Einstein Telescope: infrastructure considerations

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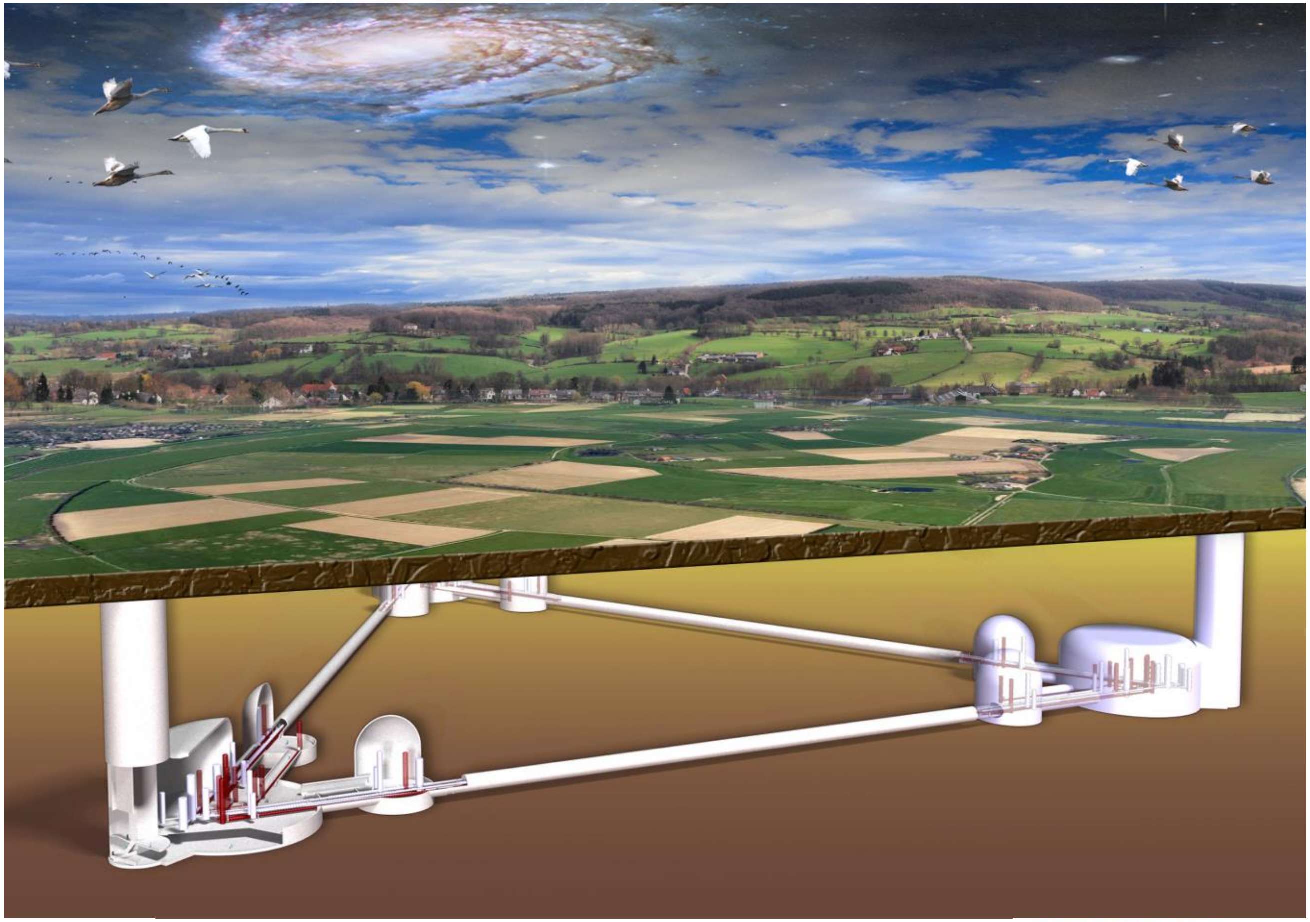
Webinar Technical Challenges Einstein Telescope, July 15, 2020



LIGO Scientific Collaboration

Advanced Virgo

Contents

Why do we need to go underground?

Advantages of the Limburg geology

Infrastructure design

Overview of the infrastructure for Einstein Telescope

Infrastructure construction

Construction of caverns, beam tubes, shafts and surface buildings

Overview of possibilities for joint research

Your input is most appreciated

Effects of seismic noise

Active and passive vibration isolation systems are used to suppress seismic noise. Gravity gradient noise (also Newtonian noise) acts directly on test masses

Newtonian noise limits sensitivity at low frequency

Important to estimate contribution

- We need a site with low ambient seismic noise
- Employ seismic sensor array
- Subtract noise from our data stream

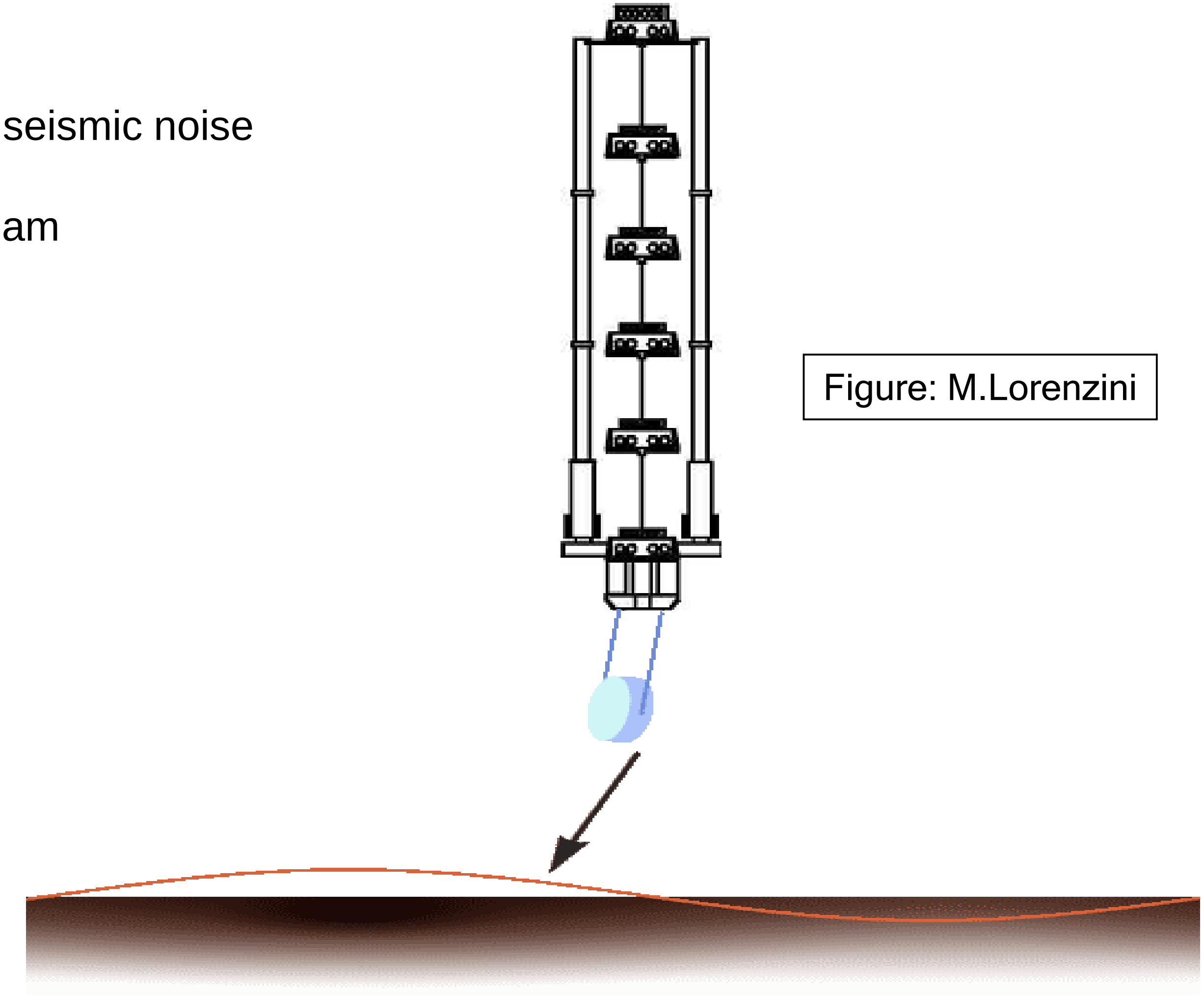


Figure: M.Lorenzini

Global study of underground site

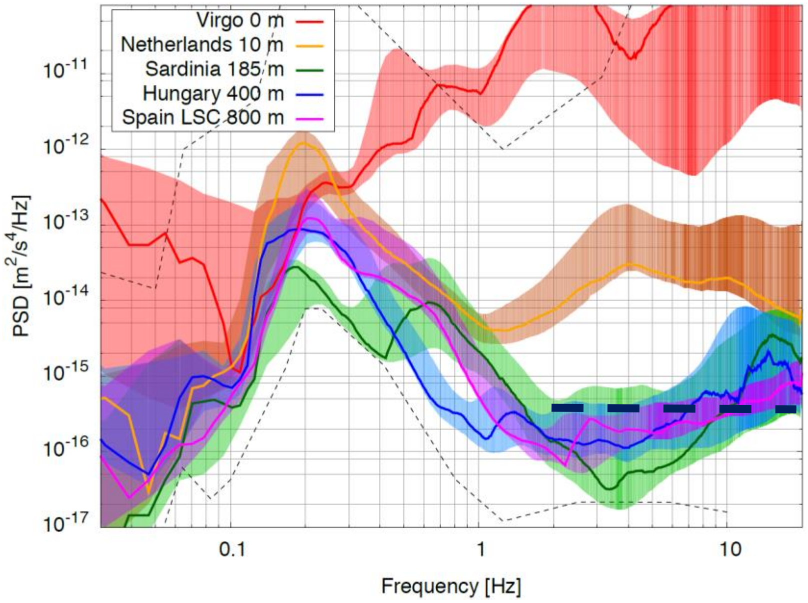
Seismic noise sources Newtonian noise. The Belgian-German-Netherlands site has good properties

Seismic studies

- 15 sites in 11 countries
- Typically 1 – 2 weeks of data
- KNMI cross check
- Worldwide effort

