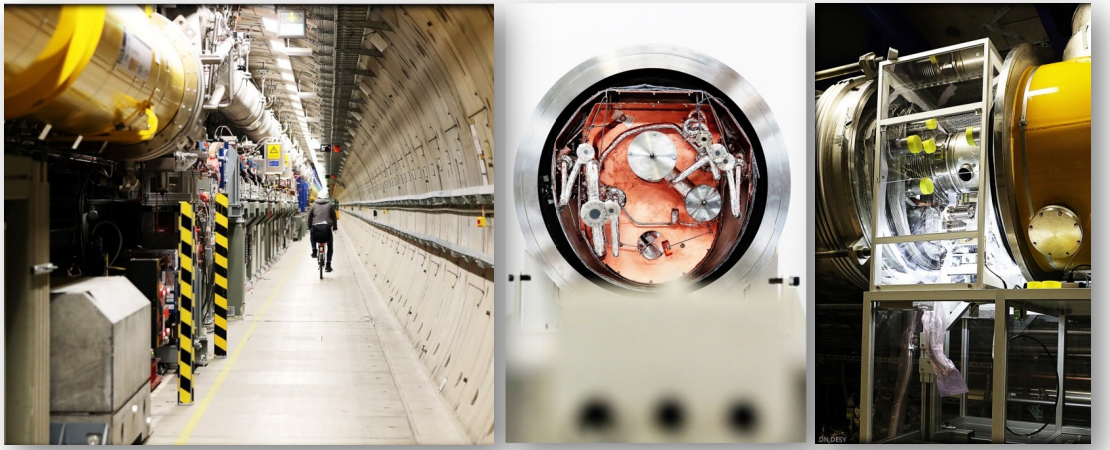
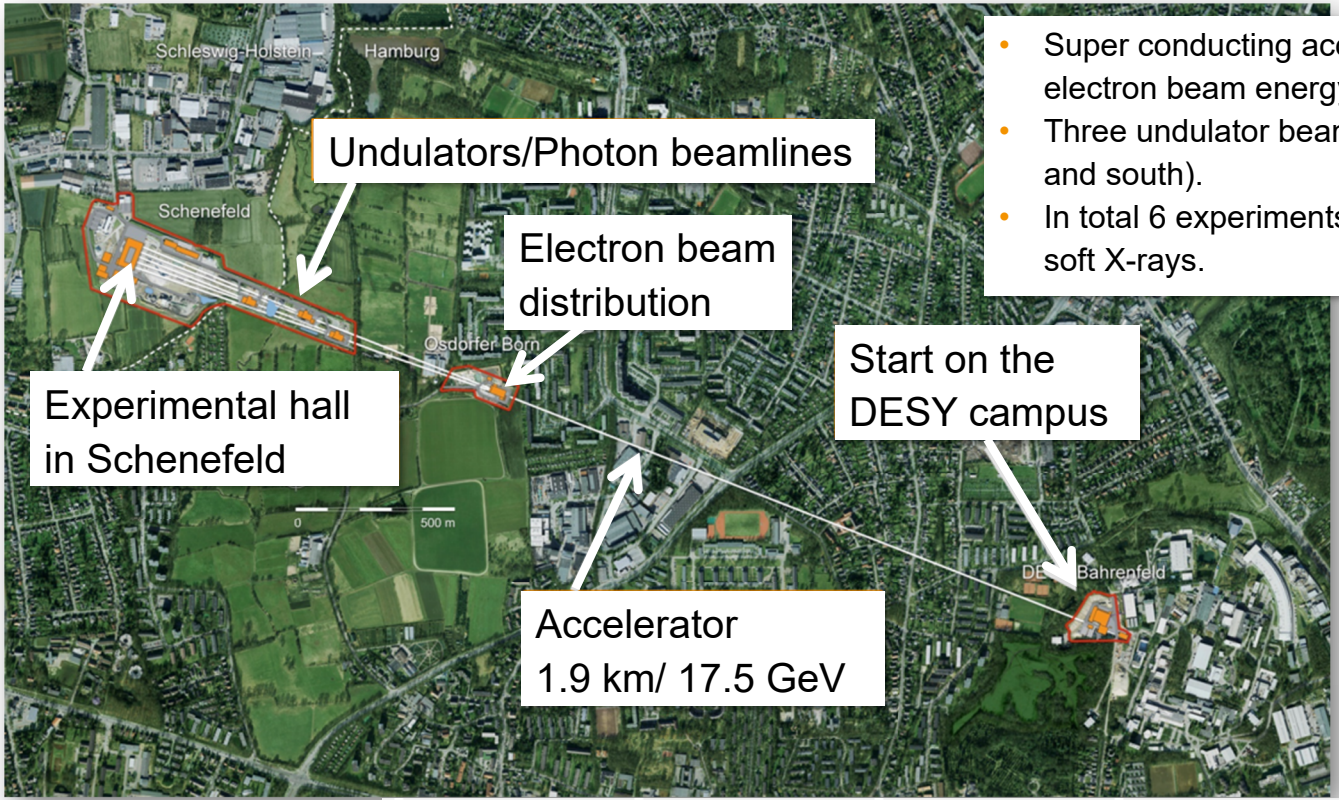
FEL Performance Achieved at European XFEL

Matthias Scholz for the operation team
IPAC‘18, April 30, 2018



European XFEL

The European XFEL between Hamburg Bahrenfeld and Schenefeld



- Super conducting accelerator with up to 17.5 GeV electron beam energy.
- Three undulator beamlines in two branches (north and south).
- In total 6 experiments, 4 for hard X-rays and 2 for soft X-rays.

European XFEL

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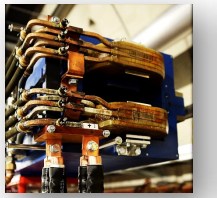
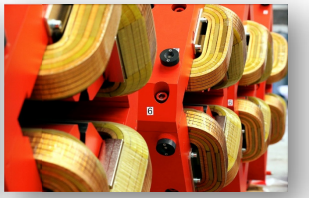
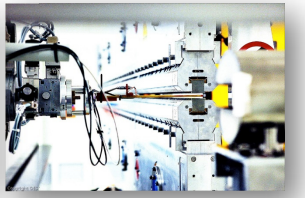
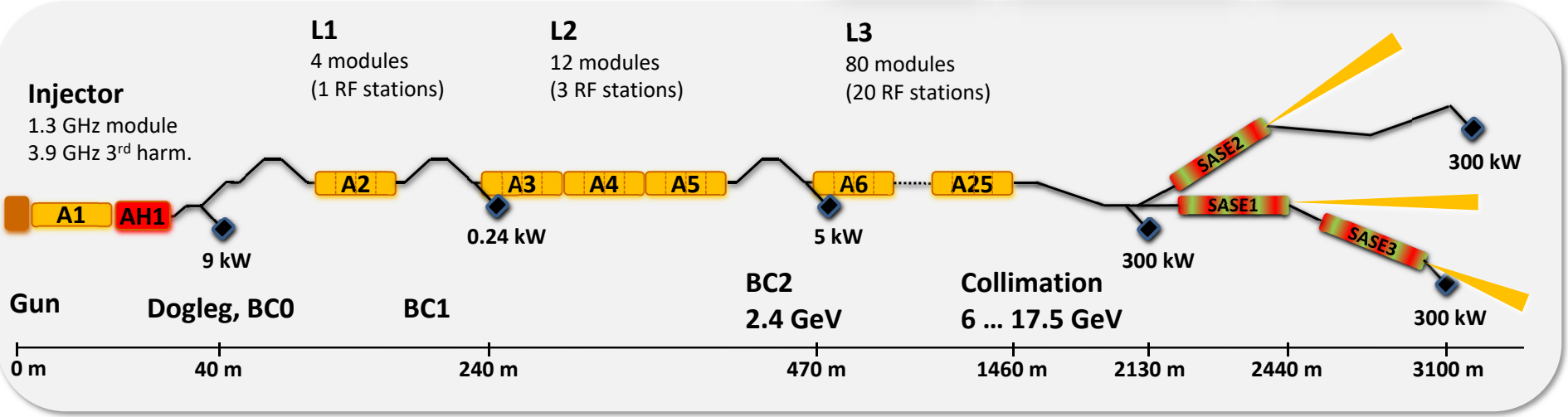
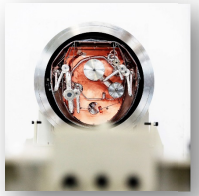
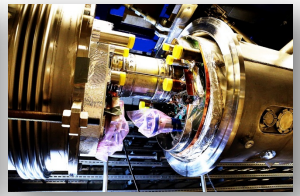
DESY.

Schematic accelerator overview

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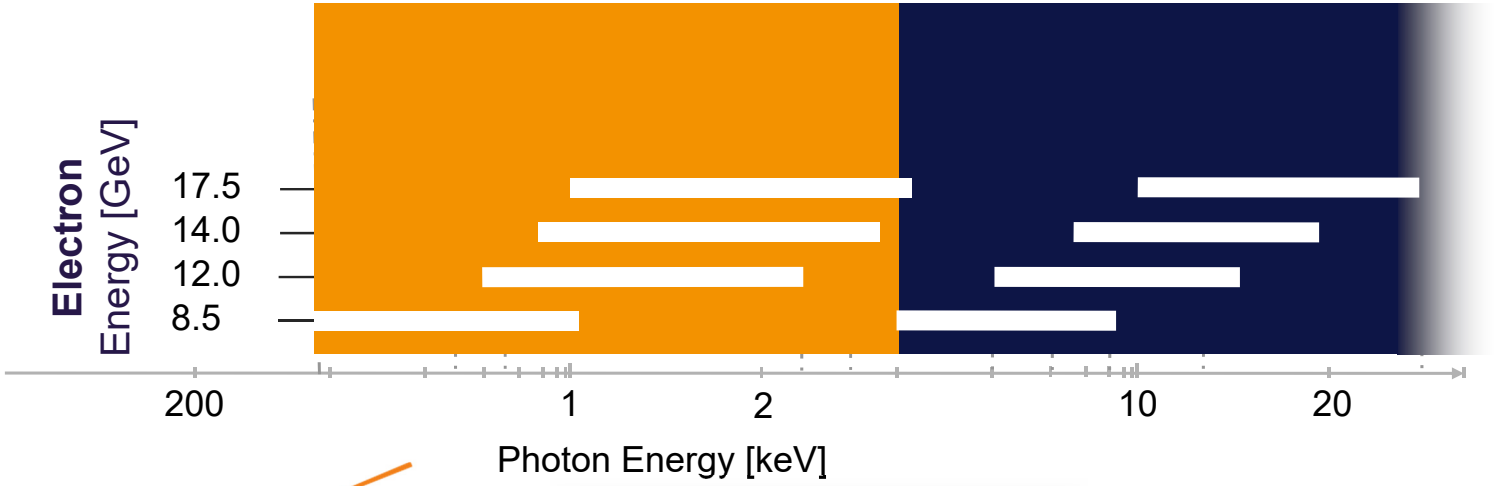
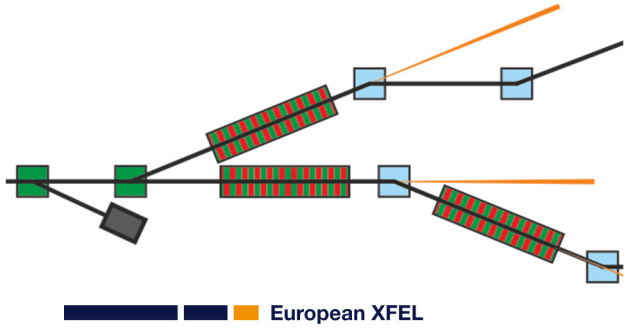
DESY.

The European XFEL covers photon energies from 0.25 keV to 25 keV





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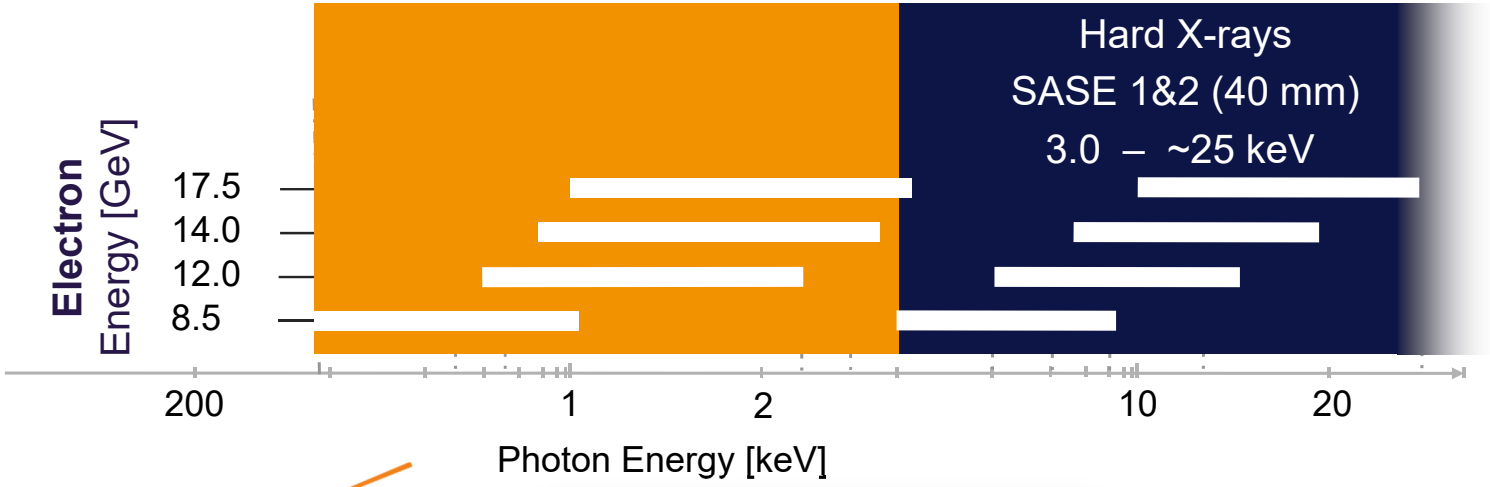

