Solar Orbiter EUI
Extreme UV Imager

EUI Cleanliness and Calibration Concepts

Udo Schühle

→ SOLAR ORBITER FACTSHEET

→ MISSION

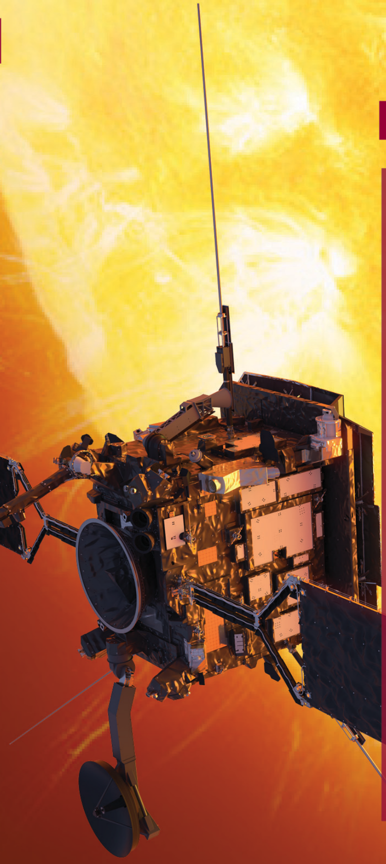
To study the Sun up close and from **high latitudes**, providing the **first images** of the **Sun's poles** and investigating the **heliosphere**

→ PARTNERSHIPS

Solar Orbiter is an **ESA** mission with strong **NASA** participation

→ SPACECRAFT

Launch mass: **1800 kg**
Science payload mass: **209 kg**
Body: **2.5 m x 3.1 m x 2.7 m**
Total length with solar arrays deployed: **18 m**
Solar panels: **6, each 2.1 x 1.2 m**
Payload power: **180 W**
Instrument boom: **4.4 m**
3 x radio and plasma waves antennas: **6.5 m each**



→ SCIENCE INSTRUMENTS

EPD: Energetic Particle Detector
PI: Javier Rodríguez-Pacheco, University of Alcalá, Spain

EUI: Extreme Ultraviolet Imager
PI: Pierre Rochus, Centre Spatial de Liège, Belgium

MAG: Magnetometer
PI: Tim Horbury, Imperial College London, UK

Metis: Coronagraph
PI: Marco Romoli, INAF – University of Florence, Italy

PHI: Polarimetric and Helioseismic Imager
PI: Sami Solanki, Max-Planck-Institut für Sonnensystemforschung, Germany

RPW: Radio and Plasma Waves
PI: Milan Maksimovic, LESIA, Observatoire de Paris, France

SoloHI: Heliospheric Imager
PI: Russell A. Howard, US Naval Research Laboratory, Washington, D.C., USA

SPICE: Spectral Imaging of the Coronal Environment
European-led facility instrument
Operations PI: Frédéric Auchère, Institut d'Astrophysique Spatiale, Orsay, France

STIX: X-ray Spectrometer/Telescope
PI: Säm Krucker, FHNW, Windisch, Switzerland

SWA: Solar Wind Plasma Analyser
PI: Christopher Owen, Mullard Space Science Laboratory, UK

→ JOURNEY TO SPACE

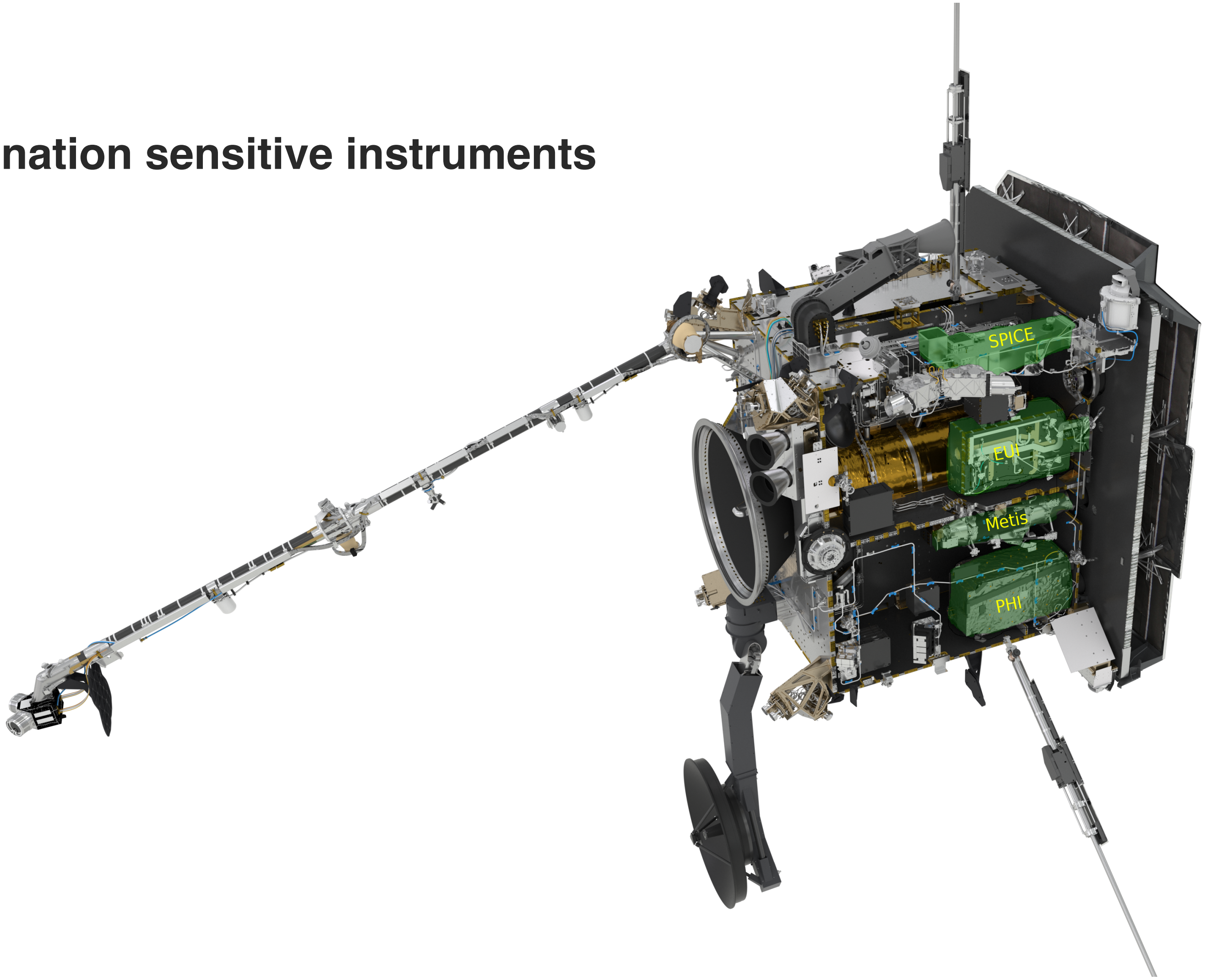
Multiple **gravity assists with Venus** will increase Solar Orbiter's inclination out of the plane of the Solar System by 24° (nominal mission) to 33° (extended mission)

Solar Orbiter will make a **close approach** of the Sun **every six months**. Its distance from the Sun varies from within the orbit of Mercury to close to the orbit of Earth

