Karlsruhe Institute of Technology

Commissioning of the cryogenic phase equilibria test stand CryoPHAEQTS

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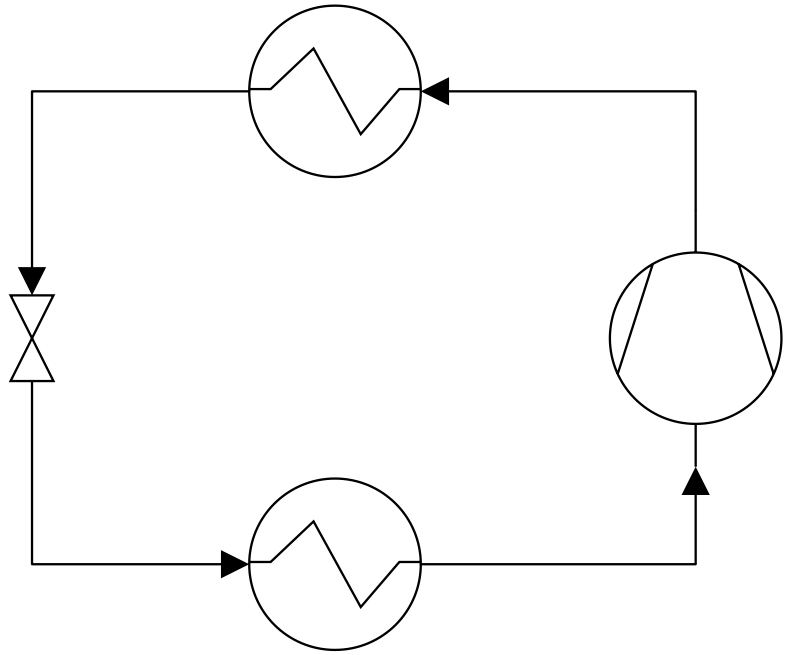
Process design essentials

How much refrigerant is needed to cool back to room temperature?

How far do we expand into vapor-liquid coexistence?



How much area is needed to reach a certain cooling capacity?

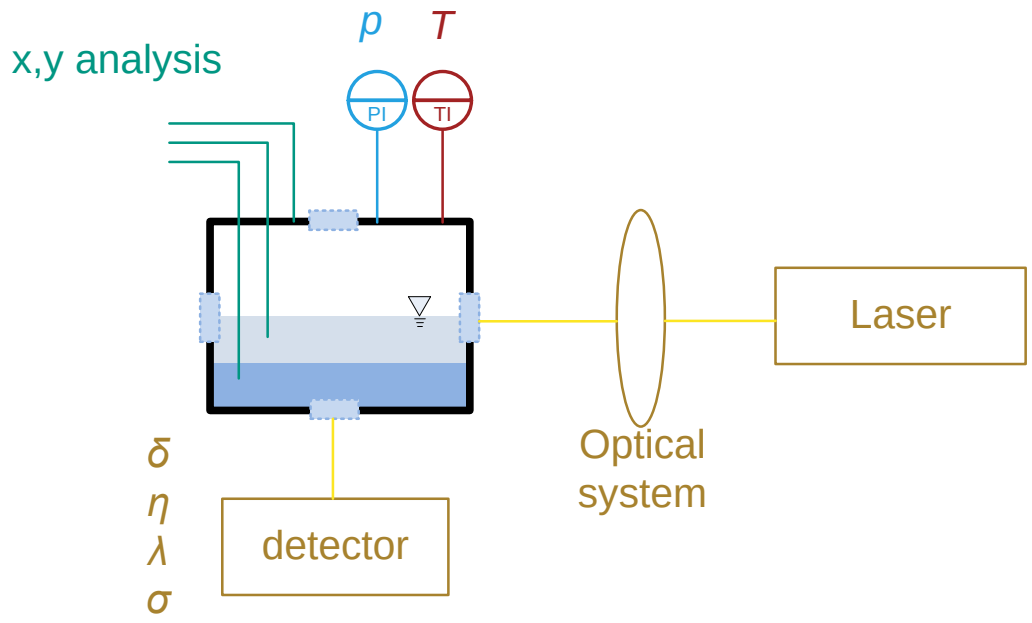
- Phase equilibria (p-T-xy data)
- Caloric state variables ($c_p, \Delta h_v$ ...)
- Transport properties (λ, ν, δ)

