

The High Energy Density (HED) instrument at the European X-ray Free Electron Laser

Clemens Prescher
Grenoble, 7.02.2019



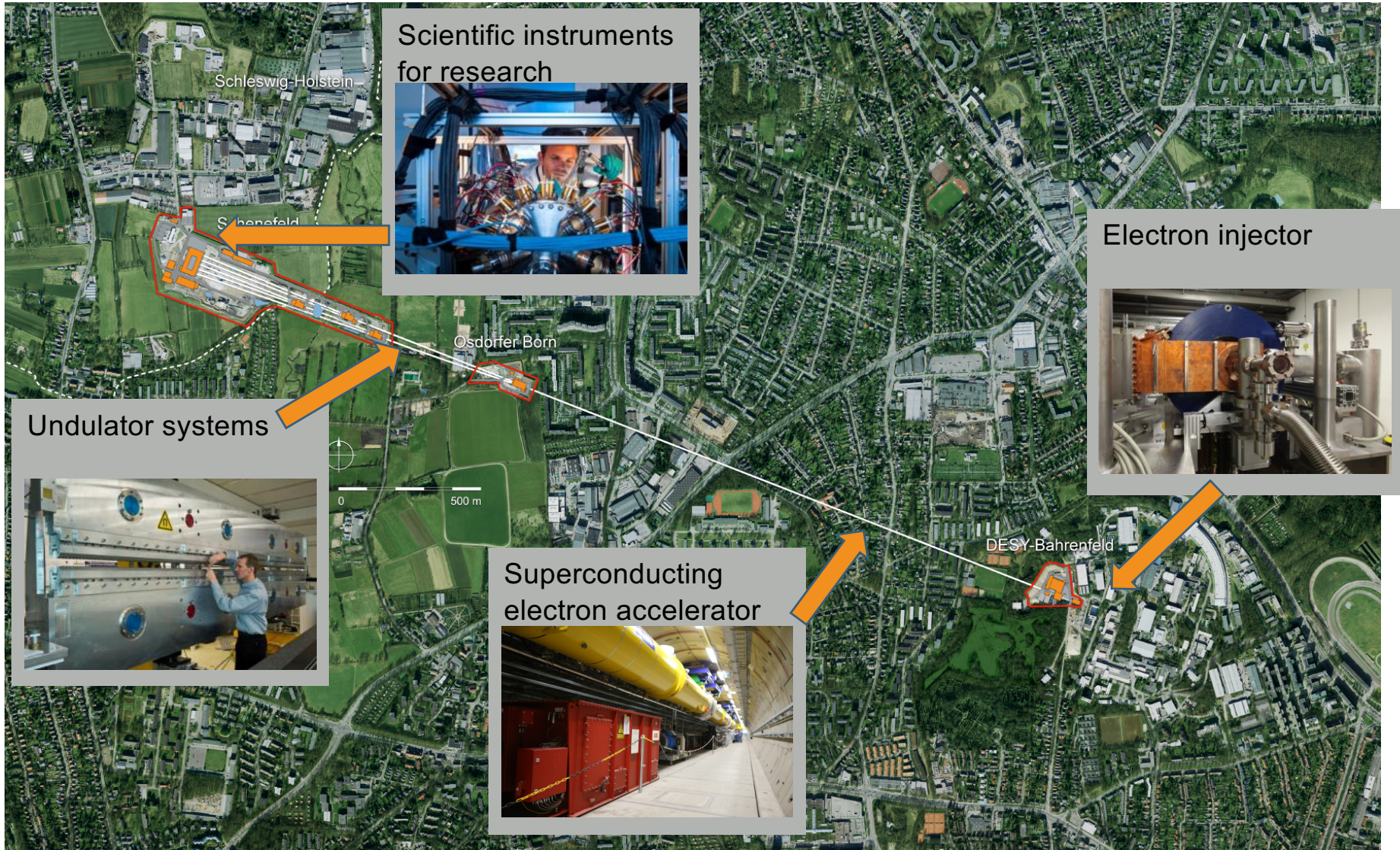
European XFEL

A new research facility



How it works

A closer look at the facility



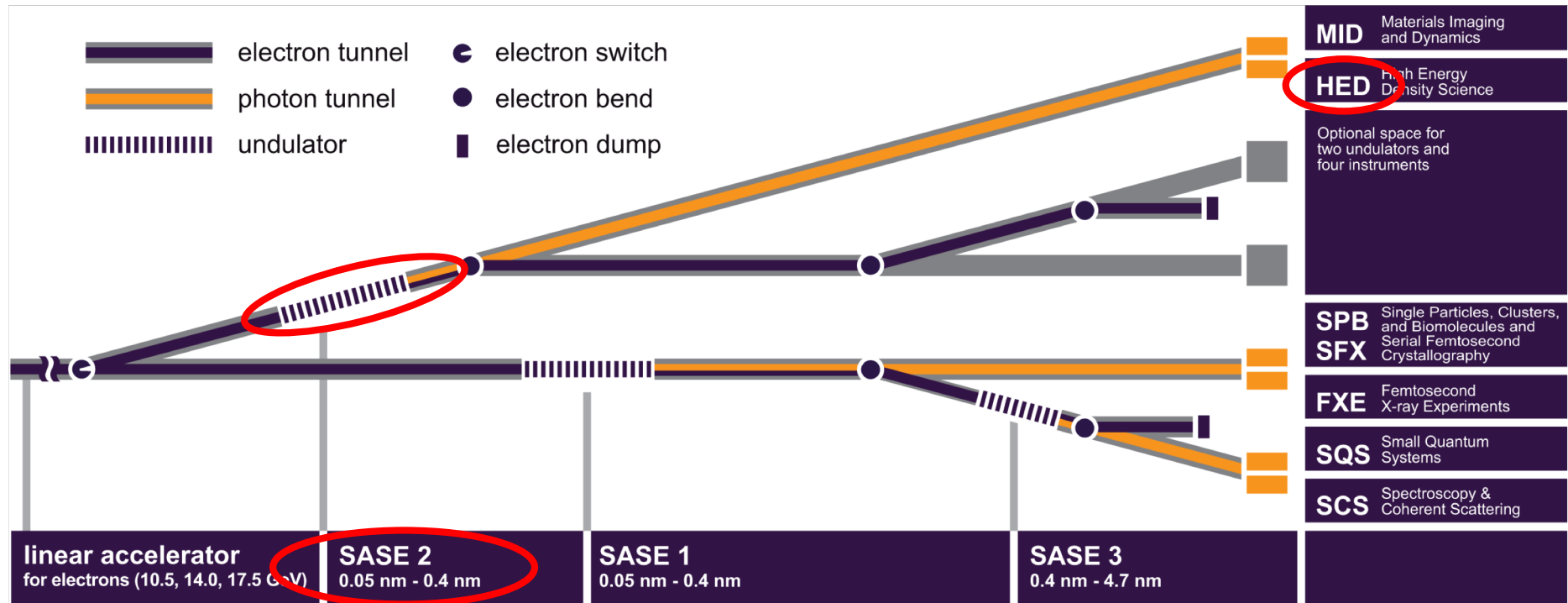
About the European XFEL



- Organized as a non-profit corporation in 2009 with the mission of design, construction, operation, and development of the free-electron laser
- Supported by 11 partner countries
- Germany (federal government, city-state of Hamburg, and state of Schleswig-Holstein) covers 58% of the costs; Russia contributes 27%; each of the other international shareholders 1–3%
- Total budget for construction (including commissioning)
 - 1.22 billion € at 2005 prices (div by 6: 200 M€ per scientific instrument)
 - 600 M€ contributed in cash, over 550 M€ as in-kind contributions (mainly manufacture of parts for the facility)

