Advanced Virgo short term upgrades

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for the Virgo Collaboration

Main contributions by:
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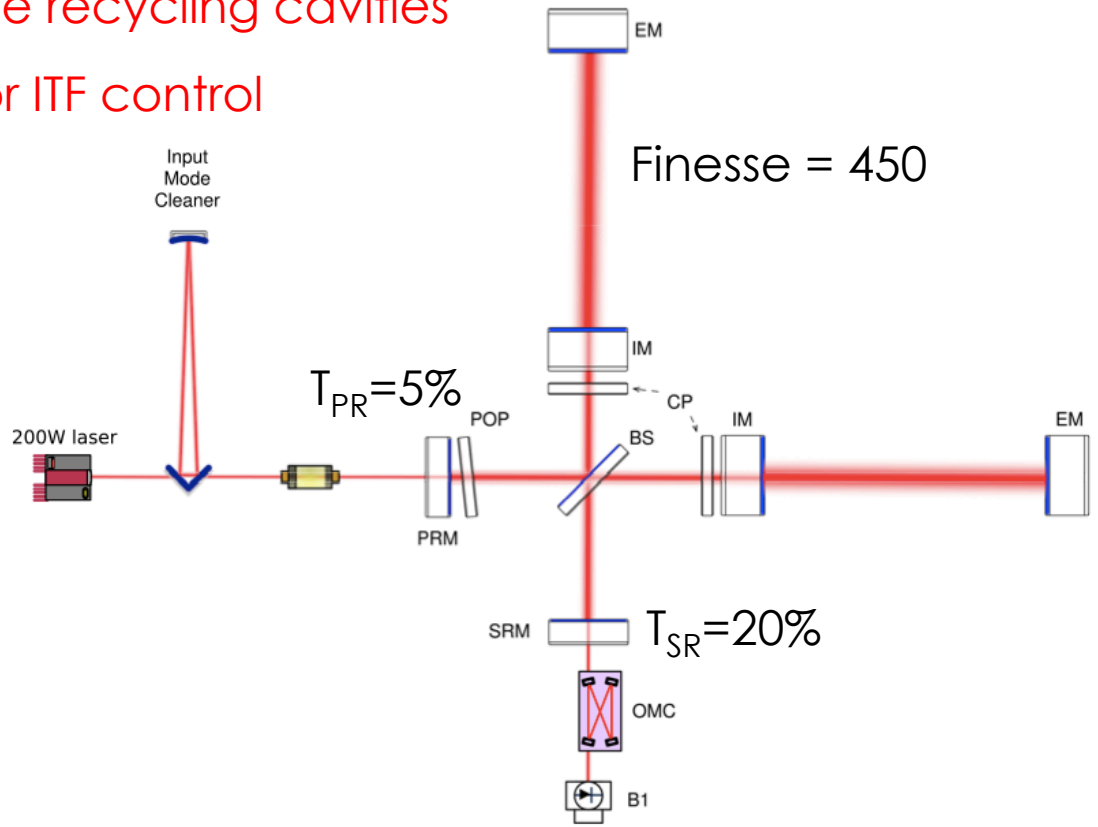
Outline

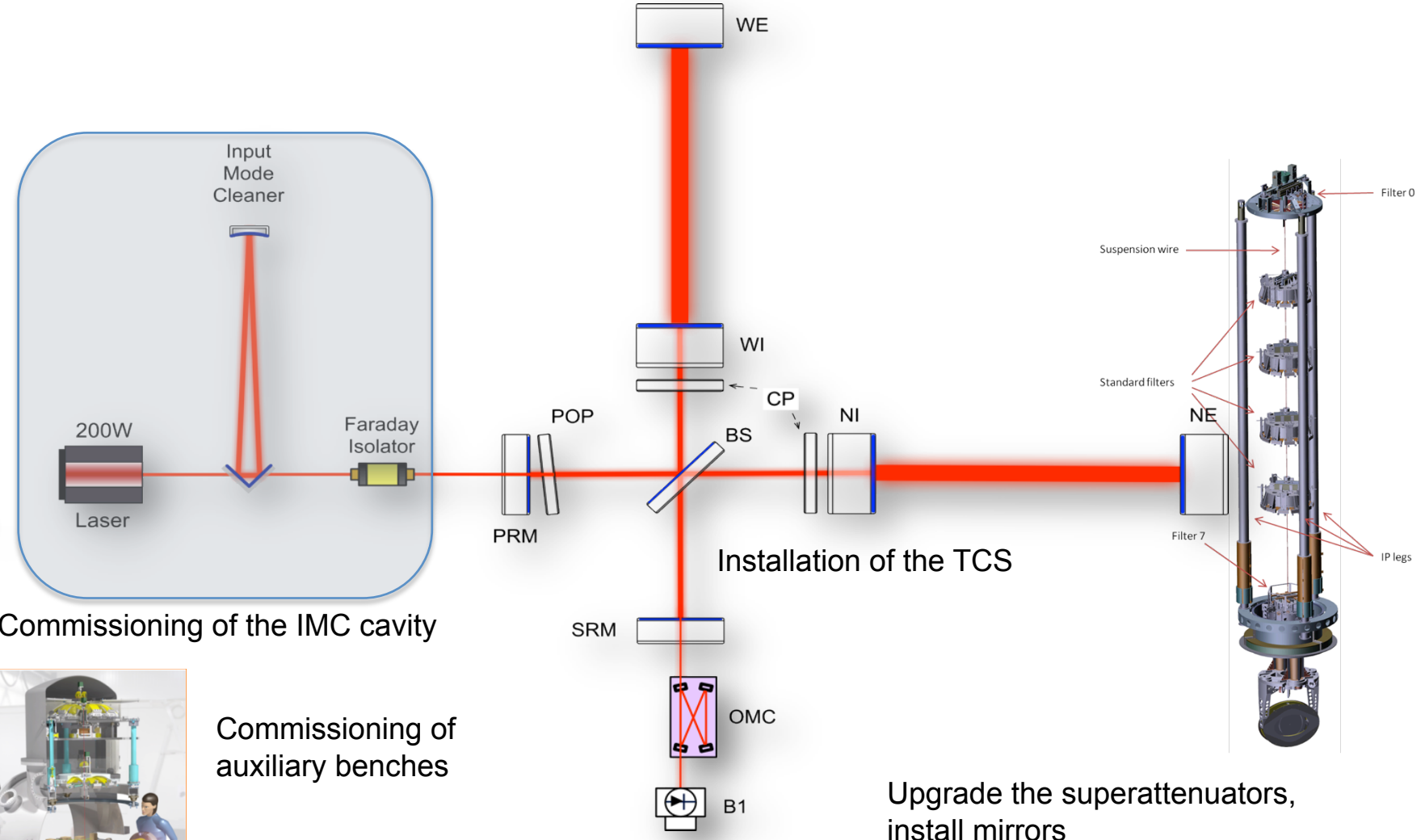
- Advanced Virgo construction/installation status and schedule
- Strategy for the next few years
- Some possible **short term** upgrades (<5 years)

Optical scheme

- Dual recycled Fabry-Perot Michelson
- Bi-concave arm-cavities
- Compensation plates
- Marginally stable recycling cavities
- Pick-off plate for ITF control

