

15 K liquid H₂ Energy Storage Unit

for future ESA science missions

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Patrícia Borges de Sousa



FACULDADE DE
CIÊNCIAS E TECNOLOGIA
UNIVERSIDADE NOVA DE LISBOA



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The background consists of several overlapping, semi-transparent sheets of paper. Each sheet features a large, bold, black question mark. The papers are layered in a way that creates a sense of depth and complexity, with some sheets partially covering others. The overall color palette is monochromatic, using shades of gray and black.

Why?

ATHENA+ observatory

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ATHENA TO STUDY THE HOT AND ENERGETIC UNIVERSE

27 June 2014

ESA has selected the Athena advanced telescope for high-energy astrophysics as its second 'Large-class' science mission.

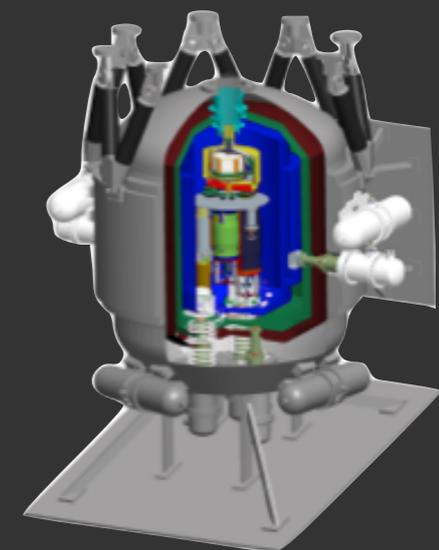
<http://sci.esa.int/cosmic-vision/54241-athena-to-study-the-hot-and-energetic-universe/>

- X-ray observatory
- L2 orbit
- 2 instruments: WFI and **X-IFU**
- **5 yr** lifetime (10 yr goal)
- To be launched in **2028**

