

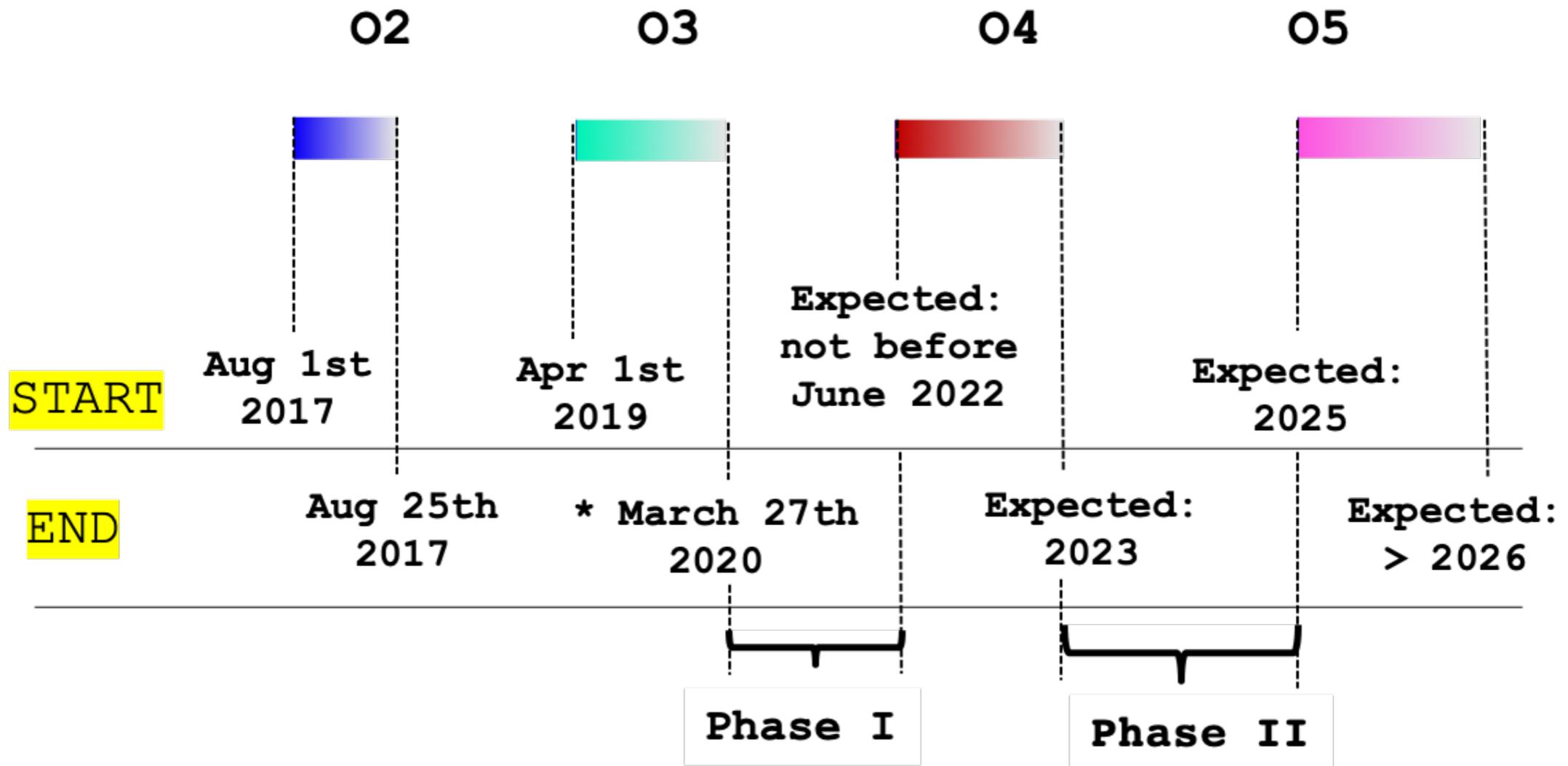


# **AdV+ Status**

**M. Tacca on behalf of the Virgo Collaboration**

**9th Belgian-Dutch GW Meeting - 2021 June 17th**

# AdV+ Timeline



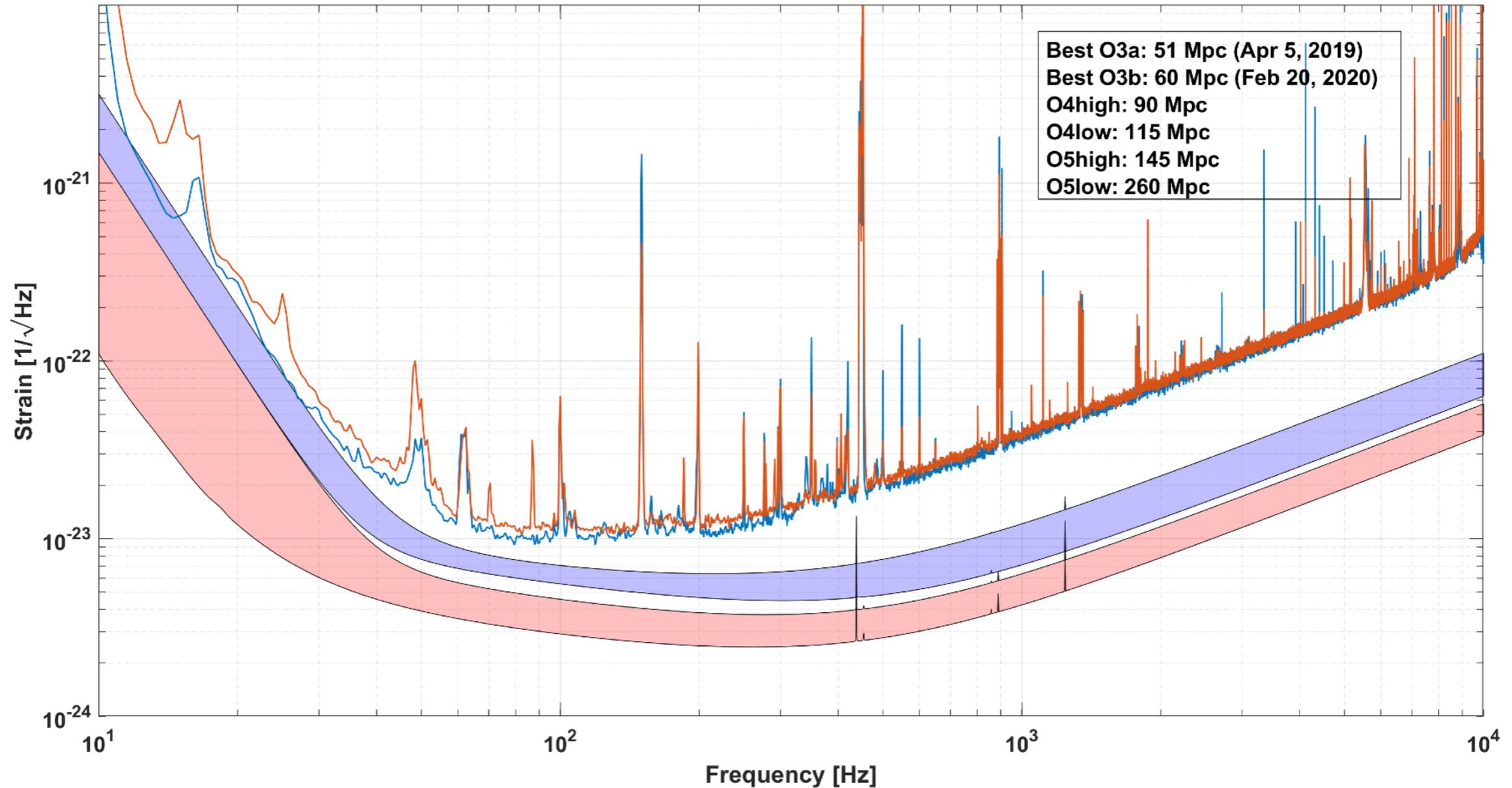
## PHASE I:

- Signal recycling mirror;
- Higher input laser power (40 W);
- Frequency dependent squeezing;
- Newtonian noise cancellation.

