

GRAVITHELIUM

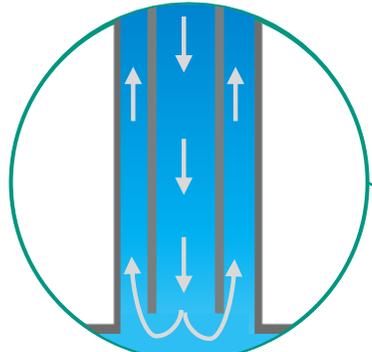
Progress Report

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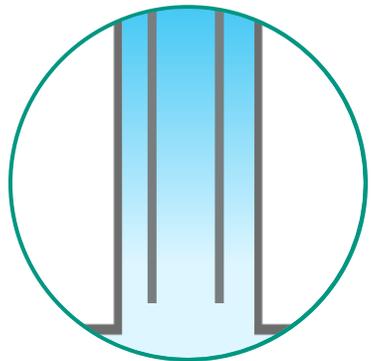


A cooling system based on He-II

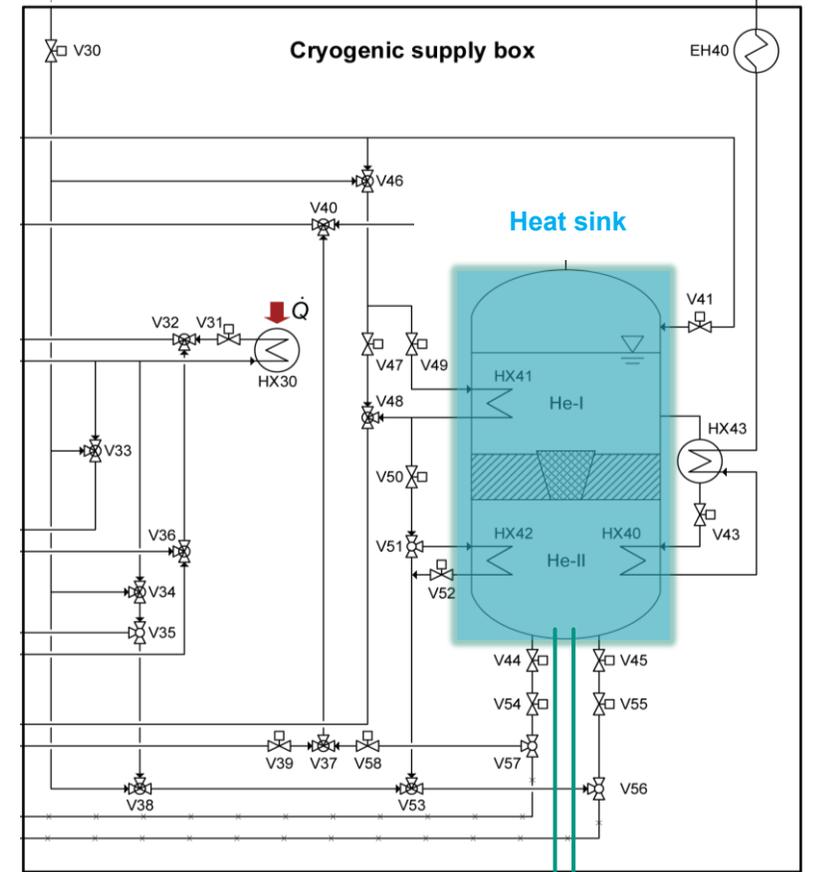
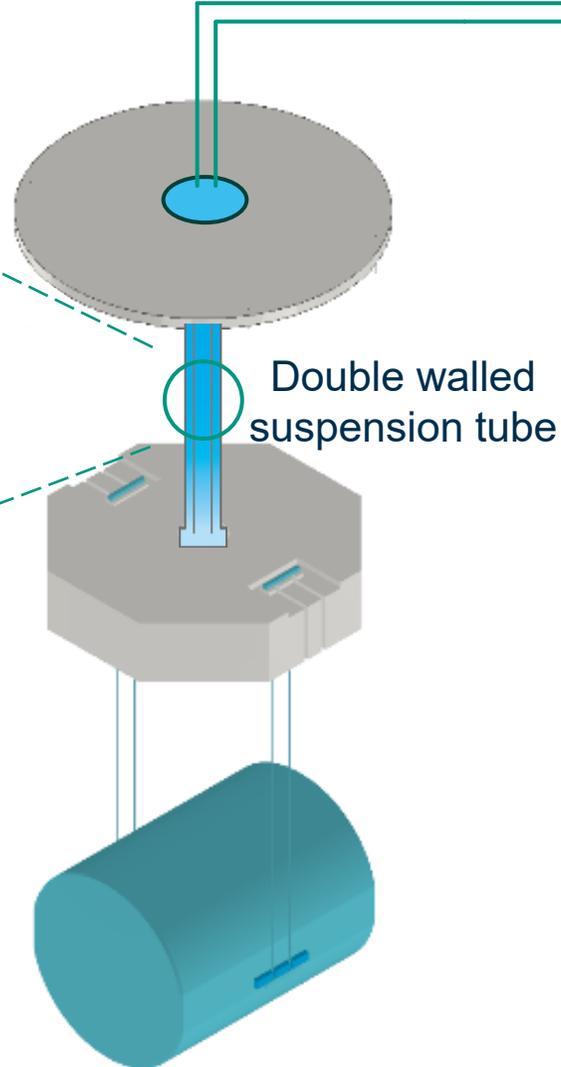
Publication