TES microcalorimeter

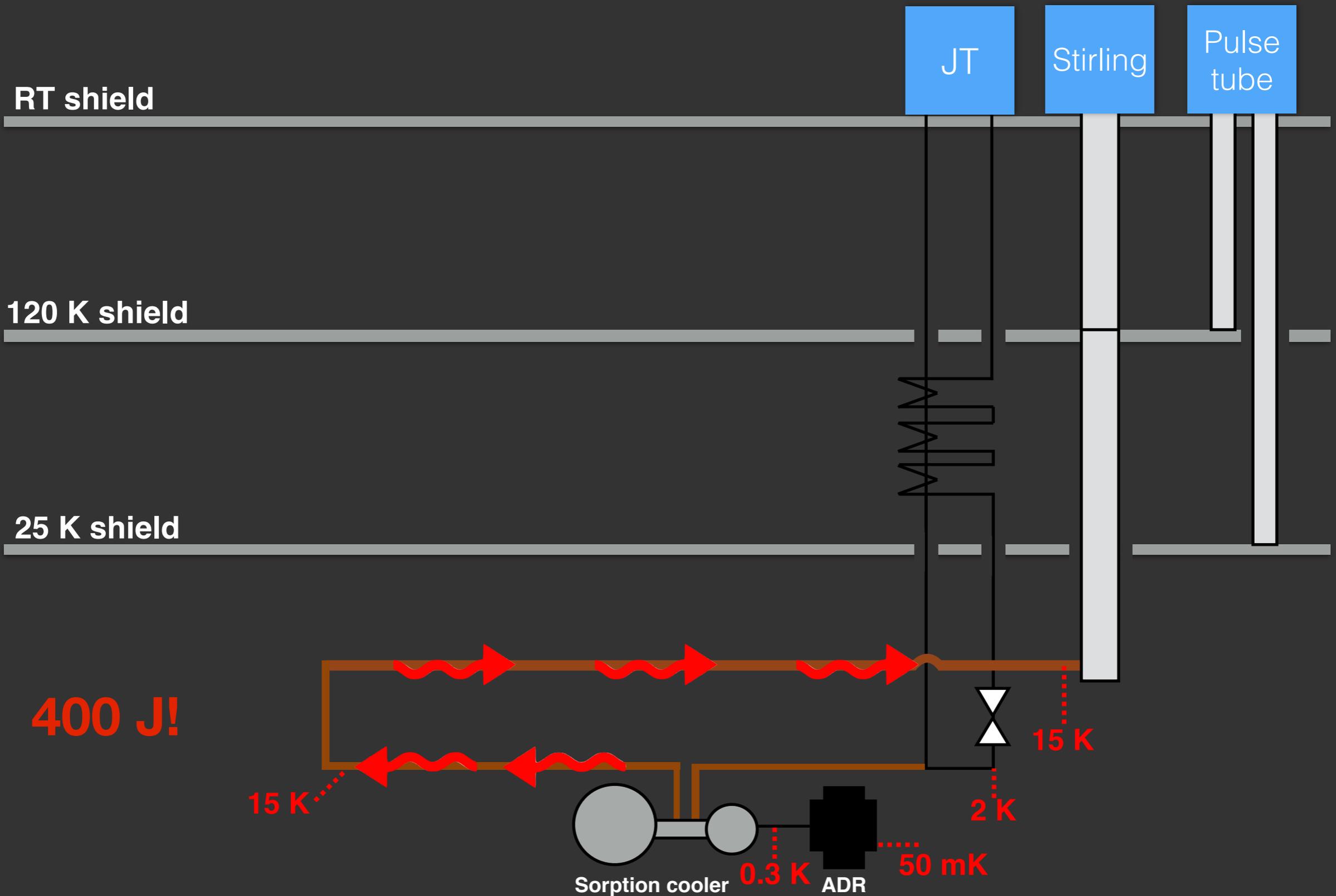
Complex cryogenic chain

Operating T is 50 mK



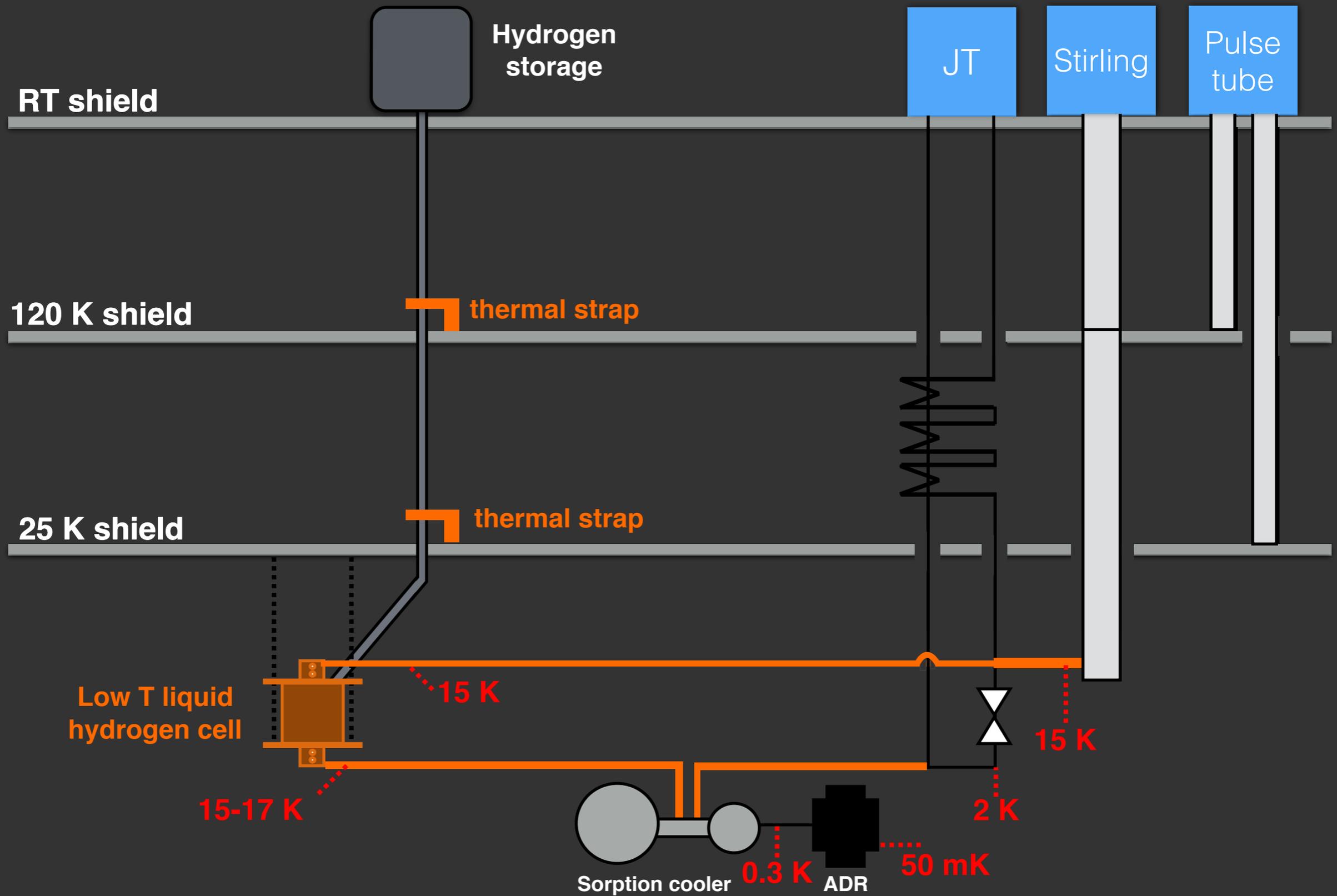
The cryogenic chain

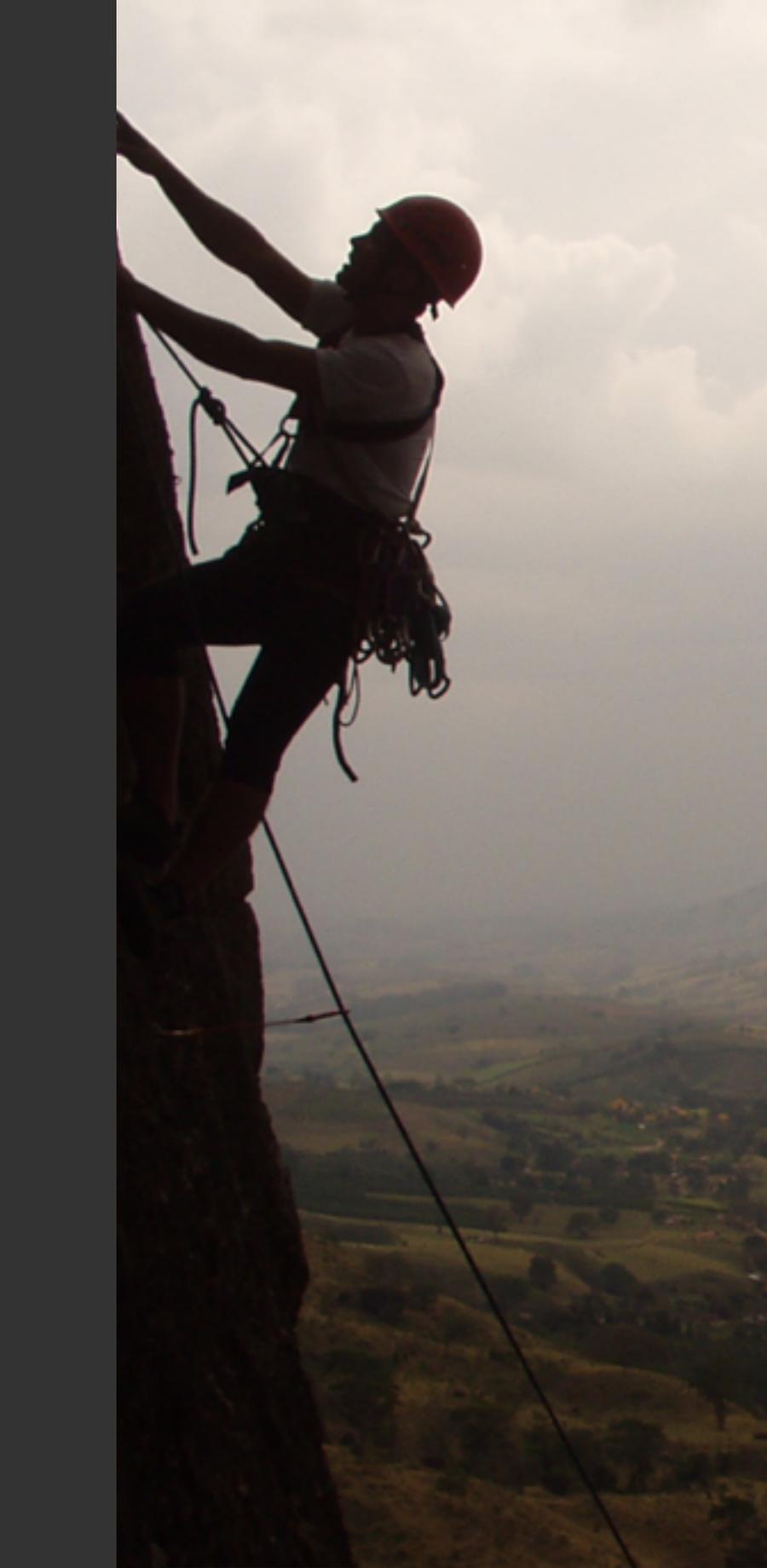
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The cryogenic chain

4



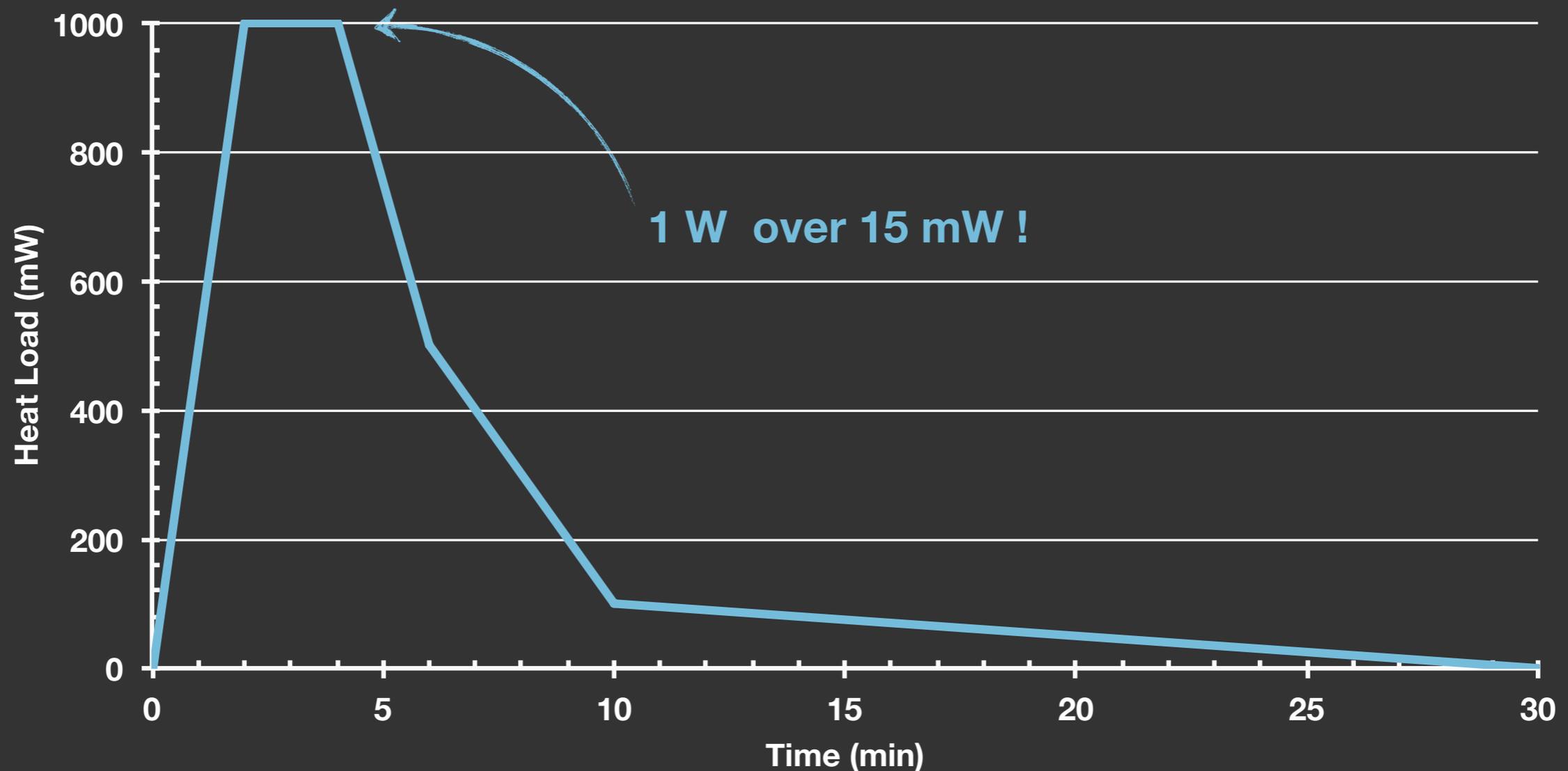


What's the challenge?