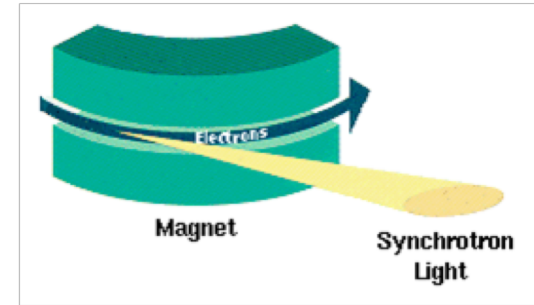
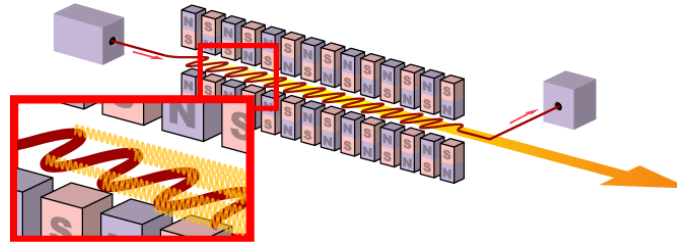
European XFEL

Beamlines and Instruments



- First lasing in SASE1 with up to 1 mJ May 2017
- Start of user operation (SASE1) Sept 2017
- Start of user operation (HED) May 2018

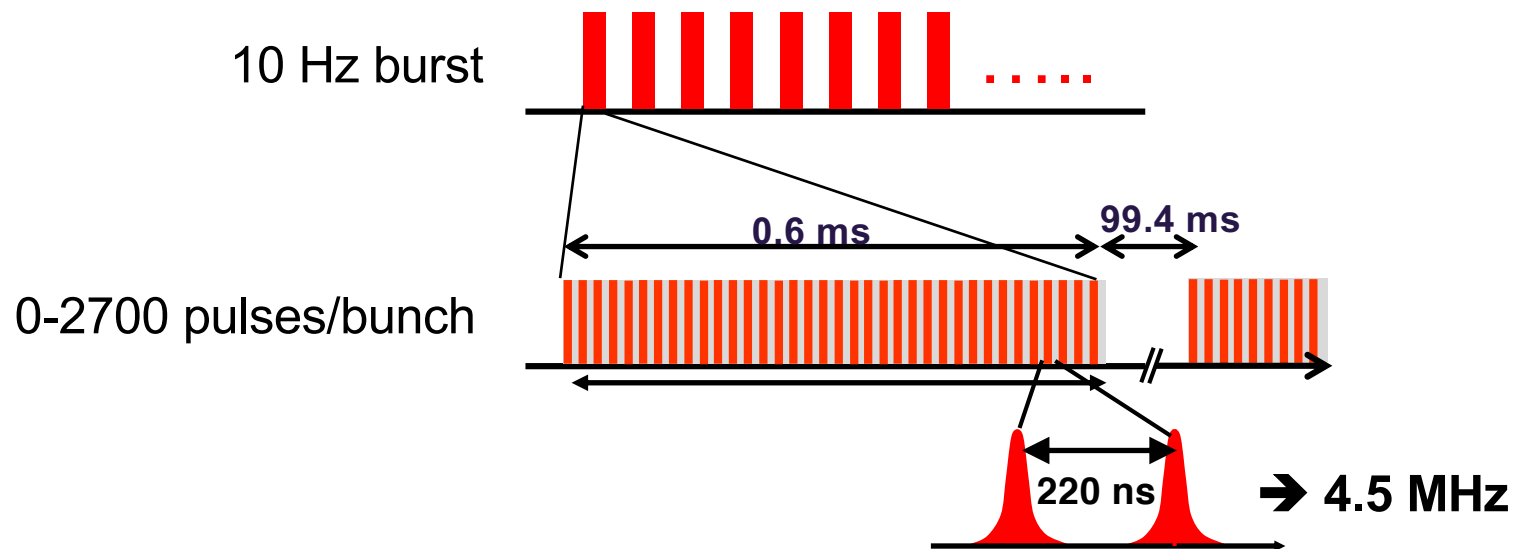
Comparison: XFEL and Synchrotron



	European XFEL	ESRF (HPLF after upgrade)
Pulse length	5 - 100 fs	~ 100 ps
Energy range	5 – 25 keV	5 – 25 keV → > 60 keV
# photons/pulse	$10^{12} - 10^{13}$	$10^{8-9} - 10^{10}$
bandwidth	0.1 % (seeded) ~ 1 % (SASE)	~ 3 % → ~ 1%
Pointing stability	~ +/- 10 um	< 1um

XFEL properties at the HED instrument (SASE2)

Fully tunable between	3 – 25 keV (3 – 5 keV with limited performance)
Pulse duration	2 – 100 fs
Number of photons per pulse	$\sim 10^{10}$ (25 keV), $\sim 10^{12}$ (5 keV)
Spot size on sample	sub- μm (HIBEF), few μm , 20 – 30 μm , 200 – 300 μm , few mm
Seeded beam	First SASE beamline to be seeded; available soon after initial commissioning
Repetition rate	shot on demand (pulse picker), 10 Hz – 27000 pulses/sec



HED: unique capabilities

Couple XFEL beam to powerful drivers

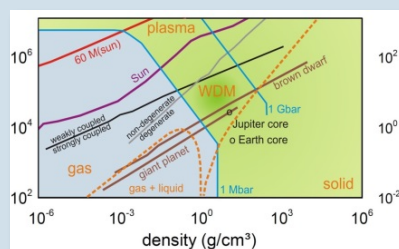
- Diamond Anvil Cells (dynamic DAC; pulsed laser heated DAC; double-stage DAC)
- Powerful optical lasers
(100 J 15 ns 10 Hz; 400 TW 30 fs 10 Hz)
- XFEL split&delay line (x-ray pump-probe) (2-20 ps delay, depending on energy)
- Up to 60 T pulsed magnetic field coil



HED Science Agenda

Laser Compression

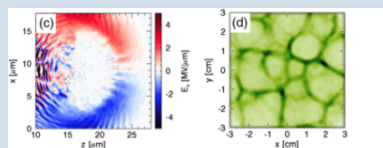
Shock & ramp compression



IC 2 for precision XRD
 IC 1 for XRD, IXS, XES
 DIPOLE-100X ns laser

Relativistic Laser-Plasmas

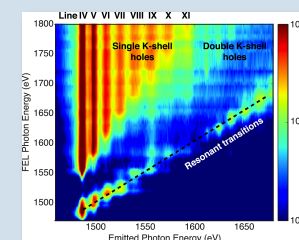
Electron transport,
 Instabilities and filamentation,
 Particle acceleration,
 High EM fields



IC 1
 Multi-100 TW laser

Isochoric X-ray excitation

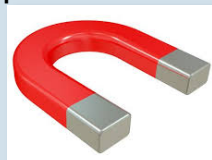
Transport properties,
 Hollow atoms, rates



IC 1 for XES, IXS, XRD
 Intense X-ray pulses, SDL

Condensed Matter in Strong Magnetic Fields

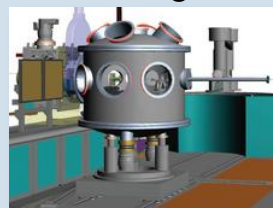
Correlated systems,
 magnetic order,
 superconductivity



