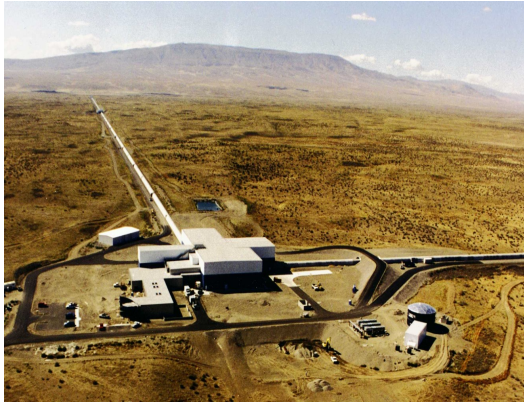# Ground-based detectors in the next years
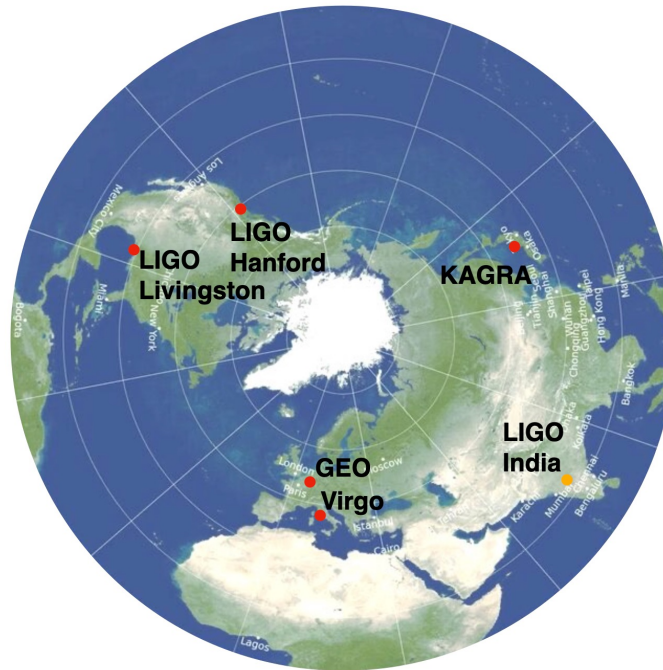
Matteo Barsuglia

GdR OG

The current detectors and infrastructures

LIGO
Livingston

KAGRA
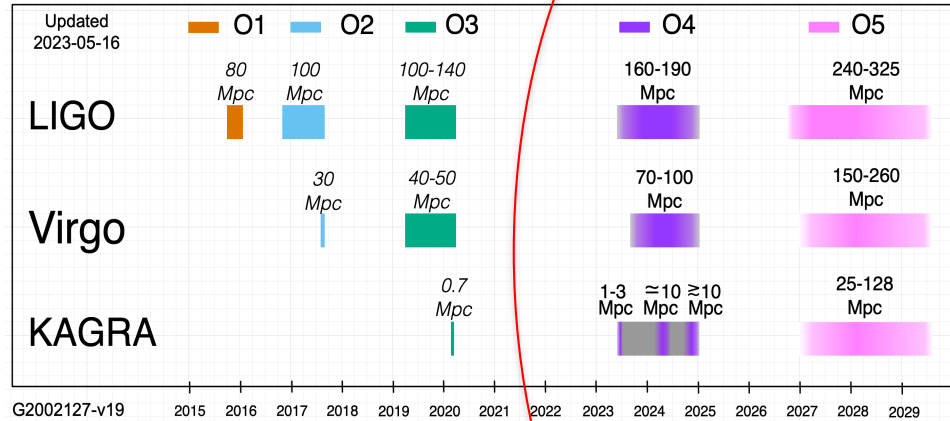

LIGO
Hanford

Virgo

LVK

Cumulative Count of Events/Candidates
O1 = 3, O2 = 8, O3a = 44, O3b = 35, Total = 126

LIGO-G2001862

Credit: LIGO-Virgo Collaboration

P2300076

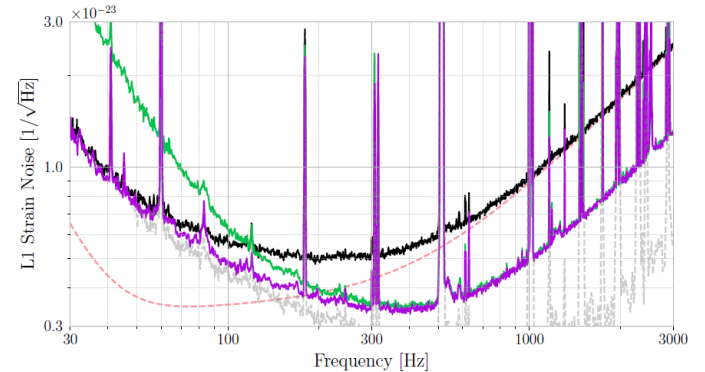|	O1	O2	O3	O4	O5
LIGO	80 Mpc	100 Mpc	100-140 Mpc	160-190 Mpc	240-325 Mpc
Virgo		30 Mpc	40-50 Mpc	70-100 Mpc	150-260 Mpc
KAGRA			0.7 Mpc	1-3 Mpc ≈10 Mpc ≳10 Mpc	25-128 Mpc

