# ET beampipe activities at CERN: Towards the TDR

*ET-beampipe team at CERN*

December 11th, 2023

# ET-beampipe team at CERN

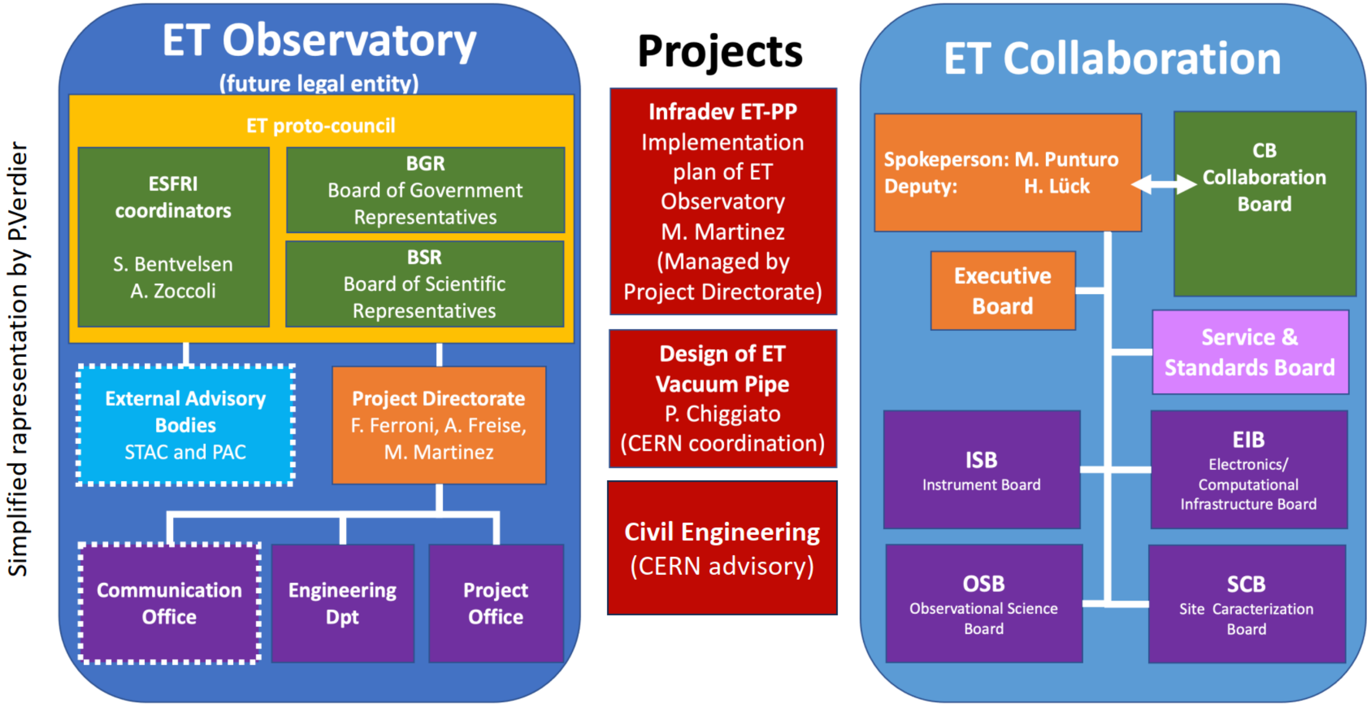
| Name | Competences |
|---|---|
| Cedric Garion | Structural mechanics |
| Carlotta Accettura | Mechanical design |
| Ana Teresa Perez | Metallurgy |
| Luca Gentini | Mechanical design |
| Gilles Favre | Manufacturing |
| Audrey Vichard | Welding |
| Stefano Sgobba | Metallurgy |
| Manjunath Dakshinamurthy | Metallurgy |
| Leonel Ferreira | Surface treatments |
| Mauro Taborelli | Surface analysis |

| Name | Competences |
|---|---|
| Luigi Scibile | Premises and logistics |
| Gregory Pigny | Vacuum control |
| Giuseppe Bregliozzi | Vacuum engineering |
| Carlo Scarcia | Vacuum engineering and metallurgy |
| Jose Ferreira | Vacuum modelling |
| Alice Michet | Vacuum measurement |
| Jan Hansen | Mechanical engineering |
| Ivo Wevers | Vacuum measurement |
| Paolo Chiggiato | Coordination |

# Where we are in the ET galaxy

The CERN's team:

- is contractually **linked to Nikhef and INFN** through the **Engineering Department**.
- receives **inputs (functional specifications) from the collaboration link persons**: Aniello Grado and Nick Van Remortel.
- gives **progress report** to the collaboration during workshops, conferences and dedicated meetings.




Source: **M. Punturo**, CERN colloquium, November 30th, 2023 (simplified representation by **P. Verdier**).

Engineering Department

ET beampipe at CERN

A. Grado & N. Van Remortel

ET Collaboration

# The main objective and deliverable

**Our main objective**: Provide the ET project with **technological solutions** for the beampipe that fulfil the requirements, and that are **less expensive than the baseline** (i.e., the existing VIRGO/LIGO beampipe).


**Our main deliverable** is the writing of the **TDR** for the ET beampipe.
The TDR will be written in **two steps**:

1. **A preliminary version by Q4-2024**, including all requirements, beampipe and baffles design, materials, installation procedures, without fabrication details (i.e., no 2-D drawings).
2. **A final version by Q4-2025** will encompass refined technical solutions. Fabrication details and 2D drawings will be included.

# Towards the TDR

Source Wikipedia: Giacomo Balla "Dynamism of a Dog on a Leash "

# How we are pursuing the TDR

**Work structure and phases**

**Personnel**

Source Wikipedia: Quentin Matsys The Money Lender and His Wife

Source Wikipedia Pieter Brueghel (II) - The four seasons, spring

**Collaborations**

**Available budget**

# How we are pursuing the TDR

## The work structure.

**WP1: engineering**
Design and engineering of the vacuum chamber

**WP2: production**
Choice of materials and manufacturing technology

**WP3: treatments**
Choice of post-manufacturing treatments

**WP4: transport**
Handling and logistics

**WP5: installation**
Installation procedure and interface with other systems

**WP6: vacuum**
Choice of vacuum pumps and valves

**WP7: prototyping**
Installation and test of a pilot sector

**WP8: coordination**
Coordination of the different work packages and contribution of collaborators

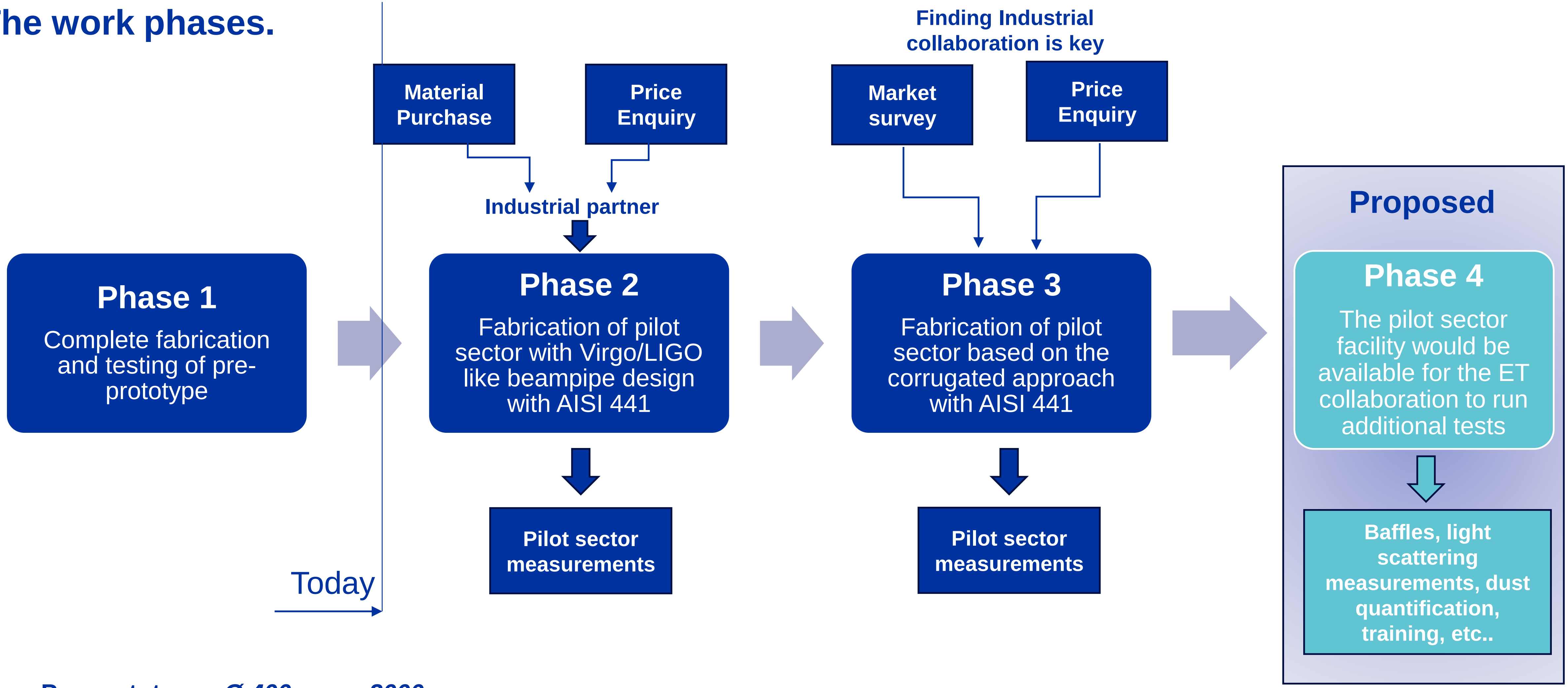
Each work package will provide **input for the TDR** and cost estimation.

The work packages are **interconnected,** and they need active coordination.

**WP1, WP2 and WP6 are the most advanced** as they started before the signature of the addendum. **WP8 is today's priority**.

# How we are pursuing the TDR

## The work phases.




- **Pre-prototype : *Ø 400 mm x 2000 mm***
- **Pilot sector : *Ø 1000 mm x 36000 mm***

# How we are pursuing the TDR: Personnel

In the same team, **all required competences** are available, **but GWT operation** for which **we rely on the Virgo and LIGO experts.**

| Name | Competences | Workpackage |
|---|---|---|
| Cedric Garion | Structural mechanics | WP1 |
| Carlotta Accettura | Mechanical design | WP1 |
| Luca Gentini | Mechanical design | WP1 |
| Ana Teresa Perez | Metallurgy | WP2/WP8 |
| Gilles Favre | Manufacturing | WP2 |
| Audrey Vichard | Welding | WP2 |
| Stefano Sgobba | Metallurgy | WP2 |
| Manjunath Dakshinamurthy | Metallurgy | WP2 |
| Leonel Ferreira | Surface treatments | WP3 |
| Mauro Taborelli | Surface analysis | WP3 |

| Name | Competences | Workpackage |
|---|---|---|
| Luigi Scibile | Premises and logistics | WP4&WP5 |
| Gregory Pigny | Vacuum control | WP6 |
| Giuseppe Bregliozzi | Vacuum engineering | WP6 |
| Carlo Scarcia | Vacuum engineering | WP2/WP6 |
| Jose Ferreira | Vacuum modelling | WP6/WP7 |
| Alice Michet | Vacuum measurement | WP6 |
| Jan Hansen | Mechanical engineering | WP7 |
| Ivo Wevers | Vacuum measurement | WP6/WP7 |
| Paolo Chiggiato | Coordination | WP8 |

By contract, during the three-year agreement, **two FTE/y of CERN staff** and **two CERN fellows** are dedicated to ET.

# How we are pursuing the TDR: Collaborations

| Institute | Subject | Type of agreement | Contacts |
|---|---|---|---|
| CNRS LAPP | Mechanical design | Informal collaboration<br>Chair of WP1 | Guillaume Deleglise |
| CNRS IJCLab | Design of ‘baseline solution’ | Informal collaboration | Denis Reynet / G. Iaquaniello |
| IFAE | Baffles design and integration | Framework agreement | Mario Martinez / Marc Andres |
| Nikhef | Pumping modules and alignment | Framework agreement | Martijn van Overbeek / Patrick Werneke / Marije Barel |
| Uni. Gent | Pipeline solution | Informal collaboration<br>(Post-doc at CERN) | Leo Kestens / Alexey Gervasyev |
| Uni. Aachen | Supervision of a PhD student | Gentner programme | Achim Stahl |
| INFN | Magnetic and surface cleaning measurements | Framework agreement<br>(PhD student at CERN) | Aniello Grado |
| Uni. Antwerp | Vac. eng. at CERN for 2 years | Collaboration agreement | Nick Van Remortel |

**Cooperation with industries**: Aperam, Arvedi, SAES,…

# How we are pursuing the TDR: Budget

We are gradually receiving:

For the payment of **two CERN fellows**: **600 kCHF** (Nikhef and INFN).

For the compensation (50% of real costs) of **6 FTE-years of staff members**, including overheads: **433 kCHF** (Nikhef and INFN, 50% each).

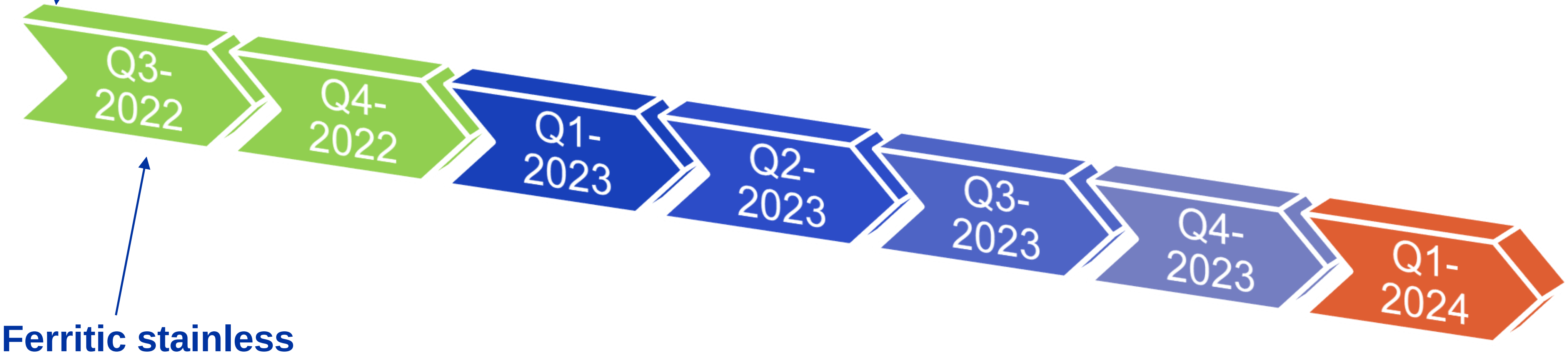
For **material**: **100 kCHF** from CERN, **50 kCHF** from INFN and **50 kCHF** from Nikhef.