## PHASE II:

- Further increase of laser power (60 W or more);
- Larger beam on end test masses;
- Better coatings.

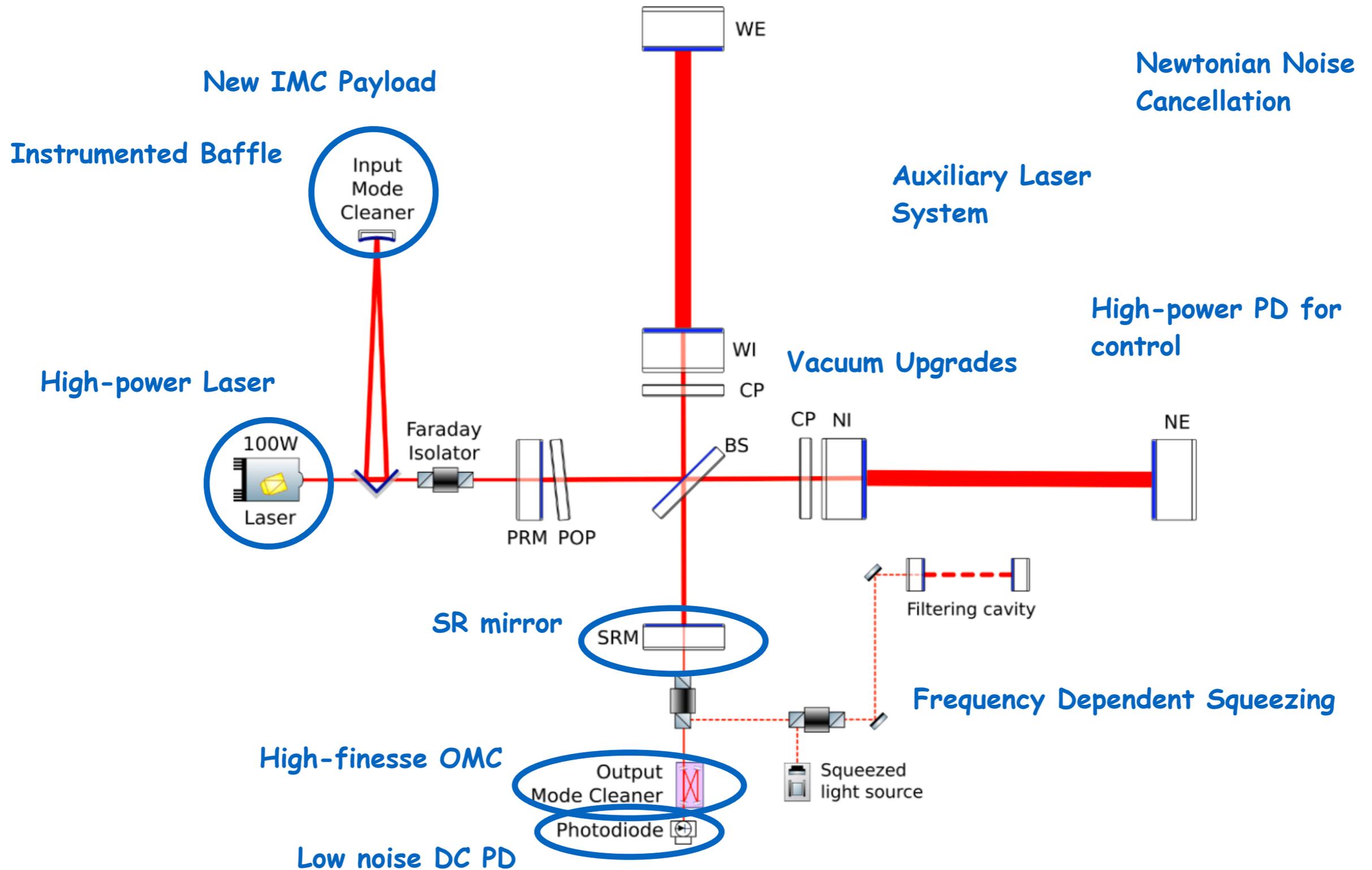
# Advanced Virgo Plus: target sensitivity



**Phase I:** reduce quantum noise, hit against thermal noise

**Phase II:** push down the thermal noise wall

# Advanced Virgo Plus Phase I

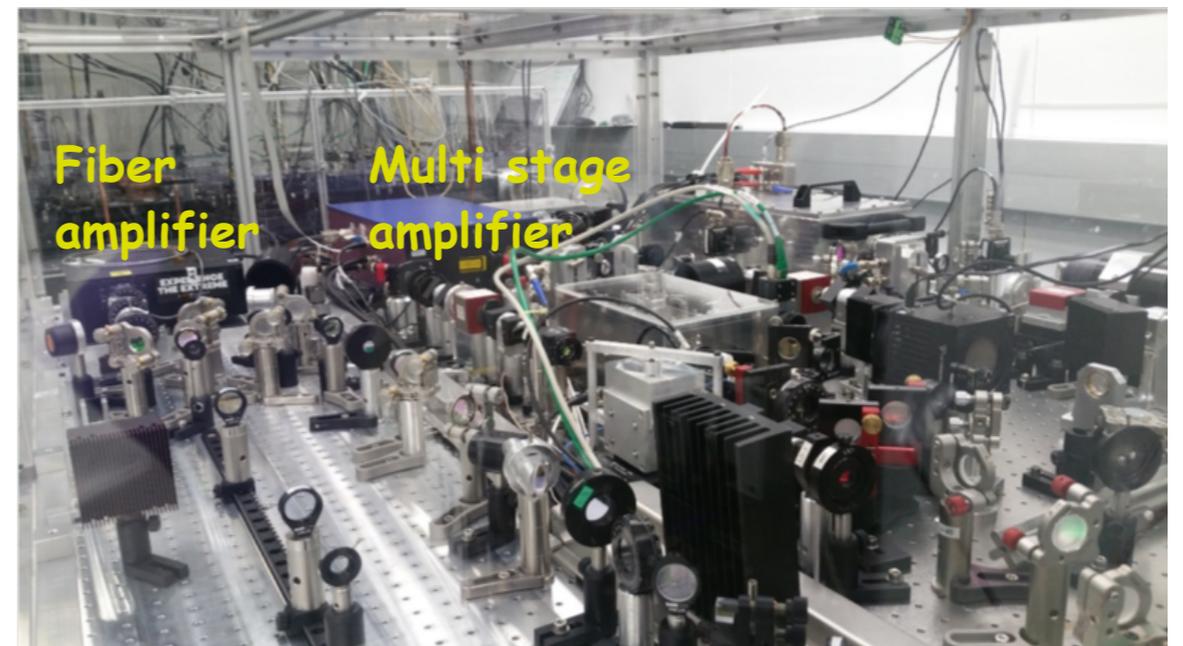
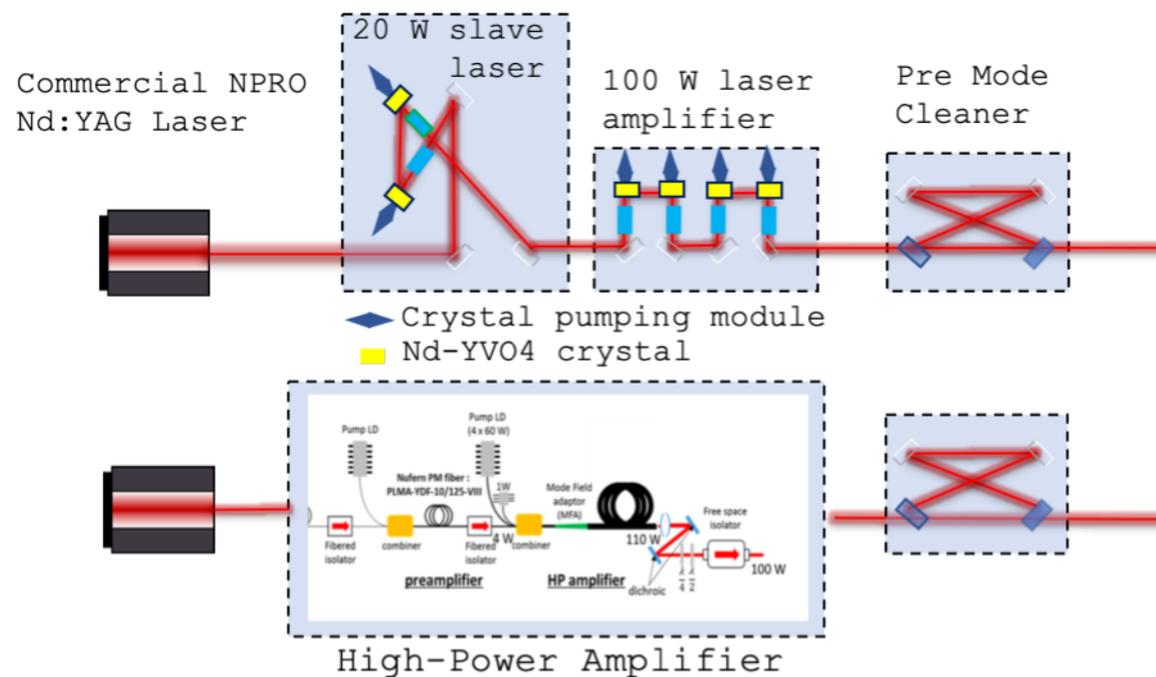


