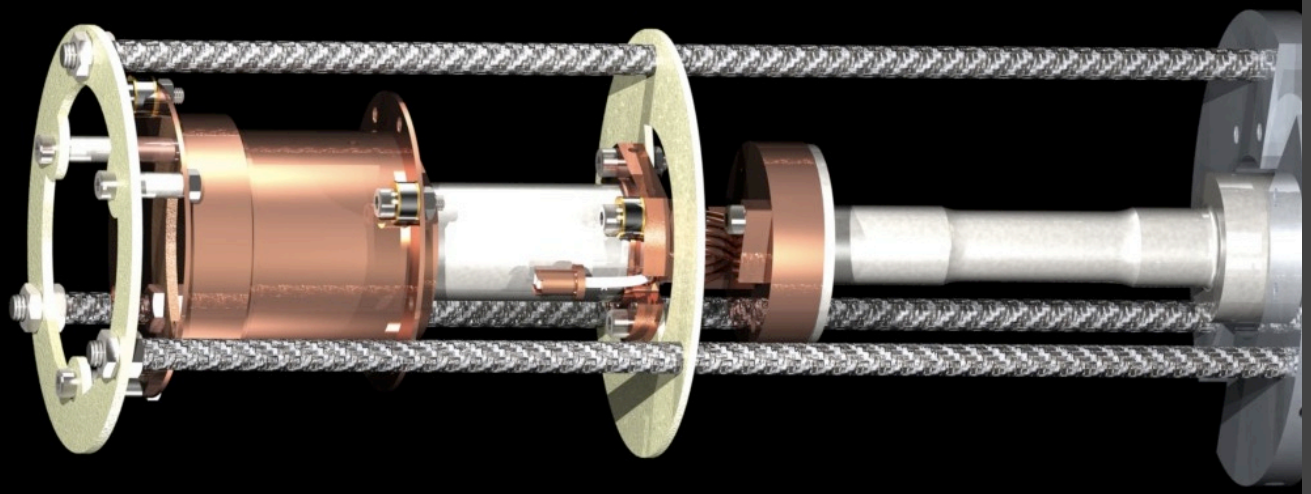


40 K Energy Storage Unit

D. Martins, P. Borges de Sousa, I. Catarino, G. Bonfait

FACULDADE DE CIÊNCIAS E TECNOLOGIA
UNIVERSIDADE NOVA DE LISBOA

ICEC 25 - 8th July 2014 – University of Twente

Why 40 K Energy Storage Unit?

FACULDADE DE CIÊNCIAS E TECNOLOGIA
UNIVERSIDADE NOVA DE LISBOA

Earth Observation or Surveillance Tracking programs

-QWIPS (Quantum well infrared photodectectors) 40 K

-Low vibration environment

Low vibration coolers <50 K

Larger Sensor Arrays

more cooling power is required

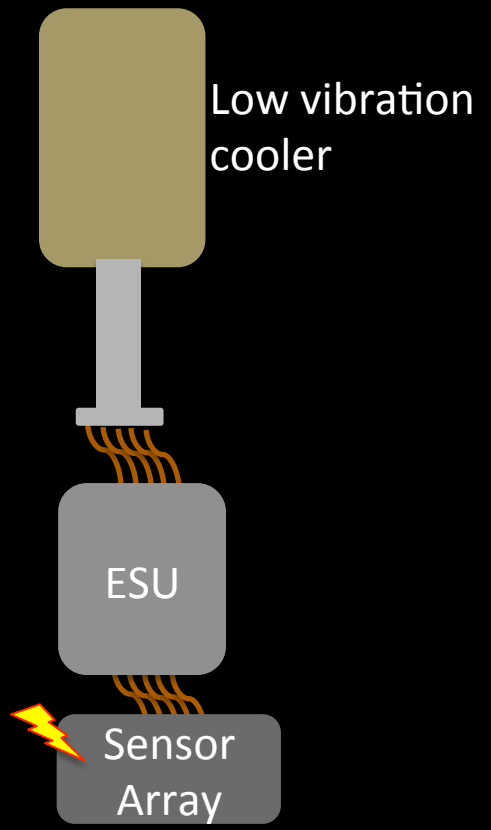
1W@ 40 K

LPTC

From: Air Liquide space cryocooler systems (2008)

Why Energy Storage Unit (ESU)?

“Cooling power booster”



- Increase the cooling power (temporarily)

- Stable temperature

To use in pulse tube coolers :1W@40 K

Why Energy Storage Unit (ESU)?

FACULDADE DE CIÊNCIAS E TECNOLOGIA
UNIVERSIDADE NOVA DE LISBOA

"Independent cold source"

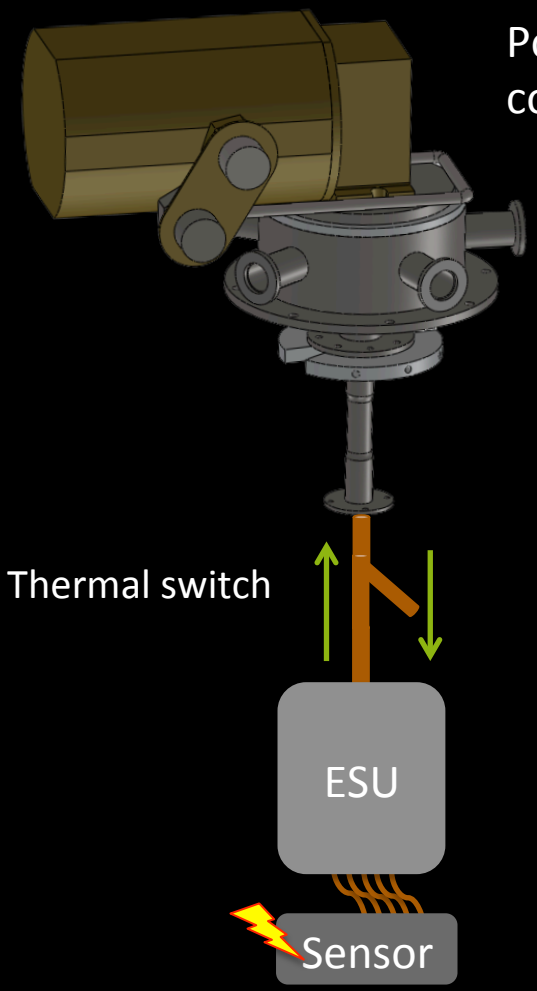
"Vibration free"

Ground applications:
- magnetic measurements
- Sensitive sensors

Powerful cooler

STOP the cryocooler:

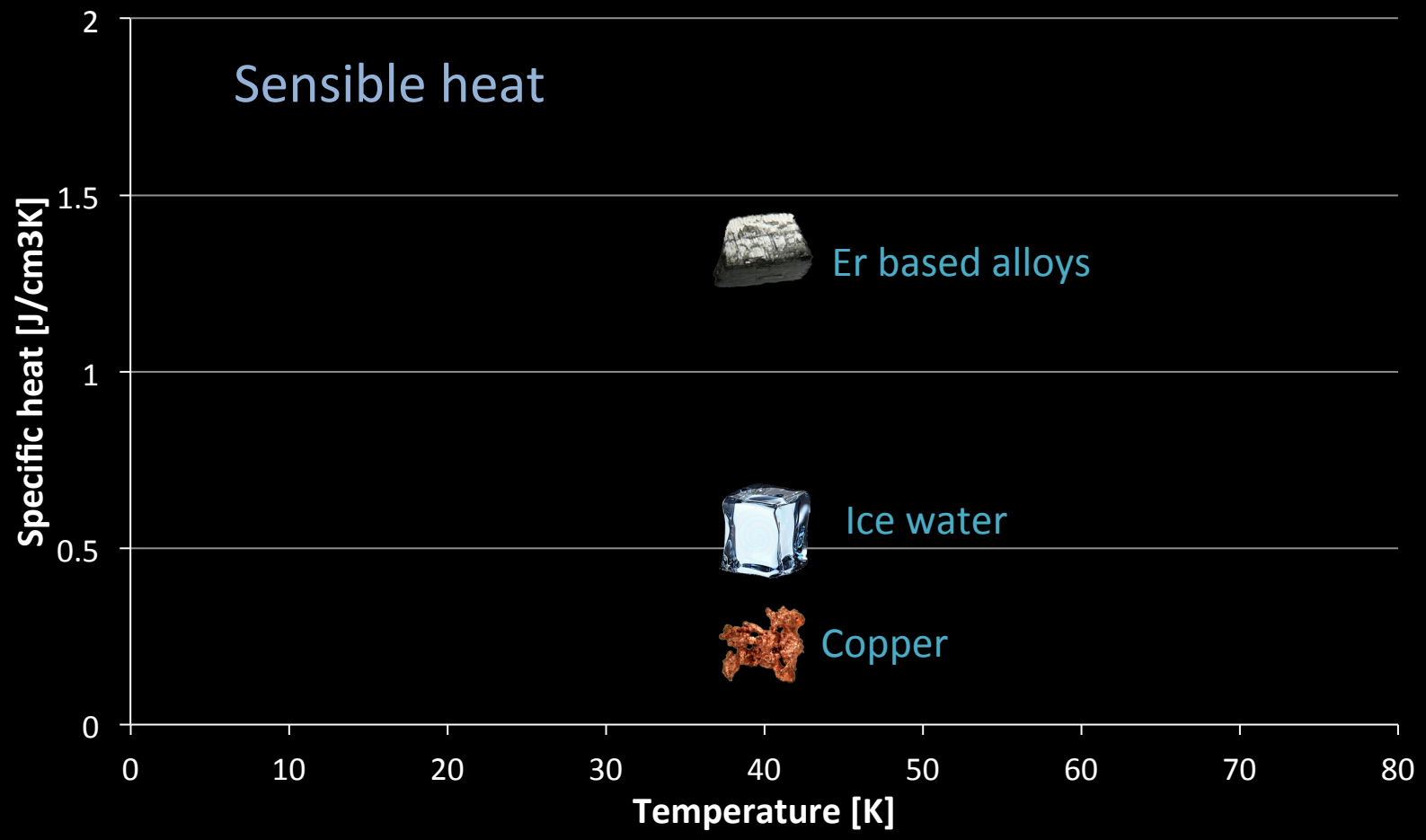
- no mechanical vibration
- no electromagnetic noise



What is an ESU?