He-I for Cool-down



He-II (no macroscopic flow)
for stationary operation



10-20 m



Publication

The Q-Factor

$$\text{STN} \sim f(T; \phi_{\text{susp}})$$

$$\text{Q-Factor} = \frac{1}{\phi_{\text{susp}}}$$

Describes material dissipation characteristic

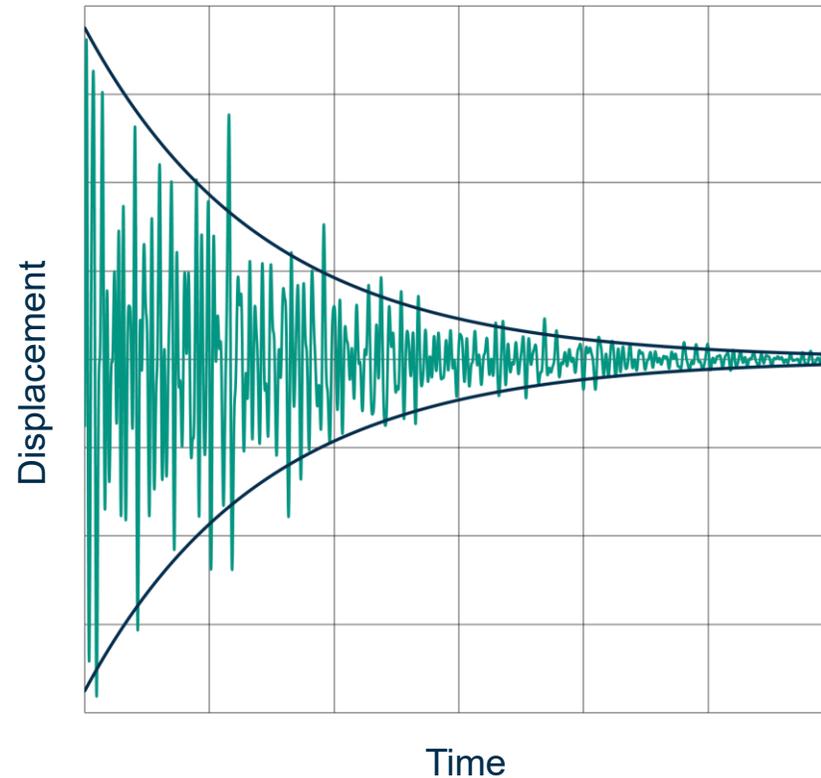
Actuation System

Sensing System

Q-Factor measured via amplitude decay over time

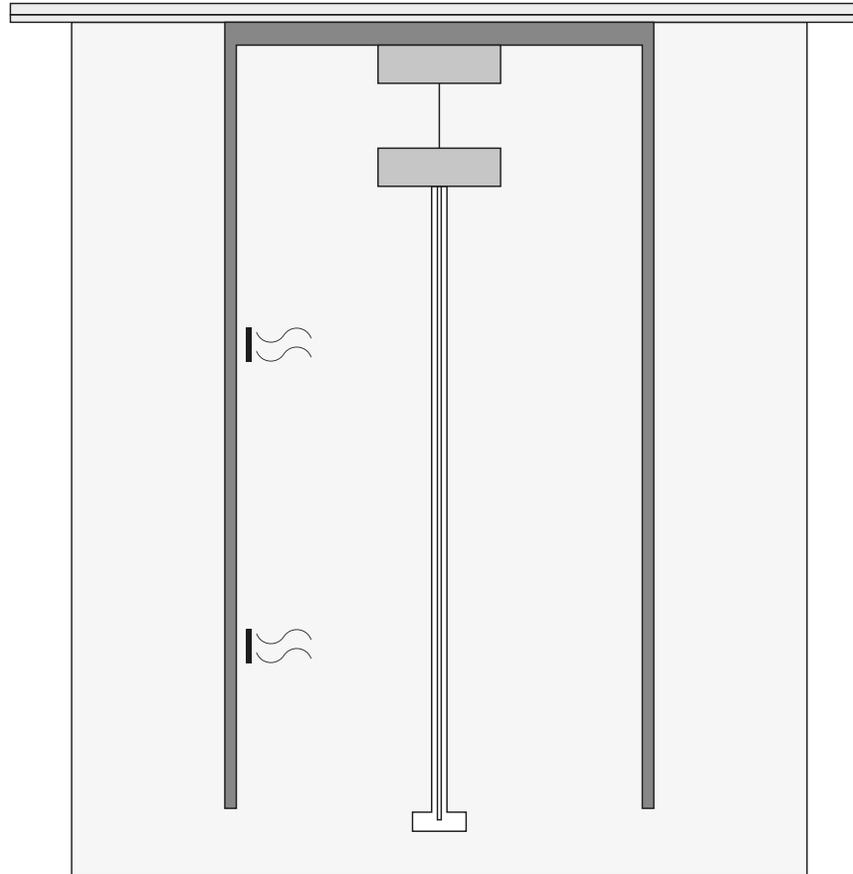
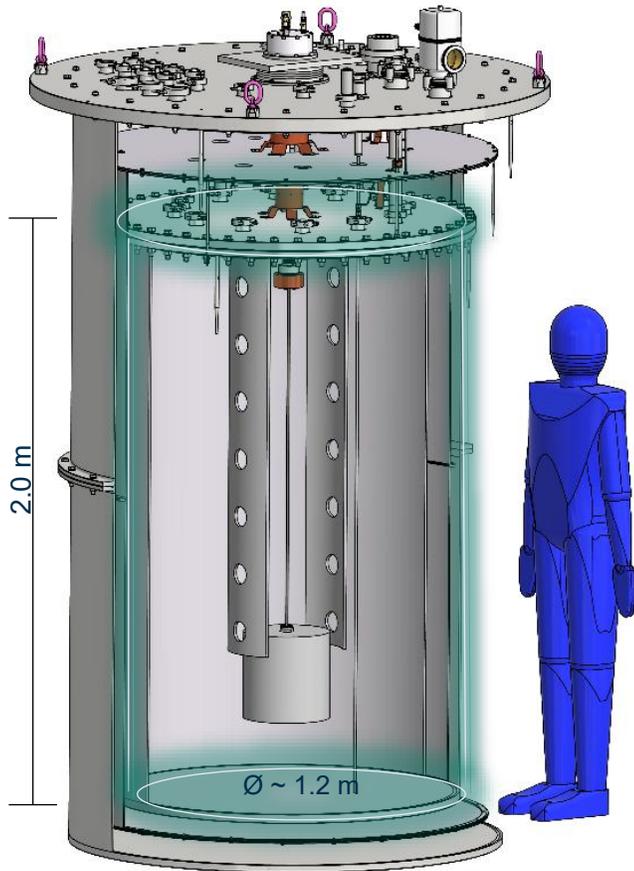
$$\phi_{\text{susp}} = \underbrace{\phi_{\text{bulk}} + \phi_{\text{thermoelastic}} + \phi_{\text{surface}}}_{\phi_{\text{intrinsic}}} + \underbrace{\phi_{\text{extrinsic}}}$$

