Status of the European XFEL Photon Beam Systems

Martin Dommach
European XFEL

Paris, June 26th 2018

Outline

- About European XFEL
- Beamline layout
- First beam on all beamlines
- Status of scientific instruments
- Future upgrades of the facility

About European XFEL

- Organized as a non-profit corporation in 2009 with the mission of design, construction, operation, and development of the free-electron laser
- Supported by 12 partner countries
- Germany (federal government, city-state of Hamburg, and state of Schleswig-Holstein) covers 57% of the costs; Russia contributes 26%; each of the other international shareholders 1–3%
- Total budget for construction (including commissioning)
  - 1.22 billion € at 2005 prices, about 170 M€ operating budget
  - 600 M€ contributed in cash, over 550 M€ as in-kind contributions (mainly manufacture of parts for the facility)

European XFEL—a leading new research facility

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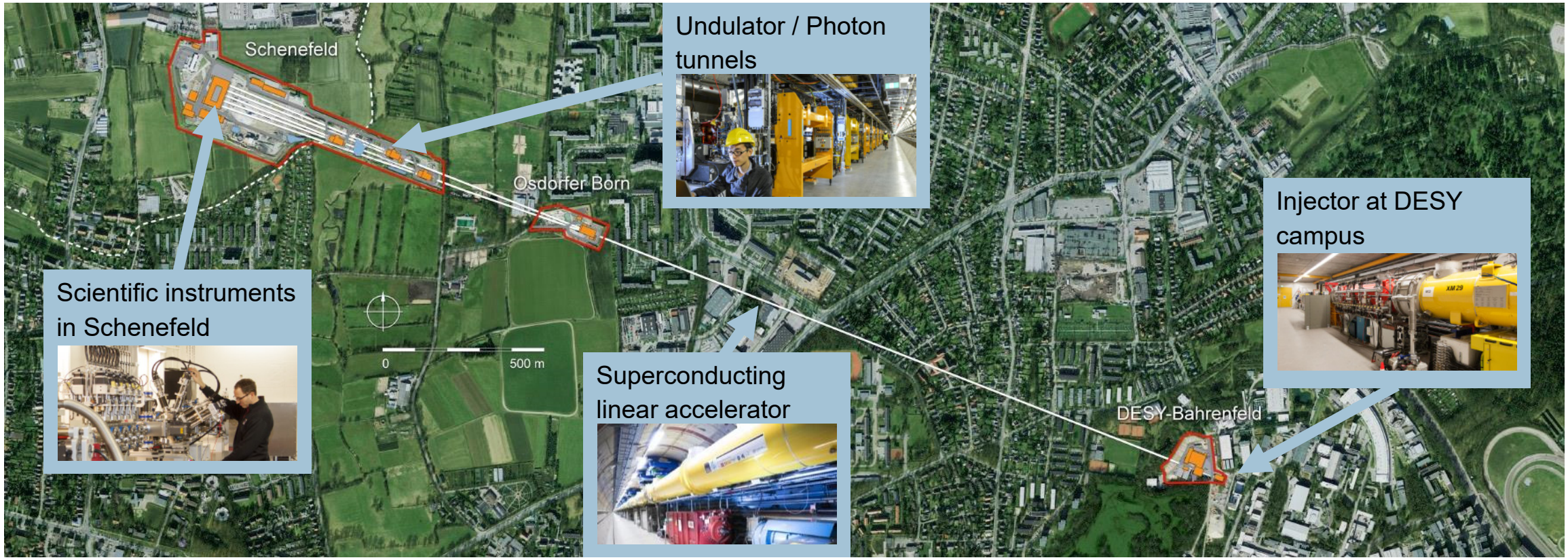
General layout of the European XFEL

General layout of the European XFEL

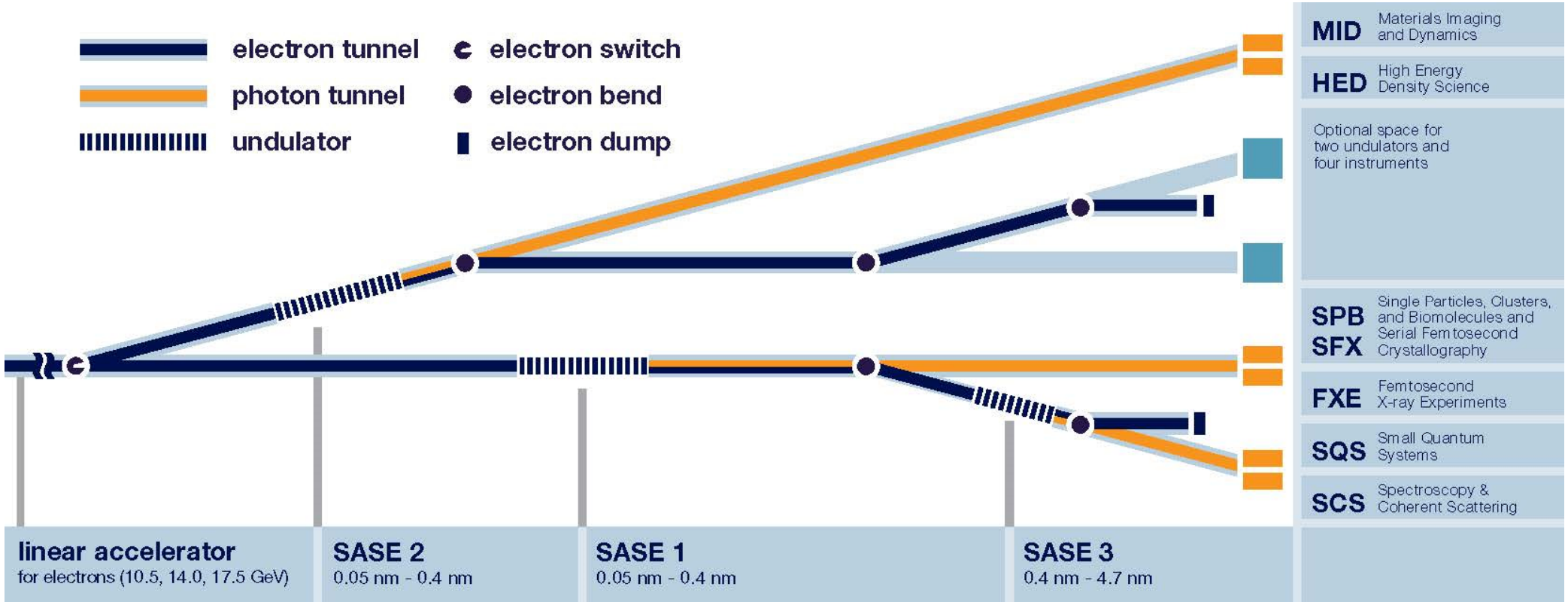


European XFEL—a leading new research facility

Schenefeld research campus on 14 August 2017

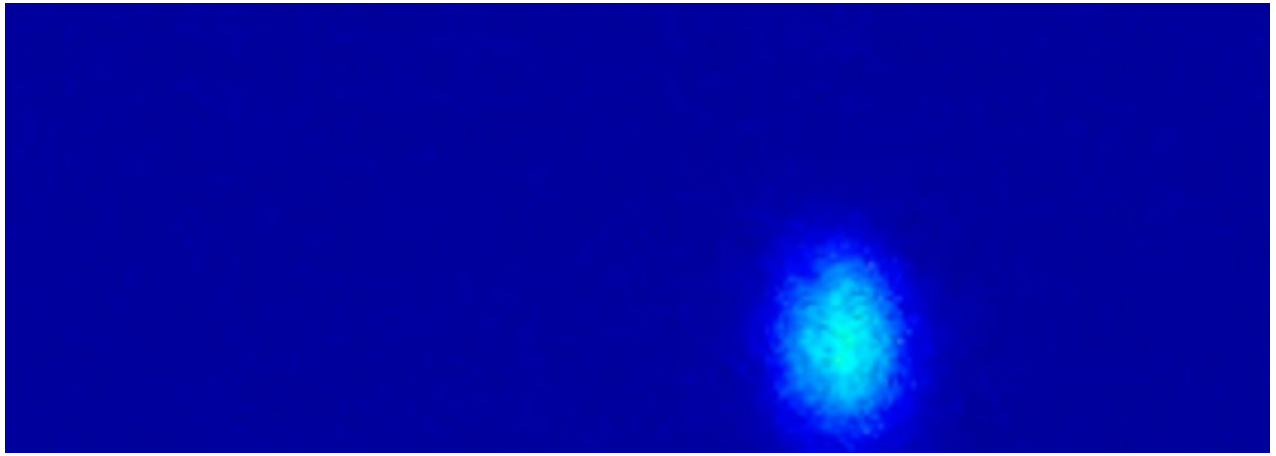
- The European XFEL is a new research facility that uses high-intensity X-ray light to study the structure of matter.
  - User facility with more than 350 employees (+250 from DESY)
  - Location: Hamburg and Schenefeld, Germany
  - September 2017 start of user operation

