Cryogenic cooling options for radiation testing

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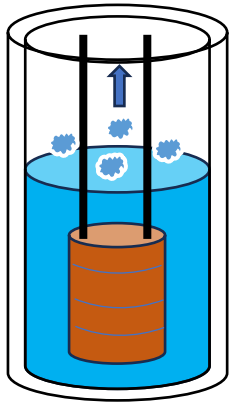
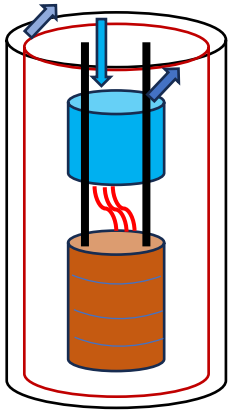
- Cryocooler based solutions
- Remote cooling loops
- Summary

Cooling options/influence on cryostat design

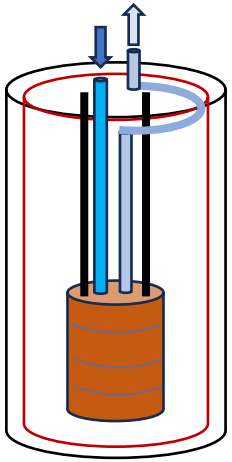
LHe based options



Bath cooling,
direct liquid contact

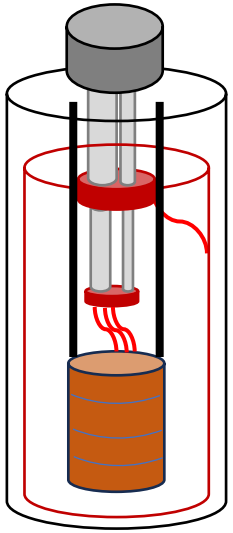


Phase separator as
cooling source,
conduction cooling

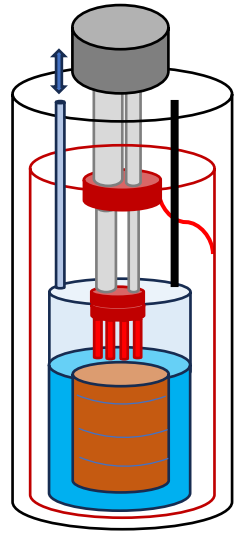


Forced flow or
natural circulation,
conduction cooling

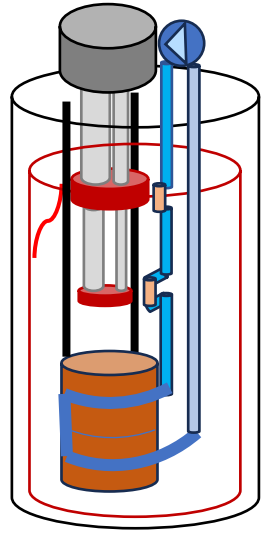
Cryocooler based options



Cryocooler,
conduction cooling



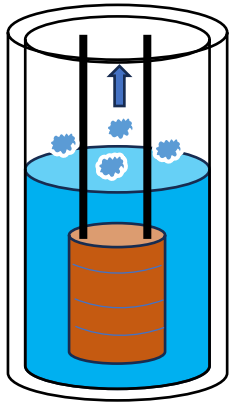
Cryocooler,
ZBO, Vapor
condensation



Cryocooler,
remote cooling

Cooling options/influence on cryostat design

LHe based options



Bath cooling,
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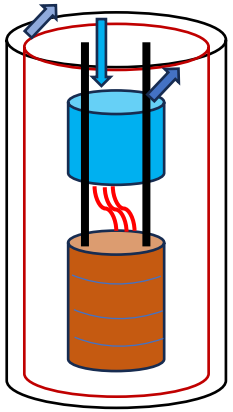

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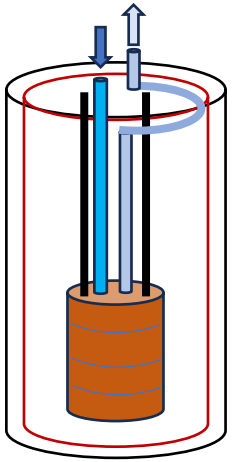

Forced flow or
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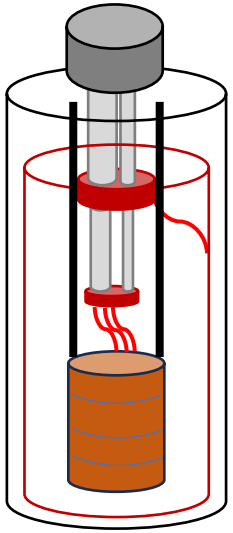
Cryocooler based options



Cryocooler,
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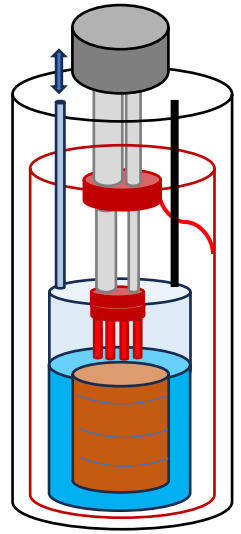

Cryocooler,
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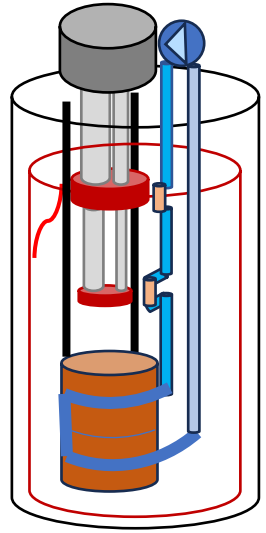
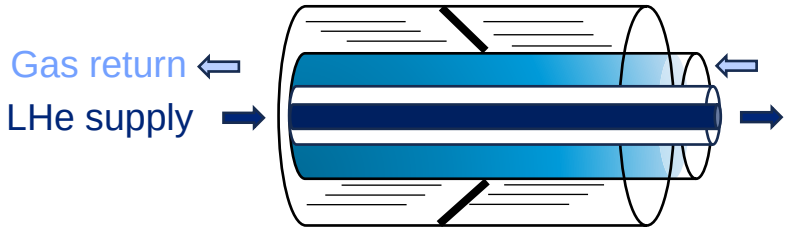


