Short notes on CERN's vacuum prototype activities for ET

M. Martínez

ICREA IFAE BIST

Next Generation Collaborative Design

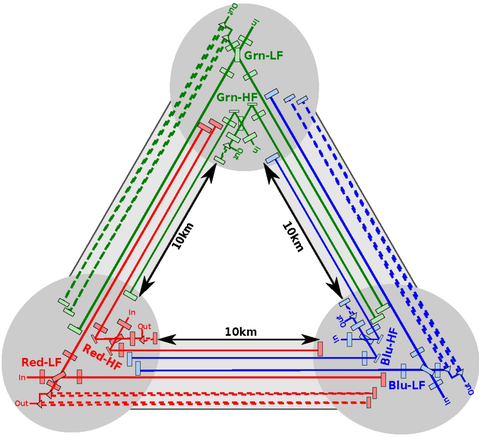
Monday 25 Mar 2024, 17:00 → 19:00 Europe/Rome

XGCD Meeting - Stray Light Control, March 25th (online)

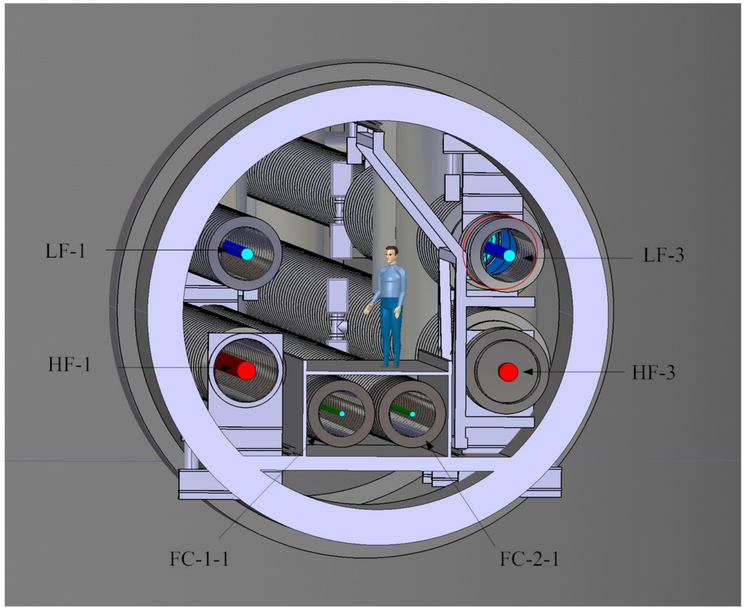
ET vacuum

~10^5 m^3

560 M€



In its current design ET involves the production of more than 120km of ~1 m diameter tubes instrumented by hundreds of deflecting baffles



The experiment runs under ultra high vacuum (UHV) conditions

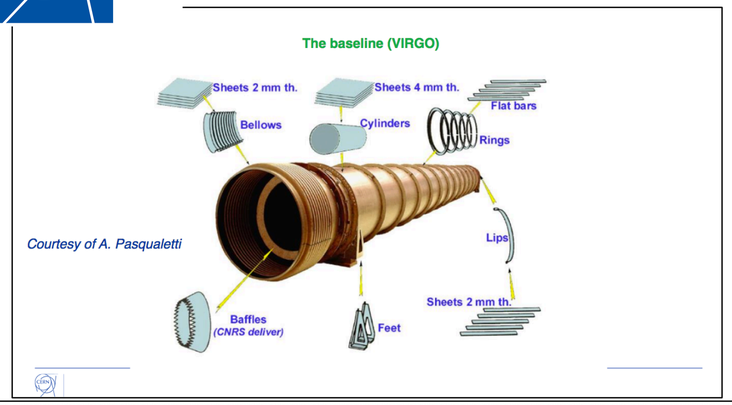
- 10^{-10} mb for H_2 , 10^{-11} mb for N_2
- 10^{-14} mb for Hydrocarbons

