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Einstein Telescope, Supernovae

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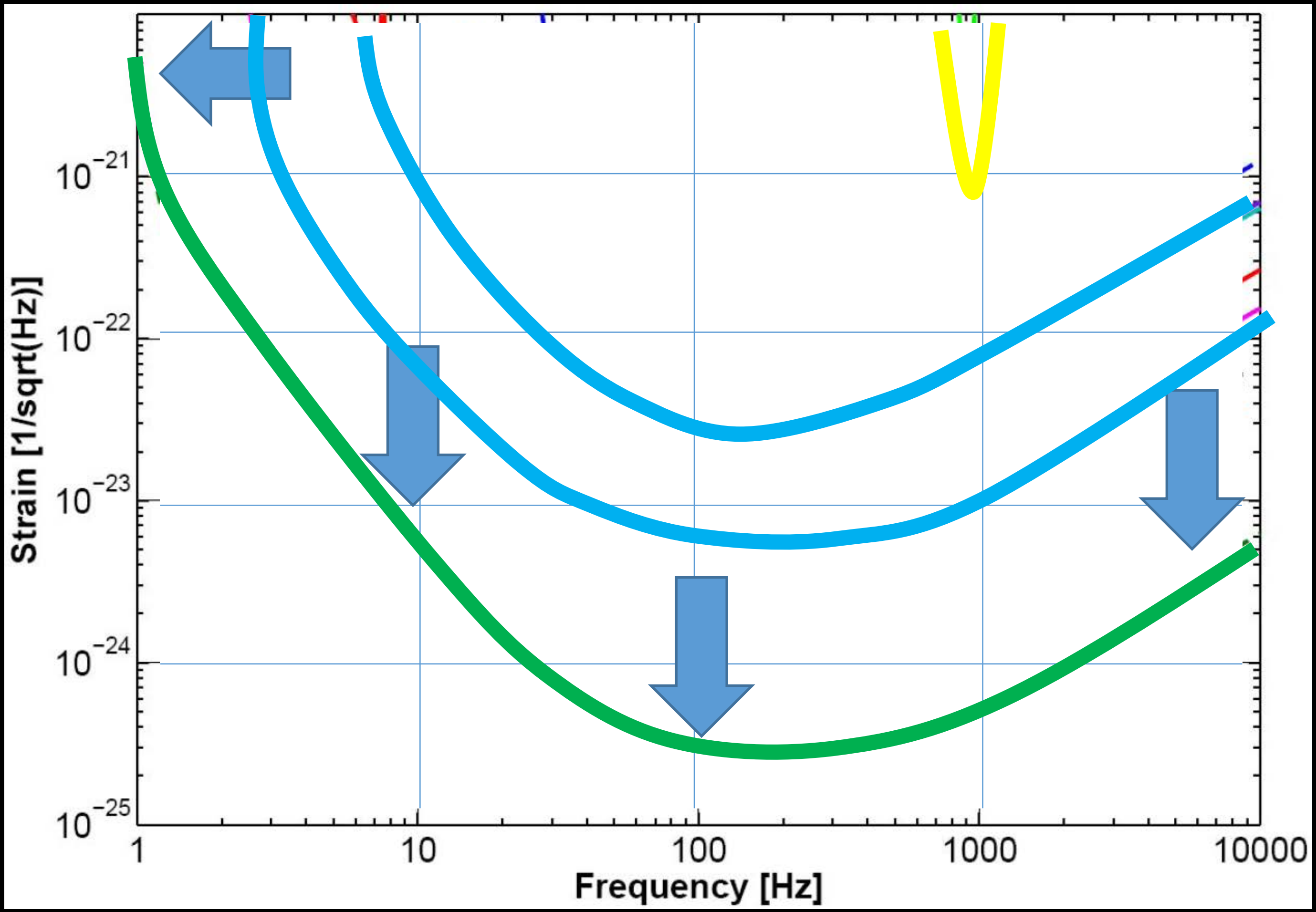
Einstein Telescope Design Study

- Funded by European Commission as project Einstein Telescope (ET) design study
- Second generation will hit an infrastructure limit
- The aim of the ET design study is to deliver its conceptual design, with particular focus on the infrastructure requirements and specifications
- Gathered together scientists from France, Germany, Italy, UK
- Assume that
  - Thermal noise of the test mass suspension can be reduced by a factor of 10, or dissipation losses by a factor 100
  - Gravity gradients remain under control
  - Frequency dependent squeezing can be achieved

Evolution of Earth bound detectors From bars to ET



Resonant bars and first generation

Second generation

Third generation:

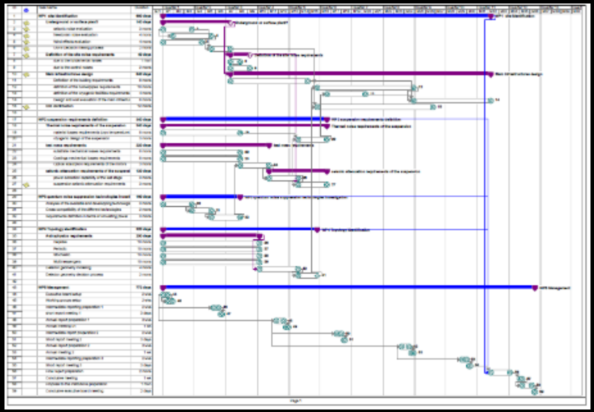
- From 10 to 1 Hz
- 10 x lower thermal noise
- 10x times lower quantum (shot) noise
- Observatory: low if not zero dead time

Targets of the Design Study

- Evaluate the science reaches of ET
- Define the sensitivity and performance requirements
  - Site requirements
  - Infrastructures requirements
  - Fundamental and (main) technical noise requirements
  - Multiplicity requirements

