Einstein Telescope conceptual design discussion

a brief introduction

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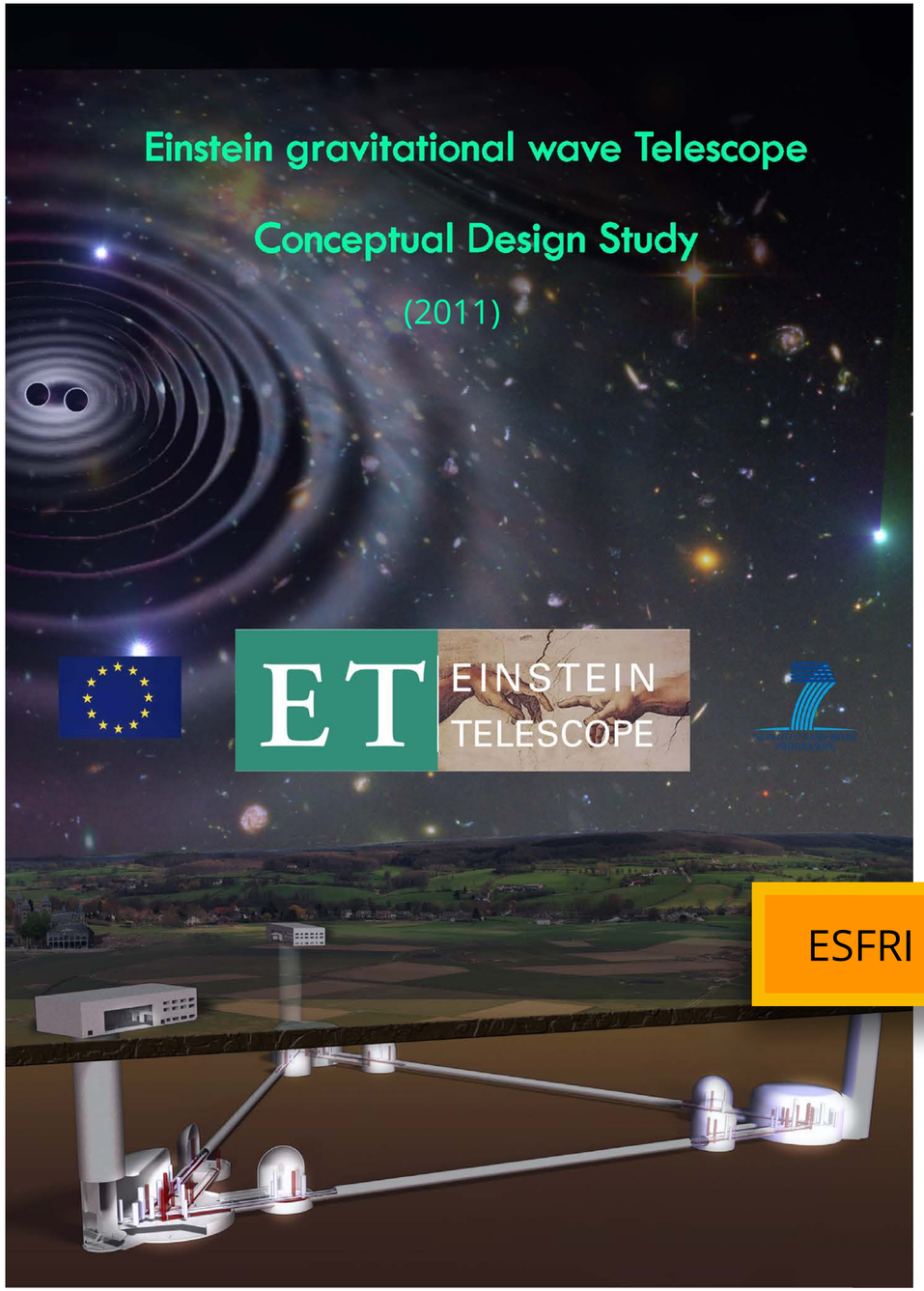
ET CoBA Meeting, 28.10.2021, ET-0438A-21