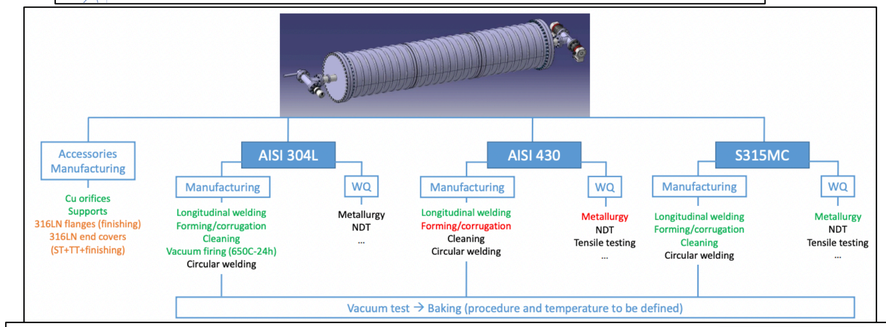
Optical requirements (reduced reflectivity and scattering of surfaces) condition the pipe design

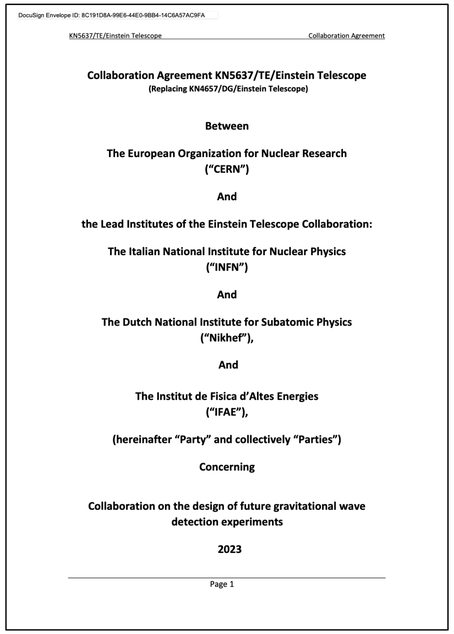
- Precise mechanics
- Surface treatments for outgassing & cleanliness
- High-quality polishing
- Optical AR coatings @ 1 – 2 microns (close to mirrors)

ET vacuum pipe design

MoU signed with CERN







DocuSign Envelope ID: 8C191D8A-99E6-44E0-98B4-14C6A57AC9FA

KN5637/TE/Einstein Telescope Collaboration Agreement

Collaboration Agreement KN5637/TE/Einstein Telescope
(Replacing KN4657/DG/Einstein Telescope)

Between

The European Organization for Nuclear Research
("CERN")

And

the Lead Institutes of the Einstein Telescope Collaboration:

The Italian National Institute for Nuclear Physics
("INFN")

And

The Dutch National Institute for Subatomic Physics
("Nikhef"),

And

The Institut de Fisica d'Altes Energies
("IFAE"),

(hereinafter "Party" and collectively "Parties")

