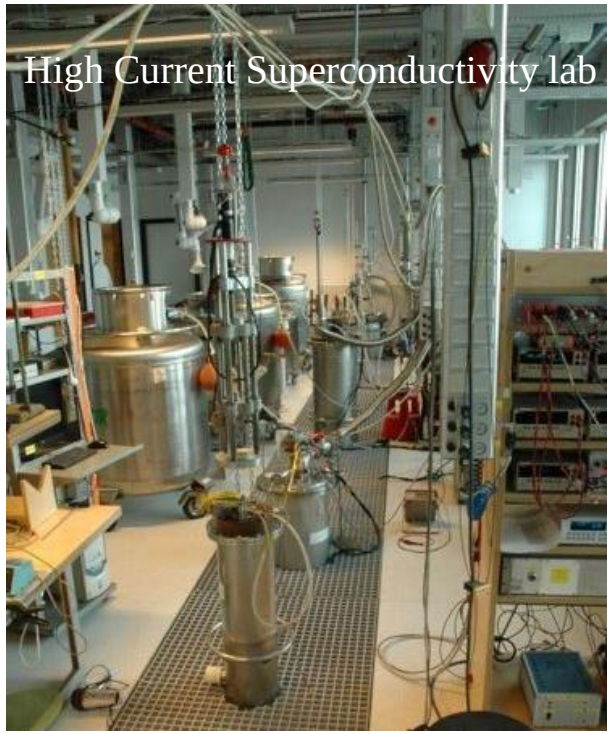
UNIVERSITY OF TWENTE.

# Sorption-based cooling technology

Marcel ter Brake (et al.)

UNIVERSITY OF TWENTE.

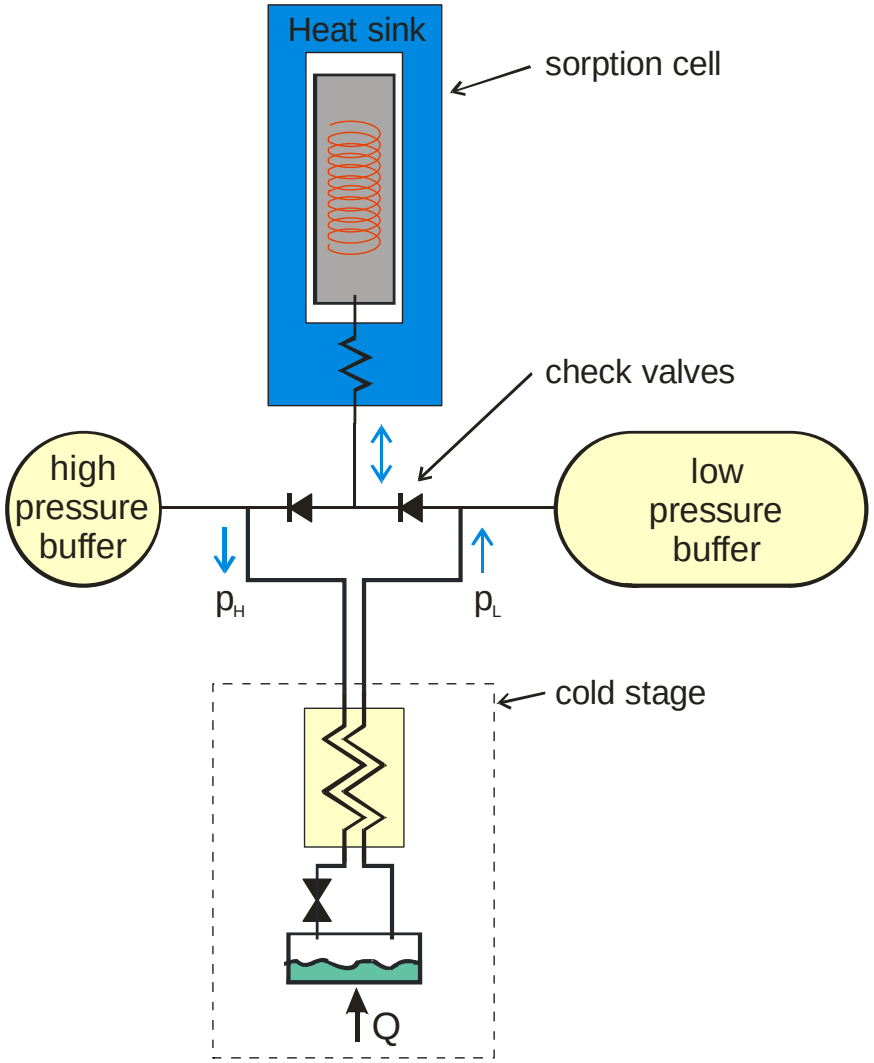



EMS

Ca. 50 persons
At this moment:
7 scientific staff
3 post-doc researchers
20 PhD students
13 BSc, MSc students
8 supporting staff



# Sorption cooler




**Sorption cooler:**

Thermal compressor instead of mechanical compressor (no mechanical moving parts)

- Far less vibrations
- Long Lifetime

ELSEVIER

Cryogenics 42 (2002) 97–108

Cryogenics

www.elsevier.com/locate/cryogenics

# Vibration-free 5 K sorption cooler for ESA's Darwin mission

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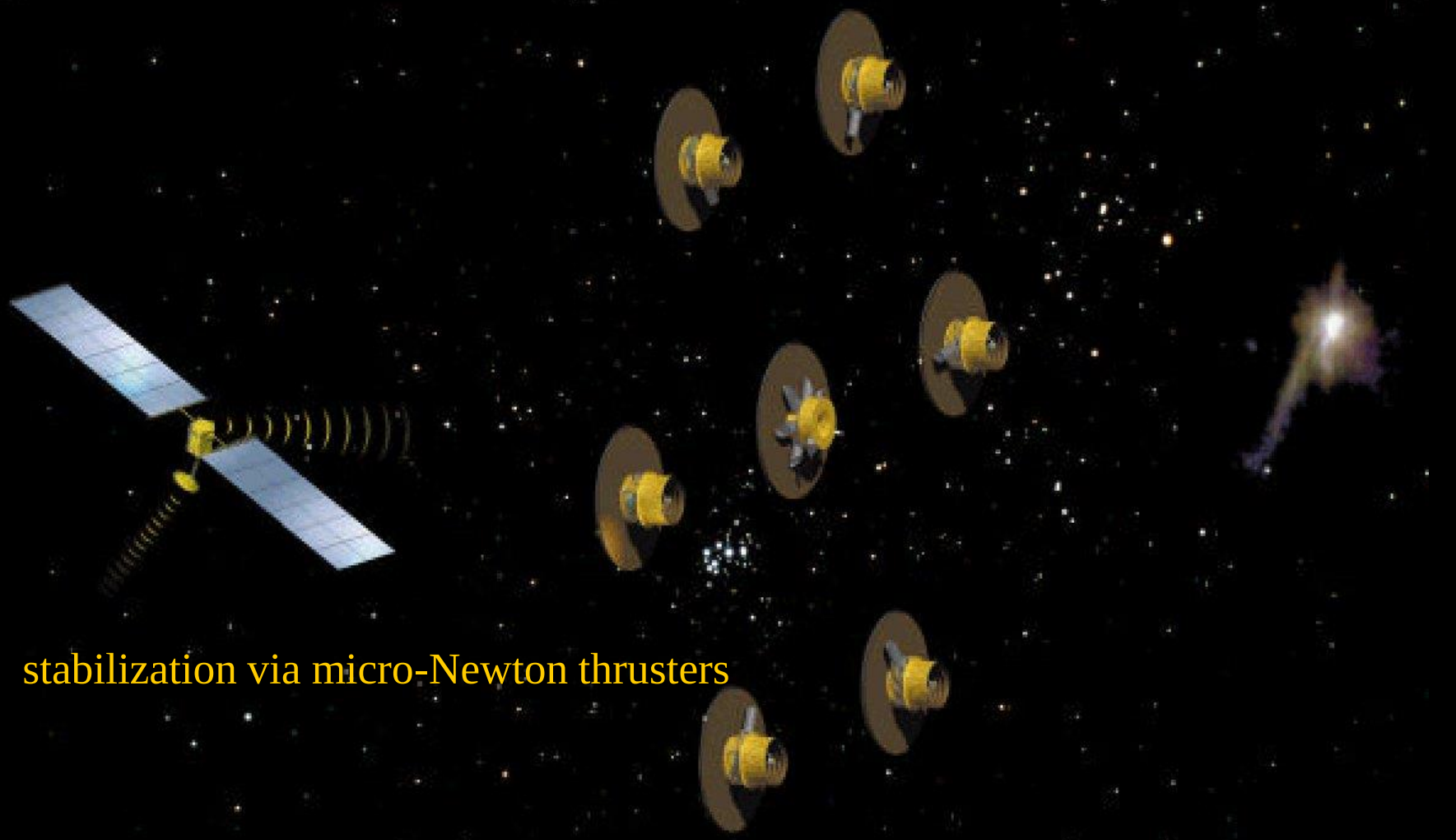
Received 8 November 2001; accepted 8 January 2002

20 years ago…

2001 – 2002: First ESA project: feasibility study “sorption cooling for Darwin mission”

DARWIN: interferometry via free-flying telescopes

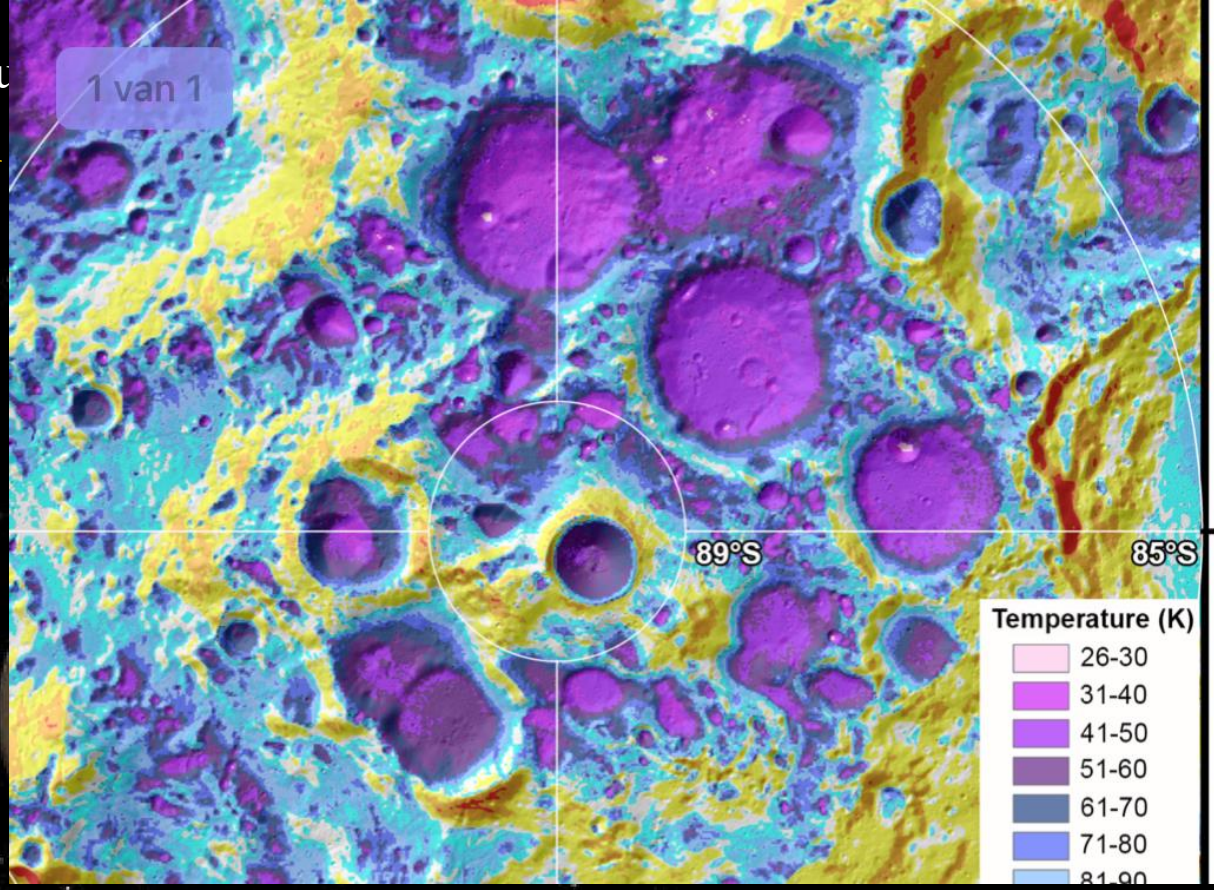


stabilization via micro-Newton thrusters

- passive cooling of telescopes to 40 K
- active 5 K detector cooling
  (utilizing passive precooling T < 50 K)

