

Accelerator facilities at DESY in Hamburg

2026 MicroTCA/ATCA Workshop for Large Scientific Facility Control

Holger Schlarb, MSK/DESY
HEPS, Beijing, 15. Sep. 2026

Covering today:

- PETRA III / IV
- FLASH / FLASH2020+
- EuXFEL / Upgrade

DESY is a centre of the Helmholtz Association
DESY develops, builds, and operates user facilities
and performs R&D and runs several science
programs



| H. Schlarb | Accelerator at DESY
2026 MicroTCA WS | HEPS, Bonn
15.09.2026

DESY activities : birds view ...



**European
XFEL**

X-Ray Free-Electron Laser
atomic structure & fs dynamics
of complex matter

PITZ in Zeuthen

PETRA
ext. East

REGAE

DESY II

PIA

SINBAD

LINAC II

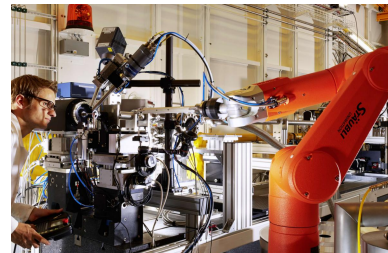
CMTB

CFEL
SCIENCE

PETRA III

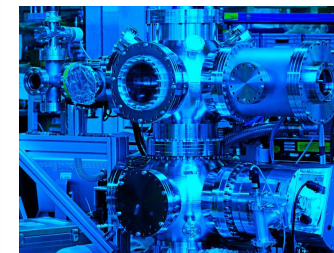
PETRA ext. Nord

FLASH



PETRA III

**Synchrotron Radiation
of Highest Brightness**
atomic structure of complex
matter



FLASH

**VUV & Soft X-ray
Free-Electron Laser**
fs dynamics of complex
matter (spectroscopy)

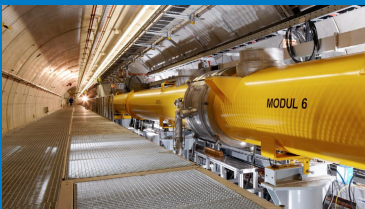
DESY Accelerator Division

Operation of user facilities for photon research and R&D for the accelerators of the future

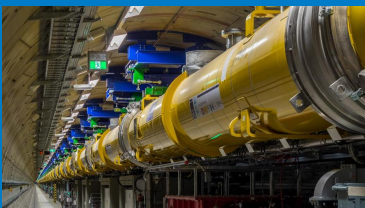
Operations



PETRA III – ready to upgrade to PETRA IV

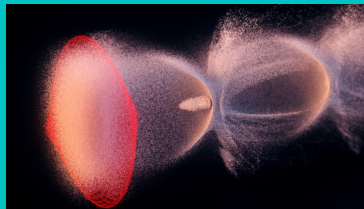


FLASH – with new capabilities

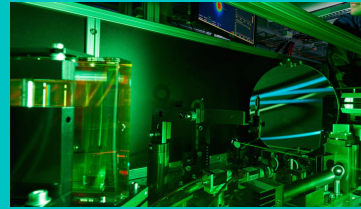


European XFEL – just finished a big upgrade

Research & Development – Toolkit



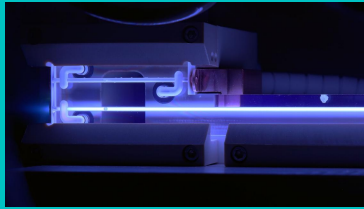
KALDERA & Plasma injector



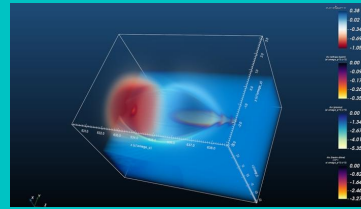
High-energy lasers



PITZ (Zeuthen)



Plasma: FLASHForward



Computing



ARES



Superconducting technology



Beam control & diagnostics



REGAE

Big project ahead



PETRA IV

Cooperations
Outreach
Innovation

Technologies such as μ TCA,
lasers and superconducting
accelerators
Medical applications with
clinical partners

Training of the next
generation
between 2020-2025:

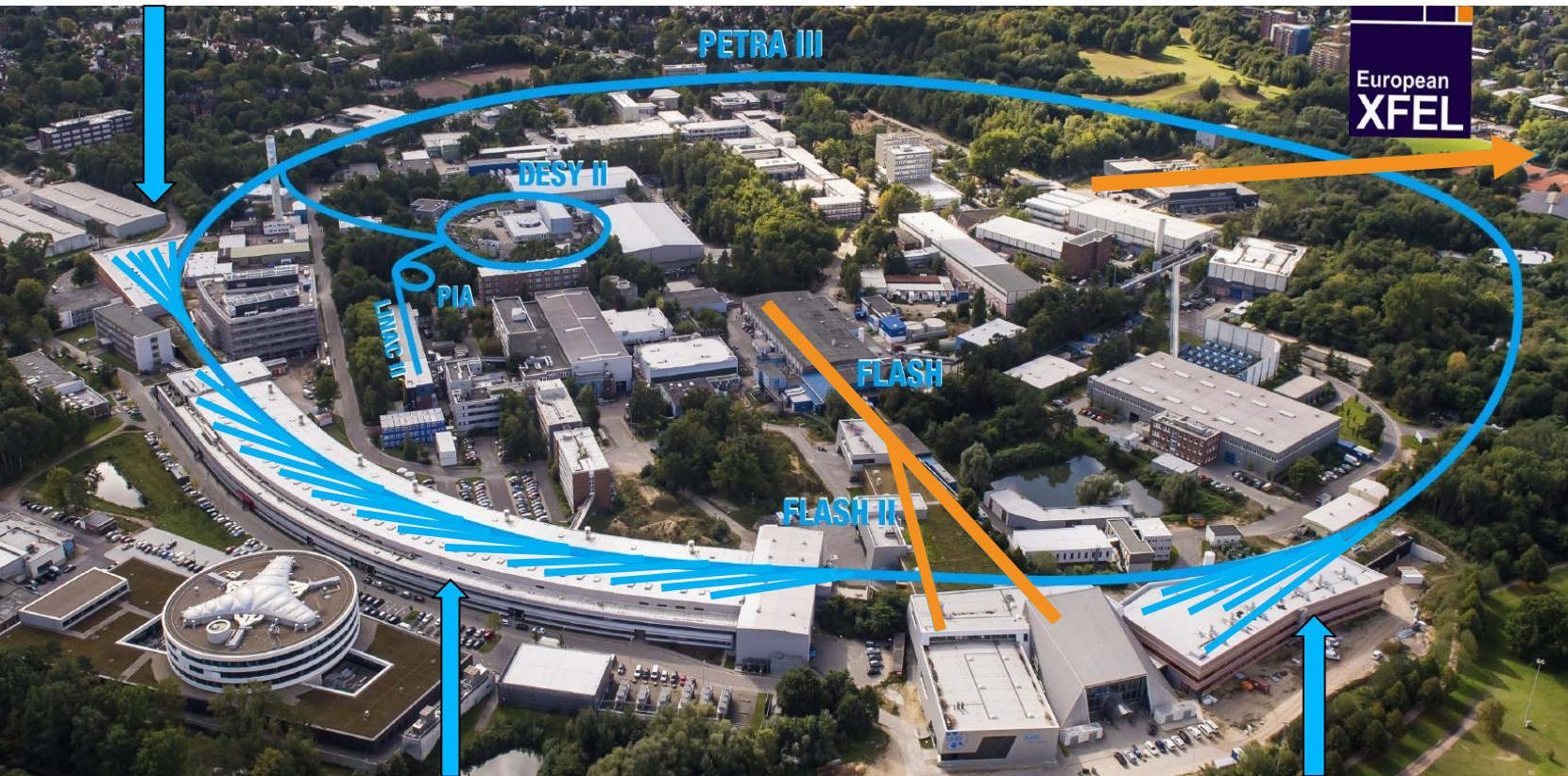
~75 PostDocs
~80 PhD, MSc, BSc
EPACE Doctoral training network

PETRA III

PETRA III is one of the core facilities at DESY

PETRA III is the world's biggest and still a quite brilliant 6 GeV storage ring light source

Ada Yonath Hall
Extension Hall East



Max von Laue Hall

Paul P. Ewald Hall
Extension Hall North

- First commissioning: 2009
- North/East extension: 2014

Parameter	PETRA III	
Energy [GeV]	6	
Circumference [m]	2304	
User Run [hours/year]	5000	
Number of beamlines	25	
Emittance (hor./ver.) [nm rad]	1.3 / 0.013	
Operational Mode	Timing	Continuous
Number of bunches	40	480
Bunch spacing [ns]	192	16
Total current [mA]	100	120

User run
scheduled: 4656 h
delivered: 4583:45h (98.4 %)

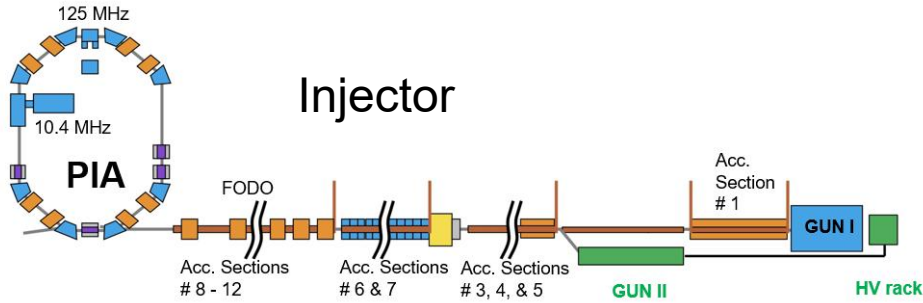
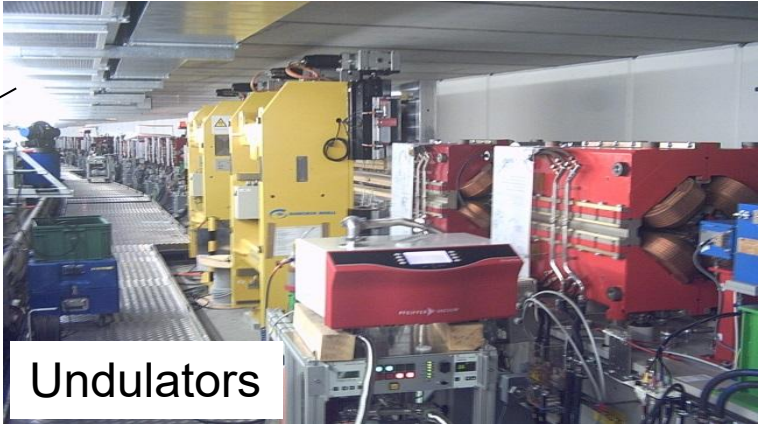
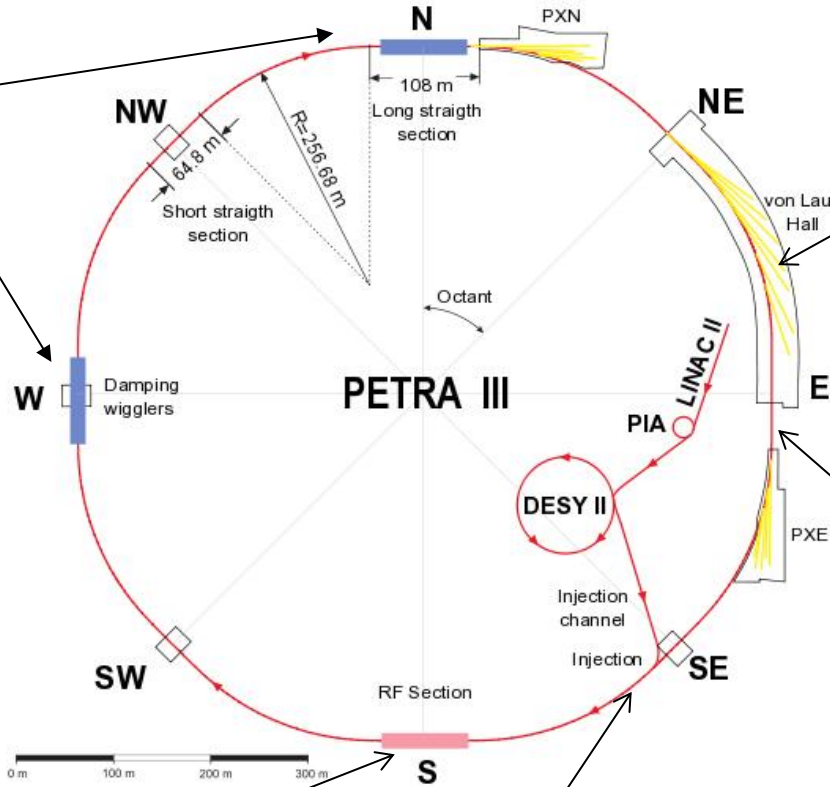
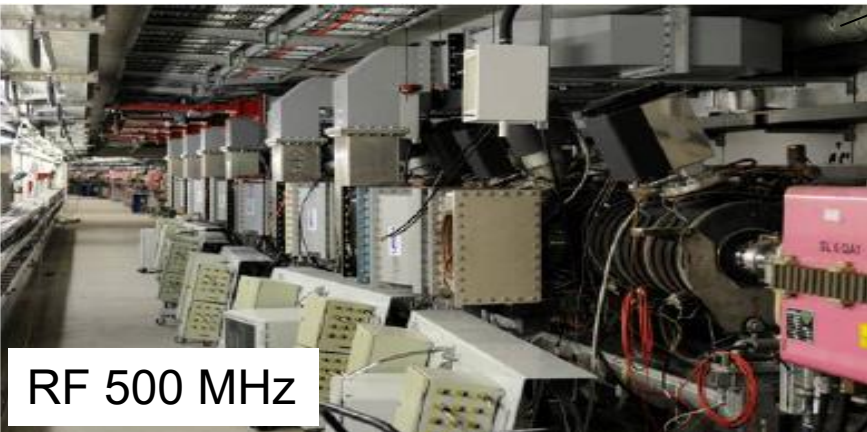
MTBF: 71 h

PETRA III

Courtesy: R. Wanzenberg



$\epsilon_x: 5 \text{ nm} \rightarrow 1.3 \text{ nm}$



Courtesy: M. Schaumann

The last open slot for an undulator was filled

Installation of the undulator PU63 was successful



The undulator is craned to the hall North West and transported through the tunnel to the Paul P. Ewald Hall (Extension Hall North).



