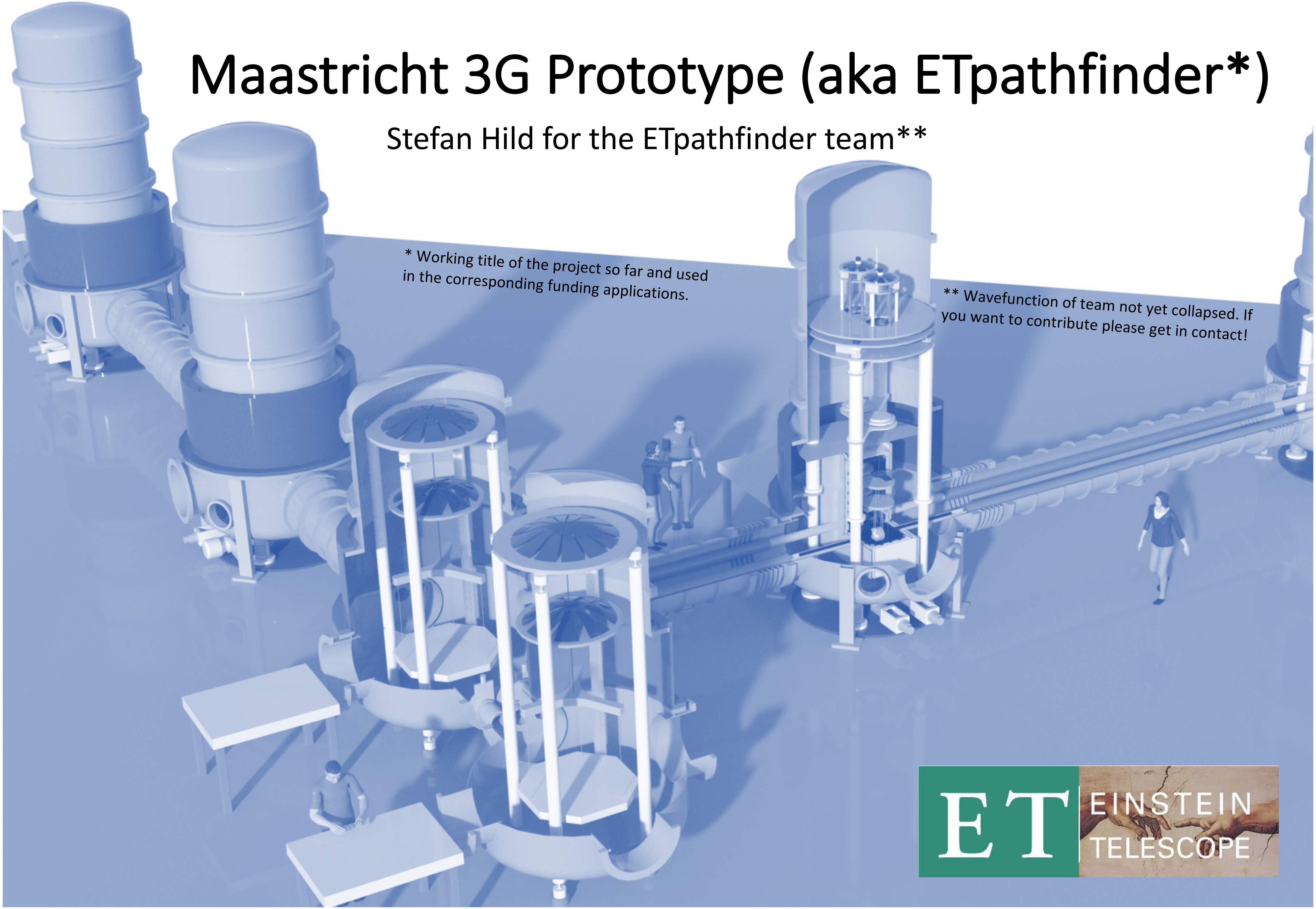
Maastricht 3G Prototype (aka ETpathfinder*)

Stefan Hild for the ETpathfinder team**



* Working title of the project so far and used in the corresponding funding applications.

** Wavefunction of team not yet collapsed. If you want to contribute please get in contact!

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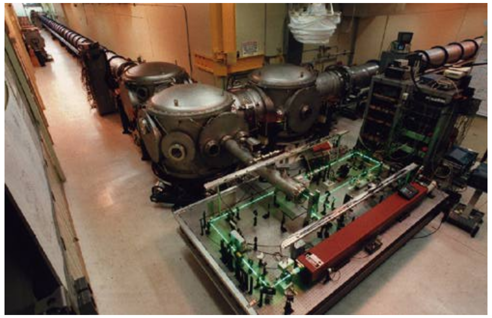
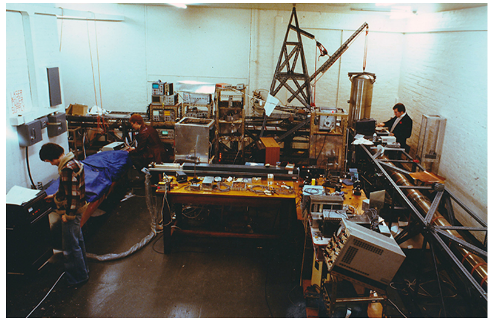
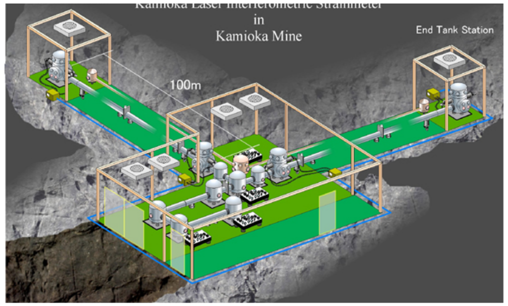
Prototypes: Past and Presence

- Prototype interferometers have been vital to develop GW detectors over the past decades.
- Garching 30m, Glasgow 10m, Caltech 40m, MIT, Gingin, Stanford, CLIO, AEI …


- **Why building yet another one?**

What R&D is needed for ET?

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Class. Quantum Grav. **28** (2011) 094013 S Hild *et al*

Table 1. Summary of the most important parameters of the ET-D high- and low-frequency interferometers as shown in figure 5. SA = superattenuator, freq. dep. squeez. = squeezing with frequency-dependent angle.

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}, 5×10^{-8}, 10^{-9} Pa	10^{-8}, 5×10^{-8}, 10^{-9} Pa
Seismic isolation	SA, 8 m tall	mod SA, 17 m tall
Seismic (for $f > 1$ Hz)	$5 \times 10^{-10}\,\mathrm{m}/f^2$	$5 \times 10^{-10}\,\mathrm{m}/f^2$
Gravity-gradient subtraction	none	none

- Let’s start from the ET-D top-level design parameters.
- Which parameters we have already achieved?
- Which ones might be easiest tested in Advanced + detectors?