- Clamp losses
- Recoil losses
- Gas damping losses
- Eddy current losses



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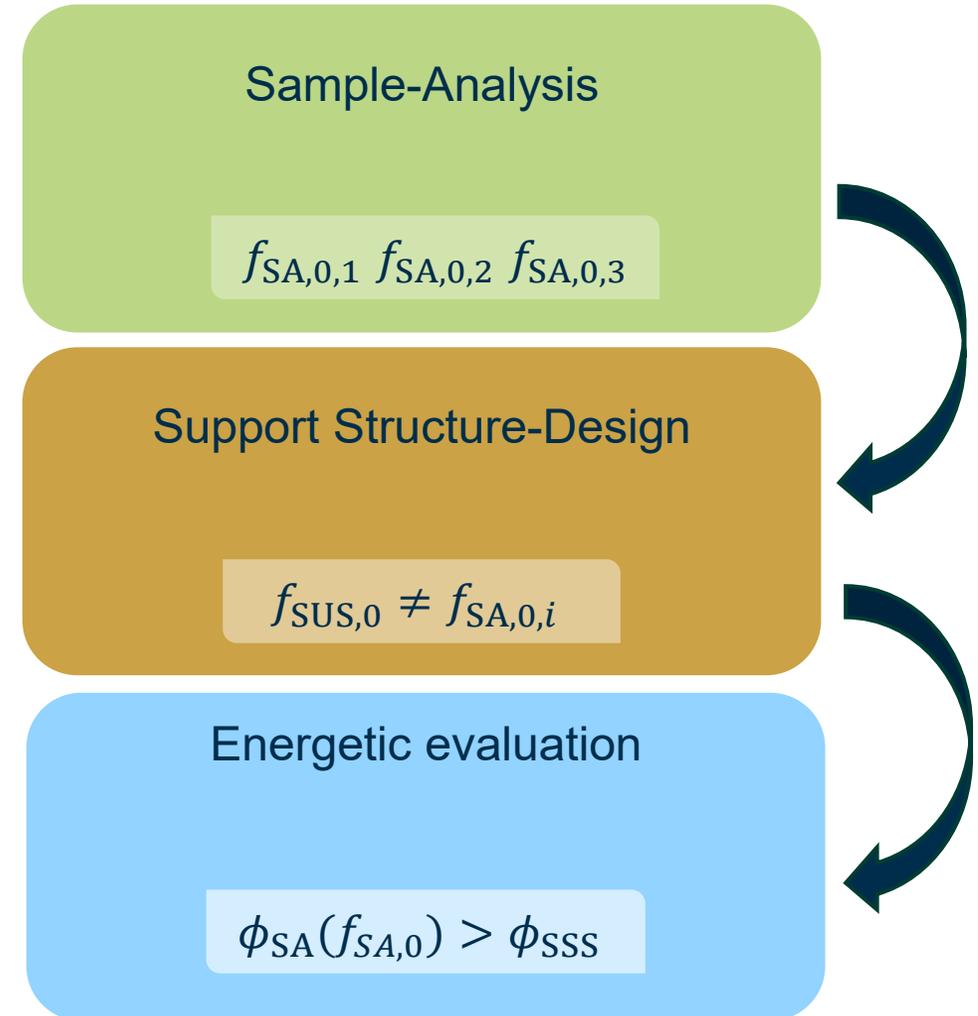
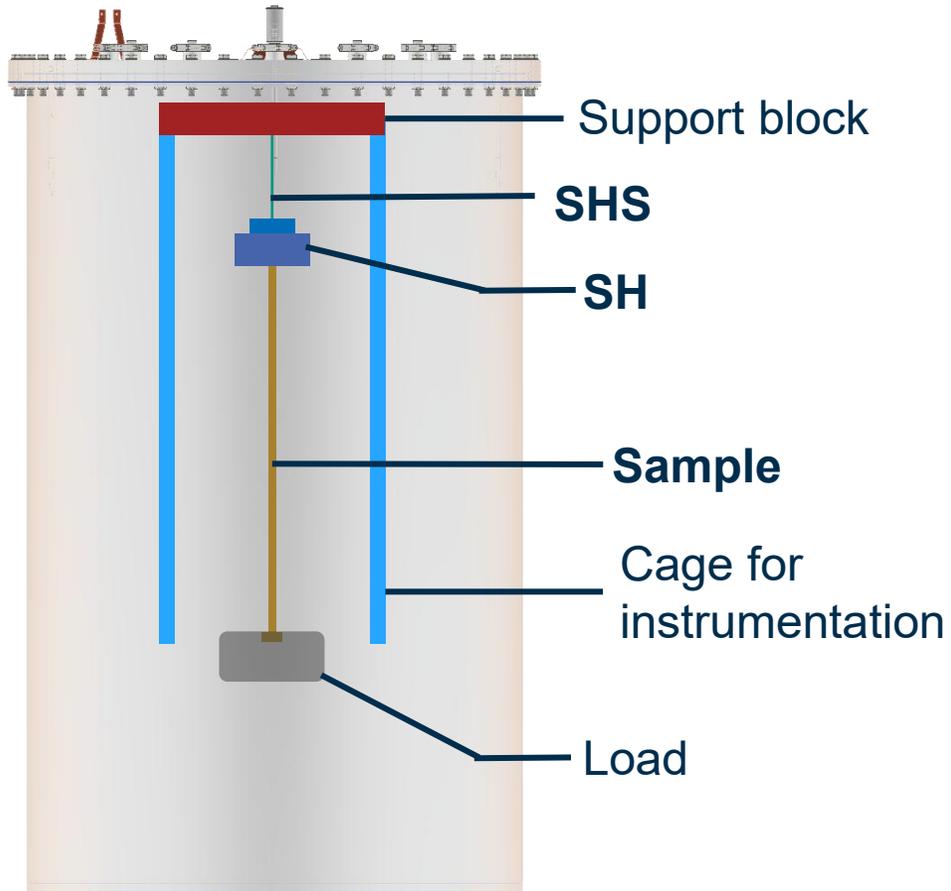
Phase I – Monolithic Suspension



- Validation of measurements through comparison with literature
- Investigation of the temperature dependence
- Investigating the dependence on stress

Test facility for fullscale
cryogenic payload
suspensions

Conceptual Sample Support Structure design approach



Sample analysis

Clamped in Sample Holder

- **Key – Assumption:** fibres can be clamped from top via thick cylindrical heads

- Sample geometry

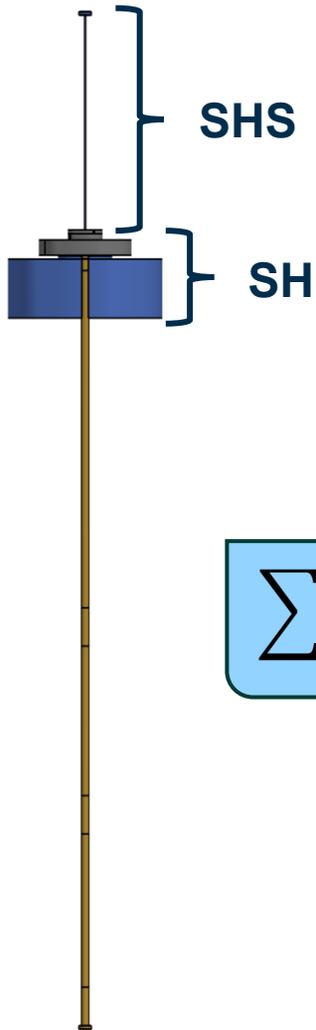
	$d_{\text{Fibre}}/\text{mm}$	l/mm	$d_{\text{heads}}/\text{mm}$
Suspension tube	9.03	1000	32
Silicon	8	1000	16
Sapphire	8	1000	32

- Sample natural frequencies

	$f_{\text{SA},0,1}/\text{Hz}$	$f_{\text{SA},0,2}/\text{Hz}$	$f_{\text{SA},0,3}/\text{Hz}$
Suspension tube	5	38	120
Silicon	6	41	120
Sapphire	8	60	205

No support structure frequencies within 5 Hz to 205 Hz

Support Structure Design



- Main geometry parameters selected via FRA
 - SHS+ SH form pendulum
 - Pendulum mode @ 2 Hz
 - Rocking mode @ 4 Hz
 - Violinmode @ 280 Hz

- Material selection via energetic evaluation

$$\sum \phi_{\text{Total}} = \frac{E_{\text{SA}}}{E_{\text{total}}} \phi_{\text{SA}} + \underbrace{\frac{E_{\text{SHS}}}{E_{\text{total}}} D \phi_{\text{SHS,mat}} + \frac{E_{\text{SH}}}{E_{\text{total}}} \phi_{\text{SH,mat}}}_{\text{Extrinsic losses}}$$

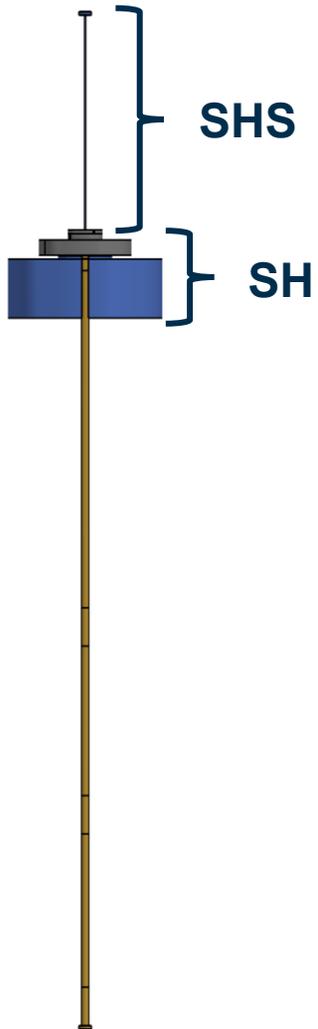
Clamp

- Clamp upper part: Titanium
- Clamp lower block: Aluminium
- $d_{\text{SH}} = 200 \text{ mm}$
- $m_{\text{SH}} = 10 \text{ kg}$

