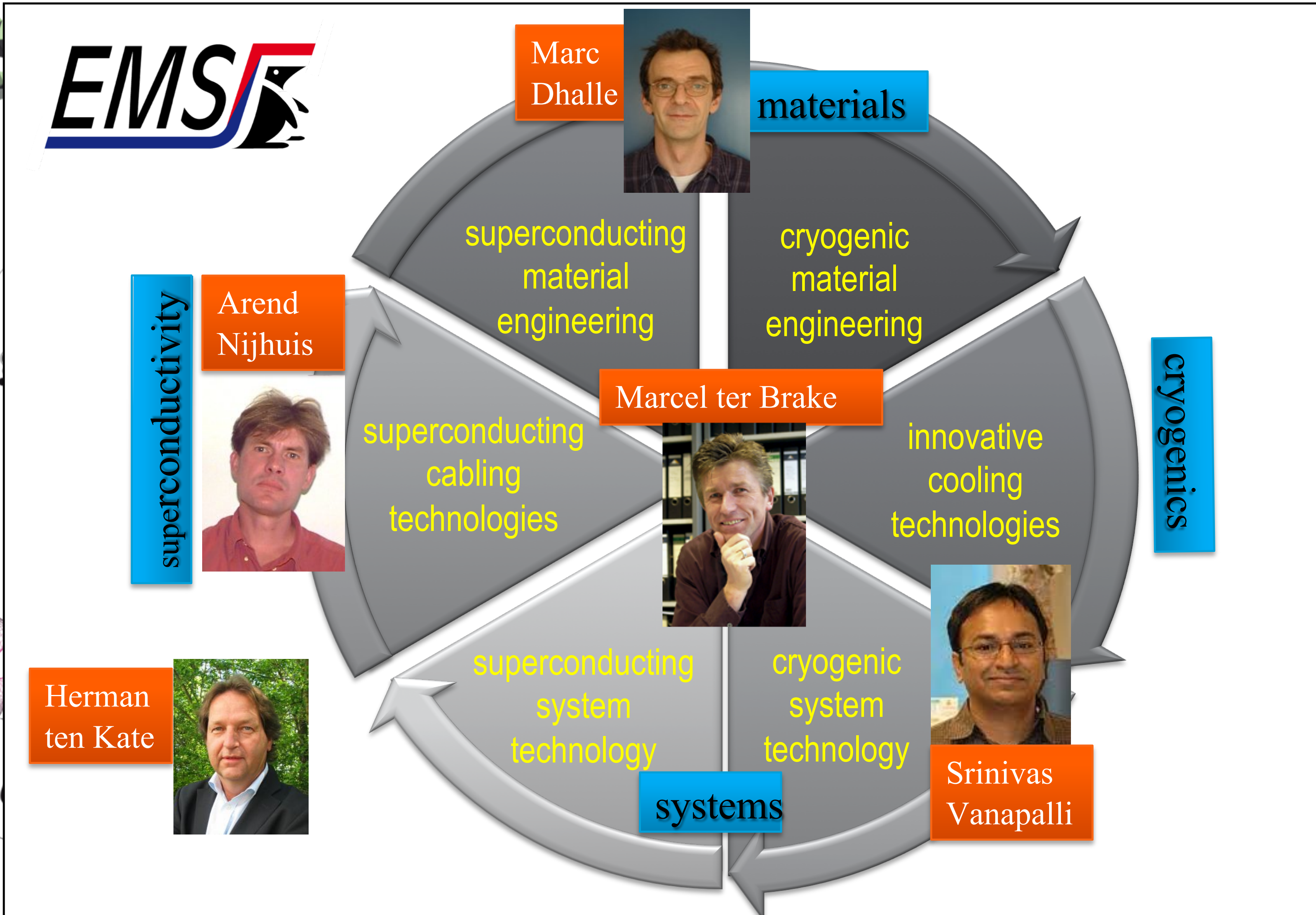
UNIVERSITY OF TWENTE.

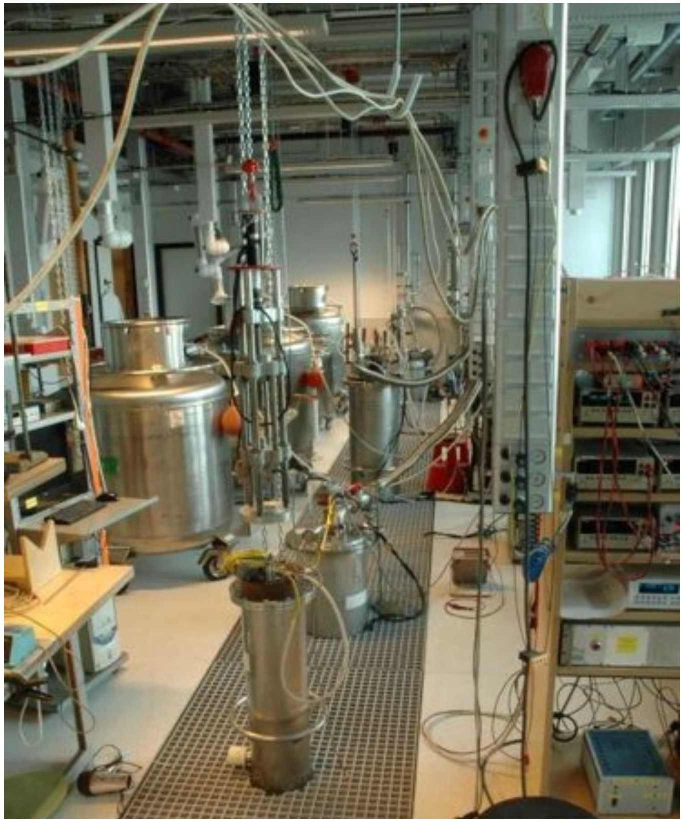
Vibration-free cooling of optical instruments

Marcel ter Brake, Srinvas Vanapalli et al.

