The status of Virgo

Raffaele Flaminio

CNRS/LAPP

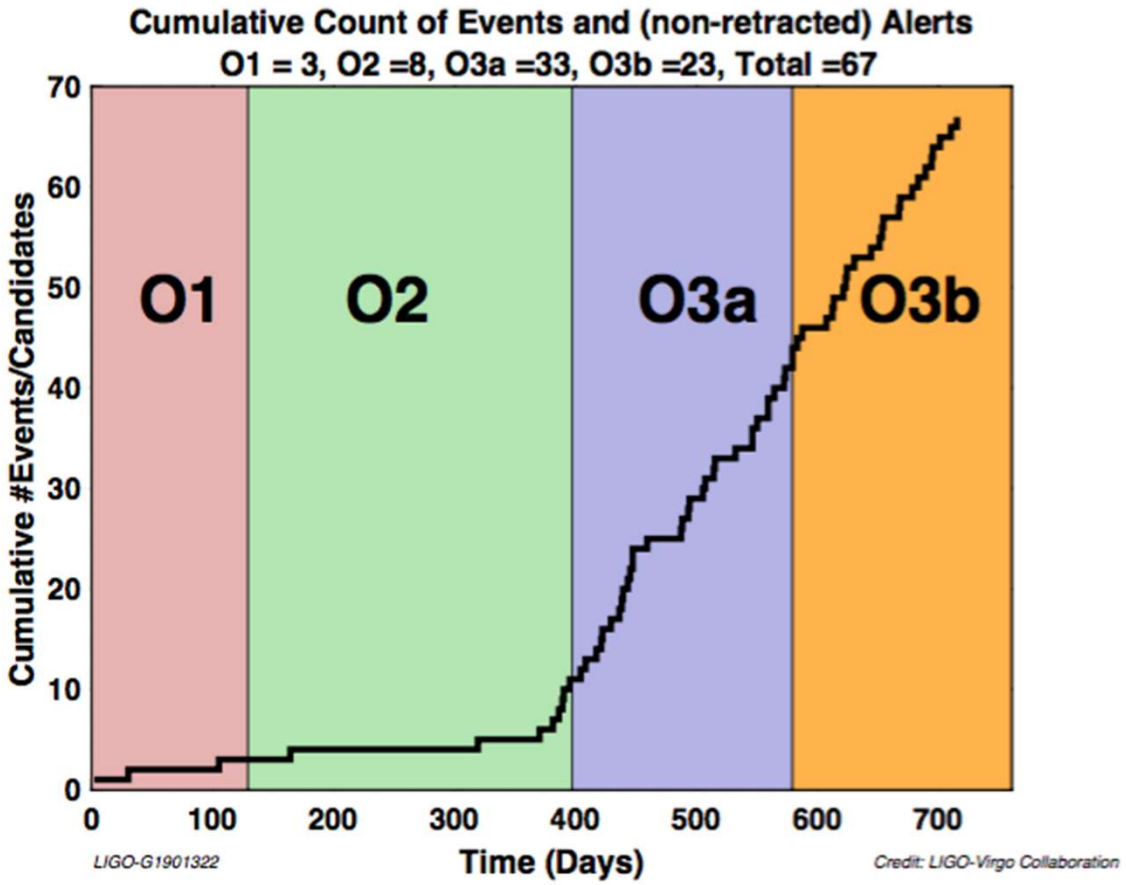
On behalf of the Virgo Collaboration

Science highlights

O3

O3 ended on March 27th, 2020

- 1 month earlier due to COVID
- 56 alerts issued during O3



GW transients catalog - 2

First six months of data analyzed

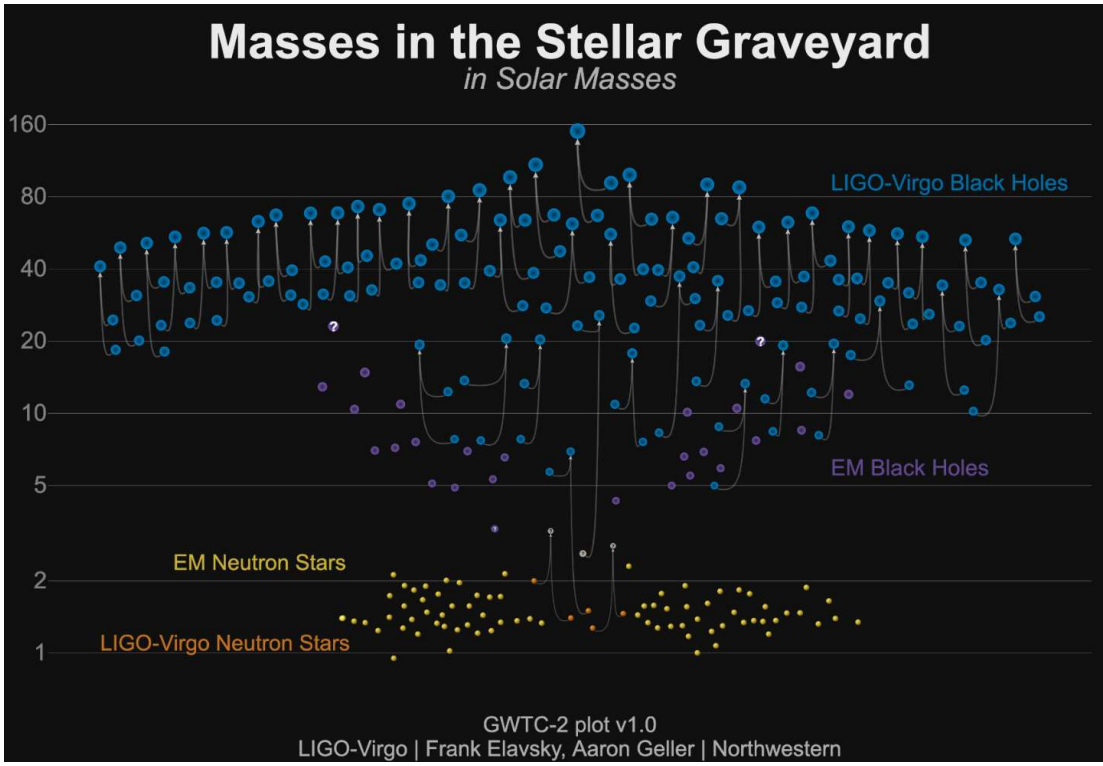
GWTC-2 released in October 2020

Several exceptional events published

GW190412: first asymmetric BBH, evidence for higher harmonics

GW190425: the second BNS merger

GW190521: a BBH with total mass over 150 times the mass of the Sun



GW190814: The most asymmetric mass ratio merger ever observed (m1/m2 = 9). The secondary mass of 2.6 Msun lies in the lower 'mass gap' $\Rightarrow$ either the lightest BH or the heaviest NS ever observed!

First observation of NS-BH mergers

The Astrophysical Journal Letters, 915:L5 (24pp), 2021 July 1 https://doi.org/10.3847/2041-8213/ac082e

Observation of Gravitational Waves from Two Neutron Star–Black Hole Coalescences

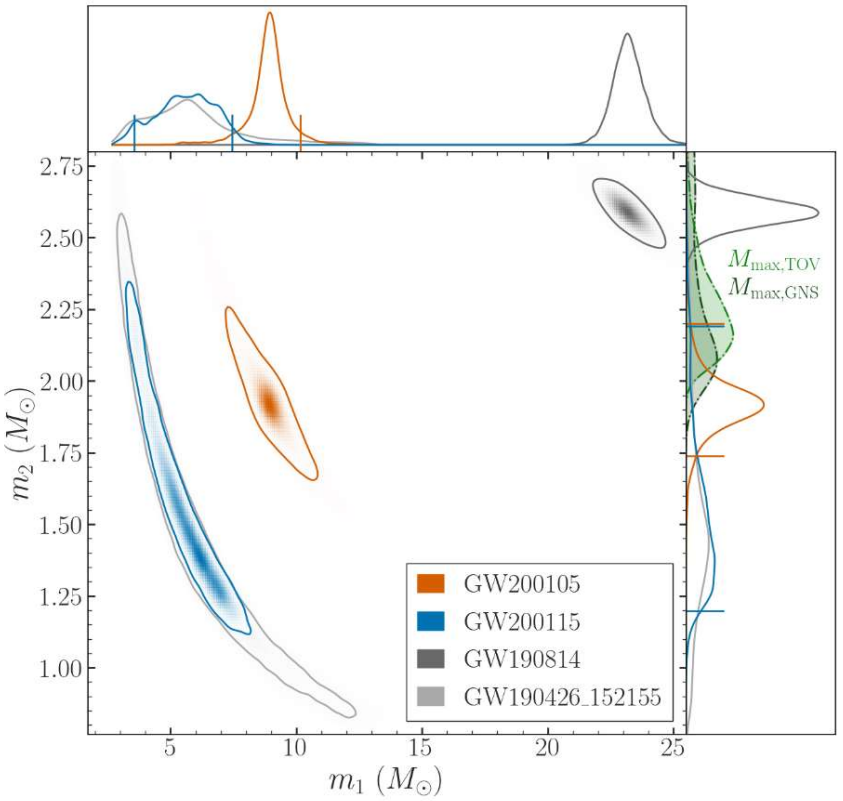
R. Abbott[1], T. D. Abbott[2], S. Abraham[3], F. Acernese[4,5], K. Ackley[6], A. Adams[7], C. Adams[8], R. X. Adhikari[1], V. B. Adya[9], C. Affeldt[10,11], D. Agarwal[3], M. Agathos[12,13], K. Agatsuma[14], N. Aggarwal[15], O. D. Aguiar[16], L. Aiello[17,18,19], A. Ain[20,21], P. Ajith[22], T. Akutsu[23,24], K. M. Aleman[25], G. Allen[26], A. Allocca[5,27], P. A. Altin[9], A. Amato[28], S. Anand[1], A. Ananyeva[1], S. B. Anderson[1], W. G. Anderson[29], M. Ando[30,31], S. V. Angelova[32], S. Ansoldi[33,34], J. M. Antelis[35], S. Antier[36], S. Appert[1],

