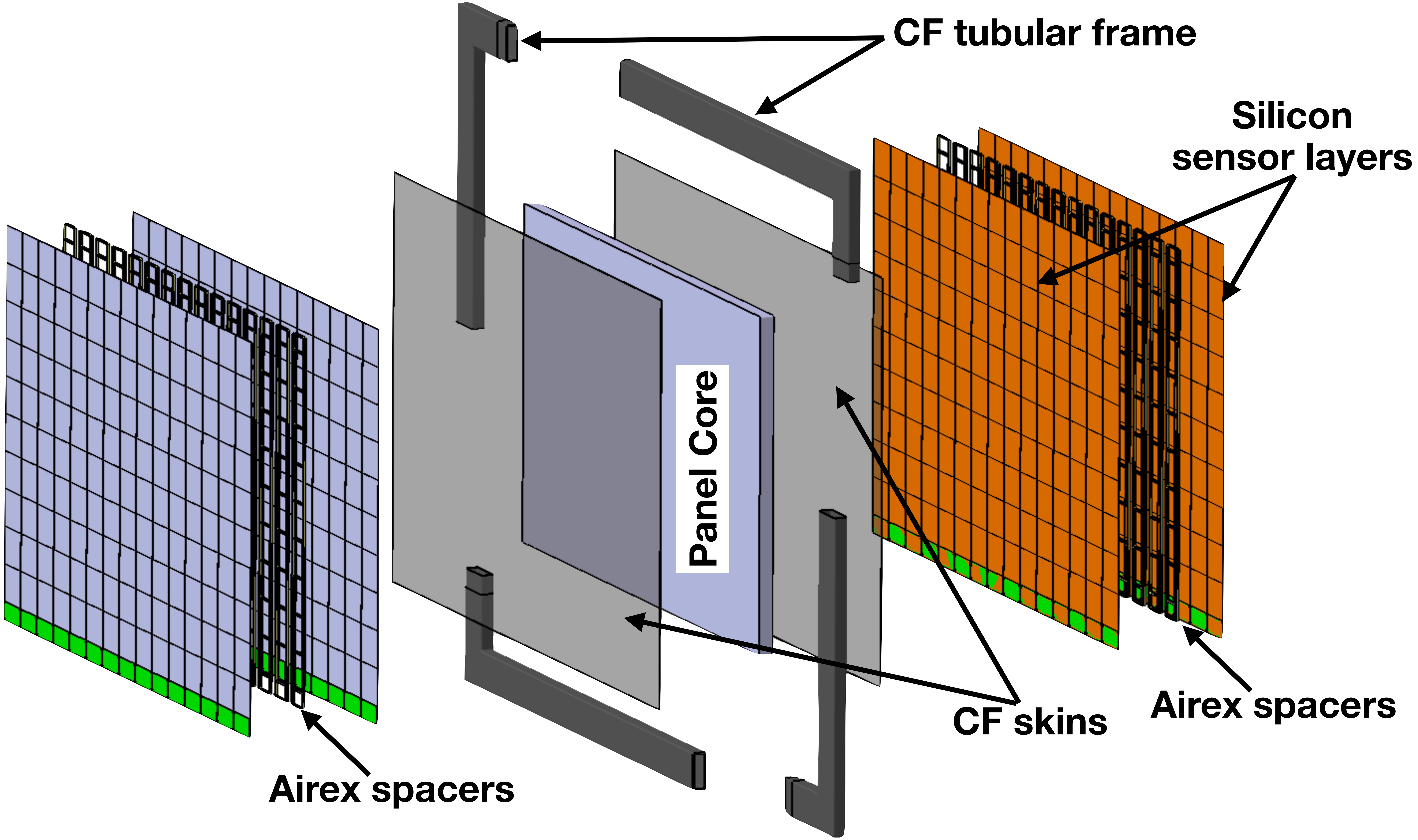
Silicon Charge Detector (SCD)

SSD: 100x100 mm²
Side panel: 1.6 x 1.1 m²
Top panel: 1.9 x 1.9 m²





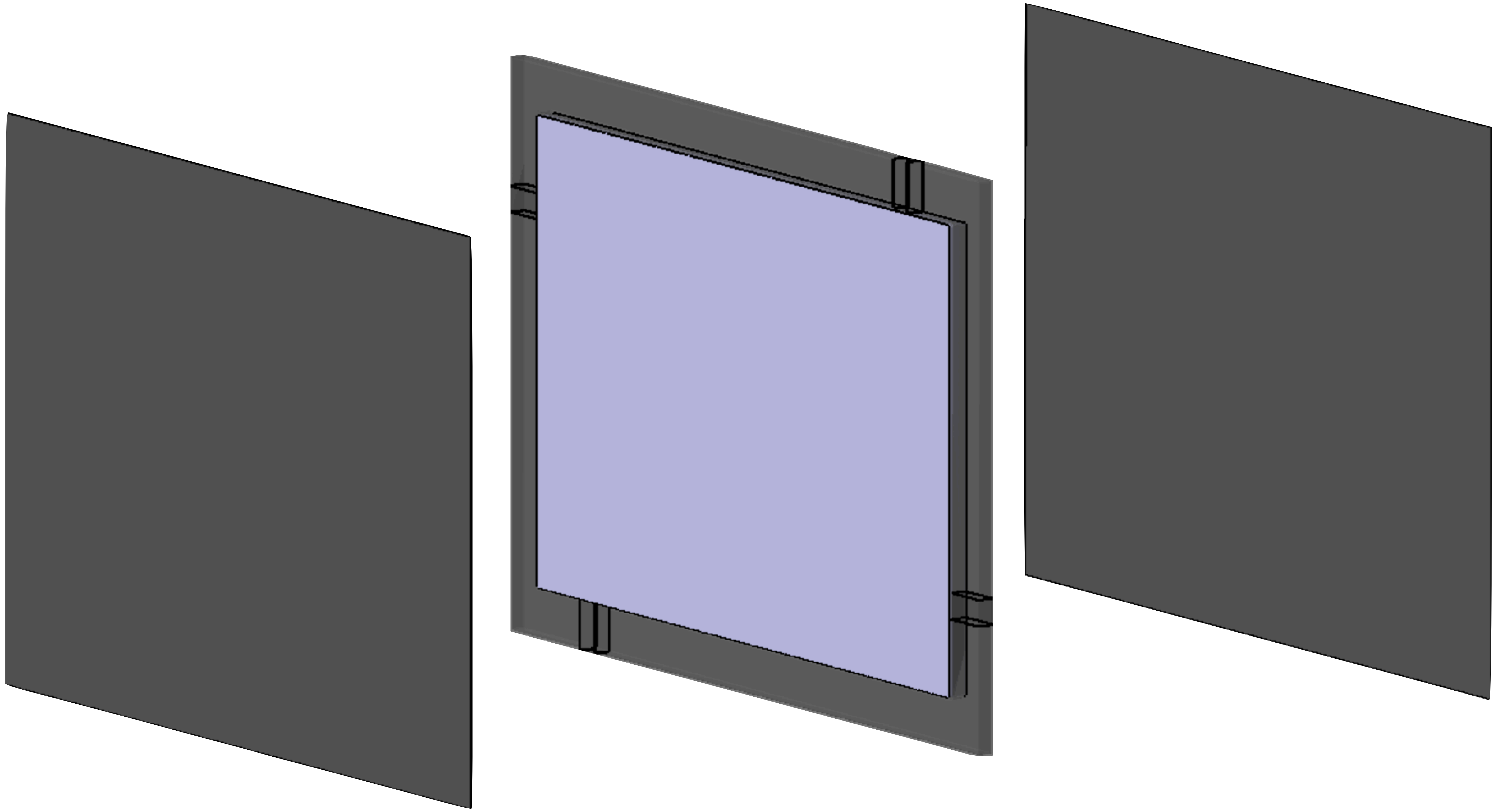
Silicon Charge Detector (SCD)



Mechanical structure - Overview

Composition:

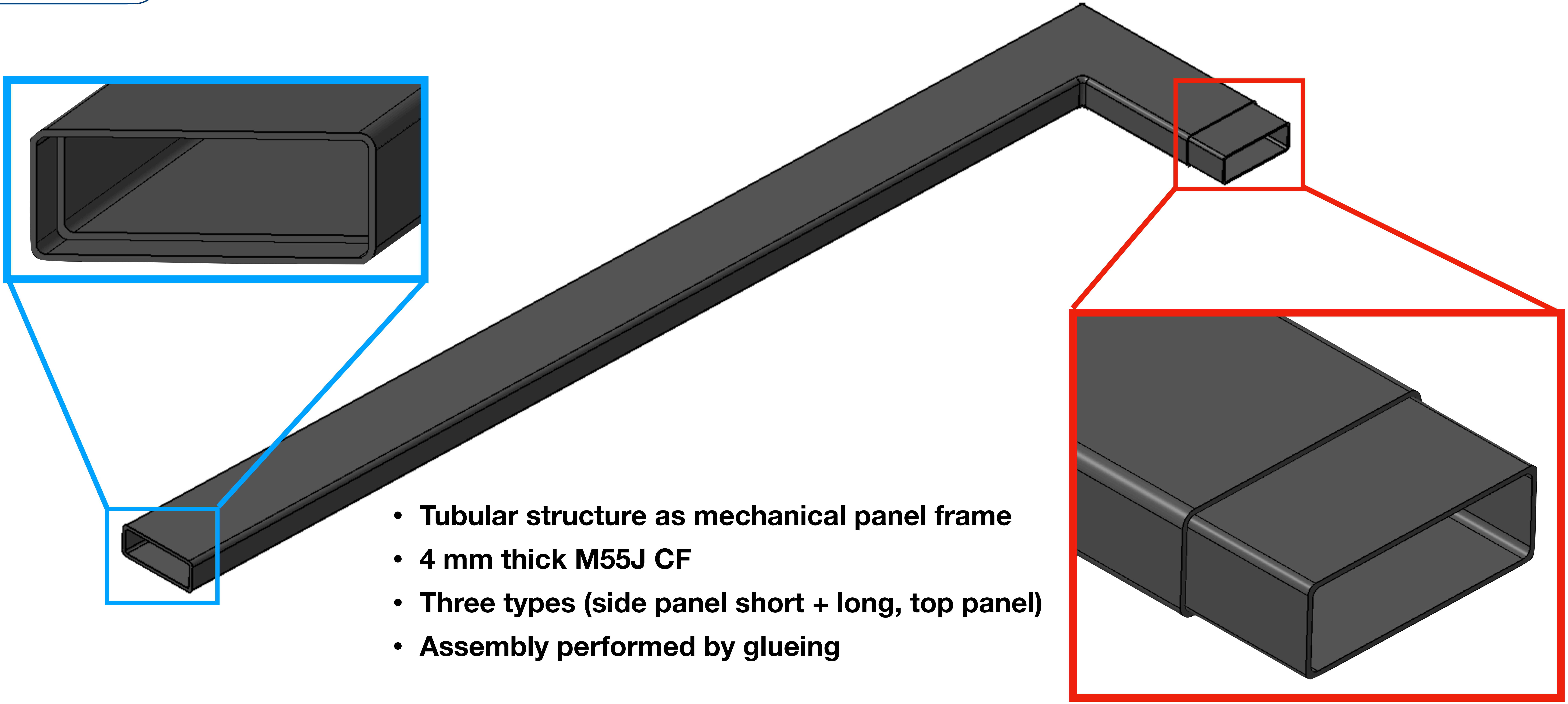
- Overall thickness for side panels: 40 mm
- Tubular structure as mechanical panel frame
- Central core 38 mm thick
  - Aluminum HC
  - CF Isogrid/orthogrid
- Top and bottom skins 1mm thick M55J



Scope:

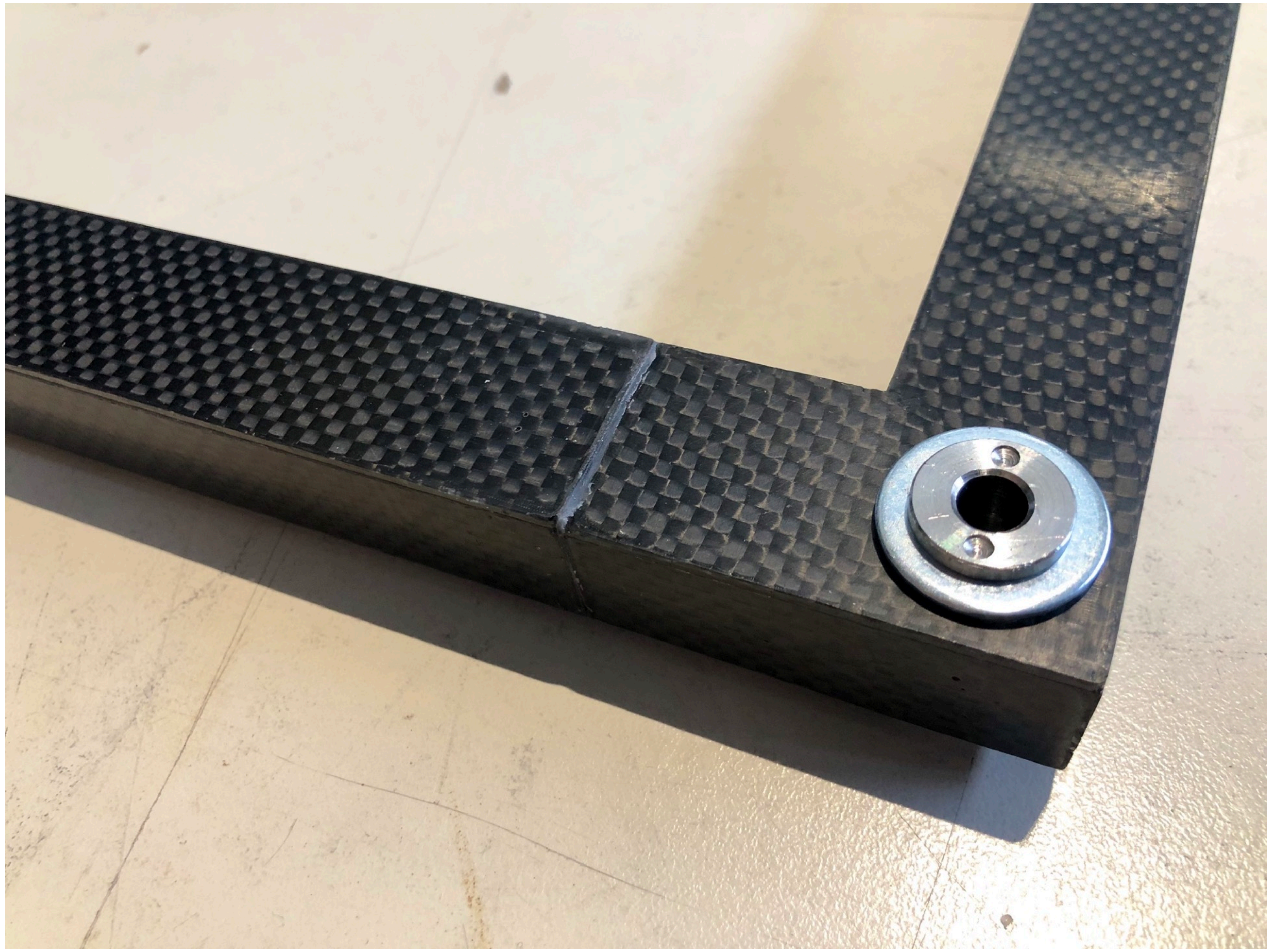
- Withstand mechanical loads at launch
- Thermal stability on orbit
- Reduced water absorption/desorption

Mechanical structure - Frame



- **Tubular structure as mechanical panel frame**
- **4 mm thick M55J CF**
- **Three types (side panel short + long, top panel)**
- **Assembly performed by glueing**