# Laser System

Target: Power in the interferometer around 40-50 W:

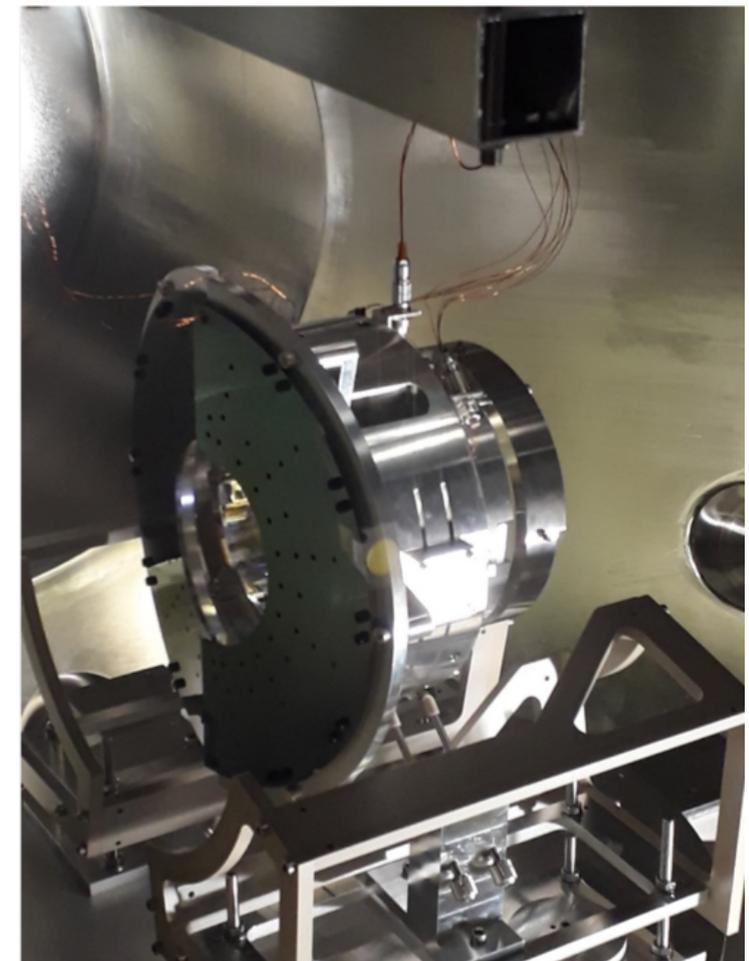
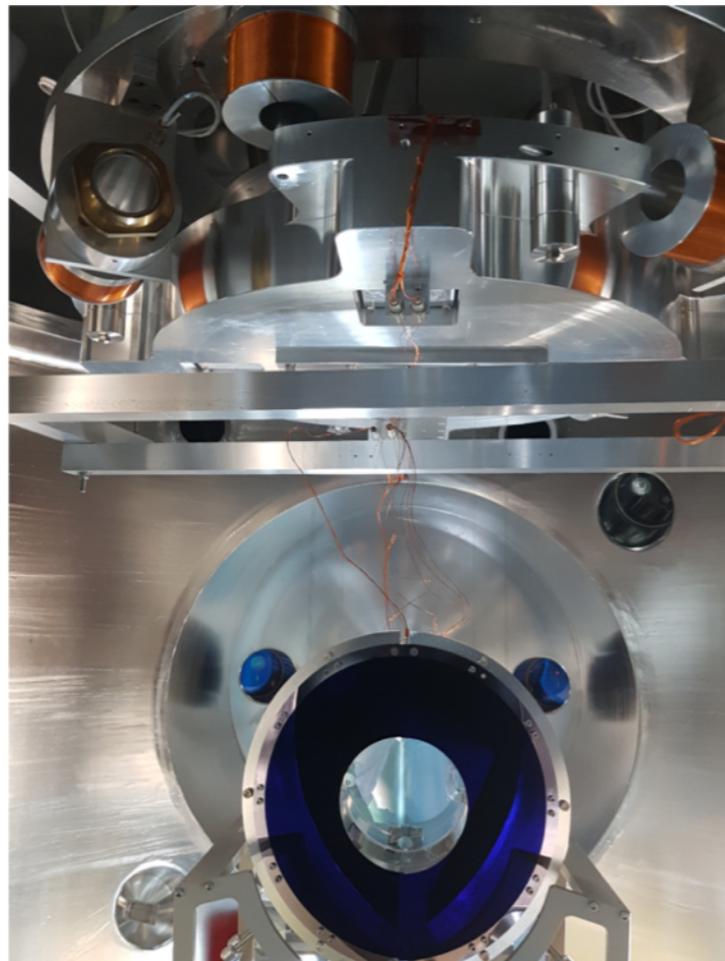
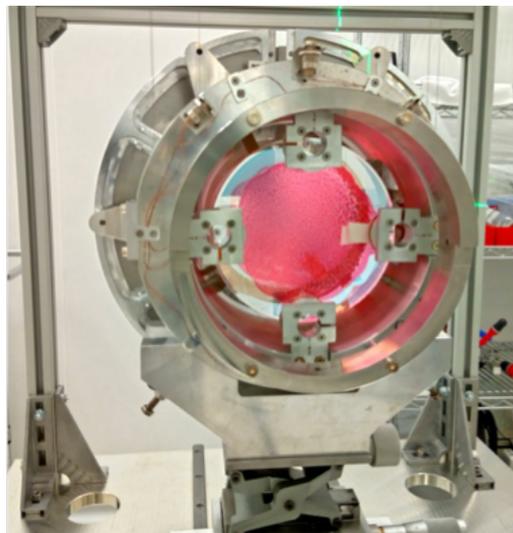
- O3: multi stage amplification scheme;
- O4: monolithic fibered amplifier.