Goniometer in IA 2
 split or 60 T solenoid coils

Diamond Anvil Cells

Fast dynamic piezo DAC
 Pulsed laser heated DAC
 Double-stage DAC



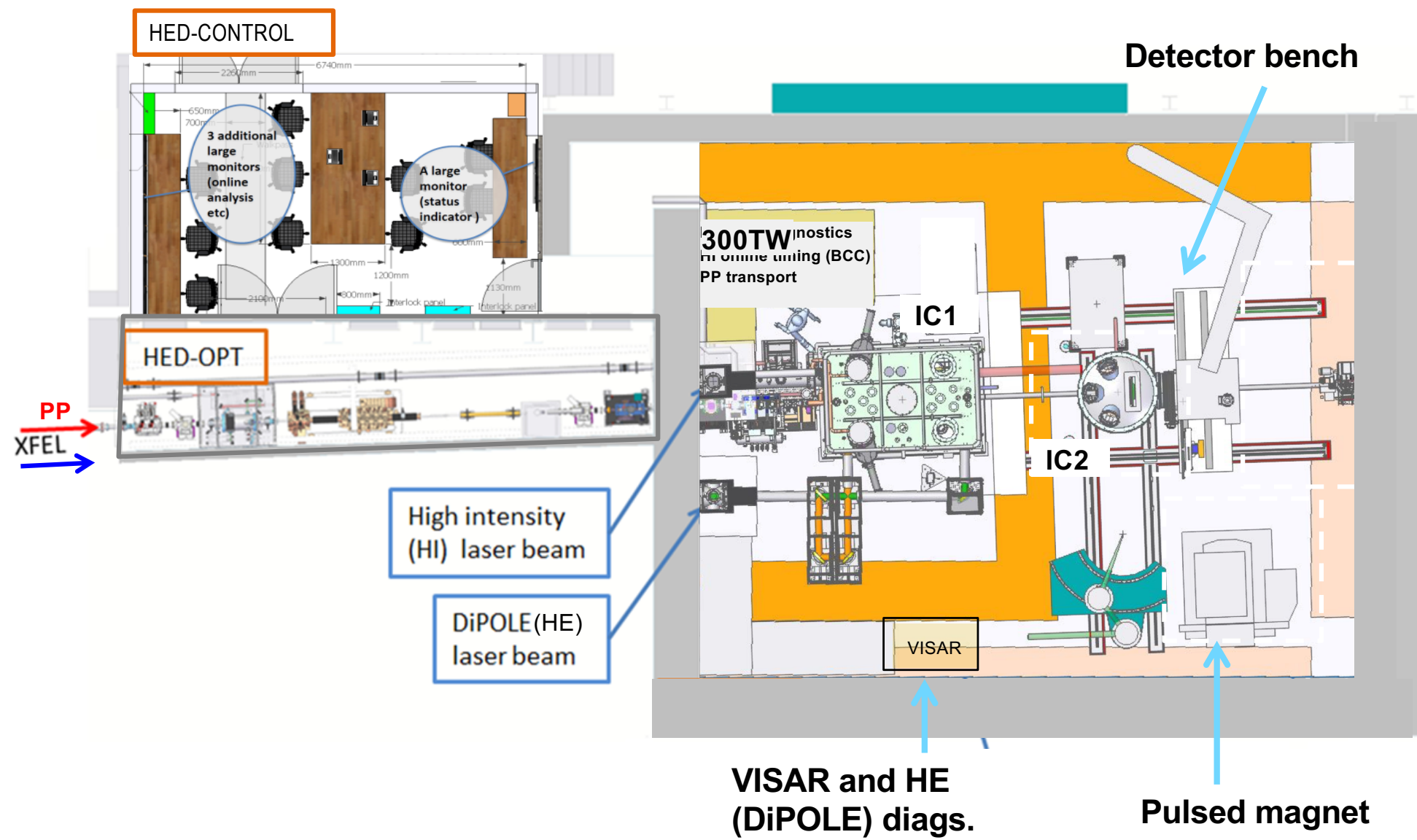
IC 2 for precision XRD
 Dynamic DAC, pulsed lasers

Many more:

Strongly excited materials
 QED vacuum birefringence
 Self-sustained reactions

...

HED hutch overview

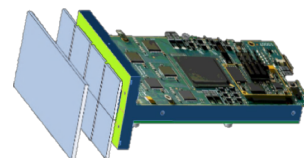
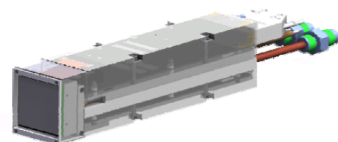


| HED Instrument at XFEL | Clemens Prescher, 07.02.2019



Day-1 x-ray detector suite at HED

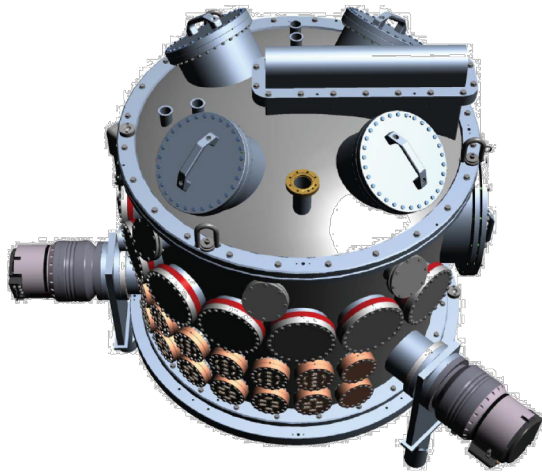
Inside IC1 in vacuum



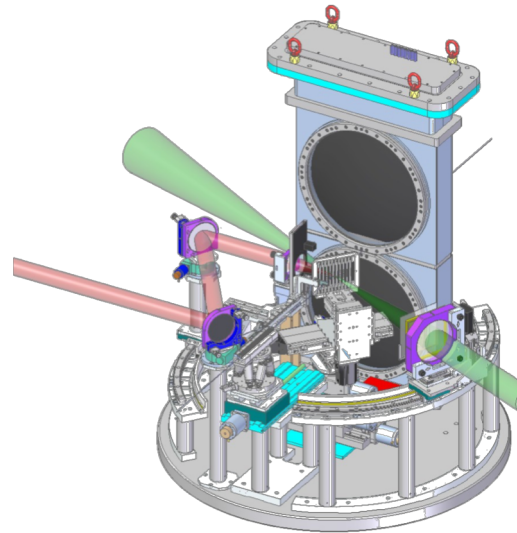
Parameters	ePix100	ePix10k	Jungfrau	Gotthard-I
	SLAC	SLAC	PSI	PSI
Sensor	300 μm Si	300 μm Si	320 μm Si (upgrade 450 μm Si)	320 μm Si
Sensor size (pixel)	704x768 (35x38 mm ²)	352x384 (35x38 mm ²)	512x1024 (40x80 mm ²)	1x1280 (8x64 mm ²)
Pixel size (μm)	50	100	75	50
Dynamic range	10 ² (@ 8 keV)	10 ⁴ (@ 8 keV)	10 ⁴ (@ 12 keV)	10 ⁴ (@ 12 keV)
Noise (eV)	< 280	< 560	< 450	< 900
Repetition (Hz)	120	120	2000 (200 tested) 0.5MHz in burst mode, 16 images on-chip memory	40,000 0.8MHz in burst mode, 128 images digital memory
# of modules	2	3	4	2

Interaction Chamber 2

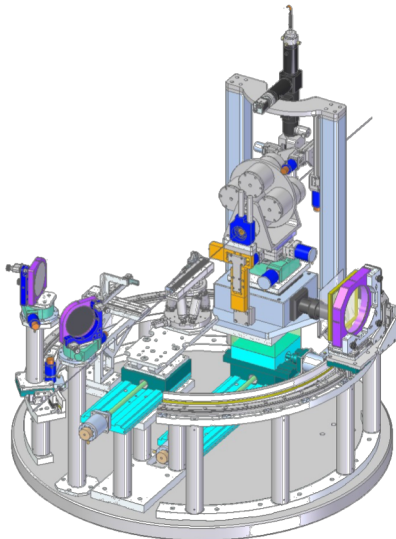
One chamber for multiple standard XRD setups