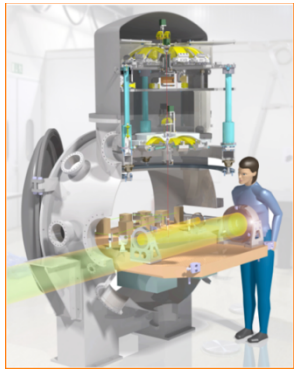


Main on-site activities



Commissioning of the IMC cavity

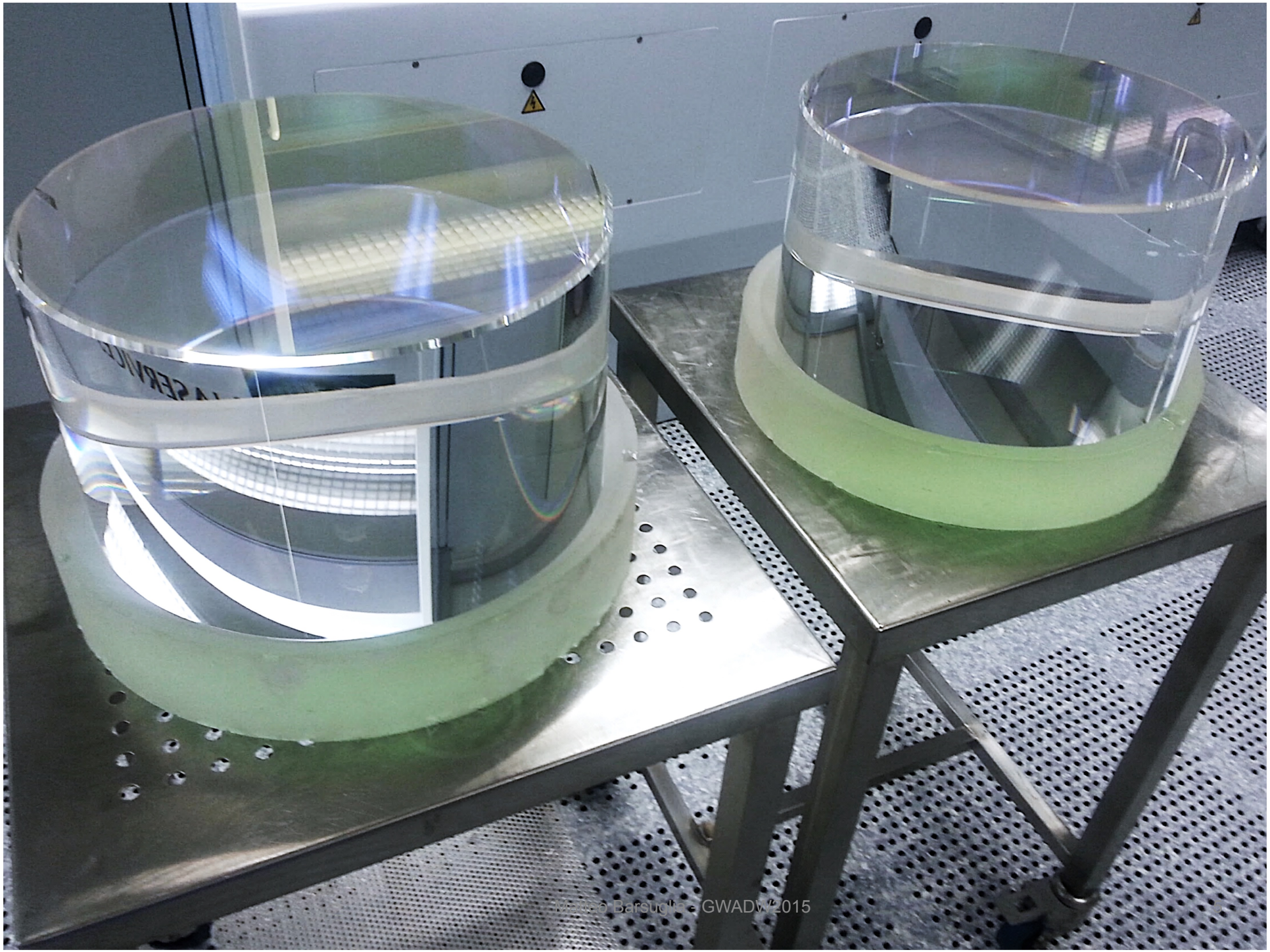
Installation of the TCS



Commissioning of auxiliary benches

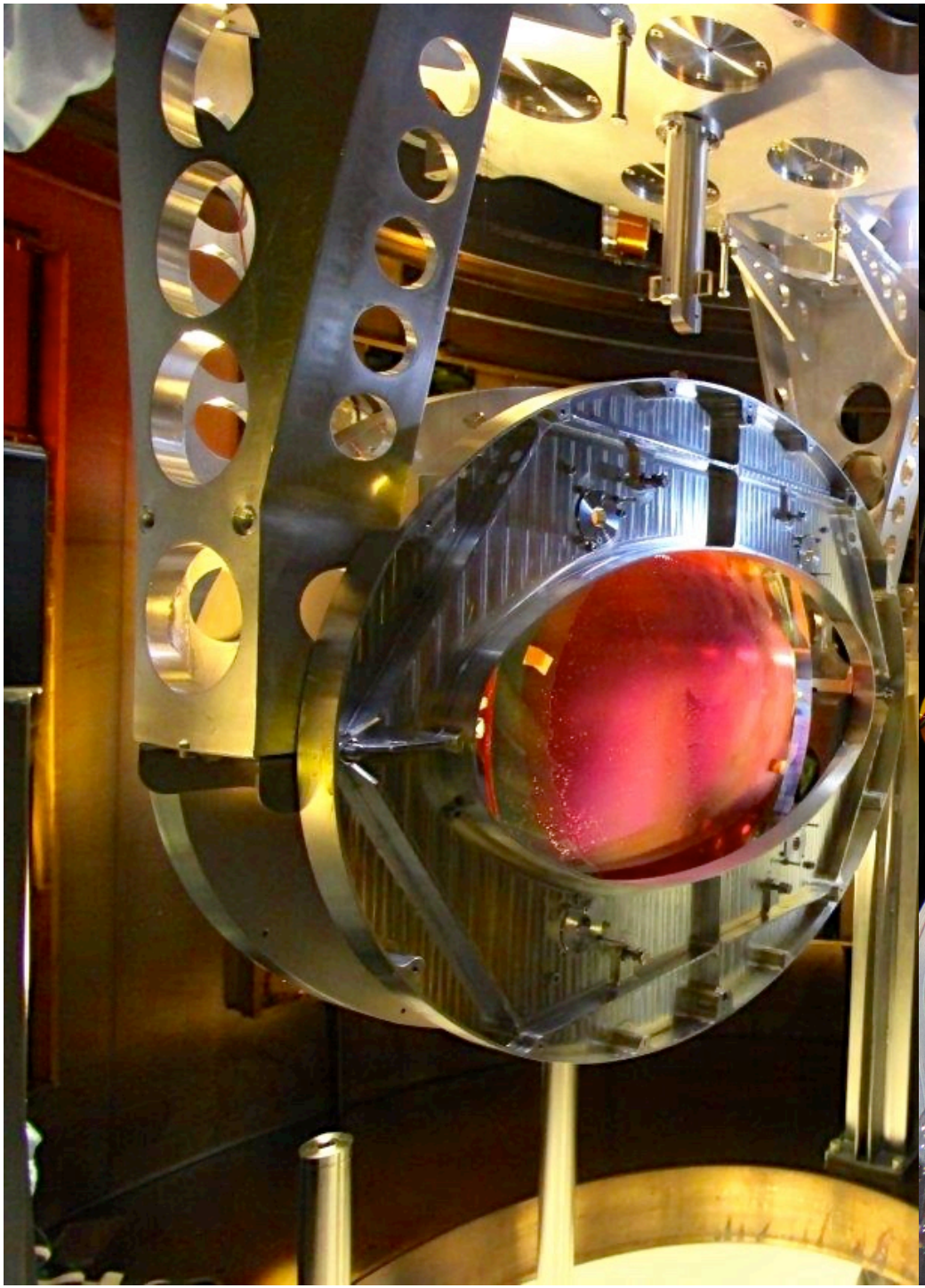
Upgrade the superattenuators, install mirrors

