



Preparatory Phase for the Einstein Telescope Gravitational Wave
Observatory

Deliverable D5.4

Functional ETO Engineering Department

Lead beneficiary: CNRS
Delivery Date: 24/03/2025
Dissemination level: internal
NAME : ET-PP-Deliverable-5.4
Version: 2.0



This project has received funding from the European Commission Framework Programme Horizon Europe Coordination and Support action under grant agreement 101079696.

Deliverable 5.4. Functional ETO Engineering Department

Document information

Grant Agreement Number	101079696
Acronym	ET-PP
Start date of project (Duration)	01/09/2022 (48 months)
Document due date	31/12/2024
Authors	P. Werneke
Deliverable/milestone number	5.4
Deliverable/milestone name	Functional Engineering Department
WP	5

Version	Date	Author	Description
0.1	February 4, 2025	P. Werneke	Creation
0.2	March 10, 2025	P. Werneke	Added chapters 4 & 5, and Executive Summary. Textual changes to the other chapters
0.3	March 13, 2025	P. Werneke	Revision of the document after comments from C. Olivetto and R. Saban. Updated chapter 2 and textual for the other chapters.
0.4	March 16, 2025	P. Werneke	Following comments from A. Freise and R. Saban: revision of Introduction, Mechanical Engineering, Integration and Coordination, and Executive Summary, textual changes to the other chapters and chapter on Budget added.
1.0	March 23, 2025	P. Werneke	Following comments from Maria Marsella on the civil engineering part in chapter 2 and Yuliya Hoika with grammar corrections on various pages.
2.0	April 10, 2025	P. Werneke	Following the comments of M. Morandin, P. Verdier, Appendix A was added and sections in chapter 2 were rewritten.

Executive Summary

The Einstein Telescope (ET) will be a state-of-the-art research infrastructure designed to measure gravitational waves. As part of the Einstein Telescope Preparatory Phase (ET-PP), the Engineering Department (ED) is responsible for providing the necessary competences to design, install, operate, maintain, and eventually disassemble the Einstein Telescope complex and its facilities. The mandate of the Engineering Department covers two primary areas: the civil infrastructure, which includes the design, construction, and long-term management of the underground and surface facilities required to host the gravitational wave detector, and the technical infrastructures, which are necessary for operating the detector, including vacuum systems, cryogenics, and other specialized systems.

This document presents the Engineering Department as a functional unit, outlining its key operational teams, structure, mandate, and budget. A key aspect of its work is the close strong alliance with the ET Collaboration and the local host teams to ensure that engineering efforts are aligned with scientific goals. While this document describes the Engineering Department within the scope of the ET-PP project, its role extends beyond this phase. The unit established today has the capability to develop into a full-fledged Engineering Department for the research infrastructure, which will be created once the ET Project is approved.

The Engineering Department consists of several specialised teams overseeing the different technical domains, including Civil Engineering, Technical Infrastructure, Mechanical Engineering, Engineering Technology, and Integration and Coordination. The department is gradually expanding its personnel and expertise as needed. The department is further supported by multiple framework collaboration agreements, including those between INFN, Nikhef, IFAE, and CERN. The agreements cover critical areas such as civil engineering, vacuum systems, technical infrastructure and occupational health and safety. In Appendix A an overview of the personnel involved in the ETO Engineering Department is provided.

To improve efficiency and coordination across the different teams and stakeholders, the Engineering Department relies on a range of specialized tools, including Building Information Modelling (BIM), Computer-Aided Design (CAD), and Product Lifecycle Management (PLM) systems. The implementation of Model-Based Systems Engineering (MBSE) is also underway to ensure consistency across multi-disciplinary engineering activities. These tools contribute to a structured and systematic approach in managing engineering data and ensuring traceability of design decisions.

The primary focus of the Engineering Department is Preparatory Phase 1, which will conclude with the site selection and principal approval for the construction of the Einstein Telescope. The main deliverable during this phase is the Preliminary Technical Design Report (TDR) for the research infrastructure, which will provide a comprehensive technical foundation for the next steps of the project.

While awaiting the formal establishment of ETO as a legal entity, the Engineering Department operates with funding provided by individual research institutions. To expand its capabilities, the department is actively working to secure additional resources from universities and research centers, broadening institutional support beyond CERN. Efforts are also underway to standardize engineering tools and software across ETO and the ET Collaboration, ensuring streamlined design and collaboration processes.

