

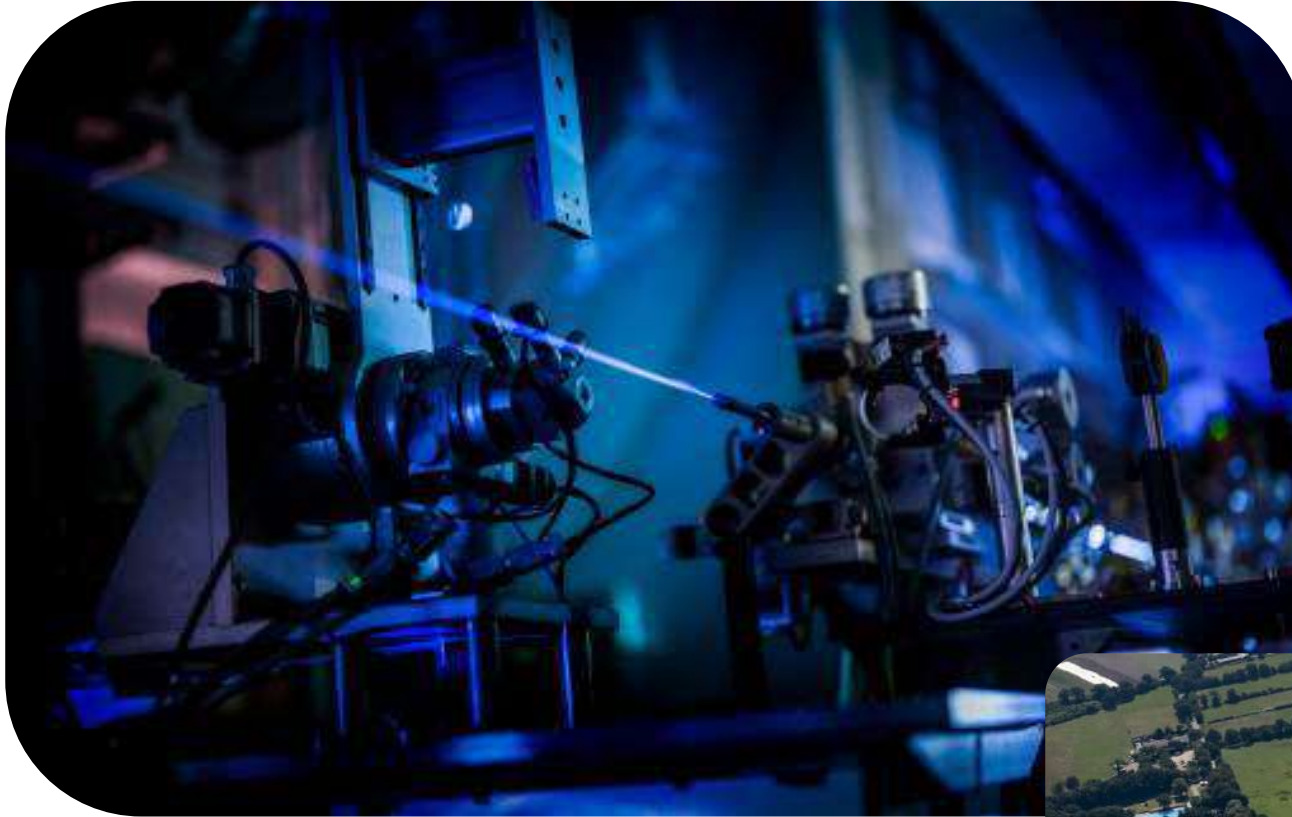
# European XFEL Enlightening Science

Antonio Bonucci  
Head of Industrial Liaison Office and  
In-kind Contributions Supply Chain

[antonio.bonucci@xfel.eu](mailto:antonio.bonucci@xfel.eu)



## European XFEL—a leading new research facility



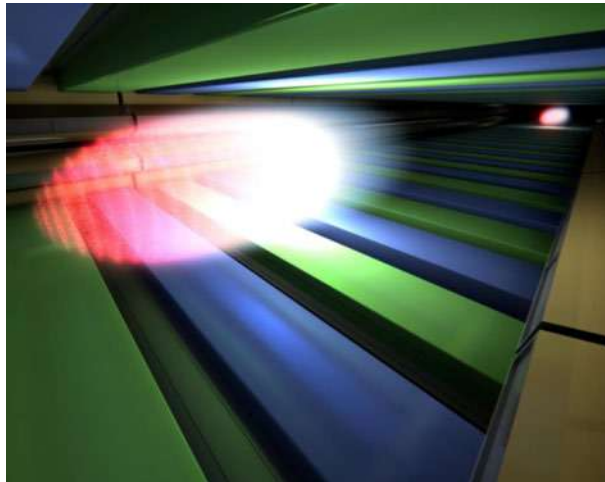
The European XFEL is a new research facility that uses high-intensity X-ray light to study the structure of matter.

- User facility with more than 500 employees (+250 from DESY)
- Location: Hamburg and Schenefeld, Germany



Schenefeld research campus on 14 August 2017

## What can the European XFEL do?



### X-ray light

See samples at atomic resolution

### Ultrashort flashes

Film (bio-)chemical reactions

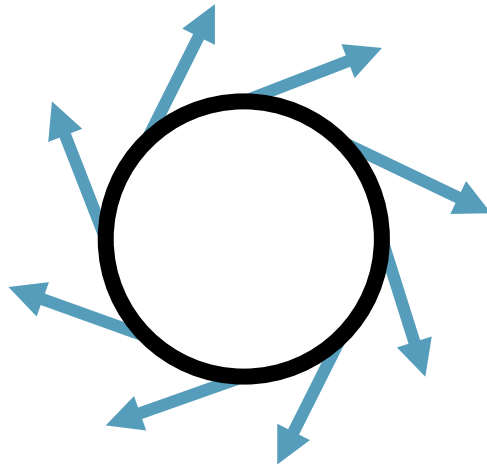
### Intense X-ray pulses

Study single molecules or tiny crystals

# Using X-rays to explore matter

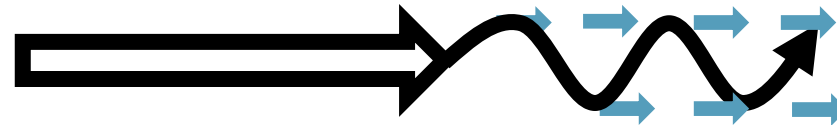
## Synchrotrons

- Electrons traveling in a wide circular path, emitting light as they change directions
- Light is UV or X-ray, but not coherent



## Free-Electron Lasers

- Electrons accelerated in a straight line and manipulated to generate light
- Light is coherent and intensely bright in very short pulses, showing objects in even more detail and revealing processes



## 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
- Total budget for construction (including commissioning)
  - 1.25 billion € at 2005 prices, about 140 M€ operating budget
  - 600 M€ contributed in cash, over 550 M€ as in-kind contributions (mainly manufacture of parts for the facility)

# European XFEL—Entwicklung einer Einrichtung

## We need a strategy for the next phase

Prof. Dr. Massimo Altarelli

### 2009–2017 Construction



- Increased efficiency
- Increased capacity
- Increased quality
- Investment in science
- Science- and challenge-driven experiments

### 2024–2030 Harvesting

Prof. Dr. Thomas Feurer

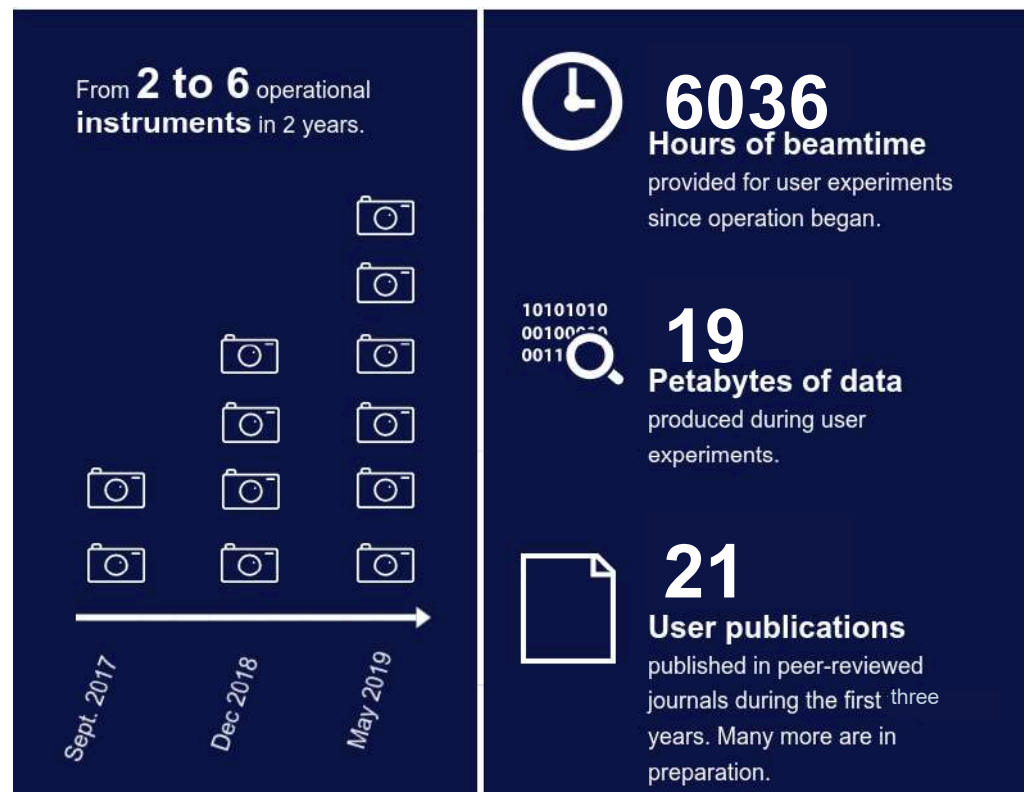
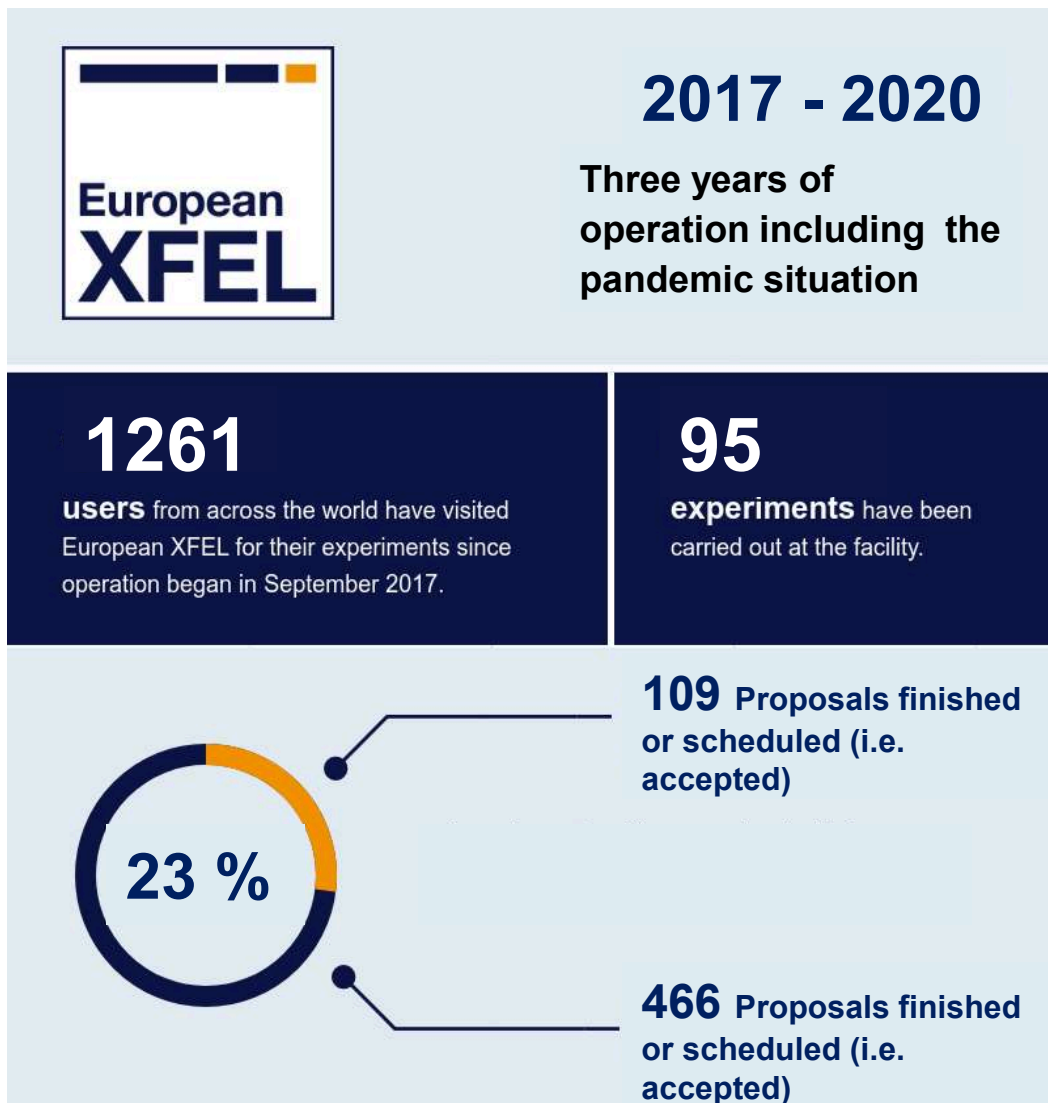
### 2018–2023 Startup

Prof. Dr. Robert Feidenhans'l

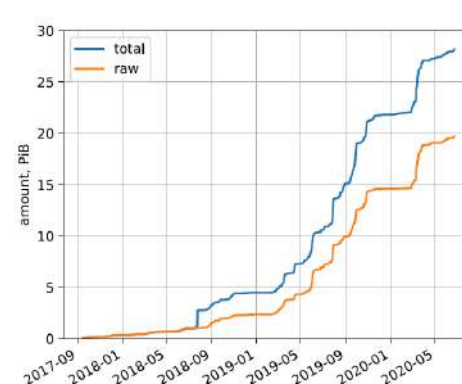
- Start of operation
- First science programme
- Many proof-of-concept experiments
- 2022 – First year of full user operation (<8 000 instrument hrs)
- New developments needed to keep competitive








Data profile



	bytes		
instrument	dtype	proc	total
SPB	3.2 PiB	8.5 PiB	11.6 PiB
MID	2.7 PiB	4.6 PiB	7.2 PiB
SCS	352.9 TiB	2.7 PiB	3.1 PiB
FXE	1.2 PiB	1.3 PiB	2.5 PiB
SQS	59.0 TiB	429.4 TiB	488.4 TiB
HED	18.4 TiB	25.6 TiB	44.0 TiB
<b>total</b>	<b>7.5 PiB</b>	<b>17.5 PiB</b>	<b>25.1 PiB</b>



## 2017 - 2022

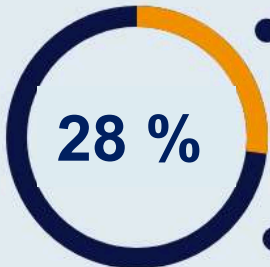
Three years of  
operation including the  
pandemic situation

### 2448

users from across the world have visited European XFEL for their experiments since operation began in September 2017.

### 247

experiments have been carried out at the facility.



28 %

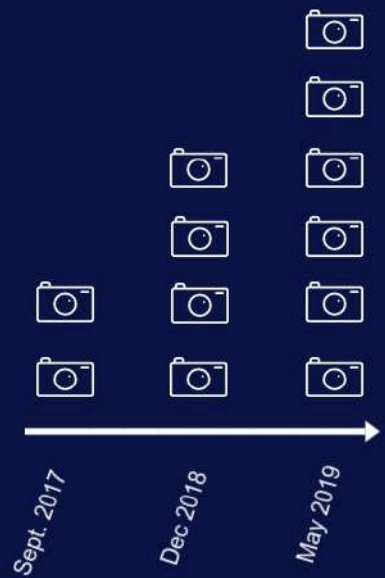
### 247


Proposals finished

### 901

Submitted experimental proposals


From **2 to 6** operational instruments in 2 years.






## 19 944

Hours of beamtime provided for user experiments since operation began.



## 19 (2020), 80 (2023)

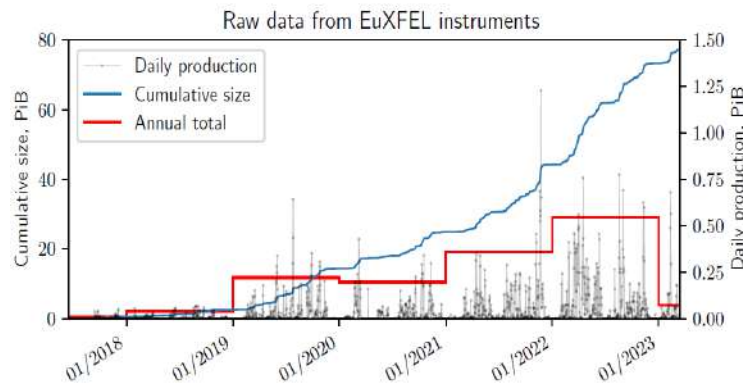
Petabytes of data produced during user experiments.



## 55

User publications published in peer-reviewed journals during the first three years. Many more are in preparation.

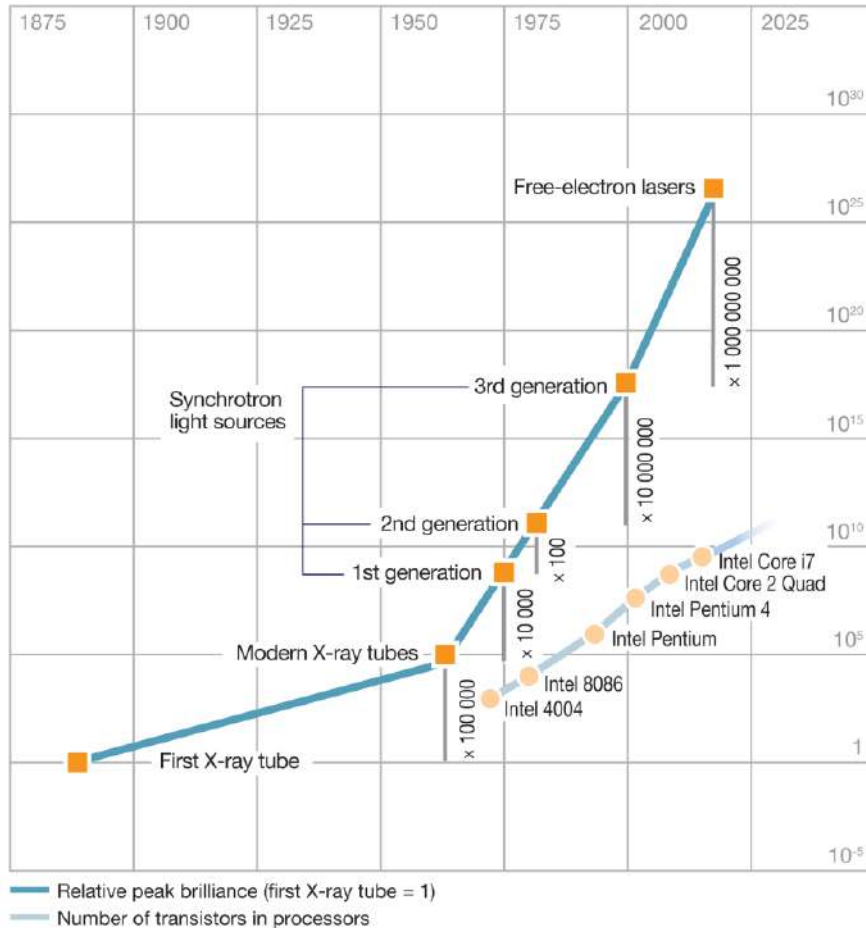
Data profile



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# Light source development



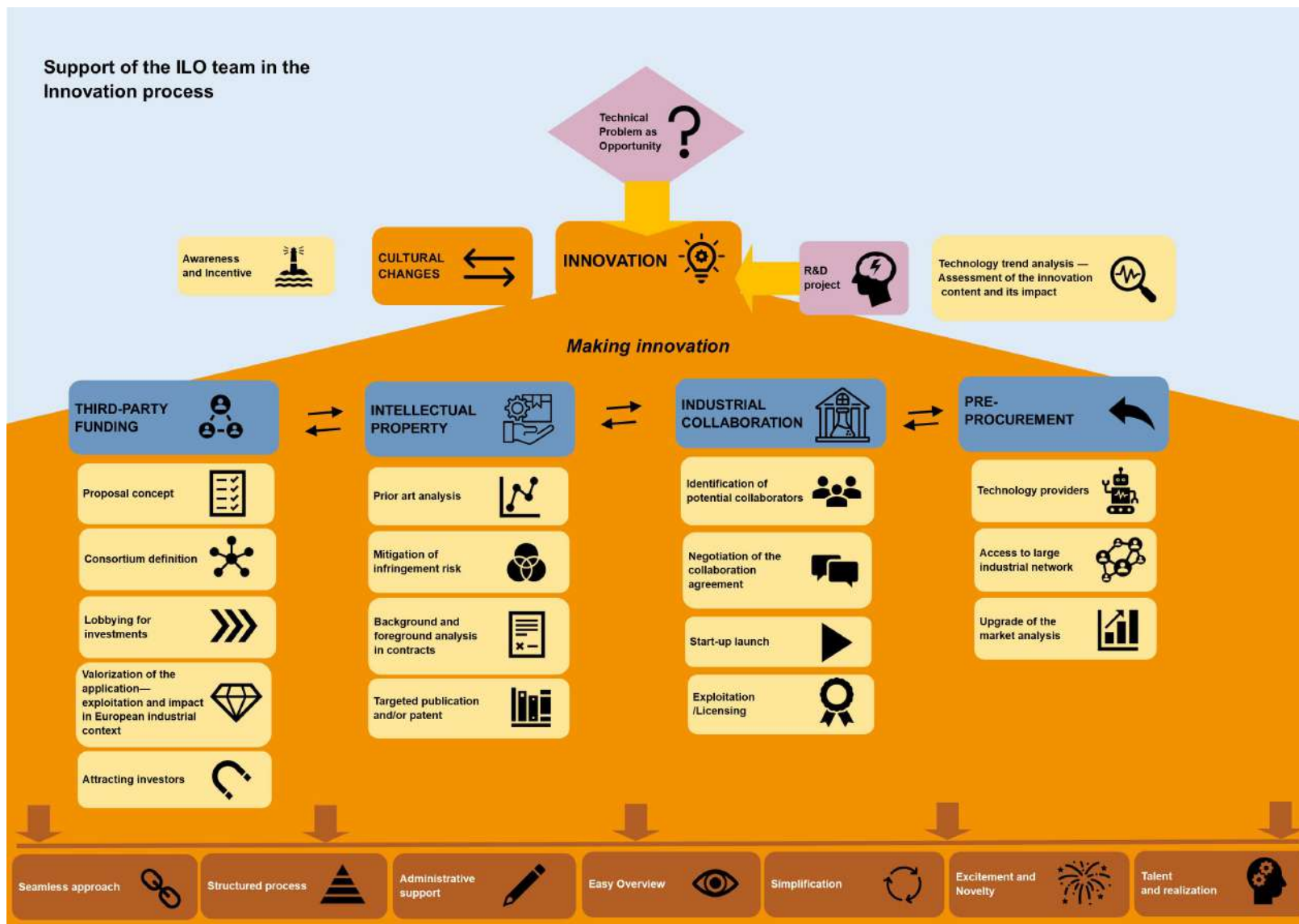
The development of light source facilities has been faster than the increase in computer processing capacity (i.e., Moore's Law)

