

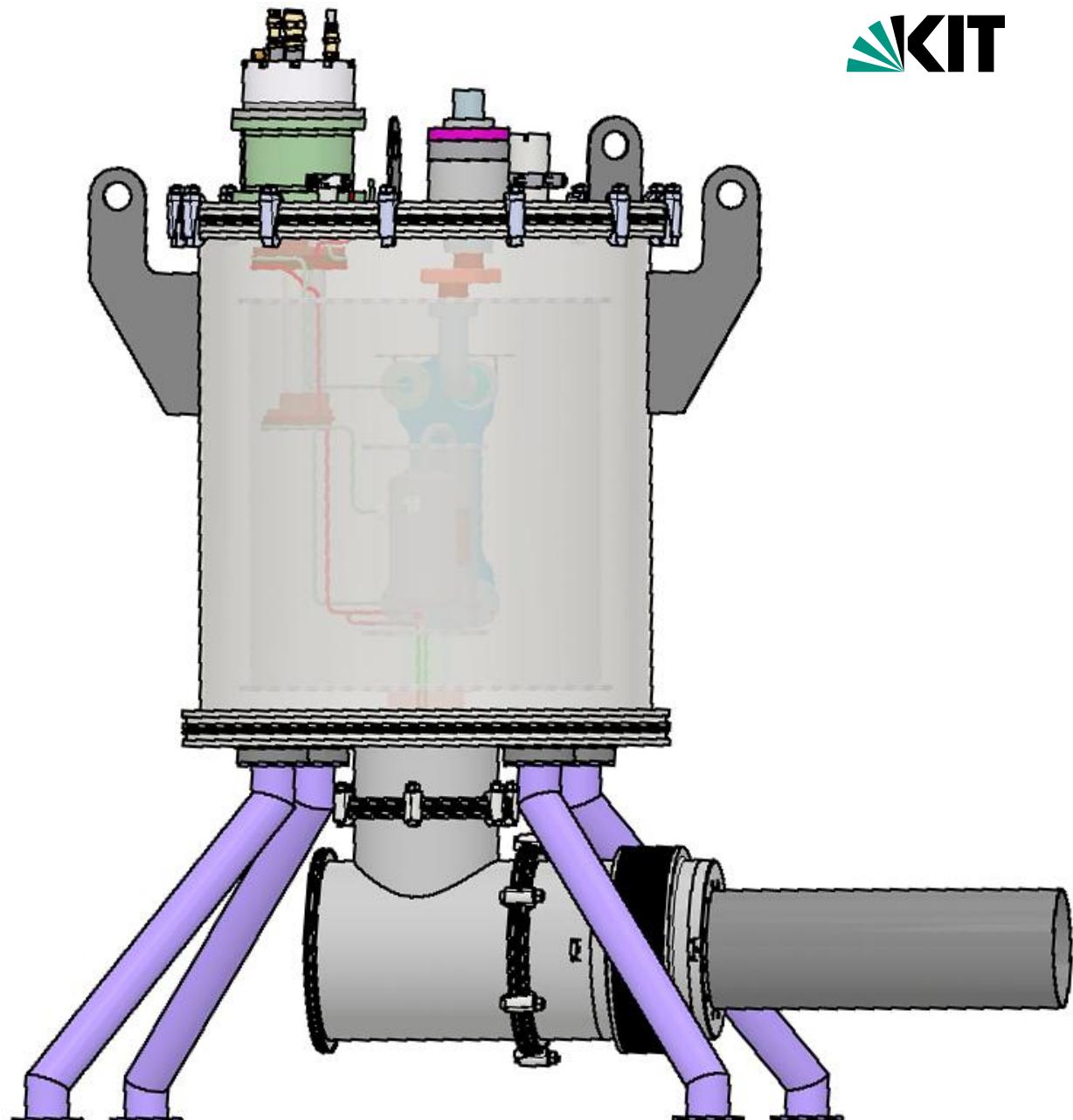
# Konzeptionelles Design eines He-II Versorgungskryostaten für die experimentelle Untersuchung kryogener Spiegelaufhängungen in Gravitationswellendetektoren

Timo Weckerle, Steffen Grohmann

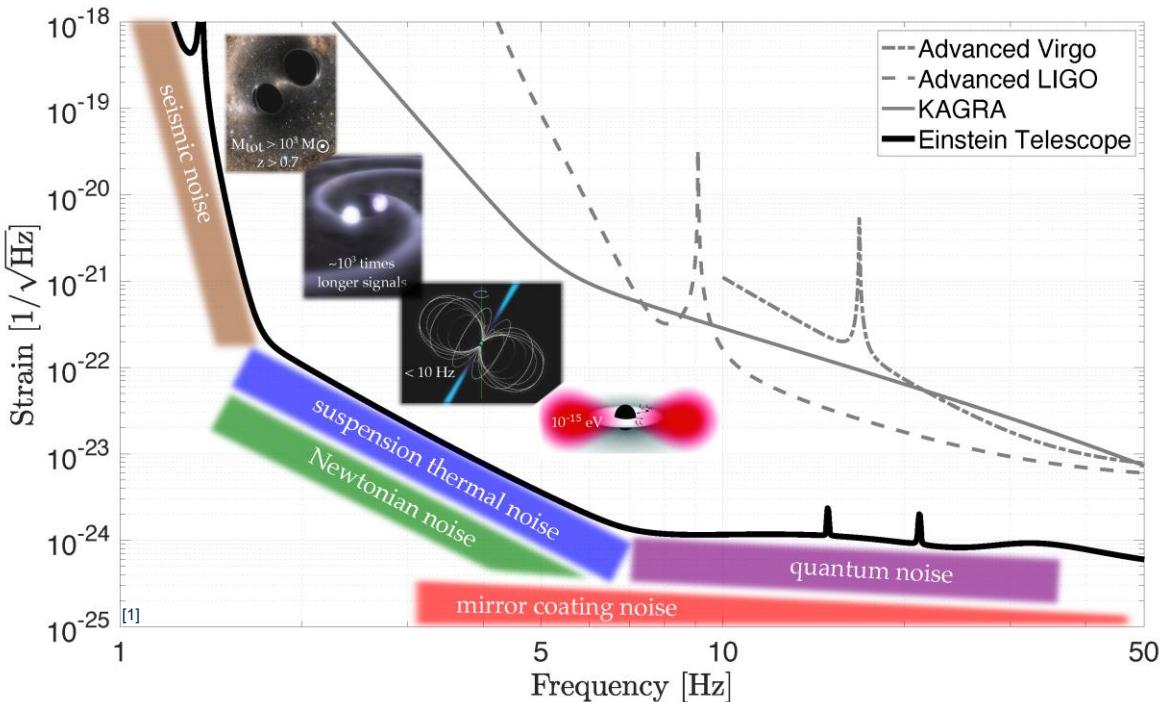
Karlsruher Institut für Technologie

Institut für Beschleunigerphysik und Technologie

Institut für Technische Thermodynamik und Kältetechnik

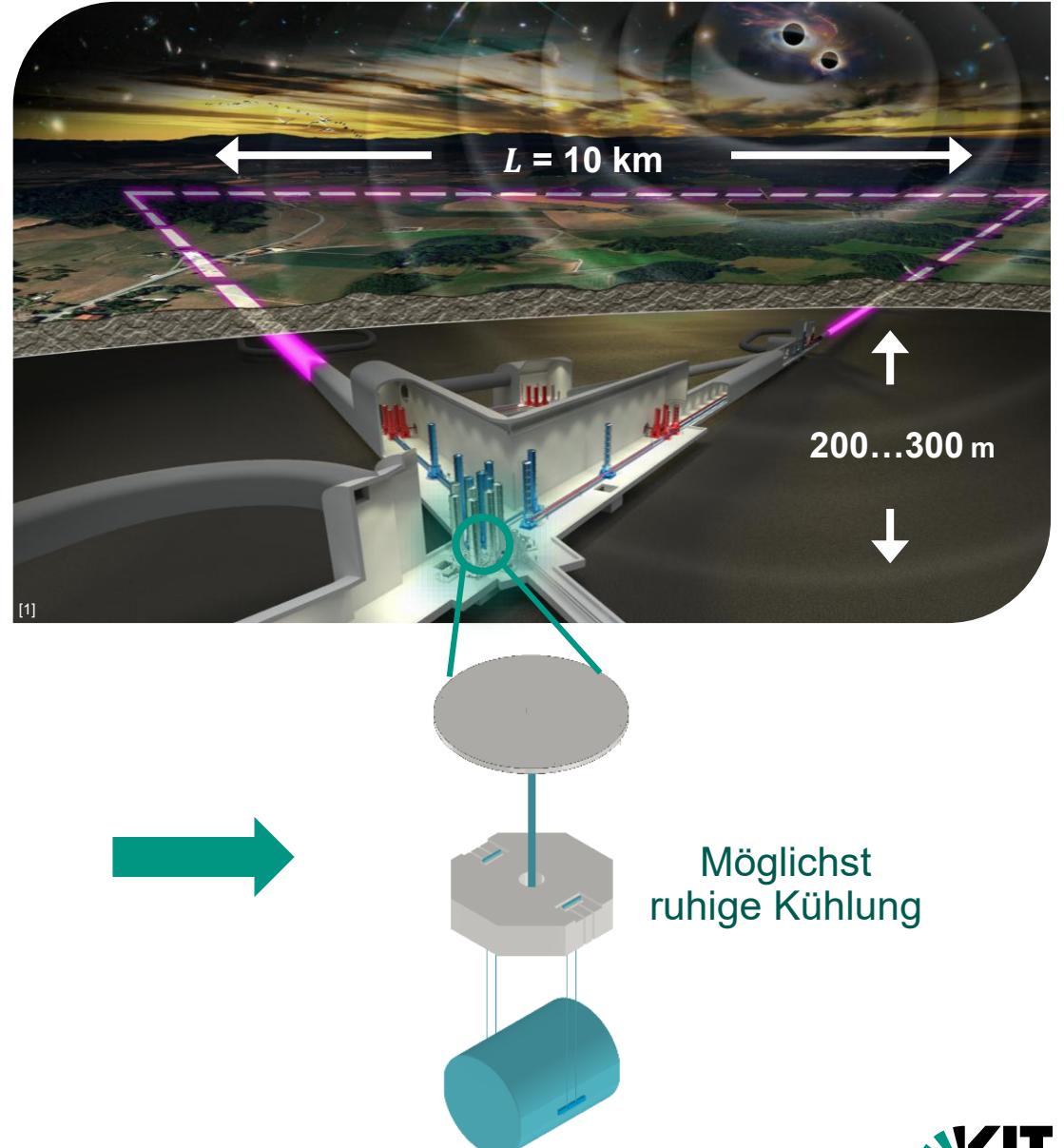


# Das Einstein Teleskop



- Gravitationswellendetektor der 3. Generation
- Bei  $f < 10$  Hz dominiert die Suspension Thermal Noise