FACULDADE DE CIÊNCIAS E TECNOLOGIA
UNIVERSIDADE NOVA DE LISBOA

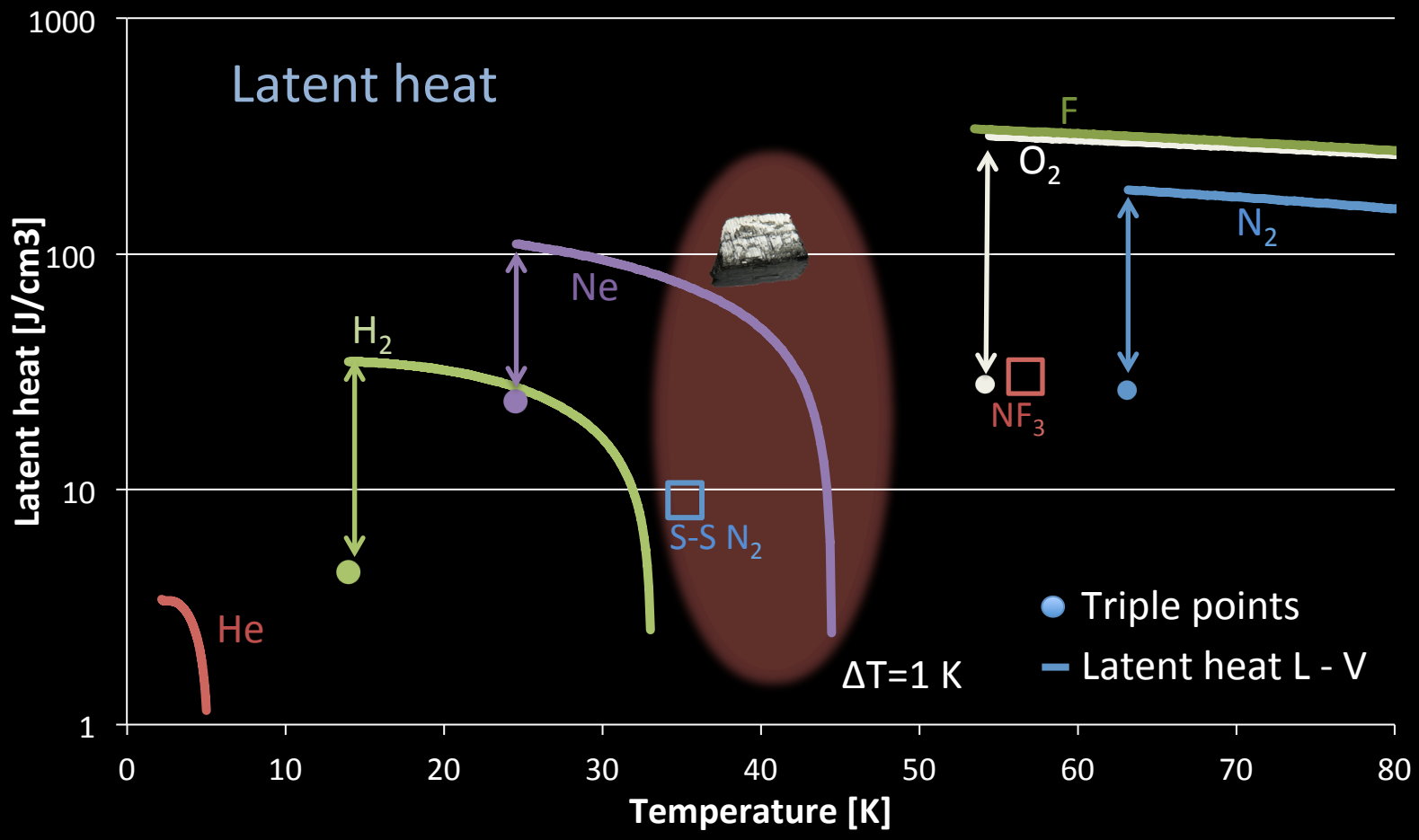
Enthalpy Reservoir



What is an ESU?

FACULDADE DE CIÊNCIAS E TECNOLOGIA
UNIVERSIDADE NOVA DE LISBOA

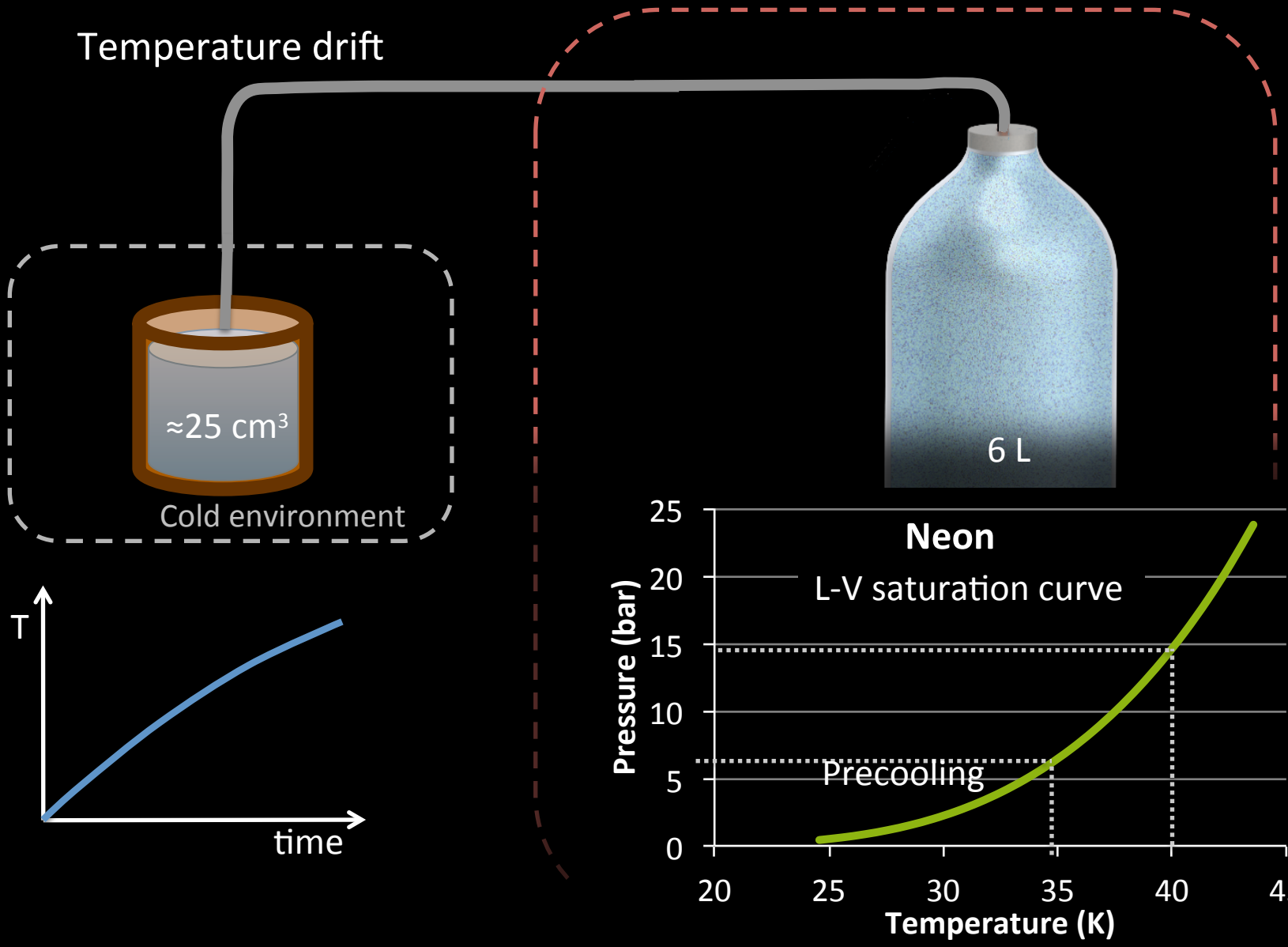
Enthalpy Reservoir



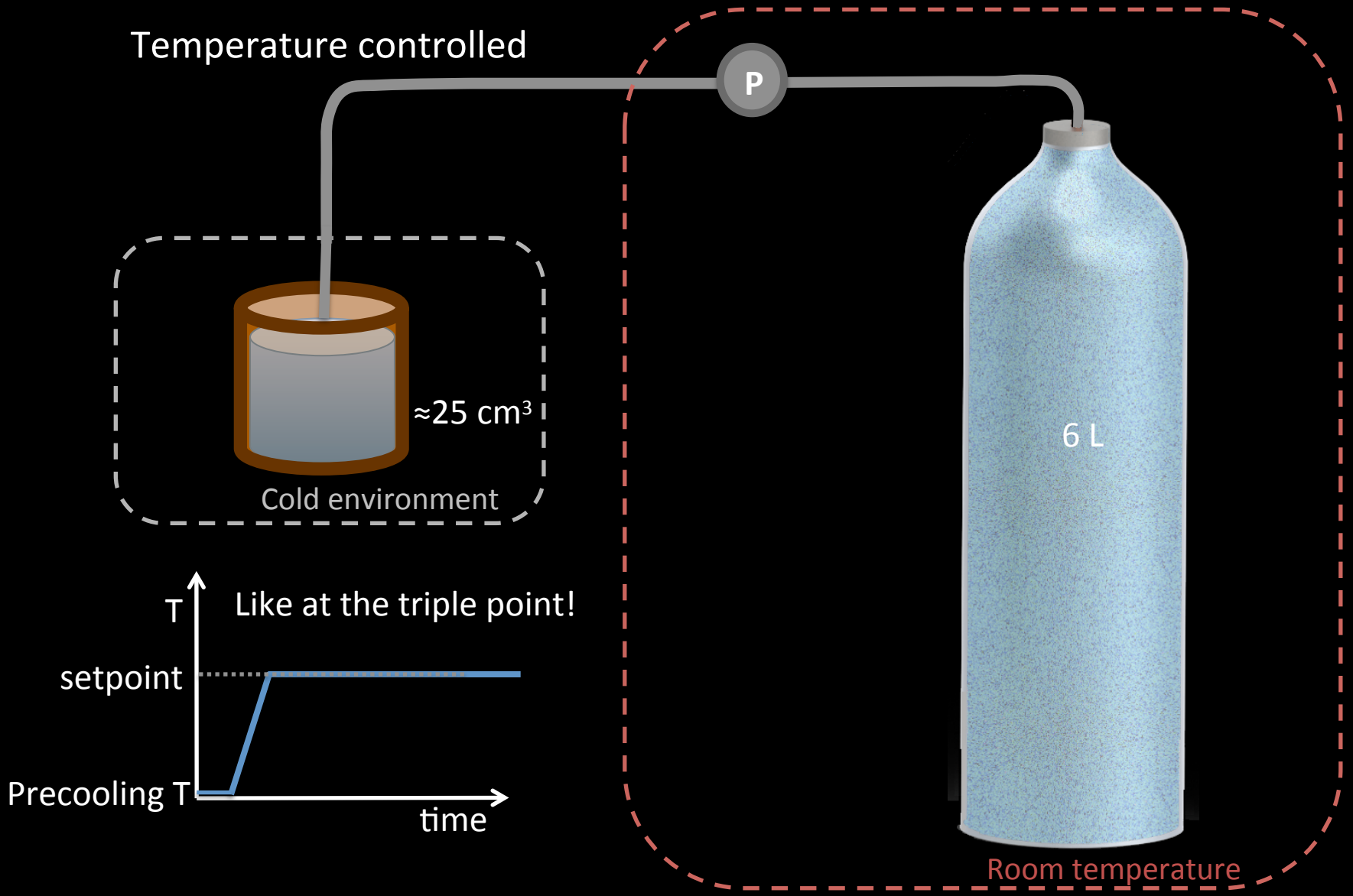
L (Liquid – vapor) >> L (solid – liquid)