GW200105

- 8.9 - 1.9 M⊙
- 170 -390 Mpc
- Livingston-Virgo
- 7700 deg2

GW200115

- 5.7 - 1.5 M⊙
- 240 - 400 Mpc
- Hanford-Livingston-Virgo
- 900 deg2



Collaboration organization

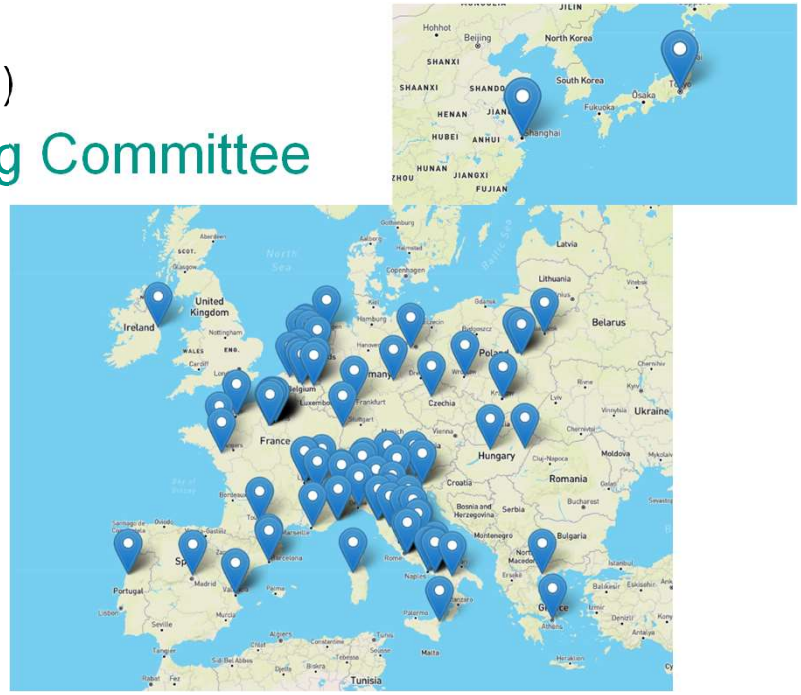
The Virgo Collaboration

~690 members, ~450 authors, 126 institutions from 15 countries

33 Groups:

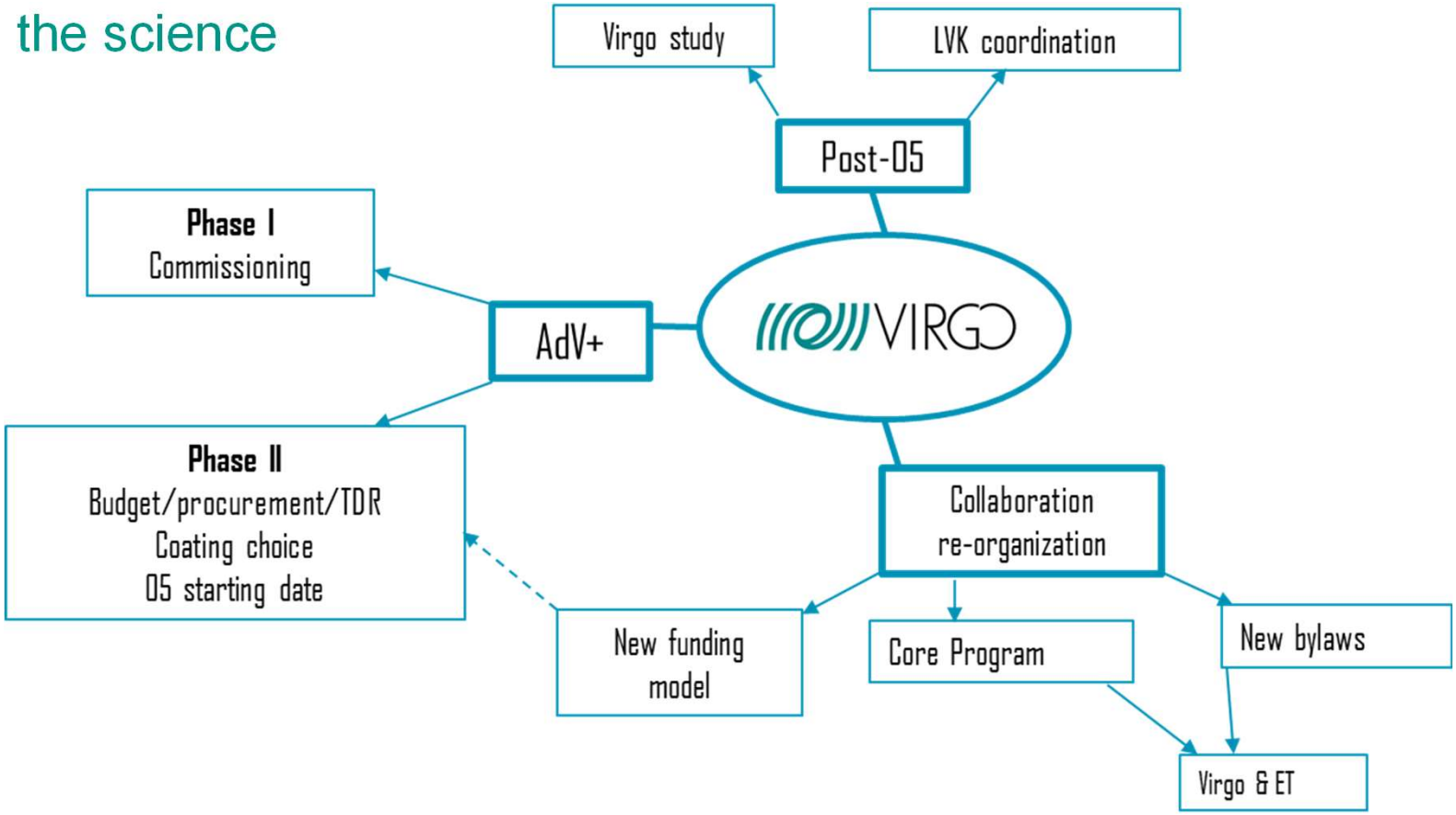
- 29 full members
- 4 in the first year (AUTh, VU, LUTH-CAEN, IFT Madrid)

9 countries represented in the Virgo Steering Committee



Main open points

Apart from the science



Virgo Organization Committee (VOC)

Toward a new statute for the collaboration

Phase 1&2: first report released, setting the stage for a new statute

Moving to Phase 3: drafting the bylaws

Final approval hopefully in fall

Main points addressed:

Membership

Governance

Organization

Collaboration life

Diversity

Virgo is committed to pursue a policy of inclusion. Several actions put in place so far

Virgo has signed the ECFA/Appec/Nuppec Diversity charter

Diversity Chair permanently invited to Virgo Steering Committee - wide

Diversity session routinely scheduled in Virgo weeks

Increasing attention to gender balance in committees and responsibility roles (e.g. VOC, post-O5 committee)

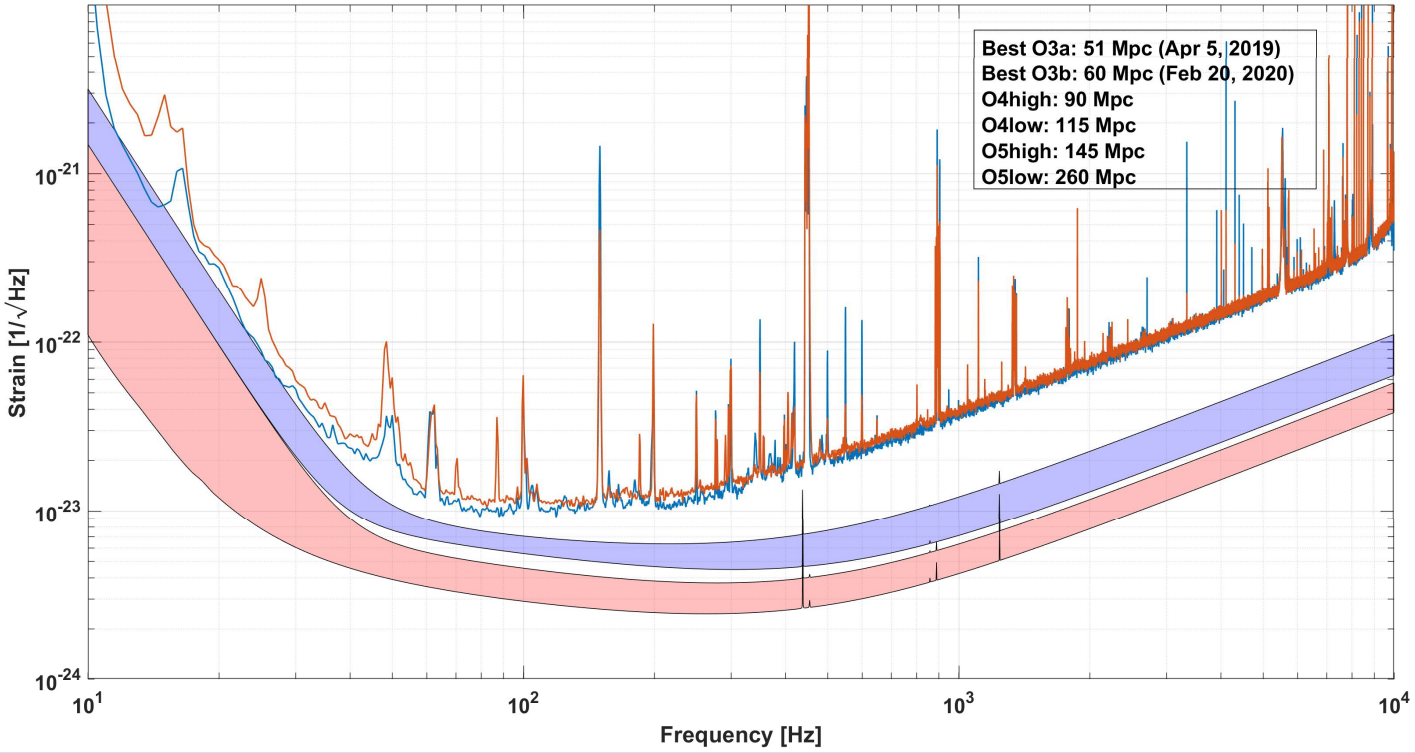
Still a long way to walk, but strongly motivated to do so

Detector status and plans

Advanced Virgo+ design sensitivity

Phase I: reduce quantum noise, hit against thermal noise. BNS range: 100 Mpc's

Phase II: lower the thermal noise wall. BNS range: 200 Mpc's or more



Advanced Virgo+: content & schedule

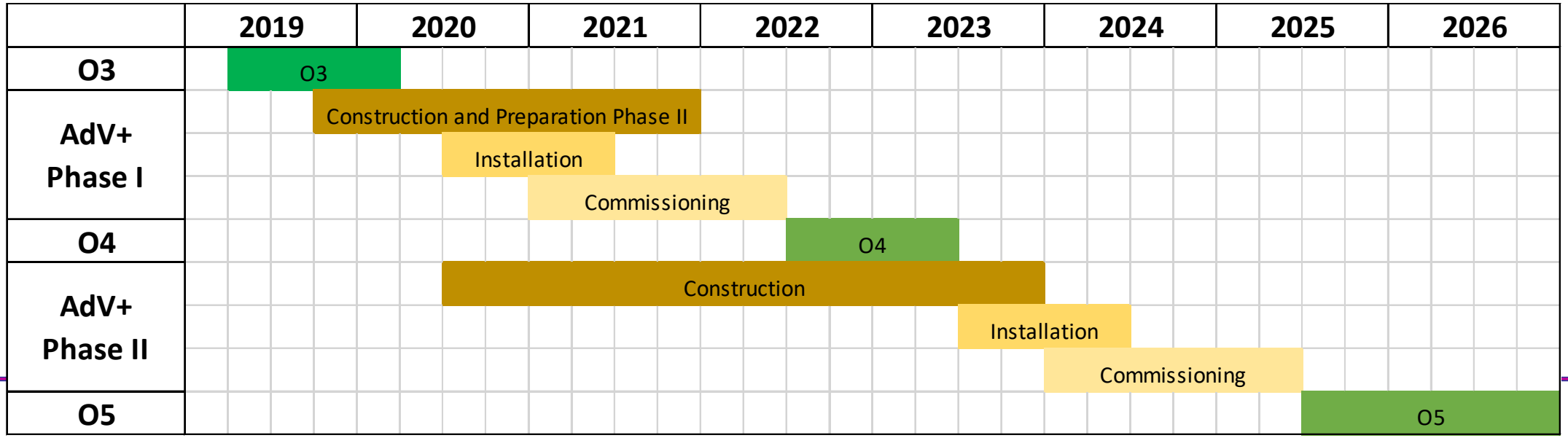
Two phases project

Phase I (before O4 run/2022)

- » Mainly an upgrade to reduce quantum noise: no mirrors change
- » Reduction of technical noises
- » Preparation of Phase II

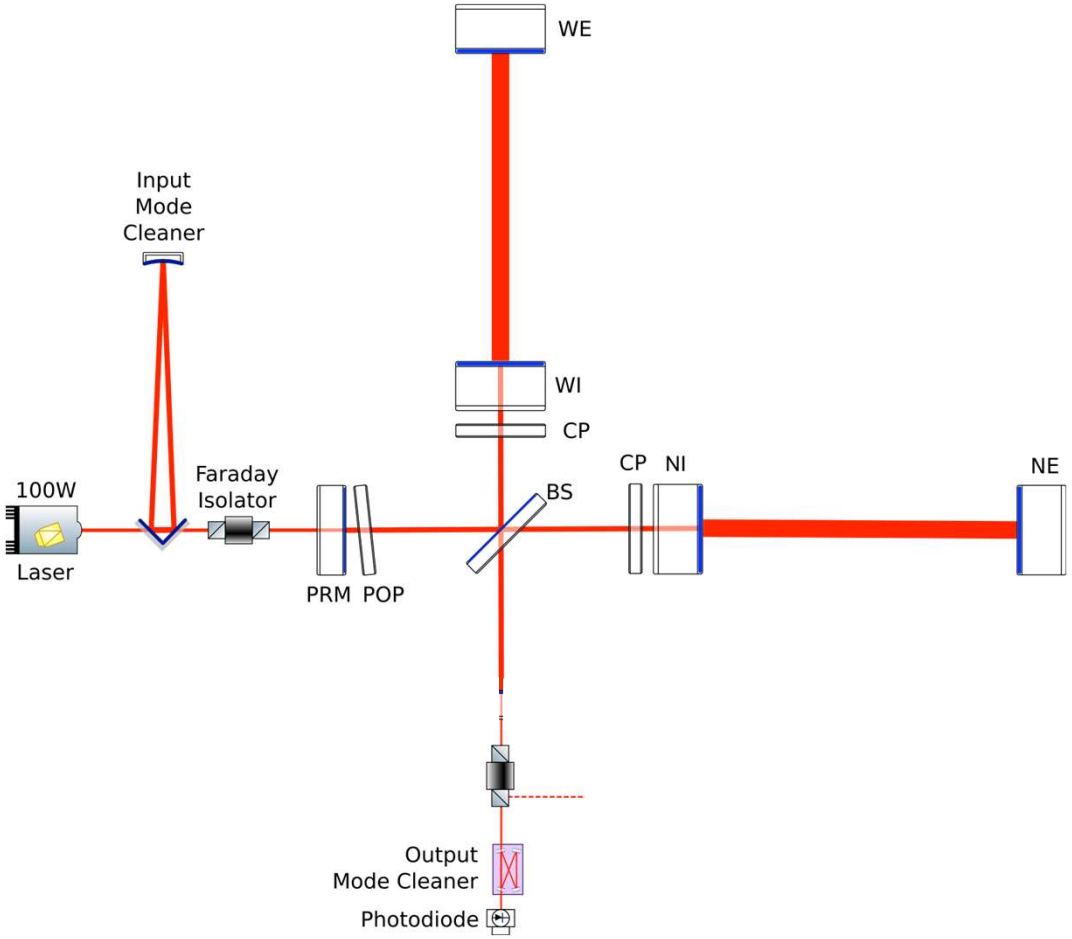
Phase II (before O5 run/2025)

