CERN

Remote Cooling System Options for a BCCCB Cryostat

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Outline

- Remote cooling options
- Cryolab remote cooling setup & CFHEXs
- PIDs and options
- Experience from a 1.3 GHz SRF dry cavity cooling setup
- Summary

LHe zero boil off cryostat: summary

Outcome summary

❑ "Stand-alone" cryo system requires refills & several associated challenges

- Impurities in the He system → SVs leak

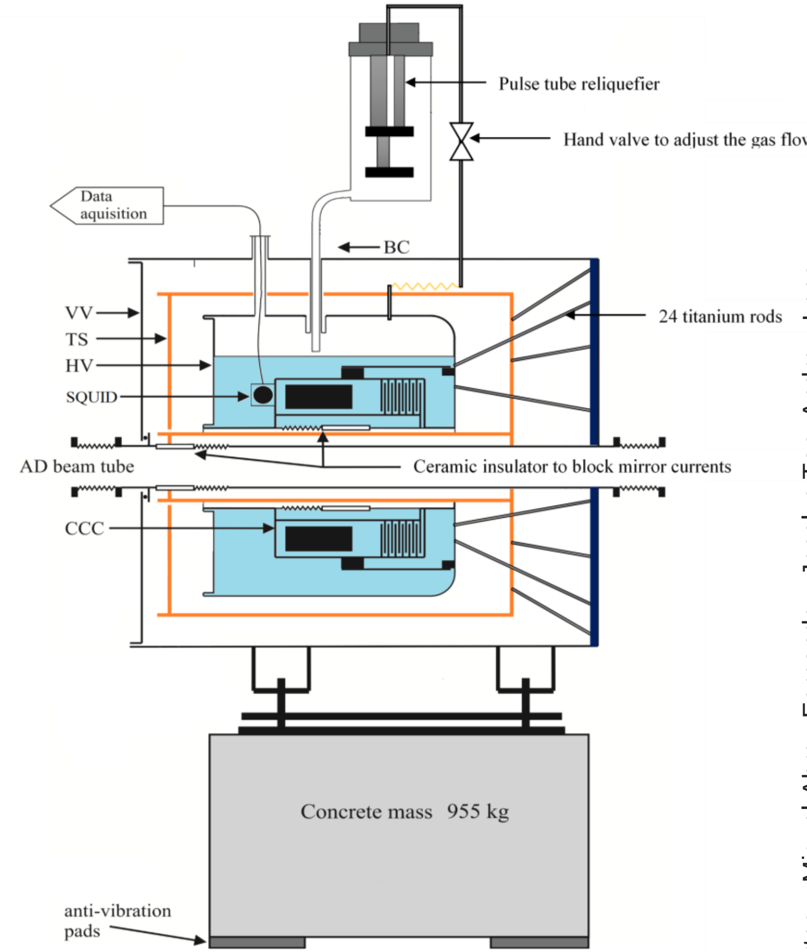
❑ $Q < 1.2$ W (0.9 + 0.3) available cooling power

❑ 12 weeks independent operation (LHe =const.)

System requirements (crucial!)

➢ Low values of:
  ➢ Mechanical vibrations
  ➢ Temperature and magnetic field variations

All this paved the way to remote cooling circuit R&D

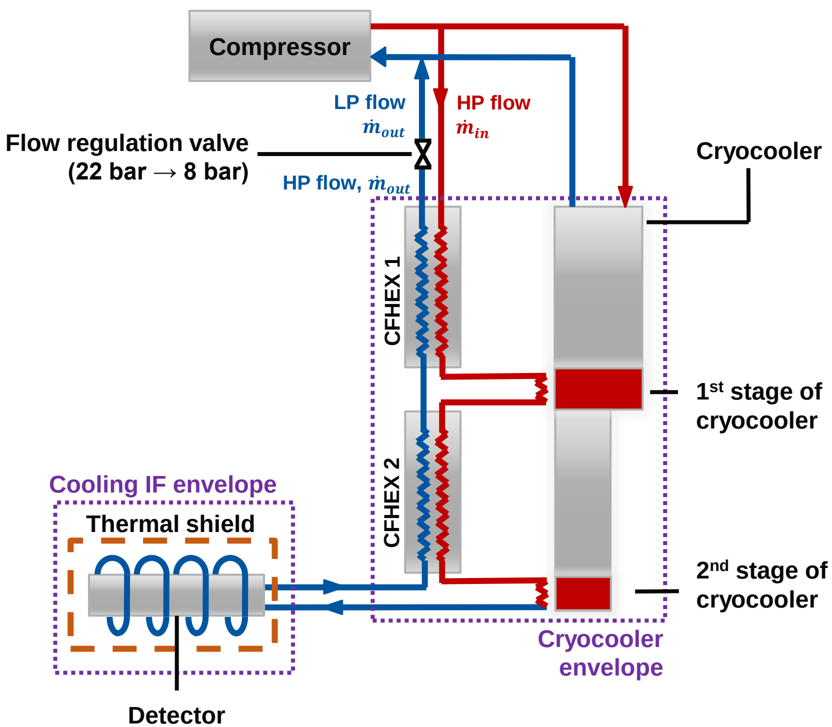


Courtesy: Miguel Abreu Fernandez, Jocelyn Tan, Andrew Lees

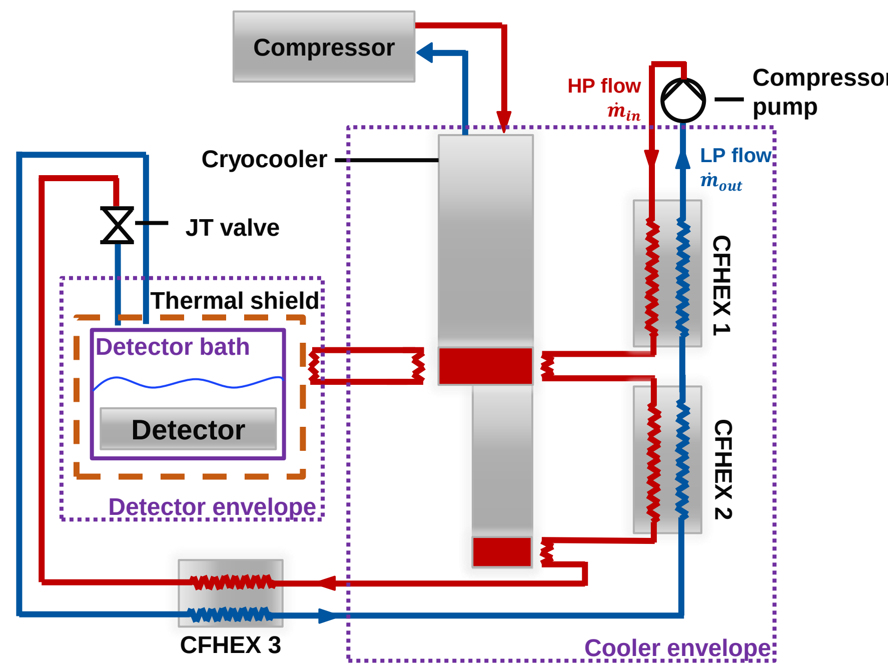
Examples of remote cooling solutions

- Proposed solution: cryocooler-based system with a **convective cooling loop**
- Principle was used before in **space, micro-cooling, gas liquefier** applications

