Virgo_nEXT

pushing the Virgo infrastructure to its EXTremes

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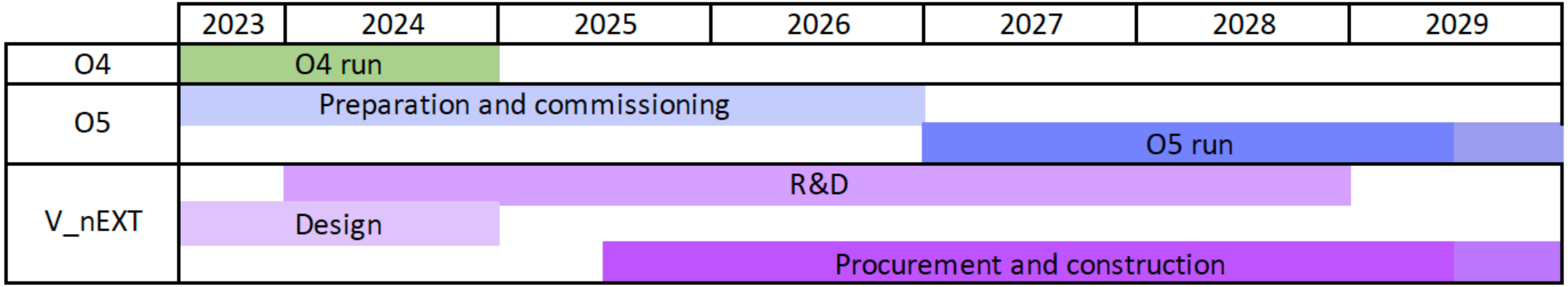
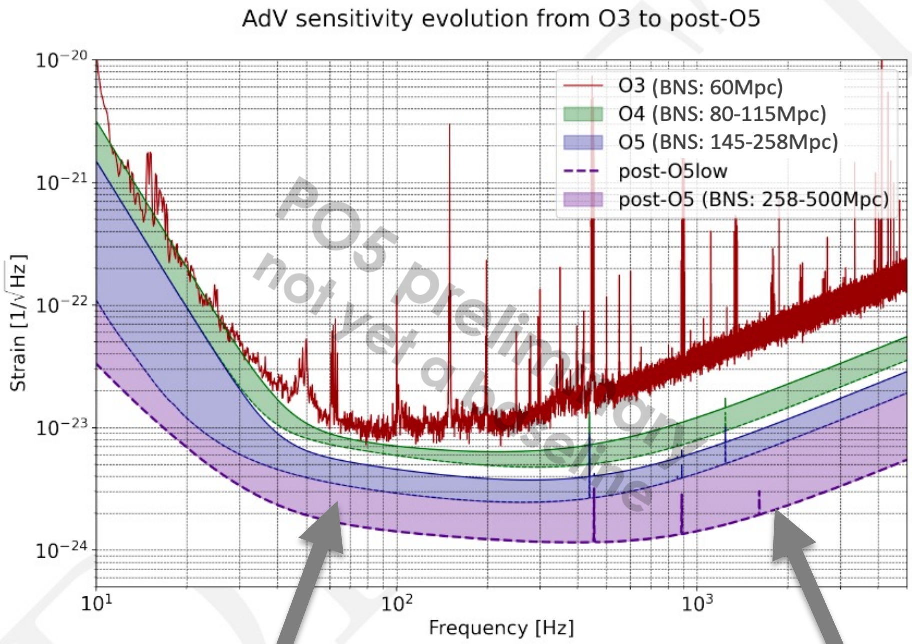
The concept study

1. A concept study for a new, substantial Virgo upgrade to fill the decadal gap between the end of O5 and the beginning of 3G operation, aiming to exploit the infrastructure to its limits
    - Show that there is the science case for a new, sustainable investment
    - Identify needed R&D topics (and synergies with 3G)
    - Focus on possible upgrades keeping 1064 nm and room temperature

- Submitted to the funding agencies (EGO Council)
- Not yet a baseline design, to be delivered end of 2024



