Elettra Sincrotrone Trieste

https://pixlr.com/image-generator/
prompt: beamline experimental station that shows sample stage, x-rays, detector and microscope (anime) (studio) (shot from above)

New opportunities and challenges of a micro-XRF/XAS beamline in Elettra 2.0

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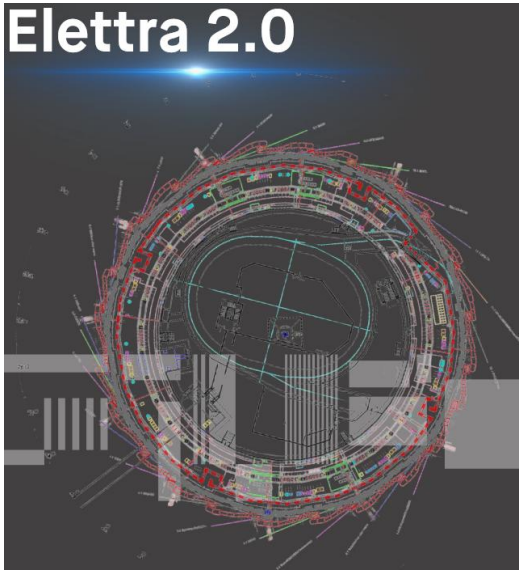
Elettra Synchrotron Trieste

Elettra Sincrotrone Trieste is an Italian multidisciplinary research center of excellence, open to the international research community, specialized in generating high quality synchrotron and free-electron laser light and applying it in materials and life sciences.

Elettra Synchrotron Trieste

After more than 30 years, Elettra is going to a major upgrade towards a forth generation synchrotron.



https://www.elettra.eu/lightsources/elettra-2-0/elettra-2-0.html

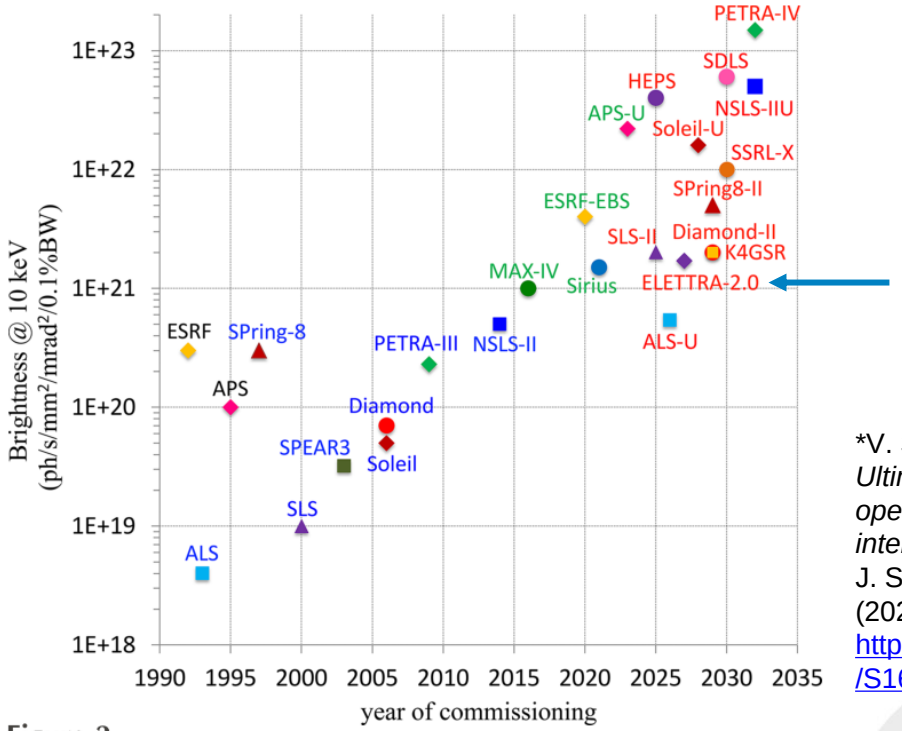


Figure 2
Evolution of brightness at 10 keV photon energy.