- » More invasive upgrade to reduce thermal noise: mirrors change

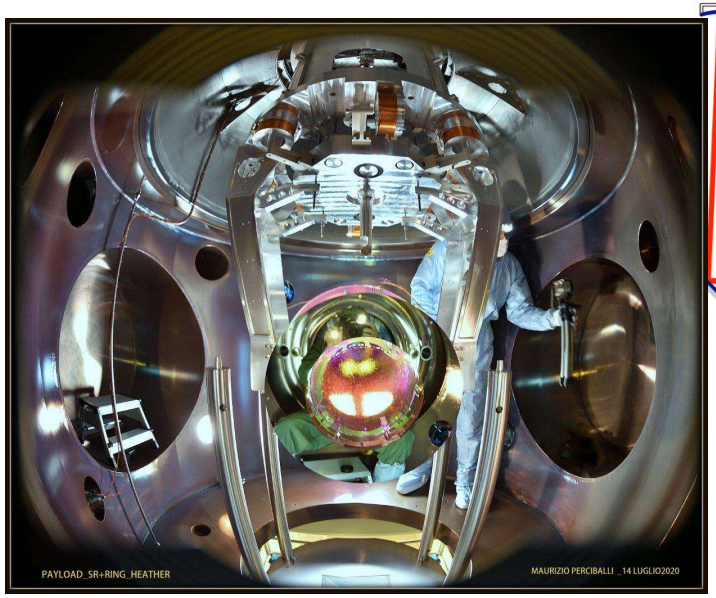


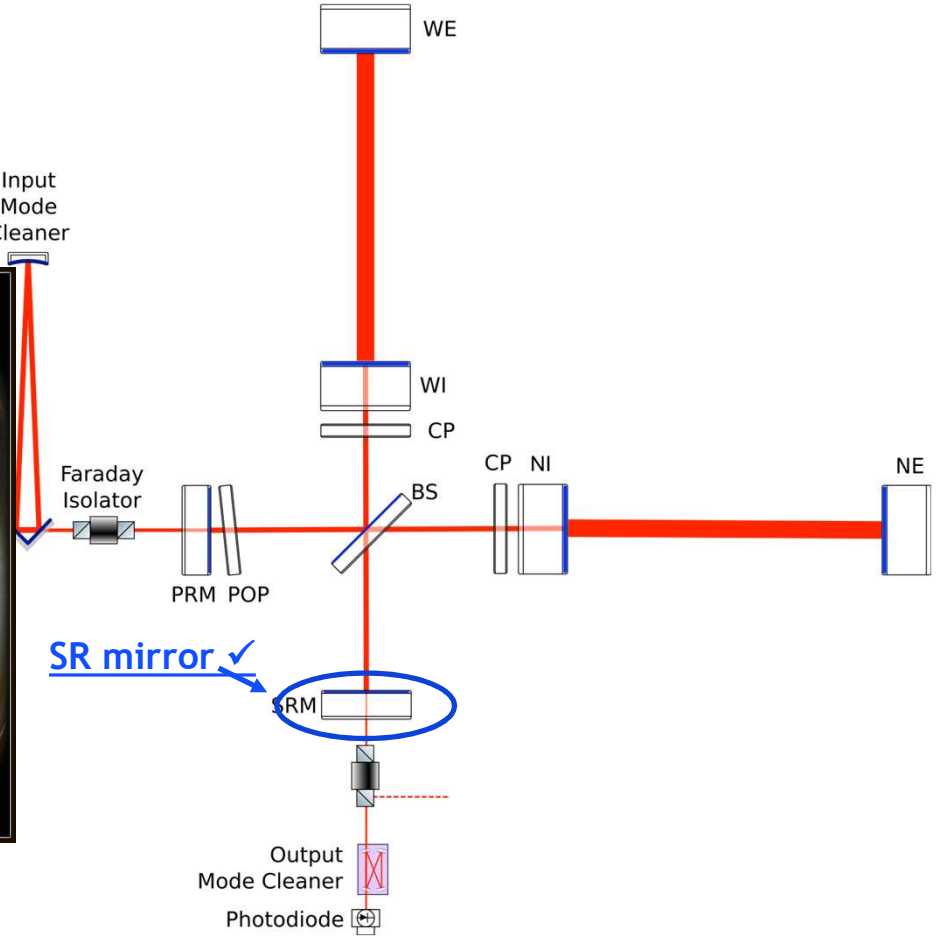
AdV+ Phase I: status

Advanced Virgo+ Phase I

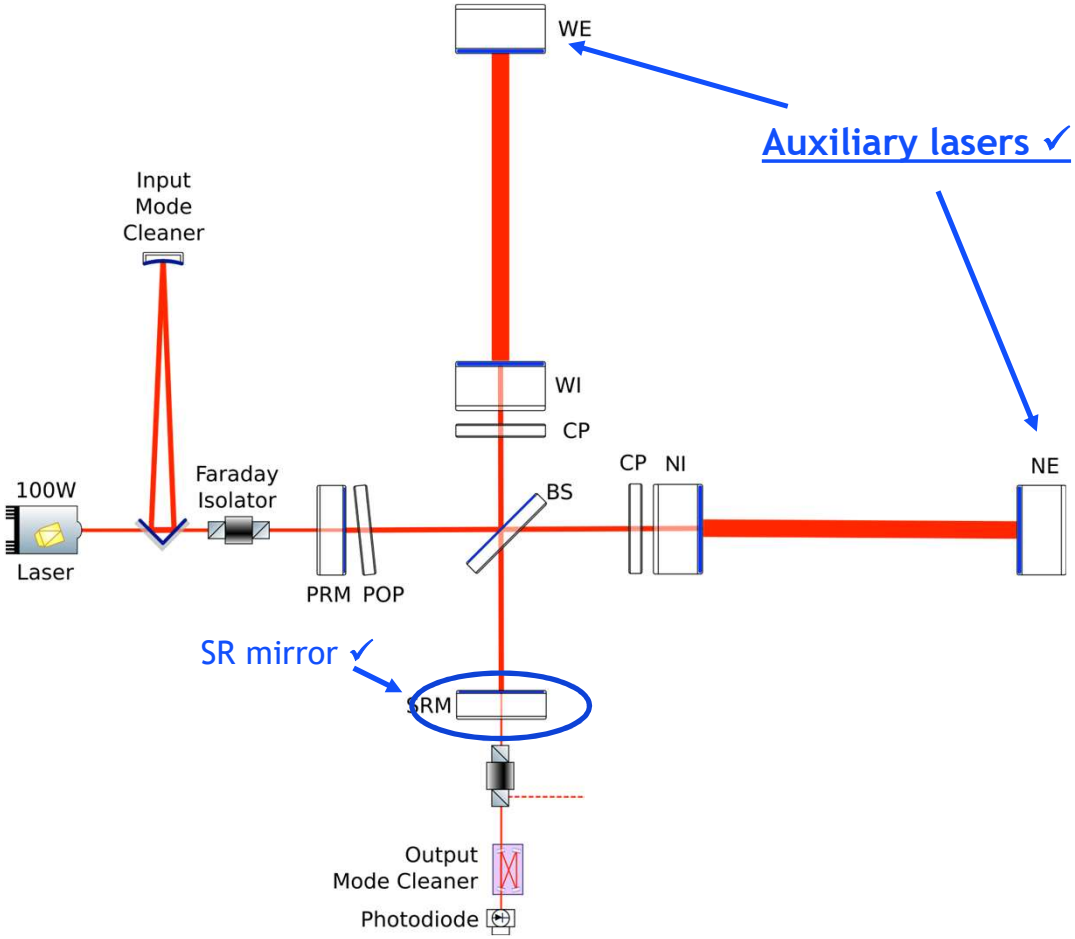


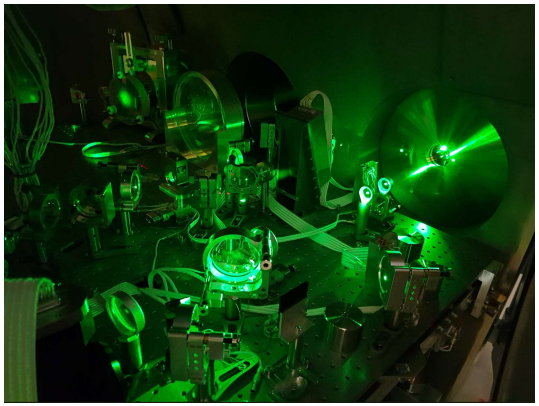
Advanced Virgo+ Phase I

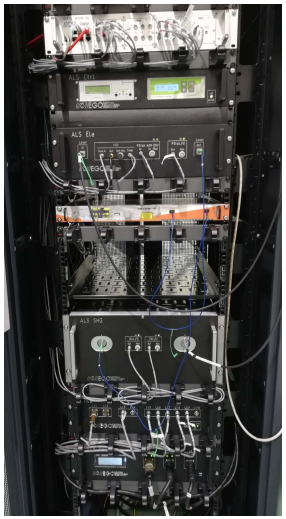




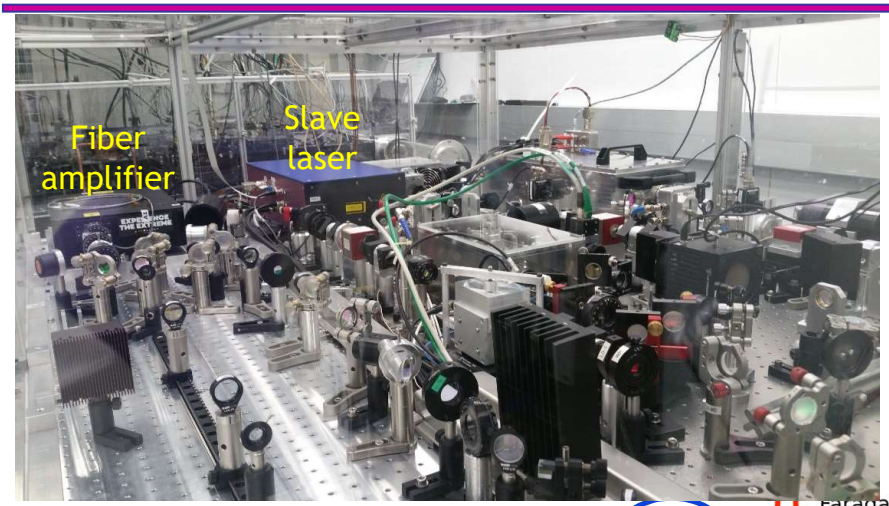
Advanced Virgo+ Phase I



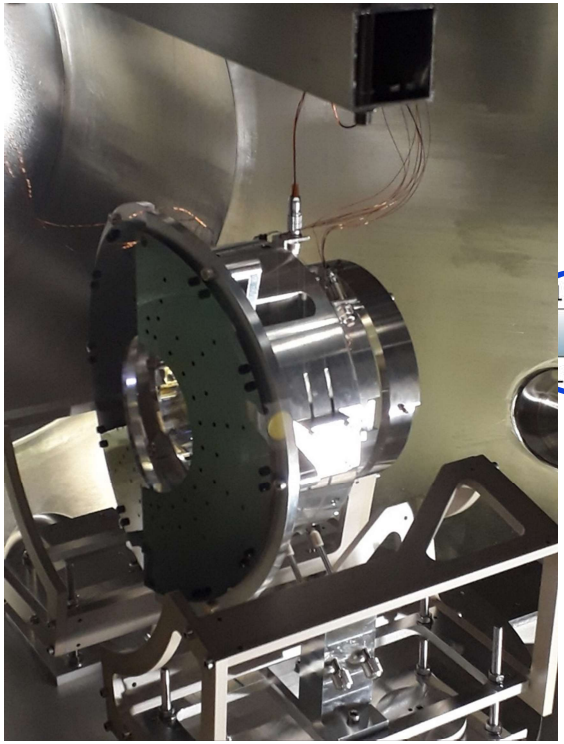


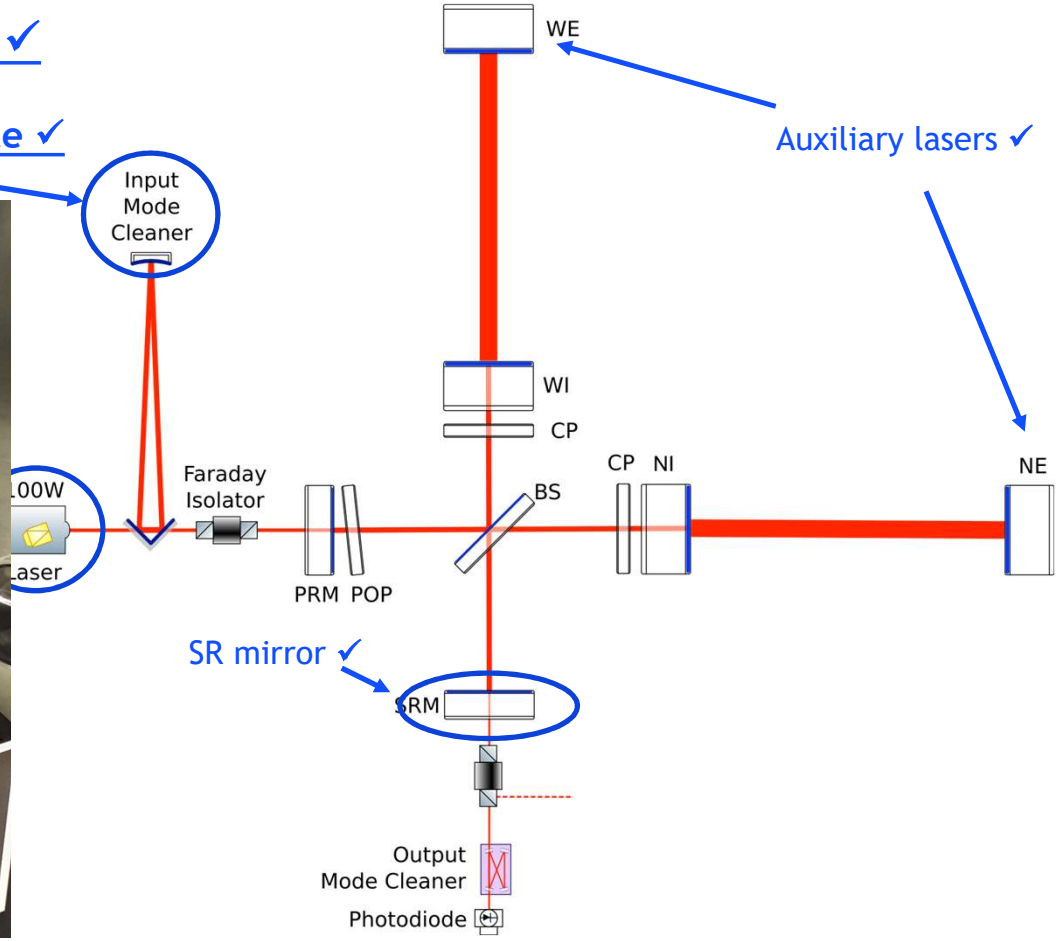


