

DESY HAMBURG.

Facility overview

Florian Burkart
ARD-ST3 annual meeting

DESY – Zeuthen, 25.06.2025

HELMHOLTZ



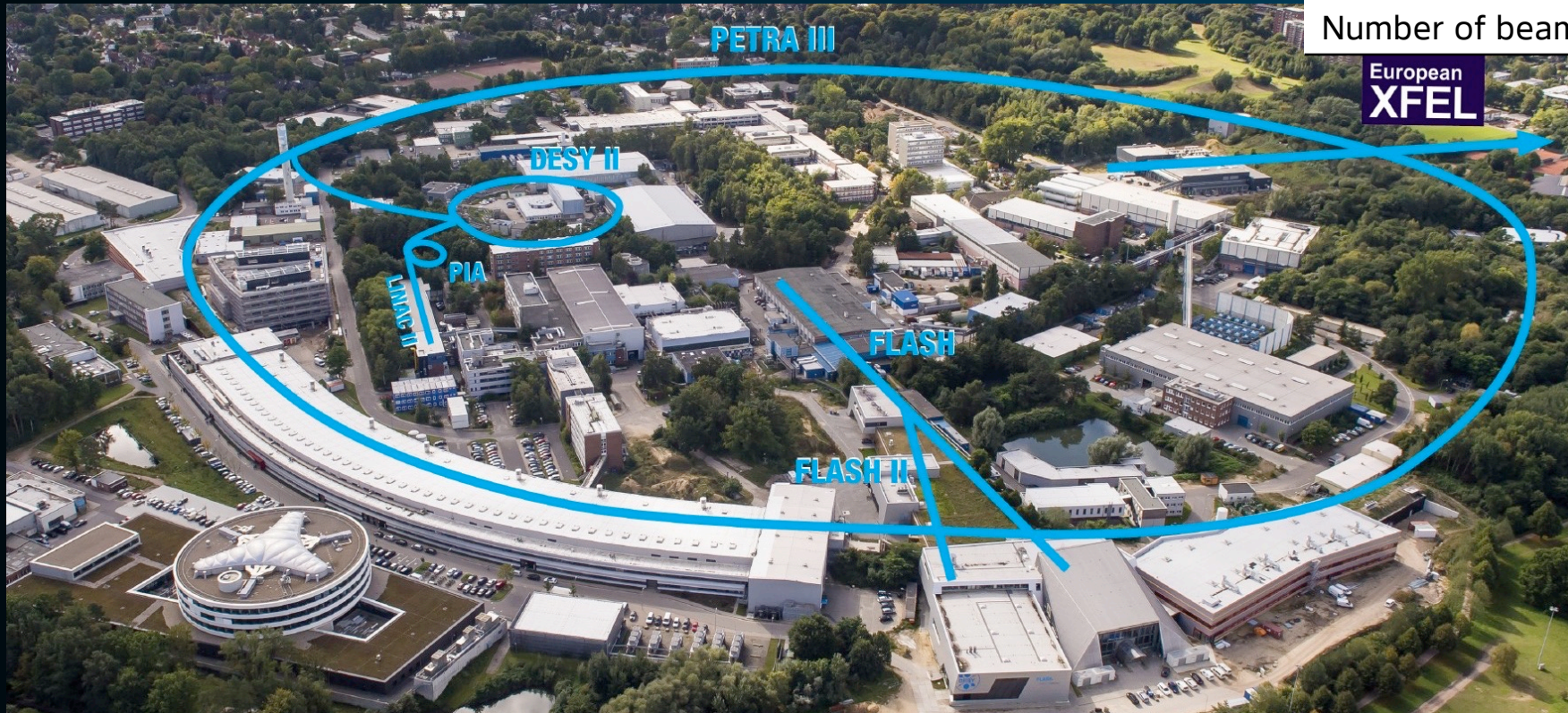
DESY has a unique combination of powerful analytical tools

They are embedded in a broad ecosystem for science and innovation



PETRA III / PETRA IV Injector chain

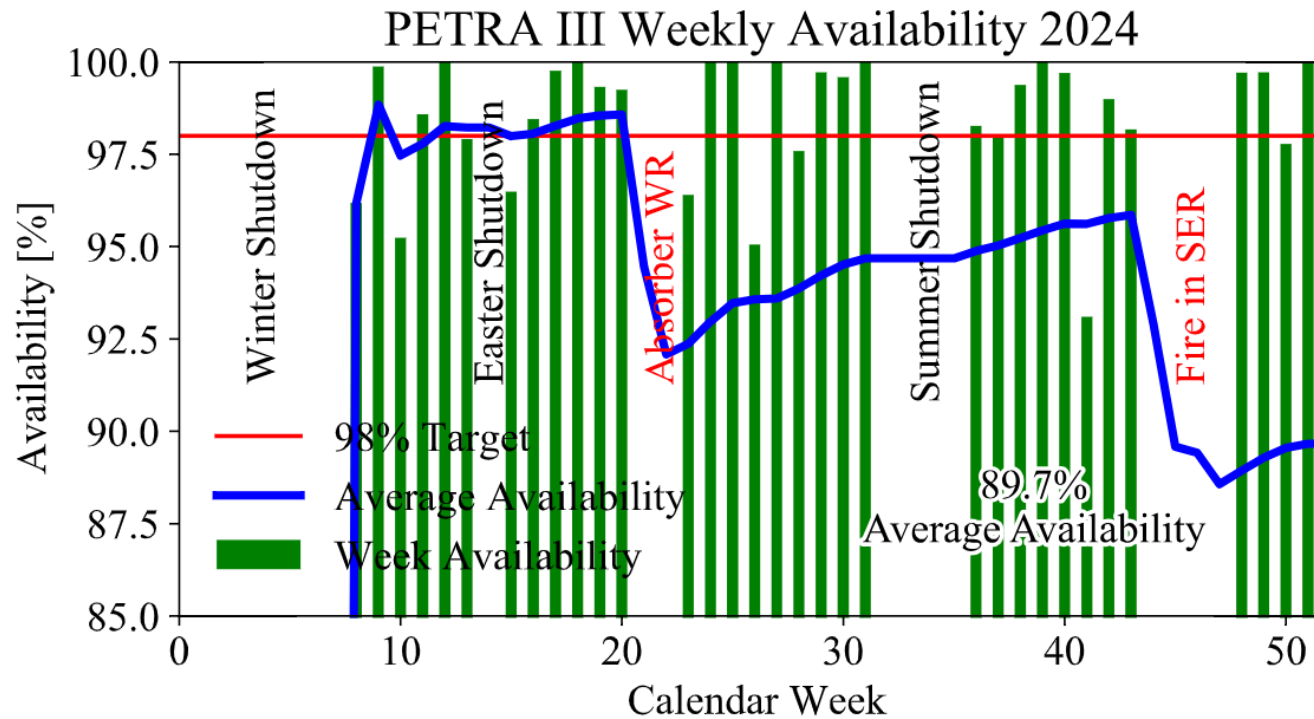
Parameter	PETRA III
Energy [GeV]	6
Circumference [m]	2304
User Run [hours/year]	5000
Number of beamlines	25



From 2019 to 2024 PETRA III delivered 675,000 h beamtime for 7300+ experiments

PETRA III statistics for 2024

Suffering from Absorber Fault and Fire in SER, while rather low number of faults in the remaining year



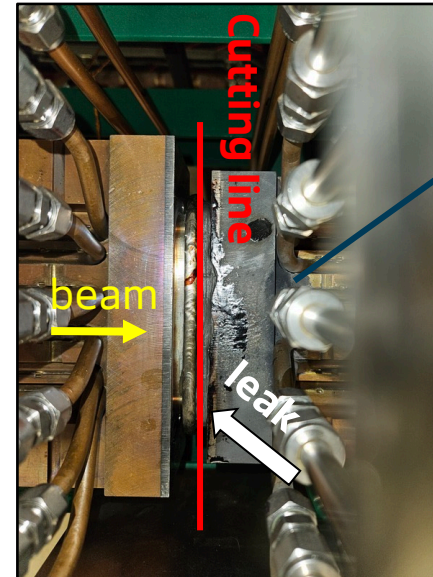
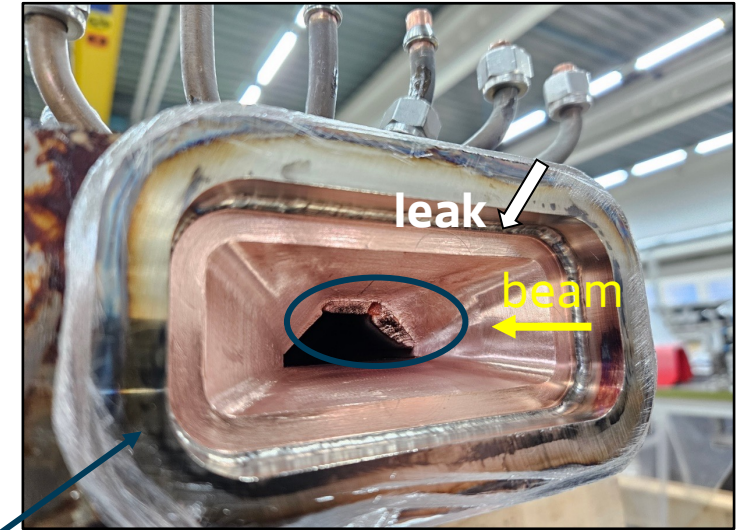
Availability	89.7 %
MTBF	68.5 h
No. Faults	60
User Hours lost	481 h

Fire and vacuum leak – 2 major incidents in the PETRA III complex

Fire in the DESY II electronic room, vacuum leaks at the two damping wiggler dumps in PETRA III



Leaking capacitor in a 40 years old septum PS created fire.
Soot on all components.
45 racks completely emptied.
All components cleaned and tested.
External specialized cleaning company.
Excellent team spirit from all divisions!
DESY II back without problems.



