

European XFEL High-Power RF System – The First 4 Years of Operation

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Abstract

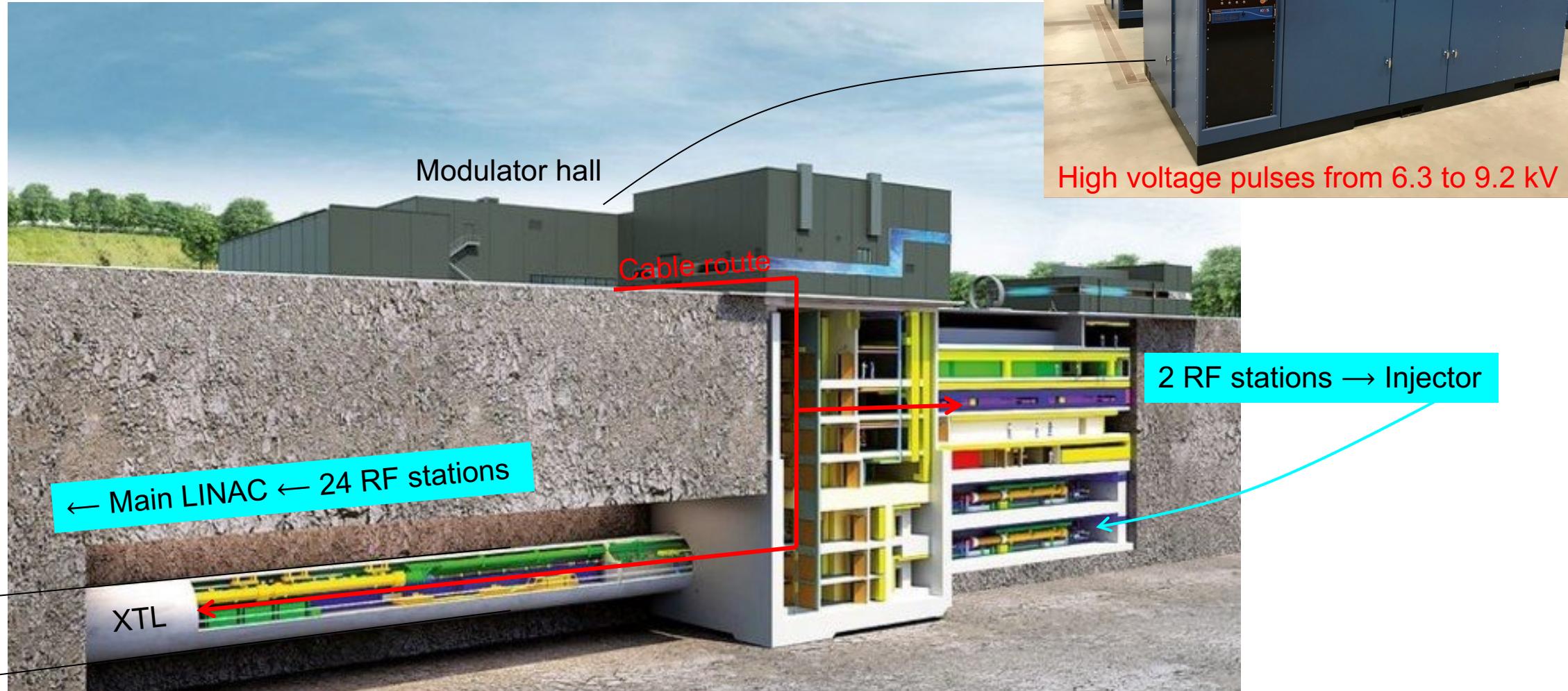
In 2016, the installation of the European XFEL was completed and its 26 RF stations started operation in 2017. Each RF station consists of a 10 MW-1.3 GHz-multibeam klystron, a HV pulse modulator and a waveguide system to supply the superconducting cavities and the normal-conducting electron gun with RF power.

During commissioning and subsequent operation, the RF stations were closely monitored and causes of failures were investigated. For the optimisation of the RF systems, the various RF station failures were evaluated according to their impact on accelerator operation and the measures to eliminate them were prioritised accordingly.

This report describes the operation experience and improvements of the high-power RF stations during the first 4 years of operation.