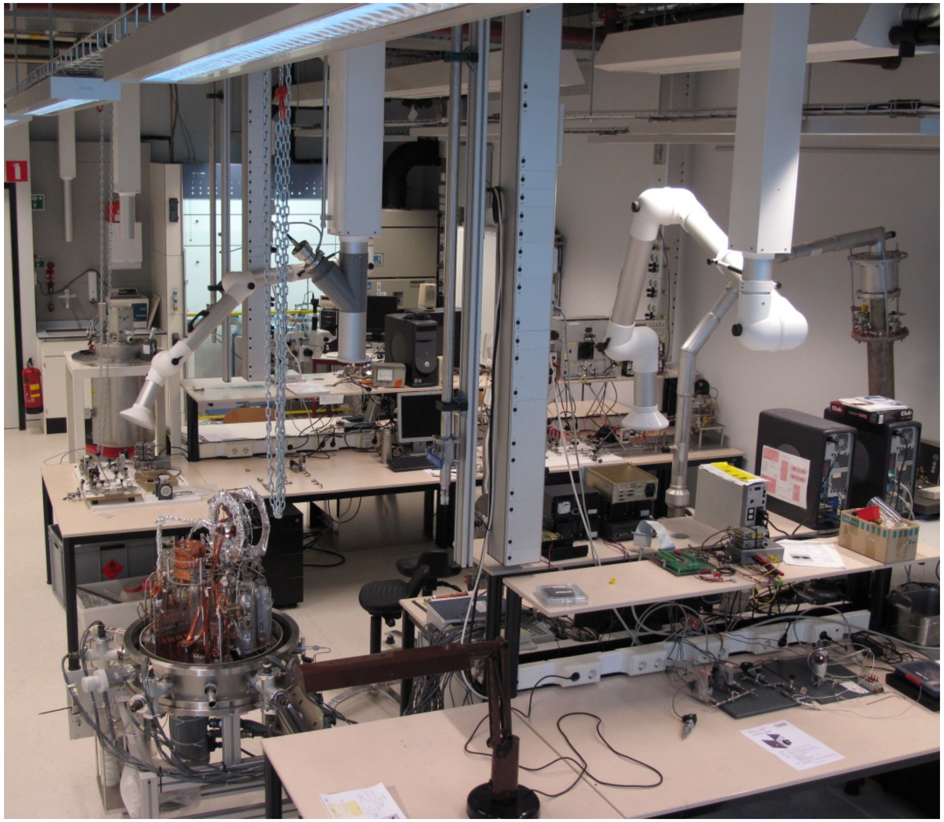
Thema-bijeenkomst “Thermal Challenges”, Mikrocentrum Veldhoven, 15 mei 2019


EMS
Marc Dhalle
materials
superconducting material engineering
cryogenic material engineering
superconductivity
Arend Nijhuis
Marcel ter Brake
superconducting cabling technologies
innovative cooling technologies
cryogenics
superconducting system technology
cryogenic system technology
Herman ten Kate
Srinivas Vanapalli
systems

University of Twente: Energy, Materials and Systems



High-current applications of superconductivity



Advanced cryogenic technologies

Vibration-free sorption-based cooler development at UT

Space coolers

- 4,5 K Helium-stage cooler
- 14,5 K Hydrogen-stage cooler

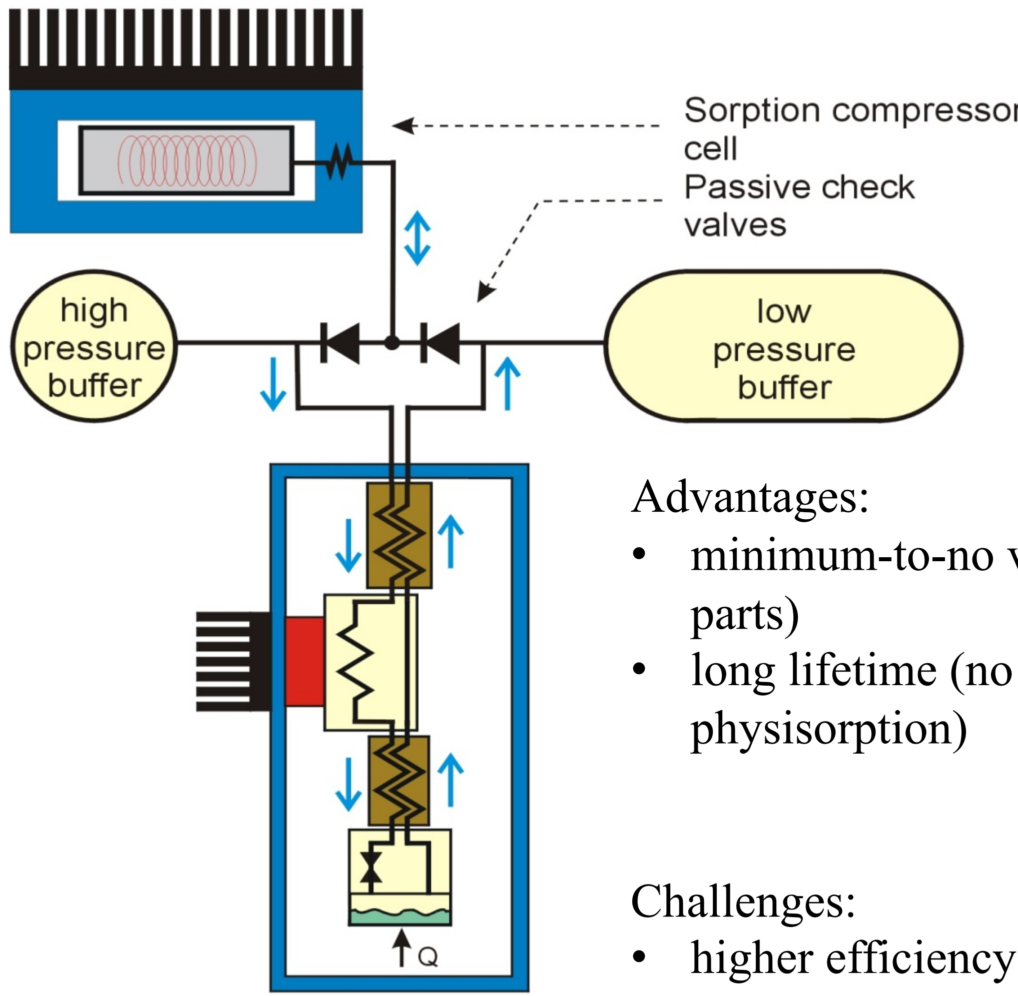
Now at TRL 5

- Sub 2K He-3 sorption-based JT cooler
- He-3 pump for closed-cycle dilution refrigerator (50 mK)

Ground-based

- ELT/METIS sorption-based cooler-chain, 4K/25K/40K sink at 70K
- Candidate cooling technology in Einstein Telescope