SHS

- Ti-6Al-4V
- $l = 300 \text{ mm}$
- $d = 1 \text{ mm}$

Energetic evaluation



$$\sum \phi_{\text{Total}} = \frac{E_{\text{SA}}}{E_{\text{total}}} \phi_{\text{SA}} + \underbrace{\frac{E_{\text{SHS}}}{E_{\text{total}}} D \phi_{\text{SHS,mat,thermoel}} + \frac{E_{\text{SH}}}{E_{\text{total}}} \phi_{\text{SH,mat}}}_{\text{Extrinsic losses}}$$

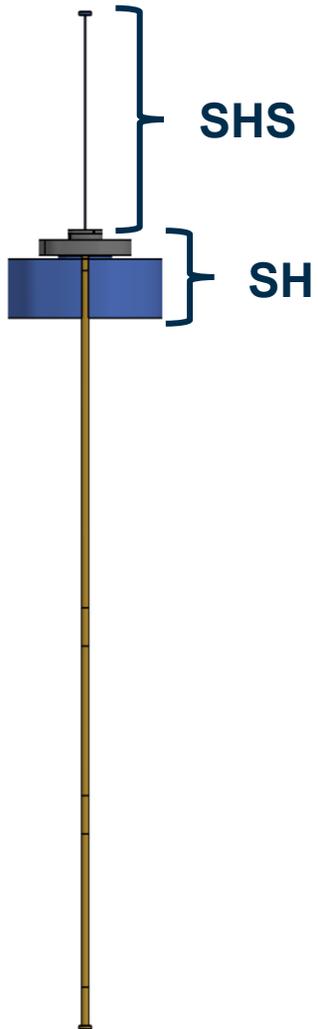
Monolithic samples

Silicon	$\hat{\phi}_{\text{extrinsic}}$	$\hat{\phi}_{\text{SA}}$	$\sum \phi_{\text{SSS}}$
$f_{\text{SA},1}$	8×10^{-9}	1×10^{-8}	2×10^{-8}
$f_{\text{SA},2}$	2×10^{-10}	1×10^{-8}	1×10^{-8}
$f_{\text{SA},3}$	1×10^{-10}	1×10^{-8}	1×10^{-8}

Sapphire	$\hat{\phi}_{\text{extrinsic}}$	$\hat{\phi}_{\text{SA}}$	$\sum \phi_{\text{SSS}}$
$f_{\text{SA},1}$	2×10^{-8}	1×10^{-8}	3×10^{-8}
$f_{\text{SA},2}$	6×10^{-10}	1×10^{-8}	1×10^{-8}
$f_{\text{SA},3}$	3×10^{-10}	1×10^{-8}	1×10^{-8}

1st mode probably not measurable due to expected recoil

Energetic evaluation



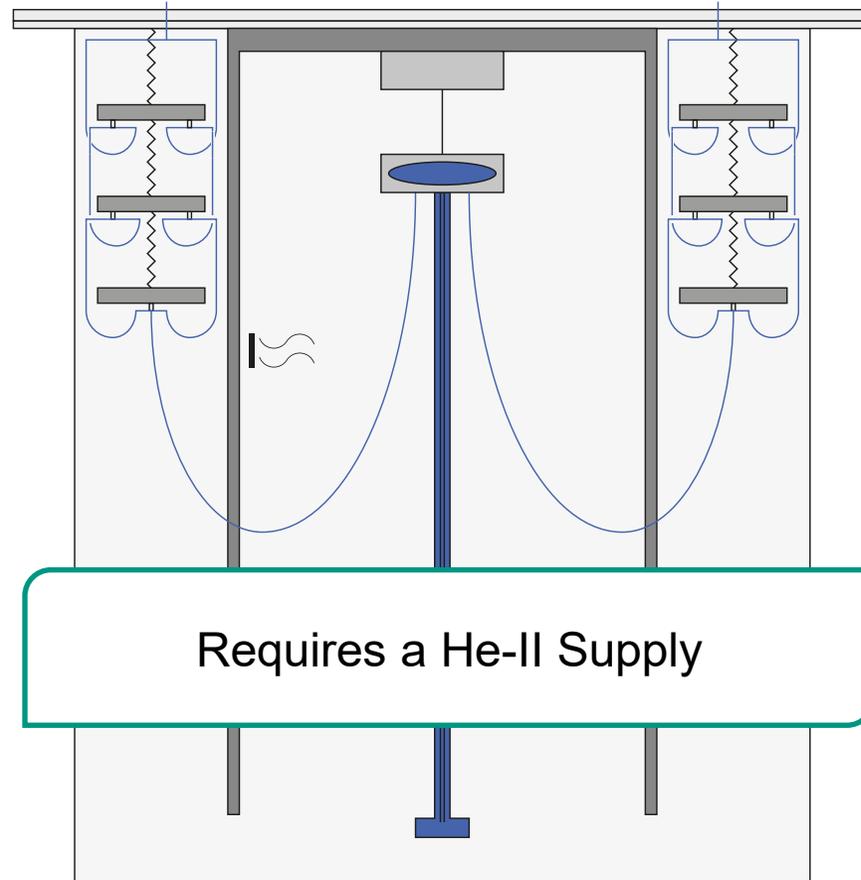
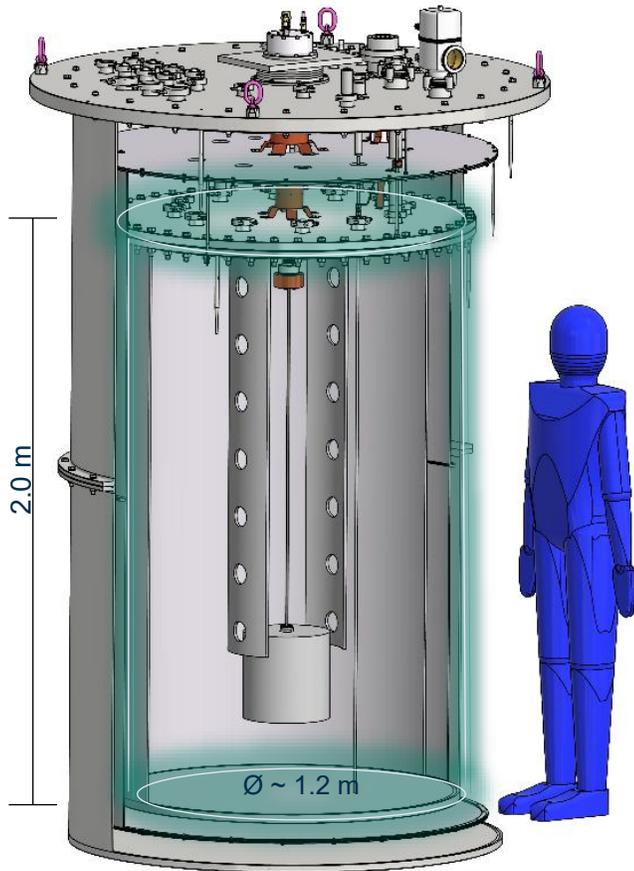
$$\sum \phi_{\text{Total}} = \frac{E_{\text{SA}}}{E_{\text{total}}} \phi_{\text{SA}} + \underbrace{\frac{E_{\text{SHS}}}{E_{\text{total}}} D \phi_{\text{SHS,mat,thermoel}} + \frac{E_{\text{SH}}}{E_{\text{total}}} \phi_{\text{SH,mat}}}_{\text{Extrinsic losses}}$$