High beam quality injected into the interferometer: 93 % TEM.



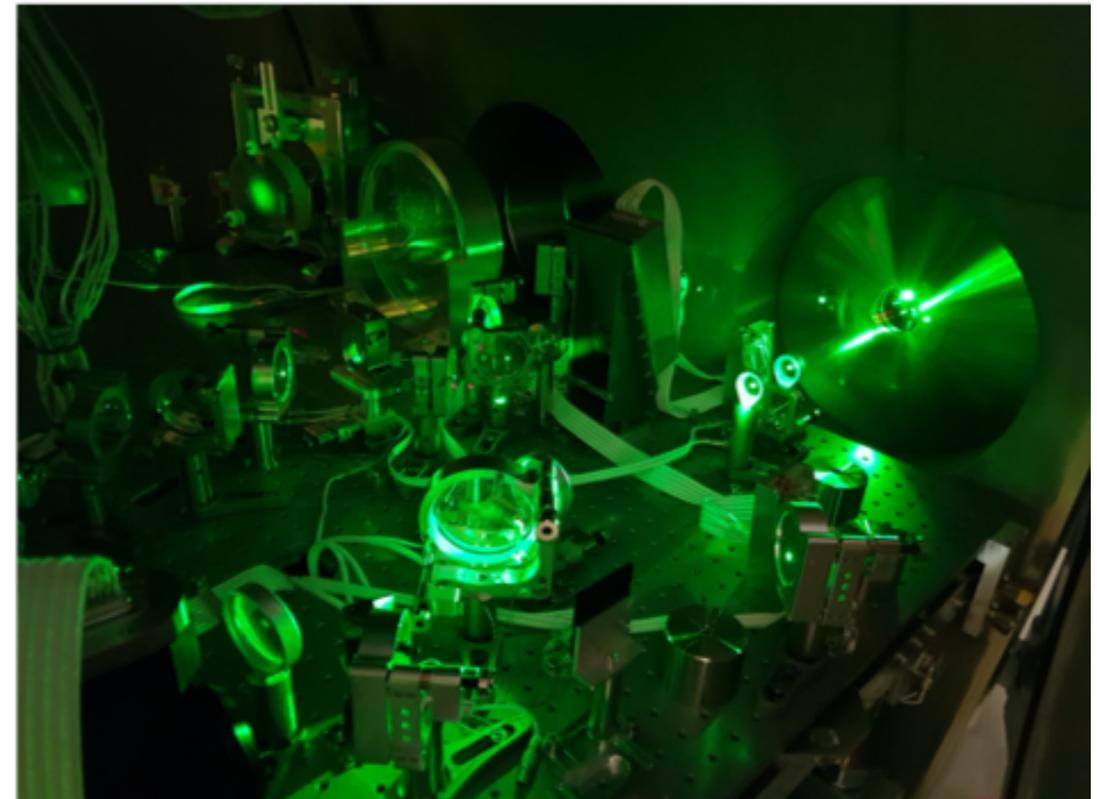
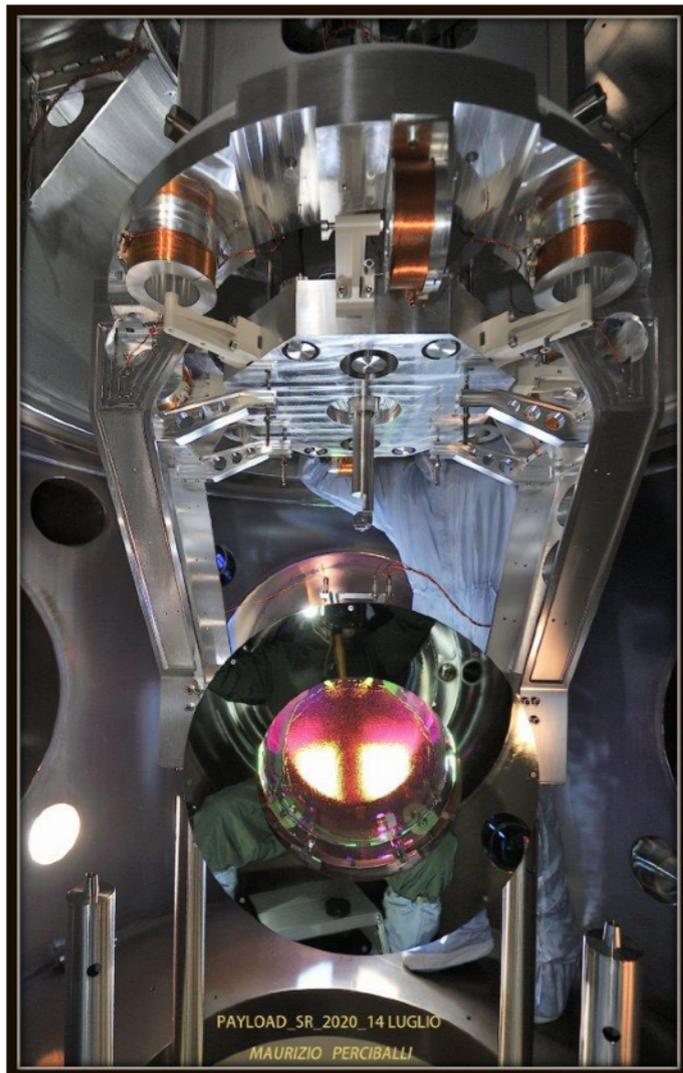
# Input Mode Cleaner: Payload and Instrumented Baffle

- Target new payload: Reduce the intra-cavity losses and improve the controllability of the system for high power operation.
- Target instrumented baffle: Measure the scattered light on the IMC end mirror and test for future baffles around the main test masses.



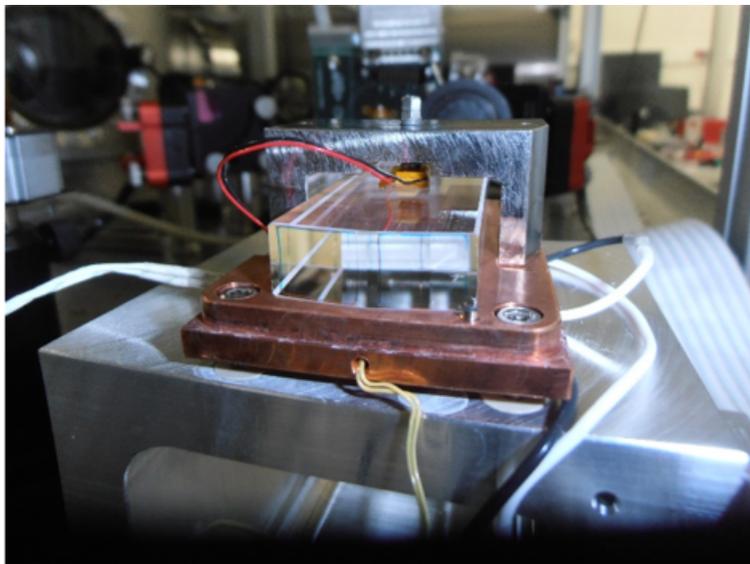
# Signal Recycling Mirror and Auxiliary Laser System

- Target signal recycling mirror: Modify and improve the sensitivity.
- Target auxiliary laser system: Control of the 3-km FP arm cavities in the first stages of the interferometer lock acquisition.



