FUTURE CIRCULAR COLLIDER

INFN LNF
Istituto Nazionale di Fisica Nucleare

ESPPU_FCC MDI

FCC-EE IR AND MDI FULL-SCALE MOCKUP

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CERN

30 September 2025
CSN1 Frascati

INFN special funds to FCC-related **R&D**

Special funds (>2 M€) have been allocated by INFN executive board to projects on future colliders, in preparation of the Next European Strategy for Particle Physics Update (ESPPU).

Three (out of four) funded projects are FCC-related and belong to CSN1

- **FCC-ee IR and MDI full-scale mockup, LNF** (co-financed by CERN)
- SRF cavities, LNL
- High Q / High gradient SRF, LASA
- Muon Collider R&D

Projects are refereed jointly by MAC and Commissione Scientifica Nazionale 1 (CSN1)

Projects timeline:
- 2022 submission
- 2024 MoU INFN-CERN
- 2024 Funding allocated

Material Budget allocated:
- CERN 200 k€
- INFN GE 90k€
- CSN1+ LNF 55 € contribution
- Pending additional requests

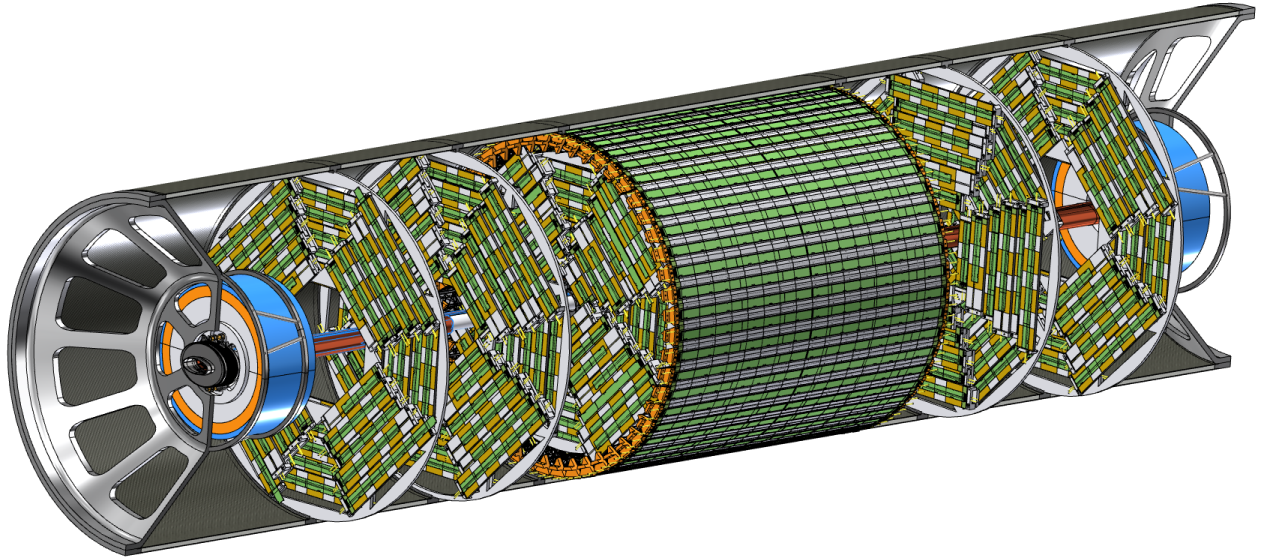
Personnel directly funded:
Mech. engineer 2y art. 36

FCC-ee IR full-scale mock-up

Activity in DRD8 https://drd8.web.cern.ch/
Mechanics & Cooling of Future Vertex and Tracking Systems

Main Components

- Actively cooled detector beam pipes in aluminium
- Bellows
- Air-cooled inner vertex in carbon fibre and kapton heaters (no MAPS)
- Outer vertex and disks in aluminium
- Vertex services integration
- Support tube in carbon fibre and honeycomb
- Lumical in lead



Deliverables:

- Construction of central chamber
- Construction of conical chambers
- Construction of bellows prototype
- Assembly of inner vertex
- Construction of wind tunnel
- Construction of outer vertex
- Construction of support tube

Milestones:

- Verification of assembled chamber cooling system
- Validation of inner vertex cooling system
- Validation assembly sequence
- Structural integrity tests

Status of measurements and validations

- **Verify liquid cooling system efficiency of beam pipes (Frascati)**
  - ✓ **Central chamber: measurement with water as liquid coolant** — **Q2-Q3 2025**
  - Central chamber: measurement with liquid **paraffin – test in preparation** — **Q3-Q4 2025**
  - Conical chambers: measurements with water – chambers fabricated, ready for EBW
  - Bellows in fabrication

- **Verify air-cooling efficiency for inner vertex detector (Pisa)**
  - ✓ **Staves fabricated**
  - ✓ **Wind tunnel assembled, measurements started** — **Q3-Q4 2025**

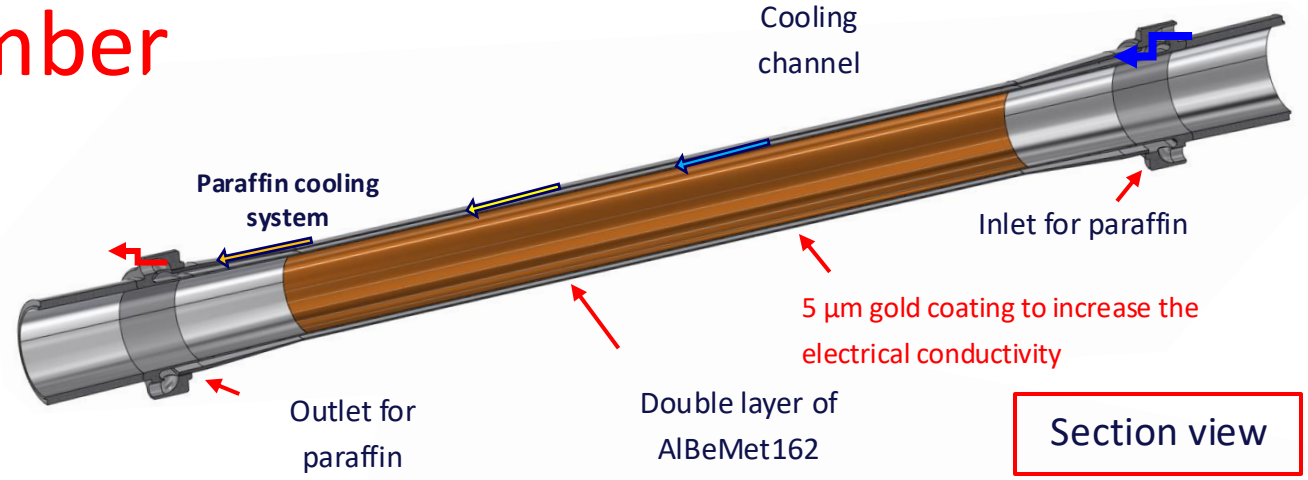
After the cooling tests: **(Frascati)**

- **Support tube fabrication (at company)**
- **Assembly all components and vertex services to the support tube** — **Targeting Q2-Q4 2026**
- **Assembly and integration tests**