Concerning

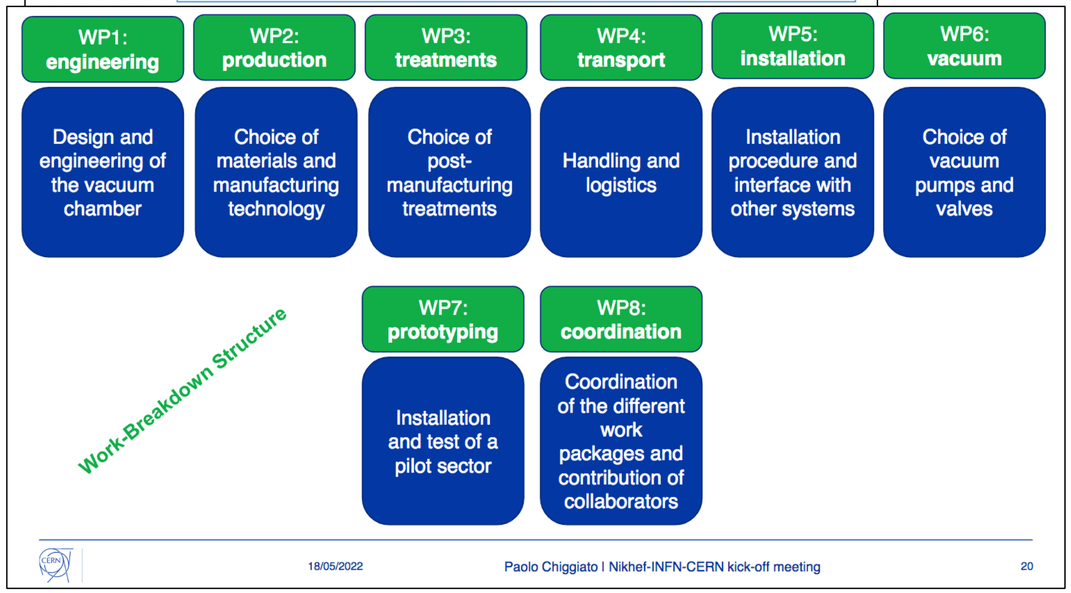
Collaboration on the design of future gravitational wave detection experiments

2023

Page 1

Global planning 2025

	First year				Second year				Third year			
	Q 1	Q 2	Q 3	Q 4	Q 1	Q 2	Q 3	Q 4	Q 1	Q 2	Q 3	Q 4
Functional specifications												
Roles and agreement with Institutes												
Optimisation of baseline, including cost analysis												
Definition of alternative solutions												
Cost & performance of alternative solutions												
Optimisation of interfaces with services/infrastructures												
Decision about vacuum design for pilot sector at CERN.												
Prototyping of the selected solutions.												
Technical design report (ET vacuum system).												



On-going effort led by CERN on the design of ET vacuum pipe

(1/3 of the total ET cost) —> Will deliver a TDR in 2 years

- Physics requirements
- Vacuum / Cryo Technology
- Cost Reduction/Optimization
- Prototyping

https://indico.cern.ch/event/1360696/

Peer Review of the ET pilot sector

Monday 22 Jan 2024, 14:00 → 18:30 Europe/Zurich

30/6-019 (CERN)

Paolo Chiggiato (CERN)

Big CERN vacuum Dept team working on ET aspects now

Videoconference — Peer Review of the ET pilot sector — Join

There are minutes attached to this event. Show them.

14:00 → 14:05 **Welcome** — 5m

Speaker: Jose Miguel Jimenez (CERN)

14:05 → 14:25 **Purpose and planning of the pilot sector.** — 20m

Speaker: Paolo Chiggiato (CERN)

Purpose and planni... | Purpose and planni...

14:25 → 14:45 **Notes on optical cavity at CERN: ET pilot sector after 2025** — 20m

Speaker: Mario Martinez-Perez (The Barcelona Institute of Science and Technology (BIST) (ES))