The request:

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- **Absorb a heat burst** from the sorption cooler
- **Heat load:** 30 min, 400 J
- Baseline cooling power is **15 mW**



Possible solutions:

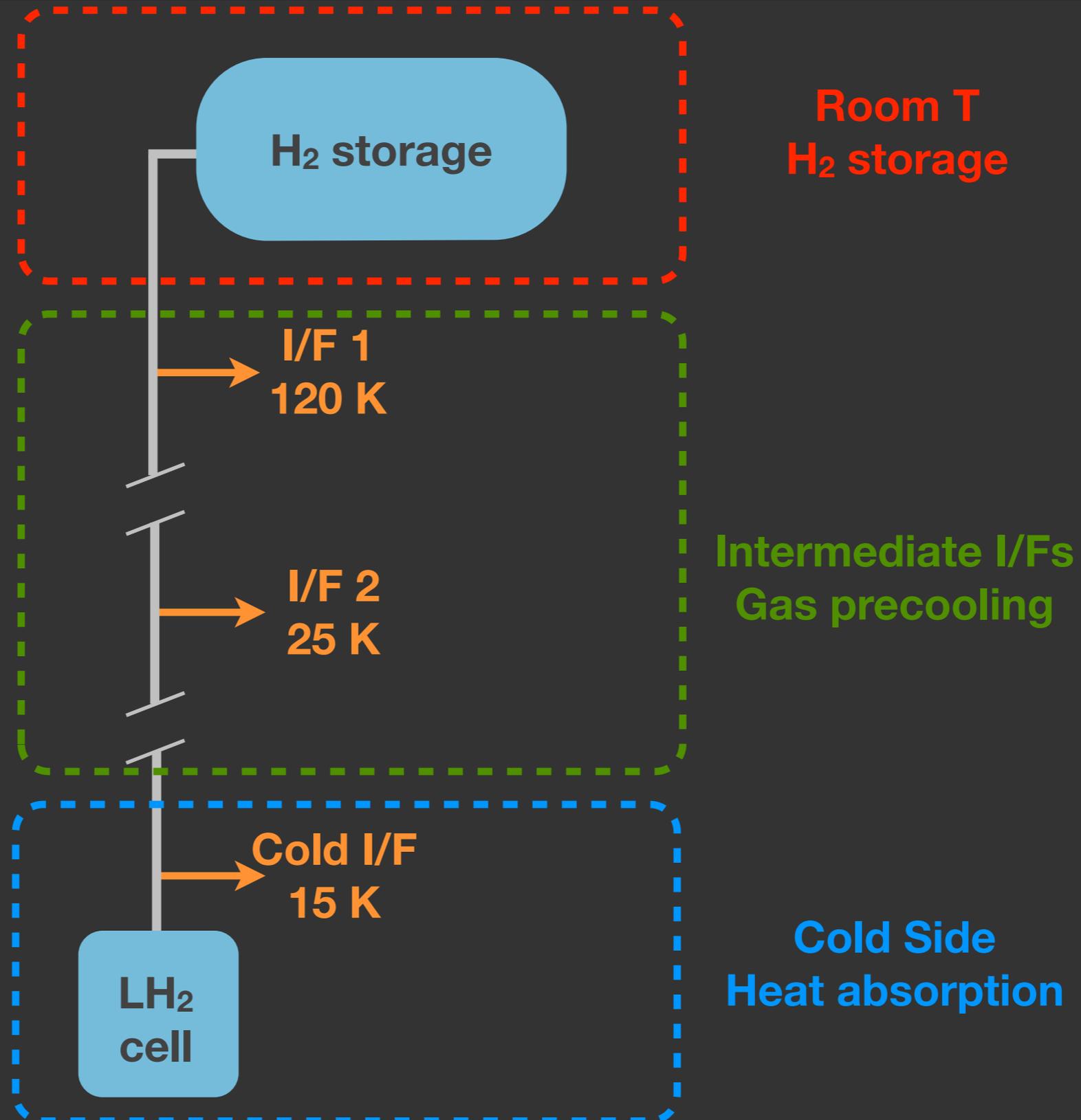
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- **For storing 400 J:**
 - Materials with **high heat capacity**
 - Latent heat at the **triple point** of H₂
 - Latent heat of **liquid-vapor phase change**

Material	Mass @ LT	Volume @ LT	Volume @ RT
Er-Ag _{0.9} -Al _{0.1}	≈ 2200 g	≈ 220 cm ³	N/A
H ₂ S-L-V	≈ 6.8 g	≈ 89 cm ³	tbd
H ₂ L-V	≈ 0.9 g	≈ 12 cm³	53 liters

Overall view of the system

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COLD side

Requirements @ low T

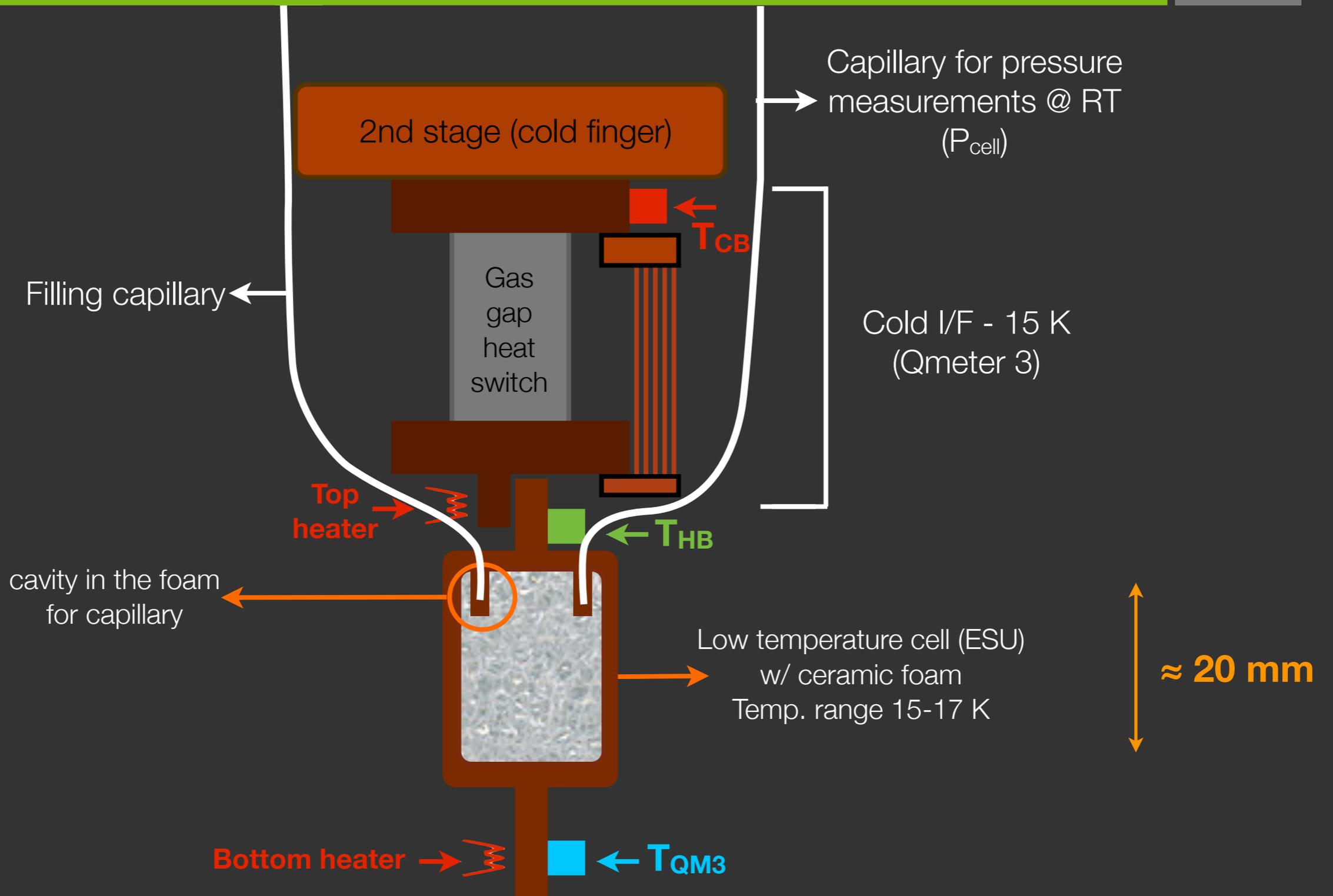
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- Absorb **440 J** in **30 min** → **13 cm³ of LH₂**
- **$T < 17$ K** at all times → **$P < 300$ mbar**
(53 liters)
- **15 mW** cooling power → **Gas pre-cooling**
- **Gravity-insensitive** → **Porous foam**
(< 250 μm)
- **Ortho-para** conversion → **Catalysis** needed?



