European XFEL

Prof. Robert Feidenhans'l
Chairman of the European XFEL Management Board

- What is the European XFEL
- Organisation
- Accelerator
- Photon systems
- Experiments
- Outlook

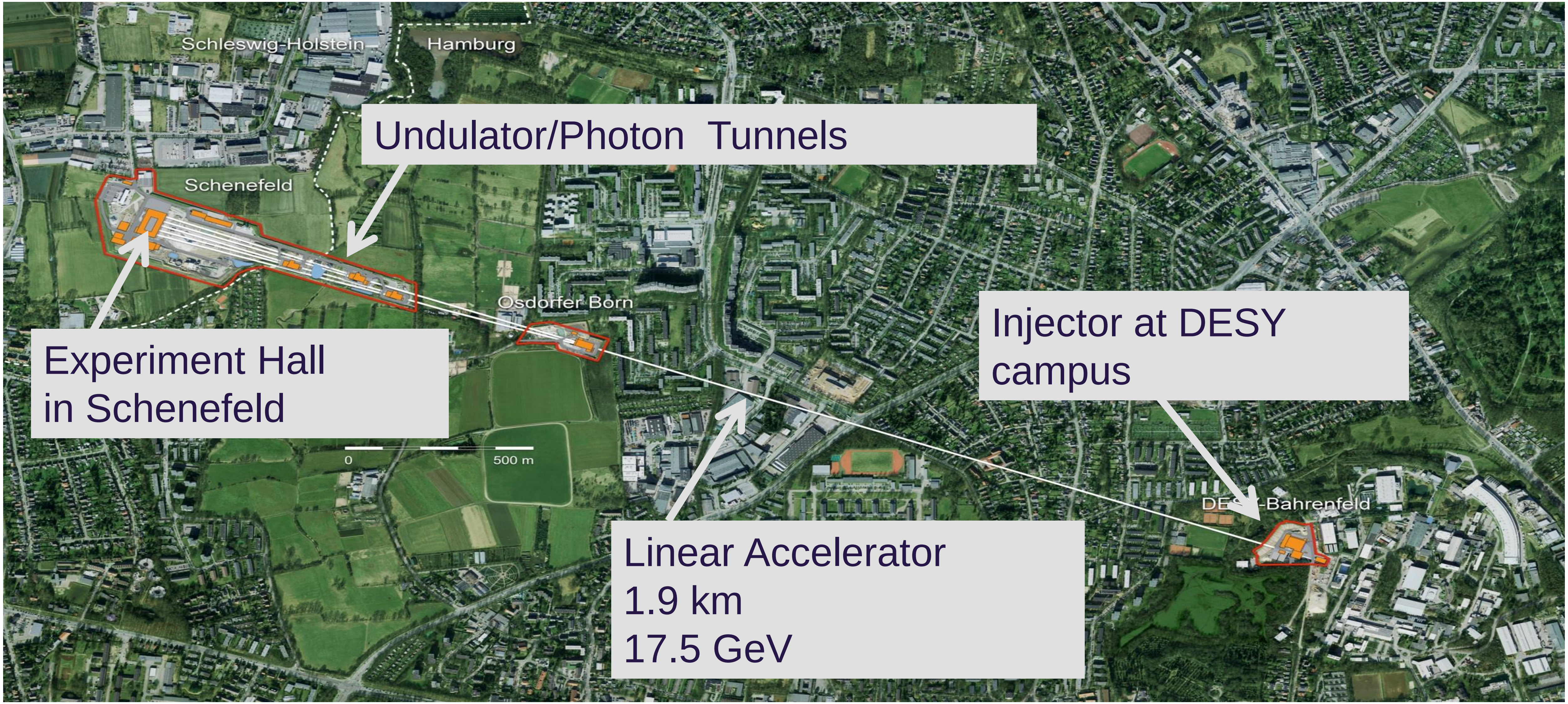
- Schenefeld und Hamburg
- European User Facility for X-ray Science
- Start of operation: July 1. 2017
- First robust users September 2017.

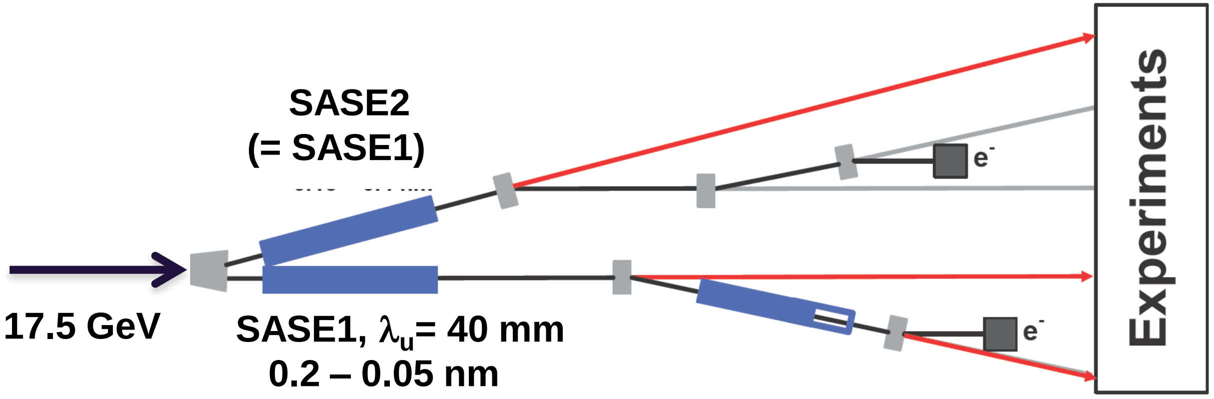
+

About the European XFEL

- Start 2009
- Task : Construction and running of the X-ray Laser Facility
- Germany (Bund, Hamburg (65 M€) und Schleswig-Holstein (25M€)) 58%, Russia 27 %, others 1–3%
- DESY operates the accelerator
- Staff XFEL about 300, Staff @ DESY about 250
- Budgets_
  - 1,22 Mrd. € (2005 prices)
  - 600 Mio € in cash, 600 Mio € in-kind
  - Expected yearly running costs about 118 Mio € (2018)

General layout of the European XFEL





Some specifications

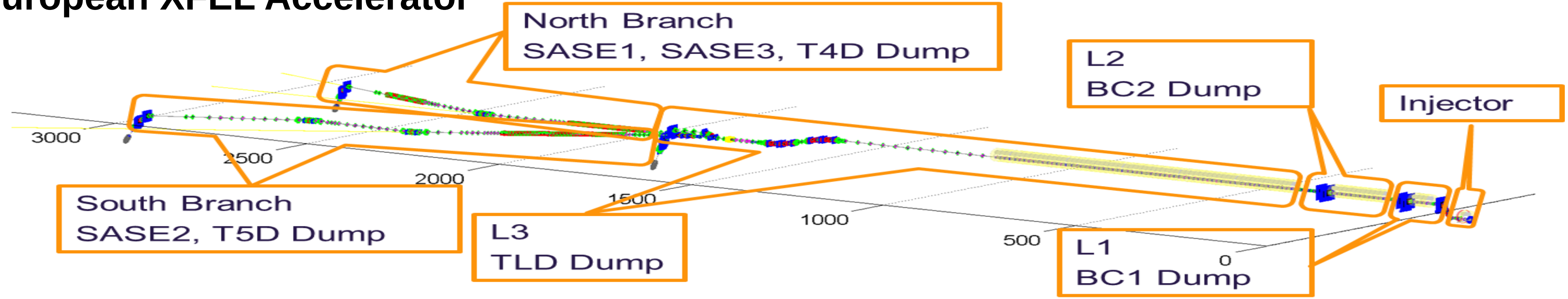
- Photon energy 0.3-24 keV
- Pulse duration ~ 10-100 fs
- Pulse energy few mJ
- Superconducting linac. 17.5 GeV
- 10 Hz (27 000 b/s)
- 5 beamlines / 10 instruments
  - Start version with 3 beamlines and 6 instruments
- Several extensions possible:
  - More undulators
  - More instruments
  - …….
  - Variable polarization
  - Self-Seeding
  - CW operation

