Advanced Virgo Status report

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Virgo collaboration

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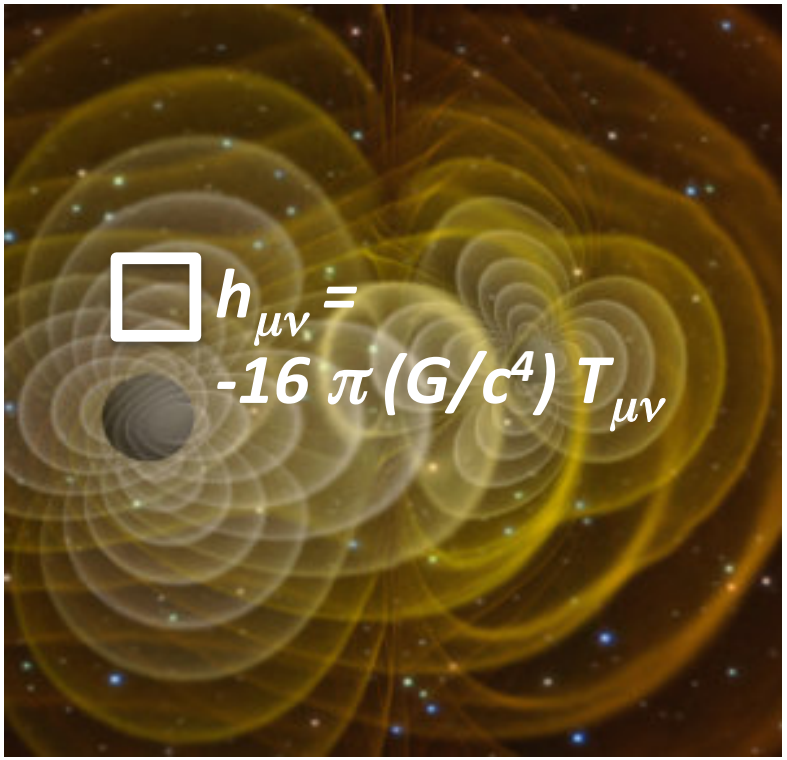


Talk outline

- Advanced Virgo in short and its challenges

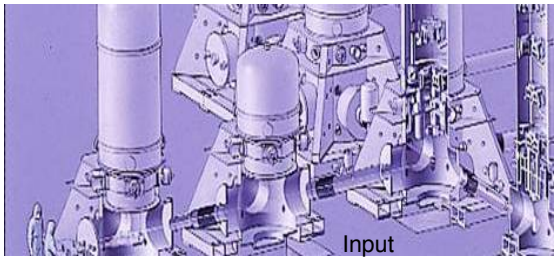
- Advanced Virgo from the construction to the integration phase

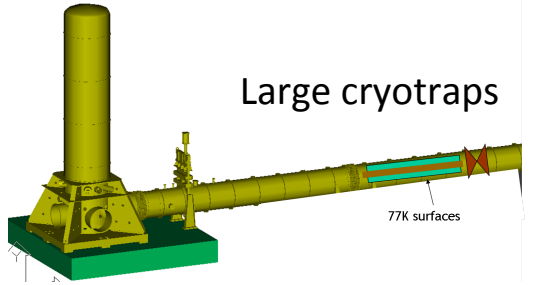
- The planning

- Conclusion

Ad Virgo in a nutshell

Larger central vacuum links





heavier mirrors
(42 kg)

new IP
tilt control

larger beam waist

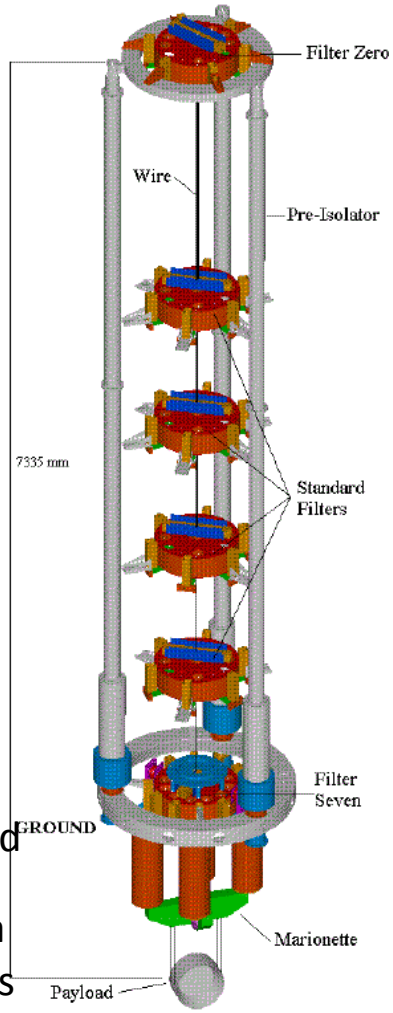
signal recycling

new payload

fused silica
suspensions

high power SSL

DC detection

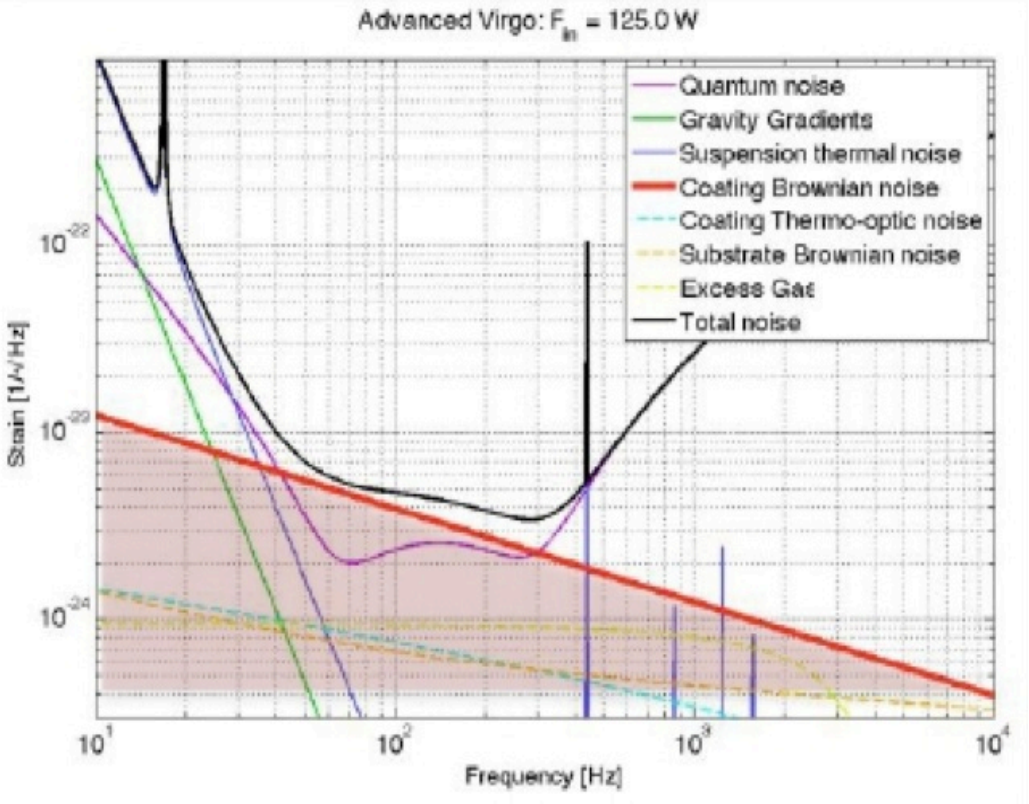


The AdV challenges

- *Mirror coating thermal noise is the dominating noise in the middle frequency range (dissipation dominated by the high refractive index layer)* ➔ Doping Ta_2O_5 with Ti has improved it, but losses are still $O(10^{-4})$

- *Advanced Virgo make use of large light beams (~5cm) on the test masses* ➔ Increase the size of the vacuum links/valves, BS diameter…

- Higher degeneracy of the optical cavity e. m. modes requires proper management of aberrations ➔ *Ultra High Optics quality and highly sophisticated active aberrations control*



Talk outline

- Advanced Virgo in short and its challenges

- Advanced Virgo from the construction to the integration phase

- Project management and planning

- Conclusion

In the middle of the integration phase

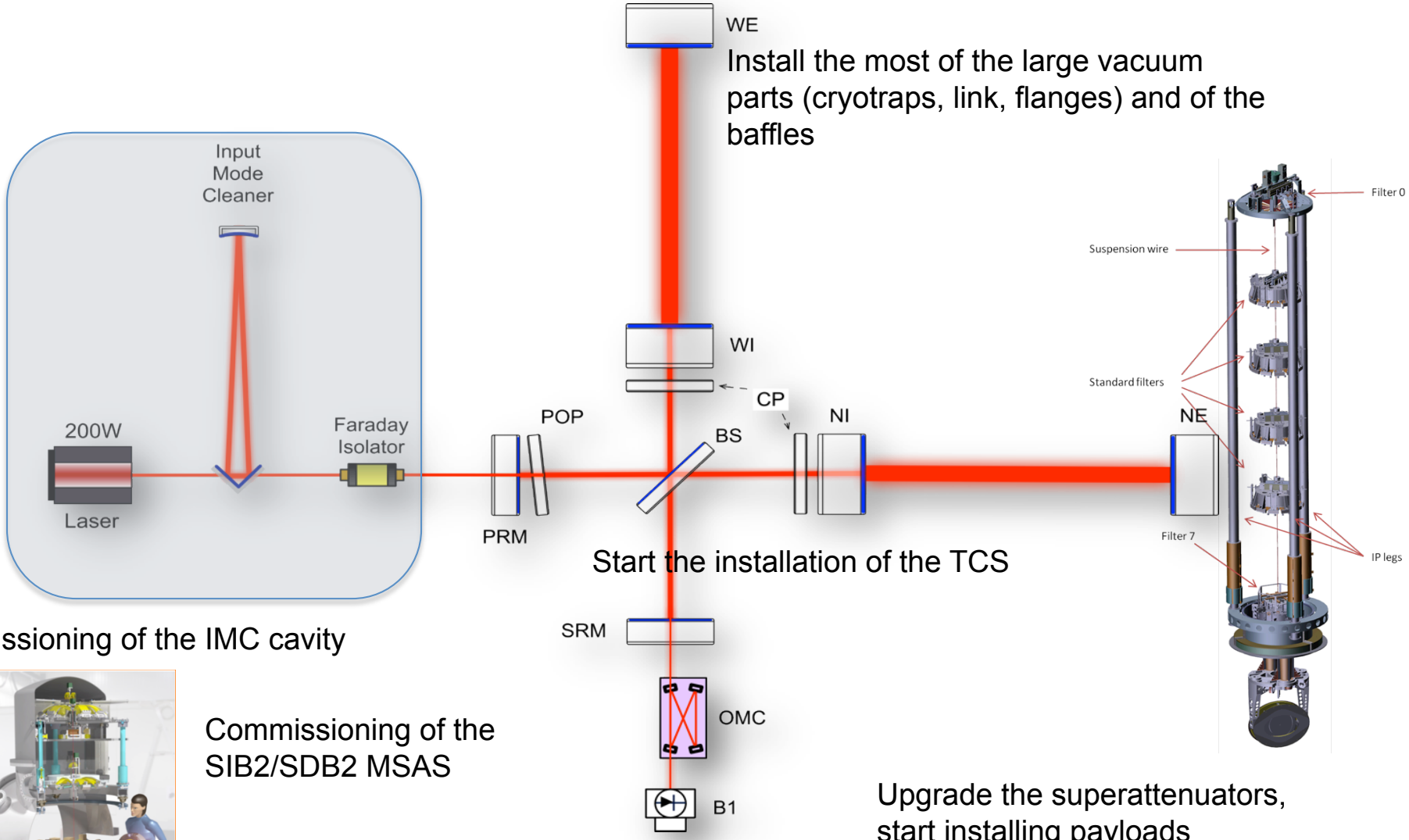
- Respecting this schedule

is a crucial goal

- Top level milestones unchanged
  - commissioning of Inj. Sys. started in 2014
  - construction ends: fall 2015

- Strategy pursued so far:
  - Start with a simplified configuration likely to speed up commissioning (no SR, low power)
  - Organize commissioning early
  - Prevent/solve installation issues through project office coordination of the weekly activities
  - Pursue an intense program of internal reviews to avoid design mistakes and verify SS readiness

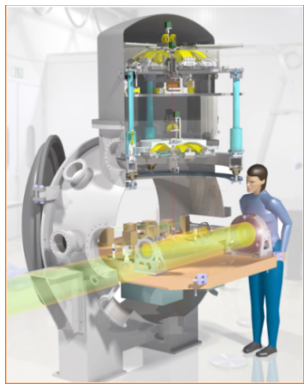
MAIN ON SITE ACTIVITIES



Install the most of the large vacuum parts (cryotraps, link, flanges) and of the baffles