The first photon beam is expected in July after the summer shut down

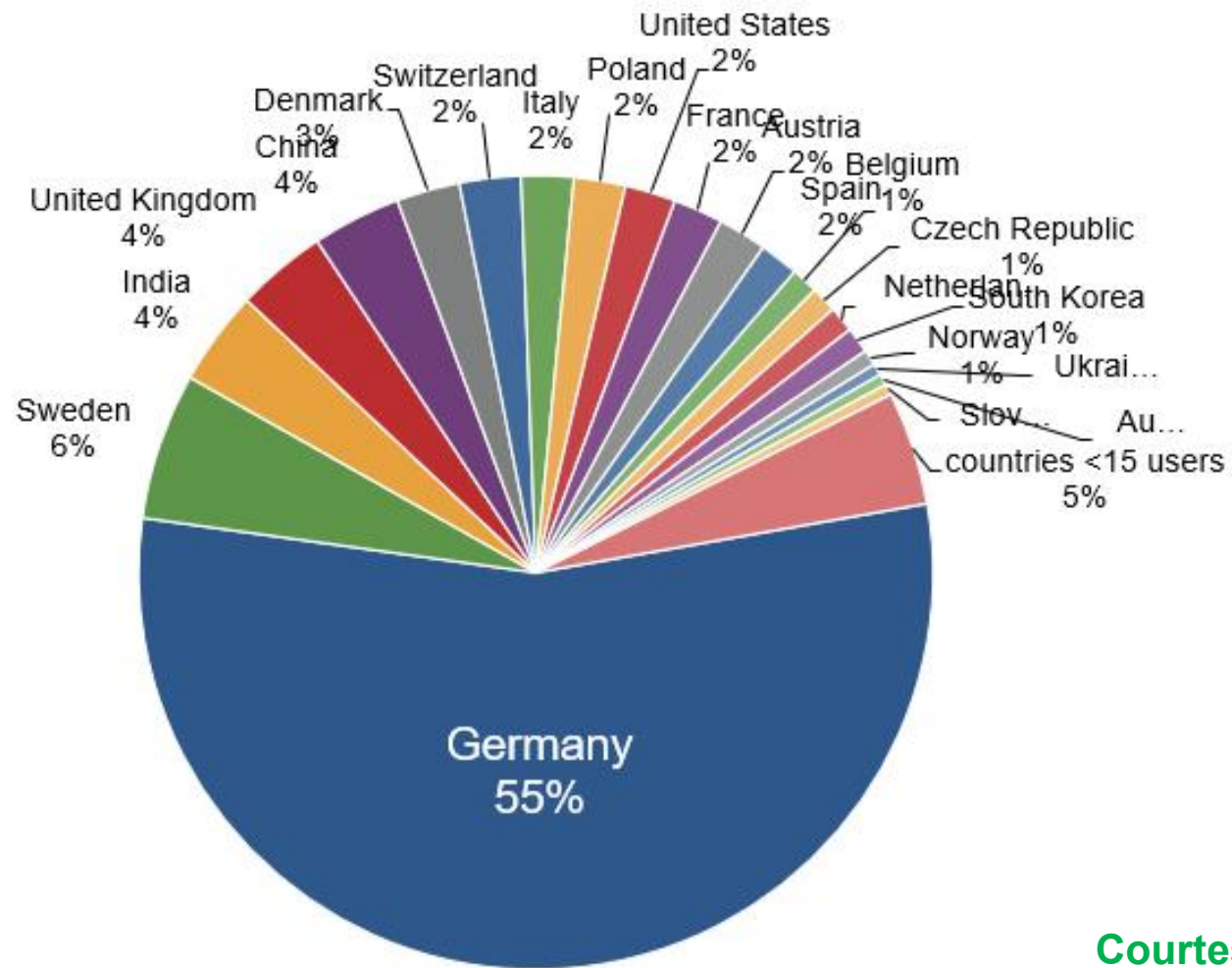
PU63

Courtesy: R. Wanzenberg

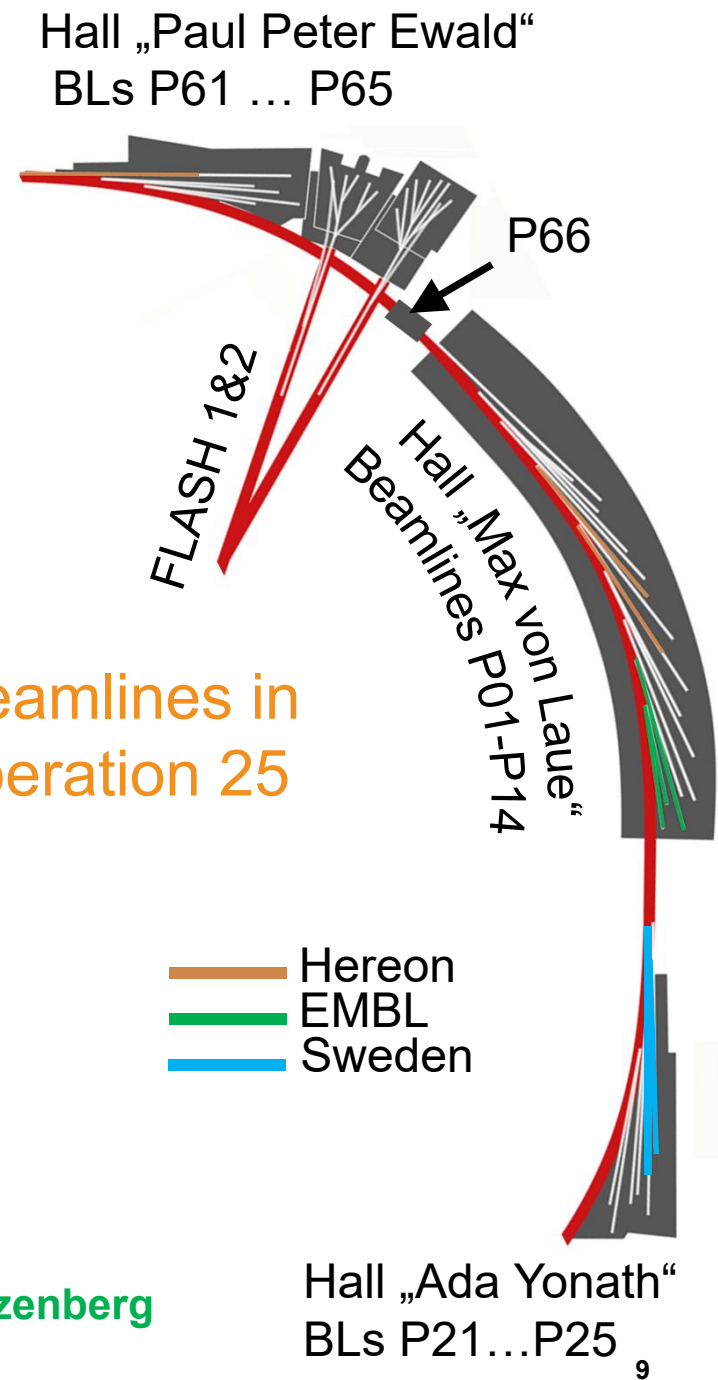
PETRA III: 3765 users from 49 countries

User visits in 2025: 8418 (on site, mail in, remote)

PETRA III user statistics in 2025



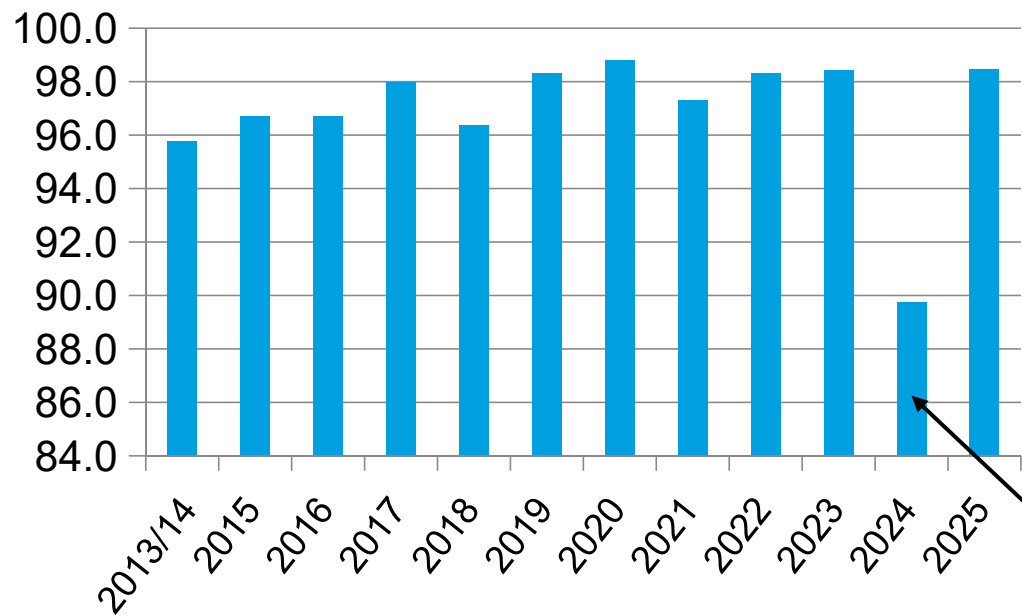
Courtesy: R. Wanzenberg



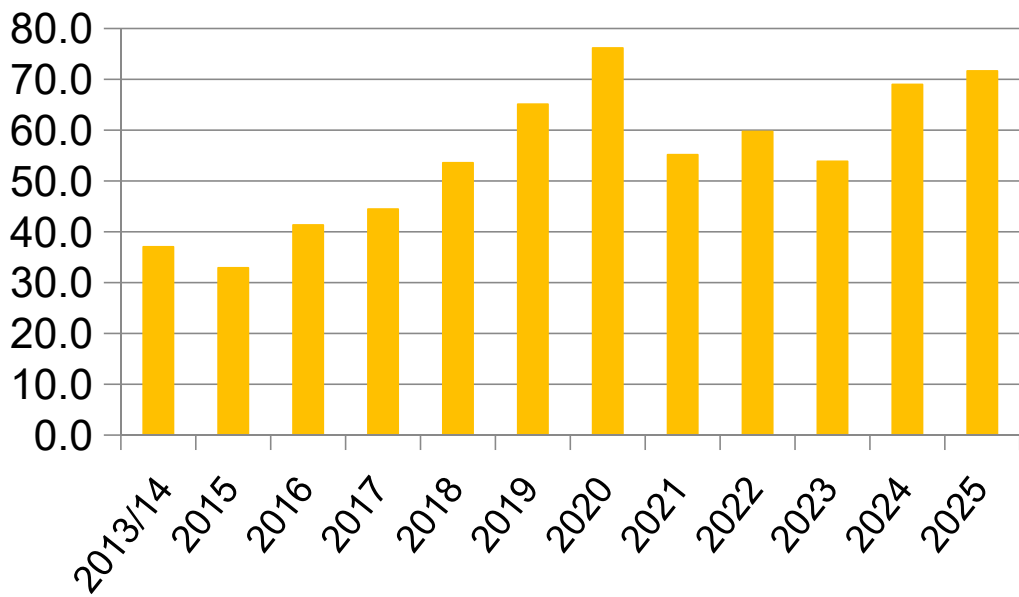
In 2025, PETRA III is back on track for high availability

A closer look into the long term statistics, the situation remains challenging

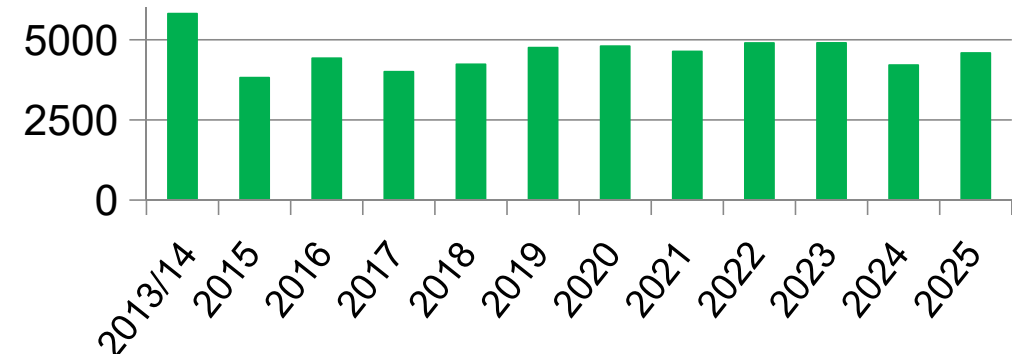
PETRA III Availability



PETRA III MTBF

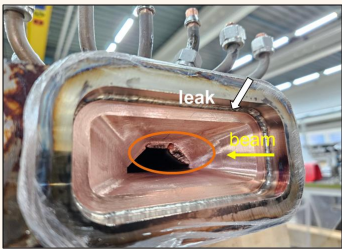


PETRA III user run / h



2024
Downtime
Absorbers
107:57 h
Fire
324:13 h

Vacuum leak at absorbers
in the wiggler sections



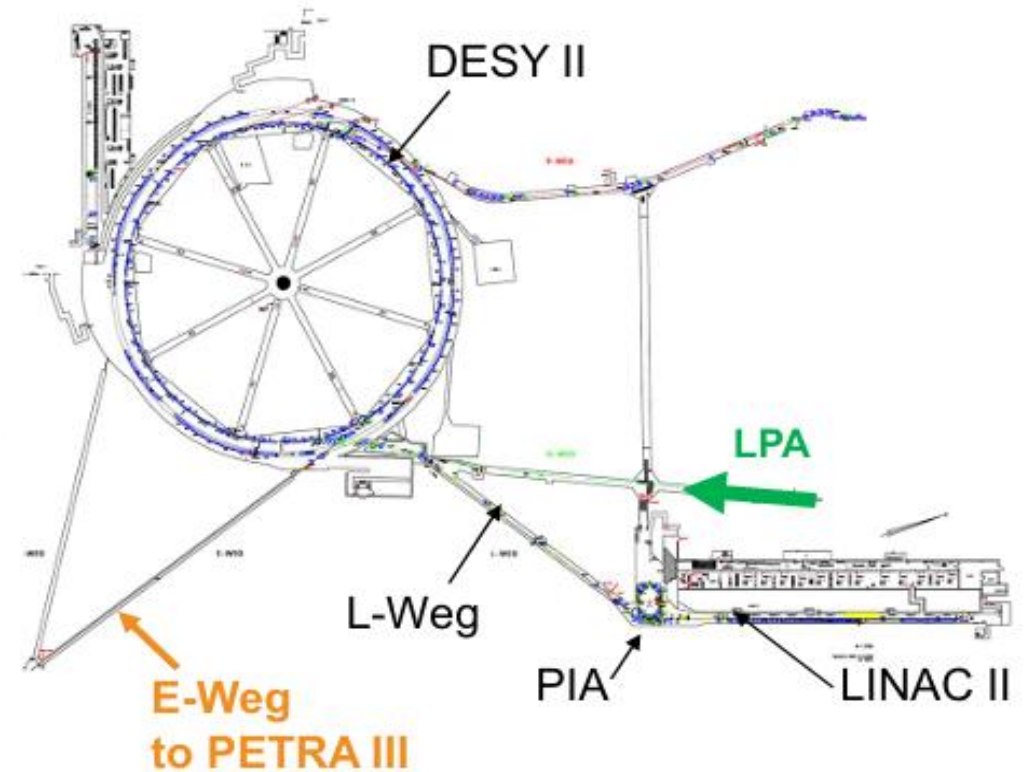
Fire in DESY II
main electronic
room



First injection of LPA beams into PETRA III

- LPA beams were produced at the LUX accelerator.
- Sent to DESY II via L-Weg.
- Machine setup with LINAC II beams.
- Beam captured and accelerated to 6 GeV.
- Transferred to PETRA III.
- Publication in preparation.

Essential for the success of the experiment at PETRA III was the possibility to switch between the two injector paths. Many thanks to the excellent work of the timing experts !