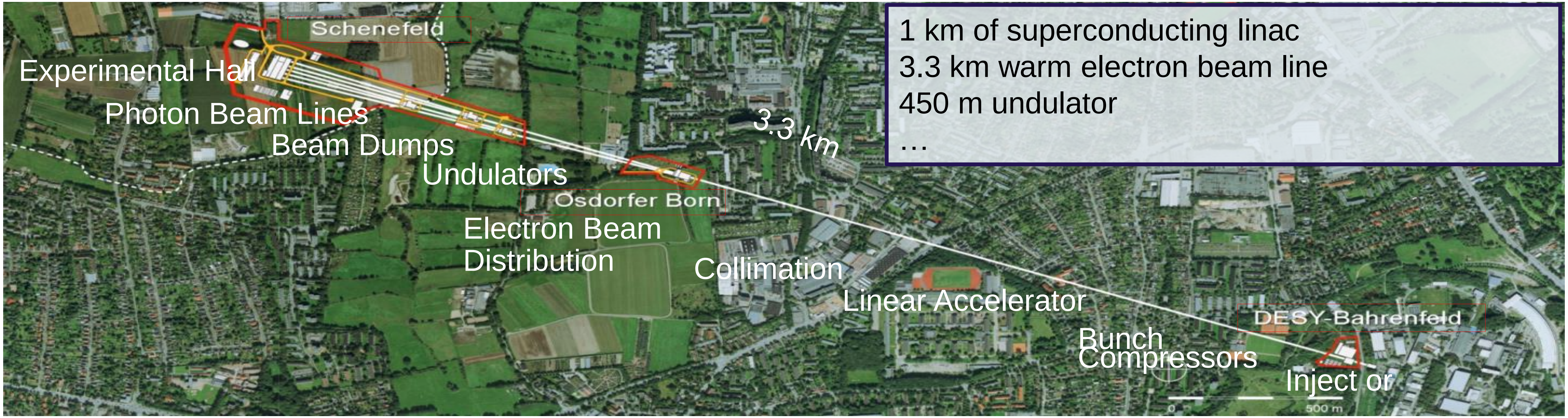
European XFEL
Accelerator Consortium

European
XFEL

Winni Decking, Hans Weise - DESY

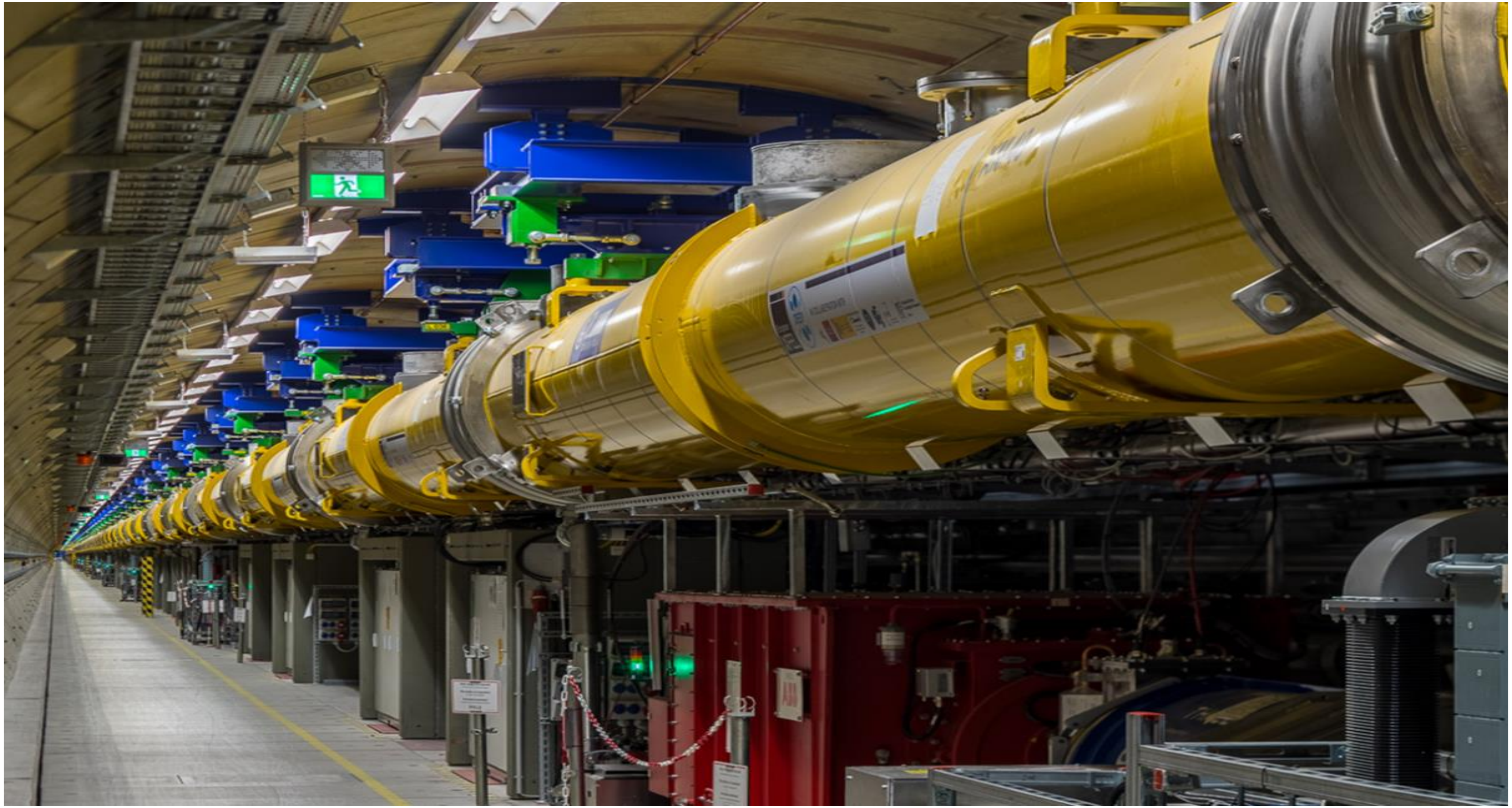
European XFEL Accelerator



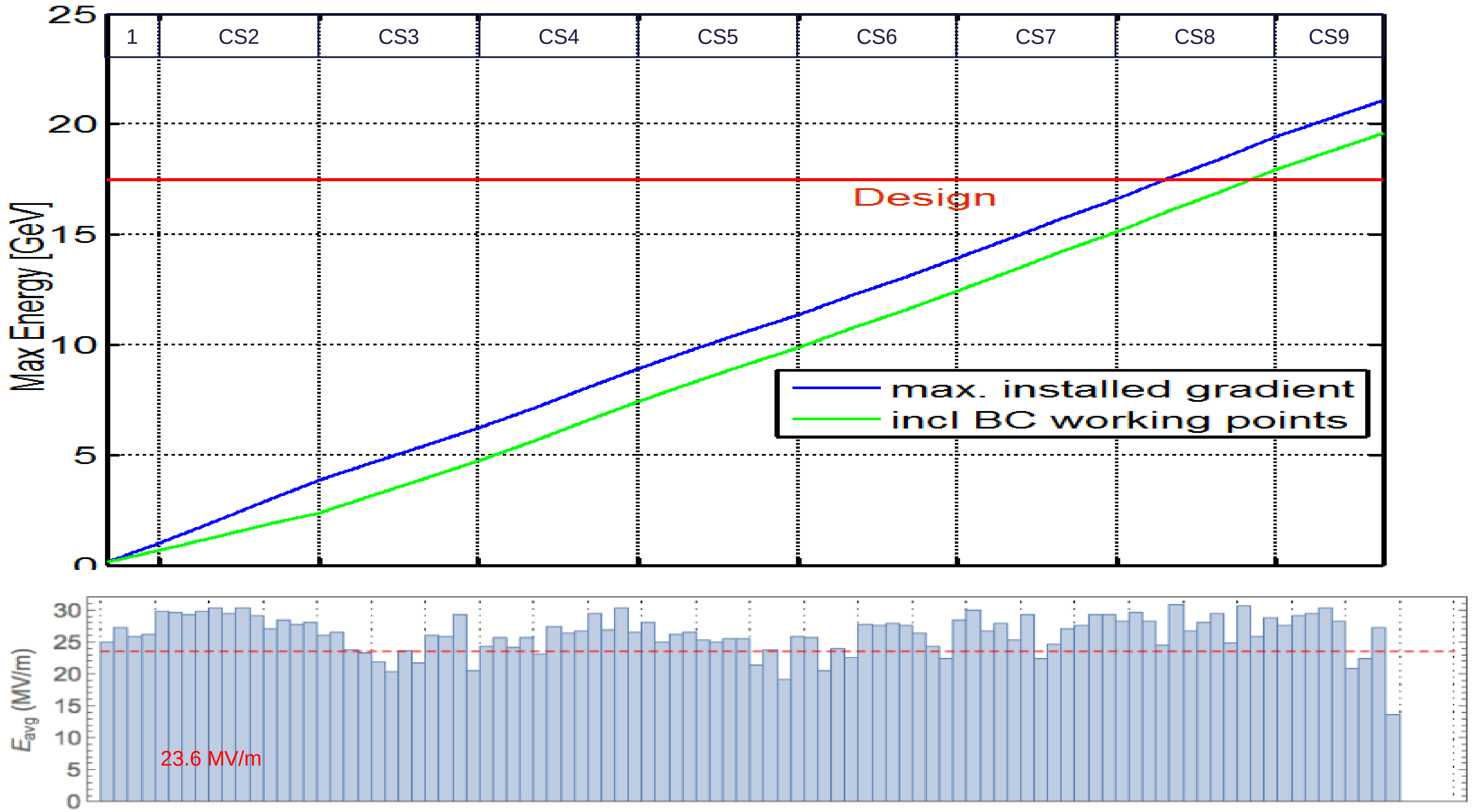


1 km of superconducting linac
3.3 km warm electron beam line
450 m undulator
…

Accelerator Modules



Energy Reach of European XFEL Modules



maximum energy reach

- after tunnel installation *and*
- according to accelerator module test

	Installed (GeV)	Module (GeV)
CS1	1.	1.05
CS2	3.89	4.06
CS3	6.29	6.72
CS4	8.91	9.49
CS5	11.38	12.09
CS6	13.92	14.76
CS7	16.63	17.62
CS8	19.42	20.44
CS9	21.09	22.23

the maximum energy during FEL operation needs to respect the bunch compressor (BC) working points

- 2.4 GeV nominal BC2 energy leads to approx. 19.5 GeV
- higher BC2 energy (e.g. 3.3 GeV) allows for > 20 GeV

increased max. energy assures higher availability

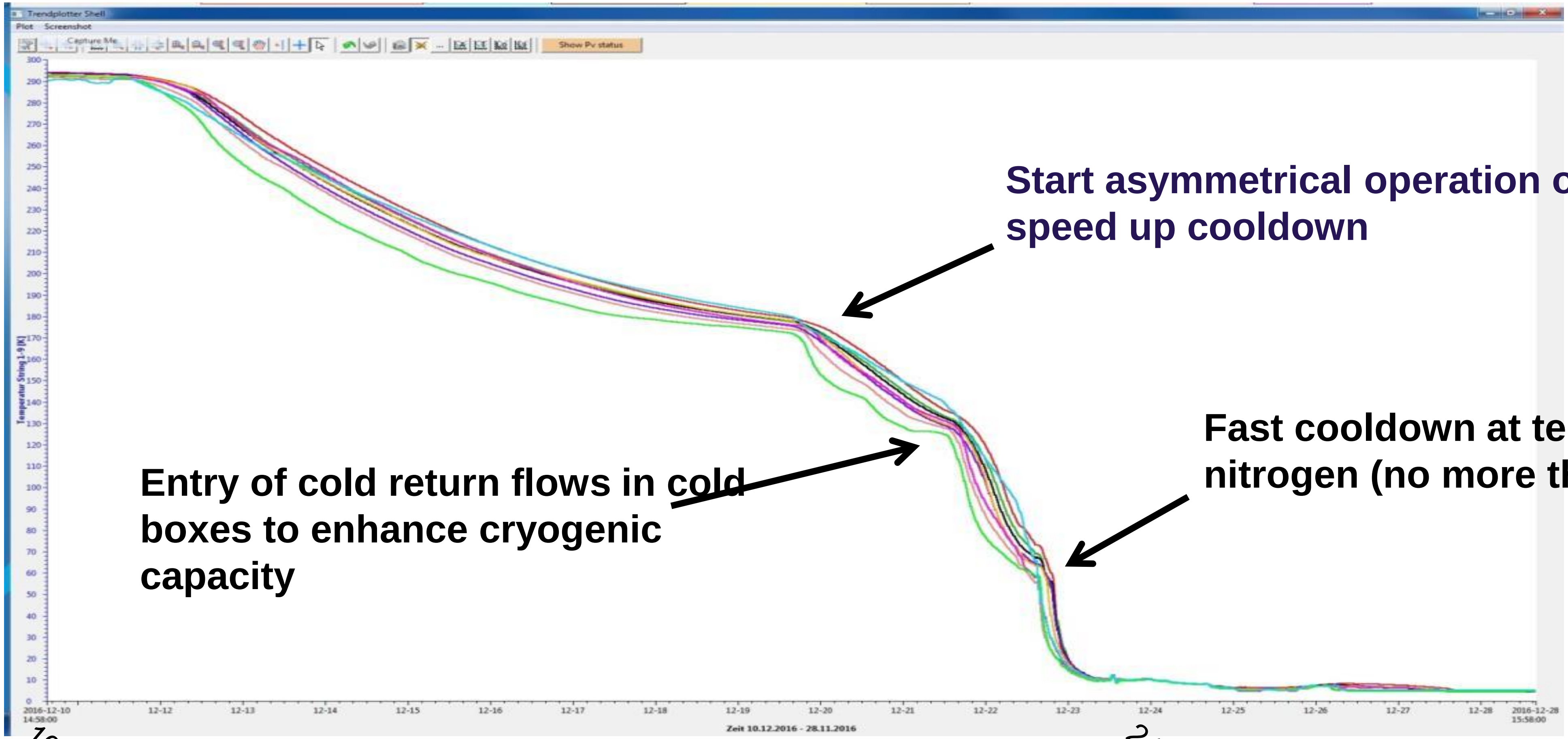
10

Injector in Operation 2015/2016

- Injector cool-down started beginning of 12/2015
- First Beam on December 18th , 2015 - commissioning till Q2/2016
- Full bunch train length (2700 bunches) reached and beam stopped in injector beam dump
- Projected emittance as expected (1...1.5 mm mrad)
- **Slice emittance measurements give 0.5 mm mrad for 500pC;** also over bunch train

11

10.12.2016: Start of Accelerator Commissioning First Cooldown of XFEL Linac (300K to 4K)



Start asymmetrical operation of two cold boxes to speed up cooldown

Fast cooldown at temperatures below liquid nitrogen (no more thermal stress)

Entry of cold return flows in cold boxes to enhance cryogenic capacity

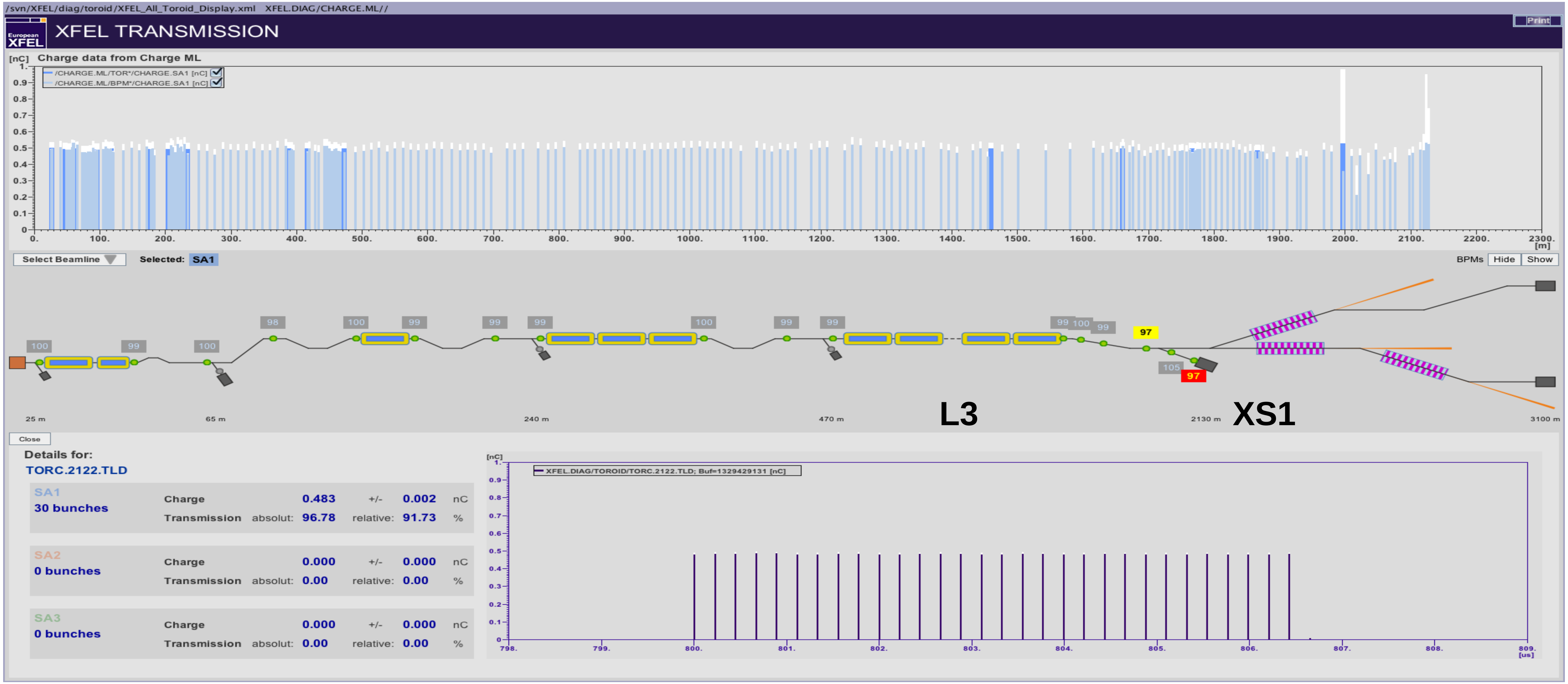
10.12.2016

24.12.2016

No Cold Leaks

12

Linac Commissioning started from Accelerator Control Room (BKR)

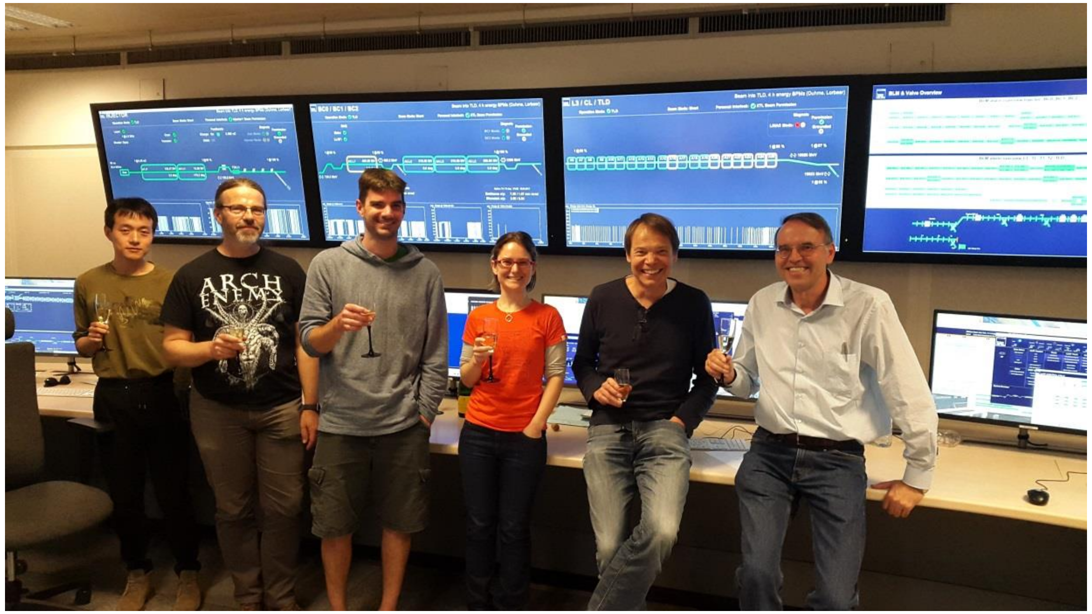

/svn/XFEL/diag/toroid/XFEL_All_Toroid_Display.xml XFEL.DIAG/CHARGE.ML//
XFEL TRANSMISSION
Print
Charge data from Charge ML
/CHARGE.ML/TOR*/CHARGE.SA1 [nC]
/CHARGE.ML/BPM*/CHARGE.SA1 [nC]
Select Beamline
Selected: SA1
BPMs Hide Show
L3
XS1
25 m
65 m
240 m
470 m
2130 m
3100 m
Close
Details for:
TORC.2122.TLD
SA1
30 bunches
Charge 0.483 +/- 0.002 nC
Transmission absolut: 96.78 relative: 91.73 %
SA2
0 bunches
Charge 0.000 +/- 0.000 nC
Transmission absolut: 0.00 relative: 0.00 %
SA3
0 bunches
Charge 0.000 +/- 0.000 nC
Transmission absolut: 0.00 relative: 0.00 %
XFEL.DIAG/TOROID/TORC.2122.TLD; Buf=1329429131 [nC]

Latest News : Mail Winni Decking April 1.