# X-ray free-electron lasers worldwide

Staff and FEL – status and challenges

Antonio Bonucci, In kind contribution manager and Industrial Liaison Office

Project	FLASH	LCLS CuRF (USA)	LCLS-II SCRF (USA)	SACLA (Japan)	European XFEL	SwissFEL (CH)	PAL-XFEL (S. Korea)	SHINE (China)	FERMI (Italy)
Max. electron energy (GeV)	1.35	15	5.0	8.5	17.5	6.2	10	8	1.55 GeV
Wavelength range (nm)	3.4-90	0.05–5.0	0.25–5.0	0.06–0.3 /8-30	0.05–4.7	0.1–7	0.06–5.0	0.05–3.1	4-100 (1.7-4)
Photons/pulse	~10 <sup>11</sup> -10 <sup>14</sup>	5 x 10 <sup>13</sup>	0.5 - 5 x10 <sup>12</sup>	~5 x 10 <sup>11</sup>	~10 <sup>12</sup> (typical at 12.4 keV)	5 x 10 <sup>11</sup> (HX) 1.2 x 10 <sup>14</sup> (SX)	10 <sup>11</sup> –10 <sup>13</sup>	10 <sup>10</sup> –10 <sup>13</sup>	3x10 <sup>11</sup> -10 <sup>14</sup> (~10 <sup>7</sup> -10 <sup>8</sup> )
Peak brilliance	1 x 10 <sup>31</sup>	4x10 <sup>34</sup> (measured at 10 keV)	2 x 10 <sup>33</sup> (simulated at 1.25 keV)	~5 x 10 <sup>33</sup>	3 x 10 <sup>33</sup> (8.3 keV simulated at saturation without seeding)	1 x 10 <sup>32</sup> –1 x 10 <sup>33</sup>	1.3 x 10 <sup>33</sup>	1 x 10 <sup>33</sup>	2x10 <sup>32</sup>
Average brilliance		5 x 10 <sup>22</sup>	3x10 <sup>25</sup>		2 x 10 <sup>24</sup> (8.3 keV simulated at saturation without seeding)				
Pulses/second	8000	120	1 000 000	60	27 000	100	60	1 000 000	50
Experiment Stations (parallel Operation)	7(2)	9 (3)		7 (3)	7 (3)	5 (2)	3 (2) Instruments 7 (2)	10 (3)	6(2)
Date of first beam	2005	2009	2023	2011	2017	2016	2016	2025	2010

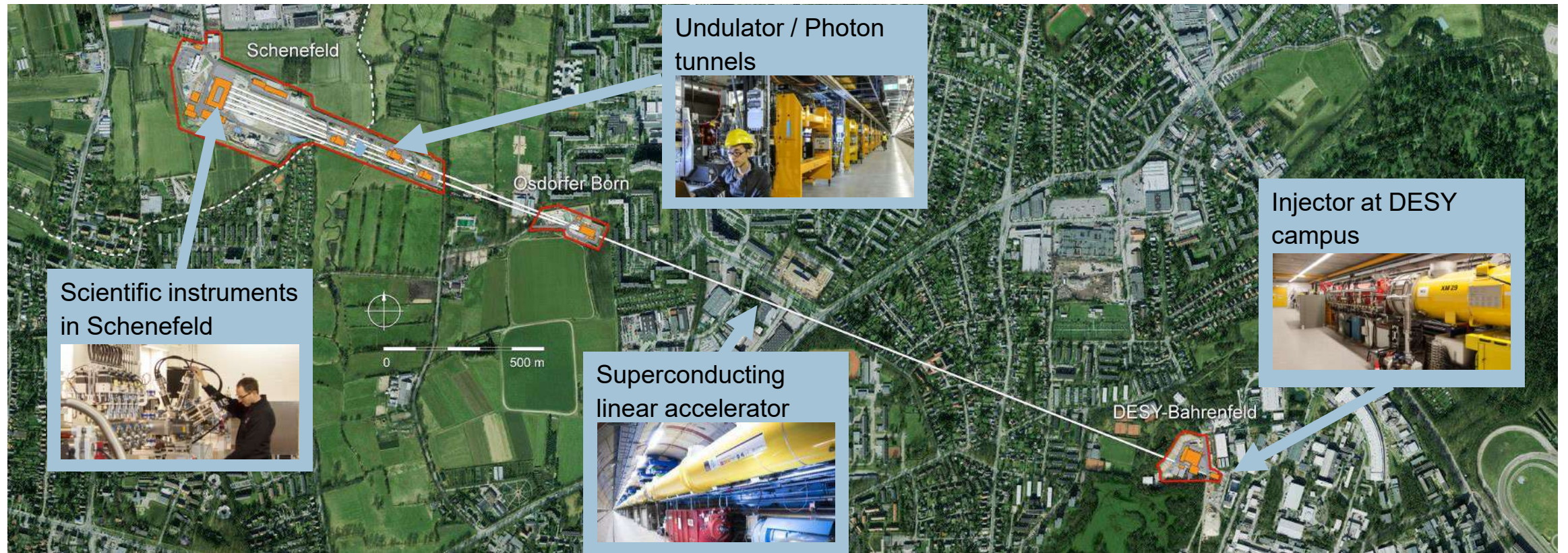


# Outline

- General presentation of European XFEL
- **Main description of the facility**
- Highlights on typical technologies in the experimental hall
- Information about procurement procedures, hints on new internal procedures
- Technologies of interest



# General layout of the European XFEL





# 3.4 km from Injector to Experimental Hall.



SC-LINAC (1,9 Km; 17,5 GeV)



Injector (Hamburg - DESY)



Undulators Sector



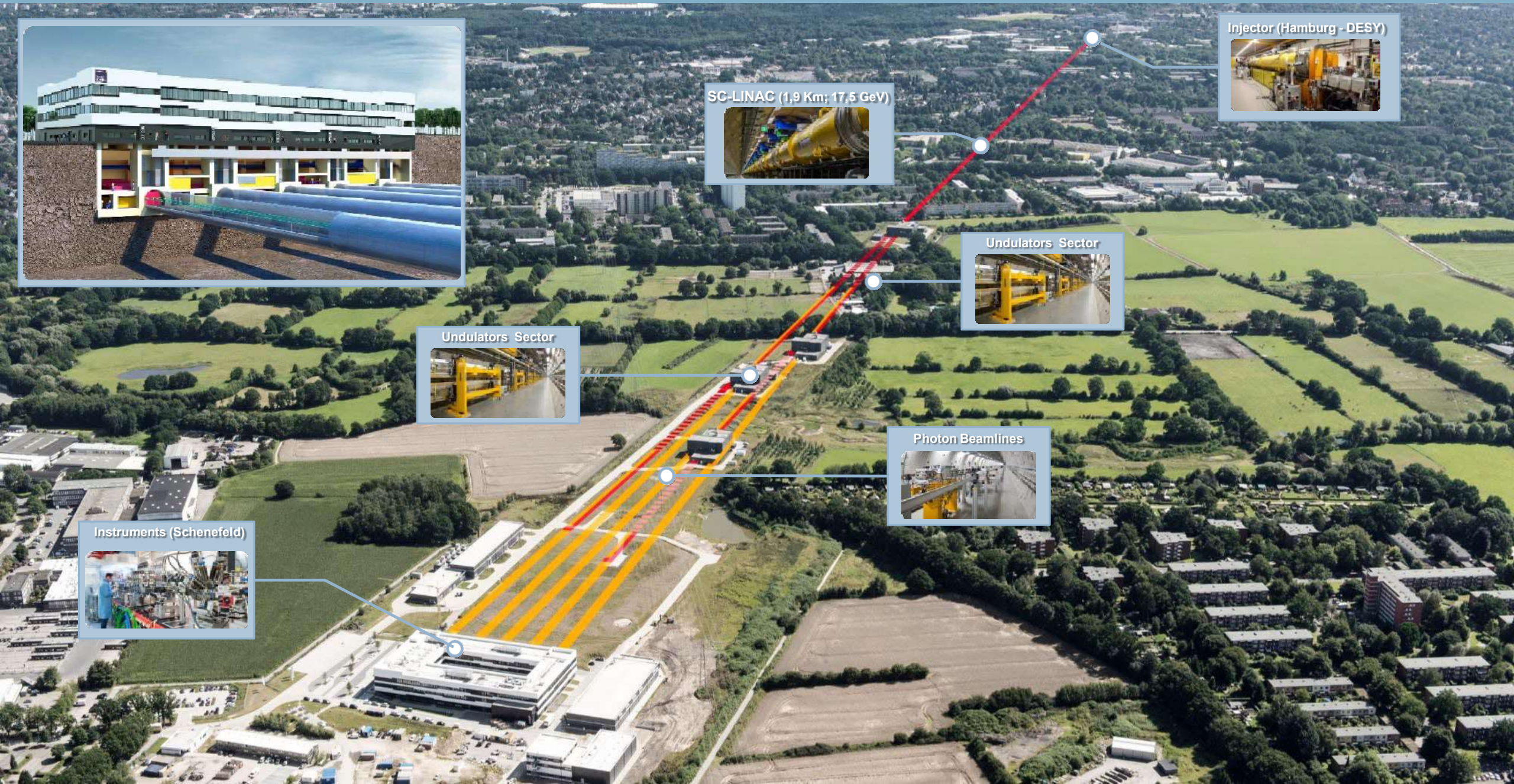
Undulators Sector



Photon Beamlines

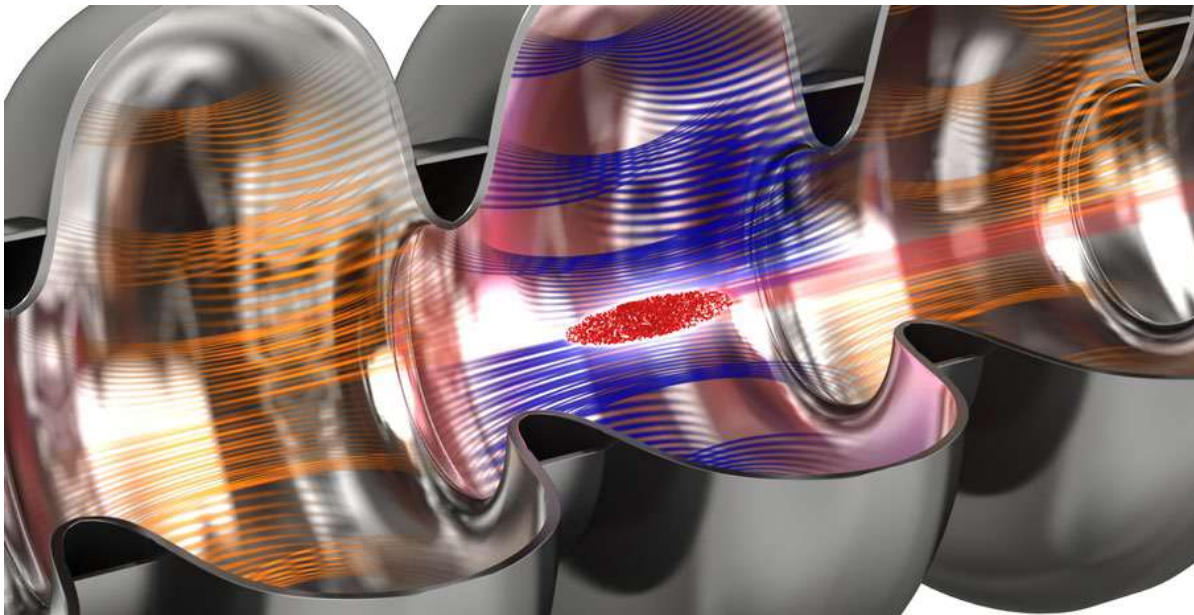


Instruments (Schenefeld)



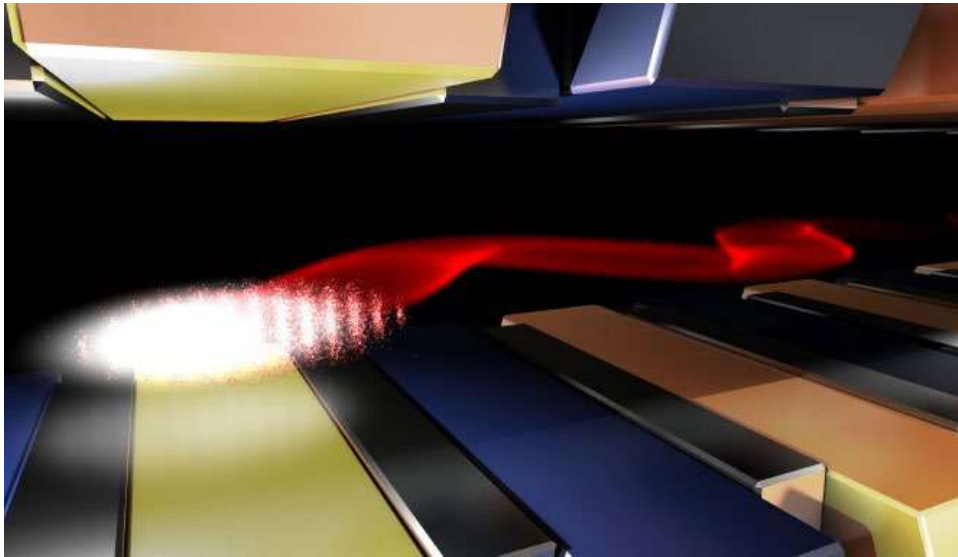


## Accelerator: electrons at close to light speed

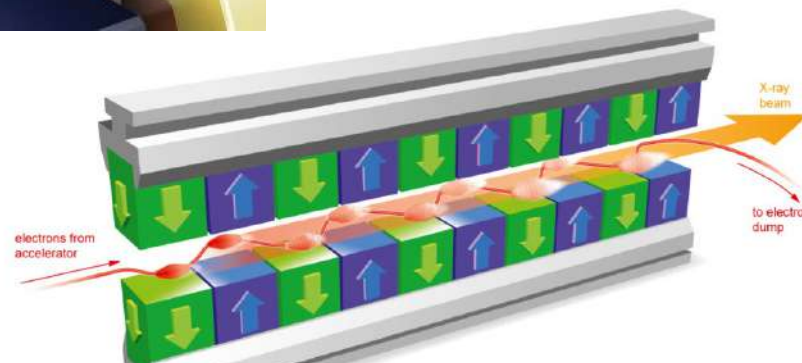


- Superconducting niobium cavities powered by intense radio frequency accelerate electrons
- Ninety-six accelerator modules over 1.7 km bring the electron bunch to near light speed and high energies

## SASE (Self Amplified Spontaneous Emission) undulators: inducing electrons to emit X-ray light



- Alternating magnetic fields cause electrons to take “slalom” course
- Electrons release X-rays with each turn
- SASE process builds intense, laser-like flashes

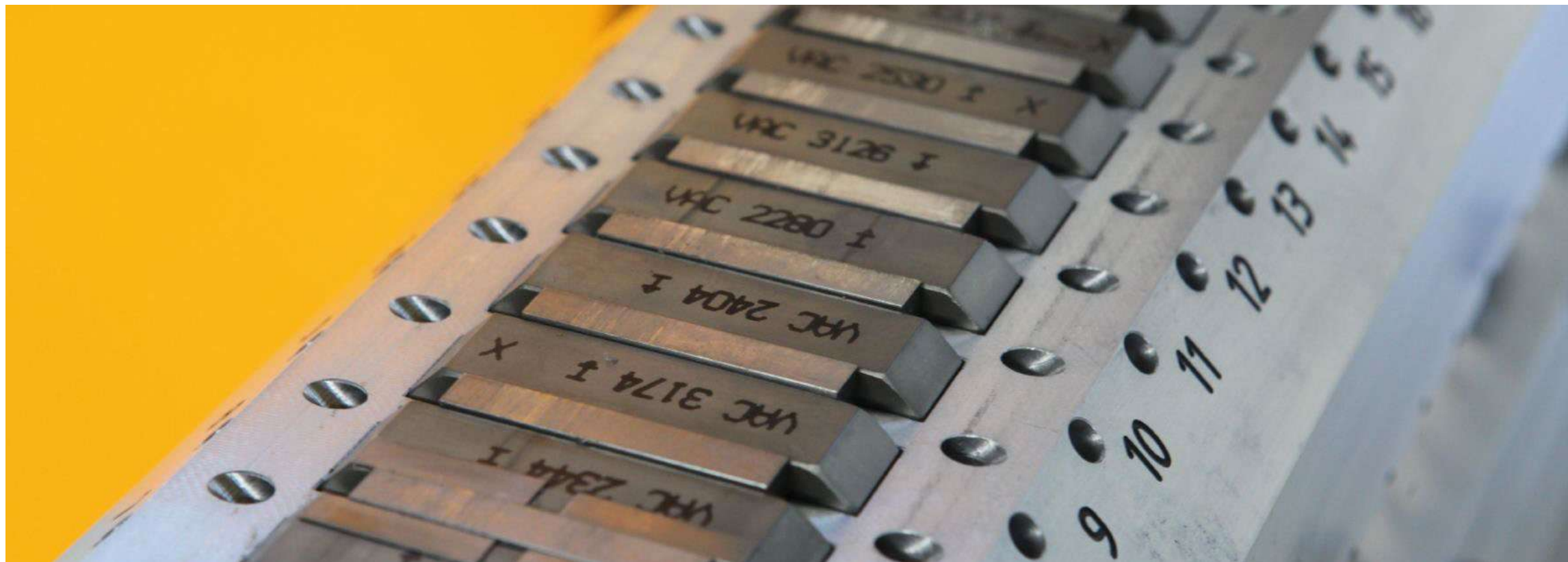


## Tuning undulators





## Undulator magnets





## Undulators in tunnel



## Procurement regulation

Please have a look at

[https://www.xfel.eu/organization/procurement/legal\\_and\\_regulatory\\_information/index\\_eng.html#laws\\_and\\_regulations](https://www.xfel.eu/organization/procurement/legal_and_regulatory_information/index_eng.html#laws_and_regulations)

### ■ Threshold EU international call for tender

Until the end of 2021, the EU threshold for construction contracts was set at 5.35 M€ and for all other supply and service contracts at 215 k€

### ■ Rules of Procedure for the award of public supply and service contracts below the EU thresholds

[https://www.xfel.eu/sites/sites\\_custom/site\\_xfel/content/e35152/e46557/e47200/e47206/xfel\\_file47209/UVgOEnglisch\\_eng.pdf](https://www.xfel.eu/sites/sites_custom/site_xfel/content/e35152/e46557/e47200/e47206/xfel_file47209/UVgOEnglisch_eng.pdf)

### ■ Procurement Ordinance

[https://www.xfel.eu/sites/sites\\_custom/site\\_xfel/content/e35152/e46557/e47200/e47206/xfel\\_file86104/VgV-ordinance-award-of-public-contracts\\_eng.pdf](https://www.xfel.eu/sites/sites_custom/site_xfel/content/e35152/e46557/e47200/e47206/xfel_file86104/VgV-ordinance-award-of-public-contracts_eng.pdf)

## Call for tender

- The European XFEL GmbH is a public-equivalent body and is therefore subject to special legal regulations concerning the award of contracts and placement of purchase orders. This includes, for example:
  - **the VOB** ("Verdingungsordnung für Bauleistungen“, regulations for civil construction contracts),
  - **the VOF** ("Verdingungsordnung für freiberufliche Leistungen“, regulations for freelance and professional services contracts)
  - **the VOL** ("Vergabe- und Vertragsordnung für Leistungen“, regulations on contract awards for public supplies and services),

[https://www.xfel.eu/organization/procurement/legal\\_and\\_regulatory\\_information/index\\_eng.html](https://www.xfel.eu/organization/procurement/legal_and_regulatory_information/index_eng.html)

- The award of contracts and placement of purchase orders fall under the responsibility of the Procurement Group

## General Purchase Conditions

- Due to the fact that we are a government-funded organization, we are not allowed to accept other terms and conditions than these. Please read them carefully and include them as part of your public tender documentation.

[https://www.xfel.eu/sites/sites\\_custom/site\\_xfel/content/e35152/e46557/e47200/e47202/xfel\\_file47204/EuXFEL\\_GeneralTermsConditions\\_01Oct2023\\_eng.pdf](https://www.xfel.eu/sites/sites_custom/site_xfel/content/e35152/e46557/e47200/e47202/xfel_file47204/EuXFEL_GeneralTermsConditions_01Oct2023_eng.pdf)



## General Purchase Conditions

If the delivery or service resulting from a works contract is carried out in accordance with the contractual conditions, it will be accepted. If a test run is agreed, the delivery or service is deemed accepted by means of a joint acceptance report after a flawless test run.

In addition, the Goods to be delivered must comply with the applicable safety regulations (e.g. EU Directive 2006/42 on machinery, EU Directive 2014/35 on the market of electrical equipment designed for use within certain voltage limits, EU Directive 2014/30 relating to electromagnetic compatibility, EU Directive 2014/68 on the market of pressure equipment, EU Directive 2011/65 on the restriction of the use of certain hazardous substances in electrical and electronic equipment, German Product Safety Act (ProdSG - Act on making products available on the Market) and be provided with all prescribed markings (e.g. CE mark), declarations (e.g. declaration of conformity, declaration of incorporation) and documents (e.g. operating instructions, assembly instructions, safety data sheets). Protective devices, markings, declarations, and documents required according to such regulations shall be taken into account in the Contractor's calculation and shall be part of the scope of delivery, even if they are not requested separately by the Client.



## General Purchase Conditions

The Contractor shall keep all images, drawings, calculations, and other documents and information (hereinafter referred to as “Confidential Information”) received for the execution of the Purchase order strictly confidential and to disclose them only to employees who have been obliged to treat them confidentially. Confidential Information may only be disclosed to third parties with the prior written consent of the Client, which must be granted in the event of proven judicial or statutory claims for disclosure. The obligation to maintain confidentiality shall also apply after the termination of this contract; it shall expire - unless otherwise agreed - five years after the conclusion of the contract or if and to the extent that the Confidential Information has become public domain.

The Contractor is liable for ensuring that no third-party property rights are violated during the execution of the contract and during the delivery and use of the delivered item or service. Upon first written request, the Contractor shall indemnify the Client against any third-party claims arising from any property right infringements.

The Client is entitled to obtain the necessary authorization for delivery, commissioning, use, resale, etc. of the delivery item or service from the owner of such property rights at the Contractor’s expense if the Contractor is unable to obtain such rights, finally refuses such subsequent performance, or is in default with subsequent performance.