EMS research: Sorption-based compressor



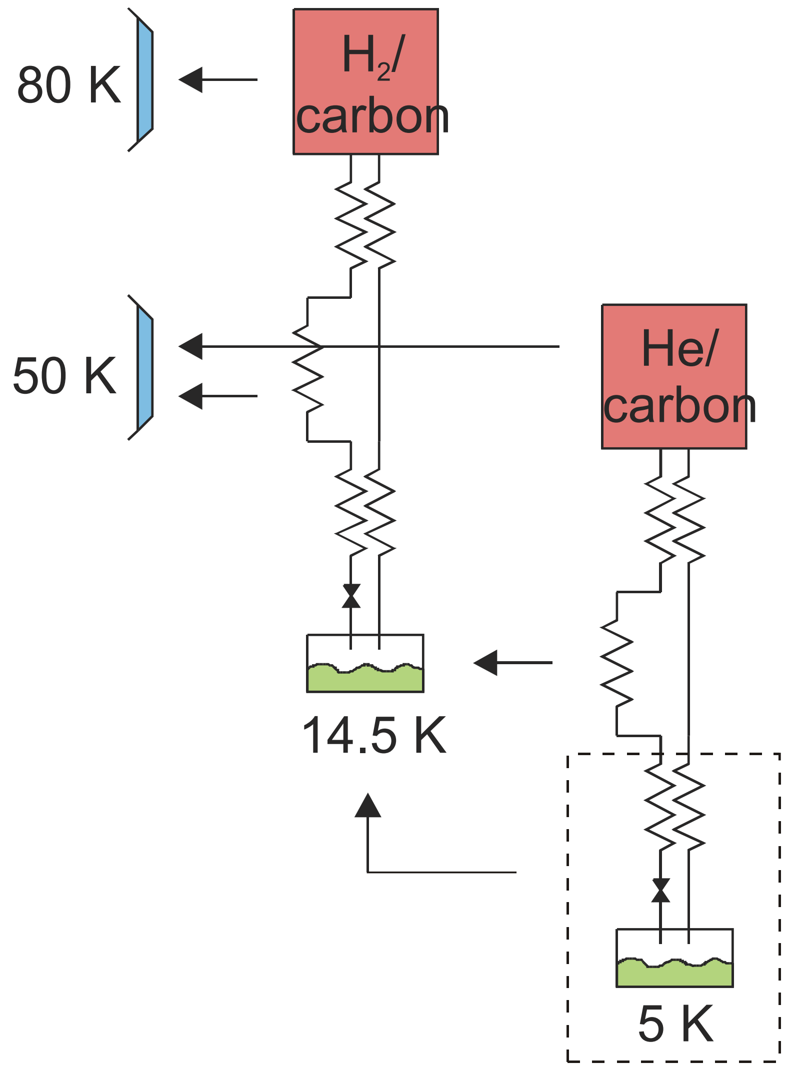
Advantages:

- minimum-to-no vibration (no moving parts)
- long lifetime (no wear and reversible physisorption)

Challenges:

- higher efficiency
  (higher adsorption, gas mixtures)
- Big Science applications

