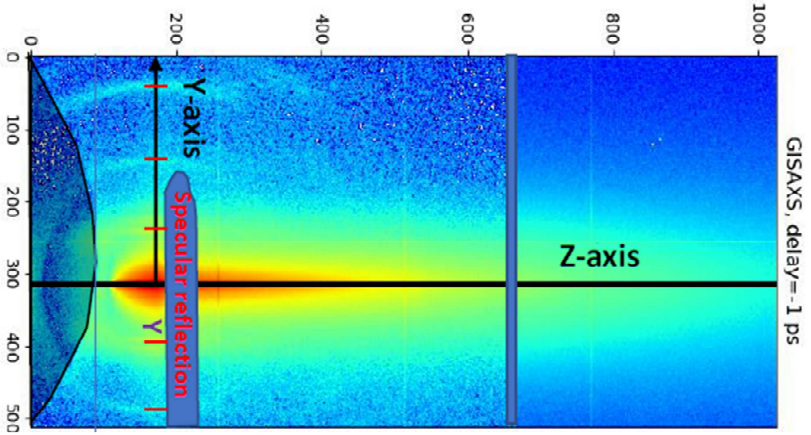
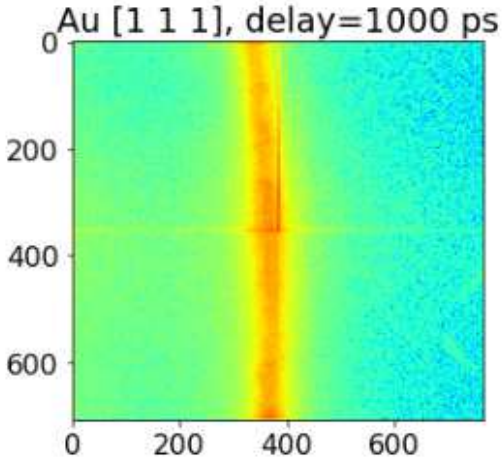
HED instrument
Technical capability and challenges for GISAXS/GID

M. Nakatsutsumi

GISAXS



GID



HED (High Energy Density) instrument and HiBEF (International Beamline for Extreme Fields) user consortium

European XFEL

HED High-Energy Density science

HiBEF User Consortium

HZDR DESY. Science & Technology Facilities Council

www.hibef.eu.

Spokesperson: T. E. Cowan (HZDR)

Interaction chamber 1 (multipurpose + spectroscopy)

Interaction chamber 2 (high pressure, XRD with large Q coverage)

HiBEF contributions

Diamond anvil cell (DAC)

Pulsed Magnets 50-60T

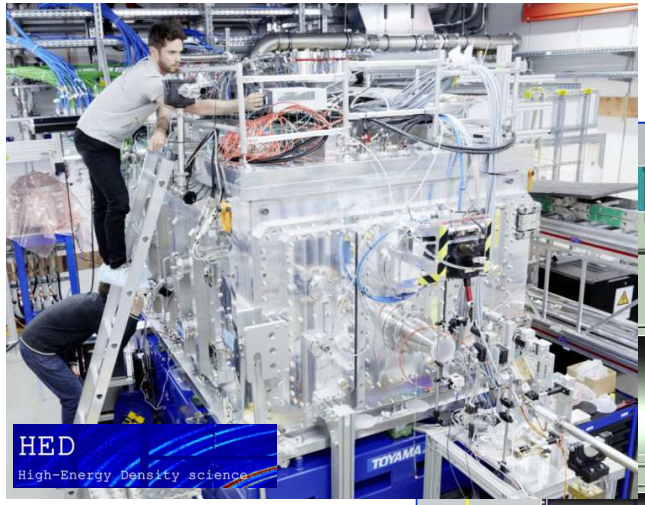
Additional instrumentation:

cnrs CELIA IM2NP LSI Centre Lasers Intenses et Applications HI JENA HELMHOLTZ Helmholtz Institute Jena