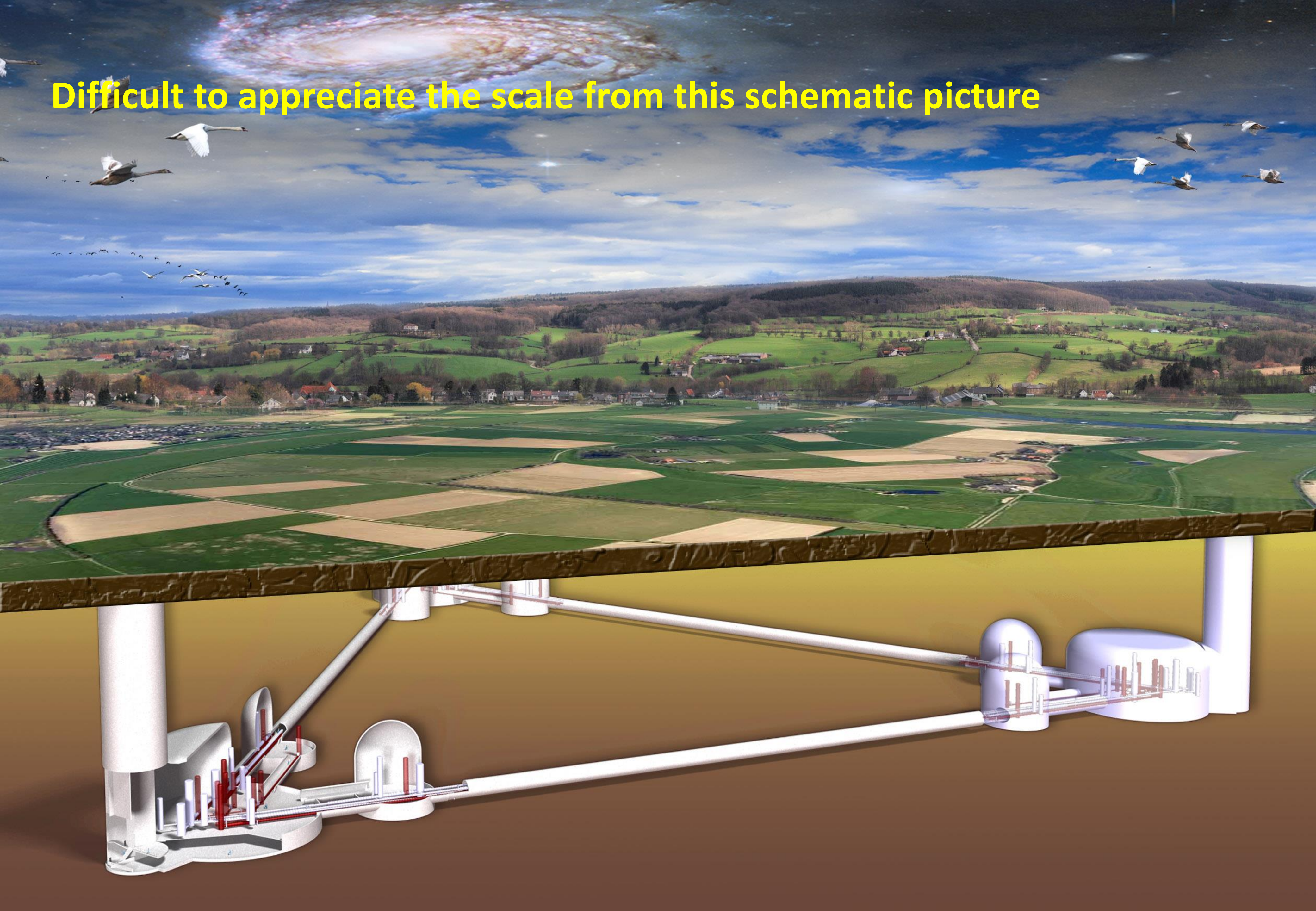
At 250 m depth we can reach our sensitivity!

Mark Beker et al.



LIGO Livingston, Louisiana

Virgo interferometer



Difficult to appreciate the scale from this schematic picture

Scale of Einstein Telescope

Comparison with the Virgo detector near Pisa in Italy

Arms are more than three times longer

Six on these interferometers

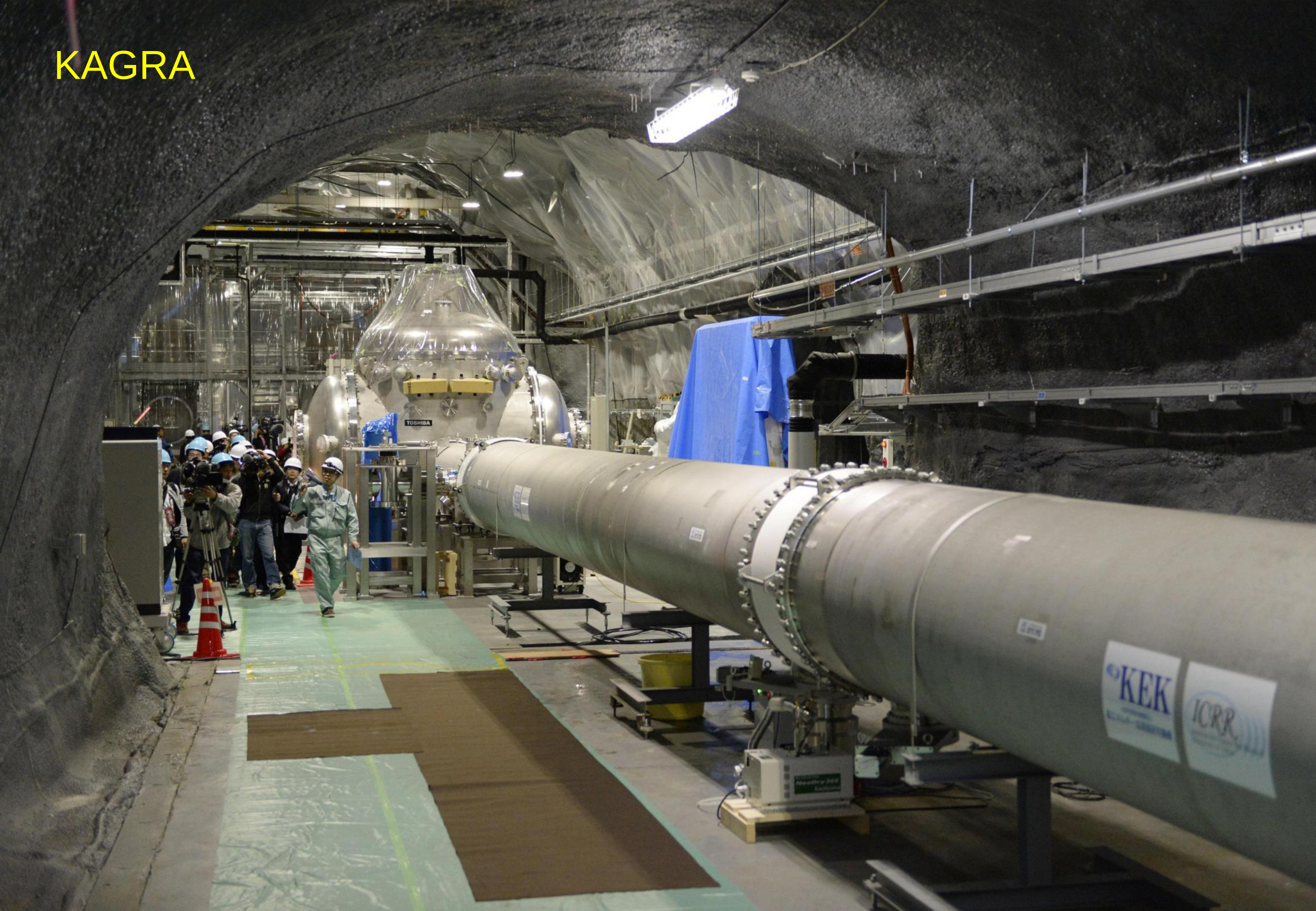
Three of these interferometers feature cryogenic optics

Everything is located about 250 m underground

KAGRA

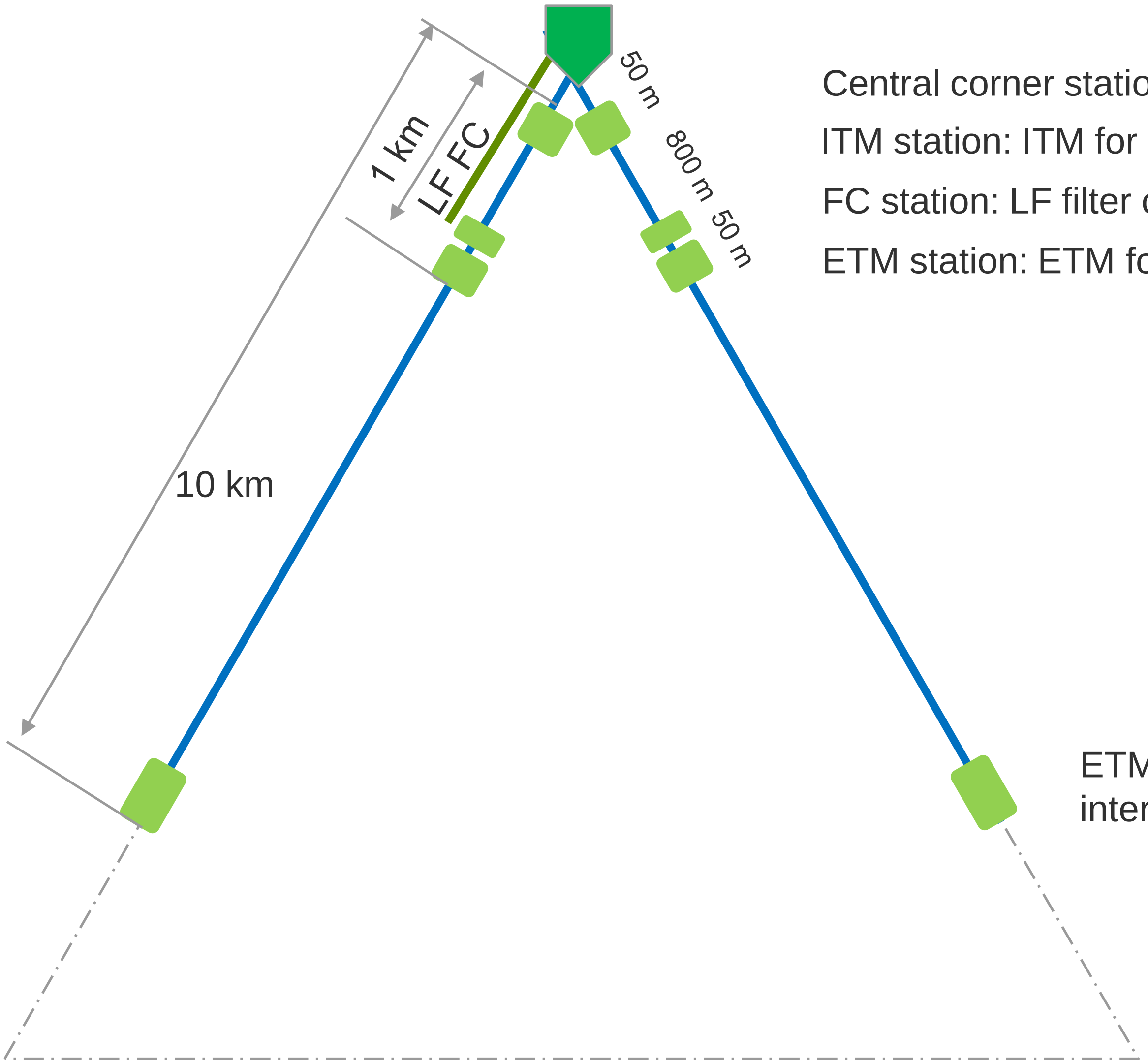
An underground interferometer with 3 km arms operational in Japan

