~850 members, ~580 authors, 143 institutions from 15 countries

37 Groups:

- 35 full members (including EGO group)
- 2 in the first year

9 countries represented in the VSC

VIRGO ORGANIZATION

Joint EGO-Virgo committee
Gemme, G Carpinelli, M

Virgo executive committee
Gemme, G

Virgo steering committee
Gemme, G

EGO
Carpinelli, M

Spokesperson
Gemme, G

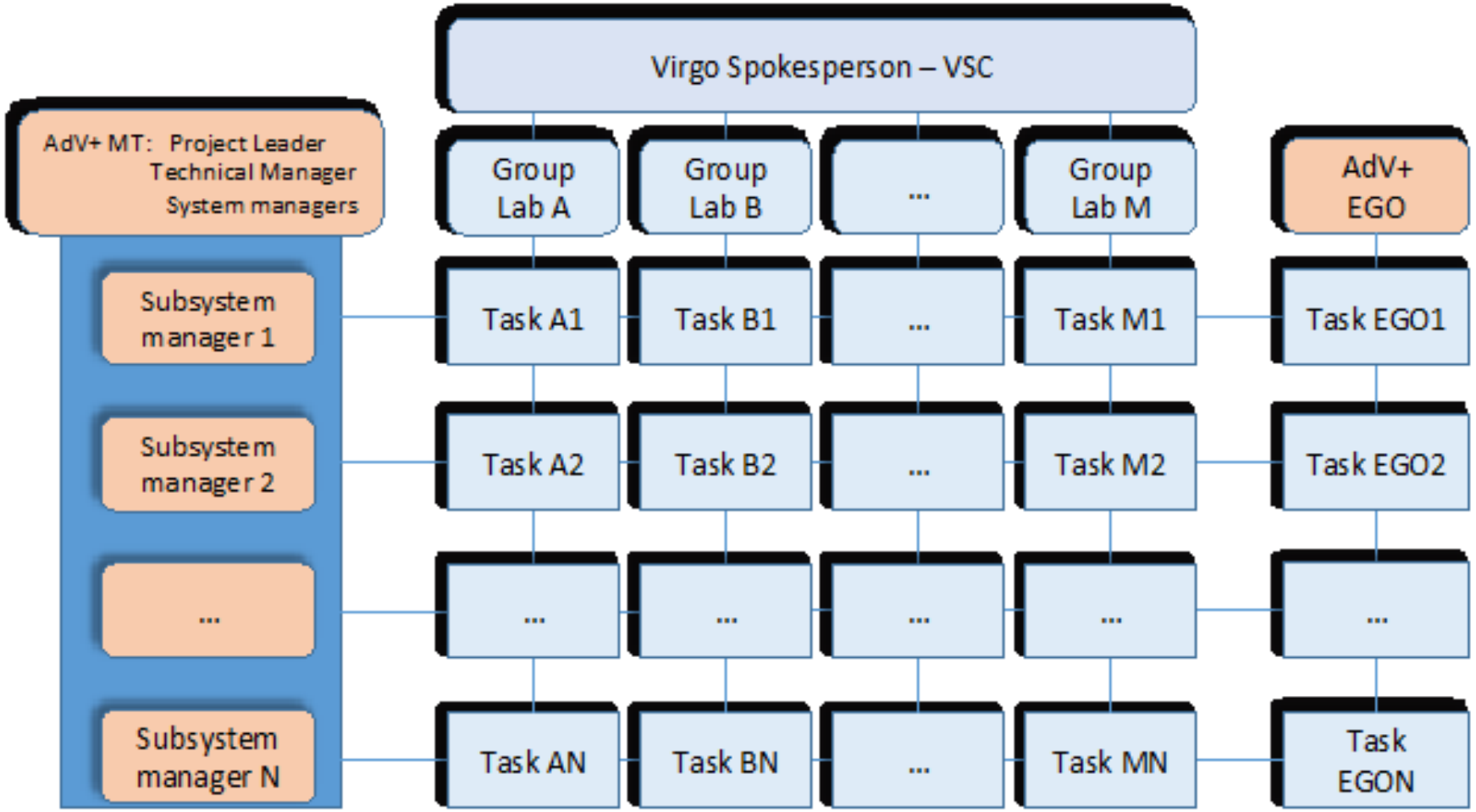
Deputy spokesperson
Marion, F

MoA review Committee
Gemme , G Marion, F

Core Program Committee
Fidecaro, F
Marion, F

Detector	Detector operations	Data analysis	Internal resources	Internal & external communication
Flaminio, R [1]	Rocchi, A	Pannarale, F [1]		
Technical management Heitmann, H [2]	**Run Planning Committee** Rocchi, A [2]	**Compact Binaries WG** Sordini, V [2]	**Ombudsperson** Fidecaro, F [1]	**Editorial Committee** Font, A [1]
System engineering Carbognani, F [1]	**Calibration WG** Rolland, L [2]	**Burst WG** Robinet, F [2]	**Collaboration authorship** Danilishin, S [2]	**Outreach** Cordero-Carrión, I [2]
Interferometer ITF Buy, C [2]	**Detector Characterization WG** Arnaud, N [2]	**Continuous Waves WG** Bejger, M [2]	**Early Career Scientists** Rinaldi, S [2] Seglar-Arroyo, M [2]	**Meetings Committee** Steinleichner, J [2]
Suspension & Mirrors SUM Vocca, H [2]	**Low Latency WG** De Pietri, R [2]	**Stochastic WG** van Remortel, N [2]	**Diversity, Equity & Inclusion WG** Regimbau, T [2]	**Speaker Committee** Chassande-Mottin, E [2]
Electronics, Software & Controls ES Was, M [2]	**Open Data WG** Trovato, A [2]		**Award Committee** Man, N	