High-pressure circuit with the cryocooler as a cooling source



JT circuit to increase the available cooling power



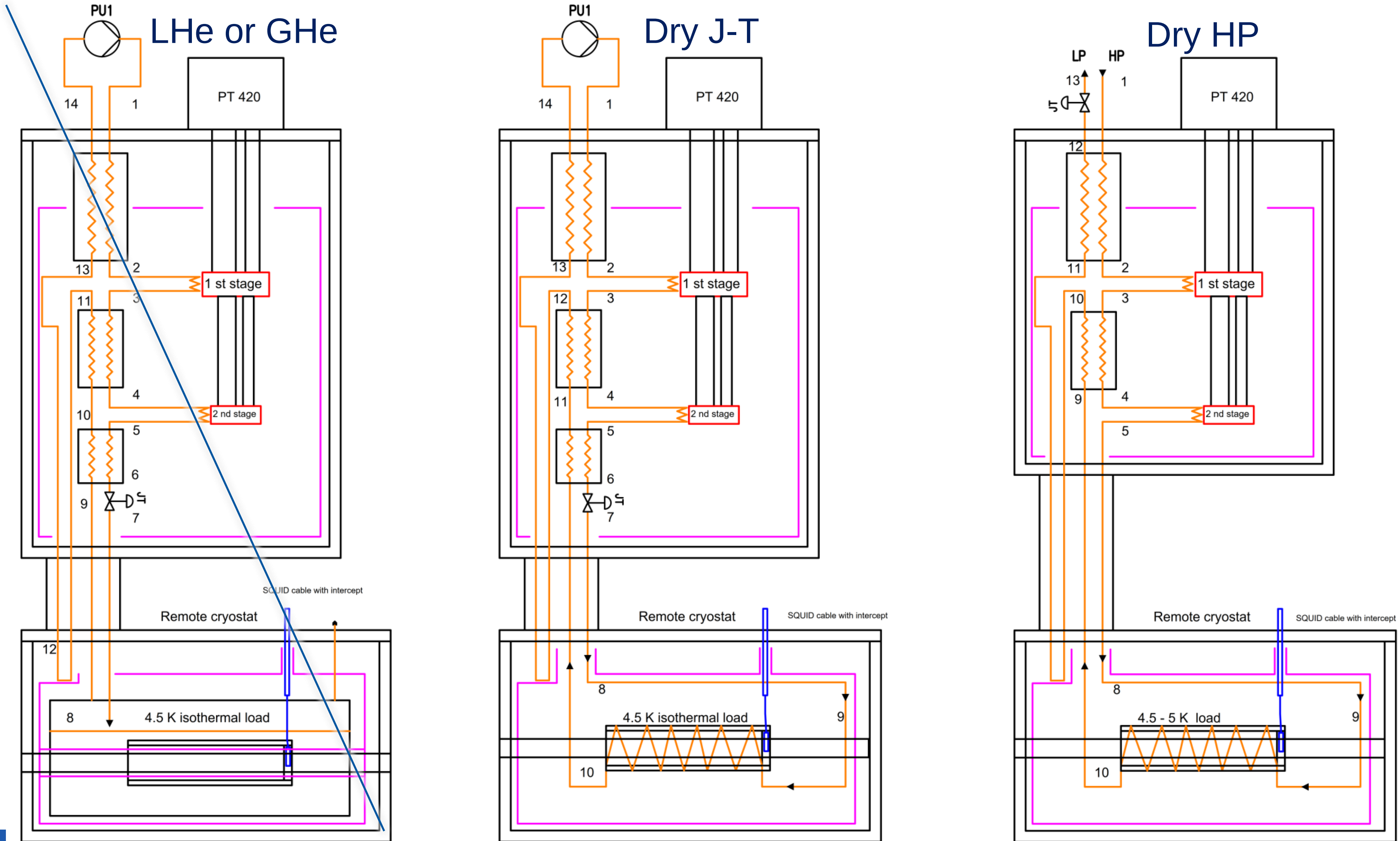
Remote cooling options

- Thermodynamic design of a remote cooling loop with a 2.5 W PTR
- Remote He cooling loop at high pressure >5 (25) bara
- Possible use of a cold circulator => CryoFan
- Dry cooling interface to the detector via its support shell