KAGRA



Infrastructure design

Einstein Telescope: single detector view



Central corner station: LF and HF BS, FC input

ITM station: ITM for LF and HF, HF telescope

FC station: LF filter cavity end, end of LF ETM cryo-shield

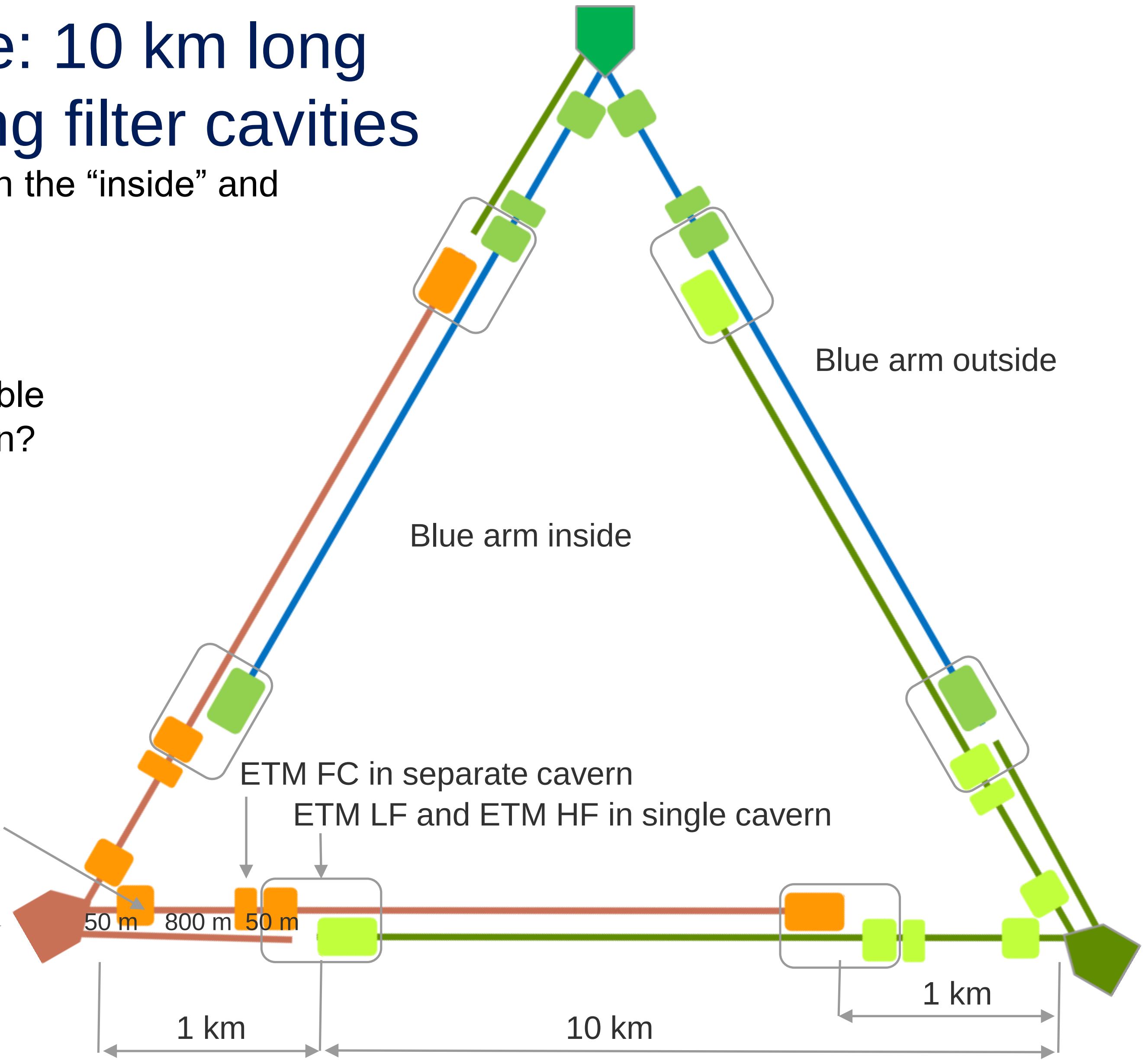
ETM station: ETM for LF and HF of *another* interferometer

ETM of LF and HF
interferometer

Einstein Telescope: 10 km long arms and 2 km long filter cavities

Detector arms alternate between the “inside” and “outside” of the tunnel

HF FC is 300 m long
There is a “natural place” available
Do we need an additional cavern?



Blue arm outside

Blue arm inside

ETM FC in separate cavern

ETM LF and ETM HF in single cavern

ITM LF and ITM HF in single cavern

Distance ITM to BS about 100 m

BS

Einstein Telescope design

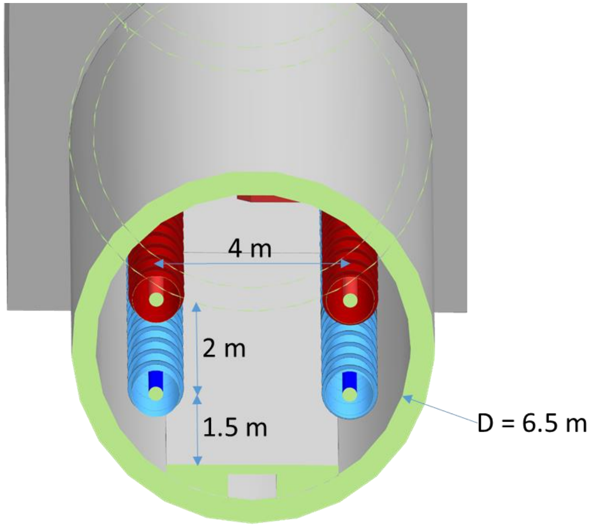
Three detectors that each consist of two interferometers: 6 ITFs in total

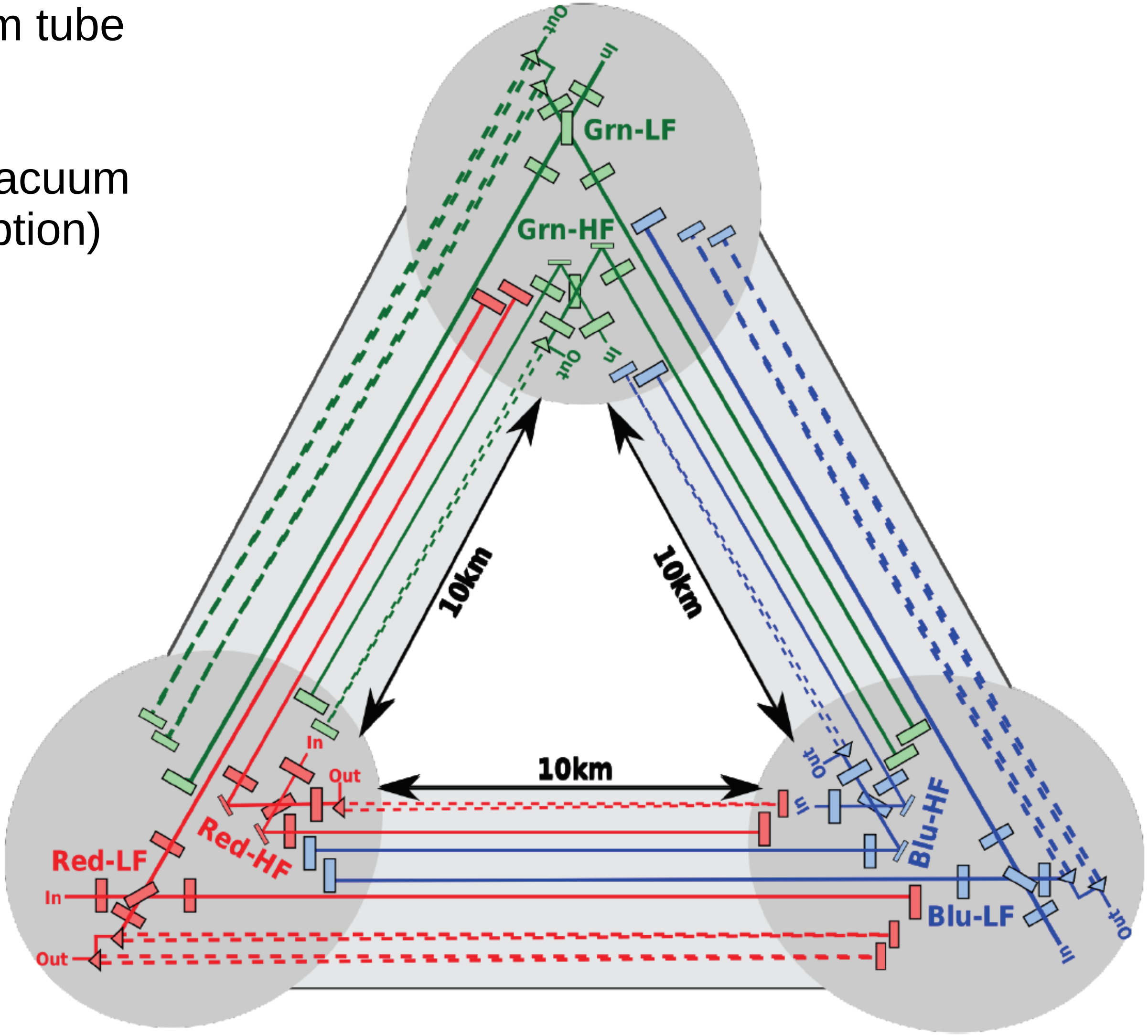
Each ITF has 20 km of main vacuum tube + several km of filter cavities