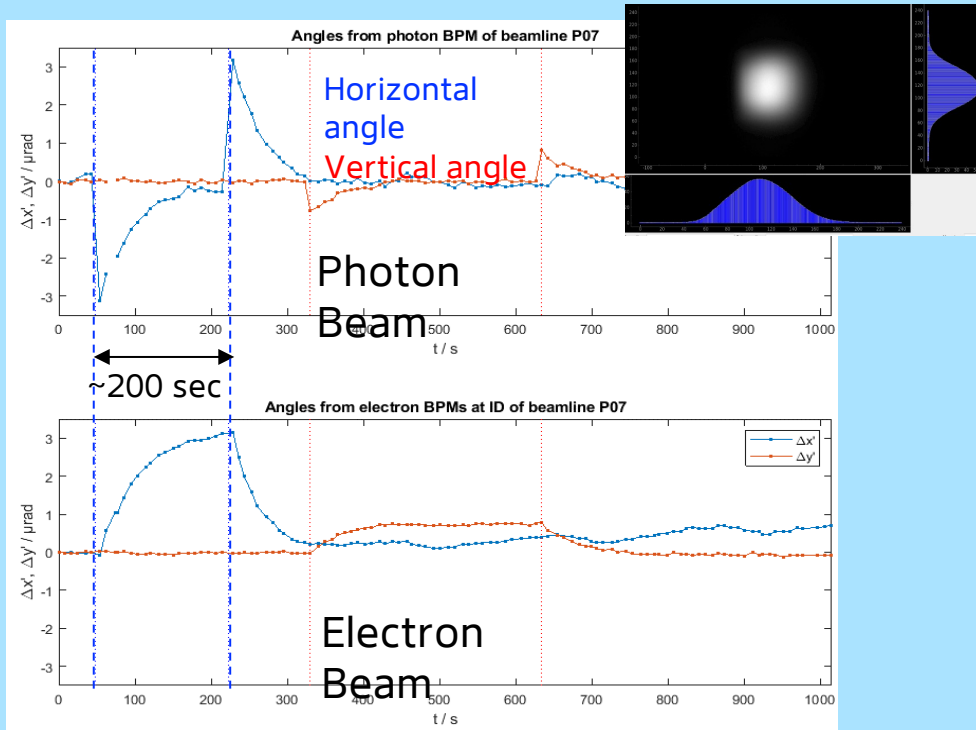
Damage analysis:

1. **Inaccurate manufacturing:** inner dimension $\sim 1\text{mm}$ too small
2. **Strong mechanical stress:** temperature drop of 30°C at each beam dump
3. **Movement of Buildings** over years

Beam Studies at PETRA III support PETRA IV Development



Current focus on beam stability and commissioning tools



Proof-of-principle study for developing a PETRA IV orbit **feedback** including **photon beam signals**

- Development of a **commissioning toolbox** based on both **classical approach** and **machine learning**.
- Testbed for HW components:
 - BPMs,
 - Hot Swap power supplies,
 - HOM damped cavity,...

Injector chain refurbishment scheduled for 2026

PIA renovation, Interlock refurbishment, parts of DESY II infrastructure

DESY II	Availability (%)
2022	99,4
2023	99,5
2024	92,6
2025	99,4

PIA (accumulator ring)

- PIA refurbishment scheduled for Sep 2026 – Dec 2026
- Exchange of magnets, vacuum chambers and installation of new diagnostics

DESY II (6 GeV synchrotron booster)

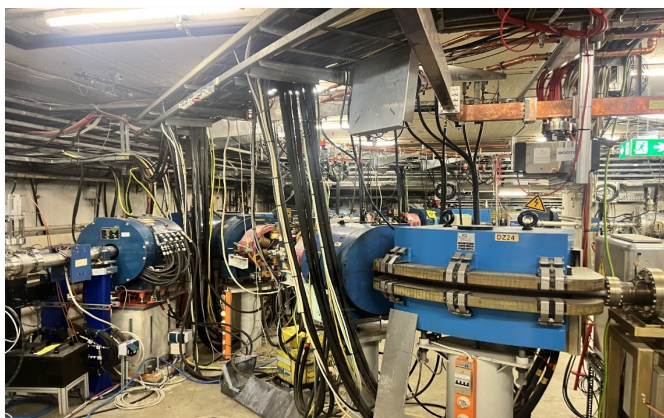
- Beams for PETRA III and testbeams (514 users in 2024) + **NEW: autonomous accelerators and novel diagnostics at DESY II**
- Accelerator still in good shape, extremely reliable. Infrastructure critical



PIA dipole magnet



March 2025: 40 years of DESY II beam operation!



PIA in operation since 1978

Beam from LINAC II / PIA via DESY II to PETRA III



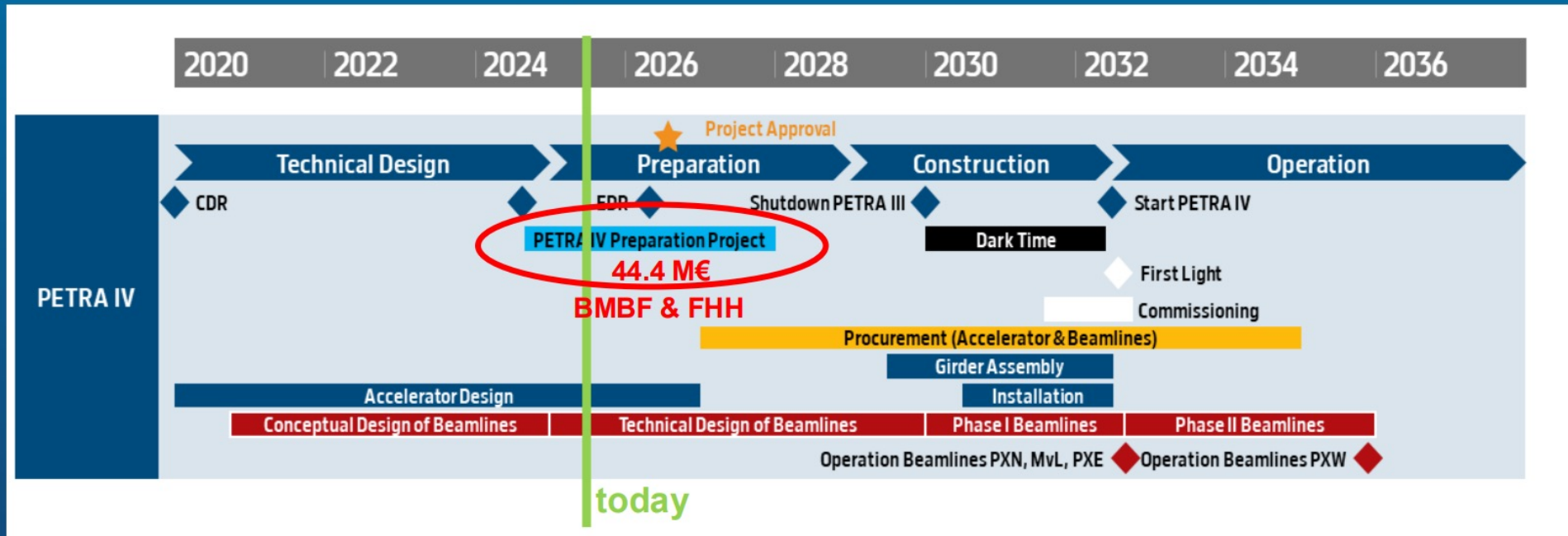
PETRA IV schedule – waiting for approval

Preparation project in full swing

PETRA IV.
NEW DIMENSIONS



- February 2024: 44.444 M€ granted for the preparation of PETRA IV
- October 2024: submission of a proposal to the BMBF “roadmap” process (“Priorisierungsverfahren”)



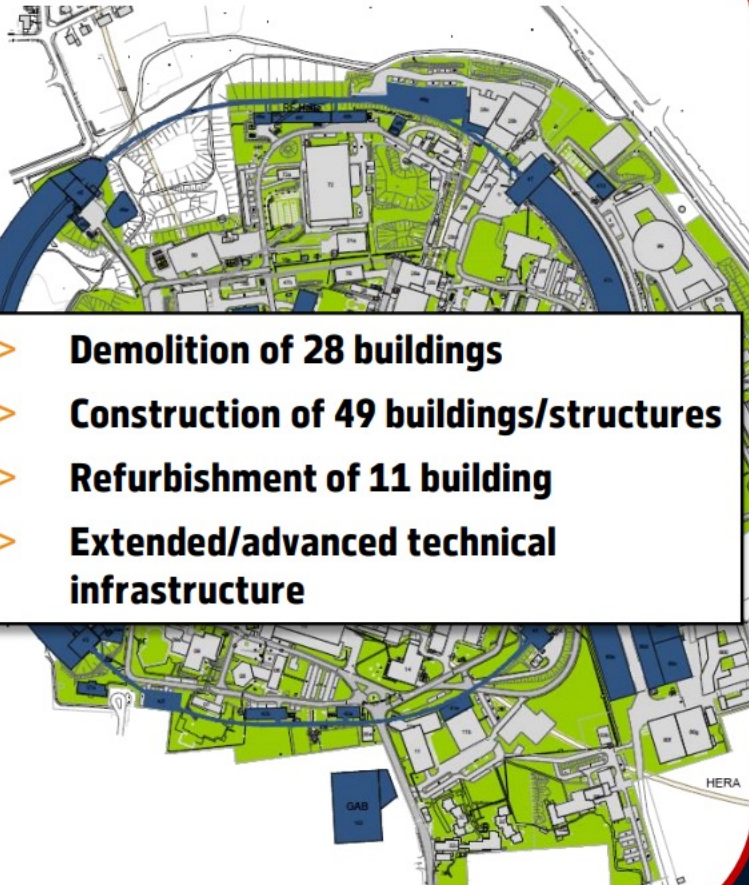
- Start of operation in 7/2032 with 19 beamlines
- Shutdown of max. 2.5 years (2030/2032)
- Project duration: 9 years (2027-2035)

- Total project cost: 1.74 billion €
 - DESY's contribution: 210 million €
 - Public funding: 1.53 billion €
- (in 2024 prices)

