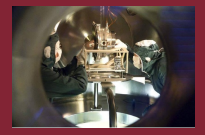
L5 – 3G Gravitational wave lab

Amaldi Research Center

SAPIENZA
UNIVERSITÀ DI ROMA

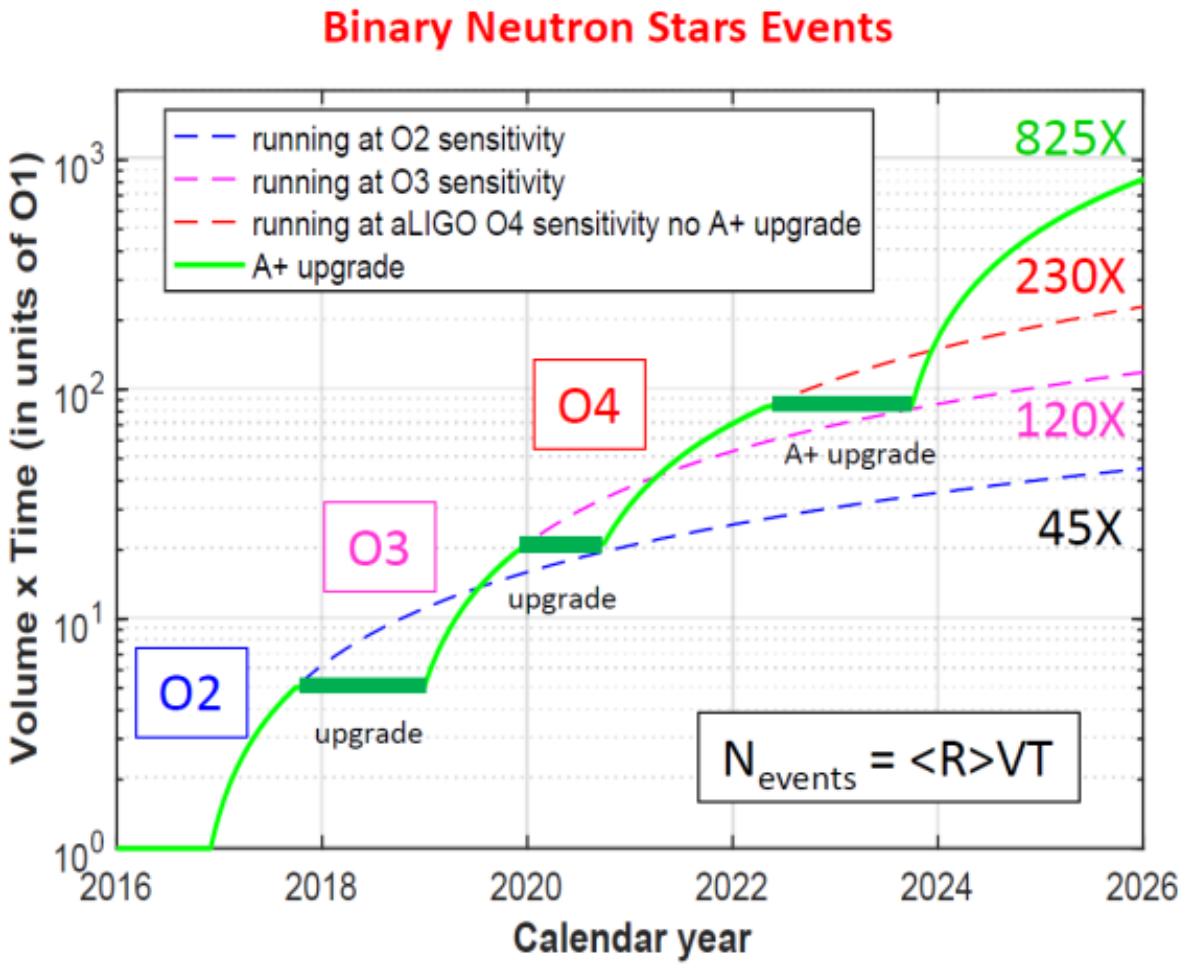


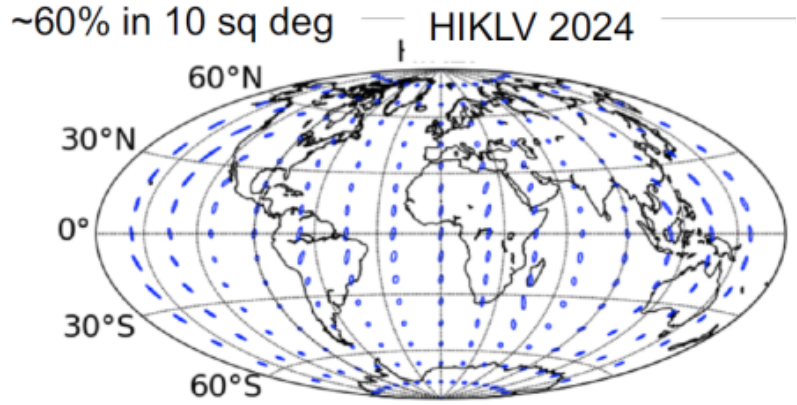
Ettore Majorana

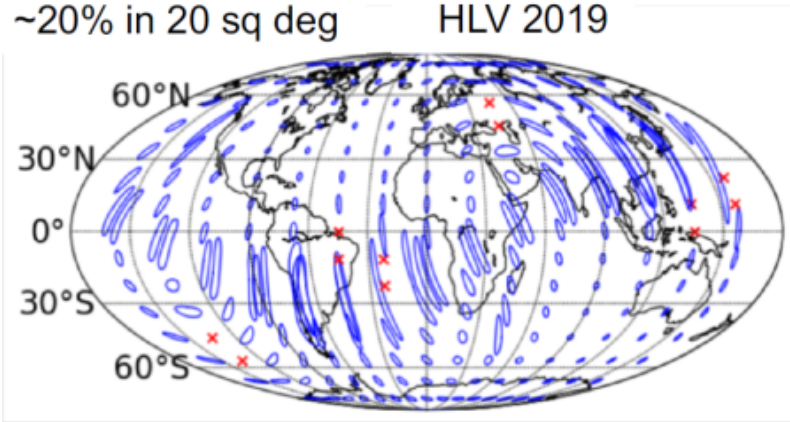
Dipartimento di Fisica, Sapienza Università di Roma - 9 December 2021

A. Cruciani, A. D'Addabbo, S. Di Pace, V. Mangano, E. Majorana, L. Natacchioni, M. Perciballi, S. Pirro, P. Puppo, P. Rapagnani, A. Rezaei and Fulvio Ricci

Plans for LIGO-KAGRA-Virgo runs





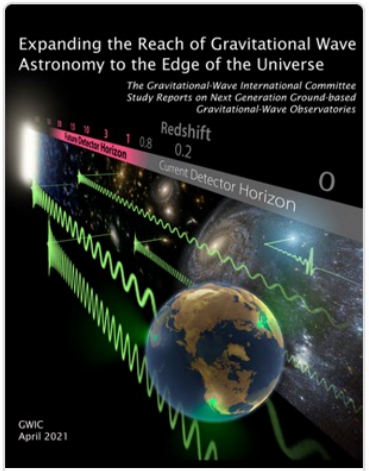


- <R> average astrophysical rate
- V volume of the universe probed → (Range)^3
- T coincident observing time

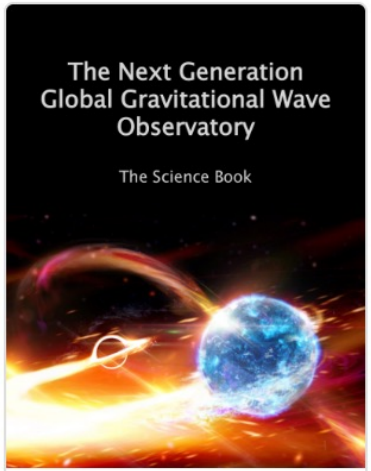
A worldwide community, a prosperous future, why ?

