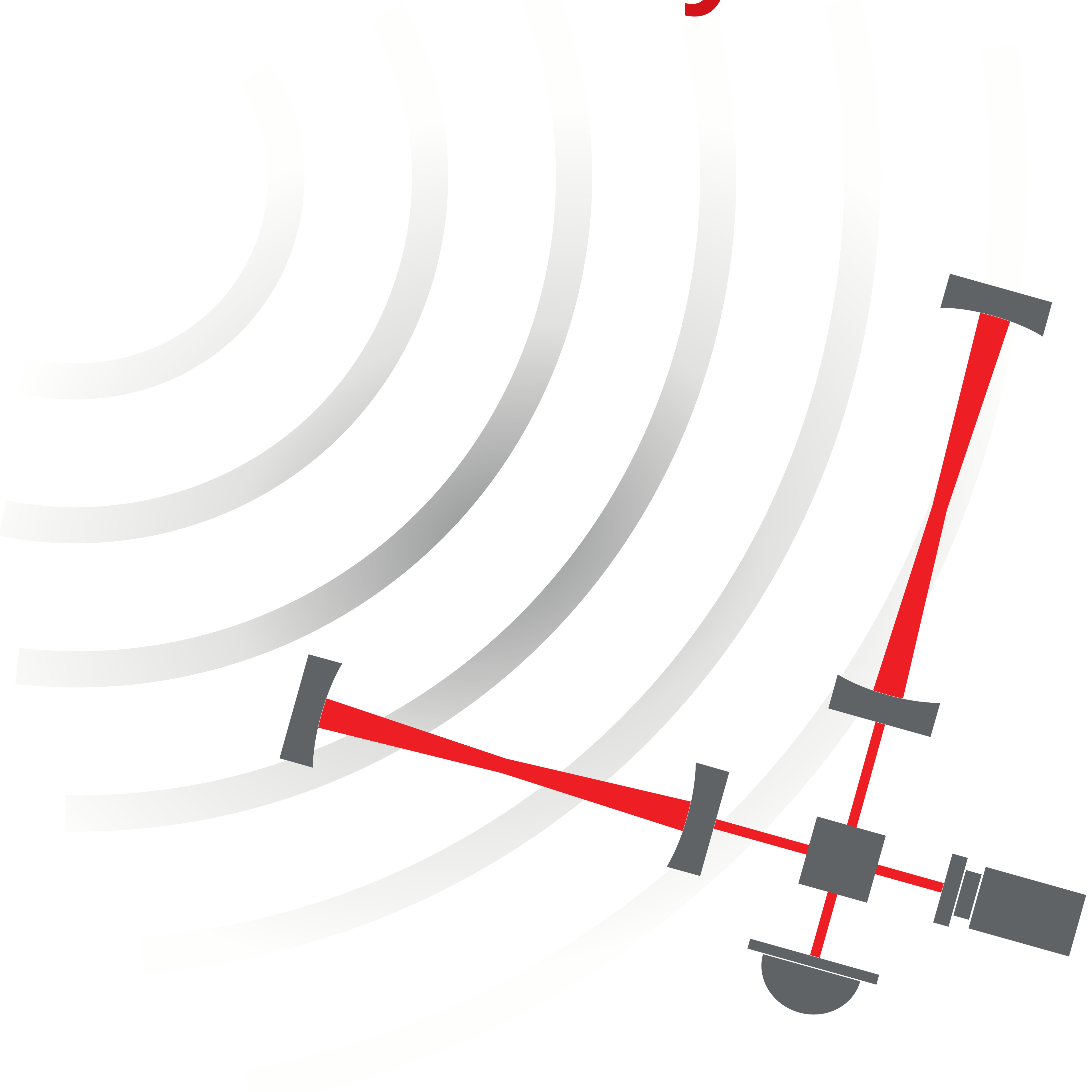
Einstein Telescope cost benefit analysis

a brief update



Andreas Freise,
ET SPI Workshop, 09.11.2021

Top down request: Cost Benefit Analysis (CoBA)

Cost Benefit Analysis seeks to provide input for:

- negotiation with funding agencies
- negotiation of the funding agencies with governments
- negotiation between governments

At each negotiation stage, we might have to present solutions for different aspects of:

- overall cost reduction
- sharing of costs between partners and institutions
- timing of construction, operation and funding

This leads to the idea to `pre-evaluate' alternative options (Plan B) before we are asked.

Key message: cost-benefit should support Plan A, and have Plan B ready in case we need it!