How does it work?

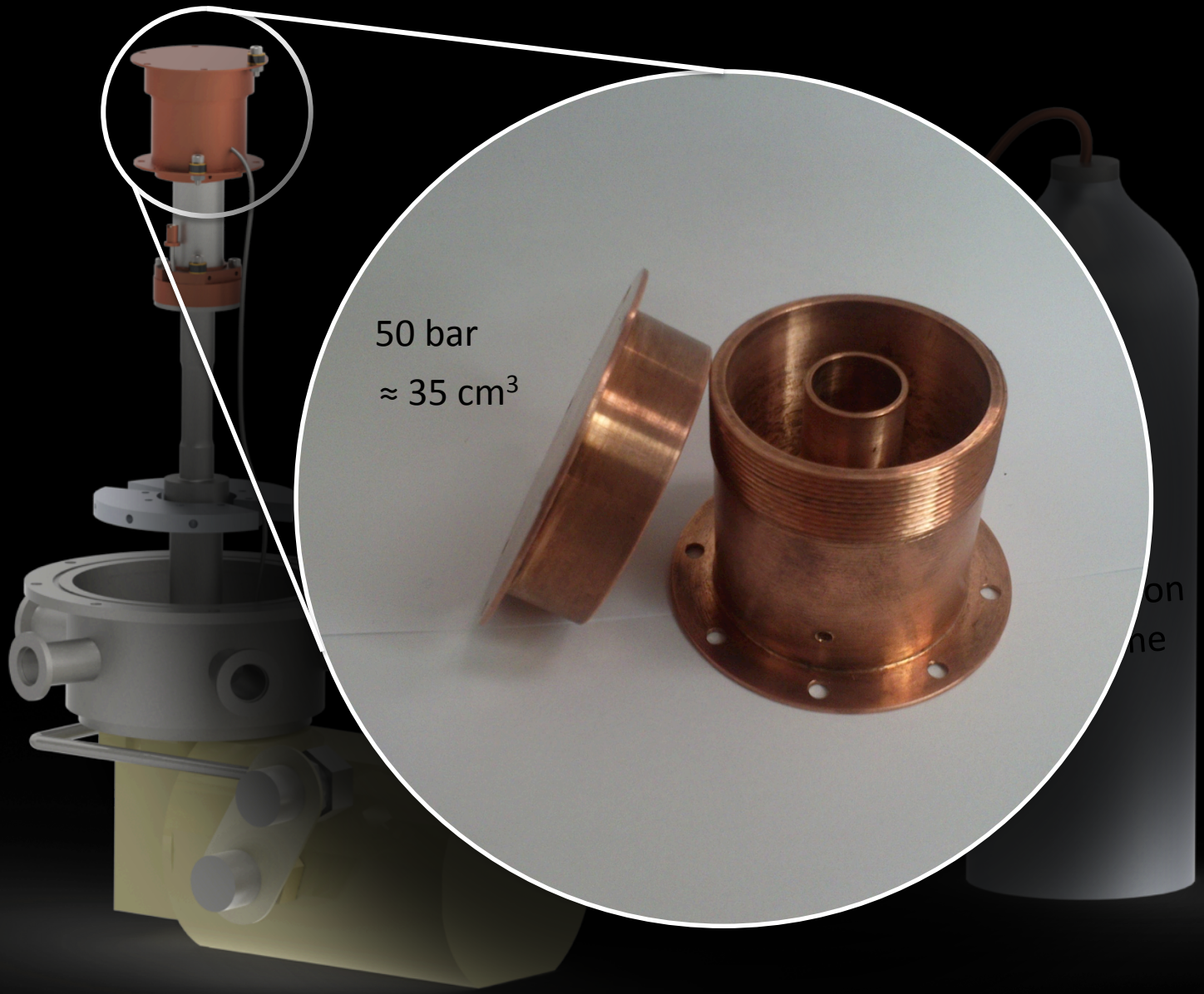
FACULDADE DE CIÊNCIAS E TECNOLOGIA
UNIVERSIDADE NOVA DE LISBOA



How does it work?