Start the installation of the TCS

Commissioning of the IMC cavity



Commissioning of the SIB2/SDB2 MSAS

Prepare the detection optics

Upgrade the superattenuators, start installing payloads

Present activity on Adv vacuum system

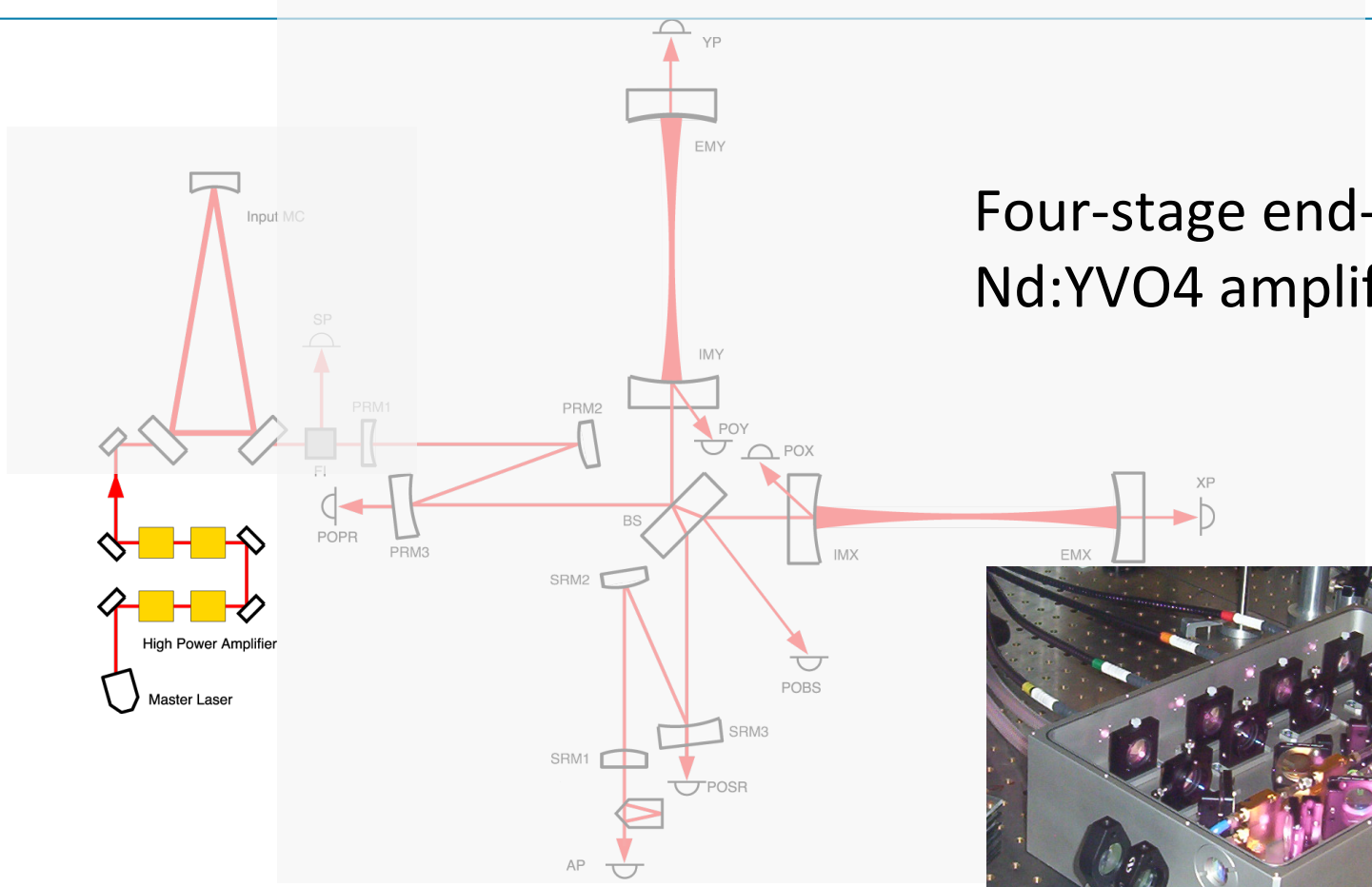
- Two cryotraps already installed at the NE and WE
- West End cryotrap test concluded successfully!
- The small cryotraps have been delivered onsite this week: we decided to provide the liquid nitrogen to these cryotraps also in automatic and we are designing the liquid Nitrogen transfer line in Central Building is well advanced.
- Baffles and related components to be installed in the vacuum links of the central building are onsite. Thus, we are installing these links:
  - PR/BS link installation has been finalized and leak tested OK.
  - the BS-SR link is well advanced
- A complete removal of Central Building towers oven panels has been performed.

Vacuum upgrade

The injection system (INJ) : the laser

60 W Laser already installed on site and in operation

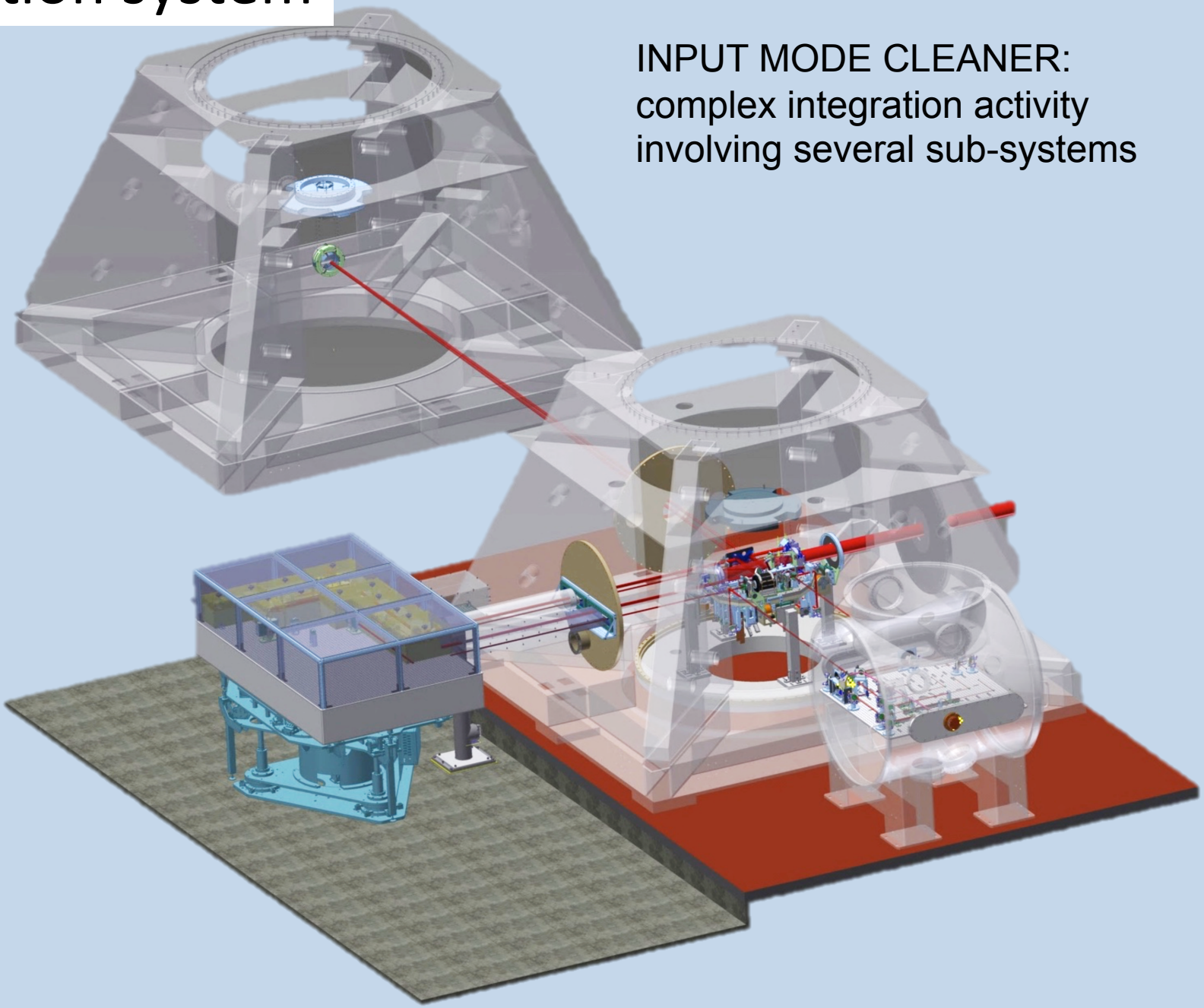
200 W FIBER LASER AMPLIFIER: still under development in France and at LZH



Four-stage end-pumped Nd:YVO4 amplifier

Injection system

INPUT MODE CLEANER:
complex integration activity
involving several sub-systems

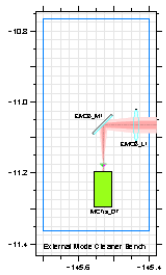


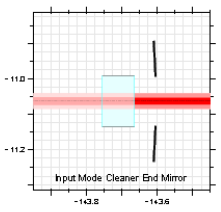
INJ general optical layout

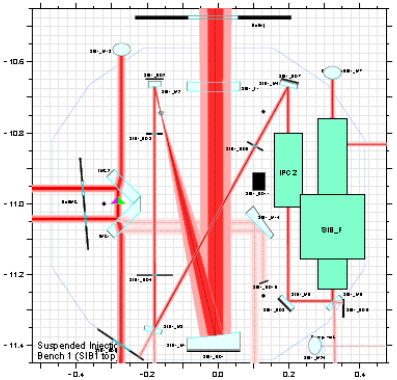
IMC end mirror

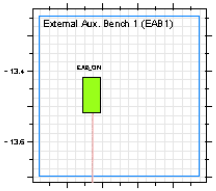
SIB1 (upper part)

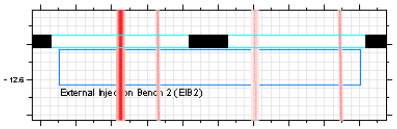
SIB2

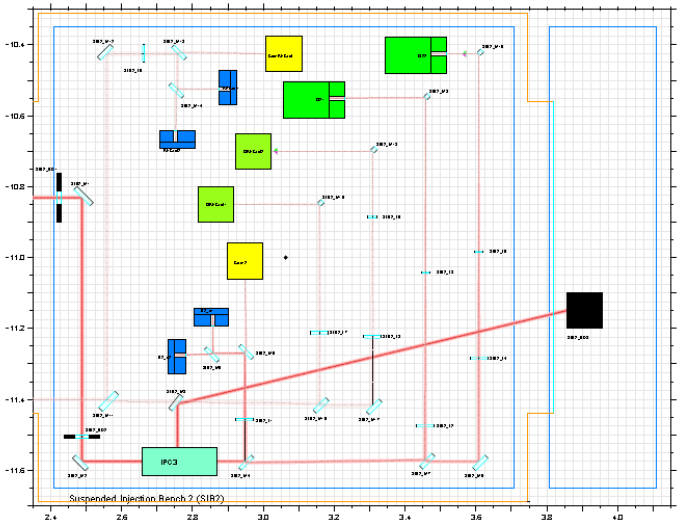


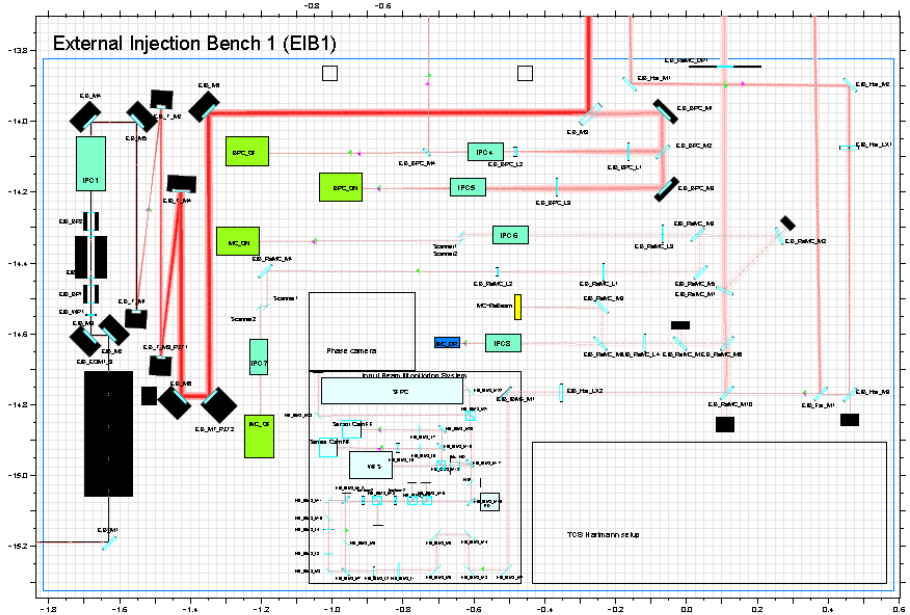


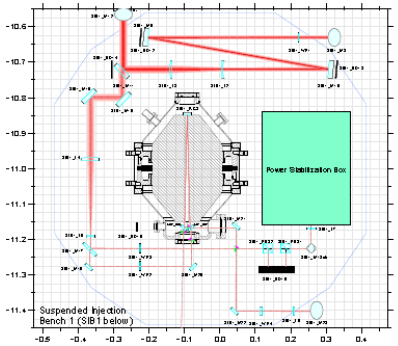




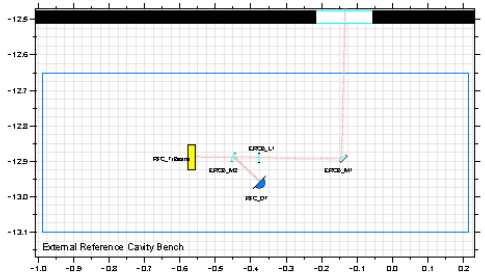






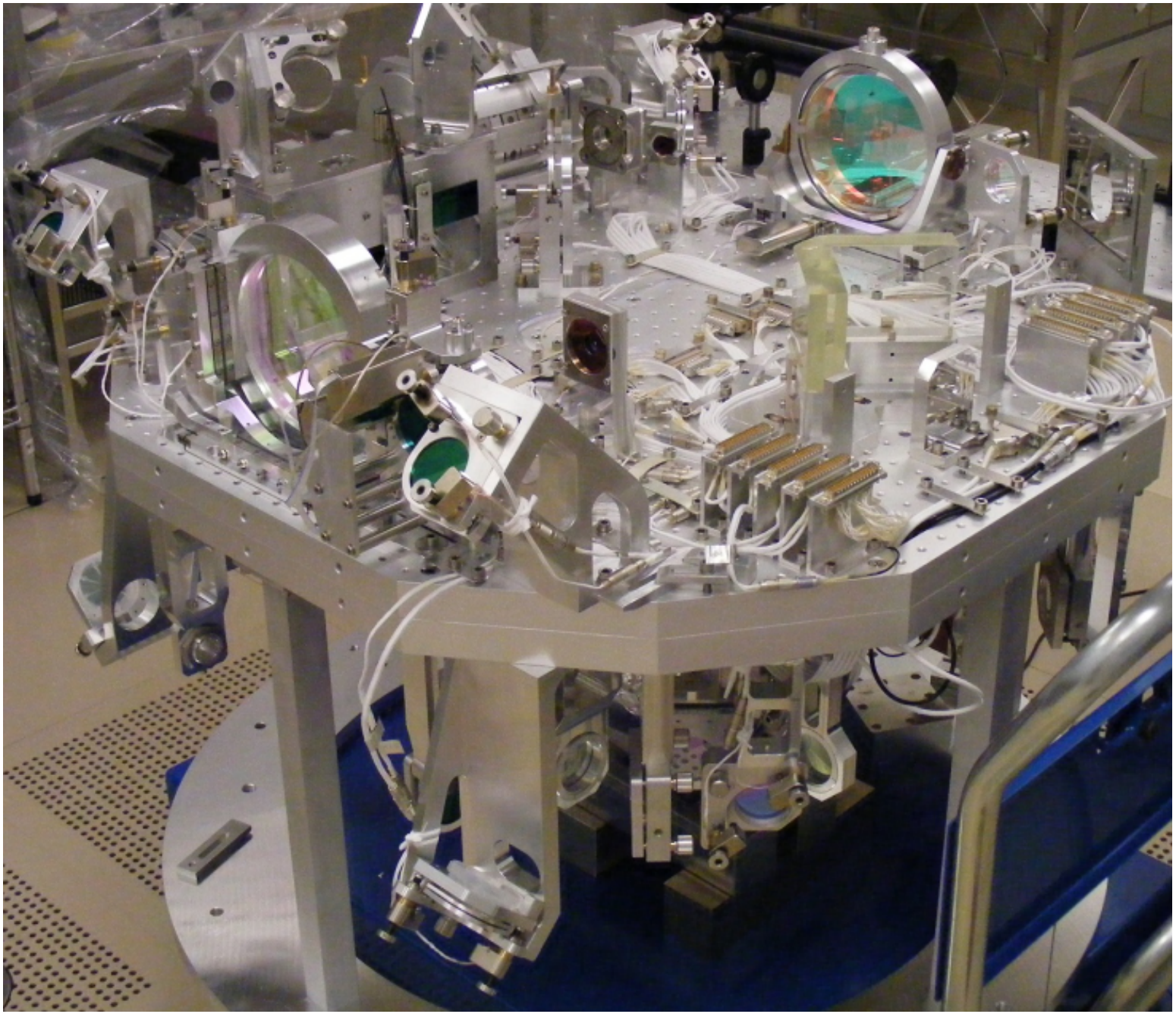


SIB1 (lower part)



SUSPENDED INPUT OPTICS BENCH (SIB1)

The most complex bench: quite small and crowded (Faraday Isolator, Input Mode Cleaner Dihedron, Mode Matching Telescope, Reference Cavity and auxiliary optics), both sides (top and bottom) used to install all the optical components.