Updated 2023-05-16

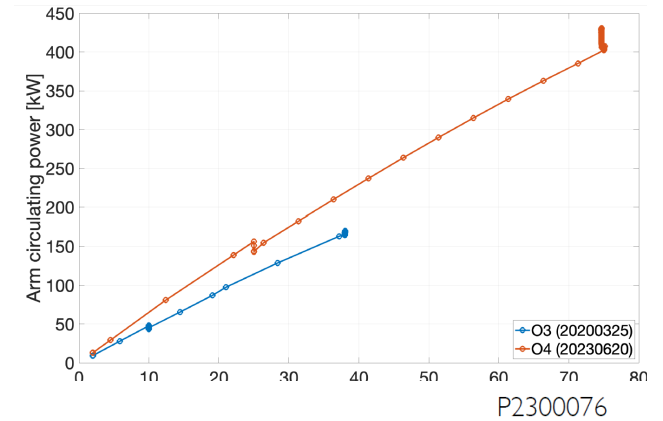G2002127-v19
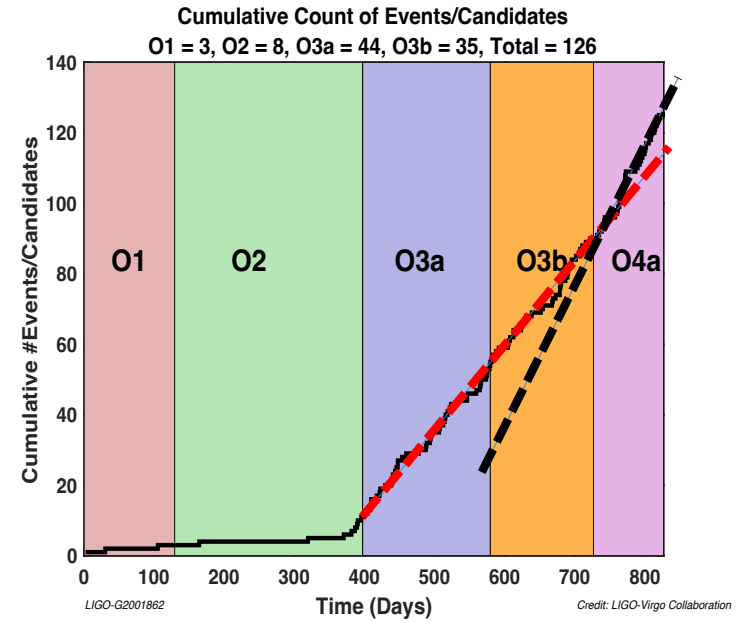
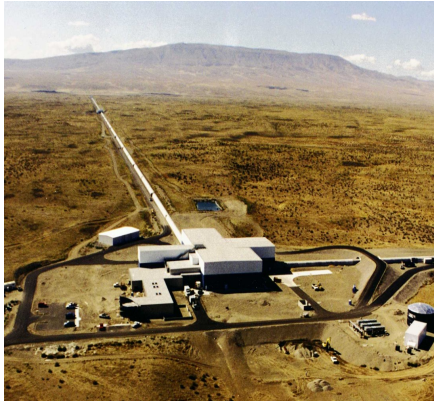Advanced Virgo+
Advanced LIGO+

First detection

90 sources

GW170817

See presentation
by Raffaele
Flaminio

GdR Meudon 2023

The current detectors and infrastructures

LIGO
Livingston

A rendering of the LIGO India site in the state of Maharashtra

India Approves Construction of Its Own LIGO
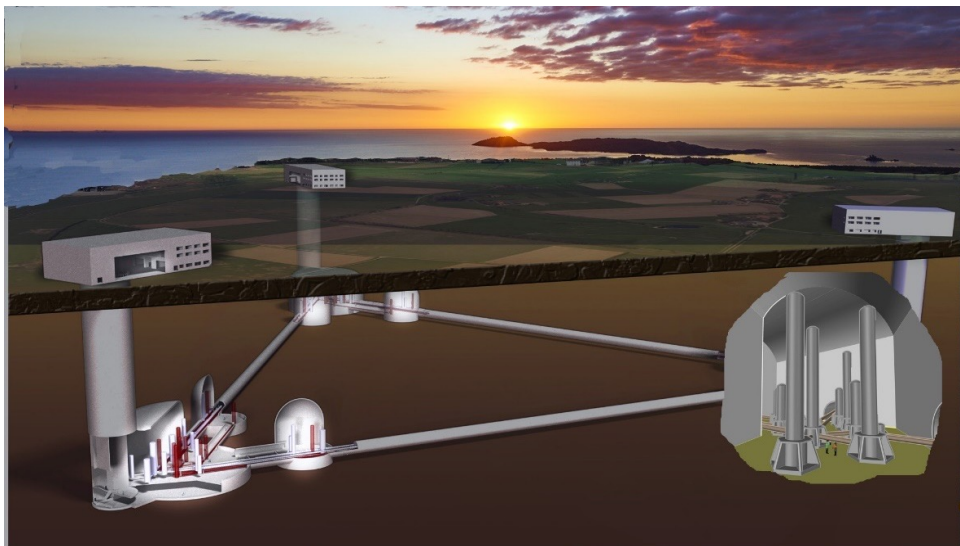
Feature Story • April 17, 2023