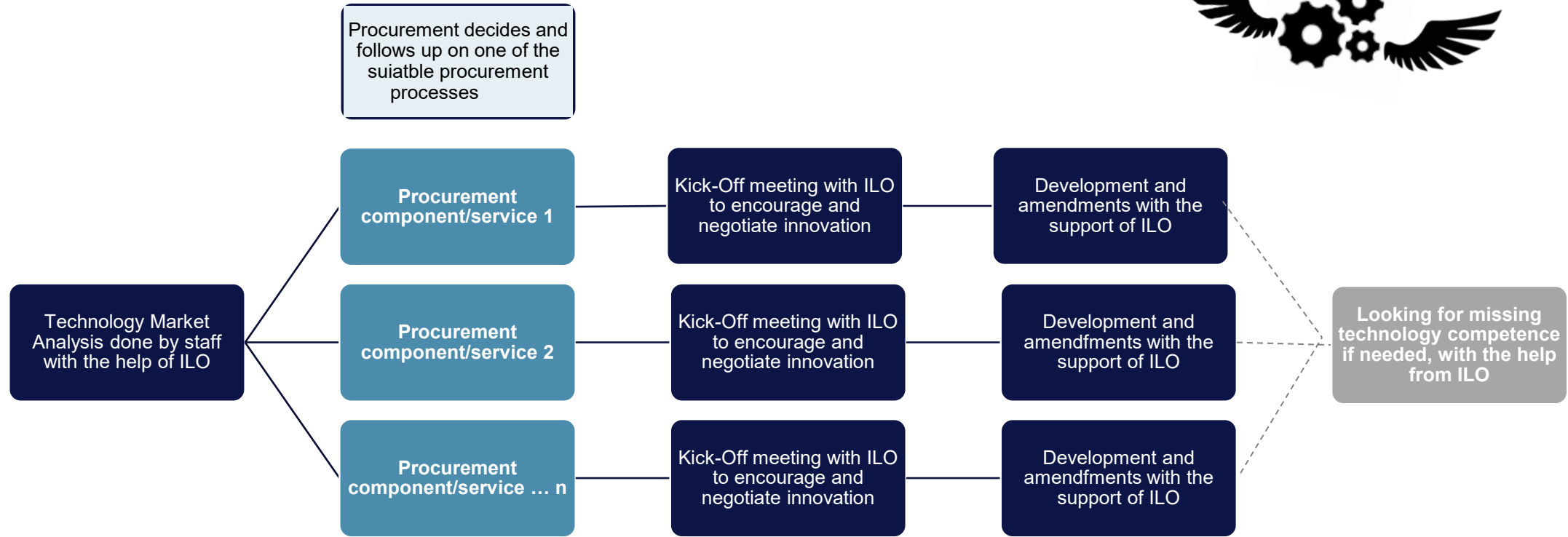
The Contractor shall grant the Client free-of-charge a non-exclusive and irrevocable license to all domestic and foreign property rights, applications for property rights, and inventions, insofar as they have arisen during the performance of this contract. Furthermore, the Contractor shall grant the Client free-of-charge an irrevocable and non-exclusive right to use all know-how and every innovation and improvement, insofar as these have arisen during the performance of this contract. The Client is entitled to transfer licenses and rights of use within the meaning of the above paragraph to its shareholders. This shall also apply beyond the term of this contract. The Contractor shall expressly agree the above rights with its subcontractors for the benefit of the Client.

## General Purchase Conditions

The Contractor shall, no later than two weeks after placing the Purchase order, notify the Client independently and in writing for each individual item of all information and subsequent changes thereto required by the Client for compliance with foreign trade and payments law in the case of export, import, and re-export, in particular:

- 3.2. All applicable export list numbers, in particular in accordance with Annex AL to the German Foreign Trade and Payments Regulation (AWV) or comparable list positions of relevant export lists including the “Export Control Classification Number” in accordance with the “US Commerce Control List” (ECCN), if the Goods are subject to the “US Export Administration Regulations” (EAR);
- 3.5. All information of the Contractor required by the Client for the fulfillment of its obligations under the EU Regulation 2023/956 establishing a carbon border adjustment mechanism; and

# Innovation procurement workflow



Procurement decides and follows up on one of the suitable procurement processes

Technology Market Analysis done by staff with the help of ILO

Procurement component/service 1

Procurement component/service 2

Procurement component/service ... n

Kick-Off meeting with ILO to encourage and negotiate innovation

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Kick-Off meeting with ILO to encourage and negotiate innovation

Development and amendments with the support of ILO

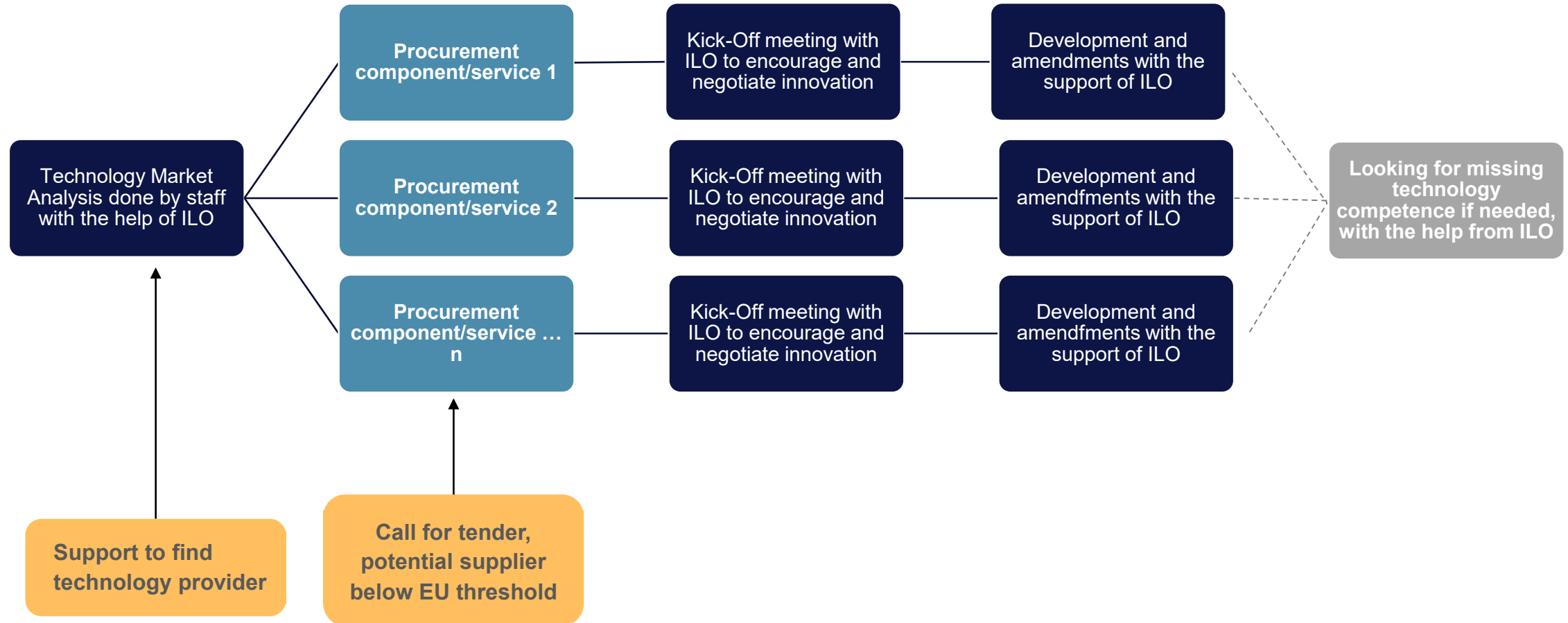
Development and amendments with the support of ILO

Development and amendments with the support of ILO

Looking for missing technology competence if needed, with the help from ILO



# Innovation procurement workflow: **National ILO** involvement







# Supplier Database: <https://in.xfel.eu/thesurvey/index.php/782712?lang=en>



Resume later    Exit and clear survey

0%

## General information

\*Company name

\*Contact name

\*E-mail

\*Job title

\*Telephone

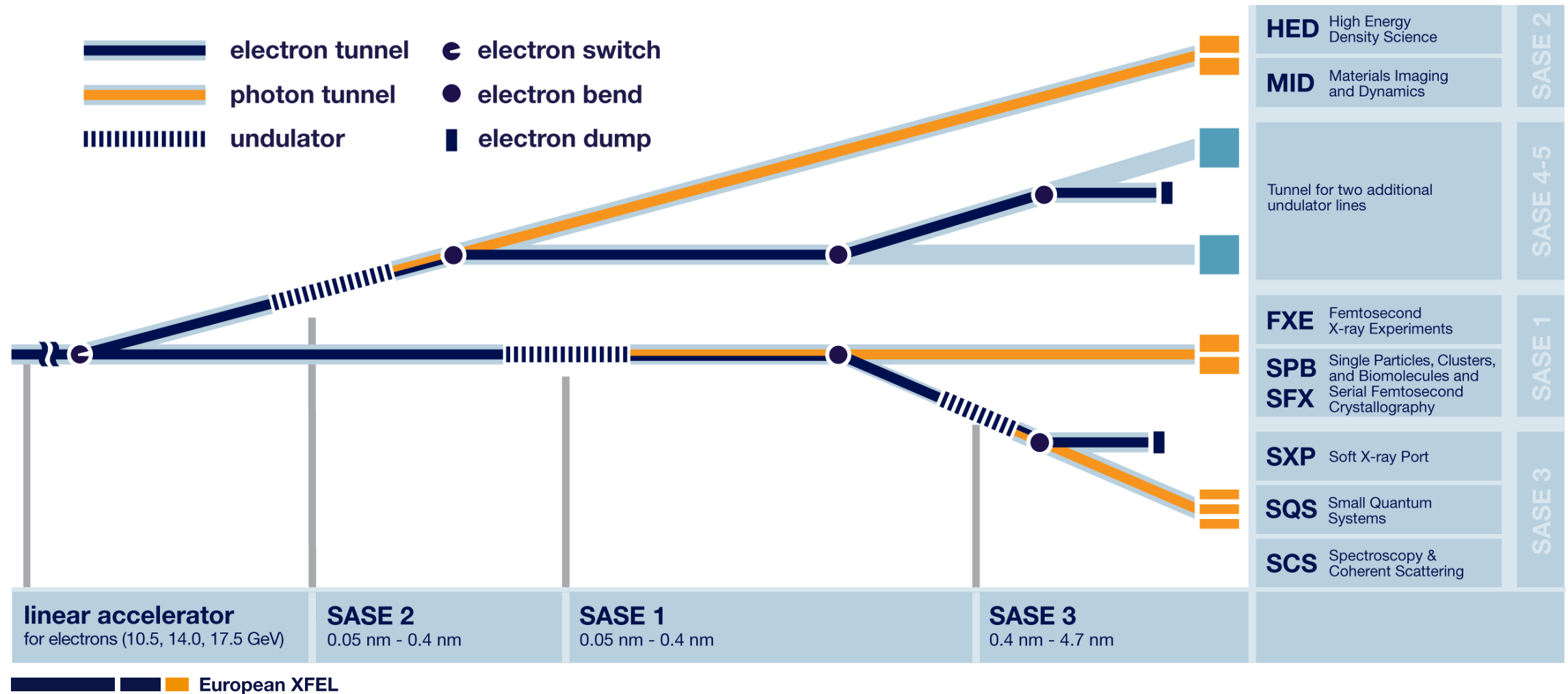
\*What is your core business model?

[Link](#)

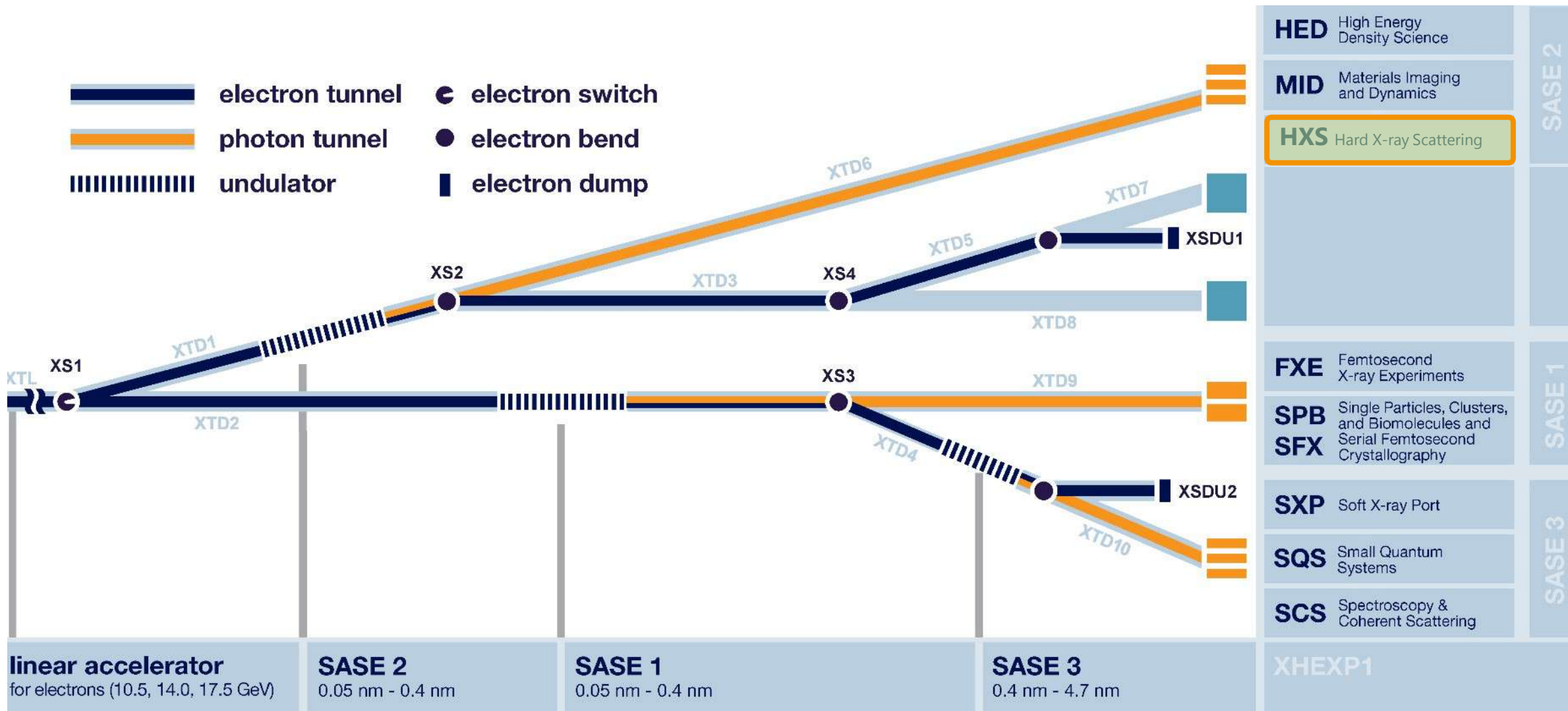
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# Beamline layout and experiment stations



# This decade: SASE2 Beamline 3<sup>rd</sup> port





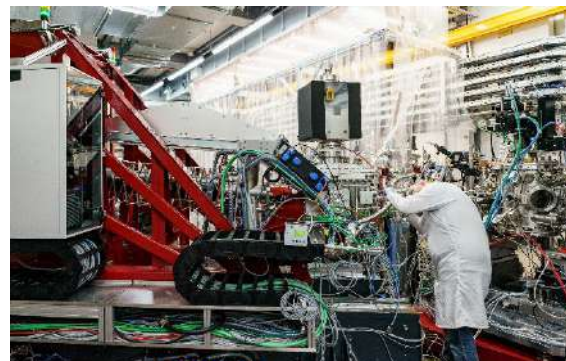
## Seven scientific instruments



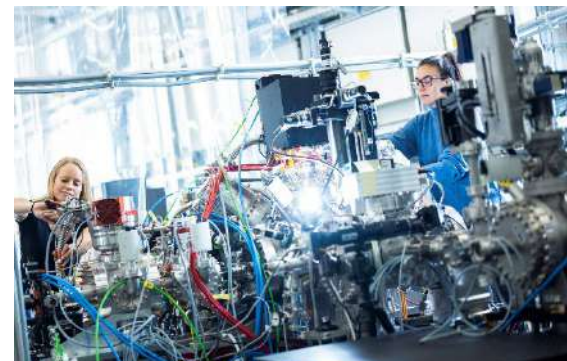
**FXE** (start Sep 2017)



**SPB/SFX** (start Sep 2017)



**SCS** (start Nov 2018)



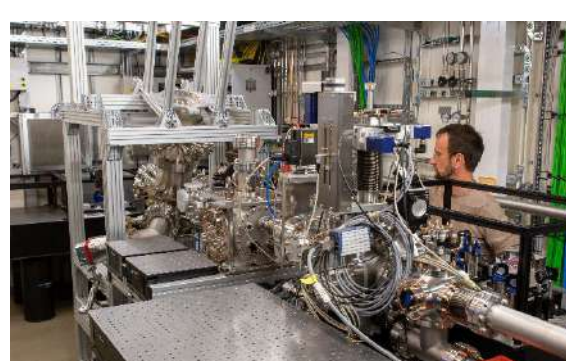
**SQS** (start Nov 2018)



**MID** (start Apr 2019)



**HED** (start May 2019)

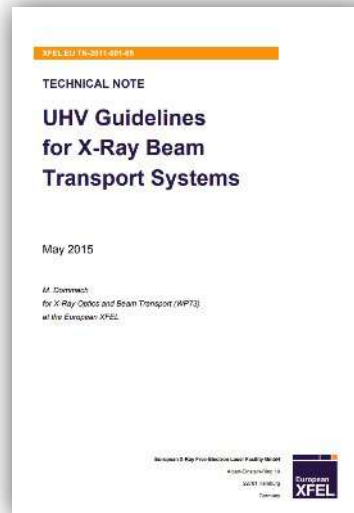


**SXP** (start summer 2023)



# Photon Beam Transport System

- According to XFEL UHV Guidelines.
- Outsourced manufacturing and cleaning.
- “Particle free“ specifications (ISO Class 5/6).
- Sectorization & Mobile clean tents.
- In-situ conditioning (specific cases): wet-cleaning, baking, plasma cleaning...
- Hundreds of meters beampipe (flanged and in-situ orbital-welded sectors)
- Standard vacuum components:
  - Pumping Stations
  - Beamline Pumping equipment (mechanical, SIP's, NEG's)
  - Controller for pumps, gauges...
  - Gauges, RGA's,...
- PLC Control system (racks, terminals, interfaces).
  - PLC terminals
  - Power supplies, connectors, cables
  - Controller for pumps, gauges...



## Some „sizing“ numbers for vacuum...

### Construction phase (2011-2017)

- Accelerator warm vacuum system: 6 M€
- Accelerator cold vacuum system : 5 M€
- Photon beamlines (warm) vacuum system: 8 M€

### Operation-related averaged procurement(\*)

- Accelerator cold vacuum system: 250 k€/year
- Accelerator warm vacuum system: 500 k€/year
- Photon beamlines (warm) vacuum system: 600 k€/year

## Die Vakuumsysteme des European XFEL

Ultrahochvakuum ermöglicht Betrieb des neuen Röntgenlasers der Superlative und erlaubt bisher unerreichte Einblicke in den Nanokosmos.

Martin Dommach, Sven Lederer, Lutz Lijje



### Einleitung

Der European XFEL ist eine internationale Forschungseinrichtung der Superlative: 27 000 Lichtblitze pro Sekunde mit einer Leuchtstärke, die milliardenfach höher ist als die der besten Röntgenquellen herkömmlicher Art, eröffnen vielfältige neue Forschungsmöglichkeiten. Wissenschaftlerteams aus der ganzen Welt untersuchen am European XFEL Strukturen im Nanobereich, ultraschnelle Prozesse und extreme Materiezustände, nehmen dreidimensionale Bilder von Viren und Proteinen auf und filmen chemischen Reaktionen. Die neue Forschungseinrichtung wird von der European XFEL GmbH betrieben, einer gemeinnützigen Gesellschaft, die eng mit ihrem Hauptgeschäftspartner, dem Forschungszentrum DESY, und weiteren wissenschaftlichen Einrichtungen weltweit kooperiert.

Für die Erzeugung des Röntgenlichtes werden hochenergetische Elektronenpakete durch eine periodische Magnetfeldanordnung im sogenannten Undulator transportiert. Dabei beginnt durch die Überlagerung des entstehenden Lichtfeldes mit dem Elektronenpaket ein sich selbstverstärkender Prozess, der schließlich einen Röntgenlaserpuls erzeugt. Dieser auch SASE (Self Amplified Stimulated Emission) genannte Vorgang wird auch bei verschiedenen anderen Lichtquellen eingesetzt. Der besonders hohe Strahlstrom, der mit dem supraleitenden System des European XFEL beschleunigt werden kann, ermöglicht die sehr hohe Leuchtstärke. Damit der SASE Prozess funktionieren kann bedarf es sehr hoher Spitzenstromstärke und sehr guter Brillanz der Elektronenpakete. Diese werden im Injektor des Beschleunigers mittels einer Hochfrequenzelektronenquelle erzeugt. In drei Elektronenpuls-kompressoren werden die Elektronenpa-

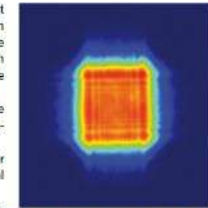
kete weiter verdichtet. Der Transport dieser sehr intensiven, komprimierten Elektronen- und Photonenstrahlpakete stellt viele besondere Anforderungen an die umgebenden Vakuumsysteme [1,2] (Abb. 1 und 2).

Im European XFEL gibt es mehrere große Vakuumsysteme mit höchst unterschiedlichen Anforderungen:

- ▶ Die Vakuumsysteme in denen der Elektronen- bzw. Photonenstrahl transportiert wird;
- ▶ Das Isoliervakuum für die supraleitenden Beschleunigermodule und der Heliumversorgung;
- ▶ Das zusätzliche Vakuumsystem der Hochfrequenzkoppler der supraleitenden Beschleunigermodule.

In diesem Beitrag wird vorrangig auf die Vakuumsysteme des Elektronen- bzw. Photonenstrahltransports eingegangen.

Das Elektronenstrahlvakuum ist in mehrere Abschnitte aufgeteilt, wobei eine wesentliche Unterscheidung zwischen dem Teil der supraleitenden Beschleunigungsmodule mit der Betriebstemperatur von 2 K und dem restlichen Beschleuniger vakuum bei Raumtemperatur gemacht wird. Der Raumtemperaturteil wird aufgrund der Vielzahl verschiedener Anforderungen wiederum



ABILDUNG 1: Ein erstes Röntgenbeugungsbild des European XFEL, aufgenommen durch eine etwa einen Millimeter große quadratische Blende am Instrument SPB/SFX. Das gleichmäßige, netzartige Muster zeigt die hohe laserartige Qualität des Lichtstrahls.

unterteilt in mehrere Sektoren: Injektion, Elektronenpulskompression, Kollimation, Undulatorbereich sowie Strahltransport. Alle diese Sektoren sind mit detaillierten Spezifikationen aus den Bereichen Vakuum, elektrischer Leitfähigkeit und Magnetisierbarkeit, Oberflächengüte, Reinheitsklasse in Bezug auf Partikelfreiheit sowie Fertigungs- und Aufstelltoleranzen versehen.

### ZUSAMMENFASSUNG

Für den European XFEL ist Vakuum eine Grundvoraussetzung für den erfolgreichen Betrieb. Neben den Vakuumigenschaften war dafür eine Vielzahl anderer Randbedingungen an die Komponenten zu erfüllen. Hervorzuheben ist hier insbesondere die erforderliche Reinheitsklasse, die für ein kilometerlanges System des Teilchenbeschleunigers und bei den Röntgenoptiken erreicht wurde. Außerdem

sind viele Komponenten speziell für den European XFEL entwickelt worden, um z.B. die hohe Elektronenstrahlqualität zu gewährleisten. Durch redundante Auslegung und Segmentierung des Vakuumsystems konnte die Inbetriebnahme in kürzester Zeit erfolgreich stattfinden. Die ersten Experimente mit dem Röntgenlaserlicht haben bereits stattgefunden.