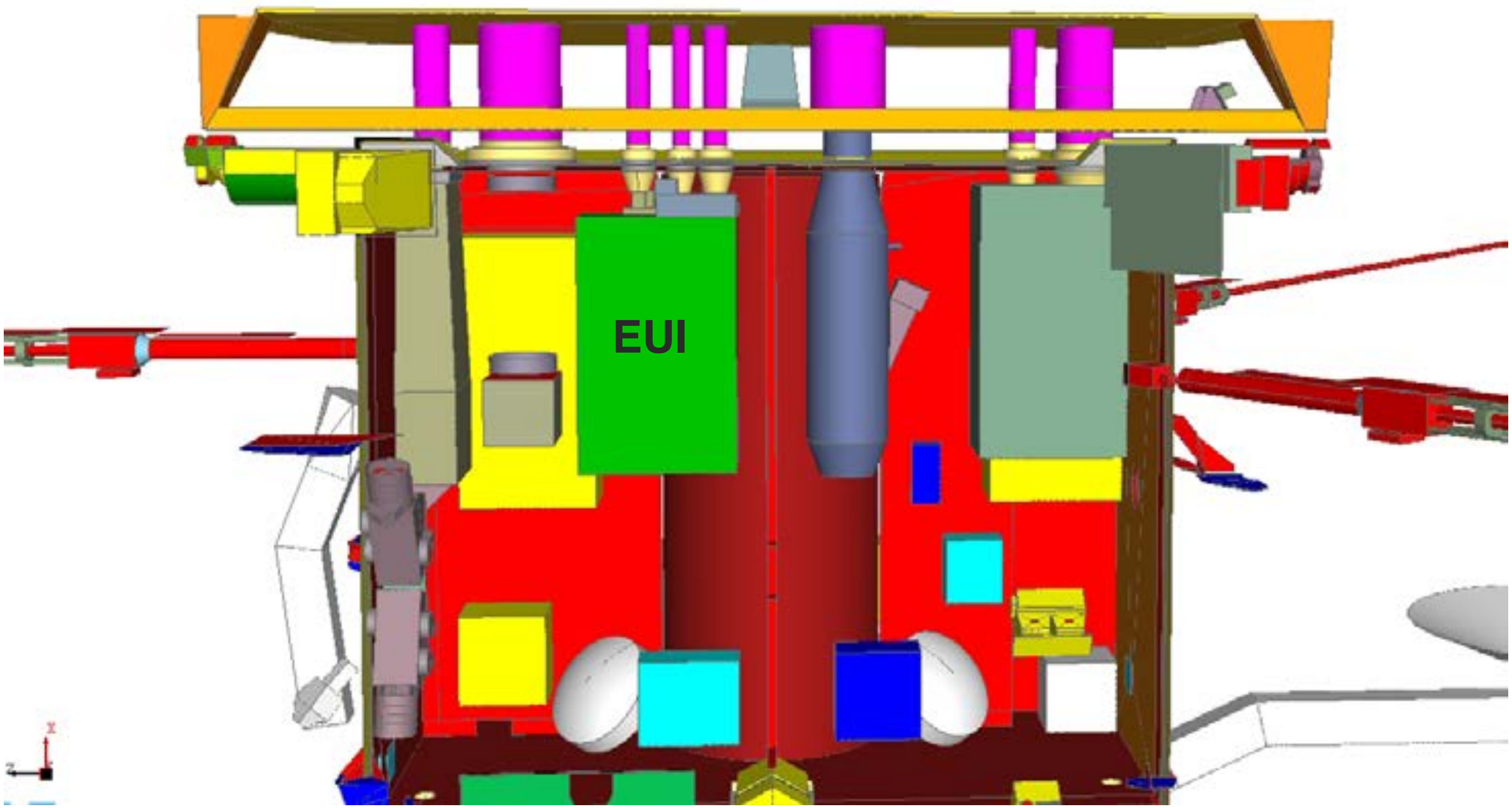
Credit: Spacecraft: ESA/ATG Medialab

Solar Orbiter S/C instruments

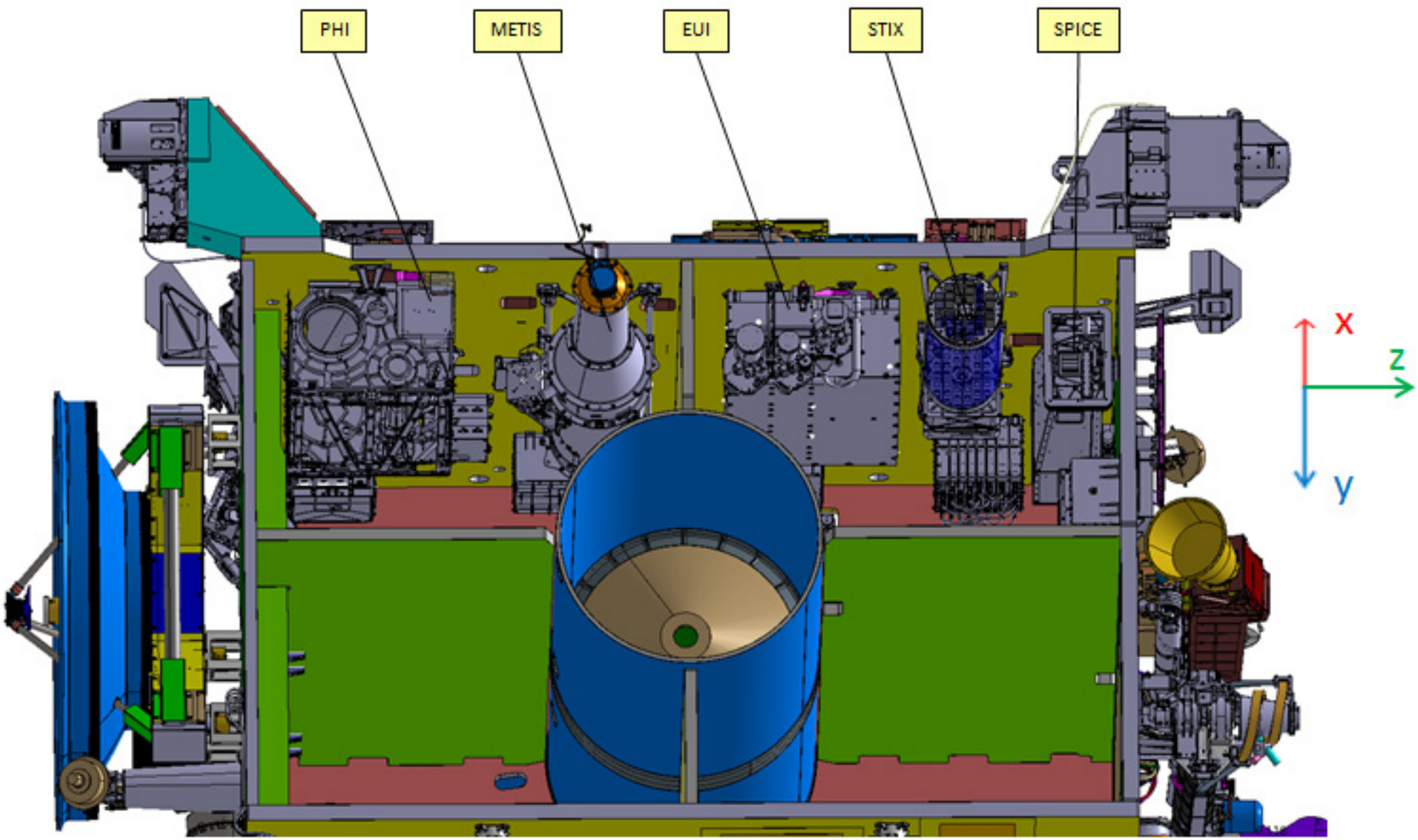
Contamination sensitive instruments



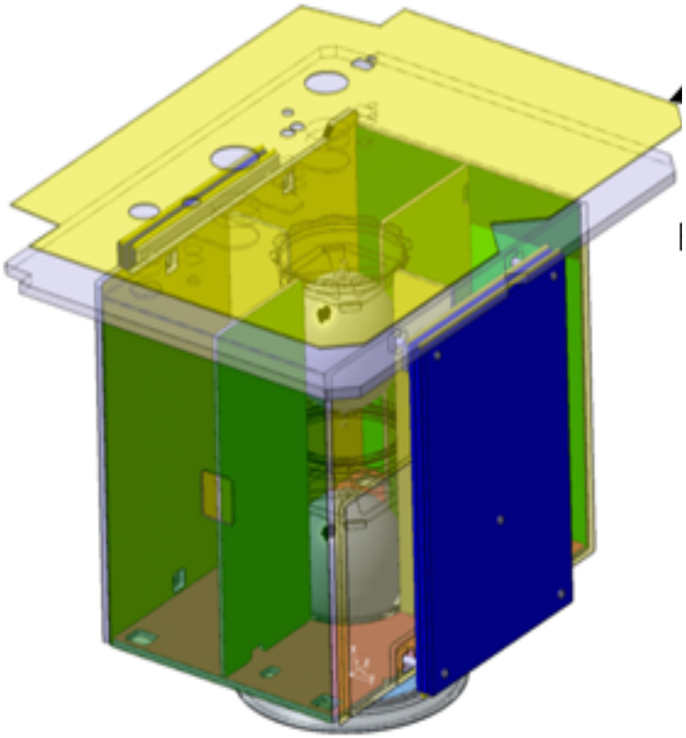
Solar Orbiter Remote Sensing Instruments

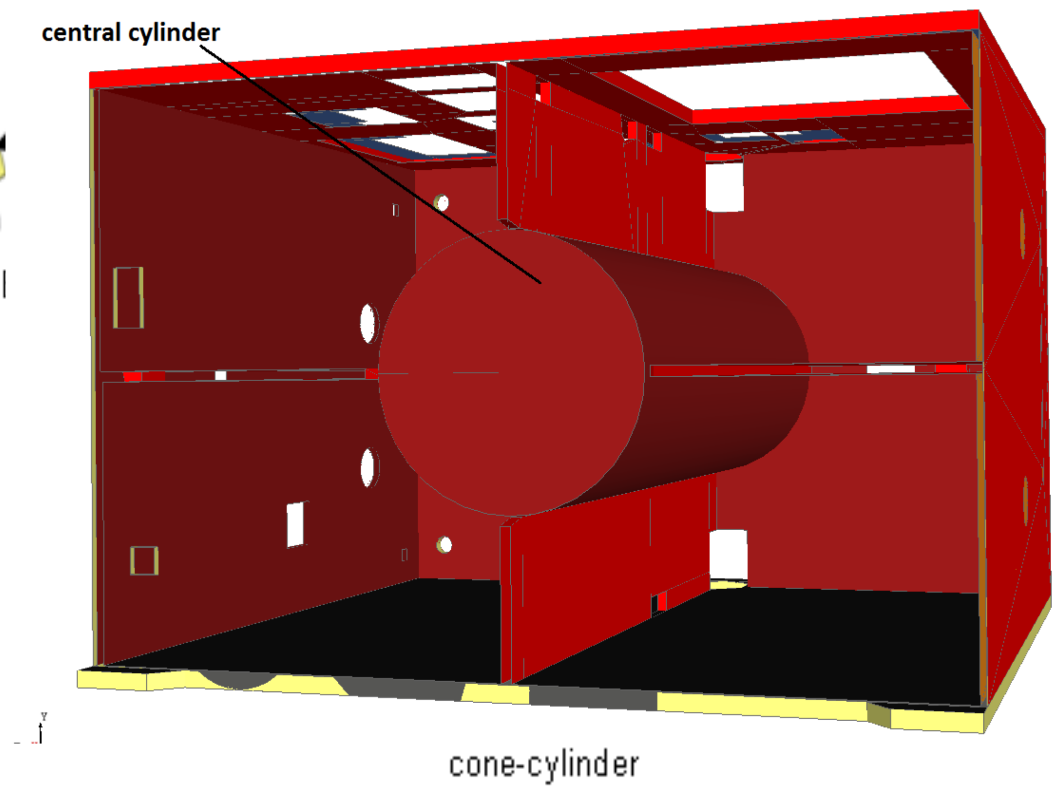


Solar Orbiter payload accommodation



Spacecraft structure





4 quadrants with small venting holes

In-flight contamination modelling

4.1.43 Contamination results for EUI_EXT_HW_PY

During the considered mission time, the target 'EUI_EXT_HW_PY' is subject to temperatures ranging from 273 K to 304 K with an average of 279 K. The EOL value for the total contamination (black dotted line) for this timespan is 20 577 ng/cm² with a maximum value of 45 708 ng/cm² occurring after 3 days, i.e., during the Pre-NMP. The main source material at the EOL is SOLO_Harness_int.

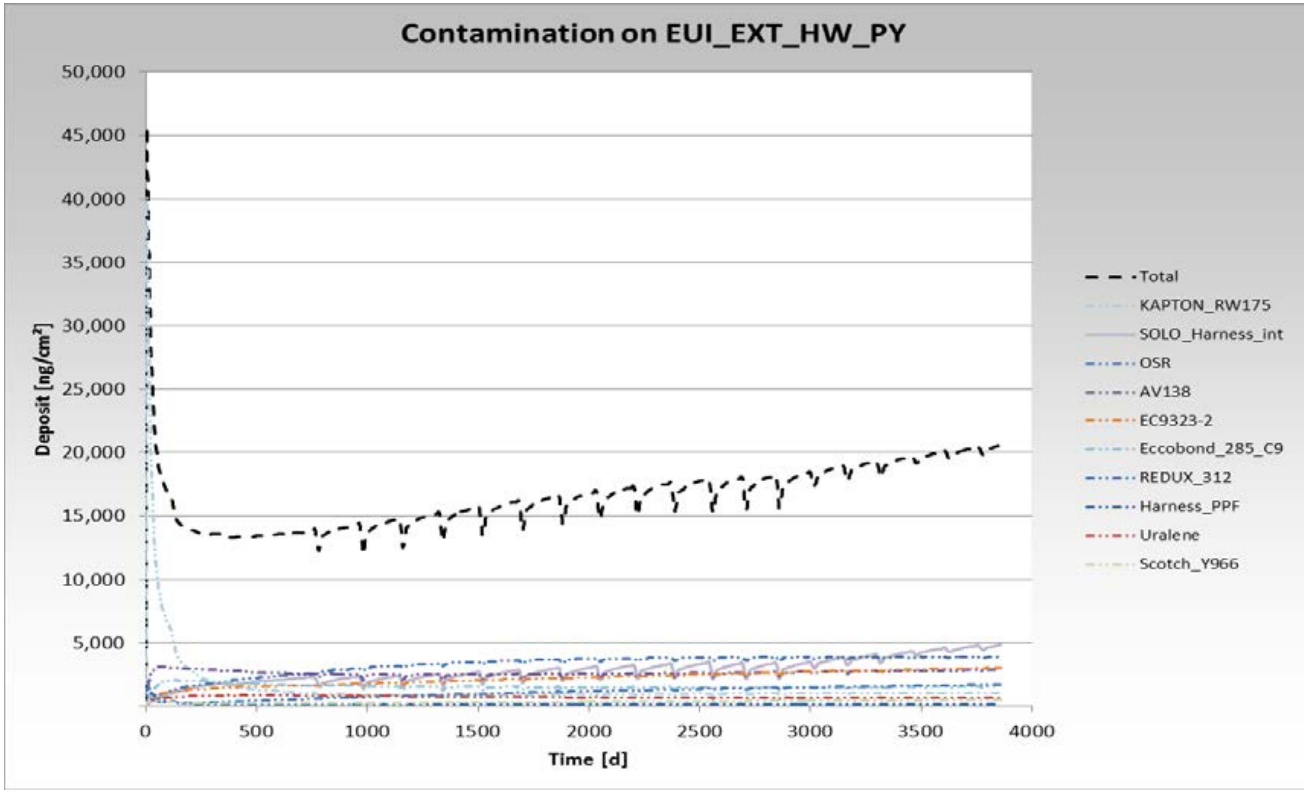
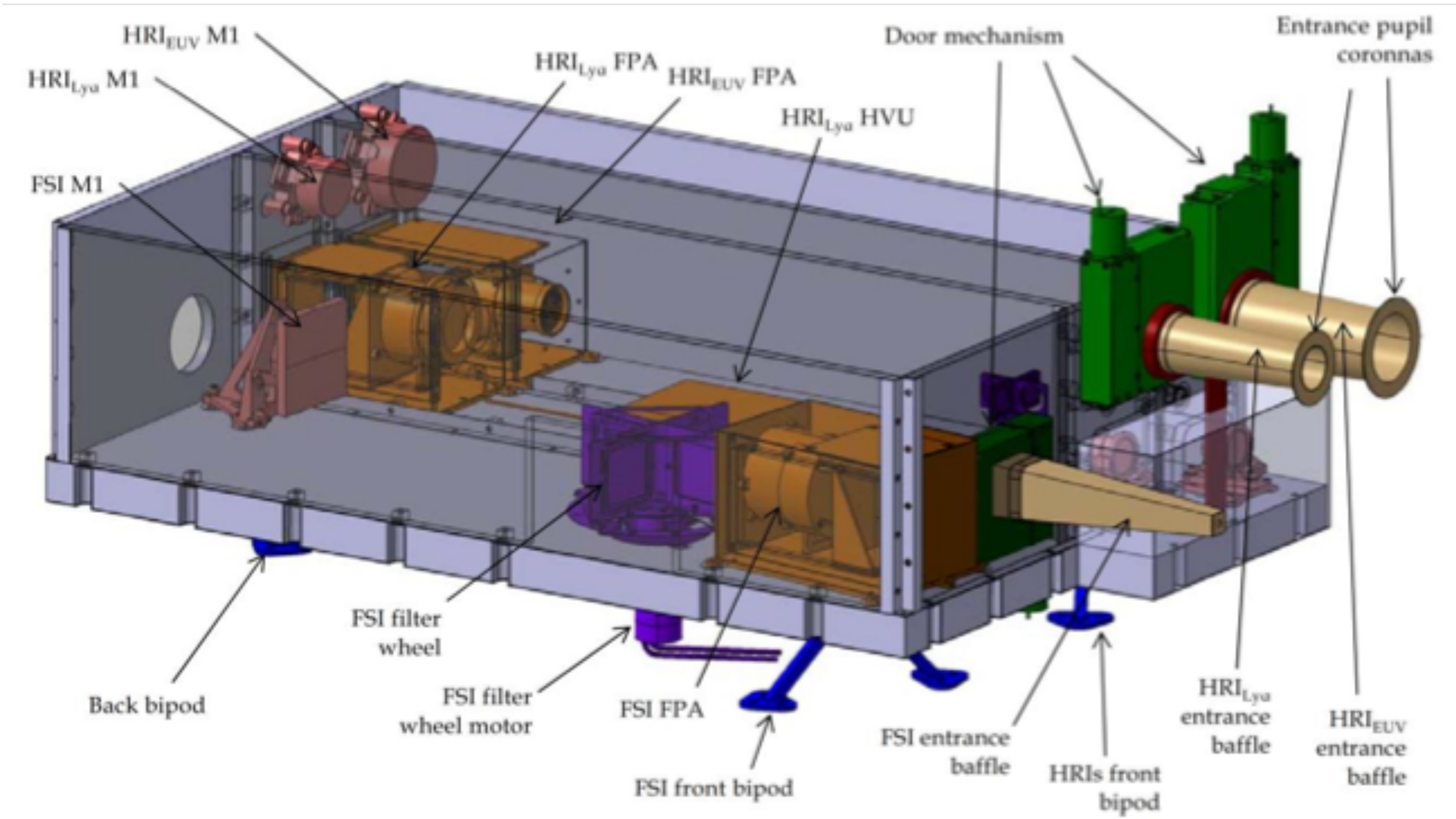
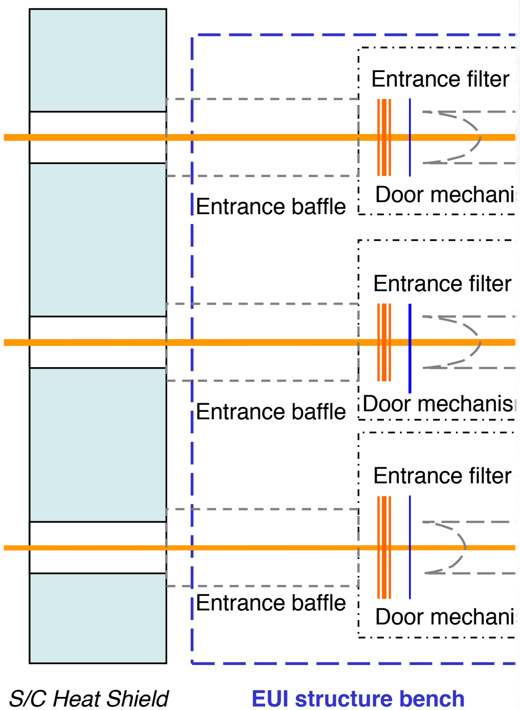


