Refrigerator Cryostats at BENSC

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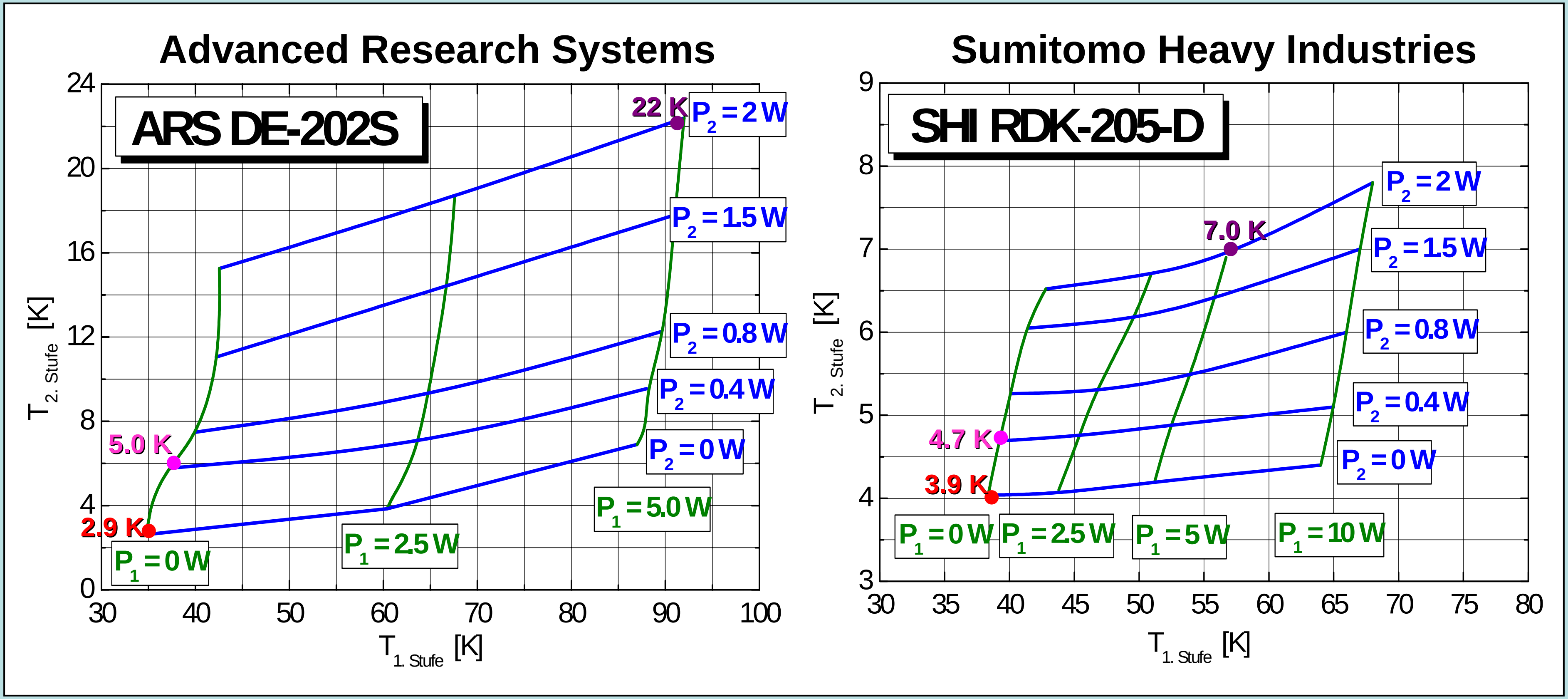
The competion: Liquid Helium-cooled versus Refrigerator-cooled

The marking: Measurements of T_{min} & T_{max} & P(T) and ΔT / T_o & $T_o(t)$

Costs for Invest & Consum and Service & Personal

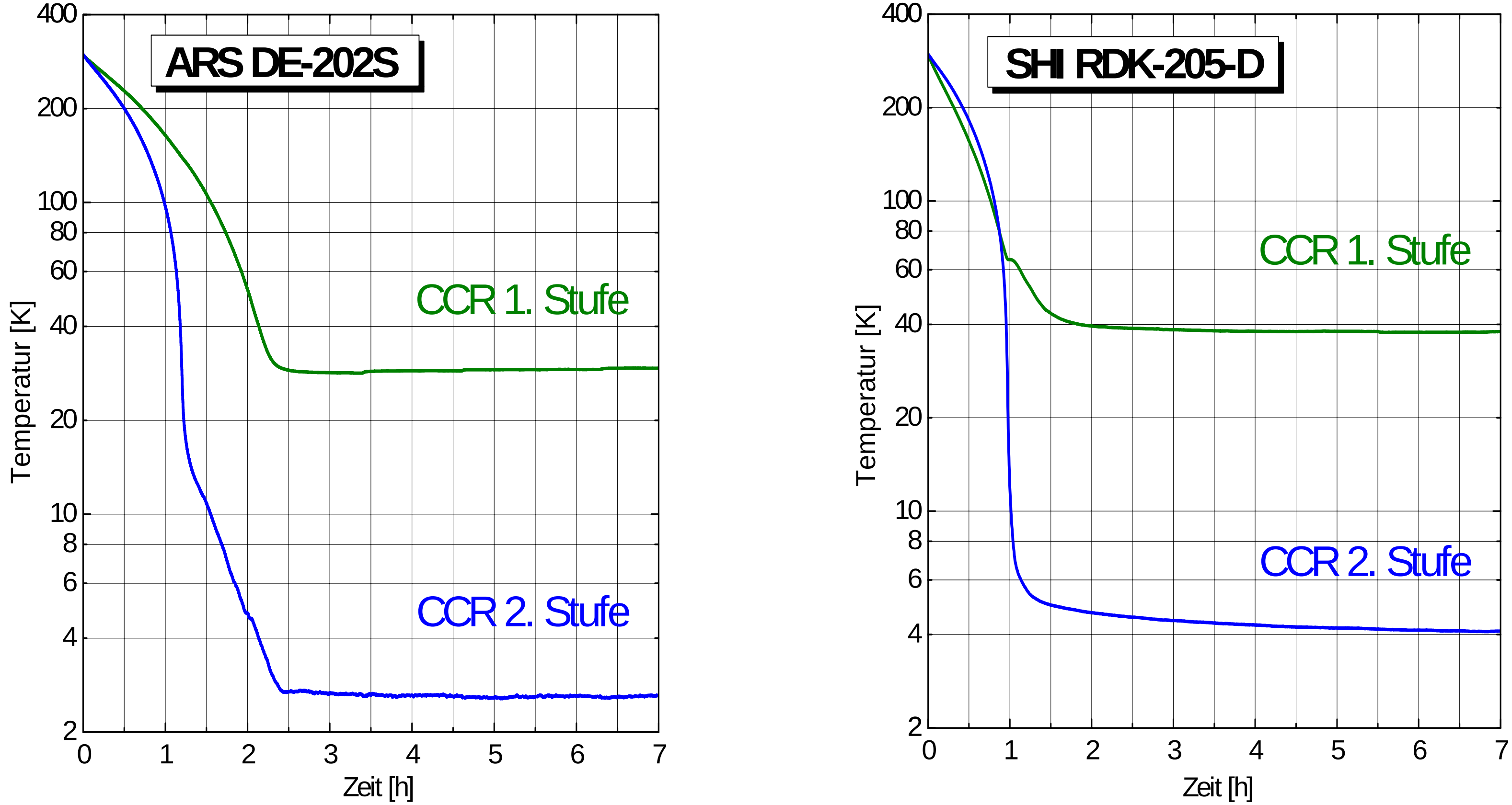
The winner is: A great variety of CCR-cryostats

Cooling power plots of two GM-CCR‘s at BENSC (manufactured and delivered in 2004)



→ **differences !!!**

Cooling curves $T_o(t)$ with minimum load



Example 1

SHI CCR in ORANGE-body

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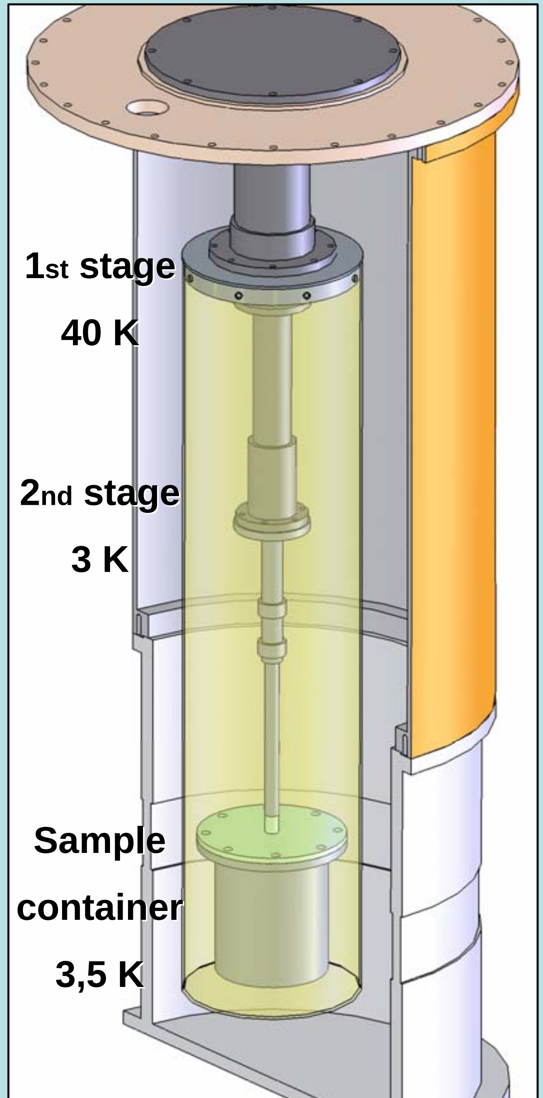
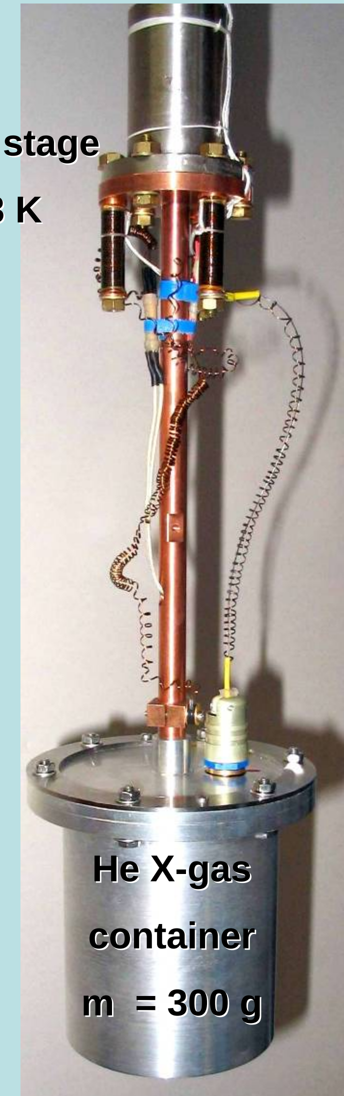
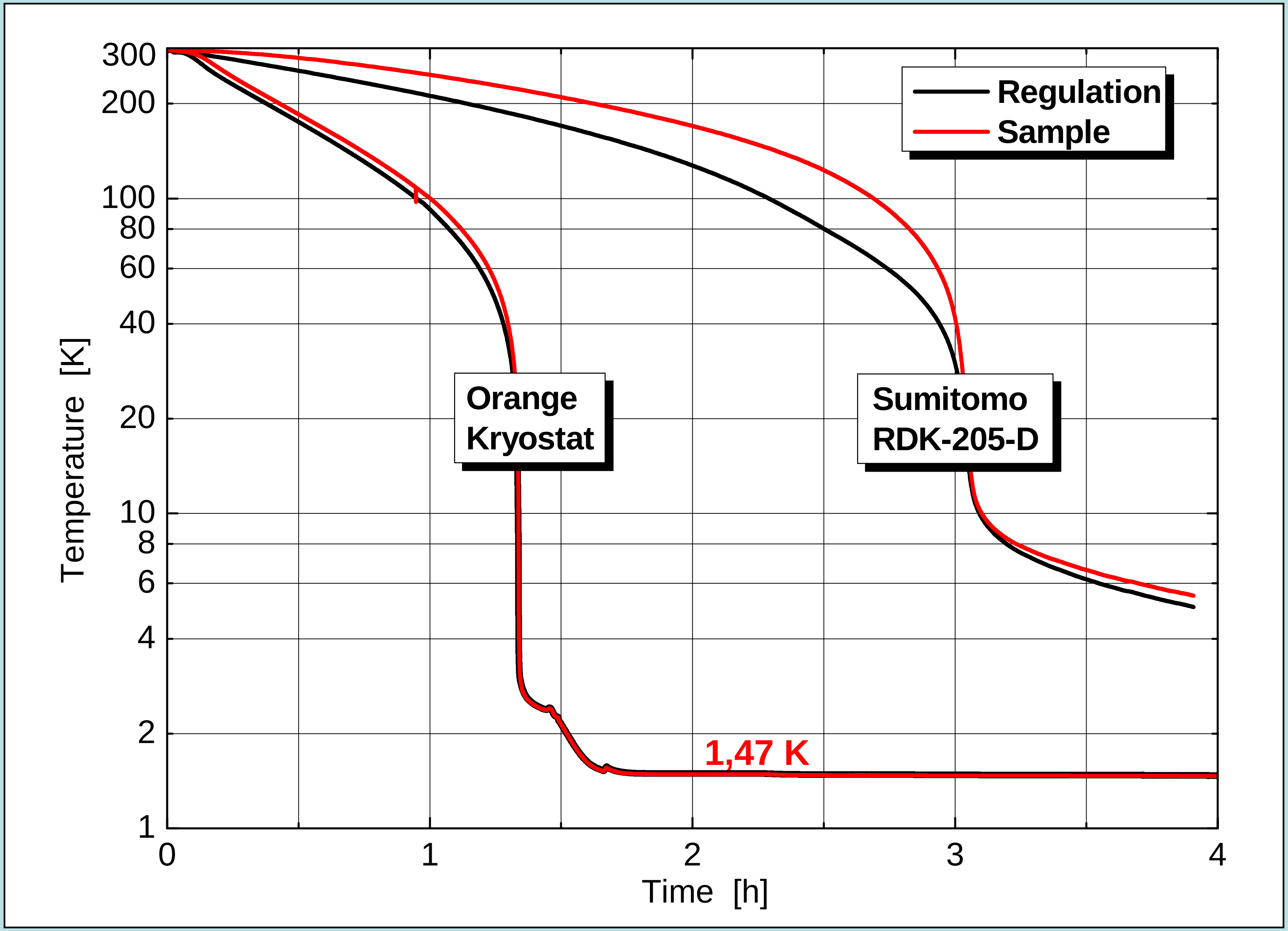
SHI RDK-205 with OS-OVC for T = 3.5 K … 400 K