ADV+ ORGANIZATION



34 members (8th largest in the collaboration), 21 authors

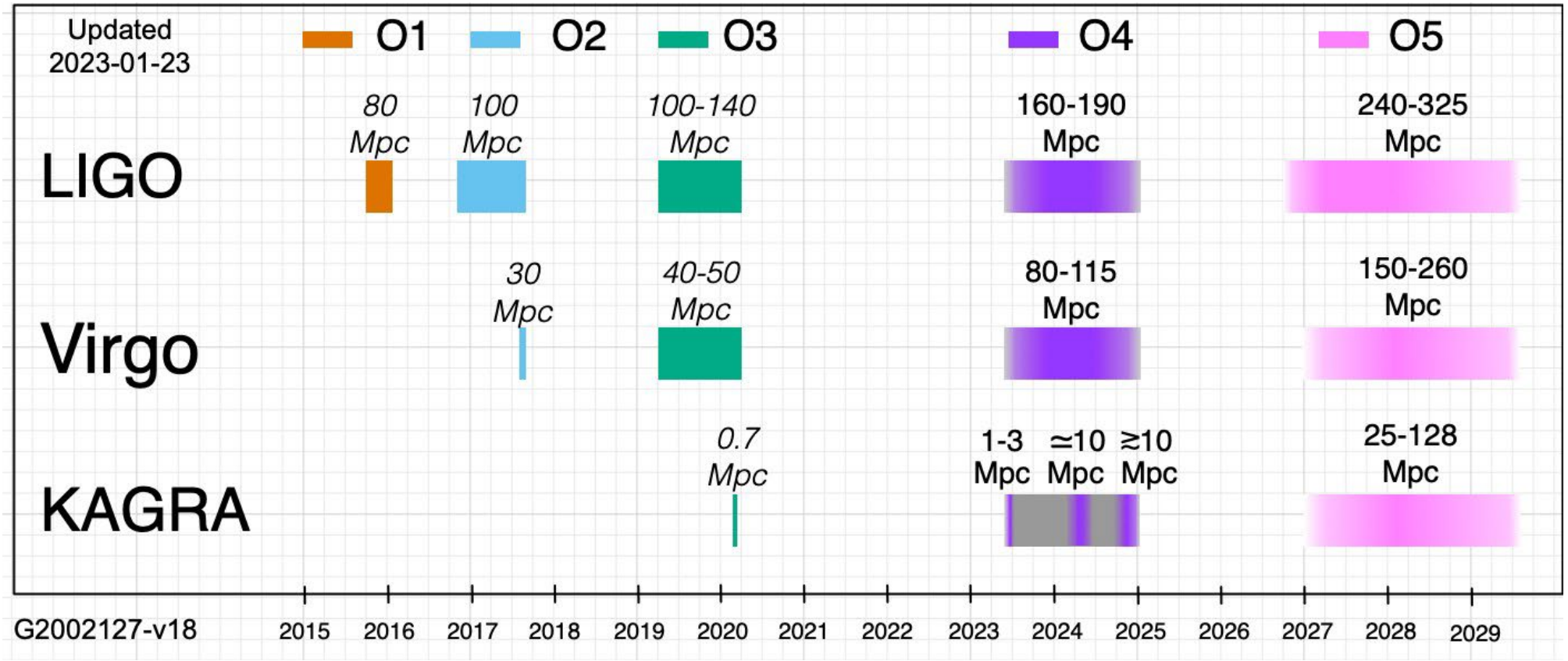
Responsibilities:

- Deputy Spokesperson and Core Program Committee co-chair (F. Marion)
- Upgrade coordinator (R. Flaminio)
- Deputy commissioning coordinator and Electronics, Software and Control system manager (M. Was)
- DETection subsystem manager (R. Gouaty)
- Data AcQuisition subsystem manager (N. Letendre)
- CALibration subsystem manager (L. Rolland)
- Squeezing Injection subsystem manager (R. Bonnand)
- CW review chair (D. Buskulic)
- Diversity, Equity and Inclusion WG chair (T. Regimbau)

VIRGO STATUS

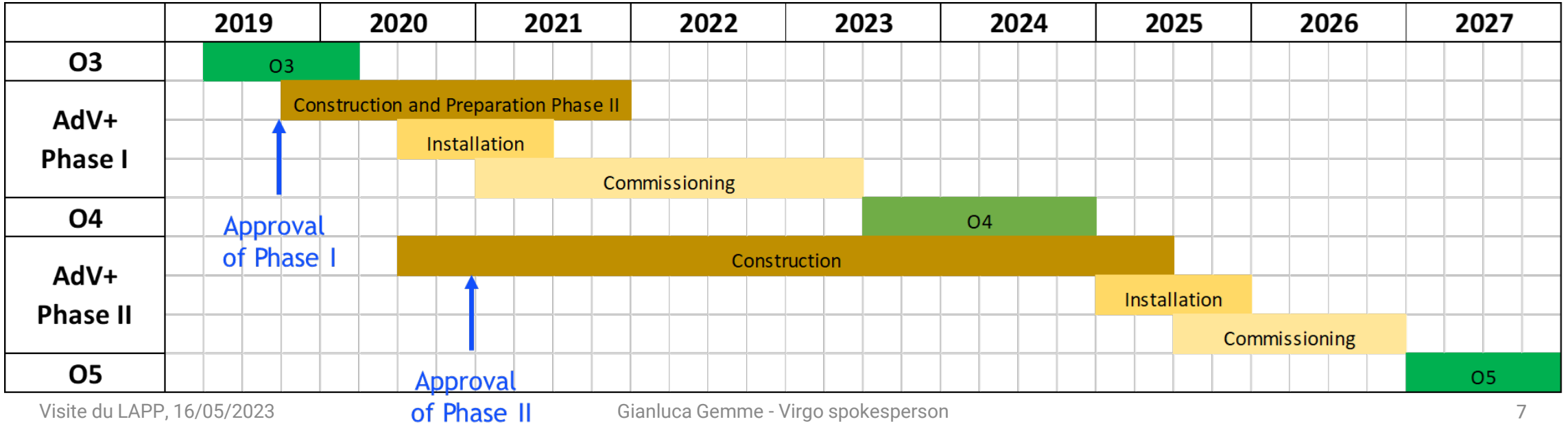
VIRGO UPGRADES AND OBSERVING RUNS

Advanced Virgo configuration(s) → AdV+ Phase I → AdV+ Phase II → Virgo_nEXT concept