PETRA IV: The ultimate 4D hard X-ray microscope for physical, chemical, and biological processes

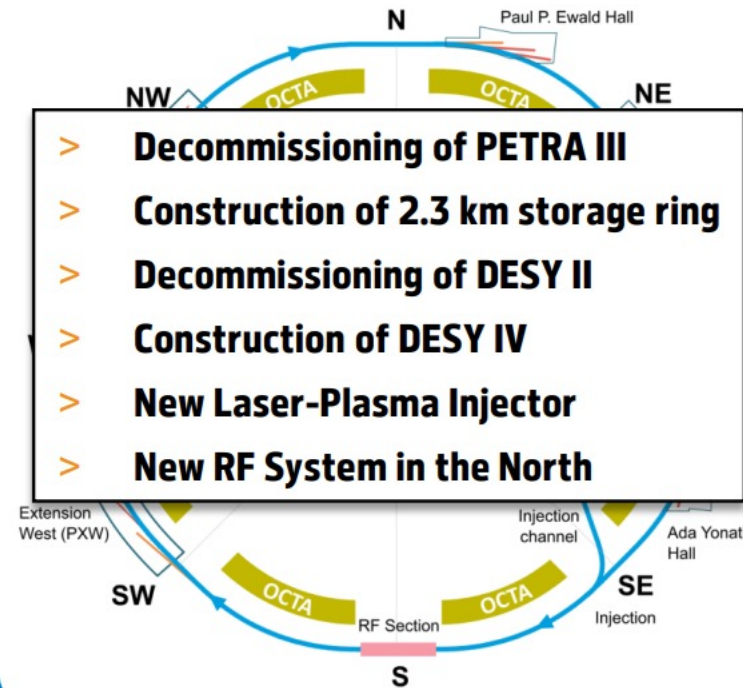
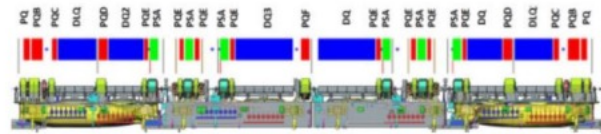
PETRA IV Strength: Brightness, Coherence, High Energy

Civil Construction and Infrastructure



- > Demolition of 28 buildings
- > Construction of 49 buildings/structures
- > Refurbishment of 11 building
- > Extended/advanced technical infrastructure

Accelerator Complex

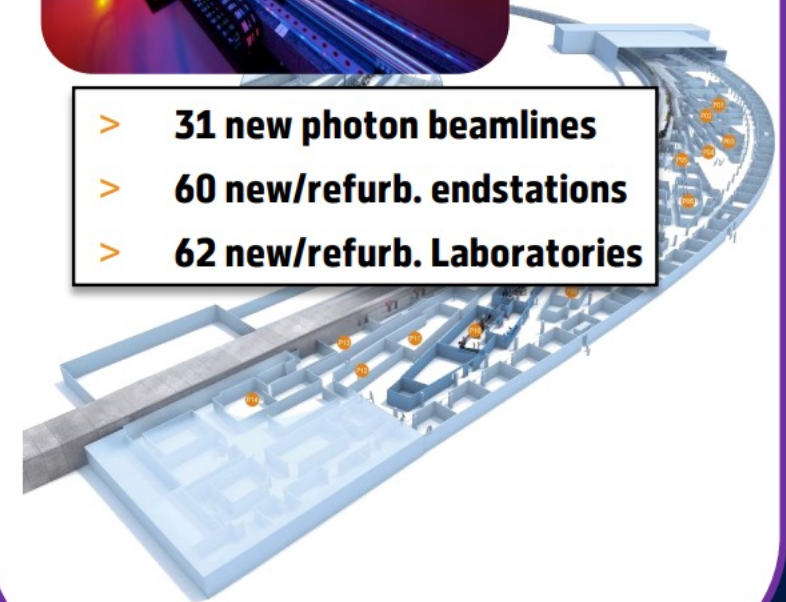


- > Decommissioning of PETRA III
- > Construction of 2.3 km storage ring
- > Decommissioning of DESY II
- > Construction of DESY IV
- > New Laser-Plasma Injector
- > New RF System in the North

Experimental Facilities



- > 31 new photon beamlines
- > 60 new/refurb. endstations
- > 62 new/refurb. Laboratories



Selected highlights

PETRA IV demonstrator girder / Energy spread reduction at LUX



Courtesy: N. Koldrack



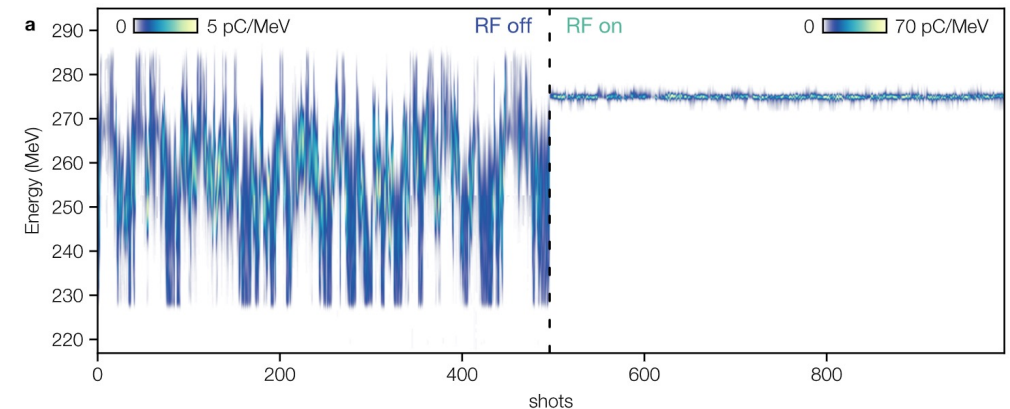
New fixed 17 cm R_{56} chicane installed



LINAC II S-band RF cavity + 100 m waveguide conditioned

Highlight of ST4

P. Winkler et al., submitted 14.11.24

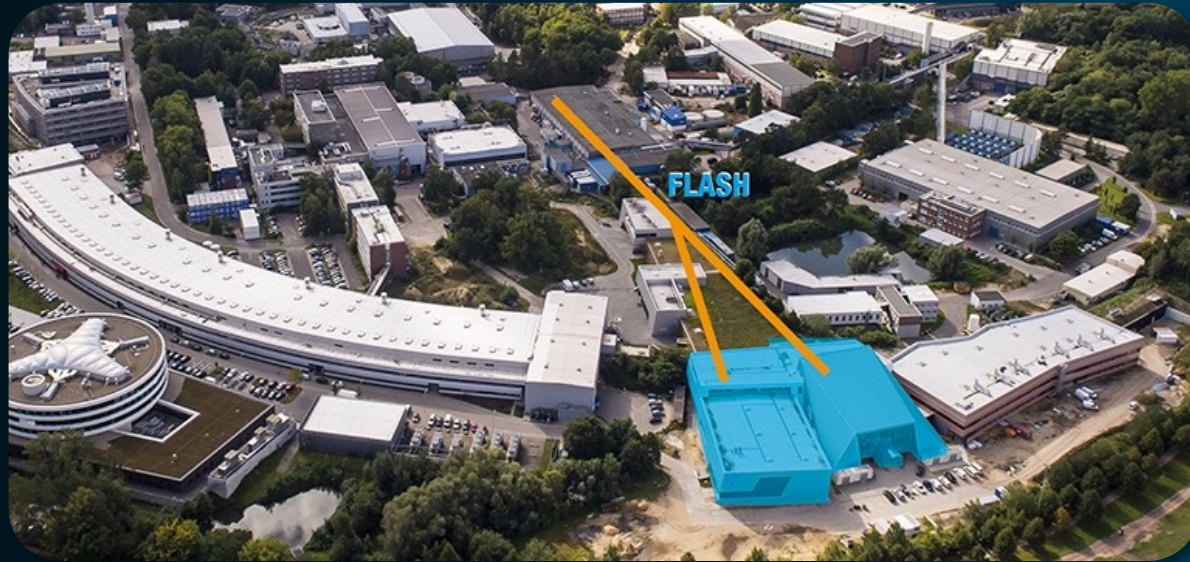


0.048% energy jitter & 0.097% energy spread

Next step: injection in DESY II

FLASH / FLASH 2020+

in upgrade shutdown



FLASH2020+

SASE & External seeding (Narrow spectral bandwidth, Longitudinal coherence) in parallel



Lucas Schaper

Linac upgrade: *Finished*

3rd BC FLASH2	Injector laser
New BCs (linac)	Energy upgrade
Laser heater	Afterburner FLASH2
Fast orbit correctors	New beamline FL23 (FLASH2)
TDS (FLASH2)	Interim P-P laser (FLASH1)

Seeding upgrade: *Now!*

High rep. rate seeding (FLASH1)
Photon diagnostics (FLASH1)
THz generation

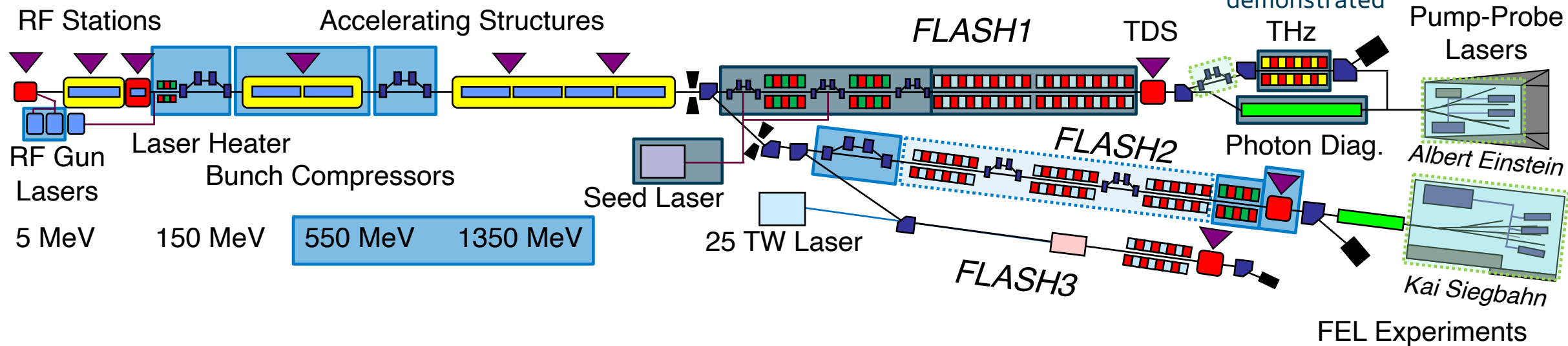
Short term upgrades

Flexible pump-probe lasers
New beamlines
Intense THz Source

Mid term upgrades

New undulator schemes (FLASH2)
New lasing concepts (FLASH2)