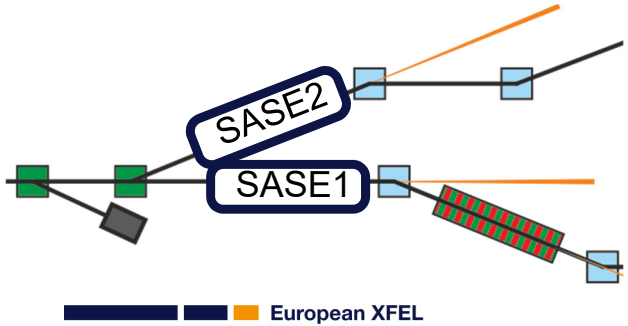

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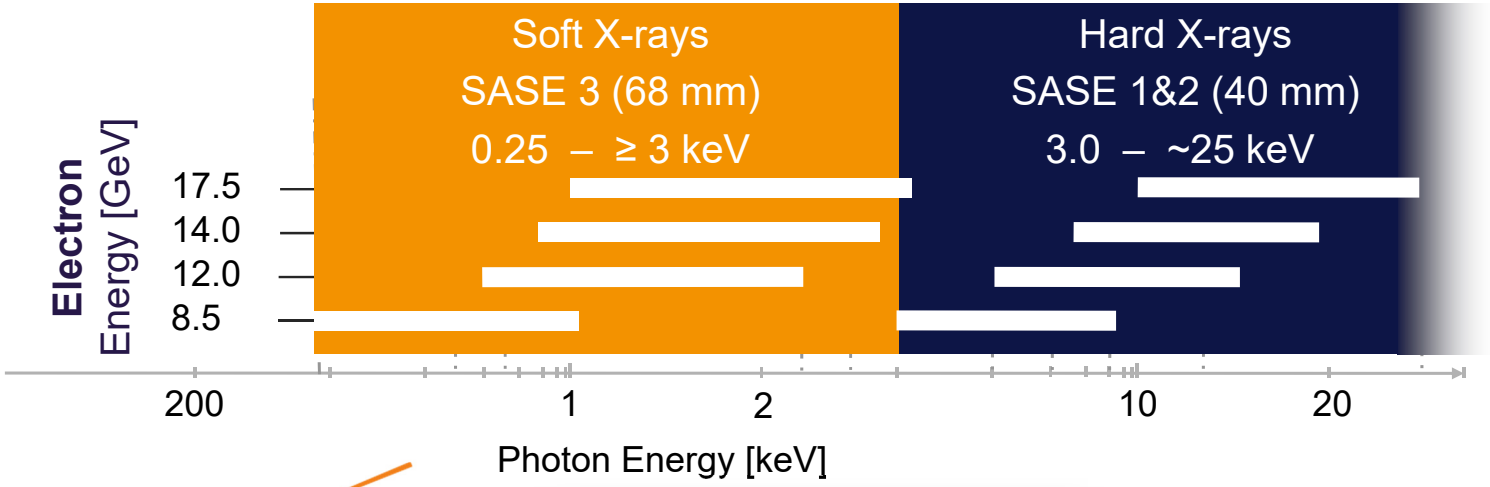

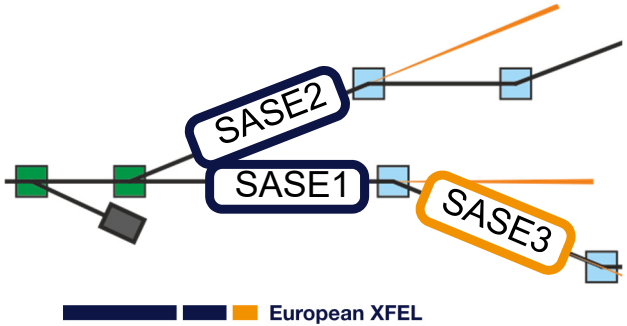

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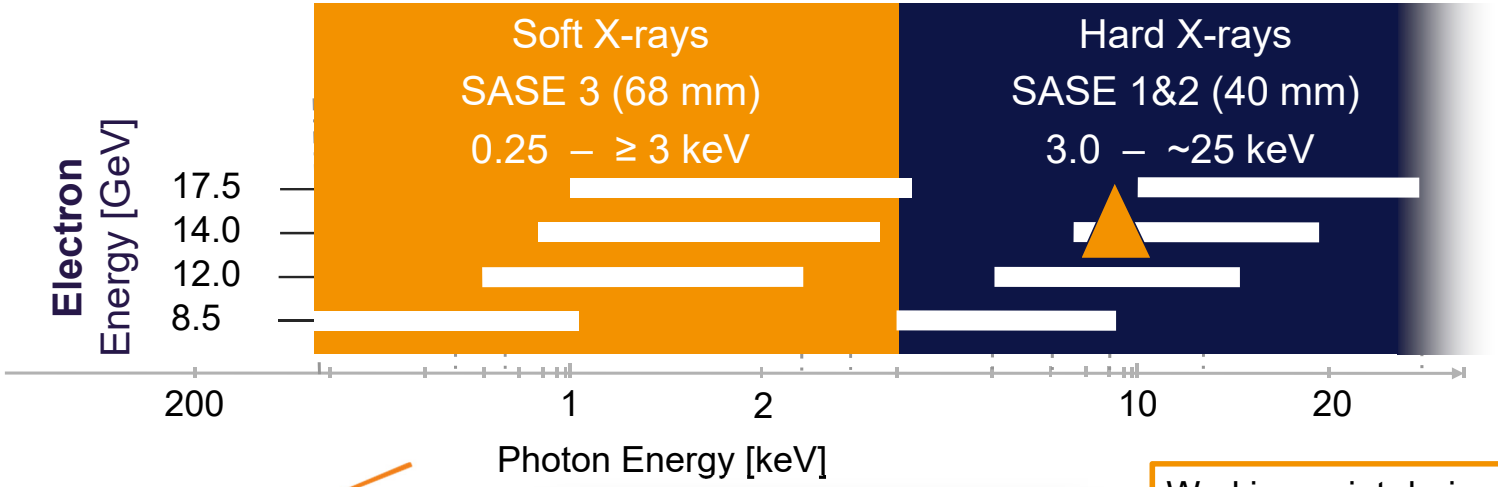

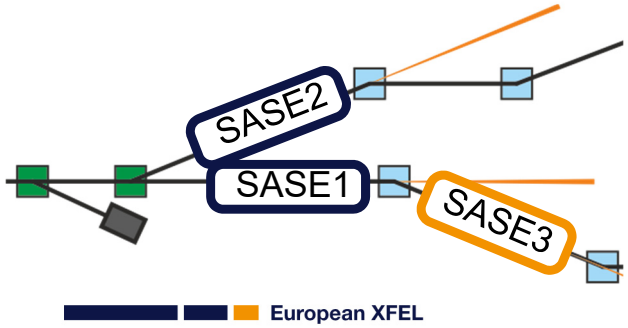

Working point during first user runs: 14 GeV electron beam energy and ~9.3 keV photon energy (SASE1).

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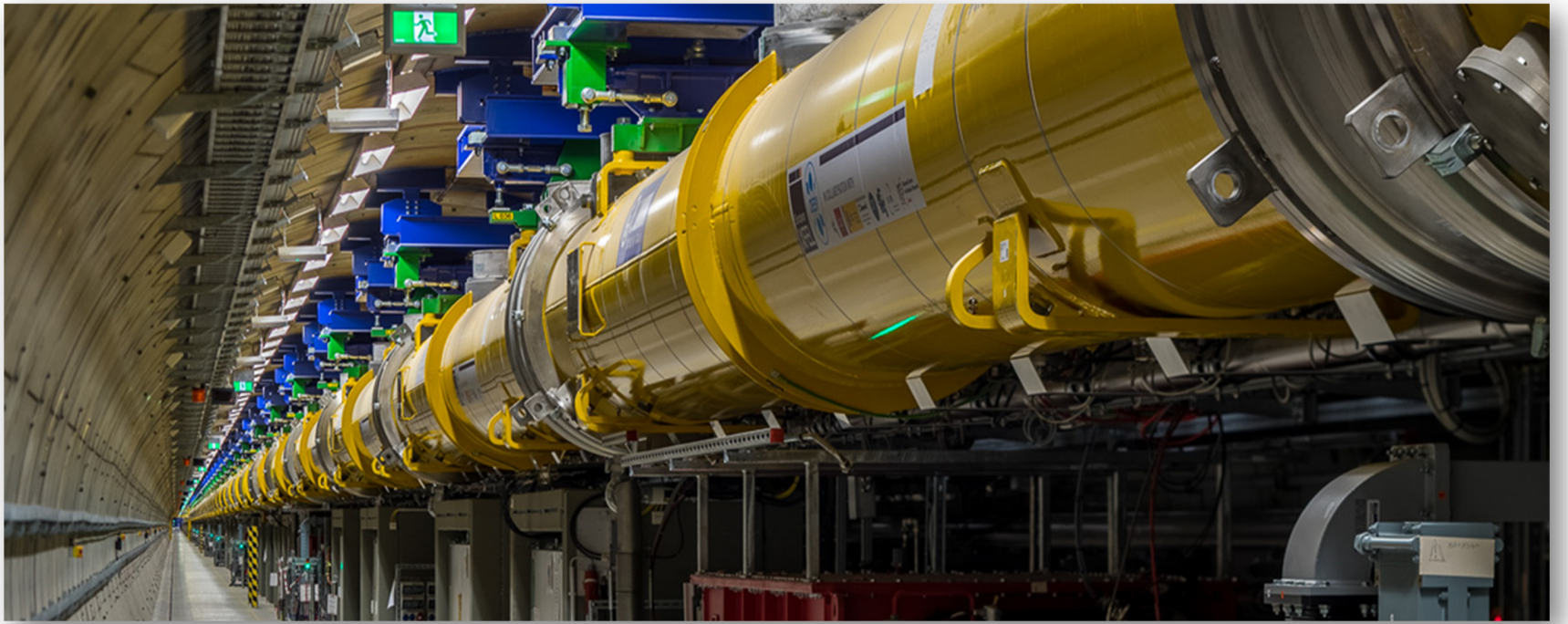
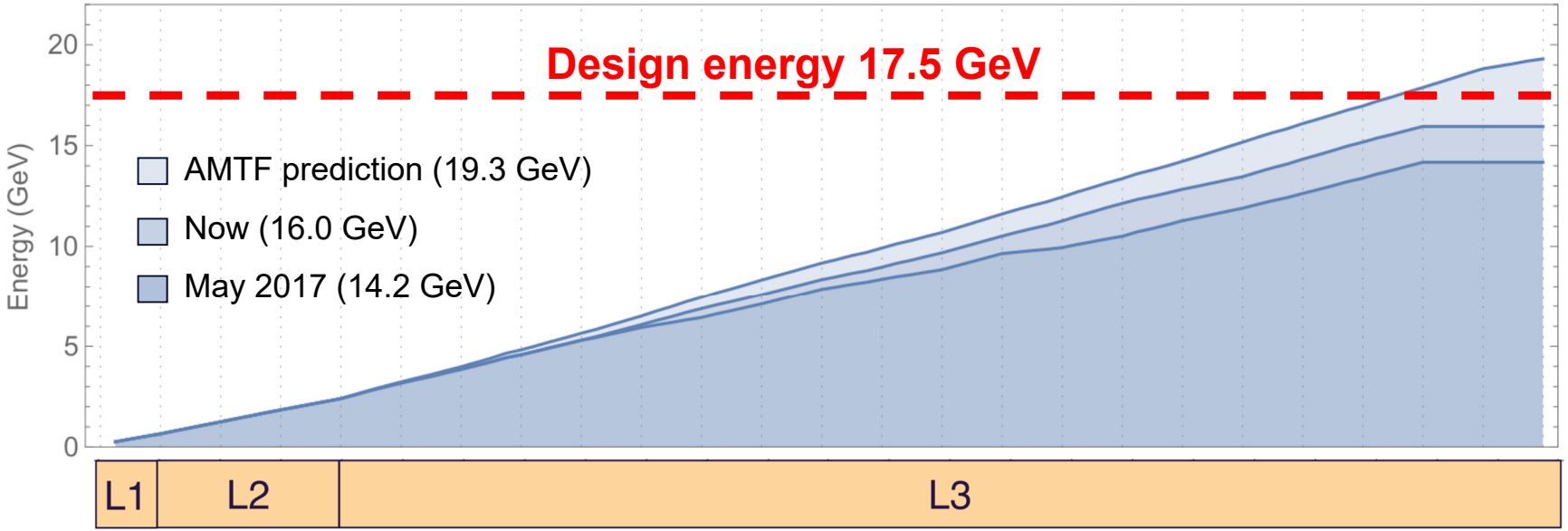
DESY.

The longest superconducting linac in the world is in operation



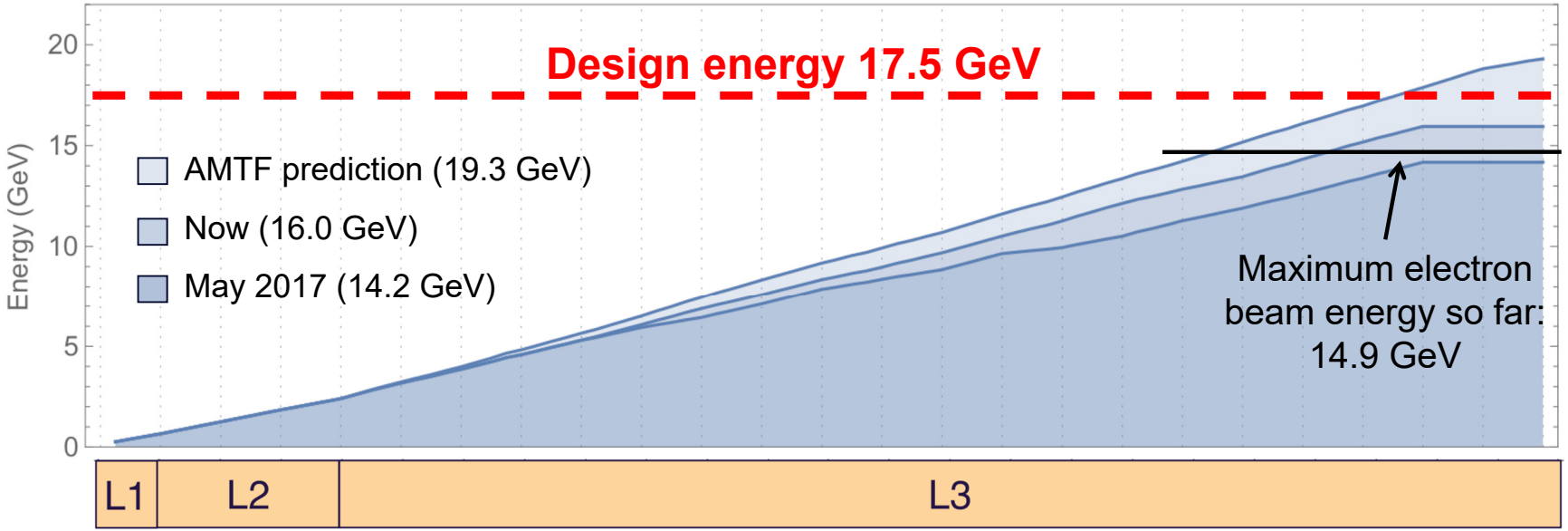
- 96 (+2) superconducting modules are installed.
- RF components and electronics rack are located below the accelerator.