The Engineering Department has made significant progress in establishing itself as a functional entity. However, further efforts are required to strengthen its operational foundation, towards supporting the successful development of the Einstein Telescope. Continued development of its organisational structure, recruitment of key personnel, and integration of advanced engineering practices will be essential for a strong foundation for the next phases of the project.

List of acronyms and abbreviations

BIM	Building Information Modelling
CAD	Computer-Aided Design
CAE	Computer-Aided Engineering
CDR	Conceptual Design Report
CNRS	Centre National de la Recherche Scientifique
ED	ETO's Engineering Department
EDMS	CERN's Engineering Data Management System
EMR	Euregio Meuse-Rhine
EN	CERN's Engineering Department
ESFRI	European Strategy Forum for Research Infrastructures
ET	Einstein Telescope
ETC	Einstein Telescope Collaboration
ET-PP	Einstein Telescope Preparatory Phase
ETO	Einstein Telescope Organisation
GW	Gravitational Waves
HSE	CERN's Occupational Health & Safety and Environment Protection Unit
IFAE	Institut de Fisica d'Altes Energies
ISB	ETC's Instrument Science Board
IJCLab	Laboratoire de Physique des 2 Infinis Irène Joliot-Curie
LAPP	Laboratoire d'Annecy de Physique des Particules
LNF	Laboratori Nazionali di Frascati
MBSE	Model-Based System Engineering
PLM	Product Lifecycle Management
PO	ETO's Project Office
MoU	Memorandum of Understanding
SCE-SAM-FS	CERN's Site and Civil Engineering – Site Asset Management – Future Studies group
TDR	Technical Design Report
TETI	Team for Einstein Telescope in Italy
TE-VSC	CERN's Vacuums, Services and Coatings group
WBS	Work Breakdown Structure
WP	Work Package

Table of Contents

1.	Introduction.....	5
2.	Organisation and Communication	6
2.1	Engineering Department Leadership	6
2.2	Civil Engineering	7
2.3	Technical Infrastructure.....	7
2.3	Engineering Technology.....	8
2.4	Mechanical Engineering	8
2.5	Integration and Coordination	9
3.	Tools and Technologies.....	9
4.	Roadmap and Milestones.....	9
4.1	Civil Engineering	10
4.2	Technical Infrastructure.....	10
4.3	Engineering Technology.....	10
4.4	Mechanical Engineering	10
4.5	Integration and Coordination	11
5.	Budget.....	11
6.	Outlook.....	11
7.	References.....	12
	Appendix A: Composition by ETO Engineering department	13

1. Introduction

The underground Einstein Telescope (ET) will be a state-of-the-art research infrastructure designed to measure gravitational waves. To support its development and long-term operation, the Engineering Department (ED) was established to provide the expertise needed to design, install, operate, maintain and eventually disassemble the Einstein telescope complex and its associated facilities.

Following the formation of the Einstein Telescope Organisation (ETO) and its mandate, the ETO Engineering Department became operational in 2023. In this context, INFRA-DEV WP5 provided the framework for the ETO Engineering Department, which is now fully integrated into ETO.

This document, 'Functional ETO Engineering Department', is a deliverable of the ET-PP project. It outlines the ETO Engineering Department as a functional unit, detailing its key operational groups, structure, mandate, and budget.

The structure and mandate of the ETO Engineering Department have been previously described in [1]. The Engineering Department's mandate covers two primary areas:

- Civil infrastructure: the design, construction, and long-term management of the underground and surface infrastructure required to house the interferometer;
- The technical infrastructures and the special systems: the systems necessary for operating the gravitational wave detector, including vacuum systems, cryogenics, and other specialized systems.

An important aspect of the Engineering Department's work is its strong alliance with the ET Collaboration and the local host consortia. These partnerships ensures that engineering efforts are aligned with scientific objectives and requirements are met. Information is shared through regular meetings, collaborative platforms, and documentation exchanges, promoting effective communication and coordination.

It is important to point out that the Engineering Department described in this document, extends well beyond the scope of the ET-PP project. The unit established today has the capability to develop into a full-fledged Engineering Department for the research infrastructure, which will be created once the ET Project is approved.

2. Organisation and Communication

The Engineering Department is structured into specialised teams, each with a separate role in ensuring the successful design, construction and operation of the Einstein Telescope. These teams closely collaborate with the ETO departments, specifically the Project Office, and interact with external partners such as the Einstein Telescope Collaboration (ETC), the local host consortia and the relevant CERN groups.