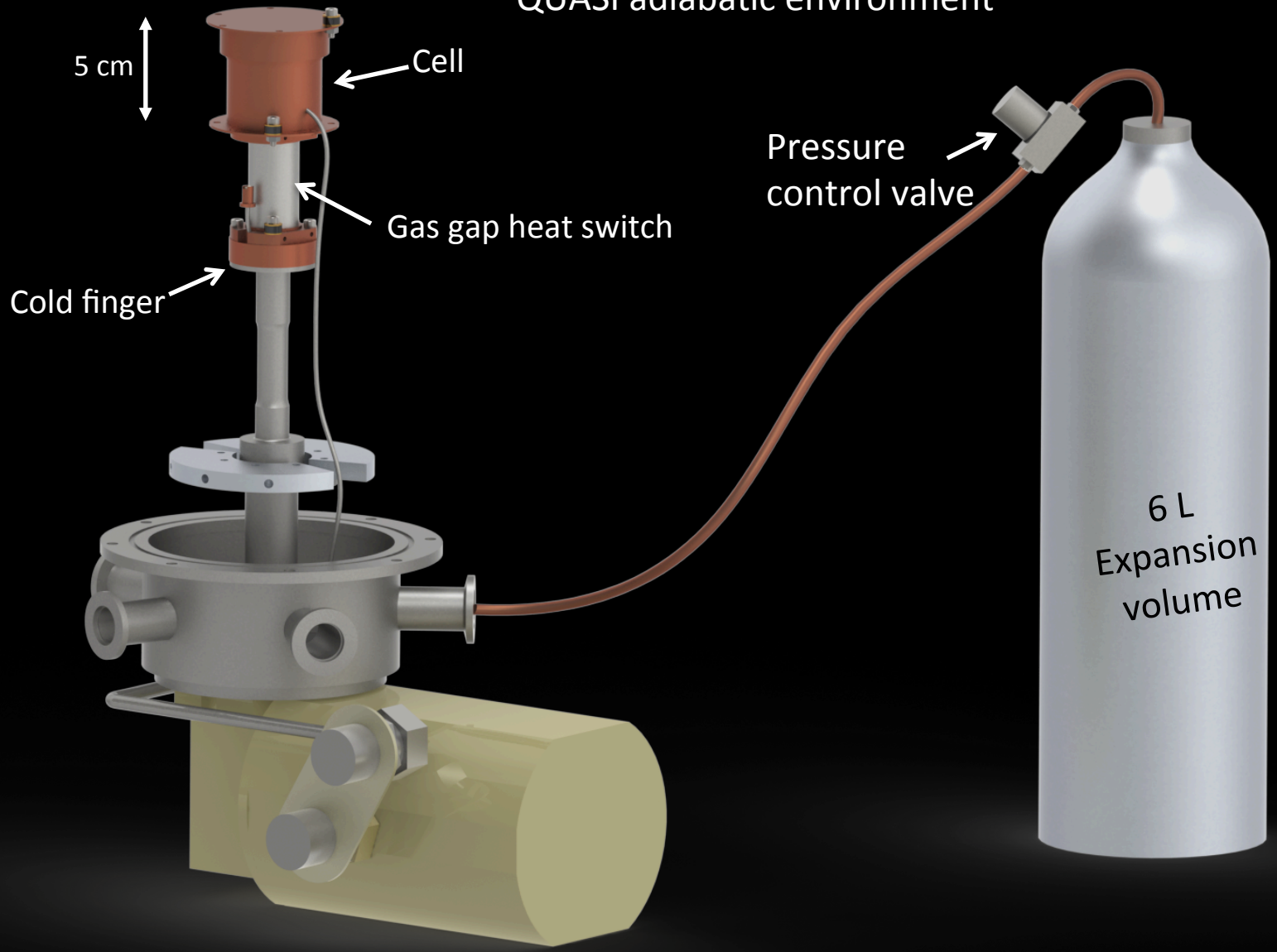


Experimental Set-up



Experimental Set-up

FACULDADE DE CIÊNCIAS E TECNOLOGIA
UNIVERSIDADE NOVA DE LISBOA



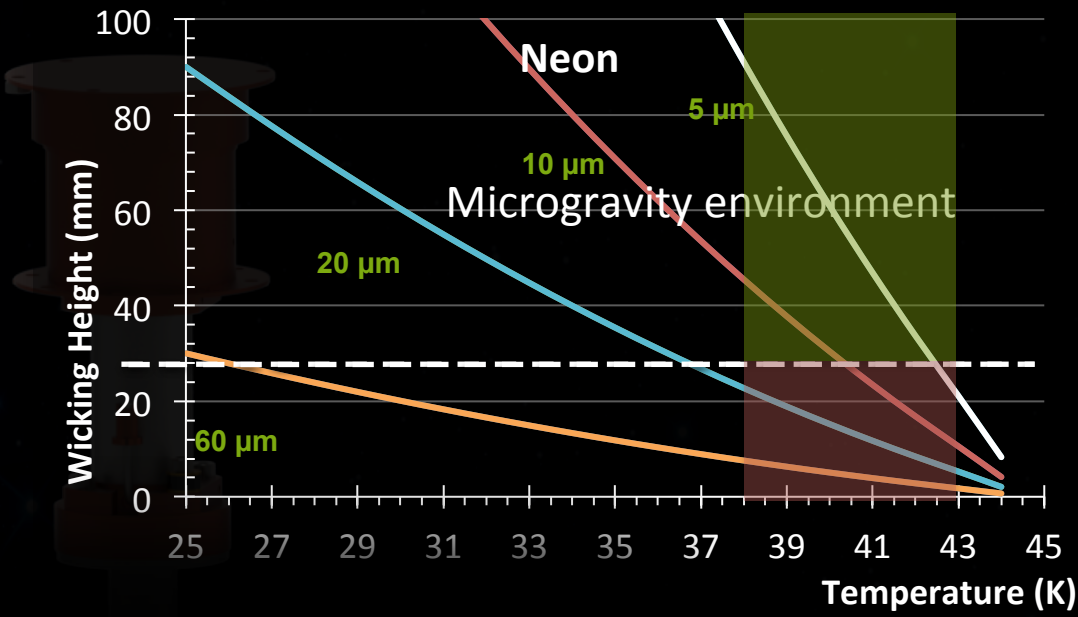
Gravity insensitive system

FACULDADE DE CIÊNCIAS E TECNOLOGIA
UNIVERSIDADE NOVA DE LISBOA

Porous material

e.g: alumina foam

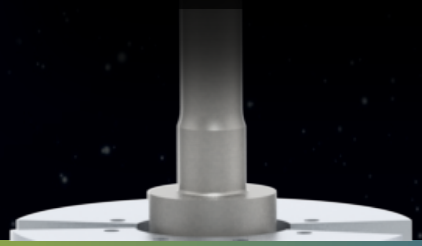
Lab environment : liquid rises to top of the cell



