Cryogenic operation of the FLASH linac at DESY below 0.5 bar

K. Jensch
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HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

DESY.

Agenda

Overview

01 Introduction

- FLASH Linac
- Why should the operating pressure of the FLASH accelerator be changed?

02 Option to fulfill the legal requirements

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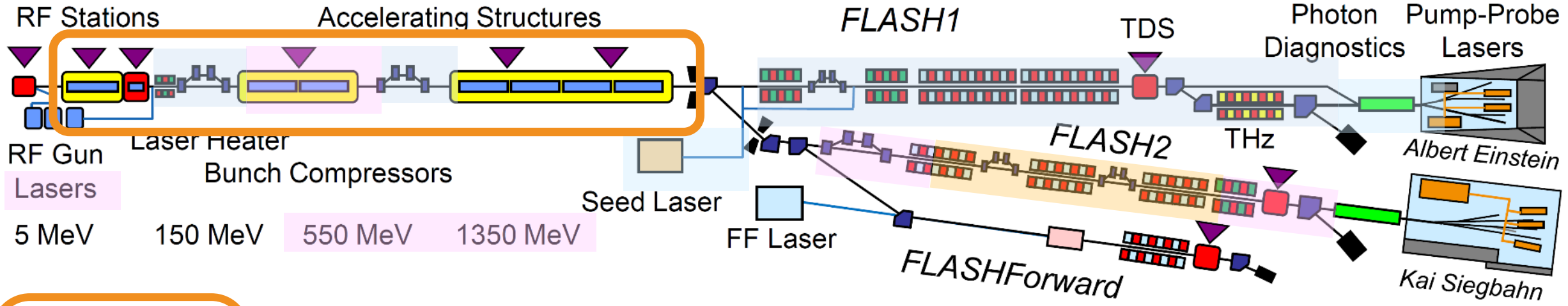
03 Solution how the changes were realized

04 Operating below 0.5bar

05 Summary

FLASH2020 to FLASH2020+

Status 2022 after the "Phase 0" shutdown



Phase 0
Energy upgrade
3rd BC (FLASH2)
TDS (FLASH2)
Injector Laser
Afterburner FLASH2

Phase 1
Variable gap undulators (FLASH1)
Pump-probe laser (FLASH1)

Laser heater in 1st BC
New 2nd bunch compressor (BC)

Phase 1+
High rep.rate seeding (FLASH1)
Photon diagnostics (FLASH1)

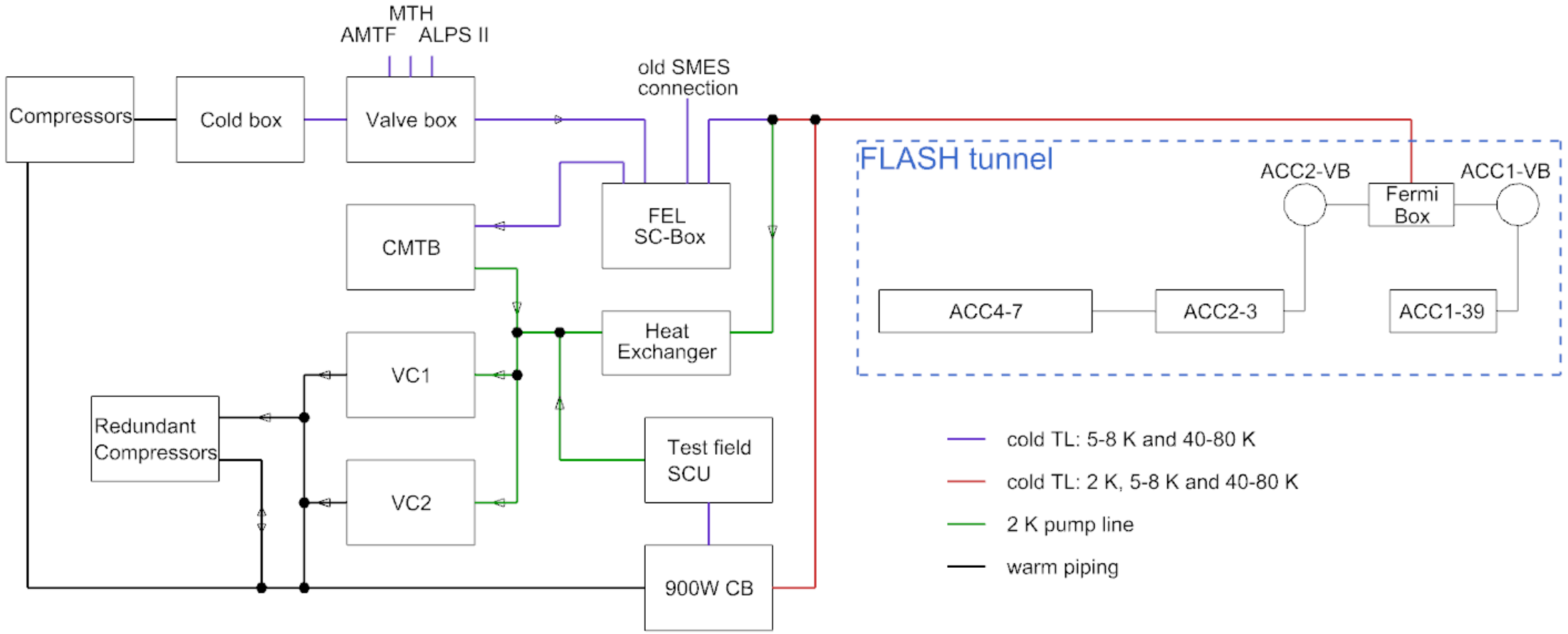
Phase 2
New variable gap undulators + chicanes
for new lasing concepts (FLASH2)