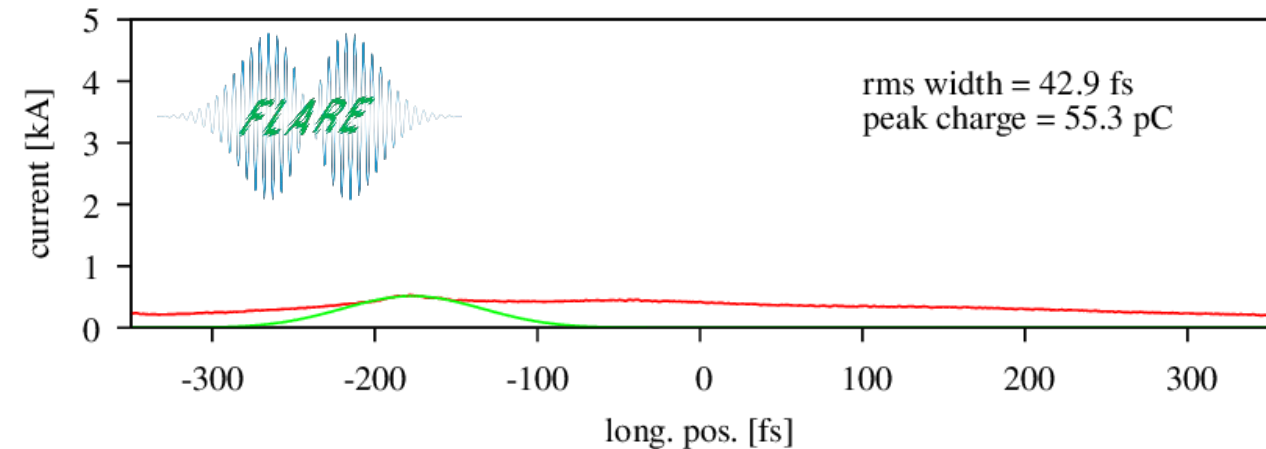
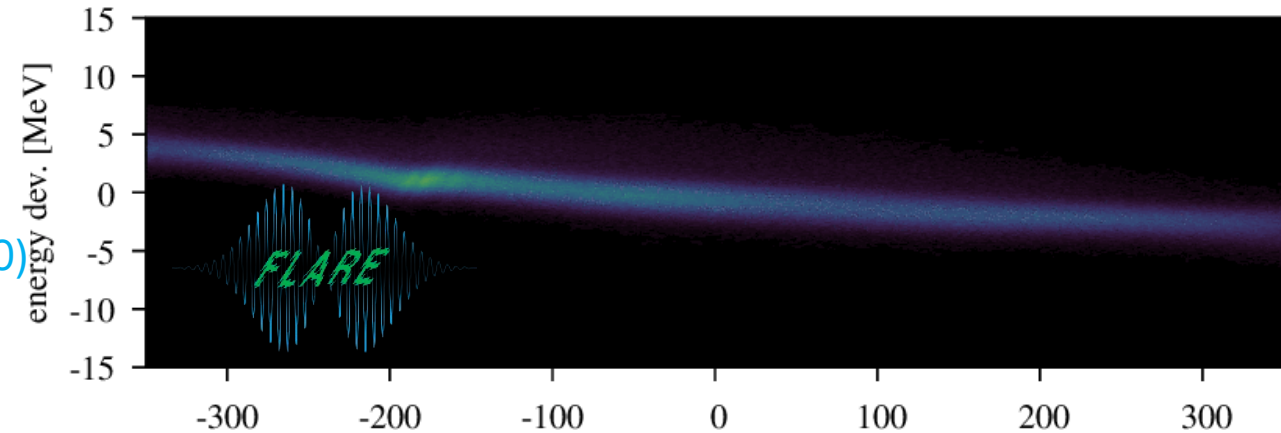
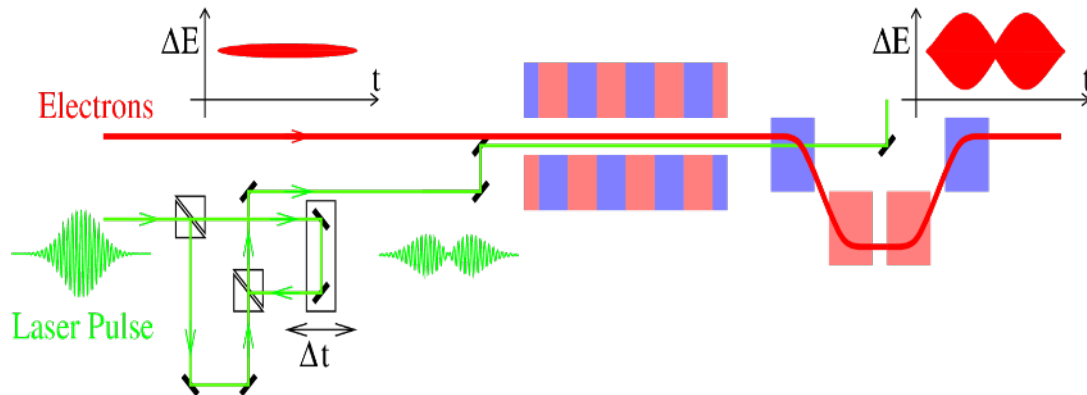
- Added new operation modes
- Increased parameter range
- Improved electron beam & diagnostics



FLARE – Advanced Laser-Heater-based Bunch Shaping

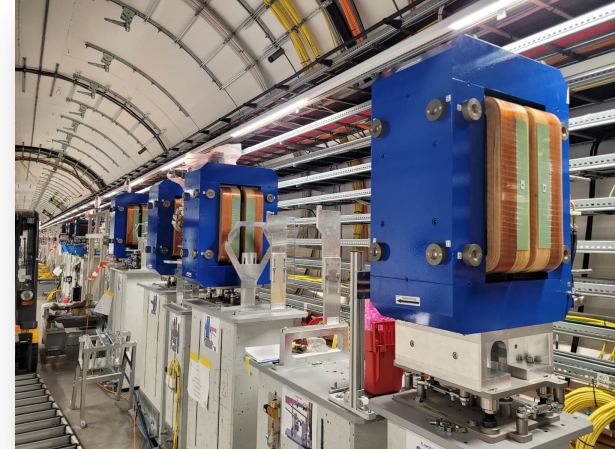
Variable pulse duration by laser heater, Sub 7 fs pulses beyond 5 kA peak

- Split, delay and then recombine laser pulse
→ non-uniform heating of electron bunch
Enables tailored **FEL pulse-length control** (Milestone ARD-10)
- **Proof of Concept achieve**
- Studies of local bunch compression ongoing



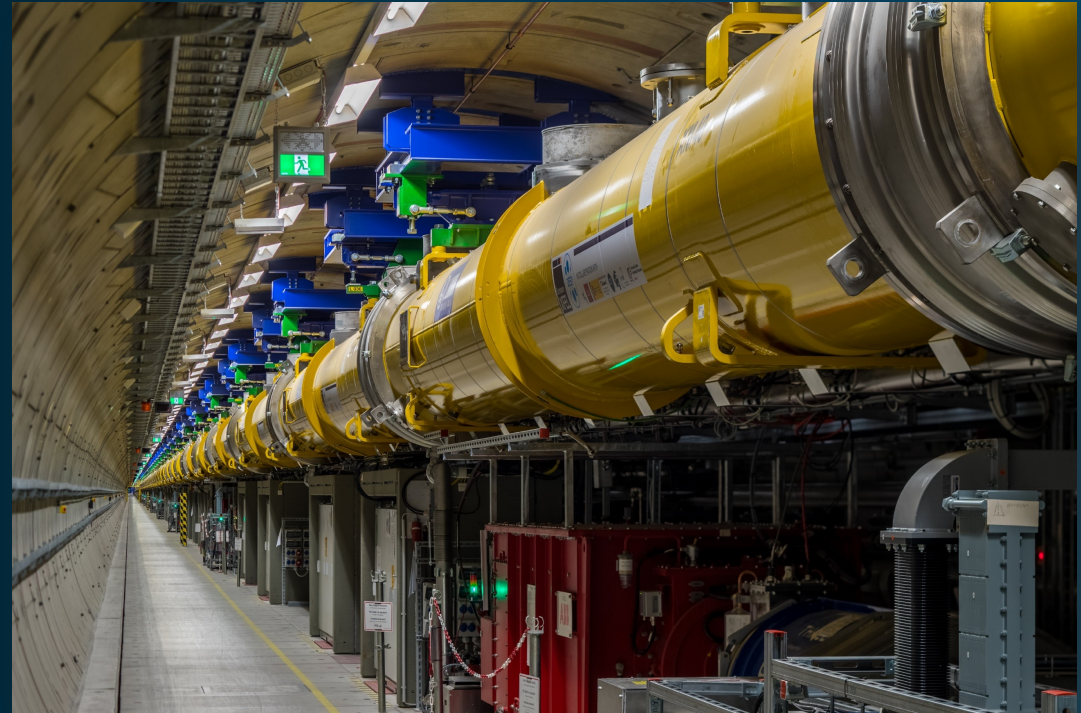
Courtesy: L. Schaper





EuXFEL

also in shutdown



The European XFEL is operating since 2017, with three parallel FELs

Present focus is on maximizing FEL up-time to enable harvesting

Courtesy: W. Decking

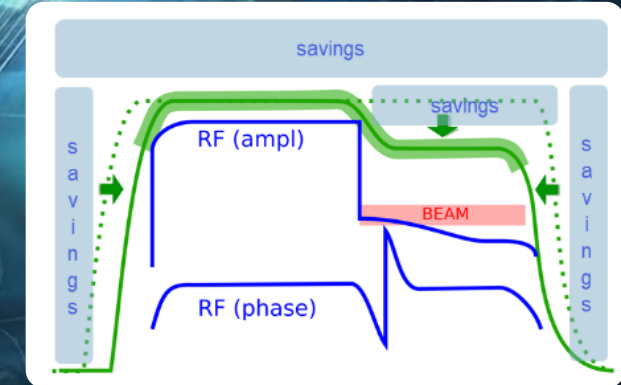


Competitive accelerator R&D program supported by European XFEL operation funds

Closely linked with MT



Example: Reducing power consumption



SRF technology: providing more pulses

- High duty cycle (HDC) and future CW operation
- Source development as key ingredient for HDC

Machine control at the frontiers of temporal resolution and autonomous accelerators

Plasma-based accelerators

- Can we double the beam energy and at what repetition rate?
- Can we use laser plasma accelerators as boosters?

