<u>Swedish Institute of Space Physics</u>:

- We are one of the world's leading research institutes in space physics
- We collaborate with all major space actors such as ESA, NASA, JAXA, ~~RosCosmos~~, ISRO, C
  Tubitak UZAY
- We have collaborations with over 50 universities and research institutes worldwide

A state research institute under the Ministry of Education.
IRF mission is basic research and research education.

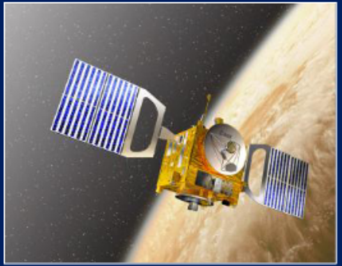
Head office in Kiruna, Location at Umeå, Uppsala and Lund.

- Solar terrestrial and atmospheric research (STAR)
- Space Plasma Physics (SPP)
- Kiruna Atmospheric and Geophysical Observatory (KAGO)
- Solar system physics and space technology (SSPT)

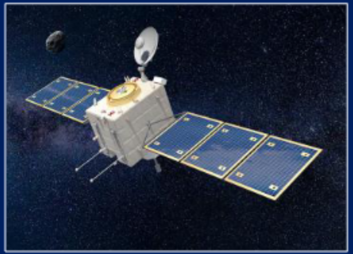
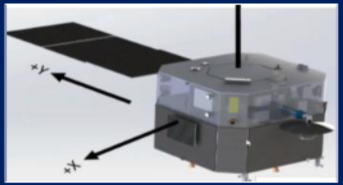
SSPT main goals:
1) Study the solar wind's interaction with various celestial bodies in the Solar System.
2) Space Technology development to support 1).
Lund.

Currently 13 active space projects. 5 s/c in-orbit!

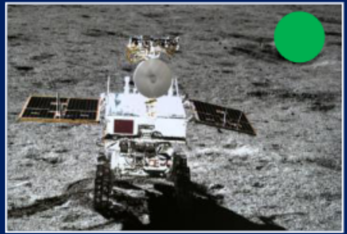
Mars/Venus (3)
MEX
VEX
ISRO Venus Orbiter

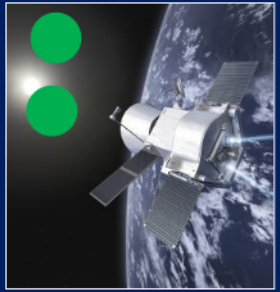

Comets (2)
Rosetta
Comet Interceptor

Moon (4)
Chandrayaan-1
Chang'e 4
Chang'e 6
AYAP-1


Mercury (2)
BC / MMO
BC / MPO



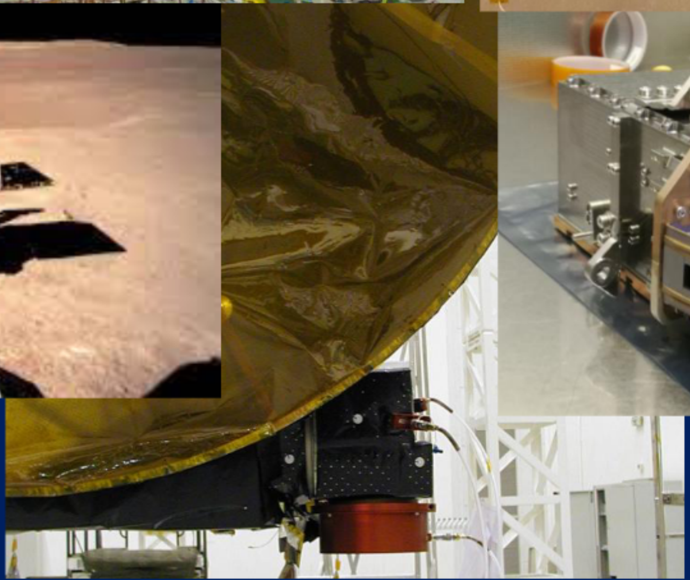
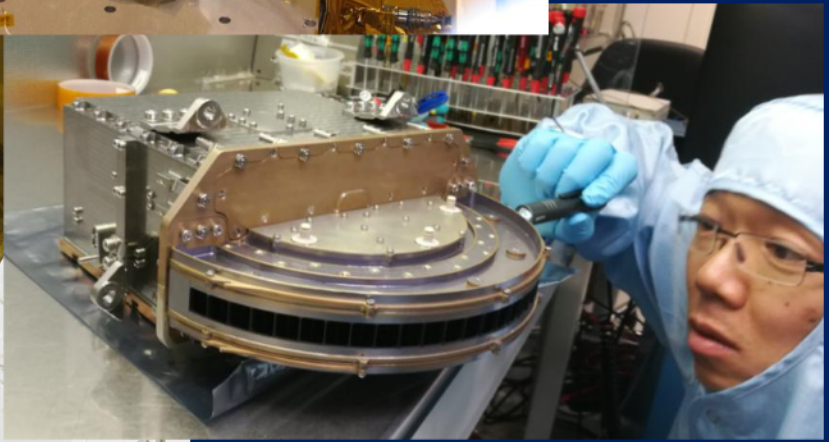
Jupiter (1)
JUICE
April 14, 2023

Products from IRF SSPT

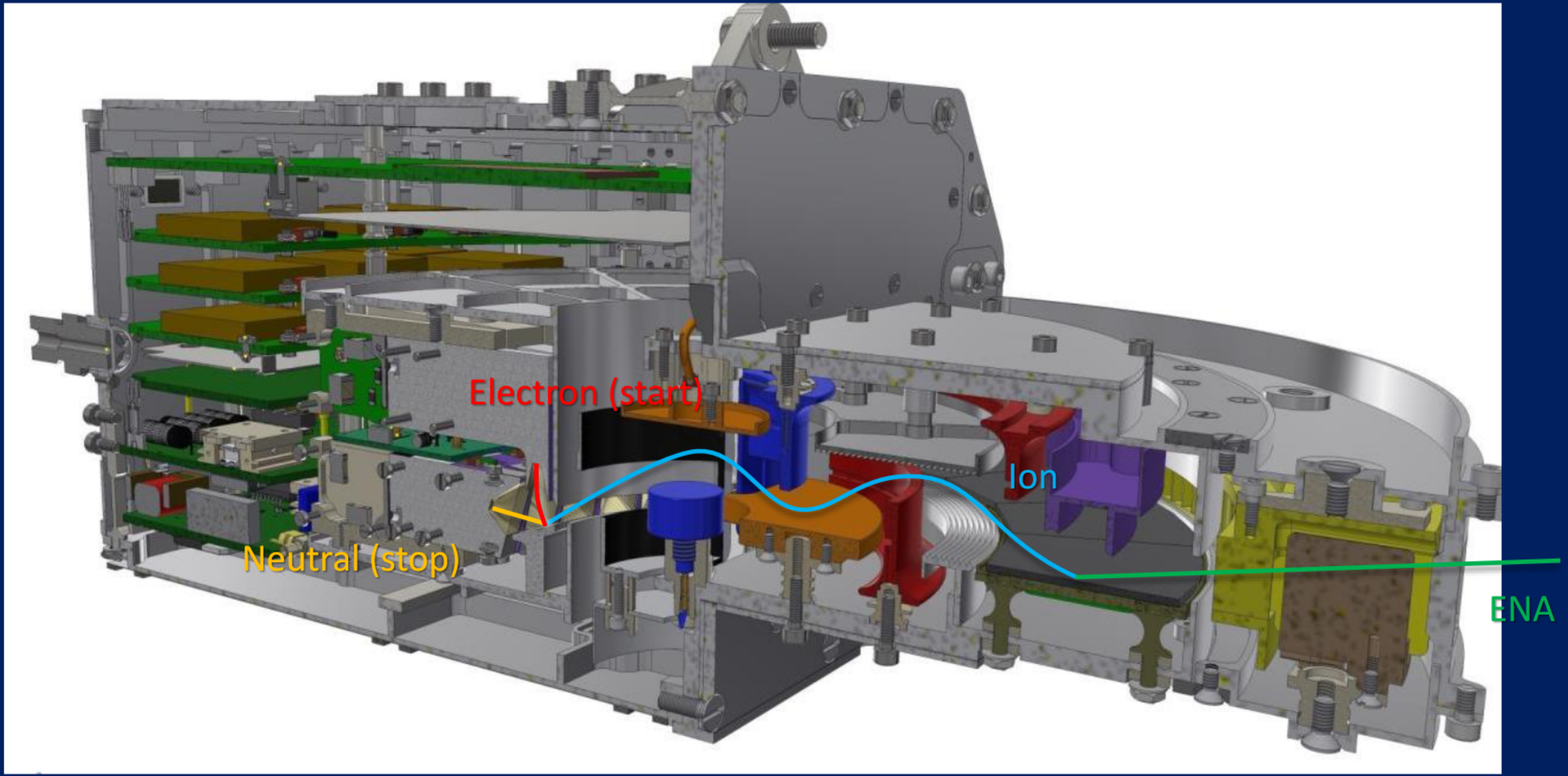
Main products is **Ion and neutral mass spectrometers** in various form to various exciting missions.



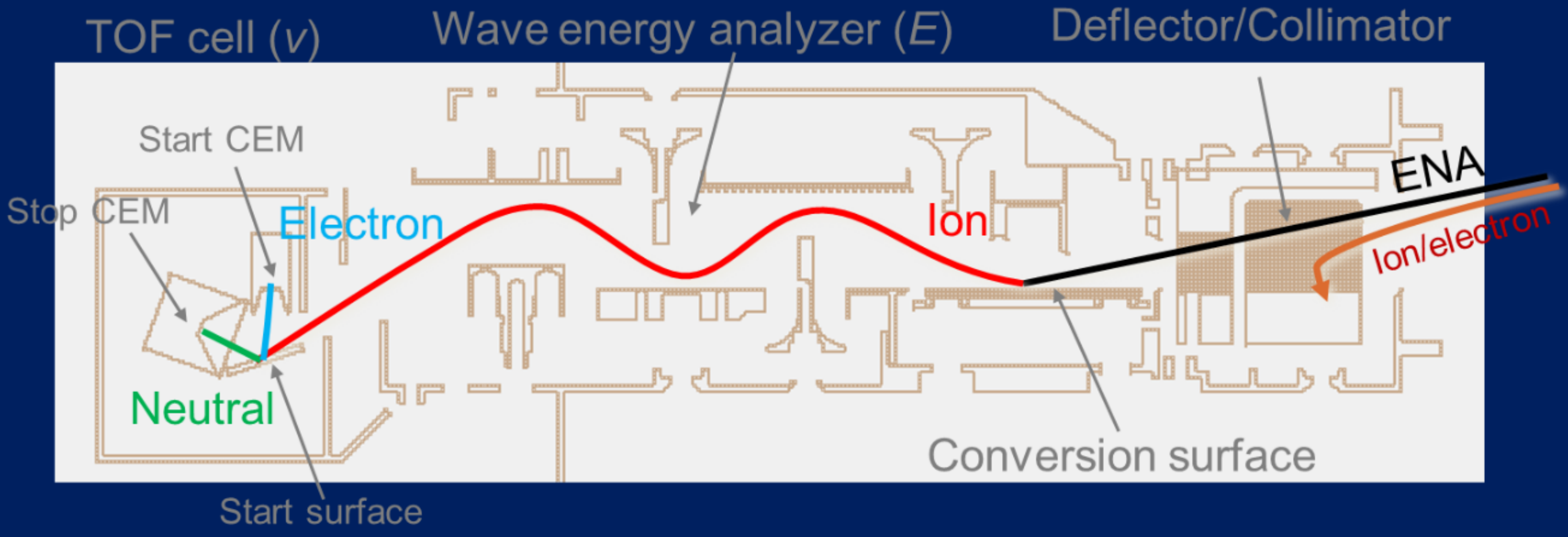


Example of typical instrument



Measurement principle



E (Ion energy analyzer)

v (TOF measurement)