2001 – 2002: First ESA project: feasibility stu

DARWIN: interferometry via




stabilization via micro-Newton thrusters

Same as in LGWA

- passive cooling of telescopes to 40 K
- active 5 K detector cooling
  (utilizing passive precooling T < 50 K)

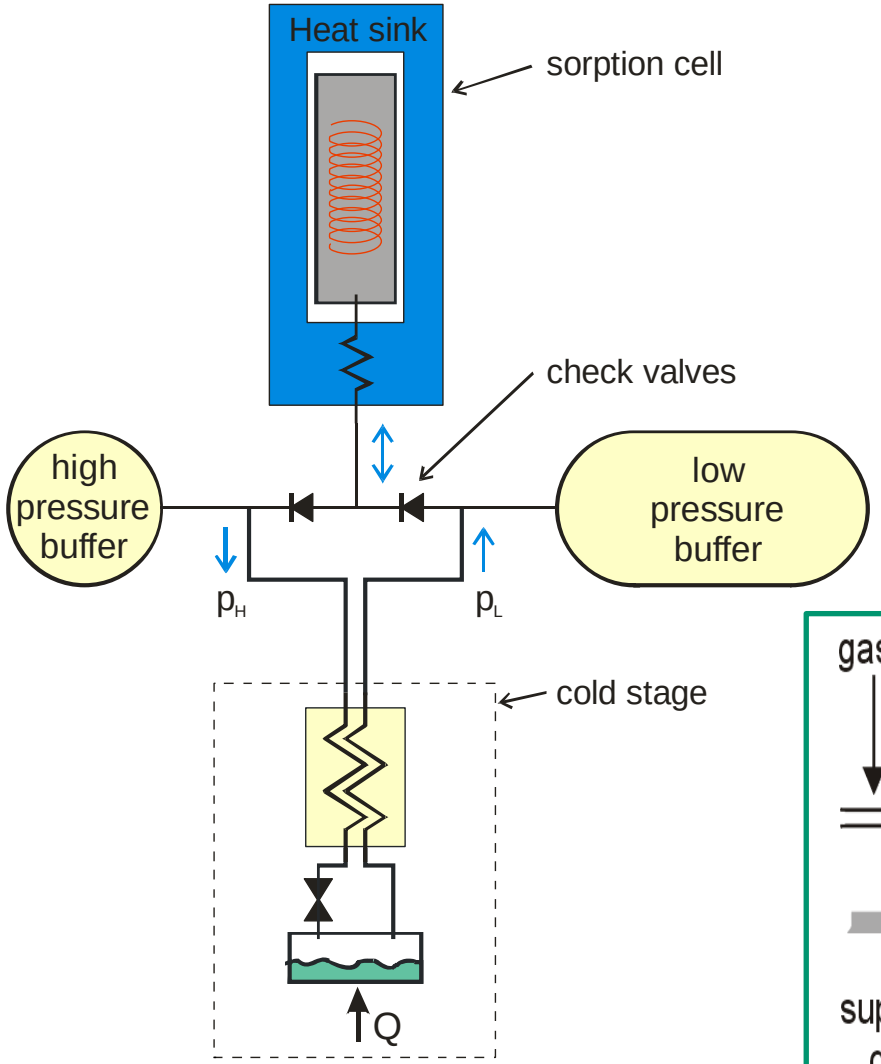
2001 – 2002: First ESA project: feasibility study “sorption cooling for Darwin mission”

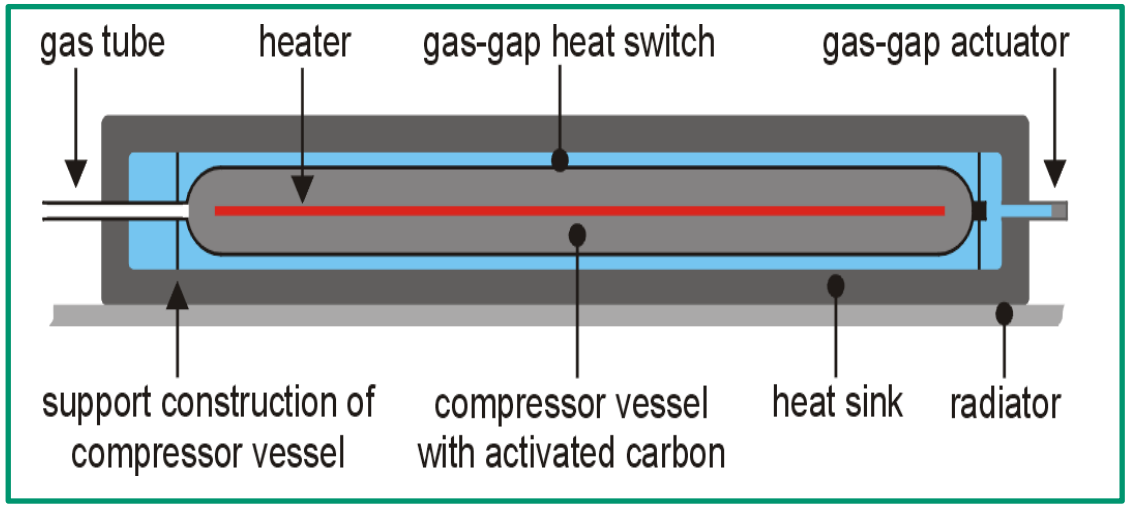
DARWIN: interferometry via free-flying telescopes

Same as in LGWA ?

| | |
|---|---|
| cooling power and temperature | 5 mW @ 4.5 K |
| passive precooling at L2 | < 2.5 W @ 50 K (< 9 $m^2$) |
| exported vibrations | < 1 μN/√Hz |
| lifetime | > 5 years |
| mass target | < 10 kg |
| temperature stability | < 1 mK for 1 hour |

