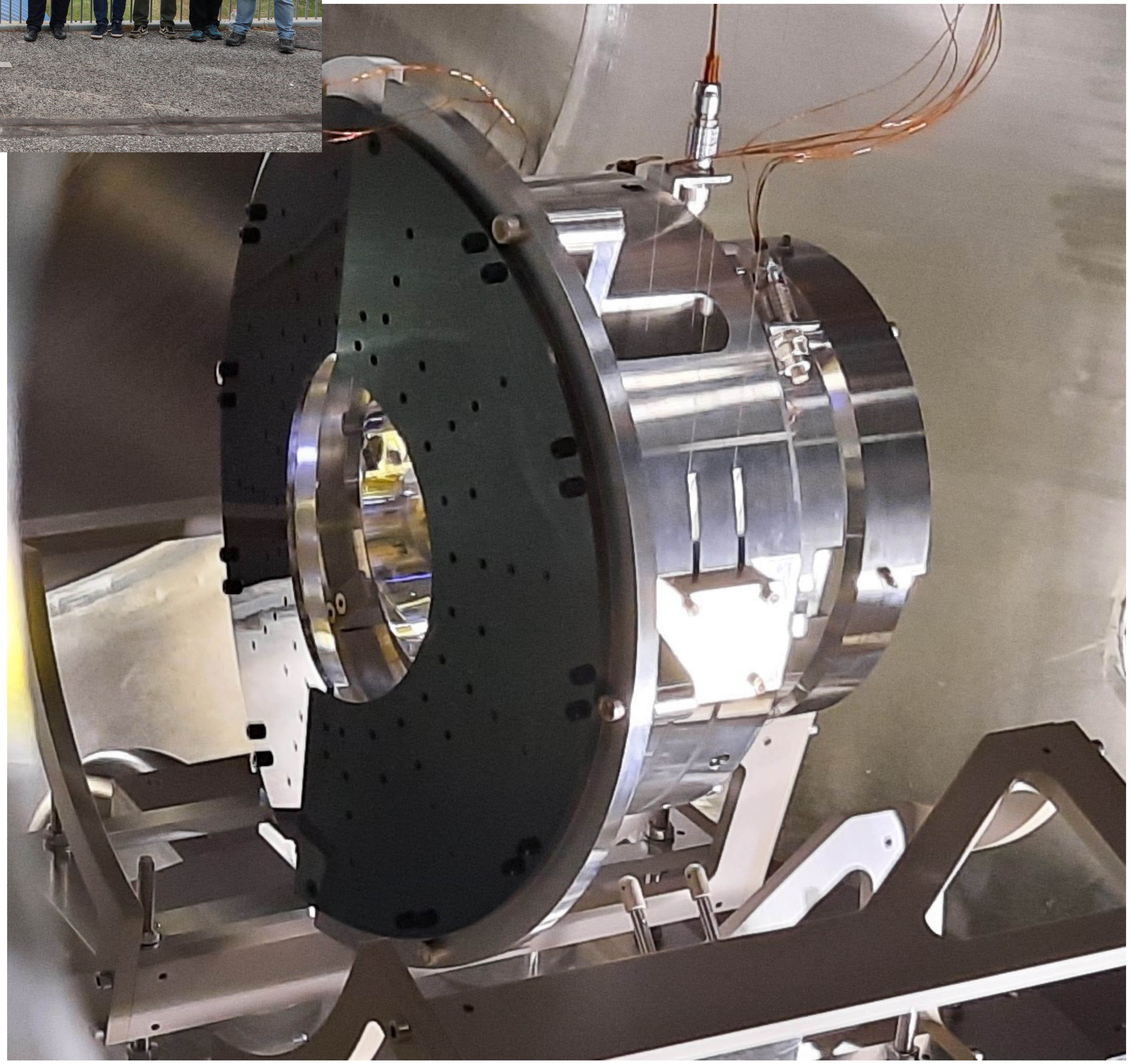
Instrumented baffles

M. Martínez

NeXt Generation Collaborative Design
Monday 22 Apr 2024, 17:00 → 18:40 Europe/Rome
Jan Harms (Gran Sasso Science Institute), Lisa Barsotti (MIT)

XGCD Meeting - Stray Light Control, April 22nd (online)

Outline

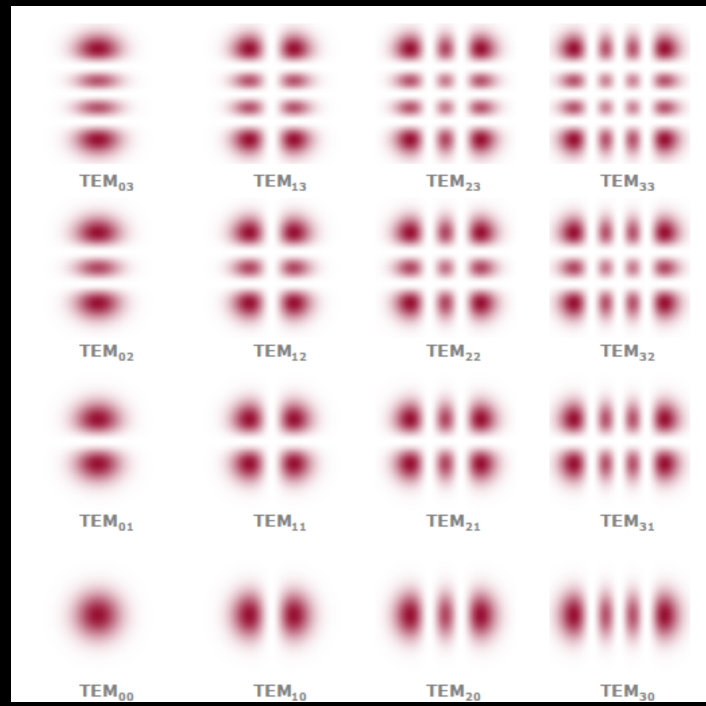


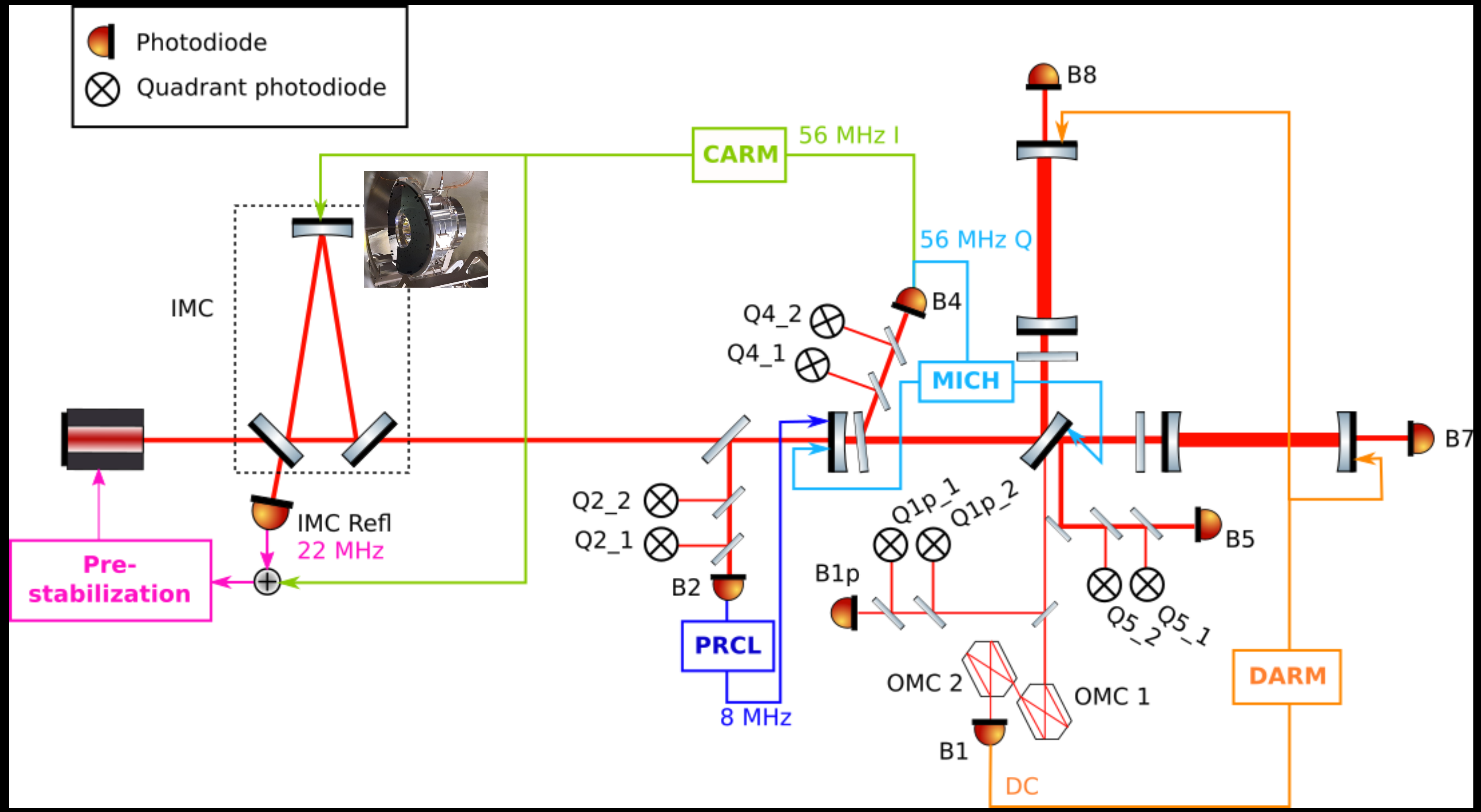
- Motivation for the use of smart baffles
- IMC demonstrator
- Construction of large instrumented baffles
- Final notes

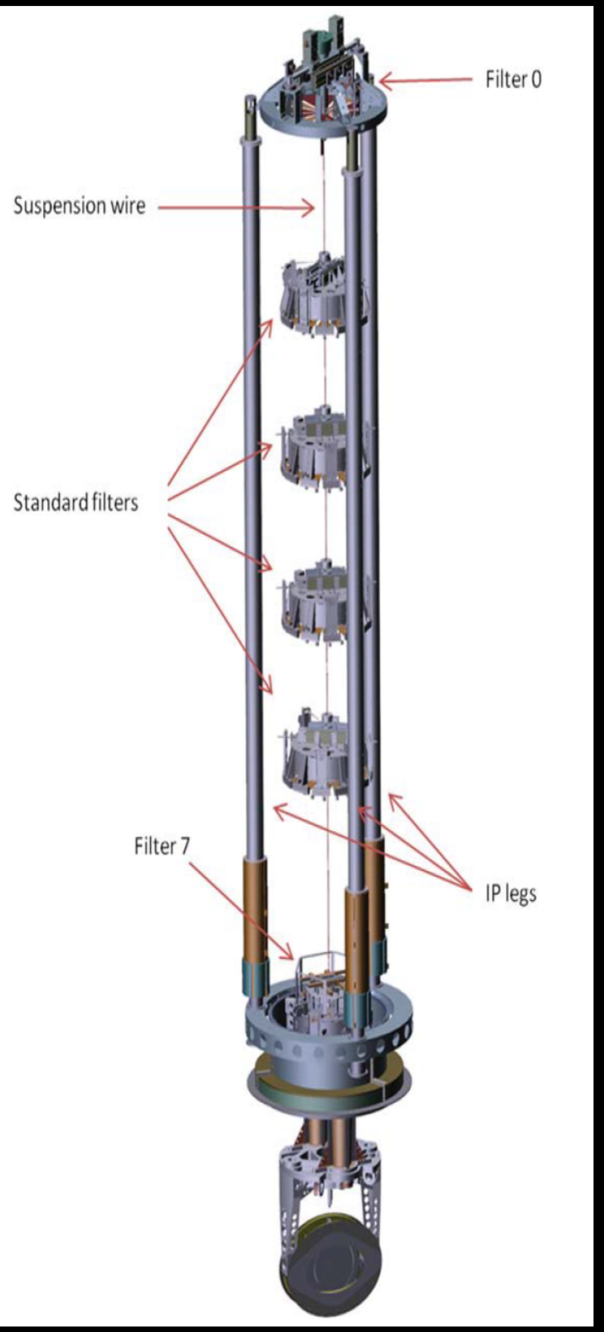
A. Romero-Rodríguez et al, 2021, Class. Quantum Grav. 38 045002
O. Ballester et al., CQG 39 (2022) 115011
M. Andres-Carcasona et al., Phys. Rev. D 107, 062001 (2023)

Use case for smart baffle

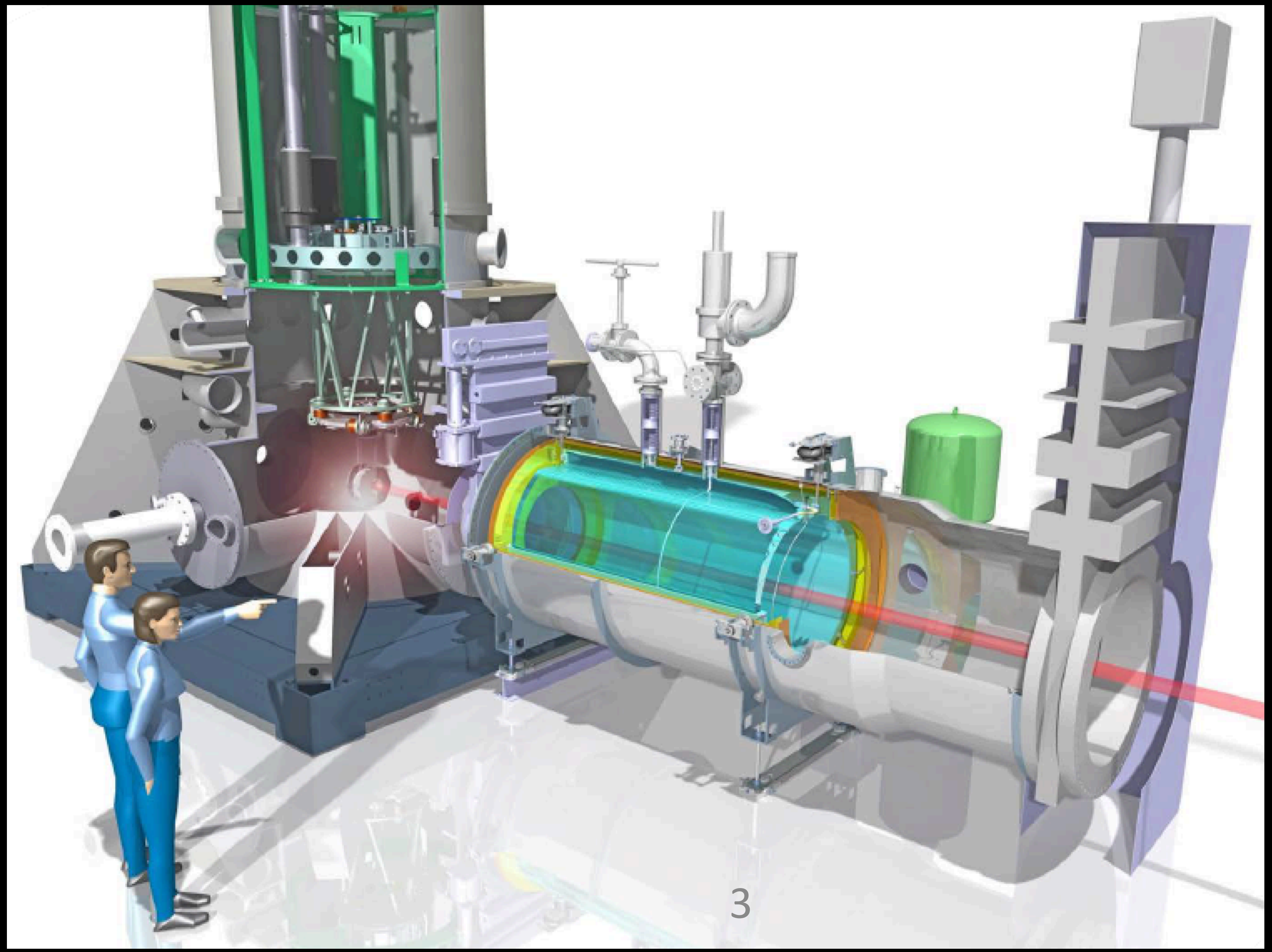
- Efficient pre-alignment of ITF
- Dynamic mapping of mirror surfaces
- Monitoring of developing laser high modes
- Correlate with ITF glitches   if DAQ is fast enough



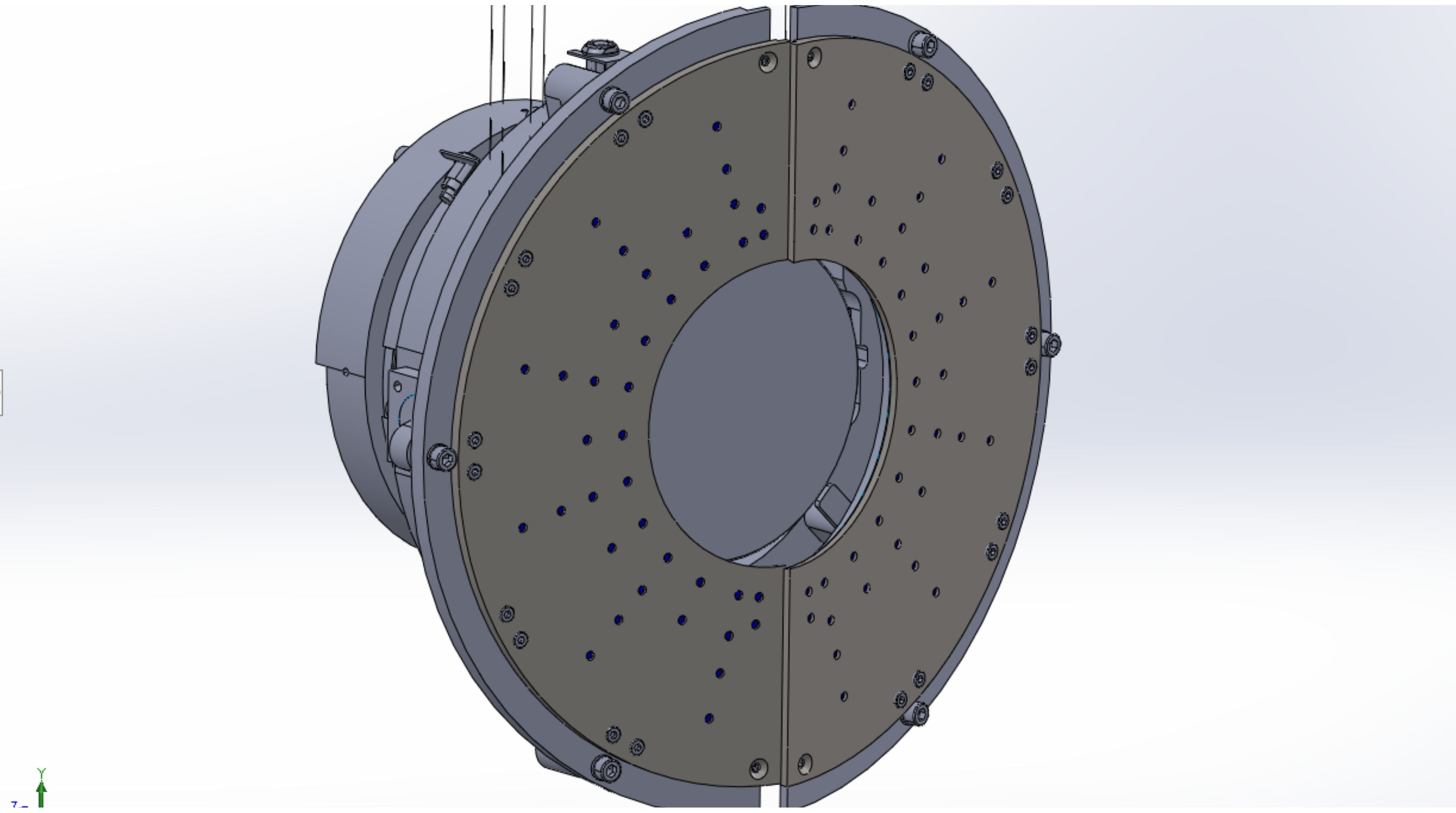


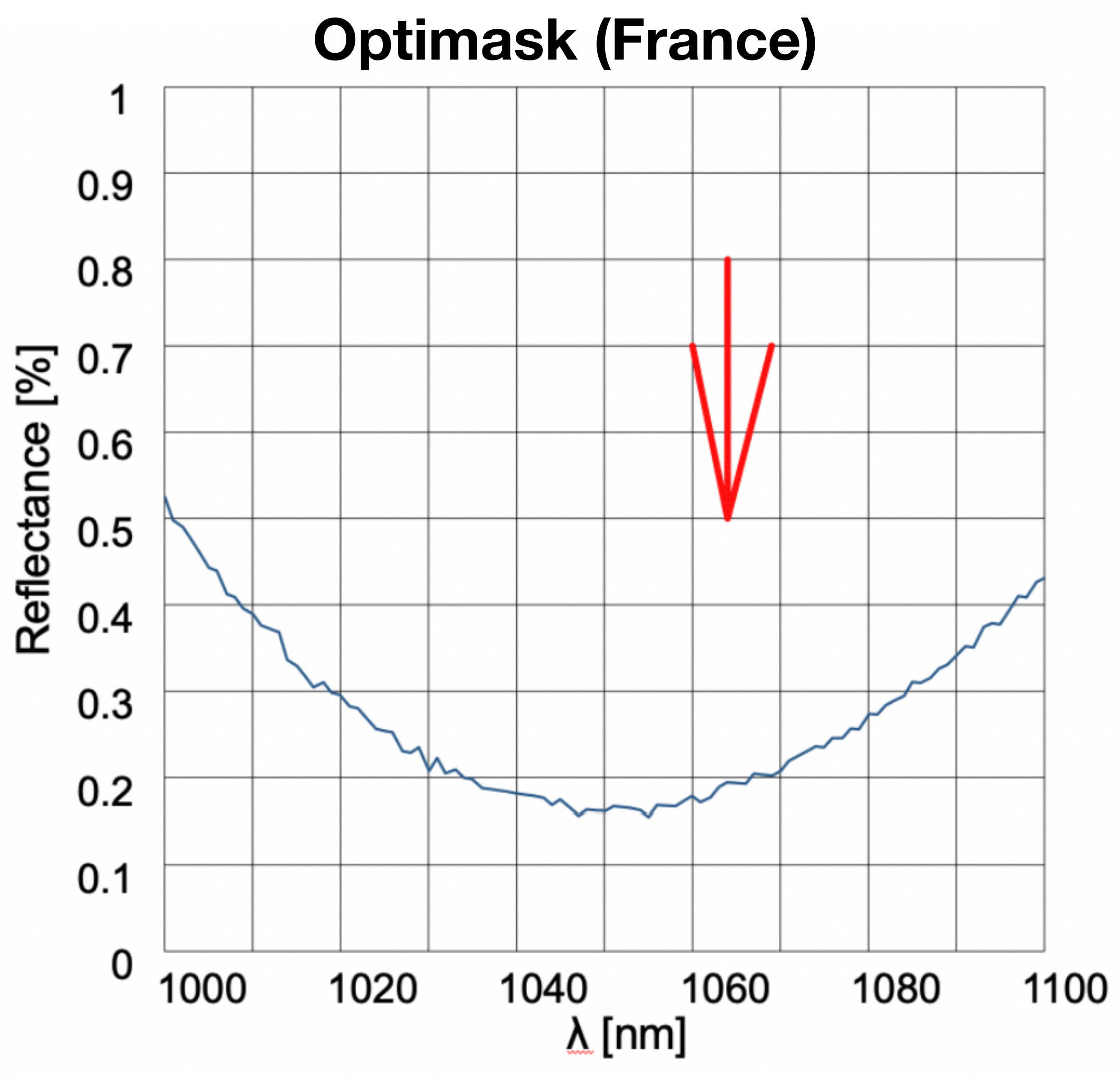


- Sensors on 1064 nm (IR)
- UHV (10^{-9} mbar)
- No active cooling possible
- Solid against baked out (100 C)
- Reflectivity less than 0.5%
- Total scattering under control
- Limited RO cabling →   wireless RO
- Negligible induced EM noise near mirrors
- ……