GWIC-3G Home Charge Committee Subcommittees Documents Meetings

GWIC Releases the GWIC-3G Subcommittee Reports on Next Generation Ground-based Observatories

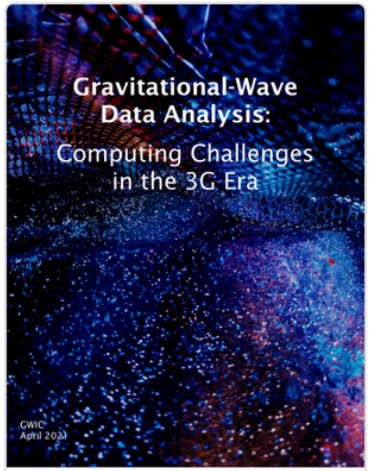


Introduction

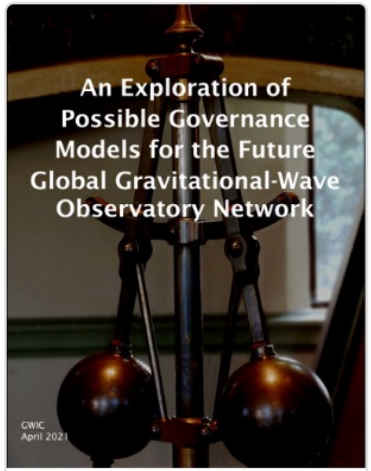


Science

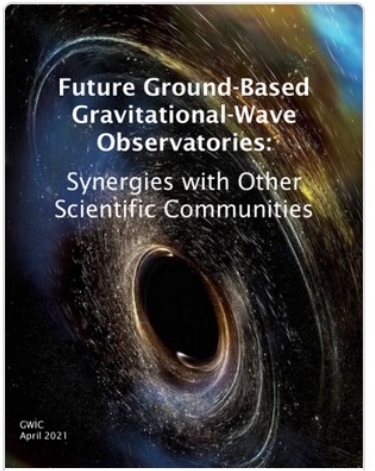
R&D



Computing



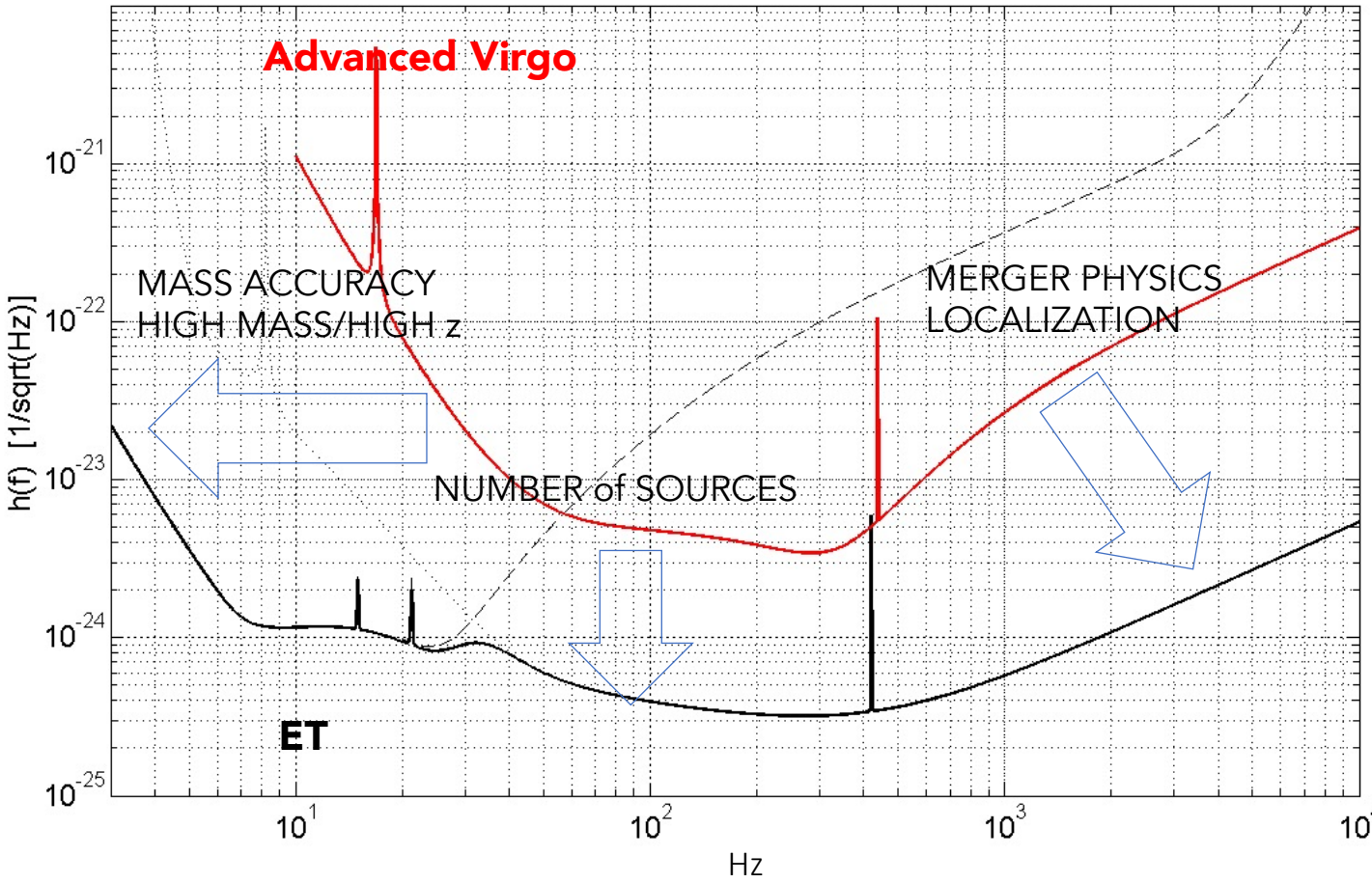
Governance

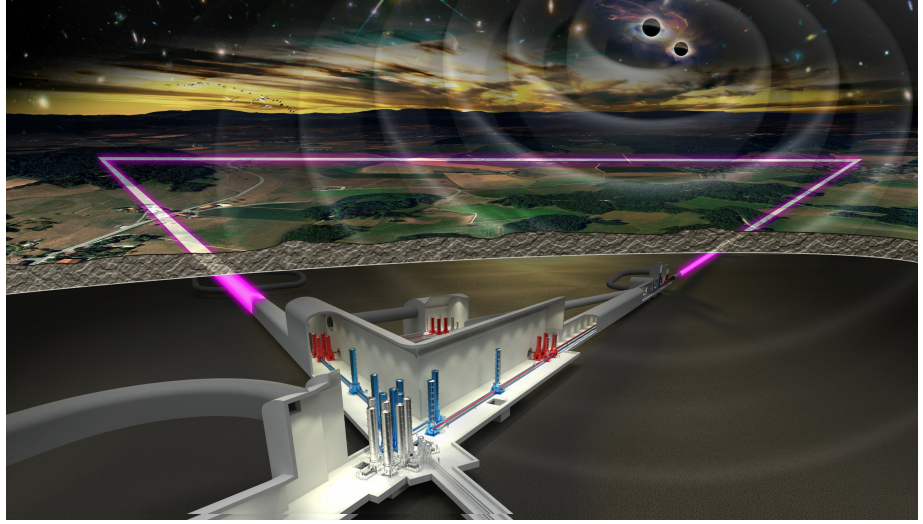


Communities

https://gwic.ligo.org/3Gsubcomm/

SENSITIVITY GOAL: ~×10-20 better





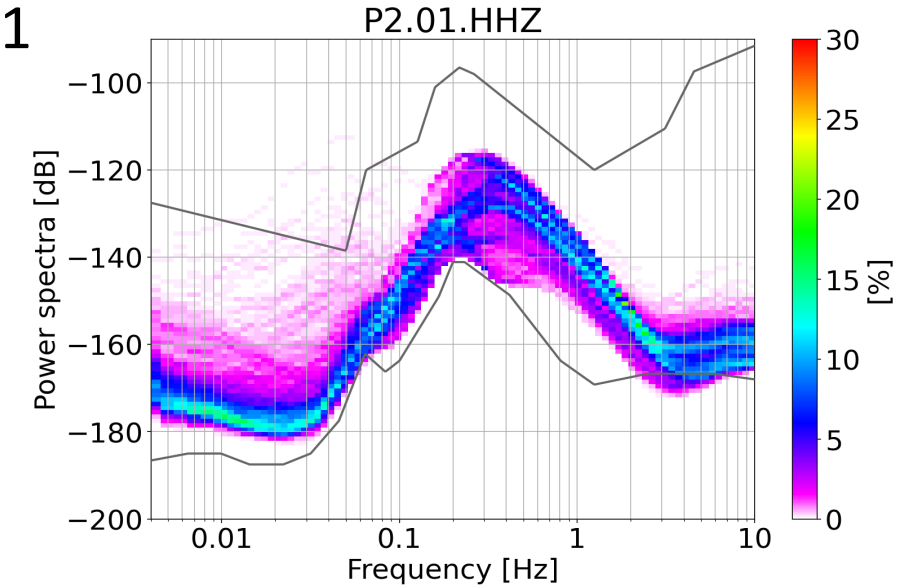
- *Merging Black Holes* ***throughout the whole universe*** and reconstruct BH demography
- Explore *new physics in gravity* and fundamental properties of compact objects
- Study the properties of the *hottest matter* in the universe
- Investigate connection between high *energy processes in radiation/particle VS gravitation*
- *Investigate primeval universe* and connections with particle physics