2009

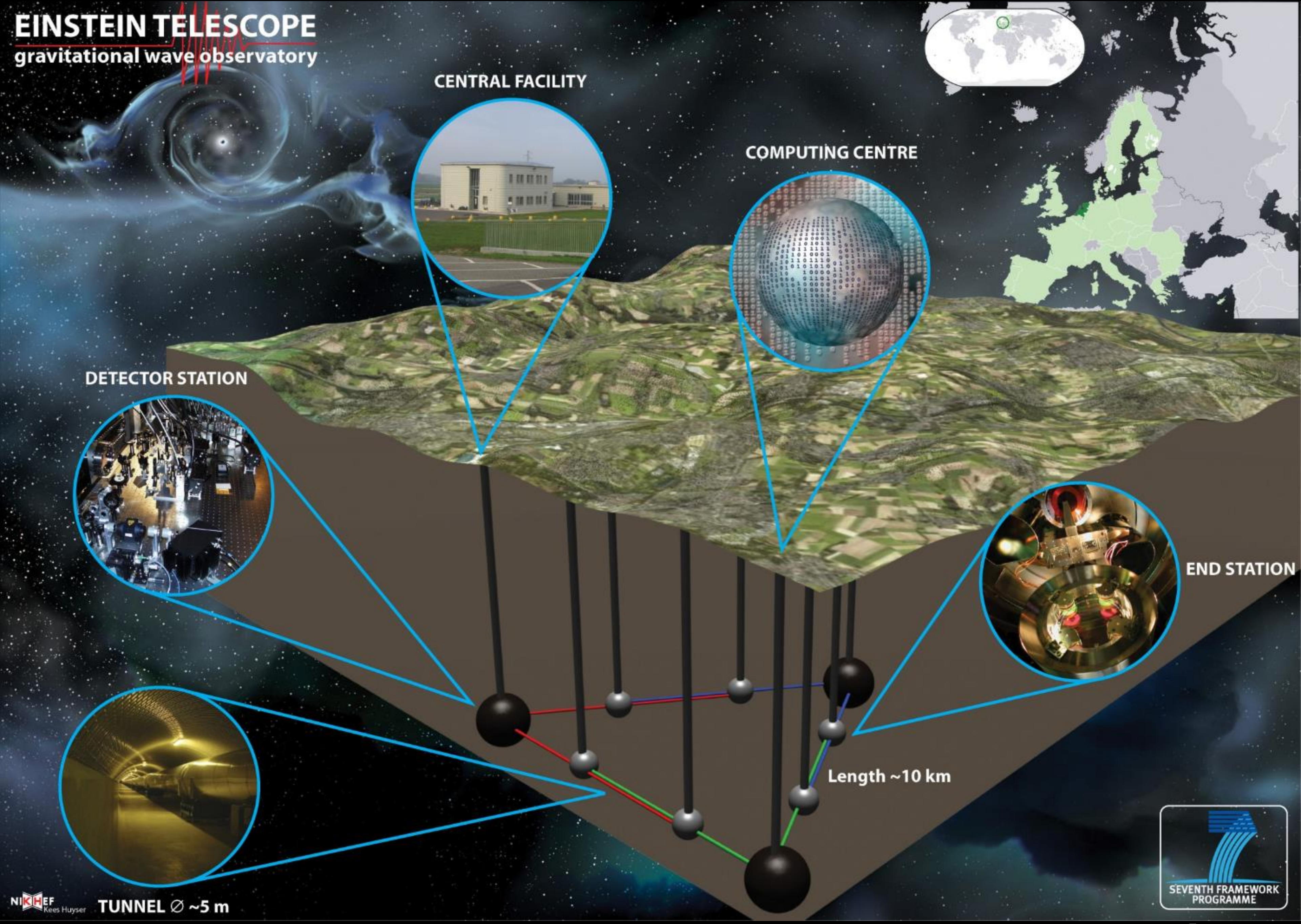
- Draft the observatory specs
  - Site candidates
  - Main infrastructures characteristics
  - Geometries
    - Size, L-Shaped or triangular
  - Topologies
    - Michelson, Sagnac, …
  - Technologies