Conceptual Design





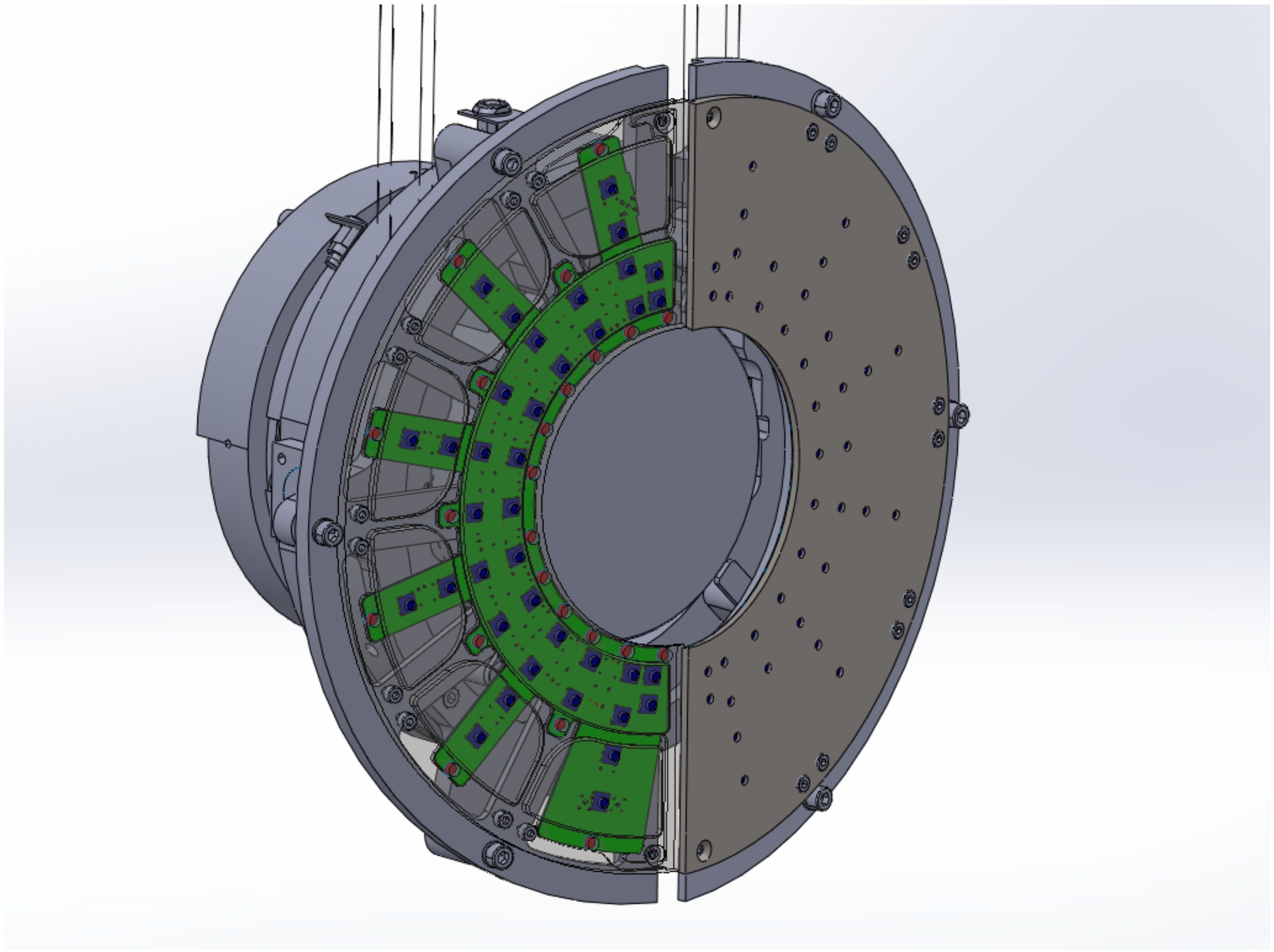
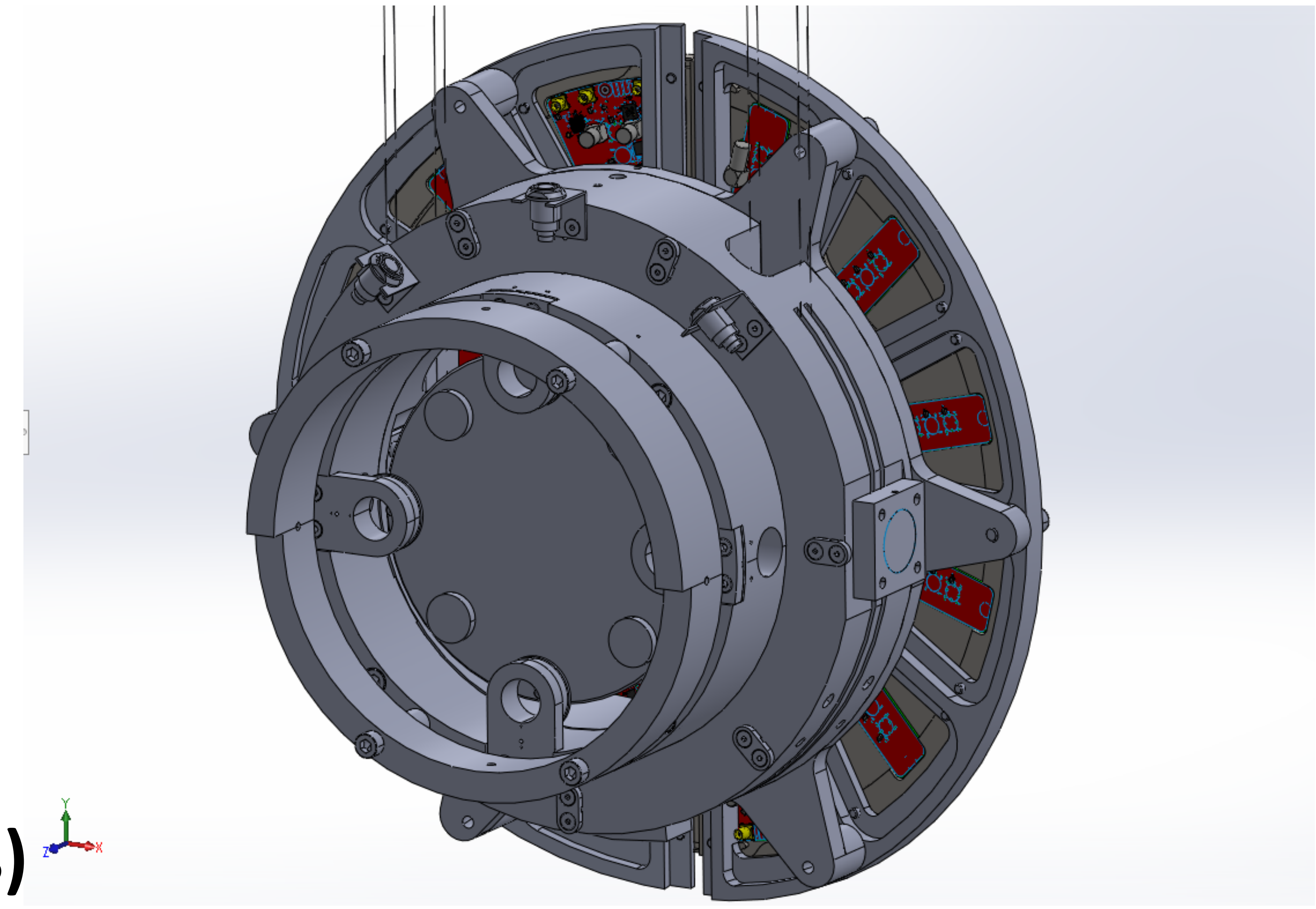


Photo-sensors located behind plate

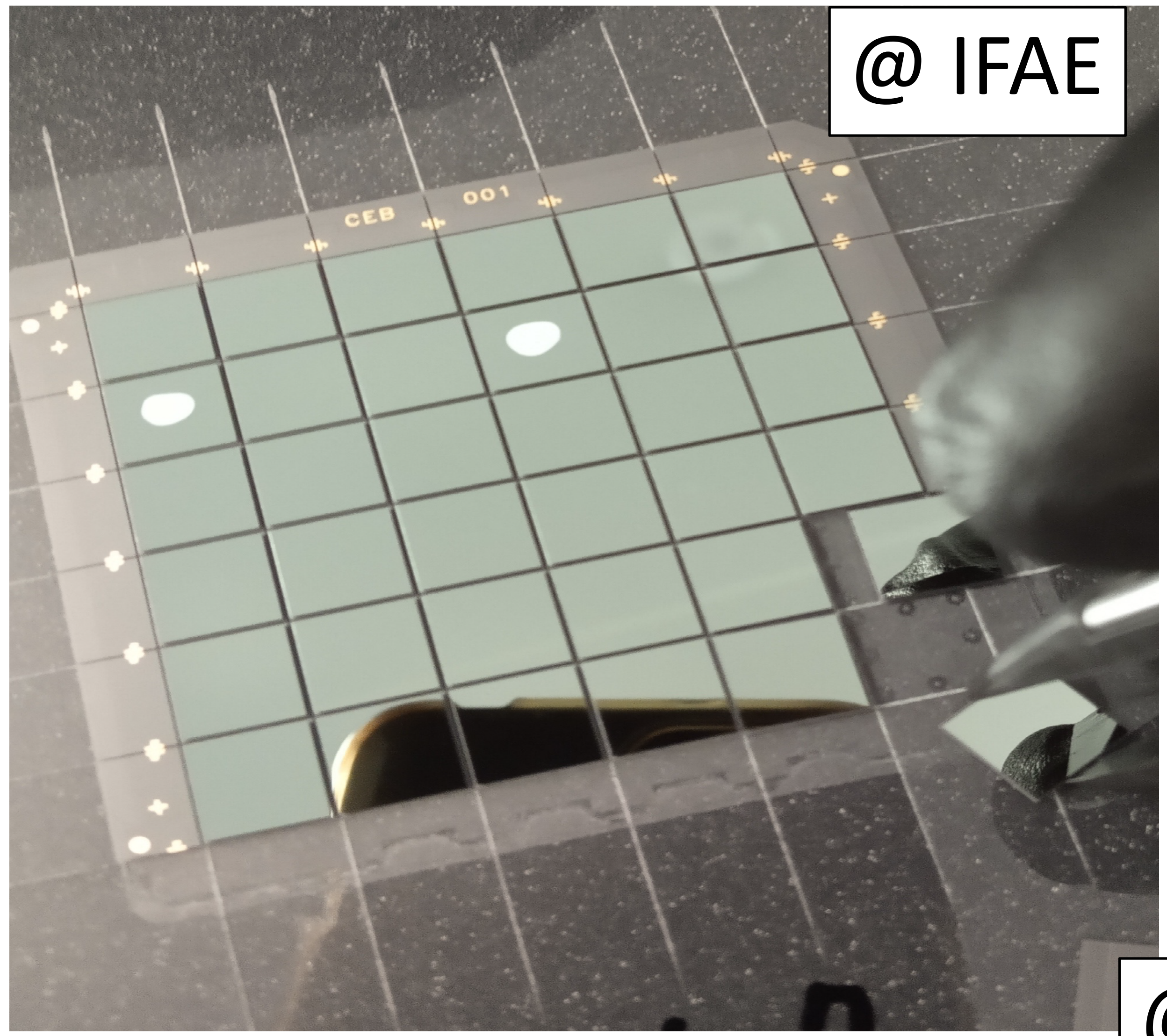


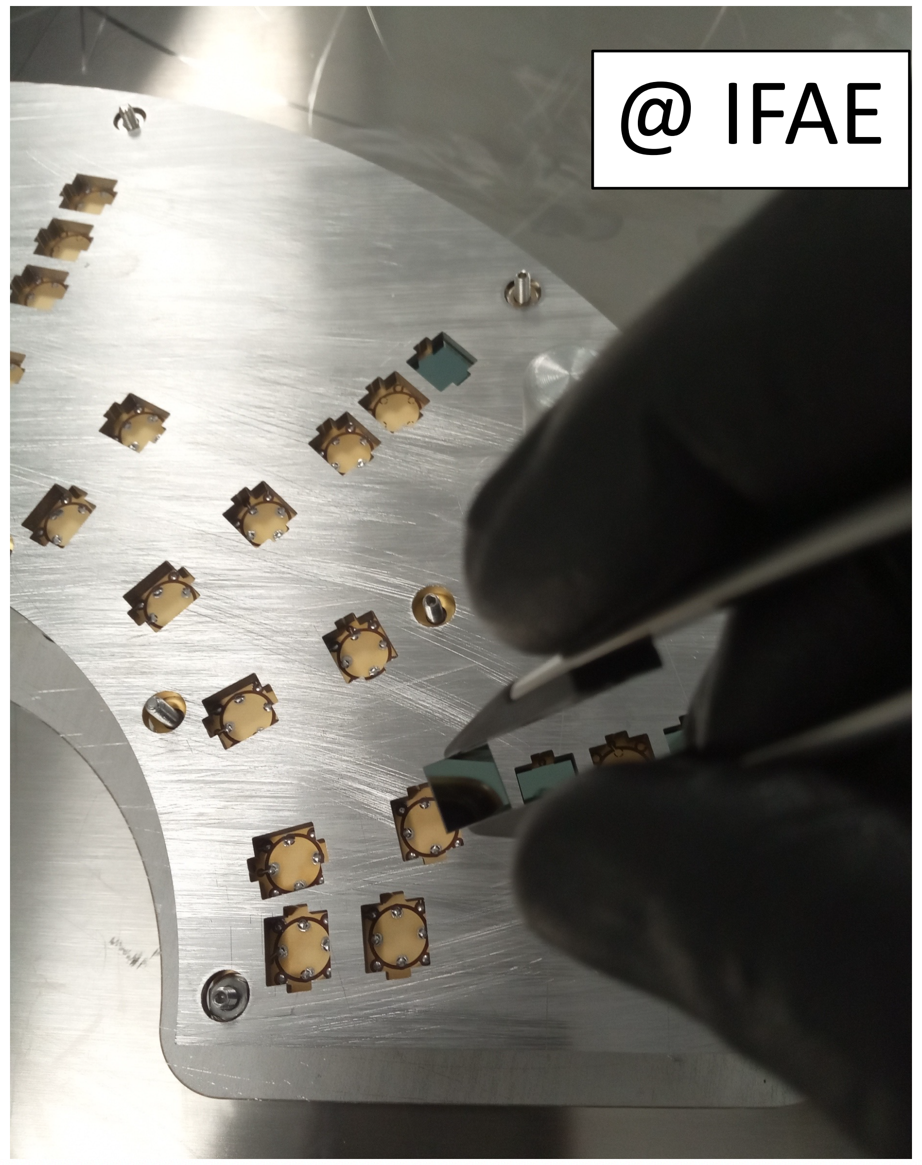
- Super #8 polished SSL 304L + AR coating (< 0.5% reflectance)
- Number of sensors 76 (38 in each 1/2 baffle)
- Sensors mounted in large PCBs
- Sensors active area 0.49 cm2
- Light reaches sensors through conical (12^o) holes of 4 mm of diameter (in the polished side)

→ Avoid scattering in edges and hide PCB from light

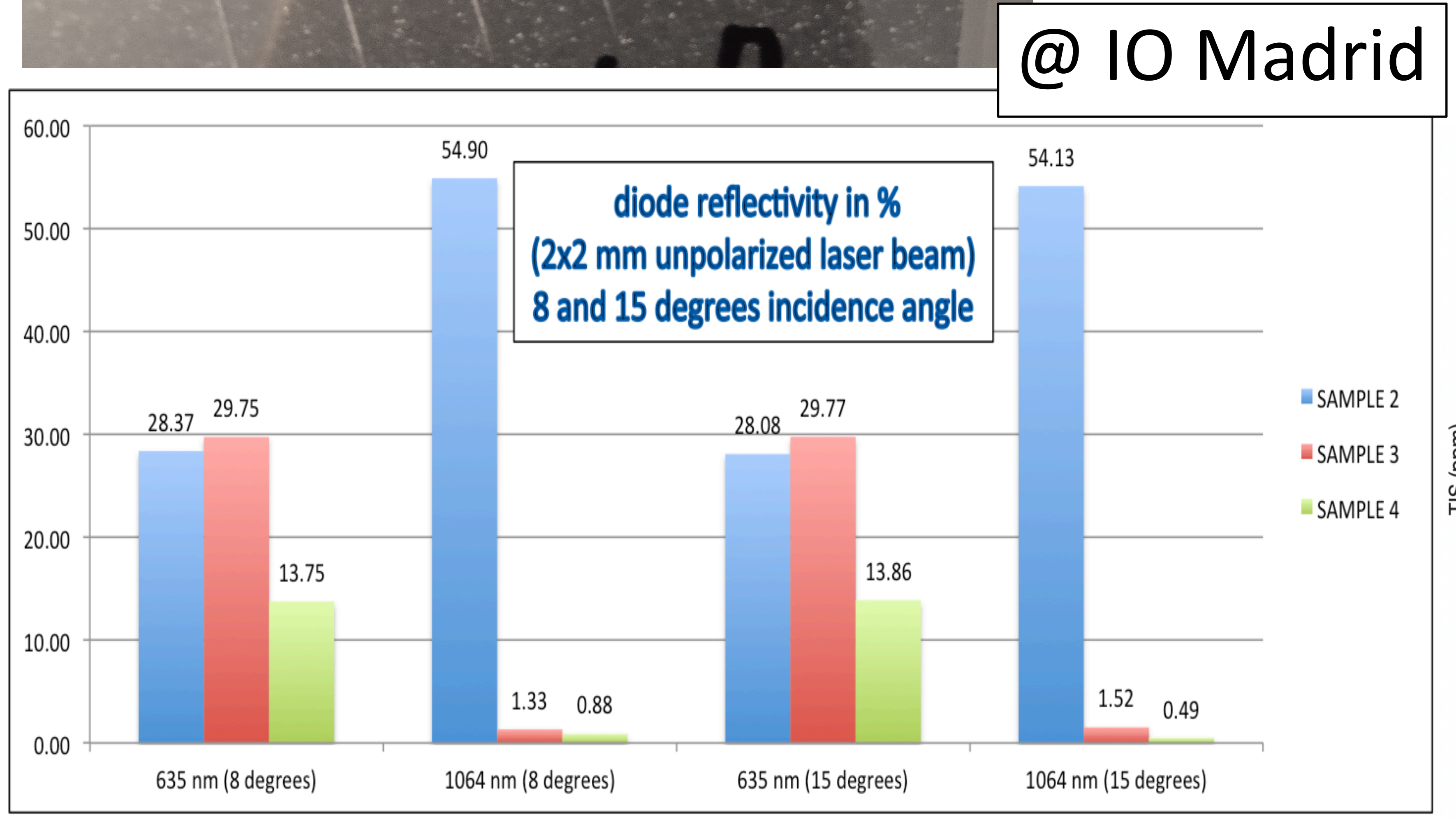
→ Knife like edges in holes and inner aperture (RoC of 10 microns)

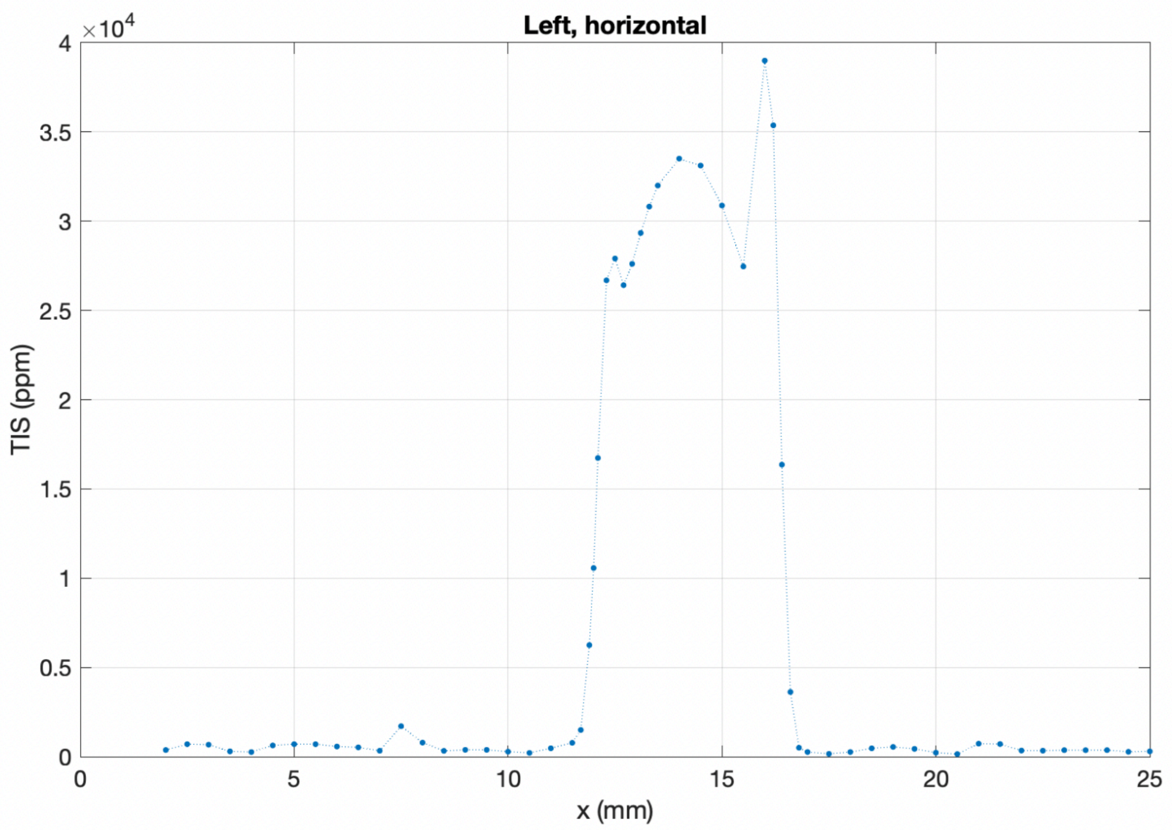
New Hamamatsu Sensors

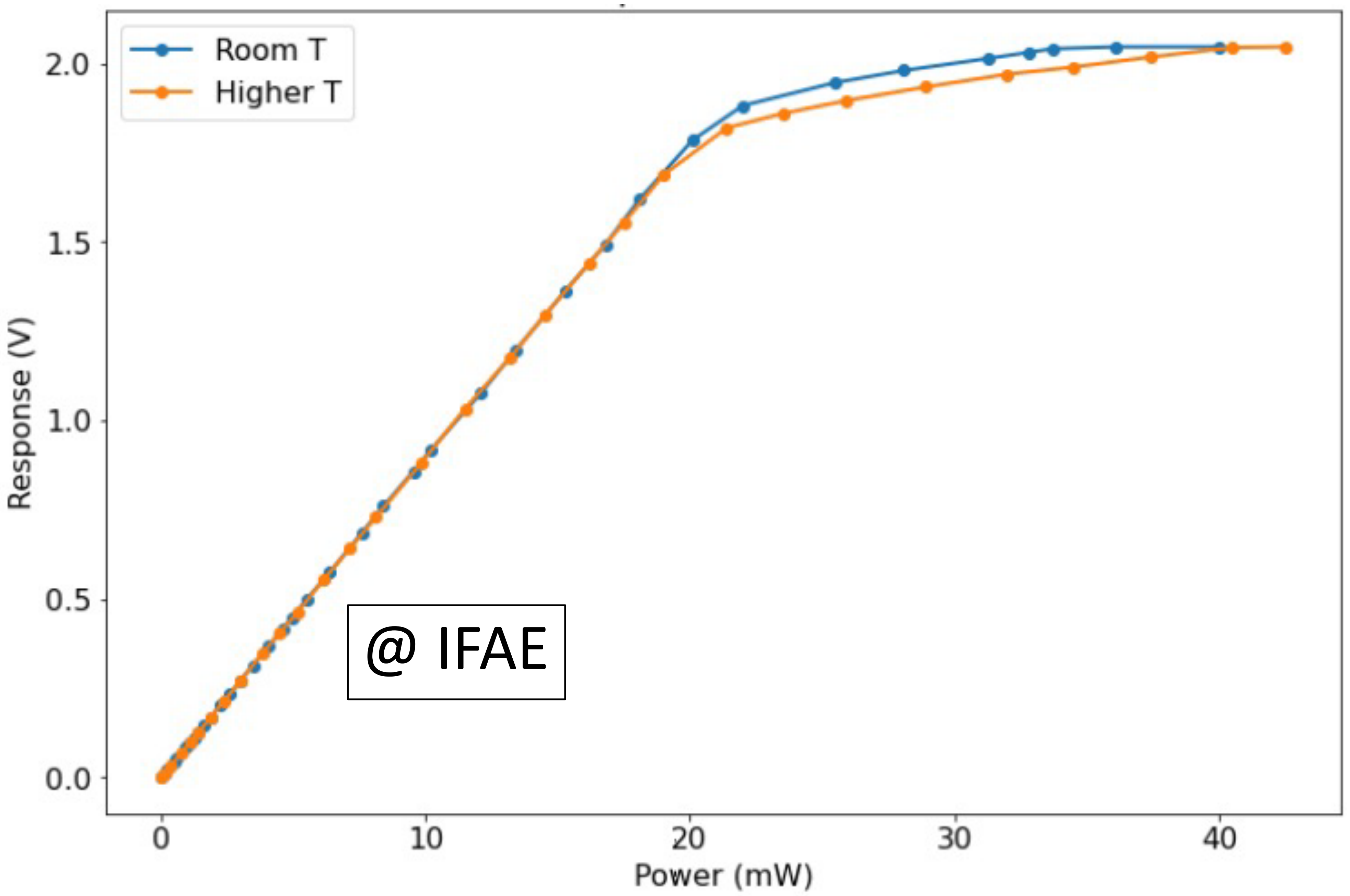




Dimensions	7.37 x 7.37 mm^2
Sensitive area	6.97 x 6.97 mm^2
Operation temperature	-40 to 100 °C
Power dissipation	50 mW
Optical coating	Anti-reflective (1.8%)
Photosensitivity	600 mA/W

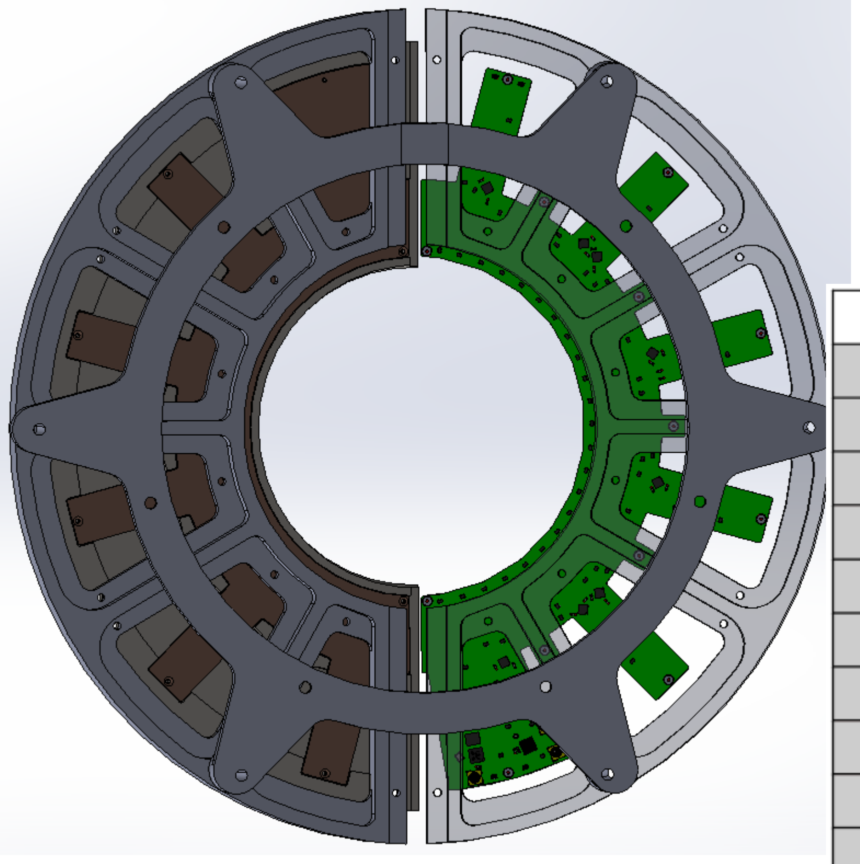






Thanks to 2-years long R&D with Hamamatsu we developed Si-based sensors
UHV compatible and with a reflectivity of about 1.2% - 1.8% reflectivity (v3 sensors)
→ First attempts to reduce to < 1 % led to non-linearity and slower sensors (v4 sensors) —> could be used but we selected v3
→ Attempt for v5 sensors with reduced TIS and special treatment of packaging ceramics did not converge……future ?

