Commissioning and First Cooldown of XFEL Linac

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Deutsches Elektronen-Synchrotron (DESY) - for the XFEL work package 13

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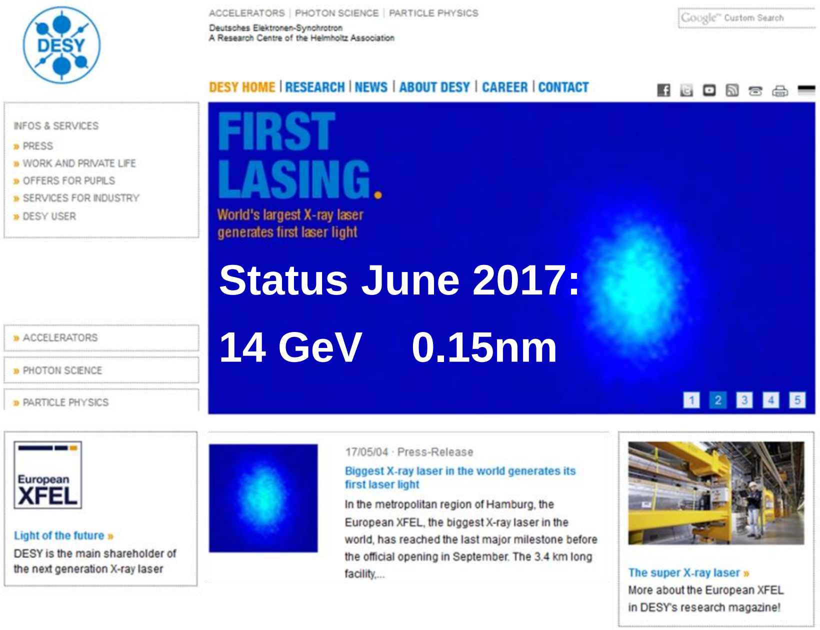
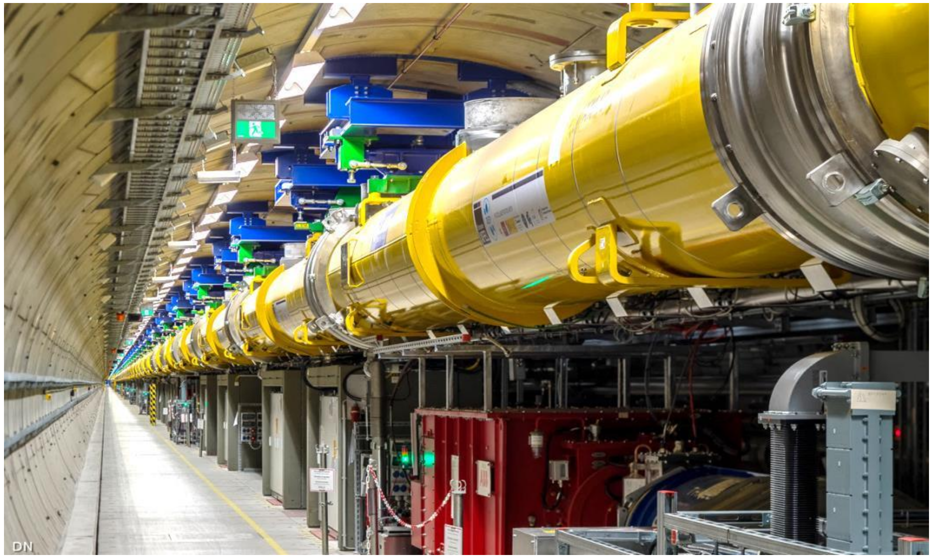
C2OrD

Overview

- XFEL cryogenic system overview
- Main cryogenic components
- Cool Down: limitations & procedures
- Cool Down of the XFEL linac and injector
- Static heat loads to the XFEL linac
- Conclusion & Acknowledgements