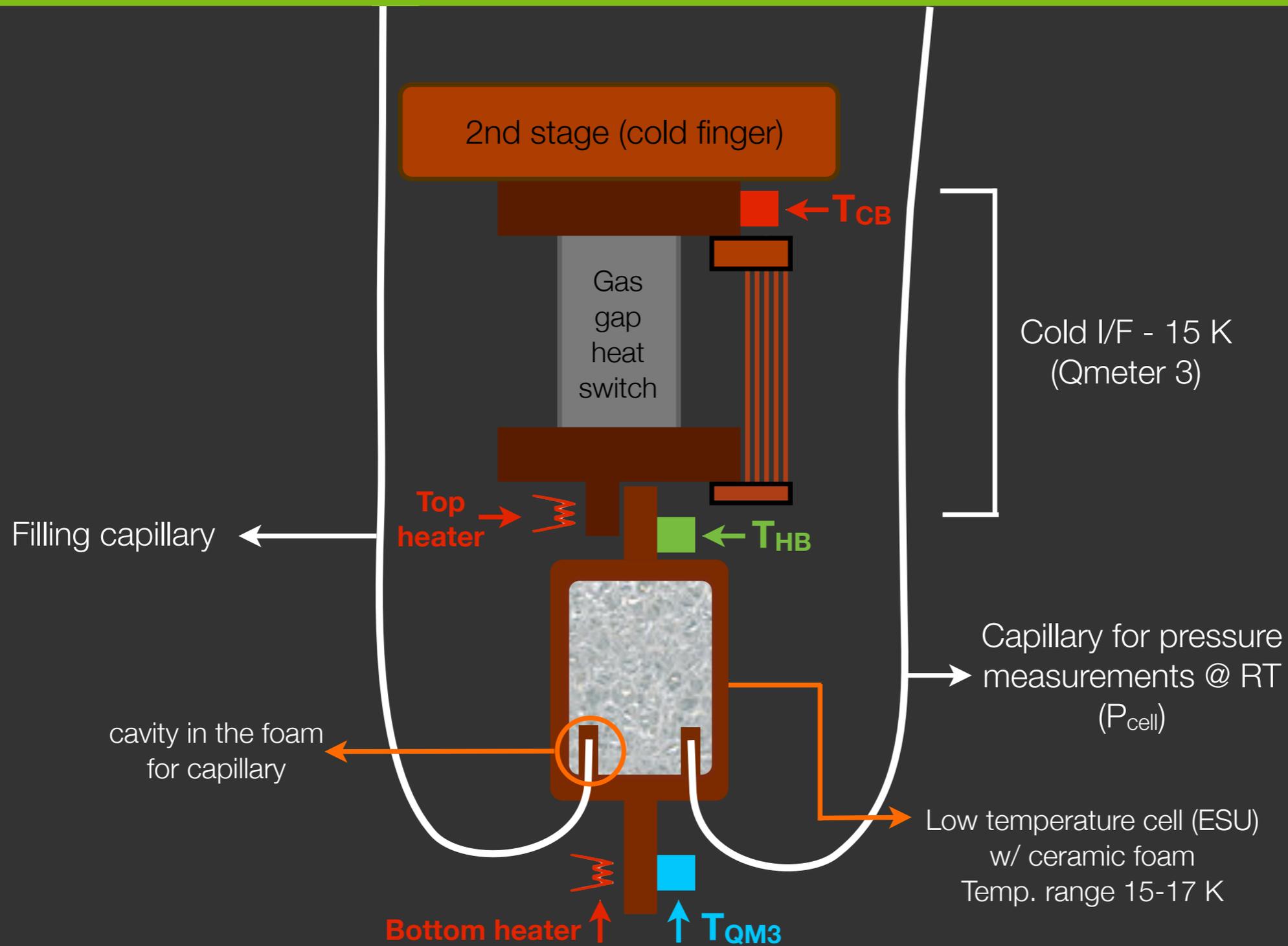
Baseline configuration

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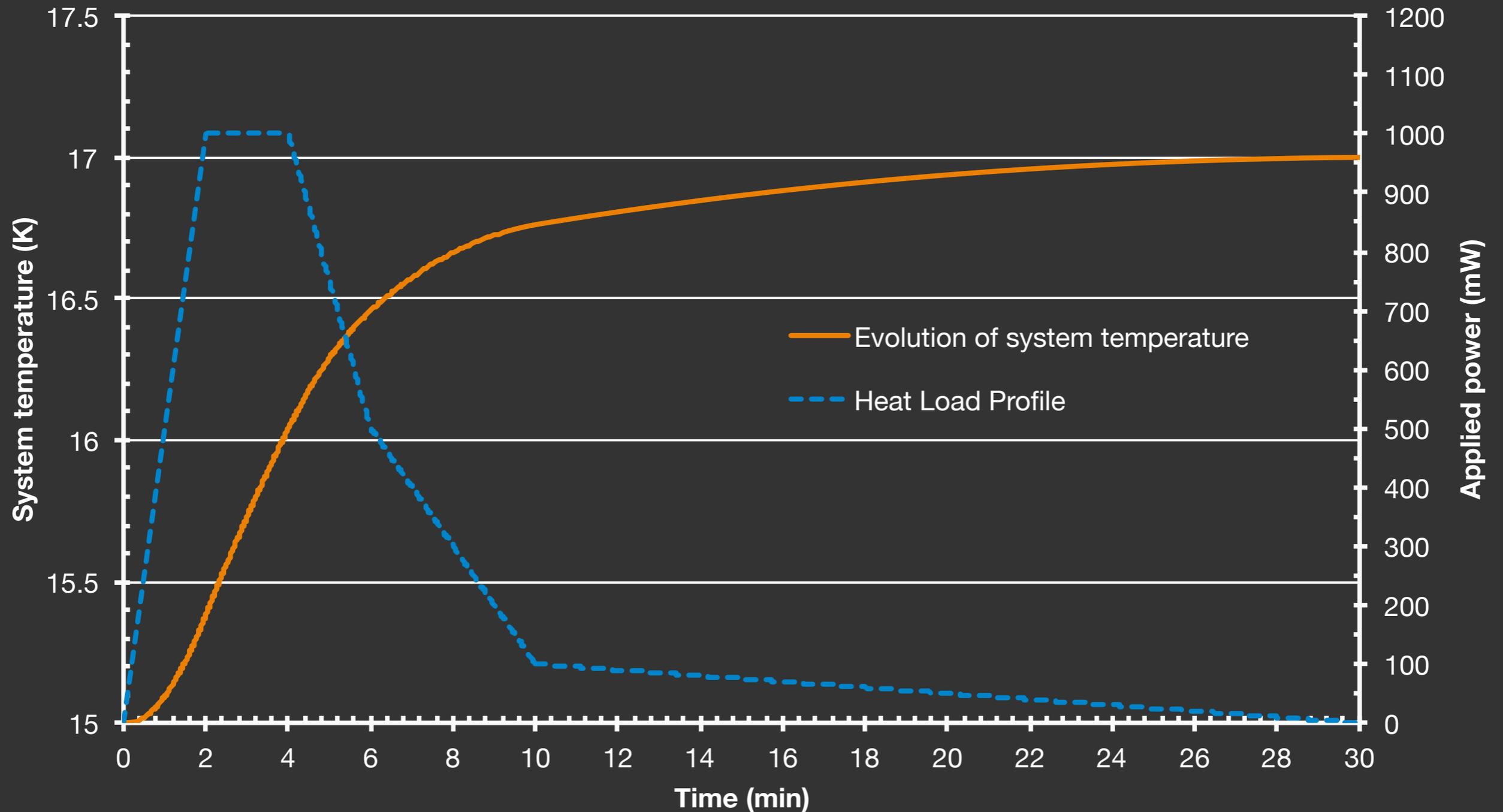
Antigravity configuration

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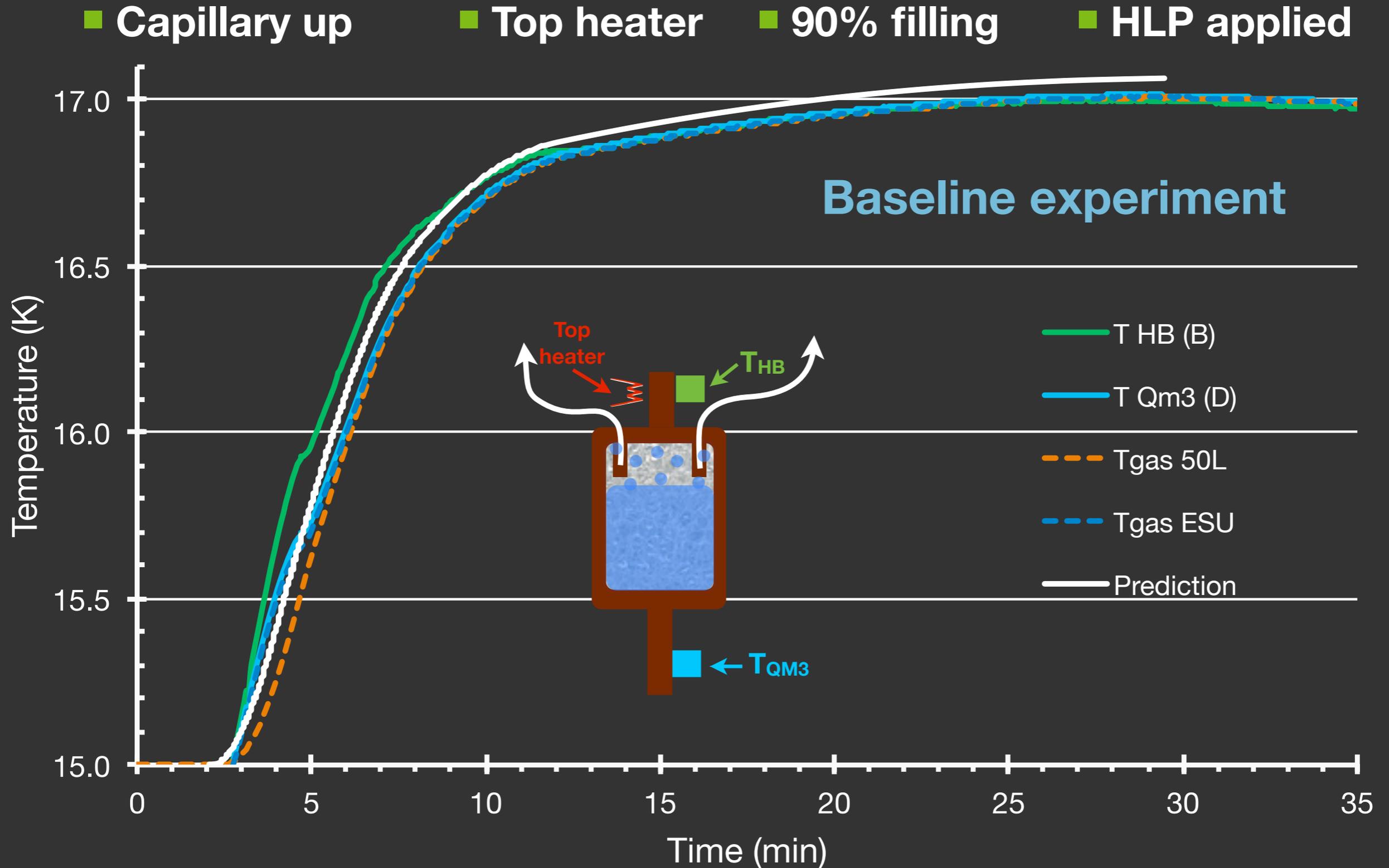
Absorbing the heat load