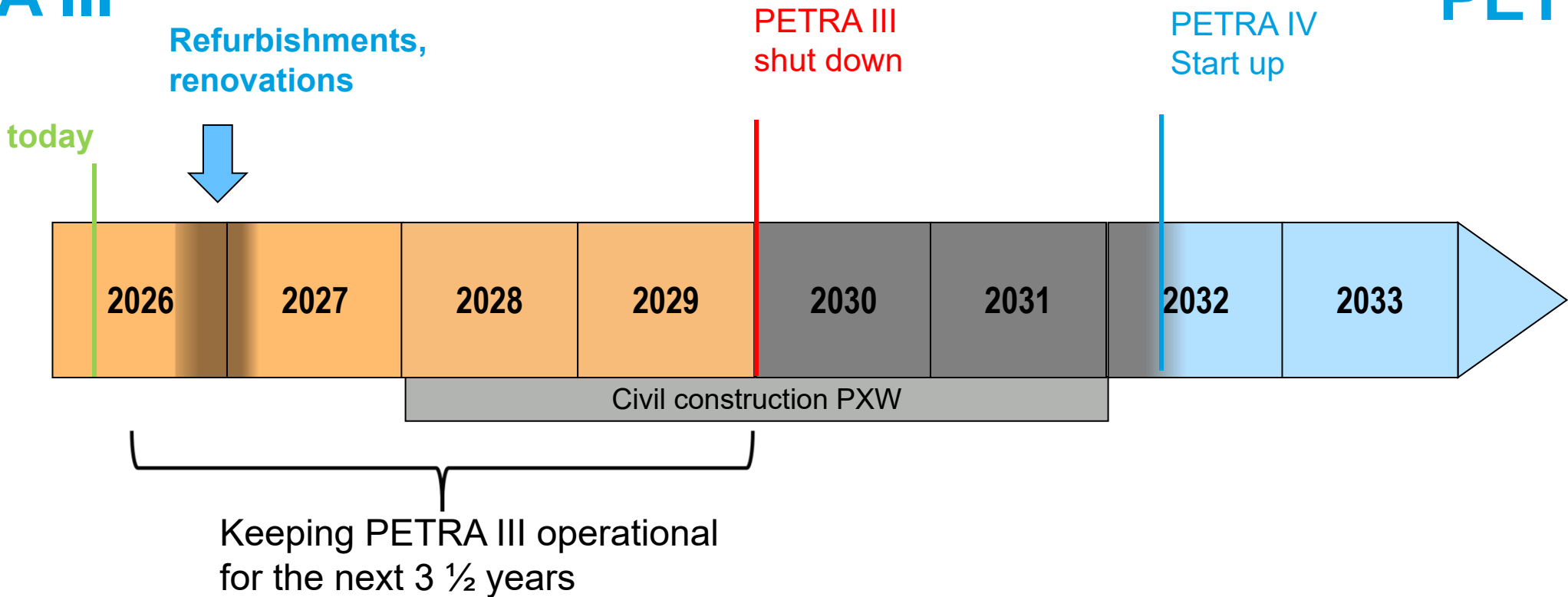
Courtesy: F. Burkart

Refurbishments will enable the further operation of PETRA III

The operation of PETRA III will continue for at least 3 1/2 years

PETRA III

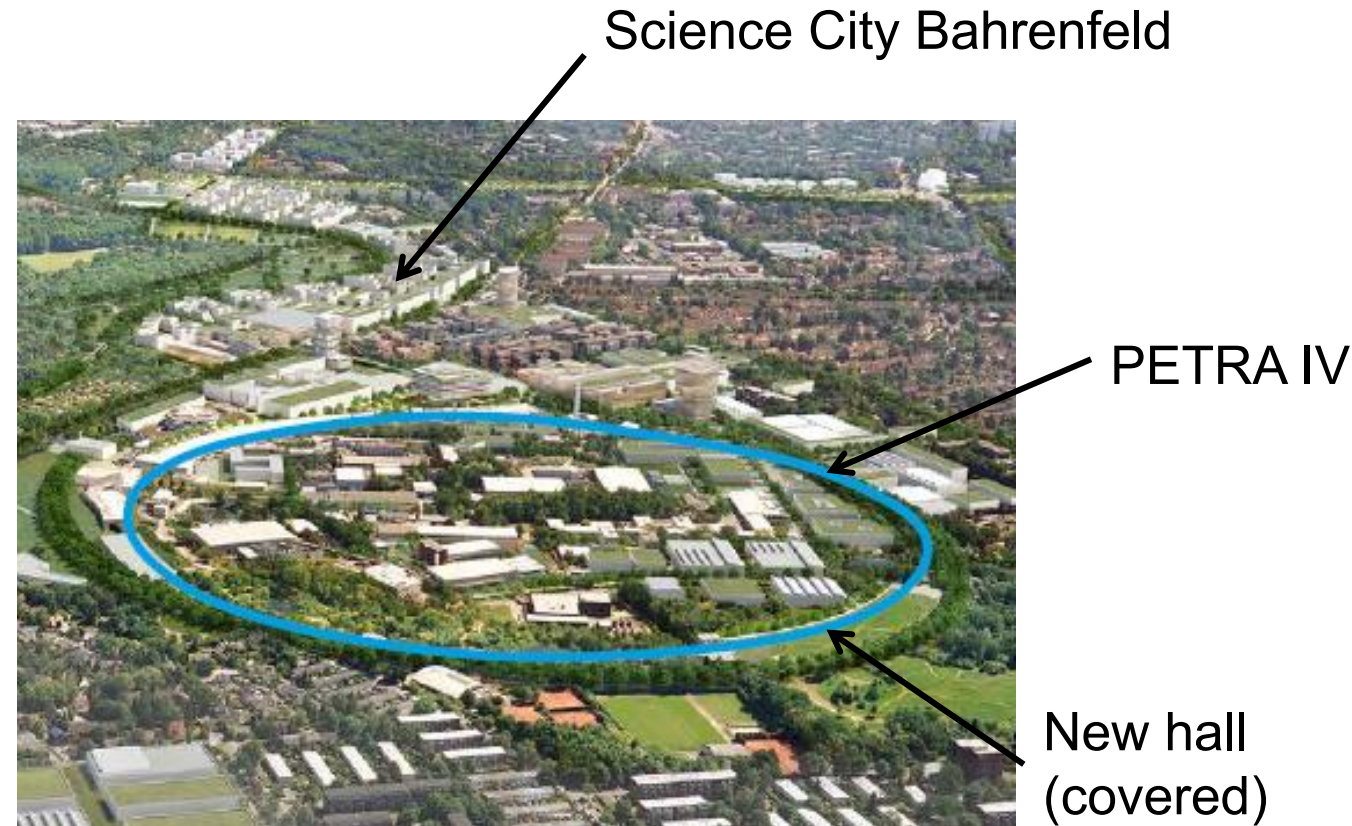
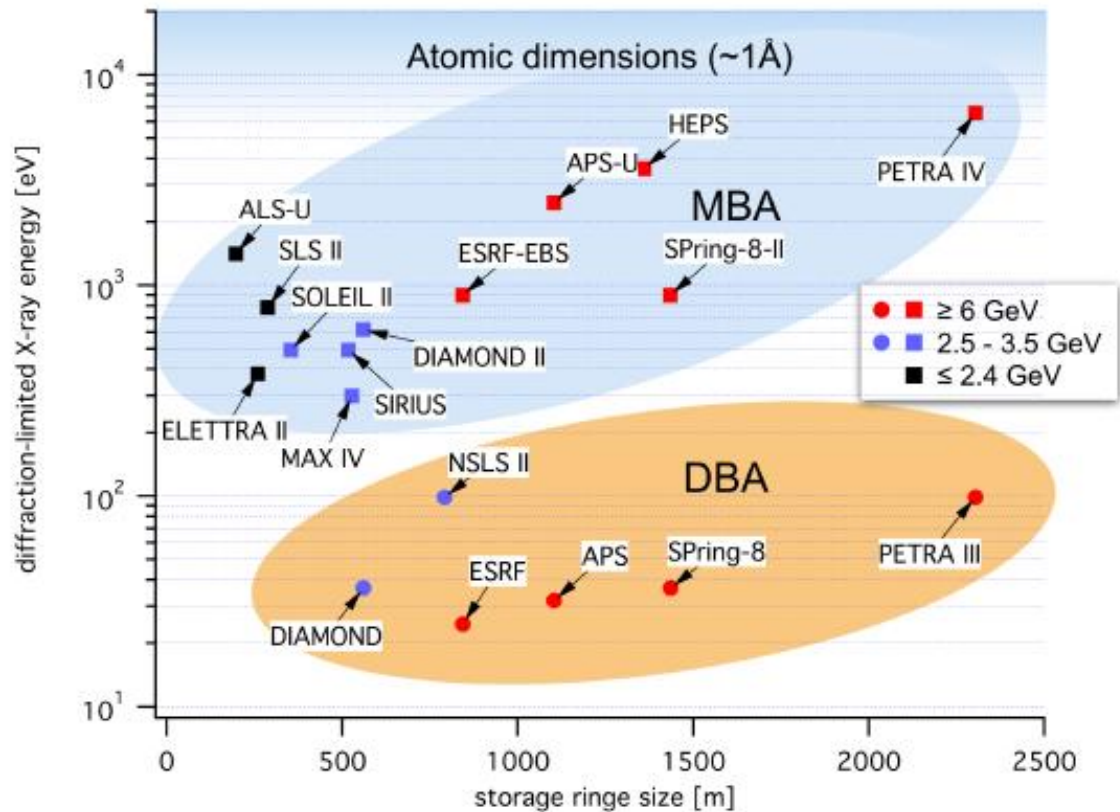
PETRA IV



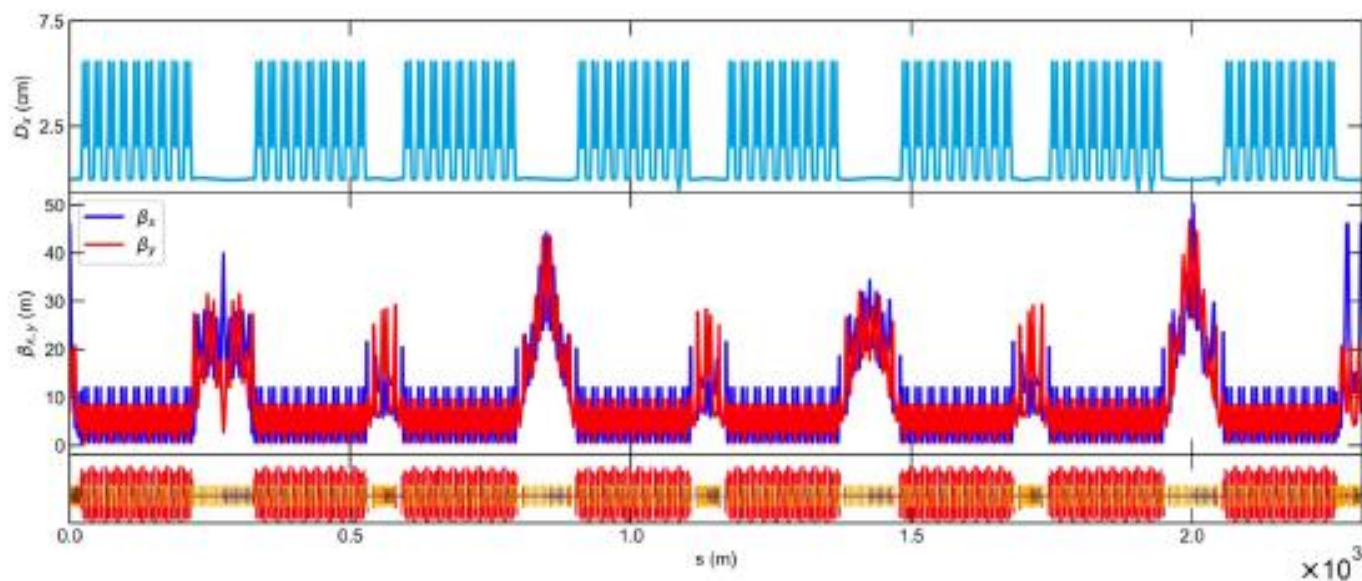
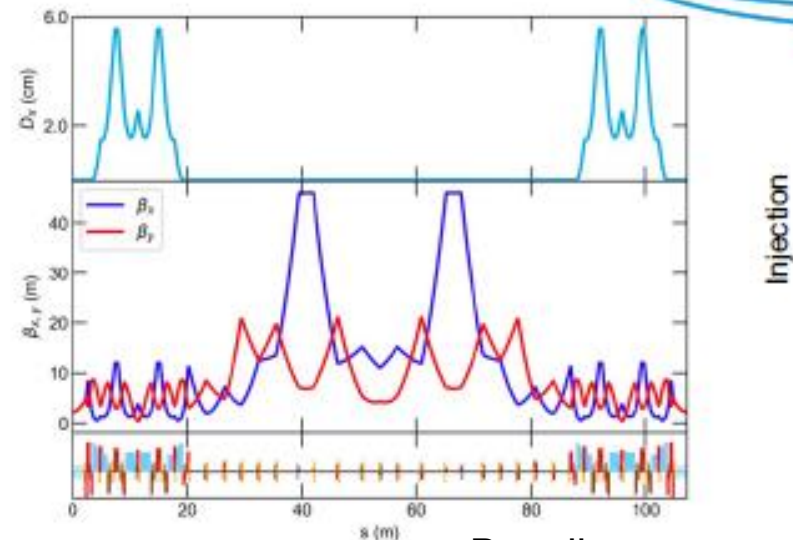
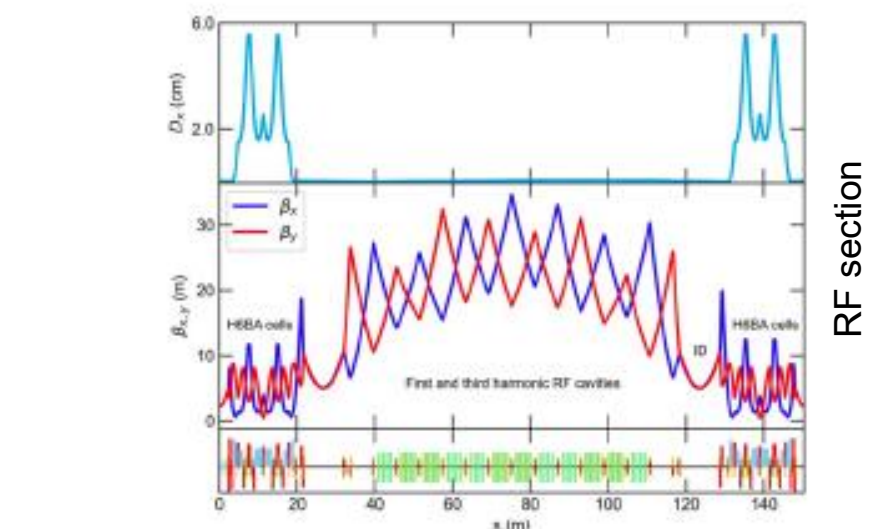
PETRA IV

PETRA IV - Motivation

- Diffraction-limited photon energy for synchrotron radiation sources and there upgrades
- Pressure for DESY to upgrade PIII → PIV to stay competitive in the world!