*V. Smaluk et al. *Ultimate brightness at operational beam intensity* J. Synchrotron Rad. (2025). 32 https://doi.org/10.1107/S1600577525002723

Elettra 2.0

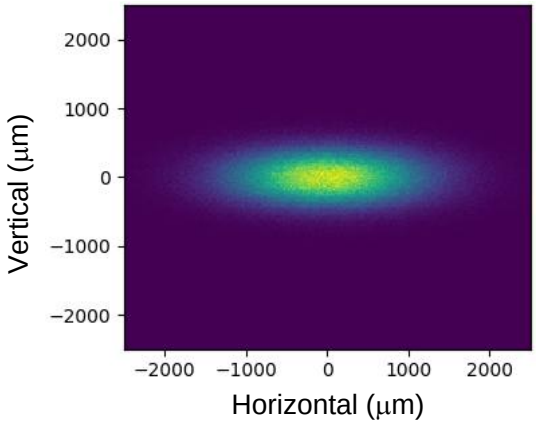
	Elettra	Elettra 2.0
Beam energy [GeV]	2.4 (25%) – 2.0 (75%)	2.4
e-current [mA]	150	400
e-beam size (LS) [μm]	286 - 16	36 - 6
e-beam divergence (LS) [μrad]	35 - 8	6 - 3