What R&D is needed for ET?

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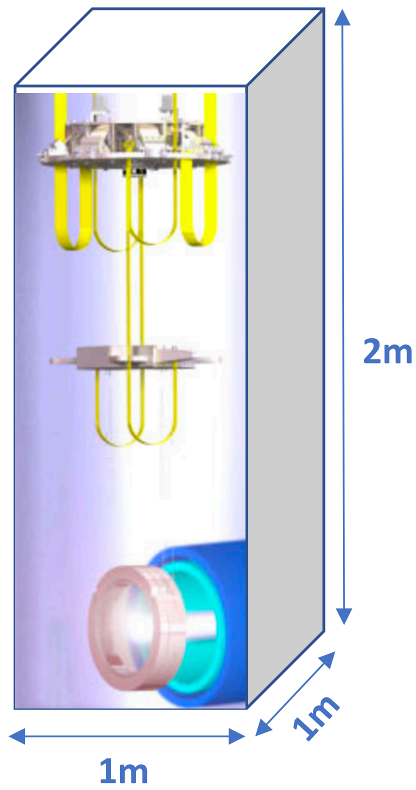
- Aspects that are better tested at A+ detectors or are not accessible to a prototype.
- Aspects could be tested in prototype but might be easier tested elsewhere
- **Cryogenic, Silicon optics at 1550nm are key technologies that need testing at scale for ET**

=> Main aim of Maastricht Prototype Interferometer

Main idea

- Starting of with a cryogenic payload volume of about 1x1x2m.



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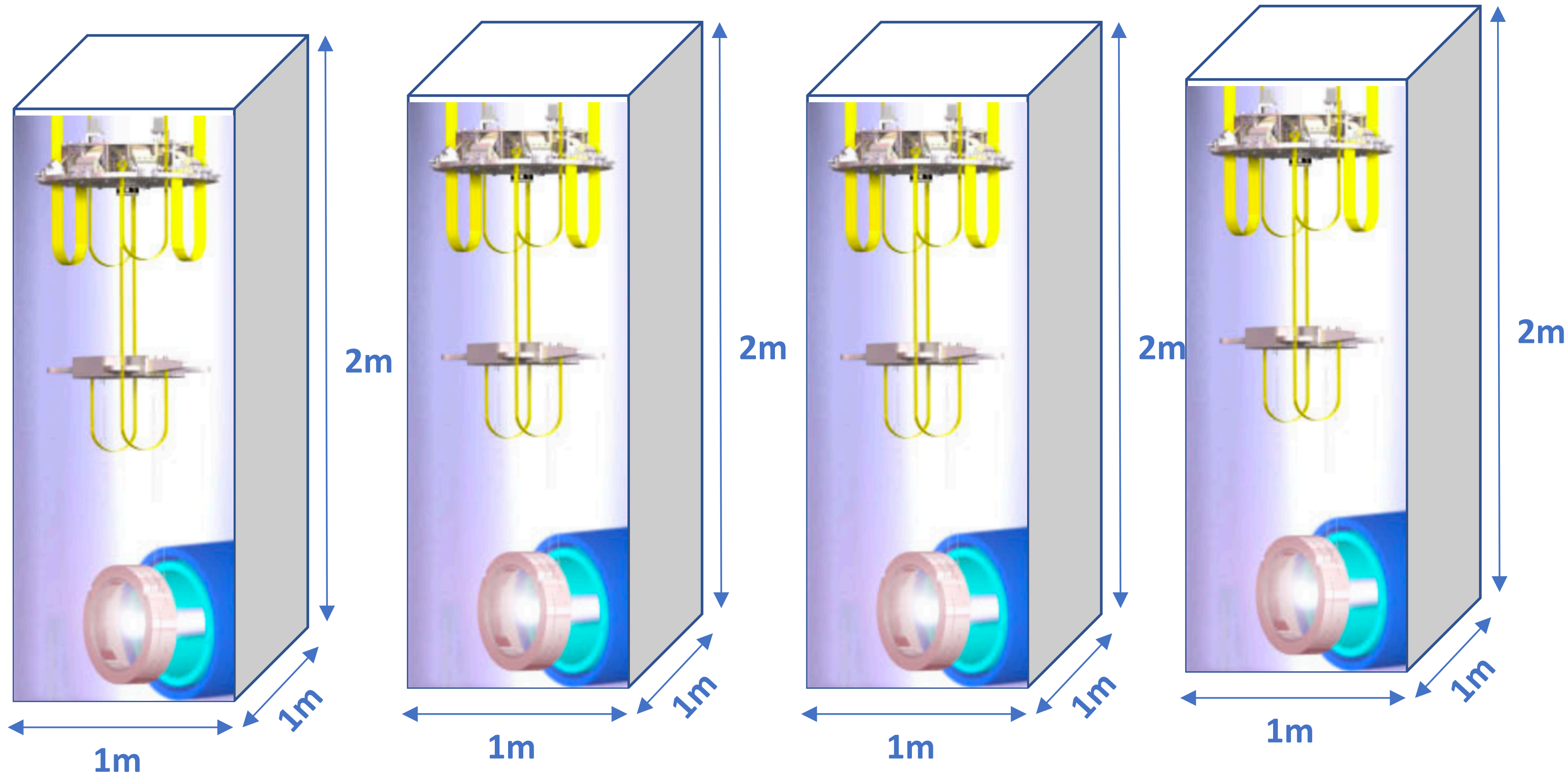

- Then if you want to test low phase noise performance you need 4 of these cryogenic payload volumes.

Footprint (I)