Cryocooler,
remote cooling

LHe transfer lines in the zone for refill



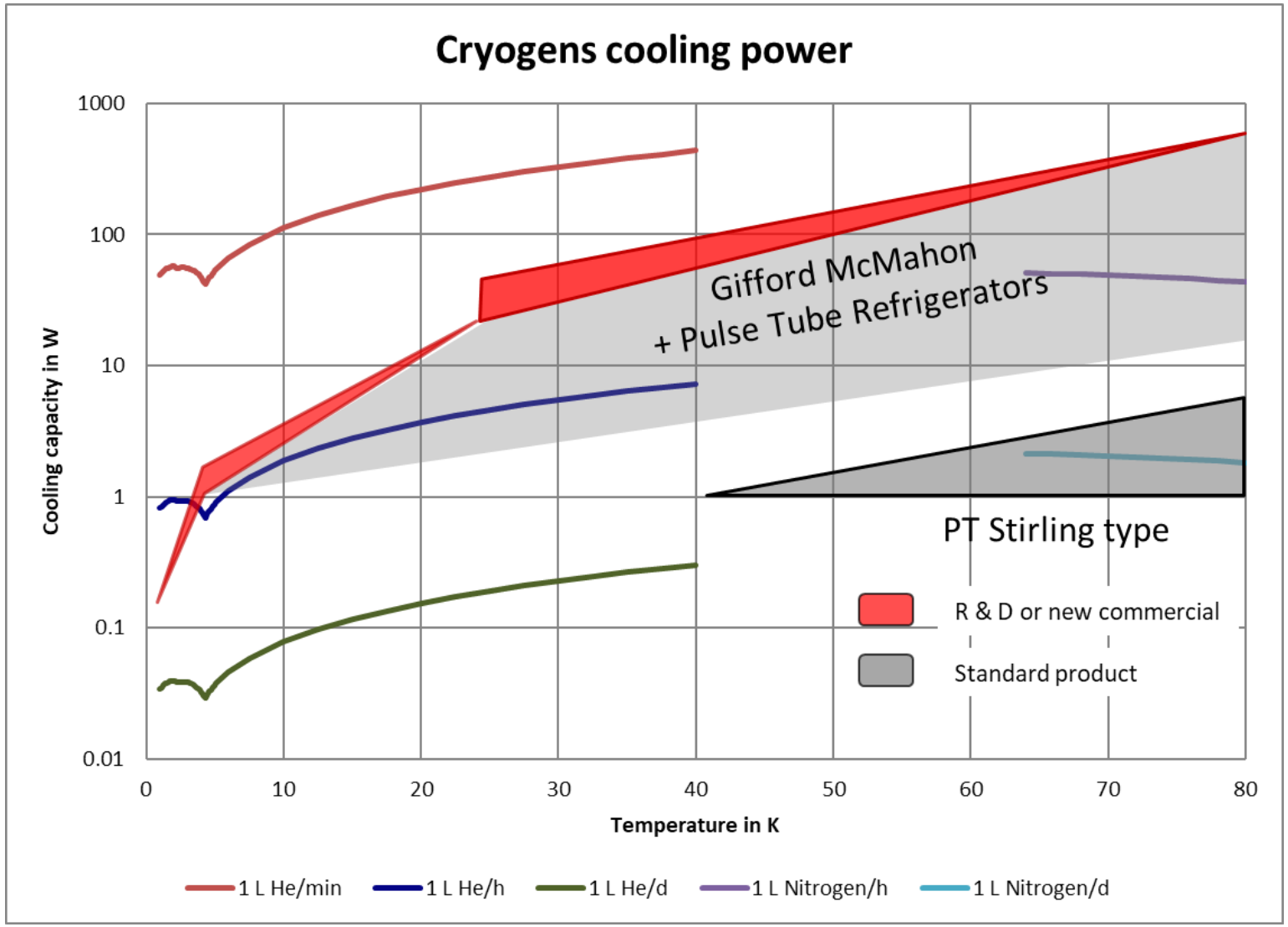
Liquid transfer lines, return
gas active shield cooling
double vacuum insulated