FLASH details: see SRF2023 **TUIAA02**, M. Vogt: "FLASH 2020+ Upgrade Project"

FLASH cryogenic supply

In 2023

- One 3.9 GHz and seven 1.3 GHz **SC cryomodules**
- Cooled by one **former HERA cryoplant,** shared with CMTB (2006), AMTF (2010), ALPS II (2021)



Why should the operating pressure of the FLASH accelerator be changed?

- FLASH is in operation since mid-1990s, first as TTF, then as TTF/VUV-FEL machine and since 2005 as FLASH.
- For the operation it was agreed mid ‘90s with the regulating authority for pressure vessel to operate the linac with 4 modules and as a test field.
- Since 2009 FLASH contains 8 modules (7x 1.3 GHz and one 3.9 GHz) and since 2005 is a user-machine
- The updated operational safety regulations (Betriebssicherheitsverordnung “BetrSichV”)
  - NO exceptions allowed! → All components above 0.5 bar at **test stands and research facilities** needs to be fully certified after major plant modifications!
- Major FLASH upgrade in 2020: two new modules has to be installed on the ACC2/3 section → it counts a major modification and the whole accelerator has to be proofed by a inspection body!
- Only two of the eight installed module fulfil the requirements → we need a plan and working solution…

Option to fulfill the legal requirements

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Option 1 “New cold accelerator”

- Six new 1.3 GHz cryomodules
- New cryo infrastructure in the linac, boxes, caps and so on

→ absolute unrealistic in terms of budget and time…

Option 2 “Decommissioning of FLASH” → No option

Option 3 “Reduction of the operating pressure in all cryo circuits below 0.5 bar”

- But cryo circuits are designed for:
  - 2K circuit – 16 mbar to 2 bar
  - 4/5K circuit – 1 to 16 bar
  - 40/80K circuit – 1 to 16 bar
- Safety lines to the installed relief valves were also designed for these pressure values

Can FLASH be operated at 0.5 bar?

Calculation and real test

Calculations were performed to verify that the existing piping system of the modules, boxes and transfer lines is sufficient for the low pressure

- For steady state operation -> It will work
- For warm up / cool down -> “Should” work, but needs to be tested (operation may take a week longer)
- Safety lines to the relief (safety) valves are definitely too small!
- Standard spring loaded relief (safety) valves will not “work”!