High-Voltage Generation

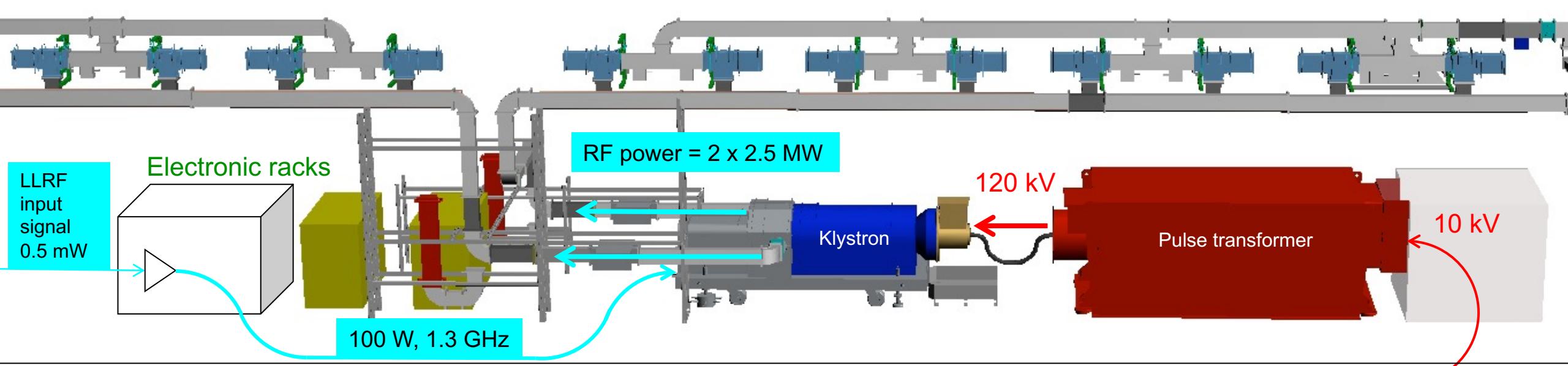
Hall with 26 modulators and cable routes for the high-voltage pulses to the RF stations.



One RF station

in the accelerator tunnel.

- Operation mode
 - With feasible voltage and power values can be seen.



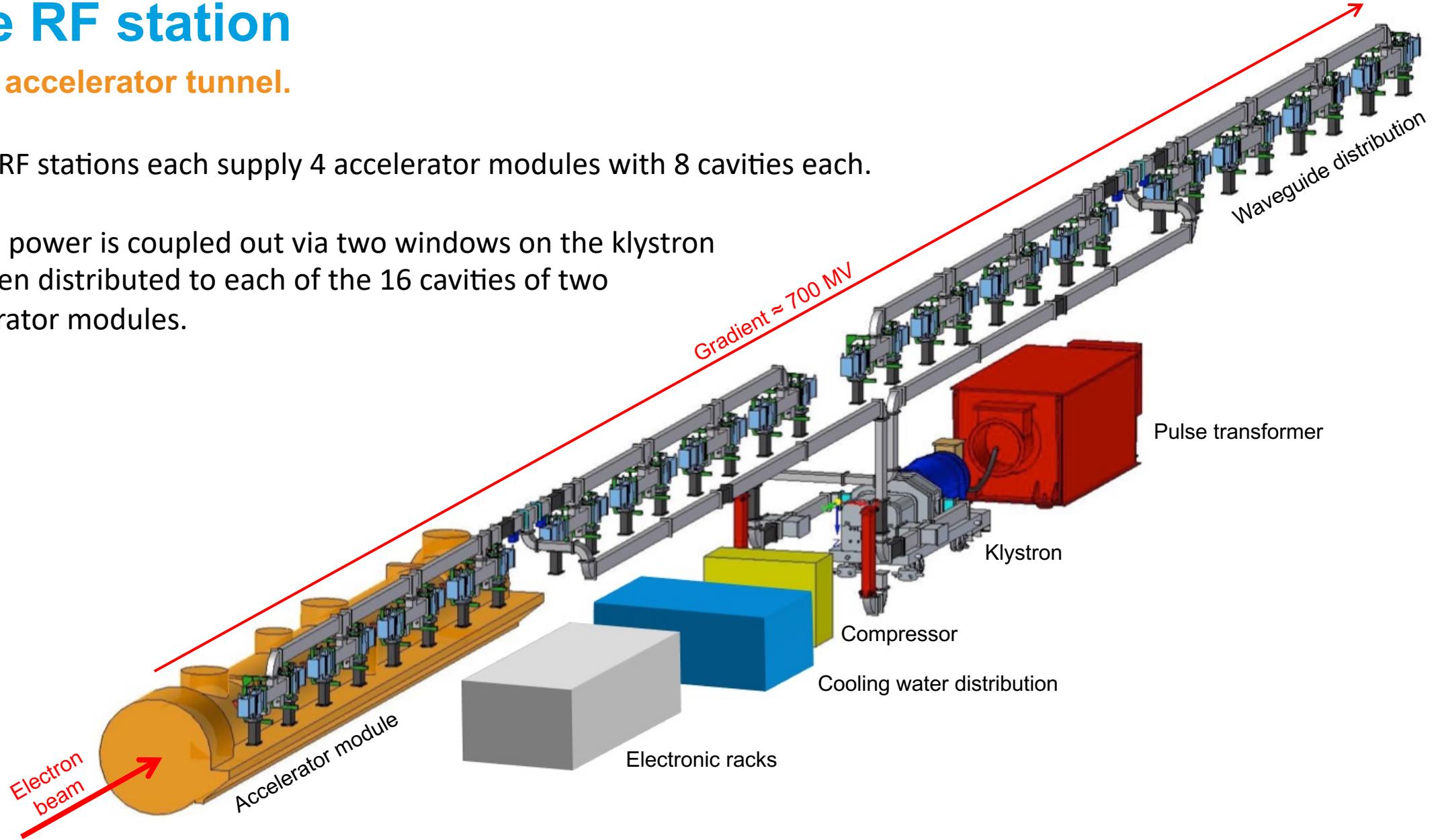
High-voltage pulses from the modulator hall, 10 Hz

One RF station

in the accelerator tunnel.

These RF stations each supply 4 accelerator modules with 8 cavities each.