European XFEL Project – superconducting Linac





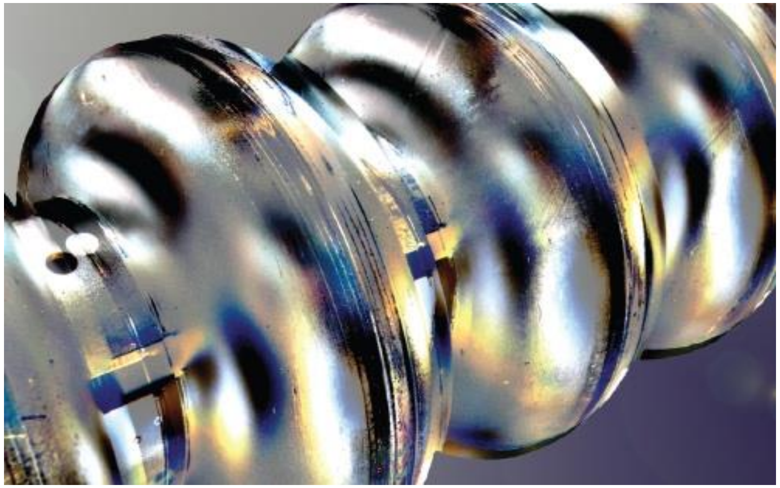
Key figures:

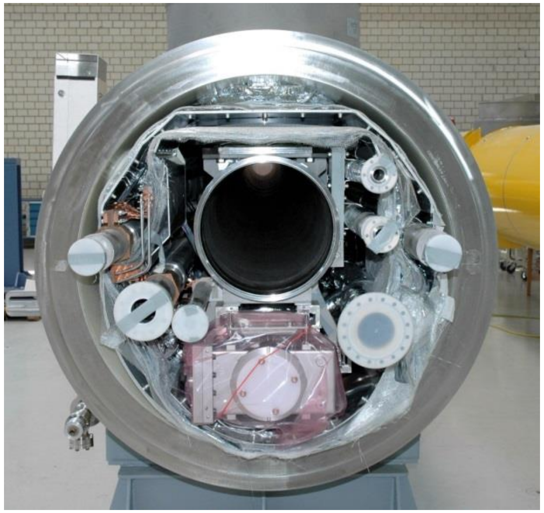
- Length of accelerator: 1500m
- Length of facility: 3400m
- Accelerator modules : 96
- Max. electron energy: 17.5 GeV
- Laser wavelength: 0.2 – 0.05 nm
- Start of regular operation: July 1st,2017

Use of ‚TESLA-Technology' for XFEL

800 superconducting 9-cell 1.3 GHz cavities

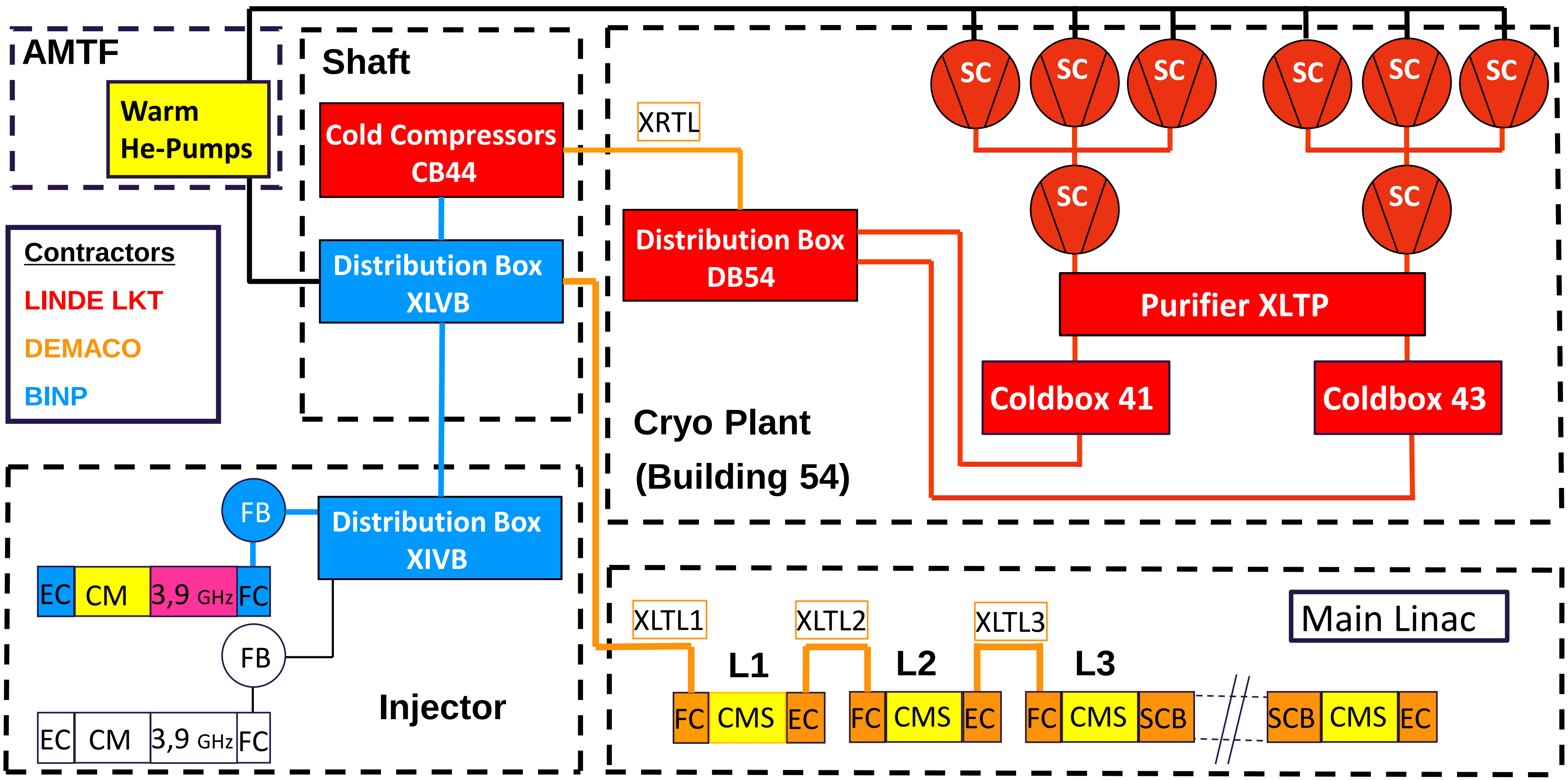
Helium II bath cooling at 2.0 K - 5/8K and 40/80K thermal shields