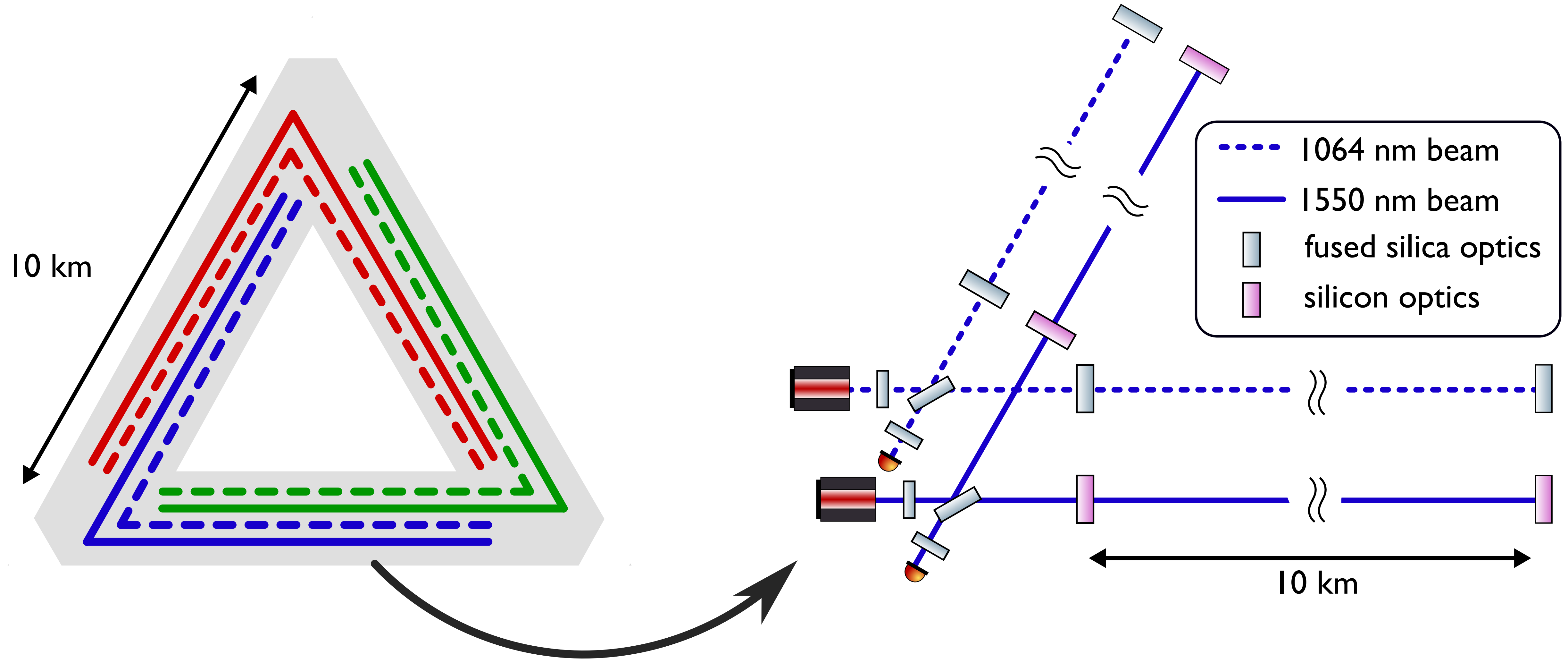
Ongoing and rapid activity

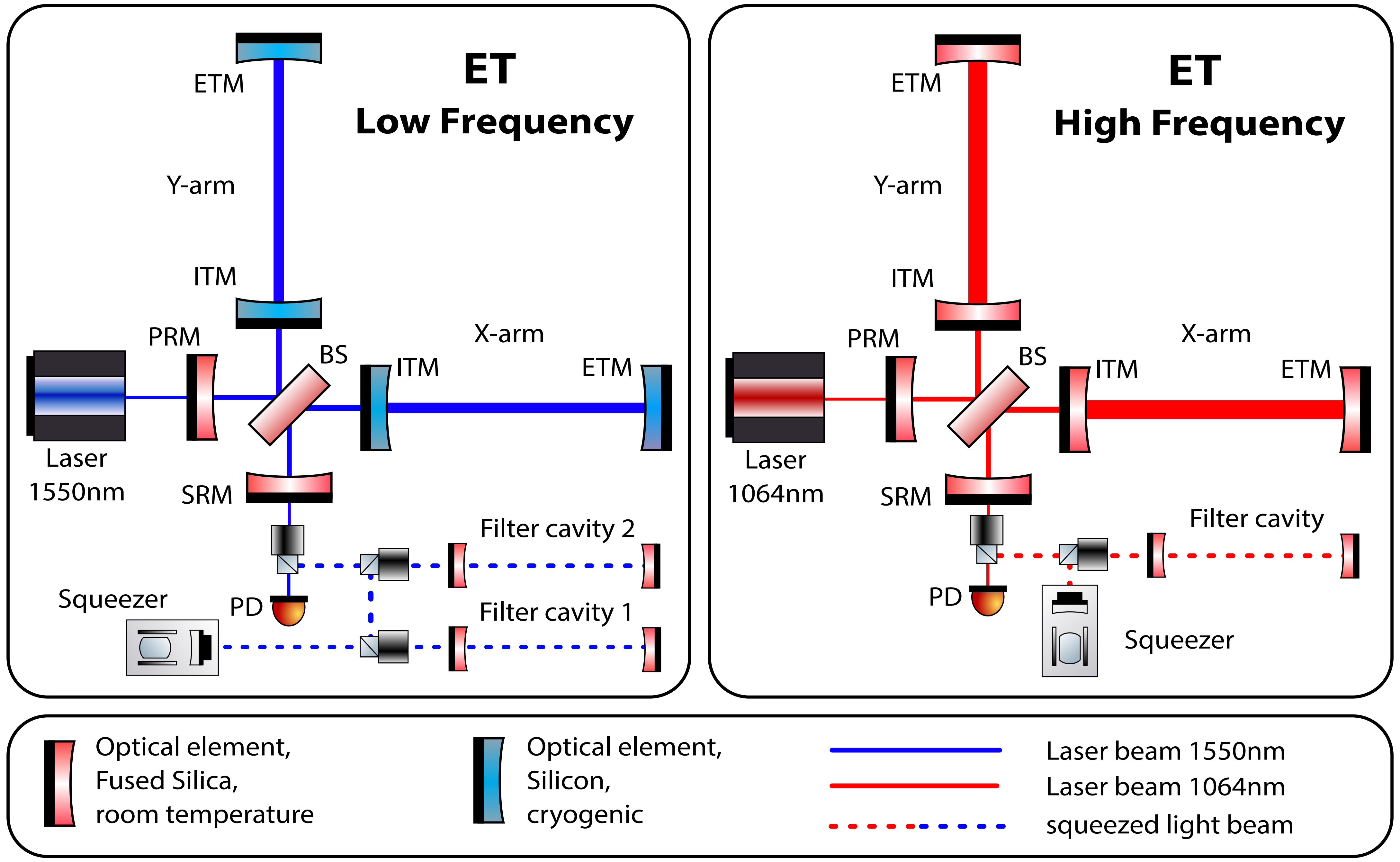
- 06.10.2021: Start of the process:, weekly meetings
- 28.10.2021: 1-day remote workshop
- 24-26.11.2021: 3-days in-person workshop

Very little time for complex activity, not sufficient time to perform a in-depth study of Plan B designs/science/costs.