# Main achievements

Source Wikipedia: Giuseppe Bottani - Athena revealing Ithaca to Ulysses

# Main achievements

**Mild steel: firing not needed to attain requirements**




**Ferritic stainless steels: firing not needed to attain requirements**

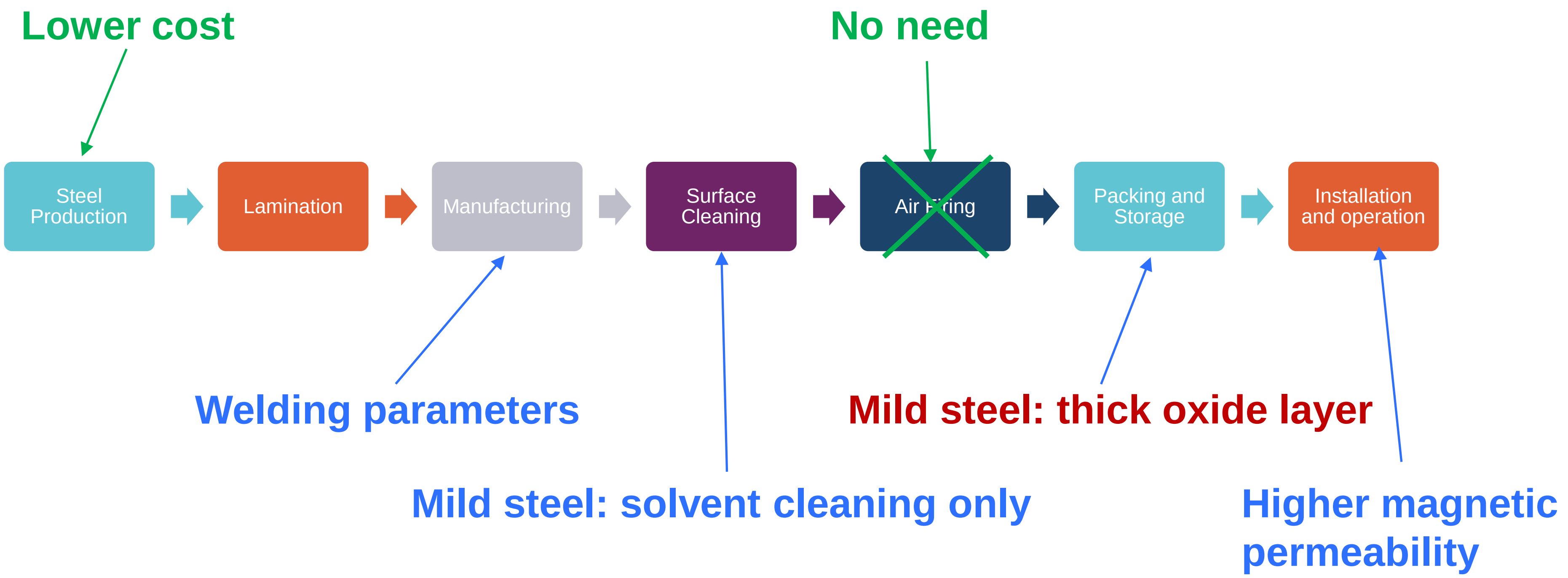
# Use of ferritic steels instead of the baseline AISI 304L

**Pros:**

- Lower cost of raw material per mass unit.
- High temperature degassing is not needed.

**Points of development:**

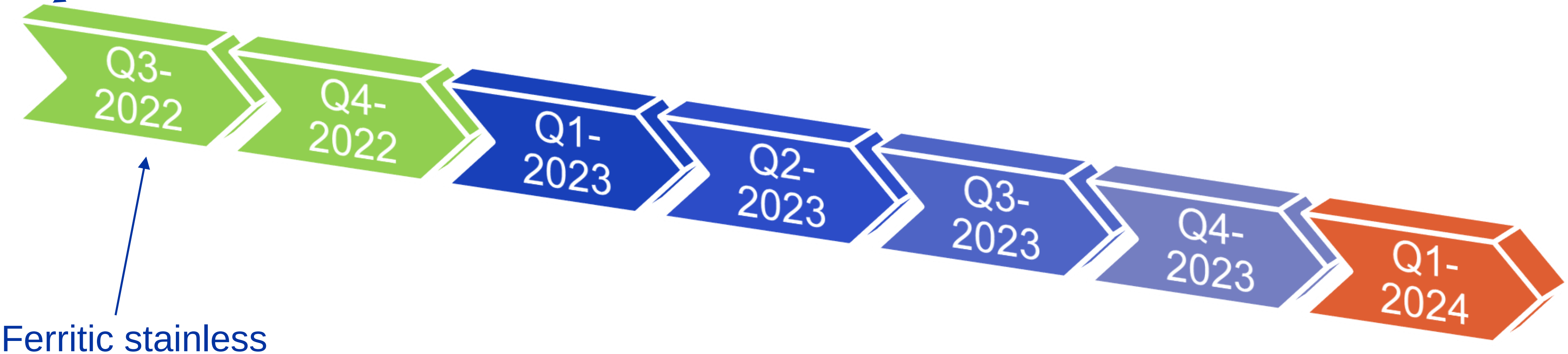
- Increase experience in ultrahigh vacuum systems.
- Calculate the effect of the high magn. permeability.
- Welding parameters to be studied in detail.
- For mild steels: procedure to prevent thick oxide formation.



# Main achievements

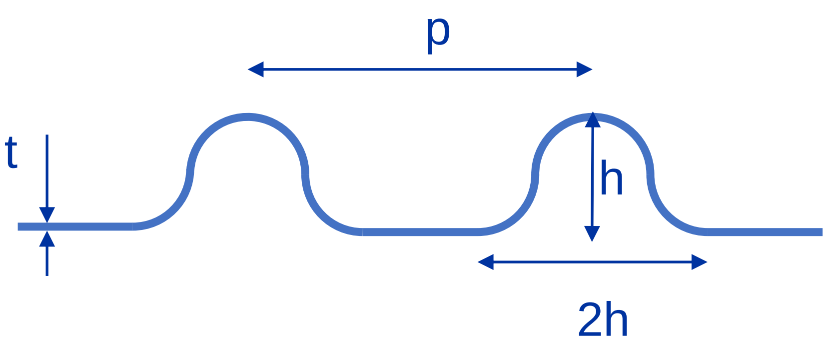
Mild steel: firing not needed to attain requirements

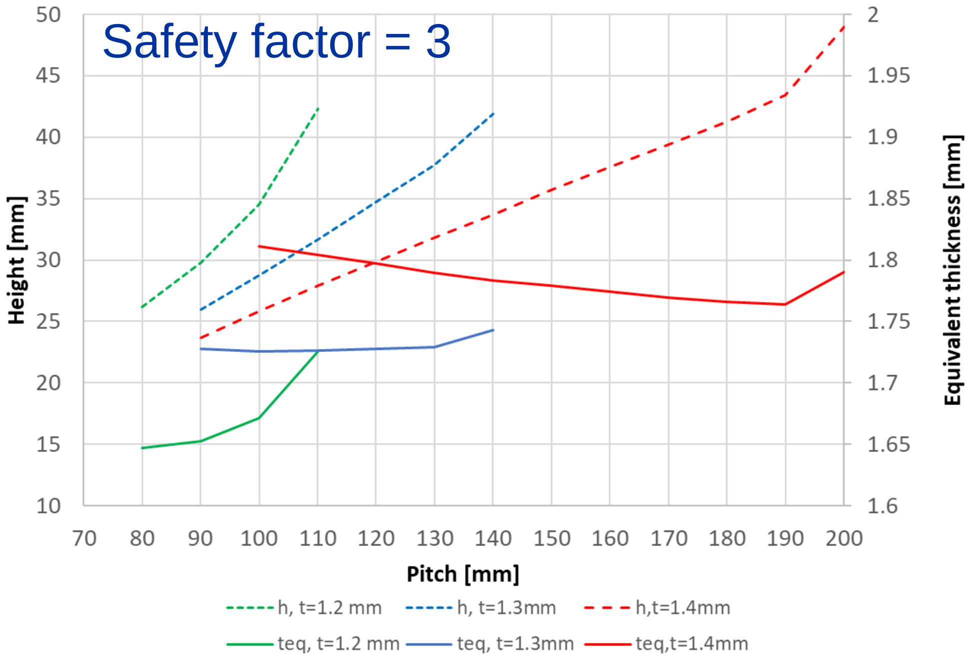
**Design of a corrugated beampipe**




Ferritic stainless steels: firing not needed to attain requirements

# Use of corrugated beampipes instead of the stiffened smooth pipes




## Pros:

- Thinner sheets (around 1.5 mm) instead of 4 mm:
  - → lower material cost,
  - → easier handling,
  - → lower elect. current for bakeout.
- Expansion bellows are not needed.
- Coil-to-pipe automatise process.

## Points of development:

- Optimisation of the support system.
- Industrialisation for ultrahigh vacuum applications.
- Optical baffle integration.

Sources:

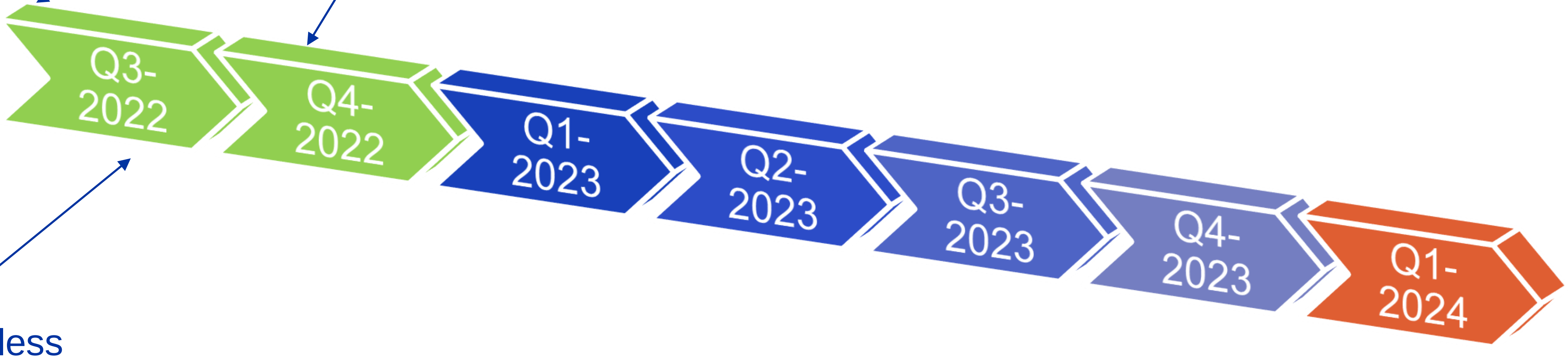
- https://www.corrugatedmetalpipe.com/corrugatedmetalpipe/spiral-corrugated-pipe.html
- https://www.prdcompany.com/corrugated-metal-pipe/

# Main achievements

Mild steel: firing not needed to attain requirements

Design of a corrugated beampipe

**Design of the pre-prototypes**

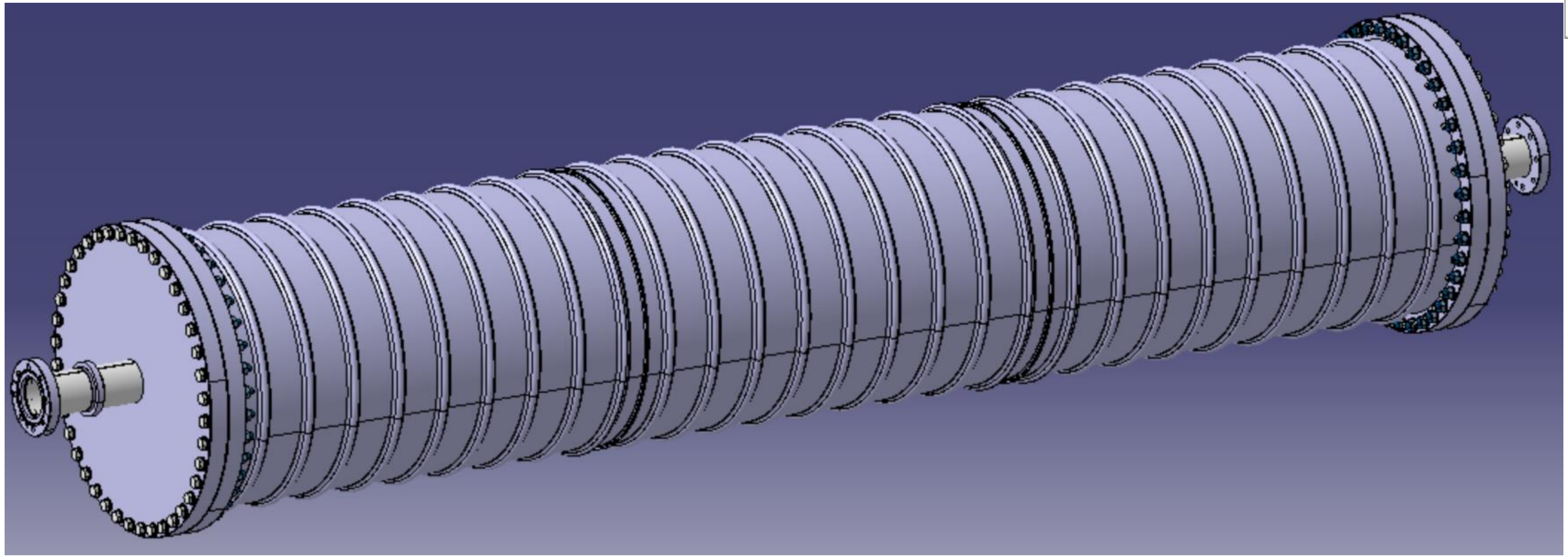


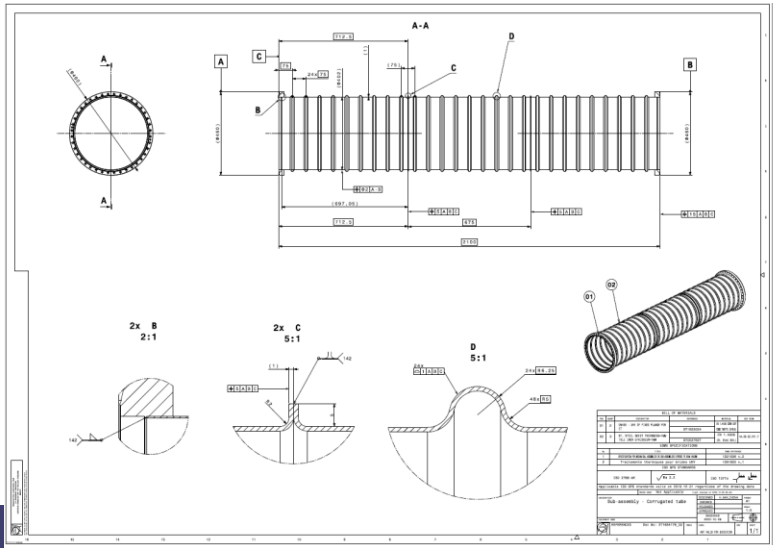

Ferritic stainless steels: firing not needed to attain requirements

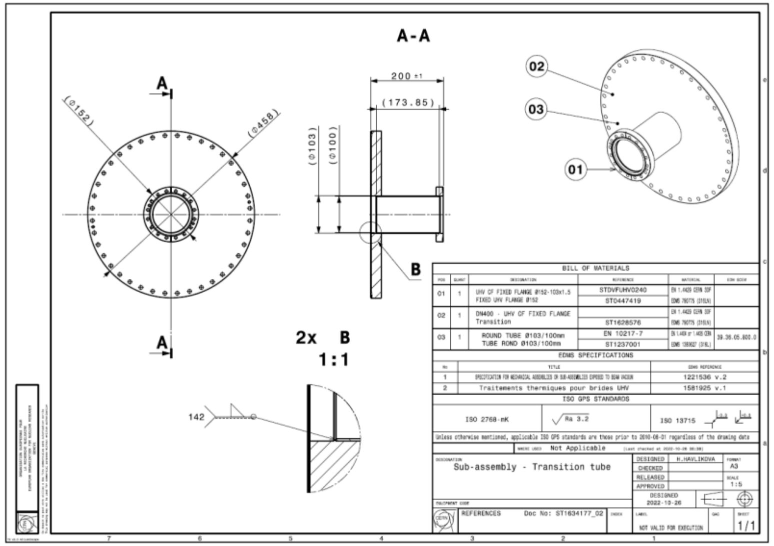
# Design of the pre-prototypes

Corrugated pipe with thin wall (thickness in the order of 1.3 mm)