Comparison of cool-down ORANGE vs. CCR



Example 2

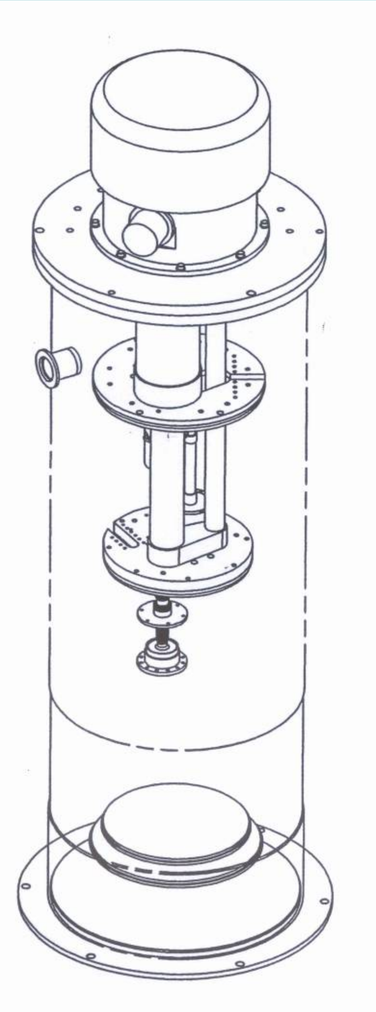
SHI Pulsetube Refrigerator

plus ^3He sorption stage

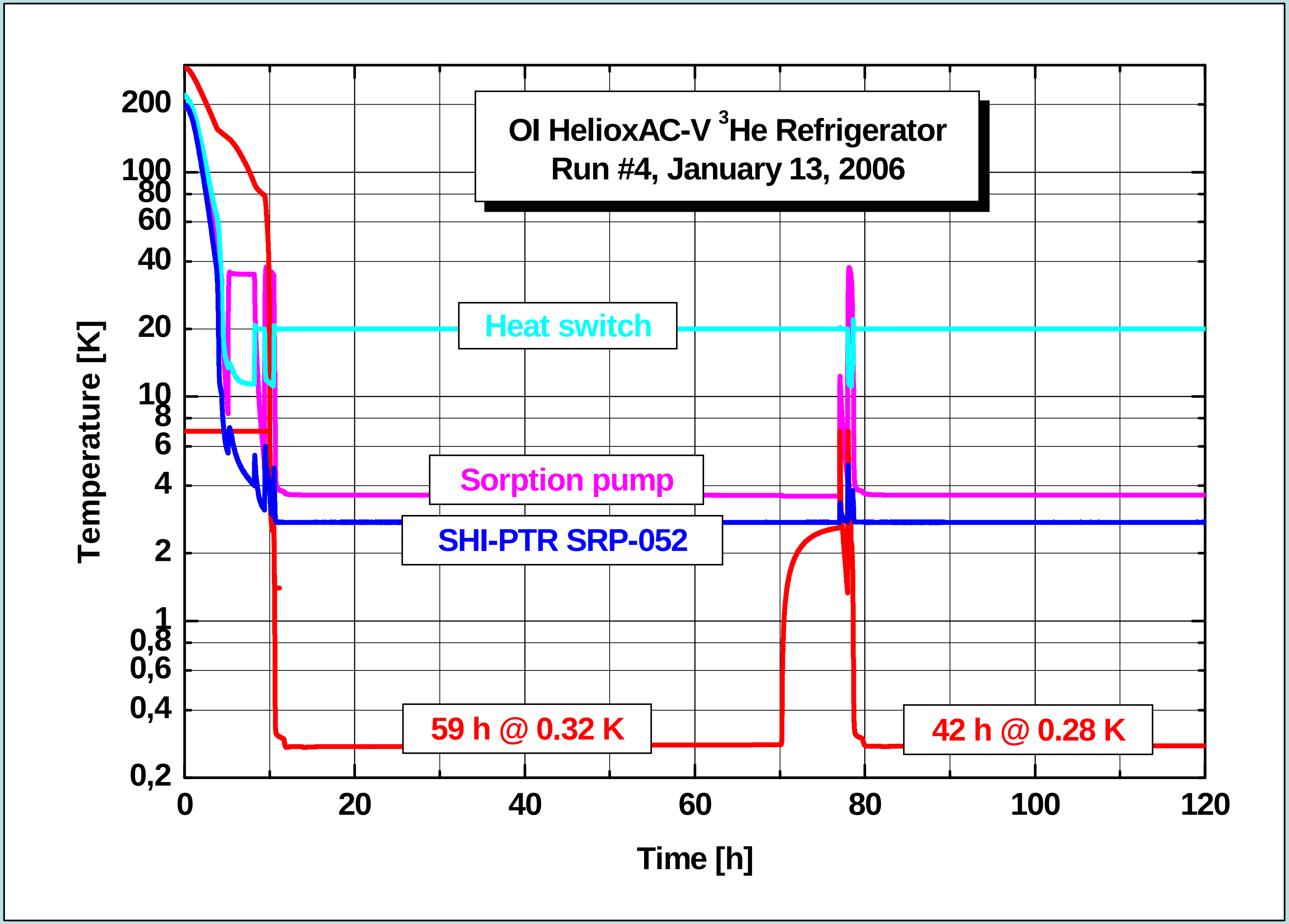
OI Heliox AC-V

OI Heliox / SHI-PTR with 3rd stage ^{3}He sorption system

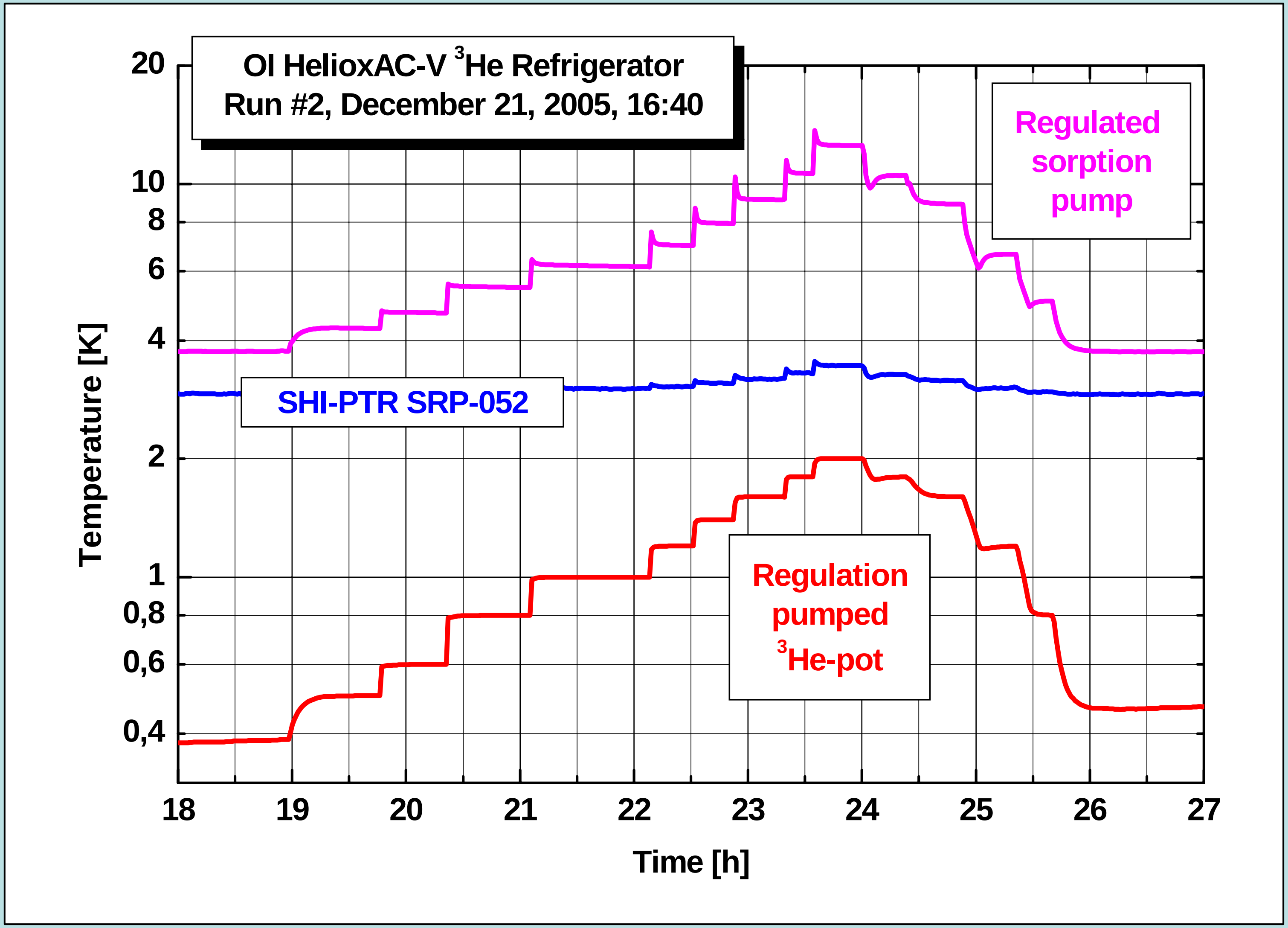
T = 0.3 K … 325 K