Figure 1 presents the organisational chart and the chain of command within the Engineering Department and illustrating the teams based on their areas of expertise [1]. The persons involved in ETO, CERN and ET-PP, including their role and affiliated institute, is provided in Appendix A.

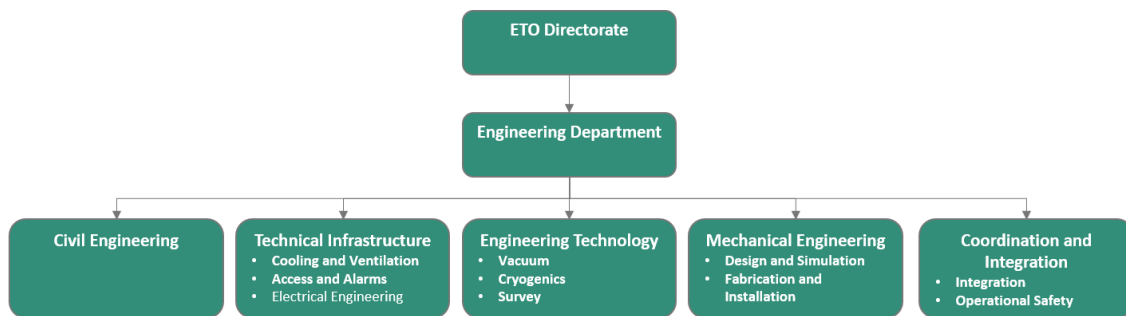


Figure 1: Engineering Department organizational chart

2.1 Engineering Department Leadership

The Head of the Engineering Department is responsible for the strategic oversight, decision-making and ensuring alignment with the broader objectives of ETO. The Head of Civil Engineering plays a key role in managing all civil infrastructure related aspects of the project and works closely with the Department Head. Both leaders are part of the ETO Management Team, where they play a strategic role in aligning engineering activities with the overall objectives of ETO.

The Department Head facilitates collaboration between the different engineering teams and the external partners, ensuring coordination across institutions. In addition to managing technical challenges and optimising resource allocation and playing a crucial role in problem-solving, ensuring engineering solutions remain feasible within the constraints of the project.

To ensure efficiency and coordination, the Department Head follows a structured communication framework. This includes weekly, biweekly, and monthly meetings with department members, members of ETO and specifically the Project Office, and the external partners. These meetings serve to align priorities, make key decisions, and facilitate effective collaboration between departments and partners. Additionally, the Engineering Department organizes a monthly meeting for all its members and the relevant CERN groups. This meeting provides a platform to share updates, exchange information, and track progress across departments and relevant CERN groups.

2.2 Civil Engineering

The Civil Engineering team is responsible for the design, procurement, construction, monitoring, maintenance, and eventual dismantling of both the underground and surface civil infrastructure [1]. Their role is essential in ensuring that all civil engineering activities align with the overall goals of the ET project, while remaining technically feasible and cost-effective. The persons involved, their role and institute can be found in Appendix A.

Led by its Head, the ETO Civil Engineering team brings together expertise in environmental and civil engineering, including geotechnics and digital modelling. To support its work, a framework collaboration agreement [2] has been established between INFN, Nikhef, and CERN. This agreement, which supports the civil engineering activities for the ET project, runs until December 31st, 2026.

In the ET project, the ET Collaboration defines the detector design and its requirements, while the local host consortia (EMR and TETI) are responsible for underground feasibility studies and local civil engineering efforts. The ETO Civil Engineering team plays a key coordinating role, ensuring strategic alignment and effective communication between the ET Collaboration and the local host consortia (see Figure 2).



Figure 2: ETO relations with local host consortia and ET Collaboration

The ETO civil engineers hold weekly meetings to review progress, with one session each month dedicated to coordination with the ED team. Additionally, monthly meetings with CERN's Civil Engineering (SCE-SAM-FS) group ensure alignment on activities under the MOU. Biweekly discussions with the local host consortia focus on detector layout aspects impacting civil infrastructure design and other specific study requirements. All meeting minutes are documented and stored in the CERN EDMS system.

Questions from the local host consortia are internally reviewed, discussed and answered in writing. Scientific questions are forwarded to the Instrument Science Board (ISB) of the ETC and responses are, after review, shared with the local host consortia. All formal writing is stored in CERN's EDMS, while issue tracking between ETO and local host consortia is managed via Gitlab.

The Civil Engineering team, in collaboration with CERN's SCE-SAM-FS group, continues to organize in-person workshops at CERN for the local host consortia. These workshops, like those held in April 2024 and January 2025, aim to share CERN's expertise in underground infrastructure and provide updates on ETO progress and advancements by the consortia.