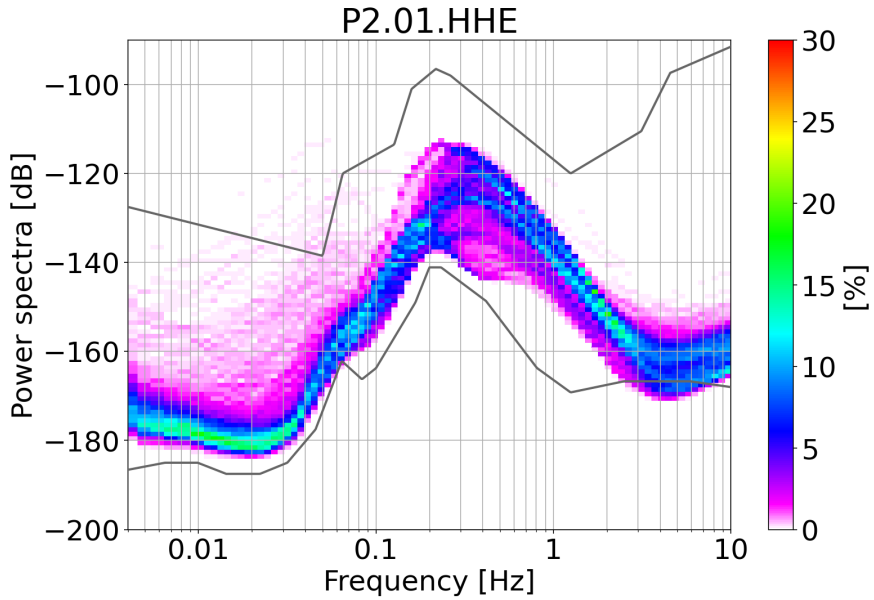
ET in Sardinia ? Who shows better locations ?

Vertical

Horizontal

October 2021





Underground (-264m)

- L. Naticchioni et al., ***Characterization of the SosEnattos site for the Einstein Telescope***, **JPCS**1468,2020
- M. Di Giovanni et al., ***A seismological study of the SosEnattos Area - the Sardinia Candidate Site for the Einstein Telescope***, **SRL**, 2020 https://doi.org/10.1785/0220200186
- A. Allocca et al., ***Seismic glitchness at SosEnattos site: impact on intermediate black hole binaries detection efficiency***, **EPJP**, 2021 https://doi.org/10.1140/epjp/s13360-021-01450-8
- Another report in preparation…

Why R&D here ?

AMALDI RESEARCH CENTER

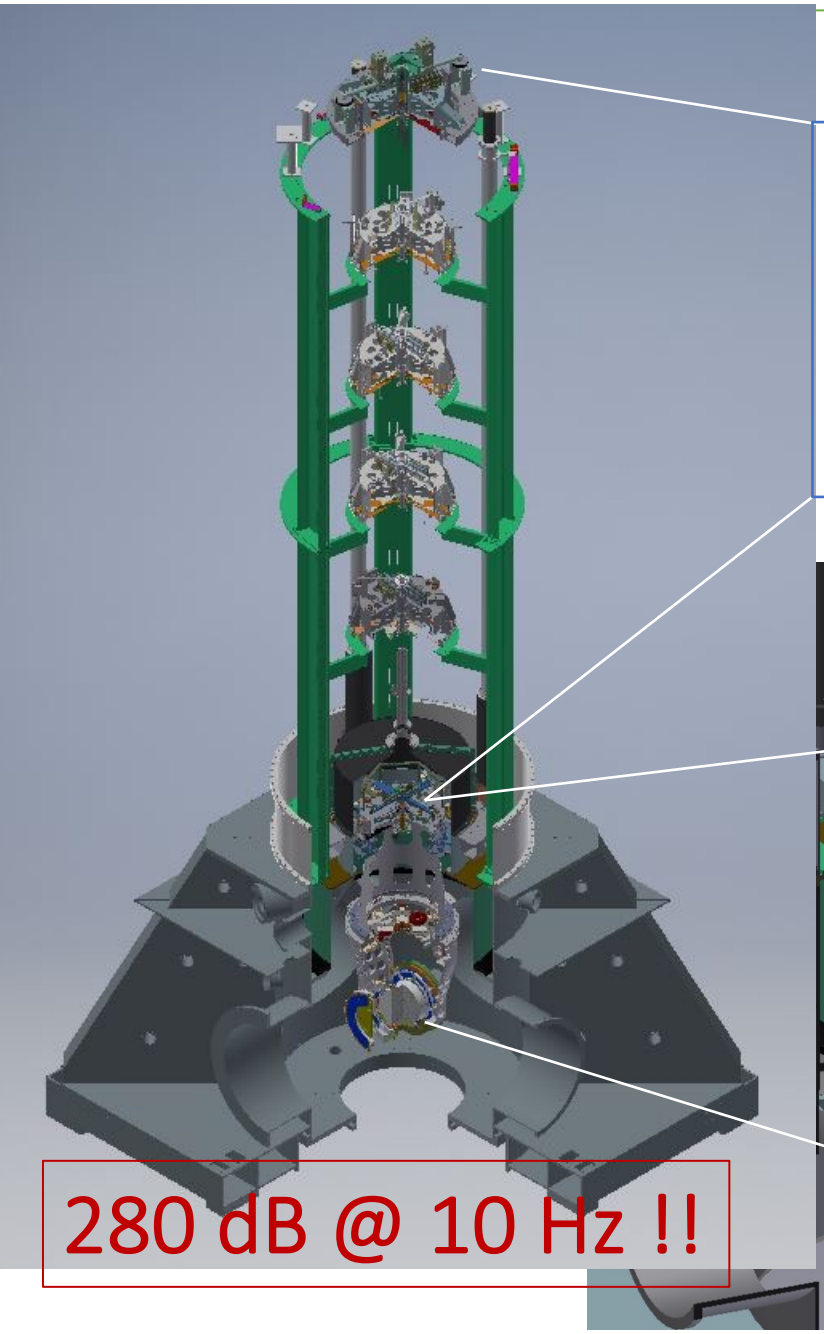
- **Narrow-band** (~30 Hz) In Italy the experimental research on GW was born in Rome in the seventies, and later at INFN-LNL, following the experience of J. Weber and the first achievements in US, by Fairbank's group in Stanford. Several historical achievements in the field of resonant bar detectors, from cryogenic long-term operation to advanced superconducting and parametric transducers.

GREAT PHYSICS BUT NO GW OBSERVATIONS !

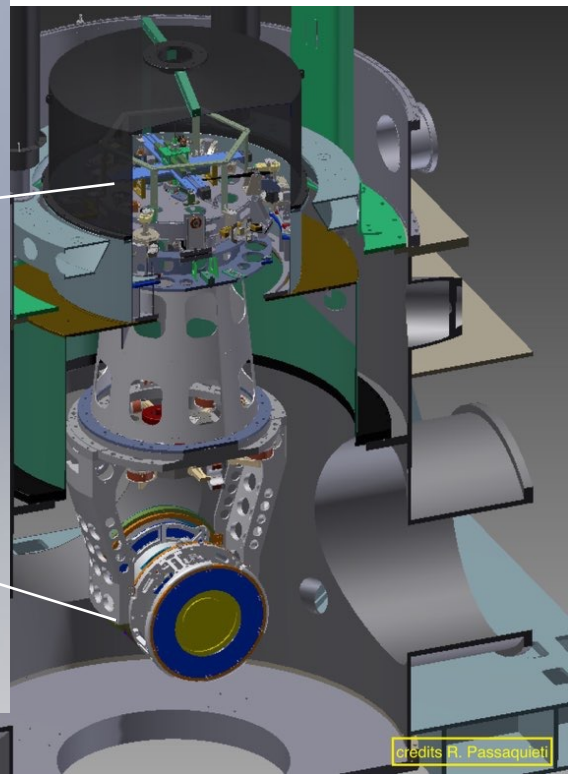
- **Wide-band** (~3 kHz) In 1994 we joined VIRGO, at room temperature, matured experience in **test-mass *payload***, **Thermal Noise**, **Vibration attenuation**, **alignment and control**. In parallel, a vision on 3rd generation GW wide-band detectors using cryogenics (EC FP6, FP7) gre-up through a permanent collaboration with KAGRA.