Cryocooler stand-alone operation

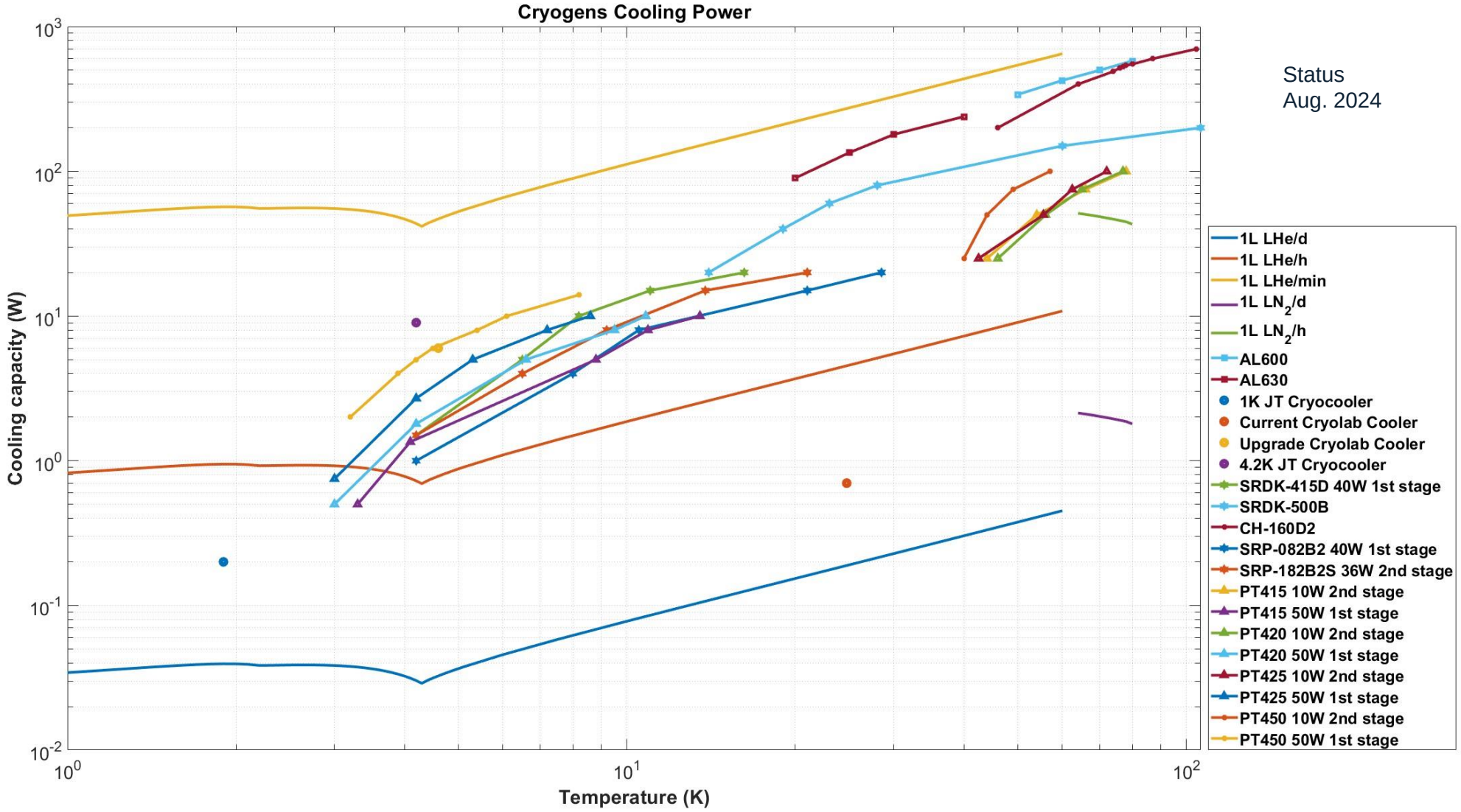
- He gas lines to the cryocooler, its materials are close to the irradiation region
- Possible activation of all internal materials (rare earth alloys)
- Radiation hardness of seals?
- Reduced lifetime?