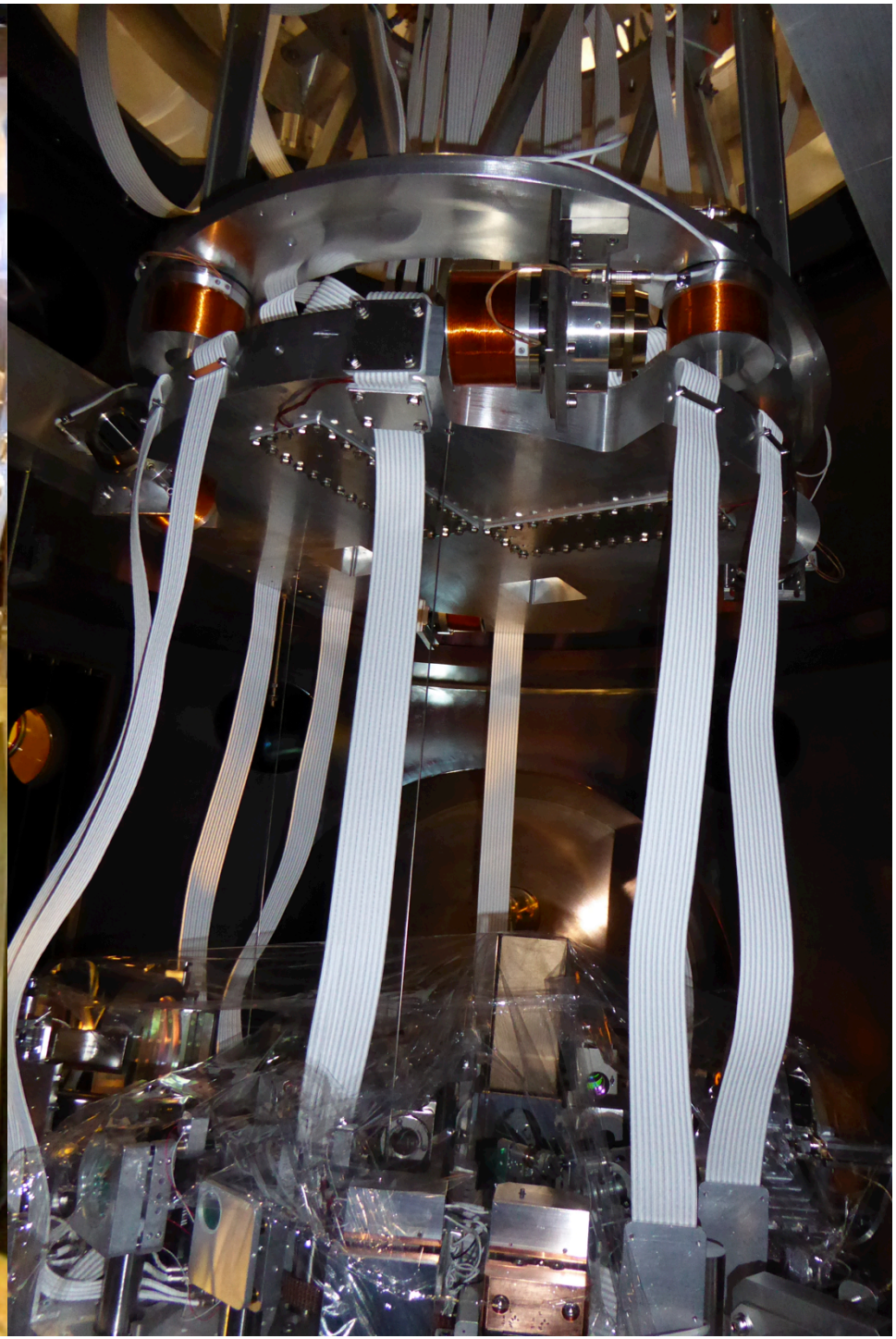
Preparation/installation of the suspended detection benches


Alessandro Bursi - GWADW 2015

Mirrors

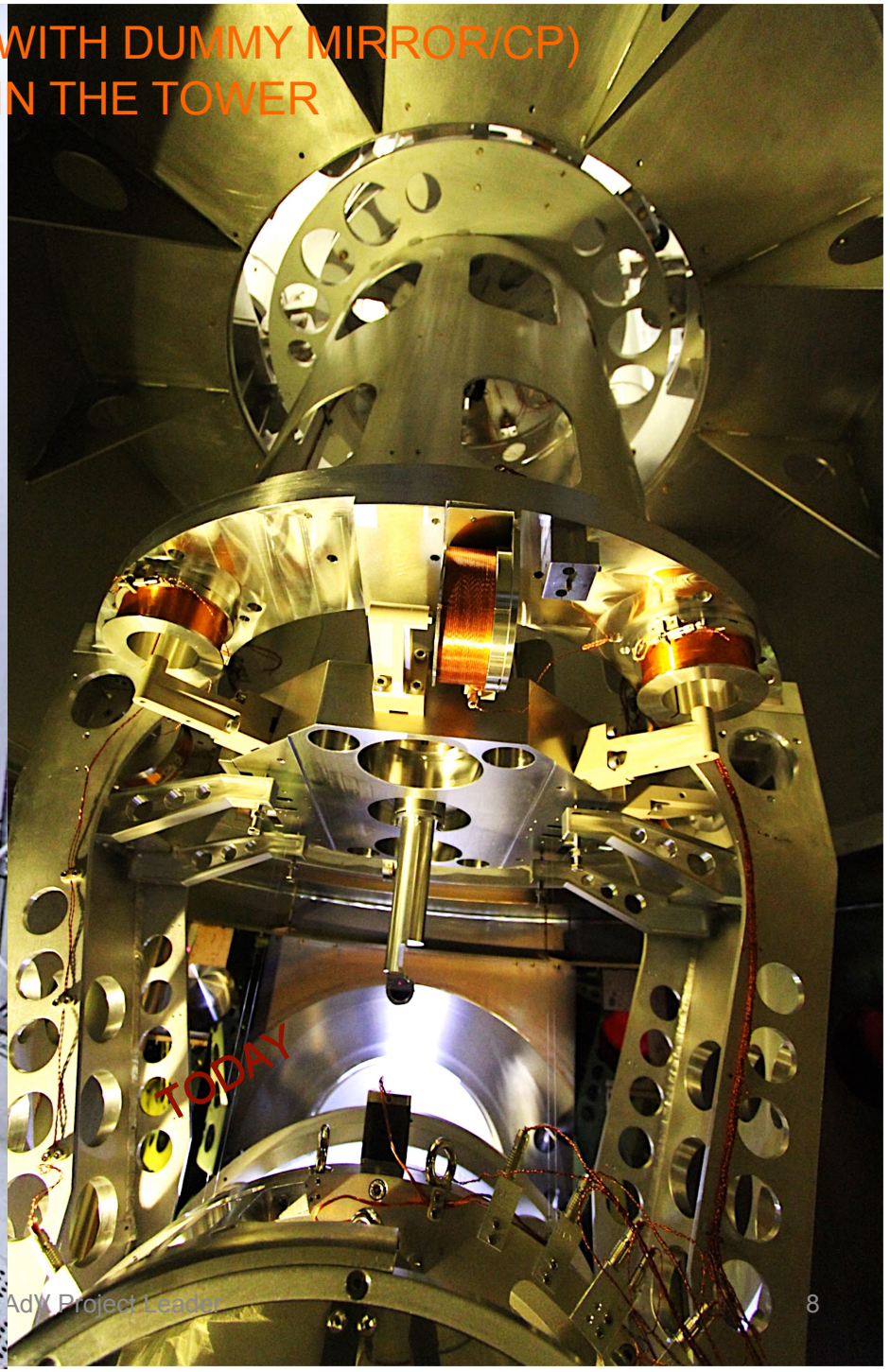
		IM02	IM04	EM01	EM03
Absorption Ø150mm @1064 nm	TDR Spec.	< 0.5 nm	< 0.5 nm	< 0.5 nm	< 0.5 nm
	Result	0.22 ppm	0.19 ppm	0.24 ppm	0.24 ppm
RMS Flatness Ø150mm	TDR Spec.	< 0.5 nm	< 0.5 nm	< 0.5 nm	< 0.5 nm
	Result	0.31 nm	0.27 nm	0.50 nm	0.35 nm
ROC	TDR Spec.	1420 m -5m, +15 m	1420 m -5m, +15 m	1683 m -3m, +17 m	1683 m -3m, +17 m
	After polishing	1425.2 m	1425.2 m	1690.6 m	1690 m
	After Coating	1424.5 m	1424.6 m	1695.2 m	1696.3 m
AR reflectivity Ø150mm 1064 nm	TDR Spec.	<100 ppm	<100 ppm	<300 ppm	<300 ppm
	Result	58 ppm	32 ppm	133 ppm	155 ppm
RTL	TDR Spec.	< 150 ppm			
	Result	25 ppm			