LIGO-India will greatly improve the localization of sources of gravitational waves

Written by Whitney Clavin
Caltech

The Indian government has granted the final approvals necessary for construction to begin on LIGO-India, a nearly identical version of the twin LIGO (Laser Interferometer Gravitational-Wave Observatory) facilities that **made history** after making the **first direct detection of ripples in space and time known as gravitational waves** in 2015. The Indian government will spend about $320 million to build LIGO-India, with first observations expected by the end of the decade.

Einstein Telescope and Cosmic Explorer

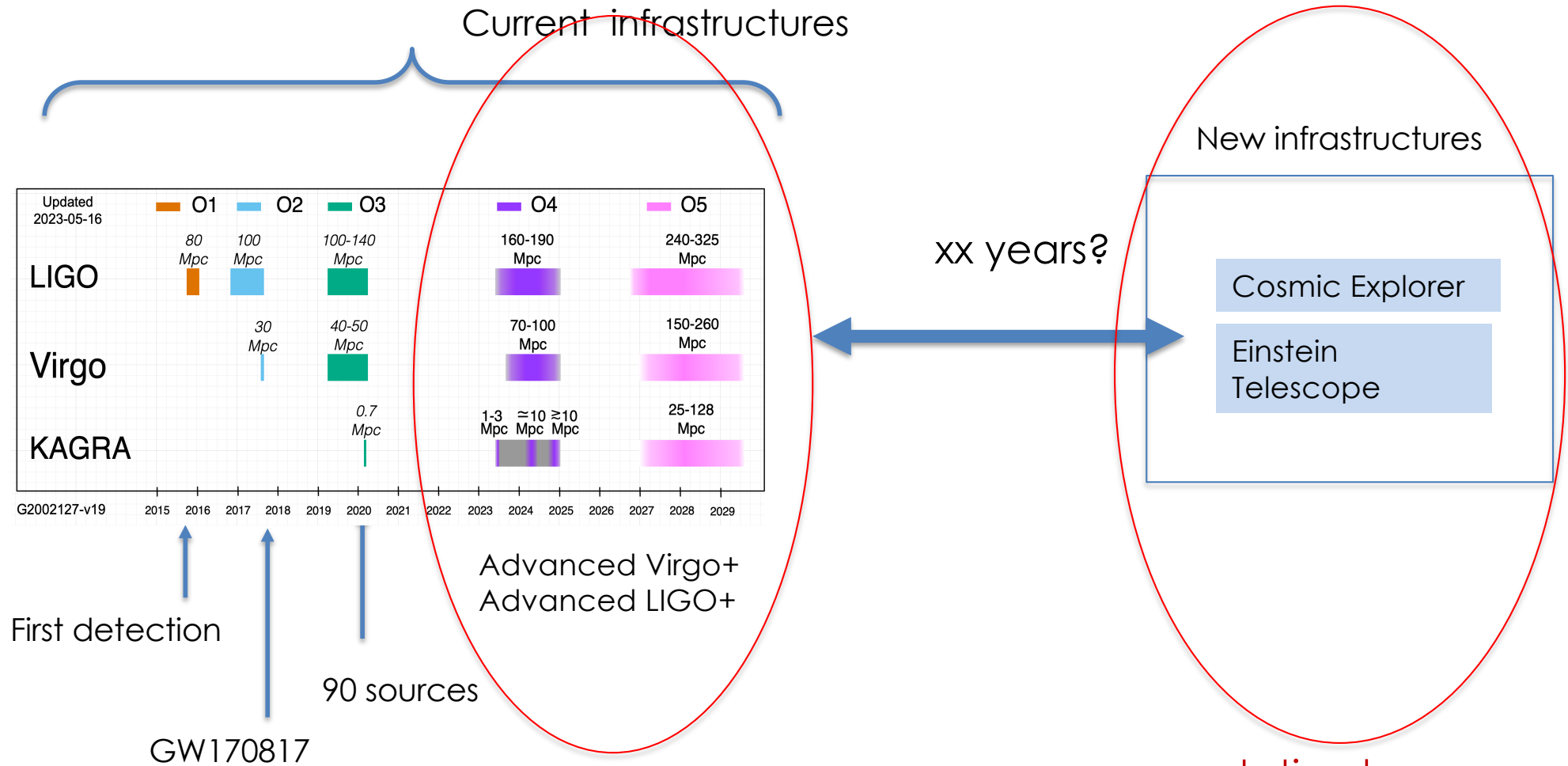See presentation by Angélique Lartaux

LVK vs ET/CE

Current infrastructures

New infrastructures

Updated 2023-05-16	O1	O2	O3	O4	O5

	80 Mpc	100 Mpc	100-140 Mpc	160-190 Mpc	240-325 Mpc
LIGO					
Virgo		30 Mpc	40-50 Mpc	70-100 Mpc	150-260 Mpc
KAGRA			0.7 Mpc	1-3 Mpc ≃10 Mpc ≳10 Mpc	25-128 Mpc

G2002127-v19   2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029

xx years?