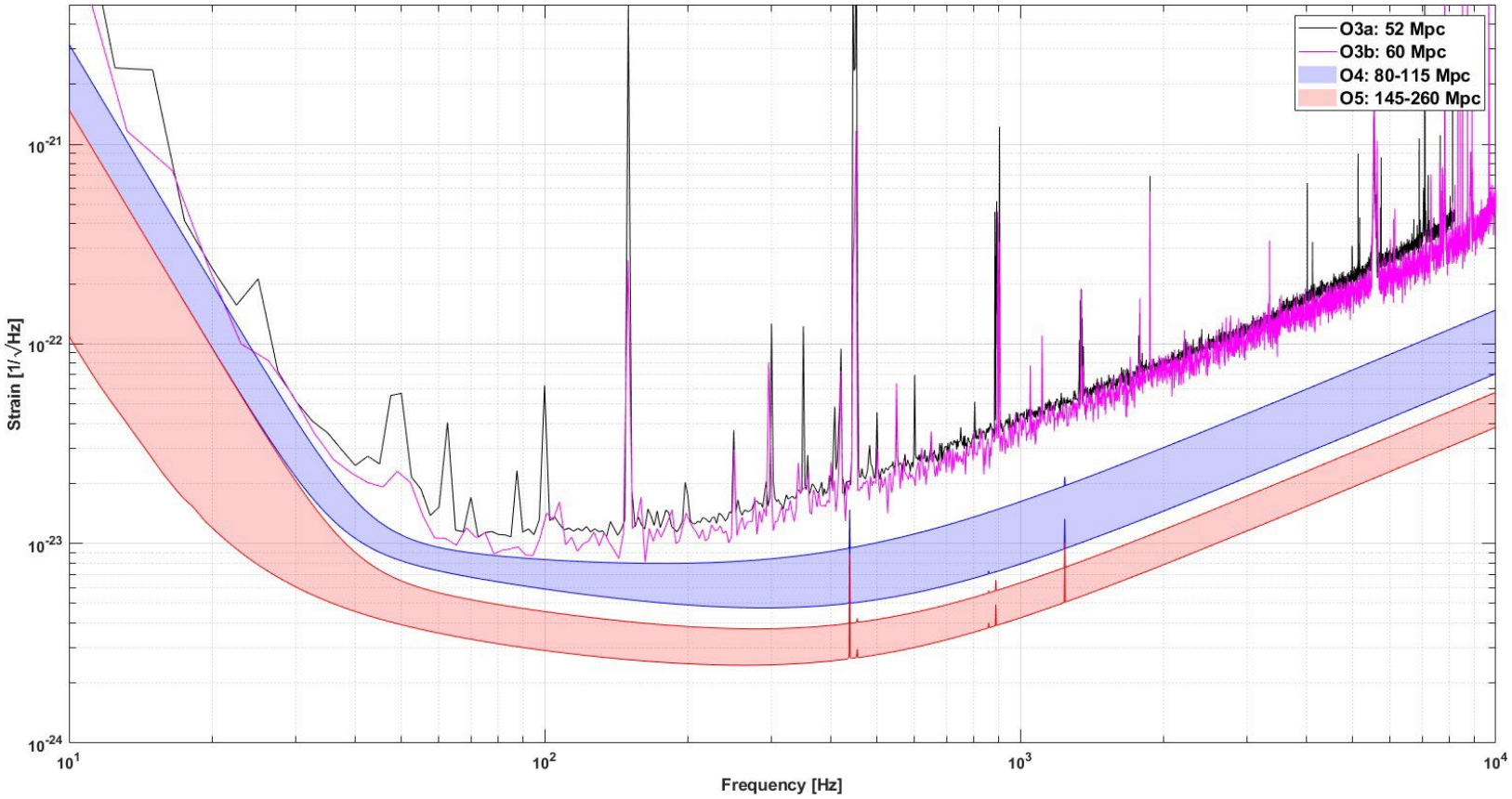
ADV+: A TWO-PHASE UPGRADE

- Phase I (before O4 run/2023-24)
  - Mainly an upgrade to reduce quantum noise: no mirrors change
  - Reduction of technical noises
  - Preparation of Phase II
- Phase II (before O5 run/2027-28)
  - More invasive upgrade to reduce thermal noise: mirrors change

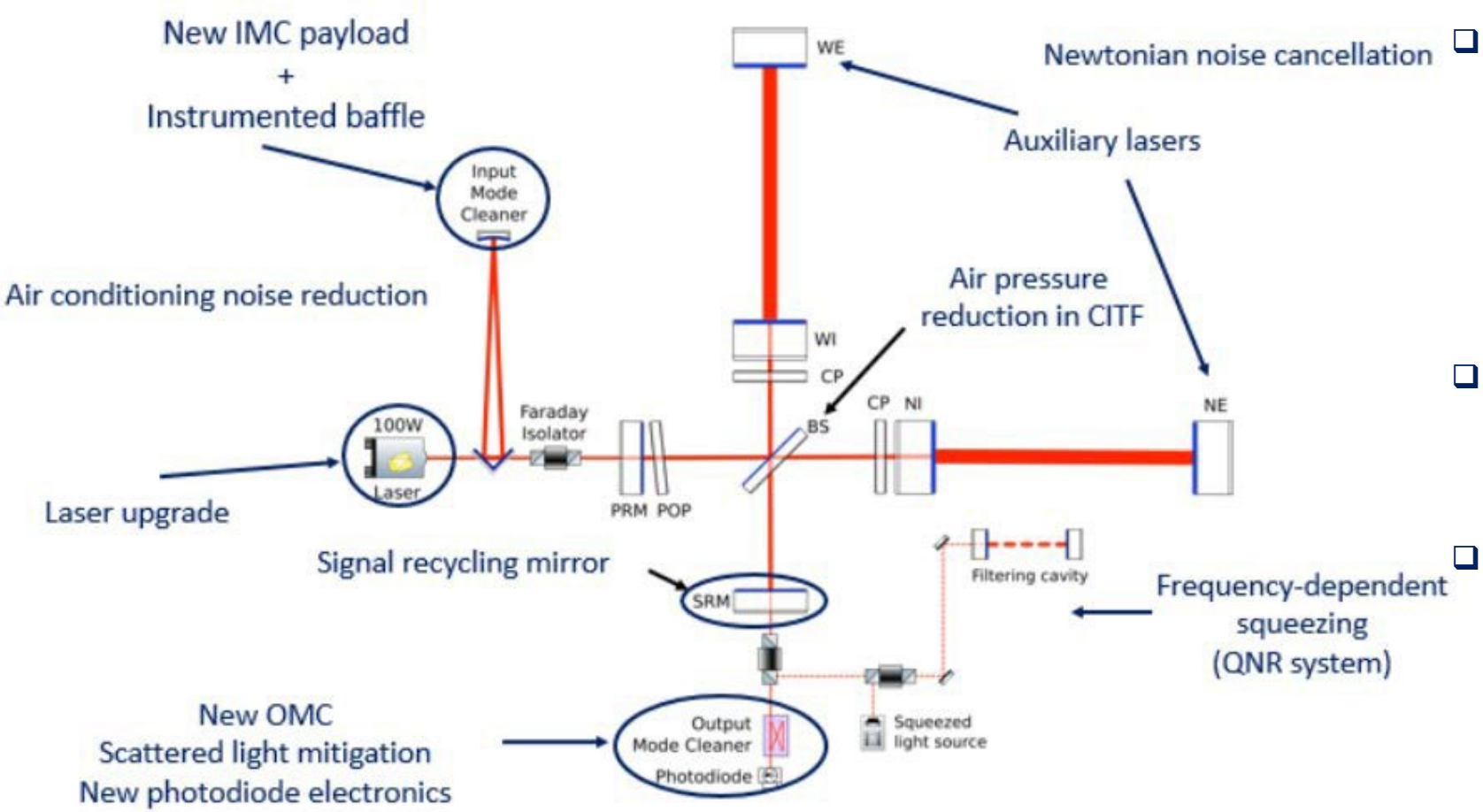


ADV+ DESIGN SENSITIVITY

- Phase I: reduce quantum noise, hit against thermal noise
  - BNS range ~ 100 Mpc
- Phase II: lower thermal noise wall
  - BNS range ~ 200 Mpc