## Hybrid permanent magnet undulators at European XFEL

**Table 1**  
Specifications for the undulator segments of the EuXFEL.

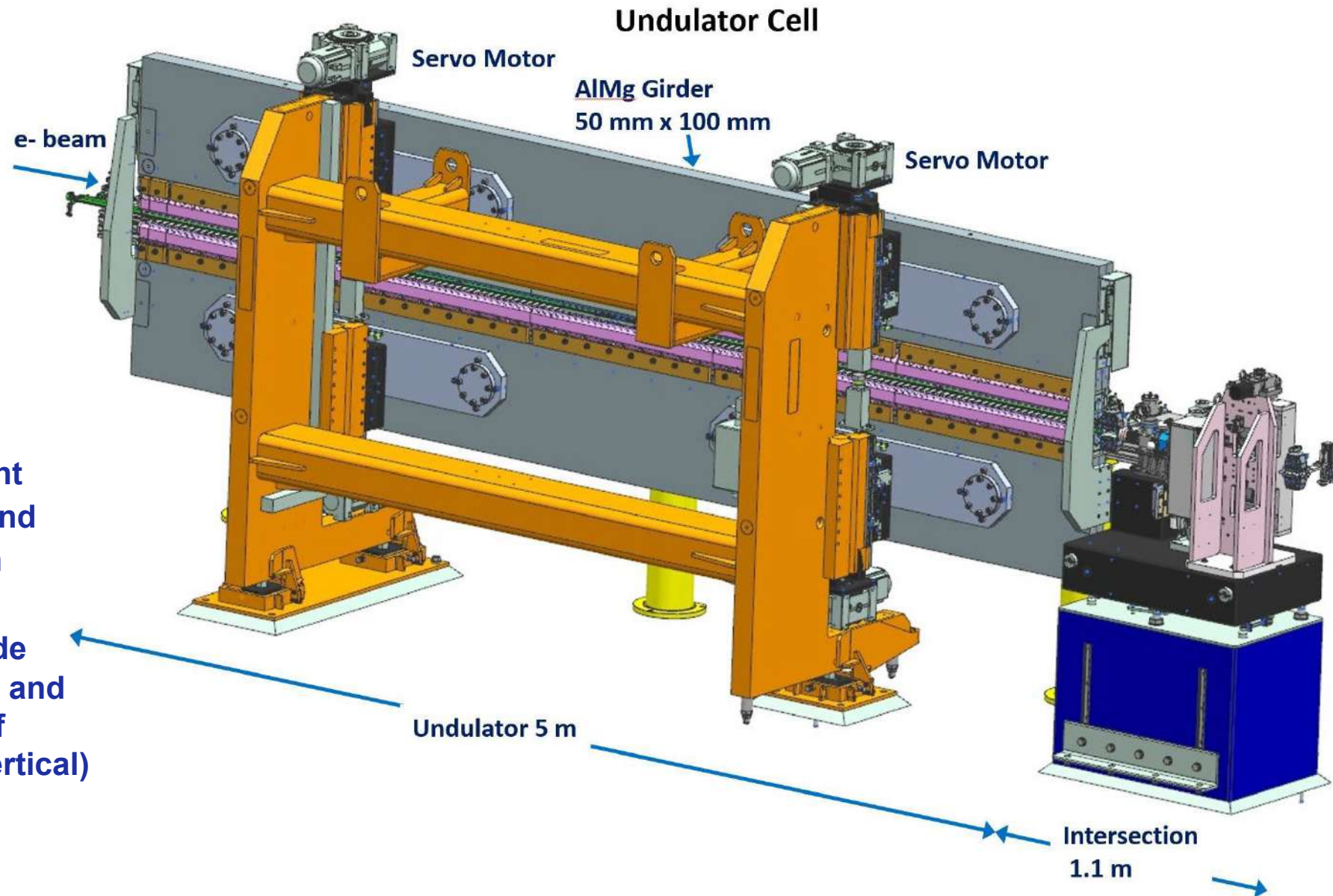
The operational ranges for gap and  $K$  parameter match user requirements (Altarelli *et al.*, 2006). Only inside are all specifications strictly fulfilled. Magnetic tuning was always performed at the tuning gap to limit gap dependence of magnetic properties, see discussion of Fig. 4.

	SASE1 / SASE2	SASE3
Undulator type	U40	U68
Period length (mm)	40	68
Segment length (m)	5	5
Total number of poles	248	146
Magnetically active poles	246	144
Number of ending poles	3	3
Operational gap range (mm)	10–20	10–25
Operational $K$ -parameter range	1.65–3.9	4–9
Maximum peak field @ 10 mm (T)	1.11	1.66
Tuning gap (mm)	14	16
Maximum gap (mm)	200	200
Maximum phase jitter ( $^{\circ}$ )	$\leq 8$	$\leq 8$
Maximum 1st $B_y$ field integral (T mm)	$\pm 0.15$	$\pm 0.15$
Maximum 1st $B_x$ field integral (T mm)	$\pm 0.15$	$\pm 0.15$
RMS of 2nd $B_y$ integral (T mm <sup>2</sup> )	<100	<210
RMS of 2nd $B_x$ integral (T mm <sup>2</sup> )	<100	<100
Radiation wavelength range (nm)	0.05–0.4	0.4–5.2
Number of segments in system	35	21
System length (m)	205	121





# Typical undulator cell at European XFEL



European XFEL planar undulators for SASE1/2/3 are hybrid permanent magnet undulators using NdFeB and soft iron poles made of cobalt iron

The beam vacuum chamber is made of extruded aluminum-magnesium and has an elliptical beam stay clear of 15 mm (horizontal) and 8.6 mm (vertical)

## Components for SCU development at EuXFEL

### Part of the SCU module:

- Cryocoolers
- Power supplies
  - ▶ Correctors and phase shifter:  $\pm 10$  A, 10 V
  - ▶ Main coils: 400-1000 A, 10-20 V  
as small as possible to fit in the tunnel
- Vacuum pumps
- CAM movers

### Elements for intersections:

- Quadrupoles, Quadrupole movers, Air coils
- Granite stone, alignment mechanism
- Absorbers, BPMs, BLMs
- Phase shifters
- RF bellows, RF valve

### SUNDAE1/2

- CuBe wires
- Vacuum pumps
- Hall probes + readout and current source
- Temperature sensors and monitors
- In vacuum (UHV) motors and linear stages
- ...

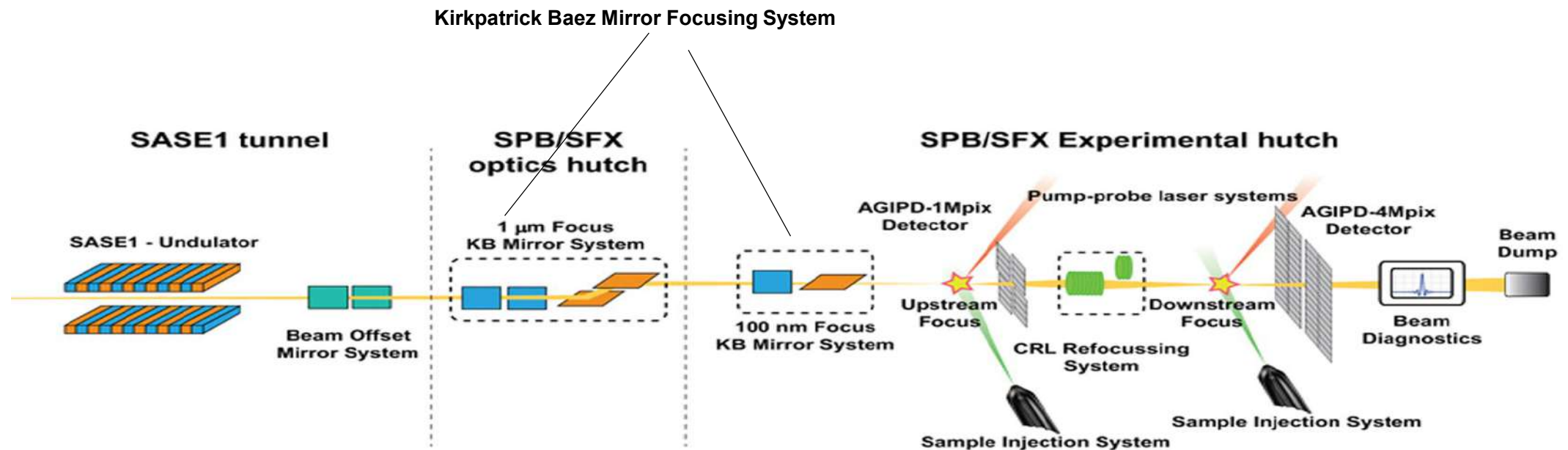
### Advanced SCU coils

- NbTi wires, HTS tapes
- Precisely machined iron few tenths  $\mu\text{m}$
- Epoxy, kapton
- ...

# SPB/SFX Instrument

[https://www.xfel.eu/facility/instruments/spb\\_sfx/science\\_programme/index](https://www.xfel.eu/facility/instruments/spb_sfx/science_programme/index)

- Diffractive imaging of micrometre-scale and smaller objects, at atomic or near-atomic resolution.
- Structural dynamics on the millisecond to femtosecond timescale.
- It consists of two experiment endstations (upstream and downstream),



# SPB/SFX Instrument

[https://www.xfel.eu/facility/instruments/spb\\_sfx/science\\_programme/index](https://www.xfel.eu/facility/instruments/spb_sfx/science_programme/index)

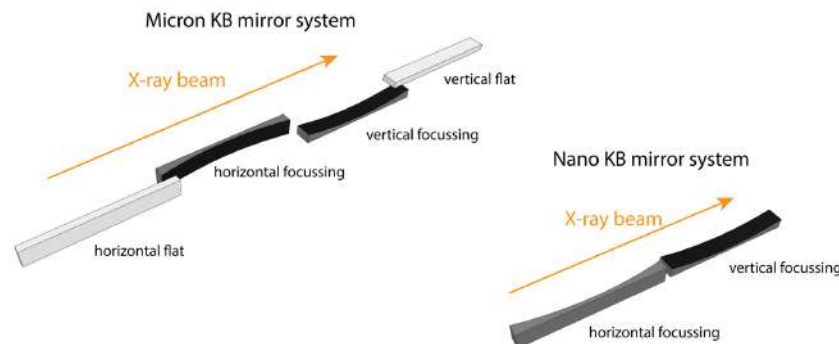
MHE	Micron horizontal elliptical KB
Deflection	Horizontal (negative $x$ )
Source—optic (centre) distance	894.779 m
Optic (centre) focus distance	24.005 m
Sagittal radius (minimum)	10 km

## Kirkpatrick Baez Mirror Focusing System

NHE	Nanometer horizontal elliptical KB
Deflection	Horizontal (positive $x$ )
Source—optic (centre) distance	915.484 m
Optic (centre) focus distance	3.3 m
Sagittal radius (minimum)	10 km

Controlled motion (relative to incident beam)	Minimum	Maximum	Resolution
$X$	-2 mm	+10 mm	<1 $\mu\text{m}$
$Y$ (coating selection)	-15 mm	+15 mm	<1 $\mu\text{m}$
$\theta_y$ (pitch)	-0.5 mrad	+5.5 mrad	<20 nrad

Controlled motion (relative to incident beam)	Minimum	Maximum	Resolution
$X$	-10 mm	+5 mm	<1 $\mu\text{m}$
$Y$ (coating selection)	-15 mm	+15 mm	<1 $\mu\text{m}$
$Z$ (astigmatism correction)	-5 mm	+5 mm	<1 $\mu\text{m}$
$\theta_y$ (pitch)	-0.5 mrad	+5.5 mrad	<20 nrad

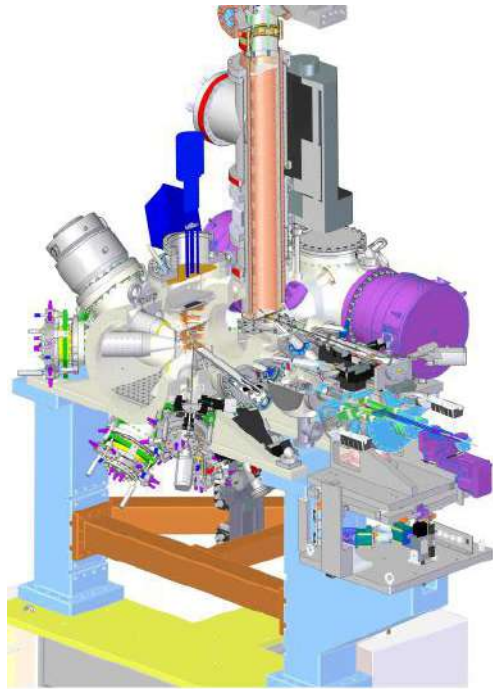




## SQS Instrument

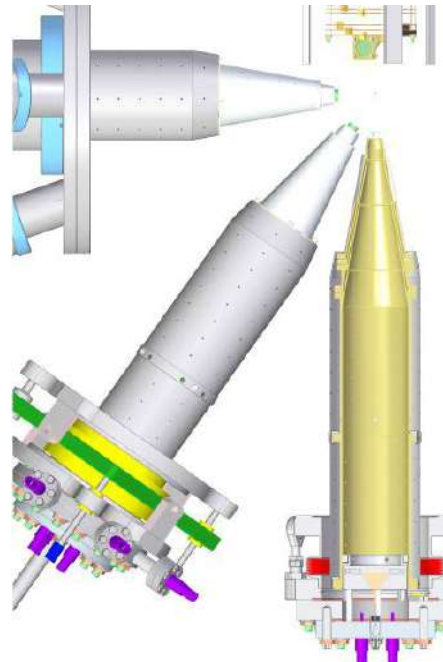
[https://www.xfel.eu/facility/instruments/sqs/index\\_eng.html](https://www.xfel.eu/facility/instruments/sqs/index_eng.html)

Investigations of fundamental processes of light-matter interaction in the soft X-ray wavelength regime.

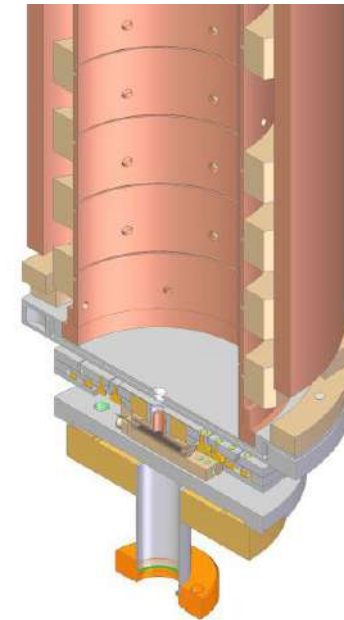


**Atomic-like Quantum Systems (AQS)**  
quantum systems, i.e. free atoms or small molecules.

The alignment of the AQS chamber with respect to the FEL beam is realized with a set-up enabling translation (50 mm) and rotational movements of the vacuum chamber with a precision of less than 0.5  $\mu\text{m}$ .



**Electron Time-Of-Flight (eTOF)**  
In combination of fast digitizer, (till 4.5 MHz)  
Detector MCP, 450 ps timing resolution

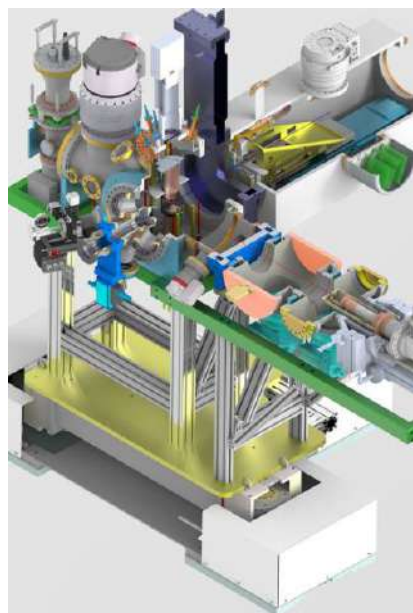


**Magnetic Bottle Electron Spectrometer (MBES)**  
Time of flight spectroscopy

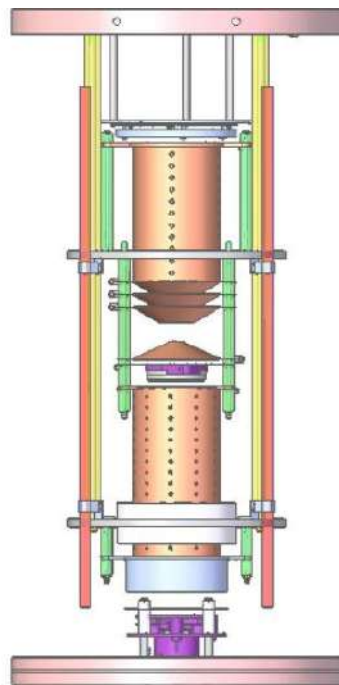
## SQS Instrument

[https://www.xfel.eu/facility/instruments/sqs/index\\_eng.html](https://www.xfel.eu/facility/instruments/sqs/index_eng.html)

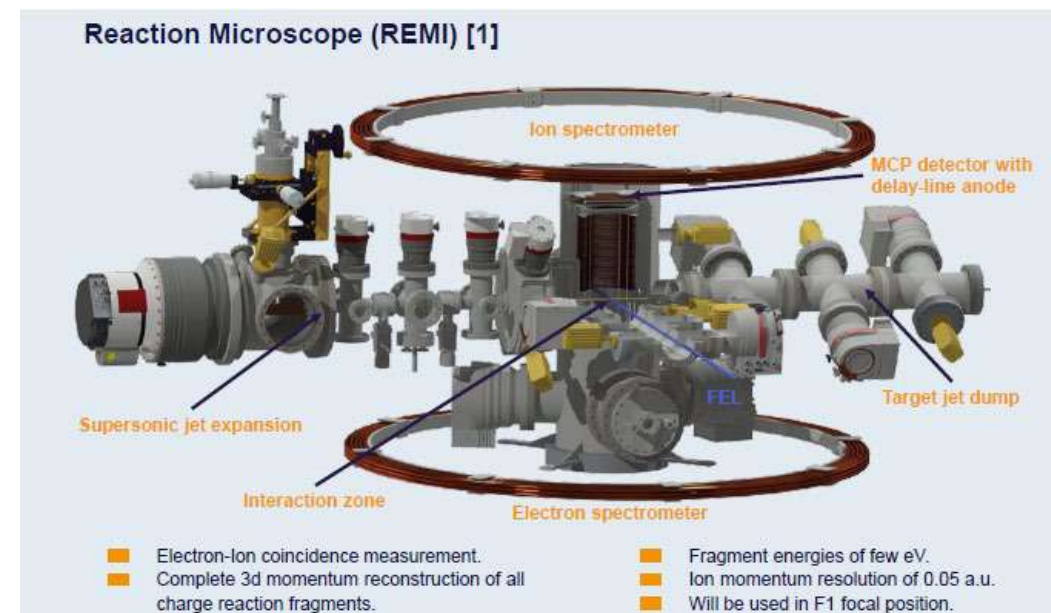
- Investigations of fundamental processes of light-matter interaction in the soft X-ray wavelength regime.



Nano-sized Quantum Systems (NQS)  
Nanoparticle The vacuum conditions in the NQS chamber are mainly limited by the imaging detector and are at best about  $10^{-10}$  mbar



Ion Time-Of-Flight (iTOF- Wiley-McLaren design)  
Velocity Map Imaging (VMI) spectrometer



A Reaction Microscope (REMI) ion and electron momentum imaging experiments in the gas phase: a three-stage supersonic gas jet four piezo-controlled apertures, nozzle 5  $\mu\text{m}$  to 300  $\mu\text{m}$ , temperatures from 5 K to 450 K

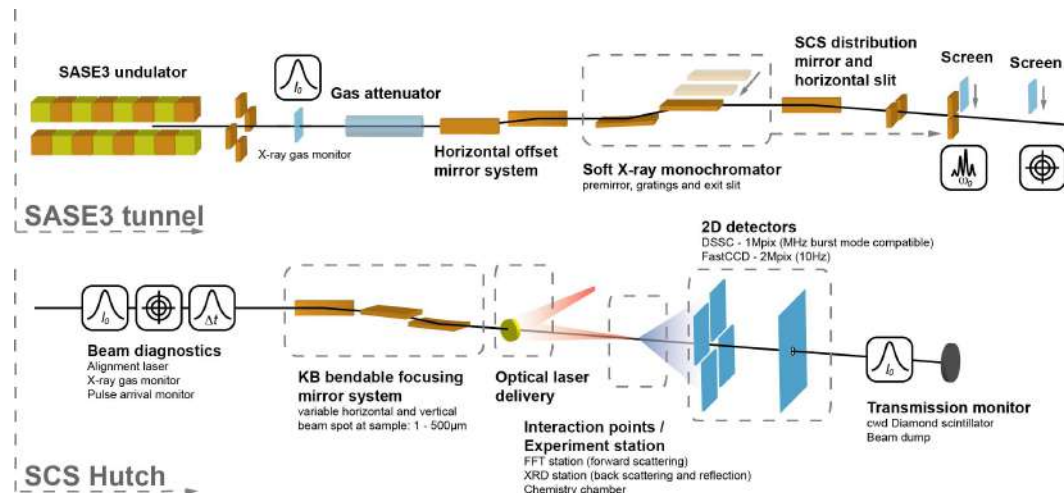
# SCS Instrument

[https://www.xfel.eu/facility/instruments/scs/index\\_eng.html](https://www.xfel.eu/facility/instruments/scs/index_eng.html)

Enables time-resolved experiments to unravel the electronic and structural properties of complex materials, molecules, and nanostructures in their fundamental space-time dimensions.

- The SCS instrumentation is equipped with:
  - the FFT experiment station (forward-scattering and transmission geometries)
  - the XRD experiment station (back- scattering and reflection geometries).
  - 2D array detectors, the 1MPix DSSC detector (4.5 MHz rep rate) and the 2Mpix FastCCD detector (10Hz), for coherent x-ray diffraction experiments
  - A high-resolution Resonant Inelastic X-ray Scattering (RIXS) spectrometer
  - a chemistry chamber station for liquid jets will be available in addition to the XRD experiment station.