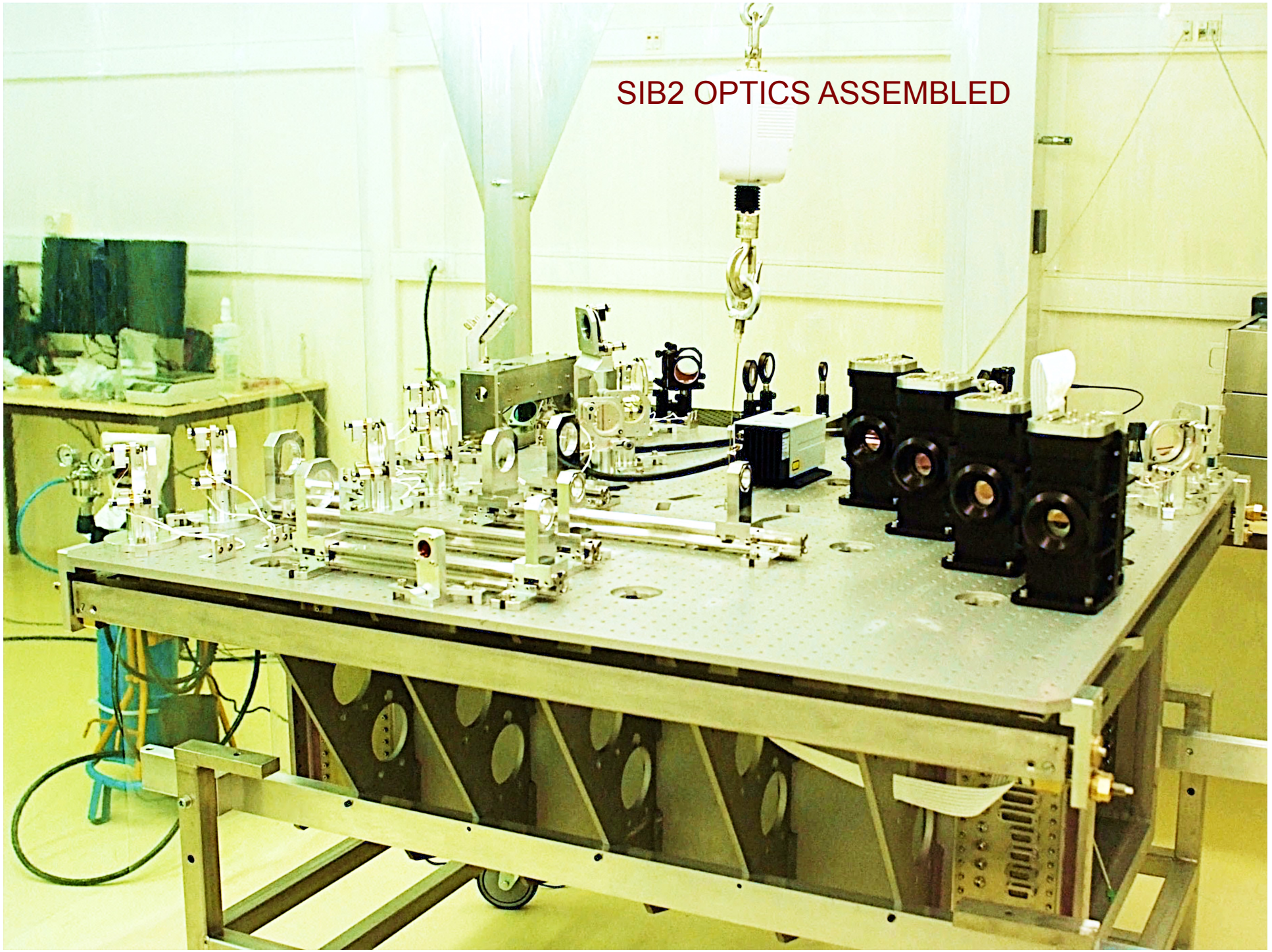


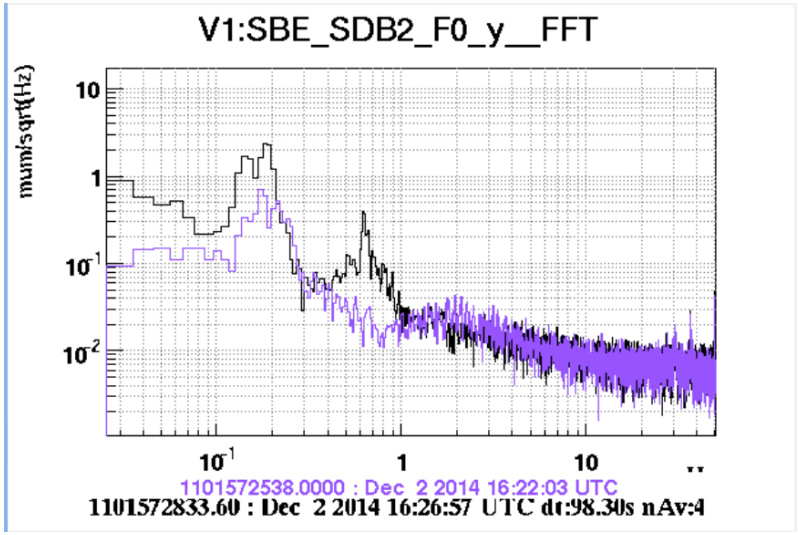


WI PAYLOAD (WITH DUMMY MIRROR/CP) INTEGRATED IN THE TOWER

Photos: M Perciballi

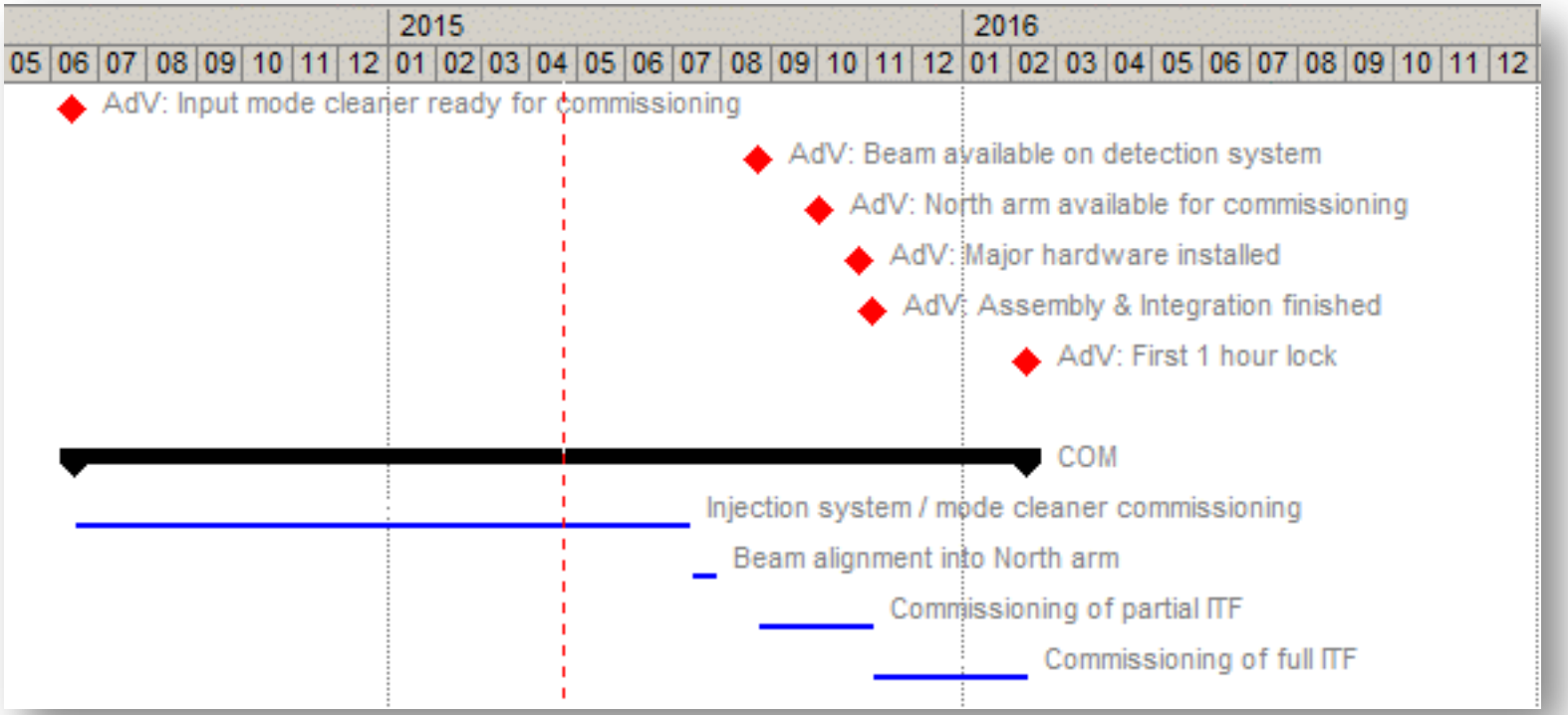



SIB2 OPTICS ASSEMBLED


V1:SBE_SDB2_F0_y__FFT
mum/sqrt(Hz)
10
1
10^{-1}
10^{-2}
10^{-1}
1
10
1101572538.0000 : Dec 2 2014 16:22:03 UTC
1101572833.60 : Dec 2 2014 16:26:57 UTC dt:98.30s nAv:4

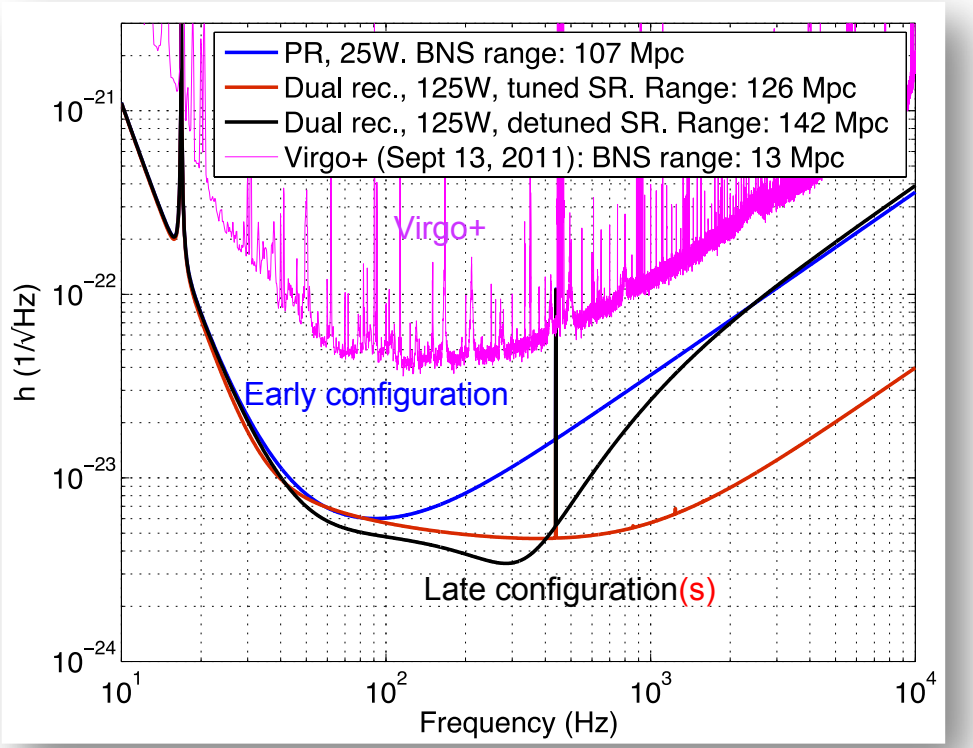
Schedule

- Main top level milestones:
  - A&I completed: fall 2015
  - Interferometer accepted: Feb 2015



2015 configuration

- Short-term goal: join the network in the O2 run
- O2 configuration: PR-mode, low power: 107 Mpc max
- Later (2017-18, TBD): installation of SR, HP laser



2017-2018 upgrade

- AdV shutdown to install the SR mirror and the HP laser
