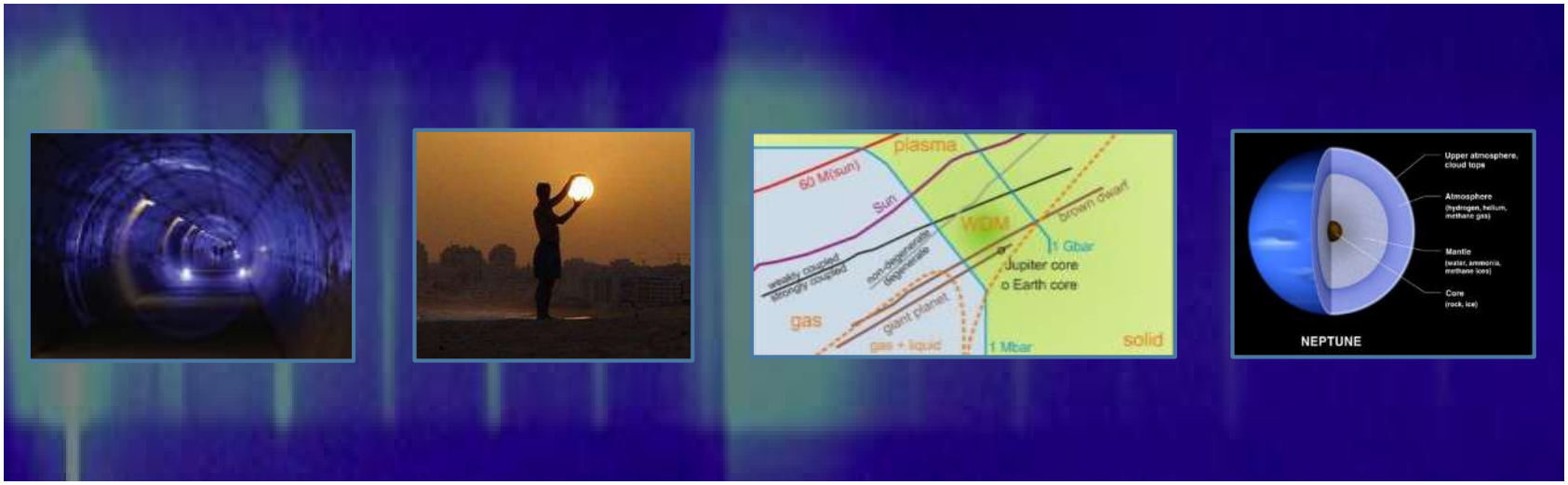
The HED Instrument at the European XFEL
Status in 2020

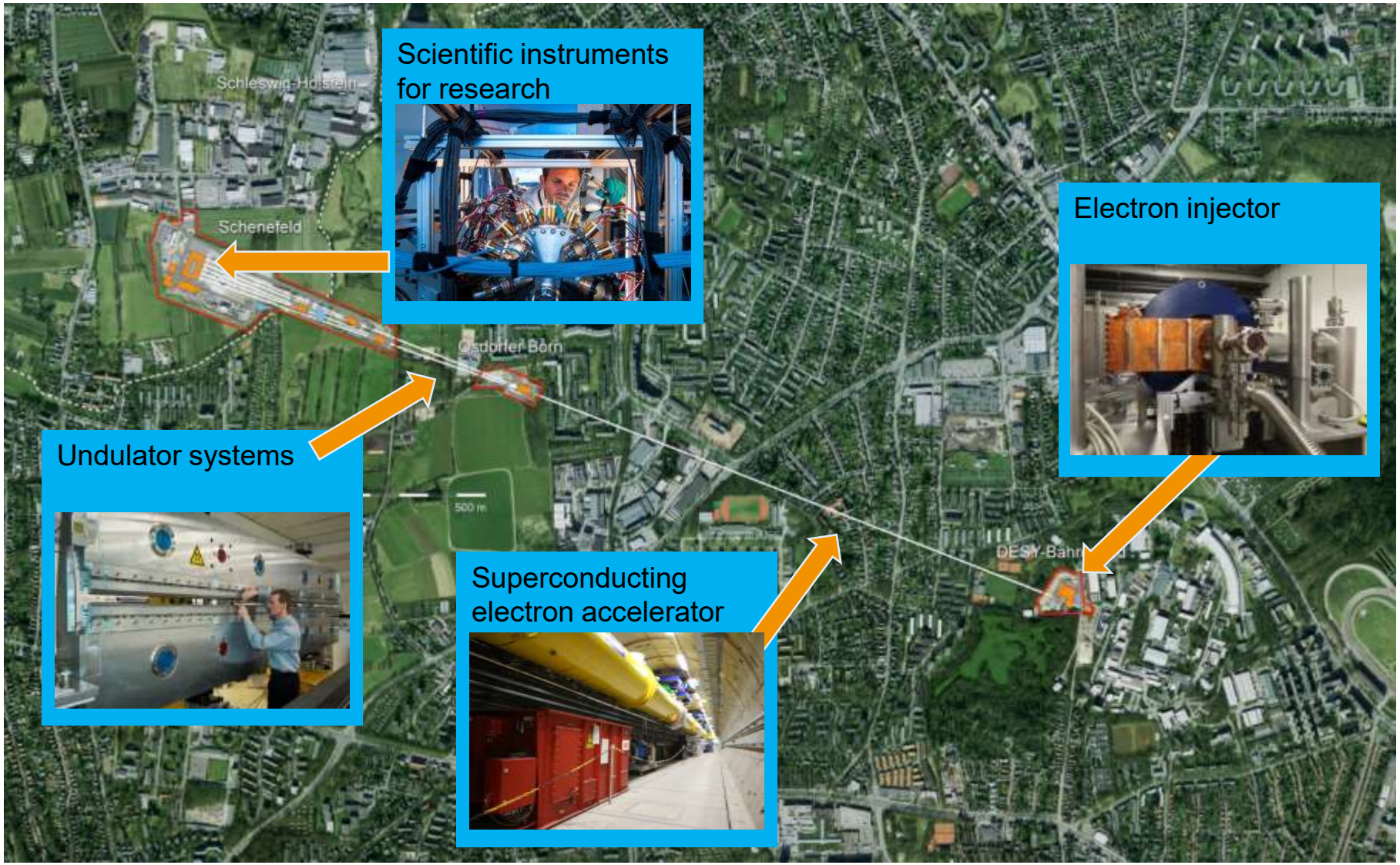
Ulf Zastrau
Group Head
HED science instrument at the European XFEL

HED-HiBEF satellite meeting to the EuXFEL/DESY UM 2020,
January 28th, 2020, EuXFEL, Germany

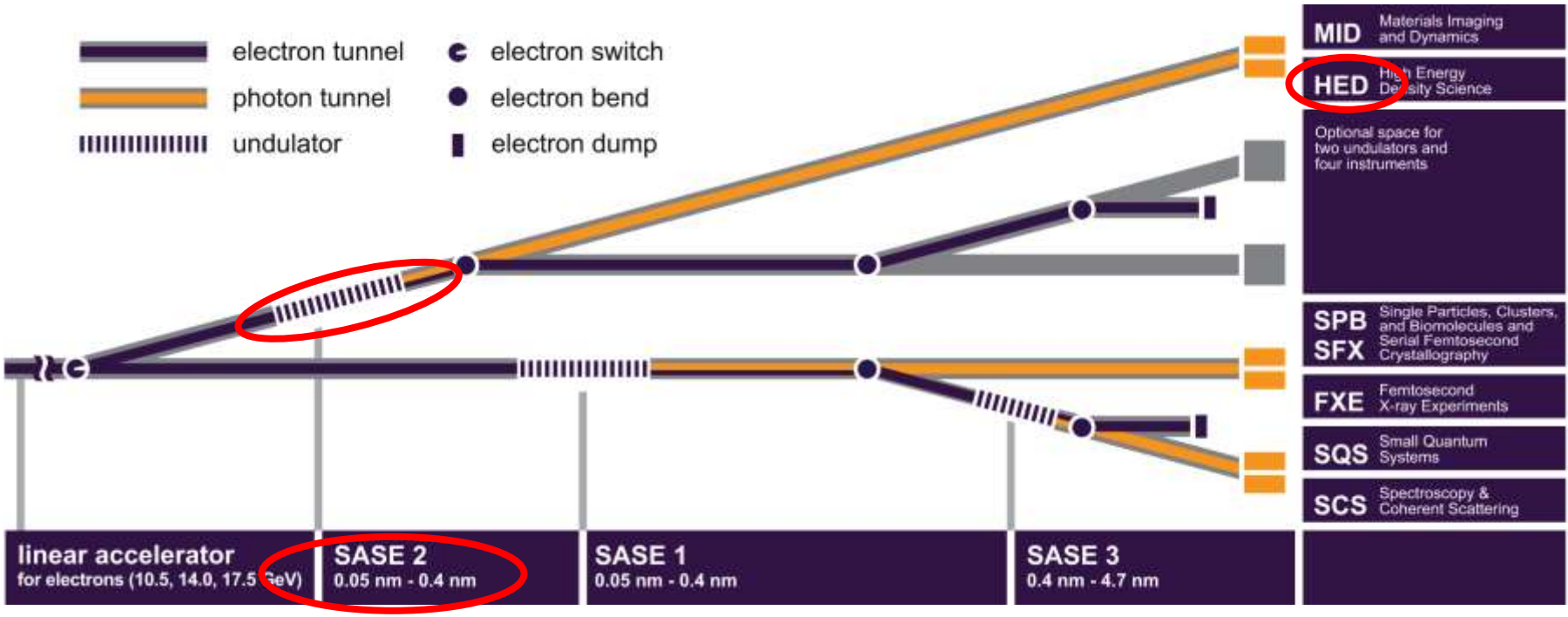


European XFEL—a leading new research facility

How it works: a closer look at the facility



European XFEL: beamlines and instruments



- 8 keV lasing in SASE1 with up to 1 mJ — May 2017
- First experiments at SASE1 — Sept. 2017
- First experiments at HED — May 2019

We achieved a lot since the last UM 2019

X-rays in HED OPT: 5 Dec 2018 – X-rays in HED EXP: 10 April 2019

HED schedules 2019, 2020

HED-HIBEF Run 3

40% x-ray time to 3 user proposals

January	February	March	April	May	June
1 Tu New Year's Day	1 Fr	1 Fr slits+dump	1 Mo 14	1 We 11.5	1 Sa
2 We	2 Sa	2 Sa XGM, IPM 1,2	2 Tu	2 Th 11.5	2 Su
3 Th	3 Su	3 Su IPM 1 and 2	3 We	3 Fr 11.5	3 Mo 23
4 Fr	4 Mo	4 Mo IC1 target stage 10	4 Th	4 Sa 11.5	4 Tu
5 Sa	5 Tu	5 Tu IC1 target stage	5 Fr	5 Su 11.5	5 We
6 Su	6 We	6 We IC1 target stage	6 Sa	6 Mo 11.5 GeV	6 Th
7 Mo 7	7 Th	7 Th CRL1 collimation	7 Su	7 Tu 11.5 GeV	7 Fr
8 Tu	8 Fr	8 Fr CRL2 focus	8 Mo 15	8 We 11.5 GeV	8 Sa
9 We	9 Sa	9 Sa CRL3 focus	9 Tu	9 Th 11.5 GeV	9 Su
10 Th	10 Su	10 Su CRL3 focus	10 We diamond inline spectrom	10 Fr 11.5 GeV	10 Mo Winterbreak 24
11 Fr	11 Mo 7	11 Mo 11	11 Th diamond inline spectrom	11 Sa 11.5 GeV	11 Tu
12 Sa	12 Tu	12 Tu ePIX100	12 Fr diamond inline spectrom	12 Su 11.5 GeV	12 We
13 Su	13 We 4BS and BIU	13 We ePIX100	13 Sa CRL4 tests	13 Mo 20	13 Th
14 Mo 8	14 Th view beam	14 Th ePIX100	14 Su CRL4 tests	14 Tu	14 Fr
15 Tu	15 Fr in OPT hutch	15 Fr JUNGFRAU	15 Mo CRL4 tests 16	15 We	15 Sa
16 We	16 Sa M1,2,3: angles	16 Sa JUNGFRAU	16 Tu	16 Th	16 Su
17 Th	17 Su M1,2,3: angles	17 Su JUNGFRAU	17 We	17 Fr	17 Mo 25
18 Fr	18 Mo	18 Mo 15	18 Th	18 Sa	18 Tu
19 Sa	19 Tu and coating	19 Tu XRD, curved rails	19 Fr Good Friday	19 Su	19 We
20 Su	20 We transm. w/ XGM	20 We XRD, curved rails	20 Sa	20 Mo 21	20 Th
21 Mo 9	21 Th IPM1 vs XGM	21 Th XRD, curved rails	21 Su	21 Tu	21 Fr
22 Tu	22 Fr ATT transm.	22 Fr 3rd harmonic	22 Mo Easter Monday	22 We	22 Sa
23 We	23 Sa CRL3 transm.	23 Sa 3rd harmonic	23 Tu	23 Th	23 Su
24 Th	24 Su SI111 mono	24 Su 3rd harmonic	24 We 11.5 GeV	24 Fr	24 Mo 26
25 Fr	25 Mo 9	25 Mo 19	25 Th 11.5 GeV	25 Sa	25 Tu
26 Sa	26 Tu SI111 mono	26 Tu	26 Fr 11.5 GeV	26 Su	26 We
27 Su	27 We SI533 mono	27 We	27 Sa 11.5 GeV	27 Mo	27 Th
28 Mo EXP Cables delivered	28 Th SI533 mono	28 Th	28 Su 11.5 GeV	28 Tu	28 Fr
29 Tu		29 Fr	29 Mo 11.5 GeV 18	29 We	29 Sa
30 We		30 Sa	30 Tu 11.5 GeV	30 Th	30 Su
31 Th		31 Su		31 Fr	

EXP hutch comm.
hardware installation, hutch access
advanced commisioning 2151 Makita EuXFEL 9 keV, CRLs
Experiment Setup/ Comm. for 2191: Si 111 mono Si 533 mono diod analyzers targets
Science program: 2180 Kraus/Kraus H2DR 6 keV 2µm focus
OPT hutch comm
EXP Cables pulled
OPT hutch comm
final hardware fixes, hutch access
advanced commisioning 2191 Zastrau/Gregori EuXFEL/U Oxford 7498 eV @ SI533 mono
Experiment Setup 2194
EXP Cables E2E
Strategic development: 2194 Schulze/Uschmann Univ Jena / HI Jena 6457 eV @ SI440 1 shift setup change to 9835 eV @ diamond 400
OPT hutch comm
Experiment Setup/ Comm. for 2151: all CRLs, detectors, special targets characterize 6keV 2µm for 2180.
Experiment Setup/ Comm. for 2180: HAPG spectrometer inline diamond spec.

HED Calendar 2019, 4th Call 40% x-ray time to 4 user proposals

July	August	September	October	November	December
1 Mo 27	1 Th	1 Su	1 Tu	1 Fr	1 Su
2 Tu	2 Fr	2 Mo 36	2 We	2 Sa	2 Mo 49
3 We	3 Sa	3 Tu	3 Th Tag d. Dt. Einheit	3 Su	3 Tu
4 Th	4 Su	4 We	4 Fr	4 Mo 45	4 We
5 Fr	5 Mo 32	5 Th	5 Sa	5 Tu	5 Th
6 Sa	6 Tu	6 Fr	6 Su	6 We 11.5 GeV	6 Fr
7 Su	7 We 5 USER (resch.d)	7 Sa	7 Mo 41	7 Th 2 COMM: IPM2	7 Sa
8 Mo 28	8 Th # 2151 Makita	8 Su	8 Tu	8 Fr 3 COMM:	8 Su
9 Tu	9 Fr CLR3, 4	9 Mo 37	9 We 16.5 GeV	9 Sa CAEP spectrom	9 Mo 50
10 We	10 Sa focus, nanofoc	10 Tu	10 Th 5 #2392 USER	10 Su 8 keV	10 Tu
11 Th	11 Su 9 keV 1mJ 1 bn	11 We 5+1 COMM:	11 Fr McWiliams IC2	11 Mo 46	11 We
12 Fr	12 Mo 33	12 Th x-ray timing	12 Sa DAC community	12 Tu	12 Th
13 Sa	13 Tu	13 Fr PAM-TW laser	13 Su 14-18 keV (MID)	13 We 11.5 GeV	13 Fr
14 Su	14 We 5+1 USER EXPT	14 Sa 10 Hz 1 bunch	14 Mo 42	14 Th 5 COMM:	14 Sa
15 Mo 29	15 Th # 2353 Lee	15 Su 7.5 - 12 keV 1bn	15 Tu	15 Fr SDL and	15 Su
16 Tu	16 Fr x-ray heating	16 Mo 38	16 We 5 IHR (ex #2314)	16 Sa SDL imagers	16 Mo 51
17 We 4.5 MHz 2 COM	17 Sa nanofocus 200nm	17 Tu	17 Th Konopkova/St'mn	17 Su 8 keV	17 Tu
18 Th FSS (8-14 keV)	18 Su 9 keV 1 mJ 1 bn	18 We CONTINGENCY	18 Fr DAC spectroscoy	18 Mo 47	18 We
19 Fr 3 IHR:	19 Mo 34	19 Th 1 IHR	19 Sa IC1	19 Tu	19 Th
20 Sa hrIXS 7.5 keV	20 Tu	20 Fr 3 COMM:	20 Su 13 keV	20 We	20 Fr
21 Su IXS 7.6 keV	21 We CONTINGENCY	21 Sa SAXS analyzer	21 Mo 43	21 Th	21 Sa
22 Mo 30	22 Th 1 IHR	22 Su 9 keV 1 bn	22 Tu	22 Fr	22 Su
23 Tu	23 Fr 3 COMM:	23 Mo 39	23 We 5 # 2293 USER	23 Sa	23 Mo 52
24 We maybe 4.5 MHz	24 Sa HIREX II	24 Tu	24 Th Dresselh/Eggert	24 Su	24 Tu
25 Th 4+1 COMM:	25 Su 8-10 keV 1 bn	25 We 3 COMM:	25 Fr BD Microscopy	25 Mo 48	25 We
26 Fr ePIX10k, JF burst	26 Mo	26 Th IC2 and VAREX	26 Sa	26 Tu	26 Th
27 Sa 8-12 keV 1-100 b	27 Tu	27 Fr 14 keV 1-100 bn	27 Su 11 keV	27 We	27 Fr
28 Su CONTINGENCY	28 We	28 Sa 2 COMM: pulsed	28 Mo 44	28 Th	28 Sa
29 Mo 31	29 Th	29 Su laser heating	29 Tu	29 Fr	29 Su
30 Tu	30 Fr	30 Mo 40	30 We	30 Sa	30 Mo 1
31 We	31 Sa		31 Th Reformationstag		31 Tu

