

FLASH HPRF System Upgrade



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HELMHOLTZ



Agenda

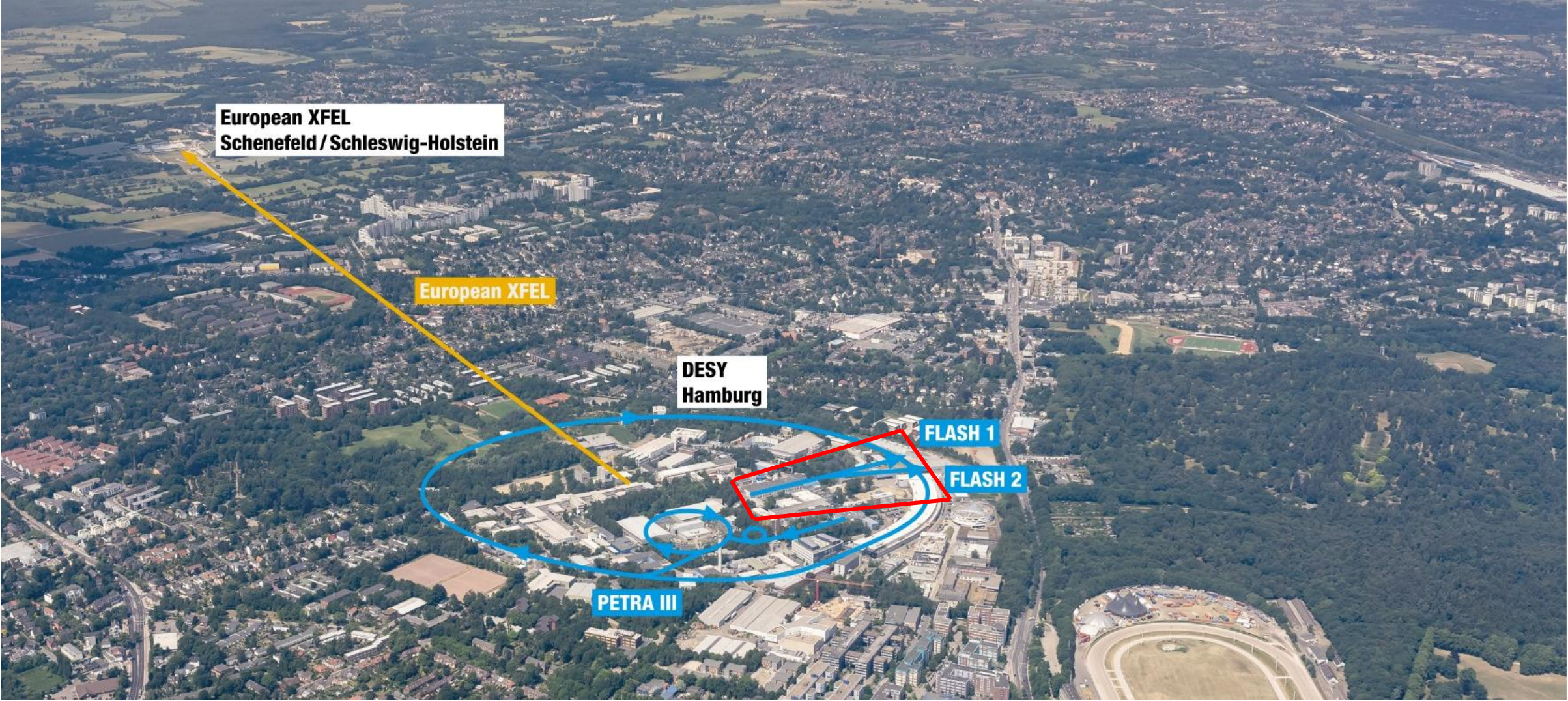
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FLASH