About 3 * (2 * 30 + 2) ≈ 130 km of vacuum tube of about 1 m diameter (assumption)

Tunnel inner diameter: 6.5 m

Tunnel will have concrete lining

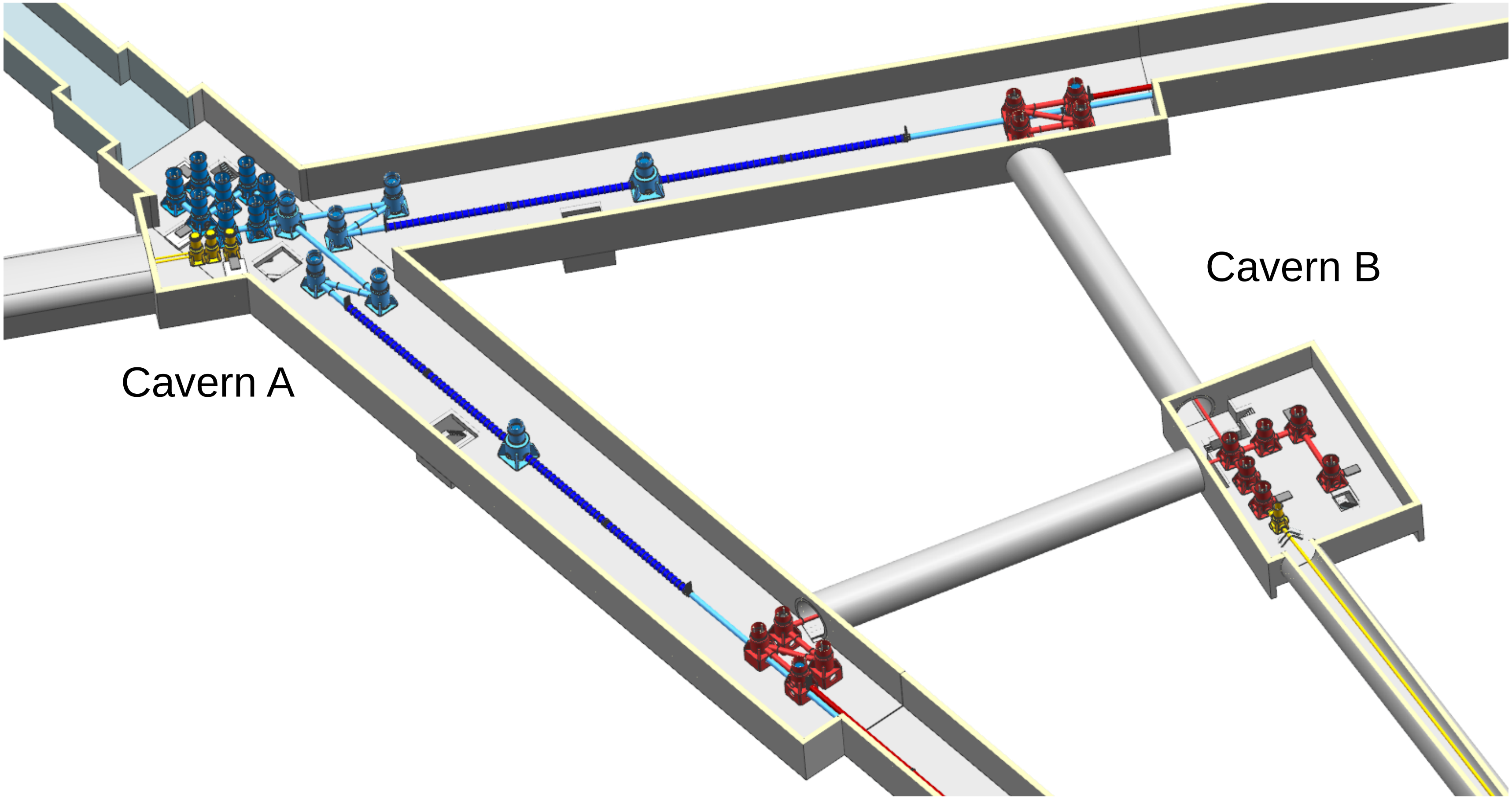




Einstein Telescope layout: corner station

Low frequency towers (blue): height = 20 m

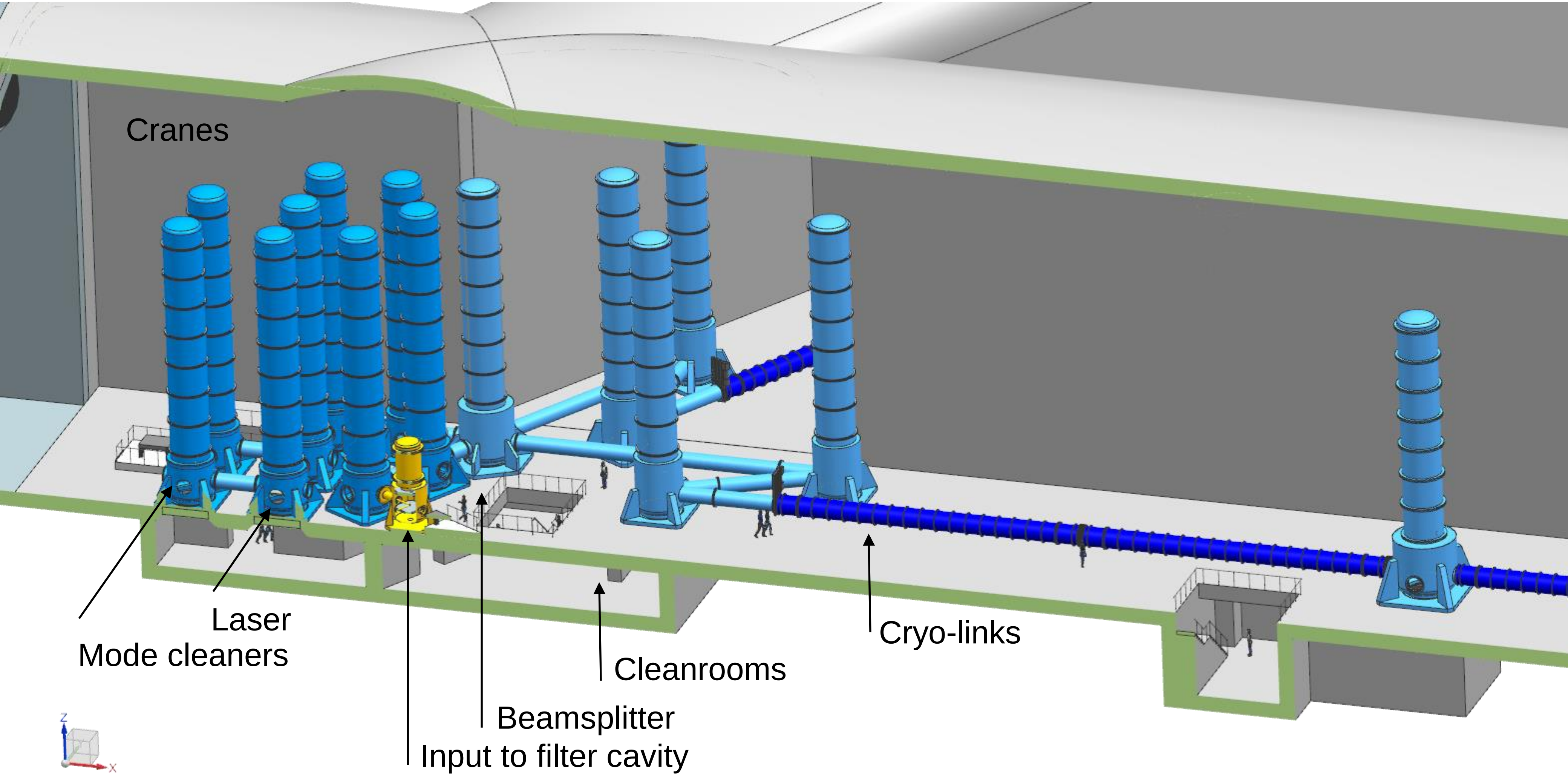
High frequency towers (red): height = 10 m



Towers for filter cavities and pick-off beams (yellow)

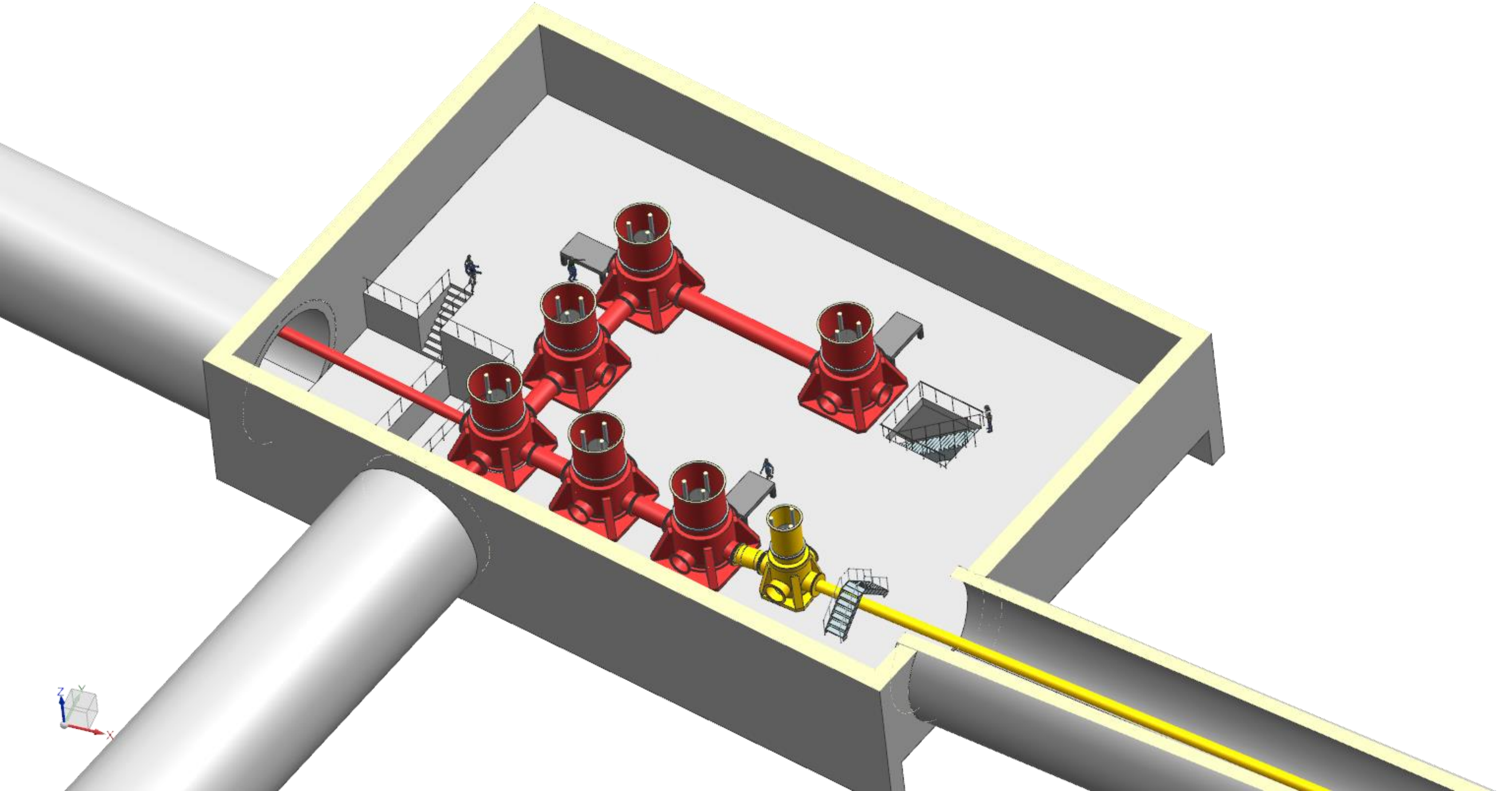
Corner station: cavern A

Houses the beamsplitter of the cryogenic low frequency interferometer
Towers are 20 m high. Cavern A dimensions are 20 m wide, 30 m high, 175 m long