Suspension tube

SA mode	$\hat{\phi}_{\text{extrinsic}}$	$\hat{\phi}_{\text{SA}}$	$\sum \phi_{\text{SSS}}$
$f_{\text{SA},1}$	2×10^{-8}	1×10^{-6}	1×10^{-6}
$f_{\text{SA},2}$	2×10^{-9}	1×10^{-6}	1×10^{-6}
$f_{\text{SA},3}$	2×10^{-10}	1×10^{-6}	1×10^{-6}

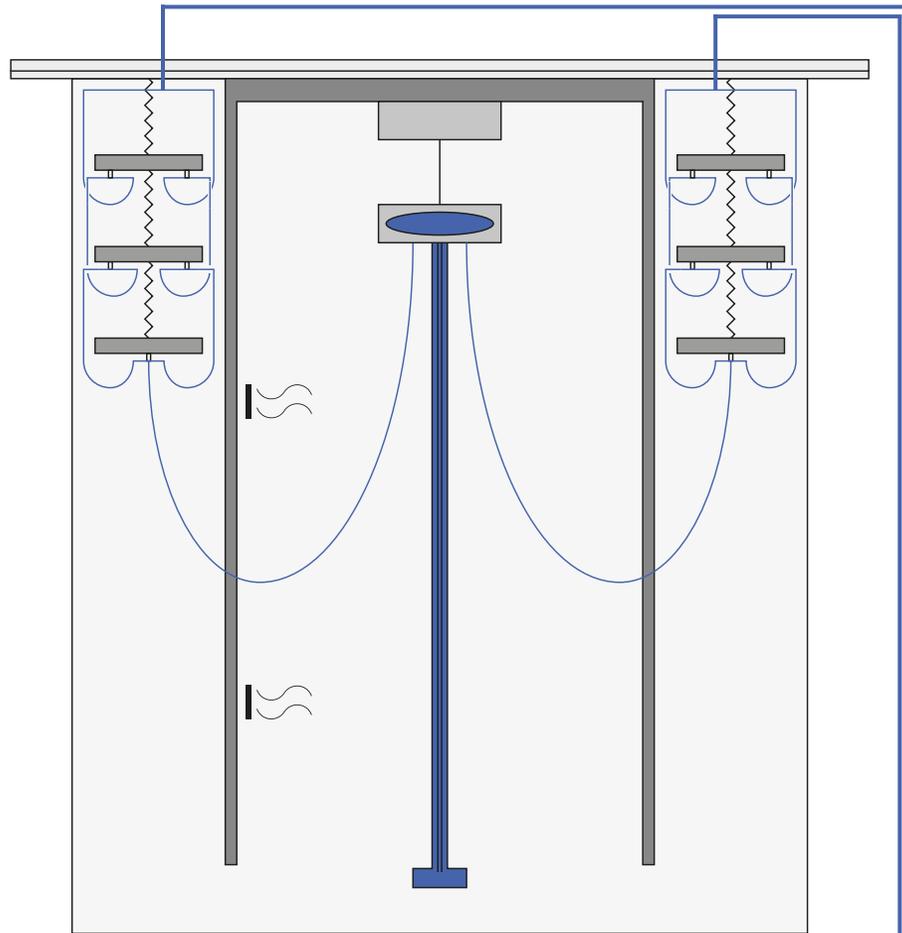
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Phase II – Suspension Tubes



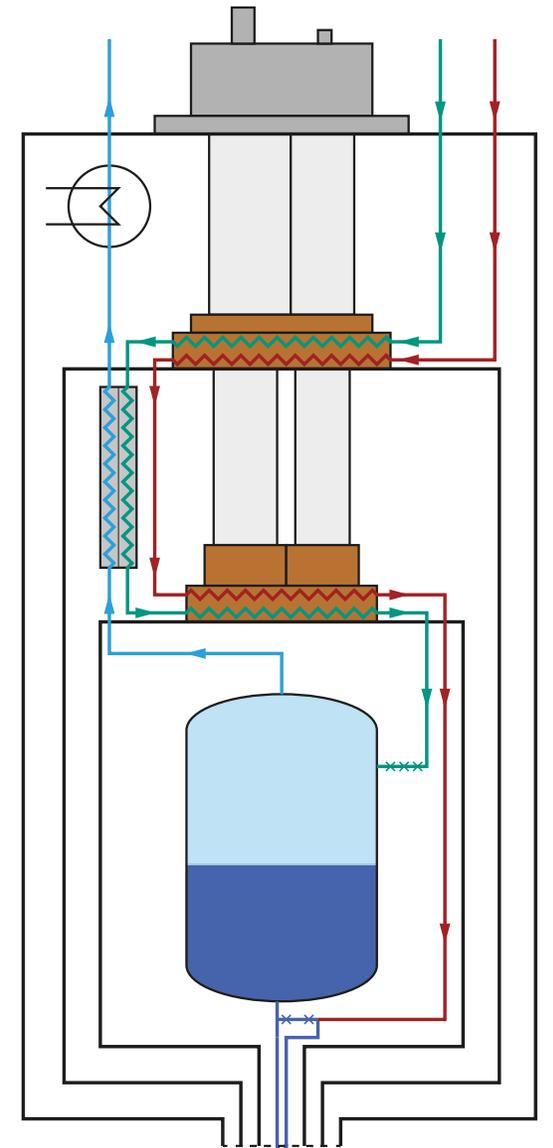
- Q-factor measurements of titanium suspension tubes filled with He-II
- Investigating the dissipative mechanisms in He-II
- Viability check for ET
- Testing vibration attenuation systems