- Three segments of 675 mm, total length of **2.1 m**
- Internal **diameter: 402 mm**
- Three materials: **AISI 304, mild steel, and AISI 441**





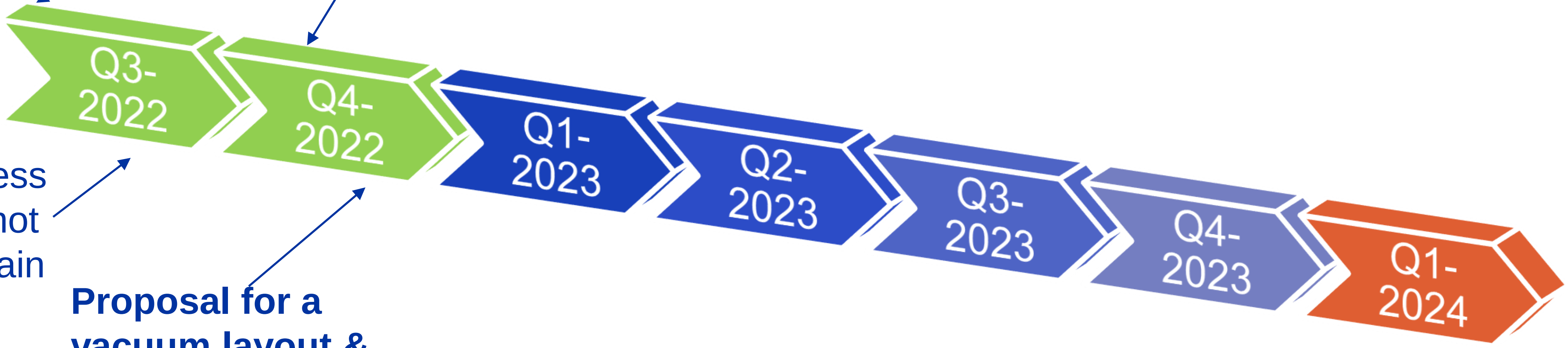



# Main achievements

Mild steel: firing not needed to attain requirements

Design of a corrugated beampipe

Design of the pre-prototypes

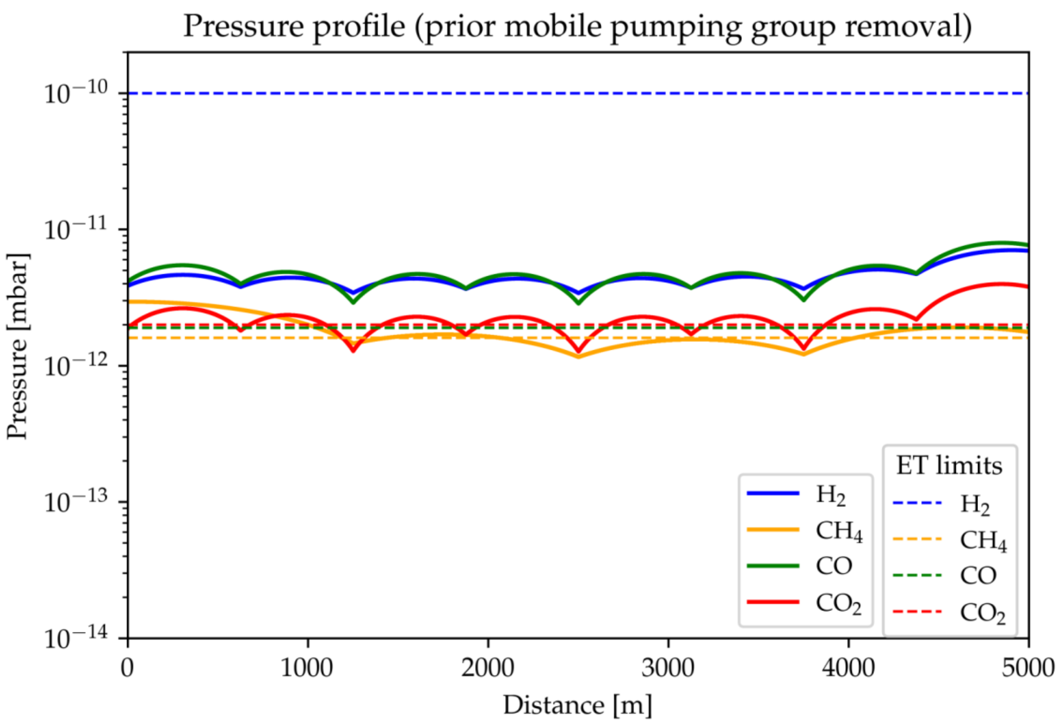


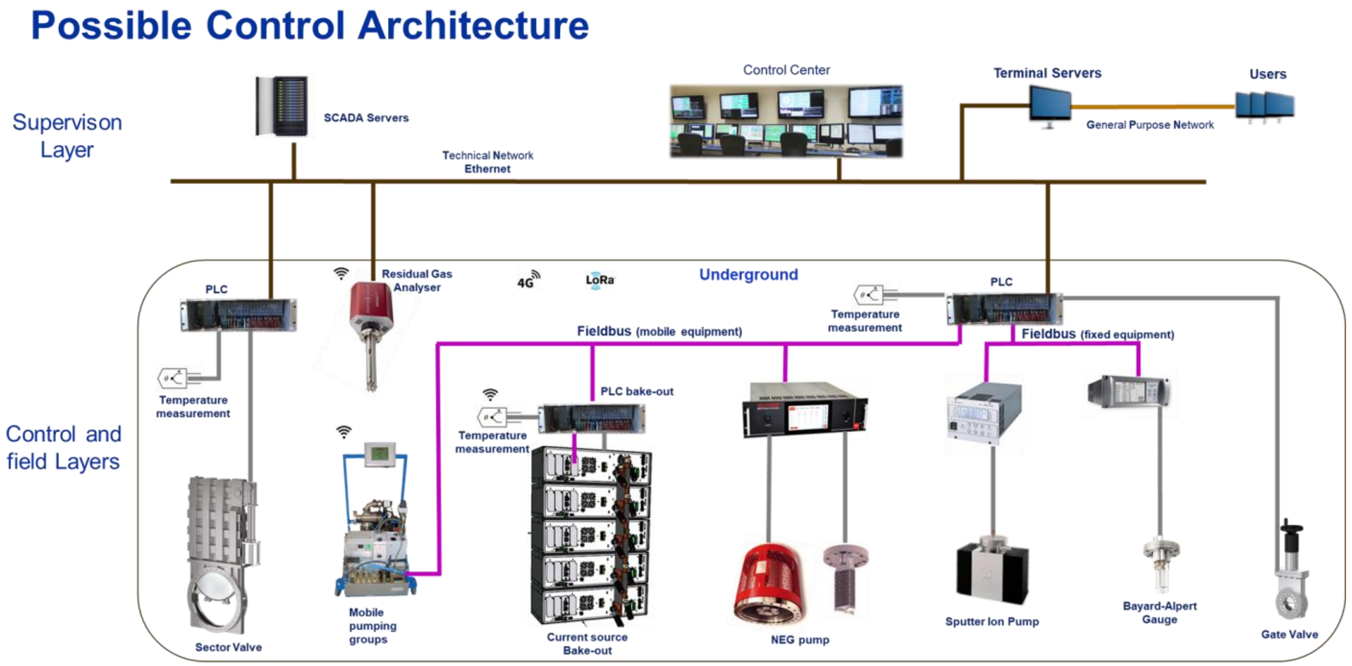

Ferritic stainless steels: firing not needed to attain requirements

**Proposal for a vacuum layout & control system**

# Proposal for a vacuum layout & control system

The **sectorisation** and the **pumping module positions** were investigated.
The partial **pressure profiles** were calculated.
We formulated the first proposal for **monitoring and control** of the vacuum system.



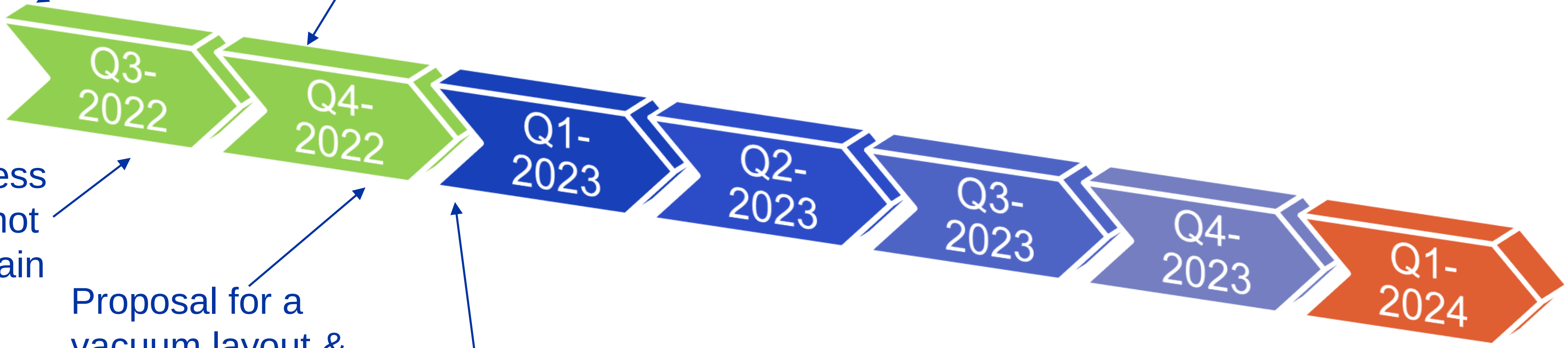



# Main achievements

Mild steel: firing not needed to attain requirements

Design of a corrugated beampipe

Design of the pre-prototypes



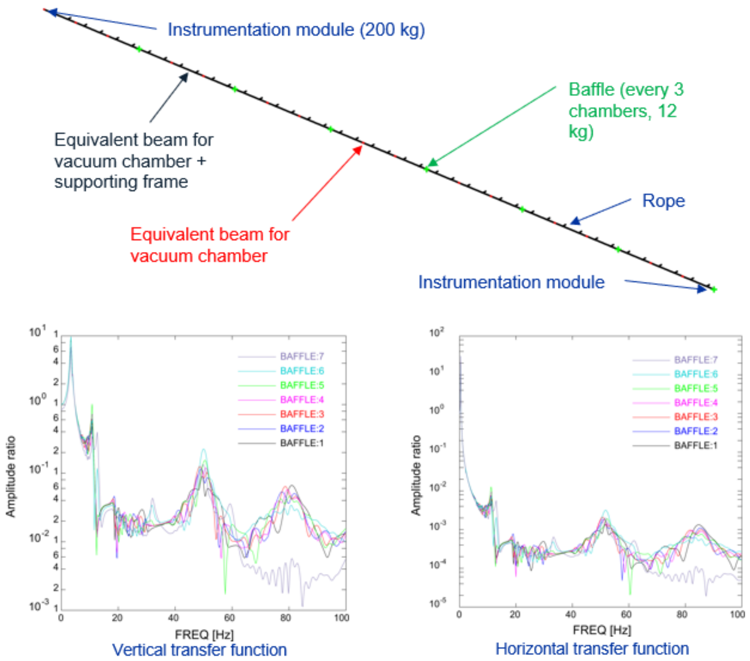

Ferritic stainless steels: firing not needed to attain requirements

Proposal for a vacuum layout & control system

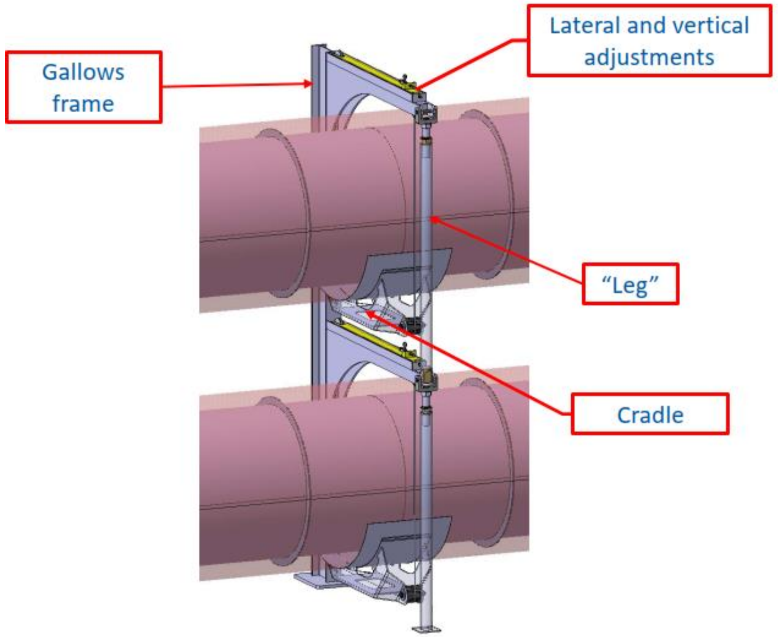
**Support system & vibration analysis**

# Proposal for a vacuum layout & control system

Vibration transfer function at the position of the optical baffles calculated for a 315 m long section.

