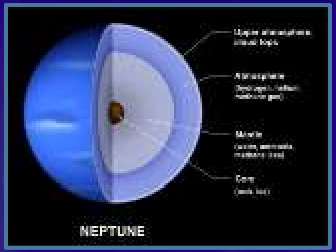
Parameters for early user experiments

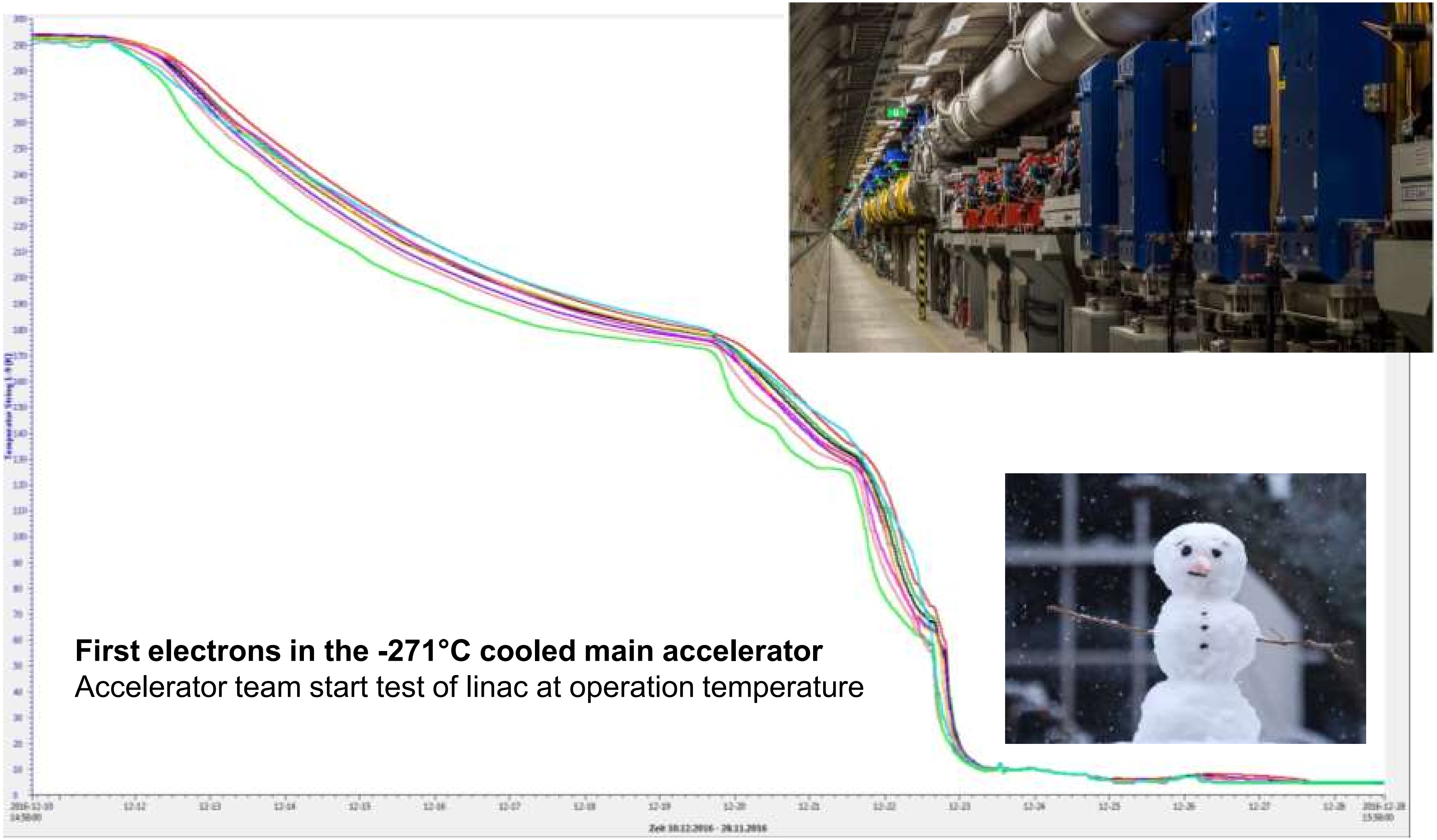
SASE2 project schedule, HED hutch status

Ulf Zastrau
High Energy-Density (HED) science group
Group leader

Schenefeld, 24 Jan 2017



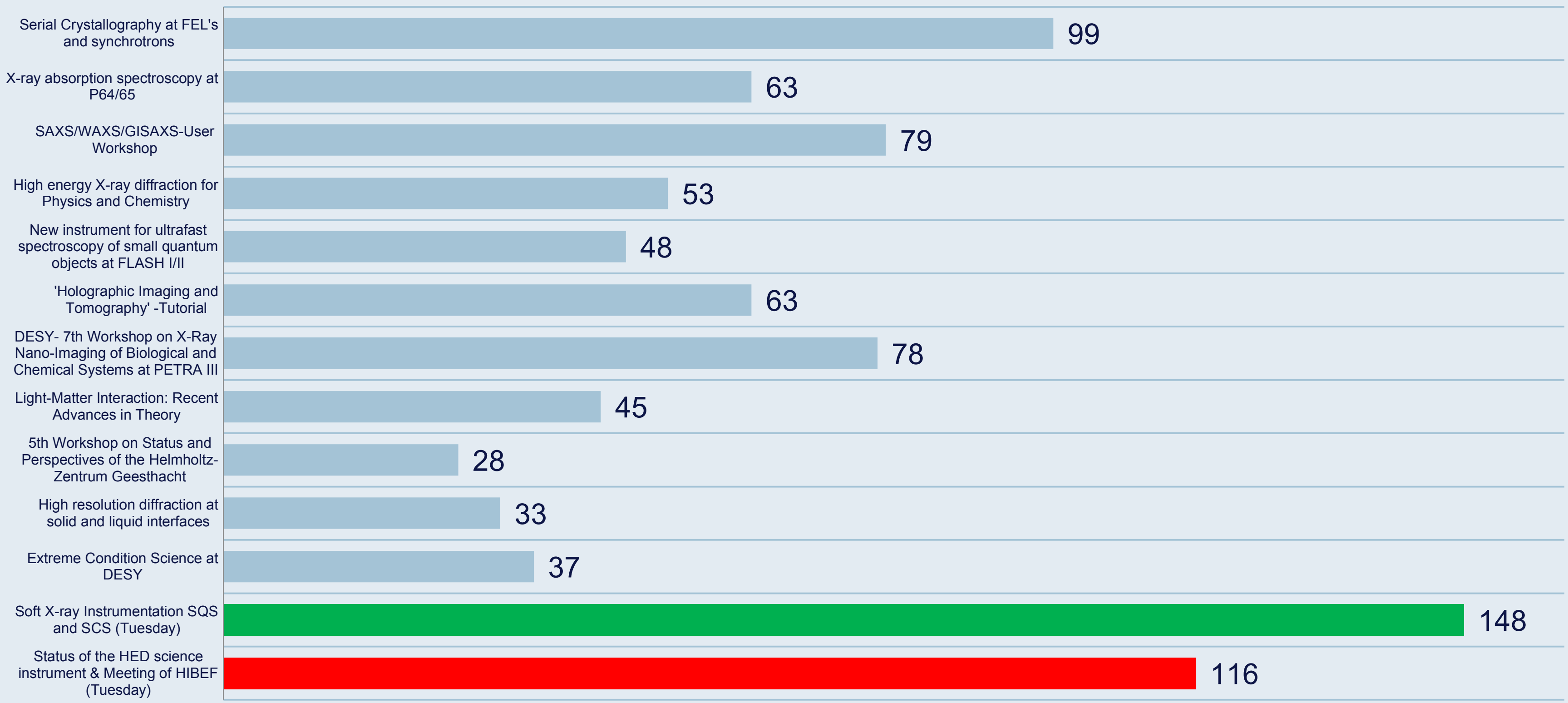
It‘s cold in Hamburg, it‘s cold in Schenefeld



First electrons in the -271°C cooled main accelerator

Accelerator team start test of linac at operation temperature

Satellite meeting attendance – thanks for your interest!



Today‘s program – part one

Tuesday, 24 January 2017

Early user experiments at the HED instrument

9:00–10:30	**Registration**		
	Tours of XHEXP experimental hall and the HED instrument		
	coffee, cookies and discussions		
10:30-13:00	**Parameters for early user experiments**	**Chair: N. N.**	
10:30	SASE2 project schedule, HED hutch status	U. Zastrau	*European XFEL*
10:50	X-ray properties at SASE2 and HED	K. Appel	*European XFEL*
11:30-12:00	**Coffee break, individual discussions**		
12:00	HED vacuum chamber IC1, x-ray detectors	S. Göde	*European XFEL*
12:30	the XFEL pump-probe laser at SASE2	M. Nakatsutsumi	*European XFEL*
13:00–14:30	**Lunch break (Room E1.172 & XFEL foyer)**		
14:30-15:00	**discussion about early user experiments**	**Chair: U. Zastrau**	

HIBEF user consortium meeting

- Dinner (self-payer) at LUSTIS, 20 min walking distance

Condensed Matter <> **Warm Dense Matter** <> Hot Dense Matter

$E_{therm} \sim E_{Fermi}$

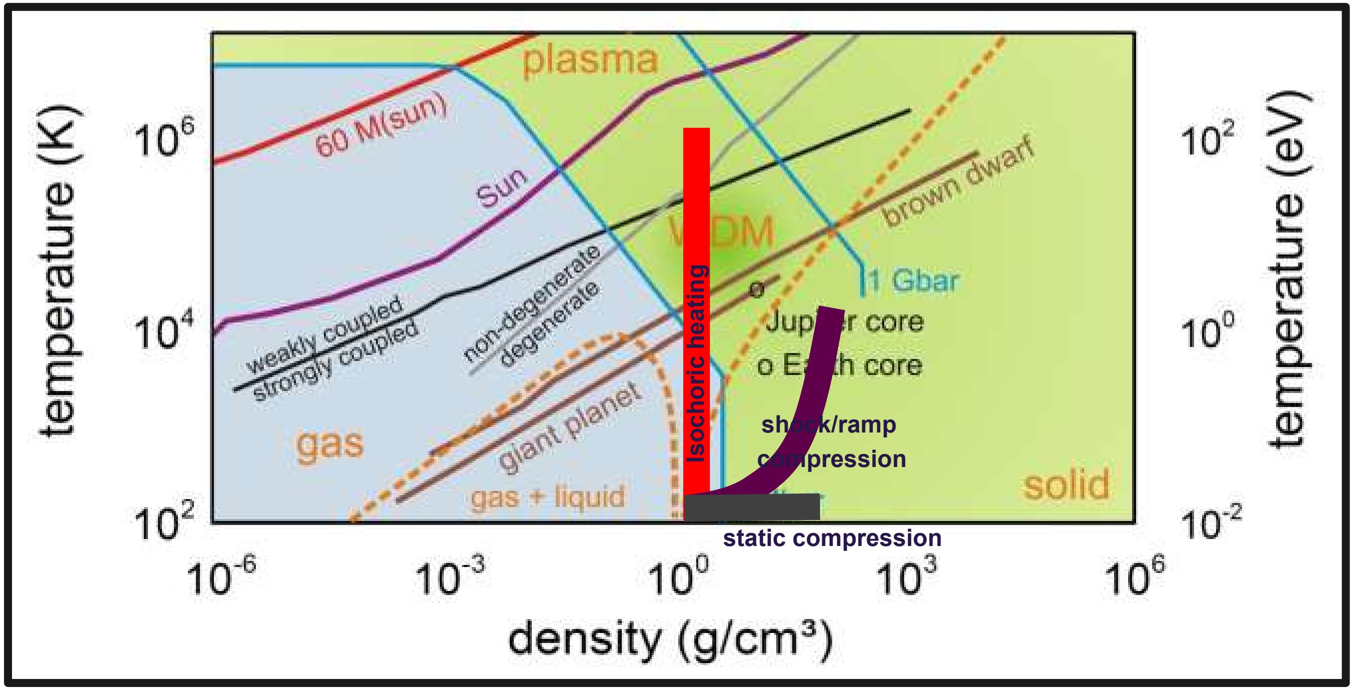
1..100 eV

$\rho_{WDM} \approx \rho_{solid}$

strong coupling

$\Gamma \geq 1$

$E_{coulomb} \sim E_{therm}$

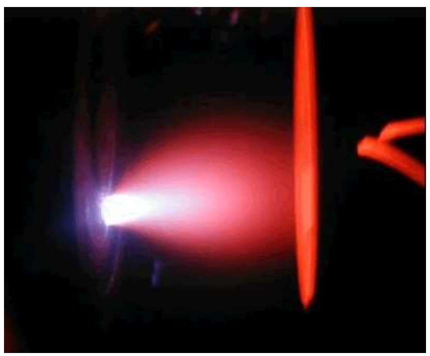


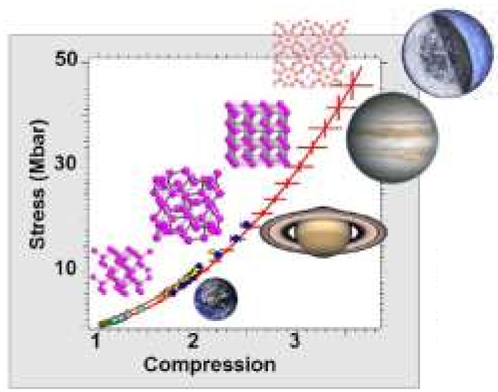
High free-electron density: penetration only up to critical density $n_c = \omega^2 \varepsilon_0 m/e^2$

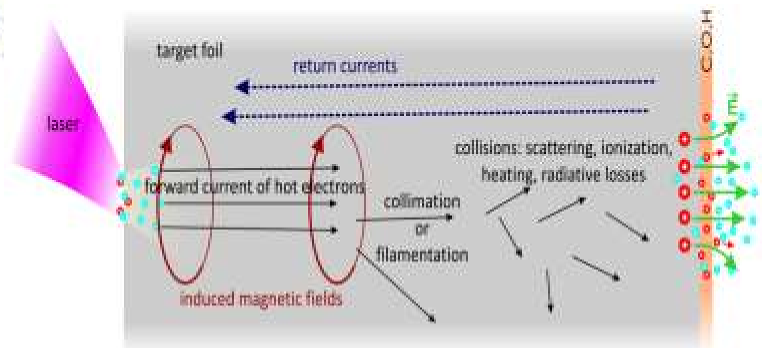
→ access to volumetric plasma parameters only by short wavelength radiation ($\omega > \omega_P$)

High-Energy Density instrument

- Ultrafast dynamics and structural properties of matter at extreme states
  - **Highly excited solids**→ laser processing, dynamic compression, high B-field
  - **Near-solid density plasmas**→ WDM, HDM, rel. laser-matter interaction
  - **Quantum states of matter**→ high field QED (future upgrade)





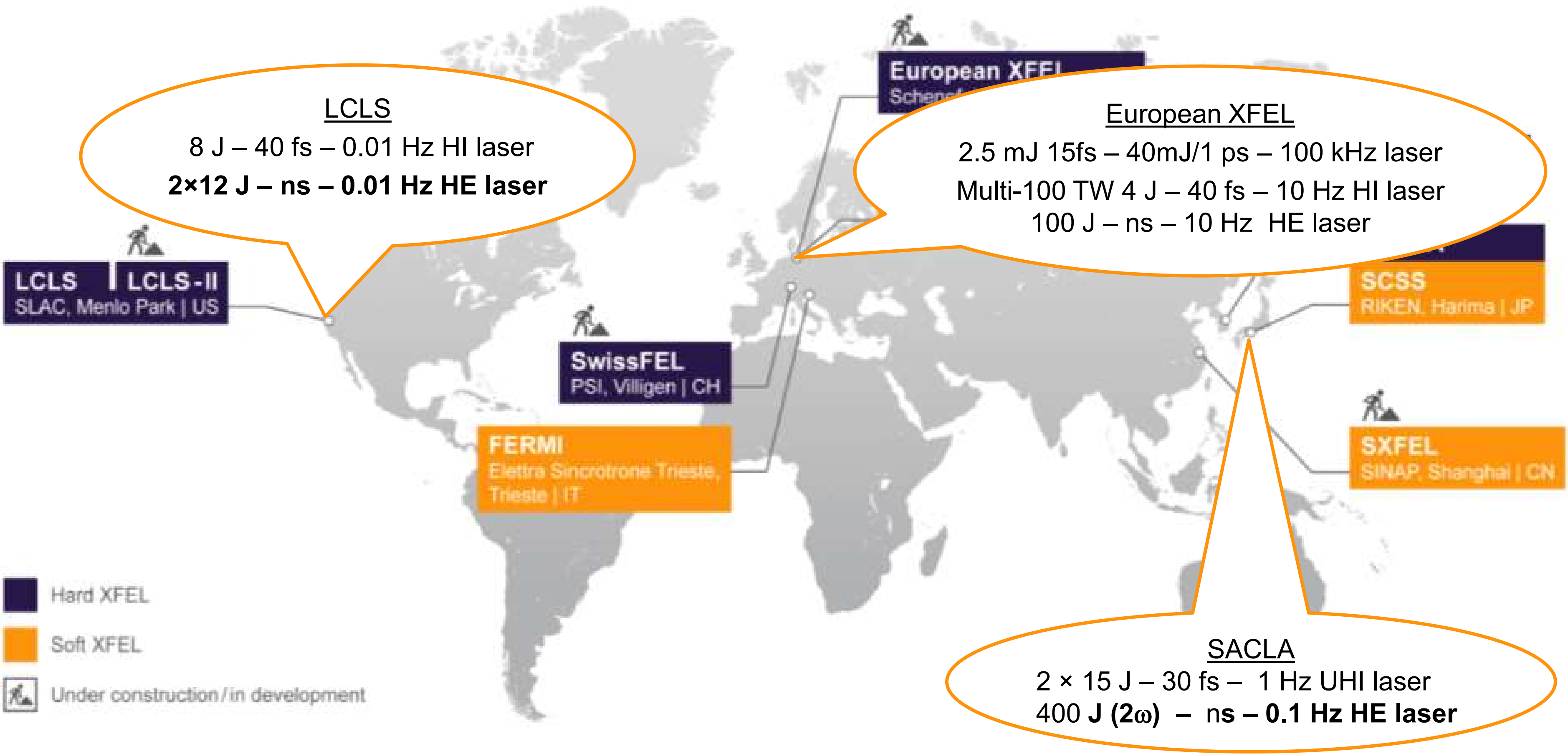


- Combination of high excitation with various X-ray techniques
  - Use of **various pump sources**: optical laser, XFEL, B-fields
  - **Various X-ray probe techniques**: XRD, SAXS, XRTS, hrIXS, XI, XAS….

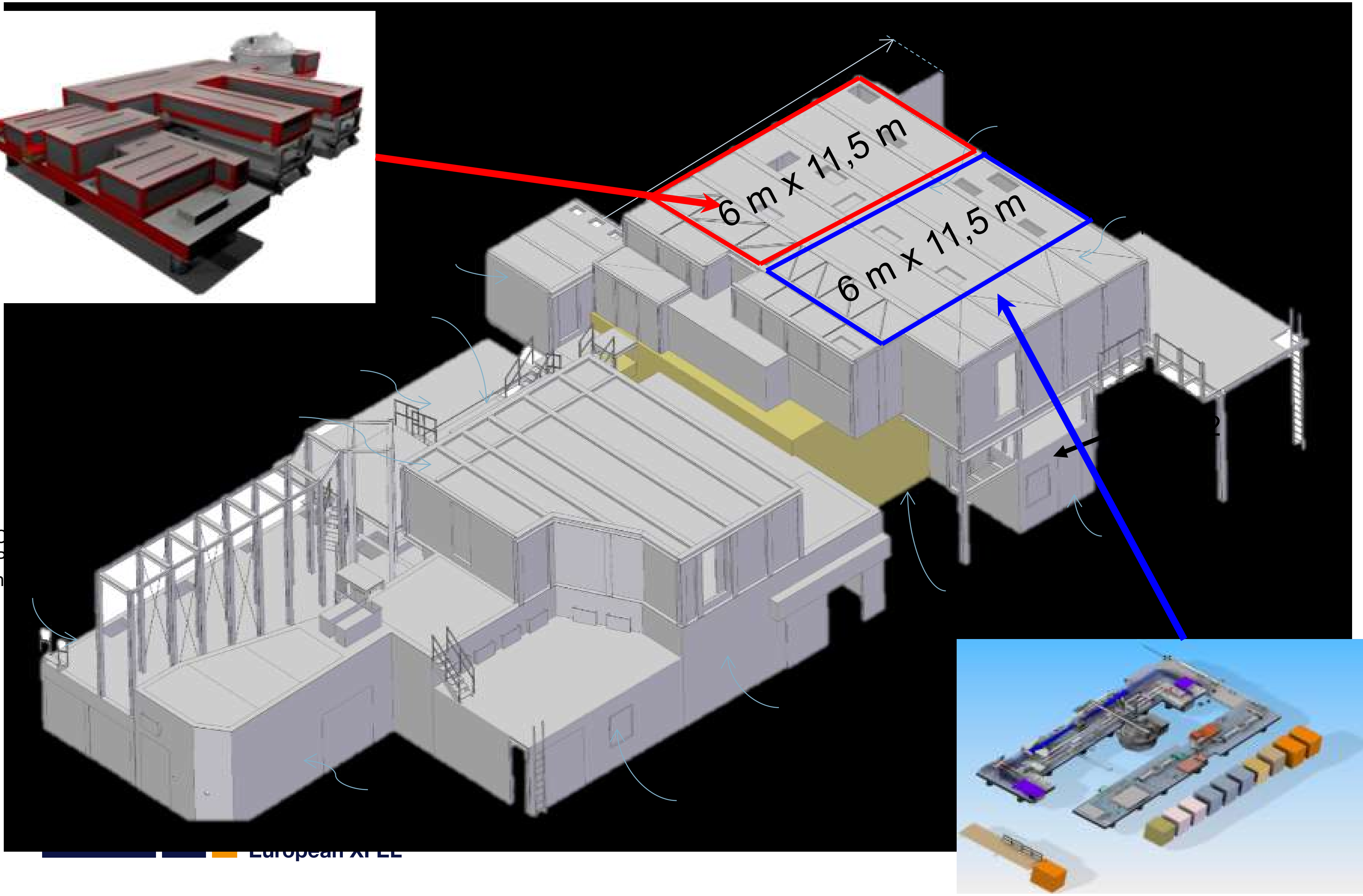
X-ray free-electron lasers worldwide

with big OLs

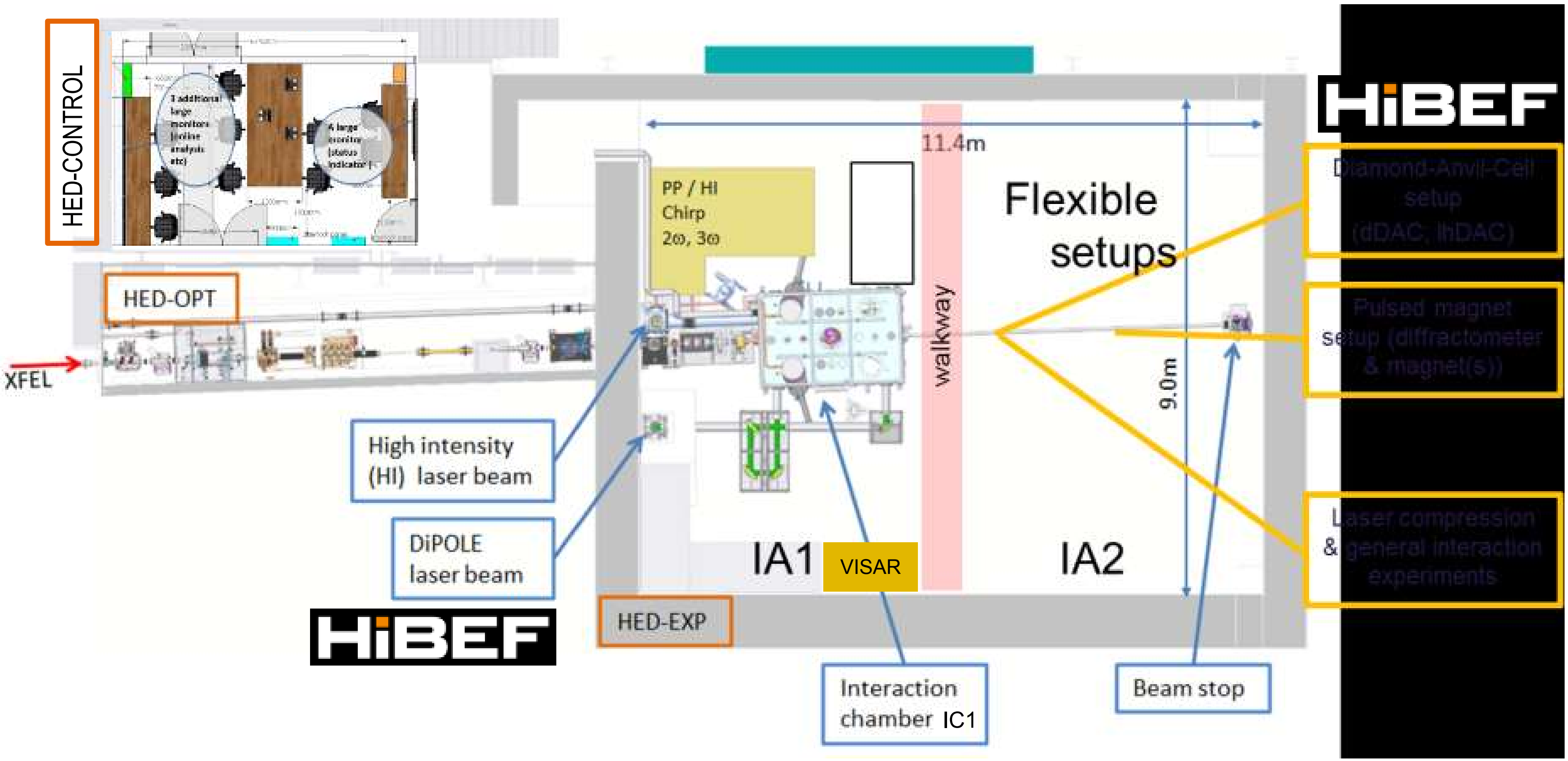
The European XFEL will put Europe in the lead among industrialized nations in a highly competitive scientific and technical environment.



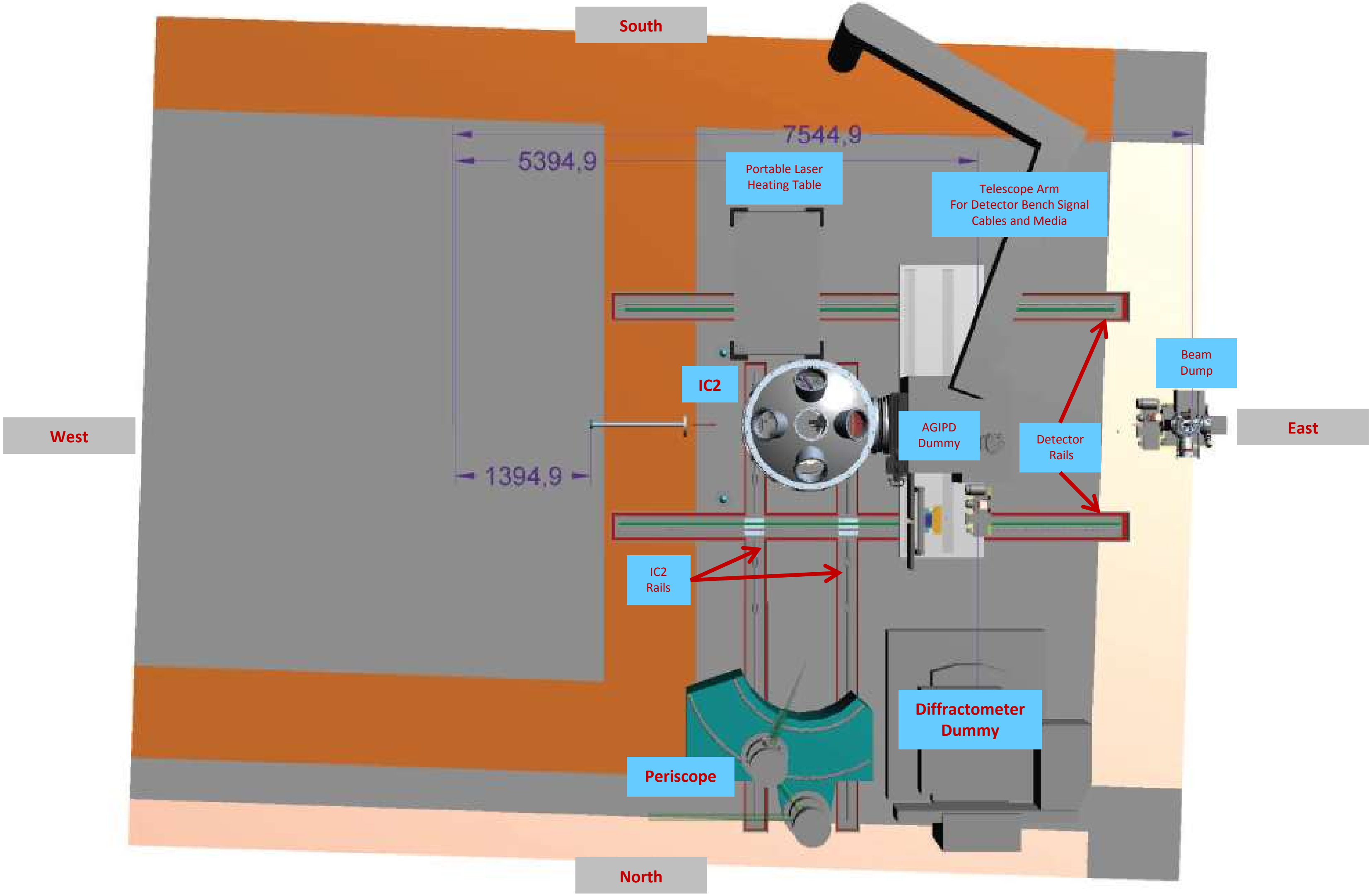
HI / HE laser locactions – on the roof!



HED hutch overview



Interaction Area 2 – a concept was developed



SASE2 milestones I/II

- March 2017 finish all „dirty works“
  - Such as drilling, grove cutting, skimming&painting, dry wall construction
- May 2017 coarse cleaning, hutch handed over to HED team
  - heavy equipment installations can start
  - IC1, posts, granites, laser transport system vessels, install rail system in IA2
- HED and HIBEF teams will start to set up the HED instrument
  - commence with the optics hutch, in parallel commission IC1
  - Optical laser beam transport system installation (space around the IC1 is tight)
- Sept. 2017 infrastructure ready, fully cleaned and painted
  - Data cables, power sockets, cooling water and gases will be available.
- Winter 2017: SASE2 undulators may be tested for first X-rays to HED instruments, depending on the overall progress.
- Dec. 2017 control systems (racks, cabling, Karabo) working, infrastucture fully ready
  - Optics hutch ready to take beam
  - Installation of delicate optical mirrors in experimental area

SASE2 milestones II/II

- Early 2018 Commission the tunnel and optics hutch devices with X-rays
  - up to the beam stop between optics and experiments hutch
  - HED tunnel devices: CRLs, monochromator, split-and-delay line
  - HED optics hutch: slits, attenuators, CRLs, spectrometer, monitors
- Spring 2018 mechanical setups around the IC1 commissioning in full swing
  - Slits, differential pumping stages from IC1, laser beam transport
  - step-by-step commissioning with x-rays, starting from the optics hutch up to beam stop
  - rooms will be interlocked frequently and access is limited
- Delivery of multi-100-TW class laser and DiPOLE laser to HED laser room
  - Unpacking, setup and full-scale commissioning will take a minimum of 6-9 months.
- Summer 2018: start of early user operation
  - Experiments in IC1, x-ray only (plus split-and-delay unit).
- End-2018: as soon as the pump-probe (PP) laser (up to 2.5 mJ short pulse at 800 nm / up to 40 mJ at 1030 nm @ 1 ps) is available, this laser can be commissioned at HED and thereafter provided for user experiments.
- 2019: Tentatively, we do not expect availability of the large HIBEF laser systems before 2019.
  - HED instrument fully operational spring 2019.

Call for proposals

- Timeline not entirely fixed, best estimate currently:
  - First call for SASE1 instruments (FXE and SPB/SFX)
    - ► published 23 Jan 2017
    - ► Experiments in second half 2017
  - Second call + 6 months
    - ► published June-August 2017
    - ► Experiments in first half 2018
    - ► SASE1 + SASE3 instruments
    - ► SASE2 (HED, MID) depends on performance
  - Third call + 6 months
    - ► Published in Dec 2017 if possible
    - ► For second half of 2018 → all instruments
  - Fourth call most likely with all HIBEF lasers (depending on perfomance)
- XFEL may ask for feedback by SAC for the first intervals for calls

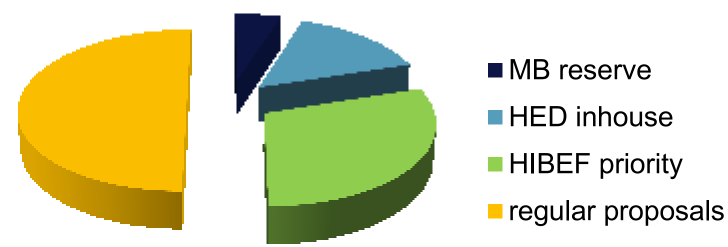
Beamtime allocation and Priority Access for HIBEF

Amount of beamtime at HED (preliminary)

- Second half of 2018: 500+ hrs for HED instrument
  - still commissioning, not fully functioning, etc.
  - depends on how well XFEL and HED operate in 2018.