GRAVITHELIUM Helium Supply Unit

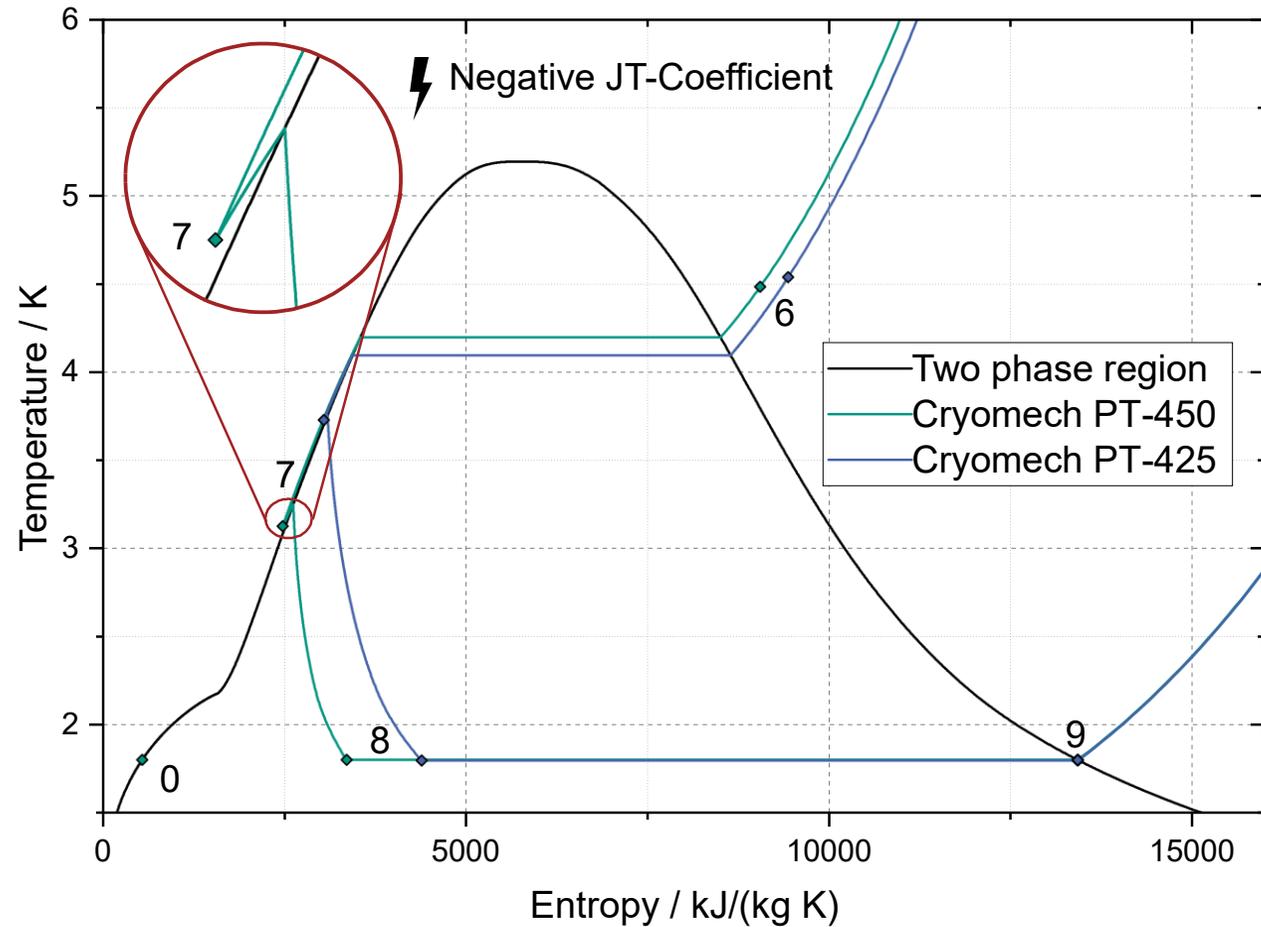
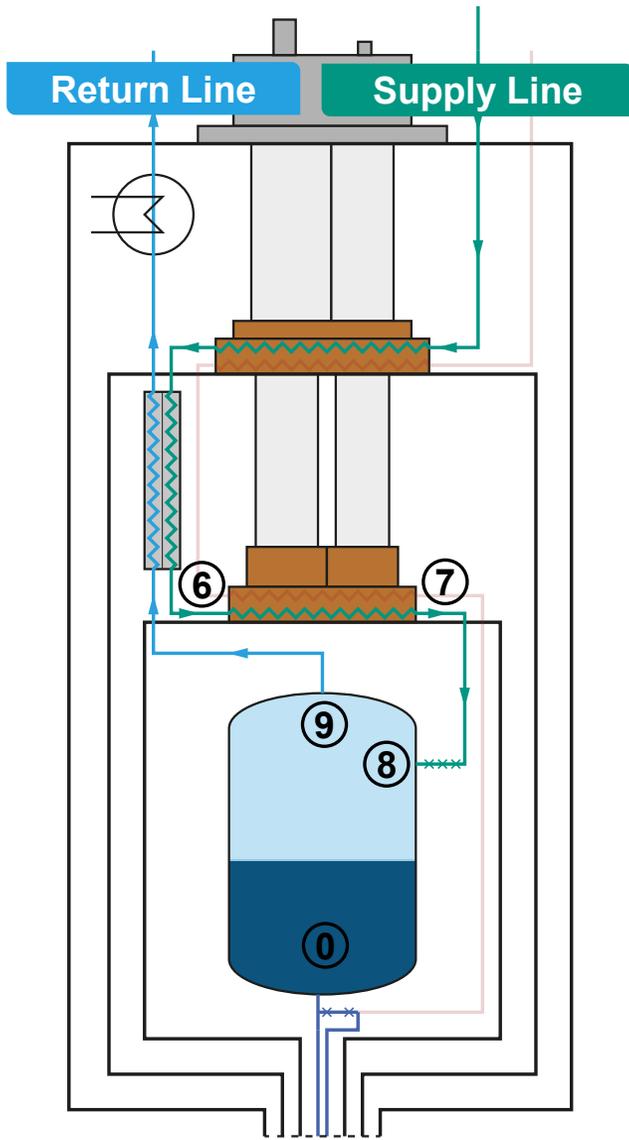


- 400 mW @ 1.8 K
- Ability to reach $T < 1.8$ K
- Fully closed helium cycle
- He-II supplied via a transferline

5m Transfer Line

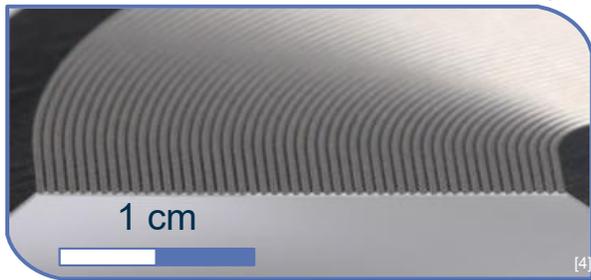
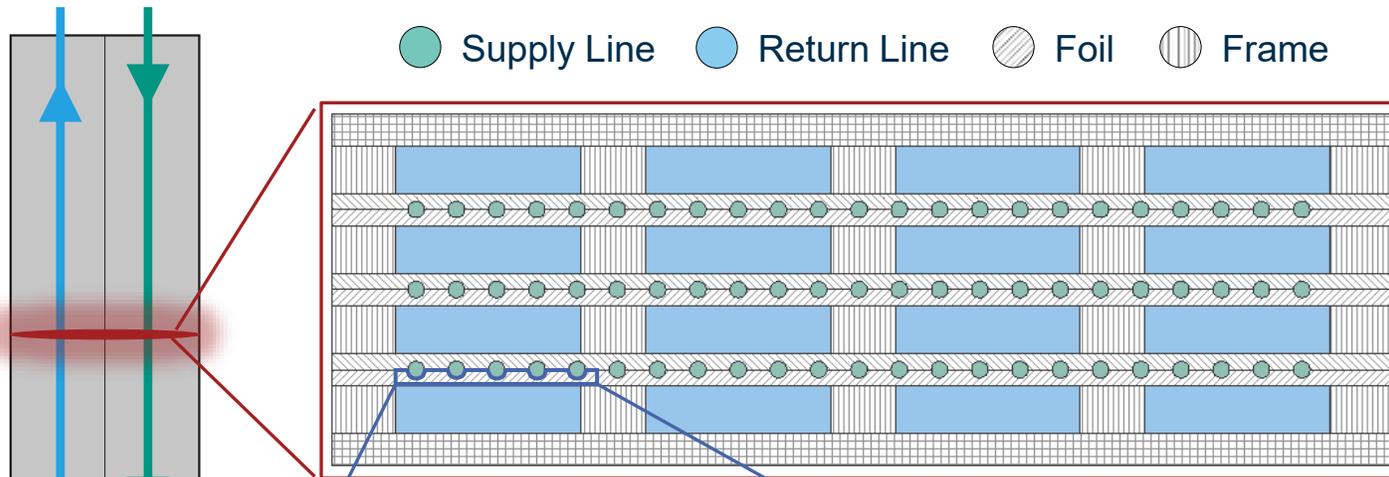


