超流動ヘリウム冷却システム技術調査研究会

ラムダ転移が介在する熱伝達特性と He II冷却の可能性

日本大学量子科学研究所
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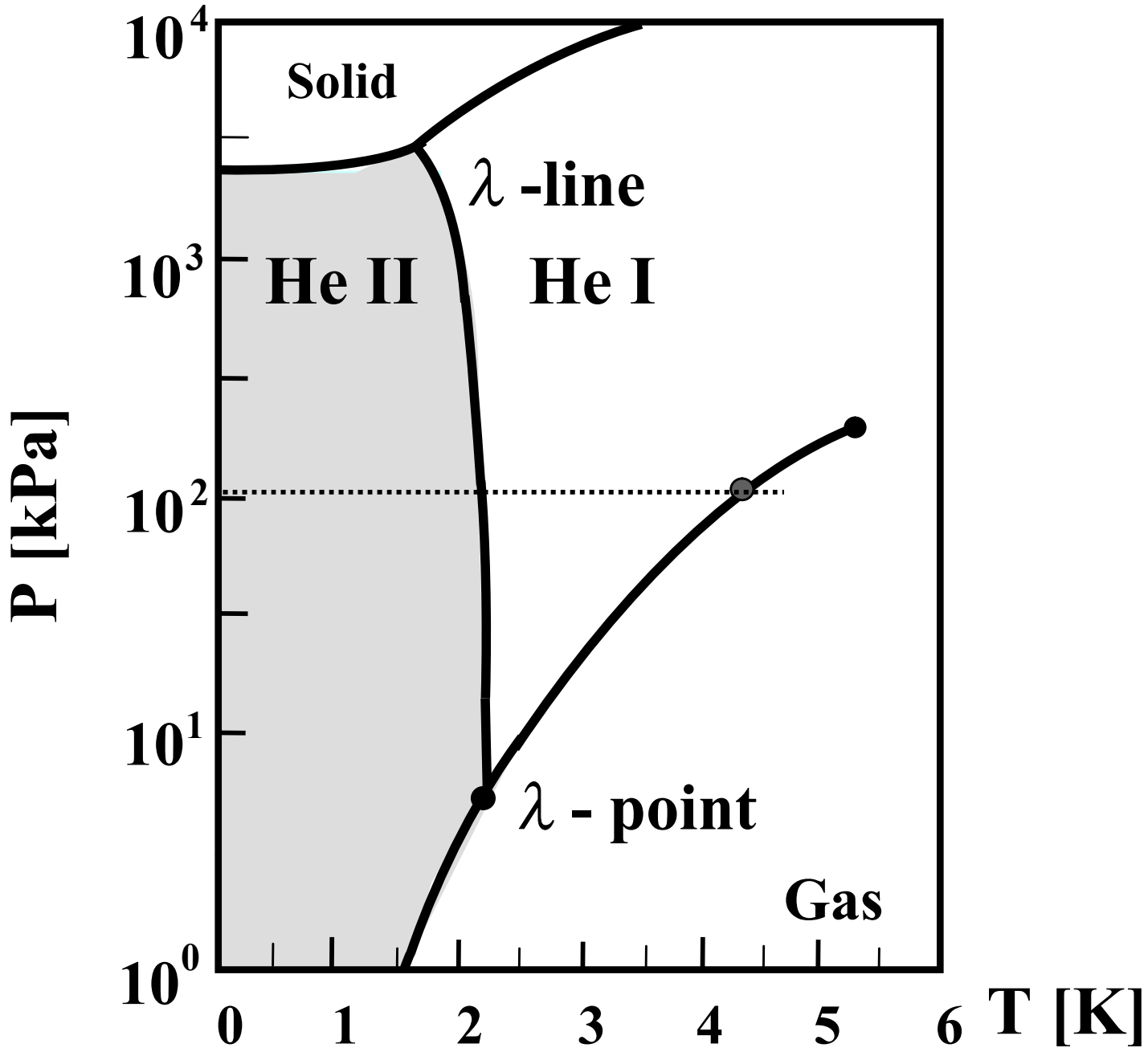
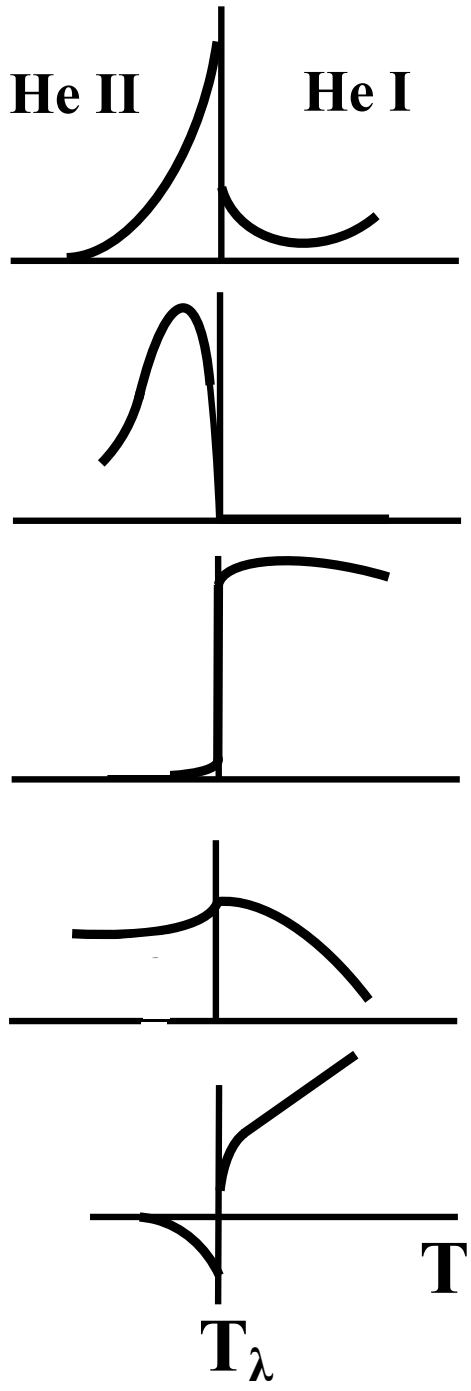
平成22年1月29日


10^4
Solid
λ -line
10^3
He II
He I
10^2
10^1
λ - point
Gas
10^0
P [kPa]
0
1
2
3
4
5
6
T [K]

