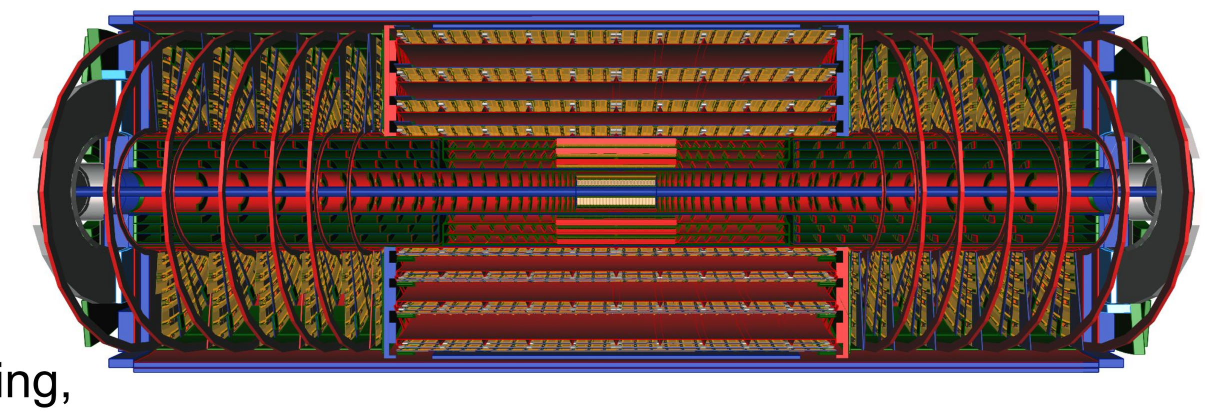
ATLAS ITk Pixel Outer Endcap CO_2 cooling system prototypes

Sonia Carrà on behalf of the ATLAS ITk group

ATLAS new inner tracker: ITk

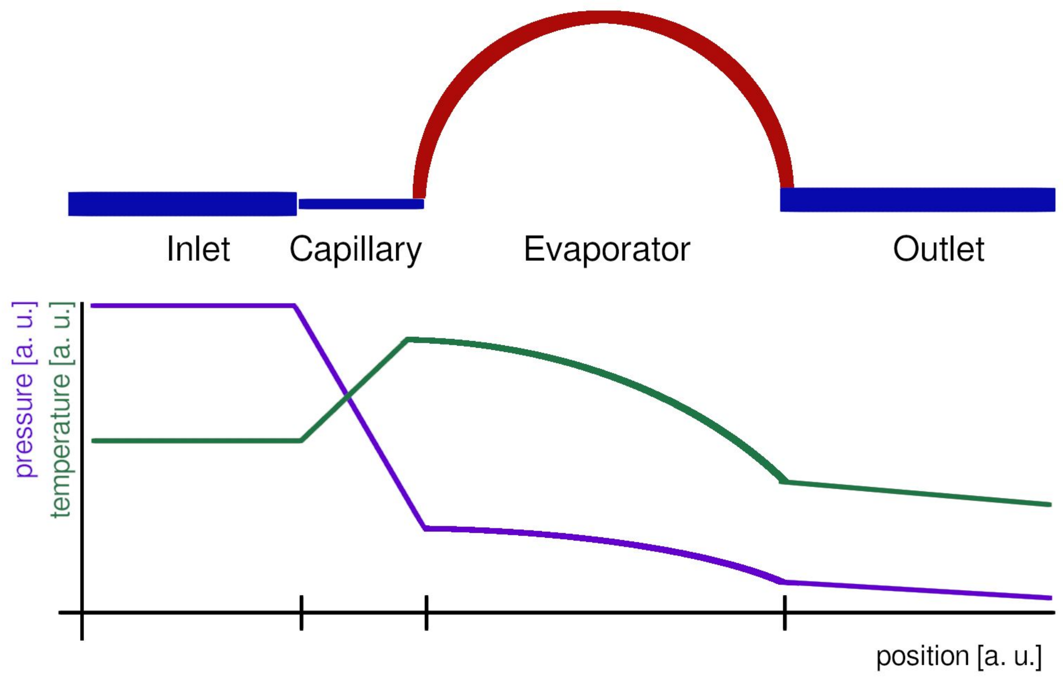


High-luminosity LHC phase starting in 2029
→ATLAS detector will be upgraded with a new **silicon inner tracker**
Silicon detector cooling is critical to prevent reverse annealing, thermal runaway and control the leakage current due to radiation damage