- 2019: regular 2000 user hours at each instrument
  - shared bunch mode using fast kicker, e.g. 3 instruments

  - 5% (8 shifts) are management reserve
  - 15% (25 shifts) is HED inhouse (commissioning, method development, research)
  - up to 30% (50 shifts) is priority access for HIBEF UC
  - minimum 50% (83 shifts) are available for regular propos



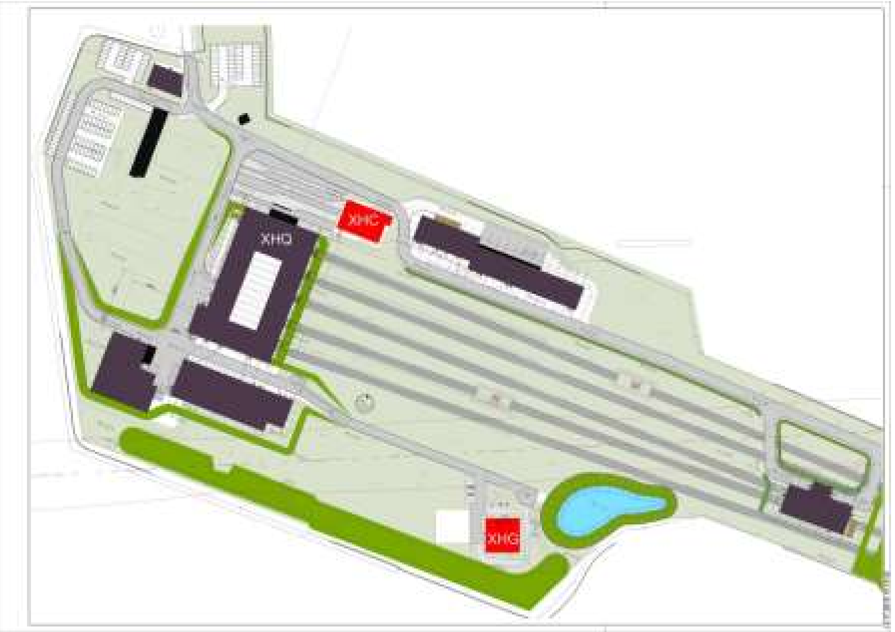
- Proposal Review Panel
  - not yet selected by XFEL

Prepare for your experiment: Funding (regular users)

- ***Current plan***: **up to 6 users in an experiment** can be funded for their participation in an experiment team – IF the scientists are **affiliated to Shareholder countries** of the European XFEL
- This generally includes economy air fare and accommodation – preferably organized through **XFEL.EU Travel Office**
- At the end of the experiment funded users need to submit a reimbursement claim
  - *Travel funding is applicable to regular users only – NOT to user consortia users in the frame of priority access beam time allocation.
  - * But if the same people (IF affiliated XFEL.EU shareholder countries) are allocated beam time in the framework of regular beam time allocation in competition with regular users, funding is applicable... *complex, isn't it?*

European XFEL Canteen and Guesthouse

- More building sites planned for 2017, in particular:
  - **Canteen building**, about 150 dining spaces, east of the entry plaza of the headquarters in the front area of the campus
  - 59-room **guesthouse** will be built on the southern part of the campus
- Both buildings available in **2018**



- Picture courtesy of Blunck + Morgen Architekten / European XFEL

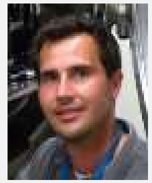
The current HED group at European XFEL

Group Leader / HED Scientists / Laser Group


Ulf Zastrau


Motoaki Nakatsutsumi


Karen Appel


Sebastian Göde


Zuzana Konôpková


Mikako Makita


Thomas Preston (7/‘17)

N.N.

N.N.


Gerd Priebe

Engineers / Technicians/Mech’s


Ian Thorpe

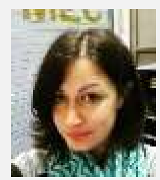

Andreas Schmidt

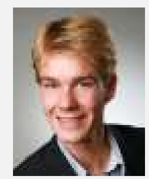

Konstantin Sukharnikov


Thomas Feldmann


Eike Martens

Externally funded PostDocs / Ph.D.s / Guest Scientists


Emma McBride
Volkswagen Foundation


Philipp Sperling
Humboldt Foundation


Wolfgang Morgenroth
BMBF

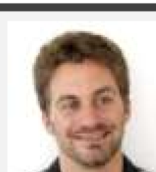

Nicole Biedermann
DFG


Bolun Chen
CAEP

Coordinator / HIBEF UC staff at European XFEL

HIBEF


Carsten Bähtz


Alexander Pelka

N.N.

N.N.


Toma Toncian (HIBEF lasers)

Monika Toncian

HIBEF at HZDR:
Klaus Knöfel
Wolfgang Seidel

Parameters for early user experiments

X-ray beam transport and properties at
SASE2 & HED

Karen Appel
High Energy-Density (HED) science group
Scientist

Schenefeld, 24 Jan 2017

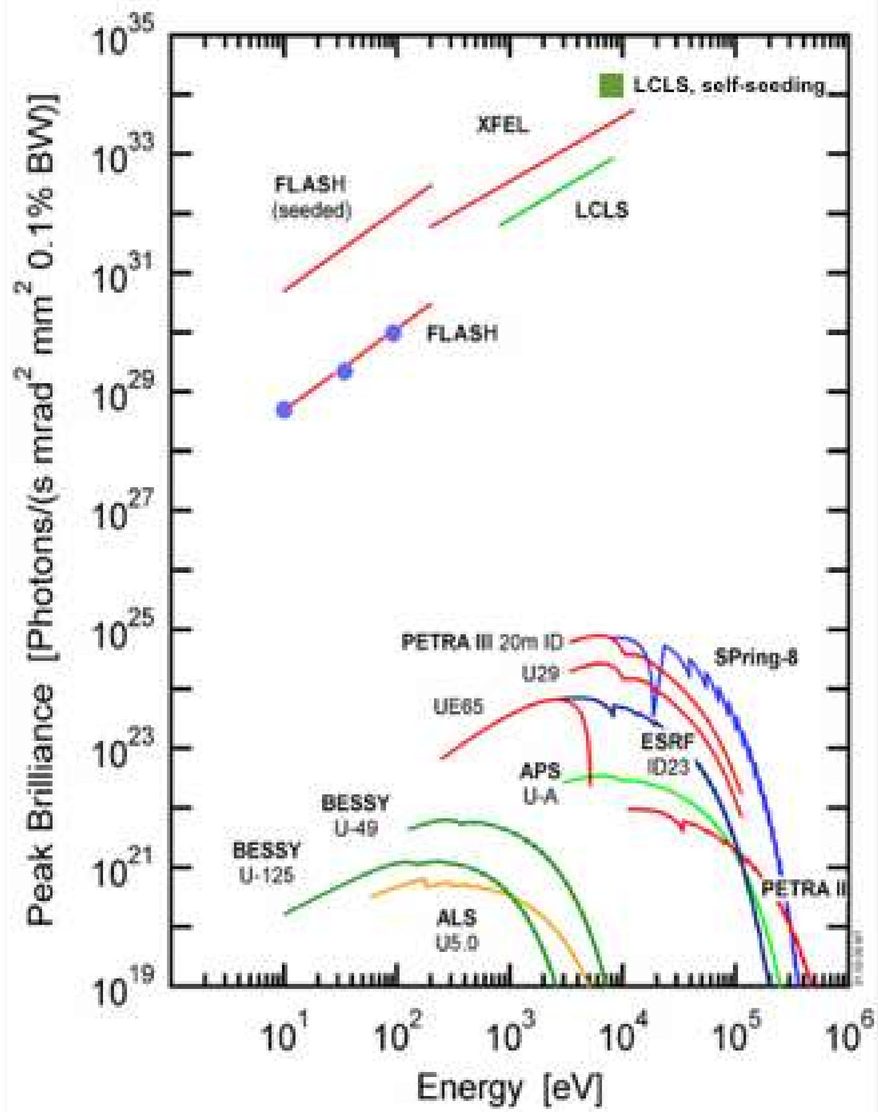
European XFEL beam properties

1. X-ray photon energies
   - Excite dense matter
     - ▶ linear, weak interaction

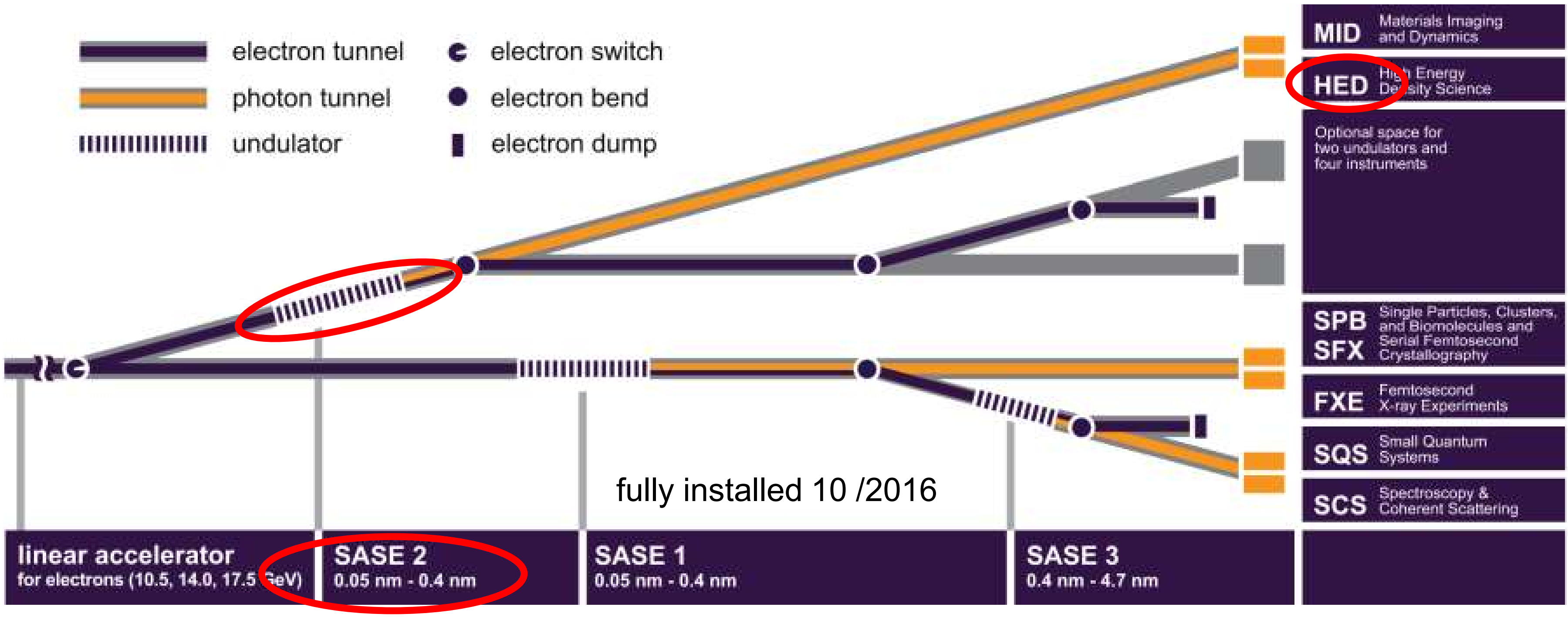
2. High peak brilliance
   - Intensity/number of photons
     - ▶ single-shot capability
   - Ultrashort pulses
     - ▶ equilibration

3. Coherent beam

Add-on: Repetition rate



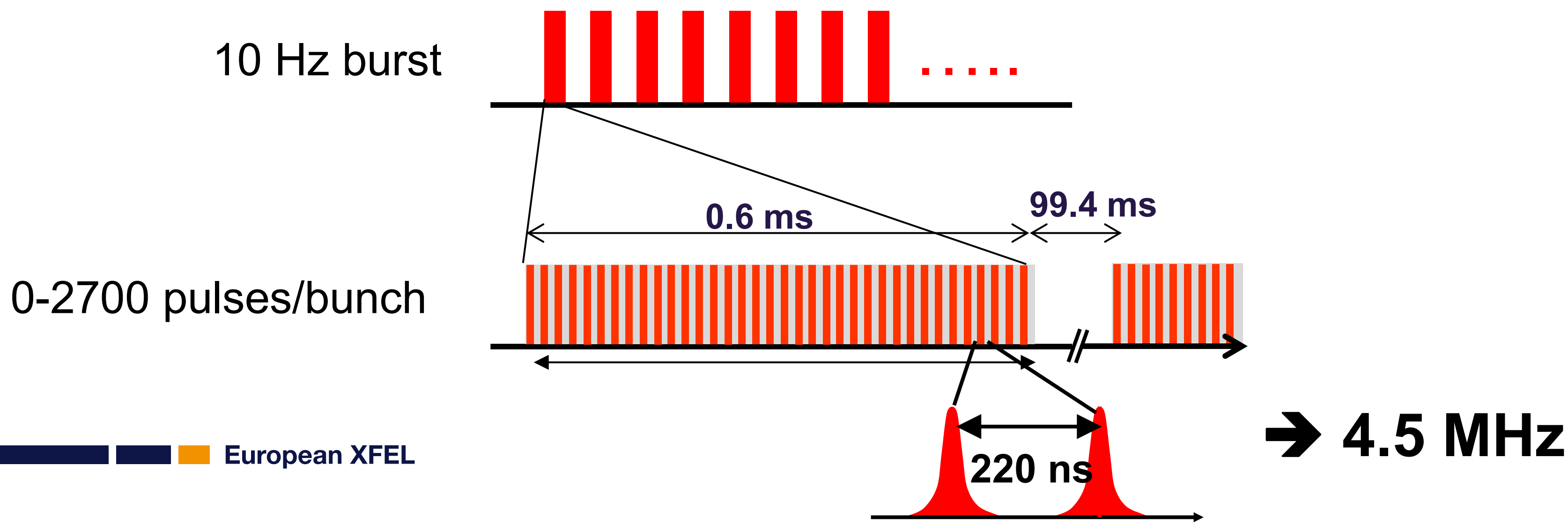
European XFEL: HED at SASE2



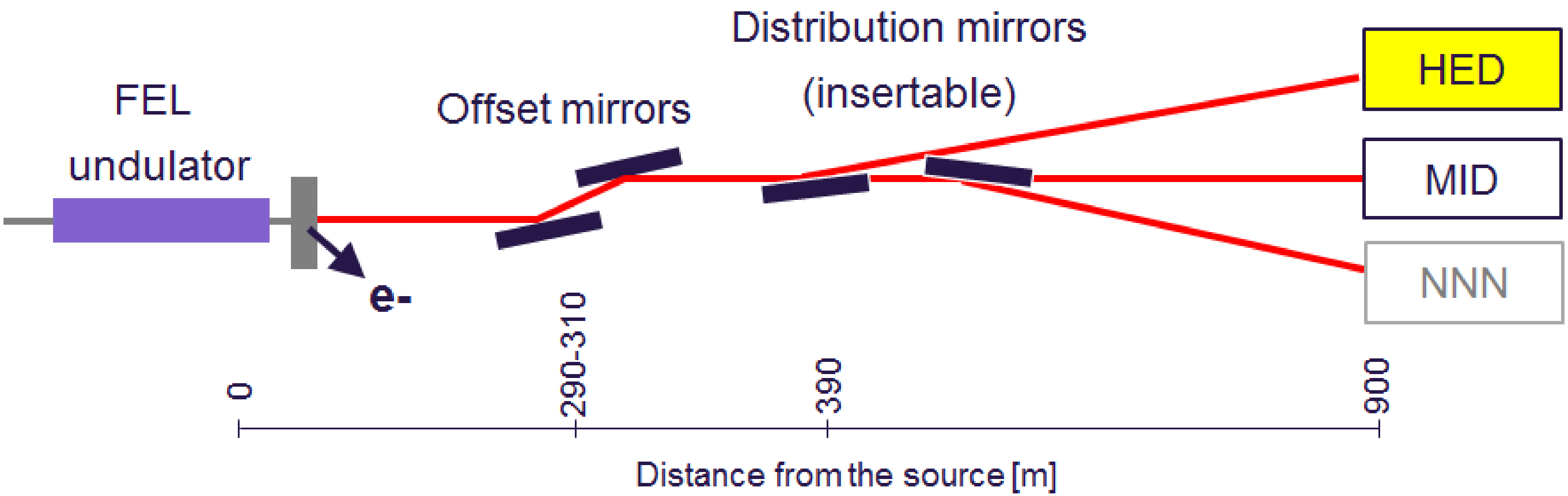
- Cool down of accelerator modules to 2 K
- First e-beam to bunch compressor 1 (last week)
- Commissioning of X-ray from April
- First experiments at SASE1: June 2017

XFEL properties at the HED instrument

Fully tunable between	**3 – 25 keV (3 – 5 keV with limited performance)**
Pulse duration	2 – 100 fs
Photons per pulse	~10^{11} (25 keV), ~10^{12} (5 keV)
Spot size on sample	sub-µm (HIBEF), few µm, 20 – 30 µm, 200 – 300 µm, few mm
Seeded beam	available in early phase
Repetition rate	shot on demand, 10 Hz – 27000 pulses/s



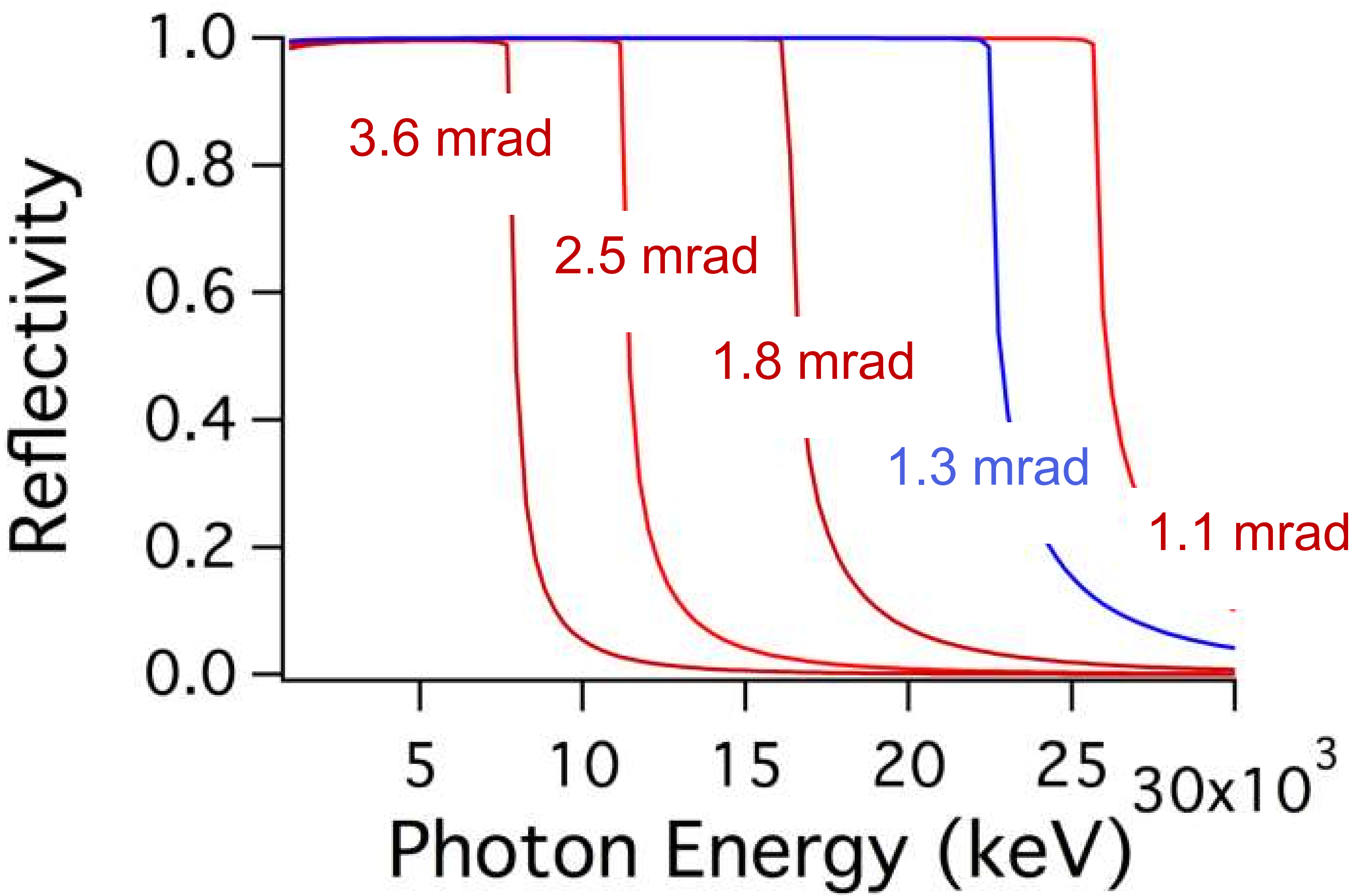
X-ray beam transport: Mirrors at HED



Offset mirrors: 1.1 – 3.6 mrad, B_4C coating, 25 keV cut off
Distribution mirror: 1.3 mrad; B_4C (21.4 keV); Si (23.8 keV); Pt (60.7 keV)

All mirrors have a useable length > 80 cm

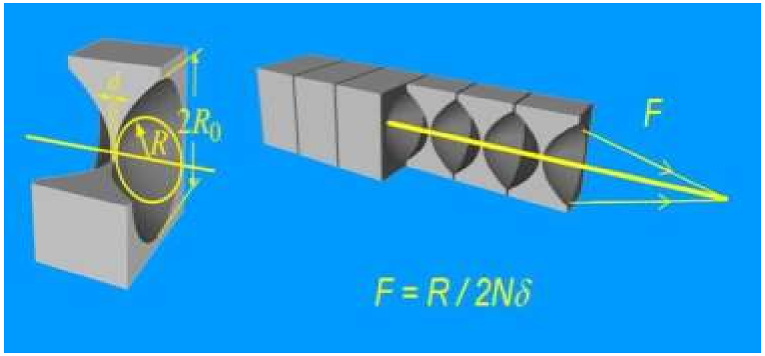
Reflectivity B_4C

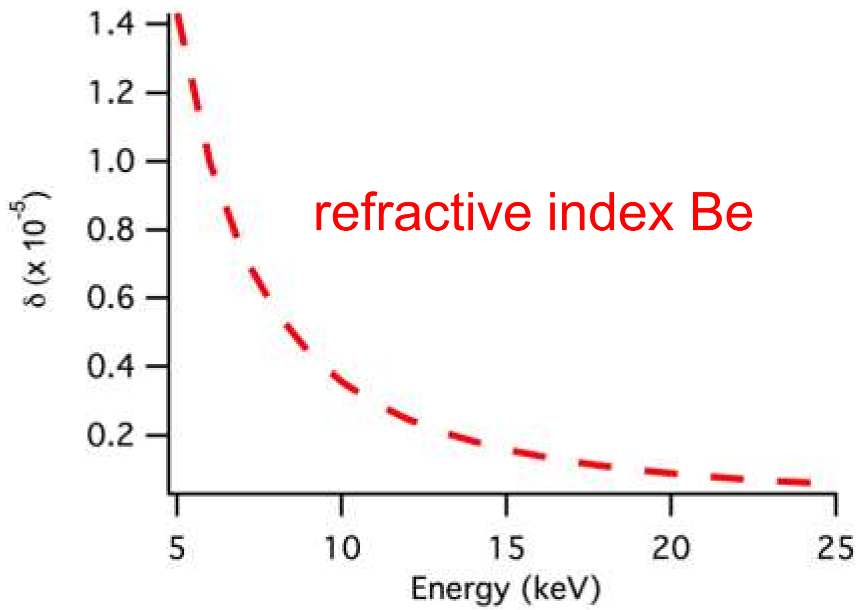


Offset mirrors
Distribution mirror

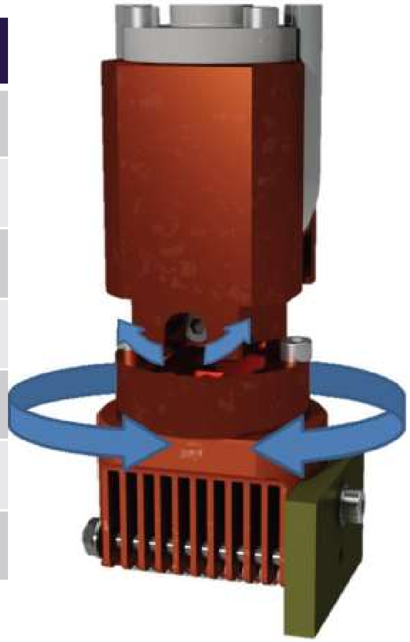
Focussing with Be compound refractive lenses

- On-axis scheme
- Energy range 5 - 25 keV
- Chromatic
- Optimized for transmission

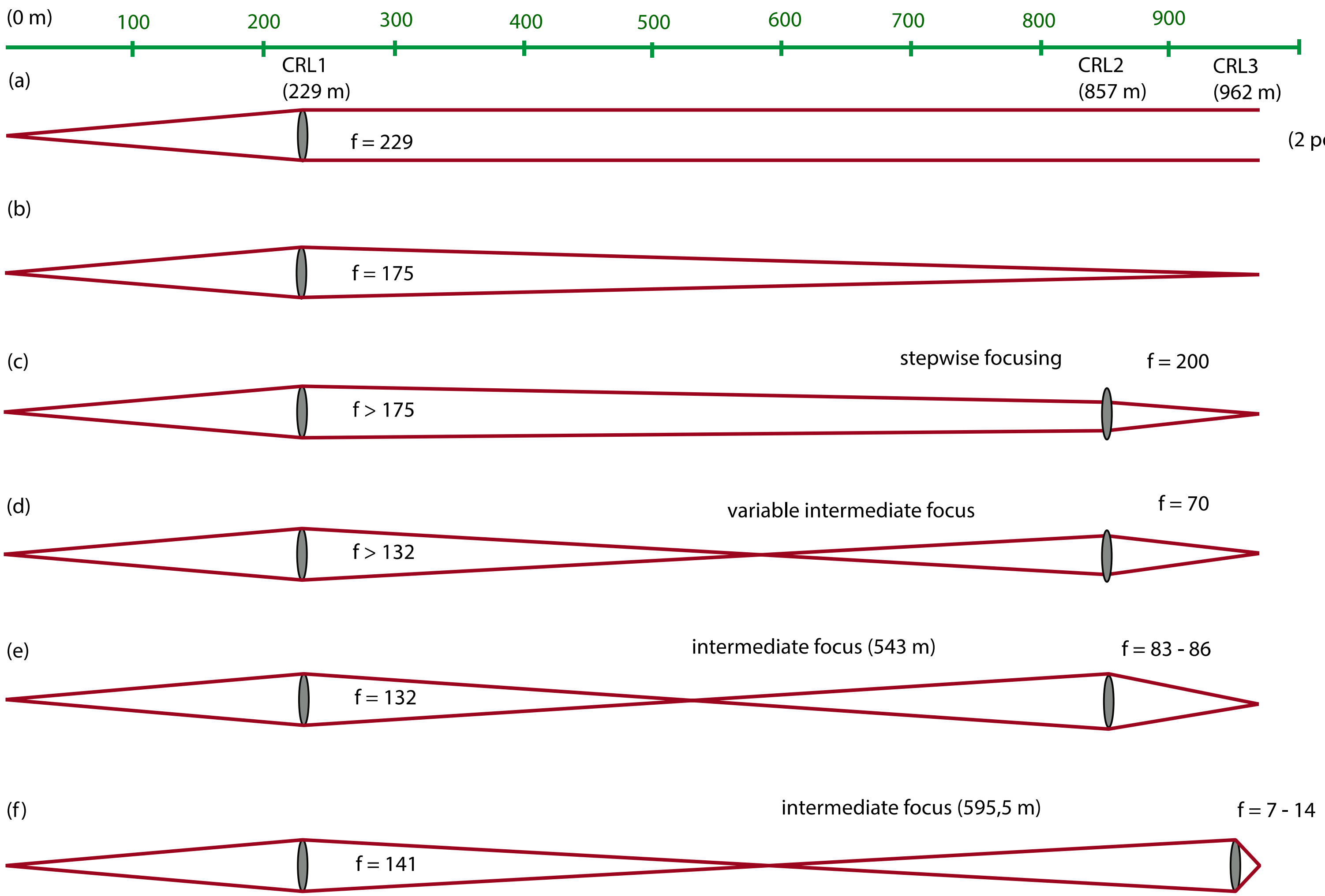




available radii (mm)
5,8
5
4
3,5
2
1
0,5



X-ray beam transport: Focusing schemes



5 – 25 keV

970 – 290 µm

260 – 160 µm

low flux

> 50µm

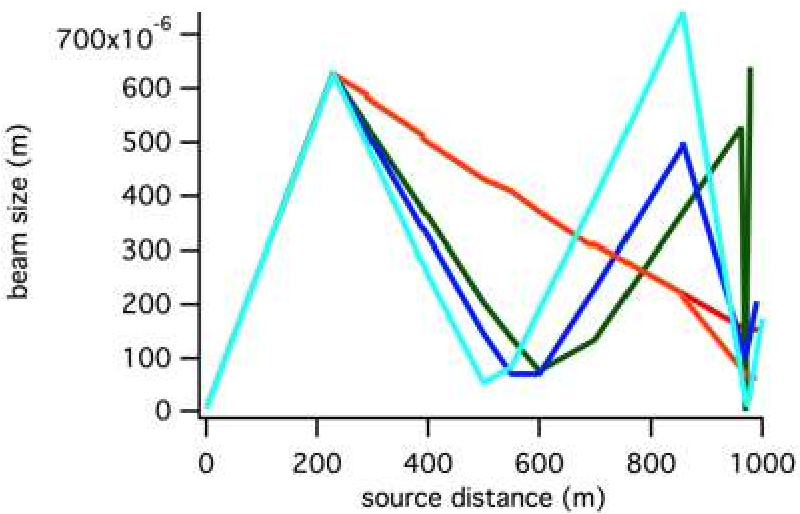
high flux

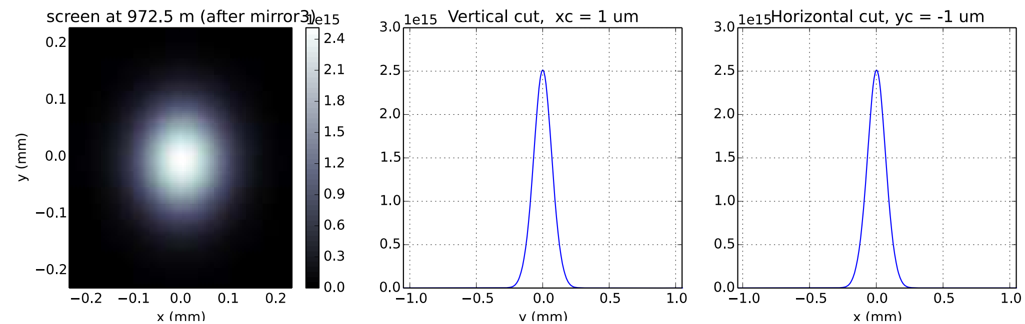
40 – 24 µm

2.6 – 1.1 µm

CRL configurations

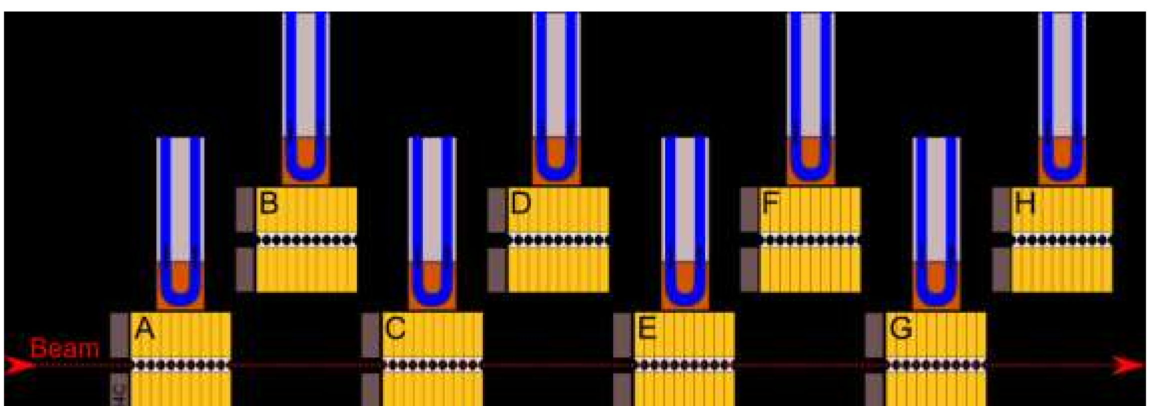
Wavefront simulations for the different lens geometries (E = 5 – 25 keV)





Example: 5 keV, 5 relevant focussing scenarios

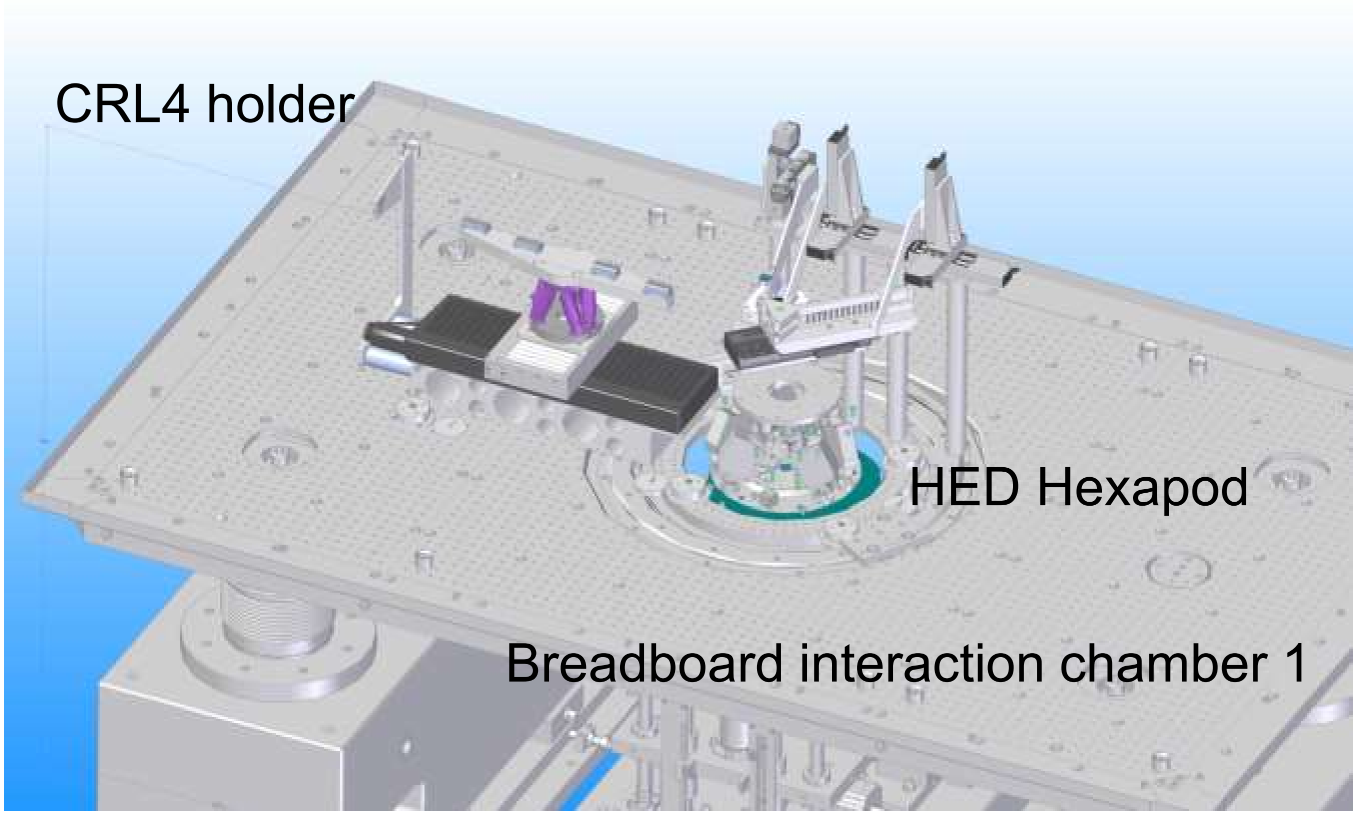
Simulations done in collaboration with Liubov Samoylova, WP73 and Thomas Roth, WP83