H6BA lattice main ring design complete



Baseline parameters

Parameter	Value
Tunes Q_x, Q_y	164.18, 68.27
Natural chromaticity ξ_x, ξ_y	-230, -196
Corrected chromaticity ξ_x, ξ_y	6, 6
Momentum compaction factor α_C	3.3×10^{-5}
Standard ID space	4.9 m
$\beta_{x,y}$ at ID, standard cell	2.2 m, 2.2 m
$\beta_{x,y}$ at ID, flagship IDs	4 m, 4 m
Nat. hor. emittance ε_x no DW, zero current	43 pm rad
Nat. hor. emittance ε_x with DW, zero current	20 pm rad
Rel. energy spread δ_E no DW, zero current	0.7×10^{-3}
Rel. energy spread δ_E with DW, zero current	0.9×10^{-3}
Energy loss per turn, lattice no DW	1.3 MeV
Energy loss per turn, lattice with DW	4.0 MeV

Courtesy I. Agapov

Girder demonstrator completed

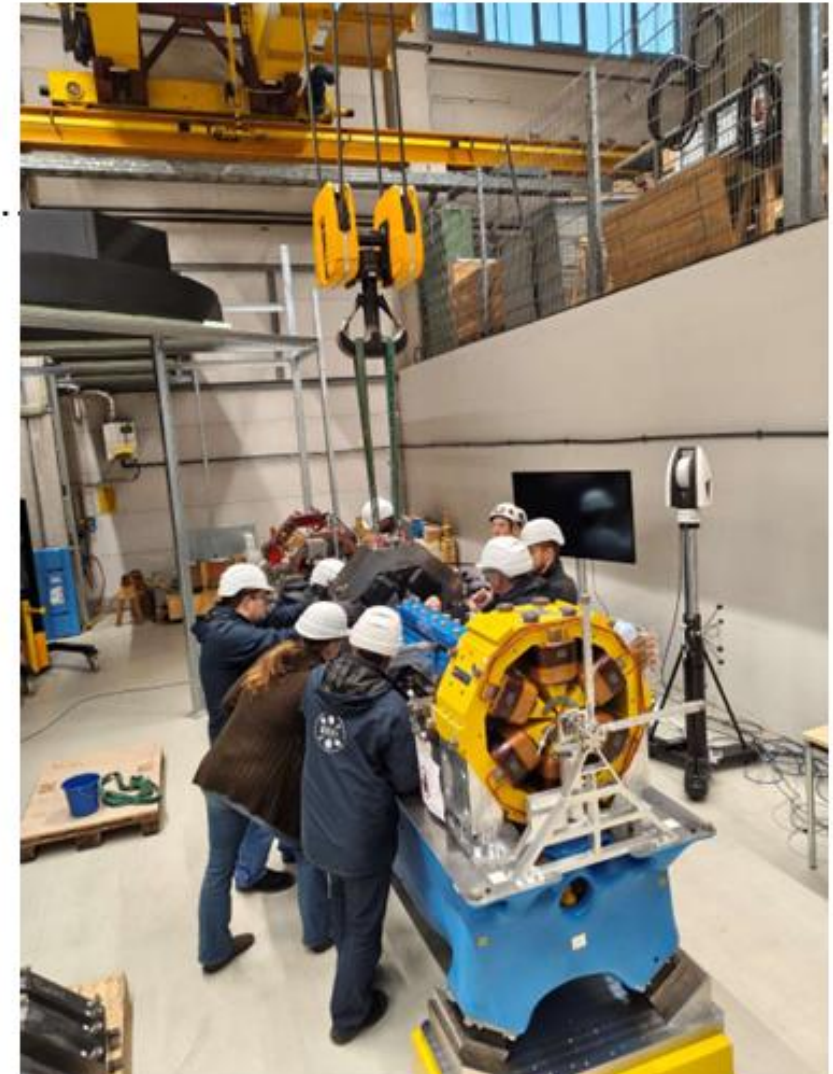
Girders and Alignment (WP2.06/WP2.07):

- girder movers assembled
- magnet support assembled
- PQA, PSA, dummies and vacuum chamber installed
- numerous tests ongoing: NEG activation, vibrations, glue behaviour, .

from CAD to prototype



Courtesy R. Bartoloni



FOFB Overview

Conceptional design



Optical links for communication routed through the tunnel and shared by 3 WPs (timing, MPS, feedback)

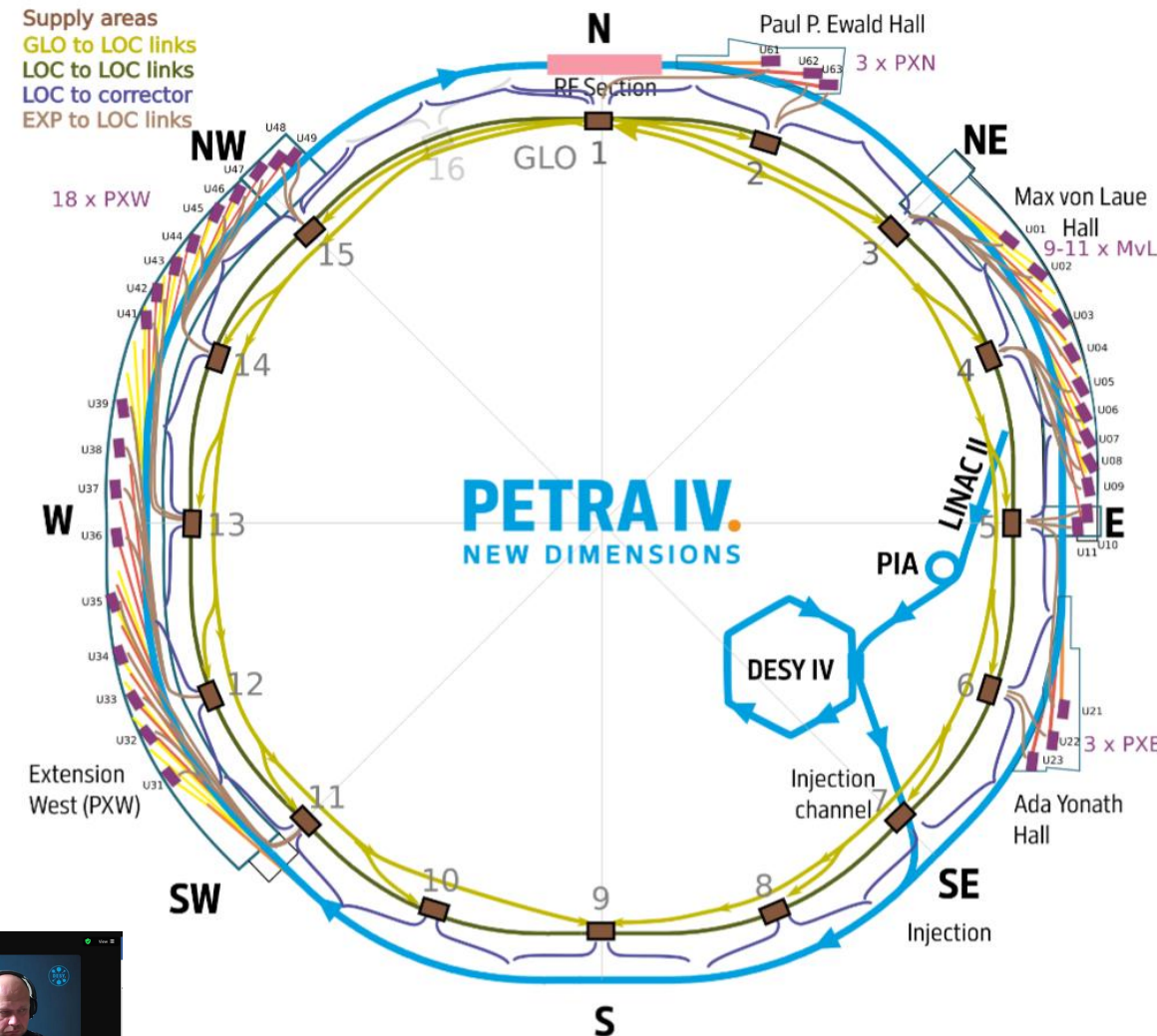
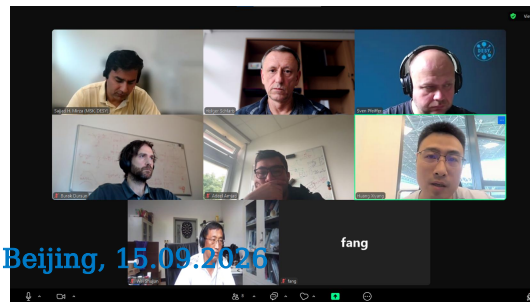
Goals

- 1 kHz disturbance suppression BW
- 10% orbit stability at IDs (option to improve towards 5% .. 3%)
- 300nm down to 150nm ... 100nm

Extended Star Topology

- 1 Global processing node
 - Close to RF section to allow RF phase feedback (APS-U studies)
- 16 Local processing nodes (15 physical locations)
 - BPM data collection (2x768 BPMs traces)
 - Interface with corrector PSs (244H, 316V)
 - Integrate experimental sites
- With global node ~ 78us latency

Cooperation with HEPS



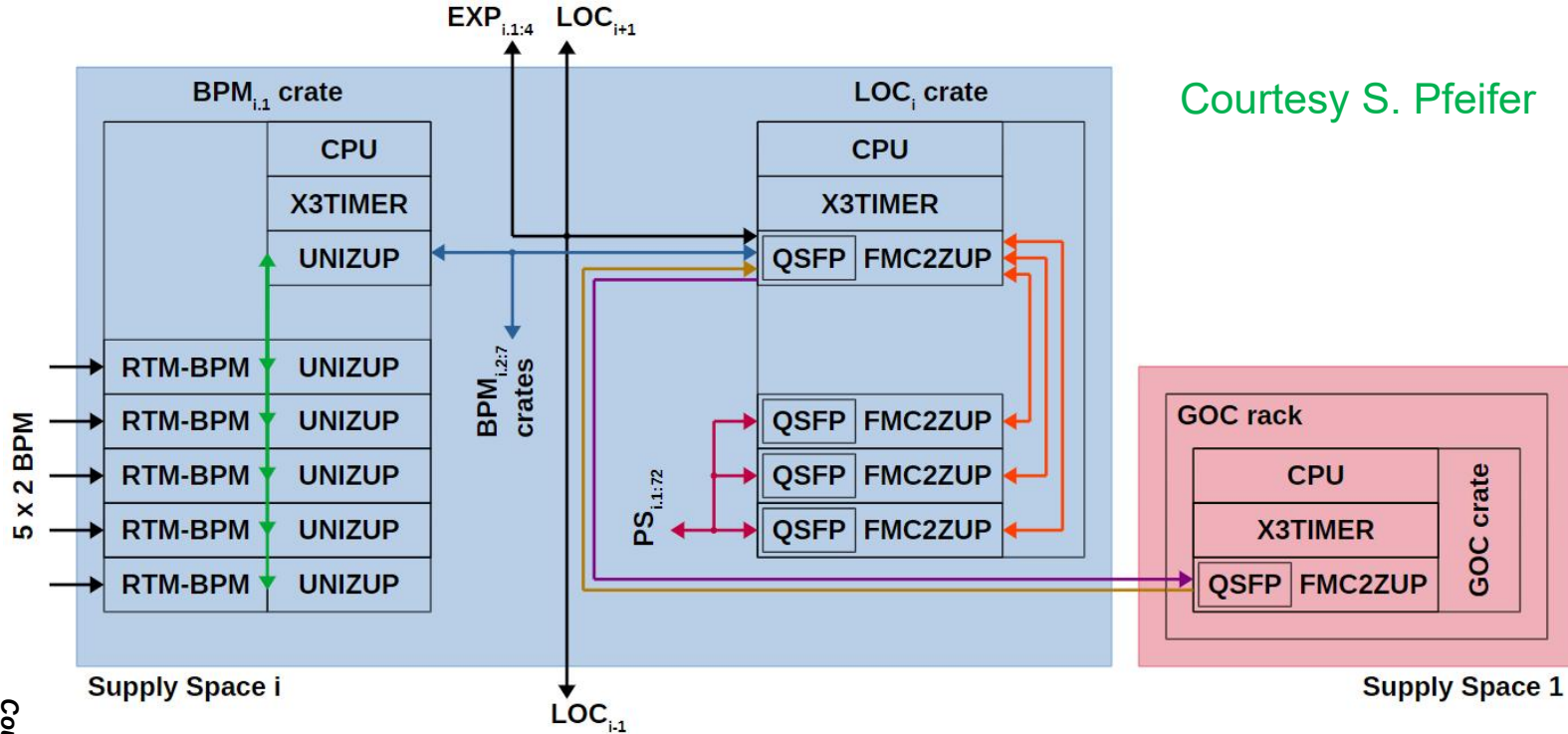
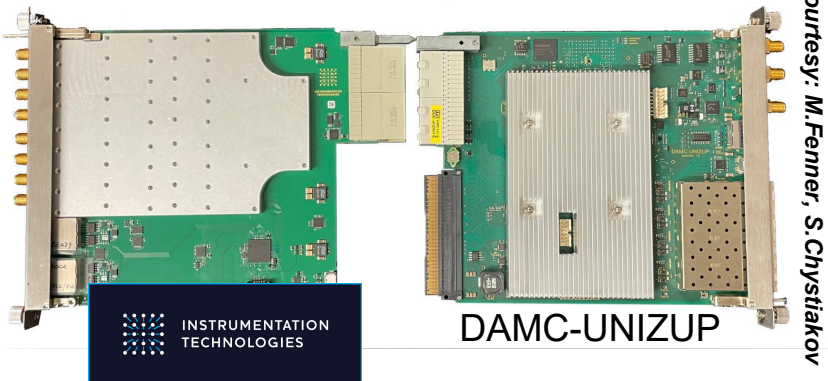
Courtesy S. Pfeifer

FOFB Overview

Current baseline concept

Pros:

- Standard modules/boards per crate
- ✓ 2x crate PS (redundant)
- ✓ MCH, CPU, x3timer (WP2.09) WORK IN PROGRESS
- 2 versions of AMC boards only (no assembly options)
 - ✓ DAMC-FMC2ZUP with *DFMC-6QSFP* (24SFP links) WORK IN PROGRESS
 - Extendable by additional AMC
 - ✓ **DAMC-UNIZUP** as BPM data collector



Courtesy S. Pfeifer



12 BPM/crate

FOFB System: only 1 component is missing

- 6QSFP → 24 SFP links, in production

BPM System:

- Boards delivered and licensed to I-Tech
- Cost-effective alternative to the DAMC-FMC2ZUP
- Test results are very good!

MBFB - PETRA IV design and tests at PETRA III

Readout with RFSoc Gen3, DAMC-DS5014DR



→ See the talk by Behzad Bograti

PETRA IV

Brightness and Timing mode

- baseline (1920b/200mA ; 80b/80mA)
- 70μA ... 1mA bunch current
- (2ns), 4ns ... 96ns bunch spacing

Dynamic range

- x10 (20dB)

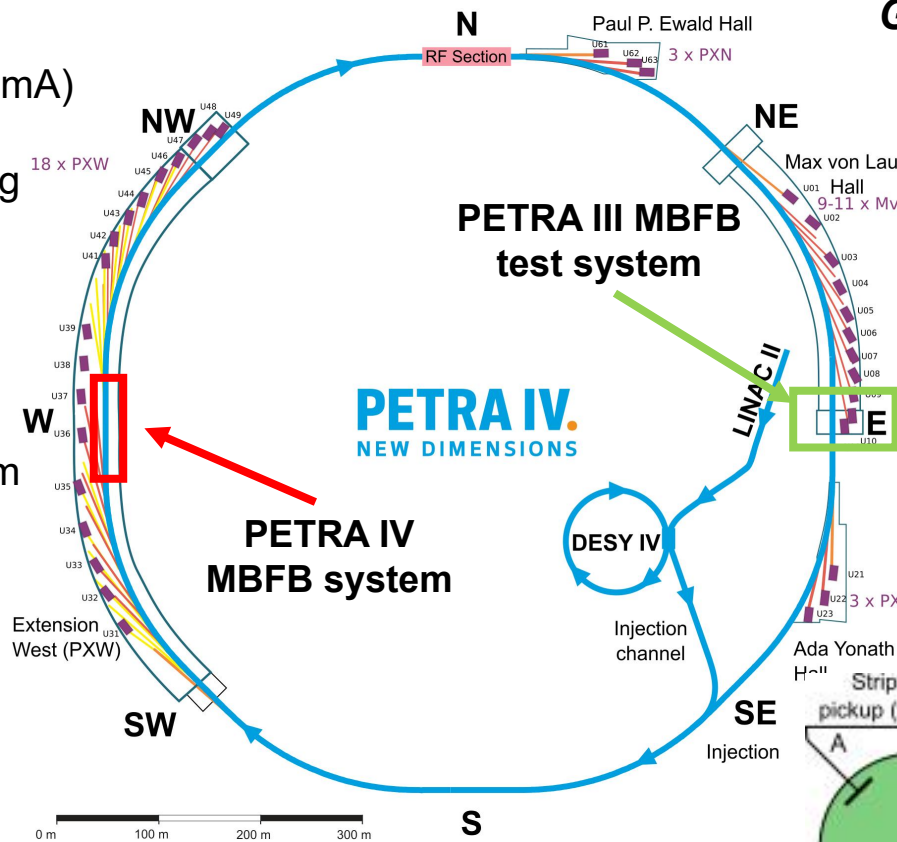
Detector range

- x1000 (60dB) – required by beam physics
- 1μm for 1mm full dynamic range

PETRA III

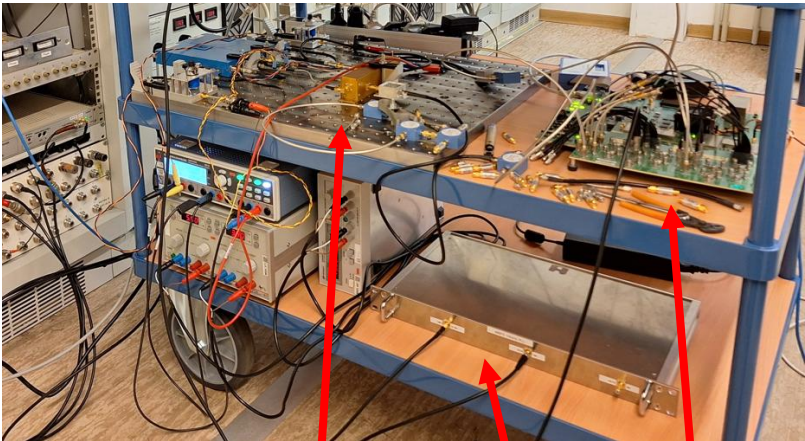
Brightness and Timing mode

- 480b/120mA ; 40b/100mA
- 250μA ... 2.5mA bunch current
- 16ns ... 192ns bunch spacing