- Dear colleagues, today we transported a 10 GeV, 30 bunch beam to the TLD dump. With L1 and L2 and nominal energy, L3 reached about 50% of its design energy gain with 13 out of its 15 commissioned RF stations on the beam. 3 more stations will be ready by end of April, the two remaining ones after the next long shut-down.

- As expected the step from 2.5 GeV to 6 GeV required some steering because of the magnet remanence, after that any energy could be reached easy with just magnet scaling.

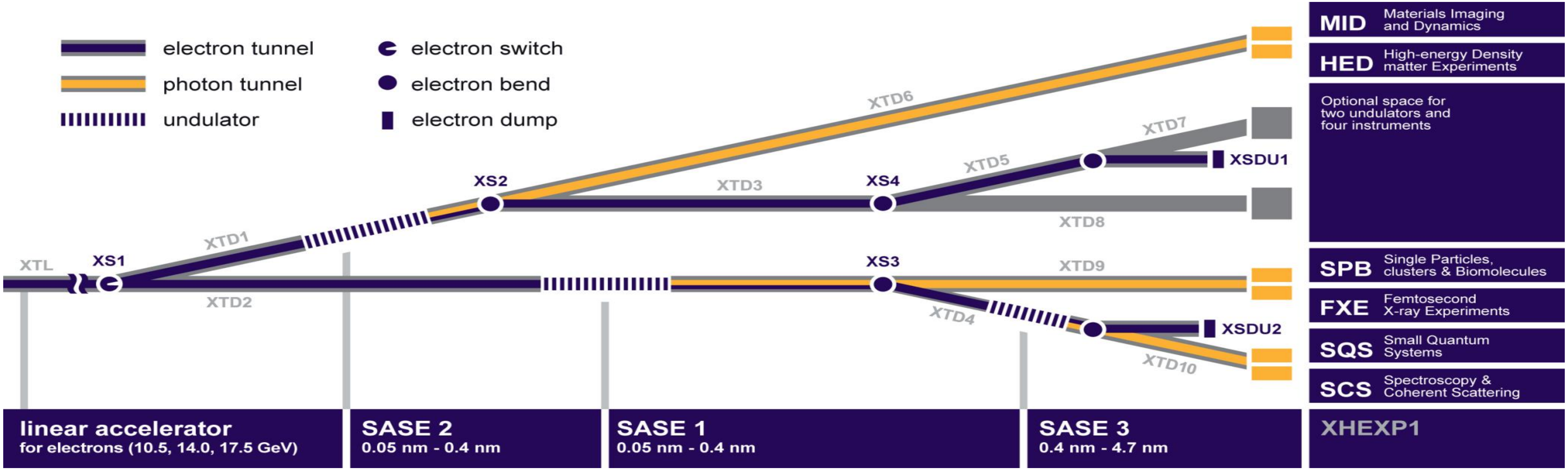
- Next steps will be setting up the bunch compression for 500 pC and raising the energy with stations A16 and A20 to about 12 GeV before we will pass into the SASE1 undulator end of April.



Overall Schedule For XFEL

1st Call for proposals (SASE1, 63 proposals)	January 2017
First lasing in SASE1	May 2017
Commissioning SASE1 and instruments	May-September 2017
Start of users operation FXE, SPB/SFX	September/October 2017 (2 months)
2nd call for proposals	Late Summer 2017
Lasing SASE3	Late Summer 2017
Lasing SASE2	Early 2018
Start users operation SASE2 and SASE3	Mid/late 2018

Undulator Segment	FEL radiation energy [keV]	Wavelength [nm]
SASE 1	3 - over 24 (Hard XR)	0.4 - 0.05
SASE 2	3 - over 24	0.4 - 0.05
SASE 3	0.27 – 3 (Soft XR)	4.6 – 0.4



Orange color: X-ray optics & Beam Transport

SASE System without

With enclosure

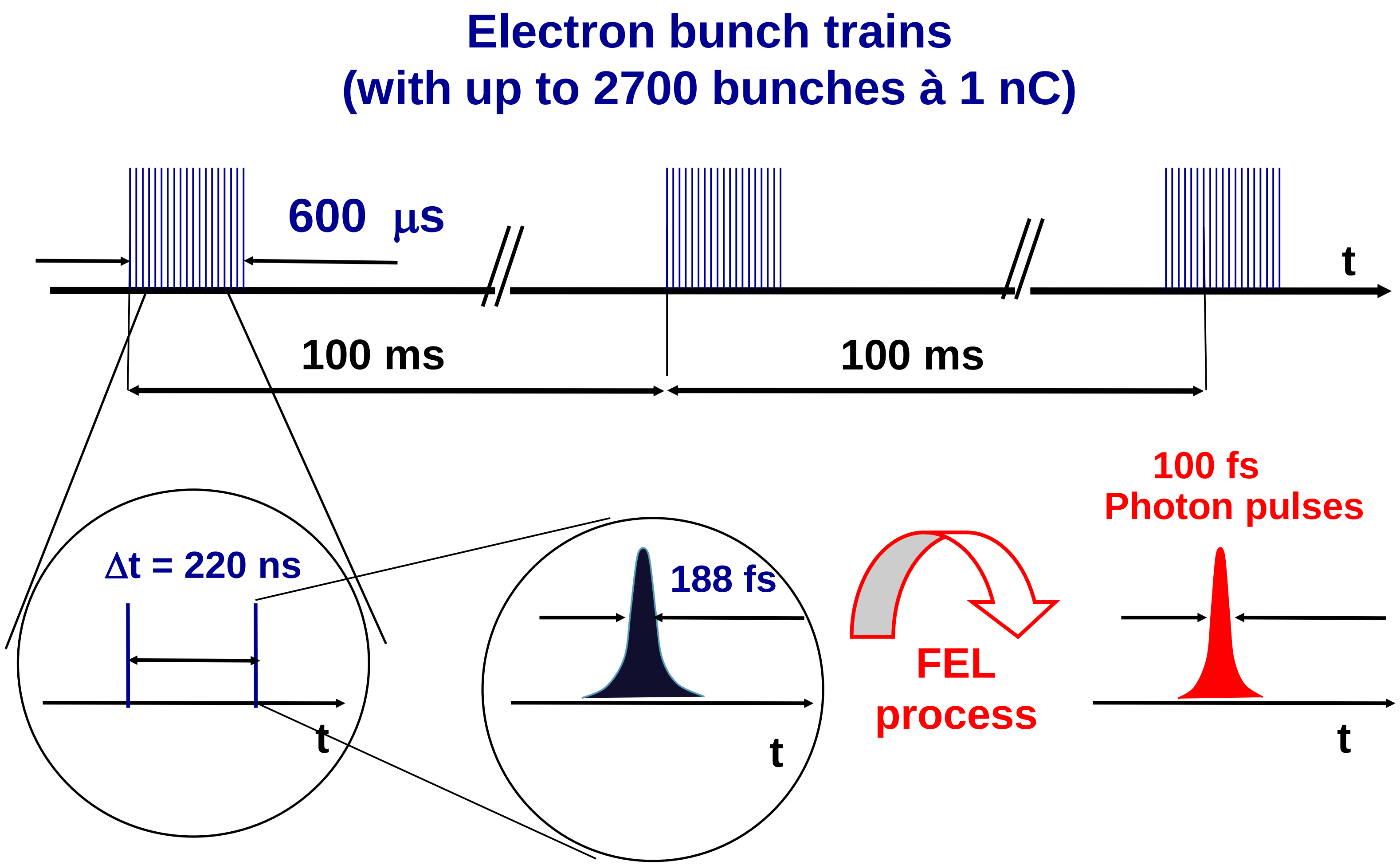
All gaps closed to 10 mm

- Hardware installed & aligned
- Control system & remote controls operational
- Air conditioning commissioned & operational

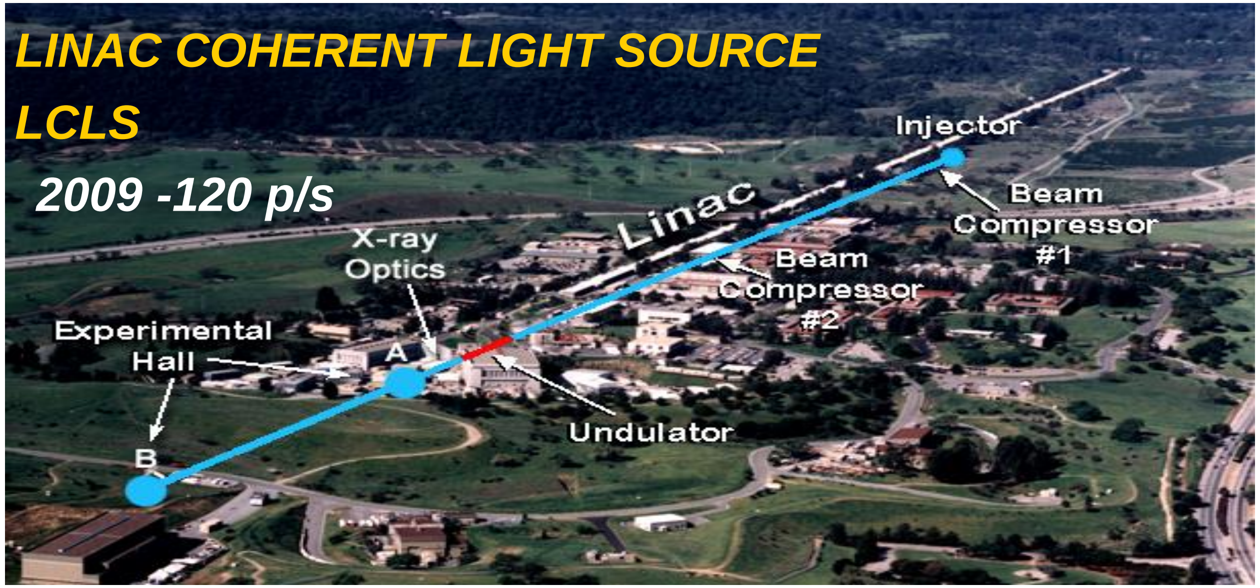
- All gaps can be closed to 10 mm
- System is fully operational
- Final system tests ongoing

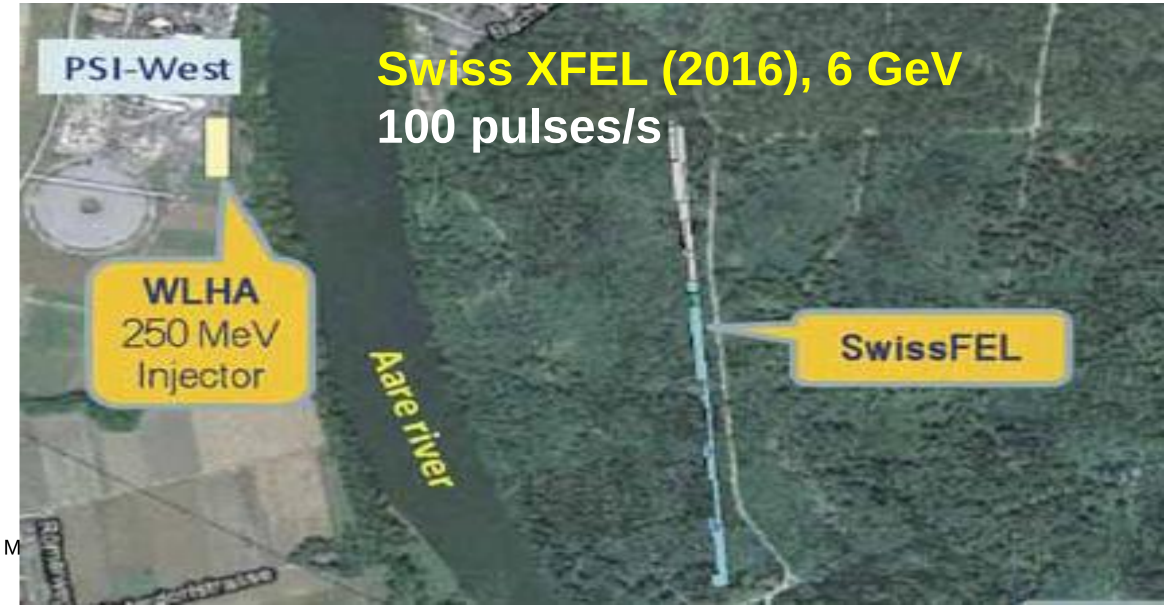
Plan: SASE3 undulator will be fully operational by the end of March 2017