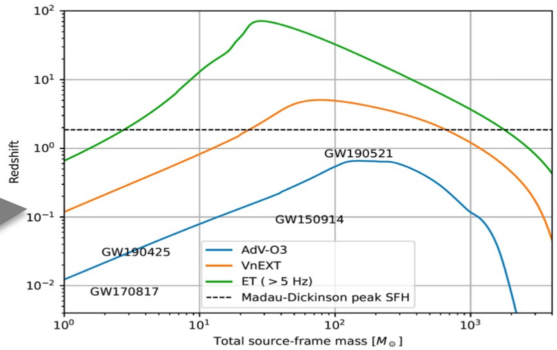
Virgo_nEXT



Baseline will be **inside this band**

Limits of the infrastructure

ameter	O4 high	O4 low	O5 high	O5 low	VnEXT_low	ET_HF
ver injected	25 W	40 W	60 W	80 W	277 W	
n power	120 kW	190 kW	290 kW	390 kW	1.5 MW	3 MW
gain	34	34	35	35	39	
esse	446	446	446	446	446	
nal recycling	Yes	Yes	Yes	Yes	Yes	
ueezing type	FIS	FDS	FDS	FDS	FDS	
ueezing detected level	3 dB	4.5 dB	4.5 dB	6 dB	10.5	10 dB
load type	AdV	AdV	AdV	AdV	Triple pendulum	
1 mass	42 kg	42kg	42 kg	42 kg	105 kg	200 kg
M mass	42 kg	42kg	105 kg	105 kg	105 kg	
1 beam radius	49 mm	49 mm	49 mm	49 mm	49 mm	
M beam radius	58 mm	58 mm	91 mm	91 mm	91 mm	
ating losses ETM	2.37e-4	2.37e-4	2.37e-4	0.79e-4	6.2e-6	
ating losses ITM	1.63e-4	1.63e-4	1.63e-4	0.54e-4	6.2e-6	
wtonian noise reduction	None	1/3	1/3	1/5	1/5	
hnical noise	"Late high"	"Late low"	"Late low"	None	None	
S range	90 Mpc	115 Mpc	145 Mpc	260 Mpc	500 Mpc	



Virgo_nEXT

- HPO: quality of the optics (point defects, optical absorptions), parametric instabilities, compensation of thermal effects (ITF controllability, achievable squeezing)
- Coating thermal noise
- Low frequency operation

Parameter	O4 high	O4 low	O5 high	O5 low	VnEXT_low	ET_HF
Power injected	25 W	40 W	60 W	80 W	277 W	
Arm power	120 kW	190 kW	290 kW	390 kW	1.5 MW	3 MW
PR gain	34	34	35	35	39	
Finesse	446	446	446	446	446	
Signal recycling	Yes	Yes	Yes	Yes	Yes	
Squeezing type	FIS	FDS	FDS	FDS	FDS	
Squeezing detected level	3 dB	4.5 dB	4.5 dB	6 dB	10.5	10 dB
Payload type	AdV	AdV	AdV	AdV	Triple pendulum	
ITM mass	42 kg	42kg	42 kg	42 kg	105 kg	200 kg
ETM mass	42 kg	42kg	105 kg	105 kg	105 kg	
ITM beam radius	49 mm	49 mm	49 mm	49 mm	49 mm	
ETM beam radius	58 mm	58 mm	91 mm	91 mm	91 mm	
Coating losses ETM	2.37e-4	2.37e-4	2.37e-4	0.79e-4	6.2e-6	
Coating losses ITM	1.63e-4	1.63e-4	1.63e-4	0.54e-4	6.2e-6	
Newtonian noise reduction	None	1/3	1/3	1/5	1/5	
Technical noise	“Late high”	“Late low”	“Late low”	None	None	
BNS range	90 Mpc	115 Mpc	145 Mpc	260 Mpc	500 Mpc	

The Case for Stable Cavities

- Inputs from commissioning: impact of HOM in the SR cavity → ITF controllability, squeezing degradation
- HPO (10x intracavity power wrt present, 4-5x wrt O5) and QNR are key ingredients of V_nEXT
- It will be extremely challenging/close to impossible to reach the targeted V_nEXT sensitivity w/o implementing stable recycling cavities

(some of the) Synergies with 3G

- Observational science, data analysis and computation, e.g.,
  i. Development of science cases (multi-messenger, fundamental physics, nuclear physics, Galactic science, environmental effects, populations, cosmology,...)
  ii. Overlapping signals, longer waveforms for template searches & inference, and early warning/low latency analysis …
  iii. Exploitation of HPU, GPUs, and novel architectures, large scale distributed architectures, infrastructures for high rate low-latency and alert management …
  iv. Synergies with other GW observatories and experiments
- Instrument science
  i. High power operation (laser, thermal compensation system, parametric instabilities, optical components)
  ii. Frequency dependent squeezing (mitigation of losses, active wavefront control)
  iii. Large test masses (optics, suspensions)
  iv. New coatings
  v. Low frequency operation (Virgo is a unique environment: V_nEXT can contribute to the de-risking of ET by studying many technical noise sources and their interplay at the LF end of the observation band)
- Maintain community of high-level experimentalists for 3rd generation. Train a new generation of experts, those who will run ET