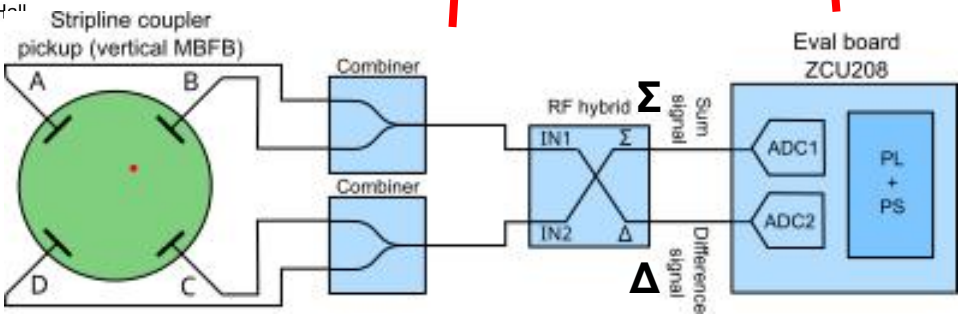


Courtesy S. Pfeifer

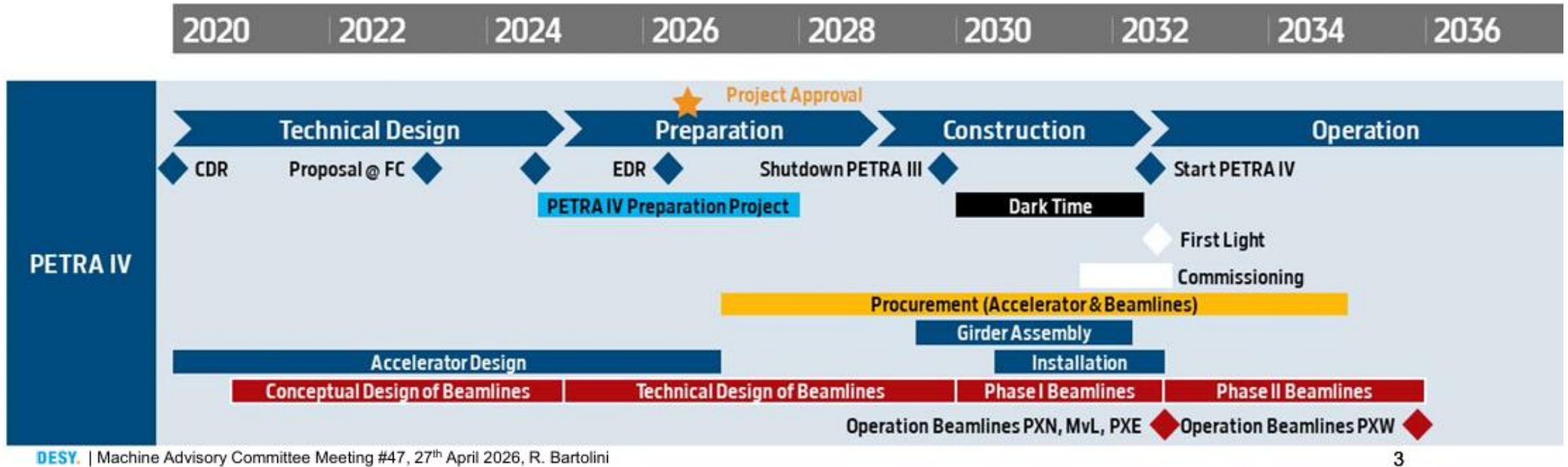
Goal to verify the MBFB performance at PIII.



5GHz PLL



PETRA IV timeline is challenging.



- Final project approval pending
- Funding flow expected ~ Q3/2027
- Will receive bridging funds

FLASH

FLASH Layout (2022)

3rd harmonic sc module 3.9 GHz



TESLA type superconducting accelerating modules 1.3 GHz



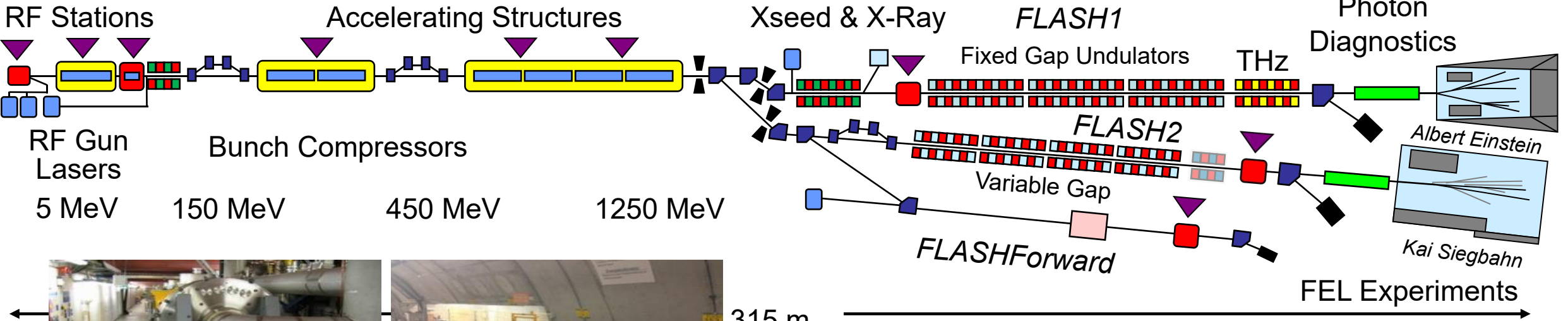
FLASH1 fixed gap undulators



Albert Einstein Hall



Courtesy S. Pfeifer



Normal conducting 1.3 GHz RF gun
Cs₂Te cathode / 5 injector lasers



Extraction to FLASH2

Courtesy: J. Rönsch

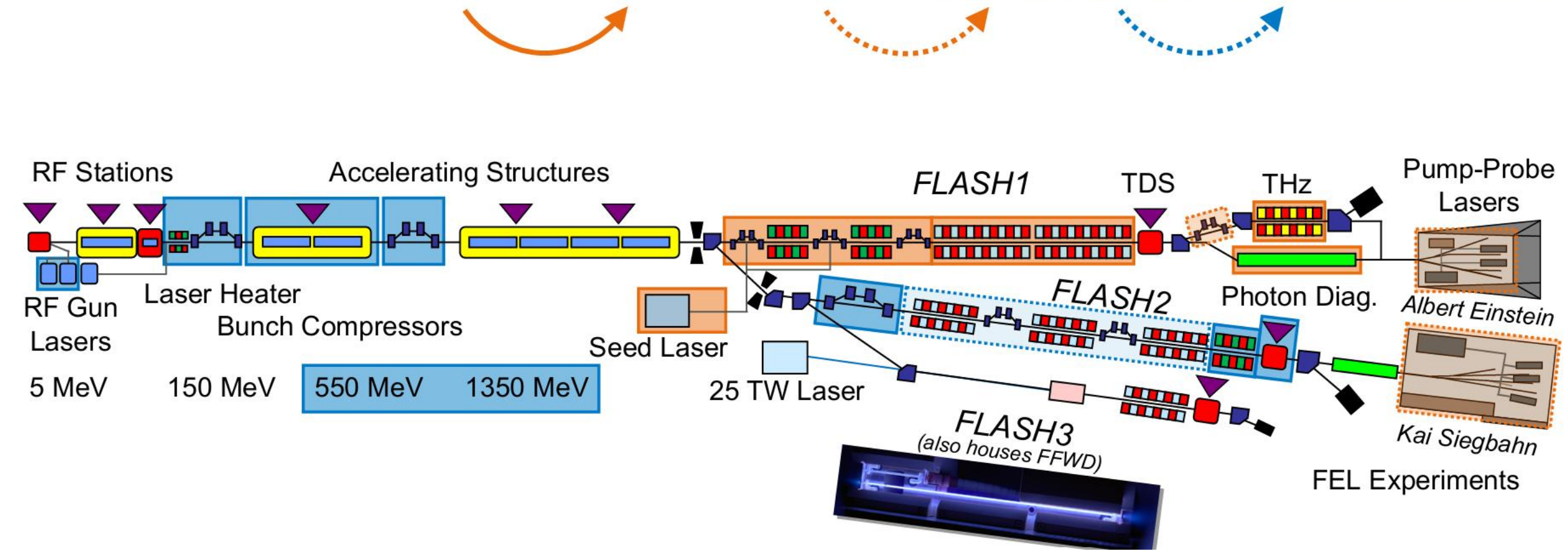


FLASH2 variable gap undulators



Kai Siegbahn Hall

FLASH 2020+ timeline

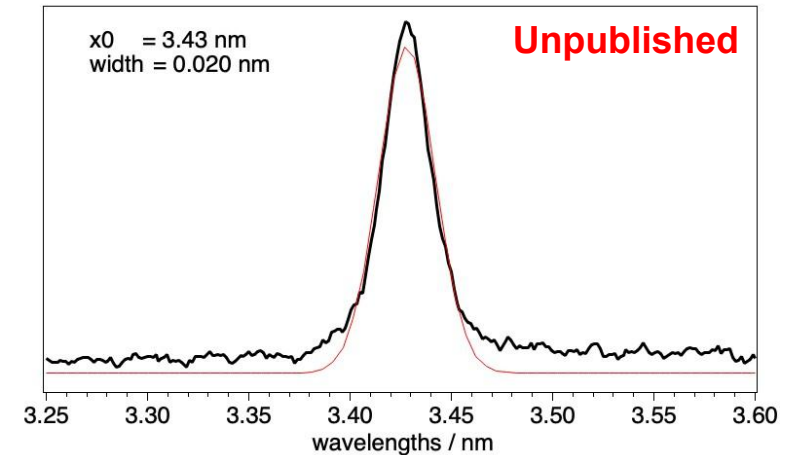


Demonstration of 3.43 nm wavelength at FLASH

As a result of the energy upgrade, FLASH can now reach photon energies extending into the oxygen K-edge

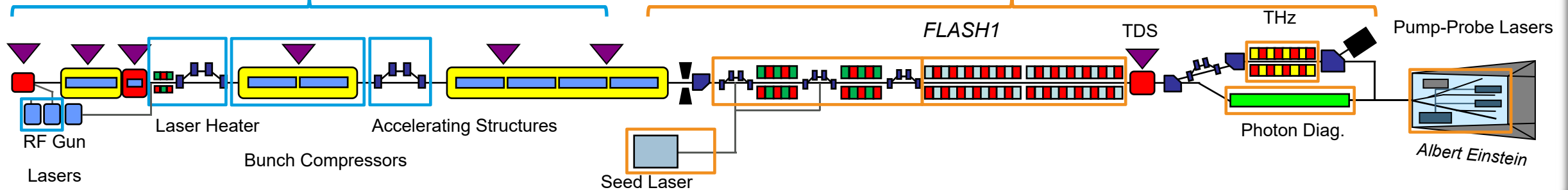


Wavelengths down to 3.43 nm delivered



Successfully upgraded

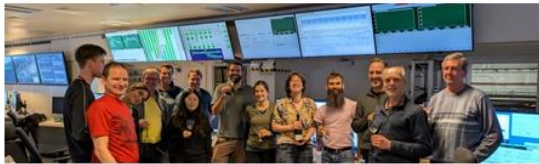
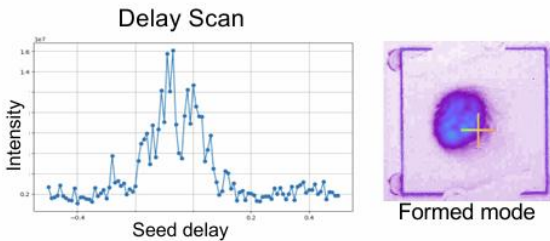
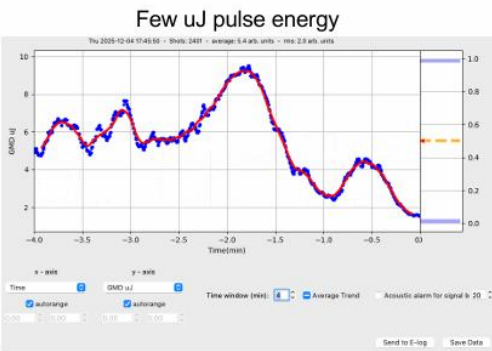
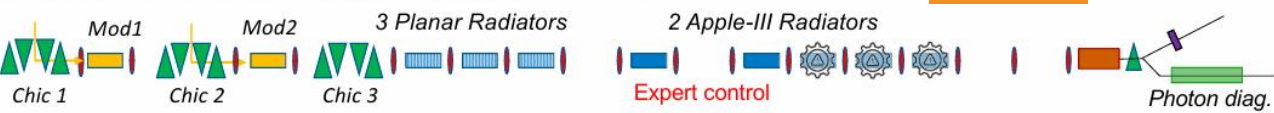
Next installations



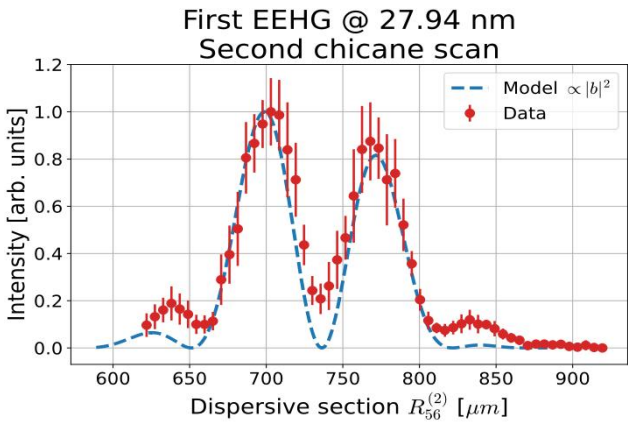
Seeding & Acc. Research

First light!