Physical property data needed for process design

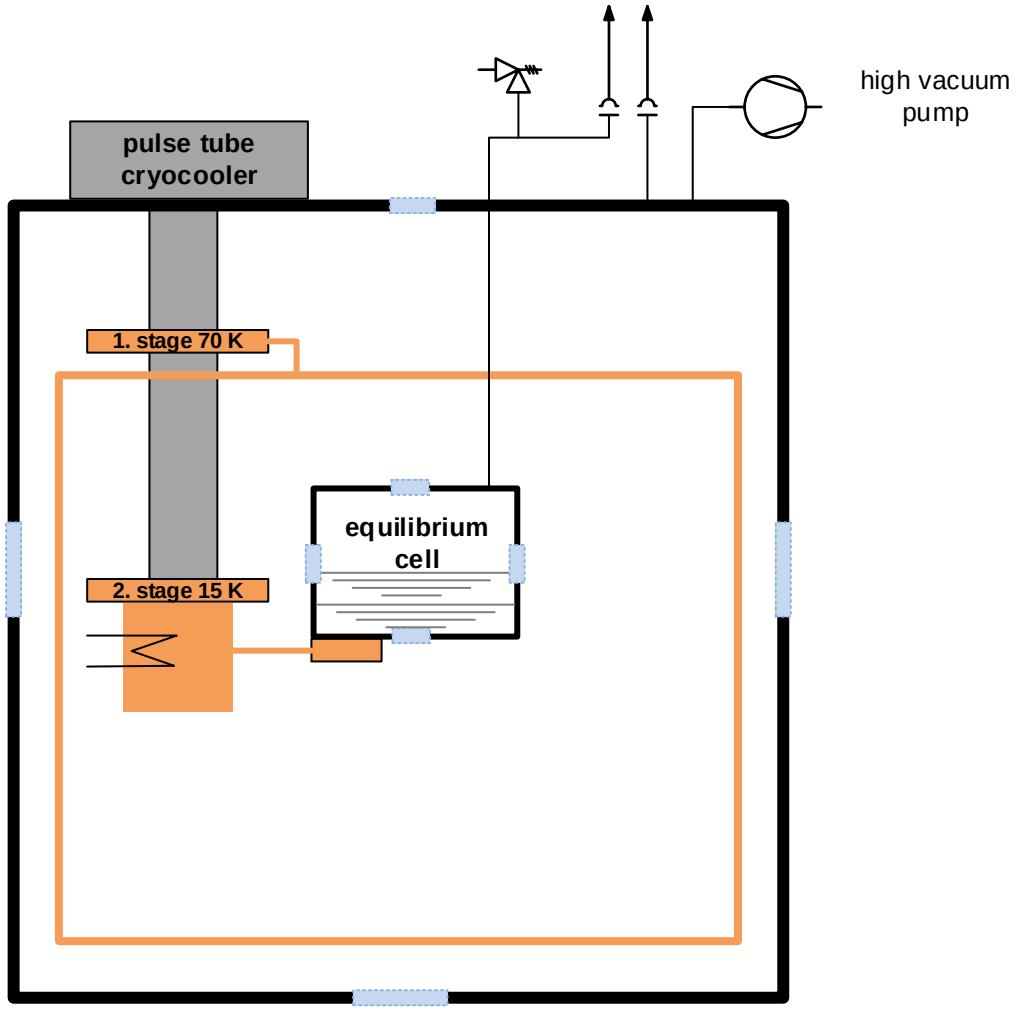
Test stand characteristics

- Phase equilibria
  - Vapor-liquid
  - Vapor-liquid-liquid
  - (Solid-liquid)
- Caloric state variables
  - Specific heat capacity of vapor phase
- Transport properties
  - Future DLS/SLS upgrade

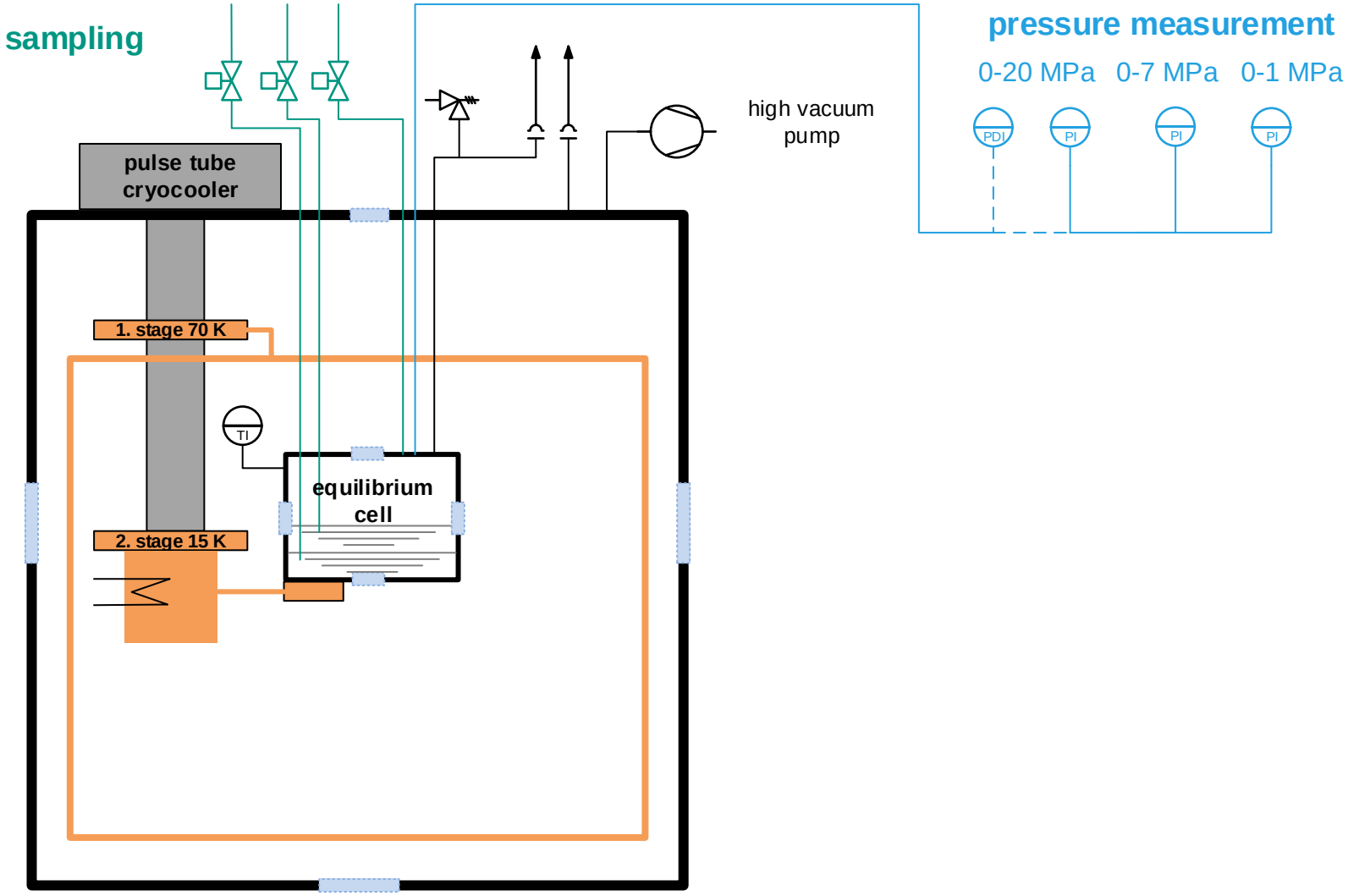
Pressure range	10 mbar to 150 bar
Temperature range	15 K to 300 K
Possible fluids	All non-toxic refrigerants