Darwin cooler system design



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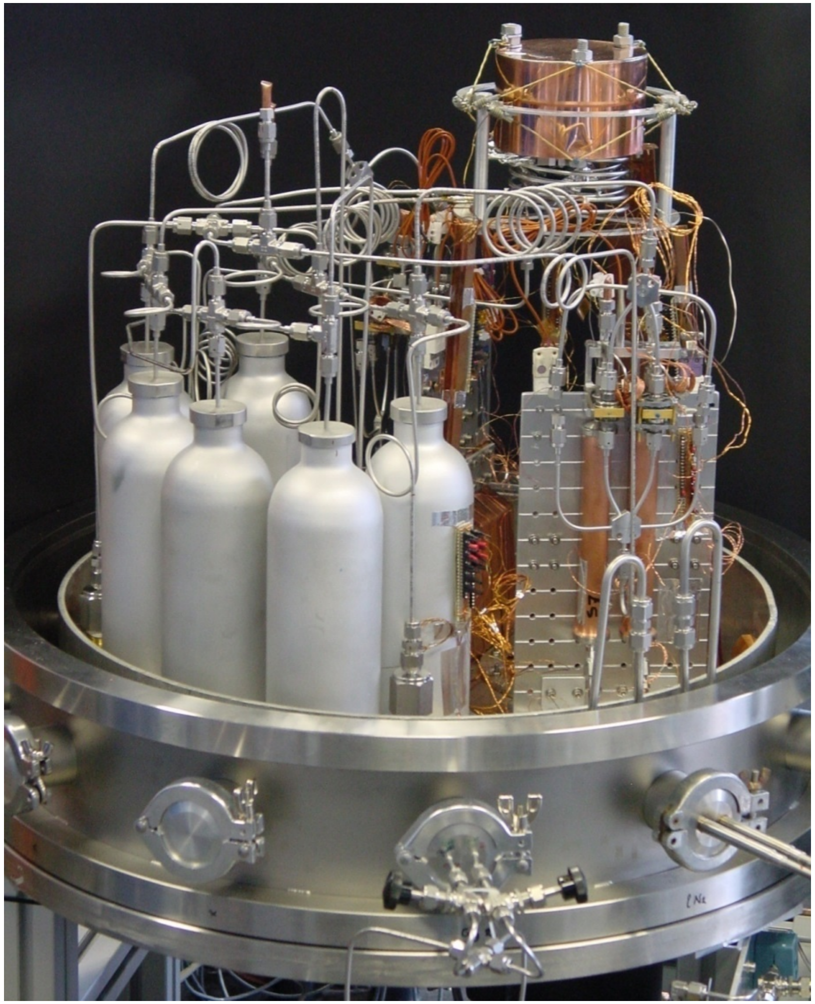
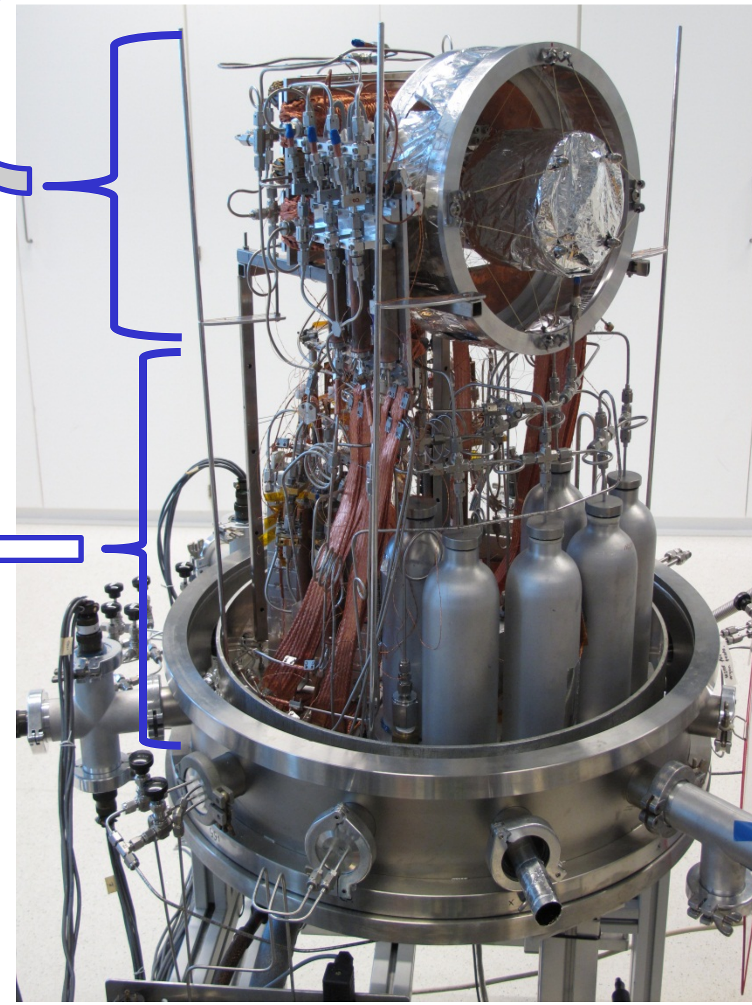
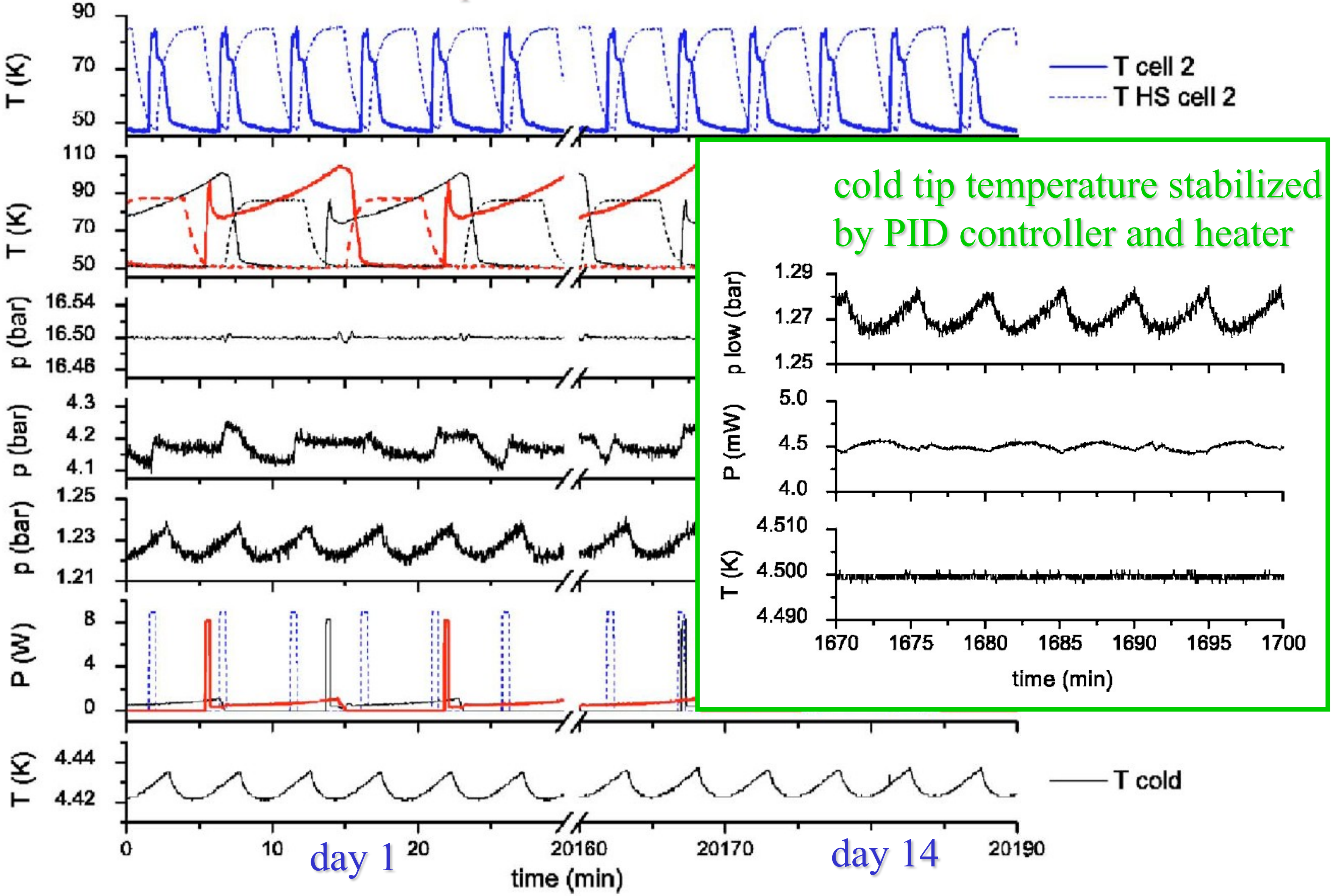
Hydrogen sorption-based cooler
90 K to 14.5 K (precooled at 50 K)





Helium sorption-based cooler
50 K to 4 K (precooled at 14.5 K)

