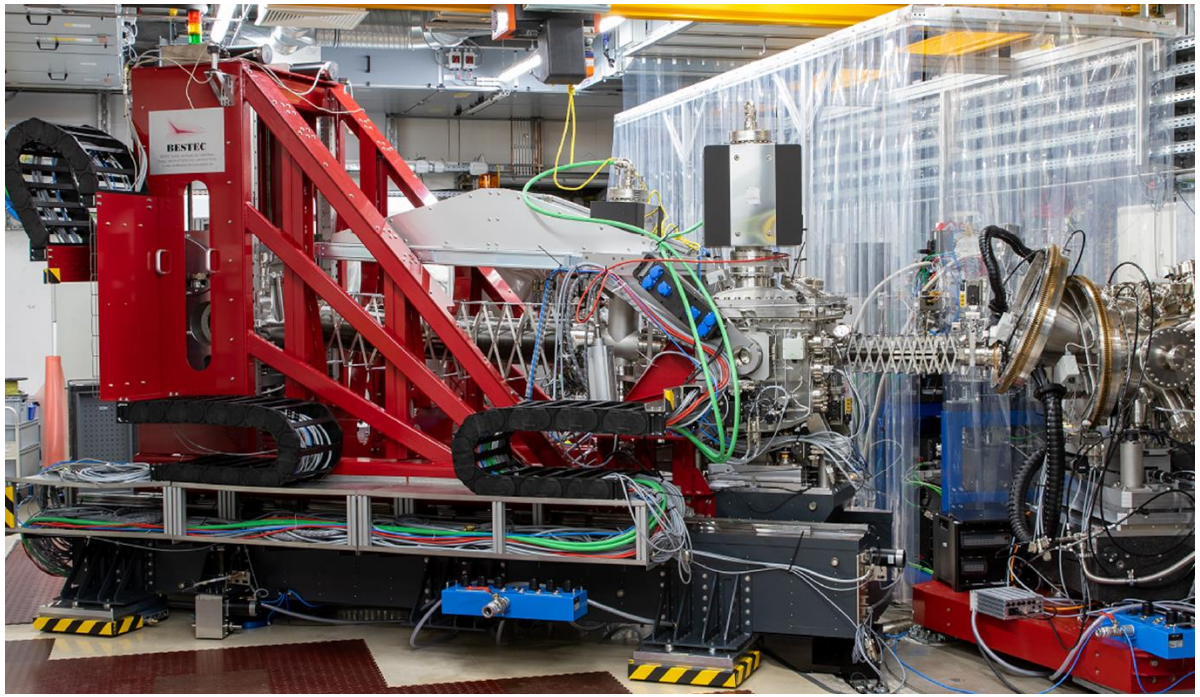
Advances on hRIXS instrument for time-resolved RIXS from quantum materials

Justine Schlappa
Spectroscopy and Coherent Scattering (SCS Instrument)
European XFEL



Schenefeld, January 23, 2025

hRIXS working group

DESY Hamburg: Tim Laarmann, Wilfried Wurth, Simone Techert
European XFEL: Andreas Scherz
Politecnico Milano: Ying Ying Peng, Giacomo Ghiringhelli
Uni Potsdam: Alexander Föhlisch

Justine Schlappa, **Giacomo Ghiringhelli**, Benjamin Van Kuiken, Martin Teichmann, Piter Miedema, Jan Torben Delitz, Natalia Gerasimova, Serguei Molodtsov, Luigi Adriano, Bernard Baranasic, Carsten Broers, Robert Carley, Patrick Gessler, Nahid Ghodrati, David Hickin, Le Phong Hoang, Manuel Izquierdo, Giuseppe Mercurio, Sergii Parchenko, Marijan Stupar, Zhong Yin, Leonardo Martinelli, Giacomo Merzoni, Ying Ying Peng, Torben Reuss, Sreeju Sreekantan Nair Lalithambika, **Simone Techert, Tim Laarmann**, Simo Huotari, Christian Schroeter, Burkhard Langer, Tatjana Giessel, Jana Buchheim, Grzegorz Gwalt, Andrey Sokolow, Frank Siewert, Robby Buechner, Vinicius Vaz da Cruz, Sebastian Eckert, Chun-Yu Liu, Christian Sohrt, Christian Weniger, Annette Pietzsch, Stefan Neppl, Friedmar Senf, **Andreas Scherz**, and **Alexander Foehlisch**

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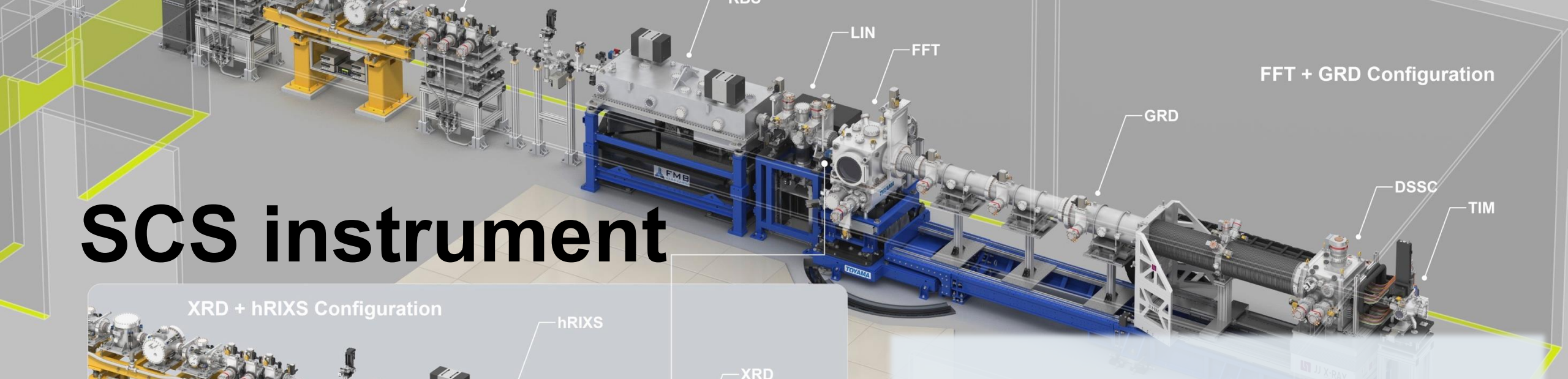
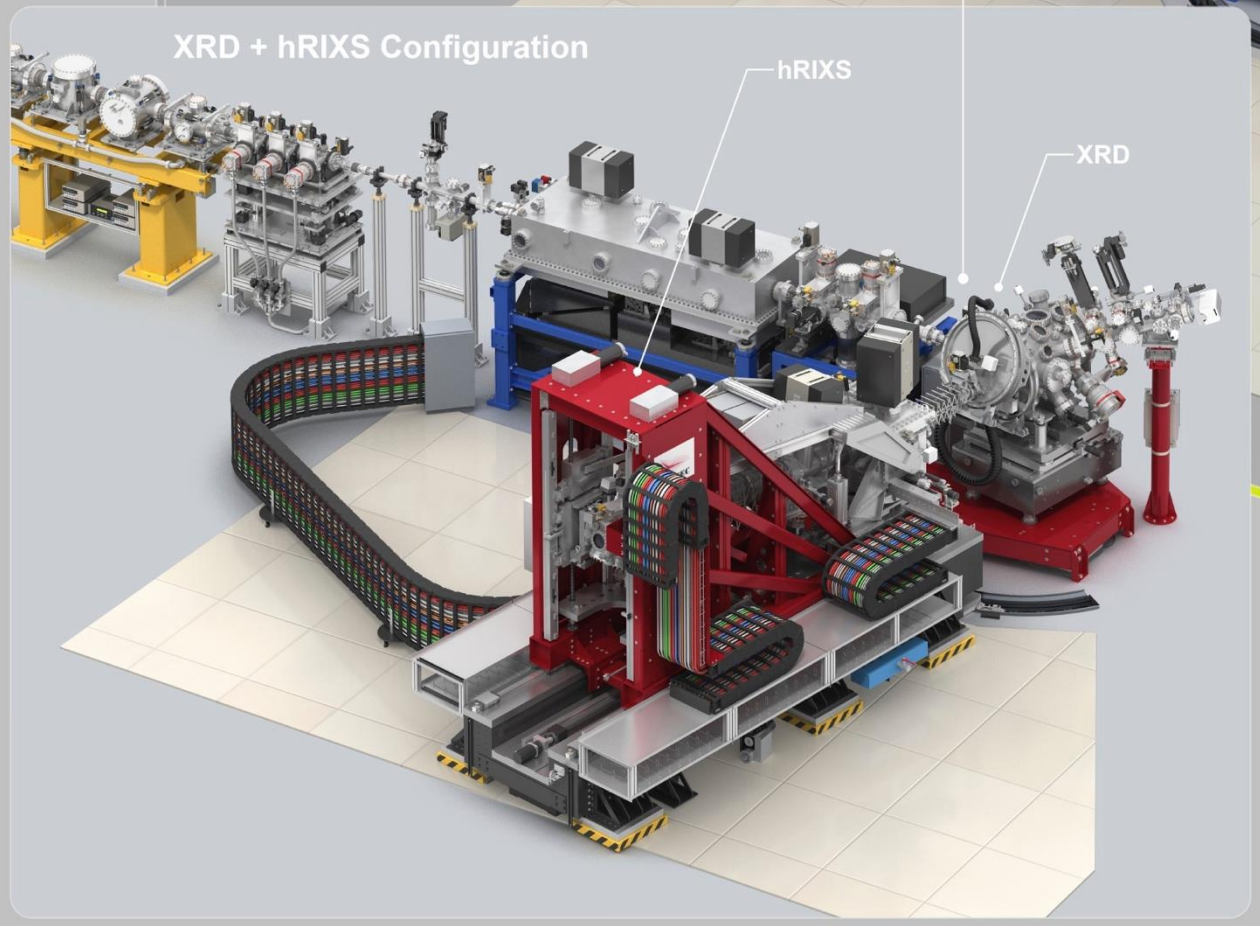
J. Synchrotron Rad. 32, 29 (2025)