Cosmic Explorer

Einstein Telescope

Advanced Virgo+
Advanced LIGO+

First detection

90 sources

GW170817

presentation by
Raffaele Flaminio

presentation by
Angélique
Lartaux

Virgo_nEXT and A#

Current infrastructures

New infrastructures

Updated 2023-05-16

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Advanced Virgo+
Advanced LIGO+
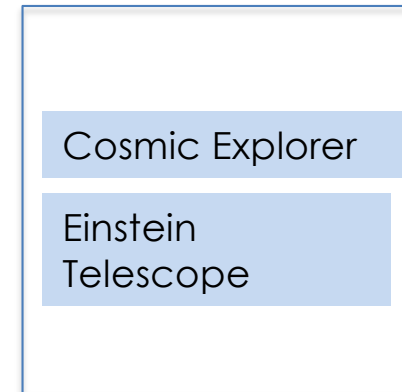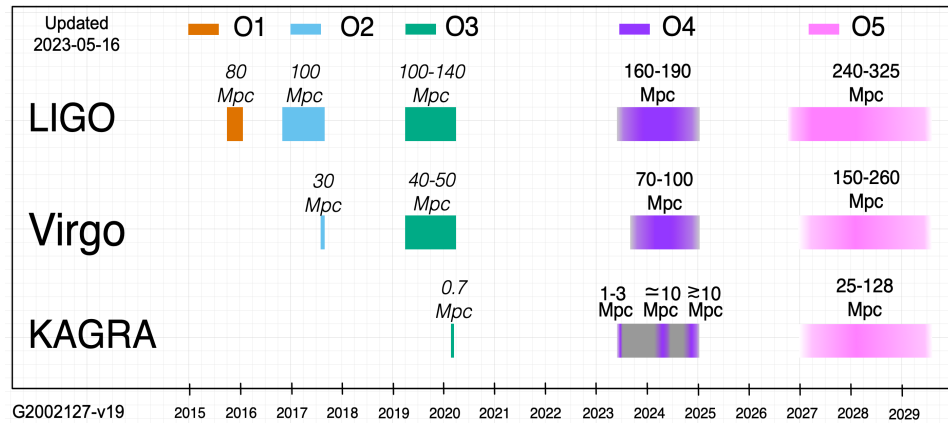
First detection

GW170817

90 sources

LIGO upgrade A#

Virgo_nEXT

KAGRA upgrade

2030's

Cosmic Explorer

Einstein Telescope

Virgo_nEXT: why

⚗ Continue Virgo's science programme in the LVK gravitational-wave detector
network

🚀 Push the potential of the existing infrastructure to its limits

🔧 Test the technologies used in the ET avoiding design mistakes and accelerating
commissioning

🕐 Fill a potential gap of a decade between the end of O5 and the first ET design
sensitivity

👥 Keep and develop the expertise of the experimental and data analysis community

⇄ Ensure smooth generational transition and training of new leaders

Work started in early 2021
Concept document 1st version May 2022

Virgo_nEXT: why

- 🧪 Continue Virgo's science progra[m]   network

- 🚀 Push the potential of the existing

- 🔧 Test the technologies used in the   commissioning

- 🕐 Fill a potential gap of a decade b[etween]   sensitivity

- 👥 Keep and develop the expertise of

- ⇄ Ensure smooth generational trans[ition]

Virgo_nEXT: beyond the AdV+ project

**A concept study**

The VIRGO Collaboration[1]