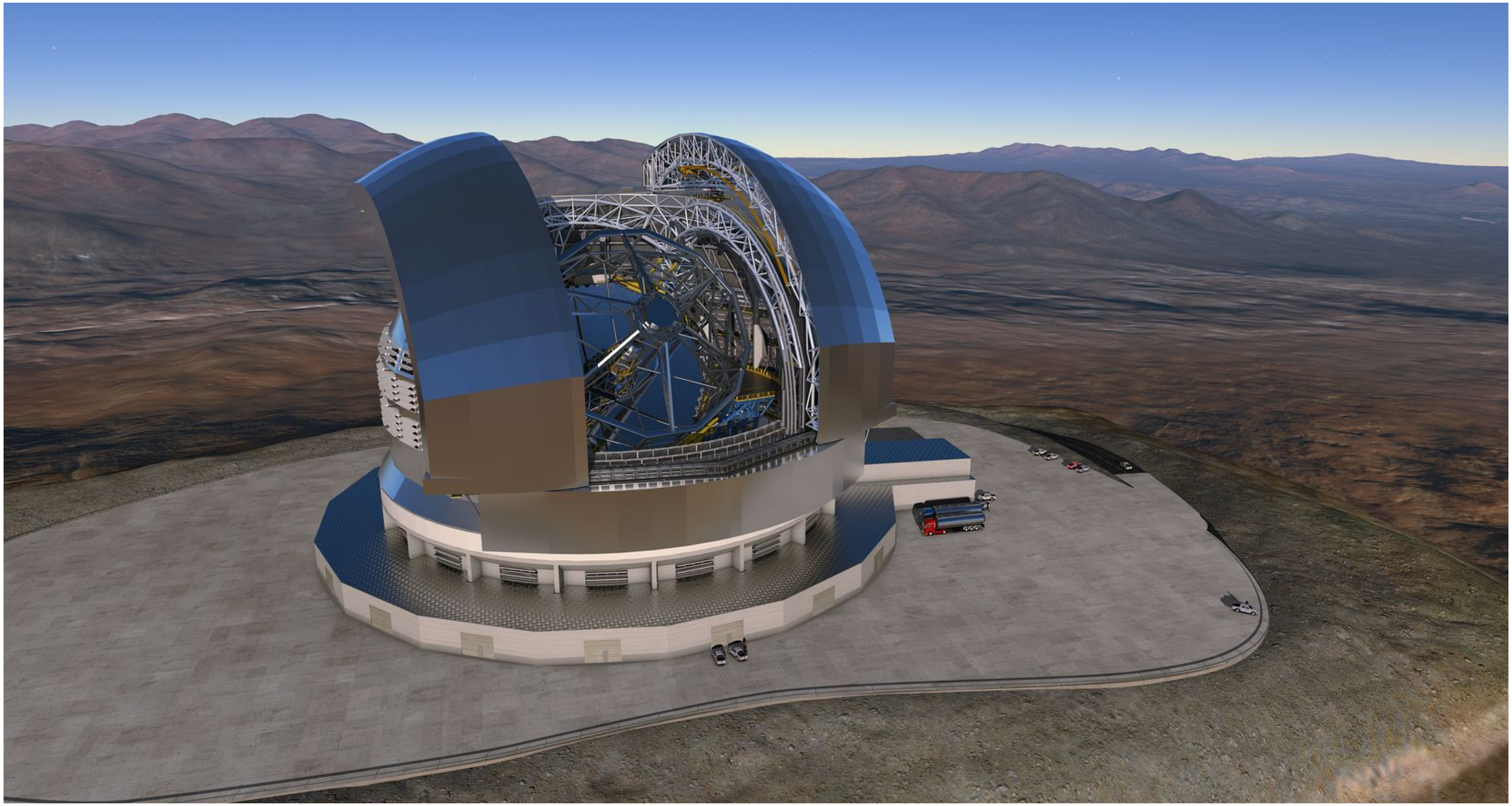
Test experiments: results



E-ELT:
European Extremely Large Telescope

European Southern Observatory

www.eso.org

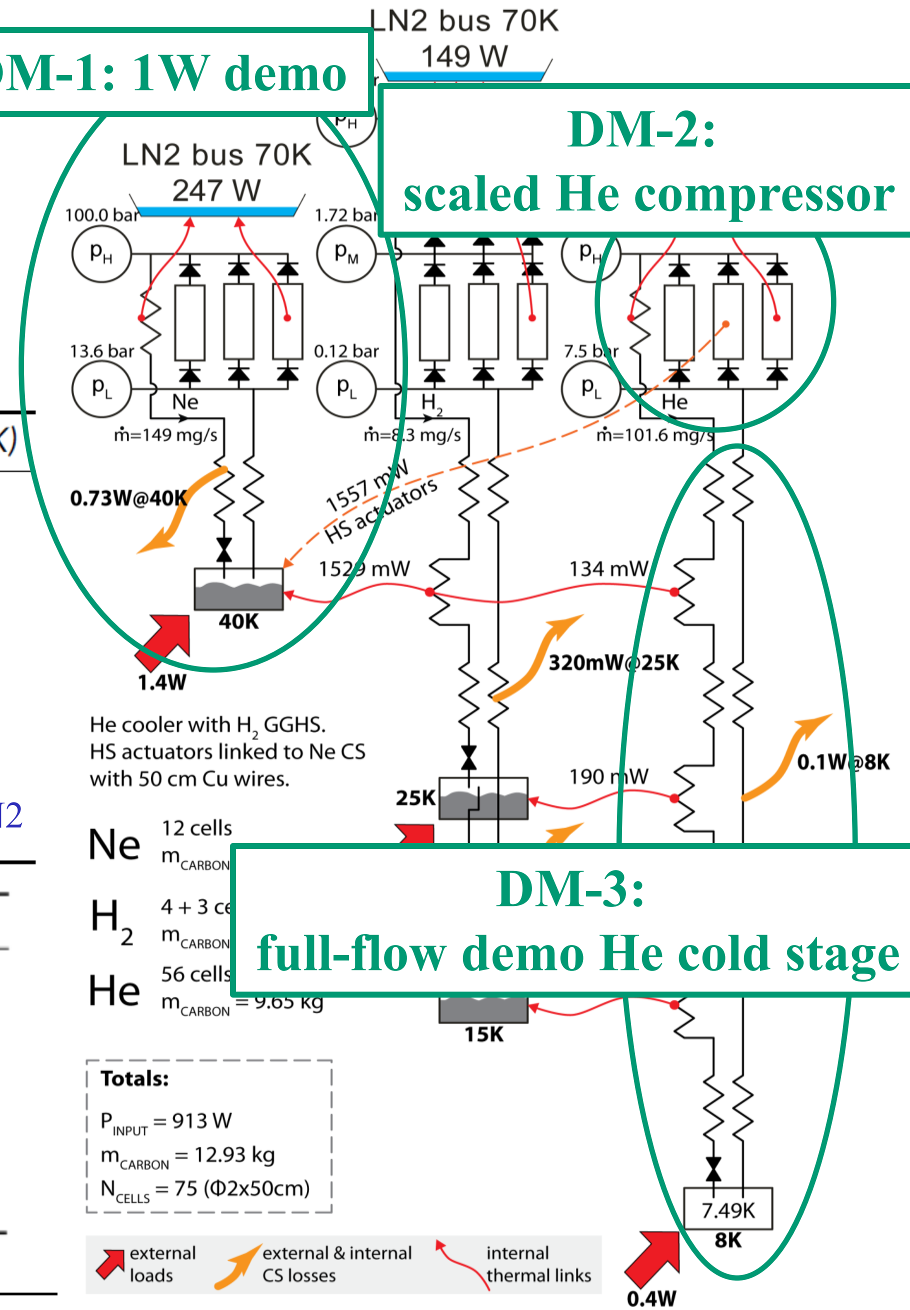


Y. Wu, “Development of a sorption-based Joule-Thomson cooler for the METIS instrument on E-ELT”, 25 November 2015, PhD thesis, University of Twente

Mid Infrared ELT Imager and Spectrograph

METIS Instrument	*Maximum required temperature (K)*	
Radiation shield	85	Liquid nitrogen (LN2) cooled
Fore Optics	85	
Cold Calibration Unit	85	
Wave Front Sensor	85	
LM-Imager	85	
LM-Spectrometer	85	