Antonio Bonucci, In kind contribution manager and Industrial Liaison Office



Parameter	Current Value
Photon energy	0.5 keV – 3.0 keV
X-ray pulse duration	10-25 fs fwhm
X-ray pulse stretching (Expected durations based on Monochromator)	80-150 fs (mono HR) 30-50 fs (mono LR)
X-ray polarization	Linear horizontal ( $\pi$ -polarization) Linear vertical and circular polarizations may become available during 2022
X-ray focal spot size at sample	5 $\mu\text{m}$ (hor & ver) tunable up to 500 $\mu\text{m}$
Mono resolving power	10.000 (HR) 3.000 (LR)
Photon energy hRIXS	0.5 keV – 1.4 keV
Combined resolving power (Monochromator & hRIXS)	Up to 10.000

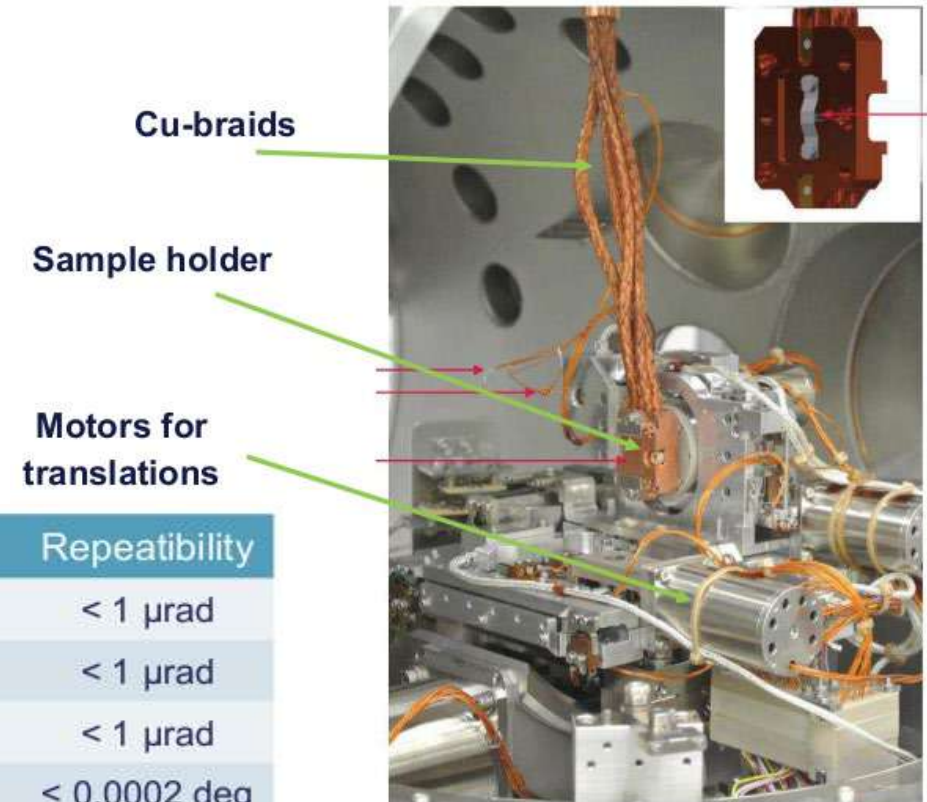
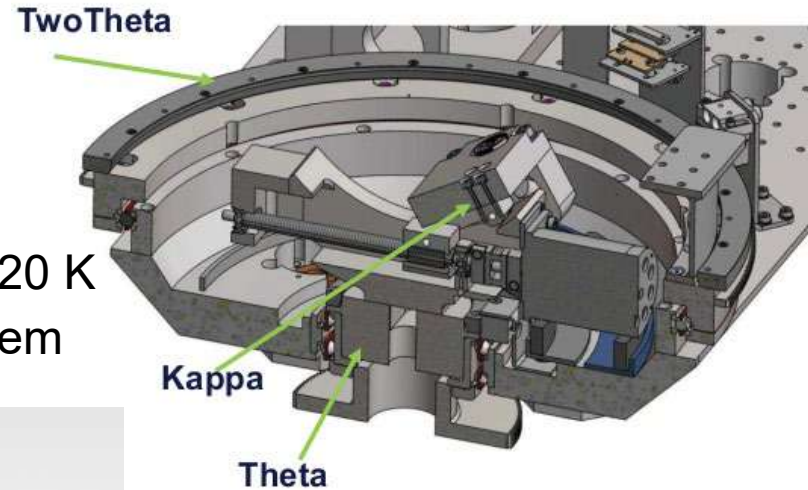


# SCS Instrument

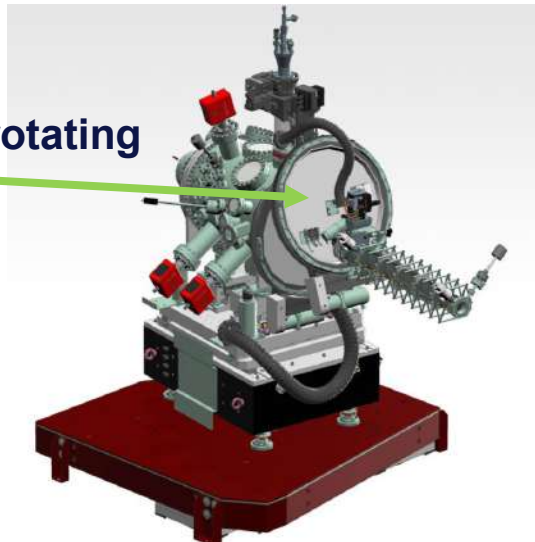
[https://www.xfel.eu/facility/instruments/scs/index\\_eng.html](https://www.xfel.eu/facility/instruments/scs/index_eng.html)

## X-ray diffractometer Inner Mechanics

- Triple-rotating flange to change scattering angle
- Sample: 6 DOF
- UHV ( $p < 10^{-9}$  mbar)
- Temperatures: RT – 20 K
- Sample transfer system



Triple-rotating flange



Motion	Range	Repeatability
TwoTheta	± 180 deg	< 1 μrad
Theta	± 180 deg	< 1 μrad
Kappa	± 30 deg	< 1 μrad
Azimuth	± 90 deg	< 0.0002 deg
X	± 5 mm	0.5 μm
Y	± 5 mm	0.5 μm
Z	± 5 mm	0.5 μm



## MID Instrument

[https://www.xfel.eu/facility/instruments/mid/index\\_eng.html](https://www.xfel.eu/facility/instruments/mid/index_eng.html)

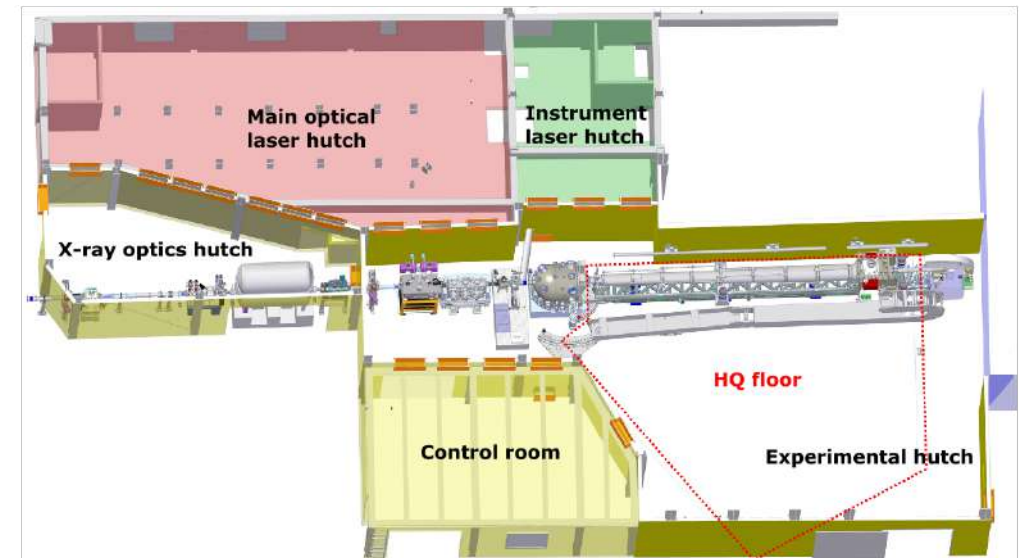
■ The scope of the MID instrument are material science experiments. The scientific applications reach from condensed matter physics, studying for example glass formation and magnetism, to soft and biological material, such as colloids, cells and viruses.

■ Special Optics:

- 2 monochromators (Si111 and Si220)
- 2 compound refractive lens (CRL) transfocator units
- Split and delay line
- High-energy Laue monochromator (optional)
- Mirror in experiment hutch (for grazing incidence liquid scattering)

■ Equipment:

- Multipurpose chamber
- SAXS/WAXS geometries with long horizontal detector arm
- Small vertical WAXS setup
- Single-pulse X-ray diagnostics
- Different detector systems (AGIPD, FastCCD)
- Optical pump laser source



## MID Instrument

[https://www.xfel.eu/facility/instruments/mid/index\\_eng.html](https://www.xfel.eu/facility/instruments/mid/index_eng.html)

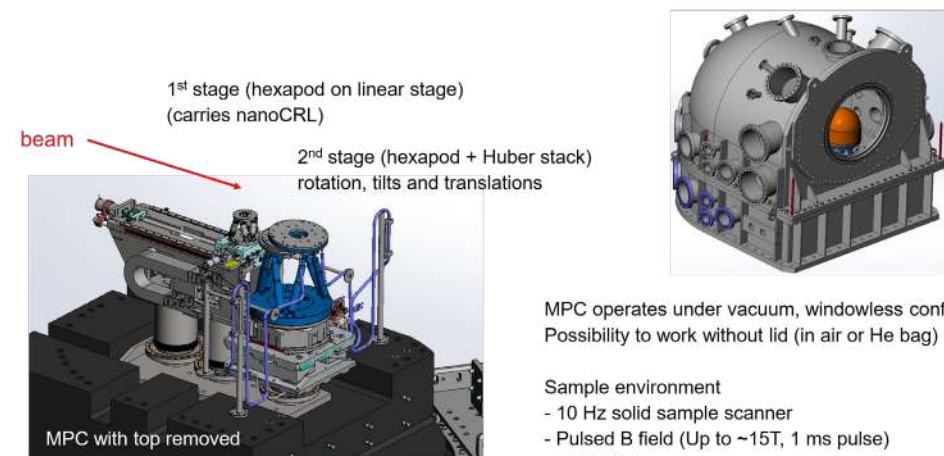
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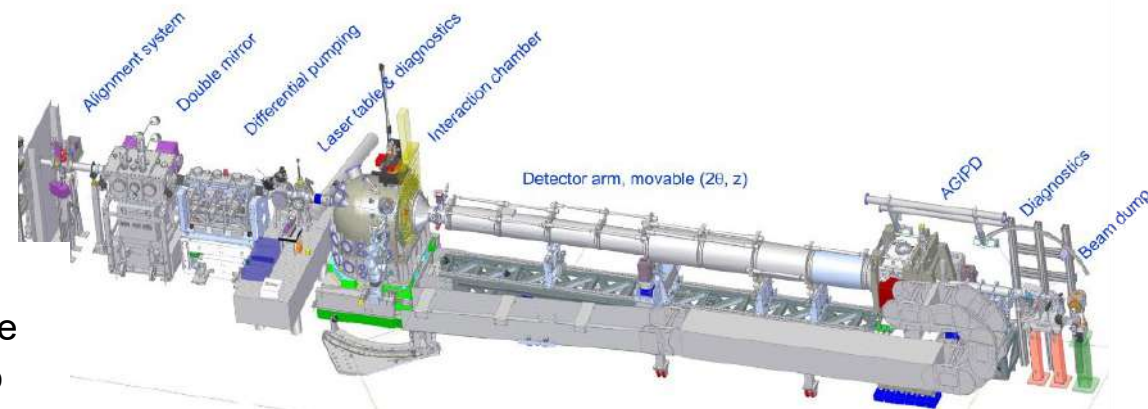
- Multipurpose chamber
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- Small vertical WAXS setup
- Single-pulse X-ray diagnostics
- Different detector systems (AGIPD, FastCCD)
- Optical pump laser source



MPC operates under vacuum, windowless config.  
Possibility to work without lid (in air or He bag)

Sample environment

- 10 Hz solid sample scanner
- Pulsed B field (Up to ~15T, 1 ms pulse)
- Liquid jet
- ....



Several different detector configurations can be achieved at the MID instrument. The option to operate a very long (8 m) horizontal scattering arm is a special feature of the instrument. The horizontal arm can move continuously in an angular range from 0° to 50°.

A floor with a flatness (1mm in 10 m) has been installed

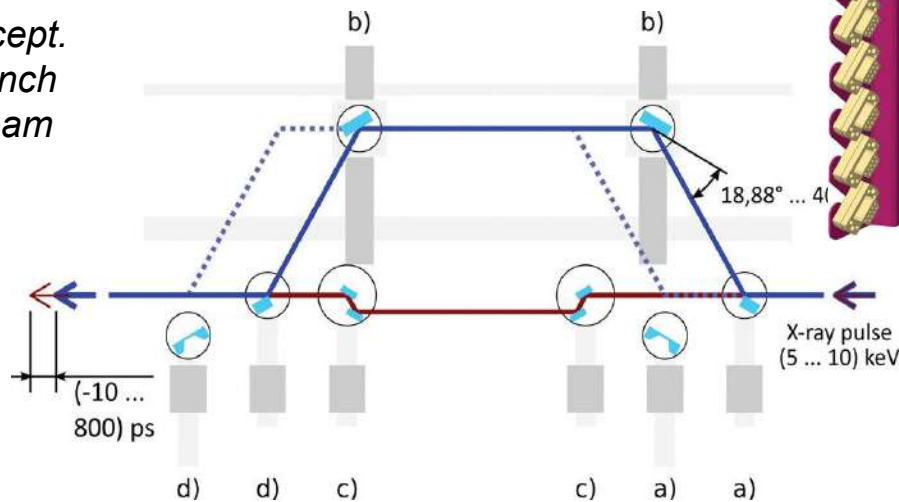
# MID Instrument

[https://www.xfel.eu/facility/instruments/mid/index\\_eng.html](https://www.xfel.eu/facility/instruments/mid/index_eng.html)

## Split and delay line (SDL)

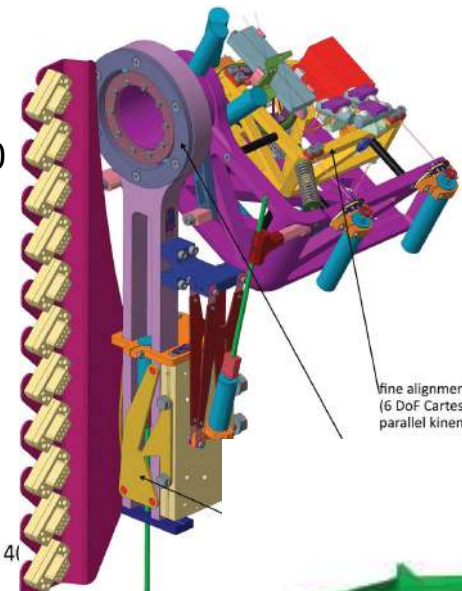
- Separate positioning stages mounted to the optical bench for all optical elements
- Demands:
  - Providing a **fast long-range travel** – in some cases of up to 1000 mm
  - Allowing a precise alignment with a **resolution in the range of single nanometre and tens of nanoradians**

*Conceptual view of the SDL indicating the mechanical concept. a) beam splitters; b) upper branch crystals; c) channel cuts; d) beam merger.*

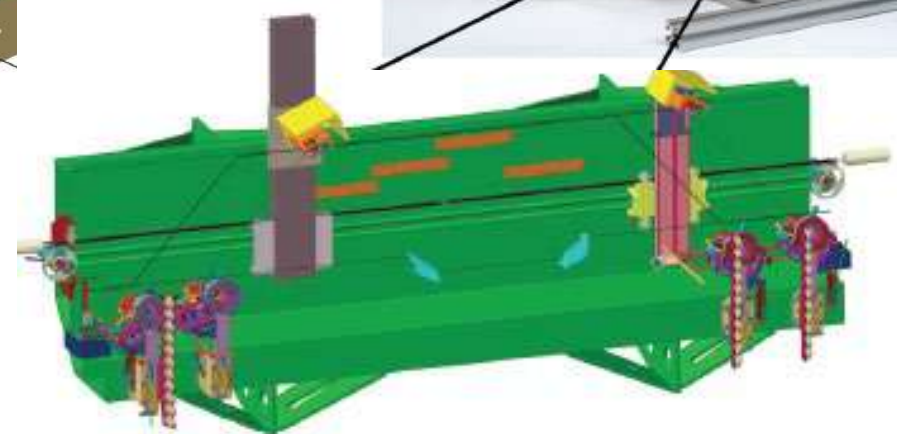
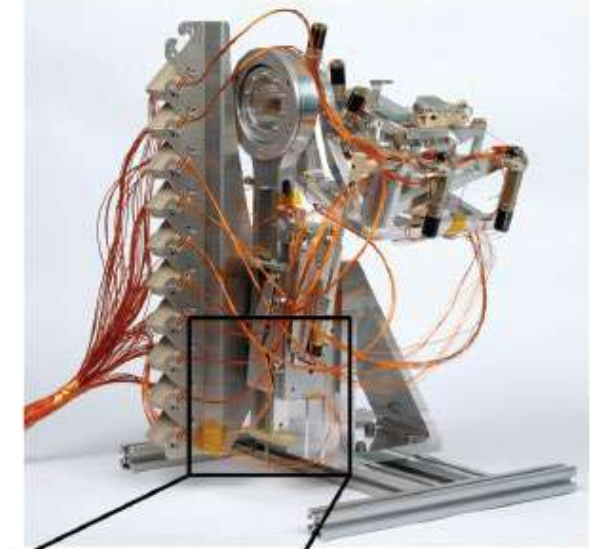


## Positioning stage for the beam splitter.

- Serial combination of coarse motion axes with a fine alignment stage
- The fine alignment stage is implemented as a 6 DoF Cartesian parallel kinematics.



fine alignment stage (6 DoF Cartesian parallel kinematics)



## HED Instrument

[https://www.xfel.eu/facility/instruments/hed/index\\_eng.html](https://www.xfel.eu/facility/instruments/hed/index_eng.html)

- Combining hard X-ray FEL radiation and the capability to apply extreme conditions of pressure, temperature or electric field using the FEL, high energy optical lasers, or pulsed magnets.

<https://www.xfel.eu/virtualtour/#node42>

- Diamond Anvil Cells (available)  
dynamic DAC; pulsed laser heated DAC; double-stage DAC
- Powerful optical lasers (2020-2021)  
100 J 15 ns 10 Hz; 400 TW 30 fs 10 Hz
- XFEL split&delay line (2021) x-ray pump-probe, 0-20 ps delay
- 60 T pulsed magnetic field coil (2021)  
cryogenic sample environment, superconductivity

The goal will be to achieve pressures of 1 TPa and temperatures up to 10 000 K using 5 ns, frequency-doubled 50 J pulses from the DiPOLE100X laser focused to 100  $\mu\text{m}$

Additional laser

	Abbreviation	Repetition [Hz]	Wavelength [nm]	Pulse energy	Pulse duration	Max. power or B field	Remarks
Pump-probe laser	PP-OL	4.5 M	~ 800	0.2 mJ / 4.5 MHz 5 mJ / 200 kHz	15–00 fs	10–250 GW	NOPA
		200 k	~ 1030	100 mJ	0.8 ps or 0.5 ns	~ 100 GW	Yb amplifier
High-energy laser	HE-OL	1–10	1057 or 1064	~ 150 J/ $\omega$ ~ 100 J/2 $\omega$	2–20 ns	~ 75 GW	Nd-glass or Nd-YAG
		< 1	528 or 532	> kJ	2–20 ns	> 500 GW	Beyond 2016
Ultrahigh-intensity laser	UHI-OL	10	~ 800	3–5 J	~ 30 fs	~ 100 TW	Ti-sapphire
		~ 1		10–30 J	~ 30 fs	~ PW	Beyond 2016
High-field pulsed magnet	HFM	0.1 – ~ 0.01	—	~ 30 kJ	> 100 $\mu\text{s}$	> 30 T	—
		< 0.01	—	> MJ	—	TBD	Beyond 2016



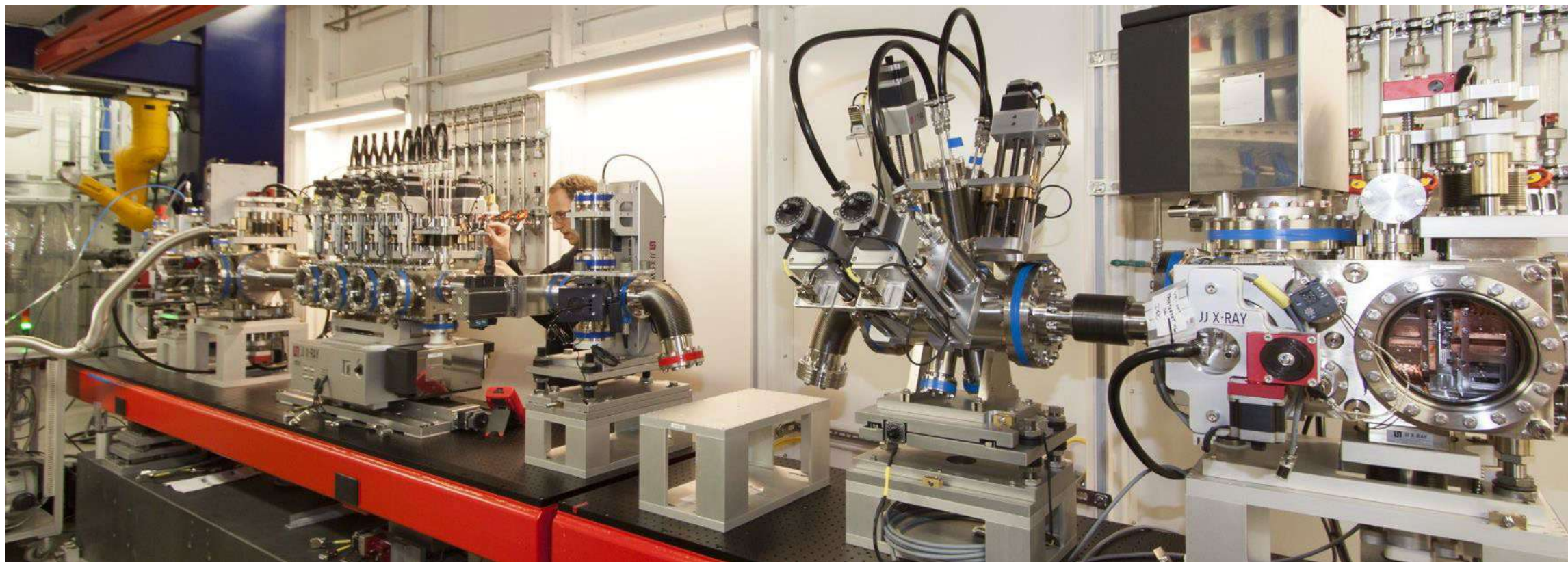
## FXE Instrument

[https://www.xfel.eu/facility/instruments/fxe/index\\_eng.html](https://www.xfel.eu/facility/instruments/fxe/index_eng.html)

- Enables ultrafast pump–probe experiments on ultrafast timescales—below 100 femtoseconds
- Supported techniques:
  - X-ray diffraction (XRD)
  - X-ray diffuse scattering (XDS), or wide-angle X-ray scattering (WAXS)
  - X-ray emission spectroscopies (XES): non-resonant, or resonant inelastic X-ray scattering (RIXS)
  - X-ray absorption spectroscopies: X-ray absorption near-edge structure (XANES), or extended X-ray absorption fine structure (EXAFS)

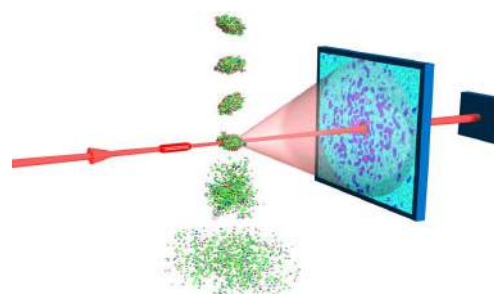
Parameter	Current value
Photon energy range	5–20 keV
Polarization	Linear (horizontal), circular (future option)
X-ray pulse duration	50 fs FWHM
Beam size	8–200 $\mu\text{m}$ adjustable (via several Be lenses)
Special optics	1 primary 4-bounce Si(111) mono 2 secondary (von Hamos, Johann) spectrometers
Optical laser wavelengths	Pump–probe (0.1–1 mJ) 800 nm (15–100 fs) Pump–probe (200 $\mu\text{J}$ ) 800 nm (50 fs, 15fs possible), harmonics, TOPAS adjustable UV-vis-NIR Pump–probe (>20 mJ) 1030 nm (850 fs) Pump–probe (>50 $\mu\text{J}$ ) 1 mm (=0.3 THz) generated via optical rectification
X-ray detectors	APD (0D, full rep. rate with MHz DAQ) Gotthard (1D, 1280 px, 50 $\mu\text{m}$ pixel pitch, 0.9 MHz) Jungfrau (2D, 1024 x 1024 px, 75 x 75 $\mu\text{m}$ pixel size, 10Hz) LPD (2D, 1 Mpx, (500 $\mu\text{m}$ ) <sup>2</sup> pixel size, 512 frames at 4.5 MHz, 3-fold dynamic gain covering 1 (SP at 12keV) to $1 \times 10^4$ per pixel)