8 cavities + sc Quadrupole = 12m Cryomodule

Overview of XFEL Cryogenic System



XFEL Cryogenic System- main components (1)

- Two former HERA refrigerators
- Overhauled
- Modified for XFEL process
- 20K return flow integrated

Contractor: Linde Kryotechnik AG (LKT)

XFEL Refrigerator Capacities

Circuit	Parallel CB operation measured, kW	17.5 GeV operation calculated, kW	17.5 GeV design specification, kW	Single CB operation measured, kW
2K	>2.56	1.46	1.90	>2.0
5/8K	>4	2.4	3.6	2.8
40/80K	>26.7	16	24	18

XFEL Cryogenic System- main components (2)

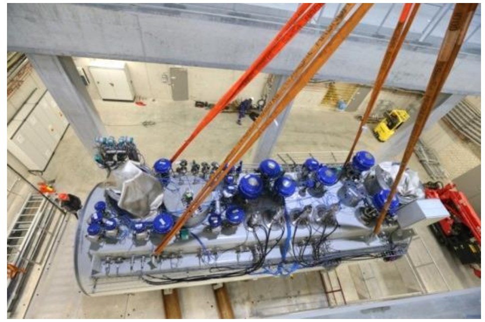
- Added refrigerator components

  Contractor: LKT

- Distribution box DB54
- LT Purifier
- Refrigerator Transfer Lines

  Cryoworld,NL

XFEL Cryogenic System- main components (3)

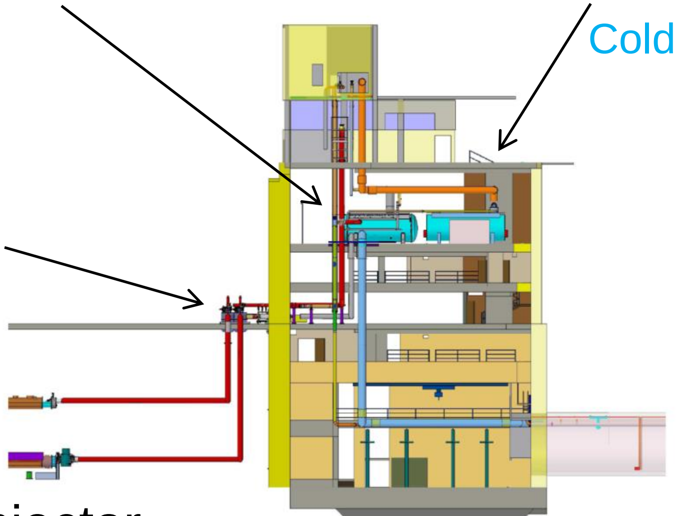


XLVB (BINP)

CB44 (LKT)