Filter paper ≈ 5 µm

$$h = \frac{4\gamma\cos\theta}{d\left(\rho_L - \rho_G\right)g}$$

γ → surface tension
ρ → density
d → capillary diameter
h → wicking height

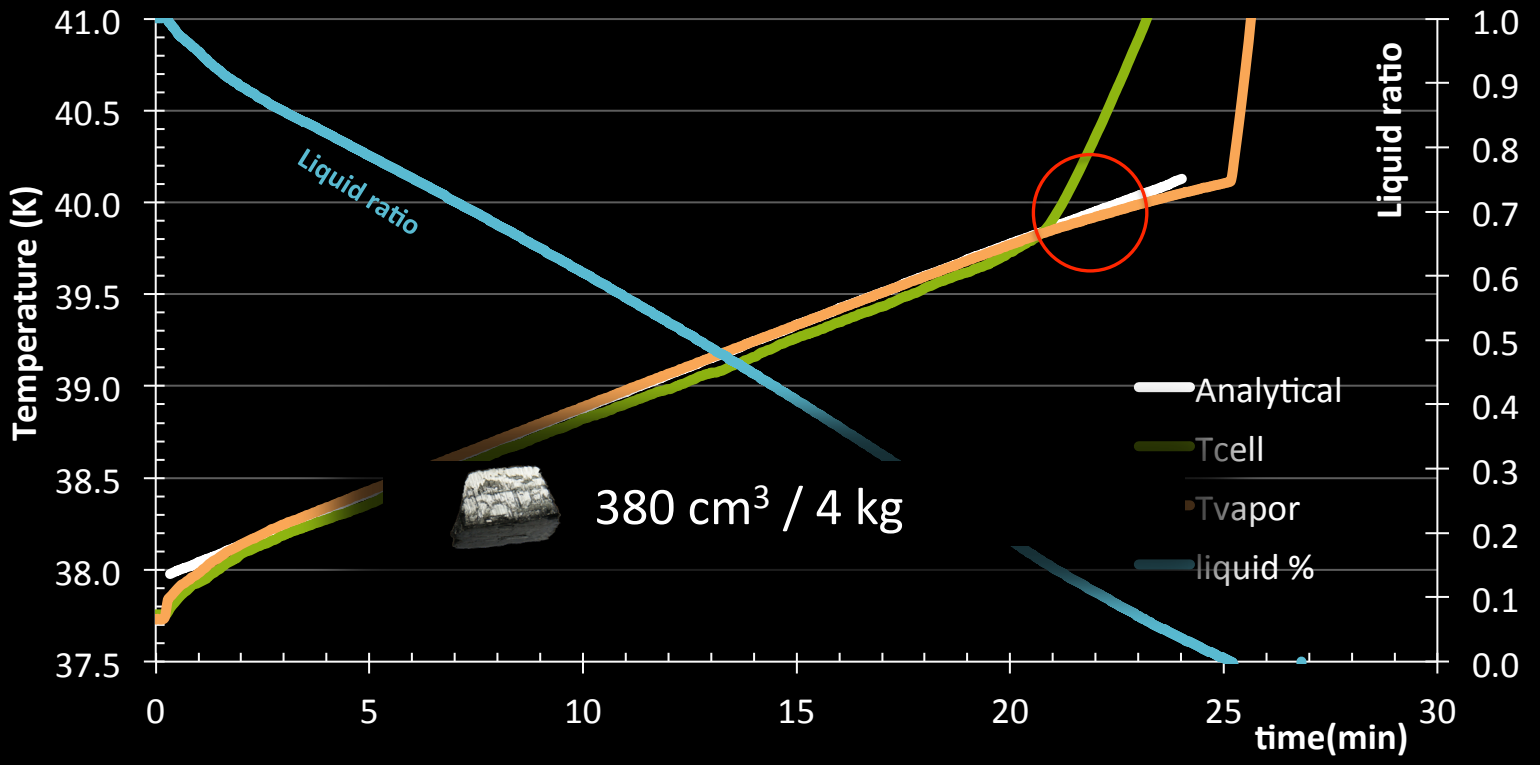


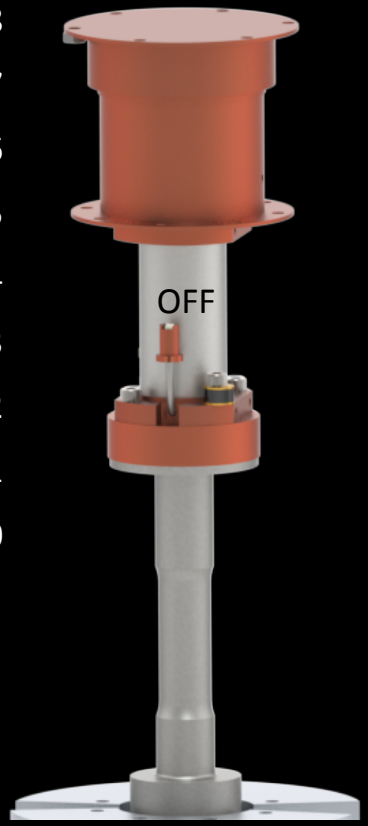
Results

FACULDADE DE CIÊNCIAS E TECNOLOGIA
UNIVERSIDADE NOVA DE LISBOA

Temperature drift mode

P= 15 bar
1 W





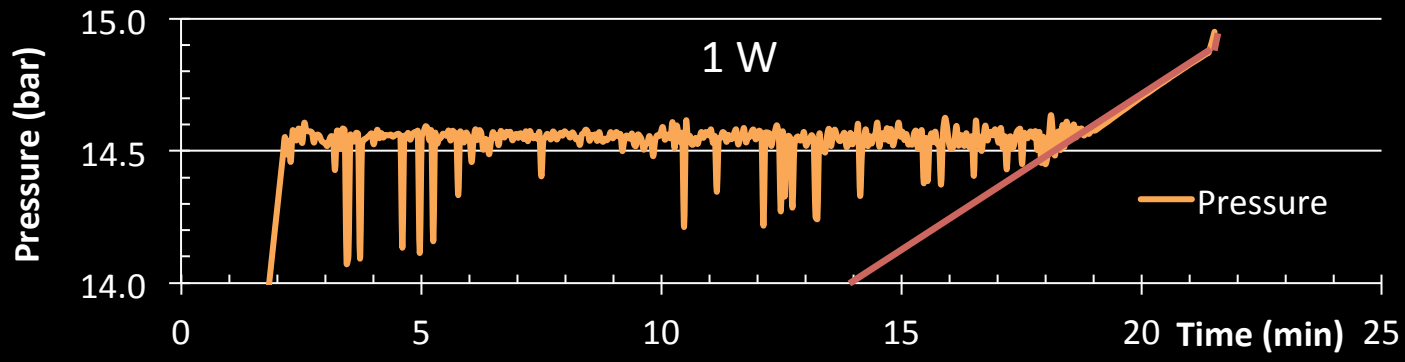
Liquid Neon → 25 cm³ / 22.5 g

Results

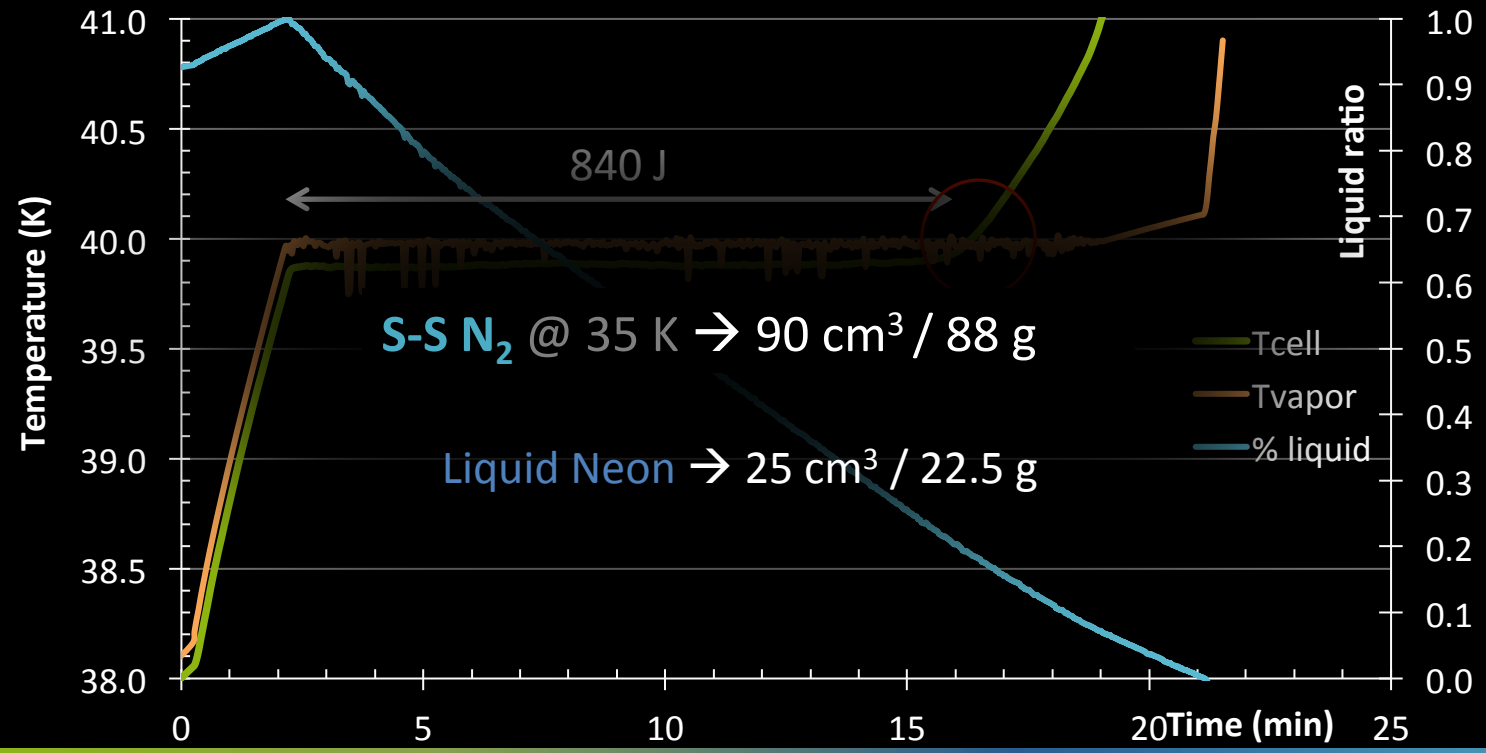
FACULDADE DE CIÊNCIAS E TECNOLOGIA
UNIVERSIDADE NOVA DE LISBOA