Stationärer Betrieb

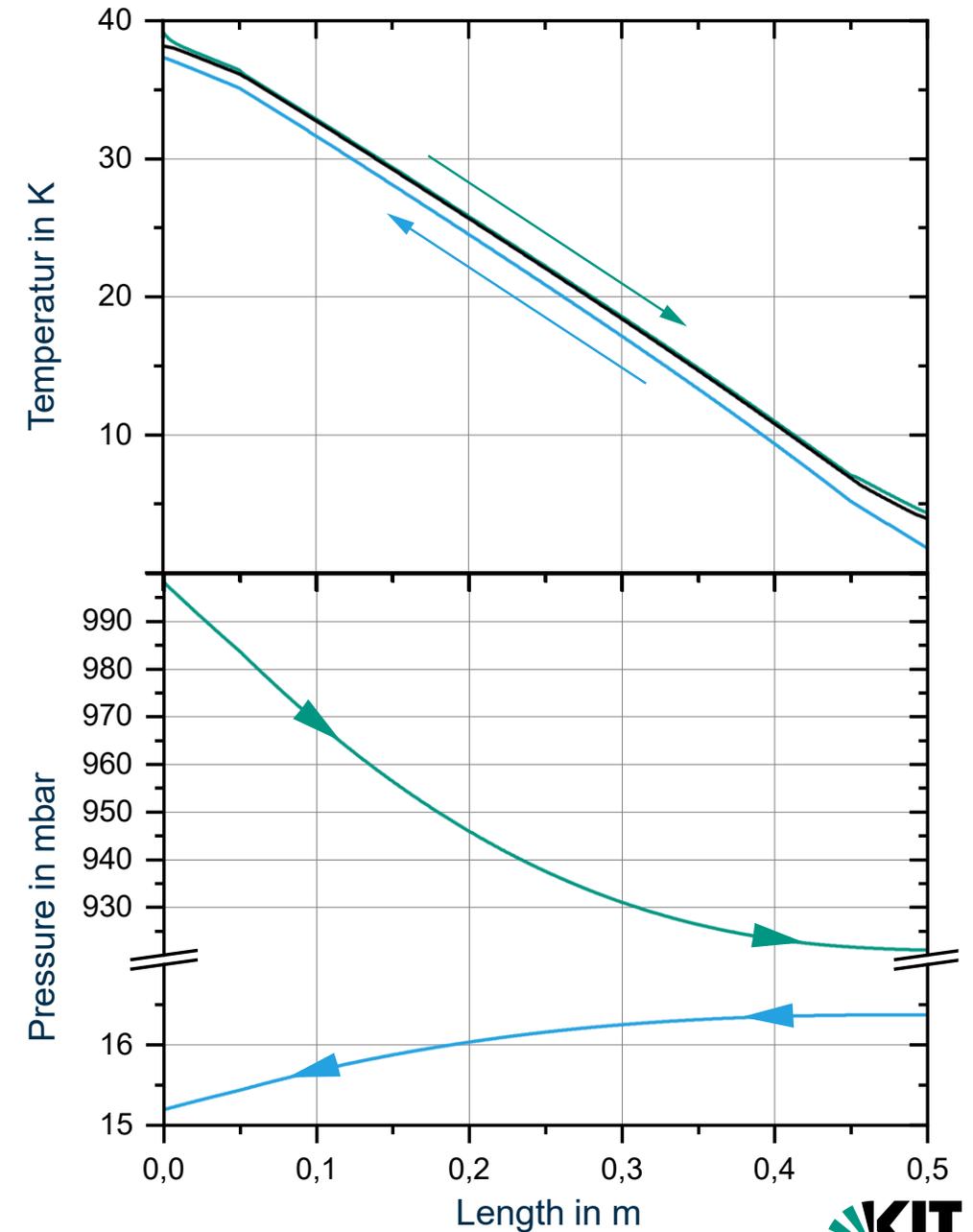


Source	T_{He} in K	\dot{Q}_c in mW	$\dot{Q}_{c,max}$ in mW	x_8 in %	P_{el} in kW
PT-425	1.8	400	640	70	14
PT-450	1.8	400	>1000	78	25
Bluefors [2]	1.8	440	-	-	>12
Jahromi [3]	1.76	250	-	-	8.8

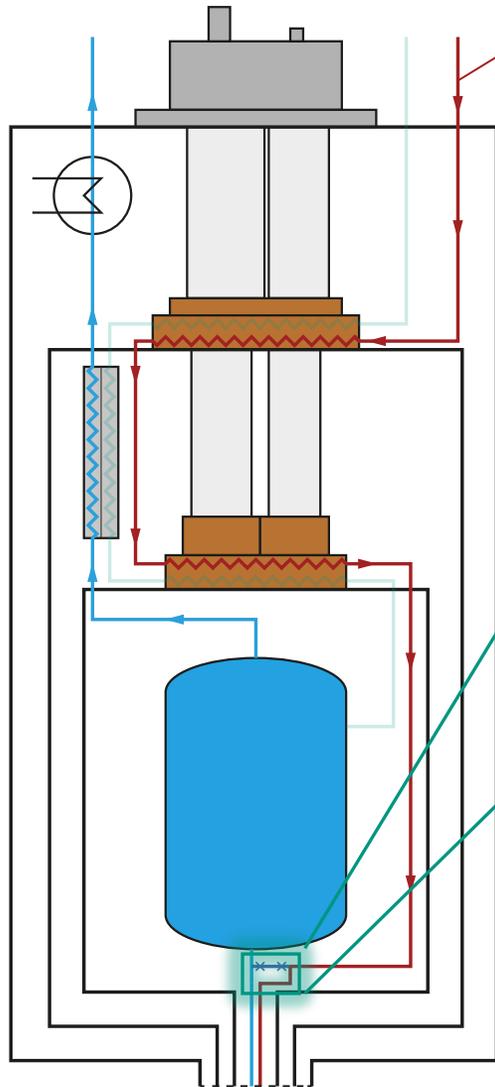
Foil-Frame Wärmeübertrager



	\dot{Q} / W	T_{in} / K	T_{out} / K	$p_{in} / mbar$	$p_{out} / mbar$	$\Delta p / mbar$
HD	4	39	4.5	998	991	7
ND	4	1.8	37	16.38	15.15	1.23



Cooldown



Warm Bypass

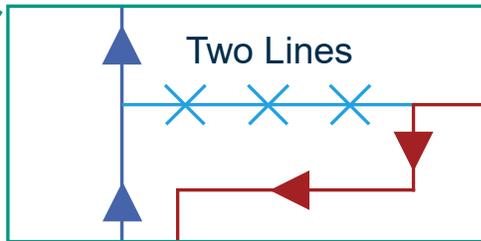
Cooling the transfer line via conduction is very time consuming