Organisation of CRL stacks: 10 lenses maximum per holder

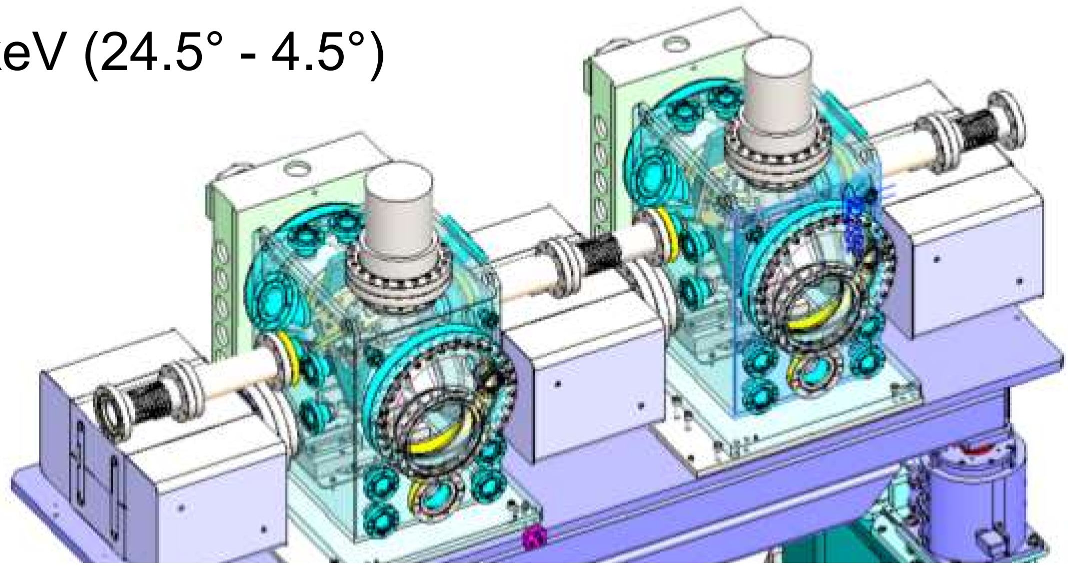
Optimisation parameters:
Number of lenses
Coverage of energy range
Available beam sizes
Transmittance

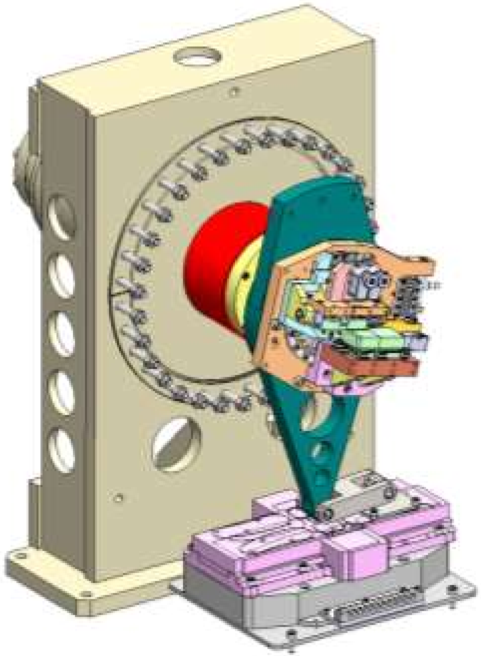
CRL4 in chamber – work in progress

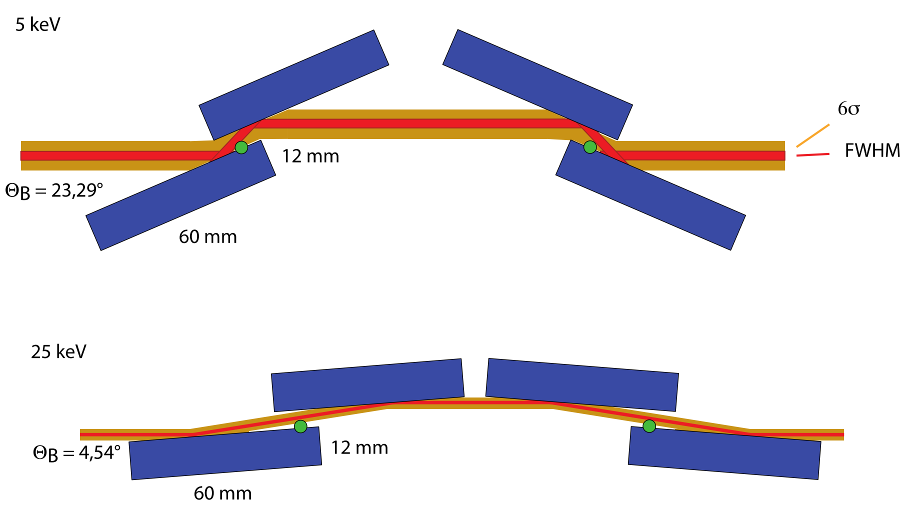


Generic channel cut monochromator

- Energy range: 5 - 25 keV (24.5° - 4.5°)
- Cryogenically cooled
- Beam size: 6σ

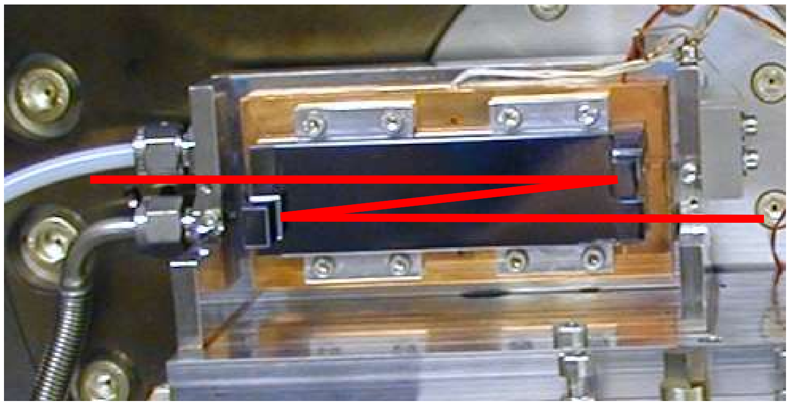


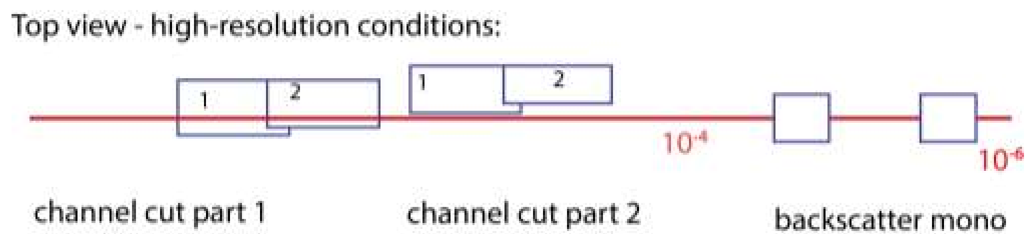


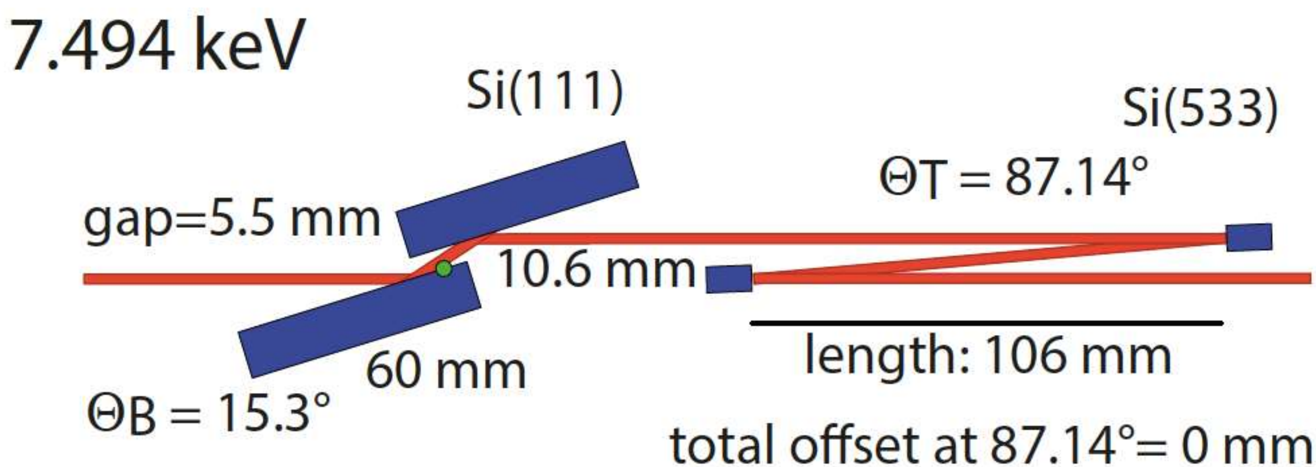


High-resolution backscatter monochromator

Facilitates high-resolution IXS (+ analyser crystals, 40 meV)

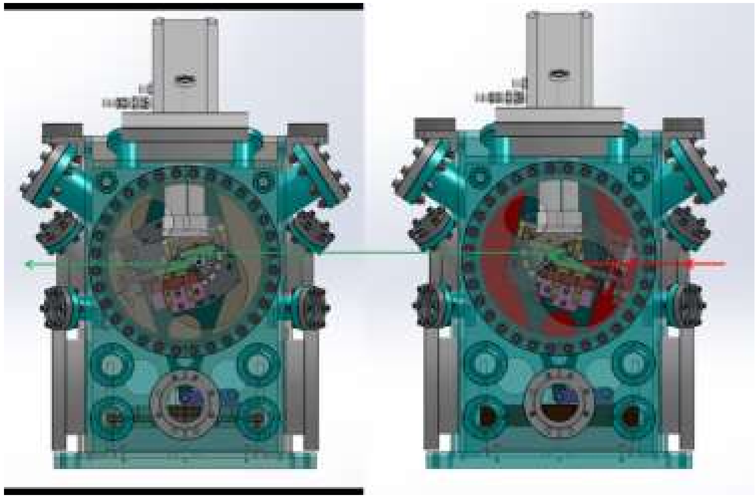






⊗E/E Si$_{533}$ 5x10^{-6}

X-ray bandwidth at HED



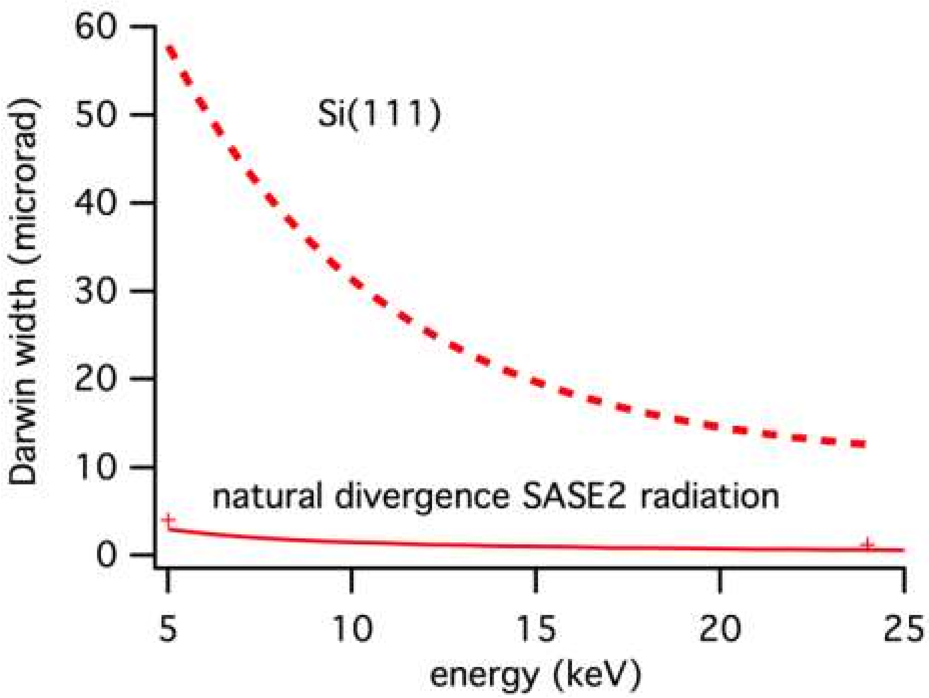
H. Sinn et al.,
TDR X-Ray Optics and Beam Transport
XFEL TR-2012-006, 73ff.

Five different bandwidth levels:

- $\Delta E/E = 10^{-2}$: wide
- $\Delta E/E = 10^{-3}$: SASE
- $\Delta E/E = 10^{-4}$: Si_{111} monochromator
- $\Delta E/E = 10^{-4} - 10^{-5}$: seeded
- $\Delta E/E = 10^{-6}$: Si_{533}

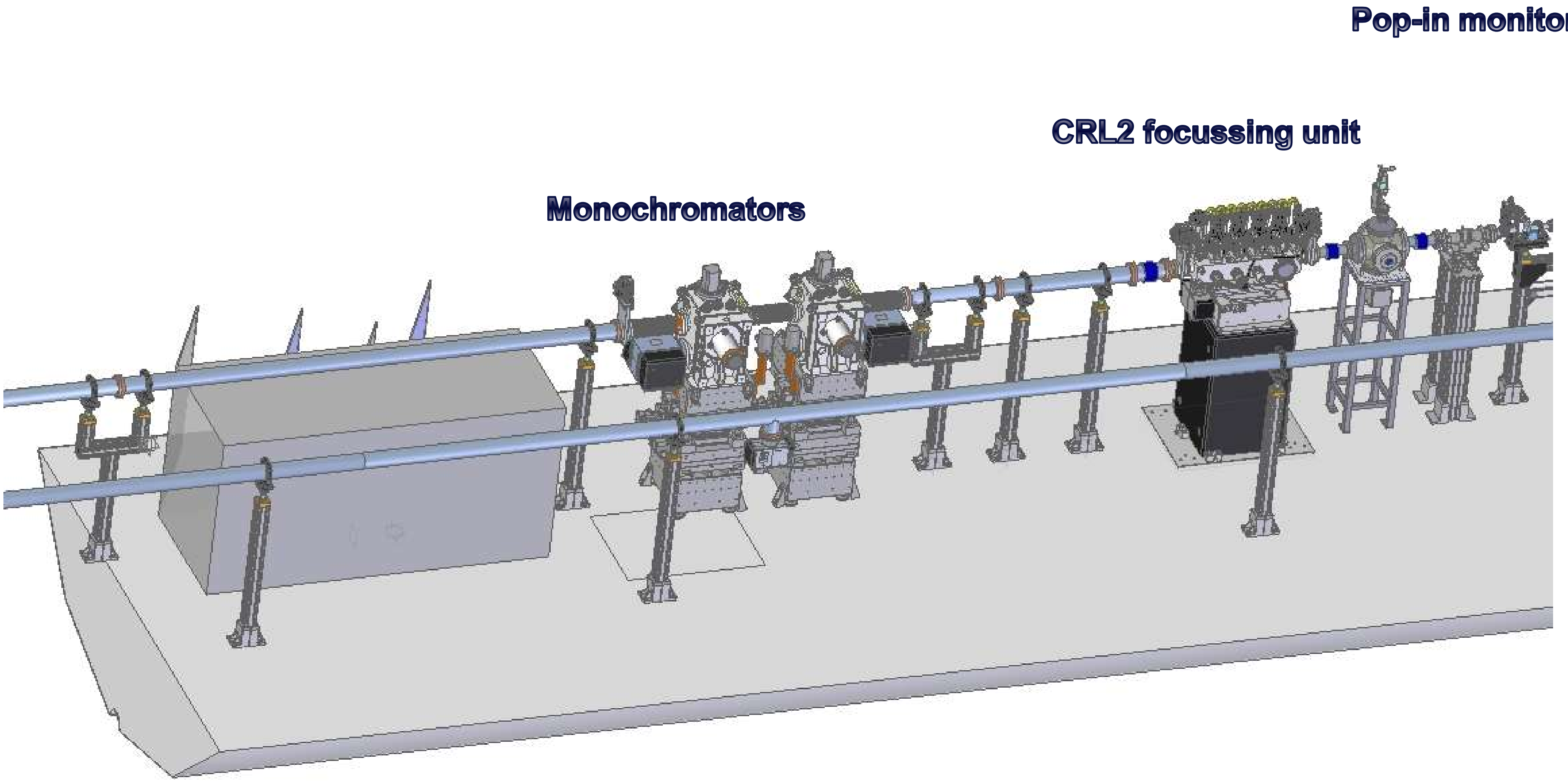
➔ 7.5 keV

Divergence of SASE2 radiation

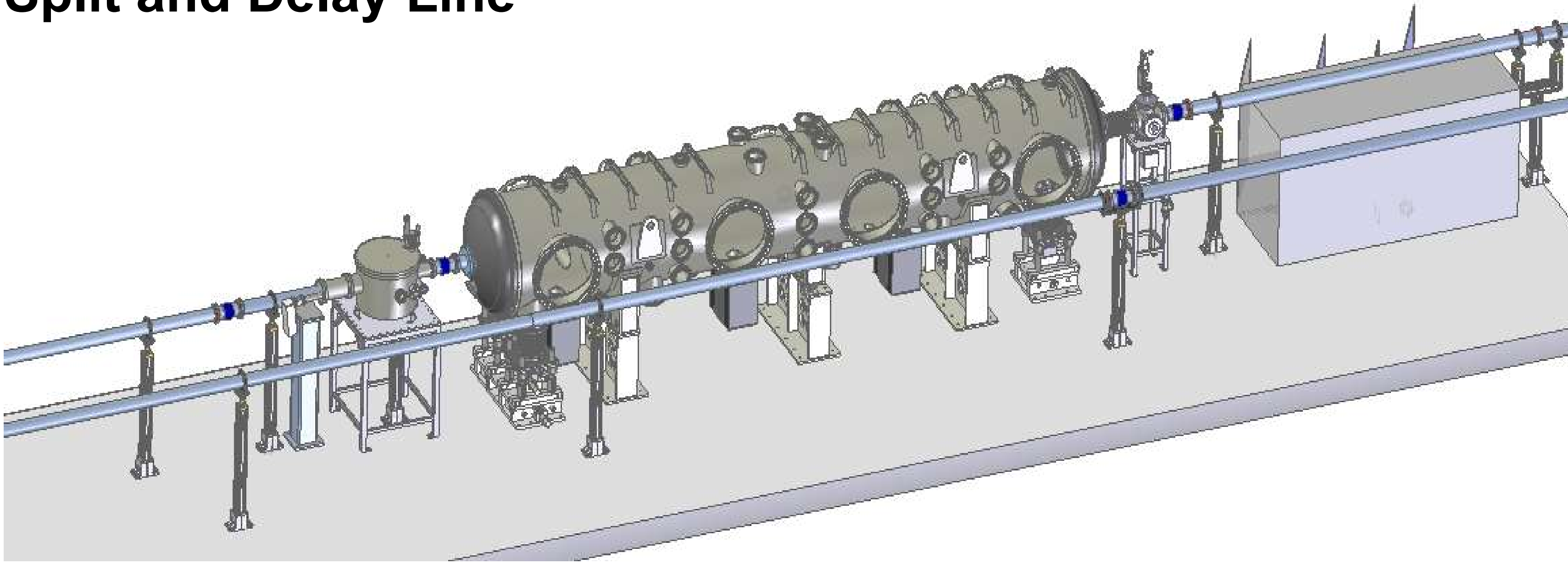


The CRL1 stack can increase the X-ray beam divergence to maximum values between 4 μrad at 5 keV and 1.2 μrad at 24 keV, when used in the intermediate-focus configuration
Divergence will be larger for CRL3 and CRL4 configurations (downstream of monochromator)

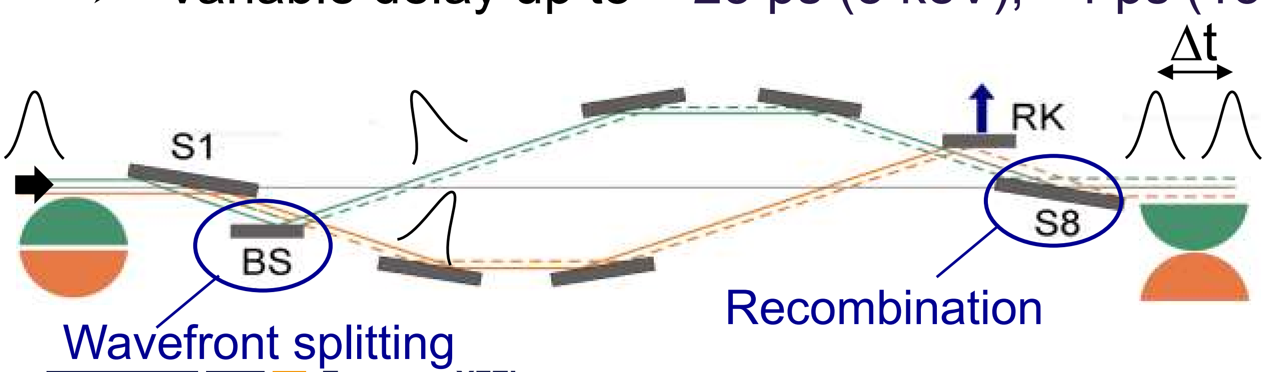
Optical elements: monochromators and CRL2



Split and Delay Line



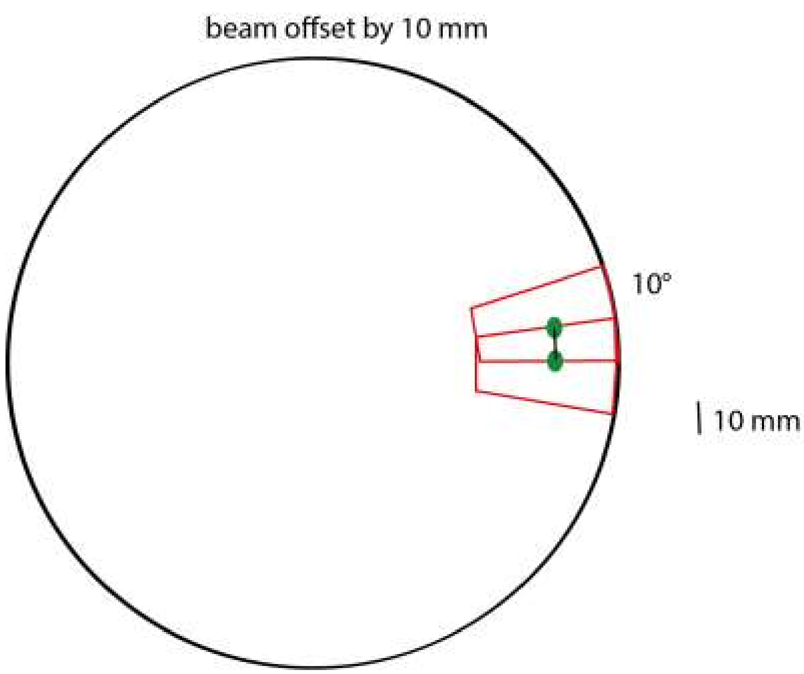
- Multi-layer mirrors
- Variable delay up to ~23 ps (5 keV), ~4 ps (15 keV), 2 ps (20 keV)