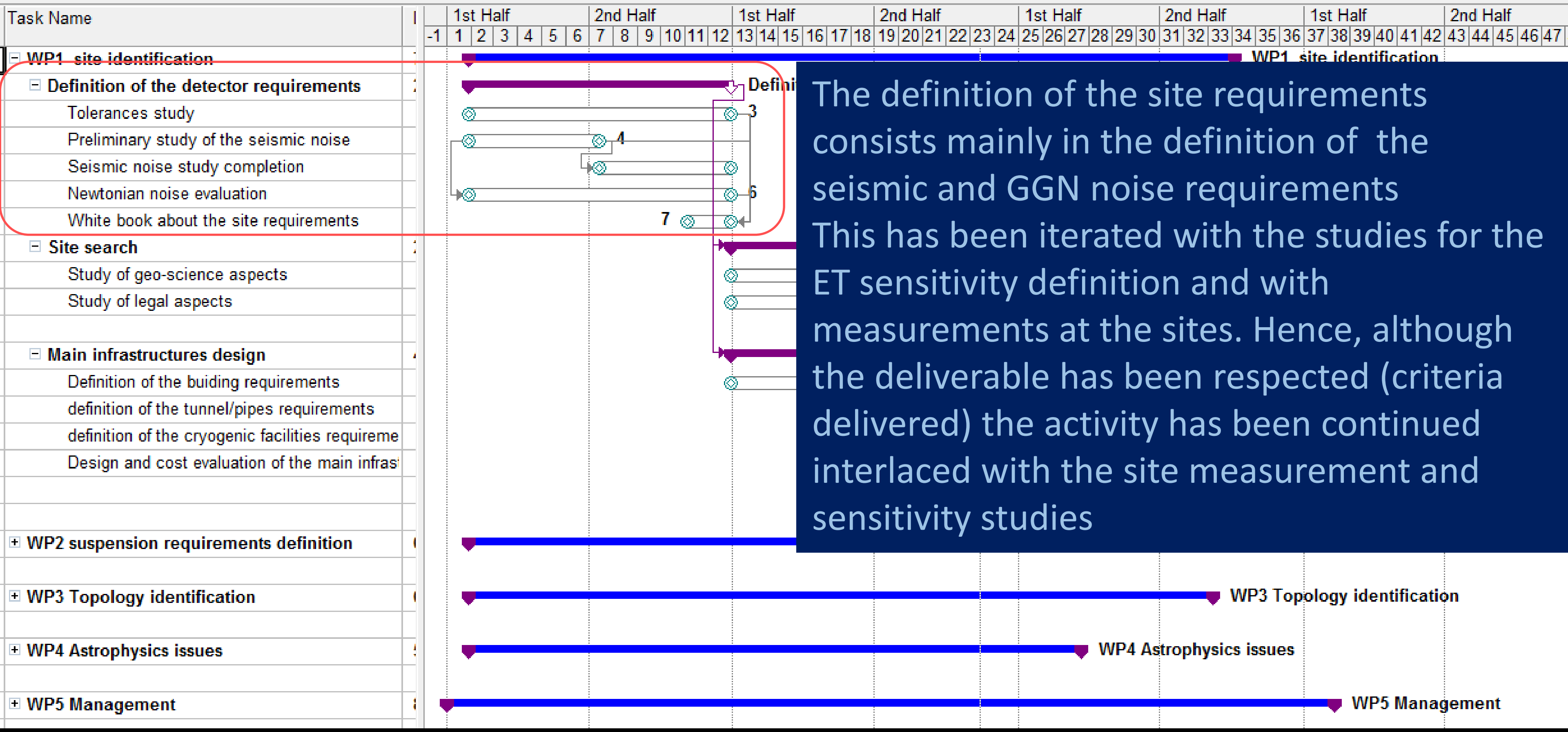
2010

- Evaluate the (rough) cost of the <u>infrastructure</u> and of the <u>observatory</u>

2011


EINSTEIN TELESCOPE
gravitational wave observatory
CENTRAL FACILITY
COMPUTING CENTRE
DETECTOR STATION
END STATION
Length ~10 km
TUNNEL ∅ ~5 m
NIKHEF
Kees Huyser
SEVENTH FRAMEWORK PROGRAMME

WP1: Site identification

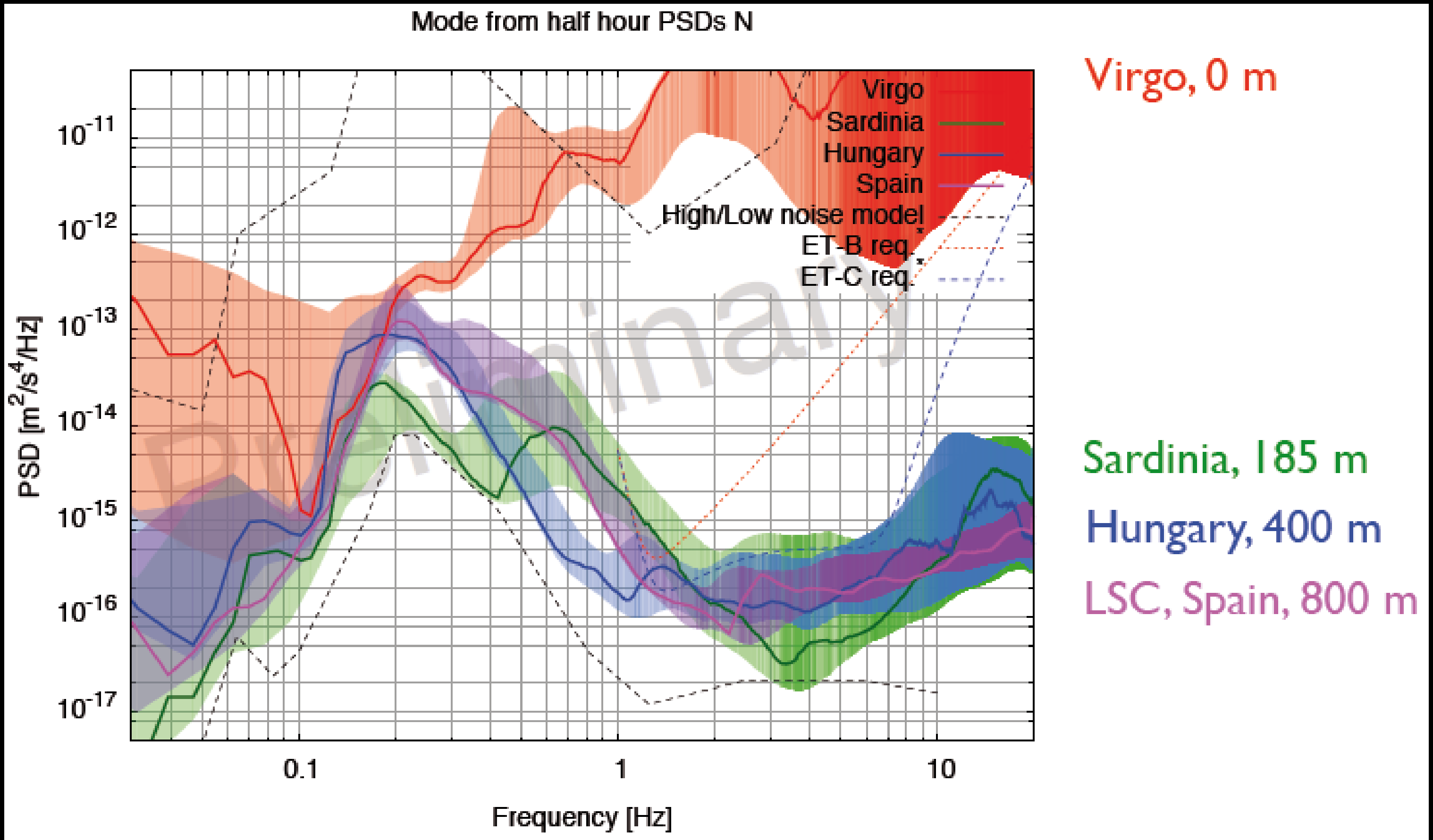


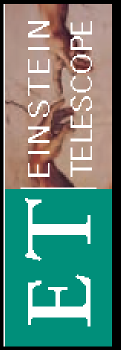
The definition of the site requirements consists mainly in the definition of the seismic and GGN noise requirements