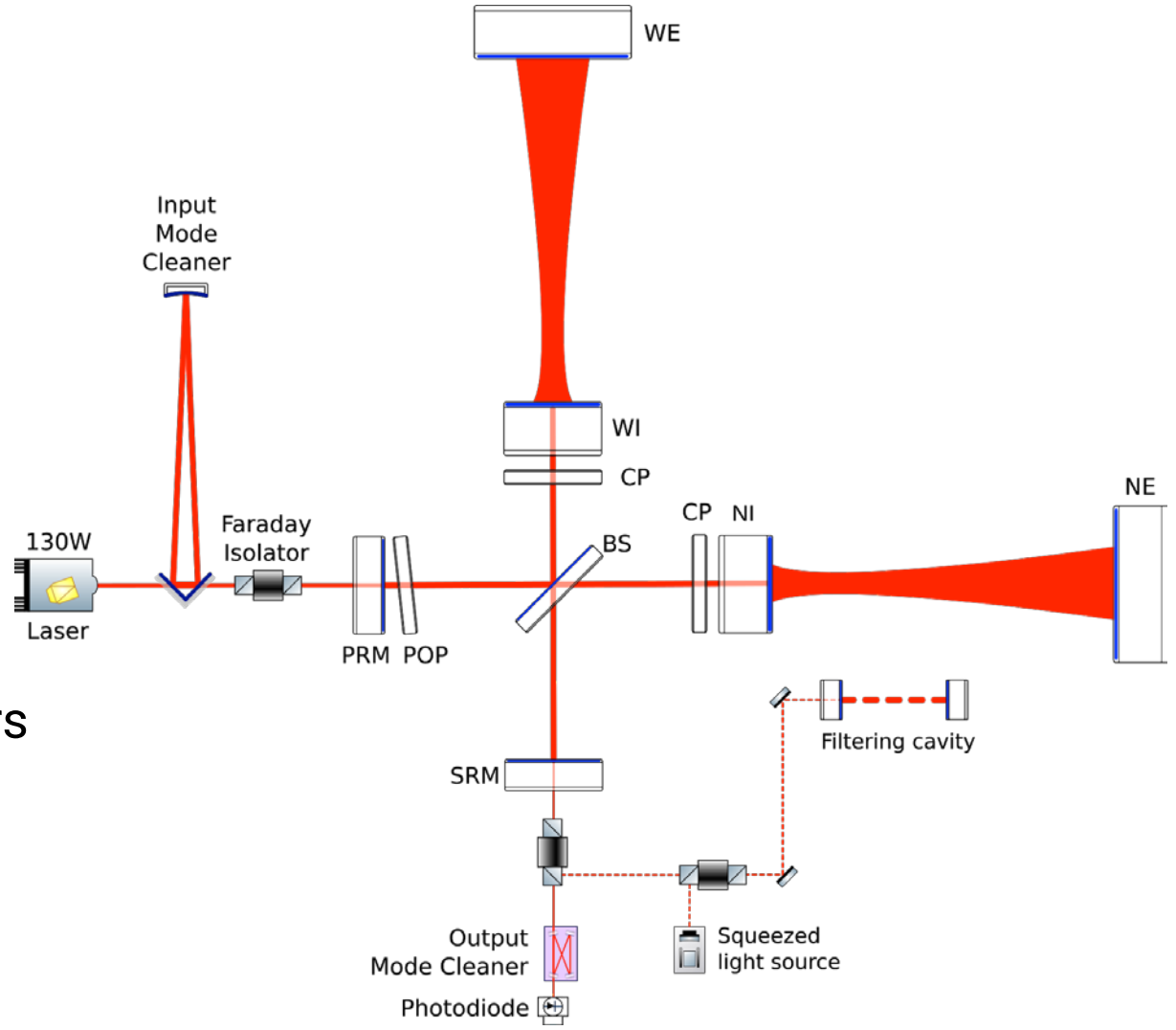
ADVANCED VIRGO+ PHASE I



- Installation within a year despite pandemic
  - Main interferometer complete in December 2020
  - Quantum noise reduction system complete in April 2021
- Commissioning
  - Started in January/May 2021 for main ITF/QNR system
- Two aspects fundamentally new (in Virgo)
  - Signal recycling
  - Frequency-dependent squeezing

ADVANCED VIRGO+ PHASE II

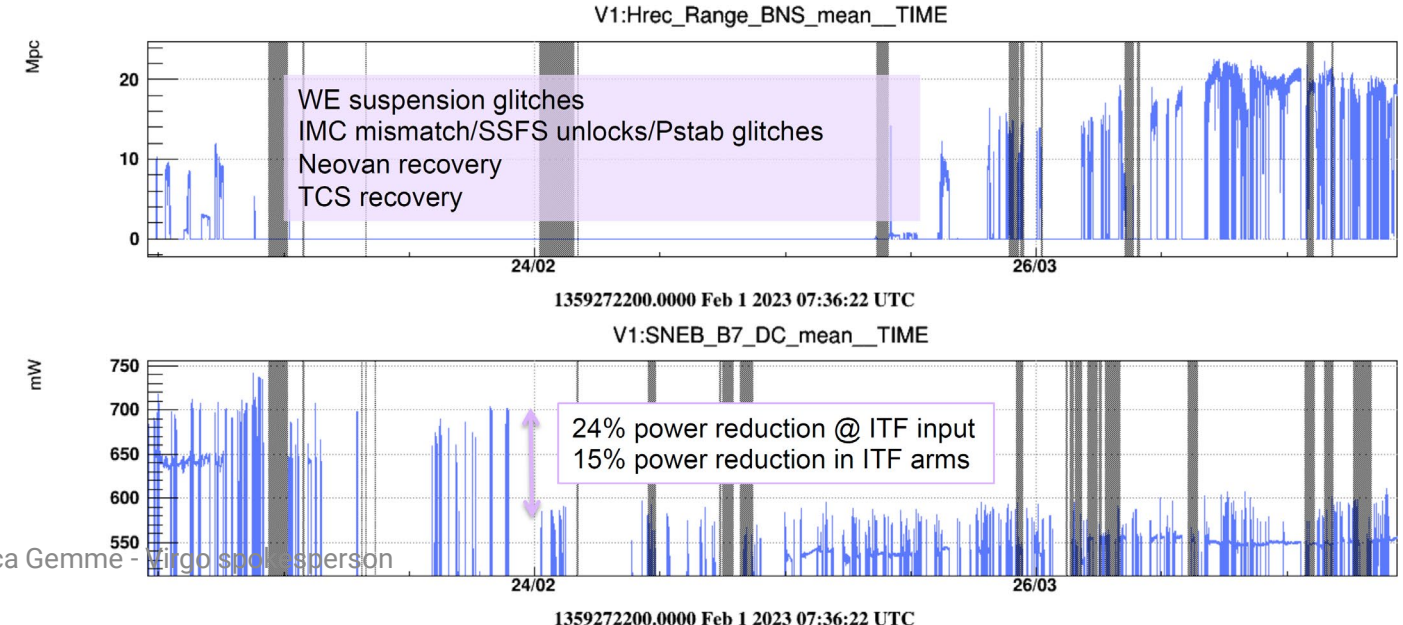
- Larger beams on end test masses
  - 6 cm radius ⇒ 10 cm radius
- Larger end mirrors
  - 35 cm diameter ⇒ 55 cm diameter
  - 40 kg ⇒ 100 kg
- Better mirror coatings
  - Lower mechanical losses, less point defects, better uniformity
- New suspensions/seismic isolators for large mirrors
- Further increase of laser power
  - 40 W ⇒ 60 W ⇒ 80 W