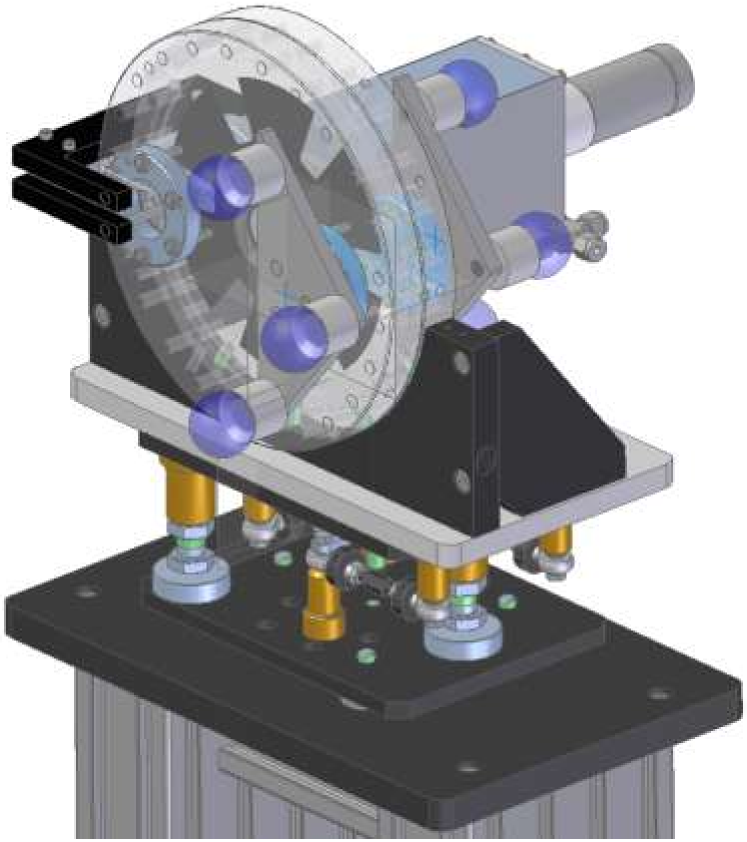


S. Roling, H. Zacharias, et al.,
SPIE conf 8504, 850407 (2012)
BMBF project 05K10PM2
University of Münster

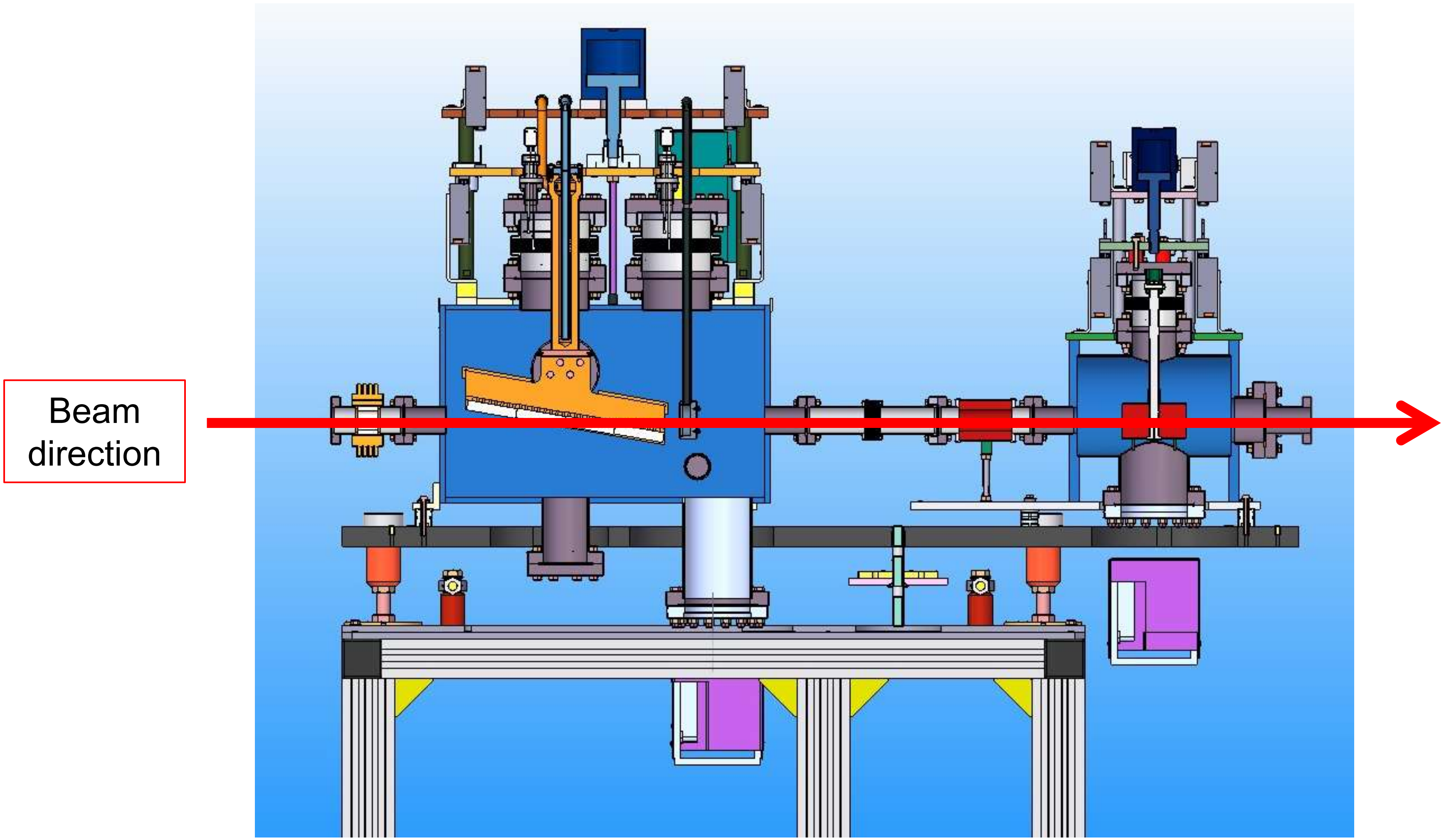
Pulse-picker

- 10 Hz or 1 Hz operation
- Rotating B_4C, Ta sandwich disk

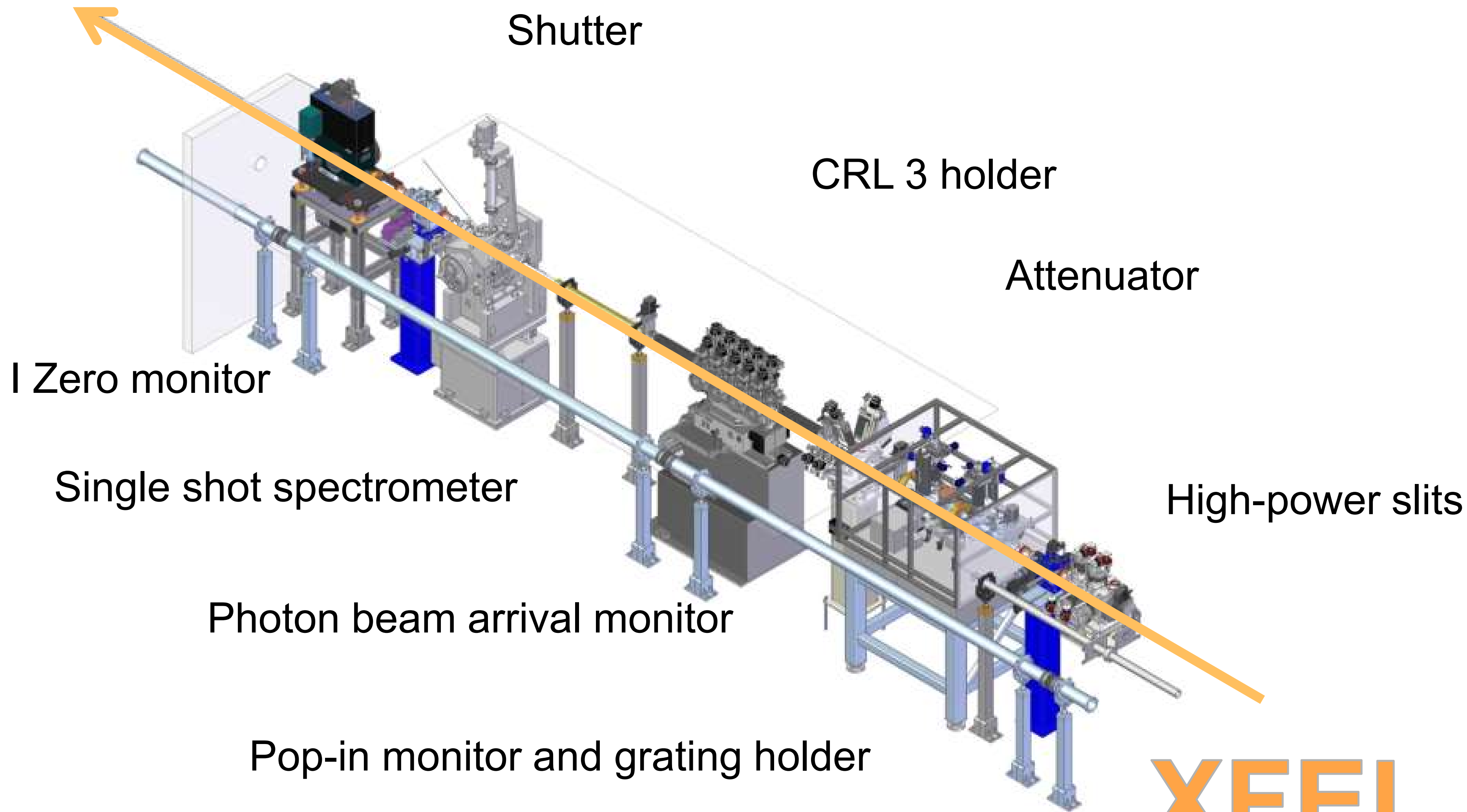




Frontend Type1 at the end of the tunnel



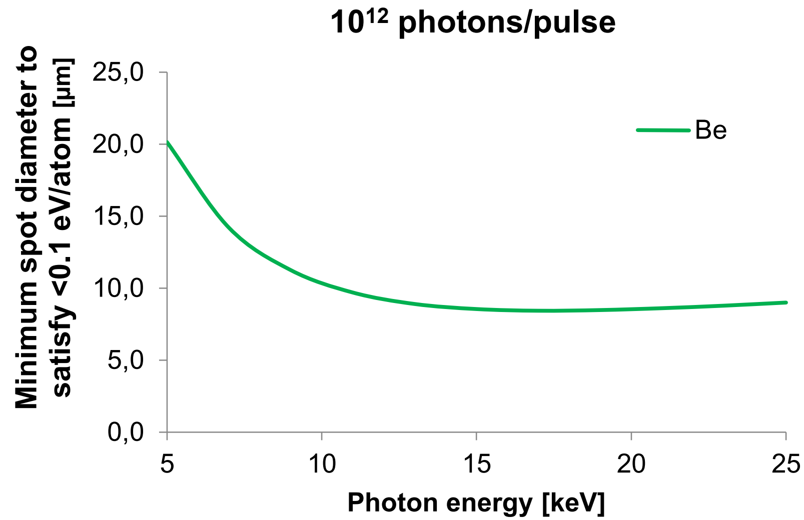
X-ray transport optics hutch



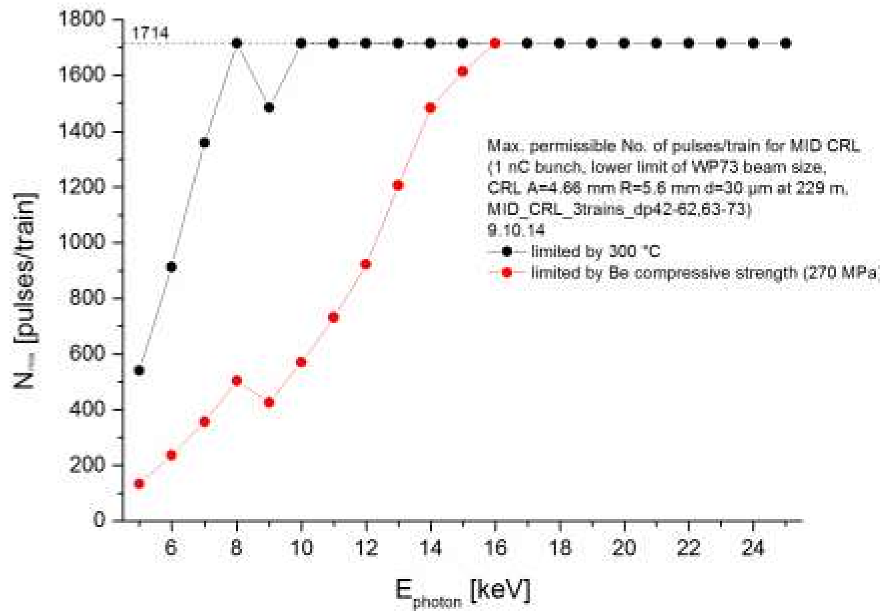
XFEL

Damage issues for instrument components: Be

- Single shot ablation

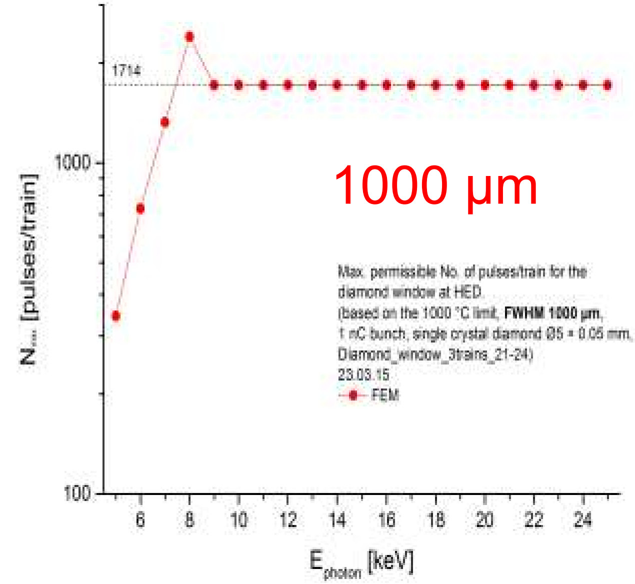


- Heating
- Stress

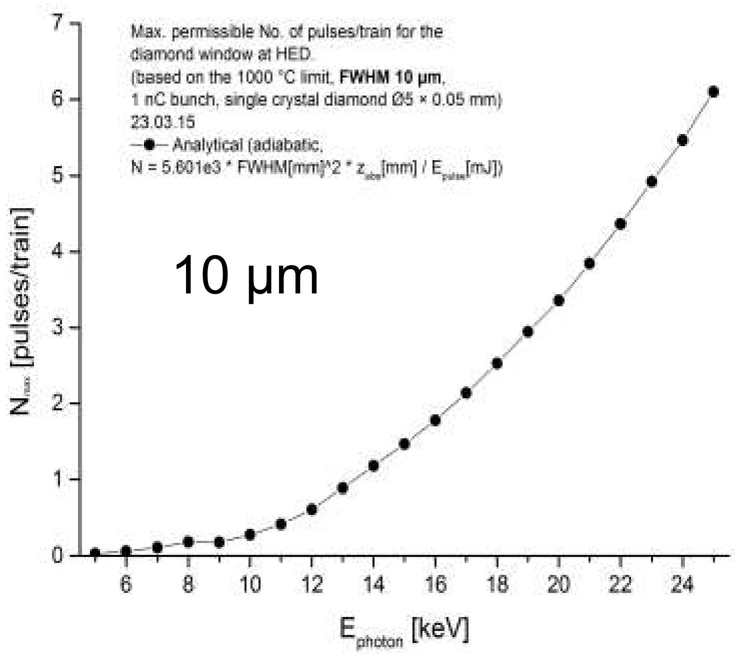


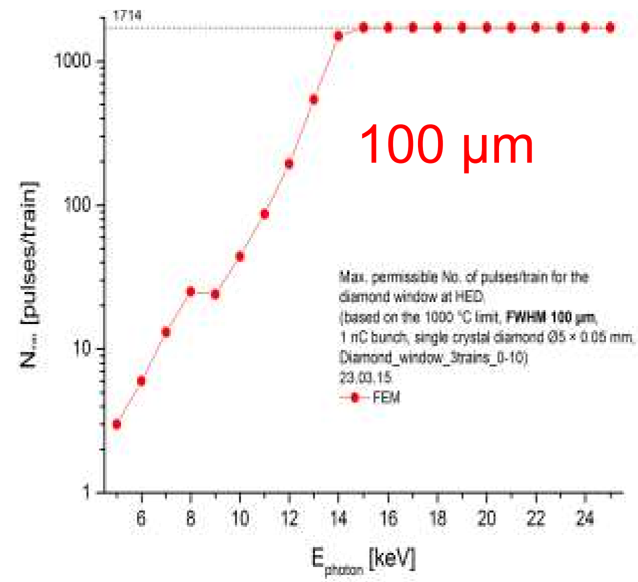
Diamond: window & grating

Limited by heating, FEM

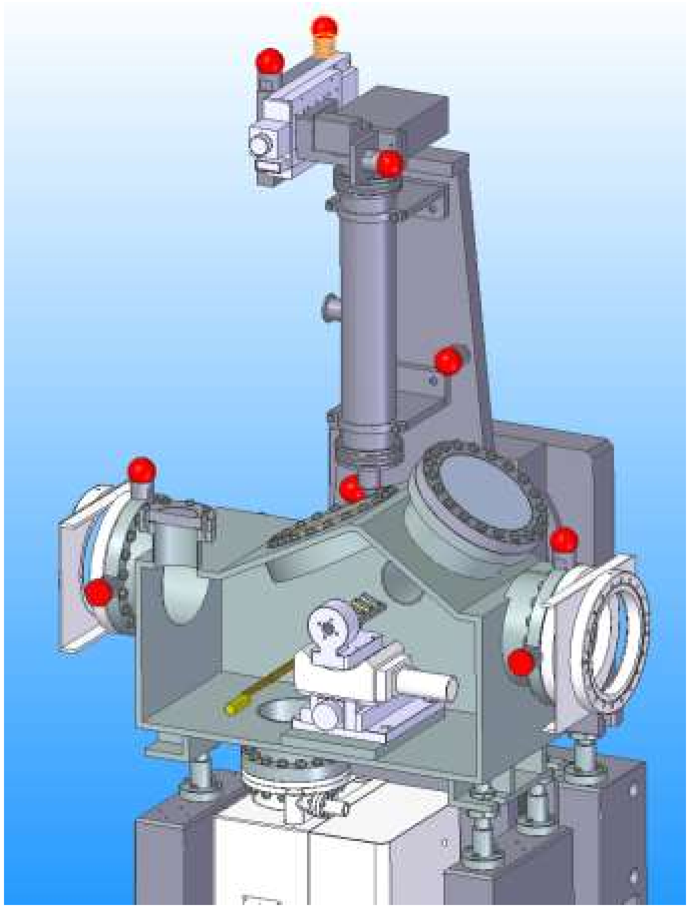


Limitation by heating, adiabatic





X-ray beam diagnostic: Spectrum monitor

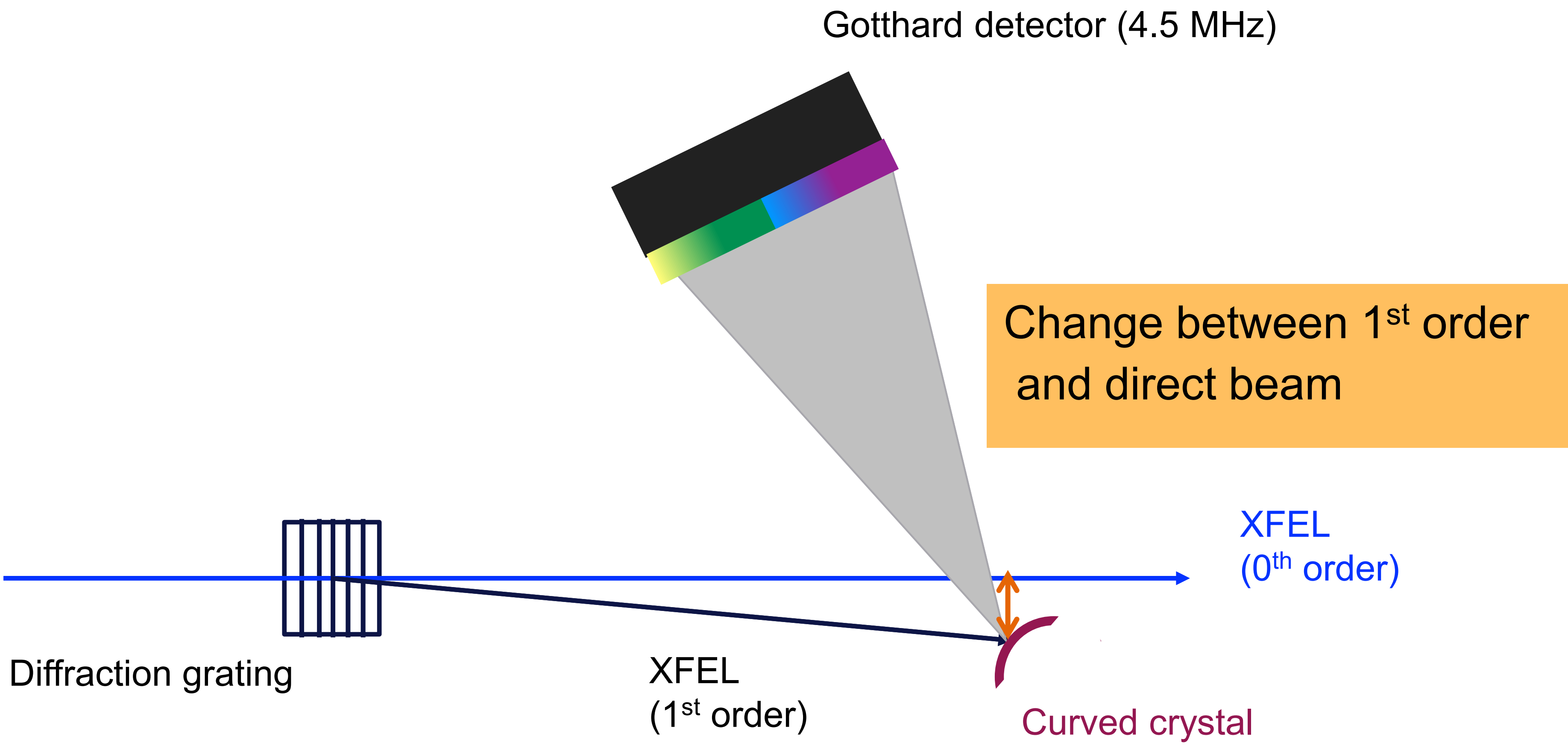


Specifications

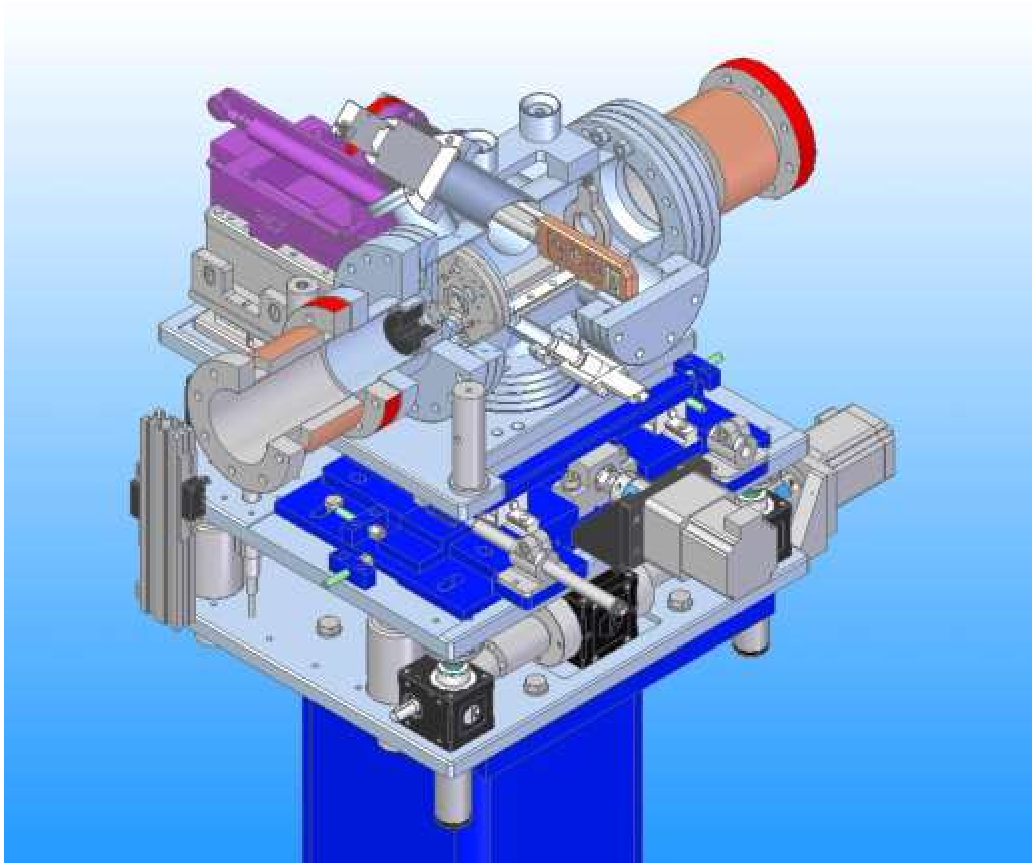
- Crystals: 4 channels, 10 μm in thickness
- X-ray photon energy: 3~25 keV (high spectral resolution up to ~15 keV)
- Energy resolution: ~$5*10^{-5}$ (up to ~15 keV)
- Spectral coverage: larger than 10^{-3} (up to ~12 keV, larger than 10^{-2} collimated with CRL1)
- Detector: Gotthard detector (1D) and optical CCD (2D), (distance to crystals: 850 mm)
- Detector rotation 60° (30° -90°)

The X-ray single-shot spectrometer (CAEP contribution)

Single shot spectrometer

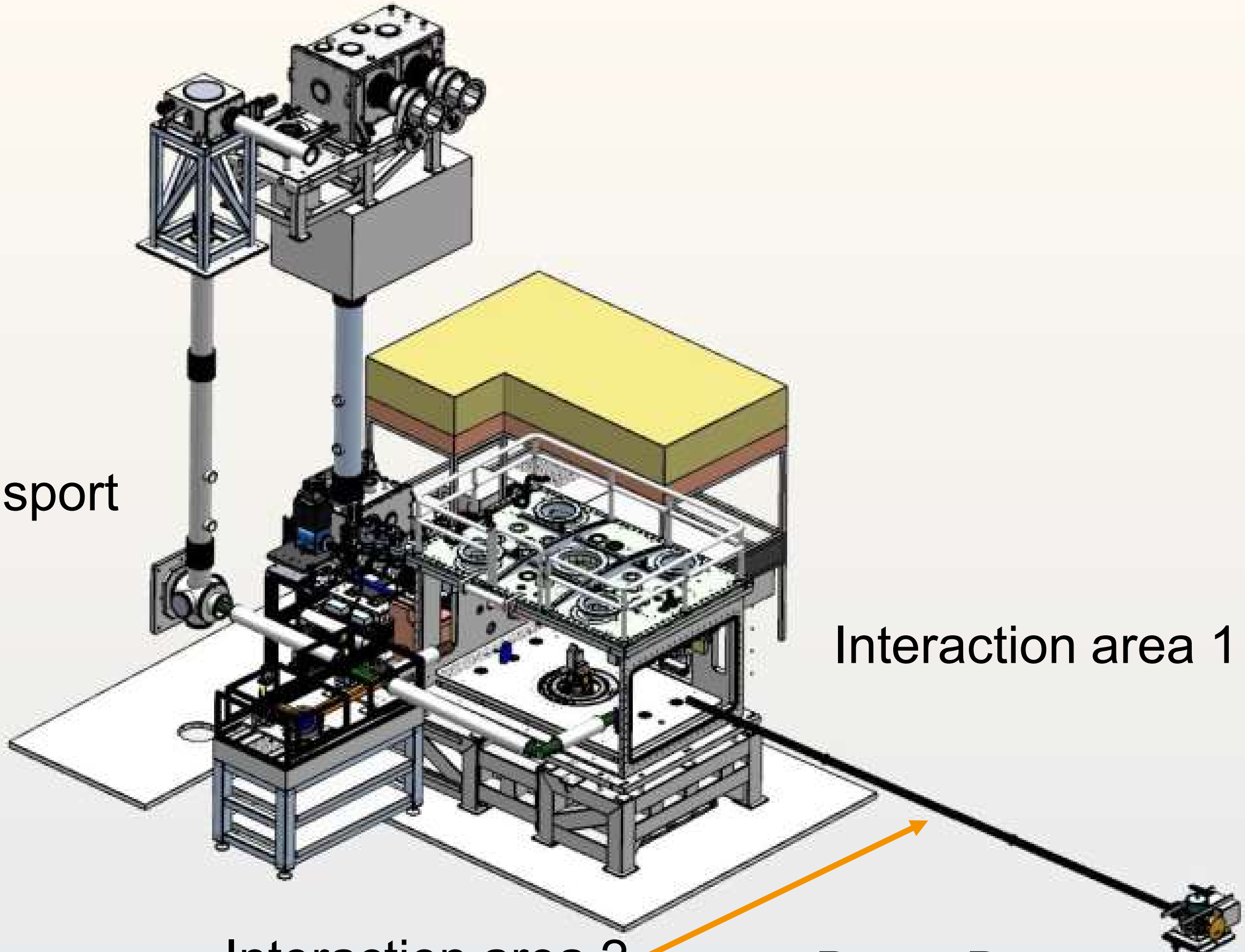


I0 monitor optics hutch

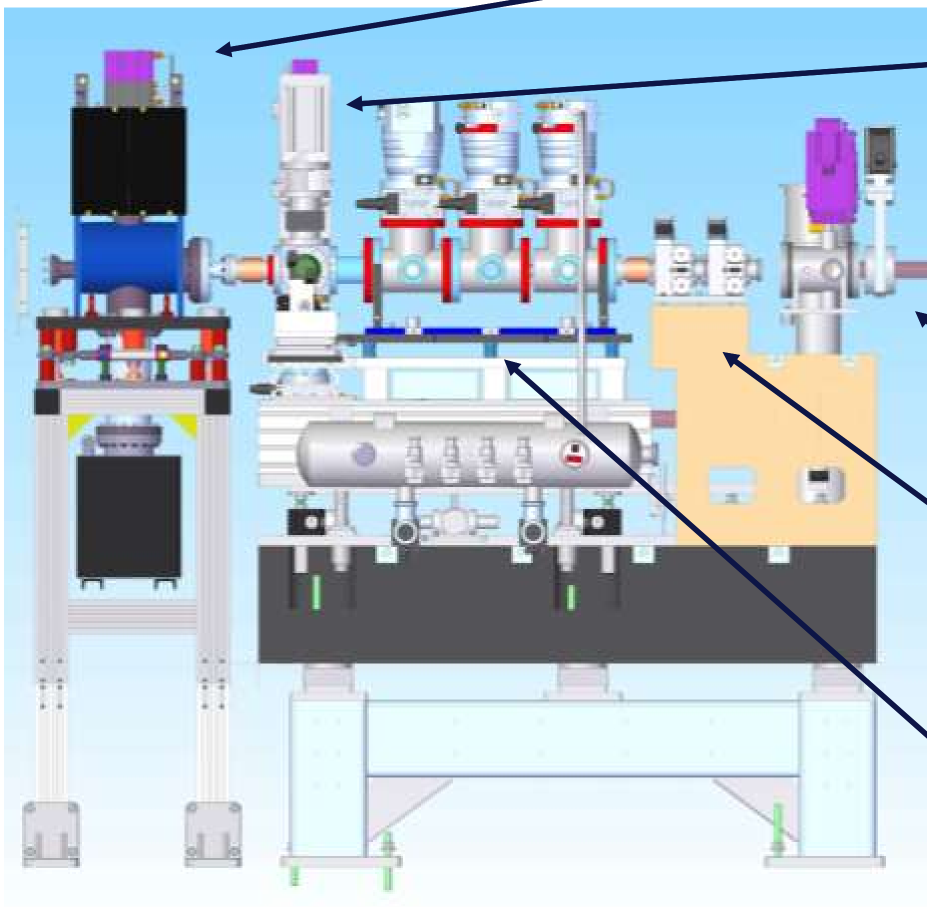


- Diamond scatterer
- Signal detection with fast diodes and optical camera
- Beam position in center of diamond disk
- Interchangeable distance between diodes and diamond

X-ray beam transport in experimental hutch



X-ray transport entrance experimental room



- Shutter for laser induced radiation
- Alignment laser
- Valve with diamond window (only restricted operation modes allowed)
- Clean up slits (low energies)
- Clean up slits (high energies)
- Differential pumping unit

($10^{-4} \rightarrow 10^{-8}$)

Possible day one experiment 2018

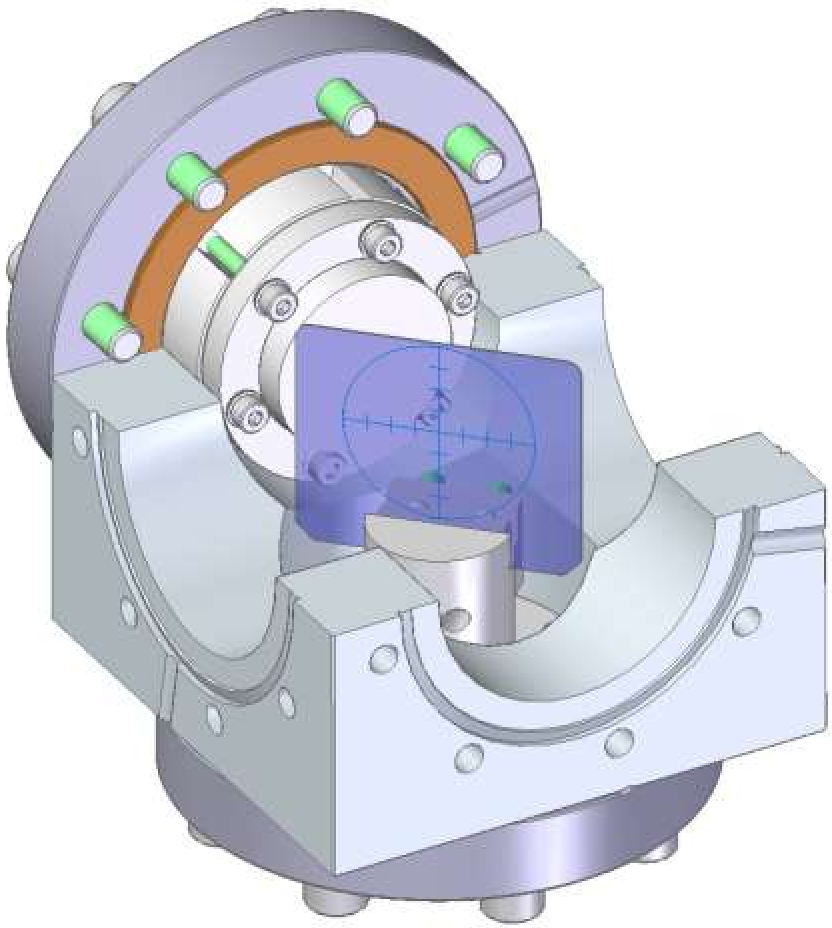
- Parameters for first commissioning and early experiments:

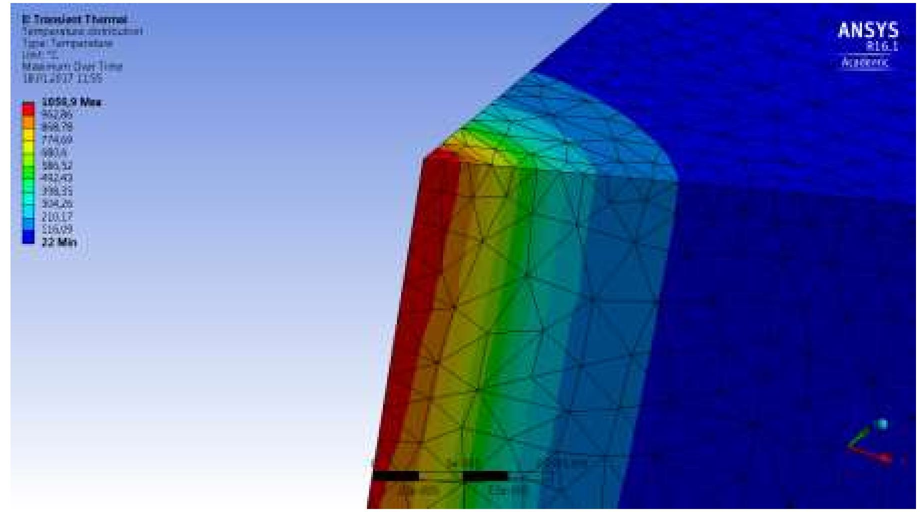
Electron energy	**14 GeV**
Photon energy	> 6 keV
Repetition rate	1 MHz (& 4.5 MHz?)
Max. number pulses per train	60 (2% of full power)
Undulator K-value	3.9
Undulator Gap	10 mm
Pulse energy	2 mJ (slightly oversaturated)
Divergence	2.2 urad
Pulse duration	43 fs (0.5 nC)
Saturation length	58 m

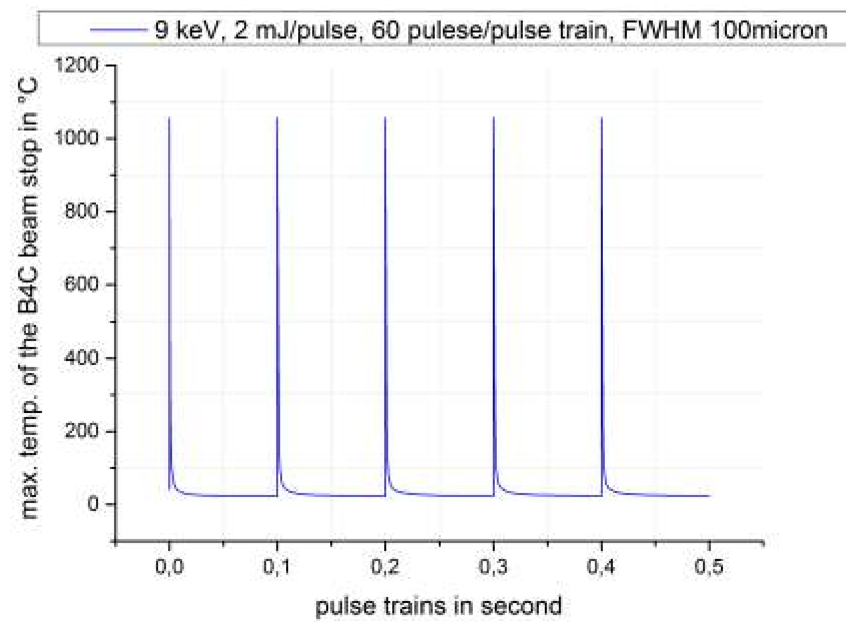
PP laser parameter: max. 2 mJ at 800 nm or 40 mJ at 1030 nm, 100 kHz, < 1 ps /400 ps

- X-ray methods: IXS using HAPG crystals, XRD
- DAC experiments: dynamic DAC and double stage DAC with high photon energies

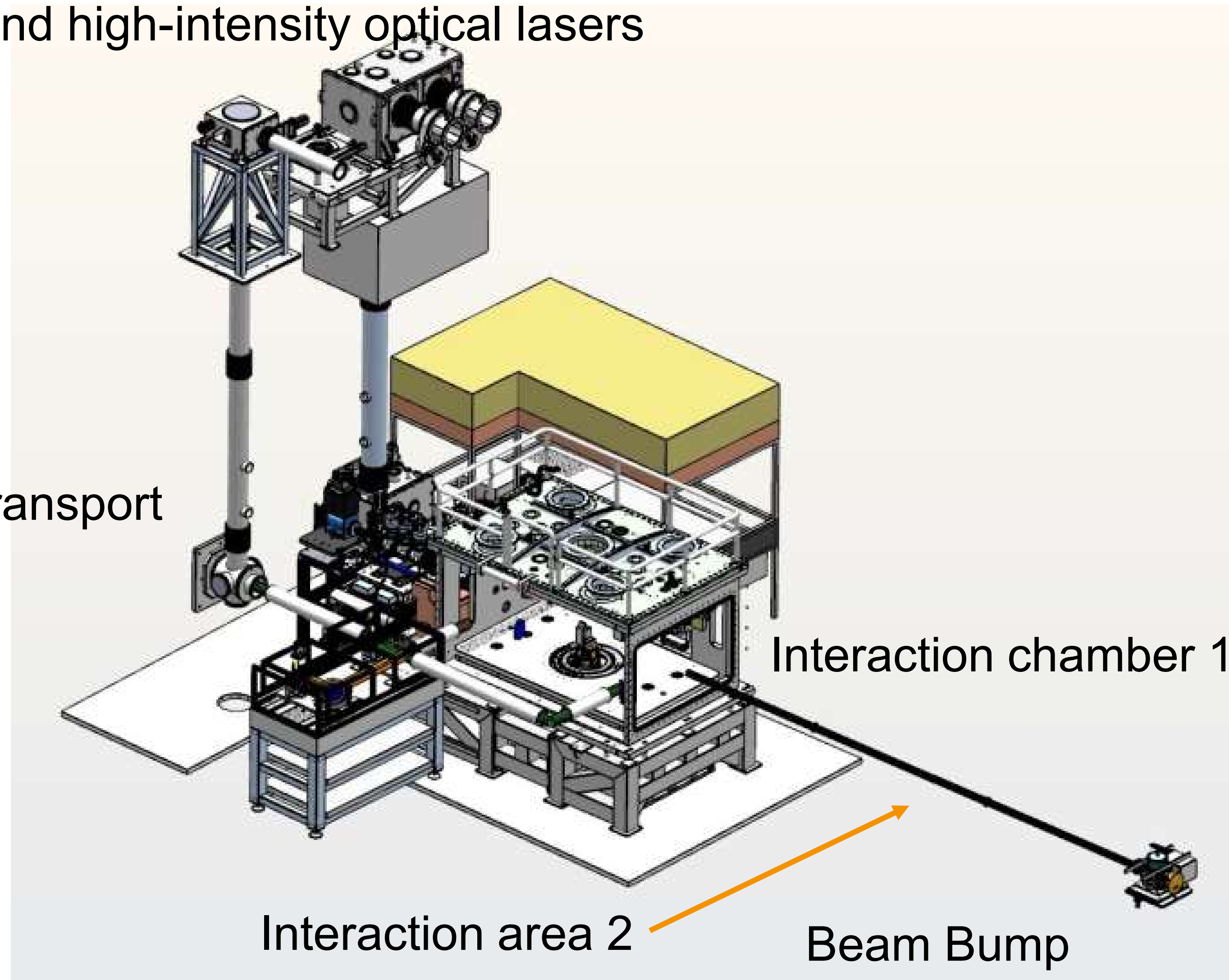
Beam dump – day1







X-ray beam transport in experimental hutch

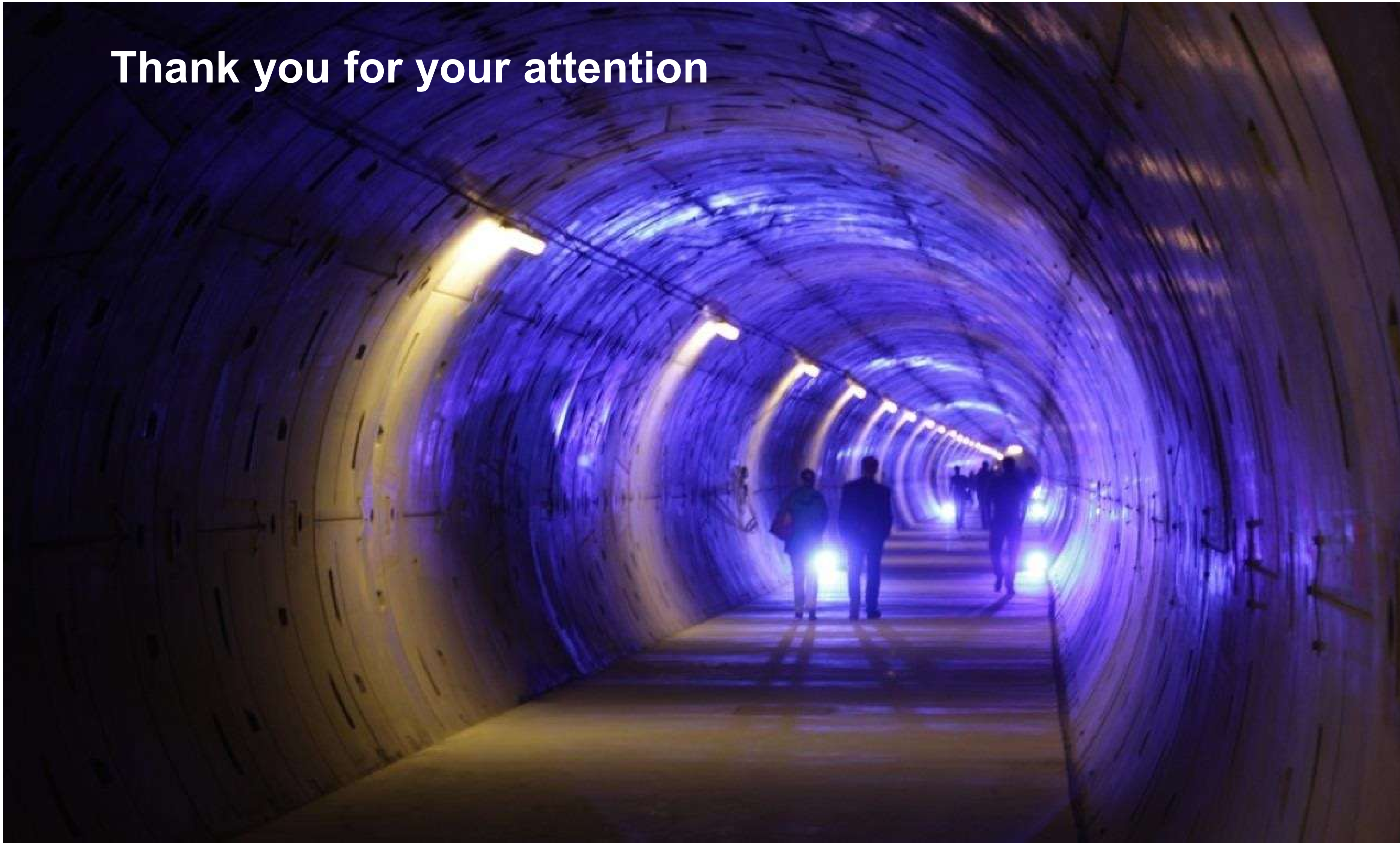


Acknowledgements

- HED group

- WP-73: Nicole Kohlstrunk, Daniele La Civita, Fan Yang, Xiaohao Dong, Idoia Freijo Martin, Liubov Samoylova, Maurizio Vannoni, Harald Sinn
- WP-74: Naresh Kujala, Jan Grünert, Wolfgang Freund
- Vacuum group: Martin Dommach, Massimiliano di Felice, Raul Villanueva Guerrero
- CIE group: Lewis Batchelor, Viktor Lyamayev, Osama Salem
- University of Münster: Sebastian Roling, Matthias Rollnick, Frank Wahlert
- And many others!

