VIRGO

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ADVANCED VIRGO

Advanced Virgo (AdV): upgrade of the Virgo interferometric detector

Participated by France and Italy (former founders of Virgo), The Netherlands, Poland, Hungary, Spain

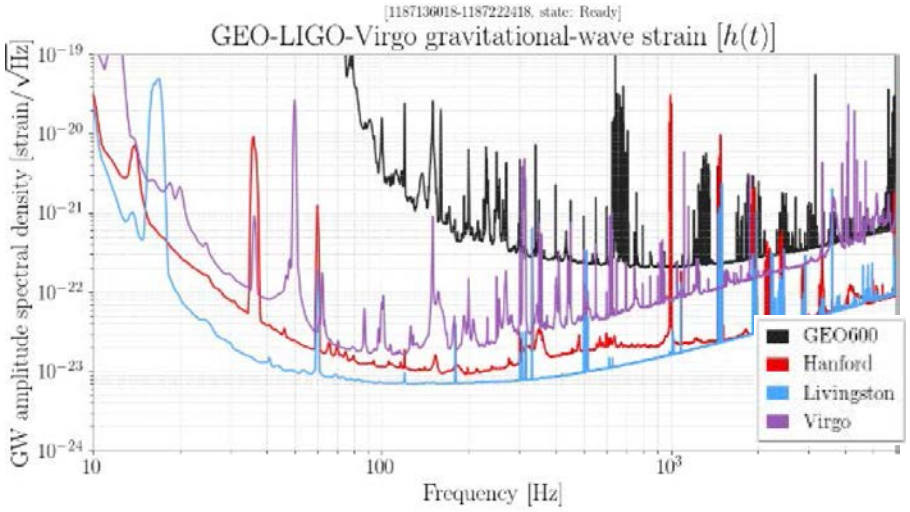
Funding approved in Dec 2009
(21.8 ME + Nikhef in kind contribution)

Project formally completed with the start of the O2 run (1 Aug 2017)

6 European countries
23 labs, ~280 authors

APC Paris
ARTEMIS Nice
EGO Cascina
INFN Firenze-Urbino
INFN Genova
INFN MiB-Parma-Torino
INFN Napoli
INFN Perugia
INFN Pisa
INFN Roma La Sapienza
INFN Roma Tor Vergata
INFN Padova
INFN Salerno/Uni Sannio
INFN TIFPA Trento
LAL Orsay – ESPCI Paris
LAPP Annecy
LKB Paris
LMA Lyon
NIKHEF Amsterdam
POLGRAW
RADBOUD Uni. Nijmegen
RMKI Budapest
University of Valencia

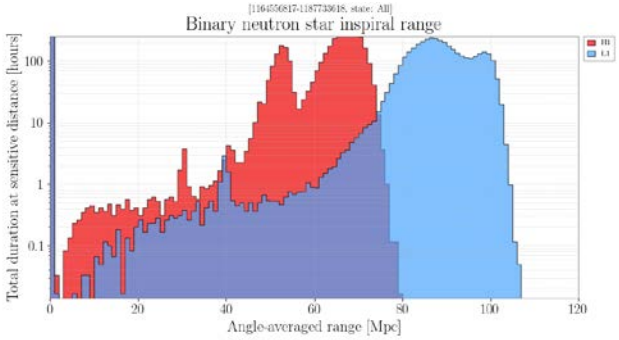
O2 SUMMARY

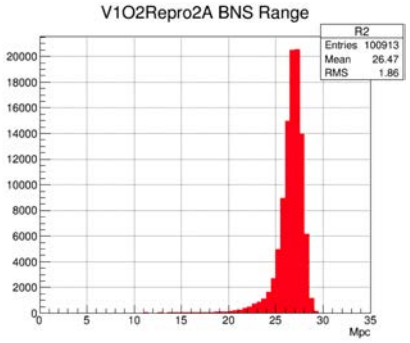


Noise budget

Many bumps and lines and some extra broadband noise

Scattered light, some sensing noise, unknown….