Overview

FLASH

FLASH at DESY



European XFEL
Schenefeld / Schleswig-Holstein

European XFEL

DESY
Hamburg

FLASH 1

FLASH 2

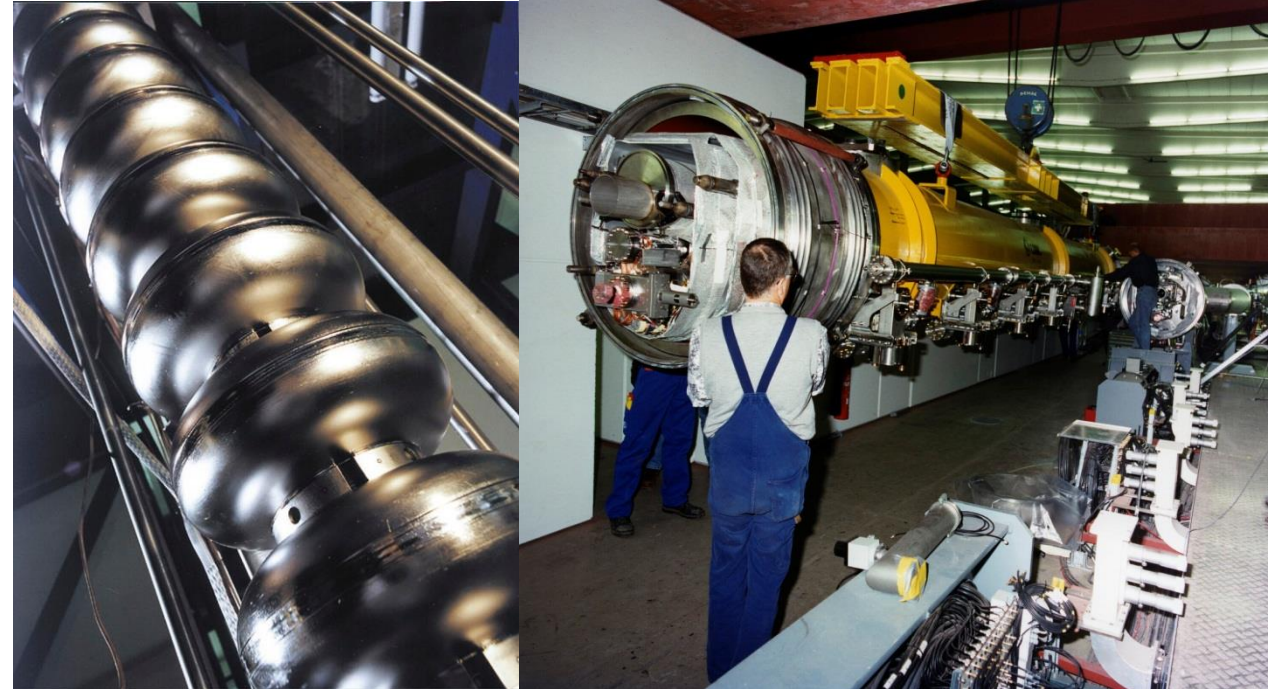
PETRA III

FLASH

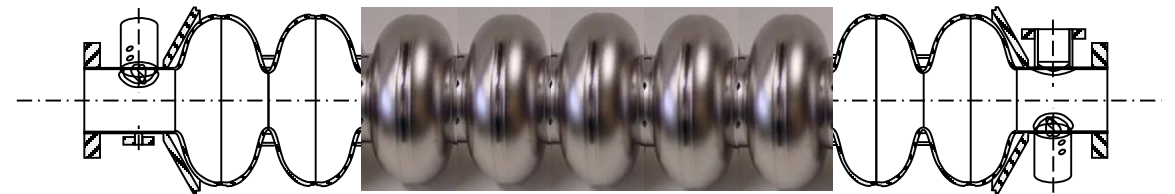
History

Setup and Upgrades

- Early 1990s start of the TESLA collaboration with the goal to develop all components for a superconducting linear collider
- Setup of the TESLA Test Facility including a small short superconducting linear accelerator for test
- During the years more components have been integrated (more sc modules, RF gun, bunch compressors, etc. and finally undulators)
- First lasing demonstrated in 2000 at 109 nm
- TTF has been upgraded and renamed to FLASH in 2002/2003 and is operated as a FEL user facility
- Further upgrades and improvements since then



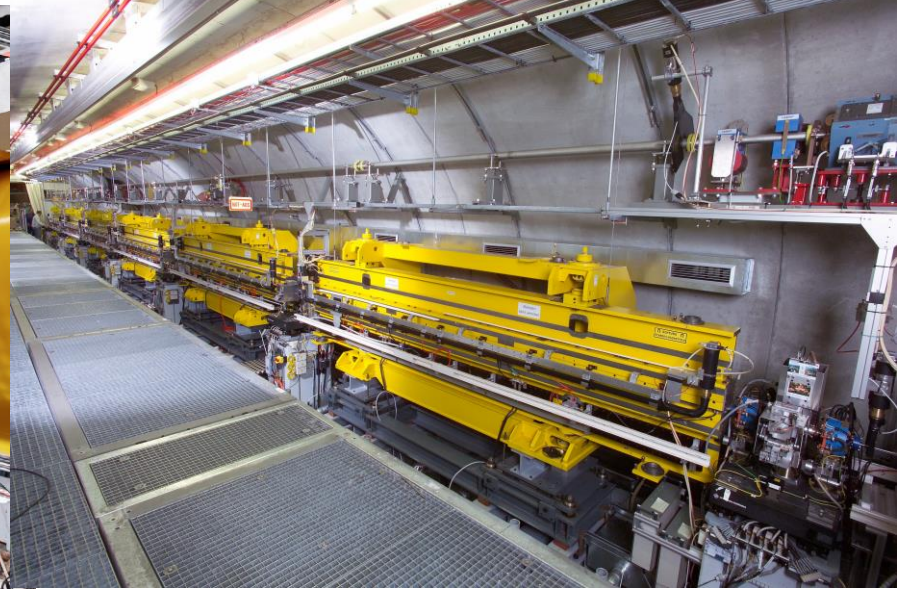
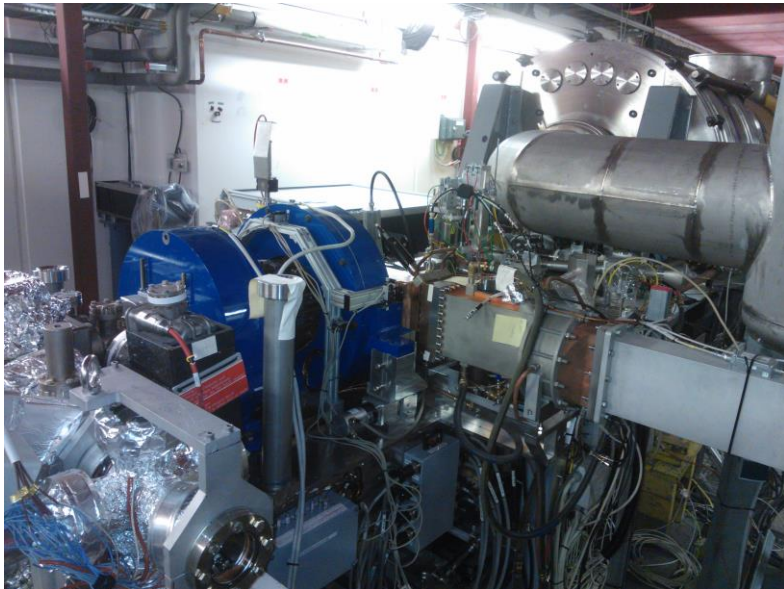
- Cavity made of niobium, operated at 2K, gradient $>23\text{MV/m}$ $Q=10^{10}$ and 1.3GHz



FLASH

Status before Upgrade in November 2021

- Linear Accelerator 1.25 GeV
- 1 RF Gun
- 56 sc 1.3 GHz cavities in 7 cryomodules
- 8 sc 3.9 GHz cavities in 1 module
- Lasing down to 4.1nm (water window)
- 5 1.3GHz HPRF stations supplying RF power to 56 sc cavities and 1 RF gun
- 1 1.3GHz HPRF station supplying RF power to 8 sc cavities
- up to 10MW ~1300us/600us RF at 10Hz
- cavity filling time ~500us/10us