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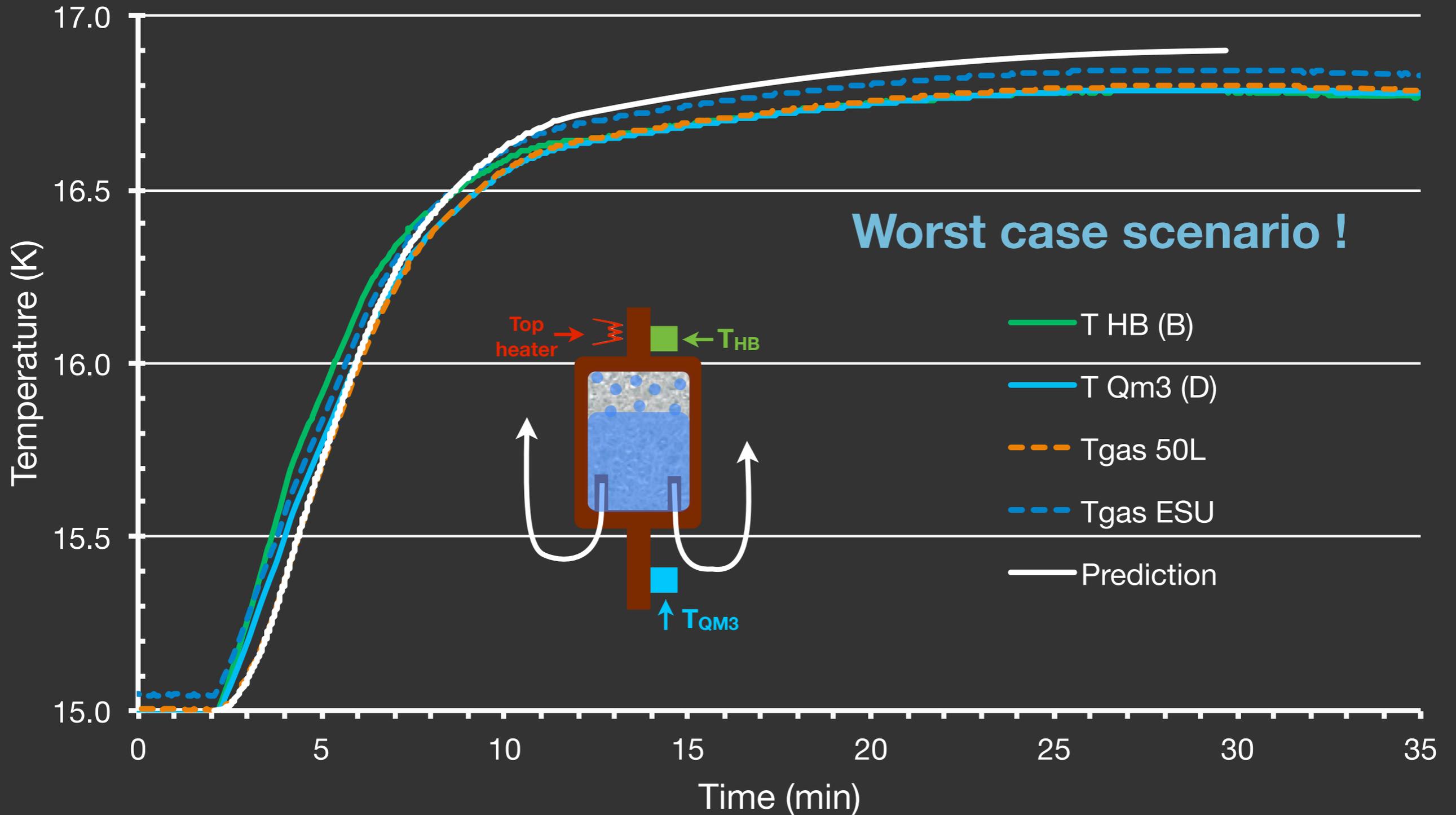
Using an expansion volume

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Using an expansion volume

■ Capillary down ■ Top heater ■ 90% filling ■ HLP applied



The image shows a close-up, angled view of a stack of numerous copper pipes. The pipes are arranged in a way that creates a strong sense of depth and repetition, with light reflecting off their metallic surfaces. The text 'INTERMEDIATE I/Fs' is centered over the image in a bold, light blue font. The background is a dark, semi-transparent overlay that allows the texture of the pipes to be visible.