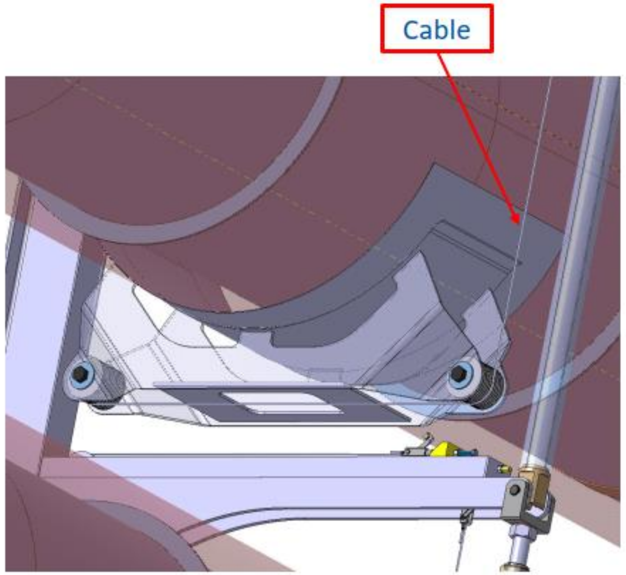



Proposal of supports aimed at reducing amplification of microseismic vibrations.




Supports

Details of the support, including electrical insulation.




Cradle (horizontal damper not represented) suspended by steel cable

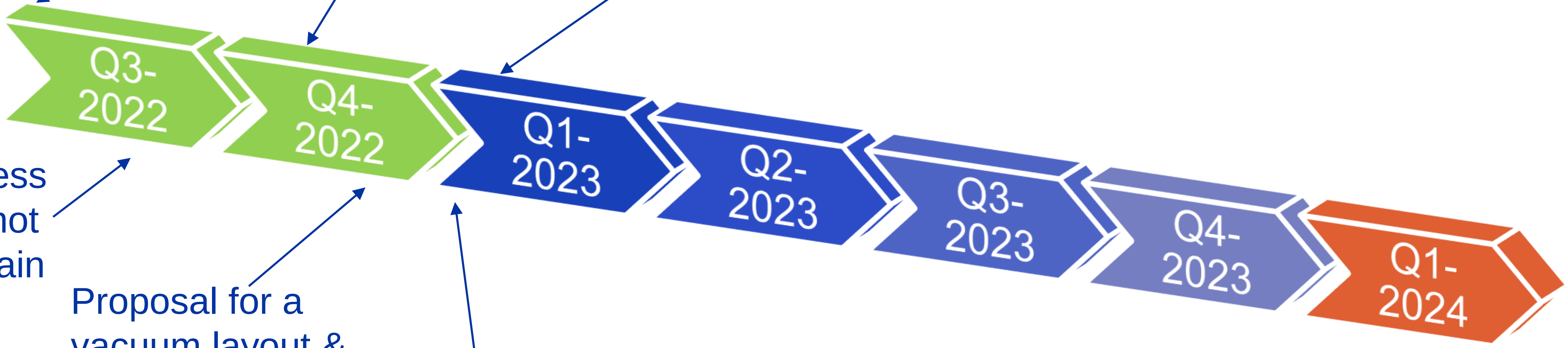
# Main achievements

Mild steel: firing not needed to attain requirements

Design of a corrugated beampipe

**Strategy for surface cleaning & metallurgical studies**

Design of the pre-prototypes




Ferritic stainless steels: firing not needed to attain requirements

Proposal for a vacuum layout & control system

Support system & vibration analysis

# Strategy for surface cleaning

Source: JettyRobot

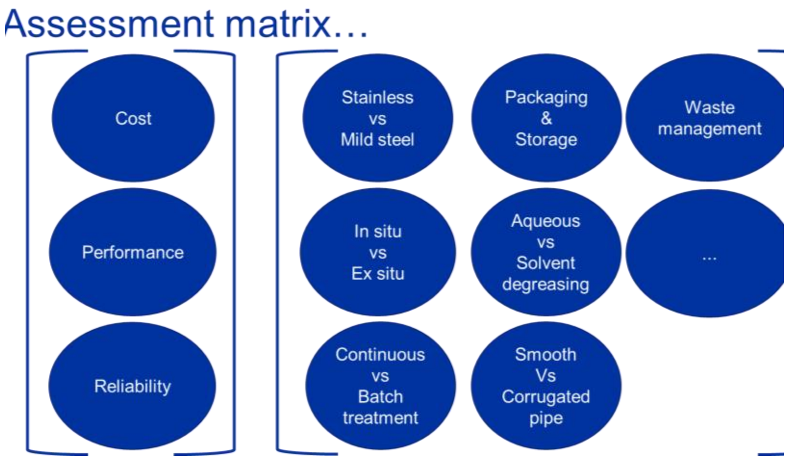
It was decided to study two cleaning methods: **solvents** and **detergents**, both in the industry or in-situ.

For the **pilot sector,** three options were selected:

- cleaning in the industry (Poligrat GmbH, after assessment)

- Cleaning by robot at CERN (JettyRobot, after assessment)

- cleaning in the CERN existing facilities; in this case, the pilot sector unit length must be lower than 7 m.

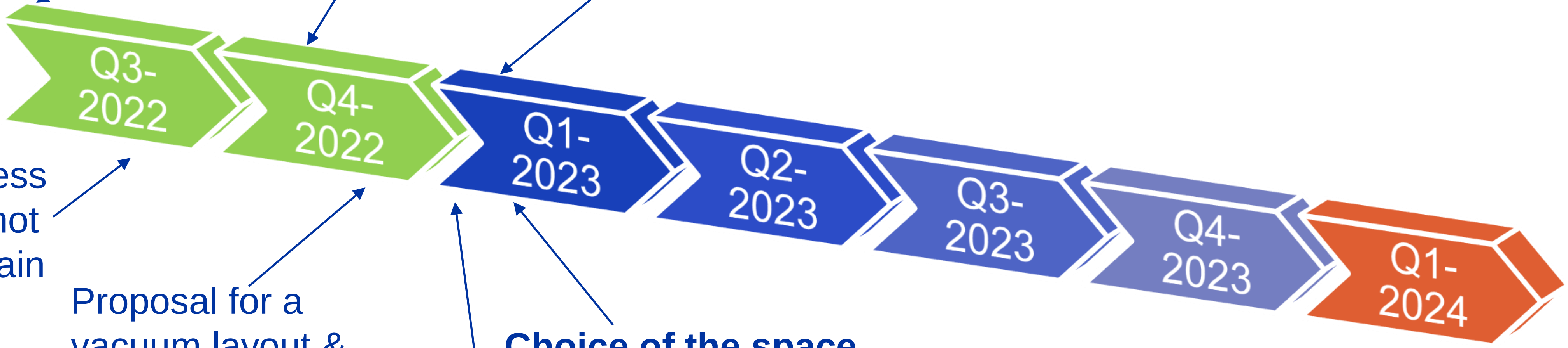
# Main achievements

Mild steel: firing not needed to attain requirements

Design of a corrugated beampipe

Design of the pre-prototypes

Strategy for surface cleaning & metallurgical studies




Ferritic stainless steels: firing not needed to attain requirements

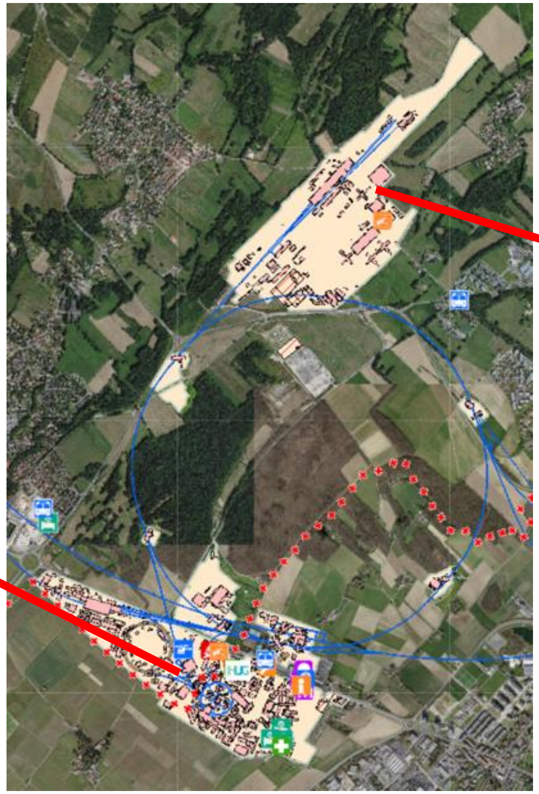
Proposal for a vacuum layout & control system

**Choice of the space for the pilot sector**

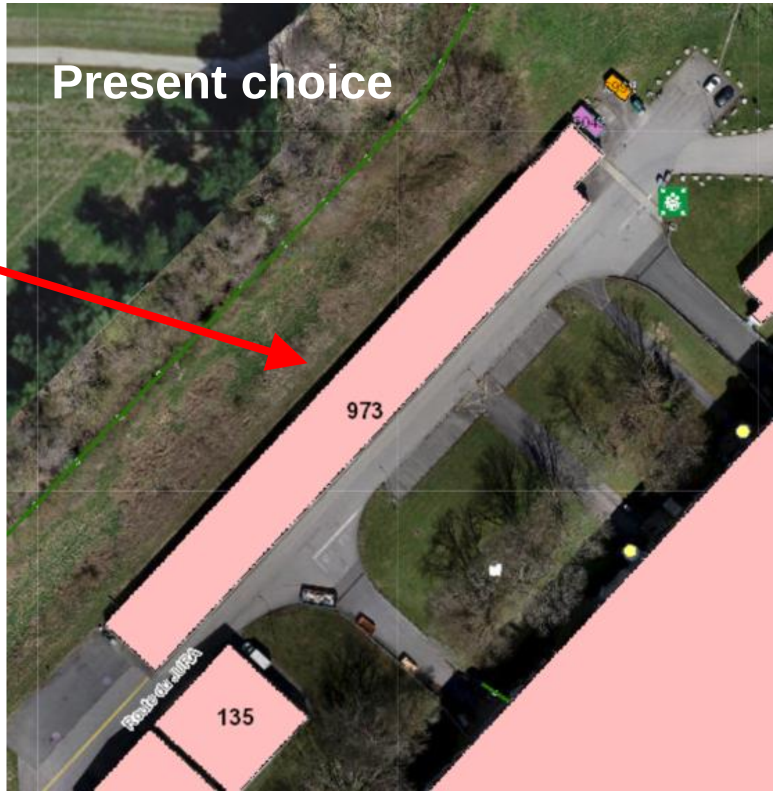
Support system & vibration analysis

# Choice of the space for the pilot sector

TT1 tunnel



Bulding 973




Pros of B. 973

- ✓ Available from Q1/Q2 2024.
- ✓ Easy access/installation.
- ✓ Sufficient space for double tube setup.

Cons of B. 973

- ✓ As it is now: no temperature and humidity control.

# Main achievements

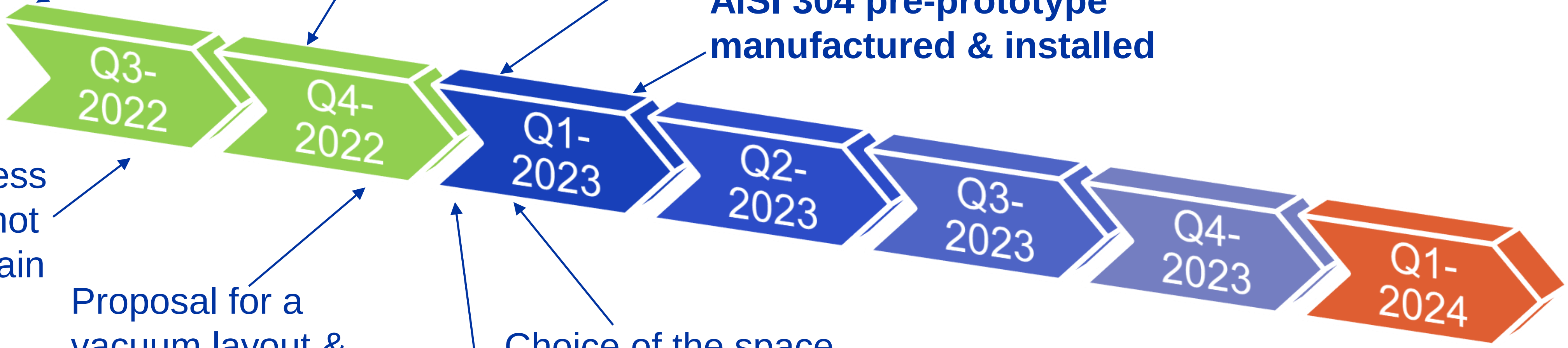
Mild steel: firing not needed to attain requirements

Design of a corrugated beampipe

Strategy for surface cleaning & metallurgical studies

Design of the pre-prototypes

**AISI 304 pre-prototype manufactured & installed**




Ferritic stainless steels: firing not needed to attain requirements

Proposal for a vacuum layout & control system

Choice of the space for the pilot sector

Support system & vibration analysis

# AISI 304 pre-prototype manufactured & installed


# Main achievements

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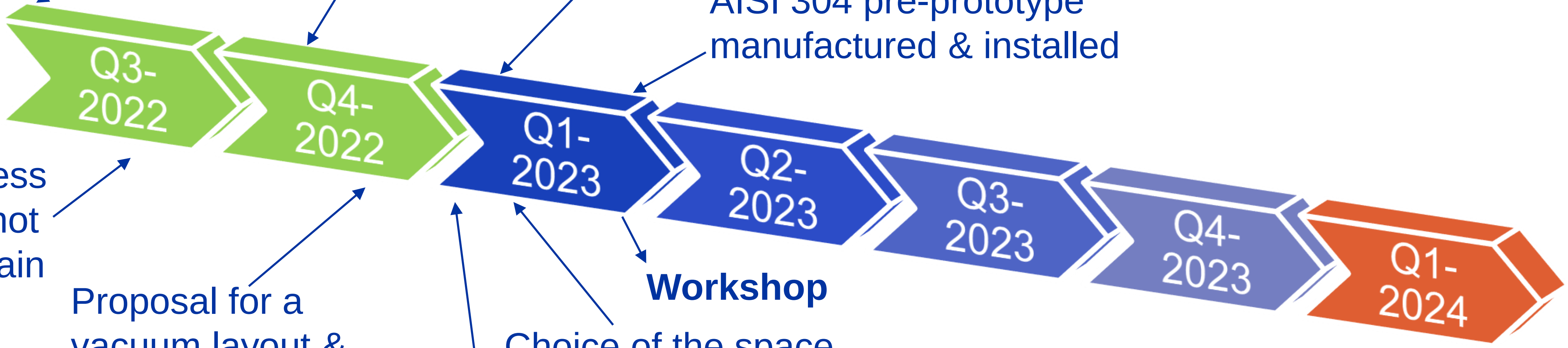
AISI 304 pre-prototype manufactured & installed