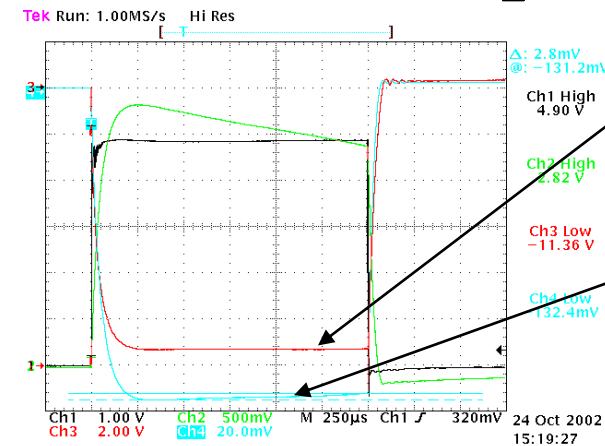
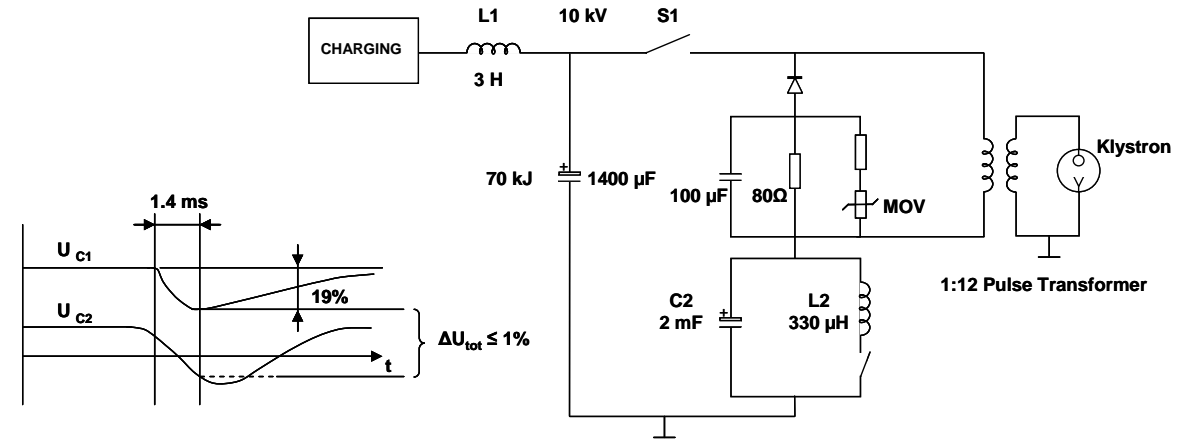


FLASH RF System

RF Stations

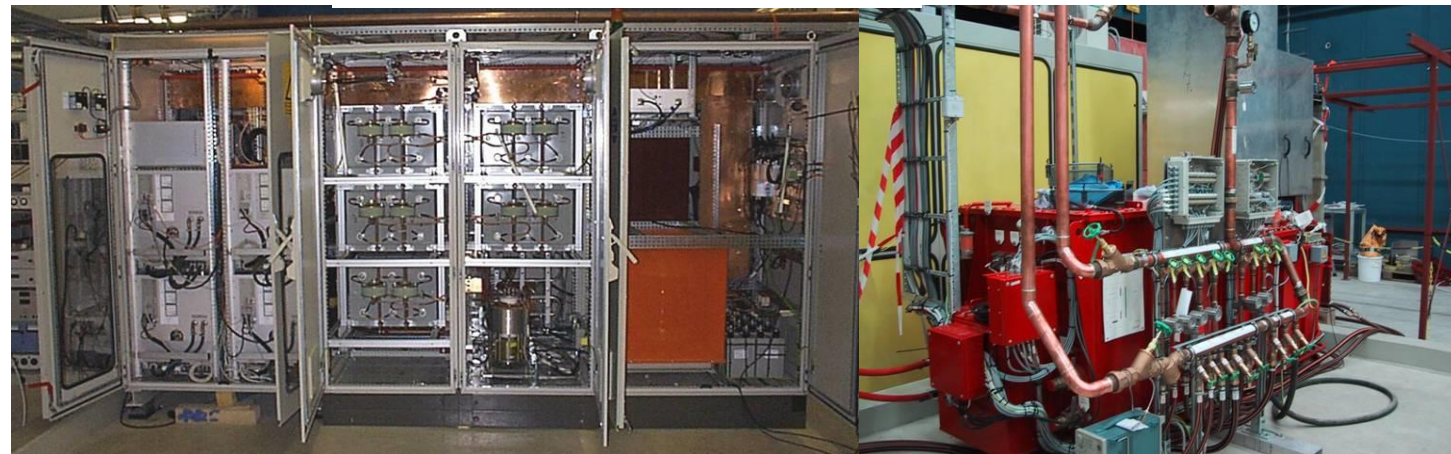
Status November 2021

- 5 long pulse Bouncer Modulators
130kV/1.7ms/10Hz
- each
 - 12kV HVPS plus 12kV pulse generator up to 12kV, 1.5kA, 1.5ms, 10Hz
 - 1:12 pulse transformer
 - Electronic racks with interlocks, timing, PSs
 - Water cooling