Cold Compressors

XIVB



Linac

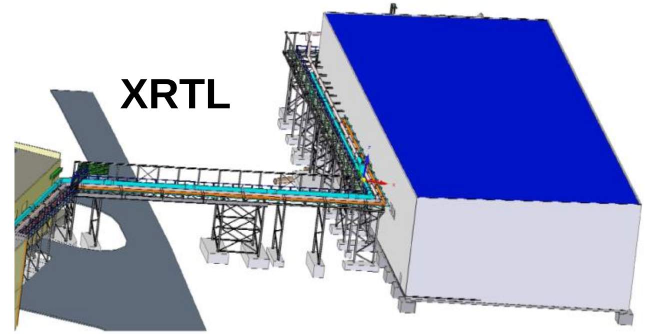
Injector

Transferline to linac XLTL1

XFEL XSE shaft bldg.

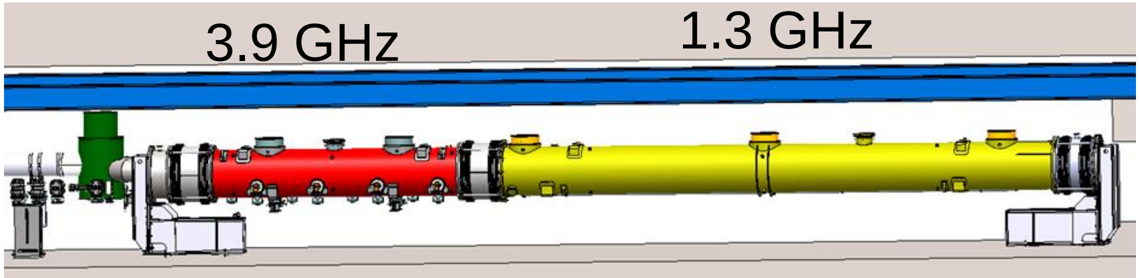
Distance: 170m

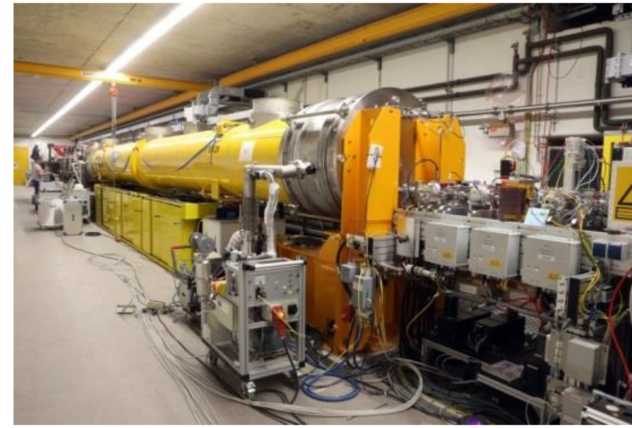
Refrigerator bldg.

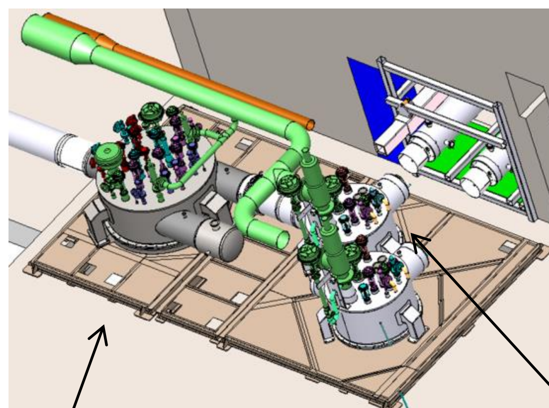


Contractor: DeMaCo

XFEL Injector cryogenic components







XIVB

FB-feedbox

Budker Institute Novosibirsk (BINP)