Ferritic stainless steels: firing not needed to attain requirements

Proposal for a vacuum layout & control system

Support system & vibration analysis

Choice of the space for the pilot sector

**Workshop**

# Workshop Beampipe for Gravitational Wave Telescopes 2023

Beampipes for Gravitational Wave Telescopes 2023

## Beampipe know-how for GW observatories

The direct detection of gravitational waves (GWs) in 2015 opened a new window to the universe, allowing researchers to study the cosmos by merging data from multiple sources. There are currently four gravitational wave telescopes (GWTs) in operation: LIGO at two sites in the US, Virgo in Italy, KAGRA in Japan and GEO600 in Germany. Discussions are ongoing to establish an additional site in India. The detection of GWs is based on Michelson laser interferometry with Fabry–Perot cavities, which reveals the expansion and contraction of space at the level of ten-thousandths of the size of an atomic nucleus, i.e. $10^{-19}$ m. Despite the extremely low strain that needs to be detected, an average of one GW is measured per week of measurement by studying and minimising all possible noise sources, including seismic vibration and residual gas scattering. The latter is reduced

C Hervet

**Beam me up**
*The participants of the March workshop that was dedicated to vacuum technologies for beampipes of next-generation gravitational-wave telescopes.*

solutions were adopted, then the
uum pipe system would amount t
the estimated cost of the CE and a
one-third of the ET, with undergr
civil engineering the dominant am
Reducing the cost of vacuum sys
requires the development of diff
technical approaches with respect t
vious-generation facilities. Devel
cheaper technologies is also a key s

Published in the July-August issue of the CERN Courier

### Workshop on Beampipes for GWT at CERN

**Institutes:**

Caltech-LIGO
MIT-LIGO
CERN
CNRS-LAPP
CNRS-IJCLab
Cornell University
DESY
EGO-Virgo
FermiLab
Forschungszentrum Jülich GmbH
Ghent University
IFAE
INFN (INAF, Roma, LNF, Perugia)
KIT
KEK
Material Forensics LLC
NIST
Nikhef
Rheinisch Westfaelische Tech. Hoch.
Syracuse University / Cosmic Explorer
The Barcelona Institute of Science and Technology
Universiteit Antwerpen
University of Padua

**Industry:**

Agilent Vacuum Product Division
APERAM
Atlas Copco
C3DM Germany
Ecoclean GmbH
FEF Aachen
Leybold
SAES Getters S.p.A
VDL ETG
Voestalpine

- 84 participants (20 from CERN)
- 26 talks
- 3 topical discussions with final reporting
- Visits to surface treatments and mechanical workshops
- CERN visit.

# Main achievements

Mild steel: firing not needed to attain requirements

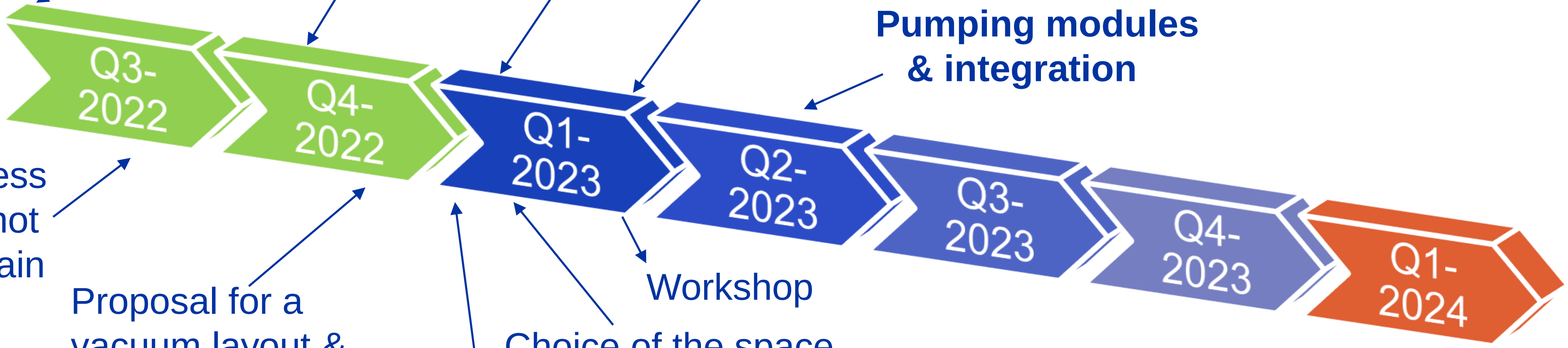
Design of a corrugated beampipe

Design of the pre-prototypes

Strategy for surface cleaning & metallurgical studies

AISI 304 pre-prototype manufactured & installed

**Pumping modules & integration**




Ferritic stainless steels: firing not needed to attain requirements

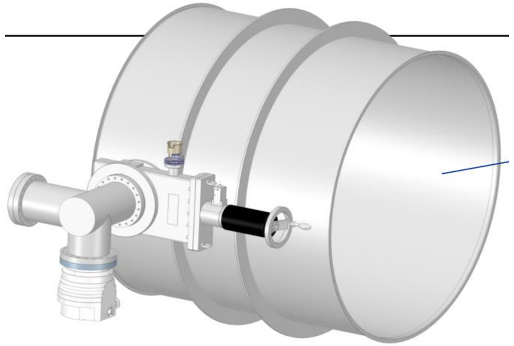
Proposal for a vacuum layout & control system

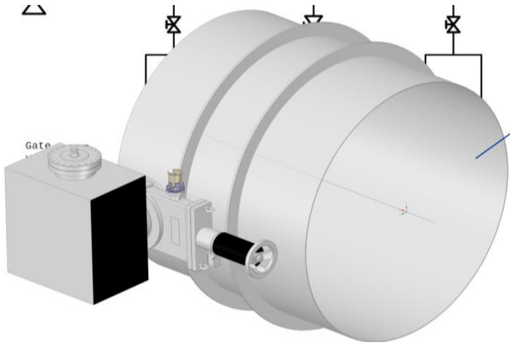
Workshop

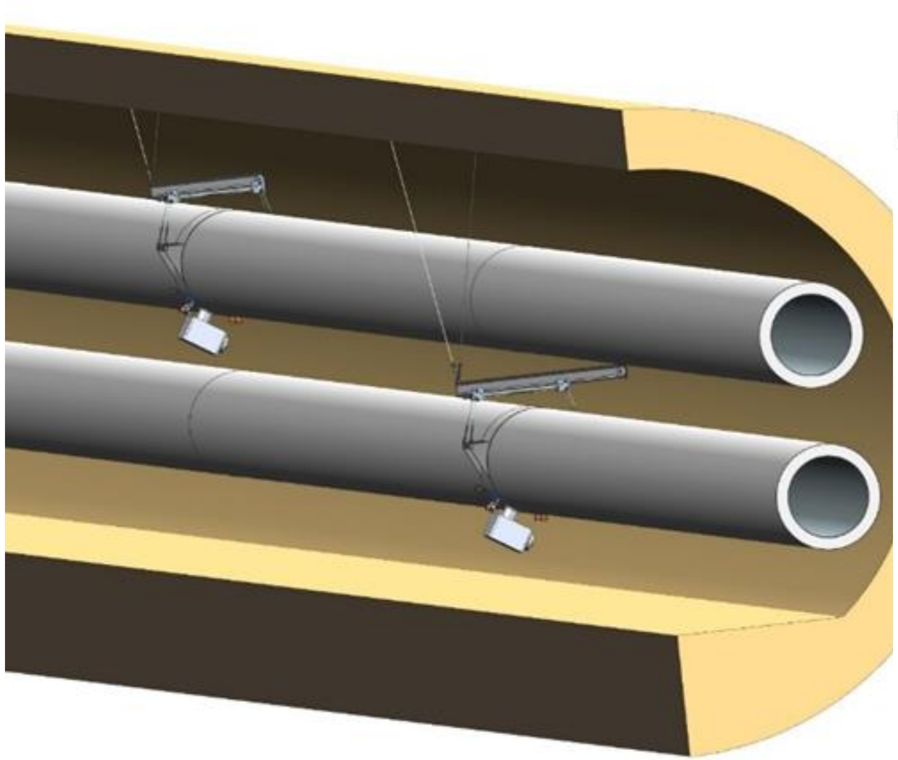
Choice of the space for the pilot sector

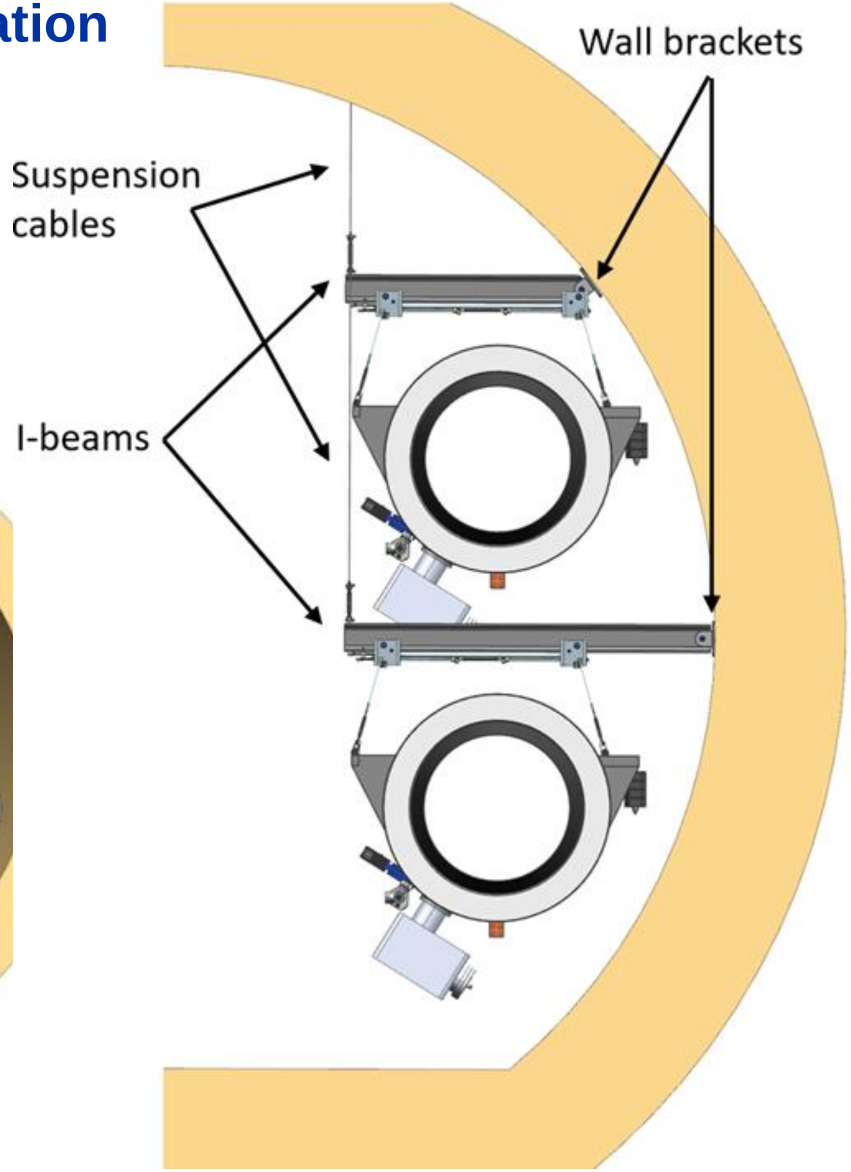
Support system & vibration analysis

# Pumping modules & their integration










Martijn van Overbeek (Nikhef)