VIR-0497D-22

Date: February 23, 2023

[1] EDITORS:
N. Arnaud, S. Bagnasco, M. Barsuglia, D. Bersanetti, G. Cagnoli, E. Capocasa, E. Cesarini, W. Chaibi, T. Dal Canton, S. Dall'Osso, S. Danilishin, V. Dattilo, J. Degallaix, W. Del Pozzo, V. Fafone, F. Fidecaro, G. Gemme, S. Hild, M. Lorenzini, M. Mantovani, M. Martinez, S. Mastrogiovanni, E. Milotti, I. Nardecchia, S. Nissanke, C. Palomba, A. Pasqualetti, R. Passaquieti, P. Puppo, T. Regimbau, A. Rocchi, L. Rolland, B. Sassolas, F. Sorrentino, A. Trovato, E. Tournefier
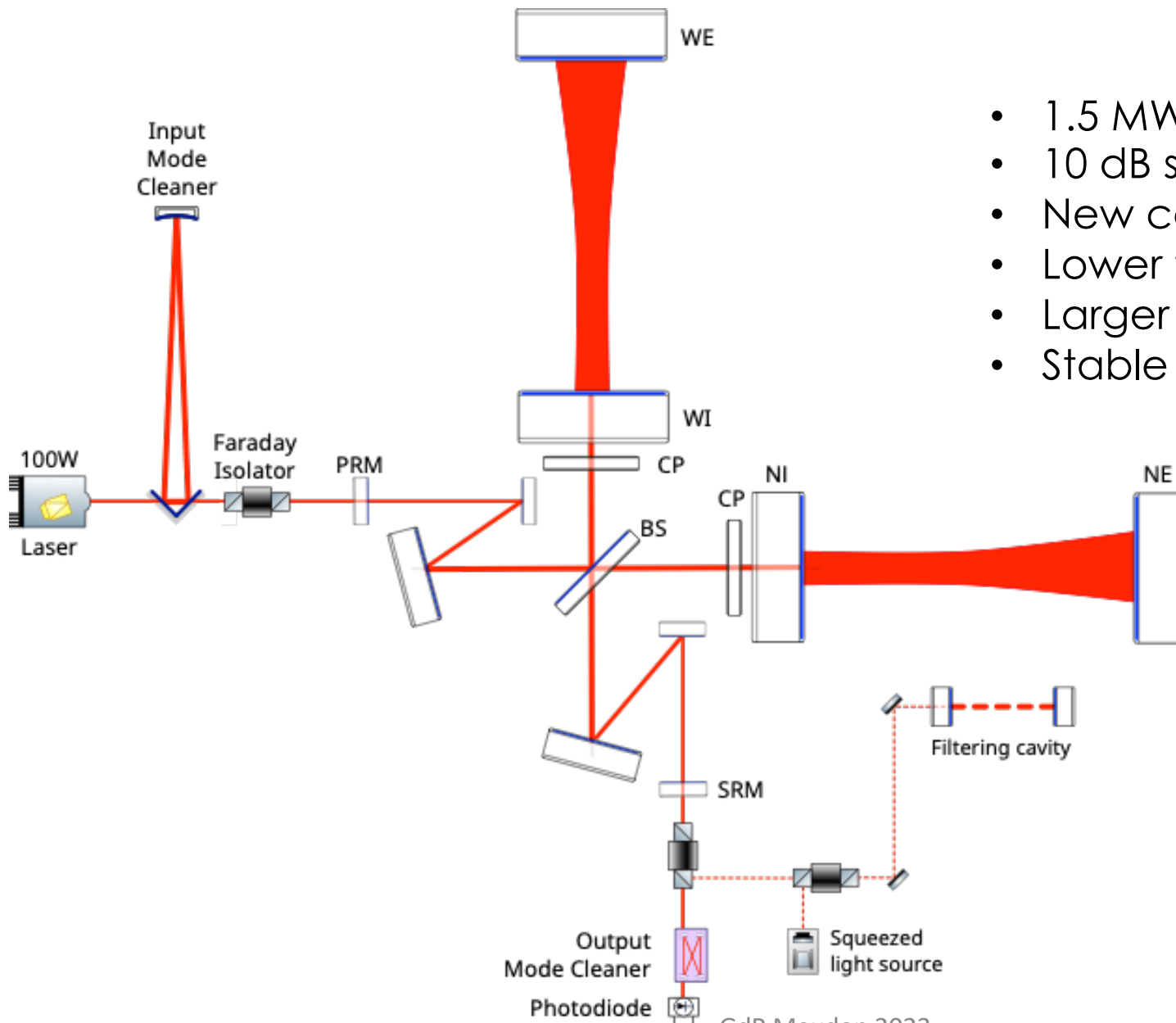
LIGO A#