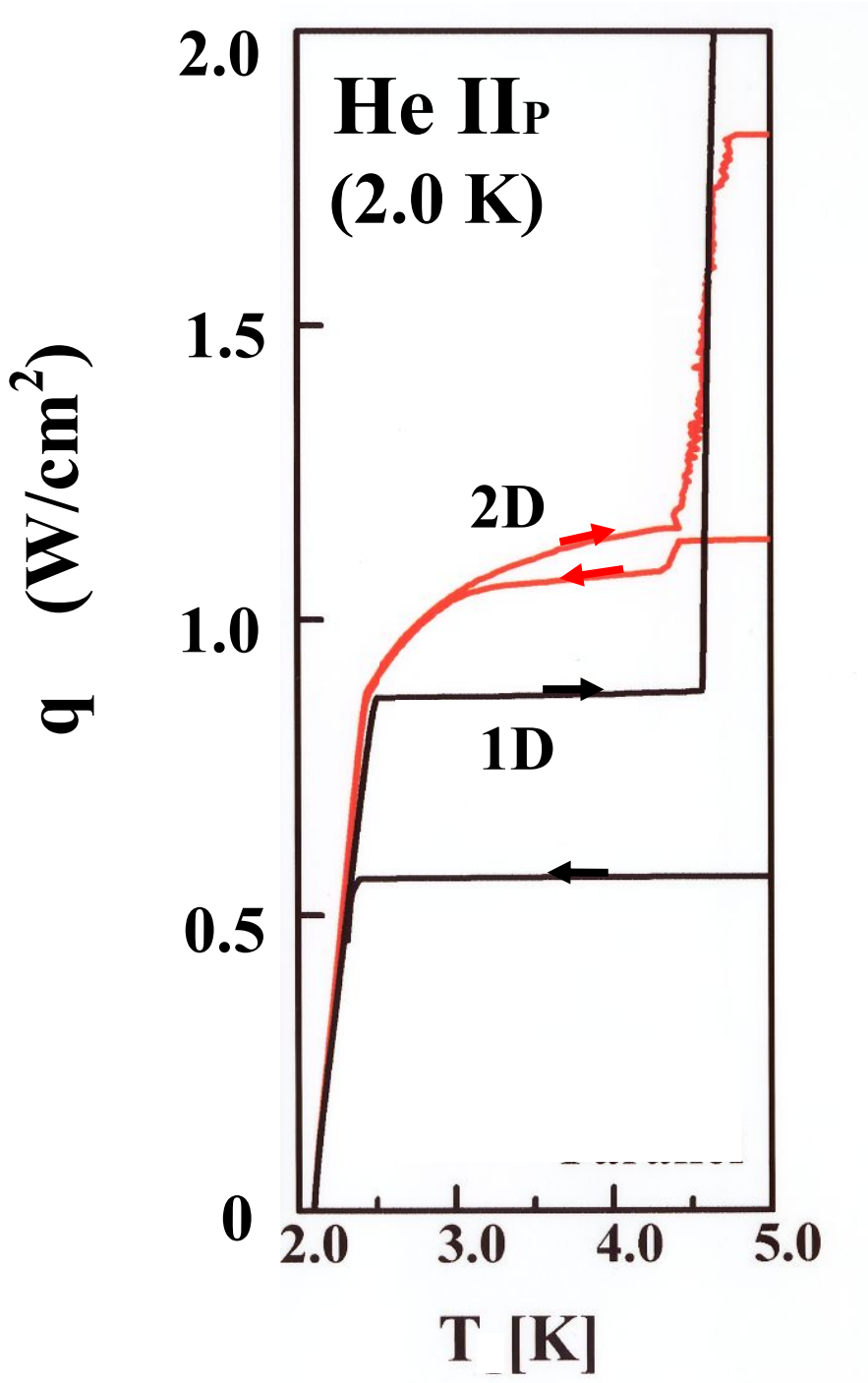
He II冷却の課題

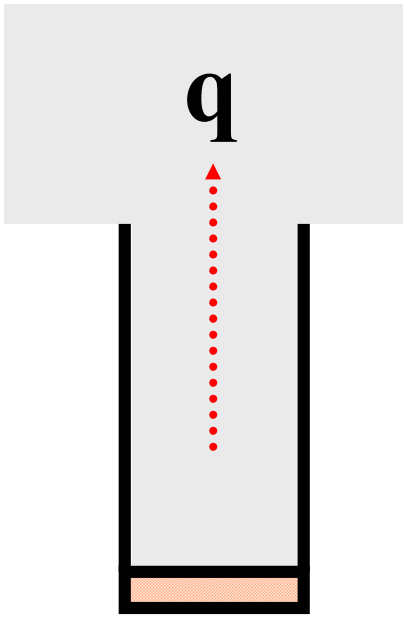
- λ－転移
- Kapitza抵抗
- 冷凍能力
- Superleak
- $\lim_{T \to 0} S = 0$