# Main achievements

Mild steel: firing not needed to attain requirements

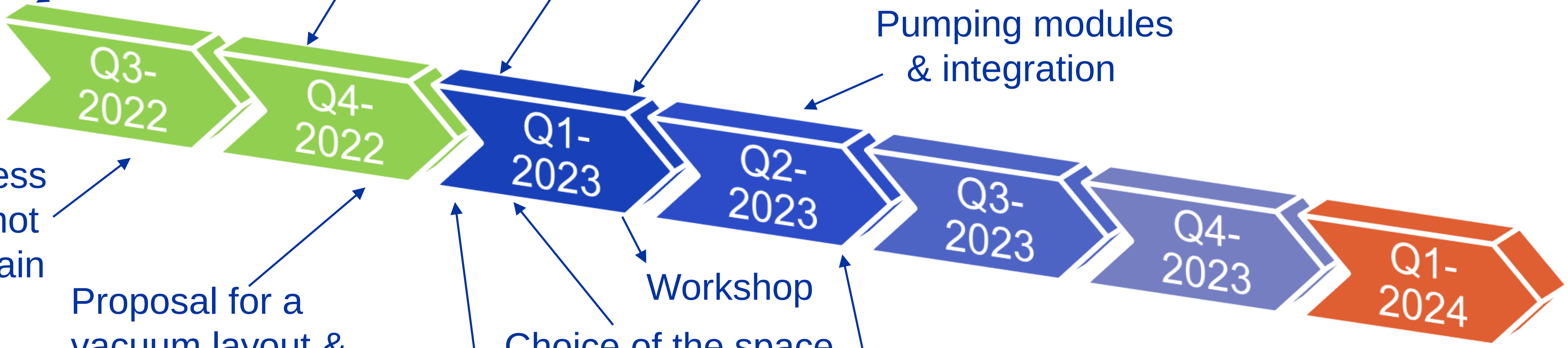
Design of a corrugated beampipe

Design of the pre-prototypes

Strategy for surface cleaning & metallurgical studies

AISI 304 pre-prototype manufactured & installed

Pumping modules & integration




Ferritic stainless steels: firing not needed to attain requirements

Proposal for a vacuum layout & control system

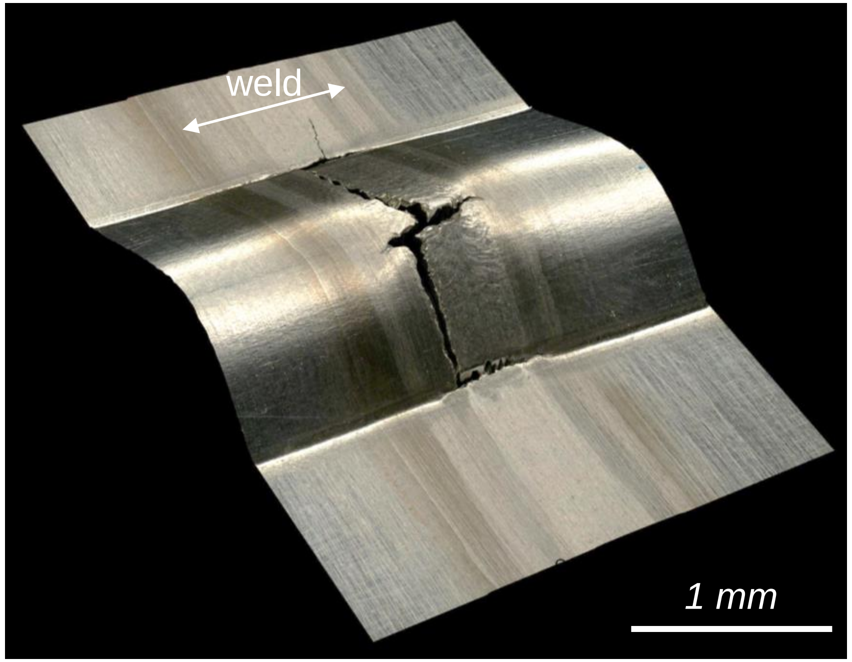
Support system & vibration analysis

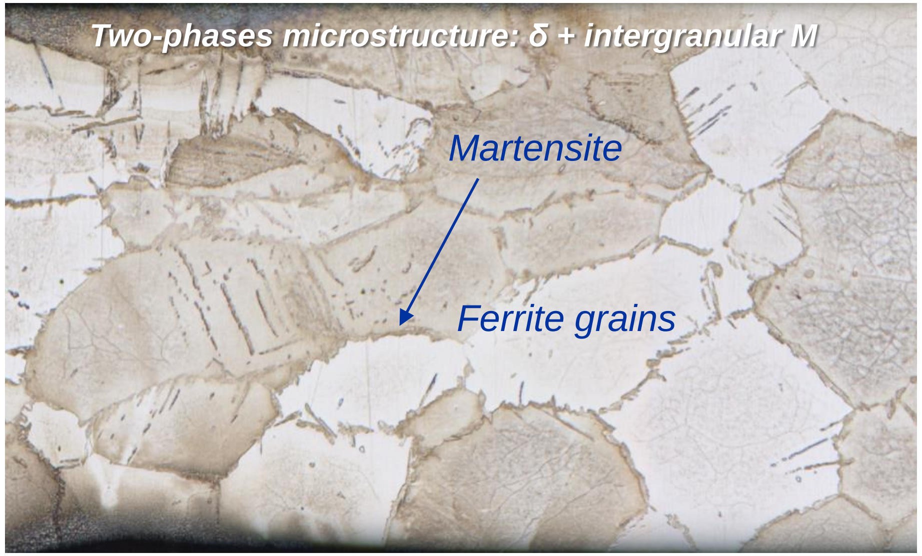
Choice of the space for the pilot sector

Workshop

**Welding studies for AISI 430, 444 and 441**

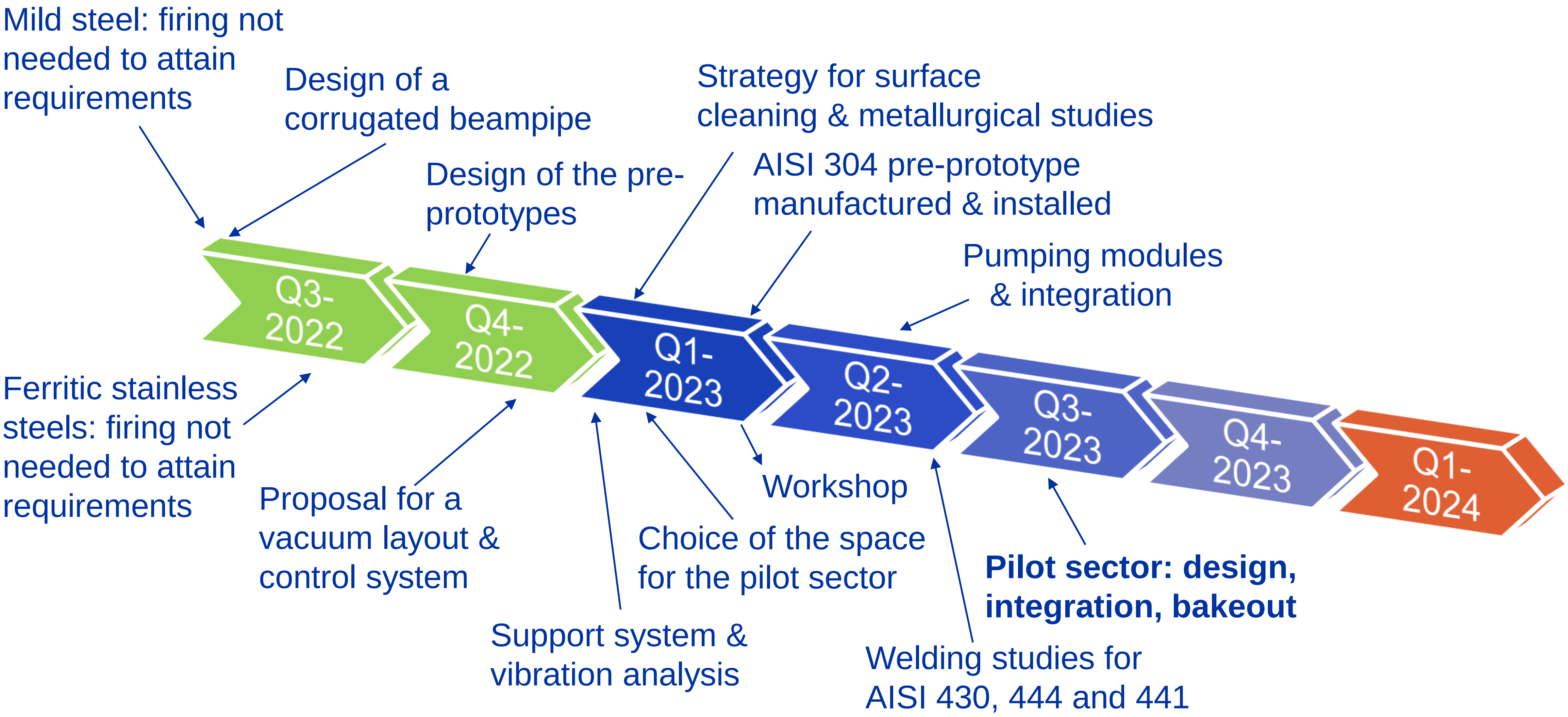
# Welding studies for AISI 430, 444 and 441

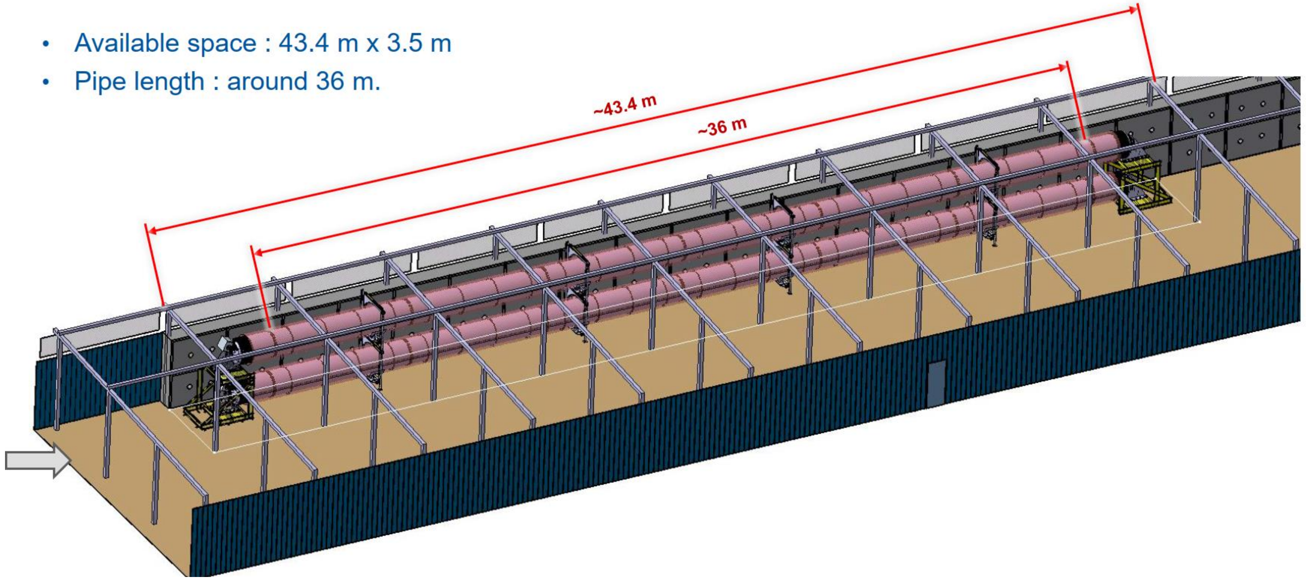

**AISI 430 TIG autogenous weld (1st trial):** The piece presented a major failure at the level of the longitudinal weld during corrugation operation. This results triggered a systematic studies of ferritic stainless-steel weldability

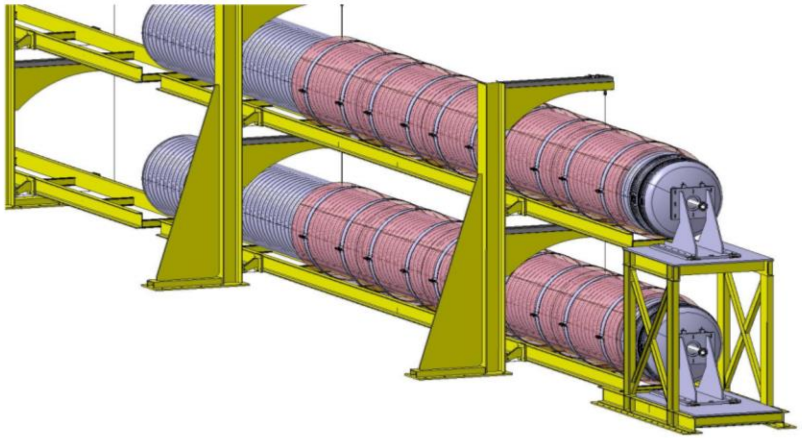
# Main achievements

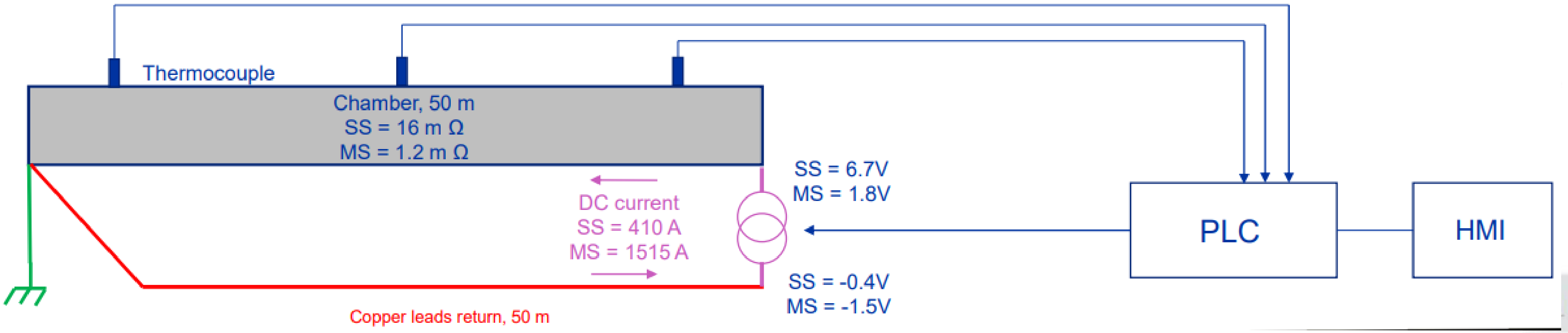


# Pilot sector: design, integration, bakeout

- Available space : 43.4 m x 3.5 m
- Pipe length : around 36 m.






# Main achievements

Mild steel: firing not needed to attain requirements

Design of a corrugated beampipe

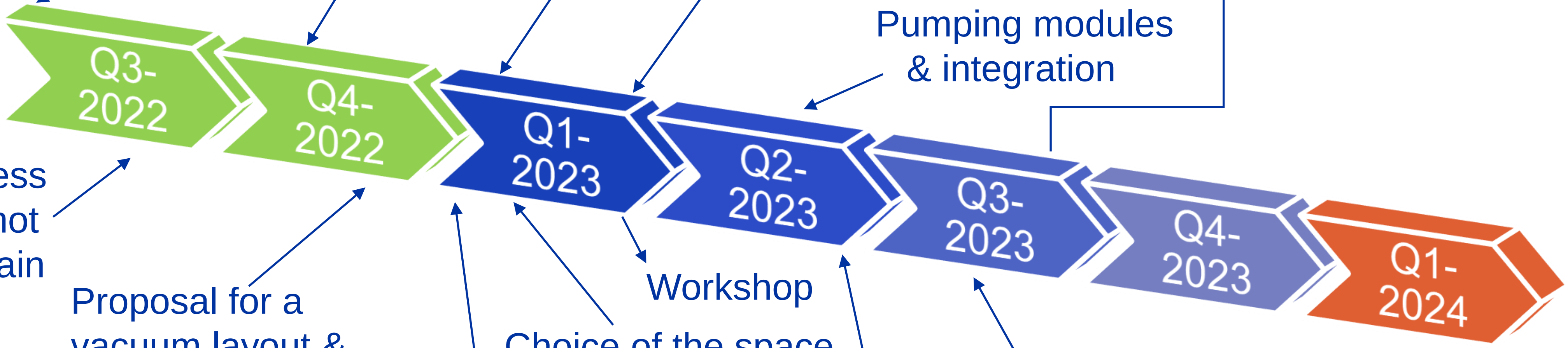
Design of the pre-prototypes

Strategy for surface cleaning & metallurgical studies

AISI 304 pre-prototype manufactured & installed

Pumping modules & integration

**Welding issues solved**




Ferritic stainless steels: firing not needed to attain requirements

Proposal for a vacuum layout & control system

Support system & vibration analysis

Choice of the space for the pilot sector

Workshop

Welding studies for AISI 430, 444 and 441

Pilot sector: design, integration, bakeout

# Welding issues solved

| | Welding methods | RT | Metallurgy | Tensile trans. | Tensile long. | Flexural long. | corrugation test |
|---|---|---|---|---|---|---|---|
| | **Weld characterization** | | | | | | |
| | TIG auto | - | Large grains | A= 17% | A=26% | - | PT OK |
| 441 | Laser CW | TBD | OK[1] | A=30% | A= 29% | PT OK | PT OK[2] |
| | Laser Pulsed | - | OK[1] | A=28% | A= 31% | PT OK | PT OK |
| | TIG auto | - | Large grains | A= 18% | A=22% | - | PT OK |
| 444 | Laser CW | - | OK[1] | A=22% | A= 30% | PT OK | PT OK |
| | Laser Pulsed | - | OK[1] | A=27% | A= 28% | PT OK | PT OK |

