Einstein Telescope: Site and infrastructure session

Jo van den Brand, Maastricht University and Nikhef, jo@nikhef.nl

Amsterdam, December 27, 2020

Program for Wednesday morning, December 2, 2020

09:00 → 12:00 **Site and Infrastructures**

Présidents de session: Domenico D'Urso, Johannes van den Brand (Nikhef)

09:00 **Introduction** 5m

Orateur: Johannes van den Brand (Nikhef)

09:05 **ARCHIMEDES measurements at Sos Enattos** 20m

Orateur: Dr Luciano Errico (University of Naples "Federico II" and INFN)

09:25 **Seismic studies at Sos Ennatos** 20m

Orateur: Tomasz Bulik (University of Warsaw)

09:45 **ET EMR: E-TEST general objectives, geological conditions and hydrogeophysical imaging** 20m

Orateur: Prof. Frederic Nguyen (University of Liège)

10:05 break 10m

10:15 **Results and implications of seismic studies in Limburg** 20m

Orateur: Soumen Koley (Nikhef)

10:35 **ET Limburg: Site selection procedure and geotechnical challenges** 20m

Orateur: Prof. Florian Amann (RWTH Aachen)

Amann.pptx

10:55 **Experience from KAGRA** 20m

11:15 **CERN's vacuum technology for the Einstein Telescope** 20m

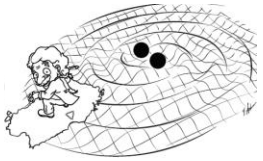
CERN has competences in vacuum technology that can be useful for the Einstein Telescope (ET). Mechanical design, vacuum and electrodynamic simulation are regularly used and internally developed to support the early stage of conceptual design. In prototyping and production phase, surface treatments and coating are an important aspect of our activity. To assist studies and production, a large set of measurement techniques is operated, encompassing surface and chemical analysis. Measurement of functional vacuum properties is a core capability, from outgassing rate measurement, through thermal analysis, to pumping speed evaluation. Cost assessment and optimization are essential tasks when achieving large projects as the high-luminosity LHC and conceiving future accelerators.

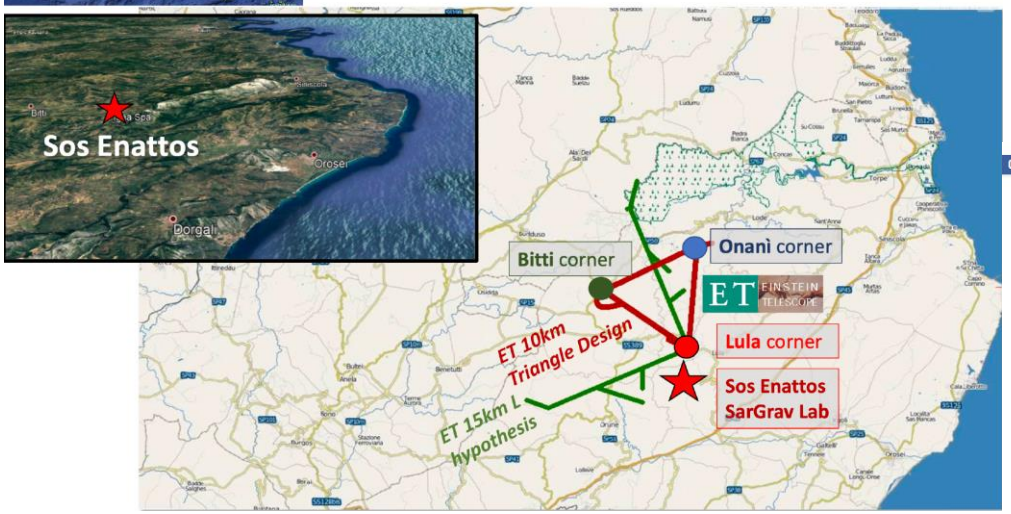
Sharing our experience in design, prototyping, construction, and operation of large vacuum systems might be profitable for the ET study at different level, and perfectly in line with the recent Update of the European Strategy for Particle Physics which calls for strengthening of synergies 'in areas of common interest and mutual benefit'.