This has been iterated with the studies for the ET sensitivity definition and with measurements at the sites. Hence, although the deliverable has been respected (criteria delivered) the activity has been continued interlaced with the site measurement and sensitivity studies

WP1: Site search-Detector requirements

- Each site has been characterized by a spectral variation plot
- The whole collection of measurements is publically available on the ET website: http://www.et-gw.eu/et-site-selection
- "Appealing" opportunities have been identified





WP

Task Name

WP2 sus
Prelim
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Prelim
Upp
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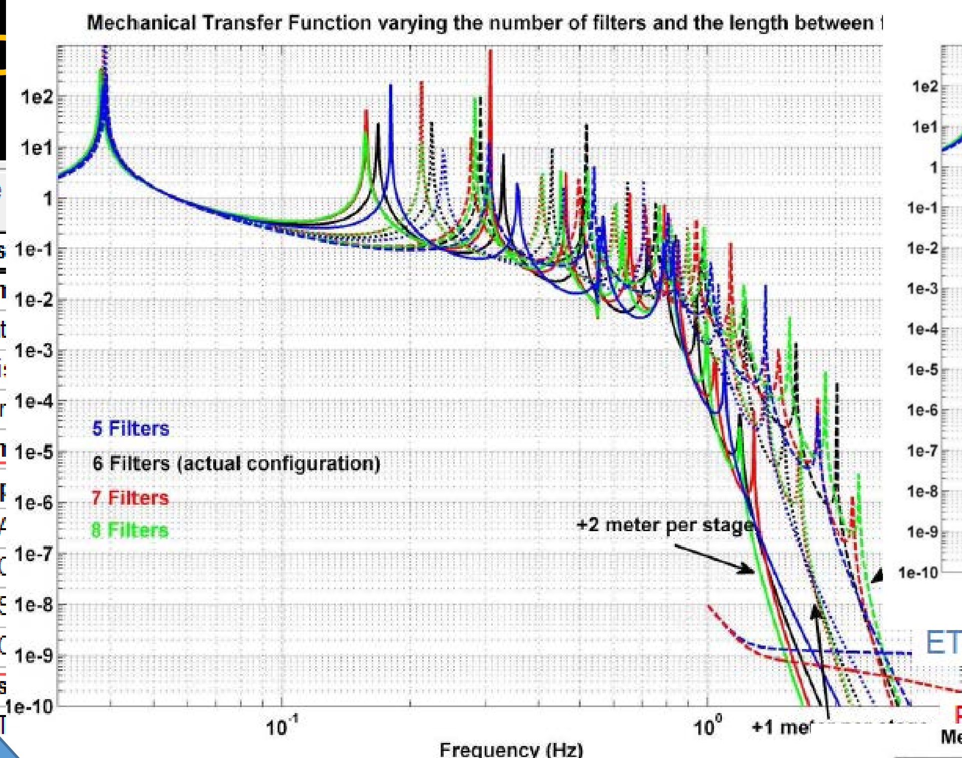
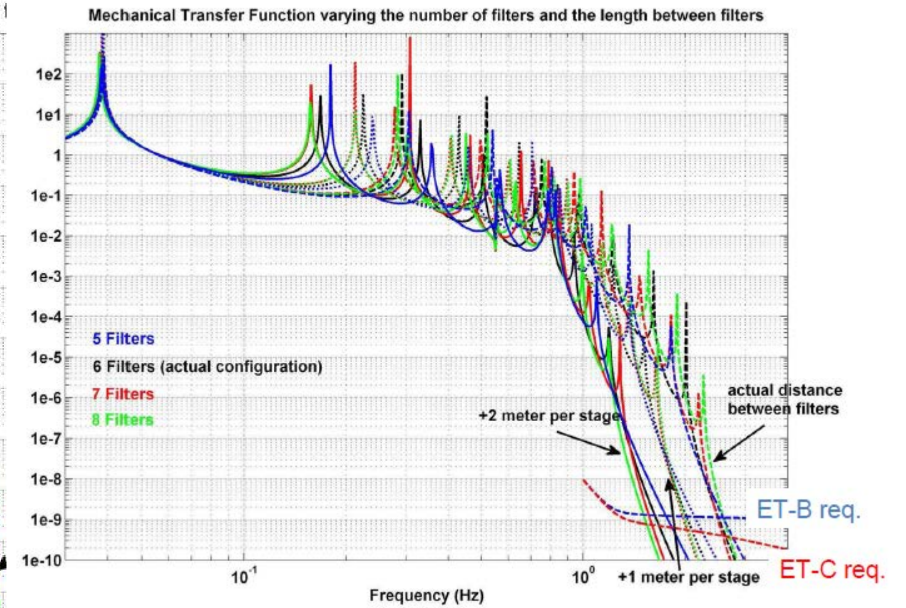
Control strategy definition
Rea and Contr
E.M.
Cooling R
Test Mass
Thermal Lin
Thermal Links
Finalisation of the s
Upper suspension
Last stage design
Optical absorpti
Fiber geometry
Criogenic design c
WP3 Topology identifi
WP4 Astrophysics issues