# Sorption cooler



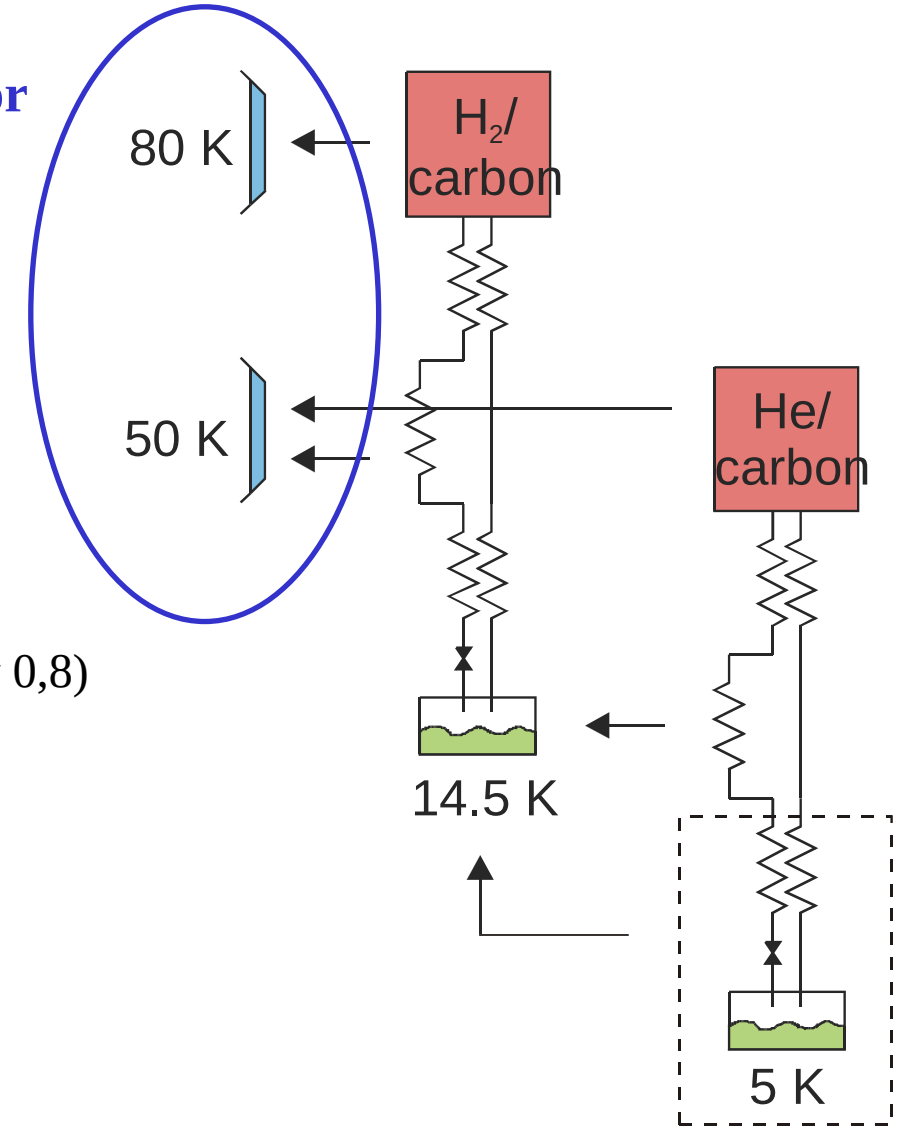
# Darwin cooler conceptual design

**In LGWA, this does not come for free !!**

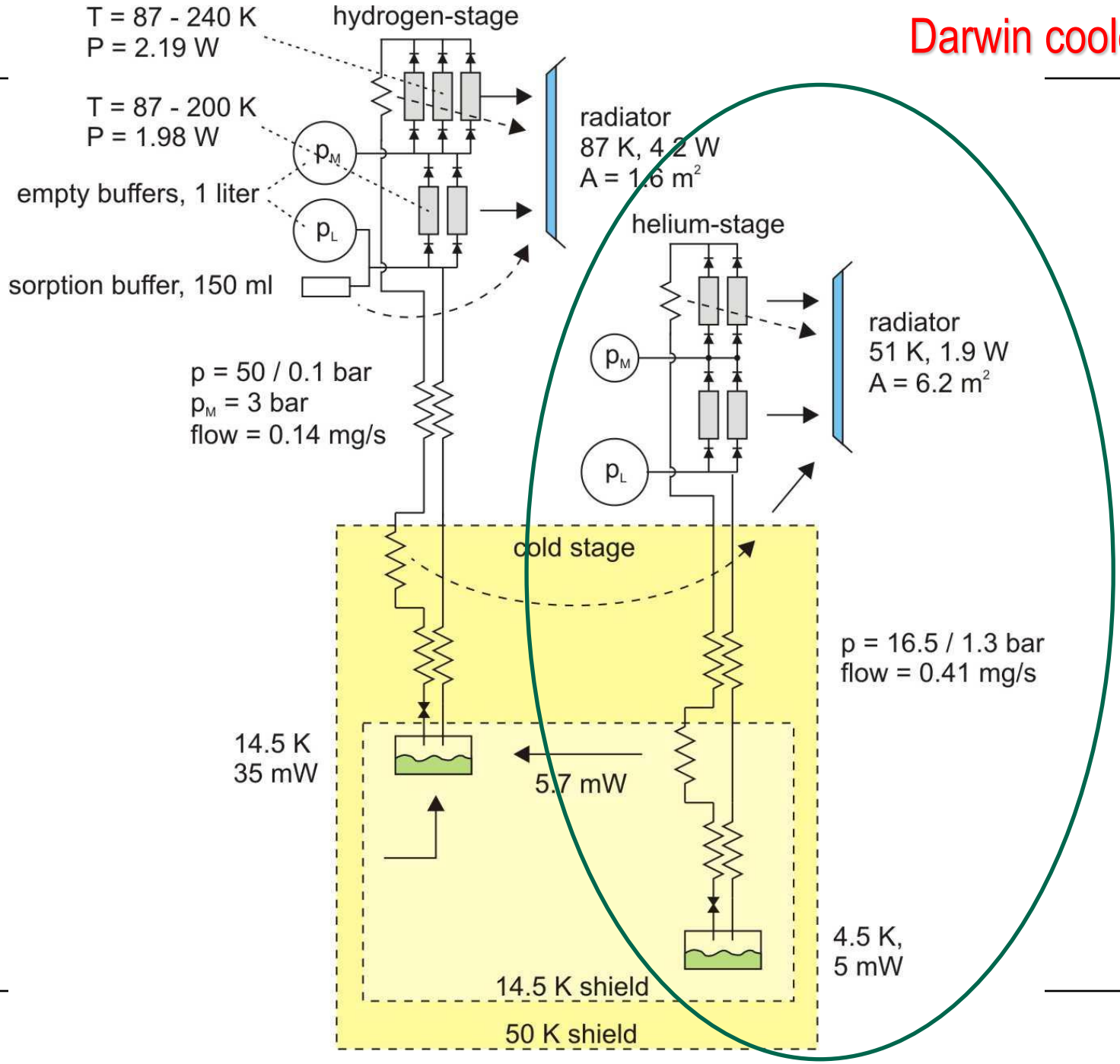
**80K: 0,54 $m^2/W$**

**50K: 3,5 $m^2/W$**

(radiator emissivity 0,8)

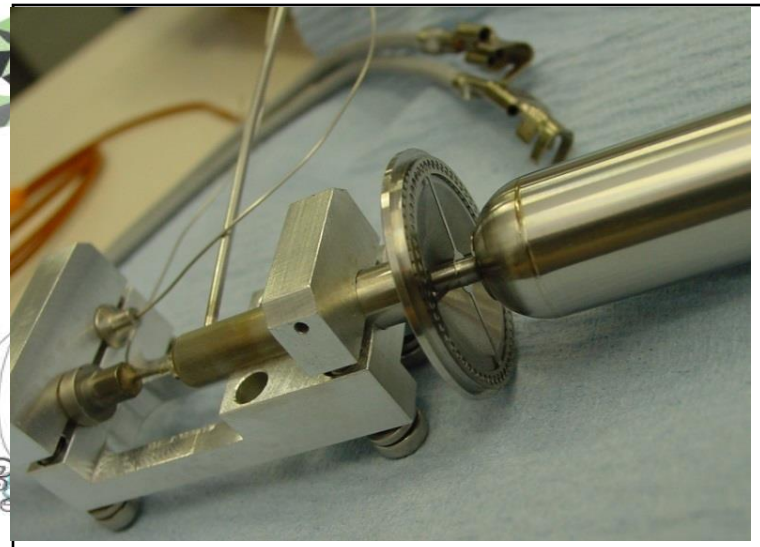


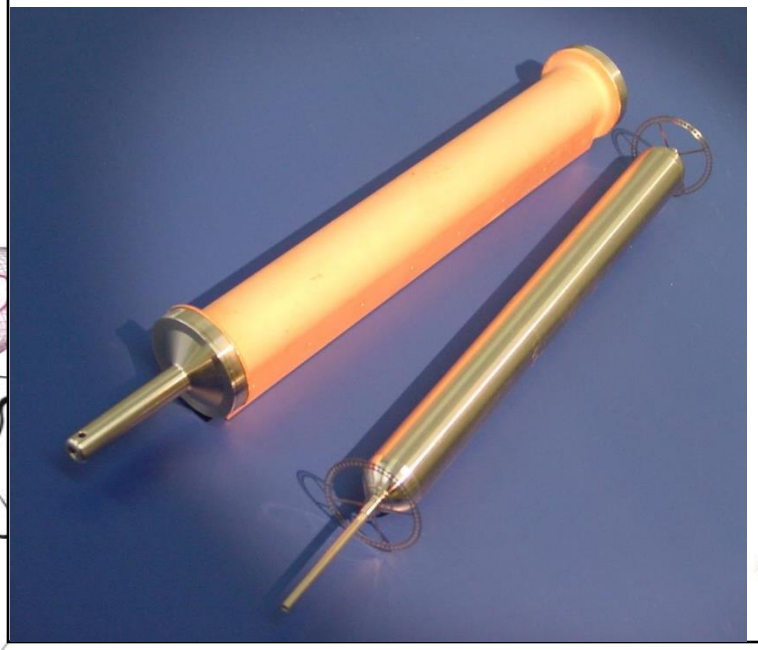
# Darwin cooler: Overall system design

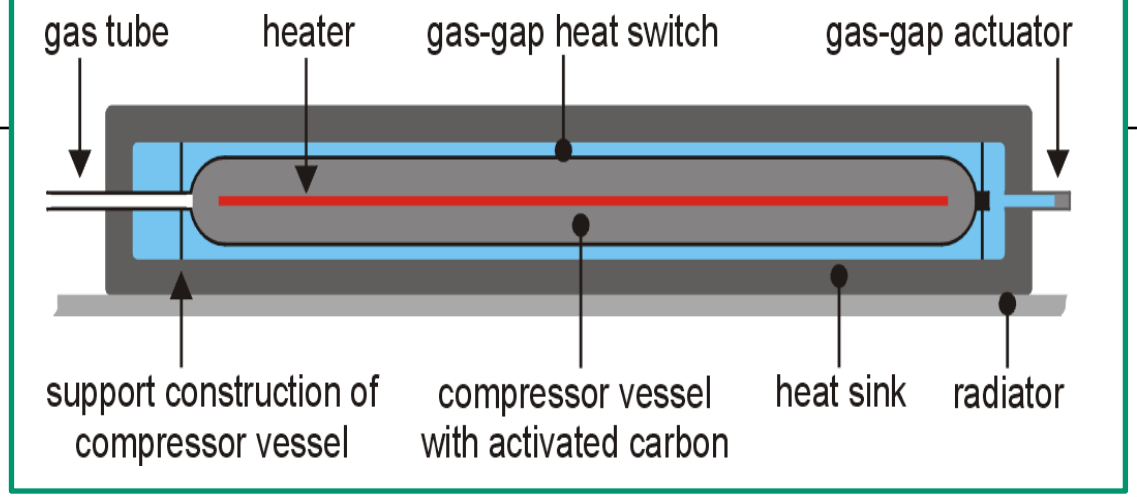


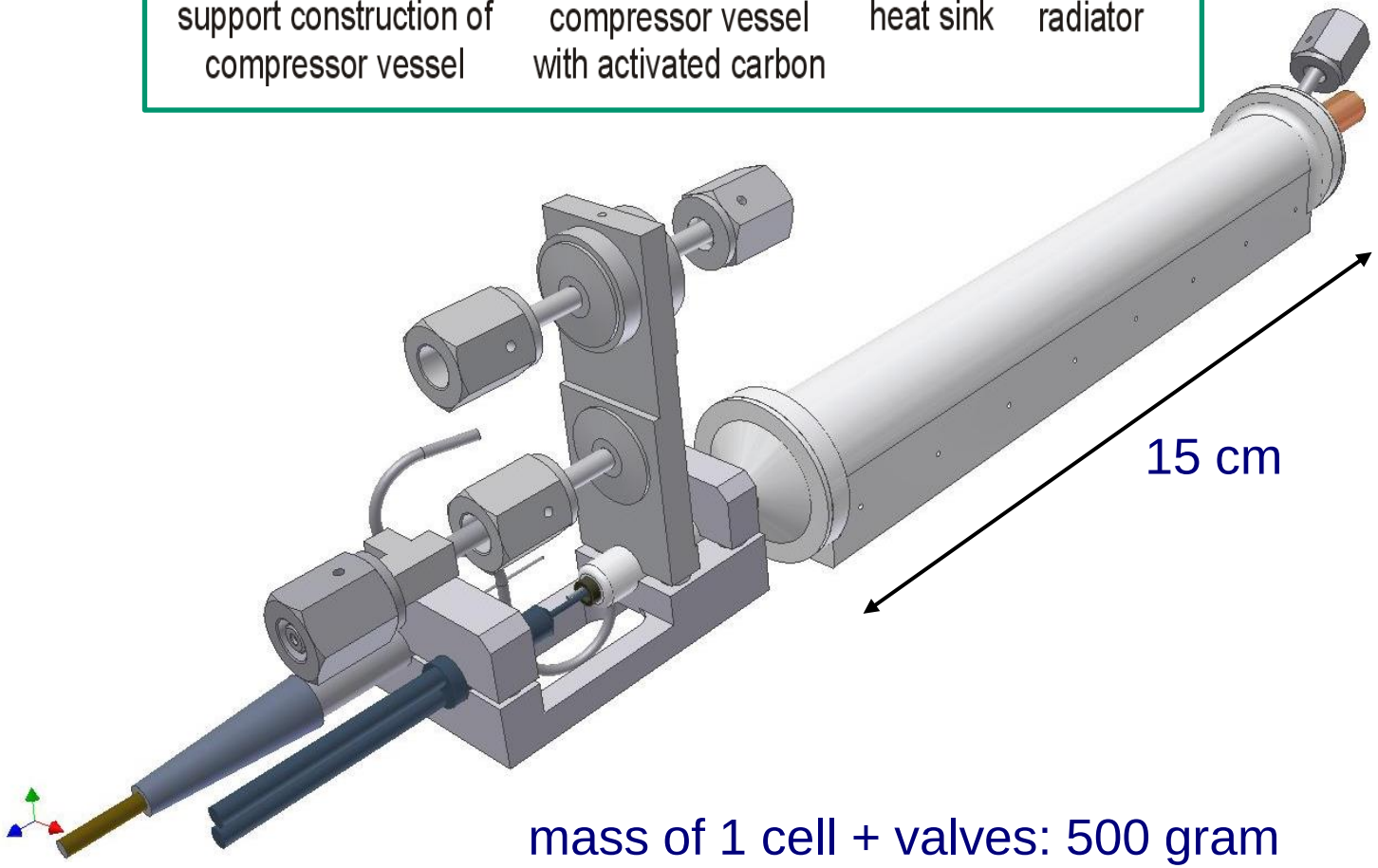

Second ESA project on Helium stage cooler (2003-2007)