GREAT ACHIEVEMENTS + OBSERVATIONS

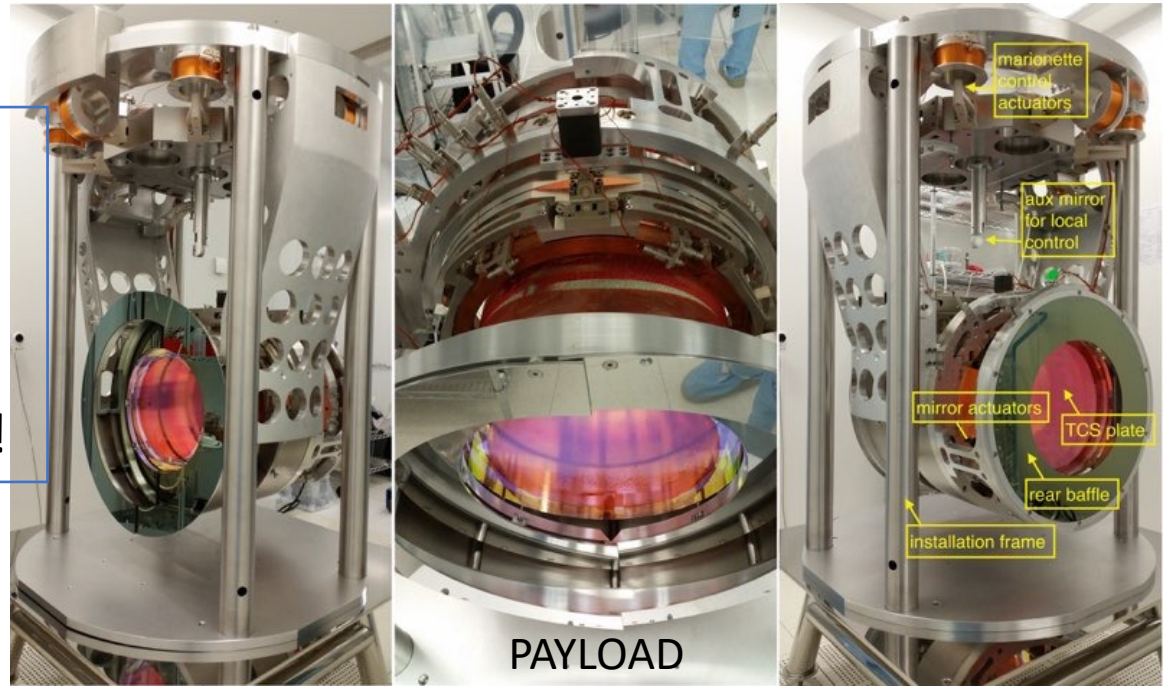
Test mass suspensions and seismic isolator in Virgo: overall system

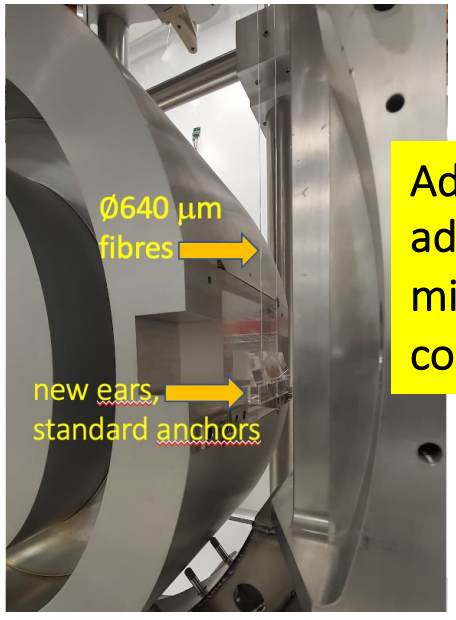


In AdV the first 5 stages of the Super-attenuator (horizontal and vertical) are roughly the same **designed 20 years ago** !!



280 dB @ 10 Hz !!