=> Pulse tube cryocoolers with He cooling remote circuits

Cryocooler performance overview

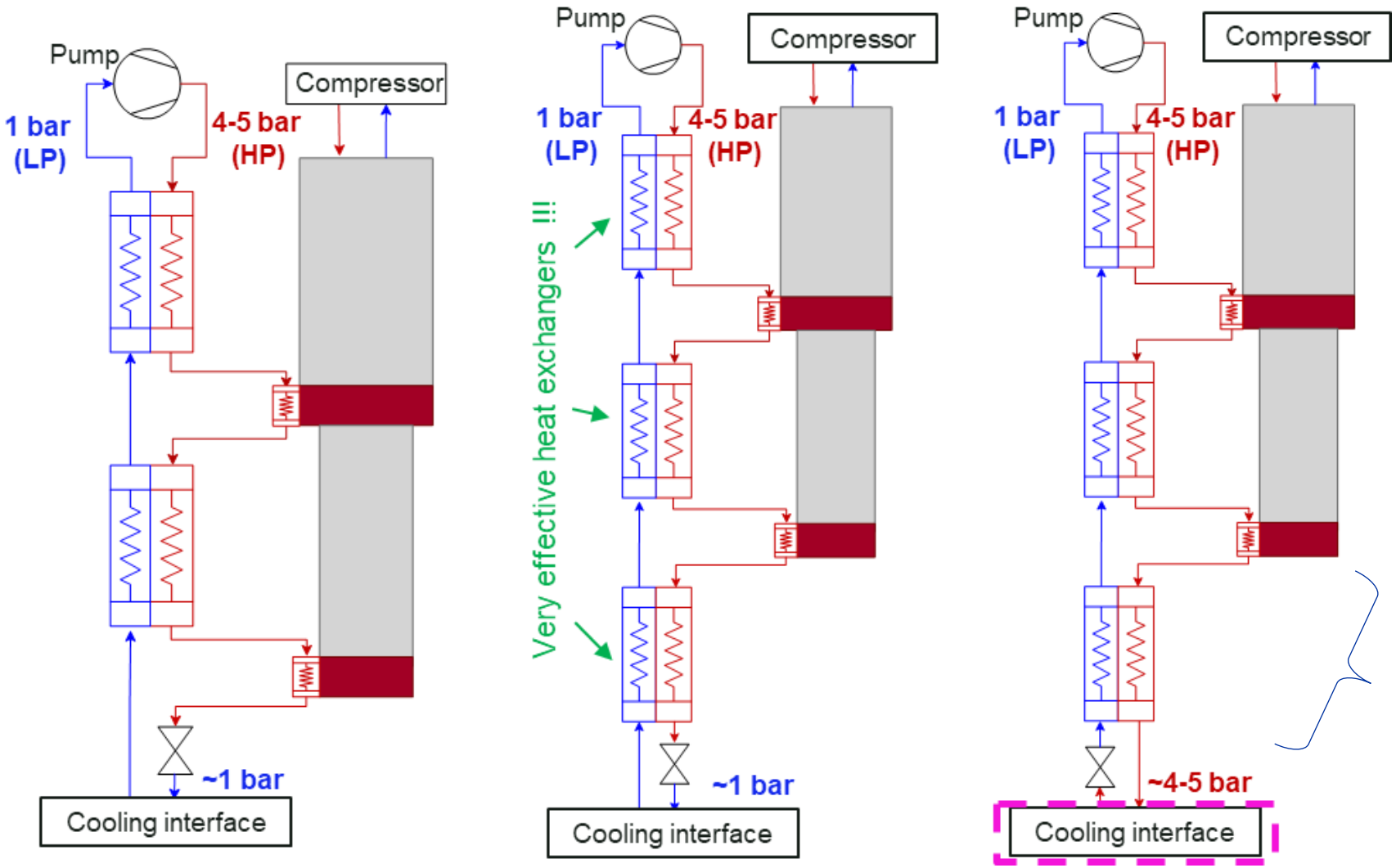


Cryocooler vs. liquid/vapour cooling

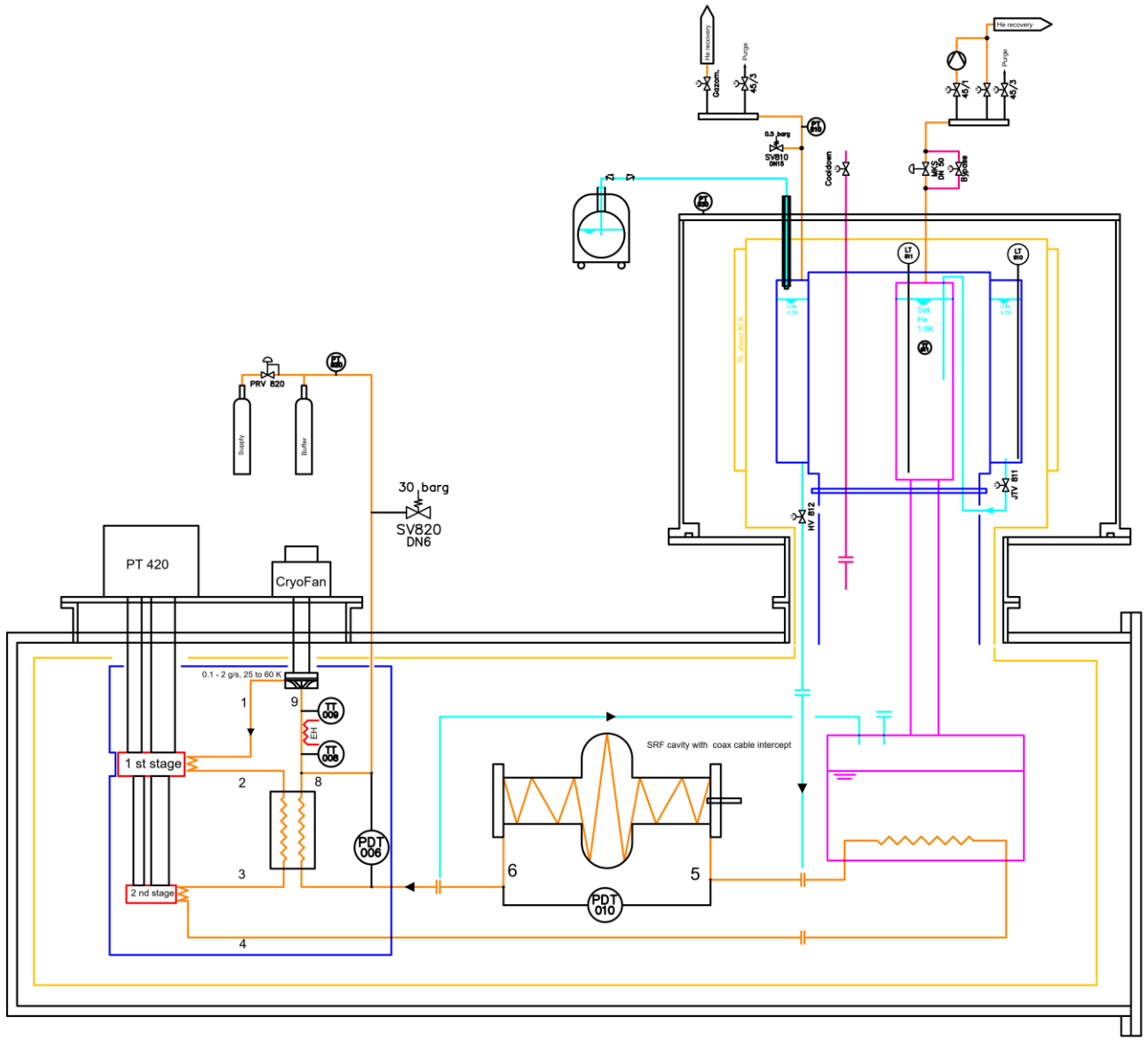


Status
Aug. 2024

Remote cooling circuits => cryocooler based