SCS instrument





hRIXS spectrometer and XRD / CHEM experiment station

in operation since 2022

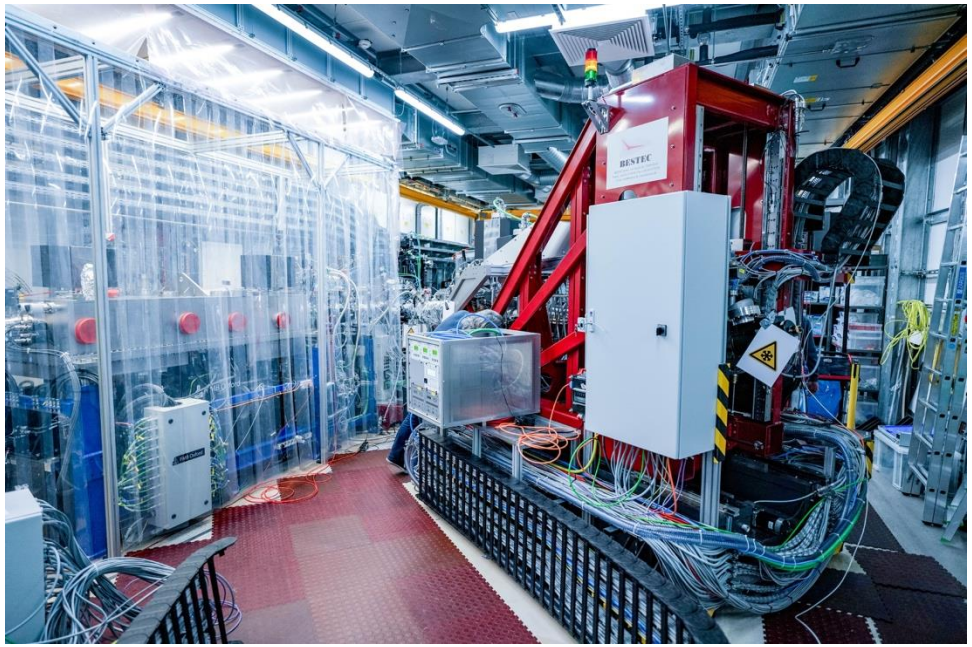
enabling backscattering geometries and reflection

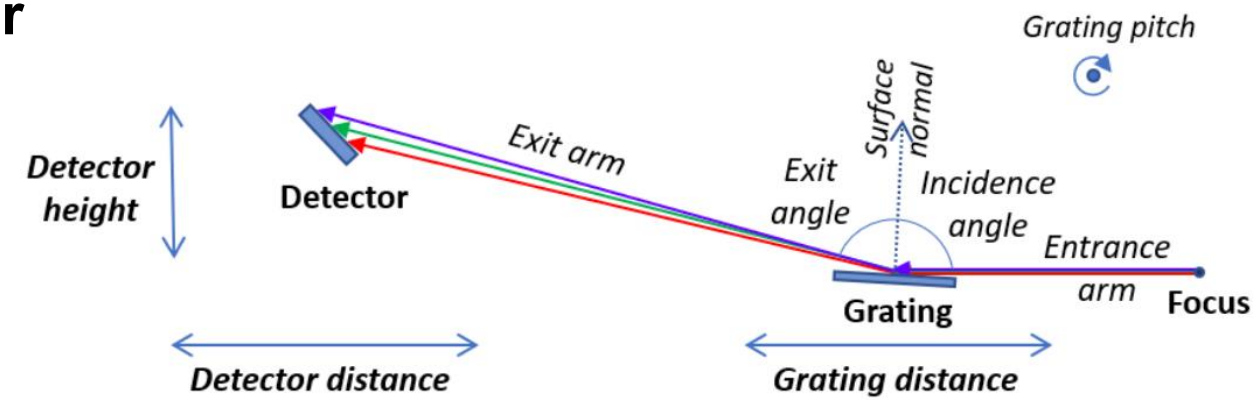
- Resonant Inelastic X-ray Scattering
- Resonant Elastic Scattering / XRD