XFEL Linac cryogenic components

Contractor: DeMaCo, NL

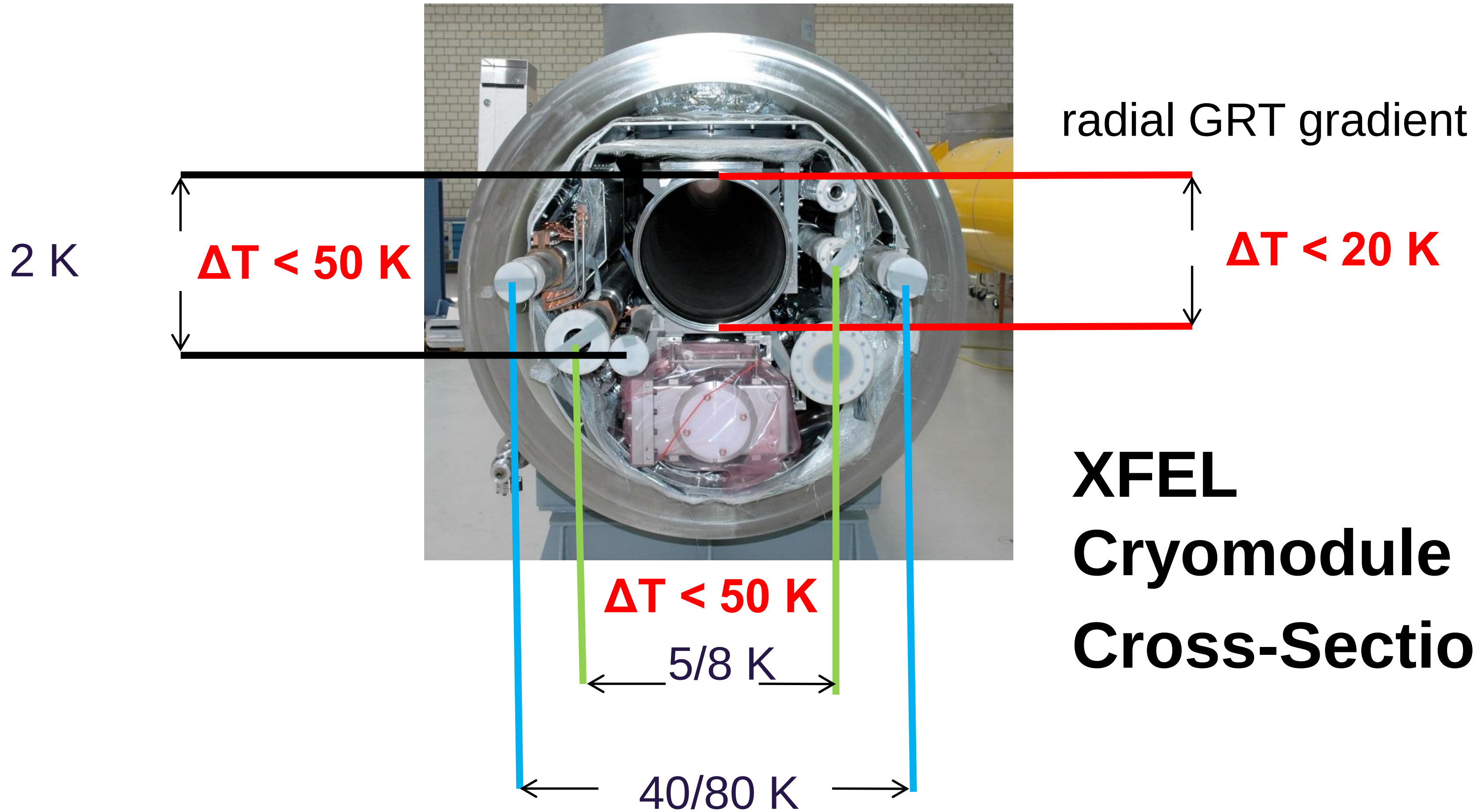
6 String Connection Boxes

3 Feed-Caps & 3 End-Caps

Transfer Lines XLTL 1, 2, 3

XFEL Cool Down: Limitations & Procedures (1)

Limitations of thermal gradients must be respected for all circuits !



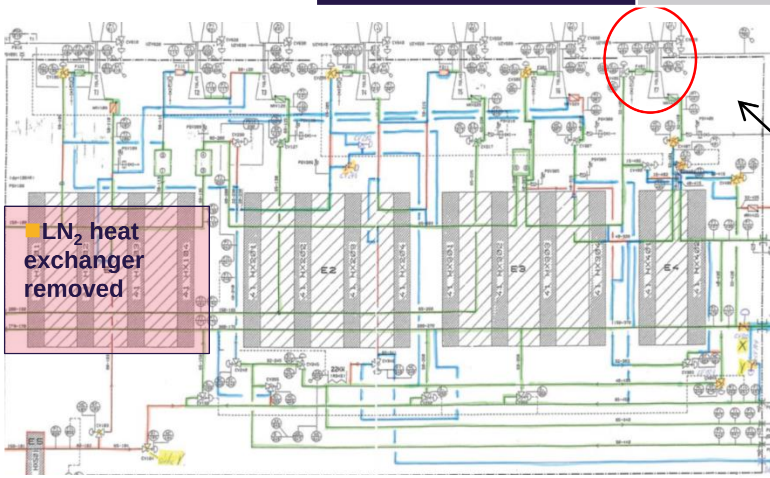
XFEL Cryomodule Cross-Section

XFEL Cool Down: Limitations & Procedures (2)