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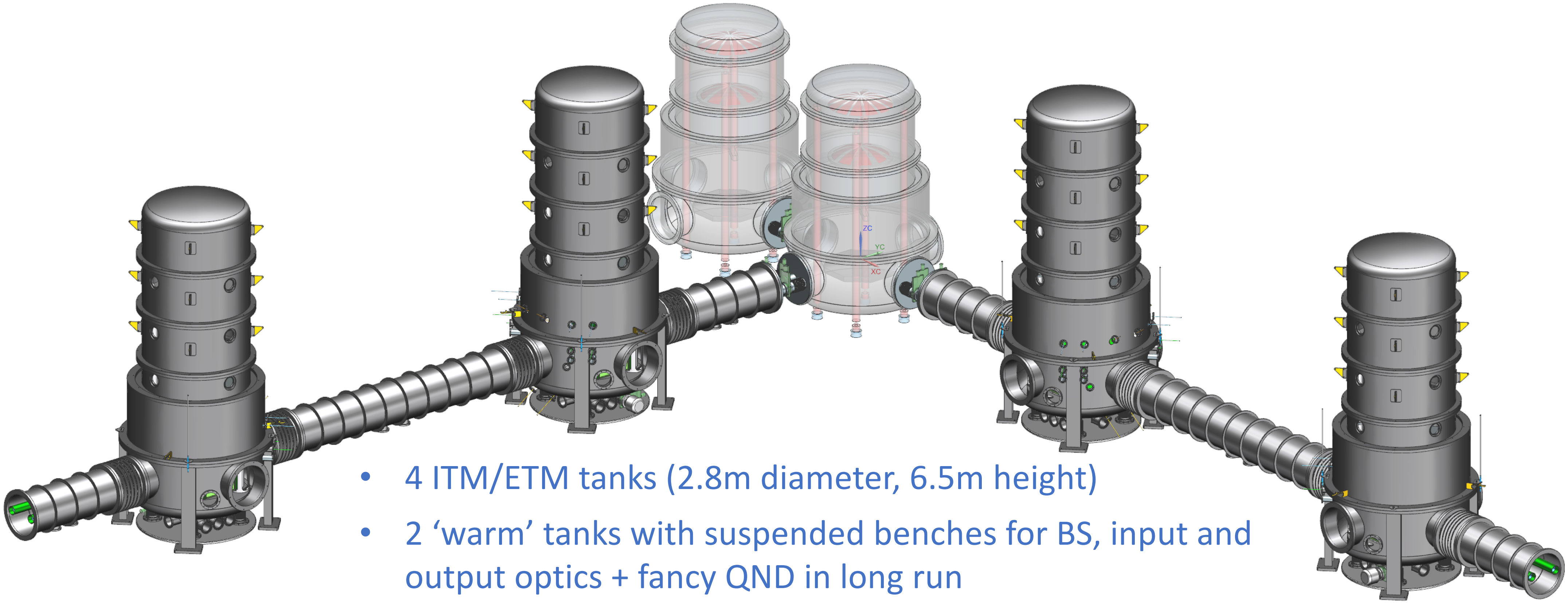
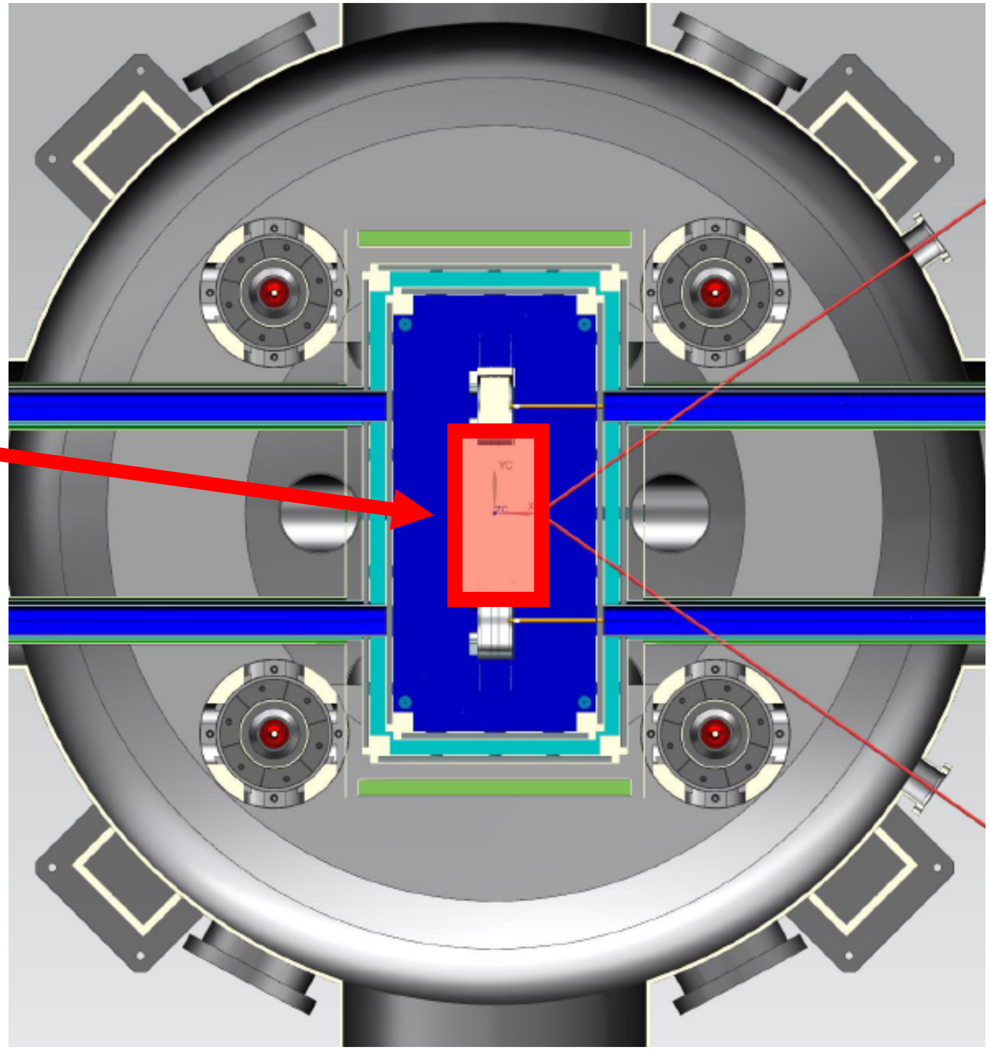