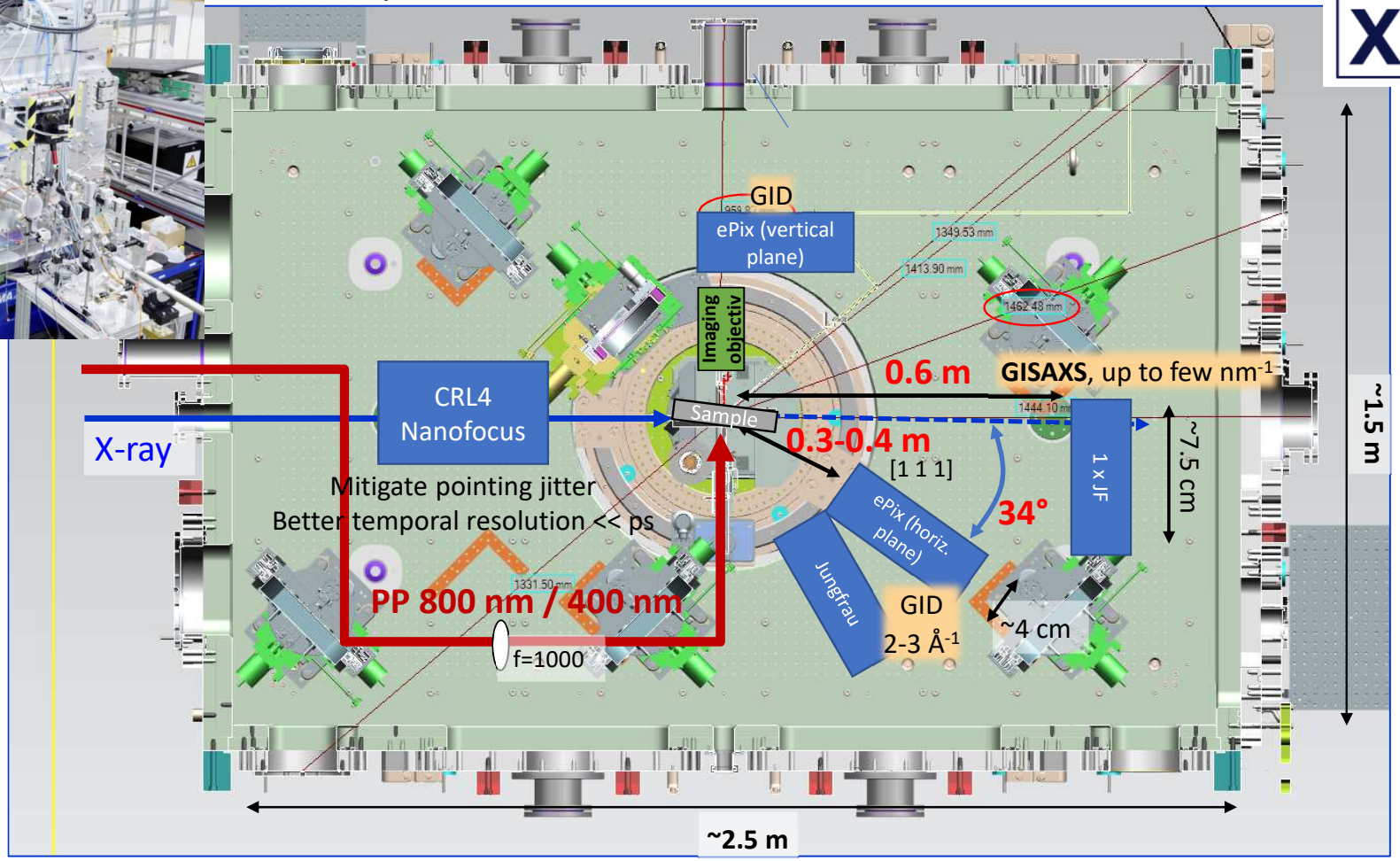
HED/HiBEF instrument paper
Zastrau et al JSR **28**, 1393 (2021)
https://scripts.iucr.org/cgi-bin/paper?S1600577521007335

DAC platform at HED: Liermann et al., J. Sync. Rad. 28, 688 (2021)

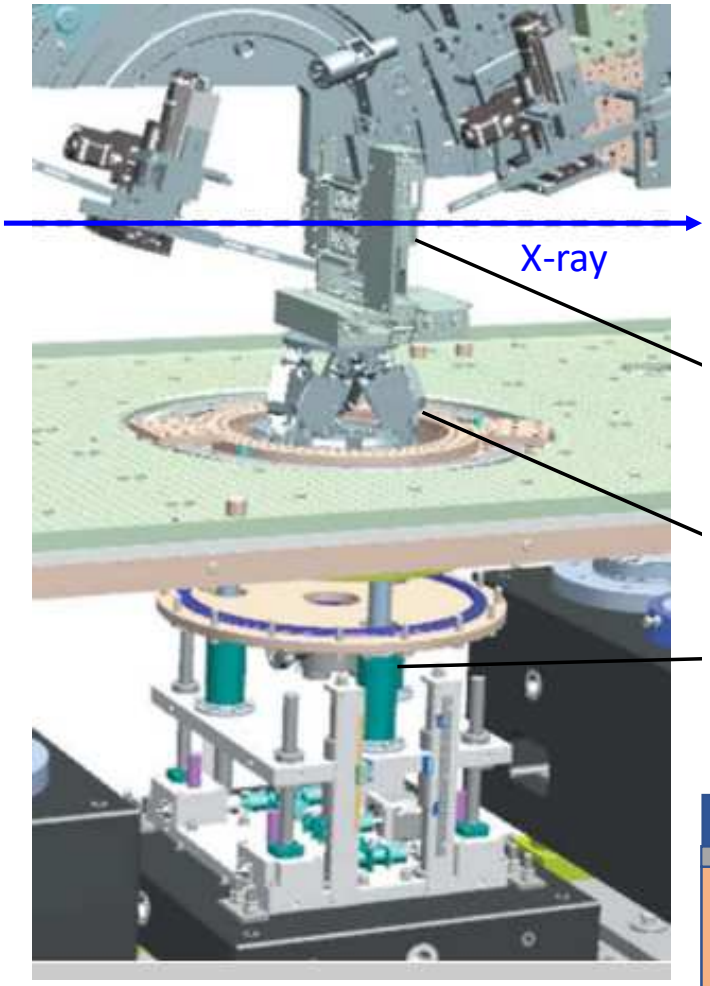
Setup for the GISAXS/GID experiments under vacuum (IC1)