Energy reach of European XFEL modules



- The accelerator is commissioned accordingly to schedule and towards expected parameters.
- **23 out of 25 RF** stations are commissioned (the last two have been ready since last week).

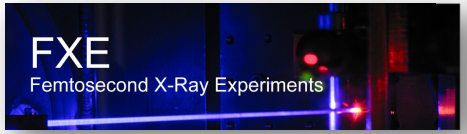
Energy reach of European XFEL modules

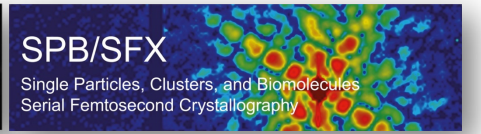


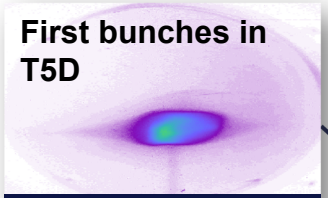
- The accelerator is commissioned accordingly to schedule and towards expected parameters.
- **23 out of 25 RF** stations are commissioned (the last two have been ready since last week).
- The maximum electron beam energy so far was **14.9 GeV**, user operation with **14.0 GeV.**

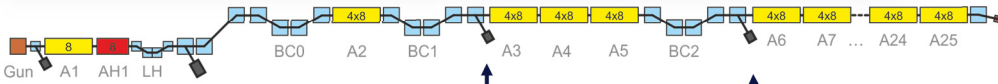
Commissioning timeline

First user runs started in September 2017 (SASE1 beamline)







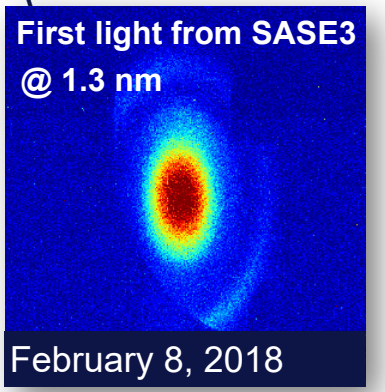


Jan 13, 2017

Jan 15, 2017 @ 130 MeV
Jan 19, 2017 @ 600 MeV

Feb 2, 2017 @ 600 MeV
Feb 22, 2017 @ 2.5 GeV

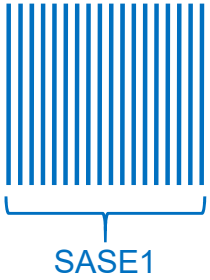
Feb 25, 2017@ 2.5 GeV
March 19, 2017 @ 6 GeV
April 8, 2017 @ 12 GeV

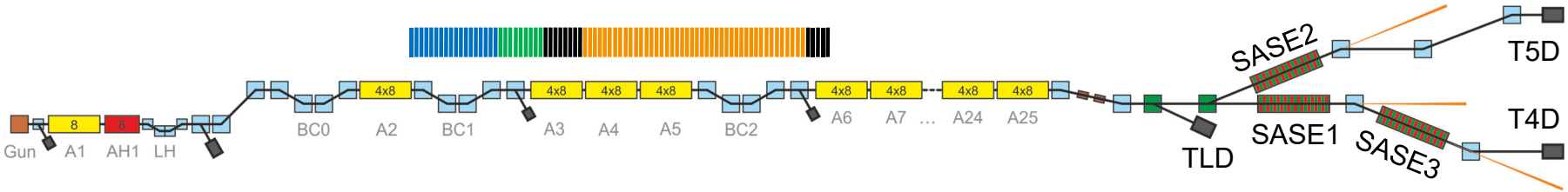


IPAC'17 talk by Winni Decking

A typical bunch pattern for user operation

… driving SASE1, SASE2, and SASE3 simultaneously.





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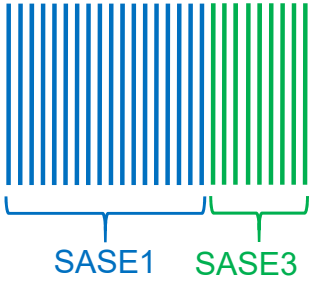
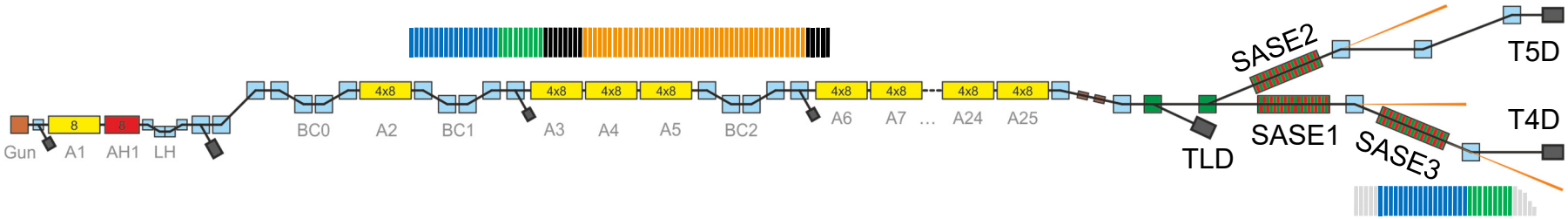


Kicked in TL to suppress lasing in SASE1



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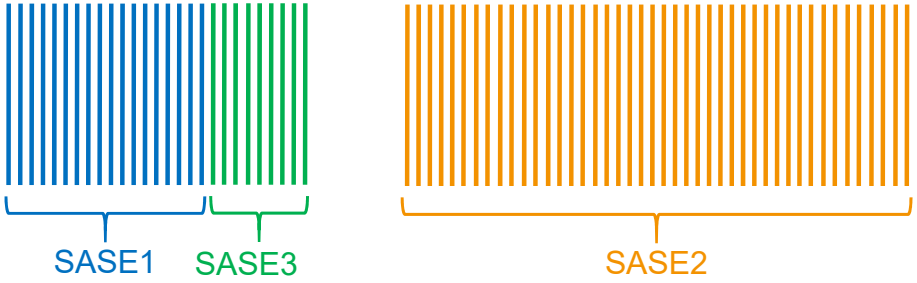

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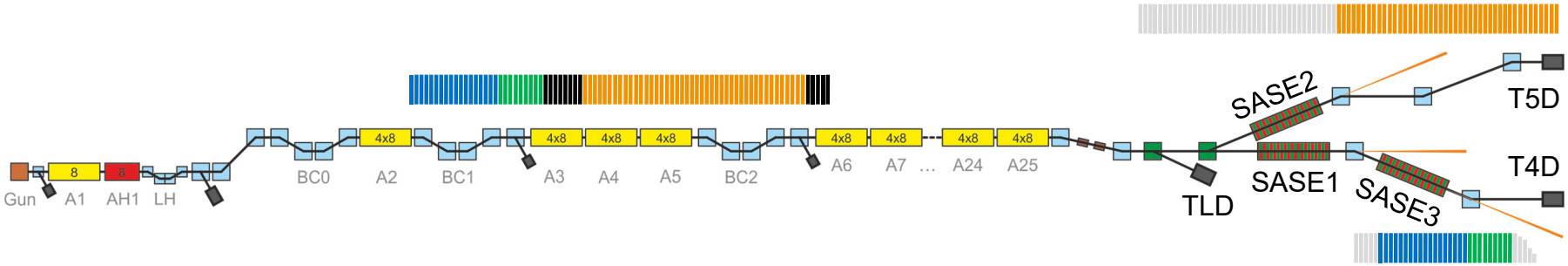

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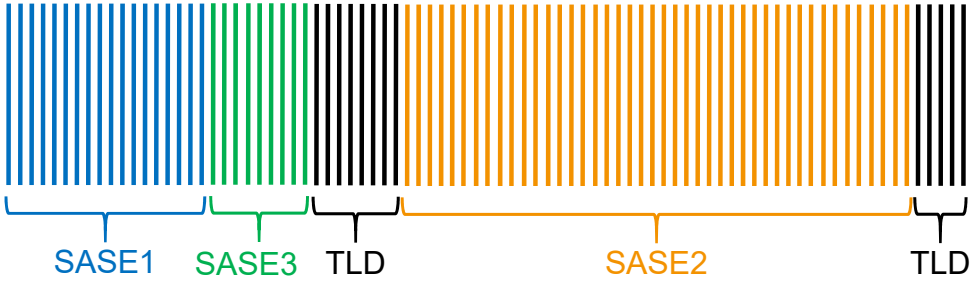
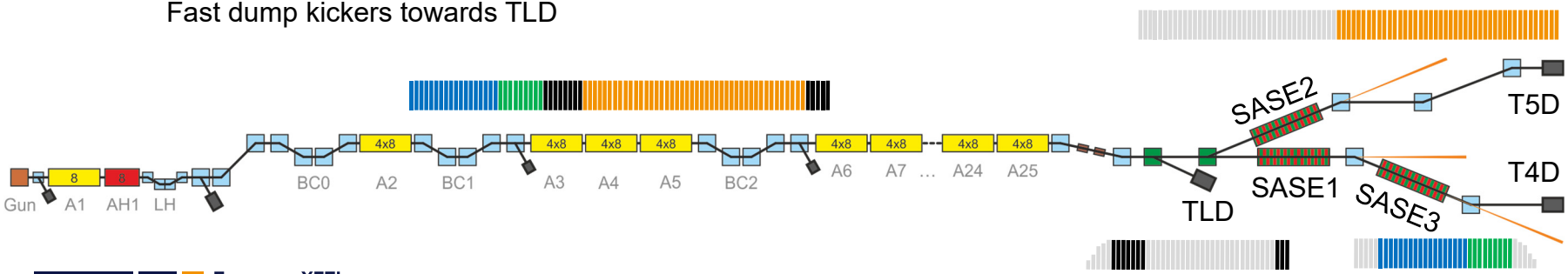
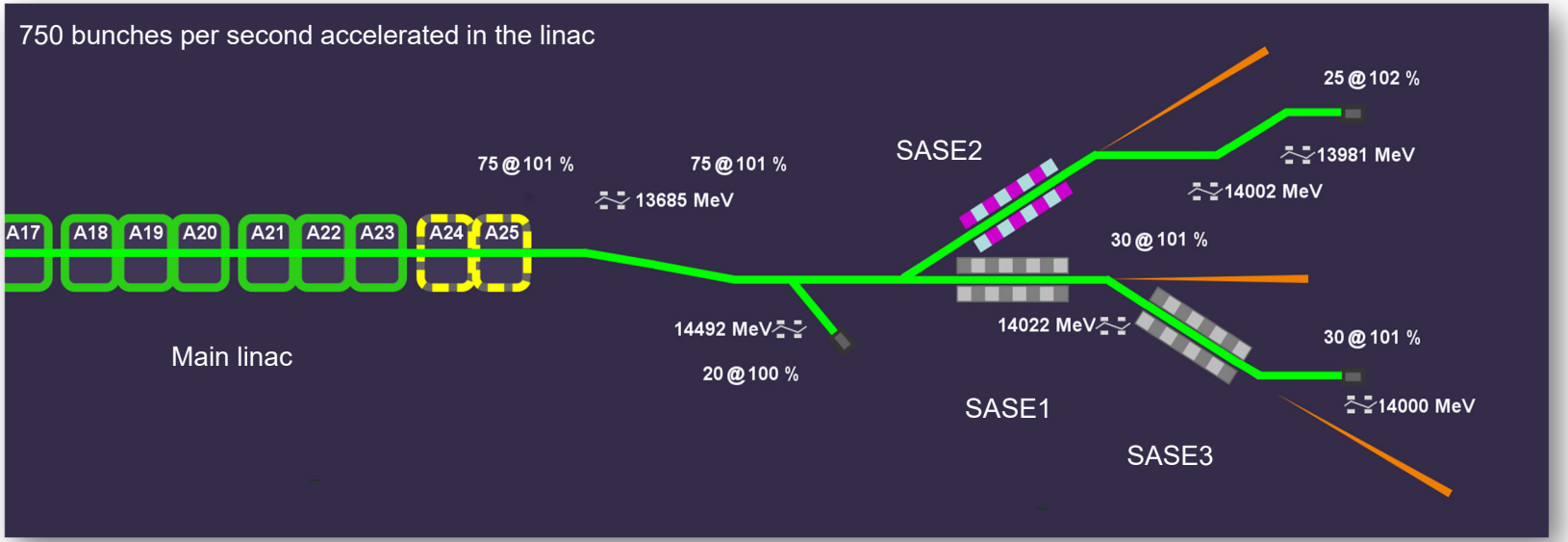


Kicked in TL to suppress lasing in SASE1

Fast dump kickers towards TLD



Parallel operation of three beamlines



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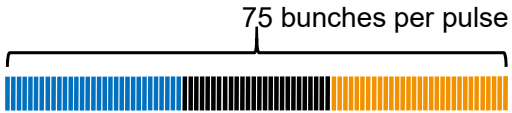