# Cooler components: compressor cell



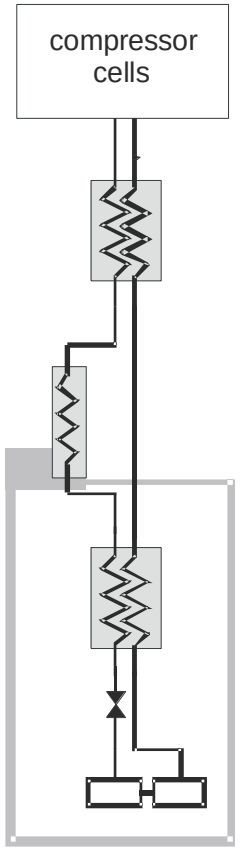





mass of 1 cell + valves: 500 gram

# Cooler components: cold stage

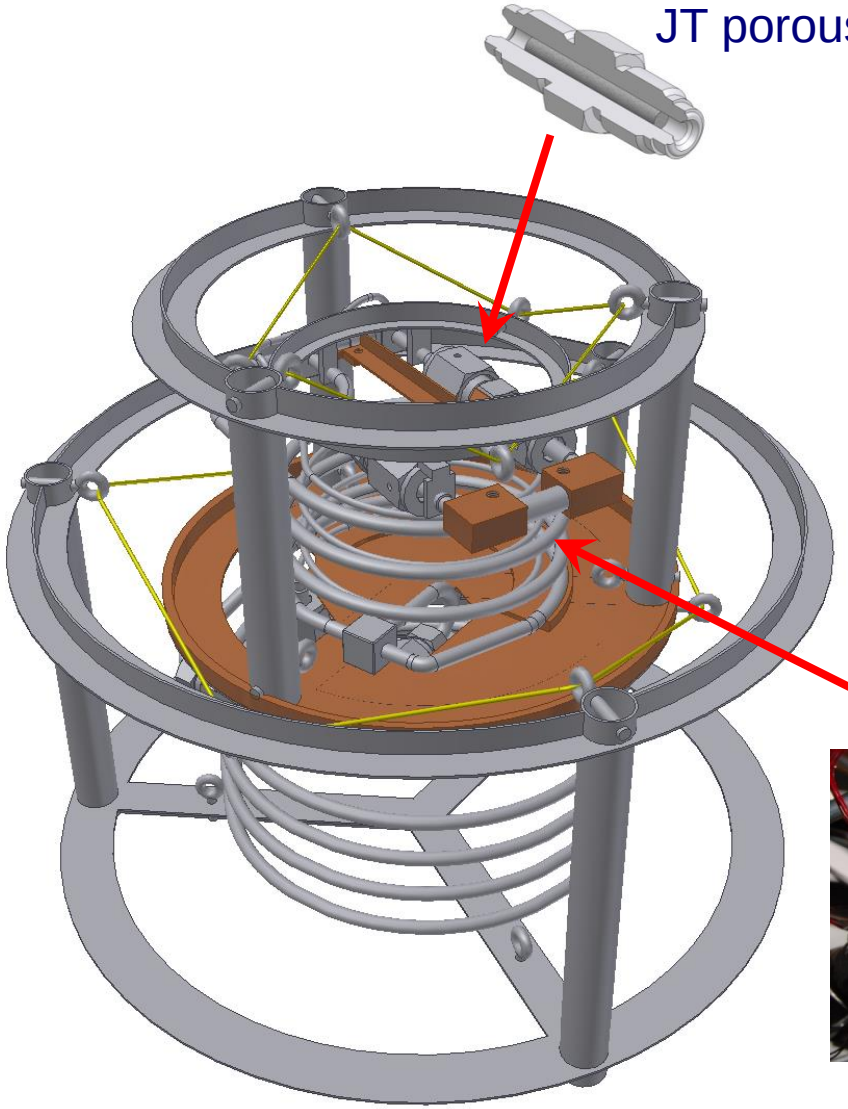


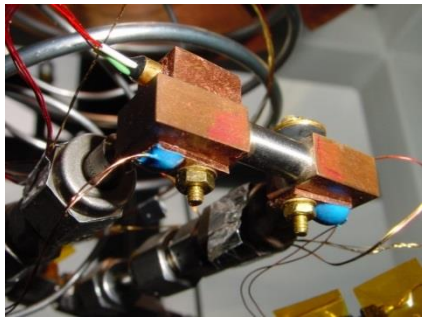

Mass: 500g

Height: 16 cm

Diameter: 17 cm

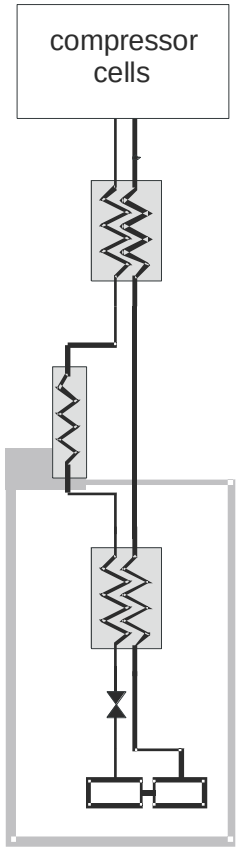
JT porous plug

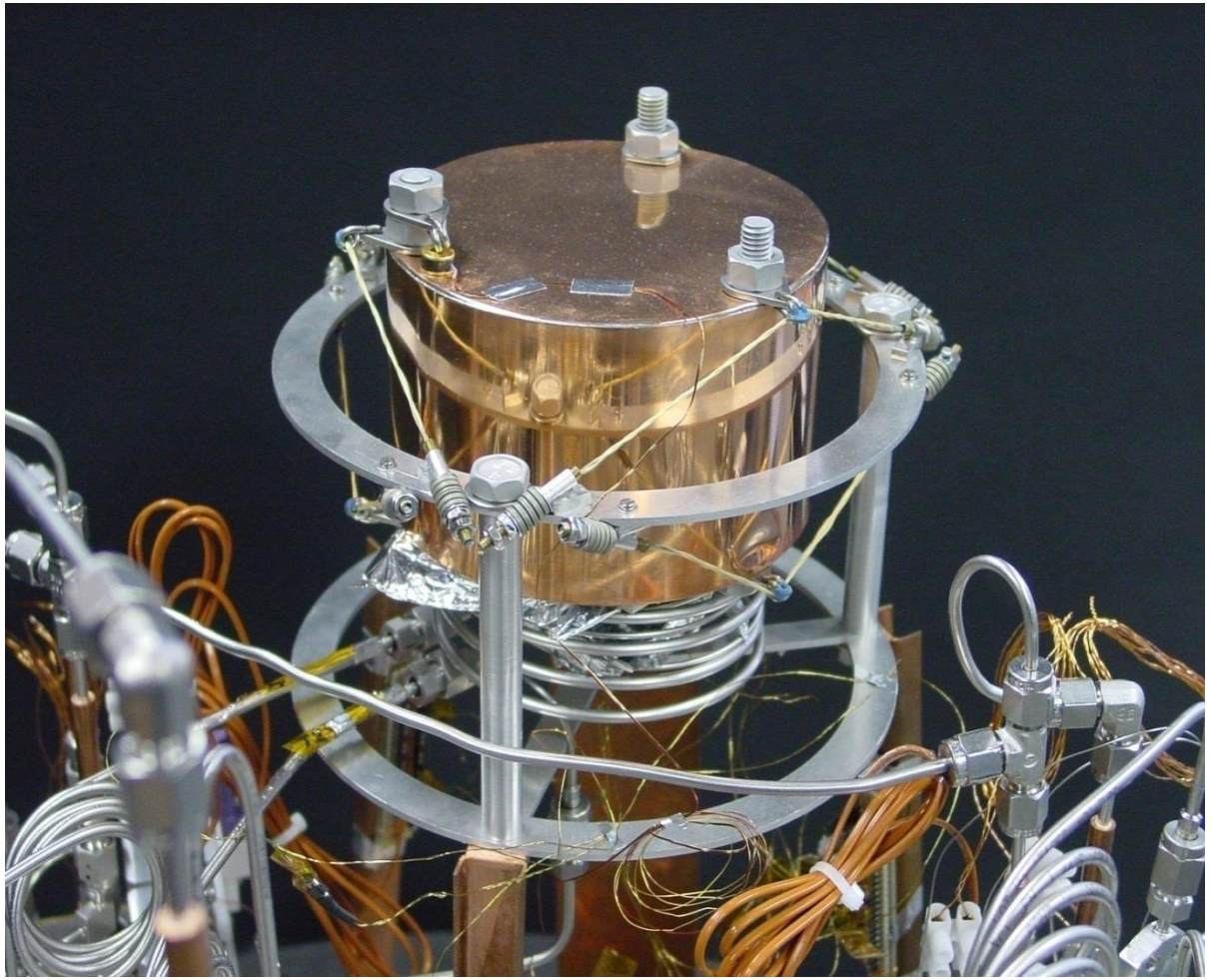




2-stage evaporator

# Cooler components: cold stage



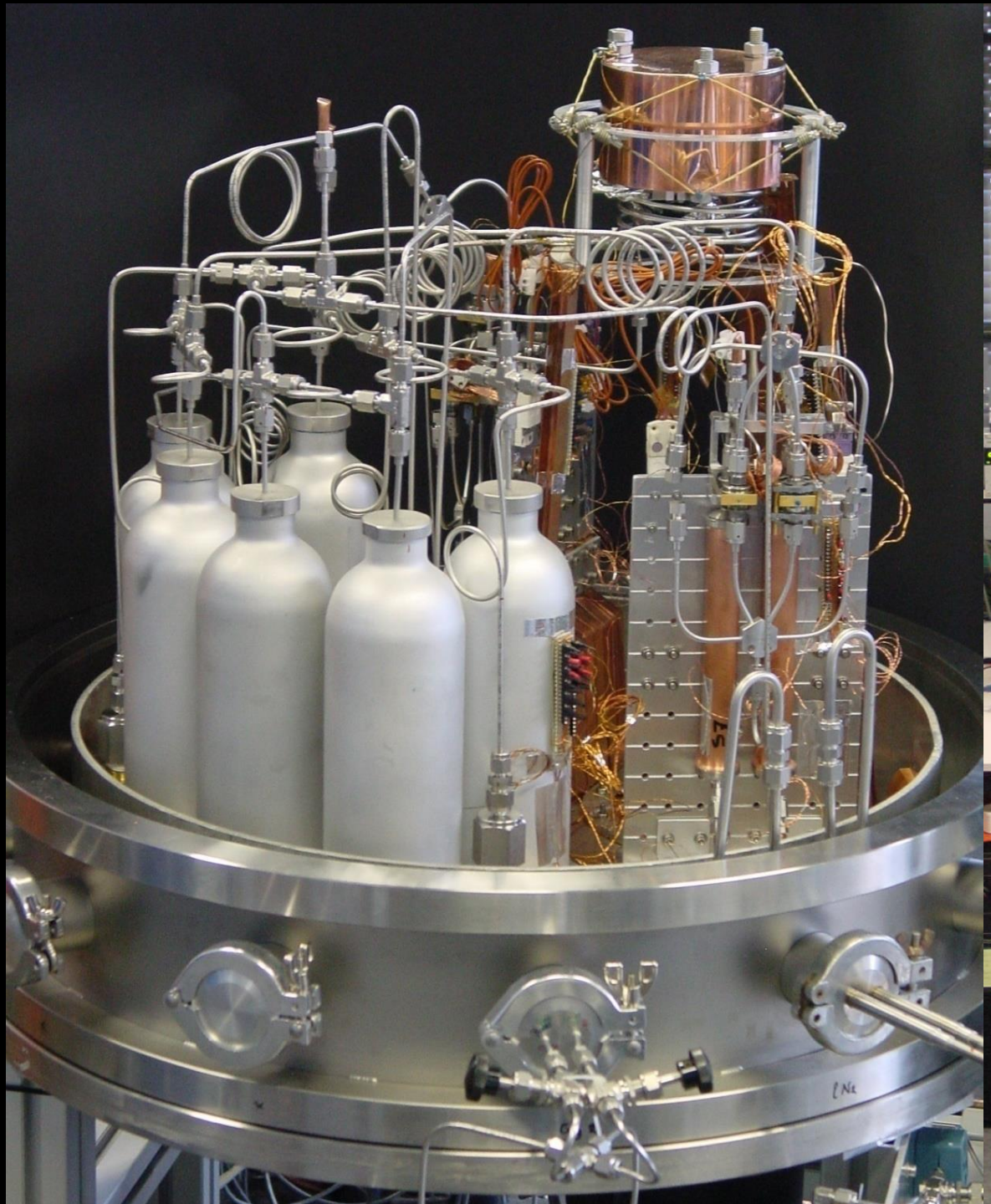



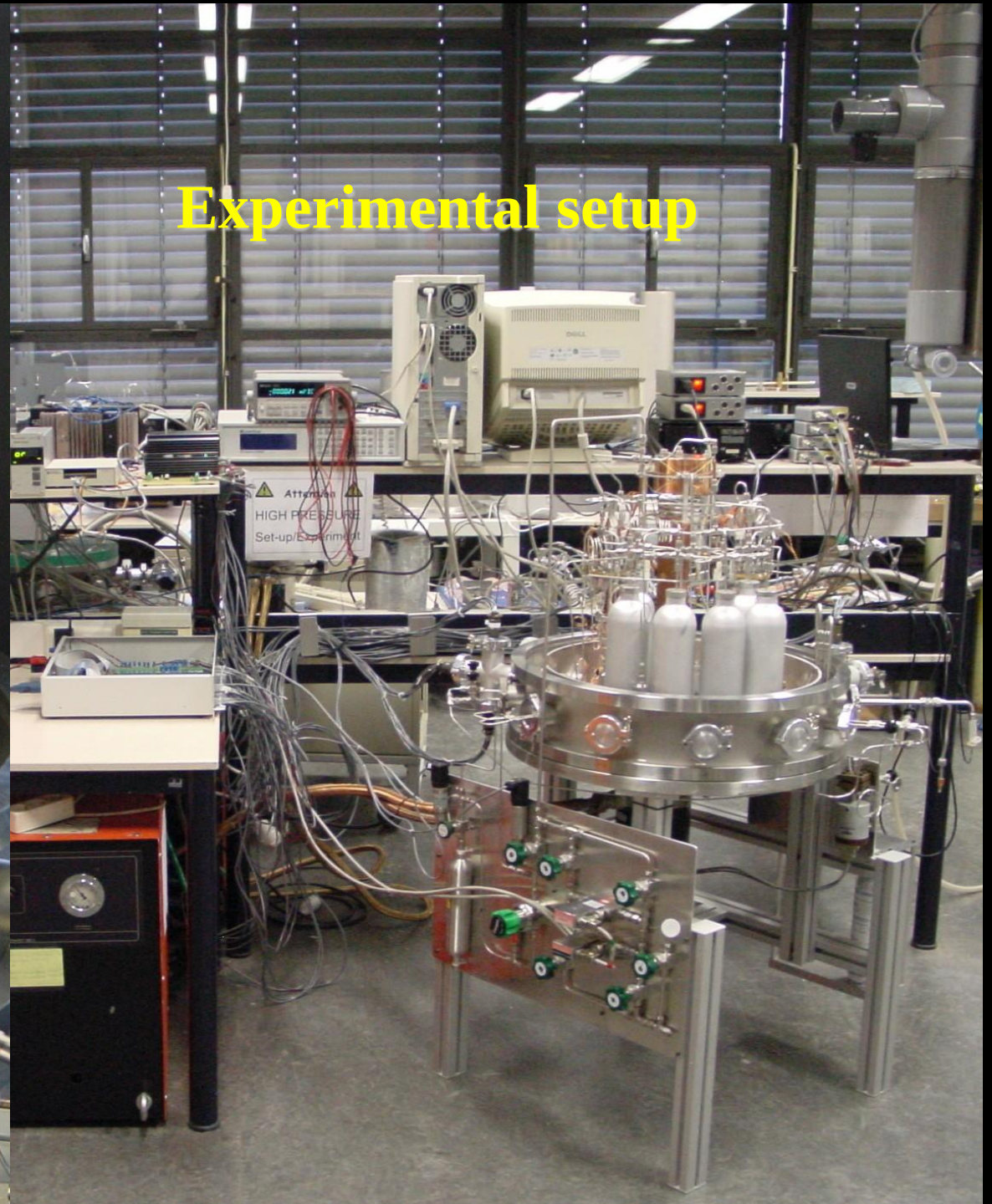
Mass: 500g

Height: 16 cm

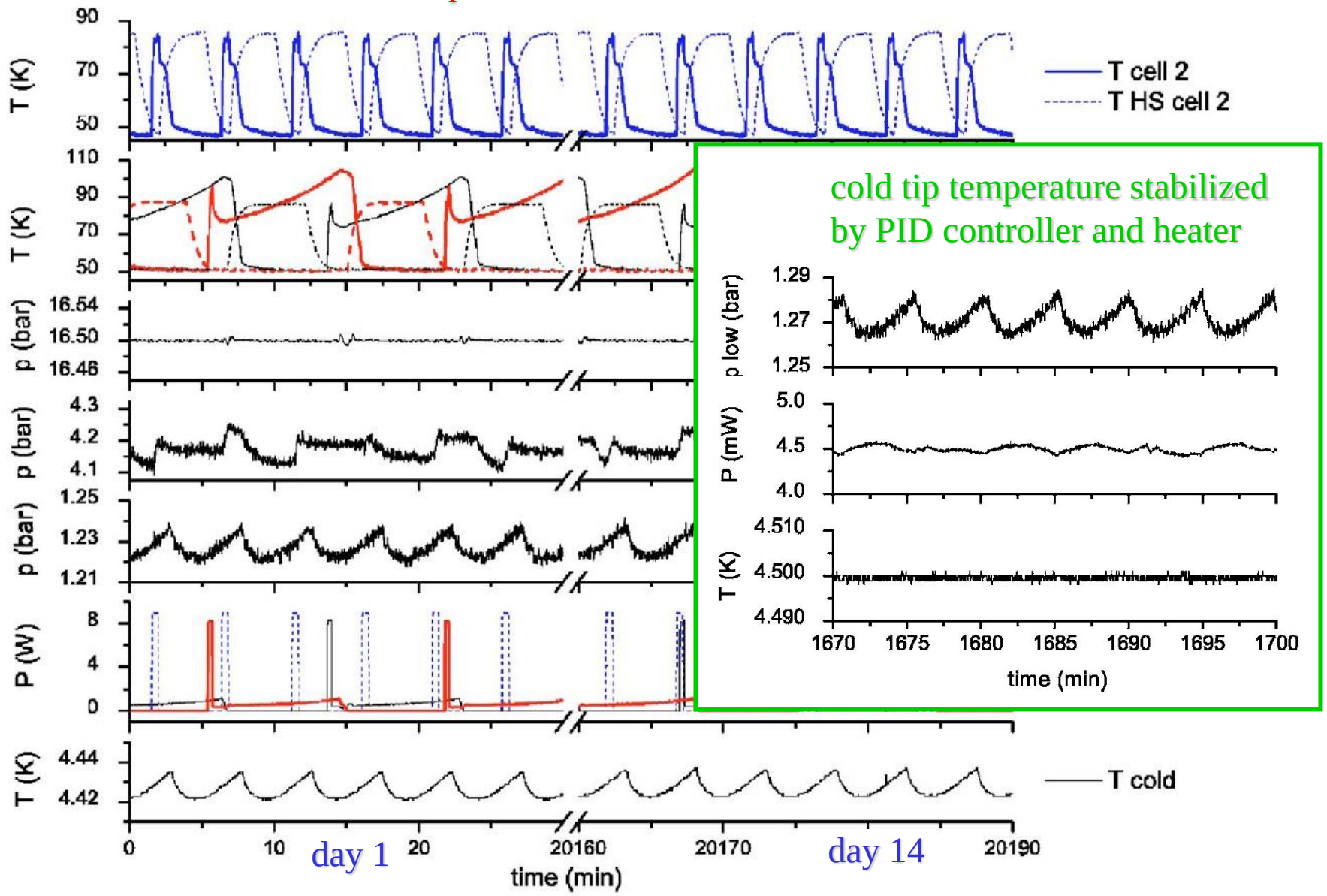
Diameter: 17 cm

# Experimental setup





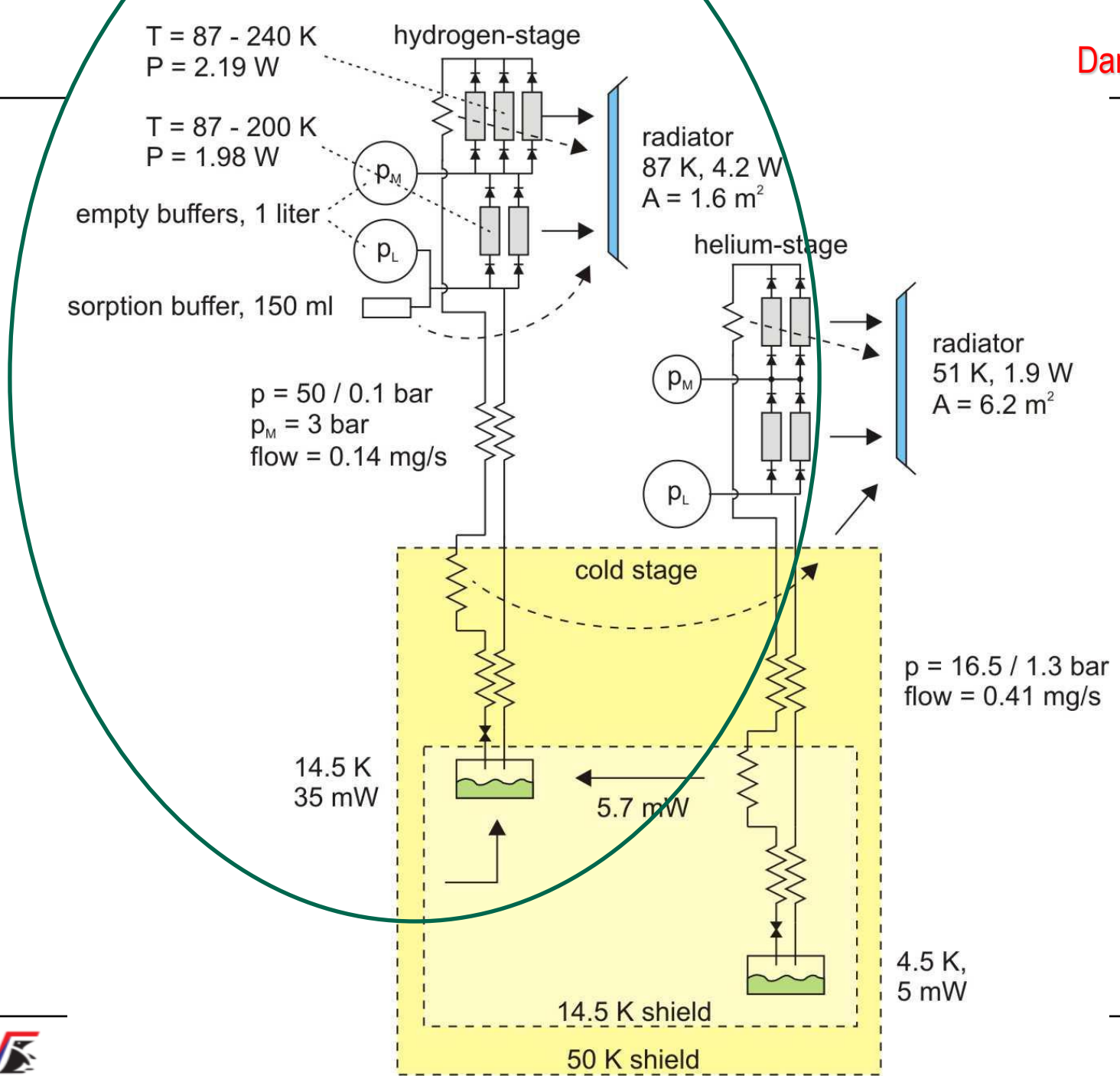
# Test experiments: results



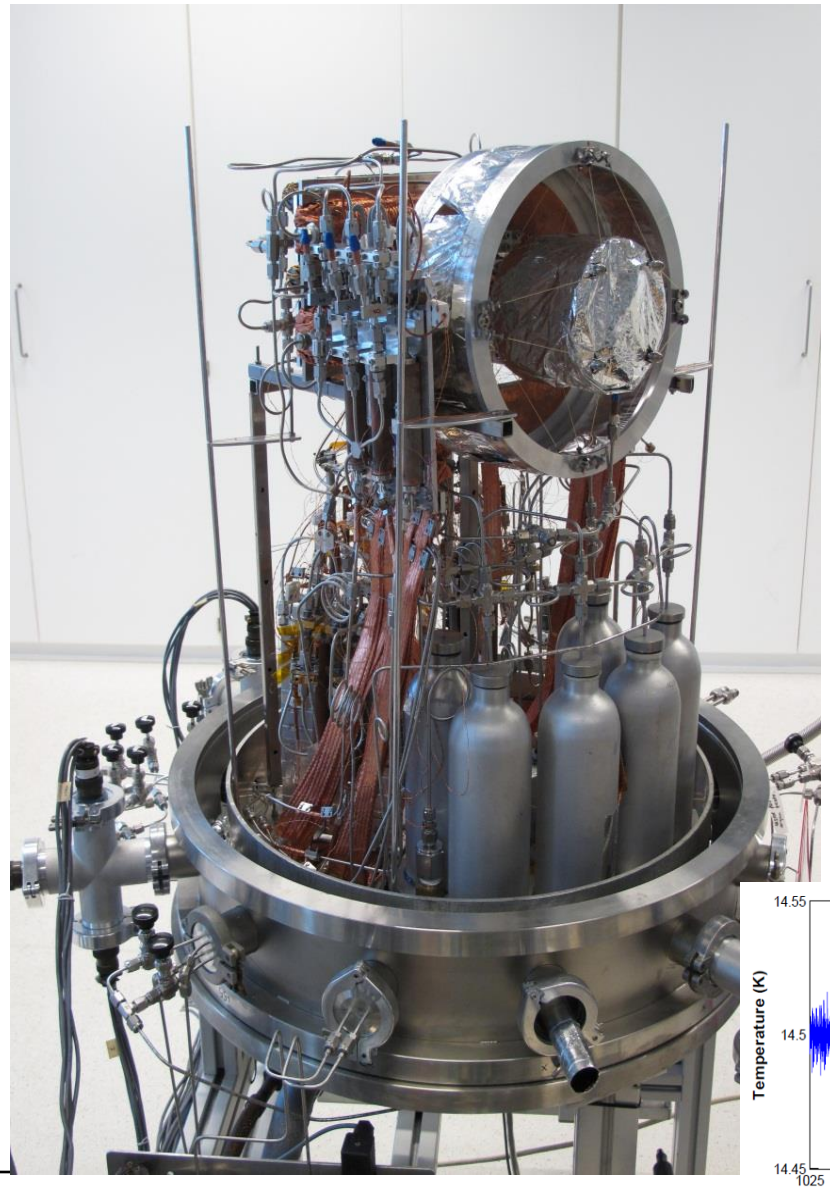
# What about cooler vibrations?

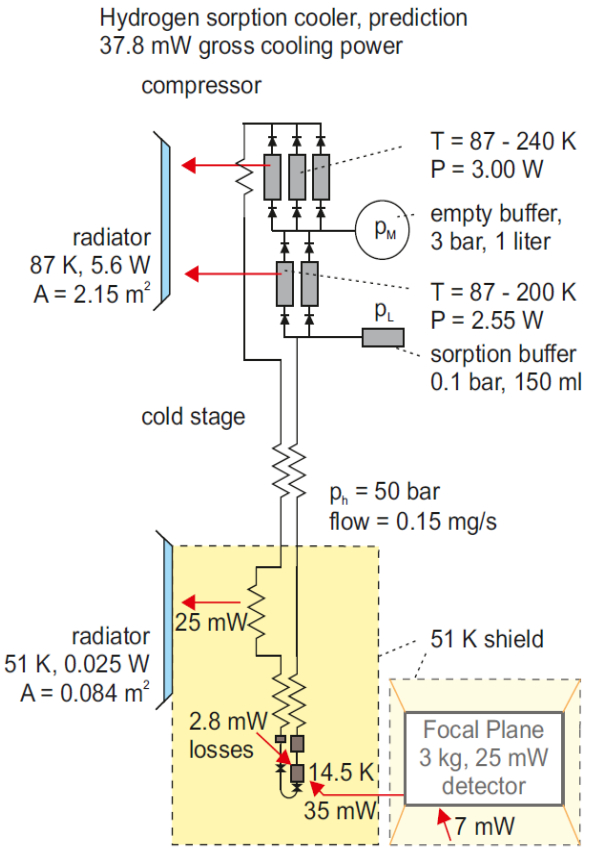
- Modeling and experiments in ESA project 16810/02/NL/Sfe considered vibration mechanisms in the Darwin cooler
- In compressor: Expansion because of T and P cycles, max force 26 nN
  Boss movement in valve: max force 10 nN