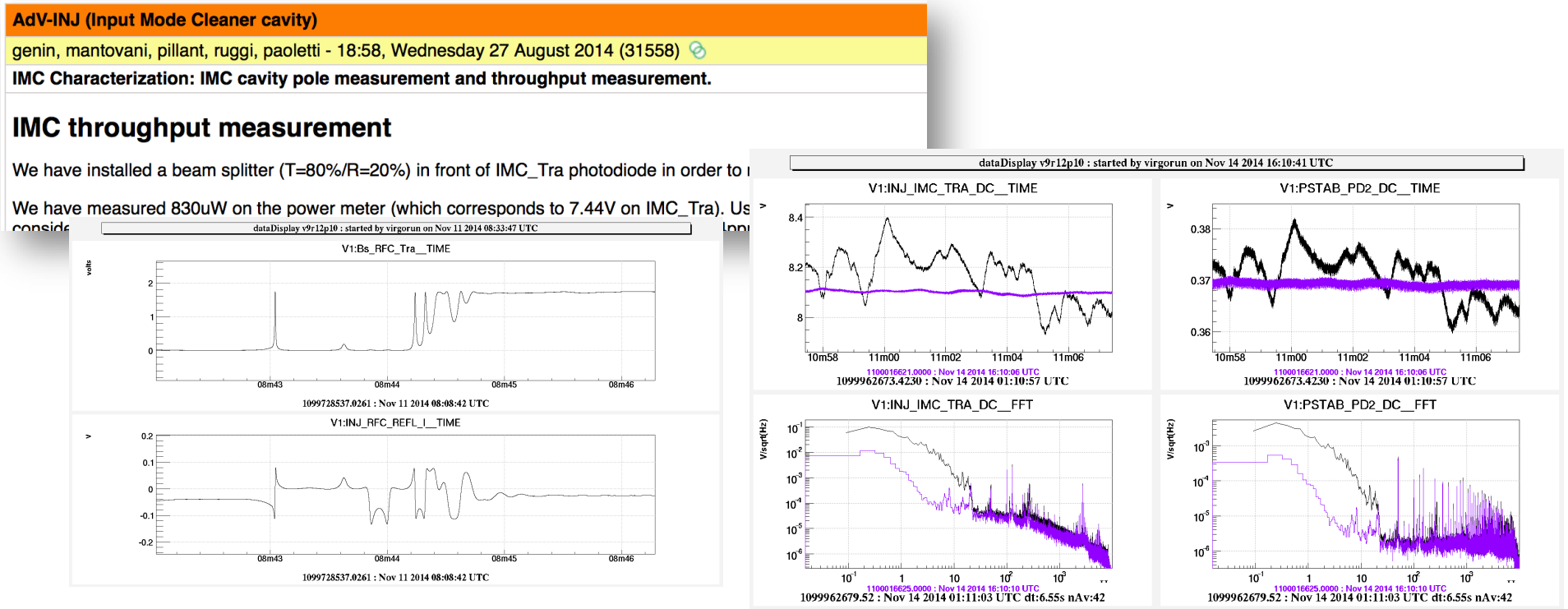


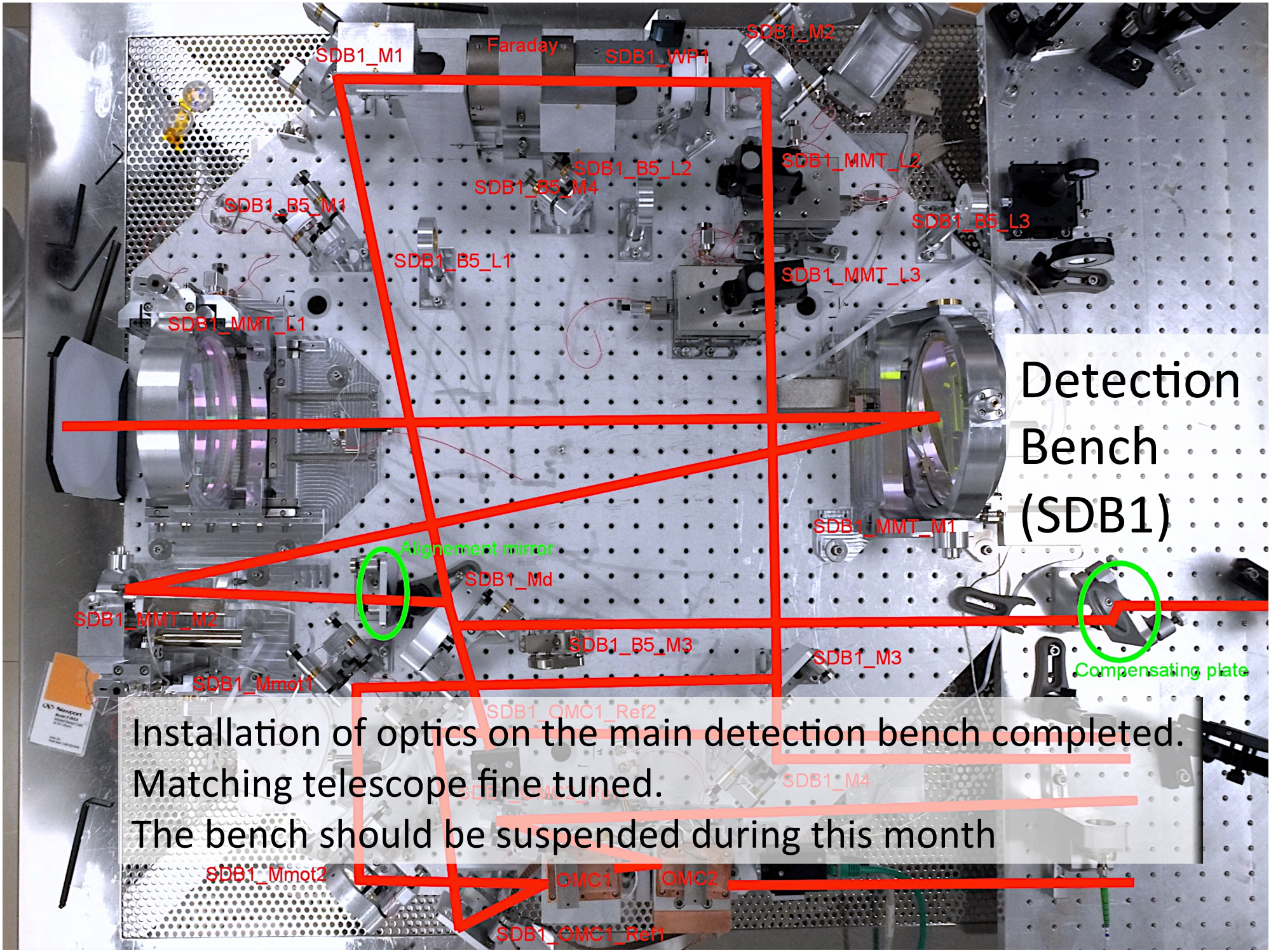
Injection System LOCKED!

- First top level milestone achieved even before the project schedule!

INJ commissioning

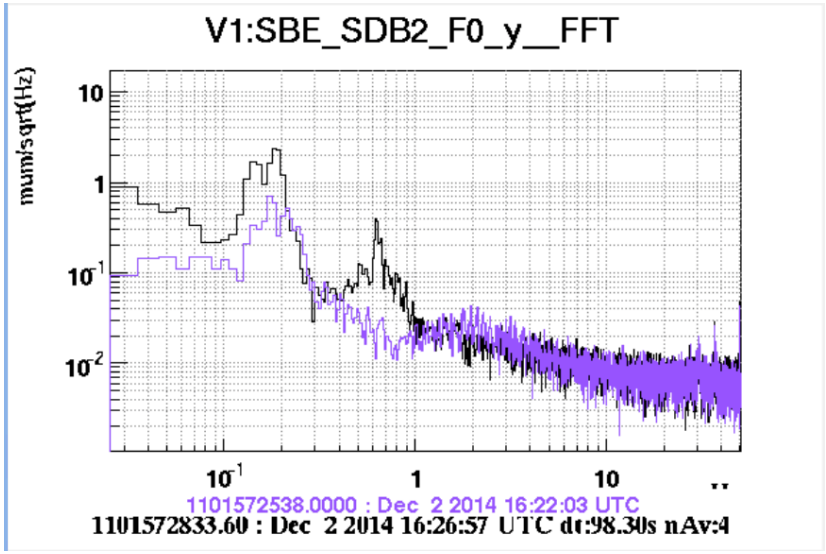
- Commissioning of the INJ in progress.
- At present an effort is on going to improve the stability and spectral features of the ph. signals
- Improve the insulation to em external noise





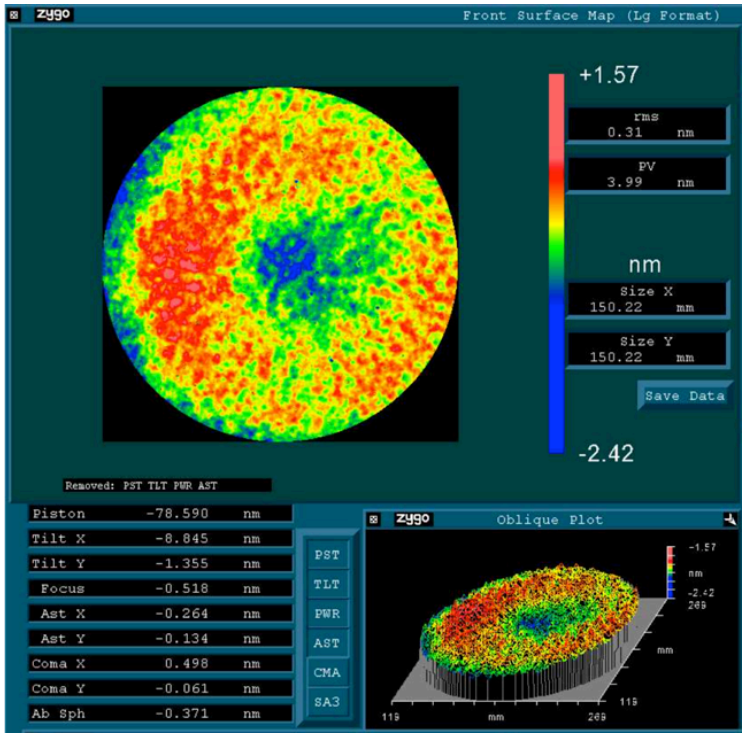
Installation of optics on the main detection bench completed.
Matching telescope fine tuned.
The bench should be suspended during this month

2 MSAS installed (SIB2-SDB2)
Pre-commissioning started.



MIRRORS

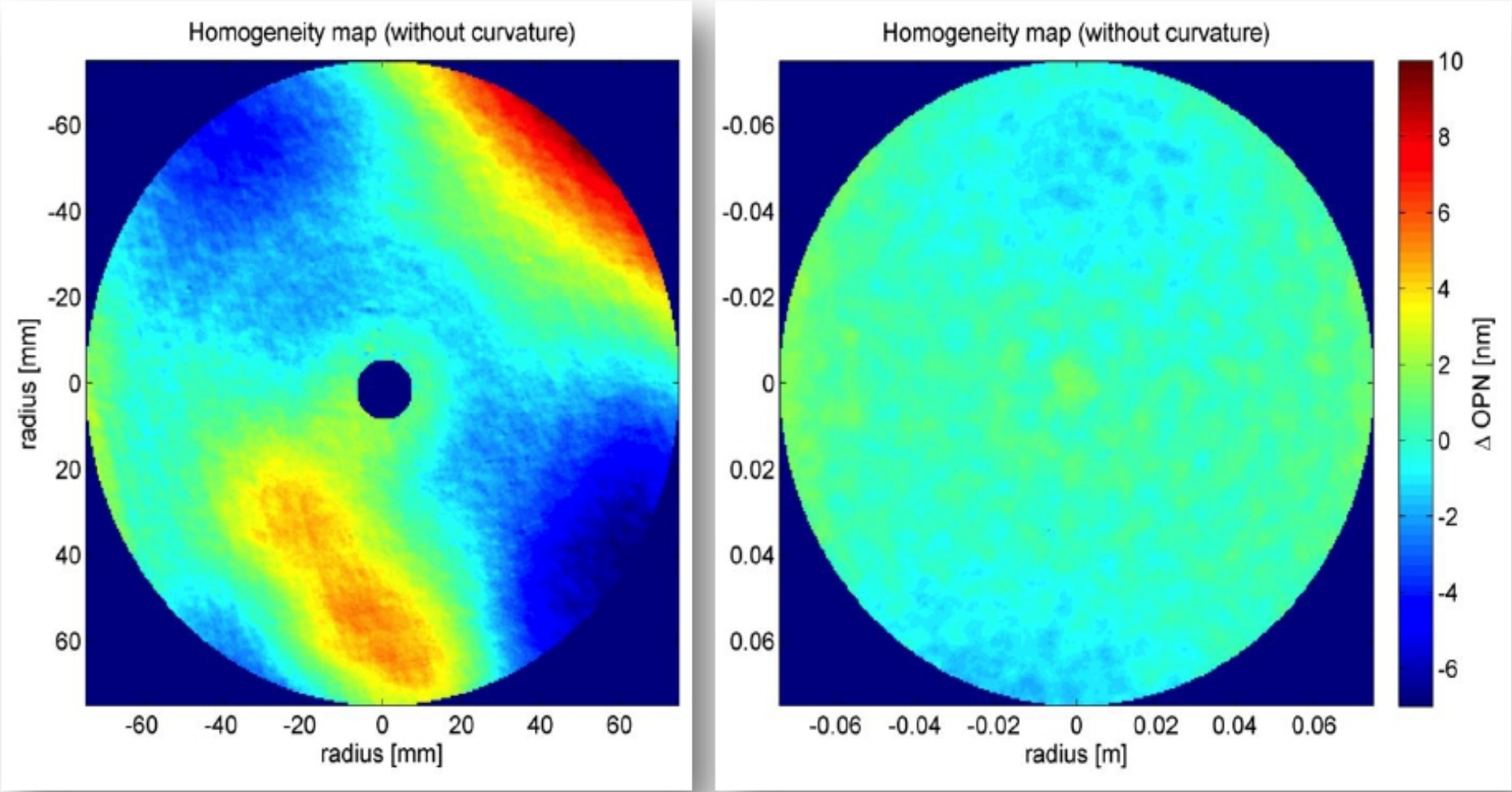
- Mirror figures are better than the specifications
- Risk reduction for aberrations and scattered light
- Using maps into simulations to predict the ITF behavior and anticipate commissioning issues