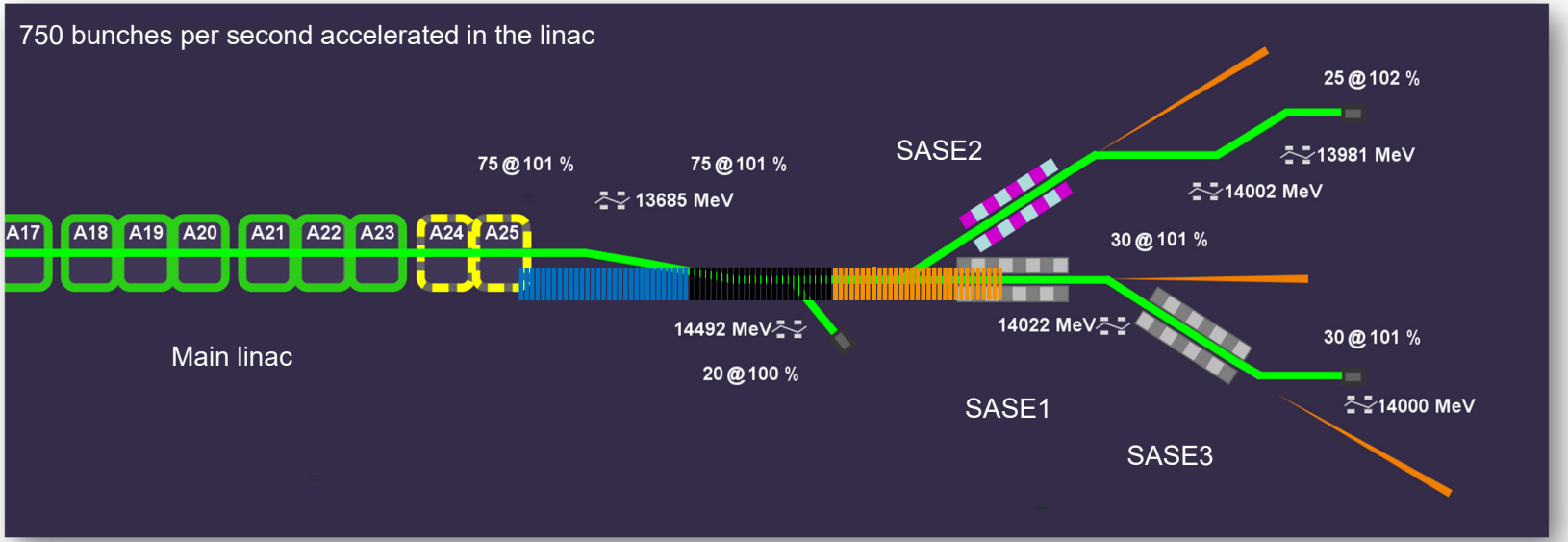

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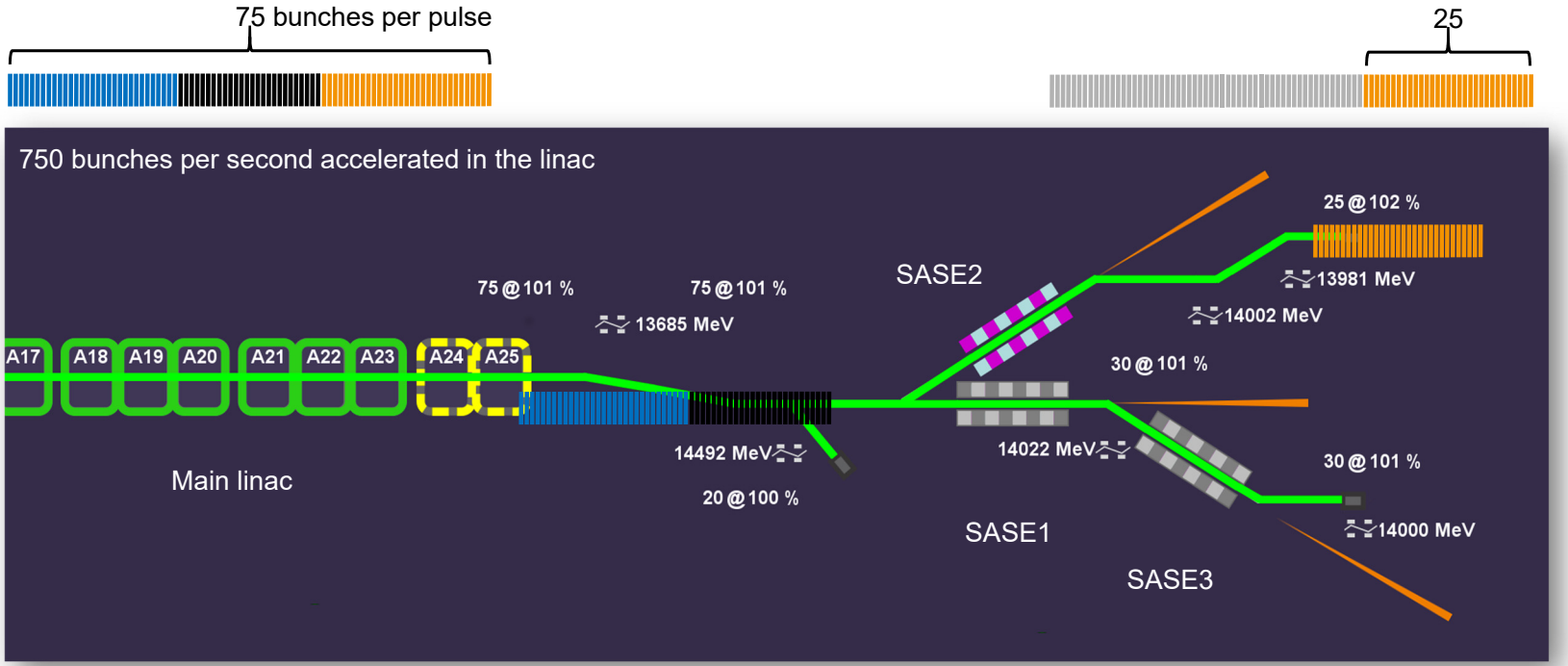

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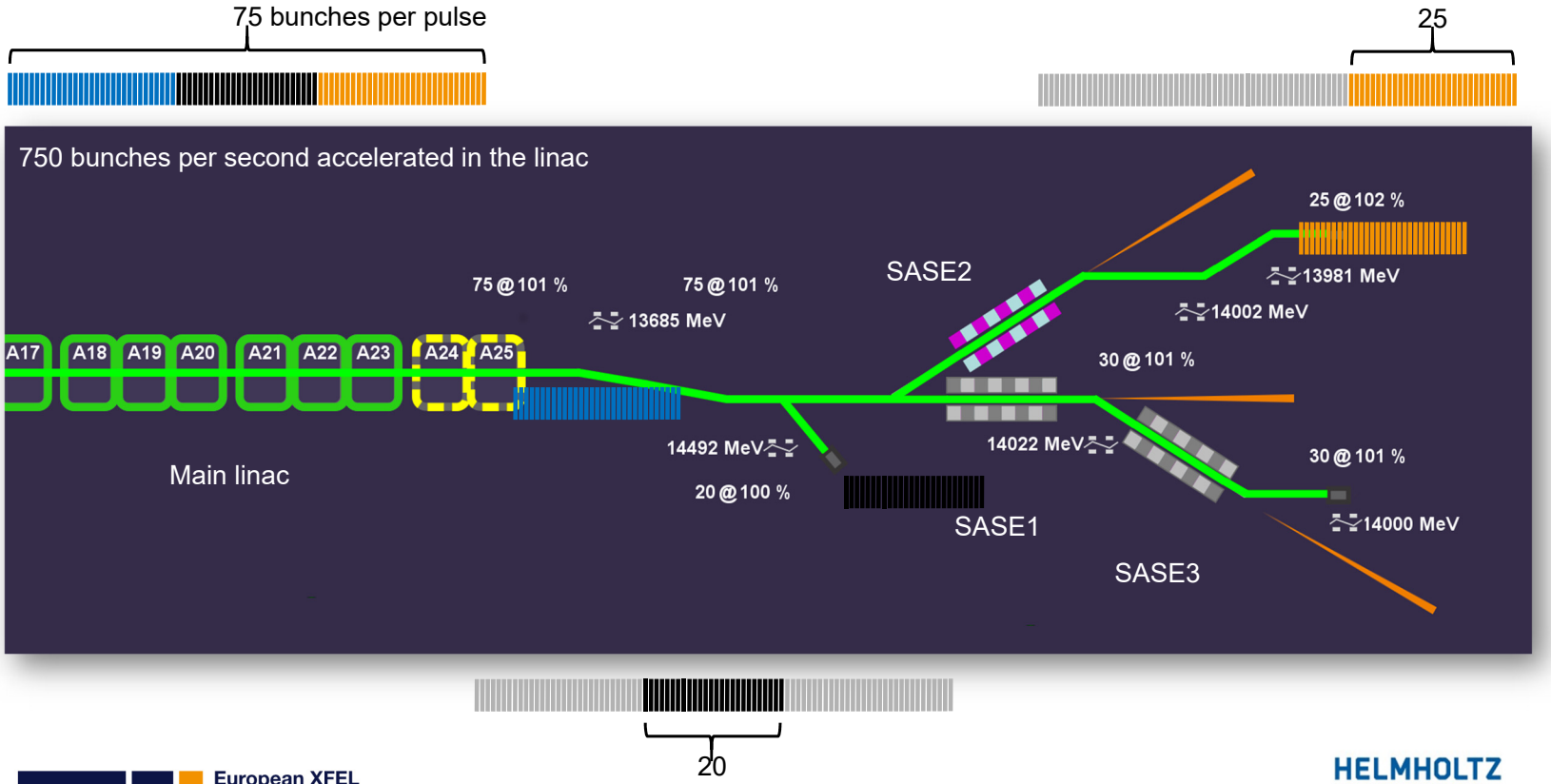

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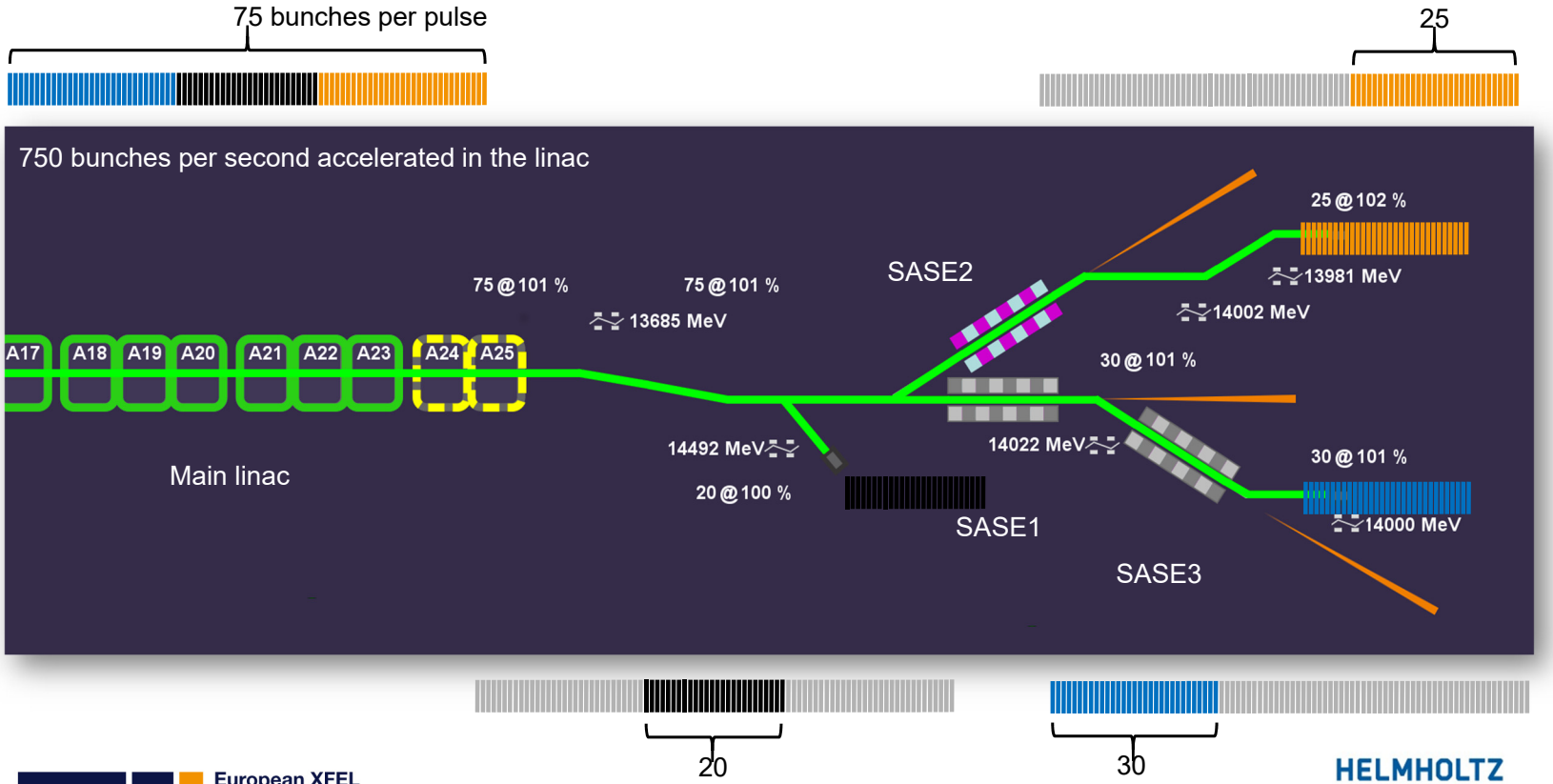


Fast feedbacks

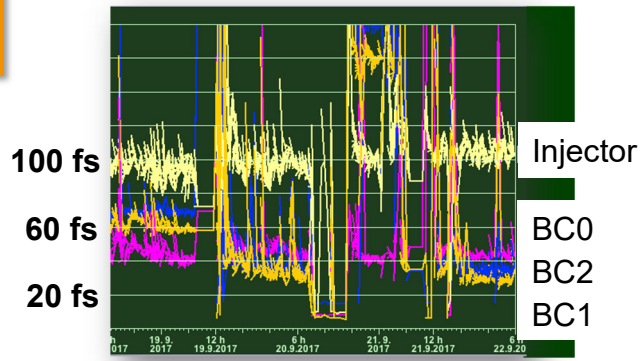
Intra bunch train orbit feedback

pk2pk ~ 30 µm

pk2pk ~ 6 µm

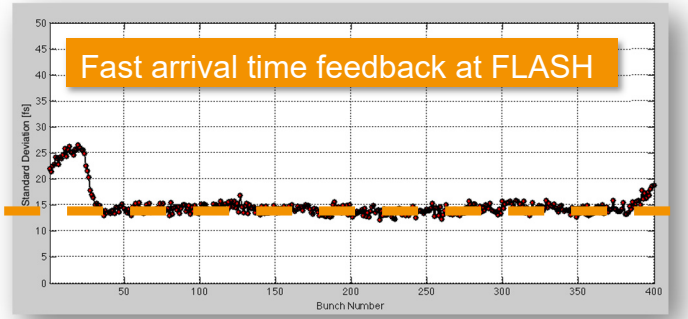
Arrival time stability

Arrival time jitter



We expect an arrival time jitter in the range of 10 fs as soon as the arrival time feedback is commissioned.