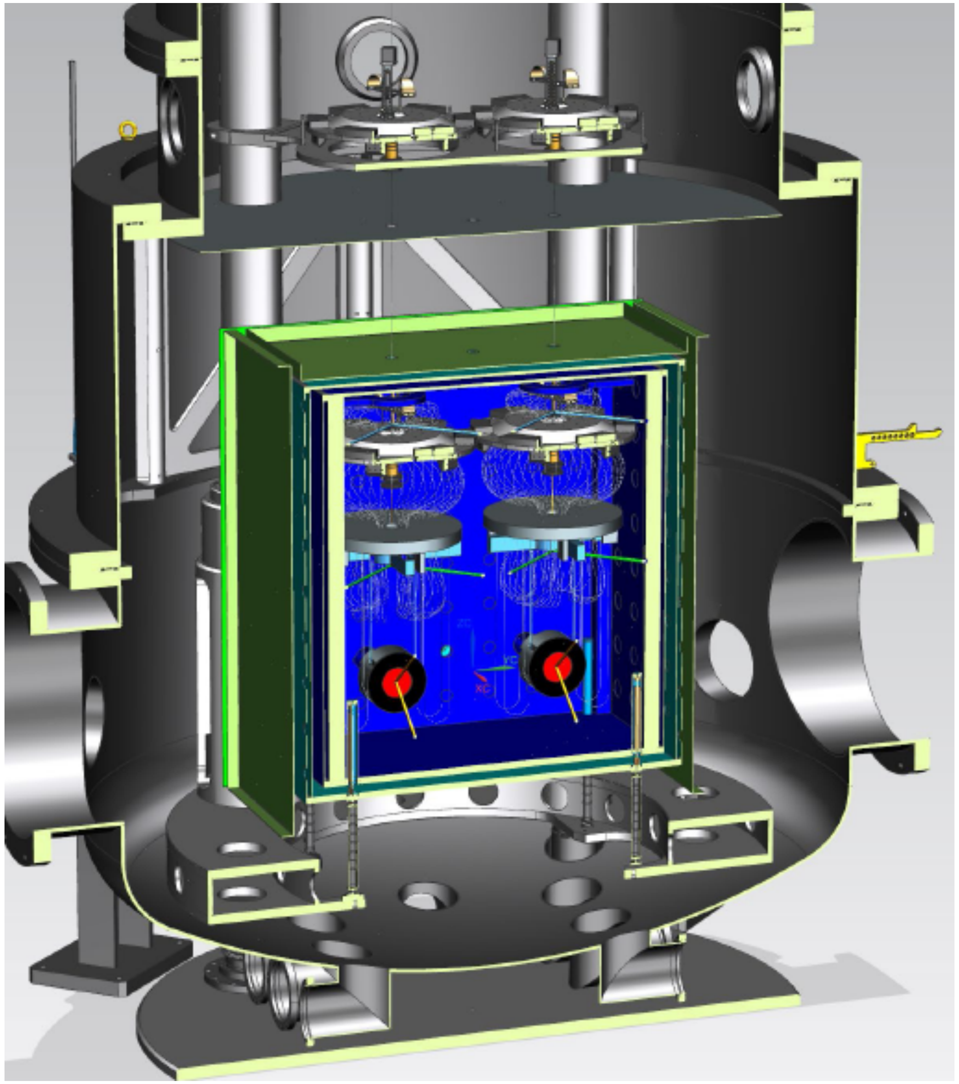
- 4 ITM/ETM tanks (2.8m diameter, 6.5m height)
- 2 ‘warm’ tanks with suspended benches for BS, input and output optics + fancy QND in long run
- Total armlength about 20m, but due to heat shields in front of ITMs and behind ETMs the cavity length will only be 9.34m.
- Tube diameter 80cm (but heat shields will have much smaller clear aperture)

Footprint (II)

- System designed to be able to test silicon mirrors of 100kg or more at 10K in the long run.
- For scale this 45cm by 22.5cm (~82kg).
- Problem: could we buy silicon mirrors of such dimensions and with the right properties right now? – probably not yet ...



Footprint – Phase 1



- In the intial phase (Phase 1) we will hang 2 small mirrors in each cryostat.
- Small mirrors = 15cm diameter and 3kg.
- That way we can operate 2 independent FPMI interferometers with a total of 8 cryogenic test masses.

Footprint – Phase 1

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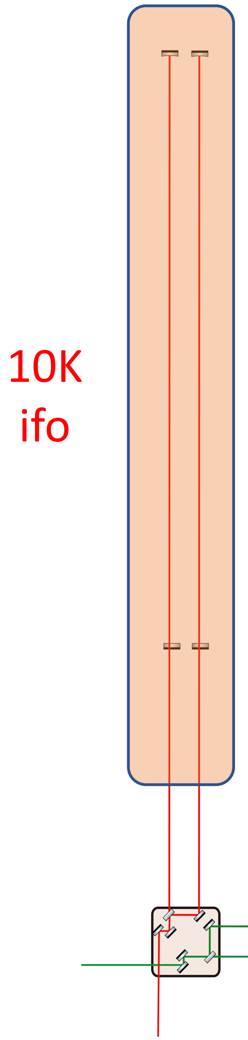
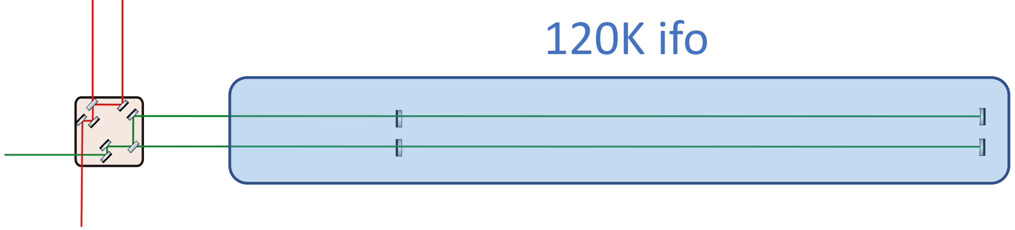
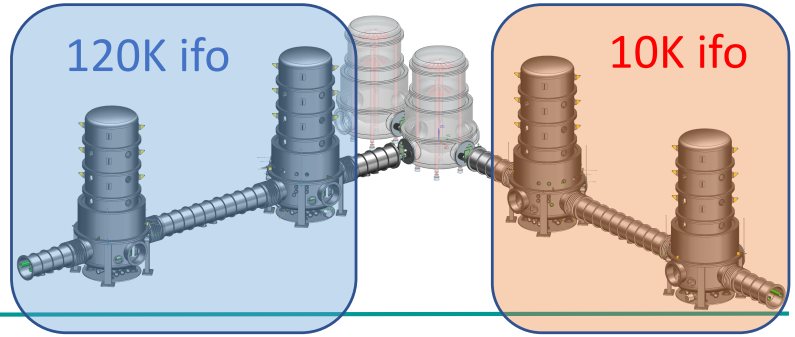
- Can arrange these 2 interferometers as 2 ‘L’.
- However if we use each arm of the vacuum system for one interferometer we can operate the two arms and hence interferometers at different temperatures: one at 120K and one at 10K.
- In principle this also allows to run the two interefreometers at different wavelength: one at 1550nm and one more towards 2um.
- **Potentially allows to explore test the full matrix of temperatures and wavelengths currently discussed.**
- For example on could operate one interferometer as in ET-D-LF config (10K, 1550nm, low power) and one in Voyager/CE config (120K, 2um, high power).







Science Goals

- Low phase noise interferometery with cryogenic silicon mirrors of up to ~100kg;
- Providing a flexible testbed to explore the full matrix of cryogenic temperatures and laser wavelength;
- Investigating the interplay of thermal noise, quantum noise and control noises in the sub 10Hz region;
- Various tests of cryogenic plants (liquids vs cryo-coolers; stable control of mirror temperature; contamination handling of mirror surfaces; low power actuators etc)
- Loads of other interesting topics (Thermal compensation; adaptive modematching; Parameteric Instabilities; etc)

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What would you like seen being test or investigated in this prototype? --- Please let us know!