Orateur: Paolo Chiggiato (CERN)

Sos Enattos

Excellent situation to have 2 candidate sites: learn from each other's experience





Yesterday's session devoted mainly to studies at the Sos Enattos site

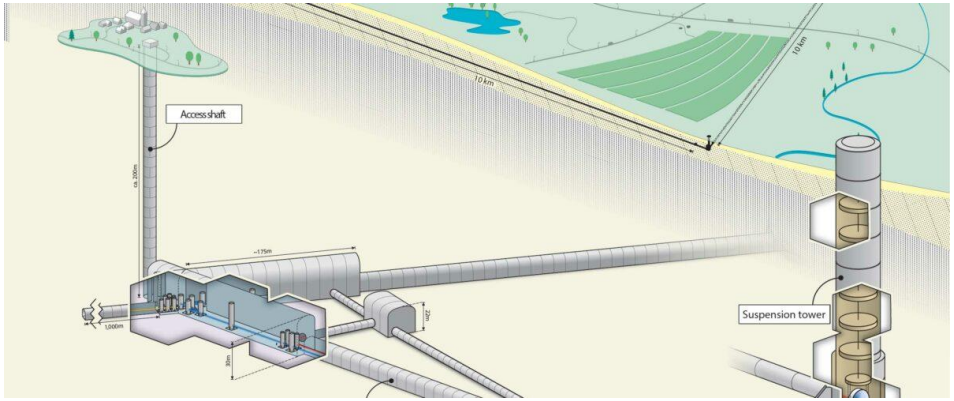
09:00 → 11:35 **Site and Infrastructures**

Présidents de session: Domenico D'Urso, Johannes van den Brand (Nikhef)

09:00	**Introduction** **Orateur**: Domenico D'Urso (University of Sassari and INFN-LNS) Introduction.pdf	5m
09:05	**Site infrastructure plan and activities at Sos Enattos** **Orateur**: Maria Marsella (Università di Roma 'La Sapienza') ET_Symposiumo_2...	20m
09:25	**Sardinia Characterization Activities** **Orateur**: Luca Naticchioni (INFN Roma) ETsymp11 SosEnatt...	20m
09:45	**Seismic Measurements at Sos Enattos** **Orateur**: Dr Gilberto Saccorotti (Istituto Nazionale di Geofisica e Vulcanologia - Sezione di Pisa) Seismic Measurem...	20m
10:05	break	10m
10:15	**Environmental noise measurements at Sos Enattos** **Orateur**: Prof. Rosario De Rosa (University of Naples "Federico II" and INFN) EnvNoise_2020120...	20m
10:35	**Study of Seismic Glitchness at Sos Enattos** **Orateur**: Prof. Enrico Calloni (University of Naples "Federico II" and INFN) Presentazione_ET_...	20m
10:55	**Civil Engineering studies at CERN** **Orateur**: John Andrew Osborne (CERN) CERN_civil_enginee... CERN_civil_enginee...	20m

Belgium-Germany-Netherlands

A network of interested scientific institutions and companies



The following institutions and organizations are already involved

The Netherlands:
Nikhef (Nationaal Instituut voor Subatomaire Fysica); Radboud Universiteit; Rijksuniversiteit Groningen; Universiteit van Amsterdam; Universiteit Maastricht; Universiteit Utrecht; Vrije Universiteit Amsterdam; NWO-I; KNMI (Koninklijk Nederlands Meteorologisch Instituut); TNO (Nederlandse organisatie voor Toegepast Natuurwetenschappelijk Onderzoek); Provincie Limburg; Ministerie van Onderwijs Cultuur en Wetenschap; Ministerie van Economische Zaken en Klimaat