and their extensions to

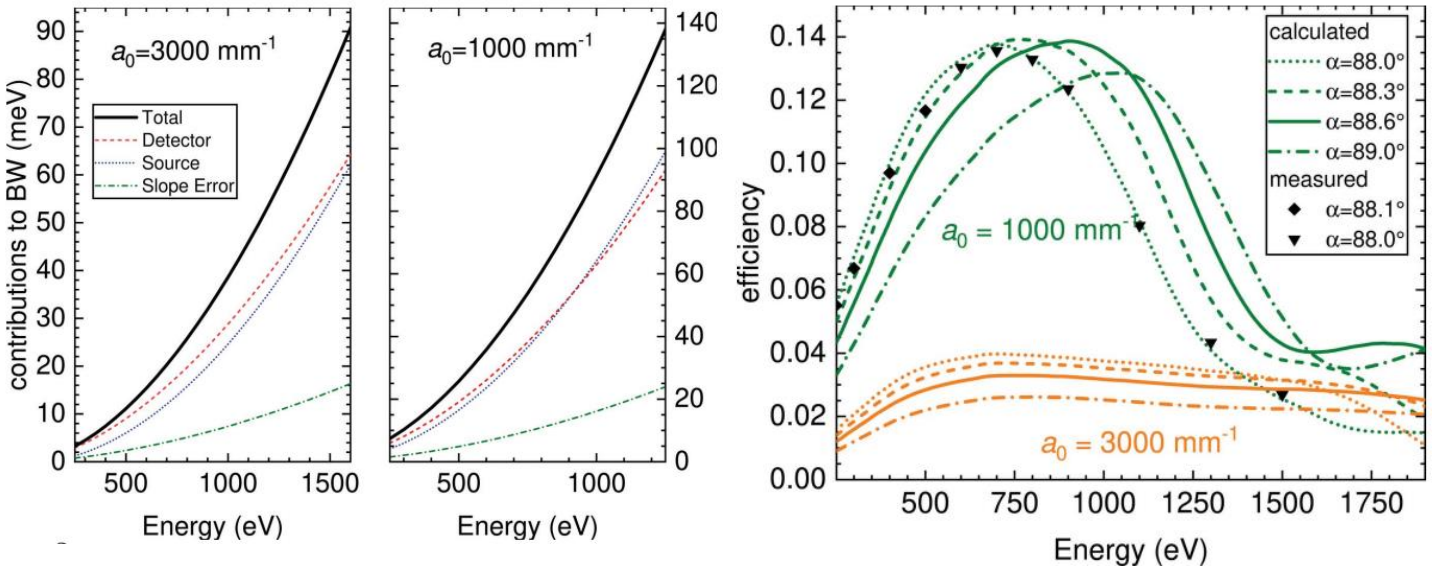
- Nonlinear X-ray-Matter Interactions
- Two color X-ray pump-probe

hRIXS User Consortium spectrometer





HR and LR Spectrometer gratings: Spherical VLS



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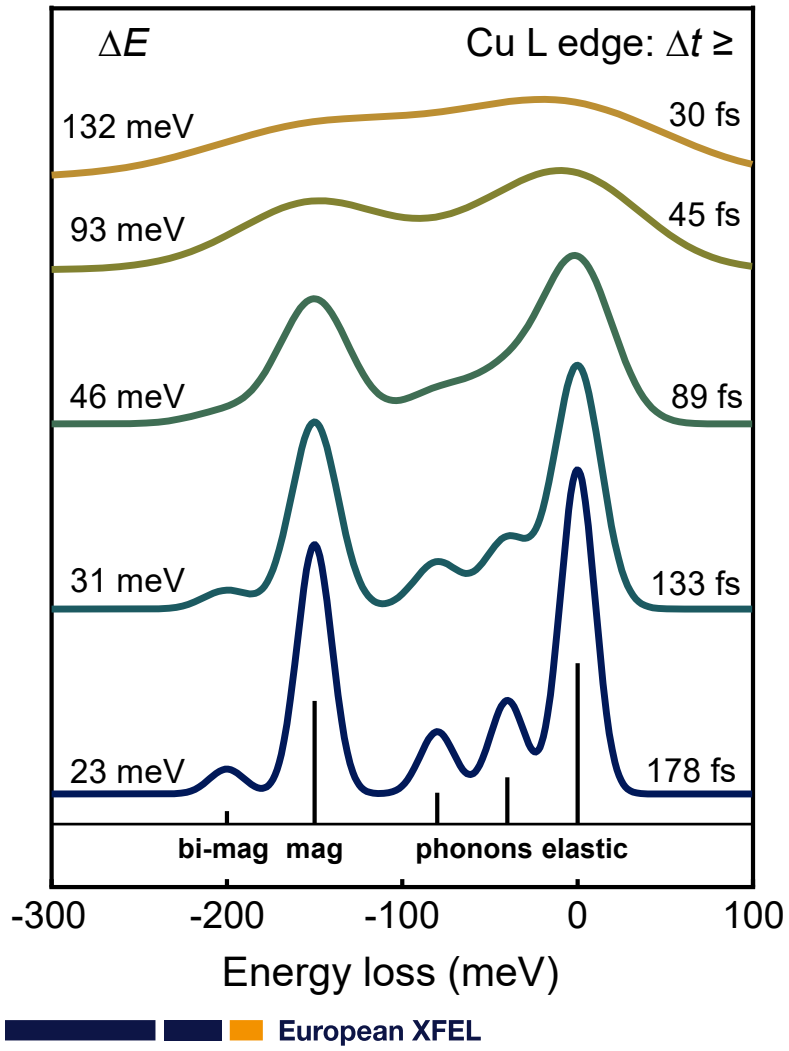
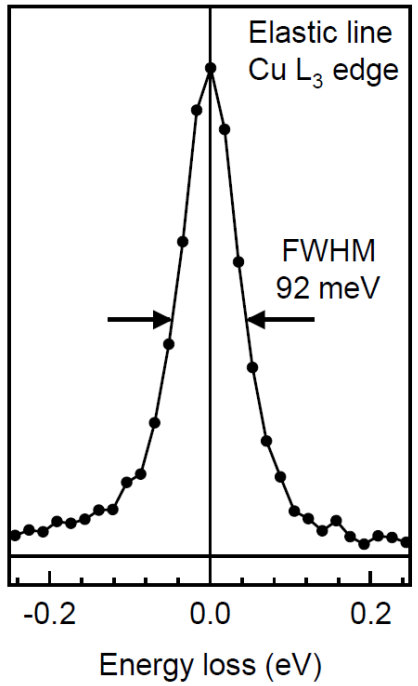
Heisenberg RIXS Spectrometer at the SCS instrument





High energy resolution

- **E/ΔE ~ 10,000** resolving power
  - Magnetic excitations in cuprates at Cu L3 edge
  - High energy phonon branches at O K edge

High temporal resolution

- **80 fs** x-ray pulse stretching

Edge	Energy (eV)	Energy res. (meV)	E/ΔE
Cu L_3	930	92	10 100
Ni L_3	853	84	10 200
O K	530	49	10 400

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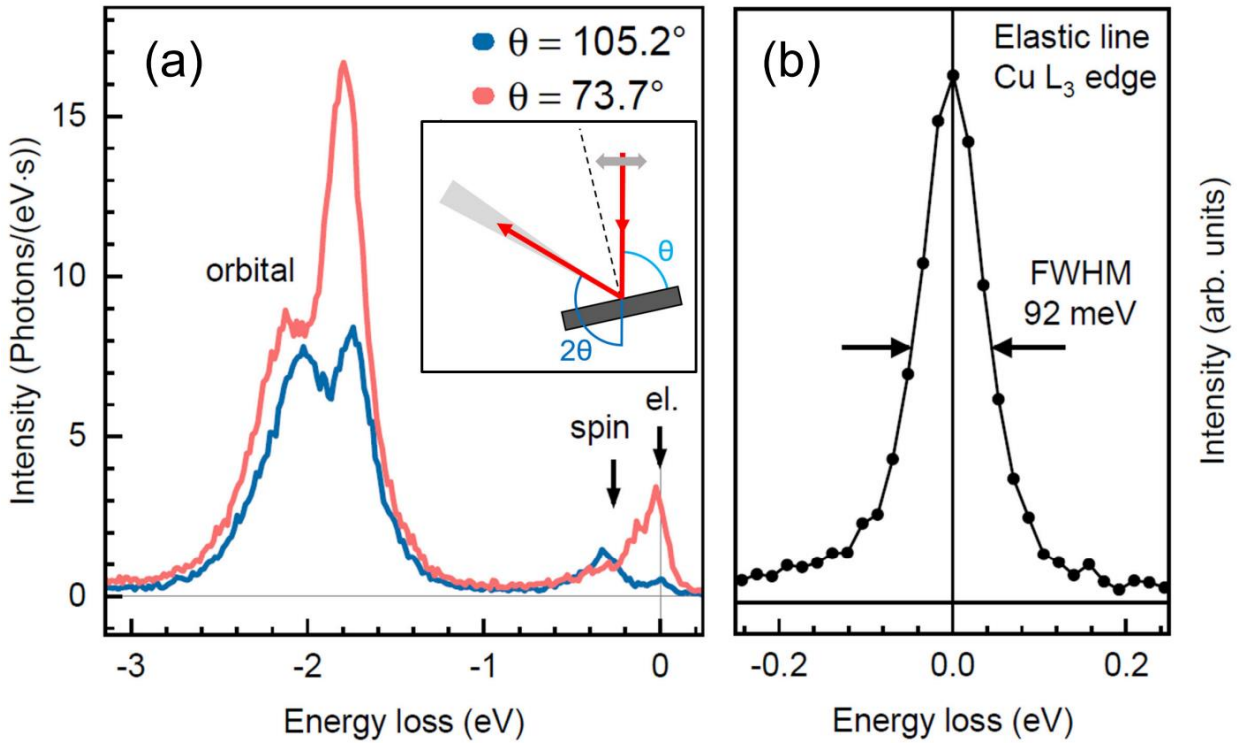
Heisenberg RIXS Spectrometer at the SCS instrument