Calendar 2020, Run5

40% x-ray time to 4 user proposals

January	February	March	April	May	June
1 We	1 Sa	1 Su ePIX rad tests	1 We Kraus 14	1 Fr TW+PAM	1 Mo
2 Th	2 Su	2 Mo	2 Th 6000 keV	2 Sa TW+PAM	2 Tu 16.5 GeV slot12
3 Fr	3 Mo pulsed la	3 Tu slot2 mono cool	3 Fr CRL3	3 Su TW+PAM	3 We Nakatsutsumi 23
4 Sa	4 Tu heating IC2	4 We Mono111 edges 10	4 Sa LC: Tom	4 Mo	4 Th 9000 eV
5 Su	5 We 6	5 Th harmonics	5 Su	5 Tu slot9	5 Fr TW or pp laser
6 Mo	6 Th	6 Fr 3 COMM	6 Mo	6 We 3 COMM 19	6 Sa
7 Tu	7 Fr	7 Sa CRL 1&3, 9 & 6 keV	7 Tu slot6	7 Th preplasma TW	7 Su
8 We 2	8 Sa	8 Su (Makita CRL3)	8 We contingency 15	8 Fr LC: Carsten, Toma	8 Mo
9 Th	9 Su	9 Mo	9 Th setup time	9 Sa 2 COMM	9 Tu
10 Fr	10 Mo TW laser	10 Tu slot3	10 Fr 2 COMM	10 Su SAXS with TW	10 We 24
11 Sa	11 Tu maintenance	11 We Makita 11	11 Sa XANES spec	11 Mo 100 pC	11 Th
12 Su	12 We 7	12 Th 9000 keV	12 Su 2 COMM	12 Tu	12 Fr
13 Mo	13 Th	13 Fr CRL4	13 Mo XANES demo	13 We 20	13 Sa
14 Tu TÜV rehearsal	14 Fr	14 Sa LC: Motoaki	14 Tu	14 Th	14 Su
15 We TÜV rehearsal	15 Sa	15 Su	15 We setup time 16	15 Fr	15 Mo
16 Th TÜV rehearsal	16 Su	16 Mo	16 Th	16 Sa	16 Tu
17 Fr	17 Mo TW laser	17 Tu intervention	17 Fr	17 Su	17 We 25
18 Sa	18 Tu EMP testing	18 We 12	18 Sa	18 Mo	18 Th
19 Su	19 We detector 8	19 Th	19 Su	19 Tu slot10	19 Fr
20 Mo TÜV test	20 Th	20 Fr	20 Mo	20 We 100 pC 21	20 Sa
21 Tu TÜV test	21 Fr beam	21 Sa	21 Tu 11.5 GeV slot7	21 Th 5 COMM	21 Su
22 We 4	22 Sa height	22 Su	22 We Schlenvoigt 17	22 Fr PAM studies	22 Mo
23 Th	23 Su etc	23 Mo	23 Th 6457 eV	23 Sa pp+TW laser	23 Tu
24 Fr	24 Mo	24 Tu slot4	24 Fr LC: Sebastian	24 Su LC: Motoaki	24 We 26
25 Sa	25 Tu Slot1	25 We Lee 13	25 Sa	25 Mo	25 Th
26 Su	26 We transmission 9	26 Th 9000 eV	26 Su	26 Tu slot11	26 Fr
27 Mo	27 Th CRL1, 2	27 Fr CRL4	27 Mo	27 We 16.5 GeV 22	27 Sa
28 Tu	28 Fr alignment	28 Sa LC: Jan-Patrick	28 Tu 11.5 GeV slot8	28 Th dDAC+AGIPD IC2	28 So
29 We UM	29 Sa SBM + gratings	29 Su	29 We contingency 18	29 Fr day: laser setup	29 Mo
30 Th UM		30 Mo	30 Th contingency	30 Sa	30 Tu
31 Fr UM		31 Tu slot5		31 Su high-Z det. test	

In our first year of x-ray operation,
40% x-ray time is given to user proposals

Facility Development

X-ray Operation (NIGHT)

X-ray Operation (DAY)

Unique capabilities arise when:

Couple XFEL beam to powerful drivers

- 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

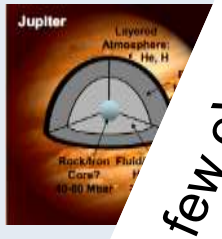
HED – research at extremes

high density $\rho > \rho_0$, T < few eV

solid density $\rho = \rho_0$, T up to keV

Laser Compression

Shock & ramp compr



XRD, IX

Long-p laser

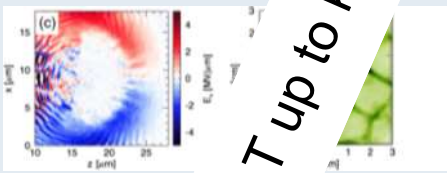
Relativistic Laser-Plasmas

Electron transpor

Instabilities and filam

Particle acceler

High EM fi



Multi-10 laser

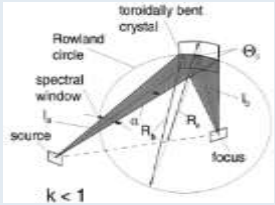
Advanced methods

Spectrometers

Advanced focusing

IXS, SAXS

Phase contrast imaging

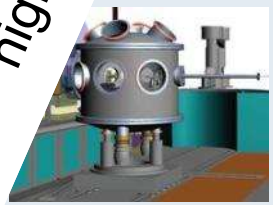


Diam vil Cells

Fast piezo DAC

Puls heated DAC

stage DAC

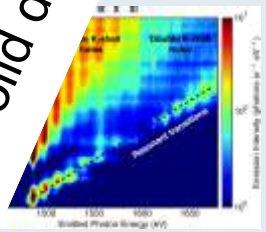


18 to 25 keV

Isochor excitation

Tra roperties,

H oms, rates



XES, IXS, XRD

Tight focusing

Further projects

Isobaric heating

Cryogenic jet targets

High-rep solids targets

EMP-hard X-ray detectors

High-purity polarimetry

…

6th call parameters (closed Dec 11, 2019), for 2020-II

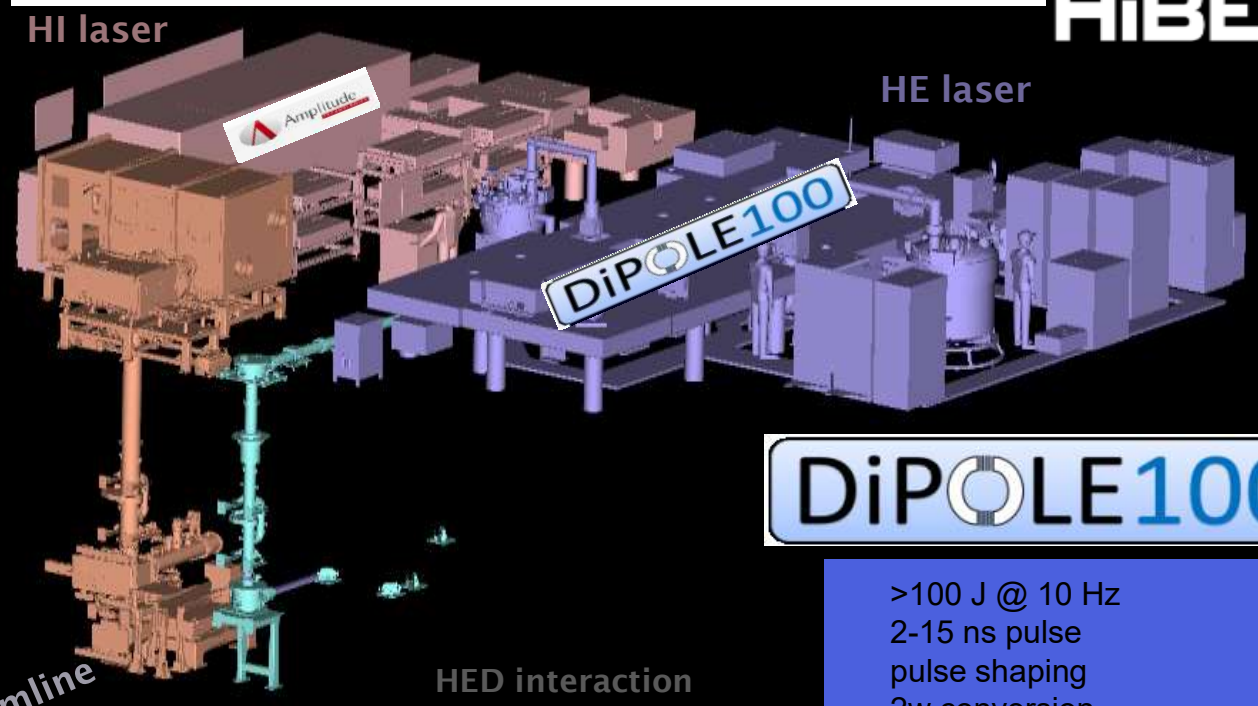
- **We (still) offer only a reduced scope**
  - 5-24 keV x-ray photon energy
  - Single pulses on demand, or 10 Hz,
    or up pulse trains with 4.5 MHz rep. rate and max. 200 µs window
  - SASE spectrum (about 0.2% bandwidth)
  - 4-bounce monochromator (1 eV bandwidth) at 10 Hz
  - High res-mono@7.49 keV (about 40 meV bandwidth) at 10 Hz
  - full focusing capability CRL 1,2,3,4
    any focus from parallel beam (few µrad divergence) down to sub-µm foci
  - "HIREX2" spectrometer in the SASE2 branch (before the separation into MID and HED) for monitoring the incident spectrum

- **optional (requires R&D support from HED)**
  - bent diamond crystal spectrum analyzer downstream of the interaction

Overview of the high energy density (HED) instrument

Amplitude TECHNOLOGIES

>100TW @ 10 Hz
>300 TW @ 5 Hz
30 fs pulses
double CPA Ti:Al_2O_3



DiPOLE100

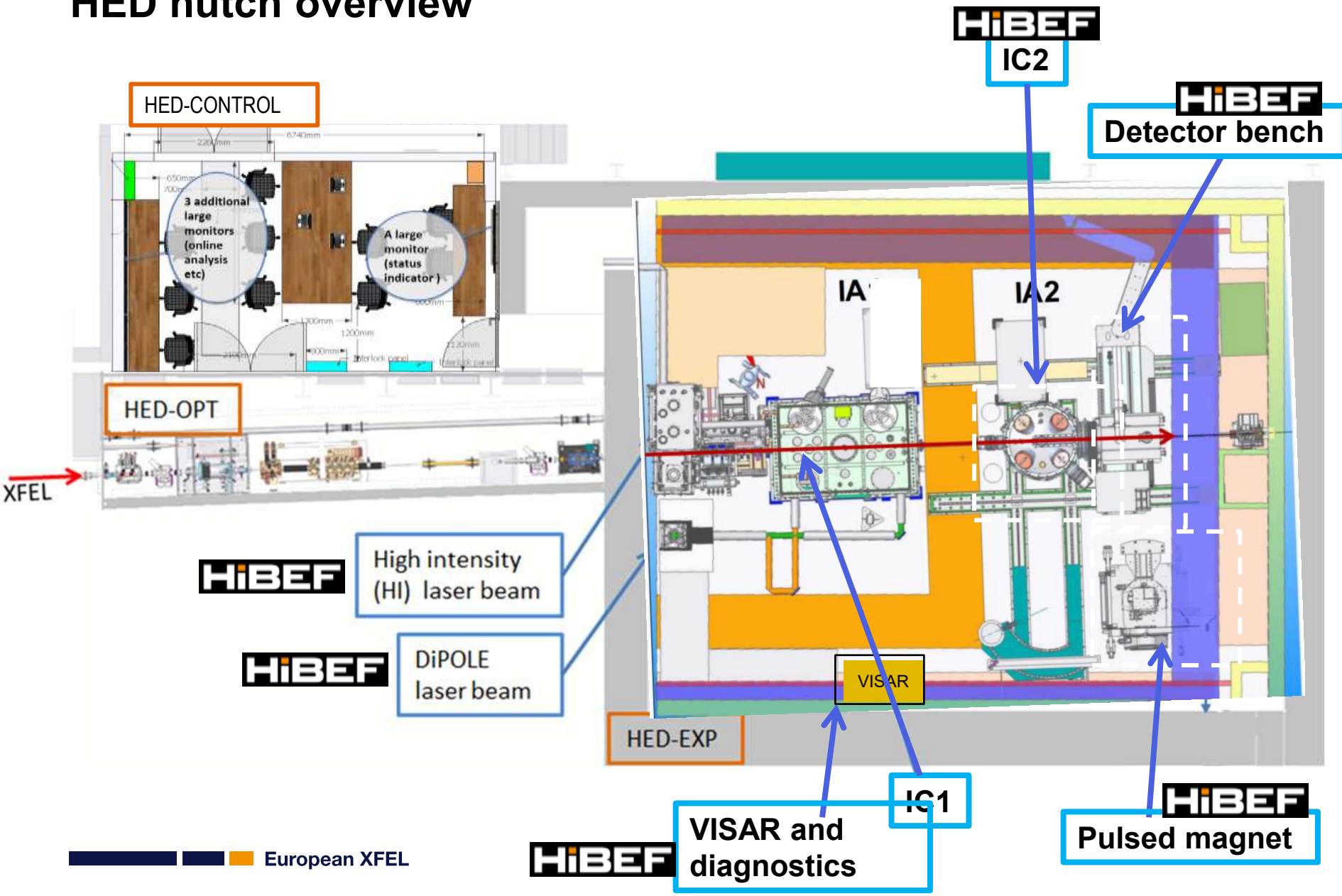
>100 J @ 10 Hz
2-15 ns pulse
pulse shaping
2w conversion

XFEL

HiBEF

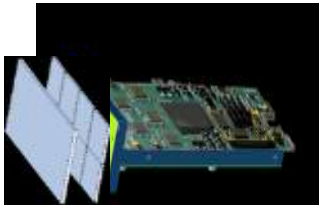
5-25 keV photon energy
~10^{10} (25 keV), ~10^{12} (5 keV) photons
2-100 fs pulses
sub-µm focus up to few mm

HED hutch overview



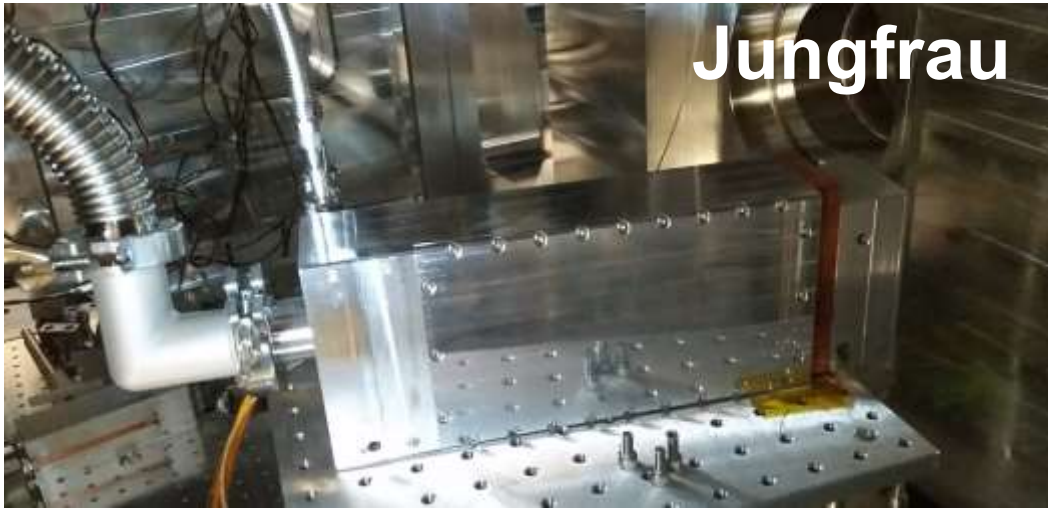
HED experimental hutch

HED vacuum compatible and compact X-ray detectors



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**

The real detectors for inside IC1



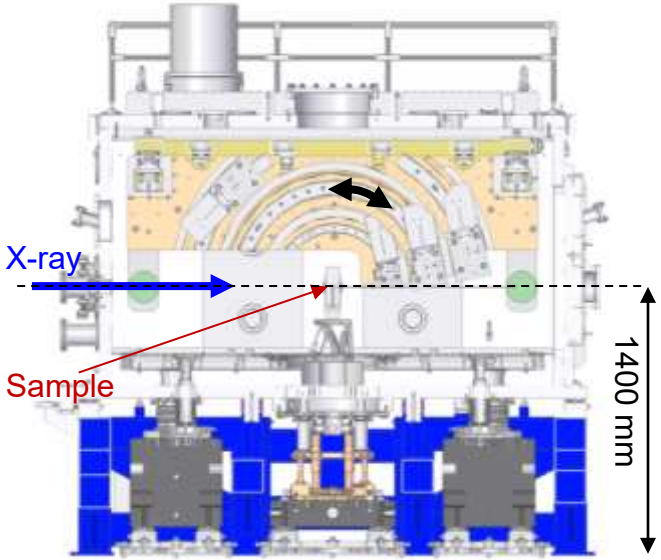
Platforms – Interaction Chamber 1

- 2 ePIX100 detectors for spectroscopy, imaging or XRD, 50um pixel pitch, ~700x700 pixels, 10 Hz. Very low noise
- 2-3 ePIX10k (gain switching, 10^4 dynamic range) for XRD or spectroscopy, 100um pixel pitch, ~350*350 pixels, 10 Hz
- 2-3 JUNGFRAU detectors (gain switching 10^4) at 10 Hz (no burst mode) for XRD or spectroscopy (pixel pitch 75um, detector size ~ 3.5*7 cm)