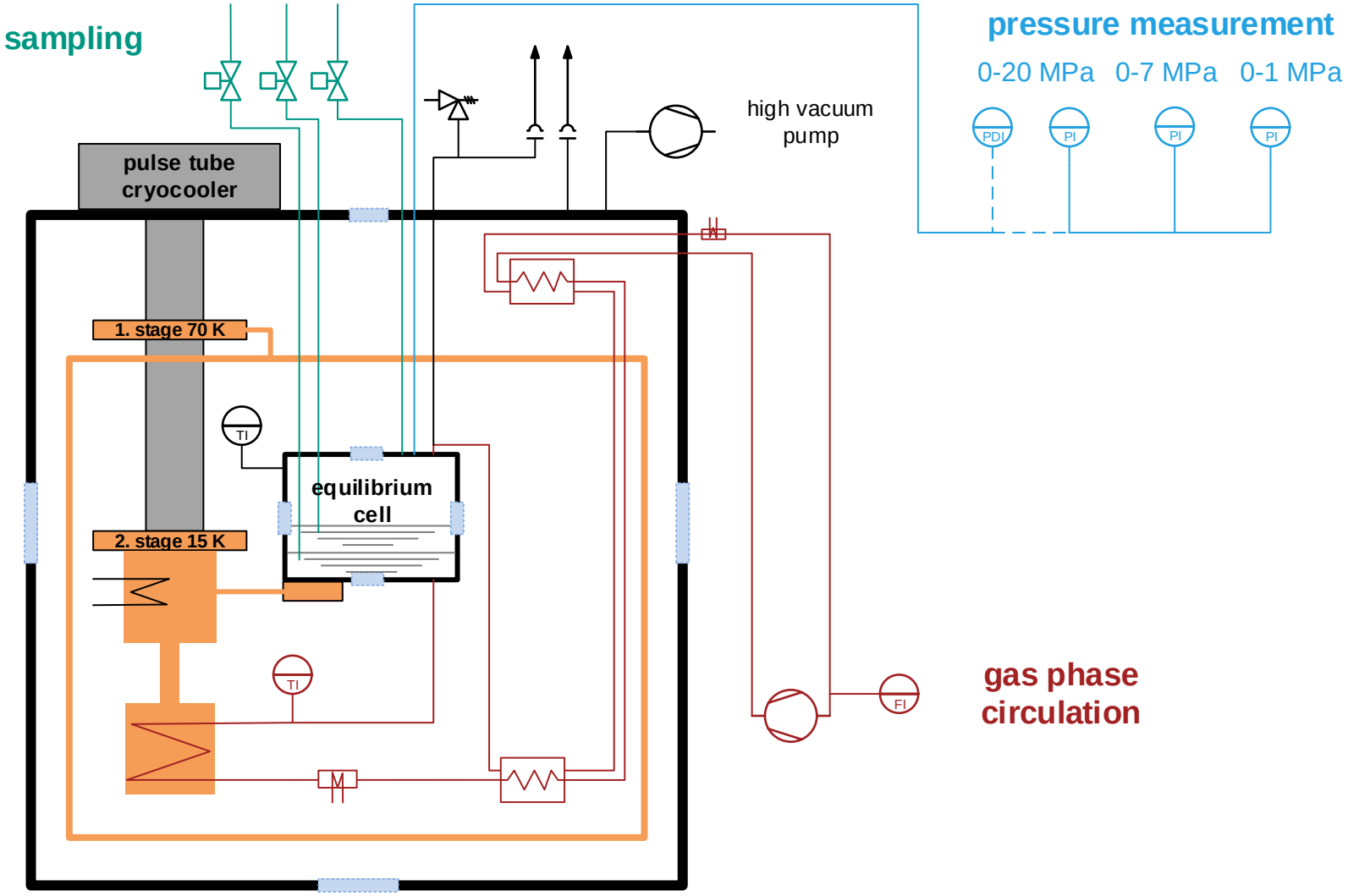
Process flow diagram 1/4



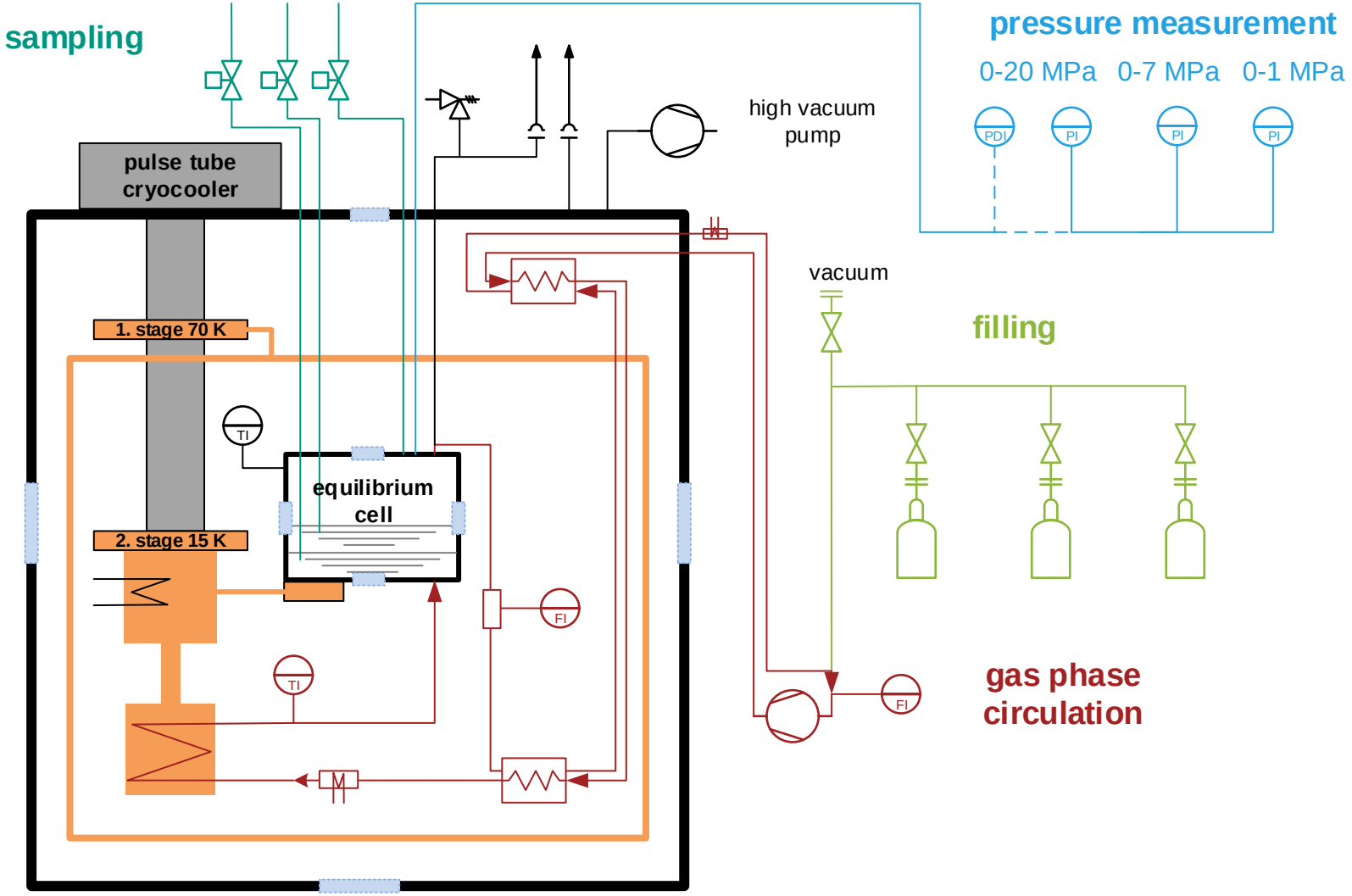
Process flow diagram 2/4