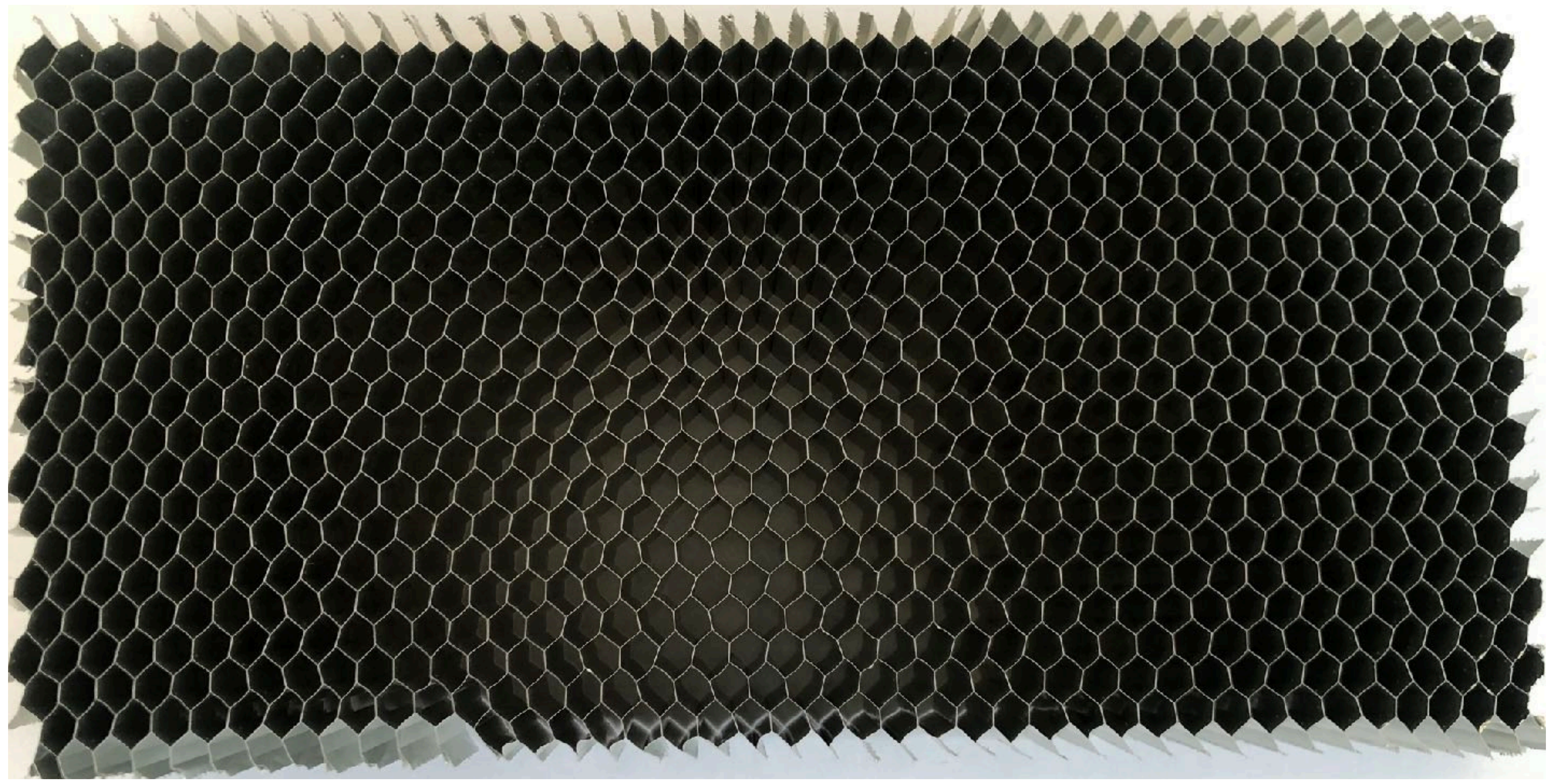
Mechanical structure - Frame



Mechanical structure - Core

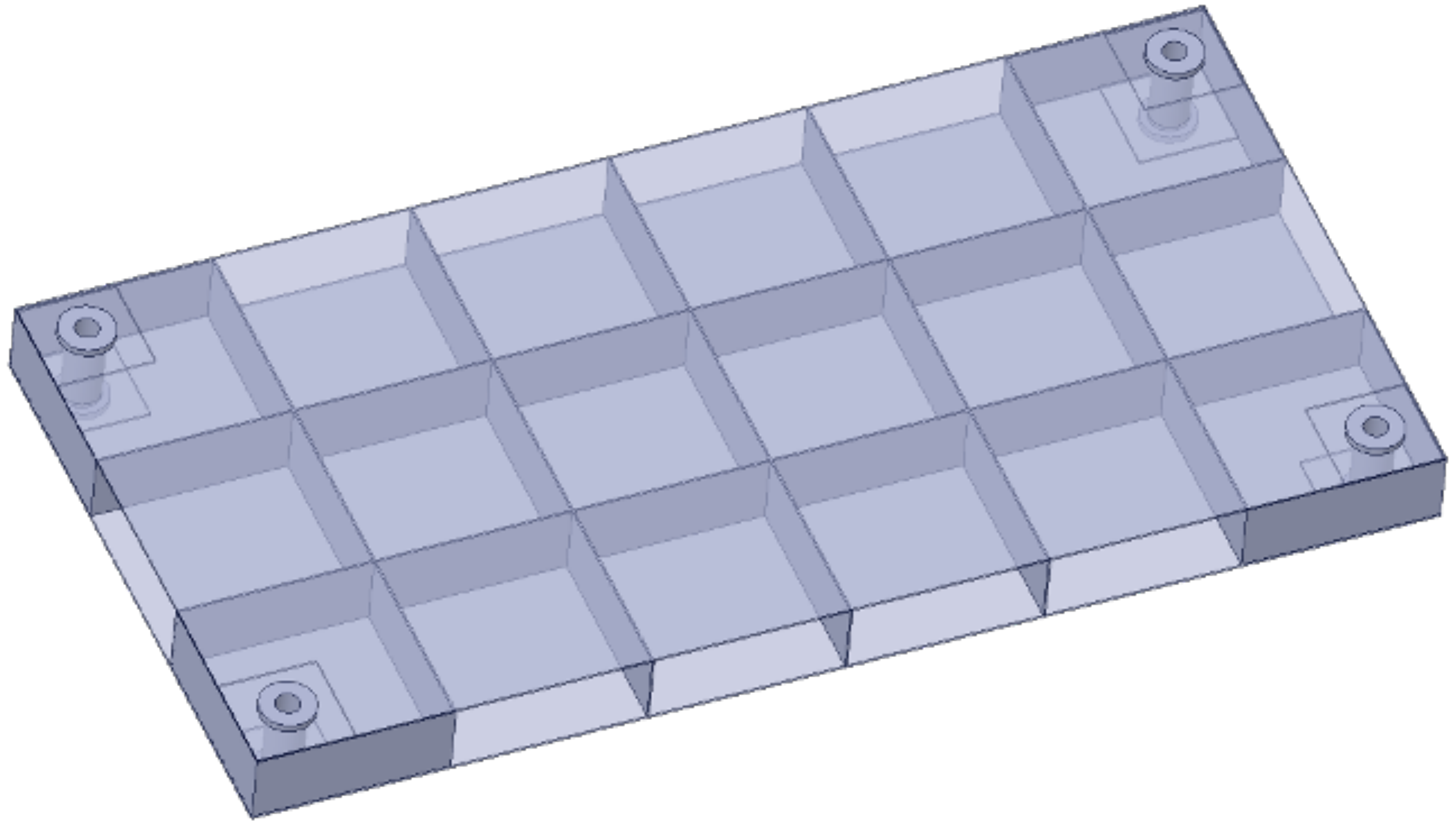
Aluminum honeycomb

- Hexcell CR-III-1/4-5052-2.3P
- Space grade HC
- Density ~ 38 kg/m^3
- Heritage from several experiments