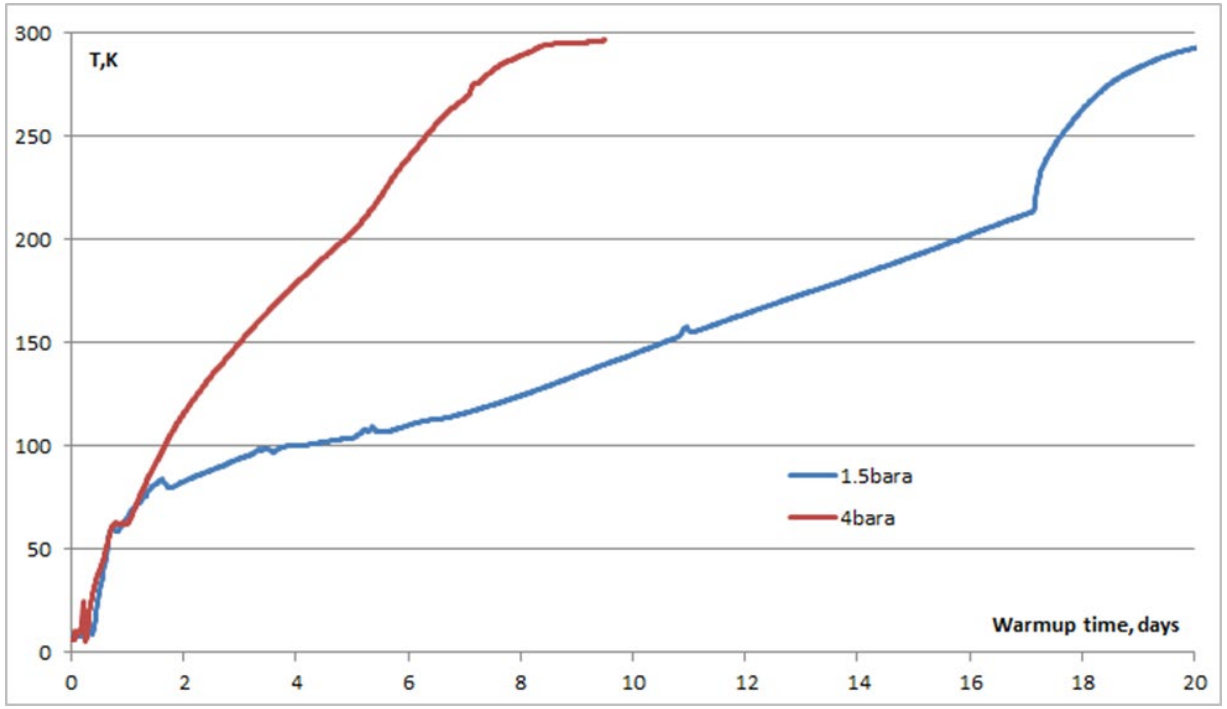
Operation test with FLASH

- Test steady state operation beginning of 2020 -> worked, 4/5K and 40/80K circuits could be operated stably
- Test warm up / cool down April 2020 -> it was a challenge for the operators to find the correct parameters, valve settings and so on “on the fly”. Some of the valves were not dimensioned for these pressure!

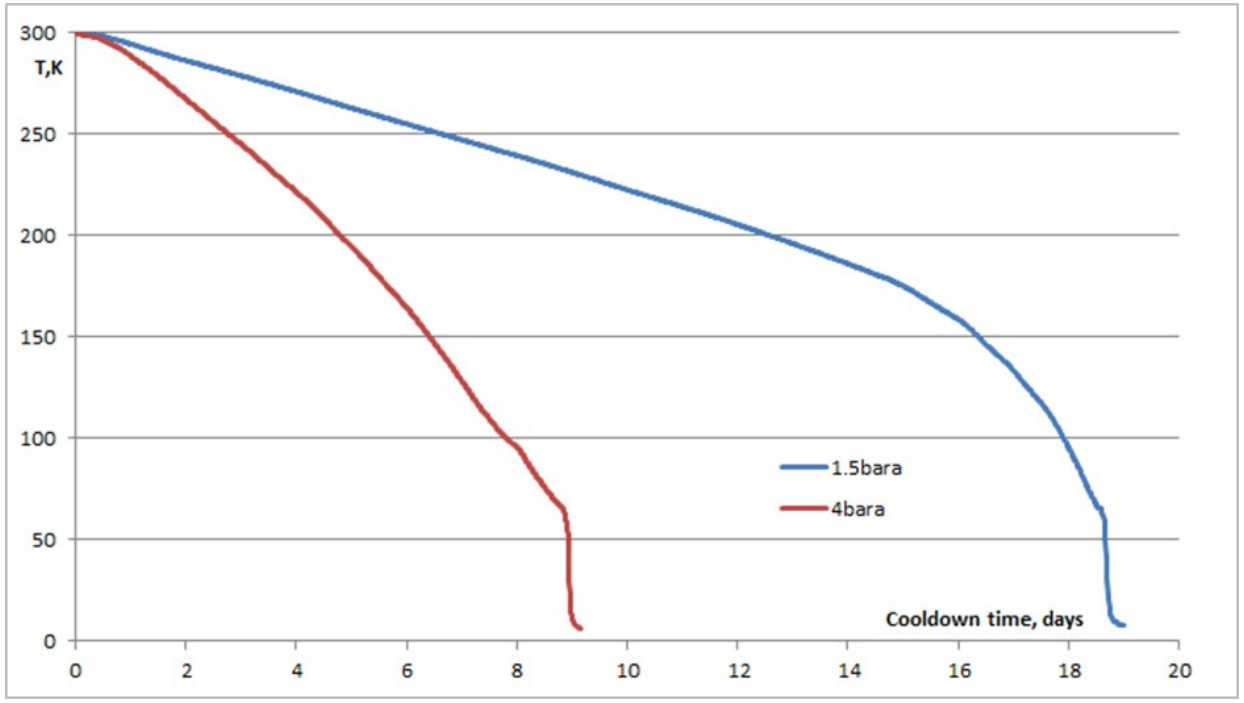
Test run warm up / cool down with max. 0.5bar

With the original pipe and valve configuration

Warm up



Cool down



Option to fulfill the legal requirements

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Burst discs -> No desired option

- Specified working pressure up to 0.49 barg is too close to the 0,5 barg set pressure
- Pump and purge actions and operation up to 0.49barg lead to shift of the breaking point of the burst discs -> the opening pressure will be reduced
- Back-pressure of 0.3 barg shifts the opening pressure -> not acceptable
- After a burst, the disc has to be replaced