Klystron
Voltage 113kV

Klystron
Current 132A



FLASH RF System

RF Stations

- 2 types of klystrons are in use at FLASH
- 3 TH2104C
- 2 TH1801



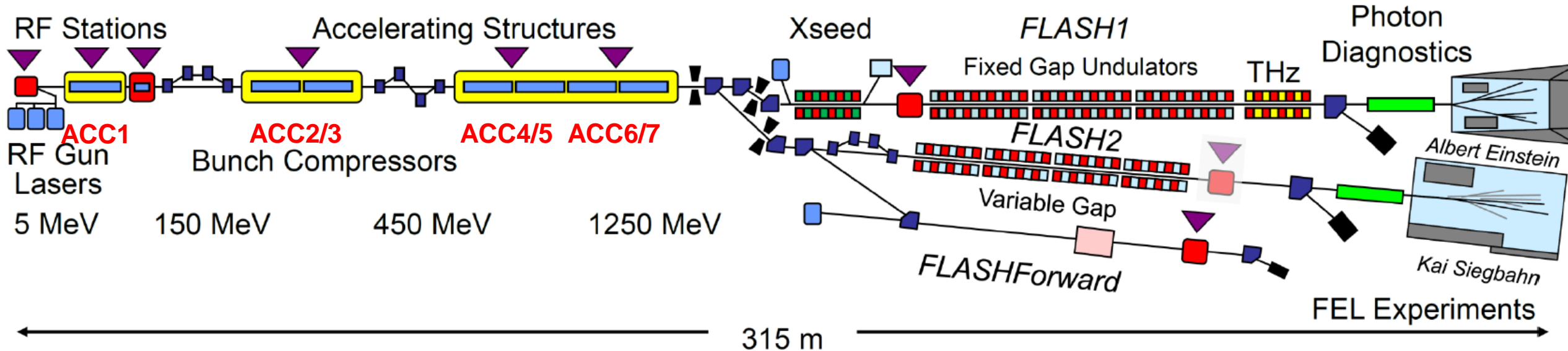
THALES TH2104C
5MW 1.3GHz 1.5ms/10Hz



THALES TH1801
10MW 1.3GHz 1.5ms/10Hz

FLASH System

Overview Status November 2021

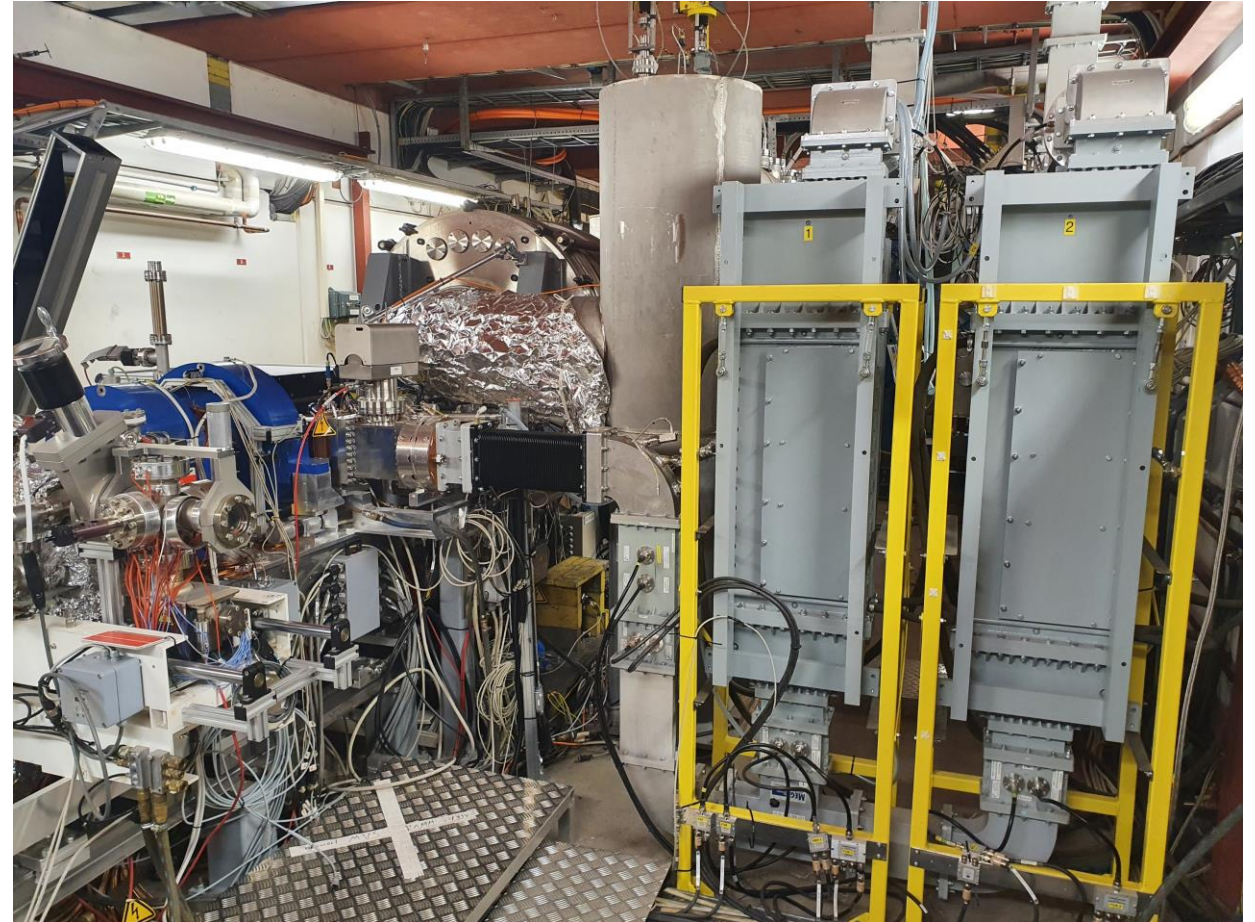


- RF Gun: 10MW typ. ~6MW
- ACC1: 5MW SBK for ACC1 typ. ~1MW supplied to 8 sc cavities
- ACC2/3: 5MW SBK for 16 cavities typ. ~3MW supplied to 2x8 sc cavities, equal power distribution
- ACC4/5: 5MW SBK for 16 cavities typ. ~4MW supplied to 2x8 sc cavities, equal power distribution
- ACC6/7: 10MW MBK for 16 cavities typ. 4-5MW supplied to 2x8 sc cavities by XFEL type waveguide distribution, maximum power for each cavity

FLASH RF System

RF waveguide distribution

- RF gun: 10MW MBK typ. ~6MW supplied in 2 ca. 20m long waveguide arms, which are combined before the RF gun