CERN-FP-Cavity.pdf | CERN-FP-Cavity.pptx

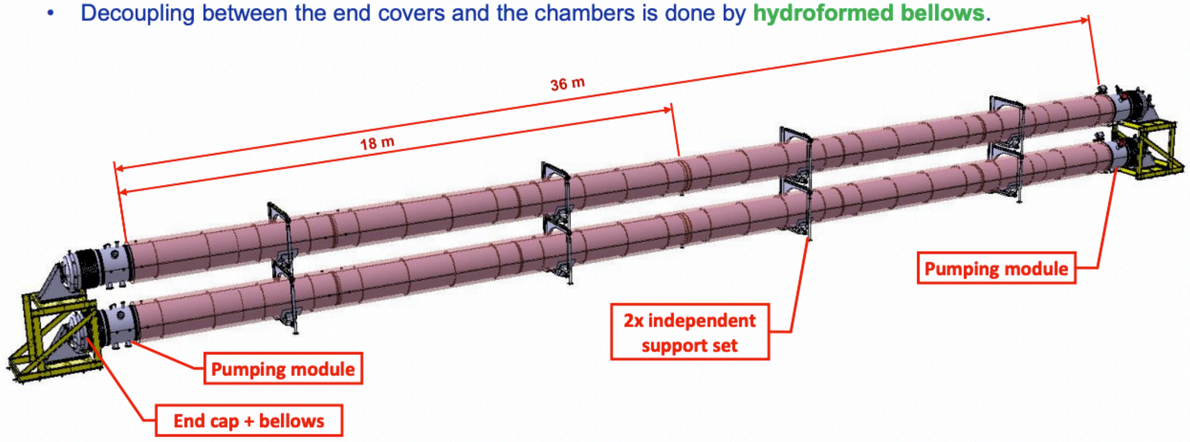
14:45 → 15:15 **Design of the ET beampipe pilot sector, including baffle integration** — 30m

Speaker: Cedric Garion (CERN)

Design_CG.pdf | Design_CG.pptx | Design_CG_Rev1.pdf | Design_CG_Rev1.pp...

Mechanical layout of the ET pilot sector at CERN

- **Two independent vacuum chambers** of around 18m will be transported and installed individually.
- Each pipe is **suspended** on independent supports and can be aligned vertically and laterally.
- Each **endcap** can be aligned laterally, vertically and longitudinally.
- Decoupling between the end covers and the chambers is done by **hydroformed bellows**.



Pilot sector : Choice of Material and

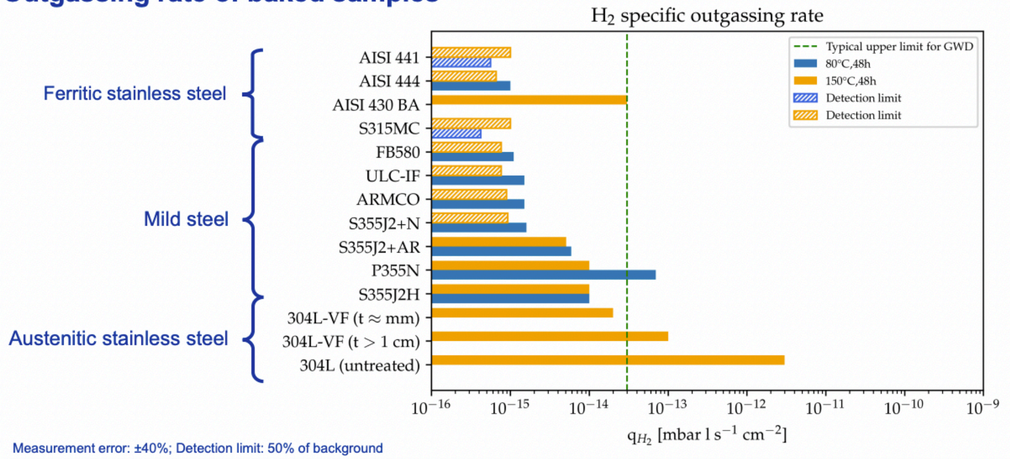
Materials	ET Vacuum requirements	Manufacturability (Welding and forming)	Corrosion resistance
AISI 304 L	Good	Good	High
S 315 MC	Good	Good	Low
AISI 441	Good	Good	High

Components	Material and dimensions (Procurement estimation)
Vacuum chamber and end caps	AISI 441, 2B surface,~ 4 mm thickness, width of coil ~1500 mm, quantity=12 tons**
Stiffeners	AISI 441 / 304L, 4-8 mm thickness, width 45-60 mm, length ~3.5m, 80-100 pieces
Sleeves	AISI 441, ~2mm thickness, standard width coil, 1 ton

** Quantity of material needed for two chambers

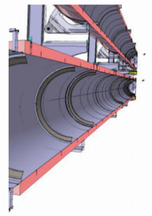
Vacuum characterization of ferritic alloys