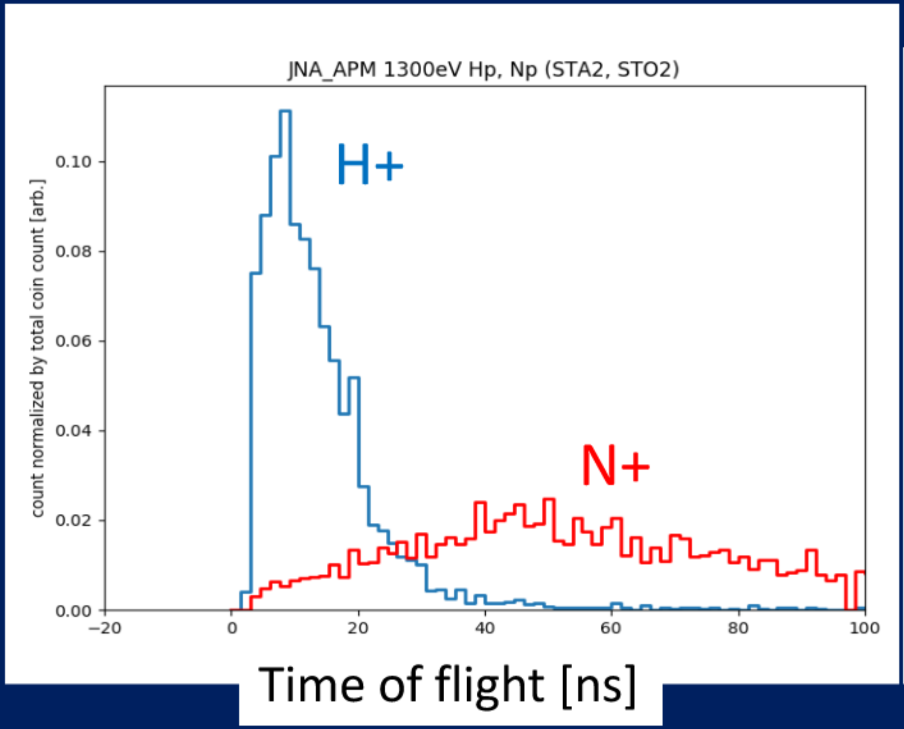
$$E_{kin} = \frac{1}{2}mv^2$$

→ Mass *m*

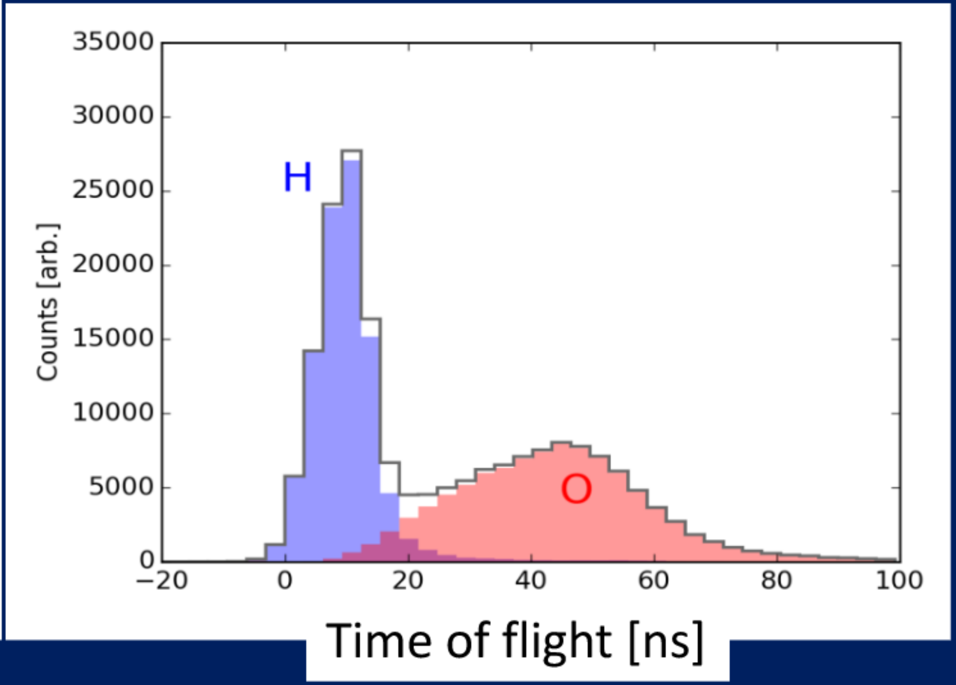
φ (collimator, start-CEMs) → *Angular distribution of incident flux*

Result test and simulation

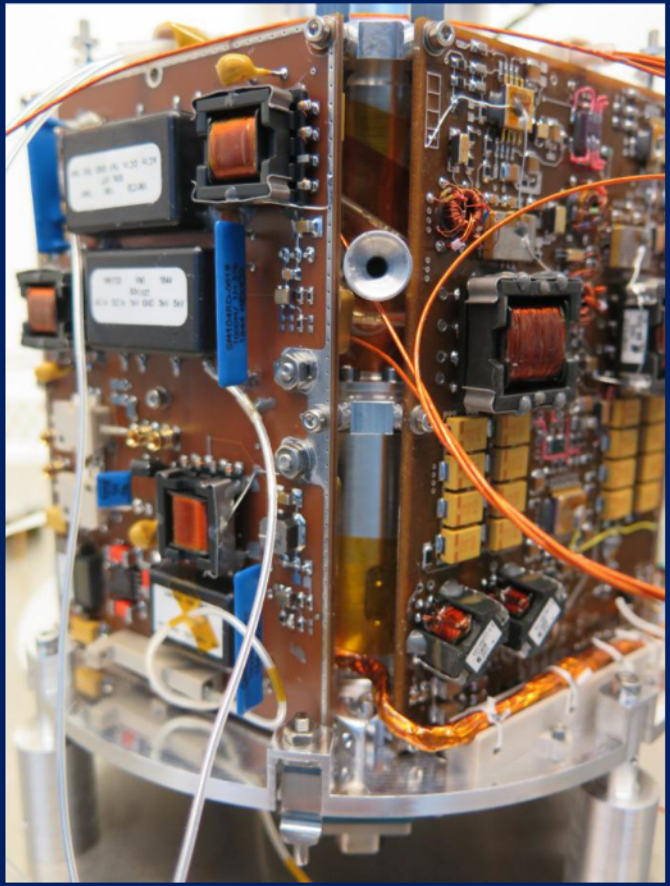
Prototype test result



Ion optical simulation



Typical electronics

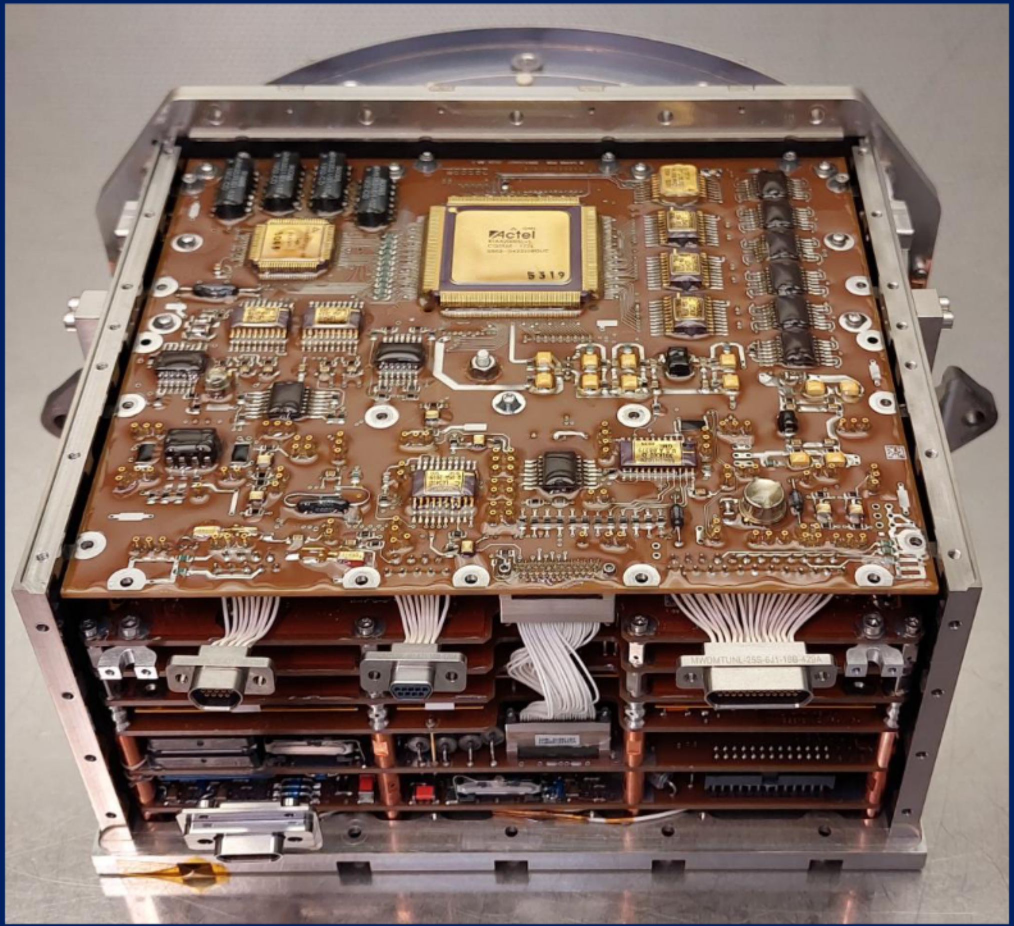


Digital design and FPGA:

- Time of flight
- CPUs
- I/F communication

Analouge electronics such:

- DCC
- High Voltage
- Charge sensitive amplifier



Radiation effects for particle instrumentation

- Total Ionising Dose effects
  -> All active parts

- Displacement damage effects
  -> Optopart such HV-optocoulper

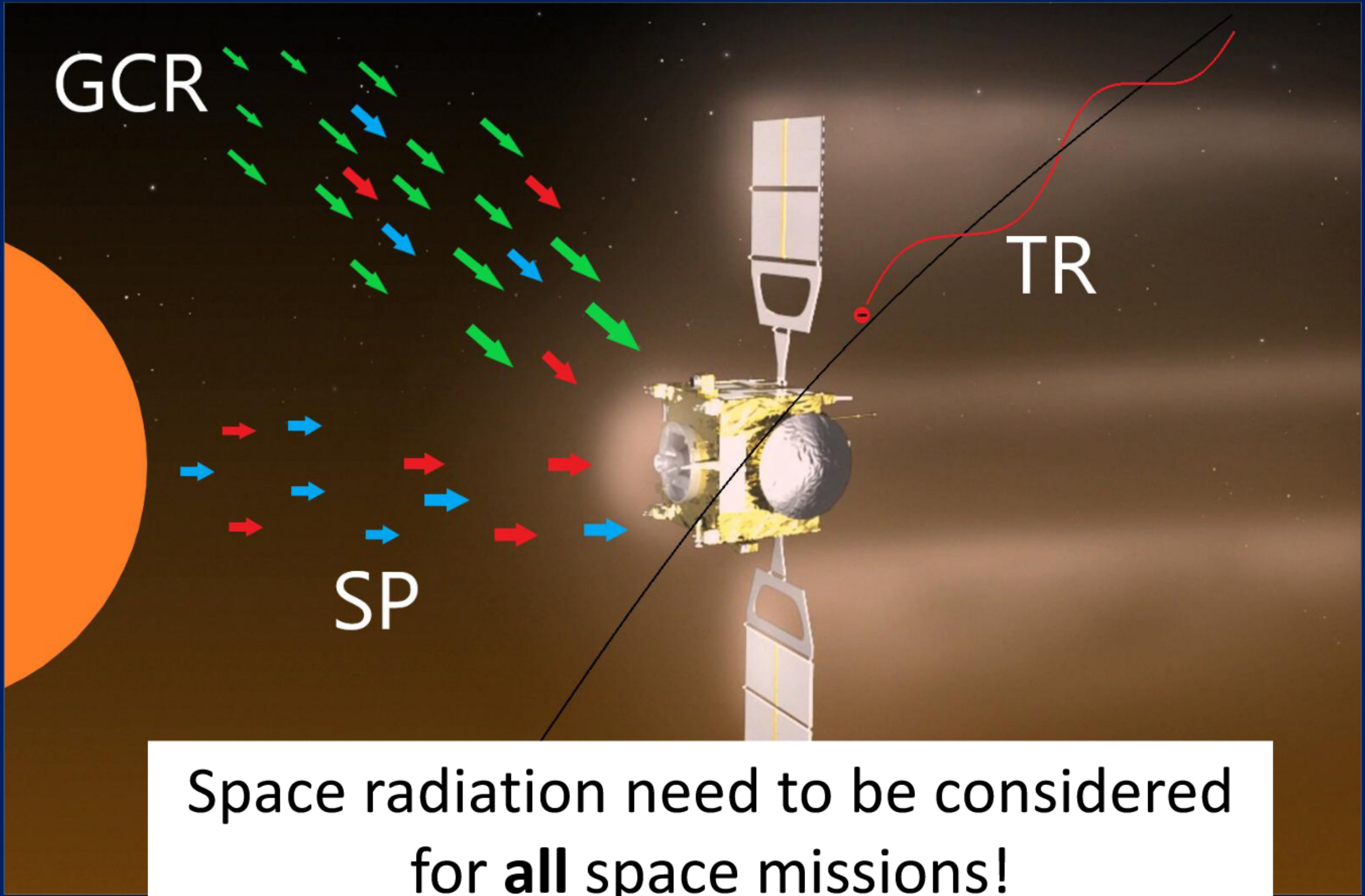
- Singel event effects
  -> All active parts

- Radiation induced background noise
  -> Detectors

Design driver @Jupiter!

- Internal discharge
  -> Floating metal parts

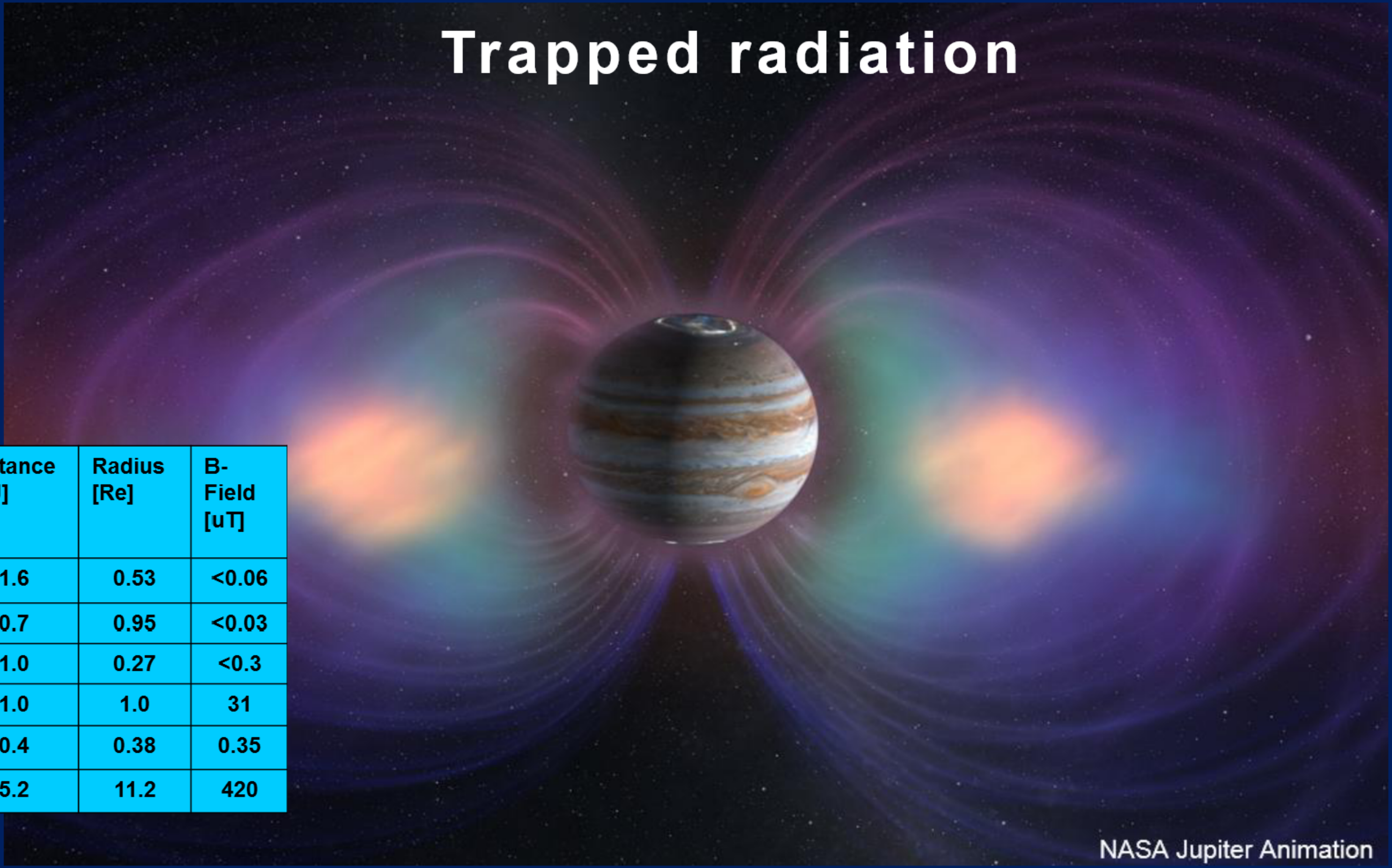
Radiation sources



Space radiation need to be considered for **all** space missions!

Trapped radiation

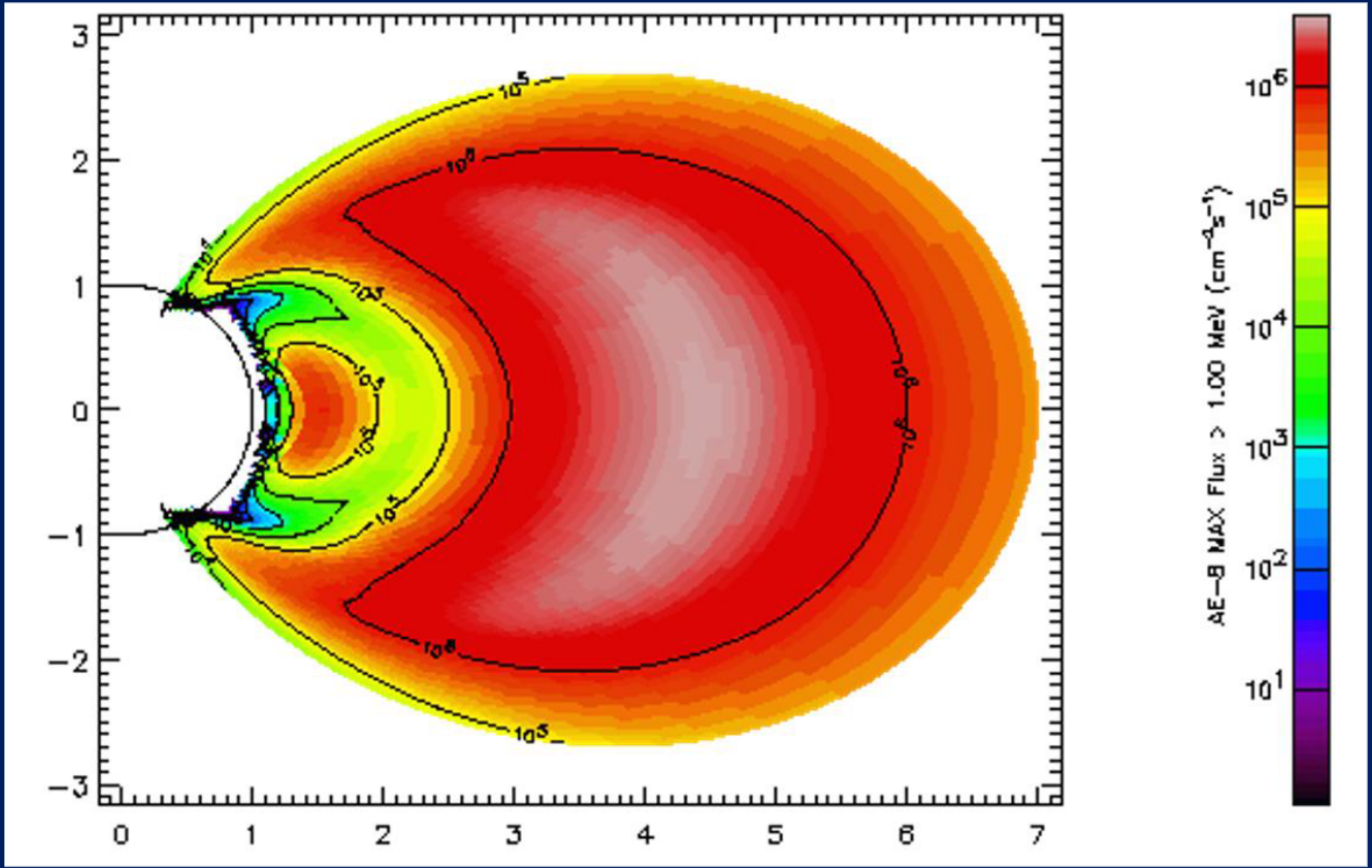
Planet/ Body	Distance [AU]	Radius [Re]	B-Field [uT]
Mars	1.6	0.53	<0.06
Venus	0.7	0.95	<0.03
Moon	1.0	0.27	<0.3
Earth	1.0	1.0	31
Mercury	0.4	0.38	0.35
Jupiter	5.2	11.2	420



NASA Jupiter Animation

Trapped radiation models Earth

NASA models AP-8 and AE-8 [Vette, 1991b] still most used.