3rd Dec. 2025: HGHG at 6th harmonic (52 nm) E=470 MeV



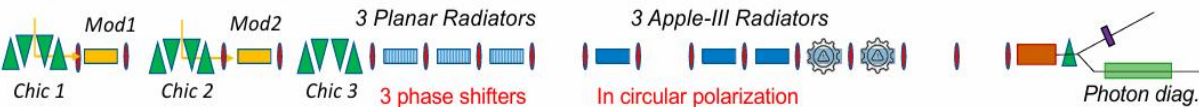
21st January 2026: EEHG (27.94 nm; $n=-1, m=12$) E=750 MeV



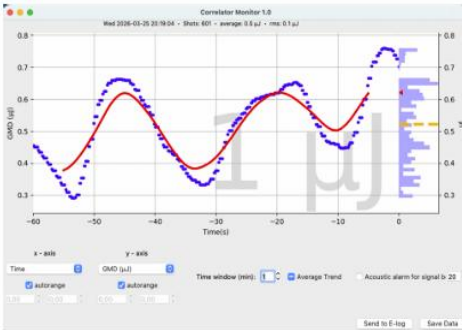
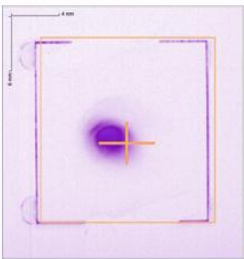
27 nm

EEHG progress towards shorter wavelengths

The freshest results (KW13): EEHG@7.966 nm ($n=-1, m=40$), E=1.3 GeV



About 1 uJ pulse energy at the shortest wavelength achieved

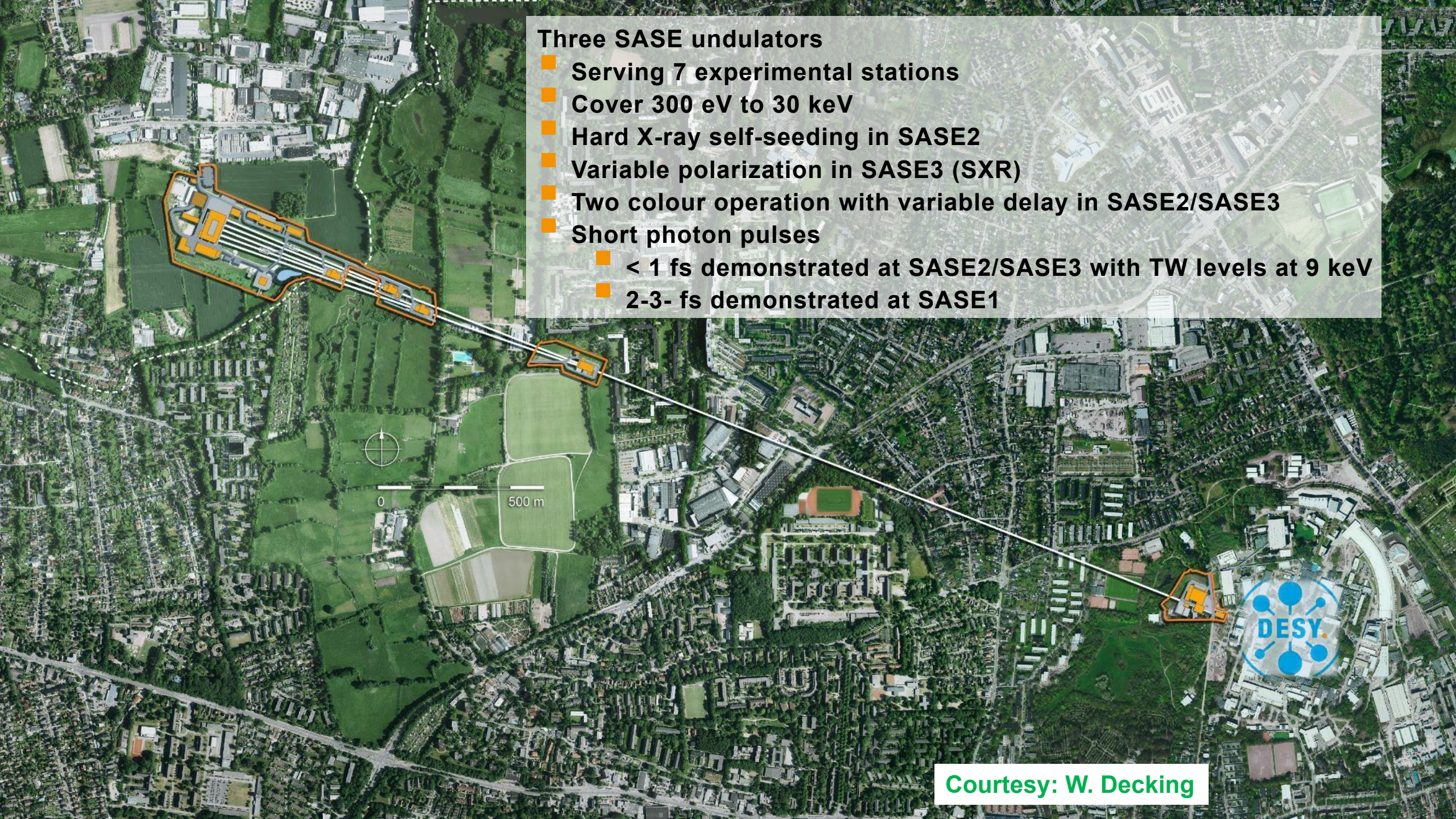


"Only" a factor 2 missing to 4 nm

European XFEL

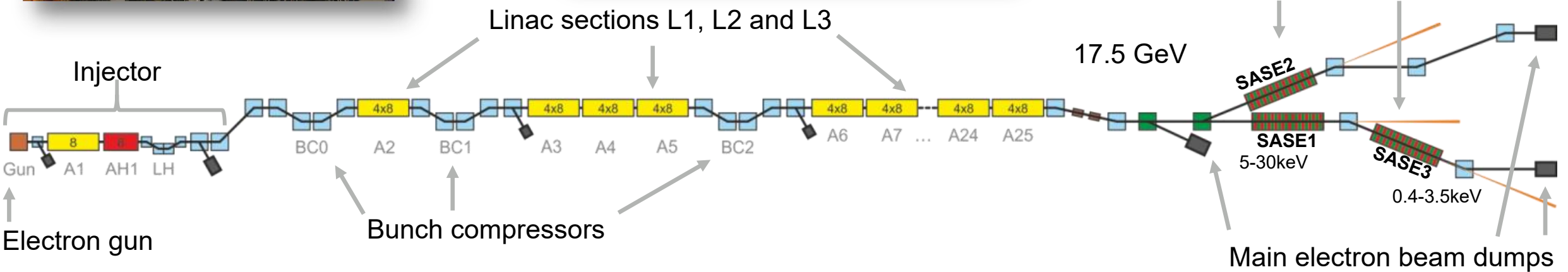
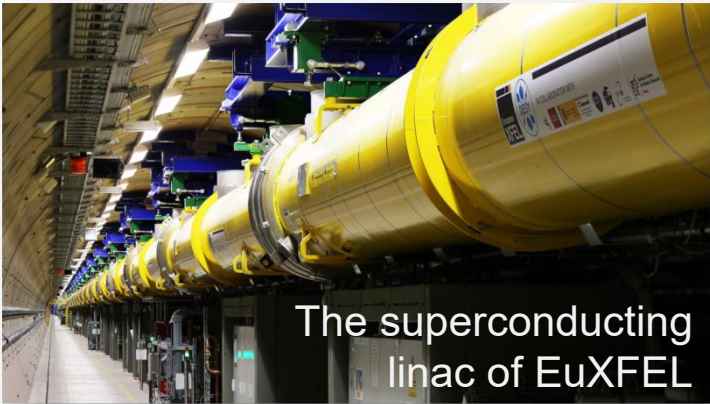
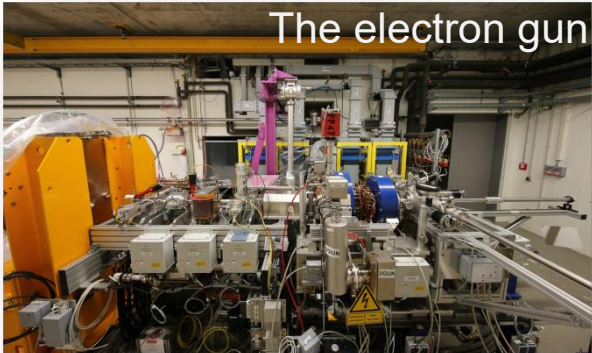
Three SASE undulators

- Serving 7 experimental stations
- Cover 300 eV to 30 keV
- Hard X-ray self-seeding in SASE2
- Variable polarization in SASE3 (SXR)
- Two colour operation with variable delay in SASE2/SASE3
- Short photon pulses
 - < 1 fs demonstrated at SASE2/SASE3 with TW levels at 9 keV
 - 2-3- fs demonstrated at SASE1



Courtesy: W. Decking

EuXFEL Accelerator



The electron accelerator is operated from the DESY campus in Hamburg Bahrenfeld.

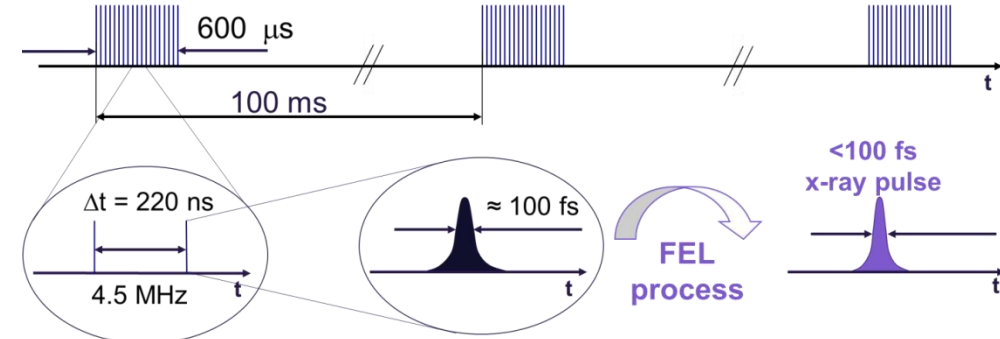
The photon beamlines and photon diagnostics as well as the instruments are operated from the EuXFEL campus in Schenefeld.

Wide dynamics range & different operation modes

Time structure & multiple beamline (SA1/SA2/SA3)

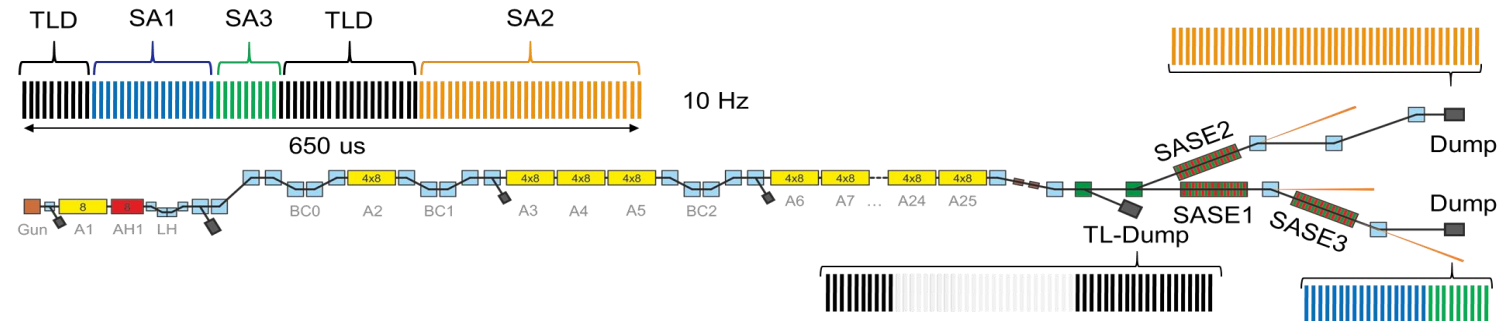
■ Pulsed operation (RF ~ 1.4ms, 10Hz)

- → 27000 / sec
- → e- bunches 220ns spaced
- 100ms separation



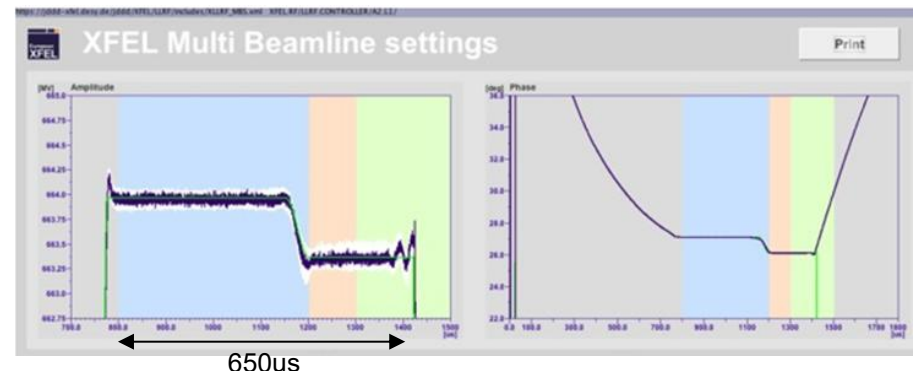
■ Bunch distribution & pattern

- Fast Kicker System
- Precise (Slow) Flat-Top Kicker
- 5/10Hz splitting



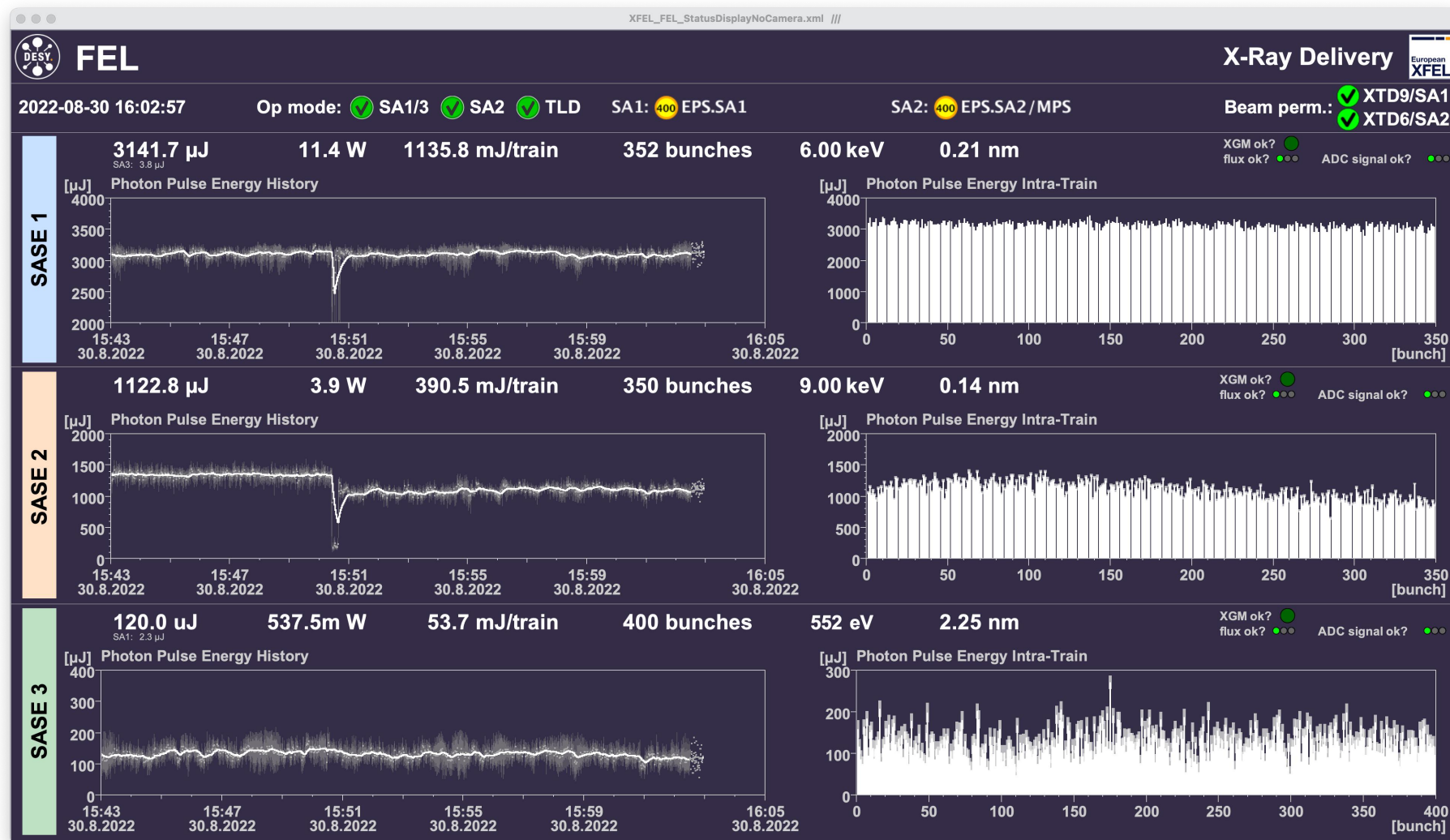
■ Change of beam properties for different beam lines

- Transients processes
- Subsystems in different states
- Large reconfigurations



Challenge:
3 machines in one.....
Coupling...