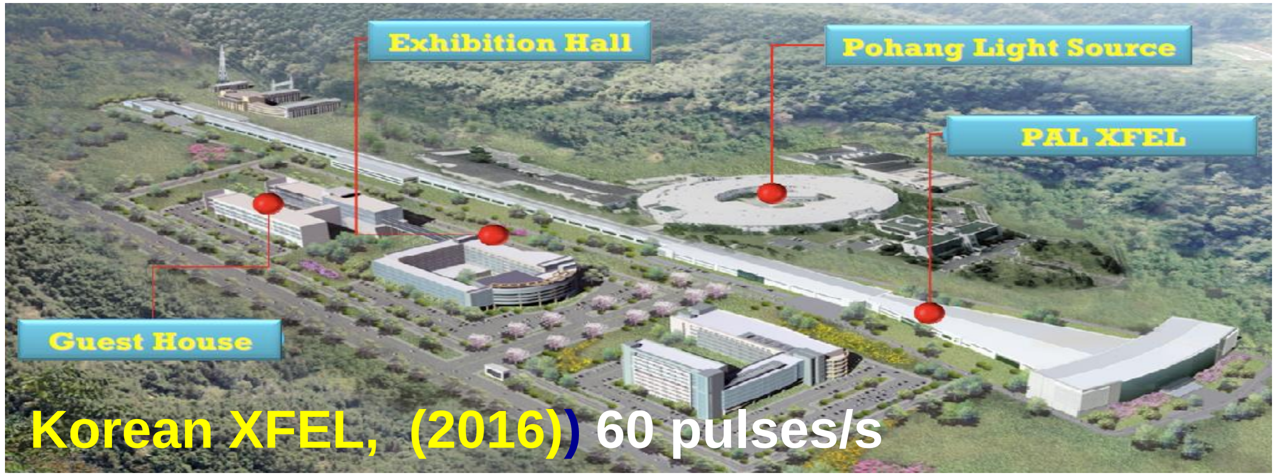
XFEL bunch structure



The European XFEL in the International Context : Hard X-ray FELS







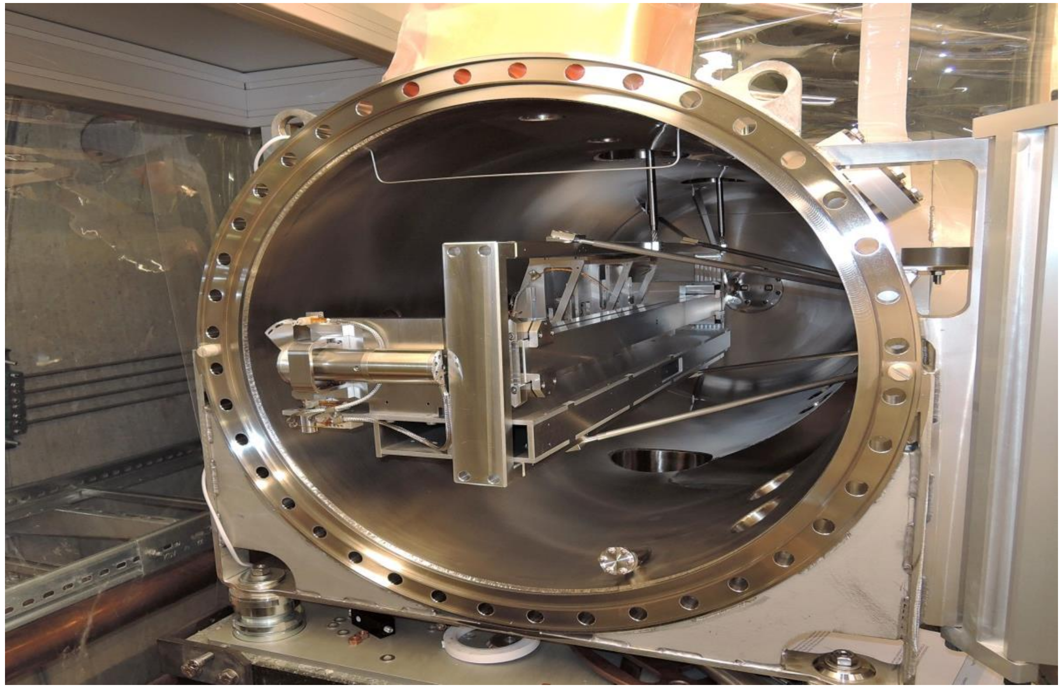
M

Comparison of the hard X-ray FEL Projects

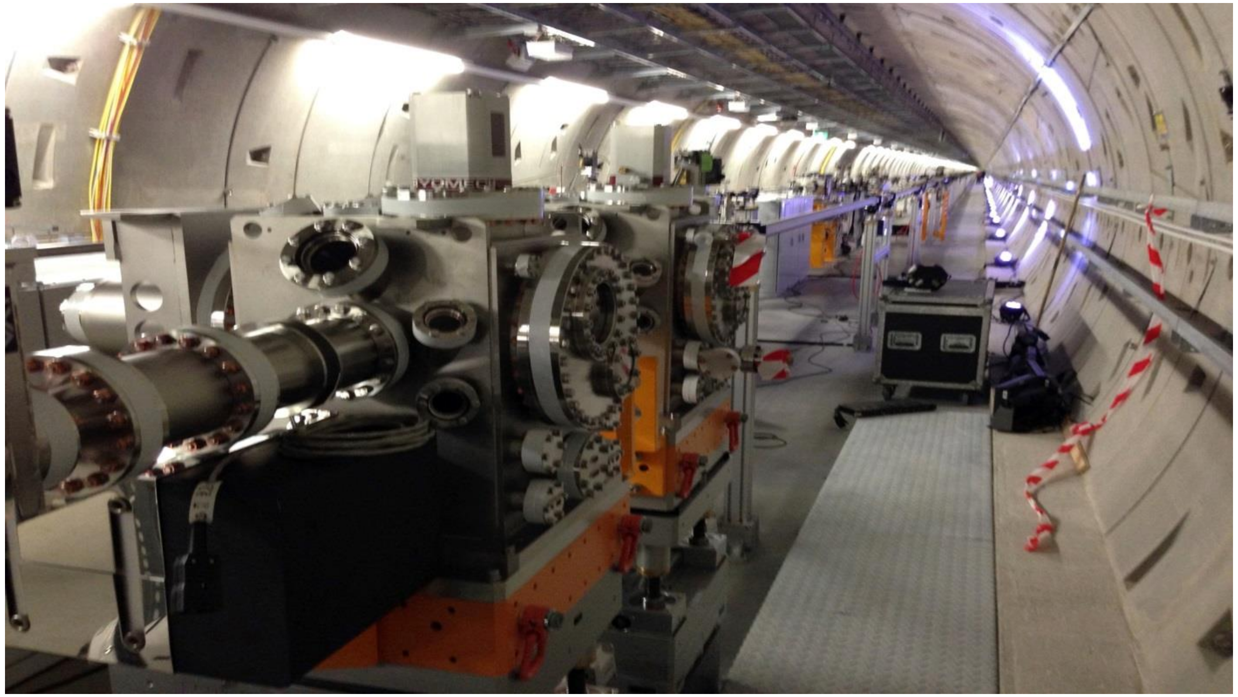
Project	LCLS I, US	SACLA, JP	European XFEL	SwissFEL, CH	PAL-XFEL, KR	LCLS II, US
Max. electron energy (GeV)	14.3	8.5	17.5	5.8	10	4
Wavelength range (nm)	0.1−4.4	0.06−0.3	0.05−4.7	0.1−7	0.06−10	0.25 – 4.7
Photons/pulse	~ 10^{12}	2 x 10^{11}	~ 10^{12}	~ 3.6 x 10^{10}	10^{11}−10^{13}	2 10^{11} – 2 10^{10}
Peak brilliance	2 x 10^{33}	1 x 10^{33}	5 x 10^{33}	7 x 10^{32}	1.3 x 10^{33}	
Pulses/second	120	60	27 000	100	60	10^5 - 10^6
Date of first beam	2009	2011	2017	2016	2016	2019

Status of SASE1 tunnel installation

- Vacuum system completed
- Installation of mirrors ongoing
- Debugging of cables + software
- Some very last cabeling (monochromator, shutters to DESY system) ongoing



Installation of bender in M2 mirror chamber with dummy mirror



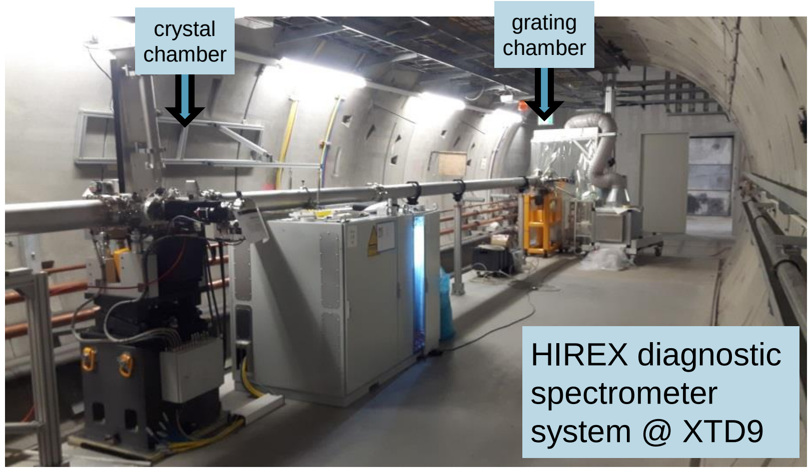
End of XTD9 tunnel with hard X-ray monochromator

Beam diagnostics SASE1 – XTD9

- all planned WP74 vacuum systems are installed in SASE1 (XTD2 and XTD9 tunnels)
- all devices are fully cabled and under technical commissioning

XGM@XTD9

HIREX crystal chamber



HIREX diagnostic spectrometer system @ XTD9

Pop-in Monitors @ XTD9

SASE1 Hutches and Infrastructure

- Fire safety in the experiment hall has been approved by the authorities
  - A real-life smoke extraction test was carried out

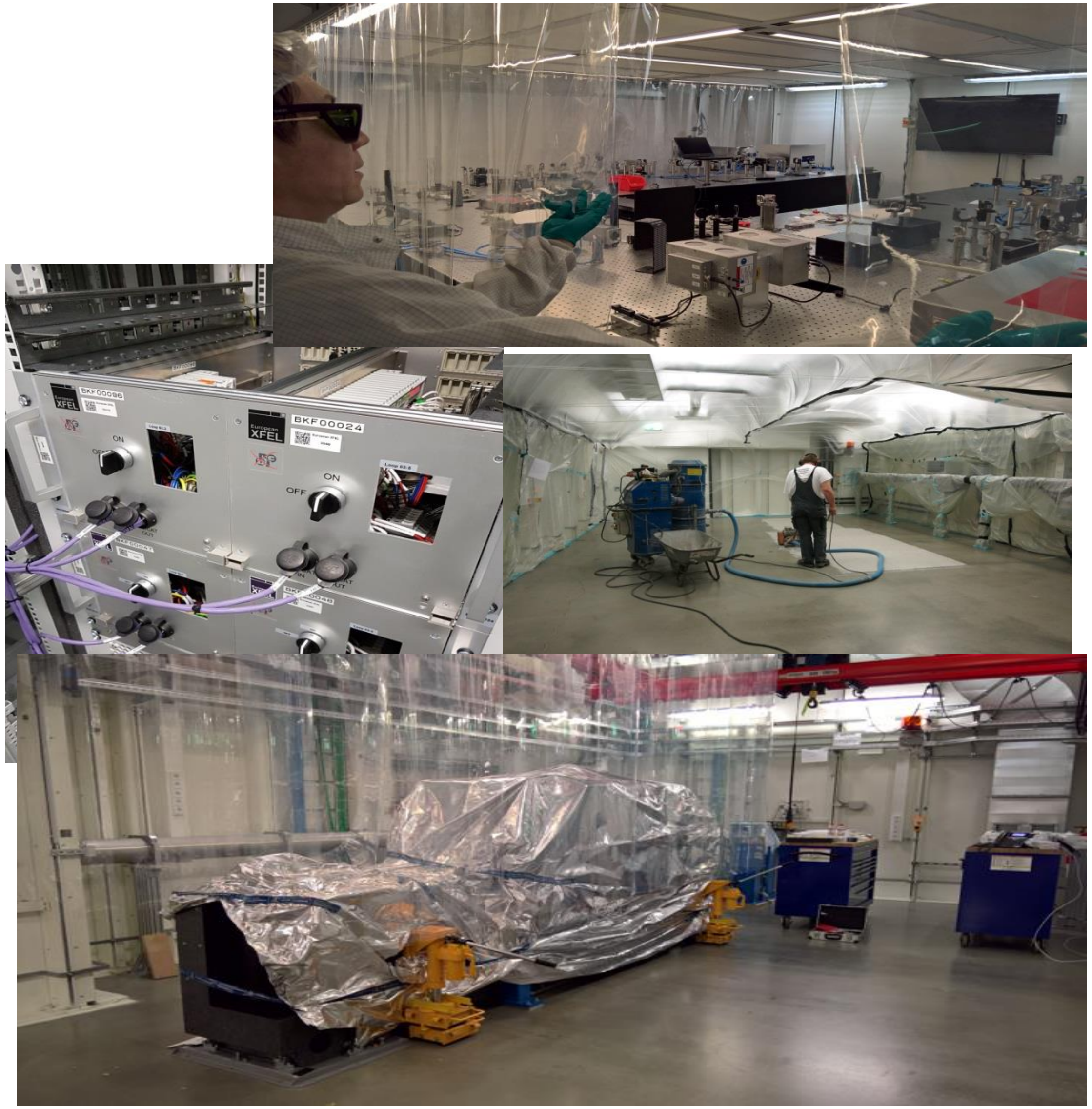
- Hutch infrastructure is operational:
  - Power, cooling, media and monitoring are handed over and running
  - AC systems are still being fine tuned

- IT systems and cabling are installed and operational

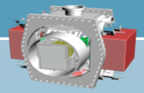
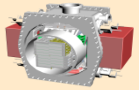
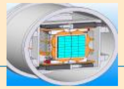
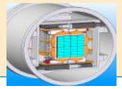
- Dedicated instrument cabling is on-going
  - Fully done for FXE
  - Fully done for SPB Optics hutch
  - 75% done for the SPB Instrument Hutch
  - In total more than 3000 cables needed to be installed with a length of almost 100km