Cold Mass & Helium Inventory

Process circuit	Cold mass [kg]	He mass transient [kg]	He mass stationary [kg]
2K	161000	5600	3600
5/8K	44000	1100	1100
40/80K	61000	200	200

25000 ltr Liquid He II



XFEL Refrigerator Cold Box

Mixing of warm and cold gas in XLVB and XIVB to keep the limitations of thermal gradients in all circuits.

Cool Down 300K -> 40K

Cold Box ‚80K‘ mode

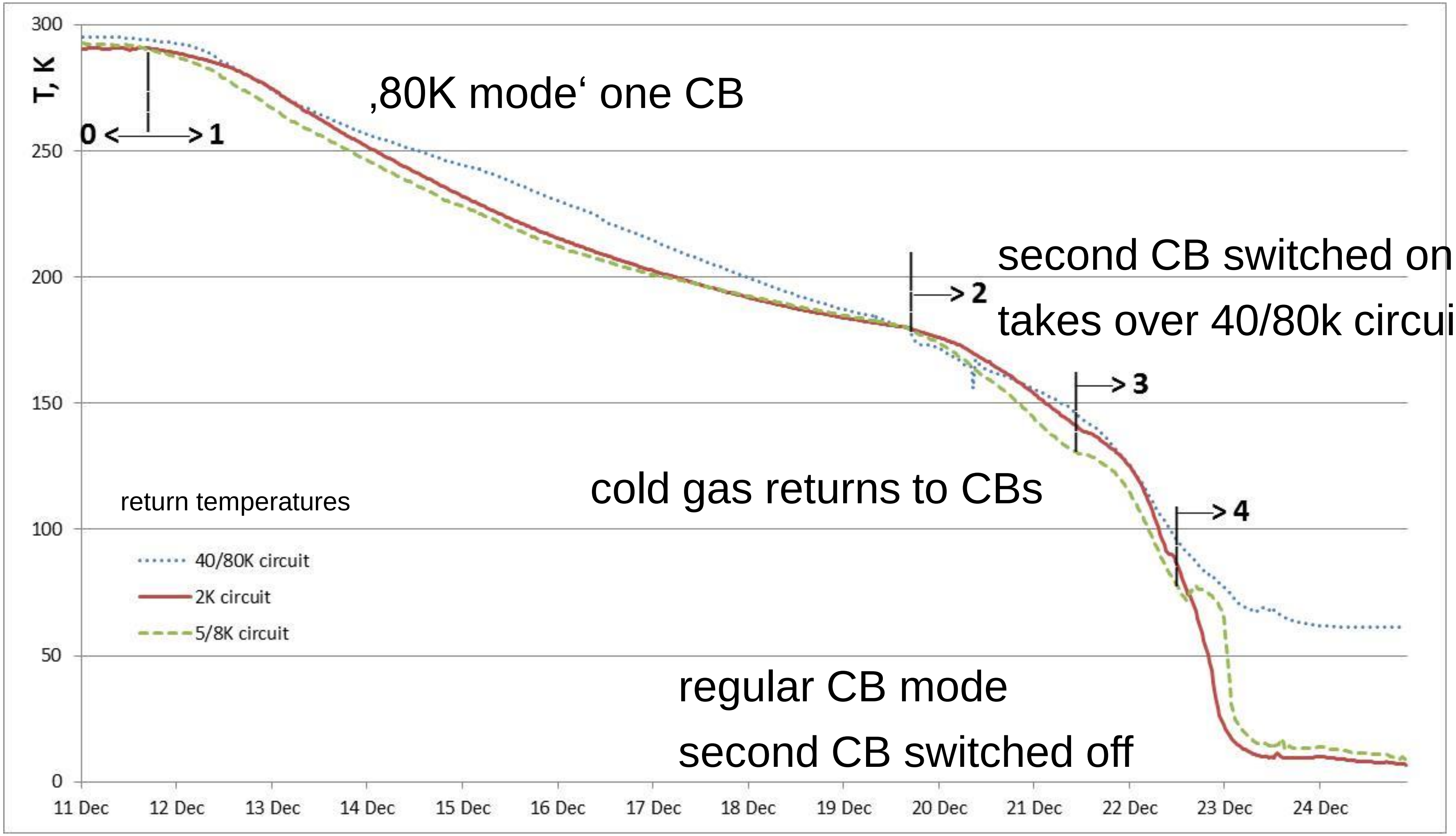
7th turbine switched off

1.9 MPa pressure for supply of all circuits

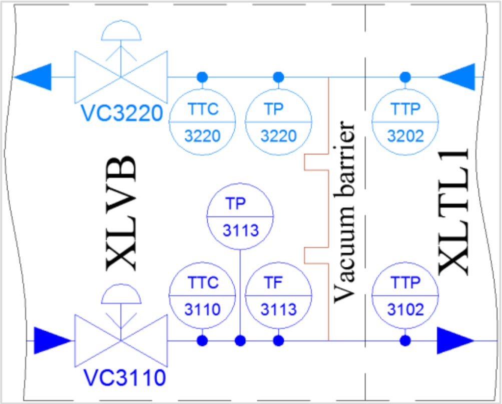
Cool Down 40K -> 4.5K

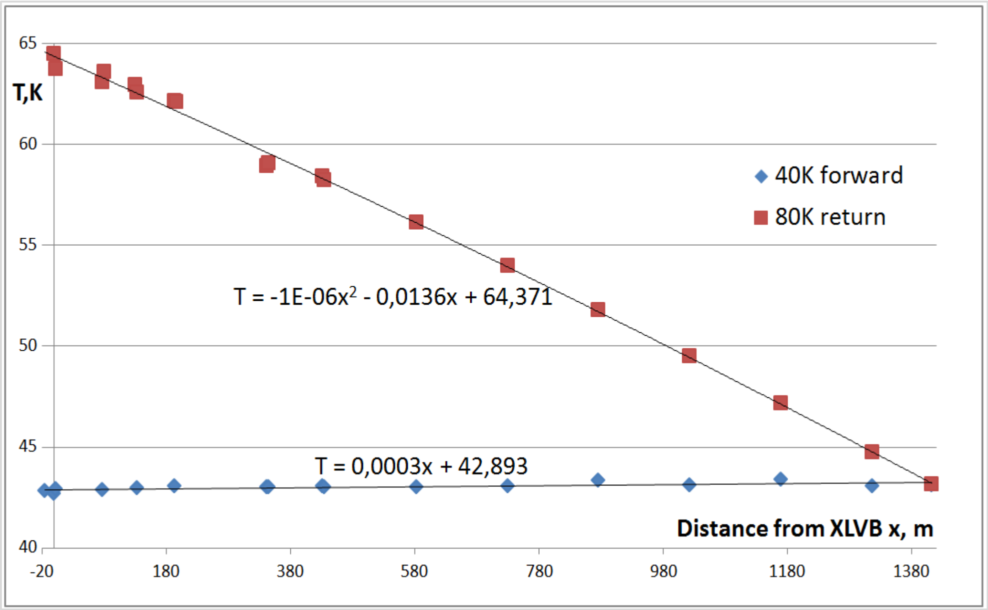
Cold Box regular mode

First Cool Down of XFEL Linac



Static heat load to the XFEL linac 40/80K shield

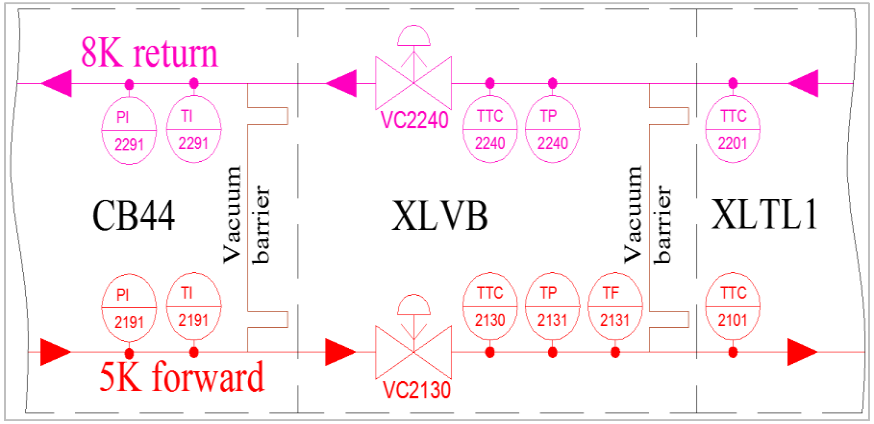


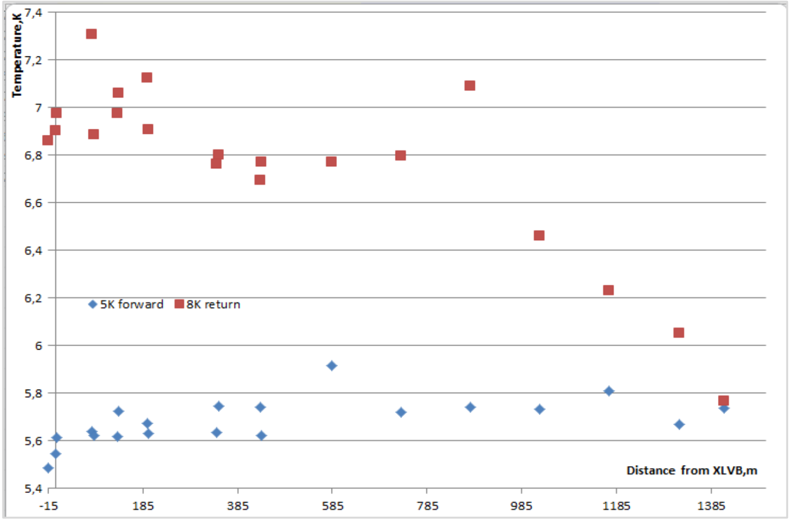


	1	2	3	4	5	6	7	8	9	Average
Flow rate, g/s	111,1	65,8	93,2	81,2	80,7	85,0	80,8	81,3	84,9	
Heat load seen by XLVB,W							9813	9616	9826	**9751,5**
Heat load seen by XLTL1,W	9224	8689	9606	9128	9364	9249	9424	9192	9374	**9250,1**