The RF power is coupled out via two windows on the klystron
and then distributed to each of the 16 cavities of two
accelerator modules.



One RF station in the accelerator tunnel.

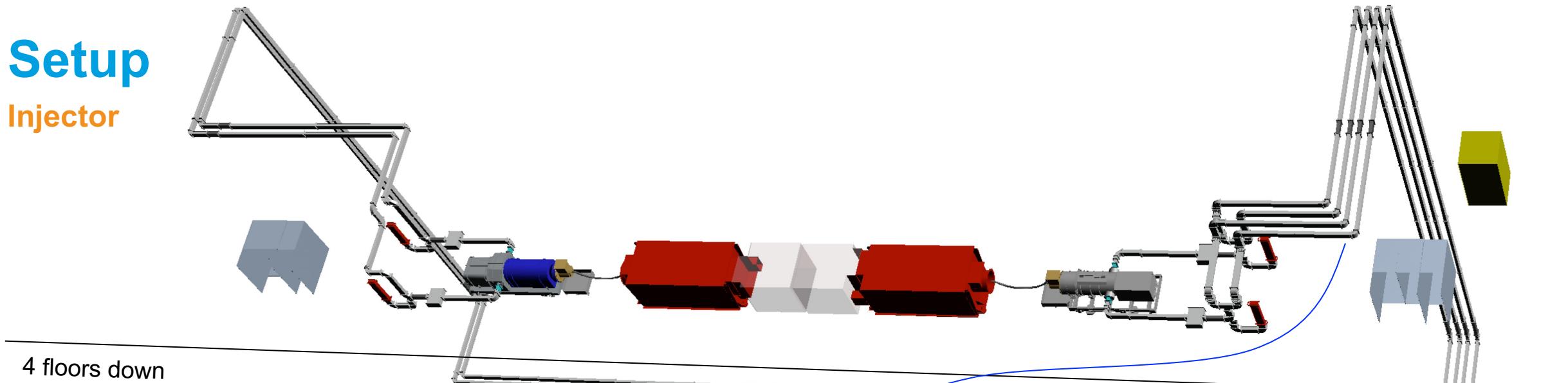
The klystrons are located below the accelerator modules.

Therefore replacing a klystron in the XFEL is more complicated than in other accelerator facilities.