SASE1 Instrument Installation, Commissioning and Safety

- Pump-probe laser room has clean-room conditions
  - installation of laser systems is on-going
- FXE day 1 configuration is installed
  - Some late floor works was required for air pads
  - Work is still on-going on some internal cabling
  - Electronics installations are complete
  - Instrument commissioning has started
- SPB/SFX Installation is on the way
- Laser interlocks are installed and programmed
  - Tests of the system are on-going
- Radiation interlocks are installed
  - Tests are somewhat delayed due to work in the tunnels
  - Completion expected end of May
- Mandatory risk assessments are being worked on



Detectors – Timeline and Status

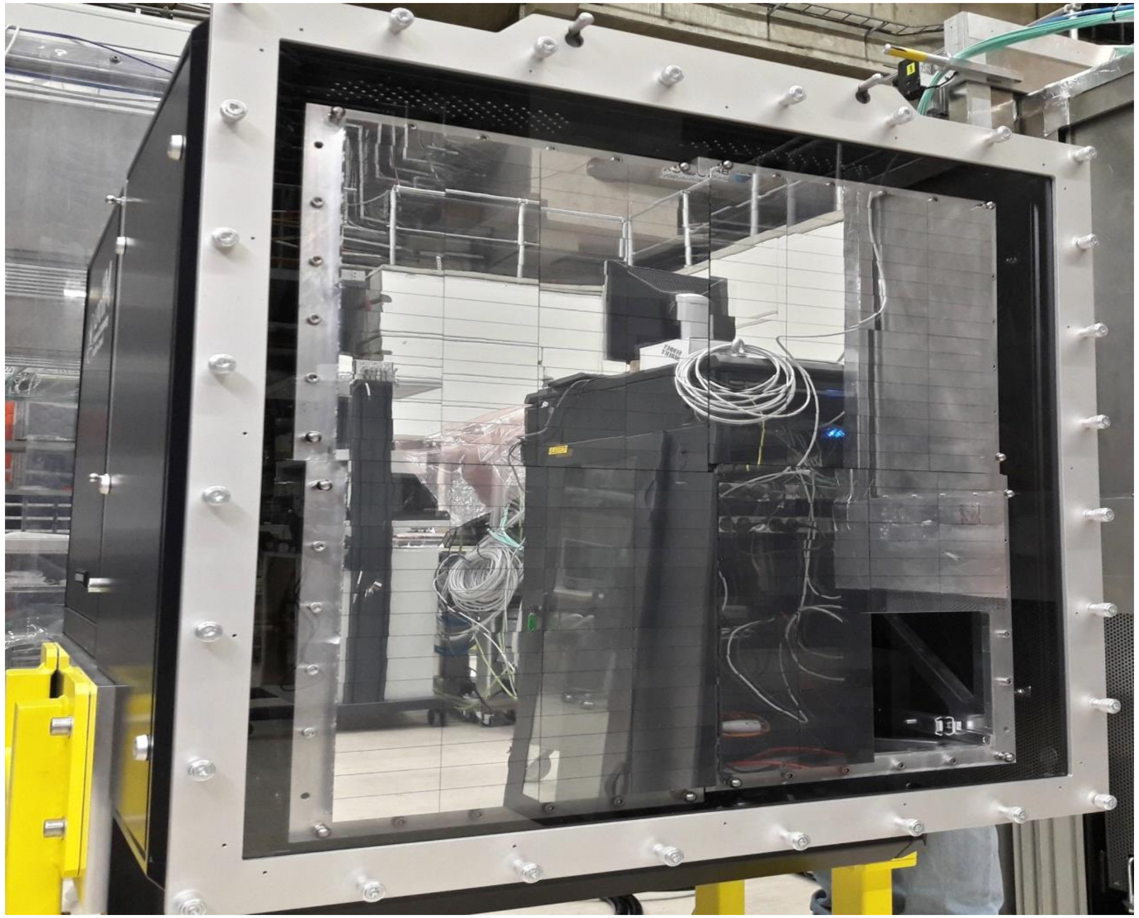
Detector System	Beam Line	Scientific Instrument	Project Status	Arrival at XFEL	Ready for Installation at Experiment
AGIPD 	SASE I	SPB	DAQ/Control Integration	December 2016	July 2017
LPD 	SASE I	FXE	Integration/Testing	February 2017	June 2017
FastCCD 	SASE III	SCS	Control Inte-gration/Calib.	May 2016	August 2017
AGIPD 	SASE II	MID	Integration	August 2017	October 2017
Gotthard V2 	SASE I-III	FXE/HED/MID/SPB/Diagnostics	Development	February 2018	April 2018
DSSC MiniSDD 	SASE III	SCS	Development	February 2018	May 2018
MCP DLD 	SASE III	SQS	Development	≈Mid-End of 2017	Approx. 1 year after delivery
DSSC DEPFET 	SASE III	SCS/SQS	Development	Sensors available 2017	

External: Development → Integration → Testing →

at XFEL: Commissioning Calibration DAQ/Control Integration → End-2-End Test → Beam Line Integration Commissioning → User Operation

LPD 1 Mpix Detector at HERA South

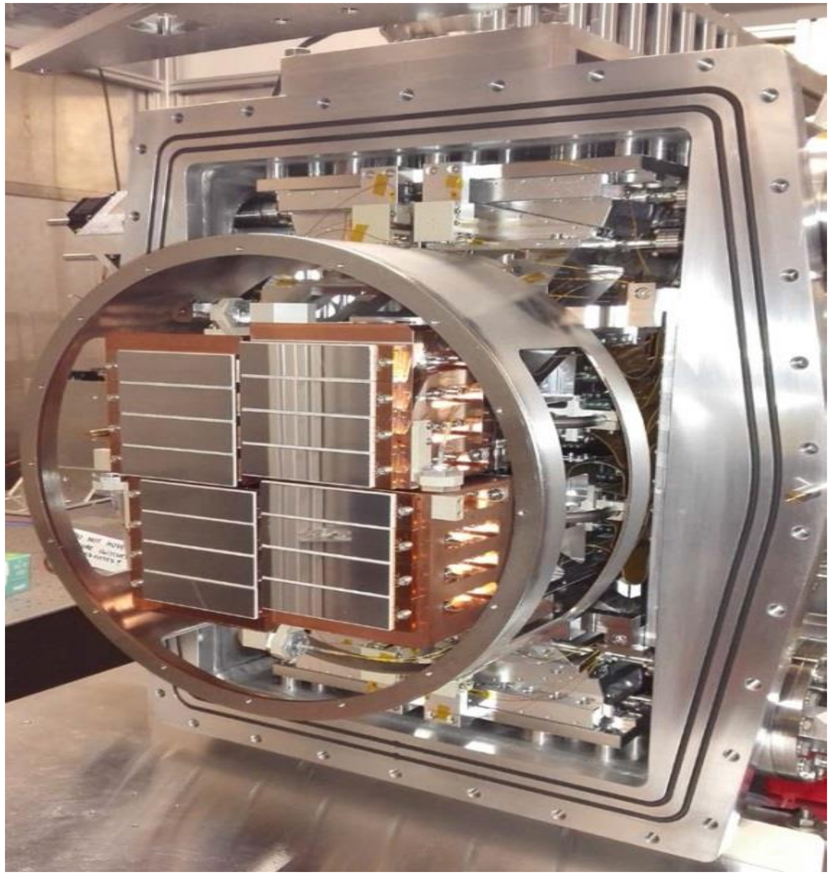
LPD Sensor Plane with Sensor Modules



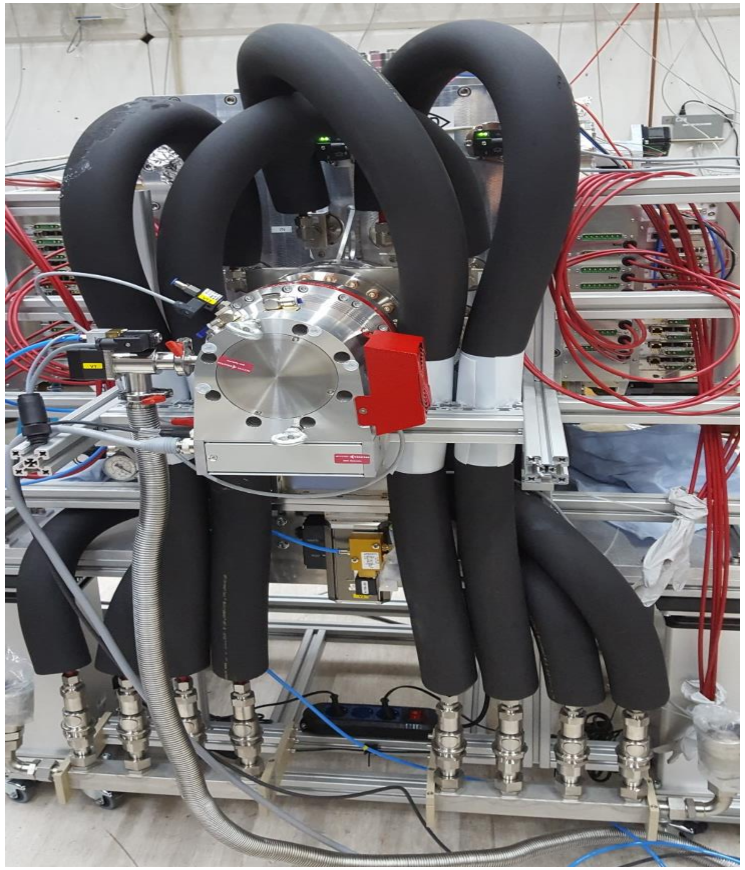
LPD Housing

AGIPD 1 Mpix Detector at HERA South

AGIPD Sensor Plane



AGIPD Connected to Cooling System



AGIPD Power System

KARABO: XTD2/XTD9 Commissioning

- 40 Components
- 20 Equipment Types
- 1030 individual Equipments

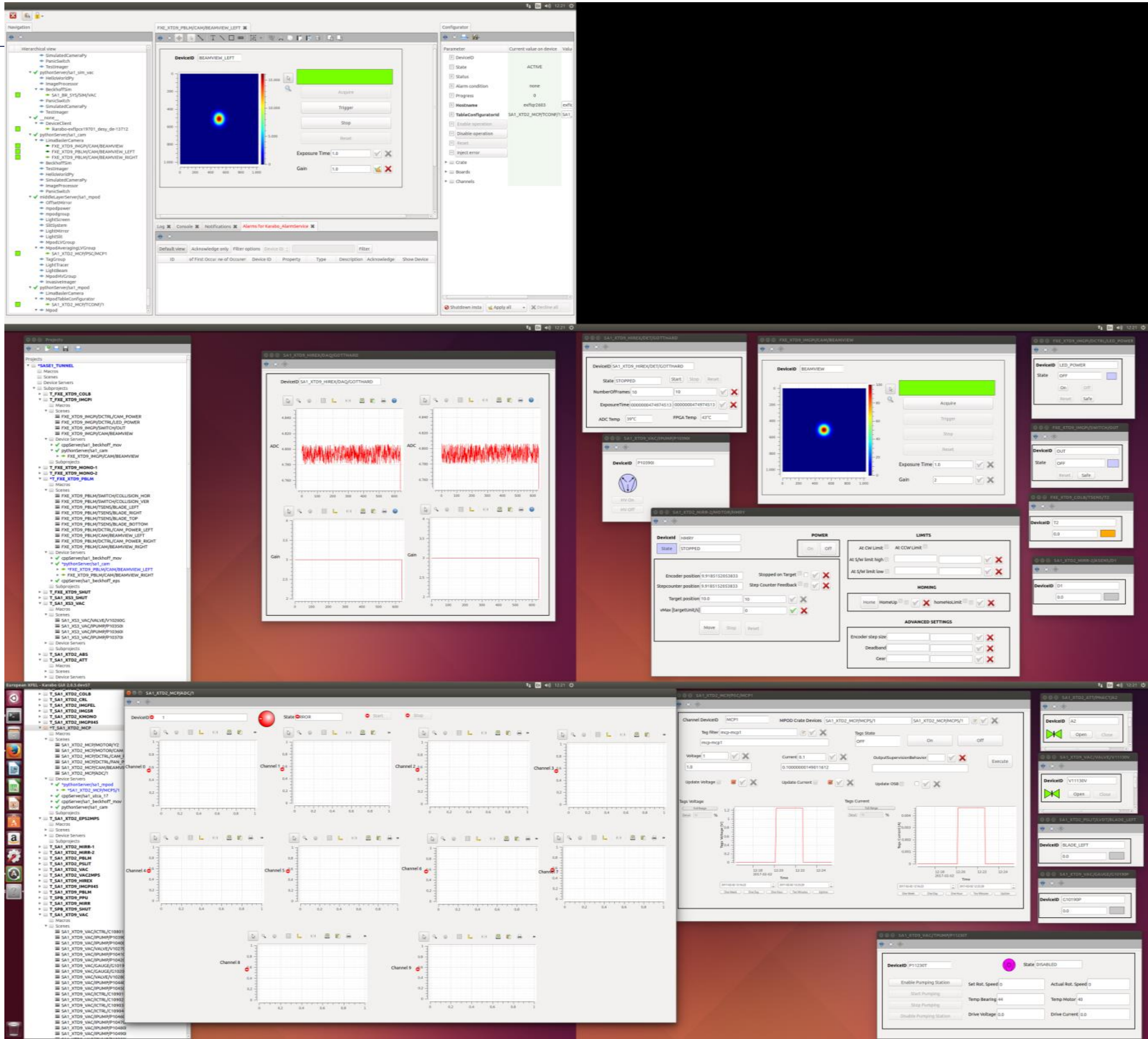
Priority for <u>Tunnel Closure</u>:

remote controllability

- Karabo 2 deployed
- All basic GUI scenes provided

Current Priorities:

- Hardware / Software handover
- Integration with Data Acquisition
- User-friendly control
  - complex scenes & features
  - macros and logics



Hard X-rays

SPB/SFX: Ultrafast Coherent Diffraction Imaging of Single Particles, Clusters, and Biomolecules

- Structure determination of single particles: atomic clusters, bio-molecules, virus particles, cells.

MID: Materials Imaging & Dynamics

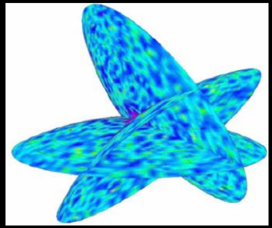
- Structure determination of nano-devices and dynamics at the nanoscale.