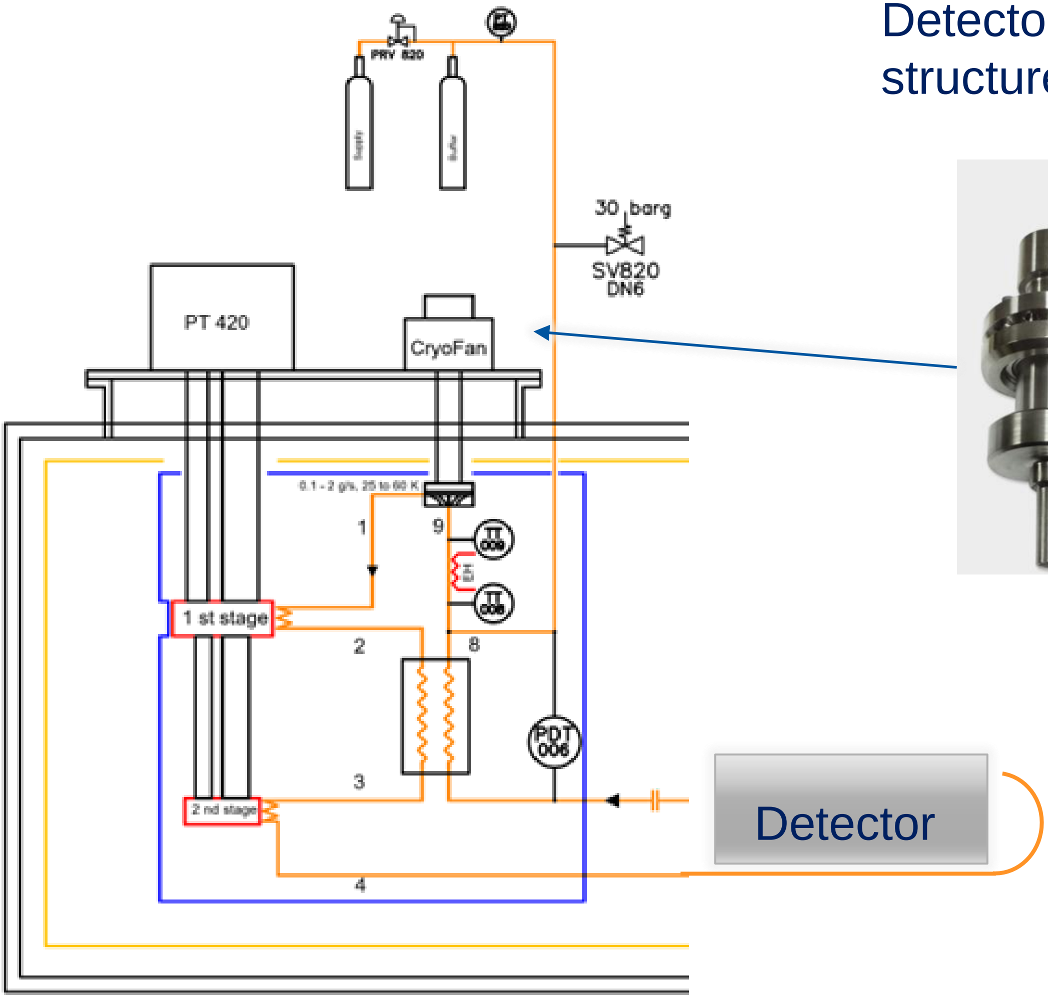
Open points:

- Magnetic core?
- Test with a system like that in a non-shielded environment

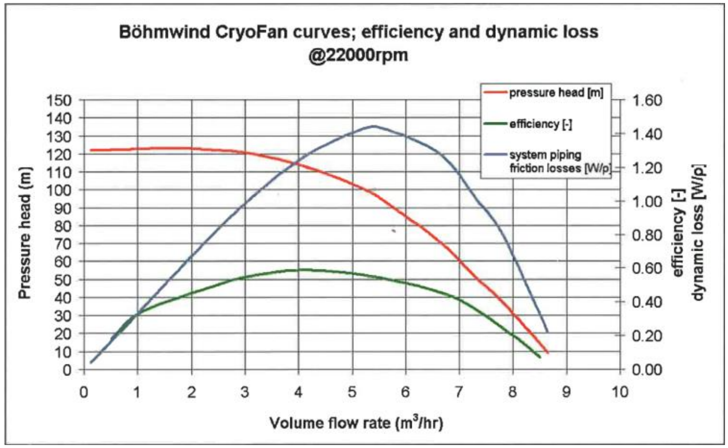
PIDs for JT based circuits



PIDs for circulator based circuits

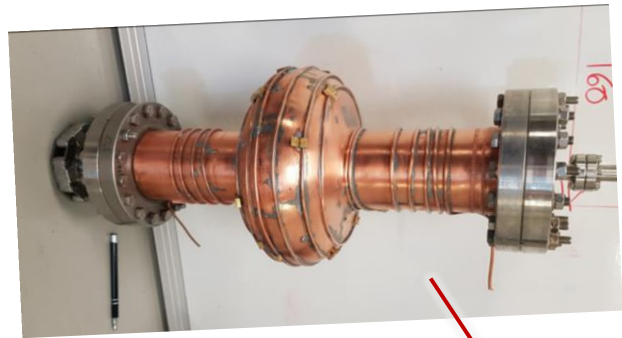


Detector interface cooling via support structure (20 kg detector?)