# Output Optics System Upgrades

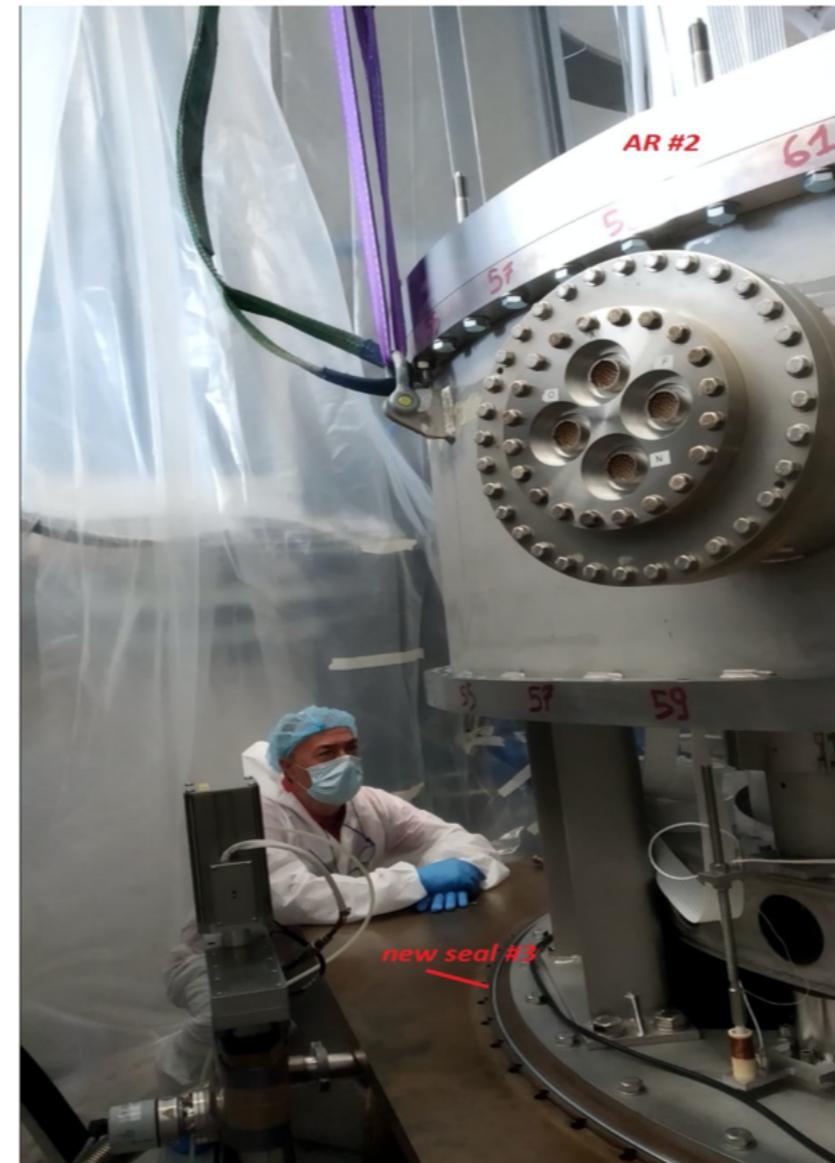
- Target new high-finesse output mode cleaner: Reduce losses at the anti-symmetric port, improve sideband filtering.
- Target scattered light mitigation: Reduce the impact of spurious and ghost beams and improve the sensitivity.



# Vacuum Upgrades

Target: Improve the vacuum level in some towers:

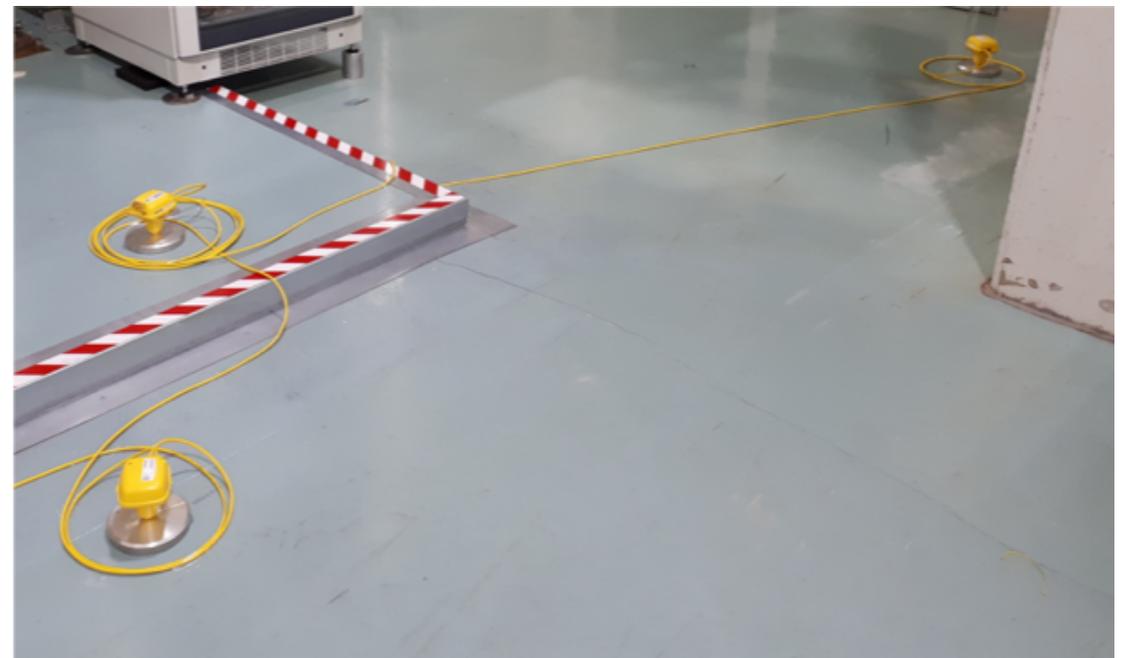
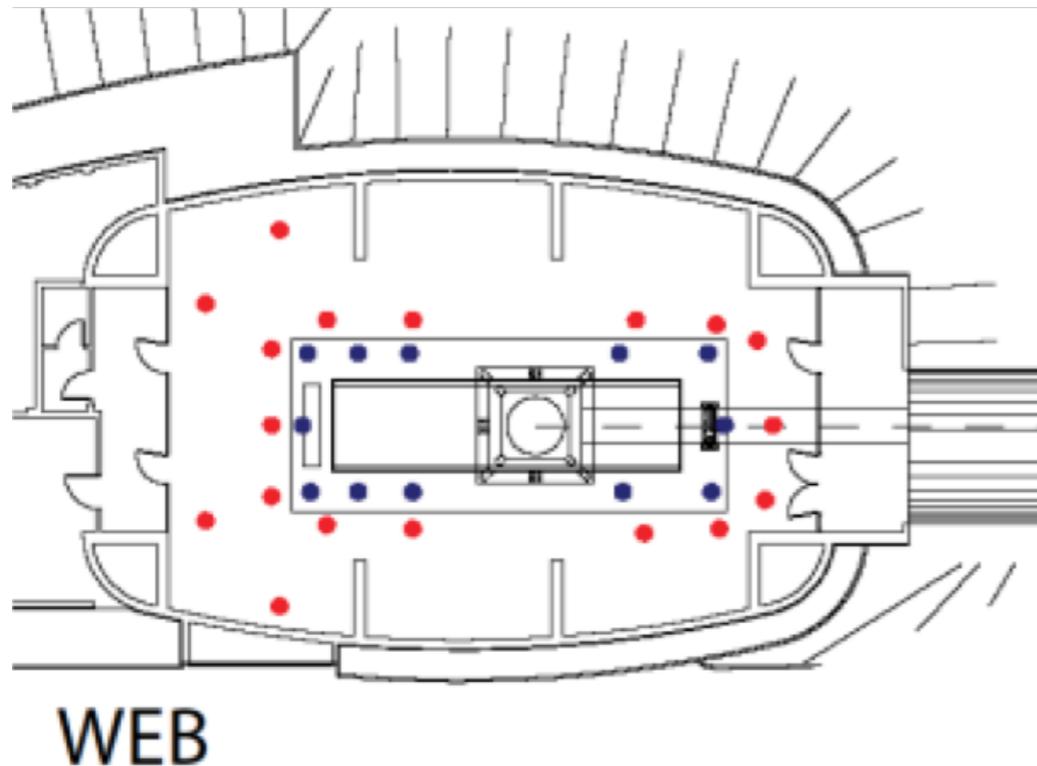
- Very small leaks have been cured;
- New system of seals installed in two towers.