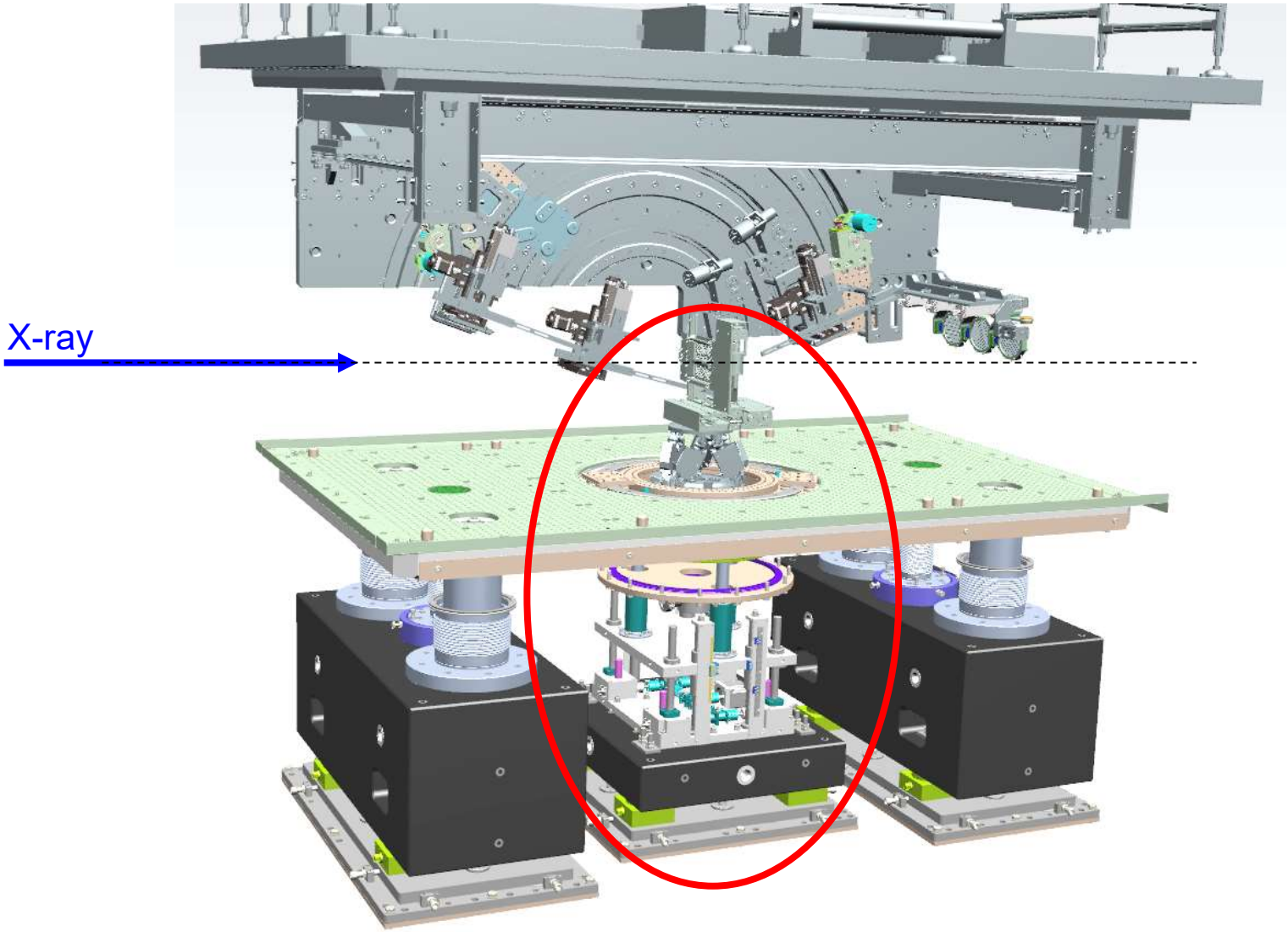
- Possibility to mount area detectors or spectrometers on curved rails in vacuum on vertical breadboard
- Von-Hamos HAPG spectrometers (RoC 50mm and 80mm, crystals available 40um HAPG, 100um HAPG, 200um HOPG)
- High-resolution monochromator and diced analyzers (Si 533) for ~50meV spectroscopy at 7.490 eV
- stepper-motor target stage on hexapod and precision rotation stage
- CRL4 for sub-µm foci

IC1 – flexible large chamber

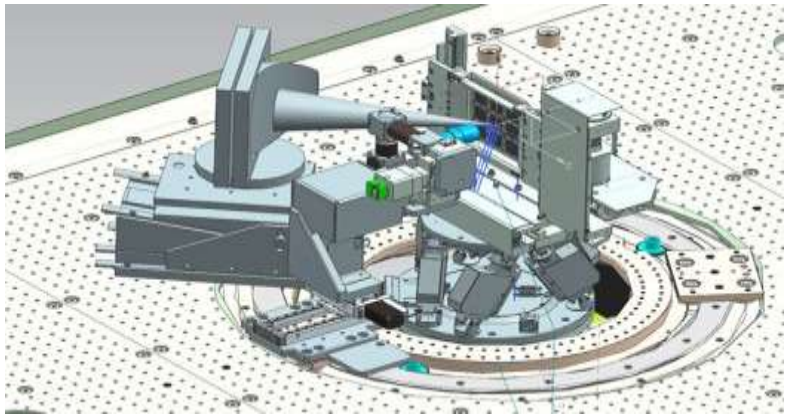
- Motorized carriages
- Arc R = 306, 517, 750mm
- Breadboard moveable in x-axis
- Mounting of X-ray detectors
- Mounting of spectrometers



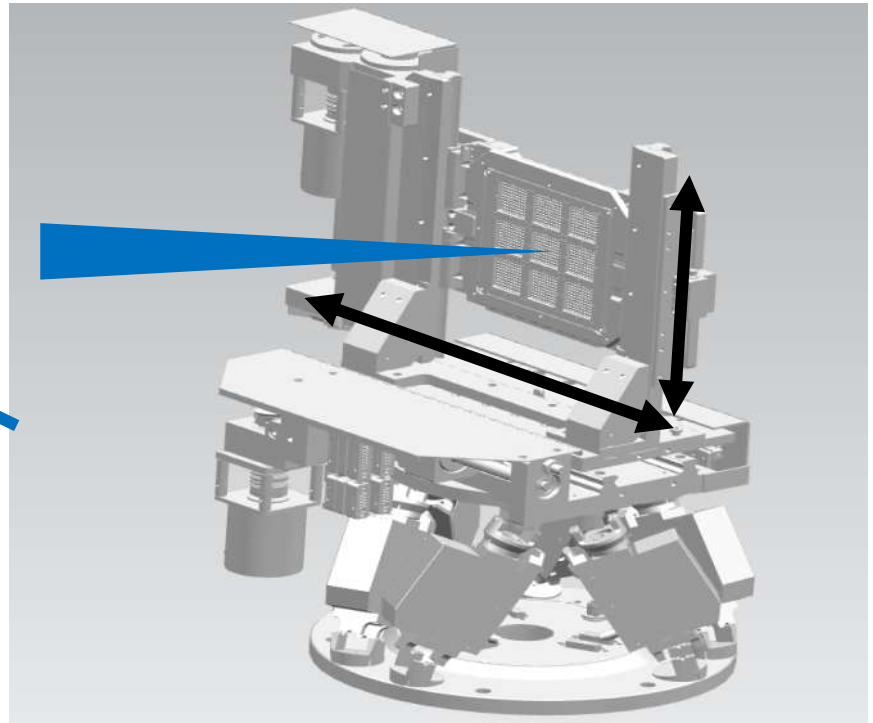
Interaction Chamber 1 (IC1)



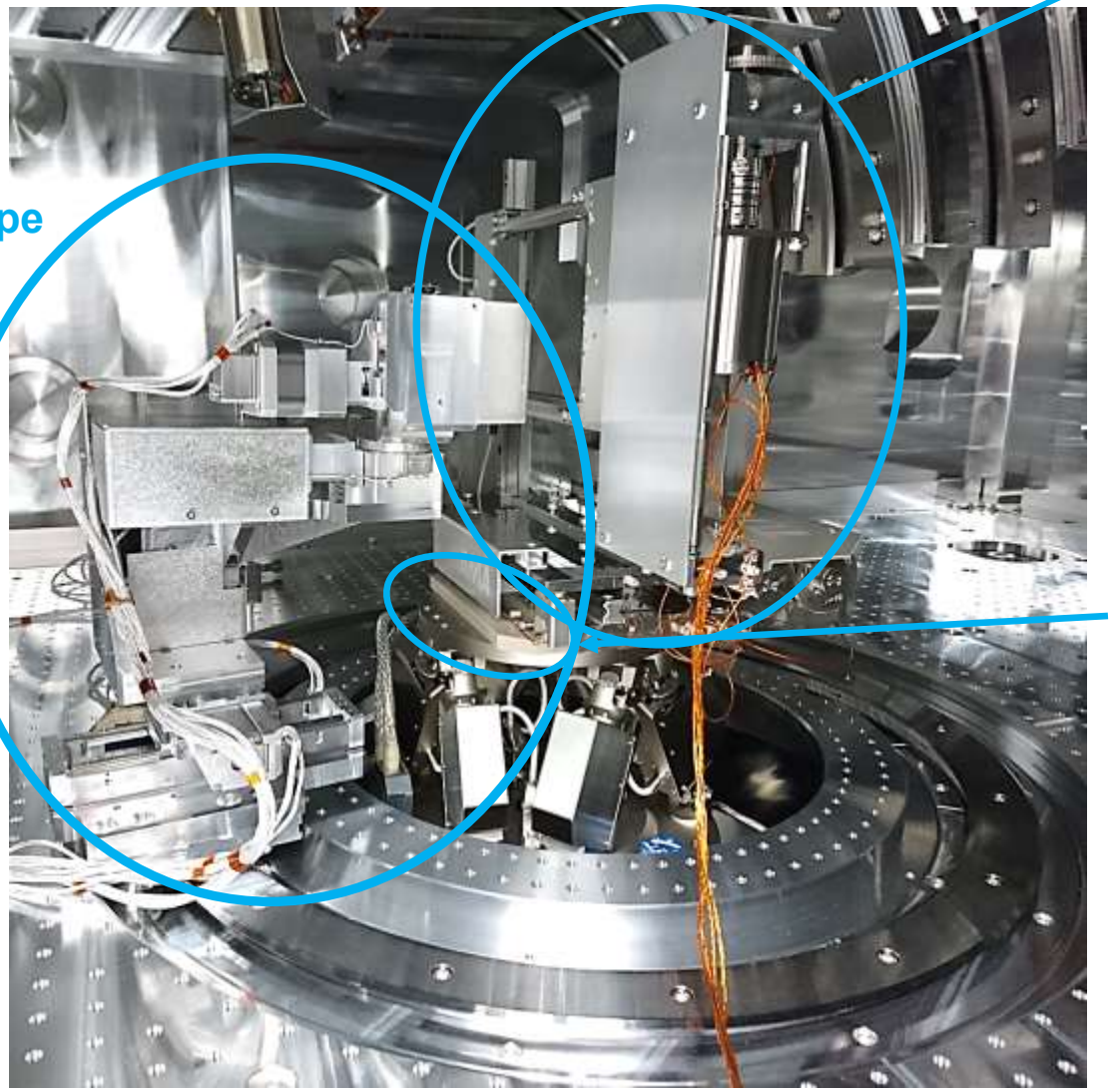
FSS (Fast sample scanner)



- Stepper motor-driven (2 axis)
- Mounted on PI hexapod
- HUBER rotationstage at the bottom



IC1 sample stack



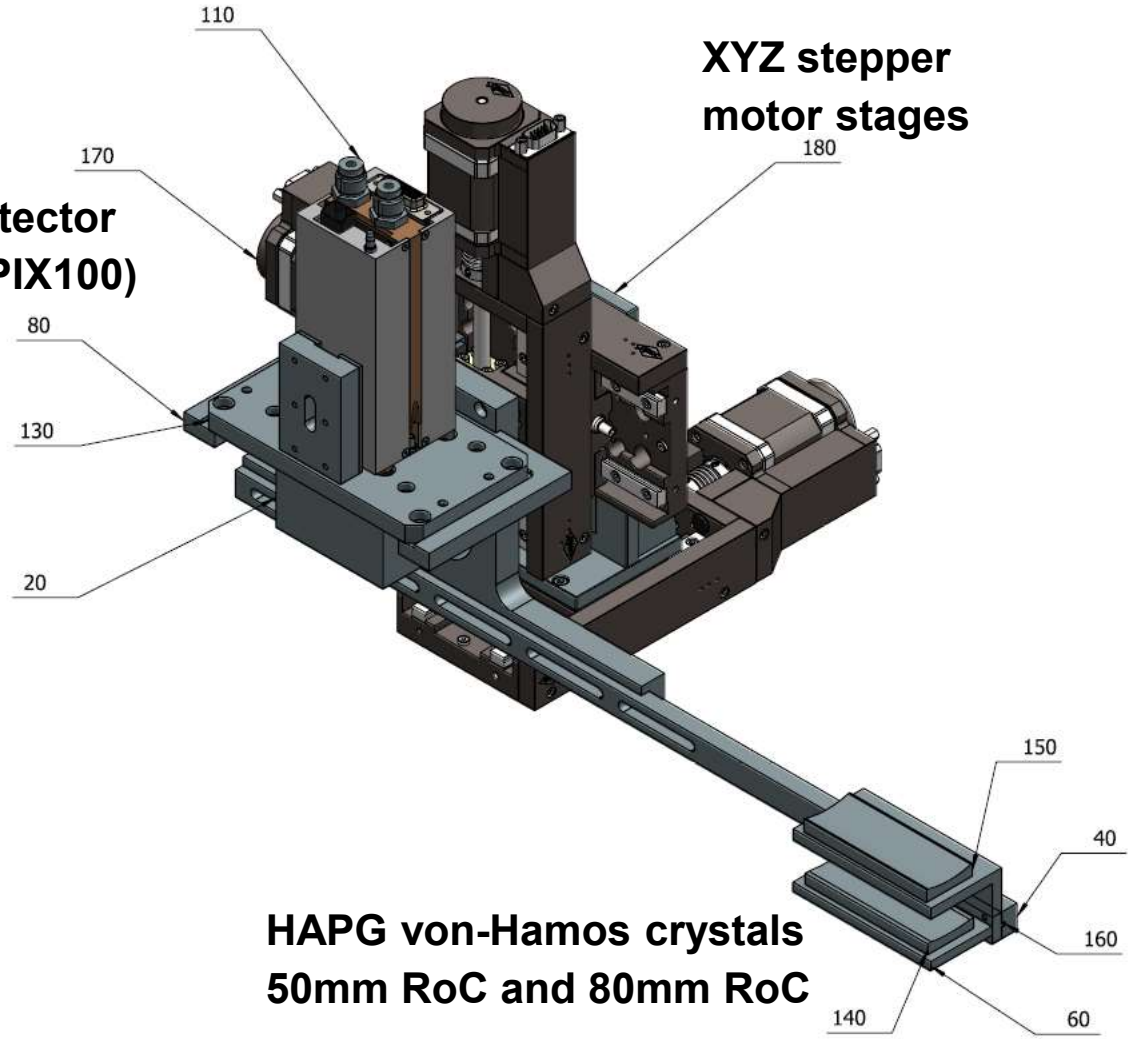
Inline microscope

'Fast' sample scanning stages

- Stepper motor
- Anodised
- Mostly Al
- Max speed 20mm/sec
- Min resolution <2µm

Insulation plate 5 – 20 mm thick

Design of HED von Hamos spectrometers



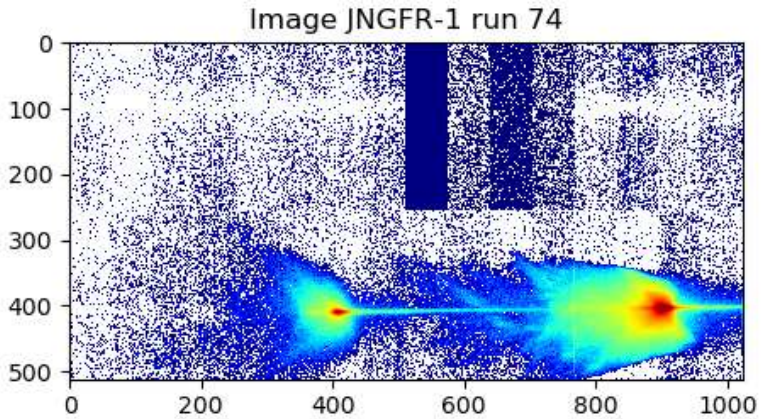
XYZ stepper motor stages

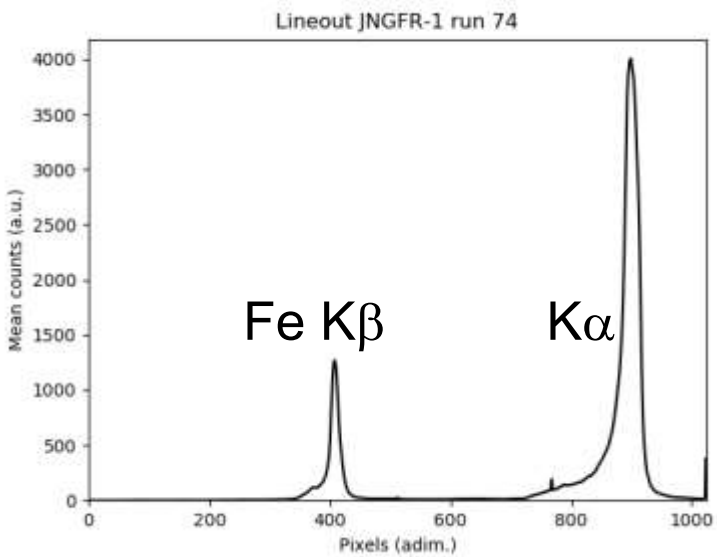
X-ray detector (here: ePIX100)

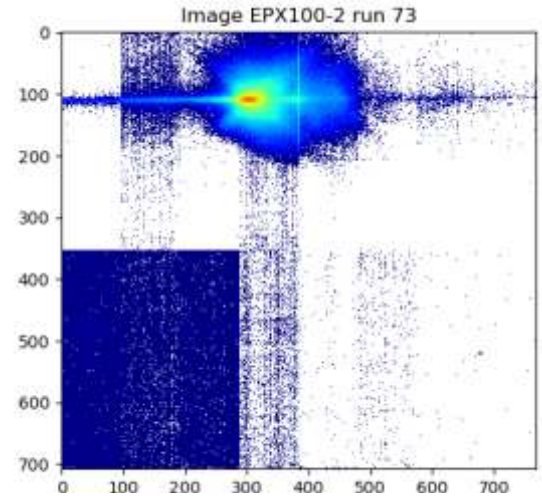
HAPG von-Hamos crystals 50mm RoC and 80mm RoC