Evaluating different ET instrument options

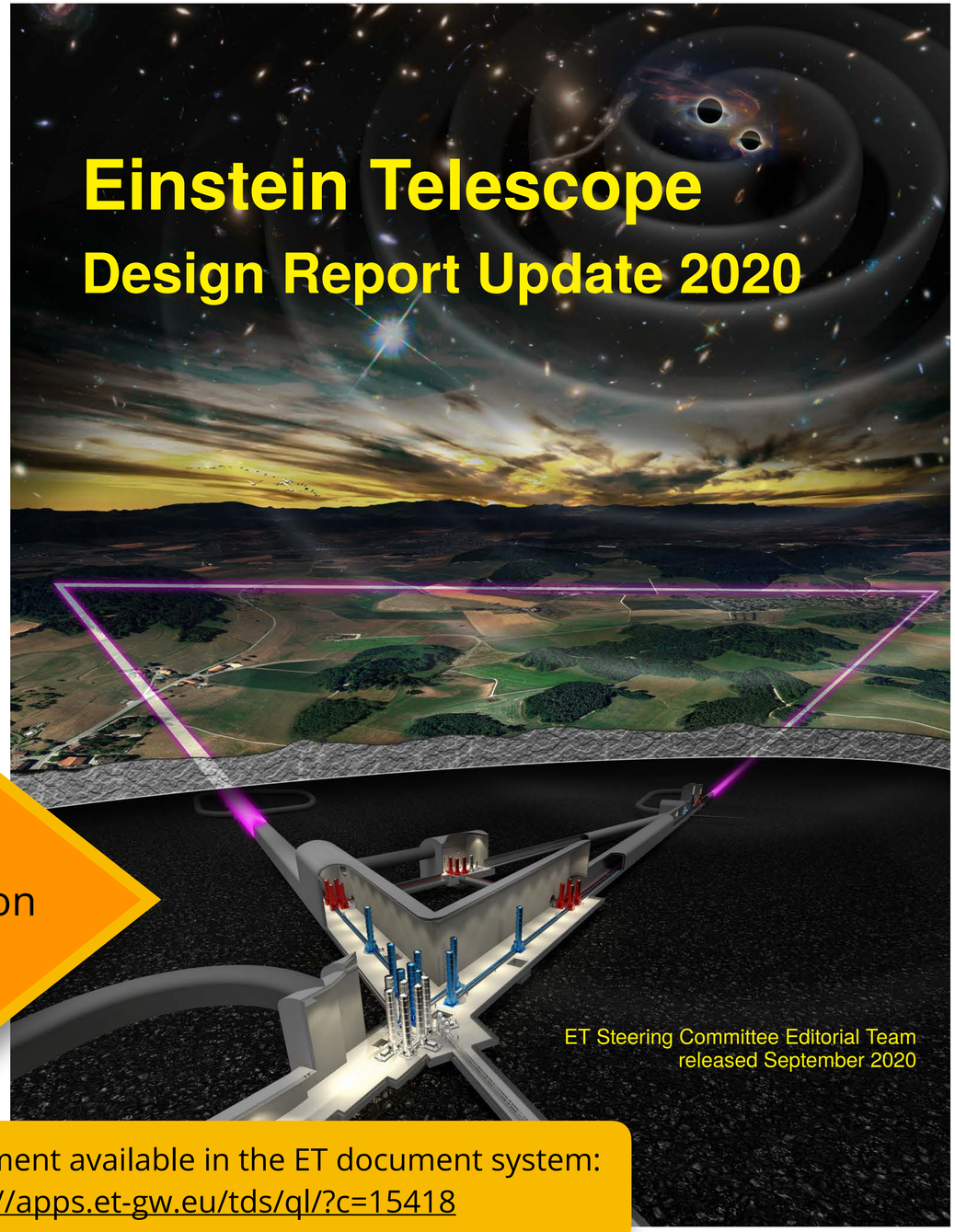
- **The method:** to evaluate the 'benefit' of different detector options, we generate sensitivity curves that describe the instrument performance, then use data-analyse codes to evaluate the science output/impact

- With GWINC we have a powerful common tool to generate and compare sensitivity curves. Design also includes issues that are not (yet) included in the sensitivity curves.

- We will present the sensitivity curves that the ISB is preparing for this activity. Key part: discussion on the limits of this approach and how to work towards a joint confidence in the result.



ESFRI Application



Document available in the ET document system:
https://apps.et-gw.eu/tds/ql/?c=15418

Conceptual design discussion

- ESFRI update: Most effort focussed on the underground infrastructure, we decided early to not update the conceptual detector design unless for correcting errors. However, we did fix a few problems, such as beam focussing or the quantum noise curve, where relevant research had been completed by ET researchers.

- Ongoing ISB work: update the design more broadly over two years, towards design reviews and a technical design.

- **Today: discussion on items in the conceptual design that are or can be critical for this cost-benefit analysis.**