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





Possible alternatives

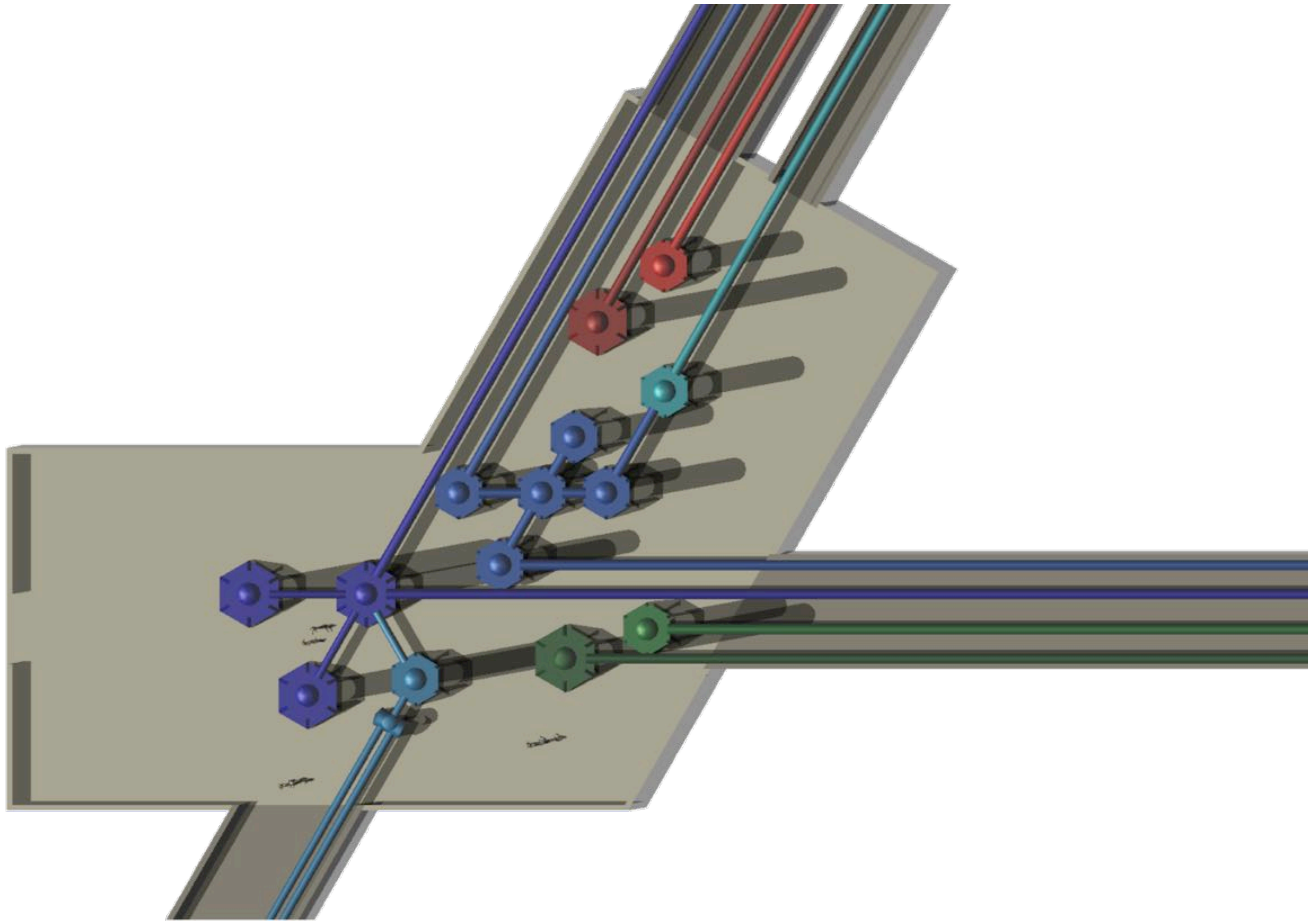
- Two L-shape detectors instead of one triangle
- Different base length of the observatory
- Different technical detector designs
- Staged approach of implementation of detectors in infrastructure
- …