Beamline layout and experiment stations

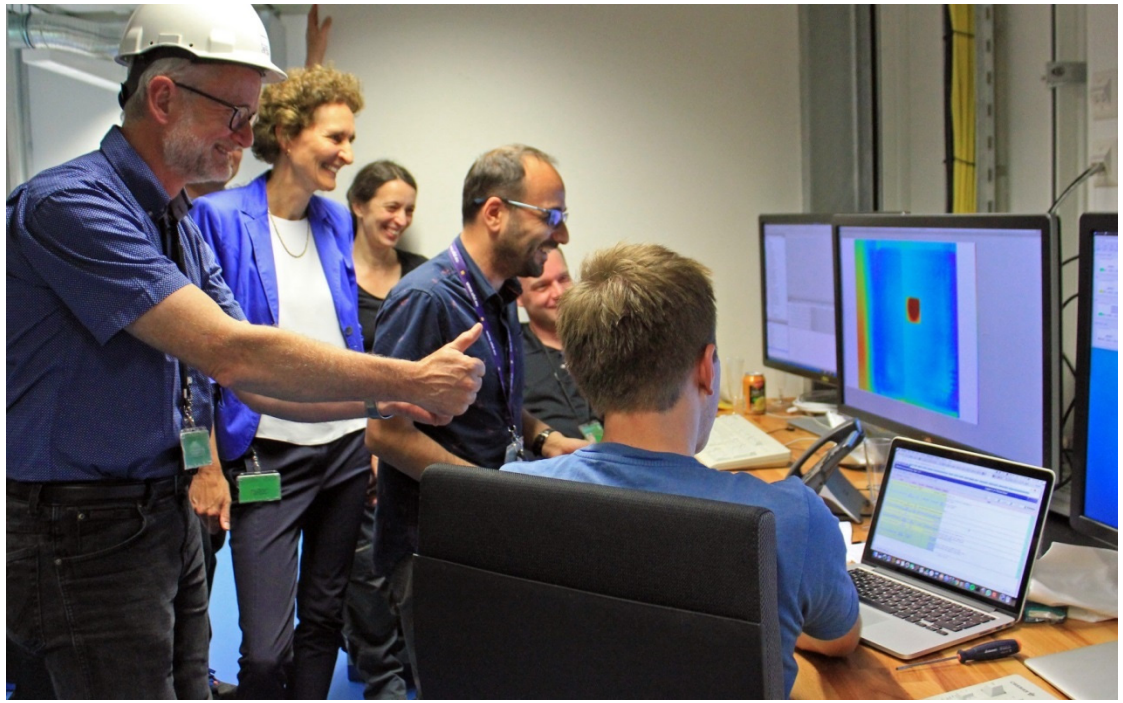


4 May 2017 - first lasing at SASE1 Beamline

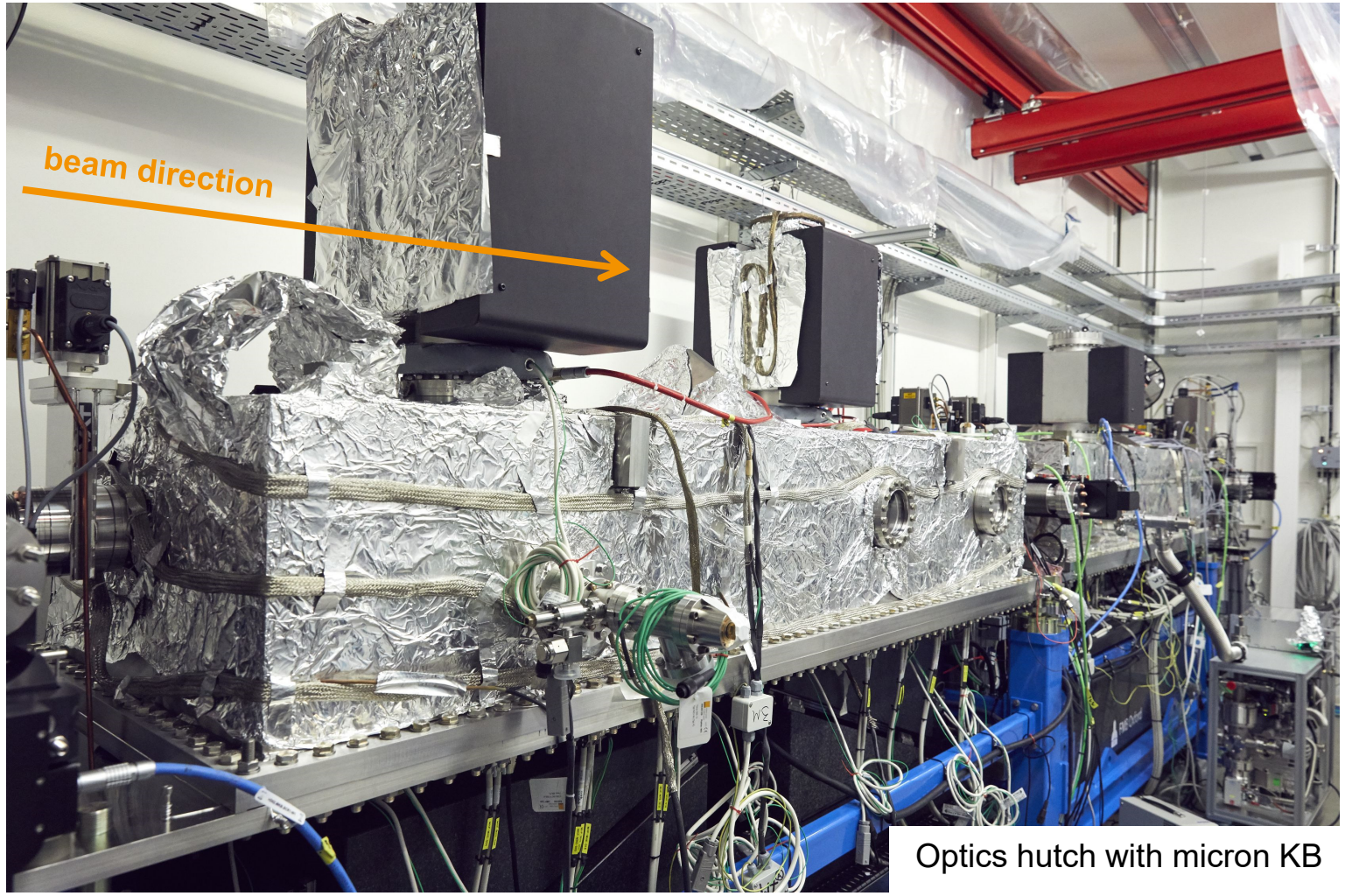
- Hard X-Ray beamline
- Serves SPB/SFX and FXE instruments
- Comissioning of tunnel components complete
- Both instruments in user operation



23 June 2017 - first X-rays in the experiment hall!



Single Particles, Clusters, and Biomolecules & Serial Femtosecond Crystallography (SPB/SFX) Instrument

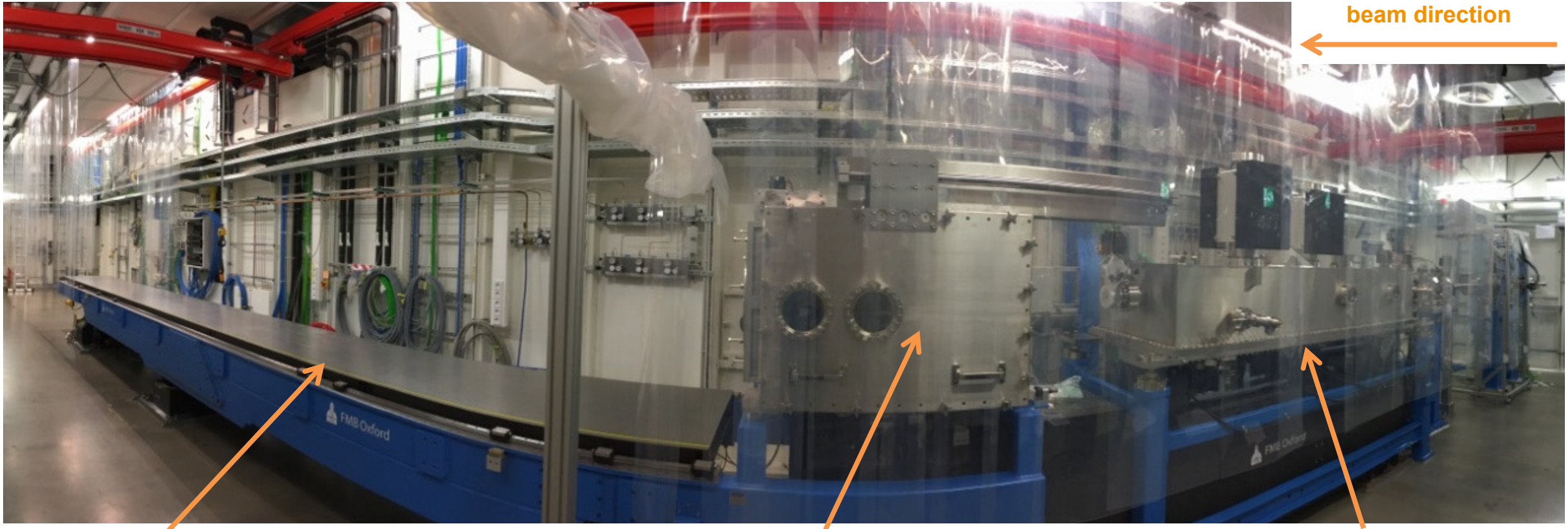


Optics hutch with micron KB

- Energy range: 3 – 16 keV
- Determination of the structure of single particles, such as atomic clusters, viruses, and biomolecules
- Focussing with two KB mirror systems
  - In optics hutch, focal size: ~1 µm mirrors installed, commissioning soon
  - In front of interaction chamber, focal size ~100 nm, mirrors to be installed in July
- User operation since September 2017
- SFX instrument: Installation 2019

Courtesy: N. Reimers

Single Particles, Clusters, and Biomolecules & Serial Femtosecond Crystallography (SPB/SFX) Instrument



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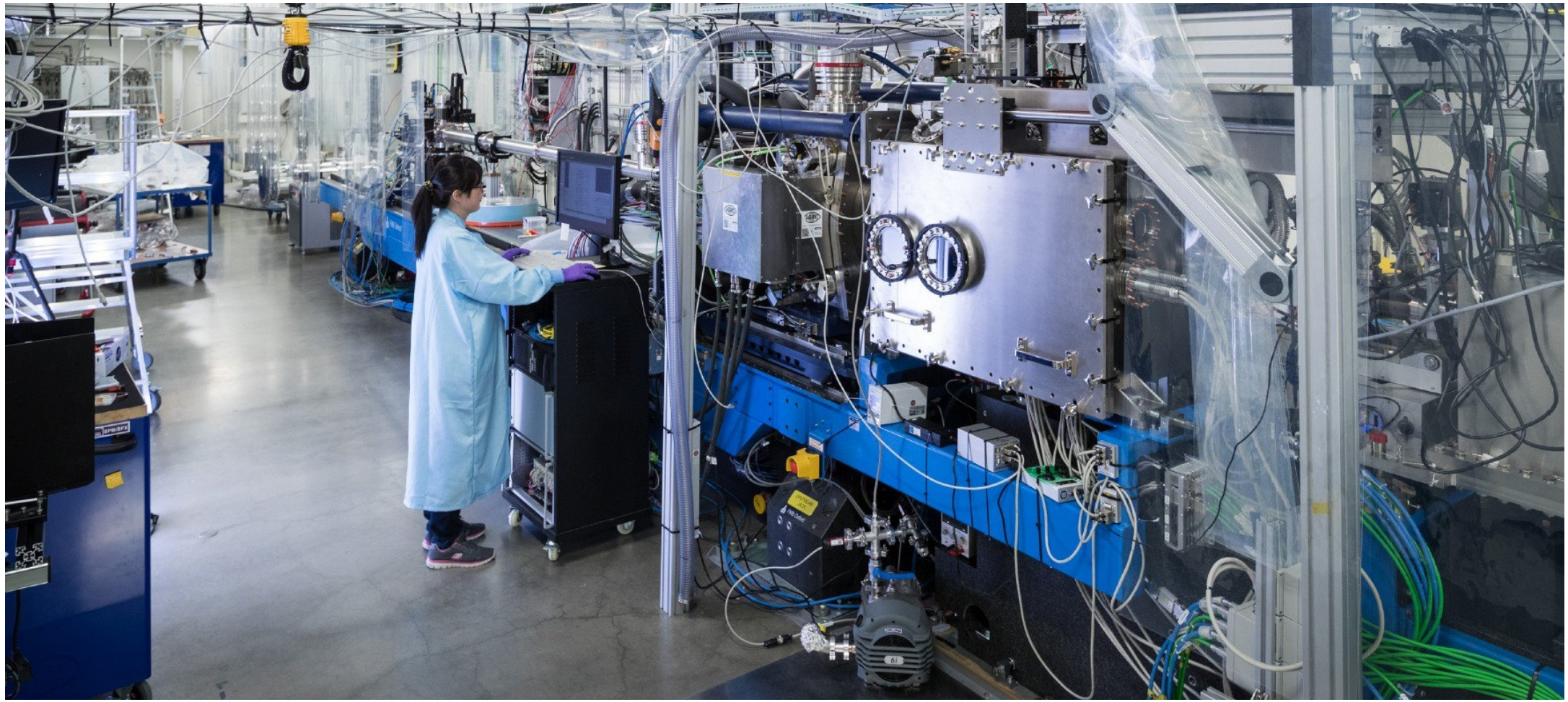