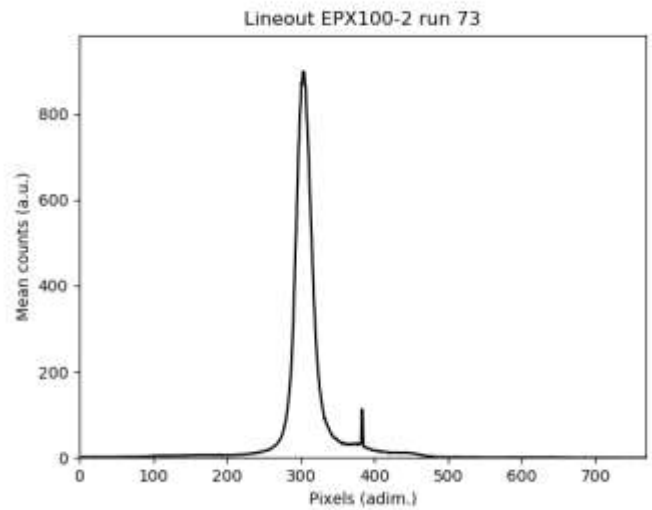
The real HAPG von-Hamos in IC1

Data from HED 50mm HAPG spectrometers and detectors



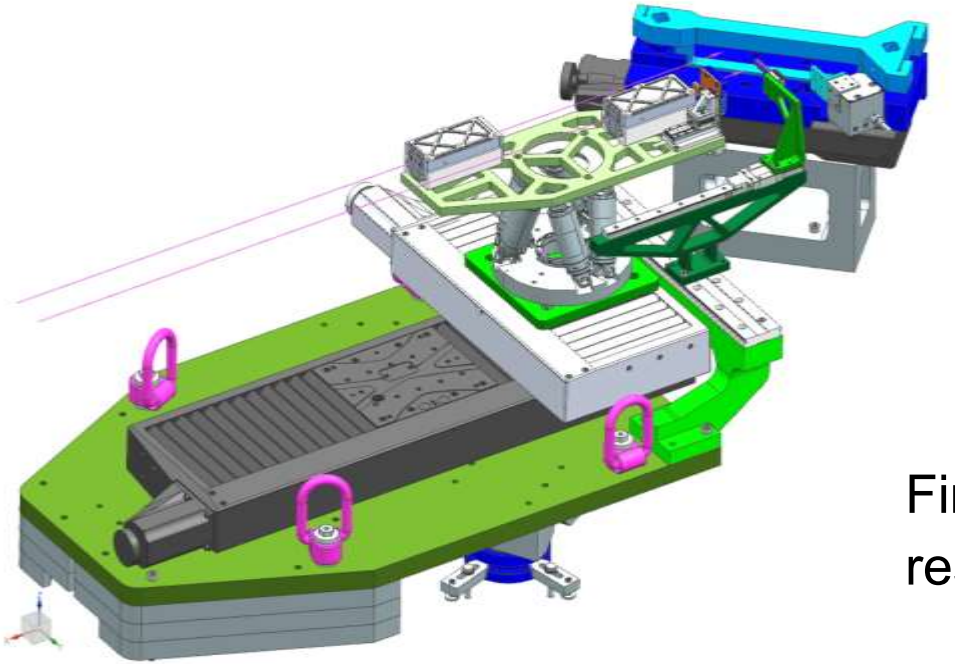






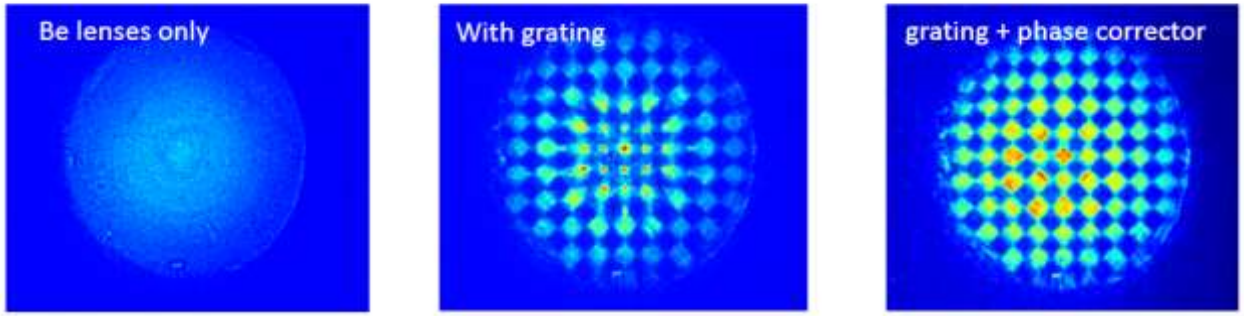
3-8 eV resolution at 6-9 keV

Nano-focused beam (CRL 4) - HIBEF contribution



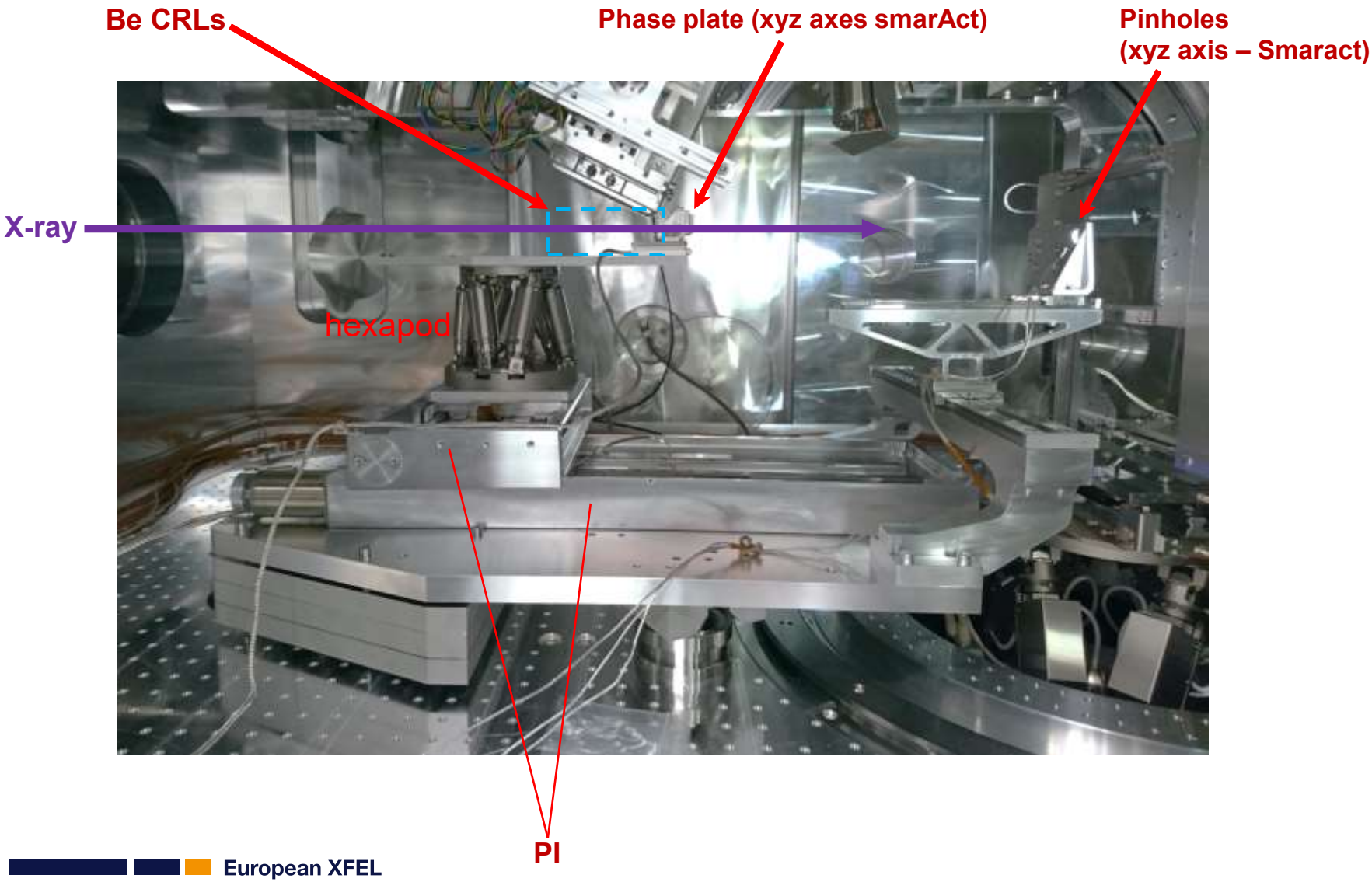
First tests in August 2019 at 9 keV, rescheduled for March 2020

Be CRL4 and phase corrector aligned for nano-focused beam



Courtesy to A. Schropp

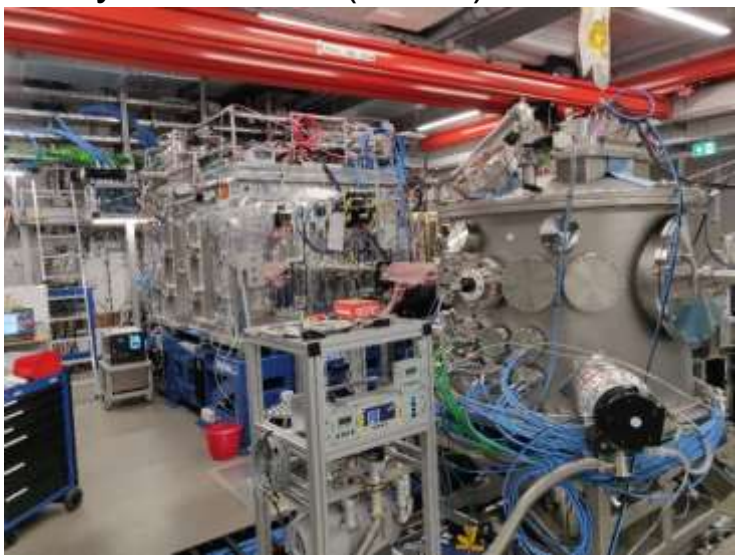
Nanofocusing Setup in IC1



Platforms – Interaction Chamber 2, pp-laser

IC2

- Diamond Anvil Cell (DAC) setup for precision XRD
- 2 VAREX flatpanel detectors in IC2 (10 Hz)
- Pulsed laser heating for DAC research
- Dynamic DAC (dDAC)

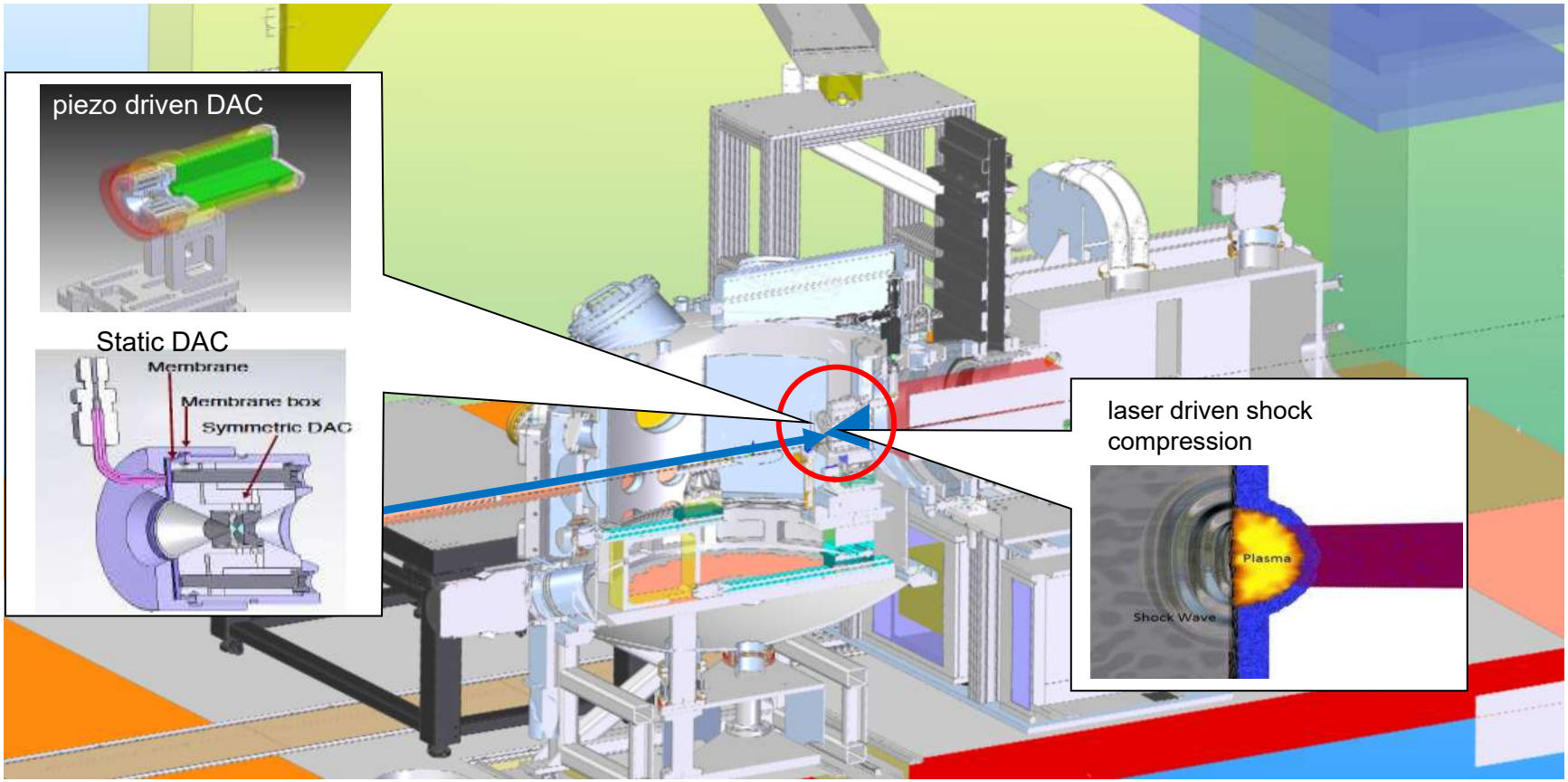


Pulsed laser heating

- double side laser heating in DACs, 2x 100 W NIR lasers in pulse mode or cw. mode. Pulse duration 10-500 ns, and >1 us possible
- temperature: time resolved spectral radiometry using streak camera system

IC2 – a new DAC platform at HED (shock setup in 2020)

First DAC community experiment Oct 9-14, 2019



CRLs → down to nm focusing

courtesy to C. Strohm

Status of the large HiBEF lasers

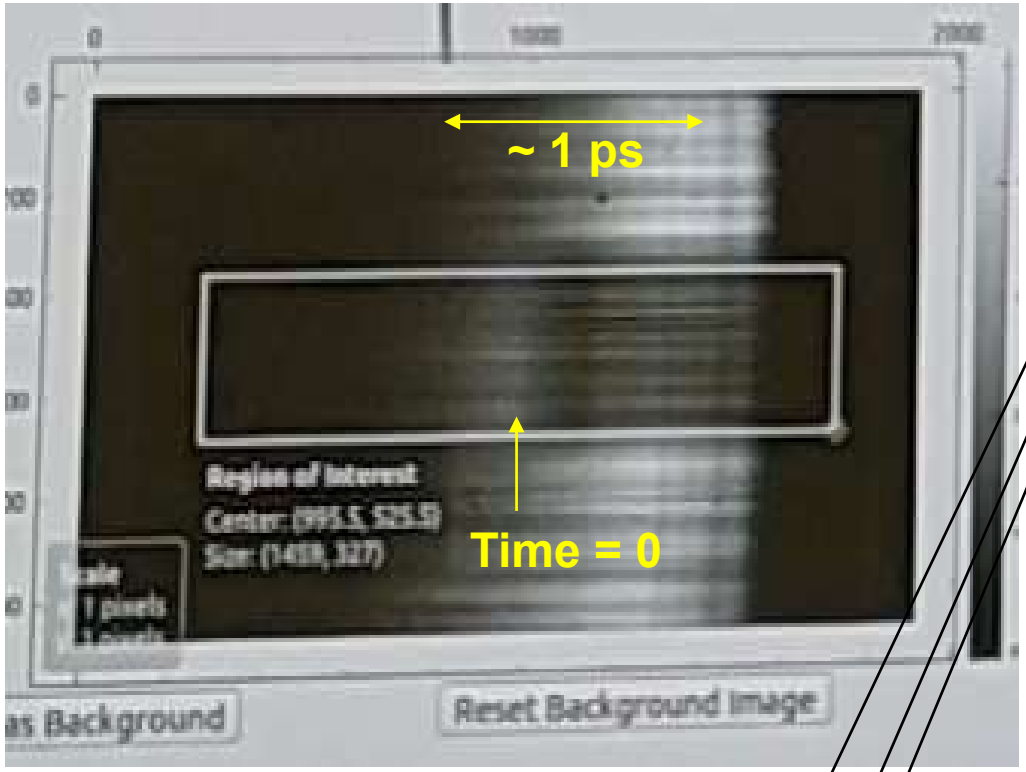
Multi-100 TW laser (Amplitude)

Installation complete
Focusing, timing: until end-2019
X-ray commissioning: 1st half of 2020
Available for Users: 2nd half of 2020
community proposal submitted

DiPOLE 100-X laser (CLF, UK)

Delivery complete
Installation at HED ongoing
Beam transport to IC1 & IC2: 2020
X-ray commissioning, VISAR: 2021
Available for Users: 2nd half of 2021

Spectral encoding (PAM)

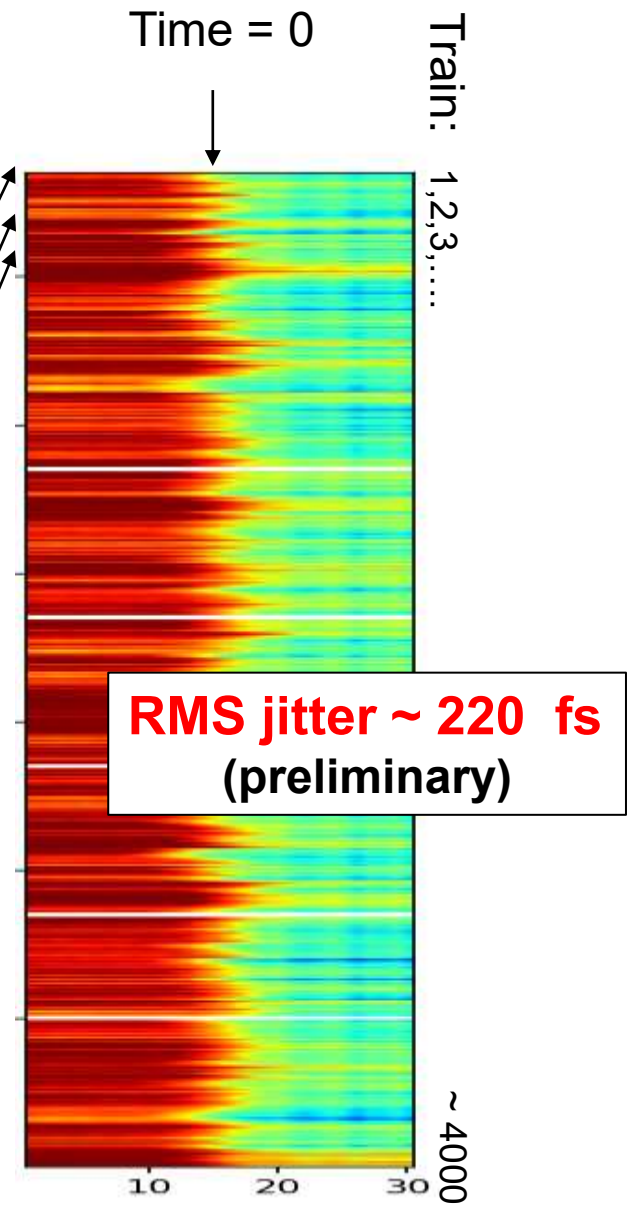


Train 1

Train 2

Train 3

Train 4 ...