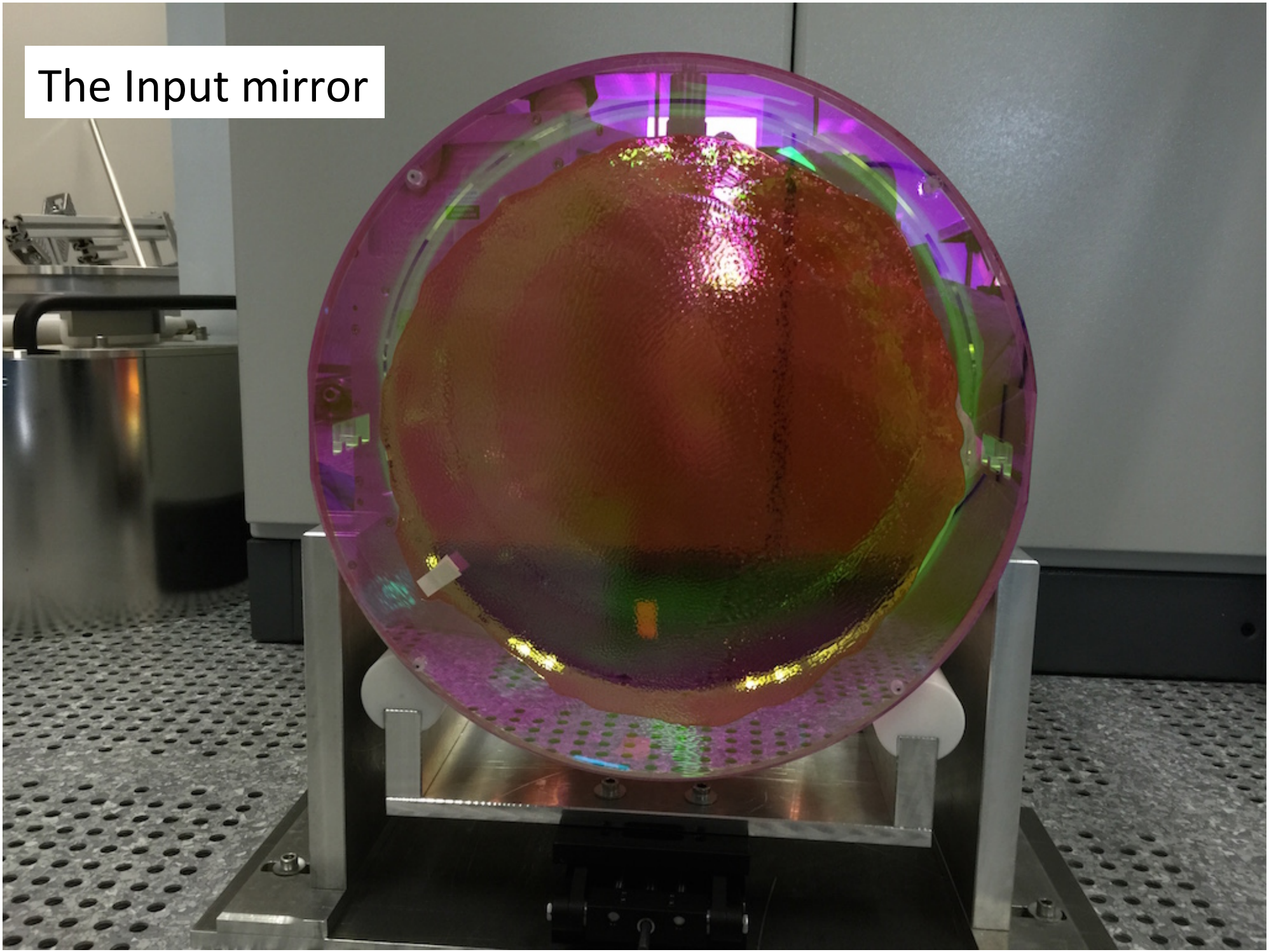


	Advanced VIRGO Requirements	LMA Measurements
Incidence 0°	removed)	∅150 mm
Radius of Curvature (m) Surface 1	1425 +/- 10 m ∅ 150 mm	1424.56 m ∅150 mm
Astigmatism amplitude (Zernike term)°	< 5nm ∅ 150 mm	0.52 nm ∅150 mm
Transmitted wavefront Incidence 0° (before coating)	x	0.77 nm RMS ∅150 mm (Curvature removed)
Average Scattering (45° incidence) Surface 1	< 10 ppm ∅ 150 mm	3 ppm ∅ 150 mm
Absorption HR Surface 1	< 0.5 ppm	0.22 +/- 0.06 ppm ∅150 mm
Transmission at 1064 nm 1° incidence	1.4 +/- 0.1%	1.375 % +/- 0.007% ∅150 mm
Transmission at 532 nm 0° incidence	0.5% < T< 2%	1.01% (witness sample, spectrophotometric measurement)
Reflectivity AR Surface 2 at 1064 nm 3° incidence	<100 ppm	58 +/- 9 ppm ∅ 150mm
Reflectivity AR Surface 2 at 800 nm 0° incidence	<1%	# 0.1% (witness sample, spectrophotometric measurement)
Reflectivity AR Surface 2 at 532 nm 0° incidence	<2%	# 0.2% (witness sample, spectrophotometric measurement)

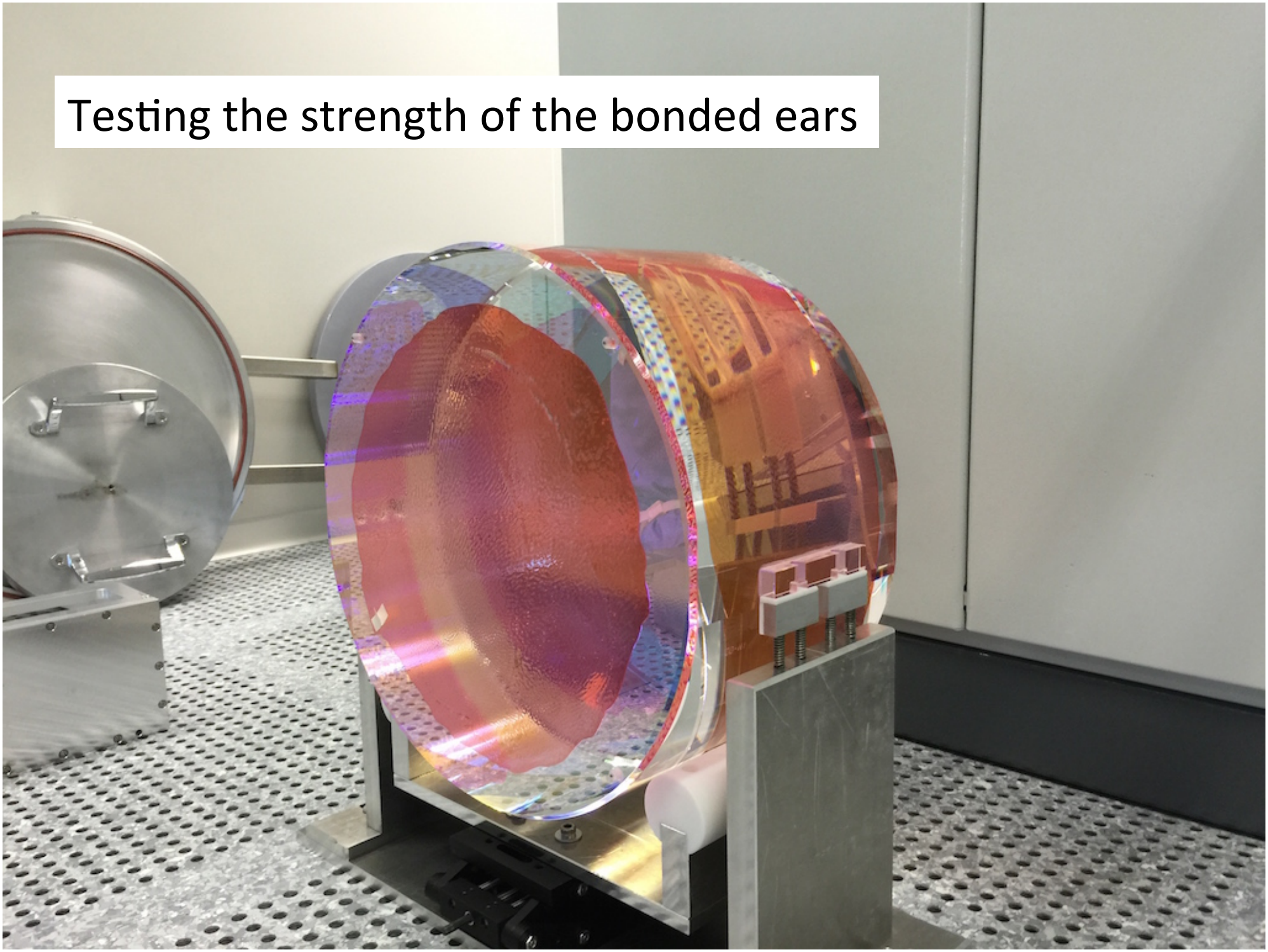
INHOMOGENEITY COMPENSATION

Current polishing technology allows to compensate the variations of the optical path length from point to point



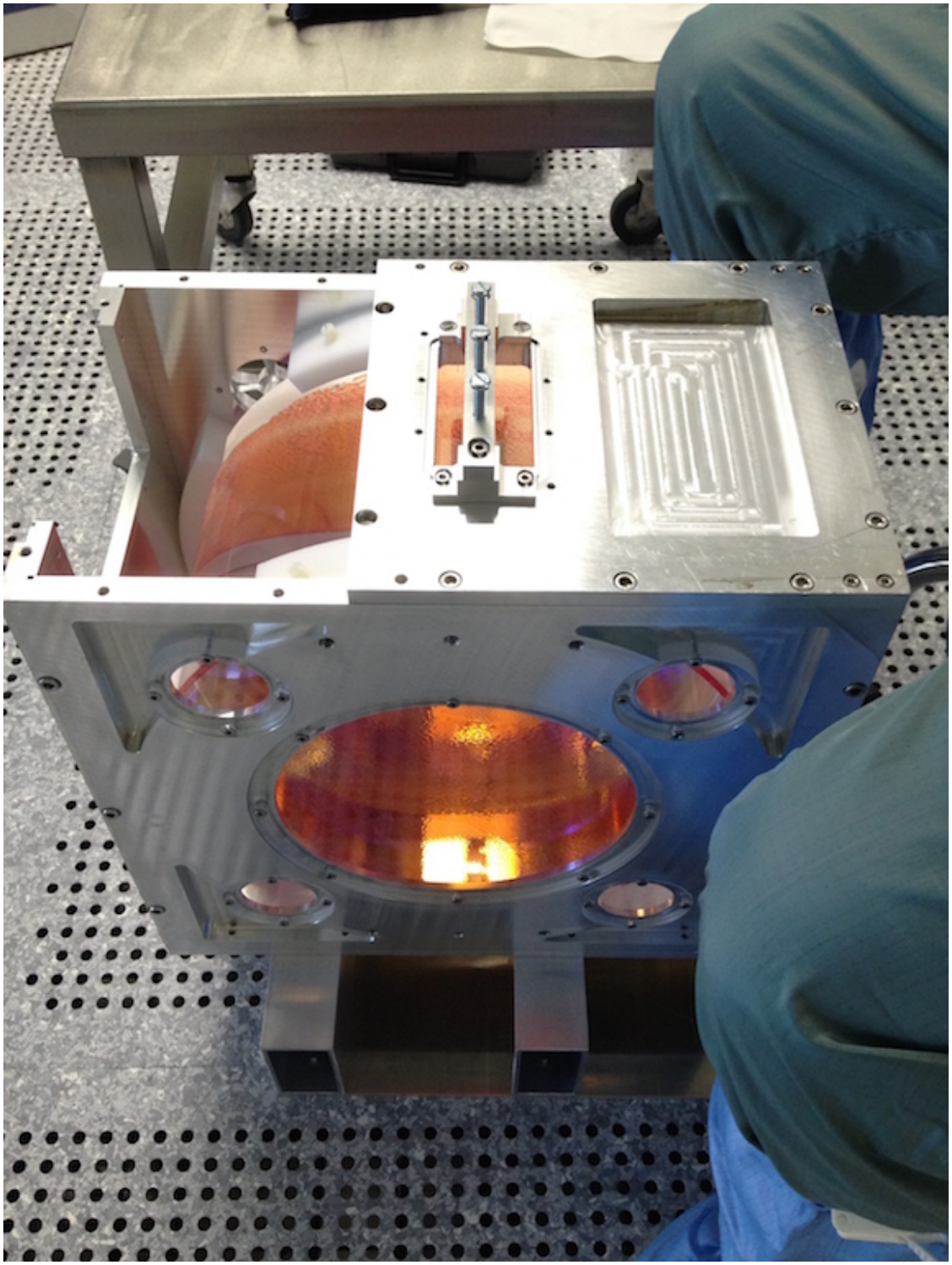

The Input mirror

Attacching the SiO_2 ears
to the lateral surfaces
of the mirror
applying the silica bonding technique


Testing the strength of the bonded ears

The mirror set in the transportation box.

The same metallic box is used in the final assembly phase in the payload infrastructure



The Payloads

Beam Splitter Payload:

Assembly and integration in the final position completed December 2014.

Input Payloads:

First Input Payload used for monolithic suspension integration tests (completed).
Second Input Payload parts in production: on site for first tests of magnetic compatibility on February.

End Payloads:

Construction started at the beginning of January.

Power Recycling Payloads:

Marionette ready, Cage in production.