  - These will complete AdV as designed. Budget is allocated
- This opens a window of opportunity to implement other changes on the detector: ~ 6 months downtime
- Modifications fitting in this window will be referred to as "*phase 1*"

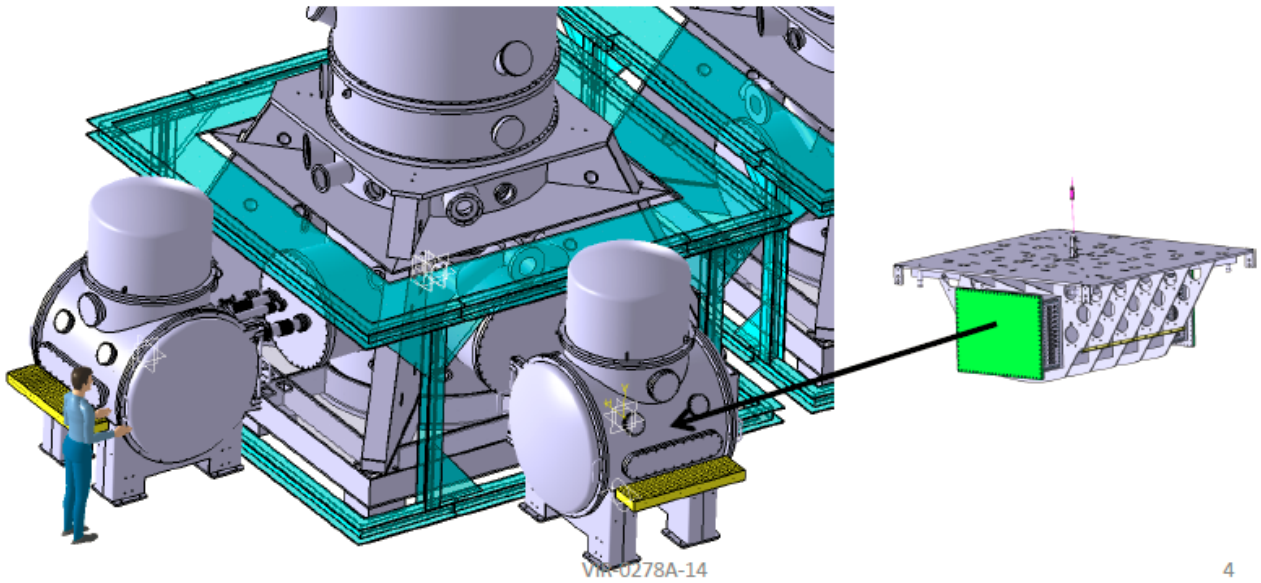
Phase 1 improvements

1. Fix detector issues discovered during the commissioning
   - e.g.: replacement of noisy sensors/electronics, replacement of damaged optics, re-design of some parts, ….
   -

2. Improve the robustness of the detector or to mitigate risks
   - Frequency independent squeezing
   - Control of aberrations
     - All/some CITF mirrors with state-of-the-art polishing?
     - Further improvement of thermal compensation system
   - Control of parametric instabilities
   - Suspension control improvement (tiltmeters)
   - …