Temperature controlled mode

Control 40 K/14.5 bar

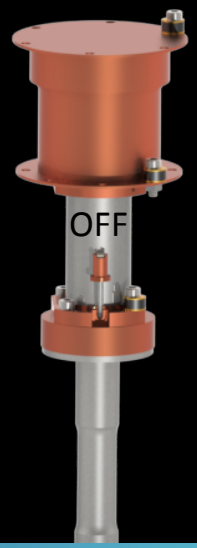


Heat power: 1 W

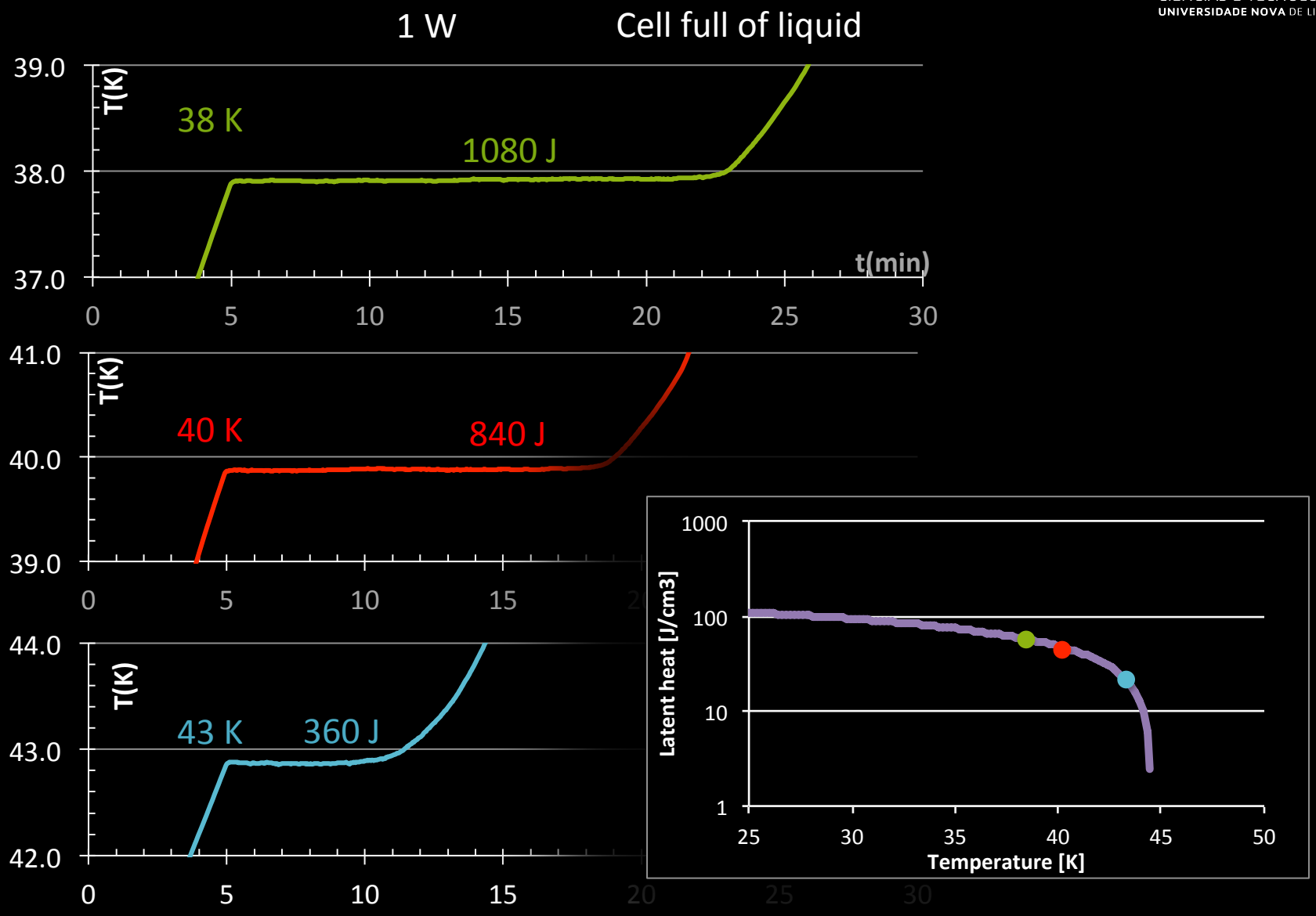


S-S N_2 @ 35 K → 90 cm^3 / 88 g

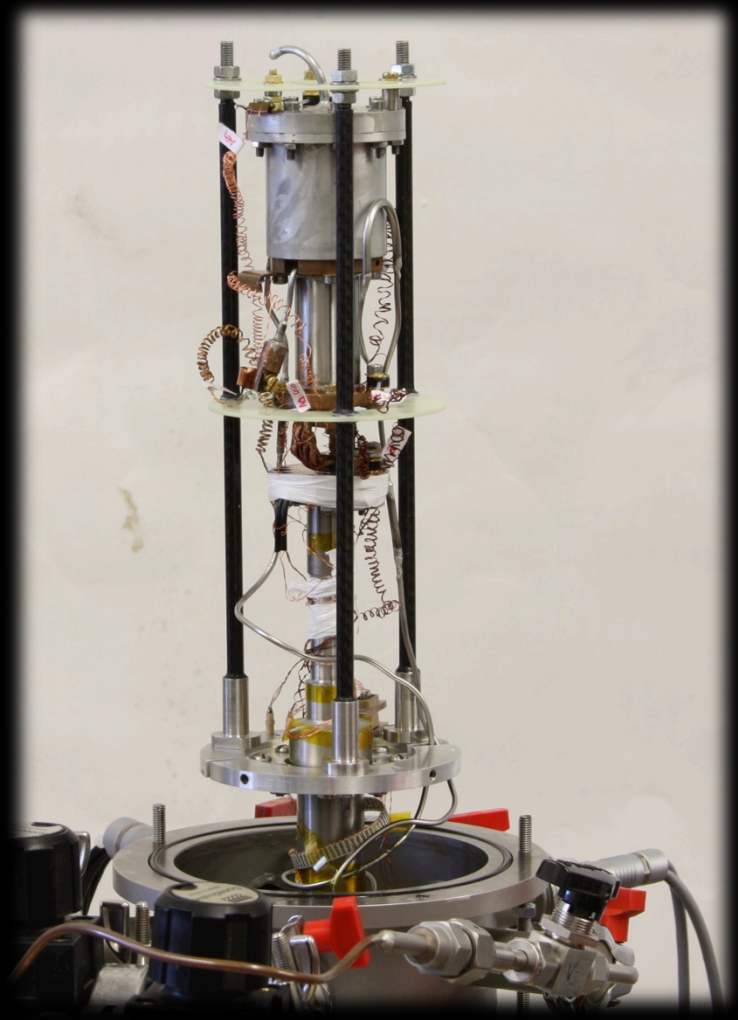
Liquid Neon → 25 cm^3 / 22.5 g

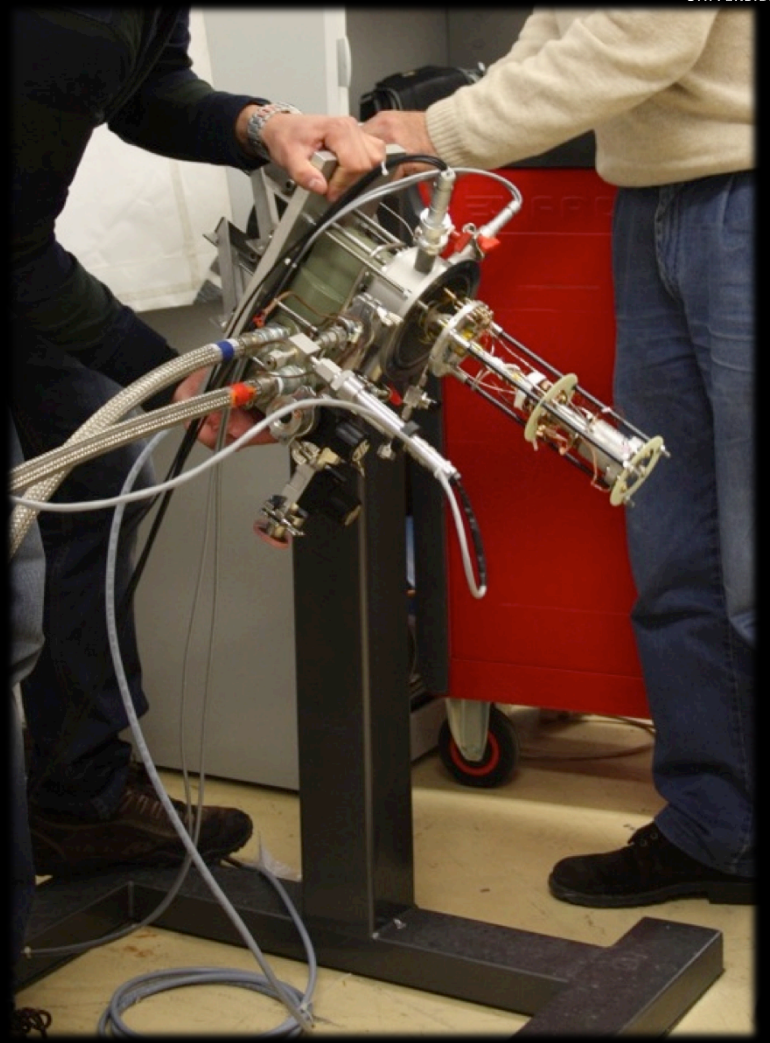


Results


1 W
Cell full of liquid
39.0
38.0
37.0
T(K)
38 K
1080 J
t(min)
0
5
10
15
20
25
30
41.0
40.0
39.0
T(K)
40 K
840 J
0
5
10
15
44.0
43.0
42.0
T(K)
43 K
360 J
0
5
10
15
20
25
30
1000
100
10
1
Latent heat [J/cm3]
25
30
35
40
45
50
Temperature [K]