Undulator U46

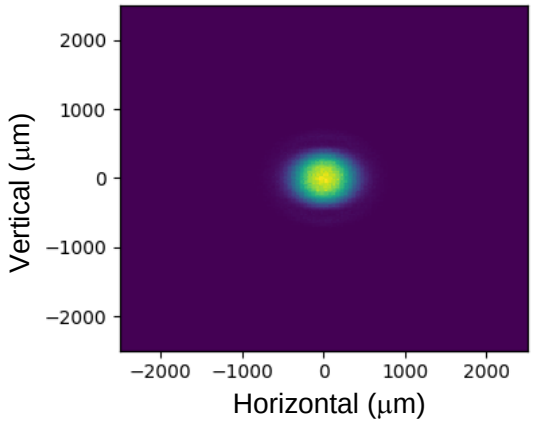
1st Harmonic:
900 eV

X-ray beam @
20 m

Elettra

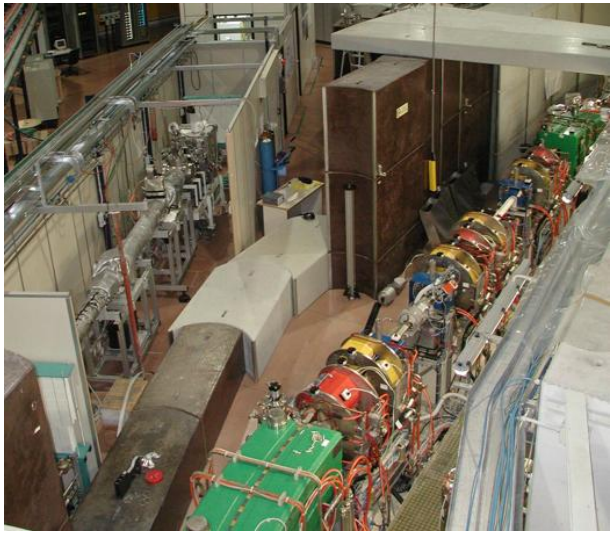


Elettra 2.0



Elettra 2.0 – Storage Ring upgrade

DBA
Double-bend achromatic



S6BA-E
Symmetric six-bend achromatic enhanced

Electron beam emittance → $\varepsilon_x \sim \frac{E^2}{N_d^3}$

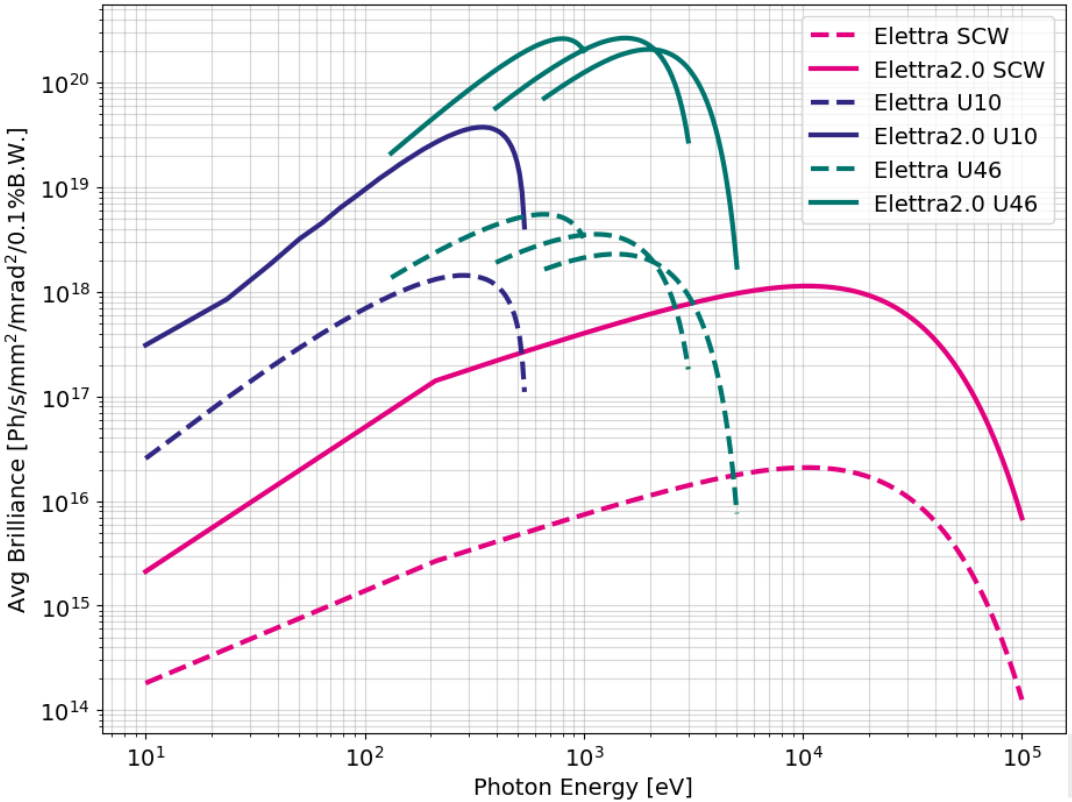
E^2 ← e^- energy

N_d^3 ← Number of dipoles

Enhanced
- Transversal and longitudinal magnetic gradients
- Reverse bending

Elettra 2.0

Increase of sources brilliance



*E. Karantzoulis et al.
Design strategies and technology of Elettra 2.0 for a versatile offer to the user community
Nuclear Inst. and Methods in Physics Research, A 1060 (2024) 169007
https://doi.org/10.1016/j.nima.2023.169007

Elettra 2.0

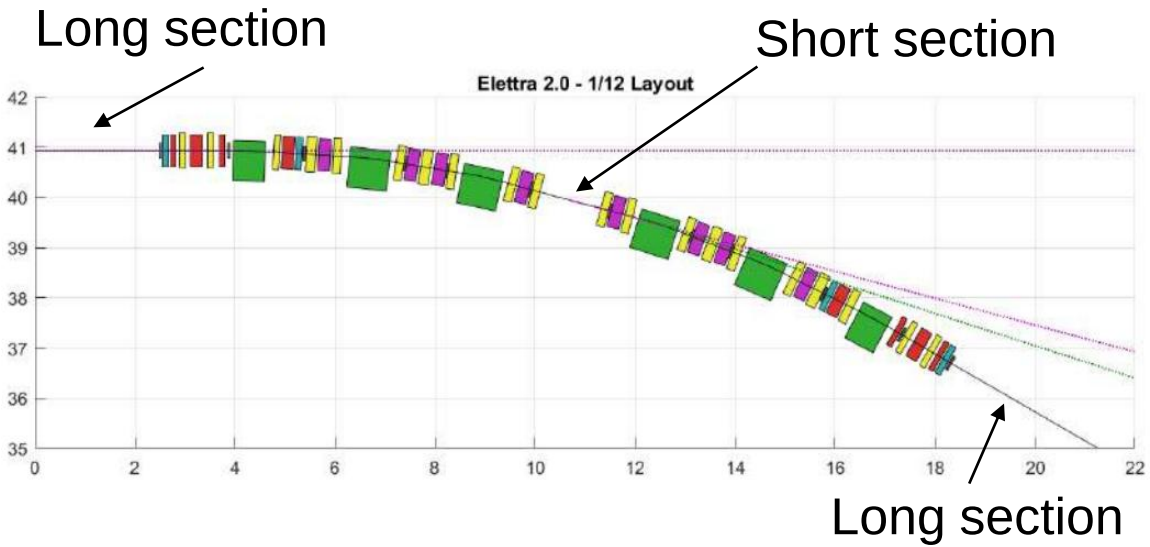
There will be more straight sections = more insertion devices