Long pulse trains

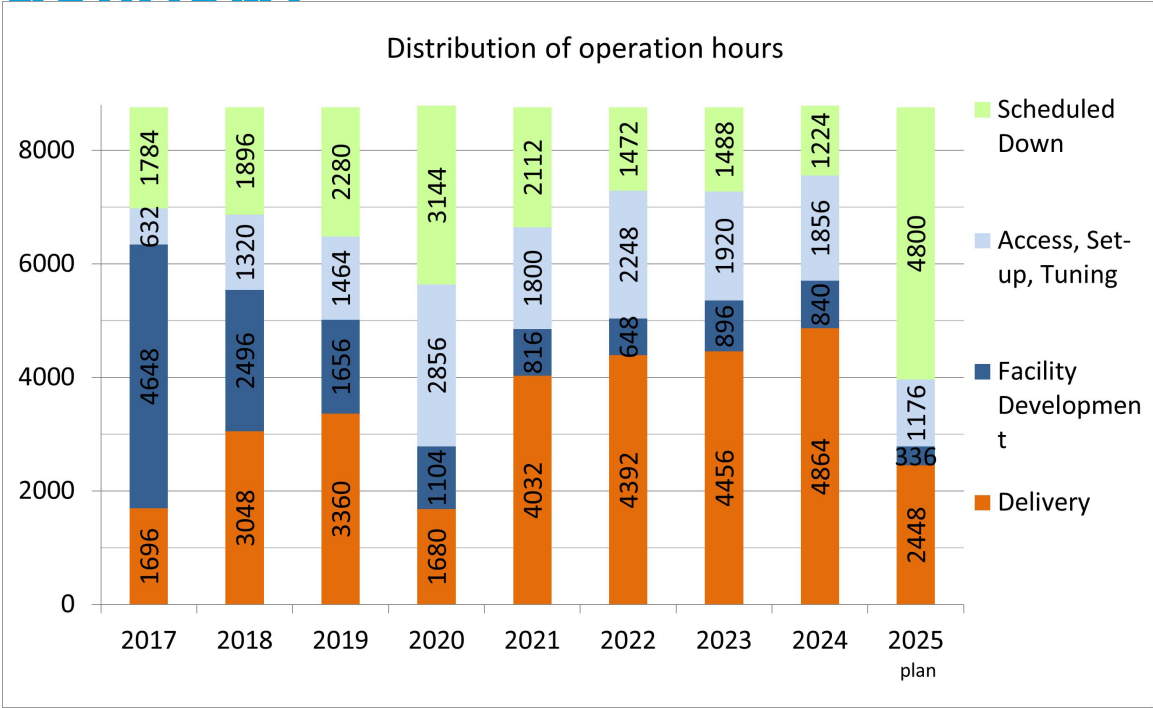


Many bunch capabilities of European XFEL are more and more apparent during user runs.

Here a total of 1142 pulses lasing at the same time

Courtesy: W. Decking

Operating > 7000 hours a year with > 4500 hours X-ray

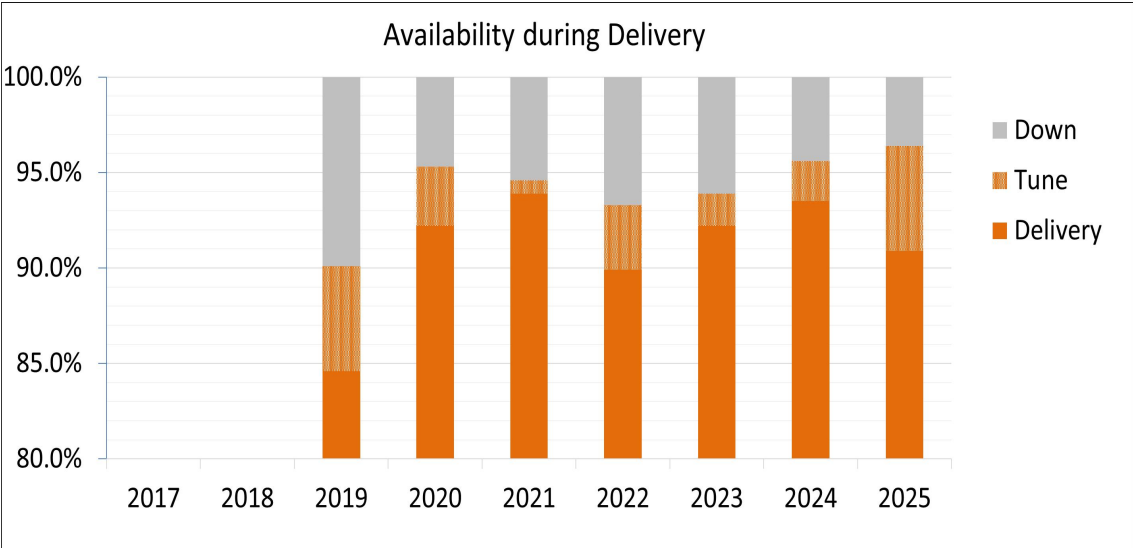


- Overall facility availability during X-ray delivery is **above 95%**
- Requires constant diligence, careful planning, strict follow-up, **and luck**

A standard year:

- 32 weeks of X-ray delivery
- 6 weeks of facility development
- 6 weeks of maintenance and installation
- 4 weeks of initial set-up, alignment, calibration
- 2 weeks of mandatory personnel safety tests
- 2 weeks of Christmas break

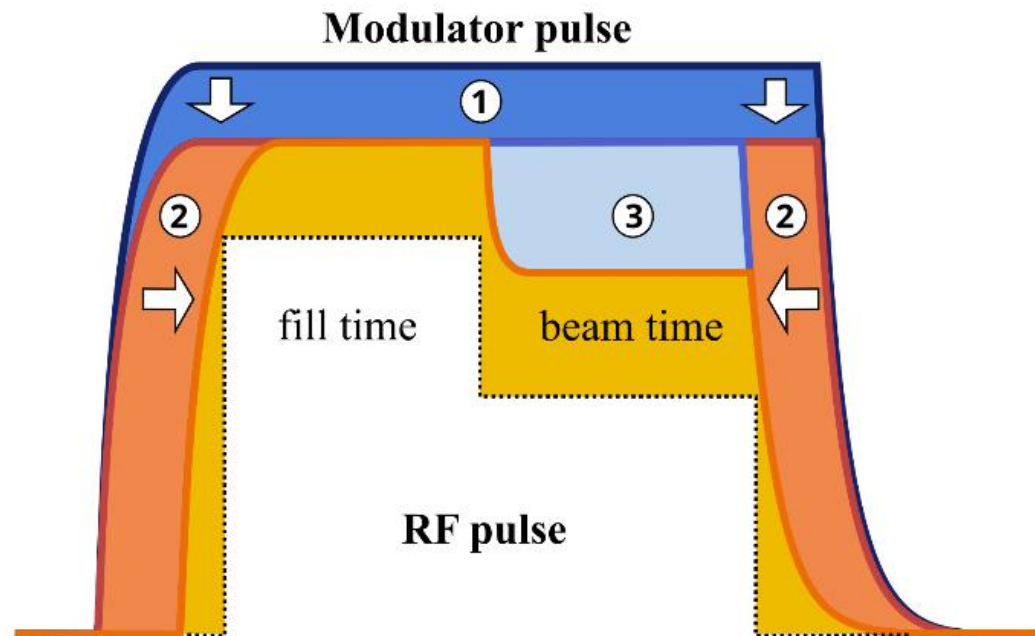
52 weeks



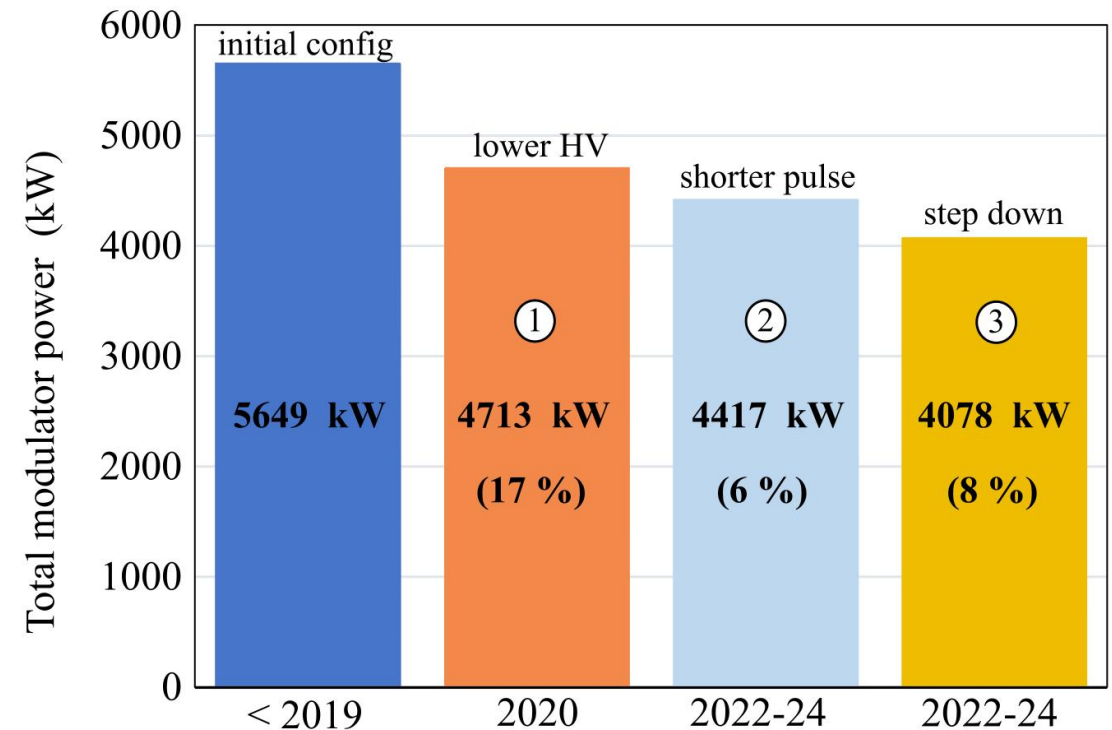
RF SAVINGS AT EuXFEL

Overview including all approaches

Note: each step can be implemented independently

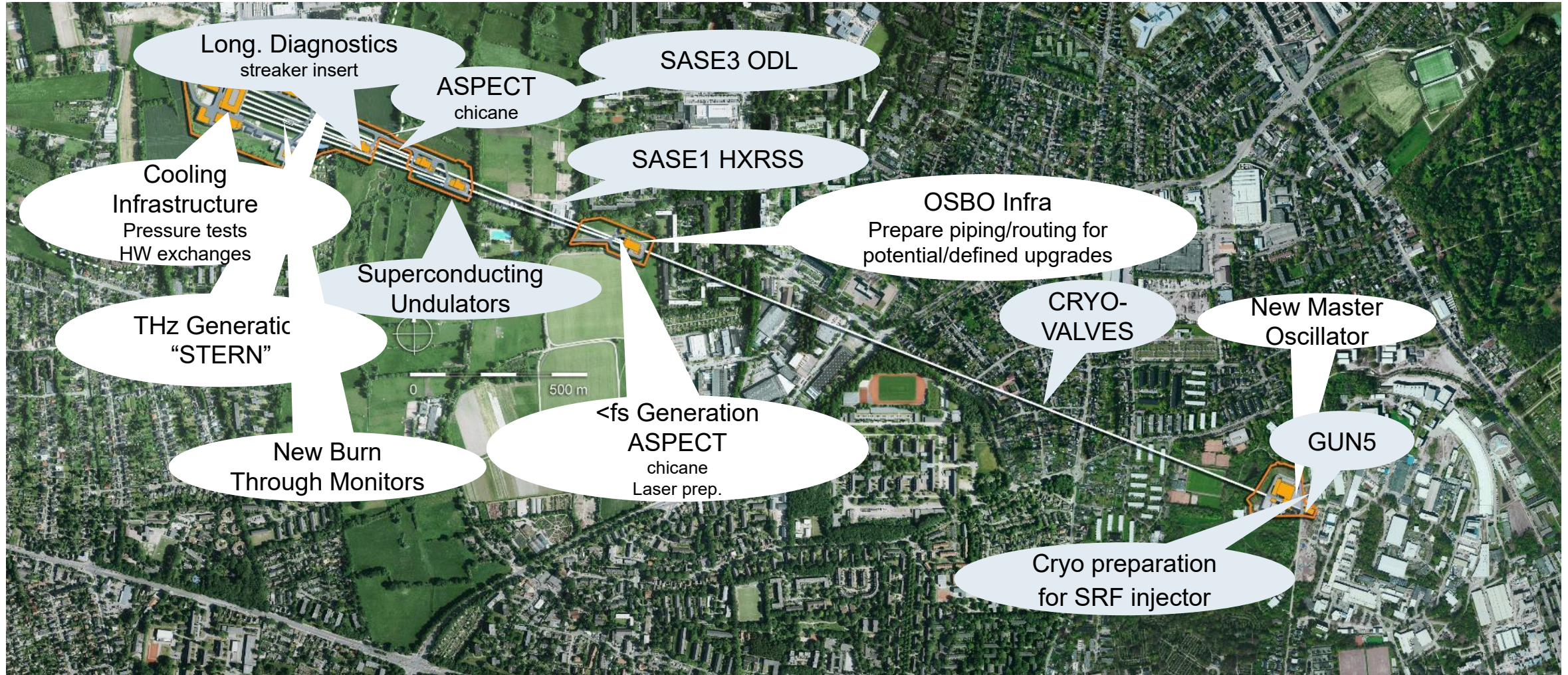


Ref. "RF-based energy savings at the FLASH and European XFEL LINACs"
J.Branlard et al. in proc. of LINAC 2024



Compared to 2019, a total reduction in excess of 1.5 MW could be achieved (28%)

Extending the capabilities of European XFEL – Installations in 2025



Courtesy: W. Decking

Gun5 in comparison to Gun4

- Reminder
 - Improved cell shape

Gun5 commissioning results

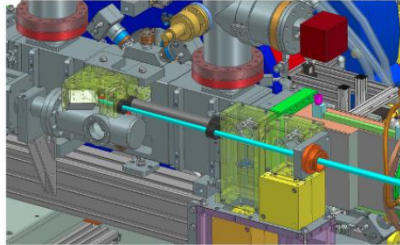
M. Krasilnikov (PITZ) and F. Brinker (MIN), 11.11.2025

5

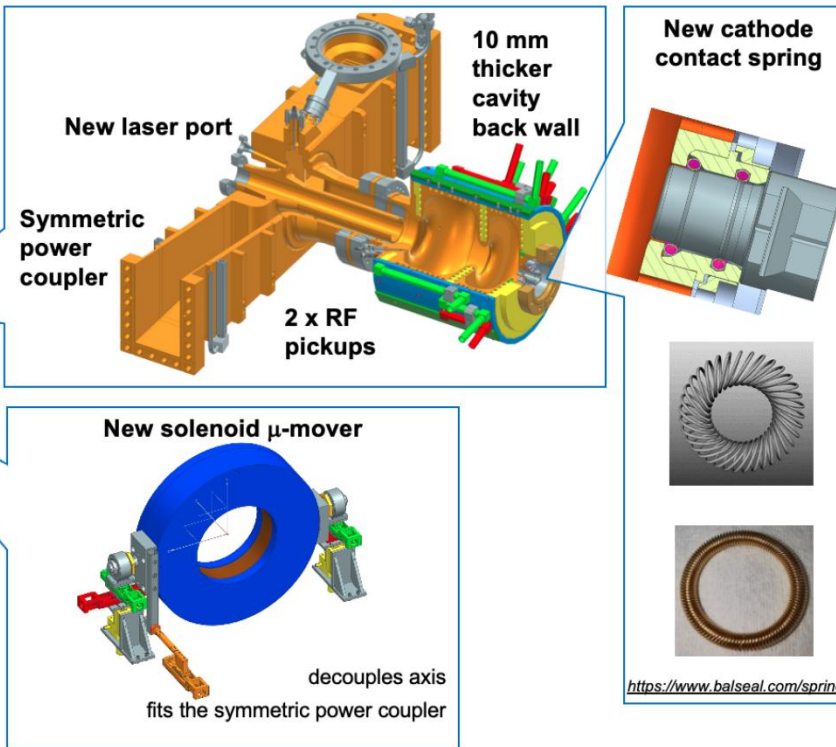
Gun5.2 Improvements

Over Gun5.1

New laser beamline → new laser port



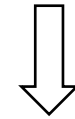
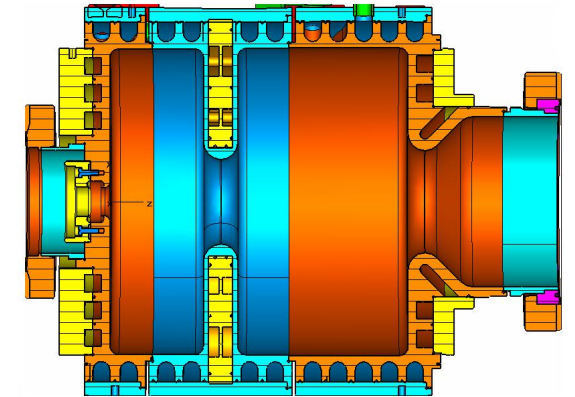
No in-vacuum mirror needed



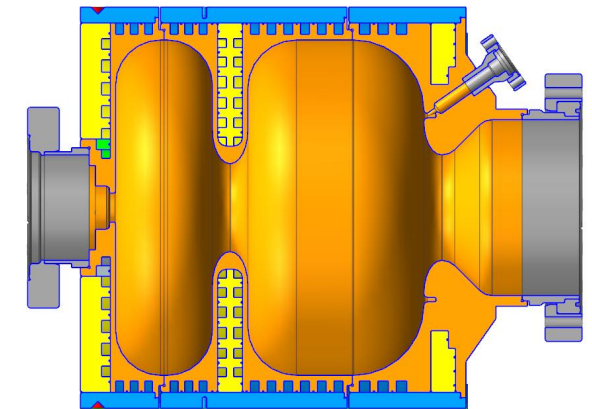
European XFEL

DESY.