- More critical (closer to cold tip): pressure fluctuations in gas lines:
  at 0.1 Hz: 3nN/√Hz; at 1Hz: 0.3 μN/ √Hz
- Two-phase flow (and boiling vibrations) prevented by heating evaporator above boiling point

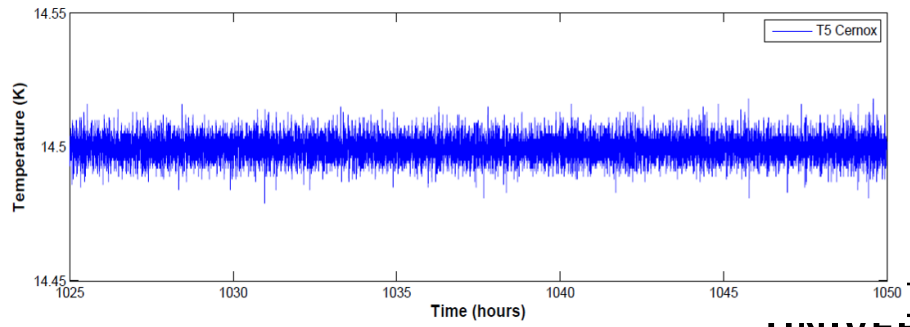
# Darwin cooler: Overall system design




Third ESA project on Hydrogen stage cooler (2008-2013)




Hydrogen sorption cooler, prediction
37.8 mW gross cooling power
compressor
T = 87 - 240 K
P = 3.00 W
radiator
87 K, 5.6 W
A = 2.15 m²
empty buffer,
3 bar, 1 liter
T = 87 - 200 K
P = 2.55 W
sorption buffer
0.1 bar, 150 ml
cold stage
p_h = 50 bar
flow = 0.15 mg/s
radiator
51 K, 0.025 W
A = 0.084 m²
25 mW
51 K shield
2.8 mW
losses
14.5 K
35 mW
Focal Plane
3 kg, 25 mW
detector
7 mW


T5 Cernox
Temperature (K)
14.55
14.5
14.45
1025
1030
1035
1040
1045
1050
Time (hours)

# Fourth ESA project, TRL5 project: vibration levels (2014-2017)

**Sinus** vibration acceleration levels

| Frequency (Hz) | Level (minimum) | Level (goal) |
|---|---|---|
| 5 - 25 Hz | 5mm out op plane<br>7mm in plane | 10mm (all directions) |