Advanced Virgo+ Phase I



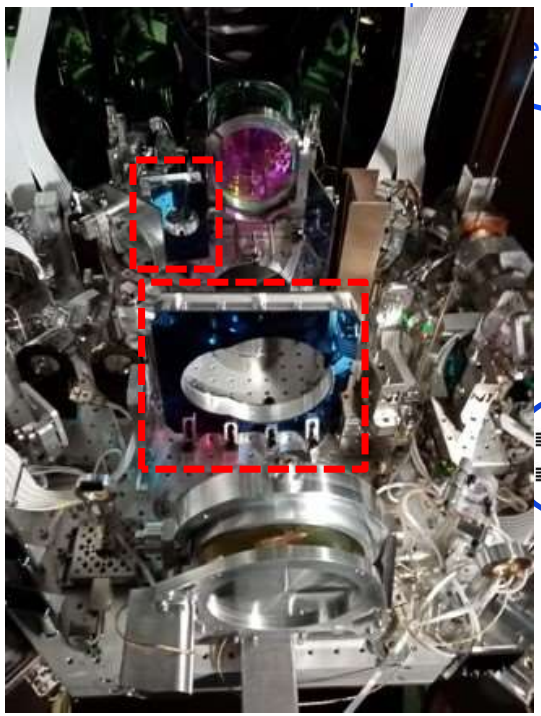
Advanced Virgo+ Phase I





Advanced Virgo+ Phase I

New IMC payload ✓

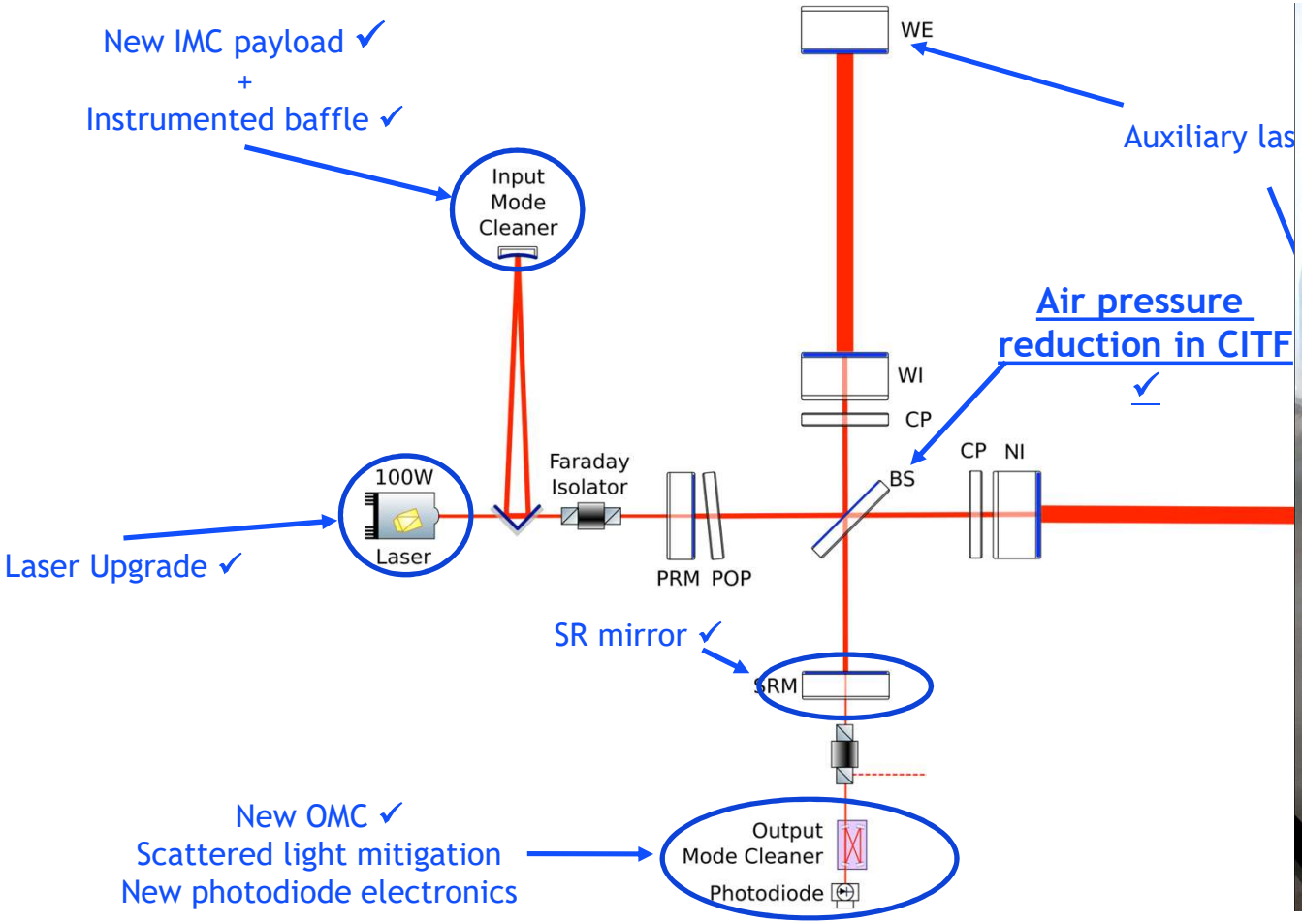


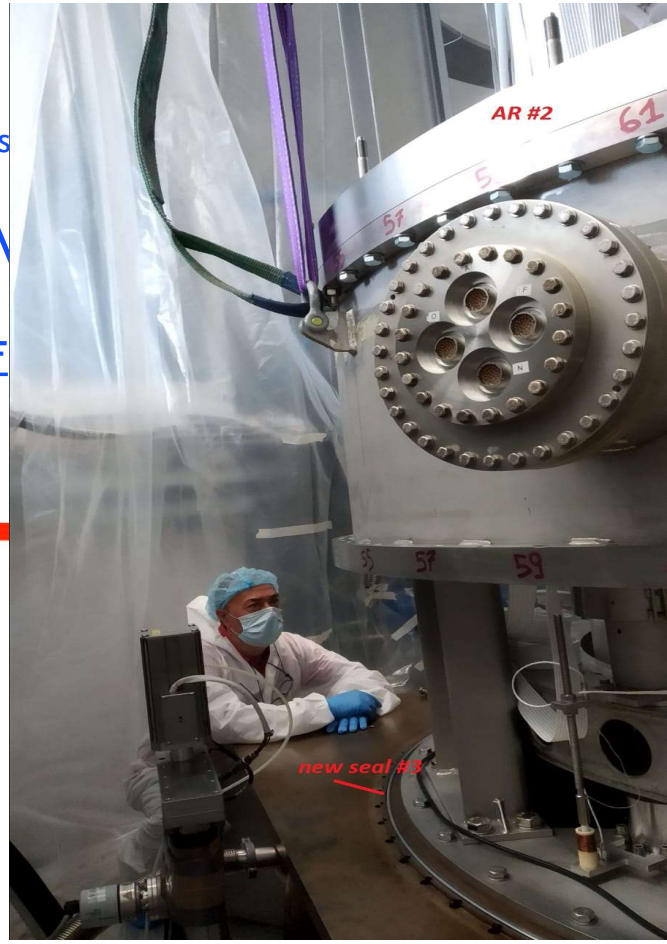
New OMC ✓

Scattered light mitigation ✓

New photodiode electronics ✓

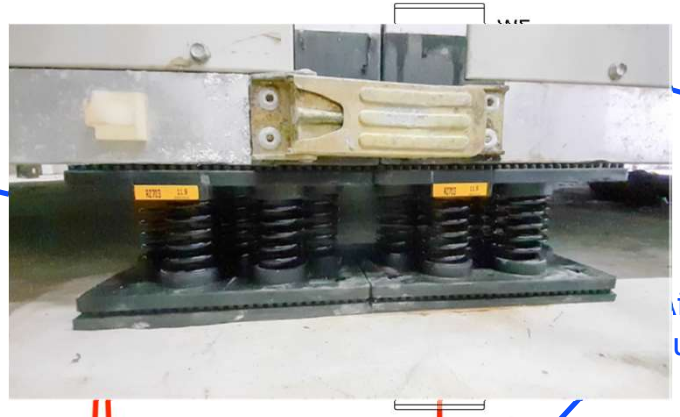
Advanced Virgo+ Phase I





Advanced Virgo+ Phase I

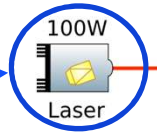
New IMC payload ✓
+
Instrumented baffle ✓