THE (VERY STEEP) PATH TOWARDS O4

STATUS

- Stable and reproducible control of interferometer mostly achieved in fall 2022, after
  - Lowering input power from nominal 40 W to 33 W (further reduced to 23 W in Feb 2023)
  - Installing new thermal actuator to correct power-recycling mirror curvature
  - Learning to deal with signal-recycling cavity with resonating higher-order modes
    - Due to Virgo specific optical configuration: marginally-stable PR and SR cavities
- Many issues since then…



MAIN ISSUES IN PAST MONTHS

- Failure of one test-mass payload
- Laser amplifier excess noise spoiling high-frequency sensitivity
  ➔ O3 laser amplifier restored
- Complexity from degeneracy of recycling cavities (see VIR-0047A-23)
  - Optical offsets in interferometer control signals
  - Excess of power on dark fringe before output mode-cleaner (contrast defect ~10^{-3})
  - Usual figures-of-merit (e.g., sidebands recycling gain) not fully reliable
  - Issues in interferometer alignment reproducibility
  - Difficult fine-tuning of thermal-compensation system

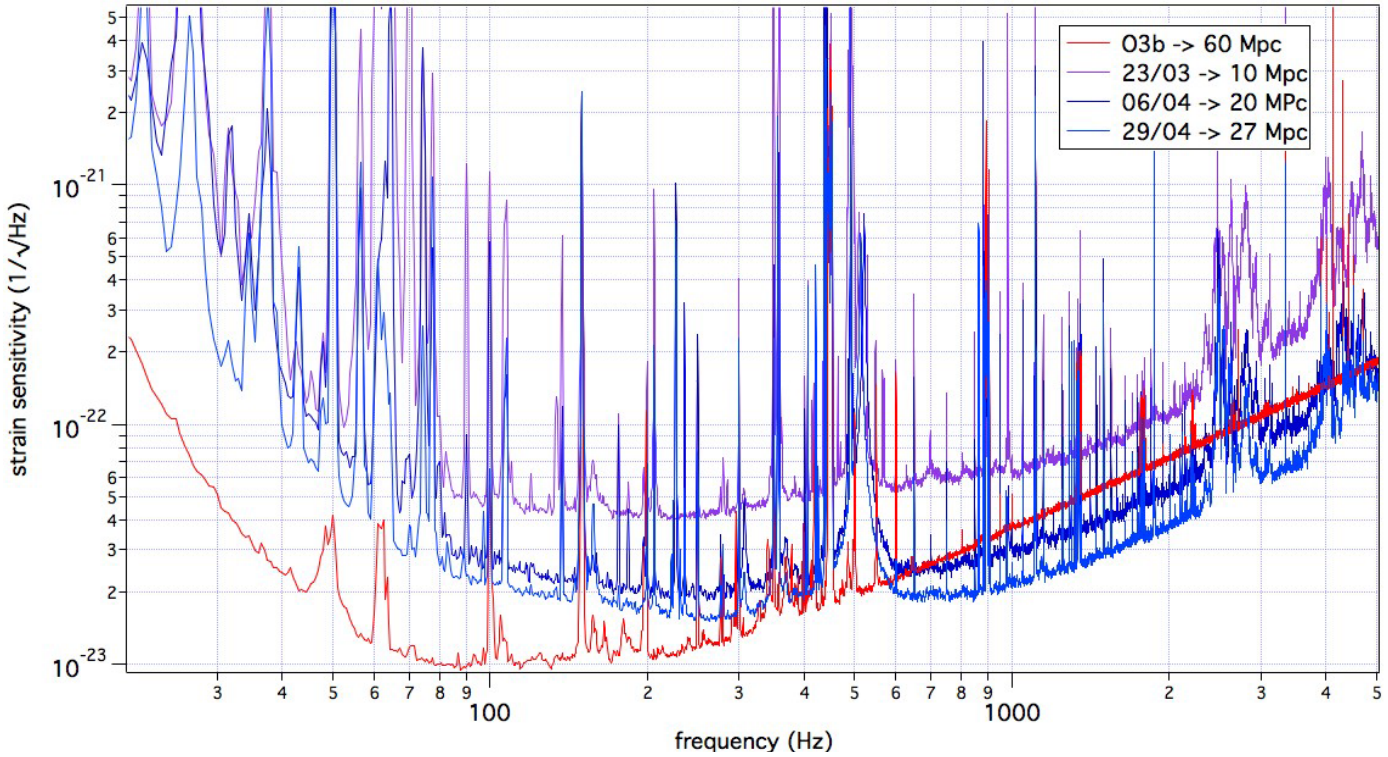
  ➔ Input power further lowered to 23 W (Feb 2023)
- Mirror thermal noise higher than expected
- …

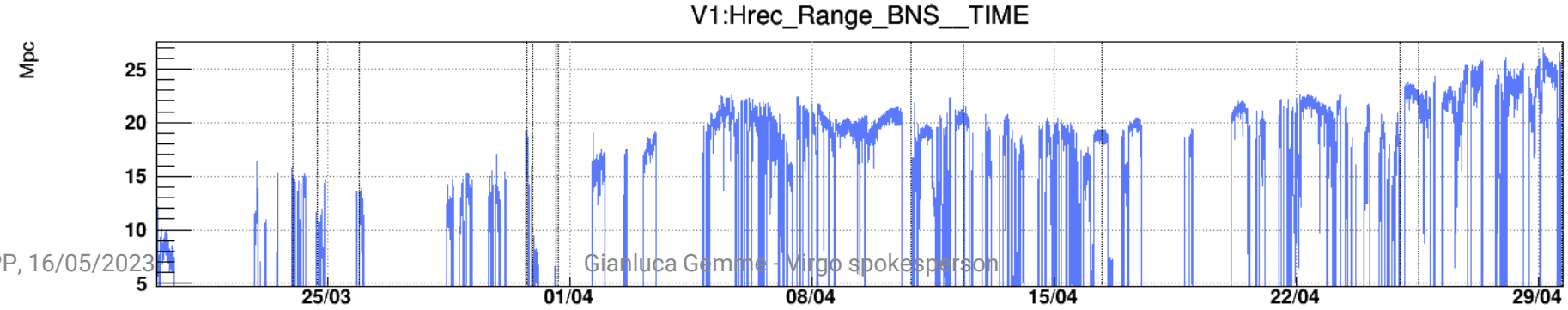
WEST-INPUT PAYLOAD INCIDENT

- Vacuum chambers of four cavity mirrors vented in Nov 2022
  - To prepare point-absorbers mitigation-system installation
- Fused-silica fibers of West-input mirror broke during venting
- Problem already experienced 6 times in 2015-2016 (+ 2 during tests)
  - Understood to be due to small particles hitting fibers during venting/pumping
  - Solved by installing protections around fibers and changing pumping/venting layout
    - No failures since monolithic-suspensions re-installation in 2018
    - 2 full ventings and 4 low-pressure ventings done since then
- Payload dismounted, repaired and reinstalled in less than 2 weeks
- Additional protection prepared and installed before payload reinstallation