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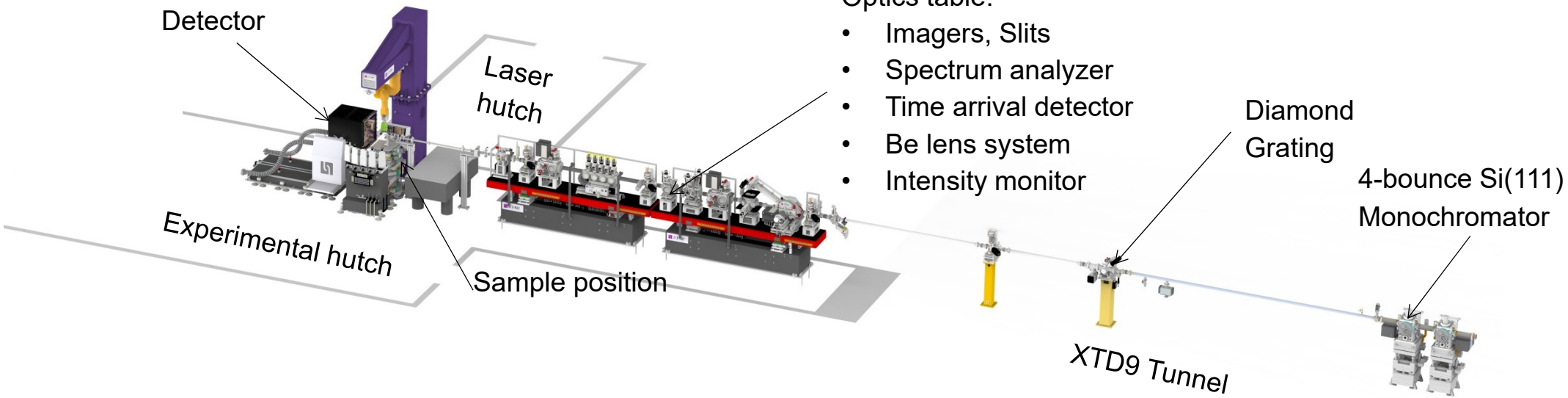
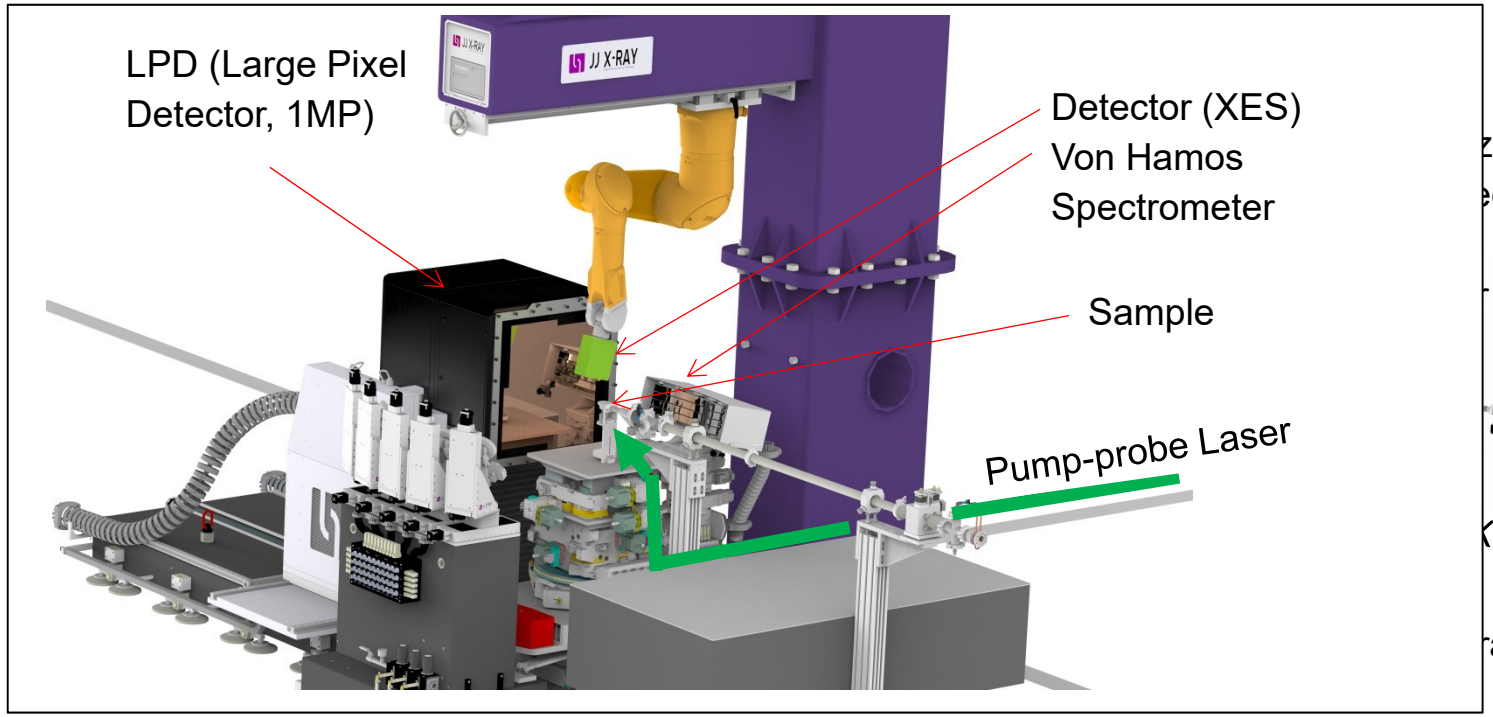
Femtosecond X-Ray Experiments (FXE) Instrument

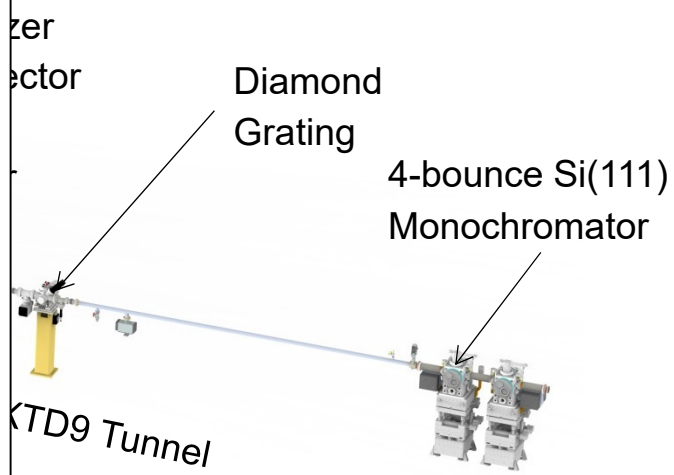


- Energy range: 5 – 20 keV
- Femtosecond X-ray experiments: Fast, time-resolved investigations of the dynamics of solids, liquids and gases.
- User operation since September 2017

Courtesy: M. Knoll

Femtosecond X-Ray Experiments (FXE) Instrument





- Femtosecond X-ray experiments: Fast, time-resolved investigations of the dynamics of solids, liquids and gases.
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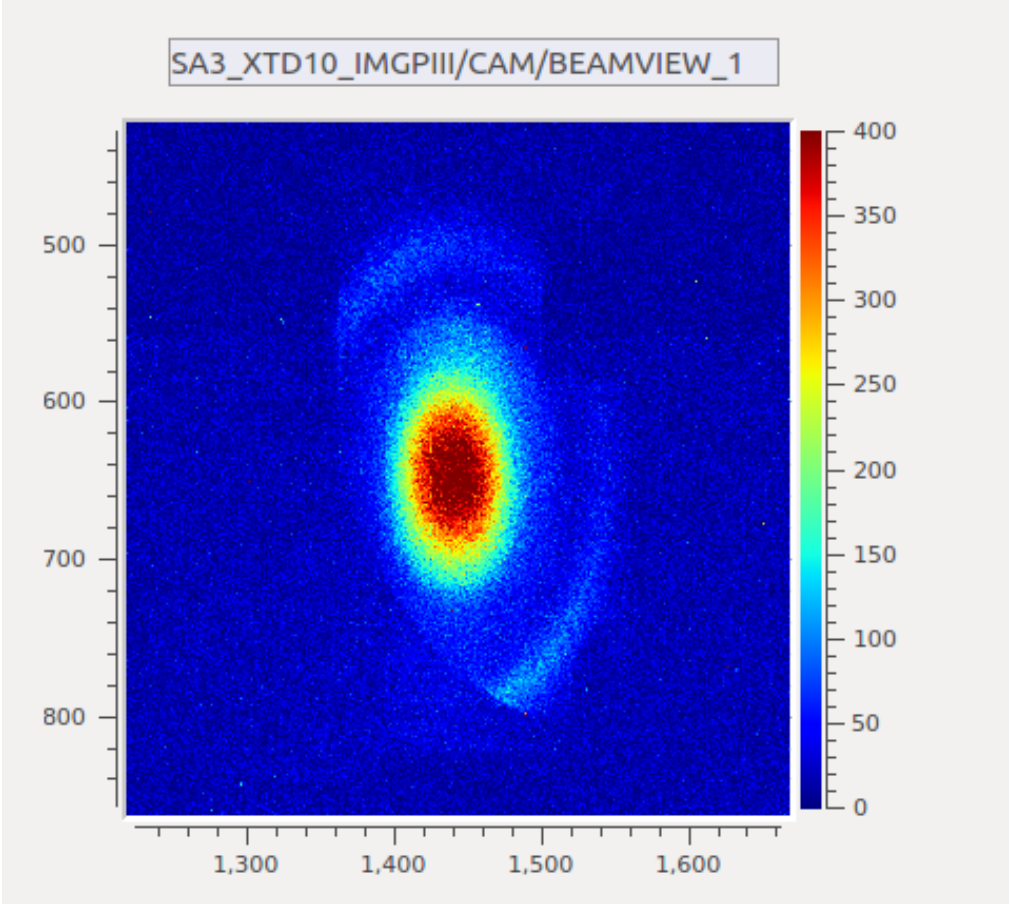
Courtesy: M. Knoll

1st lasing SASE3 beamline (February 2018)



- Soft X-Ray beamline 0.26 to 3 keV
- Serves SCS and SQS instruments
- Comissioning of tunnel components almost complete

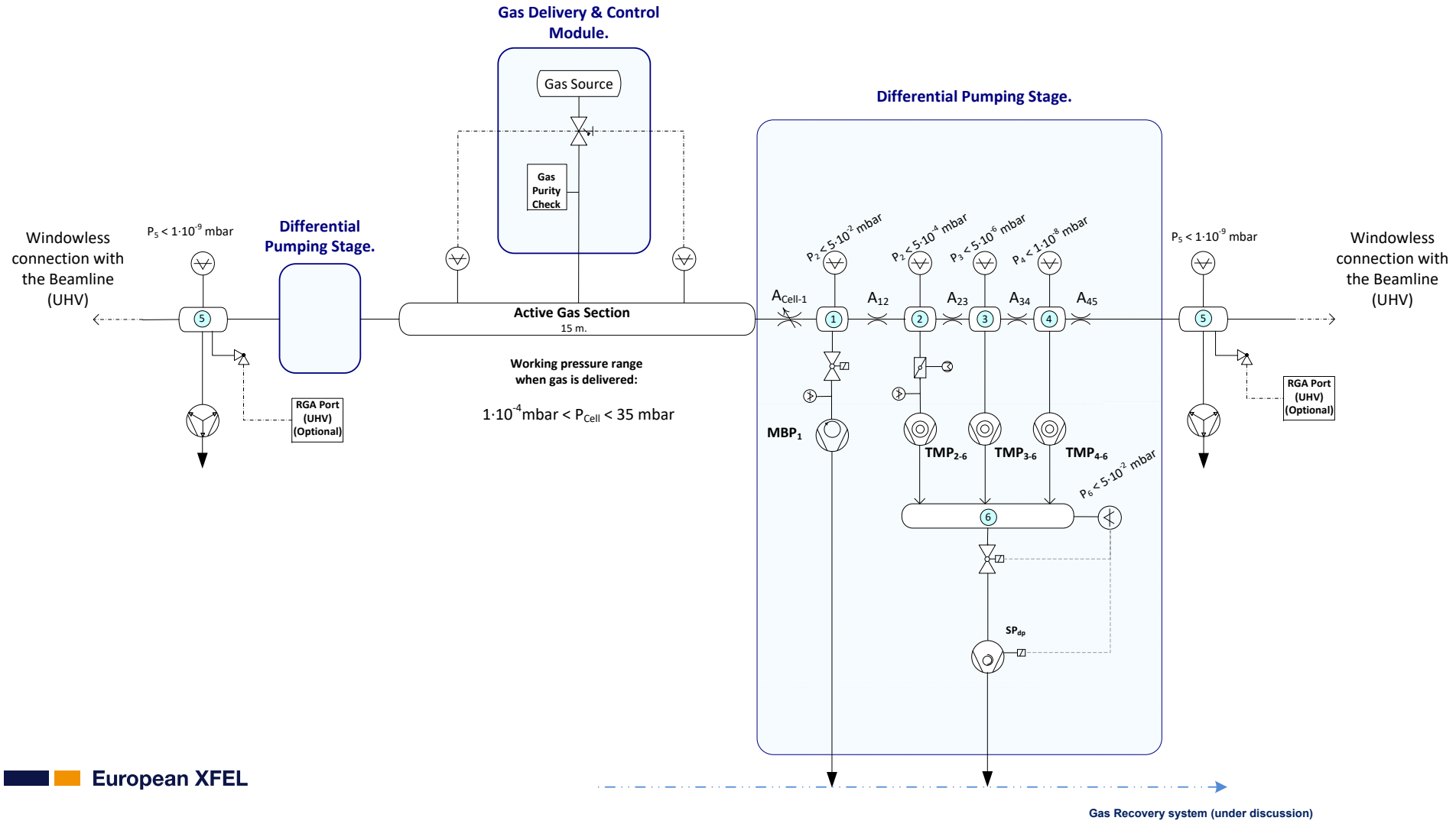
More details on SASE3 beamline comissioning:
Talk by Daniele La Civita on Friday morning
(FROAMA04)