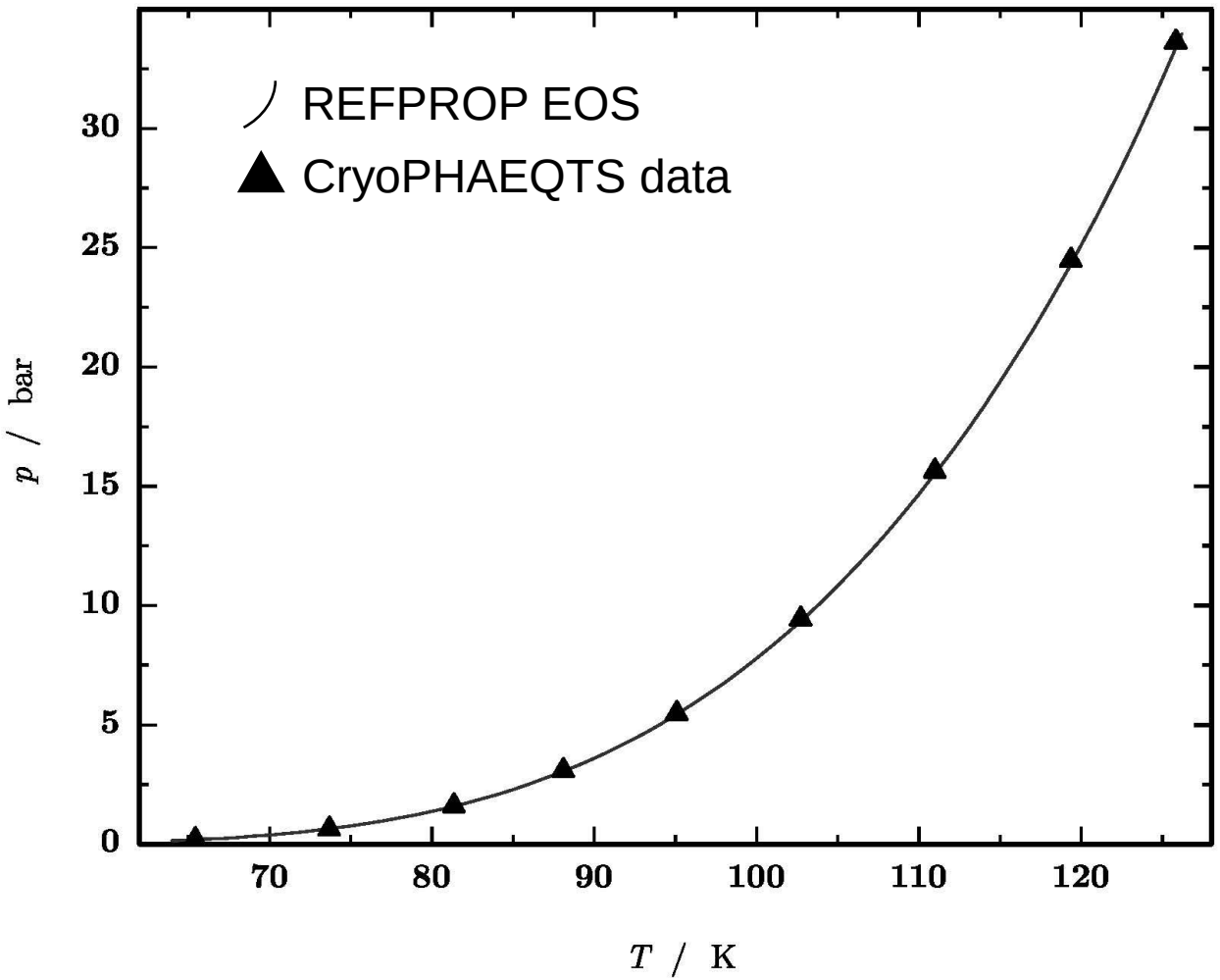
Process flow diagram 3/4



Process flow diagram 4/4

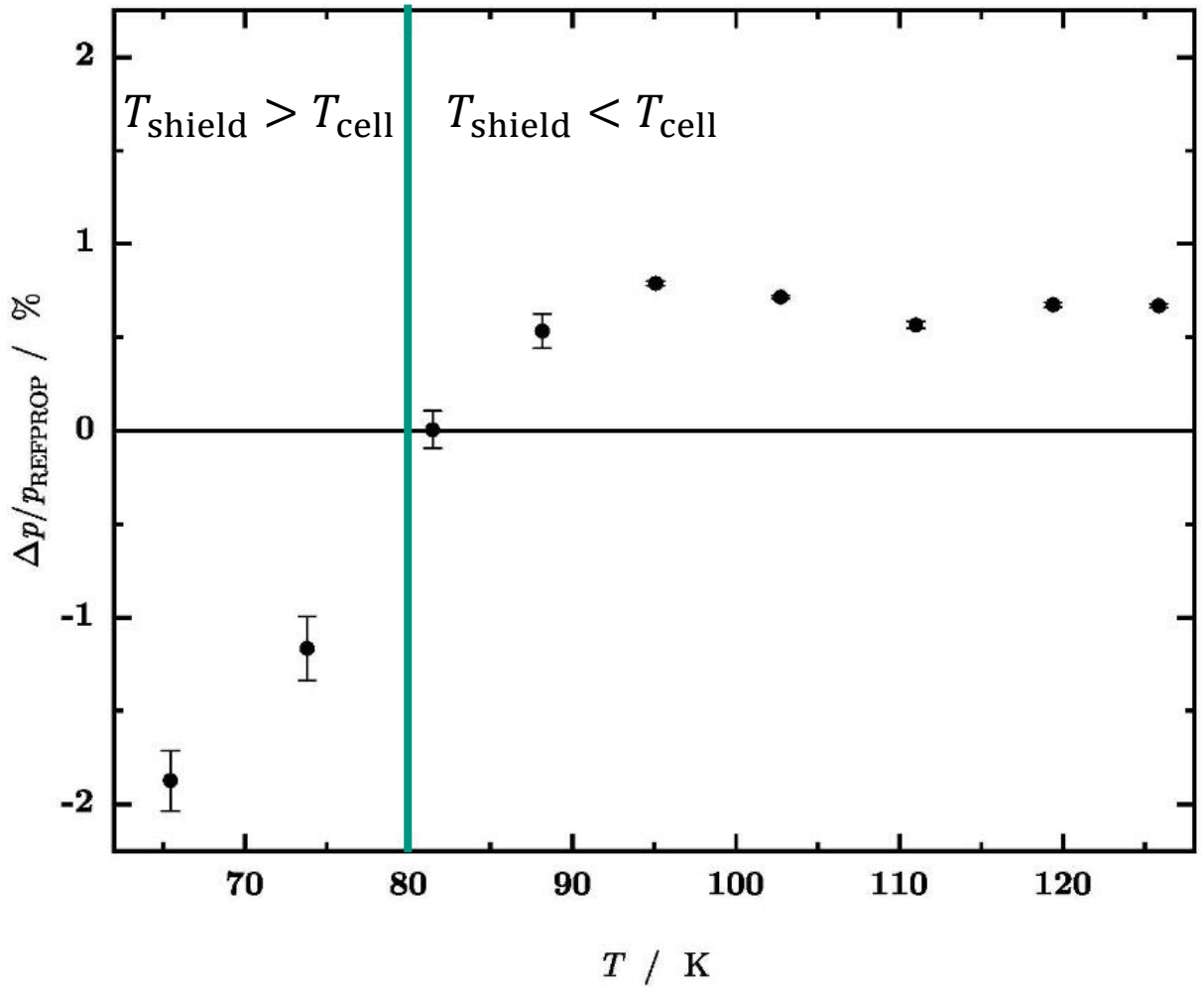


First results – vapor-liquid coexistence N_2