$$\text{STN} \sim \frac{T}{Q_{\text{Faktor}}}$$

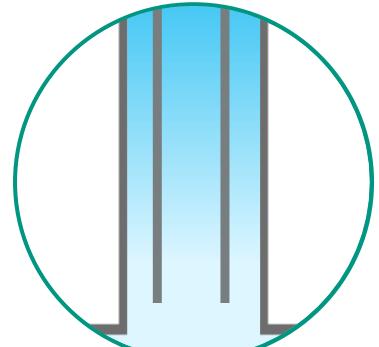


# Ein Kühlsystem basierend auf He-II

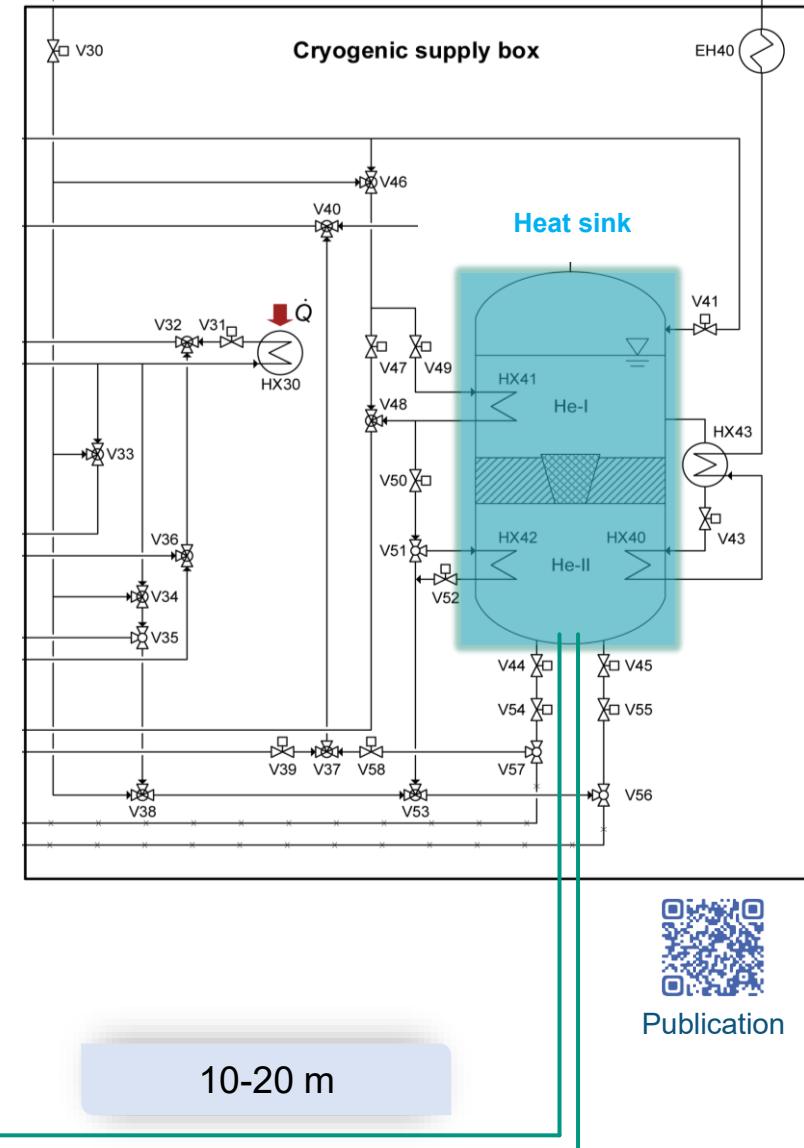
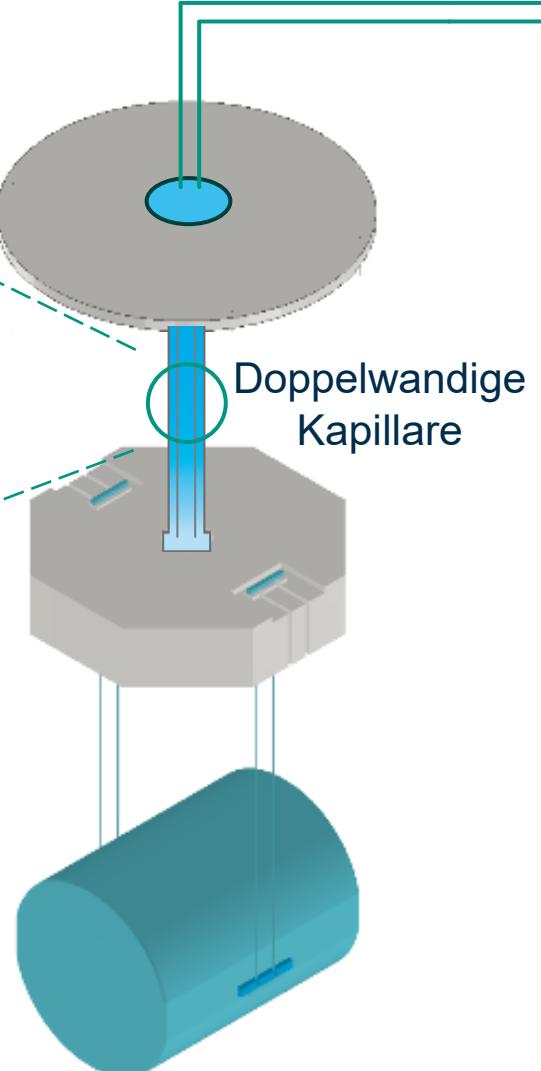
Publication



He-I Strom für Cool-down



He-II (Keine Makroskopische Strömung)  
im stationären Zustand



$$STN \sim \frac{T}{Q_{Factor}} = T \phi_{susp}$$

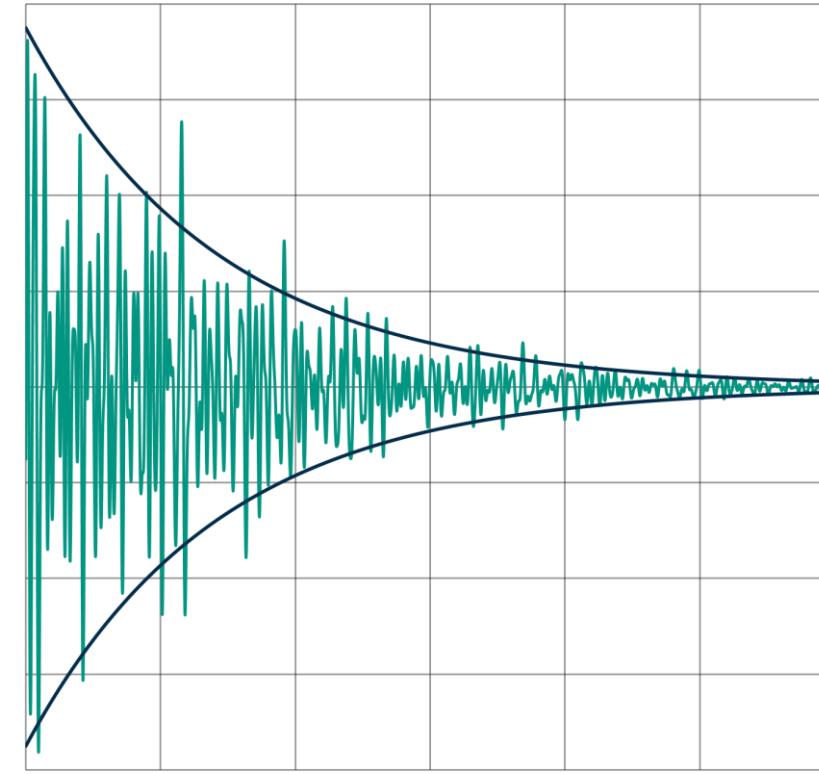
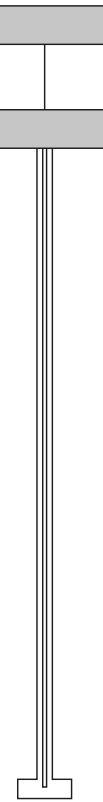
$$\phi_{susp} = \underbrace{\phi_{bulk} + \phi_{thermoelastic} + \phi_{surface} + \phi_{extrinsic}}_{\phi_{intrinsic}}$$