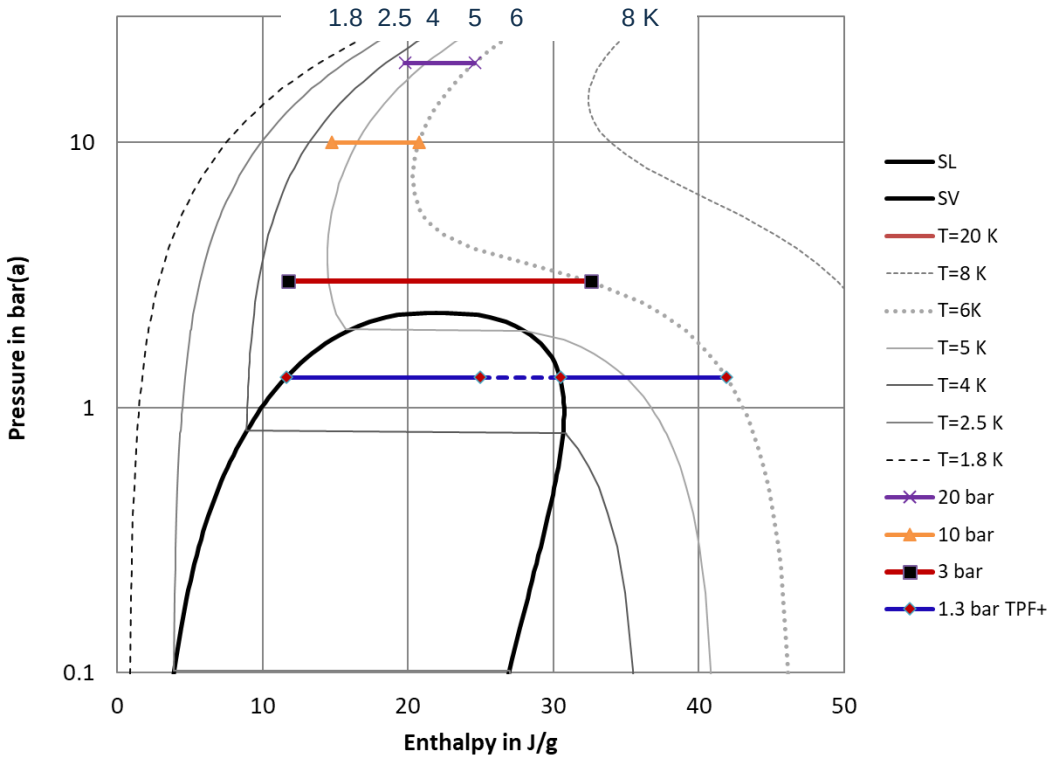


RF cavity cooling in a remote way



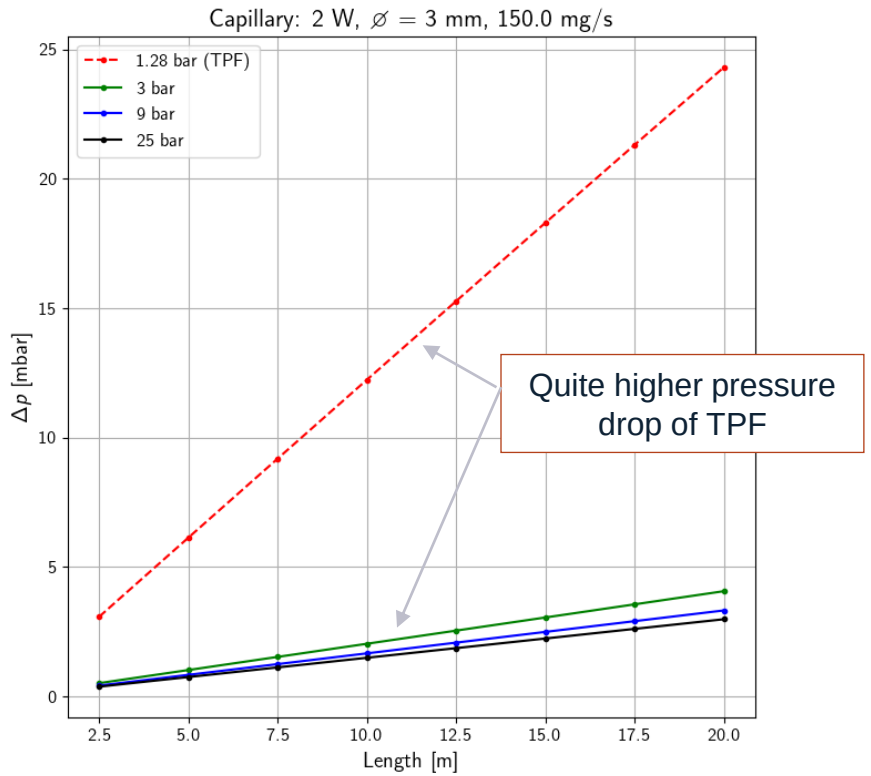
Possible fluid conditions

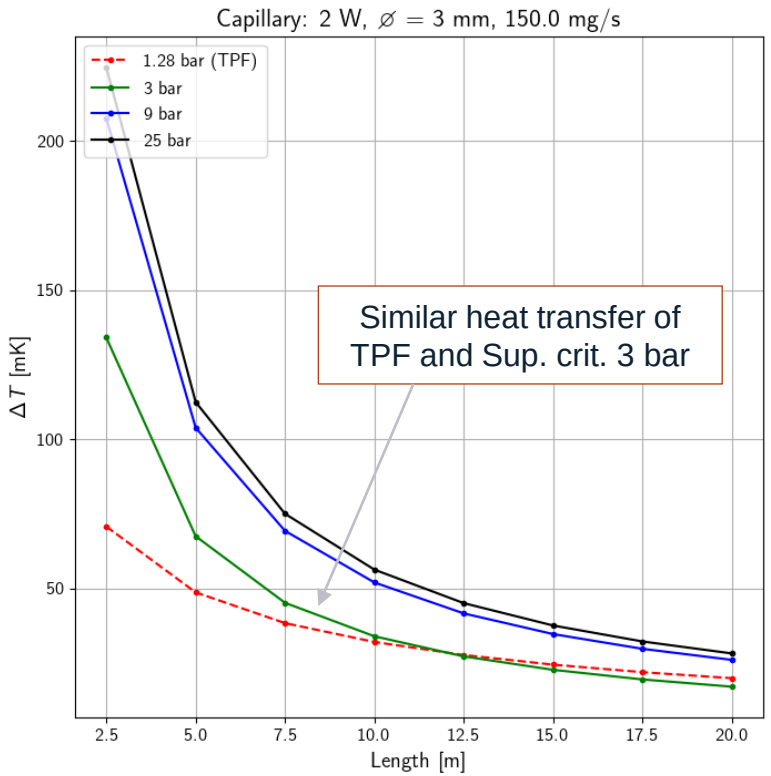
- LHe two–phase flow to 6 K
- SC He @ 3 bara, 4.5 - 6 K
- GHe @ 10 bara, 4.5 - 6 K
- GHe @ 20 bara, 4.5 - 6 K