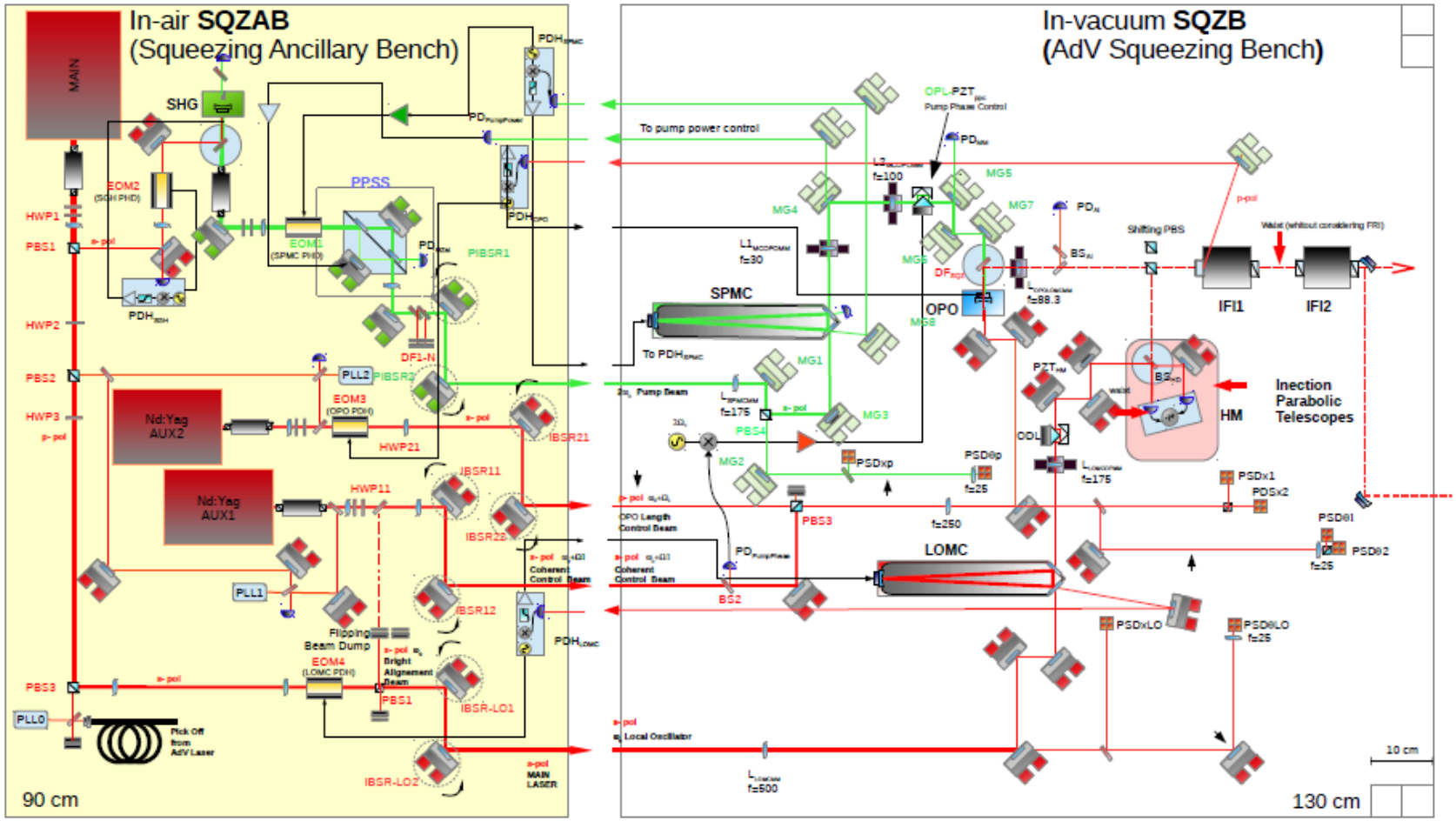
Squeezer for Advanced Virgo: intro

- The space to host a squeezer is already foreseen in the AdV detection lab
- **The Technical Design Report for a squeezer for Advanced Virgo is being completed**

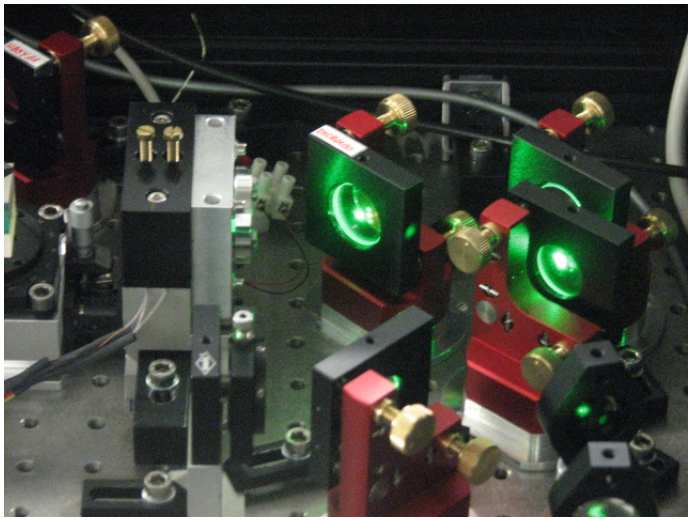


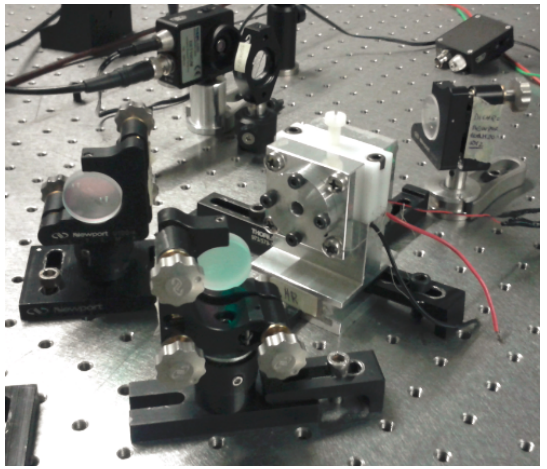
Squeezer for Advanced Virgo: design

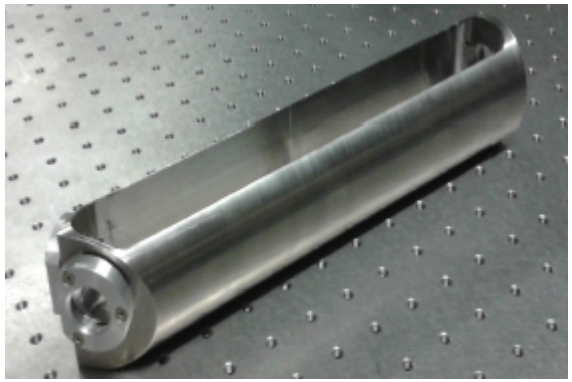
See presentation by J.-P. Zendri at LVC Pasadena 2015