Elettra

11 long + 1 short

Elettra 2.0

11 long + **5 short**

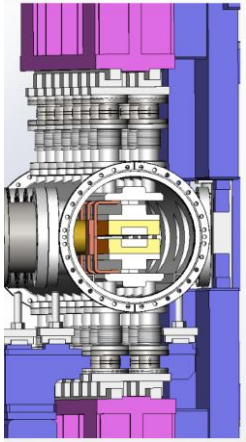


Feasibility and technical studies have been performed to install **crab cavities** to have x-ray 0.5 ps – 5 ps FWHM pulse duration

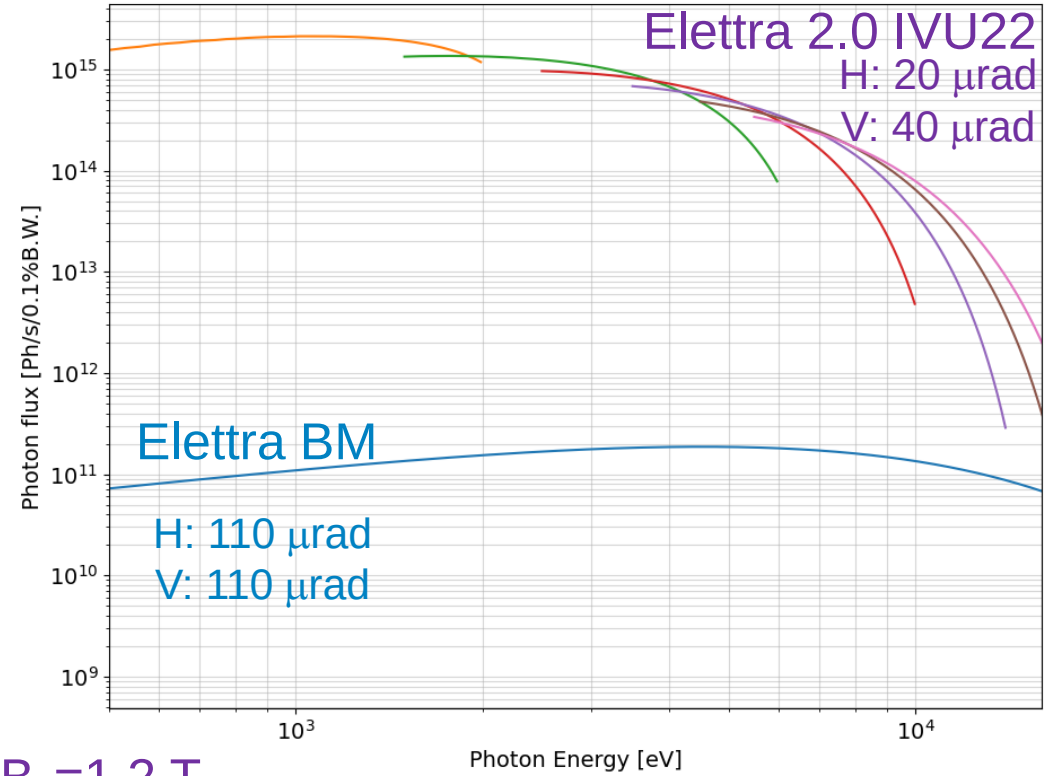