| 25 - 100 Hz | 15g out of plane<br>25g in plane | 25g (all directions) |
| Sweep Rate | 2 octaves/minute, 1 sweep up | |

**Minimum random** vibration power spectral density

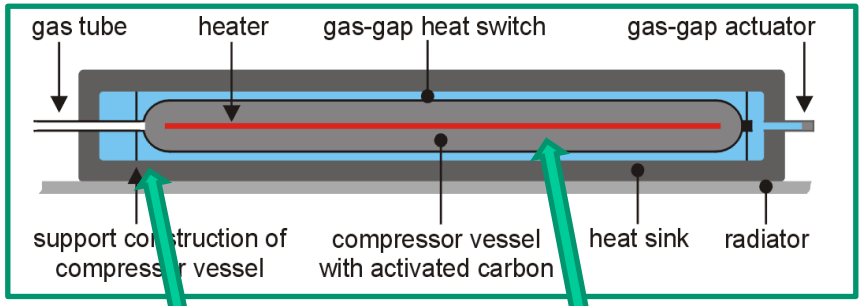
| | Frequency (Hz) | Level | g RMS |
|---|---|---|---|
| **Normal to fixation plane** | 20 – 100 | + 3 dB/oct. | 12.00 |
| | 100 – 200 | 0.4 $g^2$/Hz | |
| | 200 – 300 | 0.2 $g^2$/Hz | |
| | 300 – 2000 | - 5 dB/oct. | |
| **Other axes** | 20 – 100 | + 3 dB/oct. | 11.20 |
| | 100 – 170 | 0.1 $g^2$/Hz | |
| | 170 – 300 | 0.25 $g^2$/Hz | |
| | 300 – 2000 | -5 dB/oct. | |

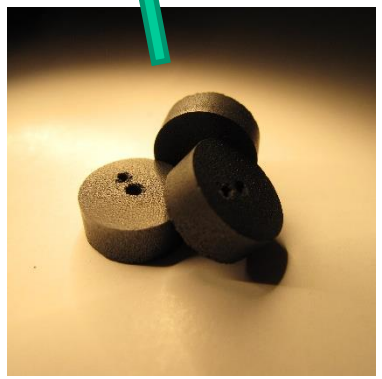
**Goal required random** vibration power spectral density

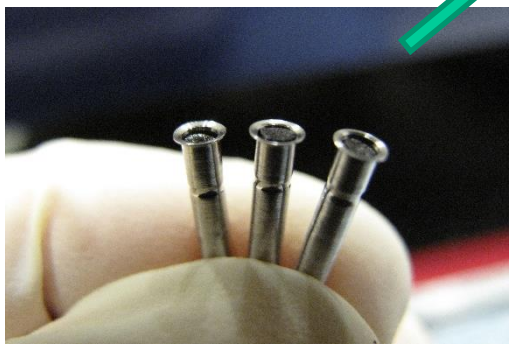
| | Frequency (Hz) | Level | g RMS |
|---|---|---|---|
| **Normal to fixation plane** | 30 – 100 | + 6 dB/oct. | 45.20 |
| | 100 – 350 | 4 $g^2$/Hz | |
| | 350 – 1000 | - 6 dB/oct. | |
| **Other axes** | 10 – 70 | + 6 dB/oct. | 15.41 |
| | 70 – 350 | 0.4 $g^2$/Hz | |
| | 350 – 1000 | - 6 dB/oct. | |