VIRGO

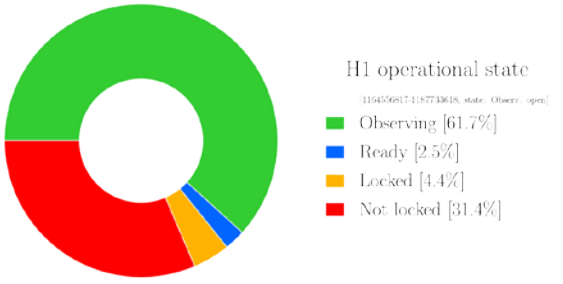
HIGHEST BNS RANGE: **28.2 Mpc**

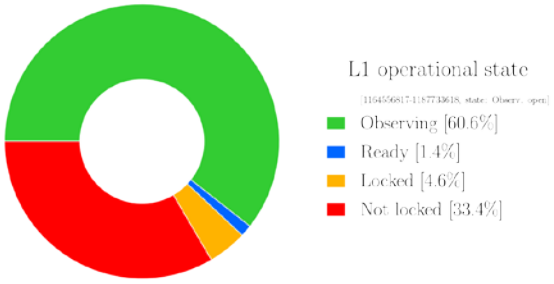
AVERAGE RANGE:

BNS 26 - BBH_{10} 134 - BBH_{30} 314 Mpc

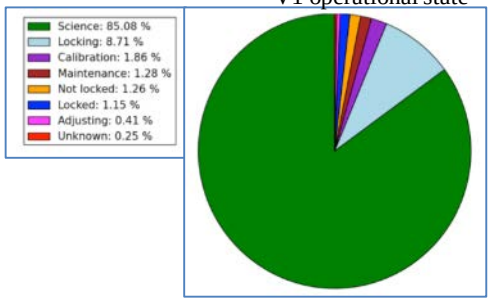
DUTY CYCLE: **85%**

LONGEST LOCK STRETCH: **69 hrs**





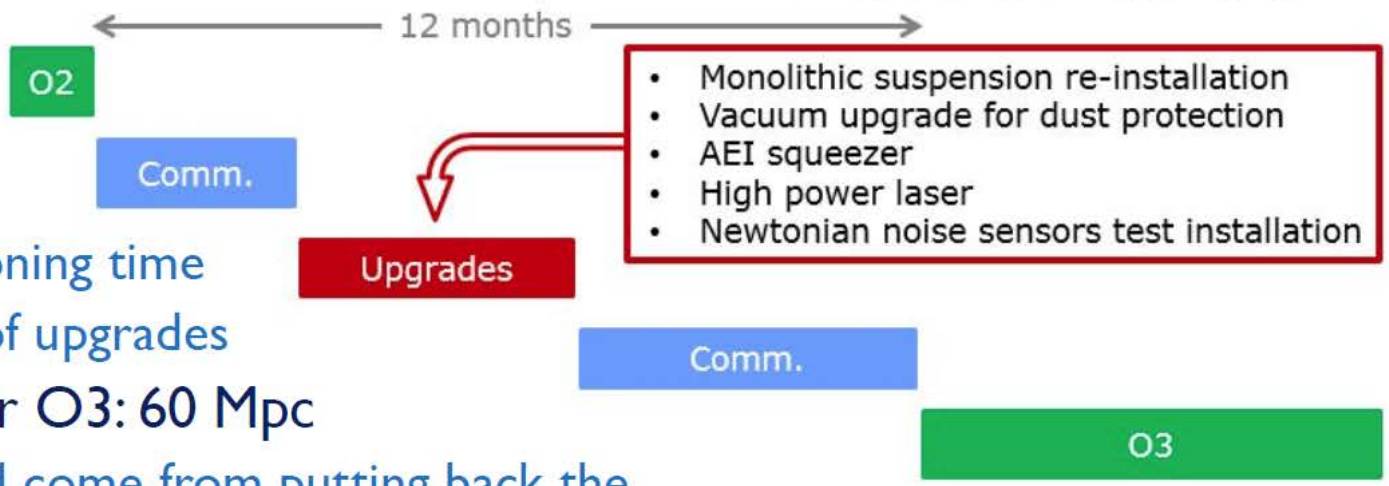
V1 operational state



LIGO-VIRGO DETECTIONS

GW event	Detection time (UTC)	Date published	Location area[n 1] (deg^2)	Luminosity distance (Mpc)[n 2]	Energy radiated ($c^2M_\odot$)[n 3]	Chirp mass ($M_\odot$)[n 4]	Primary		Secondary		Remnant		
							Type	Mass ($M_\odot$)	Type	Mass ($M_\odot$)	Type	Mass ($M_\odot$)	Spin[n 5]
GW150914	2015-09-14 09:50:45	2016-02-11	600; mostly to the south	440^{+160}_{-180}	$3.0^{+0.5}_{-0.5}$	$28.2^{+1.8}_{-1.7}$	BH[n 6]	$35.4^{+5.0}_{-3.4}$	BH[n 7]	$29.8^{+3.3}_{-4.3}$	BH	$62.2^{+3.7}_{-3.4}$	$0.68^{+0.05}_{-0.06}$
LVT151012 (fr)	2015-10-12 09:54:43	2016-06-15	1600	1000^{+500}_{-500}	$1.5^{+0.3}_{-0.4}$	$15.1^{+1.4}_{-1.1}$	BH	23^{+18}_{-6}	BH	13^{+4}_{-5}	BH	35^{+14}_{-4}	$0.66^{+0.09}_{-0.10}$