Distribution 1 MeV electron integral flux

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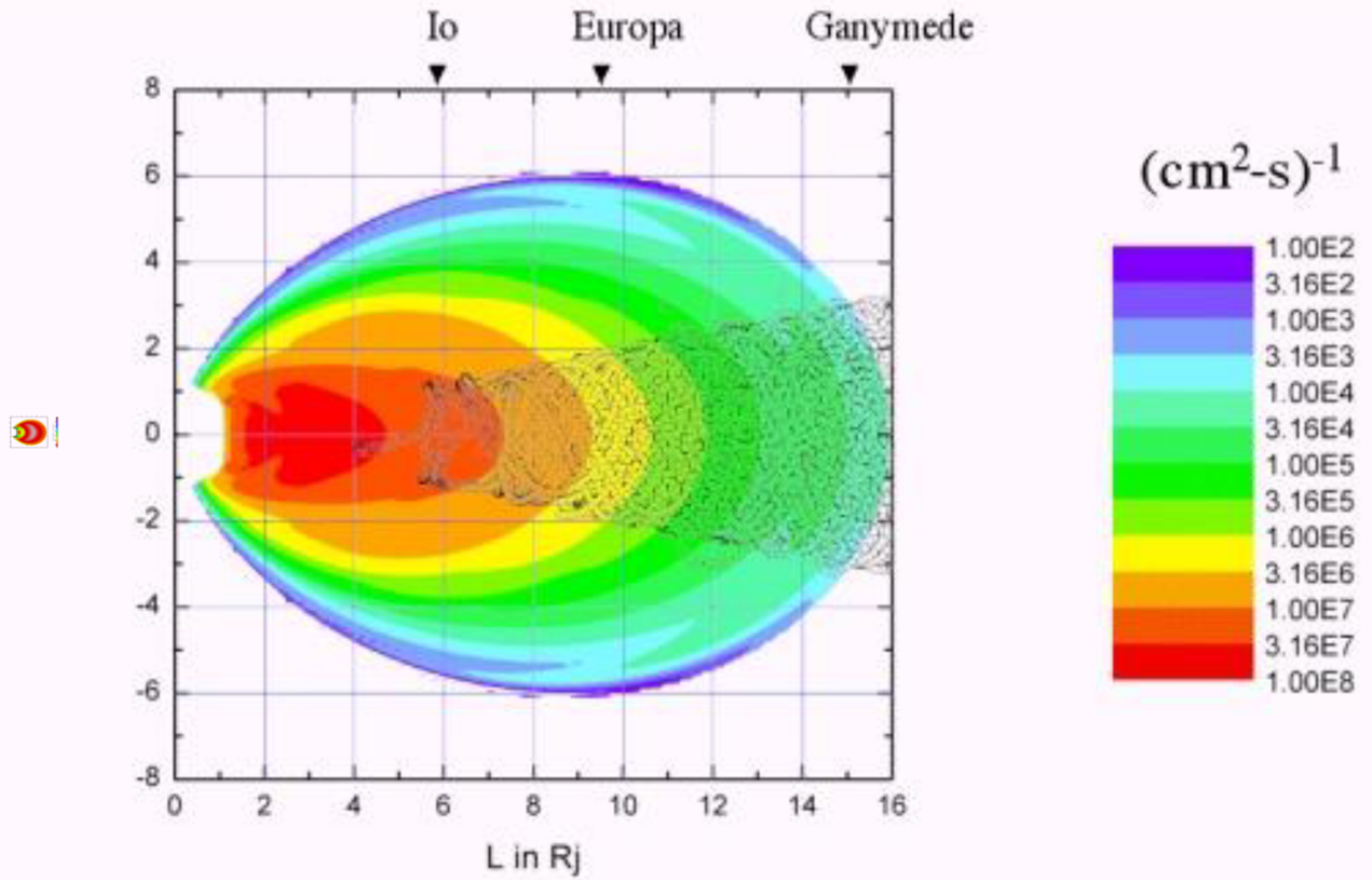
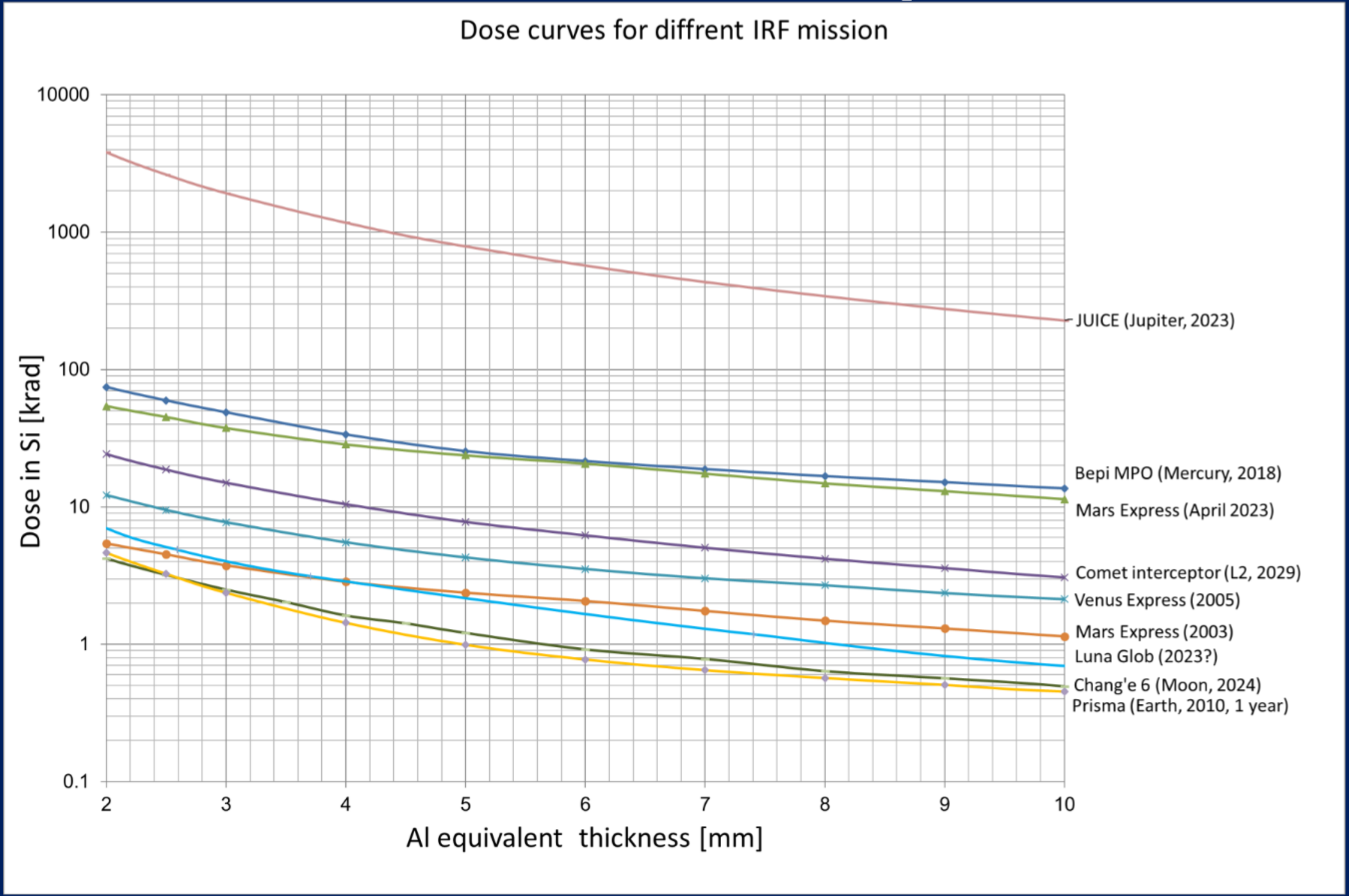
IRF
Swedish Institute of Space Physics

Trapped radiation models Jupiter



Distribution DG model 10 MeV electron integral flux, overlaid with the Galileo Trajectory

IRF instruments different space environments



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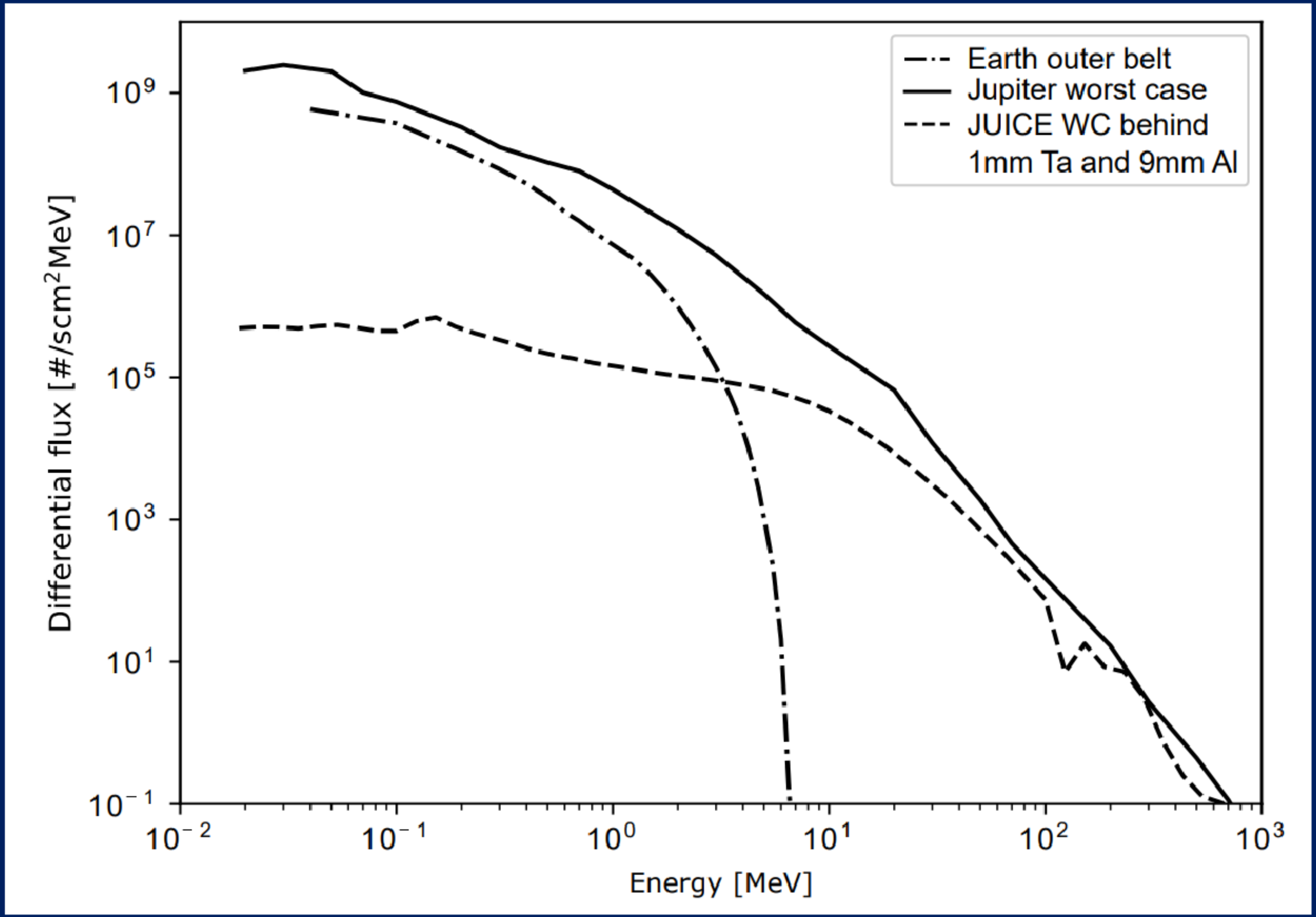
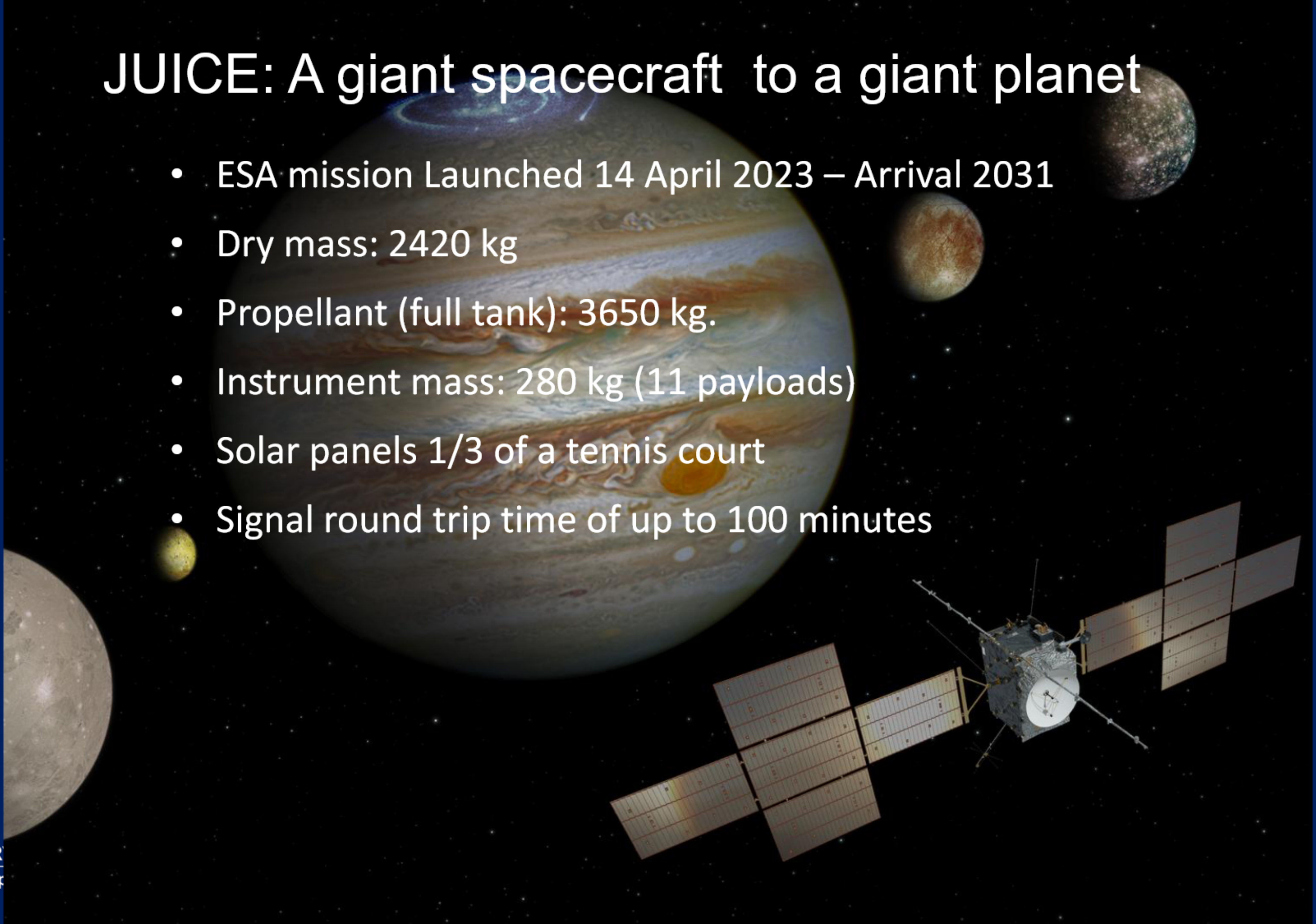
Electrons at Earth vs Jupiter