Partners & Funding

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1. *Nikhef*
2. *Maastricht University*
3. *Technische Universiteit Eindhoven*
4. *University of Leuven*
5. *Ghent University*
6. *University of Antwerp*
7. *University of Hasselt*
8. *University of Liege*
9. *Vrije Universiteit Brussel*
10. *Fraunhofer Institute for Laser Technology (ILT)*
11. *Rheinisch-Westfälische Technische Hochschule (RWTH, Aachen)*
12. *University of Twente*
13. *Flemish Institute for Technological Research (VITO), Mol*
14. *Netherlands Organisation for Applied Scientific Research (TNO), Delft*

Also input from Glasgow, AEI, Perugia …

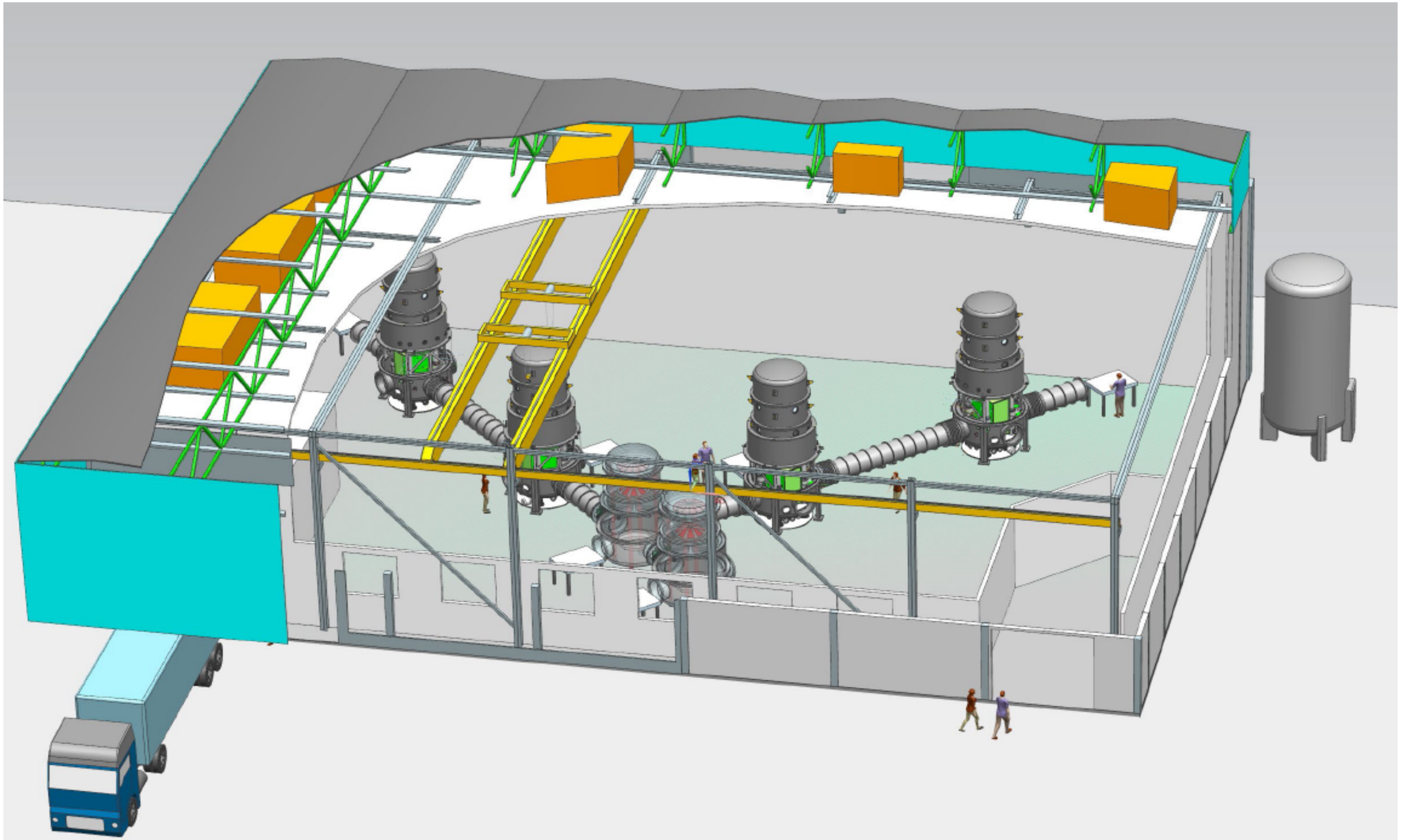
Location: **Maastricht**

Maastricht University to become a Nikhef member and starting new GW instrumentation group