Design examples from the ESFRI update

- '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



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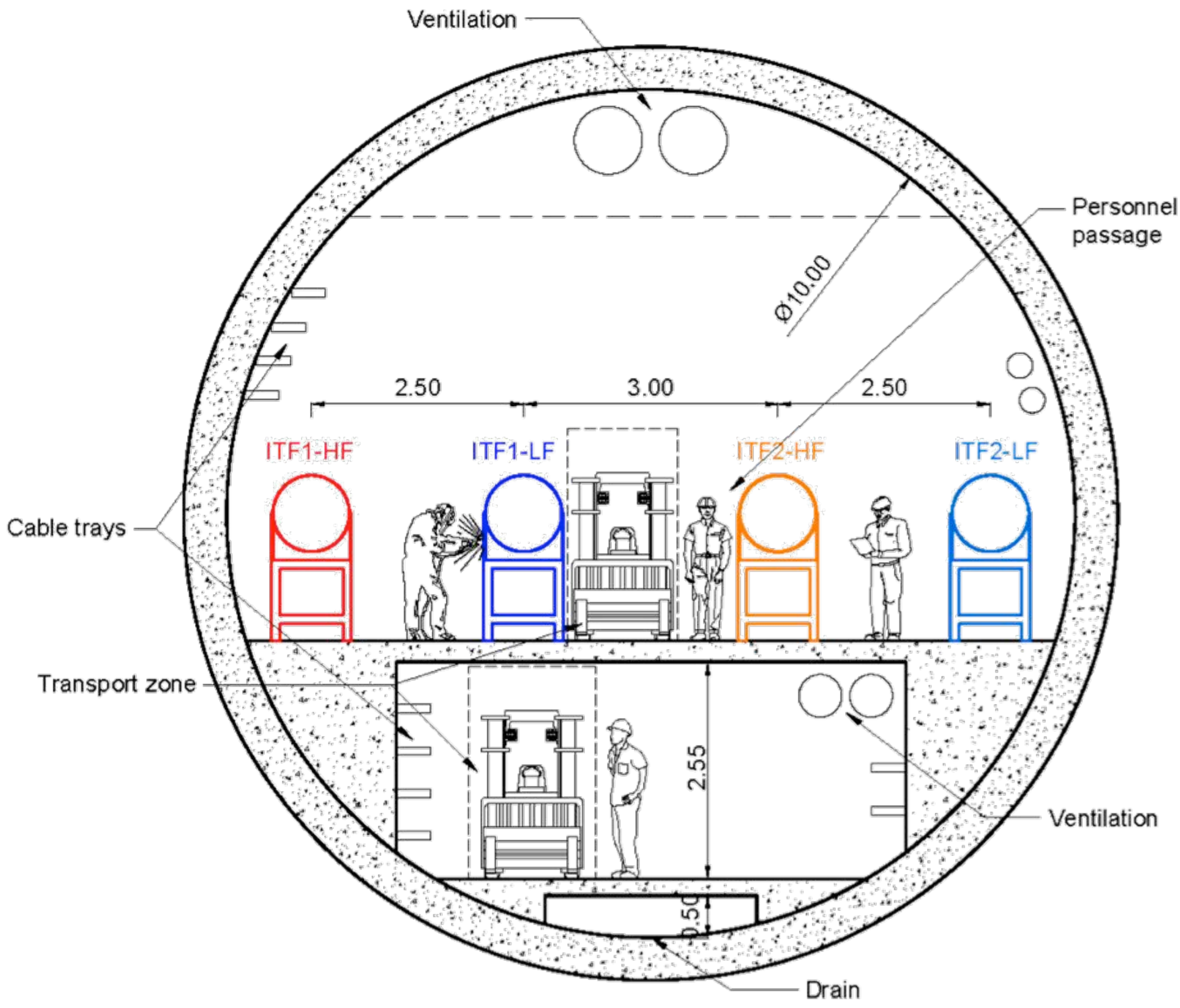
TUNNEL SECTION – ⃠$_{in}$ 10m