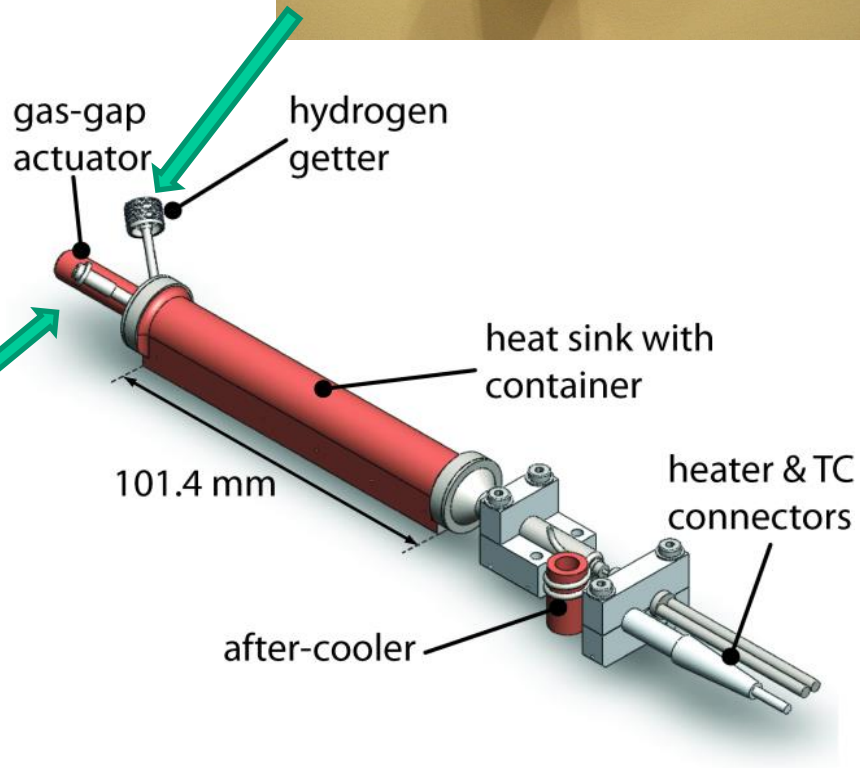
NOT

# TRL5 project: Compressor-cell redesign

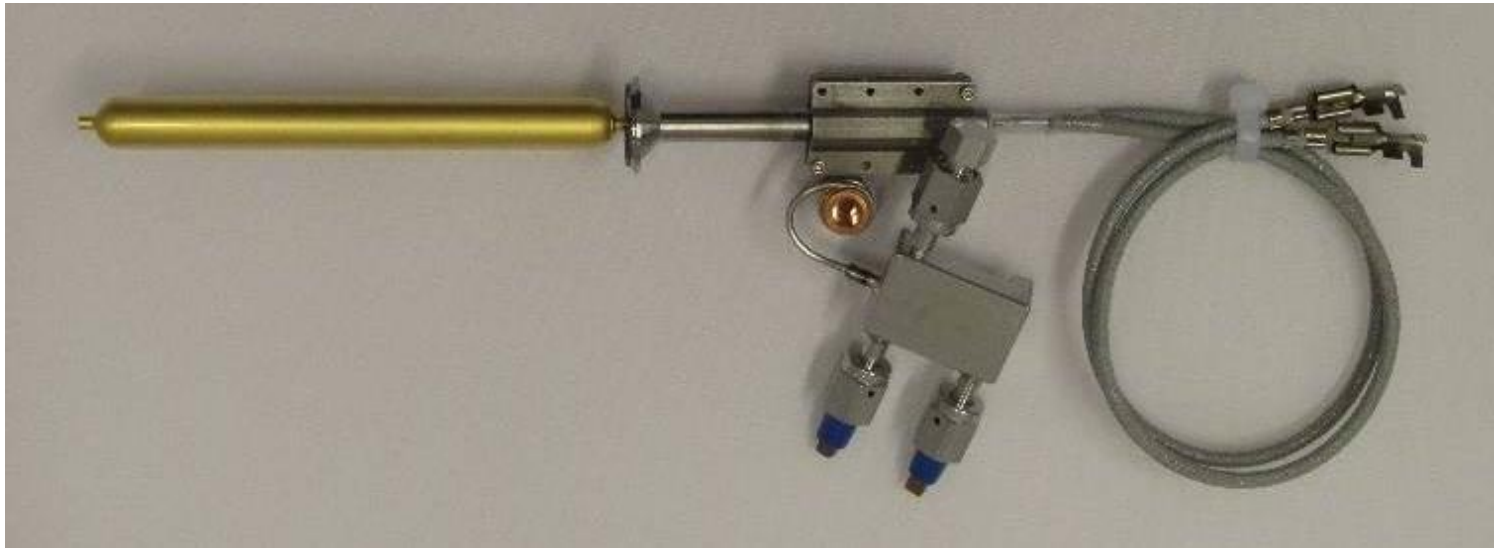


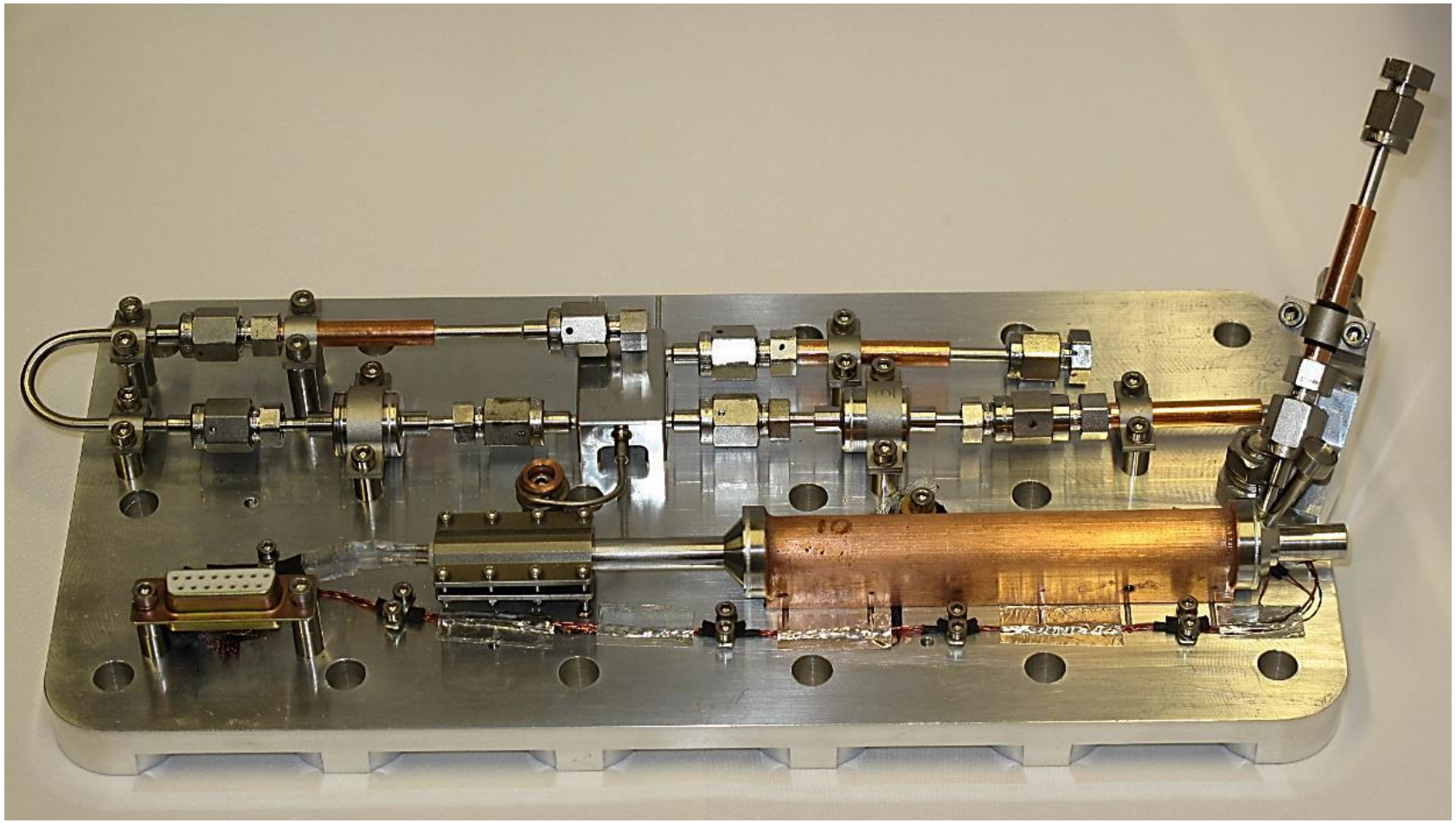




# TRL5 project: Compressor



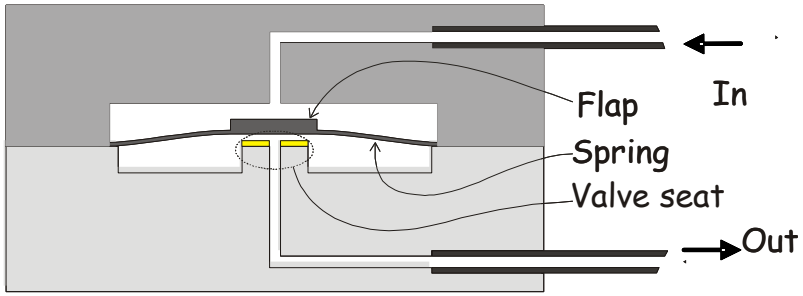
# TRL5 project: Compressor-cell on test platform

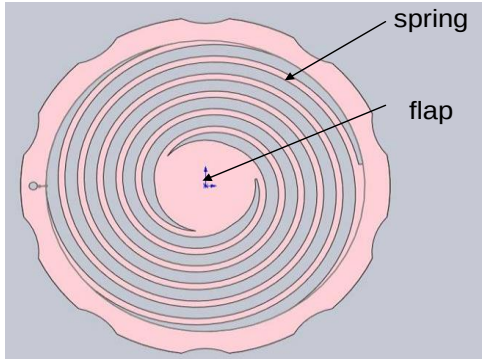


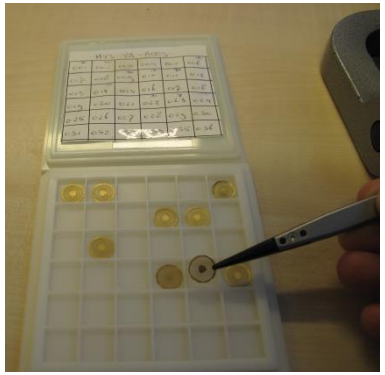
# TRL5 project: Vibration test at Thales Cryogenics

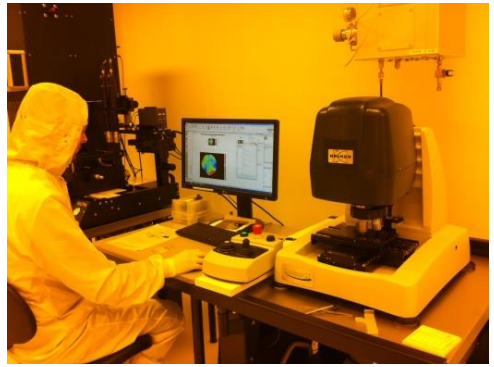

# TRL5 project: Conclusion

- Compressor cell survived launch loads; No change in compressor performance
- Check valves need to be improved. Leakage may occur, most probably due to gold depositing between seat and flap of valve. Further investigations needed.