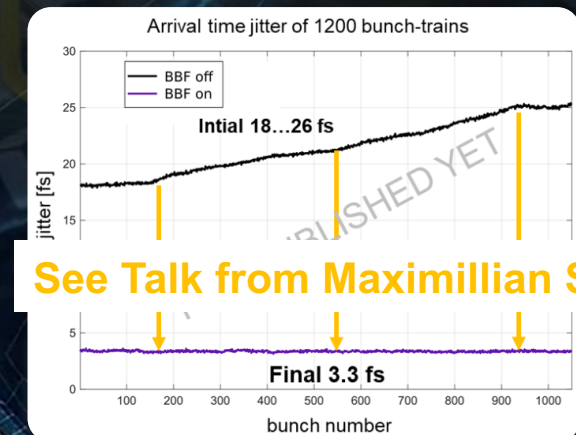
Novel FEL schemes

XFEL Oscillator, seeding, attosecond TW pulses

Exploring ultrafast electron diffraction

as complementary method to photon-based techniques

Shape modulator pulse based on operation needs
0.5 to 1 MW saving depending on operation mode

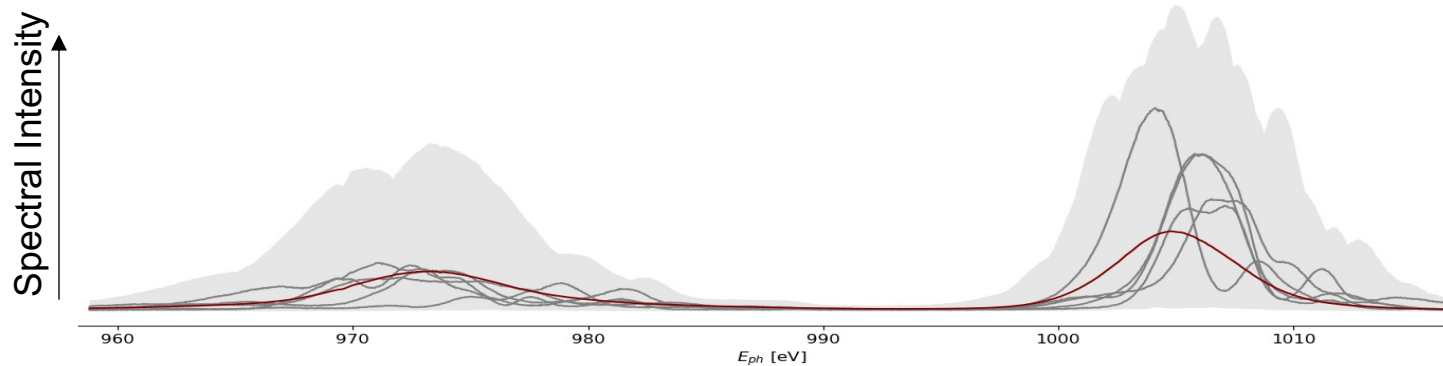


See Talk from Maximillian Schütte

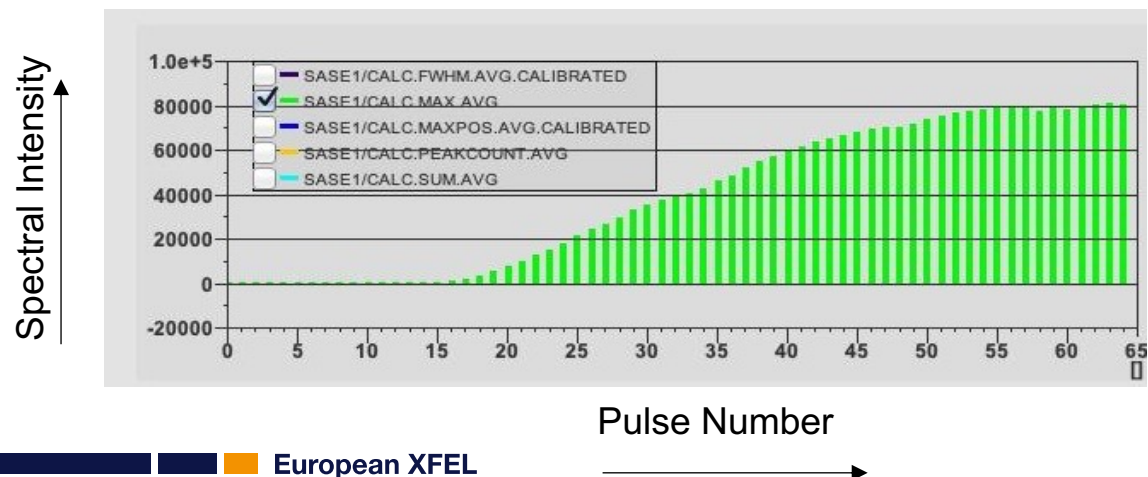
Example: Arrival time stabilization at the single femtosecond level

EuXFEL R&D Highlights

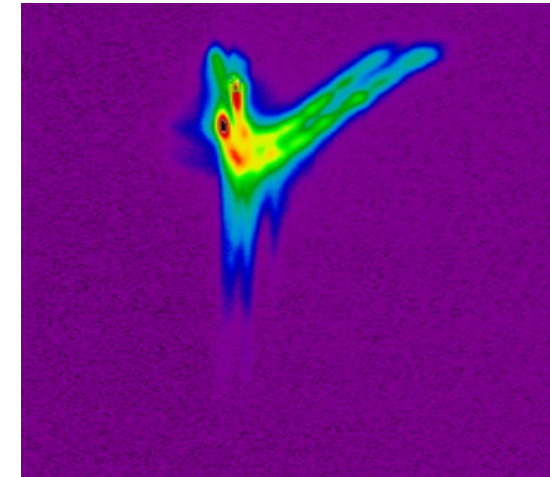
- Attosecond pulse production in both hard and soft x-rays
- For soft also two-pulses with polarization control



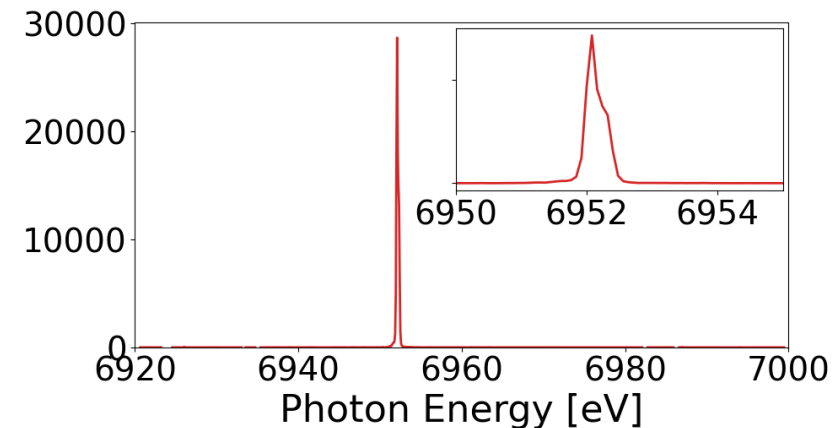
- Demonstration of a cavity based x-ray oscillator (~7keV)
- Spectral width: 250 meV (resolution limit of spectrometer)