Coolant choice

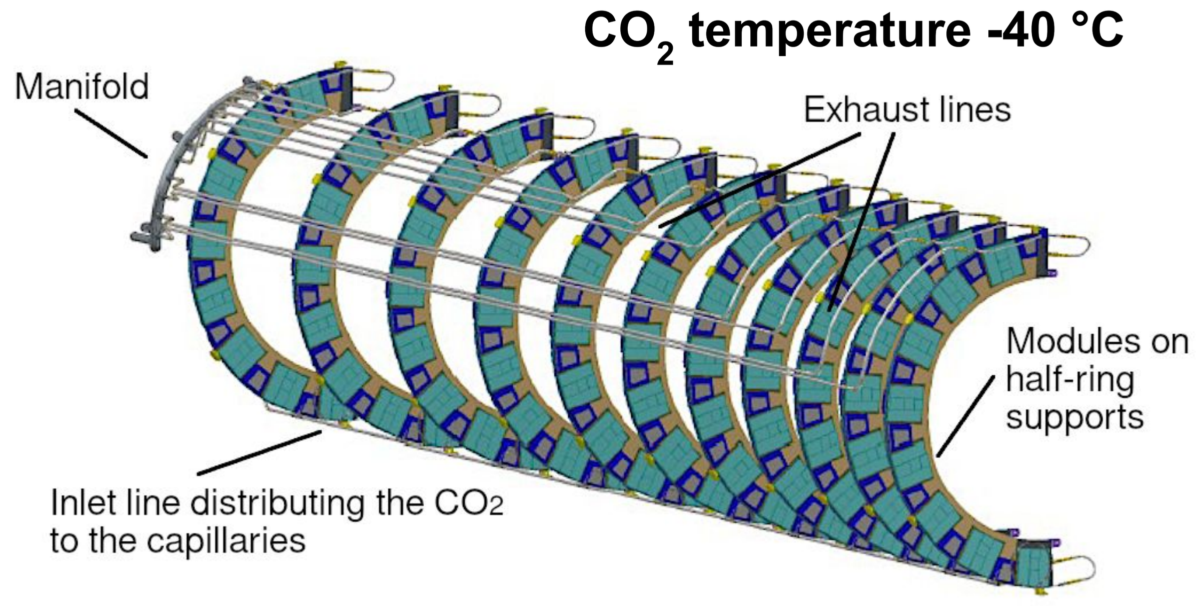
Cooling system based on **CO_2 evaporative properties**

- near isothermal, small temperature gradient along the rings/staves
- high heat transfer coefficient
- mass savings inside the detector due to smaller diameter tubing than conventional refrigerants
- radiation hard and environmentally safe



Cooling system design

CO_2 temperature -40 °C

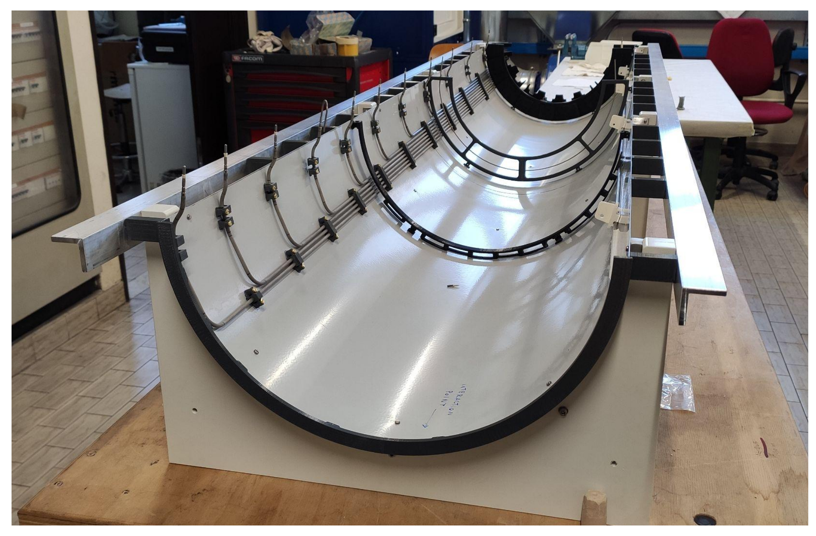


Specification:

- **temperature variation within 5 °C** in evaporator + return lines, corresponding to **pressure drop of 2 bar**
- **Total pressure drop of 10 bar**, with 8 bar in the capillaries to equalize the flow and trigger the evaporation

Manufacturing and testing

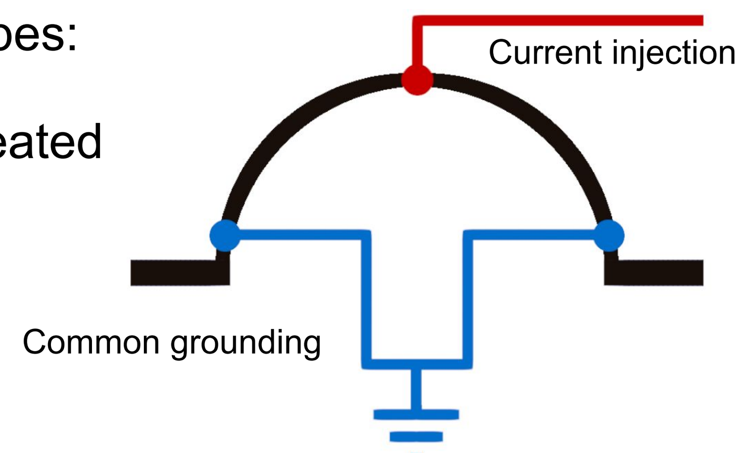
Manufacturing of prototypes and detector cooling system in the **Milan INFN Workshop**
Pipes for prototypes and detector cooling system in titanium
→ detector cooling system will be fully **welded**



Testing at the BabyDEMO cooling plant @CERN: facility is able to provide a CO_2 flow of 150 g/s with a temperature as low as -45 °C

Simulation of the **detector thermal load** in the prototypes:

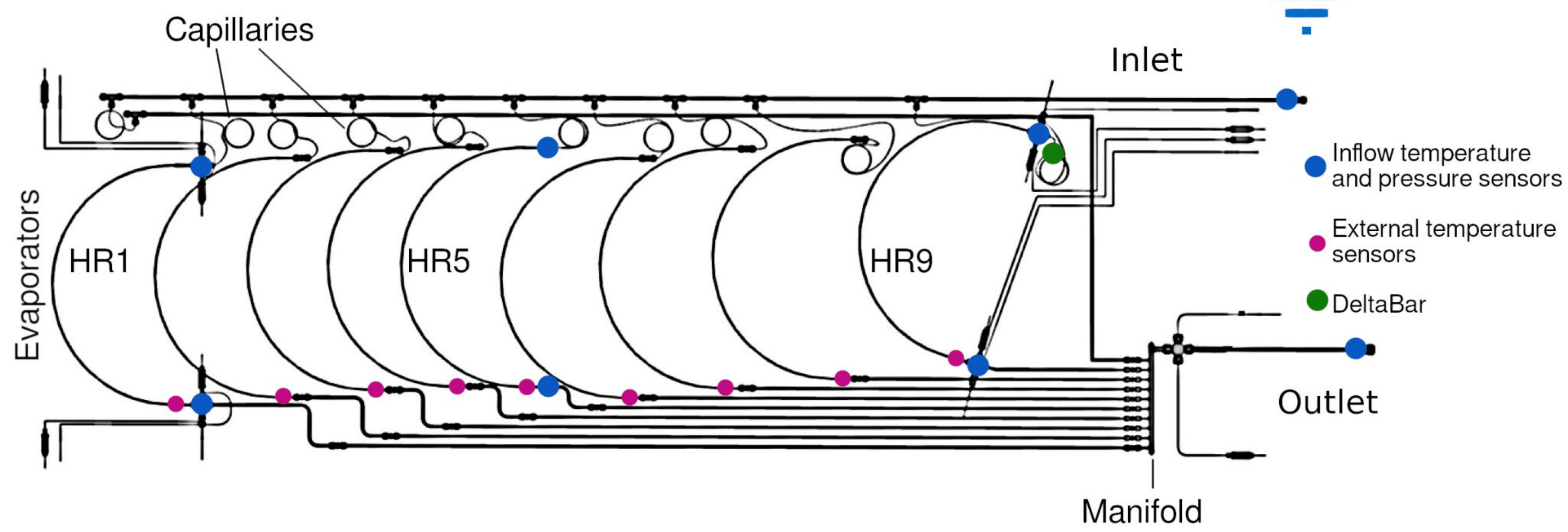
evaporator treated as resistor



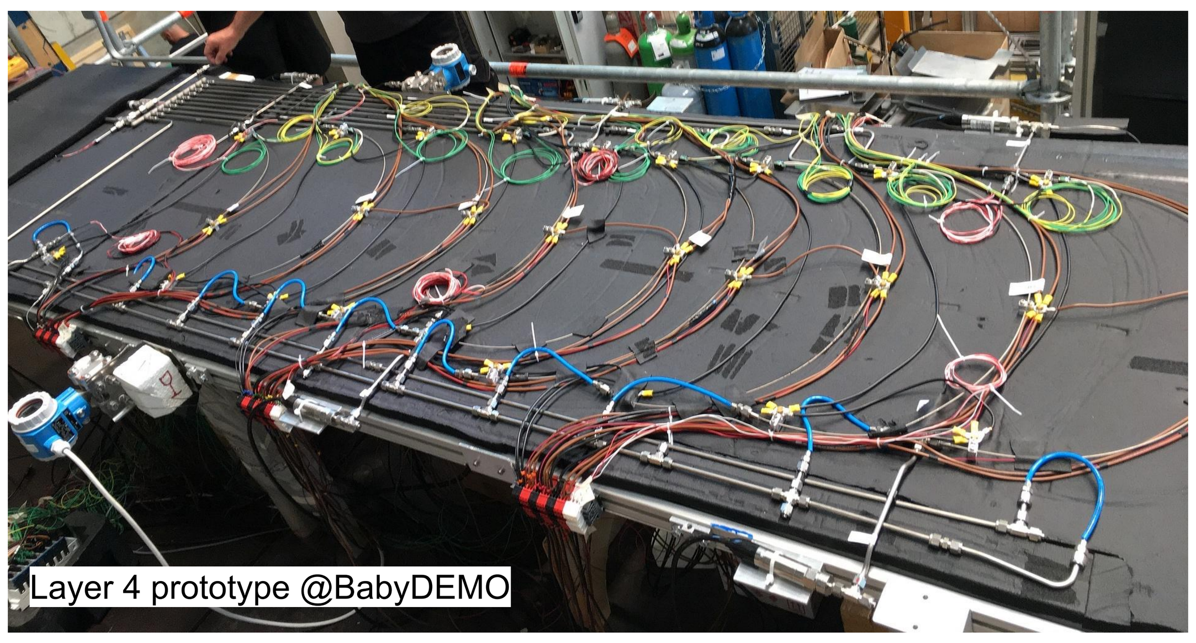
Half-shell prototype for Layer 4

Scope is to test the **functionality and stability of the cooling system** and measurement of key quantities such as temperature and pressure drop
Thermal load in normal operation conditions ~3kW