Design Update Work

some examples

ET CONCE

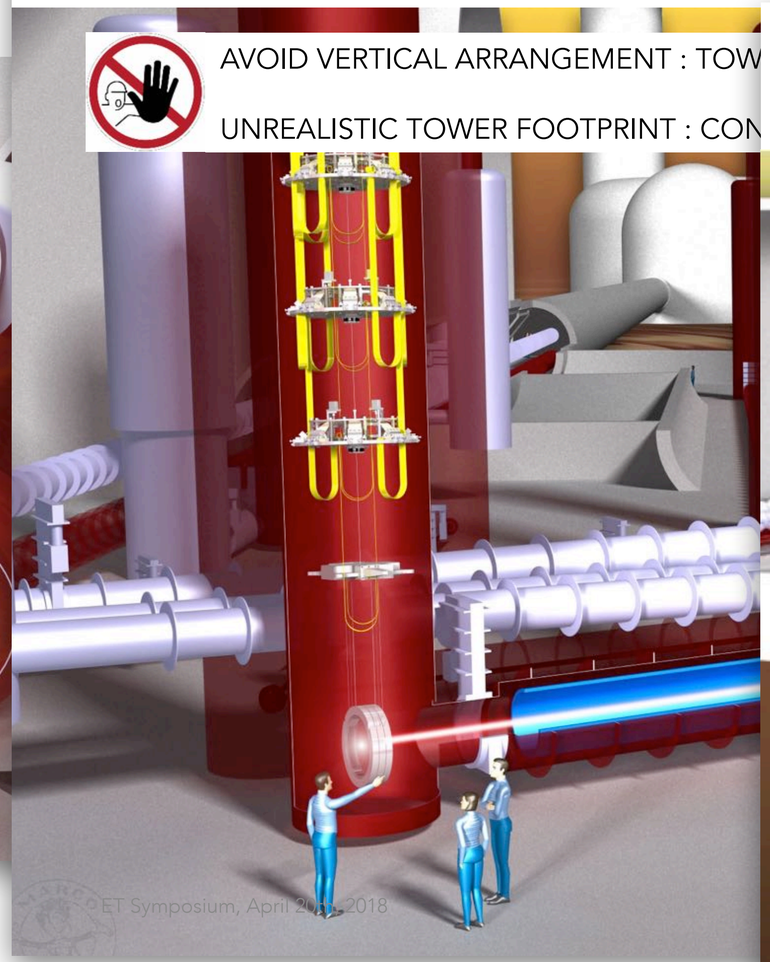
TUNNEL
TOO
CROWDED

ET Symposium, April 20th, 2018

ET CONCEPT - ISSUES

AVOID VERTICAL ARRANGEMENT : TOW

UNREALISTIC TOWER FOOTPRINT : CON

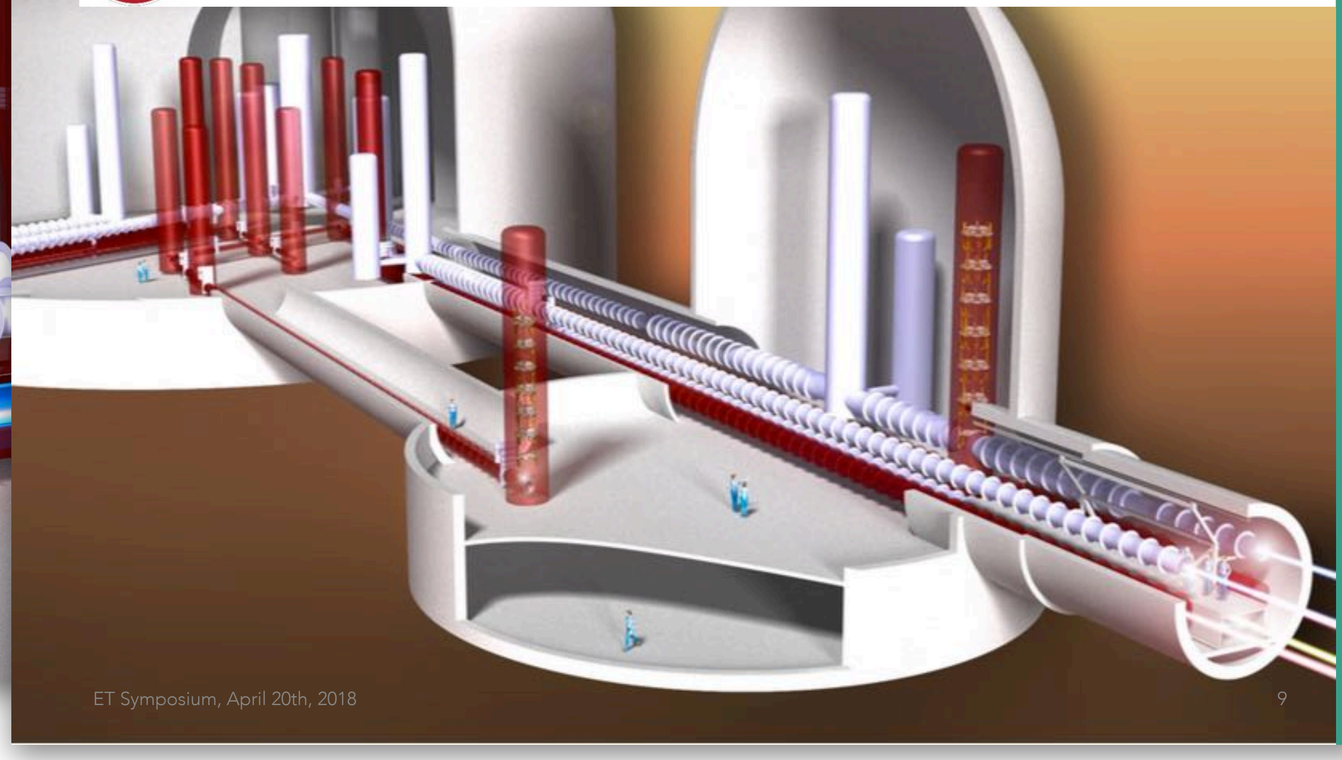


ET Symposium, April 20th, 2018

ET CONCEPT - ISSUES

MAIN CAVERN SIZE

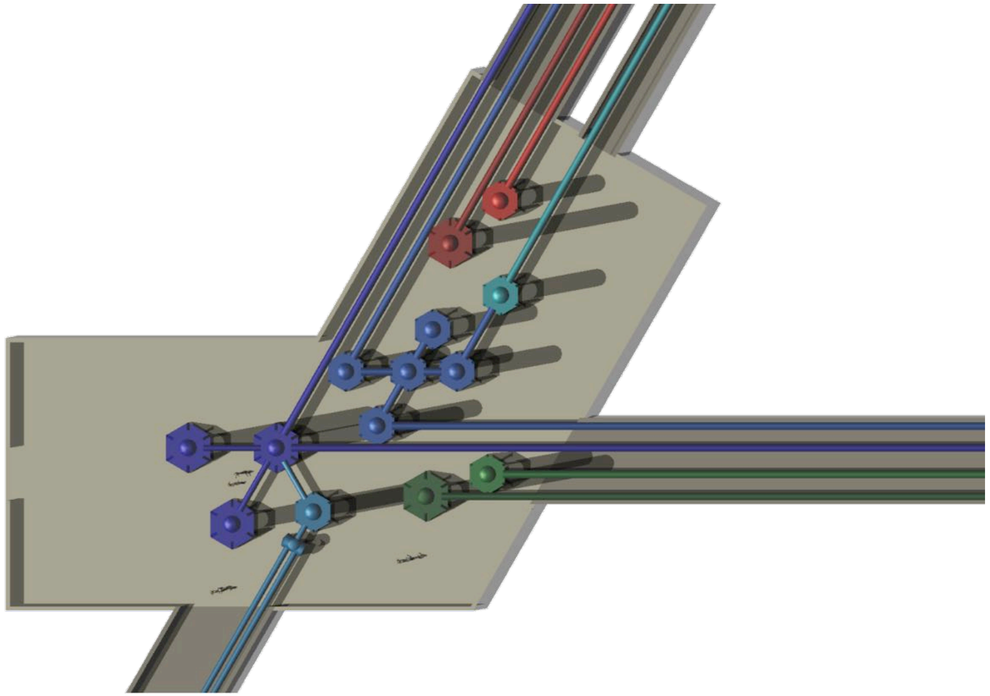
SHAPE IS CRITICAL



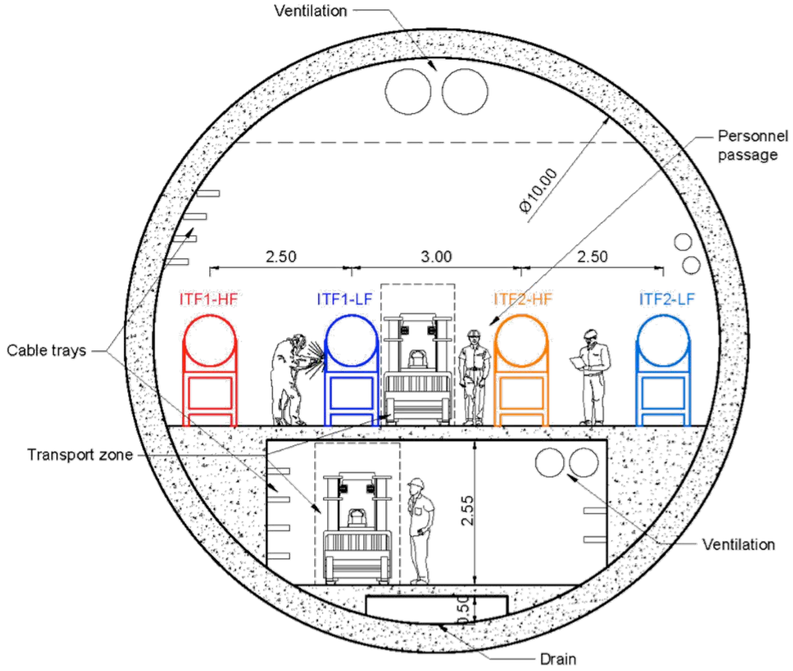
- 'Some consideration on the ET infrastructure, the case for a Sardinian site' G. Losurdo 20.04.2018 (not in TDS?)
- Similar plots in https://apps.et-gw.eu/tds/ql/?c=13309

Evolving the cavern and tunnel design