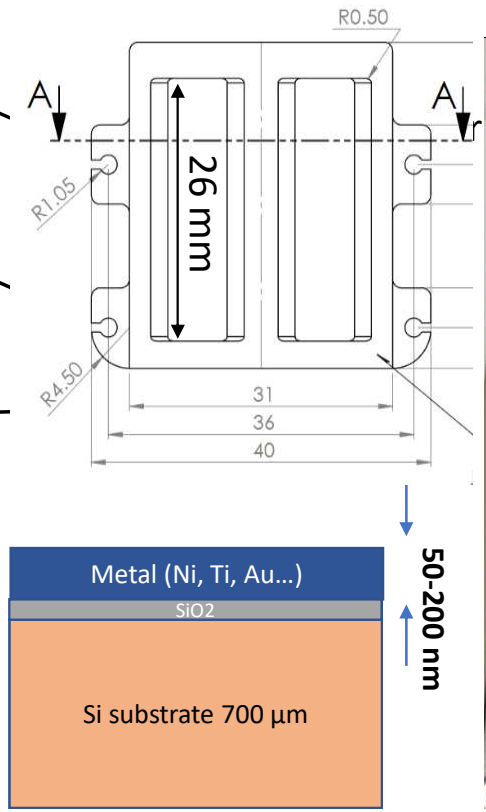


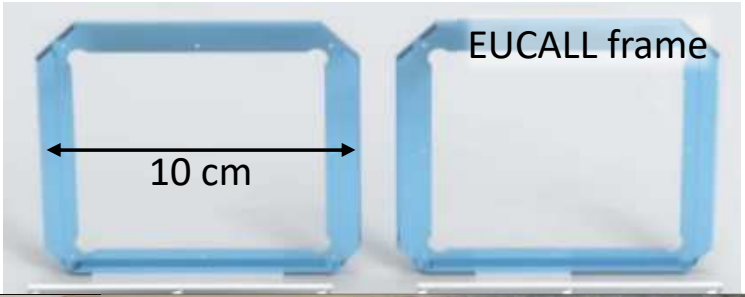
Top view, inside the IC1 vacuum chamber 10^{-5} mbar