GW151226	2015-12-26 03:38:53	2016-06-15	850	440^{+180}_{-190}	$1.0^{+0.1}_{-0.2}$	$8.9^{+0.3}_{-0.3}$	BH	$14.2^{+8.3}_{-3.7}$	BH	$7.5^{+2.3}_{-2.3}$	BH	$20.8^{+6.1}_{-1.7}$	$0.74^{+0.06}_{-0.06}$
GW170104	2017-01-04 10:11:58	2017-06-01	1200	880^{+450}_{-390}	$2.0^{+0.6}_{-0.7}$	$21.1^{+2.4}_{-2.7}$	BH	$31.2^{+8.4}_{-6.0}$	BH	$19.4^{+5.3}_{-5.9}$	BH	$48.7^{+5.7}_{-4.6}$	$0.64^{+0.09}_{-0.20}$
GW170608	2017-06-08 02:01:16	2017-11-16	520; to the north	340^{+140}_{-140}	$0.85^{+0.07}_{-0.17}$	$7.9^{+0.2}_{-0.2}$	BH	12^{+7}_{-2}	BH	7^{+2}_{-2}	BH	$18.0^{+4.8}_{-0.9}$	$0.69^{+0.04}_{-0.05}$
GW170814	2017-08-14 10:30:43	2017-09-27	60; towards Eridanus	540^{+130}_{-210}	$2.7^{+0.4}_{-0.3}$	$24.1^{+1.4}_{-1.1}$	BH	$30.5^{+5.7}_{-3.0}$	BH	$25.3^{+2.8}_{-4.2}$	BH	$53.2^{+3.2}_{-2.5}$	$0.70^{+0.07}_{-0.05}$
GW170817	2017-08-17 12:41:04	2017-10-16	28; NGC 4993	40^{+8}_{-14}	> 0.025	$1.188^{+0.004}_{-0.002}$	NS	1.36 - 1.60[n 8]	NS	1.17 - 1.36[n 9]	BH[n 10]	$< 2.74^{+0.04}_{-0.01}$ [n 11]	

FROM O2 TO O3

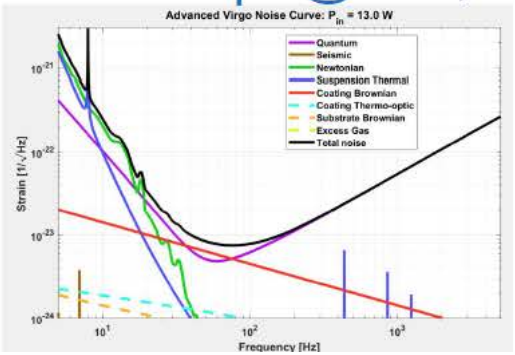


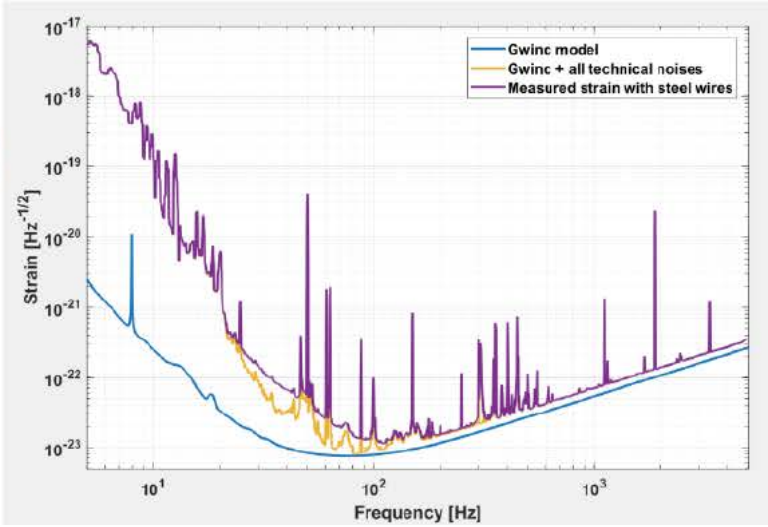
Strategy:

- Reserve commissioning time
- Limit the number of upgrades

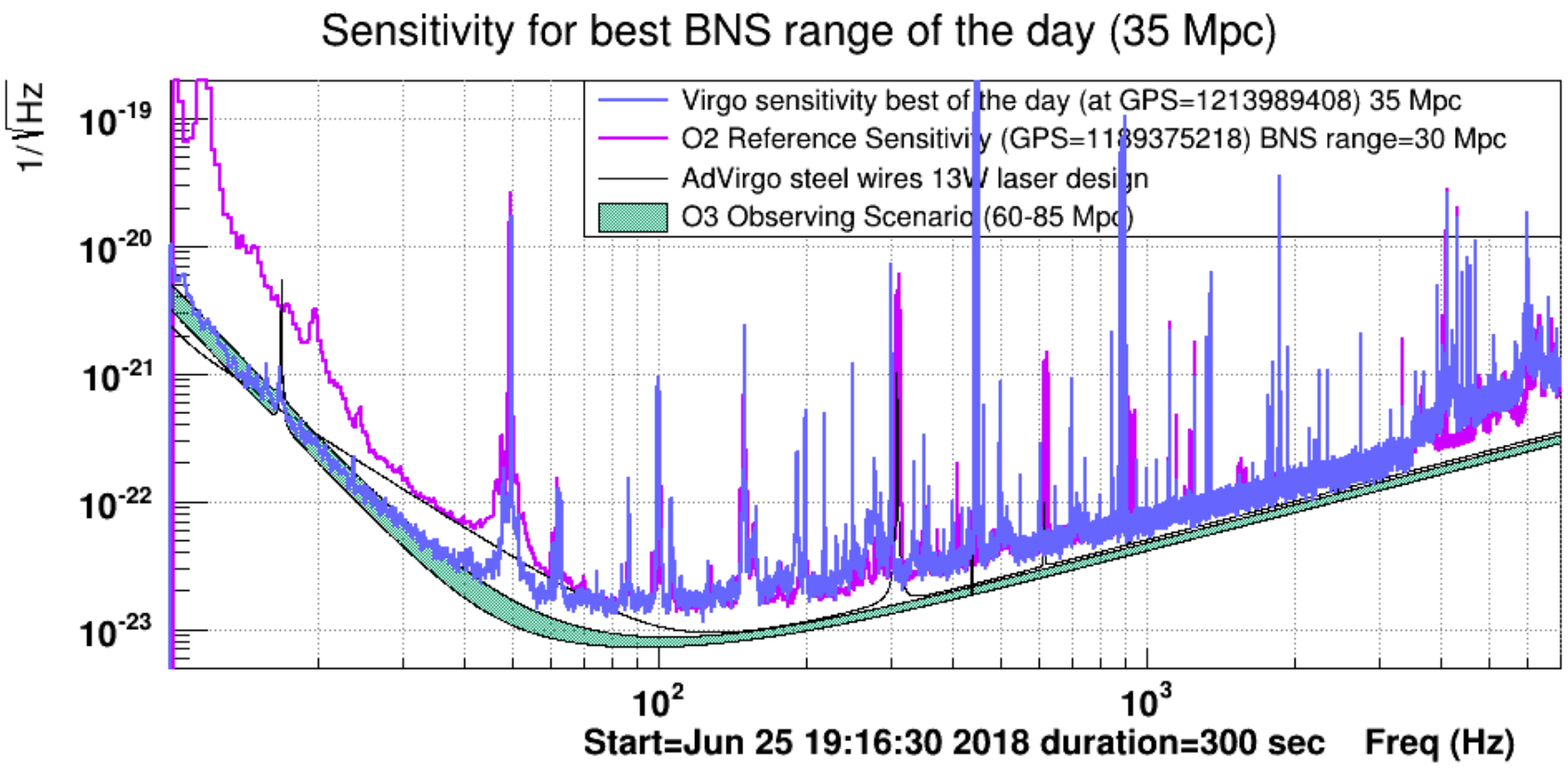
Target sensitivity for O3: 60 Mpc

- Main benefit should come from putting back the monolithic suspension
  - Removing the steel wire thermal noise from noise budget gives a 20 Mpc range increase
- Theoretical limits: 100 Mpc @13W, no squeezing