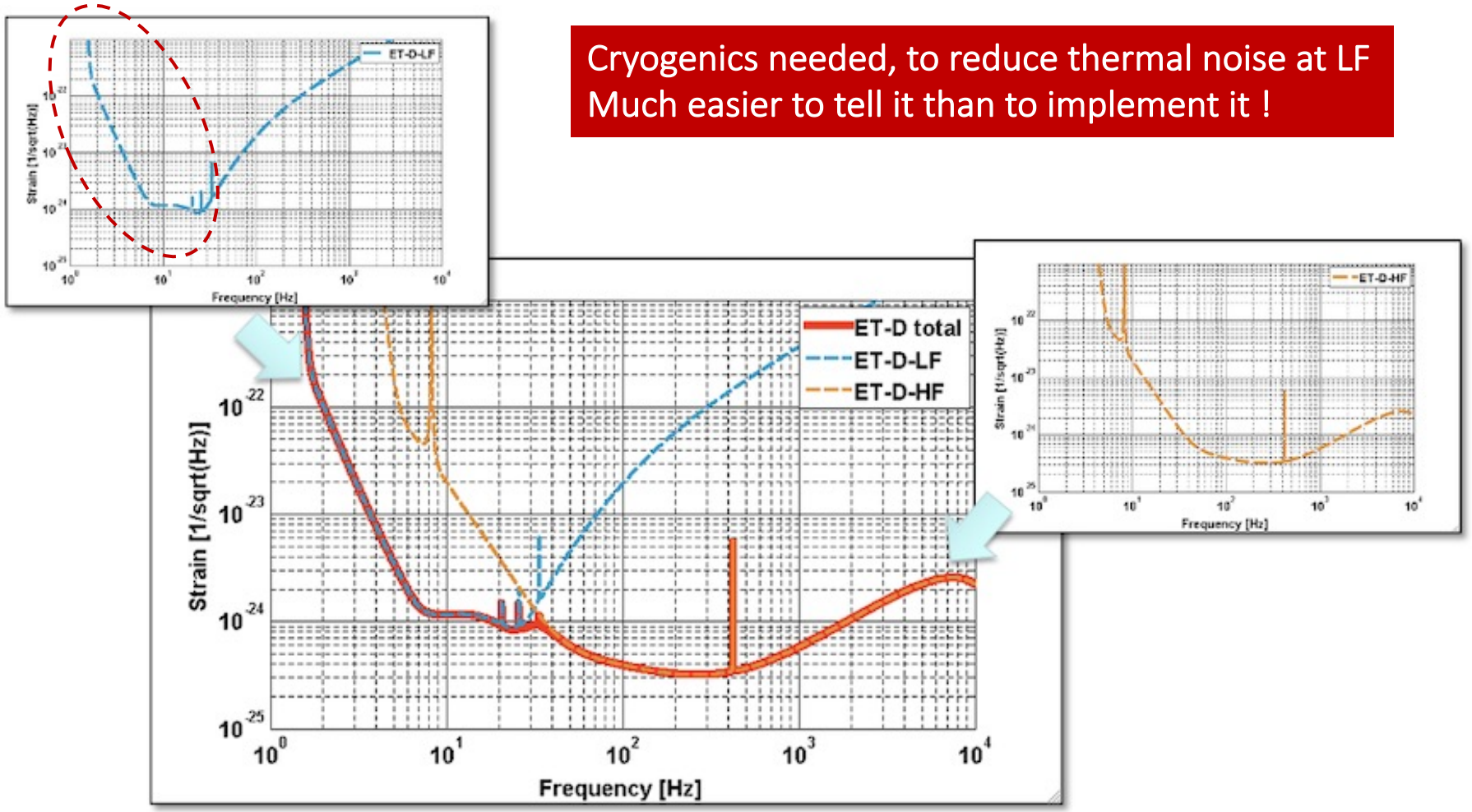




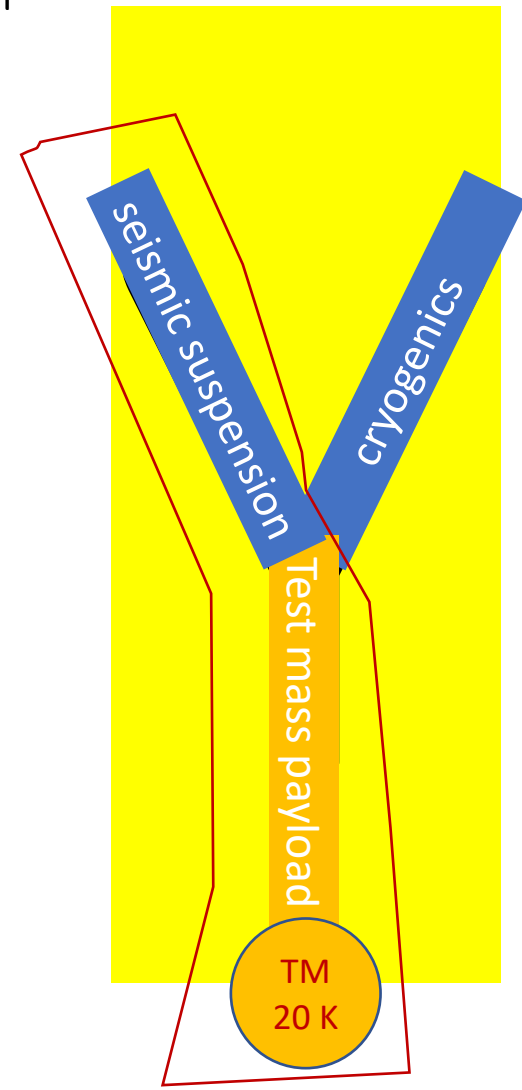
AdV+ in 2024 will adopts 105 kg mirrors to reduce coating Therma Noise

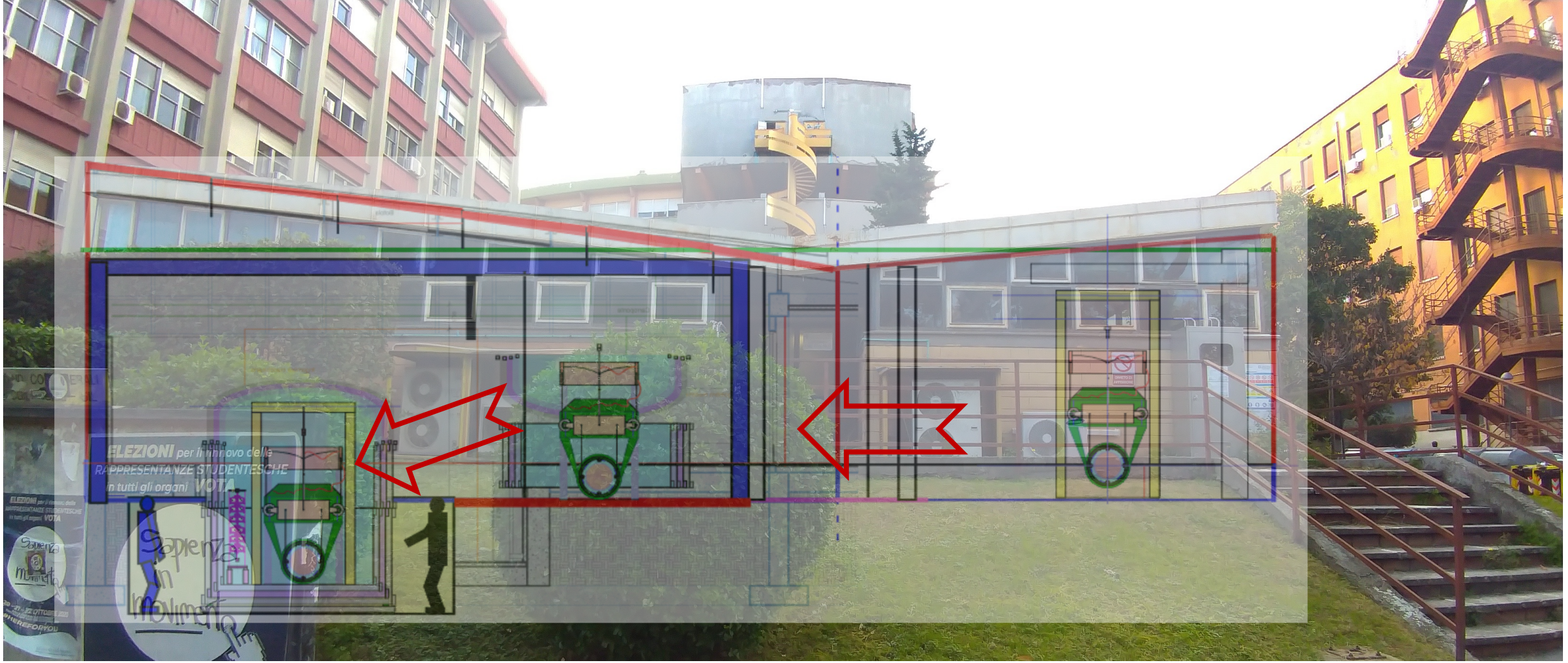
ARC-L5

- ***Cryostats*** are meant to host ***payloads***, seismic isolated systems meant to orientate the test masses and operate the detector
- L5 - is dedicated to cryogenics feasibility of ET-LF, assumed in conceptual designs 2011/2021, but never modelled/demonstrated with a fully realistic configuration.
- We plan to build a specifically designed cryostat around the concept of a reasonable 1:1 payload



Cryogenics needed, to reduce thermal noise at LF
Much easier to tell it than to implement it !