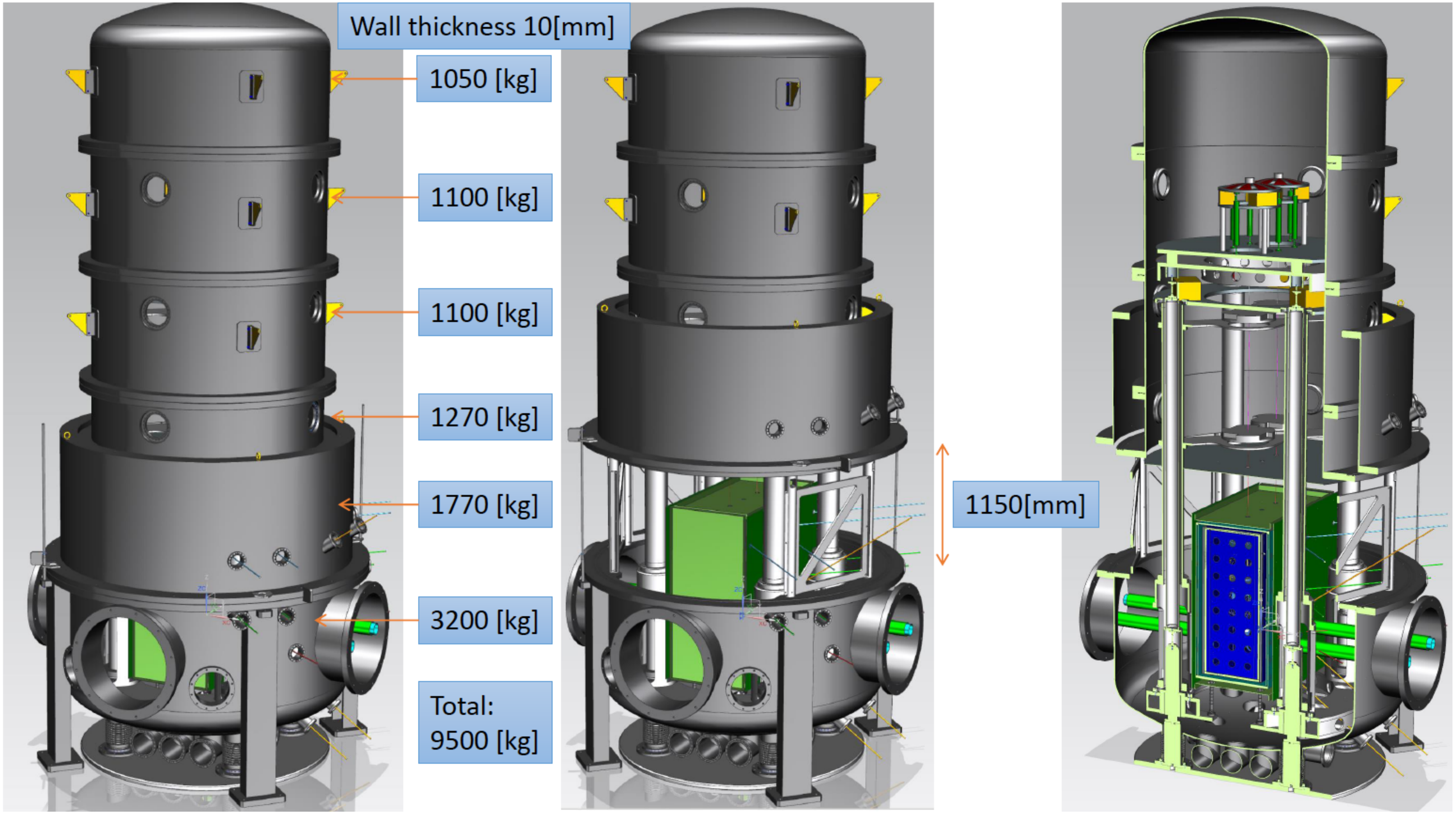
14.5 MEuro capital investment (Interreg, Institutions, Governments & Provinces)

Committed manpower of 100+ man years (staff scientists and engineers) over the next 5 years