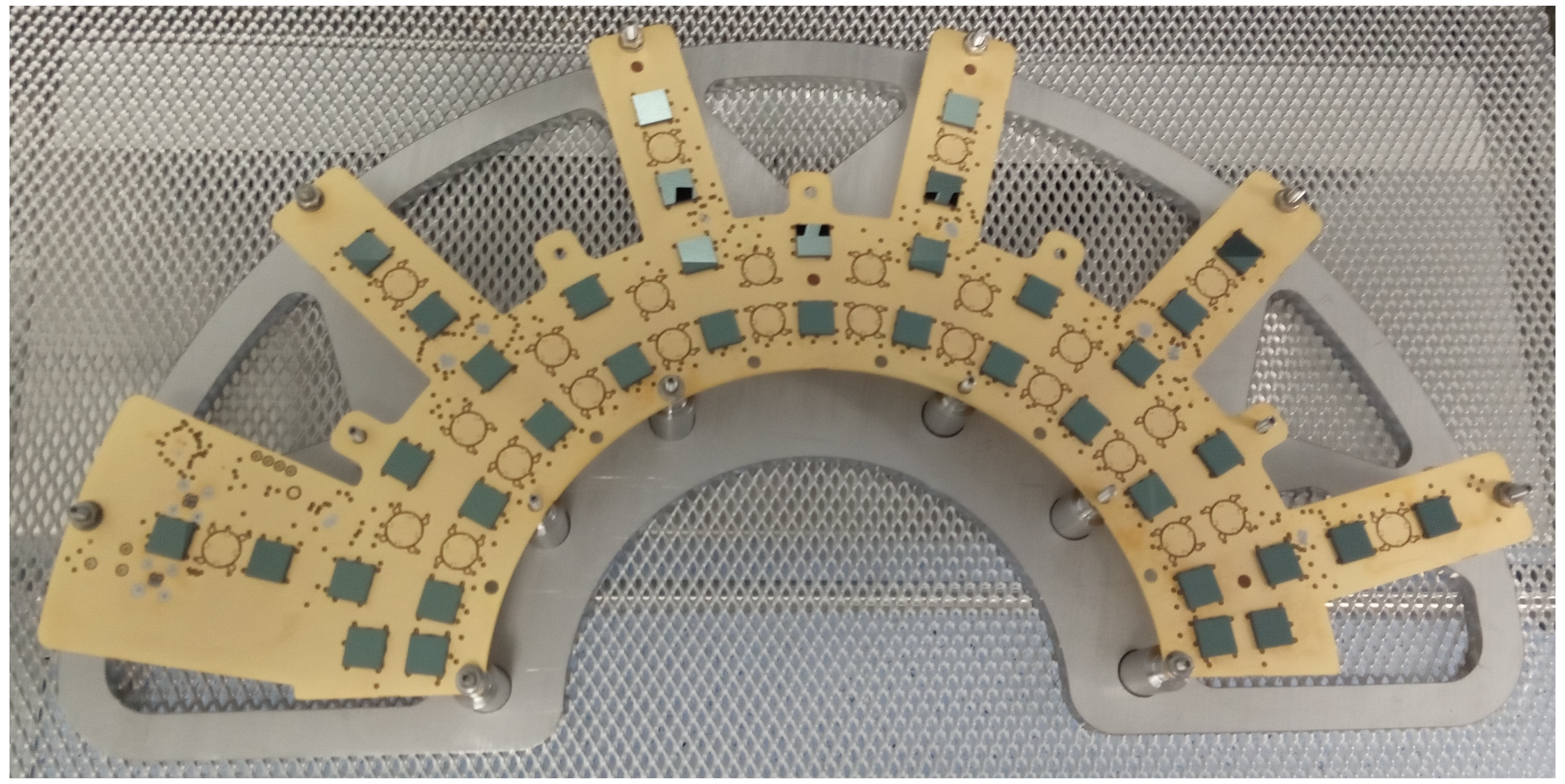
Electronics

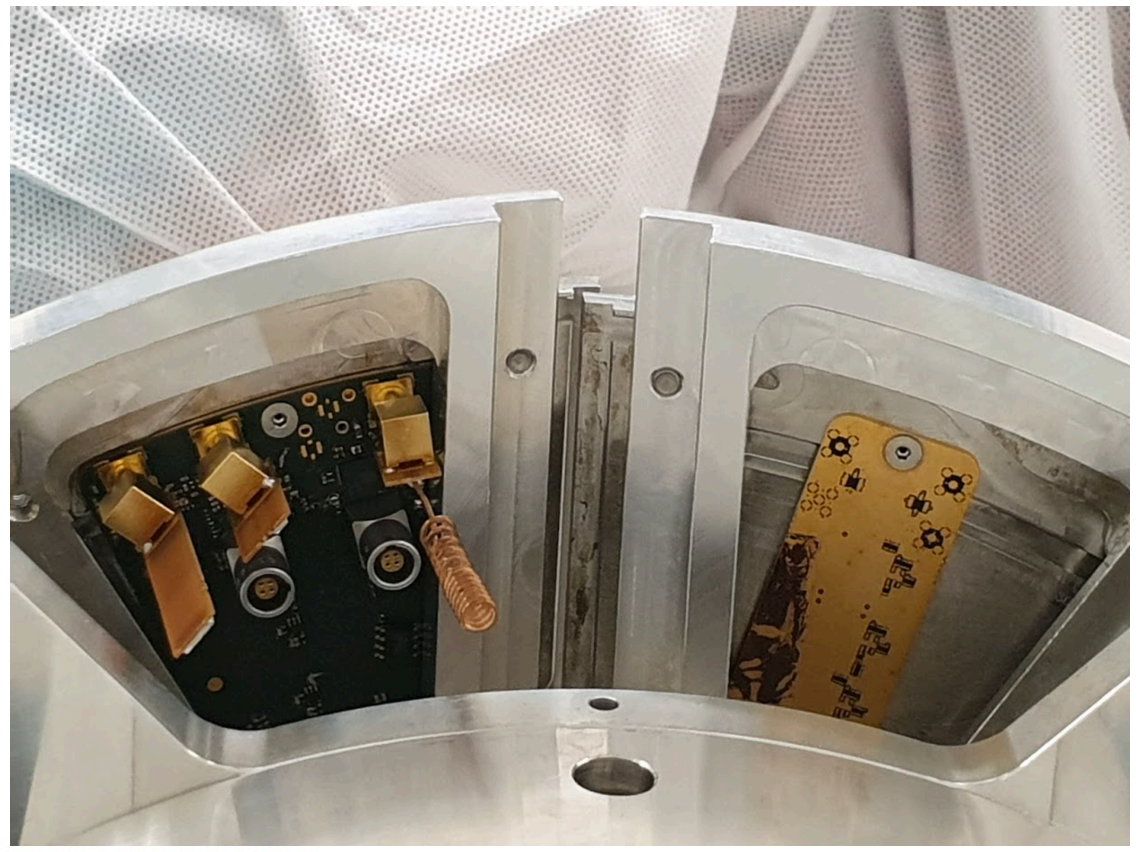


	Subclass name	Type	Material	Thickness [mm]
1		SURFACE	AIR	
2	TOP	CONDUCTOR	COPPER	0.035
3		DIELECTRIC	POLYIMIDE	0.1
4	GND_0	PLANE	COPPER	0.07
5		DIELECTRIC	POLYIMIDE	0.1
6	DIGITAL	CONDUCTOR	COPPER	0.07
7		DIELECTRIC	POLYIMIDE	0.1
8	GND_2	PLANE	COPPER	0.07
9		DIELECTRIC	POLYIMIDE	0.1
10	ANALOG	CONDUCTOR	COPPER	0.07
11		DIELECTRIC	POLYIMIDE	0.1
12	POWER	PLANE	COPPER	0.07
13		DIELECTRIC	POLYIMIDE	0.1
14	GND_3	PLANE	COPPER	0.07
15		DIELECTRIC	POLYIMIDE	0.1
16	BOTTOM	PLANE	COPPER	0.035
17		SURFACE	AIR	

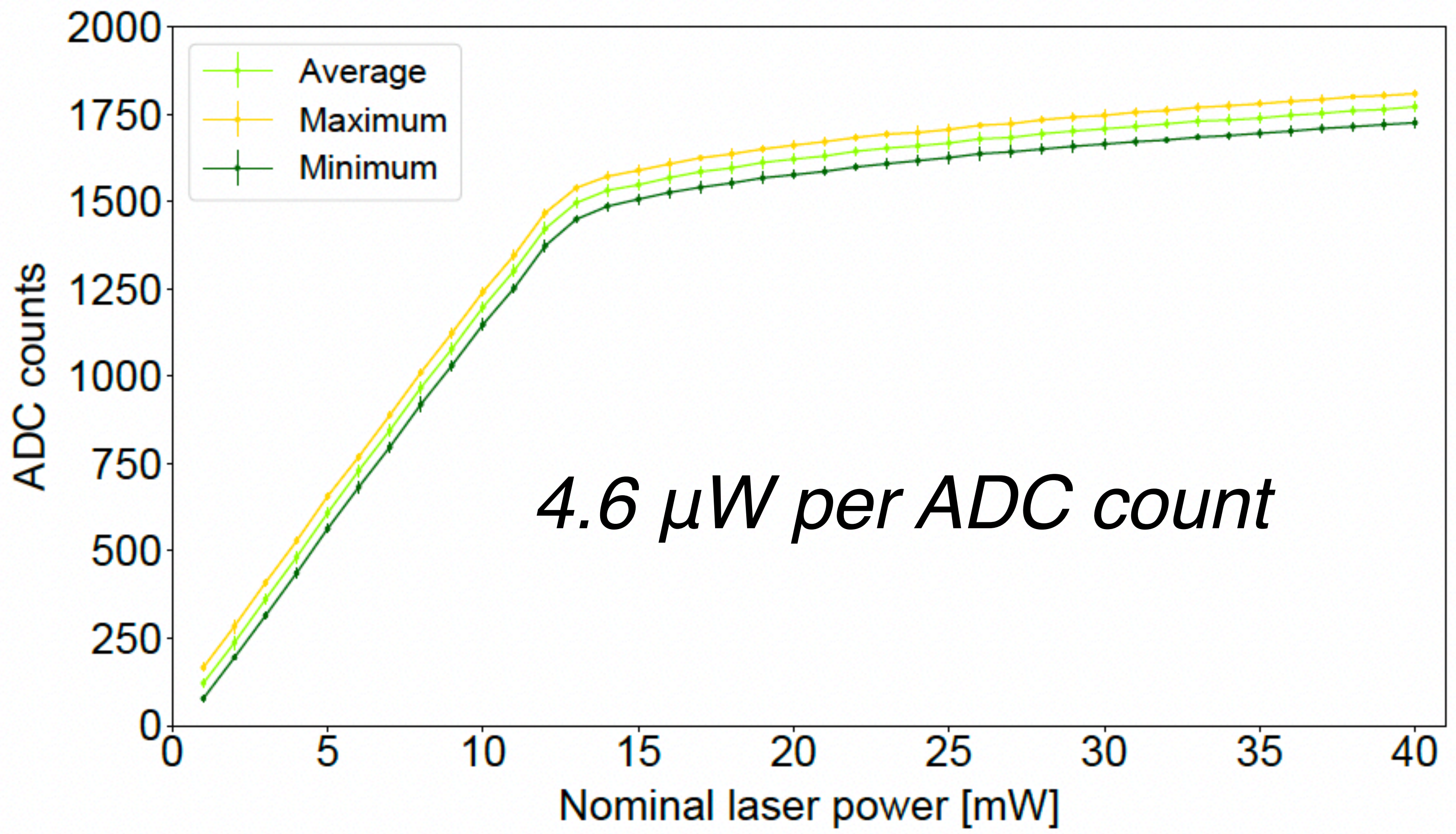
PCBs

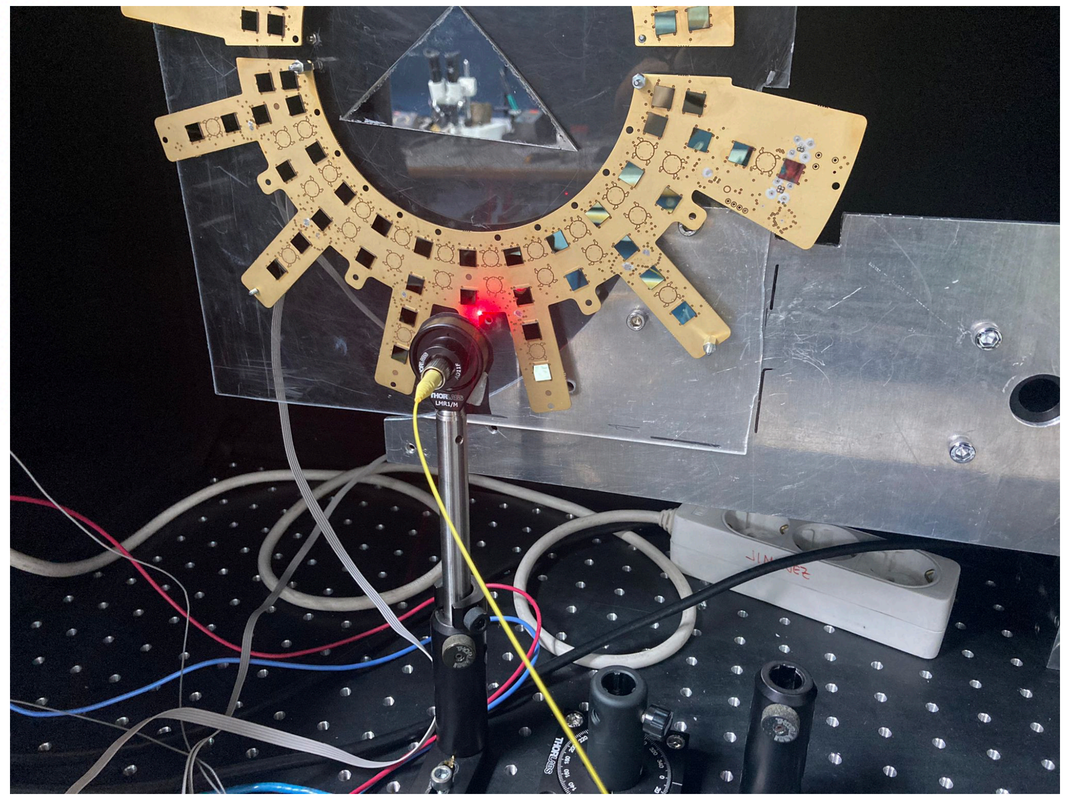
- Made of polyamide with a gold cover
- Custom shape to keep weight to minimum (100 g x 2 PCB boards)
- One PCB per half-baffle, connected with two coaxial connectors
- Reduced number of components in each PCB
- Single polarization level 3.3 VDC and total consumption < 2.5 W





Parameter	Value
Communication system	Serial and wireless
Heat dissipation	2.5 W maximum by radiation
Dynamic range	20 mW for a 1064 nm wavelength
Resolution	0.125 mW
Reading rate	2 Hz
Power / readout cables	Eight 15 m long Shielded twisted pairs
Cables type	American wire gauge 24
Cables permittivity	5.6 nF/m

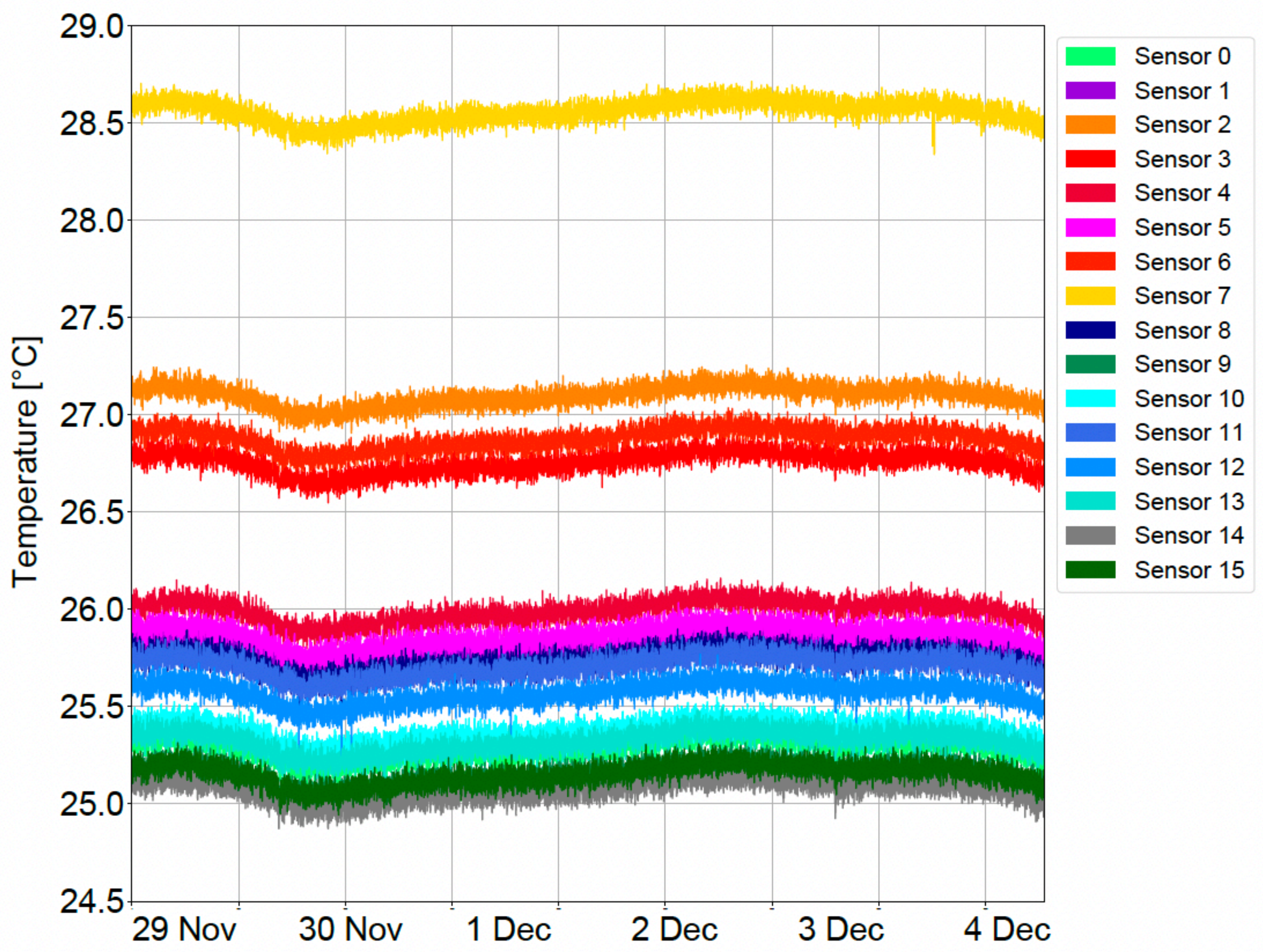


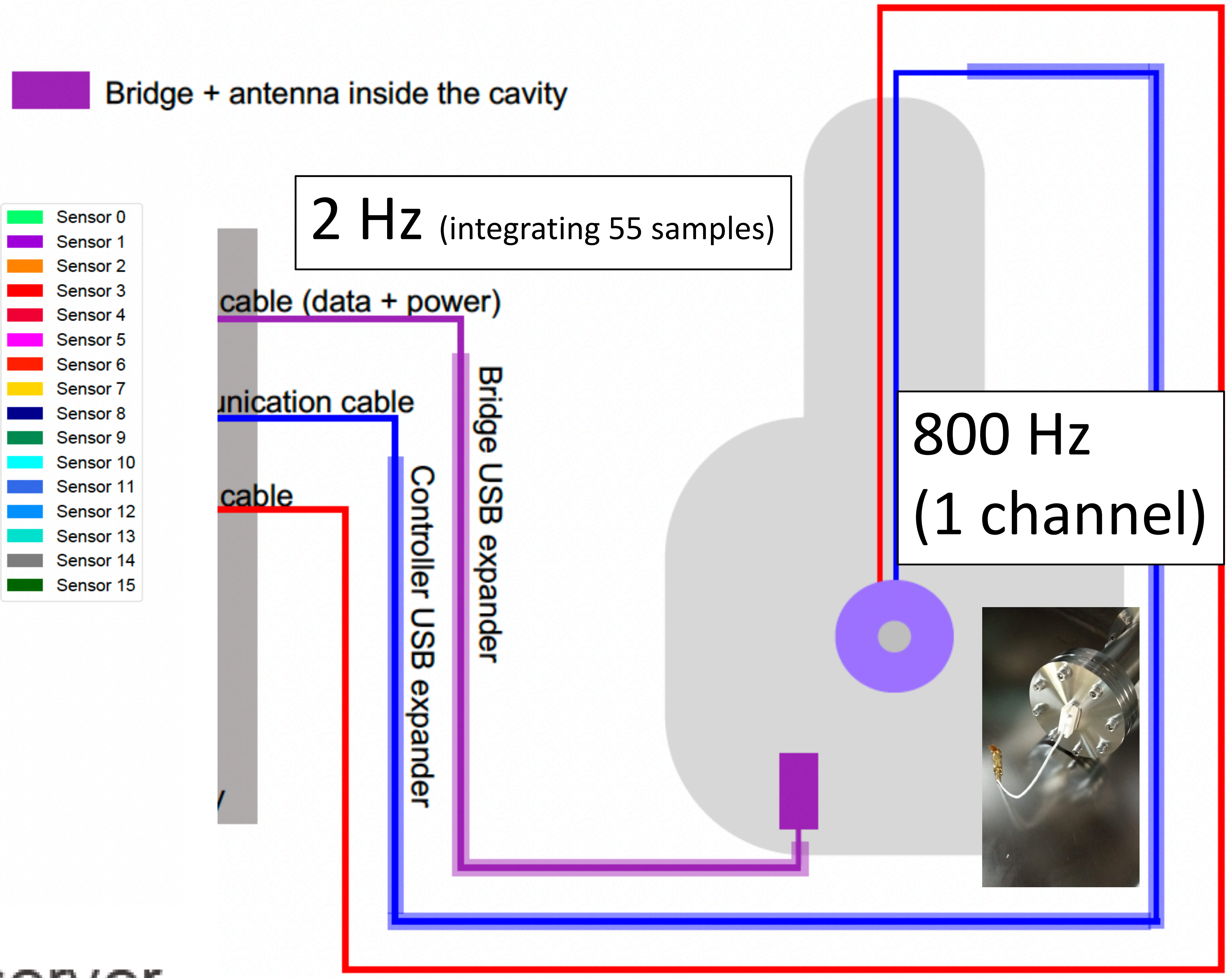


Readout & DAQ

Controller

- esp32 based
- Reads ADCs as fast as it can (~100Hz-200Hz)
- Preprocess data to send aggregated values
- Sends data to server (through bridge)





Bridge used in the PoC

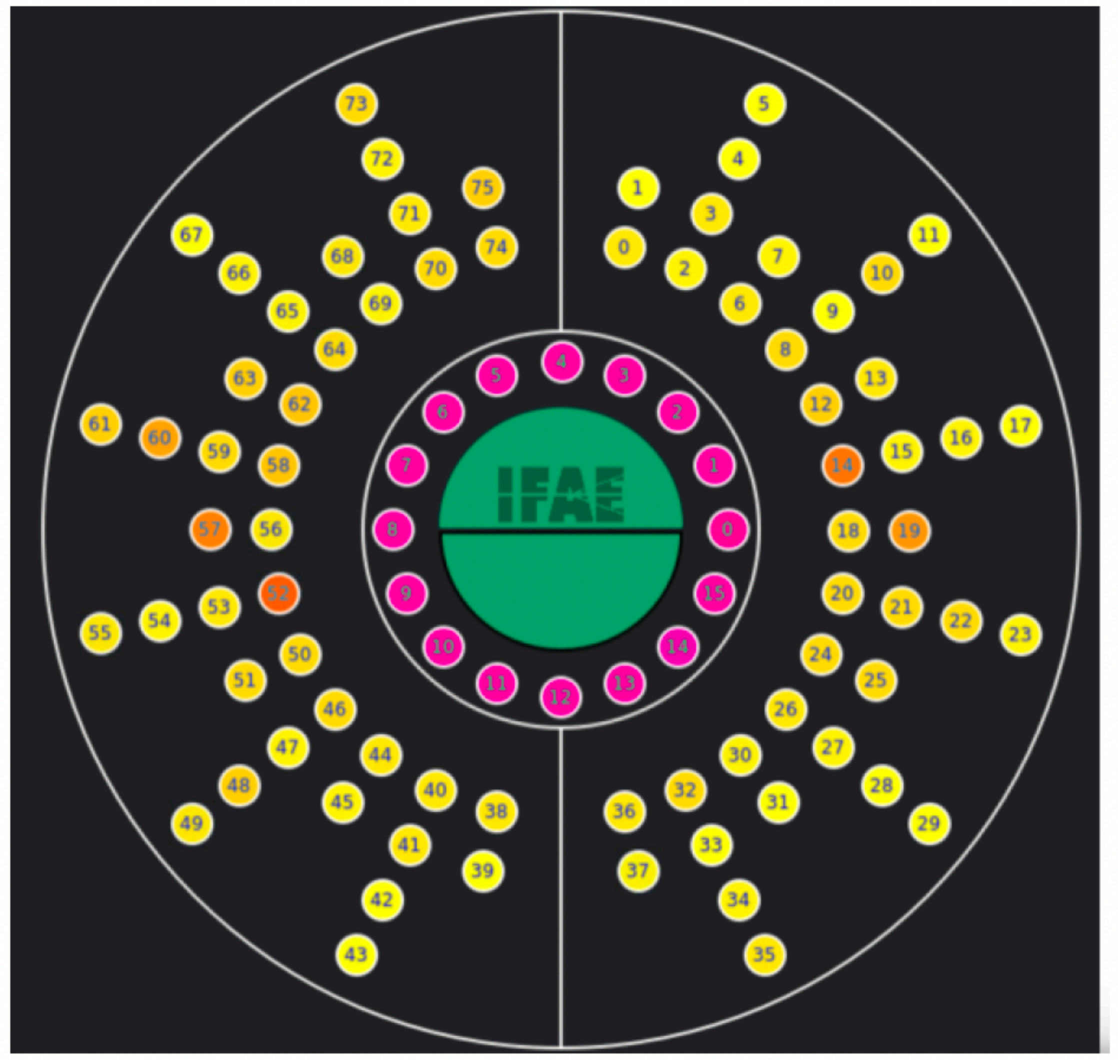
Bridge

- esp32 based
- Implements communication between controller and server

Server

Baffle control and monitoring server

- Implements interface from clients (engineering GUI) to controller
- Provides data to Virgo frame distribution (fd)