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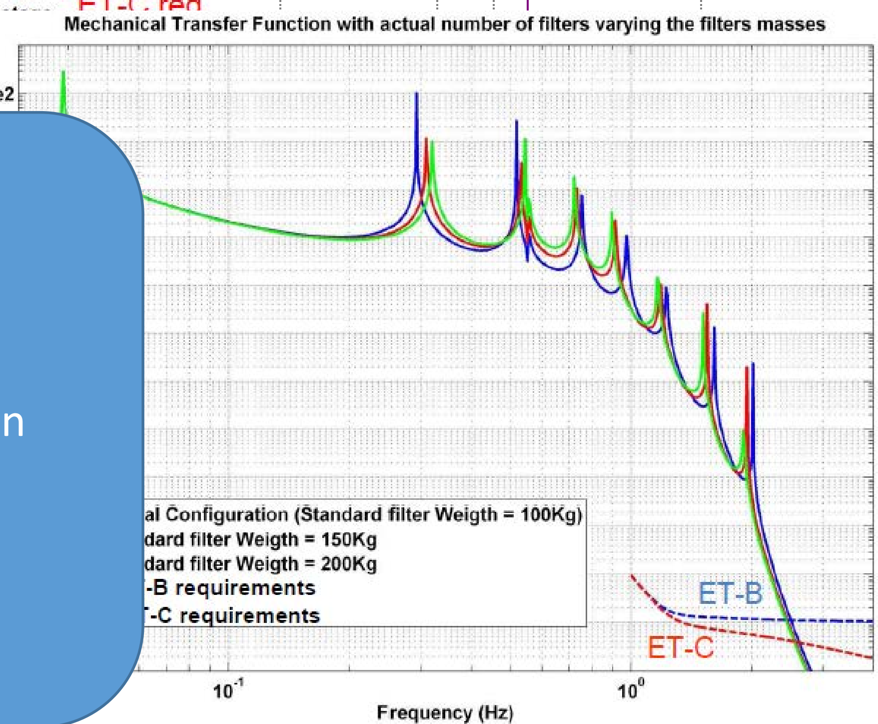
Last stage preliminary design



Attenuation strategy studied
Solution based on the Virgo experience
Analytical model of the suspension developed
- Effects of the filter number, mass and length studied

WP3: Xylophone design

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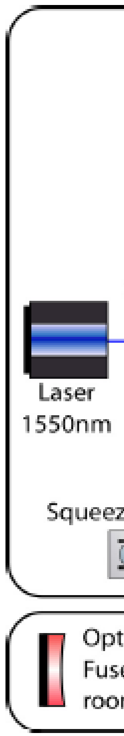
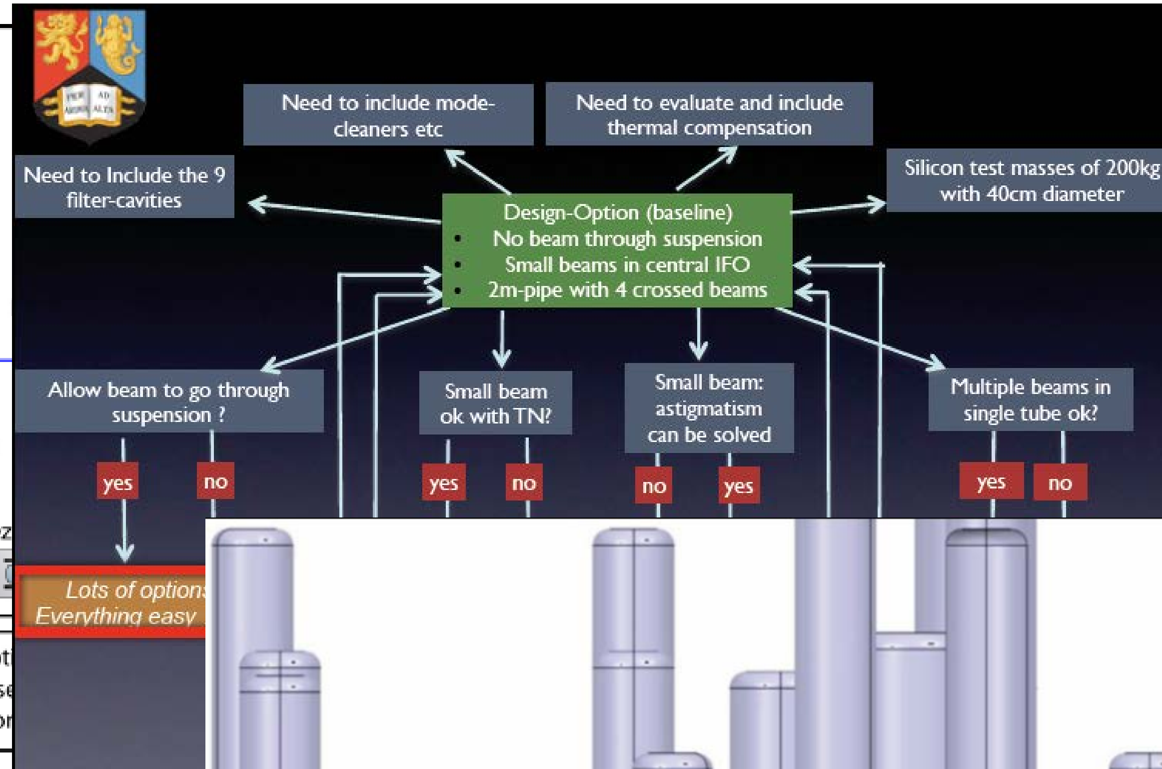
Task Name

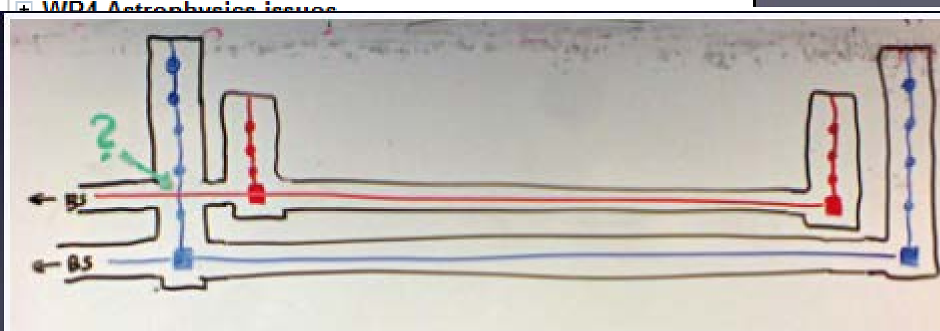
The Xylophone design "simplify" the solution but make more complex the design