- 比熱
- 熱伝導
- 粘性
- 密度
- 熱膨張率

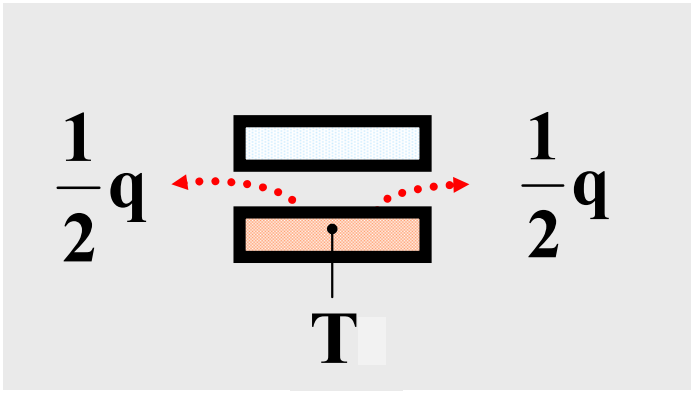


$T\lambda = 2.1768\ K$

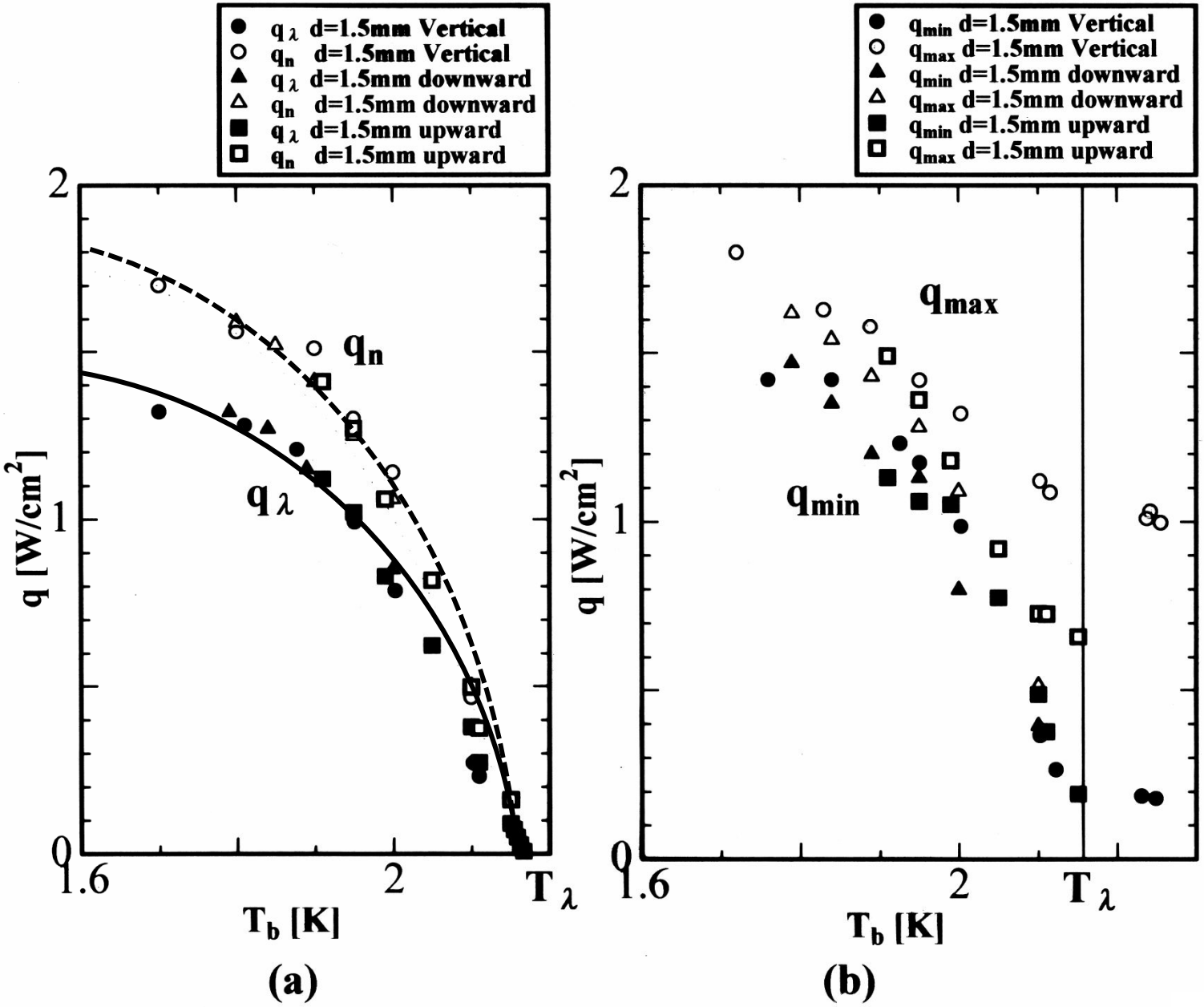




1D- channel



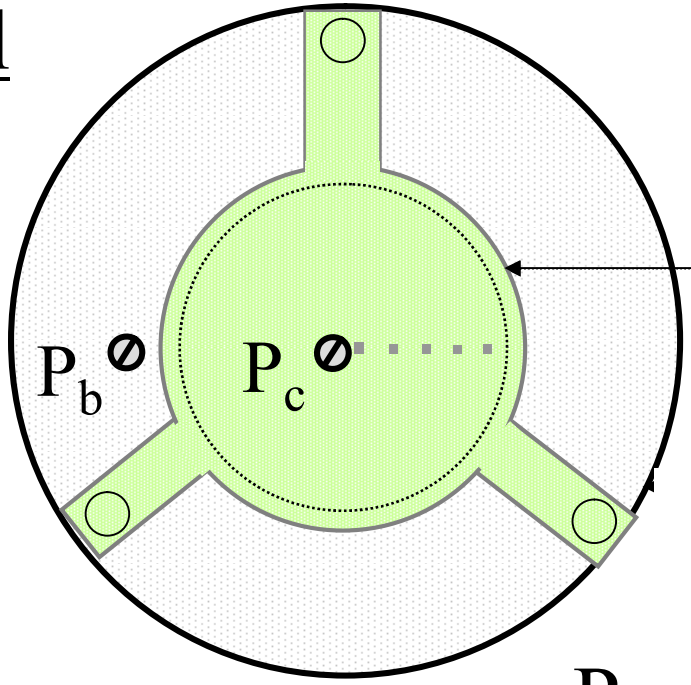
2D- channel


q_λ d=1.5mm Vertical
q_n d=1.5mm Vertical
q_λ d=1.5mm downward
q_n d=1.5mm downward
q_λ d=1.5mm upward
q_n d=1.5mm upward
q_n
q_λ
q [W/cm^2]
T_b [K]
T_λ
(a)
q_{min} d=1.5mm Vertical
q_{max} d=1.5mm Vertical
q_{min} d=1.5mm downward
q_{max} d=1.5mm downward
q_{min} d=1.5mm upward
q_{max} d=1.5mm upward
q_{max}
q_{min}
q [W/cm^2]
T_b [K]
T_λ
(b)