INTERMEDIATE I/Fs

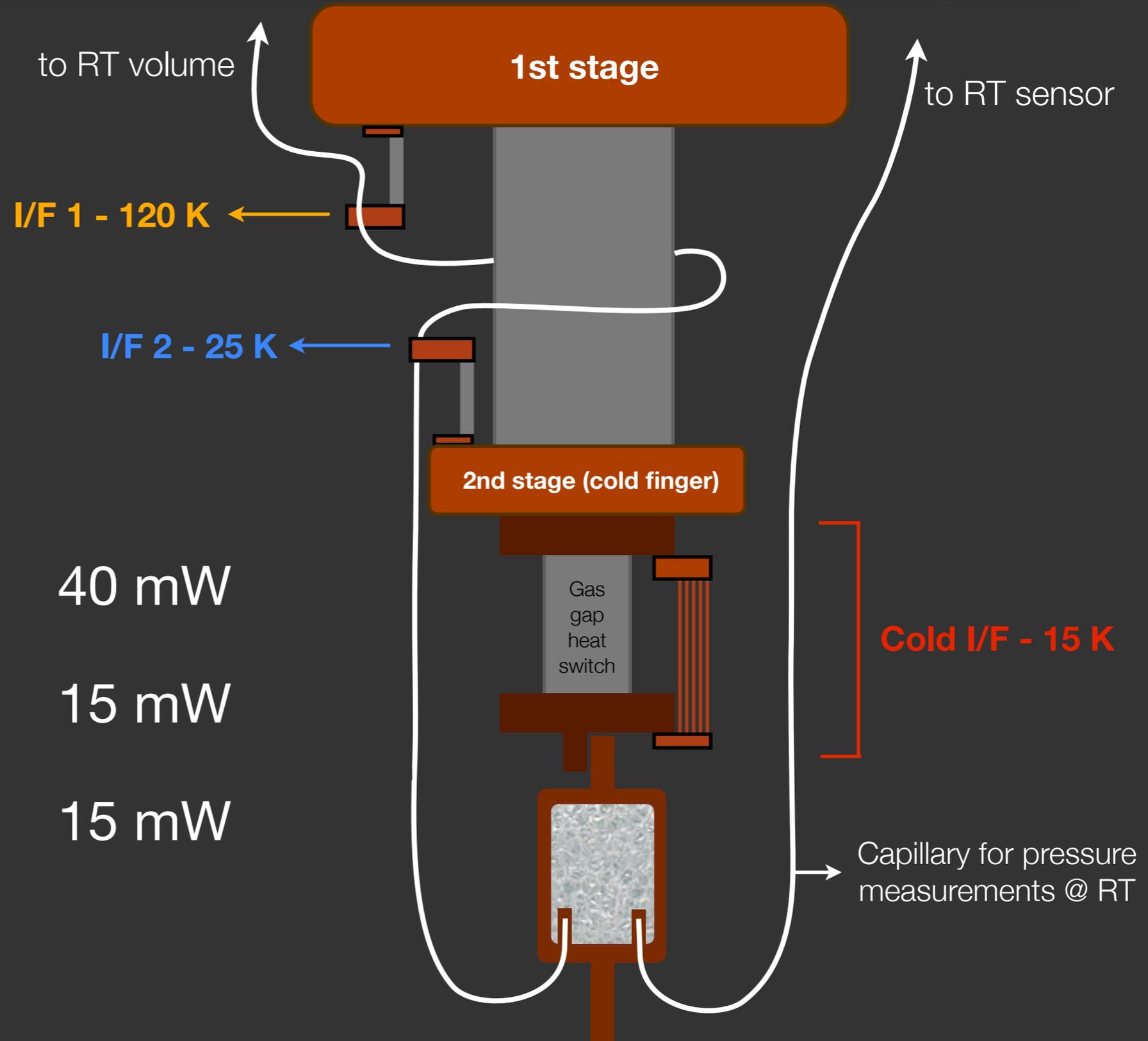
Intermediate Interfaces

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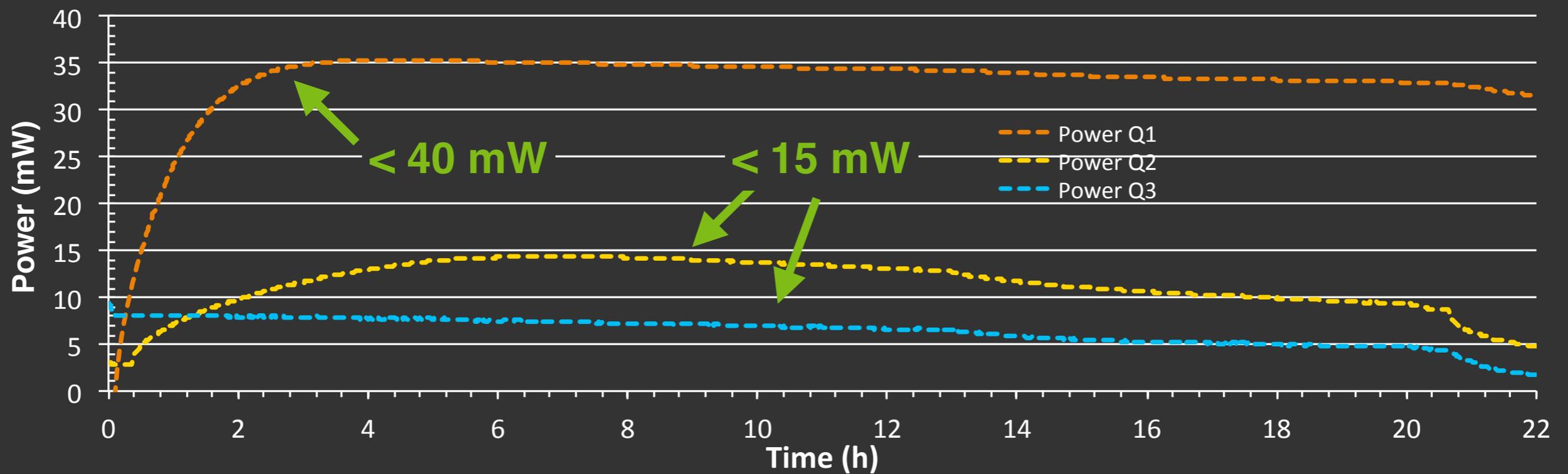
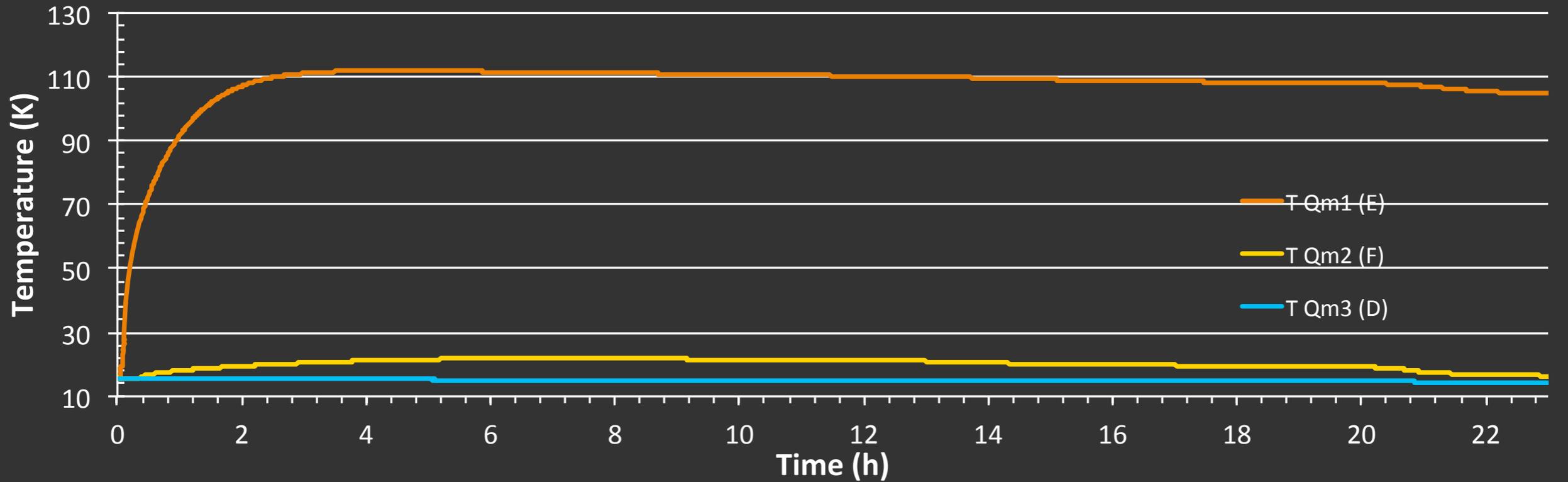
If condensation takes no less than 21 h

- I/F 1 120 K 40 mW
- I/F 2 25 K 15 mW
- Cold I/F 15 K 15 mW



Condensation phase - I/Fs

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The image features two green hydrogen storage cylinders in the background, with two metal connectors in the foreground. The connectors are silver-colored with orange seals. The text 'H2 Storage' is overlaid in a light blue font.

H₂ Storage

How to store hydrogen?

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~~Expansion
volume~~

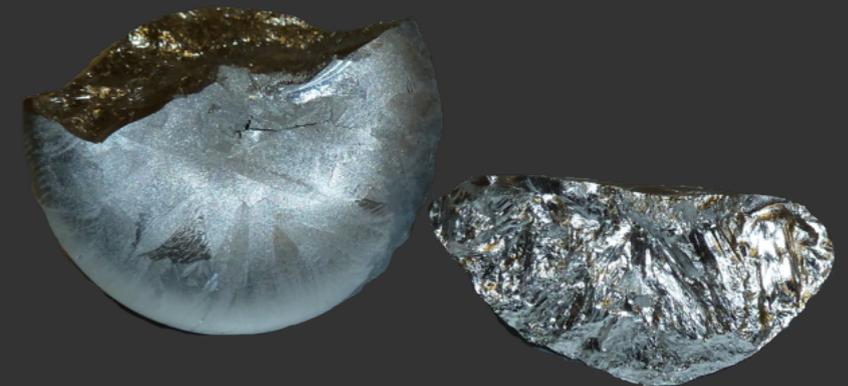
too large!

Used by Bowman *et al.*
in the Planck satellite



~~Physisorption~~

needs low T!



Chemisorption

compact @ RT!