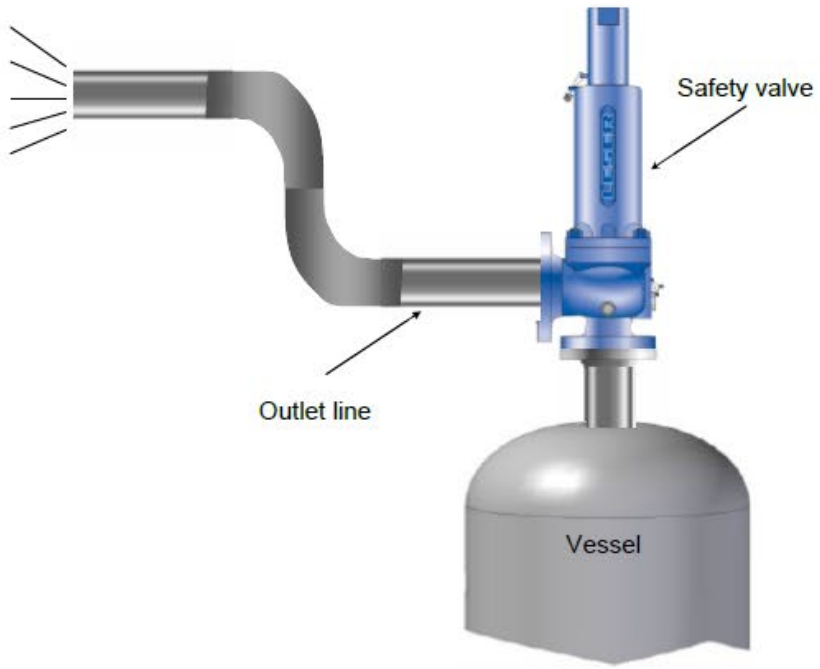
Standard spring loaded relief (safety) valves -> Not a option

- Specified working pressure up to 0.49 barg is too close to the 0.5 barg set-pressure
- Back-pressure of 0.3 barg -> the SV will open at 0,5 barg but not completely
- After the valves have opened -> the pressure must be reduced by 0.3 bar to fully reclose the safety valves

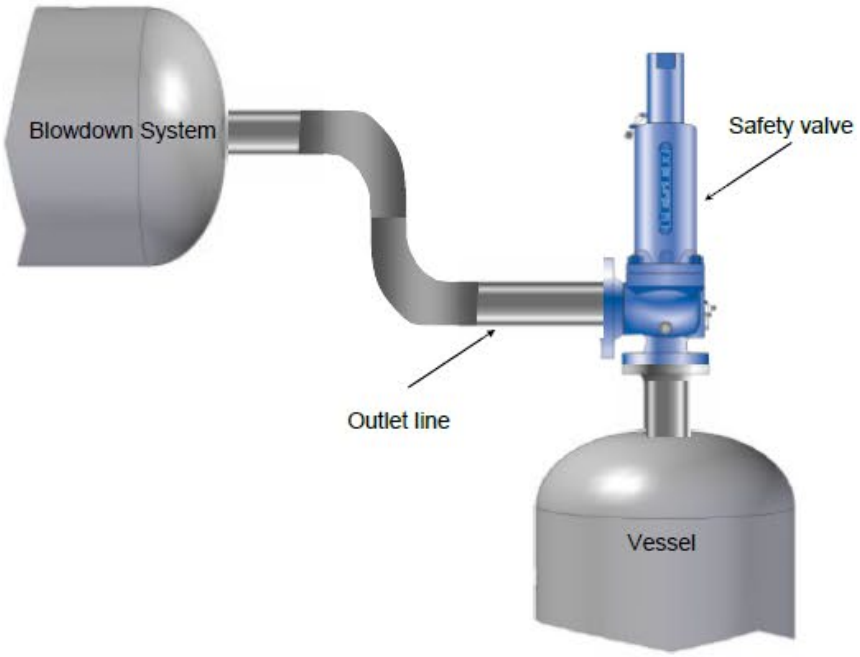
Back-Pressure

Pressure that exists at the outlet of a SV as a result of the pressure in the discharge system