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

Maß für das mechanische  
Abklingverhalten



Q-Faktor wird über Abklingkurven gemessen



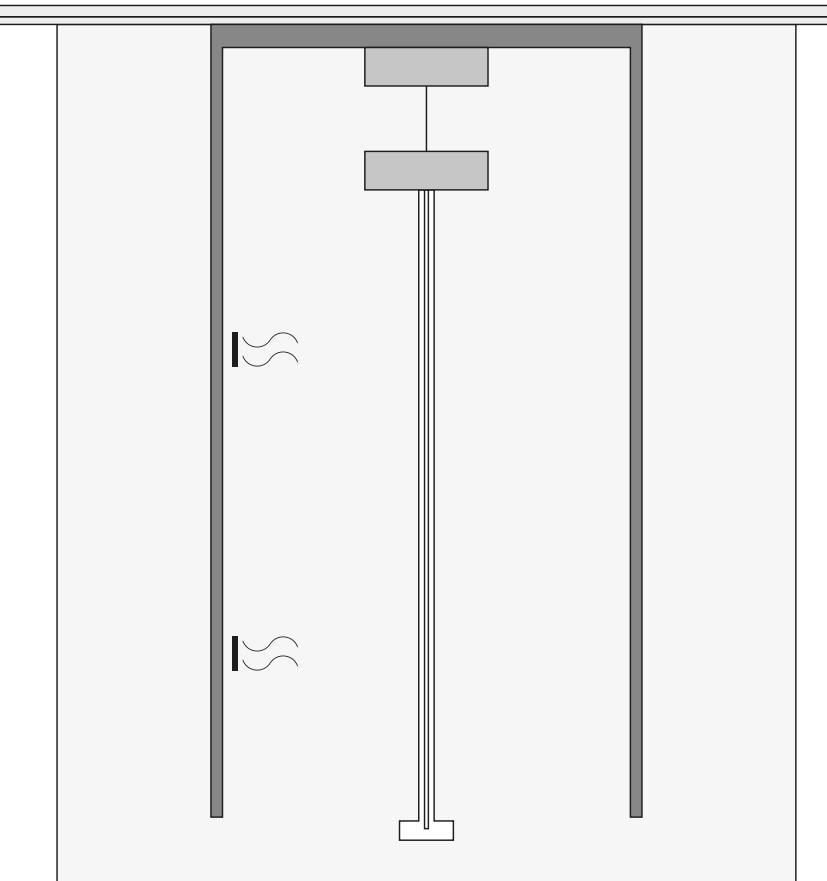
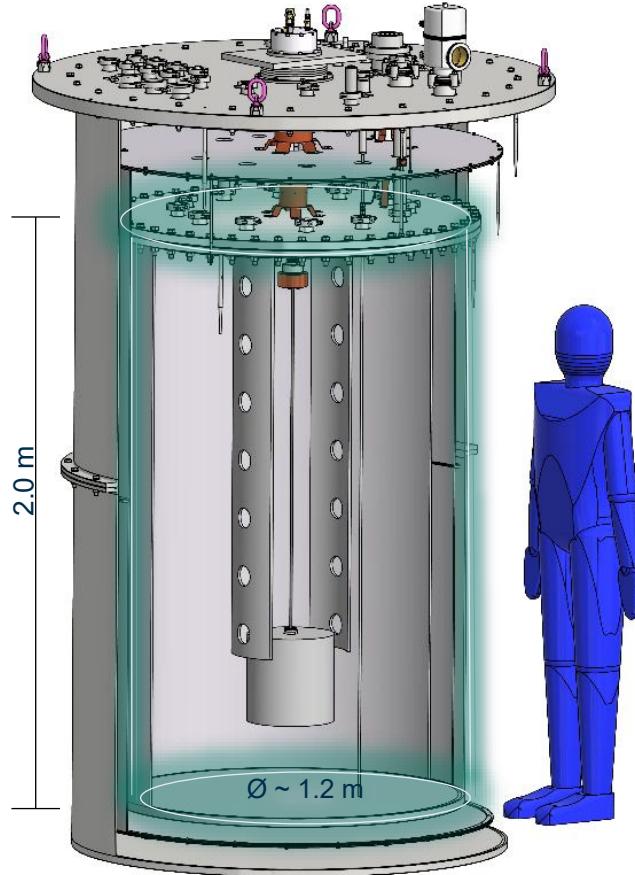
# GRAVITHELIUM

## Phase I



GRAVITHELIUM

Gravitational wave detectors  
cooled with superfluid helium



- Validierung der Messungen durch Vergleiche mit Literatur
- Untersuchung der Temperaturabhängigkeit
- Untersuchung der Spannungsabhängigkeit

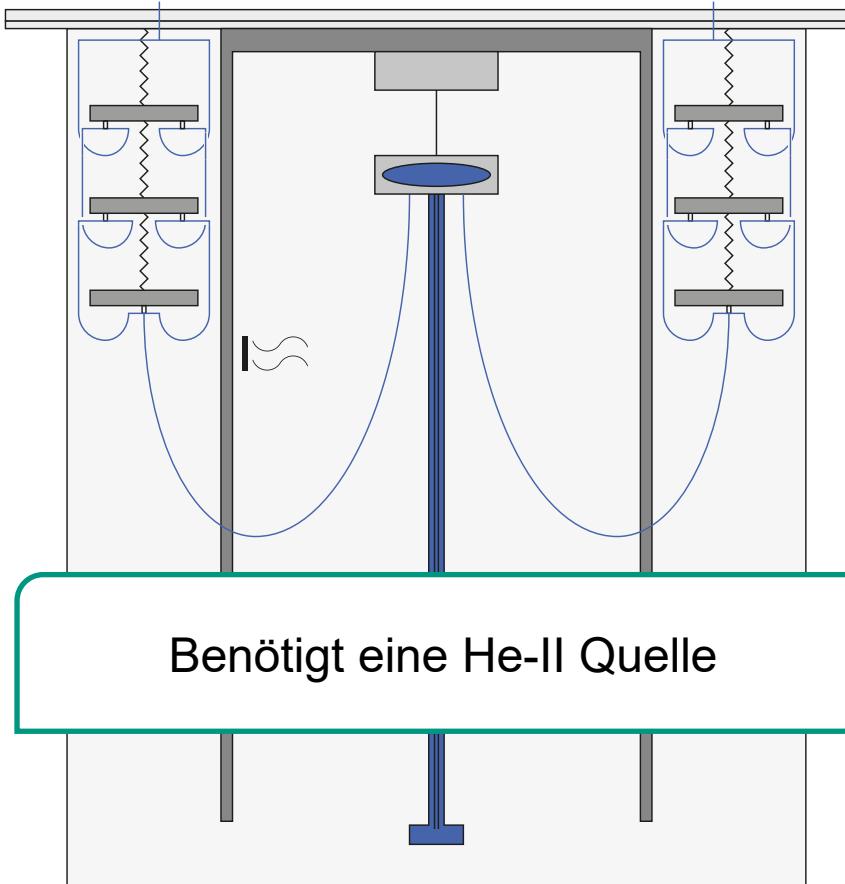
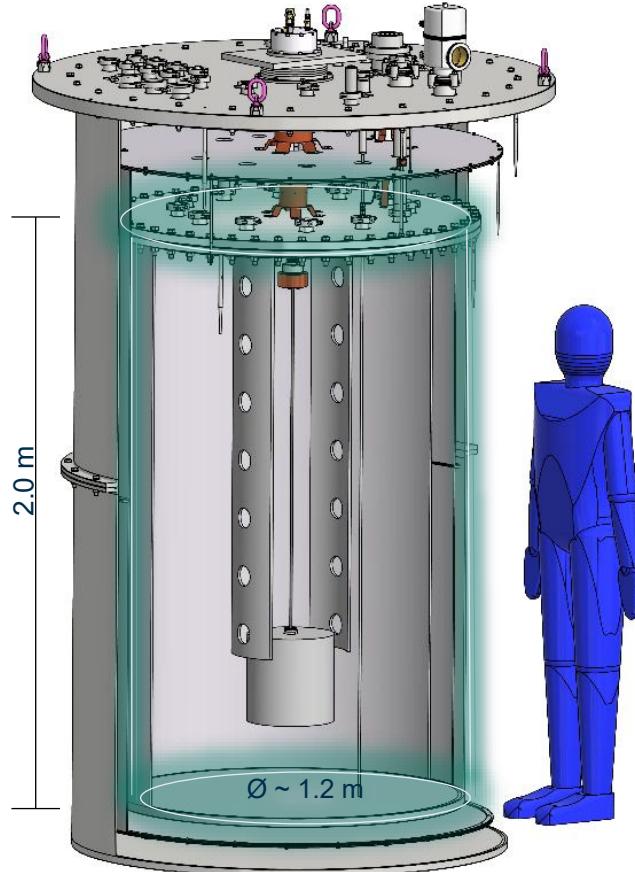
Weltweit erster 1:1-  
Versuchsstand für kryogene  
Spiegelaufhängungen

# GRAVITHELIUM

## Phase II



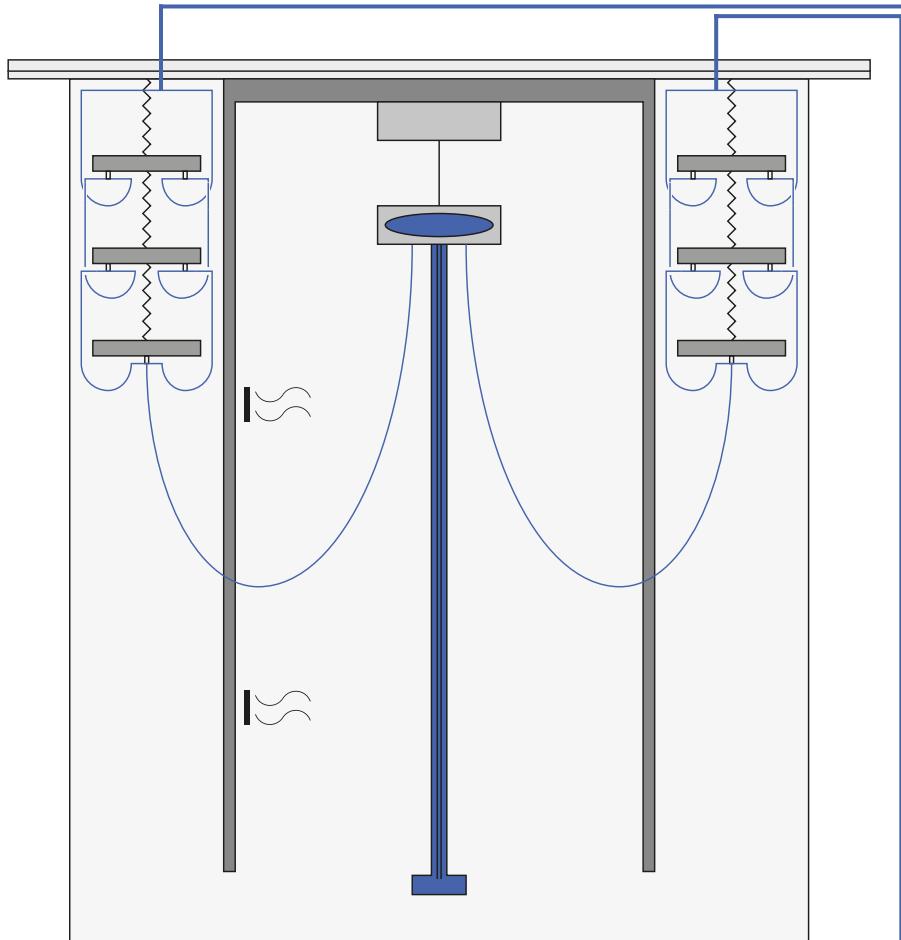
**GRAVITHELIUM**  
Gravitational wave detectors  
cooled with superfluid helium