Preliminary analysis by Jia Liu

Pump-probe (PP) laser for Run 6 (with limited capability)

- "Limited capability" refers to timing jitter, pulse energy and stability, and repetition rate. This laser will be in its early phase.
- Anticipated parameters
  - **PP laser at 800 nm wavelength**
    - ► 15 fs duration, Fourier-limited bandwidth (going for narrower bandwidth with longer pulse duration is an option)
    - ► 100 kHz, max ~2 mJ (10Hz or shot-on-demand is possible. Higher repetition than 100 kHz with lower pulse energy is an option)
    - ► Second harmonic (400 nm) is potentially available
  - **PP laser at 1030 nm wavelength**
    - ► ~ 1 ps duration
    - ► 100 kHz, max ~35 mJ (10Hz or shot-on-demand is possible. Higher repetition than 100 kHz with lower pulse energy is an option)
    - ► Second/third harmonic (515/343 nm) are potentially available

Outlook

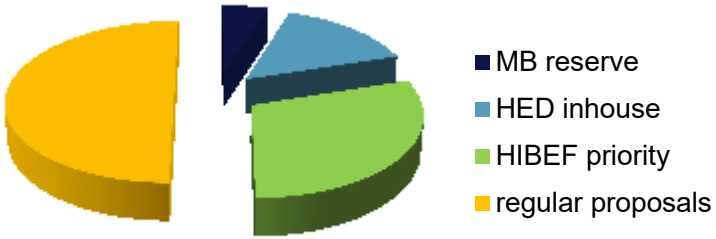
- **HED has completed 8 "early" user experiments between May-Nov 2019**
- **In 2020-I, we have scheduled 4 more user experiments**
- **HI-OL (few 100 TW) Amplitude laser**
  - 100 TW shot on target, 14 MeV protons demonstrated — 12/2019
  - community proposal by HZDR (submitted) — 2nd half 2020
- **Pump-probe laser** ready
  - Hand-over to HED — Spring 2020
  - Inhouse research activity using pp-laser — June 2020
- **DiPOLE laser (for laser-shock compression)**
  - Installation at HED — ongoing
  - Ready for users (first, only community proposal) — 2021
- **AGIPD detector delivery** — delayed
  - Mitigation scenario: Mini-half in air — 2020-II
- **Split-and-Delay line** — delayed

Beamtime allocation and Priority Access for HIBEF

Amount of beamtime at HED (preliminary)

- Every half year: **~ 14x 5-shift weeks with x-ray beam at HED instrument**
  - still commissioning new equipment and improving existing devices.
  - shared bunch mode using fast kicker, e.g. 3 instruments run simultaneously

  - 5% are management reserve
  - 15% is HED group inhouse time (commissioning, method development, research)
  - 50 to 80% are available for regular user proposals (incl. setup time)
  - After HIBEF contract has been signed, up to 30% is priority access time for HIBEF UC



- Proposal Review Panel
  - One panel per instrument
  - Independent experts
  - Meet every 6 months

The joint HED and HIBEF team at European XFEL

Great thanks to

HP Liermann & team at ECB, DESY

HED group at HZDR

X-ray focus characterisation at HED

Mikako Makita
High Energy-Density (HED) science group
Instrument Scientist

EXFEL HED Satellite Meeting, 28Jan2020

A. Schropp

S. Pikuz
S. Makarov

HIBEF UC

B. Nagler
H. Lee

J. Chalupsky
V. Hajkova
T. Burian
V. Vozda
L. Juha

European XFEL

P. Vagovic
L. Mikes
J. Grünert
N. Kujala

C. David
G. Seniutinas
P. Bougiatioti

T. Pikuz

HED beamline member

Chronologial Overview

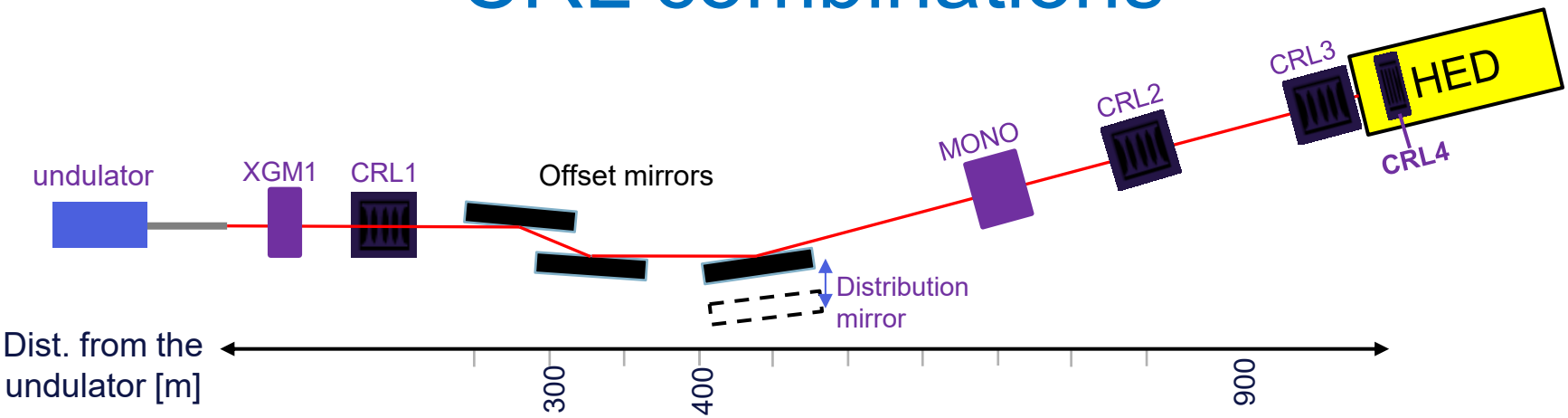
--- of the SAGA

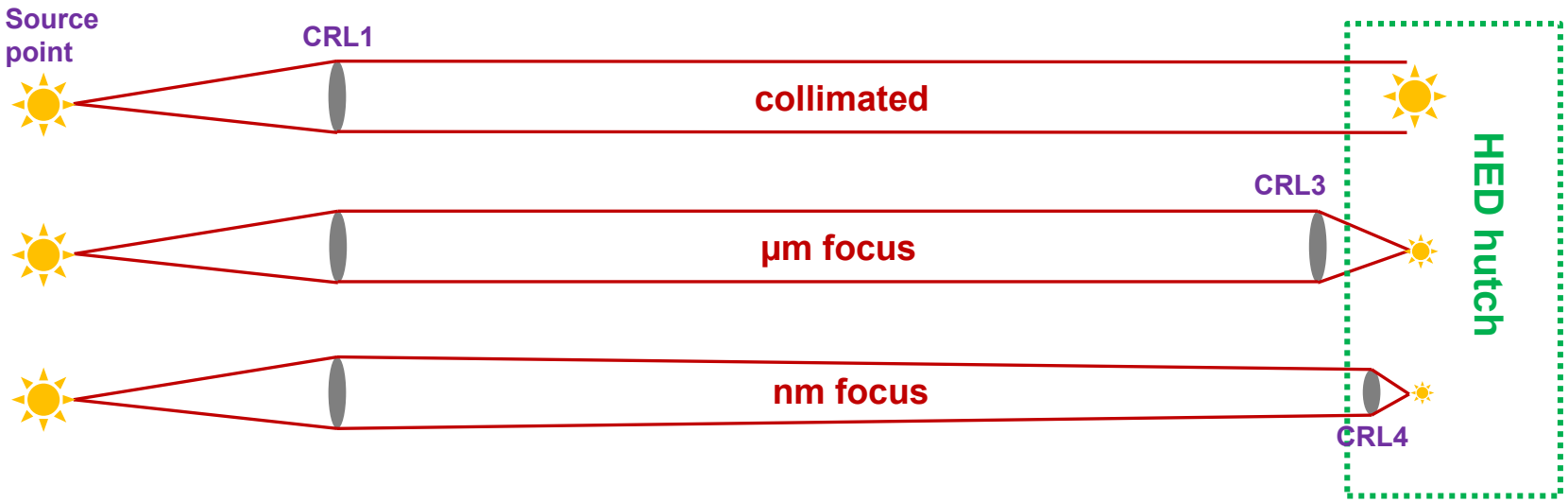
Overview

- **Progress & preliminary results**
  - **Different focusing scheme**
  - **Calibration overview**
  - **impressions**

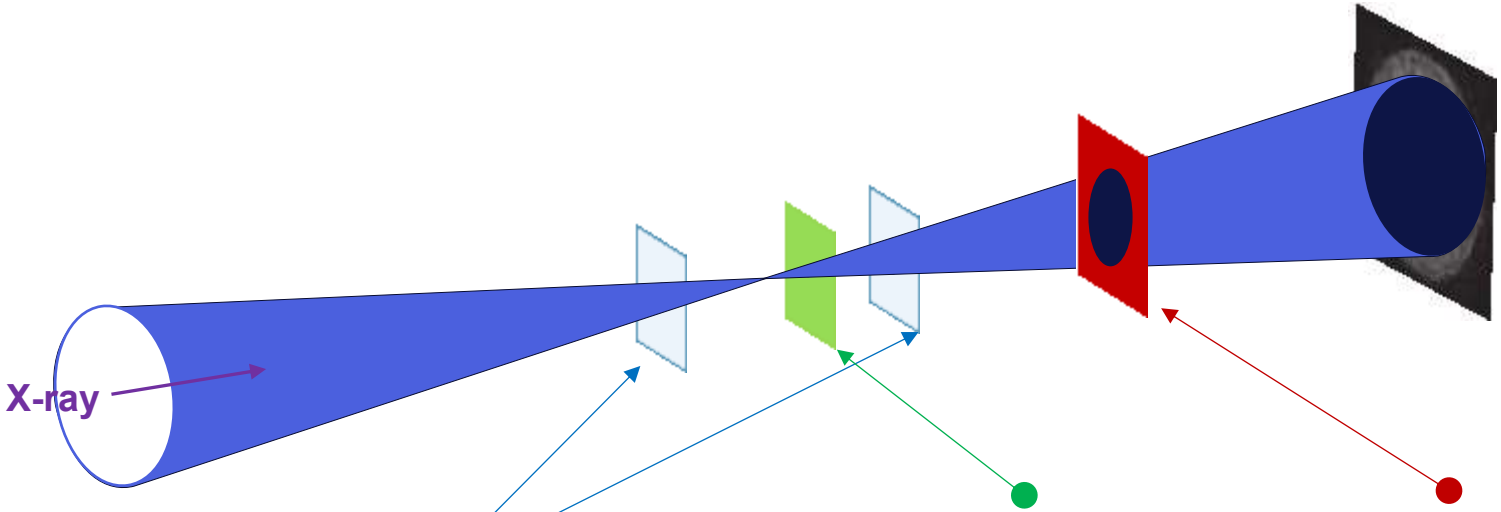
- **Future plans**
  - **Alignment**
  - **Focus estimation**
  - **‘permanent’ setup at beamline…**

CRL combinations



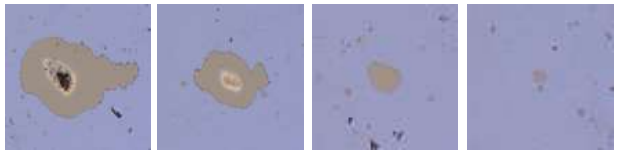


Measurement scheme

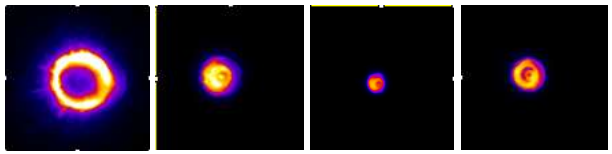


Out-situ methods

Ablation imprints

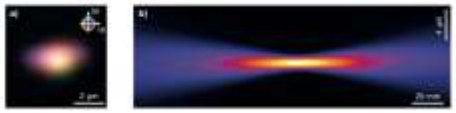


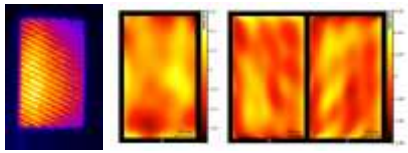
LiF Imprints



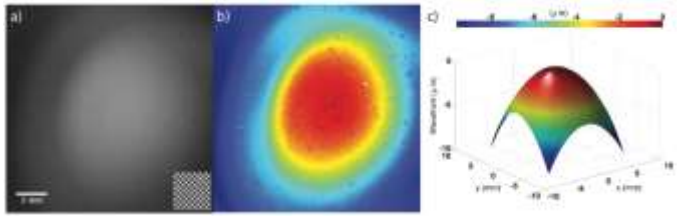
Online methods NF & FF

Near-field : Ptychography, Ronchi interferometry



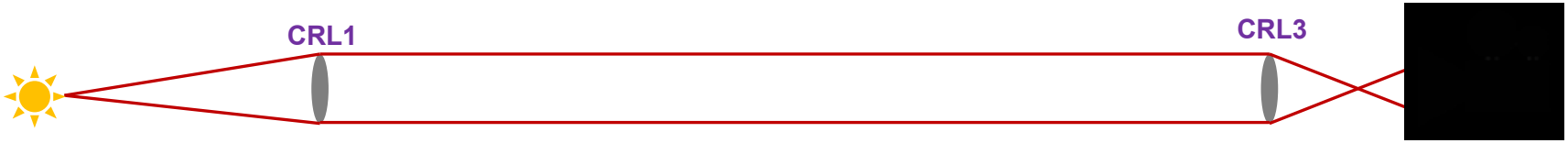


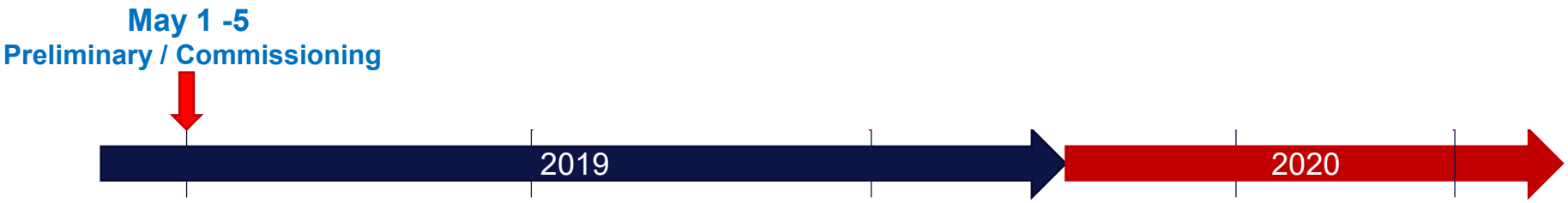
Far-field : Talbot interferometry



MAY

- Photon energy: 9 keV
- µm focus CRL(CRL3)
- Expected diffraction limited spot size: 2σ = 1.0-1.5µm

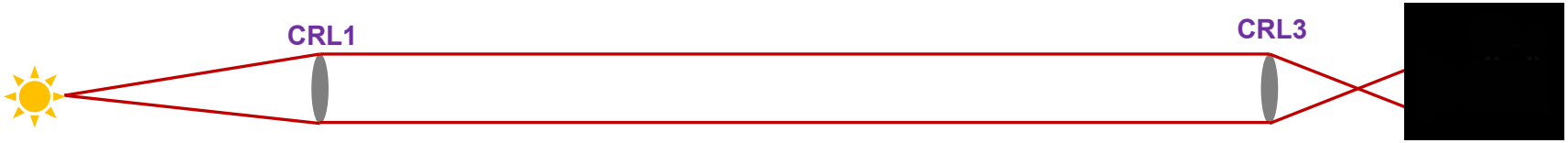




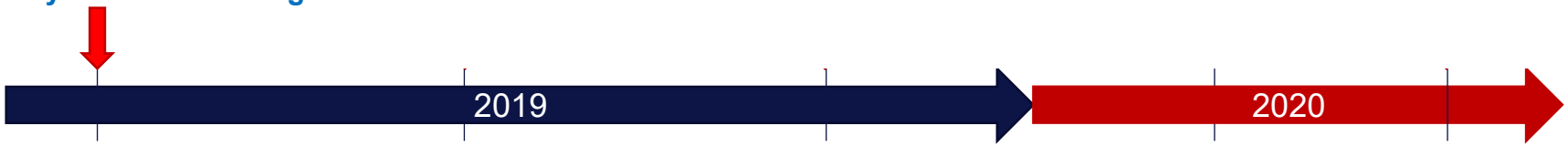
- **Average pulse energy: 1.5 mJ**
- **µm focus rough calibration**
- **Method optimisaion**
- **Beamline optimisation genera**

MAY

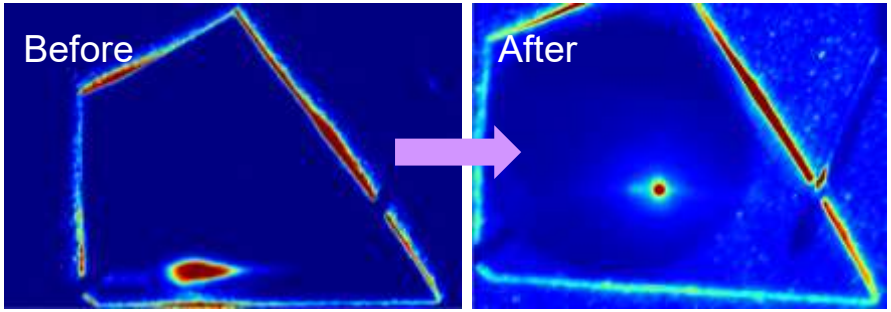
- Photon energy: 9 keV
- µm focus CRL(CRL3)
- Expected diffraction limited spot size: 2σ = 1.0-1.5µm