Belgium:
KU Leuven; UC Louvain; Université de Liège; Université de Mons; Université de Namur; Université Libre de Bruxelles; Universiteit Antwerpen; Universiteit Gent; Universiteit Hasselt; Vrije Universiteit Brussel; Agoria – Belgian federation of companies in the manufacturing industry, the digital and telecom sectors; Federaal Wetenschapsbeleid / Politique scientifique fédérale – BELSPO; Fonds de la Recherche Scientifique – FNRS; Fonds voor Wetenschappelijk Onderzoek Vlaanderen – FWO; Vlaams Ministerie van Economie, Innovatie, Werk, Sociale economie en Landbouw; Vlaams Departement Economie, Wetenschap, en Innovatie – EWI; Vlaams Agentschap Innoveren en Ondernemen – VLAIO; Vlaamse Instelling voor Technologisch Onderzoek – VITO; Walloon Region

Germany:
Eberhard Karls Universität Tübingen; Deutsches Elektronen-Synchrotron, Hamburg / Zeuthen; Fraunhofer-Institut für Angewandte Optik und Feinmechanik, Jena; Fraunhofer-Institut für Lasertechnik, Aachen; Fraunhofer-Institut für Produktionstechnologie, Aachen; Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU); Friedrich-Schiller-Universität Jena; Goethe-Universität Frankfurt; Karlsruher Institut für Technologie (KIT); Laser Zentrum Hannover (LZH); Leibniz-Institut für Kristallzüchtung (IKZ); Leibniz Universität Hannover; Max-Planck-Institut für Gravitationsphysik (Albert-Einstein-Institut), Hannover; Max-Planck-Institut für Gravitationsphysik (Albert-Einstein-Institut), Golm; Physikalisch Technische Bundesanstalt; RWTH Aachen; Technische Universität Braunschweig; Technische Universität Darmstadt; Universität Bremen; Universität Hamburg; Universität Heidelberg; Universität Rostock; Westfälische Wilhelms-Universität Münster

Low frequency sensitivity of Einstein Telescope

We are faced with a challenge: seismic noise, gravity gradient noise, …
Virgo aims at about 3×10^{-22} $/\sqrt{\mathrm{Hz}}$ at 10 Hz, Einstein Telescope at about 2×10^{-24} $/\sqrt{\mathrm{Hz}}$

Low frequency sensitivity
GW signals detected at high redshift will appear at low frequency