- Coverage from
  - 66 K to 125 K
  - 0.2 bar to 33 bar

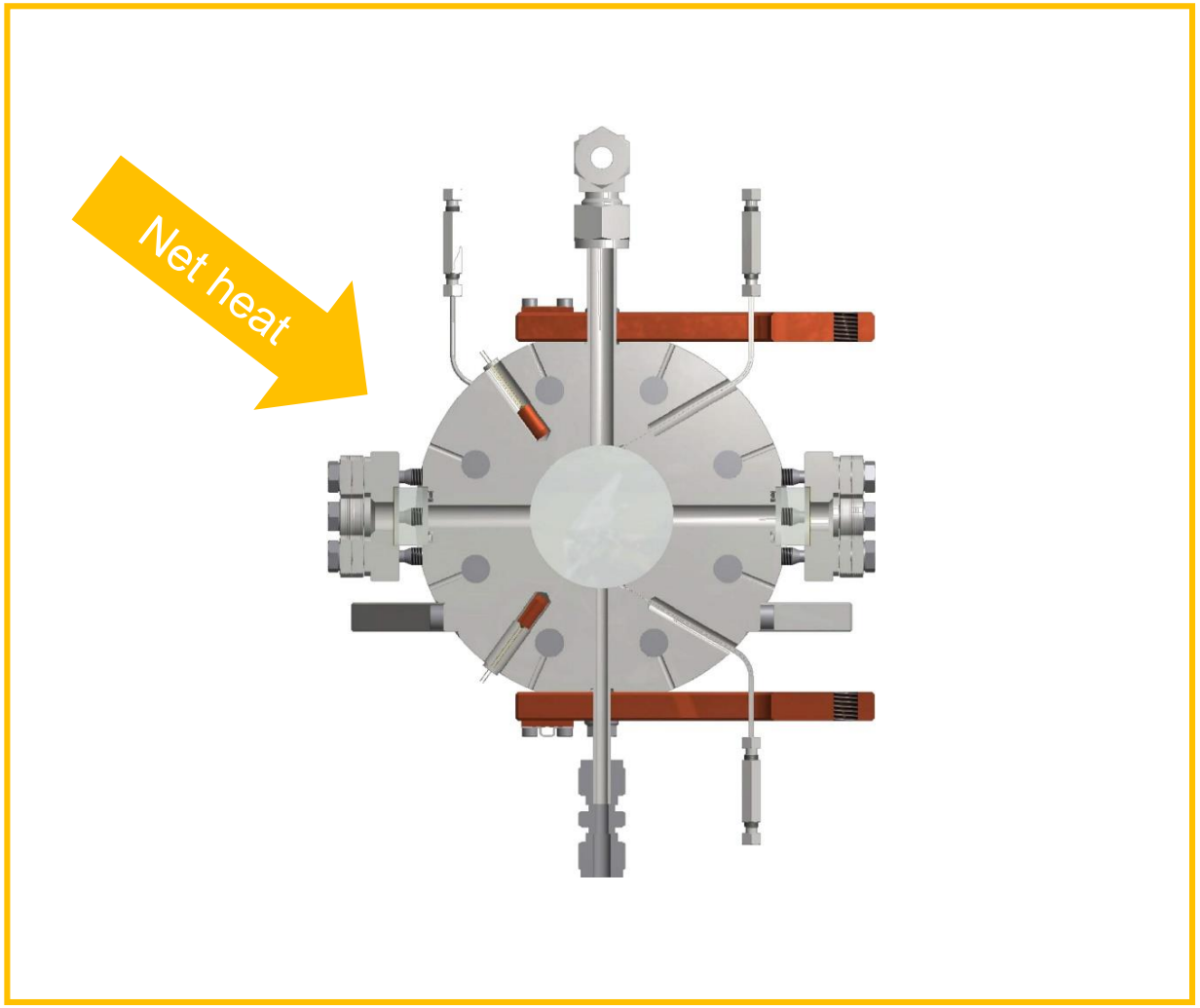
First results – deviations to REFPROP



- Deviations up to 2%
- $\Delta T = T_{upper} - T_{lower} = 200\ mK$
- Systematic error
- Error sources
  - Heat radiation
  - Heat conduction
  - Heat convection