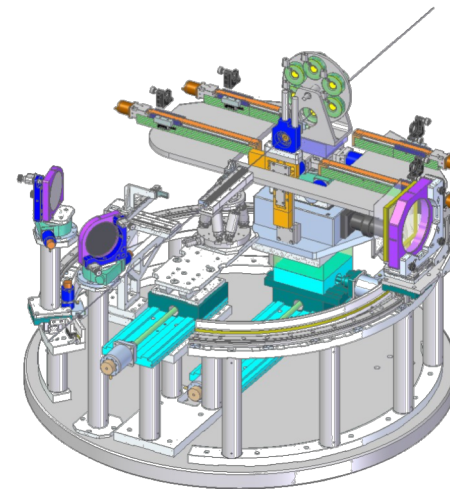
chamber



Laser shock compression



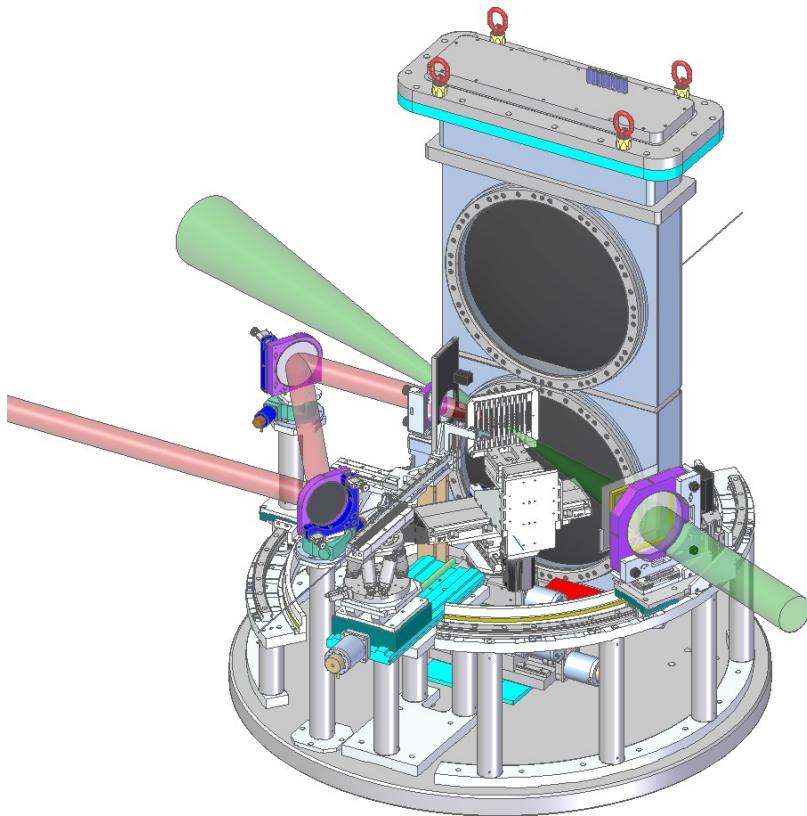
dynamic DAC
double stage DAC



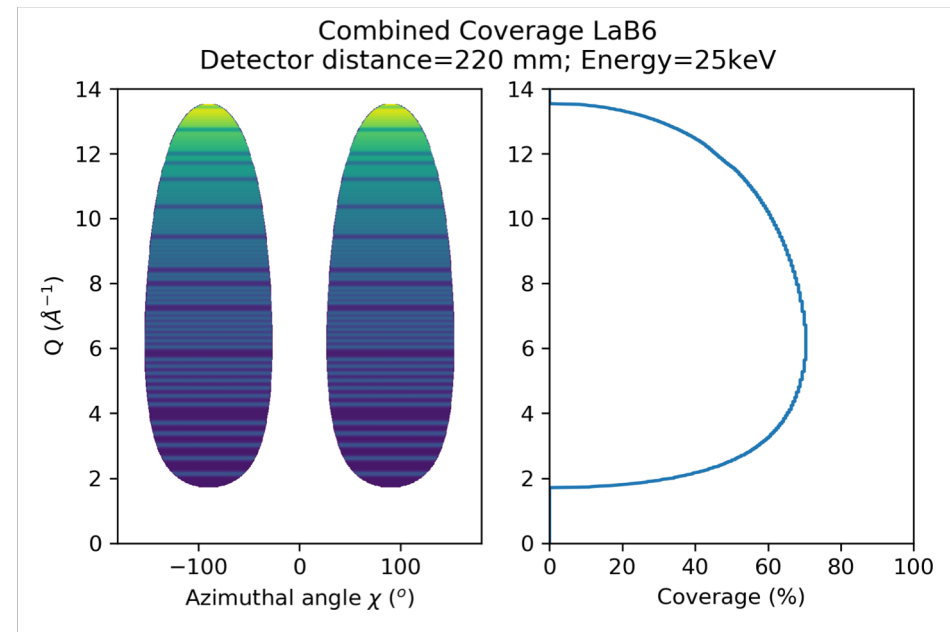
Laser heated-DAC

Interaction Chamber 2

Shock Setup



Coverage on 2 Varex 4343 CT (perp. config.)

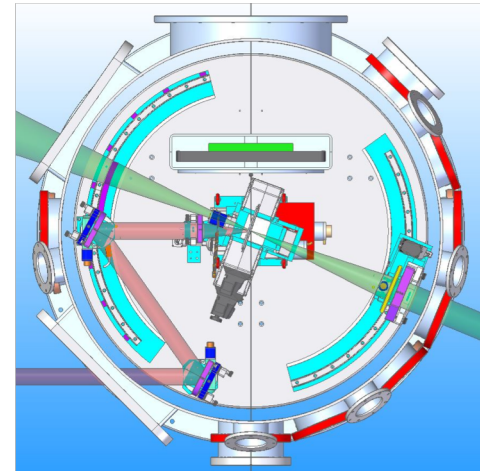


Interaction Chamber 2

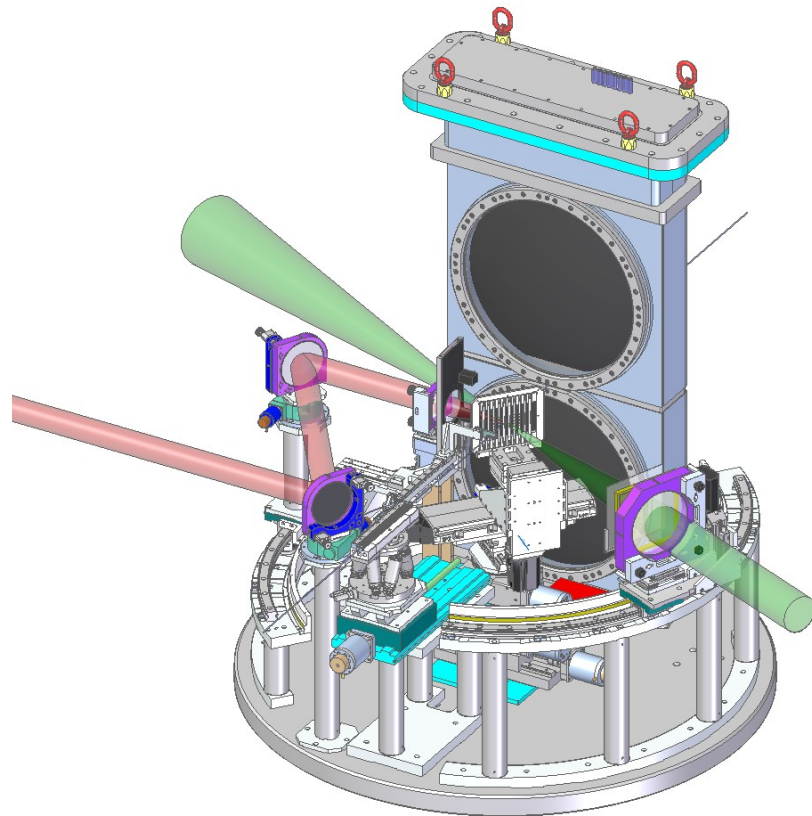
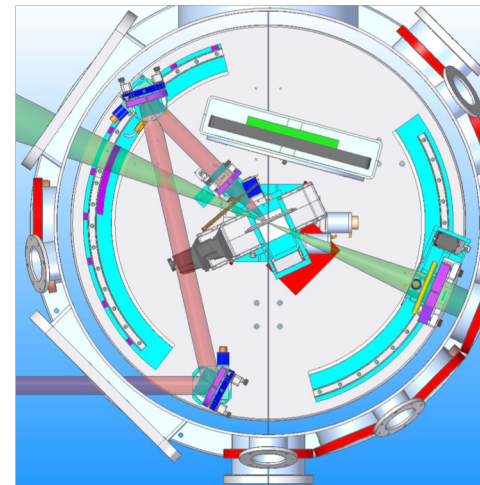
Shock Setup