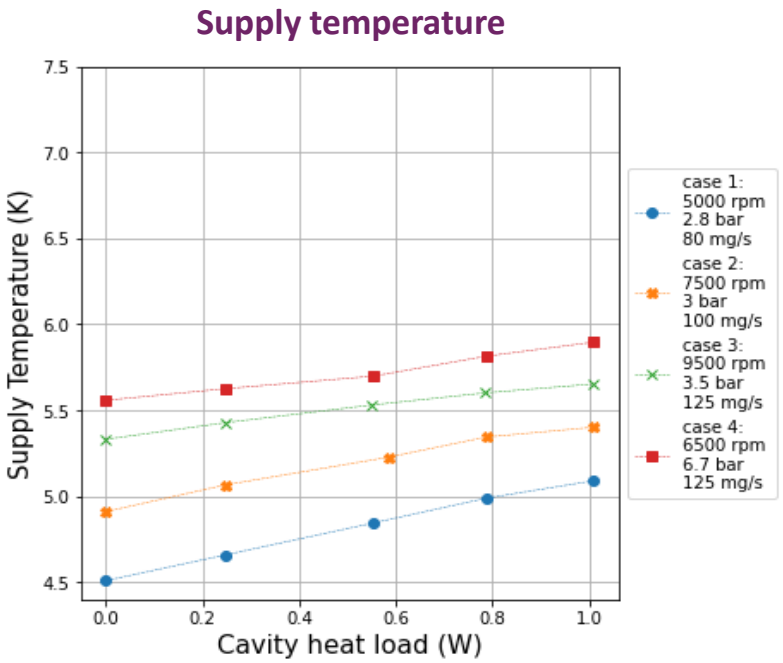
Remote cooling loop RF cavity cooling

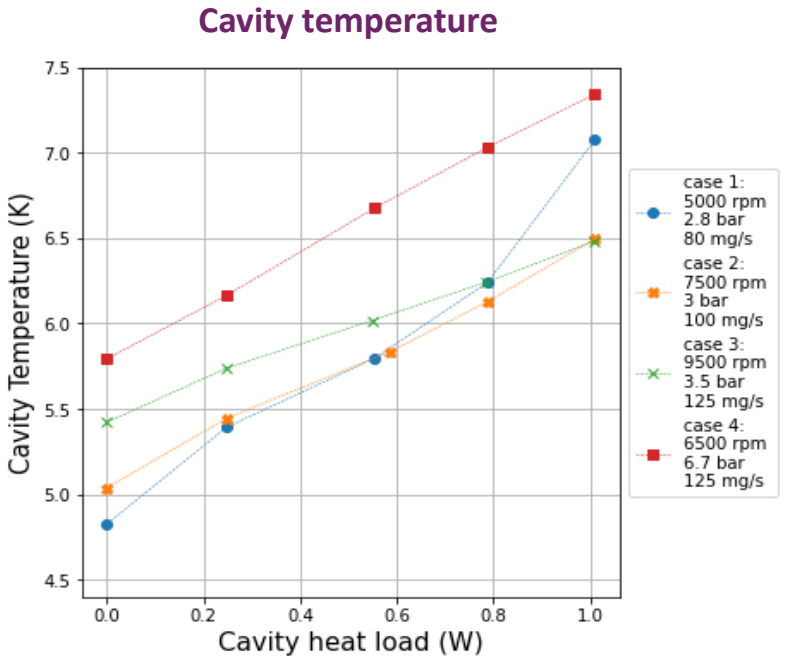
Optimum capillary fluid conditions – numerical code