GOOD PROGRESS NEVERTHELESS

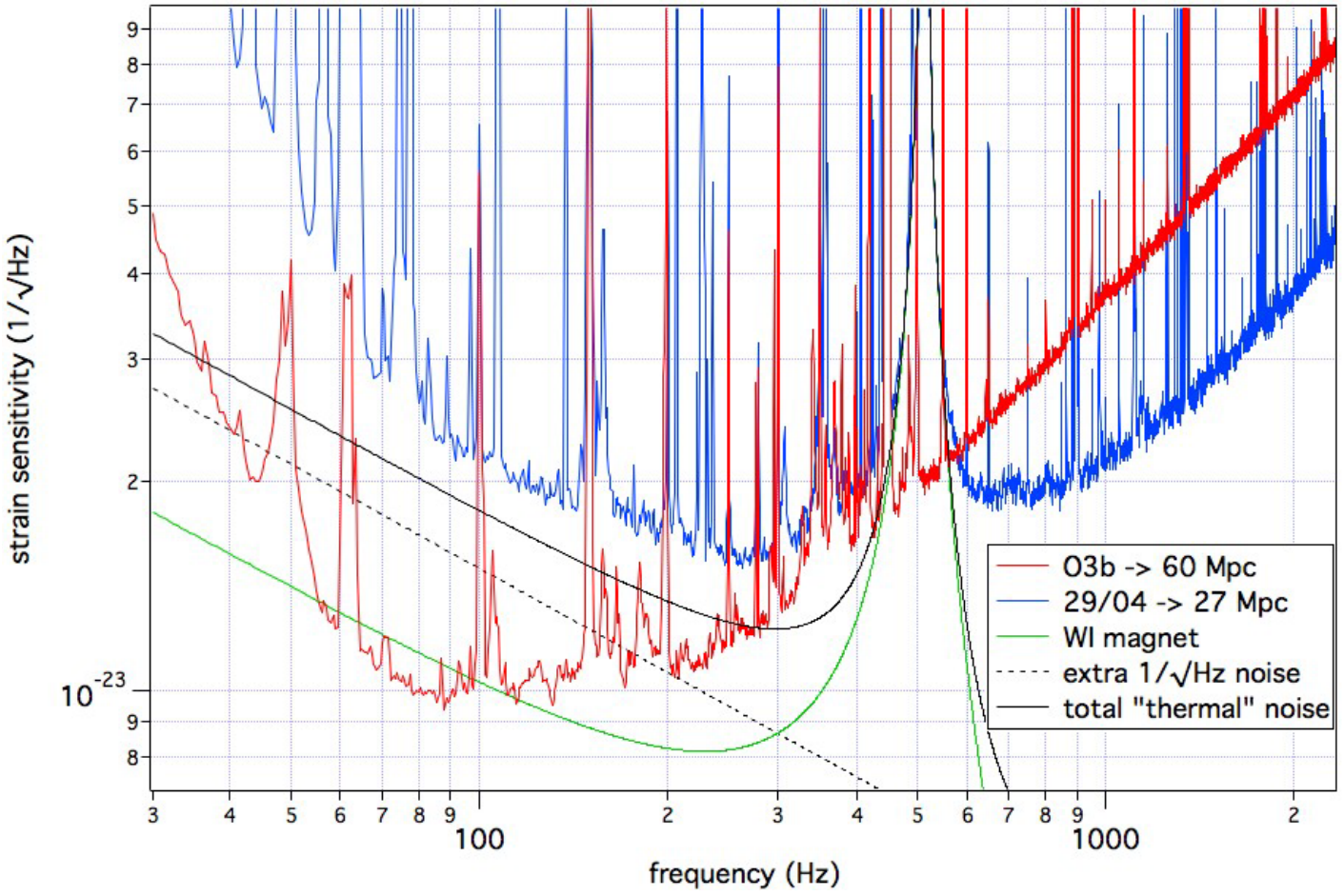
- Stable, automated lock in low-noise 2
- Progress on sensitivity
  - Several technical noises reduced
  - Better than O3 at high frequencies
    - O3 sensitivity crossed @ 350 Hz
    - Shot noise reached above 600 Hz
    - 1 dB of squeezing above 600 Hz
- But best BNS range ~27 Mpc