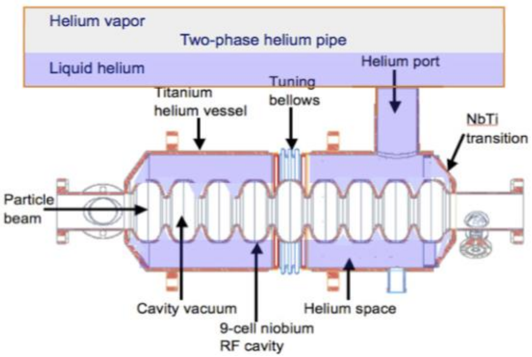


Dry cooling test stations for SRF cavities

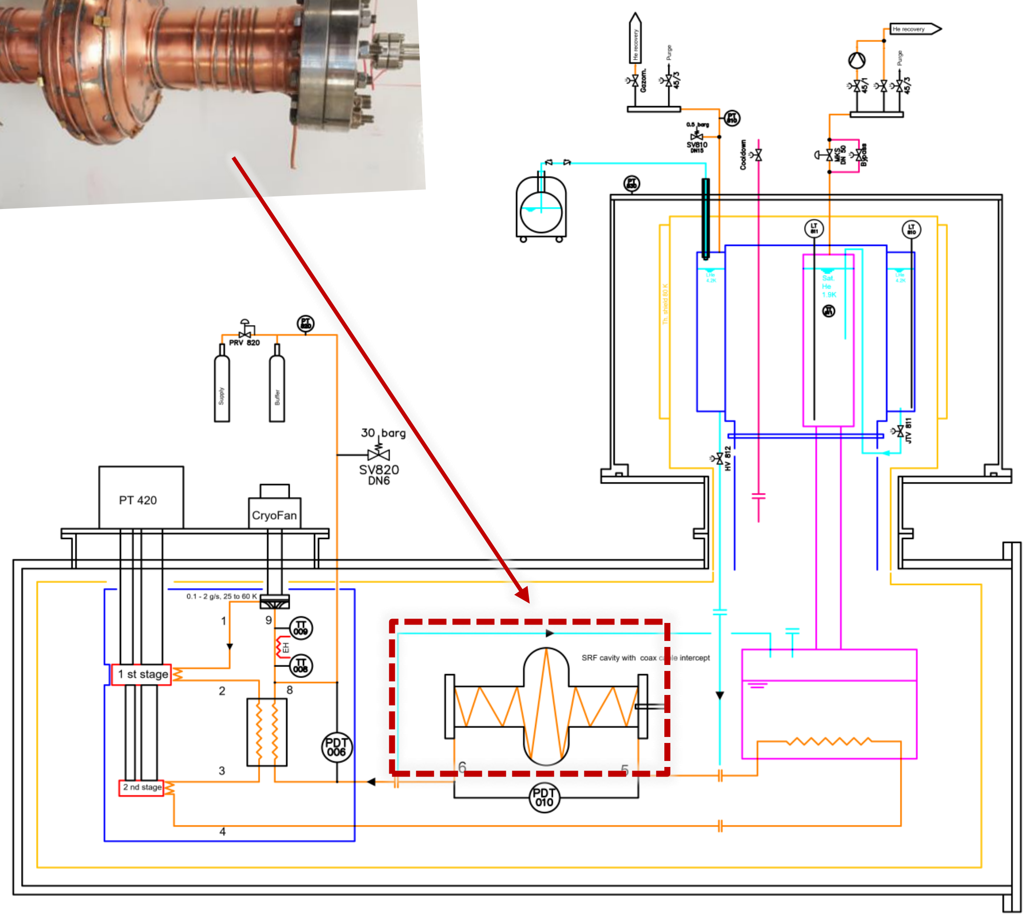
Applications: dry SRF cavity cooling

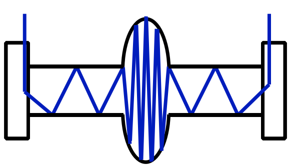


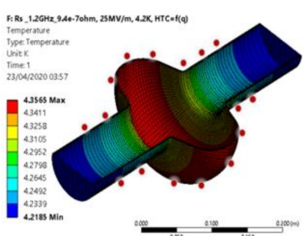
Dry cooling principle



Test setup to study dry colling (system performance, flow in the capillary)

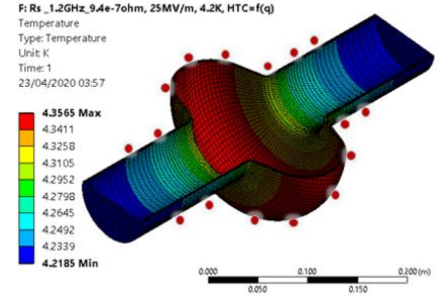




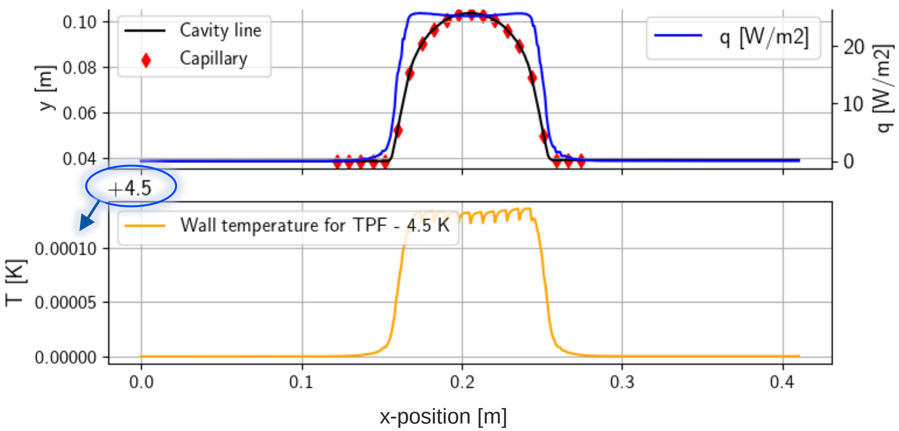


Cavity wall temperature distribution

Numerical simulation!
to be validated by the experiments

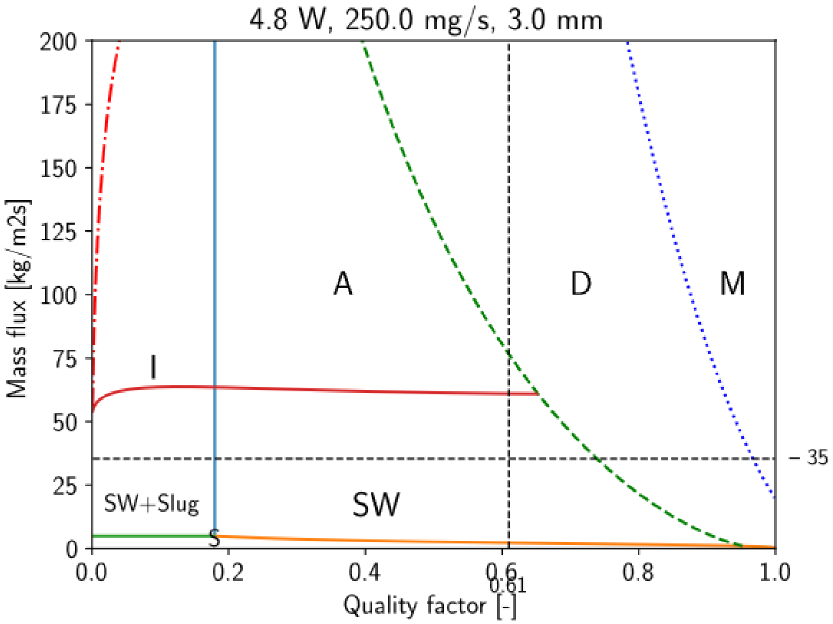


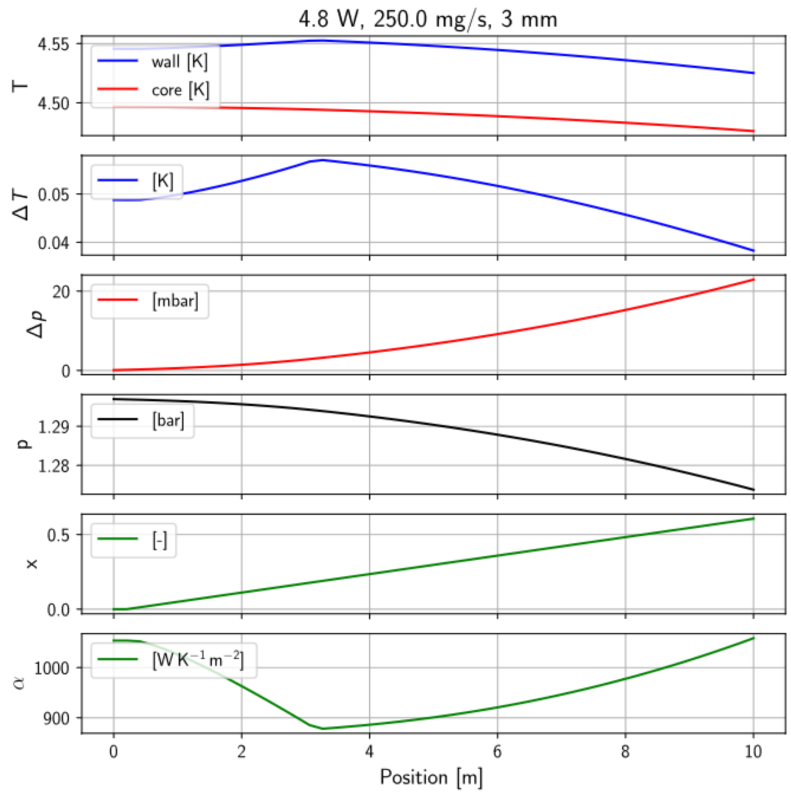
He two-phase flow (TPF)