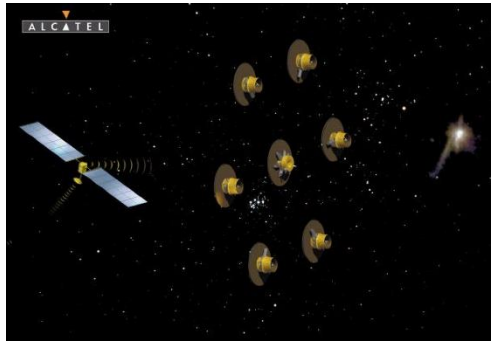





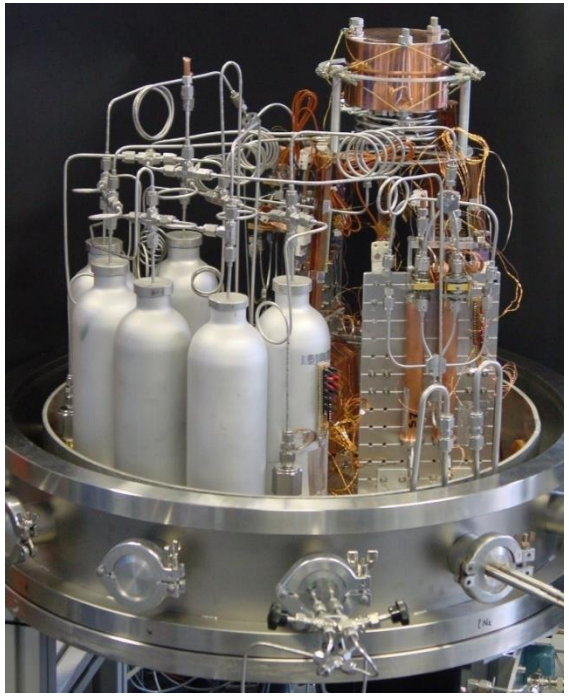
machined in 316L stainless steel

flap: Au layer 10 μm

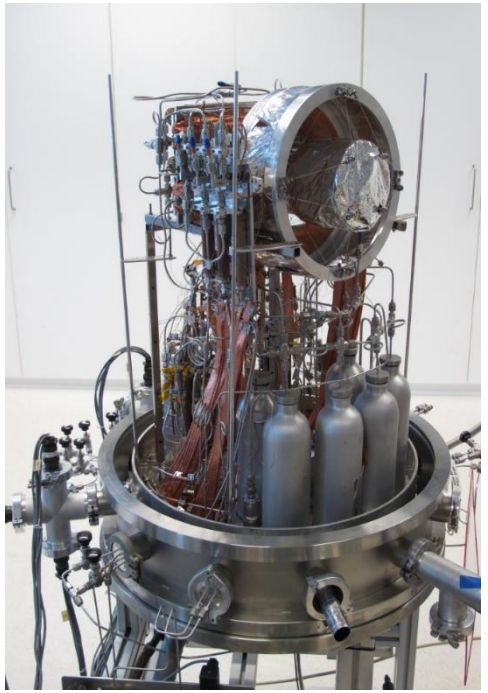
# Sorption-cooler development at University of Twente



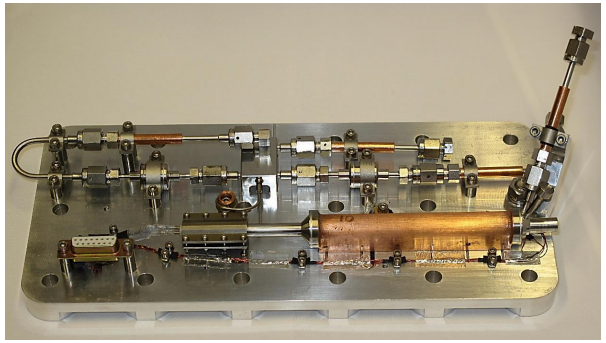

Feasibility study for
ESA-Darwin mission
(2001-2002)



4,5 K sorption-based
helium stage cooler
(2003-2007)



14,5 K sorption-based
Hydrogen stage cooler
(2008-2013)

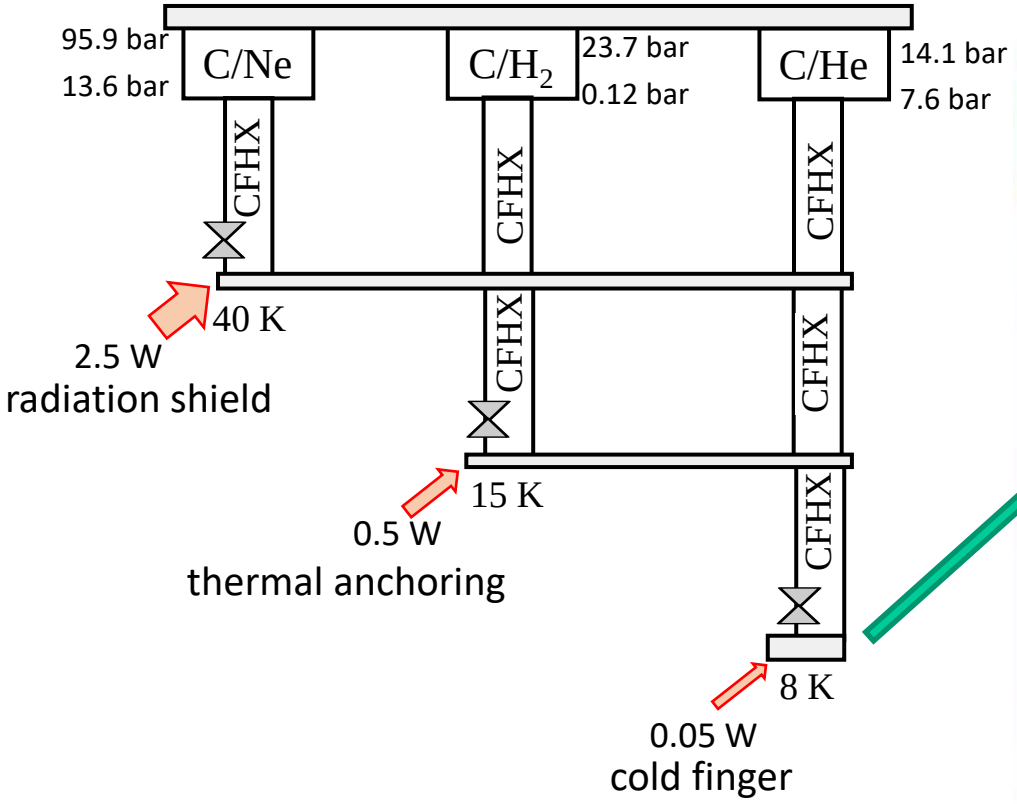


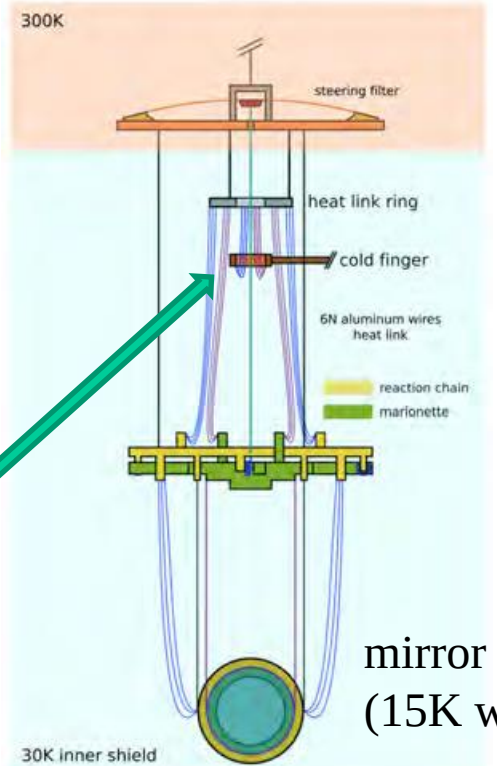
TRL 5 project
(2014-2017)

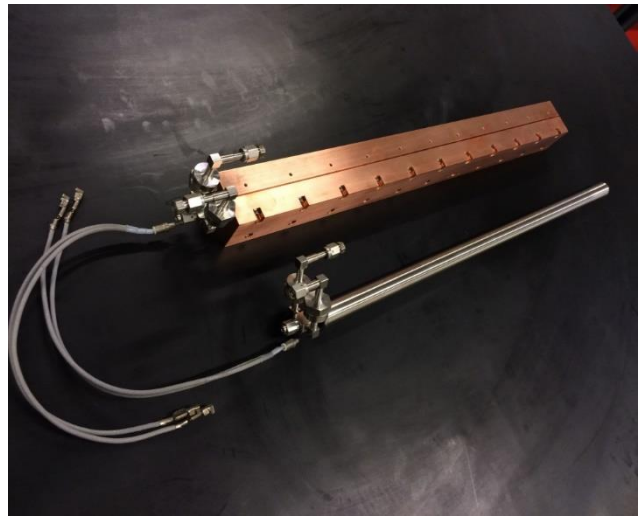
….so now what…. ??

# Since 2018: ETPF cooler chain and cryogenics

| T heat sink | Ne | $H_2$ | He | Total |
|---|---|---|---|---|
| 80 K | 25 cells<br>313 W | 5 cells<br>80 W | 12 cells<br>146 W | 42 cells<br>63 liter<br>505 W |
| 70 K | 17 cells<br>206 W | 4 cells<br>63 W | 5 cells<br>58 W | 26 cells<br>39 liter<br>327 W |



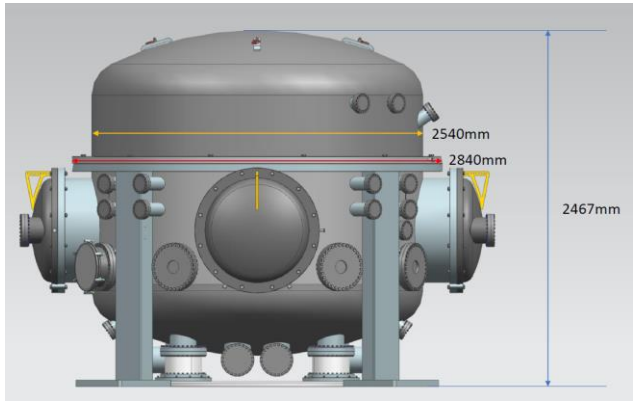



1 compressor cell housing:
5 x 5 x 60 $cm^3$ = 1,5 liter

mirror temperature still TBD
(15K would simplify the cryogenics)

# ET- Pathfinder Cryogenic Test Facility

“Twente tower”




ETPF cryogenic technologies will be developed together with UT and validated in the Cryogenic Test Facility in HDL

Einstein Telescope / NL / BE / D /

# What has to be done….

- LGWA thermal design, heat loads (temperatures of heat sink, and cold stages)
- Minimize heat loads to cold stages
- Radiator design: ca. 8 $m^2$ needed for 5 mW@4,5K + 35 mW@14,5K
- Revisit analysis on vibrations, focus on flow in gas lines and JT expansion (will be done in ETPF studies, at much larger flow)
- Improve check valve design to withstand launch vibrations

Thank you!!