2.3 Technical Infrastructure

The Technical Infrastructure team is responsible for the design, procurement, installation, operation, maintenance, renewal and eventually dismantling of the systems associated with the technical infrastructure for the civil infrastructure and the interferometer [1]. The team's activities cover various critical systems, including access and alarms, cooling and ventilation systems, electricity and underground water management.

To support these activities, a framework collaboration agreement [3] between INFN, Nikhef, and CERN was finalised and signed in March 2025. The agreement takes effect in April 2025, initiating the recruitment phase, and will remain in place until June 2028. Seven fellows will be recruited

by CERN's Engineering Department (EN) and the Occupational Health & Safety (OHS) Department to contribute to the Technical Infrastructure and Health & Safety of the underground infrastructure. The fellows are expected to start their assignments at the beginning of Q4 2025. They will be embedded within the relevant CERN groups but will operate under the requirements and guidance of the ETO Engineering Department. An overview of the Fellows per subject is provided in Appendix A.

2.3 Engineering Technology

The Engineering Technology team is responsible for the design, engineering, procurement, manufacturing, installation, operation, maintenance and renewal of the special systems associated with the interferometer [1], including vacuum, cryogenics and survey.

For the development of the 120 km vacuum beampipe a framework collaboration agreement [4] has been established between INFN, Nikhef and IFAE and CERN. Under this agreement CERN's Vacuums, Services and Coatings Group (TE-VSC) has taken the responsibility for preparing and writing the Technical Design Report (TDR), including cost estimations. In addition, the TE-VSC Group is leading the design, manufacturing and testing of a pilot sector and sharing information with the Cosmic Explorer project. INFN, Nikhef and IFAE together with CERN, have agreed on additional contributions and extended the agreement [5] until September 2027.

The development work is carried out within the TE-VSC Group and CERN's Engineering Department (EN), under the management of the Head of the TE-VSC Group and in close collaboration with the Head of the Engineering Department. The team consists of specialists from several disciplines, each contributing their expertise. In addition there are several ET-PP partner institutes that support the beampipe development at CERN. The persons involved, their role and institute can be found in Appendix A.

The TE-VSC group holds monthly meetings, also inviting stakeholders from ETO and ETC to participate. In addition, in 2023 the TE-VSC group organised a workshop on beampipes for gravitational wave telescopes, bringing together the ET and Cosmic Explorer communities. The workshop will be held again in 2025. In January 2024 a peer review was organised for the ET Pilot Sector and in January 2025 the Preliminary TDR was submitted to the ET-PP.

Currently, no formal team organisation has been established for cryogenics and survey. Due to limited resources, these items have been put on hold, as they are considered not critical for Preparatory Phase 1 and the site(s) selection process.

2.4 Mechanical Engineering

The Mechanical Engineering team is responsible for the design, engineering, manufacturing, procurement, and installation of mechanical systems for the interferometer. The work includes feasibility studies for transport and handling, operation of a future state-of-the-art workshop, subcontracting, ensuring clean operations, and maintaining all transport, handling, and lifting equipment.

Currently, no team organisation for Mechanical Engineering has been established, as the activities are not considered critical for Preparatory Phase 1 and the site(s) selection process. In the meantime, any critical issue that arises will be managed by the mechanical engineers within the Integration and Coordination team.

2.5 Integration and Coordination

The Integration and Coordination team is responsible for integration studies, interventions and changes to the GW detector and its infrastructure. Their role is to ensure that all components meet the technical requirements and integration constraints within the broader engineering framework.

Recently, the Integration and Coordination team has expanded to include three mechanical engineers, each bringing expertise in design and system integration. Their focus currently is on integration studies for key components of the interferometer for the civil infrastructure. The persons involved, their role and institute can be found in Appendix A.

The engineers have bi-weekly meetings with the Head of the Engineering Department to discuss the current and future work. Additionally, the engineers actively participate in ETO and ETC technical meetings to maintain alignment with overall system development.

Recently, the engineers have contributed to the development of the Optical Layout within the ET Collaboration and coordinated the design of the ET Detector Layouts.

3. Tools and Technologies

The ETO Engineering Department uses a range of specialized software solutions to improve efficiency and collaboration between the different stakeholders. While some of these systems are provided by the connected institutes, additional software has been procured specifically for the Engineering Department.