Gun4



Gun5



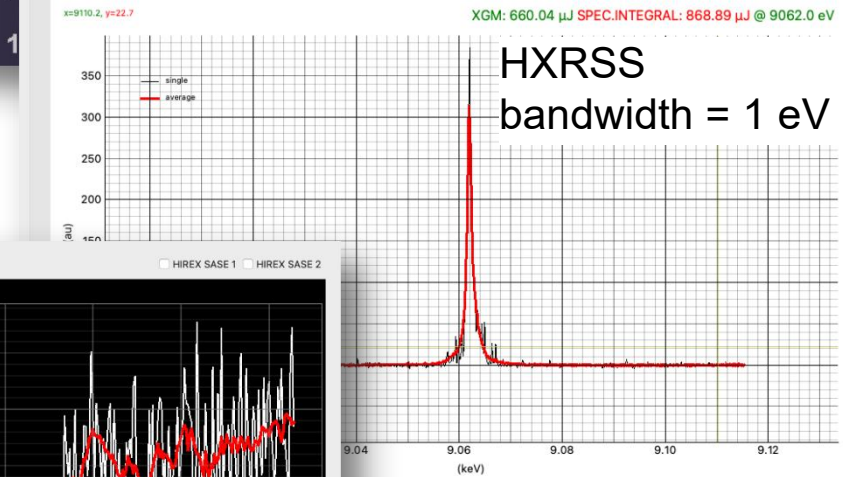
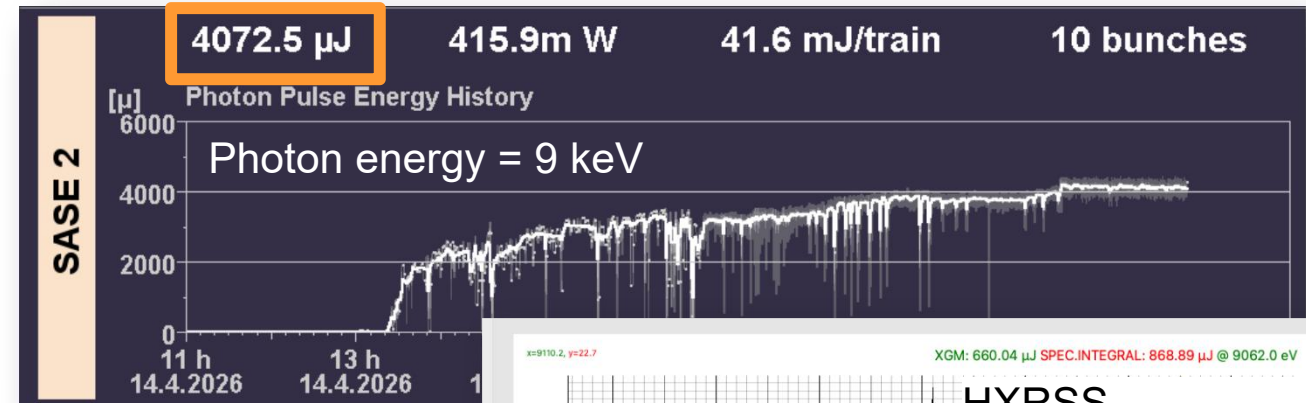
Courtesy: W. Decking

DESY.

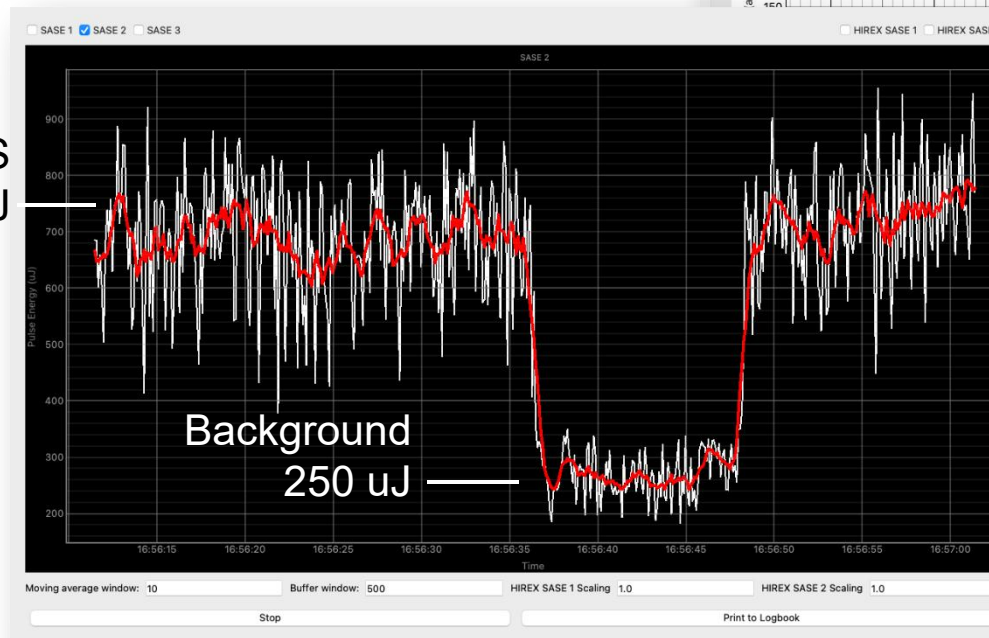
Status of SASE2 after the LIMP

Top performance recovered in spite of the alignment issues

- SASE2 could be tuned to record pulse energies of 4.2 mJ @ 9 keV in time for the first user run week in 2026.
- The HXRSS performance during this week with 750 μJ (250 μJ BG) and a bandwidth of 1 eV was matching the promised performance.
- We assume that this performance can be further improved during the following weeks.

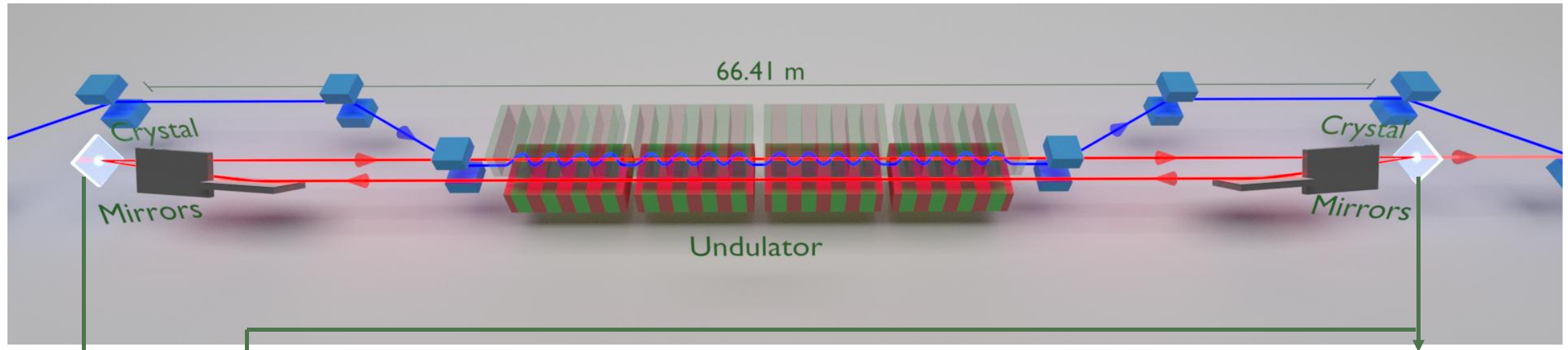


HXRSS
750 μJ



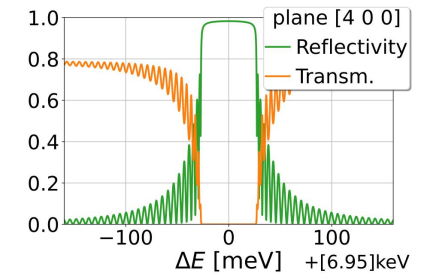
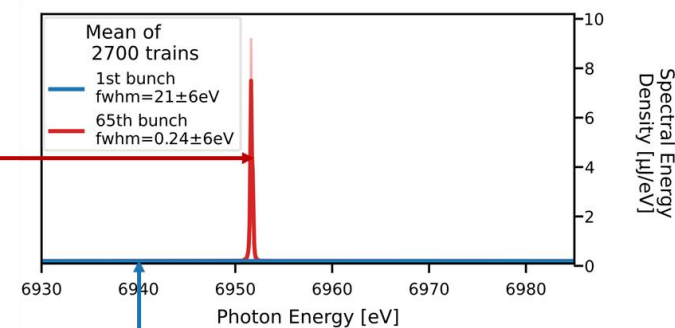
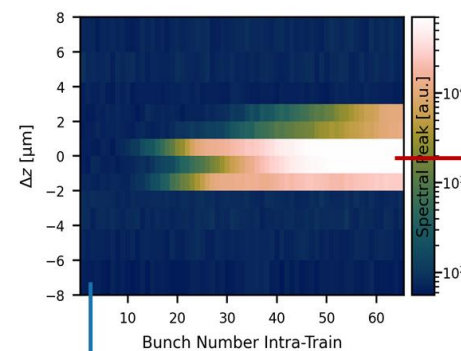
Courtesy: W. Decking

CBXFEL = XFEL in a Cavity with Monochromatizing Mirrors



Bragg's law:

$$n\lambda \approx 2d \cdot \sin\theta$$



Courtesy: P. Rauer

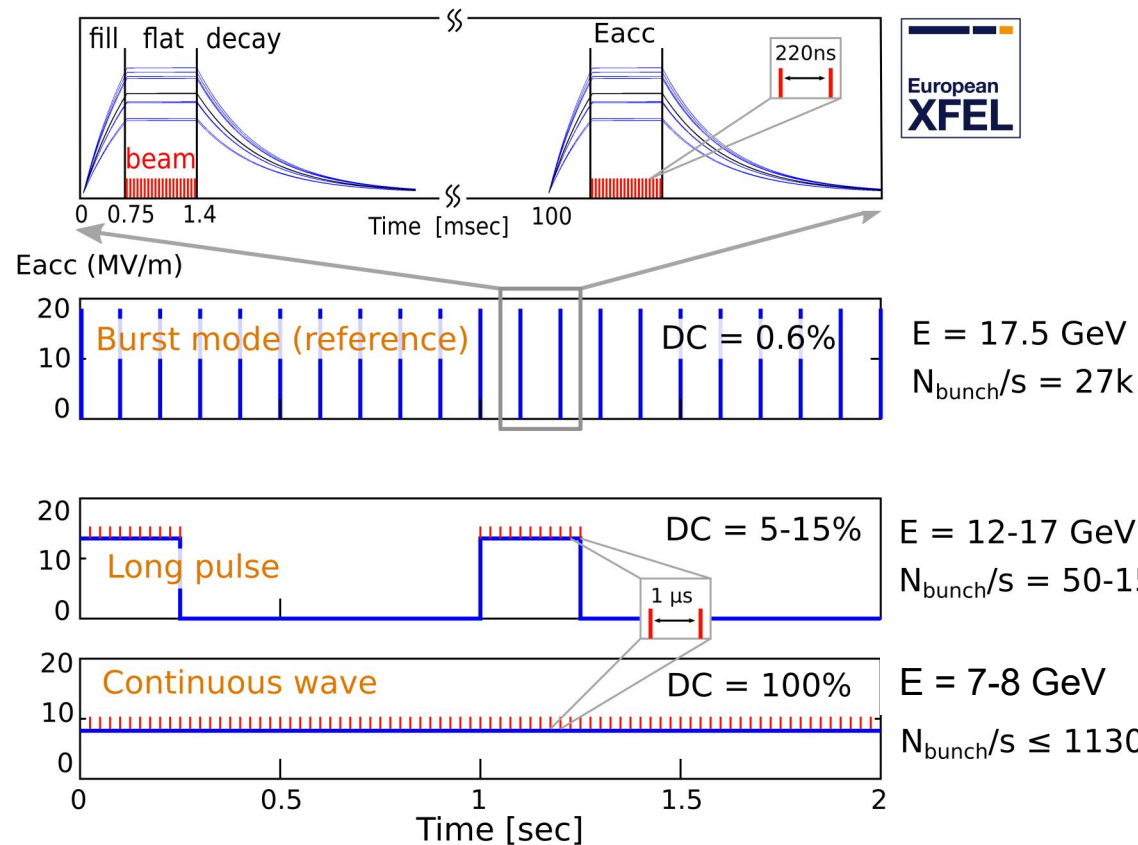
Lasing of a Cavity Based X-ray Source
Patrick Rauer, Immo Bahns, ..., Harald Sinn (submitted)



Brief reminder about what we call the “HDC upgrade”

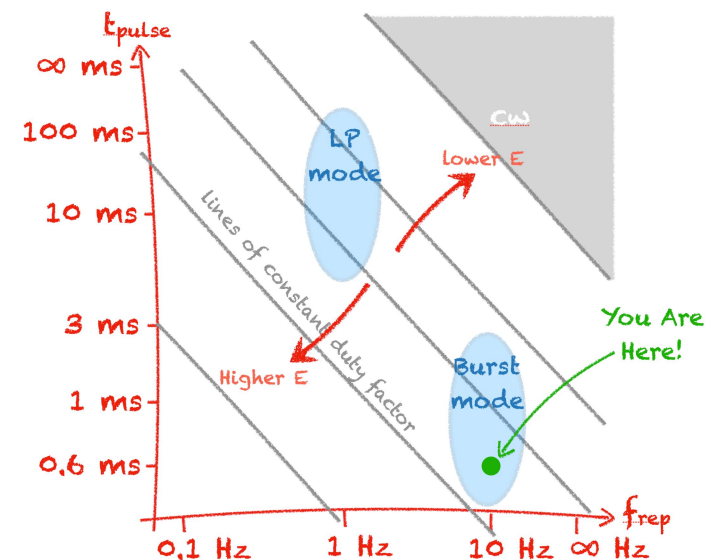
High Duty Cycle upgrade

- Burst, long pulse and CW mode of operation



TODAY (Burst)

UPGRADE (High Duty Cycle, HDC)



Courtesy: J. Branlard

Thanks to

Wim Leemans, Florian Burkart, Michaela Schaumann, Rainer Wanzenberg, Riccardo Bartolini, Ilya Agapov, Harald Reichert, Juliane Roensch, Lucas Schaper, Winni Decking, Julien Branlard, Riko Wichmann, and many more ...

for material