FLASH RF System

RF waveguide distribution

- ACC3 and 4 waveguide distributions, old layout

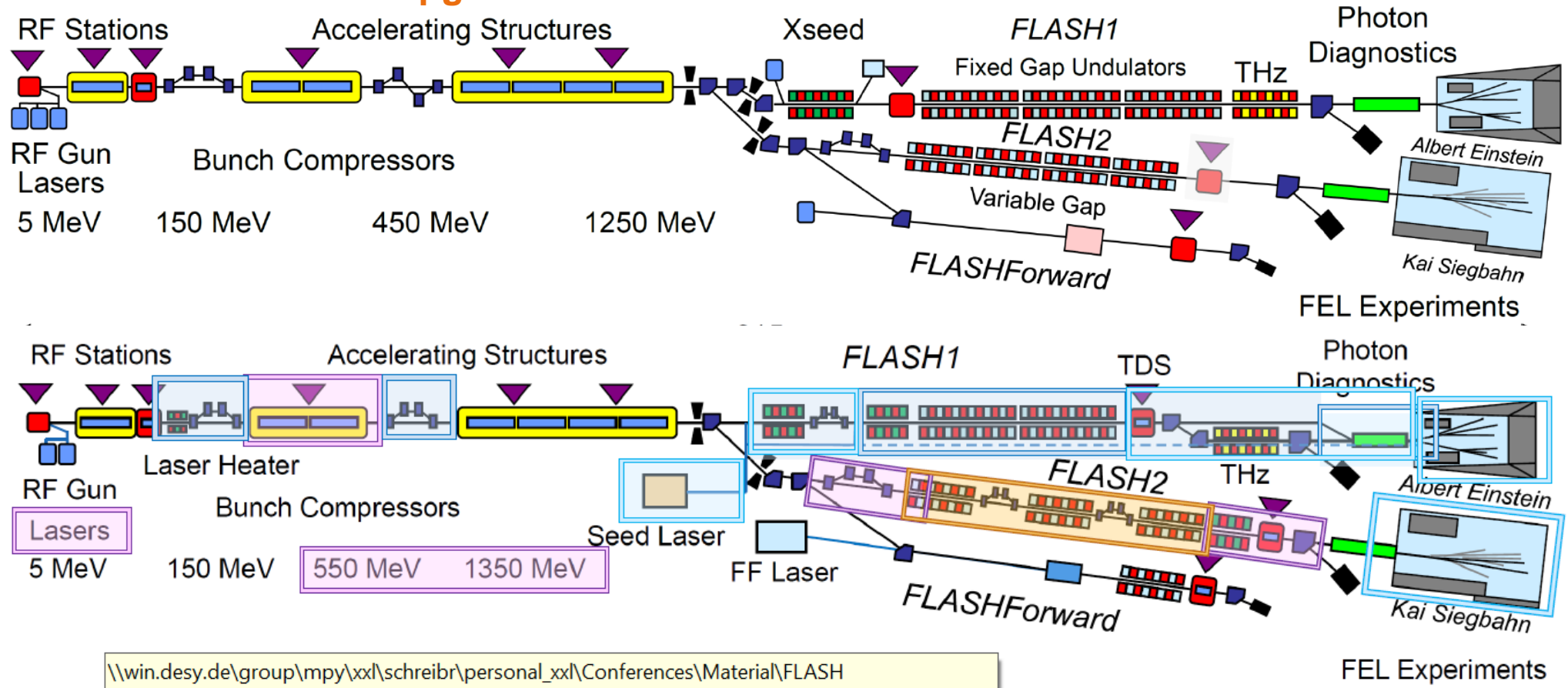


- ACC5 waveguide distribution, old layout
- ACC6 waveguide distribution, XFEL type



FLASH System

Status November 2021 and Upgrade Plan



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

Phase 1
 Variable gap undulators (FLASH1)
 Laser heater in 1st BC
 New 2nd bunch compressor (BC)
 Pump-probe laser (FLASH1)

Phase 1+
 High rep.rate seeding (FLASH1)
 Photon diagnostics (FLASH1)
 Flexible pump-probe lasers

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

Courtesy of E. Allaria, DESY

RF System Upgrade

Major upgrade renewing and replacing more than half of the existing HPRF System

RF Station Upgrade

- RF Station for ACC 2/3 has been fully replaced and will operate with a 10MW instead of a 5MW klystron
- RF Station for ACC4/5 received a new modulator and a new 5MW klystron
- All RF Stations received new interlock (technical and personnel) and timing systems, and some new PSs, water cooling system etc.
- Repair and maintenance of modulators

RF Waveguide Distribution Upgrade

- Accelerator modules ACC2/3 have been replaced by new modules and received RF waveguide distribution of the XFEL type
- RF waveguide distribution of ACC4/5 has been replaced by a modified XFEL type distribution
- Distribution for ACC6/7 were of XFEL type and were only improved
- Connecting and klystron RF waveguide distributions have been replaced for the RF stations supplying ACC 2 to 7.
- Personnel interlock waveguide switches have been replaced

FLASH Upgrade RF Station

RF Station Upgrade

- RF Station for ACC4/5 and for ACC6/7 were upgraded
- RF Station for ACC4/5 received new HV pulse modulator
- A large part of the RF waveguide distribution was removed and modified during the shutdown



RF Station Upgrade

- New RF Station for ACC 2/3 has been installed and RF Stations for ACC4/5 and for ACC6/7 have been upgraded
- New interlock and timing systems, PSs, water cooling etc. have been installed
- New waveguide switches for the personnel interlock were installed



FLASH Upgrade

RF Waveguide Distribution

RF Waveguide Distribution Upgrade



ACC2 specification

Specification for FLASH 2020+ Waveguide Distribution (WD) production

Cryomodule name	PXM2.1							
WD type	XFEL type, Left							
WD for	ACC 2							
Cavity number*	1	2	3	4	5	6	7[PU]	8
Cavity gradient**, MV/m	28.7	28.8	33	33	30.9	31.5	32.2	28.8
Cavity power***, kW	293	295	387	387	340	353	369	295

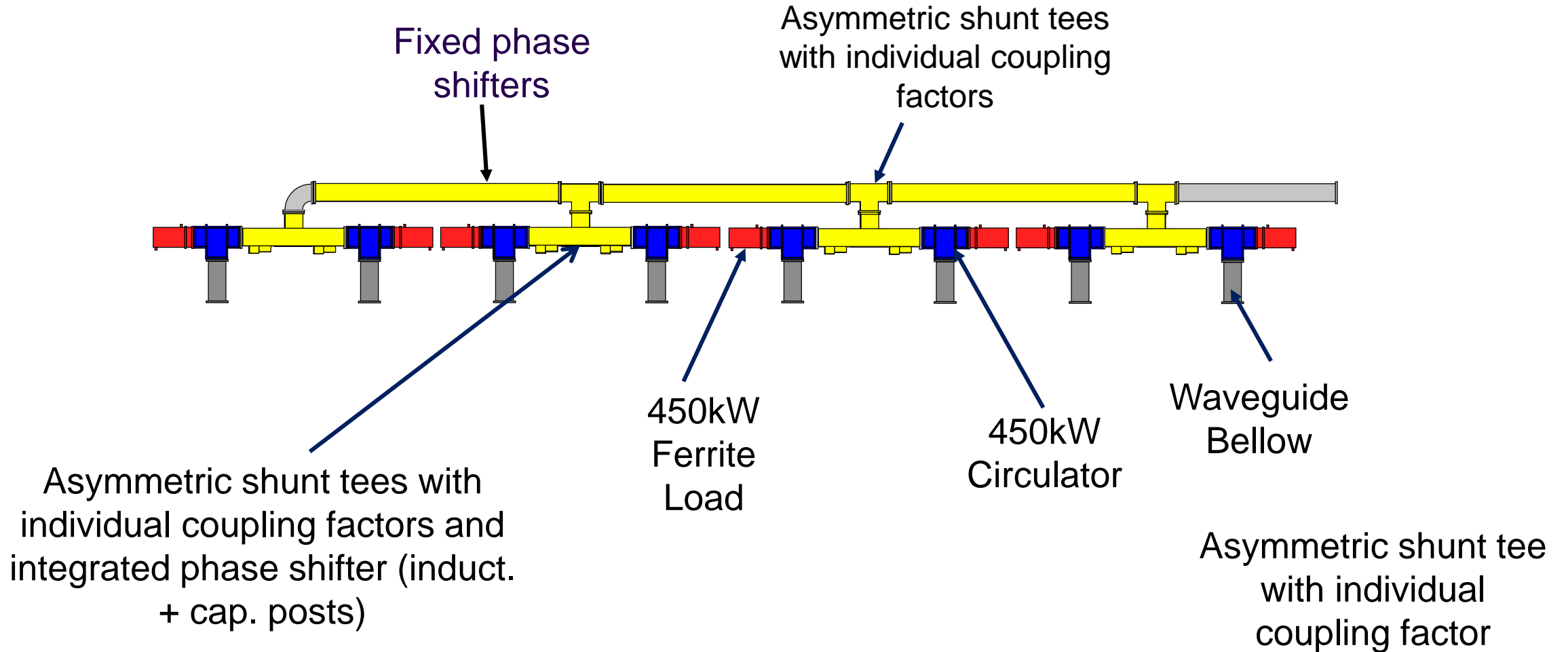
* Cavity number in the beam direction
** The cavity gradient is 1 MV/m below the cavity quench limit
*** The difference between neighboring cavities in the binary cell cannot exceed 3 dB; in specific cases it can be exceed after discussion with MHF-p experts
($Q_{ext}=3.0$, $t_{inj}=500 \mu s$)