For design and modelling, the department uses Building Information Modelling (BIM) through Revit, along with Computer-Aided Design (CAD) tools like AutoCAD, Rhino 3D, Catia, and NX. Trimble Connect facilitates the sharing of 3D infrastructure models with ETO stakeholders.

Documentation is facilitated through Overleaf, MS Word, MS Excel, and MS PowerPoint. Collaboration is supported by Microsoft Teams and structured documentation and version control are managed through CERN's Engineering Data Management System (EDMS).

To maintain consistency across multi-disciplinary engineering activities Model-Based Systems Engineering (MBSE) is being implemented by the ETO Project Office (PO).

4. Roadmap and Milestones

The Engineering Department's primary focus is on Preparatory Phase 1, which ends with the site decision and the principal approval for the construction of the Einstein Telescope. To achieve this, the Engineering Department and other ETO departments will deliver several key reports, which serve as the main outcomes of this phase:

1. The Preliminary TDR for the research infrastructure
2. TDR for the vacuum Beampipe;
3. Costing overview;
4. Risk assessment;
5. Planning report;
6. Organisational report;
7. Site(s) evaluation reports.

The final submission date of these reports is yet to be determined. However, the official ET-PP deliverables, like the TDR's, will follow the predefined ET-PP delivery schedule.

4.1 Civil Engineering

For the Civil Engineering, the main ETO milestone is the delivery of the Preliminary TDR for the research infrastructure, including a cost overview, by the end of 2026. For ET-PP, a first version of the Preliminary TDR is planned for mid-2026. An updated overall schedule for ET is currently being developed.

A roadmap definition document has been produced for the civil engineering [6]. The document outlines the major deliverables and products that are expected to be delivered by the end of Phase 1 for the Preliminary TDR. The roadmap definition document is a reference for:

- Identifying and accessing essential information necessary for developing and aligning the civil engineering design roadmap in the overall framework of ETO activity in Phase 1;
- Identifying potential gaps and defining responsibility roles for deliverables;
- Assisting in coordinating activities with local teams involved in the site studies.

Each deliverable is linked to key information, including the responsible unit for tasks or WPs, target delivery dates, necessary intermediate actions, prerequisites/required inputs, and its correspondence with the potential WBS element. Target delivery dates in the roadmap definition document represent the current knowledge of the schedules of the different stakeholders. These dates are not final and subject to change as new information regarding the timelines of ETO, ET-PP, and the local host consortia are updated and agreed upon [6].

4.2 Technical Infrastructure

For the technical infrastructure the main milestones do not align yet with the milestones of the civil engineering works. The Preliminary TDR, including a costing overview is expected to be available by September 2027. An updated overall schedule for ET is currently being defined.

As part of the framework collaboration agreement with CERN [3] on Technical Infrastructure and Safety, a detailed plan has been established, outlining CERN's participation in drafting the Preliminary TDR chapters, including cost estimations. The major deliverables for the technical infrastructure are specified in the roadmap definition document [6].

4.3 Engineering Technology

The beampipe development project was divided into eight different work packages, each with its own deliverables [7]. The main deliverable for ETO is the construction and testing of the Pilot Sector, including its validation and preparation of the TDR with a cost estimate of the complete system.

As part of the ET-PP framework, the Preliminary TDR was completed in January 2025, while the TDR is scheduled for completion in the fall of 2025. Extensive testing and optimization efforts are planned in the updated framework collaboration agreement [5]. A final update of the TDR and cost assessment are foreseen at the end of the agreement in September 2027.

4.4 Mechanical Engineering

As stated in paragraph 2.4, no team organisation has been established for Mechanical Engineering and nor has a roadmap with milestones been defined, as they are not considered critical for Preparatory Phase 1 and the site(s) selection process.

4.5 Integration and Coordination

The Integration and Coordination team has supported the ET Collaboration by providing engineering expertise and creating drawings for the ET Optical Layout in both the Triangular and 2L configurations.

These Optical Layouts serve as the bases for engineering the Detector Layouts. Following integration studies, the Detector Layouts studies define the minimum requirements for the local host consortia to design the underground infrastructure. Currently, the engineered Detector Layouts for the Triangle and 2L configurations are under review to explore potential cost reductions.

A comprehensive roadmap for Preparatory Phase 1 is under development.

5. Budget

While awaiting the formal establishment of ETO as a legal entity and the allocation of its budgets, the operational funding for the Engineering Department is provided by individual institutions, each covering its own expenses.

To manage ETO-related costs more efficiently, a dedicated group of ETO funders was established in December 2024. This fund, managed by the ETO directors, will enable the Engineering Department to expand its activities and enhance its operations until ETO is formally established as a legal entity.