May 1 -5
Preliminary / Commissioning



Collimated, optimised beam at TCC



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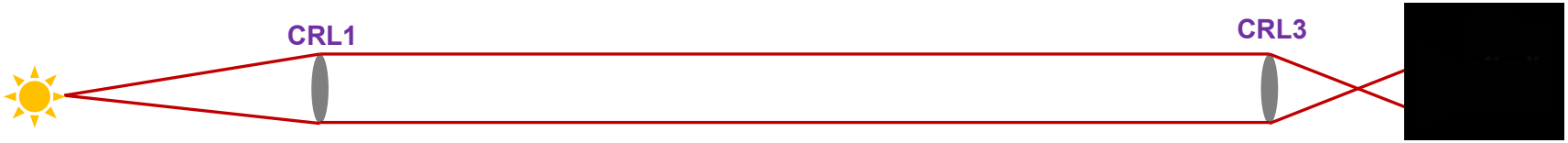
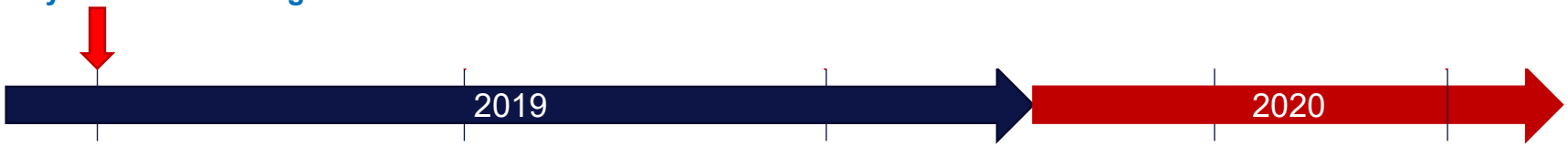
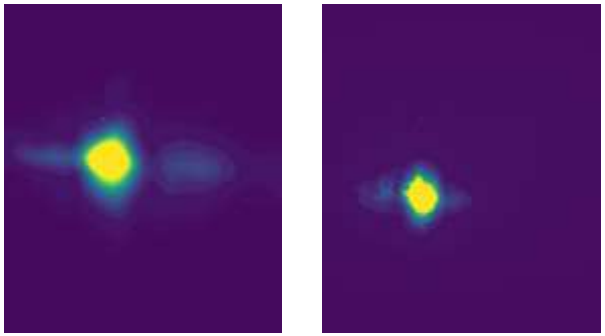
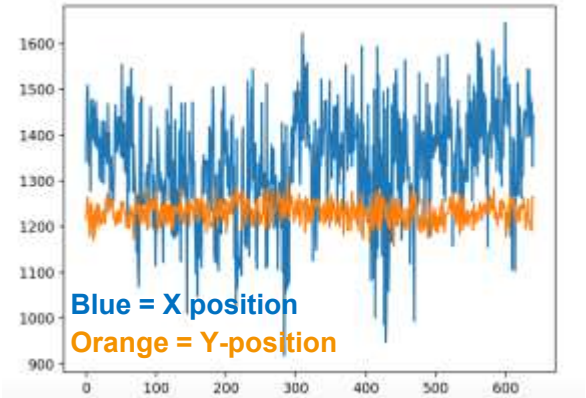


May 1 -5
Preliminary / Commissioning



Beam jitter with & without CRL3





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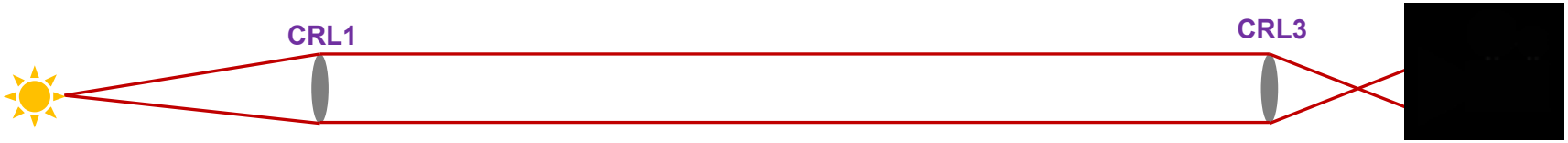
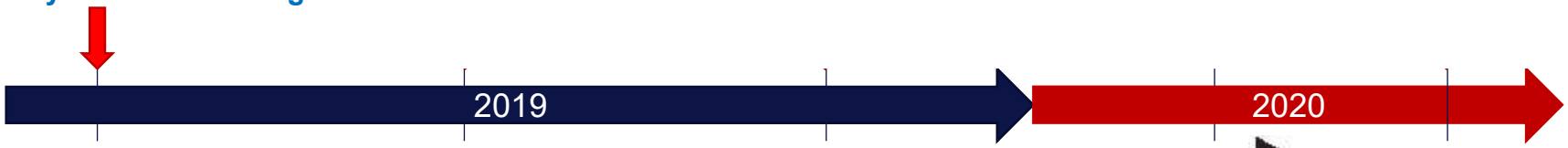
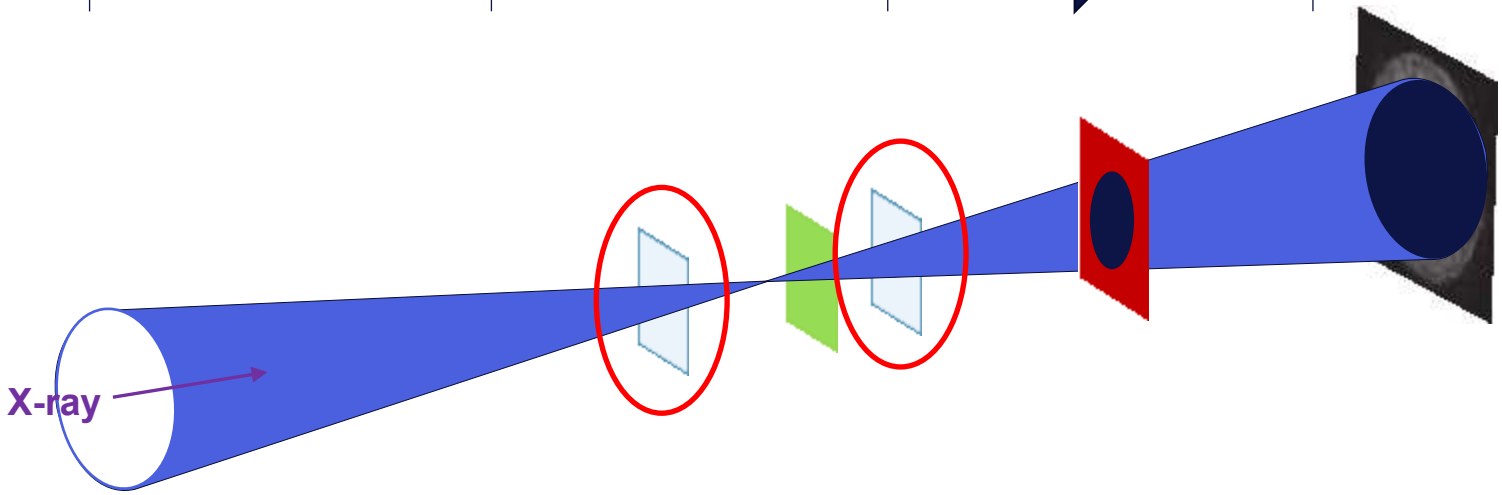
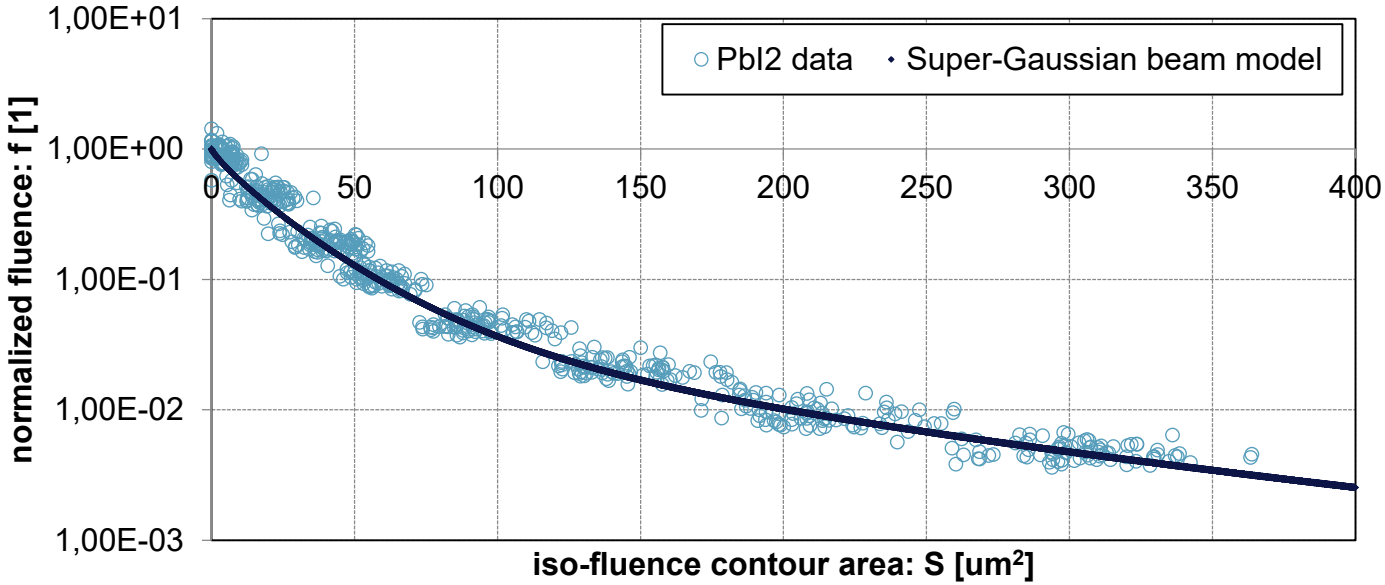


May 1 -5
Preliminary / Commissioning



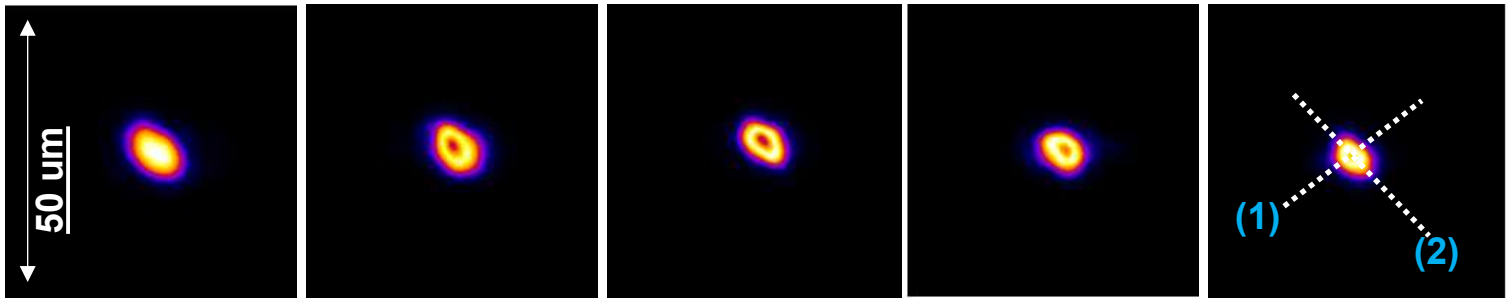


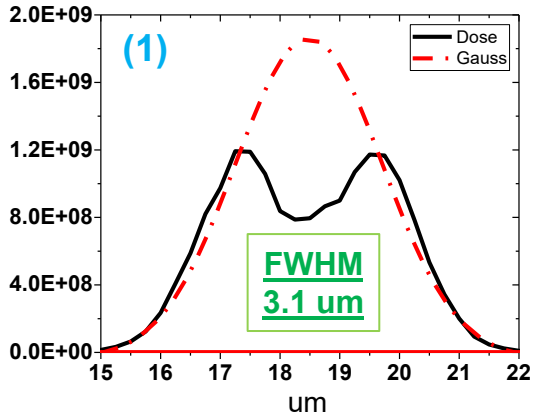
Ablation imprint

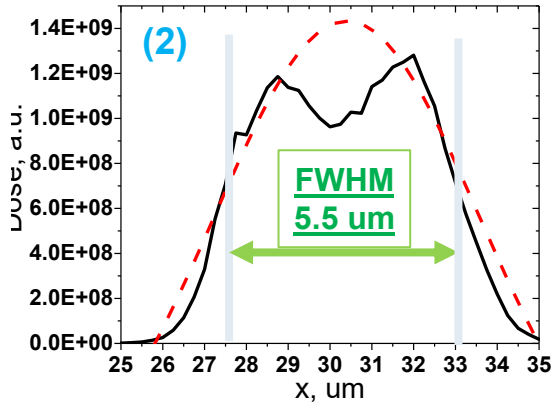


- Effective spot size A_{eff} = 25.7 um^2
- FWHM < 4 um
- 2-sigma radius: W_0 = 5.6 um

LiF : Intensity distribution in focus



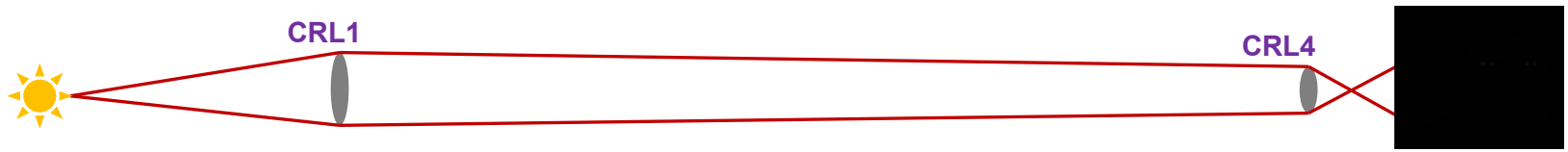


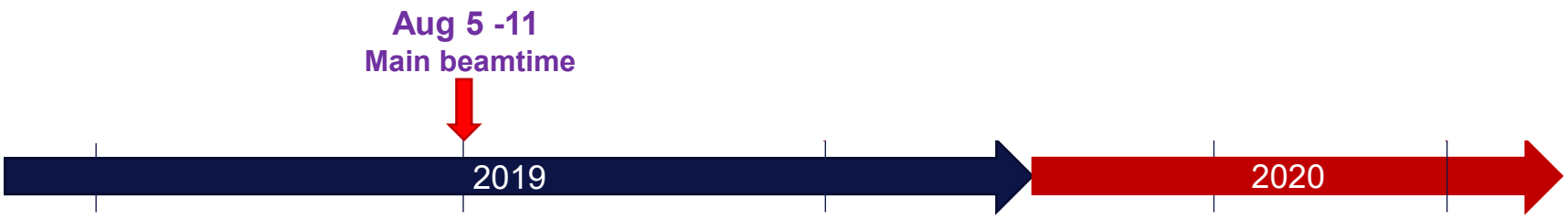


- Assuming a **linear** response : **79.82 % energy contained within FWHM**
- Assuming a **nonlinear** response : **81.46 % energy contained within FWHM**

AUGUST

- Photon energy: 9 keV
- nm focus CRL: f ~ 0.3m (25 lenses)
- Diffraction limited ~ 100nm focus
- All 5 methods to test

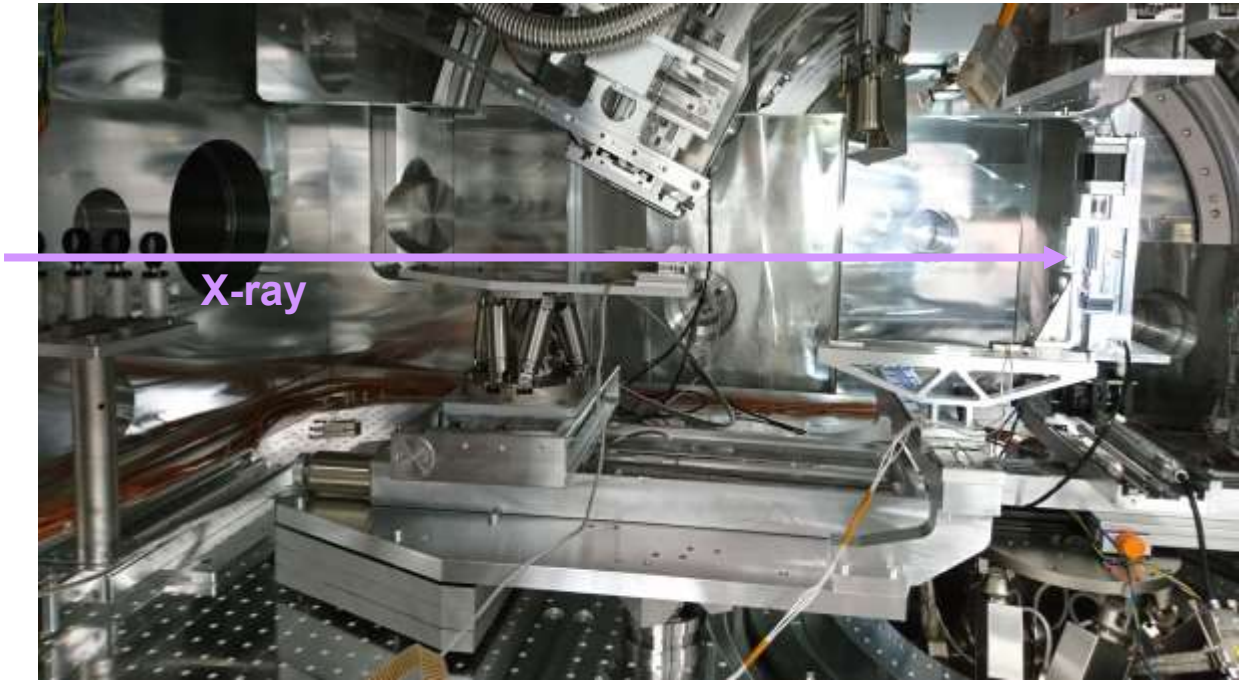




- **Machine went down**
- **Average pulse energy: 0.4 m**
- **Impression of CRL4**
- Phase plate optimisation
- Beam optimisation for CRL4