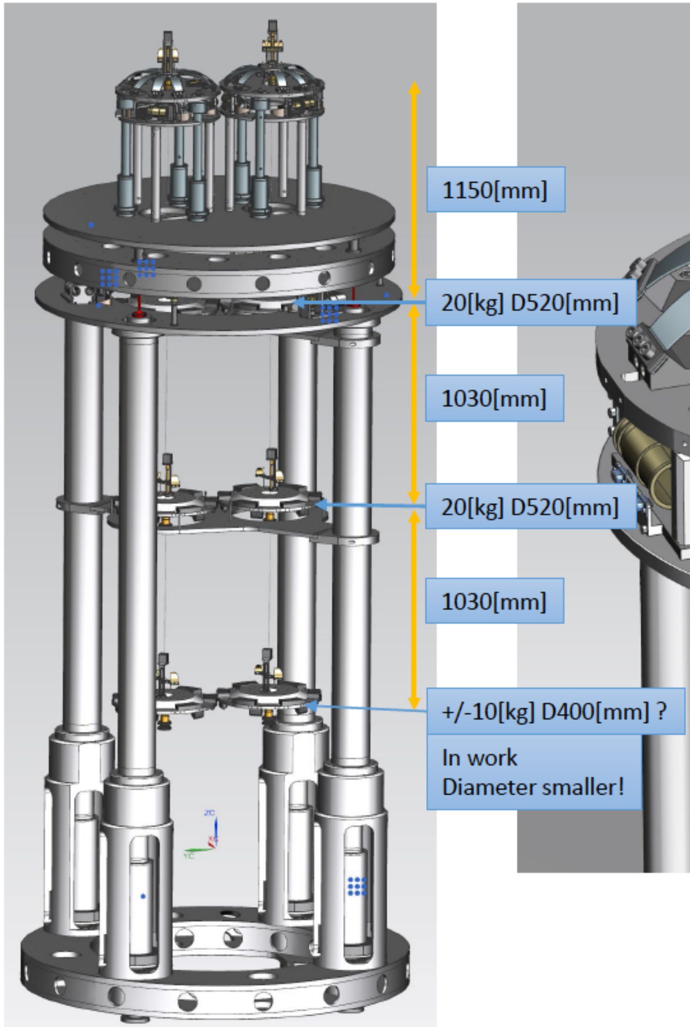
Current State

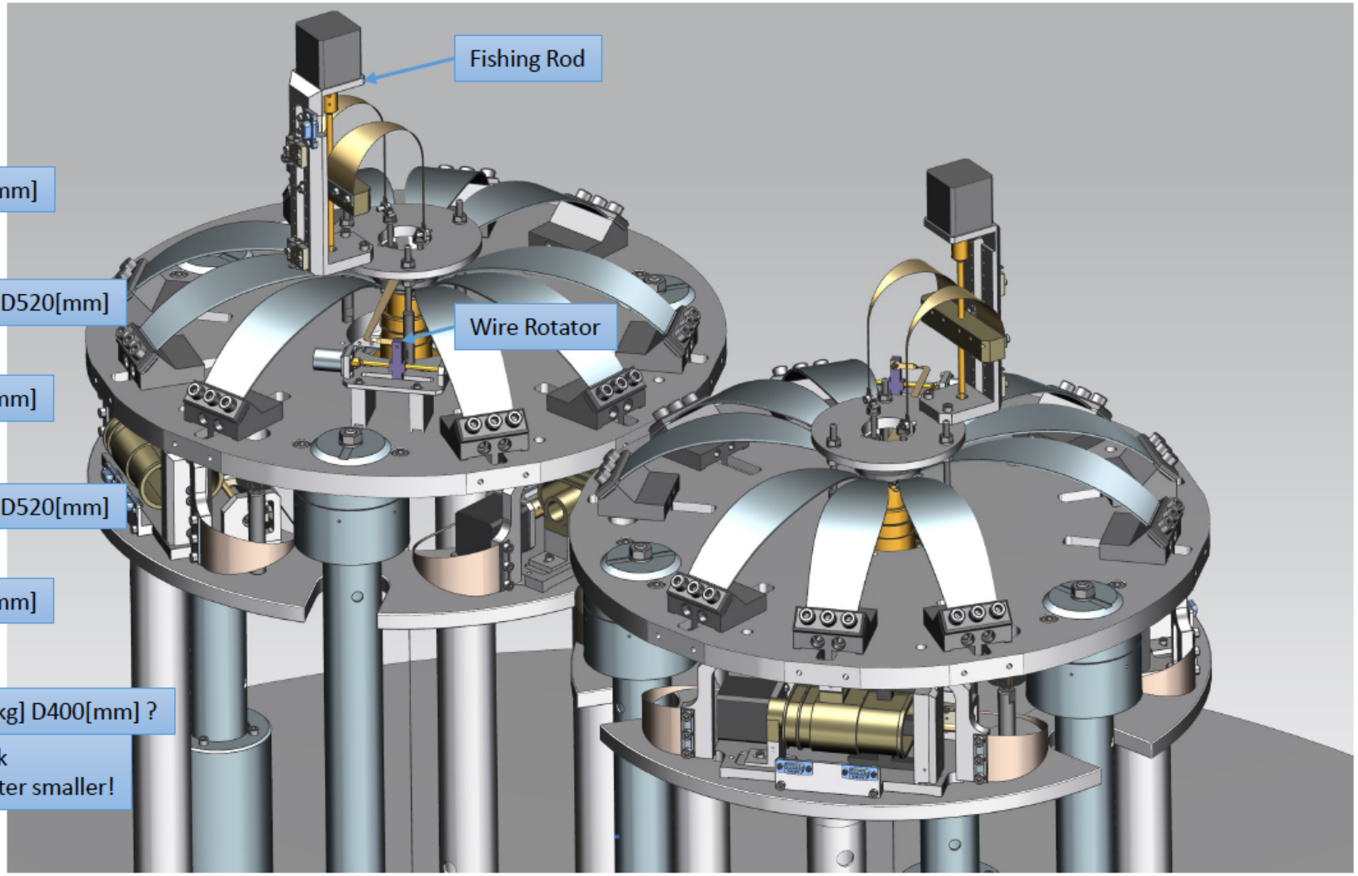


Vaccum System

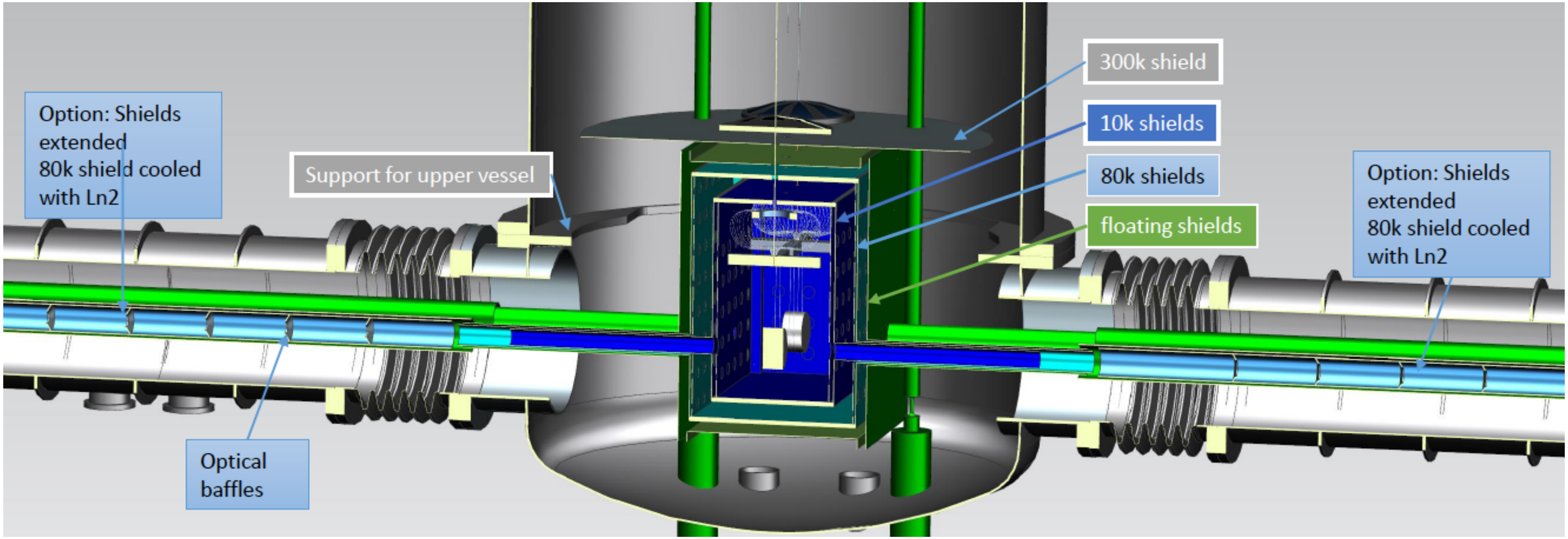


Seismic Isolation

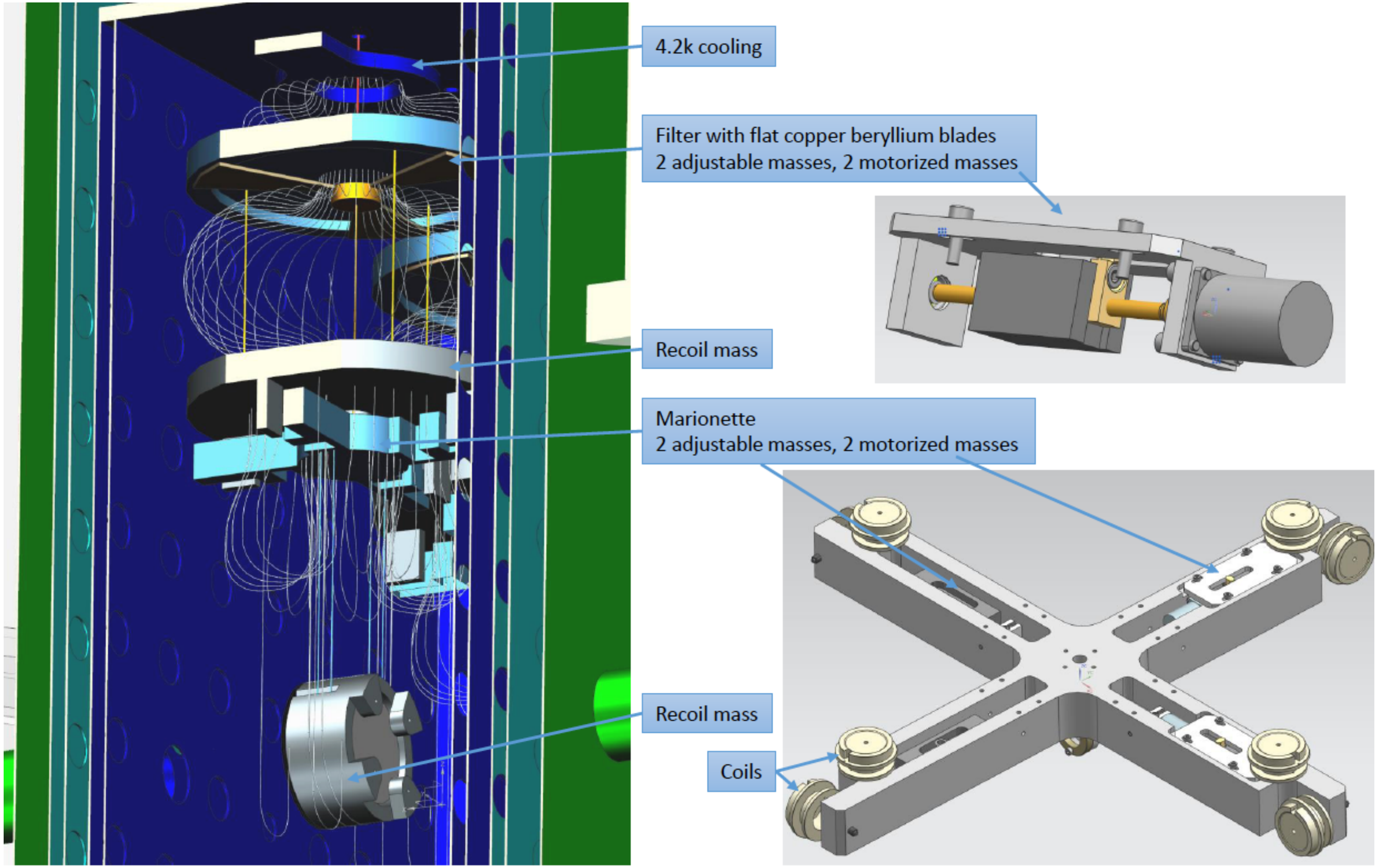




Cooling Shields



Cooling the Testmasses



Next steps

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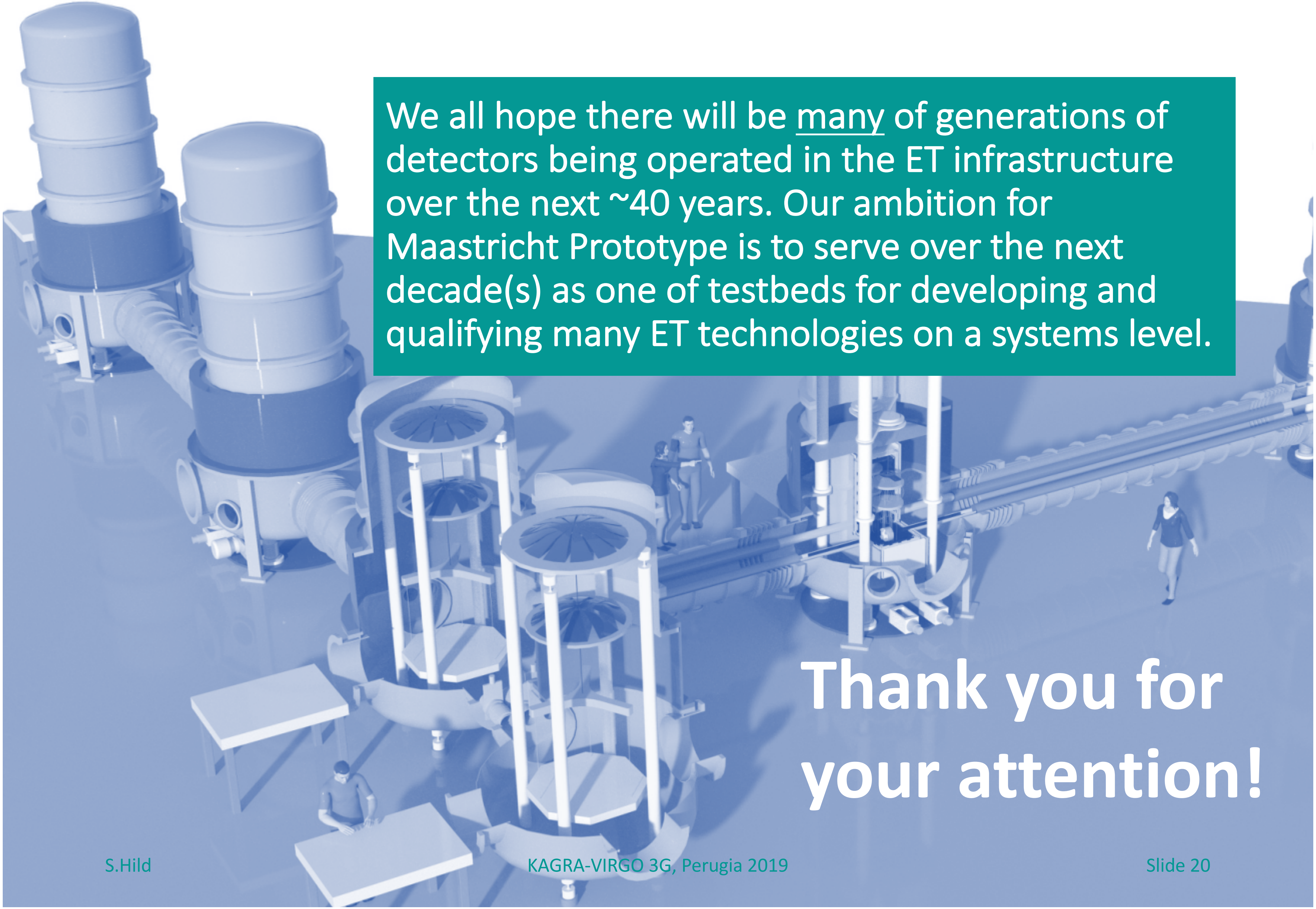
- Weekly ETpathfinder call since Nov 2018
- Continue design effort and expand to remaining subsystems. Build up noise budget.
- Define exact science targets for Phase 1 (first 3-5 years)
- Official project start: June 2019
- Establish Strategic Advisory Board
- In parallel start planning for Phase 2 (~100kg testmasses)

Opportunity bigger than what current partners can do on their own.

We welcome any kind of contribution (ideas, collaboration, contribution to subsystems, exchange of expertise + skills) from within the ET collaboration, KAGRA, LSC and beyond.

We try where ever possible to adopt a 'platform' design strategy, so that it will be possible to integrate test the community or individual groups/institutions are interested to carry out in ETpathfinder.

You are welcome to join and contribute. Please do not hesitate if you have spare bandwidth!



We all hope there will be <u>many</u> of generations of detectors being operated in the ET infrastructure over the next ~40 years. Our ambition for Maastricht Prototype is to serve over the next decade(s) as one of testbeds for developing and qualifying many ET technologies on a systems level.

Thank you for your attention!