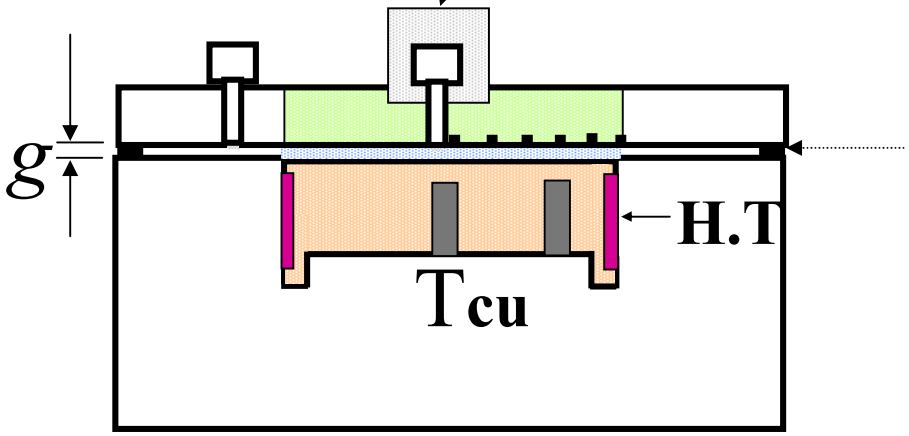
角度依存

radial 2D-channel

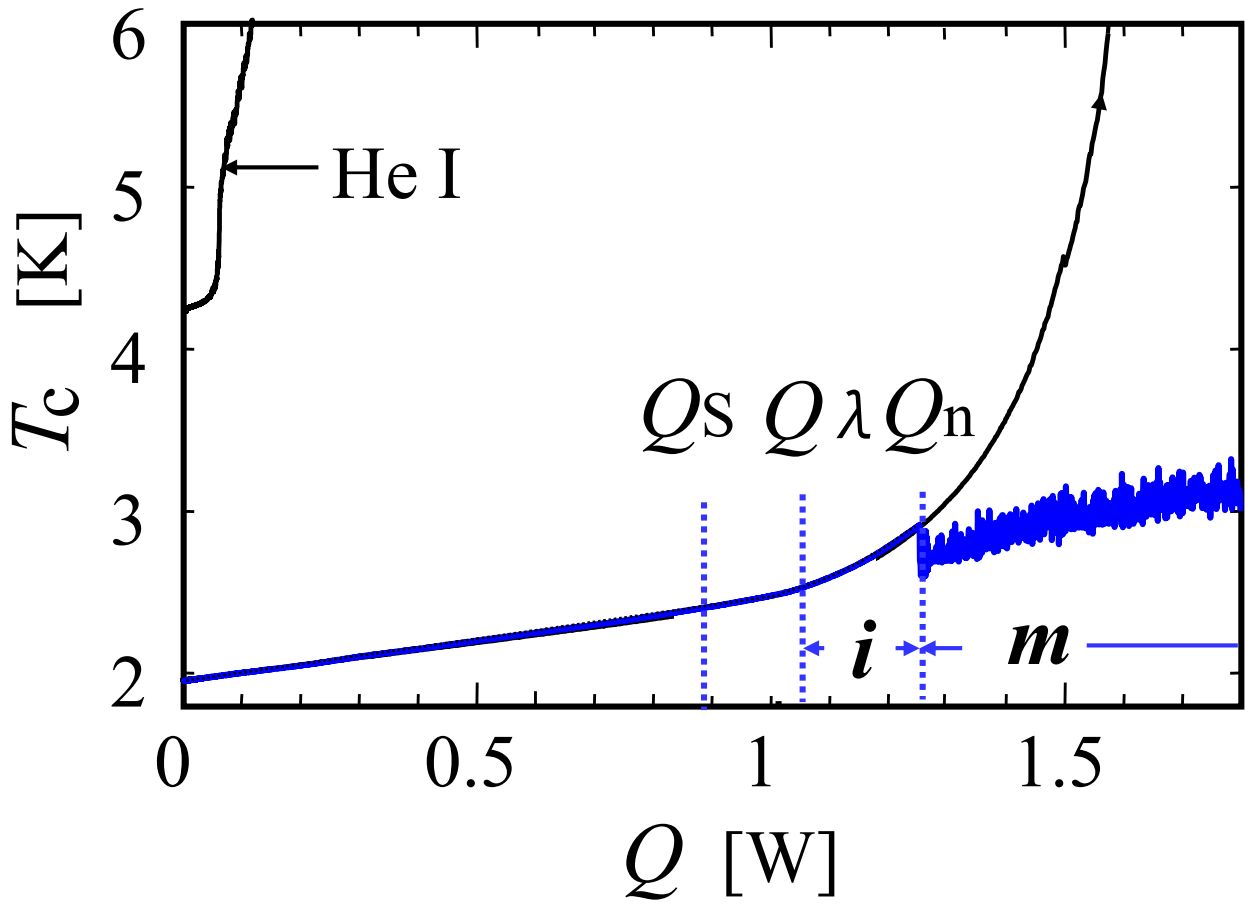
Top view



Cut view