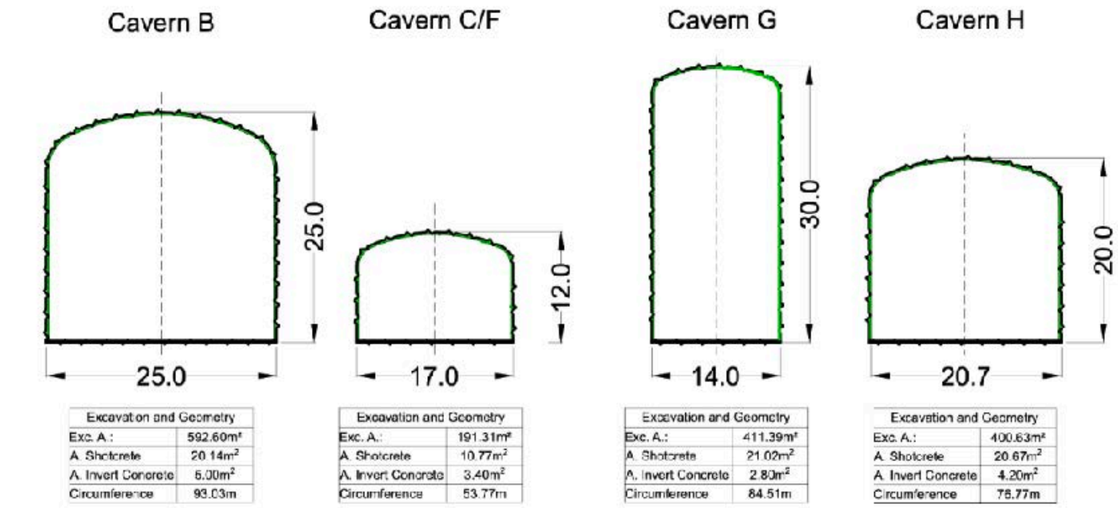
CORNER CAVERN



TUNNEL SECTION – ⦸$_{in}$ 10m



Implenia civil engineering study



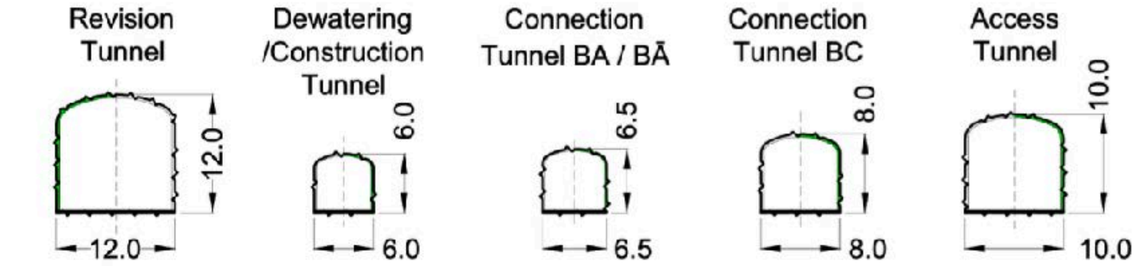
Excavation and Geometry	
Exc. A.:	592.60m²
A. Shotcrete	20.14m²
A. Invert Concrete	6.00m²
Circumference	93.03m

Excavation and Geometry	
Exc. A.:	191.31m²
A. Shotcrete	10.77m²
A. Invert Concrete	3.40m²
Circumference	53.77m

Excavation and Geometry	
Exc. A.:	411.39m²
A. Shotcrete	21.02m²
A. Invert Concrete	2.80m²
Circumference	84.51m

Excavation and Geometry	
Exc. A.:	400.63m²
A. Shotcrete	20.67m²
A. Invert Concrete	4.20m²
Circumference	78.77m

Figure 18: Clearance Profile of Caverns B, F, G and H.