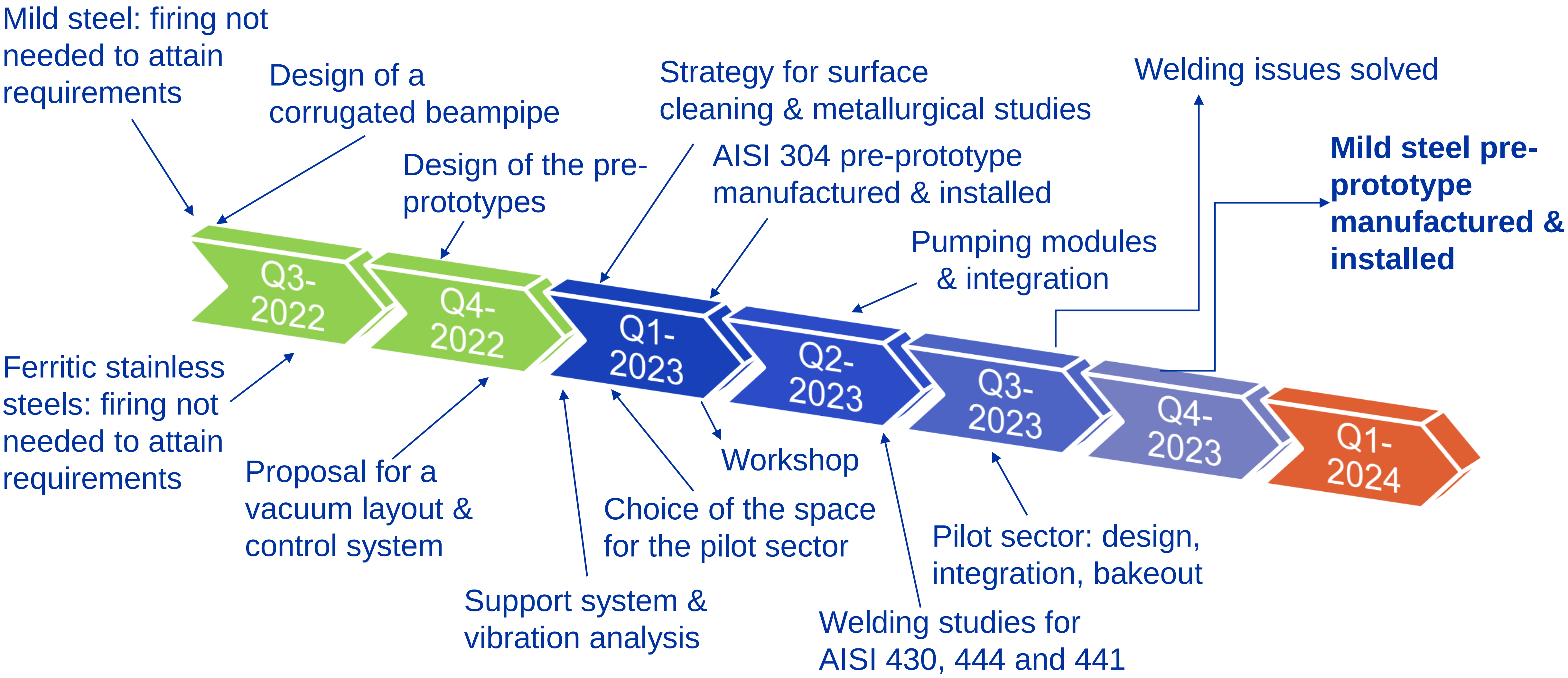
***NOTES:***
Elongation at break (A) in the BM~ 30%
[1]The compliance to be checked according ISO 13919-1 level B
Flexural test (ISO 5173 Longitudinal face bend test specimen for a butt weld - LFBB) 110 and 180°
PT : Dye Penetrant Testing. All the parts have been inspected by Penetrant Testing, and found to be conforming the standard ISO 23277 level 2x

[2] This is the only sample without any indications from PT

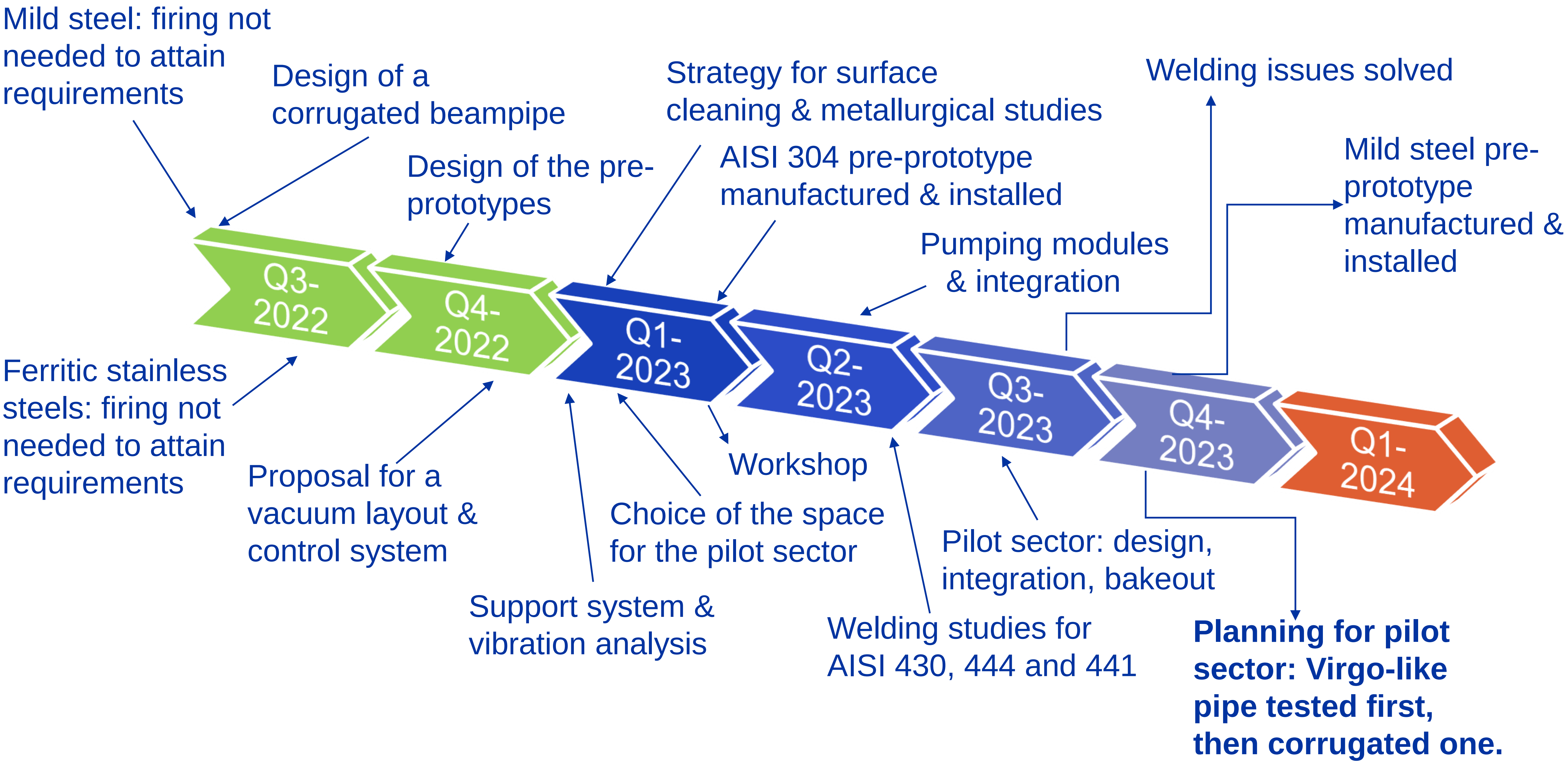


*AISI 444 Flexural test*

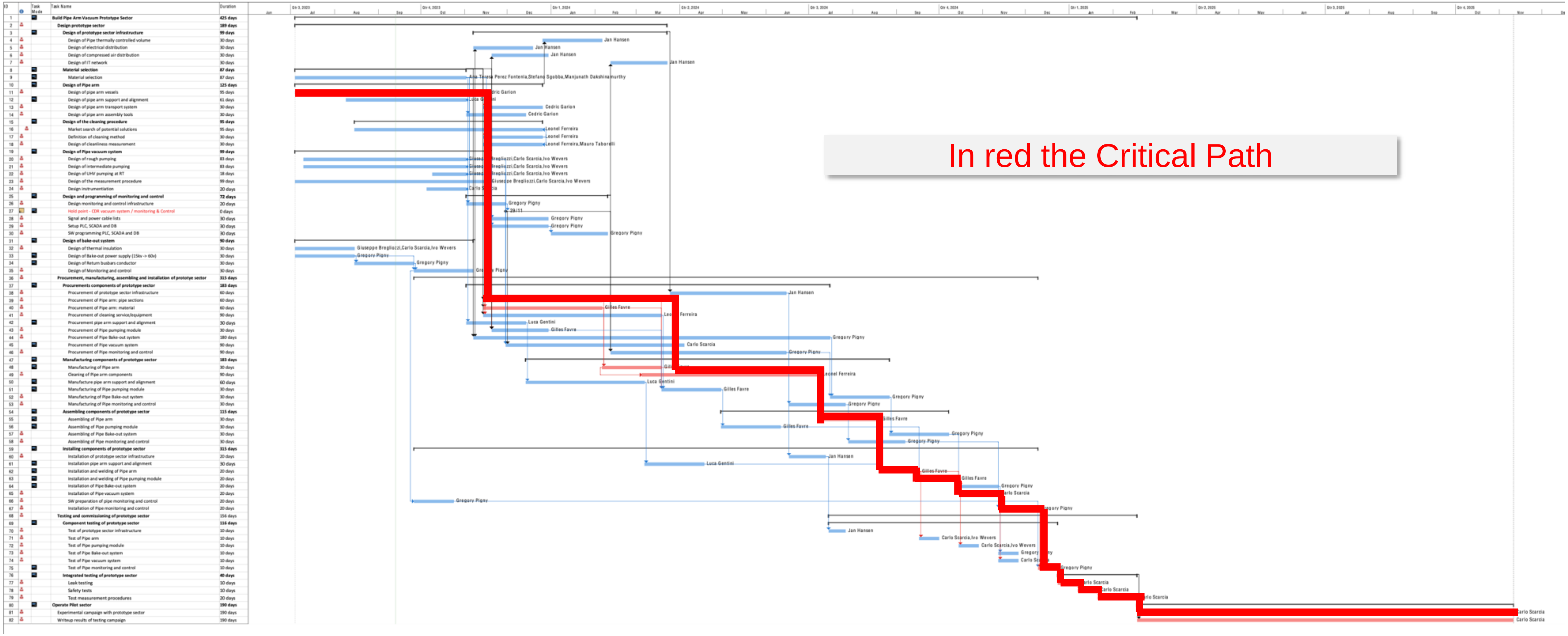
# Main achievements



# Main achievements



# Planning for pilot sector: Virgo-like pipe tested first, then corrugated one



# Planning for pilot sector: Virgo-like pipe tested first, then corrugated one

PILOT SECTOR

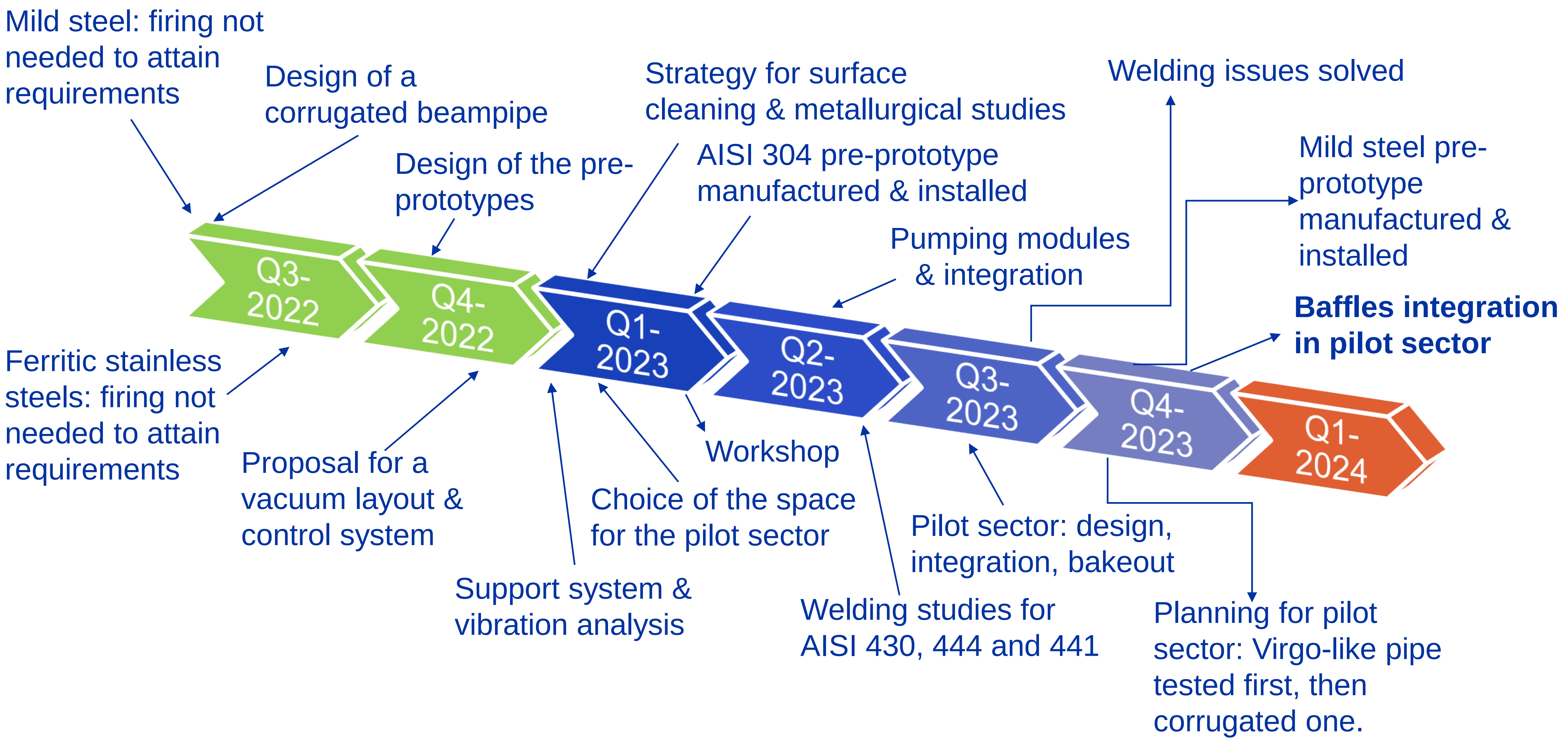
Industrial feasibility TBC

| | FEASIBLE NOW | PREFERRED | |
|---|---|---|---|
| **Ferritic AISI 441** | (+) Lower cost<br>(+) No HTT required | (+) Much lower cost<br>(+) No HTT required | (-) Higher cost |
| **Mild Steel S 315** | (+) Lower cost<br>(+) No HTT required<br>(-) Surface corrosion ? | (+) Much lower cost<br>(+) No HTT required<br>(-) Surface corrosion ? | (+) Much lower cost<br>(+) No HTT required<br>(-) Surface corrosion ? |
| **Austenitic AISI 304L** | (+) Prooven solution<br>(-) HTT required | (-) HTT required | (-) Higher cost<br>(-) HTT required |
| | **Smooth pipe/stiffeners Virgo like 3-4 mm** | **Corrugated 1.5 – 2 mm** | **Pipeline > 5 mm** |