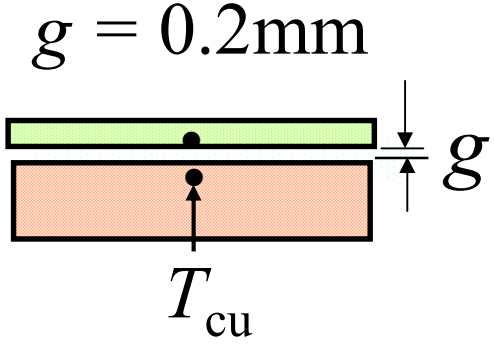


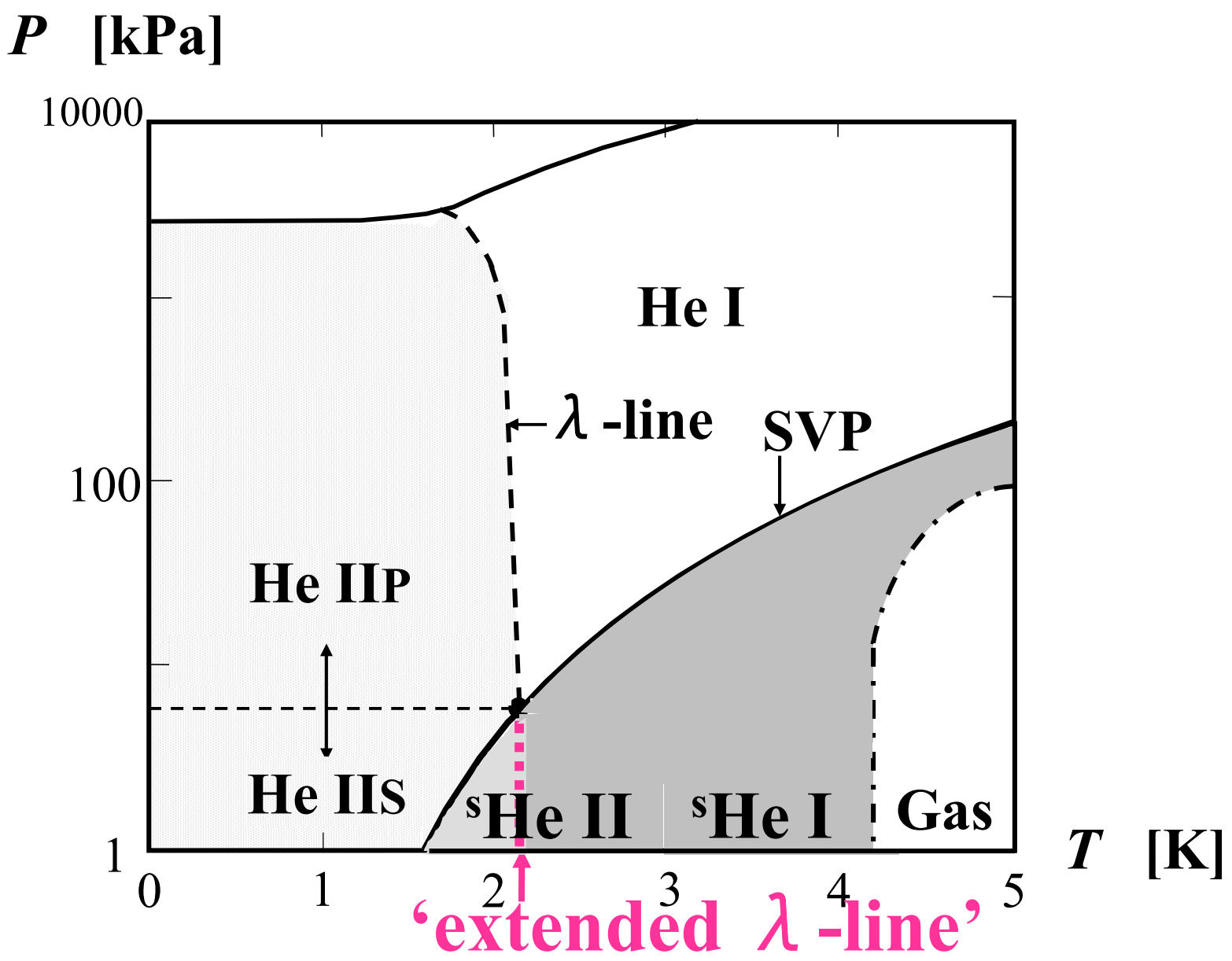
g = 0.01 mm, 0.20 mm



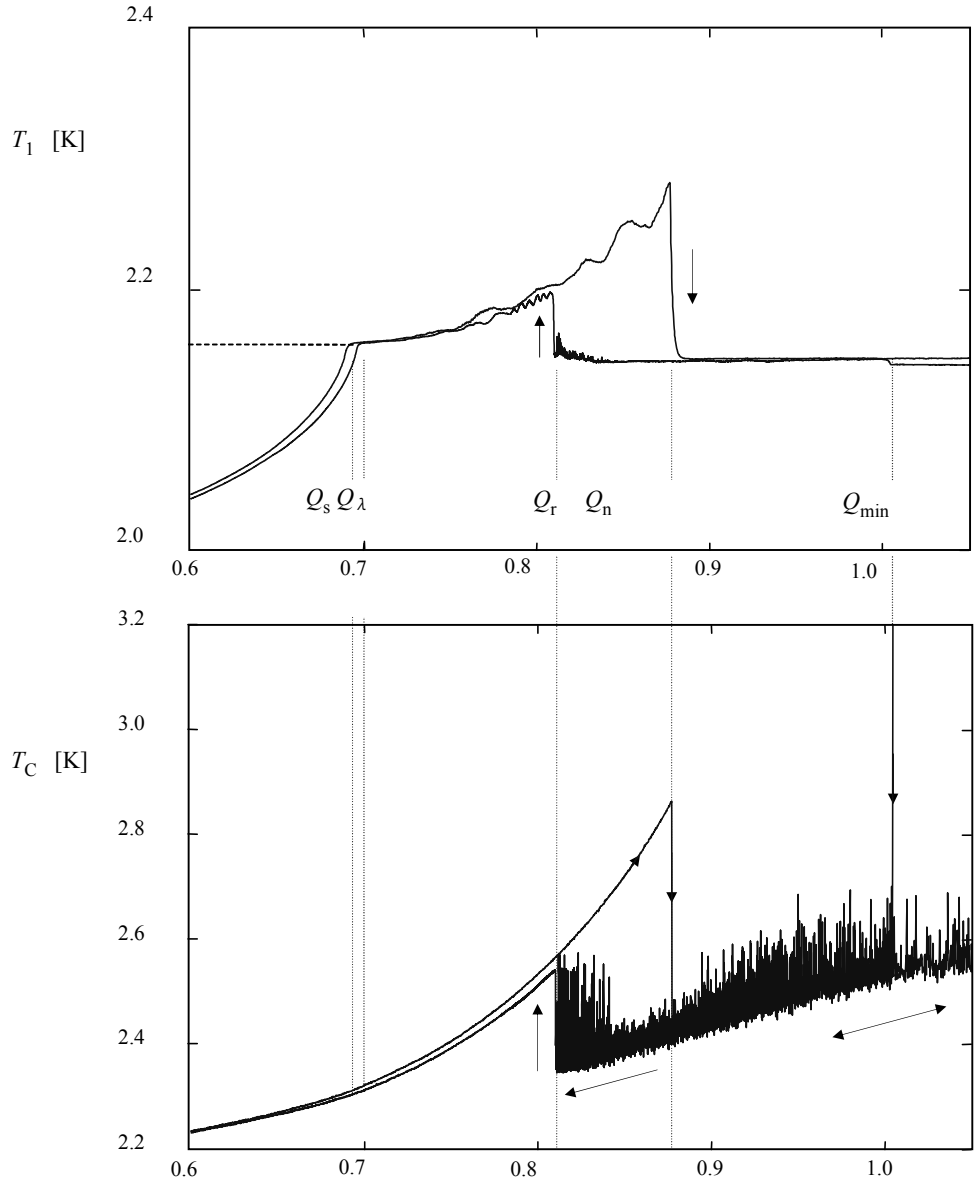
He II_P
1.95 K
1 atm.