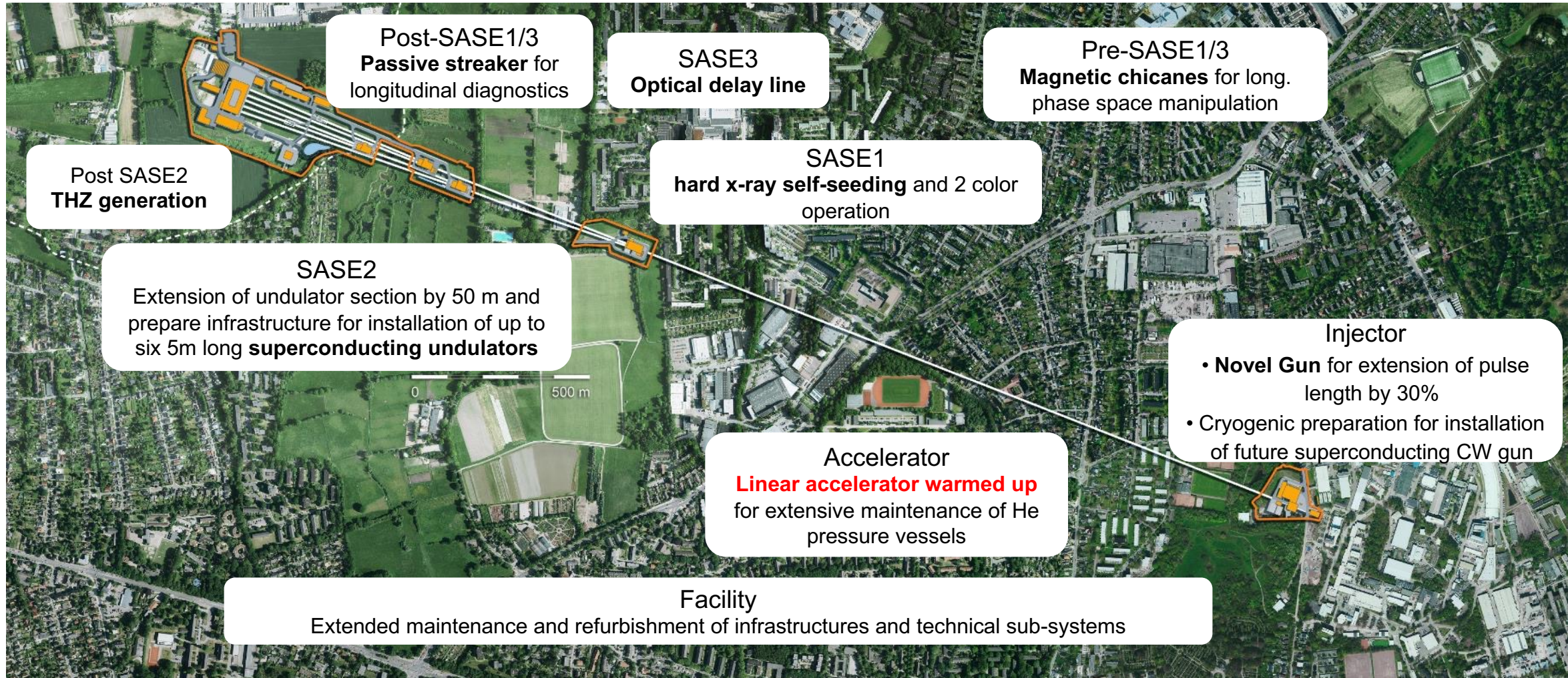
- Twin-pulse x-ray production
- Both for SASE and HXRSS



*See talk from Marc Guetg
Poster from Farzad Jafarinia*



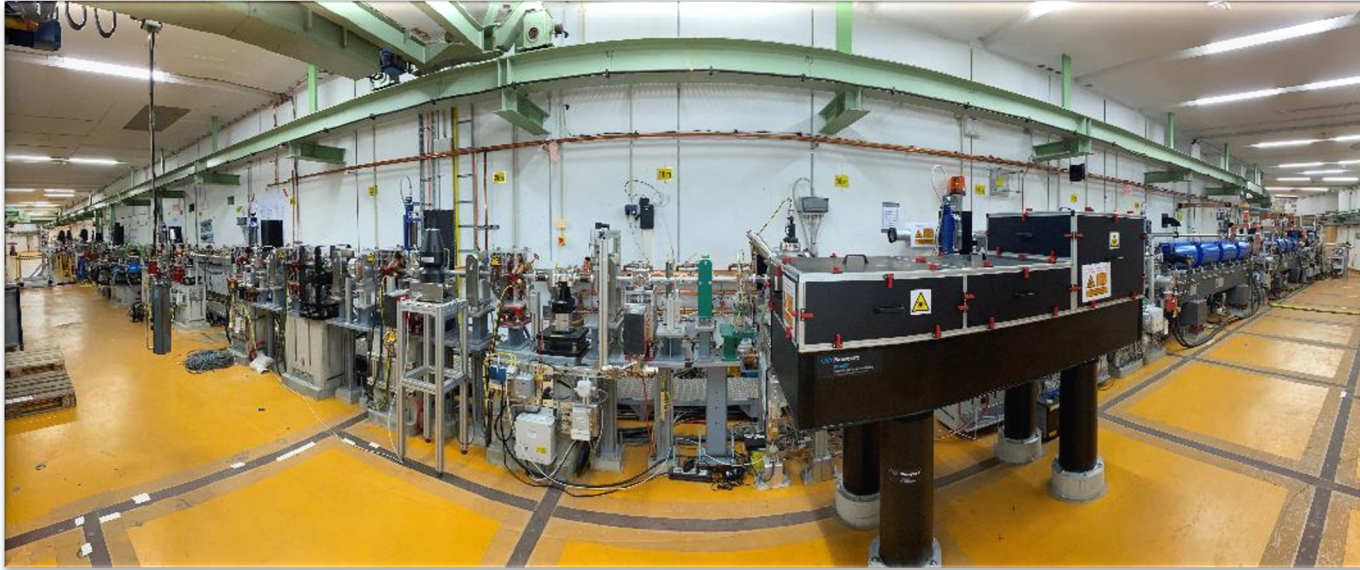
LIMP25: Extending the capabilities of European XFEL



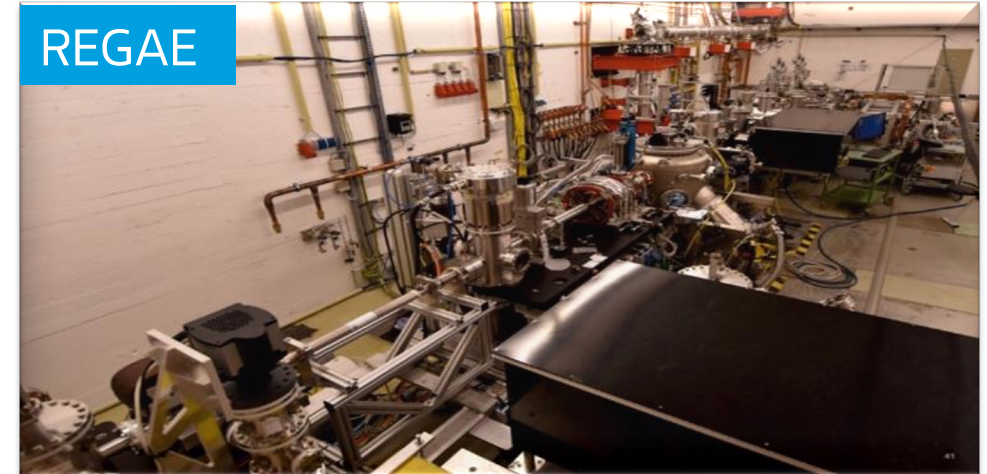
ARD activities

The ARD test facilities at DESY

Essential drivers for timely advances in ST3-topics, supporting the LK II user machines



- World-record stability
- fs long e- bunches
- Accelerator R&D
- Medical applications



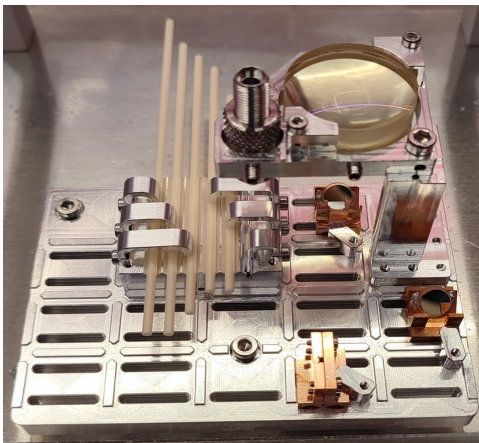
- UED facility



- Gun development
- THz FEL
- Medical applications

Accelerator R&D for user machines @ ARES

Beam instrumentation, accelerator components, medical applications



Funded by the European Union

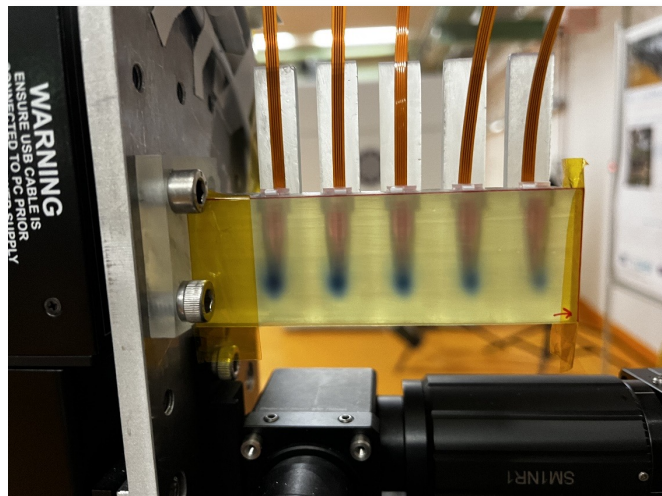
Successful tests of compact, passive bunch length diagnostics. EIC pathfinder with CNRS et al. Reconstruction algorithm development



Autonomous accelerators with KIT

DESY.

ST3 WS | F. Burkart | DESY report | 25.06.2025



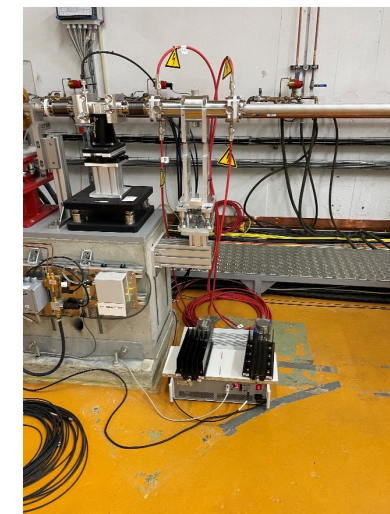
Studies for tumor treatment with high energetic electrons and FLASH parameters in collaboration with UKE and Uni Wollongong. Animal and skull phantoms and living tumor cells.



HiACTS



X Band klystron finally back from CPI. RF conditioning ongoing. 5D tomography developments on the horizon.