Cool-down and minimum temperature performance



Performance of temperature regulation at T = 0.4 K … 2 K

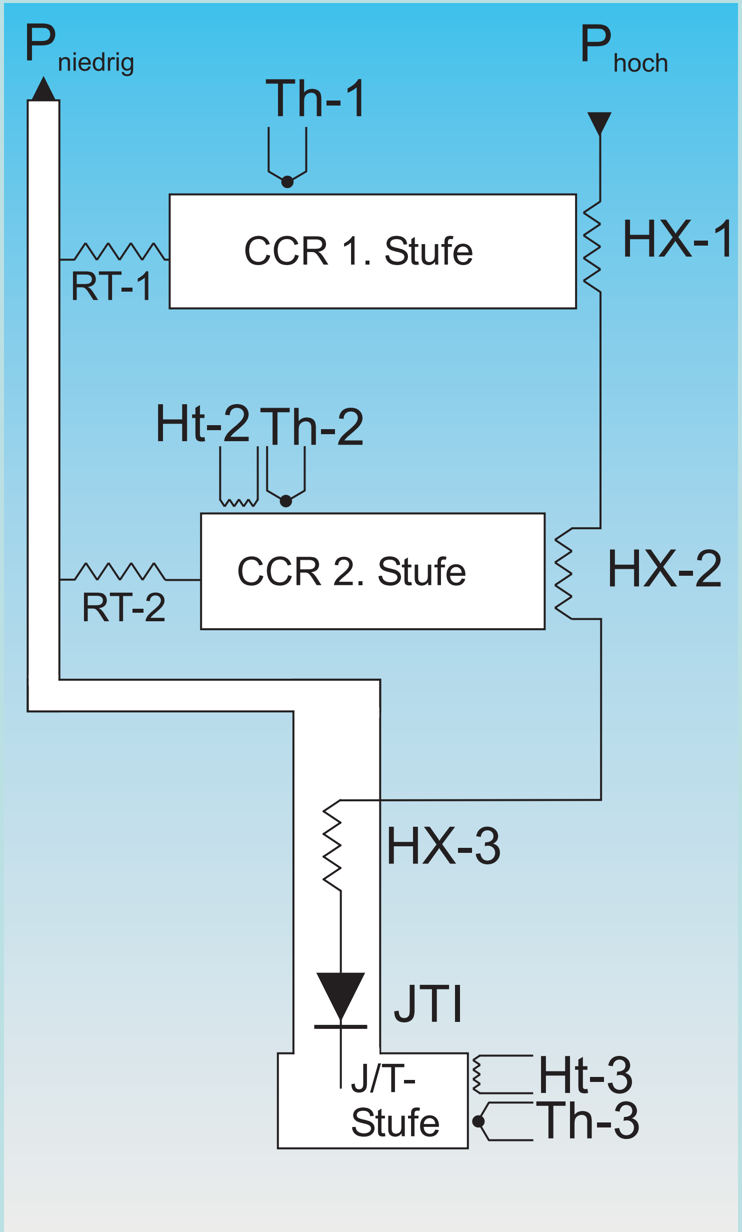


Example 3

CCR plus J/T-stage

3.1: ARS / ILL → ^{4}He

3.2: SHI / HMI → ^{4}He or ^{3}He

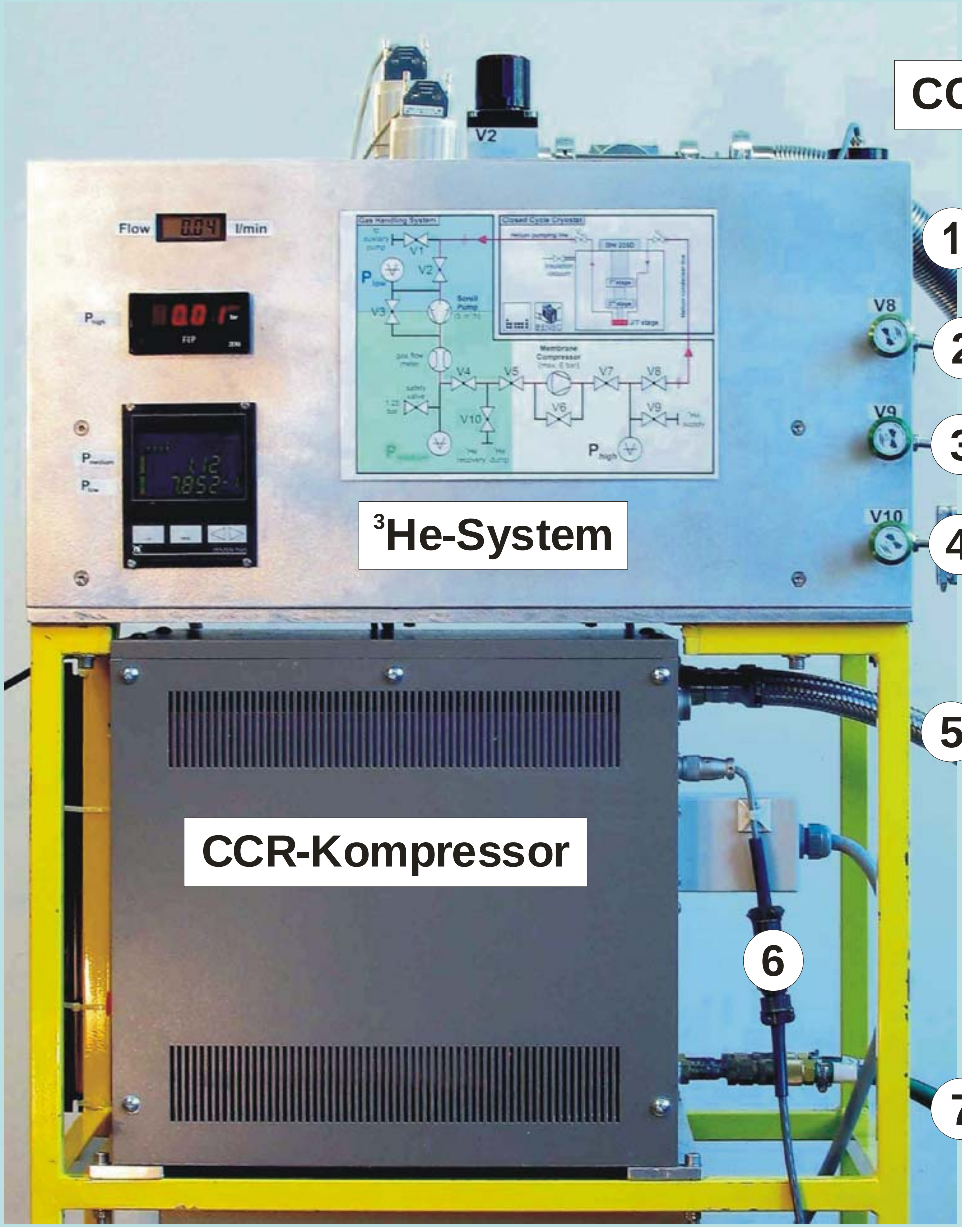
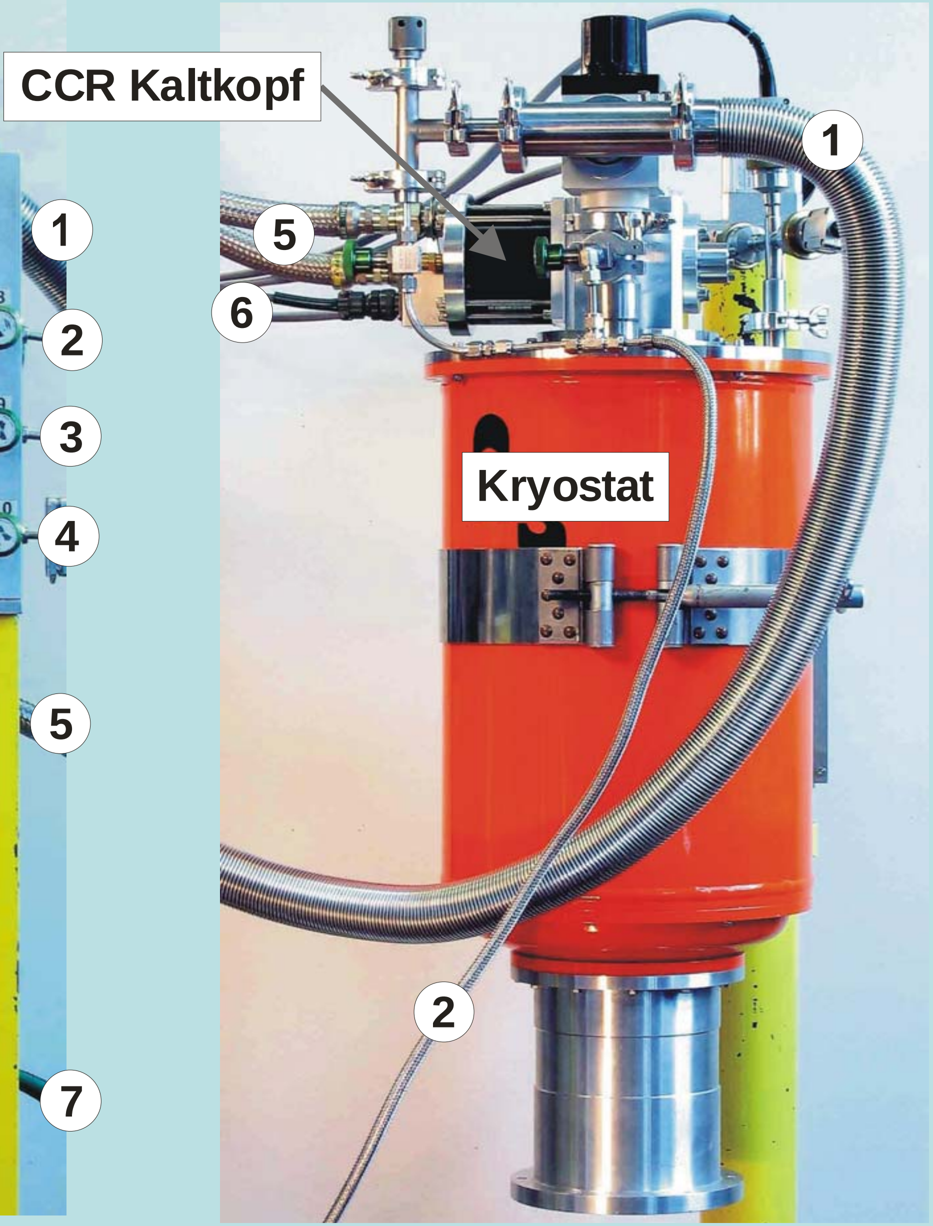