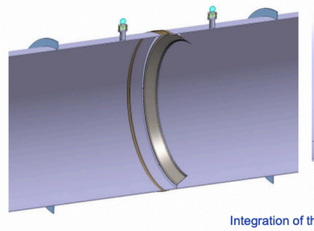
Outgassing rate of baked samples

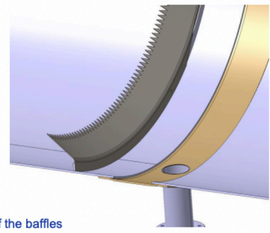


Measurement error: ±40%; Detection limit: 50% of background

Baffle integration





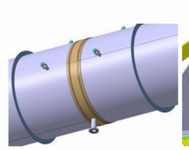


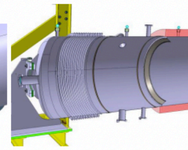
Integration of the baffles

…uum chamber:
…ith M6 holes welded inside the chamber.
…ews, vacuum fired.

…ses: without and with black nickel coating.

…carefully studied (cleanliness during assembly, weld).
…th silicon wafers for dust quantity assessment in the …ties.
…s for witness samples to implement.



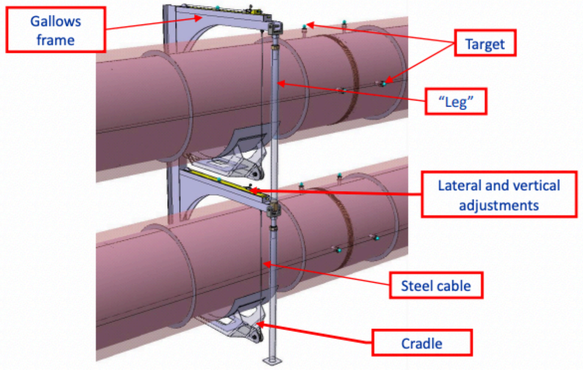


Dedicated ports for dust control assessment

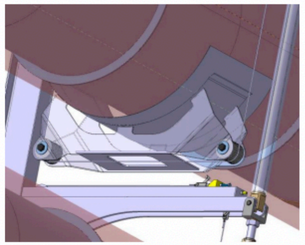
Supports & vibrations

"Light" supports based on standard beams with additional legs.
Vacuum chambers suspended by cables:

- Low stiffness.
- Low eigen frequencies.
- Easy thermal expansion.
- Free chamber:
  - No additional significant forces on the structure under vacuum, welding or re/mis-alignment.
  - Straightening under vacuum.

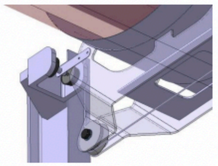


Supports


Cradle (horizontal damper not represented) suspended by steel cable

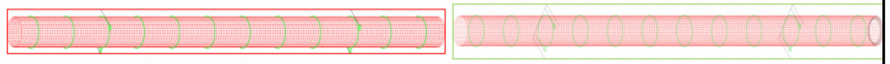
The insulated vacuum chambers lies on the cradle.

Maximum compression stress of the foam: 90 kPa (analytical estimation based on cosine pressure distribution assumption).


Conceptual design of dampers

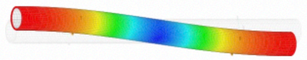
Eigen modes and transfer functions of a single suspended vacuum chamber

Two models (w/o or w/ support)
Aramid fiber ropes



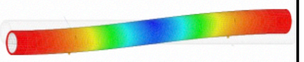
Lateral


Pendulum: 0.5 Hz (w/ & w/o)

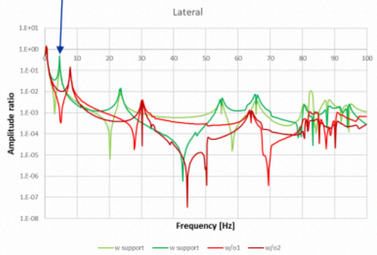

Pendulum + bending: 7.86 Hz (w/o), 4.6 Hz (w/)