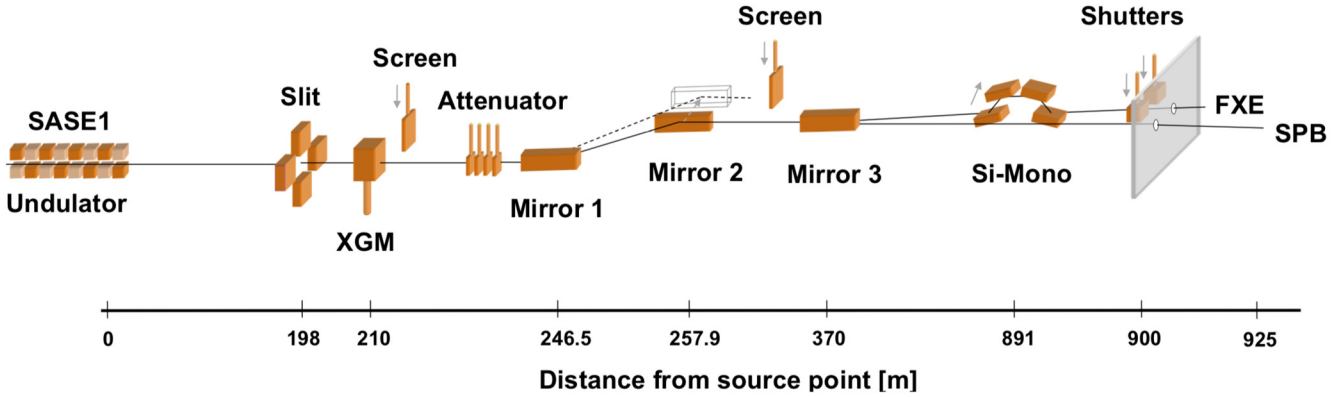
14 fs



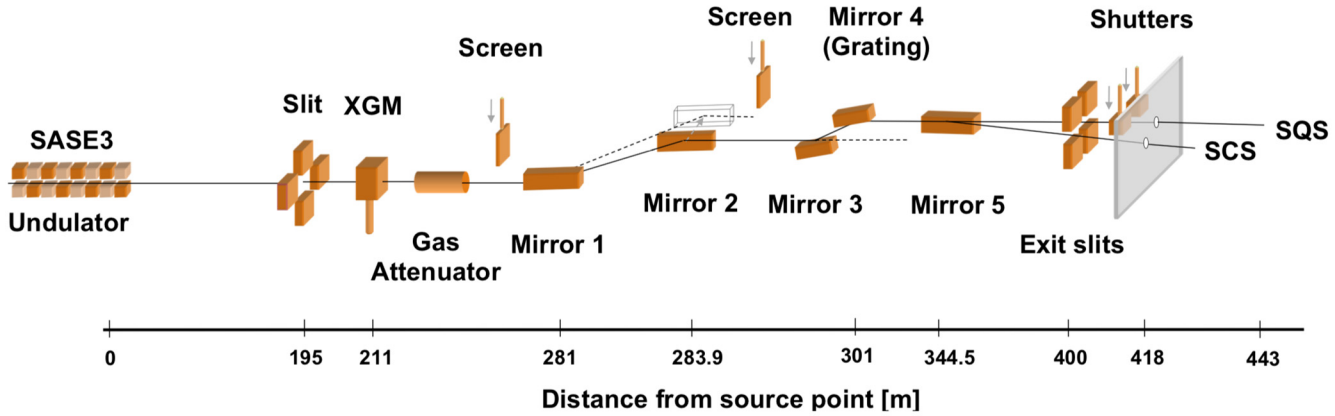
Photon beamline commissioning

The photon beamlines in the north branch are largely commissioned

hard X-ray beamline



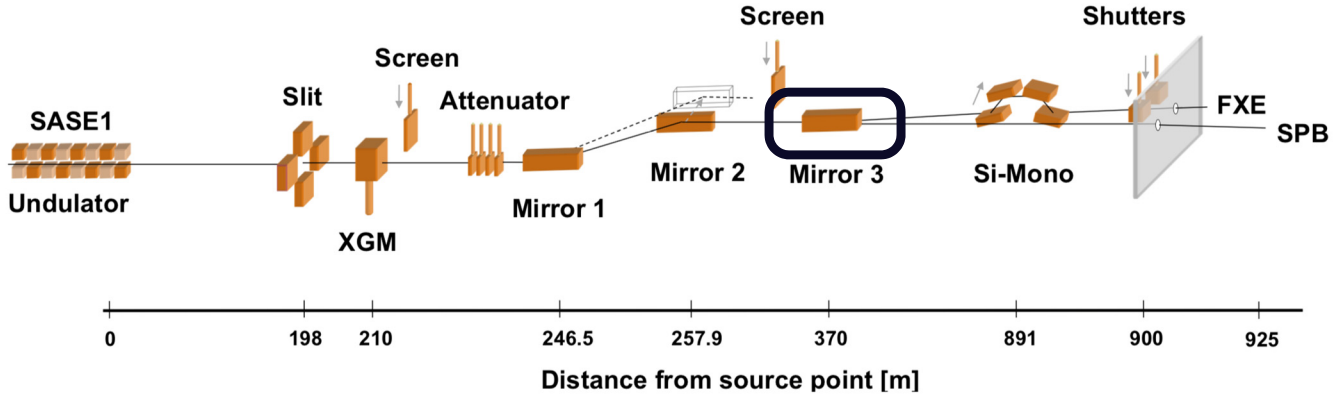
soft X-ray beamline



Photon beamline commissioning

hard X-ray beamline

photon beam mirrors



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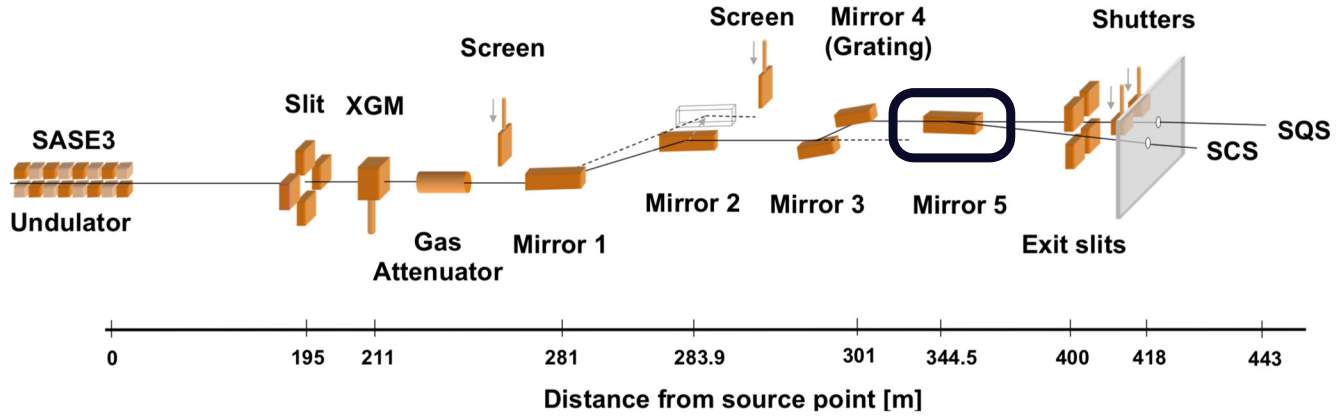
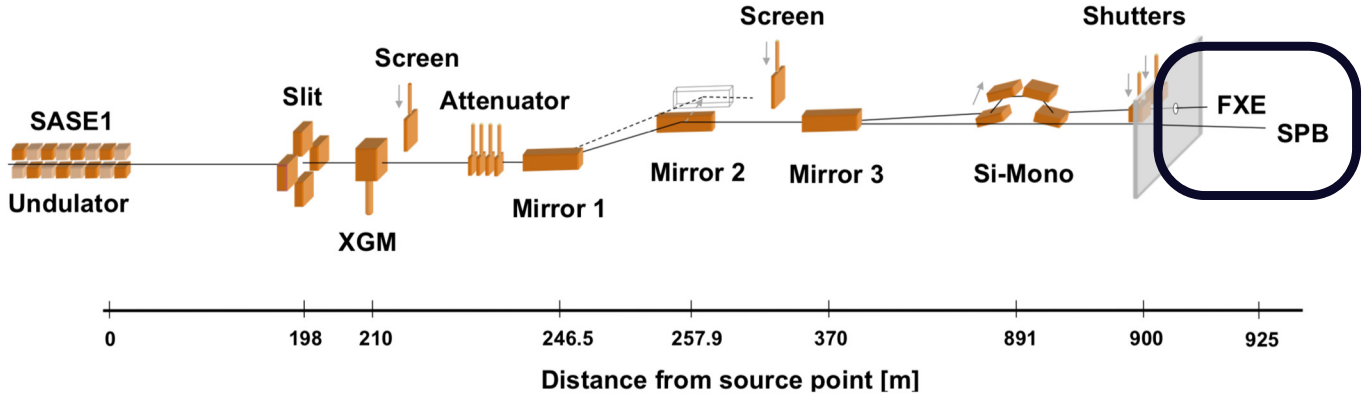