Setup

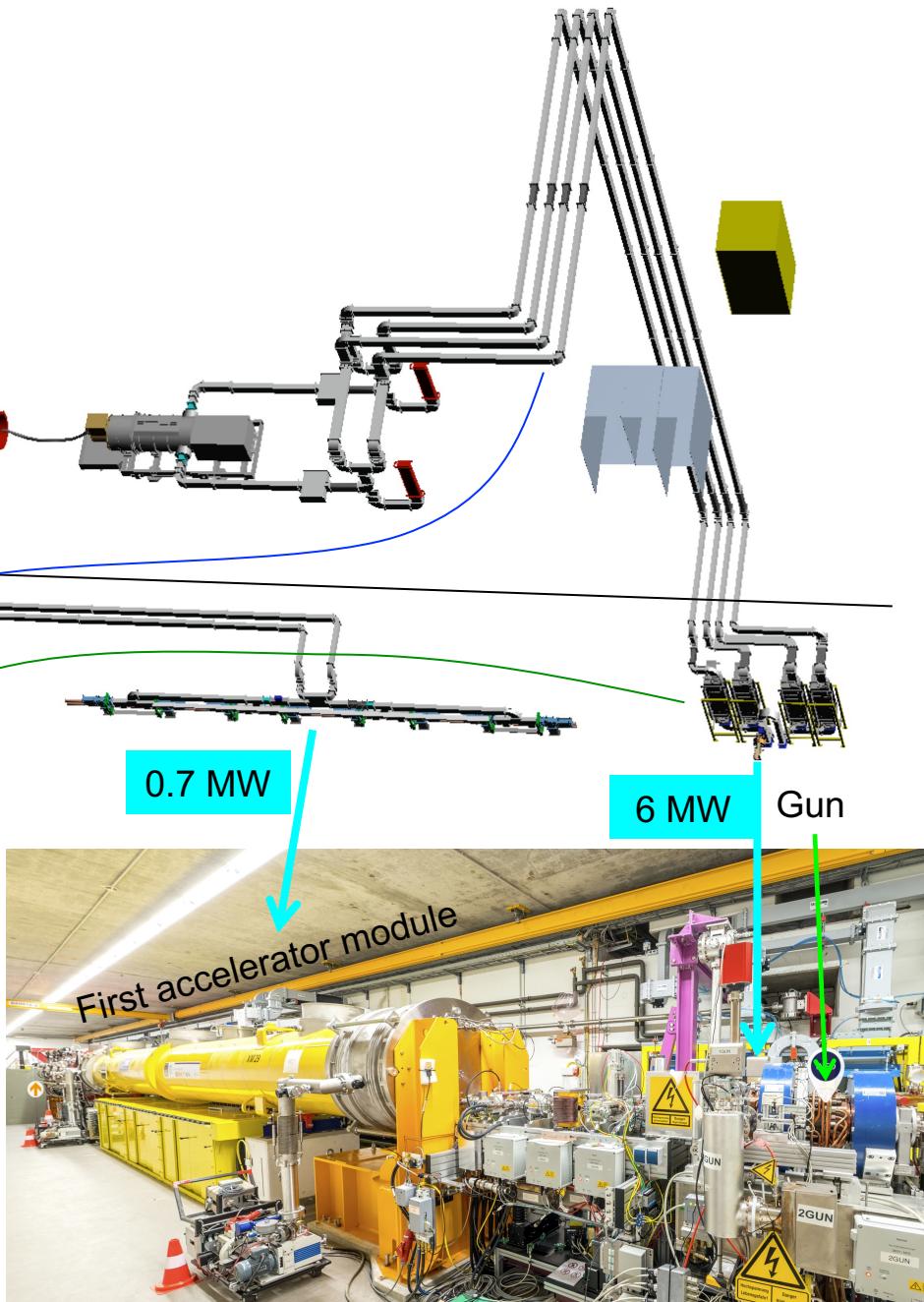
Injector



4 floors down

In order to minimise the risk of arcing on the long sections to the gun,

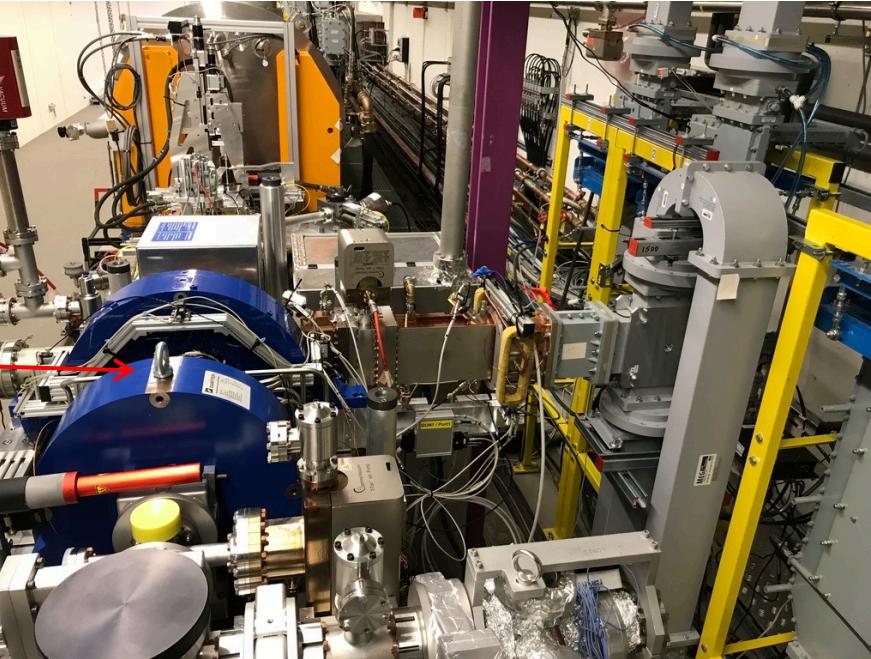
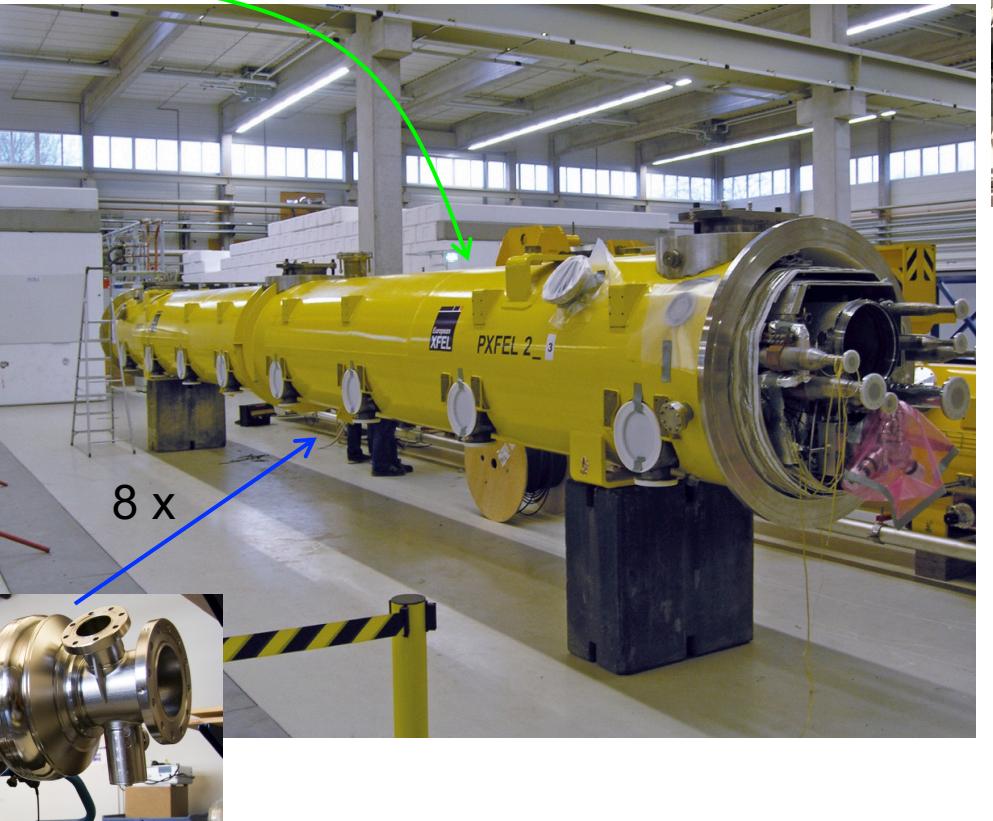
- the 6 MW (right) are split into 4 waveguide lines and
- combined again just before the gun.
 - On the last metre before the gun, we then have 6 MW of RF power in one waveguide. This increases the risk of arcing, which is reduced by increasing the air pressure in this area to 3 bar.