FCC-ee IR central chamber

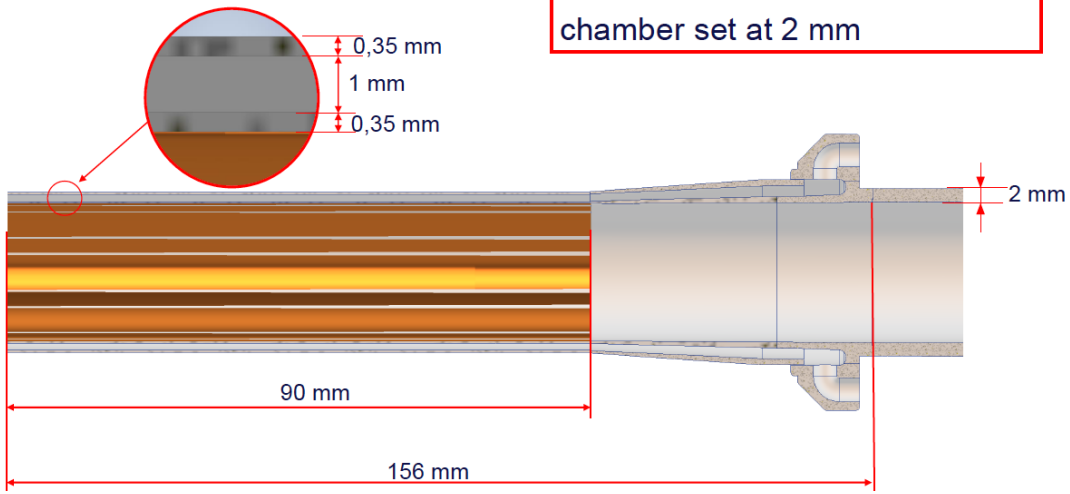
- AlBeMet 162 (62% Be, 38% Al)
- 180 mm long centered at the IP

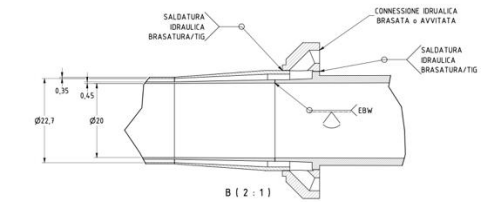
- **0.35 mm** outer radius AlBeMet162
- **1 mm gap** for paraffin
- **0.35 mm** inner radius AlBeMet162



Thickness of the chamber

Uniform thickness of the conical chamber set at 2 mm





The prototype is in aluminium:

- **0.35 mm** outer radius
- **0.9 mm gap** for paraffin
- **0.45 mm** inner radius

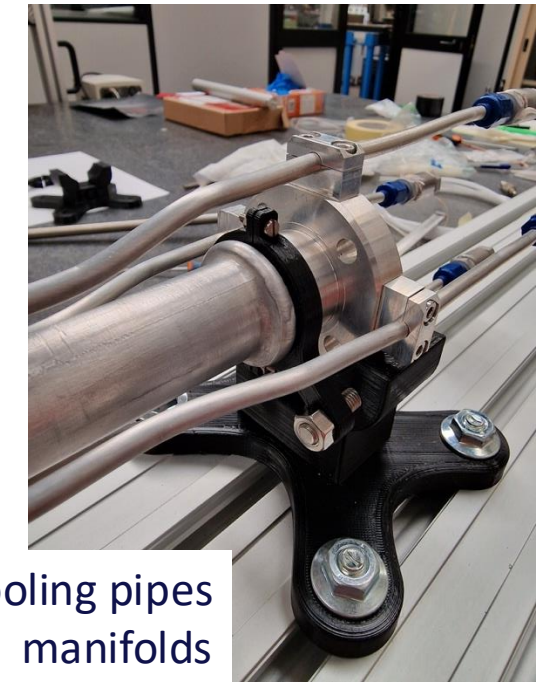
Leveraging Belle-II beam pipe design (0.4 mm Be +0.6 mm Be + 1mm paraffin)

Detector beam pipes

- **Paraffin flow (central chamber)**
  - Flow rate: 0,015 kg/s
  - Section:68,17 mm^2
  - Velocity: 0,3 m/s
  - Inlet temperature: 18°C
  - Convective coefficient: 900 W/m^2K

- **Water flow (Ellipto-Conical chamber)**
  - Flow rate: 0,01 kg/s (4 channels per side)
  - Total flow rate per side: 0,04 kg/s
  - Section: 12,25 mm^2
  - Velocity: 1 m/s
  - Inlet temperature: 16°C
  - Convective coefficient: 1200 W/m^2K

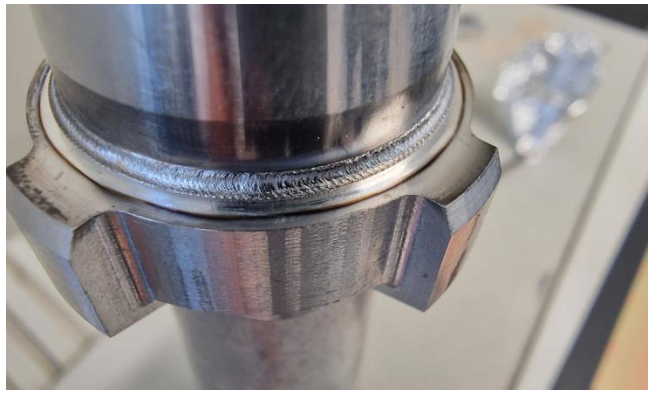
Central Chamber

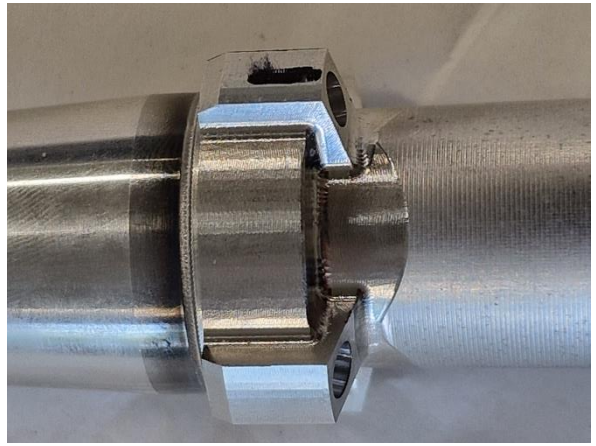


cooling pipes
manifolds

Vacuum chambers manufactured by COMEB s.r.l. (Italy)

http://www.comeb.it/





Electron Beam Welding (EBW) by Ravenscourt Eng. Limited (UK)