6. Outlook

The Engineering Department has made significant progress in establishing itself as a functional entity. While not yet fully operational, it is on the right trajectory. The primary focus remains on Preparatory Phase 1, which ends with the site selection and principal approval for the Einstein Telescope's construction.

Strengthening Departmental Capacity:

- Securing contributions from research institutes, and universities to support the department's growth;
- Reducing dependency on CERN groups by securing additional resources from research institutes and universities;
- Prioritize efforts to hire CERN engineers, after they have completed their contracts.

Standardization of Engineering Tools:

- Establishing standardized software and digital tools across ETO and the wider Einstein Telescope Collaboration to streamline collaboration, design processes, and to improve efficiency: Computer-Aided Design (CAD), and Product Lifecycle Management (PLM);

Implementation of Model-Based Systems Engineering (MBSE)

- Integrating MBSE methodologies to ensure consistency across engineering activities.
- Facilitating a systems-level approach to design, documentation, and validation of the Einstein Telescope infrastructure.

By focusing on these priorities, the Engineering Department will strengthen its operational foundation and ensure its readiness for the next phases of the Einstein Telescope project.

7. References

- [1] ET-PP Deliverable 5.3 - Structure and the mandate of the Engineering Department V2.0, 21-01-2025, <https://apps.et-gw.eu/tds/?r=19398>
- [2] Addendum No.1 KR5754/SCE To Framework Collaboration Agreement KN 5637/TE, September 2023
- [3] Addendum NO.3 KR6246 To Framework Collaboration Agreement KN 5637/TE, March 2025
- [4] Addendum NO.1 KR5427/TE To Framework Collaboration Agreement KN 4657/DG, July 2022
- [5] Amendment NO.1 To Addendum NO.1 KR5427/TE To Framework Collaboration Agreement KN 5637/TE (Replacing 4657/DG), February 2025
- [6] ETO-Civil engineering Roadmap for Phase 1 V2, 29-01-2025, <https://edms.cern.ch/document/3185053/2>
- [7] ET-PP Infra-dev Kick-off Meeting - Vacuum Pipe Design, 19-07-2022, https://indico.ifae.es/event/1393/contributions/6072/attachments/2122/3437/ET_INFRA-DEV_kick-off_meeting.pptx

Appendix A: Composition by ETO Engineering department

Name	ETO Department	Role	Institute
Department Head			
Patrick Werneke	Engineering Department	Head of the Engineering Department	Nikhef
Civil Engineering			
Maria Marsella	Civil Engineering	Head of the Civil Engineering	INFN
Jonathan Bratanata	Civil Engineering	Geotechnical Engineer	Nikhef
Wissam Wahbeh	Civil Engineering	Architect	FHNW
Anita Digiulio	Civil Engineering	Geotechnical Engineer	INFN
John Osborne	Civil Engineering	Senior Civil Engineer and responsible for the agreement	CERN
Tamara Bud	Civil Engineering	Civil Engineer	CERN
Technical Infrastructure			
2 FTE	Cooling & Ventilation	Engineer	CERN
1 FTE	Access & Alarms	Engineer	CERN
1 FTE	Electricity Engineering	Engineer	CERN
3 FTE	Occupational Health and Safety	Engineer	CERN
Engineering Technology			
Marije Barel	Vacuum	Vacuum engineer	Nikhef
Agreement with CERN on the development of the Vacuum Beampipe			
Paolo Chiggiato	-	TE-VSC group Leader and responsible for the agreement	CERN
2 FTE	-	Engineers	CERN
ET-PP partners supporting the Beampipe development at CERN			
Rafael Garcia	-	Engineer	IFAE
Marc Andres	-	Engineer	IFAE
Julia Mundet	-	Engineer	IFAE
Purnalingam Revathi	-	Engineer	University of Antwerp
Alexey Gervasyev	-	Materials Engineer	University of Gent
Alexandre Lacroix	-	Vacuum Engineer	CNRS
Guillaume Deleglise	-	Engineer	CNRS

Deliverable 5.4. Functional ETO Engineering Department

Name	ETO Department	Role	Institute
Mechanical Engineering			
-	-	-	-
Coordination & Integration			
Max Majoor	Coordination & Integration	Mechanical Engineer	Nikhef
Tommaso Napolitano	Coordination & Integration	Mechanical Engineer	INFN
Gregory Iaquaniello	Coordination & Integration	Mechanical Engineer	CNRS