Design →

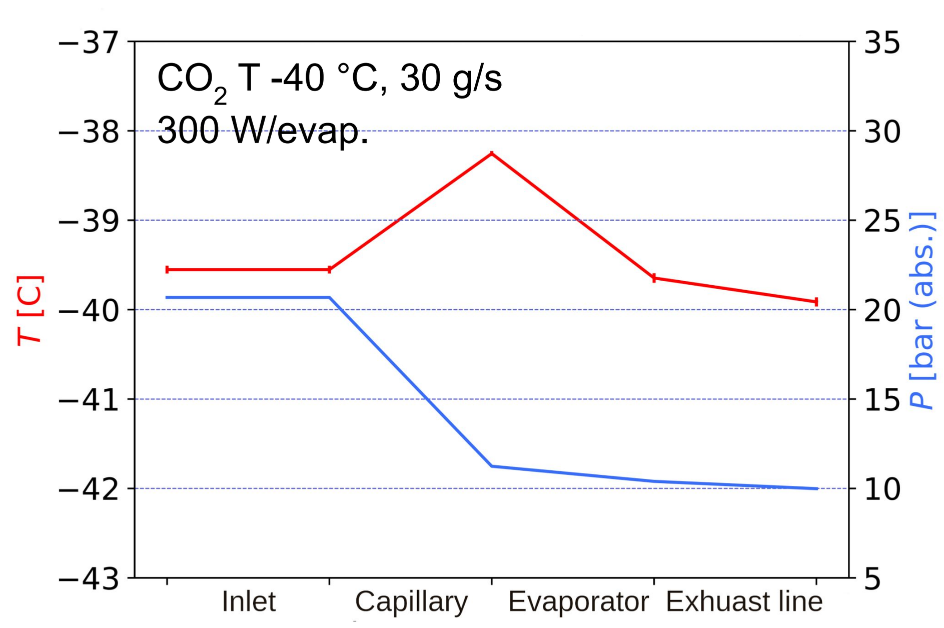


Results



Titanium additive manufacturing for the manifold by LAMA laboratory

T and ΔP along one loop in normal operation conditions



← T variation within 5°C

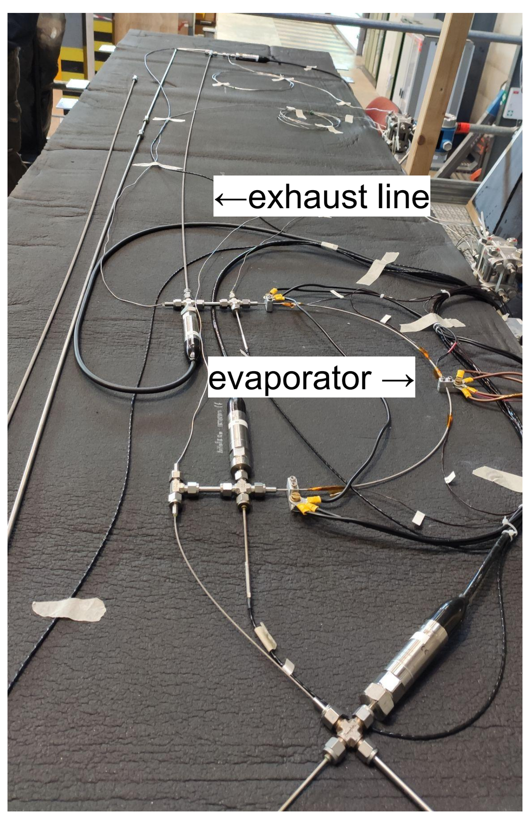
← ΔP in evaporator and return line within 2 bar

Capillaries for final detector will be sized to reach the desired 10 bar total ΔP