Two-phase flow – flow pattern map calculations

Heat loads and mass flow





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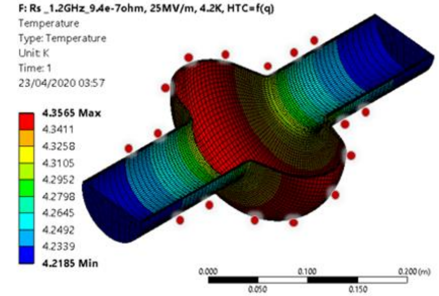
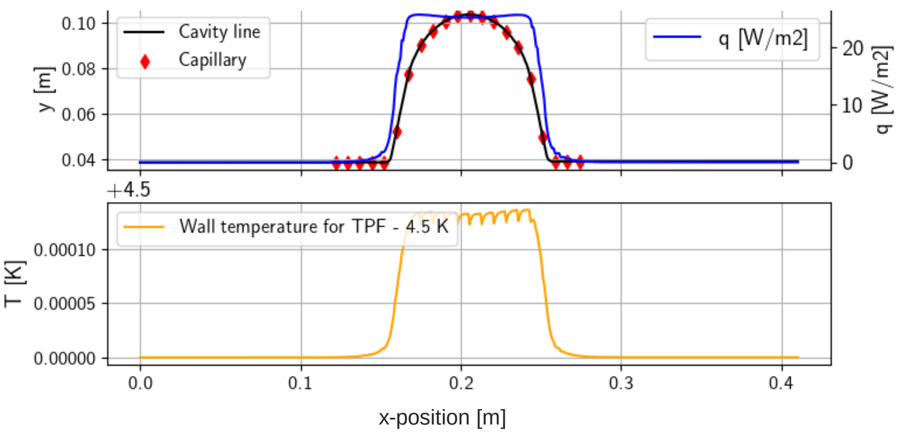


He two-phase flow (TPF)

Capillary: 21 loops, spacing 0.75 cm, length 10.57 m, power 2 W



Flow options – a comparison

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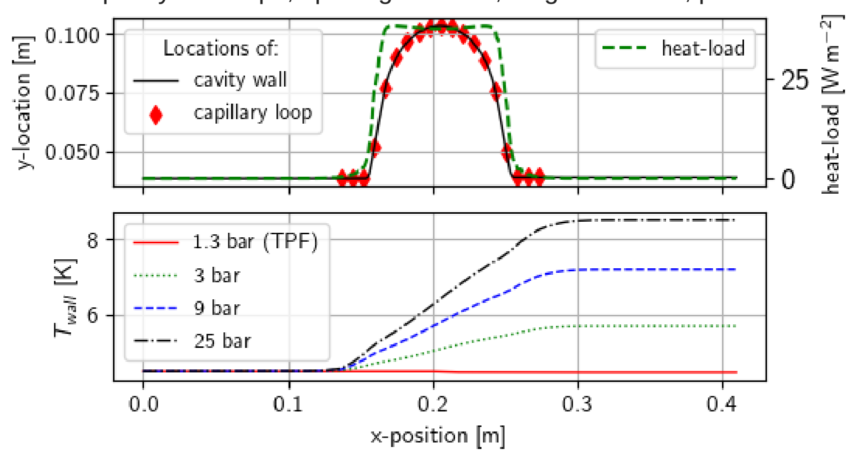
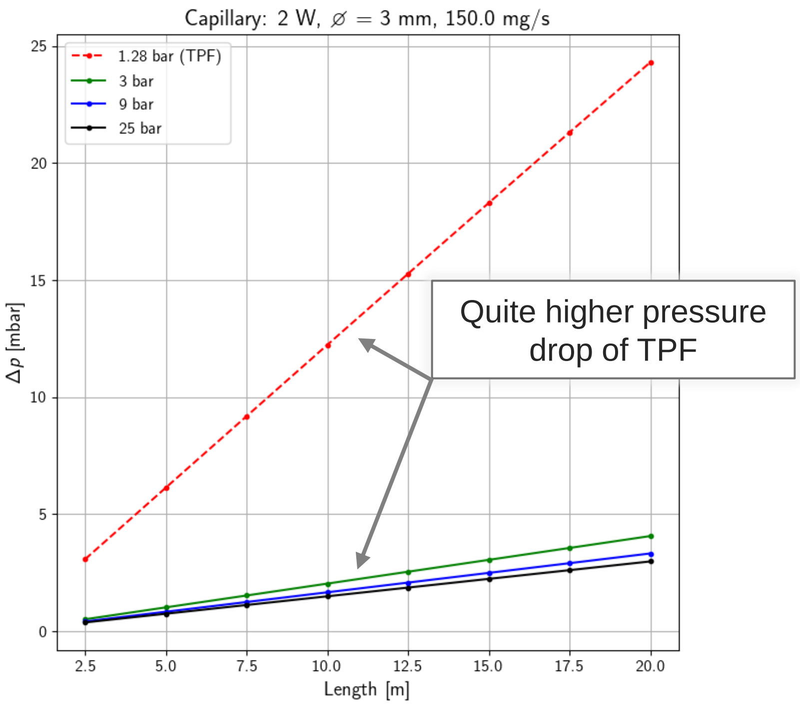


Courtesy: A. Onufrena et al. CEC 2021, IOP Conf. Series: Materials Science and Engineering