Thank you for your attention



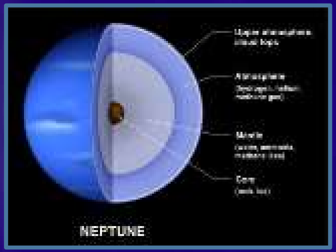
HED vacuum chamber IC1 and x-ray detectors

Sebastian Göde
High Energy-Density (HED) science group
Instrument scientist

Schenefeld, 24 Jan 2017

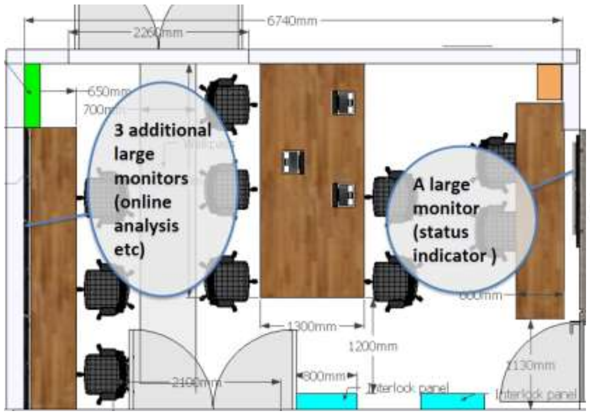
HED science at the European XFEL

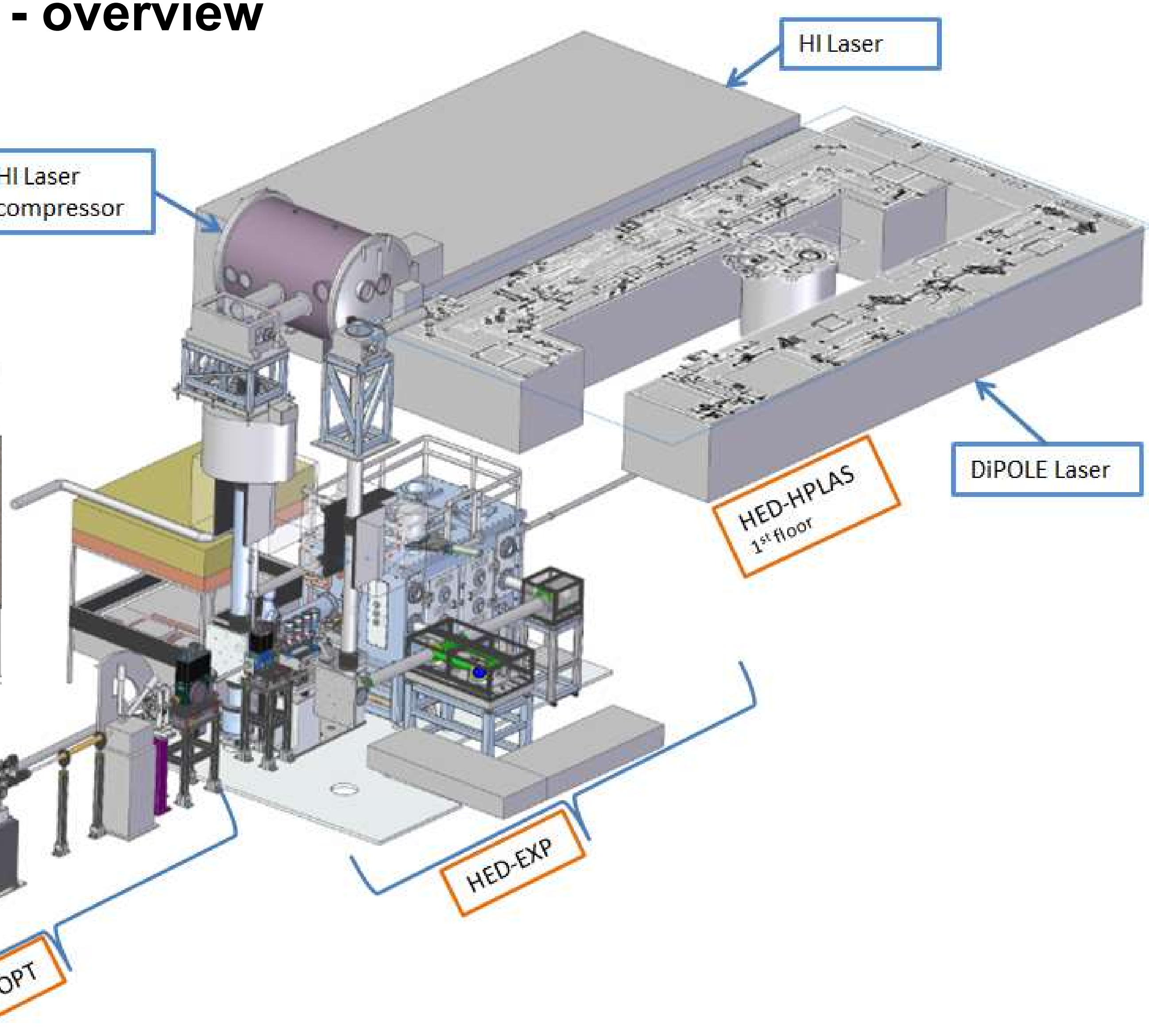
- Prepare and explore extreme conditions of temperature, pressure, electric and/or magnetic fields
- Major applications are high-pressure planetary physics, warm- and hot- dense matter, laser induced relativistic plasmas and complex solids in pulsed magnetic fields
- The extreme states can be reached by different types of optical lasers, the X-ray FEL beam and magnetic fields



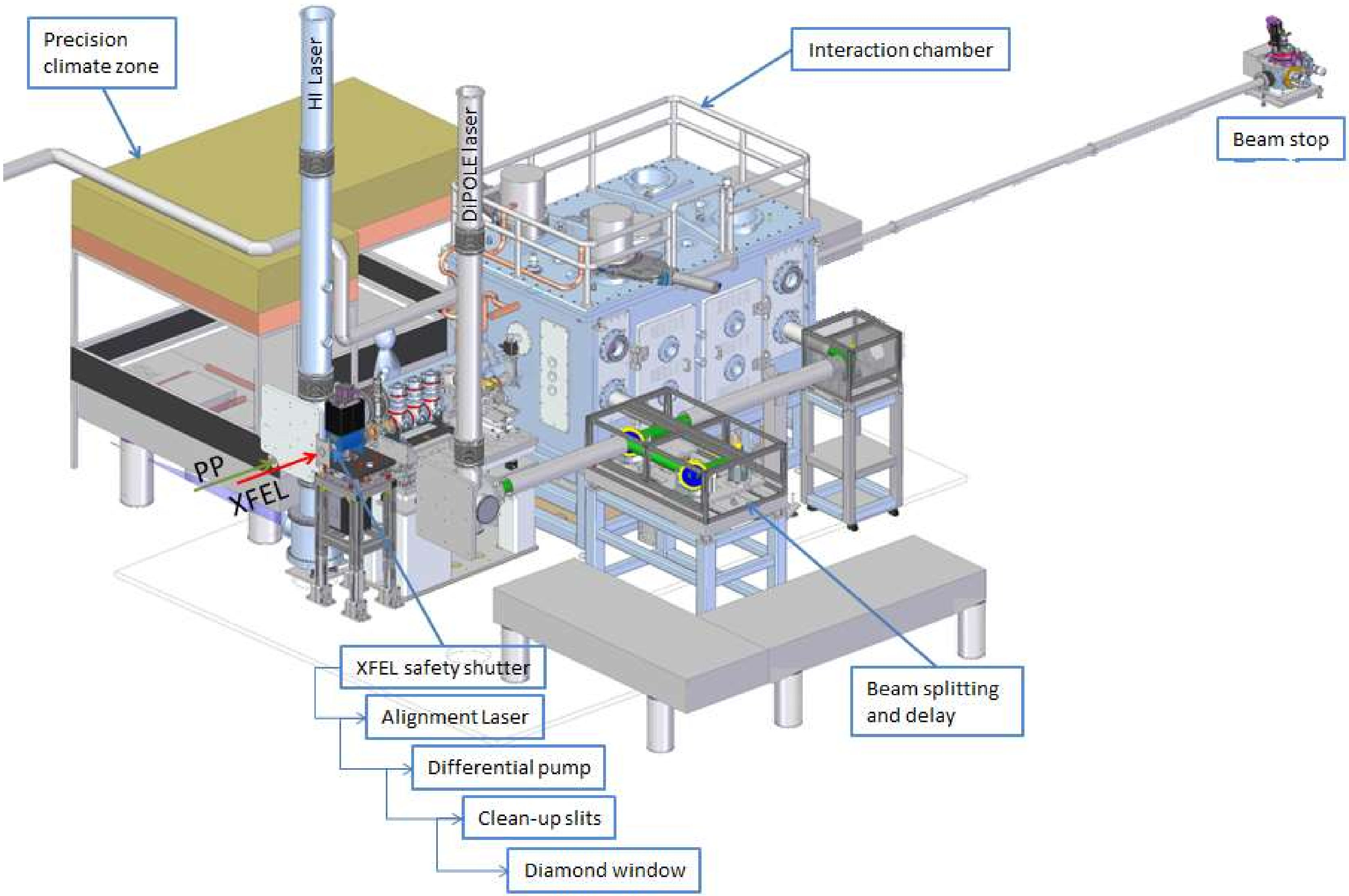
HED instrument - overview

Control room





HED experimental area and IC1



HED interaction chamber (IC1)

- All-aluminum to avoid activation during relativistic laser-plasma interaction
- Build by Toyama, Japan. Installation in spring 2017

Pioneering New Horizons in Science

TOYAMA

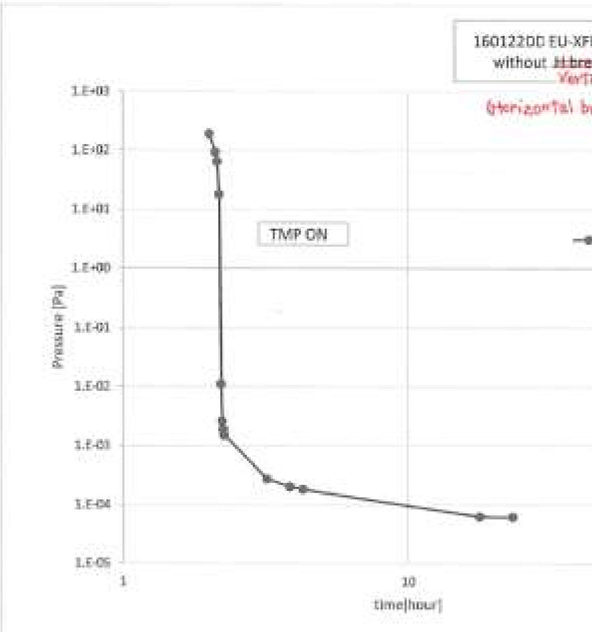
Venting cycles of <30min envisaged

Vacuum data

Date	Time	Pa
2016/10/3 14:09	0	1.10E+05
2016/10/3 16:10	2.016667	1.90E+02
2016/10/3 16:16	2.116667	9.40E+01
2016/10/3 16:18	2.15	6.60E+01
2016/10/3 16:20	2.183333	1.80E+01
2016/10/3 16:22	2.216667	1.10E-02
2016/10/3 16:23	2.233333	2.60E-03
2016/10/3 16:24	2.25	1.90E-03
2016/10/3 16:25	2.266667	1.50E-03
2016/10/3 17:21	3.2	2.70E-04
2016/10/3 18:00	3.85	2.00E-04
2016/10/3 18:26	4.283333	1.80E-04
2016/10/4 8:00	17.85	6.30E-05
2016/10/4 13:27	23.3	6.20E-05

TMP ULVAC UTM-3303FH 3300L/s
Vacuum speed N2 =3300L/s
H2 =2400L/s

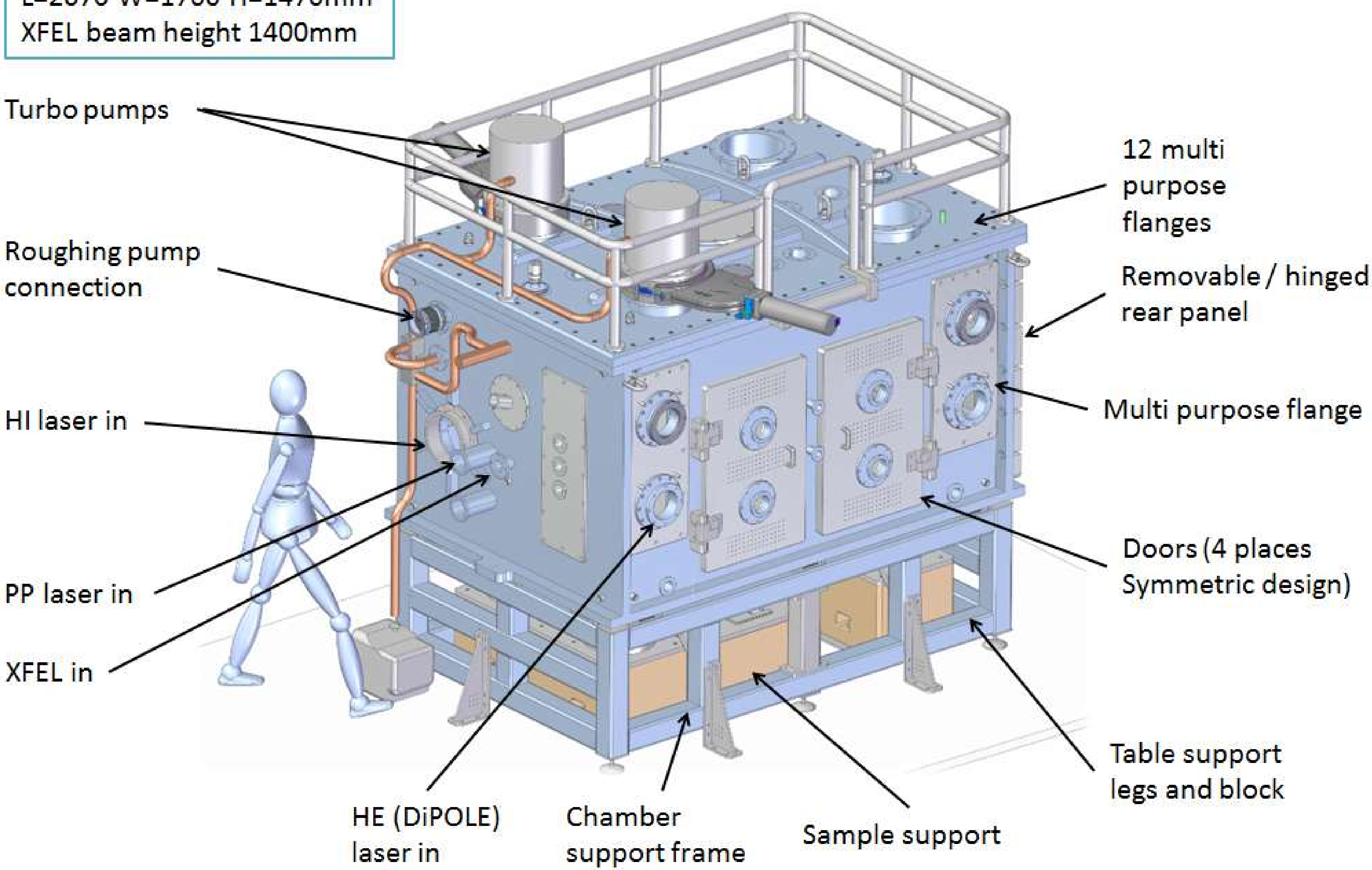
DRY Kashiyama Neodry30E 500L/m
CCG Balzers IKR060
Pirani Balzers TPR



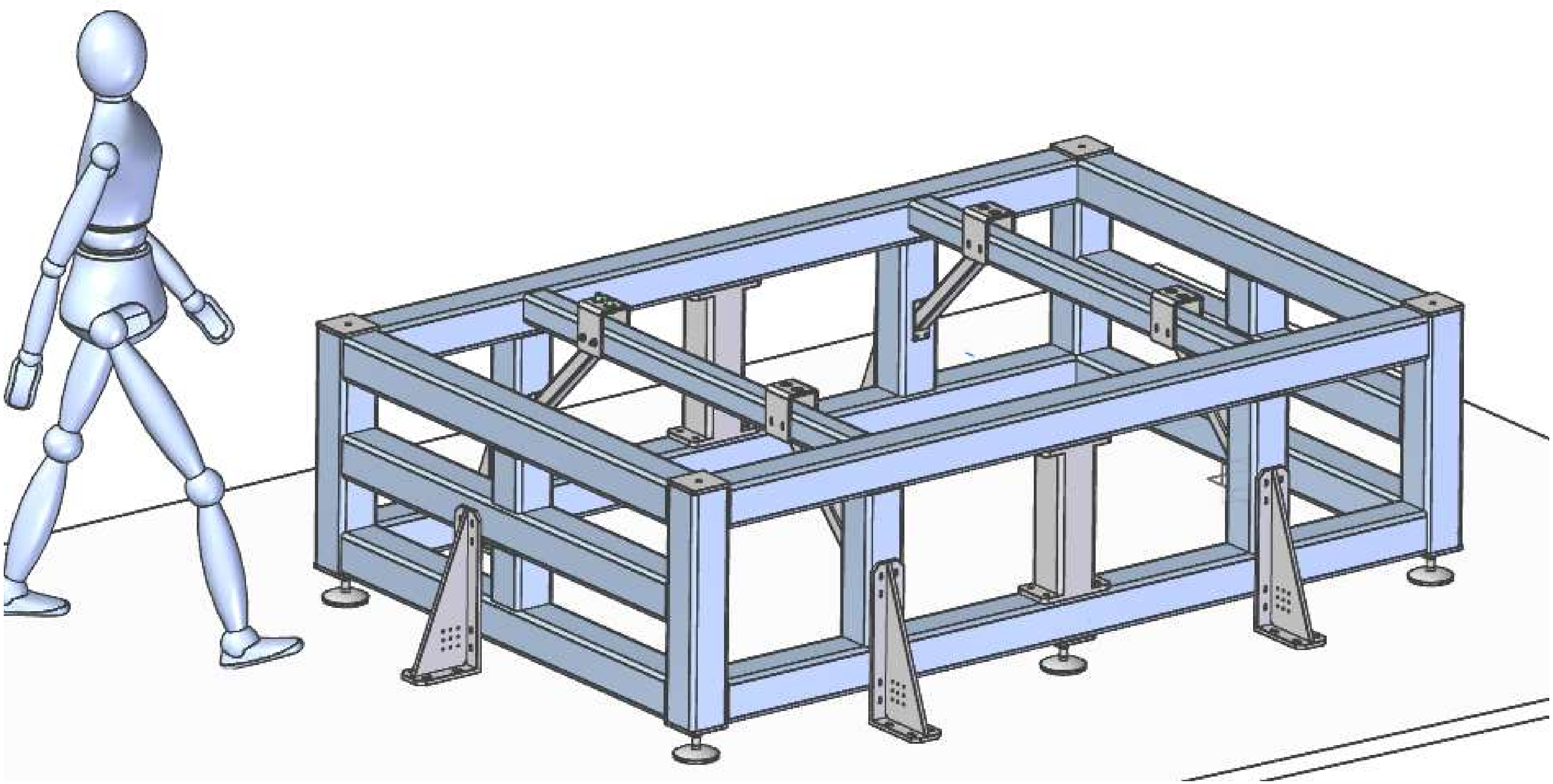
HED interaction chamber (IC1)

All support flanges on DIN ISO-K / ISO-F

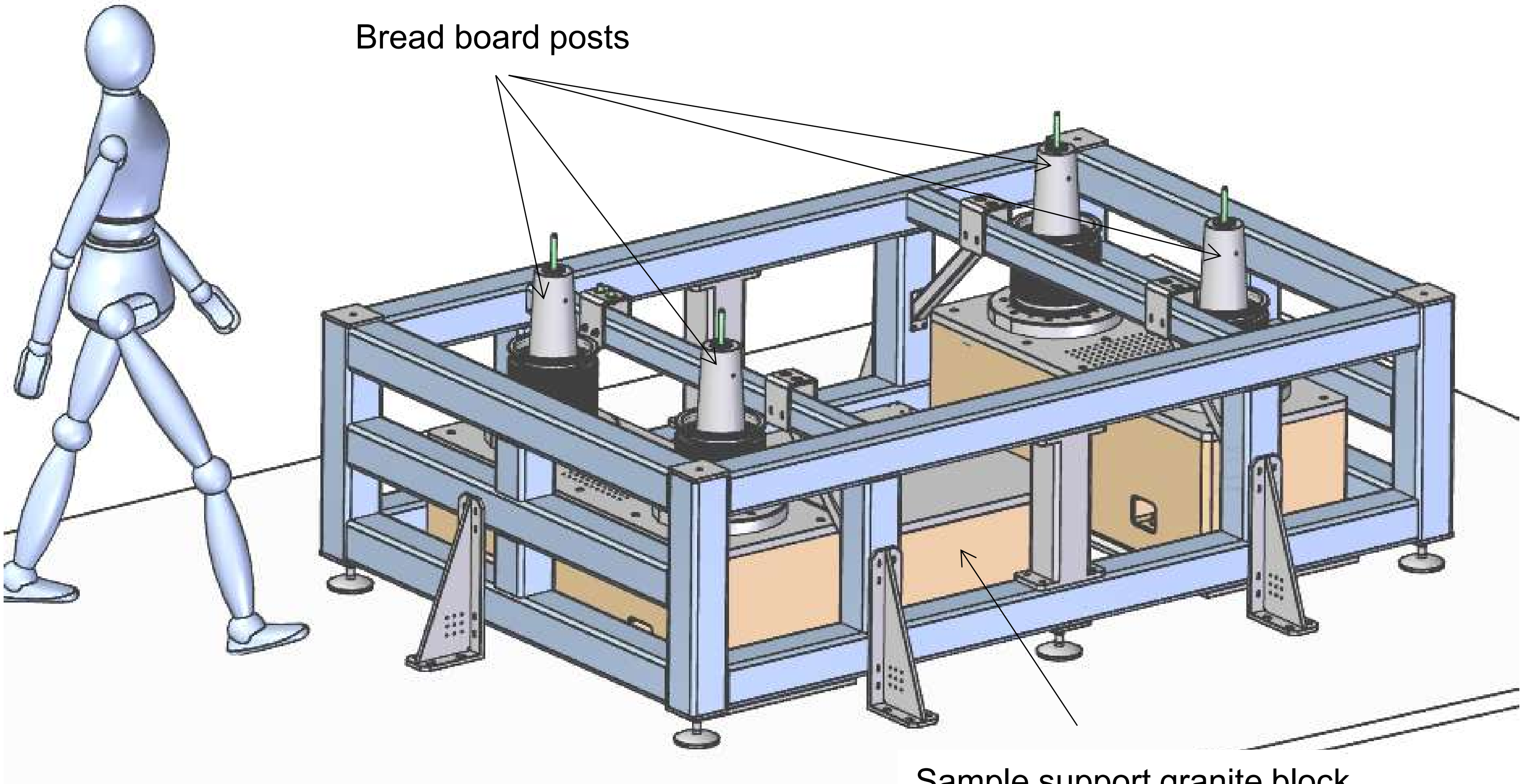
L=2670 W=1700 H=1470mm
XFEL beam height 1400mm



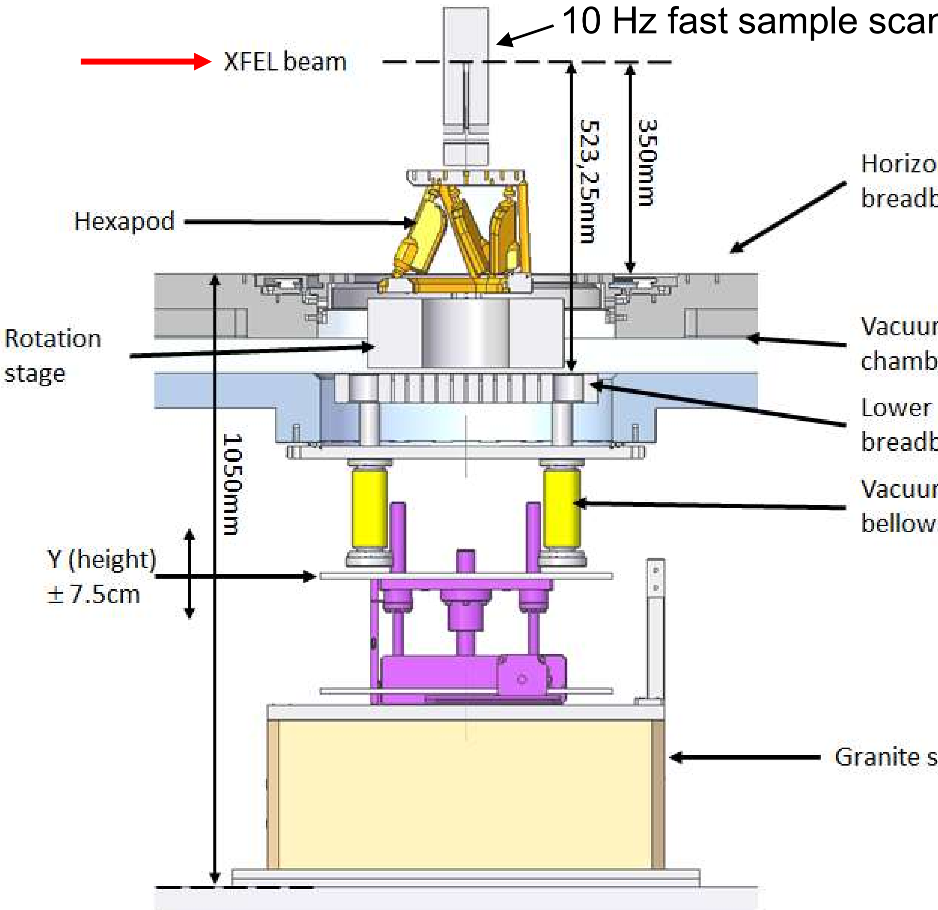
Chamber support frame

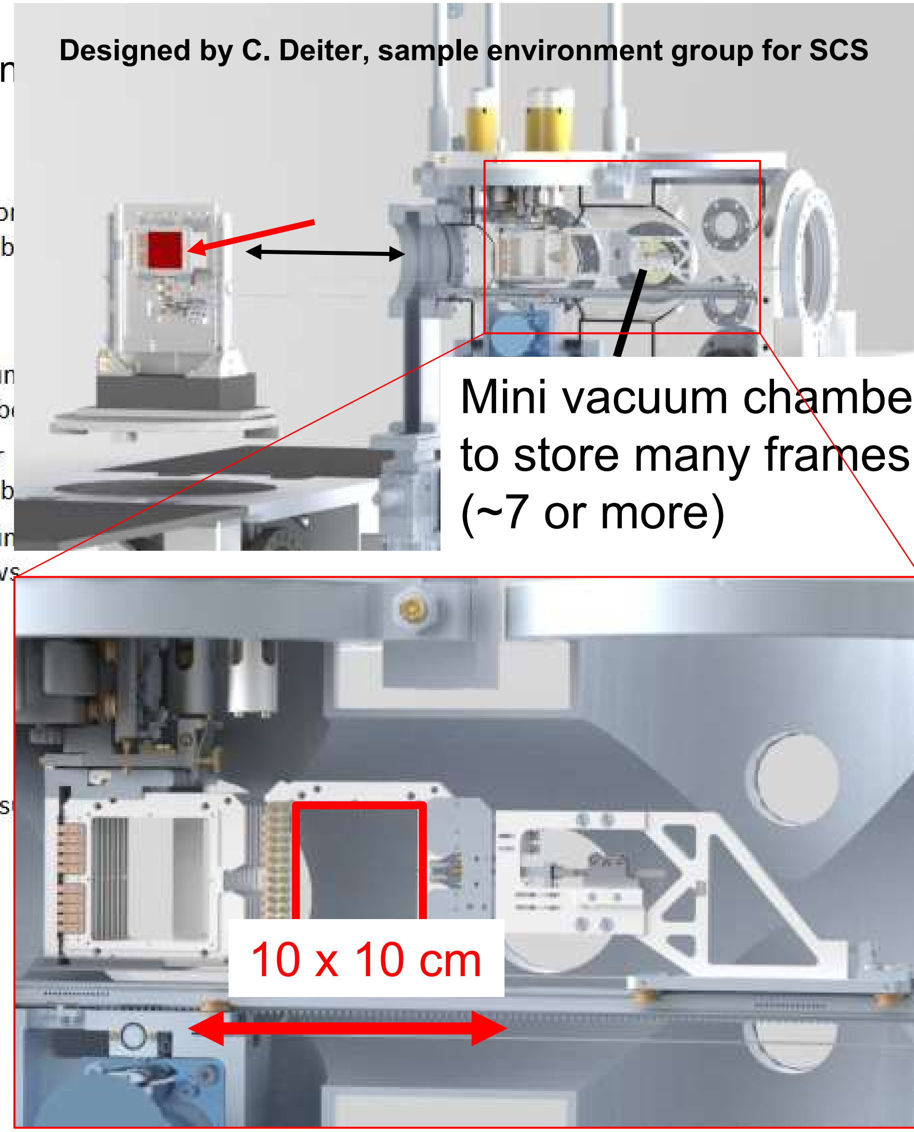


Mechanical isolated horizontal bread board and sample positioning system



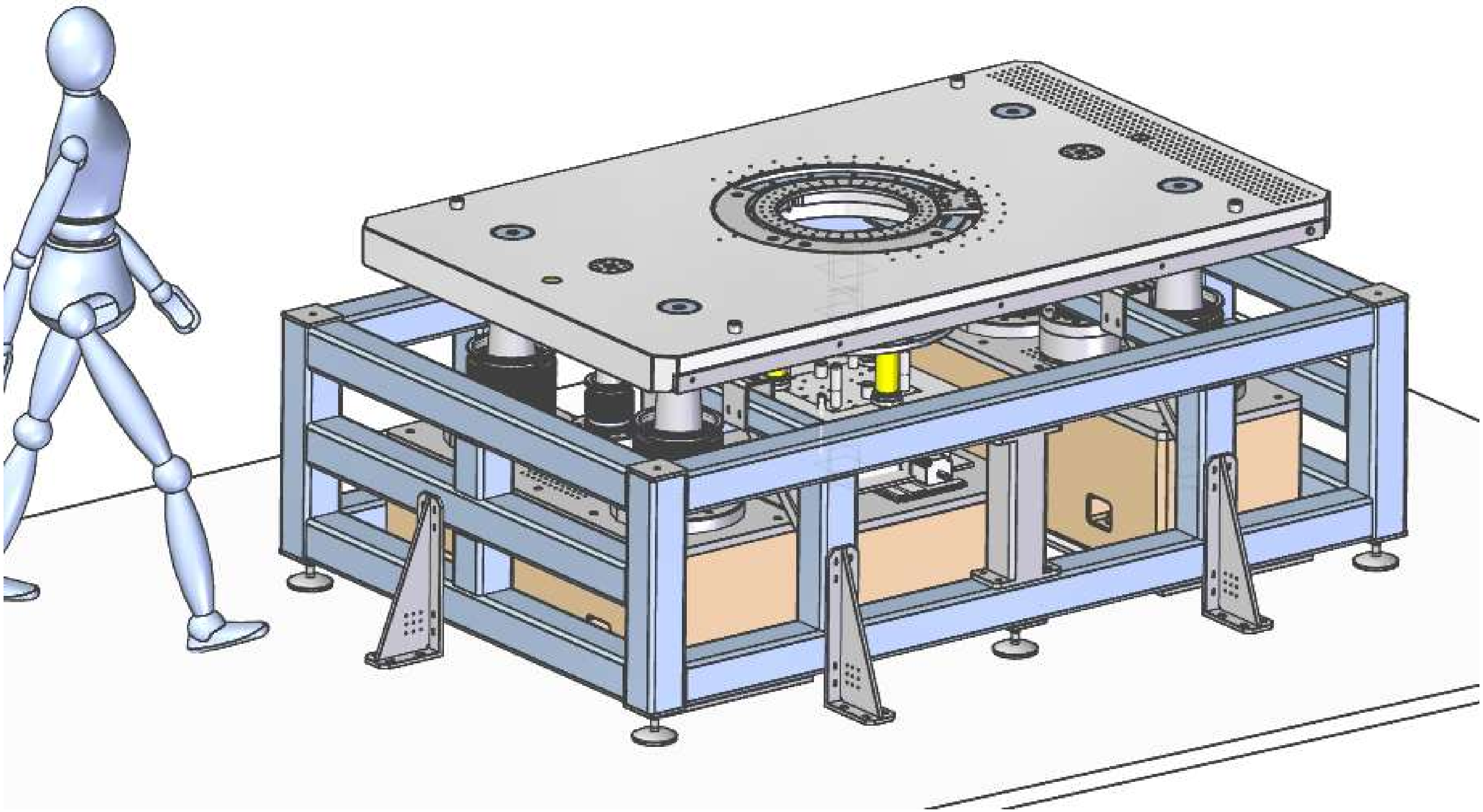
Sample positioning and scanning





Sample tower is mechanically decoupled from the chamber body

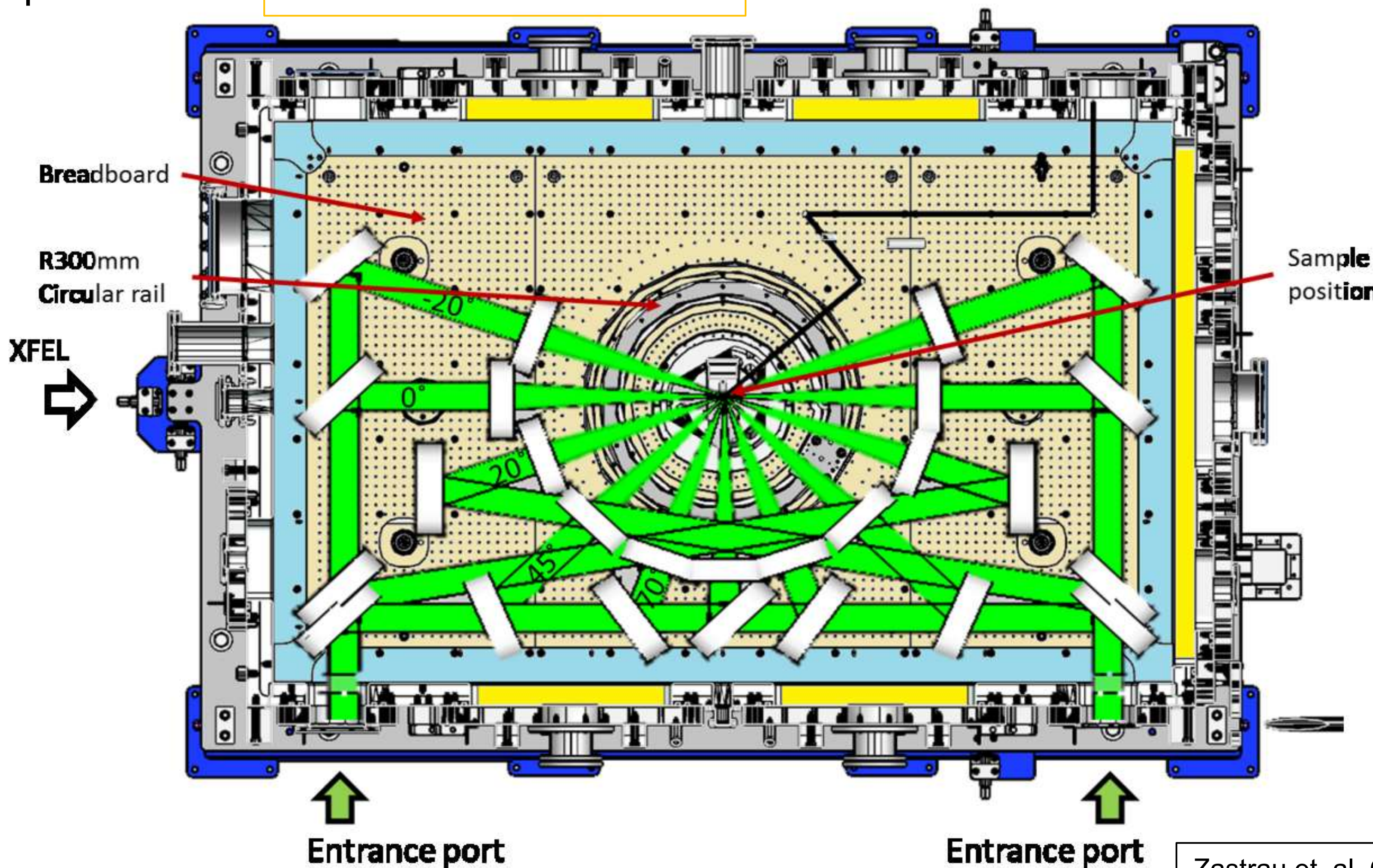
Mechanical isolated horizontal breadboard