Excavation and Geometry	
Exc. A.:	136.53m²
A. Shotcrete	9.52m²
A. Invert Concrete	2.40m²
Circumference	44.65m

Excavation and Geometry	
Exc. A.:	34.13m²
A. Shotcrete	3.04m²
A. Invert Concrete	1.20m²
Circumference	22.32m

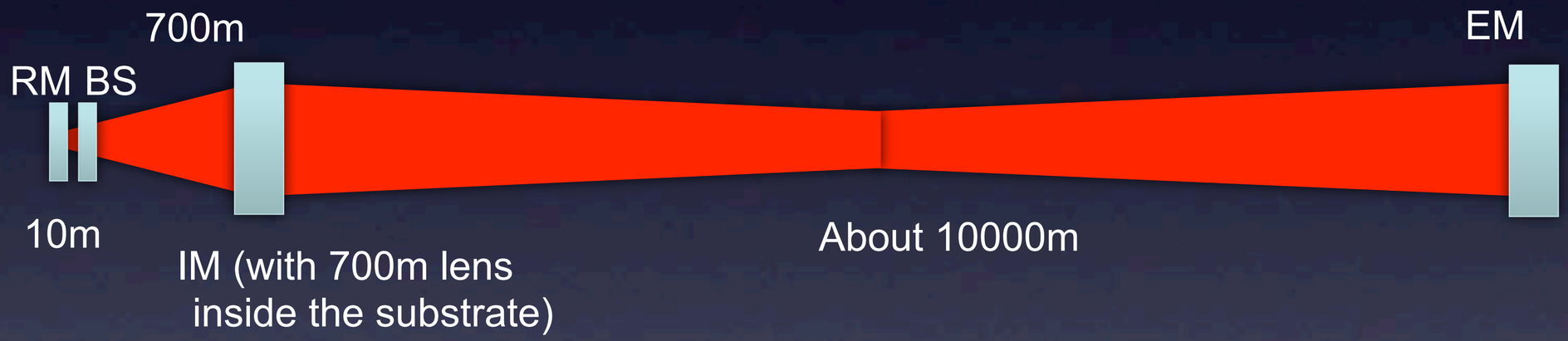
Excavation and Geometry	
Exc. A.:	40.06m²
A. Shotcrete	3.40m²
A. Invert Concrete	1.30m²
Circumference	24.18m

Excavation and Geometry	
Exc. A.:	60.68m²
A. Shotcrete	5.26m²
A. Invert Concrete	1.60m²
Circumference	29.77m

Excavation and Geometry	
Exc. A.:	90.81m²
A. Shotcrete	7.90m²
A. Invert Concrete	2.00m²
Circumference	37.21m