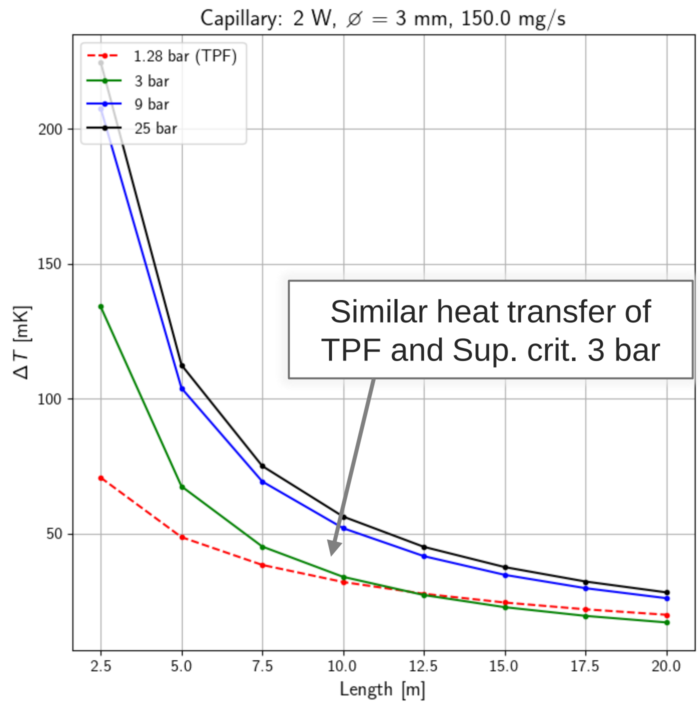
Optimum cooling tube diameter/length/fluid pressure

Numerical simulation of friction and heat transfer, a comparison of flow conditions