https://ravenscourtengineering.co.uk/

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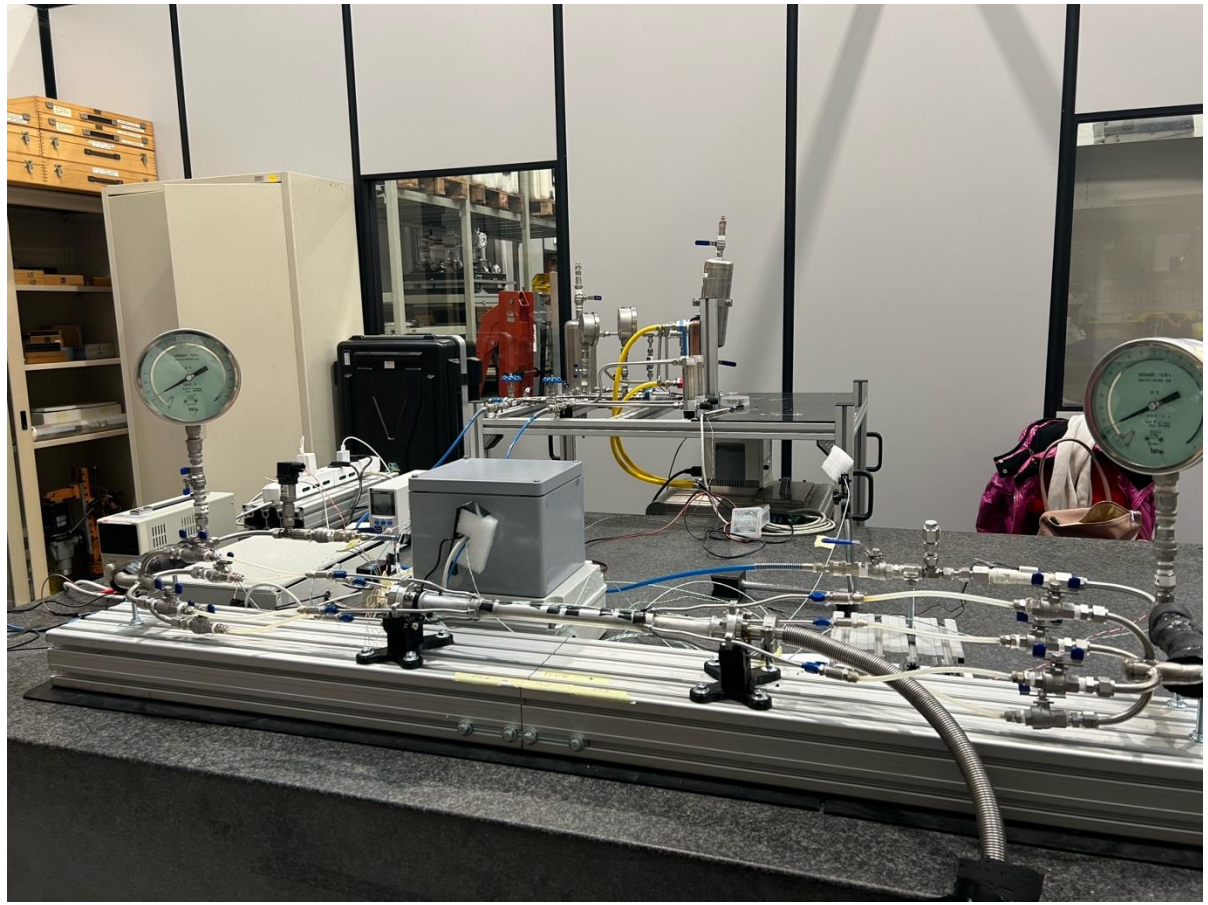
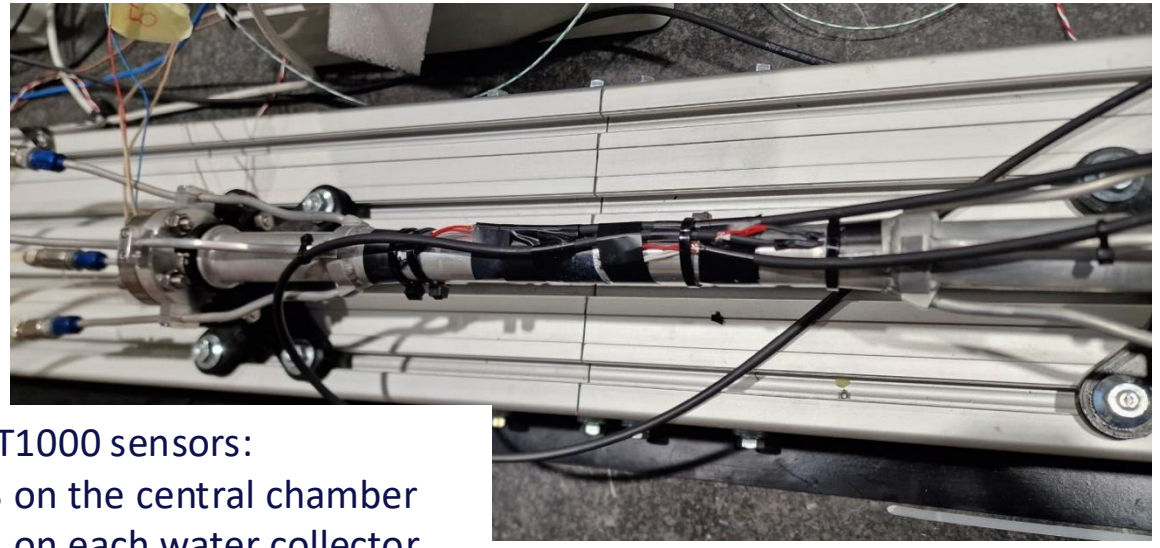
Measurement set-up



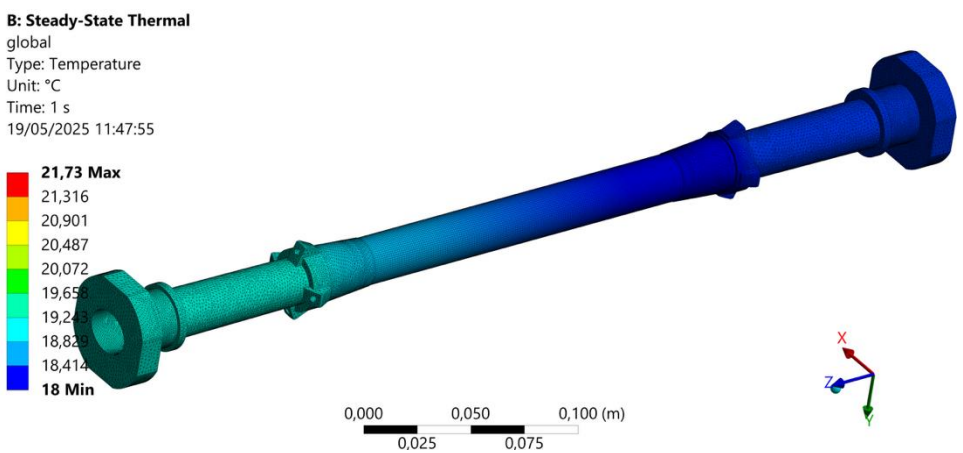


PT1000 sensors:
- 3 on the central chamber
- 1 on each water collector
- 1 environment

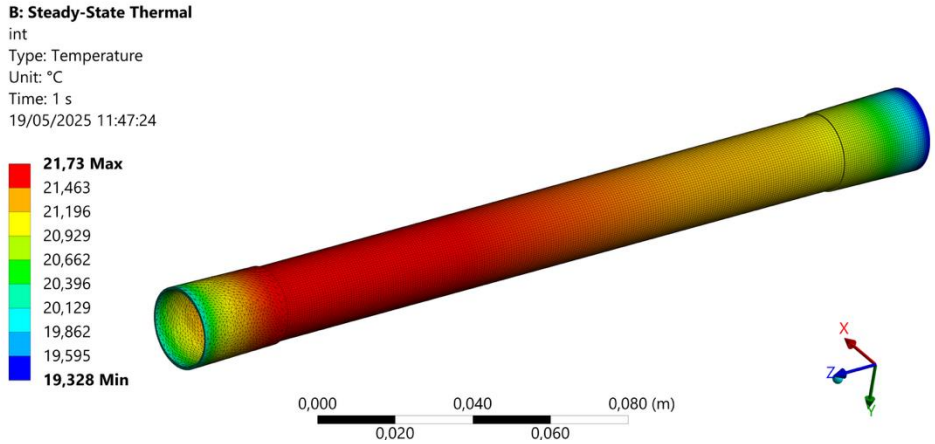
An internal ohmic heater inside the vacuum chamber simulates the beam heat load on the pipe during the beam passage.
A variable power supply controls the power deposited on the chamber.