Squeezer for Advanced Virgo: R&D



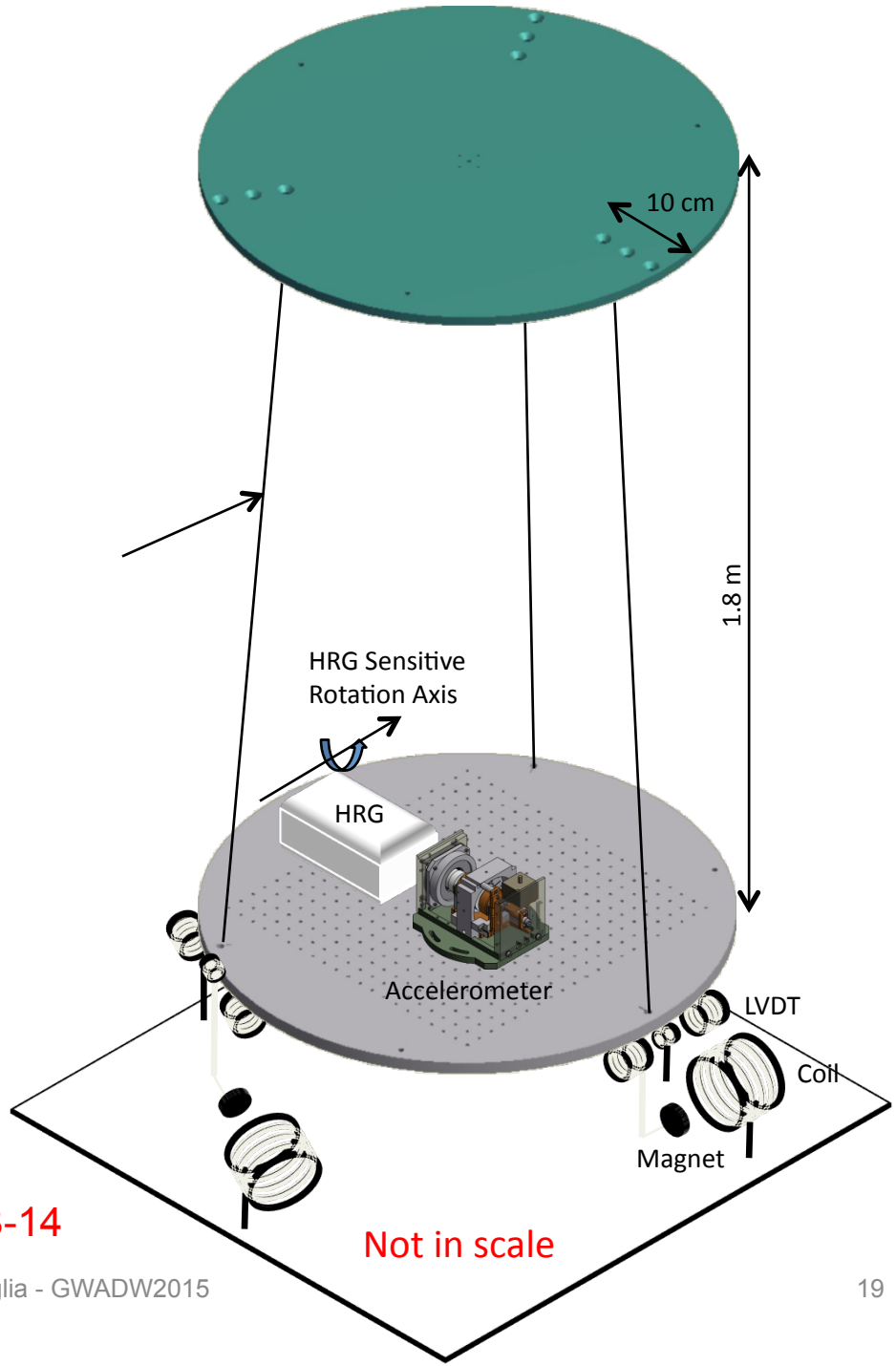




See presentation by J.-P. Zendri at LVC Pasadena 2015

Tiltmeters

- Seismic isolation makes use of an *inertial platform*
- The low-frequency performance is limited by the tilt-horizontal coupling of the accelerometers
- Improving LF performance means improving the lock robustness and the duty cycle
- R&D started

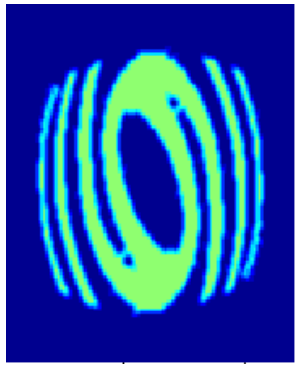


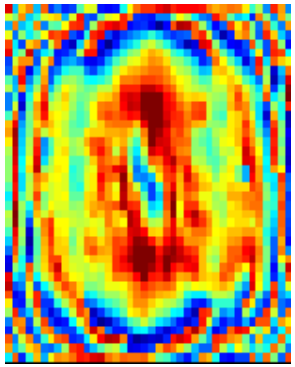
V.Boschi
VIR-0032B-14

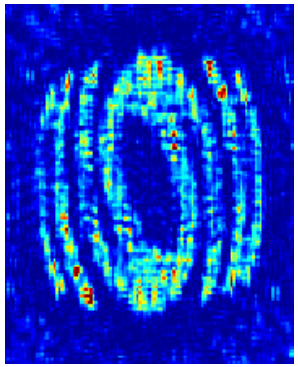
Improvements in the thermal compensation system: a few ideas

1) Precise CO_2 beam shaping for the correction of non-symmetric aberrations

DC systems (MEMS/deformable mirrors)







Simulation of the pattern projection using a 40x40 actuators device:

(left) Target pattern

(center) actuators displacement (full scale values range from -2 to 2 mm)

(right) Projected pattern

The simulation is obtained for flat incident intensity on an array composed by 40x40 micromirrors with 1 mm side length

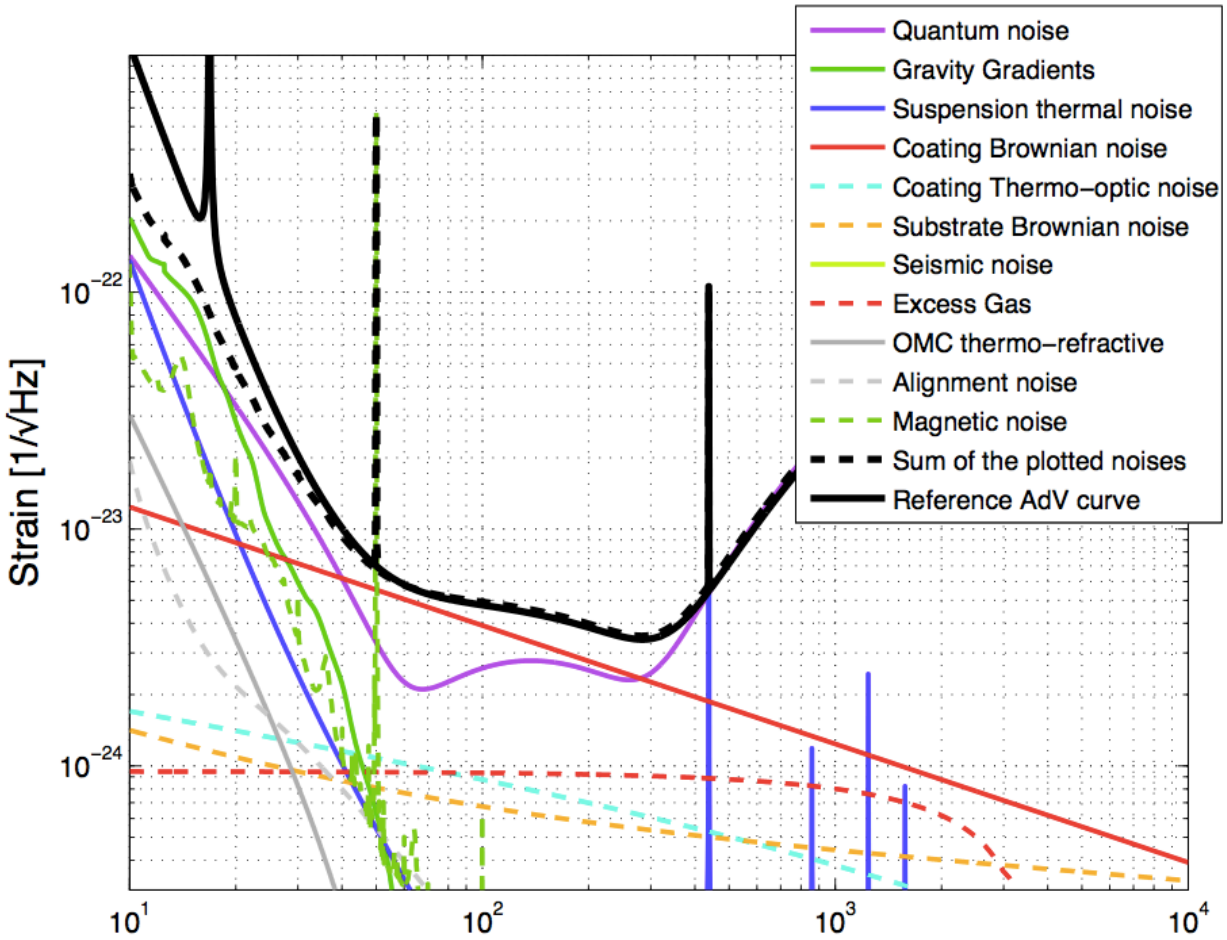
Credit V.Fafone (Roma Tor Vergata)

Phase 2 upgrades

New hardware aimed to improve the sensitivity beyond the design target with ~ the same infrastructure

- Bigger beams
- Frequency dependent squeezing
- Coatings with reduced losses
- Newtonian noise subtraction