- Untersuchung des Q-Faktors einer He-II Kapillare
- Validierung unseres Vorschlages für ET
- Untersuchung der Dissipationsmechanismen in He-II
- Proof of Concept für ein Attenuation System

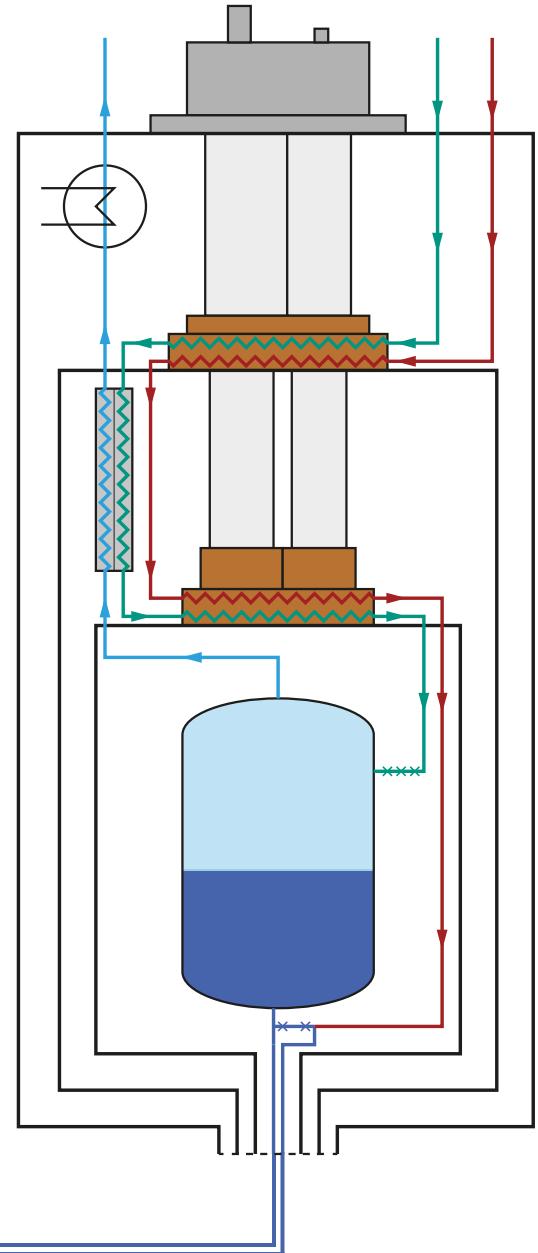
# GRAVITHELIUM

## Helium Versorger



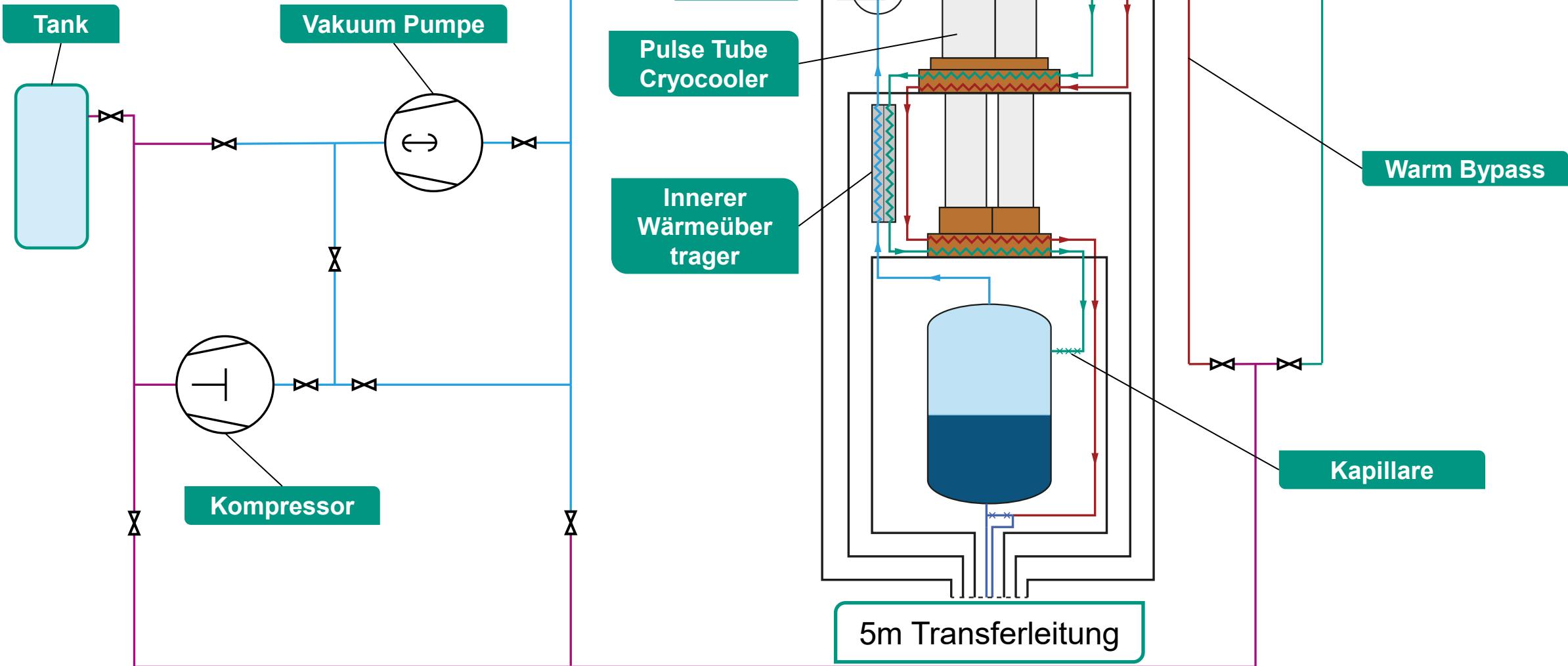
- 400 mW @ 1.8 K
- Nach unten anpassbare He-II Temperatur
- Vollständig geschlossener He-Kreislauf
- He-II wird über eine Transferleitung bereitgestellt