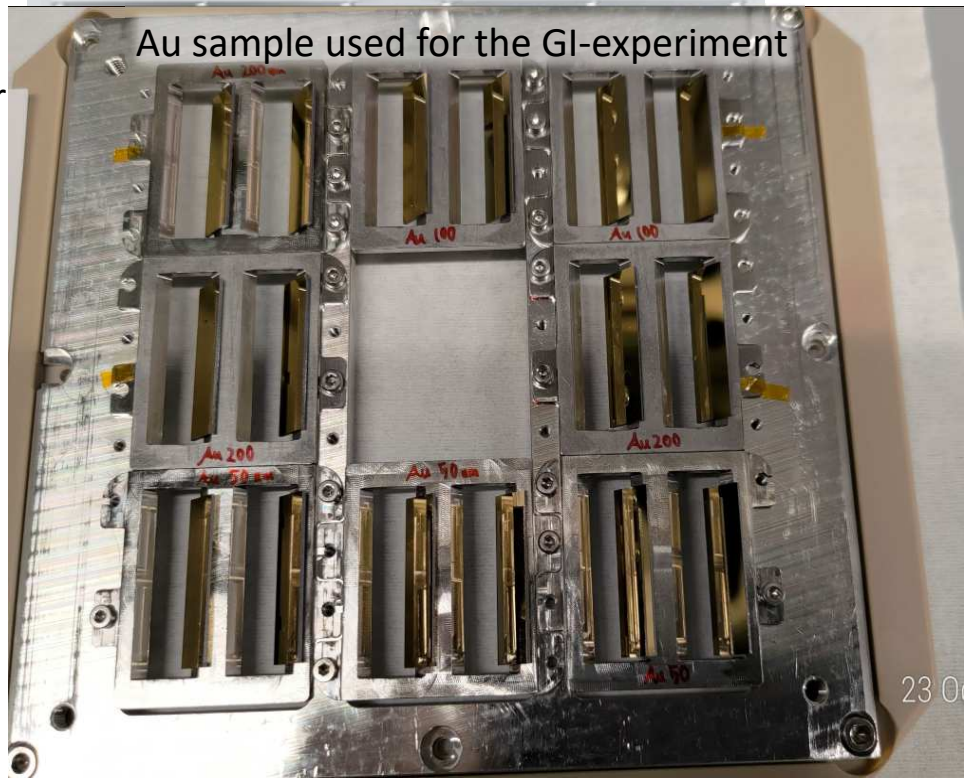


Solid sample environment at IC1 vacuum chamber



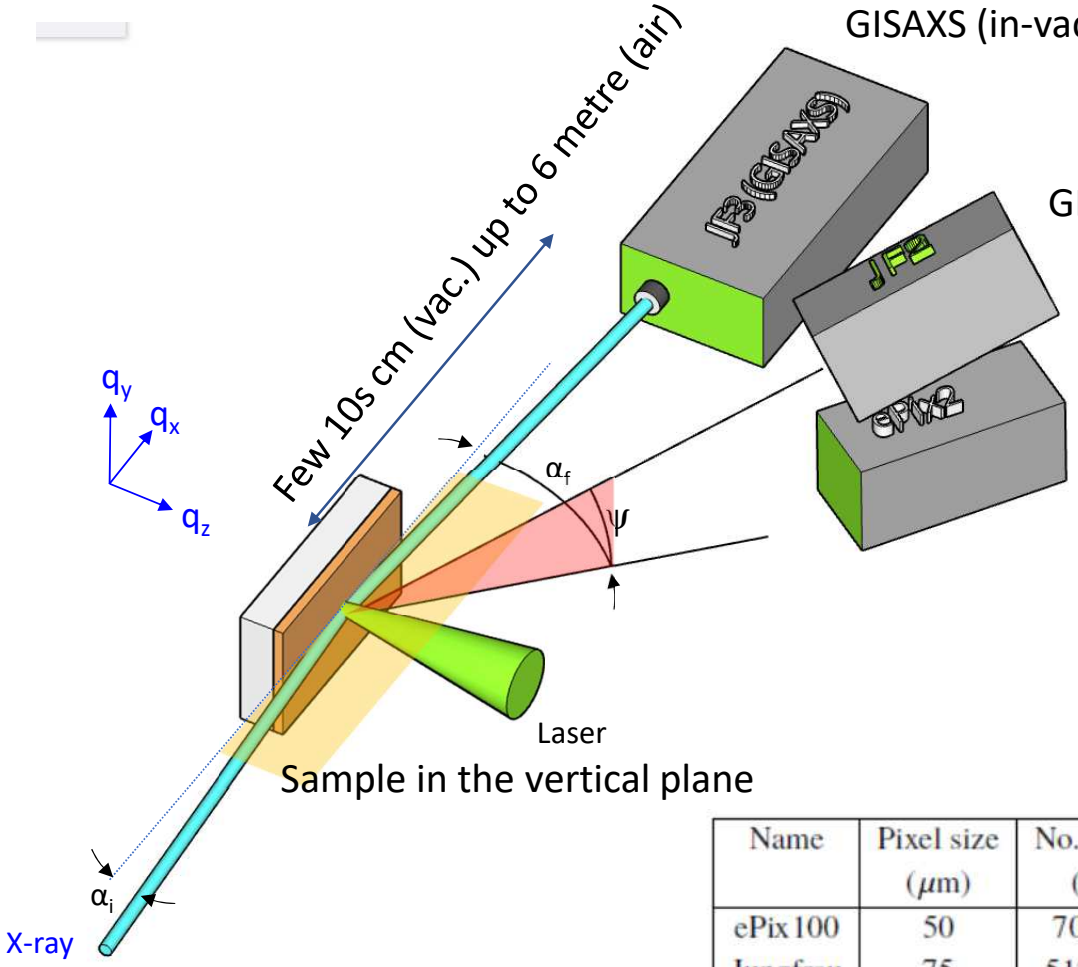






Zastrau et al JSR **28**, 1393 (2021)

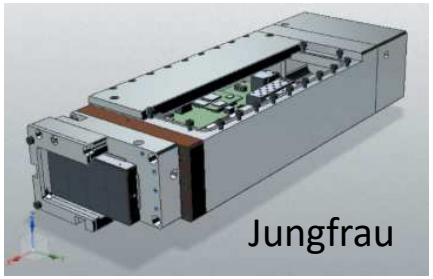
(In-vac) possible grazing-incidence geometry setup



GISAXS (in-vac. or in-air)

GID on the non-zero polar angle

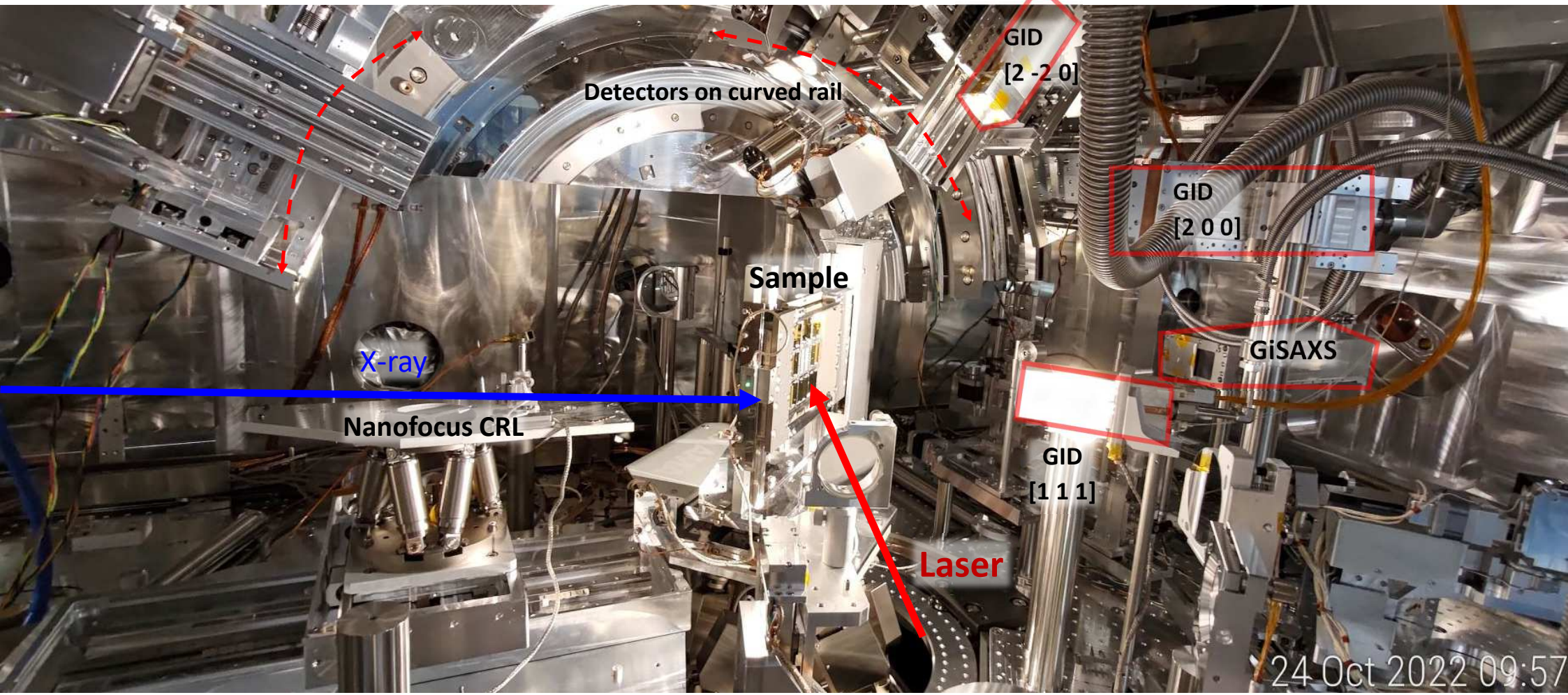
GID on the horizontal plane



Name	Pixel size (μm)	No. of pixels (adim.)	Detection area (mm^2)	Noise (eV)	Frame rate (Hz)	Dynamic Range (photons per pixel)
ePix100	50	704 × 768	35 × 38	< 280	120	10^2 8 keV
Jungfrau	75	512 × 1024	38.55 × 77.25	< 450	2400	10^4 12 keV