Heat load XLVB calc.,W	9916	8879	9892	9396	9609	9523	9691	9482	9676	**9562,6**

-> 86 W / Cryomodule – almost ‚as calculated‘ in TDR

Static heat load to the XFEL linac 5/8K shield





	1	2	3	4	5	6	7	8	9	Average
Flow rate, g/s	62,1	91,3	49,7	91,0	47,7	62,0	78,7	58,0	61,4	
Heat load seen by CB44,W	815,4	850,0	805,6	859,6	803,4	814,9	836,2	810,2	811,4	**823,0**
Heat load seen by XLVB,W	803,1	794,8	781,1	809,5	788,6	796,7	794,7	796,4	787,2	**794,7**
Heat load seen by XLTL1,W	851,3	897,0	816,1	946,3	803,3	853,4	932,9	857,7	859,3	**868,6**

-> 8 W / Cryomodule – almost ‚as calculated‘ in TDR

XFEL linac 2K heat losses – preliminary

Results of static heat load measurements of the XFEL linac 2K circuit

	1	2	3	4	5	6	7	8	9
Total flow rate,g/s	51	48	50	49	74	54	54	50	59
Total heaters power, W	477	457	484	467	1025	536	551	516	684
Heat losses,W	634	590	616	603	593	635	629	580	598

- **XFEL linac 2K static heat losses:** **609 W+/-20W** (incl.Transfer Lines)
- {Very preliminary! Dynamic losses (about 13 Gev, 18 MV/m, 10Hz)
  290 W corresponding to about Qo=>1.1 * 10E+10}

Static load: < 6.3 W / Cryomodule – almost ‚as calculated‘ in TDR

Conclusions

- Straightforward cool down of XFEL linac
- So far: about 6 month continous & stable cold operation
- So far: no indication of any cold leaks
- 40/80K, 5/8K, 2K static heat loads: as ‘calculated’
- Low heat loads allow **‘one cold-box-operation’**
- XFEL reached commissioning milestones: **14 Gev, 0.15 nm**
- Since July 1st ,2017: **XFEL in regular operation sta**te
- **2K operation: See next paper this conference**

Acknowledgements

Design and construction of the superconducting XFEL linac is based on achievements of the international

TESLA (Technology) Collaboration.

H.Edwards (†2016, Fermi National Accelerator Laboratory, FNAL, USA) was a main supporter of the collaboration from the start.

In particular, we thank our colleagues from FNAL for their contributions to TESLA cryogenics.

The basic concepts for TESLA cryogenics were developed about 25 years ago by **G.Horlitz** (†1997,DESY).

B.Wiik (†1999,DESY) started it all.

Thank you for your attention !