Established in two copies

Signed for and behalf of FLASH 2020+ team	Signed for and behalf of MHF-p:
	
Elmar Vogel	B.Yildirim
02/02/2022	02.02.2022
Data	

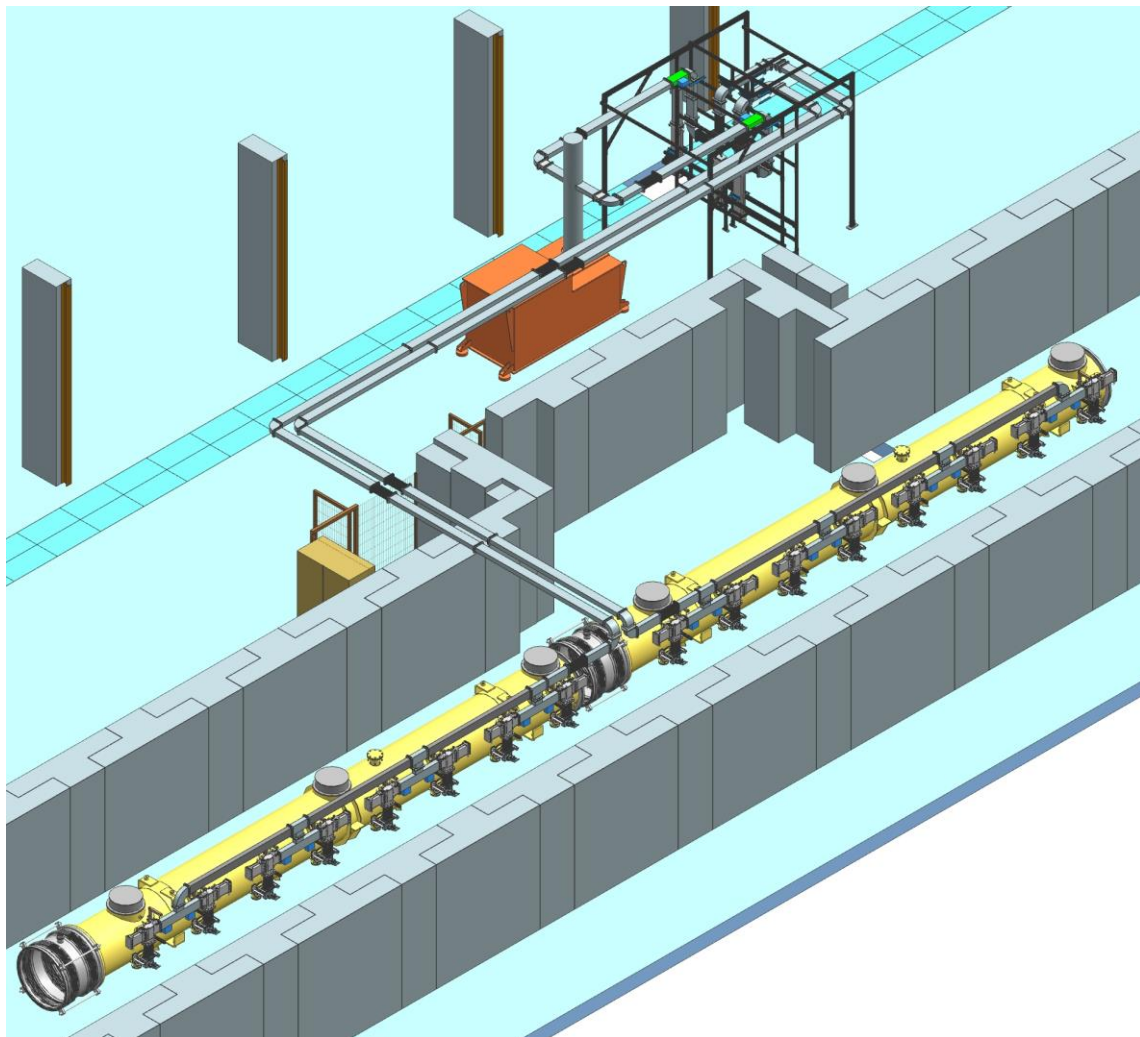
XFEL Type RF Waveguide Distribution

XFEL type distribution allows for maximum RF power for each cavity avoiding the weak cavity limit