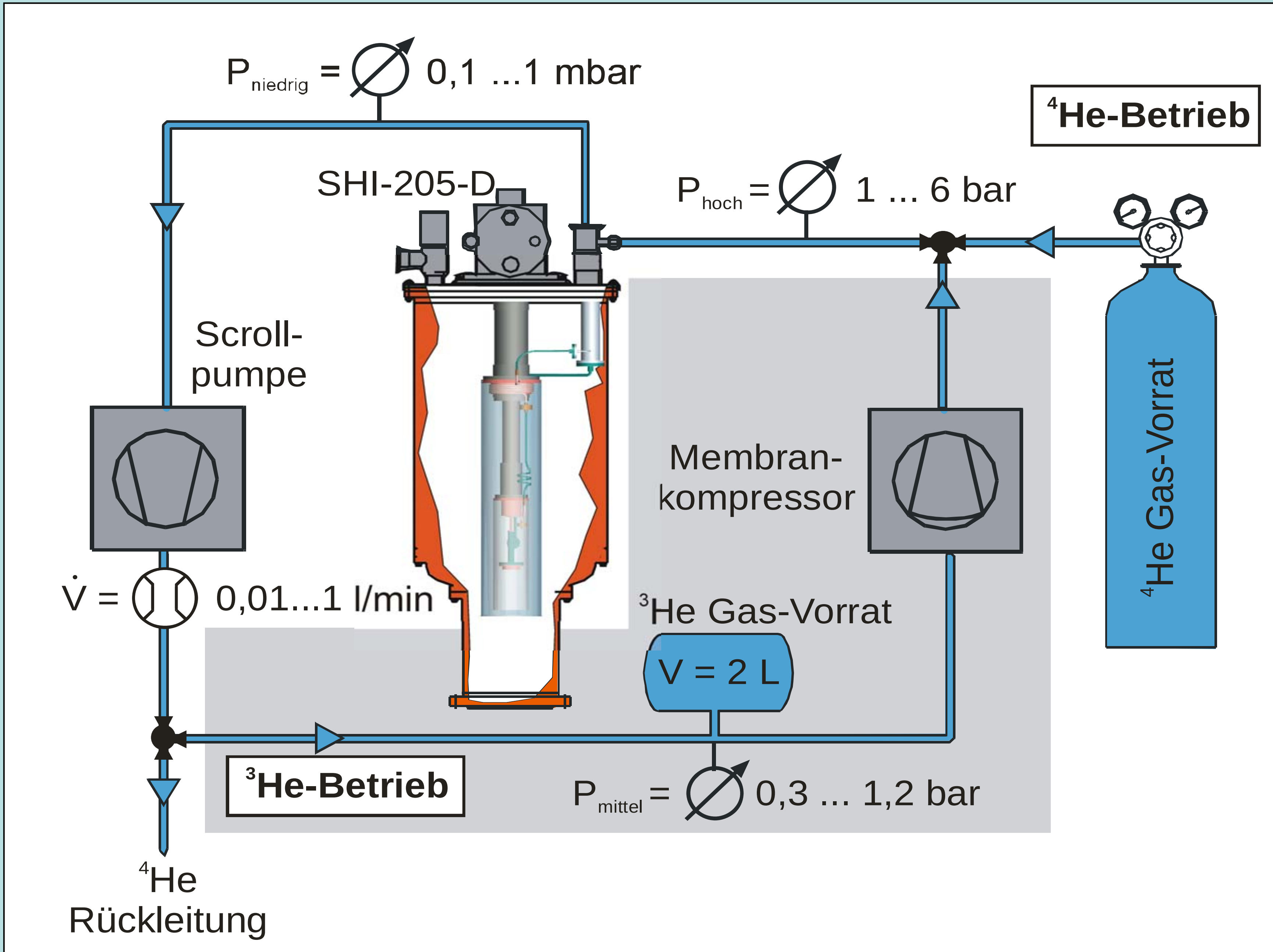
HMI diploma thesis (2005)

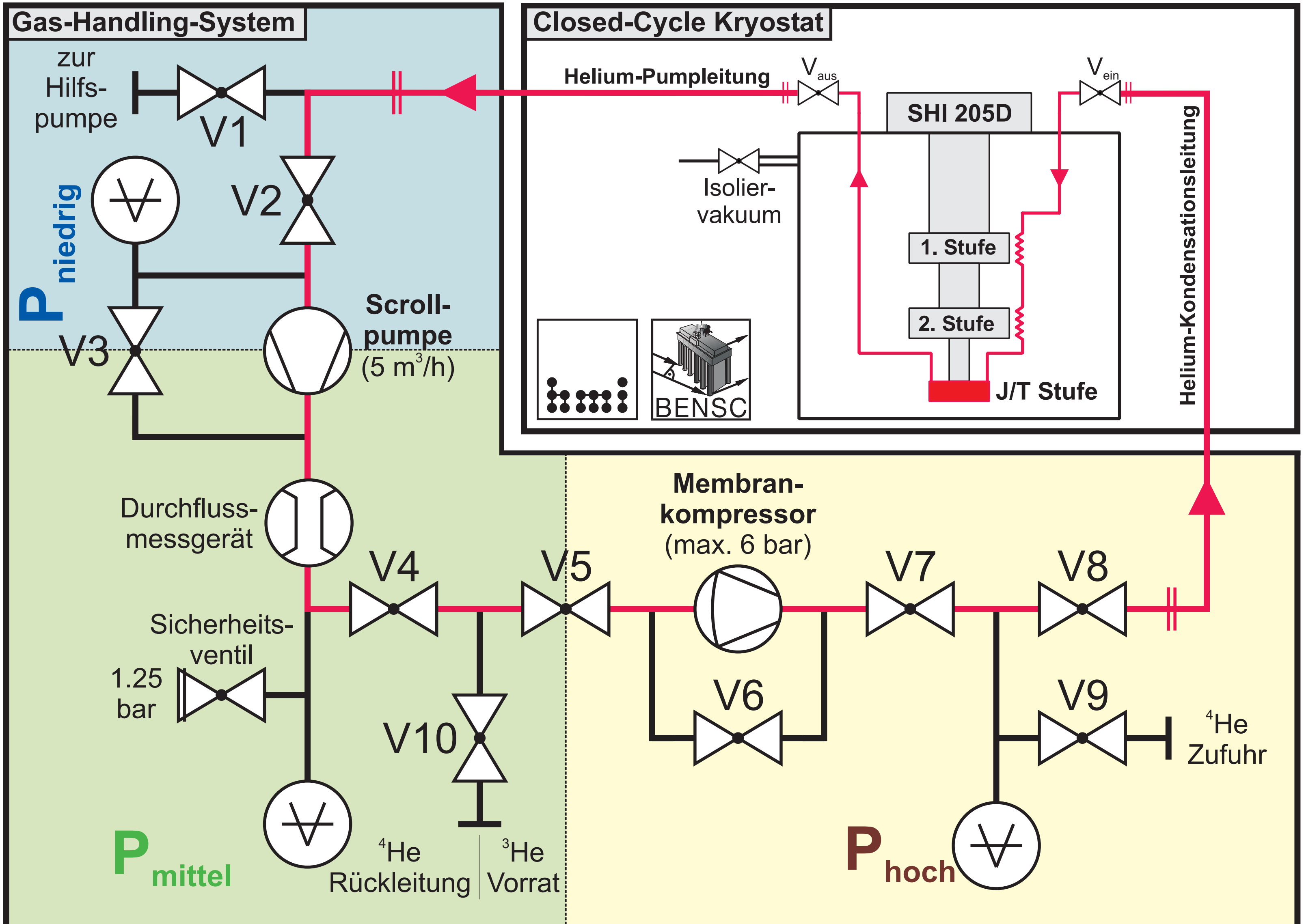
- **Bastian Klemke**
- **SHI RDK-205 + ^{3}He-JT**
- **0.7 K on n-diffractometer**

ARS & ILL co-op. (2004)

- **DE-202 + ^{4}He-JT**
- **1,7 K in 6-circle goniom.**
- **50.000 €**

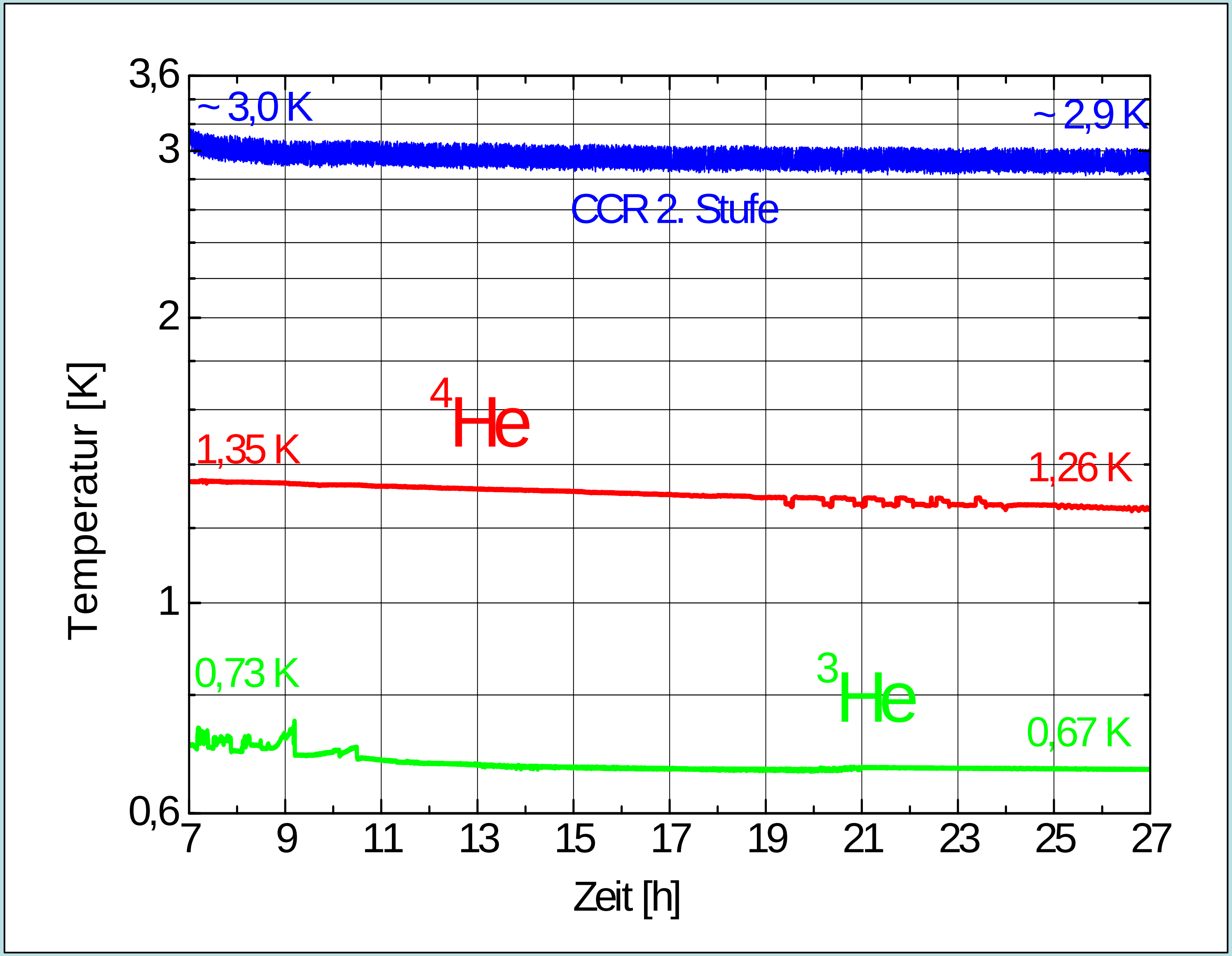

Flow
l/min
V2
V8
V9
V10
1
2
3
4
5
6
7
³He-System
CCR-Kompressor

CCR Kaltkopf
1
5
6
Kryostat
2


$P_{niedrig}$ = 0,1 …1 mbar
⁴He-Betrieb
SHI-205-D
P_{hoch} = 1 … 6 bar
Scroll-
pumpe
Membran-
kompressor
⁴He Gas-Vorrat
$\dot{V}$ = 0,01…1 l/min
³He Gas-Vorrat
V = 2 L
³He-Betrieb
P_{mittel} = 0,3 … 1,2 bar
⁴He
Rückleitung