Klačnová J. Instrum. **14** C01008 (2019); Mozzanica Sync. Rad. News **31** 17 (2018)

Impression inside the IC1 vacuum chamber



Possible science case:
fs laser-induced nano-structuring dynamics (LIPSS)

LIPSS (laser-induced periodic surface structure)
e.g, J. Bonse et al., IEEE J. selec. top. quant. elec. **23**, 9000615 (2017)

- Last 3 decades study. Both experiment and theory.
- Still missing – direct visualization of 'dynamics'
  → nm and (sub-)ps resolution, high quality data

Laser (PP)
Requirements: ≤ 100 fs, 0.1-1 J/cm^2, ≥ 100 µm spot with good homogeneity

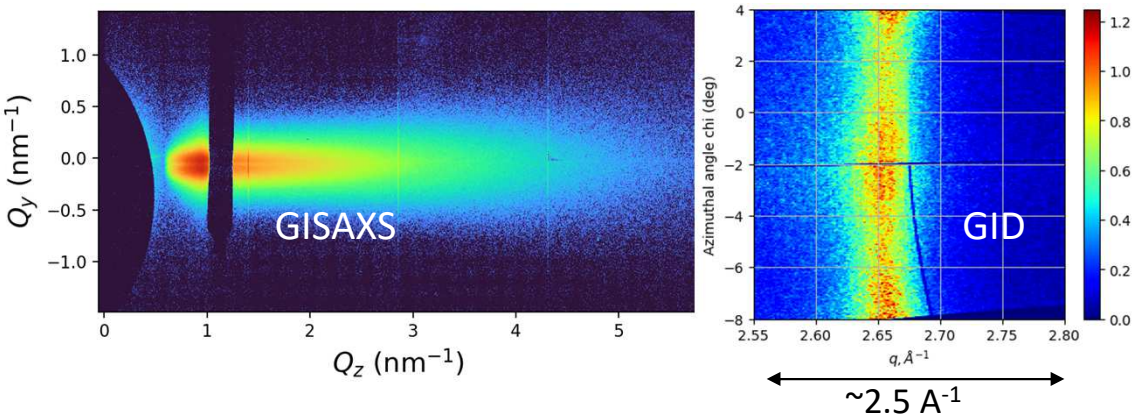
λ = 800 nm: 50 fs, 1 mJ on sample
λ = 400 nm: 50 fs, 0.1 mJ on sample
➔ 0.1 mJ, 100 µm spot → > 1 J/cm^2
➔ Gaussian profile

Shot-on-demand, 10 Hz, or up to ~200 kHz instraburst (40 pulses inside 200 µS RF window)

Polarization control, double pulses …

Detector
Jungfrau / ePix, 10 Hz

GISAXS at 50-60 cm from the sample
GID (GIWAXS) at different azimuthal/polar angle
➔ simultaneously, with limited Q-coverage
(large Q-coverage 10Hz detector in future)

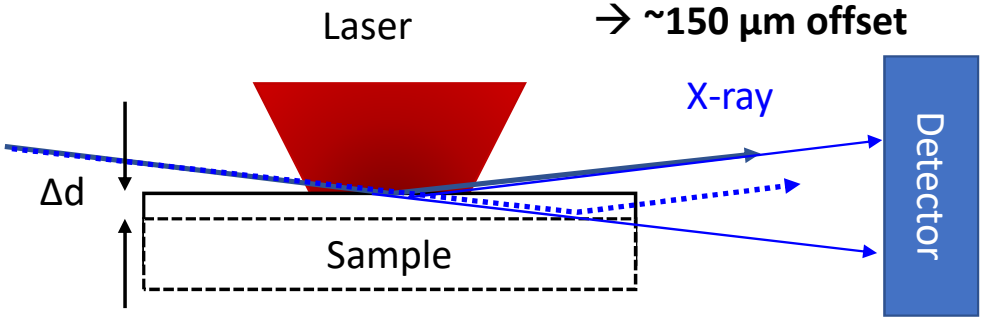


Temporal overlap (x-ray and laser) on sample
Procedure established. ~< 100 fs precision.

Pre- and post-analysis of sample on-site at EuXFEL
SEM, AFM, FIB, …

Challenges: keep spatial overlap X-ray – laser

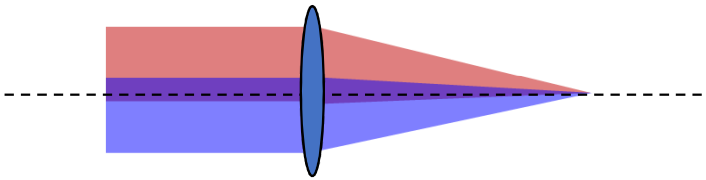
Grazing incidence, i.e. 0.7°

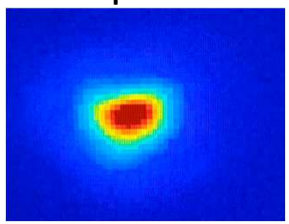


Δd = 2 µm misalignment in depth
→ **~150 µm offset**

Alignment procedure is established (for shot-on-demand)
→ Using specular reflection
→ < 2 µm precision possible