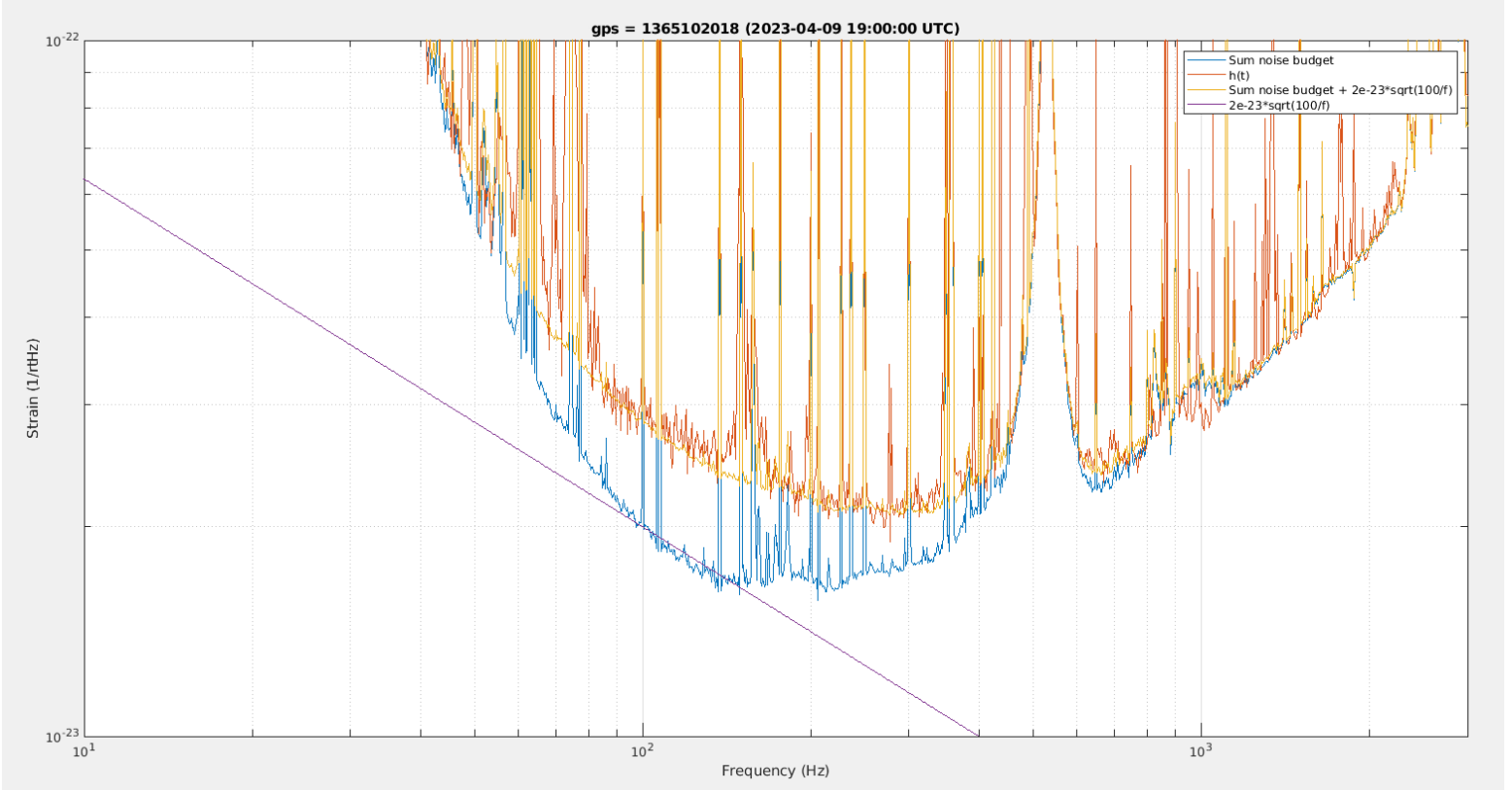
EXCESS THERMAL NOISE: DAMAGED WI MIRROR MAGNET

- Loose magnet on WI mirror
  - A consequence of WI payload failure in November
- Broad ~500 Hz resonance can be fit with thermal noise model
- Can explain part of the measured noise but not all
- Simple model and FEM agree



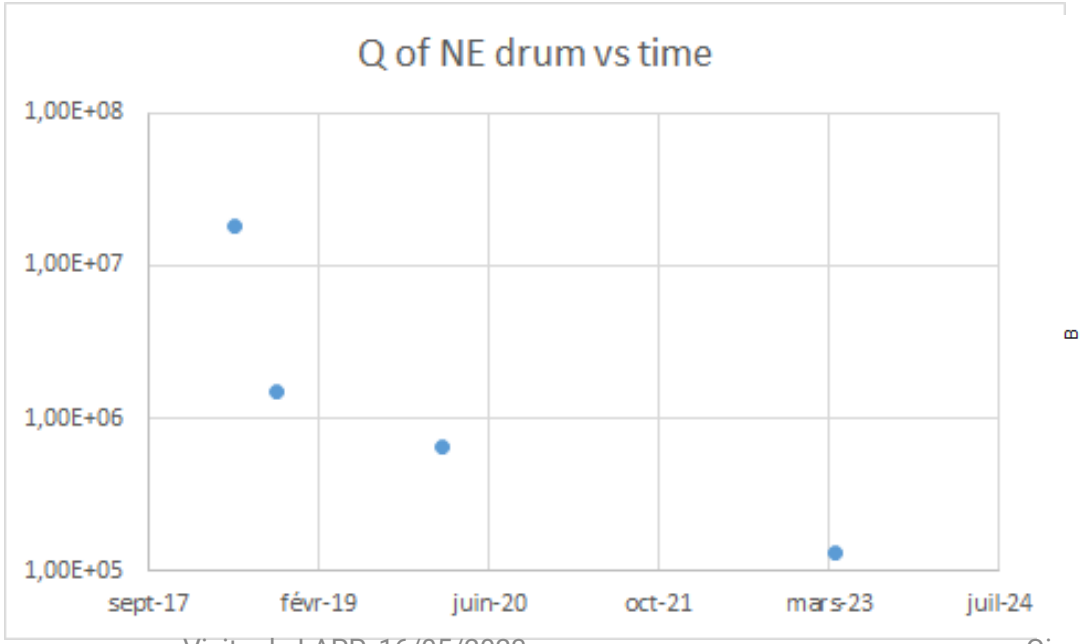
EXCESS THERMAL NOISE: NORTH END MIRROR

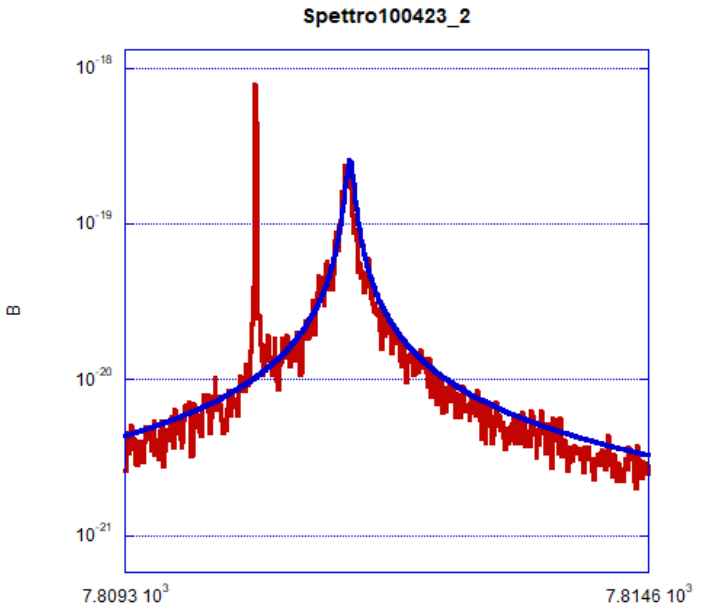
- Evidence of a (stable) 1/√f noise
- Bulk and violin modes of 4 test masses measured
- Hints that one mirror is producing excess thermal noise
  - Currently suspecting increased dissipation on NE bulk modes
- Significant limit to reach O4 target sensitivity

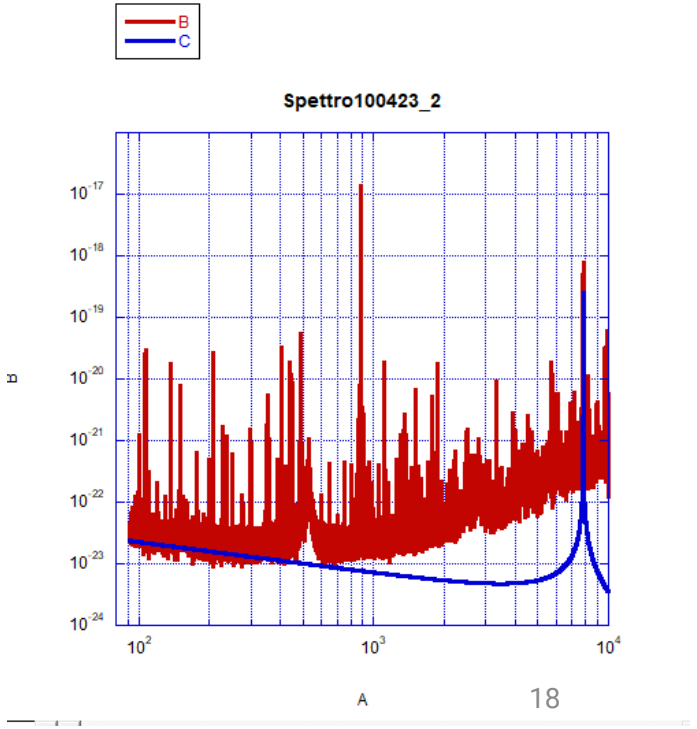


EXCESS THERMAL NOISE: NORTH END MIRROR

- Since the NE mirror has been installed in 2017, its quality factor has decreased
  - Highest Q of the first few drum modes is about 2.5E5
  - The Q of the first drum mode is 1.3E5
    - To be compared to 2E6 for WI and more than 1E7 for NI and WE
  - Upper limit of NE mirror thermal noise cannot exclude observed noise
    - However this is an upper limit