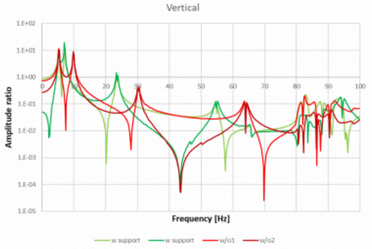
Vertical


Spring/mass: 5.3 Hz (w/ & w/o)


Spring/mass + bending: 9.86 Hz (w/o) & 7.1 (w/)

First mode of the frame





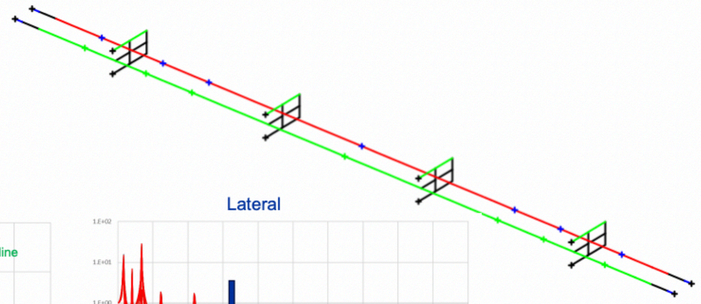
Loss factor η: Plate: 0.01, Insulation: 0.02, Chamber and baffle 0.005, Cable 0.01

This is to illustrate the effort on the understanding of vibrations and mechanical transfer factors

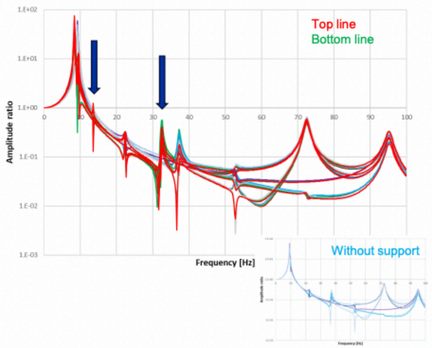
Transfer functions in the pilot sector with double lines

Model with:

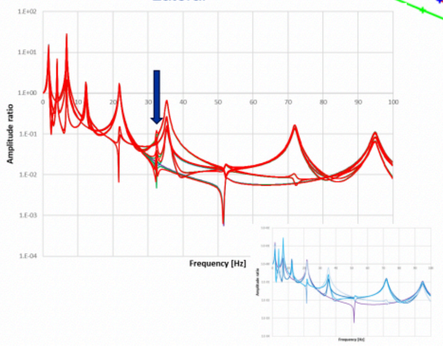
- Two lines.
- Steel cable, 6mm.
- Decoupling bellows.
- Simplified supporting frame.



Vertical



Lateral



Loss factor η: Chamber and cable 0.01, bellows and support 0.005

No major difference between the upper and lower lines.

Additional resonance at ~32Hz.

Transfer functions in the pilot sector

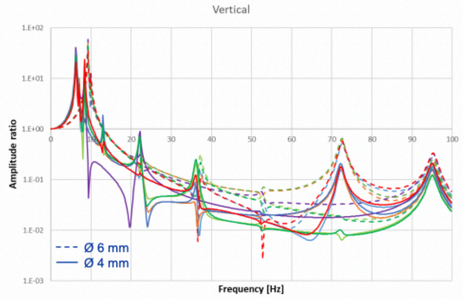
Impact of the cable with decoupling bellows

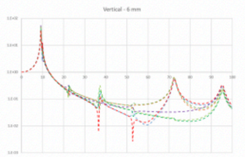
High strength synthetic ropes (e.g. aramid fiber) are the most appropriate for this application but would require some tests to define its final design.
Cables in galvanized steel are proposed and two options are considered (CERN store):

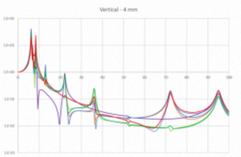
- Ø 6 mm: 114* Ø 0.39 mm, minimal breaking strength of 2000 kg.
- Ø 4 mm: 114* Ø 0.26 mm, minimal breaking strength of 935 kg.