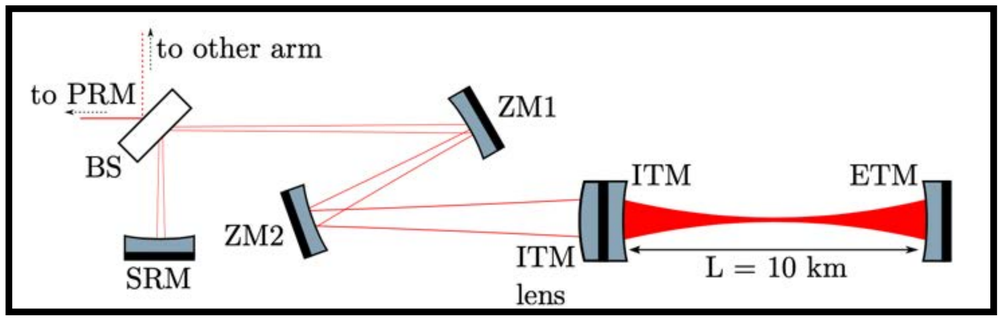
Better Beam Sizes

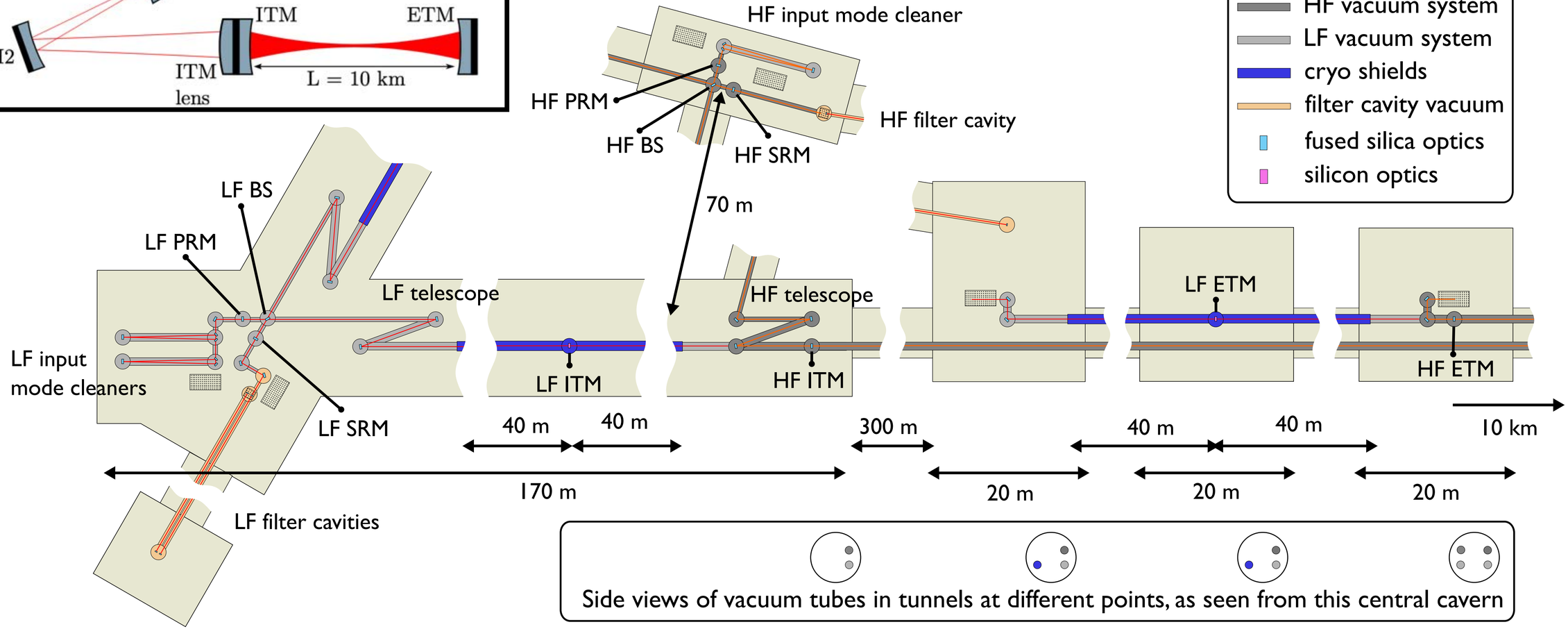
- We want to have small beams in the central interferometer.
- This could be achieved by focusing the beam down between IM and BS



- In order to reduce problems from imperfect optics, the focusing should be rather gentle. For current design we assume 700m to focus from 8cm down to 1cm.

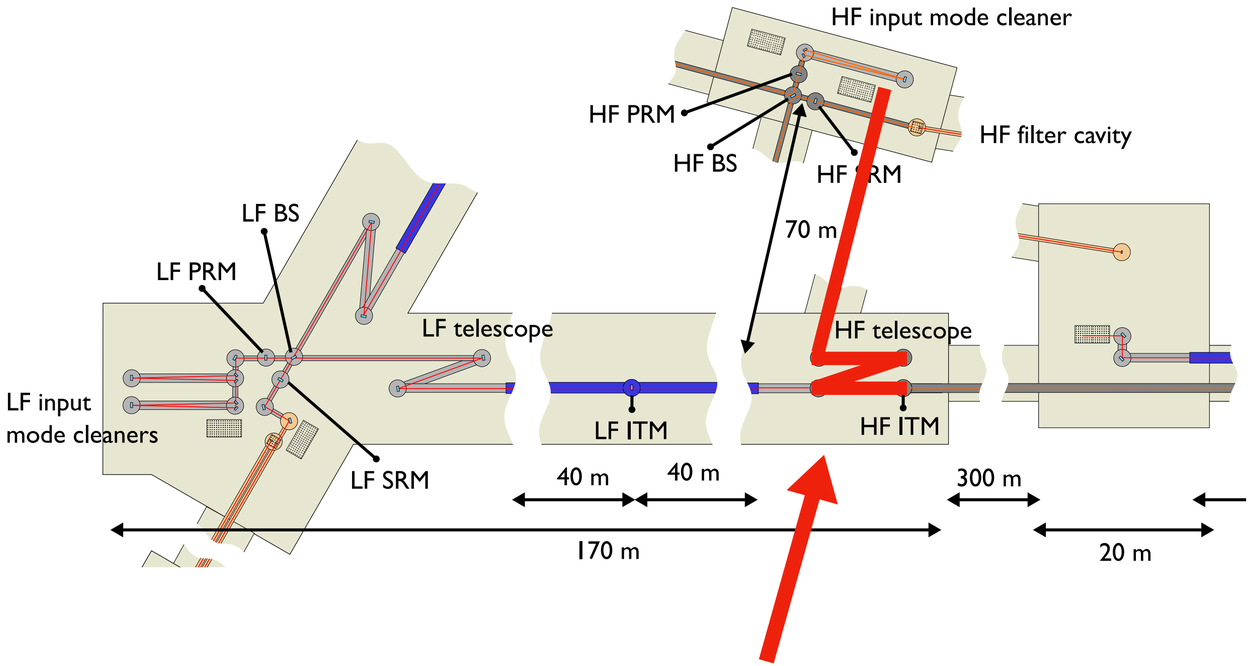
New telescope design, and full optical layout