The 1.3 GHz High Power RF system

powers the

- Electron gun
- and 97 acceleration modules
 - with 0.7 bis 6.3 MW
 - RF power.
- There are 26 RF stations in total.



Operation and optimisation

- The type, duration and frequency of failures caused by the RF stations themselves were analysed.
- With the analysis result, the optimisation potentials could be easily identified and prioritised.

Priority 1: If a klystron has to be replaced, this took several days. This process has been speeded up.

Priority 2: If smaller sub-components fail and their repair requires access to the tunnel, it takes about 1 hour to rectify the fault. The following components required repeated access in the first years of operation:

- Circuit breakers that tripped after power failures due to current peaks when switched back on.
- Electronic components that had to be reset manually.
- In late 2018 and early 2019, water hoses in the solenoid cooling circuit burst in 3 klystrons.
- Flow monitors on the water cooling of the waveguide distribution which did not release the interlock after pressure fluctuations in the cooling water system.
- In 2020, the red spider became very annoying.

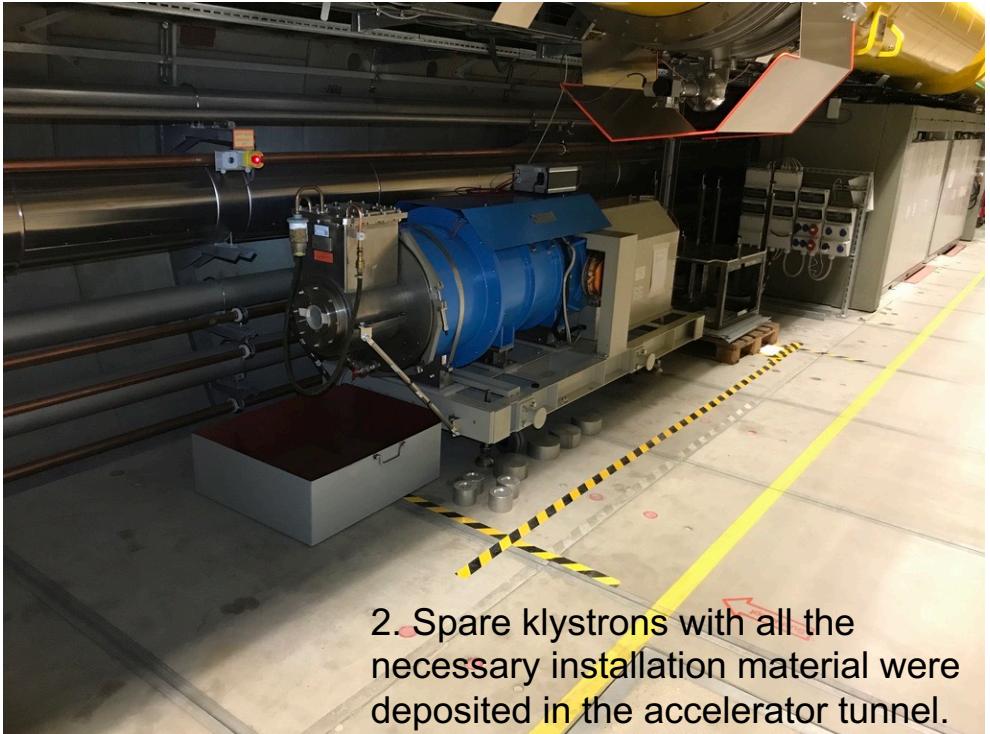
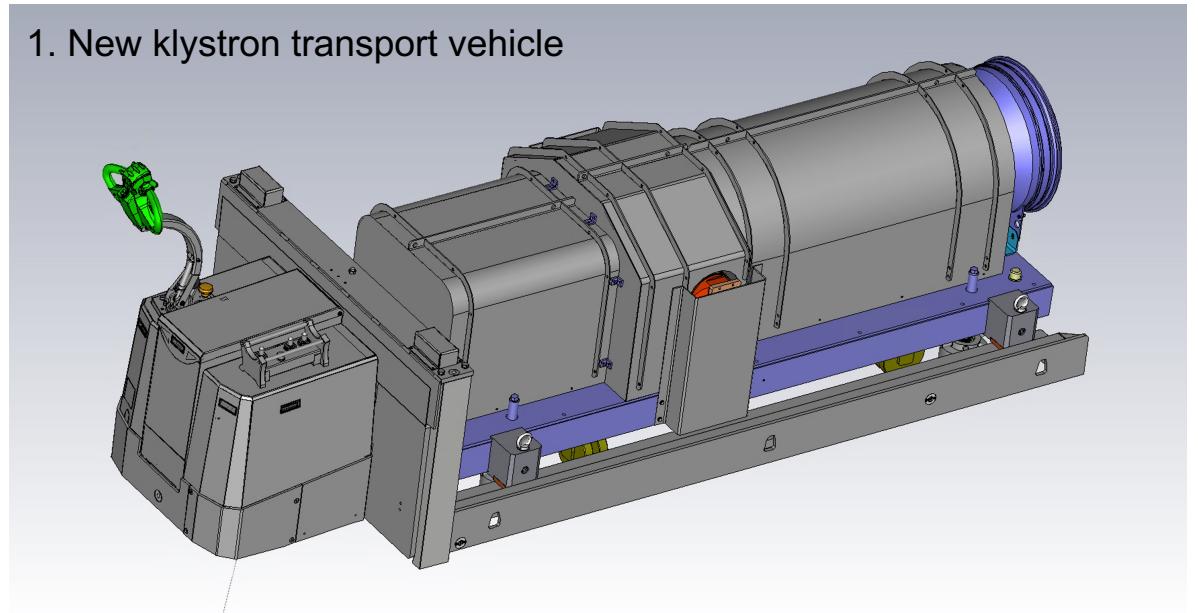