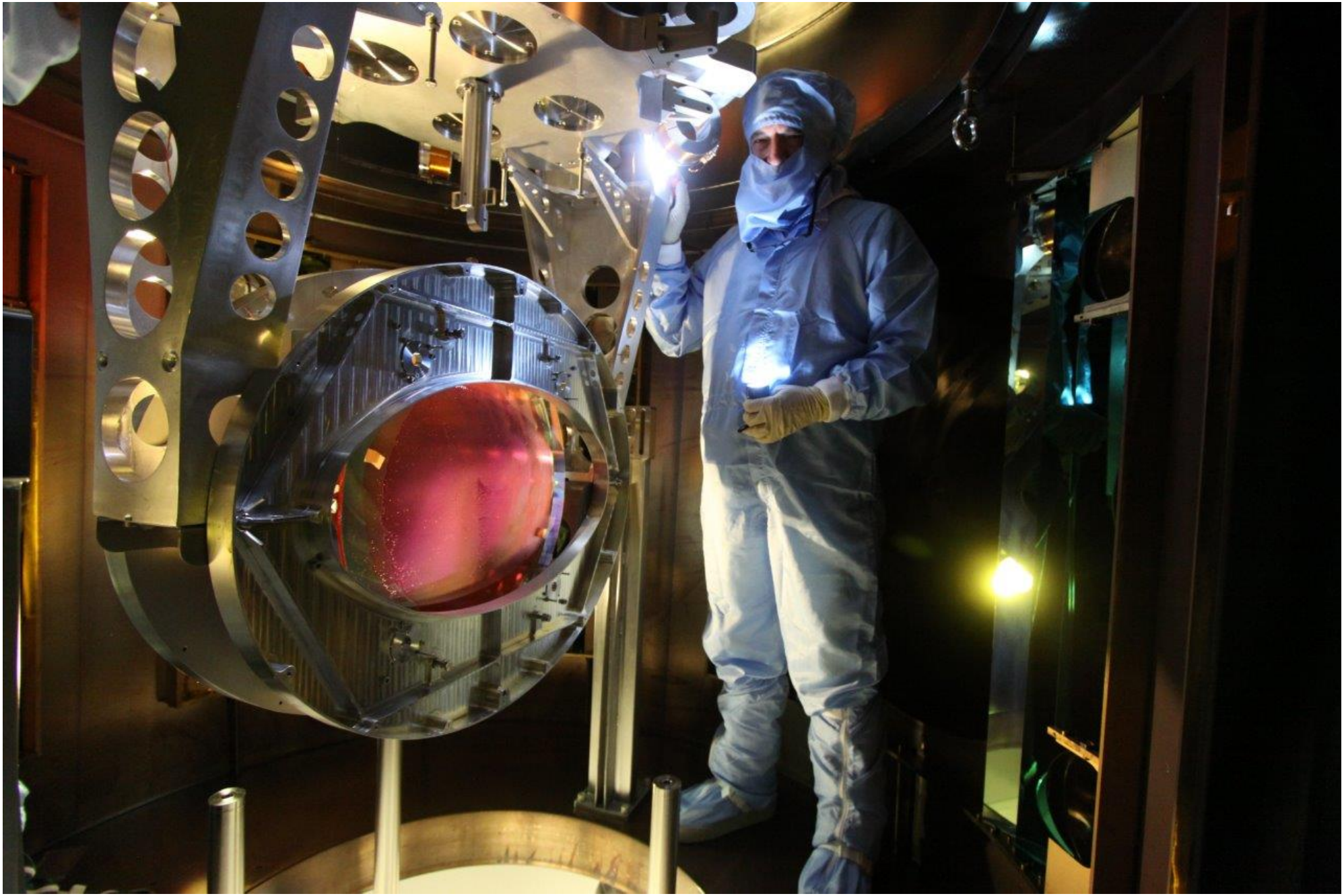
Signal Recycling:

Marionette ready, Cage in production.

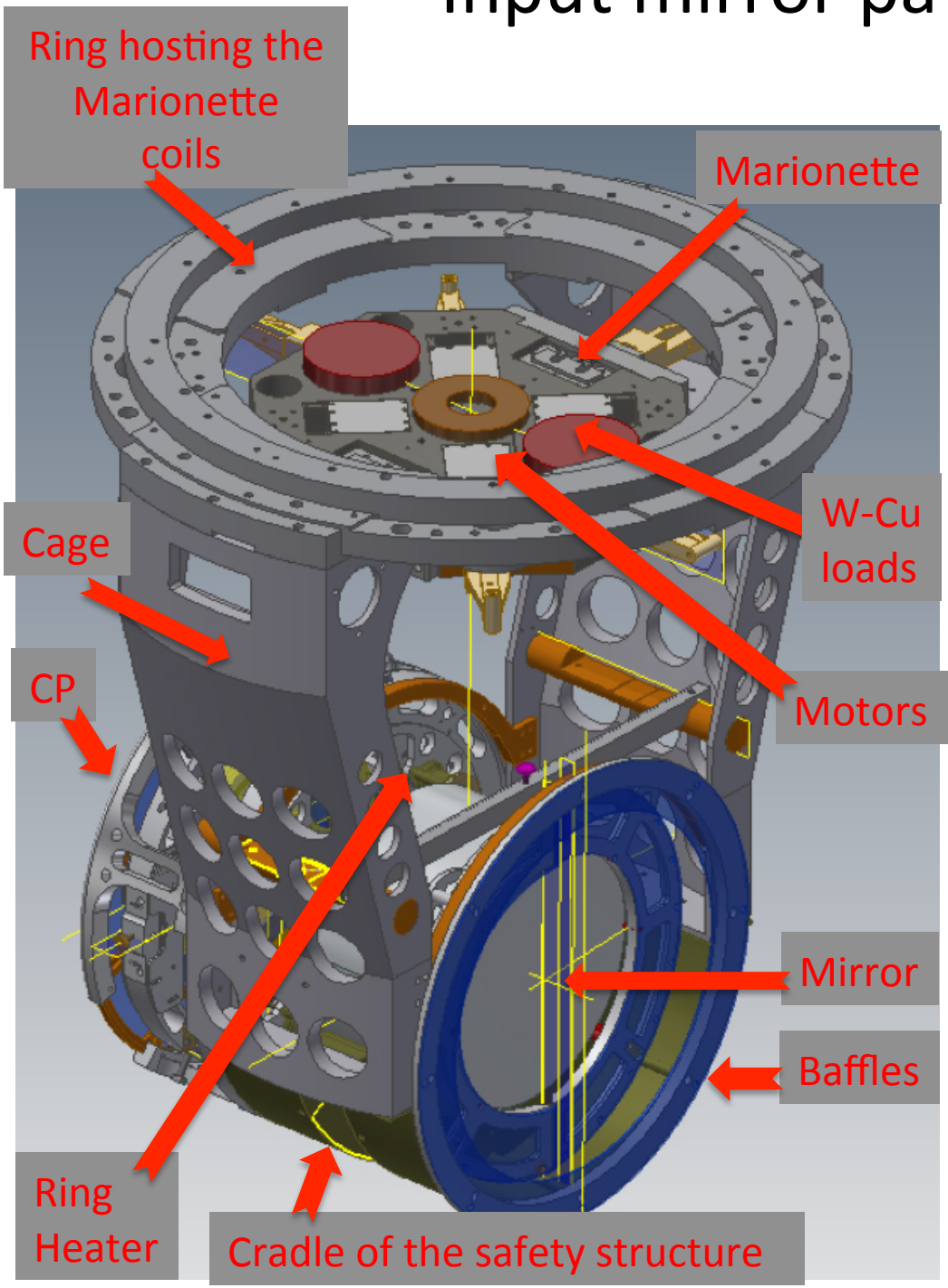
PAY Test Facility:

Infrastructure work completed

The beam splitter

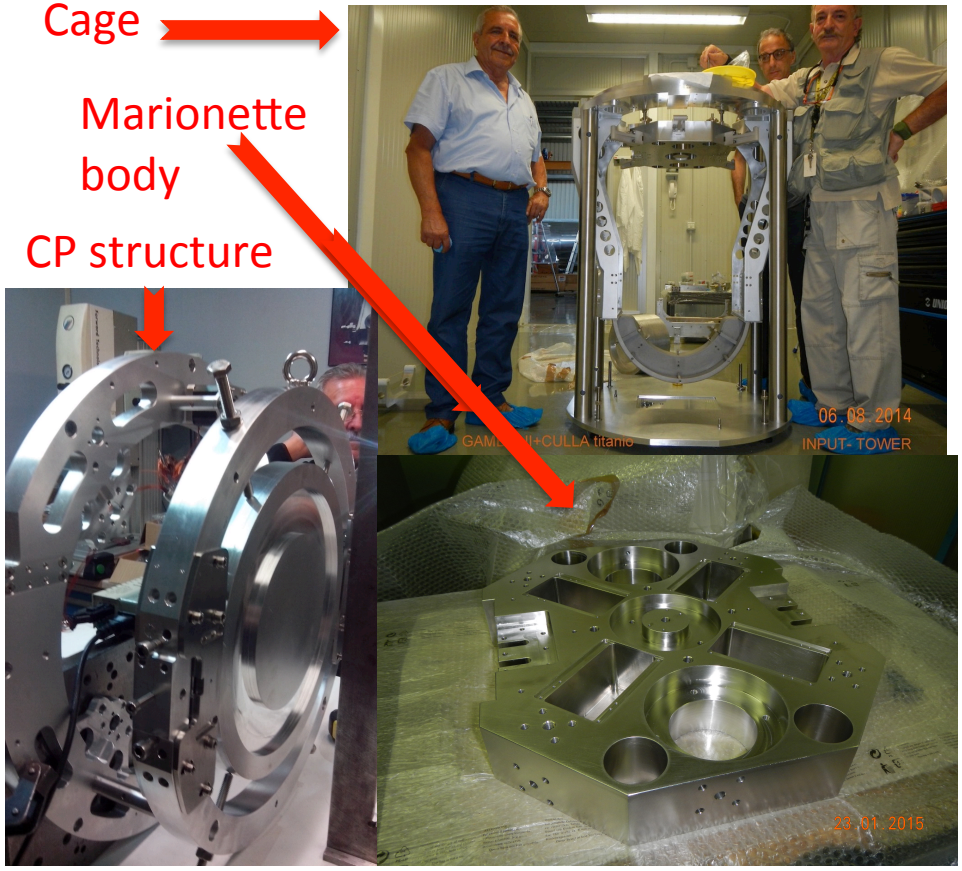


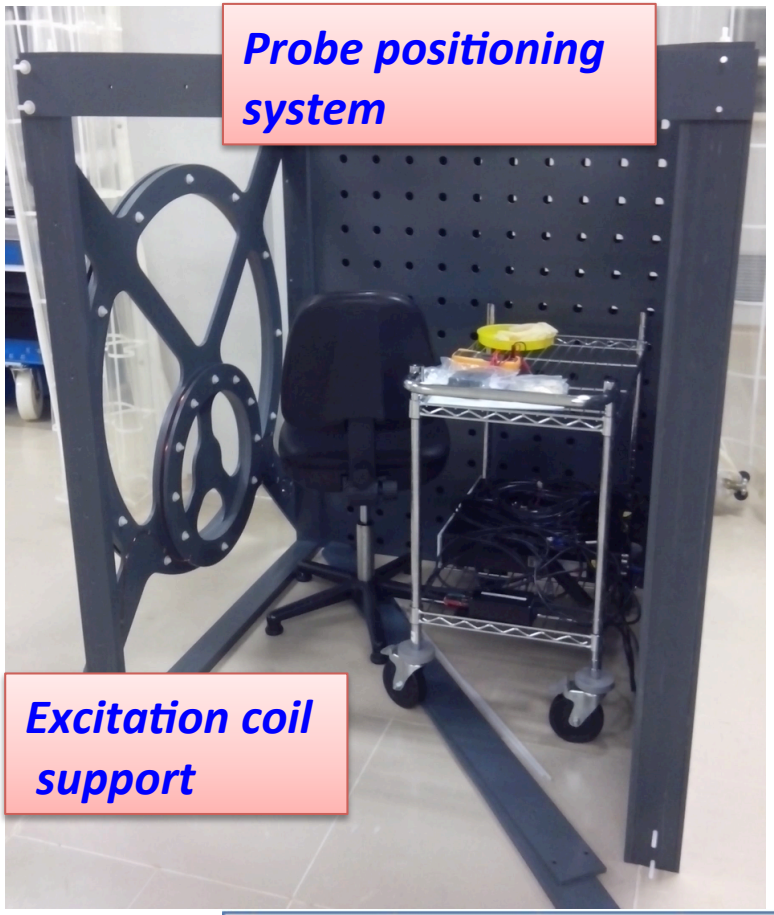
Input mirror payloads



The cage is suspended to the last filter of the super attenuator
It includes

- The TCS compensation plate
- the Ring heater for the mirror radius of curvature
- the baffles for killing the stray light

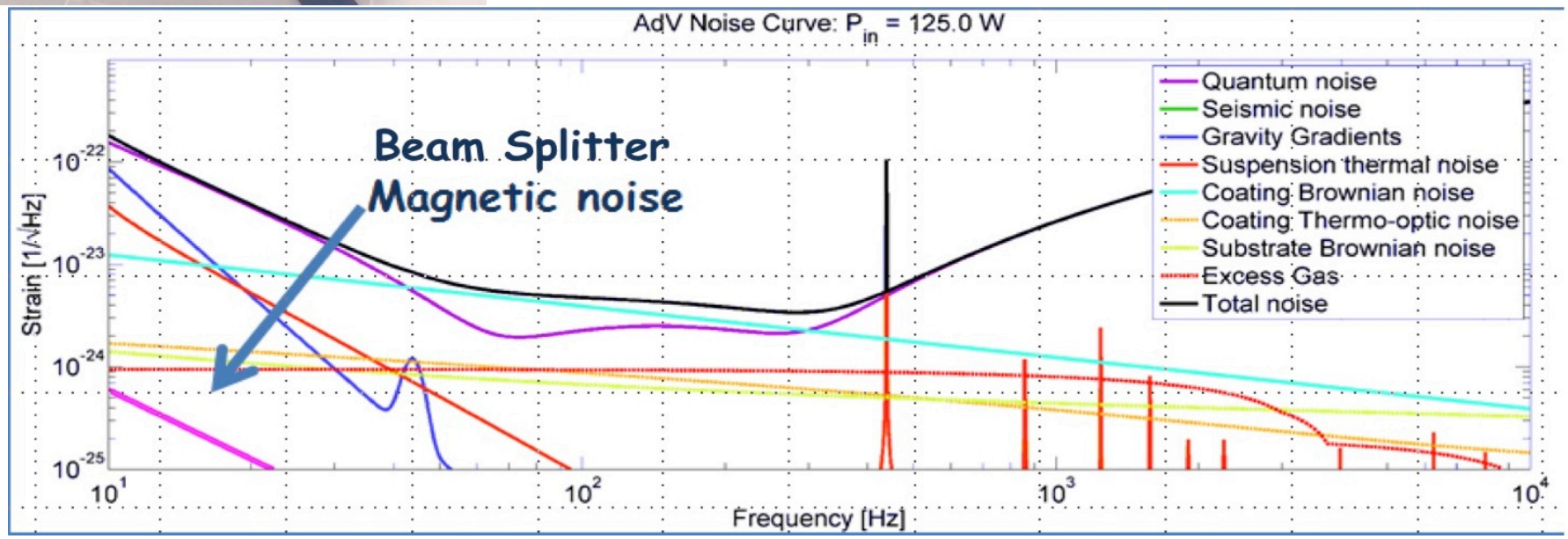




Payload Magnetic Test

***The structure of the magnetic field**, in presence of the payload, is measured in several relevant points of the space with a magnetic probe. The results are compared with those of a simulation where a FEM magnetic model of the BS payload is embedded to the same field*

- A magnetic noise facility has been assembled in the clean room under the towers in the Virgo central building
- The background magnetic field in the testing zone has been measured.
- Measurement procedure tetesd on the beam splitter payload



The vacuum chamber for testing the acoustic dissipation of the payloads suspended with the monolithic silica fibers

SUPERATTENUATORS

Bench Suspensions

The upgrade activities around the three short suspensions (MC, INJ and DET) is almost concluded.