He II_S
1.95 K
$P_b < P_\lambda$

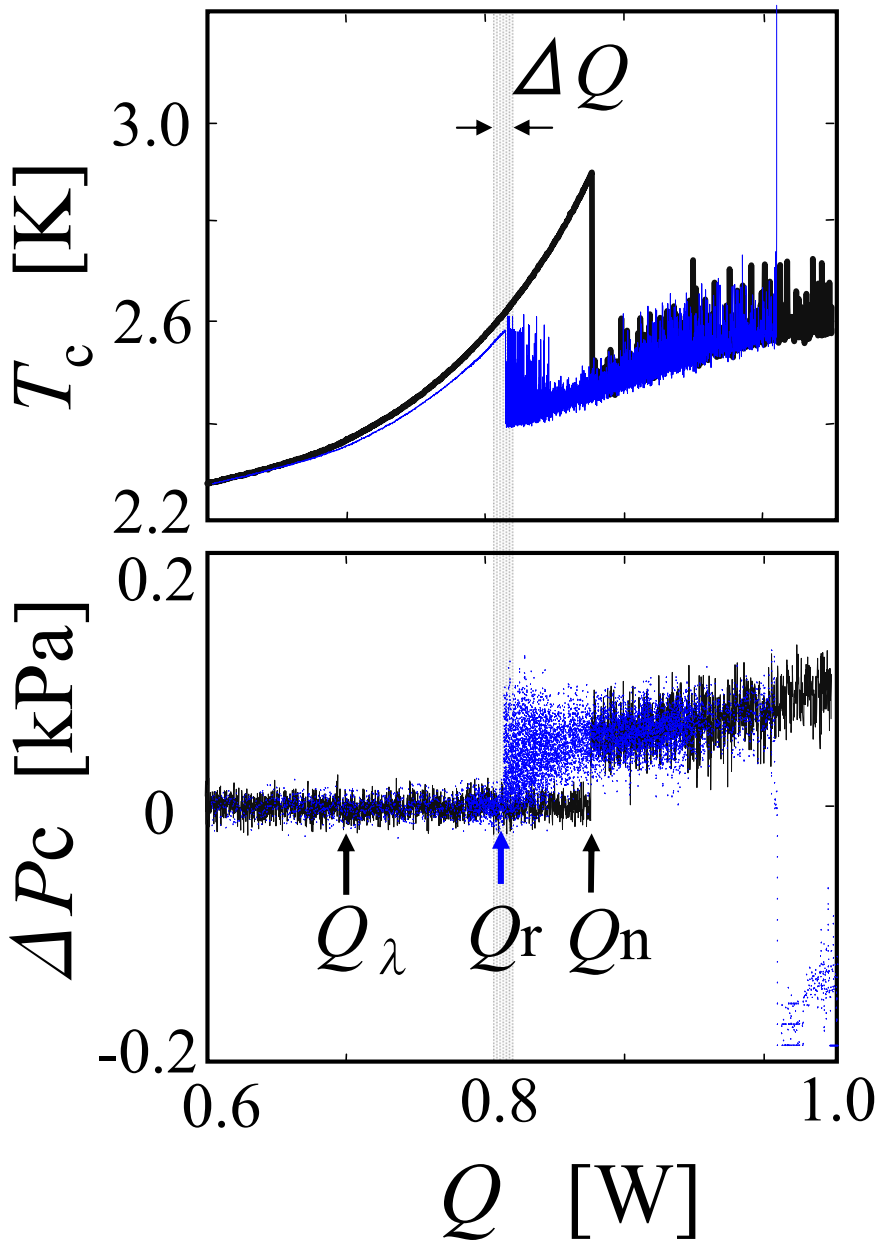


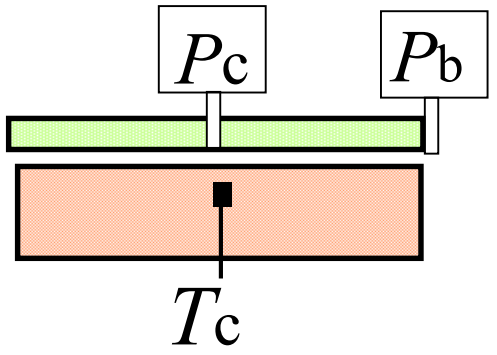


Rybarcyk LJ, Tough JT. J Low Temp Phys 1981;43:197-202.
Nishigaki K, Saji Y. Phys Rev B 1986;33:1657-62.

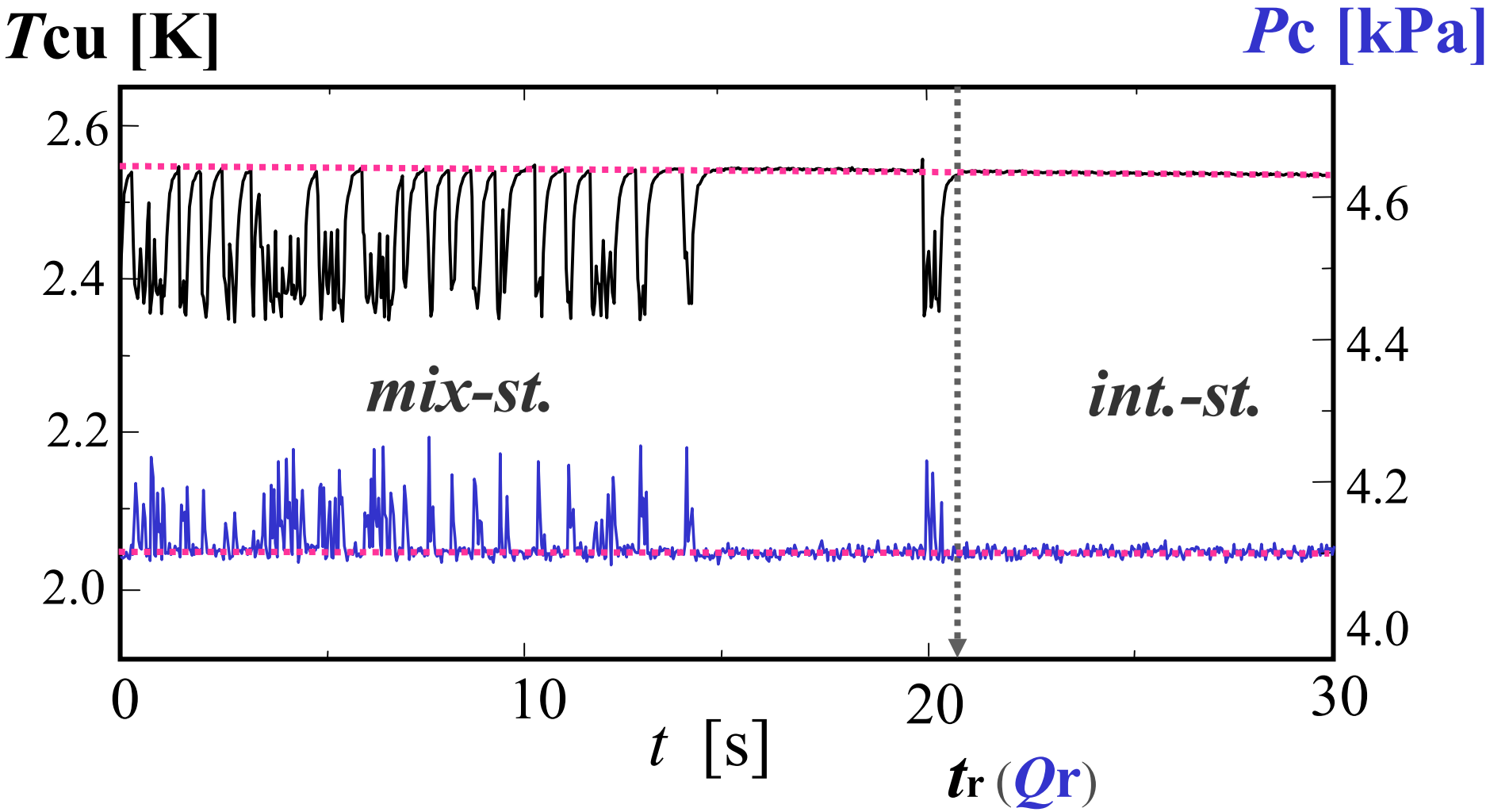

2.4
T_1 [K]
2.2
2.0
Q_s Q_λ
Q_r Q_n
Q_{min}
0.6
0.7
0.8
0.9
1.0
3.2
3.0
T_C [K]
2.8
2.6
2.4
2.2
0.6
0.7
0.8
0.9
1.0

← Plateau (熱遮蔽)