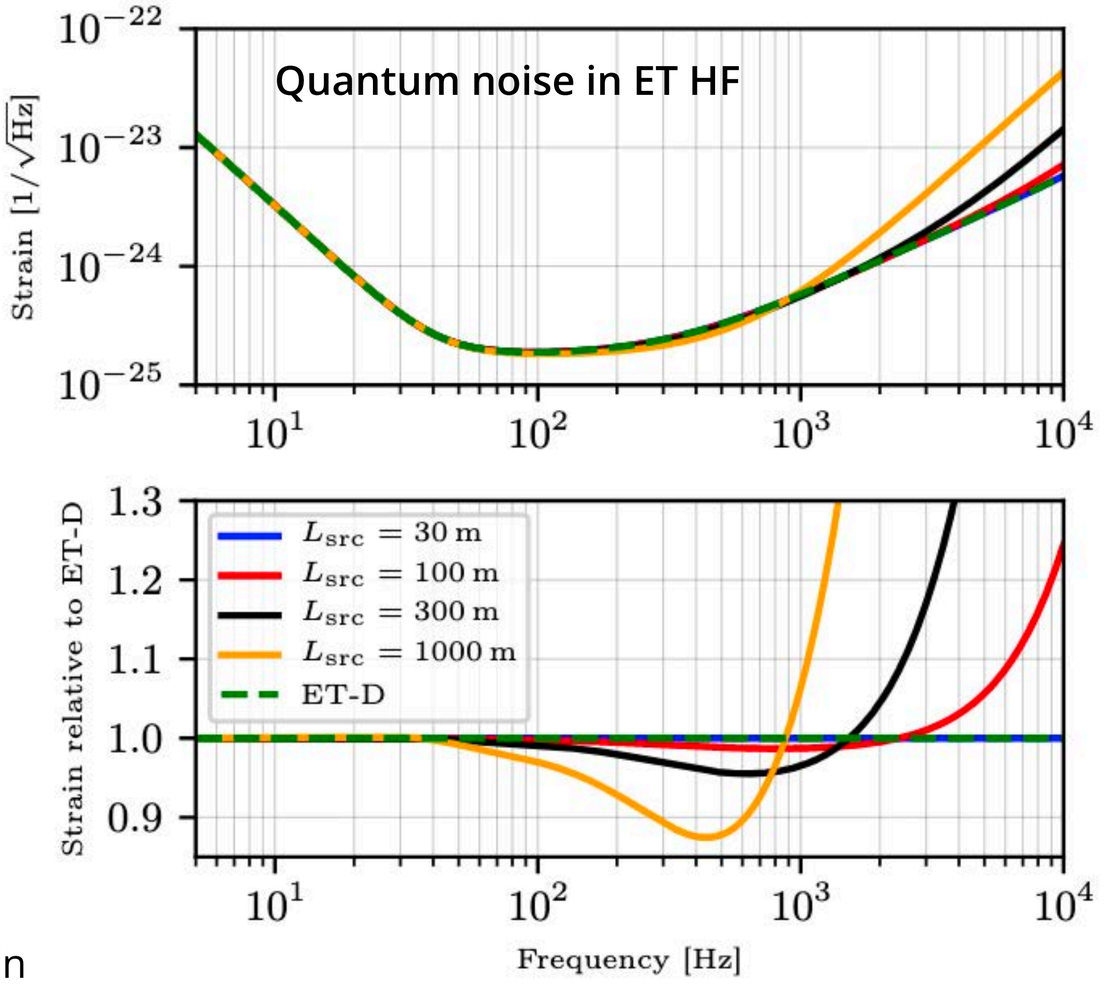


S. Rowlinson: Feasibility study of beam-expanding telescopes in the interferometer arms for the Einstein Telescope https://arxiv.org/abs/2011.02983

Correcting QNR curve for SRC length



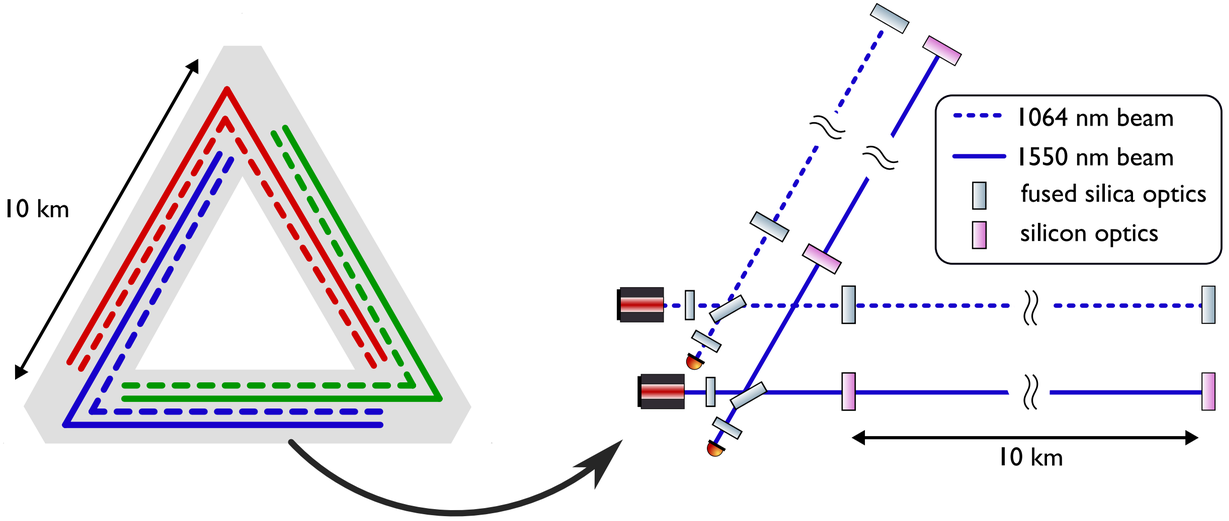
Signal Recycling Cavity (SRC)