## Assembling the scientific instruments

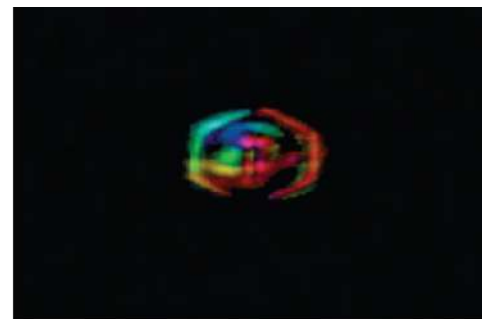
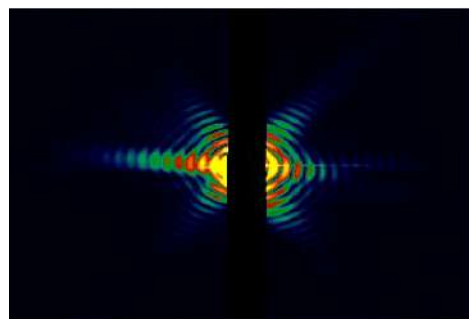
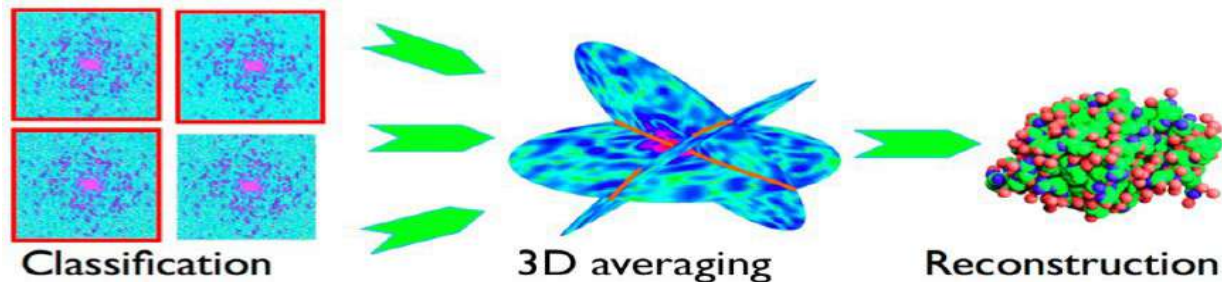




# In-kind contribution SE01 for WP79 Sample Injection Technology



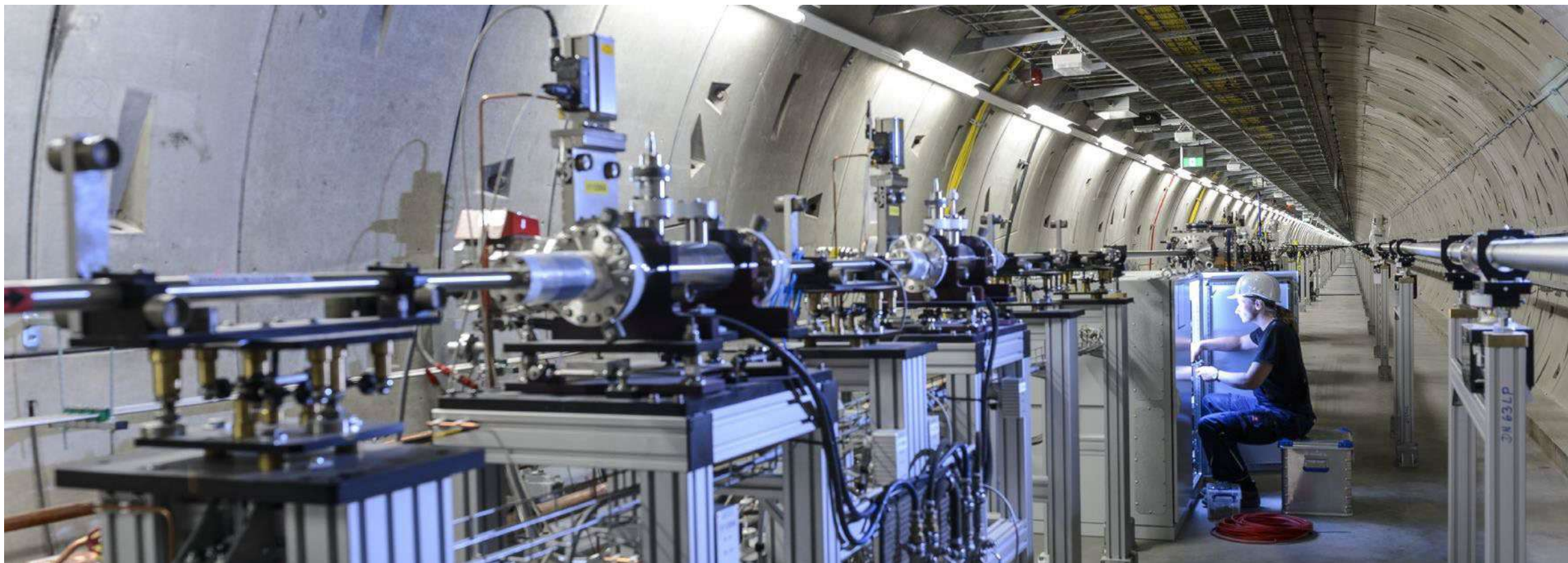
- Operation:
1. Many single particle images
  2. Classify for orientation
  3. Average each class
  4. Combine to 3D image
  5. Reconstruct



Reconstruction by Anton Barty  
Relaxed Averaged Alternating Reflection

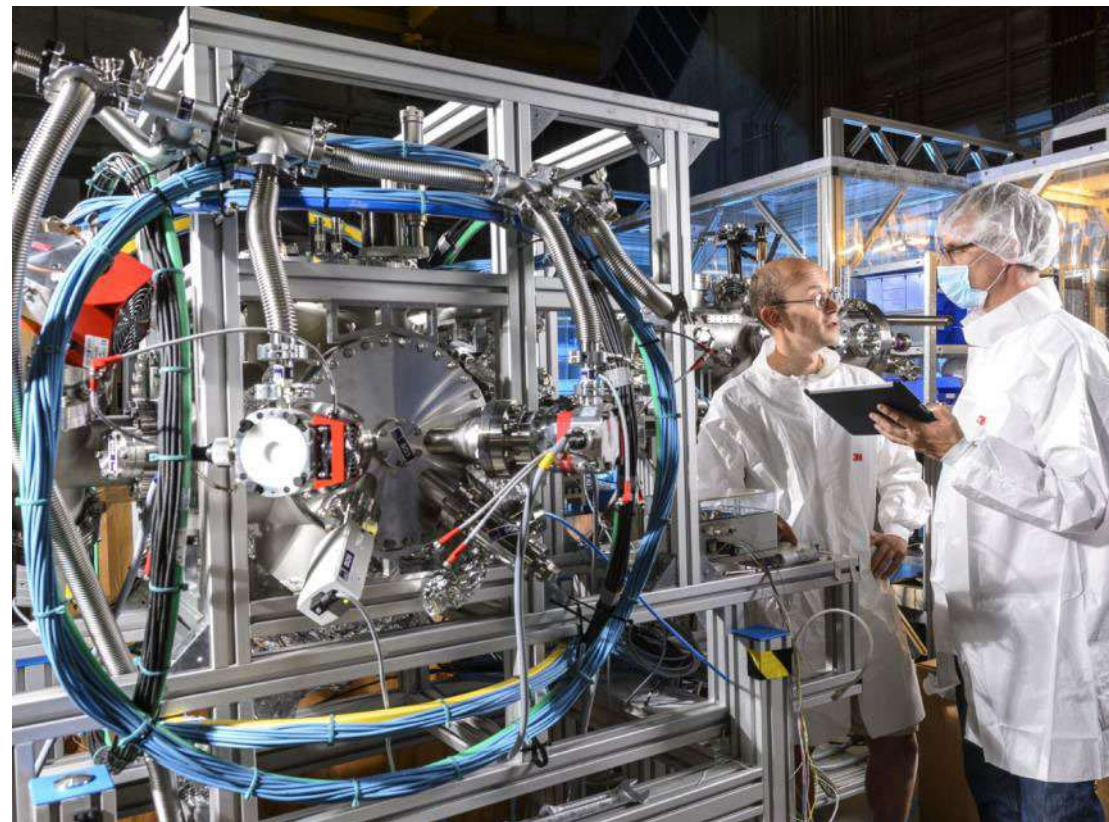
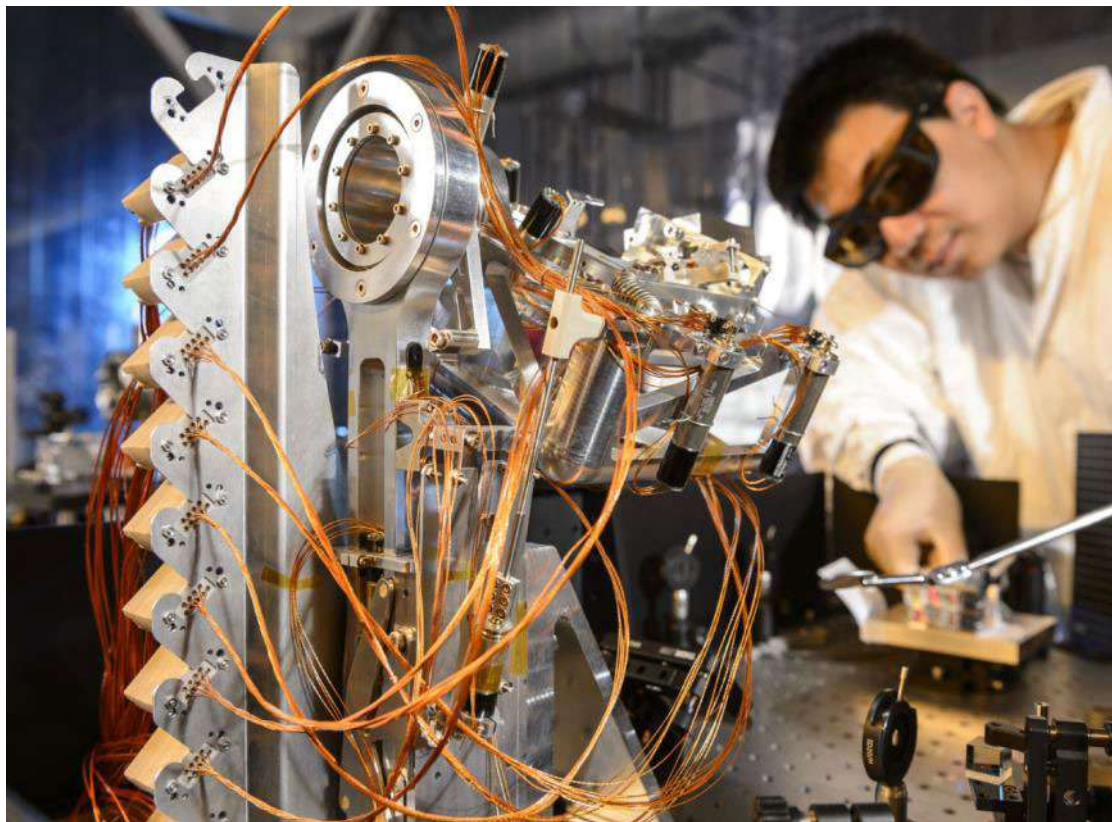


## Photon beamlines





## Assembling the scientific instruments

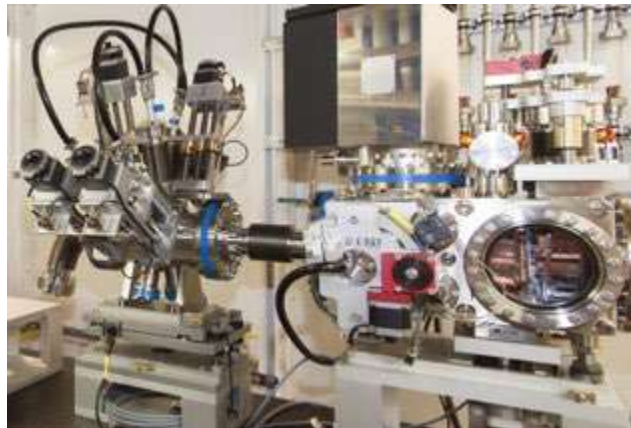




# Equipment control via Programmable Logic Controller (PLC) systems

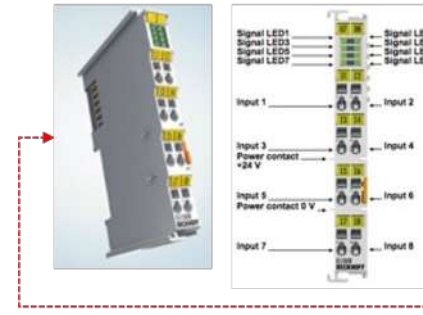


Installed PLC systems in rack room

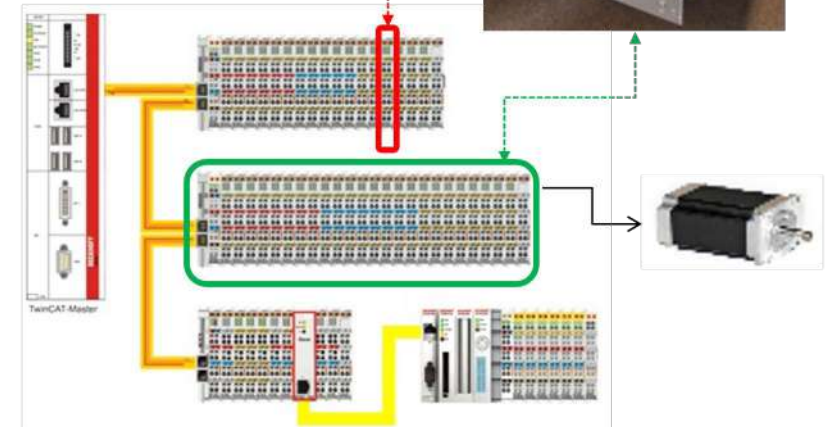


Equipment in experiment hutch  
(e.g. Motors, Valves, Pumps, Sensors)  
~12.000 equipment operated

PLC Terminals (i.e. digital input)



PLC Crate



Technical concept for most installations



# From requirements to final installs

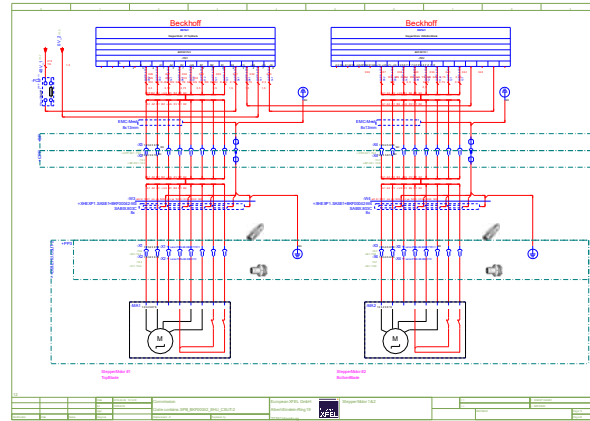
**DAQ and Control Systems**  
**COMPONENT REQUIREMENT DOCUMENT**

**Summary**

System Name	LHEAT	Interaction Area	Later Heating
System Area	IA2	Interaction Area	Interaction Area 2
System Function	HEB	System	SASE3
System Location	WCR03	Room Number	A13
System Version	A02	Floor	First Floor
System Date	12.03.18	System Name	HEB / WCR03

**Revisions**

Rev.	Date	Author	Description
1	28.03.18	AB	Added monitor signals, added interface specifications
2	28.03.2019	NC	Terminals and loop assignments
3	23.05.2019	NC / AB	Added physical information, corrected wiring WCR number
4			



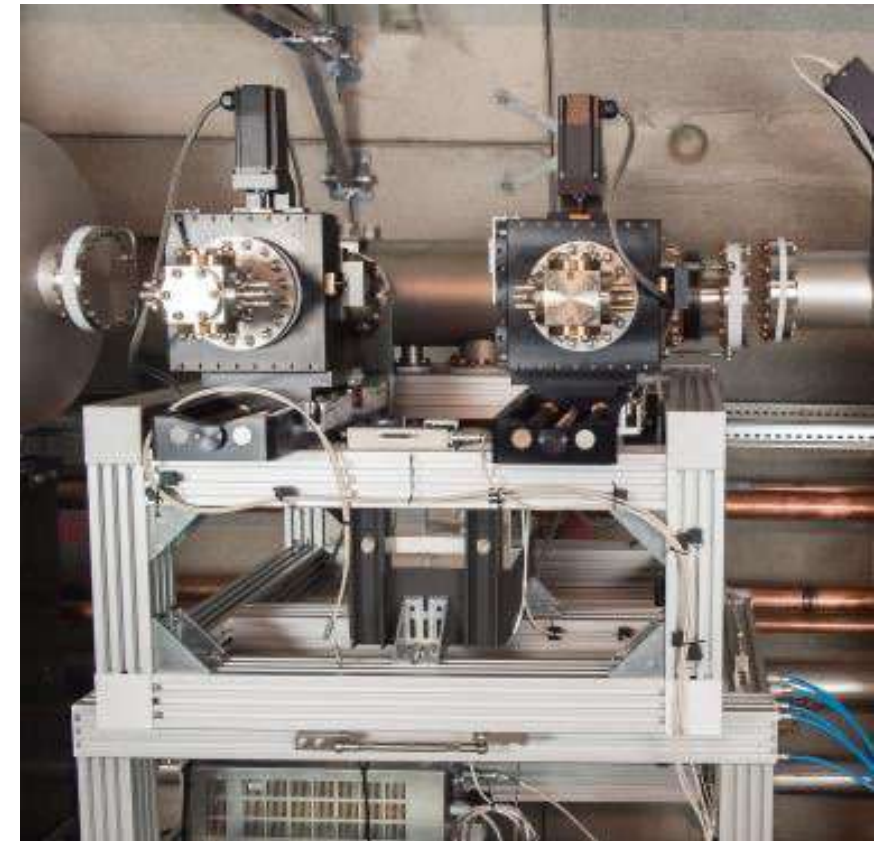
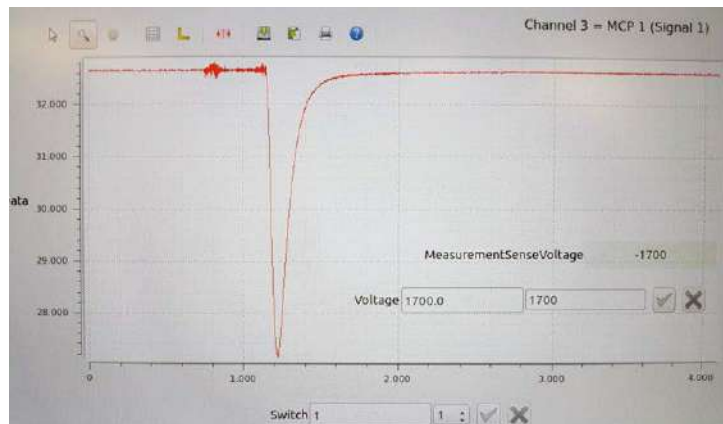
- Cabling (~200km)
  - Planning
  - Production
  - Quality control
  - Installation
  - Final check

- PLC Module (~650)
  - Production
  - Quality control
  - Installation
  - Final check

- PLC Projects / Programming
  - Interlock planning
  - Critical parameter definition
  - PLC project generation
  - Deployment
  - Checks
  - Commissioning

# Selected Applications – 100MSPS Sampling Multi-Channel Plate (MCP) Based Detector

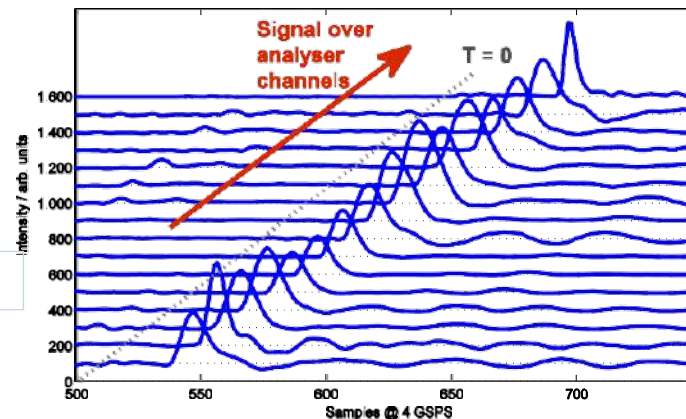
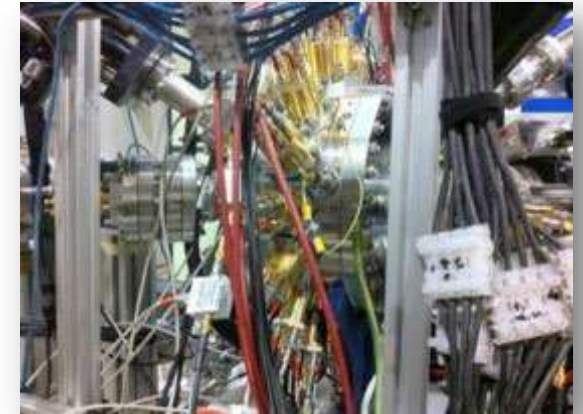
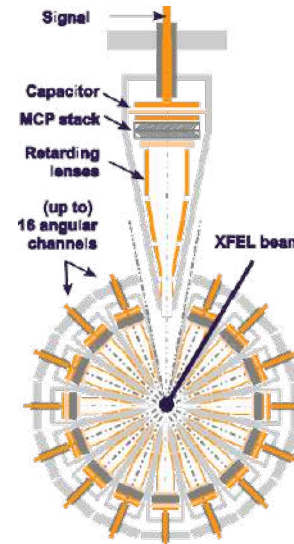
- Includes 3 MCPs and one Photo diode
- Motorized to adjust to beam or retract
- Invasive measurement of beam intensity



Courtesy: Photon Diagnostics (XPD) Group and collaborators

# Selected Applications – 4GSPS Sampling Photon-Electron Spectrometer (PES)

- Aggregation of 16 electron Time-of-flight tubes
- Electrons hitting the detector generate electrical pulses
- All 16 channels are digitized with MicroTCA Digitizer
  - 8 x SP Devices ADQ412-4G Module
  - 16 Channels @ 2/4GSPS @ 12bit
- Possible measurements:
  - Angle resolved energy spectrum
  - Polarization



Courtesy: Photon Diagnostics Group (XPD) and collaborators



## MicroTCA Standard

# μTCA®



MicroTCA 9U Crate



Advance Mezzanine Card (AMC) with a Rear Transition Module (RTM)

MicroTCA® is a modular, **open standard** geared towards a more compact, less expensive systems, without cutting back on reliability or data throughput

- Created and maintained by the PCI Industrial Computer Manufacturers Group <https://www.picmg.org/openstandards/microtca/>



- Target Applications:** Industrial control, Automation, Medical, Communication, High-Energy & Nuclear Physics among others
- Institutes/Companies involve in the definition include DESY, SLAC, Intel, Ericsson, AMD, Pentair, etc....