Photon beamline commissioning

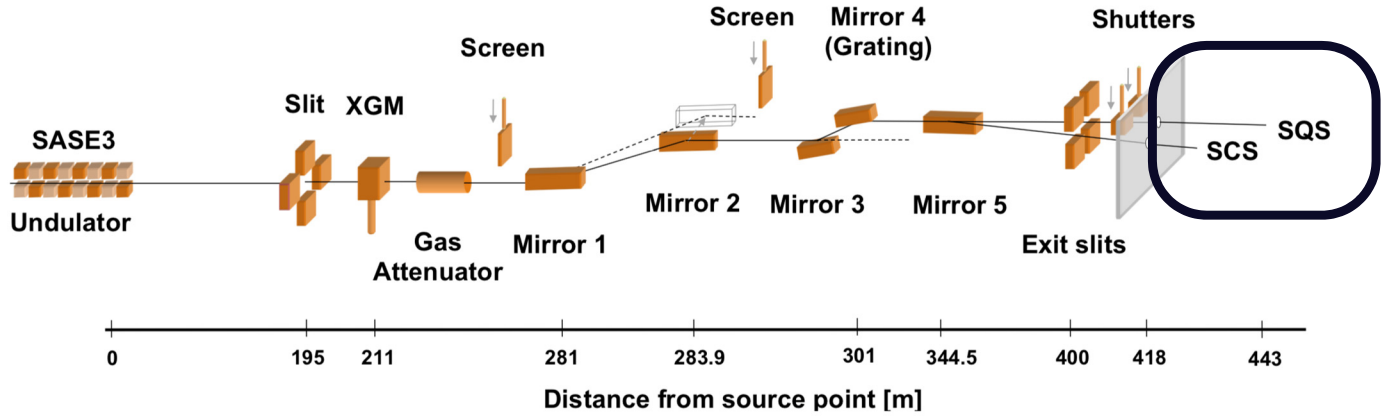
hard X-ray beamline

photon beam mirrors

two experiments



soft X-ray beamline



Photon beamline commissioning

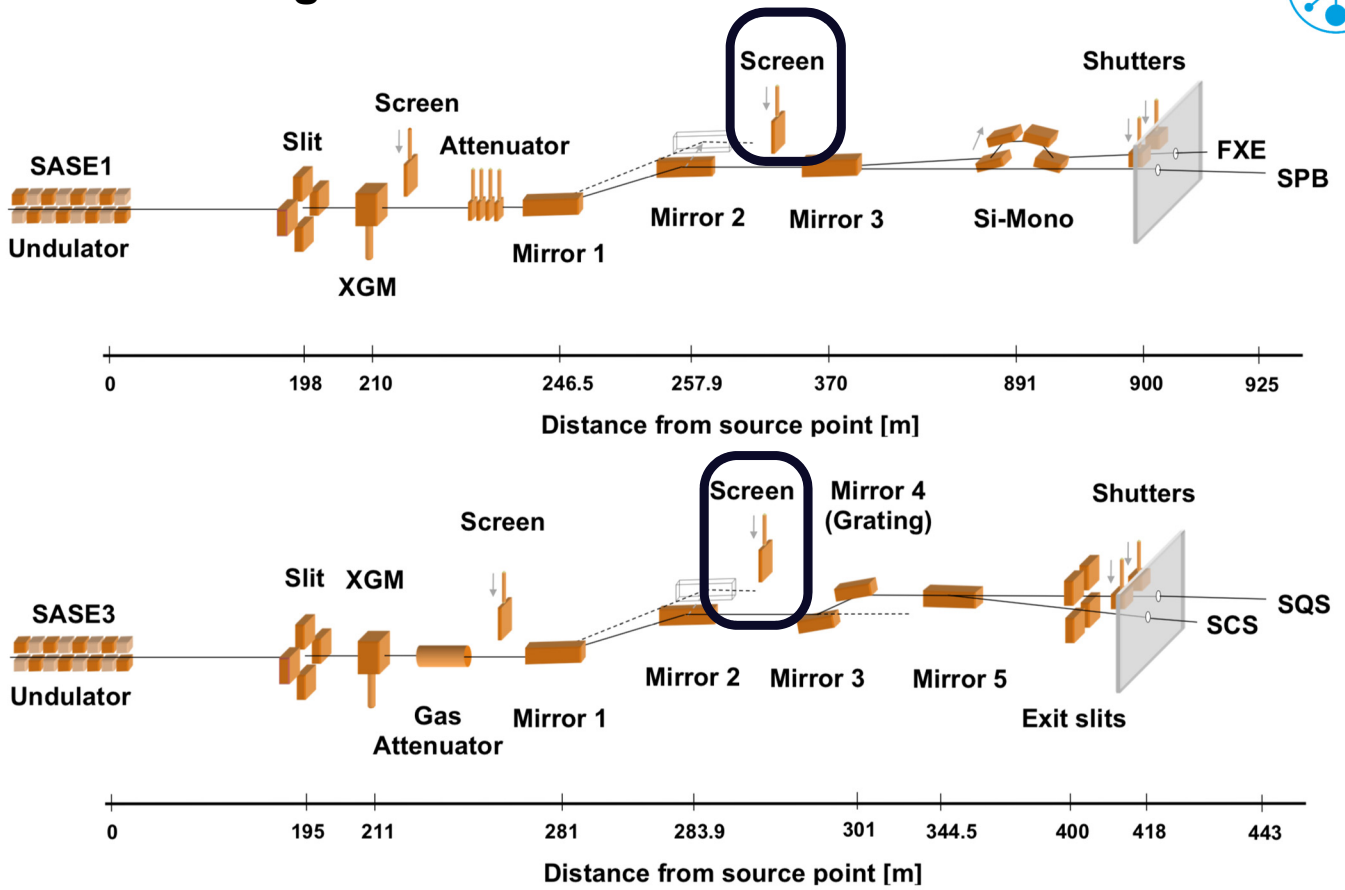
hard X-ray beamline

photon beam mirrors

two experiments

screens

soft X-ray beamline

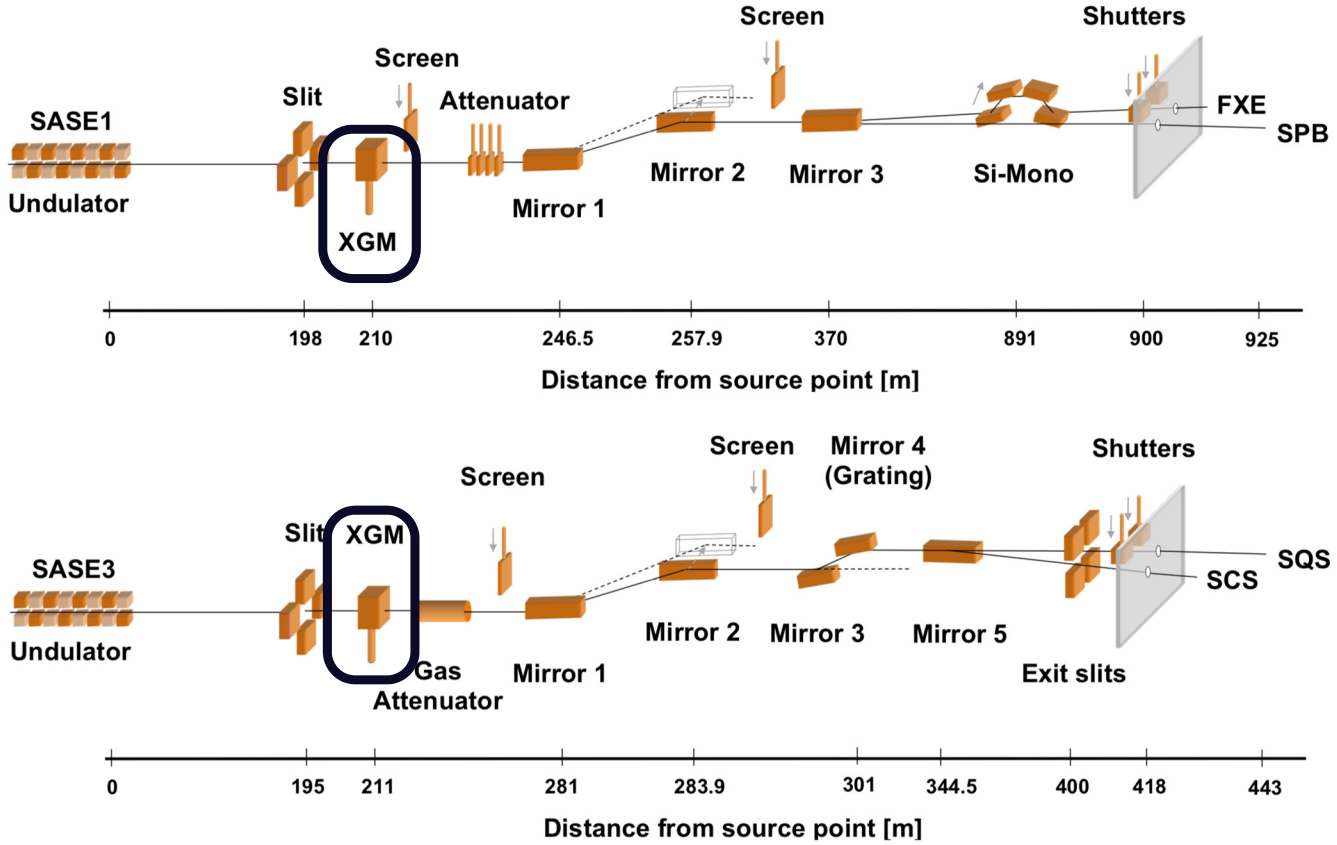


Photon beamline commissioning

hard X-ray beamline

- photon beam mirrors
- two experiments
- screens
- calibrated gas monitors

soft X-ray beamline

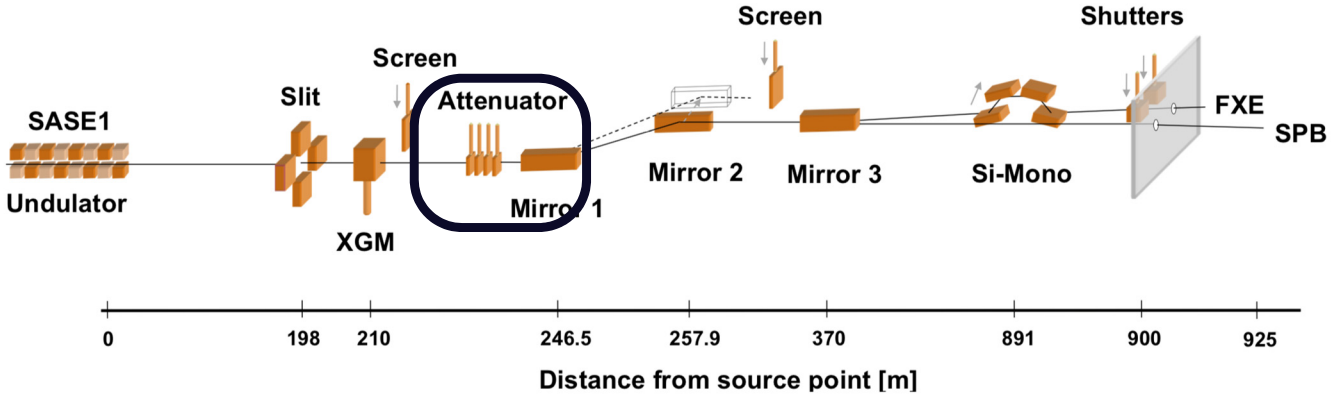


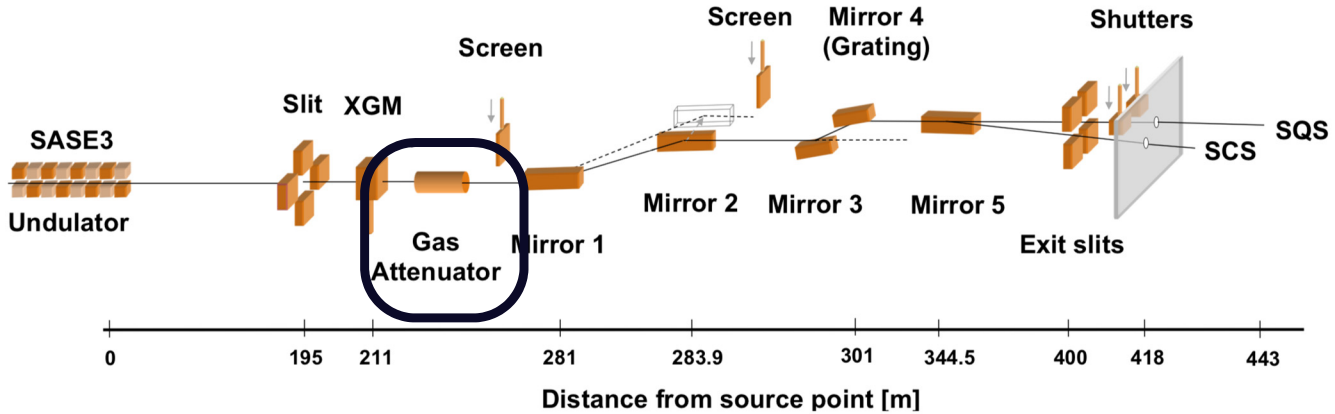
Photon beamline commissioning

hard X-ray beamline

- photon beam mirrors
- two experiments
- screens
- calibrated gas monitors
- attenuators

soft X-ray beamline





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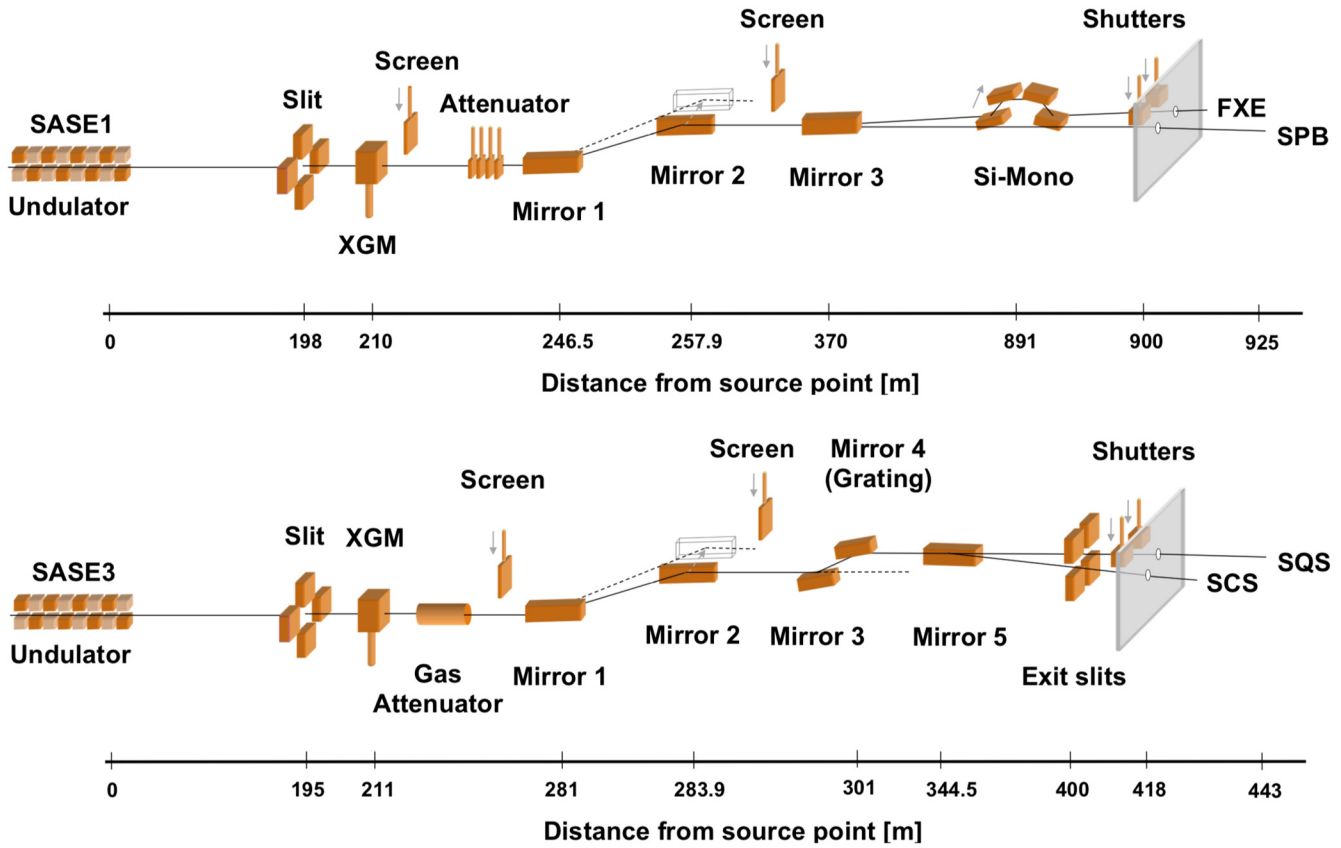
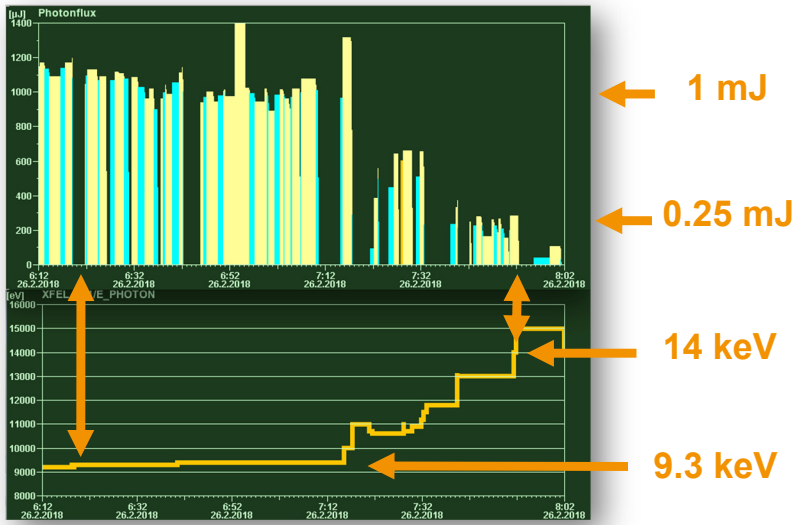


SASE photon energy in the hard X-ray beamline SASE1

- The typical photon energy for user has been 9.3 keV so far.
- The maximum photon energy achieved so far has been 14 keV.