New source for μXRF & μXAS beamline

XRF – Bending Magnet

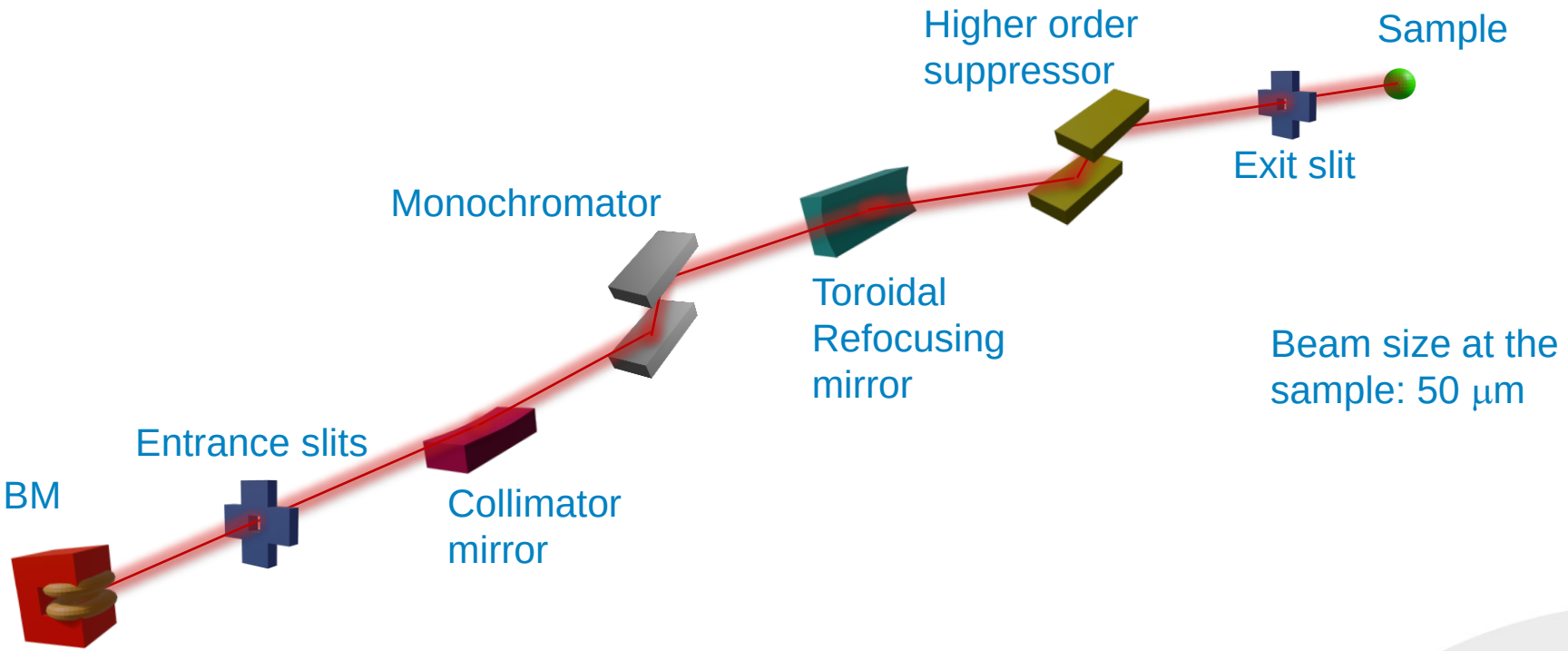
μXRF – Undulator IVU22



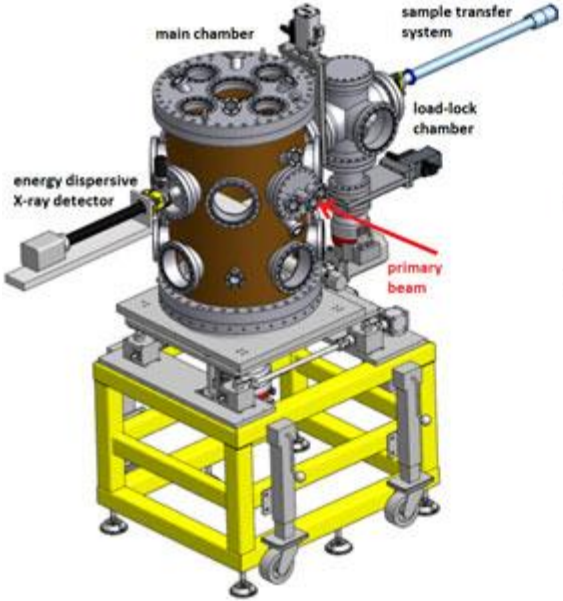
2 m long, B_0=1.2 T

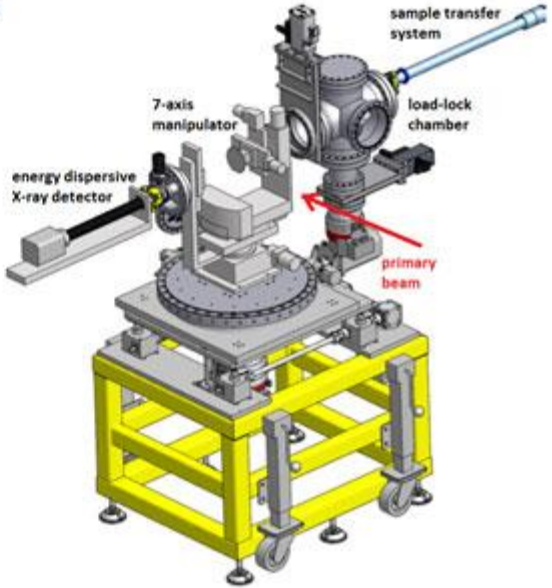


Present XRF beamline



Present XRF end station and techniques