Signals from more massive black holes will appear at low frequency

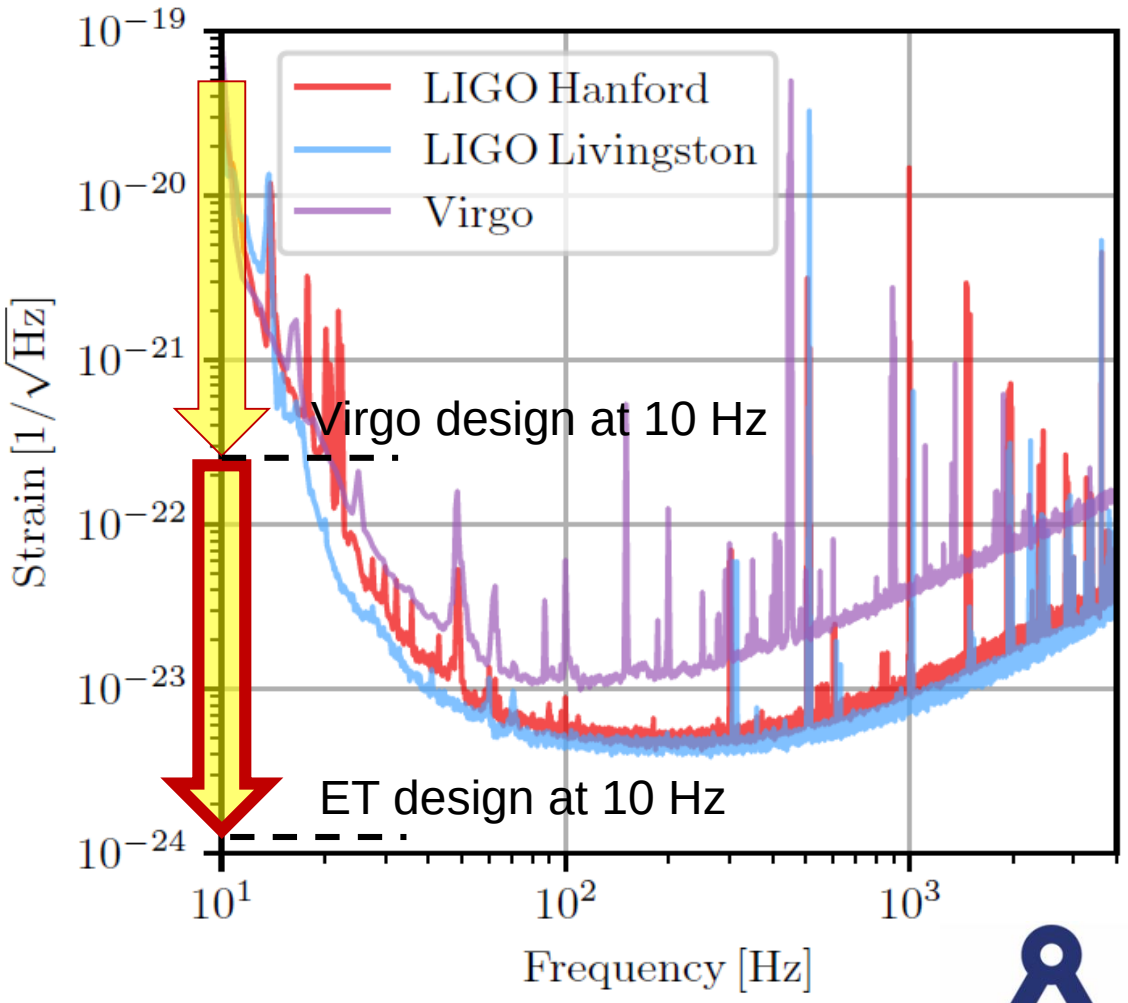
Intermediate mass black holes are important new sources