The priority 2 problems have all been permanently eliminated.

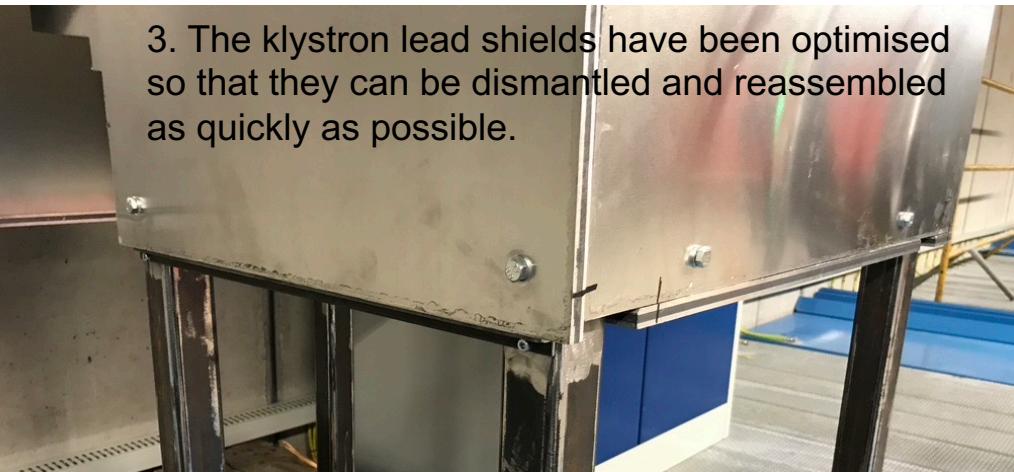
Klystron exchange

Process speed-up

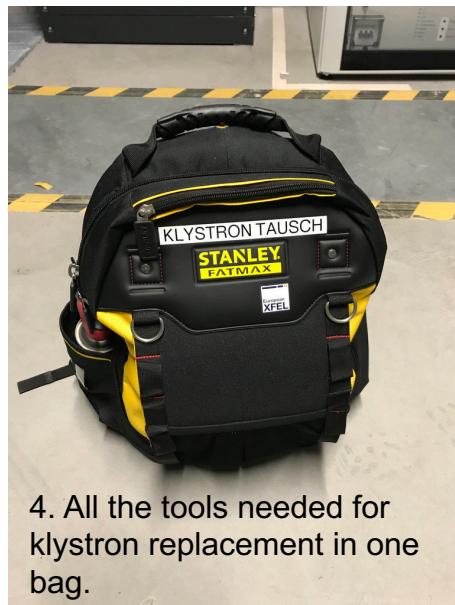
1. New klystron transport vehicle



2. Spare klystrons with all the necessary installation material were deposited in the accelerator tunnel.



3. The klystron lead shields have been optimised so that they can be dismantled and reassembled as quickly as possible.

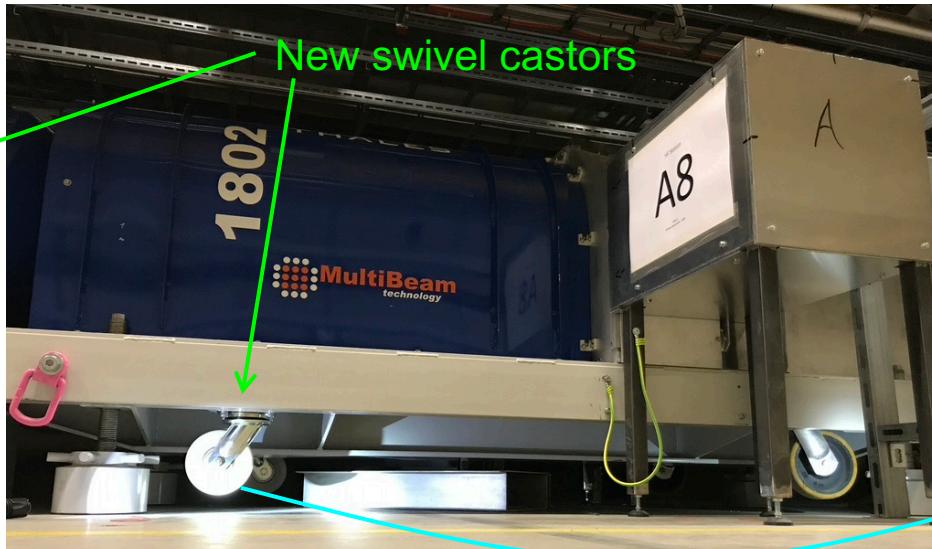
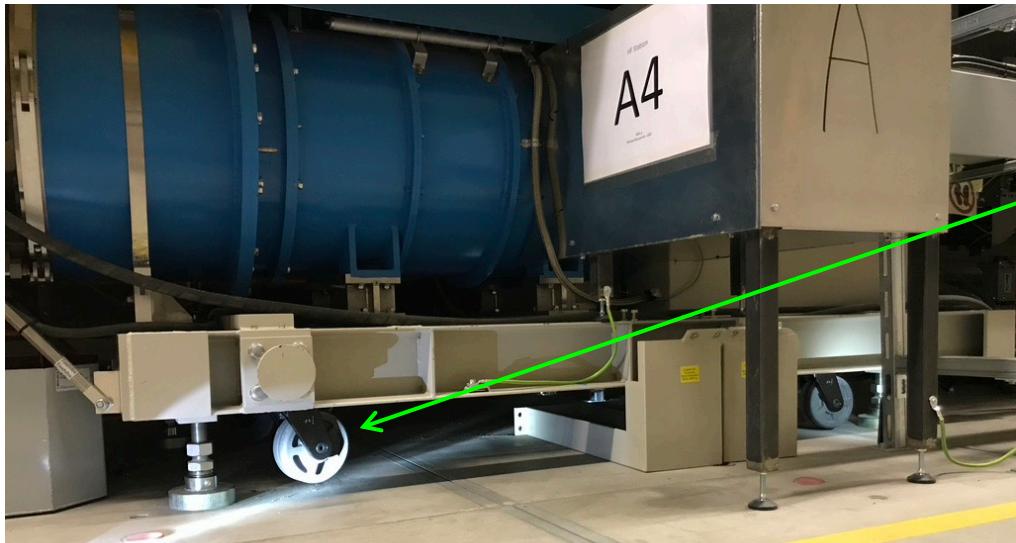