- Cross-compatibility of the different tec
- requirements definition in terms of cir
- Detector topologies modeling
- Detector geometries modeling
- Detector geometry and topology decisio
- refinement of the adopted technologies l
- refinement of the optical layout design

WP4 Astrophysics issues

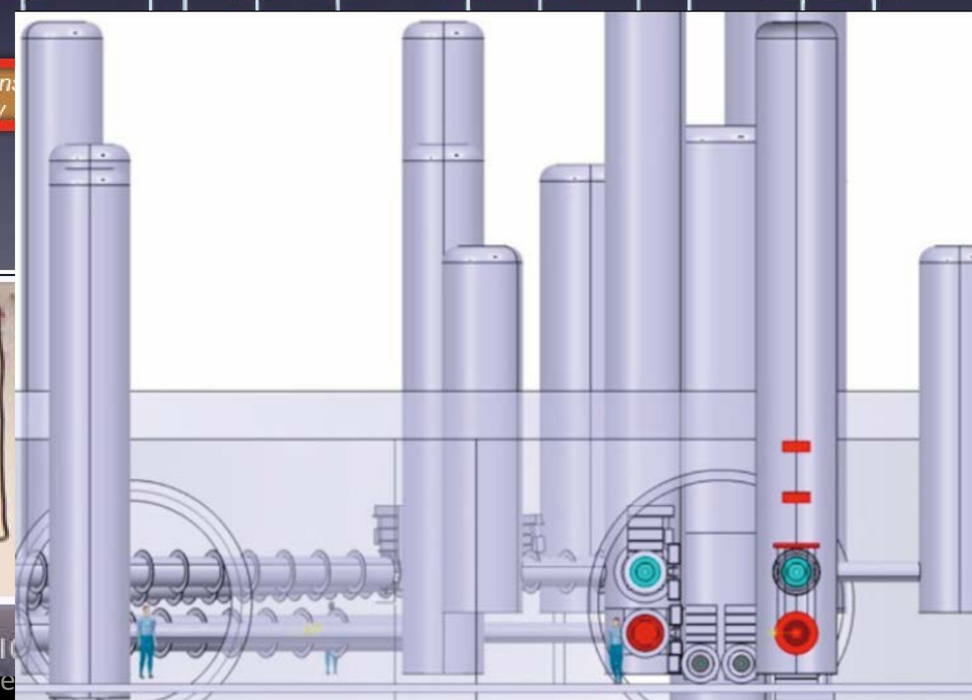






[Freise, Hild GWADW Kyoto 2010]

MTR-Brusse



[M. Doets, D. Rabeling]

Infrastructure

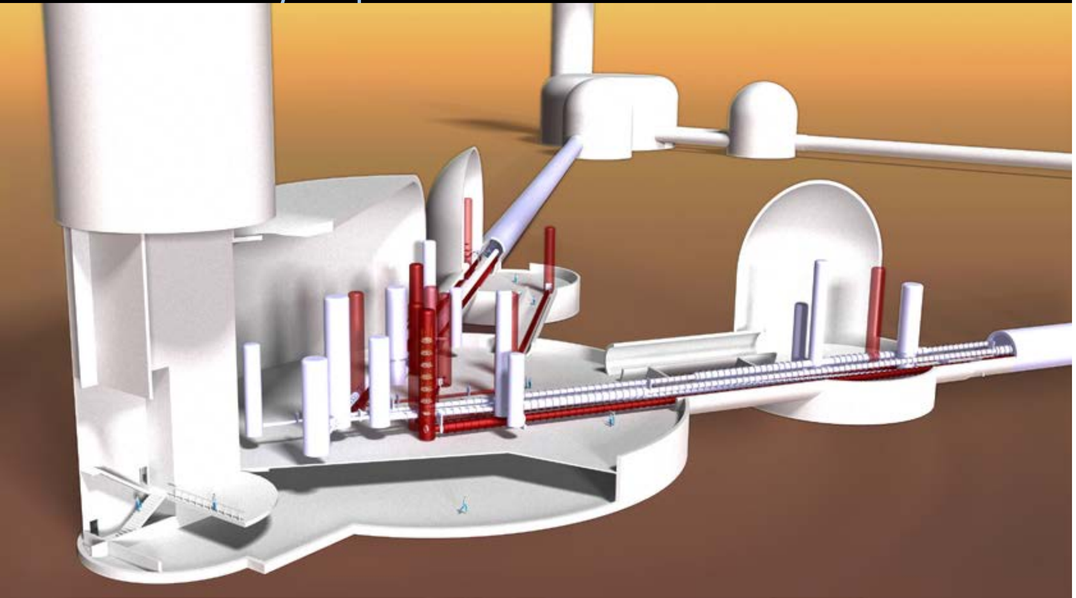
Will host several interferometers:

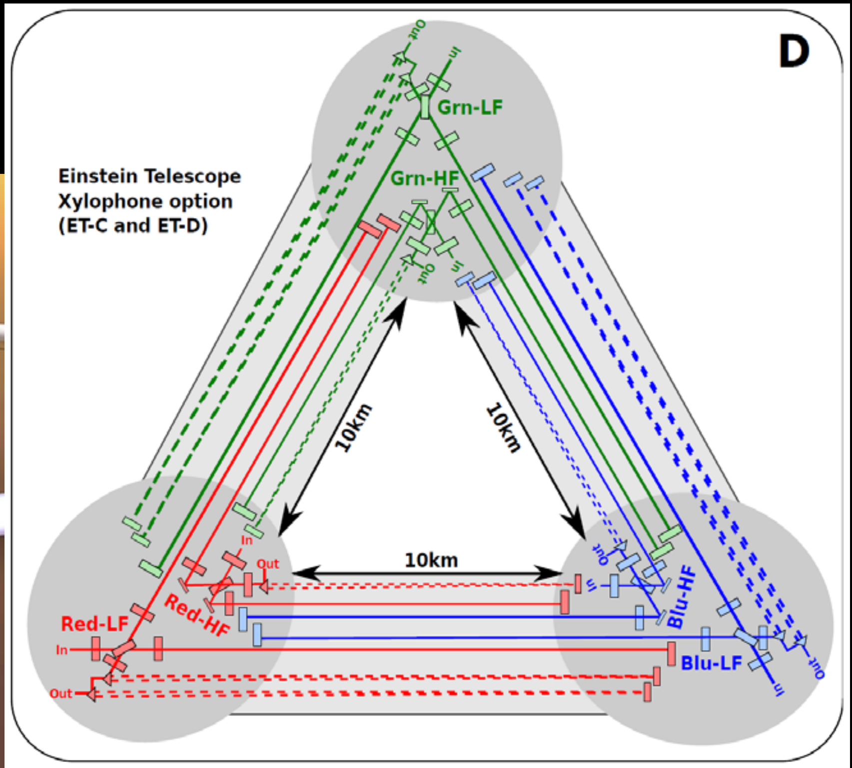
Progressive evolution and redundancy

Today's choice: three LF and three HF interferometers

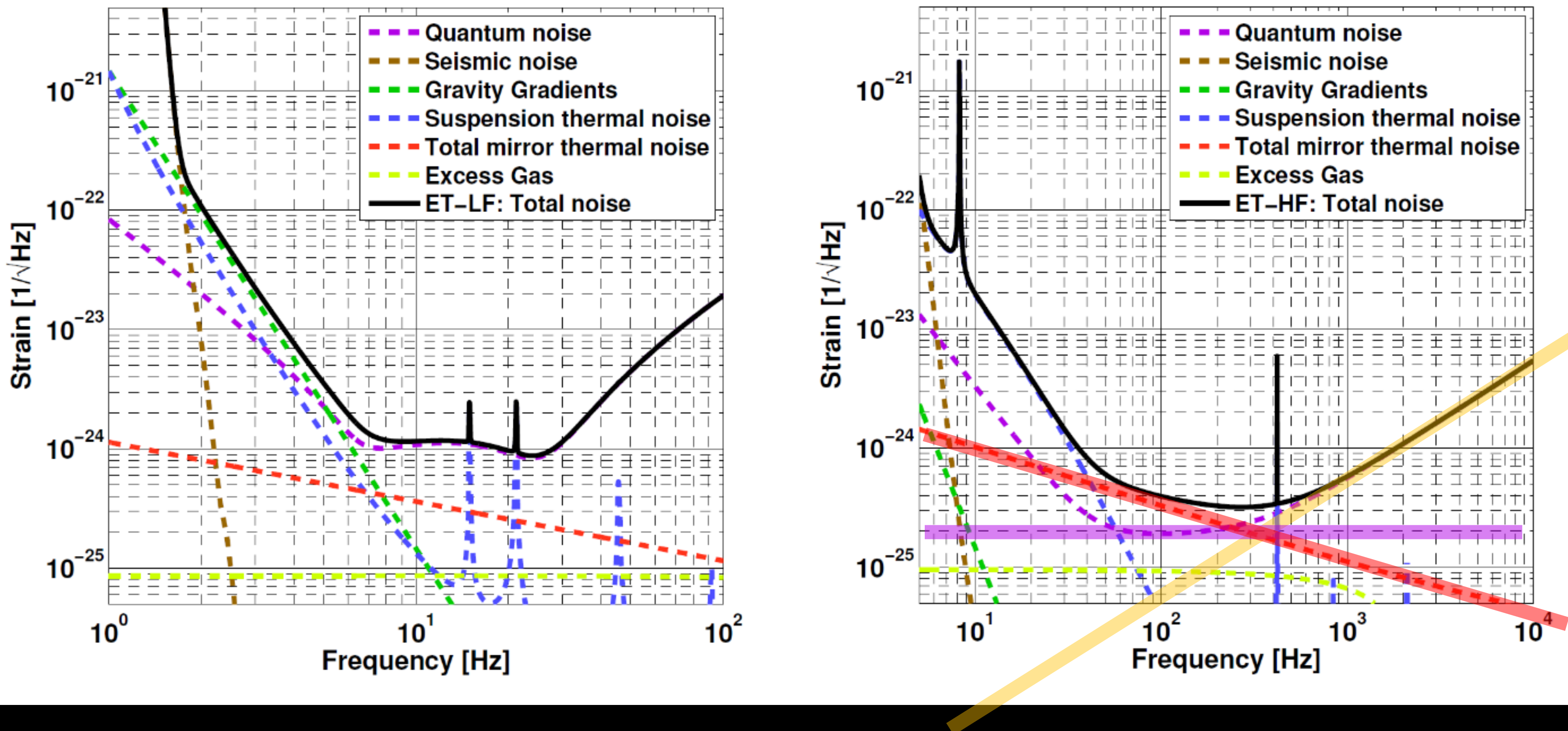
LF: cryogenic

HF: high power





Noise curves



- LF and HF interferometers, specialized in different frequency bands
- Slope at high frequency: 5 10^{-25} (1 kHz / f) $Hz^{-1/2}$ $h_n = \frac{\lambda f_{GW}}{c}\sqrt{\frac{hc}{\lambda}\frac{1}{\eta R_C P_{in}}}$
- Quantum noise level flat: 2 10^{-25} $Hz^{-1/2}$ $h_n = \frac{\lambda}{4\mathcal{F}L}\sqrt{\frac{hc}{\lambda}\frac{1}{\eta R_C P_{in}}}$
- Thermal noise: 10^{-25} (1 kHz / f) $^{-1/2}$ $Hz^{-1/2}$ room temperature