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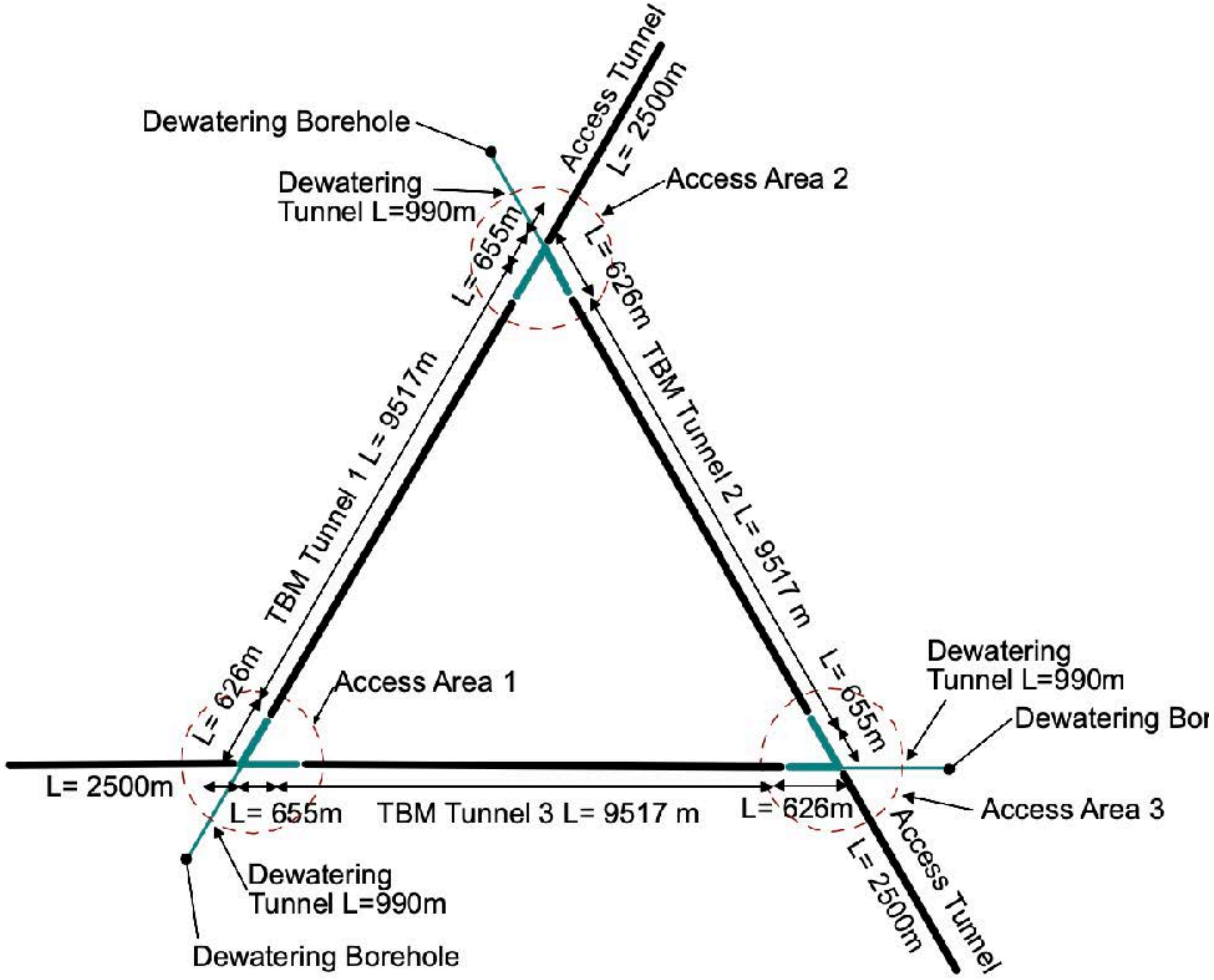
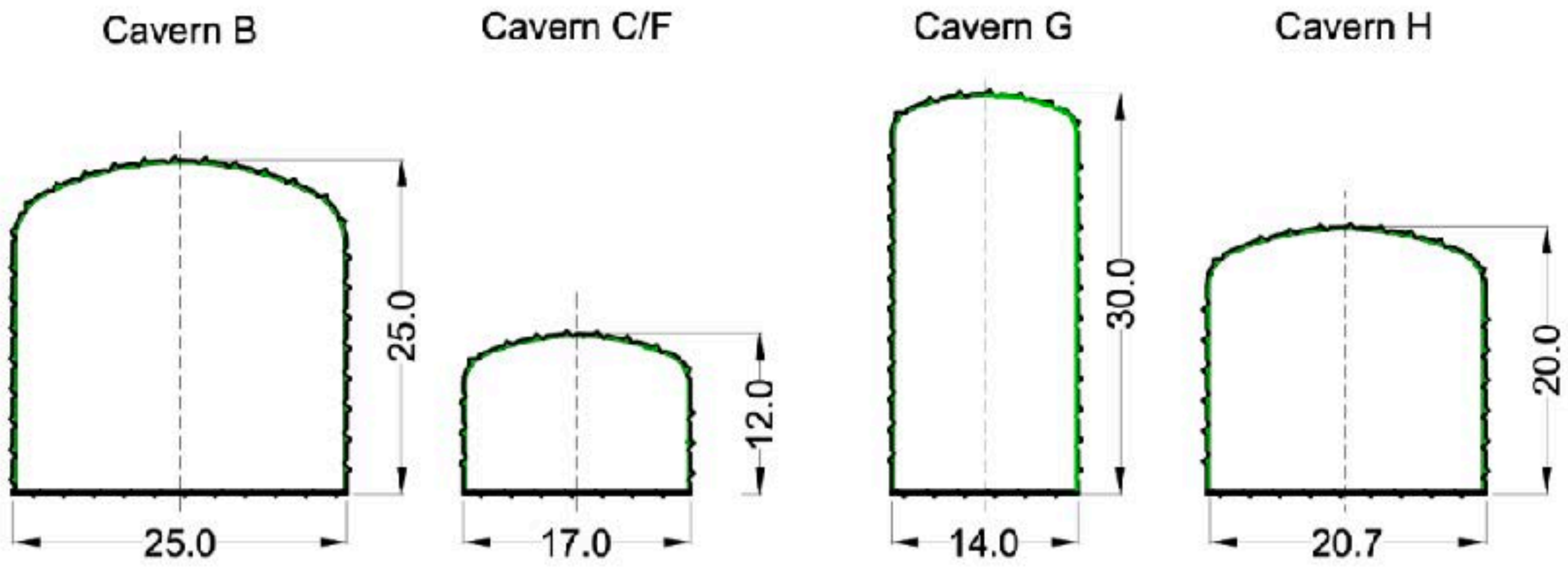
Implenia civil engineering study