Early warning systems will profit enormously from low frequency

Observation of spin precession profits from longer observation

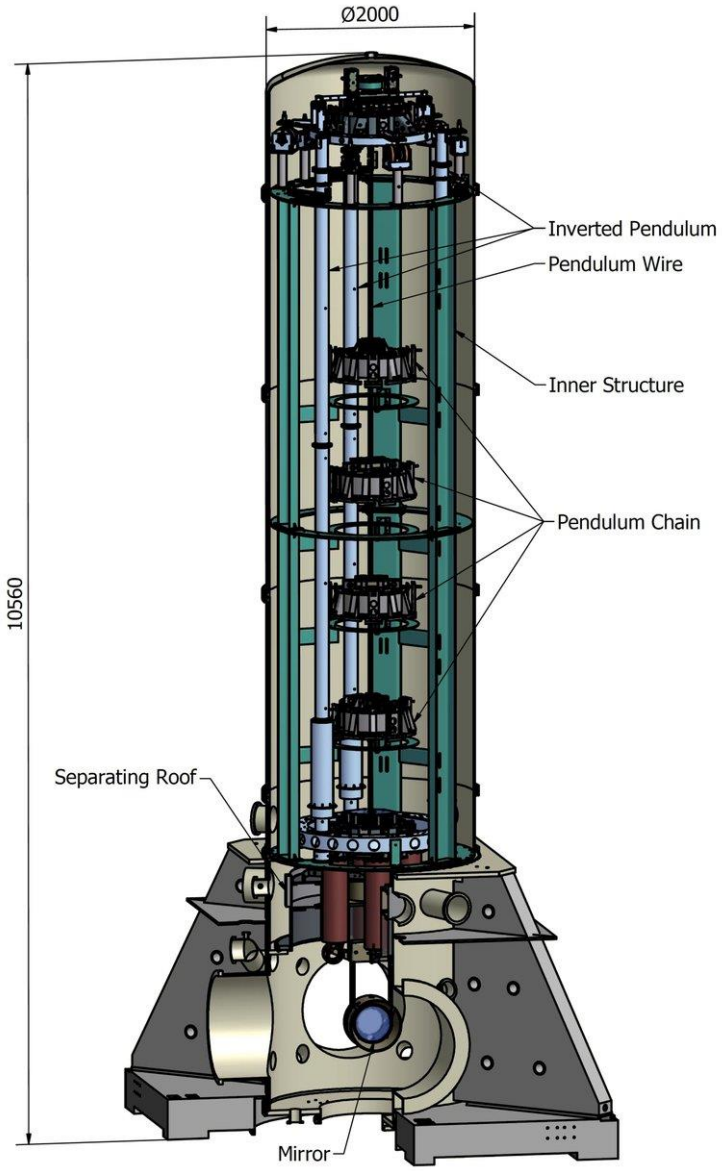
Low frequency noise
Seismic noise

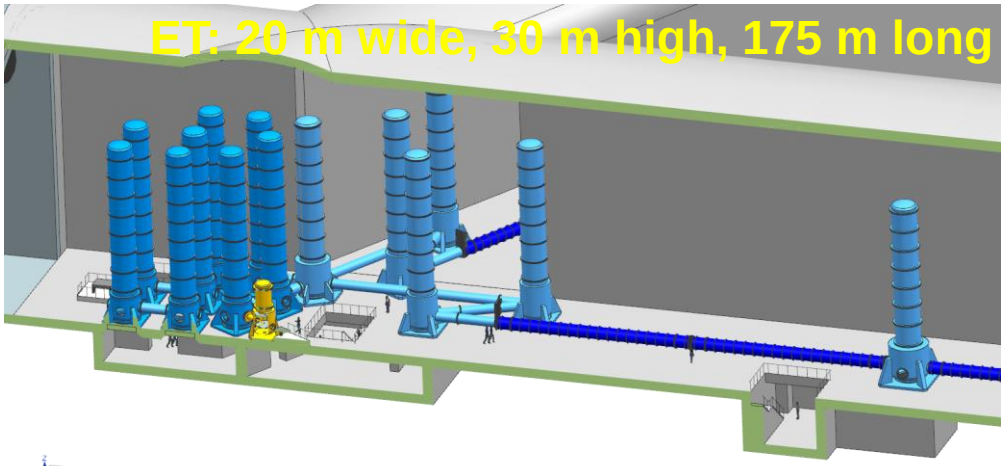
Newtonian noise



ET baseline: SAS based on Virgo's superattenuators

Can we achieve the required attenuation with a more compact system?





KAGRA inauguration

Signing of the MOA with LIGO and VIRGO
Toyama, October 4, 2019

Einstein Telescope vacuum system

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)