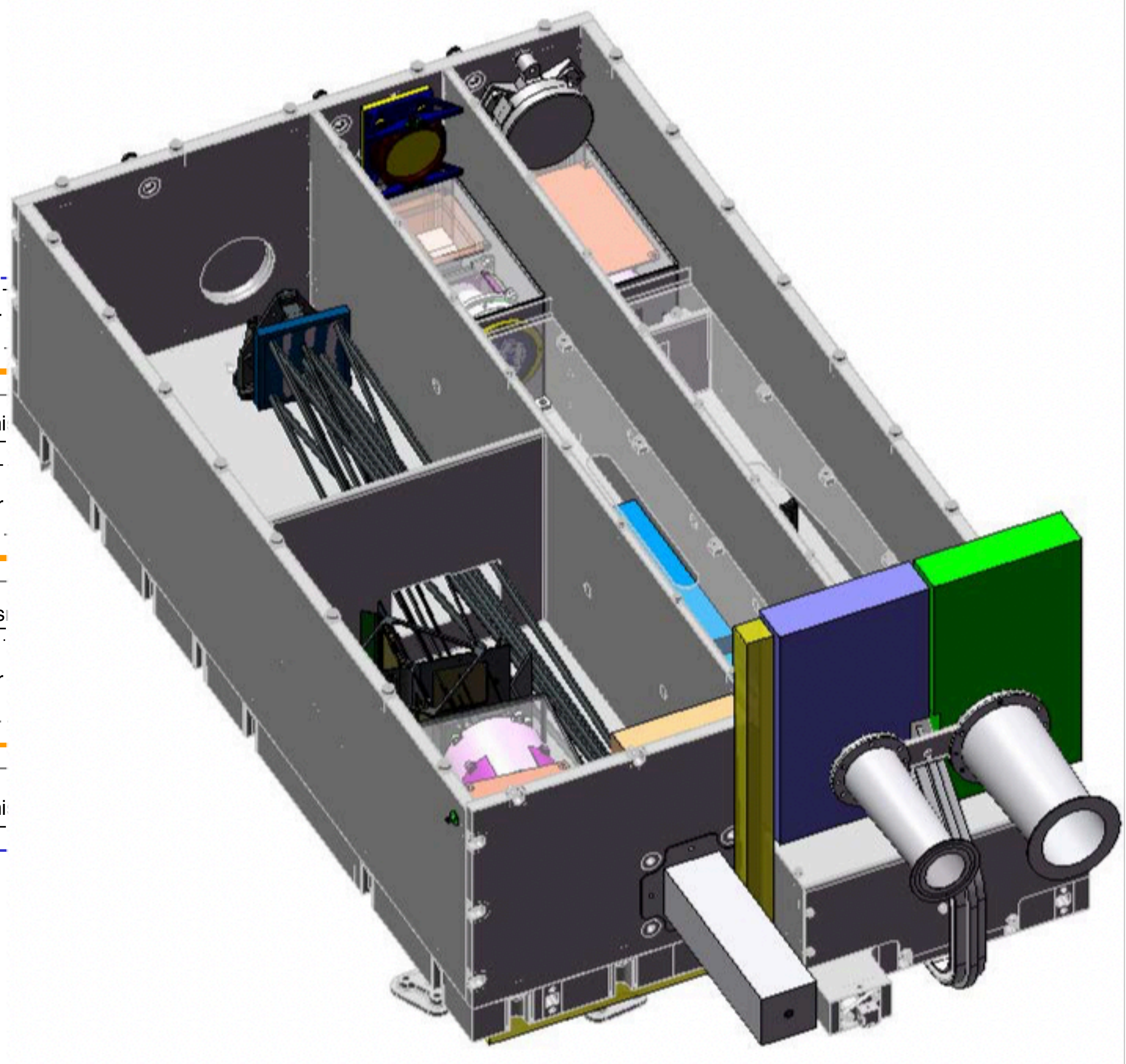
Figure 213: Contamination on EUI_EXT_HW_PY.

Instrument overview



EUI Functional Diagramme





EUI Calibration Concept

- Calibration of subsystems
- Calibration of the flight instrument

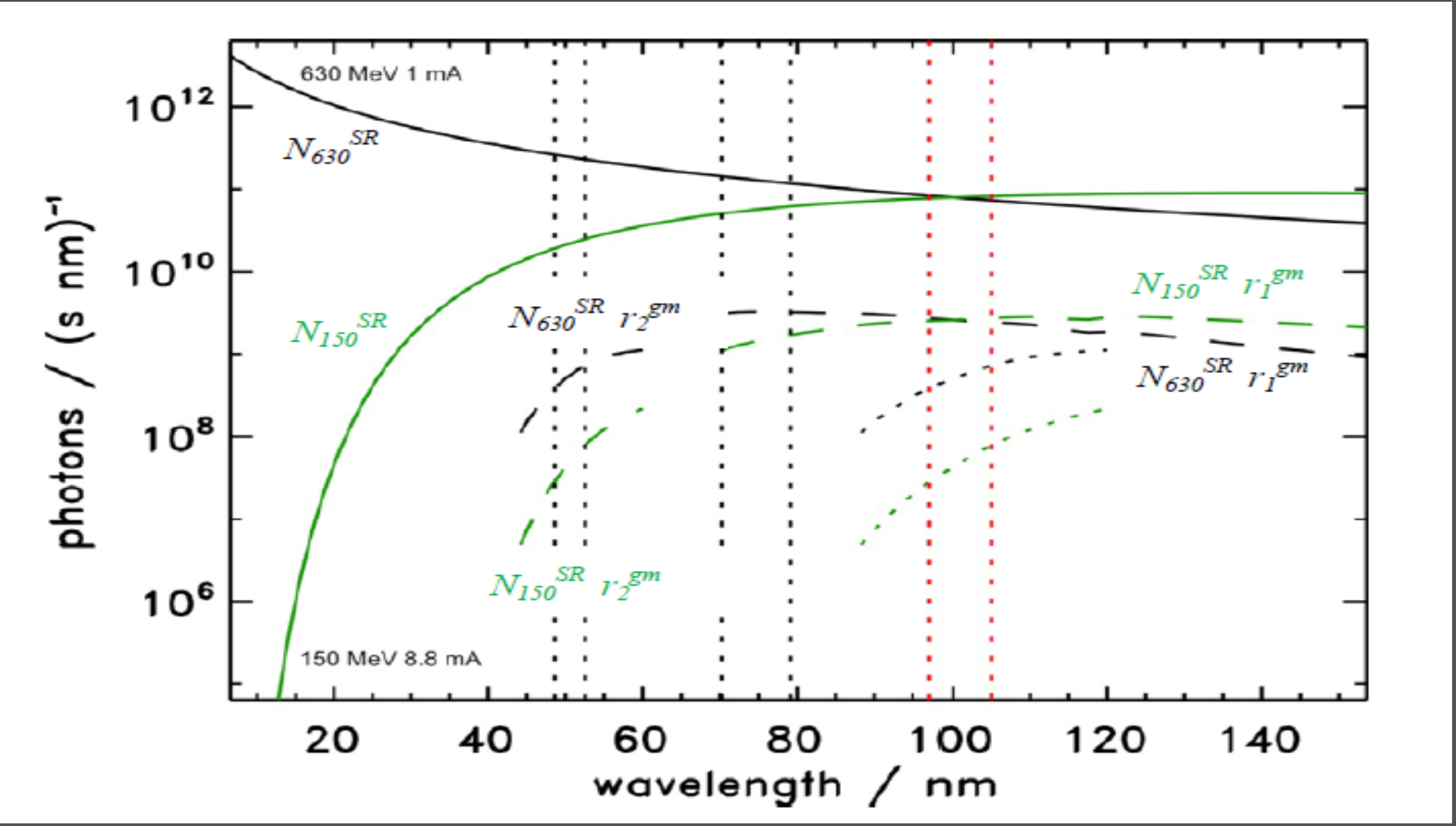
==> collaboration with PTB (Berlin)

Calibration of EUI subsystems

EUI Calibrations of Subsystems		
		FSI, HRI-EUV, HRI-Lya
Filters		Entrance filter + Focal filter
	Spectral Transmission	
	Uniformity at peak lambda	
Mirrors		Coating witness mirrors
	Spectral Reflectance	
	Uniformity at design lambda	
Detectors		QM, FM, FS
	Spectral Response	
	Out-of-band Response	
	Uniformity of Response	

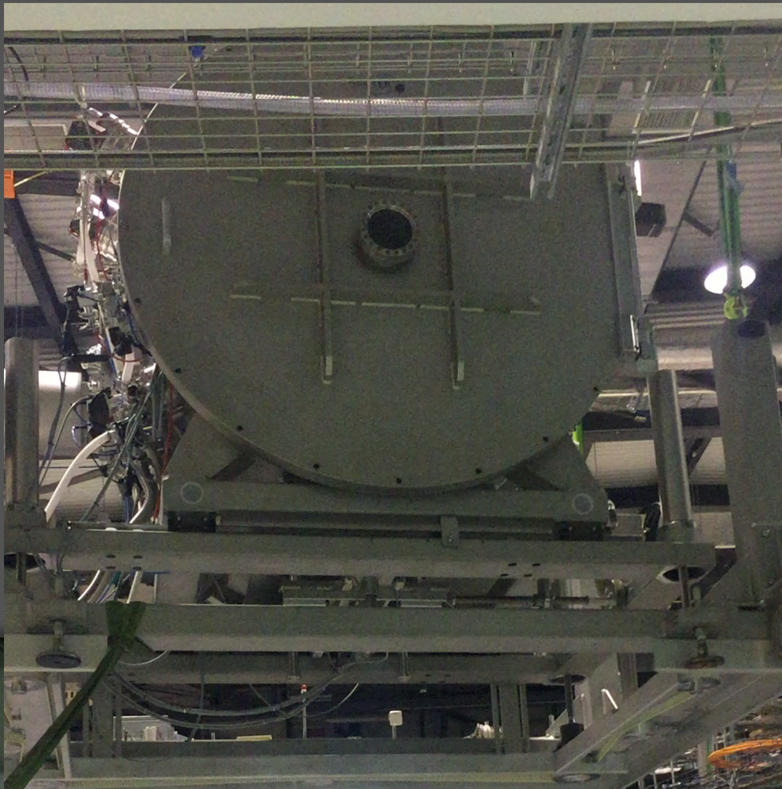
Calibration with white light synchrotron radiation

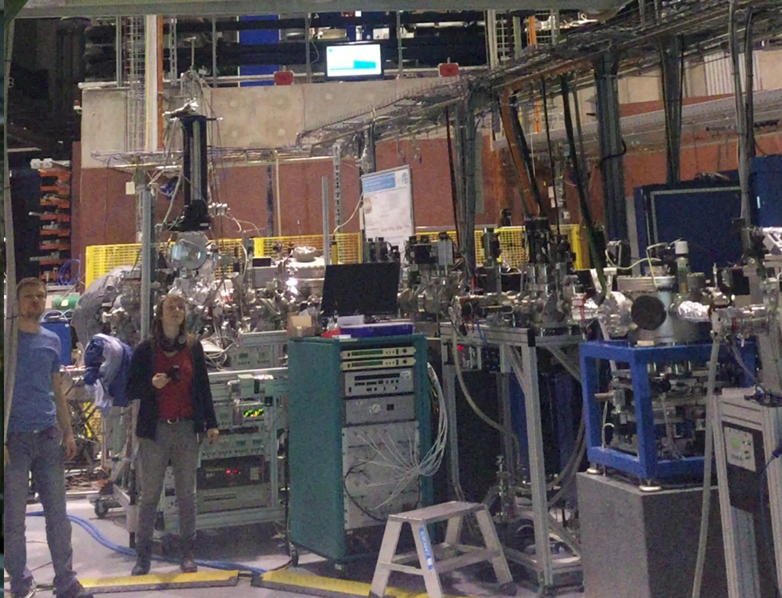
- Primary source standard, calculable precise intensity
- special operation of electron storage ring
- Continuous wavelength spectrum