Cavern B

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

Cavern C/F

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

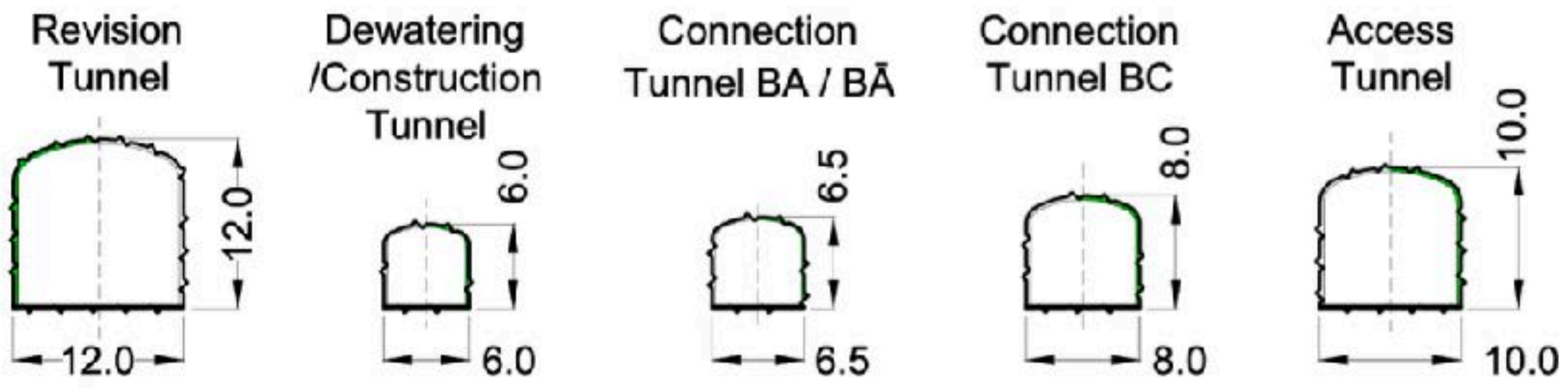
Cavern G

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

Cavern H

Excavation and Geometry	
Exc. A.:	400.63m²
A. Shotcrete	20.67m²
A. Invert Concrete	4.20m²
Circumference	76.77m