- Similar project in LIGO : A#:
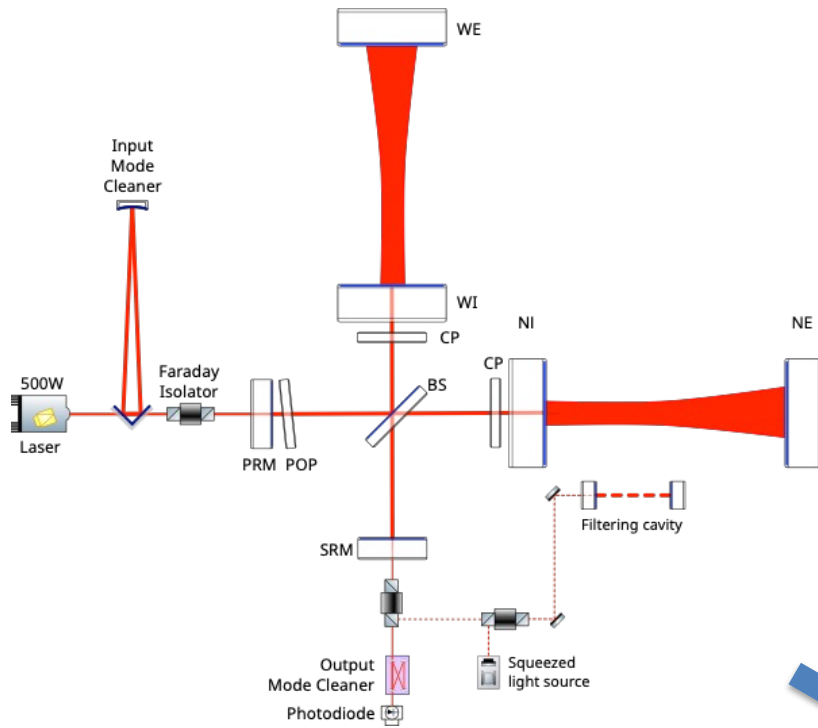 https://dcc.ligo.org/public/0183/T2200287/002/T2200287v2_PO5report.pdf
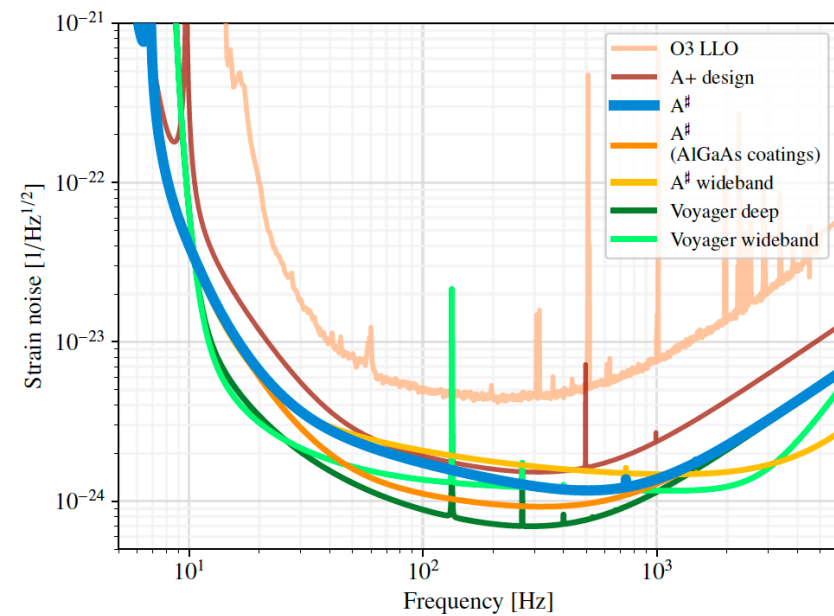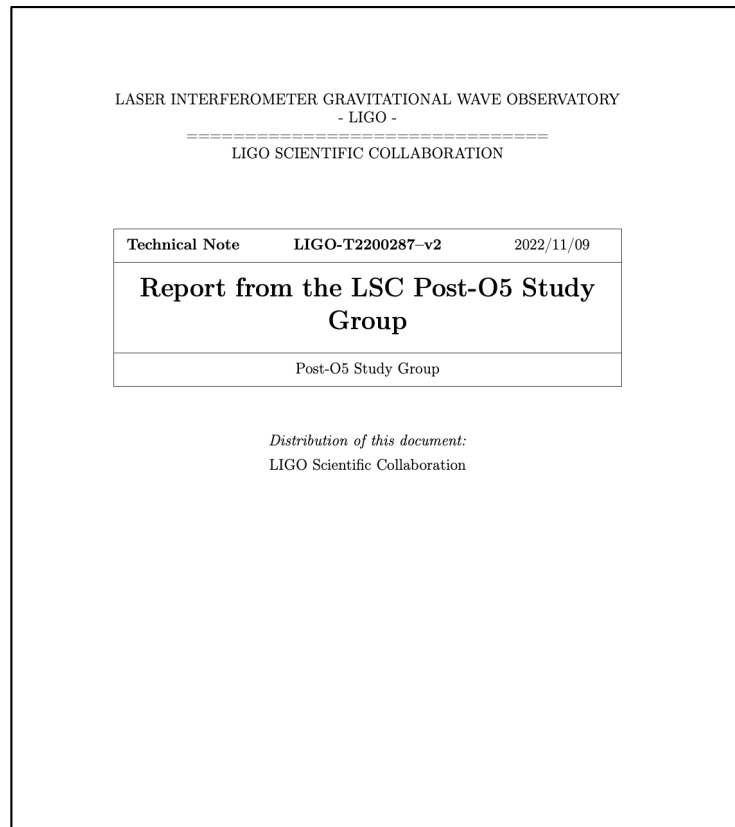
Detector concept