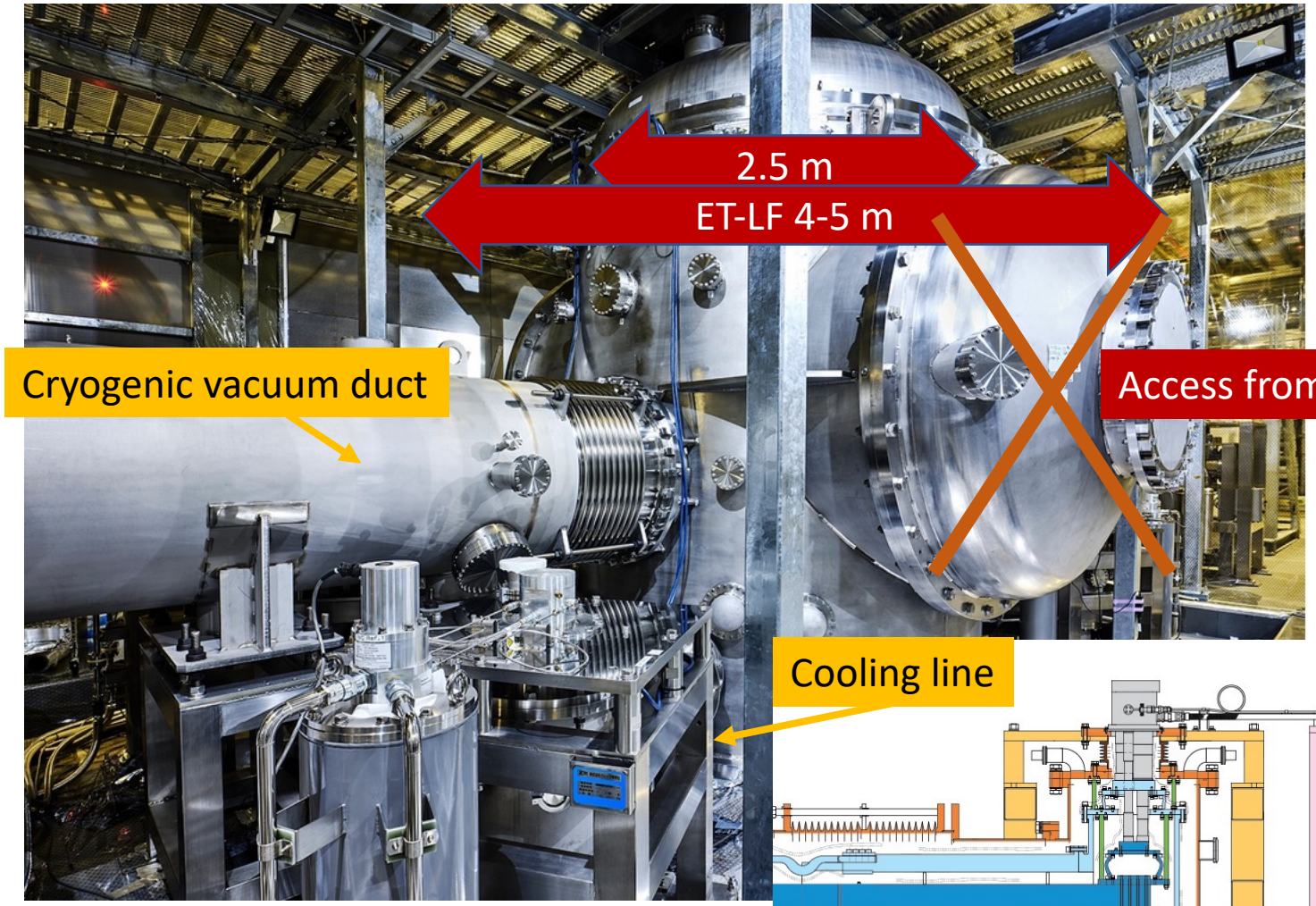


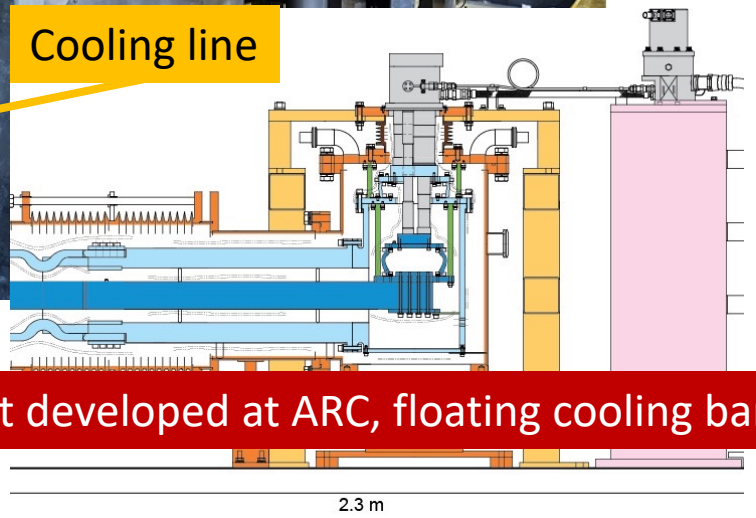
- 2019-20 Preliminary evaluation of cryostat size upon ET-conceptual design and prototype payload modelling // Hardware Purchase (cryocoolers, thermometry, position sensing);
- 2019-21 Solid conduction cooling line, easily viable concept in underground developed. visitors: N. Kimura (ARC), A. Ueda (INFN grant), T. Yamada PhD (JSPS)
- 2022 Cryostat ¾ sized design starts. Dedicated to Initial tests of cryogenic payload prototype // reconstruction works (going on)
- 12/2022 Nominal End of ARC_L5 Dip Fisica of La Sapienza (tot. 750kE, committed)


NOV 2021
Covid-19/logistics delays, works finally started from scratch

- se
- grant), T.

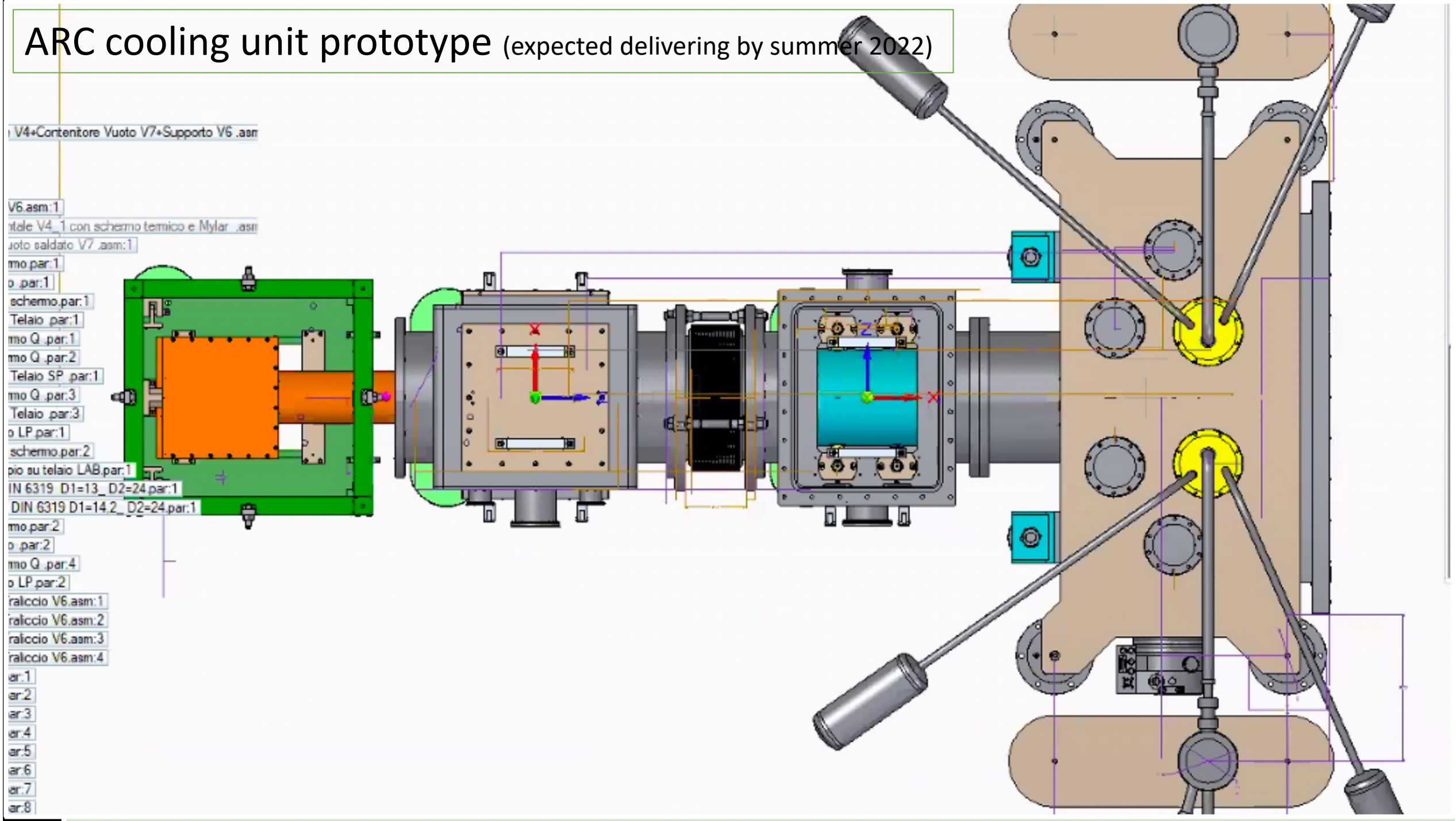
KAGRA cryostat and cooling units (at a glance)





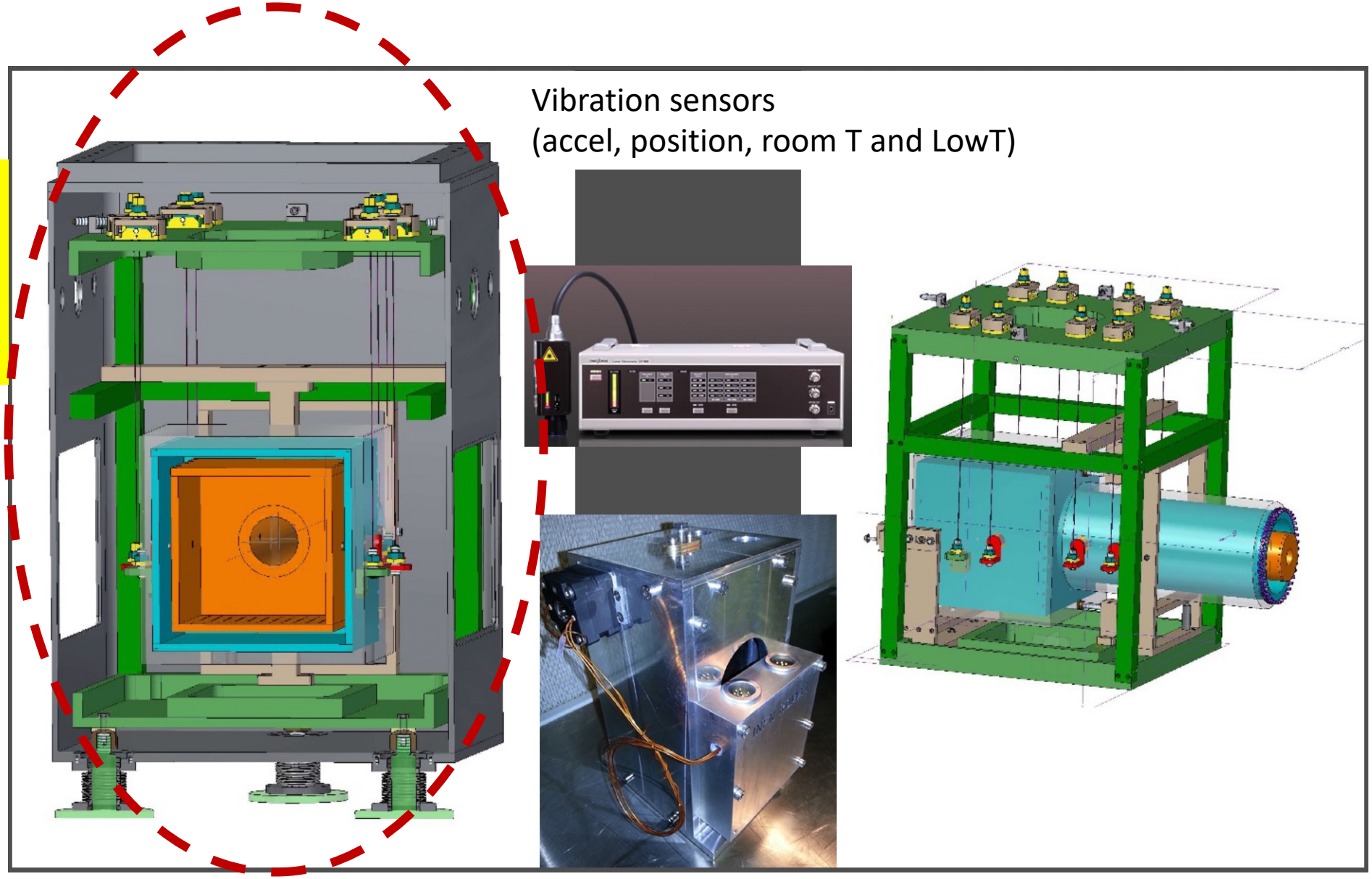
A different concept developed at ARC, floating cooling bar