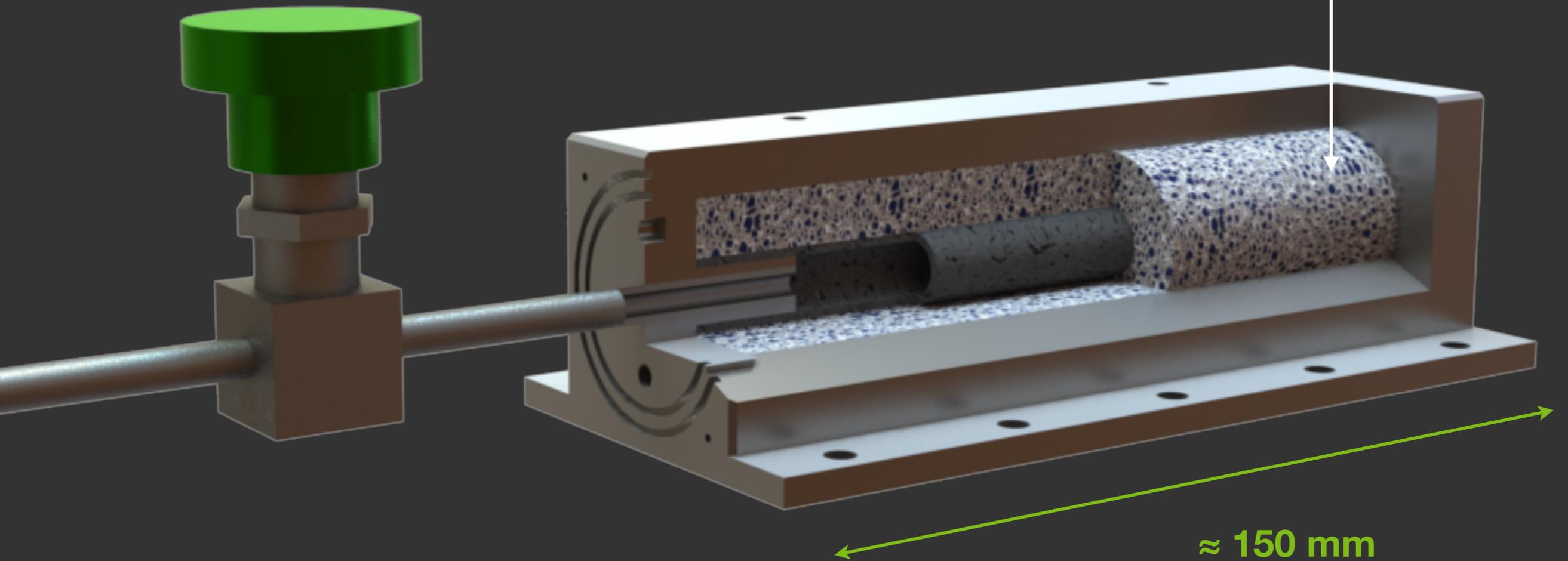
Metal hydride canister

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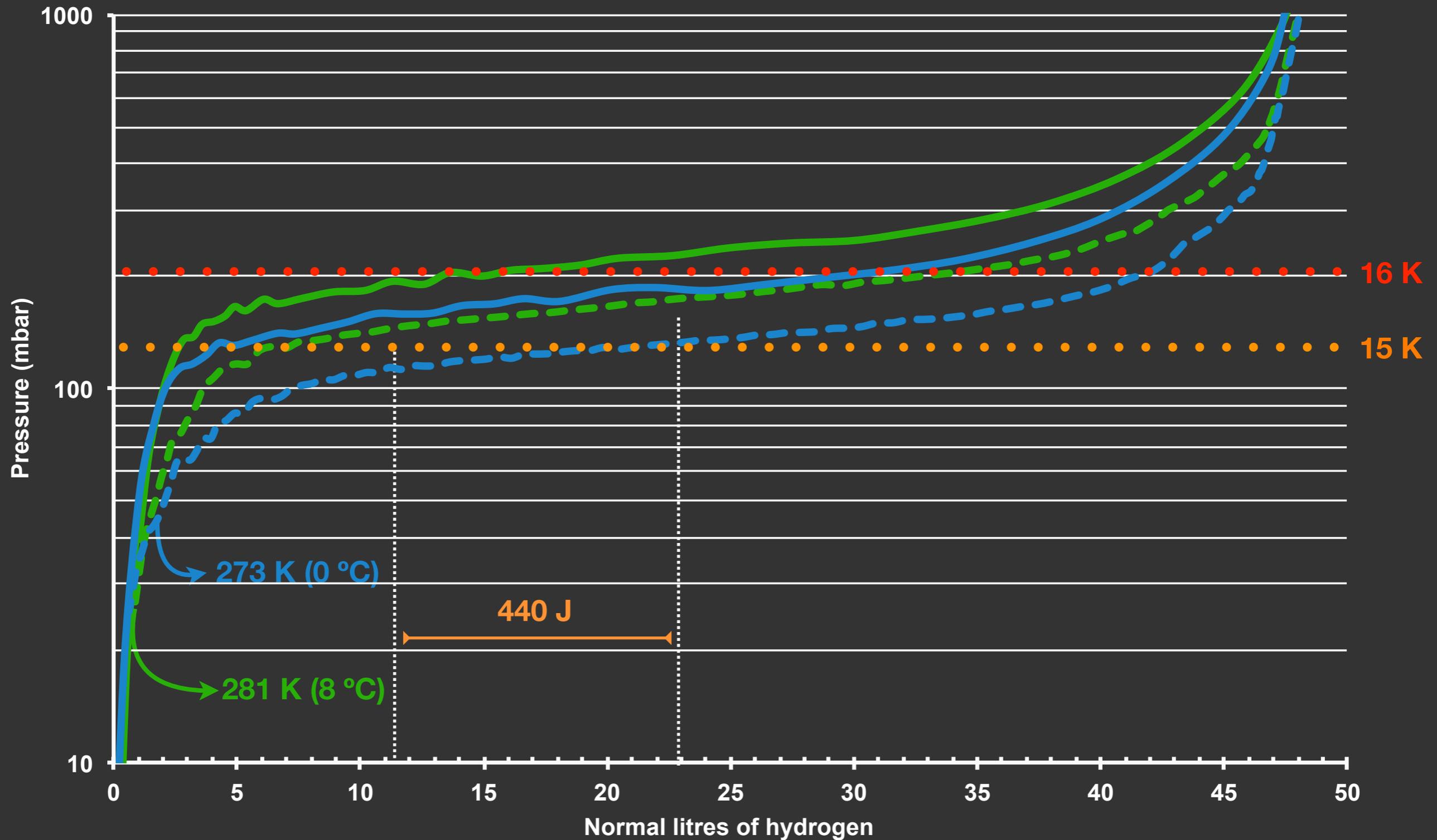
Expansion volume ≈ 56 litres