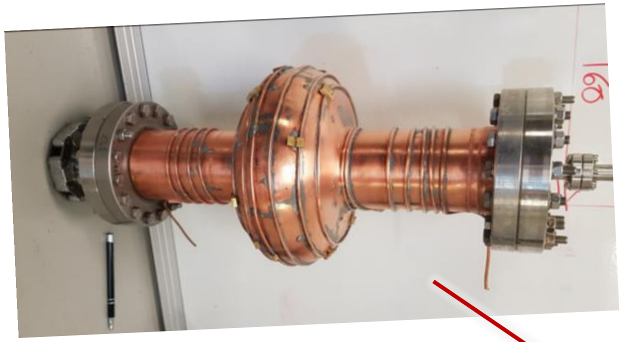
Pressure drop comparison

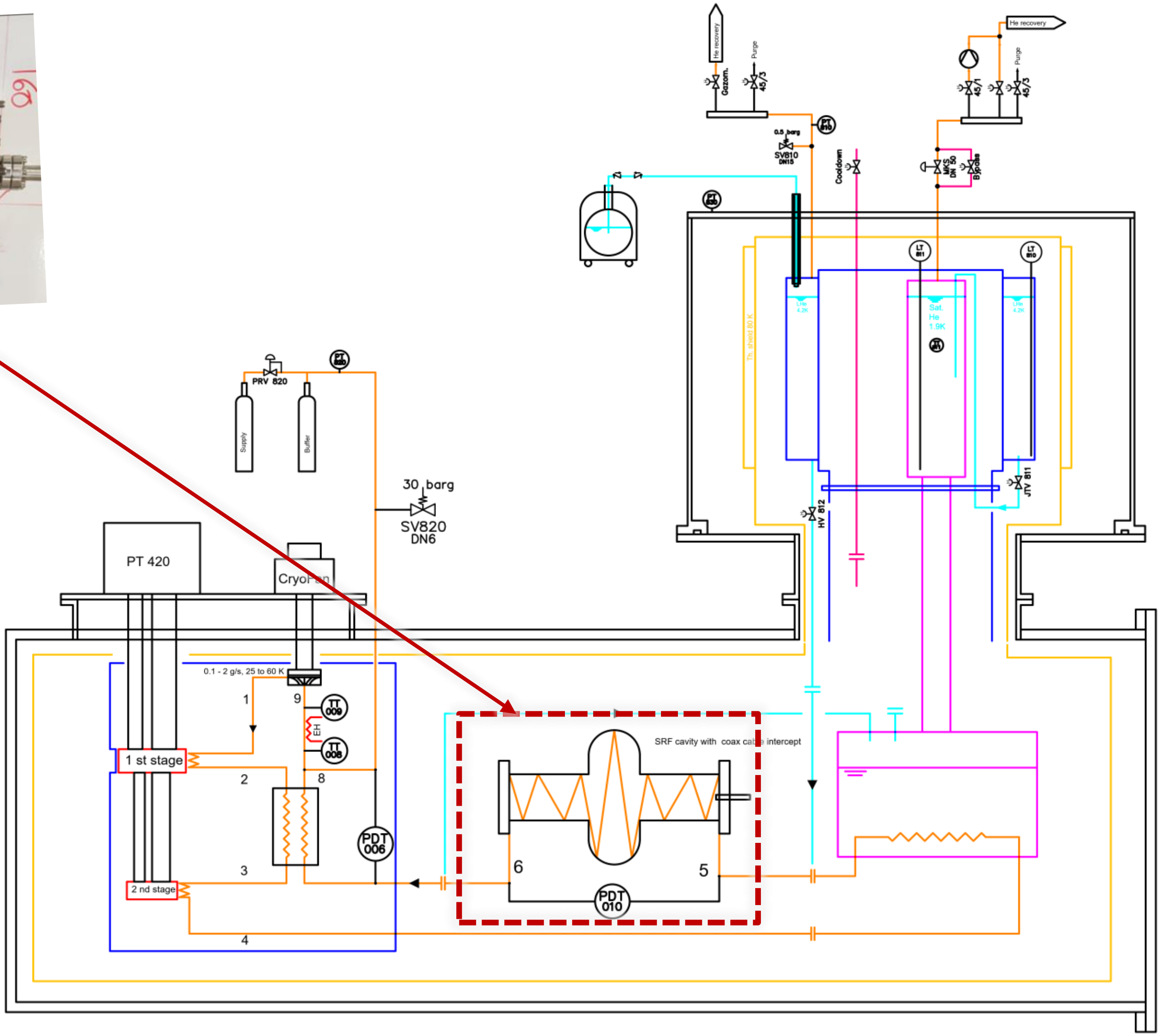


Temperature difference tube wall to fluid core

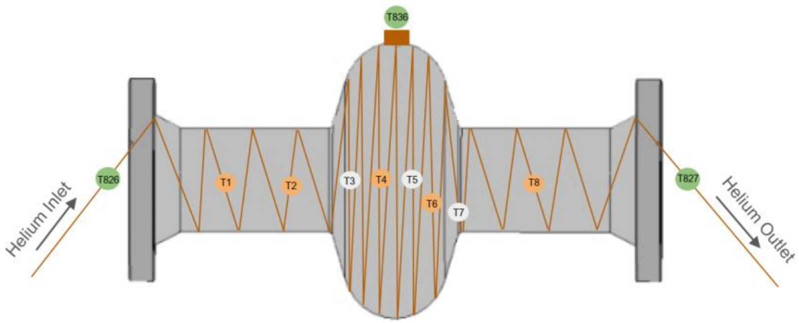


Dry SRF cavity cooling with booster HEX





1.3 GHz SRF cavity test results with booster HEX



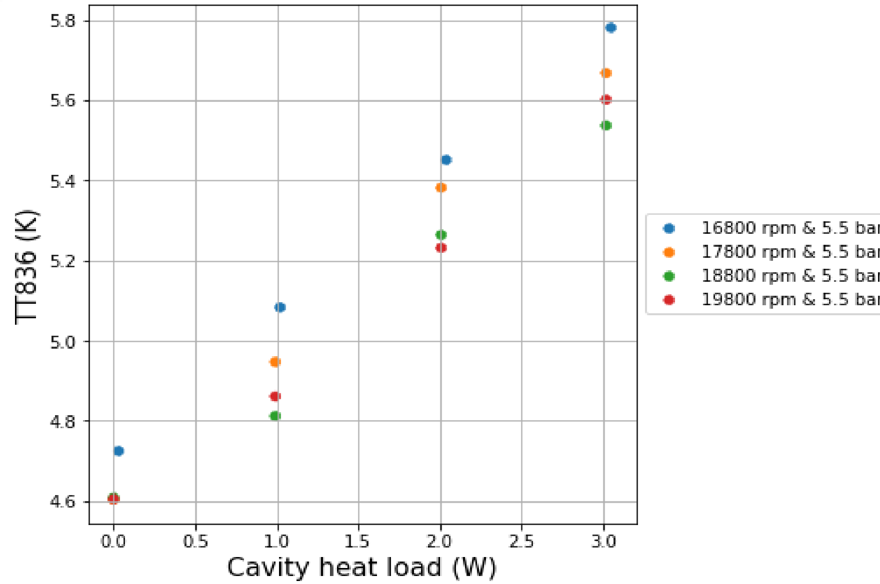
(TVO) **TT826** located on the capillary (outlet)

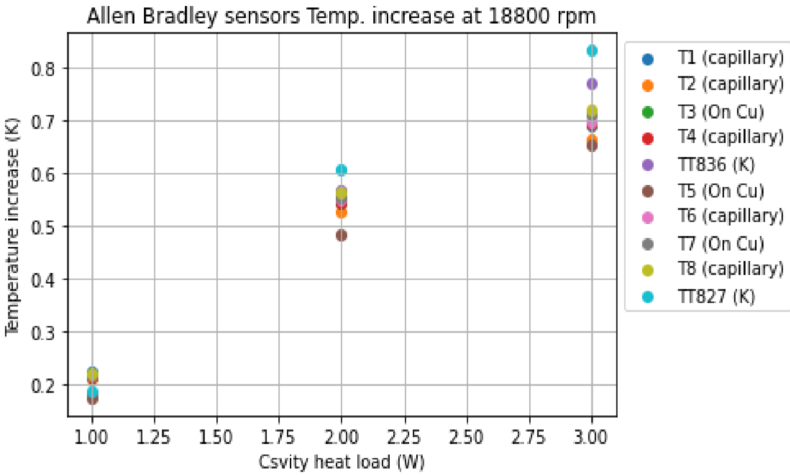
(TVO) **TT836** located on the cavity equator, measuring the average centured temperature

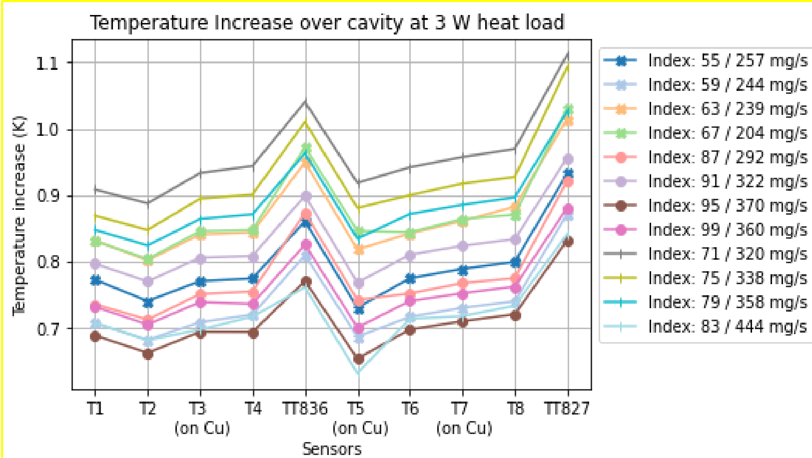
(TVO) **TT827** located on the capillary (inlet)

(Allen Bradley) **T1,T2,T4,T6,T8** located on the capillary

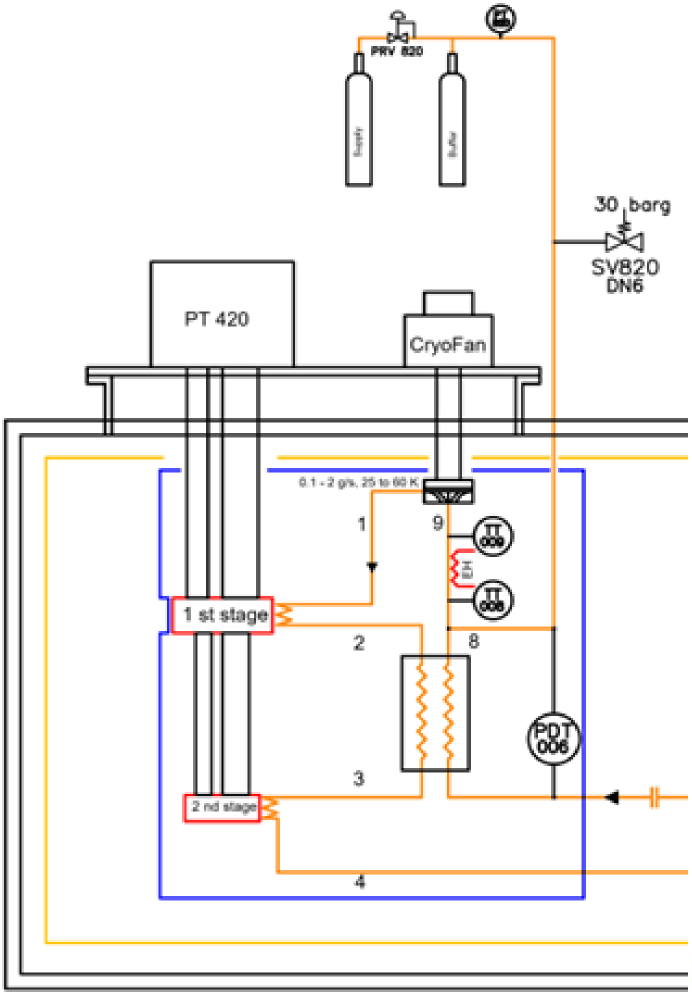
(Allen Bradley) **T3,T5,T7** located on the Cu cavity surface