# Newtonian Noise Cancellation

Target: Reduce the Newtonian noise impact by a factor 3 in the low frequency range (10-20 Hz).

- Array of seismometers installed in the experimental buildings;
- Array of microphones (not-planned at the beginning) to be installed in the next future.





# Commissioning: general overview

Commissioning phases started on 2021 January 4th

**Short-term** -> two independent systems to be commissioned:

- **Interferometer**: control of the Fabry-Perot (FP) cavities using the auxiliary green beams, control of the central interferometer (CITF) with the new SRC, control of the whole system, increase of the input power;
- **Frequency Dependent Squeezing**: recovery of the FIS with the new configuration, control of the Filter Cavity, implementation of the FDS;

**Mid-term** -> Inject the Squeezed beam into the interferometer

**Long-term** -> Noise hunting and improvements of sensitivity, stability and duty cycle

# Activities since January: Interferometer (i)

## Interferometer Sensing and Control (ISC):

- control the single FP cavities using the green auxiliary beams;
- control the central interferometer;
- approaching the control of the full interferometer;

## Auxiliary Laser System (ALS):

- finalizing the installation;
- beam pointing control system;
- investigation on residual noise;
- study of HW upgrades to improve the stability;

## Thermal Compensation System (TCS):

- Alignment sensor probes and CO<sub>2</sub> laser beam actuators;
- Fine tuning of the CO<sub>2</sub> central heating actuators;

# Activities since January: Interferometer (ii)

## Detection System (DET):

- Check of the high-power photodiodes;
- OMC alignment, matching and locking;

## Laser and Injection System (PSL & INJ):

- Re-injection of the fibered laser beam into the ITF;
- Investigation of fast unlocks;

## Optical Characterization:

- Measurement of the FP cavity losses.

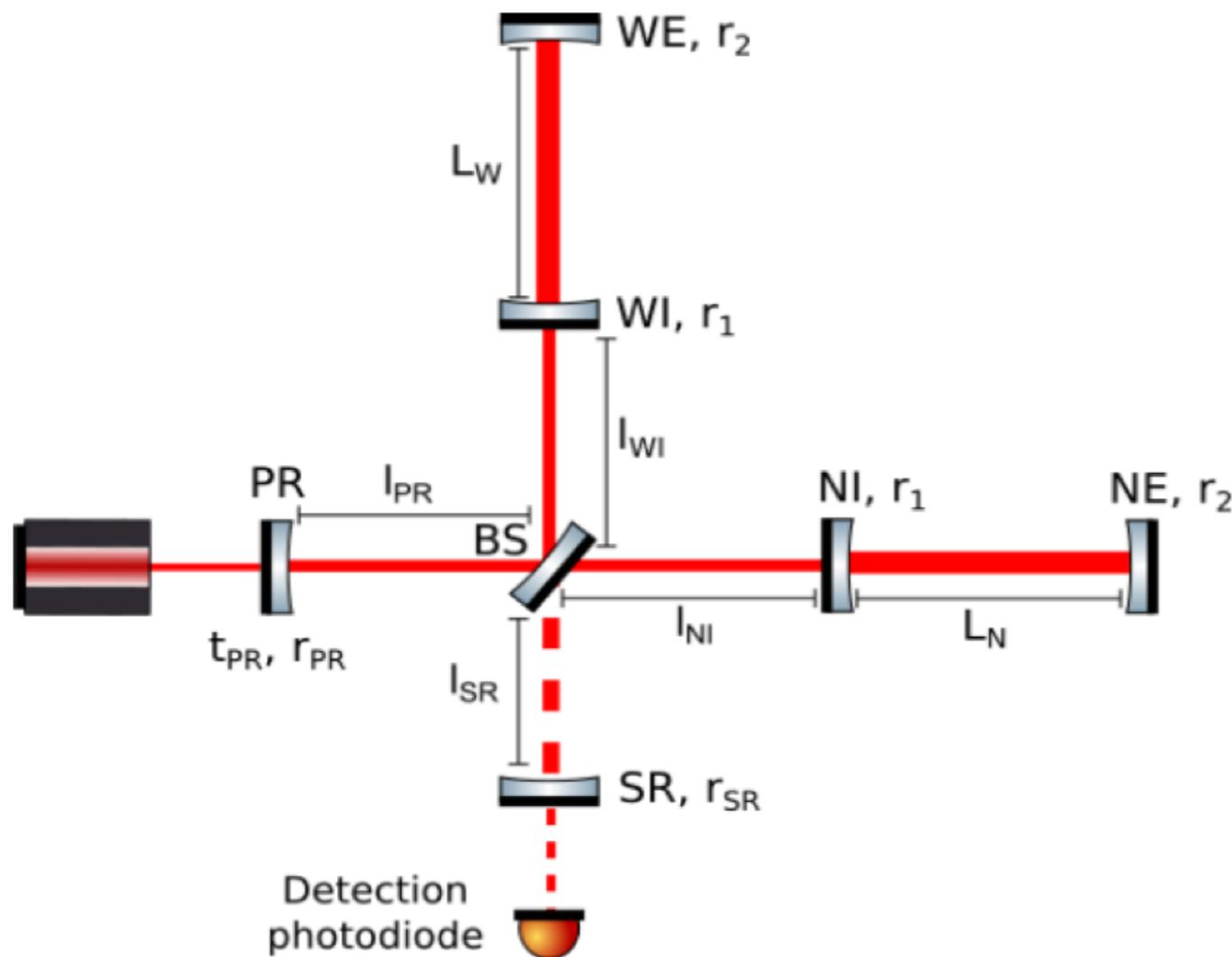
# Activities since January: Squeezing

## Frequency dependent squeezing:

- Installation concluded in April 2021;
- Pre-commissioning activities of squeezing source;
- Pre-commissioning activities of suspended benches;
- Pre-commissioning activities of filter cavity;
- Commissioning of the whole frequency dependent squeezing system started -> alignment and control of the filter cavity in progress.