SASE3 Gas Attenuator

- Windowless to avoid of optical aberrations and wavefront distorsions (i.e. when using Be or C (Diamond) foils/windows).
- No Damage Threshold (Low for solid foils vs. beam interaction)
- Diluted gaseous media = Homogeneity
- Continuous and progressive variation of the photon flux intensity
- Several gases can be used = extended capabilities without further modifications

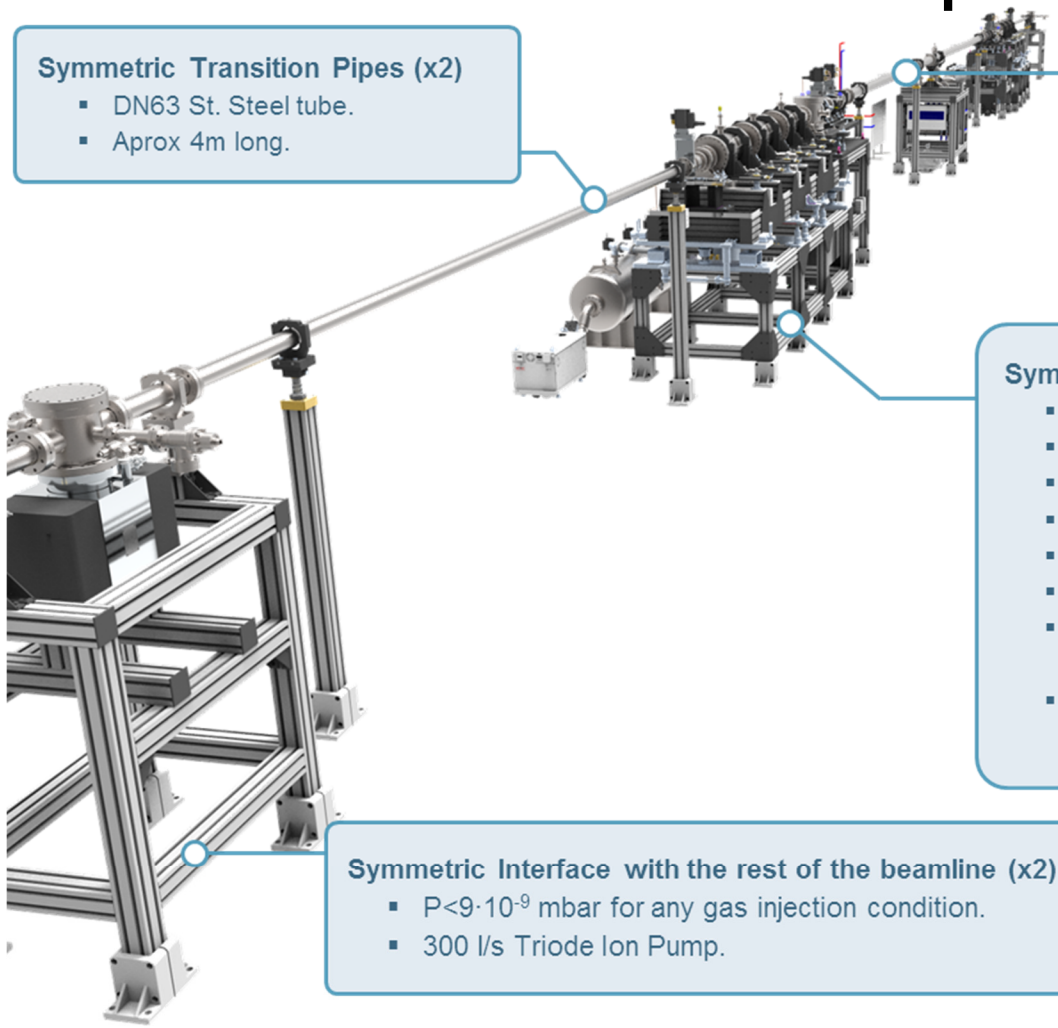
Courtesy: Raúl Villanueva

SASE3 Gas Attenuator: Concept and Design



SASE3 Gas Attenuator: Concept and Design

Symmetric Transition Pipes (x2)
- DN63 St. Steel tube.
- Aprox 4m long.



Active Gas Cell.
- DN100 St. Steel tube.
- Aprox 15m long.
- Gas Injection in mid-point.

Symmetric 4-Stages DPS Modules (x2)
- 20 mm nominal static clear aperture size (5x module).
- Static apertures = in-vacuum tubes (Stainless Steel).
- First stage insertable apertures (6 and 12 mm).
- Insertable apertures = flat disks B_4C
- 1st pumping stage: up 320 l/s multistage Roots Pump
- 2nd to 4th stages: up to 1200 l/s conventional TMP´s.
- Throttling mechanism in 1st TMP-stage (overload protection)
- Common forevacuum line + large plenum + 30 l/s multistage Roots Pump

Symmetric Interface with the rest of the beamline (x2)
- P<9·10^{-9} mbar for any gas injection condition.
- 300 l/s Triode Ion Pump.

SASE3 Gas Attenuator: Concept and Design

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- DN63 St. Steel tube.
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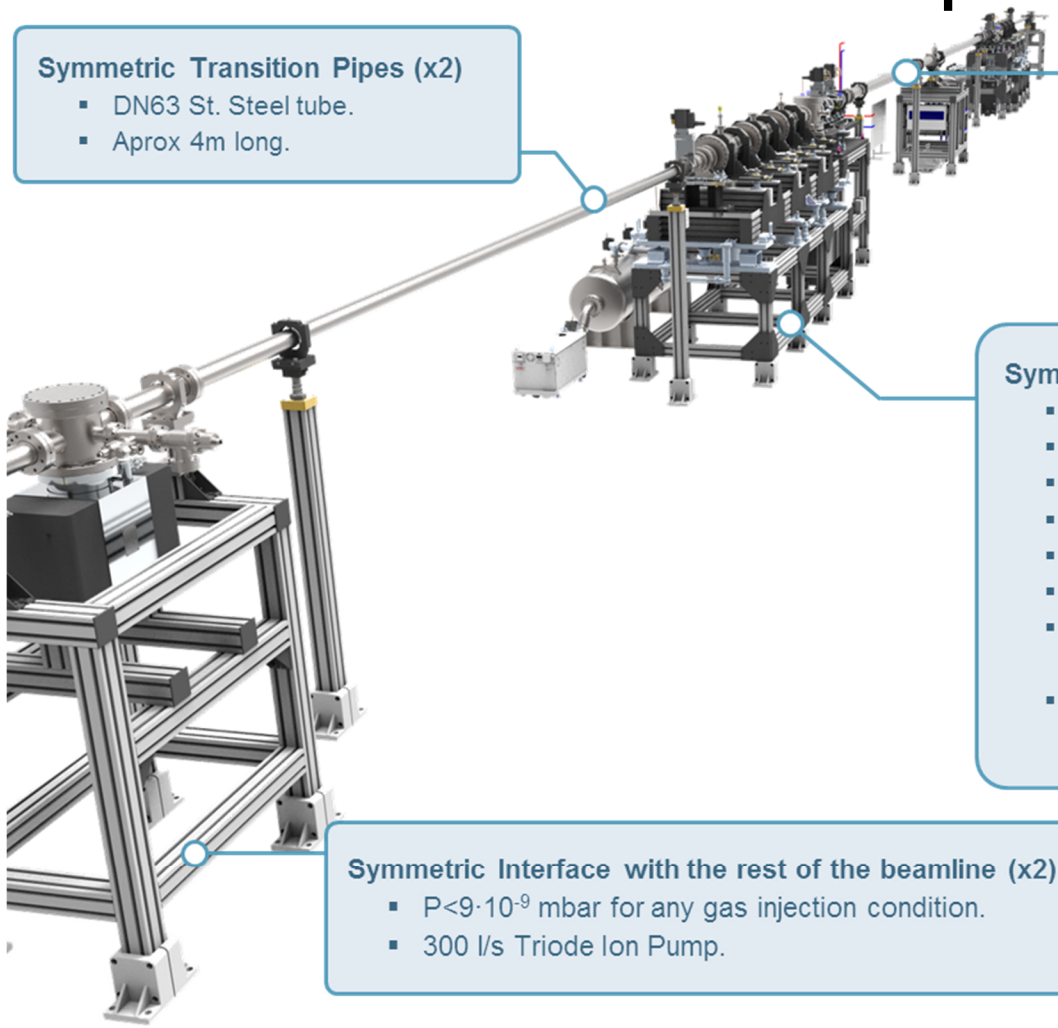

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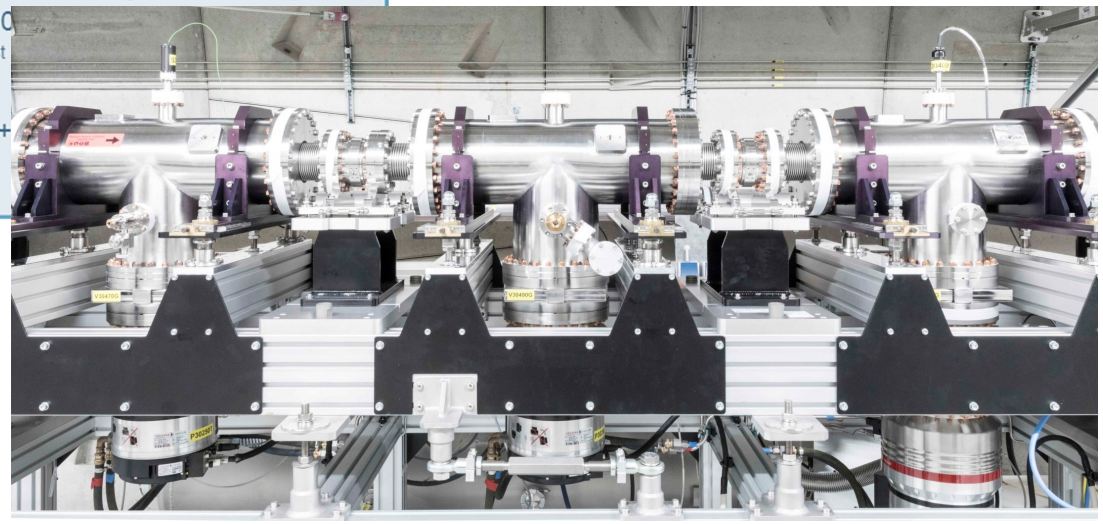