5m Transferleitung

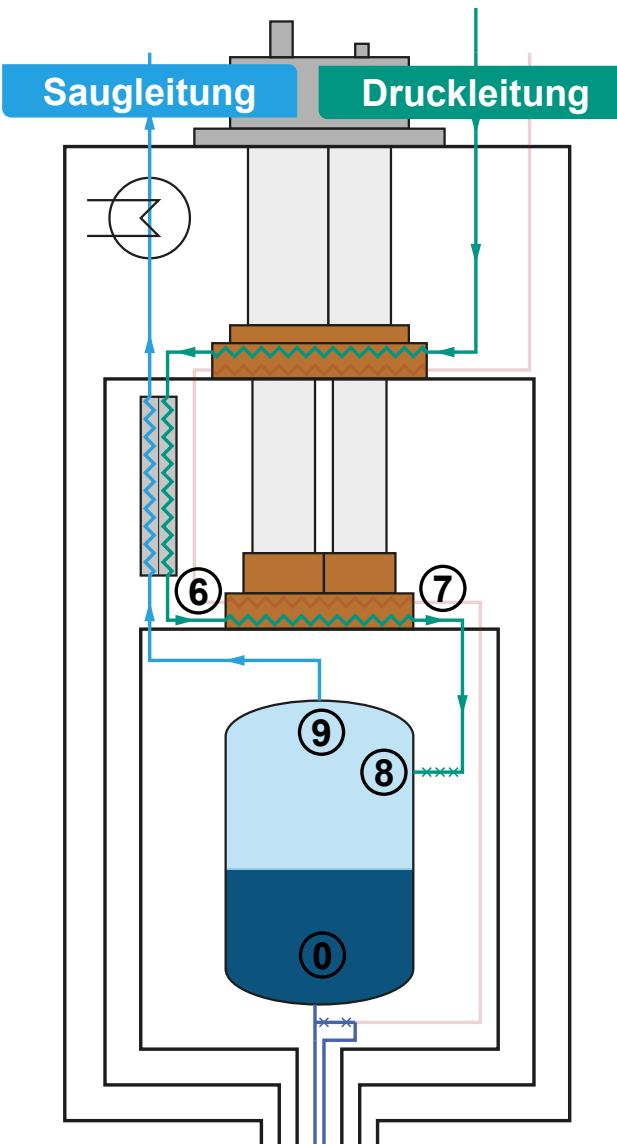


# GRAVITHELIUM

## Helium Versorger



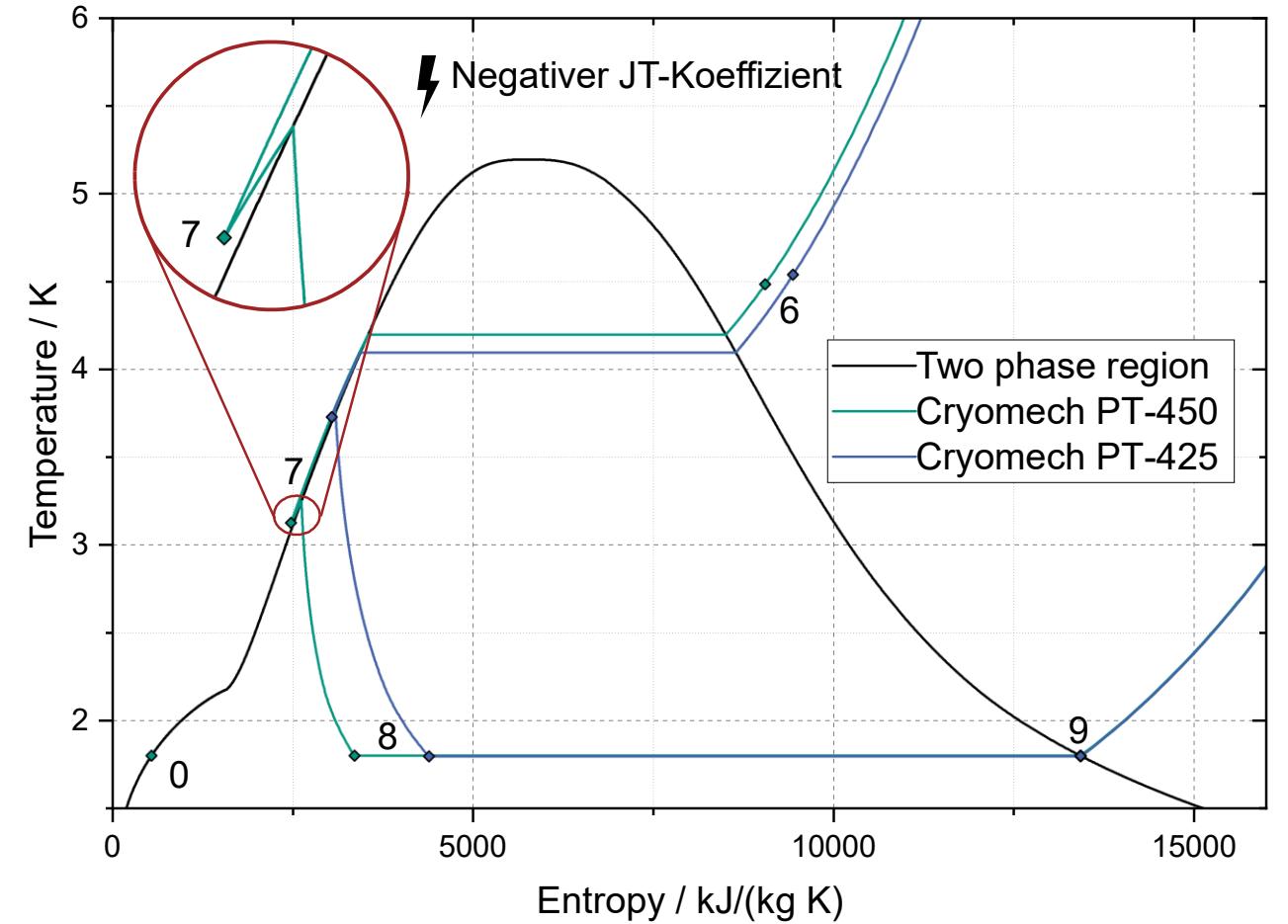
# Stationärer Betrieb



9

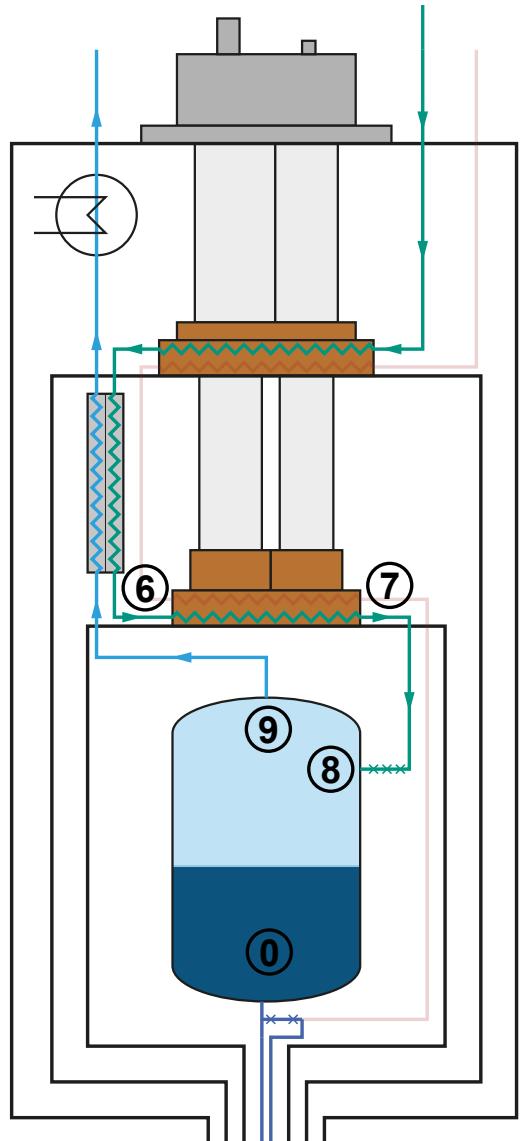
21.11.2025

Weckerle et al



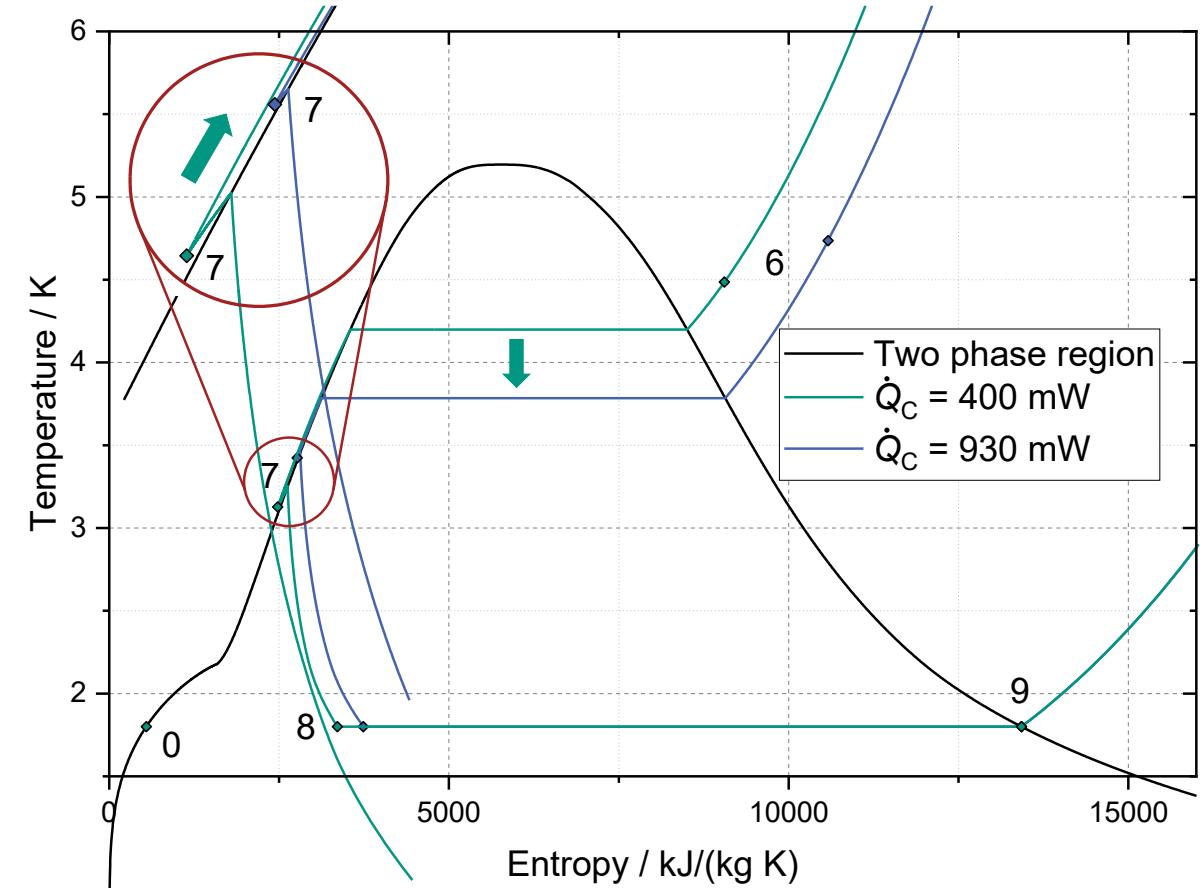
Source	$T_{He}$ in K	$\dot{Q}_c$ in mW	$\dot{Q}_{c,max}$ in mW	$x_8$ in %	$P_{el}$ in kW
PT-425	1.8	400	640	70	14
PT-450	1.8	400	1000	78	25
Bluefors [2]	1.8	440	-	-	>12
Jahromi [3]	1.76	250	-	-	8.8