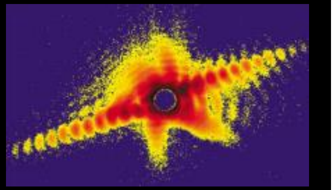
FXE: Femtosecond X-ray Experiments

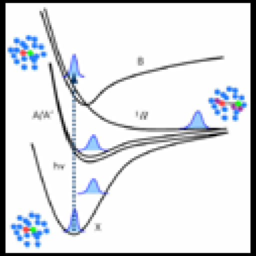
- Time-resolved investigations of the dynamics of solids, liquids, gases

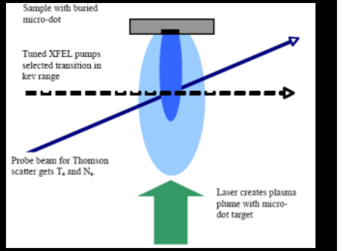
HED: High Energy Density Matter

- Investigation of matter under extreme conditions using hard X-ray FEL radiation, e.g. probing dense plasmas









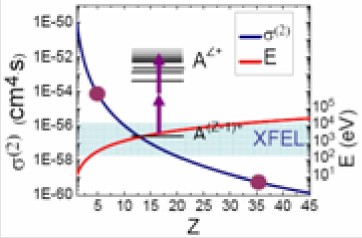
Soft x-rays

SQS: Small Quantum Systems

Investigation of atoms, ions, molecules and clusters in intense fields and non-linear phenomena

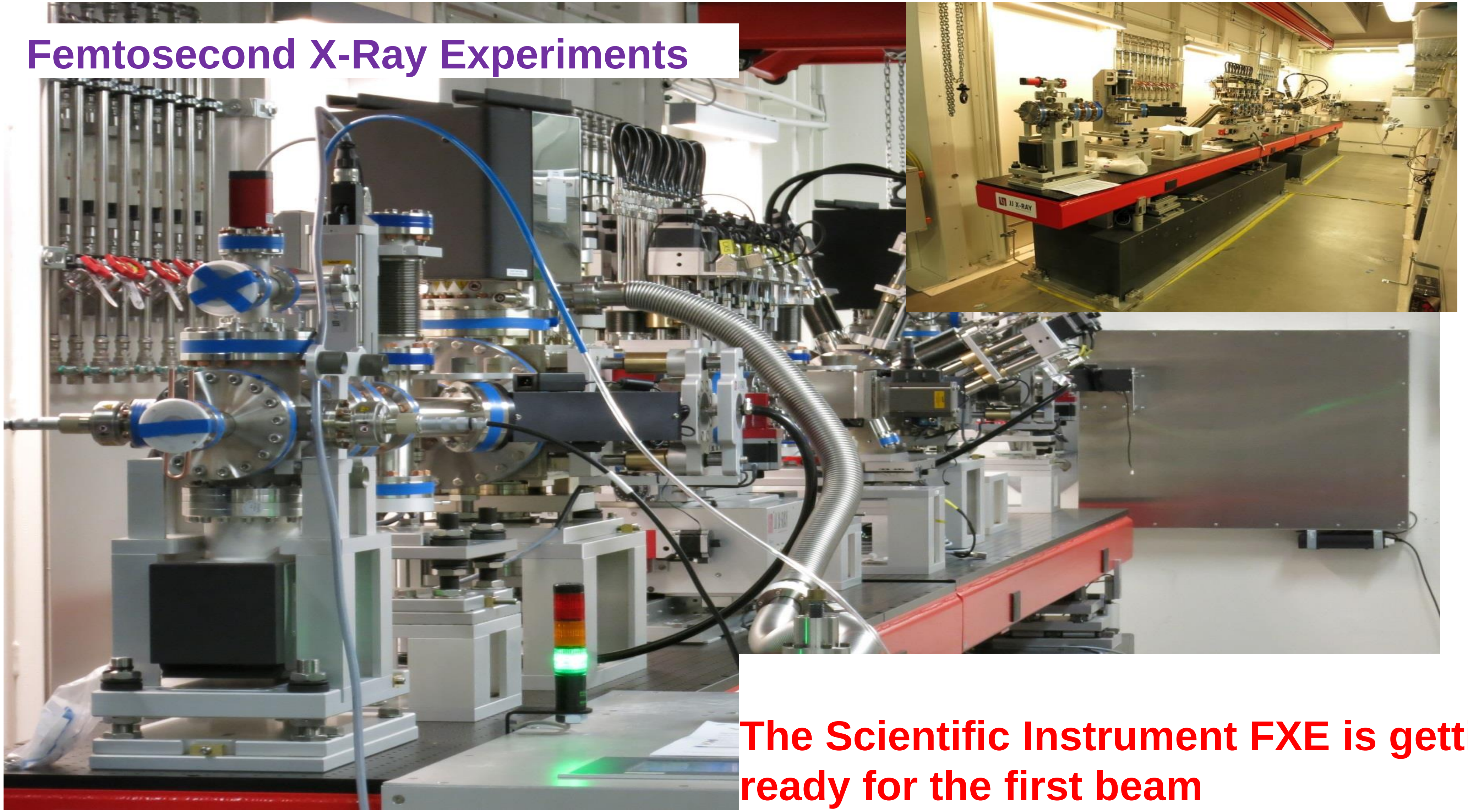
SCS: Soft x-ray Coherent Scattering/Spectroscopy

Electronic and real structure, dynamics of nano-systems and of non-reproducible biological objects



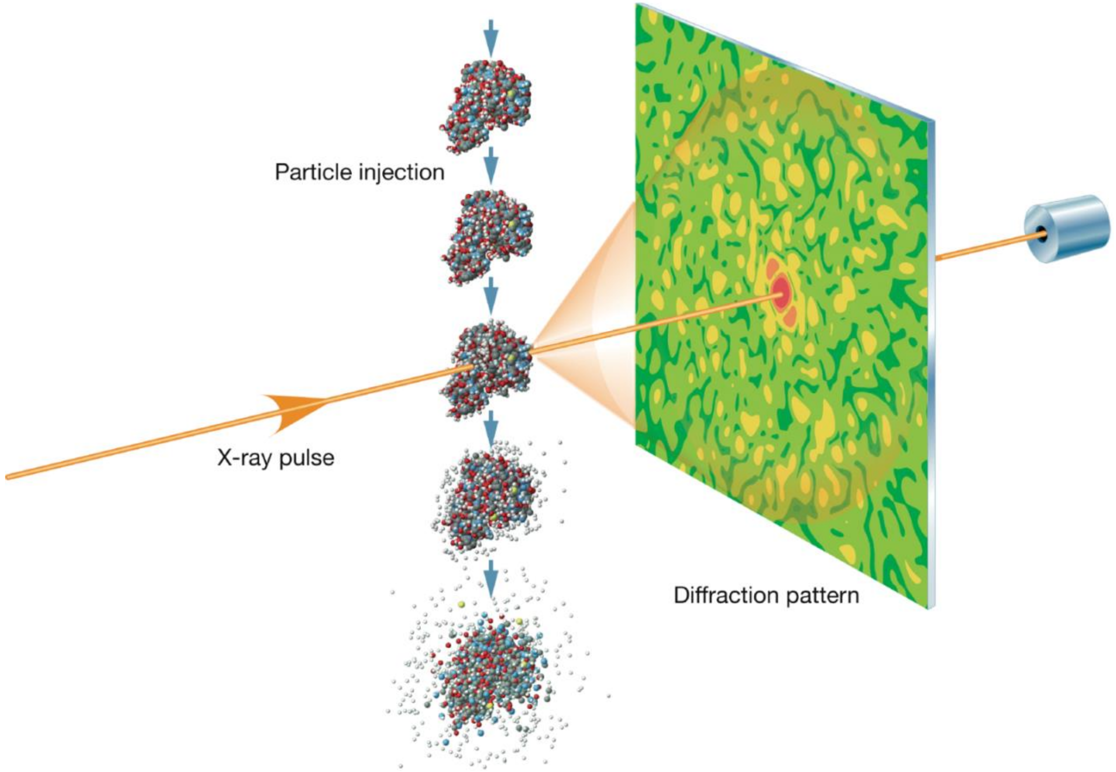
The scientific instruments

Femtosecond X-Ray Experiments



The Scientific Instrument FXE is getting ready for the first beam

SPB/SFX Structural Biology : Diffraction before Destruction



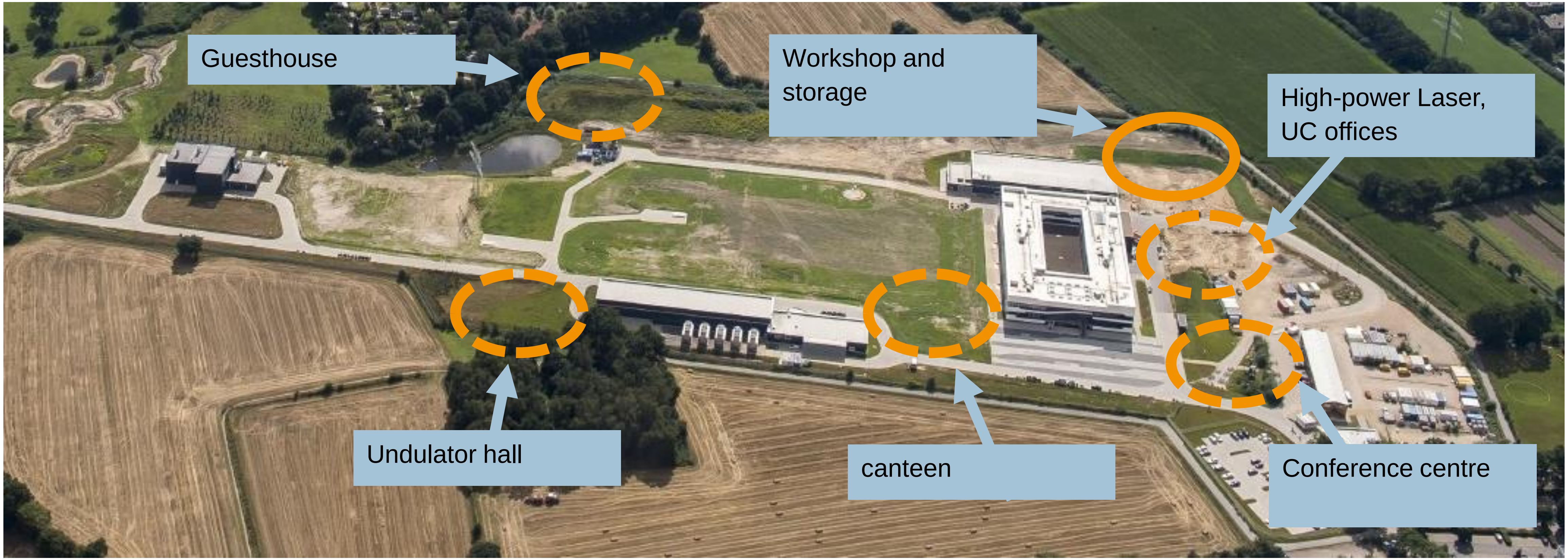
A few weeks ago at the SPB/SFX Instrument

3
3

Installation c

Optics hutch installations (mirror chambers) in early March

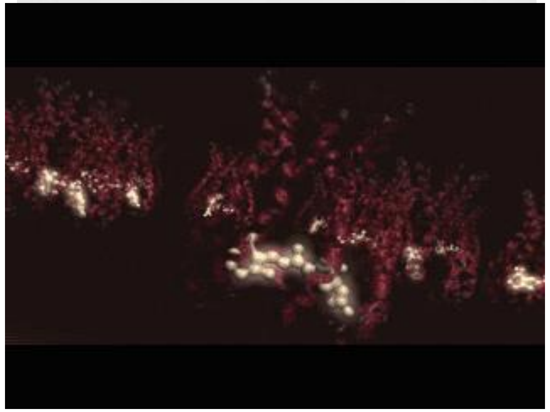
Campus development



Thank you for your attention

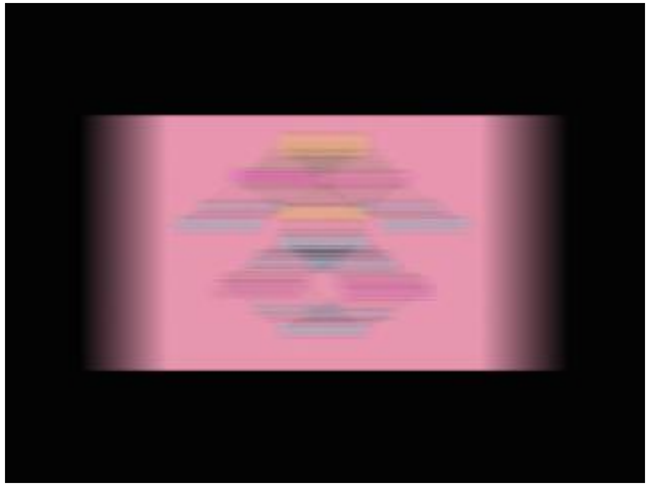
„Molekülkino" – Molekülbewegungen filmen

- Eadweard Muybridge, 1892
- European XFEL, 2017

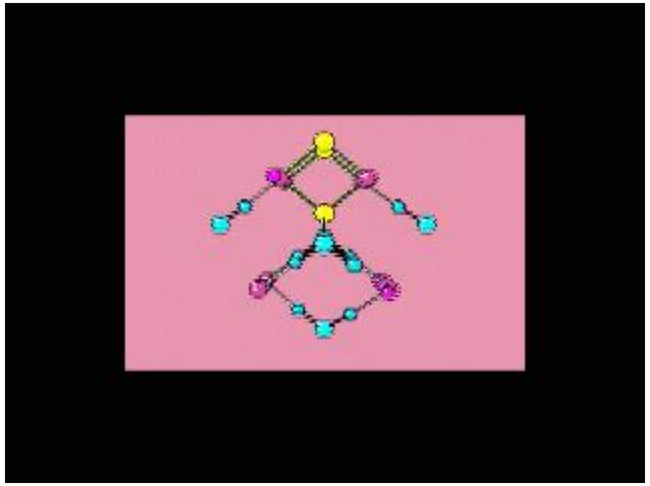


„Molekülkino“ – Molekülbewegungen filmen

Aufnahme mit niedriger Zeitauflösung
(>>100 fs)