Setup

Near-focus region

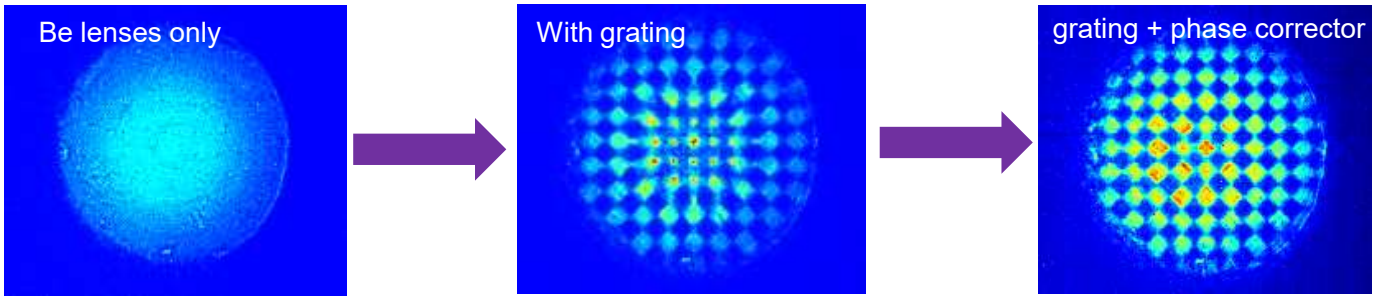


nm CRL contrimbution from A. Schropp & HiBEF

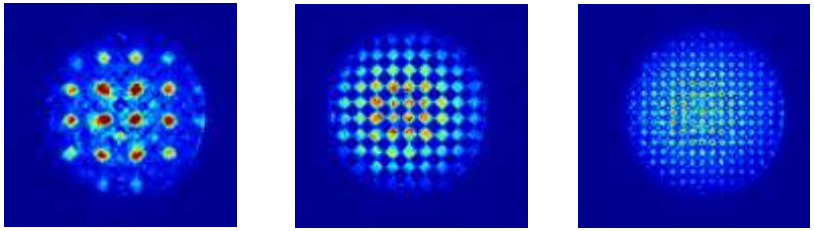
Sample stack

Talbot :

CRL & phase plate alignment and focus position estimate



Focal position estimate (manual z-scan)



Towards focus ⟷ Away from focus

Focal position at CRL4_Z=144.6mm

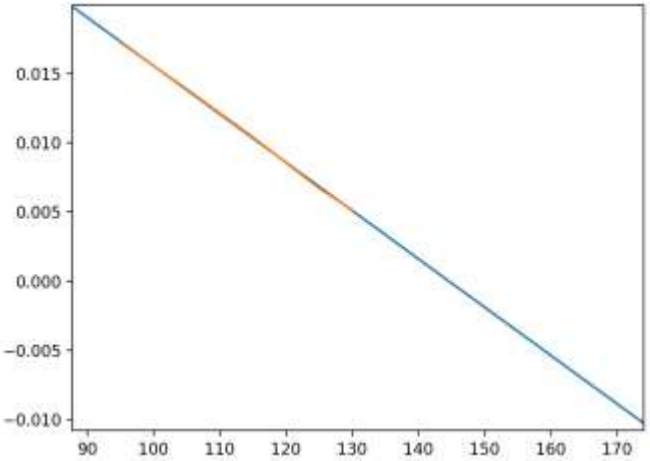
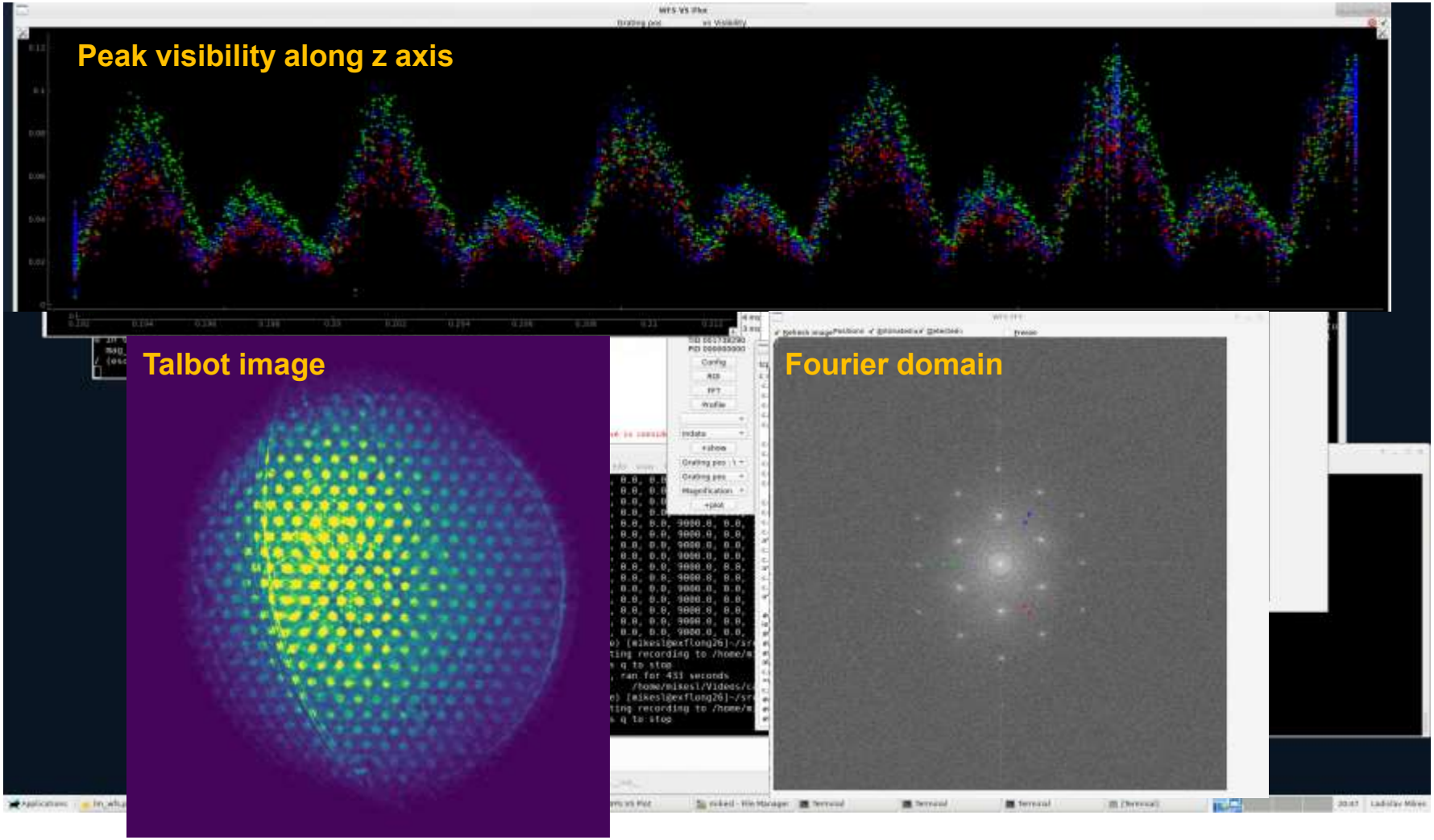


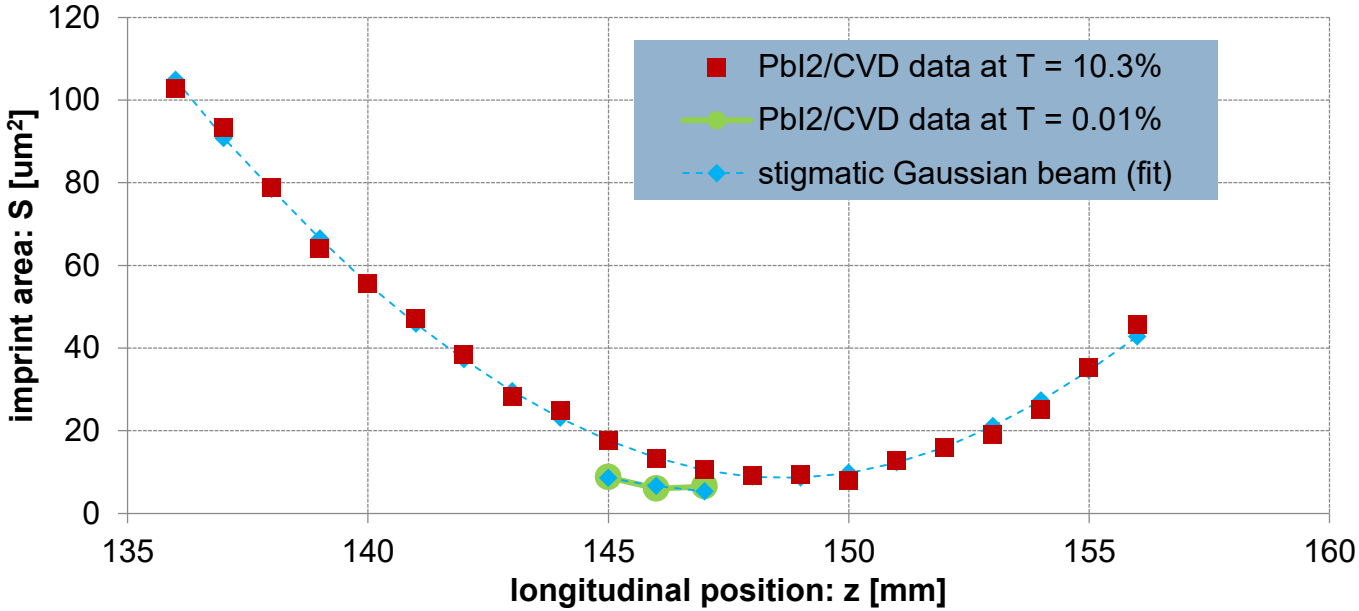
Fig: determination of focus position from Talbot fringe. X axis = CRL z-position. Y-axis = fringe frequuency. Red = measured. Blue = linear fit.

Talbot :

CRL & phase plate alignment and focus position estimate

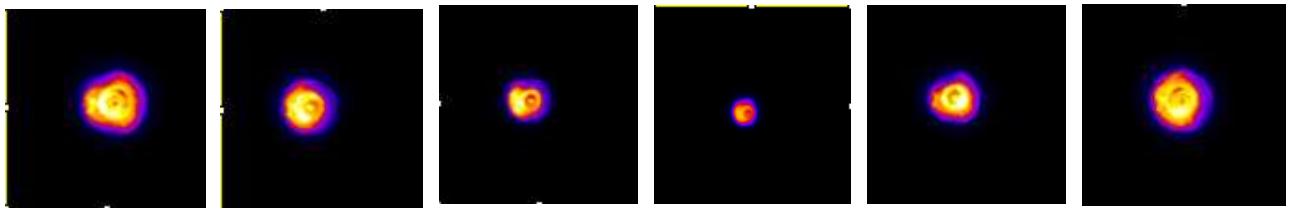


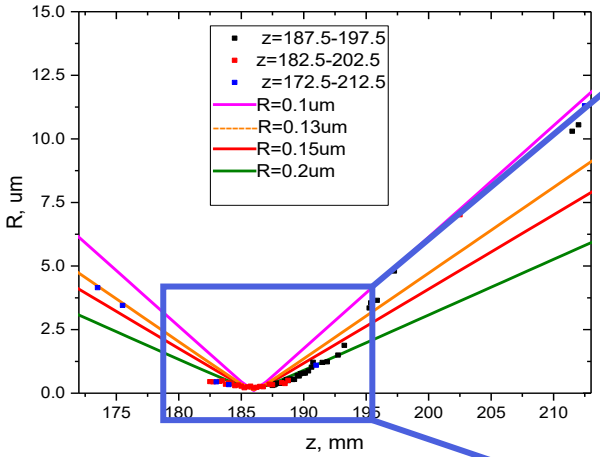
Ablation Imprint analysis

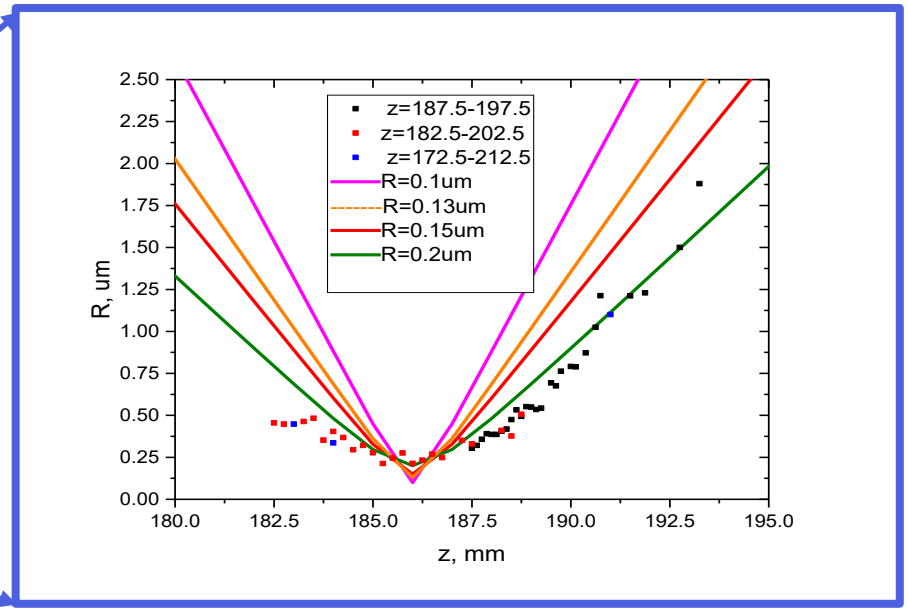


- Diameter at 1/e level: $d_{1/e}$ ~ 900nm
- FWHM : d_{FWHM} ~ 500nm
- Rayleigh range: z_0 = 3.4 mm

LiF Imprint analysis







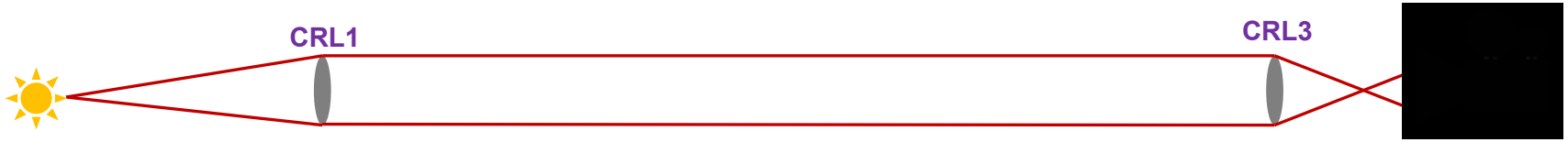
- Different fitting curves for near and far focus
- Best fitting FWHM : **d_{FWHM} ~ 350 nm ± 150 nm**
- Rayleigh range: **z_0 1 - 2 mm**

November

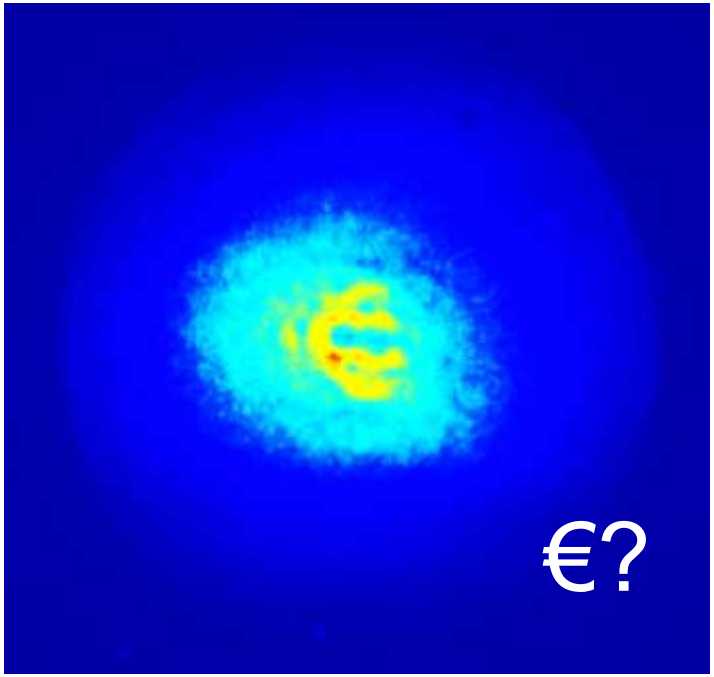
- Photon energy: 8 keV
- Collimation CRL, µm focus CRL 3
- Finalise calibration for µm range

- Average pulse energy: ~0.8 mJ
- **Damaged CRL3**
- CRL1 collimation & source point (with Talbot)

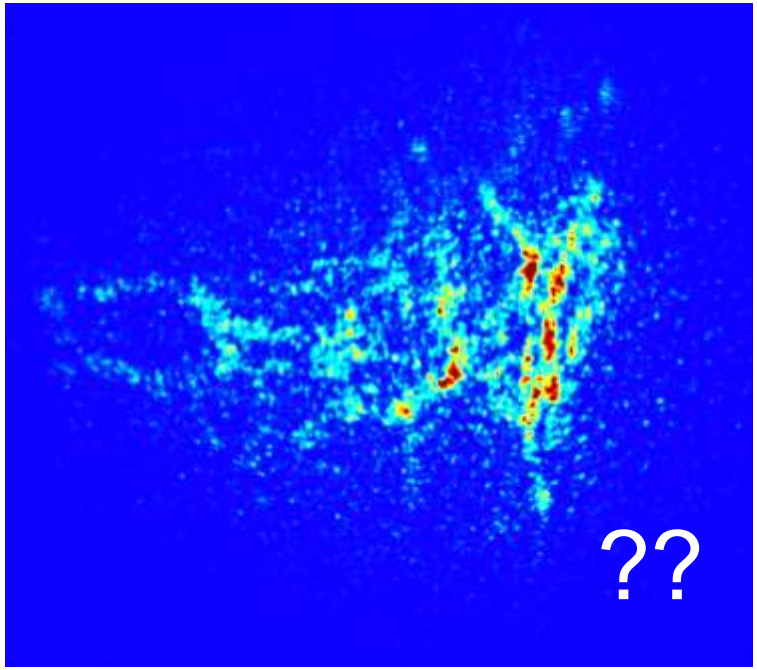
Damaged CRL?