photon pulse energy

photon energy



1 mJ

0.25 mJ

14 keV

9.3 keV

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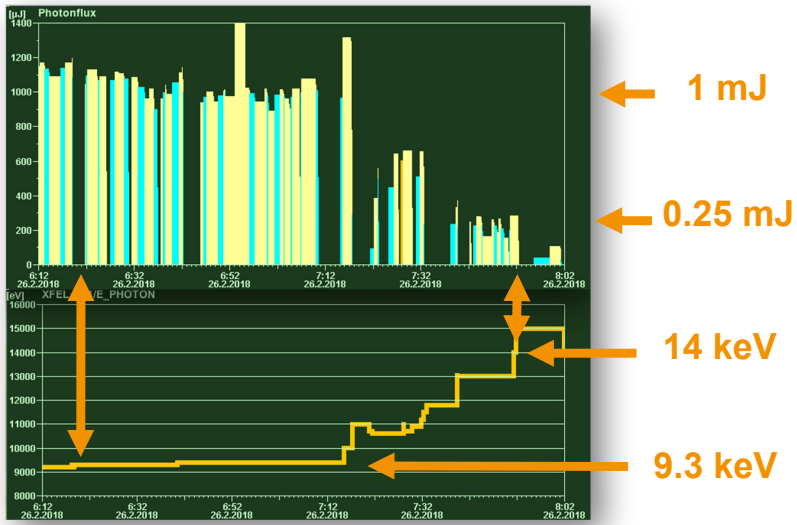
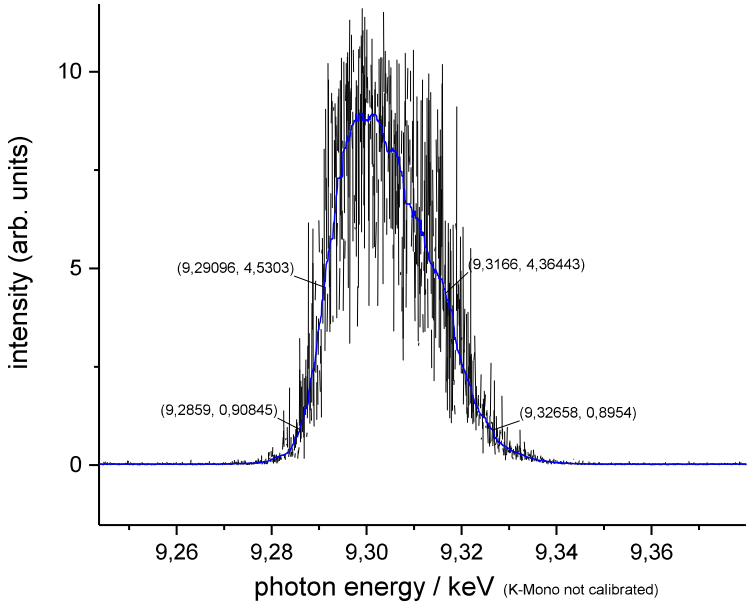
photon pulse energy

photon energy



SASE spectrum for 9.3 keV

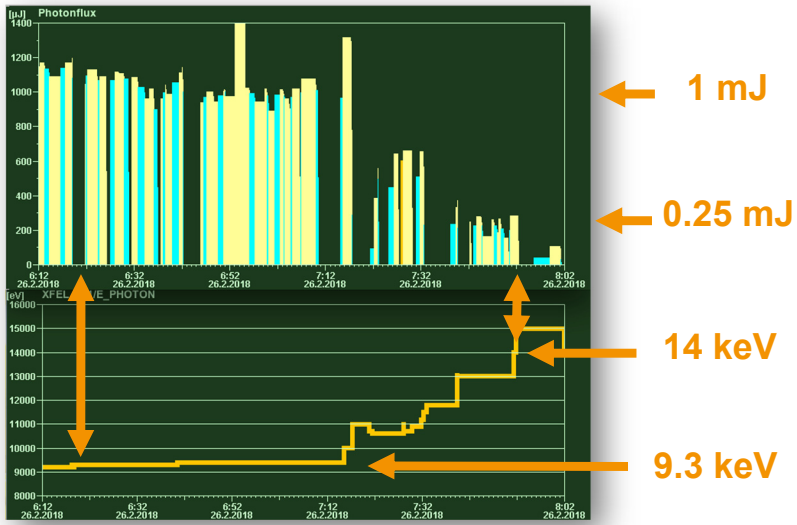


SASE photon energy in the hard X-ray beamline SASE1

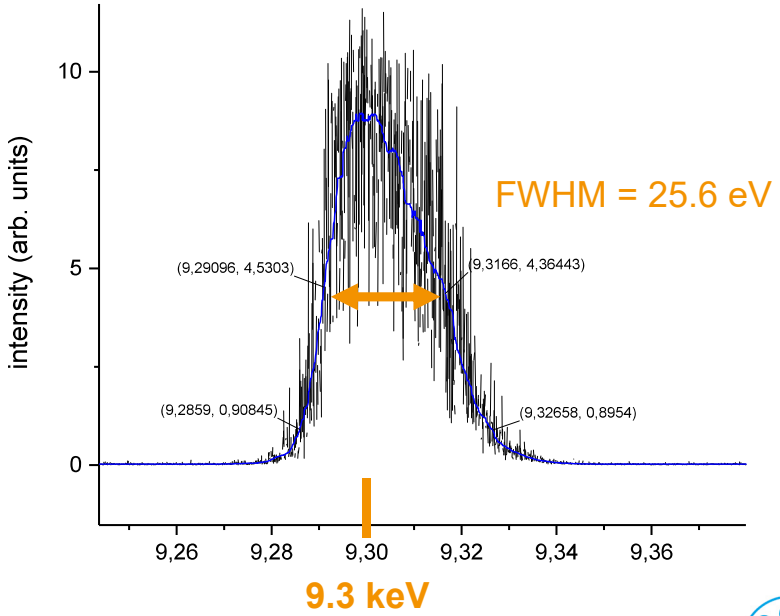
- The typical photon energy for user has been 9.3 keV so far.
- The maximum photon energy achieved so far has been 14 keV.

photon pulse energy

photon energy

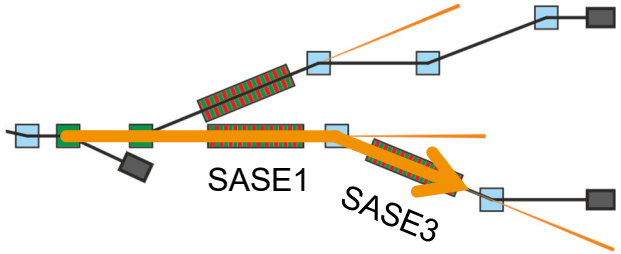


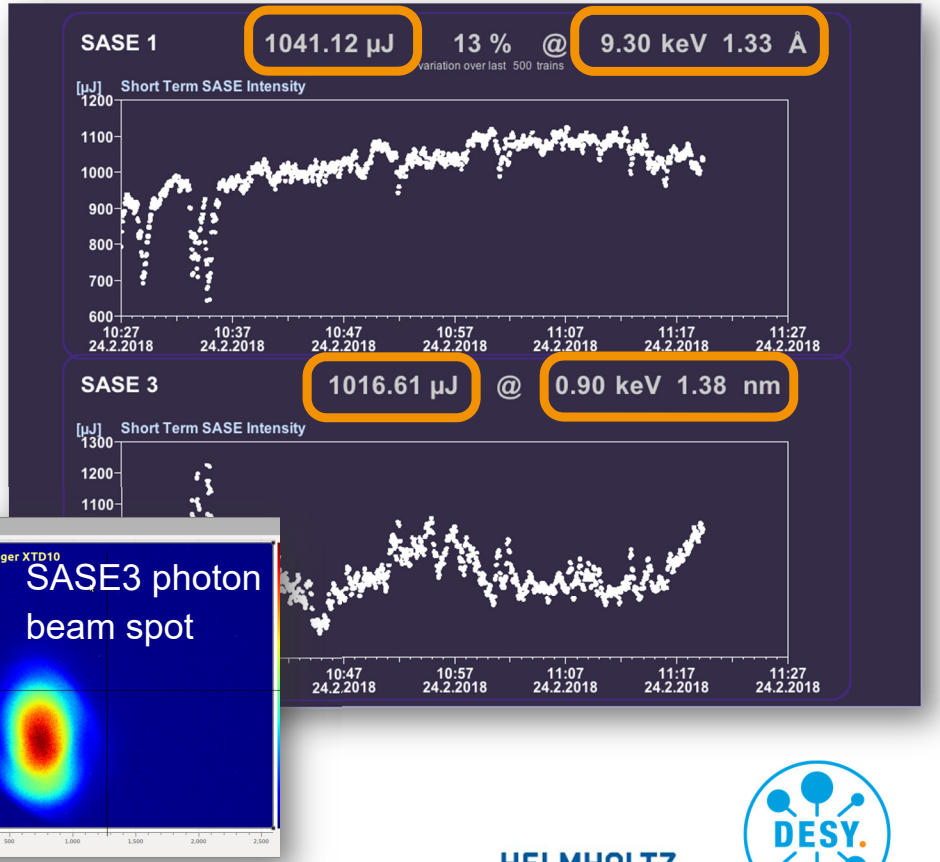
SASE spectrum for 9.3 keV



Serial operation of the hard and soft X-ray beamlines SASE1 and SASE3

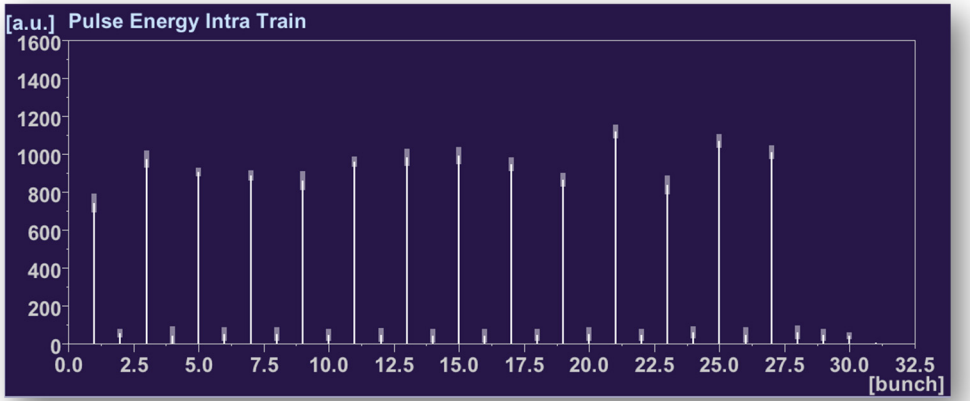
- The undulator beamlines SASE1 and SASE3 are in series.
- Bunches that lased in SASE1 do also lase in SASE3.
- The level of photon pulse energy in SASE3 depends on the level in SASE1.





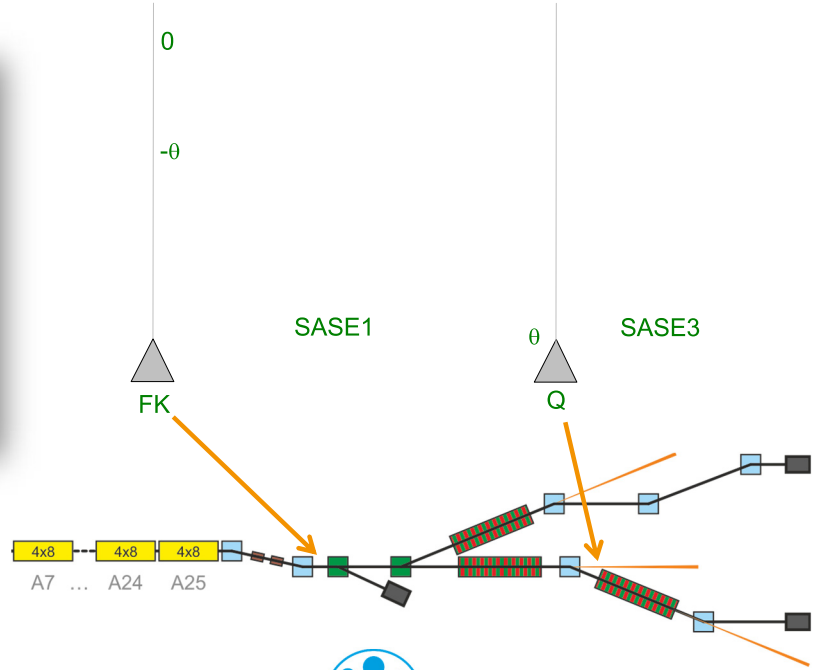
Fresh bunch lasing in SASE3

- The pulse energy of the fresh bunches in SASE3 does not depend on the pulse energy in SASE1.

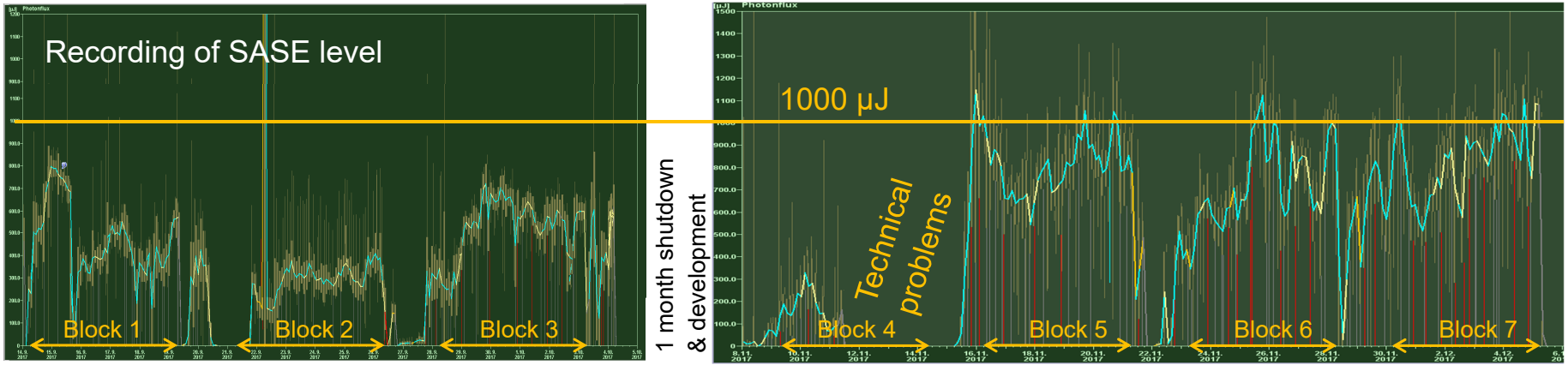


- Fresh bunch lasing in SASE3.
- Change of the repetition rate in SASE1 (as shown in this picture).