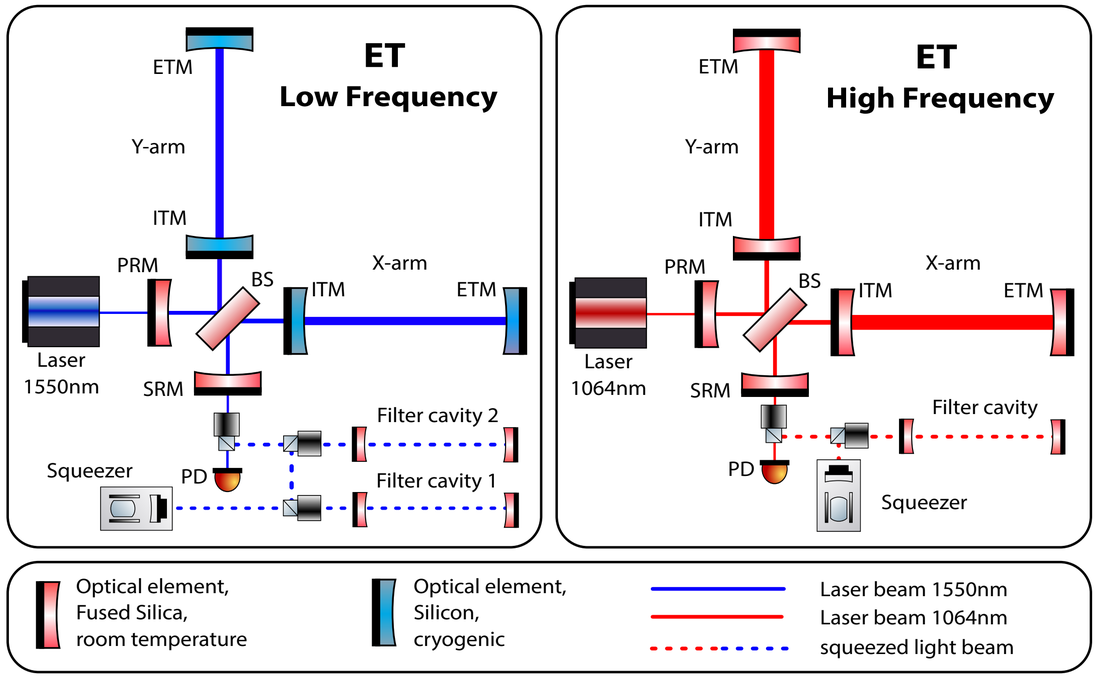


P. Jones et al., 'Implications of the Quantum Noise Target for the Einstein Telescope Infrastructure Design' (2020), https://arxiv.org/abs/2003.07468

Einstein Telescope key design parameters

Parameter	ET-HF	ET-LF
Arm length	10 km	10 km
Input power (after IMC)	500 W	3 W
Arm power	3 MW	18 kW
Temperature	290 K	10-20 K
Mirror material	fused silica	silicon
Mirror diameter / thickness	62 cm / 30 cm	45 cm/ 57 cm
Mirror masses	200 kg	211 kg
Laser wavelength	1064 nm	1550 nm
SR-phase (rad)	tuned (0.0)	detuned (0.6)
SR transmittance	10 %	20 %
Quantum noise suppression	freq. dep. squeez.	freq. dep. squeez.
Filter cavities	1×300 m	2×1.0 km
Squeezing level	10 dB (effective)	10 dB (effective)
Beam shape	TEM_{00}	TEM_{00}
Beam radius	12.0 cm	9 cm
Scatter loss per surface	37 ppm	37 ppm
Seismic isolation	SA, 8 m tall	mod SA, 17 m tall
Seismic (for $f > 1$ Hz)	$5 \cdot 10^{-10}$ m/f^2	$5 \cdot 10^{-10}$ m/f^2
Gravity gradient subtraction	none	factor of a few





ET sensitivity curve

- The official ET sensitivity curve is `ET-D' from 2011, ESFRI correction did not deviate from ET-D significantly

- New dedicated ISB working group `Observatory design and noise budget'. One of its task is to create and coordinate the official sensitivity curve. First task: re-create a similar curve to ET-D, with known model errors corrected.

- Moved to Python-based GWINC code (pyGWINC) to benefit from recent updates and better maintenance of that code, see code and parameters at: https://gitlab.et-gw.eu/et/isb/interferometer/ET-NoiseBudget

- Current status, see the following talks.

ET R+D tasks

- We are compiling a complete R+D task list, to serve as base data set for follow-up activities, such as prioritisation and towards making a project plan

	C	D	E	F	G	H	I	J
1	**Number (automatic)**	**Task name**	**Task Level**	**Divsion**	**ET LF**	**ET HF**	**Keywords**	**Task description (a few sentences to give a clear and unique description pf the task)**
2	1	Development of new or extension of optical simulation packages	1	IFO	☑	☑	simulation	
3	1.1	Development of optical simulations including polarisati	2	IFO	☑	☑	simulation	Essential to derive birefringence specifications. Must be able to includ birefringence maps
4	1.2	Development of 3D ray tracing tool	2	IFO	☑	☑	simulation	A software to simulate in 3D the main interferometer beam but also all pick off beams from tilted surfaces. (up to a certain order or power). M derive in 3D the center of mass of the optics.
								Development of a package to simulate the lock acquisation and contro
								...
175	1	Magnetic Noise computation for ET	1	ANM	☑	☐	simlation, design, hardware	New simulation tools will be required for setting empirically derived lim acceptable fields and force couplings.
176	20.1	Magnetic test facility	2	ANM	☑	☐	hardware	Stray fields and noise-impact of materials placed close to the testmas be quantified empirically, similar to vacuum-contamination tests.
177	20.2	Actuator performance	2	ANM	☑	☐	hardware, design	(with SUS) Actuators close to the LF payload must meet stringent stra requirements.
178	20.3	Magnetic shielding	2	ANM	☑	☐	simulation, design	Shielding of the test-mass and/or magnetic sources will need careful c Correction of DC gradients may be corrected with Helmholtz coils.
179	20.4	Underground environment limits	2	ANM	☑	☐	collaboration, site testing	Investigate expected levels of field, fluctuations, and gradients in underground environments. Collaboration with, eg, MIGA, KAGRA an others will be helpful.

List of of R+D discussion items

After the following talks on the sensitivity studies, we want to discuss the confidence we have in the models, and in particular collect 'homework' items for the in-person workshop.

Some topics mentioned recently:

- Large test masses
- Silicon mirrors
- Cryogenic operation of mirror
- Seismic pre-isolation
- Control noise reduction
- Newtonian noise subtraction
- High-power operation
- ...

… end