# Stationärer Betrieb



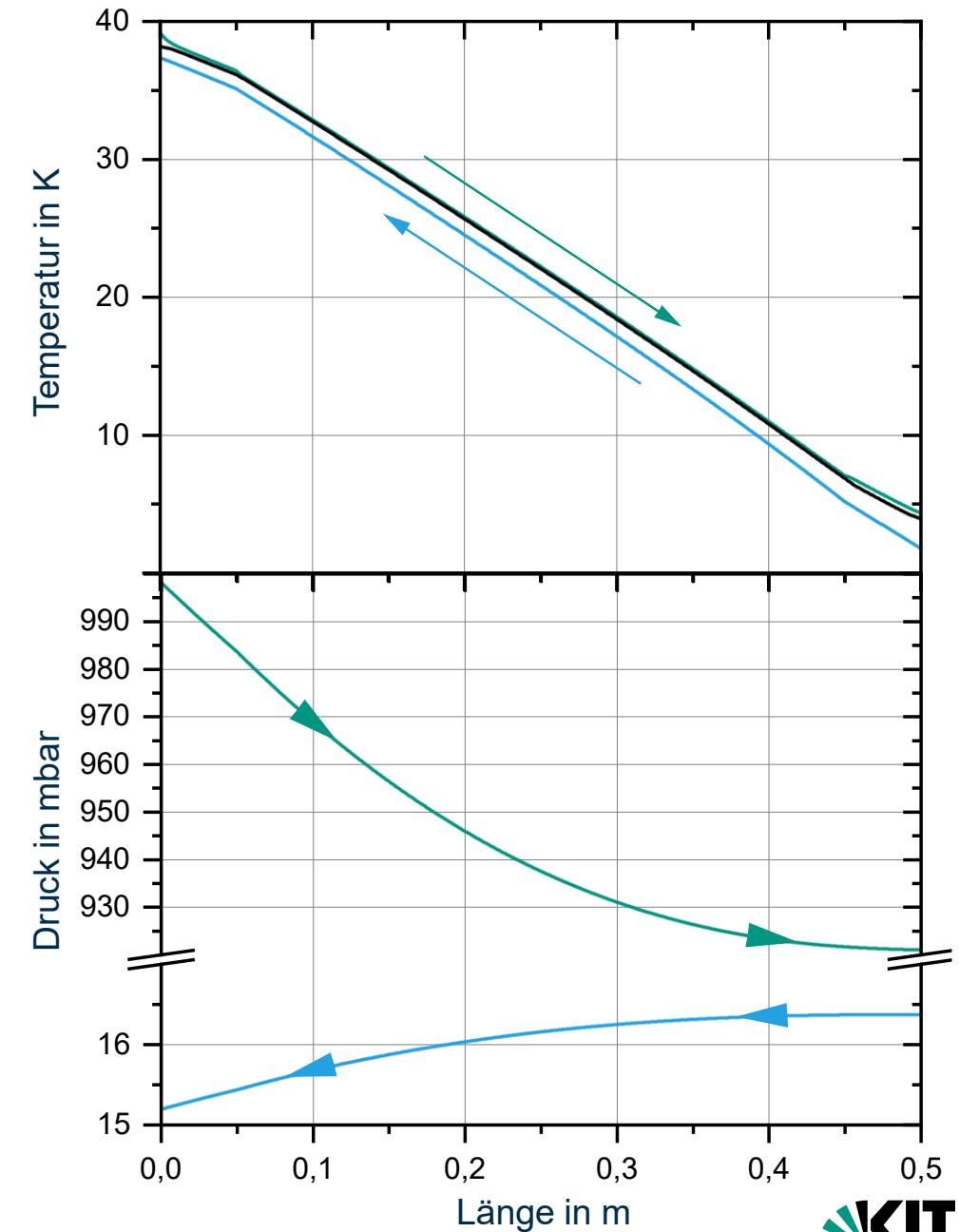
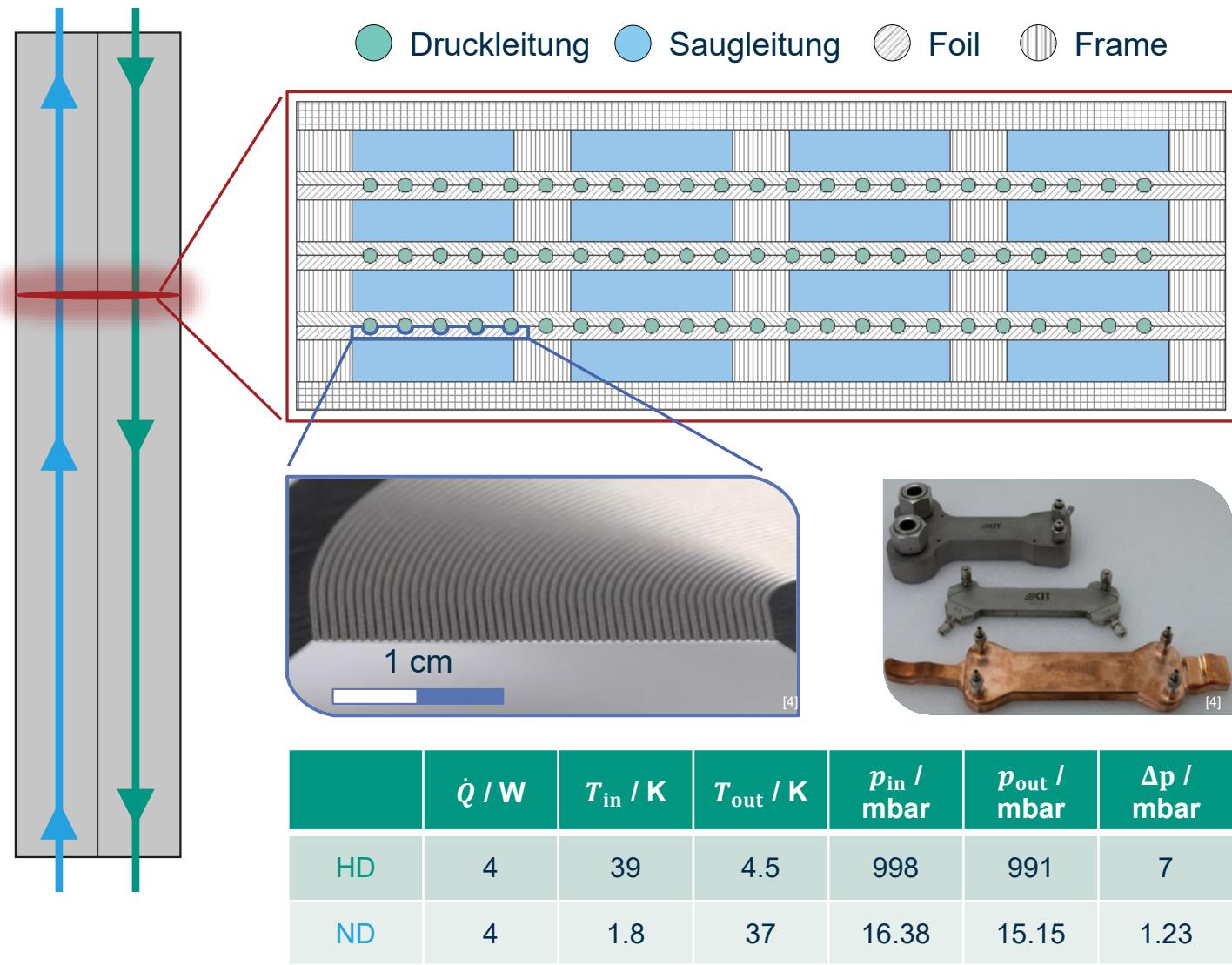
- Mehr Kälteleistung führt zu:
  - Höheren Massenströmen
  - Höheren Druckverlusten
- Höhere Massenströme
  - $T_7$  steigt
- Höhere Druckverluste
  - Siedetemperatur sinkt

Maximal mögliche  
Kälteleistung erreicht wenn  
Punkt 7 auf der Siedelinie  
liegt

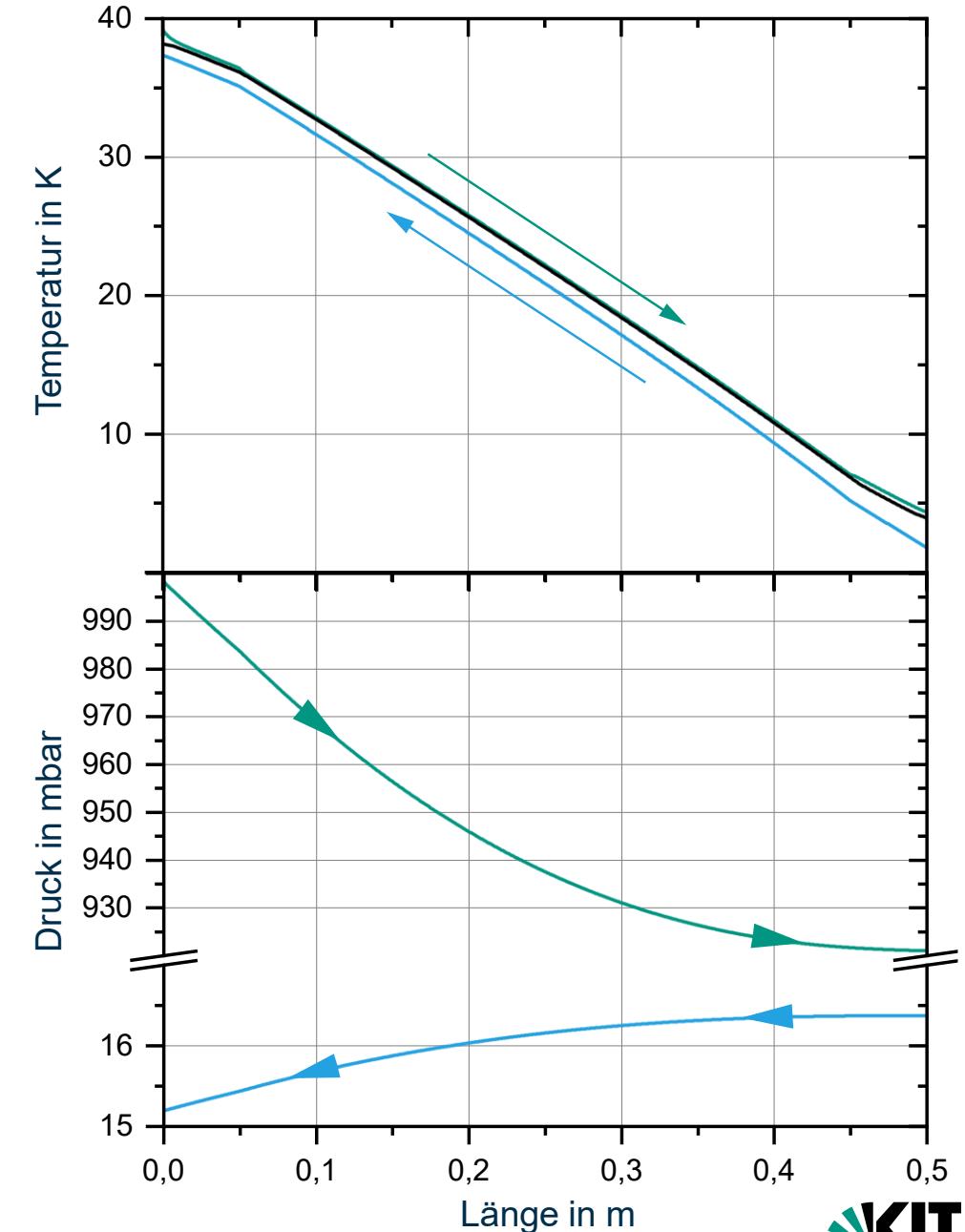
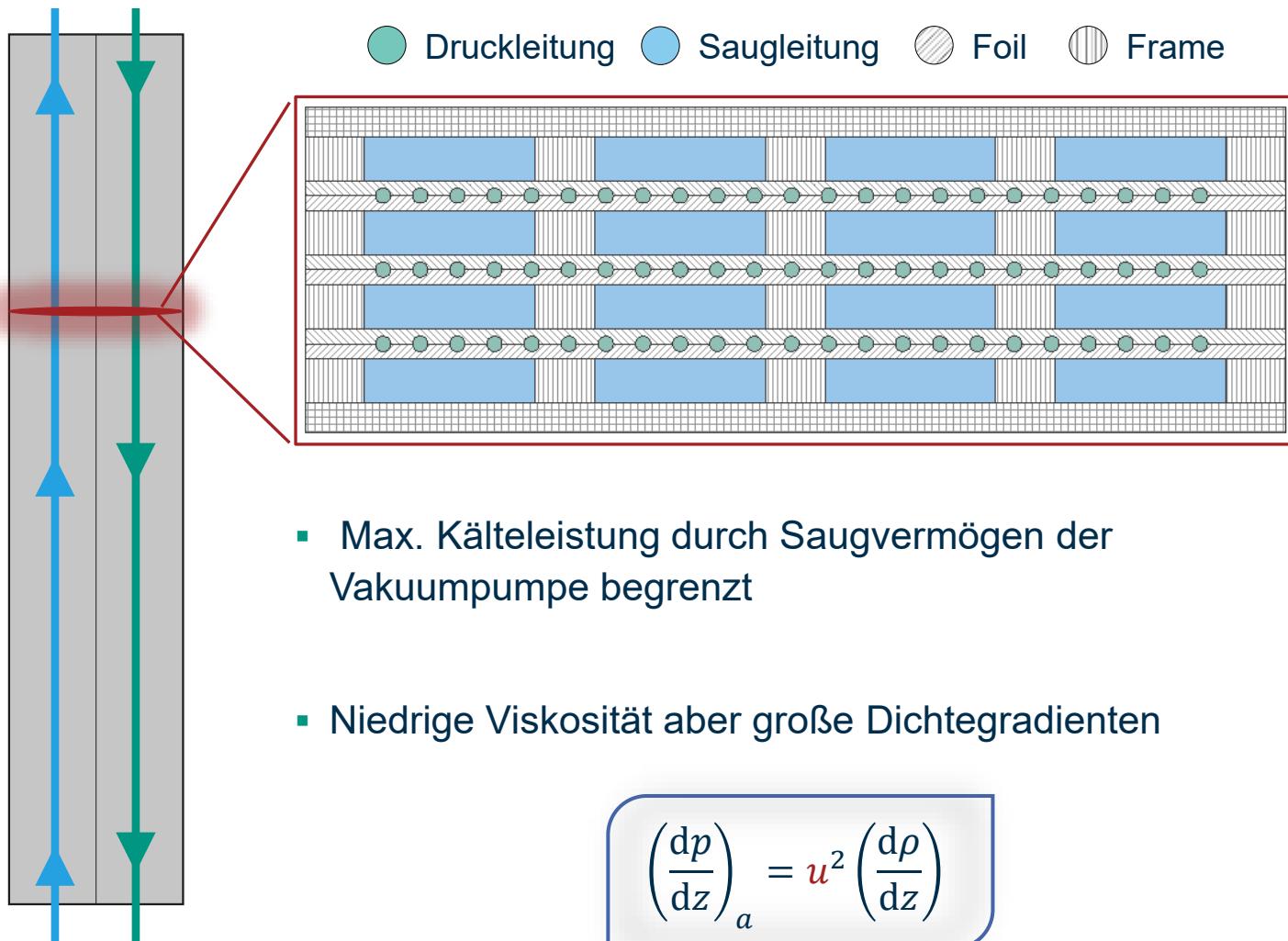