Without Back pressure



Built-up Back pressure

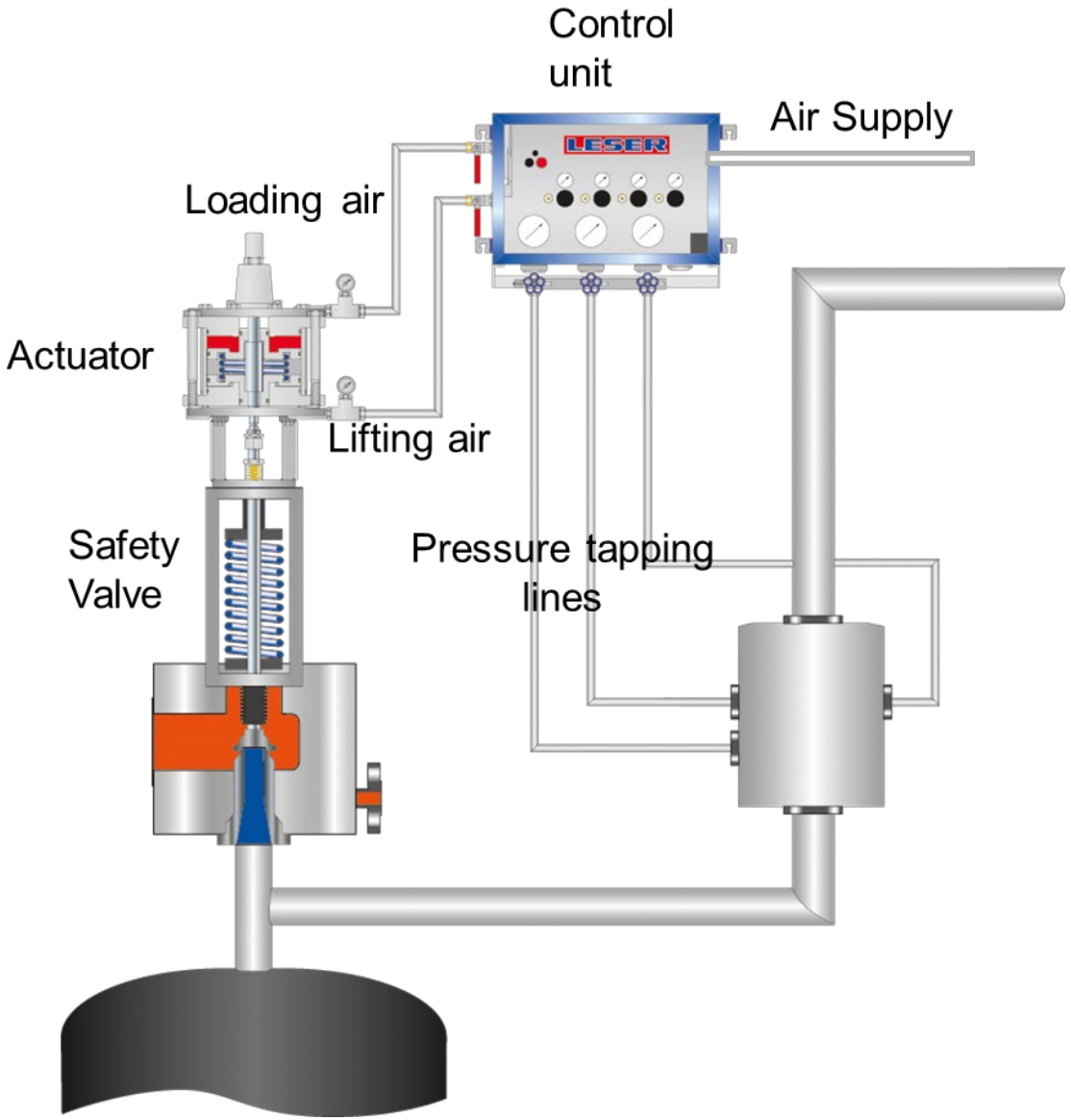


Superimposed Back pressure
System used @ FLASH
Back pressure @ exhaust manifold is maximum of 0,3 barg if the screw compressors fail.

Option to fulfill the legal requirements

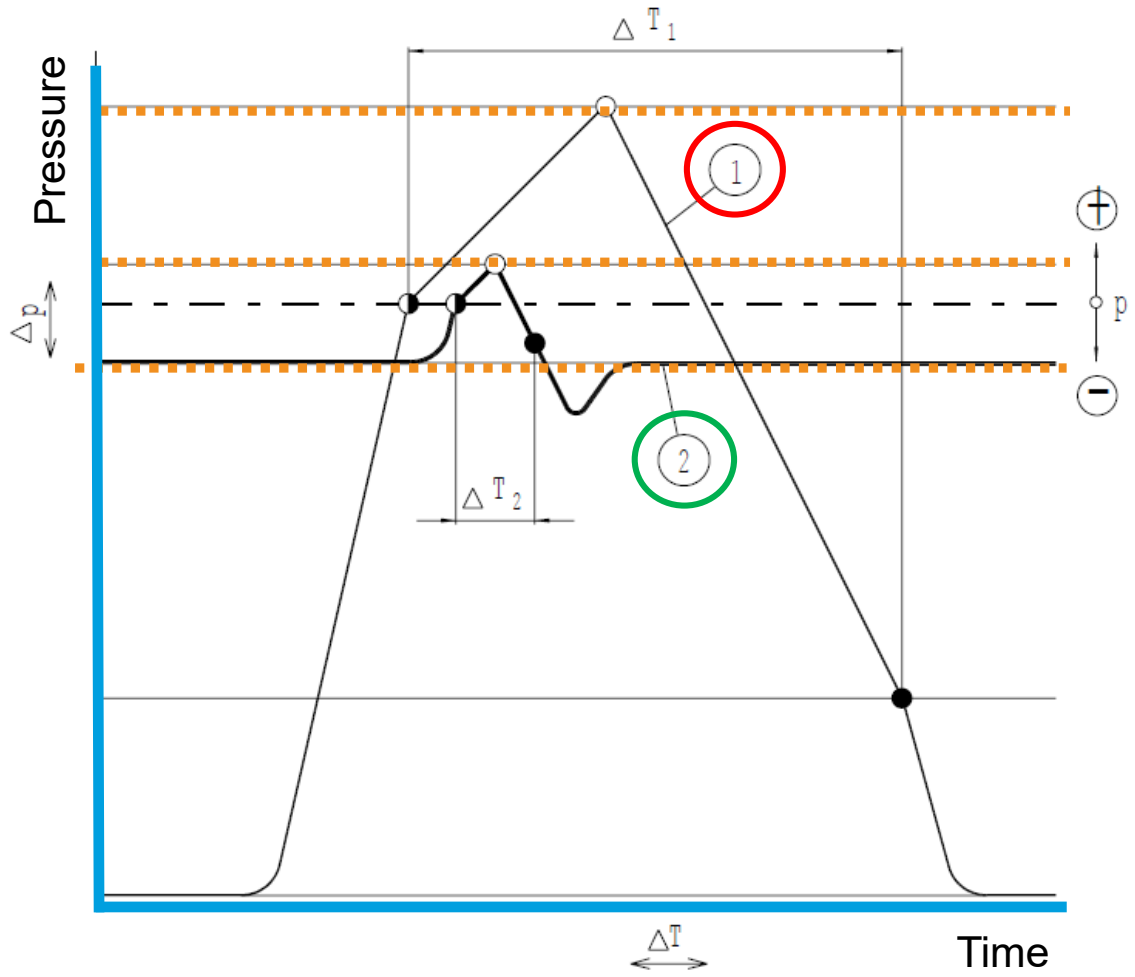
Solution -> standard spring loaded relief valves with added Pneumatic Supplementary Loading System