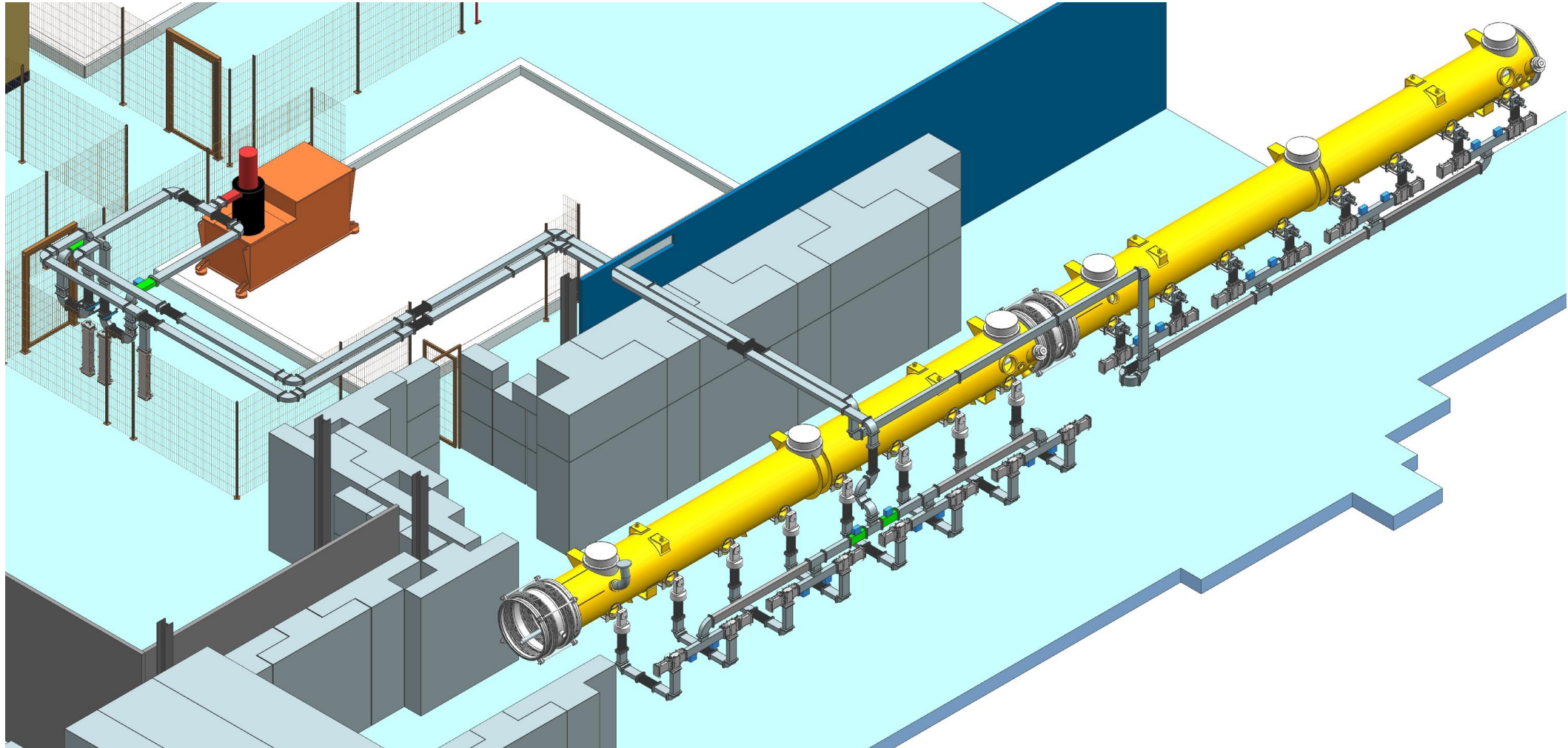
ACC2/3

Complete new waveguide distribution for the new modules ACC2 and 3



ACC4/5

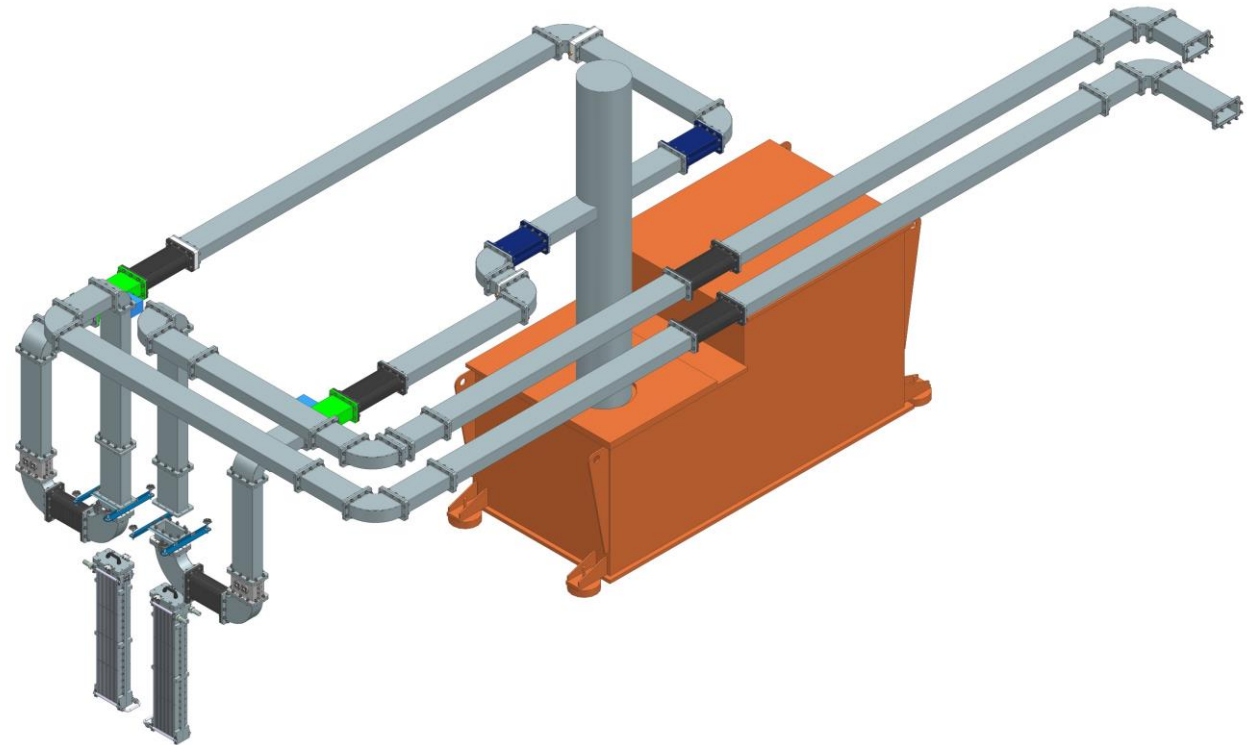
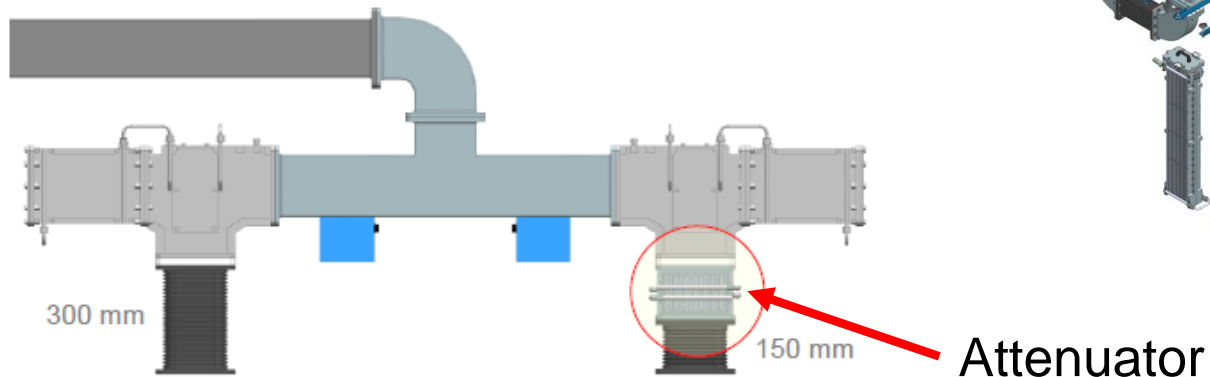
Modified and optimized XFEL type waveguide distribution for already installed modules ACC4 and 5 and new connecting and klystron waveguide distribution