ARC cooling unit prototype (expected delivering by summer 2022)



ARC cooling unit test jig (expected delivering by summer 2022)

Once tested using the test jig, the cooling line prototype will be connected to the cryostat. Its design is included in ARC plans 2022



Conclusions

FUND APPLICATIONS, a proposal based on three pillars

A, *CRYOSTAT75*) 2022-24
completion of ¾ scaled Cryostat to be installed in La Sapienza Campus in the available room

B, *CLARGELAB*)
2022-24 Extension of ARC-L5 facility (inside or outside the campus)

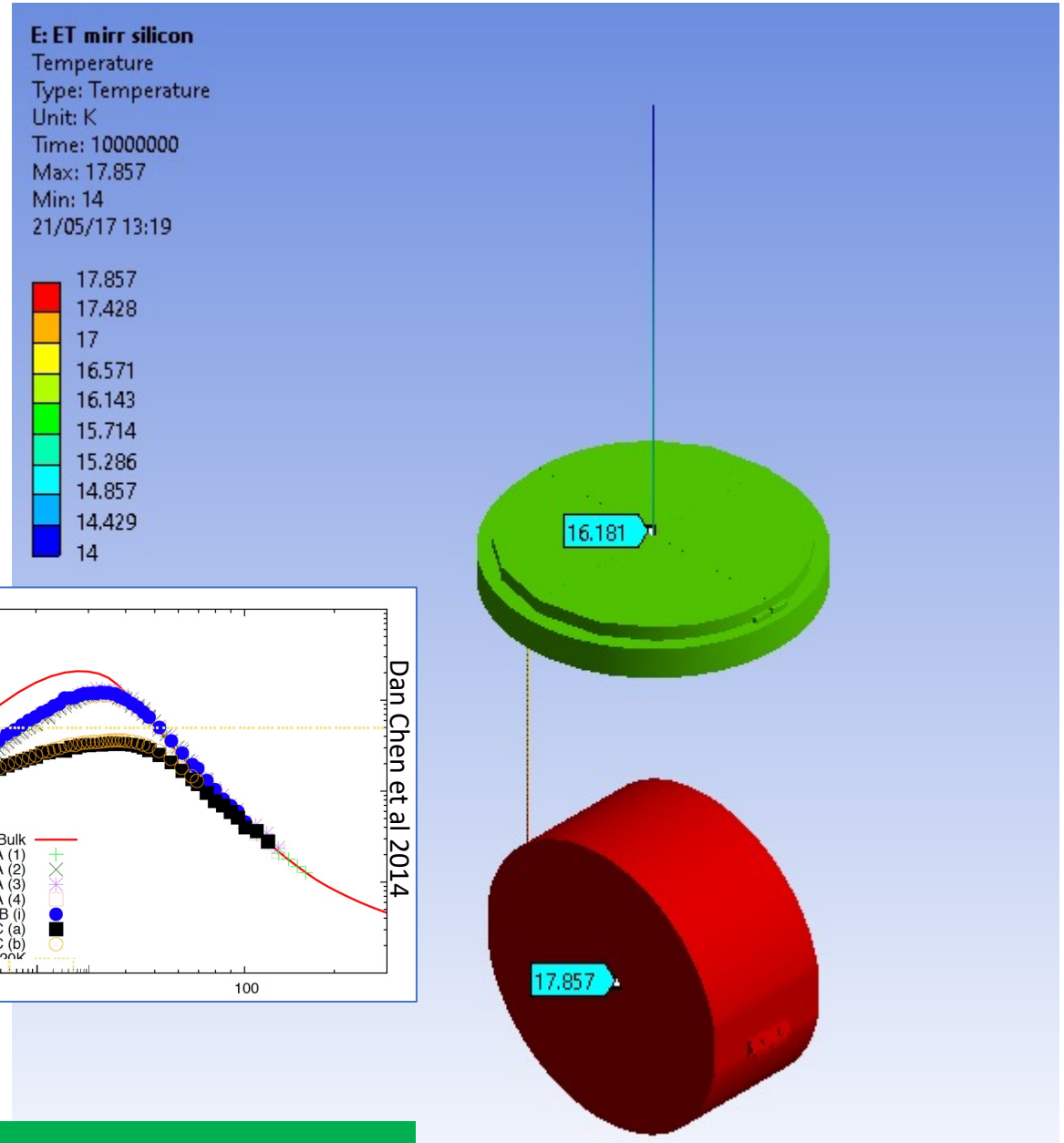
C, *CRYOSTAT100*)
2023-26 Tests of payload prototype done => commitment for a larger cooling down of 1:1 cryostat

➔ Green light for a viable design towards ET-B

Thanks !

Using sapphire rods

- Si Test Mass: 140 kg (Sapphire 150 mm thick also tested)
- TM Sapphire wires: 2.2 mm Ø - Length: 0.8 m + $2\lambda_{bending}$
- Marionette Wire: Sapphire Diam 5.0 mm
- Upper point: 14K
- Radiation component not included so far



- The system can be cooled down.
- Notice the realtively massive marionette (for AdV+ we adopt 180 kg).
- Consistent with the cryostat room
- The system works for both Si and Sapphire
- Al6N HL, capability of building 80-90-cm-long Al_2O_3

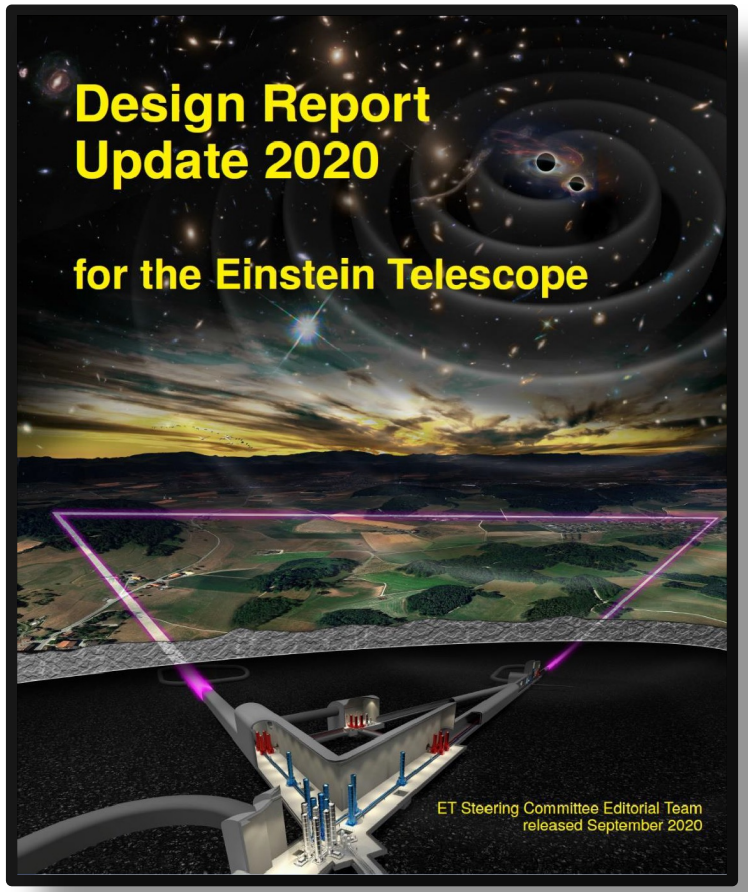
- No HL included
- No radiation included, so far

Conceptual Design Studies

https://tds.virgo-gw.eu/?call_file=ET-0106C-10.pdf

ESFRI

https://apps.et-gw.eu/tds/?content=3&r=17245



- In 2020 governments of 5 EU countries (Italy, the Netherlands, Belgium, Spain and Poland) submitted the ET application to ESFRI (European Strategy Forum on Research Infrastructure).
- July 2021 ET obtained ESFRI status, as the highest value project ever to feature on an ESFRI roadmap.