- Using “pneumatic supplementary loading system” the back pressure can be compensated and hence the system remain below 0,5 barg which is the requirement of “BetrSichV”



Pneumatic Supplementary Loading System

This system also allows to operate closer to 0,5 barg



p = Ansprechdruck / set pressure

Δ p = Druckveränderung im zu sichernden System
pressure difference in the system to be protected

Δ T = Öffnungs- und Schließzeit des Sicherheitsventils
Time of valve operation

1 = Druck-Zeit-Verlauf ohne Zusatzbelastung
Time / pressure behaviour without supplementary loading

2 = Druck-Zeit-Verlauf mit Zusatzbelastung
Time / pressure behaviour with supplementary loading

= Sicherheitsventil - Öffnungsbeginn
safety valve commencing to lift

= Sicherheitsventil offen / safety valve opened

= Sicherheitsventil geschlossen / safety valve reseated

Where there is sun there is also shade

The lower working pressure requires more and larger relief valves

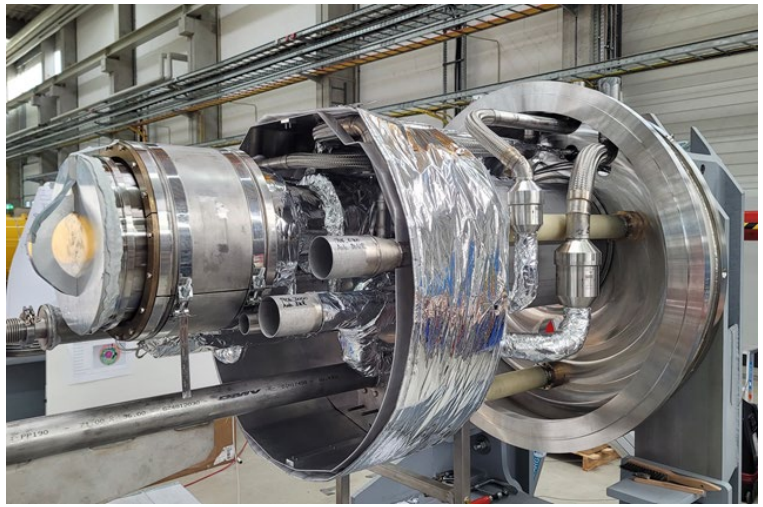
- Helium inventory nearly the same before and after changing but the differential pressure between the process circuits and the safety collector is dramatically reduced.

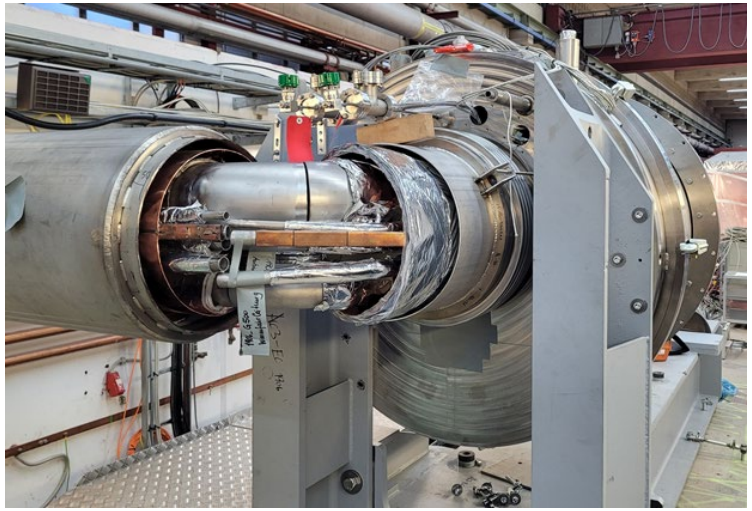
	FLASH until 2021		FLASH after
• 2K circuit –	2 bar to 0.(3)bar	→	max 0.5 to 0.(3)bar
• 4/5K circuit –	16 bar to 0.(3)bar	→	max 0.5 to 0.(3)bar
• 40/80 circuit –	16 bar to 0,(3)bar	→	max 0.5 to 0.(3)bar