Auxiliary lasers ✓

HVAC noise reduction ✓

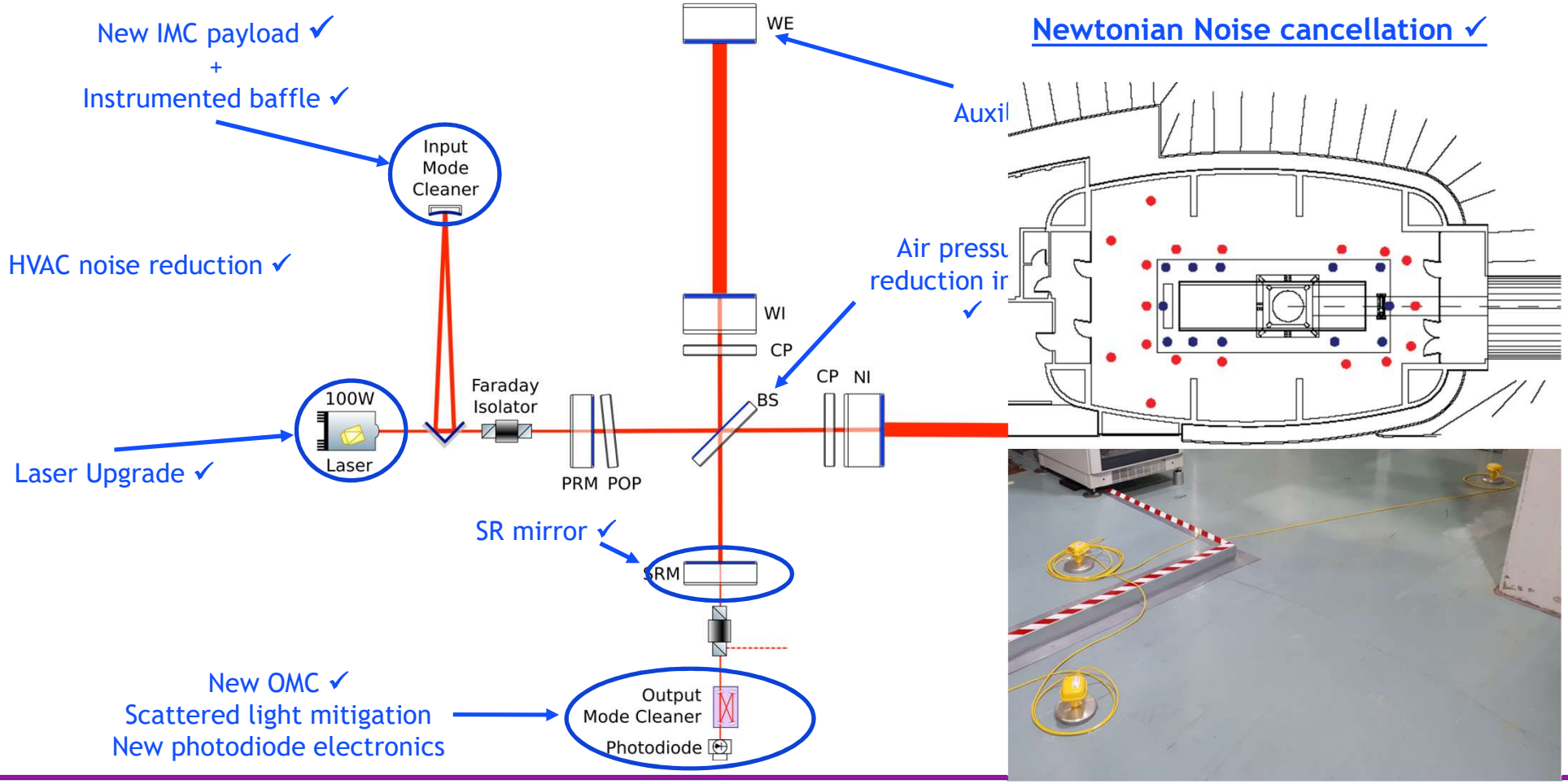
ir pressure
uction in CITF
✓



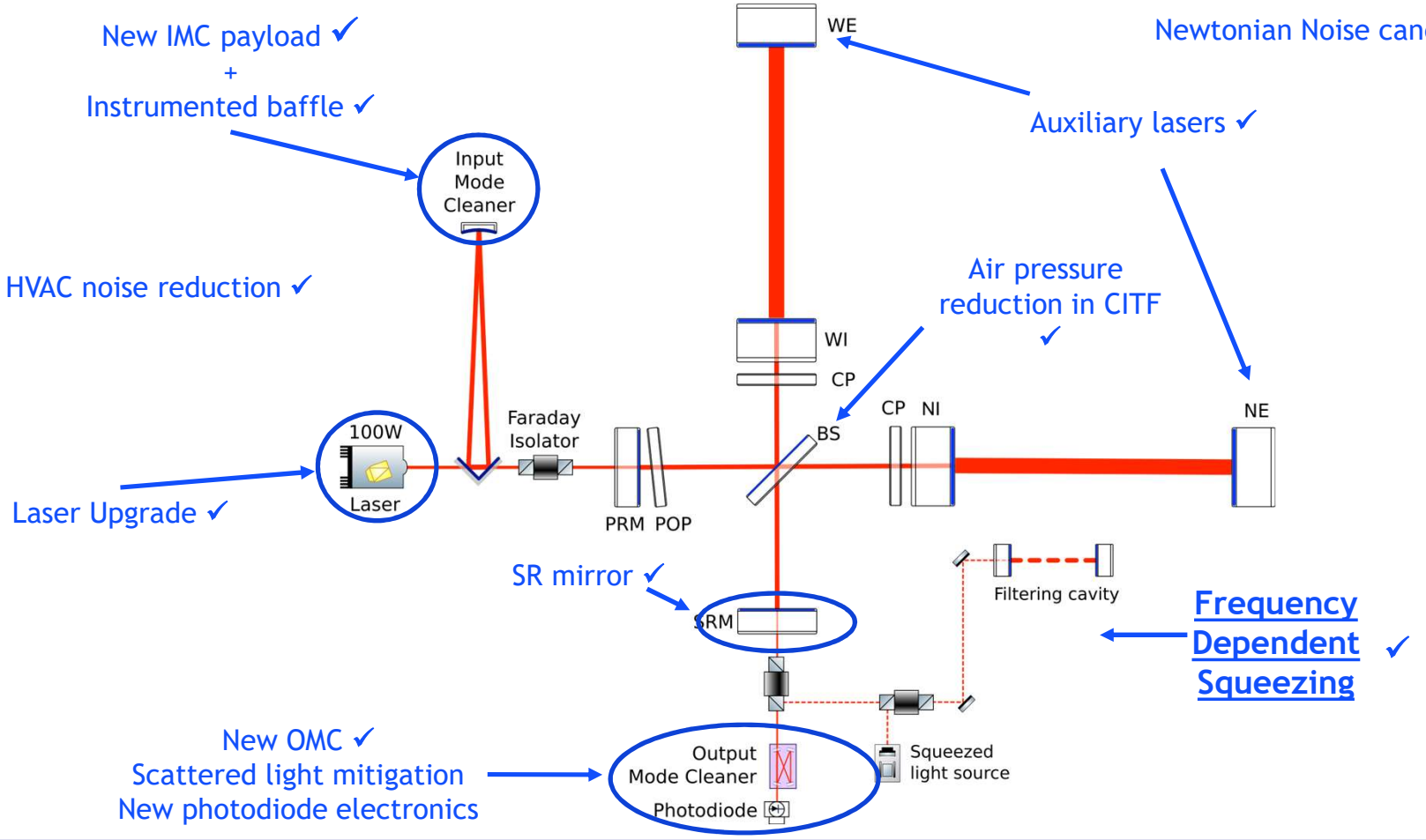
Laser Upgrade ✓

New OMC ✓
Scattered light mitigation
New photodiode electronic

Advanced Virgo+ Phase I

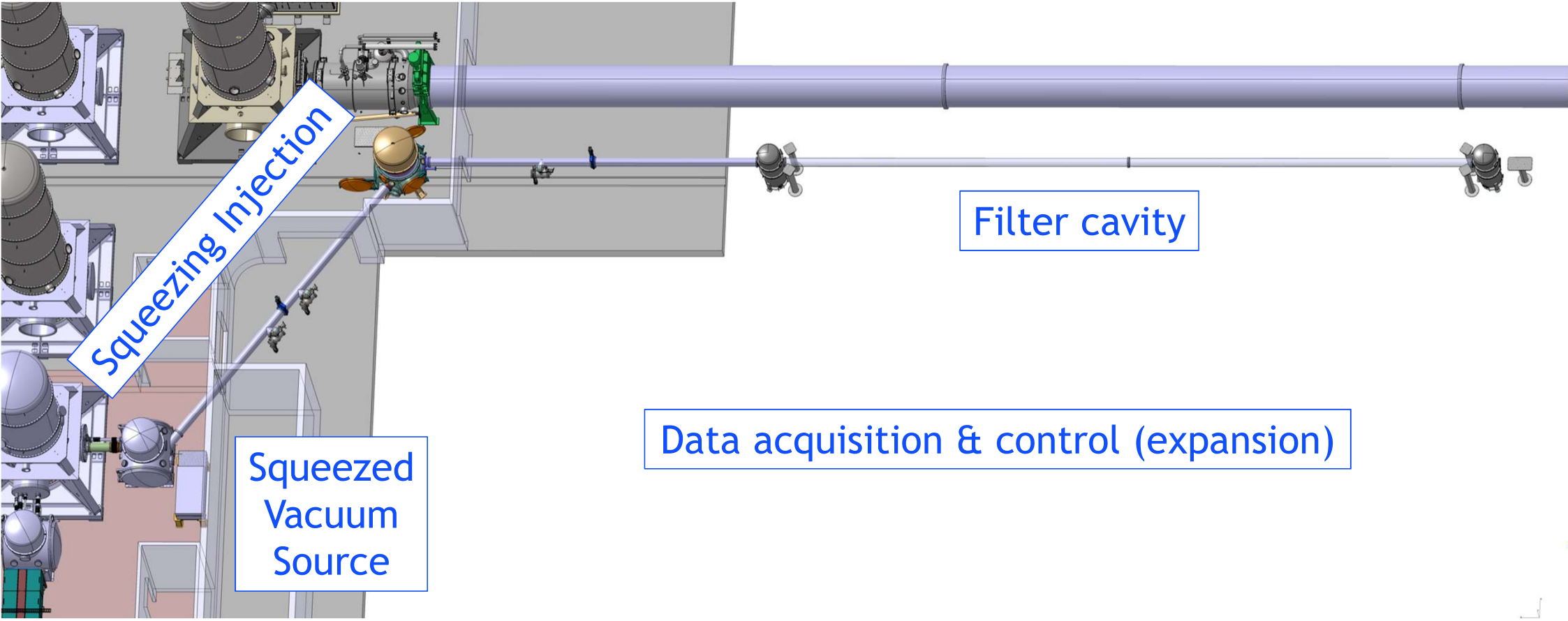


Advanced Virgo+ Phase I



Quantum noise reduction system

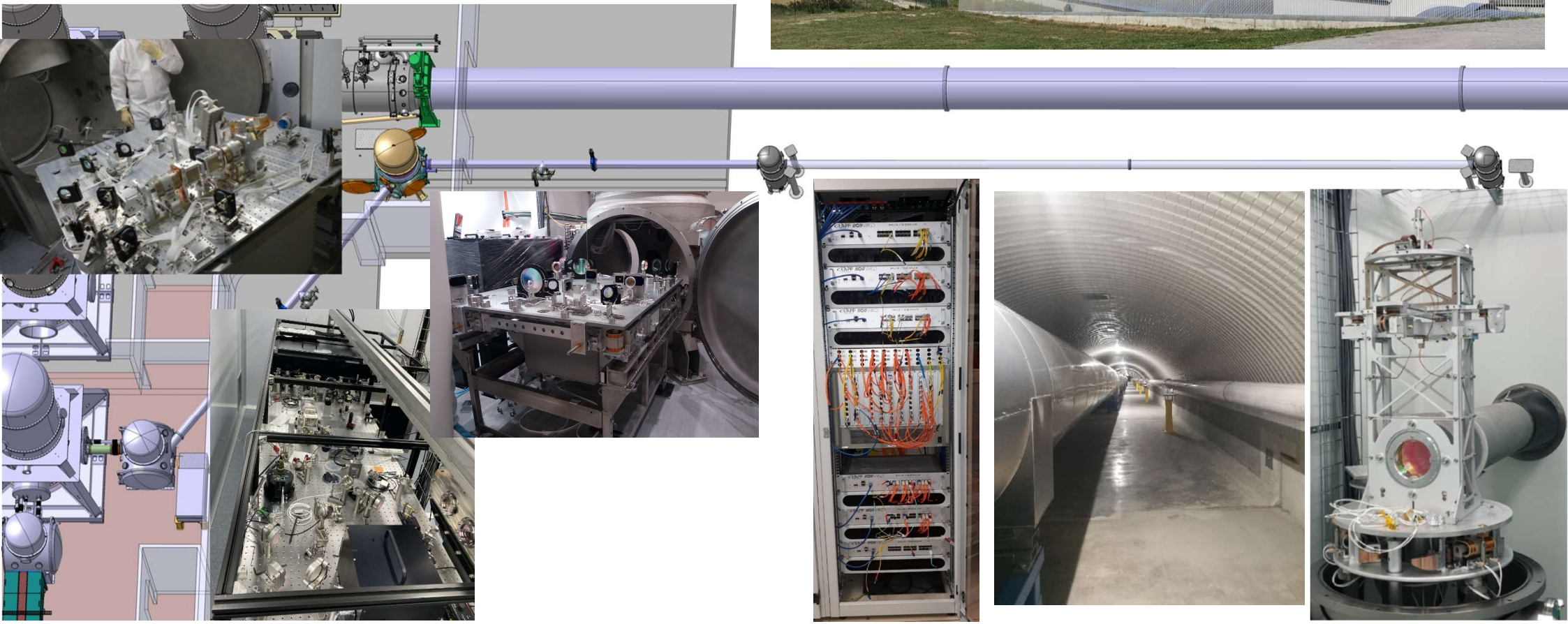
Goal: use frequency dependent squeezing in AdV+ Phase I



Quantum noise reduction (QNR)

Installation completed!

QNR commissioning started in April



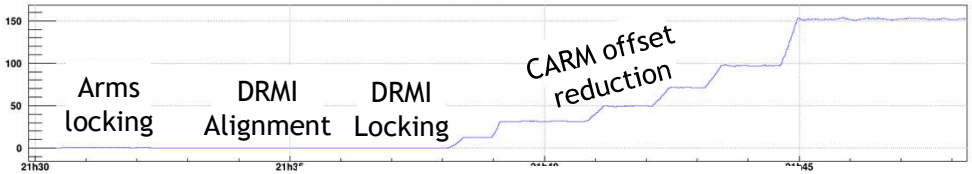
AdV+ Phase I: status today

The installation of the main interferometer was completed in December 2020

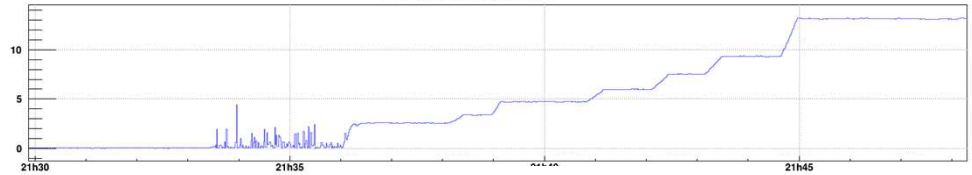
The commissioning of the main interferometer started in January 2021

- 3km arms locked with green beams ☺
- Central interferometer locked with infrared beam ☺
- Next: lock of the entire ITF

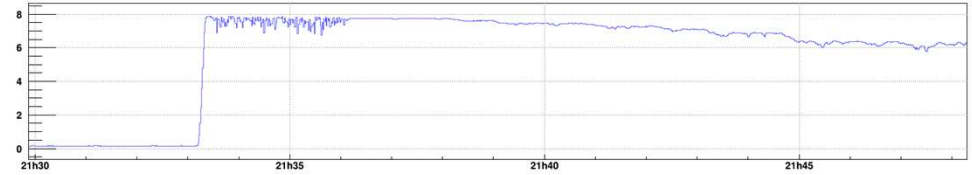
Arms transmission



Recycling cavity pick-off



Interferometer reflection