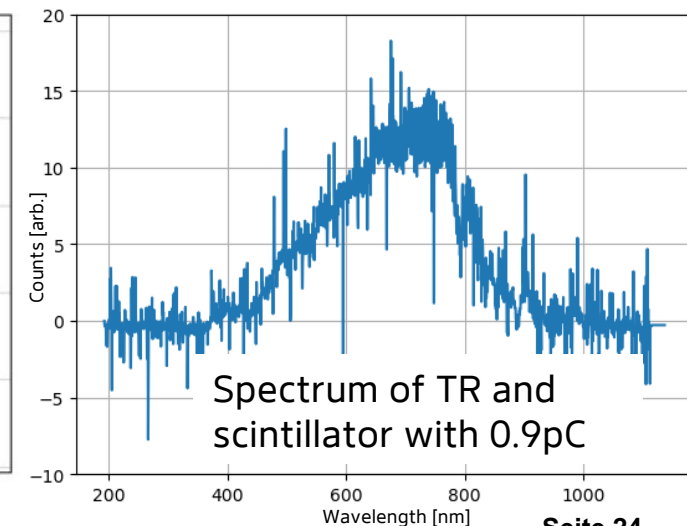
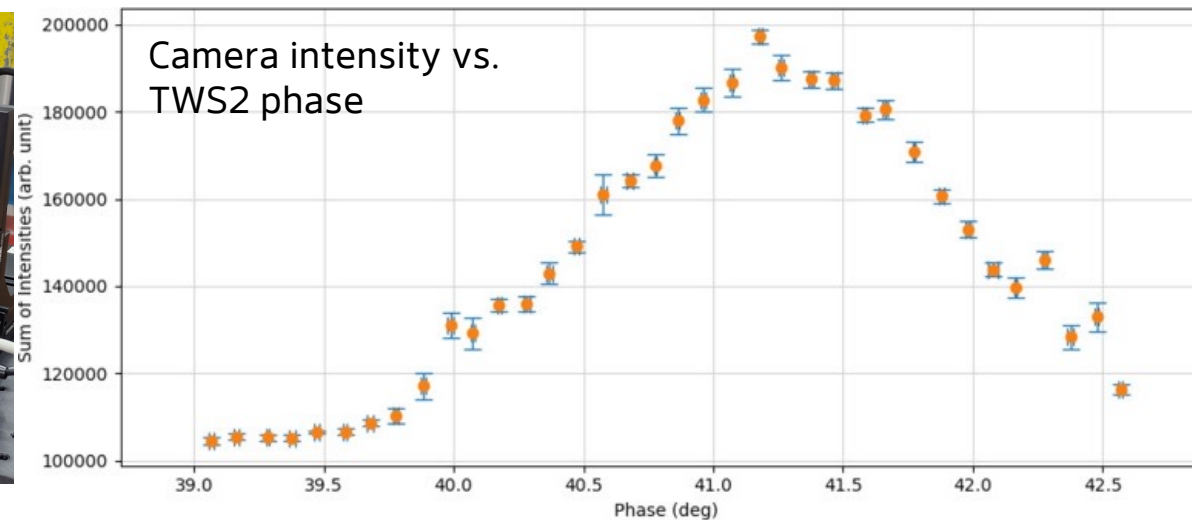
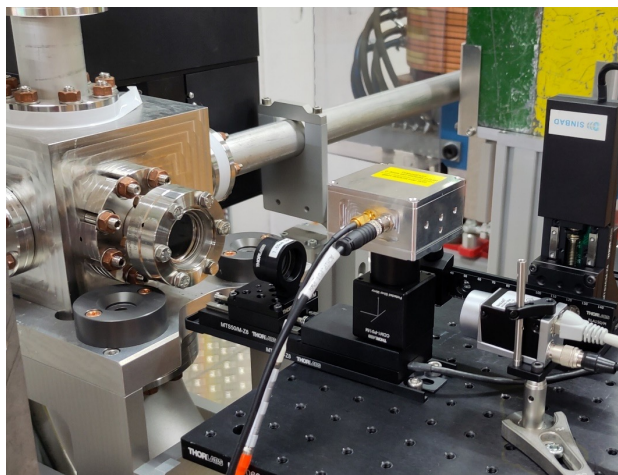
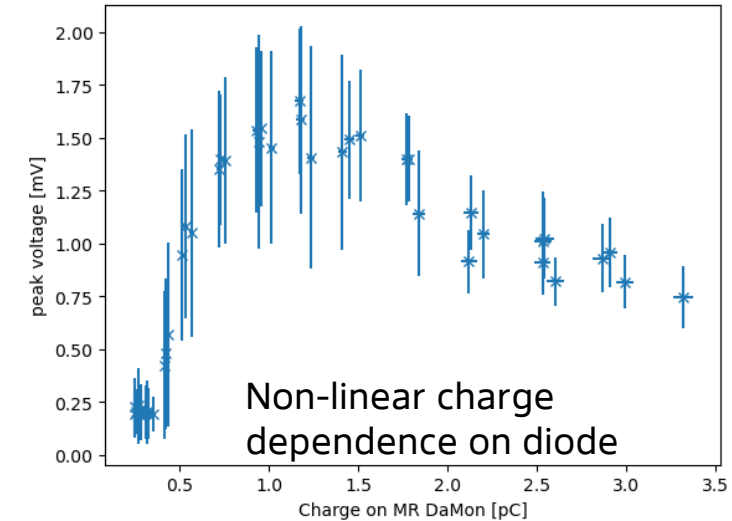
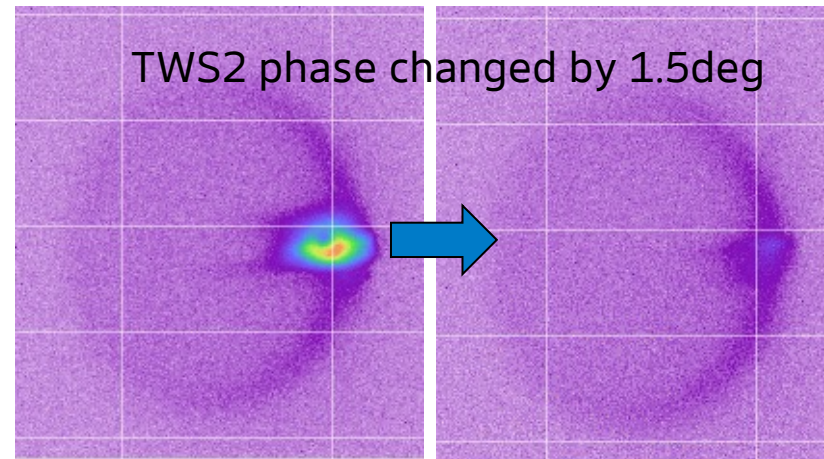
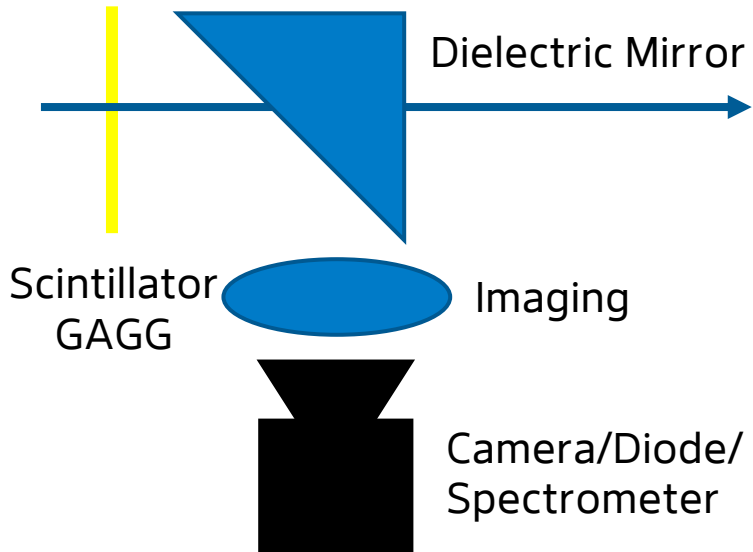


Kicker magnet tests

TR Bunch Compression Monitor @ ARES

Poster from Blae Stacey

Coherent and resonant transition radiation as bunch compression monitors towards Smith-Purcell studies



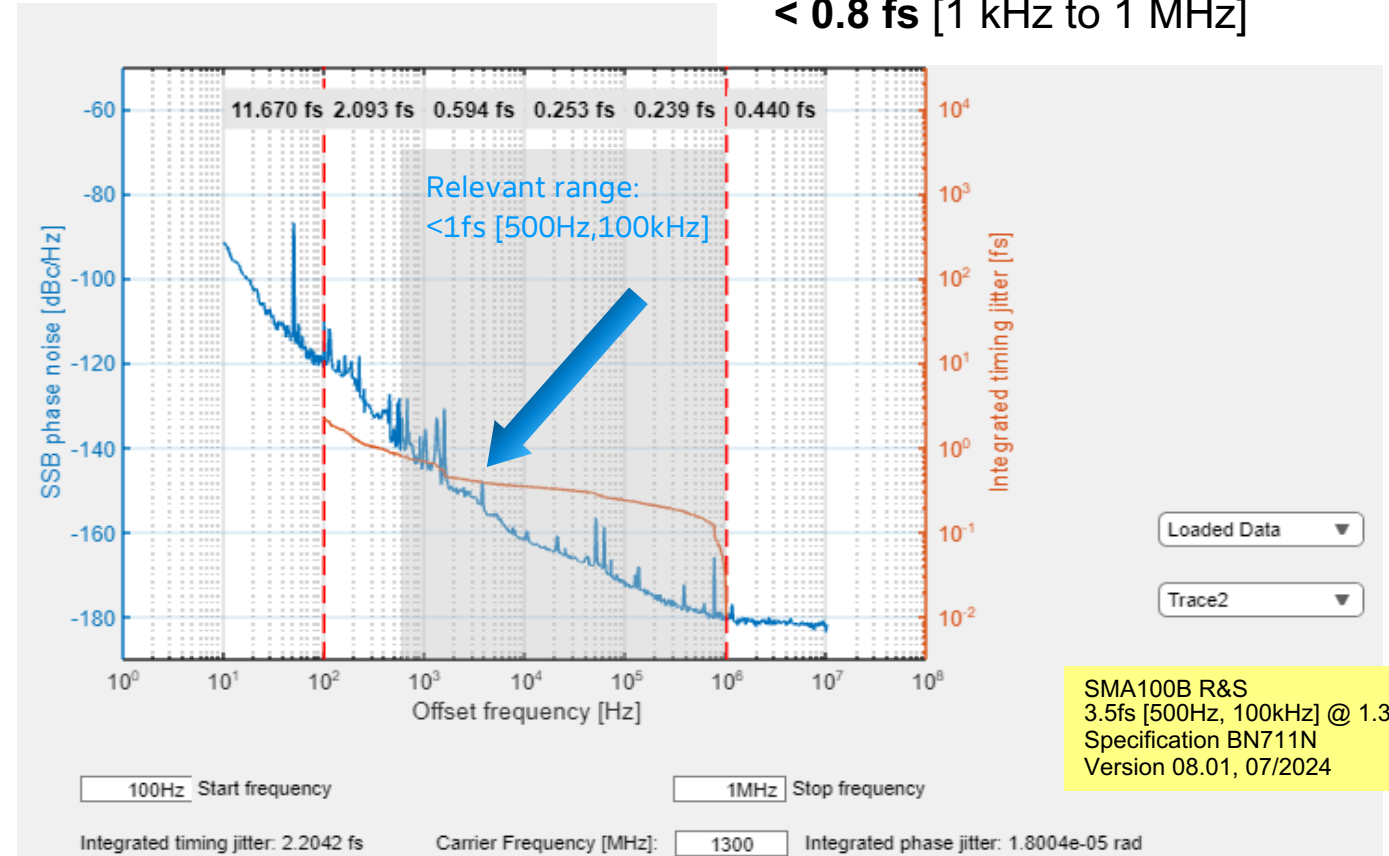
MO: Sub – 1fs Reference for Accelerators