Static RIXS from thin-film La_2CuO_4 at Cu L_3 edge:



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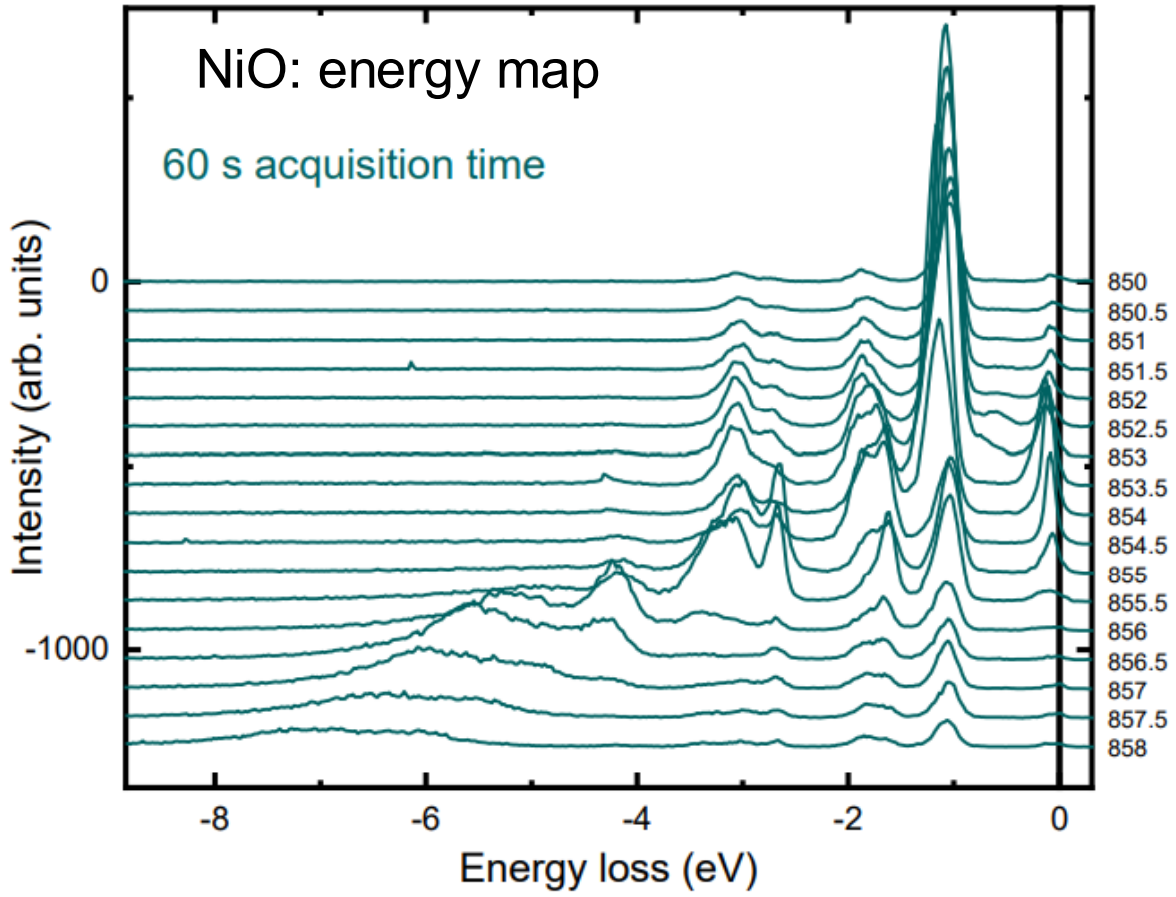
Heisenberg RIXS Spectrometer at the SCS instrument

Ni L_3-edge: 1.0 x 10^{13} ph/s on sample



High energy resolution

- **E/ΔE ~ 10,000** resolving power
  - Magnetic excitations in cuprates at Cu L3 edge
  - High energy phonon branches at O K edge

High temporal resolution

- **80 fs** x-ray pulse stretching @ Cu L3 edge

High Throughput

- Up to **1 MHz** repetition rate or 4,000 FEL pulses /sec or $\sim \mathbf{1 \times 10^{13} ph/s}$

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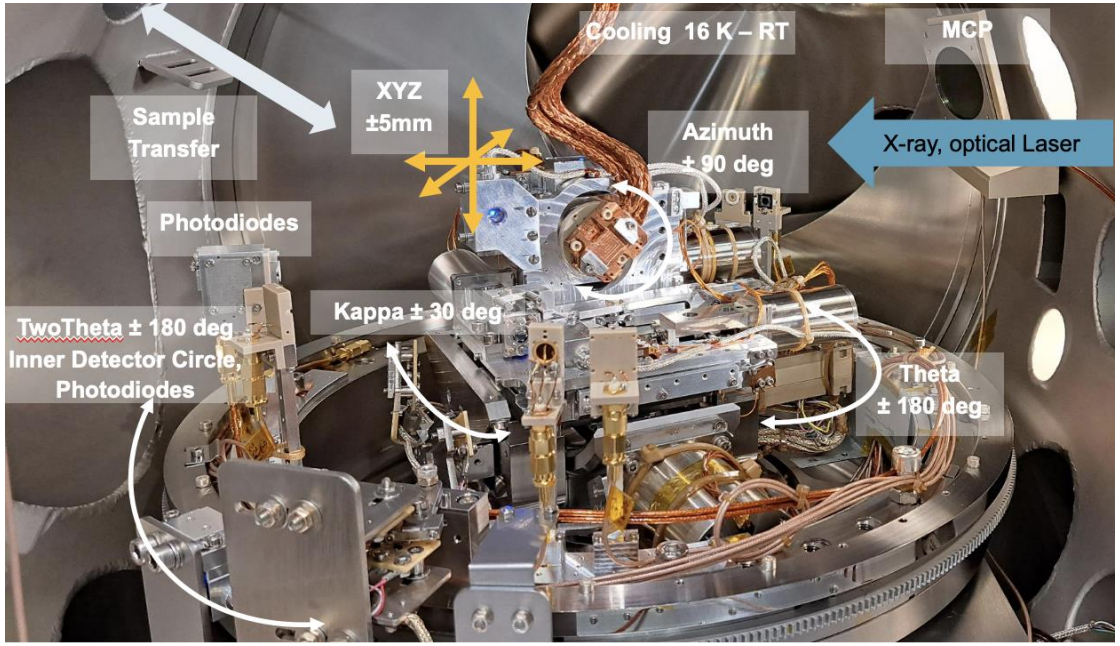
XRD experiment station and hRIXS spectrometer