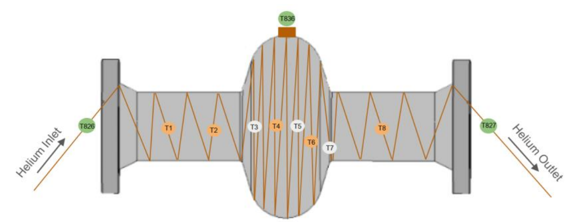


1.3 GHz SRF cavity test results, PTR alone



Parameters:

- Cooling power of the pulse tube cryocooler is rated at 1.8 W @ 4.2 K with one CFHEX
- Helium pressure (PS=30 bar, $p_{operation}$<10 bar)
- CryoFan Boehmwind operating @ max. 366 Hz and p>5 bara => ~300 mg/s He flow rate
- Residual heat loads via cavity support structure, thermal screen etc. ~0.7 W



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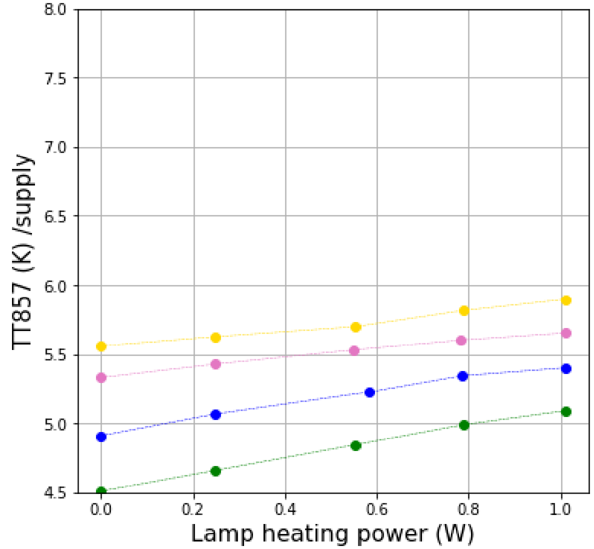
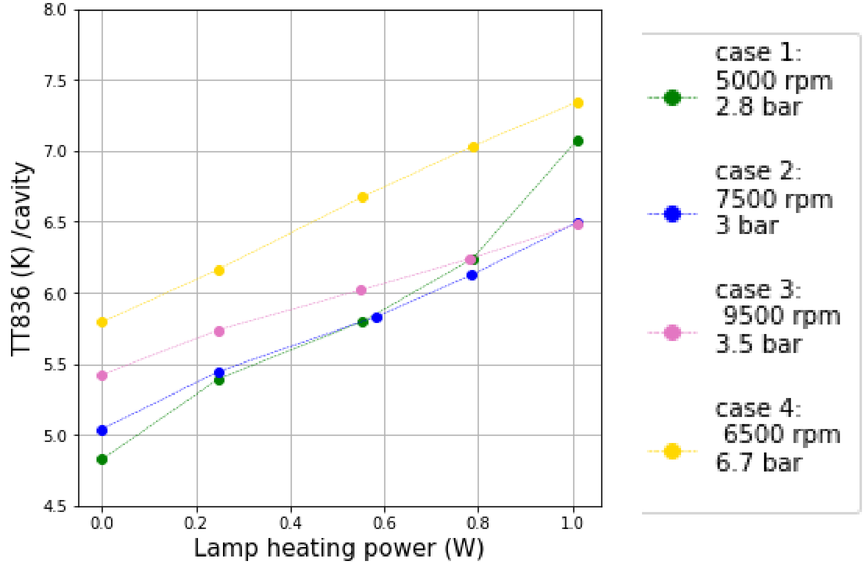
1.3 GHz SRF cavity test results, PTR alone

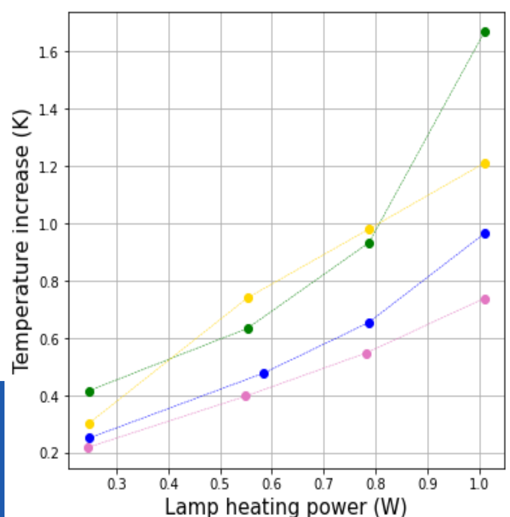
Supply temperature



Cavity temperature



Temperature increase



Summary

- Suggestion of a dry cooling option for the BCCCB with capillary circuit
- Conduction cooling interface to the detector
- Advantages of saving a LHe vessel and ceramic break
- Experimental study of cavity cooling demonstrated 1.7 W cooling power below 6.5 K
- Low mechanical disturbance version with CryoFan and p>5 bar He

Outlook

Application for BCCCB would need:

- an experimental campaign to demonstrate the feasibility and low disturbance cooling option of a real detector in unshielded environment
- requires a two-stage cryocooler, CFHEX (inhouse), stage HEXs (inhouse), CryoFan, setup
- check for cooldown time as well => 3 days
- 2 years effort with a graduate at CERN Cryolab
- sufficient time for translating this results into an operational cryostat for TT20

CL

Thank you for your attention