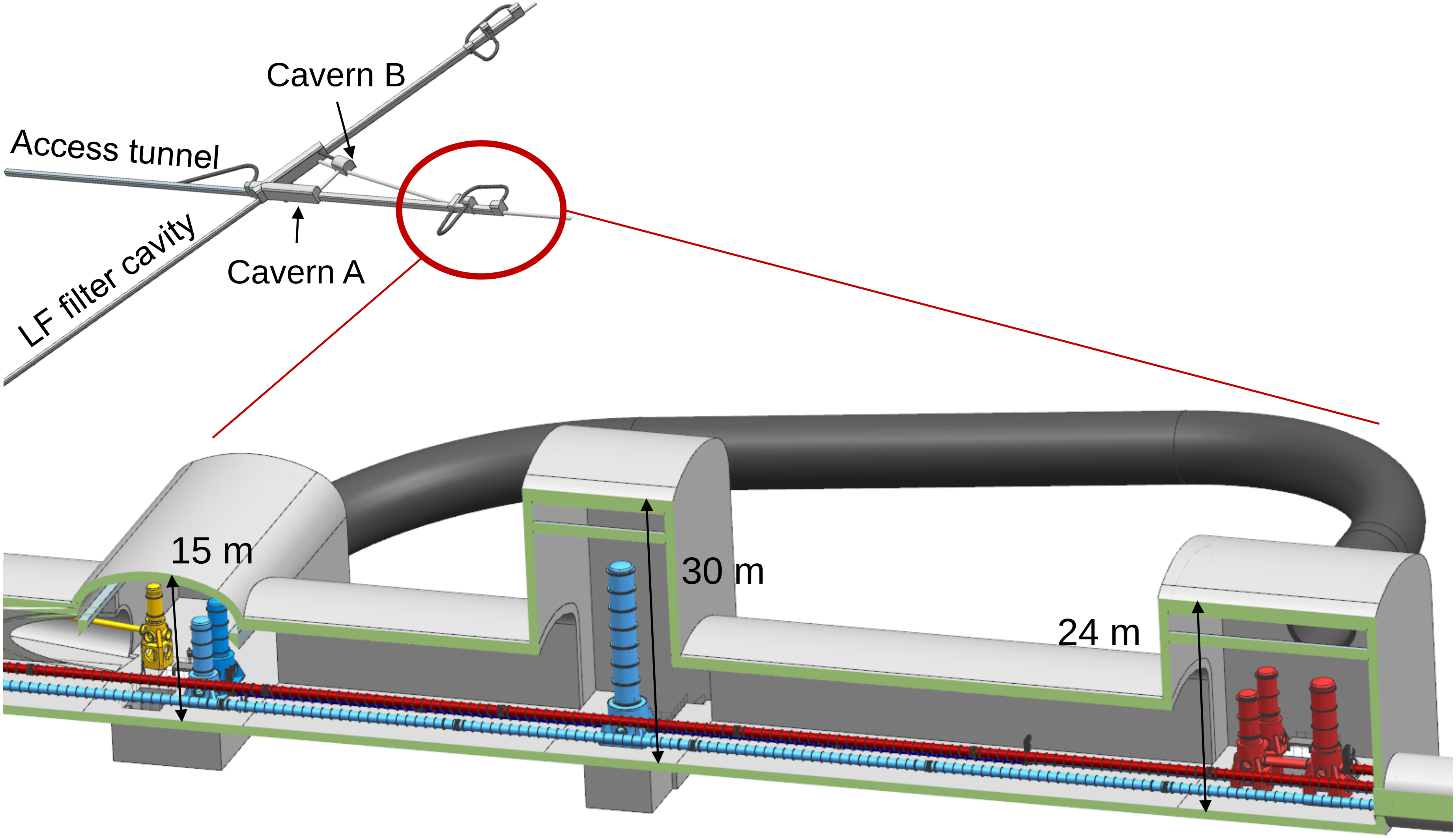


Corner station: cavern B

Houses the beamsplitter of the high frequency interferometer
Dimensions: 25 m wide, 22 m high and 35 m long