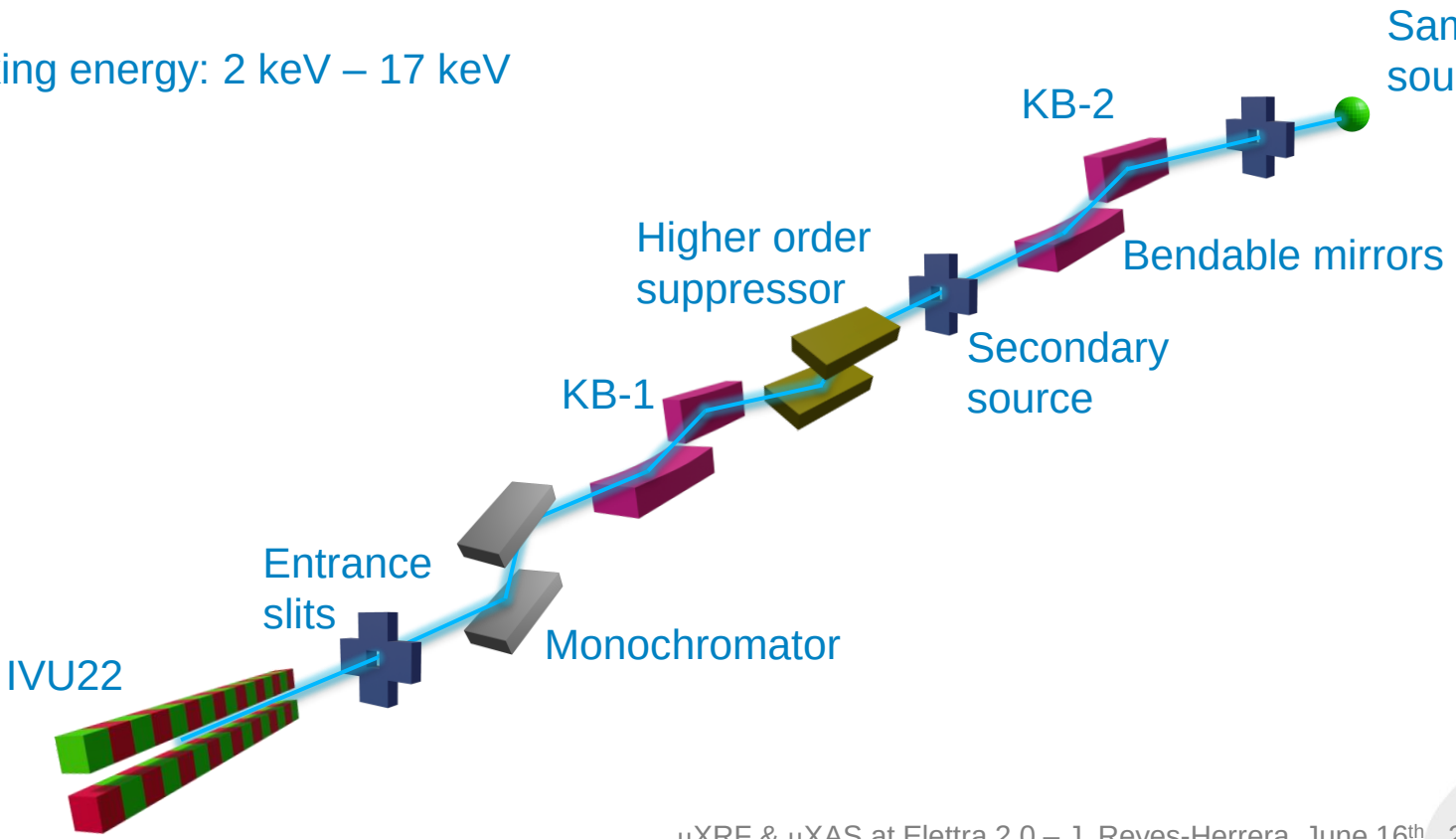


Available techniques:
- GIXRF: Grazing Incidence XRF
- GEXRF: Grazing Exit XRF
- TXF: Total Reflection XRF
- XRR: X-ray Reflectometry
- XAS: XANES, EXAFS

https://www.elettra.eu/lightsources/elettra/elettra-beamlines/microfluorescence/x-ray-fluorescence.html