Cool down via Convection required

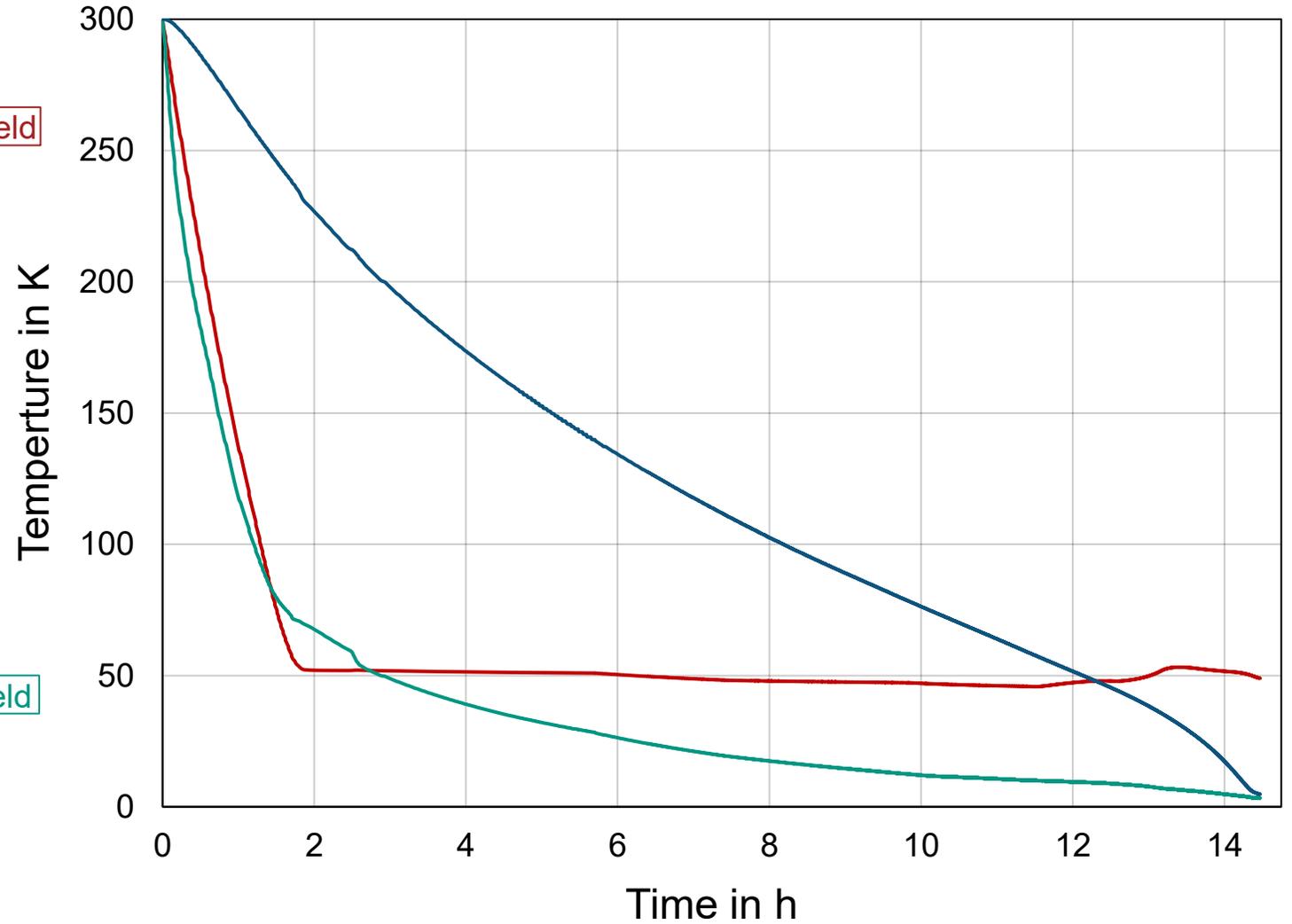
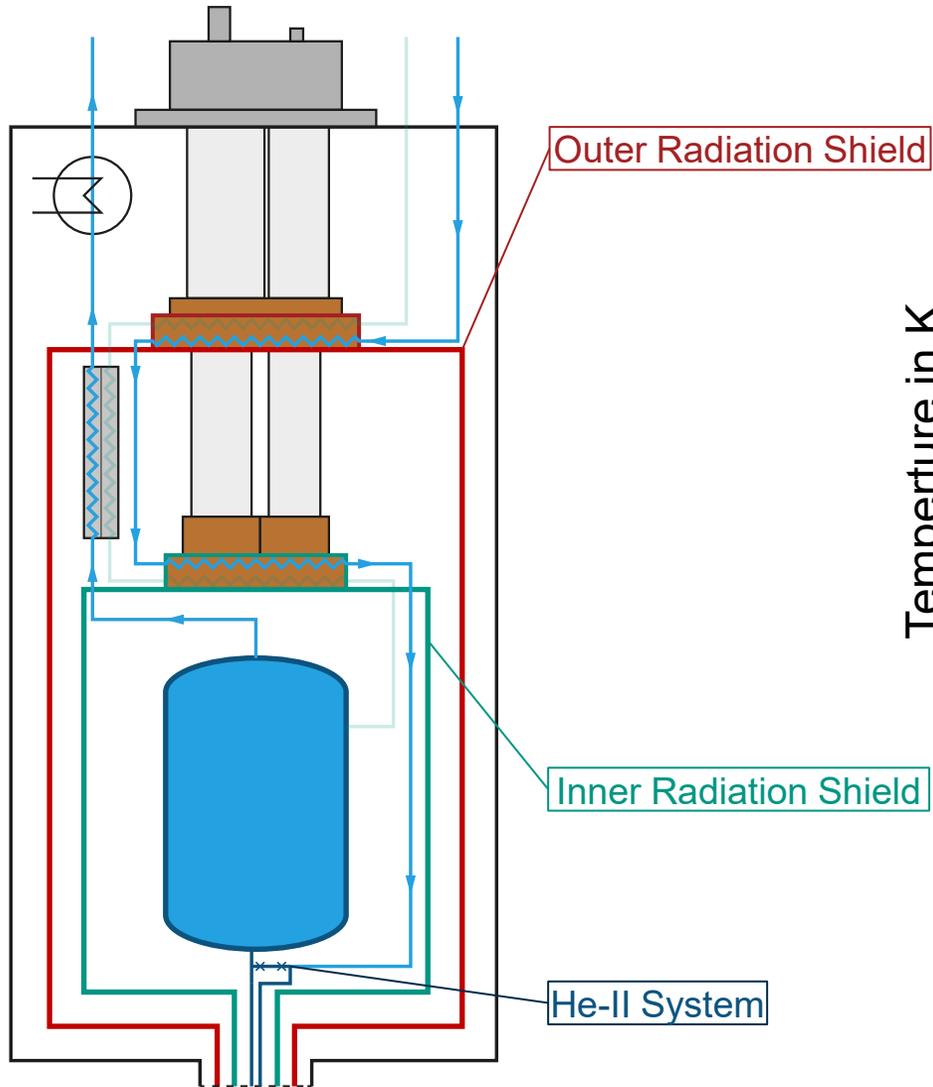
Supercritical helium to avoid condensation and boiling in the transfer line

Warm Bypass
Prohibit thermal short circuit in the internal heat exchanger

Cool down to liquid helium temperatures, then lower pressure and pump



Cooldown - Phase I



Experimental Setup