CONSEQUENCES FOR O4

- Marginally-stable recycling cavities are a structural weakness
  - But configuration might (hopefully) be manageable for O4
    - After much (on-going) effort
    - With low input power
- Yet current detector will not allow to start O4 on nominal start date with nominal sensitivity
  - Strong suspicion of excess thermal noise, would limit achievable sensitivity to ~30 Mpc
- On May 3, the Virgo Steering Committee decided that Virgo will not join O4 on May 24
  - Intervention on WI mirror to remove the damaged magnet
  - Intervention in NE tower to replace NE mirror
  - Few more months of commissioning to improve sensitivity

POST-O4 CONSEQUENCES

- Virgo_nEXT will need stable recycling cavities
  - Need for stable recycling cavities to achieve Virgo_nEXT target sensitivity reassessed in dedicated document meant to complement 2022 concept study
  - (coating thermal noise section also updated with dedicated study)

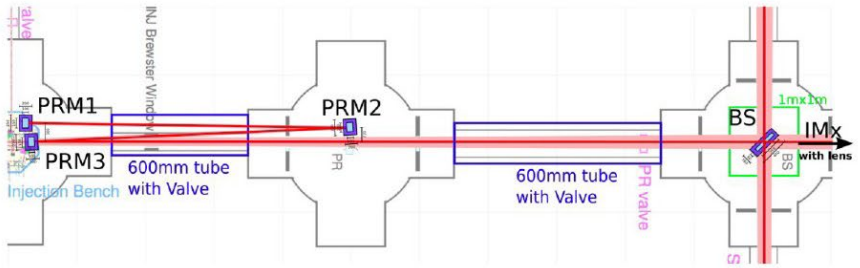
- What about O5? What does the O4 experience tell us ?
  - Will 18 months be enough for commissioning?
  - Is it realistic to increase the input power?
  - Is it viable to stick to marginally-stable recycling cavities?
  - Significant simulation effort required

- Identifying a technical solution to implement stable recycling cavities is a priority

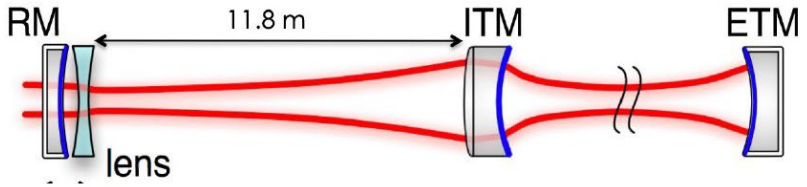
NDRC SOLUTIONS ON THE TABLE

- Multipayloads
- Design using lenses

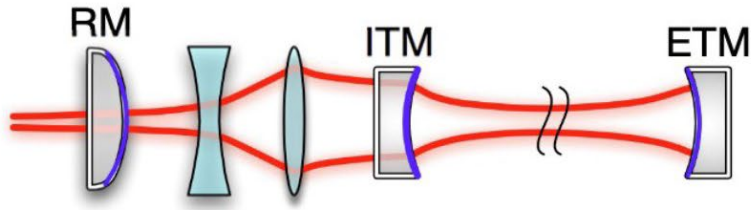
These solutions do not require new infrastructures, but need development



VIR-0025A-09



VIR-0350A-11

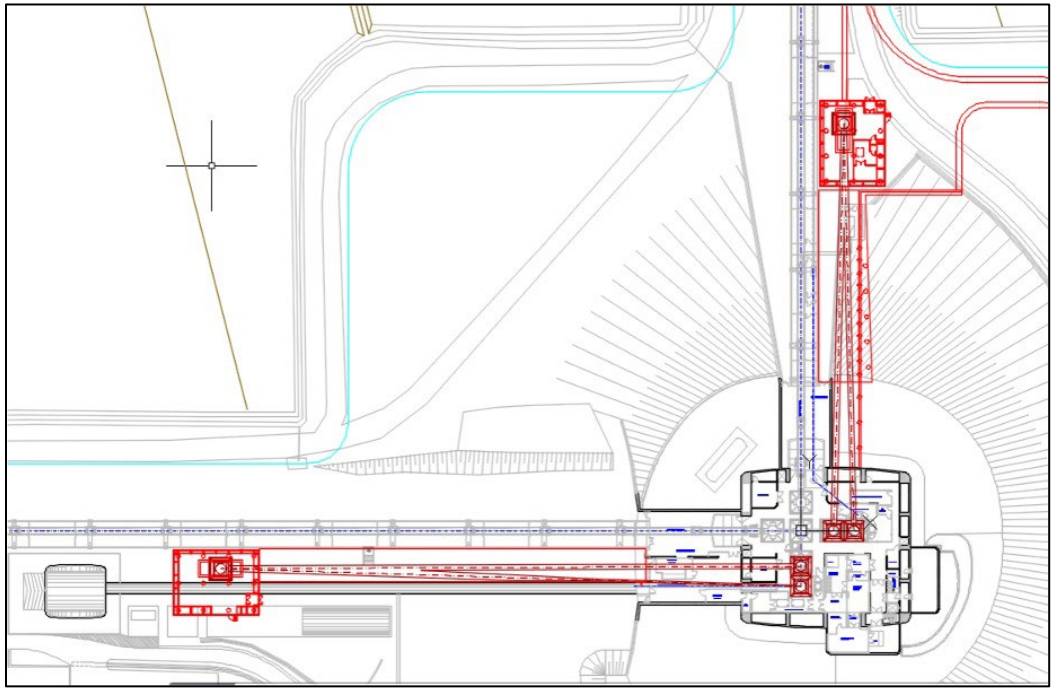


M Granata's thesis

G. Losurdo, VIR-0374A-23

NDRC SOLUTIONS ON THE TABLE

- As alternative a design for an ‘external’ (outside the existing vacuum envelope) implementation was pushed forward (2010/2011)
- Pros:
  - did not require multiple payloads on a single superattenuator;
  - much longer cavities allowed for less strong RoC and hence resulted in much lower requirements of optics
- On the other hand this solution required add new buildings, new vacuum, new suspensions … O(~10M€) in 2011 + time



S.Hild et al, LVK, March 2023

THE PATH FORWARD

- Options for anticipating the installation of stable cavities to before V_next must be assessed
- Extremely important is the **robustness and flexibility** of the possible solution identified

> From the STAC Report – Nov 2022: *It is important to try to retain some flexibility in the solution chosen – something which is too closely tailored to the present concept may cause trouble later on*

- A revision of the development program for phase 2 (and post-O5) is necessary and urgent
  - anticipation of the installation of stable cavities before O5?
  - postponement of the installation of heavy test masses to a later phase?

- The possibility of installing stable cavities before O5 needs to be studied in detail, from a technical, financial, timing and risk assesment perspectives