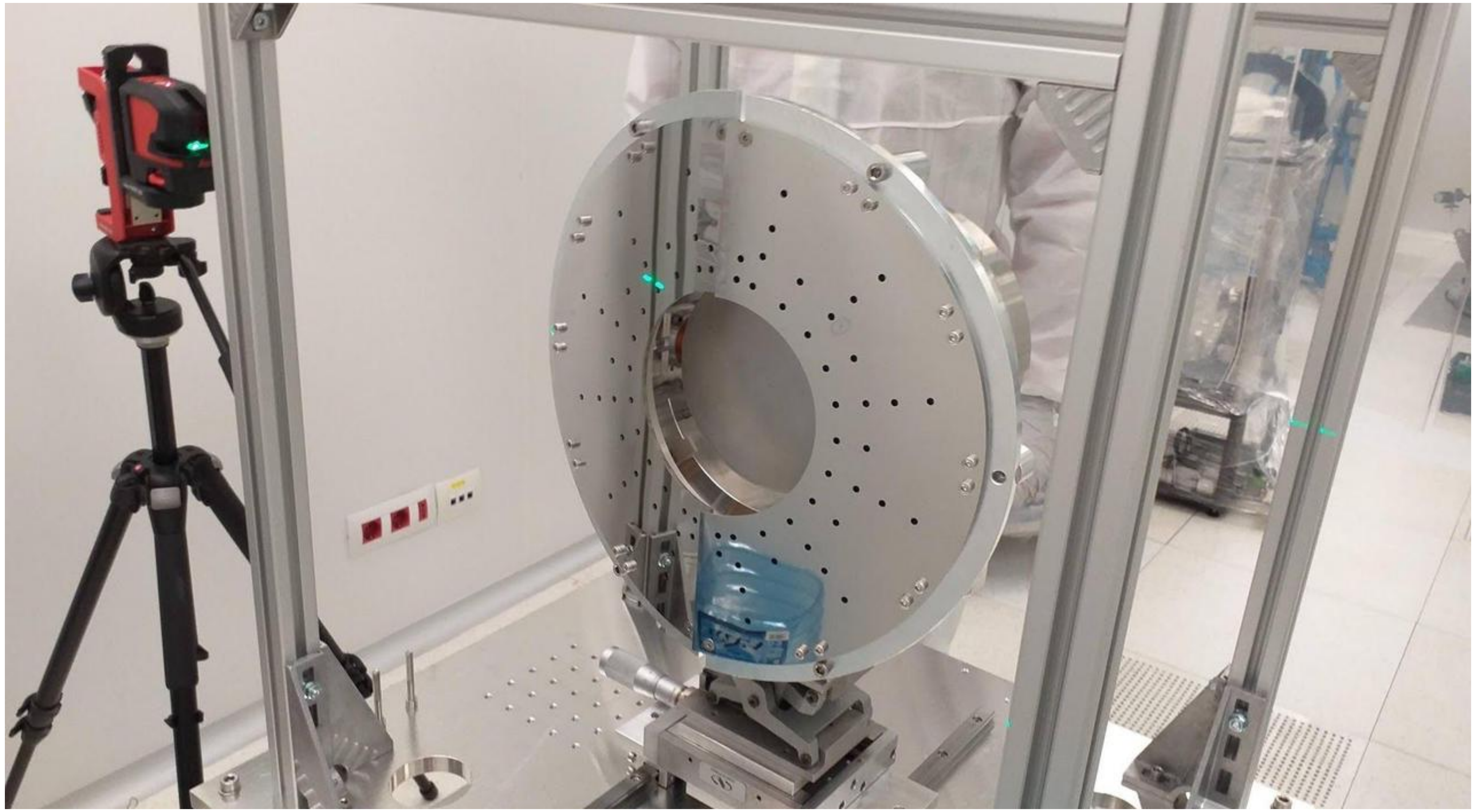


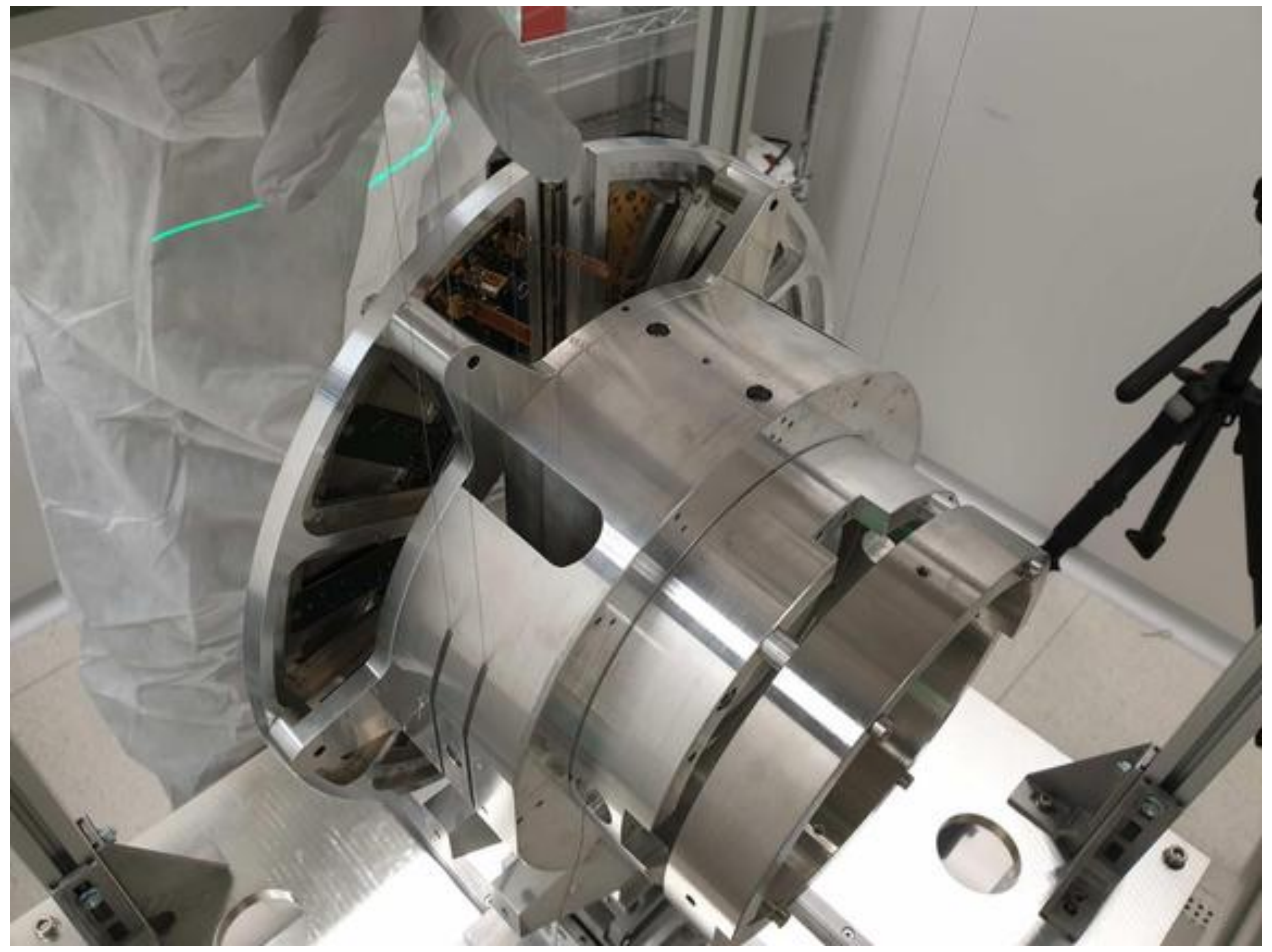
We ha sampling rate of up to 800 Hz —> 2 Hz readout rate integrating ~55 samples

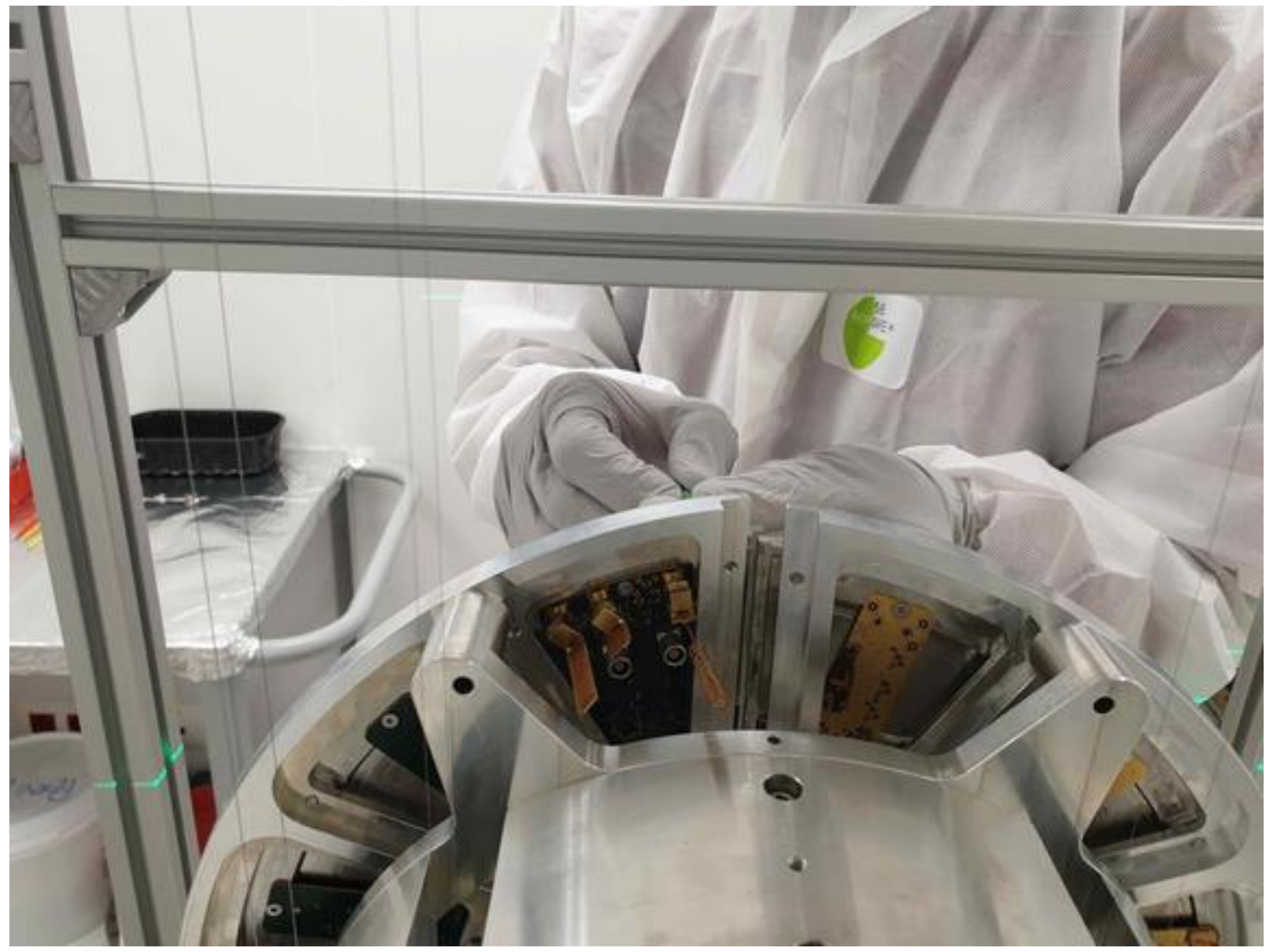
→ Faster readout (1kHz) considered for large baffles

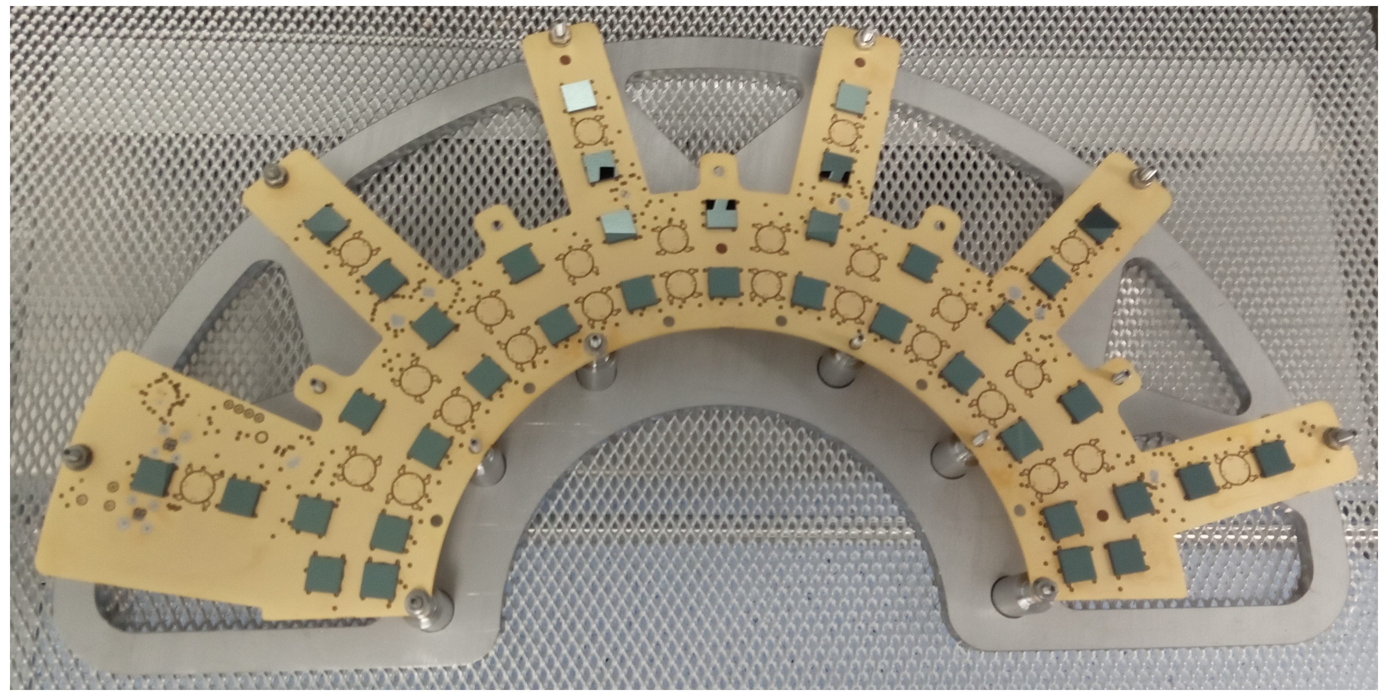
8 ADC per board incorporating temperature measurements (see plot for 5 days)

First Integration test @ EGO









A first (successful) integration test with the new IMC payload took place in October 2020

→ **Indicated the perfect balance of the mechanics**
→ **Certified the integration with electronics and connections**
→ **Indicated the real integration @ vacuum tower would be smooth**

CERN — European Organization for Nuclear Research

TE / VSC – SCC
Laboratoire de Chimie

Vacuum Surfaces Coatings

Domaine : Chimie analytique	*Date des tests:* 09.2020 *EDMS :* **2469580**
Requérants : N. Thaus– TE/VSC Tel : 162253	Réalisé par : C.Charvet

Tests de relargage de contaminations organiques (Détecteur VIRGO)

N. Thaus a réalisé des tests de dégazage avec mesures RGA de composants provenant du détecteur VIRGO. Ces essais ont été réalisés sur deux bancs de tests (TB101-2 et TB101-6).
Au cours de ces tests, des échantillons en INOX 316 100x100mm ont également été placées dans les bancs de test.
Ces échantillons ont ensuite été extraits dans du n-hexane et les résidus ont été analysés par IR-TF. L'objectif de ces analyses étant de voir si dans les conditions appliquées au banc de test, les composants de l'expérience VIRGO relarguent des contaminations organiques sur les surfaces.

Test 2 : en présence des composants :

	Valeurs intégration
[4] : Plaque Inox – PCB1	0.007
[5] : Plaque Inox – PCB2	0.012
[6] : Plaque Inox pliée en U – electronics components	0.011

Tableau des valeurs d'intégration des pics relatifs aux composés hydrocarbonés (entre 2750 et 3100 cm^{-1}) réalisés sur les spectres IR-TF transformés en absorption.

Des quantités ***négligeables de produits hydrocarbonés*** (≤0.02 u.a) ont été observées à la surface des pièces en Inox. (Cf. Fig.4 à 6).

Test 3 : en présence des composants :

	Valeurs intégration
[7] : Plaque Inox – TB2 connectors	0.006
[8] : Plaque Inox – TB2 connectors	0.001
[9] : Plaque Inox pliée en U – TB6 detector Si	0.002

Tableau des valeurs d'intégration des pics relatifs aux composés hydrocarbonés (entre 2750 et 3100 cm^{-1}) réalisés sur les spectres IR-TF transformés en absorption.

Des quantités ***négligeables de produits hydrocarbonés*** (≤0.02 u.a) ont été observées à la surface des pièces en Inox. (Cf. Fig.7 à 9).

Résultats :

Test 1 : contrôle de l'état de propreté du banc de test :

	Valeurs intégration
[1] : Plaque Inox	0.013
[2] : Plaque Inox	0.004
[3] : Plaque Inox pliée en U	0.008

Tableau des valeurs d'intégration des pics relatifs aux composés hydrocarbonés (entre 2750 et 3100 cm^{-1}) réalisés sur les spectres IR-TF transformés en absorption.

Des quantités ***négligeables de produits hydrocarbonés*** (≤0.02 u.a) ont été observées à la surface des pièces en Inox. (Cf. Fig.1 à 3).

Ces niveaux faibles de contamination correspondent au niveau d'acceptation pour les applications UHV du CERN.

2

TE / VSC – SCC
Technology Department
Laboratoire de Chimie

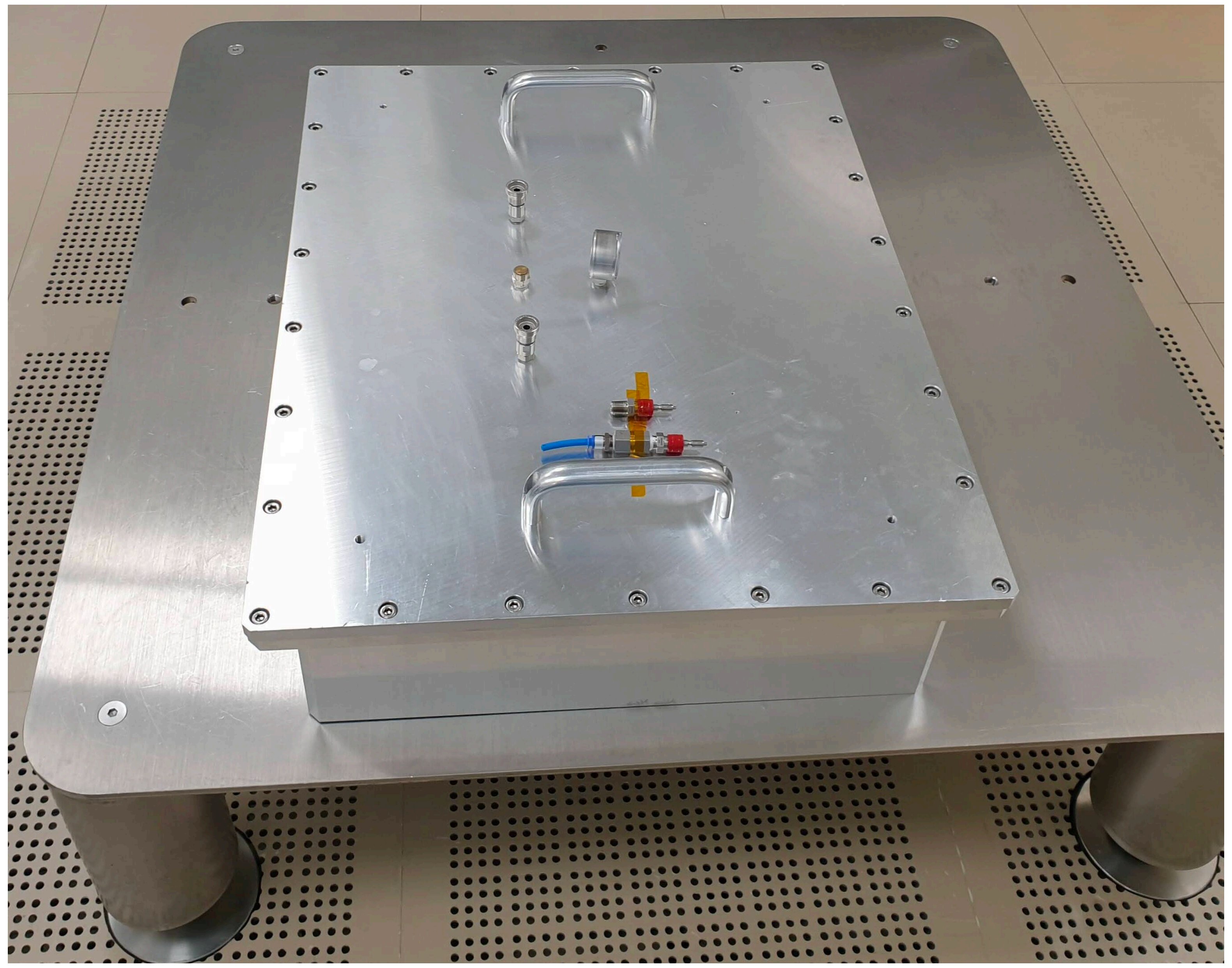
Credit: VACUUM DEPT@ CERN

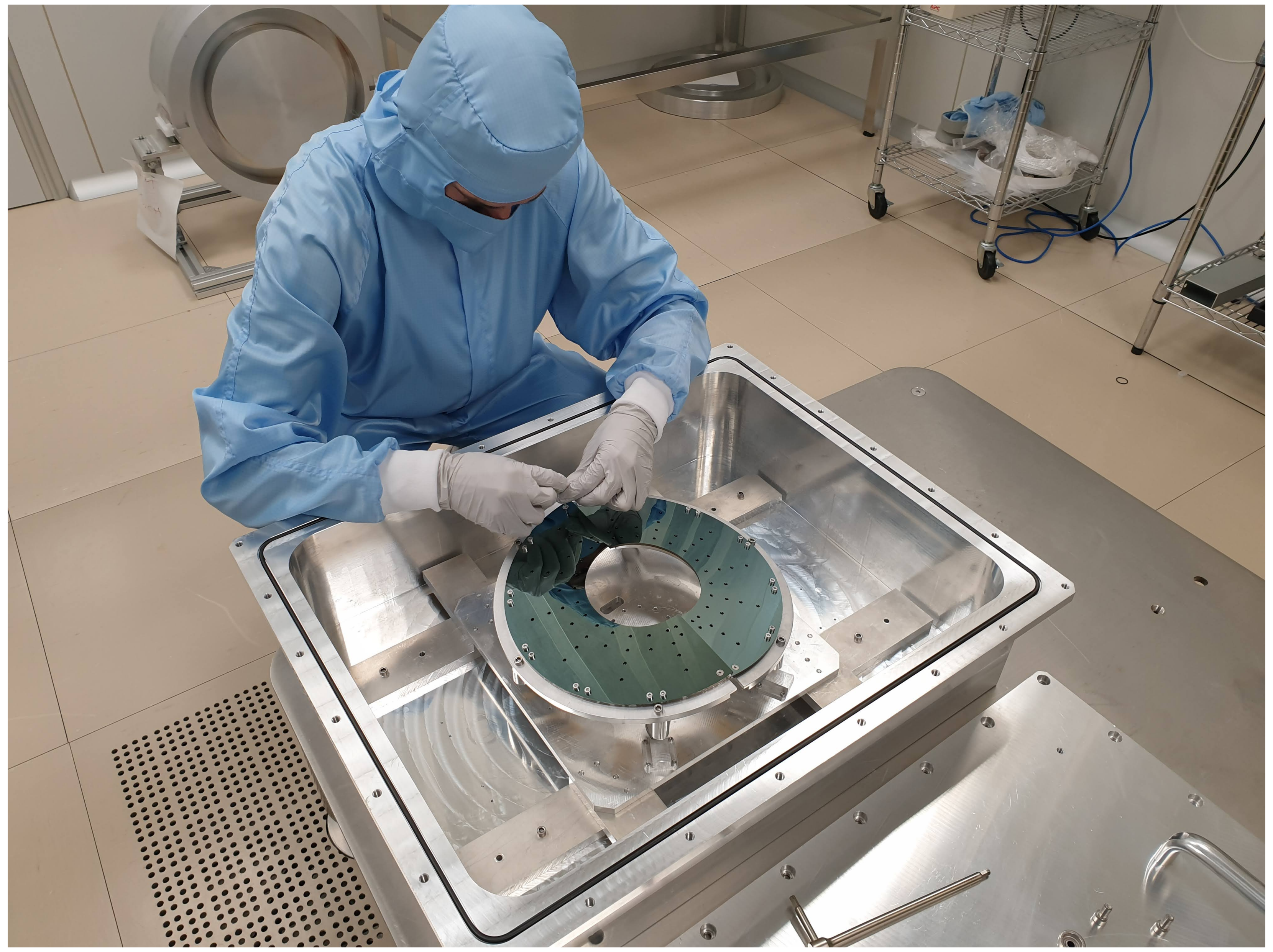
Conclusions:

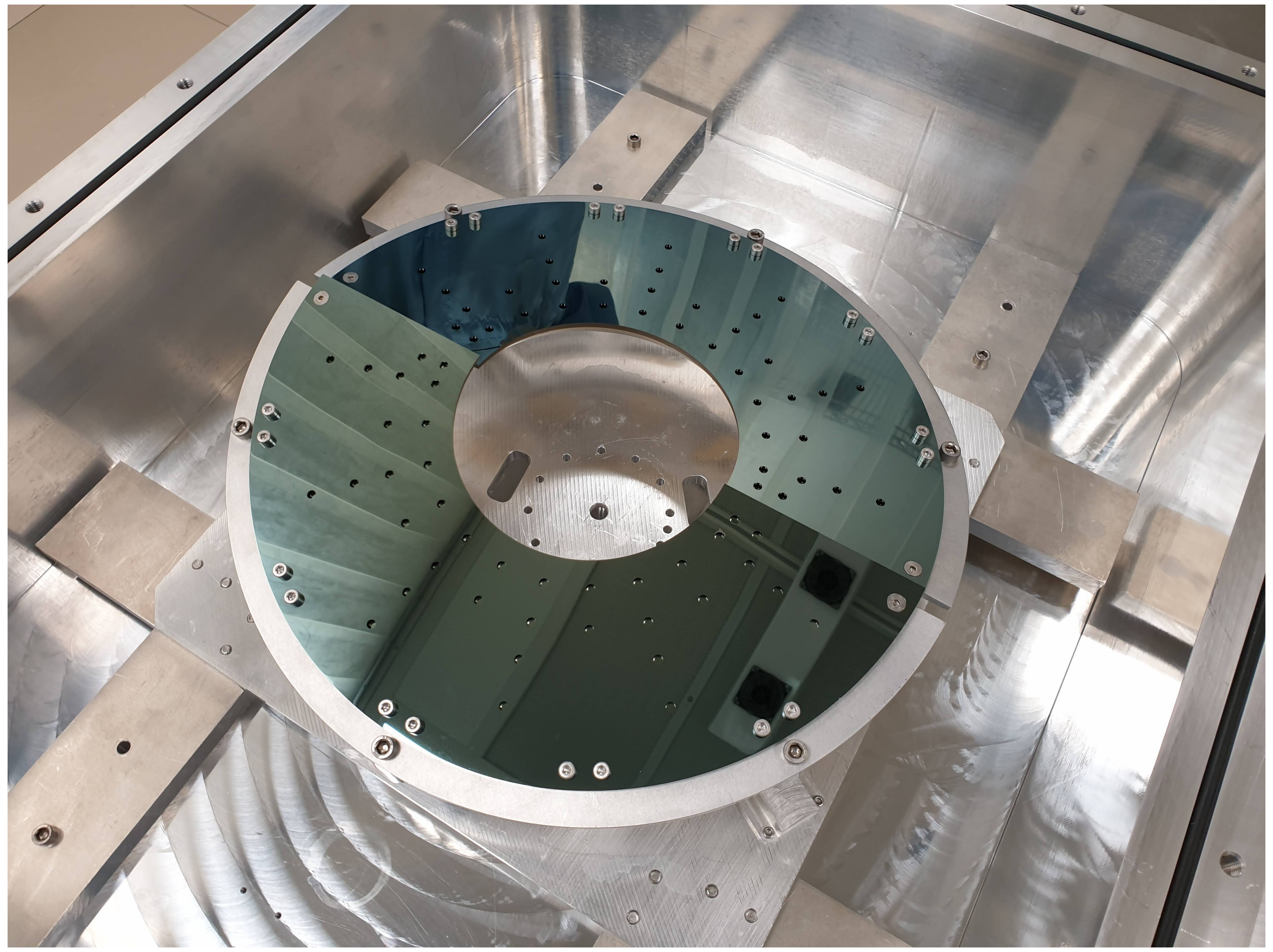
Les trois essais réalisés avec les bancs de test : contrôle de la propreté et tests en présence des composants n'ont pas permis de mettre en évidence, sur les plaques en Inox, un relargage de contaminations organiques soluble dans le n-hexane.