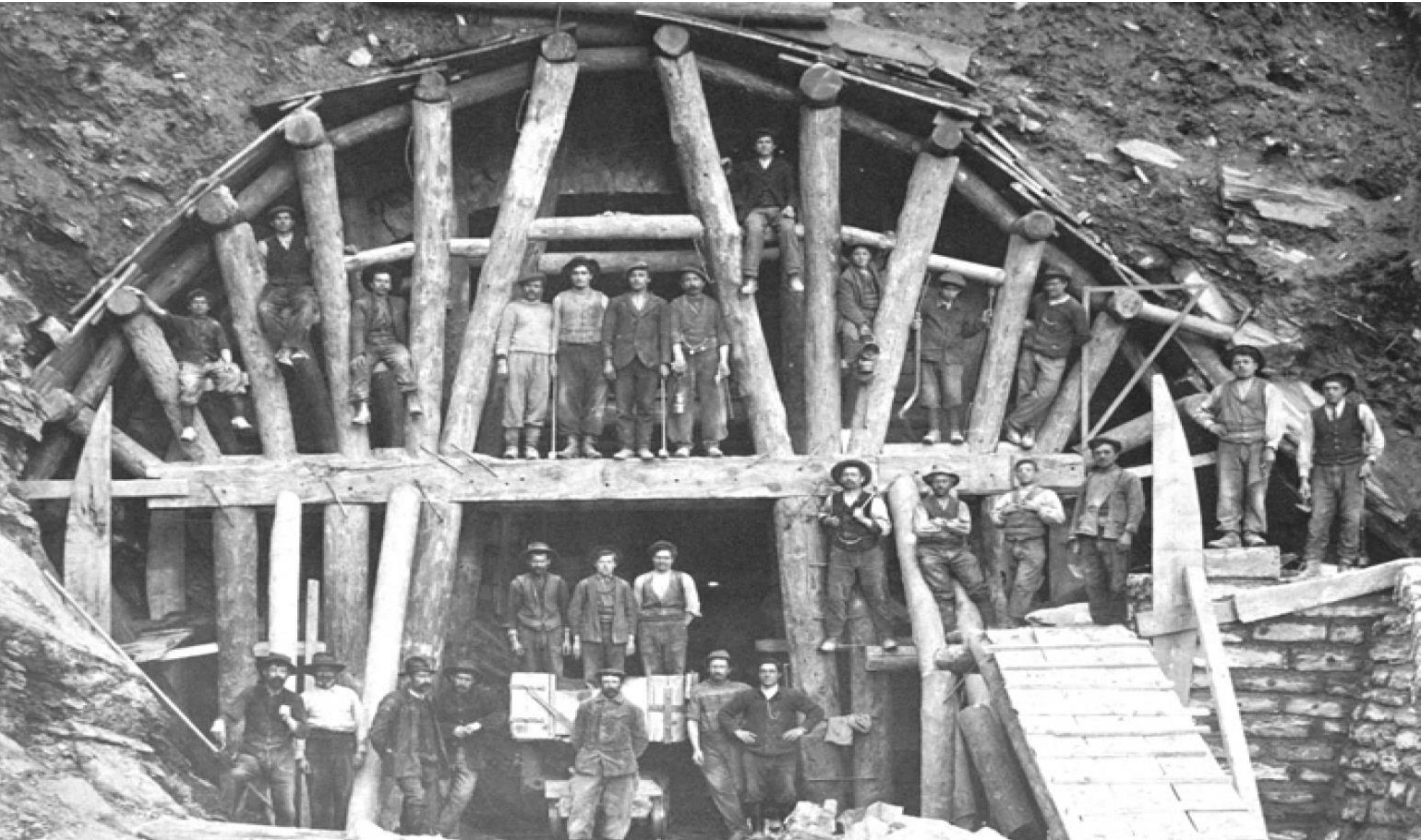


Einstein Telescope layout: caverns C, D and E

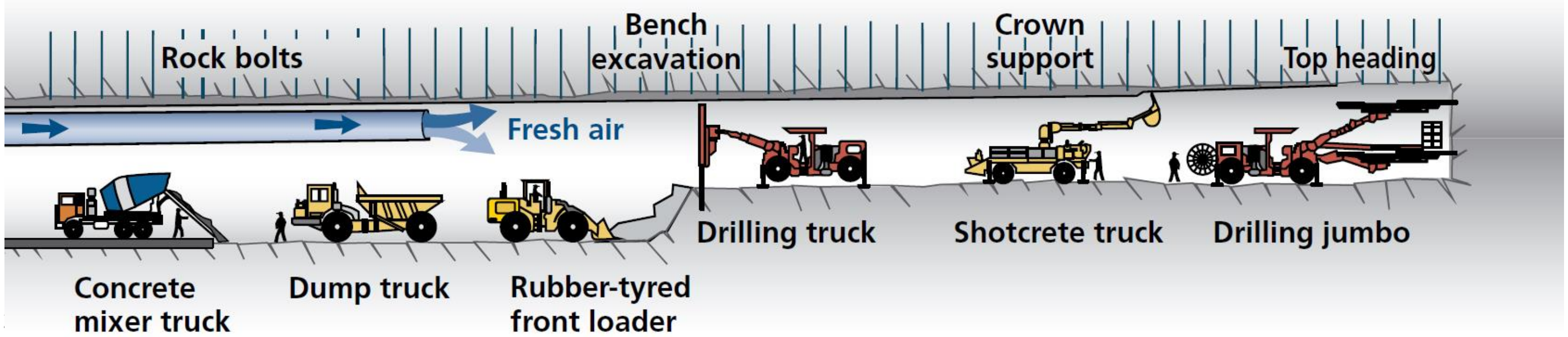


Infrastructure construction

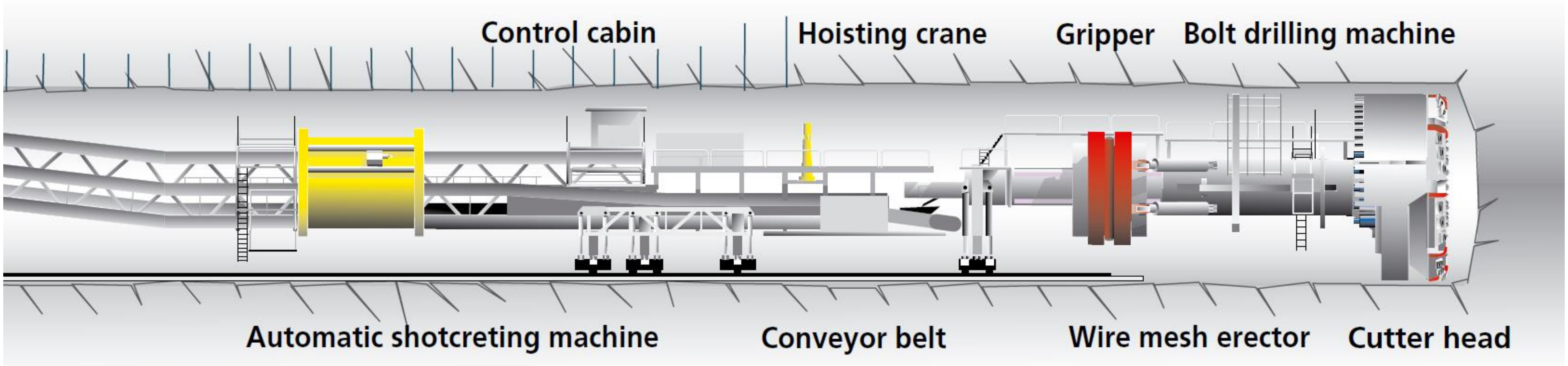
Einstein Telescope: how to construct?



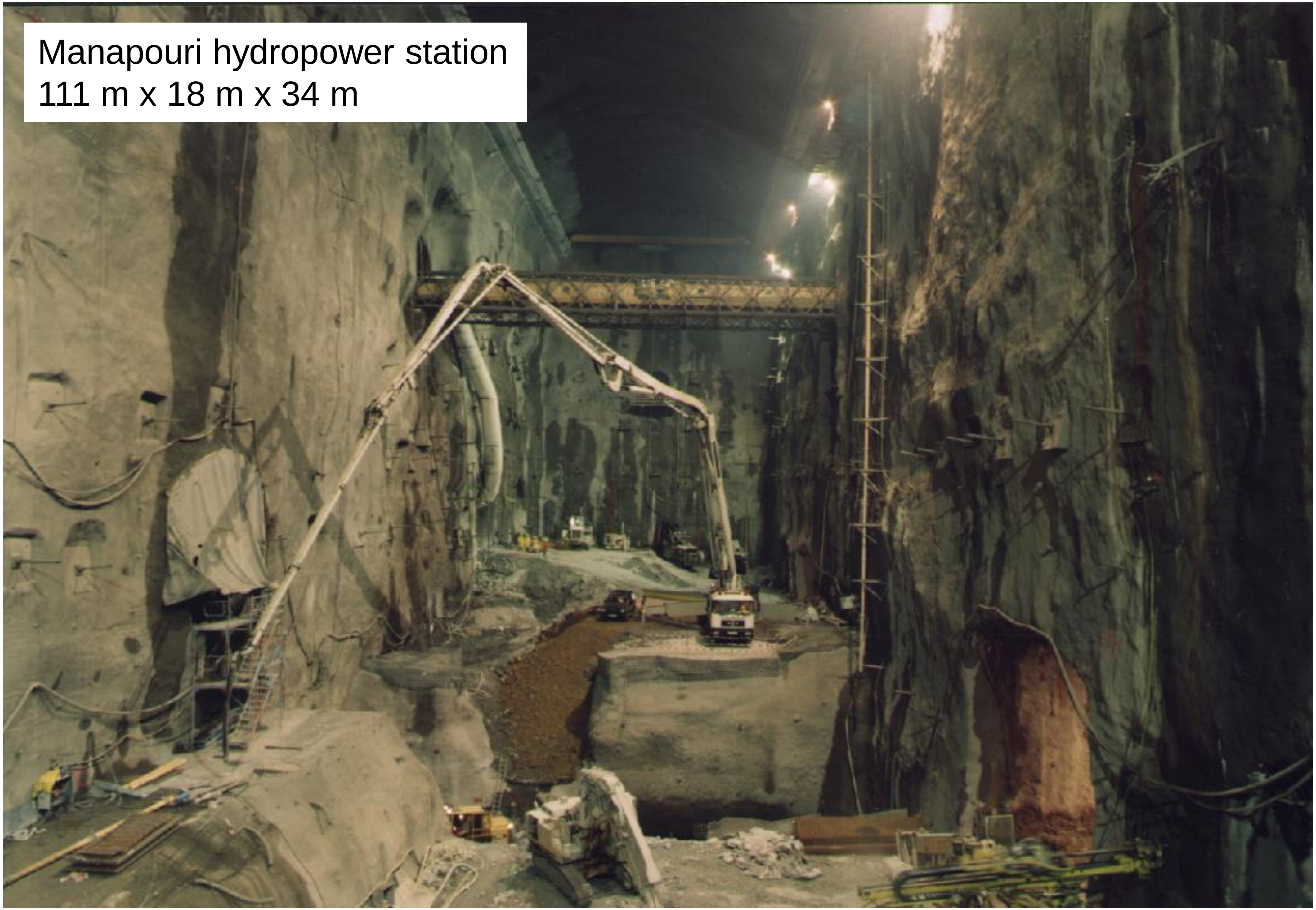
KAGRA: drill and blast



Einstein Telescope: tunnel boring machines



Large underground caverns



Manapouri hydropower station
111 m x 18 m x 34 m

LHC underground caverns

CMS: whl = 27 x 34 x 53 m

About 50k m^3

LHC Point 5 - UXC55 Point 4 End Crown Falsework - 29-03-2004 - CERN TS-CE

Atlas: has 30 m x 35 m x 53 m

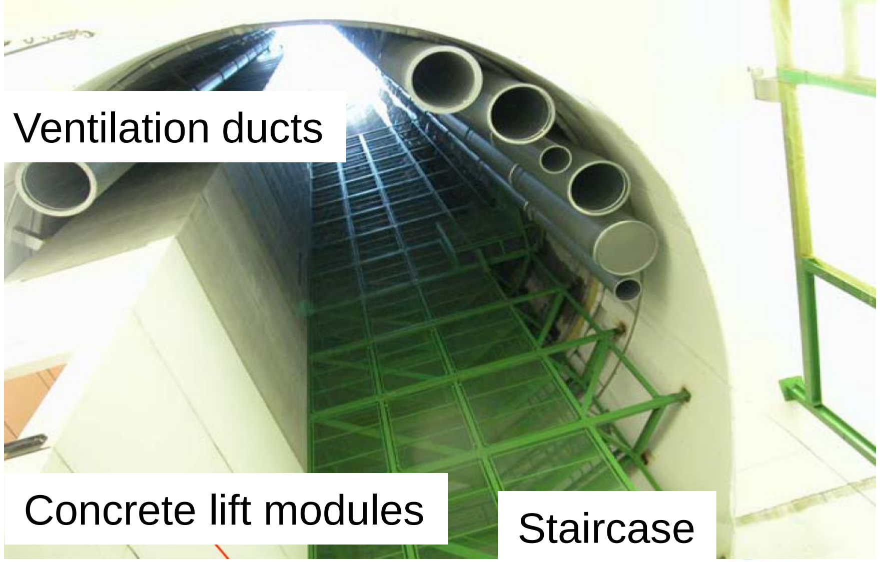
LHC Point 1 - UX 15 Cavern - Concrete walls 6th lift - 20-02-2003 - CERN ST-CE

Einstein Telescope

Cavern B: 25 m x 22 m x 38 m (about 21k m^3)