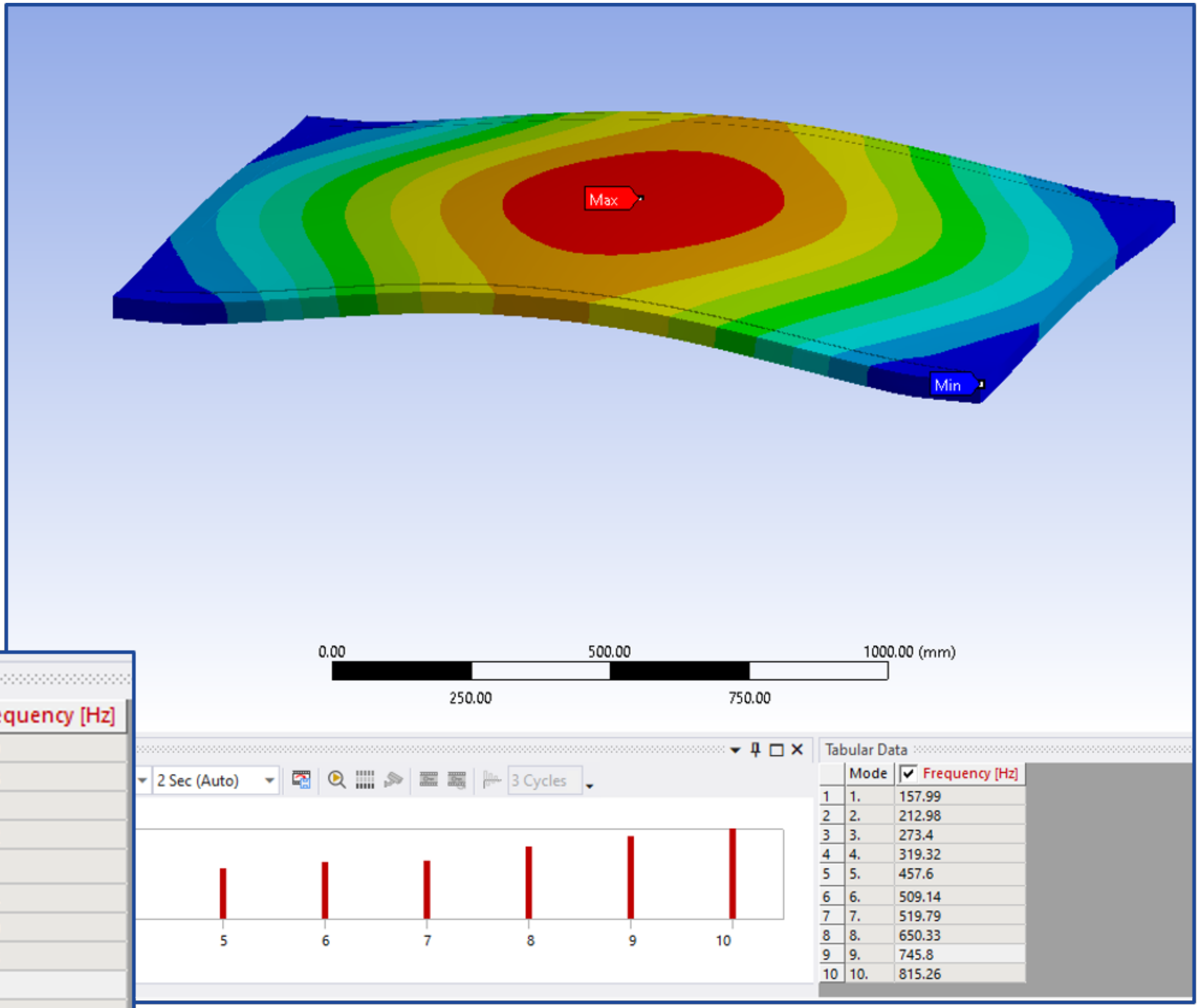
CF orthogrid

- No CTE mismatch
- More thermal stability
- M55J fiber walls
- Better for GEANT4 simulation



Mechanical structure - Orthogrid

- **Mechanical FEA to simulate effect of different cores**
- **Design parameters:**
  - **1st resonant frequency**
  - **Overall mass**
- **Comparison of several orthogrid topologies to HC**



	Mode	Frequency [Hz]
1	1.	157.99
2	2.	212.98
3	3.	273.4
4	4.	319.32
5	5.	457.6
6	6.	509.14
7	7.	519.79
8	8.	650.33
9	9.	745.8
10	10.	815.26