Ansys simulation with the prototype of the central beam pipe

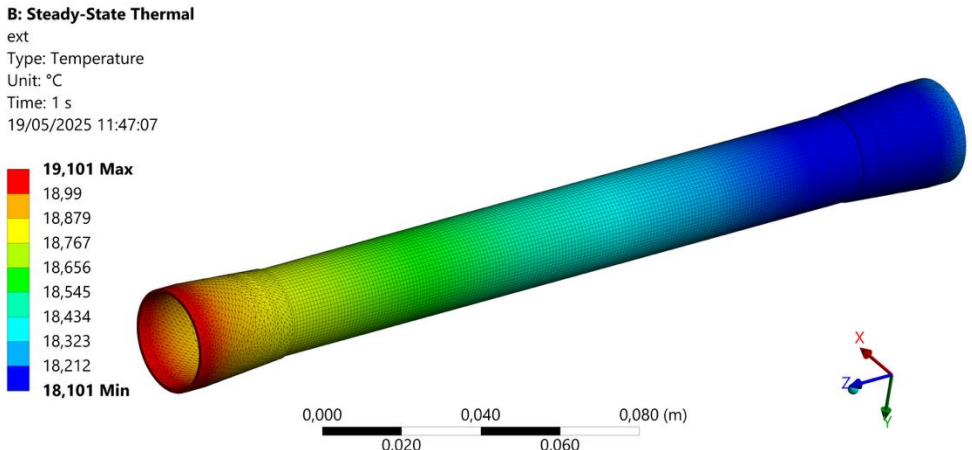
Water at 18 ºC, flow rate 1 l/min, and beam pipe at 54 W



Temperature of the external side of the the beam pipe

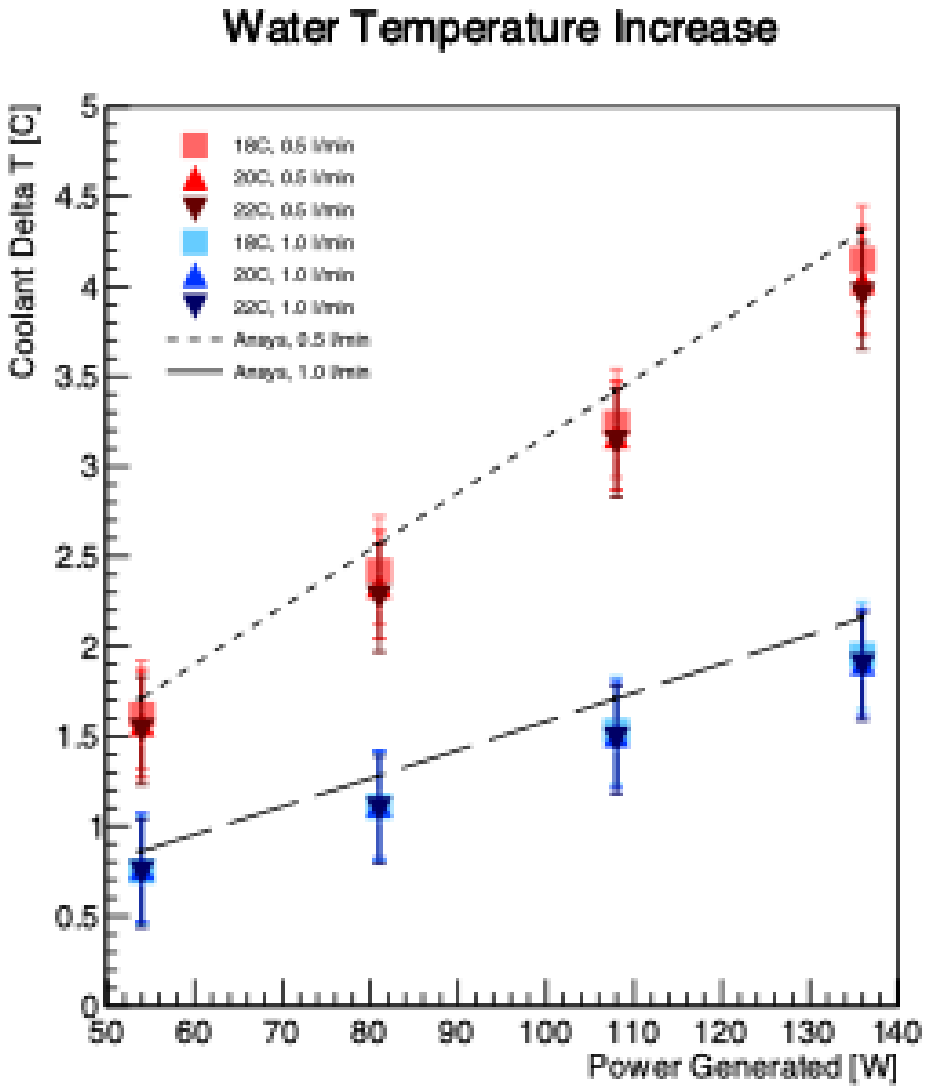


Temperature of the internal side of the the beam pipe



water temperature

Measurements with the prototype of the central beam pipe



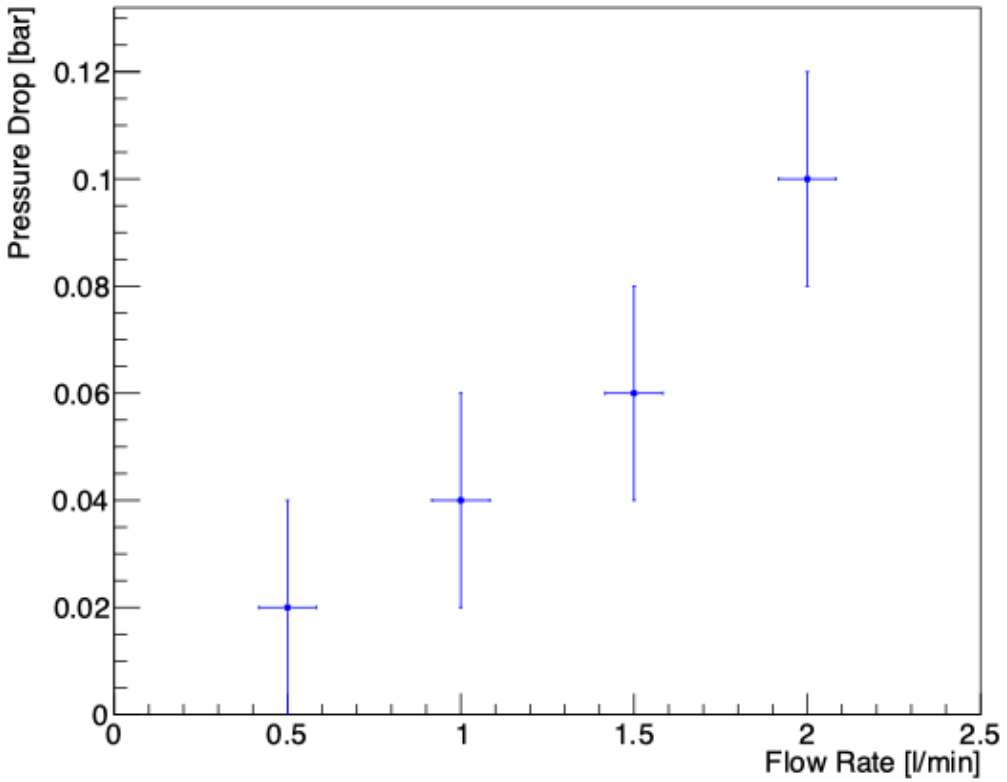
Water as coolant

- **Each measurement corresponds to the water temperature increase for a given power on the beam pipe for a flow rate of 0.5 l/min and 1 l/min.**