MH canister $\approx 150 \text{ cm}^3$

Aluminium foam
+ $\text{LaNi}_{4.8}\text{Sn}_{0.2}$

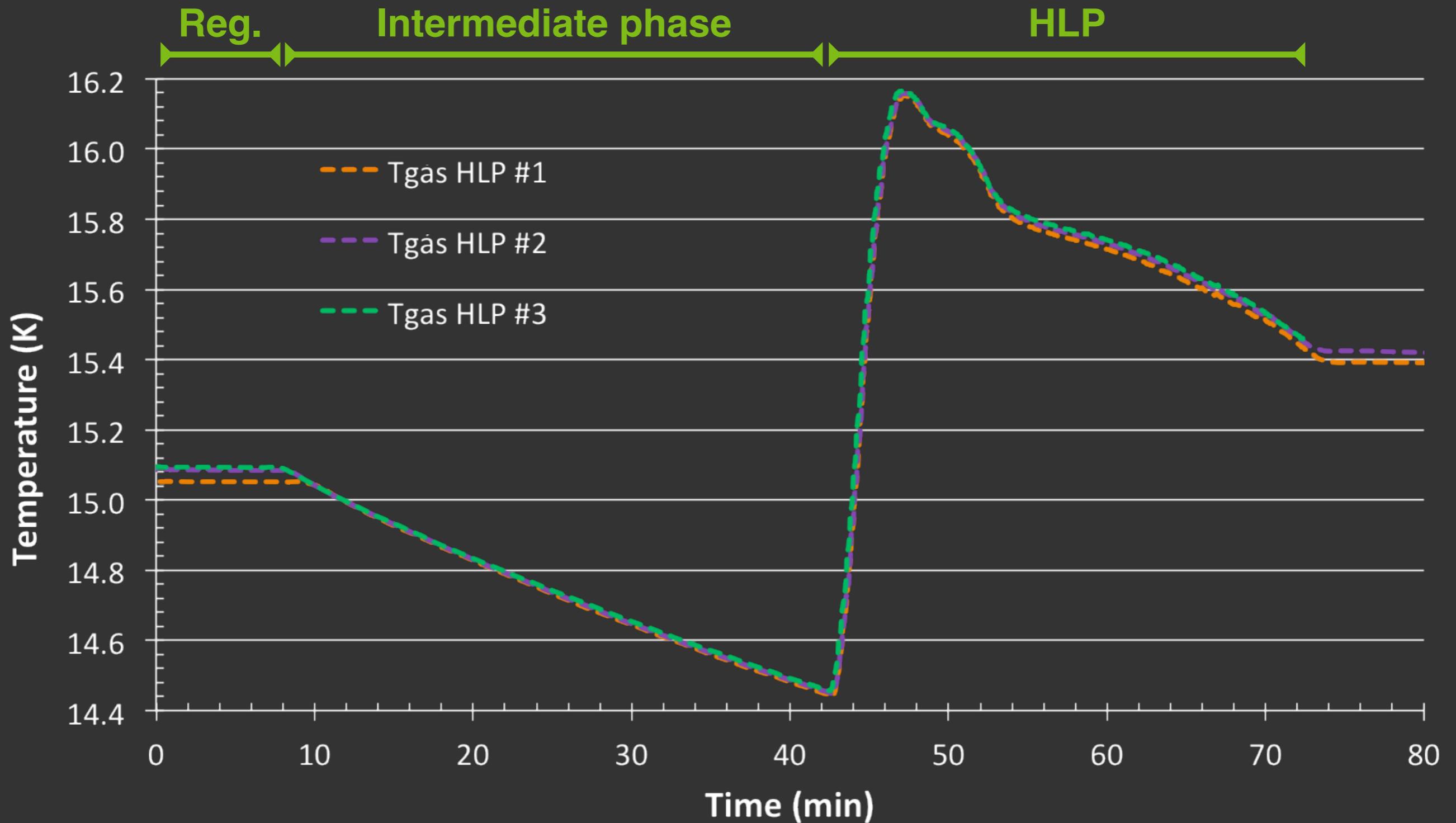


Absorption/desorption data



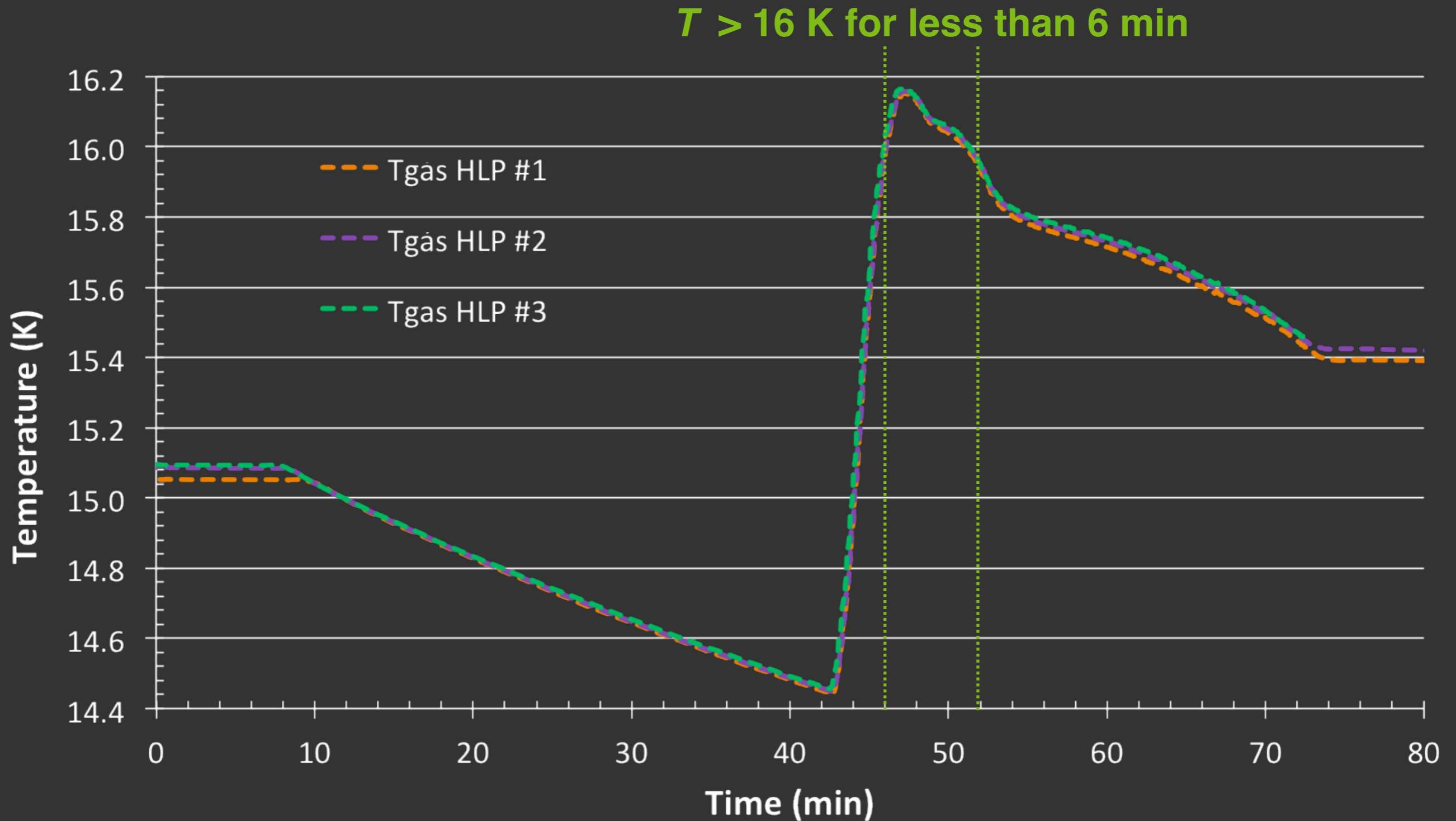
ESU cycling with MH canister

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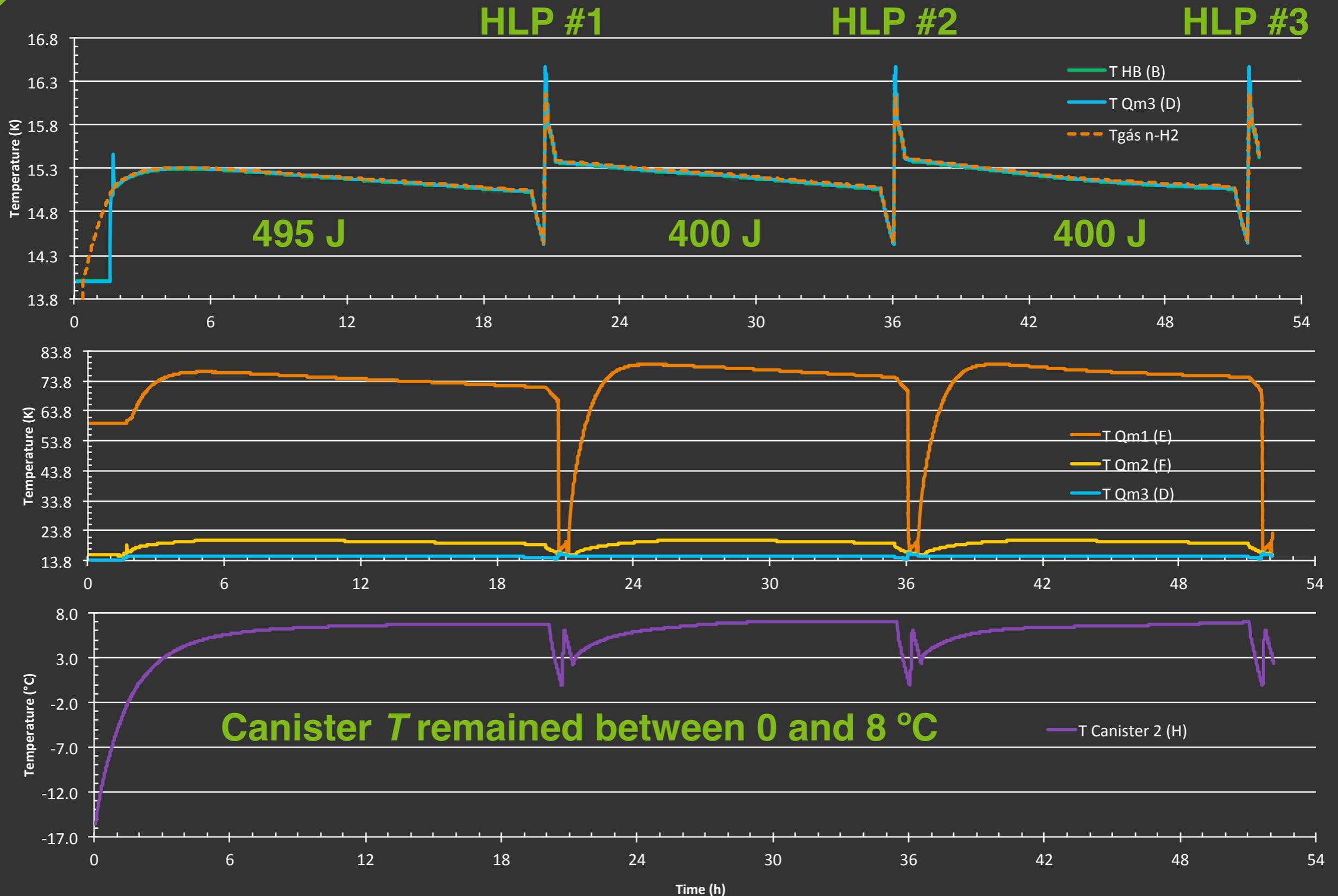
ESU cycling with MH canister

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ESU cycling with MH canister

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Future work

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- **Development Model:**

- Design & construction of DM ✓
- Performance testing ✓

- **Cryocooler "makeover":**

- Design & construction of a cryocooler suitable for EM testing ✓

- **Engineering Model:**

- Design & construction of the EM (AST) ✓
- Performance testing **IN PROGRESS**
- Shaker & thermal shock tests (AST)
- System qualification

TRL 9

TRL 8

TRL 7

TRL 6

TRL 5

TRL 4

TRL 3

TRL 2

TRL 1

Technology development
& demonstration in
relevant environment



- **Martin Linder**



- **Daniel Martins**
- **João Noite**



- **Patrícia Borges de Sousa**
- **Gonçalo Tomás**
- **Jorge Barreto**
- **Isabel Catarino**
- **Grégoire Bonfait**



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- **Patricia de Rango**
- **Richard Haettel**

Thank you!