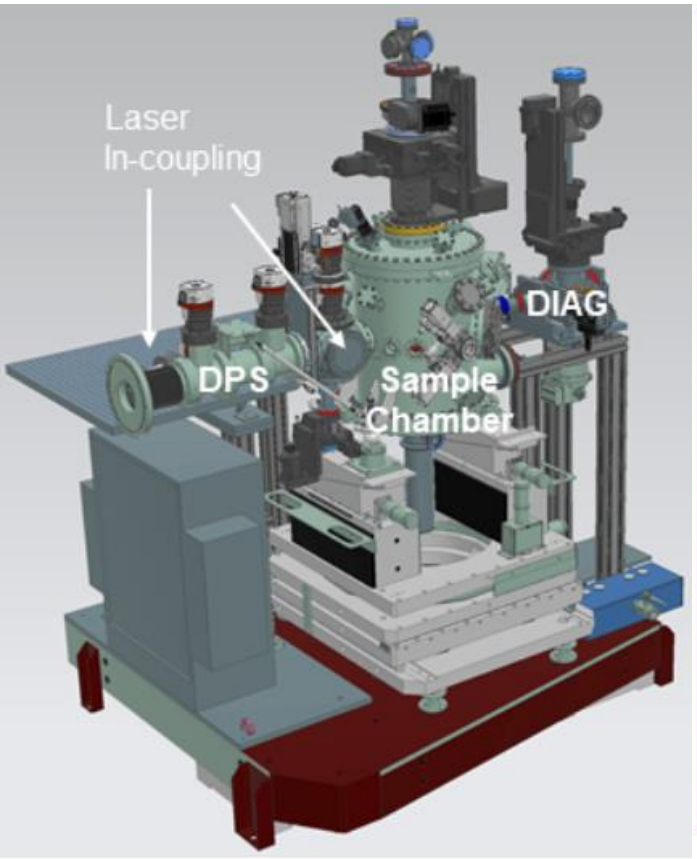


hRIXS parameters	
Photon energy	0.25 (0.45 SA3) – 1.5 keV
Combined resolving power	Up to 10.000 (mono HR) 3.000 (mono LR)
Transmission	~10^{-6}
Scattering angle	65 – 145 deg Default: 125 deg

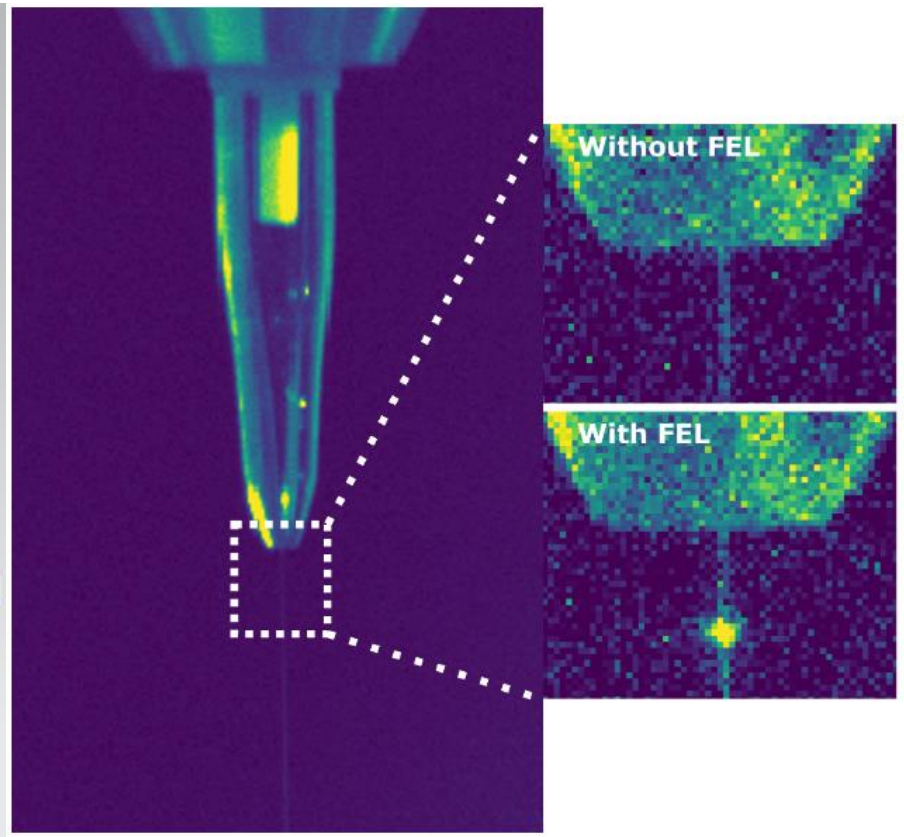
Motion	Range	Repeatibility
Detector TwoTheta	± 180 deg	< 1 µrad
Sample Theta	± 180 deg	< 1 µrad
Sample Kappa	± 30 deg	< 1 µrad
Sample Azimuth	± 90 deg	< 0.0002 deg
Sample X, Y, Z	± 5 mm	0.5 µm
Sample Temp	16 K – RT	

Chemistry Sample Environment

CHEM Chamber



Jet in Operation



See Talk of Benjamin van Kuiken

* Time-resolved RIXS studies of chemical systems
* Liquid-jet sample environment

Upgrades

Availability of Variable Polarization at SASE3: new opportunities for tr-RIXS

- included in user calls for 2025-I

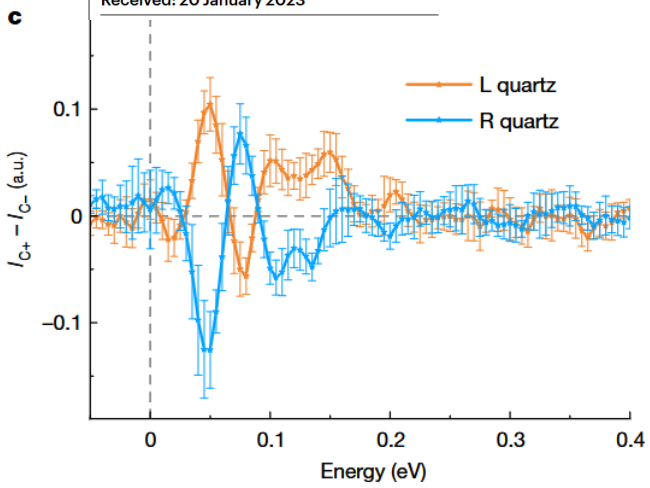
Polarization mode	LH/LV/C+/C-
K-Range	9.59 – 3.38
Photon Energy Range [keV]	
@8.5 GeV	0.163 – 1.137
@11.5 GeV	0.299 – 2.082
@14 GeV	0.443 – 3.085
@16.5 GeV	0.615 – 4.286

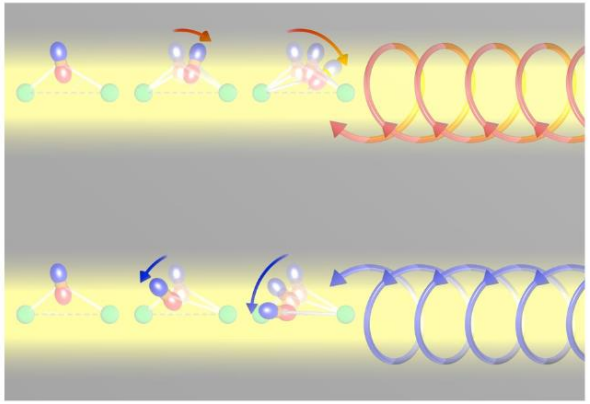
Article

Chiral phonons in quartz probed by X-rays

946 | Nature | Vol 618 | 29 June 2023
https://doi.org/10.1038/s41586-023-06016-5
Received: 20 January 2023