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



Revision Tunnel

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

Dewatering /Construction Tunnel

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

Connection Tunnel BA / BĀ

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

Connection Tunnel BC

Excavation and Geometry	
Exc. A.:	60.68m²
A. Shotcrete	6.26m²
A. Invert Concrete	1.60m²
Circumference	29.77m

Access Tunnel

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

Evaluating different ET instrument options

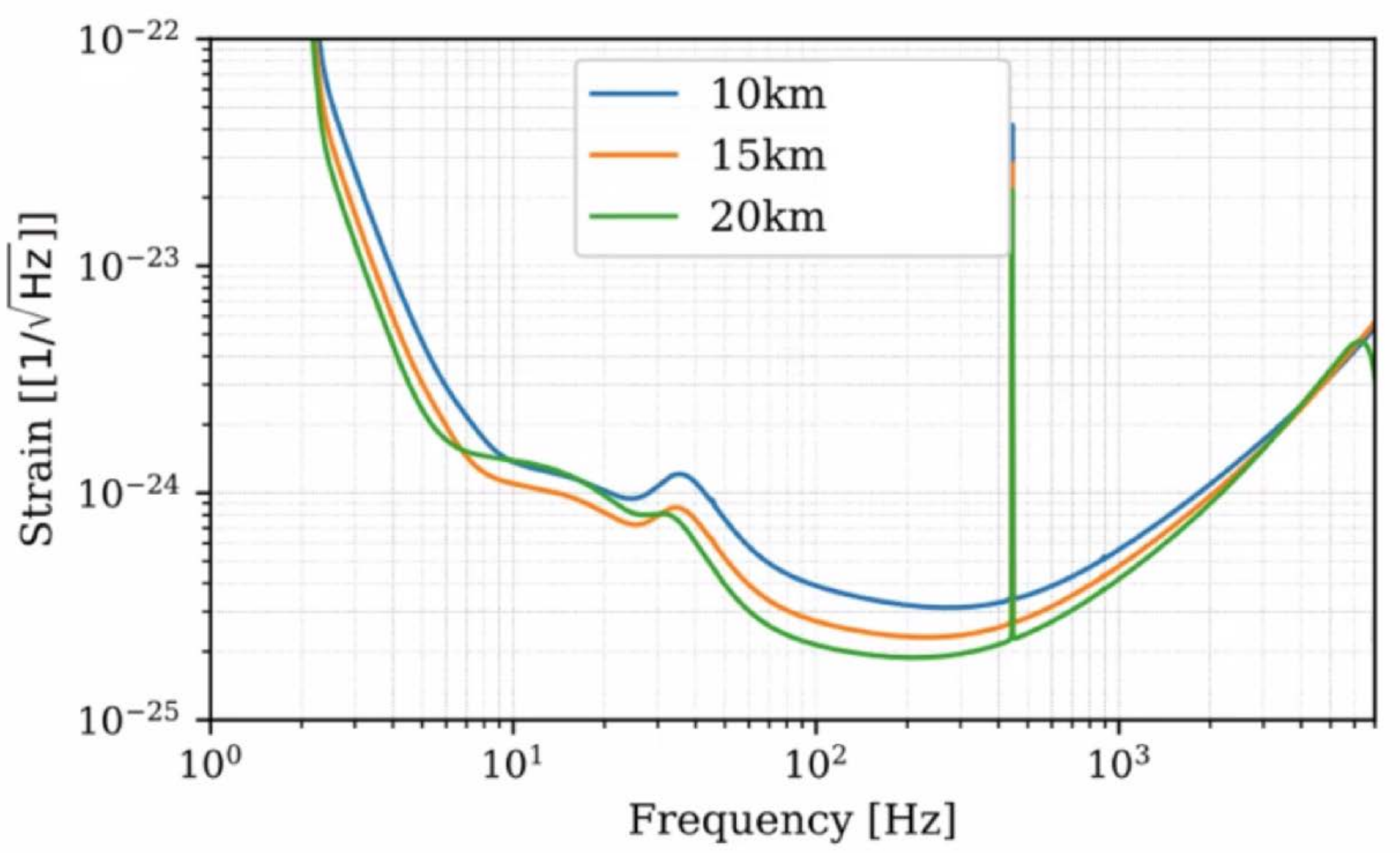
- **The method:** to evaluate the 'benefit' of different detector options, we generate sensitivity curves that describe the instrument performance, then use data-analyse codes to evaluate the science output/impact

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

- We (OSB) run data analysis codes to estimate the impact on science output of ET for different sensitivity curves. This process is easy for some science targets, not so easy for others.