2lift
WAY OF LOADING

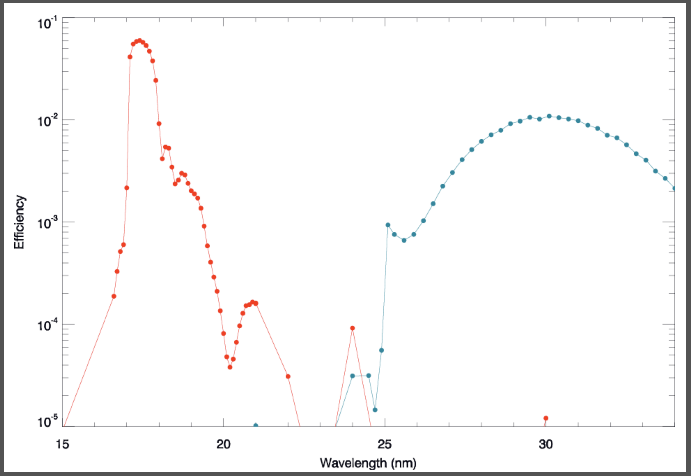
t the MLS calibration beamline



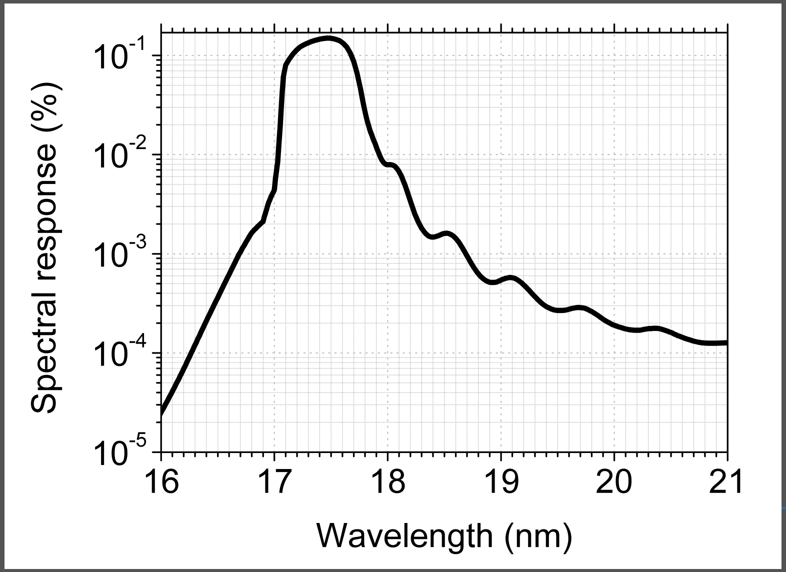


Calibration Results of EUI channels

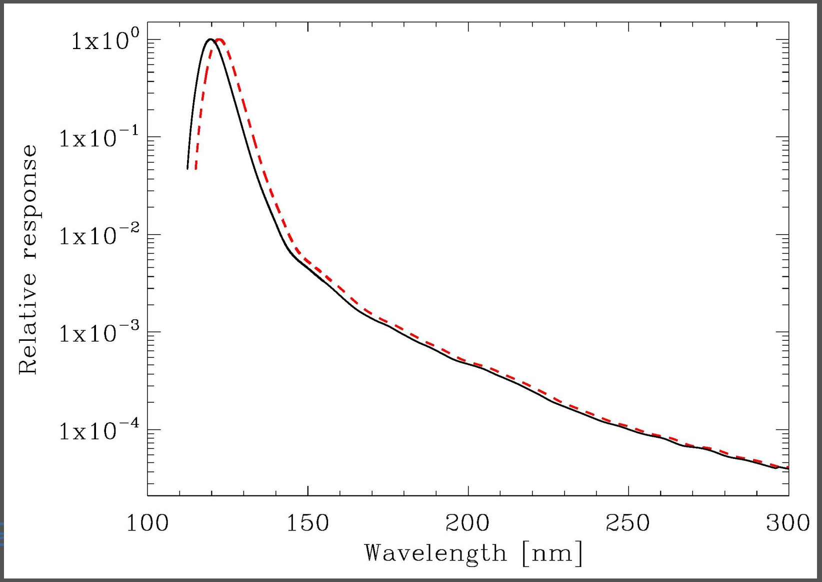
Relative response of FSI



Relative response of HRI EUV



Relative response of HRI Lya



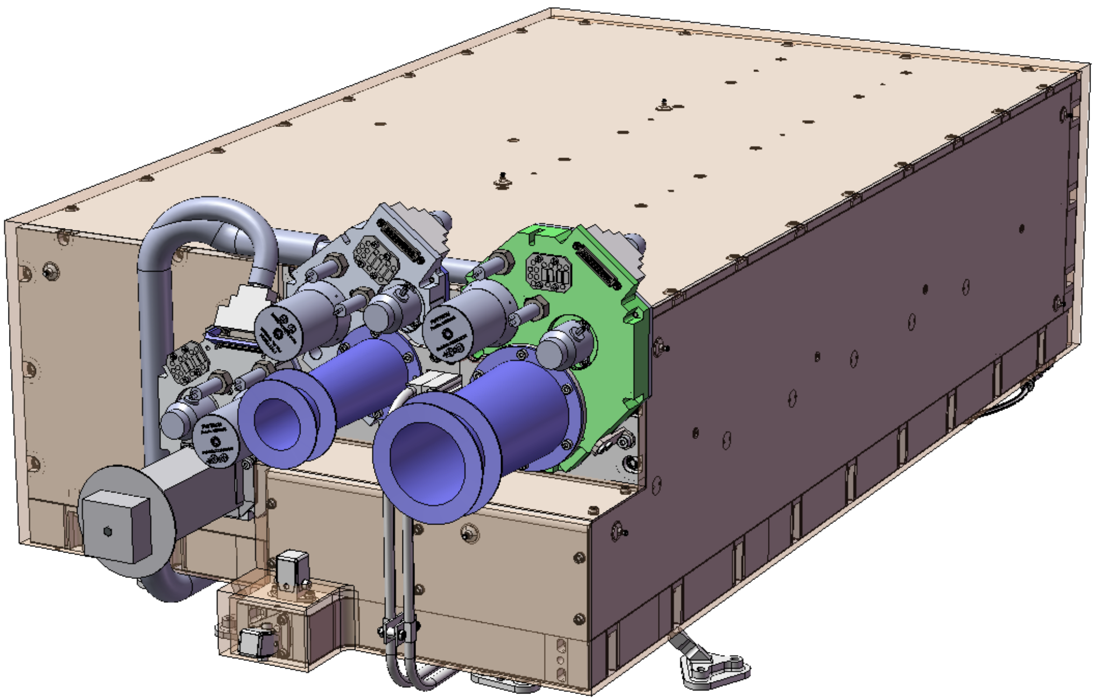
EUI Cleanliness Concept

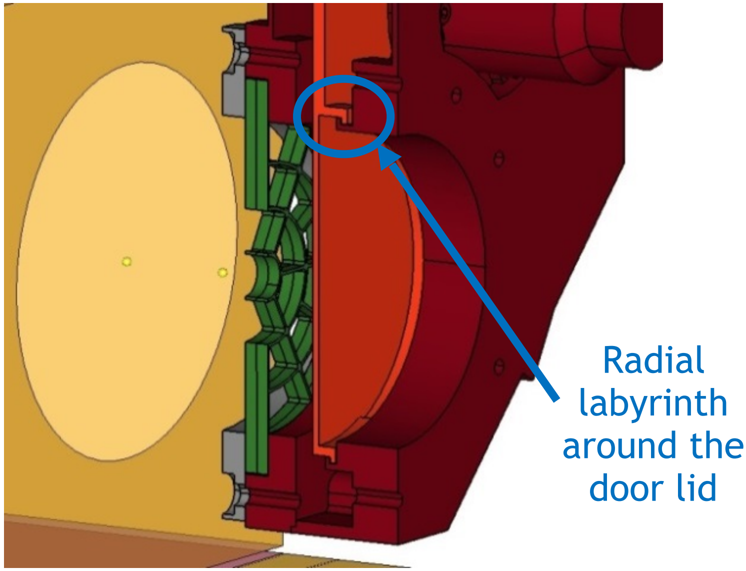
- keep degradation at a minimum
- keep calibration stability

==> design for cleanliness

EUI doors design

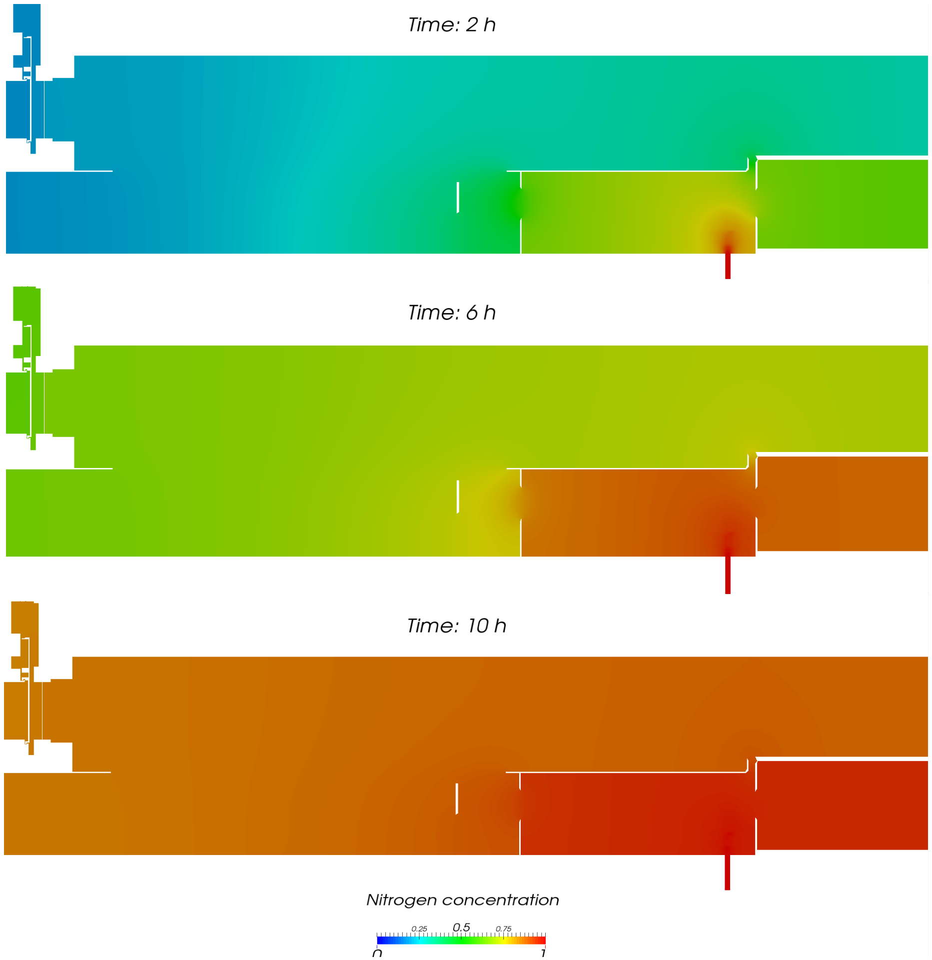
- New door design
  - Simpler mechanism → no sealing
  - Labyrinths sized for depressurization and purging → purge rate increased to ensure positive ΔP during purge
  - NB: Interface with bench structure with GoreTex ring





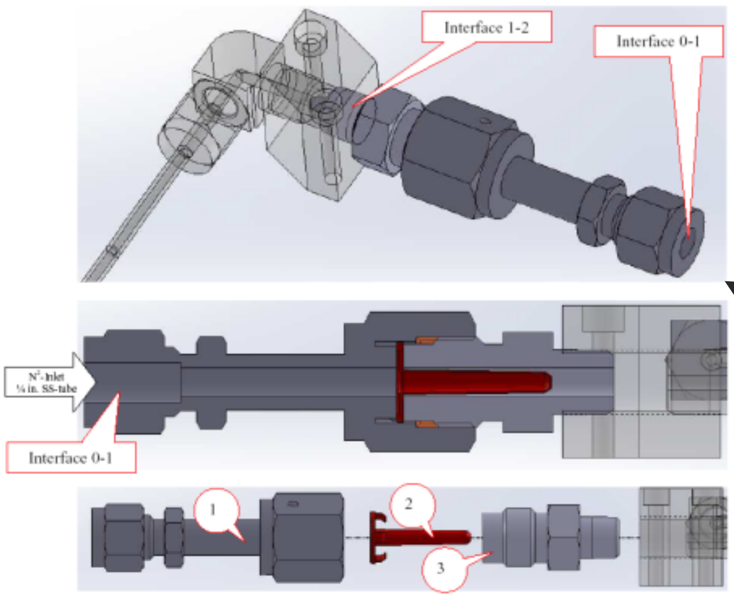
EUI design

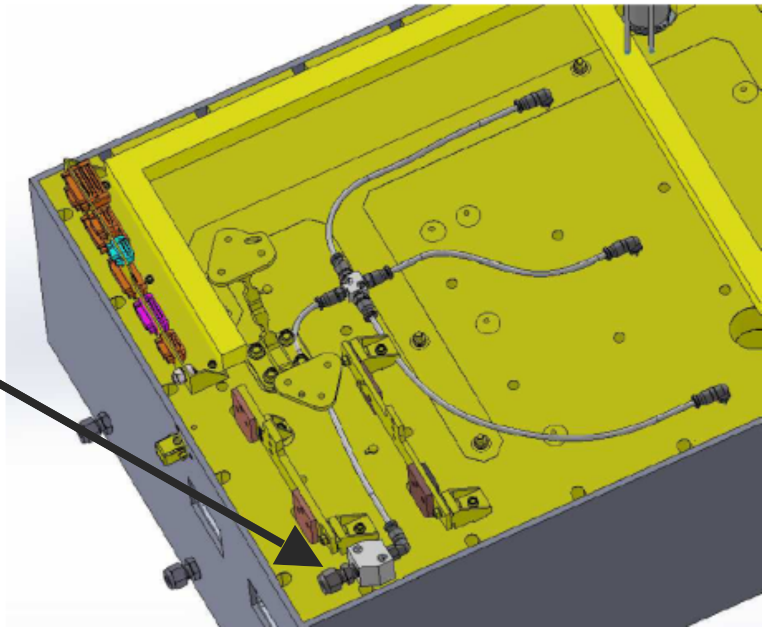
- Purge computation results



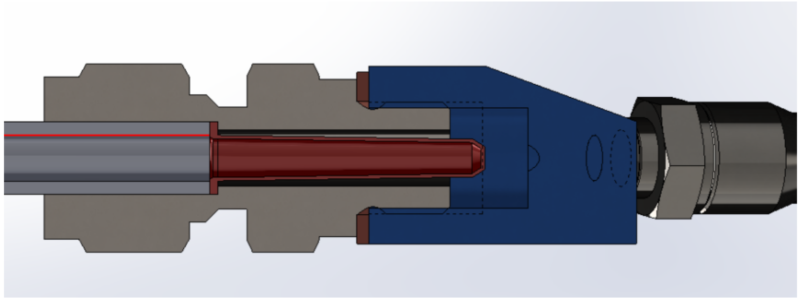
EUI purge system design

- Purge inlet interface
  - SS-400-1-4 to S/C
  - OBS external pipes for flow distribution to three channels