- The total numbers of required relief valves more than doubled
- The dimension of the new relief valves increased, e.g. DN20 to DN50

Integration of the new relief valves

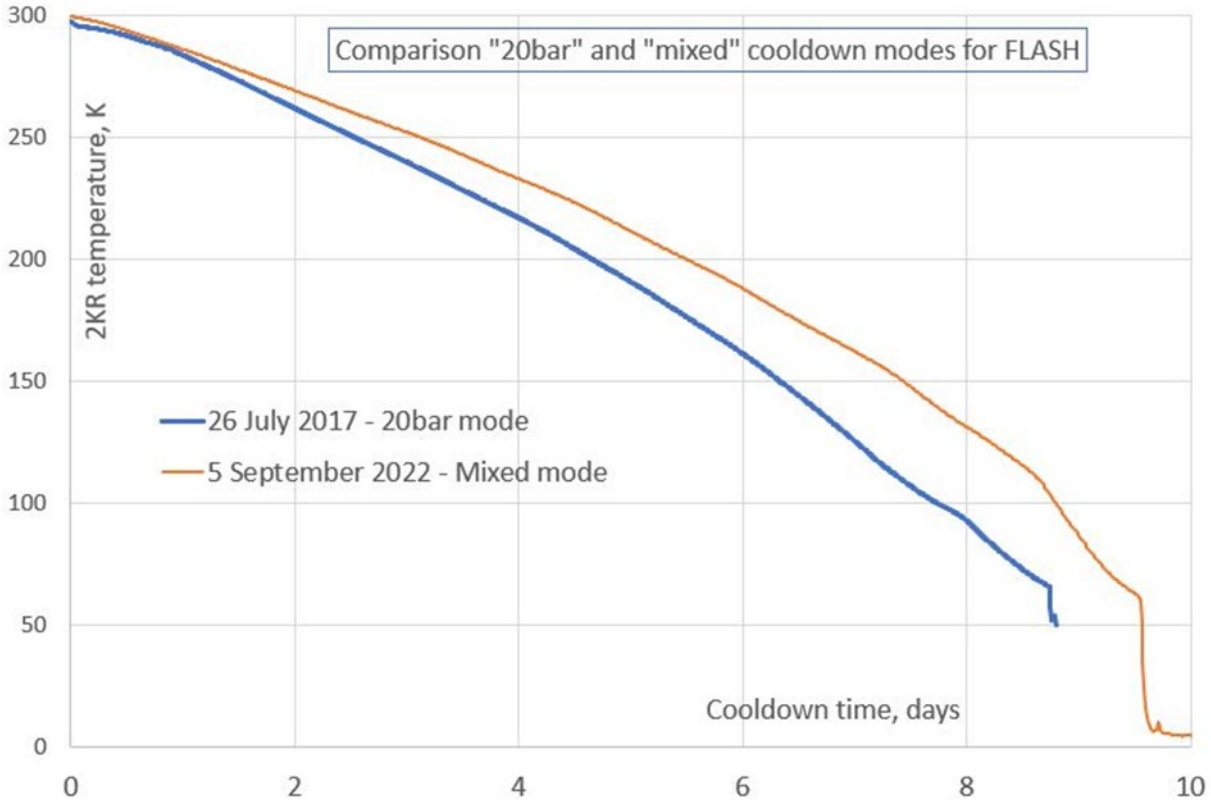
Some impressions





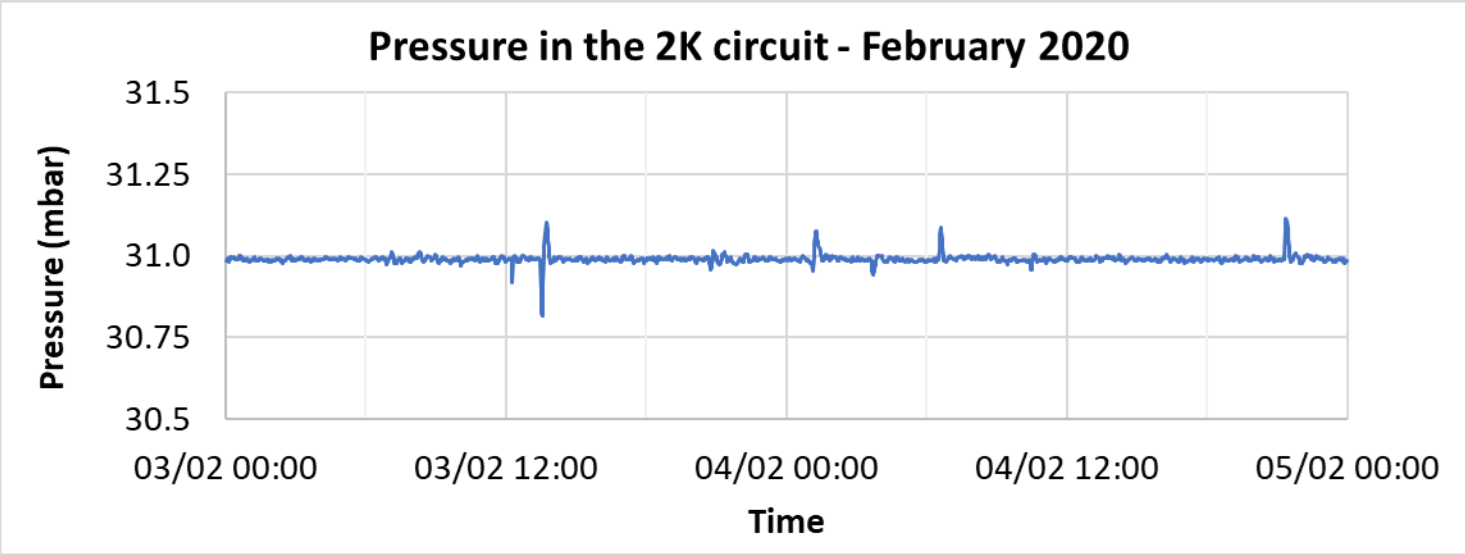
Cooling cycles and cool down with new configuration