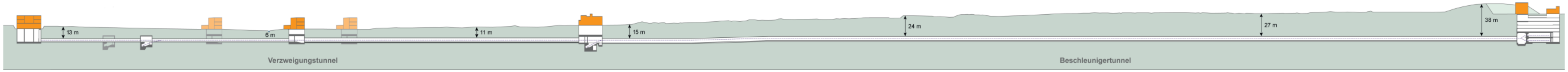


Aufnahme mit dem European XFEL
Zeitauflösung (<100 fs)

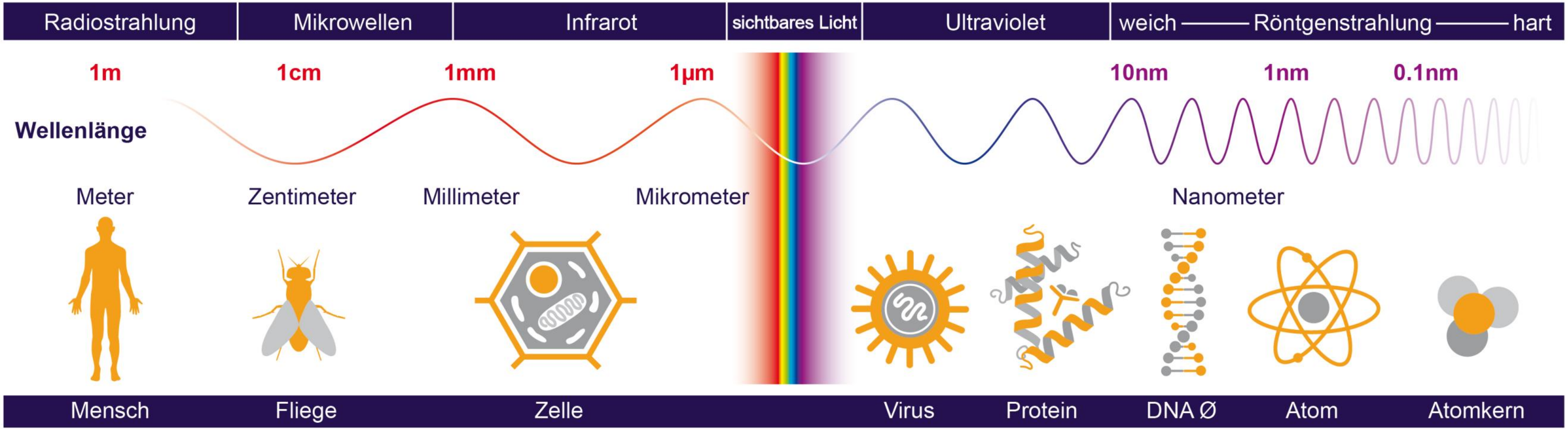


Höhere Zeitauflösung ermöglicht schärfere Bilder und Filme, die Molekularbewegung zeigen.

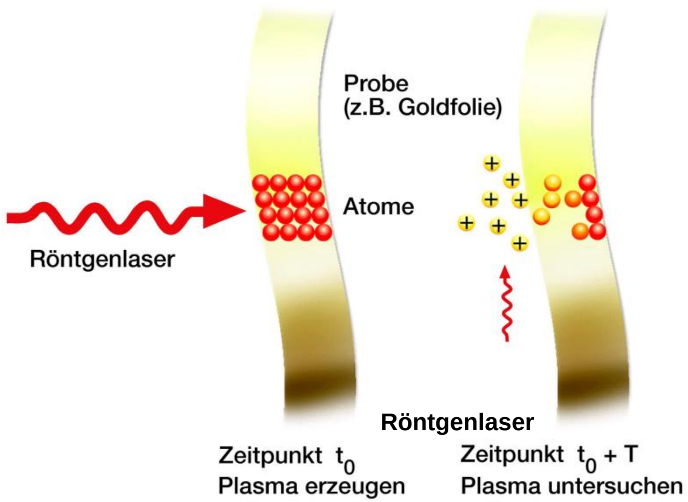
Eine große Anlage zur Untersuchung kleiner Objekte…

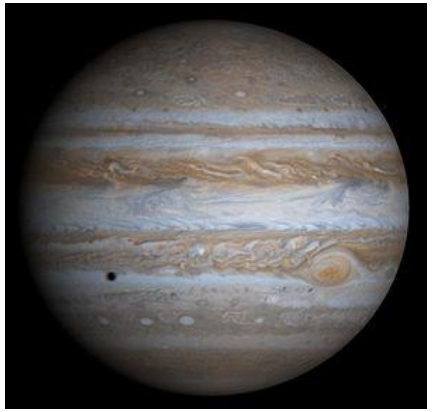


Gesamtlänge: 3,4 km



…und unter extremen Bedingungen



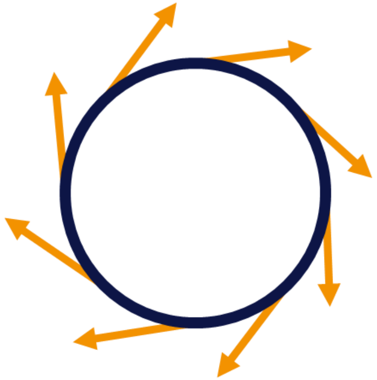


- Erzeugung von Plasmen bei hohem Druck und Temperatur sowie hoher Dichte zur Untersuchung mit dem Röntgenlaser
- Plasmen mit Eigenschaften ähnlich denen im Inneren von Planeten, z. B. auch Exoplaneten

Röntgenstrahlen zur Untersuchung von Materie

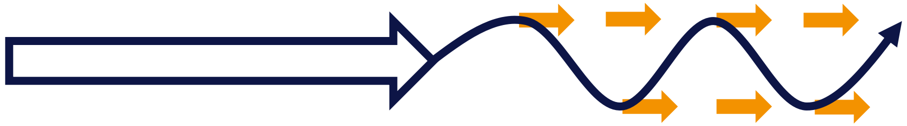
Synchrotrone

- Elektronen werden auf einer Kreisbahn beschleunigt und senden bei Richtungsänderung Licht aus.
- UV oder Röntgenstrahlung, nicht kohärent.



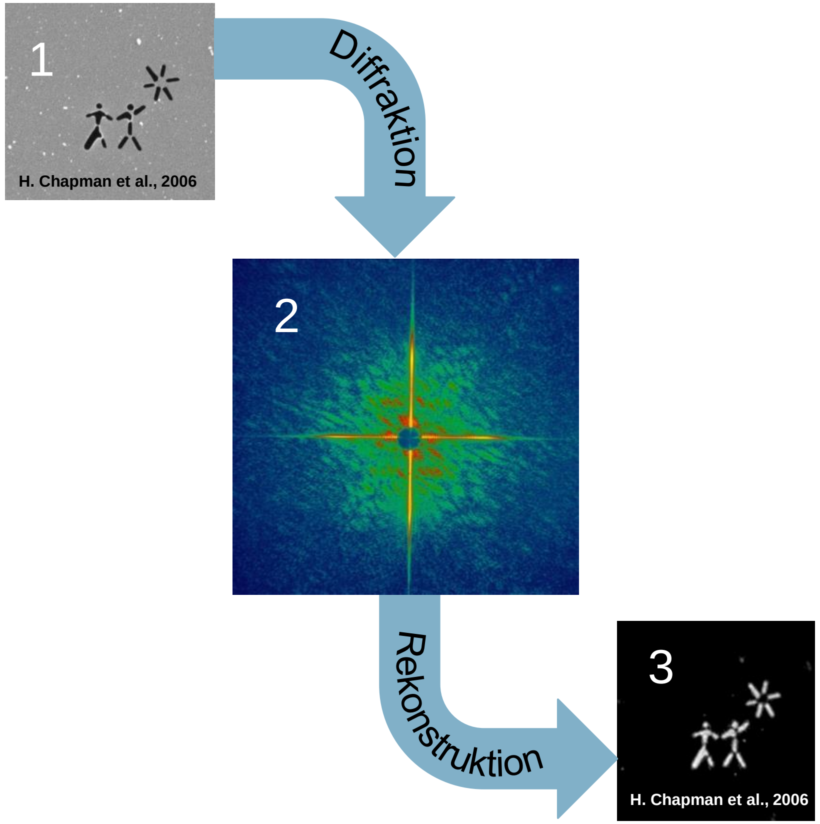
Freie-Elektronen-Laser

- Elektronen werden auf einer geraden Strecke beschleunigt und auf einen Slalomkurs gebracht. Dabei senden sie Licht aus.
- Das Licht ist kohärent, extrem brillant und besteht aus sehr kurzen Pulsen (Lichtblitzen).
- Detailgenaue Untersuchung von Objekten und Entschlüsselung von Prozessen.



Bilder ohne Kameralinse

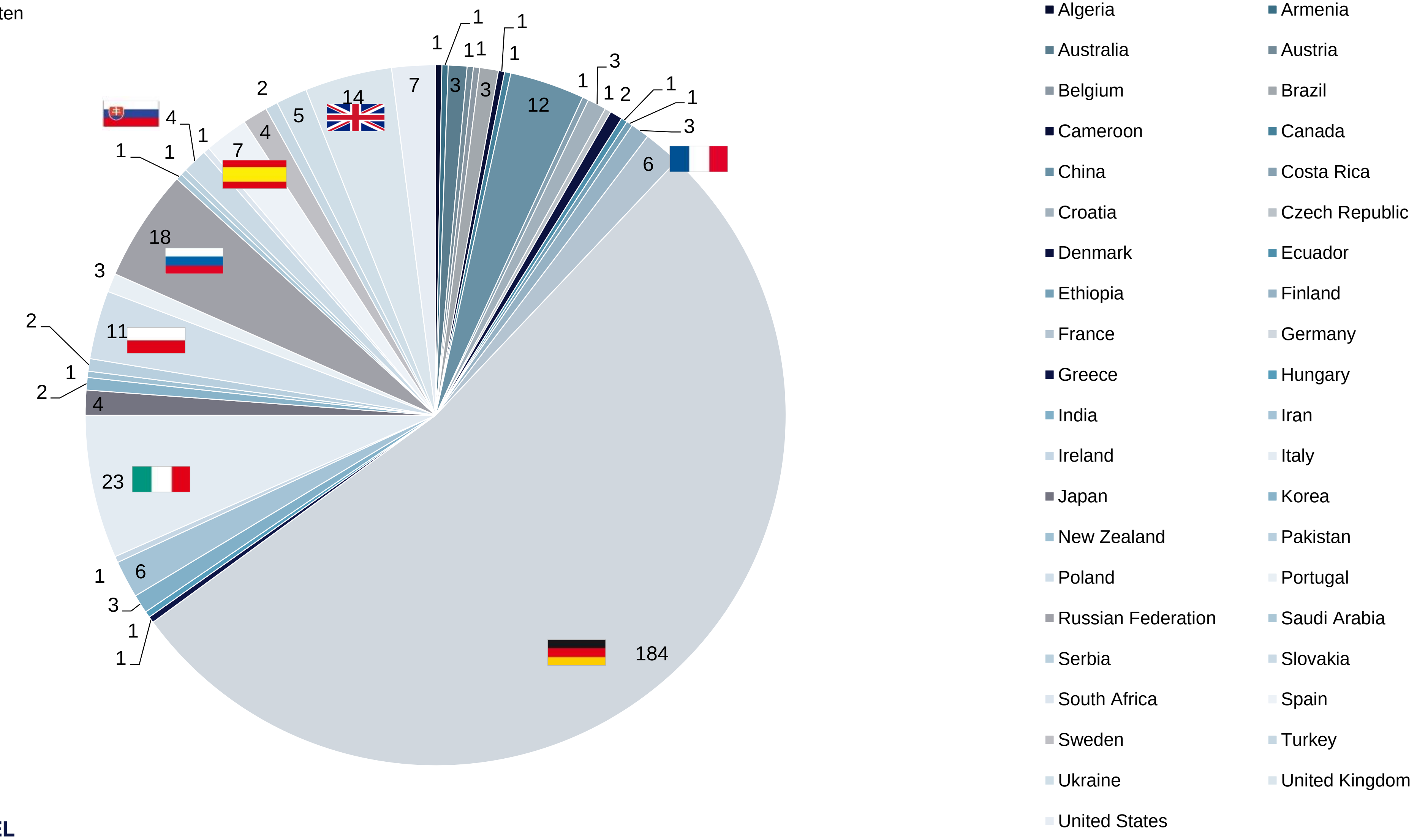
- Laue und Bragg entwickeln Kristallographie-Methode (1912–1914)
- Ähnliche Methoden werden heute bei Röntgenlasern eingesetzt



- Röntgenstrahlen werden gestreut (1, mikroskopische Formen auf einer Metallfläche)
- Detektoren nehmen gestreute Röntgenstrahlen auf (2, Streubild)
- Original kann aus Detektordaten detailgenau rekonstruiert werden (3, rekonstruiertes Bild)