Gas-Handling-System
zur Hilfs-pumpe
V1
V2
V3
P niedrig
Scroll-pumpe (5 m³/h)
Durchfluss-messgerät
Sicherheits-ventil
1.25 bar
V4
V5
V10
P mittel
⁴He Rückleitung
³He Vorrat
Closed-Cycle Kryostat
Helium-Pumpleitung
V aus
V ein
SHI 205D
Isolier-vakuum
1. Stufe
2. Stufe
J/T Stufe
BENSC
Helium-Kondensationsleitung
Membran-kompressor (max. 6 bar)
V6
V7
V8
V9
⁴He Zufuhr
P hoch

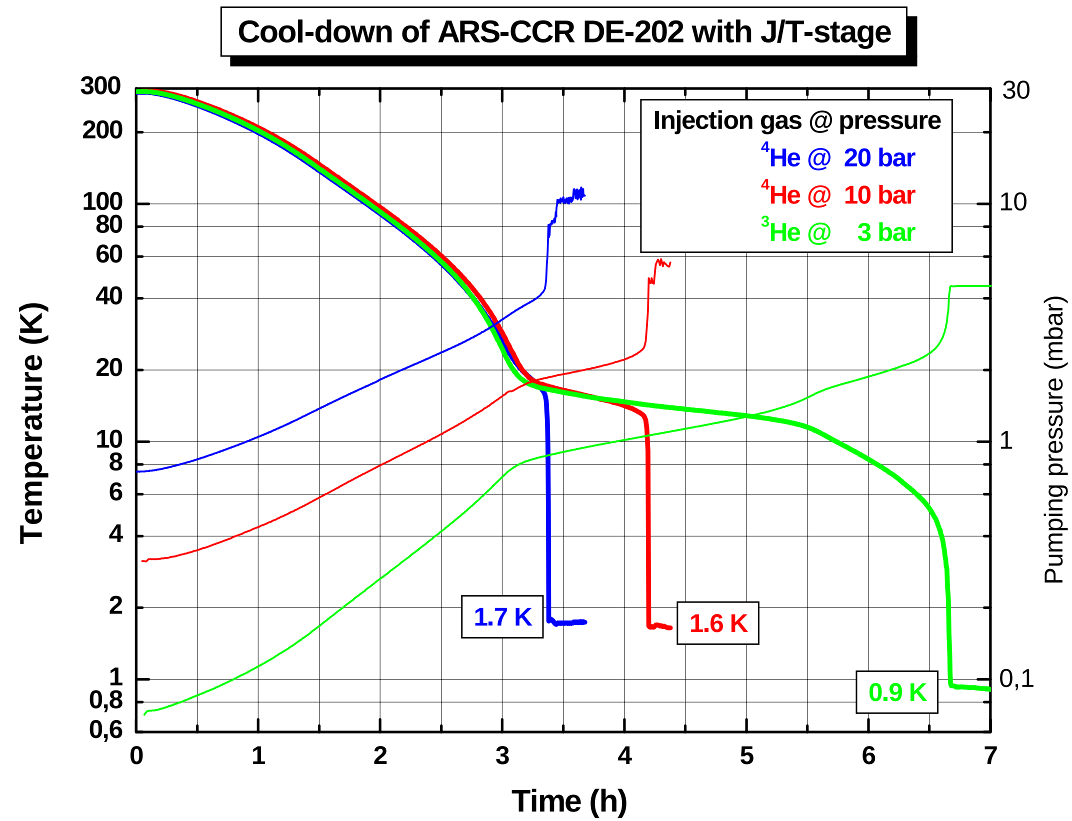
Minimum temperature performance

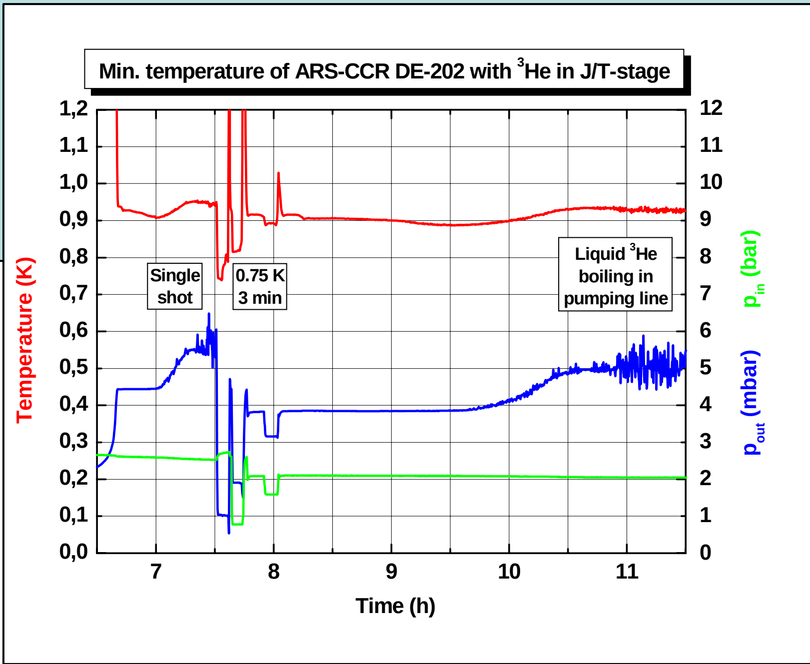


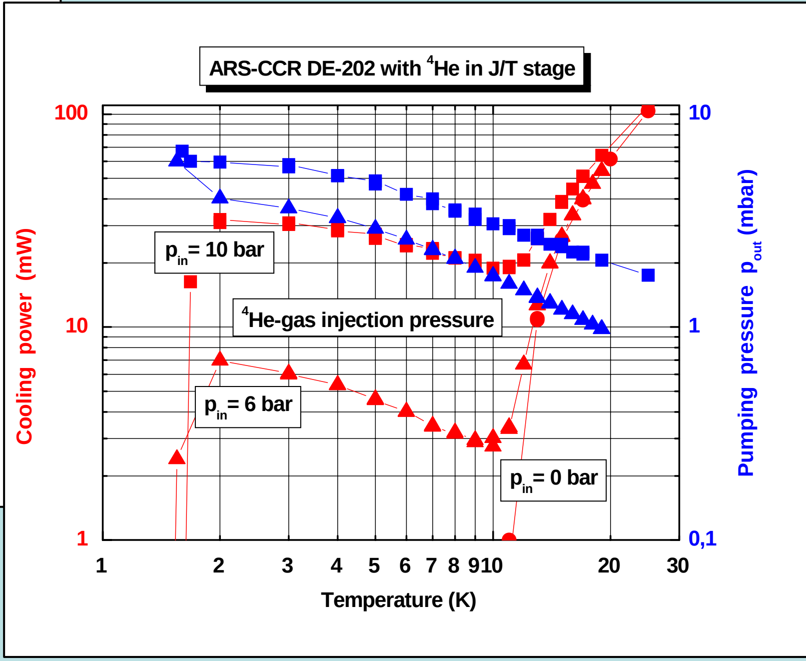
ARS DE-202 with ^{4}He-J/T as 3rd stage

Delivered July 2006 for HMI‘s diffraction instrument MAGS at synchrotron beamline (BESSY)

Performance at low temperature







Example 4

4.1: TransMIT Stirling Refrigerator

4.2: TransMIT Pulstube Refrigerator

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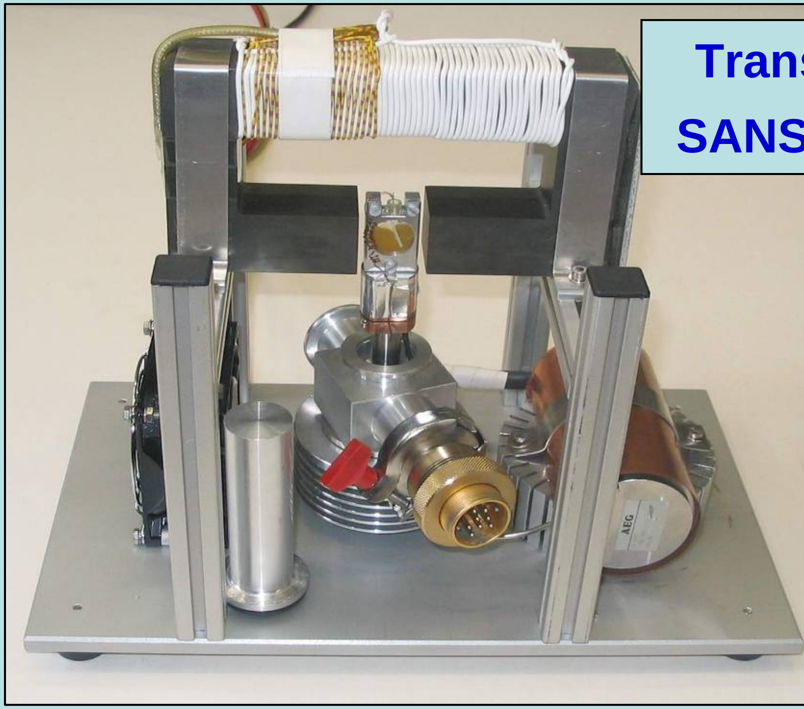
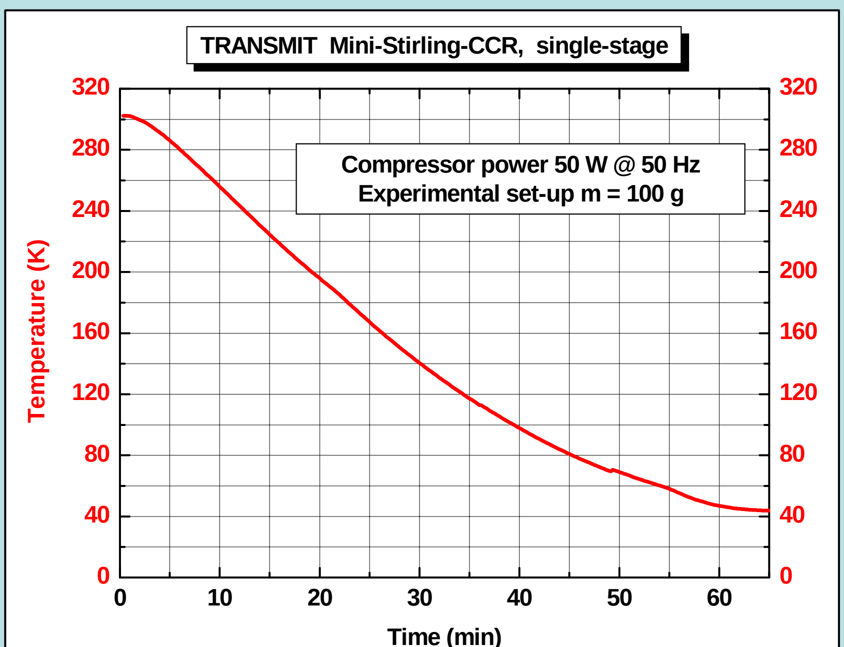
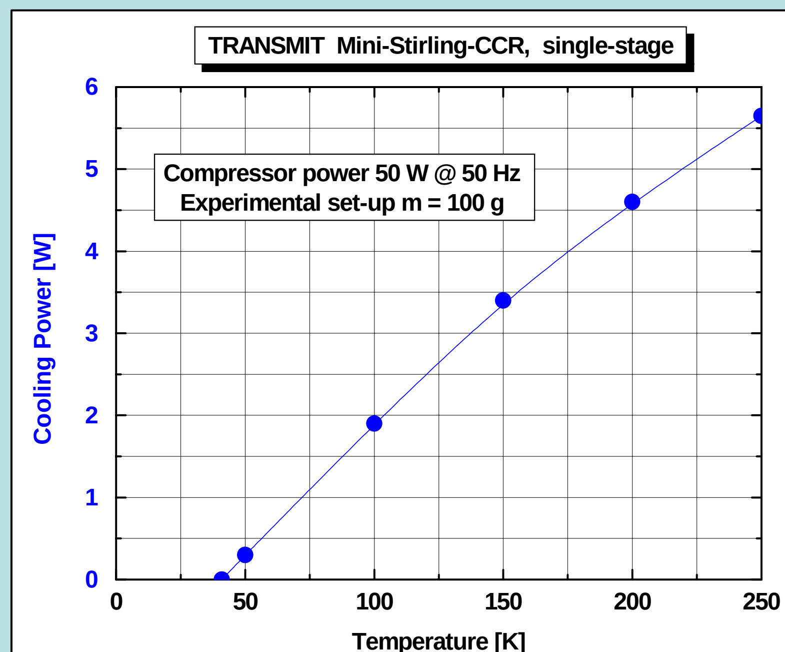
also → Sun Power, Air Liquide, …