Installation of QNR has been completed in April 2021

The commissioning of QNR started in May 2021

- Filter cavity aligned and locked with the green beam

AdV+ Phase I: next steps

Interferometer locking

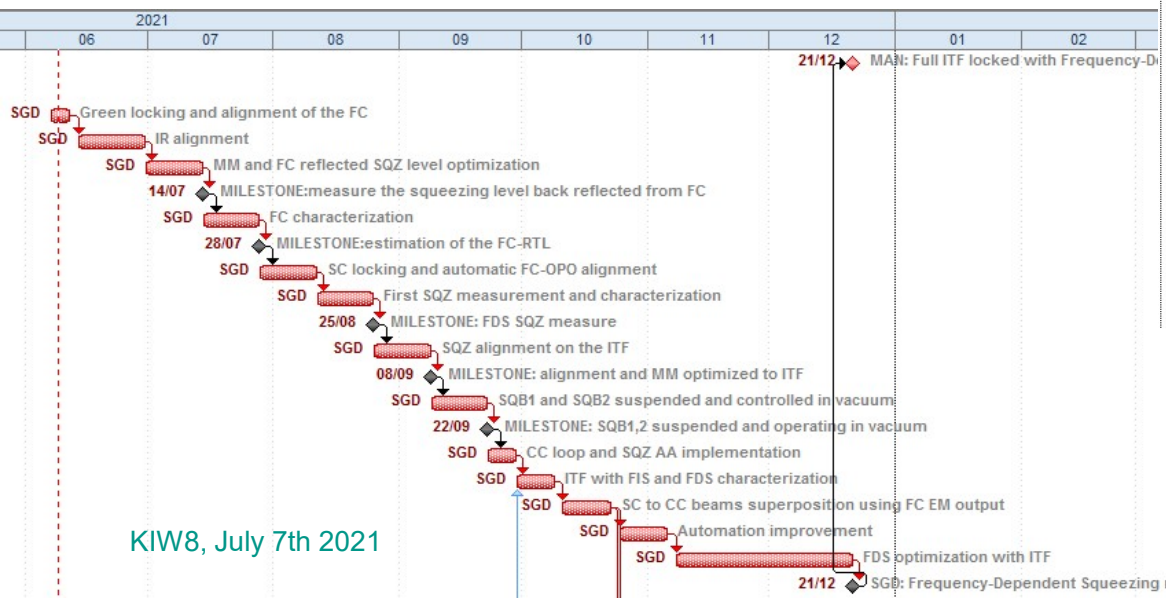
Locking at 25 W : June (some delay on this task)

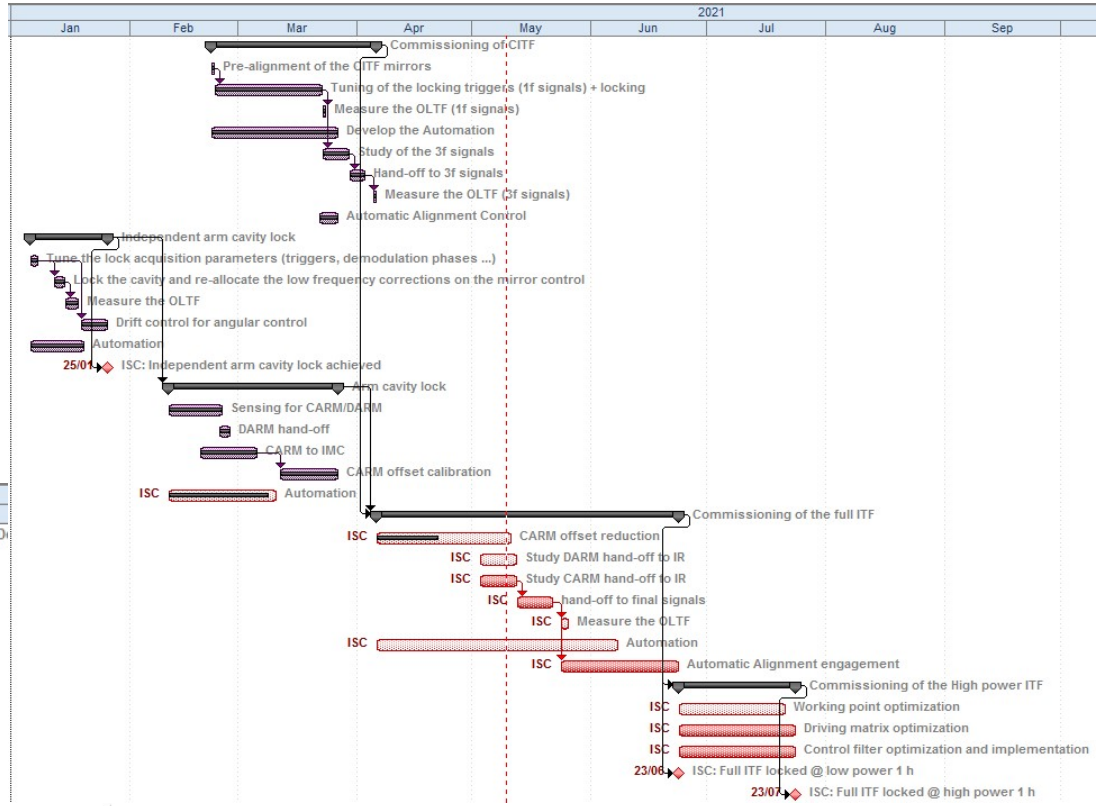
Locking at 40 W: July-August

QNR commissioning

First squeezing dependent measurement: August

Completion of QNR integration with ITF: Fall





AdV+ Phase I: next steps

After interferometer locking

- Interferometer optical characterization
- Interferometer optical tuning
- Scattered light mitigation
- Noise hunting
  - » First without QNR
  - » Then with QNR

Preparation for O4

June 2022: Start of O4

- LIGO-Virgo-KAGRA discussions ongoing: start of O4 might be delayed by a couple of months

AdV+ Phase I: noise hunting

Most of noise hunting is about investigating the effect of technical noises

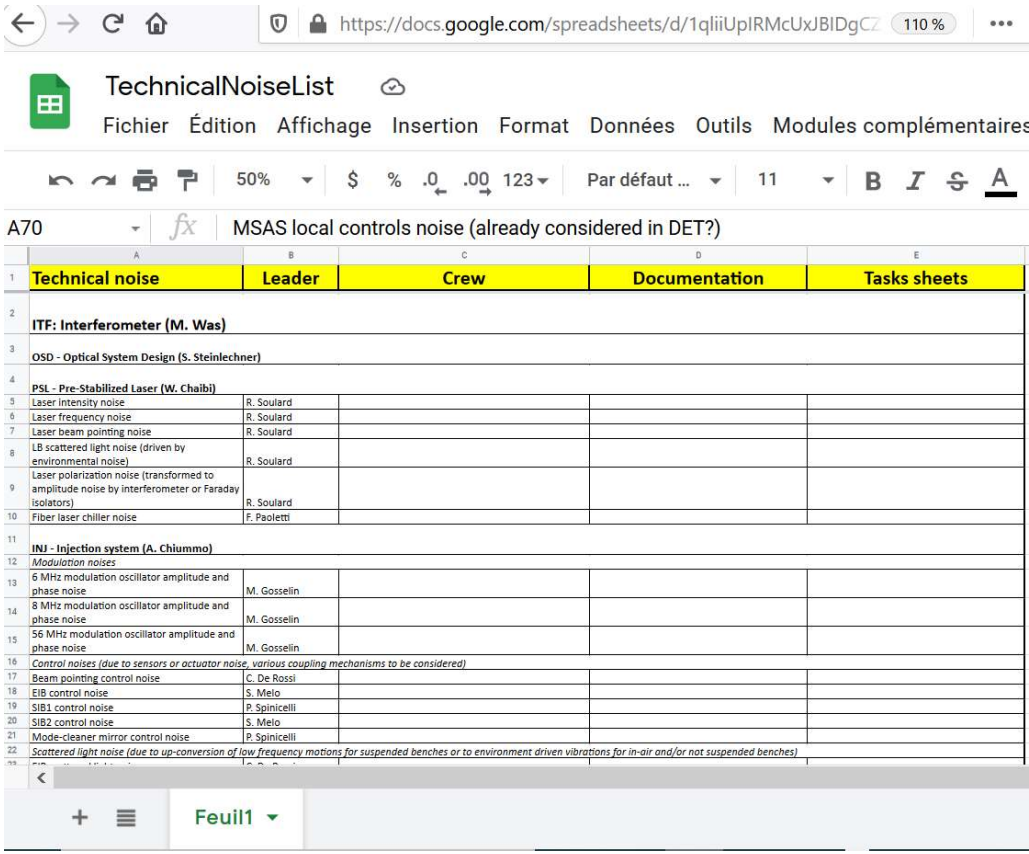
List of potential technical noises updated