Kälteleistungen von >1W @ 1.8 K mit PT-450

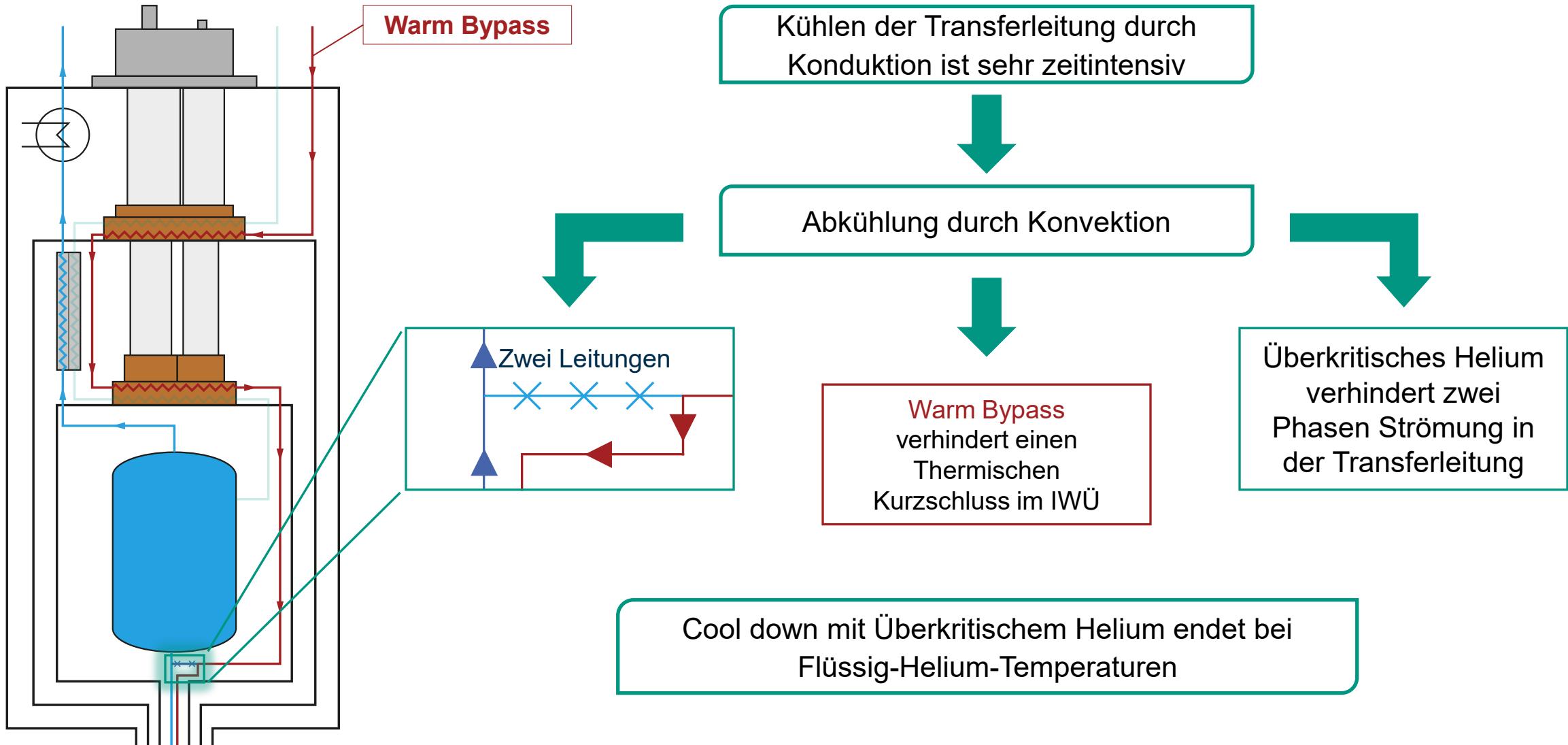
# Foil-Frame Wärmeübertrager



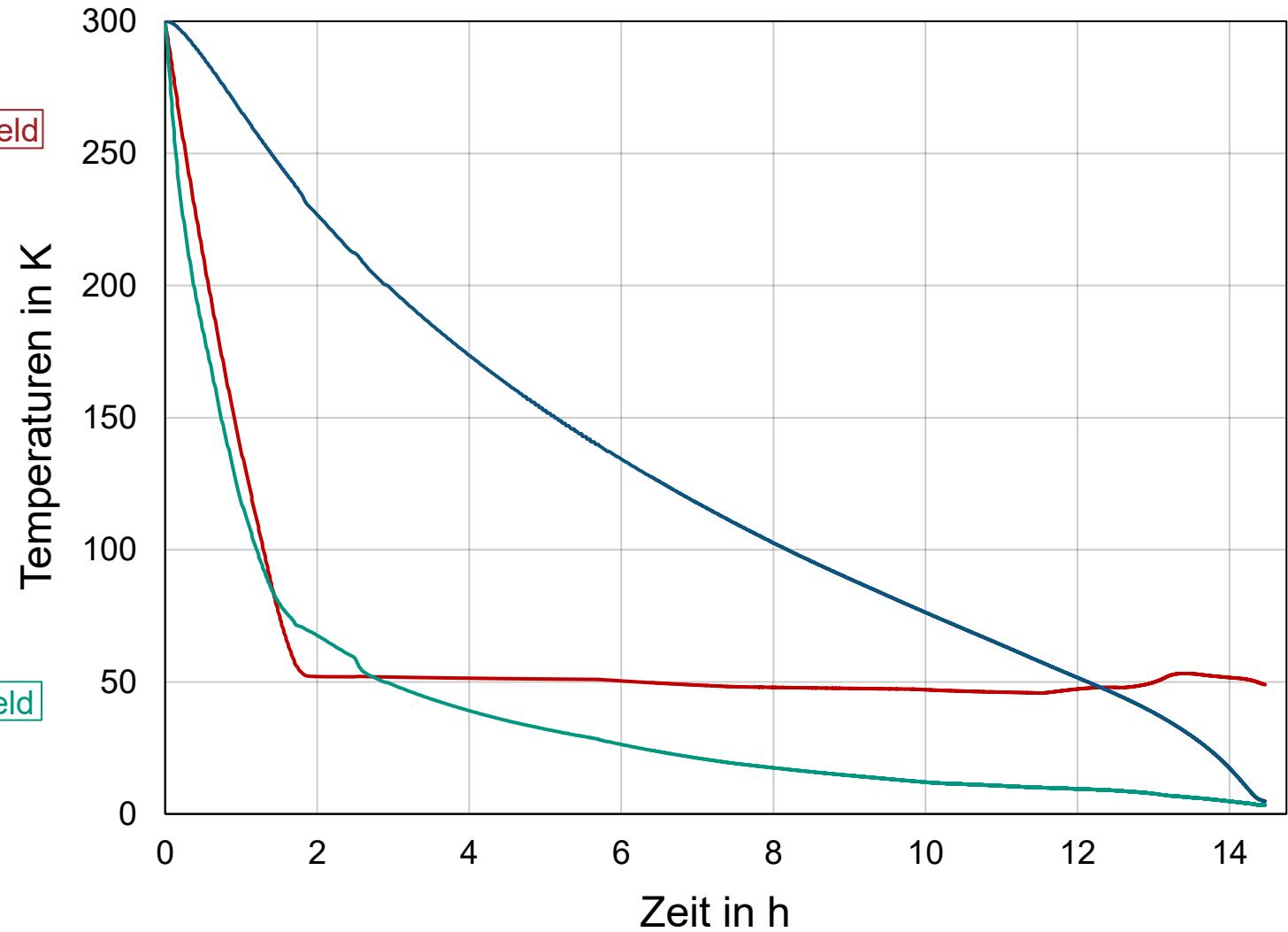
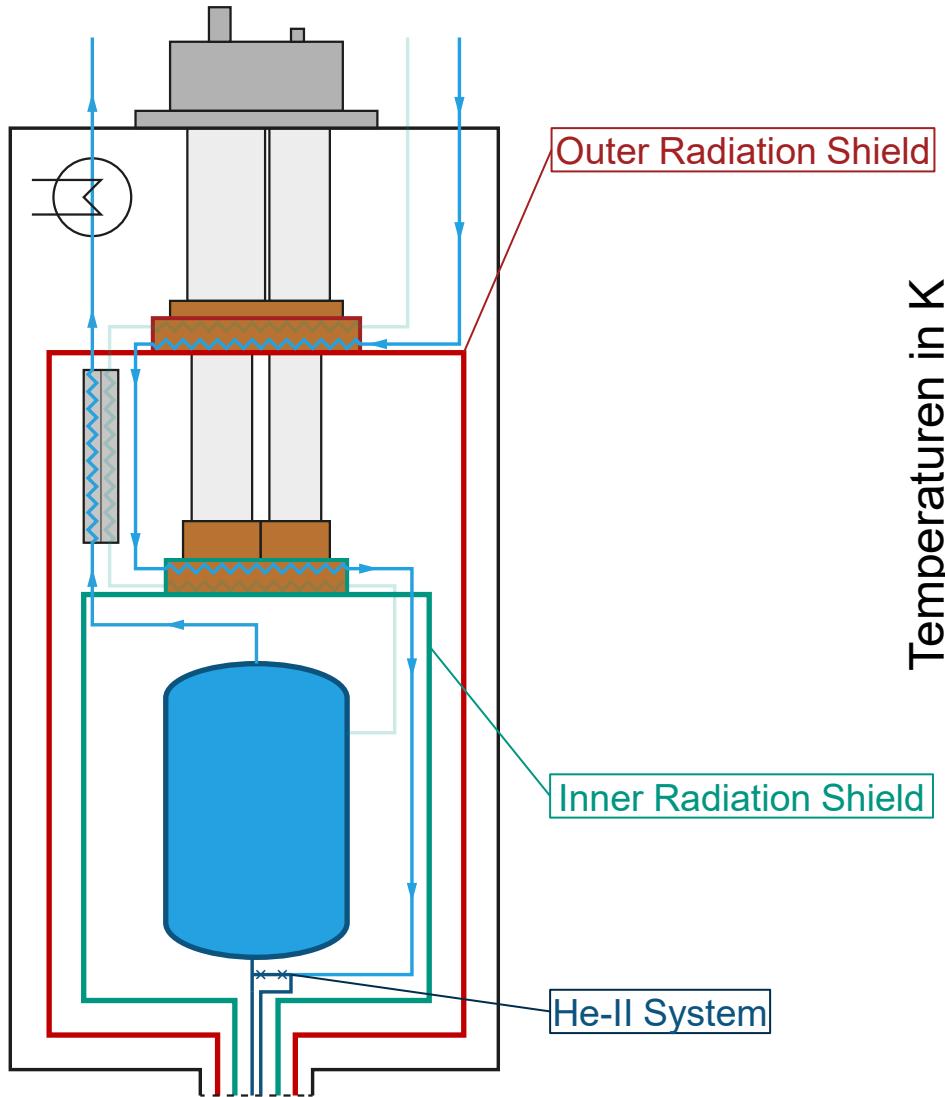
# Foil-Frame Wärmeübertrager



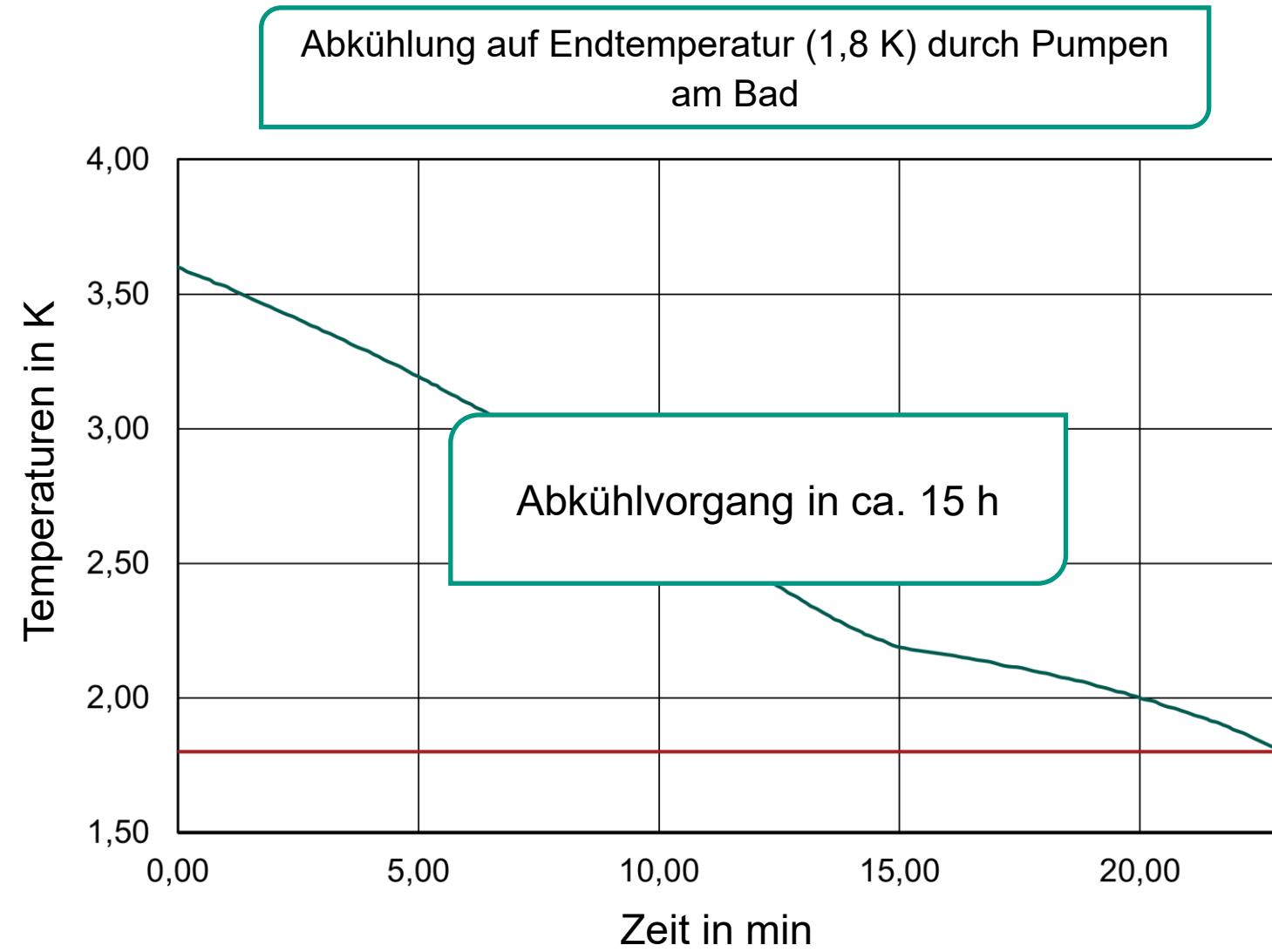
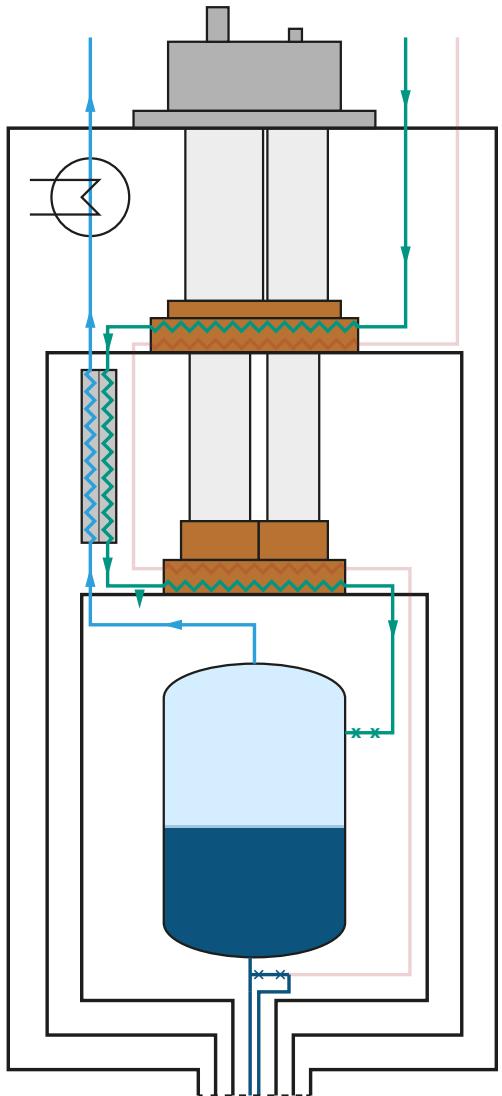
# Cooldown



# Cooldown – Phase I



# Cooldown – Phase II



# Quellen

[1] - S. D. Pace et al. (2022), DOI: [10.3390/galaxies10030065](https://doi.org/10.3390/galaxies10030065)

[2] - PT425 1K Pulse Tube Cryocooler. Bluefors.com. Feb. 22, 2019. <https://bluefors.com/products/pulse-tube-cryocoolers/pt425-1k/>

[3] - Amir E. Jahromi et al., Modeling, development, and experimental validation of a Joule–Thompson superfluid refrigerator using a pulse tube cryocooler

[4] - D. Gomse et al. „Entwicklung eines Wärmeübertragers für kryogene Gemischkältekreisläufe“, 2016. DKV Tagung Kassel



## GRAVITHELIUM

Gravitational wave detectors  
cooled with superfluid helium