ACC6/7

Minor adjustments to XFEL type distribution and new klystron waveguide distribution

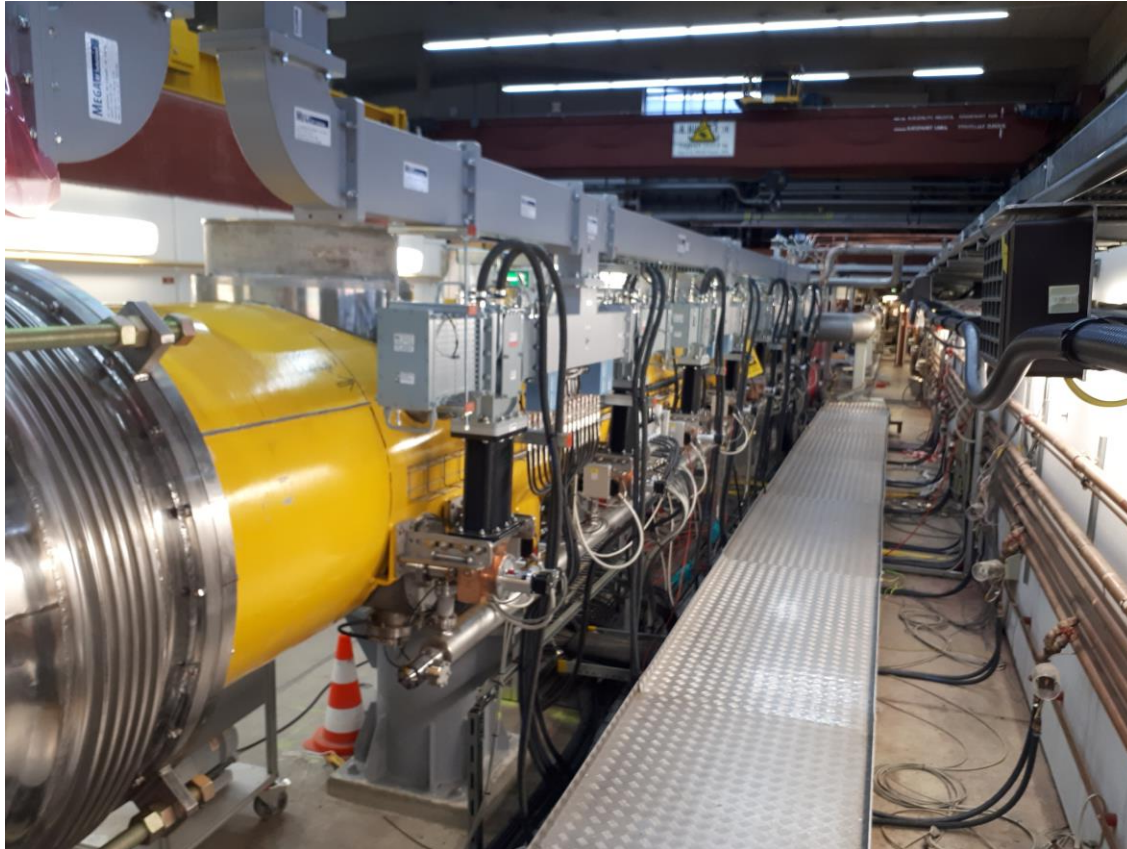
- 3 attenuators have been installed between the cavity and the isolator already before.
- Two of the them have been installed for ACC6 (0.8 dB for cavity 2, 1.2 dB for cavity 8)
- third one with 5.1 dB has been used at ACC7 for cavity 8.
- The reduction of power to these limiting cavities allowed to increase the power to the other cavities and thus the total power to the modules.
- This improvement resulted in a total beam energy gain of about 20 MeV, which is equivalent to one additional cavity.



FLASH tunnel



ACC2 and 3 in the FLASH Tunnel

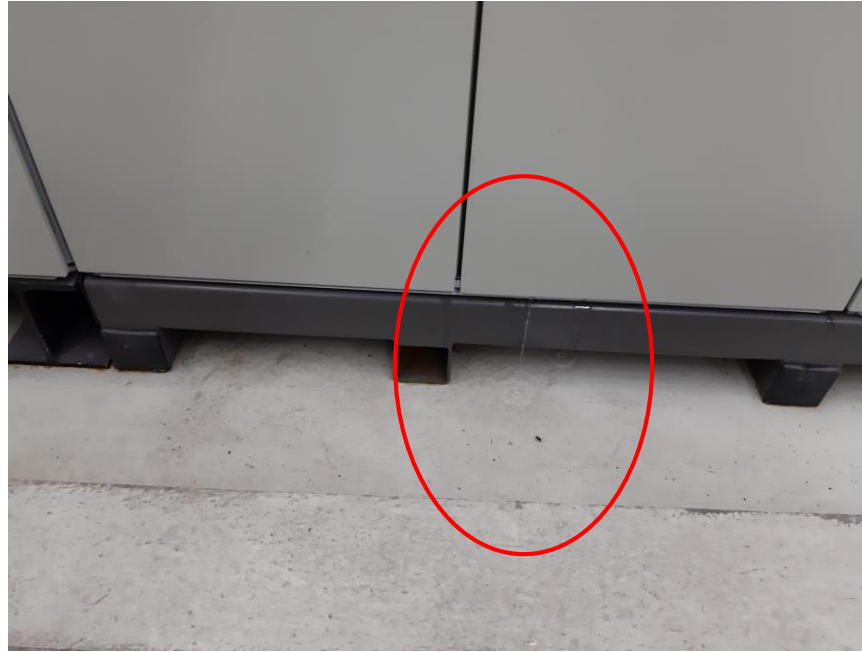


Summary

- 1 of 5 RF stations has been renewed
- 1 of 5 RF stations has received a new HV modulator
- All 5 RF stations got additional new subsystems
- New or improved RF waveguide distribution systems of the XFEL type avoiding the weak cavity limit have been installed
- FLASH will reach 1.35GeV allowing to decrease the FEL laser wavelength further beyond 4nm
- Warm commissioning has been finished
- RF gun operation has been restarted
- Cool down is in progress

Broken Component Transparency

- Water cooling failure of IGCT main switch



Thank you

Contact

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