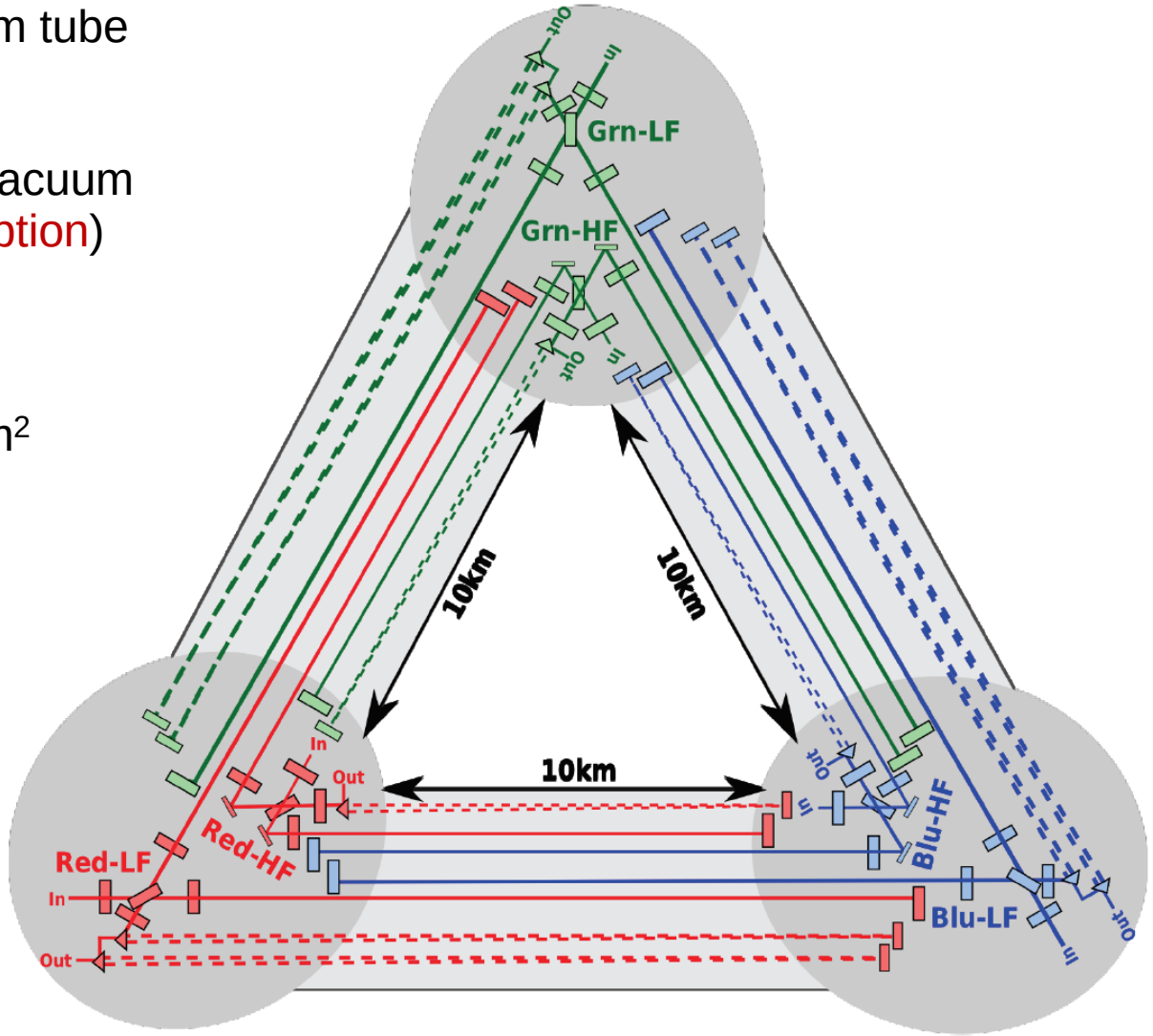
Total volume: about 120,000 m^3

Total surface area: about 420,000 m^2

Target pressure of < 10^{-10} hPa

Hydrocarbon pressure < 10^{-14} hPa

For comparison LHC at CERN:
- **Beam tubes: 2,000 m^3**
- Cryo-magnet insulation: 9,000 m^3
- Cryo distribution line: 5,000 m^3



CERN-GW R&D program together with industry

We should pursue a joint collaboration with Cosmic Explorer

Participants from steel and car industry: employ mild steel

Tata Steel Ijmuiden
Producer of low carbon steel
Vacuum treatment to de-hydronize steel
Enamel coatings

VDL Group
International industrial and manufacturing company
Car industry, CERN CLIC cavities

Settles
Focus on the creation of new technology, manufacturing processes and/or equipment