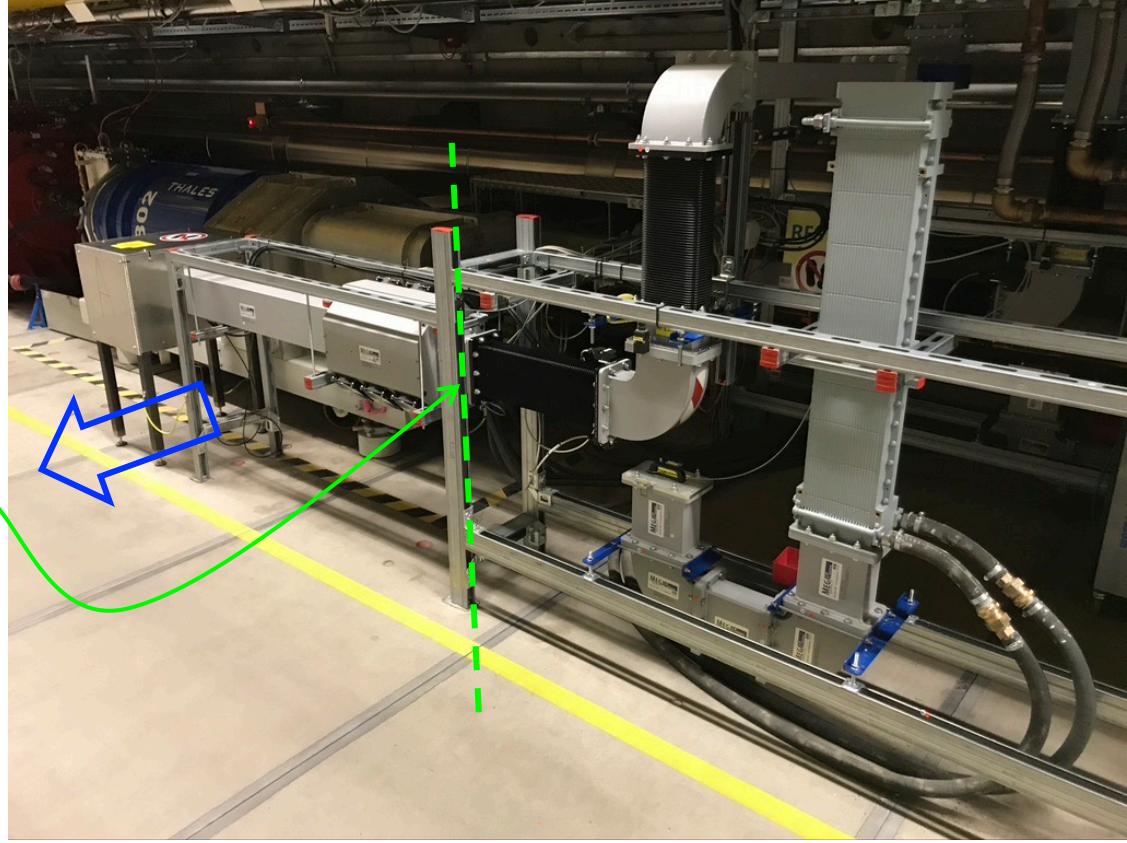


4. All the tools needed for klystron replacement in one bag.

Klystron exchange

5. Swivel castors

- Almost all Klystrons are equipped with swivel castors.
- The amount of work involved in replacing the klystron is significantly reduced because the waveguides only have to be removed up to the 1st bellow, as the klystron can now be moved out and back in perpendicular to the beam direction.
- Before that, all the waveguides on the gangway side had to be removed.