Hiroki Ueda[1,2]✉, Mirian García-Fernández[3], Stefano Agrestini[3], Carl P. Romao[4], Jeroen van den Brink[5,6], Nicola A. Spaldin[4], Ke-Jin Zhou[3] & Urs Staub[1]✉





ARTICLE OPEN

Check for updates

Probing magnetic orbitals and Berry curvature with circular dichroism in resonant inelastic X-ray scattering

Michael Schüler[1,2,3]✉, Thorsten Schmitt[4] and Philipp Werner[3]

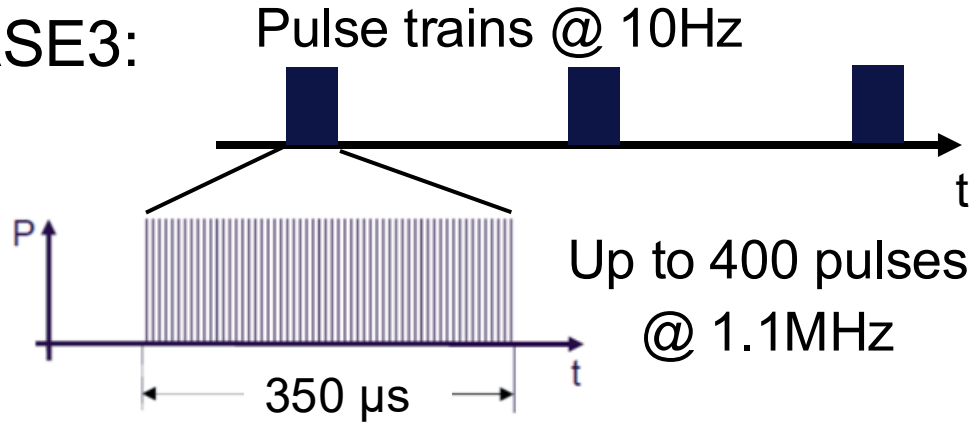
npj Quantum Materials (2023)8:6

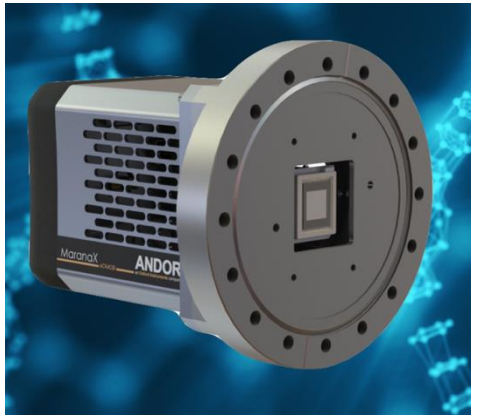
Detector upgrades

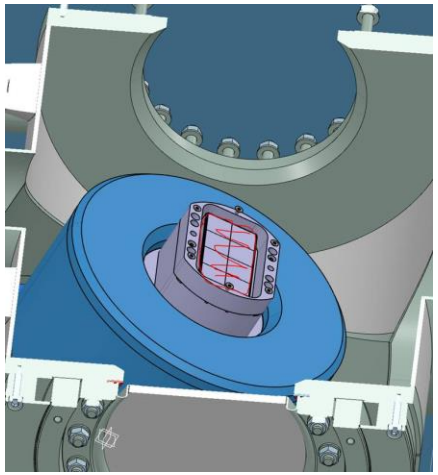
Train-resolved detector: In operation since 2024-I

- Marana-X
  - Back-illuminated CMOS
  - Pixel size 11 µm (22.5 mm chip size)
  - → No dead time for readout
  - → Lower data noise due to analysis by train
  - → Improvement of temporal resolution

SASE3:







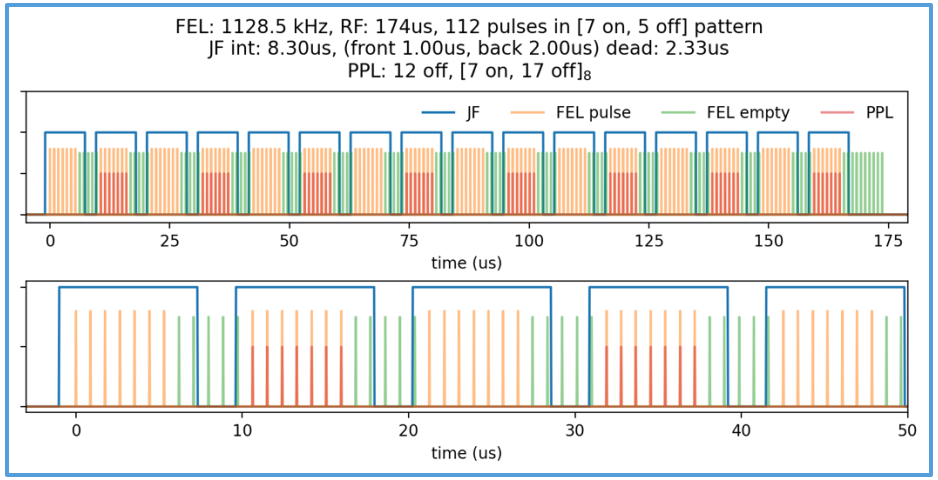
Pulse-resolved detector: Under development

- Jungfrau
  - Thin entrance window, iLGAD
  - Rectangular pixels (trixels): 25 µm x 225 µm, resolution of few µm
  - Rep. rate up to 1 MHz, storage of 16 frames
  - → Inter-train resolved data, potentially pulse-resolved
  - → Higher spatial resolution

JUNGFRAU for hRIXS: commissioning in 2024-II

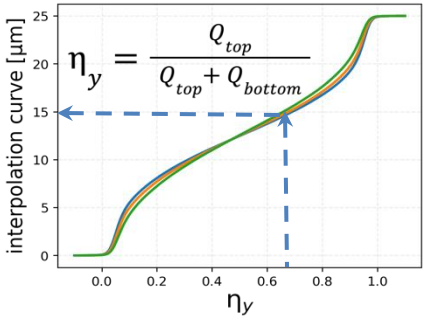
Nino Duarte (European XFEL)
Viktoria Hinger (PSI)

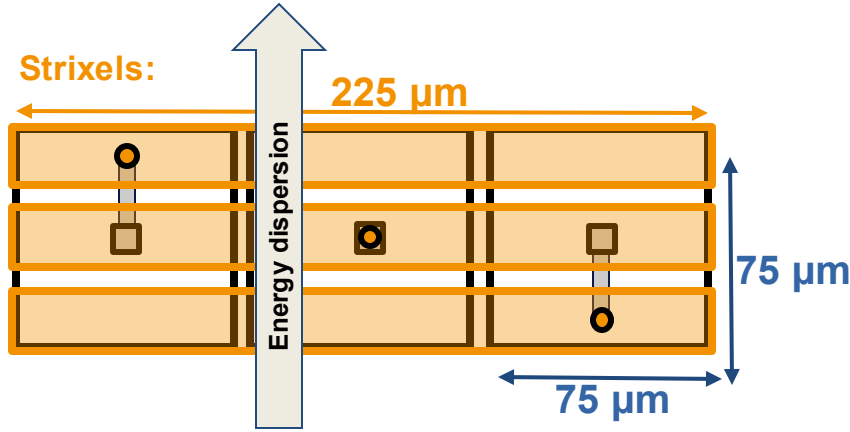
Inter-train resolved data:

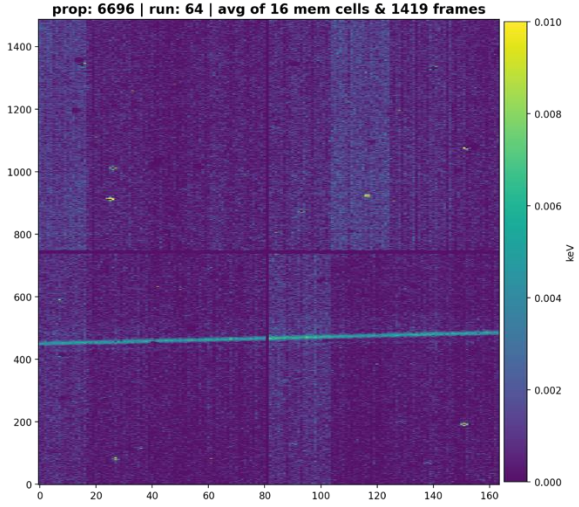


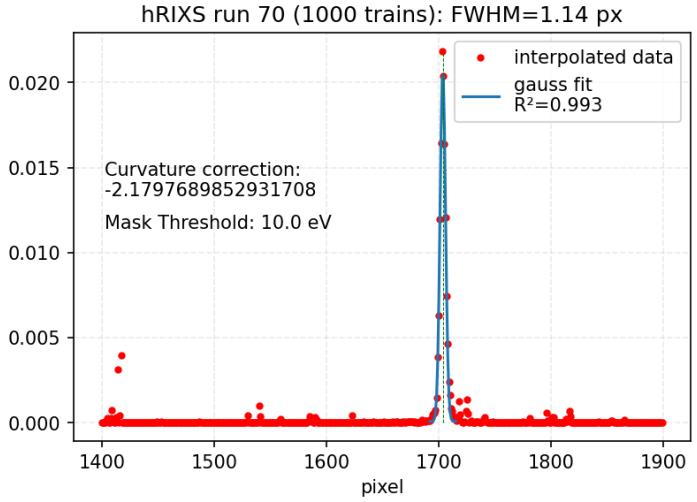
- Was used to collect part of user data
- Still under analysis

Strixel: charge sharing and interpolation:





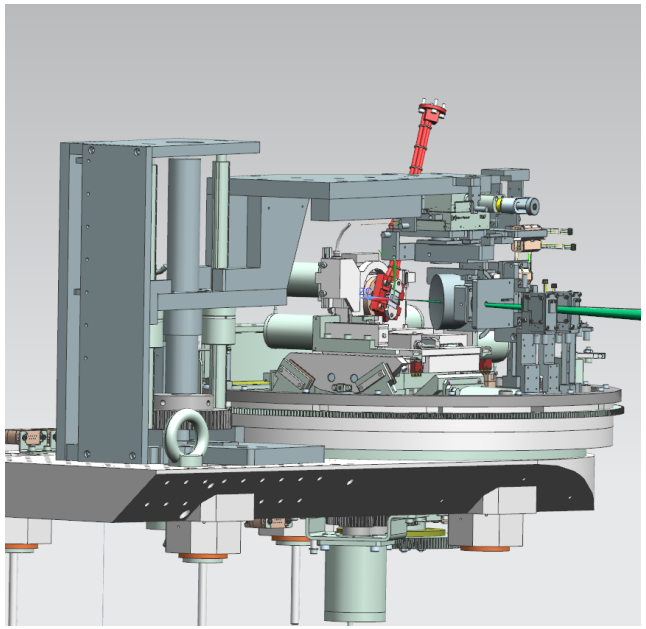


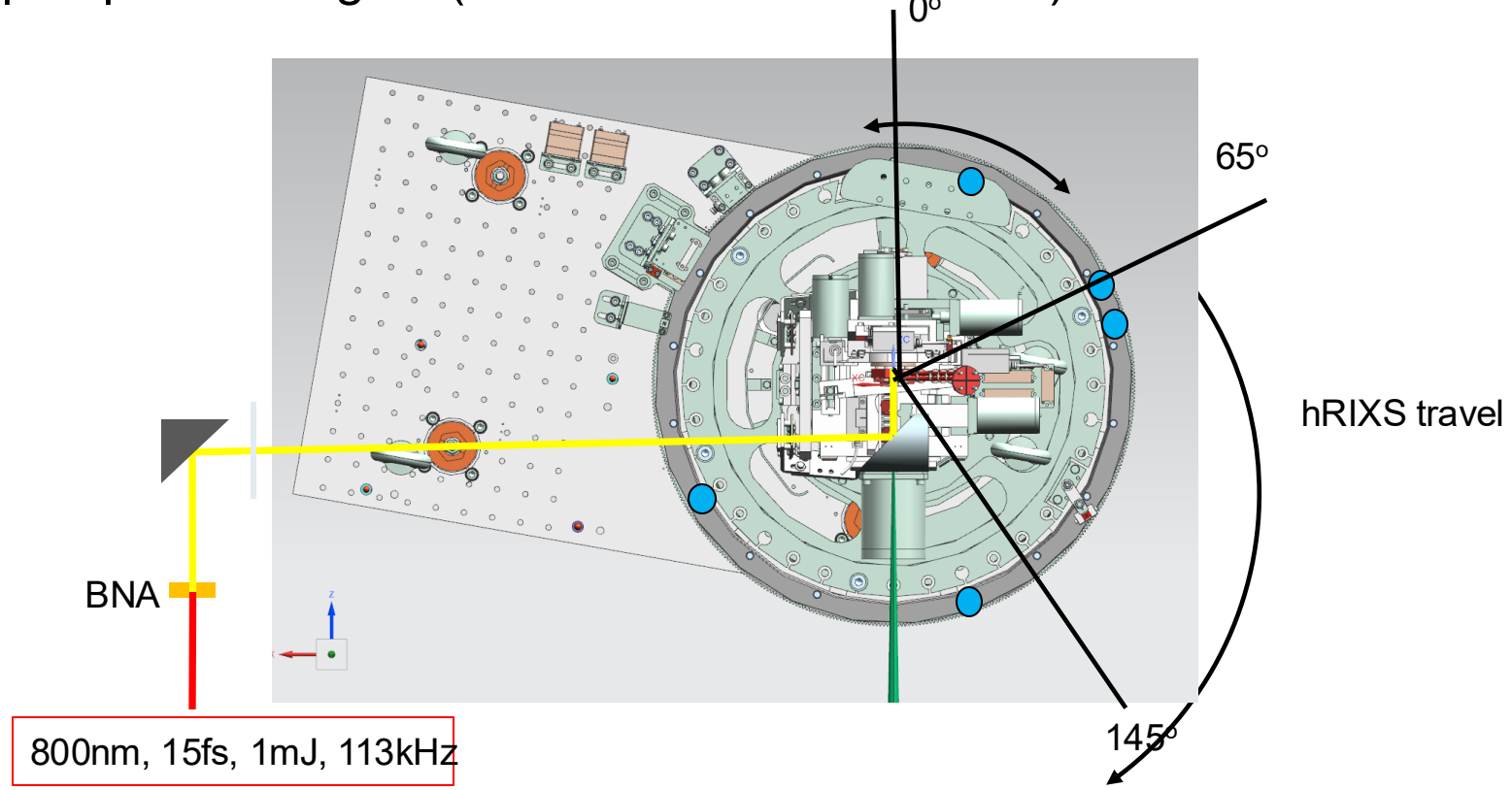


New pump in-coupling scheme, including THz at XRD

See Talk of Robert Carley

- Generation and in-coupling of THz pump (commissioning)
- Installation of in-coupling mirror at short (2 inch) distance, intrinsically stable with inner mechanics (up to now 2m focal distance using LIN chamber)
- Additional options for selecting pump wavelenghts (use of OPA more feasible)