Tabular Data

	Mode	Frequency [Hz]
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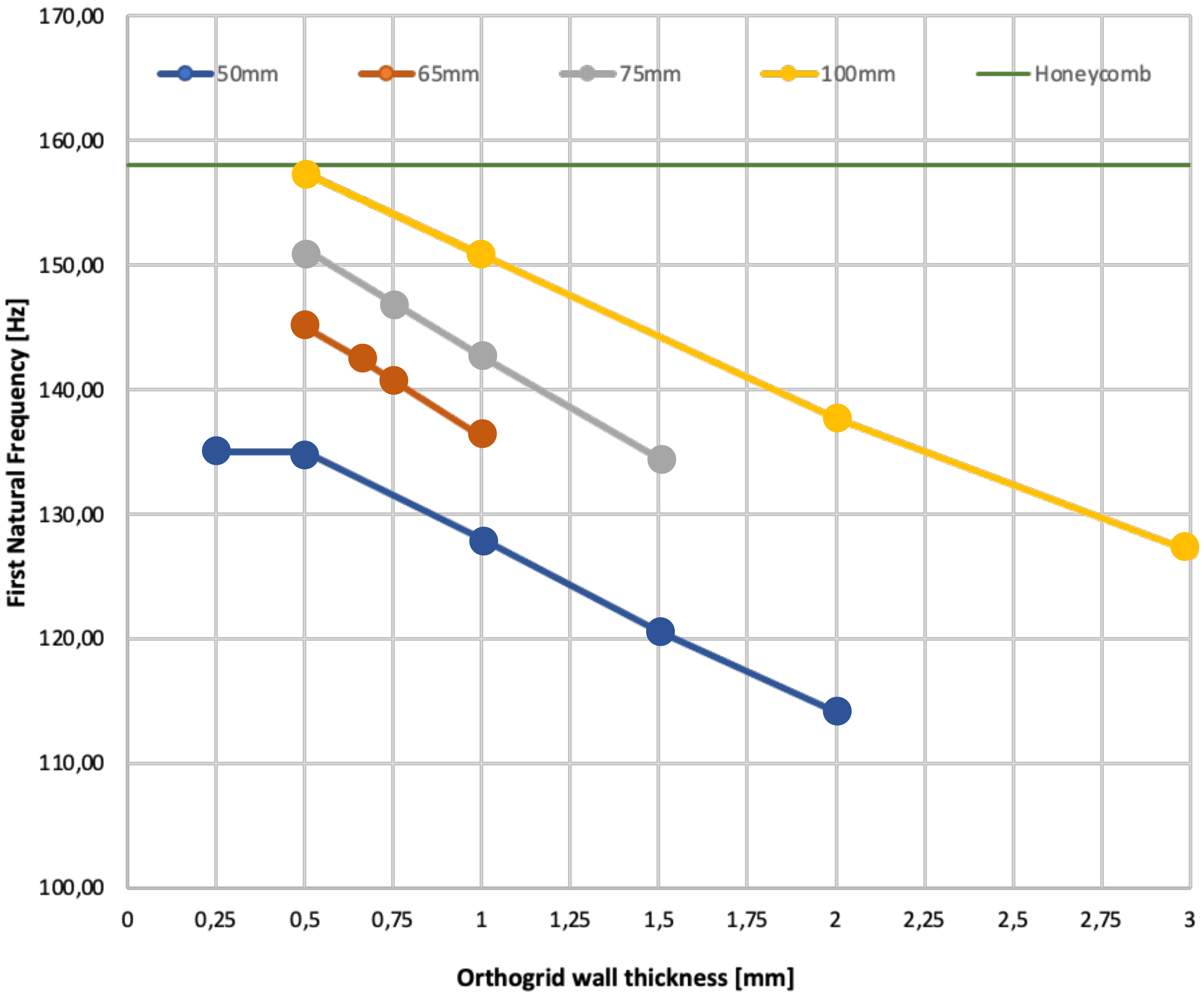
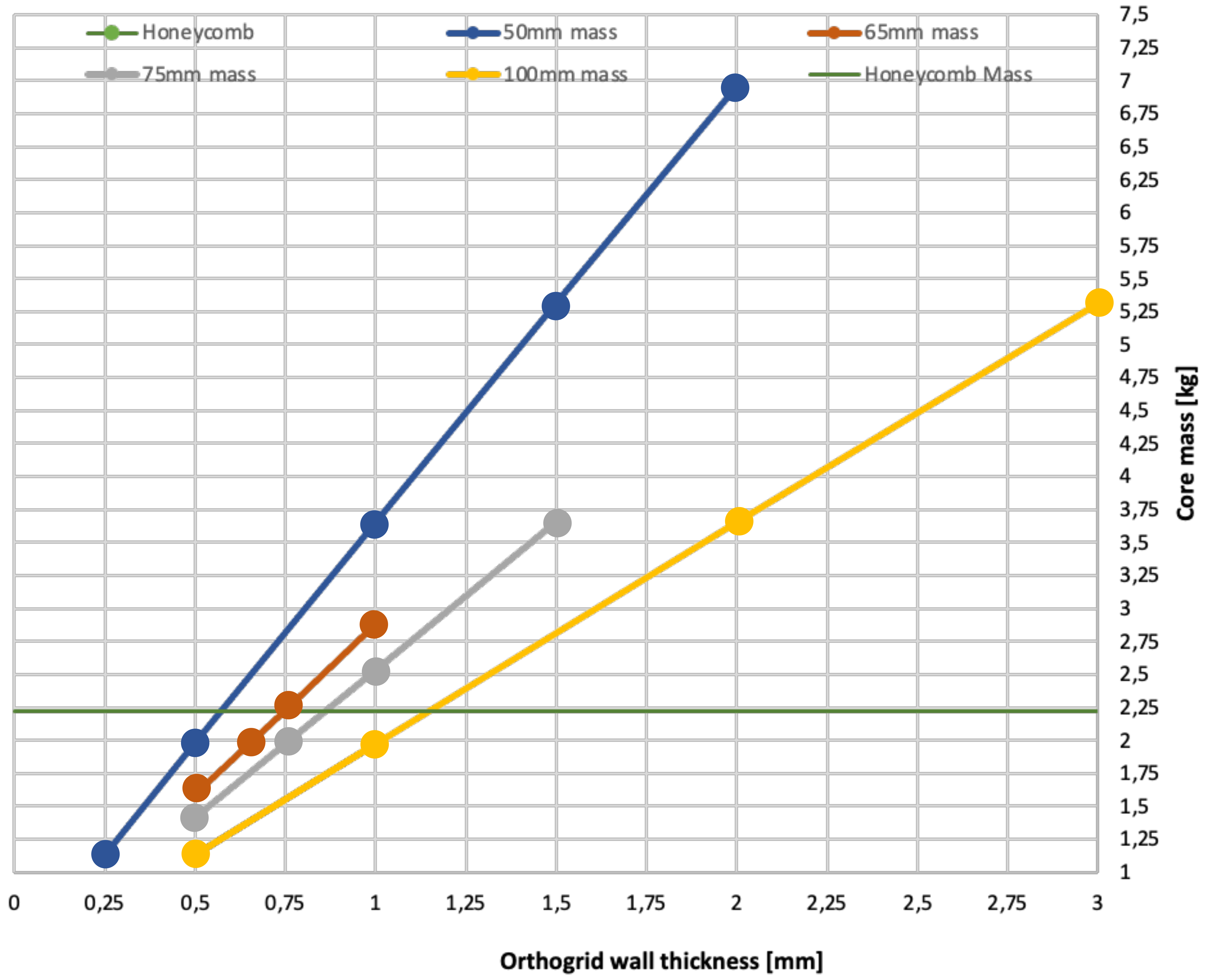
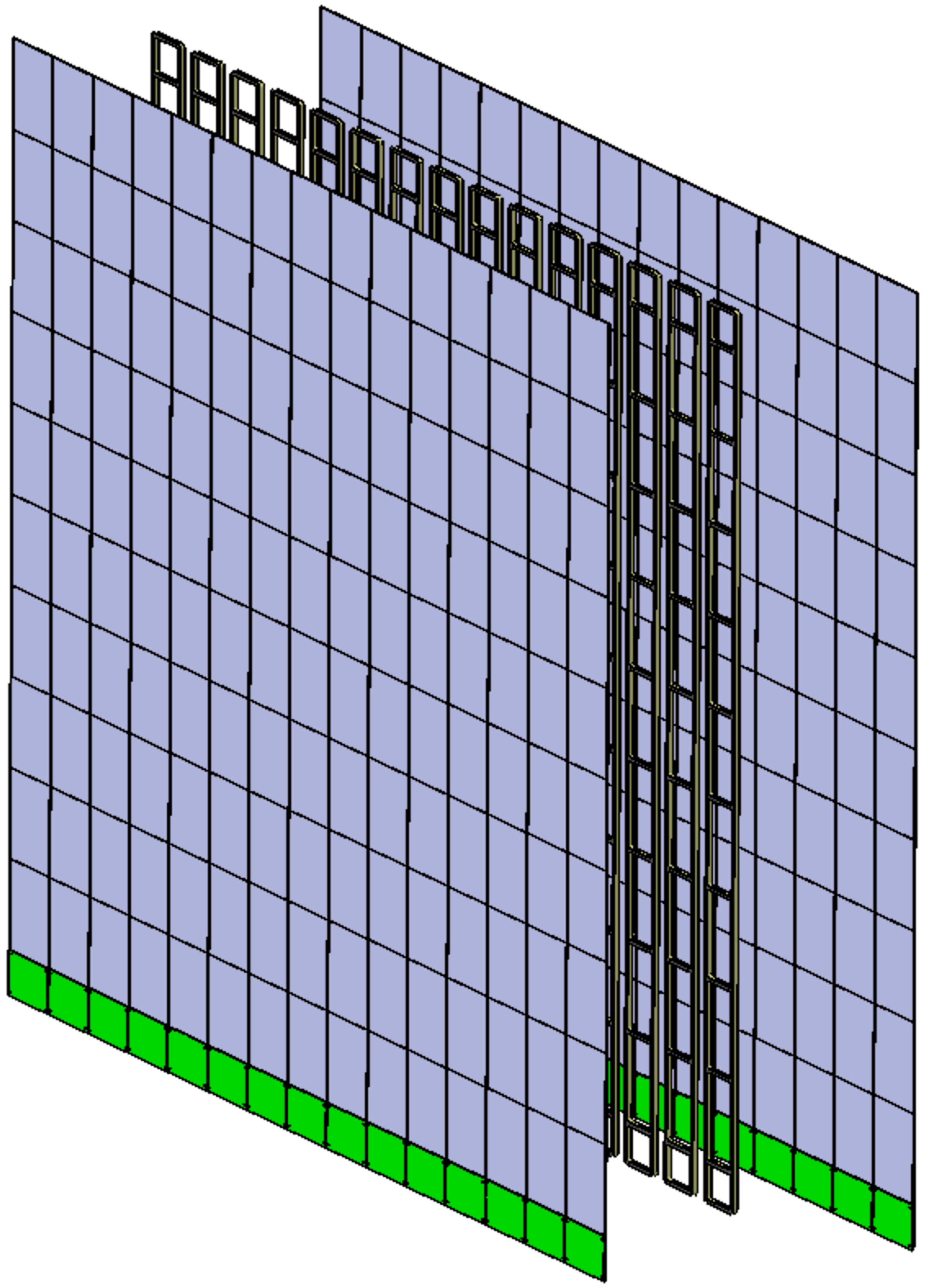
Mechanical structure - Orthogrid