LHC project: CMS shaft

Diameter of about 20 m, while 10 m diameter is foreseen for Einstein Telescope



Ventilation ducts

Concrete lift modules

Staircase

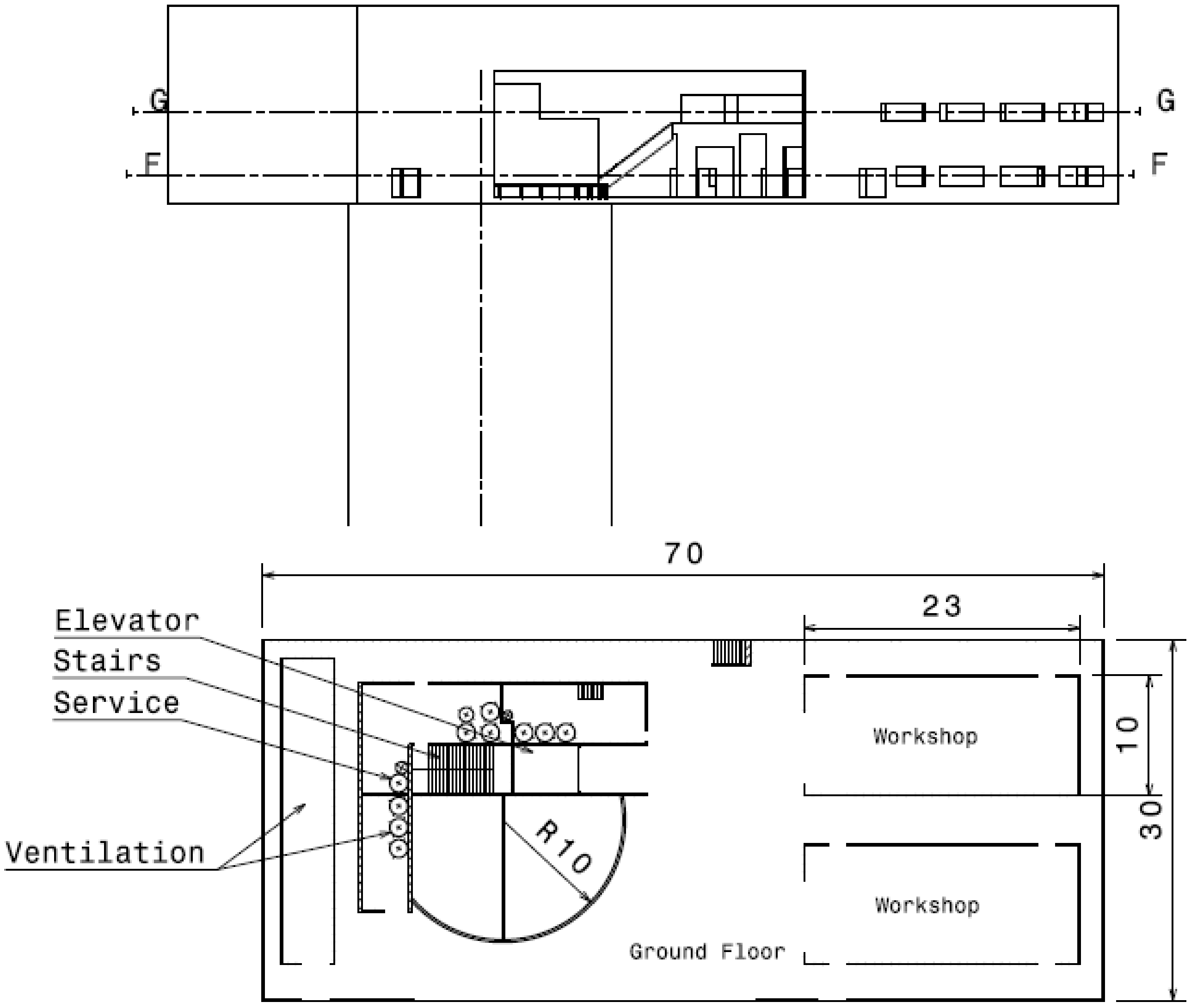
LHC project: surface buildings

Building used during construction. Later as cleanrooms

Dimensions: L = 70 m, W = 30 m

2 workshops (23 m x 10 m)
    o vacuum tubes
    o cleanrooms later?
Large entrance doors
Ventilation system (outside?)
Cryo-coolers, services

Lifting facility
- D = 20 m
- Excavation entrance (TBMs?)
- Stairs, Elevator



Section view F-F
Scale: 1:500

Timeline Einstein Telescope

Sites qualification	now – 2023
ESFRI proposal submission	2020
ESFRI decision	2021
Site decision	2023
Research infrastructure operational design	2023 – 2025
Research infrastructure construction	2026 – 2032
Detector installation	2030 – 2034
Operation	2035

Overview of possibilities for joint research

Slides to guide discussion

First attempt, so likely incomplete …

Creating a smart infrastructure

Creating optimal conditions for hosting Einstein Telescope

- Understanding the environment: geology, seismic surveys, borehole studies, …
- Cleanroom facilities
- Security and safety systems

Minimizing the effects of the infrastructure on our measurements

- Low noise equipment: HVAC systems, (water) pumps, vacuum equipment, electronics, acoustic isolation, …
- Temperature stability

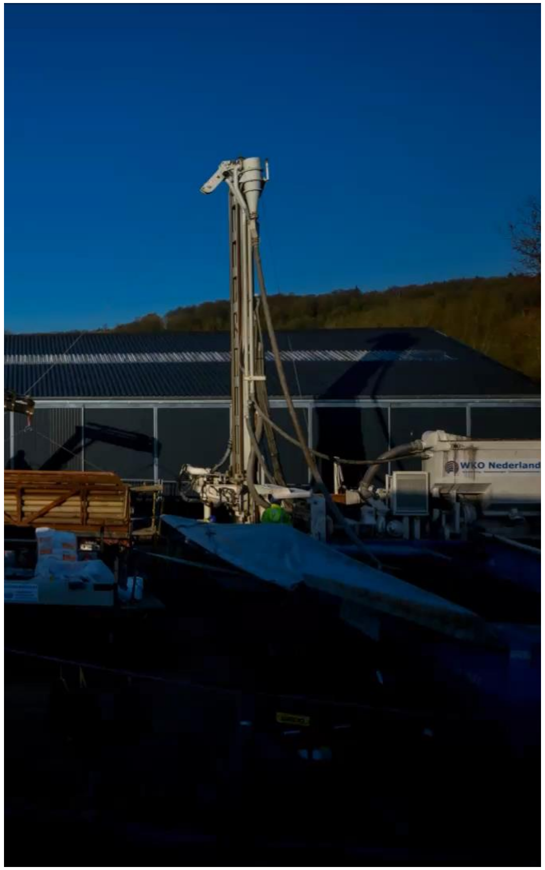
Maximize the benefits of Einstein Telescope for the region

- Minimizing the impact of construction
- Integrating the observatory in the environment
- Spin off activities, outreach activities: exhibition, outreach center

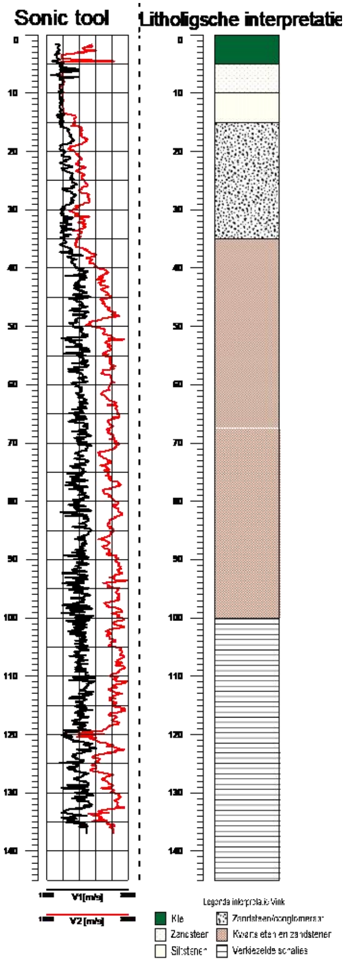
What is unique about the geology?

The geology of the Zuid-Limburg border area: hard rock with on top a layer of soft absorbing and damping soil. In addition the region is free of disturbing (man-made) seismic activities

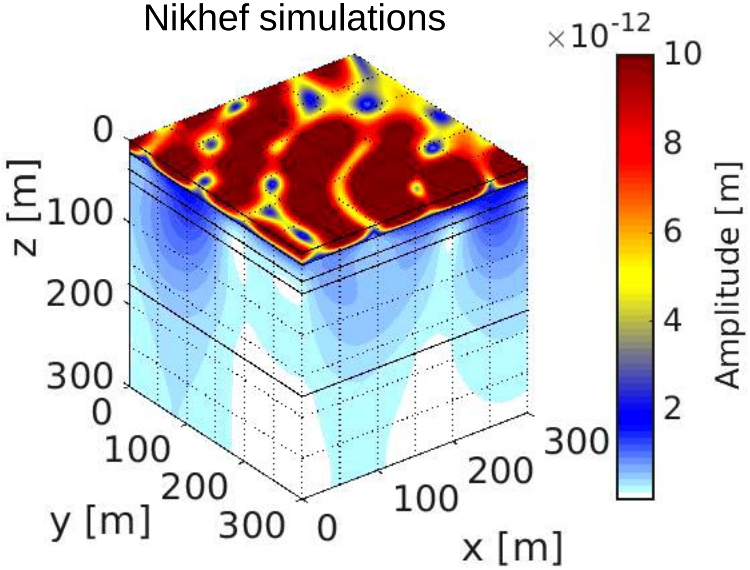
Antea borehole



Deltares research



Nikhef simulations



TNO and EBD

Creating optimal conditions for hosting Einstein Telescope

Security and safety systems

Hardware systems: fire, escape routes, …
but also legal issues, training…

Cleanroom facilities

Optical surfaces are illuminated with up to 200 kW/cm^2 in current interferometers

Even low-level contaminants can result in laser damage to optics

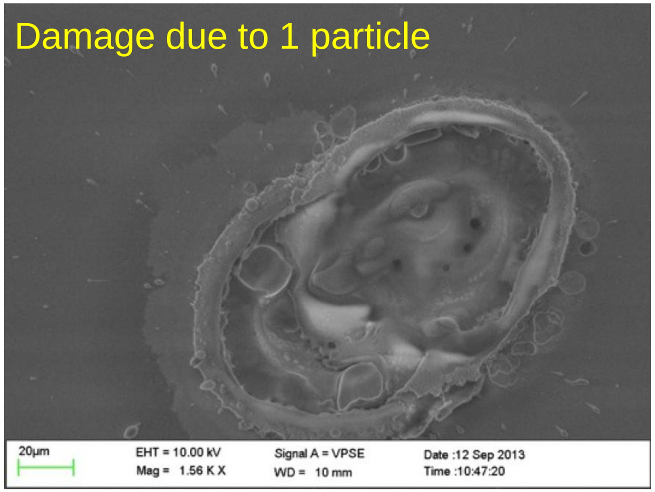
Requirements for absorption on cavity surfaces: 0.5 ppm per surface with 0.1 for contamination

LIGO vacuum chambers operate in an ISO 5 (Class 100) environment

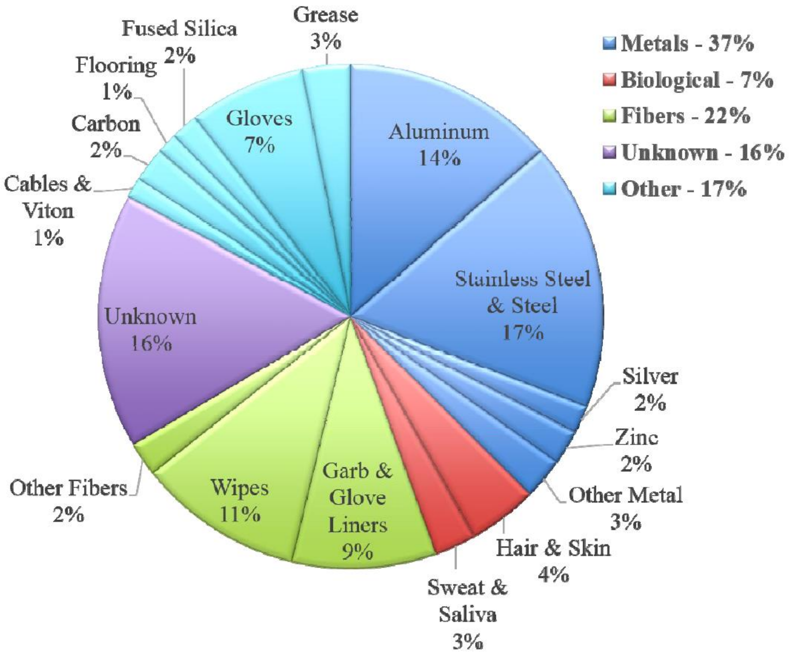
Materials: LIGO Vacuum Compatible Materials List, NASA outgassing specifications