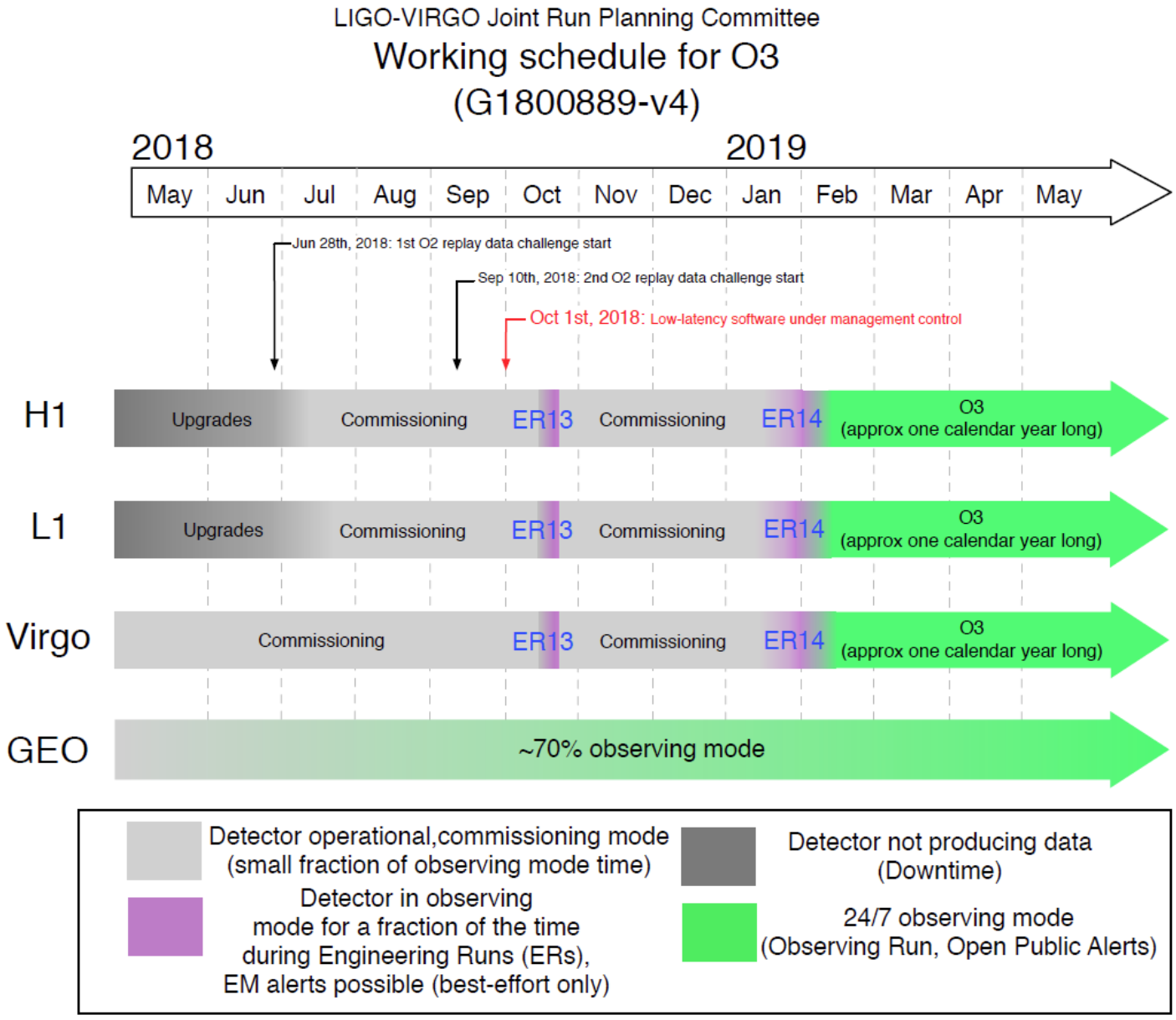




FROM O2 TO O3


Sensitivity for best BNS range of the day (35 Mpc)
1/√Hz
10^-19
10^-20
10^-21
10^-22
10^-23
Virgo sensitivity best of the day (at GPS=1213989408) 35 Mpc
O2 Reference Sensitivity (GPS=1189375218) BNS range=30 Mpc
AdVirgo steel wires 13W laser design
O3 Observing Scenario (60-85 Mpc)
10^2
10^3
Start=Jun 25 19:16:30 2018 duration=300 sec
Freq (Hz)

FROM O2 TO O3


LIGO-VIRGO Joint Run Planning Committee
Working schedule for O3
(G1800889-v4)
2018
2019
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun 28th, 2018: 1st O2 replay data challenge start
Sep 10th, 2018: 2nd O2 replay data challenge start
Oct 1st, 2018: Low-latency software under management control
H1
Upgrades
Commissioning
ER13
Commissioning
ER14
O3
(approx one calendar year long)
L1
Upgrades
Commissioning
ER13
Commissioning
ER14
O3
(approx one calendar year long)
Virgo
Commissioning
ER13
Commissioning
ER14
O3
(approx one calendar year long)
GEO
~70% observing mode
Detector operational,commissioning mode
(small fraction of observing mode time)
Detector in observing
mode for a fraction of the time
during Engineering Runs (ERs),
EM alerts possible (best-effort only)
Detector not producing data
(Downtime)
24/7 observing mode
(Observing Run, Open Public Alerts)

WHAT NEXT?

2.5 G: a set of upgrades capable of enhancing the sensitivities of the current detectors (event rate 5-10x)
AdV+ in Europe; A+ in USA

- Timeline: ~2024
- Cost: ~20÷30 M€

3 G: new infrastructures/detectors capable of reaching the early universe. One order of magnitude gained in sensitivity wrt 2G

- Timeline: ~2030
- Cost > 1 G€

Einstein Telescope: European project for a nested assembly of 6 co-located interferometers, 10 km long

- underground
- bandwidth extended to 1 Hz
- cryogenics

Cosmic Explorer: US project for a 40 km interferometer

Bridge to future 3G GW **astrophysics, cosmology, and nuclear physics**
Stepping stone to **3G detector technology**
Can be observing within **6 years** (2024)