- Located at the DESY campus, the **MicroTCA Technology Lab** offers a wide range of related services (hardware, training, consulting...)
- <https://techlab.desy.de/>



# General MicroTCA Infrastructure



### MicroTCA Crates

Large 12 slot 9U and small 6 slot 2U (including MCH, Power Supply and CPU)

~60 Crates



### X2Timer

XFEL Timing System module for synchronization (clocks and triggers) and pulse parameters from NAT

~100 Cards



### DAMC2

Required for Clock & Control system for fast 2D detectors, VETO System, Machine Protection System and photon beam loss monitors from DESY



### SIS8300

Fast 125MSPS ADC with 10 channels and 16bit resolution for diagnostics and detectors from Struck Innovative Systeme

~300 Channels

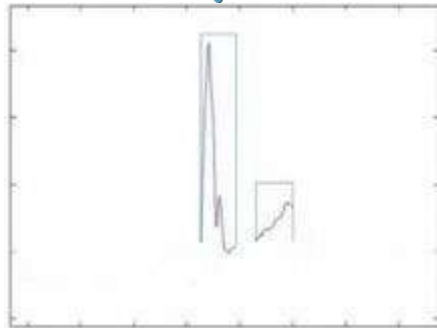
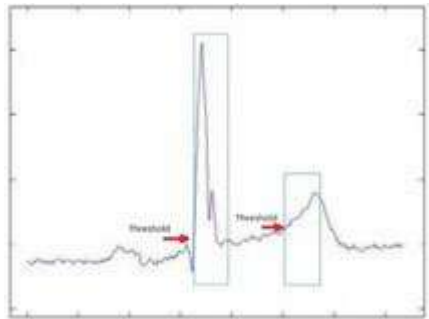


### ADQ412/ADQ14/ADQ7

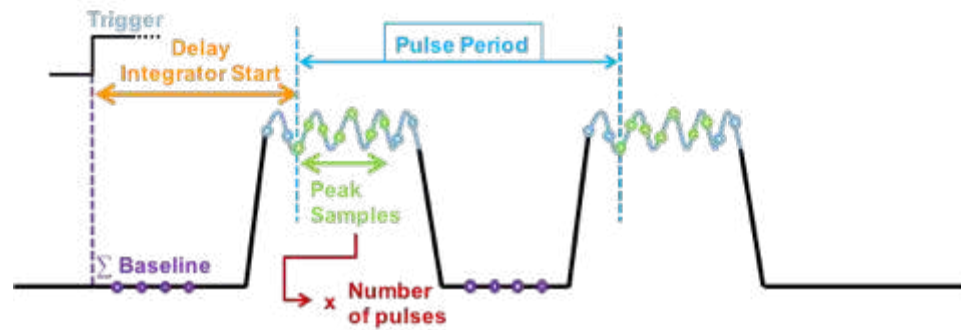
High-speed digitizers from 1.8GSPS to 10GSPS with 12 to 14 bit resolution from Teledyne SP Devices

~100 Channels

# FPGA processing algorithms and interfacing standards – Signal processing

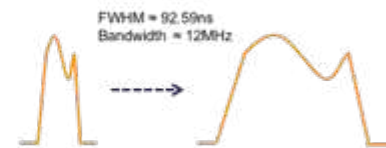


Zero Suppression

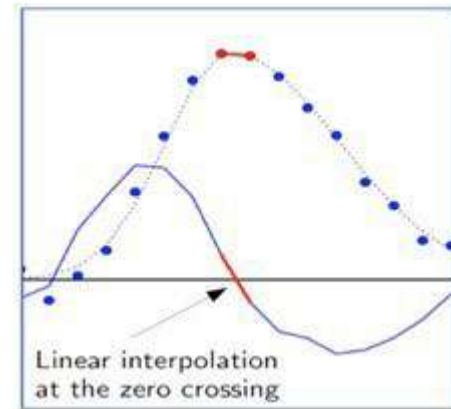


Pulse Stretcher RTM

- 10 SMA Connectors
- 2 Direct channels
- 8 Stretched channels
- Configurable DC Output  
Open/+1.2V/-1.2V



Pulse Integration



Peak Time Detection




# Handling Data and Complexity

## X-Ray Detectors at EU.XFEL Instruments


SASE I High E	Single Particles, Clusters and Biomolecules (SPB)	AGIPD	Gotthard V1/2	Jungfrau	Hard X-rays
	Materials Imaging & Dynamics (MID)	AGIPD	Gotthard V1/2	ePix Jungfrau	
	Femtosecond X-ray Experiments (FXE)	LPD	Gotthard V1/2	Jungfrau	
	High Energy Density Matter (HED)	Jungfrau	Gotthard V1/2	ePix Jungfrau	
SASE III Low E	Small Quantum Systems (SQS)	DSSC	MCP	Soft X-rays	
	Spectroscopy and Coherent Scattering (SCS)	DSSC	Fast CCD		

**100 MB/s - 10 GB/s**  
**10 Hz burst**


## Custom FPGA-based Data Producers at EU.XFEL




**MicroTCA Crates**  
Large 12 slot 9U and small 6 slot 2U (including MCH, Power Supply and CPU)




**X2Timer**  
XFEL Timing System module for synchronization (clocks and triggers) and pulse parameters from NAT



**DAMC2**  
Required for Clock & Control system for fast 2D detectors, VETO System, Machine Protection System and photon beam loss monitors from DESY



**SIS8300**  
Fast 125MSPS ADC with 10 channels and 16bit resolution for diagnostics and detectors from Teledyne



**ADQ412/ADQ14/ADQ7**  
High-speed digitizers from 1.8GSPS to 10GSPS with 12 to 14 bit resolution from Teledyne SP Devices

**1 MB/s - 1 GB/s**  
**10 Hz burst**

# Investigation and evaluation of FPGA platforms, tool chains and machine learning

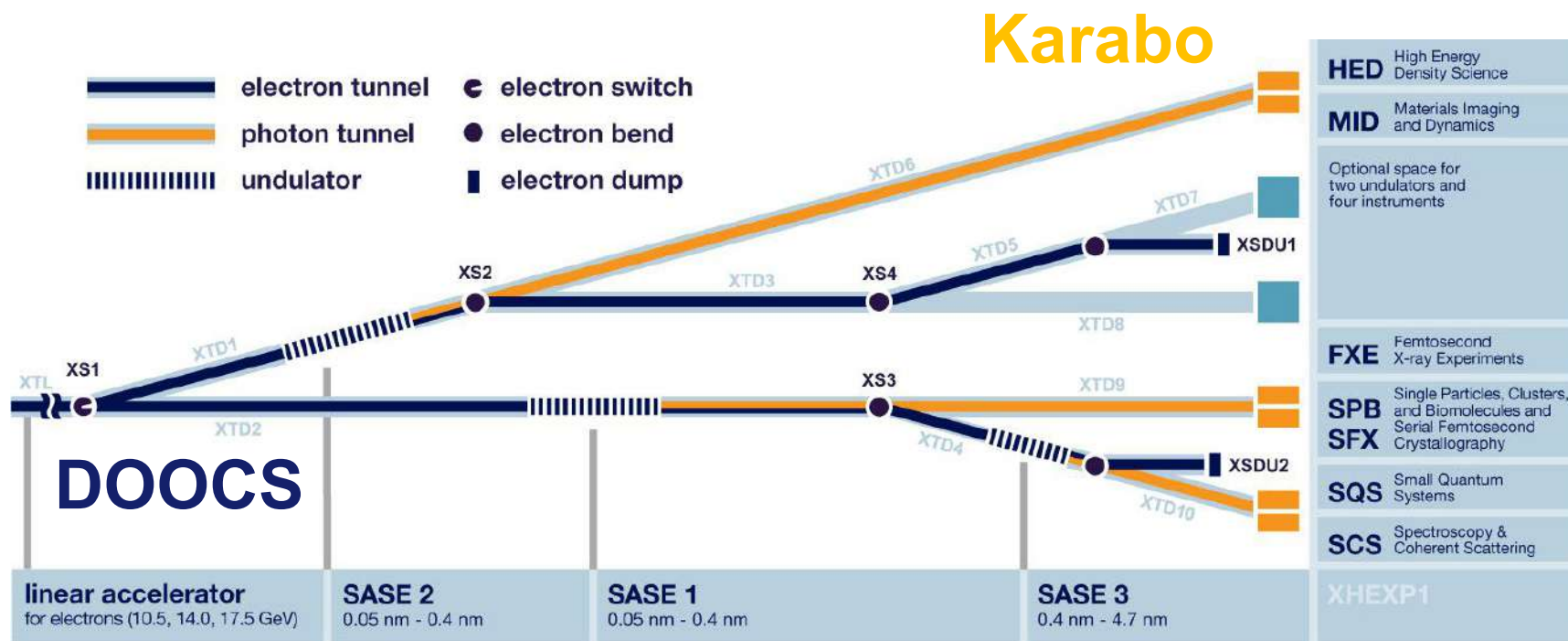
- Multiple solutions are available which use **OpenCL, HLS compilers, graphical interfaces...**
  - Quicker prototyping, focus on testing, easier code maintenance and easy of deployment in hardware
  - Keep in mind that **custom develop** for XFEL will always be necessary
- Companies provide solutions with standard interfaces that incorporated these tools/workflows
  - Not just from FPGA vendors (AMD/Intel)

AMD XILINX Virta<sup>™</sup> HLS Intel<sup>®</sup> High Level Synthesis Compiler Intel<sup>®</sup> FPGA SDK for OpenCL<sup>™</sup> Software Technology

MathWorks<sup>®</sup> CacheQ SIEMENS C++ SystemC Catapult LIBS Fmax Target ASIC FPGA eFPGA



# Beamline layout and experiment stations





# Data Drivers at the Facility

## X-ray Detectors

SASE I High E	Single Particles, Clusters and Biomolecules (SPB)	AGIPD	Gotthard V1/2	Jungfrau
	Materials Imaging & Dynamics (MID)	AGIPD	Gotthard V1/2	ePix Jungfrau
	Femtosecond X-ray Experiments (FXE)	LPD	Gotthard V1/2	Jungfrau
	High Energy Density Matter (HED)	Jungfrau	Gotthard V1/2	ePix Jungfrau
SASE III Low E	Small Quantum Systems (SQS)	DSSC	MCP	
	Spectroscopy and Coherent Scattering (SCS)	DSSC	Fast CCD	

**100 MB/s - 10 GB/s**  
**10 Hz burst**

## Custom Digitizer and FPGA solution



**MicroTCA Crates**  
Large 12 slot 9U and small 6 slot 2U (including MCH, Power Supply and CPU)

**X2Timer**  
XFEL Timing System module for synchronization (clocks and triggers) and pulse parameters from NAT

**DAMC2**  
Required for Clock & Control system for fast 2D detectors, VETO System, Machine Protection System and photon beam loss monitors from DESY

**SIS8300**  
Fast 125MSPS ADC with 10 channels and 16bit resolution for diagnostics

**ADQ412/ADQ14/ADQ7**  
High speed digitizers with 125MSPS to 14 channels

**1 MB/s - 1 GB/s**  
**10 Hz burst**

## Commercial Cameras

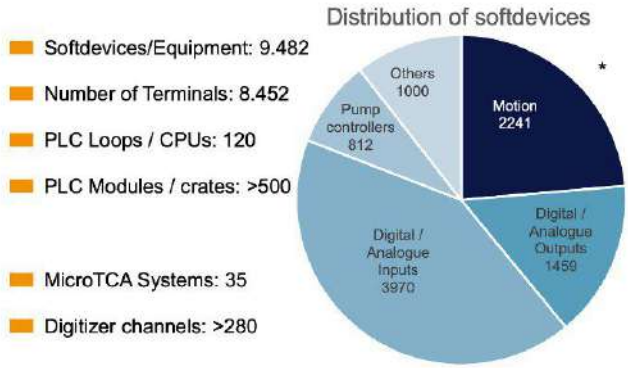
Model	Type	pixels	readout noise	frames/second	bits/pixel	QE	In vacuum	low temperature	pixel size	size (mm2)	Add.	saturation
[jacA1601_20gm]	CCD	2 Mp	9.4 e-	20	12	46%	no	no	4.4µm	7.2x5.4	G	8.4 ke-
[jacA1600_50gm]	CCD	2 Mp	11.6 e-	55	12	40%	no	no	5.5µm	8.8x6.6	G	18.5 ke-
[jacA2440_20gm]	CMOS	5 Mp	2.3 e-	23	10/12	68%	no	no	3.45µm	8.4x7.1	G	10.4 ke-
[jacA3800_10gm]	CMOS	10 Mp	5.6 e-	10	12	46%	no	no	1.67µm	6.4x4.6	G	2.8 ke-
[jacA1660_50gm]	CMOS	2 Mp	22.0 e-	60	12	47%	no	no	4.5µm	7.2x5.4	G	6.8 ke-
[jacA2500_14gm]	CMOS	5 Mp	6.4 e-	14	12	57%	no	no	2.2µm	5.7x4.3	G	6.7 ke-
[jacA2040_25gm]	CMOS	4 Mp	13.8 e-	25	7	62%	no	no	5.5µm	11.3x11.3	G	11.9 ke-
[jacA720_290gm]	CMOS	VGA	6.6 e-	291	10/12	62%	no	no	8.9µm	5.0x3.7	G	21.0 ke-
[jacA1920_40gm]	CMOS	2.2 Mp	6.7 e-	42	10/12	70%	no	no	5.86µm	11.3x7.1	G	31.9 ke-
[jacA640_70gm]	CCD	VGA	11.6 e-	120	12	59%	no	no	5.6µm	3.7x2.8	G	16.0 ke-
[jacA1300_50gm]	CMOS	1.3 Mp	24.7 e-	60	12	54%	no	no	5.3µm	6.8x5.4	G	7.7 ke-
[jacA2300_25gm]	CCD	4 Mp	?	26	12	?	no	no	5.5µm	12.8x9.6	G	?
[jacA1900_50gm]	CCD	2 Mp	11.9 e-	51	12	39%	no	no	5.5µm	10.8x5.9	G	?
[jacA3688_16gm]	CMOS	6 Mp	3.2 e-	16	10/12	81%	no	no	2.4µm	7.4x5	G	?
[jacA2600_30gm]	CMOS	5 Mp	11.6 e-	21	10	96%	no	no	4.8µm	12.4x9.8	G	8.2 ke-



**1 MB/s - 100 MB/s**  
**10 Hz burst**

photo from <https://www.avsupply.com/ITM/18888/AVA2300-25GM.html>

## PLC systems and other "slow" data



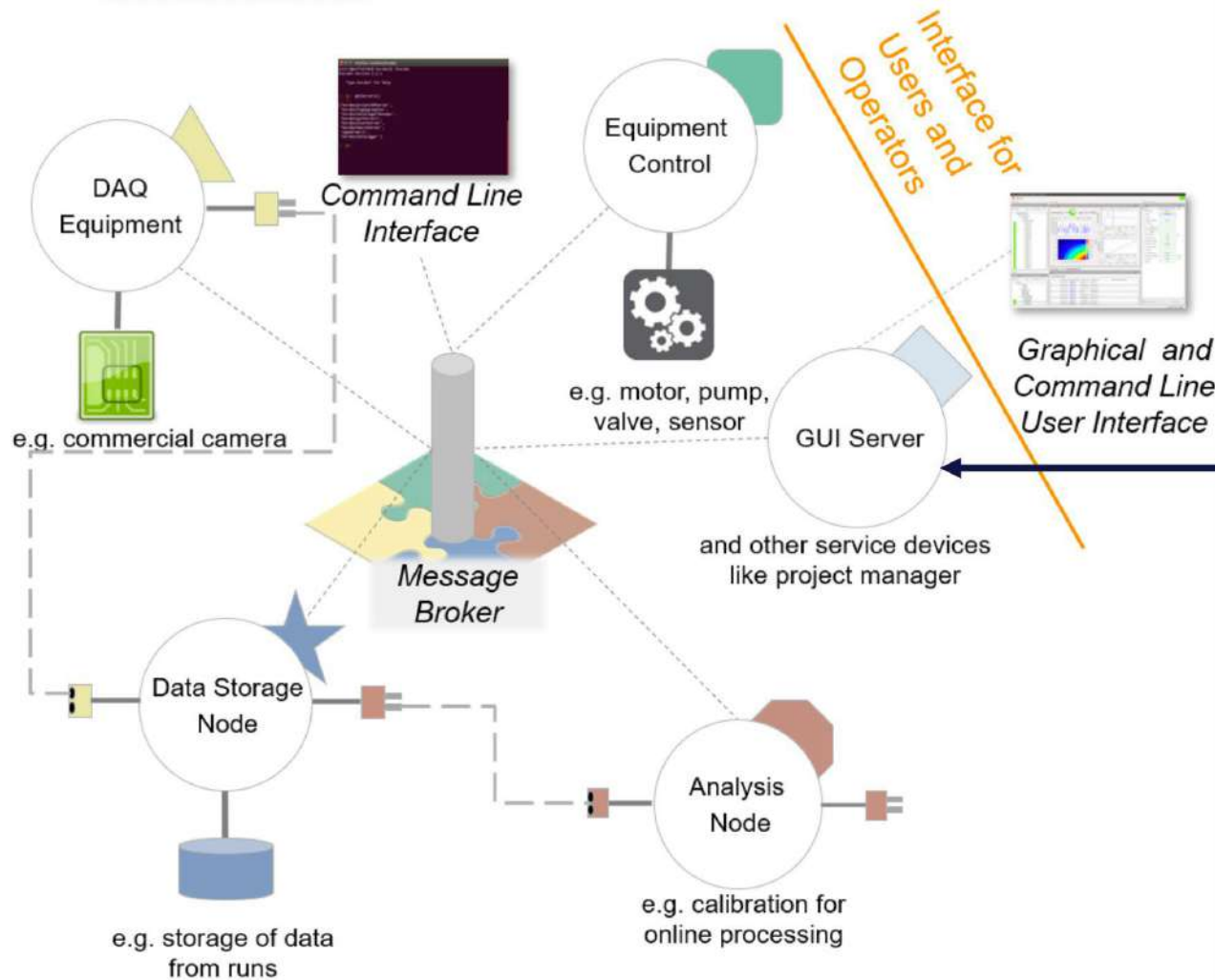
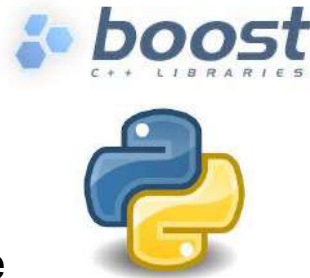
**1 B/s - 1 MB/s**  
**event driven**

## Karabo - A SCADA Framework: Motivation

- \* 2010/11: Onsite review of control solutions at LCLS, ALBA, DIAMOND, ESRF, PSI, FLASH
  - \* DAQ (MHz detectors and others)
  - \* control
  - \* "slow control" logging
- \* EPICs channels were not then suited for DAQ
- \* Tango was in the middle of a concentrate on Java or C++
- \* → exflsuite → **Karabo** is a given name in southern Africa. It means "answer" in SePedi , Sesotho and Setswana

# Karabo - A SCADA Framework: Architecture

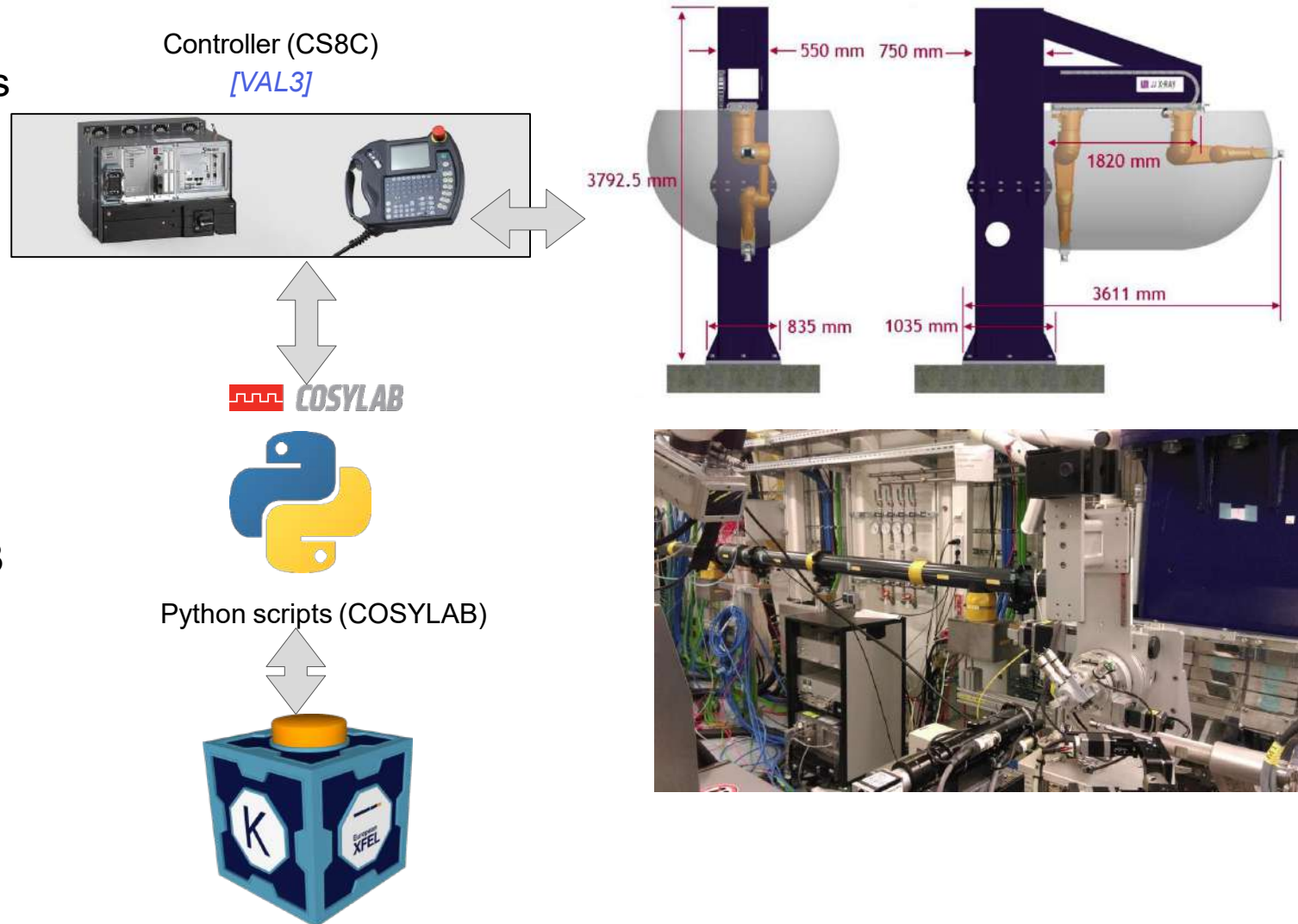
- \* pipeline (p2p) connections (scientific/large) data
  - \* Scatter/Gather/Copy/Distribute
  - \* Block/Drop on congestion
  - \* TCP
  - \* Also GUI Server – GUI client
  - \* Capable of saturating a 10G line
  
- \* GUI Server:
  - \* Gateway to the Control system
  
- \* Dynamic, discoverable topology
  - \* No central database instance





# Industry Contributions – a few existing Examples: FXE Stäubli Robot - COSYLAB

- \* Stäubli robot arm to position detectors as part of a Johann spectrometer
  - \* VAL3 language – no in house expertise
  - \* Safe volume requirements
- \* COSYLAB provided async python 3 library on top of VAL3 code
- \* Karabo integration against COSYLAB library was done in house



## Industry Contributions – a few existing Examples: Andor Cameras - AstroTech

- \* Some Cameras have a windows SDK
  - \* Windows IPC interfaces to camera
  - \* Interface software written by Astrotech supports various camera models: Andor models, Shimadzu HPC
  - \* Interface to Karabo relatively generic
  
- \* Avoids the need for Windows programming in CTRL group
  
- \* Reliable interface layer that has scaled to various camera types



<https://www.shimadzu.de/hyper-vision-hpv-x2>



<https://www.labcompare.com/1321-Imaging-Camera/4914543-Zyla-5-5-sCMOS-camera/>

## Technology of interest - 2022



- **UHV vacuum chambers in Aluminum alloy**, with bi-metallic flanges, without use of welding, in the direction of the beam.
- **Hard X-ray Wavefront Sensor (HXWFS)** device based on the Hartmann sensor
- **Interferometer solution** capable of measuring the longitudinal position of a carriage (about 0,5-1,5 cm width and 3mm height) over a more than 8m-long straight line, with a required accuracy of the longitudinal position measurement is 1um
- **Polycrystalline CVD diamonds** (chemical vapour deposition)
- **High resolution Raman confocal microscopy**
- Mechanical design and delivery of **optical holding systems** and its **large UHV chamber** with manual and remote micrometric control adjustment.
- **UHV compatible linear translation stages** moving in the vertical/horizontal axis by a travel range of more than 2 cm till 7 cm, with a spatial movement resolution less than 0,1 um
- **X-ray coatings of X-ray coatings** in B4C, metals (for instance Platinum, Gold, Chromium) for mirrors and gratings (made typically by silicon)
- **X-ray mirrors** large about 1 m (or even more) with a substrate in Silicon single crystal <100>, Meridional radius >200 Km, surface height error <20 nm peak to valley.
- **Semi-customized XUV spectrometer** with spectral range between 5 –200 nm, spectral resolution  $\lambda / \Delta\lambda$  300-1200 and spatial resolution less than 15  $\mu\text{m}$  with 3 Modes of operation - Beam inspection, angularly dispersed XUV spectroscopy, focusing along non-dispersion axis.
- **Laser engraving machine**, table top device with a writing area that can contain a square with a size more than 120mm. The machine must be able to write on rods/tubing down to 5mm diameter.
- **Cold finger** with an integrated probe holder with two grooves for a temperature sensor and a hall probe.