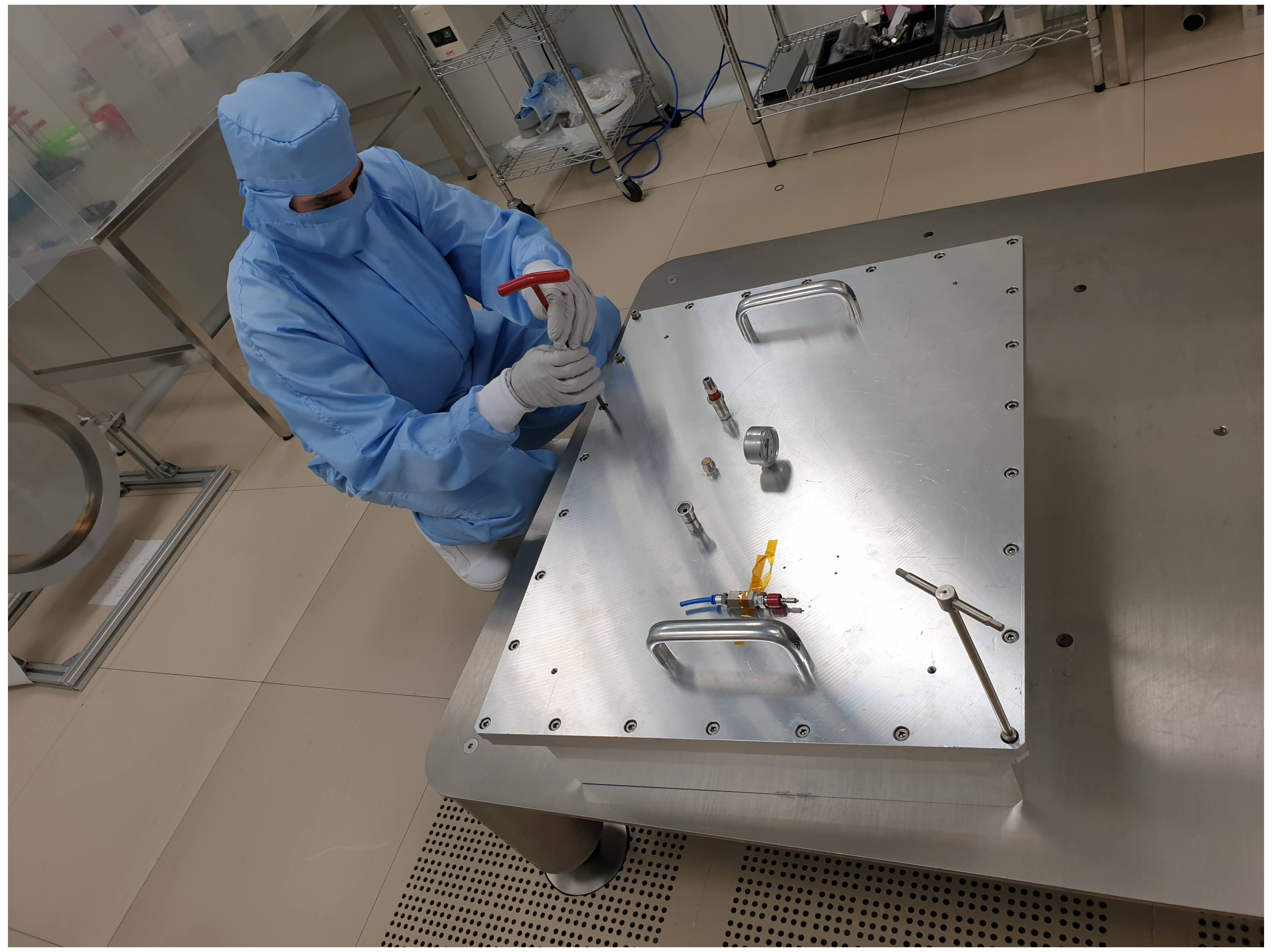
Ces niveaux faibles de contamination correspondent au niveau d'acceptation pour les applications UHV du CERN.

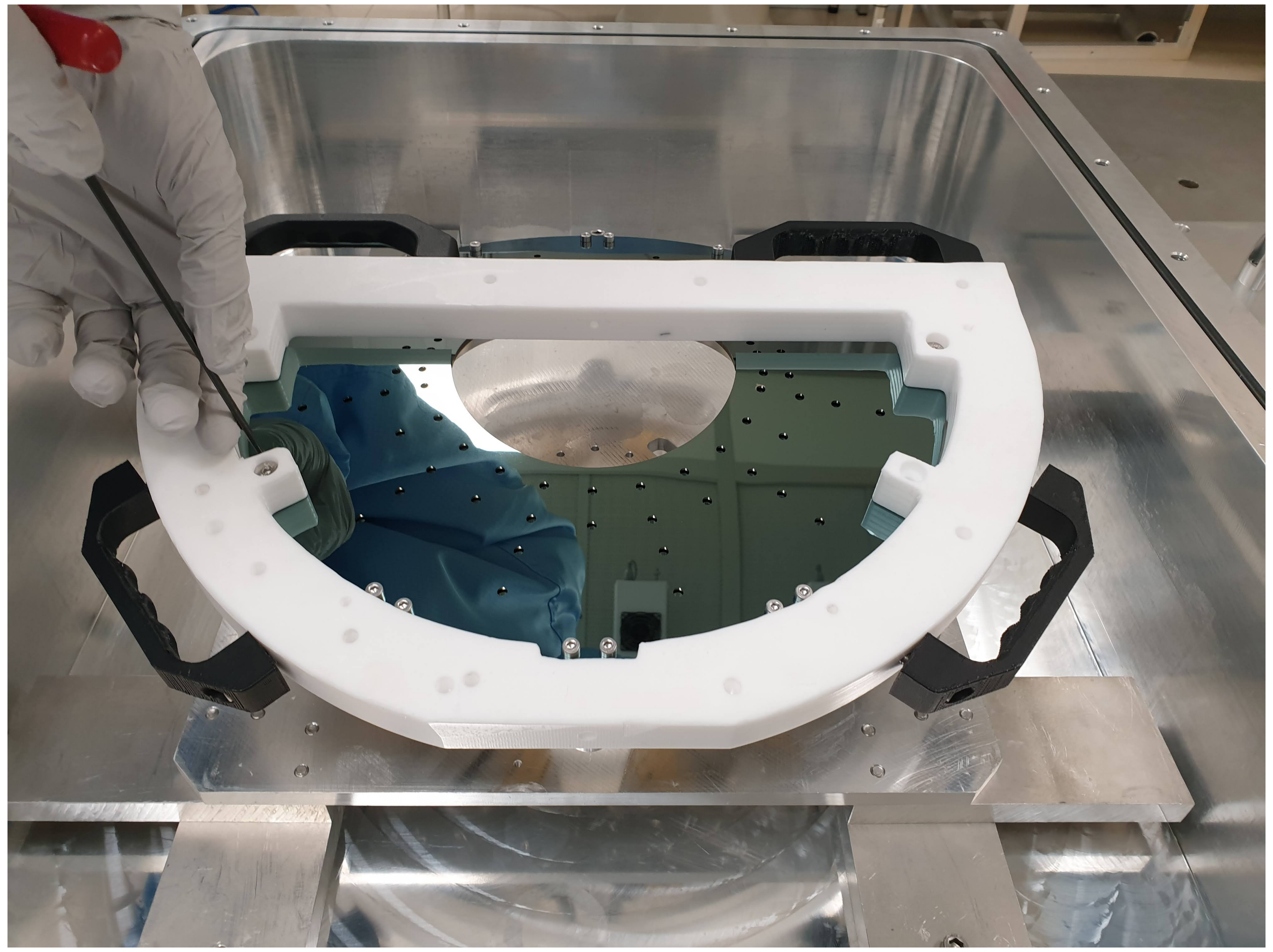
Installation @ IMC end mirror (April 2021)

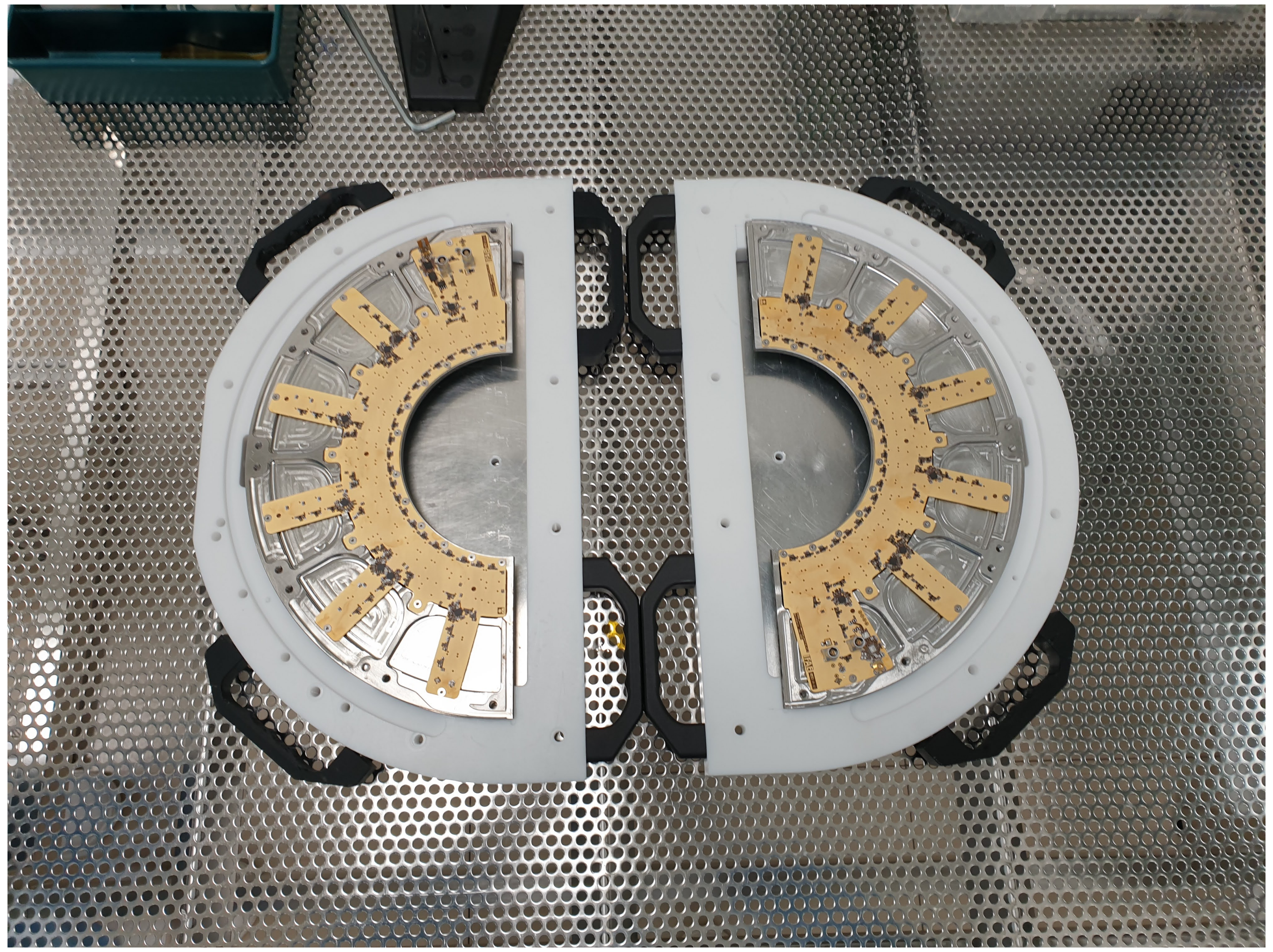




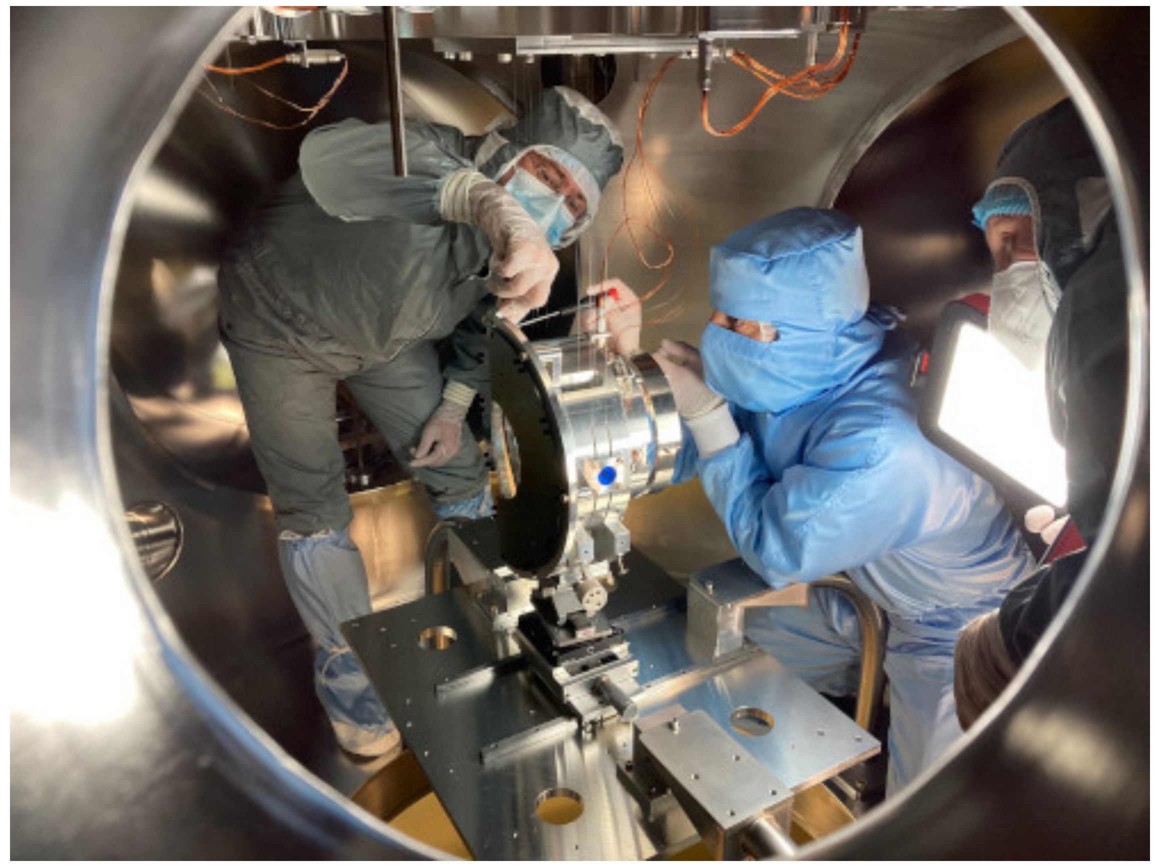




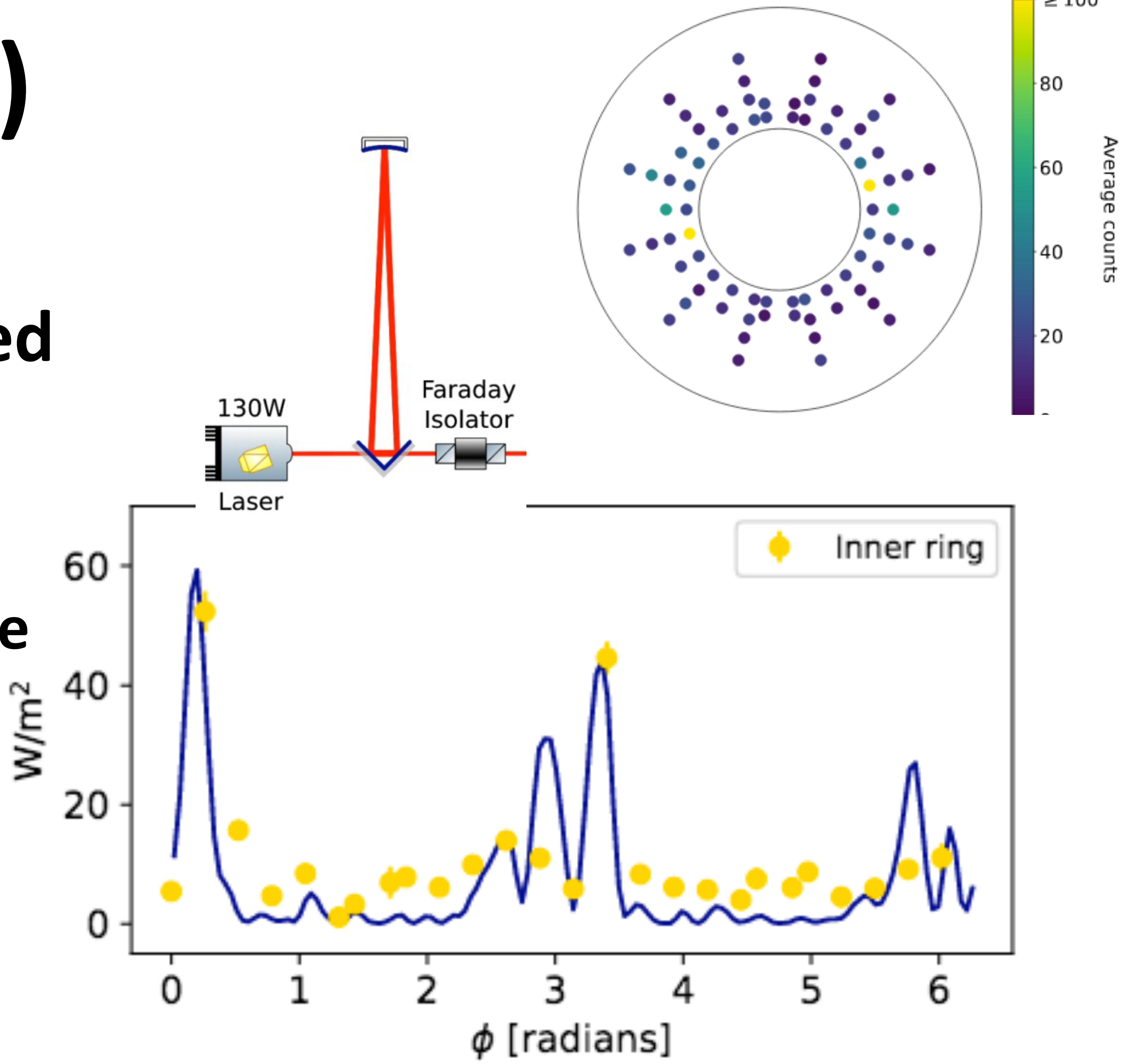




Instrumented baffle @ Virgo (2021 - now)

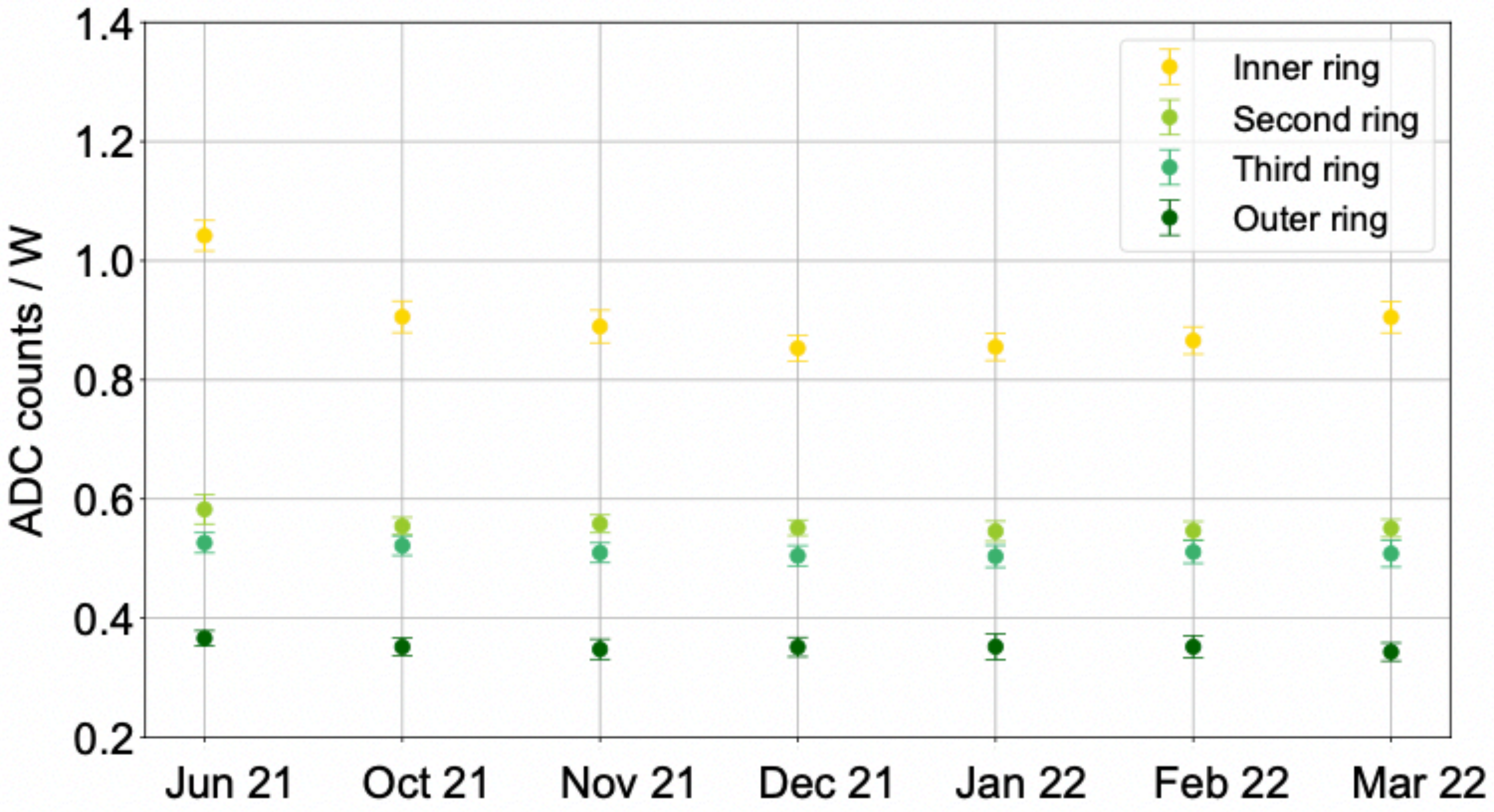


3 years of stable operation with no degradation of cavity observed



The installation of the first instrumented baffle in Virgo has demonstrated that the active monitoring of the stray light at the core optics of interferometers is feasible