different shock geometries

> perpendicular

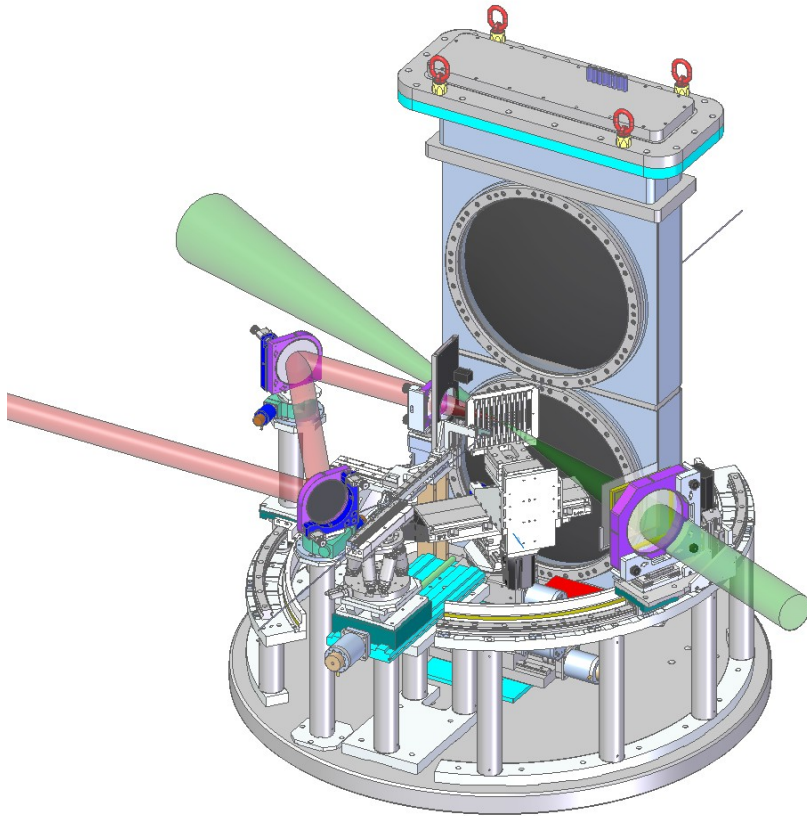


> colinear



Interaction Chamber 2

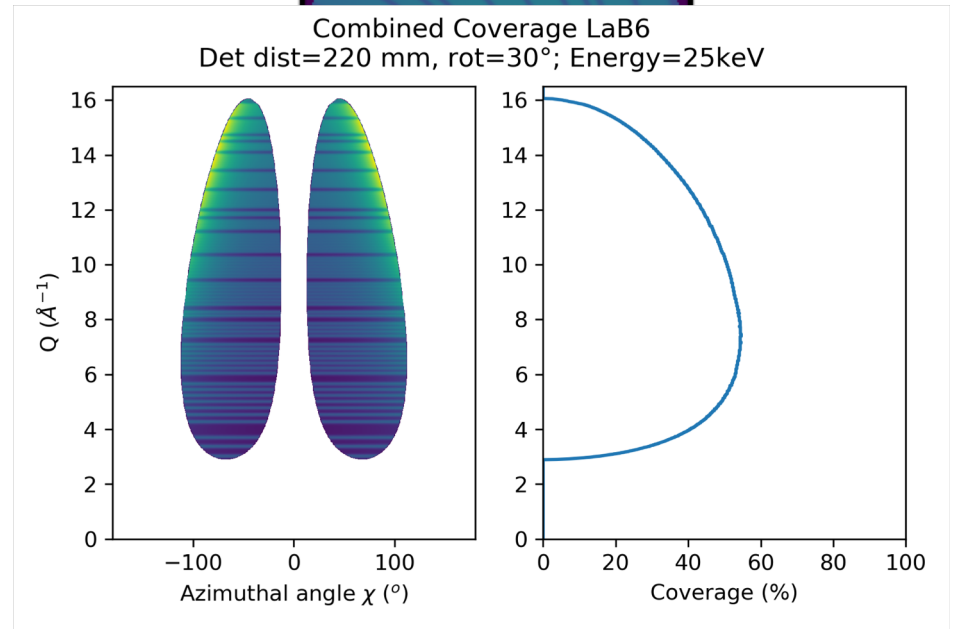
Shock Setup



Detector Projection LaB6
Det dist=220 mm, rot=30°; Energy=25keV