On each Super attenuator:

- ✓ a standard seismic filter has been added in the multistage pendulum chain to improve passive filtering performance;
- ✓ a few triangular cantilever blades have been added and/or changed on mechanical filters to support the increased load;
- ✓ the suspension wires have been replaced by new ones due to different distance between two consecutive filters;
- ✓ a better tuning of the IP, moving the cut-off frequency of the pre-attenuation stage below 90 mHz (65 mHz for MC and INJ), has been done. [Only the IP flex joints of INJ suspension have been increased in diameter];
- ✓ the three IP feet have been equipped with PZT actuators and LVDT sensors to control ground tilt;
- ✓ cabling vacuum side.

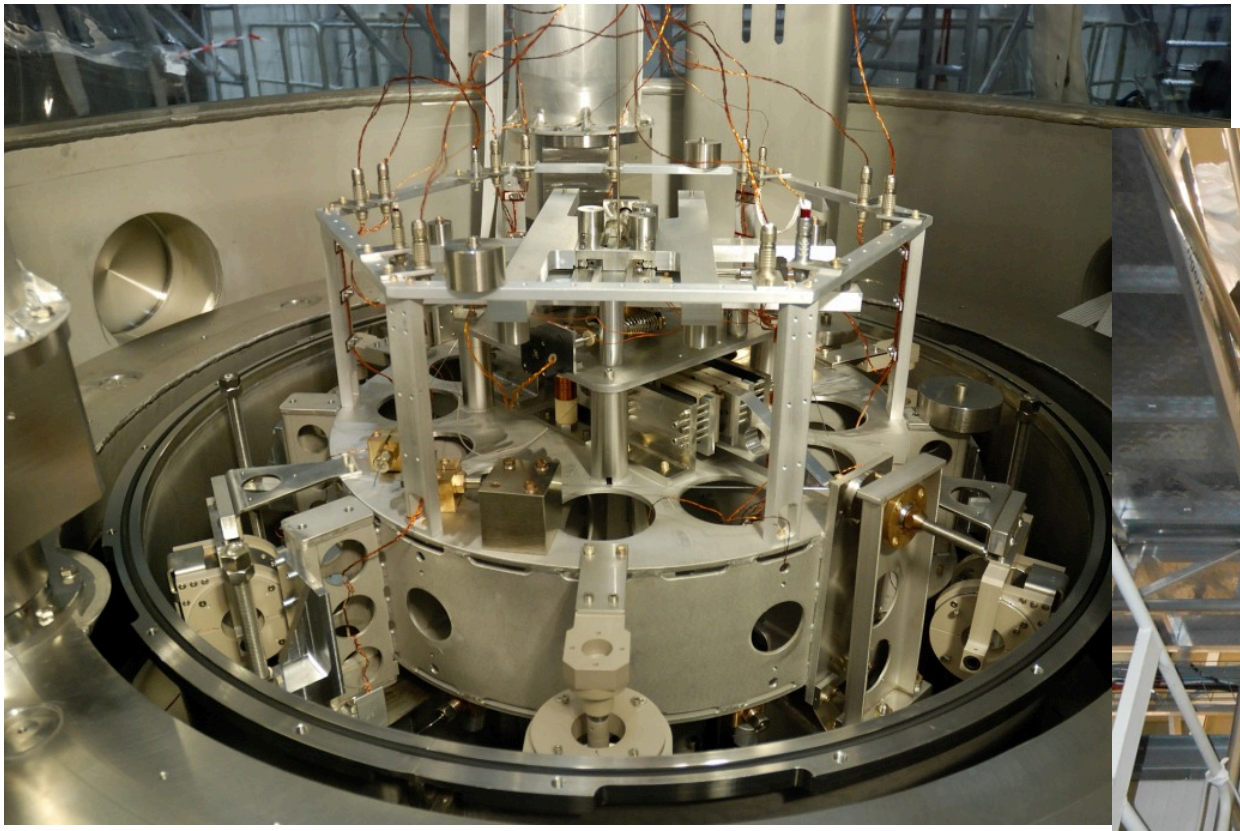
Suspensions for the suspended optical elements

The upgrade activities on long SA are focused on the last stage suspension (the F7) and in the region nearby, due to the new payload geometry.

On the long SA will have:

- ✓ new F7 – one model for BS, PR and SR and a second model for the suspension along the F-P cavities;
- ✓ new distribution of seismic filters along the chain;
- ✓ monitoring system surrounding F7 body for feedback control purpose;
- ✓ IP with monolithic legs (same diameter as in VIRGO);
- ✓ PZT and LVDT installation on IP feet;
- ✓ new IVC with a "cover cake" covering F7.

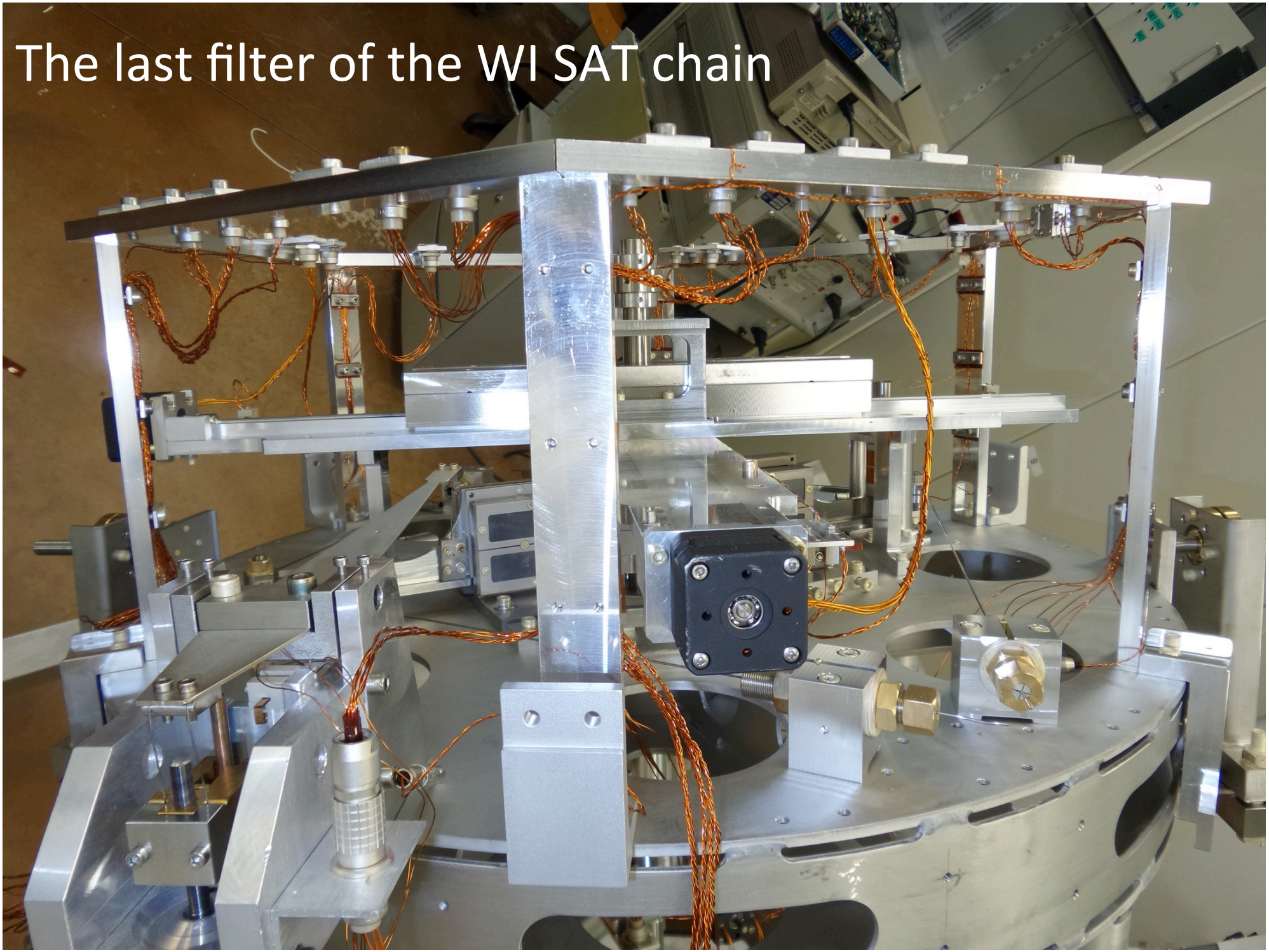
Beam Splitter Suspension



The last SAT filter of the BS chain in place surrounded by its monitoring system

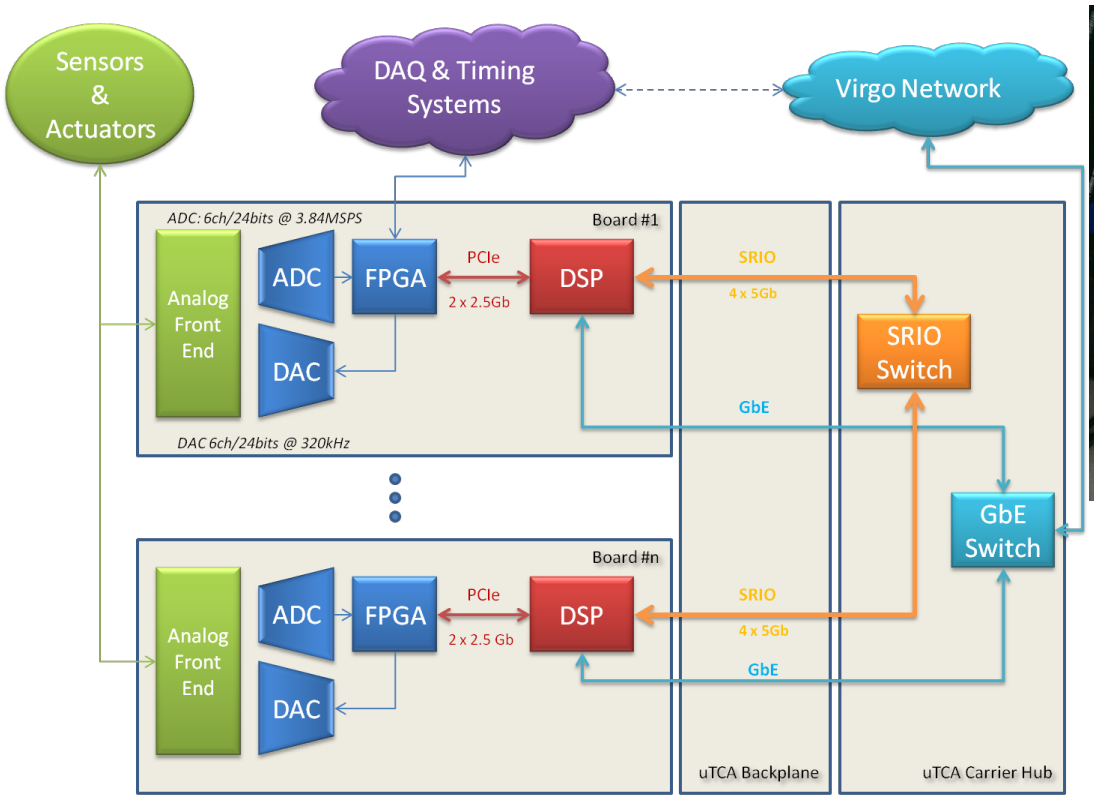
The last SAT filter of the BS chain during the installation

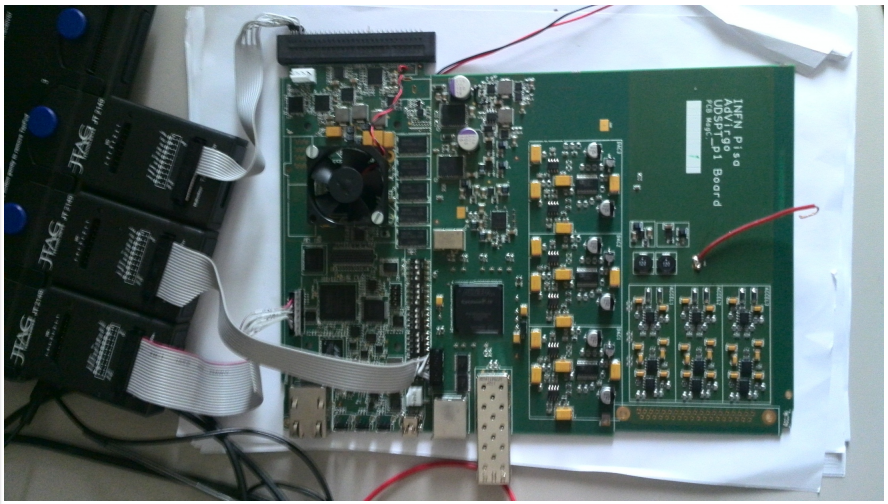
The last filter of the WI SAT chain



SAT status

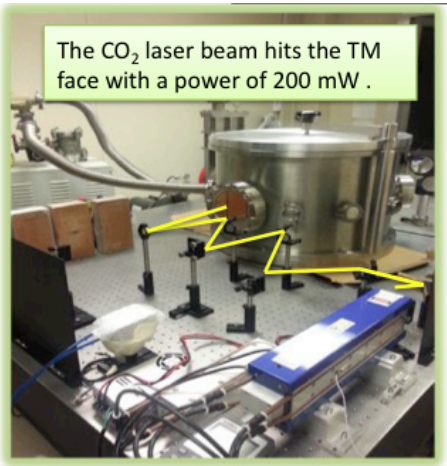
- Beam Splitter assembled and the pre-commissioning is started.
- West Input mirror upgrade for of the last SAT filter and payload test to be completed in January.
- Detection bench upgrade for bench installation on the way; integration foreseen by first week of February.
- SAT control electronics: first final set of the SAT control boards delivered at the end of February.