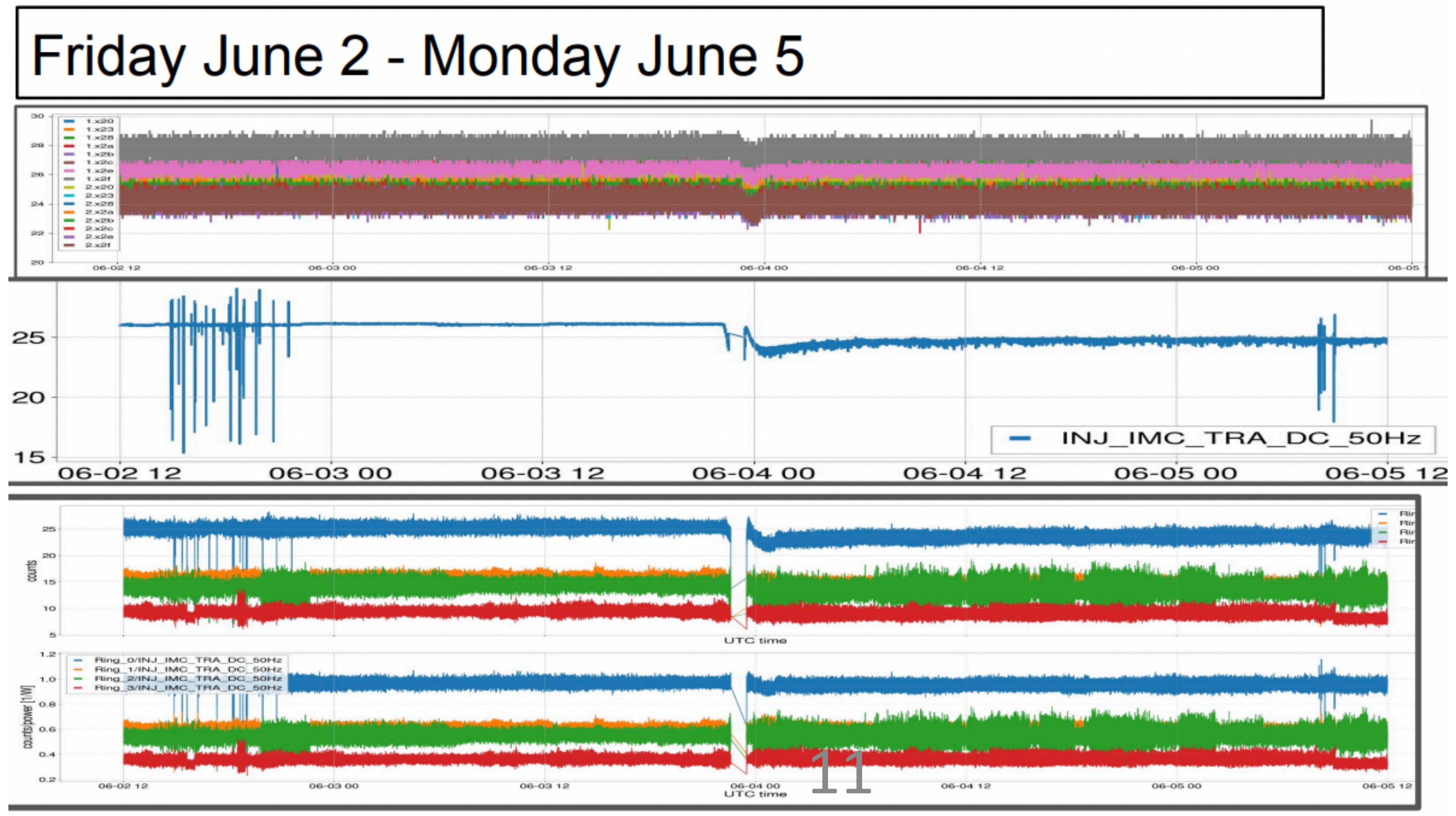
O. Ballester et al., CQG 39 (2022) 115011



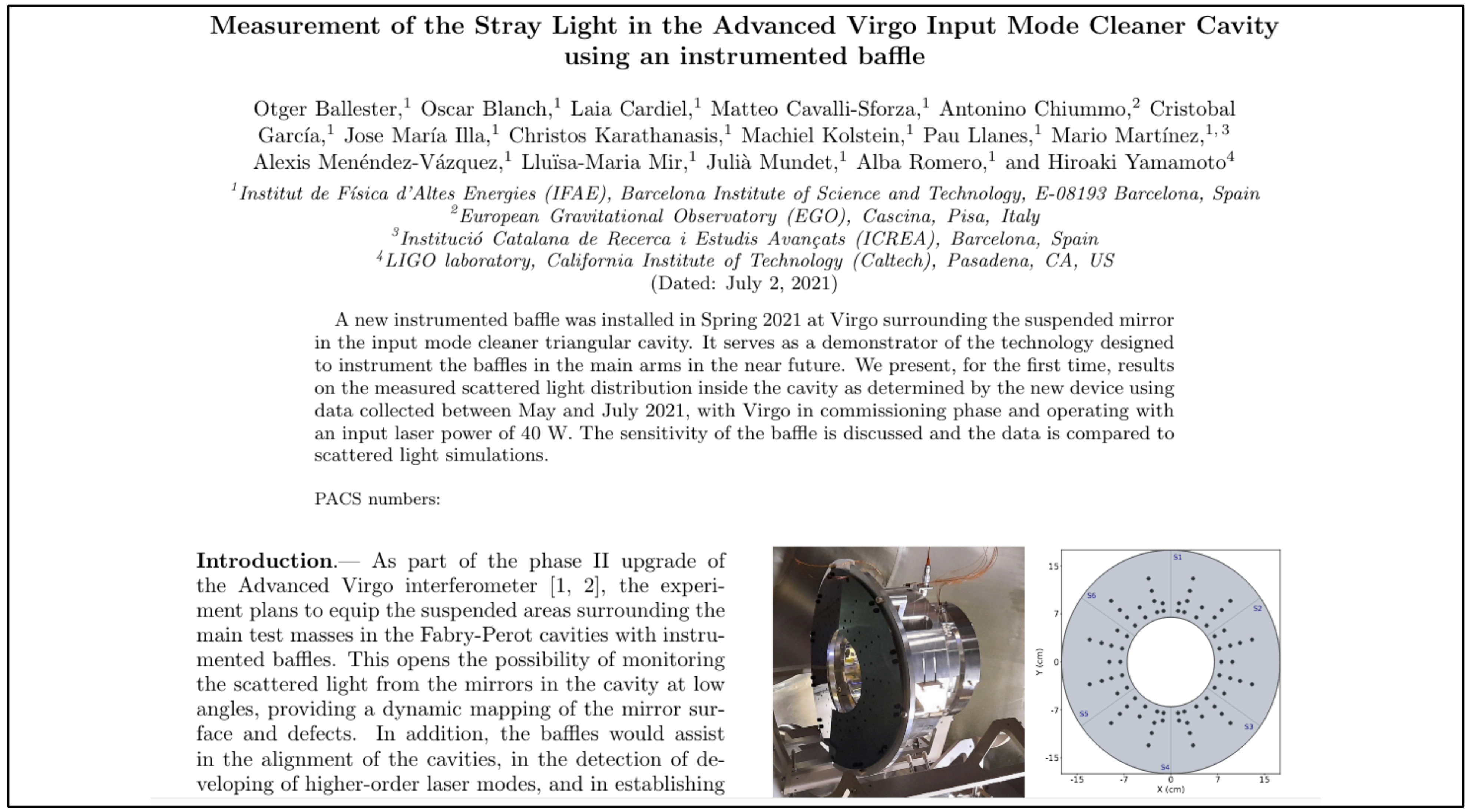
Comparison with SIS simulations of IMC

Confirmed sensitivity to mirror maps

Running 24/7 stable



Long publication and EGO STAC



Measurement of the Stray Light in the Advanced Virgo Input Mode Cleaner Cavity using an instrumented baffle

Otger Ballester,[1] Oscar Blanch,[1] Laia Cardiel,[1] Matteo Cavalli-Sforza,[1] Antonino Chiummo,[2] Cristobal García,[1] Jose María Illa,[1] Christos Karathanasis,[1] Machiel Kolstein,[1] Pau Llanes,[1] Mario Martínez,[1,3] Alexis Menéndez-Vázquez,[1] Lluïsa-Maria Mir,[1] Julià Mundet,[1] Alba Romero,[1] and Hiroaki Yamamoto[4]

[1] *Institut de Física d'Altes Energies (IFAE), Barcelona Institute of Science and Technology, E-08193 Barcelona, Spain*
[2] *European Gravitational Observatory (EGO), Cascina, Pisa, Italy*
[3] *Institució Catalana de Recerca i Estudis Avançats (ICREA), Barcelona, Spain*
[4] *LIGO laboratory, California Institute of Technology (Caltech), Pasadena, CA, US*

(Dated: July 2, 2021)

A new instrumented baffle was installed in Spring 2021 at Virgo surrounding the suspended mirror in the input mode cleaner triangular cavity. It serves as a demonstrator of the technology designed to instrument the baffles in the main arms in the near future. We present, for the first time, results on the measured scattered light distribution inside the cavity as determined by the new device using data collected between May and July 2021, with Virgo in commissioning phase and operating with an input laser power of 40 W. The sensitivity of the baffle is discussed and the data is compared to scattered light simulations.

PACS numbers:

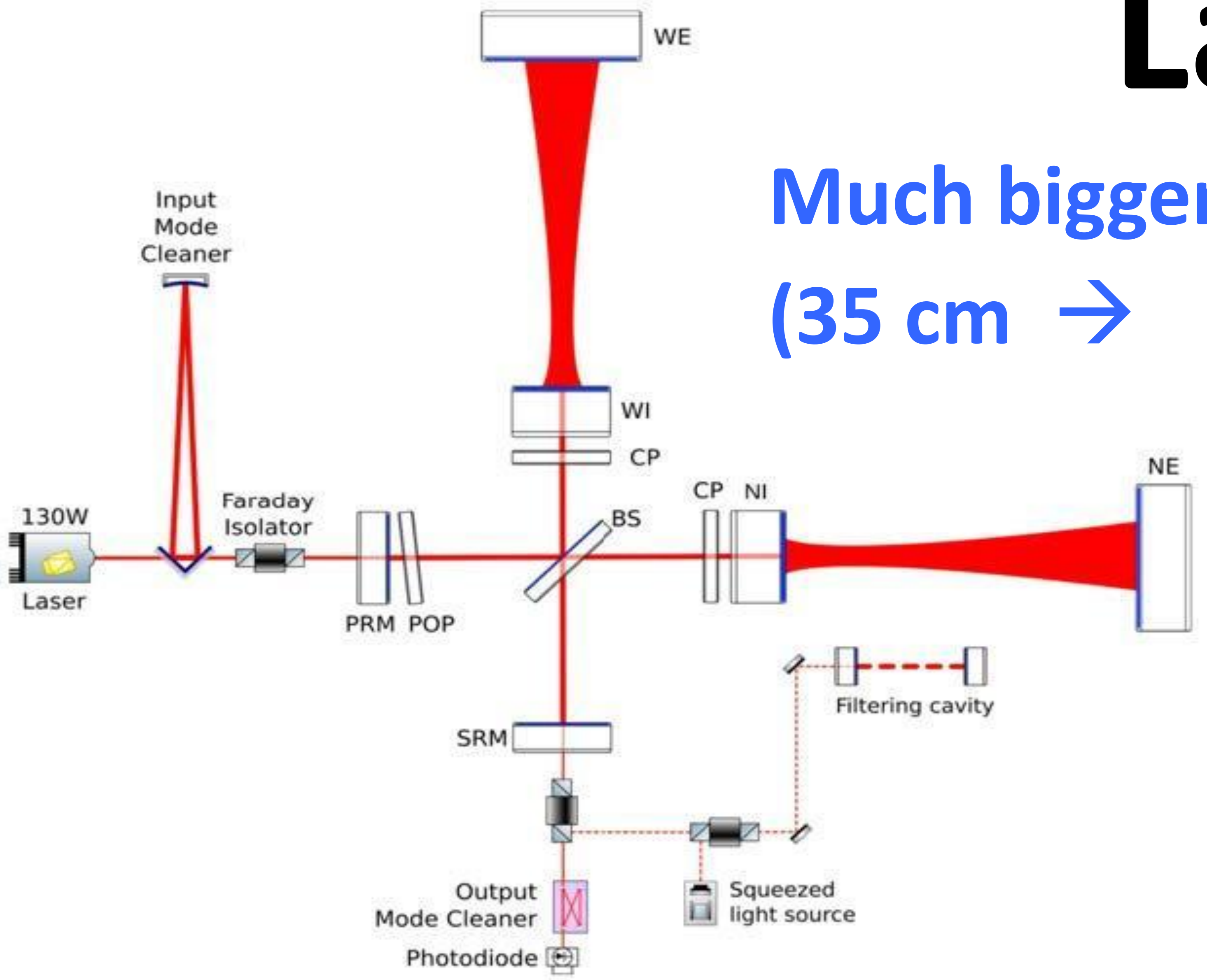
Introduction.— As part of the phase II upgrade of the Advanced Virgo interferometer [1, 2], the experiment plans to equip the suspended areas surrounding the main test masses in the Fabry-Perot cavities with instrumented baffles. This opens the possibility of monitoring the scattered light from the mirrors in the cavity at low angles, providing a dynamic mapping of the mirror surface and defects. In addition, the baffles would assist in the alignment of the cavities, in the detection of developing of higher-order laser modes, and in establishing

M. Andres-Carcasona et al., Phys. Rev. D 107, 062001 (2023)

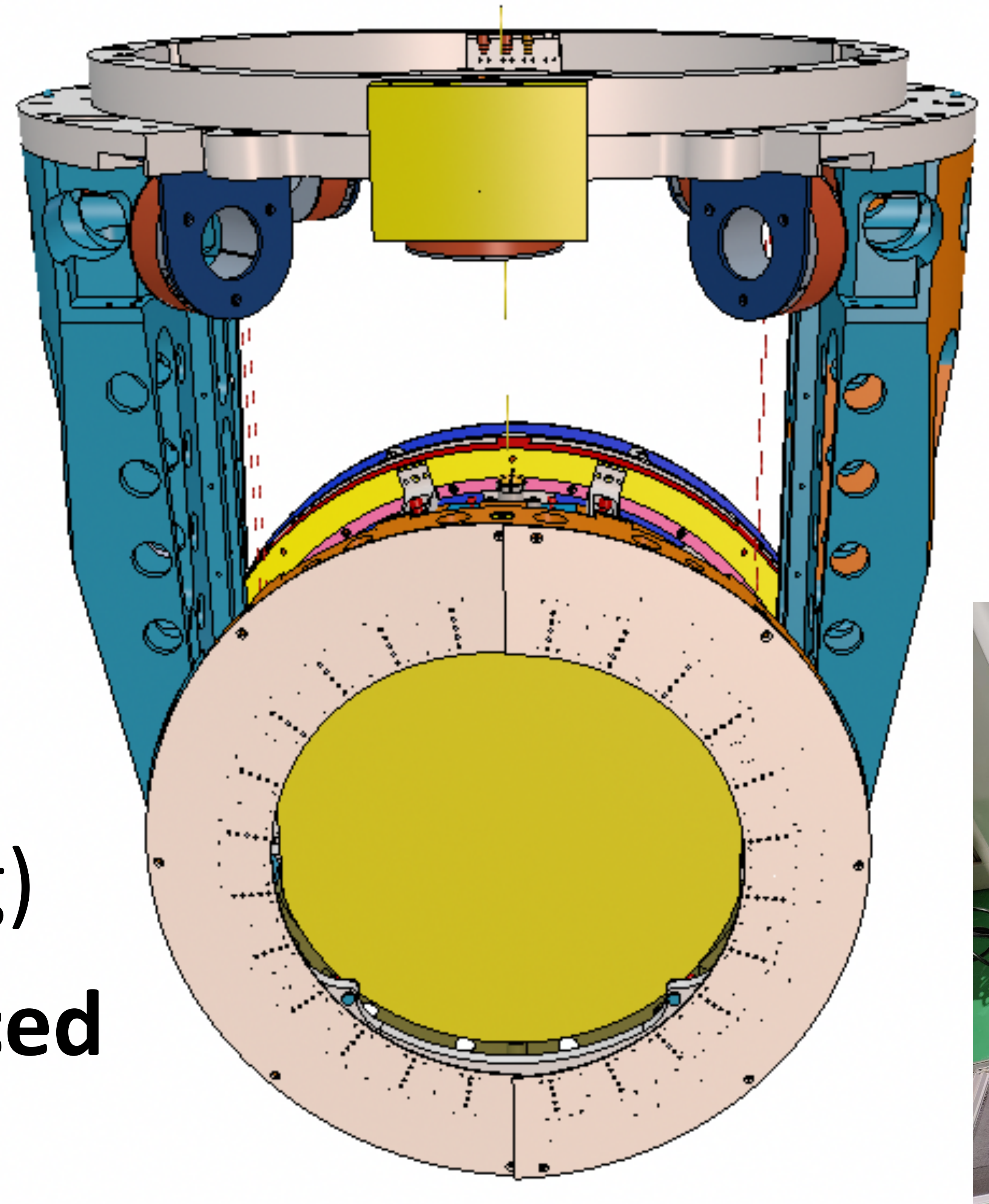
From EGO and Virgo June 2021
Scientific and Technical Advisory Committee Report:

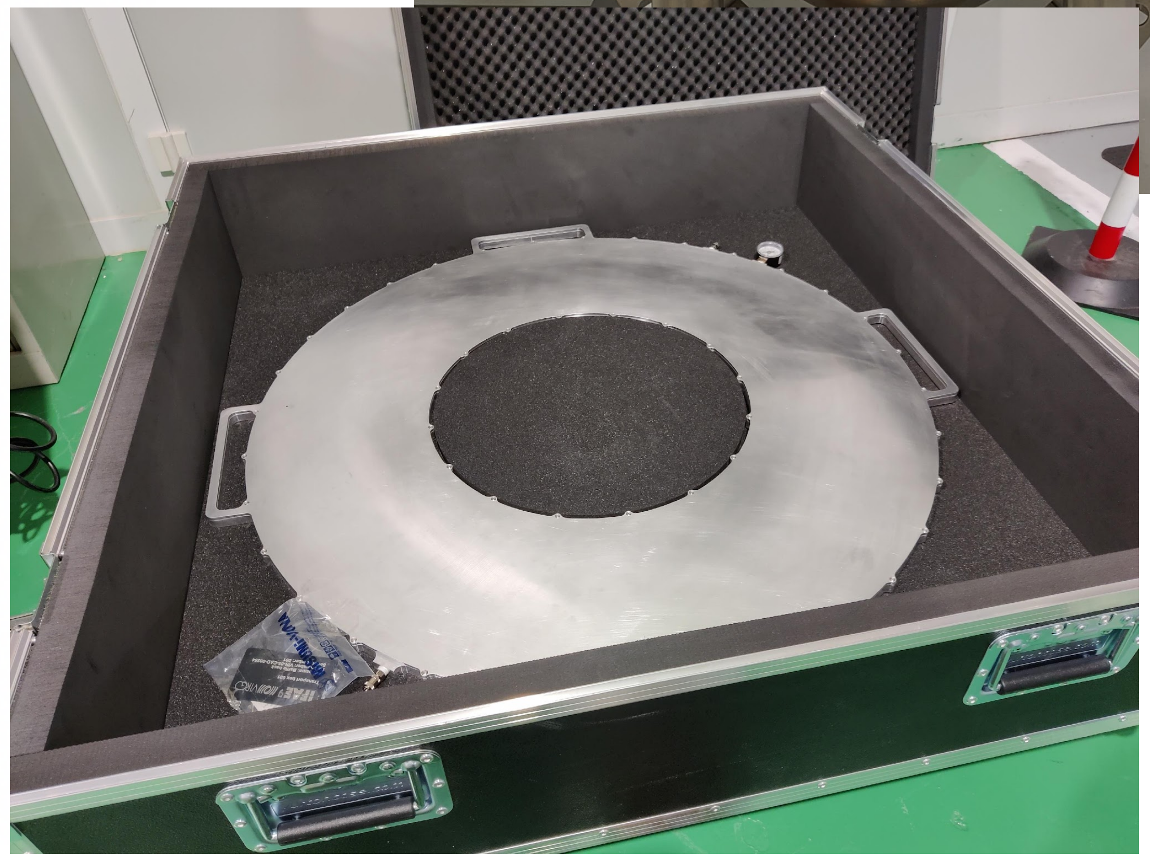
"The instrumented baffles have been installed. This can provide very useful additional data on the scattering from the optics, providing feedback to the mirror polishing and coating. This will be useful not only for O4 and O5 but also to plan for next-generation observatories (ET and CE) to refine the mirror requirements."

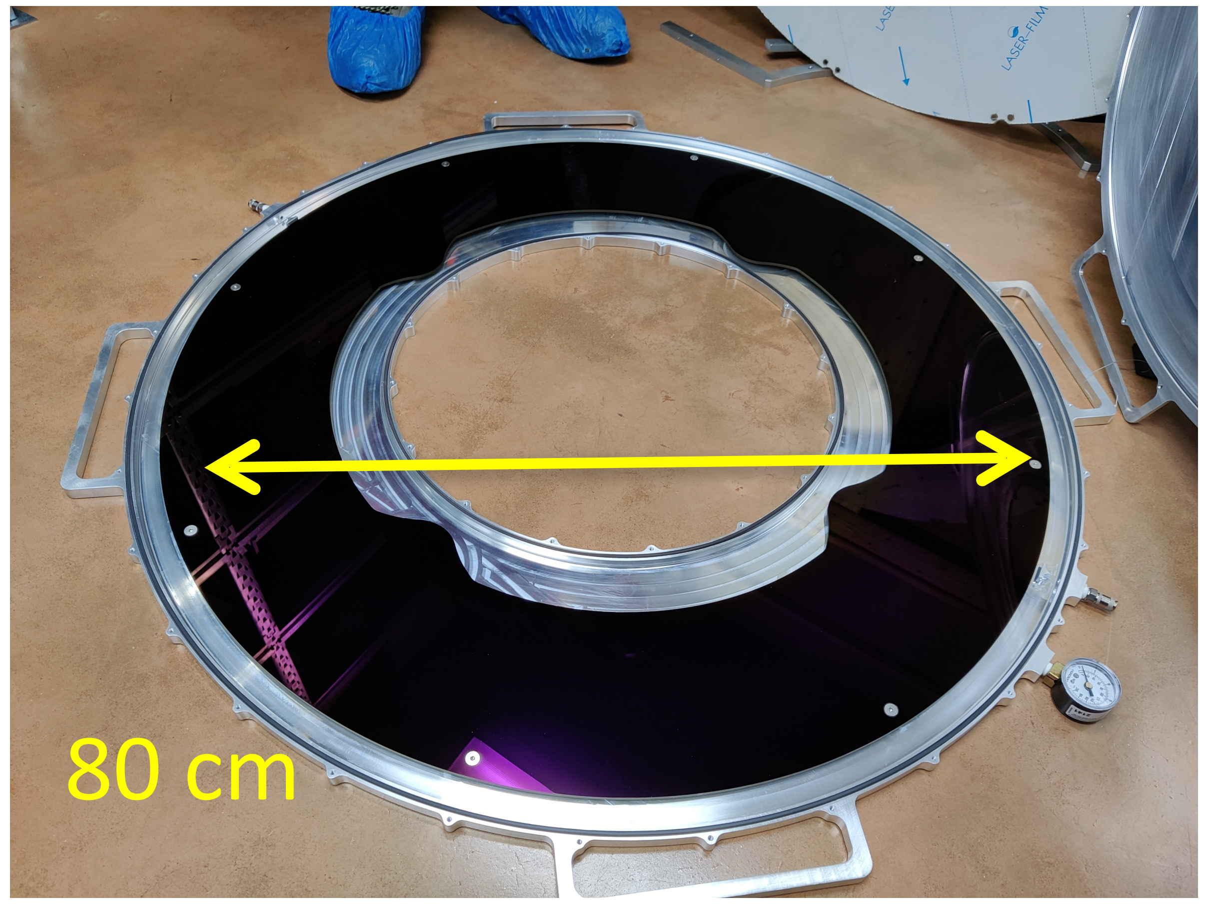
Large baffles



Much bigger than IMC
(35 cm → 80 cm)