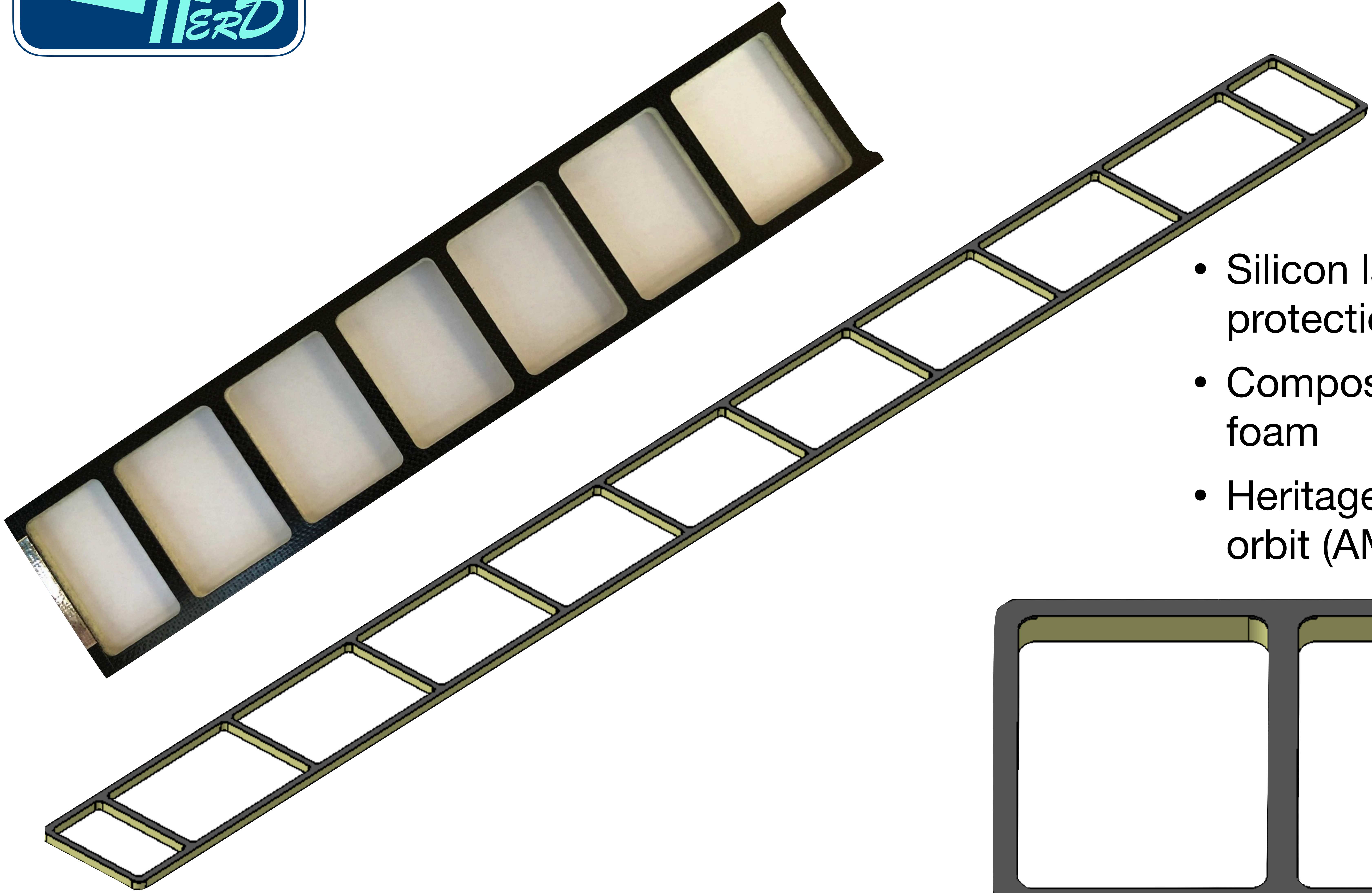


Silicon detector layers

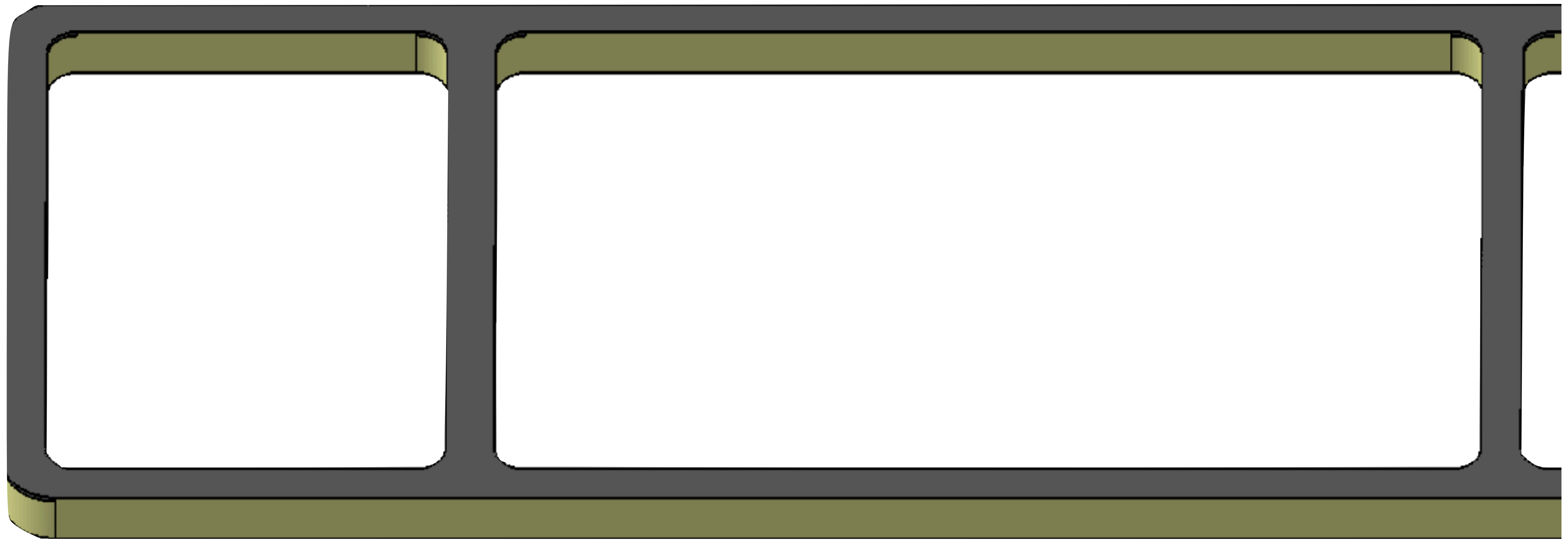
- Two detecting layers per side (X+Y)
- Electronics on same side for both detected coordinates
- Each layer separated by Airex-CF spacers
- High mechanical stability required



Silicon sensors' spacer

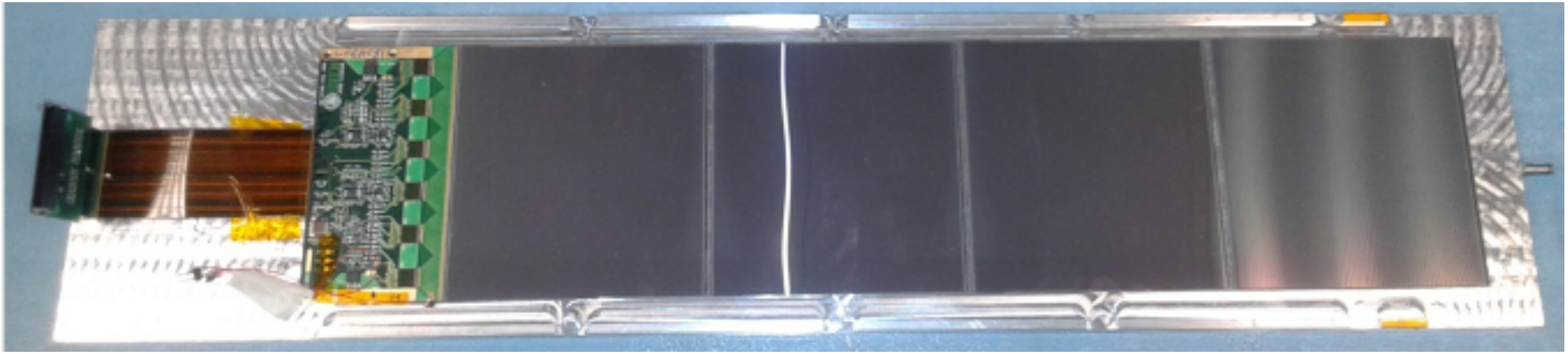


- Silicon layers spacers for wire-bond protection
- Composite material -> CF skin + Airex foam
- Heritage from previous experiments on orbit (AMS-02)