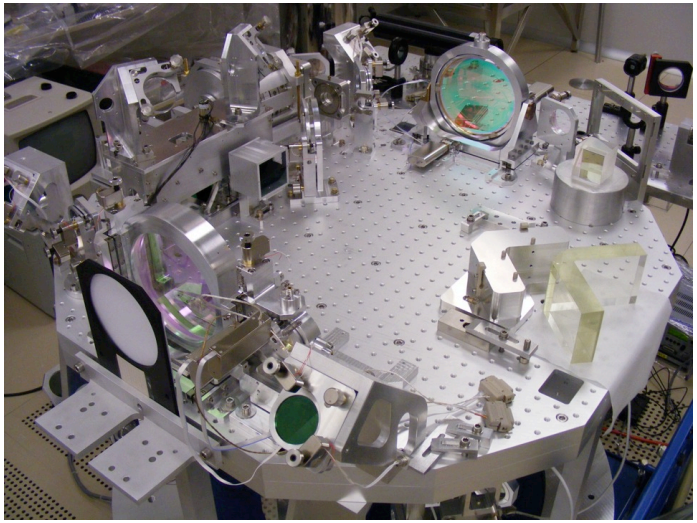
Advanced Virgo sensitivity

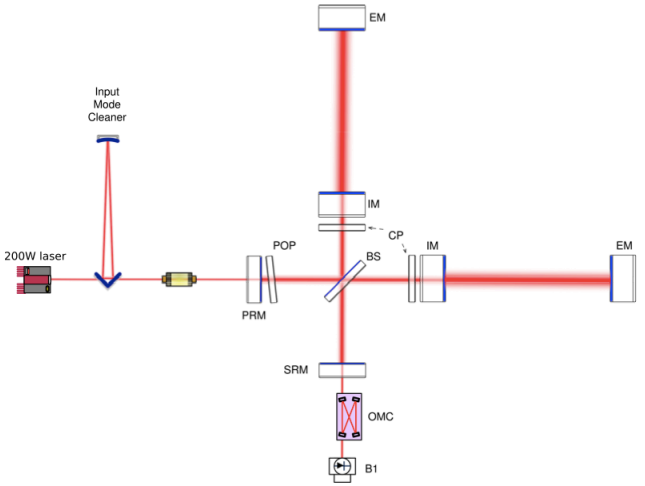


Bigger beams/1

See also M.Tacca review talk about optical methods to reduce thermal noise

- Detailed investigation planned in the next years
  - cavity losses
  - Recycling cavity stability and requirements for aberration control
  - Compliance with input/output optics
  - Alignment sensitivity





Bigger beams with same mirrors size/2

- Real coating maps from Advanced Virgo
- Mirror aperture: 330 mm
- **Losses only due to low spatial frequency and clipping**

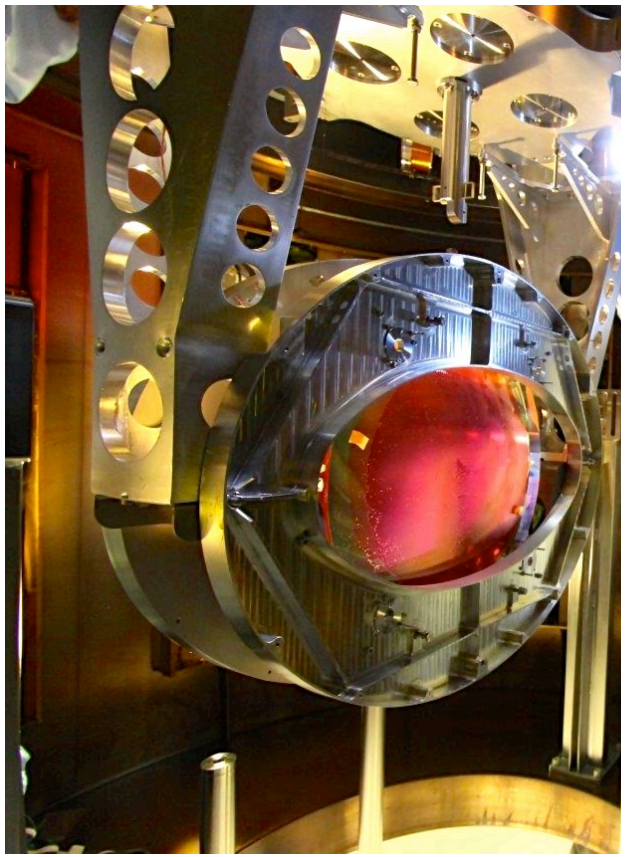
Preliminary

RoC IM [m]	RoC EM [m]	Beam radius IM [mm]	Beam radius EM [mm]	RTL loss [ppm]
1420	1683	49	58	12
1390	1653	60	71	27
1385	1648	63	75	73
1380	1643	68	80	280

Oscar simulation by J.Degallaix

Bigger beams with bigger mirrors

- New suspensions needed
- In Virgo we have already suspended a 55 cm optics (BS)
- >35 cm mirrors with good optical properties possible in the next ~ 5 years?
- Of course, many things to be checked



Coating deposition improvements at LMA in the next ~5 years

- Planetary motion (2 mirrors at a time)
  - Optics with $\varnothing_{max} < 40$ cm
  - Uniformity goal for 2016 : < 0.5 nm rms on Ø 30 cm
  - **Research started**

- Single rotation (1 mirror at a time)

  Possible evolution at LMA
  - No masks, no planetary → no spirals
  - $\varnothing_{max}$ = 60 cm, 200 kg substrate mass
  - Able to deposit nanolayers
  - Uniformity: < 0.5 nm rms on Ø 40 cm
  - In-situ optical control of coating thickness

Coating losses possible improvements

AdV Coatings

ITMs – $\Phi_c = 1.4 \pm 0.2 \times 10^{-4}$
ETMs – $\Phi_c = 2.0 \pm 0.3 \times 10^{-4}$
Granata, VIR-0204A-15

- Increase of the annealing temperature
  - Replacing Ti:Ta_2O_5 with nanolayers of SiO_2 and TiO_2

$\phi_{nlc} = 1.3\ 10^{-4}$ (after annealing 24h @ 300 C)

AdCoat Collaboration, « single » film of 19 layers

  - Mixing high index oxides:

$Zirconia_{0.6}$-$Tantala_{0.4}$ Promising

$Titania_{0.75}$-$Tantala_{0.25}$ Cristalline Scattering?

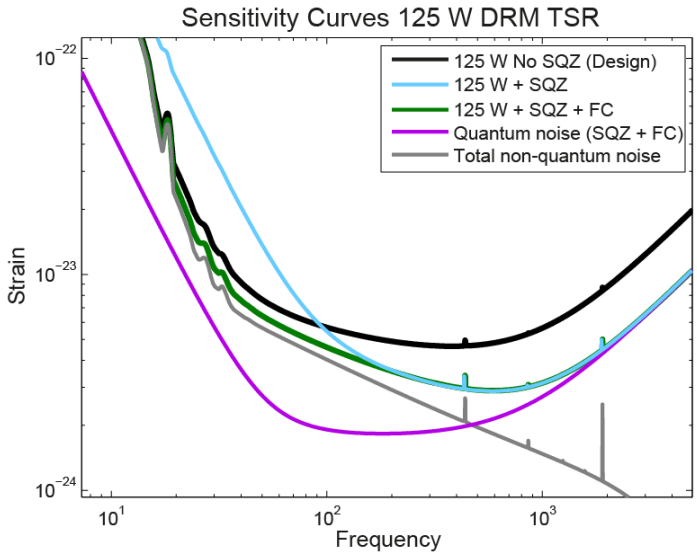
- New materials
  - Lowest layer of the coating stack made of amorphous silicon

Frequency dependent squeezing

Issues
- Infrastructure
- Experience
- Integration in the interferometer

- Discussion started

Simulation exercise
- 15 % total optical losses, 15 mrad phase noise
- 100 m long filter cavity
- 10 dB input squeezing (into filter cavity), 7 dB at readout
- 20 % improvement in both BNS and BBH ranges (same thermal noise)



Summary

- AdV is advanced installation/integration phase
  - Expected completion: end of 2015
- Mid-term target: join the O2 science run in a simpler configuration
- Plans for a squeezer (installation in 2017-2018 TBD?)
- Discussions started about possible plans for detector improvements in the next 5 years
  - Coatings
  - Bigger beams
  - Frequency dependent squeezing
  - Aberration control
  - Tiltmeters
- Ground for collaborative effort