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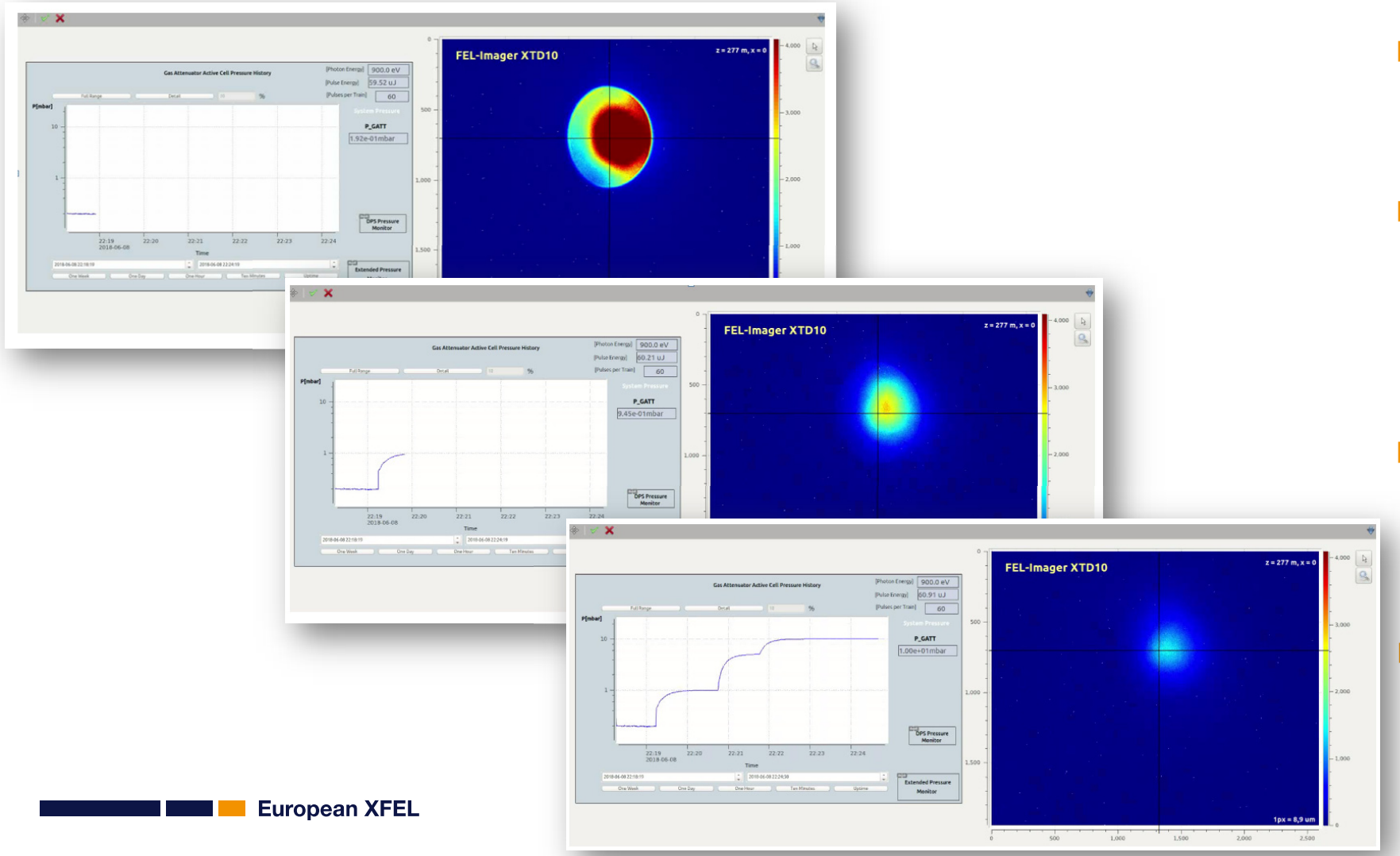
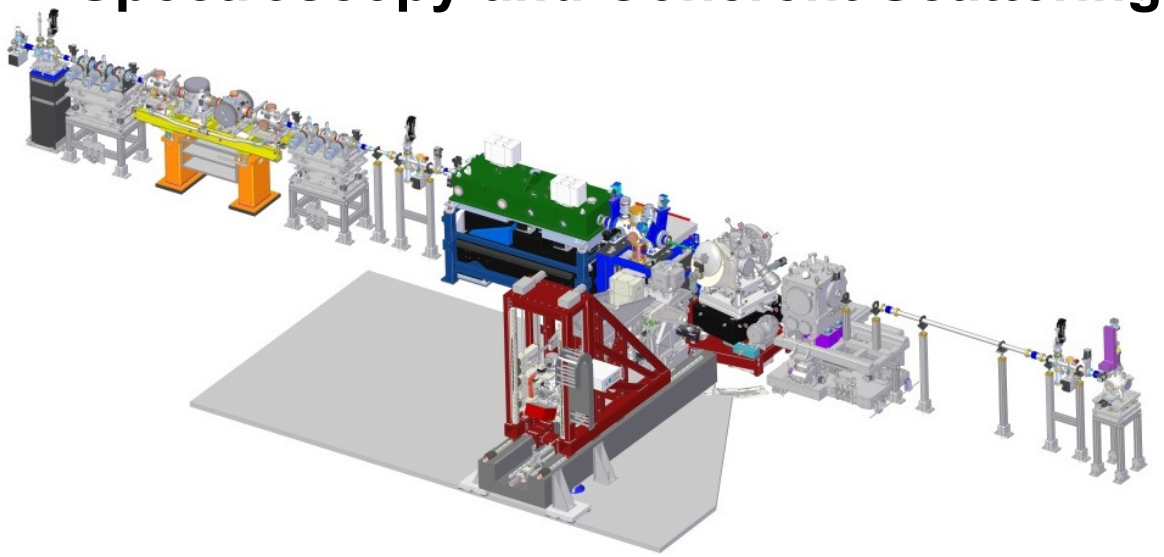
SASE3 Gas Attenuator: First commissioning results



- Differential Pumping with nine orders of magnitude between the gas cell and interfacing UHV beamline
- Gas Attenuator shows excellent performance with P = $1 \cdot 10^{-4}$ to 35 mbar (N_2)
  - Transmission with 0.5 mbar N_2 @900 eV ≈ 0.02
- Software development is still ongoing:
  - PID control for closed loop operation
  - Full process automation
- Commissioning will continue:
  - With second gas (Ar)
  - 1st Turbo stage conductance control

Spectroscopy and Coherent Scattering (SCS) Instrument



- Energy range: 0.5 – 3 keV
- Determination the structure and properties of large, complex molecules and nano-sized structures
- Precision bent KB System: focus: 1,5 x 1,5 µm² to 0,5 x 0,5 mm²
- Timeline:
  - Component installation until mid July
  - Start of commissioning with X-Rays: July 25th
  - First users expected in November 2018

Courtesy: J.-T. Delitz

Spectroscopy and Coherent Scattering (SCS) Instrument

Integration of high-precision floor into normal concrete (civil construction vs. fine polished floor

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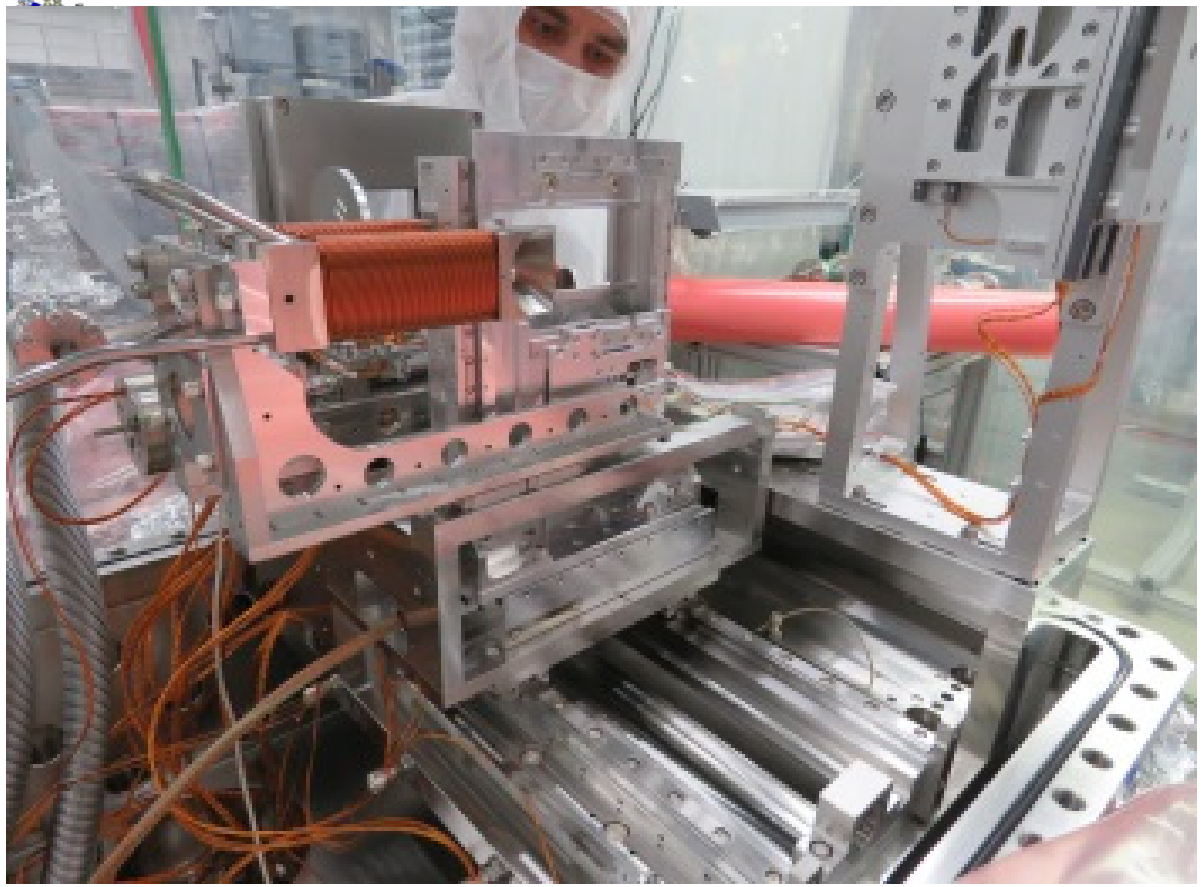

10 Hz XY-scanner with twin coil magnet and transferable sample frame with load-lock

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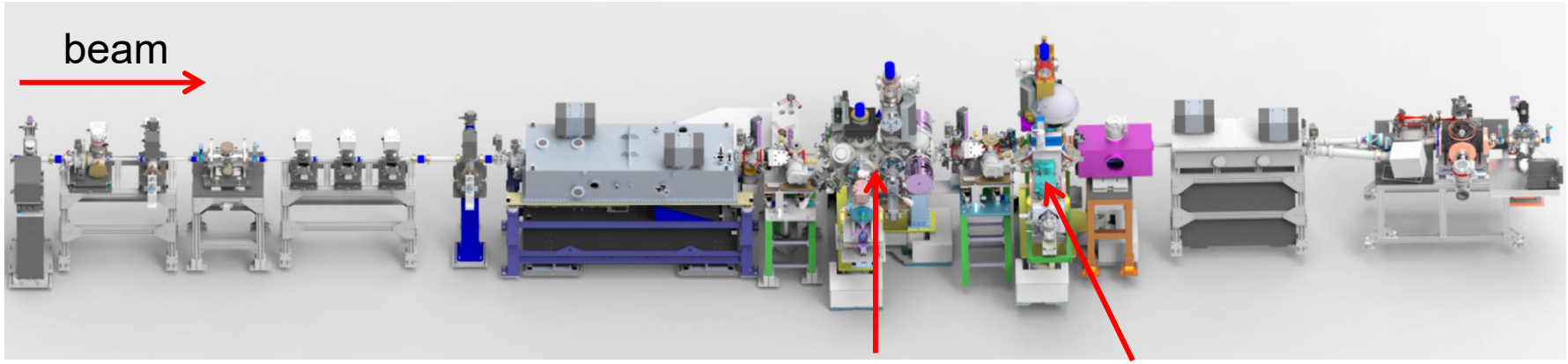
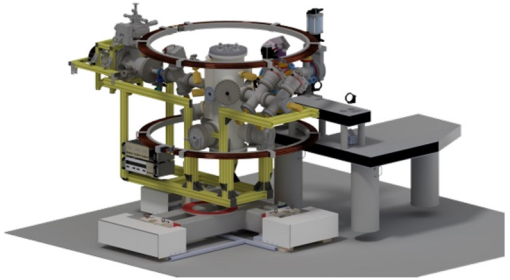
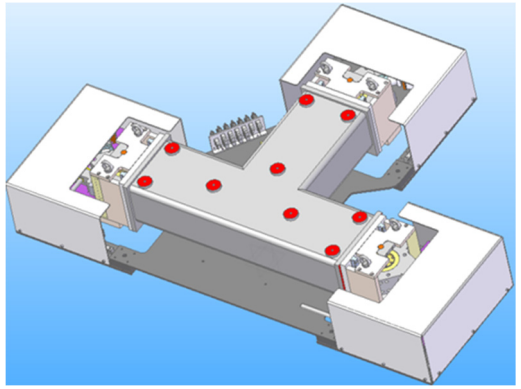
Small Quantum Systems (SQS) Instrument