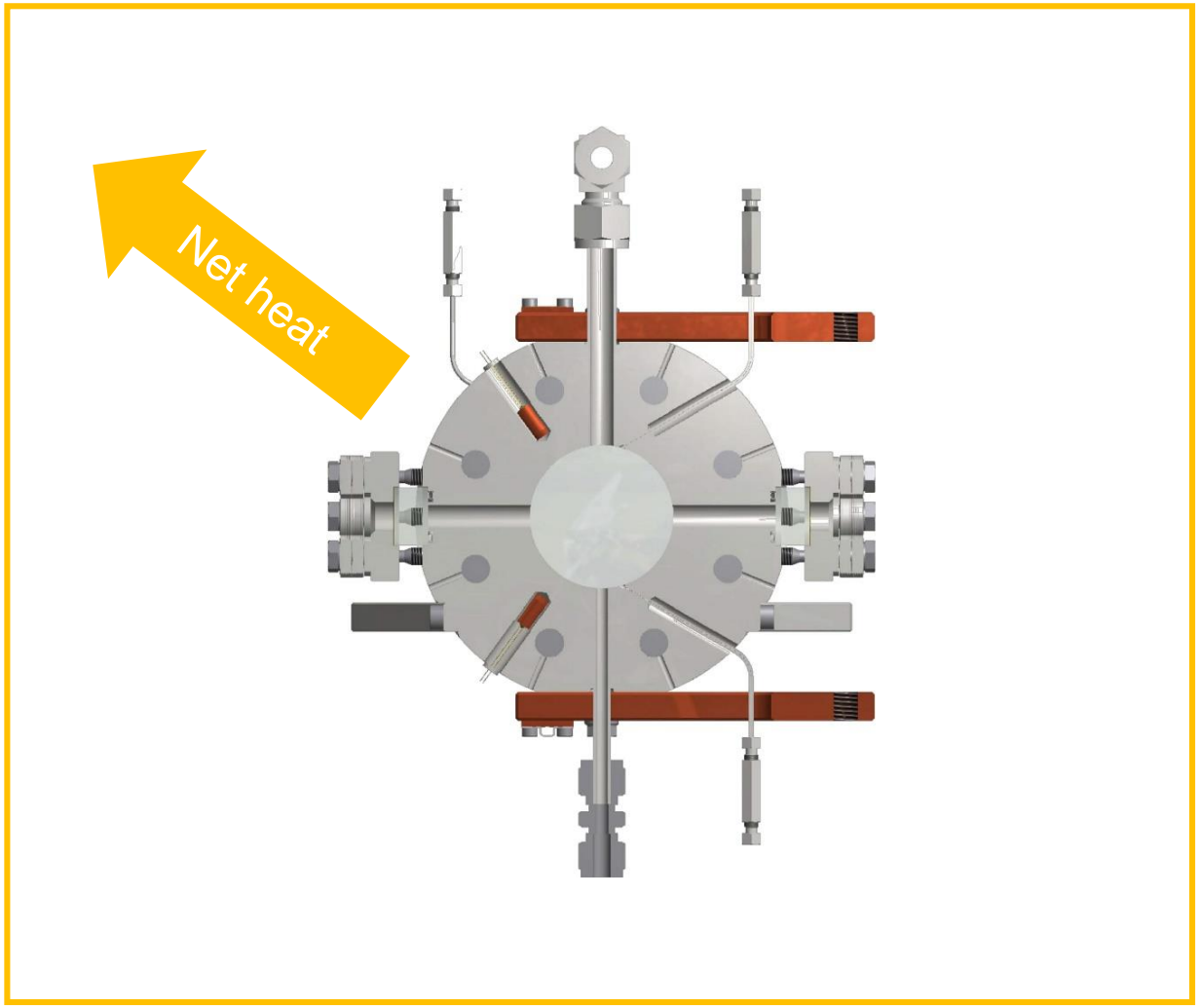
Error sources - radiation

$$T_{\text{shield}} > T_{\text{cell}}$$

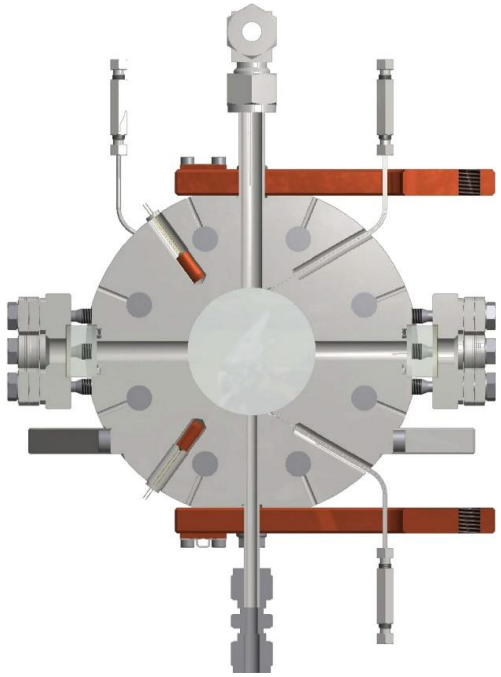


Error sources - radiation

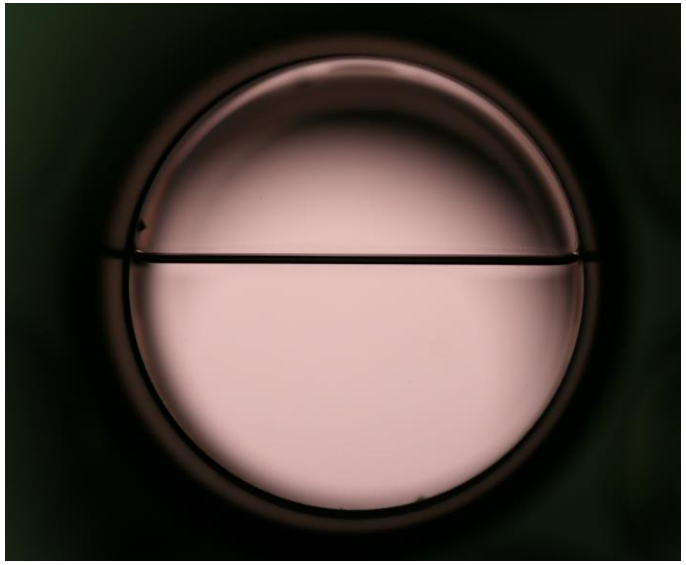
$$T_{\text{shield}} < T_{\text{cell}}$$



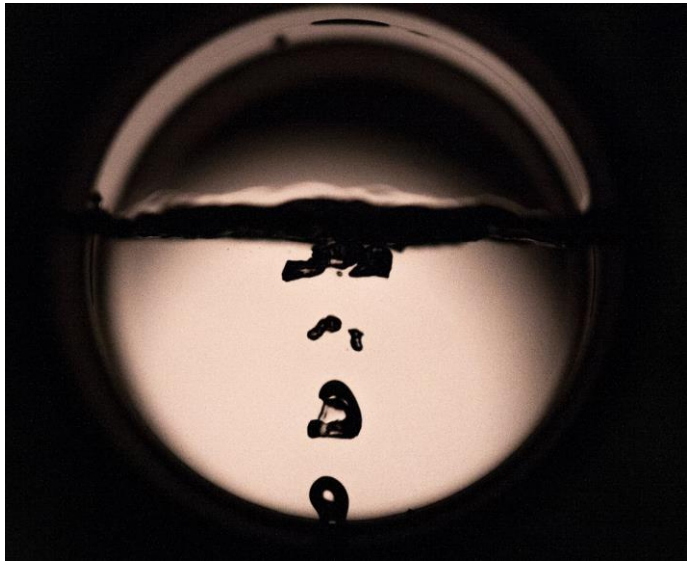
Error sources – heat convection



without gas phase circulation



with gas phase circulation

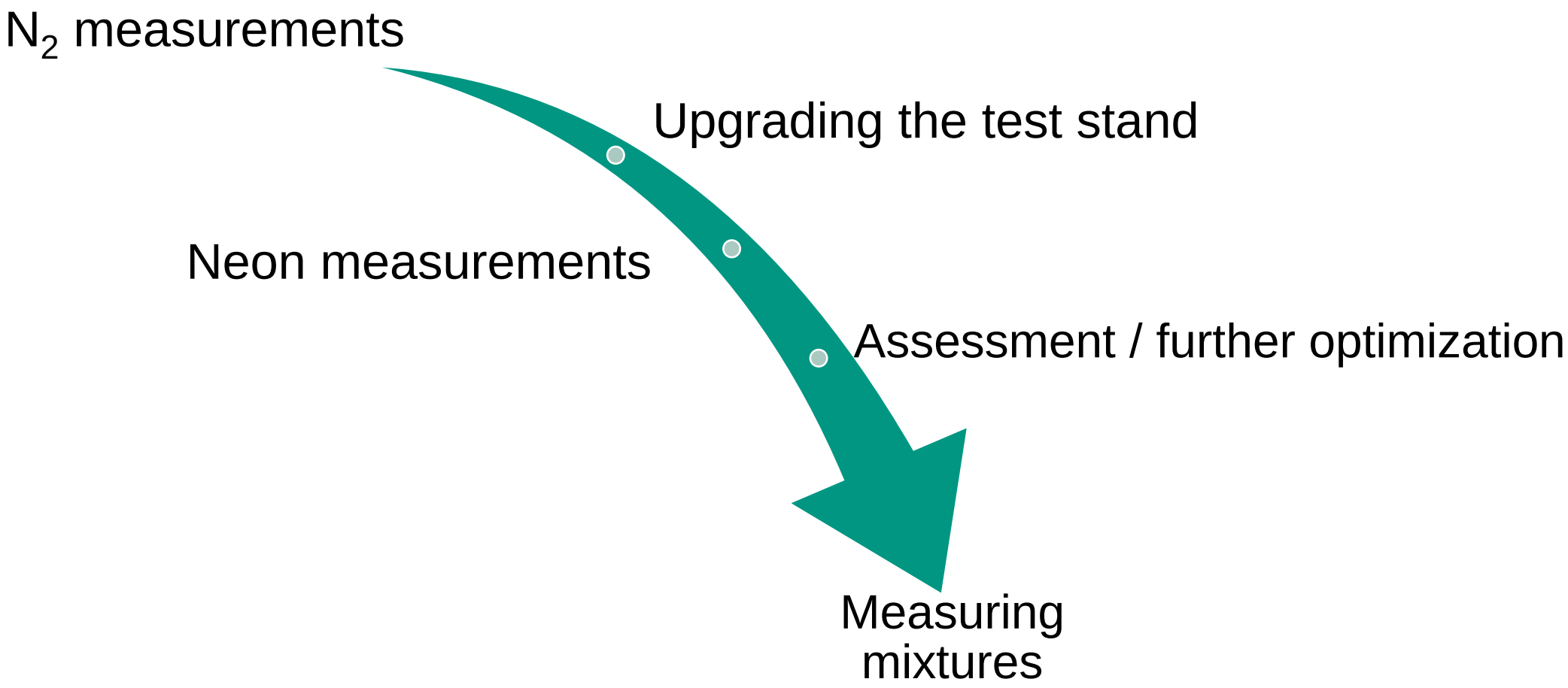


$\Delta T = T_{upper} - T_{lower}$	380 mK	160 mK

@95 K

- Convective heat transport reduces inhomogeneity
- Further improvement by enhanced bubble distribution

Next steps


N_2 measurements
Upgrading the test stand
Neon measurements
Assessment / further optimization
Measuring mixtures

Conclusion

- First N_2 measurements show accordance with REFPROP data
- Identification of systematic errors leading to temperature differences in the equilibrium cell
- Suggested improvements will be tested this summer