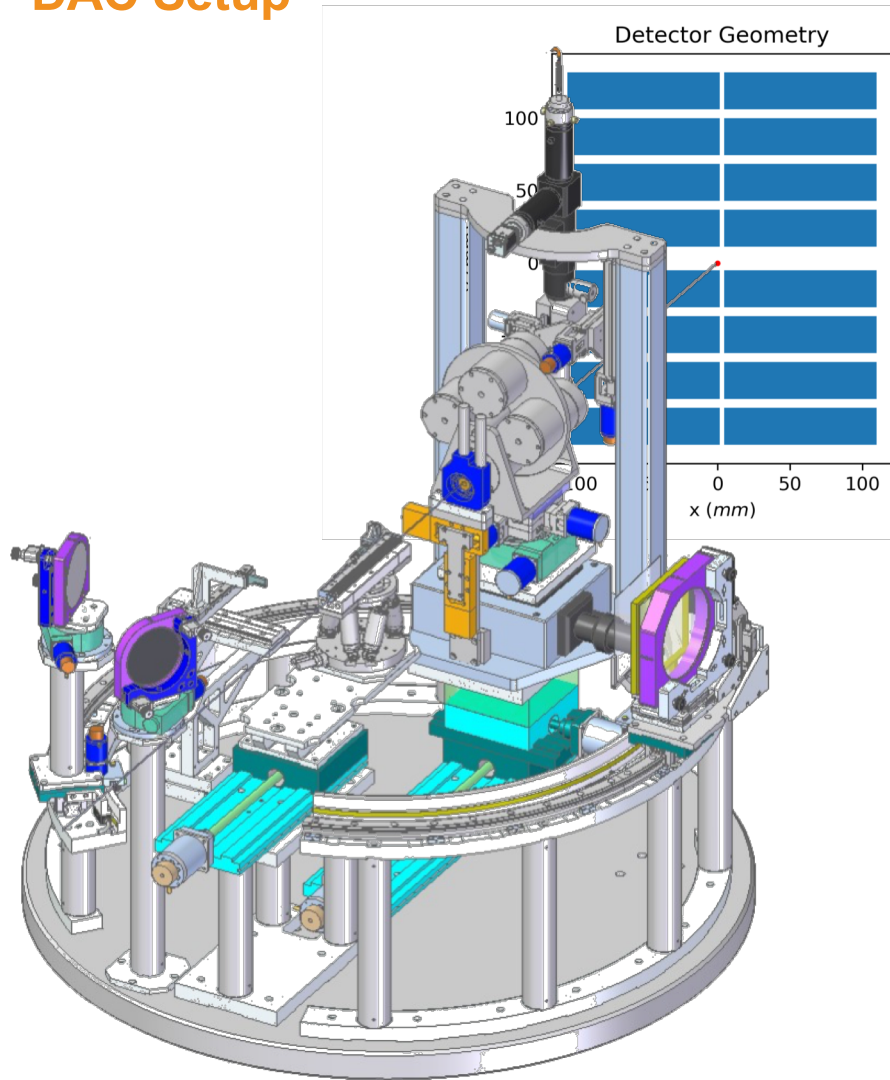


Combined Coverage LaB6
Det dist=220 mm, rot=30°; Energy=25keV

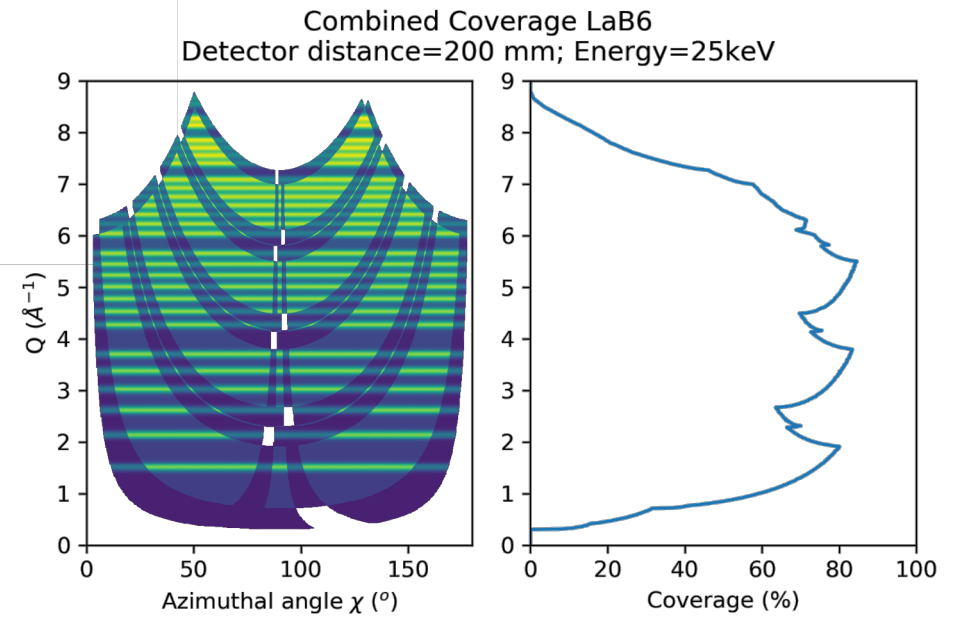


Interaction Chamber 2

DAC Setup

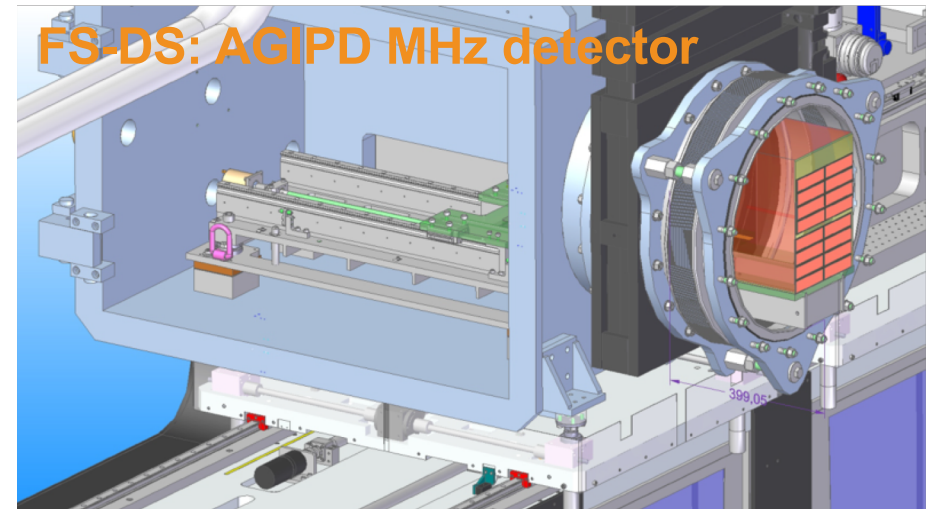
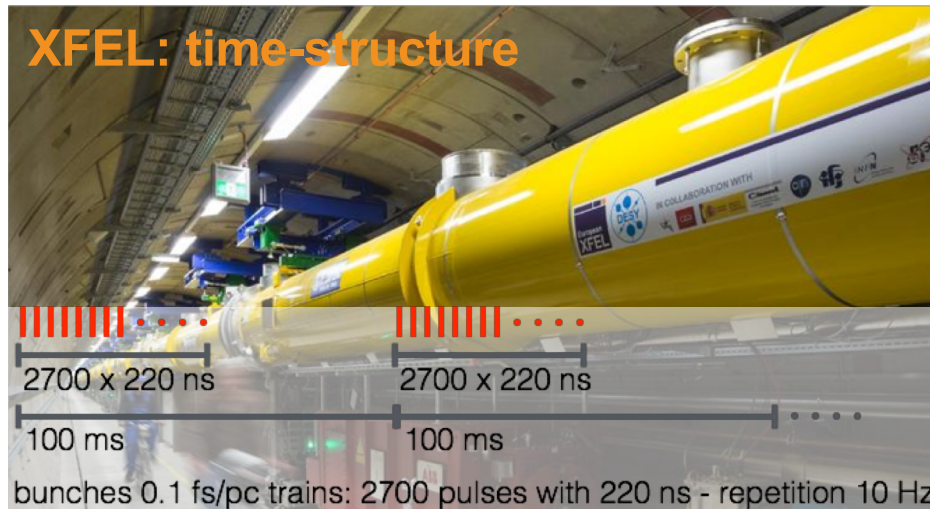