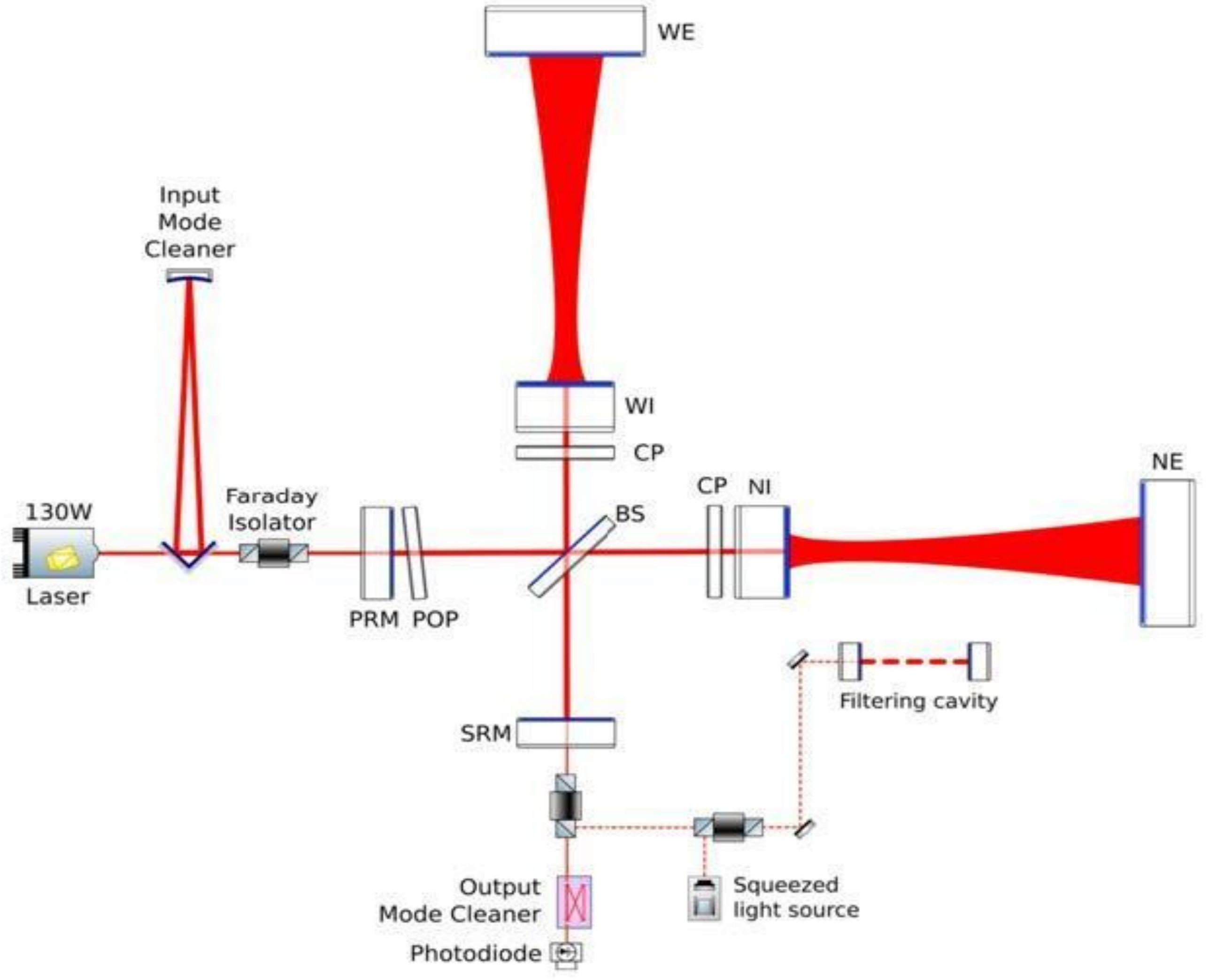




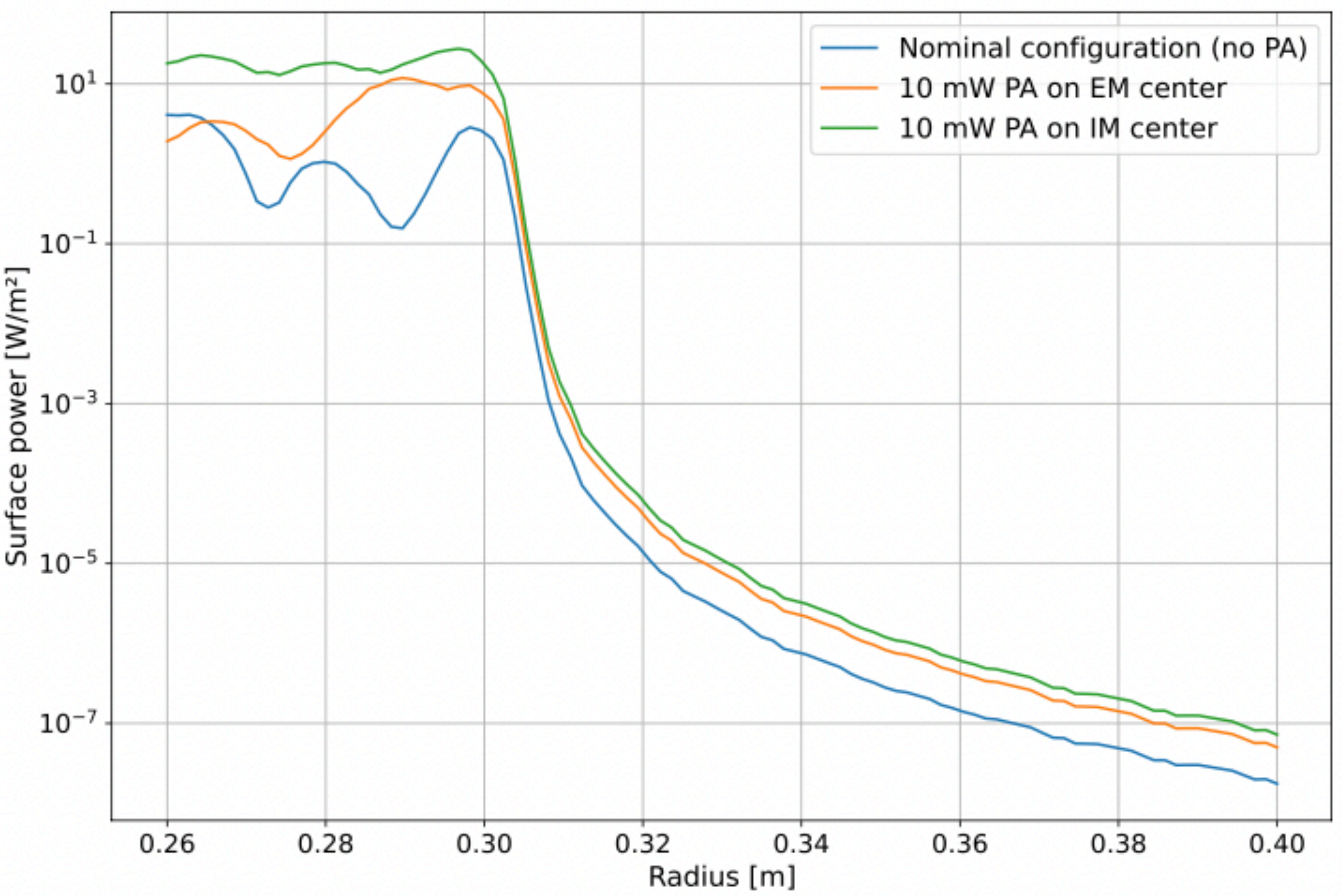


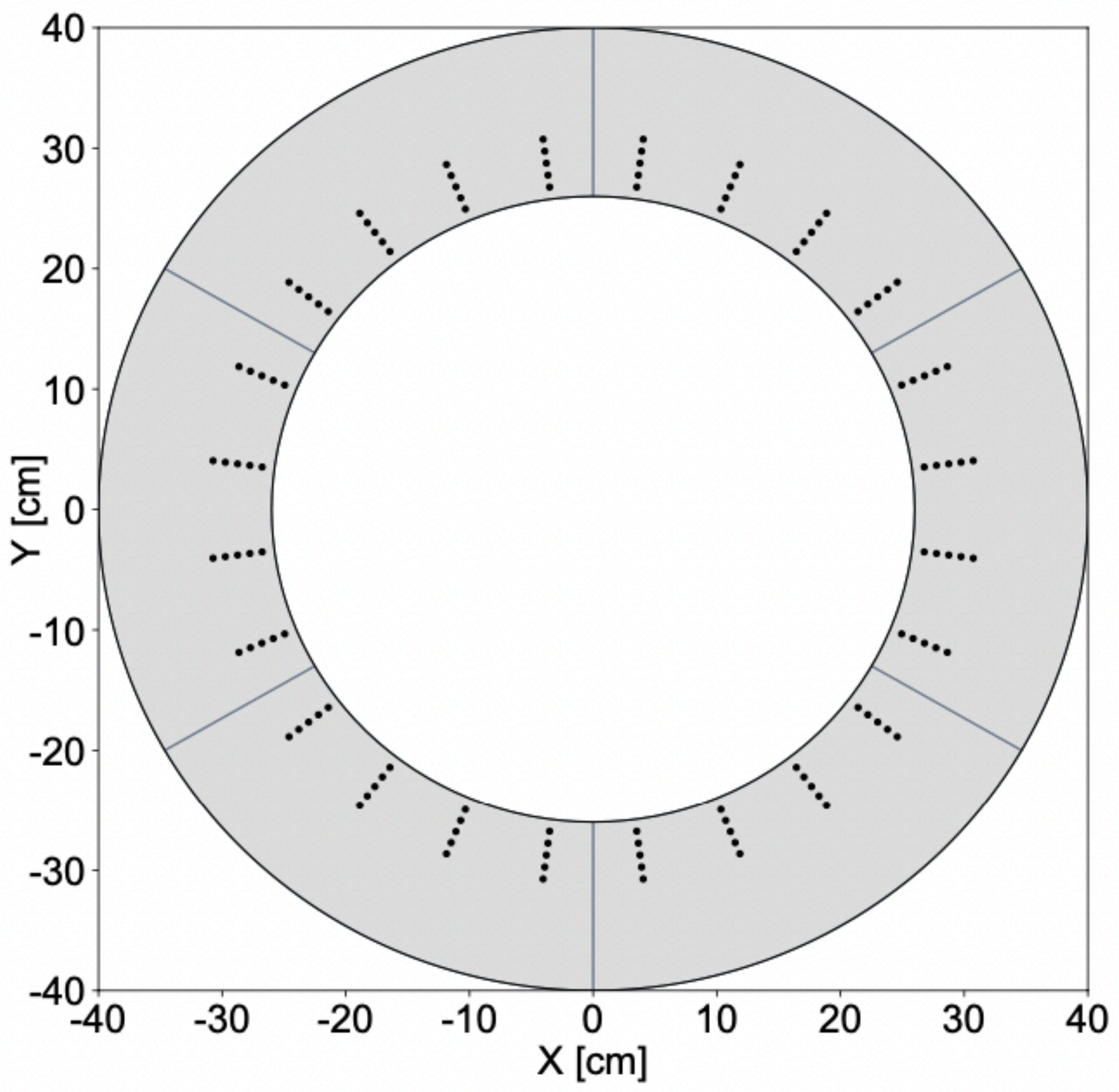
- In the framework of large mirrors (100kg)
- **New instrumented baffles being produced**
  - 120 sensors distributed in 5 rings
  - New DAQ at 1kHz / serial + wireless readout
  - Further Improvements on material (starting from 316L super #10 polished)
  - Encapsulation of the FE electronics [no line of view between FE and mirror]
  - Further steps adopted in cleaning process (in house and also in industry)
  - Dedicated EMI scans to prevent any EM interference with nearby controls
  - Non-instrumented backside baffles produced and stored in coffins with N_2

Simulations for Large Baffles

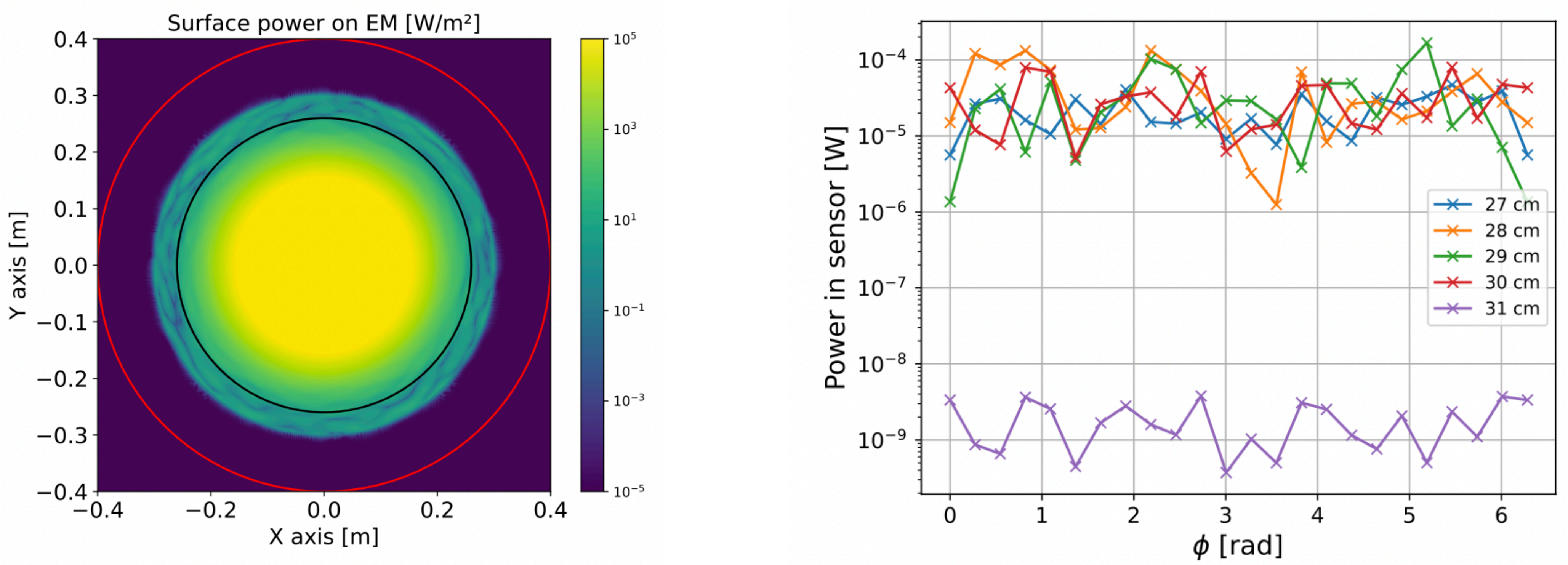


Mirrors with point absorbers

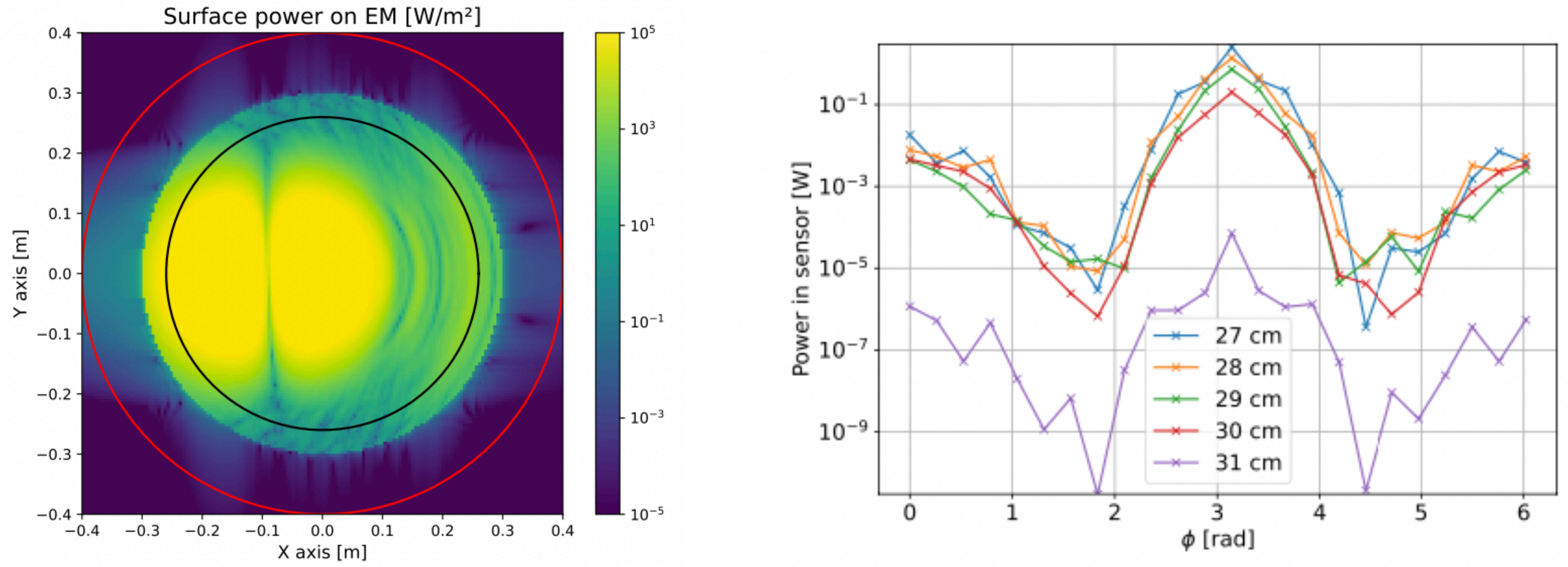




Nominal configuration



Mis-aligned configuration (0.8 micro rad)



Using SIS simulations we showed the potential of instrumenting baffles

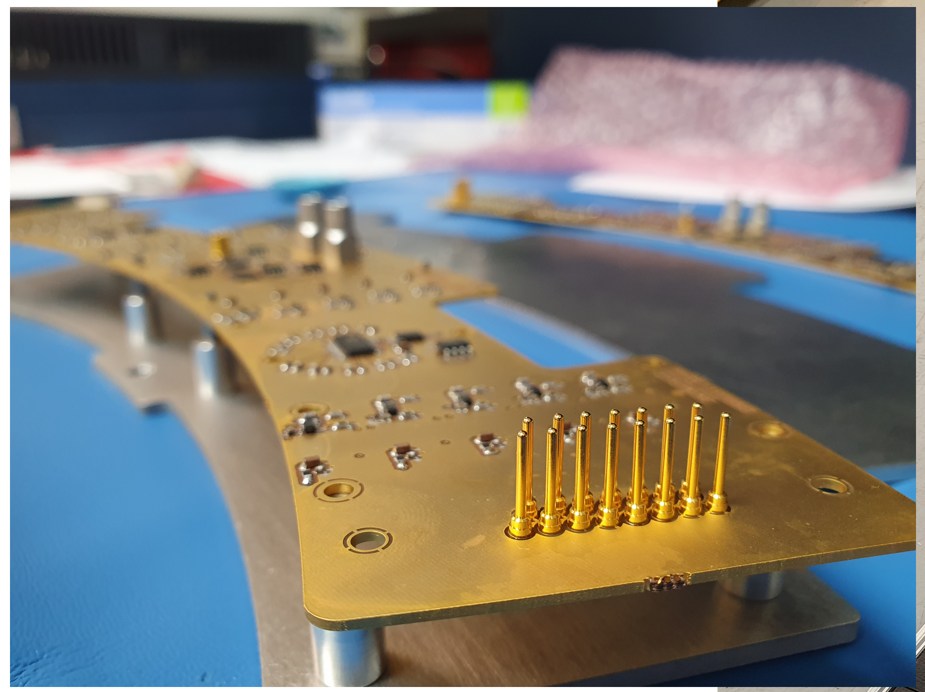
- Pre-alignment of the optical cavity
- Detection of point absorbers in the mirrors
- Large sensitivity to mirror optical characteristics (scattering, surface roughness)
- Correlation with glitches —> 1kHz readout + adapted DAQ gains / ring

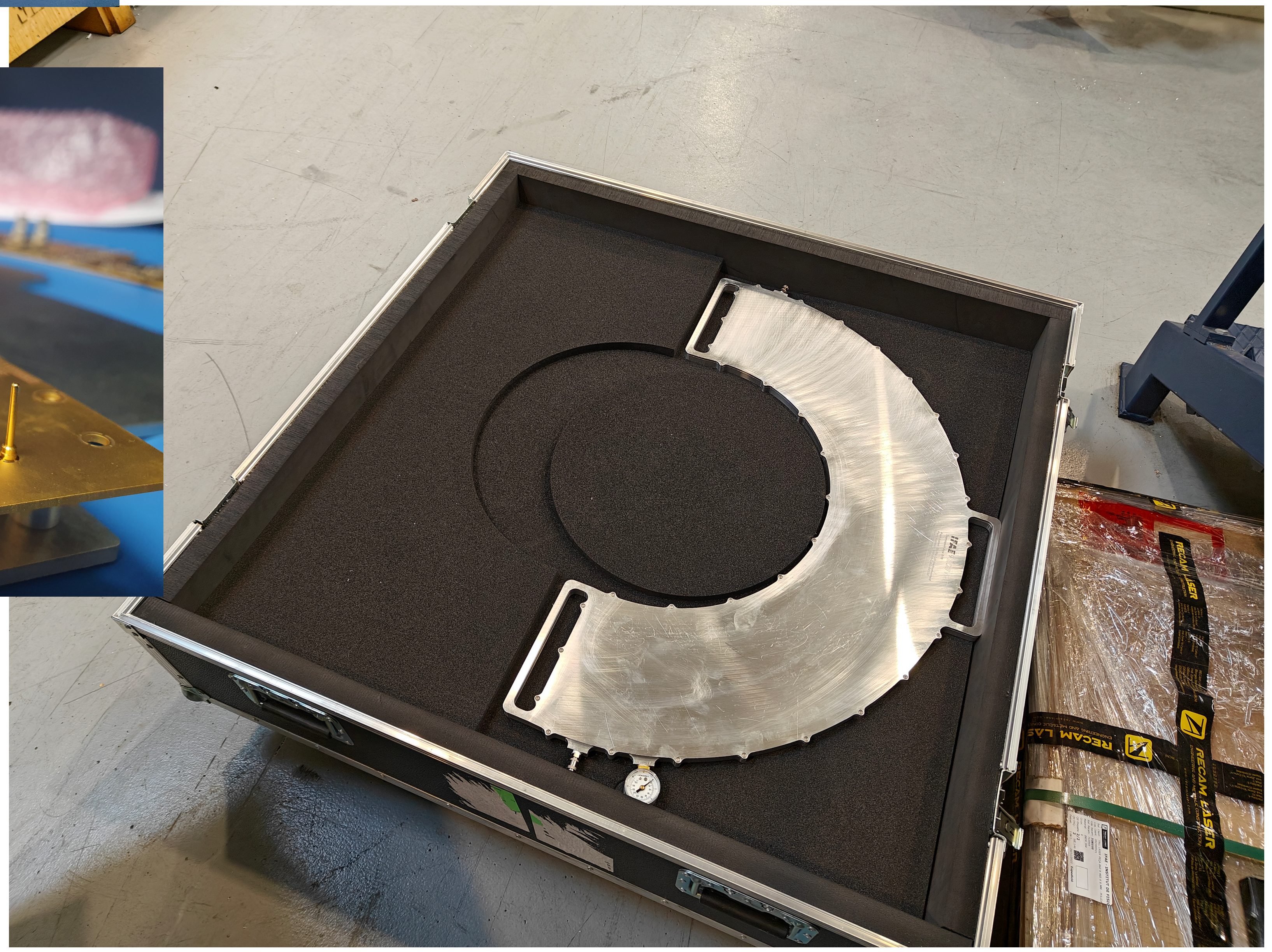
A. Macquet et al., Class. Quantum Grav. 40, 077001 (2023)

In close collaboration with H. Yamamoto (Caltech)

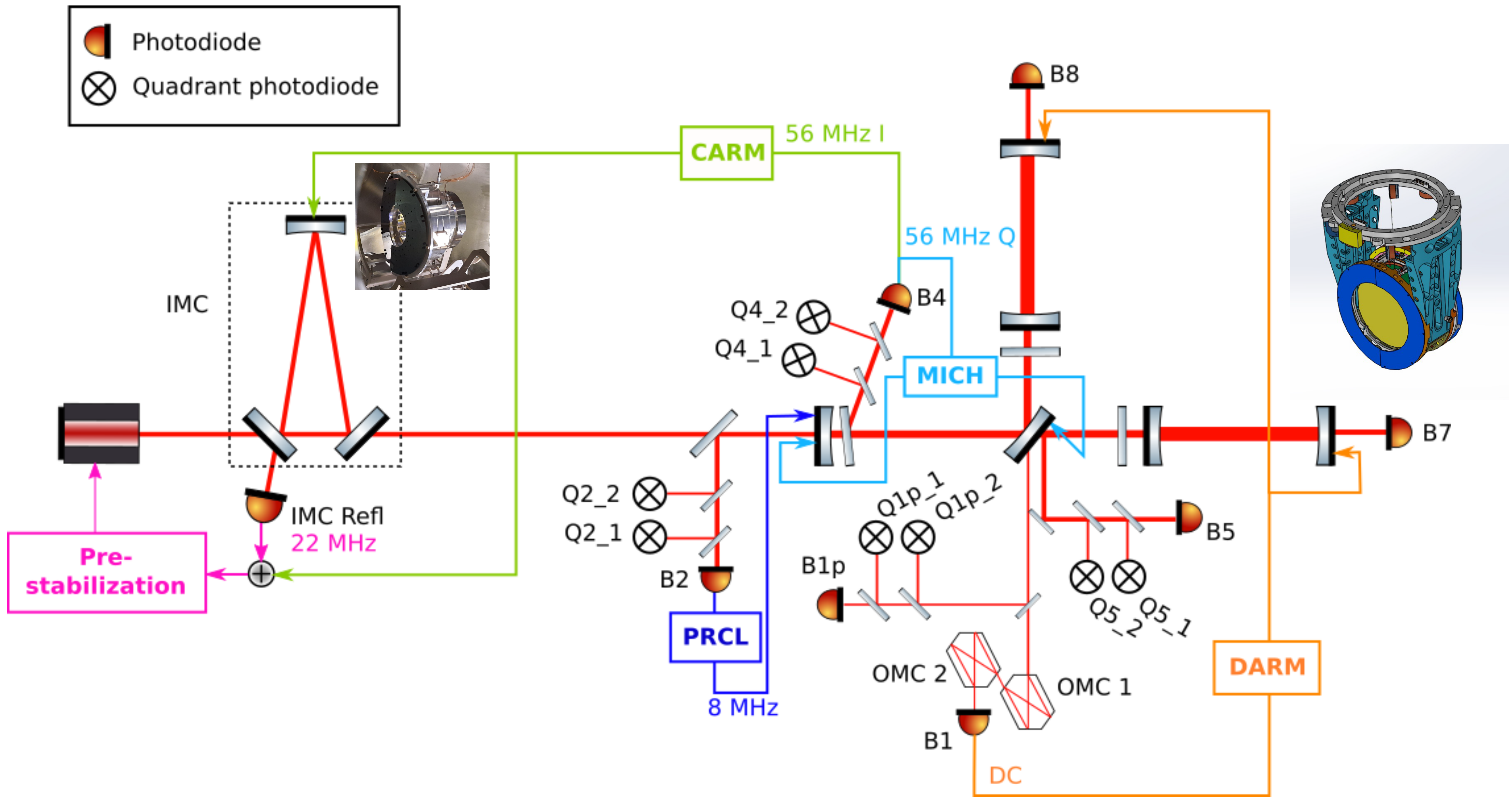
Production readiness

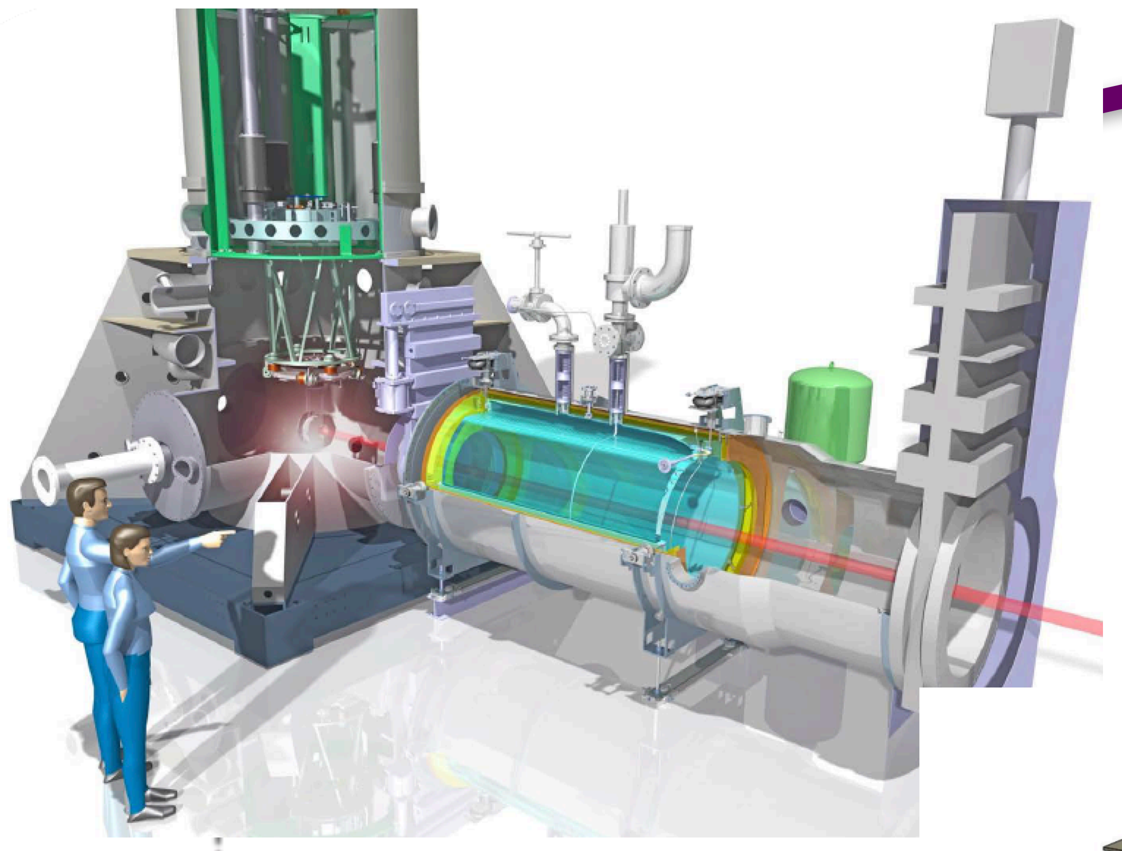
- **Baffle mechanics is essentially ready**
  - Final cleaning process taking place @ IFAE and in industry
  - Coffins for baffle preservation are being produced @ IFAE
  - Optical coating : Considering the possibility of Black-Nickel
- **Final version of PCBs are being produced**
  - Mounting Si-sensors @ IFAE
  - PCBs sent to CERN for extra cleaning
  - In parallel we are concluding the UHV certification @ CERN
  - In parallel a separate campaign for UHV certification @ EGO
  - EMI scan in industry @ IFAE campus
- **Final calibration campaign of photosensors is being launched**
  - Sensor by sensor calibration in optical setup @ IFAE
- **DAQ and Slow Control system is being finalised**