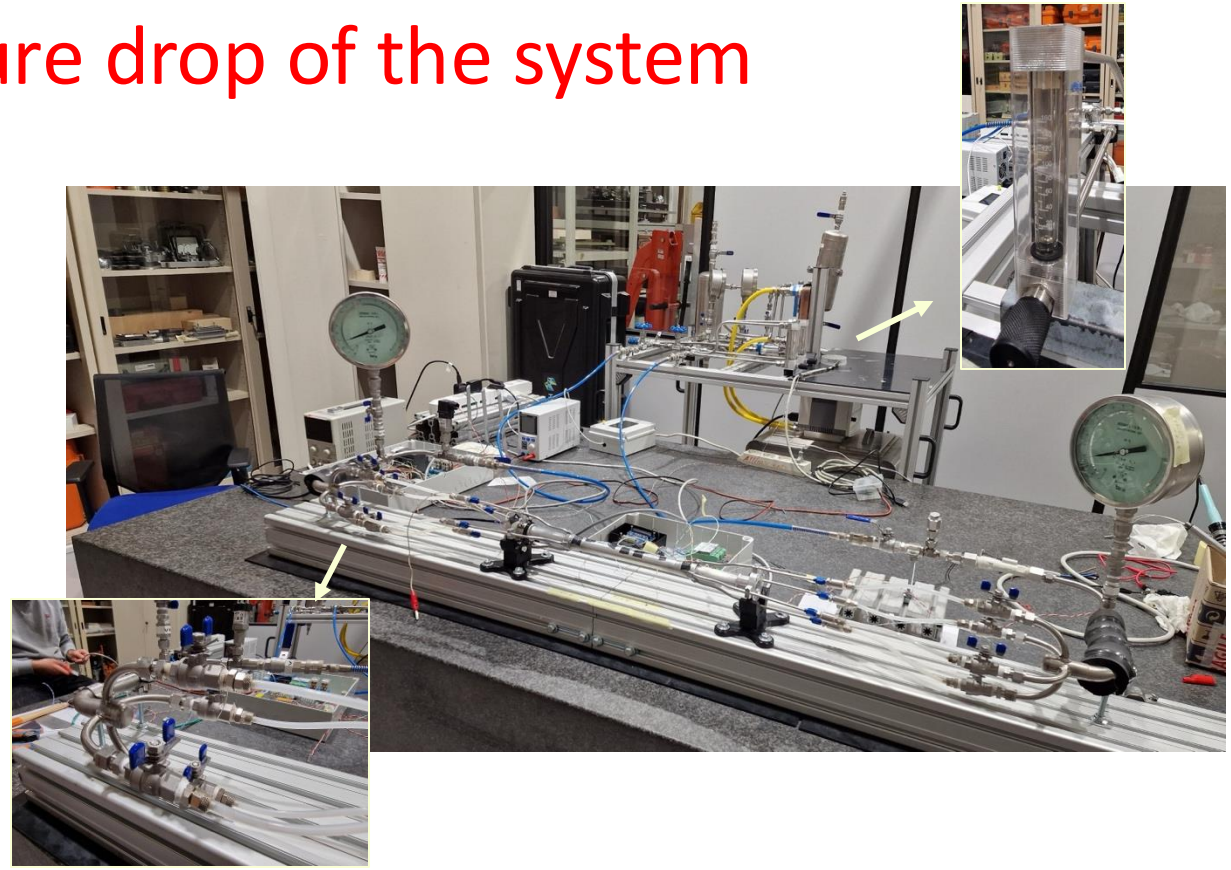
- 54 W is the nominal beam heat load on the beam pipe.
- Measurements in good agreement with expectations.
- Linear behaviour as expected.

Measurements of the pressure drop of the system

Pressure drop versus the flow rate



Behaviour as expected.



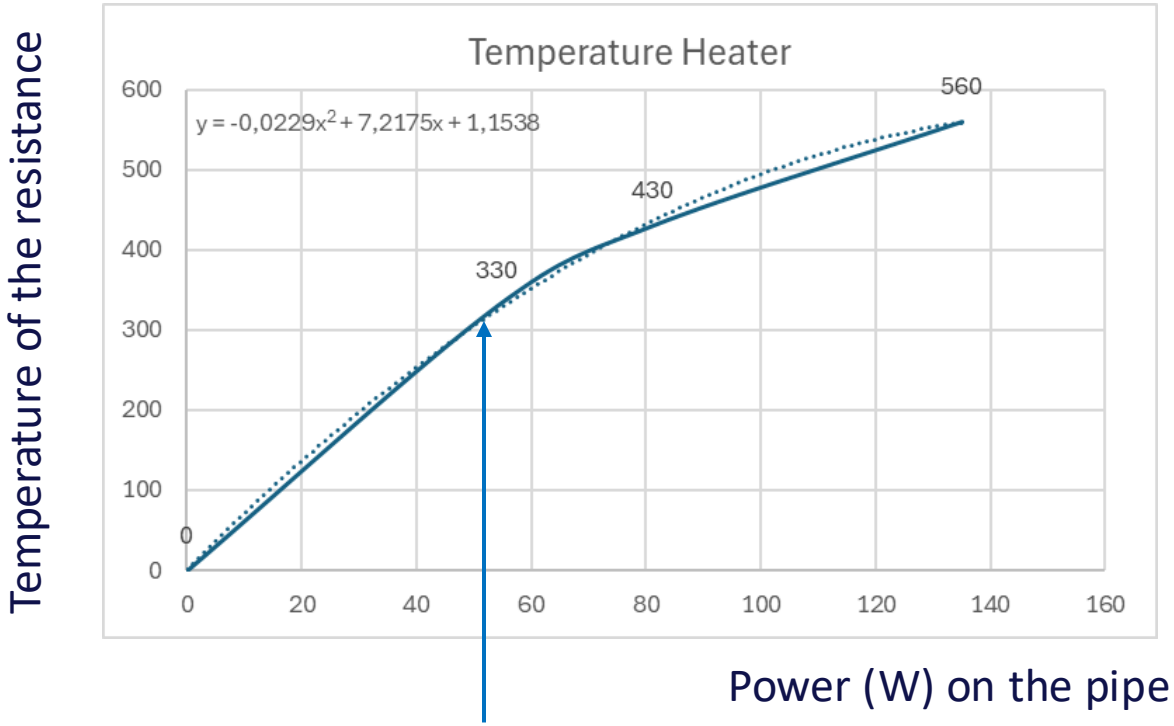
- Further measurements planned to characterise the system and to determine the pressure drop only at the beam pipe.
- Differential flowmeters would help to increase the accuracy.