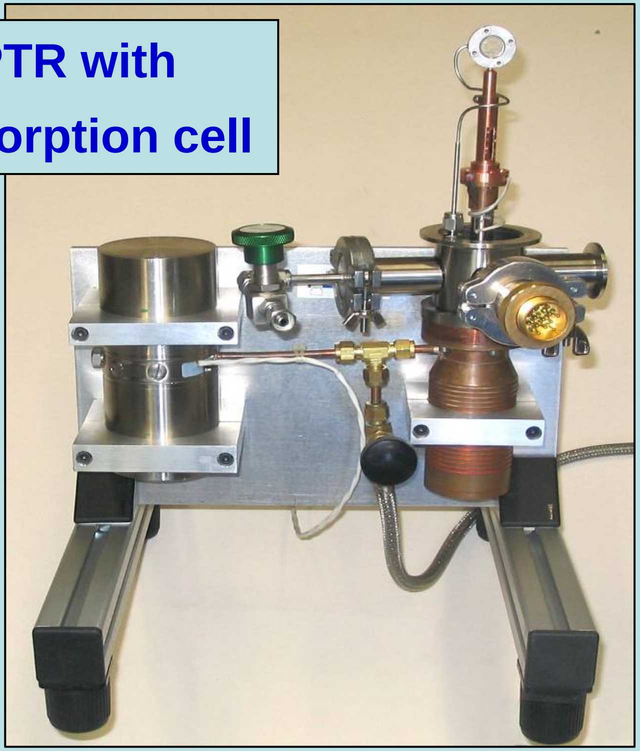
TransMIT Stirlingmotor
SANS 10 kHz AC magnet

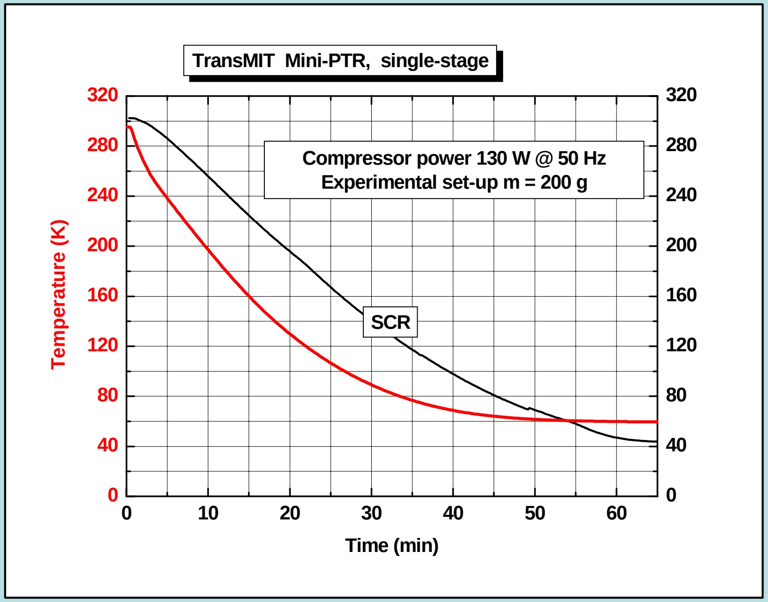


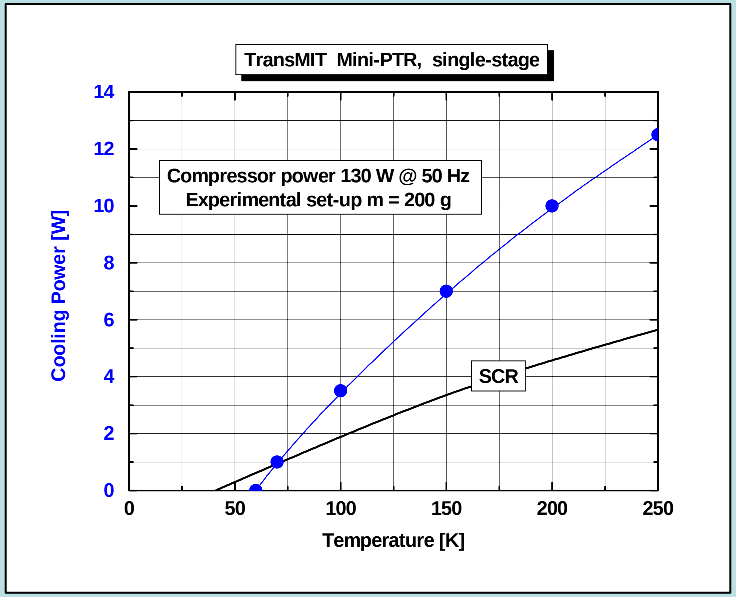




TransMIT PTR with SANS gas adsorption cell







Refrigerator cryostats

-performance in beamline experiments –

<u>T-range low:</u> 325 K → 2.5 K → 1.4 K (^{4}He) → 0.3 K (^{3}He)

<u>T-range high:</u> 4 K → 600 K … 800 K

<u>T-regulation & ΔT-stability:</u> within LS-340 quality

<u>Cooling power:</u> ~500 g in 1 h with CCR of ~1 W @ 4 K

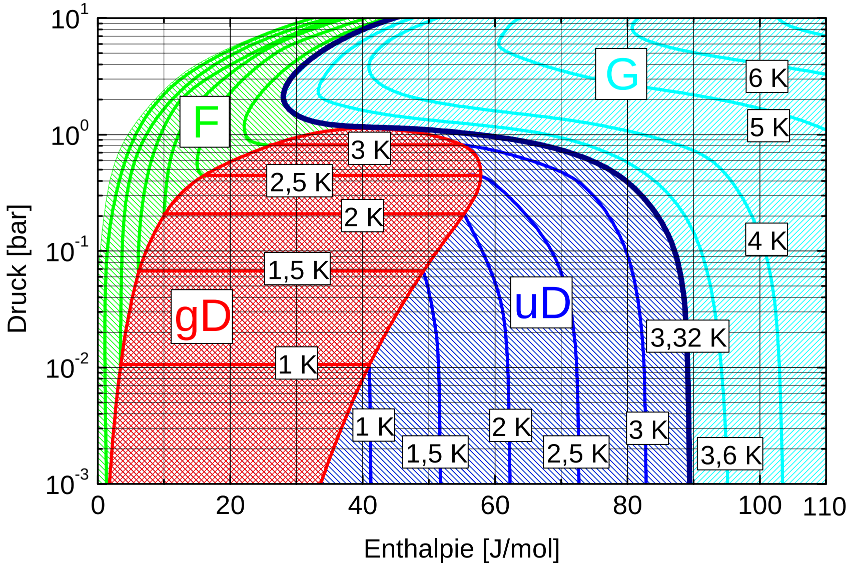
<u>CCR or PTR:</u> PTR vibrations are smoother;

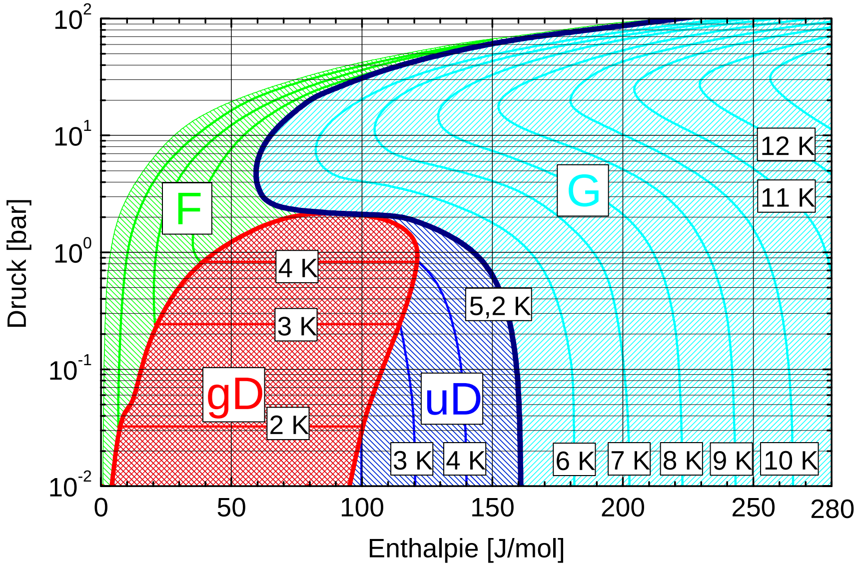
Temps lower → ^{4}He: 2.2 K and ^{3}He: 1.3 K !!!