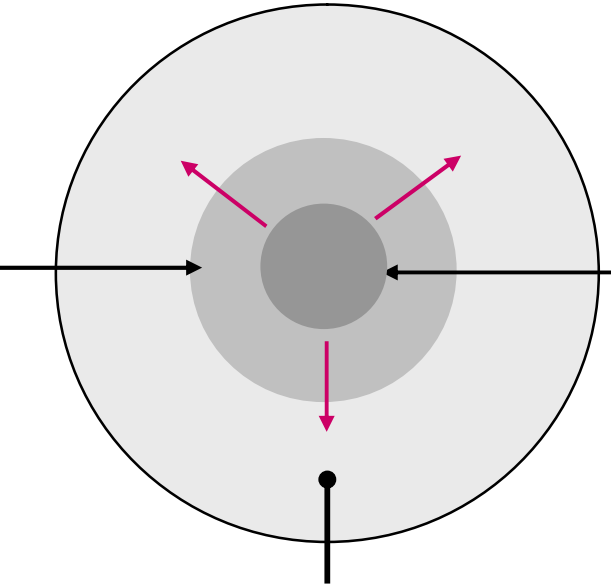


$$\Delta Pc = Pc - Pb$$



$T_b = 1.95$ K, $P_b = 4.1$ kPa

intermediate state



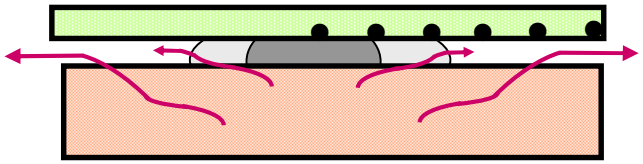
^{s}He II

^{s}He I

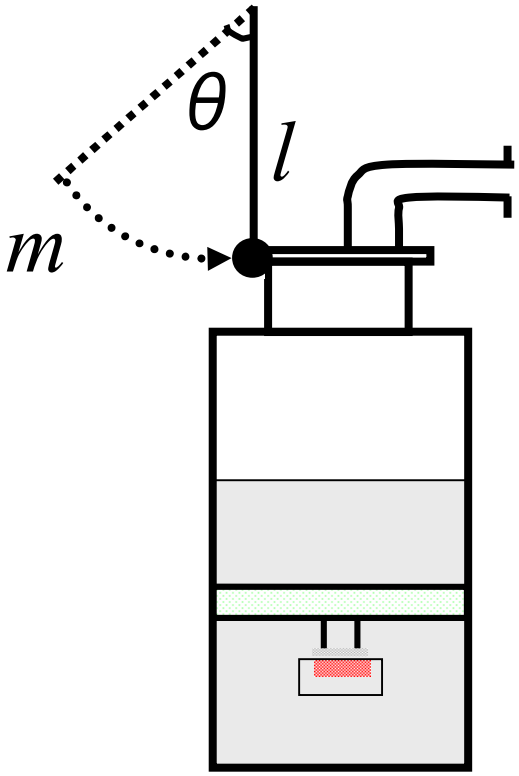
non-viscous
conductive
fragile

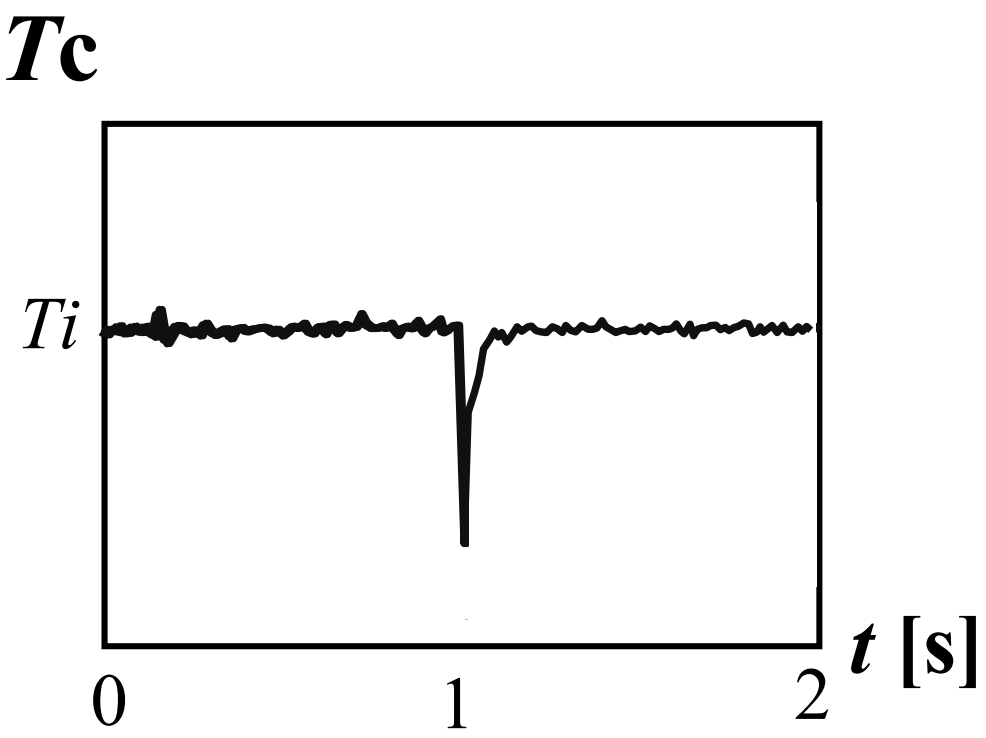
He IIs

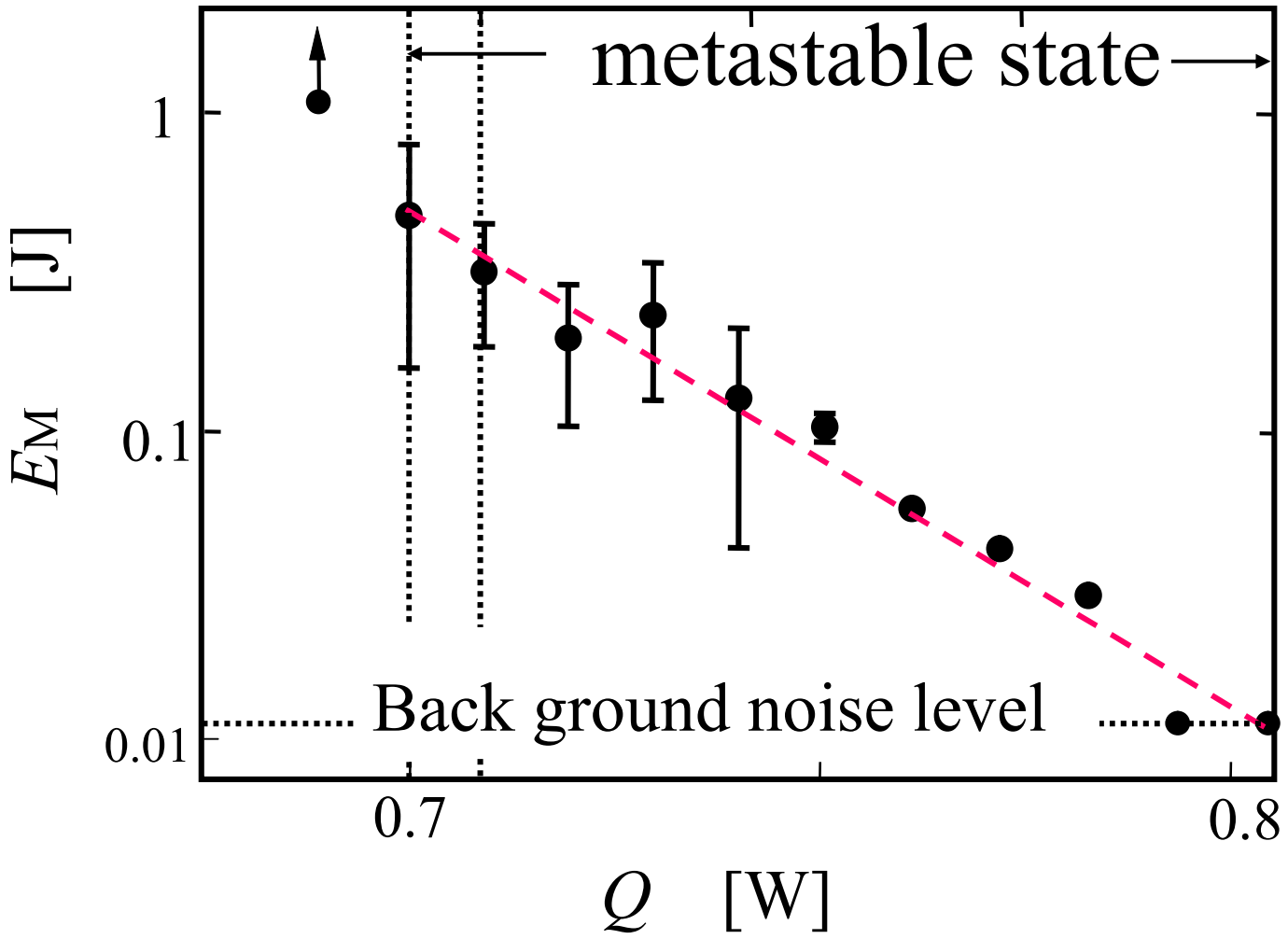
viscous
less conductive