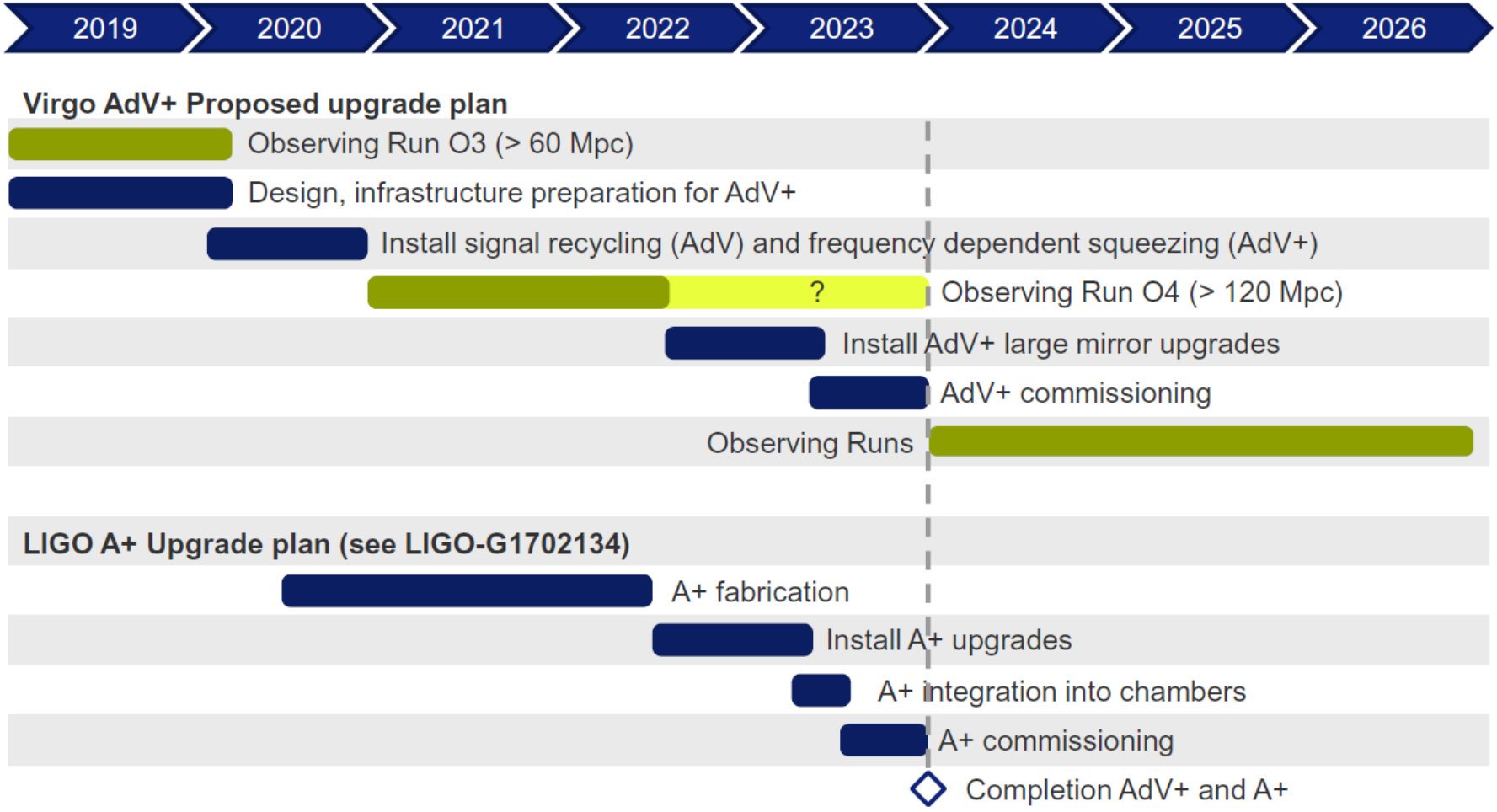
Upgrades split in two phases:

Phase 1: BNS range up to 160 Mpc
– frequency dependent squeezing (Genova)
– newtonian noise cancellation (Genova)