- Photon Energy 0.26 – 3 keV
- Instrument will examine the quantum mechanical properties of atoms and molecules
- Two end stations can be installed simultaneously
- User operation starts November 2018



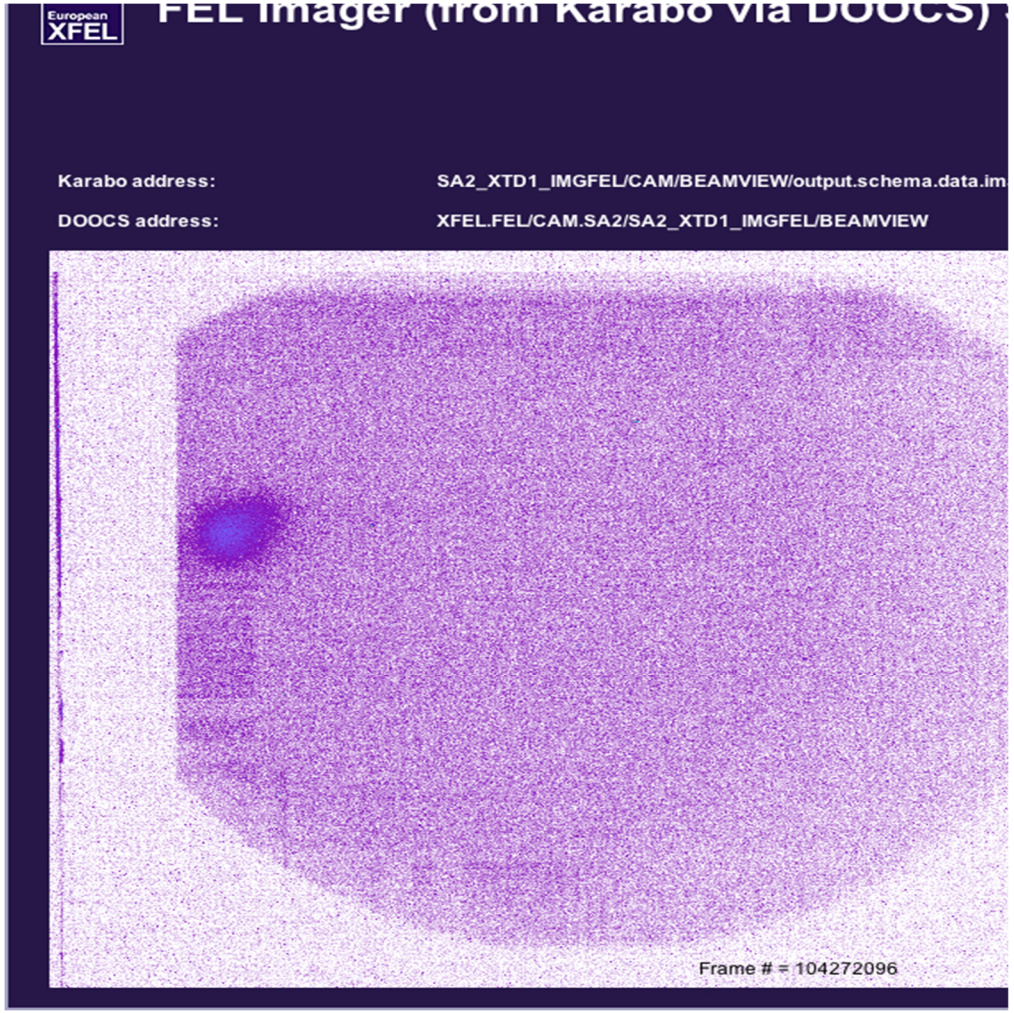
Third End Station out of the beamline ready to be installed in focus 1 or 2 on demand



Alignment bases are installed bellow the End Station and on air pads. In this way End Stations can be positioned and aligned during the beamtime change (few days). The bases have 6 DOF with accuracies of 1µm and reproducibilities of 5µm for payload of 600 kg

Courtesy: J. Montaño

First Lasing at SASE2 on May 1st, 2018



- First indications of lasing on Imager
- Hard X-Ray beamline 3 to 25 keV
- Serves MID and HED instruments
- Comissioning of tunnel components has started and continues in August
- User operation from spring 2019 on

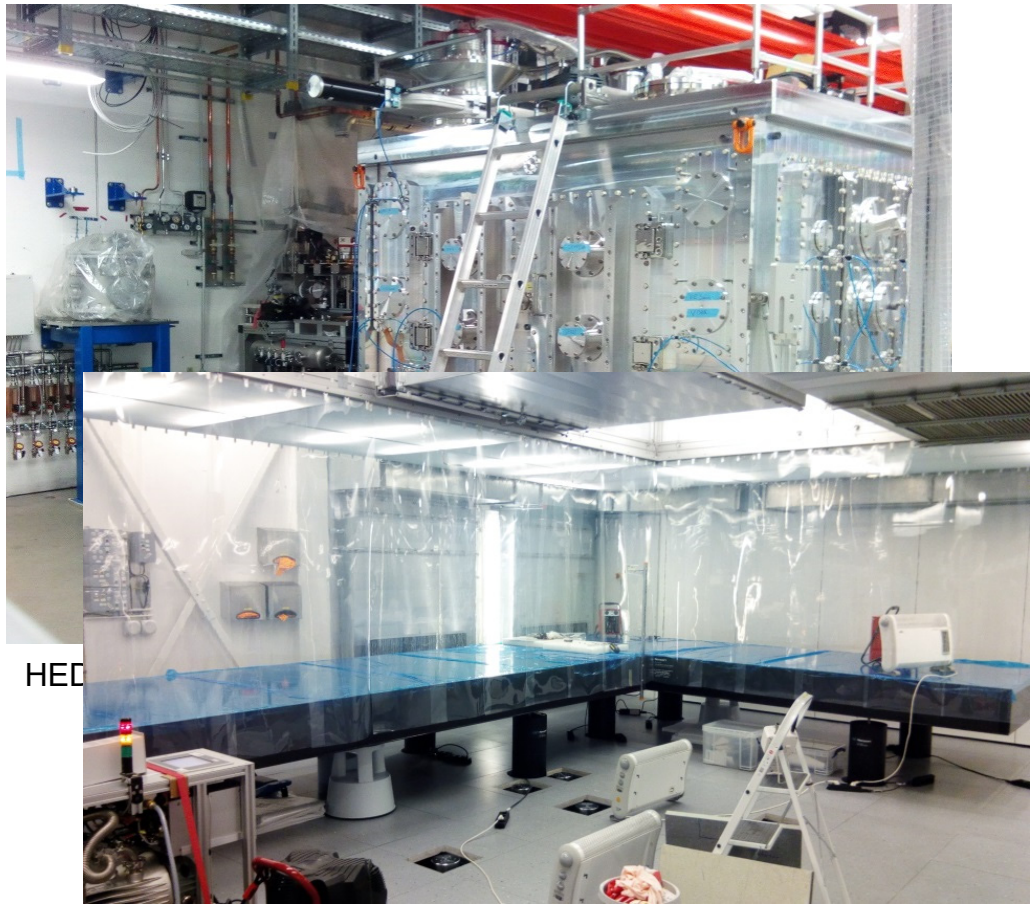
High Energy Density (HED) Instrument

HED interaction chamber 1

- Energy range: 5 – 25 keV
- Will look into some of the most extreme states of matter in the universe, such as the conditions at the centre of planets
- Scientific application: high energy density, plasma, planetary science
- All-aluminium interaction chamber 2.6 x 1.8 x 2.5 m (LxWxH), 60 mm thick, e-beam welded
- High power laser: TW short pulse, 100 Joule long pulse, Pump Probe Laser
- Timeline:
  - Installation to be completed by Autumn 2018
  - Alignment and commissioning until February 2019
  - Installation of the Tera watt laser by end of August 2018
  - Installation of the DiPOLE 100J laser in summer 2019
  - First X-rays in the hutch around spring 2019, first users soon thereafter

Courtesy: I. Thorpe

High Energy Density (HED) Instrument



HED

Tables and climate zone installed for the Tera Watt laser system

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Courtesy: I. Thorpe

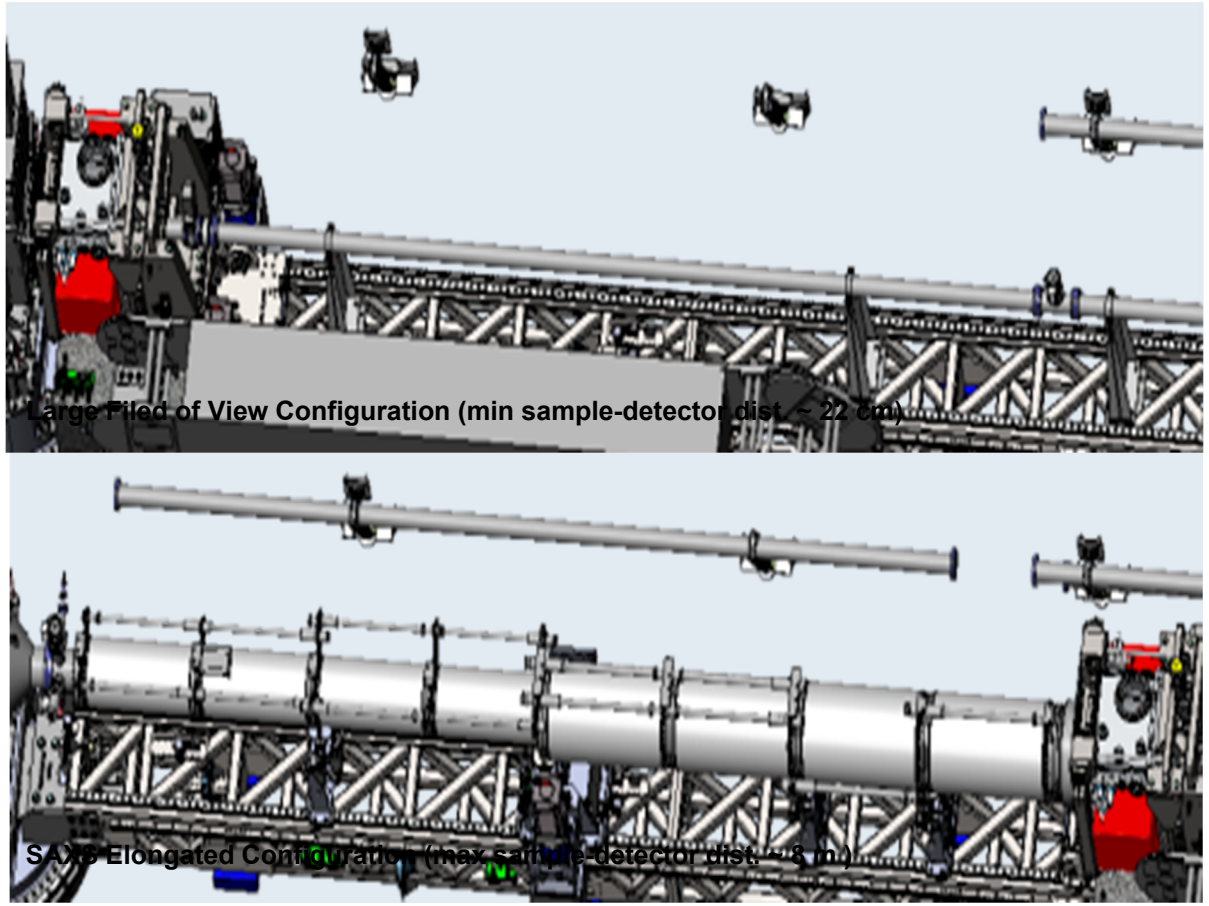
Material Imaging and Dynamics (MID) Instrument