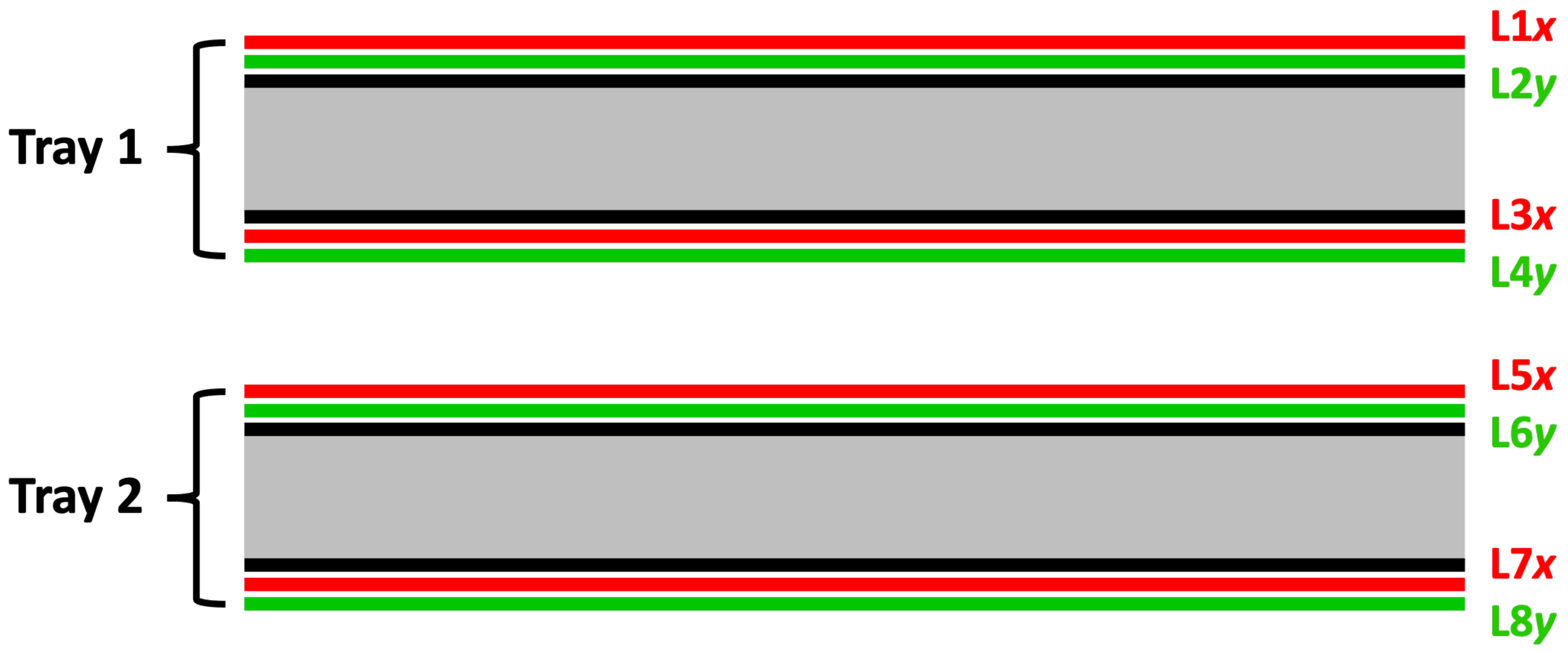


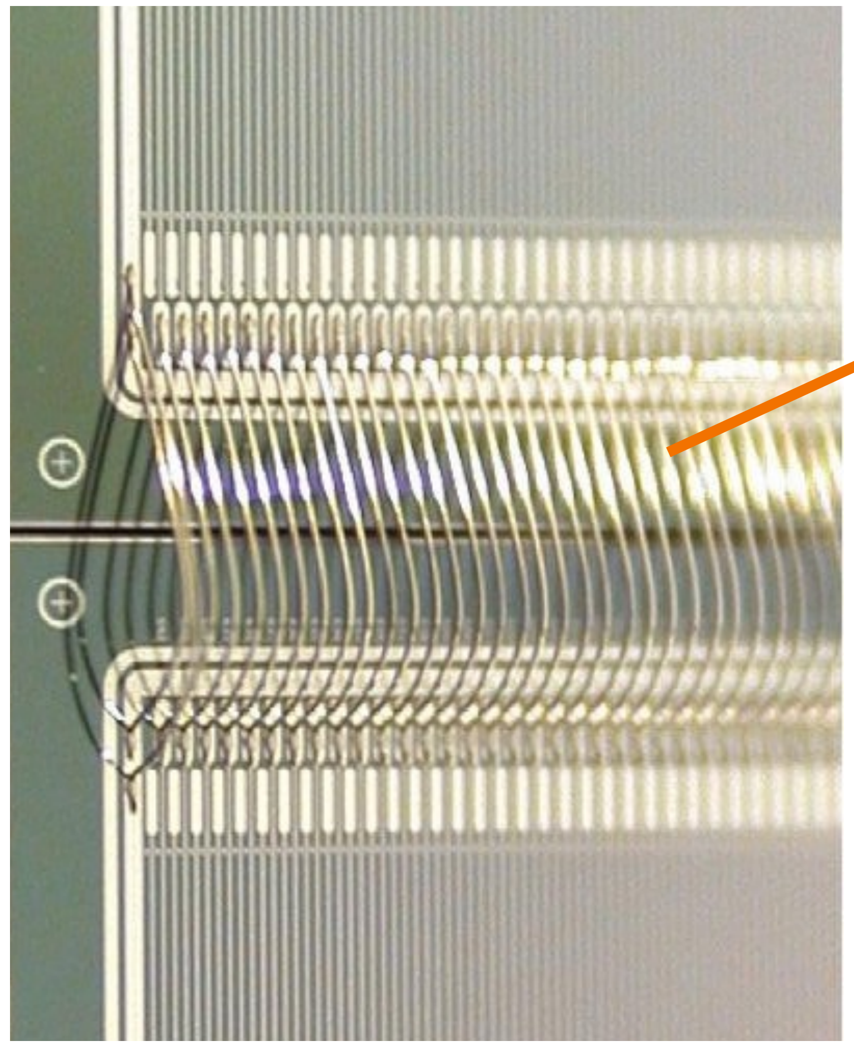
Detecting layer

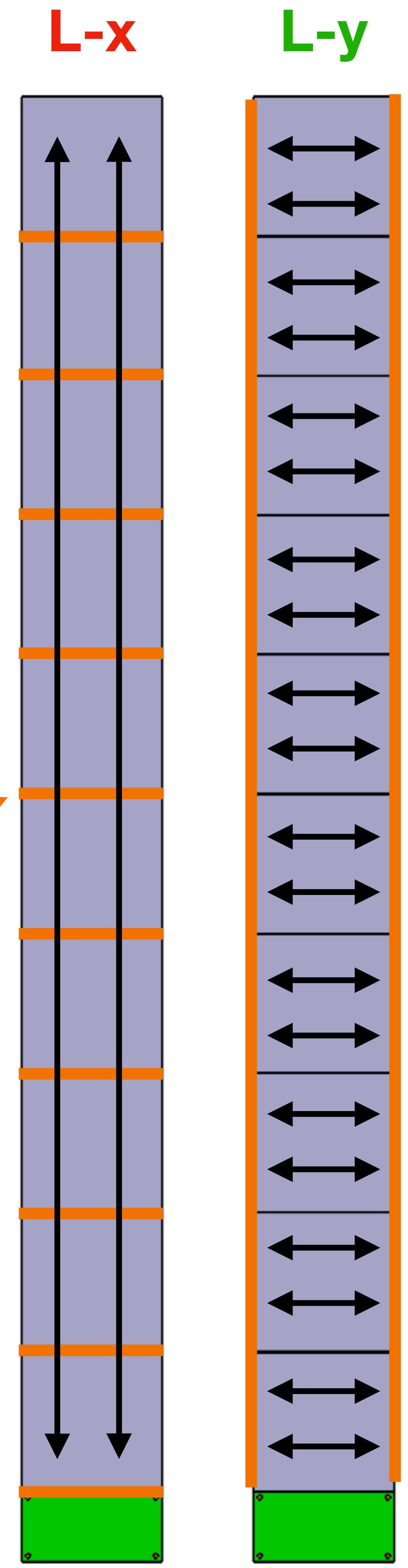
Ladder Back Bone (LBB)