Surface corrosion resistance TBE

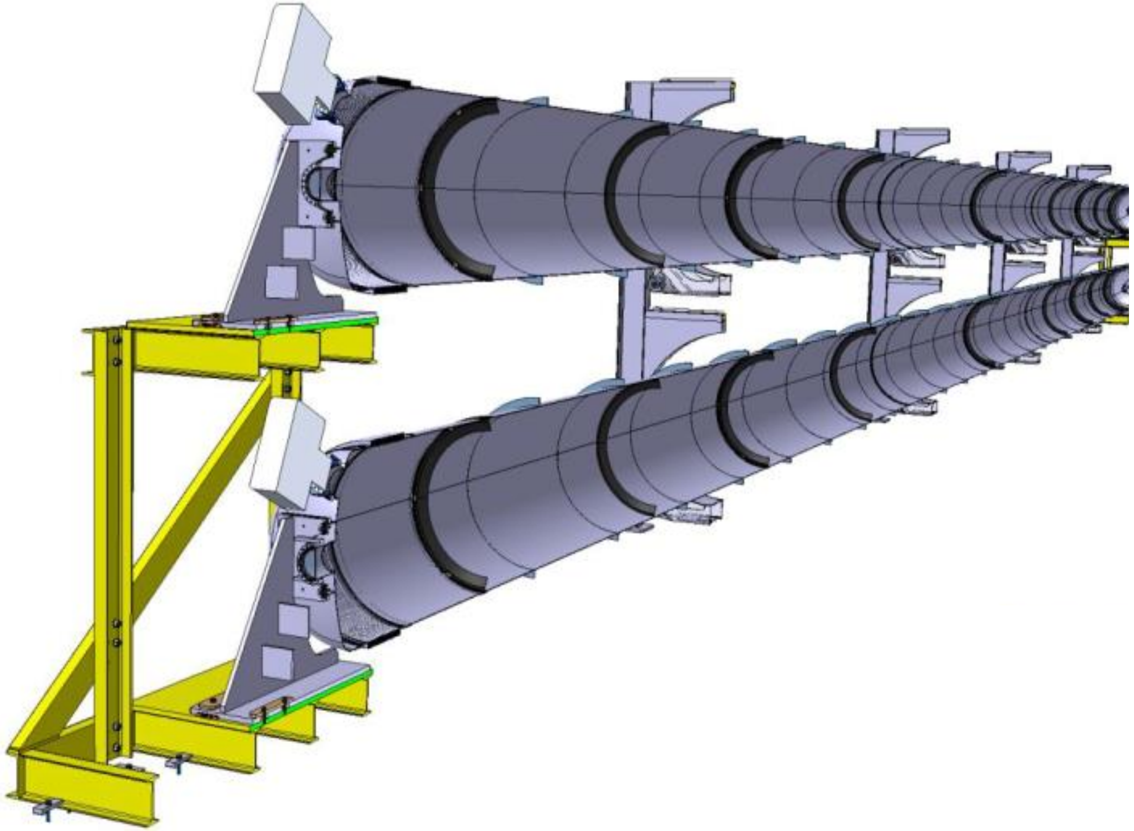
**HTT** - High Temperature Treatment
**Costs** - relative to the Virgo like baseline.

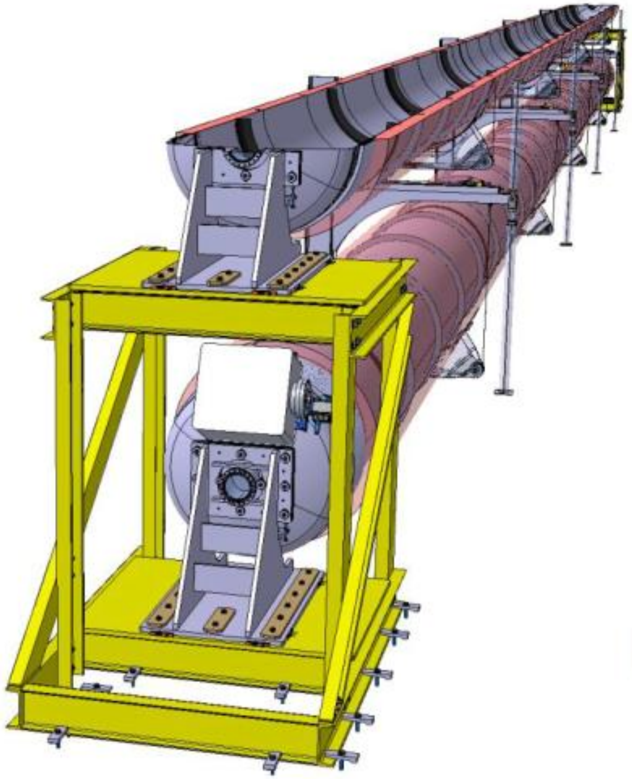
# Main achievements

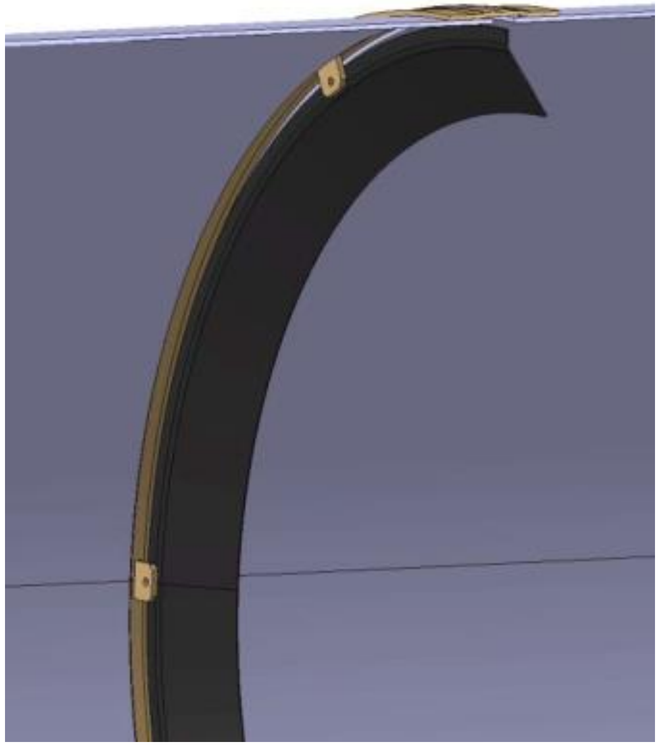


# Baffles integration in pilot sector

Work performed in collaboration with the **IFAE team**.







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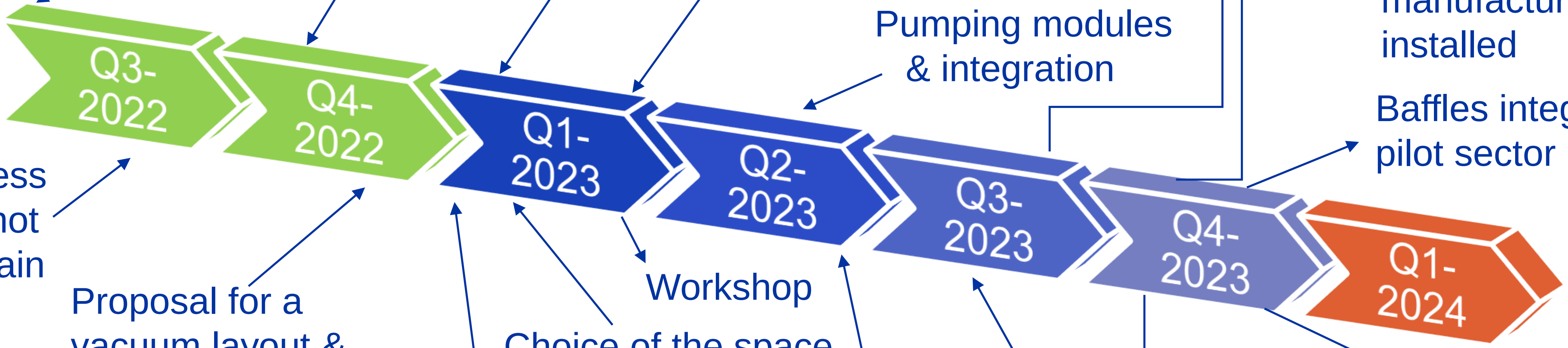
Baffles integration in pilot sector




Ferritic stainless steels: firing not needed to attain requirements

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**First cleaning results**

Planning for pilot sector: Virgo-like pipe tested first, then corrugated one.

# First cleaning results in the industry

- Poligrat facility can clean pipes up to 15 m in length and 1.2 m in diameter
- Cleaning is done by recirculation of internal surface
- Cleaning trials performed on samples as-received and samples with standard CERN contamination
- FTIR and XPS studies ongoing

Ferritic samples cleaning procedure:
- Degreasing at 50 °C, 10 minutes;
- Rinsing;
- Drying in air;
- Packed in aluminium foil.

## Threshold for UHV compatibility at CERN: %C = 31.3

| Sample | Ag | Al | C | Ca | Cr | F | Fe | Mo | N | Na | Nb | O | P | Pb | Si |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mild Steel - as received I | 0.06 | 2.2 | 51.8 | 0.1 | - | 0.04 | 6.6 | - | 6.3 | - | - | 30.1 | 2.9 | - | - |
| Mild Steel - as received II | 0.01 | 0.4 | 52.5 | 0.3 | - | 0.05 | 9.2 | - | 5.9 | - | - | 29.4 | 2.3 | - | - |
| Mild Steel - standard contamination I | 0.01 | 1.2 | 53.8 | 0.1 | - | 0.04 | 7.1 | - | 6.0 | - | - | 29.1 | 2.6 | - | - |
| Mild Steel - standard contamination II | 0.03 | 0.6 | 52.1 | 0.1 | - | - | 10.0 | - | 5.7 | - | - | 28.8 | 2.8 | - | - |
| Ferritic Steel - as received I | - | - | 35.4 | 0.5 | 3.3 | 0.6 | 12.8 | 0.5 | 0.5 | 3.8 | 0.3 | 37.7 | 0.4 | 0.1 | 4.2 |
| Ferritic Steel - as received II | - | - | 46.0 | 0.5 | 2.7 | 0.5 | 12.5 | 0.4 | 1.0 | 0.2 | 0.3 | 31.8 | 0.3 | 0.1 | 3.7 |
| Ferritic Steel - standard contamination I | - | - | 23.9 | 0.2 | 4.4 | 0.7 | 18.2 | 0.5 | 0.4 | 0.2 | 0.6 | 45.1 | 0.5 | 0.1 | 5.2 |
| Ferritic Steel - standard contamination II | - | - | 31.2 | 0.3 | 4.0 | 0.7 | 15.5 | 0.5 | 0.6 | 0.2 | 0.4 | 40.5 | 1.0 | 0.1 | 5.0 |

Poligrat degreasing process

| | As | C | Cr | Cu | F | Fe | K | Mo | N | Nb | O | P | Pb | Si | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***Mild Steel Firbimatic #1*** | 1.2 | 24.3 | - | 4.4 | - | 19.5 | 0.1 | - | 2.5 | - | 47.5 | - | - | - | 0.5 |
| ***Mild Steel Firbimatic #2*** | 1.1 | 28.8 | - | 2.9 | - | 17.3 | 0.04 | - | 2.7 | - | 46.6 | - | - | - | 0.5 |
| ***Ferritic Steel Detergent #1*** | - | 12.6 | 6.1 | - | 1.0 | 17.0 | 0.1 | 0.6 | - | 0.5 | 55.1 | 0.7 | 0.2 | 6.2 | - |
| ***Ferritic Steel Detergent #2*** | - | 13.6 | 5.0 | - | 0.8 | 15.8 | 0.2 | 0.5 | - | 0.5 | 55.1 | 0.7 | 0.2 | 7.5 | - |

CERN degreasing process

There are margins of improvement.

# Short-term objectives

AISI 441 pre-prototype manufactured & installed

Purchasing of AISI 441 coils for the pilot sector (12-week lead-time)

**Review of the options proposed for the beampipe pilot sector**

Price enquiry for manufacturing of Virgo-like pipe

Beginning of market-survey procedure for manufacturing of corrugated pipes

Q1-2024

Cleaning tests with robot.

# Review of the options proposed for the beampipe pilot sector

This review aims to:

- **Provide peer advice** on the validity and maturity of choices made for the ET beampipe pilot sector, encompassing materials and their qualification, design, fabrication, vacuum systems, and bakeout procedures.

- Evaluate the **proposed support system** and provide constructive feedback for enhancement.

- Assess the feasibility and effectiveness of the proposed **baffle integration** within the sector.

- Review the **proposed experimental** program and offer guidelines for potential extension and improvement.

- Evaluate and provide comprehensive guidance on the **dust control plan**.

- Assess the **maturity** of the study to facilitate the launch of **price enquiries for fabrication processes**.

# Conclusions

- The **TDR is the most important deliverable** of our participation in the ET project,
- The TDR will be **issued in two stages**: a preliminary one in Q4-2024 and, one year later, the final one.
- Today, we have **clear objectives**, right **personnel**, adequate **premises**, and hopefully **budget** to **attain our target**.
- **Discussions** with and **feedbacks** from GWD experts are essential.
- At the present time, our work is focused on the **construction of the pilot sector**. This infrastructure could require **additional personnel during installation and operation**.
- The results that will be obtained with the pilot sector could affect the final stage of the TDR.