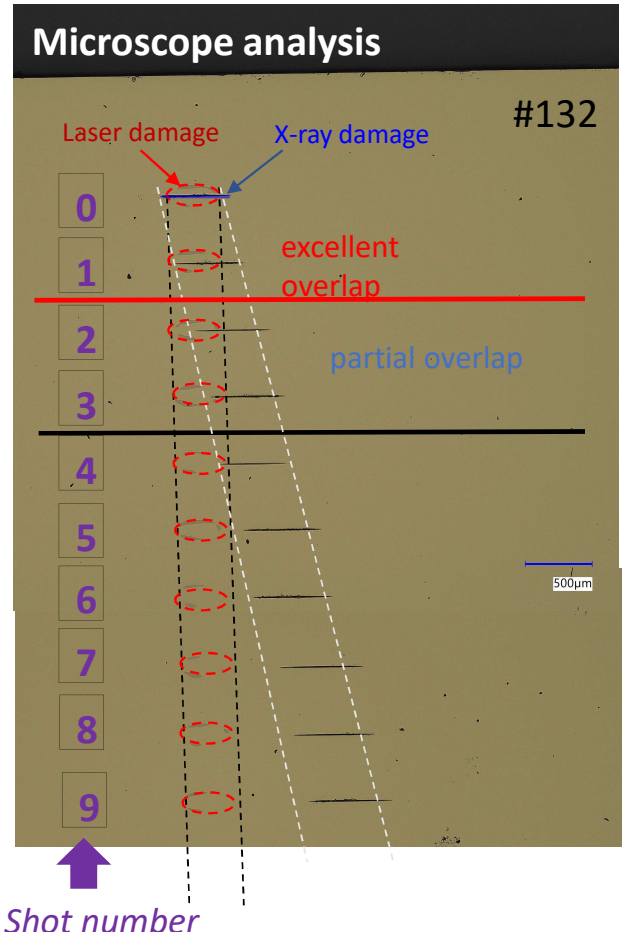
X-ray pointing fluctuation
→ Using the focusing CRL very close (~30 cm) to sample



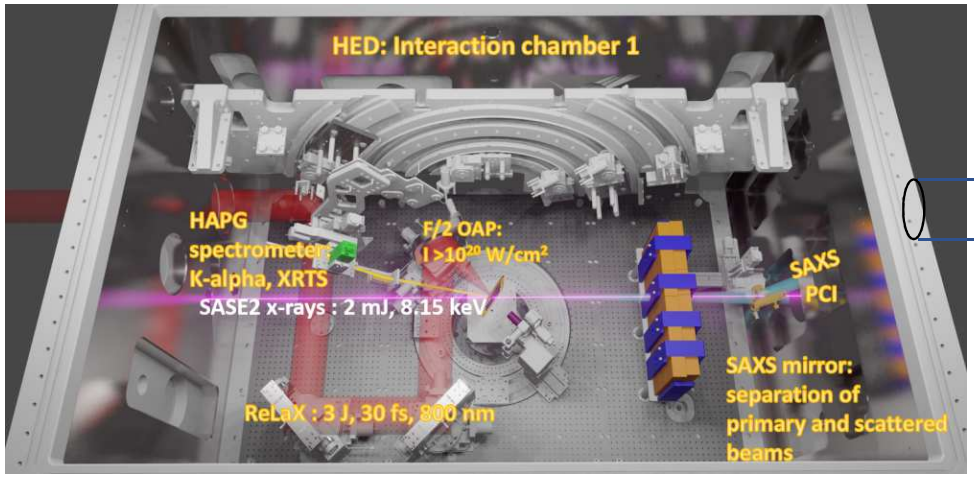


→ Sub-µm beam – footprint < 100 um, temporal res. < 300 fs (even better in self-seeding)

Still a challenge
→ **beam walk-off during 1D or raster scan**

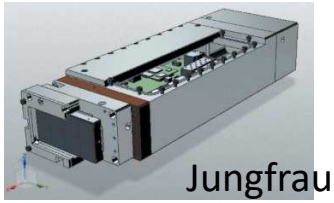


Possible science case:
Propagation of surface current/plasmons-polaritons at electron-relativistic laser intensity