Interferometer parameters

- Outline main choices

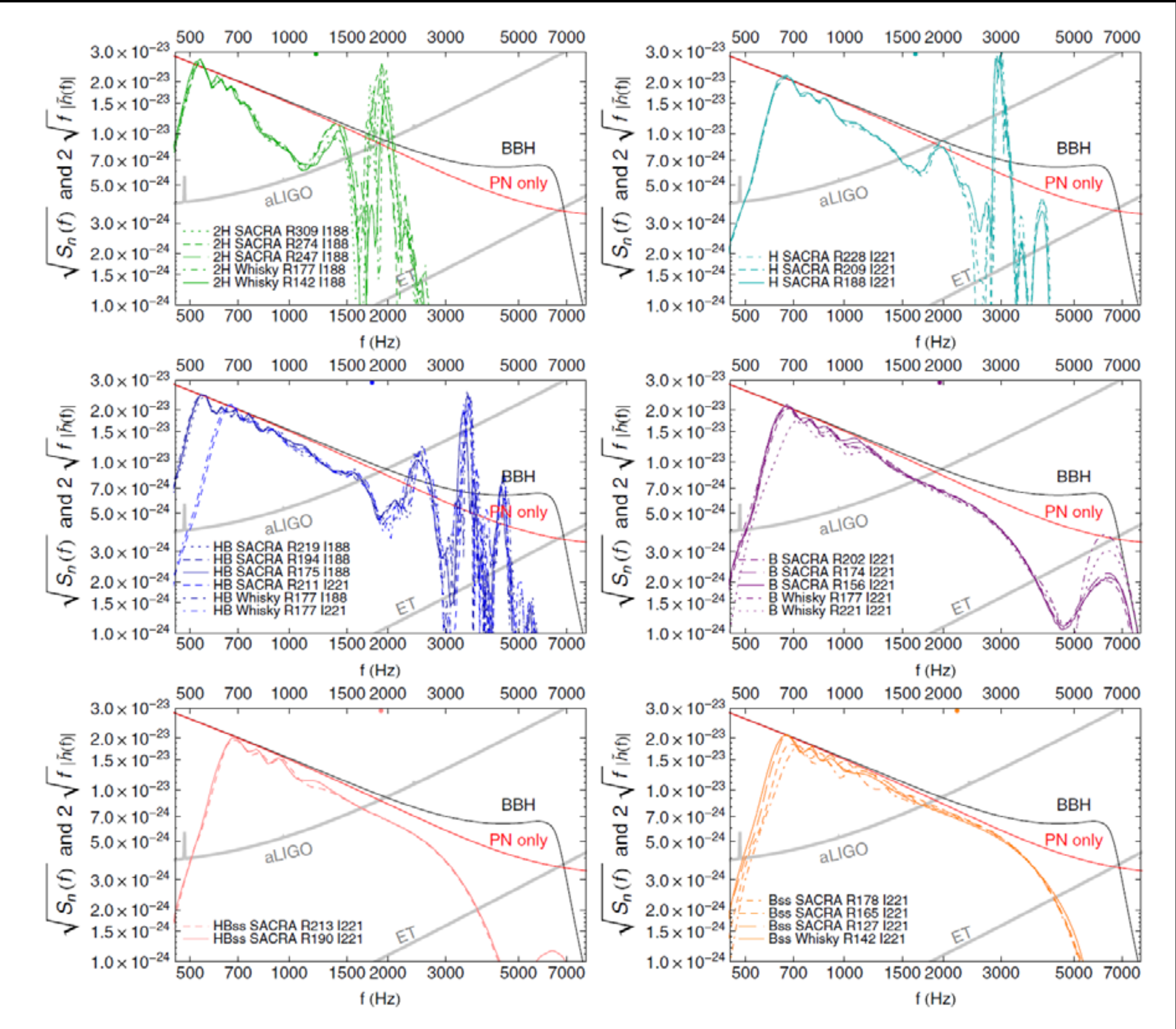
Parameter	ET-D-HF	ET-D-LF
Arm length	10 km	10 km
Input power (after IMC)	500 W	3 W
Arm power	3 MW	18 kW
Temperature	290 K	10 K
Mirror material	Fused silica	Silicon
Mirror diameter / thickness	62 cm / 30 cm	min 45 cm/ TBD
Mirror masses	200 kg	211 kg
Laser wavelength	1064 nm	1550 nm
SR-phase	tuned (0.0)	detuned (0.6)
SR transmittance	10 %	20 %
Quantum noise suppression	freq. dep. squeez.	freq. dep. squeez.
Filter cavities	1×10 km	2×10 km
Squeezing level	10 dB (effective)	10 dB (effective)
Beam shape	LG_{33}	TEM_{00}
Beam radius	7.25 cm	9 cm
Scatter loss per surface	37.5 ppm	37.5 ppm
Partial pressurefor H_2O, H_2, N_2	10^{-8}, $5 \cdot 10^{-8}$, 10^{-9} Pa	10^{-8}, $5 \cdot 10^{-8}$, 10^{-9} Pa
Seismic isolation	SA, 8 m tall	mod SA, 17 m tall
Seismic (for $f > 1$ Hz)	$5 \cdot 10^{-10}\,\mathrm{m}/f^2$	$5 \cdot 10^{-10}\,\mathrm{m}/f^2$
Gravity gradient subtraction	none	none

More emphasis to high frequency?

- We have learnt that for CCSNe have also characteristic signatures around 100 Hz
- Lowest noise is to be found in that band
- Lower noise at medium-high frequency requires better measurement noise
- Until now the working solution is to use squeezed vacuum states
- Limitation comes from losses on the squeezed vacuum path
- Additional interest above 1 kHz from NSNS coalescence

Additional interest from NSNS events

- Read et al PRD 88 (2013) 044042
- Features up to 7 kHz



Conclusions from a detector point of view: rekindling of HF

- Until now emphasis was on low frequency: higher signals from higher masses
- From a different perspective more remote sources
- High frequency probes the structure of the source
- Good high frequency performance is now a must for the third generation, together with 100% live time
- Opportunity for second generation detectors before third generation becomes operational