Gravity insensitive system





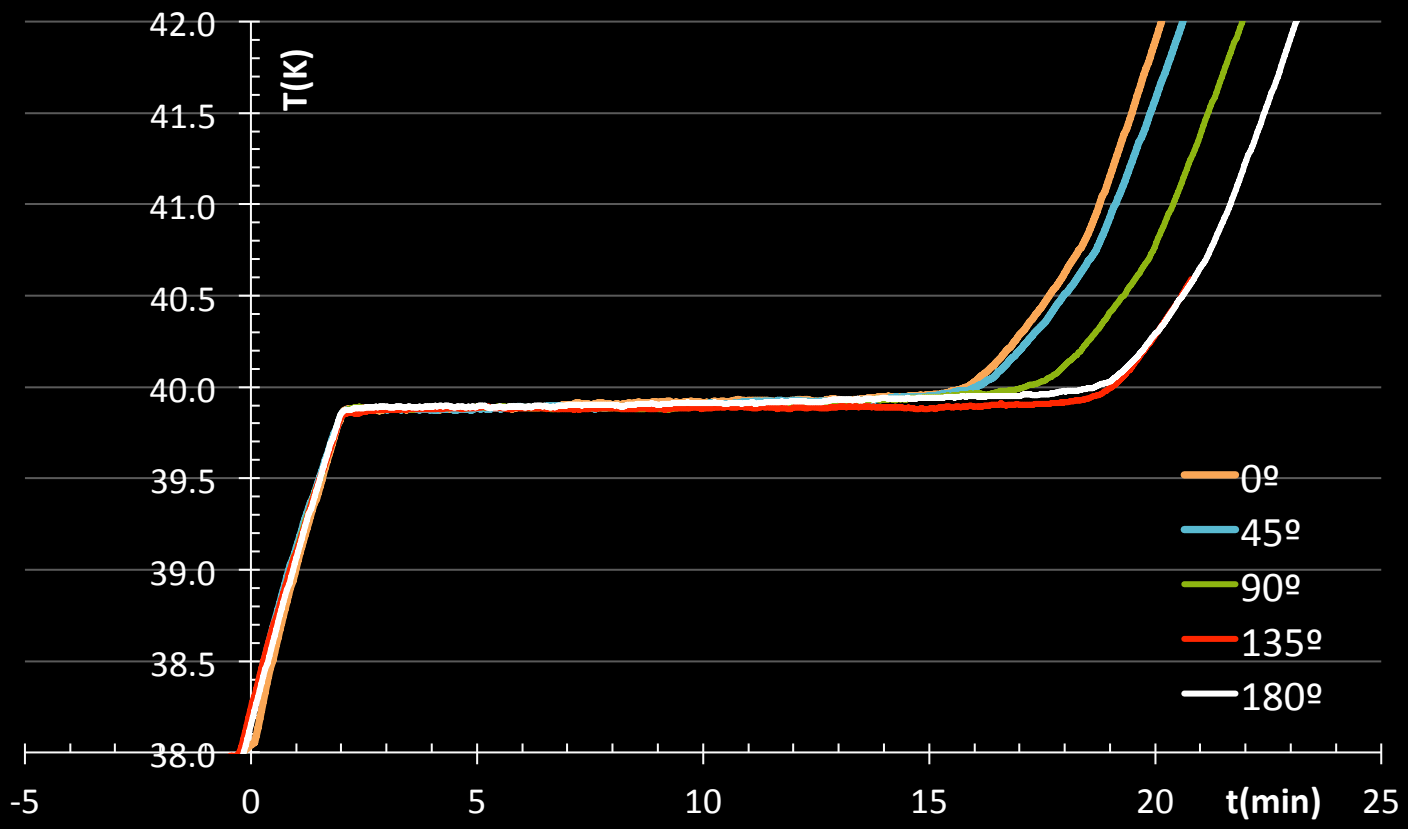
FACULDADE DE
CIÊNCIAS E TECNOLOGIA
UNIVERSIDADE NOVA DE LISBOA

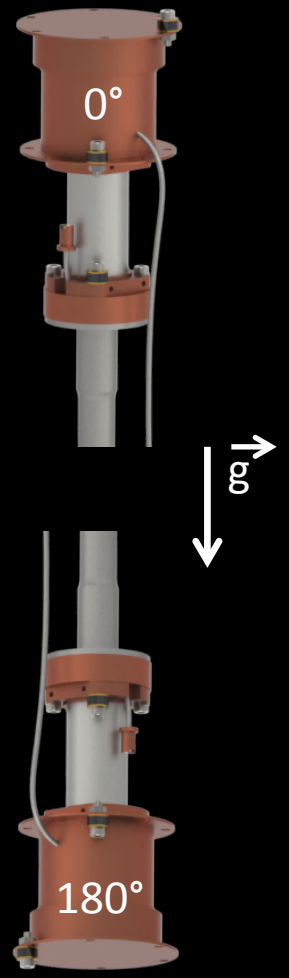
Gravity insensitive

FACULDADE DE CIÊNCIAS E TECNOLOGIA
UNIVERSIDADE NOVA DE LISBOA

1 W

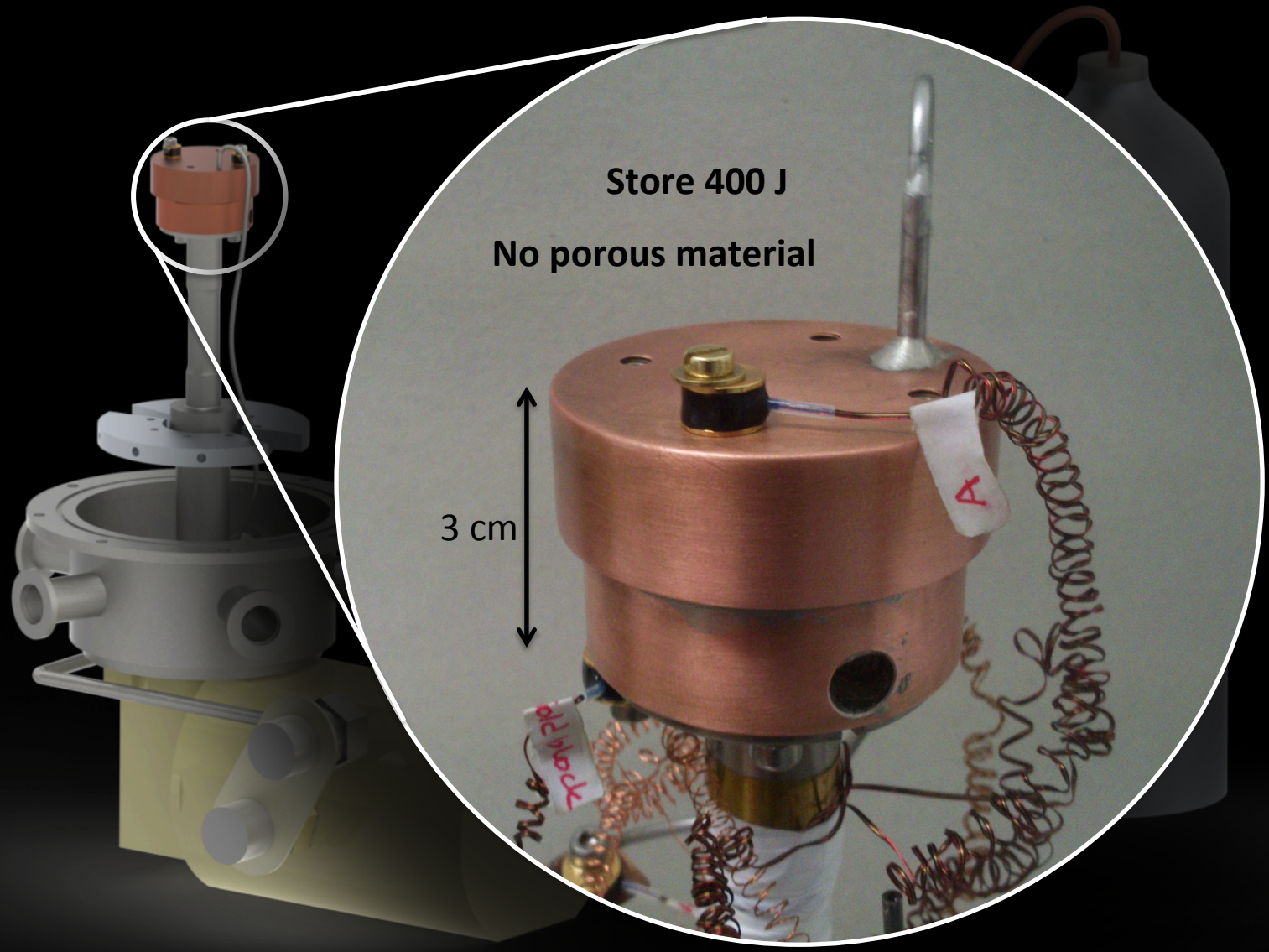
Different orientations



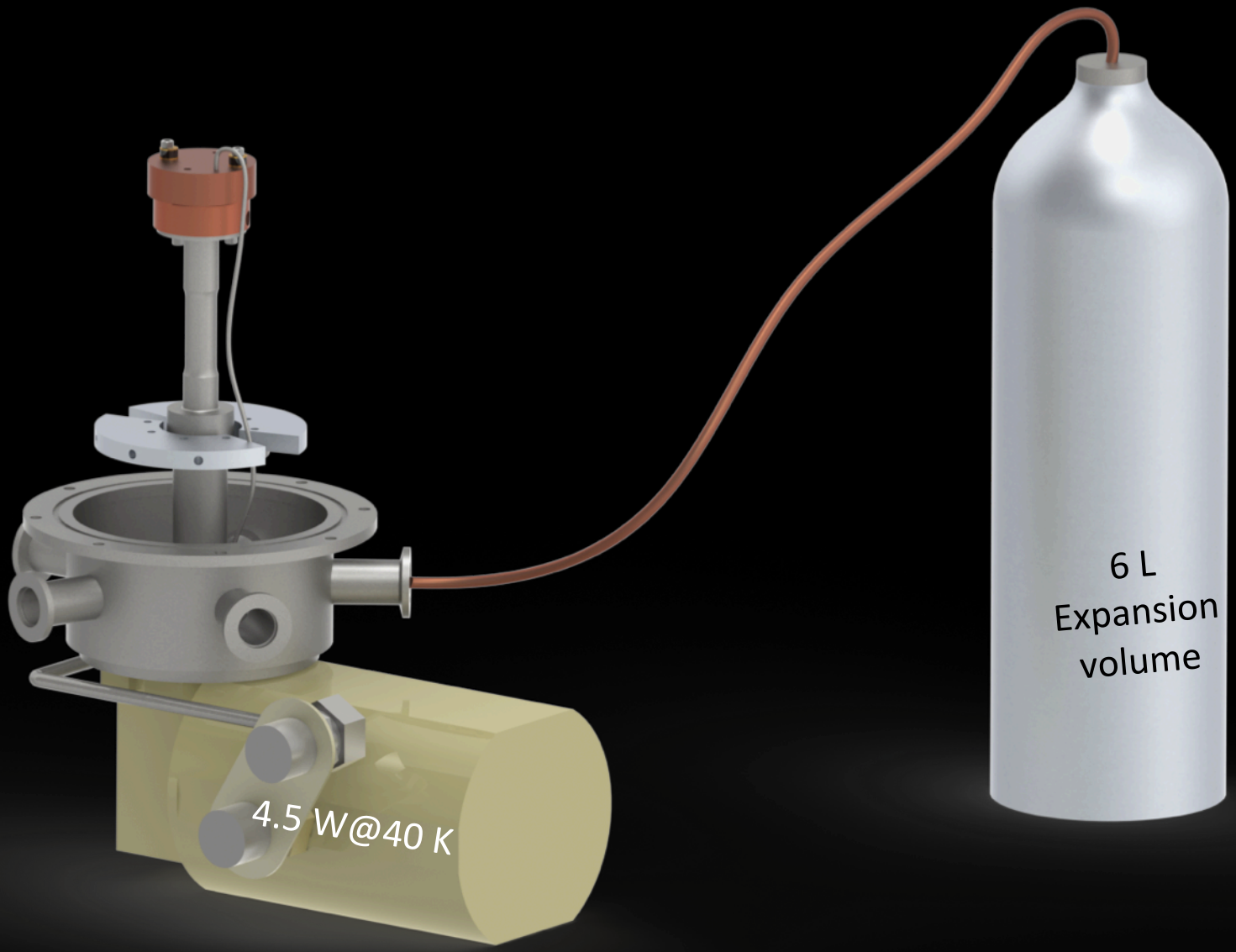


initial liquid filling 100%

Booster mode



Booster mode

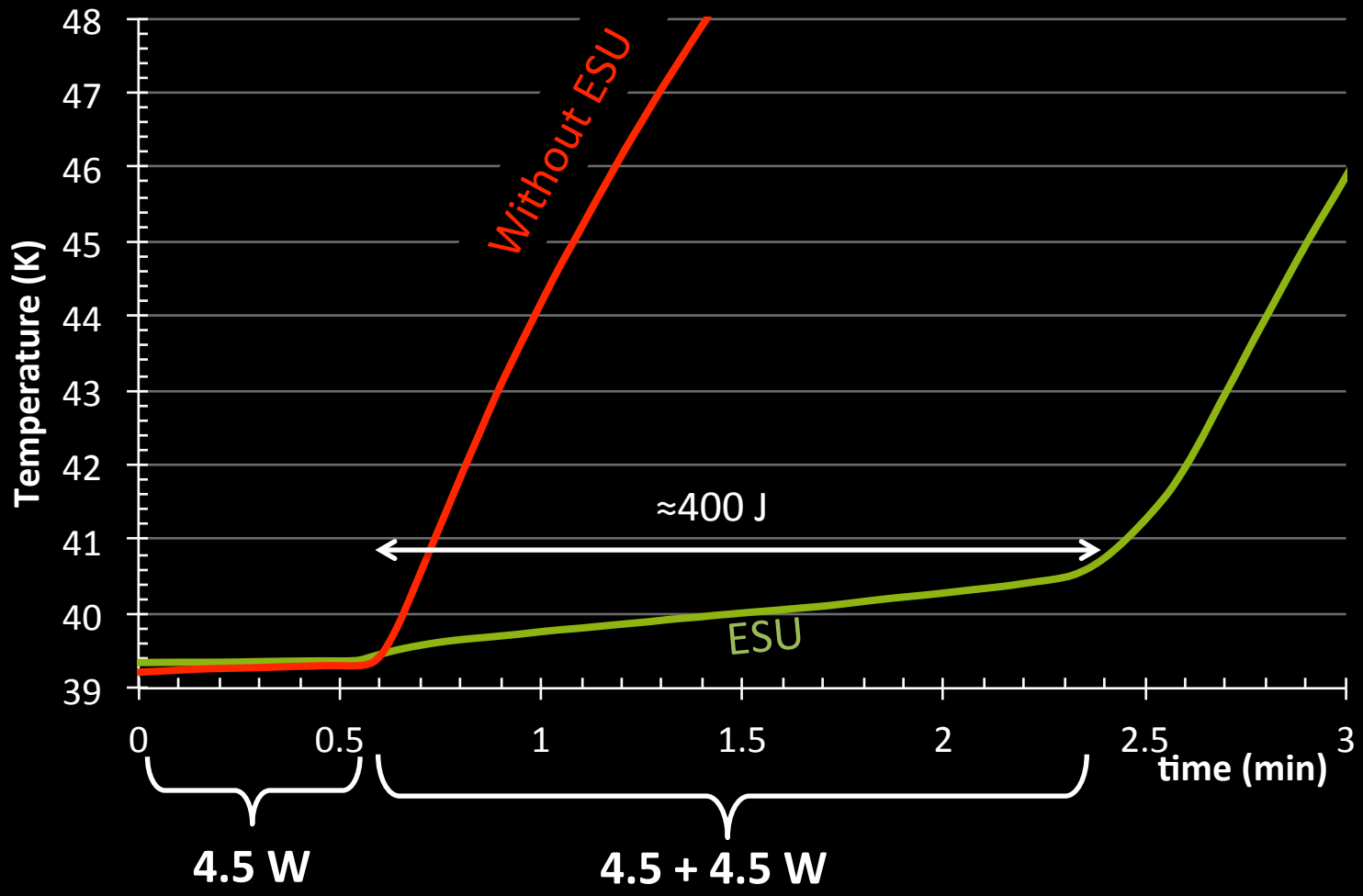


FACULDADE DE
CIÊNCIAS E TECNOLOGIA
UNIVERSIDADE NOVA DE LISBOA

Booster mode

FACULDADE DE CIÊNCIAS E TECNOLOGIA
UNIVERSIDADE NOVA DE LISBOA

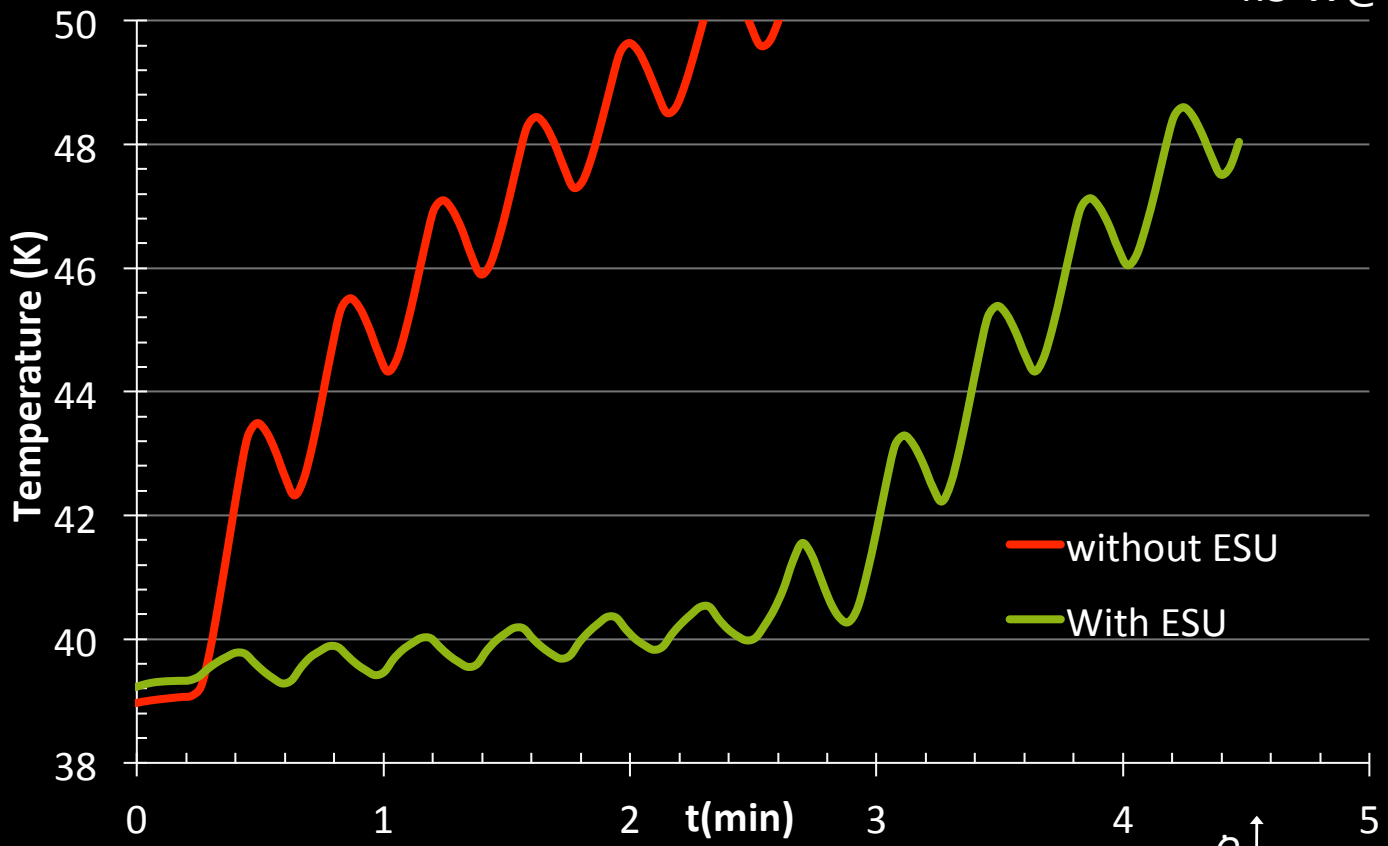
4.5 W@40 K GM- cryocooler

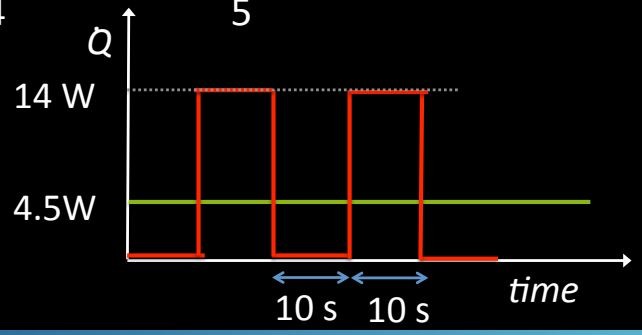


Booster mode

FACULDADE DE CIÊNCIAS E TECNOLOGIA
UNIVERSIDADE NOVA DE LISBOA

4.5 W@40 K GM- cryocooler





Conclusion

FACULDADE DE CIÊNCIAS E TECNOLOGIA
UNIVERSIDADE NOVA DE LISBOA

Liquid Neon ESU between 35 K and 43 K developed