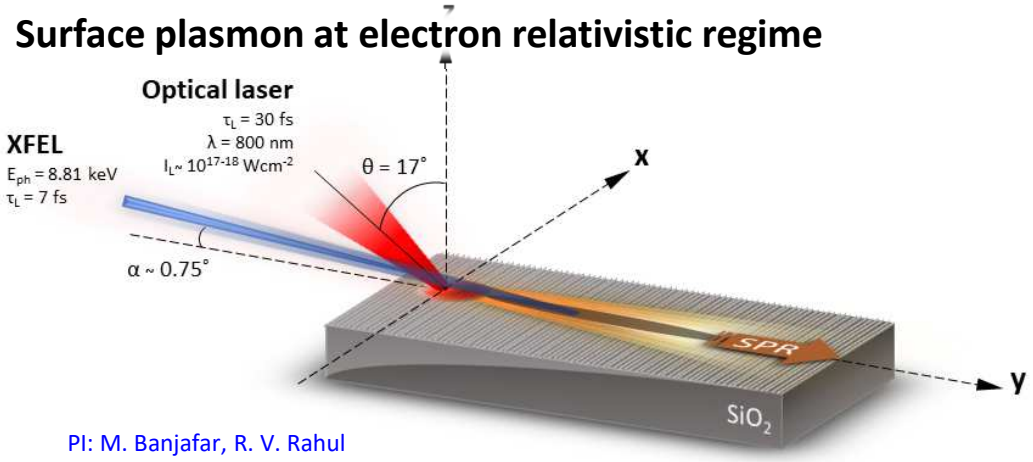
ReLaX 100 TW laser
3J / 30 fs

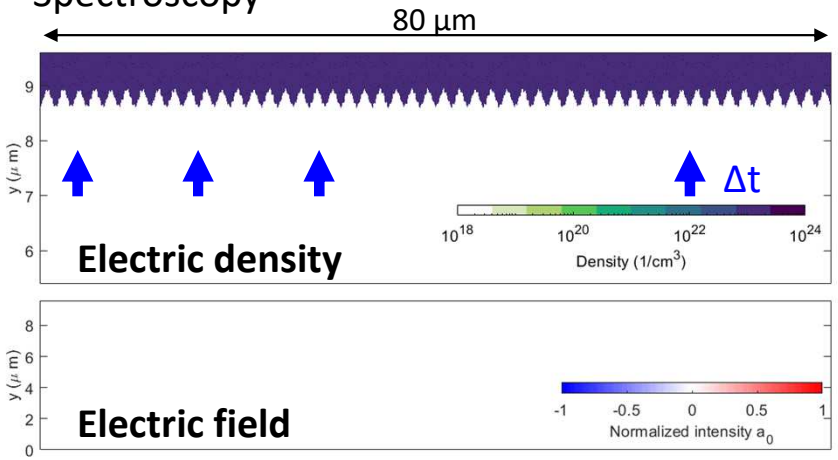
GISAXS
About 6 m from sample



- Place the detector far away to mitigate the plasma self-emission
- GISAXS OK, GID probably not.
- Spectroscopy

Surface plasmon at electron relativistic regime

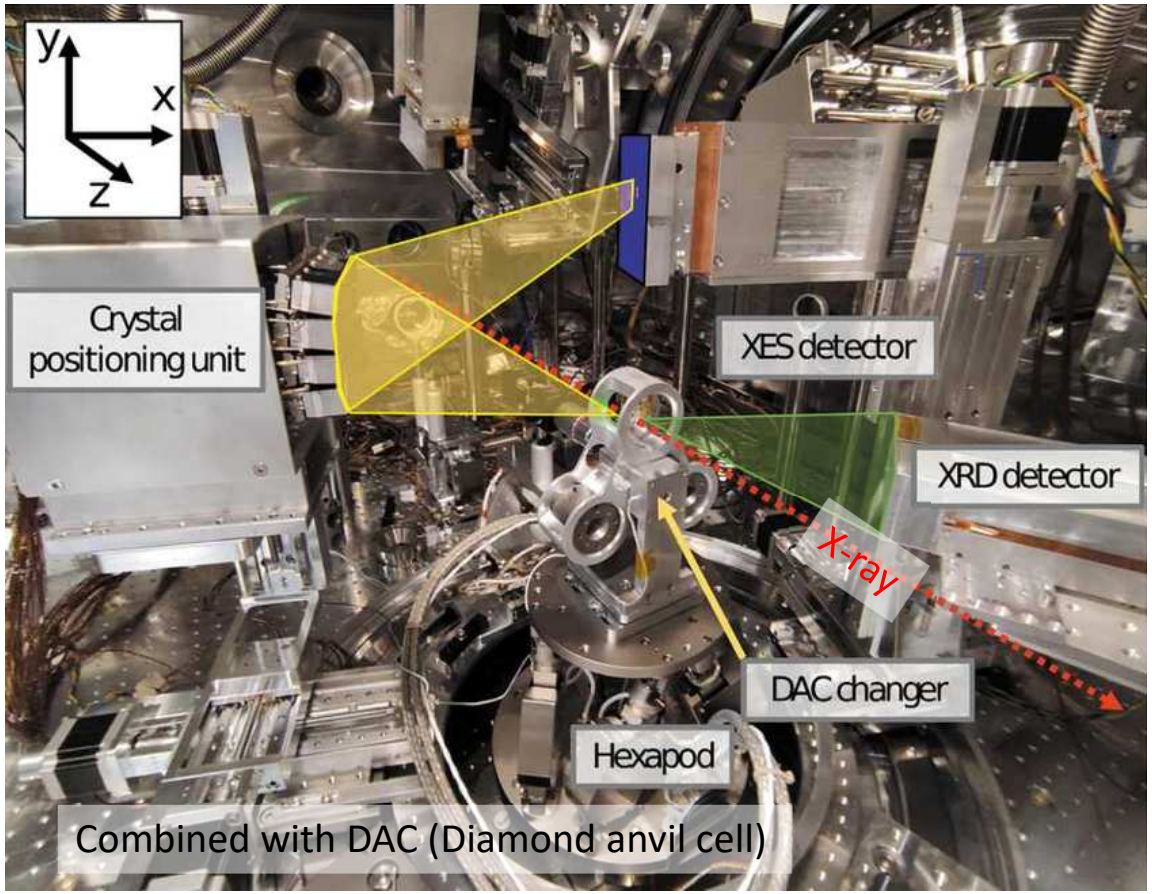




PI: M. Banjafar, R. V. Rahul

Other possible components/devices

In-vacuum Von Hámos spectrometer for XES



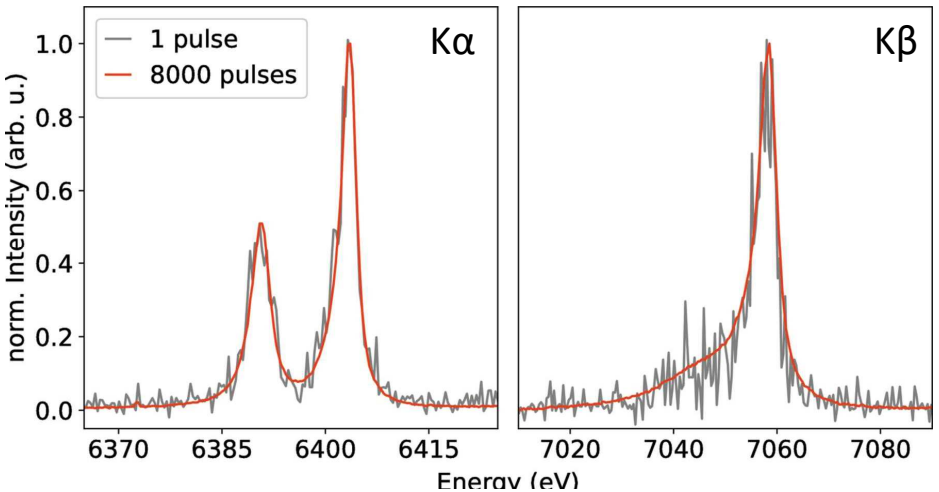
Kaa, Konôpková et al., JSR 30, 822, (2023)

90 deg in the horizontal plane.