LM-Band Detectors	40	3-stage sorption cooler starting from subcooled LN2
N-Band Imager	25	
N-Band Detector	8	

Stage	*Helium*	*Neon*	*Hydrogen*
Working Fluid	He-4	Ne	H2
Carbon	Saran	Saran	Saran
Heat Sink Temperature (K)	70	70	70
Low Pressure (Bar)	7.50	13.6	0.122
Intermediate Pressure (Bar)	-	-	2.00
High Pressure (Bar)	14.3	112	23.8
Mass-flow (mg/s)	101.4	148.5	8.343



DM-3 experimental results

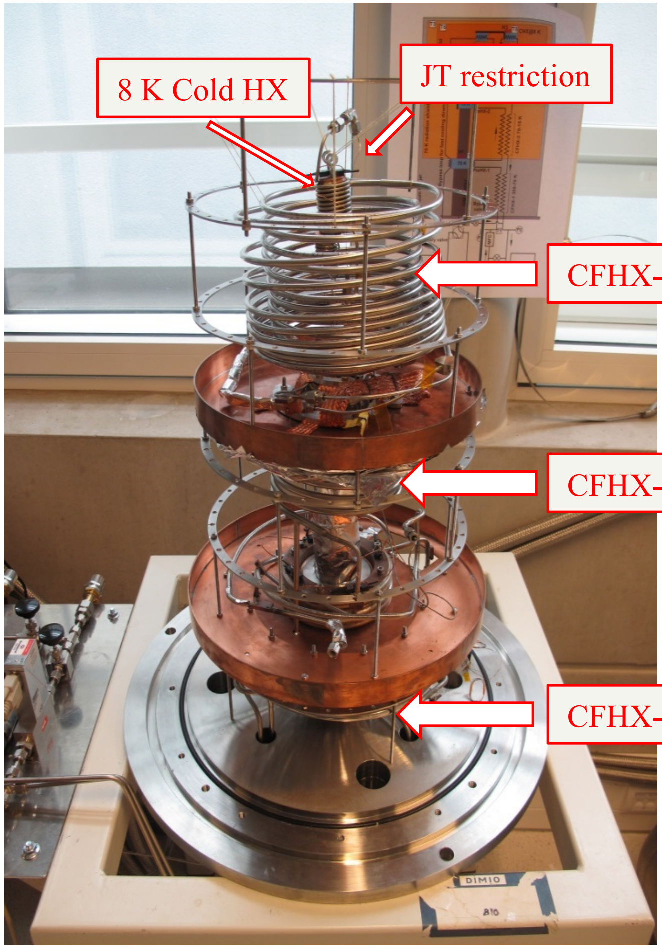
	Average	← in 30 minutes → Max.	Min.
Tc (T8)	**7.977**	7.996	7.933
Qc (H3)	**0.422**	0.424	0.417
p_{high}	14.960	15.076	14.798
p_{low}	7.307	7.392	7.202
mf	99.950	102.728	98.436