- Energy range: 5 – 25 keV
- Coherent diffractive imaging (CDI) and X-ray photon correlation spectroscopy (XPCS)
- MID will be able to image and analyze nano-sized devices and materials used in engineering
- Ready for user operation in spring 2019

For more information about MID instrument see poster of Gabriele Ansaldi on Wednesday: “Materials Imaging and Dynamics Station (MID) at the European X-Ray Free-Electron Laser” WEPH43

Courtesy: G. Ansaldi

Material Imaging and Dynamics (MID) Instrument



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Simultaneous lasing at SASE1+SASE2+SASE3 - May 2nd 14h47

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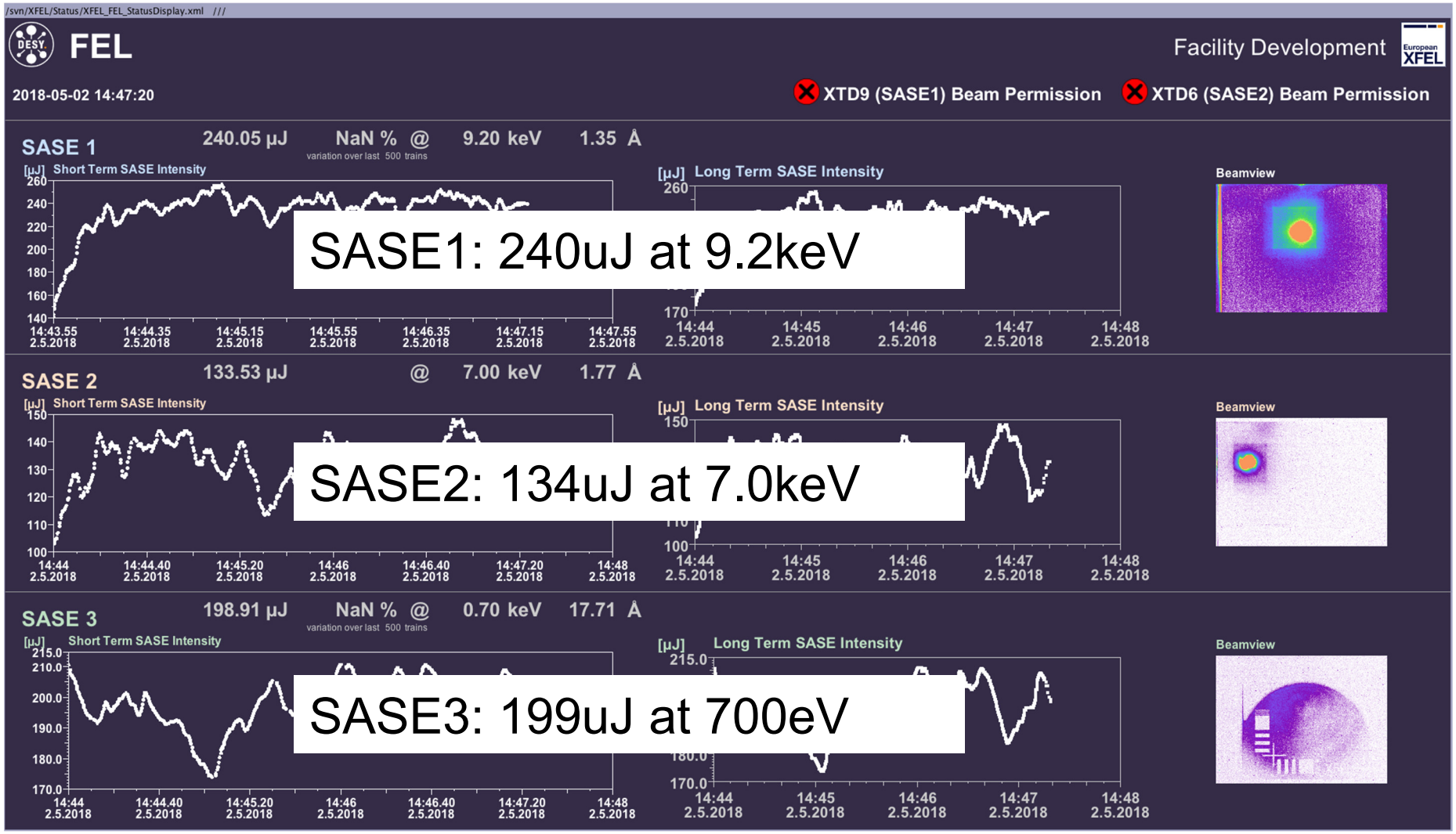
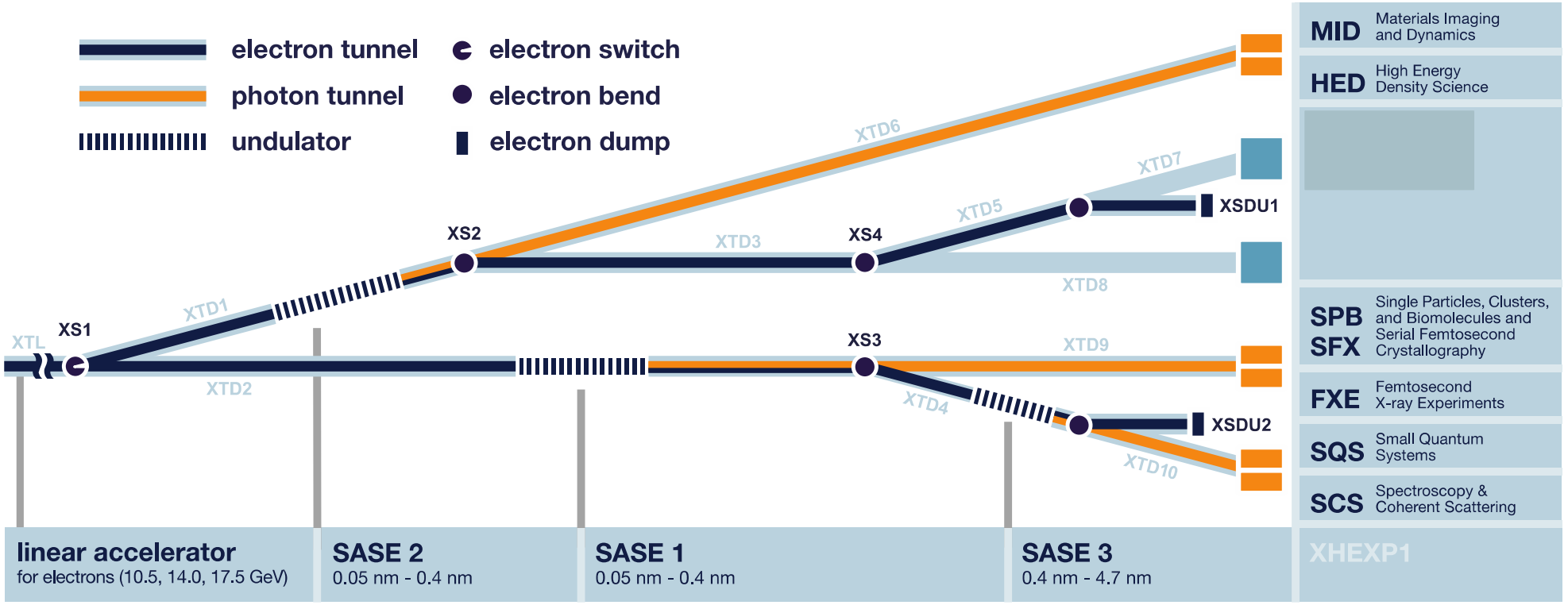


Future upgrades of the facility (below ground)



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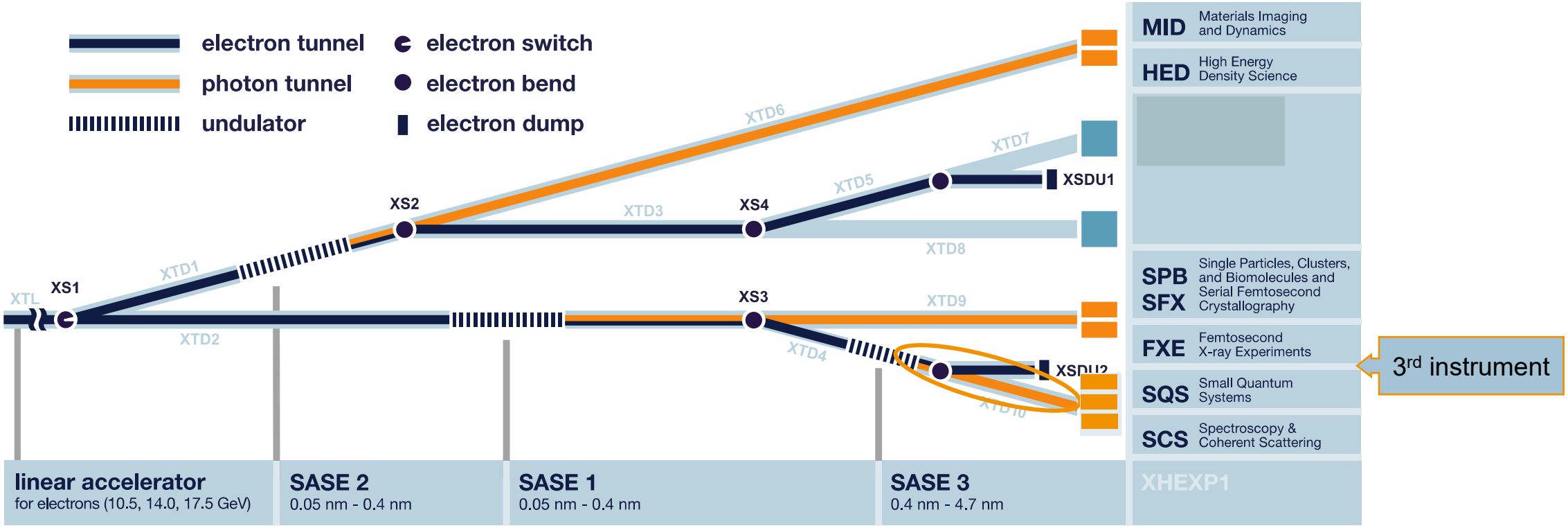