Huge potential for **cost savings** by avoiding stainless steel construction

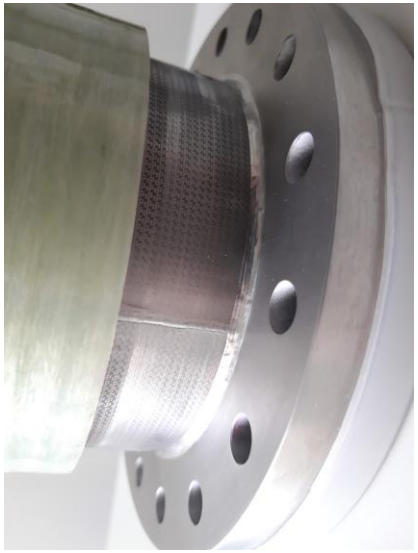
Numerous issues: construction, assembly, valves, pumping, …

Connections to other innovative activities
Hyperloop project, fuel cells, …

Other approaches: two concentric tube design

Option of an independent inner and out vacuum space

Decouple atmospheric load from UHV requirements



Timeline Einstein Telescope

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

There is a window of opportunity to do R&D that can lead to **significant cost savings**

Underground construction and vacuum represent > 85% of the cost of ET

Preparation phase

Activity	Cost [M€]	Actualised cost [M€]	Start	End	Note
Site Qualification	15	14	2019	2022	Complex series of activities, going in parallel in the two candidate site, aiming to the qualification of the sites (compliance with the stringent ET requirements)
Funding schemes for the two sites	0	0	2019	2023	Definition of the two funding schemes for the two candidate sites. Interaction and negotiation between countries
Site Comparison	1	1	2022	2023	Evaluation of the two candidatures, using also external panels, experts and companies
RI Technical Design completion	38	31	2023	2025	Completion of the preliminary design, realisation of the definitive and operative design by specialised external companies.
Governance definition -ERIC	1	1	2021	2024	Study and definition of the governance structure of ET
Land acquisition	19	15	2023	2025	Acquisition of the land for the excavation and for the realisation of the surface infrastructures
Funding schemes for the two sites	0	0,0	2019	2023	Activity addressed to the definition of the financial schemes for the two candidatures
Technology development	95	81	2019	2028	R&D activity addressed to the development of the technologies needed for ET. This activity is already started since years and it is partially based on the technology developed for the upgrade of the current detectors
Detector design completion	2	2	2022	2025	Completion of the detector design after the selection of the site
Tot	171	145			

Construction phase

Activity	Cost [M€]	Actualised cost [M€]	Start	End	Note
Infrastructure costs	932	635			
Excavation	781	540	2026	2031	Excavation of the underground tunnels with TBMs and of the caverns. Cost based on the evaluation by two independent external companies
Direction of the civil works	9	6	2025	2032	Evaluation based on the 1% of the underground and surface infrastructures realisation cost
Civil works in surface	98	62	2028	2033	Realisation of the technical and civil infrastructures on the surface. Cost evaluation based on the Conceptual Design study
Services underground	44	27	2030	2033	Technical infrastructures serving the
Detector costs	804	552			
Vacuum system	566	391	2026	2031	Vacuum plant, pumps and pipes
Suspension system	48	33	2026	2031	Filtering and suspension systems
Cryogenics	45	31	2026	2031	Cryogenic plants
ET installation	20	11	2032	2035	Contracts and activities for the installation of the ET components
Total	1736	1187			

Now is the time to focus on R&D to achieve significant cost savings

Relatively modest investments in R&D related to Infrastructure and Vacuum may have a strong impact

Window of opportunity

- Proposal submitted to ESFRI Roadmap in 2020
- Implementation at the earliest in 2026

Strong partnerships

- MOU with CERN in place
- Window of opportunity for R&D
- Industrials and academic partnerships

Instrumentation development

- Vacuum studies on beam tubes and coatings
- Vibration isolation → underground construction
- Sensors and control systems
- Optics, scattered light, coatings, …
- …