IEST-STD-CC1246 standardizes the criteria for PCLs

Witness wafers, “FBI” samples, …



Molecular analysis of specimens collected with FBI sample tool in vacuum chambers

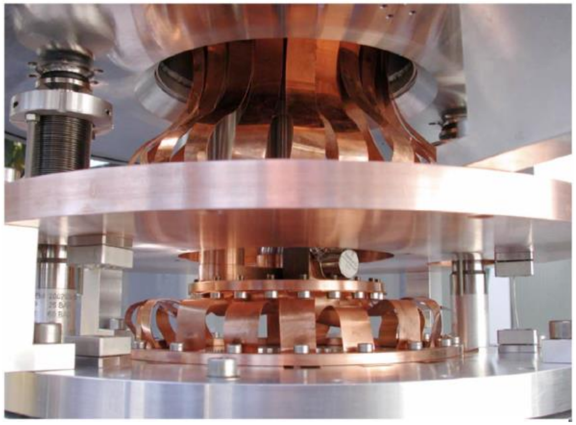


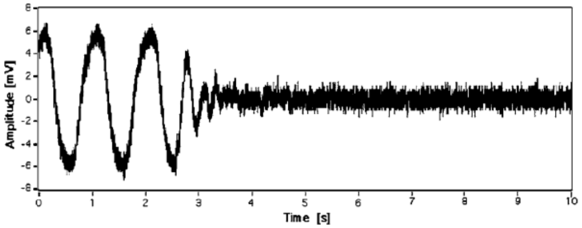
Creating a smart infrastructure

Minimizing the effects of the infrastructure on our measurements

- Low noise equipment: HVAC systems, (water) pumps, vacuum equipment, electronics, acoustic isolation, …
- Temperature stability

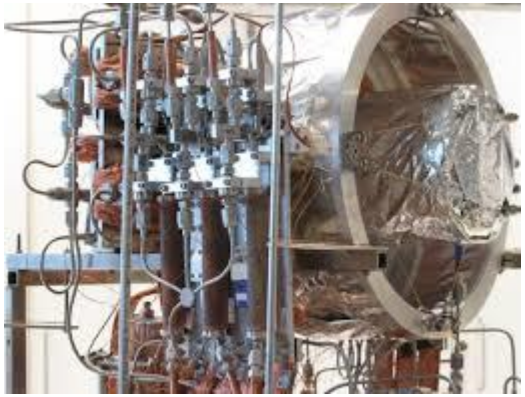
Pulse tube cooling

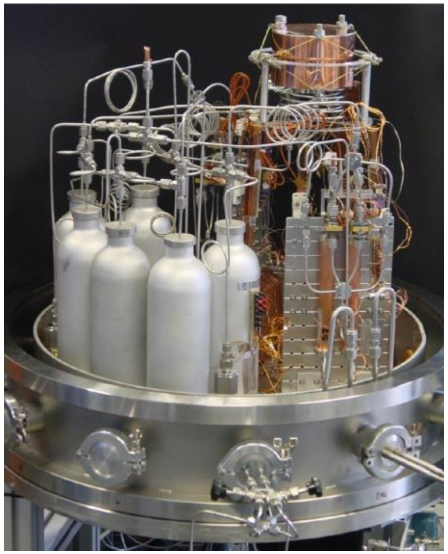




S. Caparrelli et al., Rev. Sci. Instrum. **77**, 095102 2006

Vibration-Free Cooling Technology to Replace Mechanical Compressors in Sensitive Space Applications



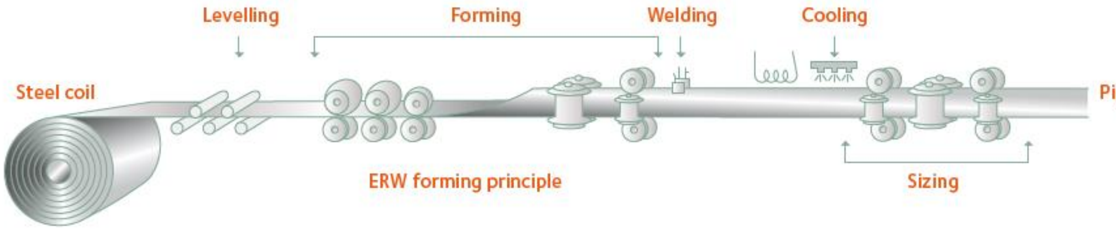


Marcel ter Brake et al., Thema-bijeenkomst “Thermal Challenges”, Mikrocentrum Veldhoven, 15 mei 2019

Maximize benefits of Einstein Telescope for the region

Minimizing the impact of construction

Local factory for beam tube production: about 8,000 segments (16 m)



ourtesy of SCC Nigeria

ourtesy of Corinth Pipeworks

Courtesy of Corinth Pipeworks (Greece)

Pickled and oiled coils ready for overseas shipment (Fos-sur-Mer)

SAWH API 5L pipes being inspected during the coating operation.

Einstein Telescope: in harmony with its environment

Integrating the observatory in the environment

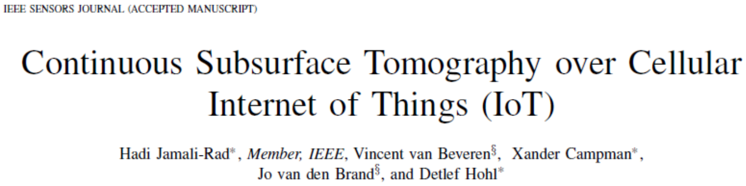
Top science in a top region

Outreach activities: exhibition, outreach center

Examples of spin-off from gravitational wave research

IoT-based wireless seismic quality control

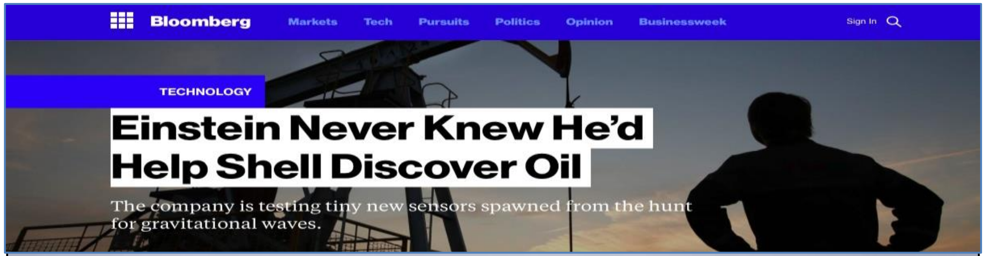
Hadi Jamali-Rad[1], Xander Campman[1], Ian MacKay[2], Wim Walk[1], Mark Beker[3], Jo van den Brand[3], Henk Jan Bulten[4], and Vincent van Beveren[4]



IEEE SENSORS JOURNAL (ACCEPTED MANUSCRIPT)

Continuous Subsurface Tomography over Cellular Internet of Things (IoT)

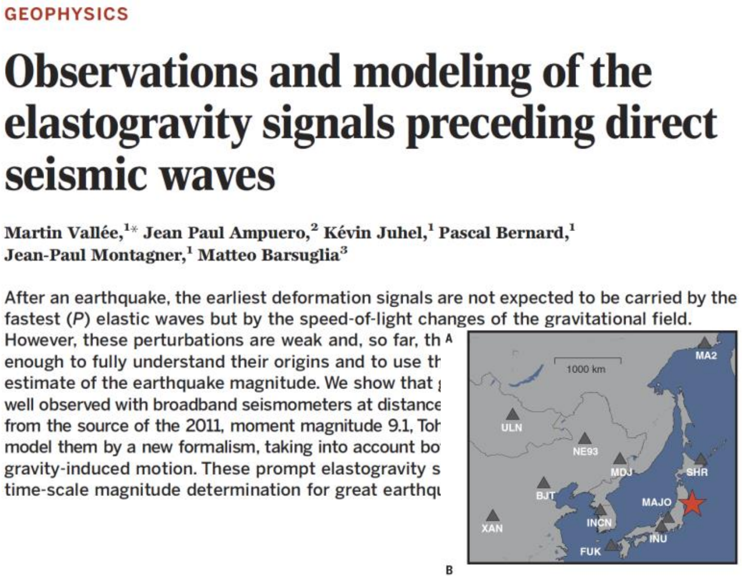
Hadi Jamali-Rad*, *Member, IEEE*, Vincent van Beveren§, Xander Campman*,
Jo van den Brand§, and Detlef Hohl*



Einstein Never Knew He'd Help Shell Discover Oil

The company is testing tiny new sensors spawned from the hunt for gravitational waves.

Smart seismic sensor networks (www.innoseis.com)

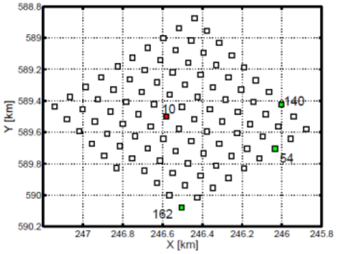


GEOPHYSICS

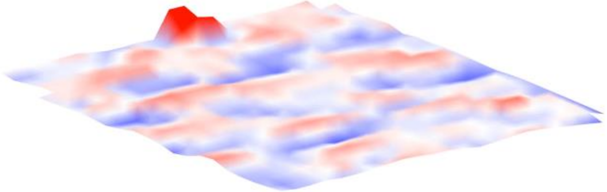
Observations and modeling of the elastogravity signals preceding direct seismic waves

Martin Vallée,[1]* Jean Paul Ampuero,[2] Kévin Juhel,[1] Pascal Bernard,[1] Jean-Paul Montagner,[1] Matteo Barsuglia[3]

After an earthquake, the earliest deformation signals are not expected to be carried by the fastest (*P*) elastic waves but by the speed-of-light changes of the gravitational field. However, these perturbations are weak and, so far, th
enough to fully understand their origins and to use th
estimate of the earthquake magnitude. We show that
well observed with broadband seismometers at distance
from the source of the 2011, moment magnitude 9.1, Toh
model them by a new formalism, taking into account bo
gravity-induced motion. These prompt elastogravity s
time-scale magnitude determination for great earthqu



Earthquake monitoring



Thank you for your attention! Questions?