- The fast dump kickers can be used to start a betatron oscillation for bunches that should not lase in SASE1 but in SASE3.
- A DC corrector upstream SASE3 cancels the oscillation.

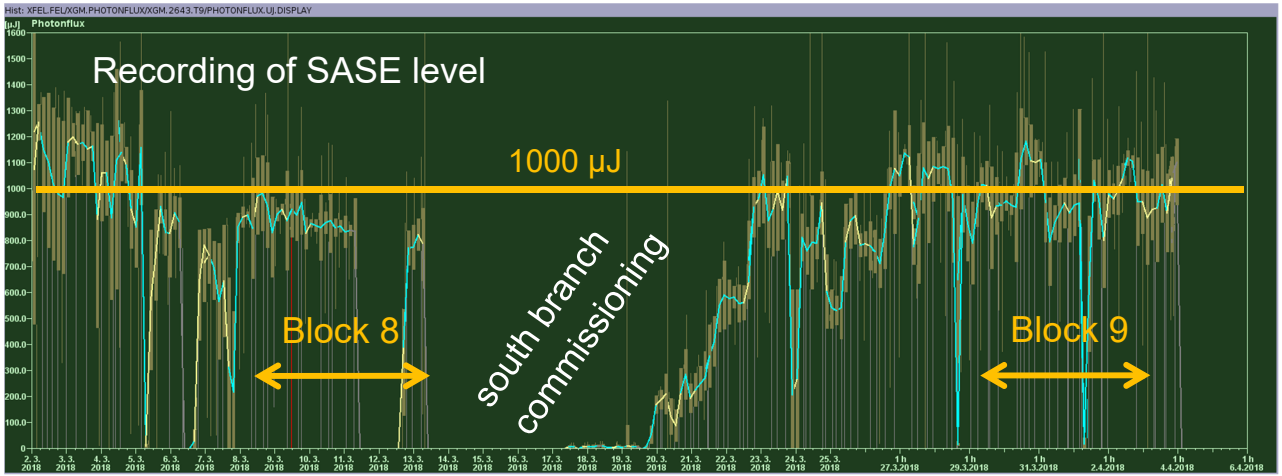


User runs block 1-7 in 2017: SASE performance



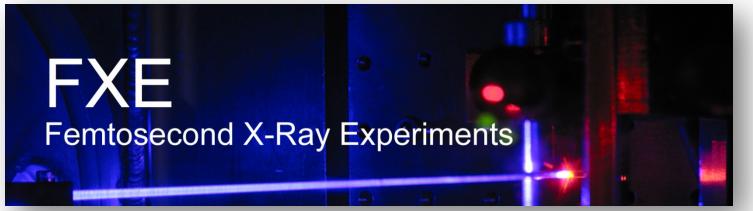
- Seven 5 day user blocks starting 14/09
- Availability (= SASE delivery above threshold) between almost 0% (Block 4) and well above 90% (Block 6&7).
- Little tuning needed (because of limited flexibility offered), but frequent small wavelength changes and variation of bunch number (1-30).

User runs in 2018: SASE performance

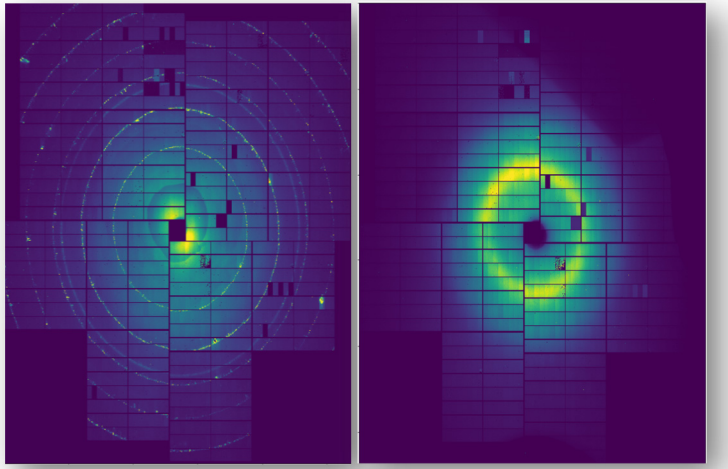


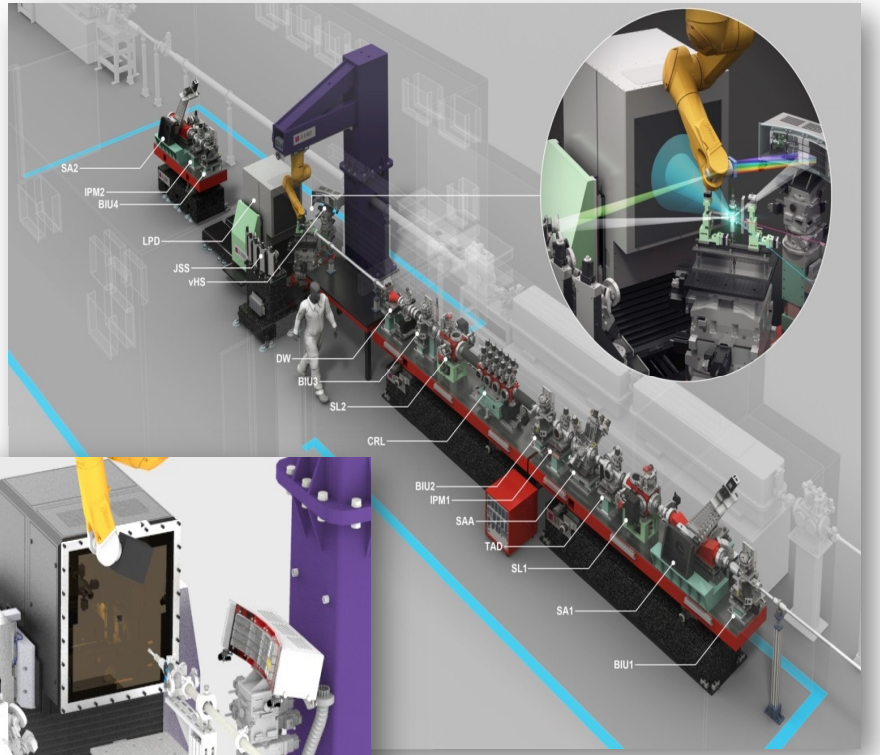
- Two 5 day user blocks so far in 2018.
- A higher SASE pulse energy could be provided compared to the user blocks in 2017.

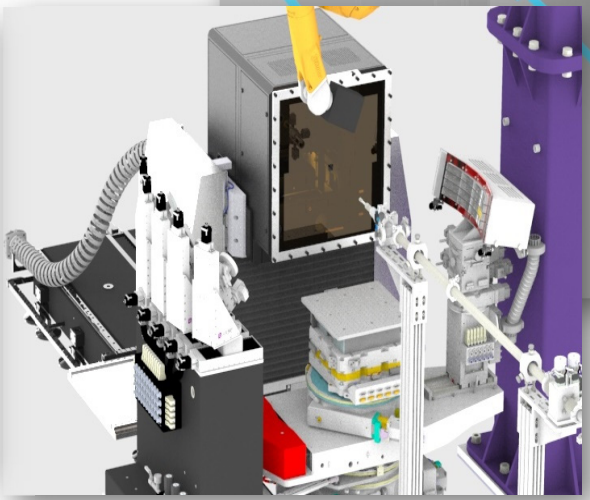
FXE instrument



LaB_6 calibration powder, ~140 mm to detector
LPD single shot images







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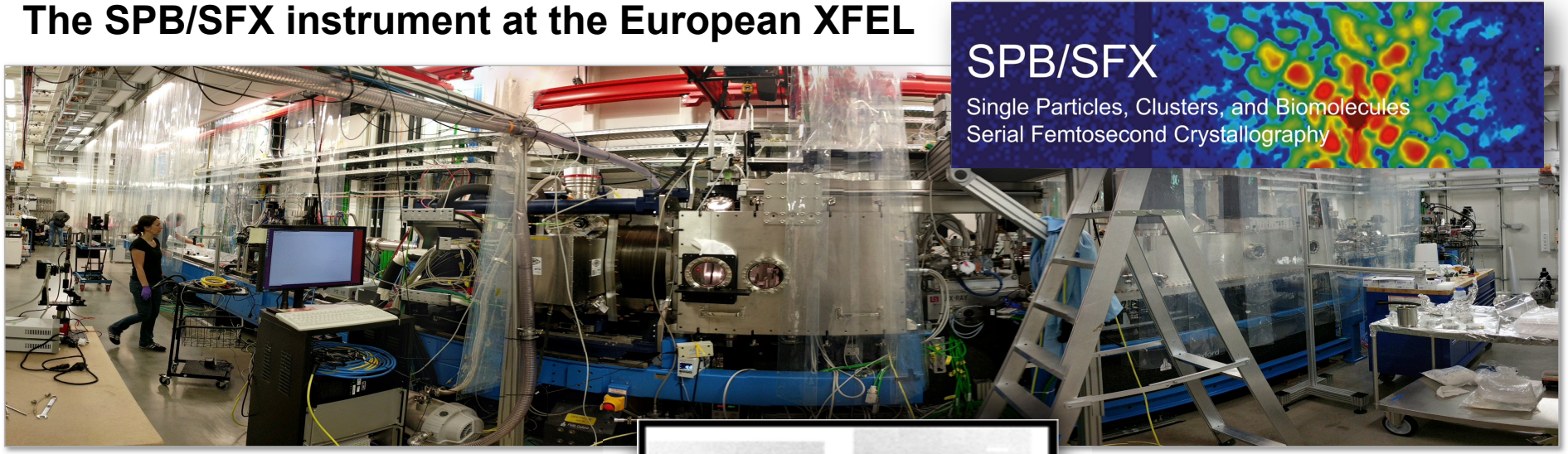
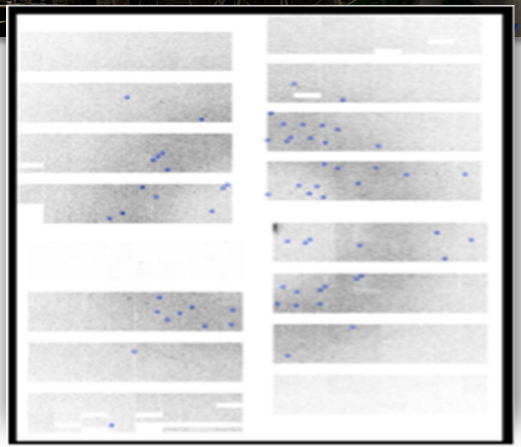
The SPB/SFX instrument at the European XFEL



The SPB/SFX instrument is used for serial crystallography and other structure determination experiments (particularly biology).

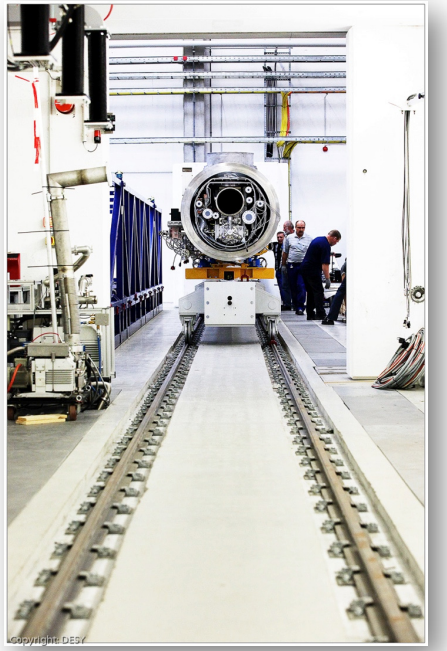


(Left) Early crystallography data from SPB/SFX, which has been successfully used to determine the structure of a test biomolecule.

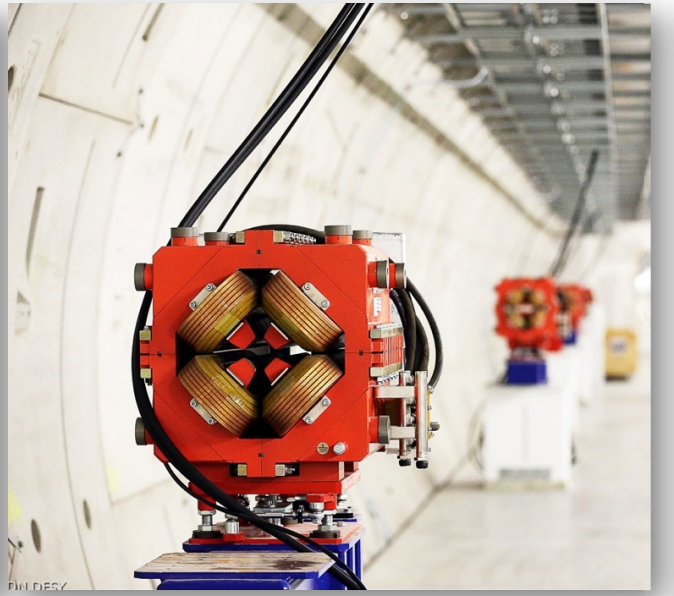
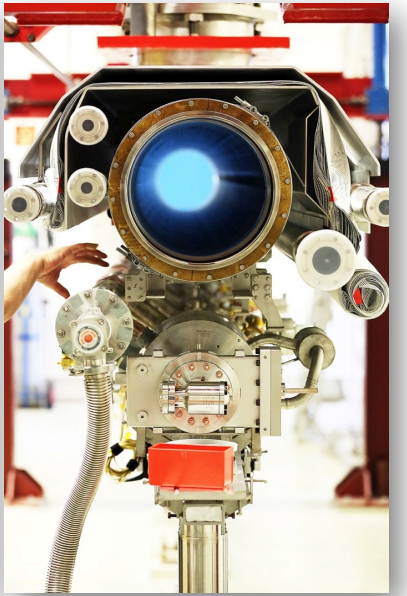
Plans

- Design electron beam energy (about 17.5 GeV) by summer 2018.
- Full # of bunches after linac by end of 2018.
- Increase maximum photon energy to 15 keV.
- First lasing SASE2 (Mai 2018).
- Improving performance and flexibility of all beamlines.

- Installation of self-seeding chicanes (December 2018).
- First user experiments in the soft X-ray beamline SASE3 (end of 2018).
- About 1200 h experiment commissioning & 1600 h user operation.





Thank you for your attention

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