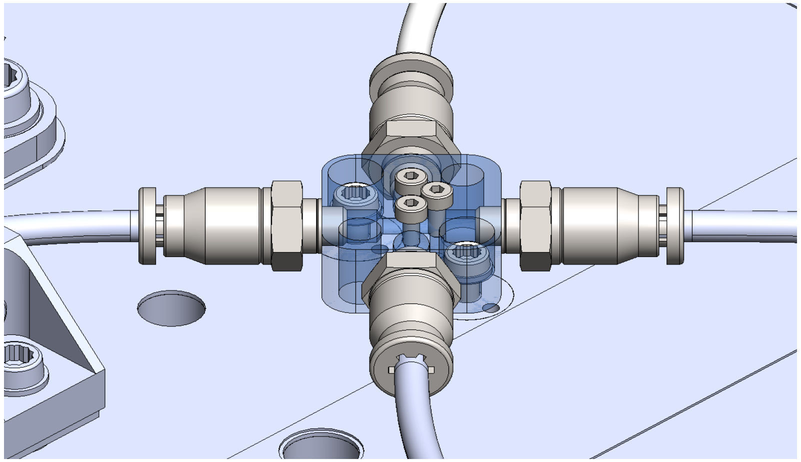


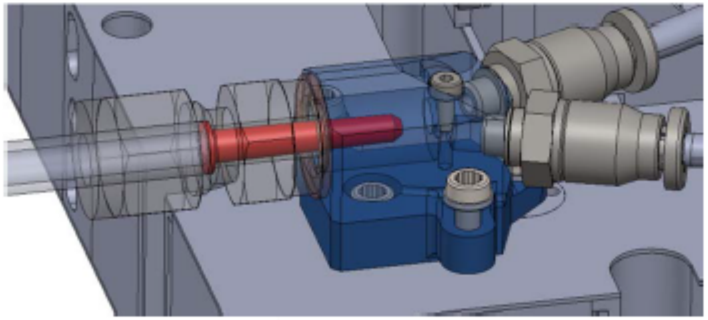


Purge inlet filter and distribution



- Inlet particle filter ≥ 0.4 µm
- Teflon tubing
- Flow-rate adjustment with set-screws
- Total mean flow-rate = 2.56 liter/hr
  - HRI_{EUV} → 0.64 liter/hr
  - $HRI_{Ly\text{-}\alpha}$ → 1.28 liter/hr
  - FSI → 2 x 0.32 liter/hr



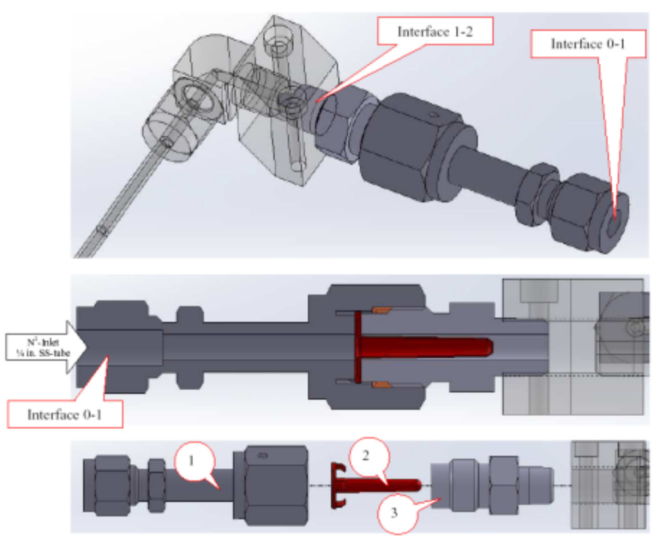


designed by PMOD/WRC, Davos

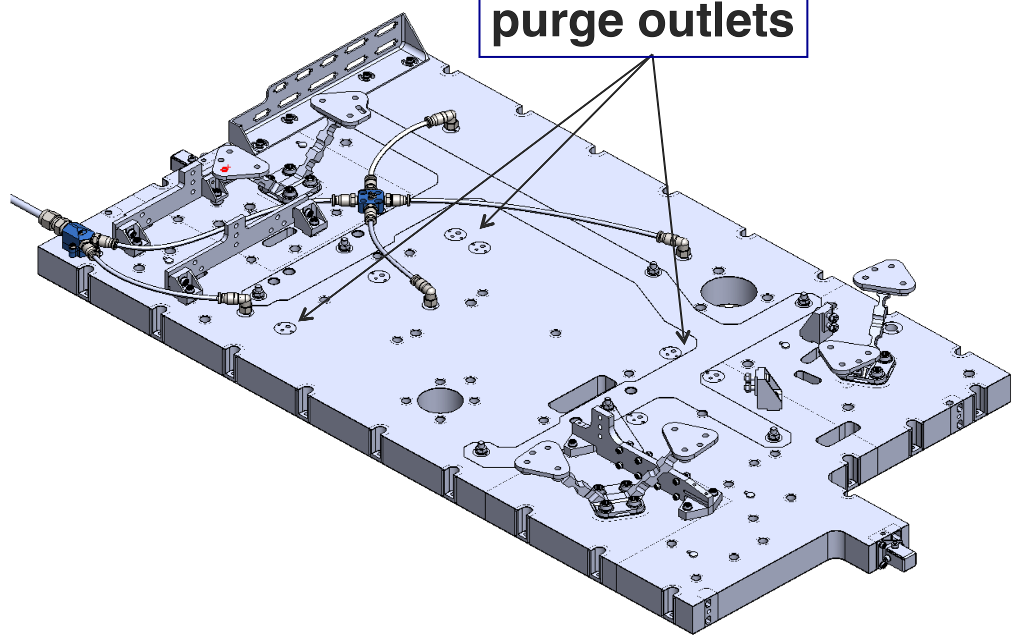
Purge inlet & outlets

- purge interface Swagelock stainless steel model
  - EUI agrees to use SS-400-1-4 (smallest)
    - → Only one inlet for the three channels and a dedicated piping system under bench (Swagelok/Festo parts)
    - → <u>Total flow rate is 12 – 80 l/h for the only inlet)</u>

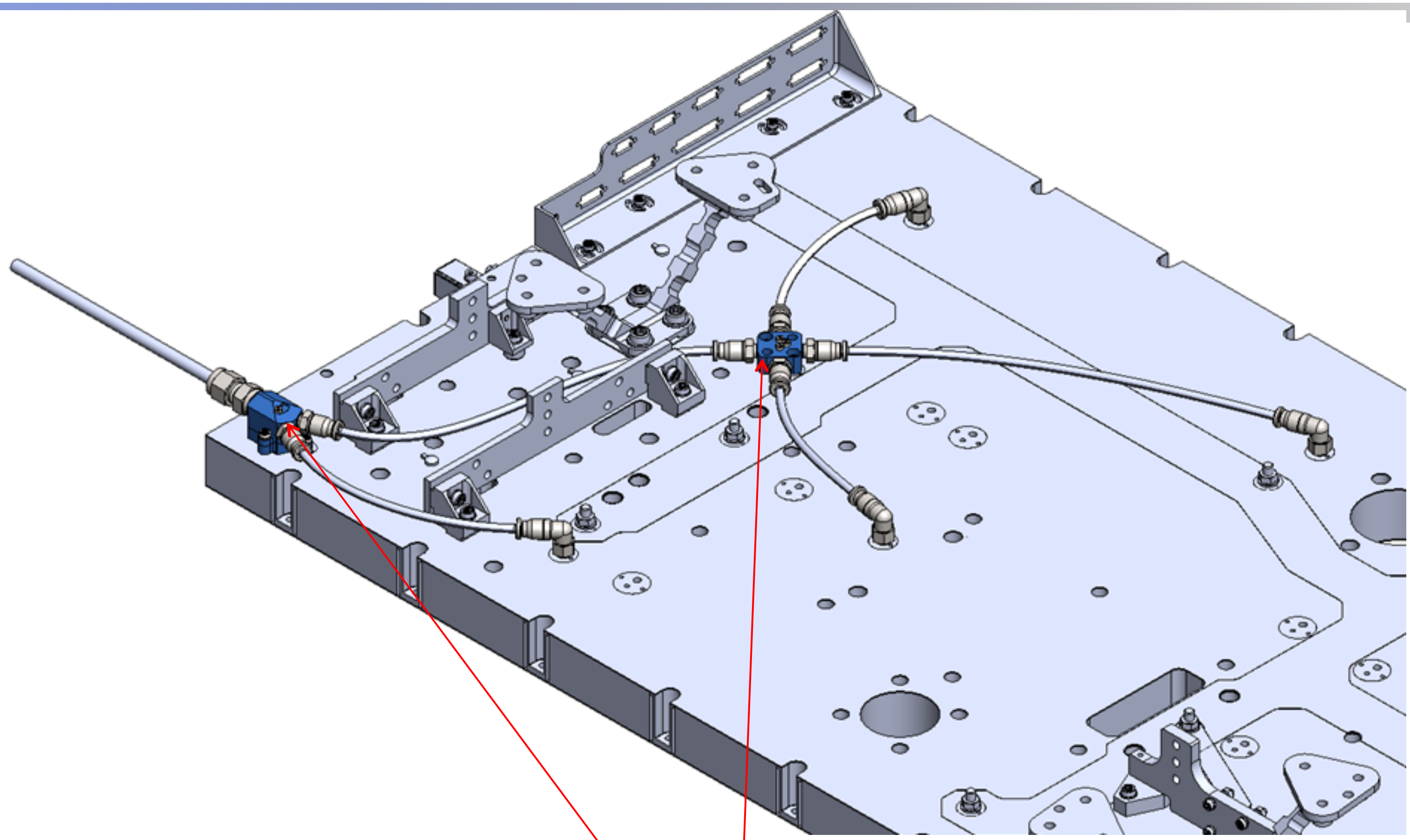
purge inlet



purge outlets



Distribution of purge gas



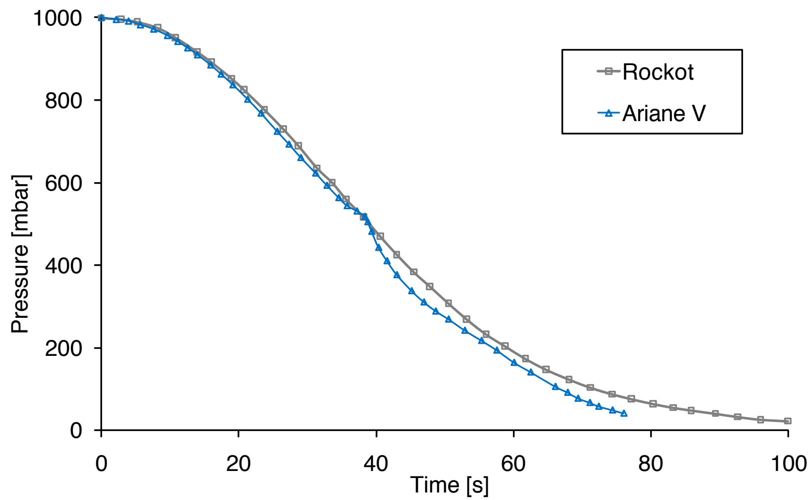
Adjustment of the set-screws until following flow-rates are achieved:

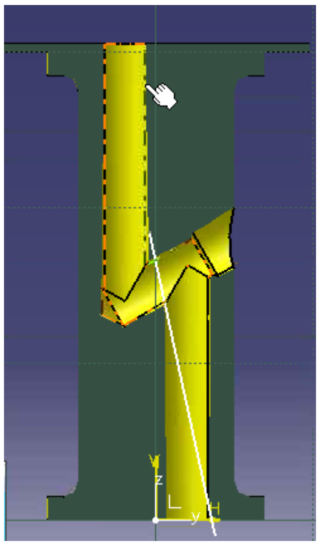
- HRI_{EUV} → 0.64 l/h
- $HRI_{Ly\text{-}\alpha}$ → 1.28 l/h
- FSI.1 → 0.32 l/h
- FSI.2 → 0.32 l/h

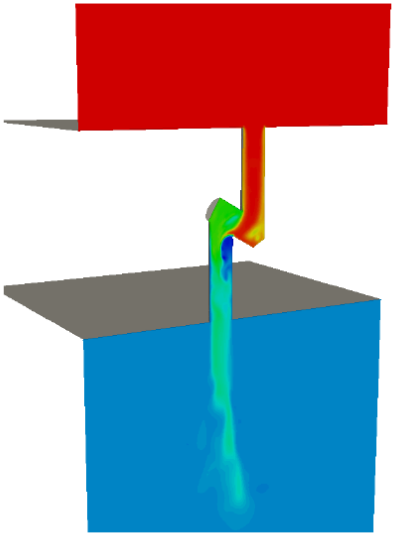
Set screws to adjust individual flow rate