Expected maximum load on the cable is 7.5 kN.

Vertical





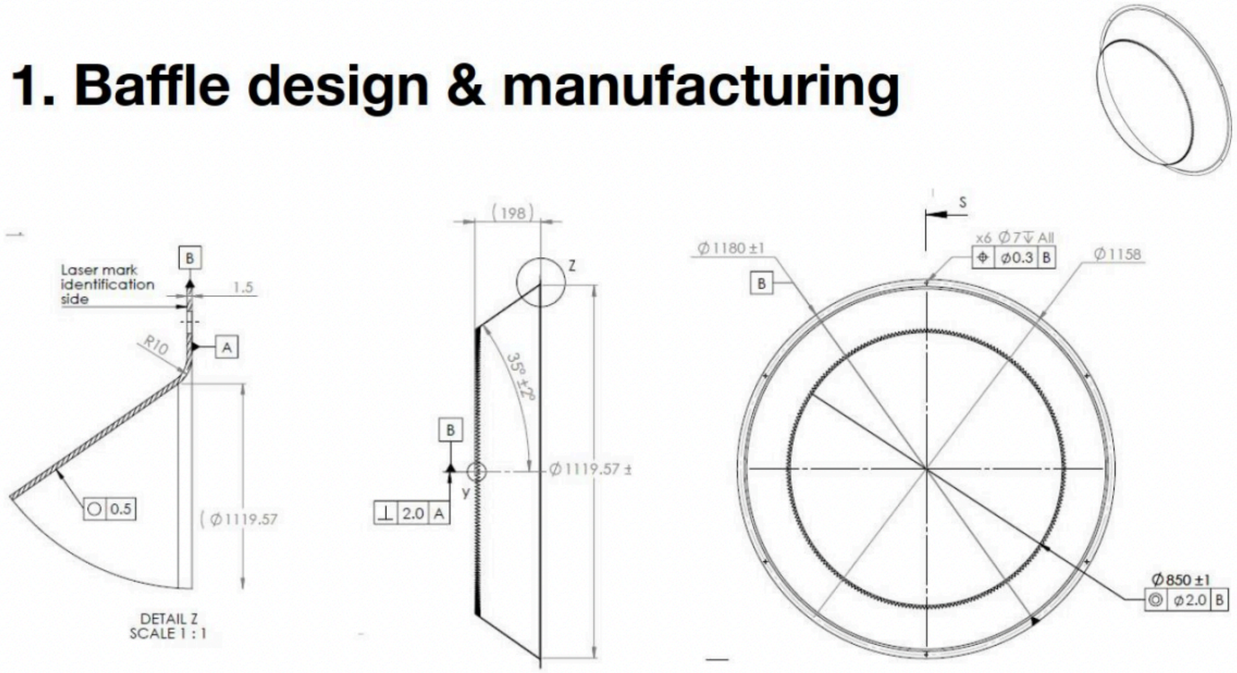


Loss factor η: Chamber and cable 0.01, bellows 0.005

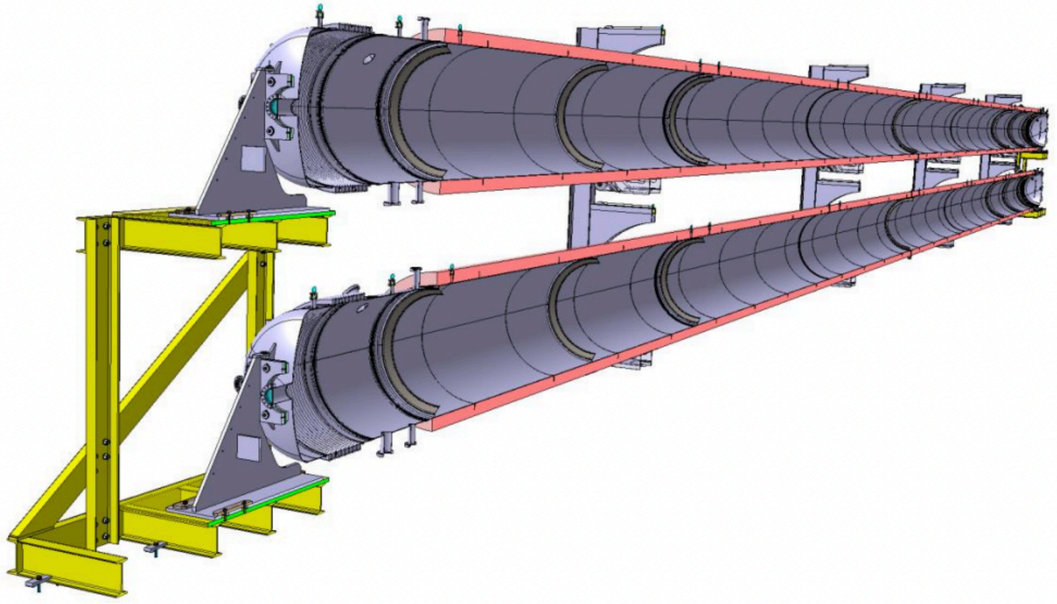
No impact on the lateral behavior.
Significant impact of the 4mm cable:
- Lower amplitude ratio.
- Decoupling of the first two modes.

Baffle integration

1. Baffle design & manufacturing



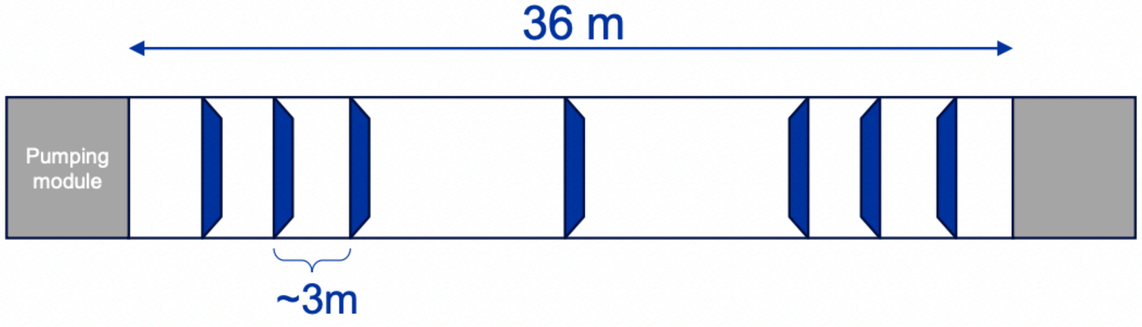
Courtesy J. Mundet (IFAE), for information



Design and procurement by IFAE.

Number and position of baffles being refined.

Should a baffle be placed in the middle of the 6m long segment, specific chambers of 3m long would be considered.



Planning

Preliminary experimental programme

Extension of the experimental programme, to be validated.

	2023				2024				2025				2026			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
TDR writing																
Material removal and cleaning of B. 973																
Installation of services (WiFi, electricity)																
Design of support and beampipes																
Design of tooling																
Design of bakeout system, cabling and instrumentation racks																
Place orders for all required material																
Manufacturing, reception tests and cleaning																
Manufacturing and delivery of the baffles																
Assembly and leak detection																
Test programme																

Preliminary experimental programme:

- **Outgassing rate** measurements of **all vacuum components** to be installed in the pilot sector:

  - Valves (all metal and Viton sealing gaskets).
  - Materials and surface treatments for the baffles.
  - Gauges.
  - Materials that are not the one of the beampipe (i.e., AISI 441)