Arm6 only

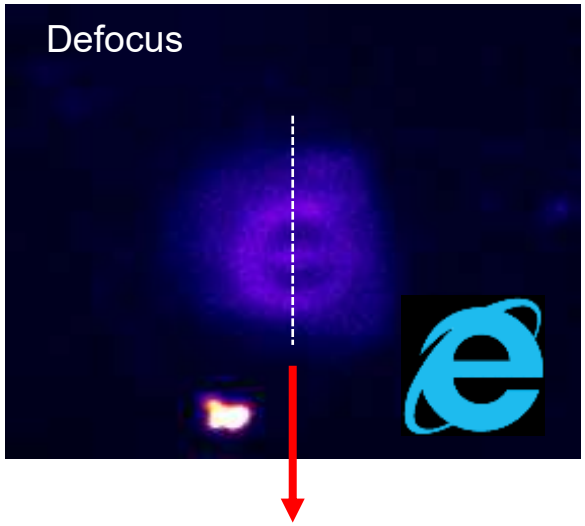


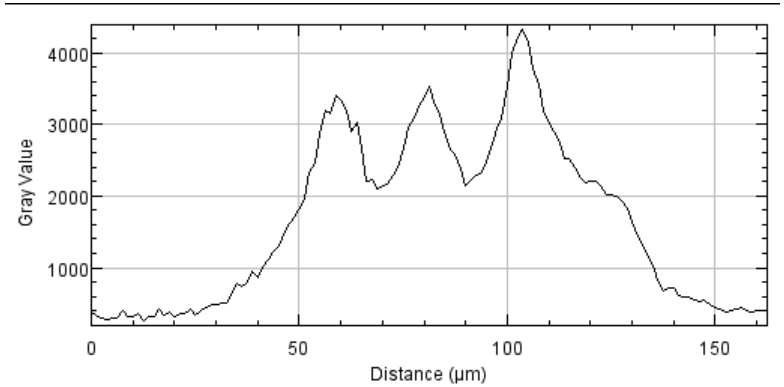
Arm7 only

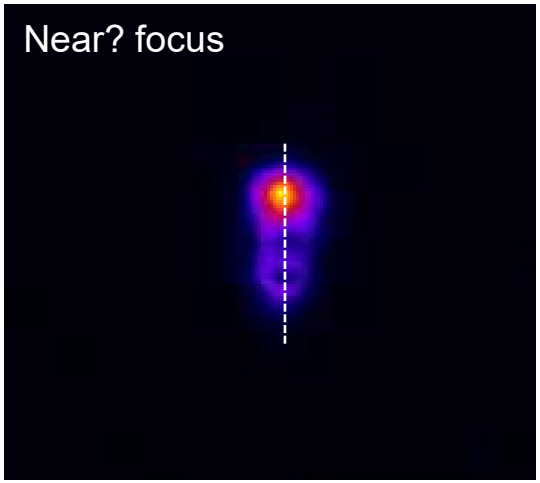


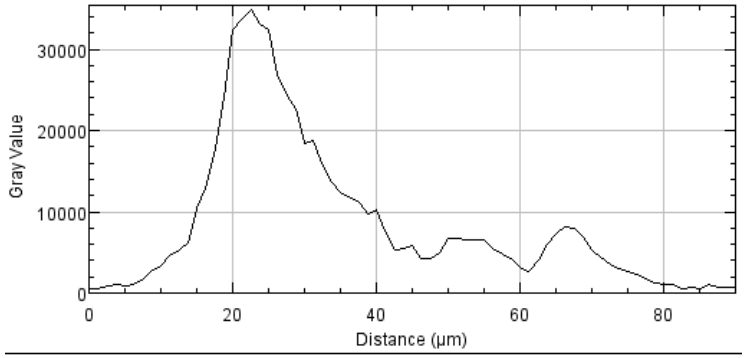
Confirmation of Damaged CRL…

Defocused beam, with a strong halo and very strange, but stable (Φ like) profile



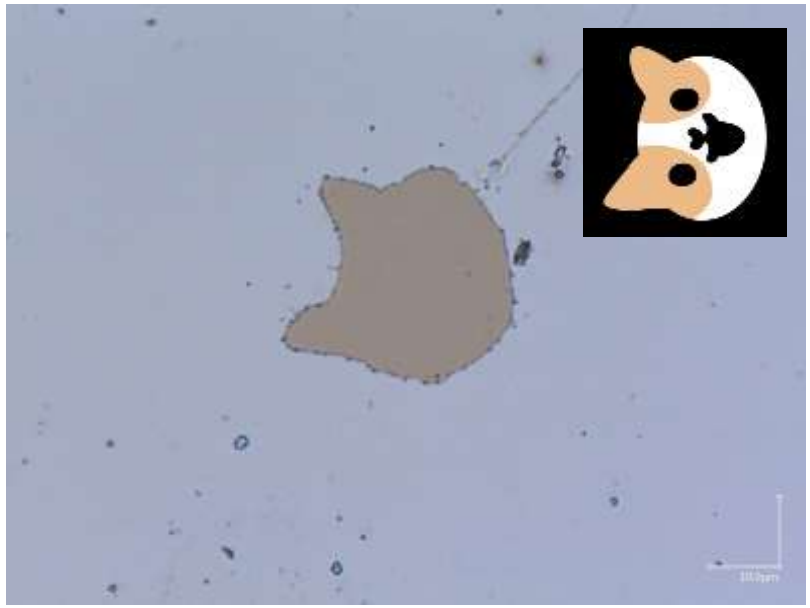


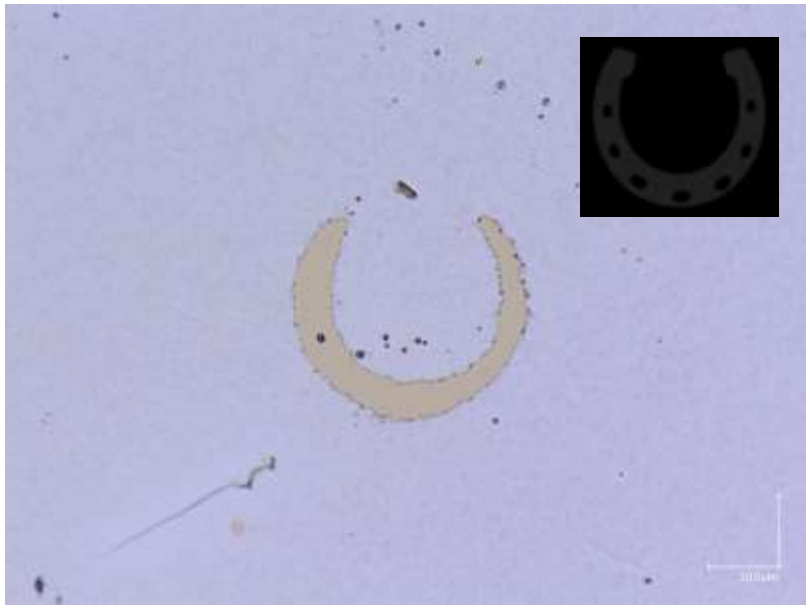




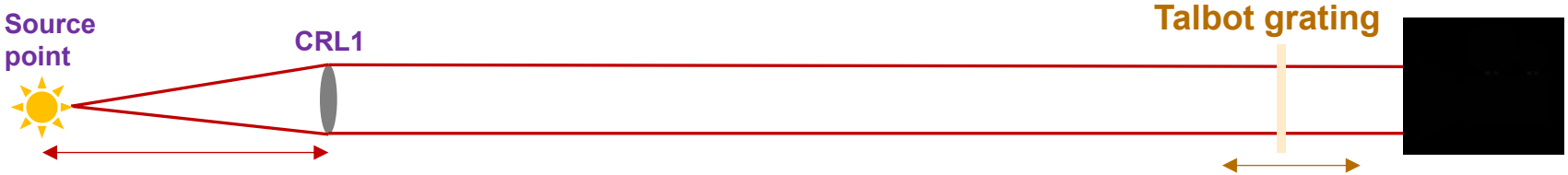
Confirmation of Damaged CRL…

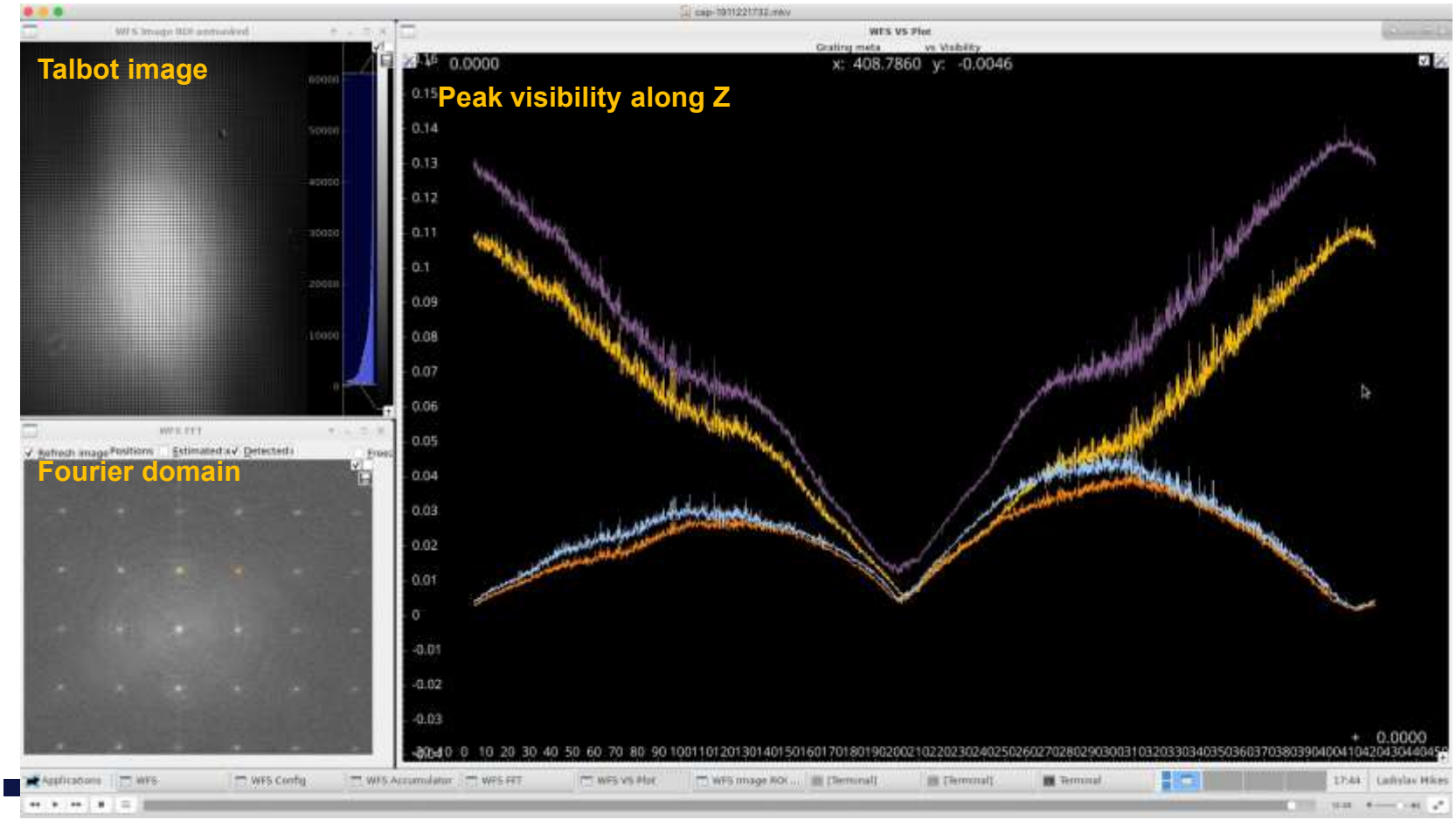
Towards focus ⟷ Away from focus





In the meantime parallel beam analysis…





March 2020!

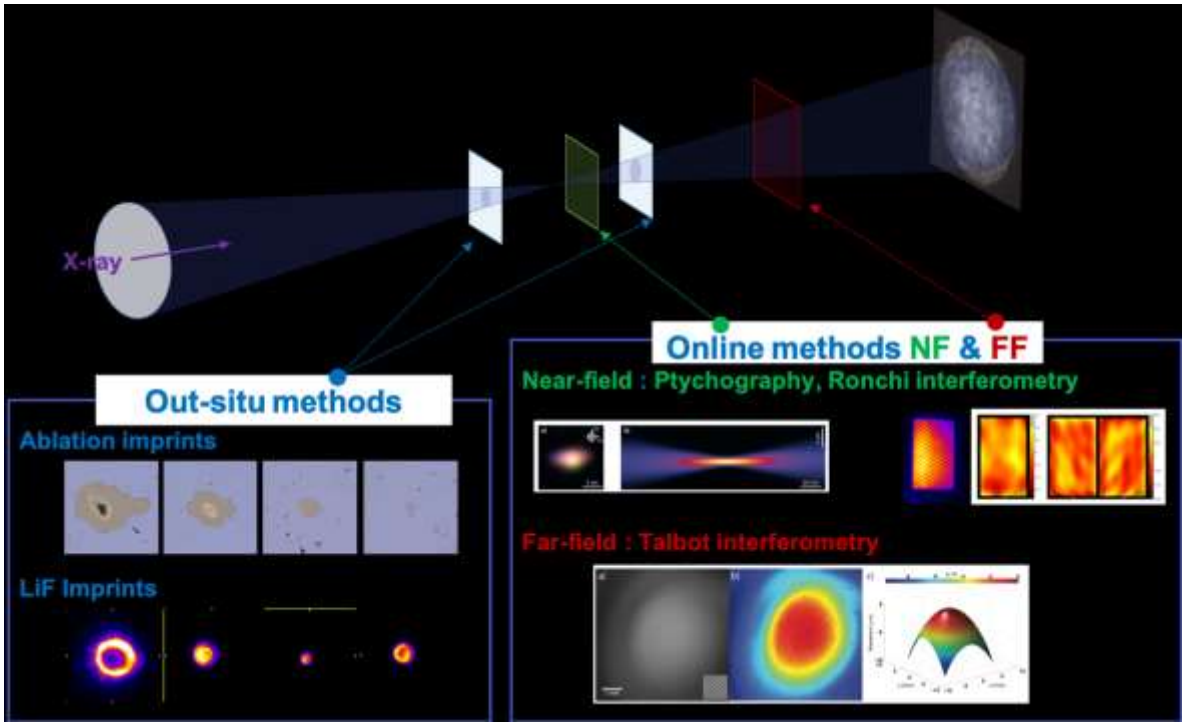
May 1 -5
Preliminary / Commissioning

Aug 5 -11
Main beamtime

Nov 8 -10
Commissioning

March 9 -15
Main beamtime

2019 → 2020



- **CRL4** round up analysis
- Phase plate profiling
- **CRL3 (new)** characterisation
- Optimum method for different focusing configuration

Summary

CRL impressions so far

- µm focus FWHM ~ 4µm

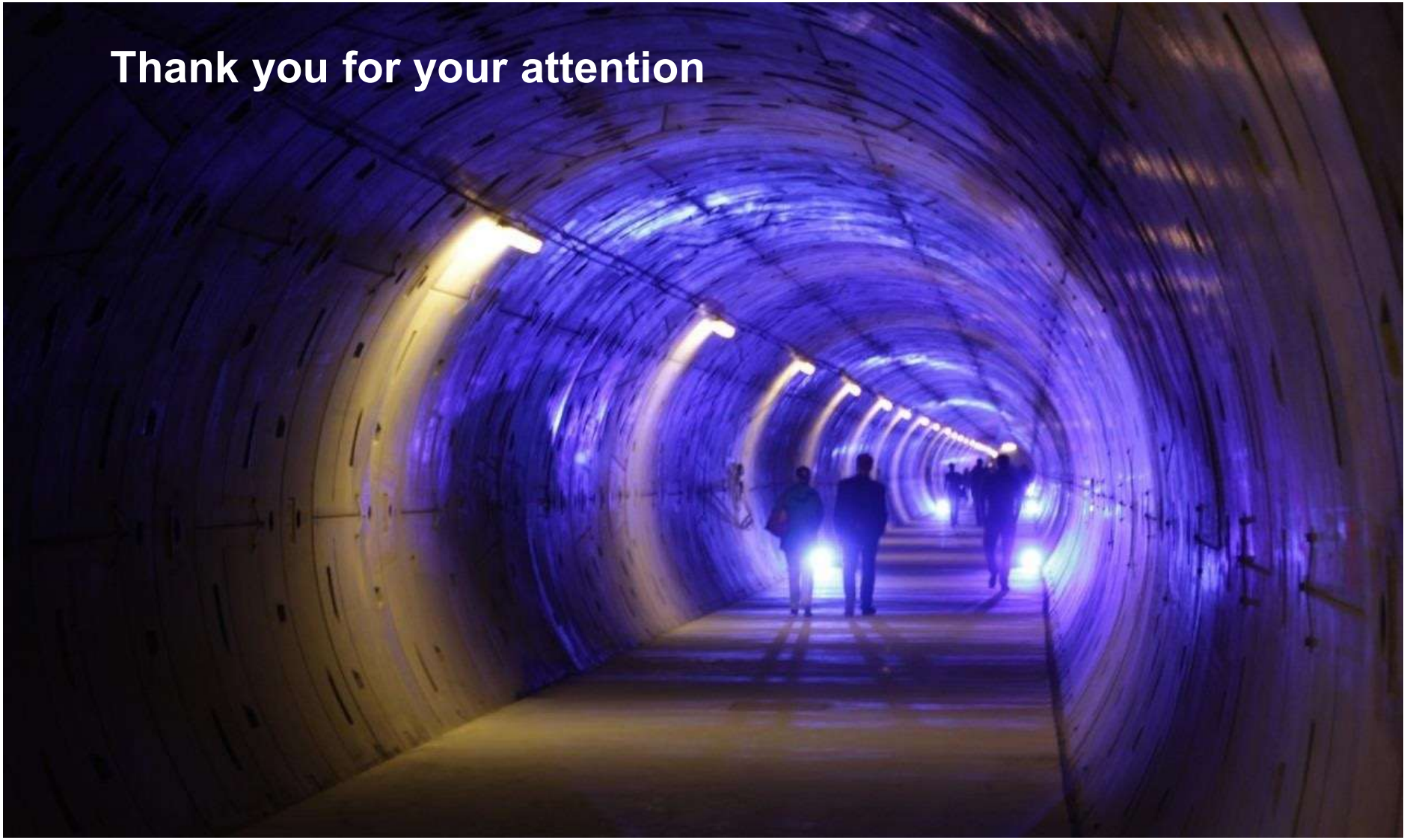
  Next => Confirm, and possibly improve
- nm focus FWHM estimate ~ 260 - 500 nm

  Next => Higher resolution measurement, with & without mono
- Development & Demonstration of methods

  Next => Ongoing, and going well ☺

Further plans

- Long term solution at HED ?
  - ”Permanent” setup
  - Source point for collimation in the tunnel
  - Strategy of focus measurement for each experiments


Thank you for your attention