Measurements with paraffin as pipe coolant

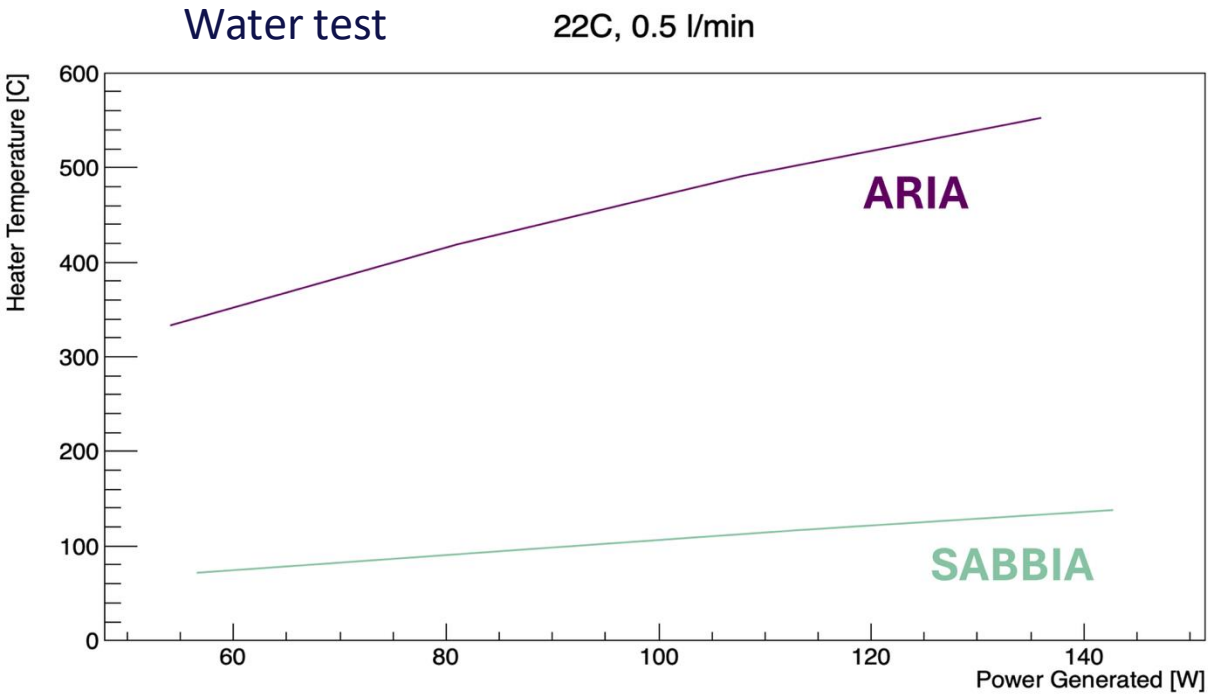
Liquid paraffin:

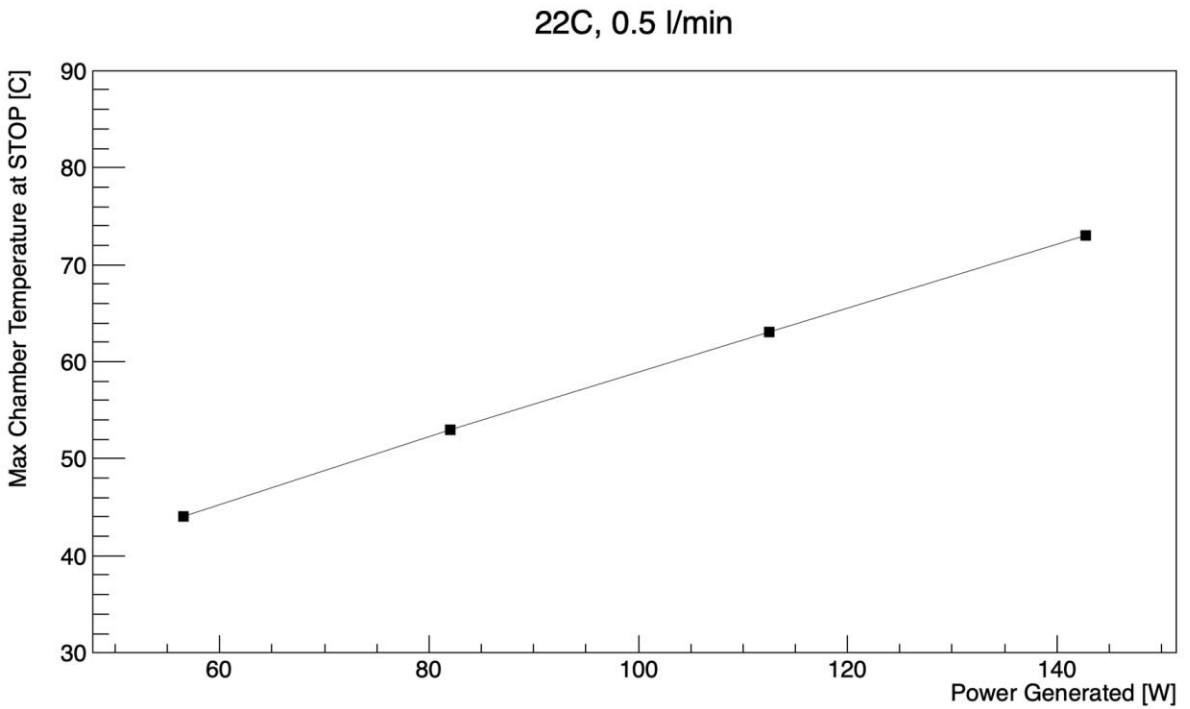
- Flash point 215 ºC
- Auto-ignition point between 245°C to 370°C

- **Paraffin will not be in direct contact with the heater**, as EBW guarantees good insulation. However, security measures are required.



Heating by conduction rather than radiation





- Internal beam pipe filled with sand reduces drastically the temperature of the resistance required to heat the pipe to the nominal 54 W
- Risk with paraffin greatly reduced
- Will try also magnesite to further improve conduction

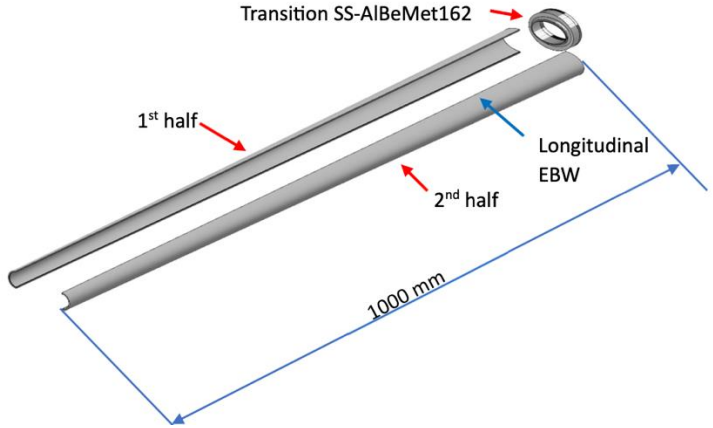
- Test with paraffin foreseen in the coming weeks