# Interferometer: overview (i)

Five longitudinal degrees of freedom to be controlled



$$DARM = \frac{L_N - L_W}{2}$$

$$CARM = \frac{L_N + L_W}{2}$$

$$MICH = l_{NI} - l_{WI}$$

$$PRCL = l_{PR} + \frac{l_{NI} + l_{WI}}{2}$$

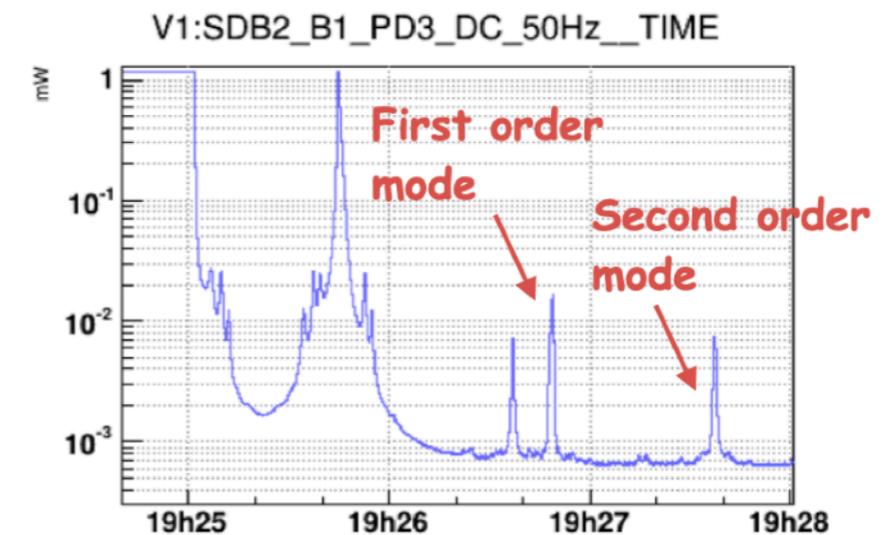
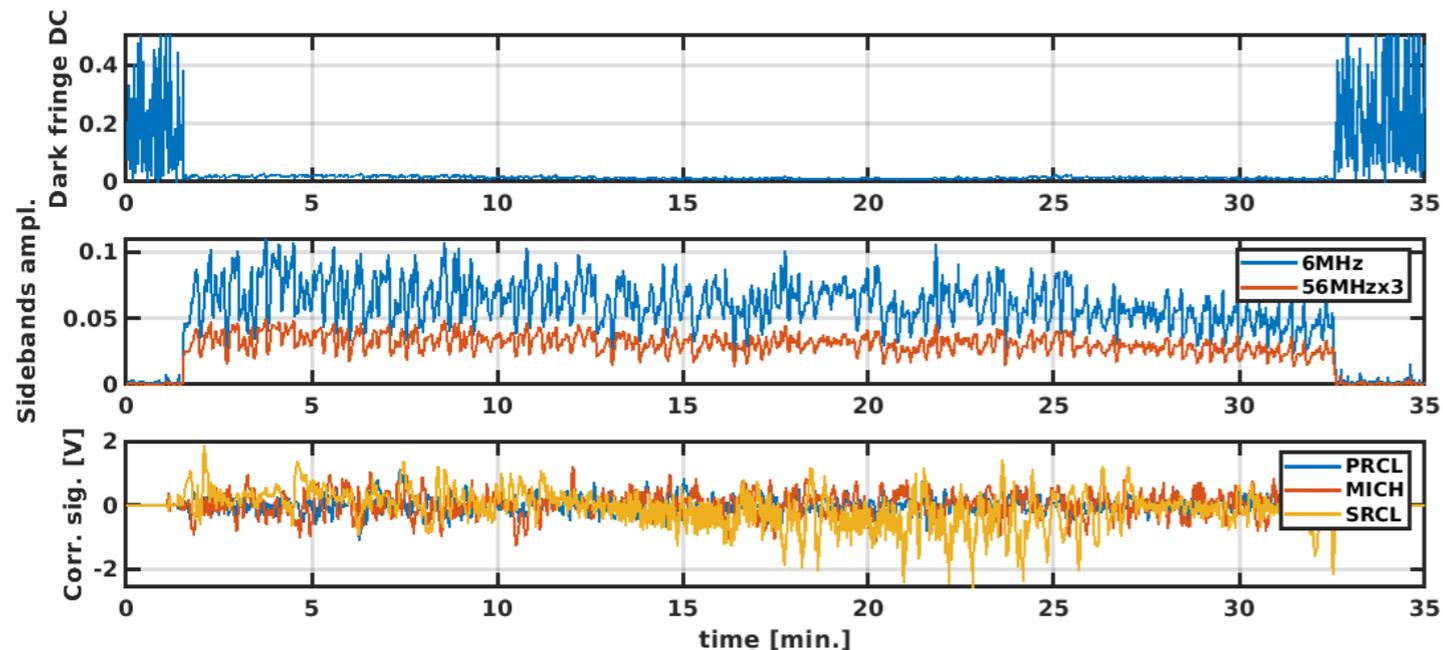
$$SRCL = l_{SR} + \frac{l_{NI} + l_{WI}}{2}$$

# Interferometer: overview (ii)

- FP arm cavities locked independently from the IR beam using green auxiliary beams -> CARM offset;
- FP arm cavities using green beams -> two beatings between green beams by the arms and a green beam generated in the central area -> frequency difference between them: beating error signal;
- Central interferometer (PRCL, MICH, SRCL) locked using the IR beam;
- Reduce the CARM offset with the central interferometer locked to have also the IR resonance for the FP arm cavities.

# Interferometer highlights

- Lock of the green laser on the FP arm cavities with and without IR beam lock;
- Central interferometer locked with the IR beam;
- CARM offset reduction in progress;
- High-finesse OMC locked and characterized.

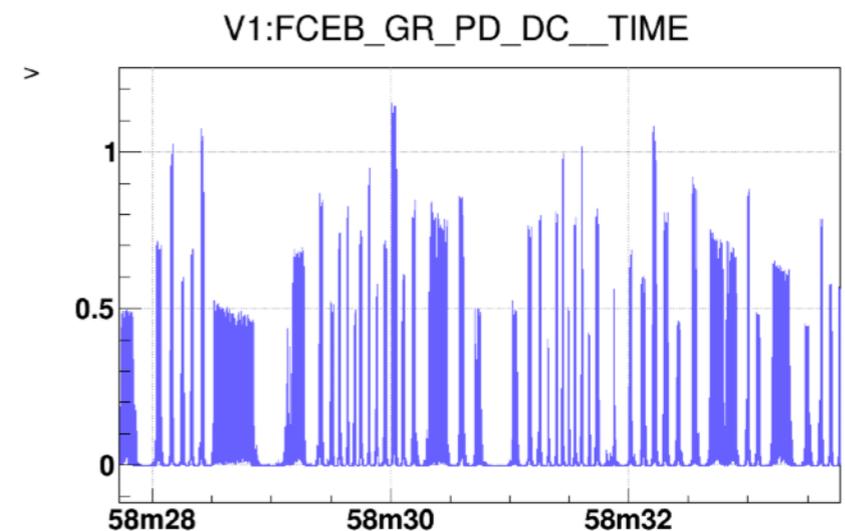
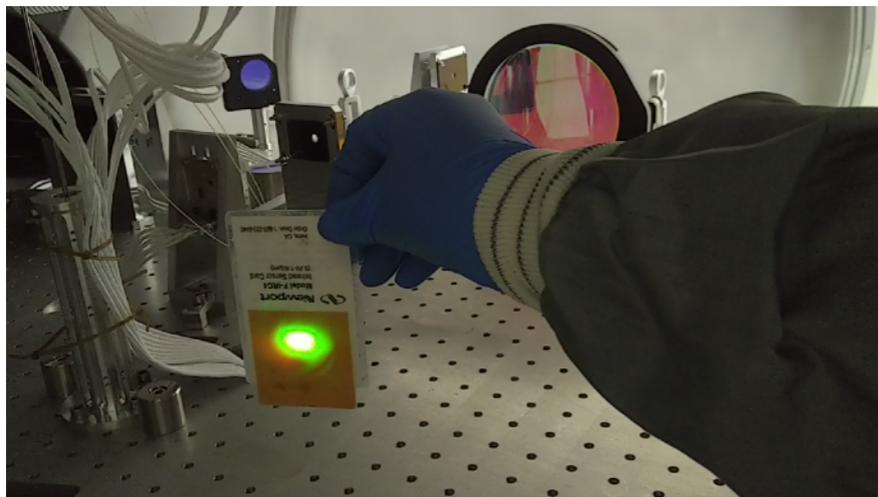
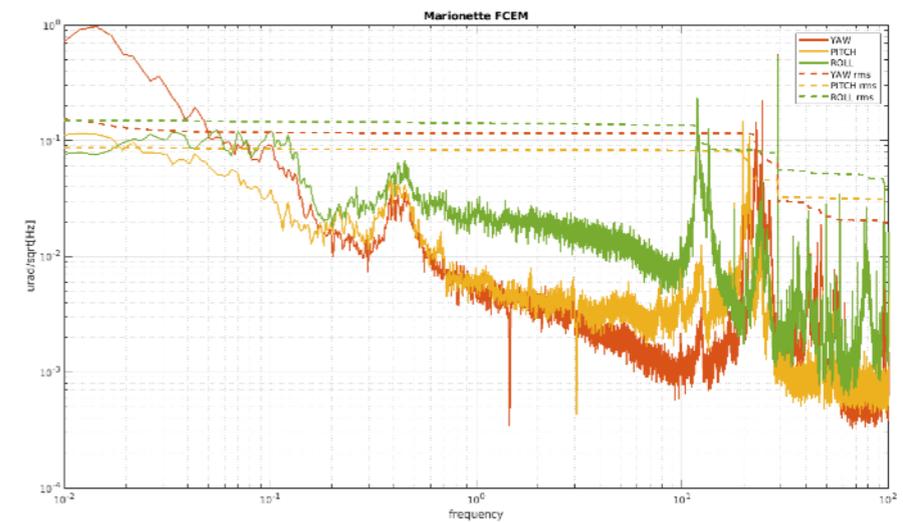
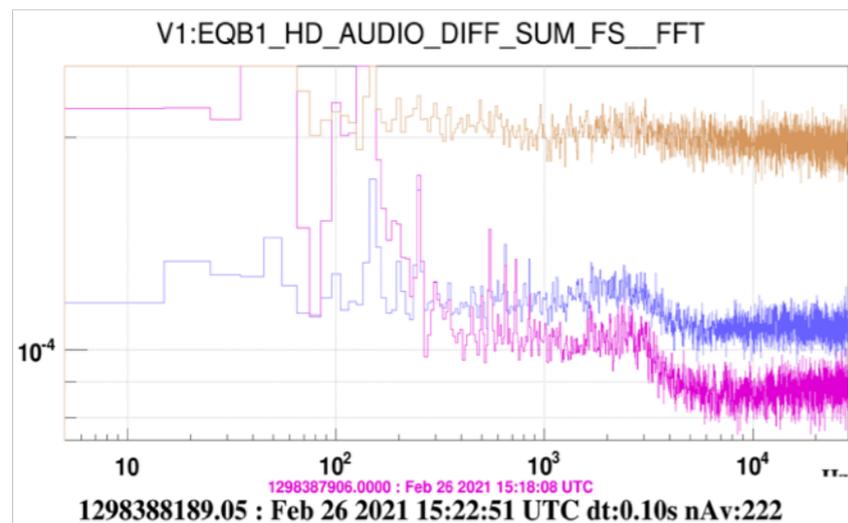