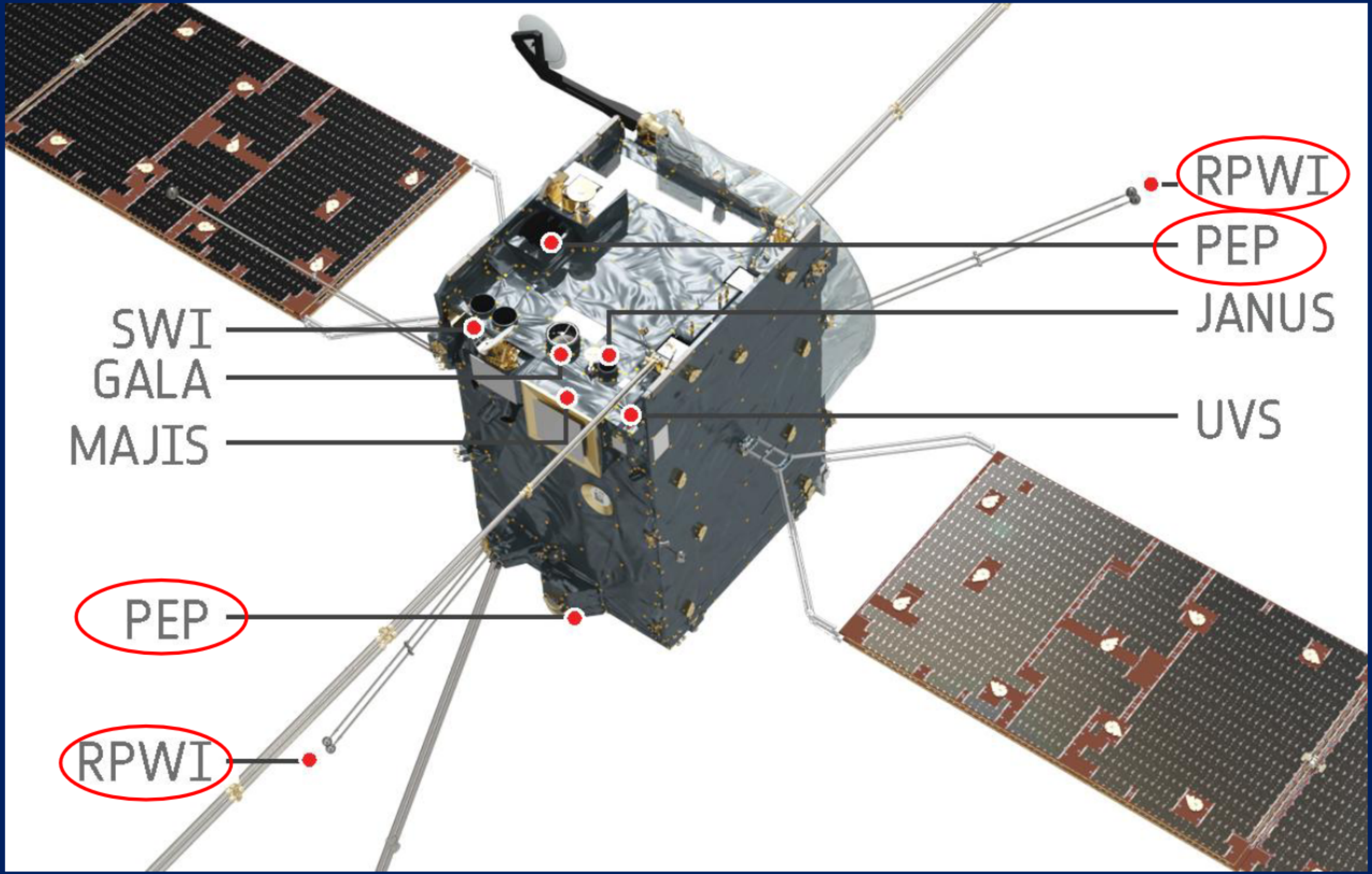


JUICE: A giant spacecraft to a giant planet

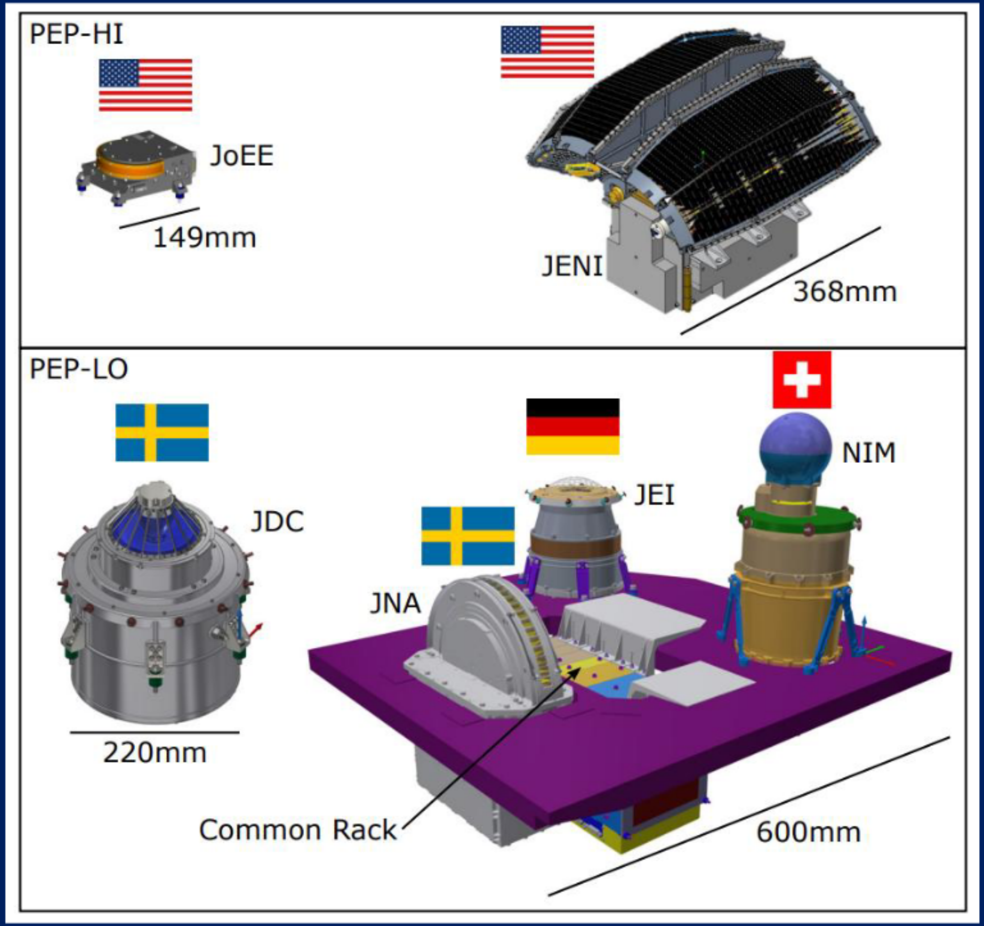
- ESA mission Launched 14 April 2023 – Arrival 2031
- Dry mass: 2420 kg
- Propellant (full tank): 3650 kg.
- Instrument mass: 280 kg (11 payloads)
- Solar panels 1/3 of a tennis court
- Signal round trip time of up to 100 minutes