Coverage on AGIPD



AGIPD detector

Exploiting the timing structure of the XFEL bunch train

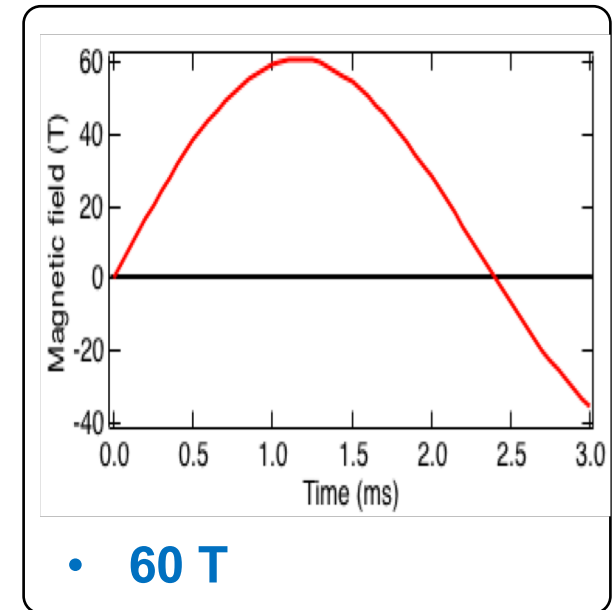
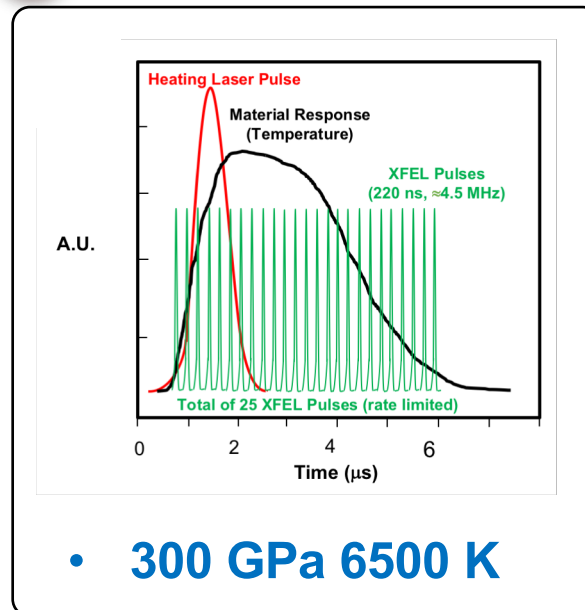
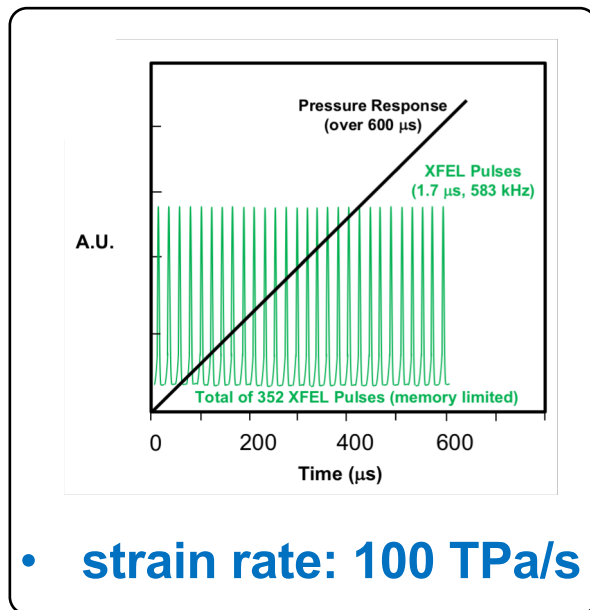
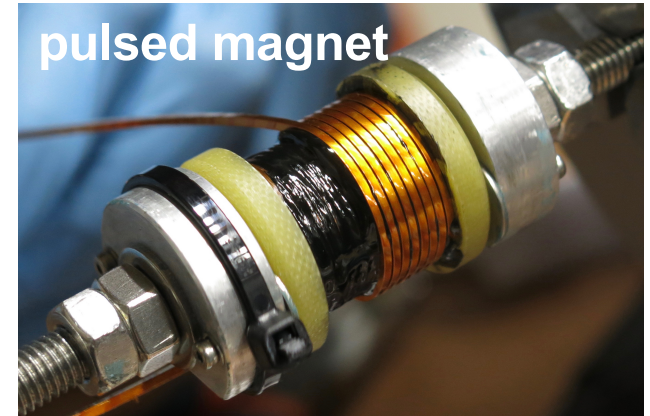
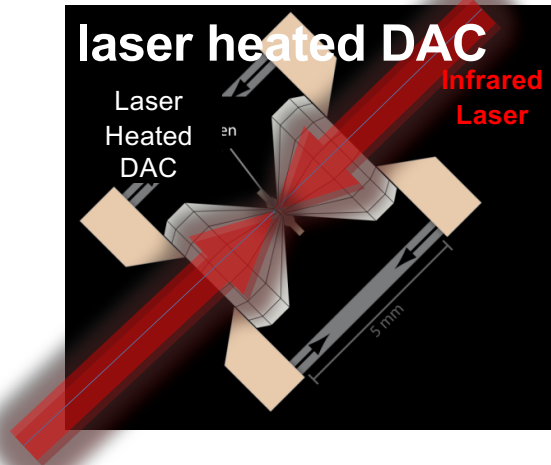
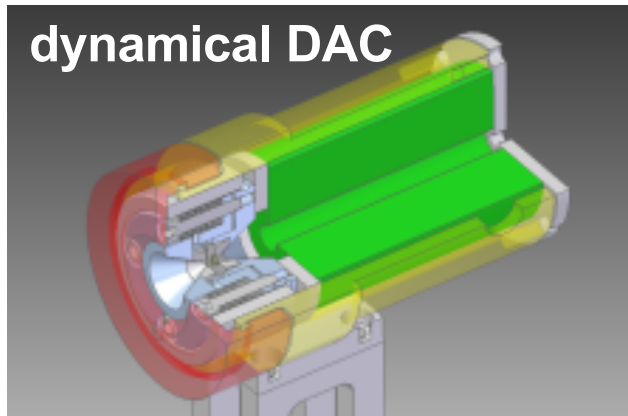


Sensor

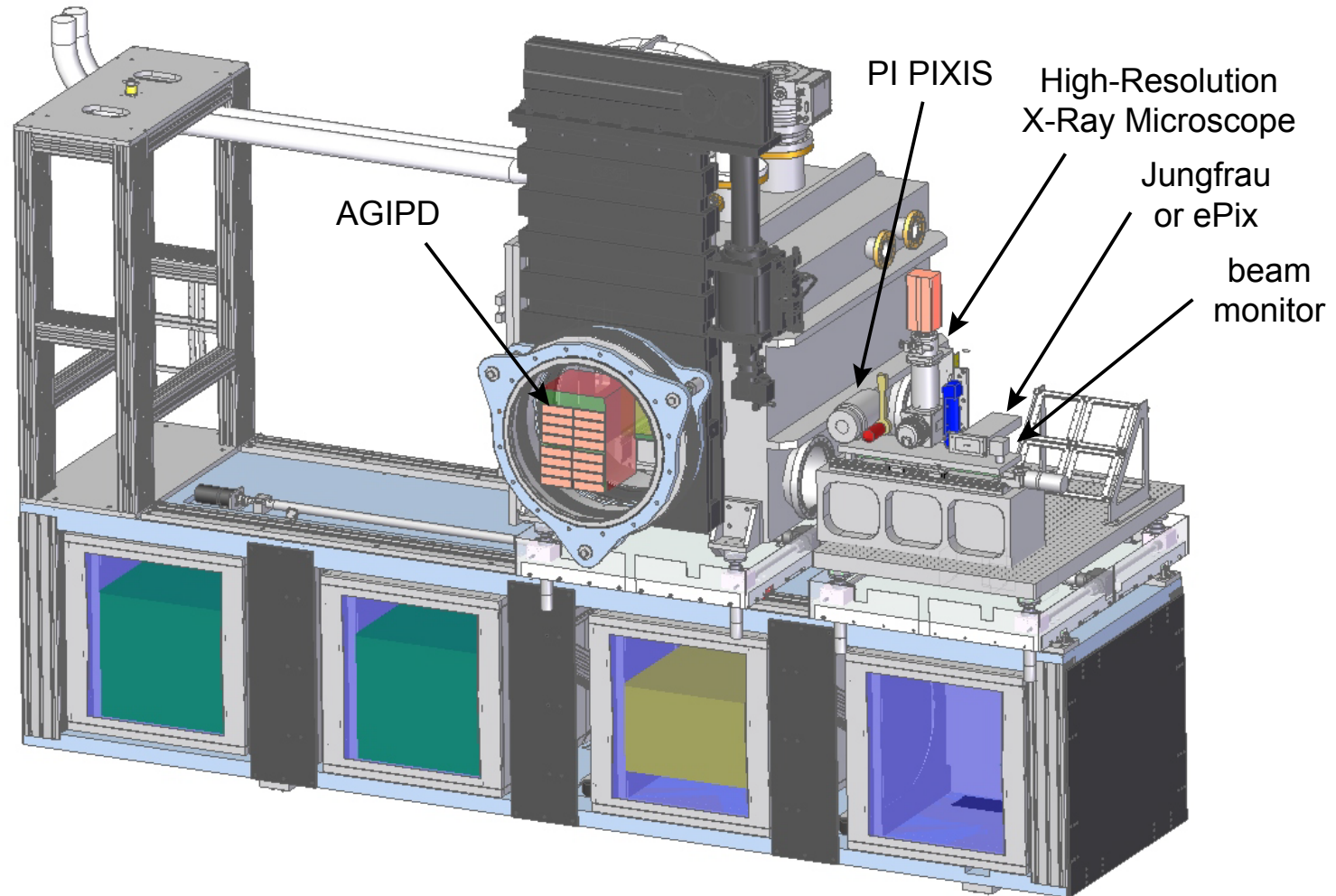
- day 1: Si 500 μm , later high-Z (GaAs)
- pixel size: 200 μm · 200 μm
- 1 M-pixel: 8 twin modules with 2 · 512 pixel · 128 pixel
- 352 images at 4.5 MHz