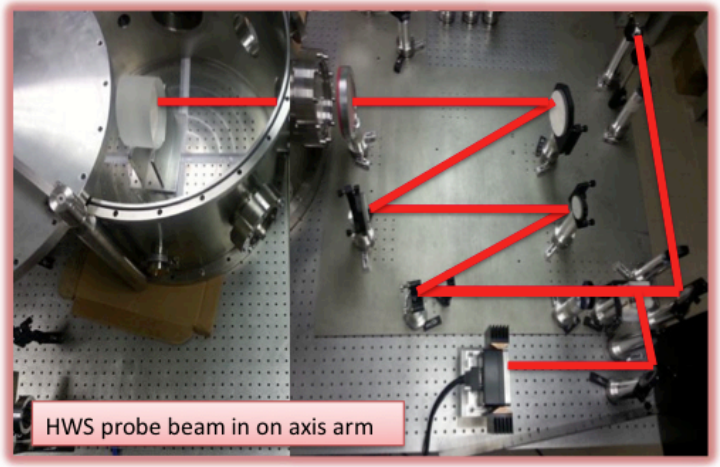


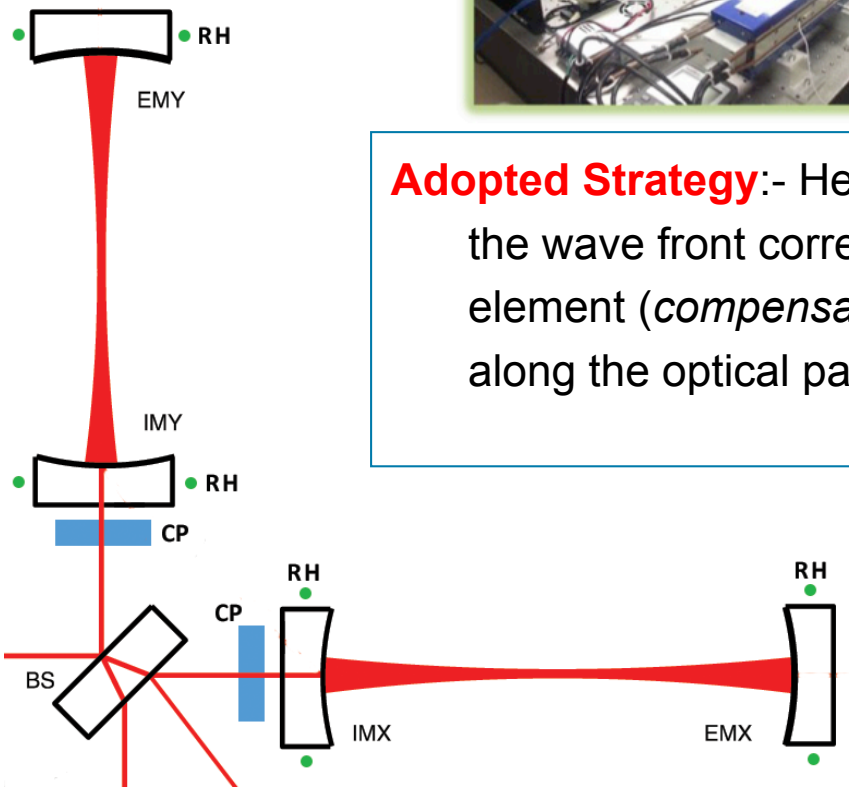


Board prototypes (4 pcs – 24 inputs / 24 outputs) produced last August and today under intensive test

Thermal Compensation System







Adopted Strategy:- Heating ring around the test masses +CO_2 laser for the wave front correction of the power recycling mirror + extra optical element (*compensation plate*) suspended to the payload cage set along the optical path and in front of the input test masses

Preparative works including lasers cooling circuits for the TCS bench assembly isstarted.

- 50W CO2 laser has been switched on for the first time here onsite. A rough alignment with a visible laser has also been performed.
- The Ring heater mounting in CB ISO3 clean rooms has started.

A glance beyond AdV Virgo

- We started to study how to implement an AdV squeezing bench

  - R&D and training activities spread in various Virgo labs

New manpower joined VIRGO to support this development, thanks also to the Marie-Curie and Miur–PPPS- PRIN 2012 fellows

A technical design report is in preparation:
Task 1: Infrared injection system and stabilization and Phase locking to the other systems (Padova/Napoli)
•Task 2: Second harmonic production and stabilization (Padova?Napoli)
•Task 3: Cavity squeezing (TorVergata/LKB)
•Task 4: Homodyne detection: electronics (Roma1) and optical test (Perugia/Camerino/Roma/)
•Task5: Filter cavities (LAL/LKB)

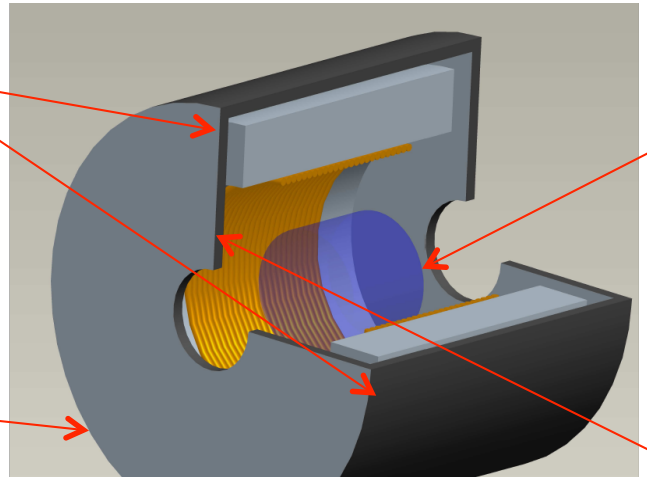
EGO will host the future integration phase @Cascina

Some of the R&D and training efforts in the Virgo labs

Tn/Pd :
Faraday
Isolator

Permanent magnet:
Samario-Cobalto alloy
Field **1.12T**
:**Vacuum Schmelze (VACOMAX 240 HR)**

µ-metal: **Fe-Co (Vanadium impurities)**
Field : **2.35T**
Vacuum Schmelze (VACOFLUX 50)

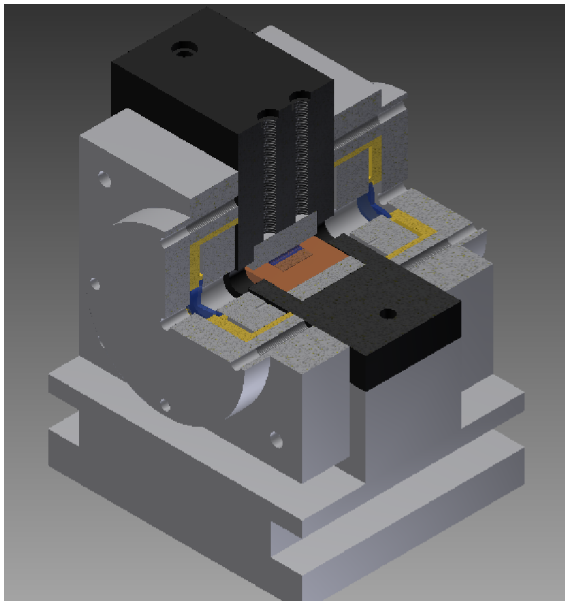


Crystal: **TGG (Tb3Ga3O12)**
Ø: **25.4mm**
h: **20mm**
Northrop Grumman Corporation

Corrective coli of the magnetic field

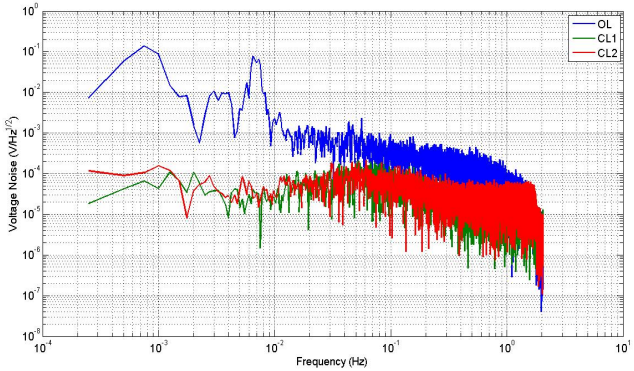
Roma- Tov

Concentric cavity
Design compromise between the need to minimize the air gap and maximize the cavity stability



Napoli

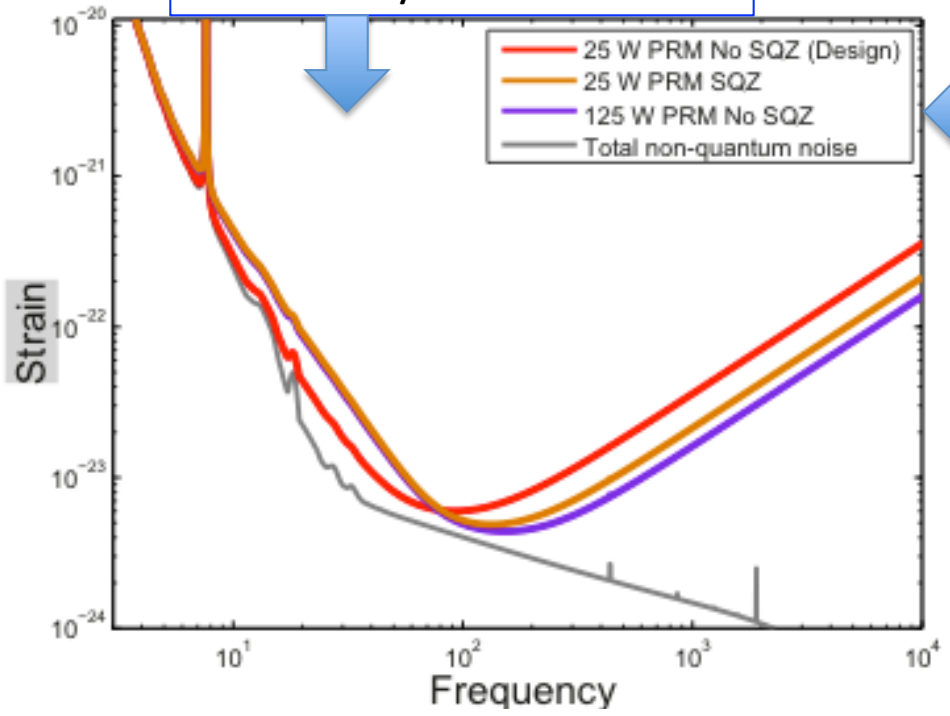
Laser amplitude control



Auxiliary clean room for the payload test:
it can be used also for the squeezing bench development

AdV with and without Squeez.: ***preliminary***

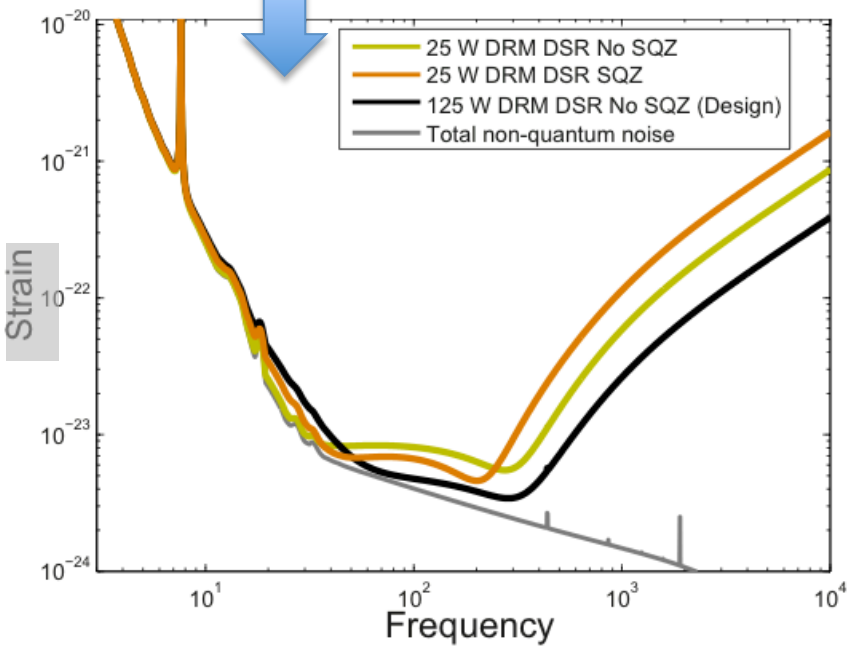
Power recycled Michelson



Configuration	*BNS*	*BBH*
25 W No SQZ	**111.4**	**1029.2**
25 W SQZ 7.9 dB	103.0	619.0
125 W No SQZ	112.2	649.0

Configuration	*BNS*	*BBH*
25 W No SQZ	121.8	1303.4
25 W SQZ 7.9 dB	130.5	1317.7
125 W No SQZ	**146.4**	**1164.6**

Dual Recycled Michelson with Detuned Signal Recycling



Credits to Sheon Chua – LKB- Paris

Talk outline

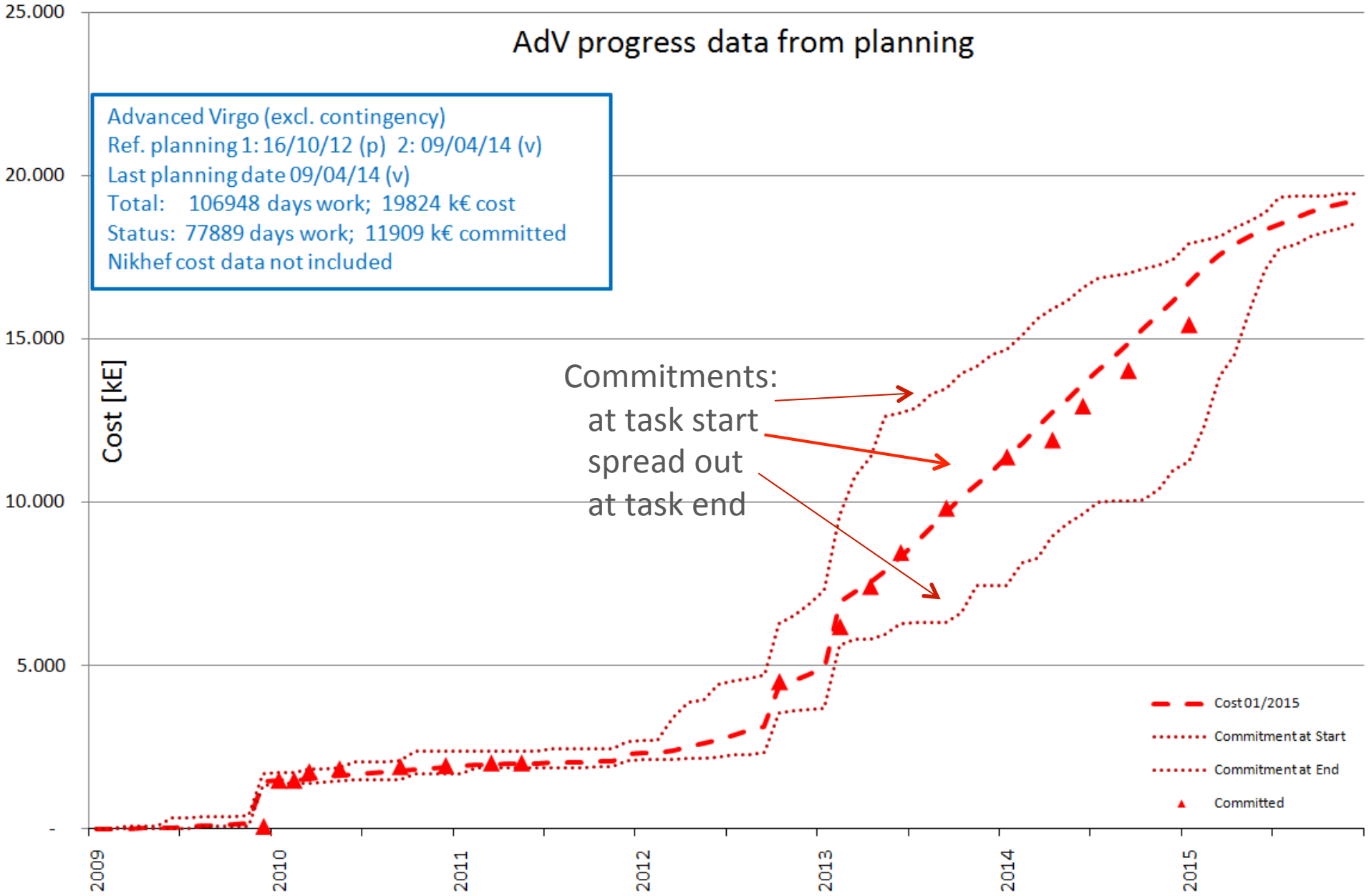
- Advanced Virgo in short and its challenges