in 30 minutes

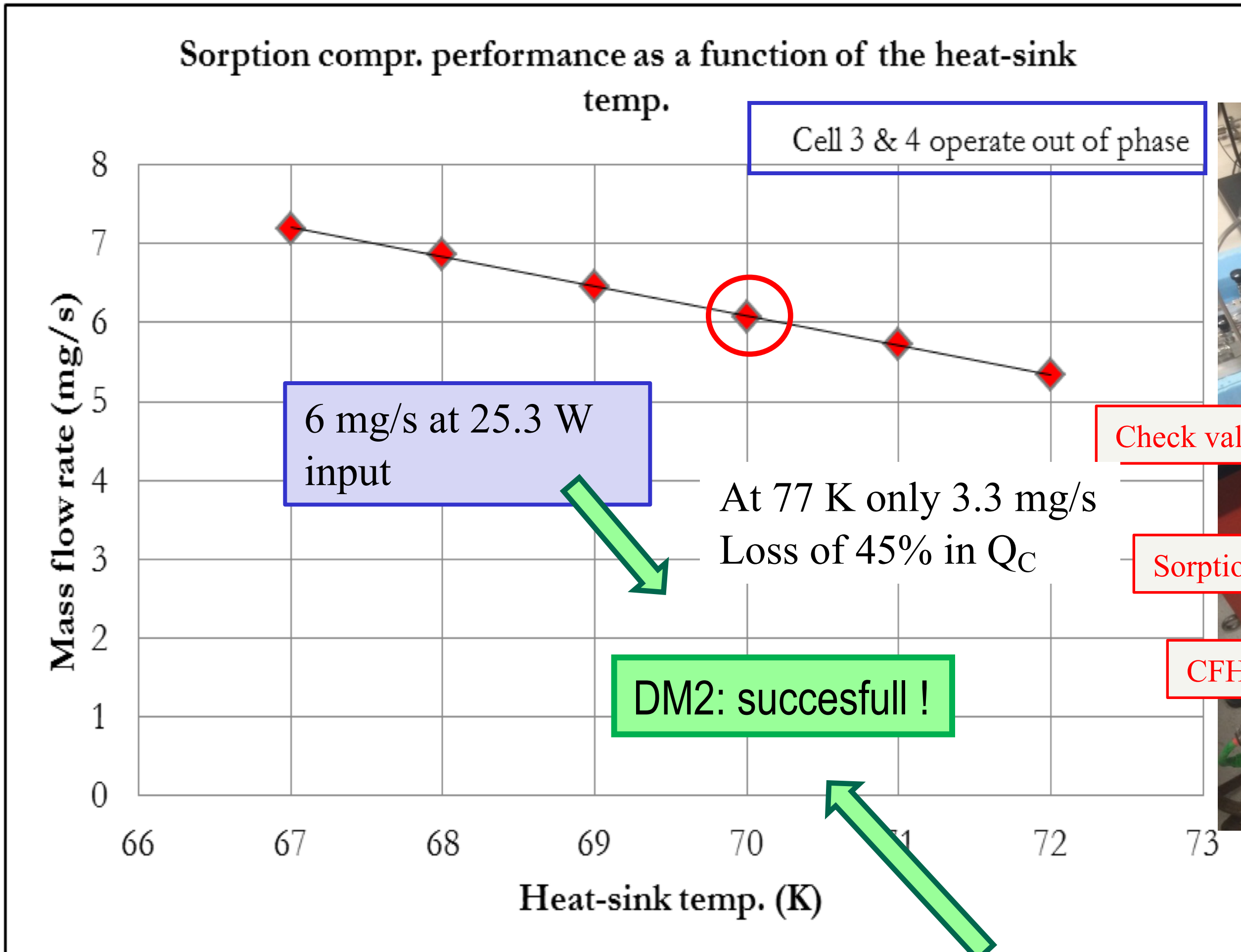
- Temp. stability < 0.07 K
- Q_c stability < 10 mW

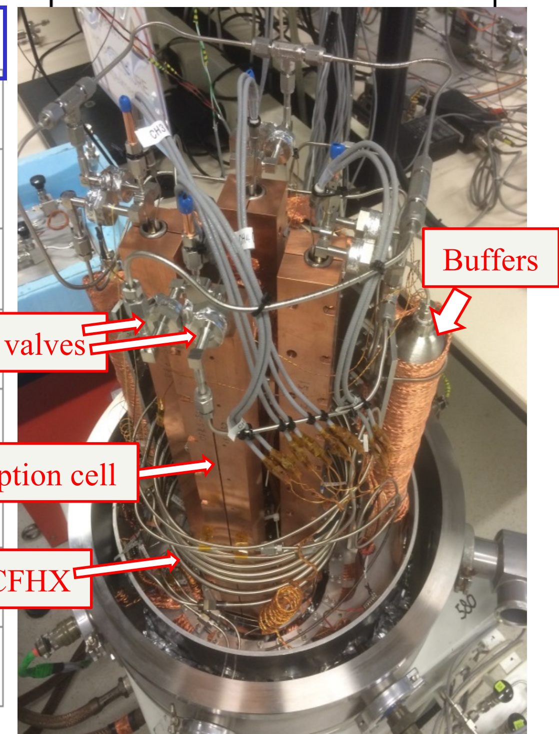
Req: 100 mg/s
0.4 W @ 8 K

DM3: succesfull !