DiPOLE laser transport inside chamber

Top view

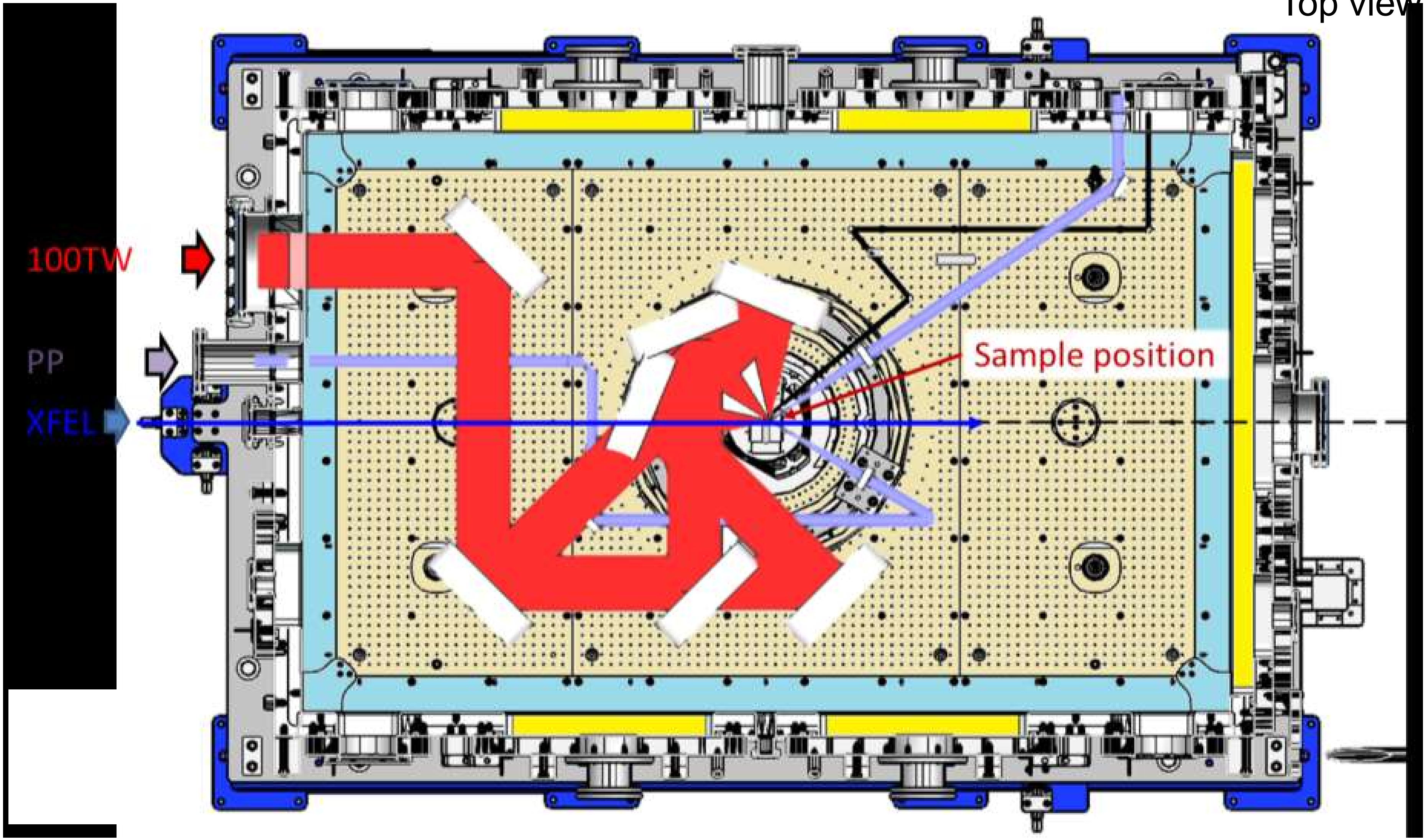
Beam size 75 x 75 mm²



Zastrau et. al, CDR page 116

100TW laser, 140mm beam diameter transport.
Example for 0, 45, 90˚ with respect to the XFEL

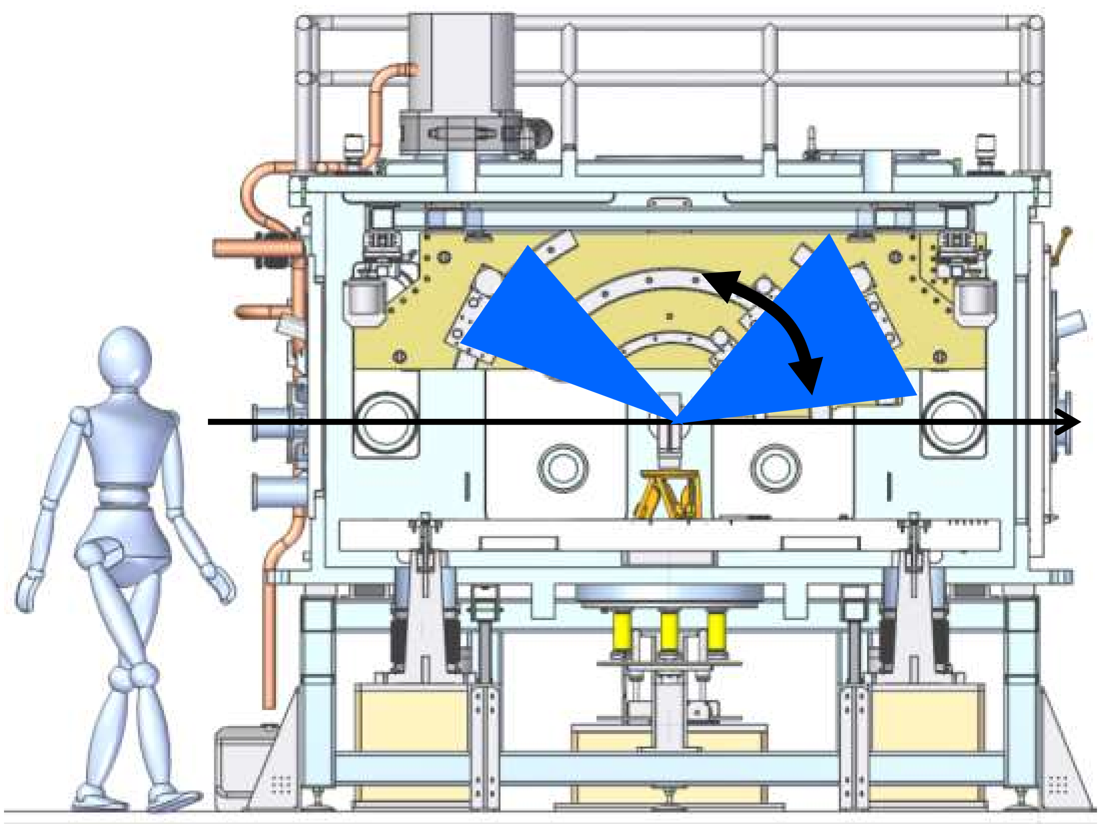
Top view

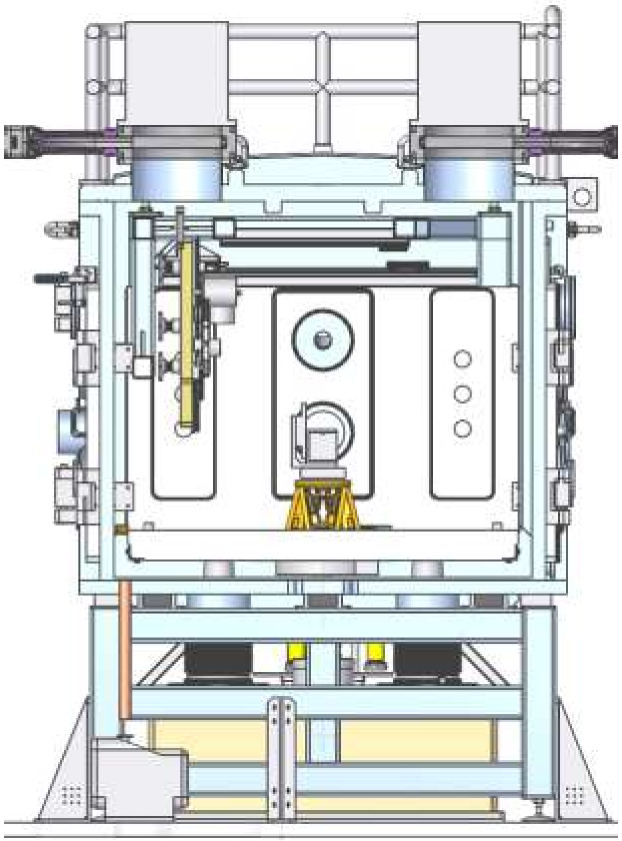


Vertical bread board for flexible detector positioning and scanning

- Seeding available, 4-bounce monochromator available, ΔE ~ 1eV
- IXS (HAPG spectrometers, diced analysers) on curved rails to scan scattering angles

Measure plasmon dispersion in compressed matter ~ 1Mbar





Key requirements for x-ray cameras in IC1

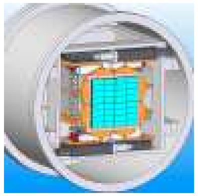
SASE2 undulator

- Hard X-ray source →3 – 25 keV photon energy, 10^{-3} natural bandwidth
- Repetition rate →10 Hz bunch trains with up to 2700 pulses
- Pulse energy →10^{8} – 10^{13} phts / 100 nJ – few mJ
- Pulse duration →2 to 100 fs

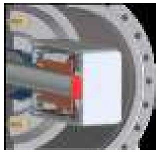
- Vacuum compatible ($p<10^{-5}$ mbar)
- Compact dimensions and low weight
- Modular assembly to large area detectors
- >10Hz frame rate
- Integratable into DAQ/Karabo

Not suitable for IC1:

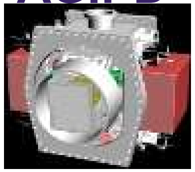
DSSC



FastCCD



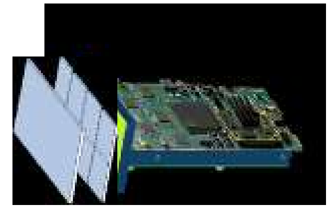
AGIPD

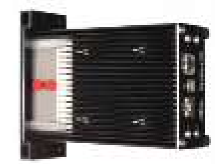


IA2 (HIBEF)

LPD

Day-1 x-ray detector suite at HED





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)	~180	~360	~450	~900
Repetition (Hz)	120	120	2000 1MHz in burst mode, 16 images on-chip memory	2000 1MHz in burst mode, 150 images on-chip memory
# of modules	**2**	**3**	**4**	**2**

Low noise and small pixel detector: ePix100

ePix100 characteristics and measured performance.

Pixel per ASIC	384 × 352
Pixel size (µm)	50
Noise r.m.s. (eV)	360
Maximum signal (8 keV photons equivalent)	100
Frame rate (Hz)	120
Sensor thickness (µm)	300/500

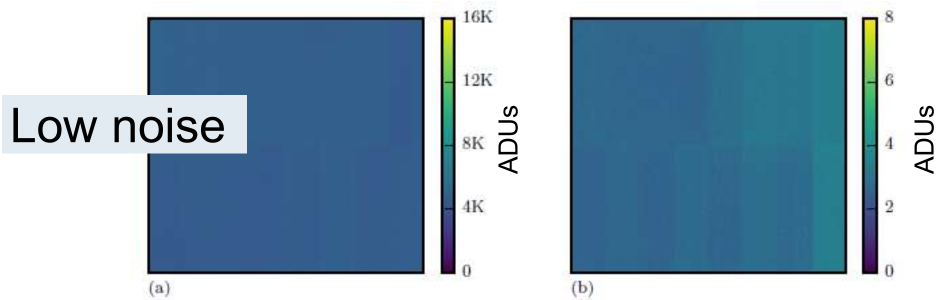
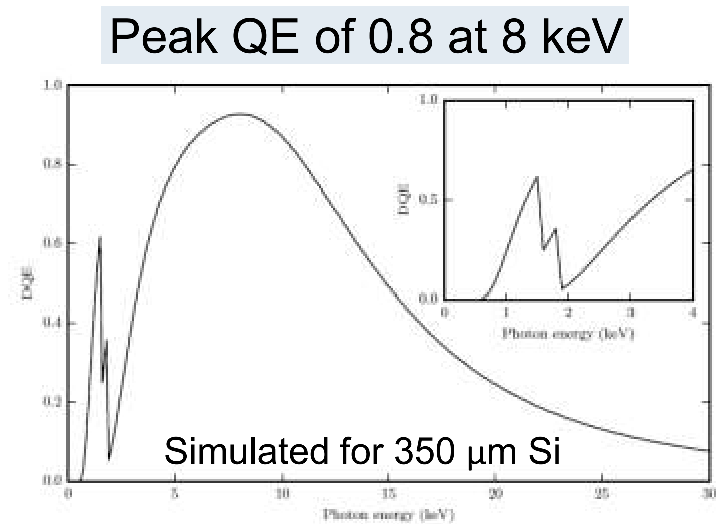
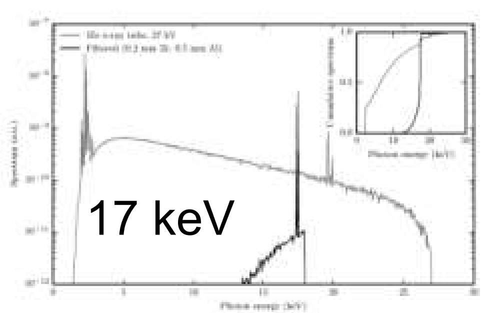


Figure 1. Dark and noise maps of a camera with fully biased sensor (200 V) and an integration time of 50 µs, with standard configuration (temperature compensation on, TC) and calculated over 1024 frames; (a) dark map (average), showing good uniformity; (b) corresponding noise map (root mean square, rms) showing very low noise and good uniformity.





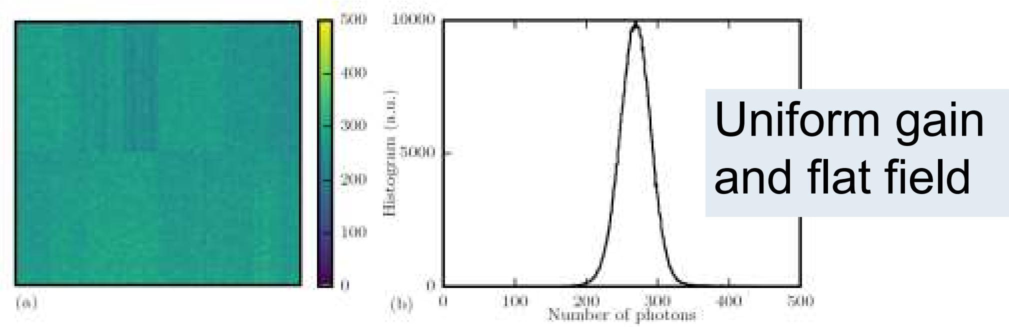
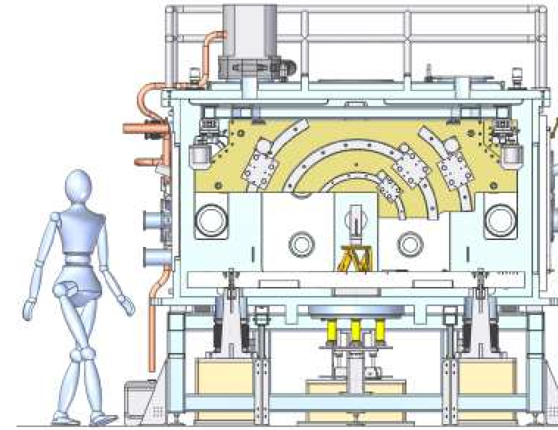


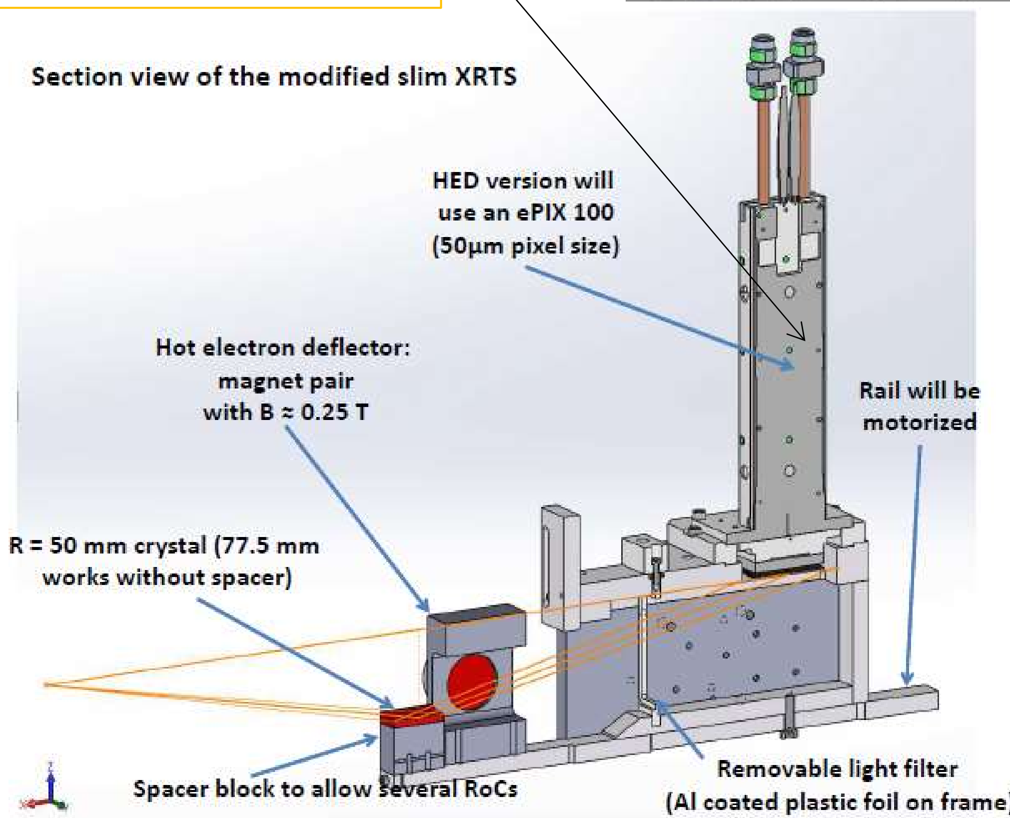
Figure 6. Flat field calculated on the same data used in Fig. 4: (a) shows the flat field map which is somewhat nonuniform due to suboptimal gain and flat field calculation; (b) shows the corresponding histogram, showing 270.0 ± 21.9 photons/pixel.

Low noise and small pixel detector for x-ray spectrometers

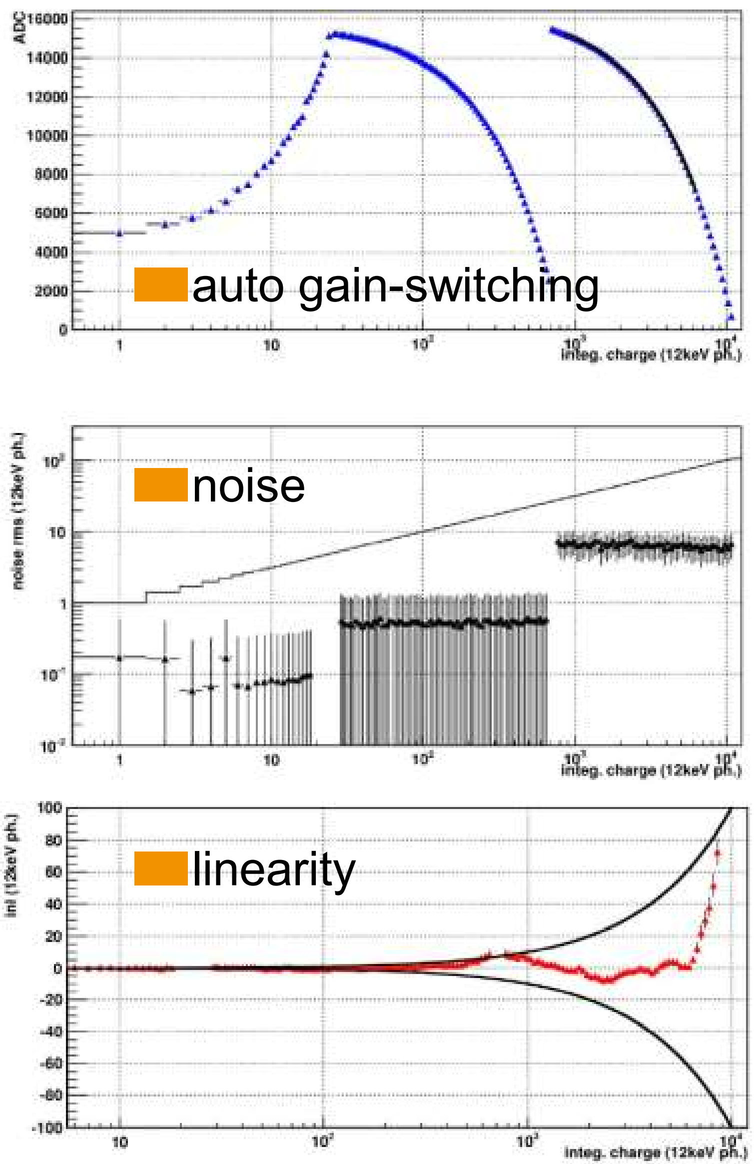


ePix100 (2D, 50 µm, 10 Hz)

Gotthard (1D, 50 µm, 150 frames at 1 MHz)



High dynamic range (HDR) detector: JUNGFRAU



- Similar perfomance for **Gotthard-I**

Detector specifications

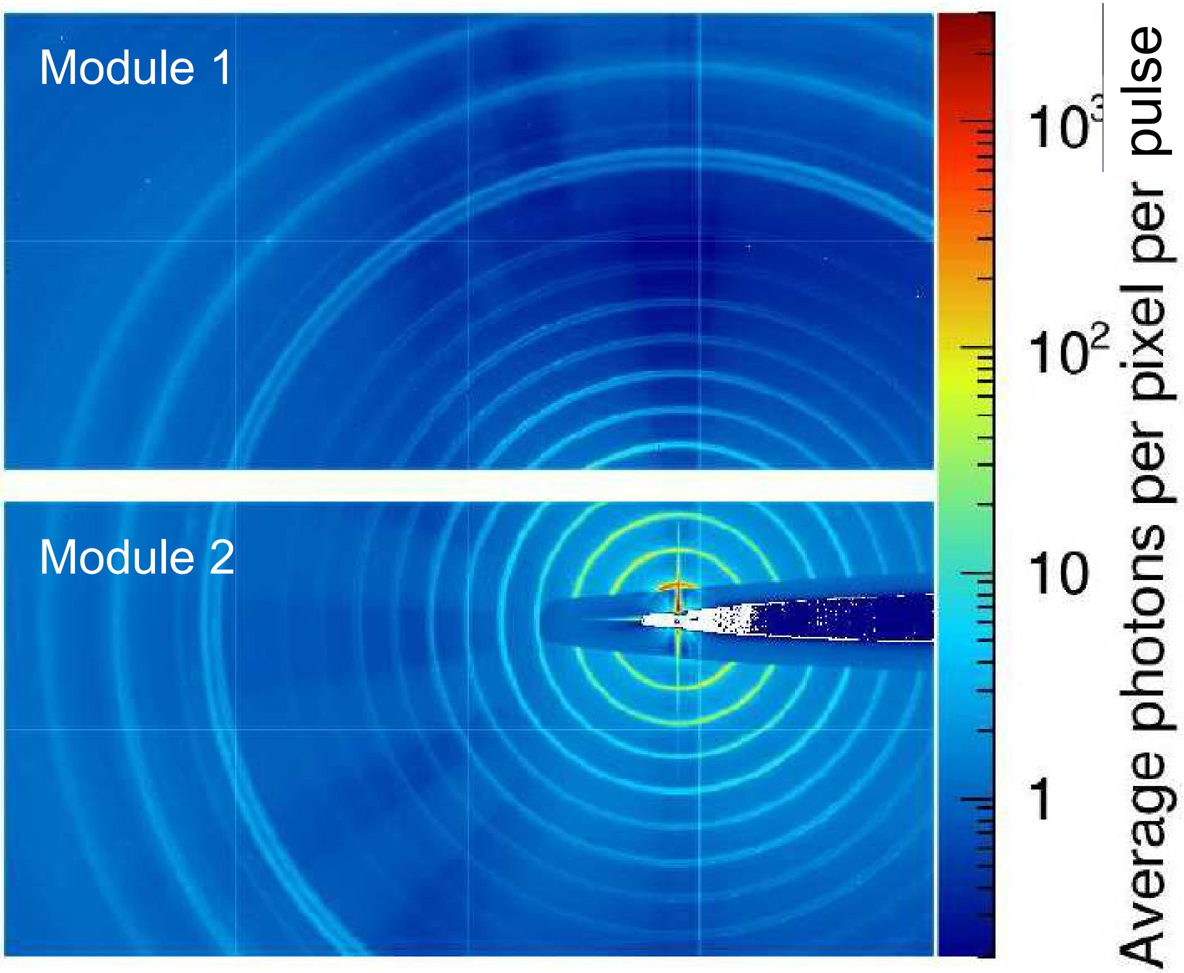
ASIC technology	UMC110nm
mudule pixel count	525k
mudule size	80x40 mm^2
sensor thickness	320-500 µm
pixel size	75x75 mm^2
dynamic range	up to 10^4 12keV photons
noise r.m.s.	~120 e.n.c.
min Energy	<3 keV
linearity	better than 1%
point spread function	1 pixel
dead time	~200ns
ext. power consumption	30 W /module
cooling	liquid
readout time = 1 / frame rate	2.1kHz with 10GbE
rate capability @ syncrotron (with 10GbE)	10^4 x 2.4 10^3 = 2.4x10^7 photons per ch. per s

from J. Smith et. al, TDR-PSI (2015)

Performance demonstration of JUNGFRAU at LCLS

Silver behenate (AgBe) powder measurement

- full beam transmission
- 9.5 keV photons
- 10-15 um beam size



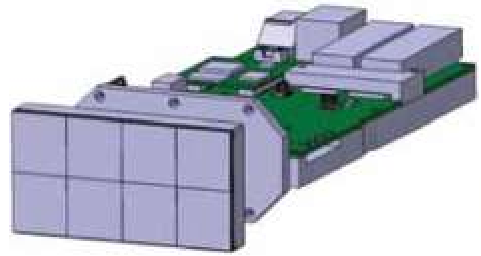
Courtesy B. Schmidt, PSI

HDR detectors for x-ray scattering and imaging

Single modules for SAXS, XI

Can be placed at variable distances
(inside IC1 or outside)

JUNGFRAU

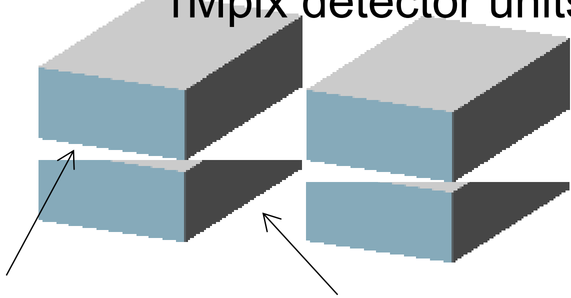


ePix10k
(first prototype test 2017)

‚Large area‘ detector for XRD

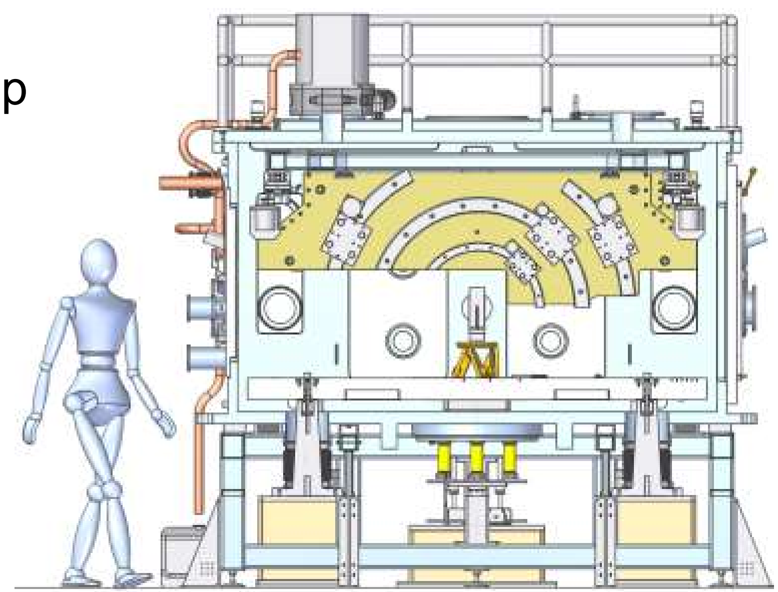
Combination of modules with fixed/adjustable gap

1Mpix detector units



Min. horizontal gap
2.7mm (36px)

Min. vertical gap
0.6mm (8px)



X-Ray diagnostics and Detector specification requirements *covered*

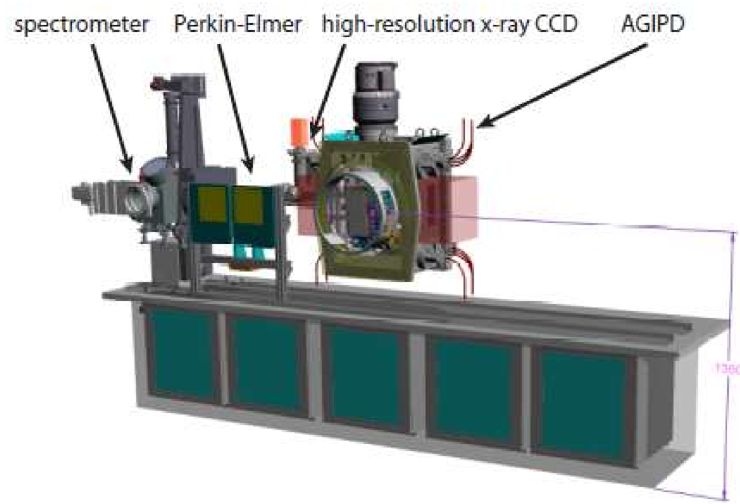
	Angular resolution [μrad]	Pixel	Dynamic range	Central hole	Comments
XRD (forward)	~ 500	$\geq 10^6$	high $\geq 10^4$	yes	Single experiments could require all types (Bragg, powder, and non-crystalline scattering) while their requirements are different. In the Bragg case, the beam intensity needs to be reduced.
XRD (large q)	1 000	$\geq 10^5$	medium $\geq 10^3$	no	Diffraction at large angles (e.g. parts of powder rings), detectors close to sample.
SAXS	20–50	10^6	high $\geq 10^4$	yes	Forward scattering inside vacuum.
XI	20–50	10^6	high $\geq 10^4$	no	Similar to SAXS requirements, but without central hole.
Spectroscopy	50–100	$\geq 10^5$	medium $\geq 10^3$	no	Various types for different spectrometers. Using 1D detector enables fast readout.