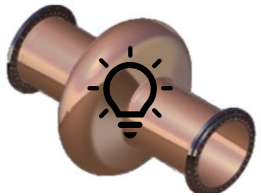


Heat load introduction to the cavity



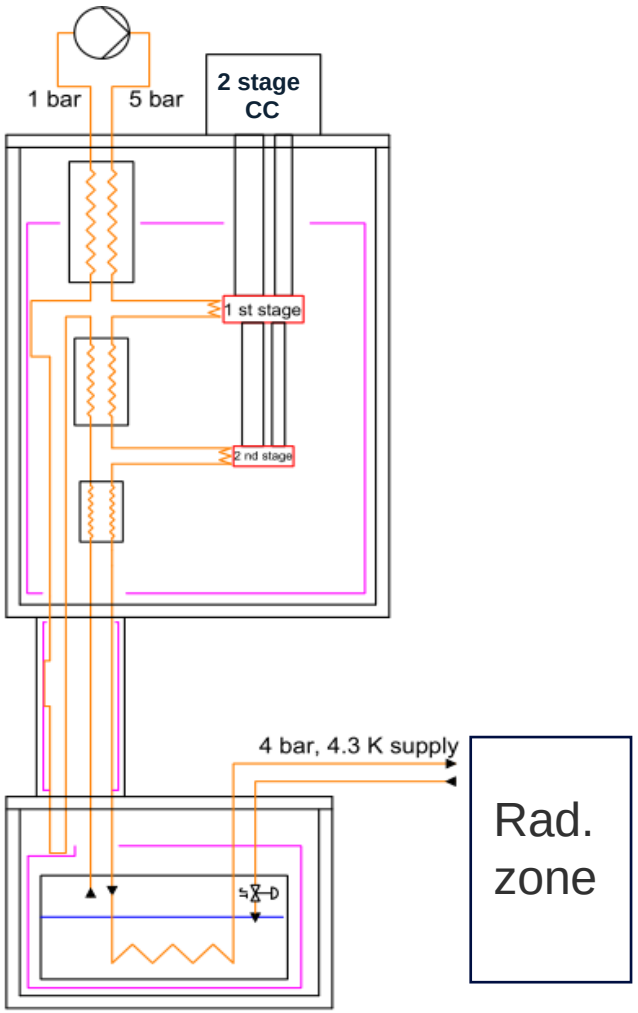


→ Additional halogen lamp to mimic uniform heating as expected from RF loads

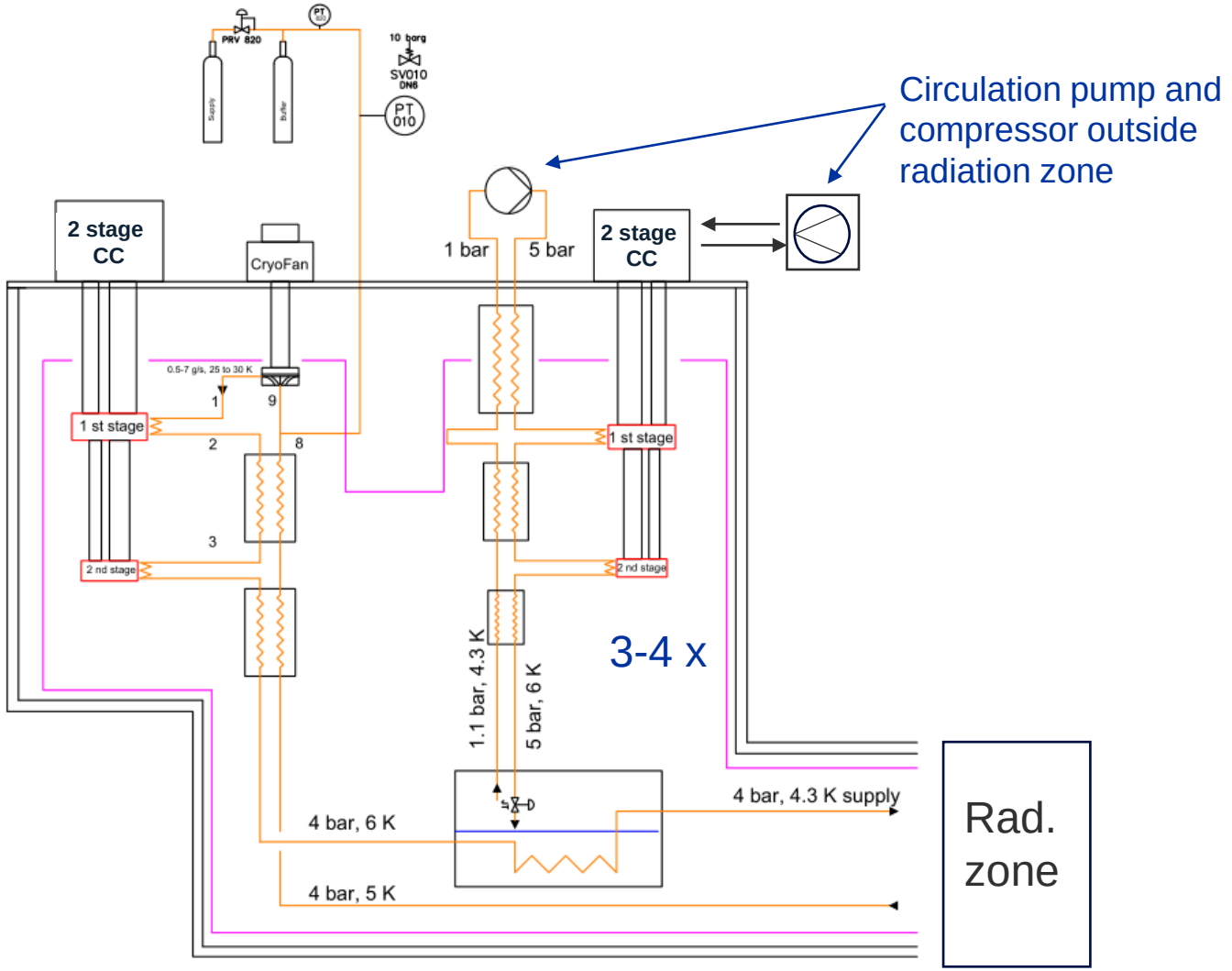


Remote cooling loops with boosted performance

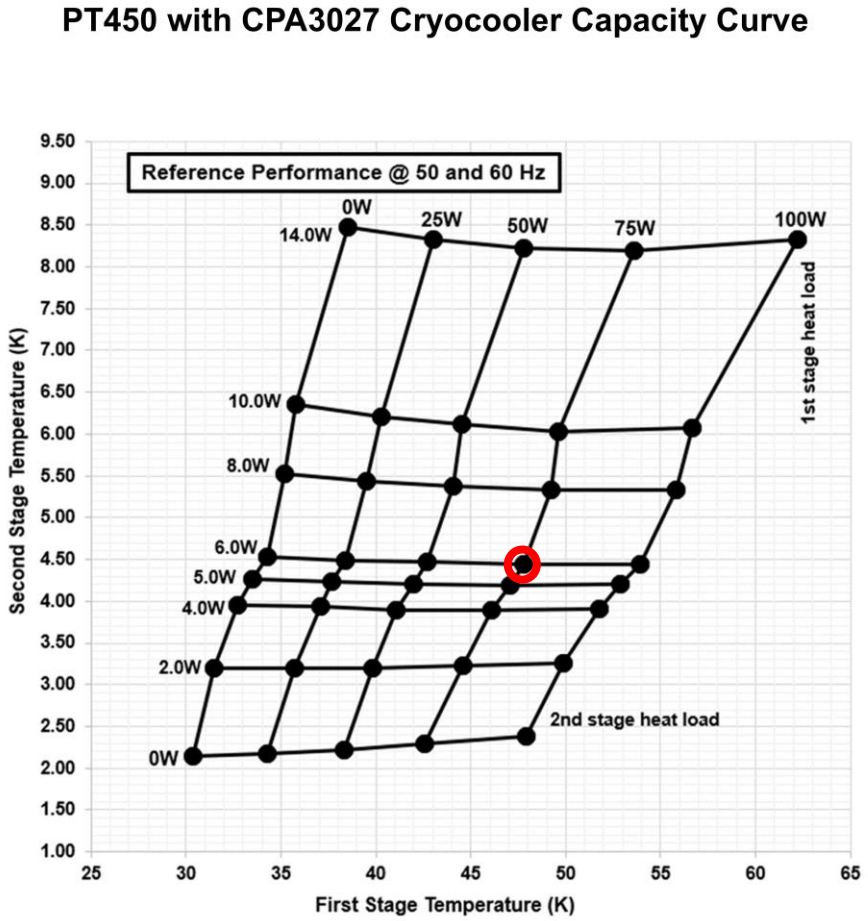
Subcooled 4 bar cooling loop



Subcooled 4 bar cooling loop – high Q

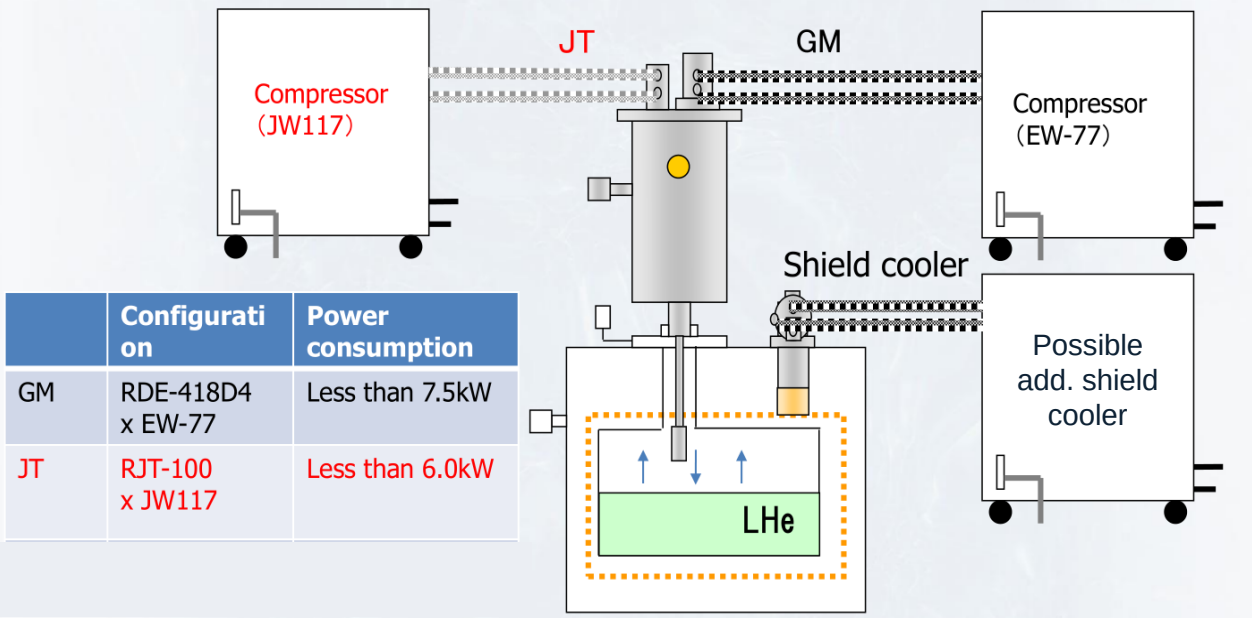


Latest developments (high cooling power at 4.2 K)



Source: Bluefors, Cryomech, Two-stage pulse tube refrigerator, P_{el}=25-27 kW (50 or 60 Hz)
https://bluefors.com/products/pulse-tube-cryocoolers/pt450/#downloads, photo courtesy Bluefors.