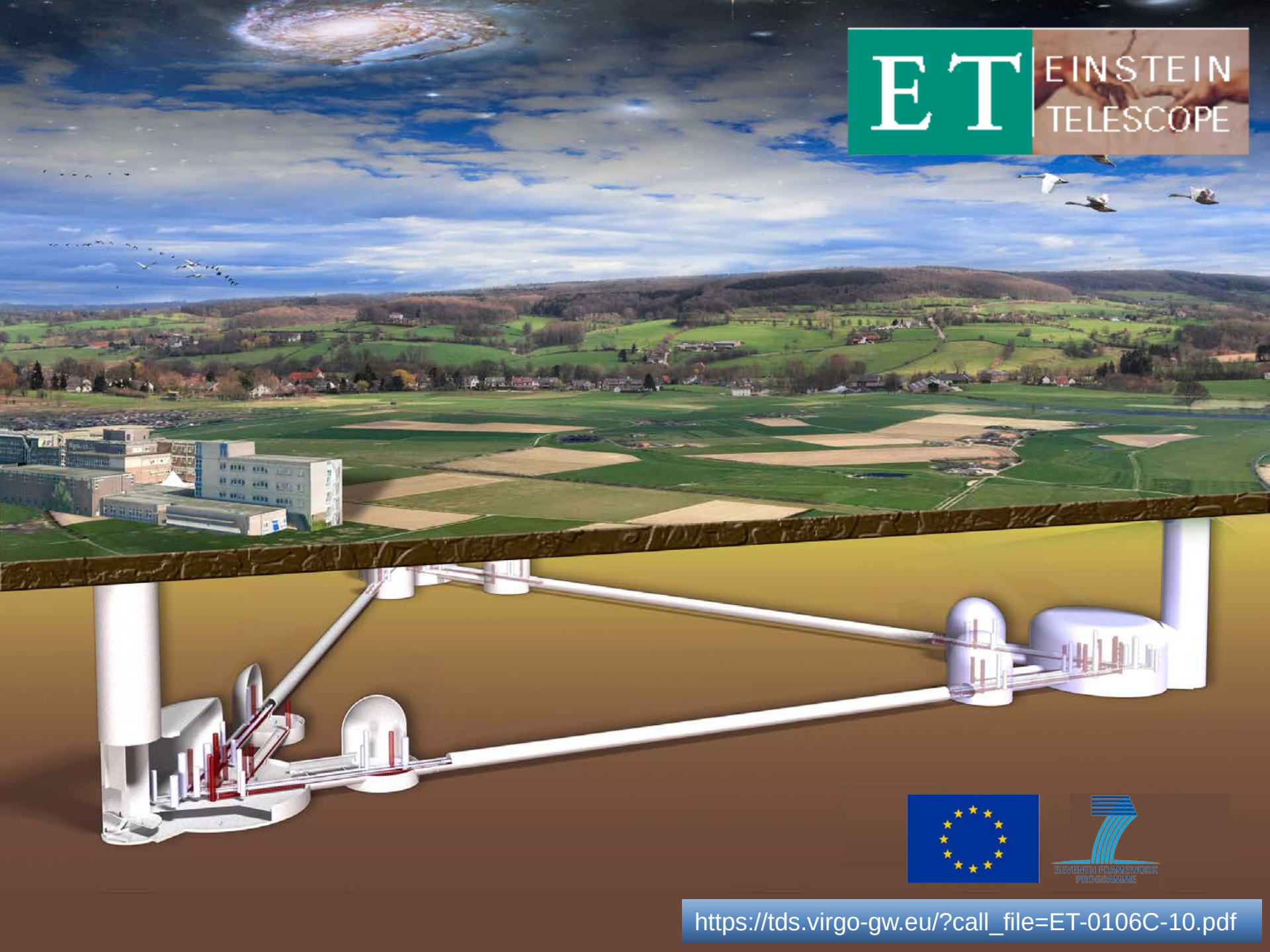
Phase 2: BNS range up to 260 (300) Mpc
– new, larger mirrors
– new suspensions
– factor 3 of coating thermal noise reduction (Genova)

TENTATIVE TIMELINE

Five year plan for observational runs, commissioning and upgrades



Note: duration of O4 has not been decided at this moment


ET
EINSTEIN
TELESCOPE
SEVENTH FRAMEWORK
PROGRAMME
https://tds.virgo-gw.eu/?call_file=ET-0106C-10.pdf

- SENSING AND CONTROL/COMMISSIONING
  (D. Bersanetti)
- COMPUTING AND CONTROLS
  (L. Rei)
- SQUEEZING
  (F. Sorrentino)

VIRGO@GE
R&D, DA AND SIMULATIONS

- OPTICAL COATING R&D
  (M. Canepa)
- DEVELOPMENT OF INNOVATIVE SA VERTICAL FILTERS
  (R. Musenich)
- FEM SIMULATIONS – NEWTONIAN NOISE
  (A. Chincarini, S. Farinon, A. Cirone)

- EM FOLLOW-UP OF GW TRIGGERS