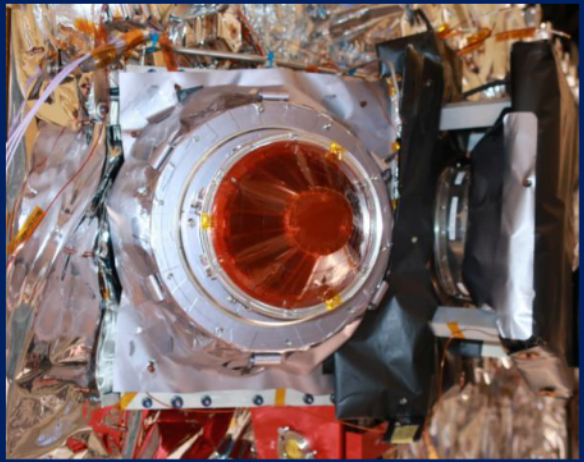


Swedish contribution on JUICE

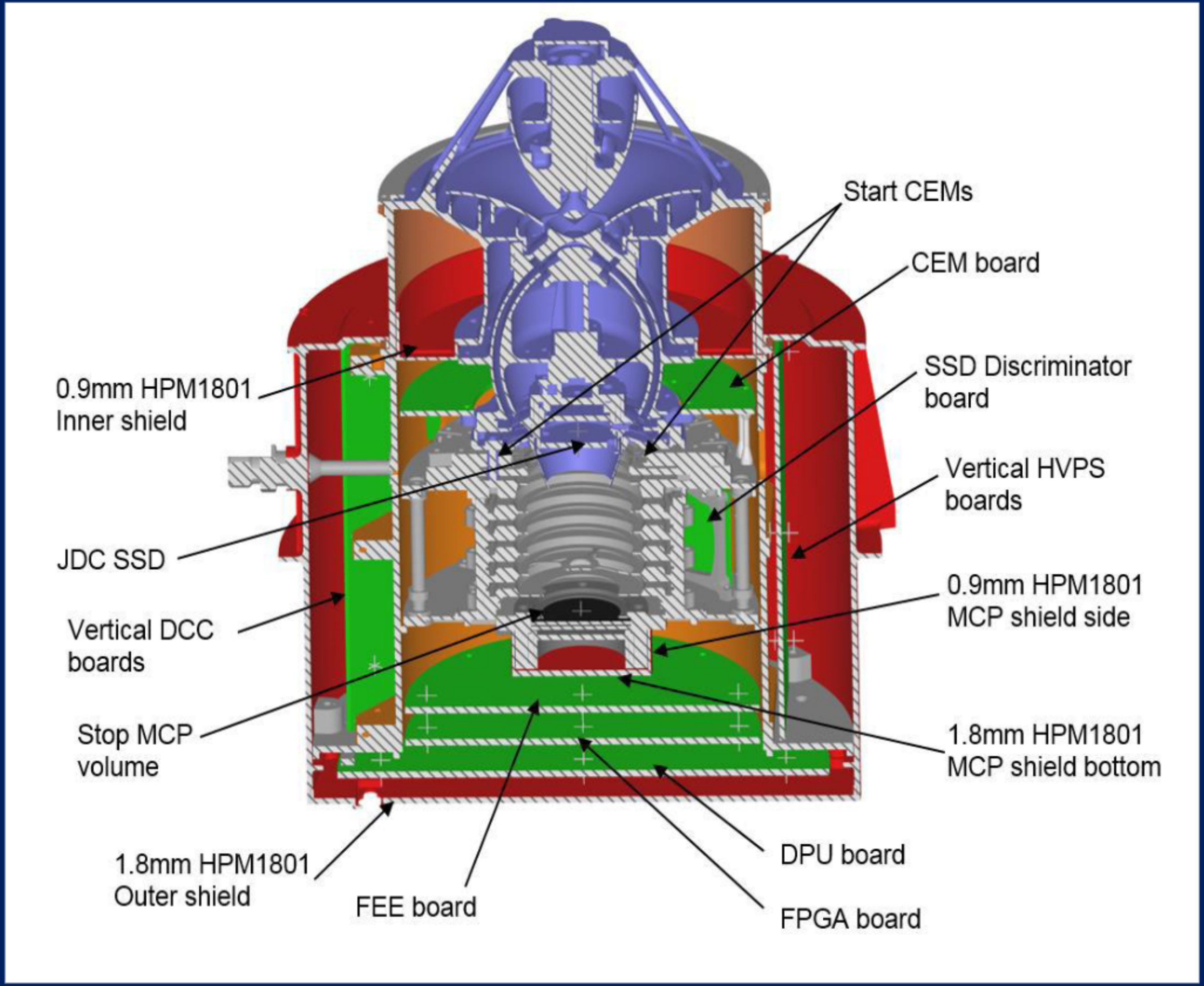


Mitigation step 1 – System level shielding

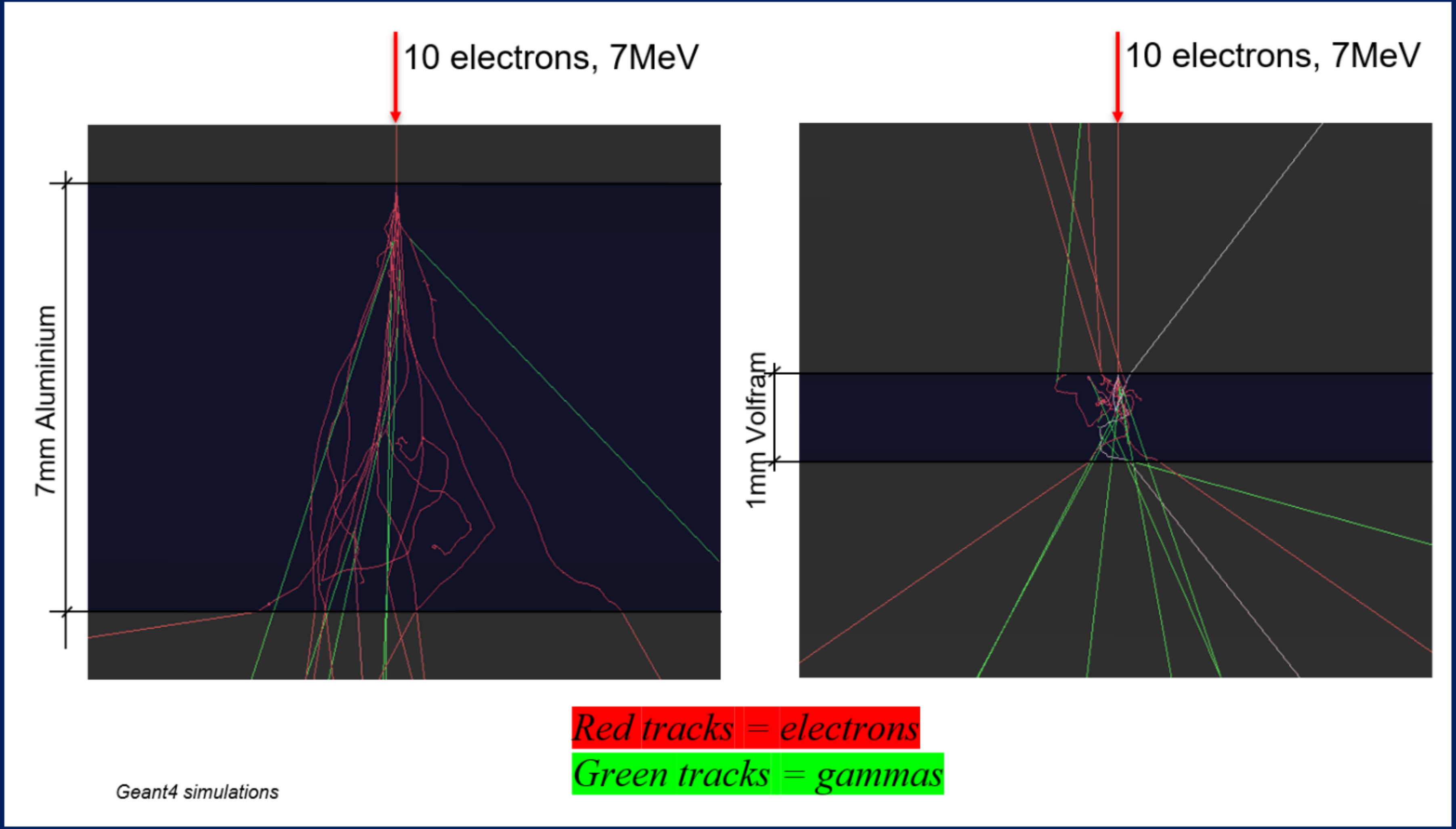




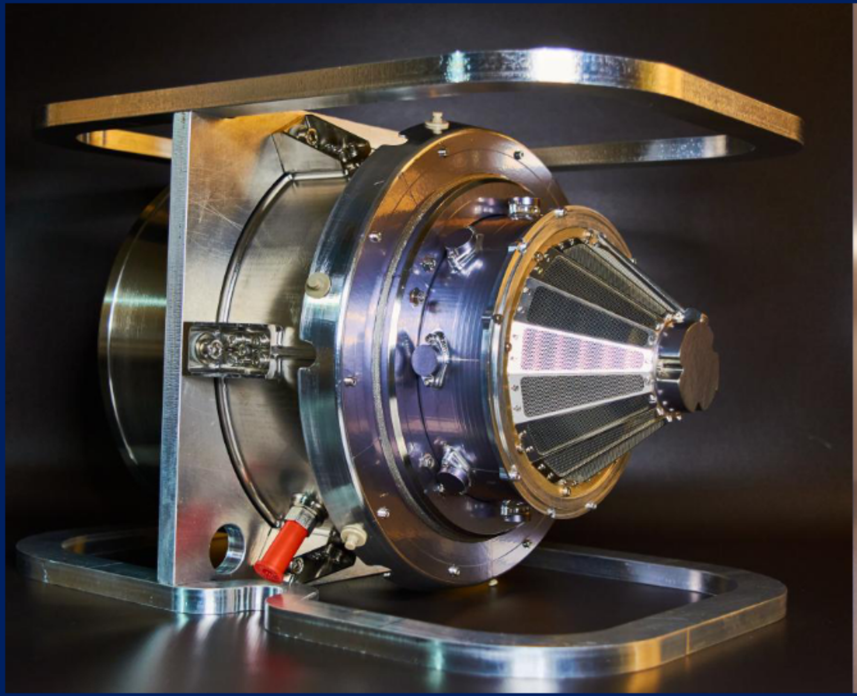
Mitigation step 2 – Sub unit shielding and location optimisation