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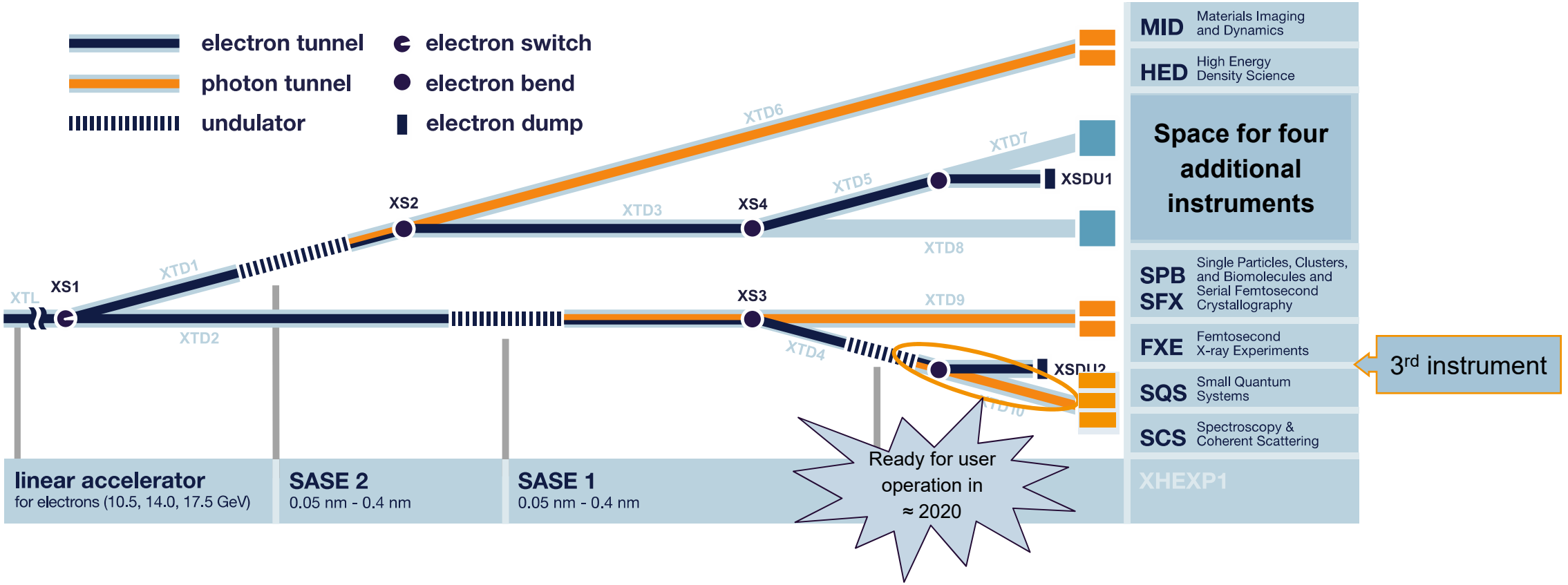

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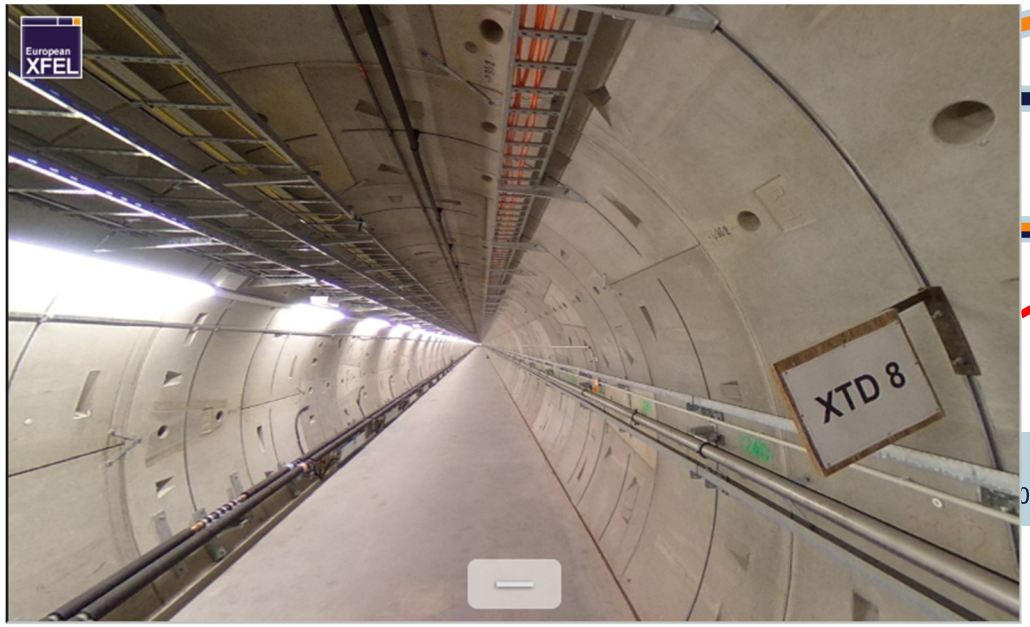
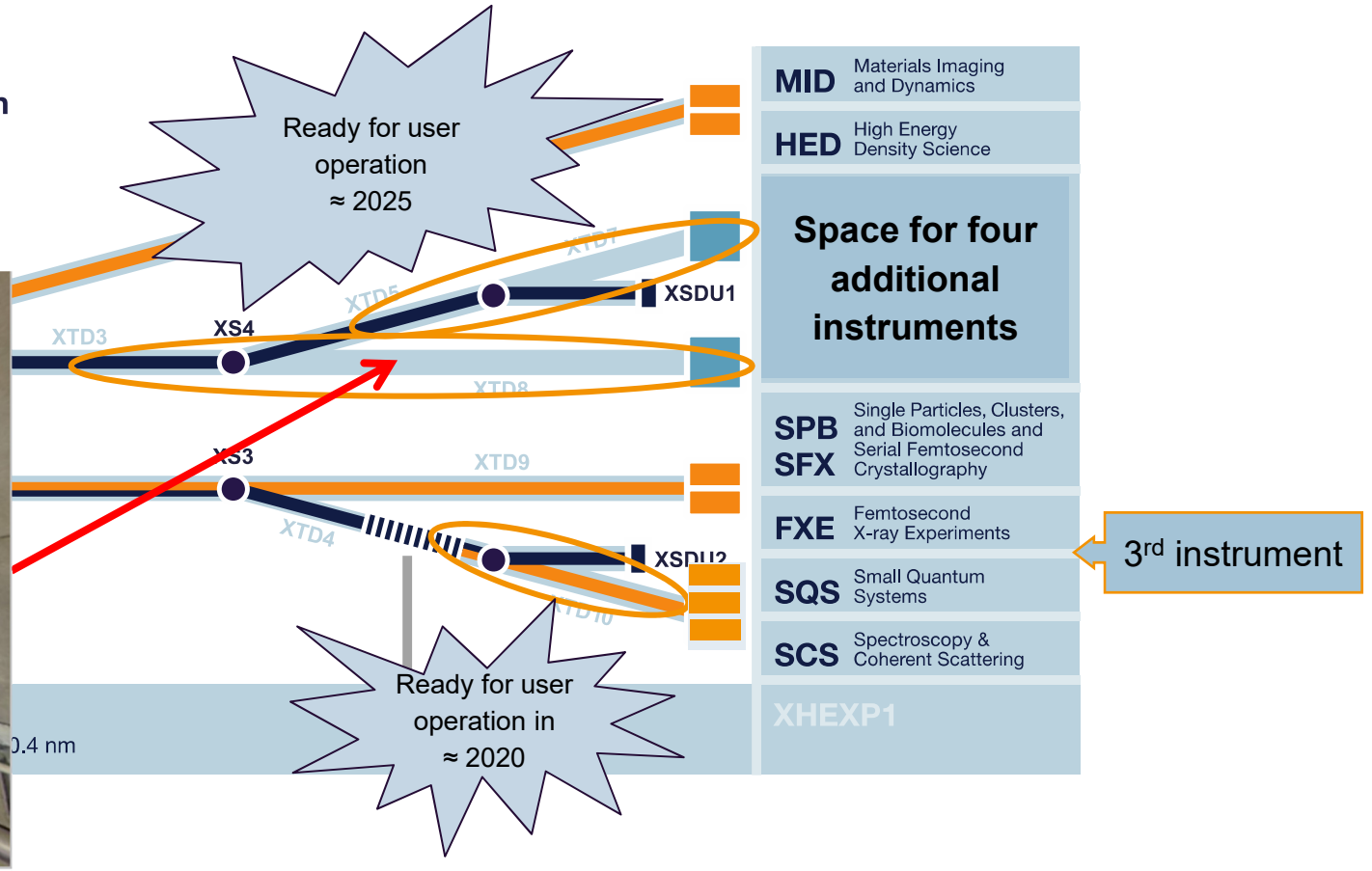
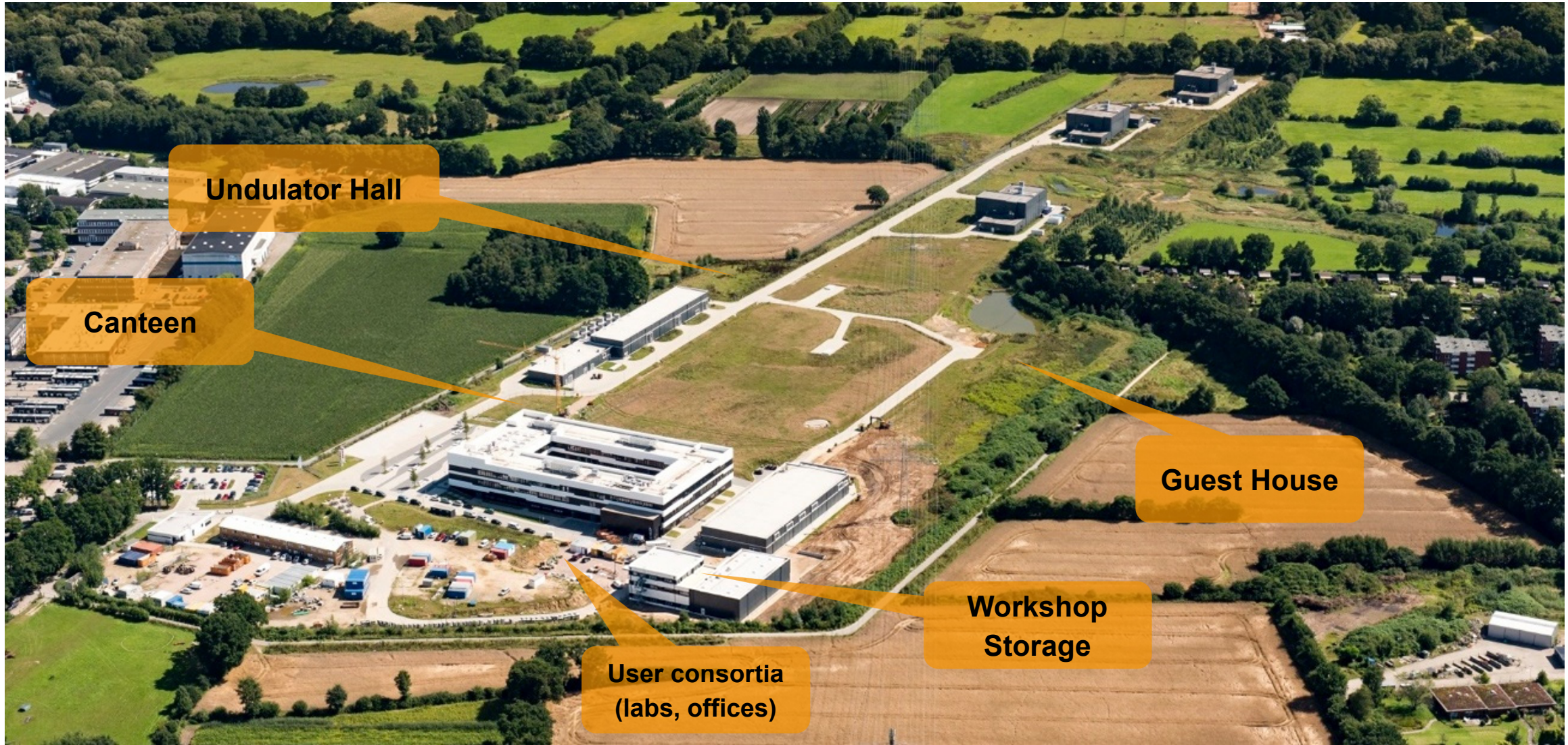




Future upgrades of the facility (above ground)



Many thanks to…

- European XFEL groups:
  - Vacuum
  - X-Ray Optics
  - X-Ray Photon Diagnostics
- Instrument engineers, who contributed to these slides
- DESY accelerator colleagues

Thank you for your attention!