X-Ray diagnostics and Detector specification requirements *covered*

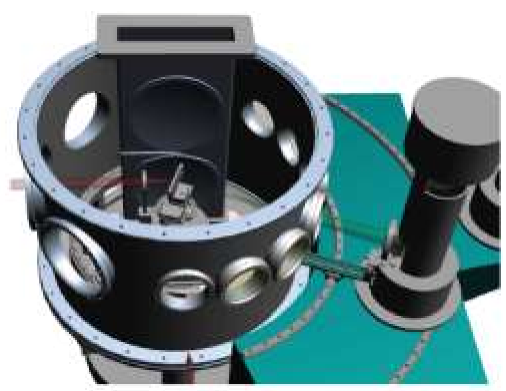
	Angular resolution [μrad]	Pixel	Dynamic range	Central hole	Comments
XRD (forward)	~ 500	$\geq 10^6$	high $\geq 10^4$	yes	Single experiments could require all types (Bragg, powder [illegible] non-cr[illegible]e scattering) [illegible] their [illegible]ements are different. [illegible] the Bragg case, the beam intensity needs to be reduced. ePix10k Jungfrau
XRD (large q)	1 000	$\geq 10^5$	medium $\geq 10^3$	no	Diffr[illegible] at l[illegible]gles (e.g. parts of [illegible]der ri[illegible] detectors close t[illegible] sample. ePix100 ePix10k
SAXS	20–50	10^6	high $\geq 10^4$	yes	Forward scattering insi[illegible]um. Jungfrau
XI	20–50	10^6	high $\geq 10^4$	no	Simi[illegible] SAXS requ[illegible]eme[illegible]t without [illegible]al hole. ePix100 Jungfrau
Spectroscopy	50–100	$\geq 10^5$	medium $\geq 10^3$	no	Vari[illegible]es for different spectromet[illegible] [illegible]g 1D detector enables fast [illegible]t. ePix100 Gotthard-I

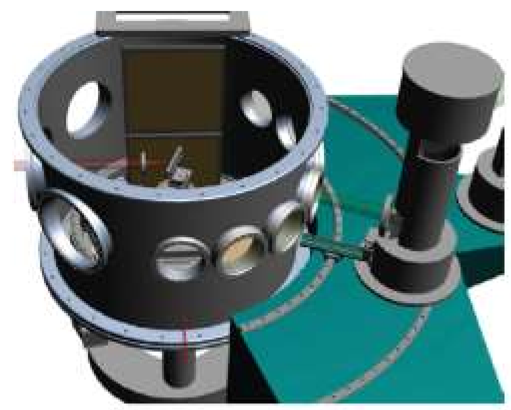
Outlook: other detector solutions

- HIBEF detector bench system. Rail system allows to select and position different detectors:
  - 1Mpix AGIPD
  - Perkin Elmer
  - High-resolution CCD (small pixel)



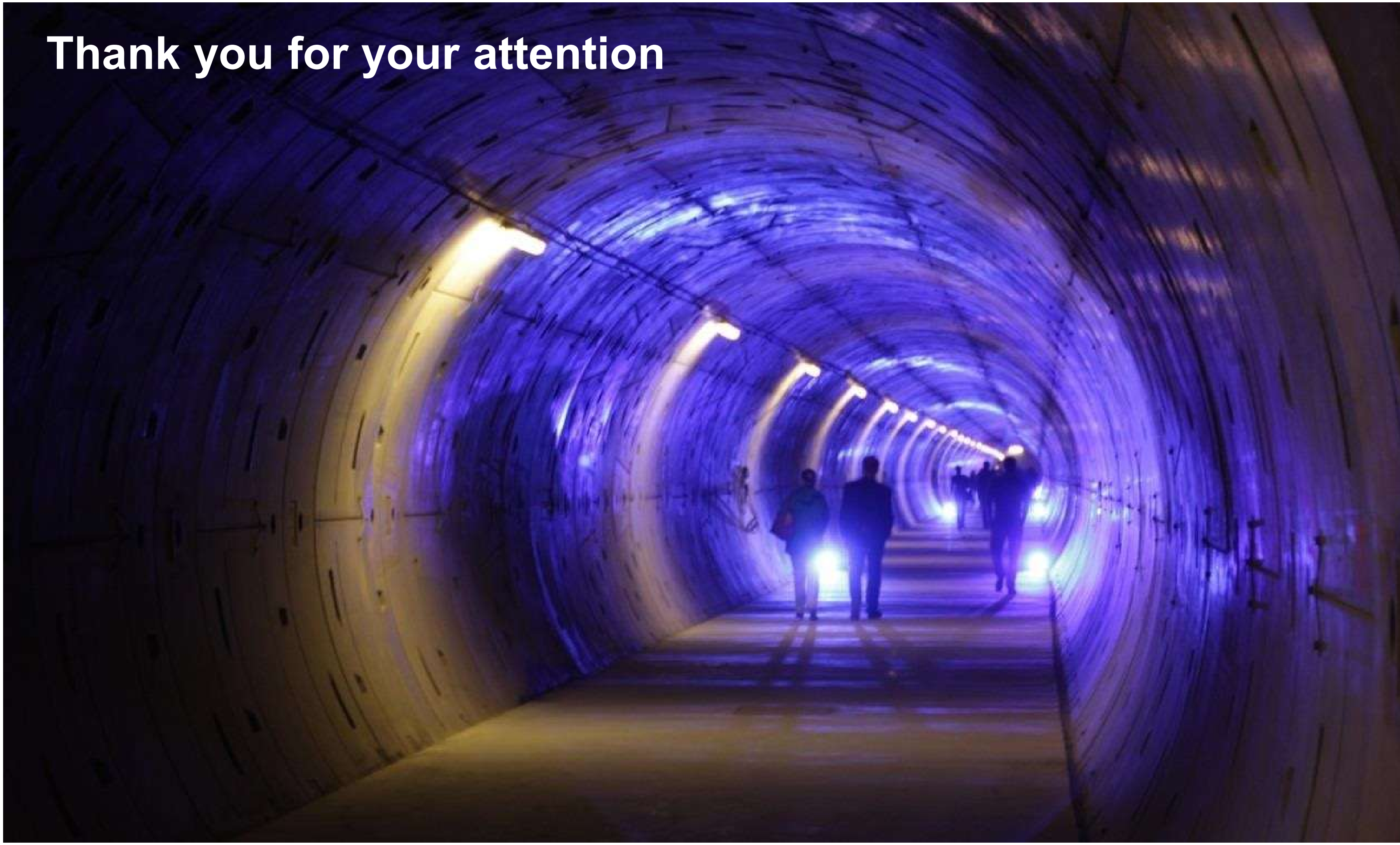
- In-vacuum enclosure for Perkin Elmer detectors (similar to the concept at IA2 – HIBEF)





Flat panel XRD 4343CT

Thank you for your attention



The XFEL pump-probe optical laser for the HED instrument

Motoaki Nakatsutsumi
High Energy-Density (HED) science group

Schenefeld, 24th Jan 2017

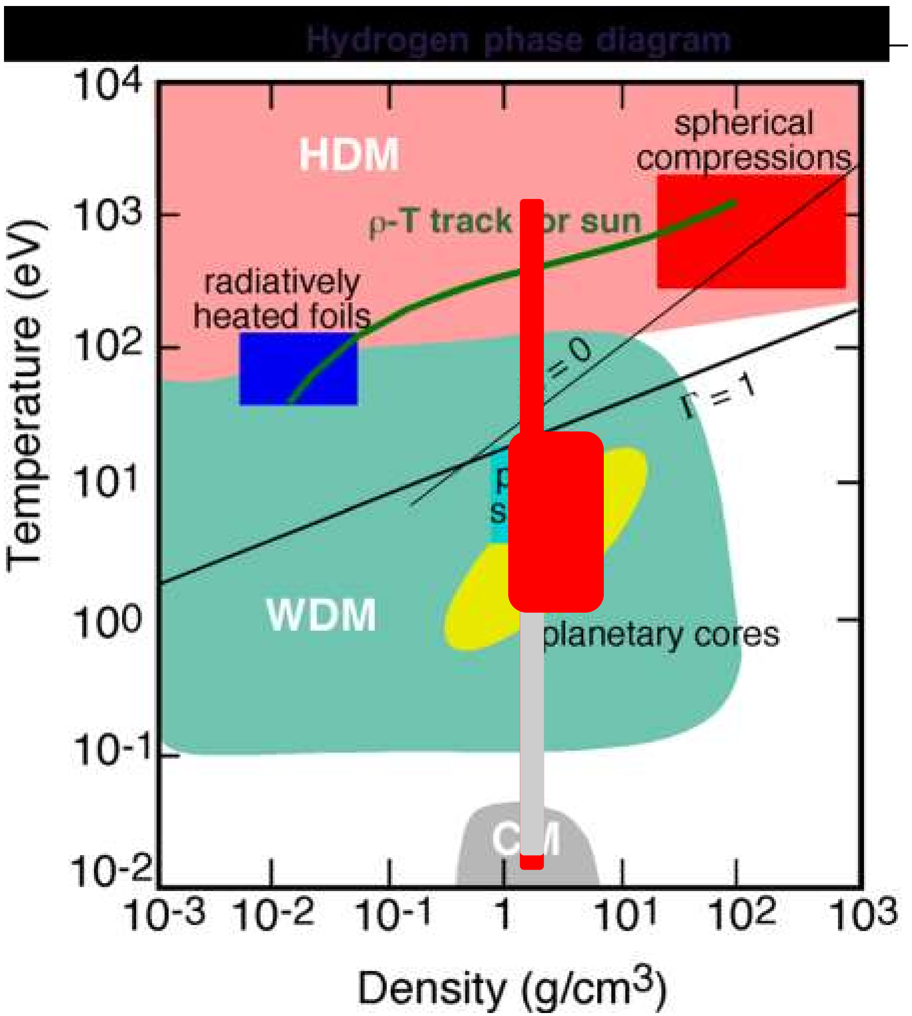
European XFEL

HED
High-Energy Density science

Outline

- **Ultrafast burst-mode pump-probe (PP) optical laser**
  - Concept
  - Operation mode
  - Applications
  - Beam delivery
- ***X-ray* – *optical* relative arrival timing monitor (XFEL – PP)**
- ***Optical* – *optical* relative arrival timing monitor (PP – HI 100TW)**
- **Summary and outlook**

3 optical lasers as pump sources



In-house R & D by OL group

- Pump-Probe (PP) >10^{17} W/cm^2
  - → 0.2–2 mJ, 0.1–4.5 MHz, ~15 fs
  - → 1–40 mJ, 0.1–4.5 MHz, ~1 ps
- ≥100 TW high-intensity (HI)
  - → >10^{20} W/cm^2
  - → > 3 J, 30 fs, 10 Hz on sample
- High energy (HE)
  - → 100J, 2–15ns, 1-10Hz
  - → ~3x compression, ~10Mbar

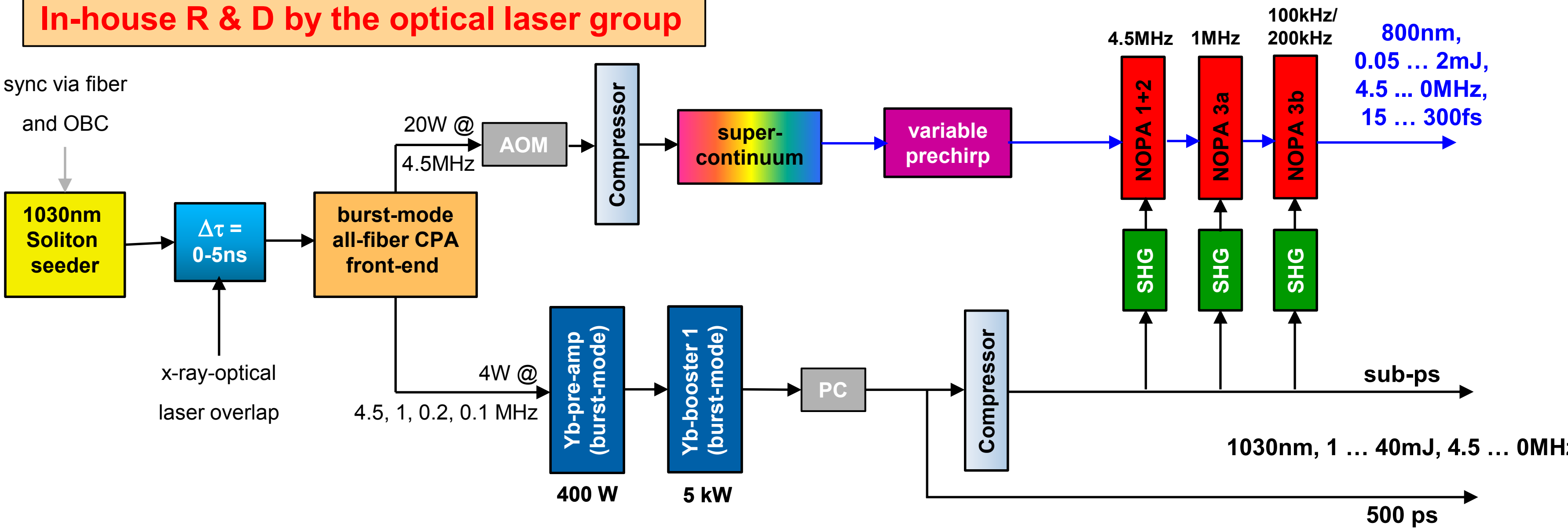
HIBEF → T. Toncian's talk

Pump-Probe (PP) laser goals

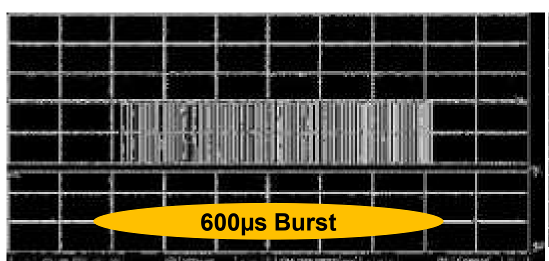
- For all 6 experimental stations. 3 X-ray beams (SASE1, 2, 3), 3 lasers.
  - Up to 60% of experiments require optical lasers
- Match XFEL: 10Hz burst, 0 – 4.5MHz
- Arbitrary pulse pattern selection: 10Hz, 1Hz, shot-on-demand
- Ultrashort pulses with high energies, stability and tune-ability

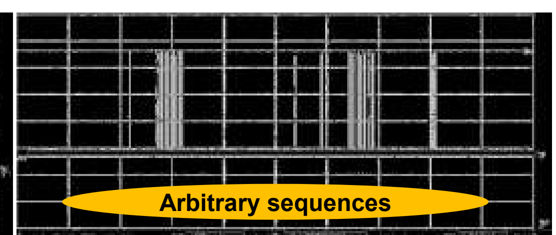
Pump-Probe (PP) laser concept: ***fs-pumped NOPA***

In-house R & D by the optical laser group



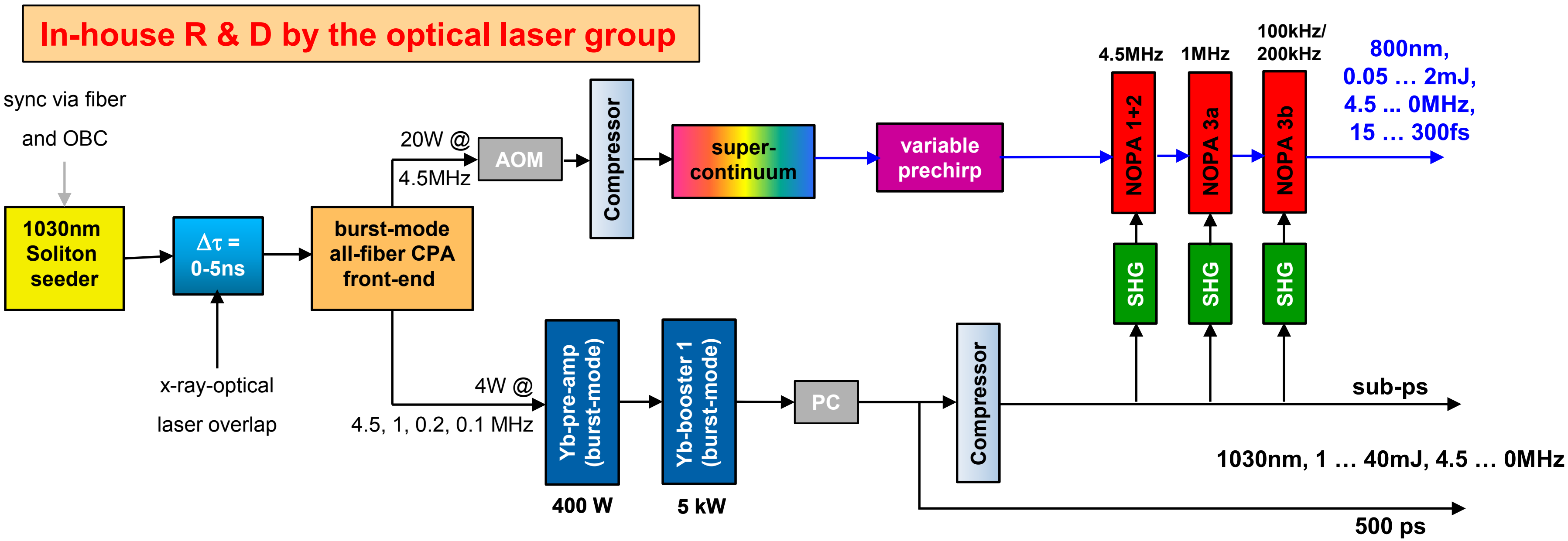
- Burst-mode Yb-all-fiber CPA front-end: 2 synchronous outputs, 100kHz, 200kHz, 1MHz and 4.5MHz
- White light seed generation in YAG (Δλ ≥ 700 – 900 nm) & variable pre-chirp
- Burst-mode 3-stage Yb:amplifier chain (Innoslab-technology): up to 40 mJ, 100kHz – 4.5MHz
- Arbitrary pulse and burst selection for „pulse-on-demand“ (PoD)
- NOPA with 4 set points





Courtesy: OL group (G. Palmer, M. Lederer)

Pump-Probe (PP) laser concept: ***fs-pumped NOPA***



1. A. Dubietis, G. Jonusauskas, and A. Piskarskas, "Powerful femtosecond pulse generation by chirped and stretched pulse parametric amplification in BBO crystal," Opt. Commun. 88, 437–440 (1992)
2. G. Cerullo and S. De Silvestri, "Ultrafast optical parametric amplifiers," Rev. Sci. Instrum. **74**, No. 1 (2003)
3. M.J. Lederer, M. Pergament, M. Kellert, and C. Mendez, "Pump–probe laser development for the European X-Ray Free-Electron Laser Facility," Paper 8504-20, SPIE Conference on Optics and Photonics 2012, 12–16 August 2012, San Diego, invited talk.
4. M. Pergament, M. Kellert, K. Kruse, J. Wang, G. Palmer, L. Wissmann, U. Wegner, and M. Lederer, "High power burst-mode optical parametric amplifier with arbitrary pulse selection," Optics Express, Vol. 22, Issue 18, pp. 22202-22210 (2014)
5. M. Pergament, M. Kellert, K. Kruse, J. Wang, G. Palmer, L. Wissmann, U. Wegner, M. Emons, M. J. Lederer, "340W Femtosecond Burst-mode Non-collinear Optical Parametric Amplifier for the European XFEL Pump-probe-laser," Advanced Solid State Lasers, 04-09. October 2015, Berlin, Germany, ATu4A.4

Courtesy: OL group (G. Palmer, M. Lederer)

Pump-Probe (PP) laser concept: ***fs-pumped NOPA***

λ		
τ_{FWHM}	15…300fs	1ps

2.5 mJ / 15 fs/ 5 μmϕ
→ > 10^{17} W.cm^{-2}

40 mJ / 1 ps
→ ~ 10^{17} W.cm^{-2}
@ 5 μmϕ
→ ≥ 10^{14} W.cm^{-2}
@ 100 μmϕ

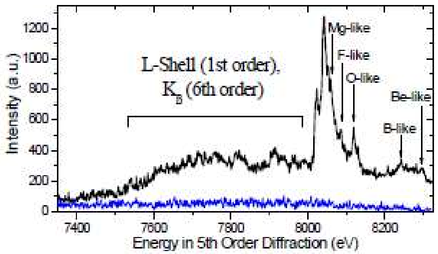
Set point	max. f_{rep} [MHz]	E_{pulse} [mJ] @ 800nm	E_{pulse} [mJ] @ 1030nm
1	4.5	0.05	1
2	1	0.2	4
3	0.2	1	20
4	0.1	2	40

1. A. Dubietis, G. Jonusauskas, and A. Piskarskas, "Powerful femtosecond pulse generation by chirped and stretched pulse parametric amplification in BBO crystal," Opt. Commun. 88, 437–440 (1992)
2. G. Cerullo and S. De Silvestri, "Ultrafast optical parametric amplifiers," Rev. Sci. Instrum. **74**, No. 1 (2003)
3. M.J. Lederer, M. Pergament, M. Kellert, and C. Mendez, "Pump–probe laser development for the European X-Ray Free-Electron Laser Facility," Paper 8504-20, SPIE Conference on Optics and Photonics 2012, 12–16 August 2012, San Diego, invited talk.
4. M. Pergament, M. Kellert, K. Kruse, J. Wang, G. Palmer, L. Wissmann, U. Wegner, and M. Lederer, "High power burst-mode optical parametric amplifier with arbitrary pulse selection," Optics Express, Vol. 22, Issue 18, pp. 22202-22210 (2014)
5. M. Pergament, M. Kellert, K. Kruse, J. Wang, G. Palmer, L. Wissmann, U. Wegner, M. Emons, M. J. Lederer, "340W Femtosecond Burst-mode Non-collinear Optical Parametric Amplifier for the European XFEL Pump-probe-laser," Advanced Solid State Lasers, 04-09. October 2015, Berlin, Germany, ATu4A.4

Courtesy: OL group (G. Palmer, M. Lederer)

Pump-probe laser applications at the HED instrument

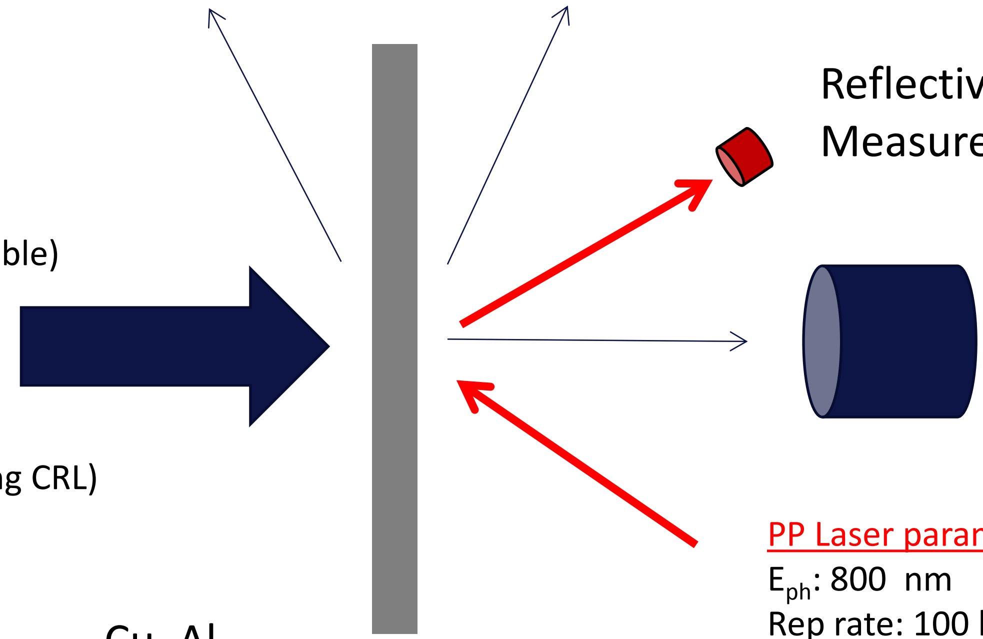
Isochoric X-ray heating; Electron coupling dynamics; Equilibration times (e-e, e-ion)



XES (front)

XES (rear)

Reflectivity/Polarimetry Measurement (ne, Te)



Transmission (attenuation)

Cu, Al,….
Stacked/layered targets

<u>XFEL parameters:</u>

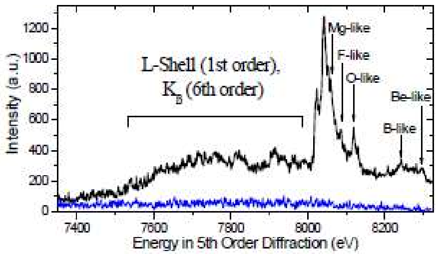
E_{ph}: 8-25 keV (tunable if possible)
Rep rate: 100 kHz
Bandwidth: 10^{-3} - 10^{-4}
Pulse duration: 15-500 fs
Photon flux: > 2×10^{11} (>1 mJ)
Focus: 1 micron (variable using CRL)
Timing jitter: < 15 fs

<u>PP Laser parameters:</u>

E_{ph}: 800 nm
Rep rate: 100 kHz
Pulse duration: 15 fs
Photon energy: < 1 mJ
Timing jitter: < 15 fs

Pump-probe laser applications at the HED instrument

Isochoric optical heating; Shock-compression; Electron coupling dynamics; Phase transitions

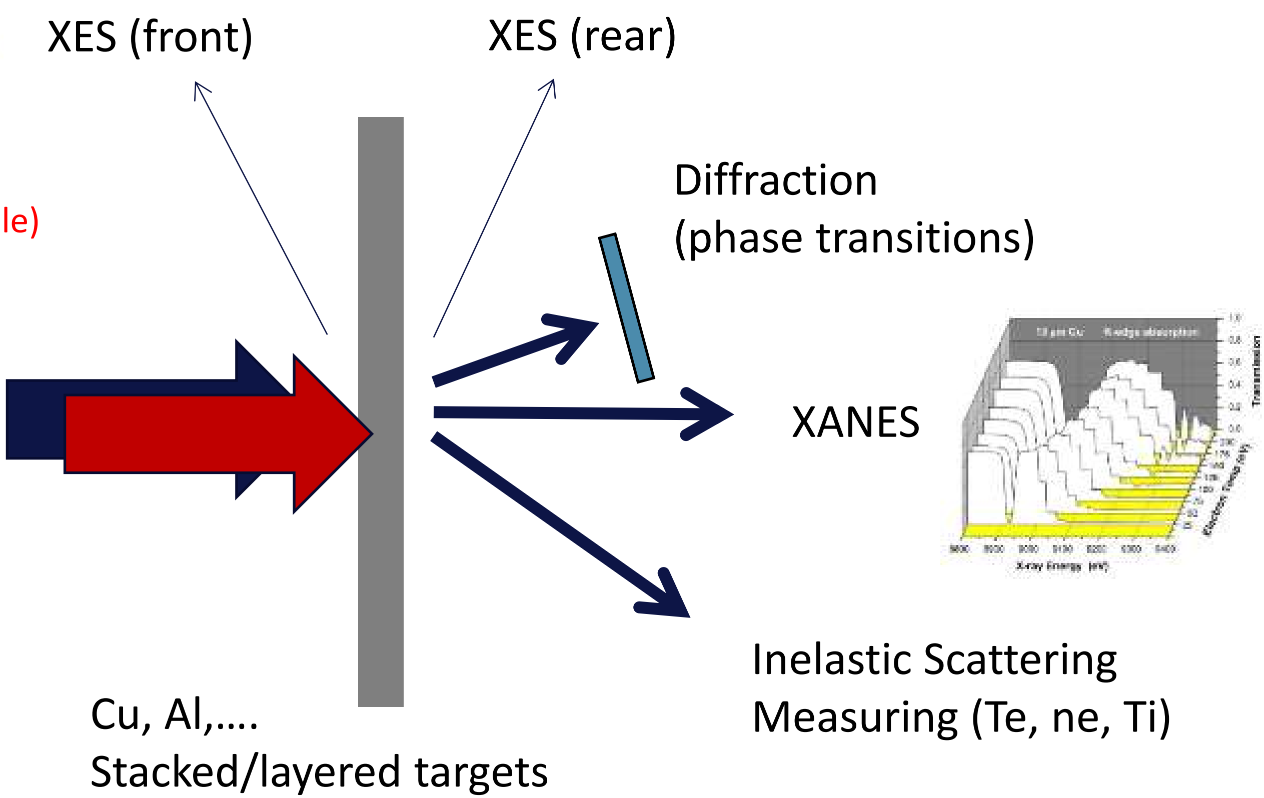


<u>XFEL parameters:</u>

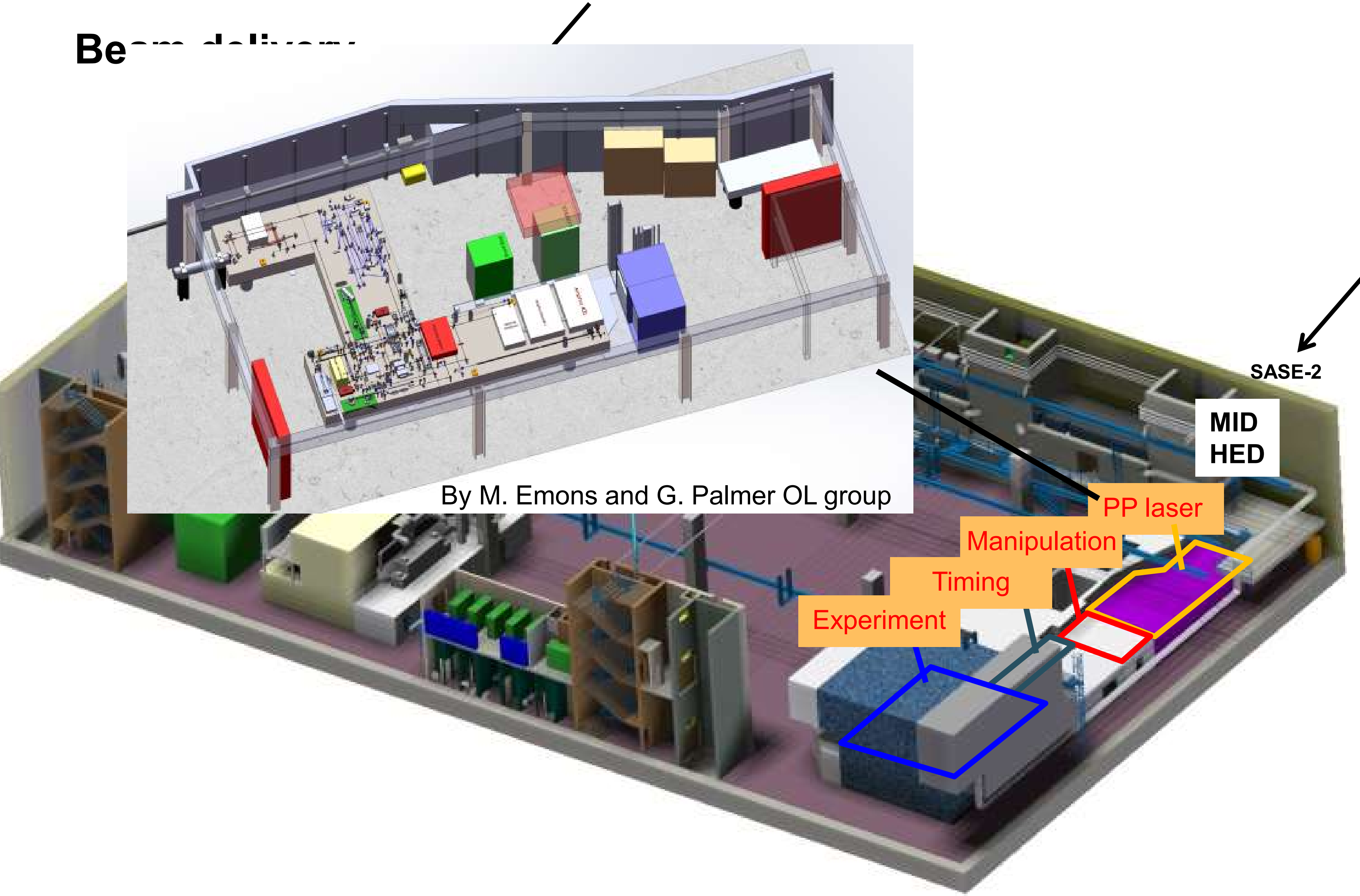
E_{ph}: 5-12 keV (tunable if possible)
Rep rate: 10 Hz
Bandwidth: 10^{-3} - 10^{-4}
Pulse duration: 15 fs
Photon flux: > $2x10^{11}$ (>1 mJ)
Focus: 1 micron
Timing jitter: < 15 fs

<u>PP Laser parameters:</u>

Eph: 800 nm
Rep rate: 10 Hz
Pulse duration: 15-800 fs
Photon energy: 1 -100 mJ
Timing jitter: < 15 fs

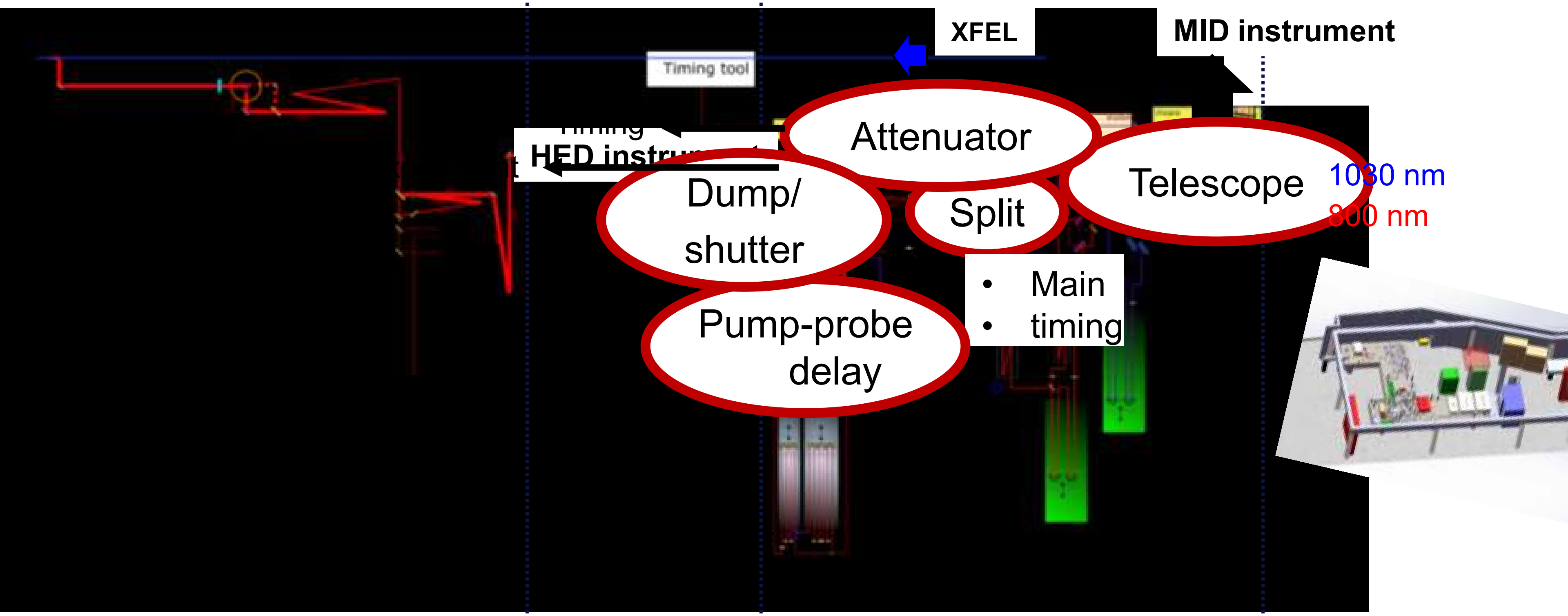


Beam delivery



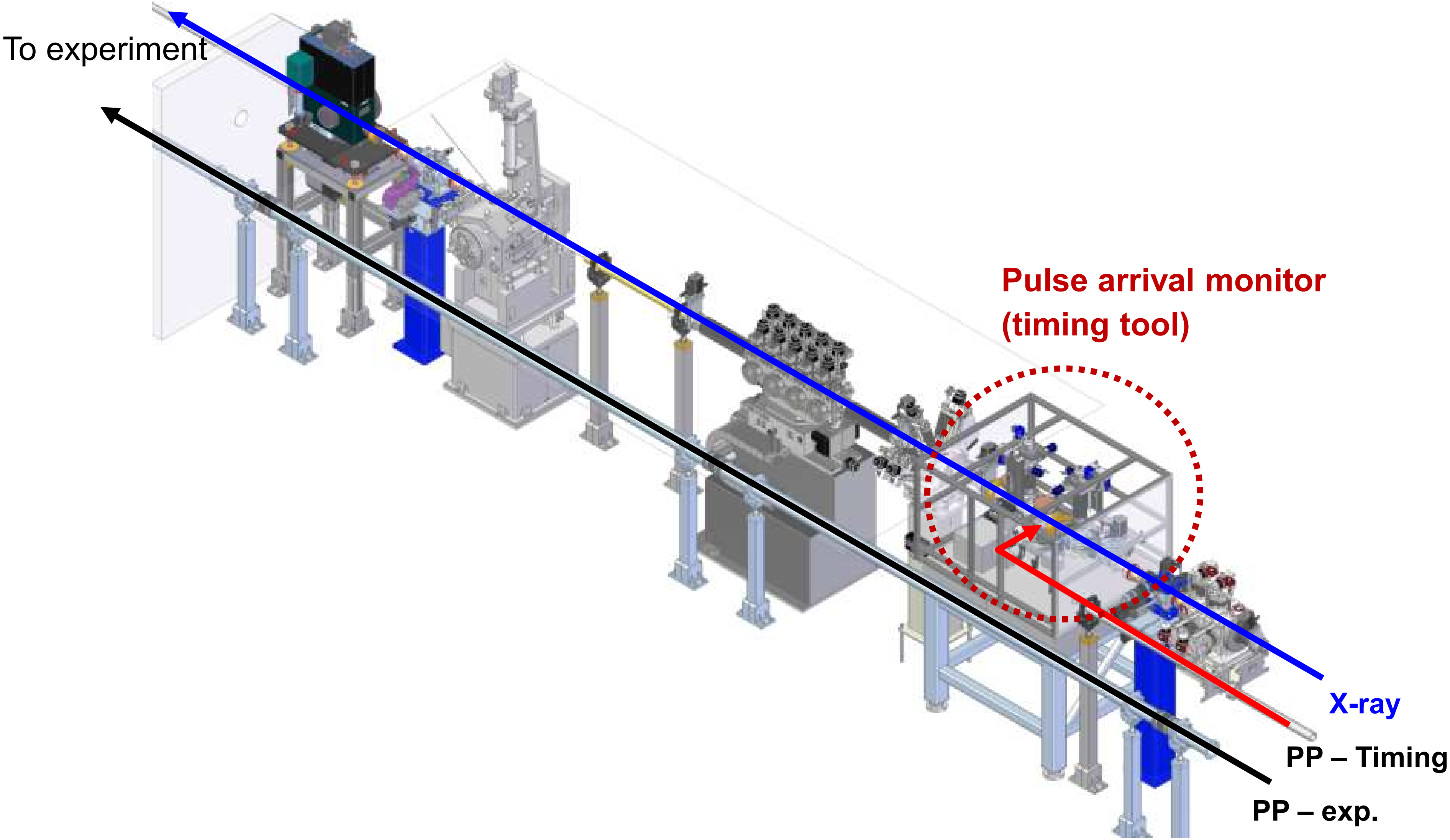
PP transport overview

Sample chamber



HED-EXP	HED-OPT	COM - LAS	SA2-LAS
Experiment	**Timing**	**Manipulation**	**Laser hutch**

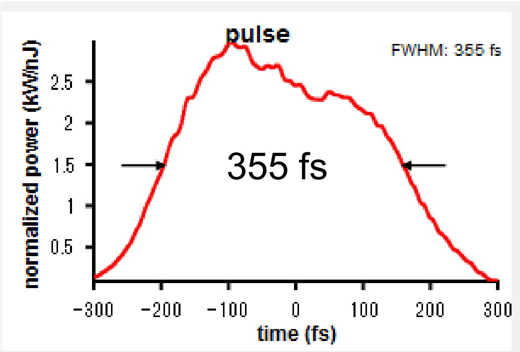
HED – OPT hutch



Dispersion management of 800 nm NOPA pulse (~126 nm bandwidth)

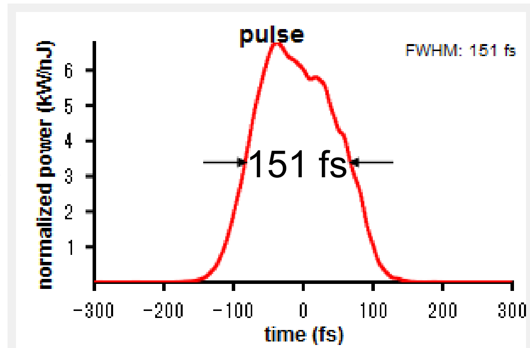
Pulse duration

After final NOPA. Negatively chirped.