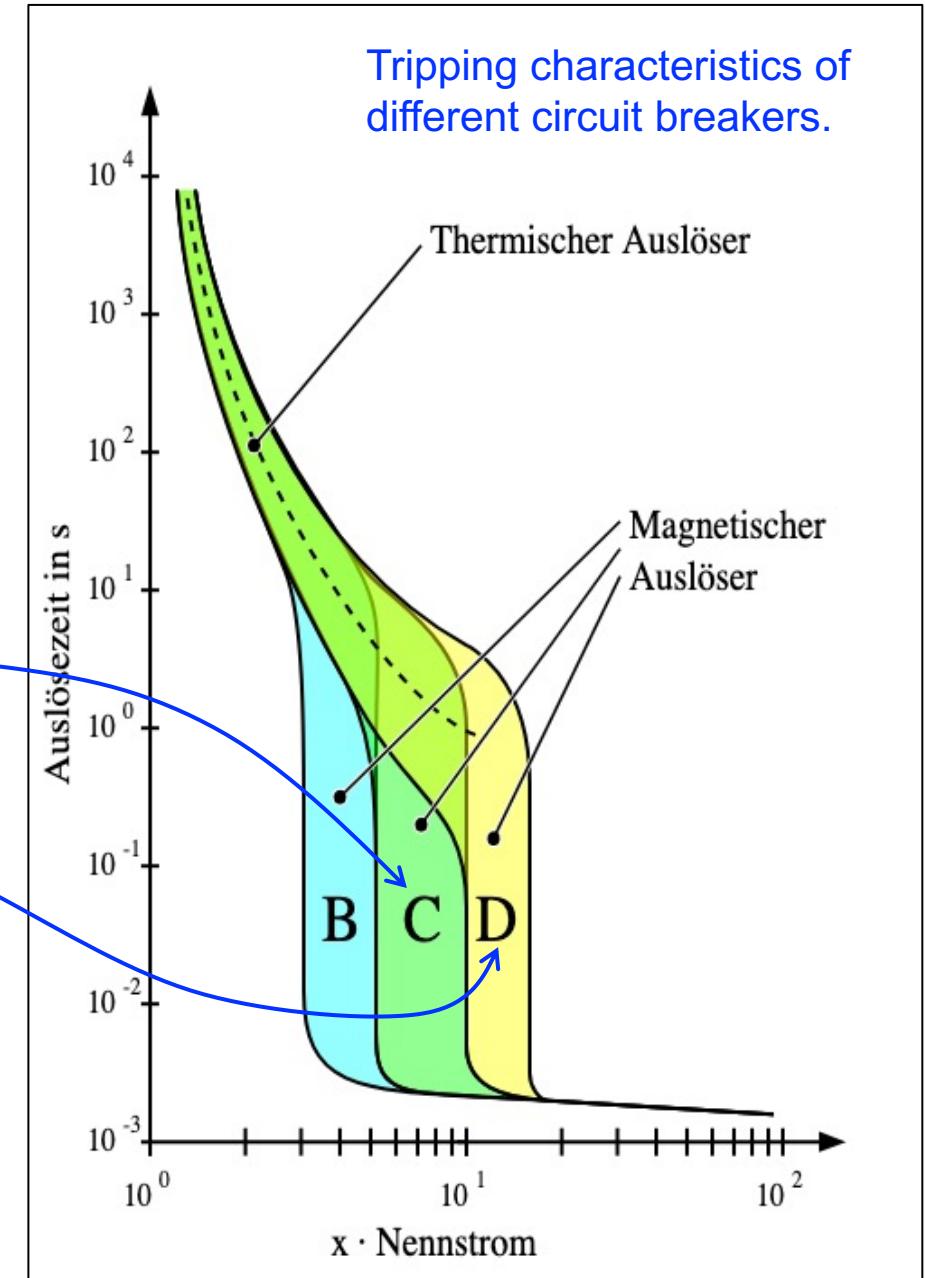
Original fixed castor
not swivelling



Electronics

Circuit breakers

- During power failures, it happened that circuit breakers tripped.
- This was investigated and measurements showed that when a complete electronics cabinet was switched on again, inrush currents occurred that were sufficient to trigger the standard circuit breaker (C-type) used.
- New installed D-type circuit breakers that tolerate 2 times higher and 10 times longer inrush current solved the problem.



Summary

- In the first 4 years of XFEL operation, the reliability of the high-power RF system was significantly increased.
- Remarkable is the low klystron consumption so far
- and the fact that there are hardly any problems with the complex waveguide distributions.