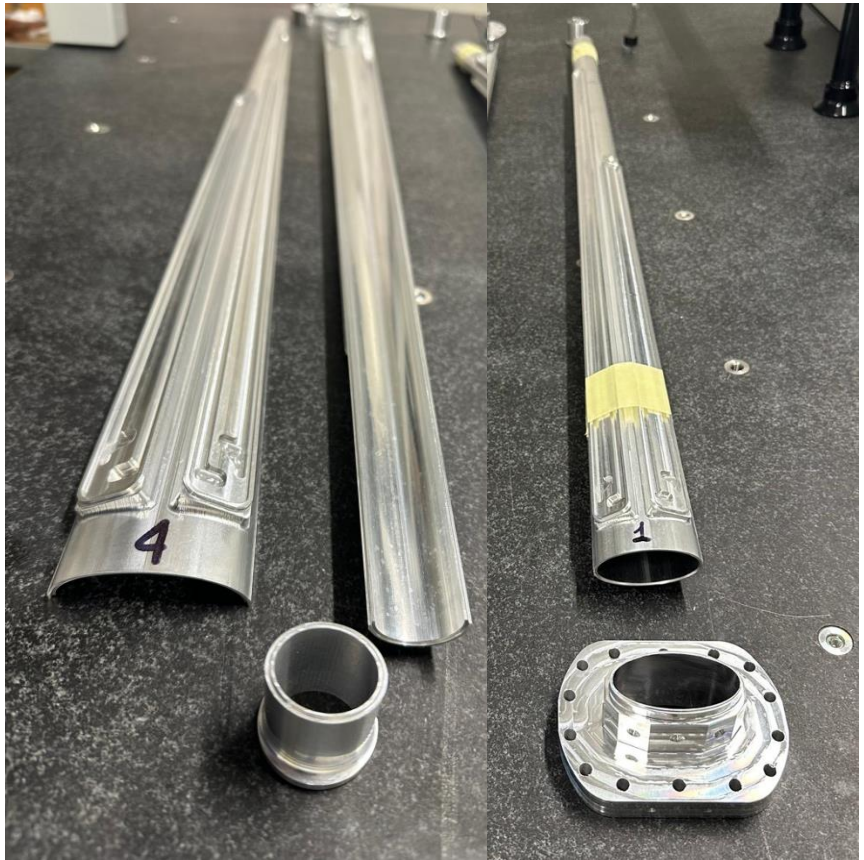
POTENZA	Temperatura massima camera
54 W	44 °C
81 W	53 °C
104 W	63 °C
136 W	73 °C

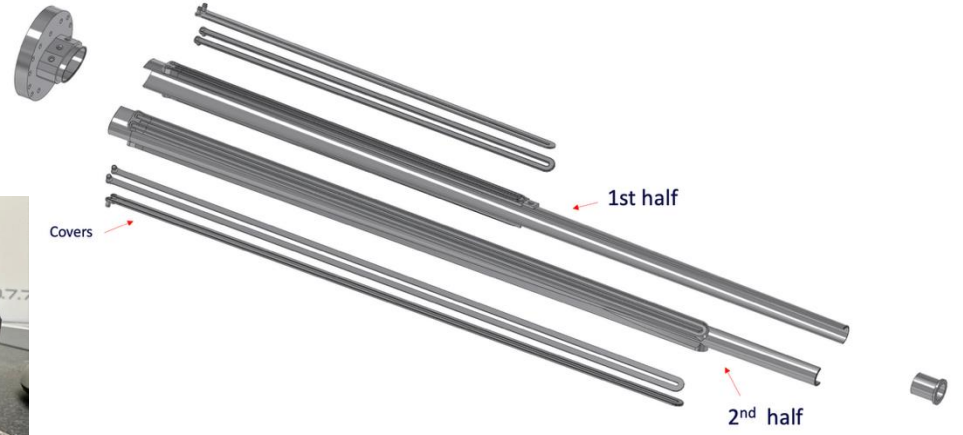
Conical Vacuum Chambers

Presently in UK for EBW

Prototype in aluminium.
Conical chambers are fabricated in two halves that need to be welded with EBW.
The cover part of the water cooling channels will be brazed on top.



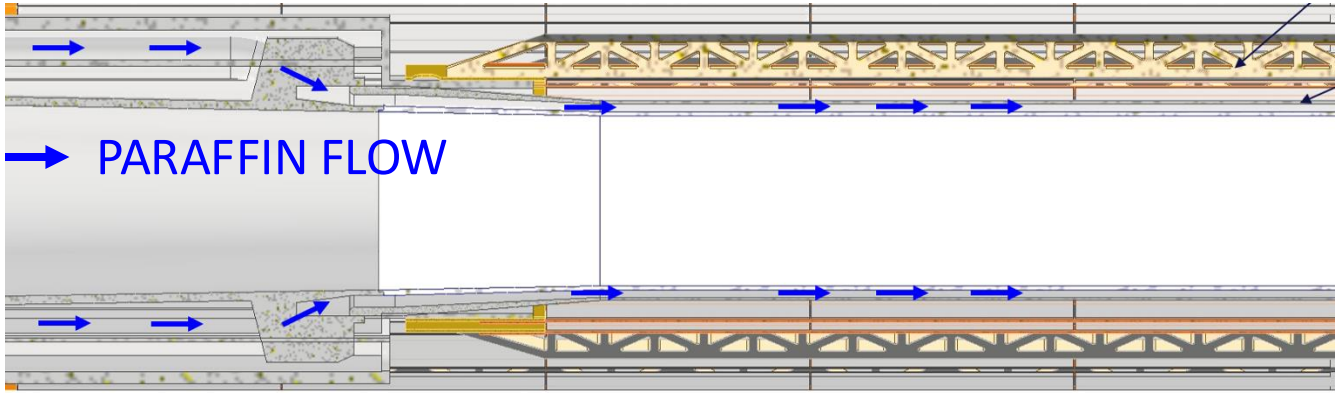




Detector beam pipe and vertex detector integration

Study fits perfectly in DRD8

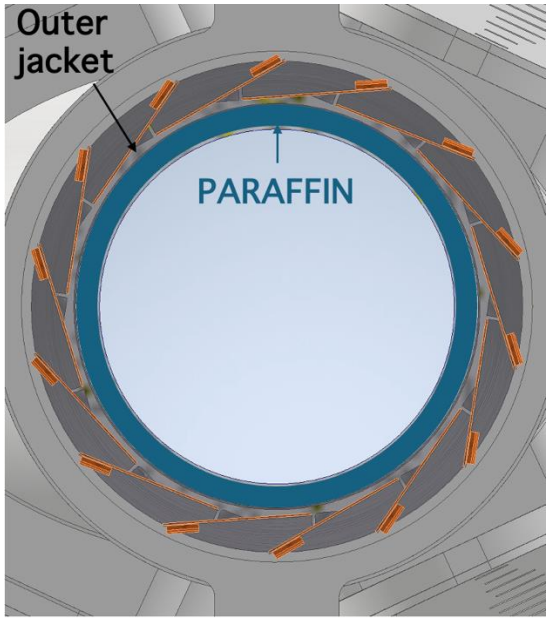
The R&D with the mockup allows optimisation of the design



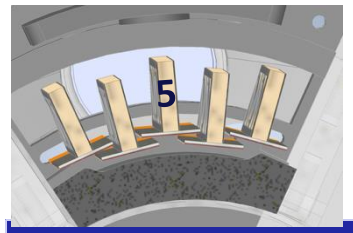
Layer 1 only ~ 2 mm away from the outer wall of the beam pipe

Why not to use the paraffin to cool the layer 1?