- 1.5 MW power in the cavities
- 10 dB squeezing
- New coatings
- Lower technical noises
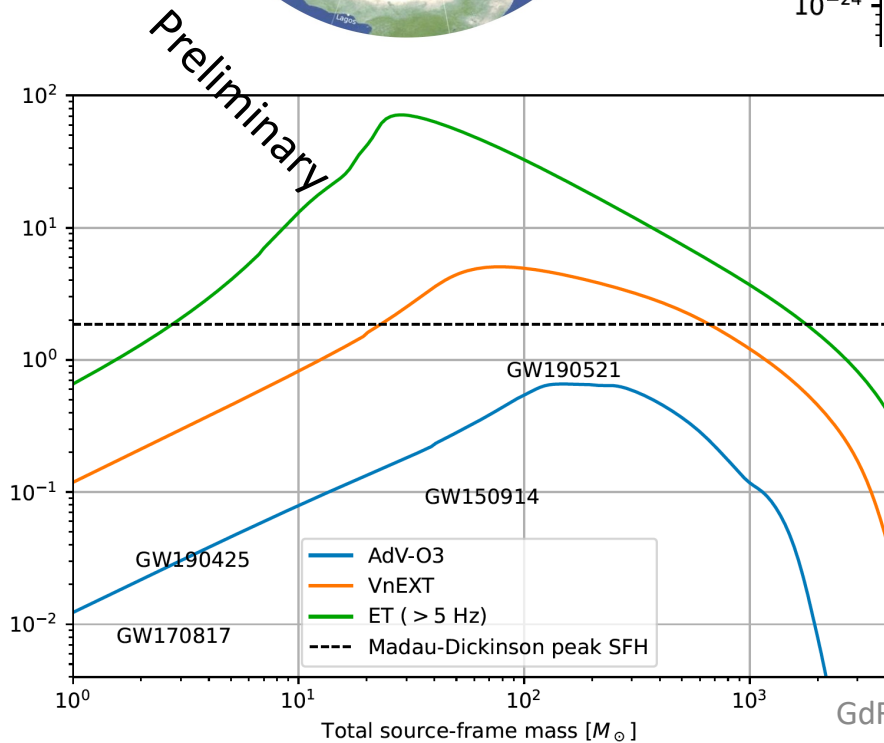- Larger input test masses
- Stable recycling cavities

WE

Input Mode Cleaner
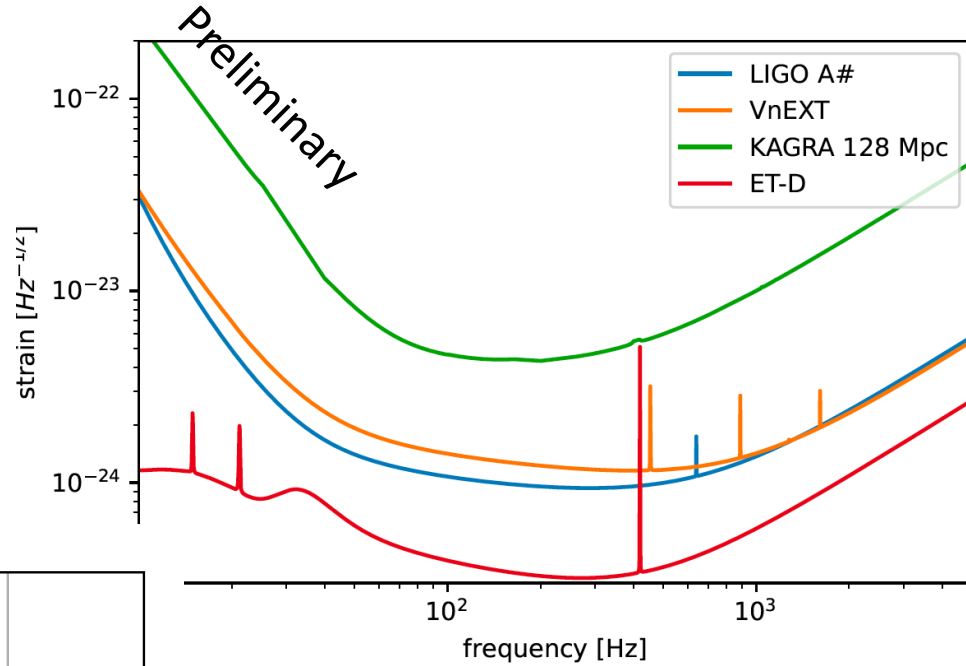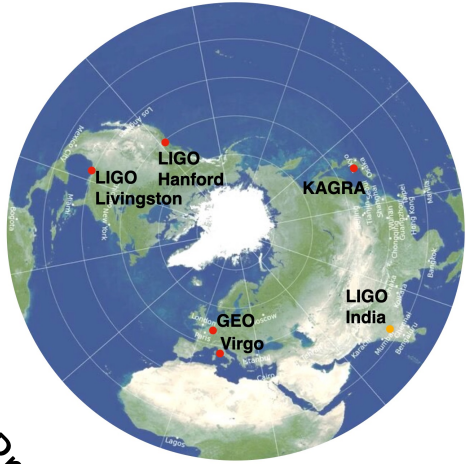
100W Laser