EUI venting

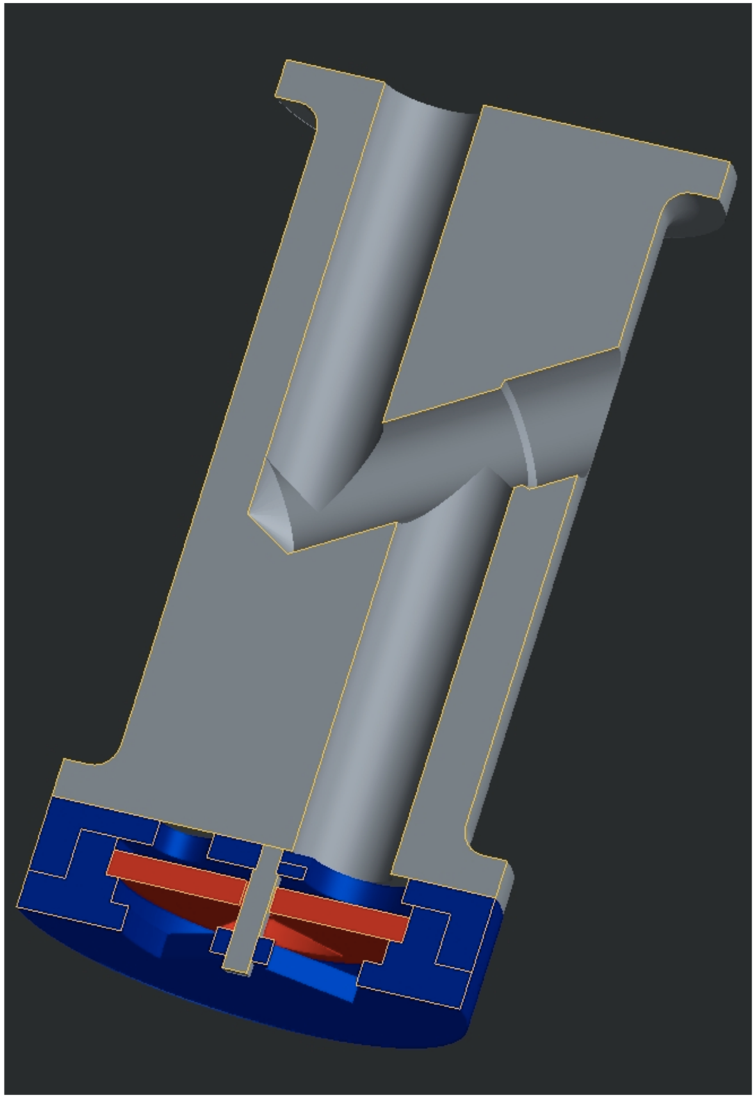
- Launch
  - External pressure
    - 1 to 0 bar with peak of 6200 Pa/s
  - Venting holes
    - 2 / 4 labyrinths in HRI / FSI channel
    - 2 mm² venting cross-section per litre volume 2 outlet per channel (drilled in dedicated inserts)

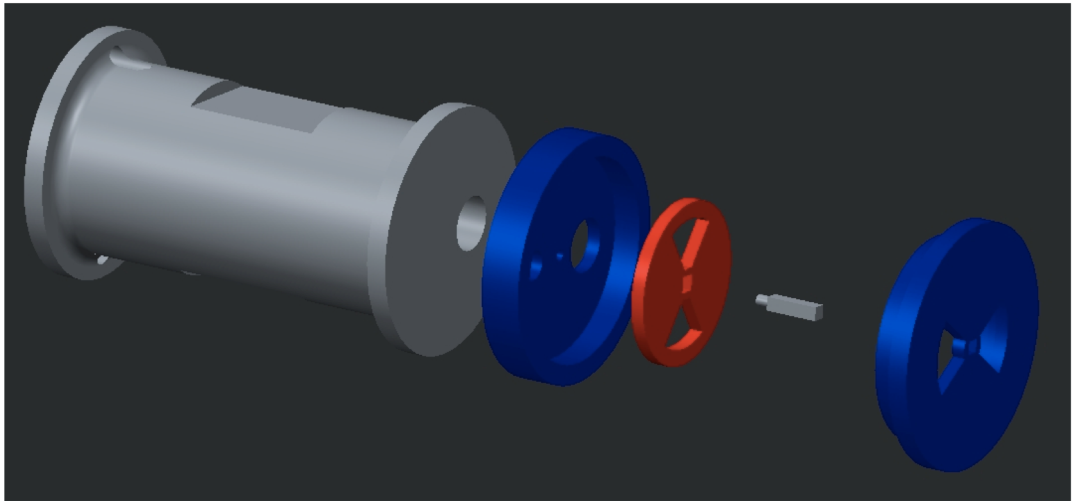






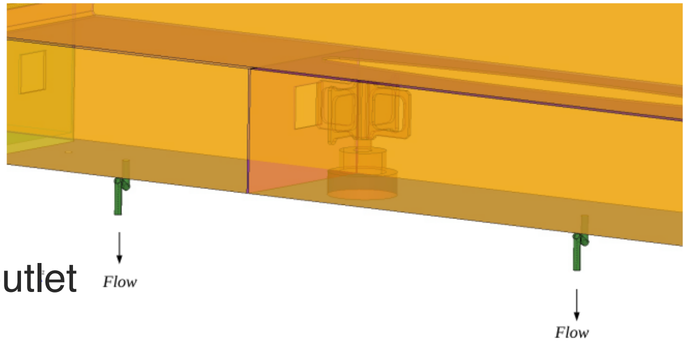
Venting valves for Lya Channel

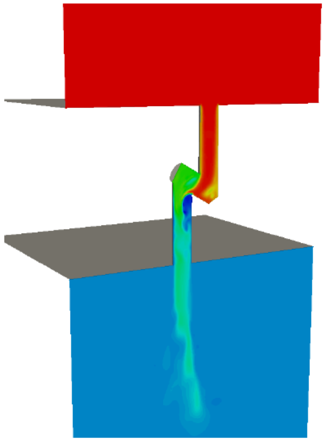




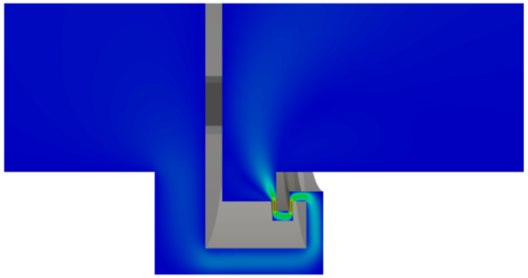
EUI design update

- New door design
  - Door labyrinth sizing
    - 2 venting outlet in the bench
    - door labyrinth ⇔ one additional venting outlet
  - CFD analysis
    - → Limited ΔP around entrance filters (< 2 mbar) during launch and purging
    - → Overpressure (0.001 mbar) during purging (compromise with launch venting)
    - → Few hours to fill cavity with N_2 (> 80% in 10 hours)

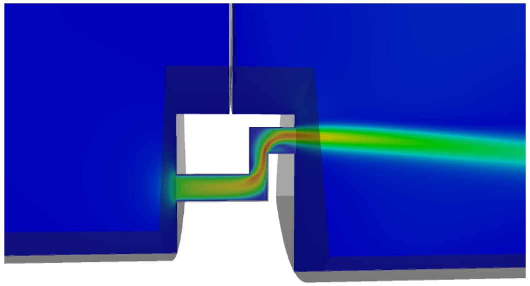




Venting outlet head loss coefficient computation



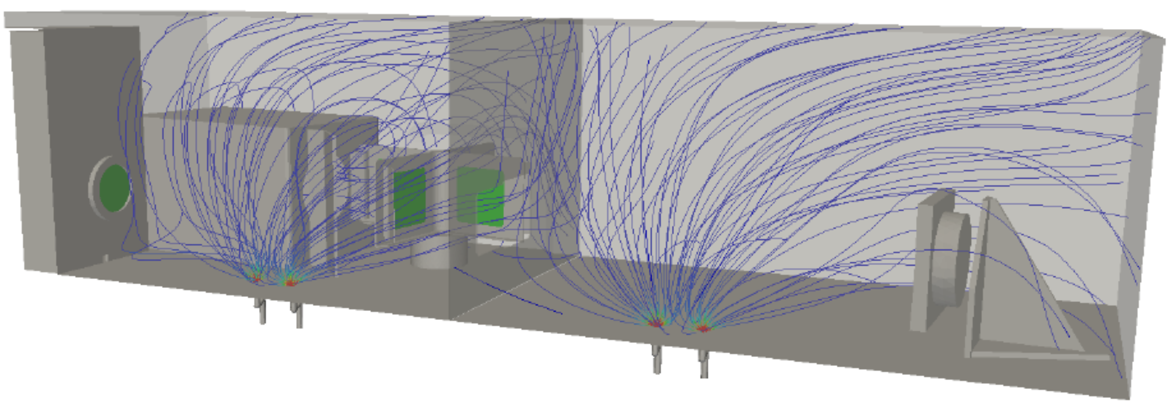
Door labyrinth head loss coefficient computation

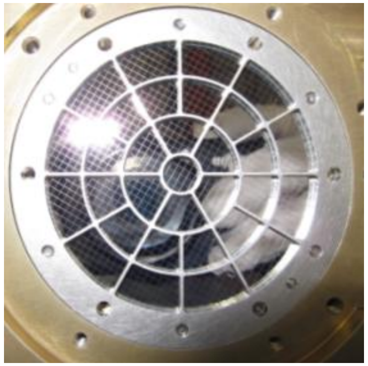


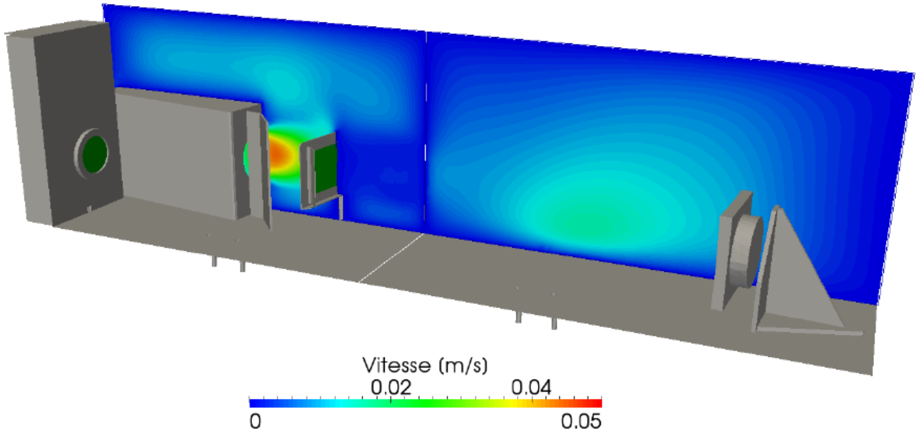
Filter labyrinth head loss coefficient computation

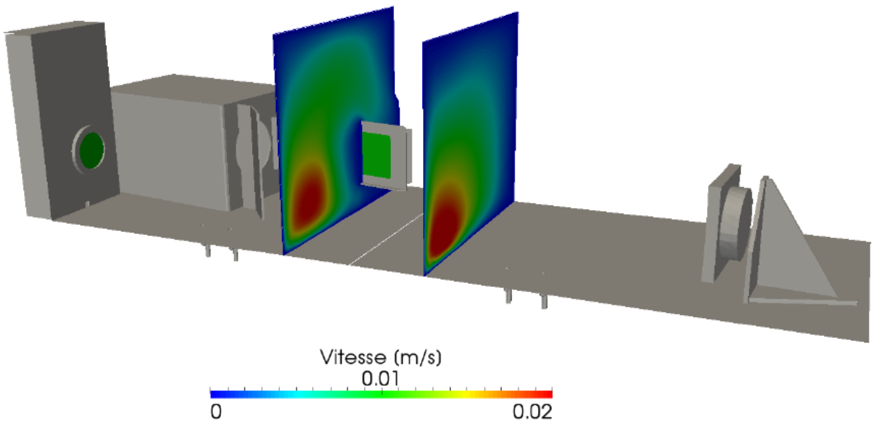
EUI venting simulation

- Launch
  - Impact on filters
    - ΔP around filter wheel and entrance filter << 1mbar