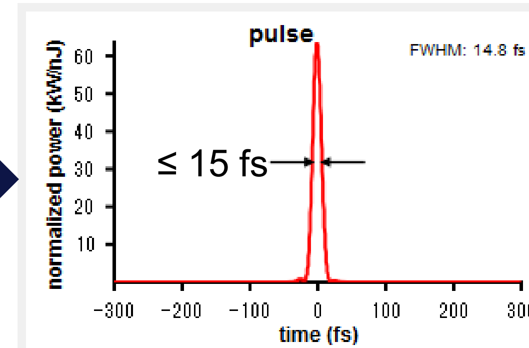
~20m air
~15mm SiO2 window

Entrance of the vac. sample chamber

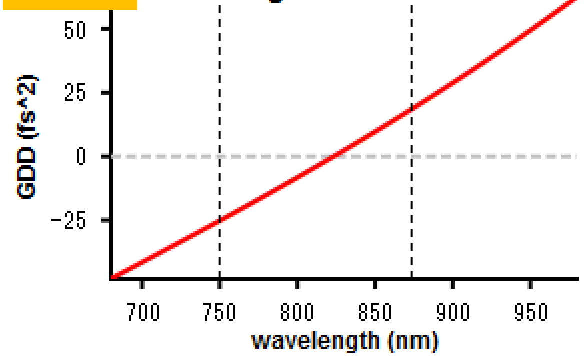


~17 mm SiO2 plate

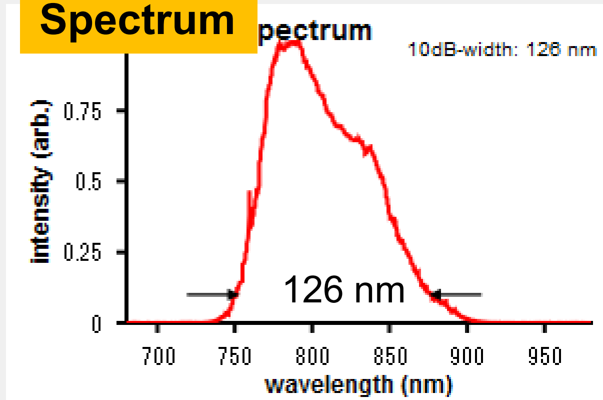
On sample

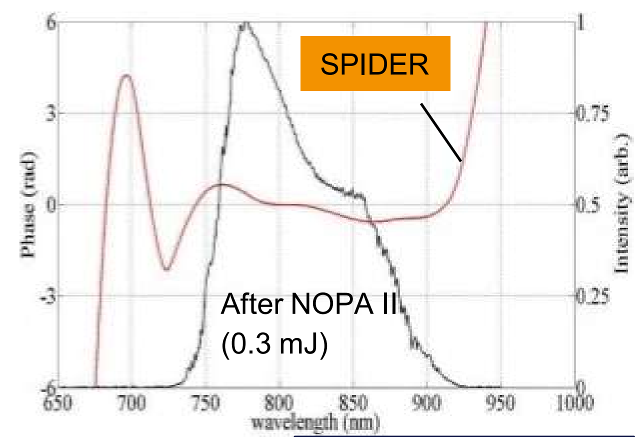


GDD



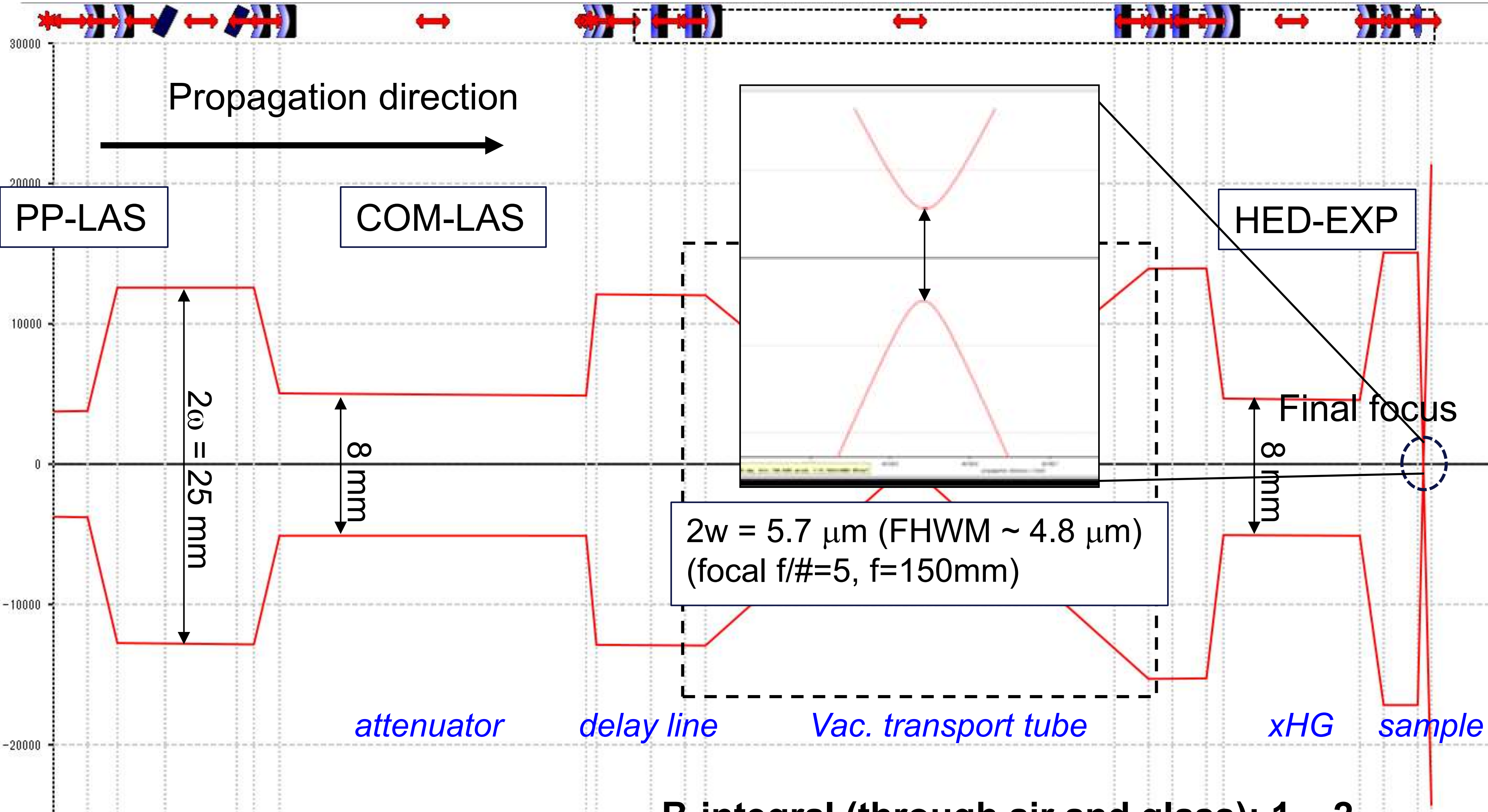
Spectrum





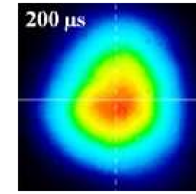
Courtesy: OL group

B-integral management

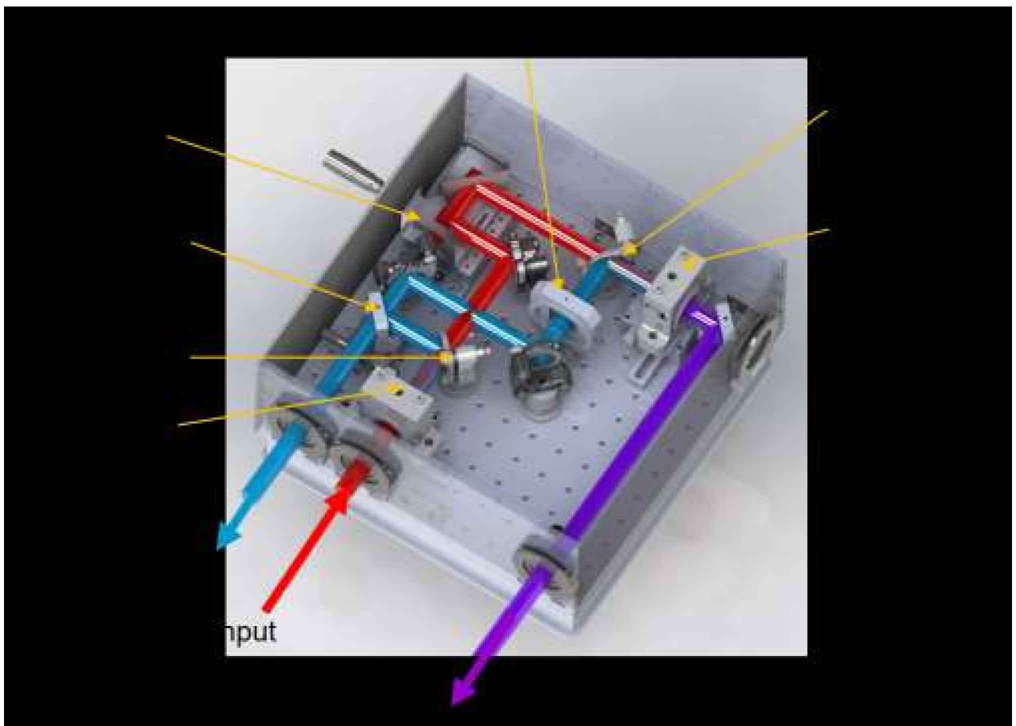


B-integral (through air and glass): 1 – 2

Frequency conversion



- With Beta Barium Borate (BBO) crystals, type I phase matching
- Optical laser group took the lead on design, built and test experiments (G. Palmer)
- Small breadboard footprint 300 x 300 mm

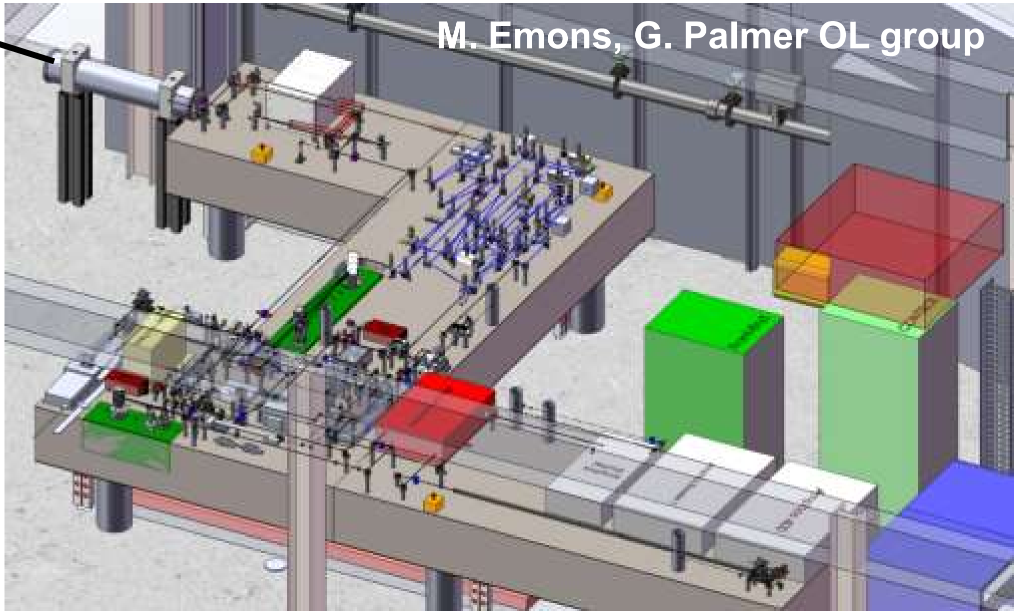


	(mJ)	η	BBO Thickness
800 nm (15 fs)	**2.0**		
400 nm	0.48	20%	110 µm
266 nm	0.028	1.7%	40 µm
1030 nm (850 fs)	**36**		
515 nm	20	56%	1000 µm
343 nm	9	31%	750 µm
257 nm	5.4	16%	400 µm

G. Palmer OL group

SASE2 pump-probe laser installation plan

To experiment



- **1 laser for 2 experiments**
- **Schedule***
  - **Components + comm. laser in laser room: Begin 2018**
  - **Beam handed over to HED : Sept. 2018**
  - **Installation of beam transport optics up to the sample in parallel**

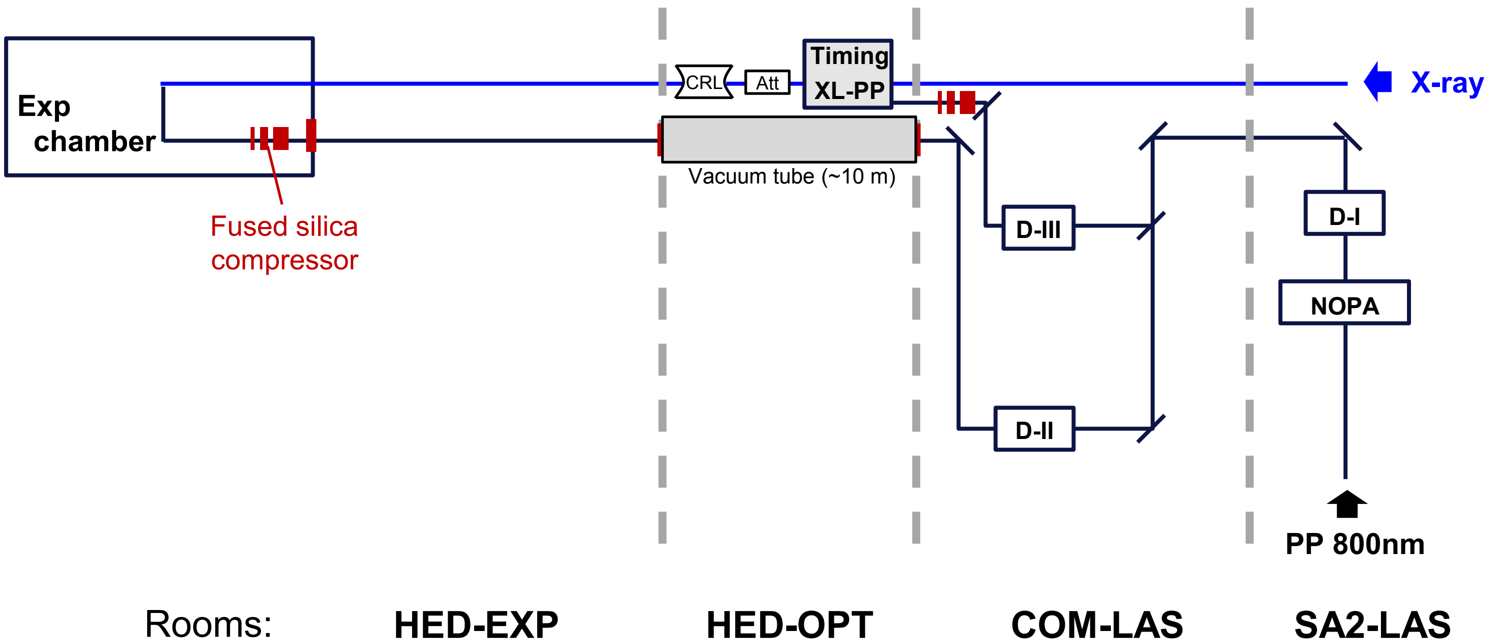
    (Hutch infrastructure ready, fully cleaned in Sept. 2017)
  - **Commissioned, laser ready for users : End 2018 - begin 2019**

* depends on SASE1, 3 progress (lasers, infrastructure, cntl.). step-by-step commissioning:

Pulse arrival relative timing jitter measurement concept

- Temperature +/- 0.1 deg for almost all optical paths
- Humidity controlled
- Laminar flow from AC, actively avoid air fluctuation

For all laser beams, 'absolute' timing will be measured at the TCC with respect to the X-ray. (before each shift etc)



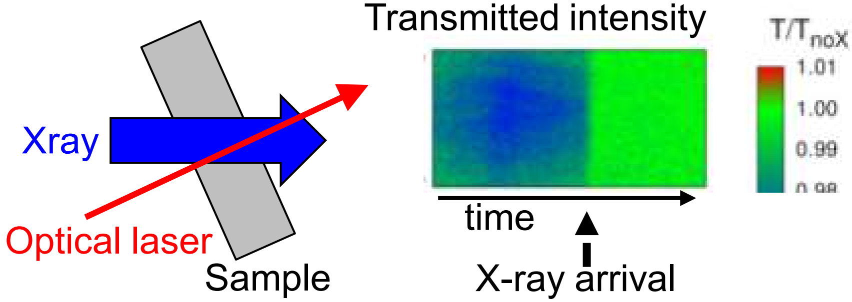
800nm and 1030 nm synchronization is measured / actively feedback in the laser hutch (balanced cross correlator)

Timing jitter measurement between the X-ray and the PP

Expected shot-to-shot jitter: ~ 20 fs + floor vibration, temperature/humidity drift…

Change in transient optical properties due to x-ray photo-excitation

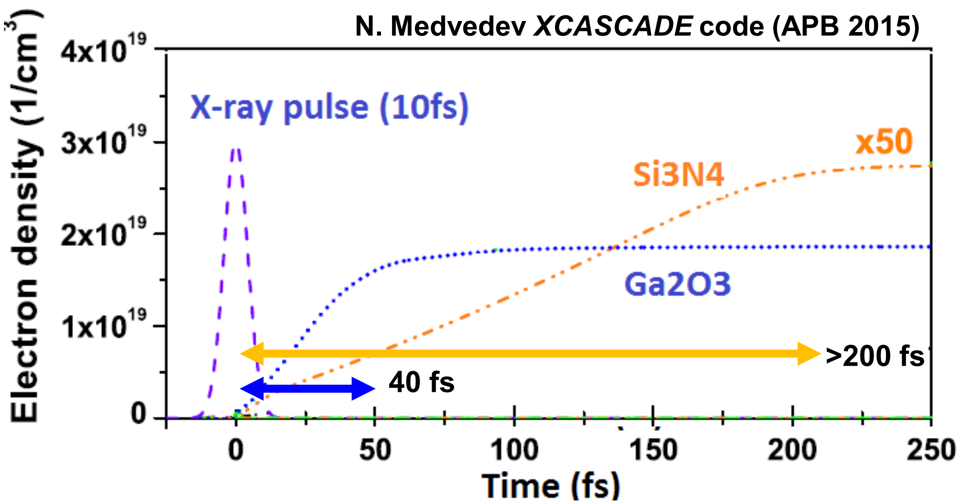
- Upstream, before x-ray attenuator, CRL
- 'Spatial'- and 'spectral'-encoding
- Optimize samples for different hν.
  - ➔ absorption, cascading time



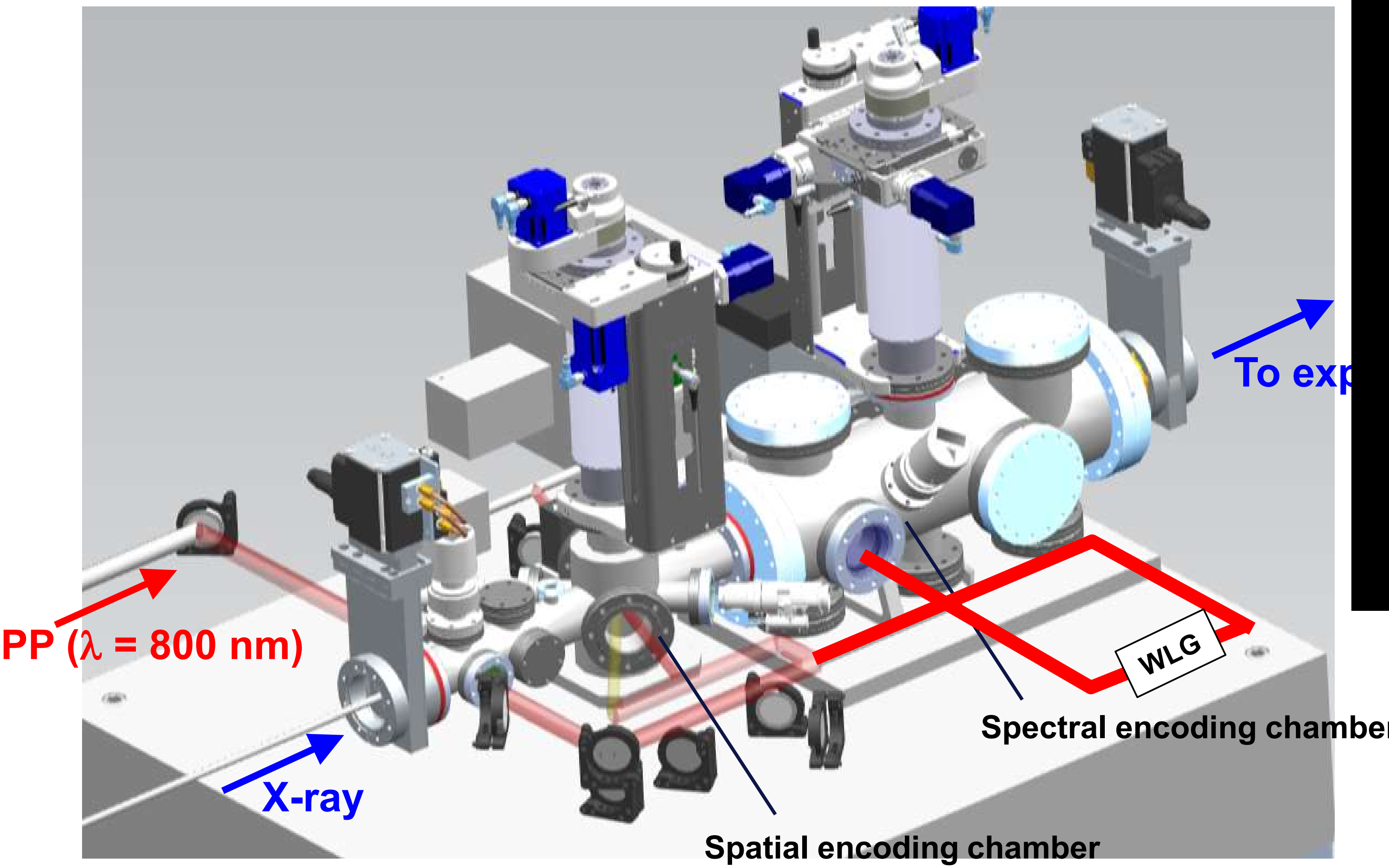
M. Bionta et al., Optics Exp. 19, 21855 (2011)
M. Harmand et al., Nat. Phot. 7, 215 (2013)
Riedel et al., Nat. comm. (2013)
…

	Sample choice
~ 5 keV	SiO_2, diamond, Si_3N_4
~ 8 keV	SnO_2
> 10 keV	Ga_2O_3, $SrTiO_3$, GaAs

Cascading time (10fs 24 keV XFEL)



Timing jitter measurement between the X-ray and the [redacted]

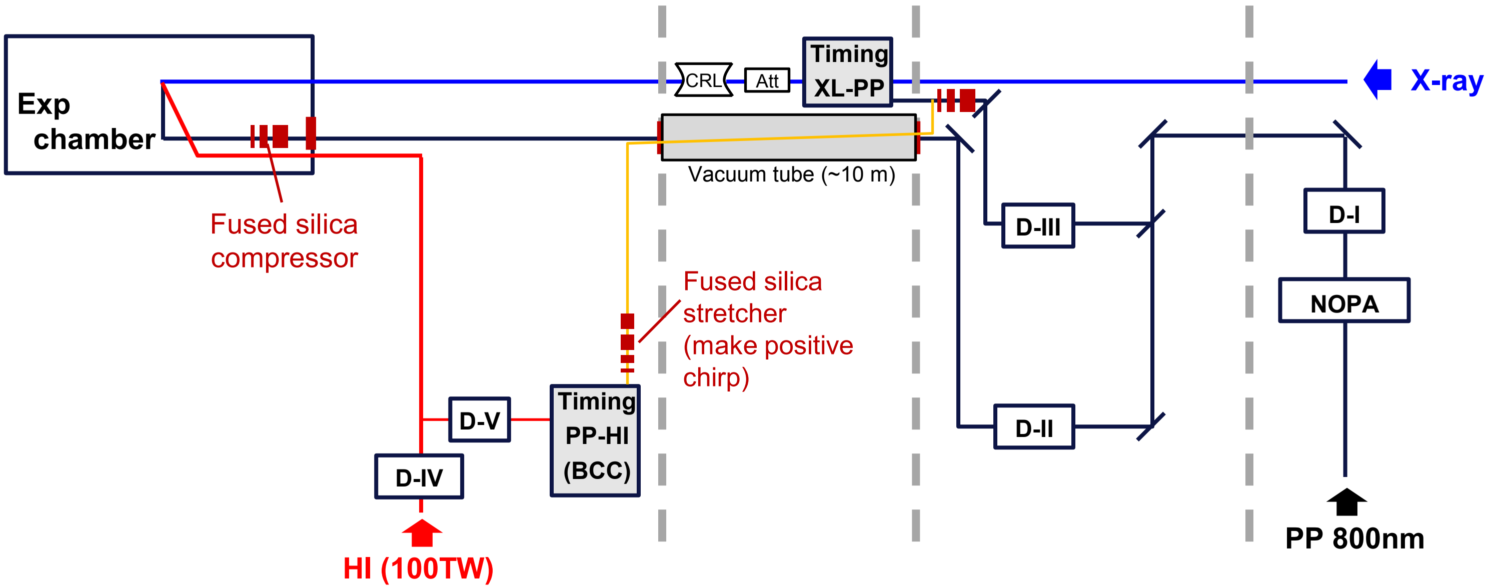


Ian Thorpe, K. Sukharnikov (HED), Jia Liu (WP-74)

HI laser (100 TW) arrival timing measurement

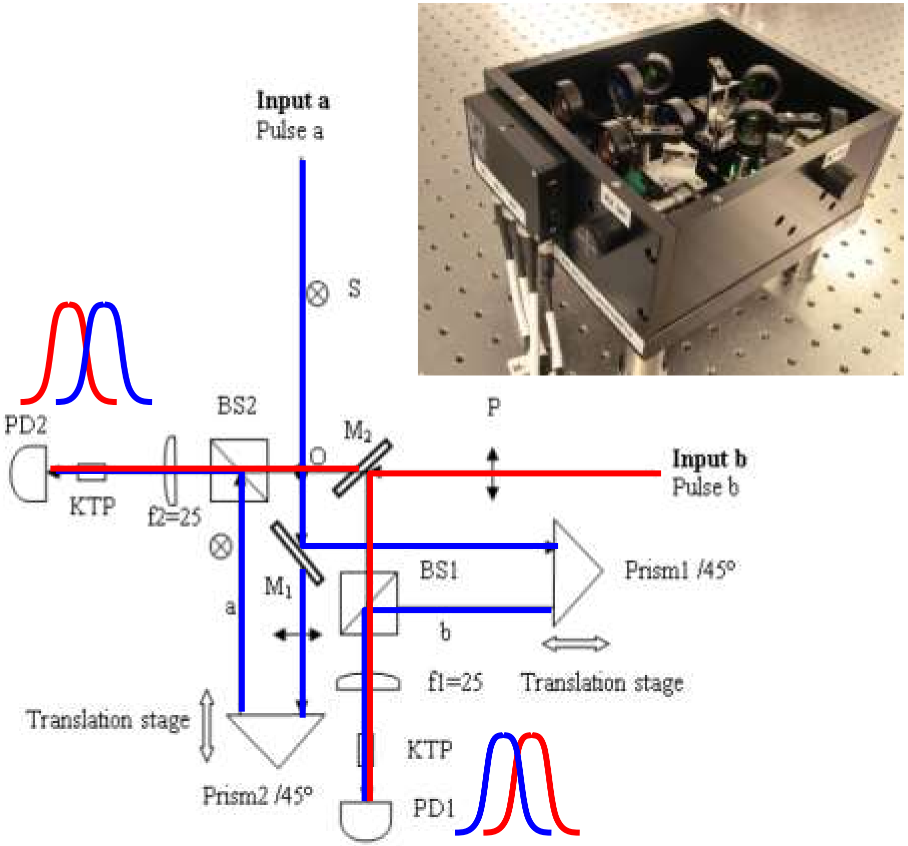
~ balanced cross optical correlator ~

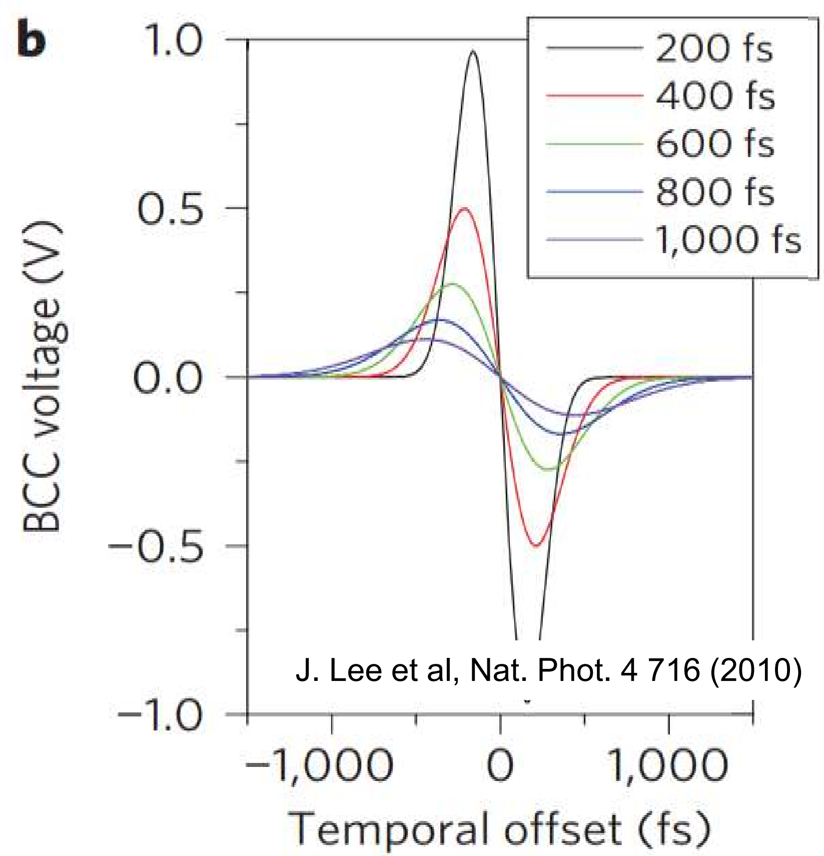
- Timing tool located ~10 m upstream from the sample (space around the IC1 is tight)
- Difficult to bring a HI split beam to the timing tool (path length always longer for the split beam)
- Split the beam before the HI compressor ➔ future



- PP – HI **optical** cross correlation ➔ **'Balanced cross correlator'**
  - Effort initiated by the OL group for NOPA/pump beam synchronization (J. Wang) **~ fs precision**

HI laser (100 TW) arrival timing measurement





- A highly linear proportionality to the temporal offset,
- Zero offset = zero signal. Precision determined by the noise (not by photodetectors): **~ fs precision**

J. Wang OL group

Summary

- **Ultrafast burst-mode pump-probe (PP) optical laser**
  - Concept – nonlinear OPA
  - Operation mode – 2 wavelength (800 nm / 15 – 300 fs, 1030 nm / ps), 4 set points
  - Applications
  - Beam delivery – dispersion, B-integral, spherical aberration management
- ***X-ray* – *optical* relative arrival timing monitor (XFEL – PP)**
  - 10 m upstream from the sample, special / spectral encoding
- ***Optical* – *optical* relative arrival timing monitor (PP – HI 100TW)**
  - Balanced cross correlator

thanks to Laser Group WP78:

Mikhail Pergament
Martin Kellert
Kai Kruse
Jin Wang (BCC)
Guido Palmer (whole PP laser issues)
Gerd Priebe (HI/HE lasers)
Laurens Wissmann
Ulrike Wegner
Moritz Emons (whole PP laser issues)
Daniel Kane
Sandhya Venkatesan
Tomasz Jezynski
Florent Pallas
Max Lederer (group leader)

Thank you for your attention

https://indico.desy.de/conferenceDisplay.py?confId=16772

European XFEL

HiBEF USER CONSORTIUM

HED High-Energy Density science

Workshop: High Intensity Laser Matter Science at The HED Instrument at The European XFEL

5-6 April 2017 *European XFEL, Schenefeld*

Europe/Berlin timezone

Search

Overview

Scientific Programme

Registration

Registration Form

List of registrants

Accomodation

List of hotels including transfer information

How to get to the European XFEL

The High-Energy-Density (HED) instrument at the European XFEL and the HIBEF User Consortium are inviting for the Workshop: High Intensity Laser Matter Science at the HED instrument at European XFEL. This event will cover technical details of the available experimental infrastructure, early user experiments and future plans, as well as technical details of the available experimental infrastructure. It is ideally addressing potential users that intend to submit a project to the HED instrument in one of the first calls for proposals. The meeting aims also at paving the path for discussion and future collaborations.

The scientific topics to be covered include:

- properties of highly-excited solids
- ionization dynamics at high intensities
- relativistic laser plasma interaction
- high energy density states of matter
- energetic particle propagation in matter
- investigation of microscopic dynamics details of laser-driven radiations and acceleration of particles (mostly in solid density systems)
- XFEL probing techniques for high-intensity laser matter Interactions (e.g., X-Ray Thomson Scattering, Small Angle X-ray Scattering, Coherent X-ray Diffraction Imaging, X-ray Faraday Rotation, X-Ray Diffraction, X-ray Absorption Spectroscopies,...)
- probing QED effects

Registration now open (deadline: 28 Feb. 2017)

Organizing committee:

Motoaki Nakatsutsumi - European XFEL,
Toma Toncian - Helmholtz-Zentrum Dresden-Rossendorf.

Advising committee:

Ulf Zastrau - European XFEL,
Thomas Tschentscher - European XFEL,
Ulrich Schramm - Helmholtz-Zentrum Dresden-Rossendorf,
Thomas Cowan - Helmholtz-Zentrum Dresden-Rossendorf.