Si or Ge analyser crystals
< eV energy resolution

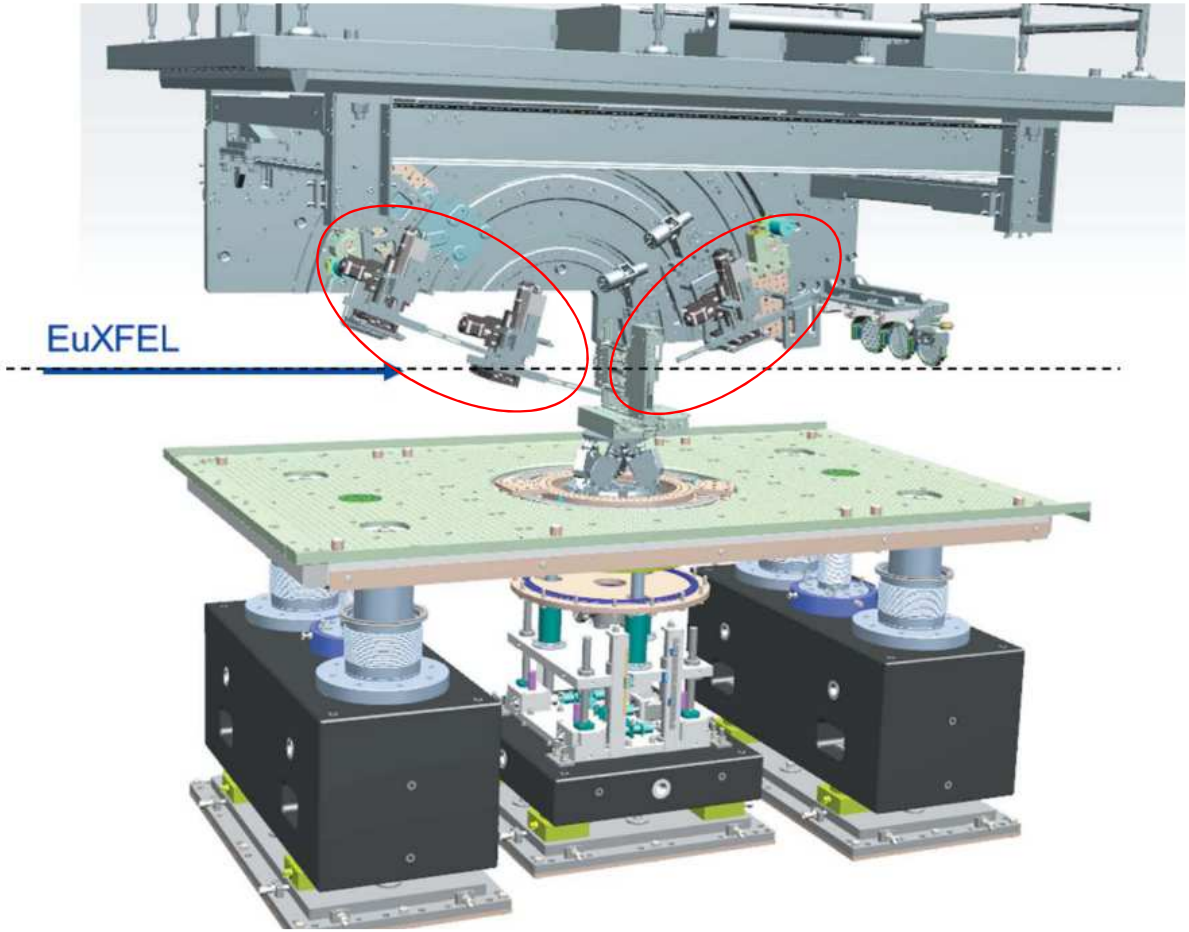
Cylindrically bent four-crystal spectrometer
Bragg angle 60 – 80 deg

6 – 11 keV

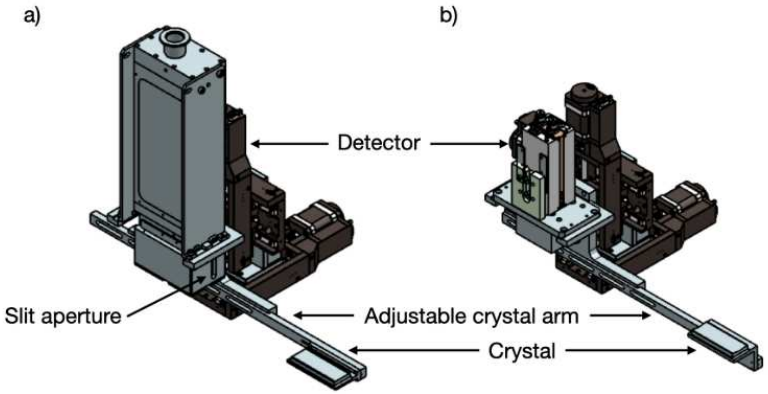


Forward and backward spectrometer in Von Hámos geometry

On the vertical breadboard rail, allows Q scan



Zastrau et al., JSR **28** (2021)



- Thomson scattering, backward Compton scattering
- Shielding around the detector allows operating them together with 100 TW laser.

Preston et al., JINST **15** P11033 (2020).