Finis

Pressure – Enthalpy – Diagram

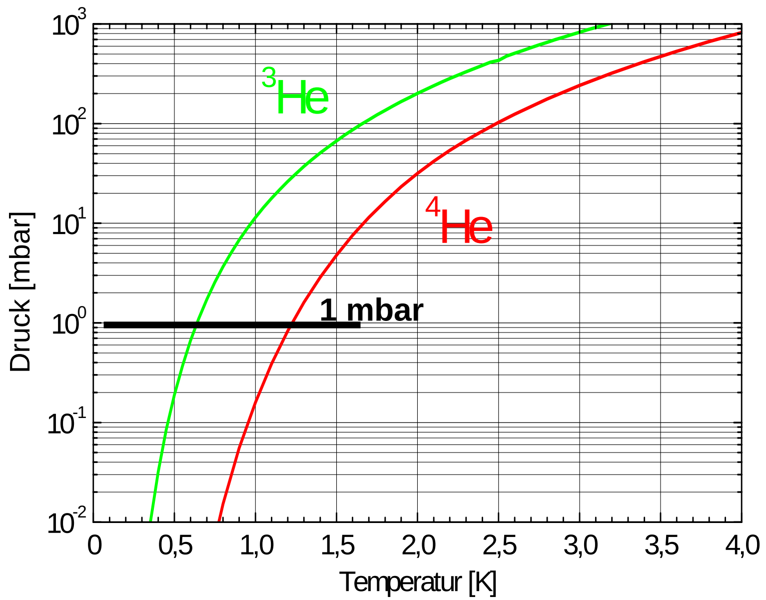
^3He (CP: 3,3 K / 1 bar) ^4He (CP: 5,2 K / 2 bar)

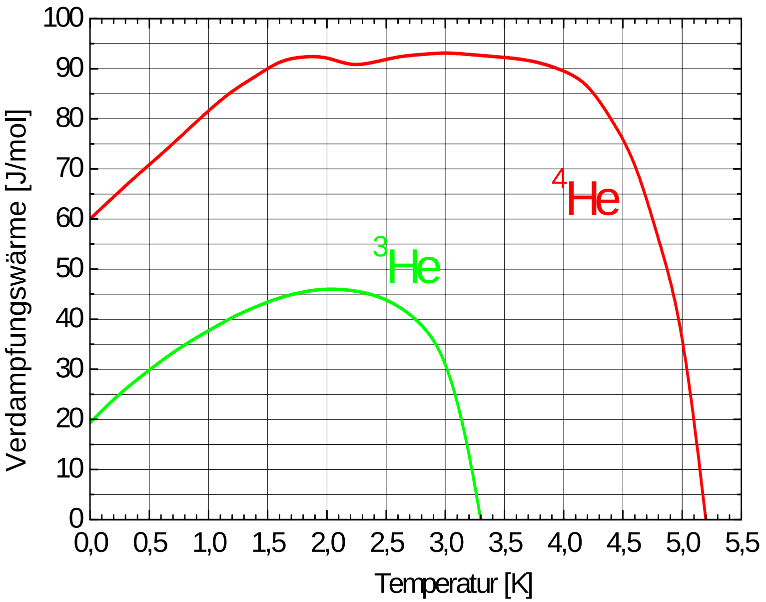




Vapor pressure

Latent heat

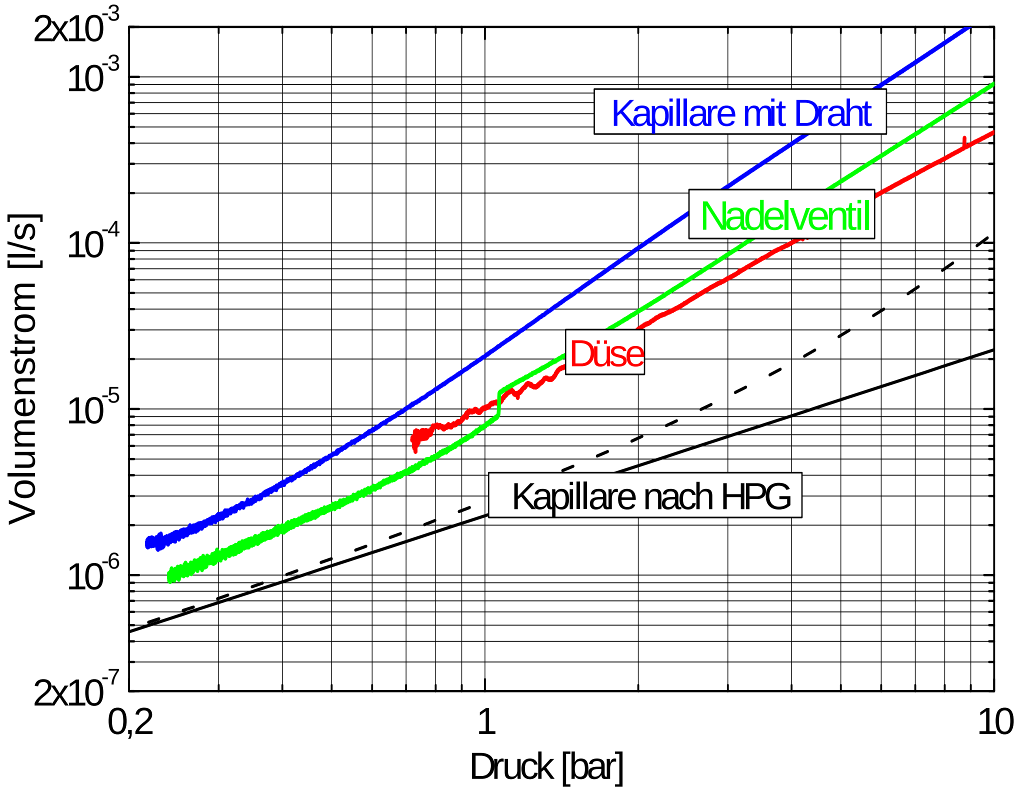


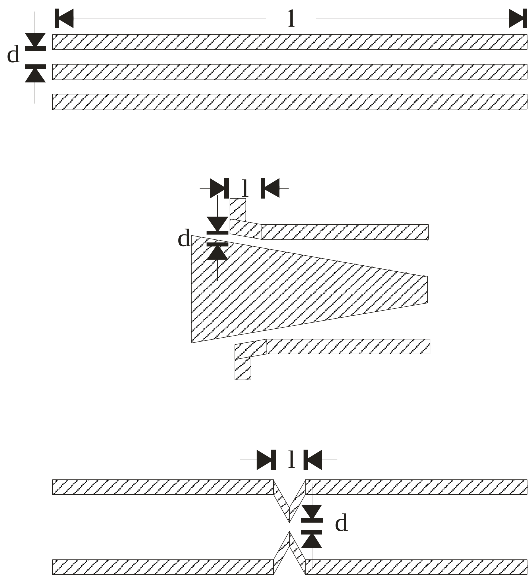


p ~ 1 mbar: T ~ 1,2 K bzw. 0,6 K

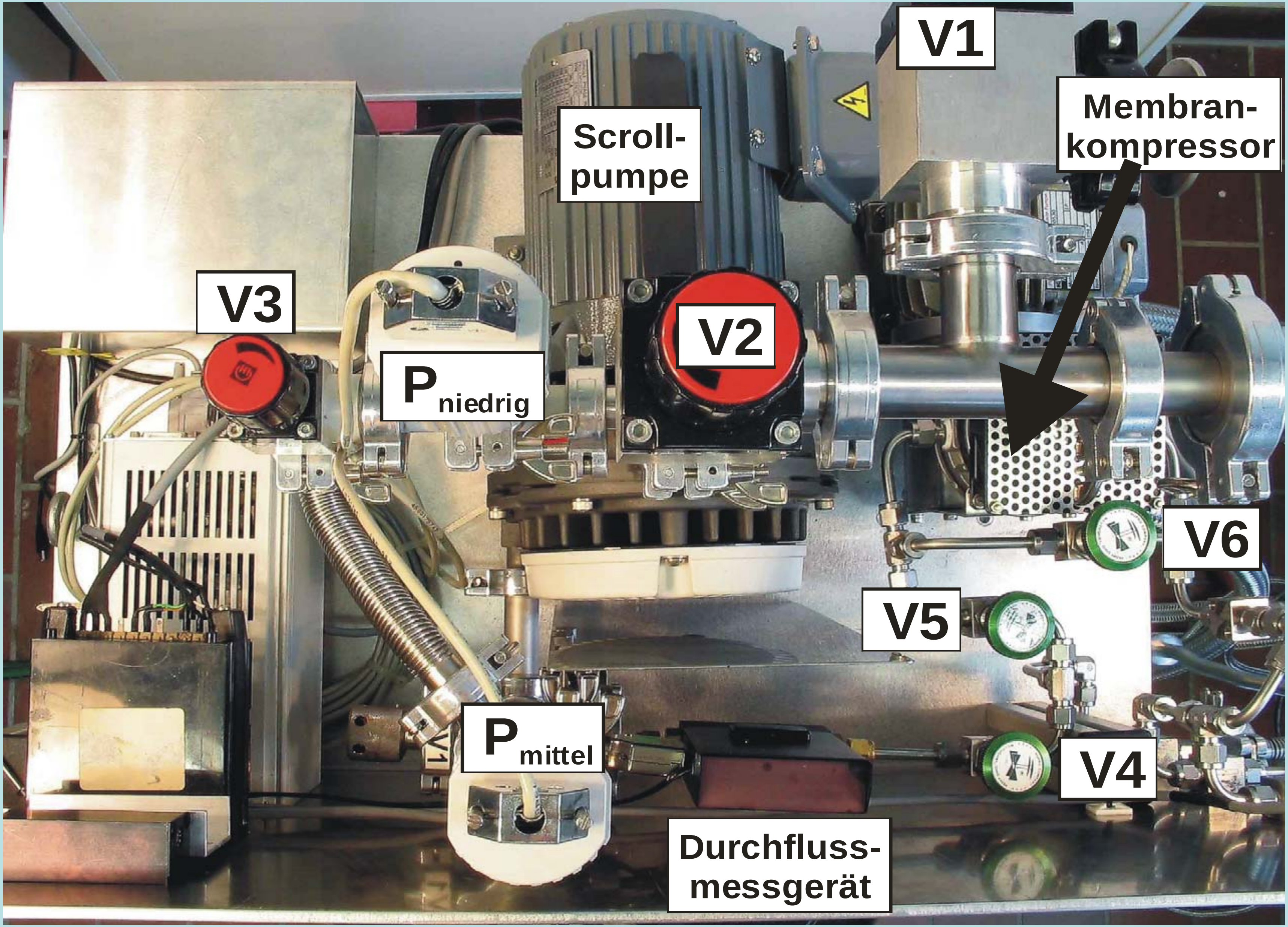
$\Delta V/\Delta t \sim 10^{-4}$ mol/s → $P_L \sim 5 \ldots 10$ mW