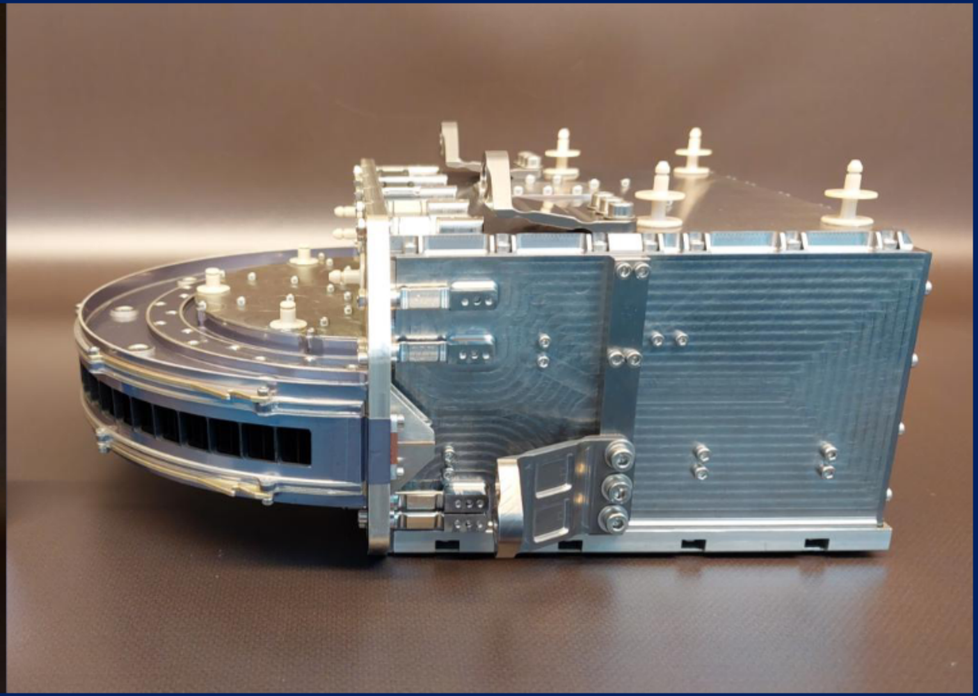
Selection of shielding material



Shielding mass



JDC total mass 8.2 kg

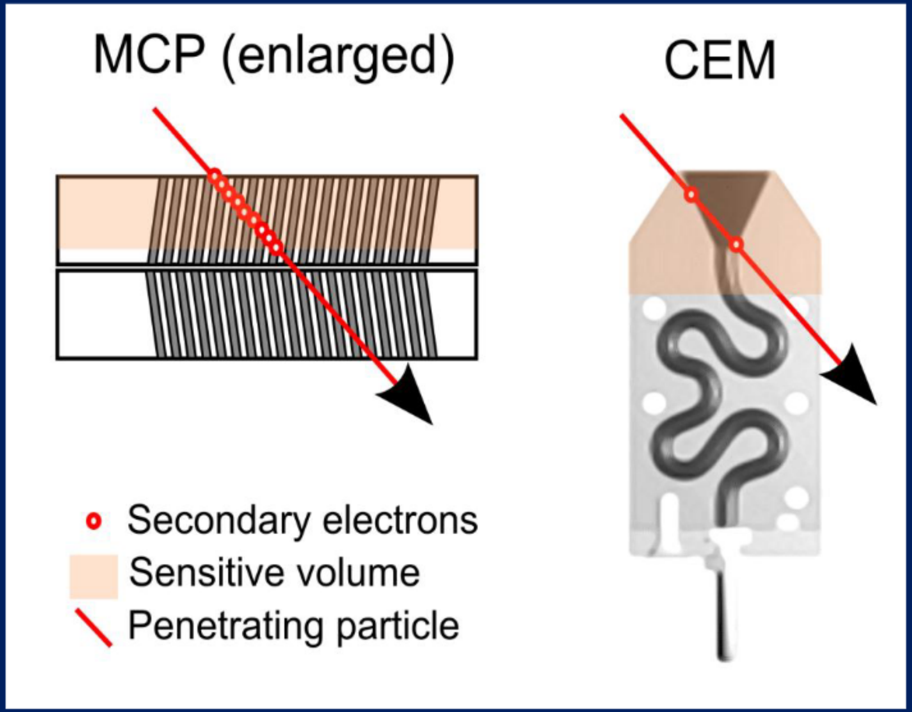


JNA total mass 5.9 kg

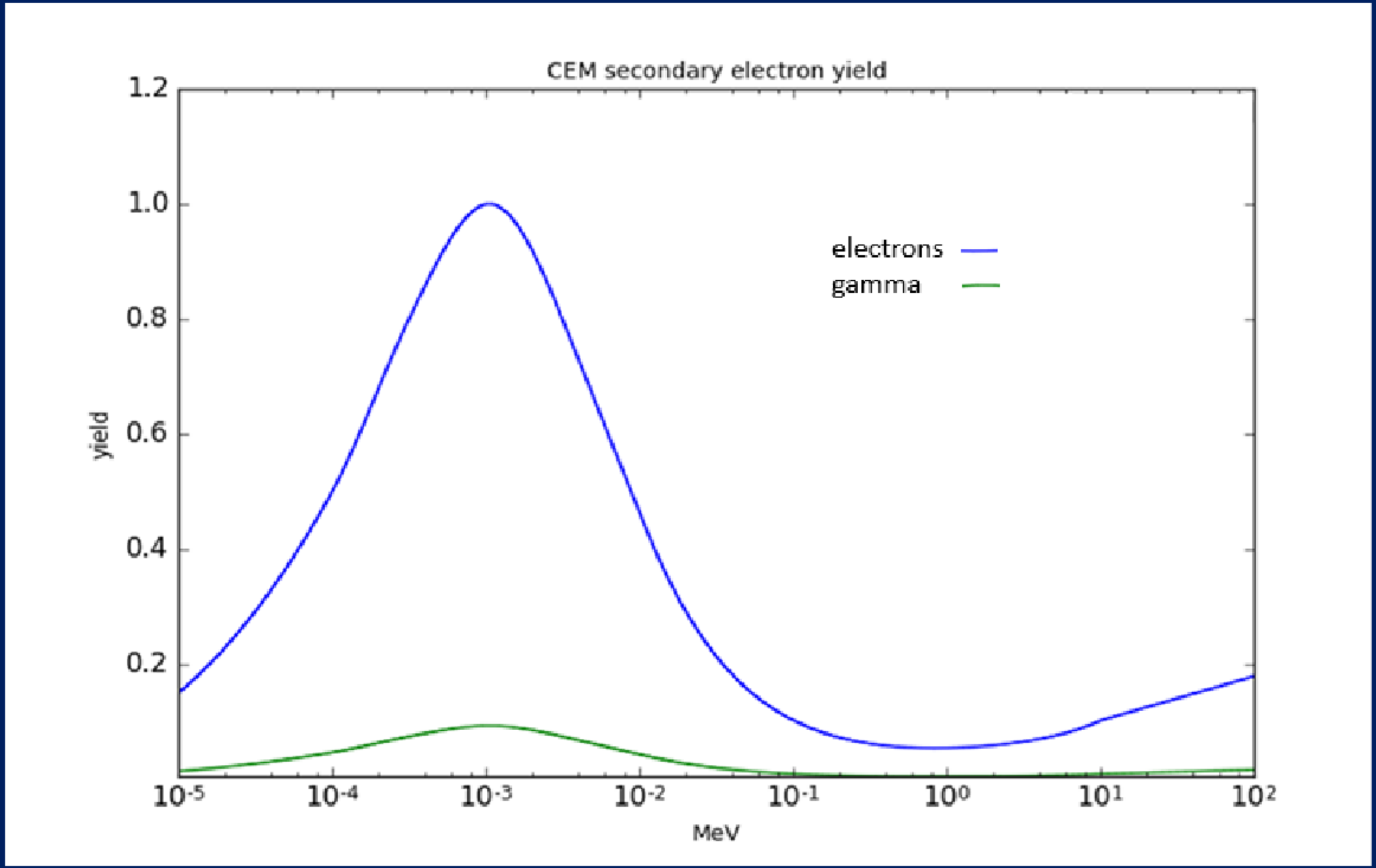
PEP total mass **60 kg**, of this is approximately **50% shielding**

Mitigation step 3 – selection of parts

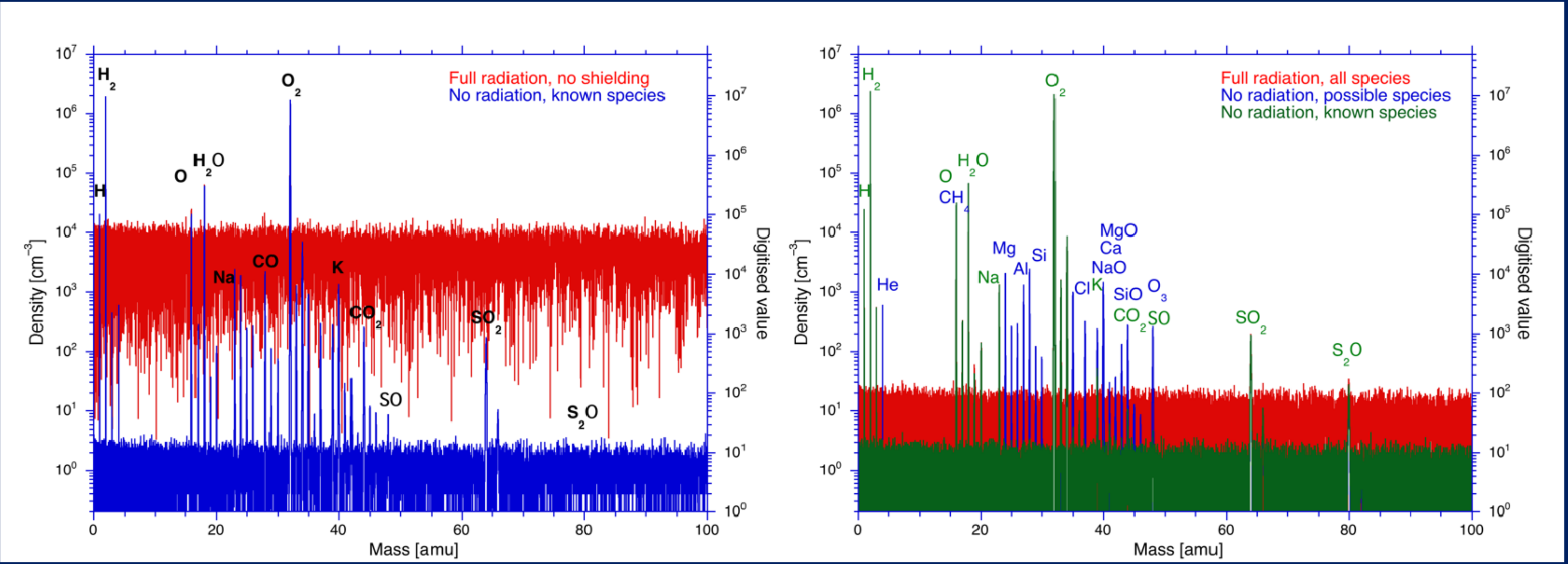
MCP (Microchannel plates) vs **CEM (Channel Electron Multiplier)**



RIBN – Detector sensitivity



Example RIBN @Jupiter



NIM performance

Wurz, P et.al *JUI-JHU-PEP-RP-001-i2.4_PEP_Instrument_Scientific_Performance_Report_(SE-120), University of Bern*

Mitigation step 3 – selection of parts

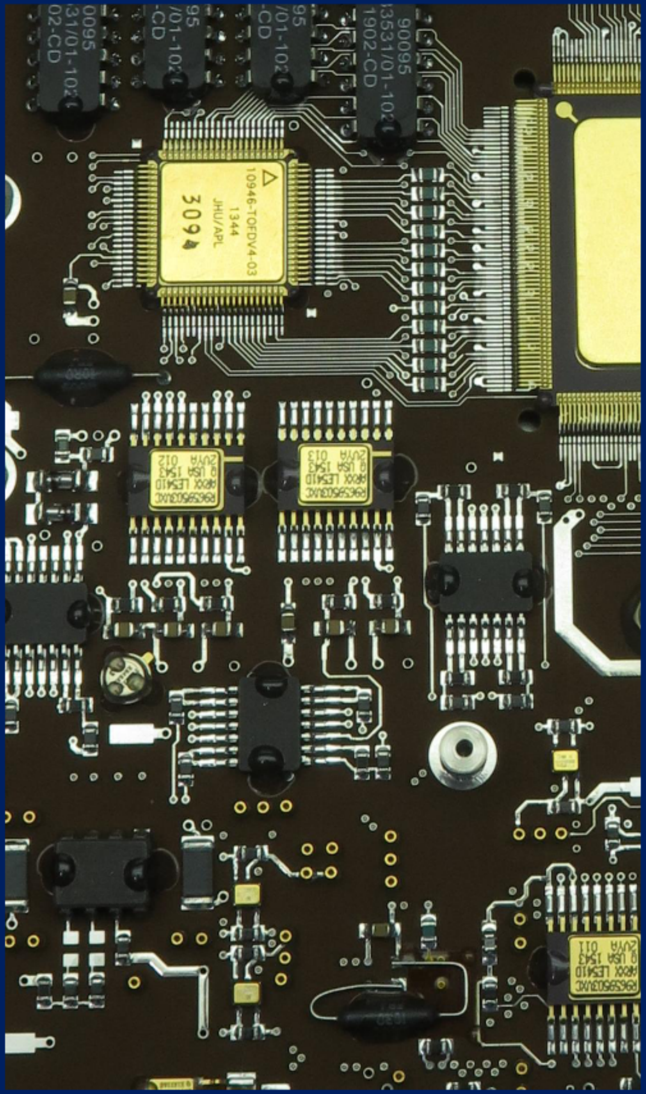
JUICE project:

Environment Safety Factor (ESF) = 2

Radiation Design Margin ≥ 1

Shielding design reduces calculated total dose 40-80krad (including ESF).