- Organized by system and subsystems
- 132 entries

Responsible for each technical noise identified

Next steps

- Collect documentation and task sheets for each technical noise
- Prepare noise hunting plan



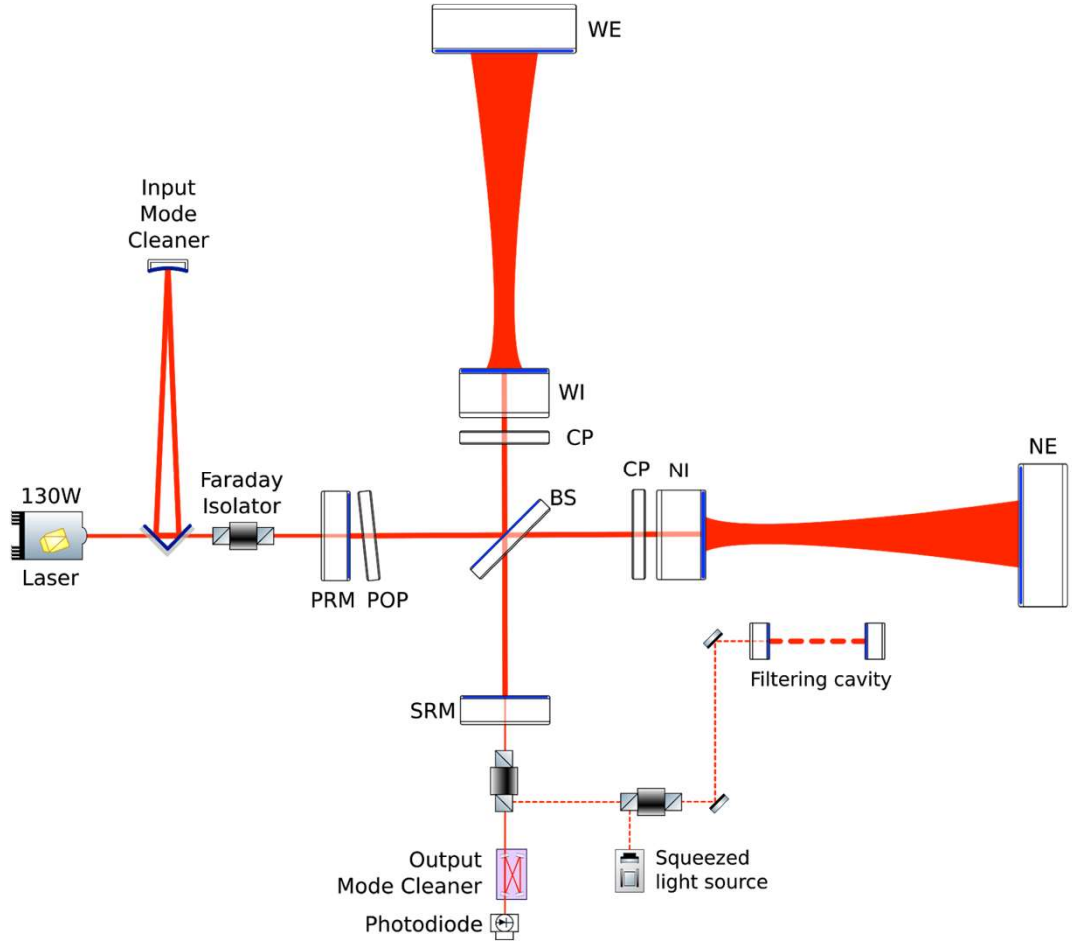
Technical noise	Leader	Crew	Documentation	Tasks sheets
ITF: Interferometer (M. Was)				
OSD - Optical System Design (S. Steinlechner)				
PSL - Pre-Stabilized Laser (W. Chaibi)				
Laser intensity noise	R. Soulard			
Laser frequency noise	R. Soulard			
Laser beam pointing noise	R. Soulard			
LB scattered light noise (driven by environmental noise)	R. Soulard			
Laser polarization noise (transformed to amplitude noise by interferometer or Faraday isolators)	R. Soulard			
Fiber laser chiller noise	F. Paoletti			
INJ - Injection system (A. Chiummo)				
Modulation noises				
6 MHz modulation oscillator amplitude and phase noise	M. Gosselin			
8 MHz modulation oscillator amplitude and phase noise	M. Gosselin			
56 MHz modulation oscillator amplitude and phase noise	M. Gosselin			
Control noises (due to sensors or actuator noise, various coupling mechanisms to be considered)				
Beam pointing control noise	C. De Rossi			
EIB control noise	S. Melo			
SIB1 control noise	P. Spinicelli			
SIB2 control noise	S. Melo			
Mode-cleaner mirror control noise	P. Spinicelli			
Scattered light noise (due to up-conversion of low frequency motions for suspended benches or to environment driven vibrations for in-air and/or not suspended benches)				

AdV+ Phase II: status

Advanced Virgo+ Phase II

Main changes

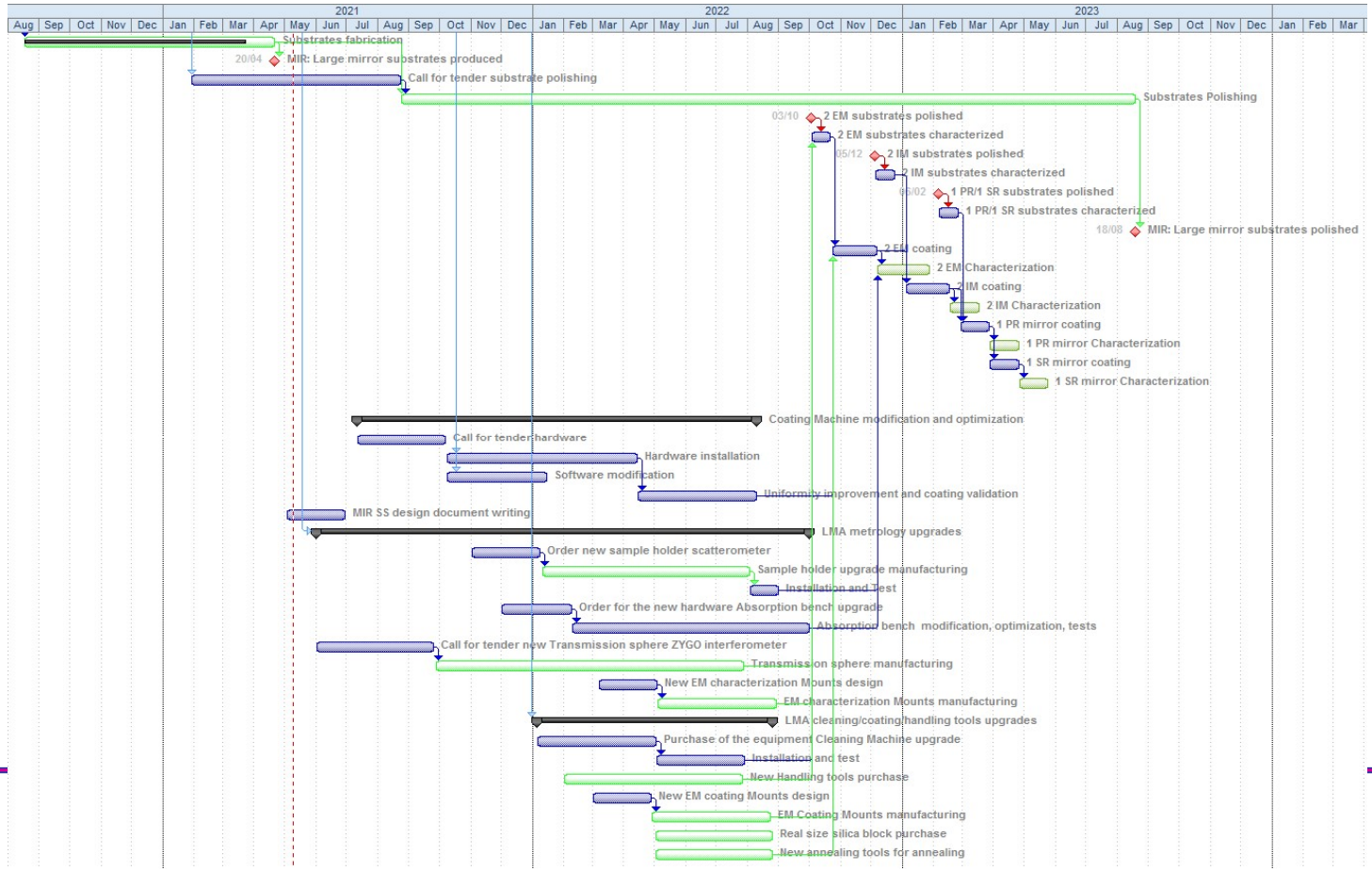
- Larger beams on end test masses
  - » 6 cm radius ⇒ 10 cm radius
- Larger end mirrors
  - » 40 kg ⇒ 100 kg
- Better mirror coatings
  - » Lower mechanical losses, less point defects, better uniformity
- New suspensions/seismic isolators for large mirrors
- Further increase of laser power
  - » 40W ⇒ 60W ⇒ 80 W



Mirrors

Project schedule imposed by mirror production (high risk)

Constrained by budget availability



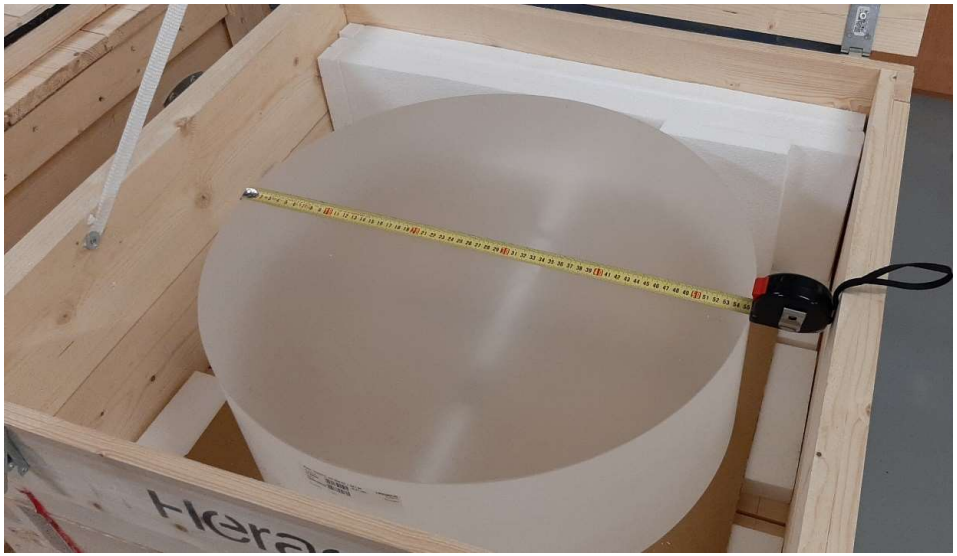
Mirrors

Status

Substrates acquired and received at LMA ☺

Call for tender for the mirrors polishing now starting at CNRS (EGO could not do it)

Several upgrades at LMA needed to prepare the realization of the mirrors



Which coating?