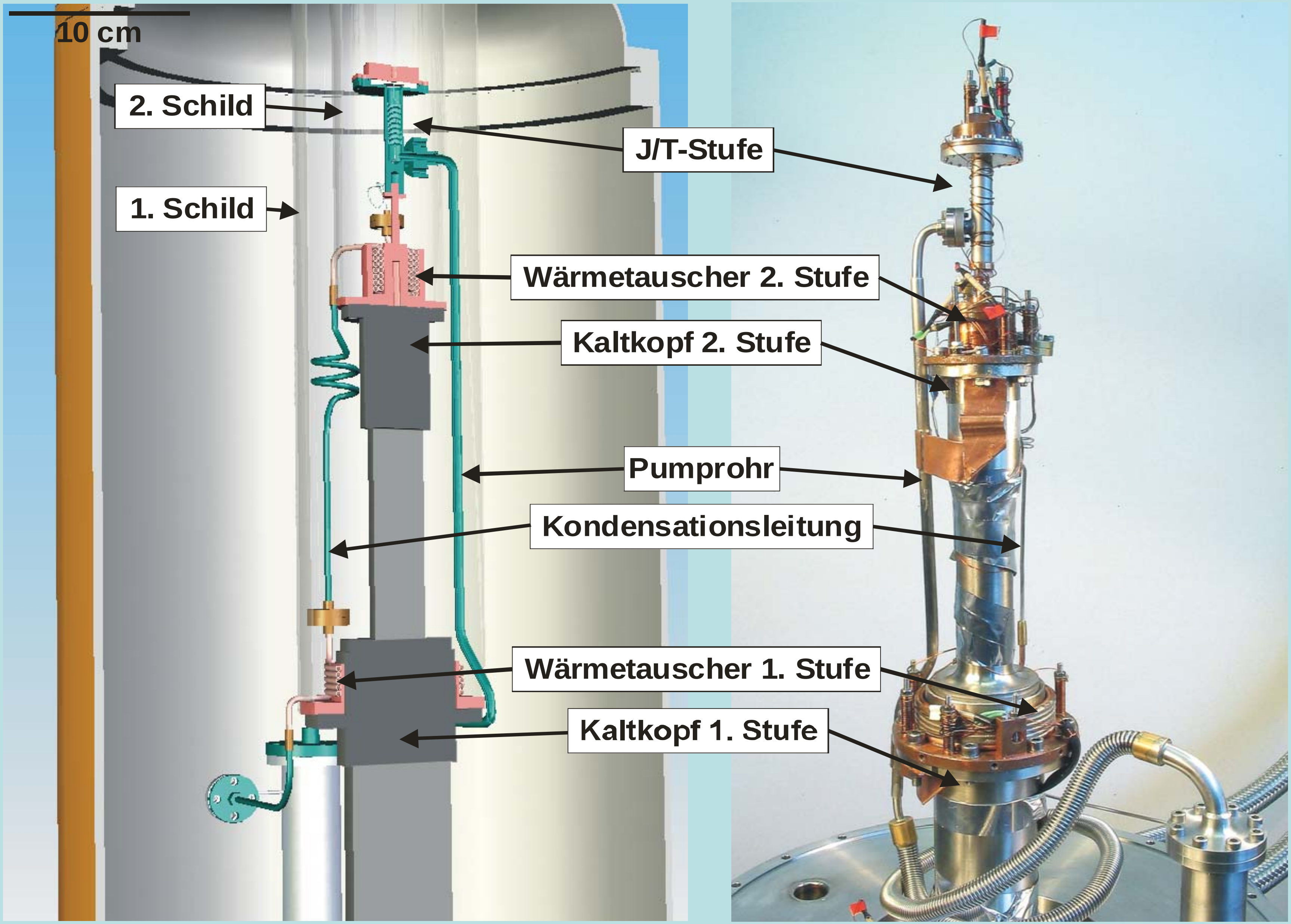
Gas flow trough 3 types of J/T-valves



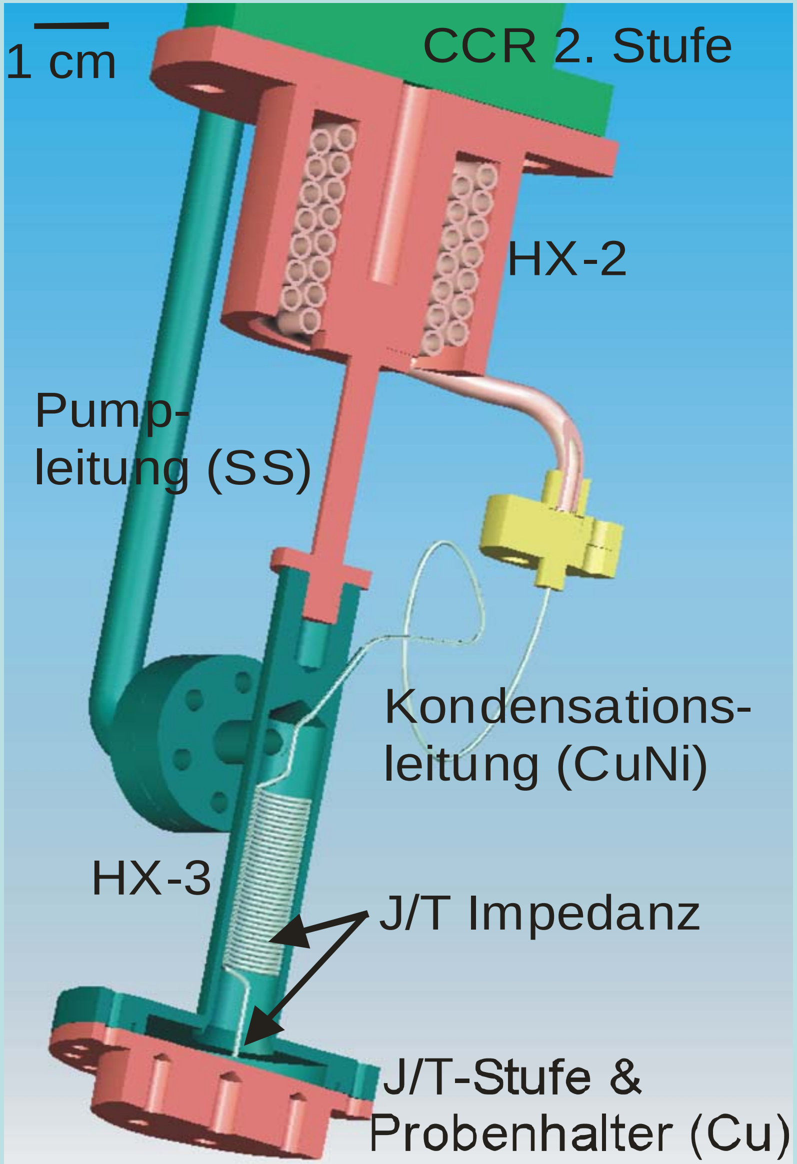


Viscous flow: $\Delta V/\Delta t = \Delta p \, \pi \, R^4 / 8 \, \eta \, L$; Expansion of capillary: $R = R_o \, (1 + 3 \cdot 10^{-3} \, \Delta p)$

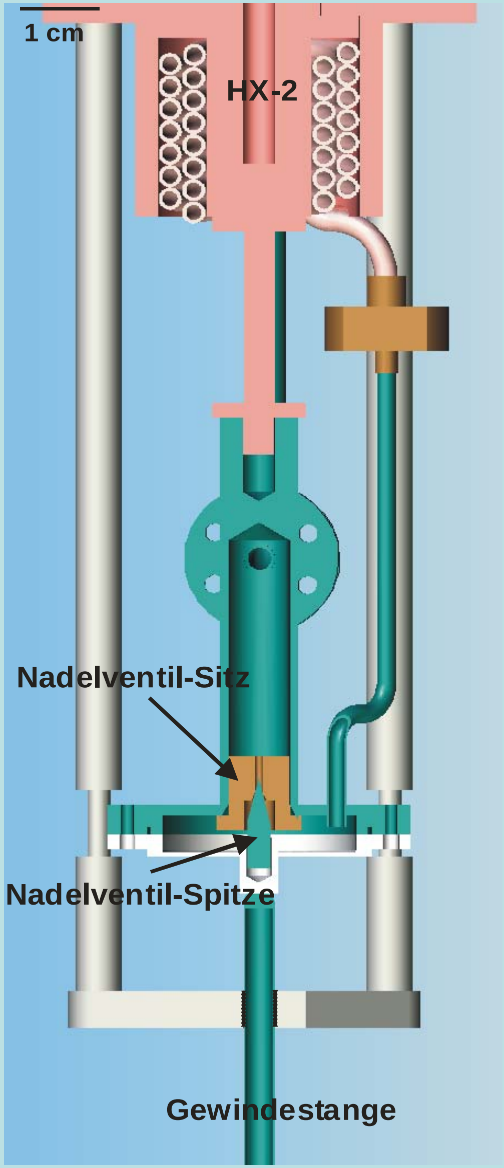

V1
Membran-
kompressor
Scroll-
pumpe
V3
V2
P niedrig
V6
V5
P mittel
V4
Durchfluss-
messgerät


10 cm
2. Schild
1. Schild
J/T-Stufe
Wärmetauscher 2. Stufe
Kaltkopf 2. Stufe
Pumprohr
Kondensationsleitung
Wärmetauscher 1. Stufe
Kaltkopf 1. Stufe

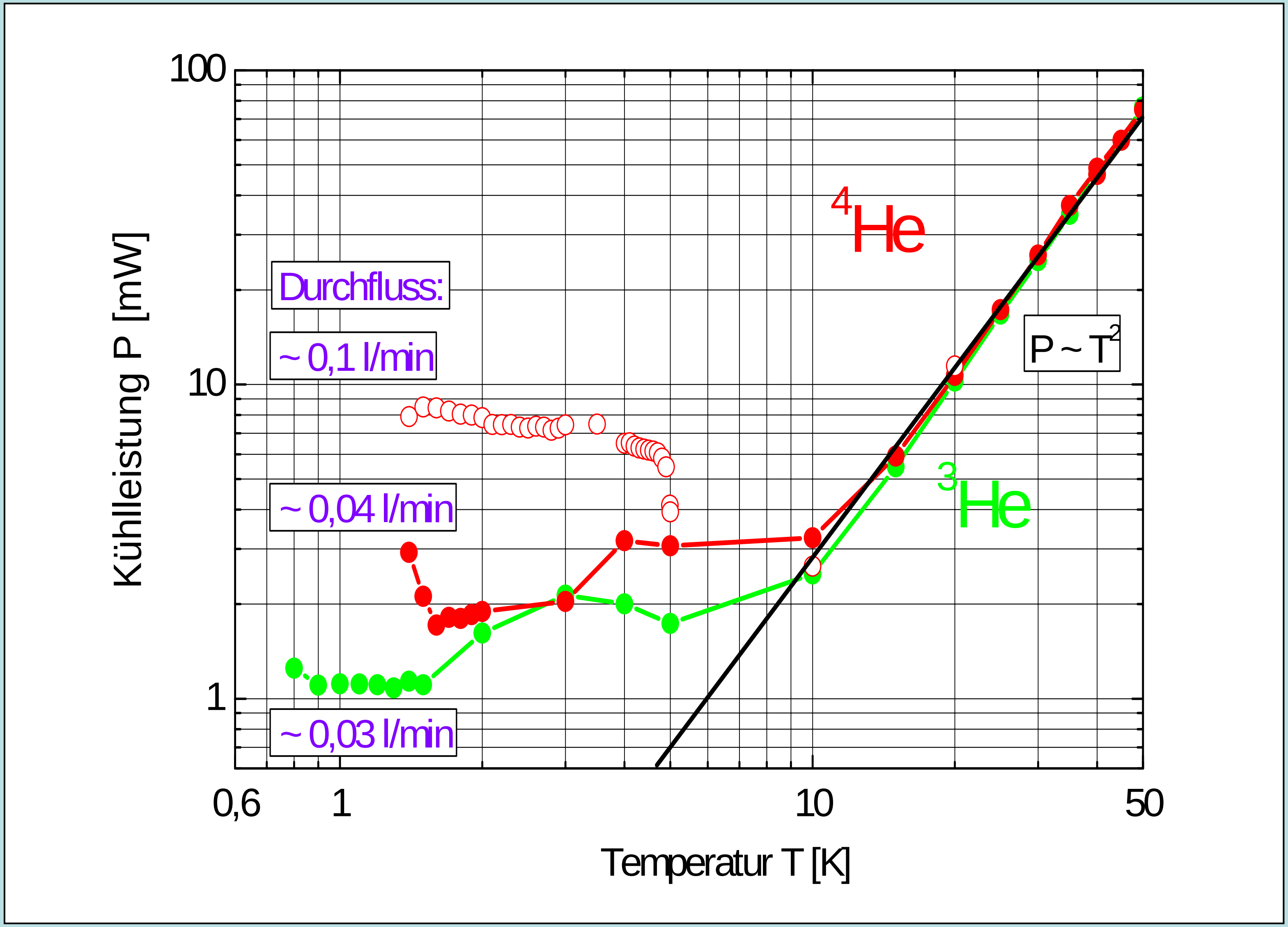
Design J/T-stage and LHe-chamber



Design of needle valve



Cooling power of J/T-stage with different flow



PID-controled temperatures $\Delta T / T_o < 0{,}1\ \%$ with $\tau < 1 \ldots 5$ min