## Technology of interest - 2023

- **(piezo) actuators with controllers** that are encoded, UHV compatible, with low magnetic permeability ( $< 1.01\mu\text{r}$ ), few Newton force and with nanometric resolution
- 50-100 pieces of **compound refractive lenses made of pure beryllium**
- **High time resolution, 4 channel real-time oscilloscope** with more than 25 GHz bandwidth, more than 70 GS/s sample rate and more than 13 Gb/s serial trigger Sensitivity is requested better than 3 mV-1 V/div.
- **Linear stage** that moves in horizontal direction a static load more than 2500N
- **Pulse tube with compressor** separated from the installation flange for low vibration application, UHV compatible, with low magnetic permeability (about  $1.05\mu\text{r}$ ) and able to extract more than 20W at less than 100K.

## Campus constructions

Plans for the other major part of the European XFEL:

- ❑ An accommodation service, the facility's 59-room Guest House - were finalized and it is in operation.
- ❑ ...and a 940 m<sup>2</sup> building for tuning and measuring the facility's X-ray generating undulators was just finalized.
- ❑ A visitor centre, including school laboratories and an auditorium, was approved by the European XFEL Council in November 2018. It will also receive significant funding from Schleswig-Holstein.
- ❑ A building housing infrastructure for the HED instrument as well as offices for staff members and users has been finalized.

## Outline

- General presentation of European XFEL
- Main description of the facility
- Highlights on typical technologies in the experimental hall
- Information about procurement procedures, hints on new internal procedures
- Technologies of interest



## Typical topic of the Call for Tender - 2022



- New construction of a **compressed air centre, room air and refrigeration installations**
- Frame contracts for the **cleaning of workwear and cleanroom clothing**
- **Manufacture and supply of a partial discharge measuring system**
- **Job ads for personnel recruitment measures**, framework contract
- Framework contract **for maintenance on the XFEL KTK cooling towers**
- **Installationsarbeiten für die Aufzugsanlage** (construction)
- **Electrical-Earth-Cable-Connectors Infrastructure-West**
- 1st **construction phase** of the infrastructure measures West on the Schenefeld Campus
- Installation work for the **electrical engineering** in the compressed air centre
- **Joinery work** for the new office building XHO
- **Structural work** for the Visitor Centre XHV
- Construction of the outdoor facilities for the **connection lines** to the new office building XHO
  
- **Production and Supply of XBS-L Magnets**



## Calls for Tender 2023

- Ballasts for discharge lamps or tubes
- DC current transformers
- Manufacture and supply of diode rectifiers
- Manufacturing and supplying 200A load switches
- Sanitary facilities XHV
- Facade for the visitor center XHV
- Heating and cooling for the visitor center
- Building automation for the visitor center XHV
- Fire alarm and voice alarm system for the visitor center XHV
- Sanitary plants for the visitor center XHV

## Examples of current Calls For Tender

■ [https://www.xfel.eu/organization/procurement/calls\\_for\\_tender/index\\_eng.html](https://www.xfel.eu/organization/procurement/calls_for_tender/index_eng.html)



## Example of a recent Call For Tender

### ■ Motorized Girder for 2D Detectors at the SCS Instrument

<https://ausschreibungen-deutschland.de/522235> Motorized Girder for 2D Detectors at the SCS Instrument  
Referenznummer der Bekanntmachung 2019 Schenefeld

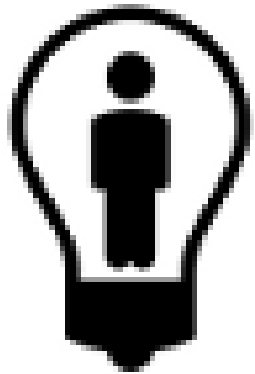
XFEL needs a detector girder that will Support different types of 2D detectors for scientific experiments in the low photon energy regime at the SCS instrument. The key functionality is the motorized, horizontal long travel distance of the main detector, referred to DSSC. This movement is enabled via a sleigh for which the remaining degrees of motion are implemented and motorized.

The detector girder consists of 5 parts

- 1- the first part is a 3 meters long stationary main module which supports the supply lines for media and cables for the detector.
- 2- The second part is a 2 meters long extension module which can be optionally installed upstream of the main module depending on the experiment configuration. In some cases, a short extension unit of the main and extension modules is needed as a third removable component.
- 3- On top of the main and the extension modules a long translation stage can be manually moved along the beam direction.
- 4- This long translation stage of about 3 meters in length has further a motorized linear stage which allows for moving the detector during experiments along the beam direction.
- 5- Finally, a fully motorized sleigh with 4 degrees of motion for fine alignment forms a generic interface to the detector housings and directly supports the main detector.

## LEAPS & HR<sup>4</sup>tech

- **LEAPS** – the League of European Accelerator-based Photon Sources – is a strategic consortium initiated by the Directors of the Synchrotron Radiation and Free Electron Laser user facilities
- **LEAPS** consists of 16 organisations representing 19 light source facilities across Europe



One of the current leading LEAPS projects - **HR<sup>4</sup>tech** – celebrates proactive innovation and industrial exchange through fostering of industrial ecosystem within LEAPS facilities.

Join our LinkedIn group today to find out all about #LEAPStechnologynews #LEAPSprojectupdate #LEAPScallforsolution or #LEAPScallforpartnership

<https://www.linkedin.com/groups/12579230/>

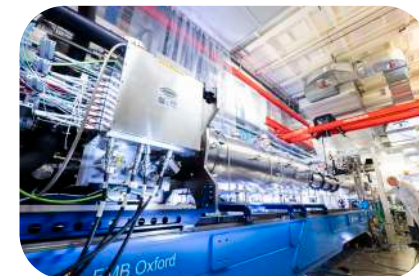
## Conclusion

- European XFEL is an international big science large facility
- The construction is completed but there are a lot of opportunities to collaborate on new devices
- We have organized a network of national ILOs for technology survey. Dr. Francesco d'Acapito is the Italian representative
- The national ILOs are informed by the European XFEL about:
  - Technology of interest
  - New calls for tender
  - Survey of potential suppliers for purchasing below the EU threshold limit, in the area of innovation procurement

For any question please write to **ilo@xfel.eu**

## Overview of the publicly-awarded national tender over 25k EUR- 2022

Shutterbox Version 2.0	<b>Amphos GmbH</b>	DE
Non-Linear Crystals	<b>Castech Inc.</b>	CN
Door closing system for new office building	<b>Interflex Datensysteme GmbH</b>	DE
CVD Diamond Attenuator	<b>Diamond Materials GmbH</b>	DE
payroll accounting	<b>Lohndirekt GmbH</b>	DE
Turbopump	<b>Pfeiffer Vacuum GmbH</b>	DE
Housing for Large Pixel Detektor	<b>STFC UKRI</b>	UK
Replacement detector head	<b>Surface Concept GmbH</b>	DE
Precisions Stages for Beam Splitting	<b>SmarAct GmbH</b>	DE
Conversion to LED lighting in experiment hall	<b>Schubert-Nord GmbH</b>	DE
Timing External Interface TEI; Timing Internal Interface TII	<b>ATP Elektronik GmbH</b>	DE
X-ray absorber CVD diamond	<b>Diamond Materials GmbH</b>	DE
Nitrogen (liquid and gaseous)	<b>Linde GmbH</b>	UK (DE)
Vacuum-insulated liquid nitrogen manual filling stations	<b>Cryotherm GmbH &amp; Co. KG</b>	DE
Rental and maintenance of the liquid nitrogen plant	<b>Linde GmbH</b>	UK (DE)
Self-contained self-rescue device	<b>Dräger Safety AG &amp; Co. KGaA</b>	DE
HPLC System for SCS	<b>Shimadzu Deutschland GmbH</b>	JP (DE)
Air Coils - Undulator System	<b>RISSE electronic GmbH</b>	DE
Diamond grating	<b>XRnanotech GmbH</b>	CH
Dynamic and Precise High Repetition Rate Sample Scanner	<b>Aerotech GmbH</b>	US (DE)

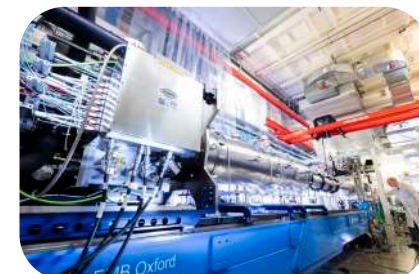




## Overview of the publicly-awarded national tender over 25k EUR- 2022

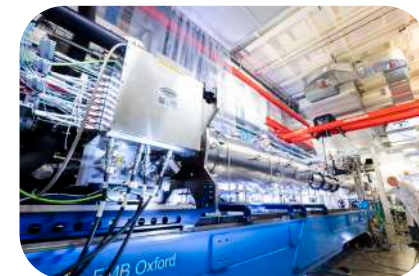
Turbo Pumps	<b>Pfeiffer Vacuum GmbH</b>	DE
Ad placement - Job advertisements	<b>AS Mediendesign</b>	DE
Spare parts for X-Ray Scattering Imaging System	<b>PINK GmbH</b>	DE
Linear Motions System Spare Bellow	<b>Hositrad Holland B.V.</b>	NL
Stages for moving detectors	<b>OWIS GmbH</b>	DE
multistage roots pumps	<b>Kashiyama Europe GmbH</b>	JP (DE)
Stepper motor module & various parts	<b>Beckhoff Automation GmbH &amp; Co. KG</b>	DE
Patsnap License extension	<b>PatSnap (UK) Limited</b>	UK
residual gas analyzers	<b>MKS Instruments Deutschland GmbH</b>	US (DE)
spare part connectors in various sizes	<b>Lemo Elektronik GmbH</b>	DE
Turbomolekularpumpen & Zubehör	<b>Pfeiffer Vacuum GmbH</b>	DE
Motorized stages	<b>Standa UAB</b>	LT
Turbopumps, drive electronics, accessories	<b>Pfeiffer Vacuum GmbH</b>	DE

Turbo Pumps	<b>Pfeiffer Vacuum GmbH</b>	DE
ERP - EAM Licenses and Maintenance	<b>Intergraph PP&amp;M Deutschland GmbH</b>	US (DE)
Spare parts for power supplies	<b>JEMA s.a.</b>	BE (FR)
Herriott cell and GTI mirrors	<b>Layertec GmbH</b>	DE
Power supplies and frames	<b>TDK-Lambda Germany GmbH</b>	JP (DE)
High resolution VUV/XUV Spectrometer	<b>Indigo Optical Systems GmbH</b>	DE
Low noise power supplies	<b>W-IE-NE-R, Power Electronics GmbH</b>	US/DE



## Overview of the publicly-awarded national tender over 25k EUR- 2022

Expansion of the compressed air system (compressor and associated control)	<b>Kaeser Kompressoren SE</b>	DE
Temporary employment Electronics technician Industrial engineering	<b>Adecco Personaldienstleistungen GmbH</b>	DE
EtherCAT IP20 equipment	<b>Beckhoff Automation GmbH &amp; Co. KG</b>	DE
Support Service für ERP-System	<b>Infor (Deutschland) GmbH</b>	US (DE)
Special mirror for Optical Delay Line	<b>Carl Zeiss SMT GmbH</b>	DE
Actuators for special mirrors	<b>Standa UAB</b>	LT
Bayard-Alpert Pirani Combination Gauge with EtherCAT Interface	<b>INFICON Aktiengesellschaft</b>	CH
Pirani and Cold Cathode gauges with controller	<b>MKS Instruments Deutschland GmbH</b>	US (DE)
Helium bundle	<b>Air Products GmbH</b>	US (DE)
Achromatic delay plate made of quartz	<b>Bernhard Halle Nachfl. GmbH</b>	DE
Maintenance Electrical low voltage systems SASE 1, 2, 3	<b>Schubert-Nord GmbH</b>	DE
TruLaser Station 7000 – Laser Cutter	<b>Trumpf Laser- und Systemtechnik GmbH</b>	DE
vacuum system for SXP	<b>SAES Getters S.p.A. (Avezzano Unit)</b>	IT
Relocation, calibration and maintenance of magnetic measuring benches	<b>Kugler GmbH</b>	DE
AC-coupled 4-channel digitizer	<b>Teledyne Signal Processing Devices Sweden AB</b>	SE
High dynamic range 3rd order autocorrellator	<b>UltraFast Innovations GmbH</b>	DE
High quality waveplates for pump-probe laser setup	<b>Bernhard Halle Nachfl. GmbH</b>	DE
Dual Lock -in amplifier and Digital boxcar integrator	<b>Zurich Instruments AG</b>	CH
Highly reflective mirrors	<b>Layertec GmbH</b>	DE
A Hard X-ray Wavefront Sensor (HXWFS)	<b>Imagine Optic S.A.</b>	FR
Superconducting Undulator Coils	<b>Simic S.p.A.</b>	IT
Turbo pumps	<b>Pfeiffer Vacuum GmbH</b>	DE
End user training	<b>itc. Training &amp; Consulting GmbH</b>	DE
Additional licenses	<b>Infor (Deutschland) GmbH</b>	US (DE)
Vacuum system, several vacuum valves	<b>VAT Deutschland GmbH</b>	CH (DE)



# Overview of the publicly-awarded national tender over 25k EUR- 2022

## Construction

Rahmenvertrag Gerüstbauarbeiten	<b>Teupe &amp; Söhne Gerüstbau GmbH</b>	DE
Rahmenvertrag Tischer-Beschlagarb.	<b>Tischlerei Stephan Kahl GmbH</b>	DE
Druckluftzentrale im XHVAC, Erweiterter Rohbau	<b>C.H. Maack GmbH &amp; Co. KG</b>	DE
XHO Tischlerarbeiten	<b>Die Tischler Möbelwerkstätte</b>	DE
XHVAC- Druckluftzentrale MSR-Technik	<b>Sauter-Cumulus GmbH, Niederlassung Hamburg</b>	DE
XHV Blitzschutzanlage	<b>NDB Elektrotechnik GmbH Co. KG</b>	DE
Bautenschutzarbeiten im Bestand (Beton Verpressarbeiten)	<b>Berton Bautenschutz Betonservice</b>	DE
XHO Blitzschutz	<b>D.H.W. Schultz und Sohn GmbH</b>	DE
SASE 3 - Erweiterung der Wartung von 2 auf 4 Jahre	<b>Caverion Deutschland GmbH</b>	FI (DE)
XHO - Personenaufzugsanlage	<b>KONE GmbH</b>	FI (DE)
Austausch der Feuerlöschleitung im Medientunnel	<b>Kliewe GmbH</b>	DE
XHO, Wämedämm- und Brandschutzarbeiten	<b>A.S. Dämmtechnik GmbH</b>	DE
Austausch der Feuerlöschleitung im Medientunnel	<b>Kliewe GmbH</b>	DE
XHO, Wämedämm- und Brandschutzarbeiten	<b>A.S. Dämmtechnik GmbH</b>	DE
XHVAV + XHEXP, Lieferung und Montage eines vermaschten Druckluftsystems incl. Druckluftzentrale	<b>PLA Pumpen und Anlagenbau GmbH</b>	DE
XHEXP, Hallenbüro	<b>Jansen Systembau GmbH &amp; Co. KG</b>	DE
Rahmenvertrag für Sanitärarbeiten nach STL B	<b>Küker &amp; Böttcher OHG</b>	DE
XHO Fliesenarbeiten	<b>Michael Schulze Fliesen GmbH</b>	DE
XHO, MSR-Technik	<b>Sauter-Cumulus GmbH</b>	CH (DE)
Rahmenvertrag über Maler- und Lackierarbeiten	<b>Axel Stiboy Malereibetrieb GmbH</b>	DE
SASE3 SXP, Technische Gase Druckluft	<b>Dräger Medical ANSY GmbH</b>	DE
Neubau XHO, Putzarbeiten	<b>CC Putz GmbH</b>	DE
XFEL Gelände West, Lieferung Montage Trafo, Schaltanlagen	<b>WISAG Elektrotechnik Nord GmbH &amp; Co. KG</b>	DE





# Overview of the publicly-awarded national tender over 25k EUR- 2022

## Construction

Framework contract for scaffolding work	<b>Teupe &amp; Söhne Gerüstbau GmbH</b>	DE
Tischer-Beschlagarb framework contract.	<b>Tischlerei Stephan Kahl GmbH</b>	DE
Compressed air center in XHVAC	<b>C.H. Maack GmbH &amp; Co. KG</b>	DE
XHO joinery work	<b>Die Tischler Möbelwerkstätte</b>	DE
XHVAC- Compressed air control unit MSR-Technik	<b>Sauter-Cumulus GmbH, Niederlassung Hamburg</b>	DE
XHV lightning protection system	<b>NDB Elektrotechnik GmbH Co. KG</b>	DE
Building protection work in existing buildings (concrete grouting)	<b>Berton Bautenschutz Betonservice</b>	DE
XHO lightning protection	<b>D.H.W. Schultz und Sohn GmbH</b>	DE
SASE 3 - Extension of maintenance from 2 to 4 years	<b>Caverion Deutschland GmbH</b>	FI (DE)
XHO - Passenger lift system	<b>KONE GmbH</b>	FI (DE)
Replacement of the fire extinguishing line in the media tunnel	<b>Kliewe GmbH</b>	DE
XHO, Thermal insulation and fire protection works	<b>A.S. Dämmtechnik GmbH</b>	DE
Replacement of the fire extinguishing line in the media tunnel	<b>Kliewe GmbH</b>	DE
XHO, Thermal insulation and fire protection works	<b>A.S. Dämmtechnik GmbH</b>	DE
XHVAV + XHEXP, Delivery and installation of a mixing compressed air system including compressed air center	<b>PLA Pumpen und Anlagenbau GmbH</b>	DE
XHEXP, hall office	<b>Jansen Systembau GmbH &amp; Co. KG</b>	DE
Framework contract for sanitary work according to STL	<b>Küker &amp; Böttcher OHG</b>	DE
XHO tile work	<b>Michael Schulze Fliesen GmbH</b>	DE
XHO, MSR-Technik	<b>Sauter-Cumulus GmbH</b>	CH (DE)
Framework contract for painting and varnishing work	<b>Axel Stiboy Malereibetrieb GmbH</b>	DE
SASE3 SXP, Technical gases Compressed air	<b>Dräger Medical ANSY GmbH</b>	DE
New building XHO, plaster work	<b>CC Putz GmbH</b>	DE
XFEL Gelände West, Delivery assembly transformer, switching channels	<b>WISAG Elektrotechnik Nord GmbH &amp; Co. KG</b>	DE





## Awarded calls for tender 2022



<u>Document number</u>	Description	Contracting authority	<u>Publication date</u>	Company	<u>Company country</u>
<a href="#"><u>546237-2022</u></a>	Germany-Schenefeld: Excavating and earthmoving work/ die Erdarbeiten zu der Baumaßnahme XHV Type of procedure: Open procedure	European XFEL	07.10.2022	Groth & Co. Bauunternehmung GmbH	Germany
<a href="#"><u>443737-2022</u></a>	Germany-Schenefeld: Personnel and payroll services Type of procedure: Open procedure	European XFEL	12.08.2022	AS Mediendesign	Germany
<a href="#"><u>441587-2022</u></a>	Germany-Schenefeld: Miscellaneous furniture and equipment/ Realisierung der Planung, also die Herstellung der Ausstellung (inkl. Ausstellungs- und Möbelbau) XHV Type of procedure: Competitive procedure with negotiation	European XFEL	12.08.2022	Archimedes Exhibitions GmbH	Germany
<a href="#"><u>271435-2022</u></a>	Germany-Hamburg: Analysis services/Probenahme und Analyse von Kühlwasser aus Rückkühlwerken Type of procedure: Open procedure	DESY	20.05.2022	SGS Institut Fresenius GmbH	Germany
<a href="#"><u>253930-2022</u></a>	Germany-Schenefeld: Laboratory, optical and precision equipment (excl. glasses)/Superconducting undulator afterburner PRE-SerieS prOtotype (S-PRESSO) Type of procedure: Negotiated procedure without a call for competition	European XFEL	13.05.2022	Bilfinger Noell GmbH	Germany
<a href="#"><u>217961-2022</u></a>	Germany-Schenefeld: Time accounting or human resources software package Type of procedure: Competitive procedure with negotiation	European XFEL	26.04.2022	LÜTH & DÜMCHEN Automatisierungsprojekt GmbH	Germany
<a href="#"><u>217958-2022</u></a>	Germany-Schenefeld: Time accounting or human resources software package Type of procedure: Competitive procedure with negotiation	European XFEL	26.04.2022	HR4YOU AG	Germany

## Awarded calls for tender 2022



<u>Document number</u>	<u>Description</u>	<u>Contracting authority</u>	<u>Publication date</u>	<u>Company</u>	<u>Company country</u>
<a href="#"><u>24654-2022</u></a>	Germany-Schenefeld: Engineering design services for mechanical and electrical installations for buildings/Planung der Technischen Ausrüstung für das Visitor and Conference Center Type of procedure: Open procedure	European XFEL	17.01.2022	Pinck Ingenieure Consulting GmbH & Co. KG	Germany
<a href="#"><u>17194-2022</u></a>	Germany-Schenefeld: Fire-alarm system installation work/ Neubau Bürogebäude XHO - Brandmeldeanlage Type of procedure: Open procedure	European XFEL	14.01.2022	Alarm- und Sicherheitstechnik B.W. GmbH	Germany
<a href="#"><u>16111-2022</u></a>	Germany-Schenefeld: Supervision of building work/uüberwachung (LPh 8) für die Technische Ausrüstung für den Neubau des Bürogebäudes XHO Type of procedure: Open procedure	European XFEL	12.01.2022	Pinck Ingenieure Consulting GmbH & Co. KG	Germany
<a href="#"><u>606019-2022</u></a>	Germany-Schenefeld: Structural shell work/Neubau Visitor Center XHV, Rohbauarbeiten Type of procedure: Open	European XFEL	02.11.2022	Meier Hoch-/Tiefbau GmbH	Germany
<a href="#"><u>601993-2022</u></a>	Germany-Schenefeld: Cameras/Ultrafast speed camera with a Megahertz Rate Sampling for MHZ microscopy Type of procedure: Negotiated without prior call for competition	European XFEL	31.10.2022	Shimadzu Deutschland GmbH	Germany
<a href="#"><u>581902-2022</u></a>	Germany-Schenefeld: Payroll management services Type of procedure: Open	European XFEL	21.10.2022	Lohndirekt GmbH	Germany
<a href="#"><u>20524-2022</u></a>	Germany-Schenefeld: Caretaker services Type of procedure: Restricted procedure	European XFEL	14.01.2022	x	x
<a href="#"><u>17294-2022</u></a>	Germany-Schenefeld: Switching station installation work/Neubau Bürogebäude XHO - Erstellung der Mess-, Steuerungs- und Regelungstechnik Type of procedure: Open procedure	European XFEL	14.01.2022	x	x

**Thank you for your attention**