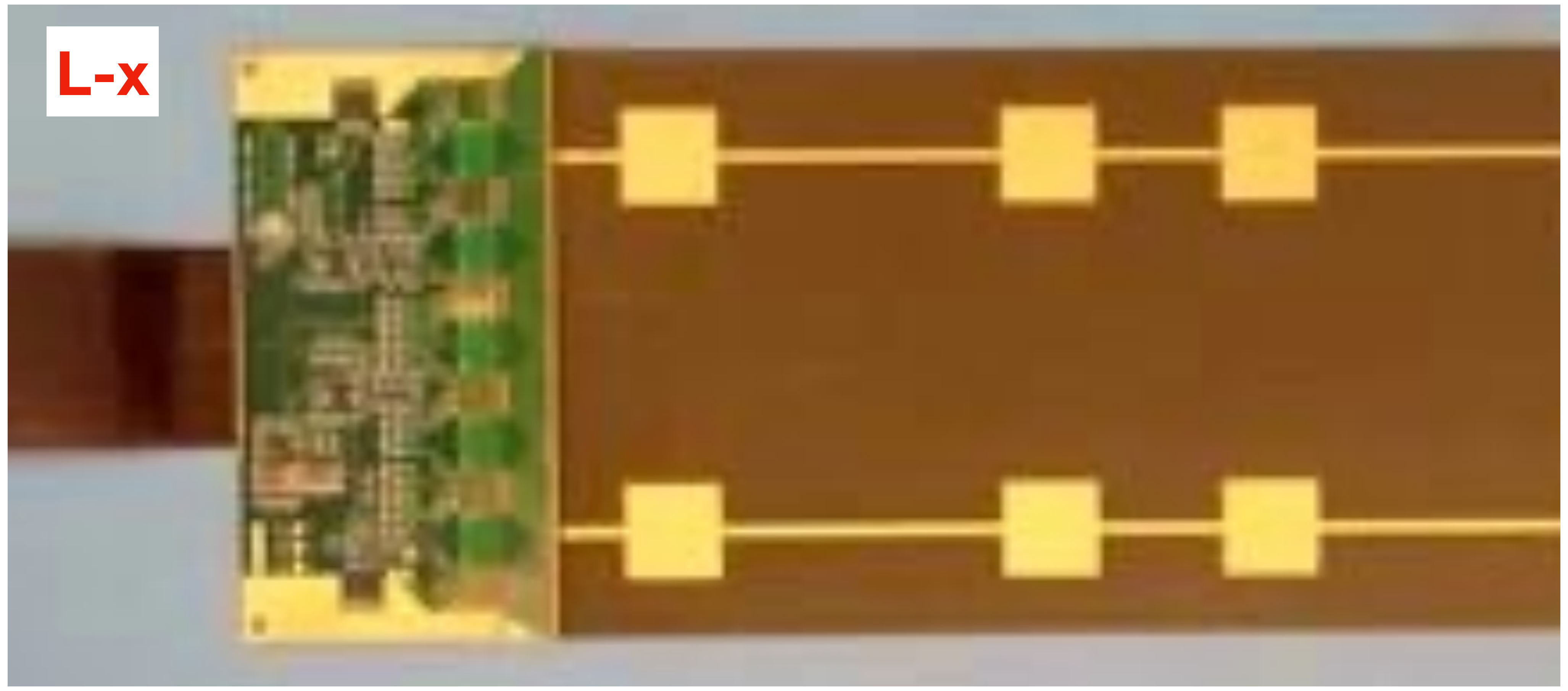


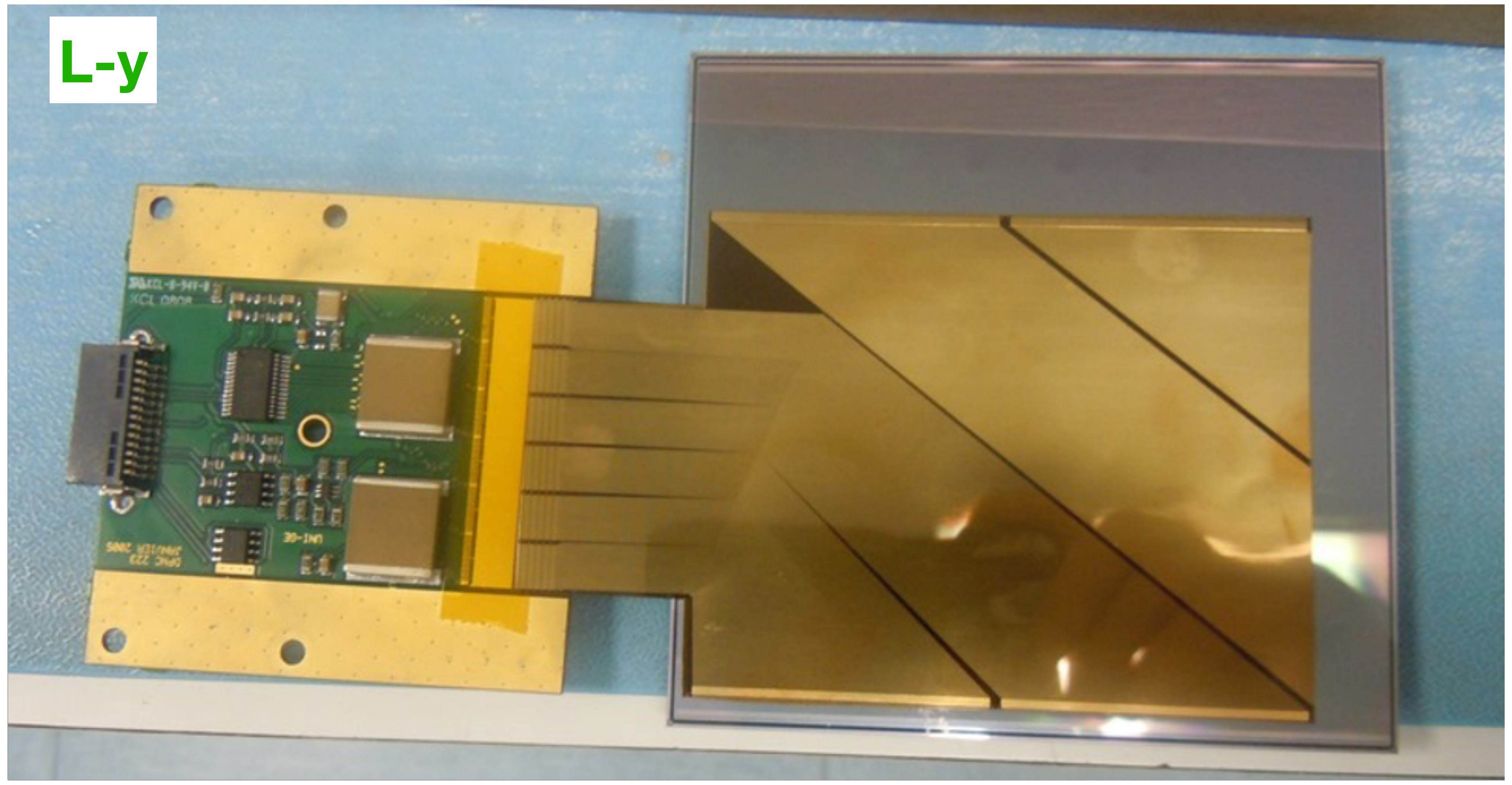
Ladder Back Bone (LBB)











Next steps and conclusions

Next steps:

- Material samples characterisation and comparison with FEA
- Frame sample production and dynamic characterisation
- Production and testing of quarter side plane prototype
- Production, testing and comparisons of different core materials and topologies
- Dynamic characterisation of Airex spacers with silicon dummy sensors

Thanks for your attention!