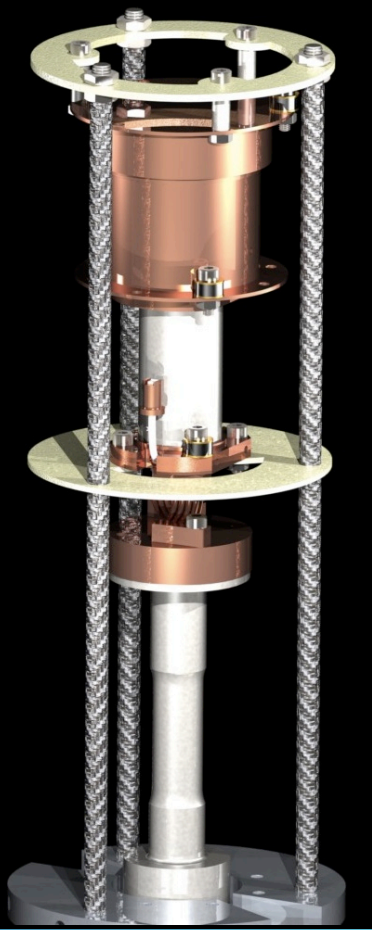
- Working at constant Temperature : Like at a triple point!
  - Tuneable temperature
  - More compact cold cell

-Gravity insensitive system

- Porous material < 5 µm

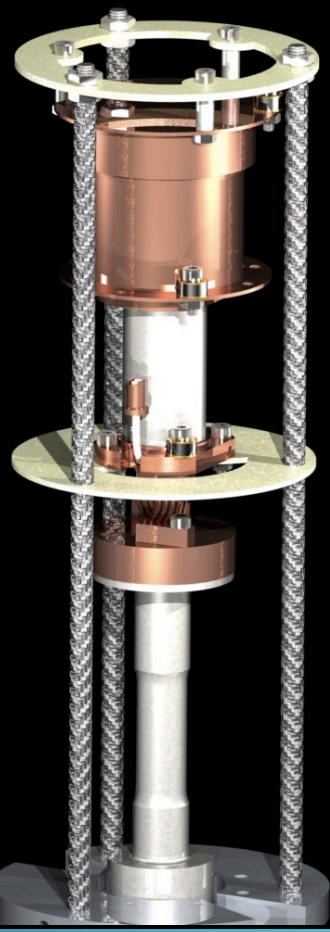
-2 different configurations:
Booster mode and independent cold source

- 900 J @ 40 K as independent cold source
- 400 J @ 40 K as booster mode

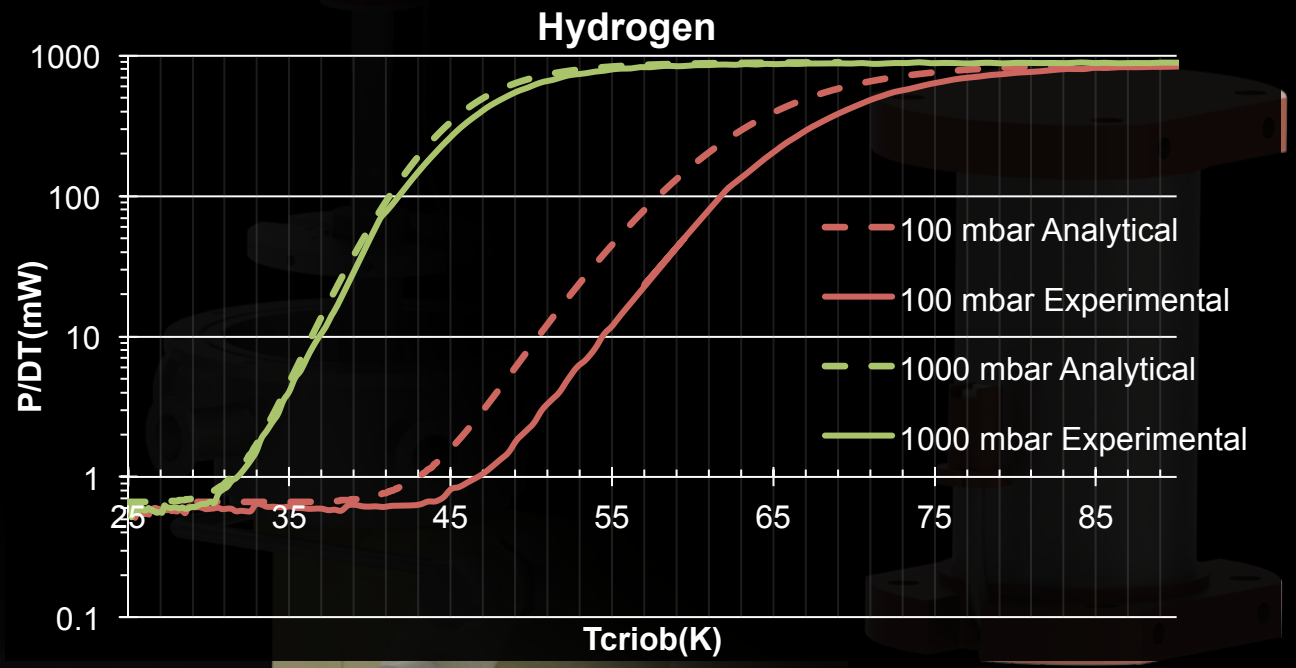


FACULDADE DE CIÊNCIAS E TECNOLOGIA
UNIVERSIDADE NOVA DE LISBOA

Thank you!



Experimental Apparatus



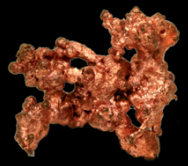
What is an ESU?

FACULDADE DE CIÊNCIAS E TECNOLOGIA
UNIVERSIDADE NOVA DE LISBOA

Enthalpy Reservoir

Sensible heat

-Materials with high Cp


Latent heat

-Cryogenic fluids

	Erbium	Copper	Ice water	Neon	SS- N_2
@40 K	1.3 J/cm^{3}K	0.5 J/cm^{3}K	0.3 J/cm^{3}K	50 J/cm^3	9 J/cm^3
Mass (g)	2400	8500	1400	20	110
Volume (cm^3)	380	960	1500	20	110

Store 1000 J → [38 K ,40 K]

Temperature drift = 2 K

Constant T