Selected EEE parts TID Tolerance ≥ 100krad



Mitigation step 4 – Signal optimisation

Detector coincident and anti-coincident scheme

Anti-coincidence with anti-coincidence SSD

Anti-coincidence with neighbouring detectors

Noise subtraction

Include continuous background measurement modes. Fore ground signal is switched off and only background noise is recorded.

Mitigation step 5 – Operation

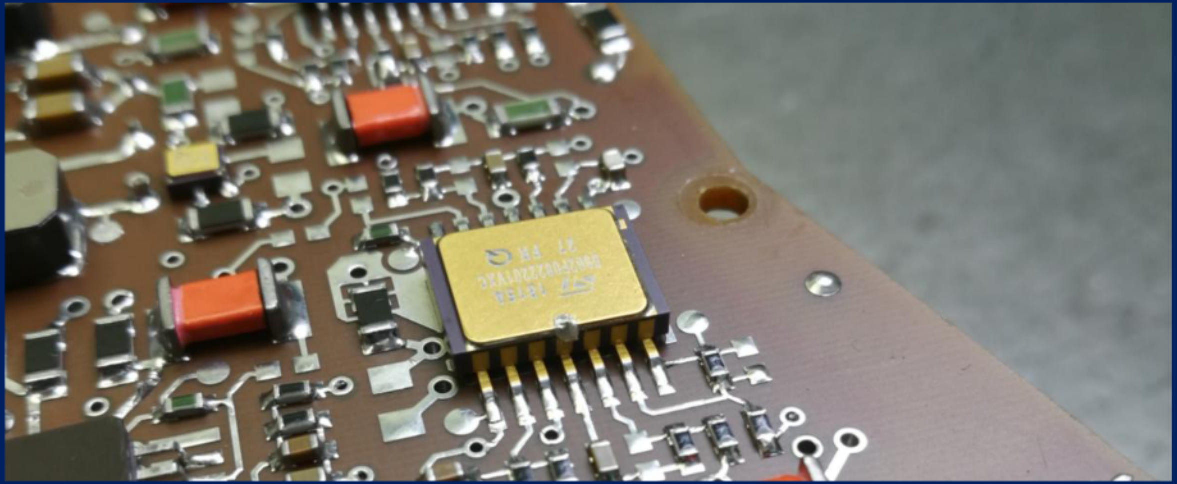
Instrument only ON when science goal can be fulfilled.

Non bias semi conductor layer is less prone to collect charges from ionising radiation.

Detector degradation (charge extraction) will be less if they are not biased.

Summary radiation mitigation at Jupiter

- **1. System level shielding- > M**utal shielding with other equipment and S/C
- **2. Unit level shielding** -> Deposit dose in structure instead of electronics and detectors, used most effective shielding material. Place more sensitive parts in well protected locations
- **3. Part selection ->** Maximum resilience on detectors and electronics for the specific mission. Apply margin on radiation tolerance.
- **4. Signal optimisation –>** Detector coincident and anti-coincident scheme. Record background for post process subtraction.
- **5. Operation ->** Have unit on when science goal can be reached.

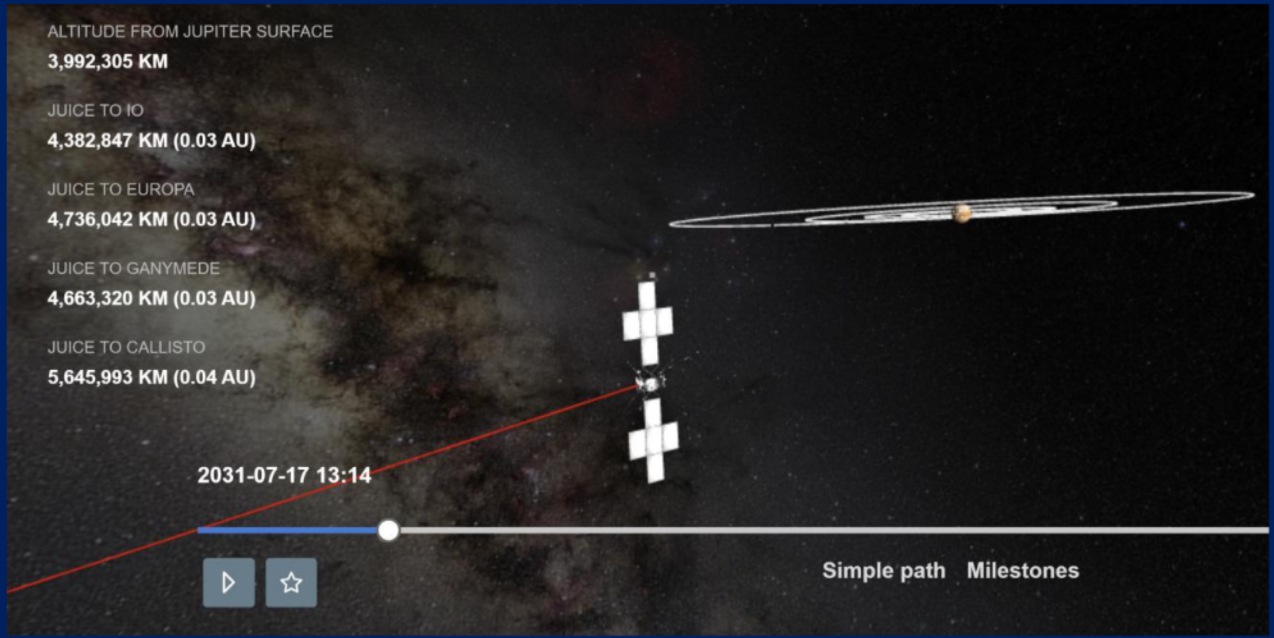


Radiation testlab at IRF

- Co-60 source for TID test of electronics or other equipment.
- Test on ground is very import

https://spacelab.irf.se/

Extra slide:
Is the radiation dangerous at Jupiter

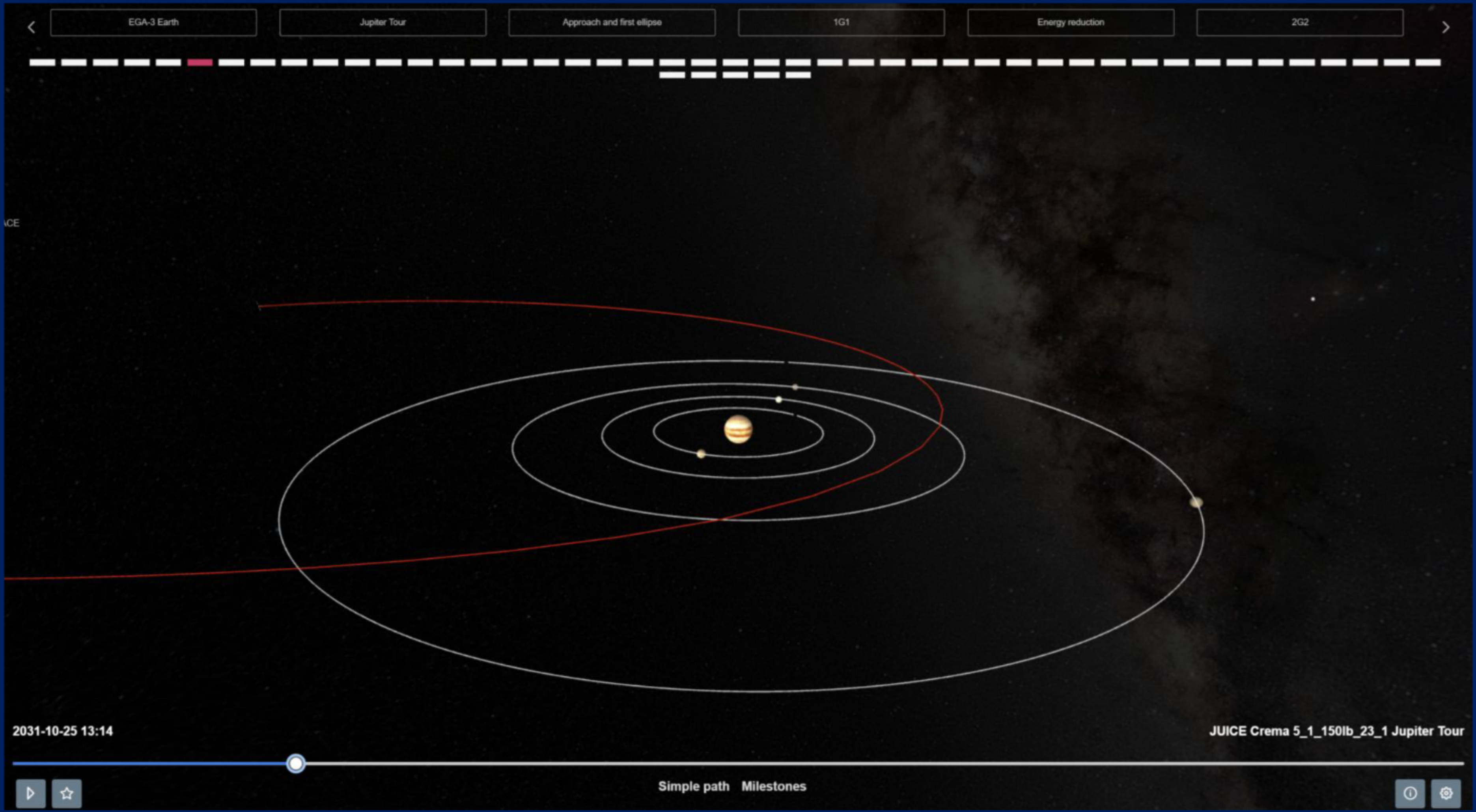


You are onboard JUICE behind 10mm of Alu shielding

Date	Days	Body dose	Effect
2031-07-17	0	0 Gy	Quite ok☺
2031-08-04	18	1.5 Gy	Depression of blood production
2031-09-05	50	4 Gy	Cataract
2031-09-15	60	5 Gy	hair loss
2031-09-25	70	6 Gy	Skin erythema
2031-10-25	100	7 Gy	LD90

Extra slides:

How far would you get before LD90?



https://juicept.esac.esa.int/where/