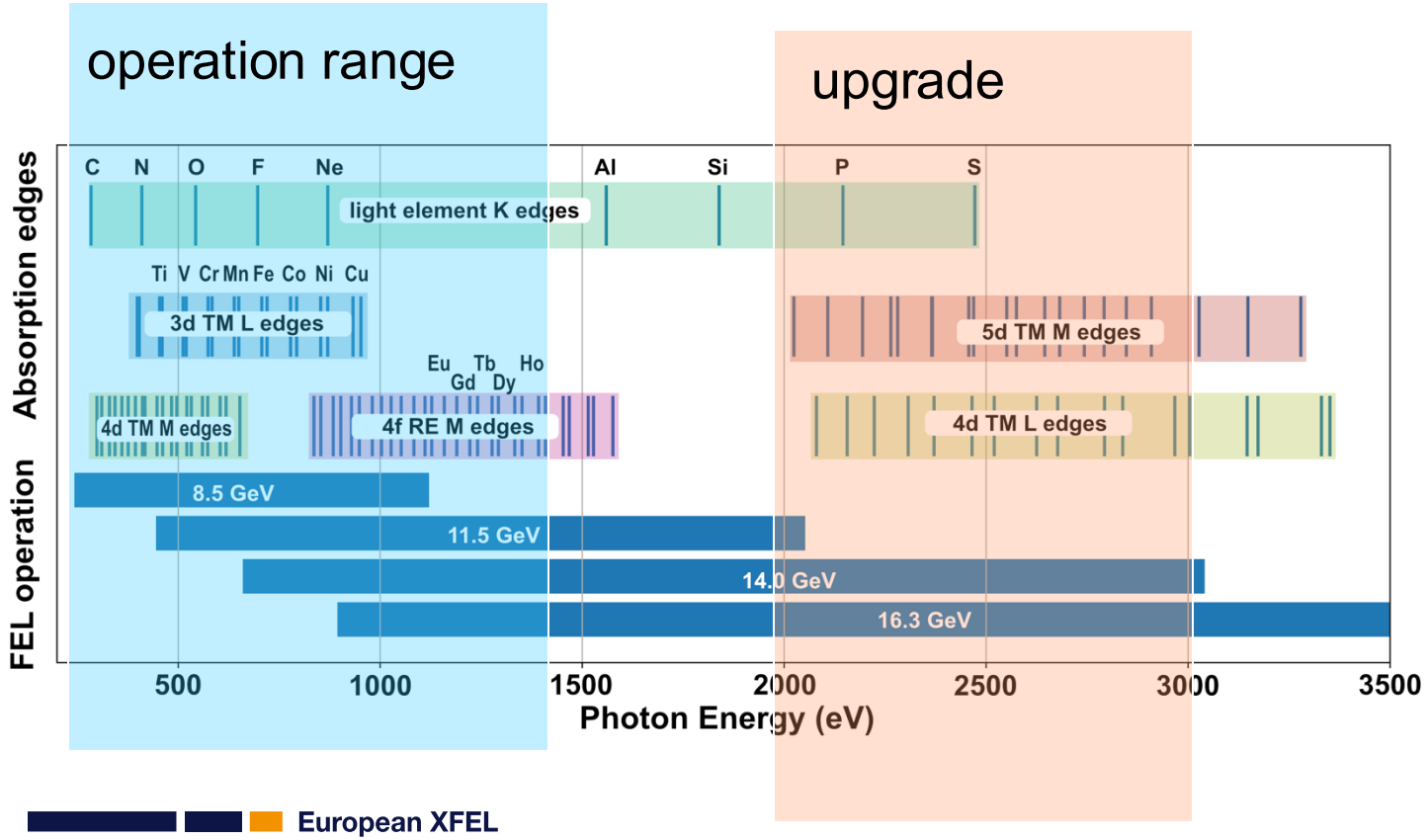
Upgrade SASE3 Monochromator

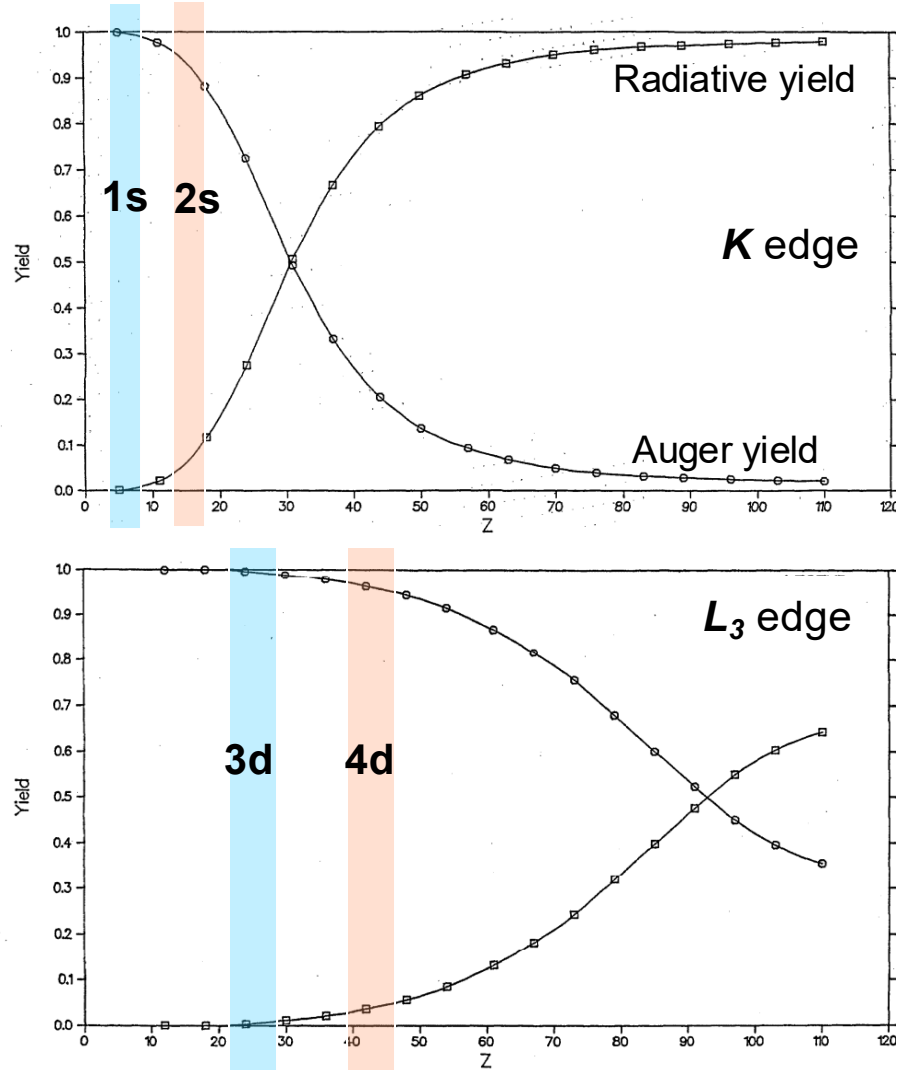
- Longer high-resolution monochromator grating: 150 l/mm, 350 mm
  - Will improve combined energy resolving power of RIXS experiments by about factor 2 (currently limited by monochromator to 10,000)
  - Will increase monochromator transmission

See Talk of Natalia Gerasimova

hRIXS upgrade towards higher photon energies: tender x-ray range

- SCS instrument delivers photons up to 3000 eV
- Current operation hRIXS: up to 1500 eV
- Tender x-ray range challenging due to lower throughput, however radiation yield higher than for soft x-rays





M.O. Krause, J. Phys. Chem. Ref. Data 8, 307 (1979)

Thank you!

Contact: scs@xfel.eu

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