- From the construction to the integration phase

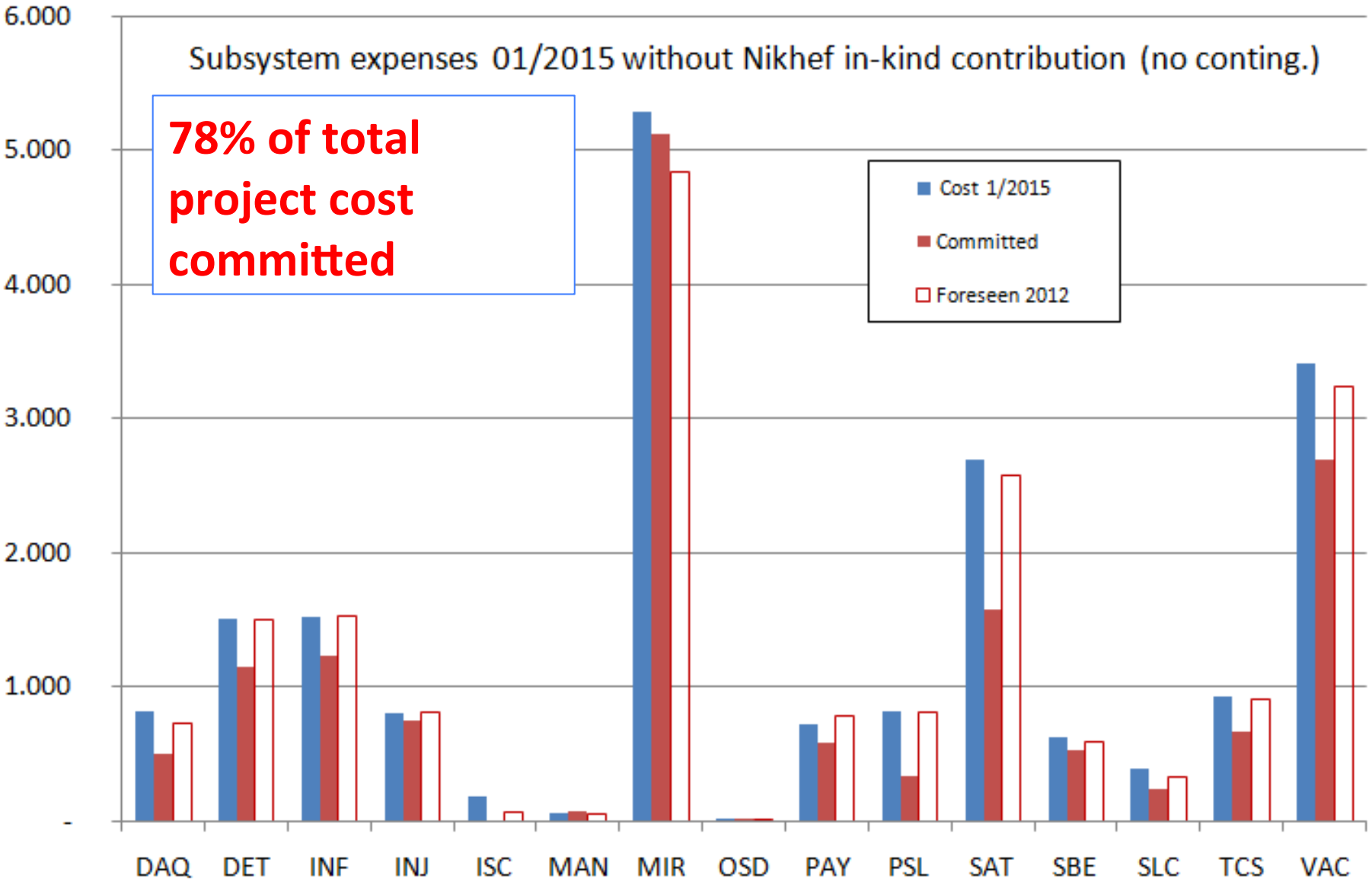
- Project management and planning

- Conclusion

Progress (commitments)



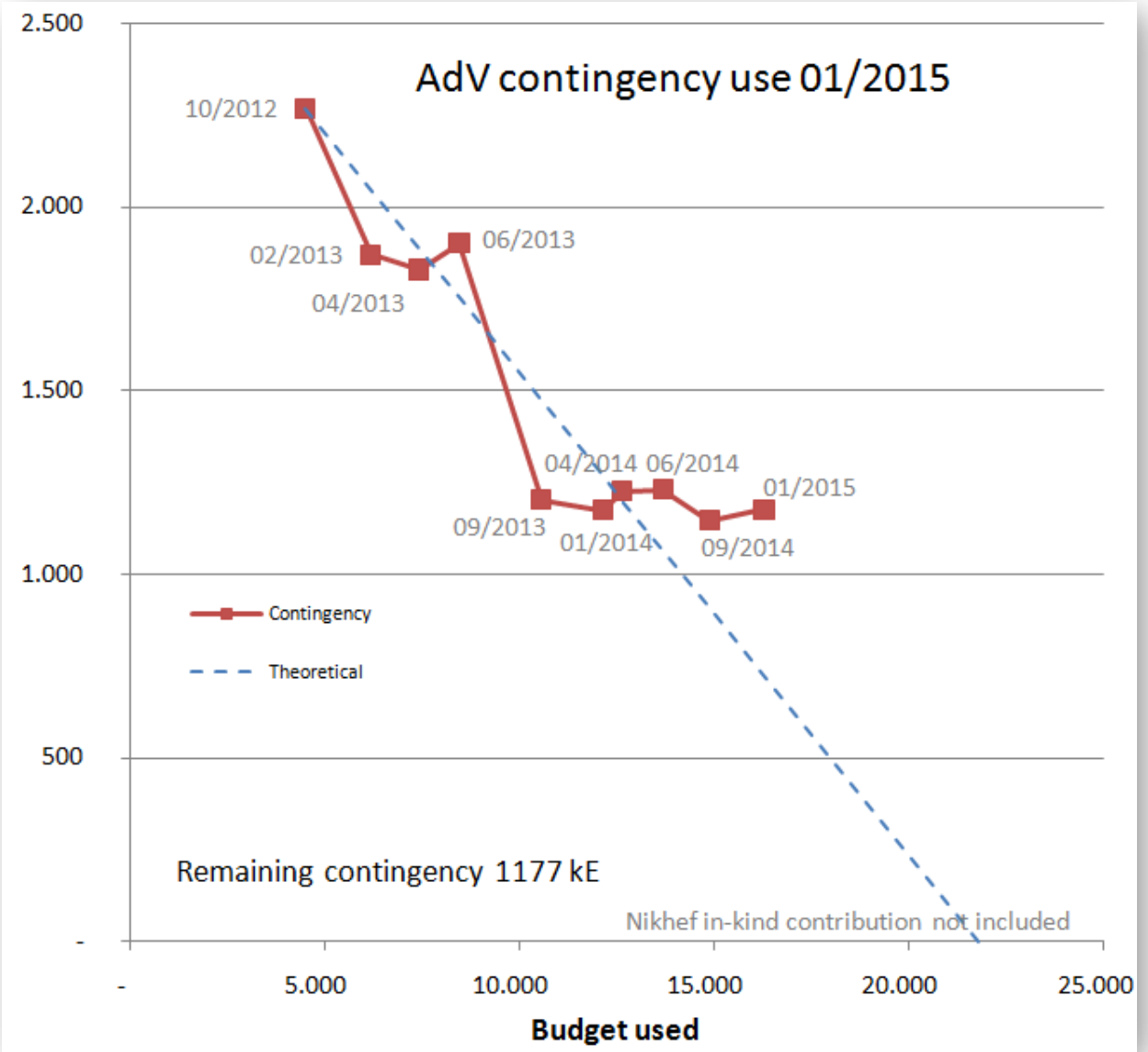
Budget distribution on the AdV sub-systems



Budget under control

Provisional plots:
at present the planning and the budget is under review

- "Linear" spending of the contingency
- Big jumps mainly due to investments for the manpower support

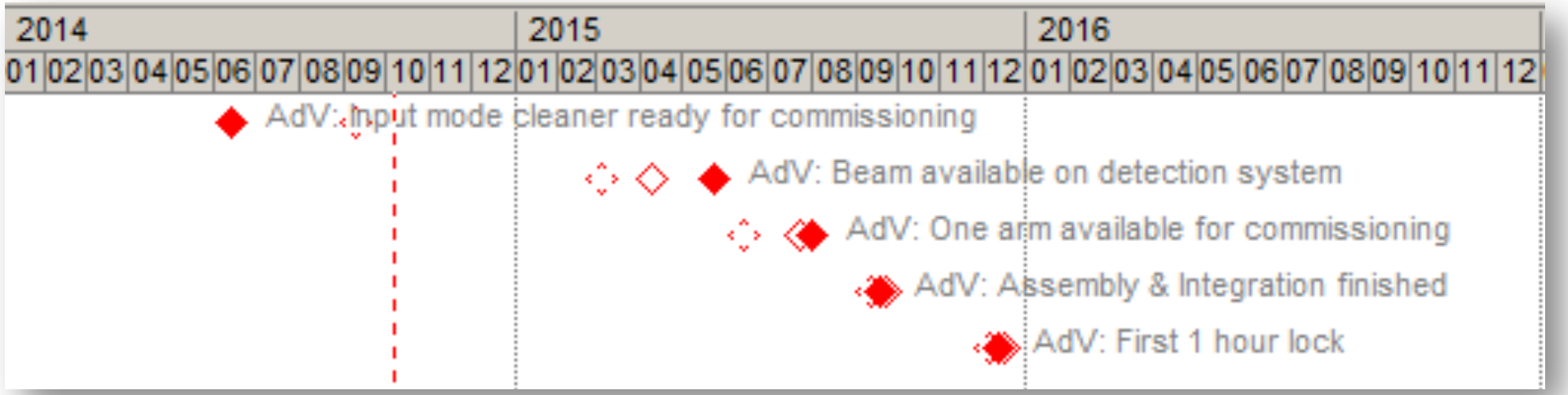


Planning issues: intermediate milestones under stress

- A huge effort must be done on the super attenuators and payloads both on the mechanics and electronics.
  - We have a HUGE technical work to adapt a well known mechanical system for suspending the new payloads.
  - An entire new chain is under construction for suspending the signal recycling mirror.
  - We don't expect significant technical risks
  - The super attenuator electronics (15 year old) has been re-designed from the scratch, following a new philosophical approach.
  - Delivery of the first set of the final boards is expected for the end of February. Then, the test based on the control of the SA top stage will start.
  - A paln to mitigate the risk on the electronic installation and controlling super attenuators and payloads, has been put in place.

Top level milestones

- Several internal milestones are shifting the date of the end of the project seems to remain stable up to now.
- Delays are being absorbed by optimizing the planning structure and reducing the time for the anticipated commissioning tasks



Talk outline

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Conclusion

- We are facing the crucial phase of the installation:
  - Many activities in parallel
  - Strong coordination/integration effort
- The first suspended optical element of the AdV interferometer is in place
- Schedule is extremely tight, but all the groups are fully committed towards the final goal

- We have started later than LIGO and with less resources, but we are working hard to maintain our commitments
- The “first lock” will mark the end of the AdV project and the full transition to the commissioning phase toward the science run.
- We are governing this transition, which is already started with the commissioning of the injection system


Advanced
Virgo
Thanks for the attention

Extra slides

Highlights of the Data Analysis and Computing Issues

AdV COMPUTING @ EGO

EGO Activities are in time:

- Upgrades of Computing hardware
  - Fiber optics backbone
  - Local Area Network backbone
  - Core of IT infrastructure
- Upgrade of the control room (computers, monitors and cameras) done!

Off line computing strategy

- The first VIRGO computing plan is dated 2002
  - ✓ The first "historical" document was prepared under the supervision of the former DA coordinator, F. Cavalier

- Afterwards, an *AdV computing plan* has been produced recently (2014) - *VIR-0129H-13*, followed by the *Advanced VIRGO Computing Infrastructure's Implementation Plan, VIR-0177A-14*

- Then, the computing needs are reviewed on annual bases. The computing needs 2015 doc is in preparation (deadline November 20th).

- CPU request will increase continuously in time to scan progressively larger parameter space of the searches.

- Main strategy for the off-line analysis:
  - ✓ we support the use of more CCs under GRID/CLOUD and LIGO-Condor clusters.

Data storage and Computing

- Cascina (EGO) hosts the Tier-0 – Data are stored there for a maximum time of 6 month
- The instrument ``Primary data" are distributed to two Tier-1s: one full copy in each CC, maximum latency of 1 day
    - CC1 ➔CC-IN2P3 (Lyon-France)
    - CC2➔CNAF-INFN (Bologna – Italy)
- CC1 , CC2 + comp. resources in the various labs are are the structures used for the offline science analyses ➔ more than 2000 core
- Recently we obtained to increase the CNAF limitation for running on more than 1 kcore in parallel. Negotiation is on the way to go up to 4kcore

DA activity

- A long debate on the science priorities was triggered by the NSF reply to the LIGO request for supporting the renewal of the computing infrastructure.
- This issue monopolized the LV data Analysis and in particular the f2f meetings (Boston - August 8th , Stanford - LVC meeting August 24th , Atlanta - January 30th)
- It is a painful activity, but
  - a great occasion for checking the status of the software tools for the GW detection,
  - an important lesson to push for an use optimization of the available computing resources
- A hard work for a good result!
  - We have now a provisional strategy for prioritizing the O1 explotation
    - ✓ The ranking criteria are based on the discovery potential, weighted by readiness and by the projected computing cost.
    - ✓ We expect the most important uncertainties to be clarified as various studies complete and the pipelines are frozen.
  - We have defined a new methodological approach in LVC, crucial for supporting the future request for getting extra computational resources