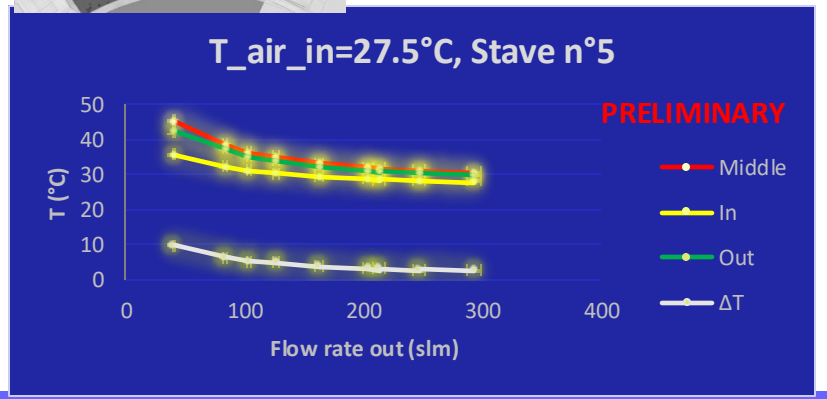
Needs an integrated design



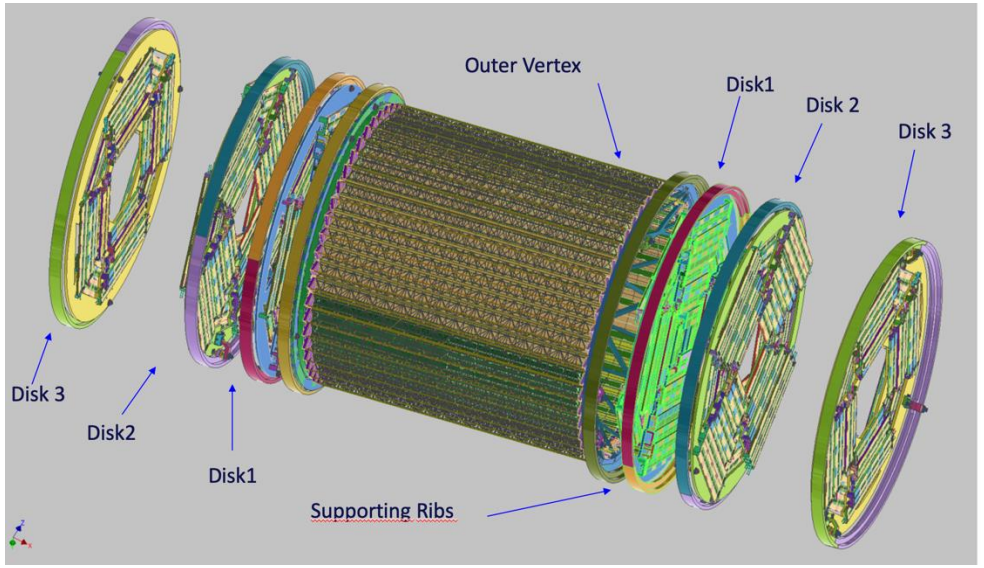
Compressed air system installed in Pisa



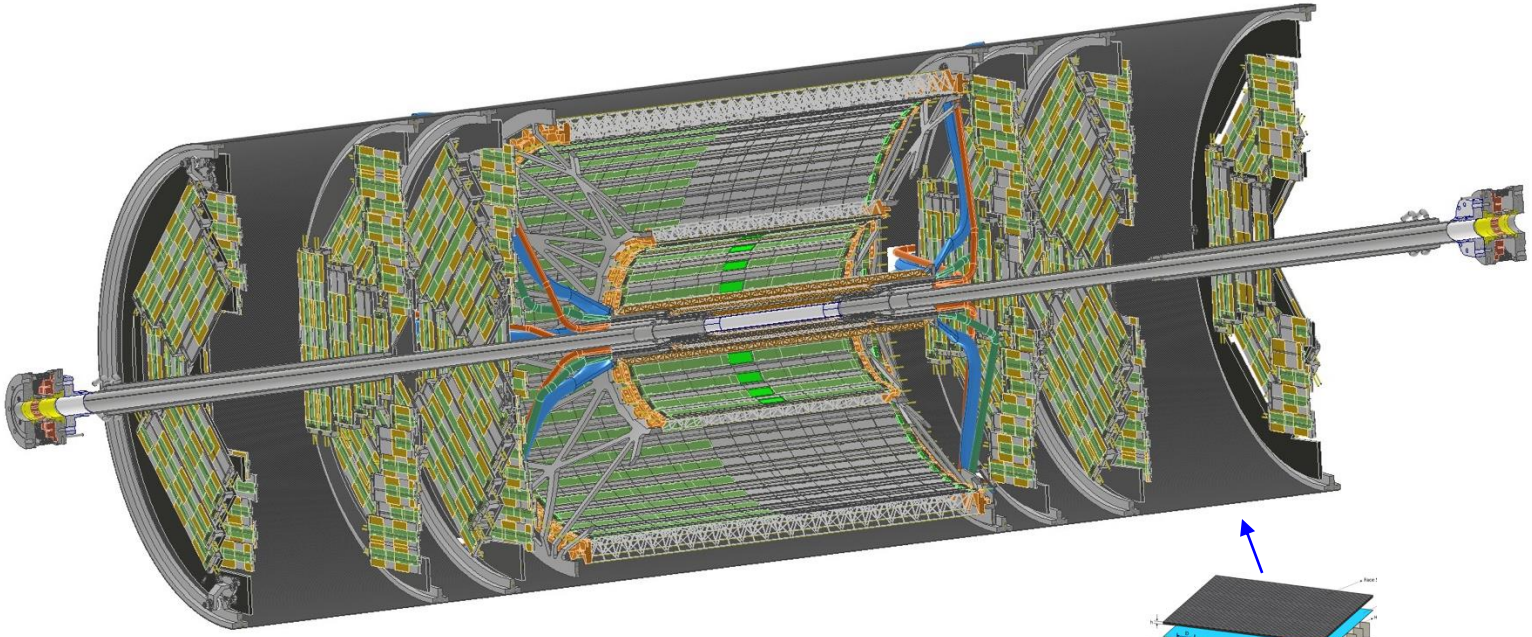
Staves under thermal testing



Integration and Assembly sequence



Disks and Barrel Prototypes (Pisa)



Support tube provides integration of beam pipes, vertex and LumiCal (Pisa), endcaps and lumical supports (Frascati)

Support tube material

1mm CF + 4mm HC + 1mm CF

Assembly sequence

INFN Team

LNF

- M. Boscolo
- S. Cantarella
- A. Ciarma (art. 36)
- E. Di Pasquale
- F. Fransesini (art. 36)
- S. Lauciani
- G. Luminati
- G. Sensolini (senior)
- Servizio impianti a fluido Divisione Tecnica (P. Tuscano)
- Servizio elettrotecnica Divisione Tecnica (Z. Caroleo)
- Servizio vuoto Divisione Acceleratori
- Servizio sicurezze

Pisa

- G. Ammirabile (AdR Tecnologico)
- F. Bosi (senior)
- A. Moggi
- F. Palla
- Servizio progettazione meccanica
- Servizio alte tecnologie

Support from INFN-Perugia
G. Baldinelli and C. Turrioni on vertex cooling simulations

Plans

- Cooling tests on beam pipe both with water and paraffin
- Air-cooling tests on inner vertex detector
- Manufacturing of the support tube, disks, bellows, lumical

- Assembly & Integration test
- Test of structural integrity of central beam pipe

- Integration of a hardware alignment system: studies ongoing at CERN