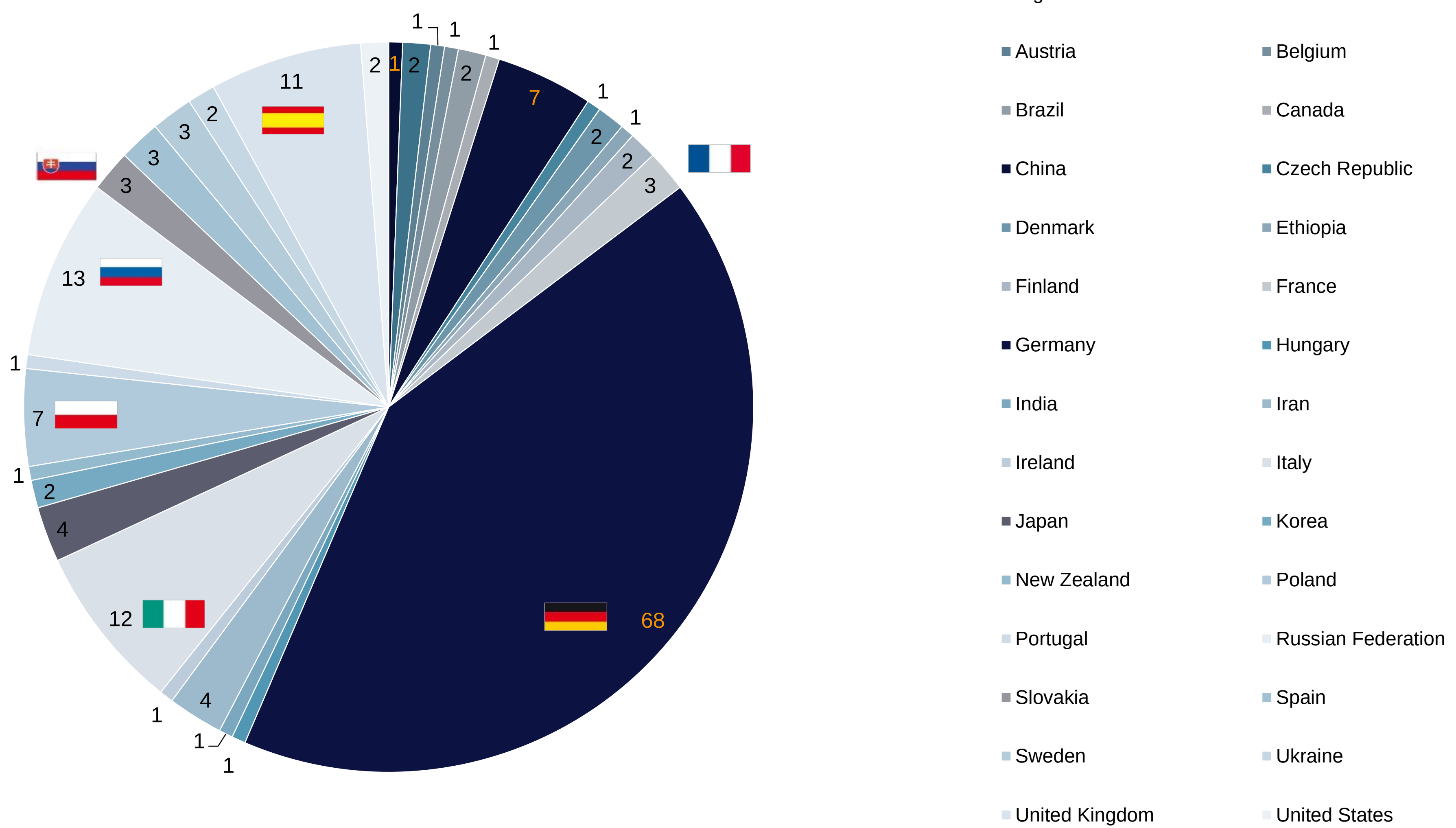
European XFEL-Belegschaft nach Ländern*

* inkl. 11 doppelte Staatsbürgerschaften



Wissenschaftliche Mitarbeiter nach Ländern*

* inkl. 7 doppelte Staatsbürgerschaften



Visualisierung des Hauptgebäudes: Sommer 2017…

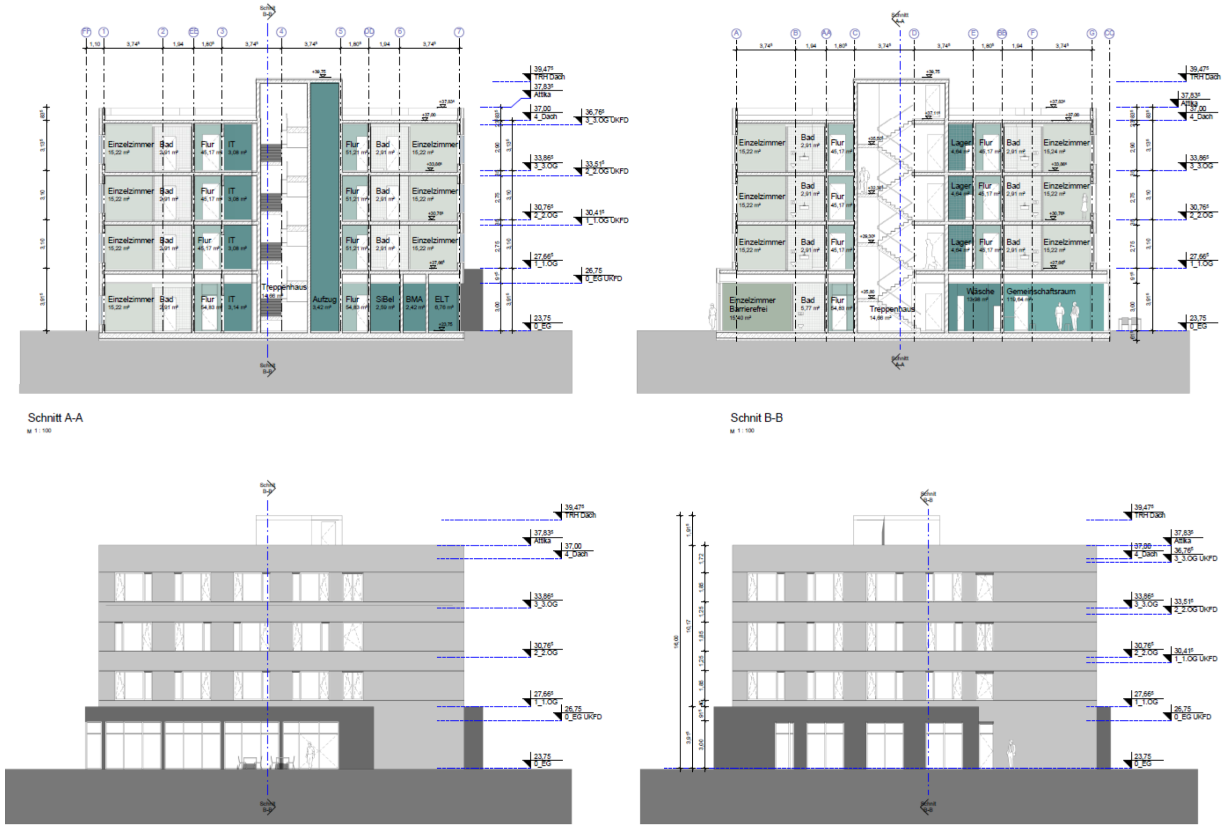
…Vorplatz mit Blick auf das geplante Kantinengebäude

Geplantes Kantinengebäude für Nutzer, Mitarbeiter und Gäste

- Geplanter Baubeginn April 2017
- Fertigstellung Sommer 2018
- Sitzplätze für 150 Personen

Geplantes European XFEL-Gästehaus

- Baubeginn im Juni 2017
- Fertigstellung im Sommer 2018
- 56 Zimmer mit 59 Betten



Chancen/Anwendungen: Chemie, Materialwissenschaften und vieles mehr

- Bilder mit atomarer Auflösung zeigen Abläufe an Katalysatoren
  - Bessere Katalysatoren verringern Schadstoff-Emissionen
  - Optimierte Produktionsprozesse, weniger giftige Abfallprodukte
- Neue Möglichkeiten, Struktur und Eigenschaften von Materialien zu untersuchen
  - Entstehung von Eigenschaften wie Haltbarkeit, Leitfähigkeit, Magnetismus
  - Verminderung der Zahl der Atome zur Speicherung digitaler Information → Laufwerke mit höchster Speicherdichte/Kapazität
- Viele weitere Anwendungen in Physik, Nanowissenschaften, Umweltforschung, Energieforschung, …

Fortschritte bei der Inbetriebnahme des European XFEL

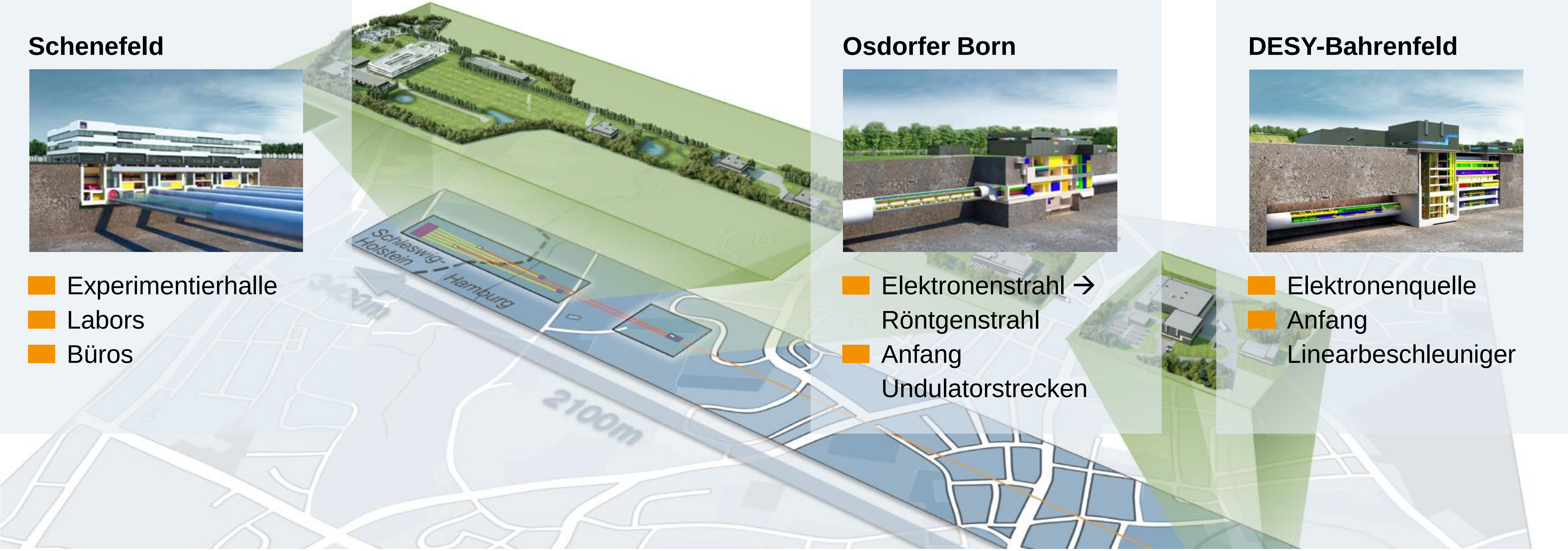
- Abkühlung des Beschleunigers – *abgeschlossen*
- Inbetriebnahme Beschleuniger – *läuft*
- Erste Bewerbungsphase für Experimente – *läuft*
- Erstes Röntgenlicht („first lasing“) – *Mai 2017*
- Inbetriebnahme Instrumente – *Sommer 2017*
- Nutzerbetrieb an 2 von 6 Instrumenten – *September/Oktober 2017*
- Weiterer Ausbau des Nutzerbetriebs mit 6 Instrumenten – *bis Sommer 2018*

Besuch von Ministerpräsident Torsten Albig im August 2016

Offizieller Beginn der Inbetriebnahme im Oktober 2016

Übersicht Campus Schenefeld mit geplanter Kantine und Gästehaus (hellgrau)

Die Forschungseinrichtung im Überblick



Schenefeld

- Experimentierhalle
- Labors
- Büros

Osdorfer Born

- Elektronenstrahl → Röntgenstrahl
- Anfang Undulatorstrecken

DESY-Bahrenfeld

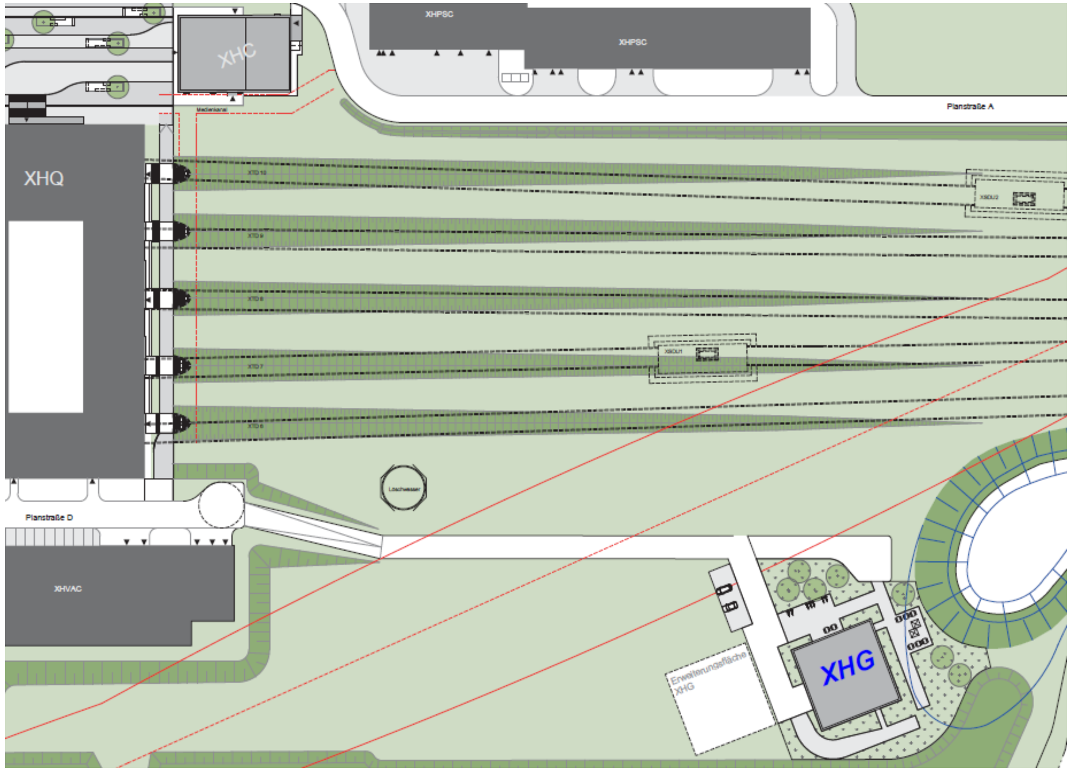
- Elektronenquelle
- Anfang Linearbeschleuniger

Canteen

- Start of construction works: April 2017
- Completion of the building: Summer 2018

Guest house

- Start of construction works: June 2017
- Completion of the building: Summer 2018



Some Combined GUI Scenes