ΔP in the evaporators for decreasing CO_2 flow

30 g/s is a safe working condition, dry-out at ~15 g/s

One loop prototypes



Flat prototypes of **one loop for Layer 2 and 3:**

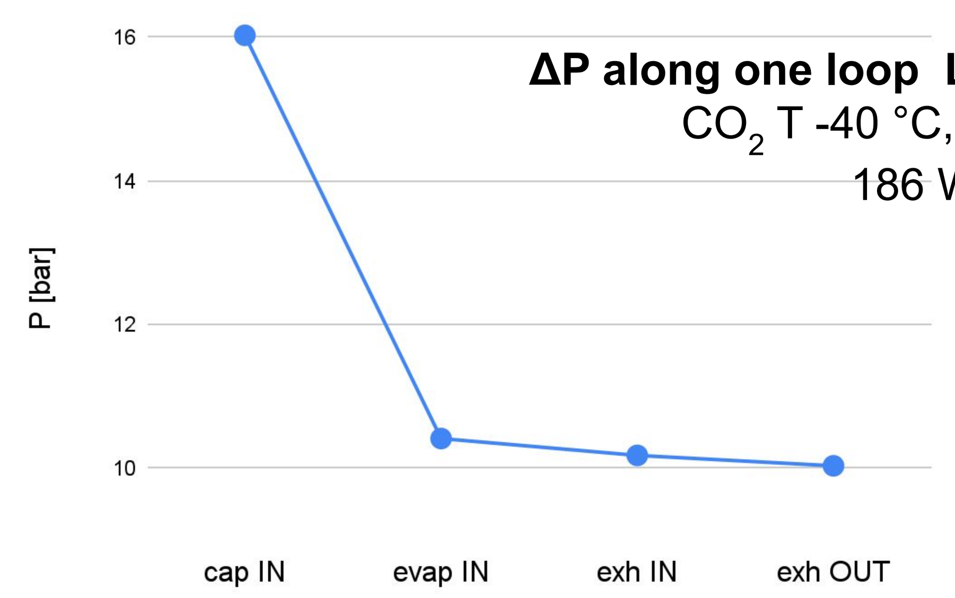
capillary, evaporator, and exhaust line

Scope was to finalized design choice for exhaust line pipe

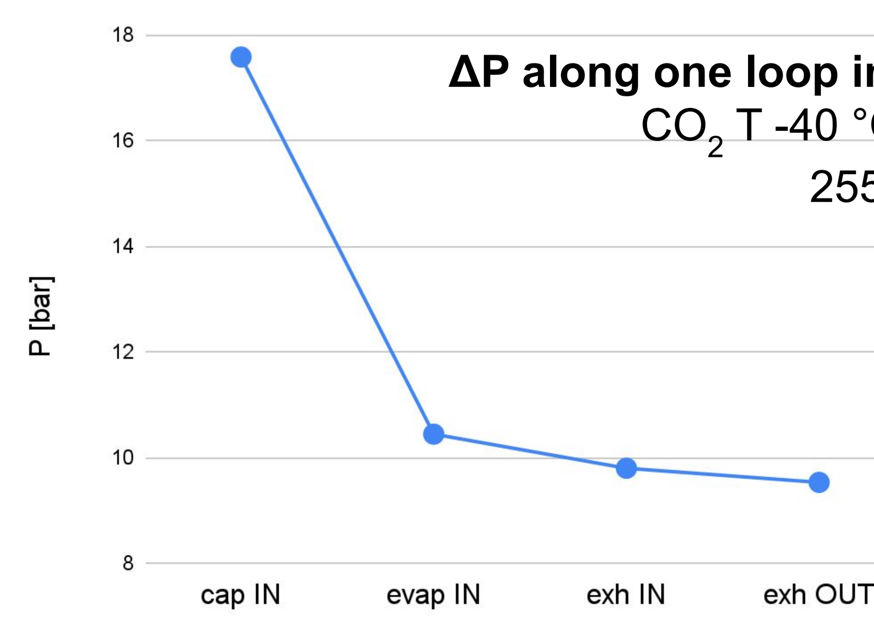
Tested at BabyDEMO plant →

Data will be used to size the capillaries to reach the desired 10 bar total ΔP

ΔP along one loop Layer 2
CO_2 T -40 °C, 1.8 g/s
186 W/evap.



ΔP along one loop in Layer 3
CO_2 T -40 °C, 2.6 g/s
255 W/evap.



ΔP in evaporator and exhaust within the specification both in Layer 2 and 3

Conclusions

- ➔ Systems were proved to be stable under all the conditions tested
- ➔ Use of additive manufacturing parts has been proved
- ➔ Total pressure drops were consistent with the requirements of the system specification

ATLAS ITk
https://atlas-collaboration.web.cern.ch/

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