Latest developments (high cooling power at 4.2 K)

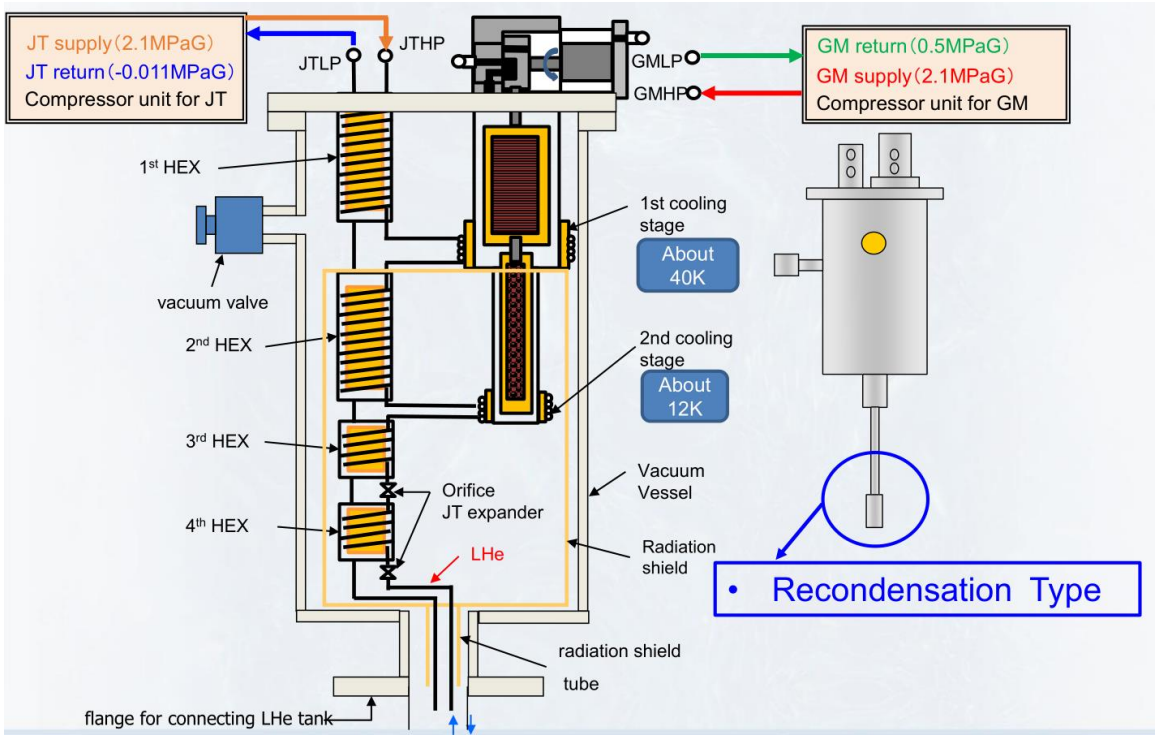


	Configuration	Power consumption
GM	RDE-418D4 x EW-77	Less than 7.5kW
JT	RJT-100 x JW117	Less than 6.0kW

GM-JT cooler

> 9 W @ 4.2 K cooling power at the CIF

Now also as open ”loop” system available!



Source: Introduction of GM – JT cooling system, A. Euler, Sumitomo

Conclusion

- Testing radiation hardness of materials at low temperature
- LHe cryostats vs. cryocoolers based options
- Cooling performance
- Pushing the frontier of cryocooler performance => add. J-T circuits
- Remote cooling circuits to reduce the amount of materials exposed

- New applications for R&D and stand-alone cryostats

Thank you for your attention