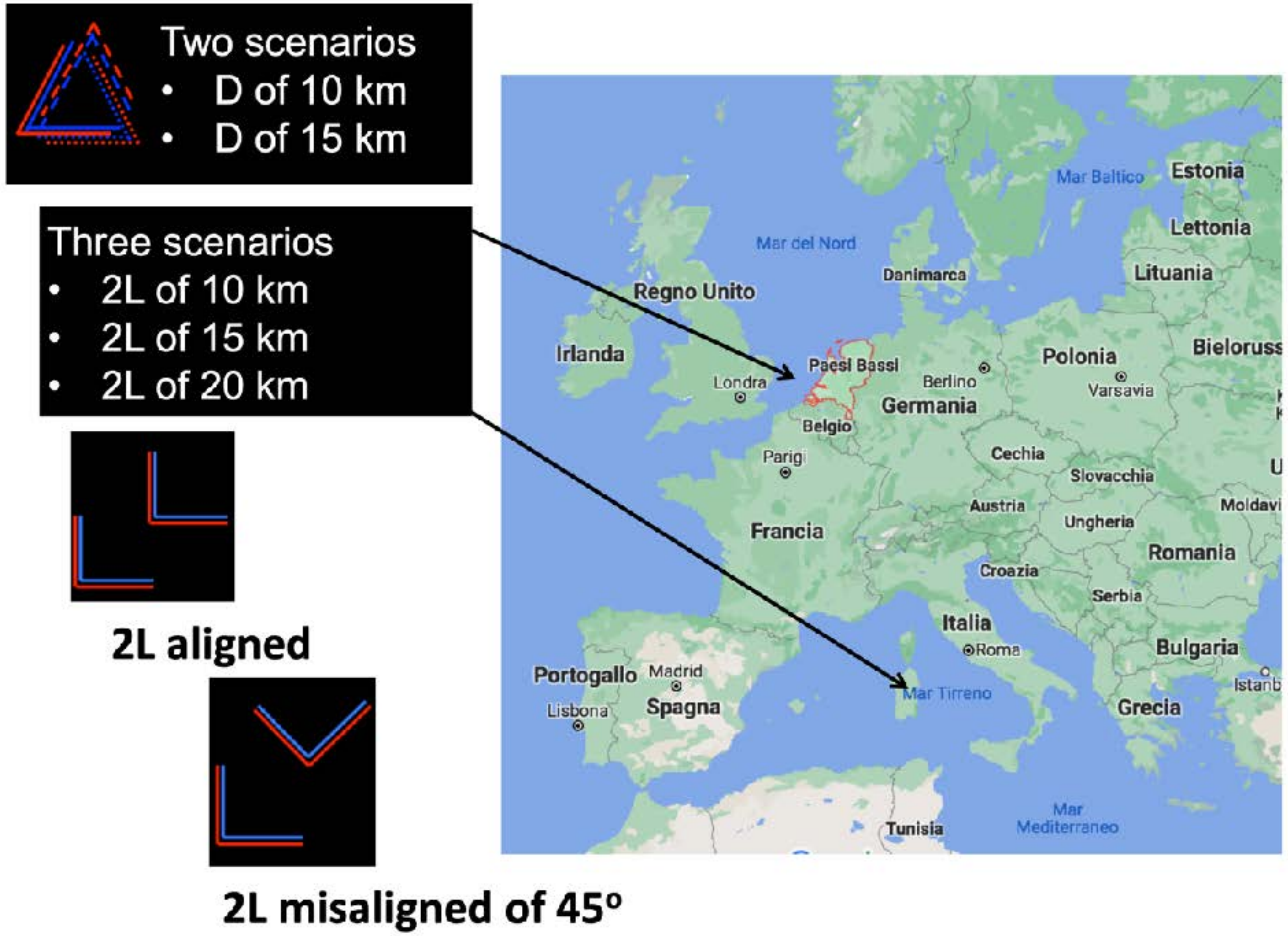
- We (who?) evaluate the cost of the different scenarios, dominated by the civil infrastructure (both underground and surface).

Preliminary: sensitivity options



Teng Zhang: https://apps.et-gw.eu/tds/ql/?c=16160

Preliminary: science impact, considered options



Marica Branchesi: https://apps.et-gw.eu/tds/ql/?c=16164

Preliminary: example, sky localisation

Scenario	Number of detections per year	Number of detections per year Sky-loc < 20 deg^2	Number of detections per year Sky-loc < 100 deg^2
Triangle (10 km)	42732	68	514
Triangle (15 km)	100080	190	1326
2L(15 km) aligned	90036	16	198
2L(15 km) misaligned	85680	102	860
2L(20 km) aligned	109584	34	272
2L(20 km) misaligned	108072	150	1230

[M. Branchesi]

- Warning: triangle effects such as null-stream not included here!

Summary

- Cost benefit analysis is underway, so far we have discussed details of the process
- ISB provided preliminary sensitivity curves and OSB did preliminary simulations, both to establish the procedure
- More preparation currently underway towards 3-day workshop later this month

… end