DM-2 scaled He sorption compressor: results

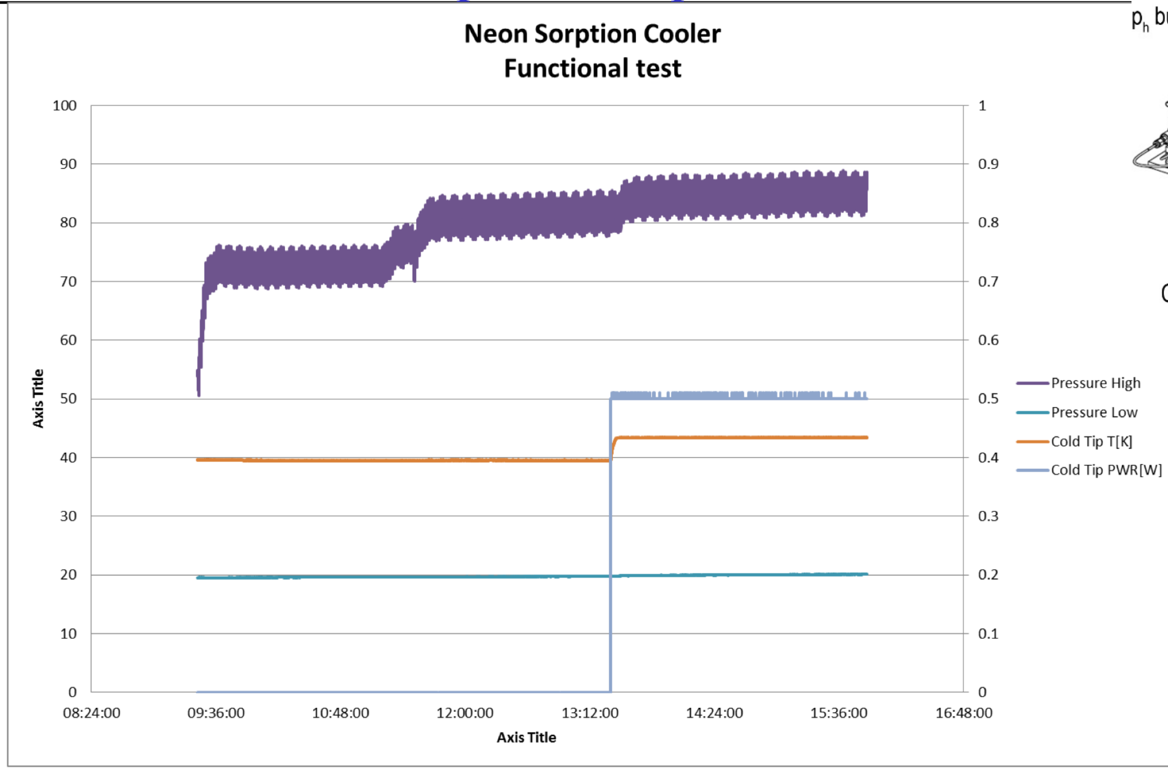


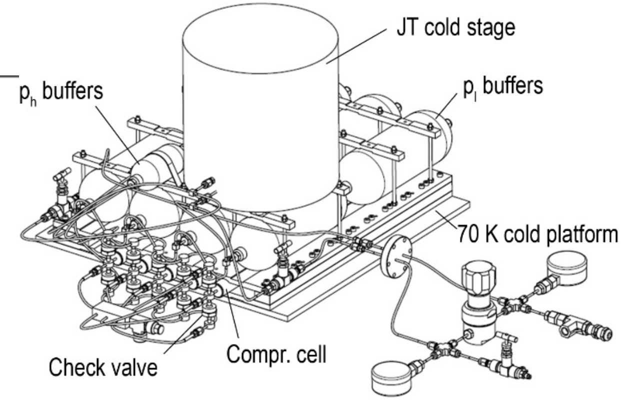


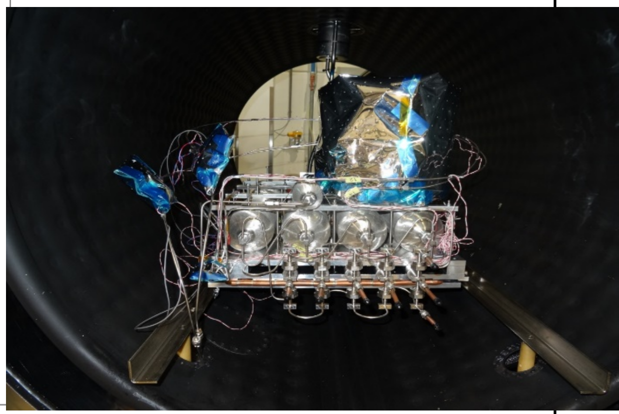
Switchless compressor design: 43 cells, input 676 W
101.4 mg/s; 0.5 W @ 8K (+25% in Qc, + 10% in Pin)

Corresponding to 2 cells, input 31.4 W: 4.7 mg/s

DM-1 scaled Ne sorption compressor: results

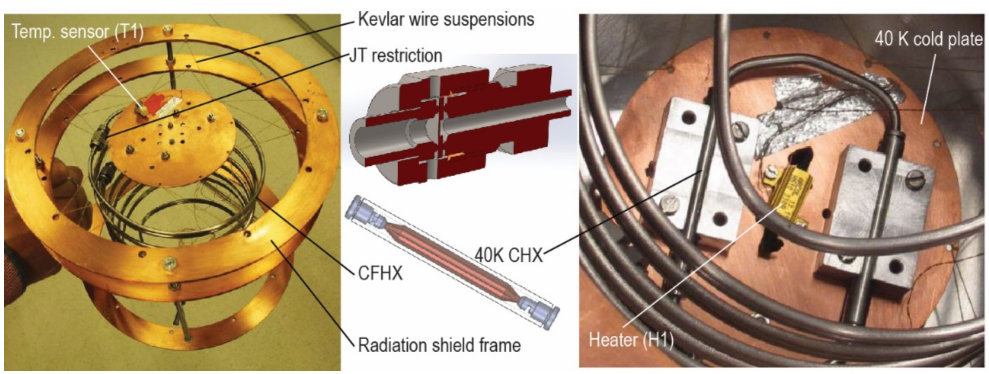




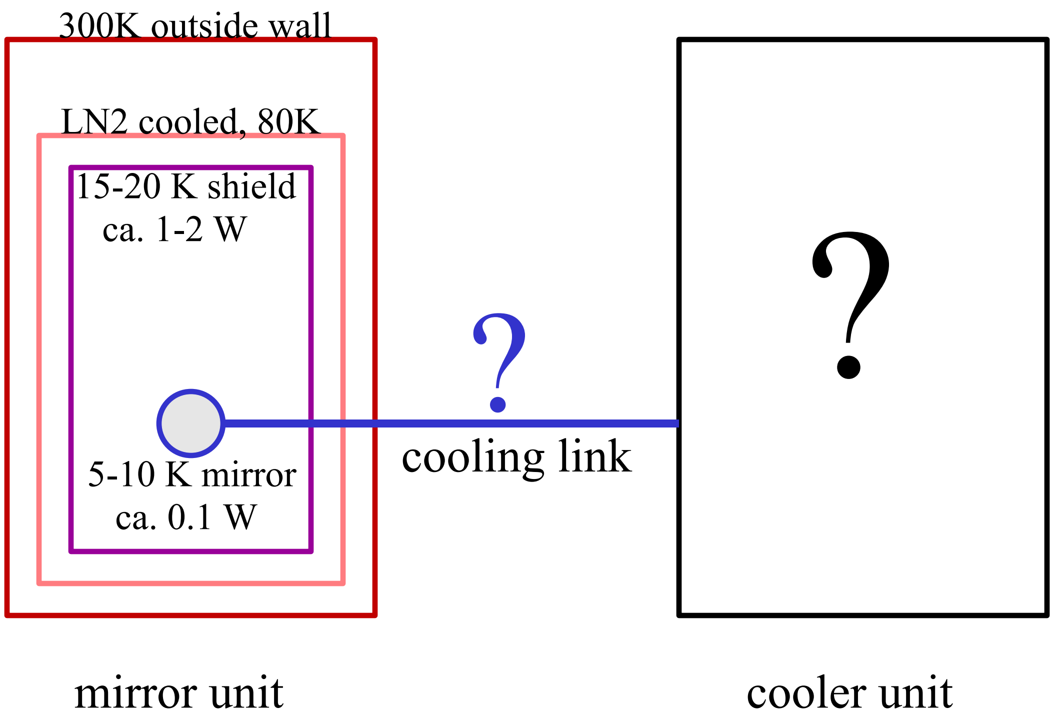


System could not be operated at design conditions (e.g. heat sink at Airbus at 77K):
Measured 0.5 W (would be ca 1 W at 70K sink)
Measured T at 0.5 W load: 42 K

DM2: "close to" succesfull !



Follow-up in Einstein Telescope



Separation between cooler and mirror units:

- ultra clean vacuum space required (no moisture on mirror, prior to cooler start vacuum pressure < 10^{-7} mbar)
- minimize vibrations

Sorption-based cooling: Technology that is enabling BIG science!