AGIPD detector

Exploiting the timing structure of the XFEL bunch train

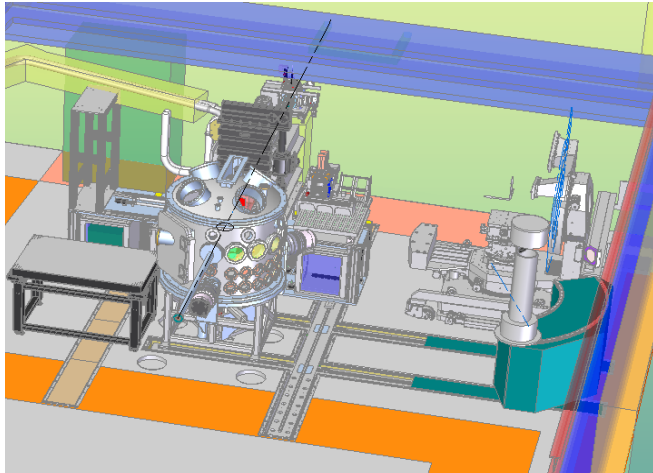


Detector Bench

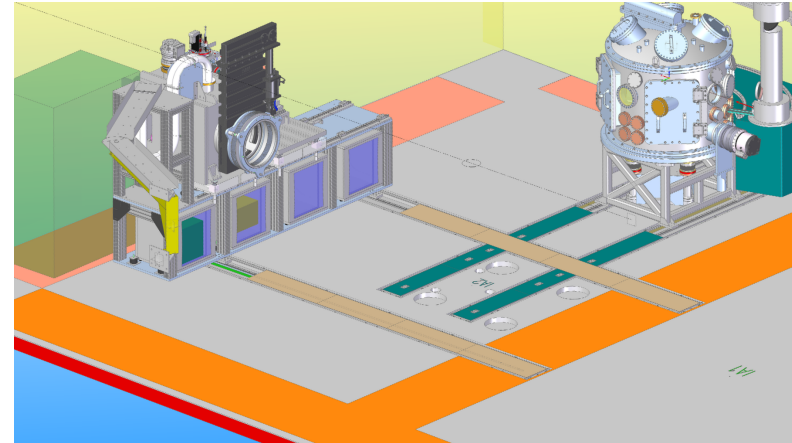


Detector Bench

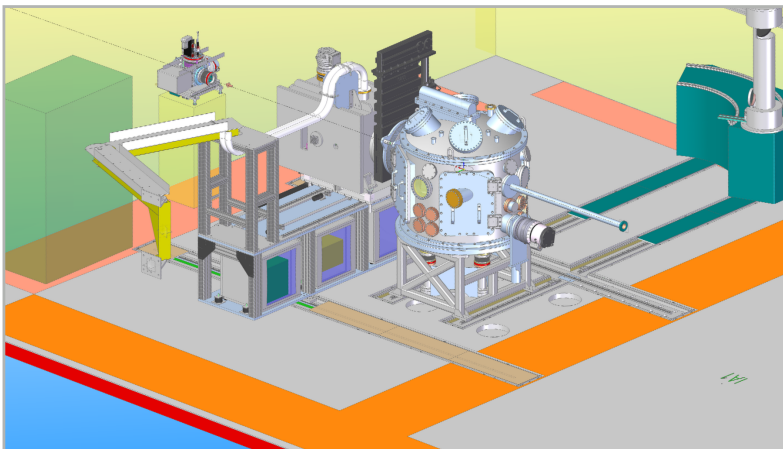
Rail system



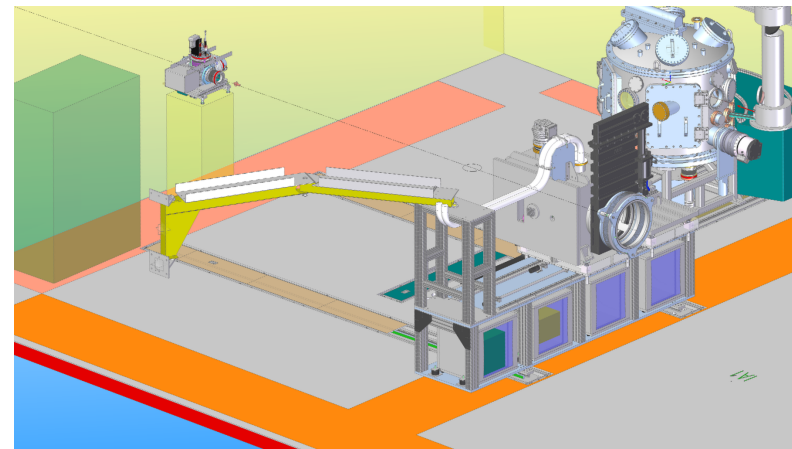
parking position



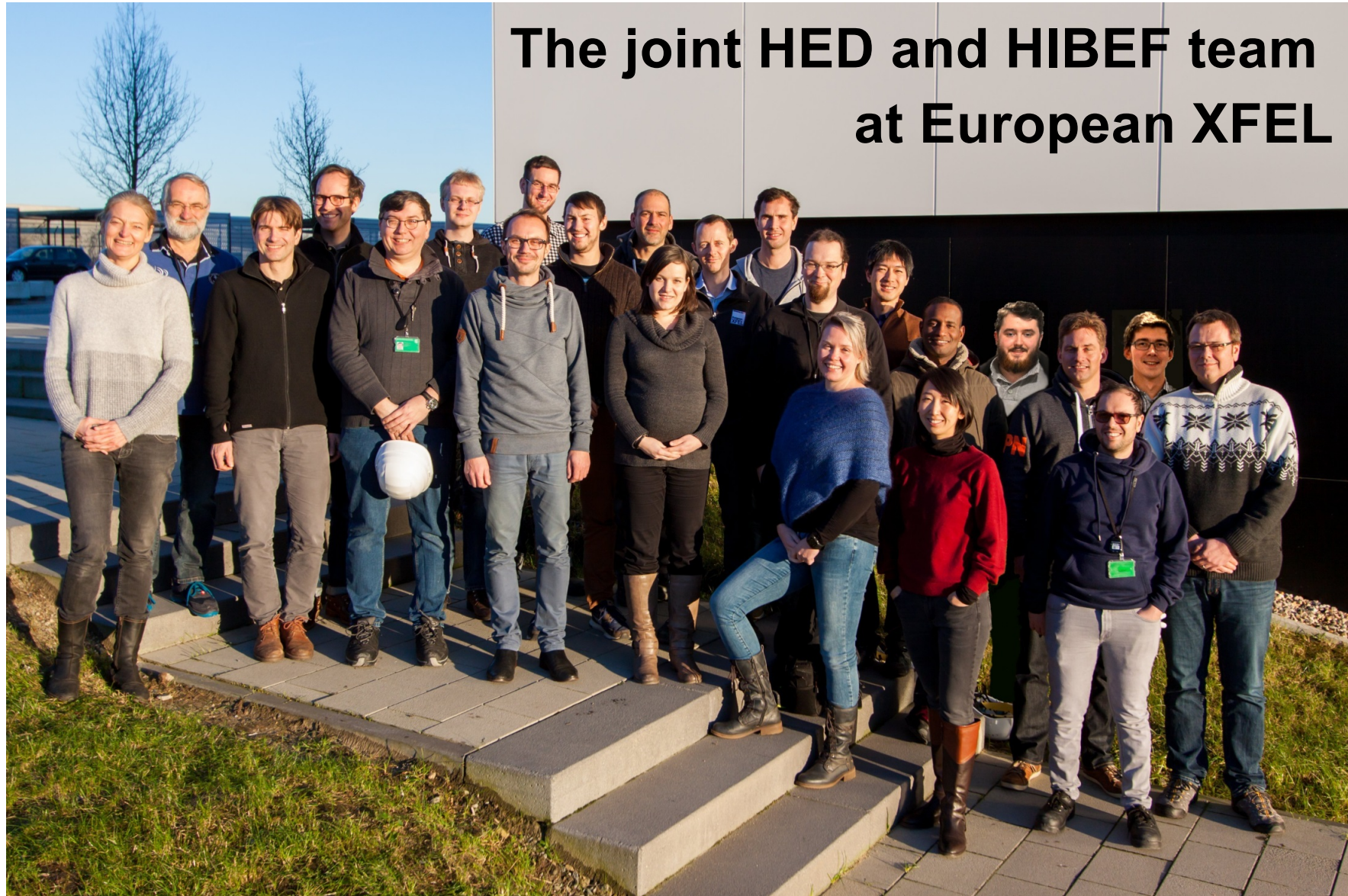
docked to interaction chamber 2



docked to interaction chamber 1



Thank you



Contact

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