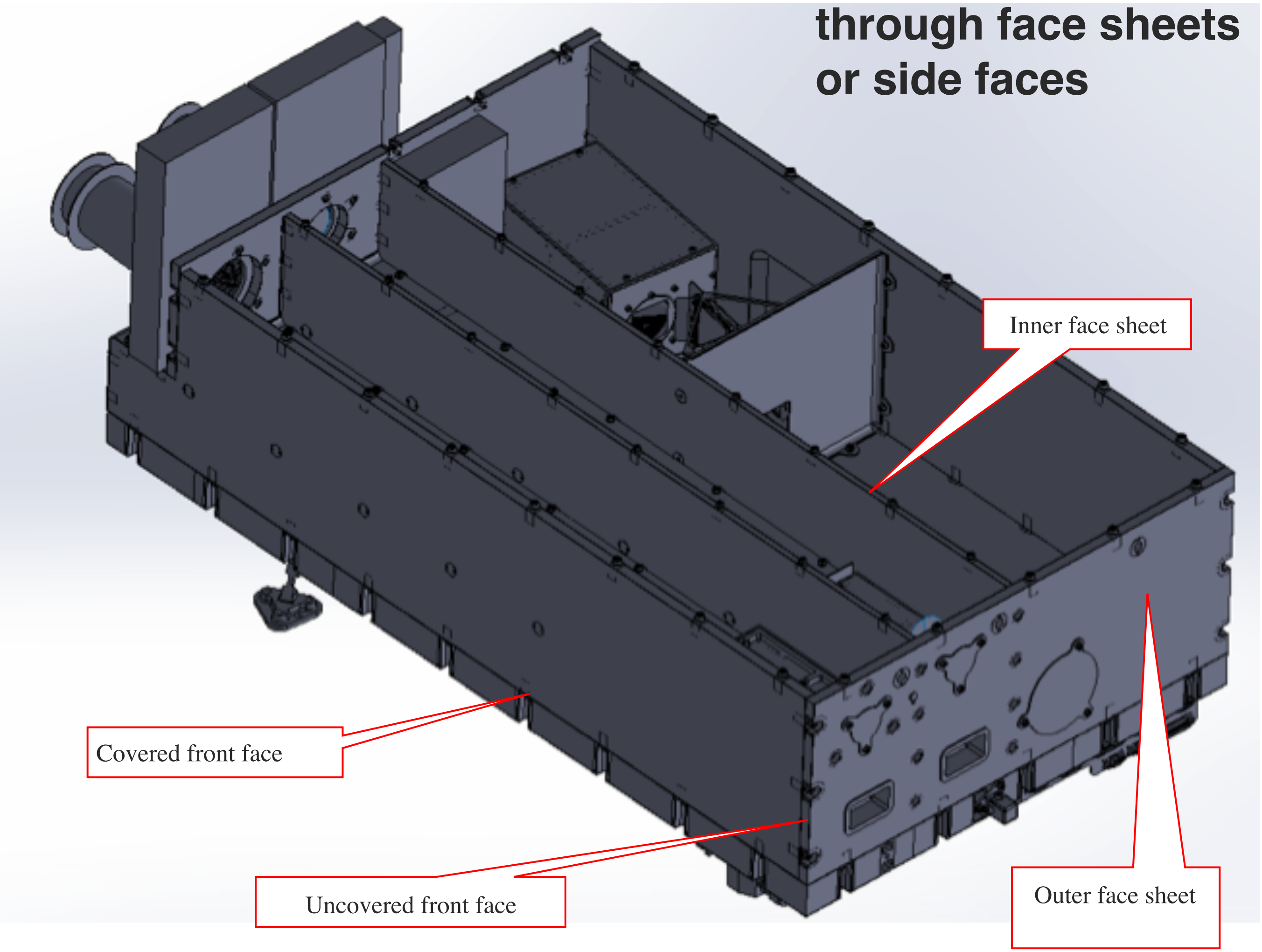






Venting of CFRP structure panels

Venting under the MLI: through face sheets or side faces

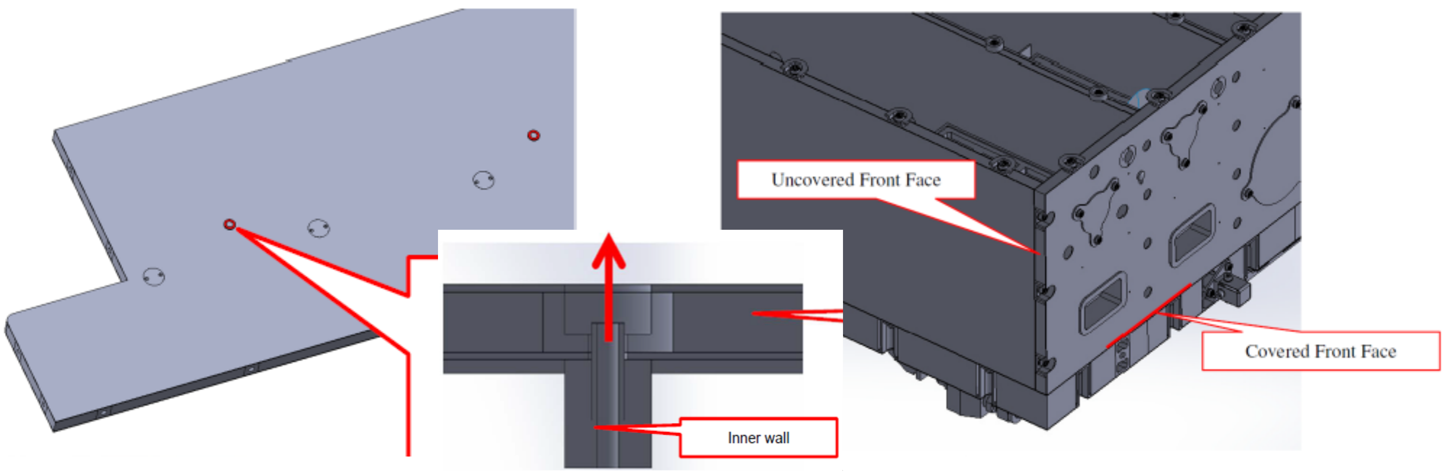


Venting of CFRP structure panels

Venting of CFRP panels

Venting – External panels

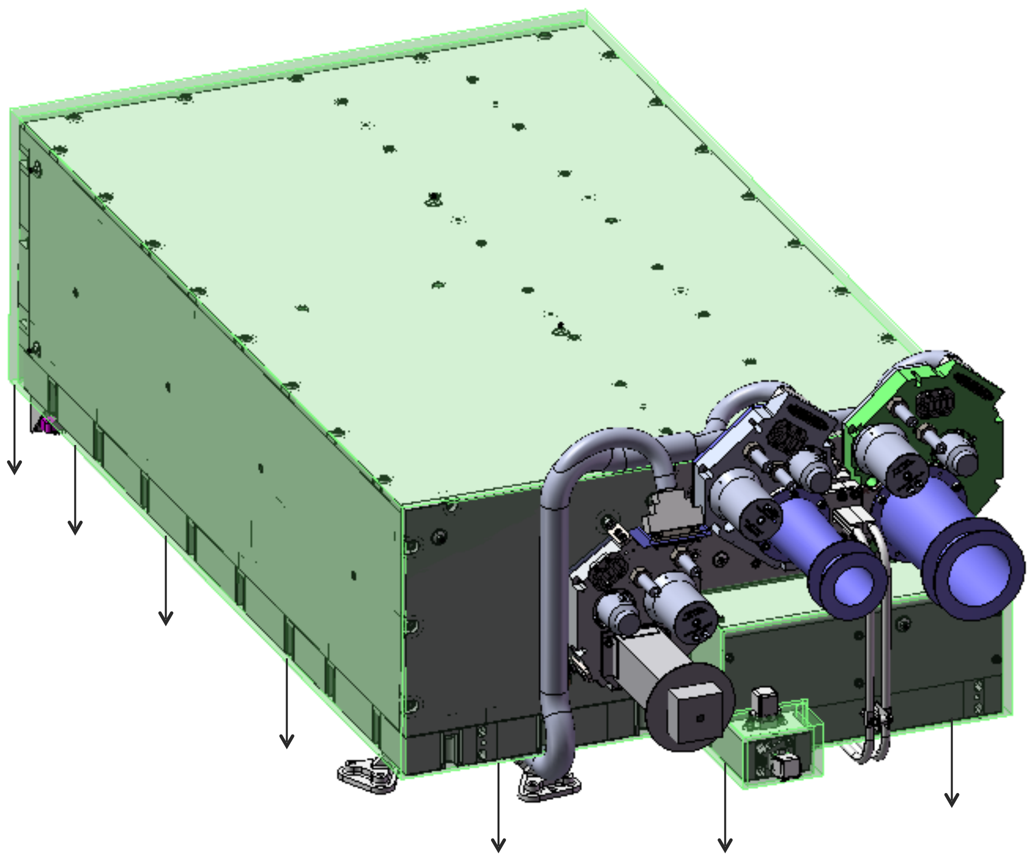
- venting inserts on outer faces
- perforated Kapton tape on open side faces
- venting of internal panels through top panel



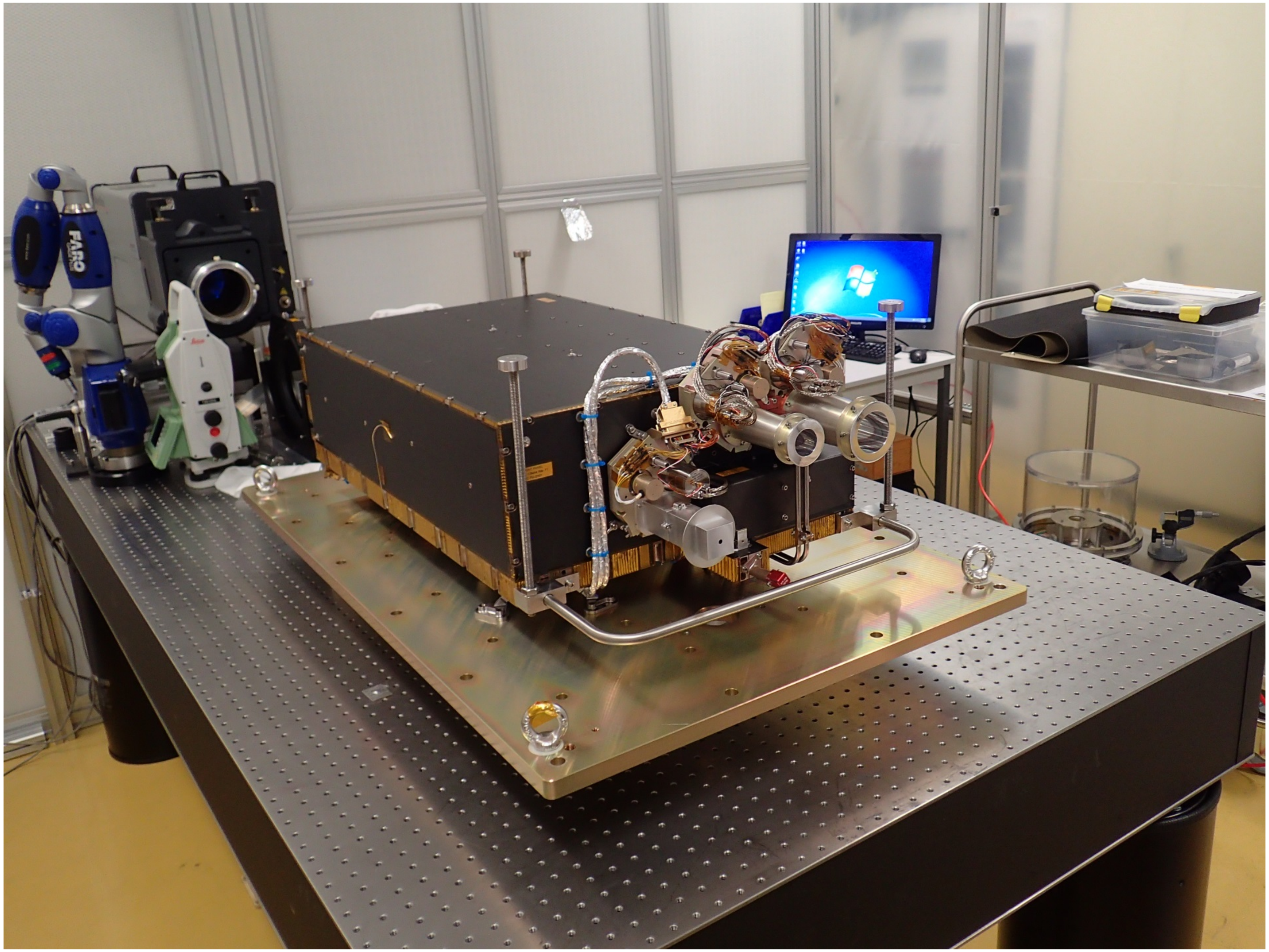
MLI venting

- EUI OBS MLI

  = 2 layers of Mylar → no micro-perforation → venting by bottom part, around unit), as per on STM



CFRP housing structure



EUI purging requirements

- EID-B requirements
  - The prime contractor shall ensure after EUI delivery almost continuous purging of the EUI structural housing with clean and dry nitrogen gas until launch.
  - The longest duration **without purging shall be limited to 30 minutes per any 24 hours**, except during the vacuum tests sequences. ==> was extended to 60 minutes by Prime request.
  - The Prime Contractor shall purge EUI, after delivery, with **gas quality grade** 5.0, i.e., 99.999% vol N_2, <3 ppm O_2, <5 ppm H_2O, < 0.5 ppm hydrocarbons. Synthetic air of the same quality may be used. Before delivery, gas quality used will be Grade 6.0 (or BIP 5.2) ==> was changed to MIL-PRF Grade C quality by prime.
  - The purging **flow rate** shall be **in the range 12 – 80 l/h**. ==> was implemented by flow restrictive capillary.
  - **The maximum purge pressure spike shall be 0.003 bar.** ==> changed to 30 mbar/minute
  - The purge shall be maintained with a log of all purge interruptions.
  - During AIV of the spacecraft and on the launcher inside the fairing a gas supply is required to sustain a flow rate in the range 12 – 80 l/h.
  - The Prime Contractor shall ensure that after re-pressurisation of vacuum chamber, the clean gas is supplied through the purge inlet connector on the spacecraft. ==> changed to a slight overpressure to be maintained.

    NB: during vacuum chamber repressurization, the purging system can be used but shall not be the only source of re-pressurization. If used, the purge flow shall be controlled to have a maximum of 0.5 l/h. ==> changed to 12 l/h.
  - The spacecraft test plan shall not include a specific opening of the internal EUI-OBS doors, except when under vacuum. ==> changed to never opening.

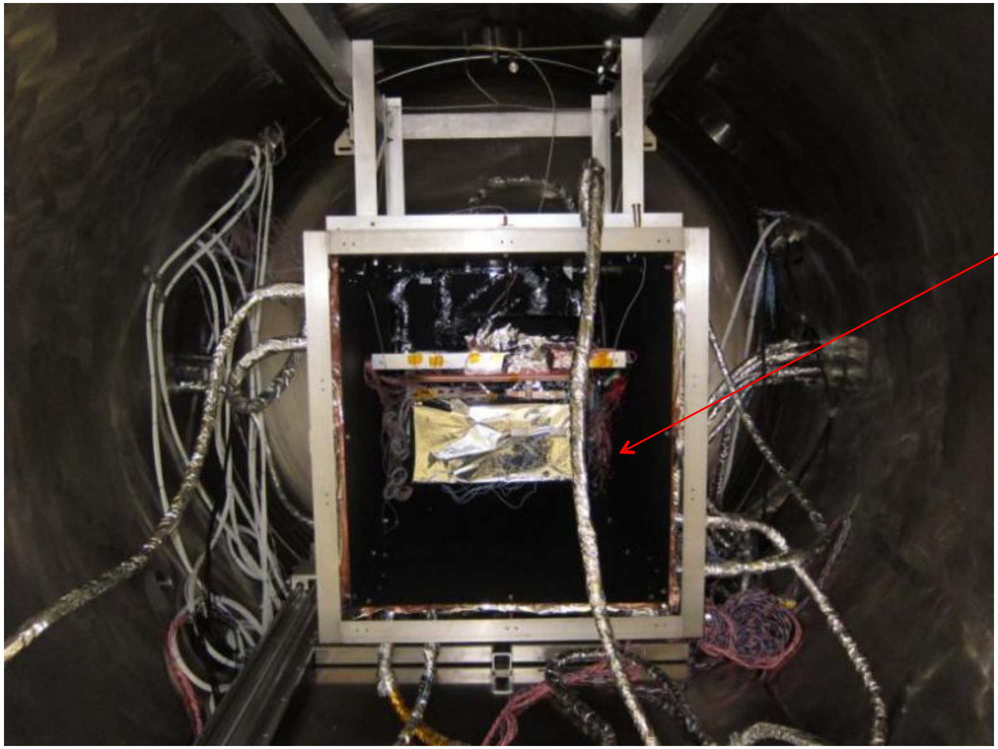
✦ **Purging during flight to the launcher to be maintained**