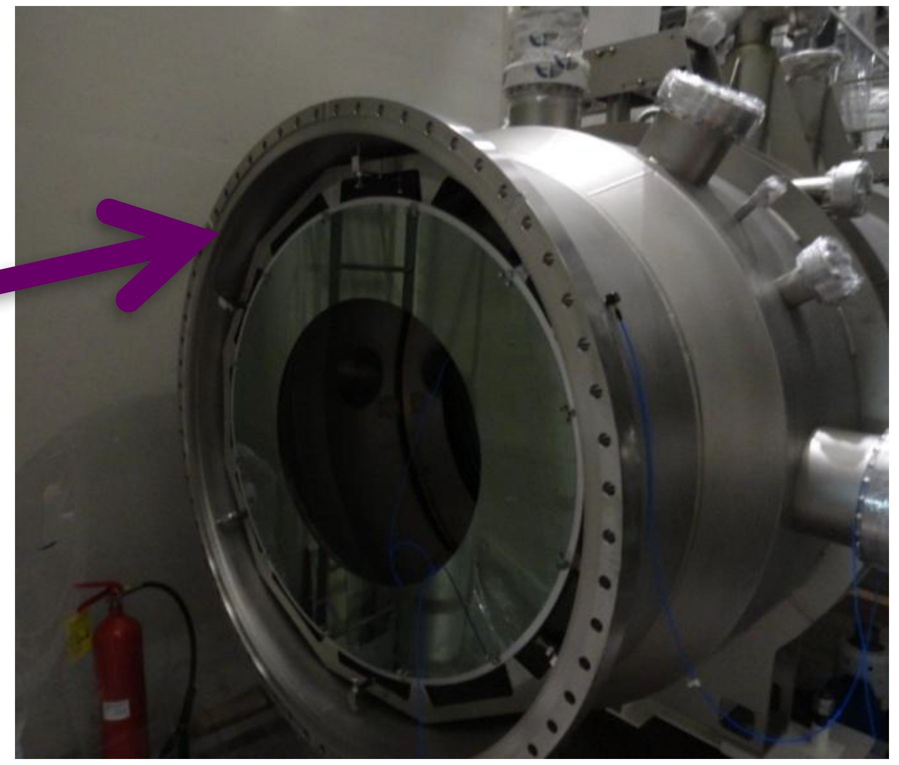


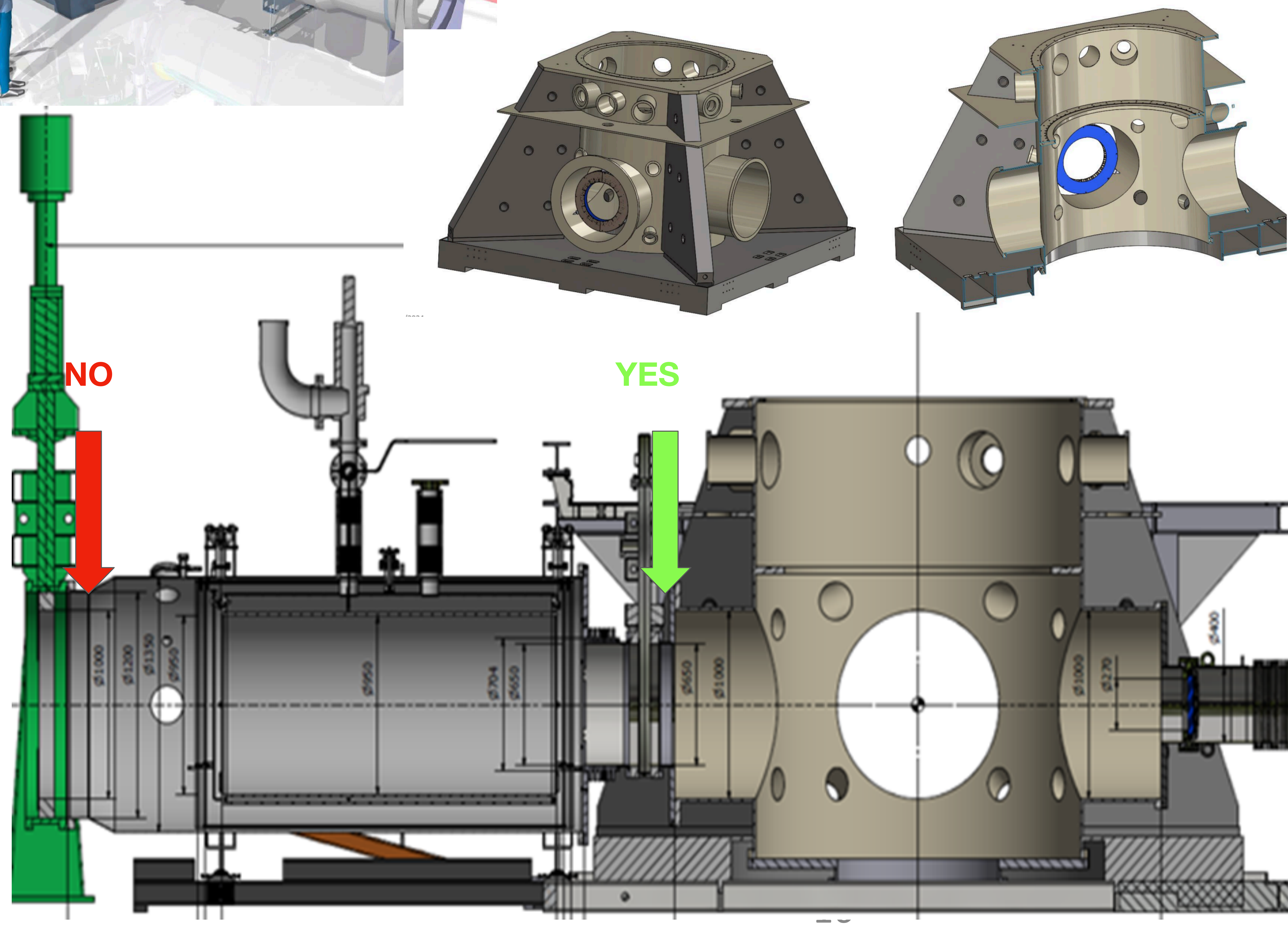


Revisiting installation plans









The installation of large mirrors is now being postponed (post-O5 operation)

Ongoing conversations in Virgo to install the instrumented baffles at the entrance of the ETM towers instead of existing passive one

—> Same performance in terms of light exposure
—> Further reduced risks (away from the mirrors)
—> Installing following the same approach as the cryobaffles
—> Springs to dump tube vibrations —> evaluating it.
—> Feasible without drastic interventions in cryotrap / arms

—> Instrumented baffle will be supplied with a passive backside baffle suppressing / deflecting scattered light from the nearby mirror

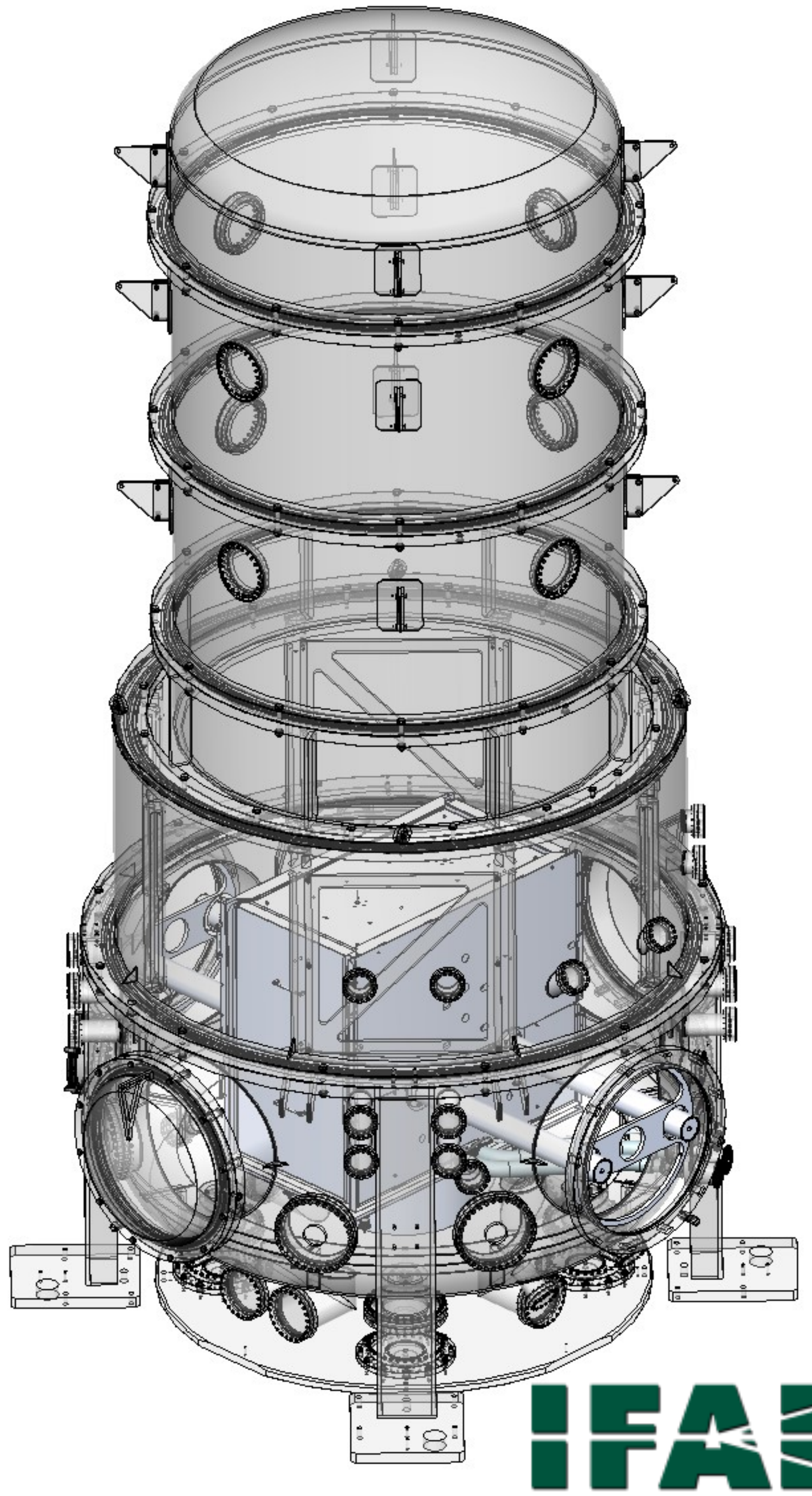
—> If confirmed we will enter into the production of 1+ more baffle

ETpathfinder

A collaboration established with Etpathfinder @ Maastricht

→ IFAE redesigned the cryo-shielding [paid by Nikhef]
→ IFAE will contribute to its installation in 2024

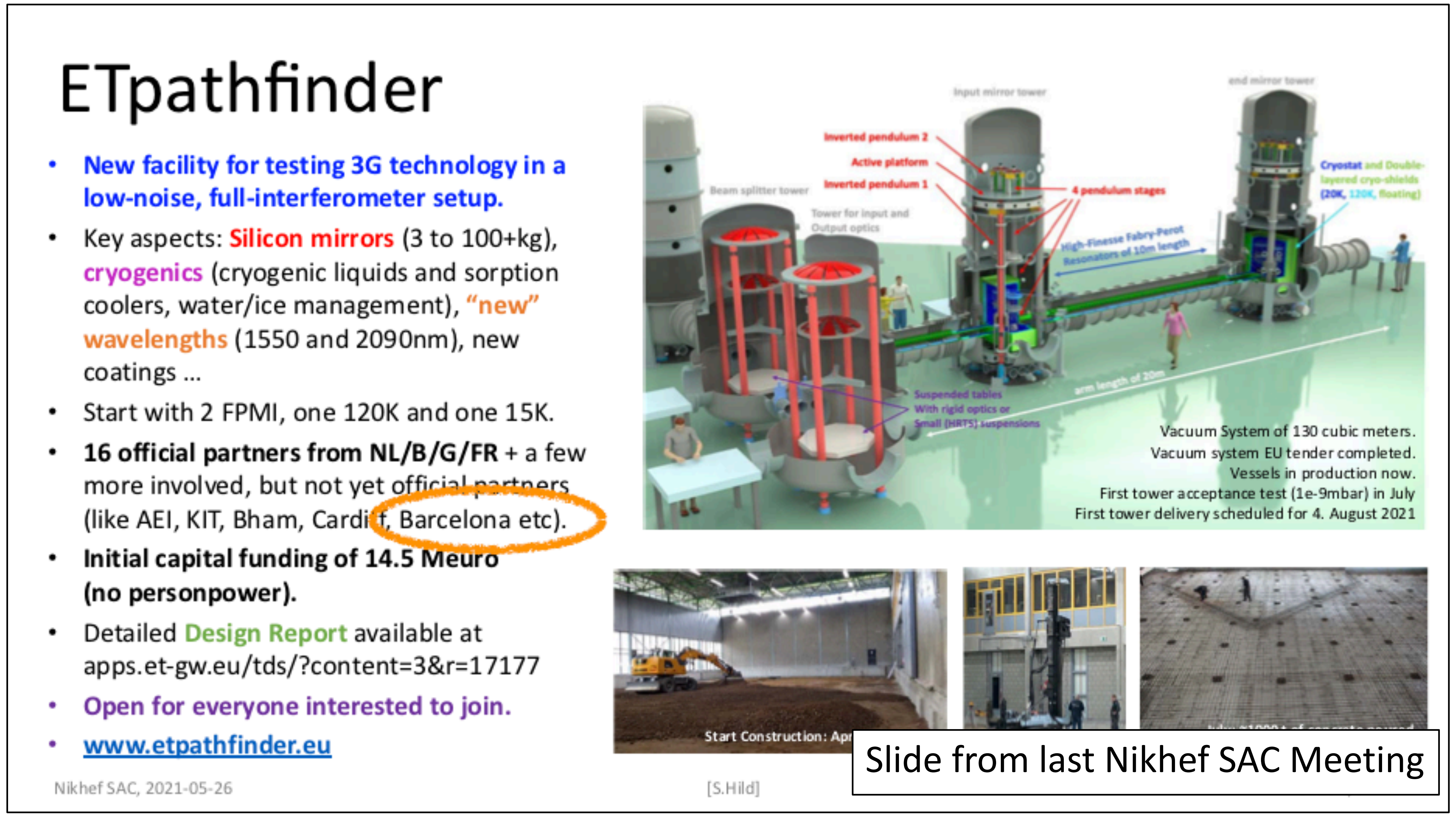
→ Pre-alignment & monitoring of the mirror surface
(instrumented baffle with sensors for λ = 1550 nm)
(Existing sensors at 1064 nm already in place)



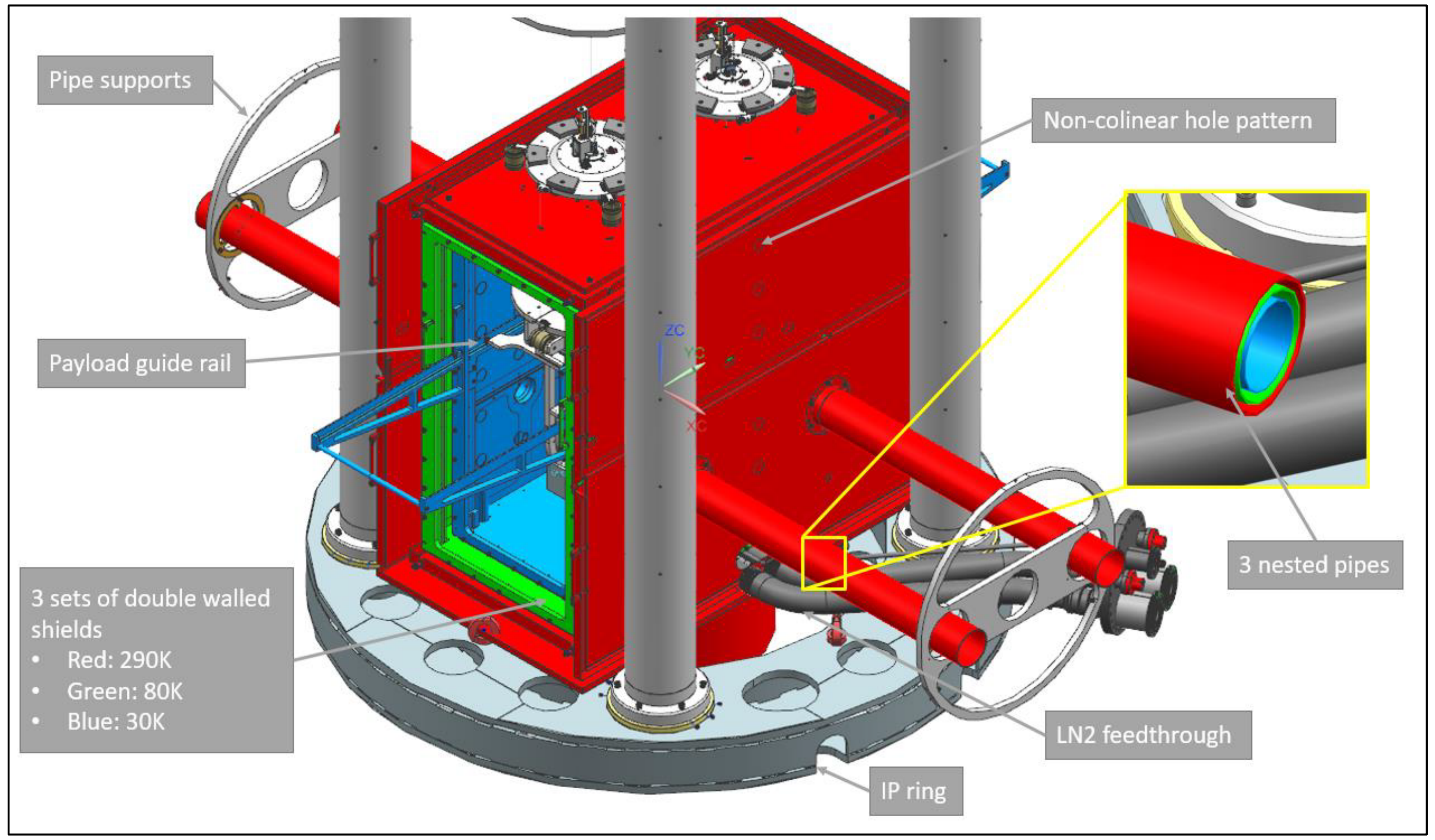
Funds requested to initiate an R&D on coated
InGaAs sensors @ 1.5 microns

Idea is to put two small baffles at the tower entrance equipped to 8 - 12 sensors facing the mirrors @ 10 m distance

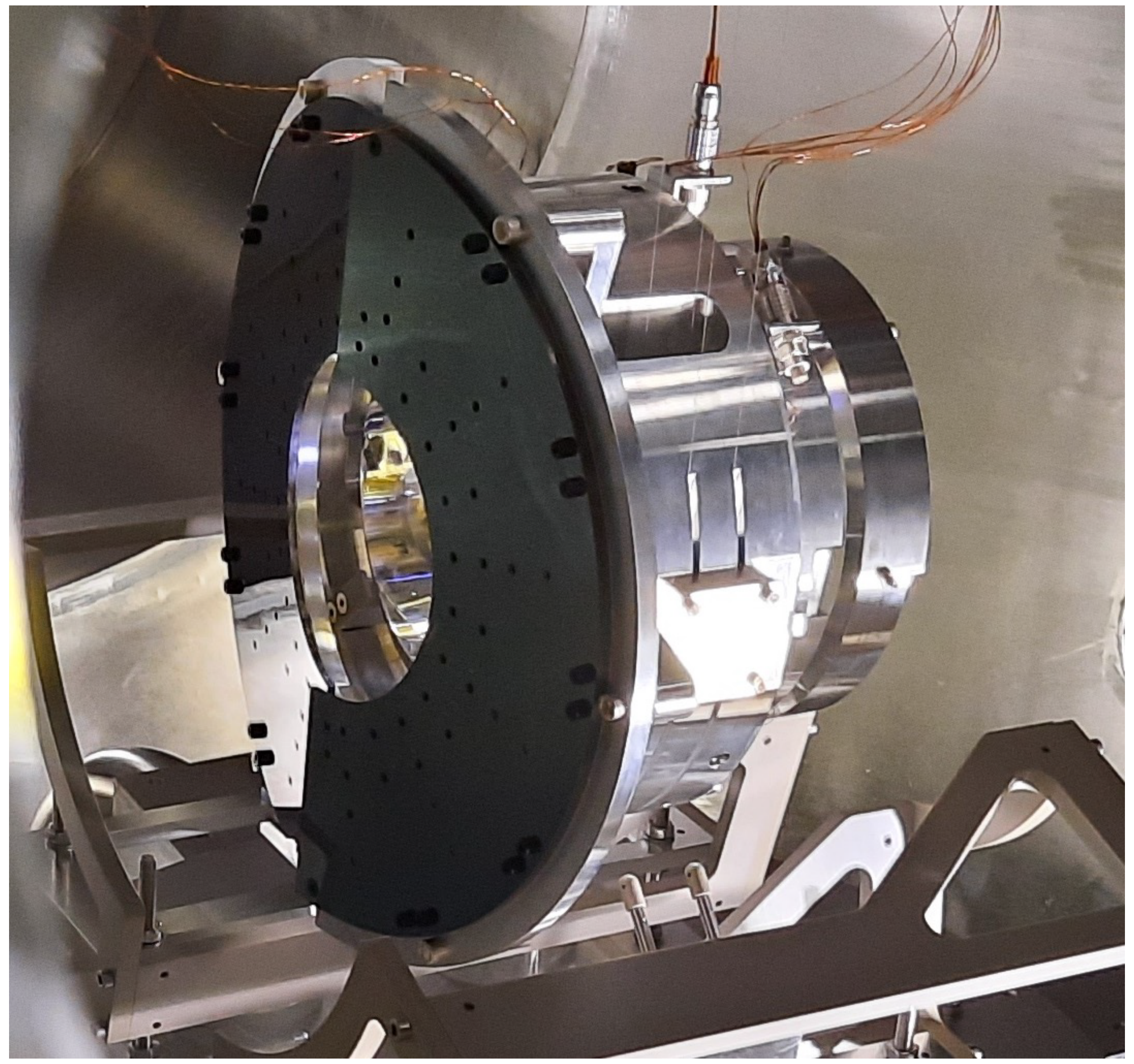
Ongoing simulations to determine light power received by the sensors



Slide from last Nikhef SAC Meeting

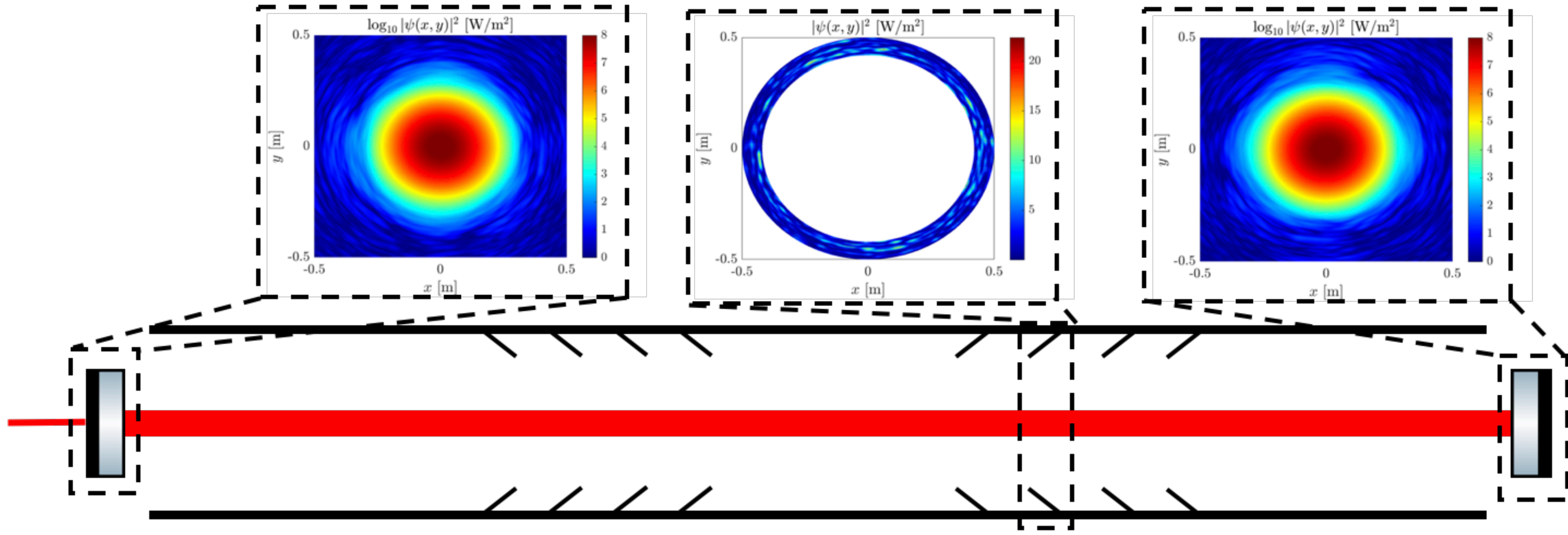


Final notes



- Starting now detailed ET simulation of pre-alignment @ cavity + mirror defects vs signals on baffles as done for AdV+

- We look forward for extending our work in ET to CE —> would justify an extended stay in USA this year (Marc) paid by our EU project.



ET highlight talk by Marc Andrés

- Happy to share our R&D progresses