- FLASH, XFEL, ARES Reference Upgrade:
1.3GHz, 3.0GHz, +46dBm, Health monitoring

- Absolute **Phase-noise** :

Integrated Jitter:

- < 12 fs [10 Hz to 100 Hz]
- < 1.8 fs [100 Hz to 1 kHz]
- < **0.8 fs** [1 kHz to 1 MHz]



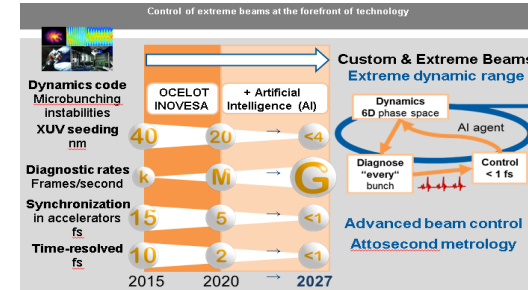
KVG Quartz Crystal
Technology GmbH
info@kvg-gmbh.de



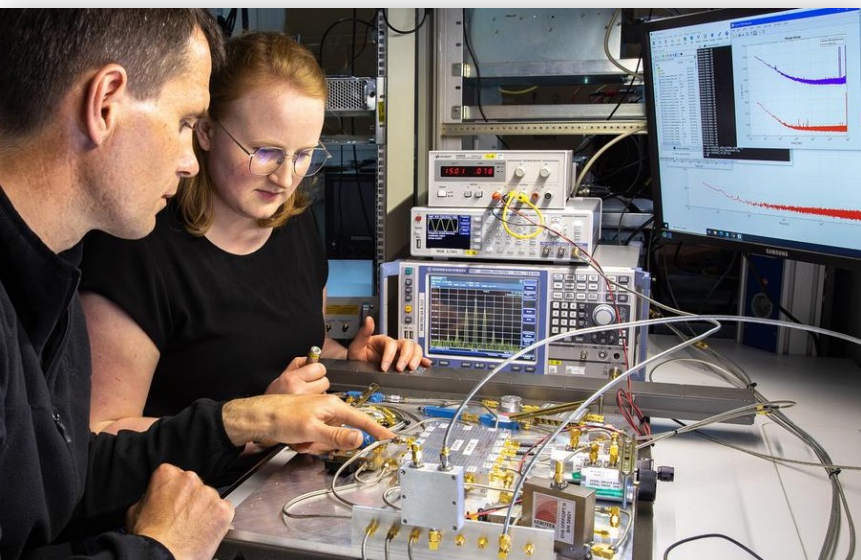
- - Improvement of int. jitter from 38 fs to 0.8 fs [1kHz, 1MHz]
- fs-laser systems locked to the reference show significant improvement in arrival time stability

From as RF-Control to next generation Analyzers

Industry Applications of Carrier-Suppression-Interferometer (CSI)



CSI prototype $\approx 10\text{as}$ (Record) ✓



L. Springer *et al.*, "Phase Noise Measurements for L-Band Applications at Attosecond Resolution," in *IEEE TIM*, doi: 10.1109/TIM.2022.3170975.

First CSI at CMTB $< 200\text{as}$ ✓



F. Ludwig *et al.*, publication in preparation
Physical Review Accelerator and Beams

Talk
Sub-fs SRF
control CMTB
M. Hoffmann

Attosecond Analyzers

$< 10\text{fs}$ Heterodyne today
 $< 2\text{fs}$ Heterodyne in progress
 $< 200\text{as}$ Heterodyne/ CSI Hybrid

$< 10\text{as}$ Analyzers (1 Port)
 $< 10\text{as}$ Analyzers (2 Port)
 $< 10\text{as}$ Analyzers (3 Port)

Why is this important?

- Improve Accelerator Subsystems

■ Huge impact on technology & industry (next 10 years):

Courtesy
of F. Ludwig

Next generation of analyzers
Selection & Development of RF Devices

Accelerators
R&D
Aerospace
Automotive
Industry
Telecommunication
Medical

(RF Controls, References, HPAs, SSAs)
(Knowledge advantage in design)
(Radar, Sensors, Receivers)
(Vehicle 2 Vehicle, V2 Infrastructure)
(Test & Measurement)
(Higher data throughput 5G, 6G, Satellite)
(MRI etc., high-power devices)

A bit more general

Moving all accelerators controls and required infrastructures to CAST

Overlapping shutdowns of all machines required - in January 2027 possible



*Planning ongoing.
Coordinator: A. Brinkmann (MBB)*



PoF evaluation



Ilja Bohnet
Anna Born
Sören Wiesenfelt

First name	Family name	Affiliation	Country
Siegfried	Bethke*	Max-Planck-Institut für Physik	Germany
Norbert	Holtkamp*	SLAC National Accelerator Laboratory	USA
Joel	Butler	Fermi National Accelerator Laboratory	USA
Simone	Campana	CERN - European Organization for Nuclear Research	Switzerland
Pierluigi	Carini	INFN Istituto Nazionale di Fisica Nucleare	Italy
Gabriella	Cranmer	Brookhaven National Laboratory	USA
Kyle	Demarteau	University of Wisconsin - Madison	USA
Marcel W.	Erdmann	Oak Ridge National Laboratory	USA
Martin	Fass	Rheinisch-Westfälische Technische Hochschule Aachen (RWTH)	Germany
Deborah	García López	Weizmann Institute of Science	Israel
Gaston	Heeger	Universidad Autónoma Madrid	Spain
Karsten M.	Henderson	Yale University	USA
Stuart	Hodgson	Thomas Jefferson National Accelerator Facility	USA
Keith	Ishikawa	SLAC National Accelerator Laboratory	USA
Tetsuya	Karis	RIKEN SPring-8 Center (RSC)	Japan
Olof	Lucotte	Lund University	Sweden
Arnaud	Nir	CNRS - Centre National de la Recherche Scientifique	France
Yosef (Yossi)	O'Sullivan	Weizmann Institute of Science	Israel
Erin	Schoenlein	Uppsala University	Sweden
Robert W.	Shariv	SLAC National Accelerator Laboratory	USA
Isaac	Smith	Universitätsmedizin Göttingen	Germany
Nigel		TRIUMF	Canada

Daniel Zaifmann

Next: strategic evaluation 2026!



2:00 PM		4:30 PM	
ARD parallel contributions			
2:00 PM	Welcome and introduction to ARD	5m	
Speaker: Wim Leemans (M (Beschleuniger))			
ARD-1_LeemansW... ARD-1_LeemansW...			
2:10 PM	SRF Cavity R&D	11m	
Speaker: Lea Stedter (MIL (Supraleitende Beschleuniger Technologie))			
2-Stedter_MT_ARD.pdf 2-Stedter_MT_ARD.p...			
2:21 PM	Advanced CW SRF Injector	11m	
Speaker: Dmitry Bazyl (MIL (Supraleitende Beschleuniger Technologie))			
3-Bazyl_MT_ARD.pdf 3-Bazyl_MT_ARD.pptx			
2:35 PM	Diagnostics and Dynamics of Extreme Beams	11m	
Speaker: Florian Burkart (MIL (Elektronen und Linearbeschleuniger))			
4-Burkart_MT_ARD... 4-Burkart_MT_ARD...			
2:50 PM	Stability, Controls and Synchronization	11m	
Speaker: Marie Kristin Czwalinna (DESY MISK)			
5-Czwalinna_MT_AR... 5-Czwalinna_MT_AR...			
Speaker: Andreas Maier (MIL (Laser für Plasma Beschleunigung))			
6-Maier_MT_ARD.pdf 6-Maier_MT_ARD.p...			
3:20 PM	Laser Plasma Injector for Storage Rings	8m	
Speaker: Paul Viktor Winkler (MIL (Laser für Plasma Beschleunigung))			
7-Winkler_MT_ARD... 7-Winkler_MT_ARD...			

HELMHOLTZ



Deutsches Elektronen-Synchrotron DESY
Helmholtz-Matter
Status Report 2021-2024
Volume I

DESY

Scientific Evaluation, February 10th - 14th, 2025

Research for grand challenges.

Summary

- Thanks again Holger!
- It is busy on the DESY campus (FLASH 2020+, PETRA IV, XFEL LIMP)
- A lot of R&D activities at the LK2 user machines and test facilities
- Very wide portfolio of ST3 activities at DESY
- Successfully finished PoF Centre evaluation.
- Preparing for strategic evaluation in 2026.

I'm looking forward to a great workshop!!
Thanks a lot Zeuthen!



Vielen Dank

Kontakt

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