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OMC residual mismatch < 1%

# Quantum Noise reduction highlights

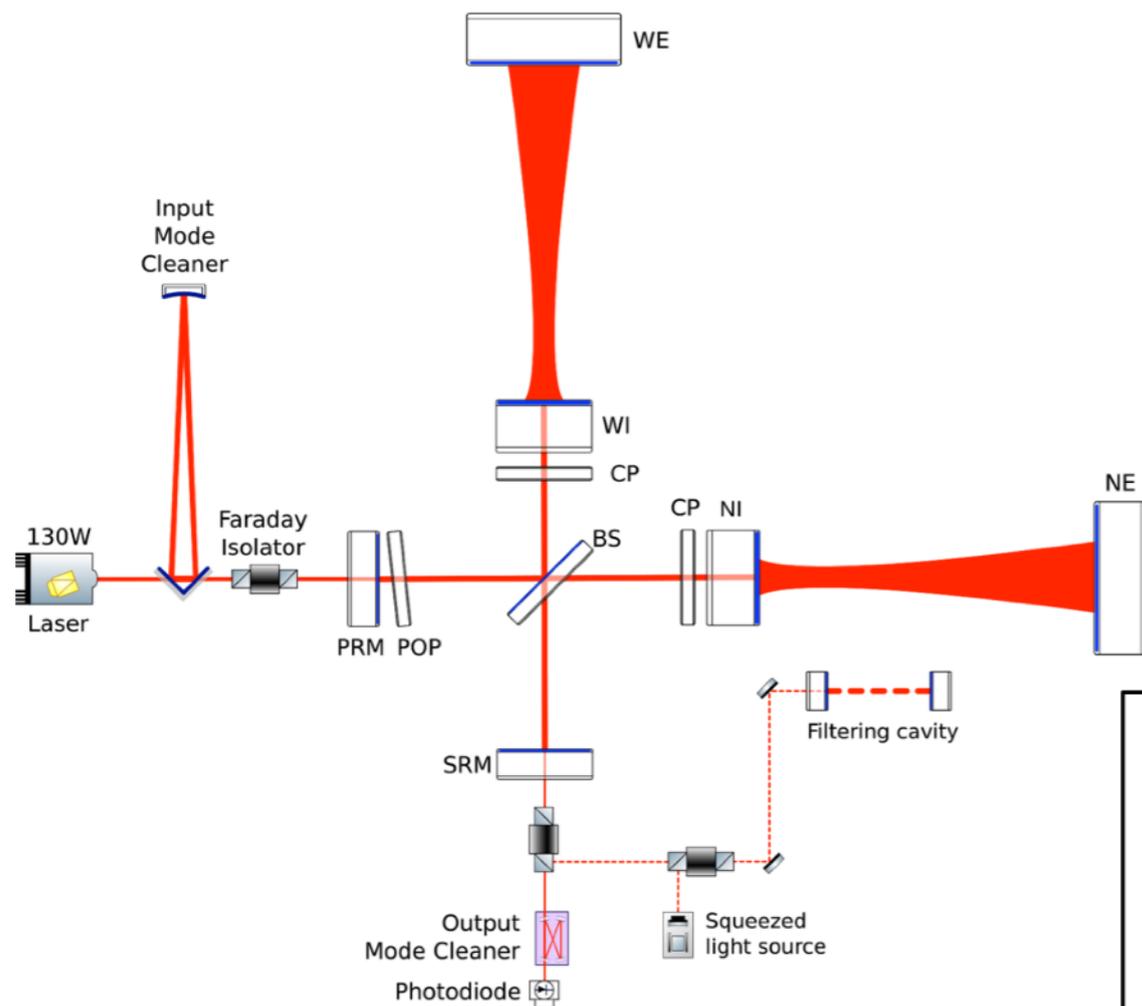
- Squeezing source characterization in progress: low SQZ level -> nonlinear optics to be replaced;
- Suspended benches and mirrors controlled in vacuum;
- Alignment of the system with green and IR beams in progress;
- Control algorithms implementation in progress.



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# Advanced Virgo Plus Phase II highlights

- Optical design almost done;
- Technical Design Report in progress;
- Large mass prototype successfully suspended.



# Conclusions & Next Steps

- AdV+ phase I installation completed;
  - AdV+ commissioning started on January 4th;
  - FP arm cavities locked independently using the green beam;
  - Central interferometer locked using the IR beam;
  - Work on the full interferometer control in progress;
  - High-finesse OMC characterization completed;
  - Commissioning of the QNR system started
  - AdV+ phase II design and first prototypes in progress.
- 
- Lock of the full interferometer;
  - Increase the input power;
  - Noise hunting to improve sensitivity and stability;
  - AdV+ phase II design and construction.

**TARGET: lock the whole interferometer and produce sensitivity curve in the next few weeks**