✦ **Purging on the launcher to be maintained**

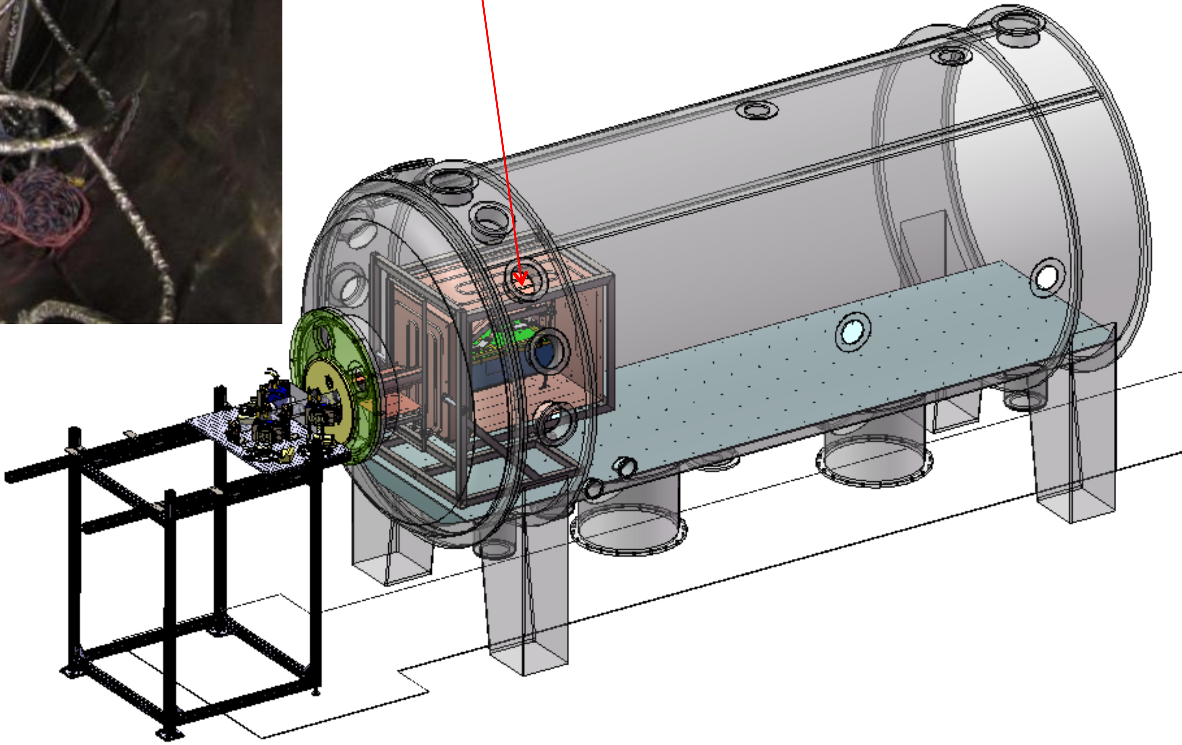
EUI cleanliness monitoring

- Particular and molecular witness samples
  - Will follow the unit all along its AIT activity
  - Allows cleanliness monitoring (after assembly, vibration, vacuum/bakeout tests…)
  - Some witness samples also on S/C MY panel during AIT
- Types of witness samples
  - Particular:
    - PFO
    - Monitored @CSL
  - Molecular:
    - Metallic witness plates (ECSS Q-70-05C – indirect method)
    - Monitored by FTIR @CSL

EUI vacuum tests



OBS STM unit in vacuum chamber



Vacuum thermal bake out

- Bake out with monitoring by RGA, witness plates and
- Temperature-controlled Quarz- Crystal Microbalance TQCM
- with SUCCESS CRITERION:
  - monitor the TQCM frequency f / Hz
  - until rate of change of frequency f“ /Hz/h/h is < 1%

Bake out analysis

8.2. TQCM criteria

The TQCM record over the bakeout is show in next figure.

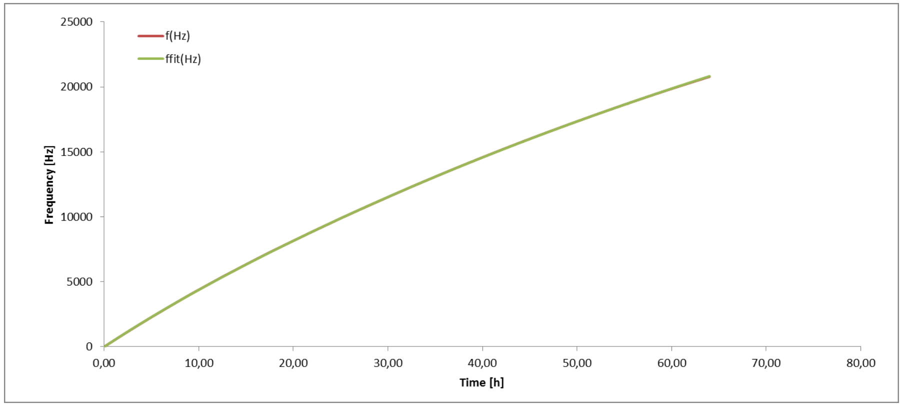


Figure 8-2: EUI FM cameras bakeout – TQCM frequency record

The deviation of linearity (f''/f') success criterion is shown in next figure, and is lower than 1% at end of bakeout.

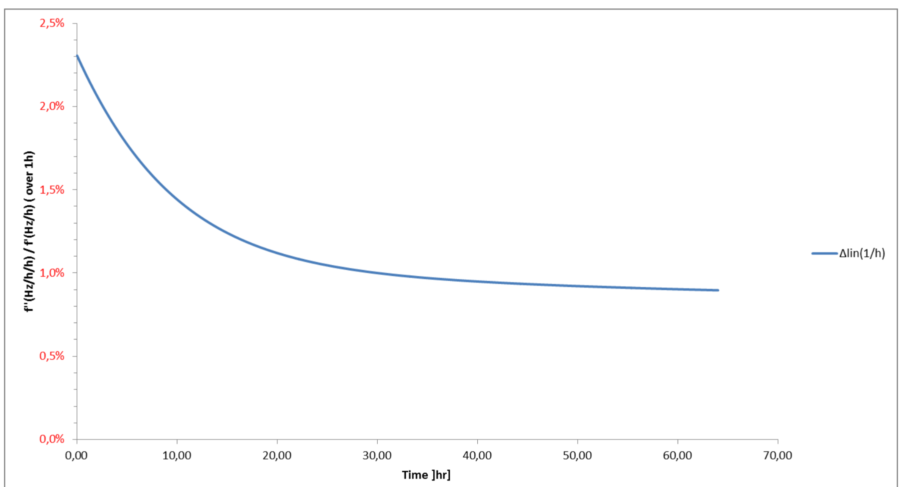
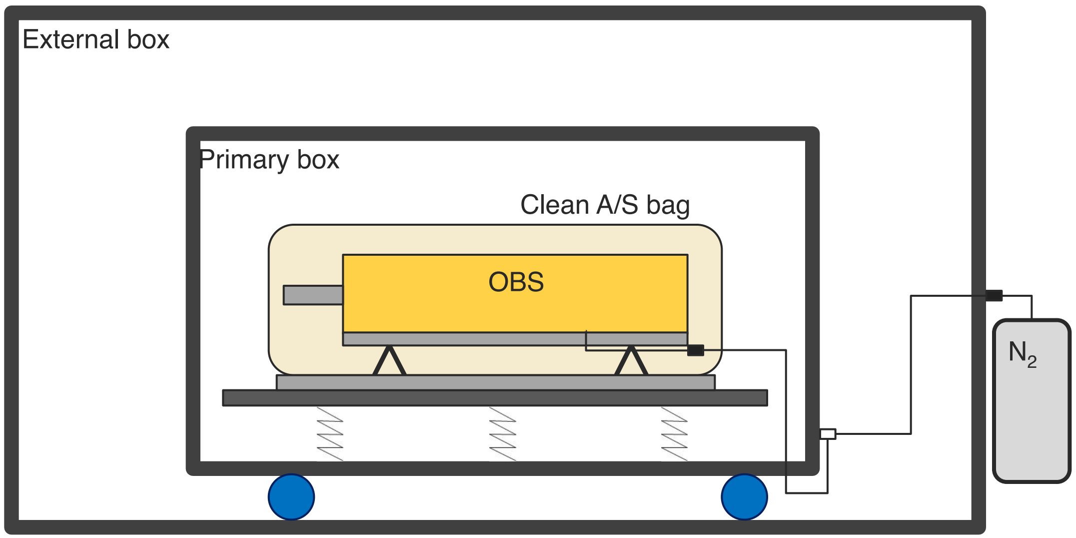


Figure 8-3: EUI FM cameras bakeout –Δlin(1/h) using fitted TQCM data

EUI OBS transport container

- Inner ('primary box') and outer ('external box') containers
  - OBS wrapped in clean anti-static bag, and fixed on a transport plate in the primary box
  - Primary box on a damping system in the external container
  - External box equipped with purging system for primary box (same inlet interface SS-400-1-4 than in OBS)

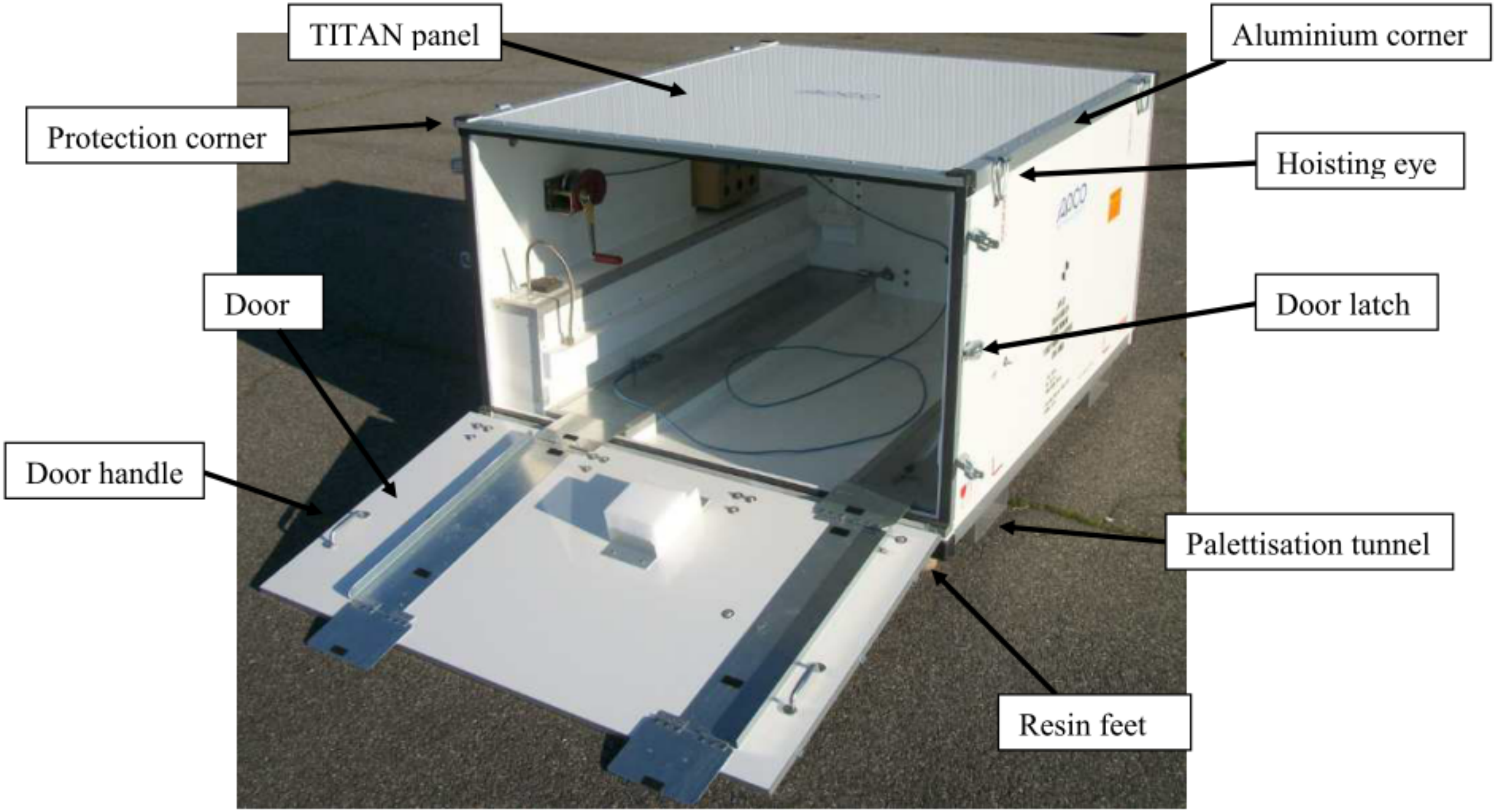


EUI OBS transport container

- Primary box
  - It can be use in clean room class 100.
  - It is equipped with a breathing valve, a desiccant box and a humidity indicator to provide the ambient environment.
  - The breathing valve regulates the pressure inside the primary box at ± 17 mbar.
- Secondary box
  - It an be use in clean room class 100.000.
  - It is equipped with monitoring of humidity, temperature and pressure.

EUI OBS transport container

- Outer container



EUI OBS transport container

- With STM unit

S/C transportation and launch site activities

- **Purging during flight to the launcher to be maintained**
  - was major concern because of re-pressurization of airplane during decent.
  - Antonov aircraft takes 10 minutes decent phase. makes 100 mbar over-pressure possible inside container.

- **Purging on the launcher to be maintained**

Acknowledgements

- Solar Orbiter Mission: ESA
- Spacecraft: Airbus D&S
- EUI instrument: CSL, MSSL, IAS, PMOD/WRC, MPS