very fragile



stability test







T_b = 1.95 K, P_b = 4.25 kPa, g = 0.15 mm

He II-Cryogeniocsの可能性

- 高熱負荷 冷却

  gradual transition (安定化マージン)

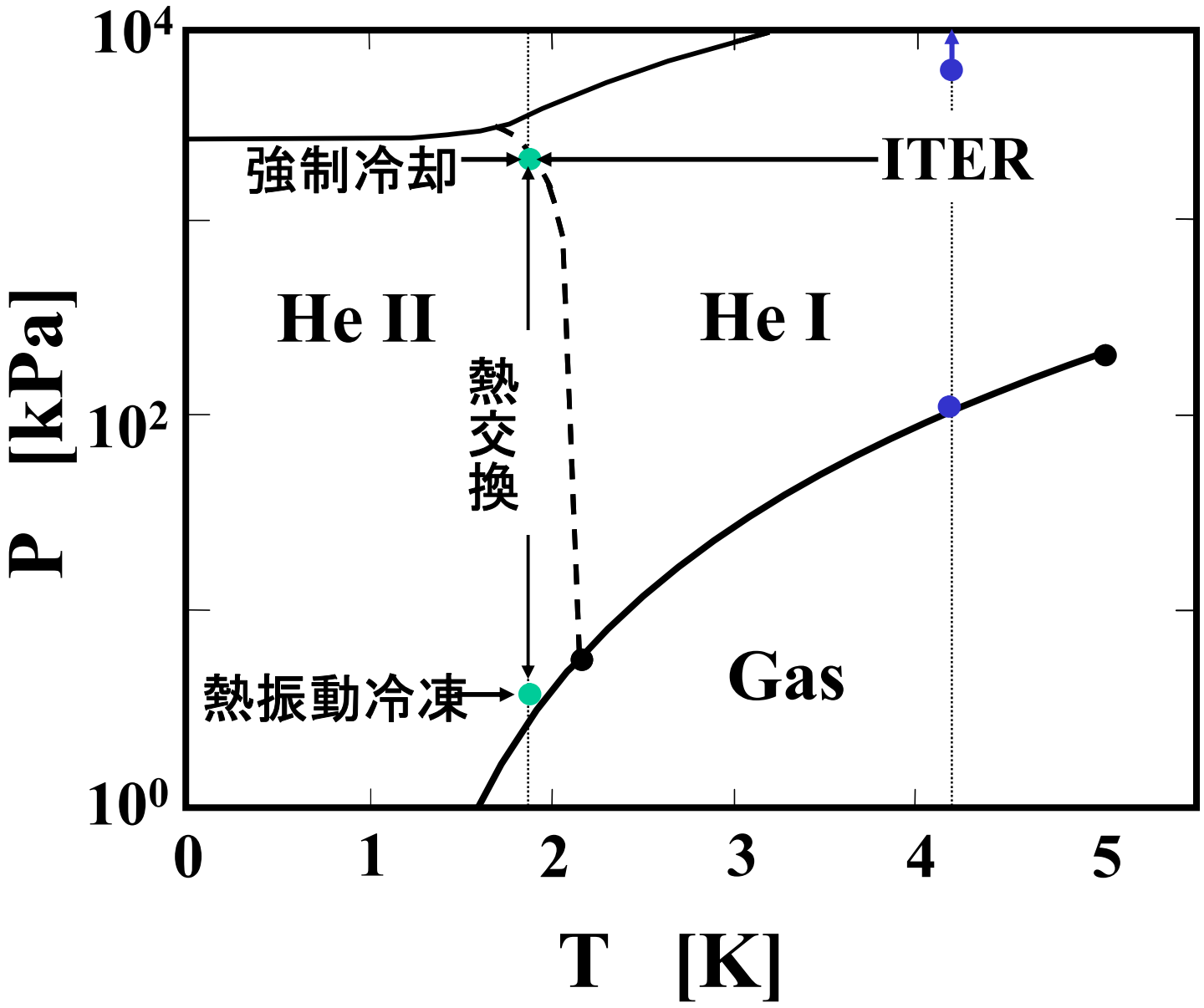
  He IIp forced flow

- 高熱交換効率化

  mixed state, plateau

- 断熱遮蔽

  intermediate state, non-superleak, plateau


10^4
10^2
10^0
P [kPa]
強制冷却
ITER
He II
He I
熱交換
熱振動冷凍
Gas
0
1
2
3
4
5
T [K]