  (A. Chincarini)

VIRGO@GE
EXTERNAL PROJECTS

In corso

- PRIN 2015 (F. Sorrentino – Quantum Optics lab)
- San Paolo – Bando 2017 (M. Canepa)
- PREMIALE 2017 (G. Gemme)

Sottomessi

- PRIN 2017 (3 progetti: Gemme, Chincarini, Sorrentino)
- Progetti di grande rilevanza ITA-USA (Gemme)

ANAGRAFICA E SERVIZI

RICERCATORI e TECNOLOGI

1	Bersanetti Diego	Assegnista	1,00
2	Canepa Maurizio	PO	0,40
3	Chincarini Andrea	Ricercatore	0,60
4	Cirone Alessio	PhD	0,60
5	Farinon Stefania	Primo Tecnologo	0,30
6	Gemme Gianluca	Primo Ricercatore	0,55+0,05 PRIN 2015
7	Musenich Riccardo	Primo Ricercatore	0,30
8	Rei Luca	Assegnista	1,00
9	Robotti Nadia	PO	0,20
10	Sorrentino Fiodor	Ricercatore	0,55+0,05 PRIN 2015
	TOTALE		**5,50+0,10**

SERVIZI E PERSONALE TECNICO

Officina Meccanica	2
Davide Bondi	80