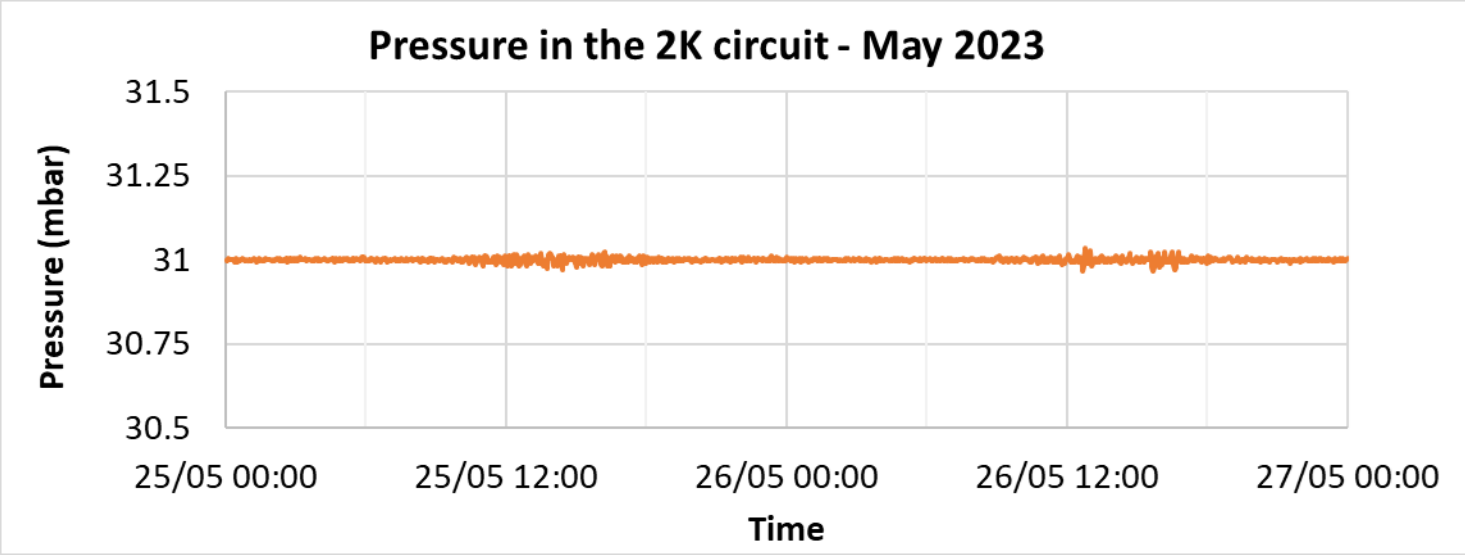
- Since 2002, FLASH has seen 9 cool-downs and 8 warm-ups
- Average cool-down/warm-up time (to 4 K):
  ~10 days each
- Expected a slightly longer cool down with 0.5 bar operation, but no substantial difference in cool down duration observed
  - Some issues with mixing warm gas and cold gas in the 4 K forward line → more practice needed!
  - FEL sub-cooler box in 2017 already cold, in 2022 cooldown together with FLASH



2K Pressure stability for the Cavity

- Average pressure stability better than 0.1 mbar (75 mTorr)
- Values not affected by 0.5 bar operation





Summary

One year of 0.5 bar operation

- Low pressure but nearly same Helium inventory required more and larger relief valves
- Slight higher static heat loads due of more and larger safety lines
- The system is more sensitive to disturbances
  - A faster reaction time is needed
  - Modification under discussion for next shutdown
- The system is more sensitive to to changes in parallel systems (AMTF, CMTB, ALPSII)
  - More caution needed during parallel and transient operation
- Recovery after a outage takes longer, more caution needed to avoid opening of relief valves

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Thank you for your attention!

and

Thanks to my colleagues where I could pick up information and slides

Contact

DESY. Deutsches
Elektronen-Synchrotron

www.desy.de

Kay Jensch
MKS Group
Kay.jensch@desy.de
+49 (0) 40 8998-3010