❖ **Constitution of the ET collaboration**
❖ **Site definition (2024)**

Virgo + KAGRA experiences

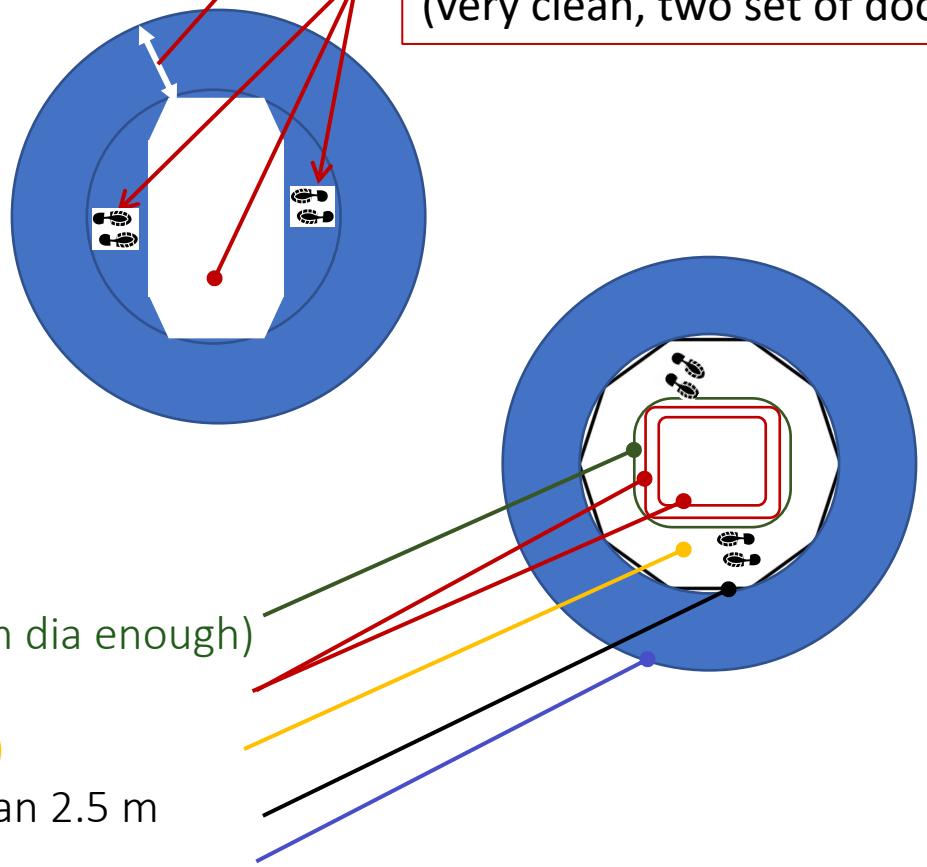
Side entries, 2 sets of doors, horizontal dimension.

Schematic Exercise :
case study rescaling internal shield
of KAGRA upon AdV+LM/ET seed parameters

- 150-200 kg mirror payload with cage
- auxiliary attenuators for HL
- side doors VS manholes (one per shield)

Inner shield separation (two shields + superinsulation)

Inner shield room, once the payload is integrated it is suitable to work on a small payload standing outside (very clean, two set of doors needed !)

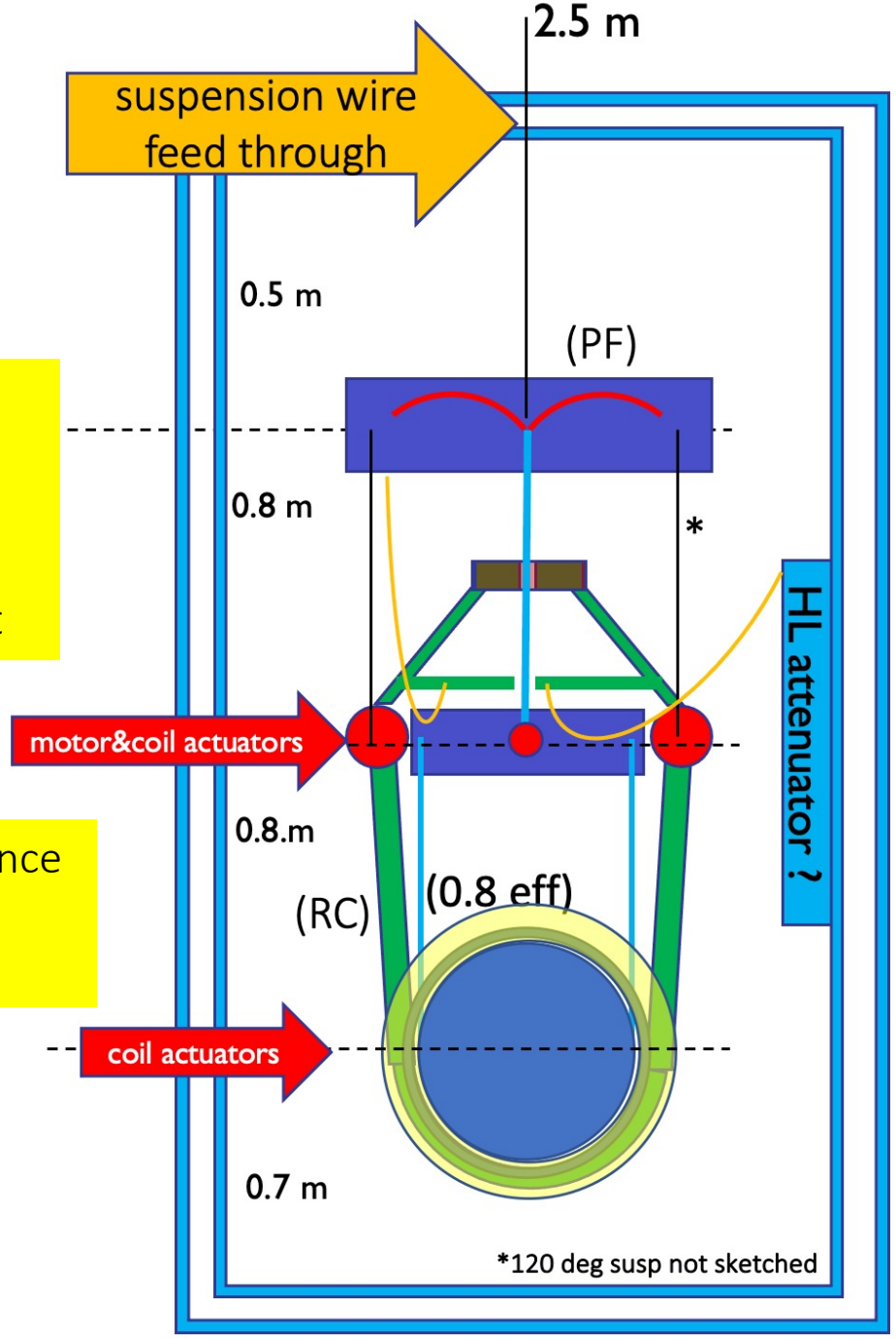


- 1 flange VAC rectangular (if circular, 1.2-1.3 m dia enough)
- 2 manholes (entering from bottom)
- 50 cm all around the payload (feet clearance)
- Inner thermal shield diameter not smaller than 2.5 m
- Minimum outer dia of VAC chamber 4.2 m

HEIGHT: minimum 3 m inside the inner radiation shield

proper design of a viable payload, which starts from sensitivity demand, ensures also the minimum requirements for the cryostat

a possible, significant, difference envisaged (WRT KAGRA): “cage” reaction mass



SIZE STUDIES 2020