Faraday Isolator

PRM

WI

CP

NI

CP

NE

BS

SRM

Filtering cavity

Squeezed light source

Output Mode Cleaner

Photodiode

Stable cavities

Stable cavity configuration

Marginally stable recycling cavities configuration

Possible GW detector network after 2030 (Virgo_nEXT, A#, KAGRA)

O3 (AdV) ~ O(10^2) BBH /year
O5 (AdV+) ~ O(10^3) BBH/year

"O6" (upgraded network)

~ O($10^{4)}$ BBH/year
~ O(10^3) BNS /year

The Virgo Collaboration, Virgo nEXT, beyond the AdV+ project; A concept study, Virgo internal note VIR-0497D-22

Science case

- Discovery potential

  - Cosmology - H_0.
  - Nuclear physics – phase transitions
  - Isolated spinning neutron stars
  - Astrophysical stochastic background
  - Ringdown – nature of black-holes
  - Post-merger signal

- Constraints (or surprises)

  - Test of general relativity
  - Dark matter
  - Black-hole distributions / population sciences
  - Supernovae

- Multi-messenger astrophysics

  - GRB, FRB, kilonovae
  - Alerts
  - Synergies with other observatories

Virgo_nEXT: beyond the AdV+ project

A concept study

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Why Virgo_nEXT

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🚀 Push the potential of the existing infrastructure to its limits

🔧 Test the technologies used in the ET avoiding design mistakes and accelerating commissioning

🕐 Fill a potential gap of a decade between the end of O5 and the first ET design sensitivity

👥 Keep and develop the expertise of the experimental and data analysis community

⇄ Ensure smooth generational transition and training of new leaders

Virgo_nEXT vs Einstein Telescope
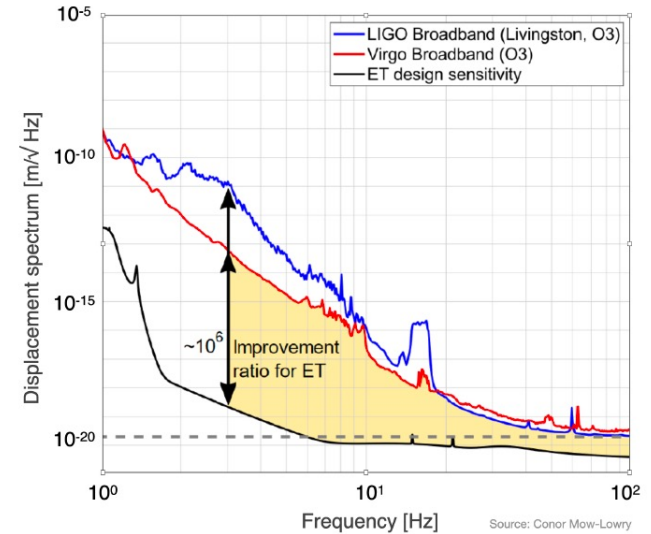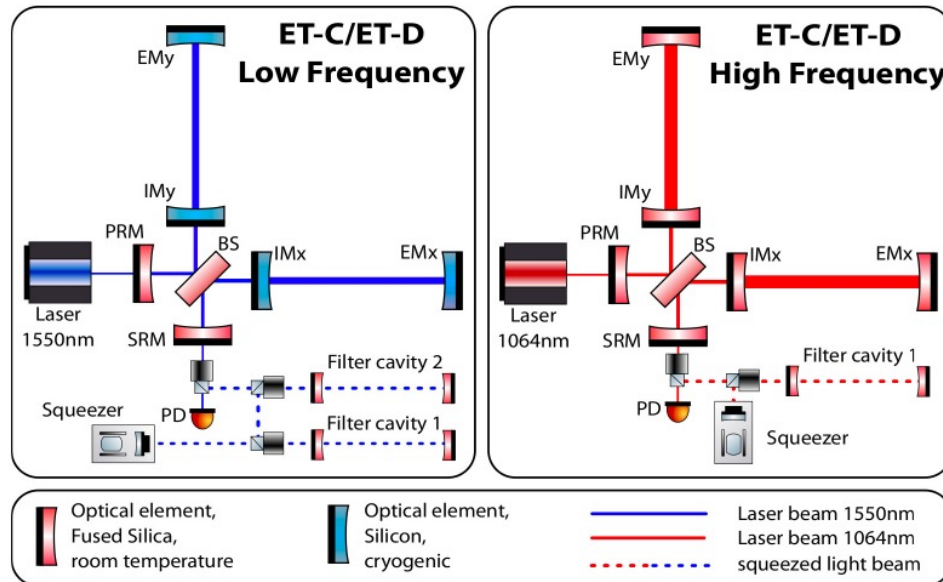
ET-high-frequency: longer arms, underground with Virgo_nEXT technologies

ET-low-frequency: cryogenic, low frequency technical noises similar to the Virgo_nEXT ones

Why Virgo_nEXT

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Strategy in France:

- Maintain priority on Virgo but be strongly present in ET
- Maintain a coordination and optimize interfaces Virgo-ET

Comments? Questions?