Coordination with LIGO

AdV+ and A+ will implement a common low-CTN coating formulation

AdV+ and A+ will make a coating selection together in June-July

Two candidates left

SiN/SiO_2

$Ti:GeO/SiO_2$

Both performing well in terms of mechanical losses

Absorption is the critical parameter

Ti:GeO/SiO2 multilayer gives 3-4 ppm

Measurement on SiN/SiO2 multilayers not available yet

Decision to be made during the summer

Super Attenuators and Payloads

Super Attenuators and Payloads for Large End Mirrors

Development of blades springs and anti-magnetic springs for super-attenuators started

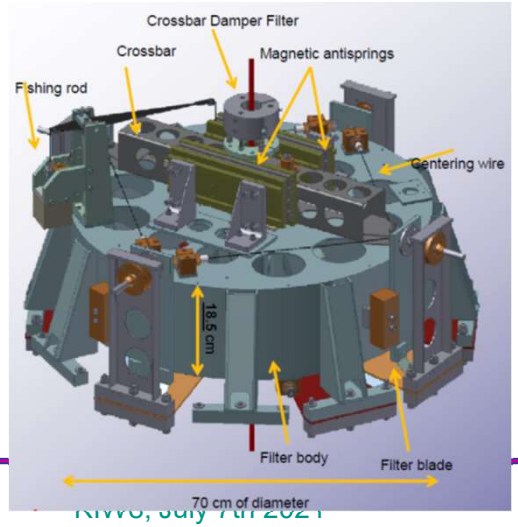
Construction of large payload prototype started

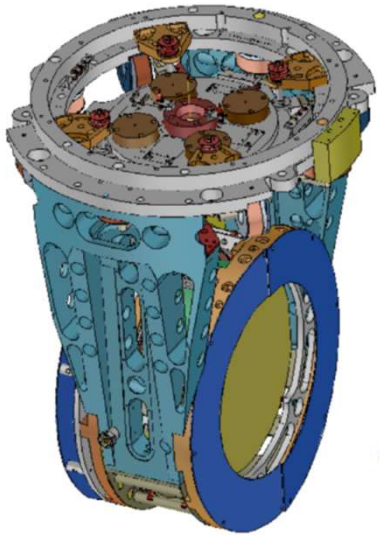
Goals:

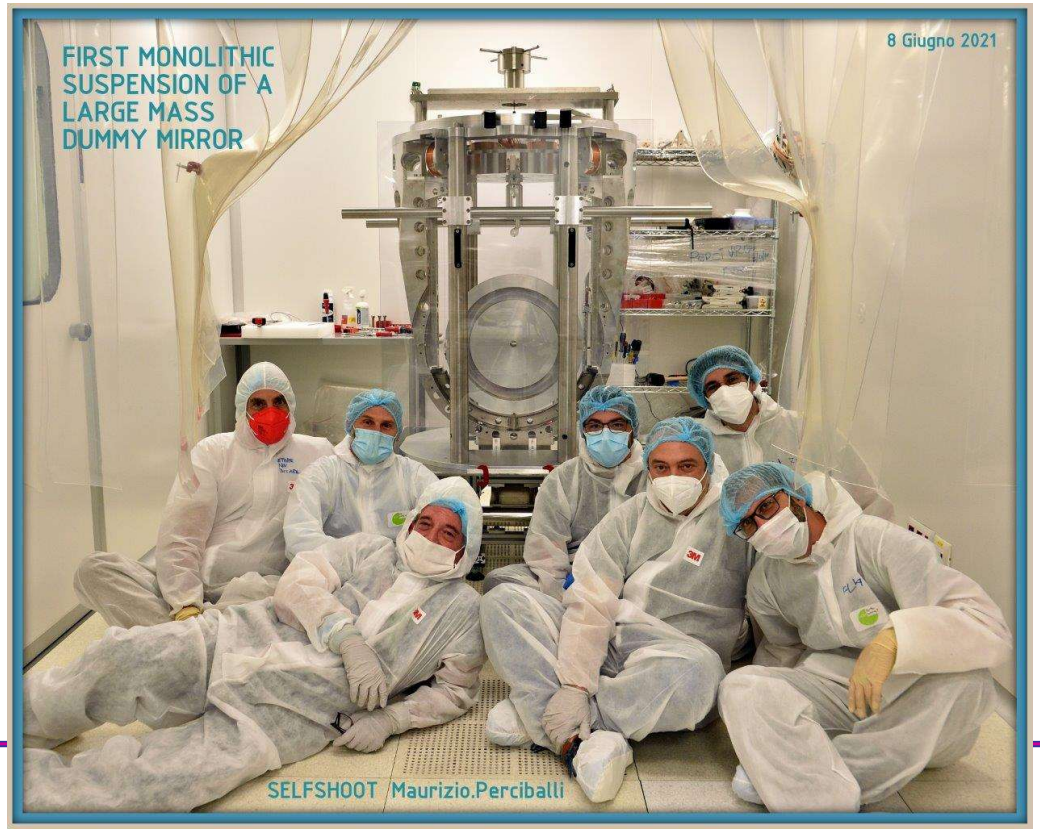
Design by the end of the year

Construction in 2022-2023

Installation from mid-2023 (at the end of O4)







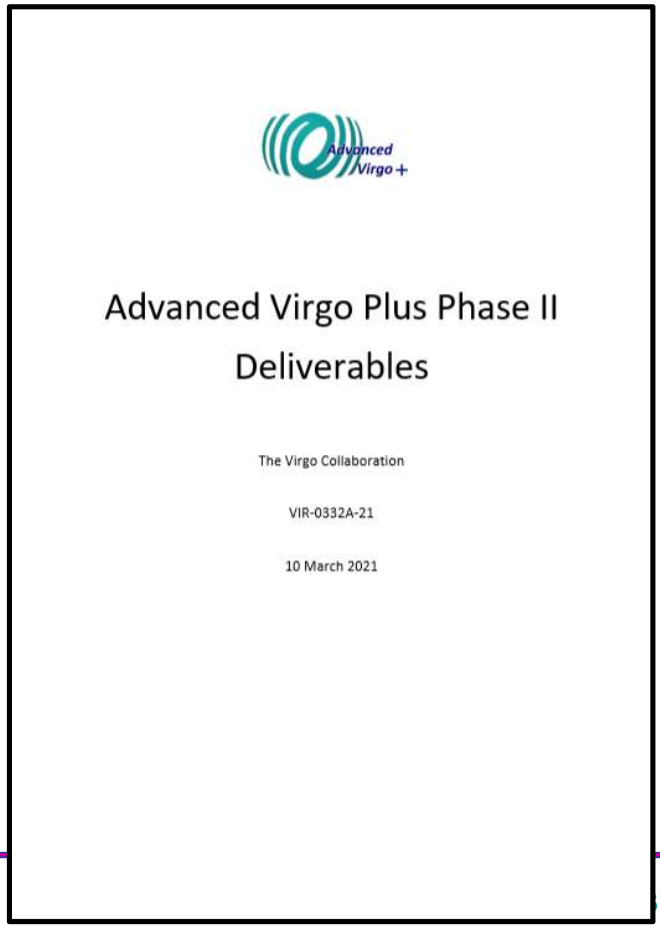
Other upgrades for Phase II

Main actors apart from mirrors and suspensions (in terms of budget)

- Vacuum
- Thermal compensation system
- Detection
- Injection
- Pre-stabilized laser
- Instrumented baffles

List of deliverables for AdV+ Phase II available

Writing of TDR and of its review started


Advanced Virgo Plus Phase II
Deliverables

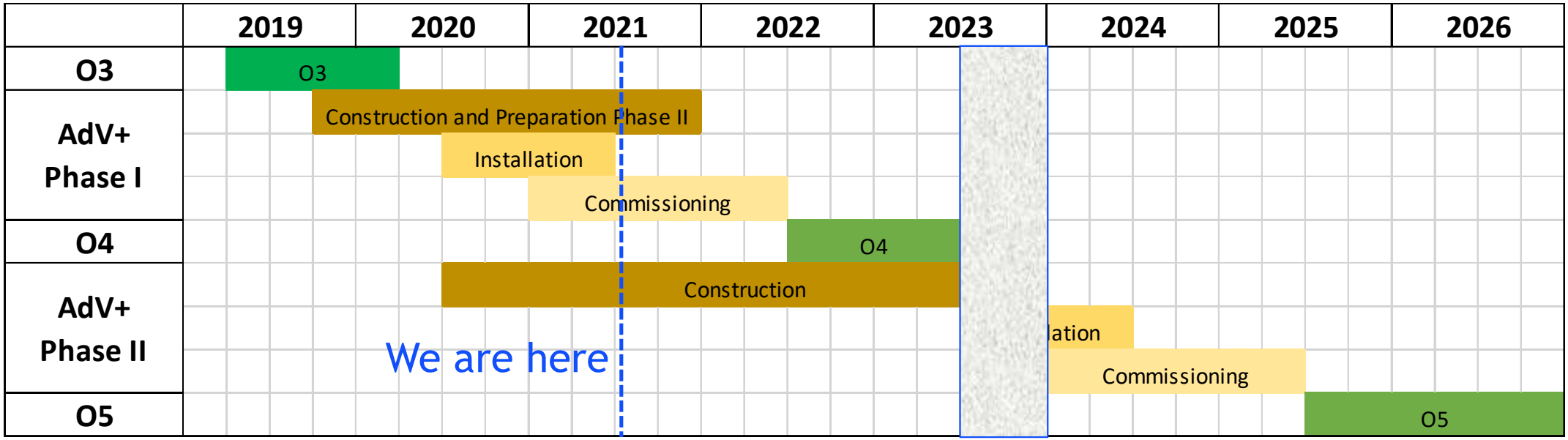
The Virgo Collaboration

VIR-0332A-21

10 March 2021

AdV+ Phase II schedule

About two years left to complete the construction of the AdV+ Phase II



Beyond AdV+?

Beyond AdV+?

Breaking news!

June 30, 2021

The European Strategy Forum on Research Infrastructures (ESFRI) decided to include the Einstein Telescope (ET) in the update of its roadmap for 2021

ESFRI European Strategy Forum on Research Infrastructures

Strategy Report on Research Infrastructures
ROADMAP 2021

PRESS RELEASE

ESFRI announces the 11 new Research Infrastructures to be included in its Roadmap 2021

€4.1 billion investment in excellent science contributing to address European challenges

After two years of hard work, following a thorough evaluation and selection procedure, ESFRI proudly announces the **11 proposals** that have been scored high for their science case and maturity for implementation and will be included as new Projects in **the ESFRI 2021 Roadmap Update**.

The new ESFRI Projects are:

EBRAINS - European Brain ReseArch INfrastructureS, a distributed digital infrastructure at the interface of neuroscience, computing and technology, offering scientists and developers advanced tools and services for brain research.

EIRENE RI - Research Infrastructure for EnvIRonmental Exposure assessment in Europe, the first EU infrastructure on human exposome (environmental determinants of health).

ET - Einstein Telescope, the first and most advanced third-generation gravitational-wave observatory, with unprecedented sensitivity that will put Europe at the forefront of the Gravitation Waves research.

EuPRAXIA - European Plasma Research Accelerator with Excellence in Applications, a distributed, compact and innovative accelerator facility based on plasma technology, set to construct an electron-beam-driven plasma accelerator in the

Beyond AdV+?

O5 will end in 2026. ET will not start taking data before 2036

There is at least 1 decade to be covered by 2G+(++)

There will be room for improving the detector after AdV+ and reach the ultimate infrastructure limits

The discussion ahead:

- Scenarios for improving Virgo (science, technologies, timing, costing)
- Needed R&D
- Perspective in the context of 3G advent

Beyond AdV+?

Post-O5 Committee

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Charge - pursue a preliminary study of the viable scenarios for upgrading Virgo beyond the AdV+ program. The study should assess:

The options for design choices and technology implementation which promise to improve the sensitivity or the robustness of the detector and give an estimate of their gain;

The sensitivity which could be achieved for different investment scenarios;

The technical readiness of the various options and the R&D perspectives;

The scientific case for the various scenarios.

To be coordinated with LIGO and KAGRA: towards a "Post-O5 network" debate

Conclusion

A lot of science out of O3!

First observation of NS-BH mergers

The Virgo collaboration is growing

Detector

AdV+ Phase I (for O4)

- » Installation of AdV+ Phase I completed !
- » Commissioning/locking of interferometer progressing

AdV+ Phase II (for O5)

- » Design progressing
- » Substrates received, call for tender for mirrors polishing launched
- » Coating decision to be made soon

Post-O5

- » Committee settled up, coordination with LIGO and KAGRA necessary