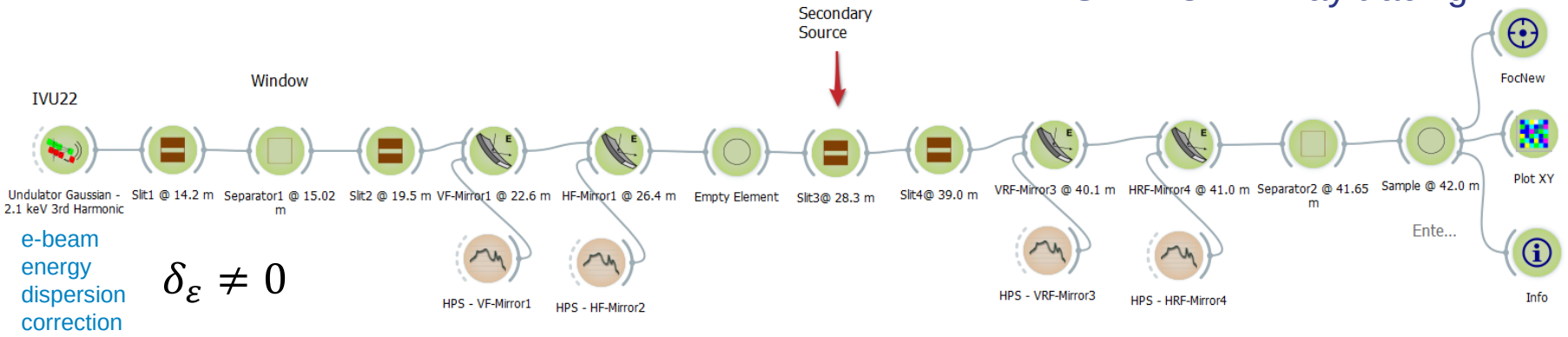
New μ-XRF beamline

Working energy: 2 keV – 17 keV



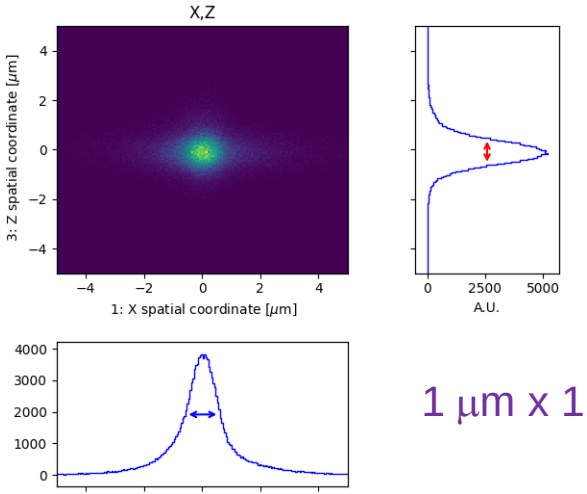
New μ-XRF beamline

SHADOW4: Ray tracing

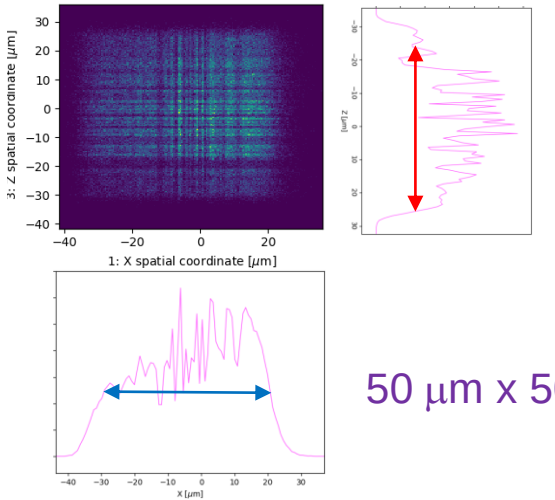


e-beam energy dispersion correction

$\delta_\varepsilon \neq 0$



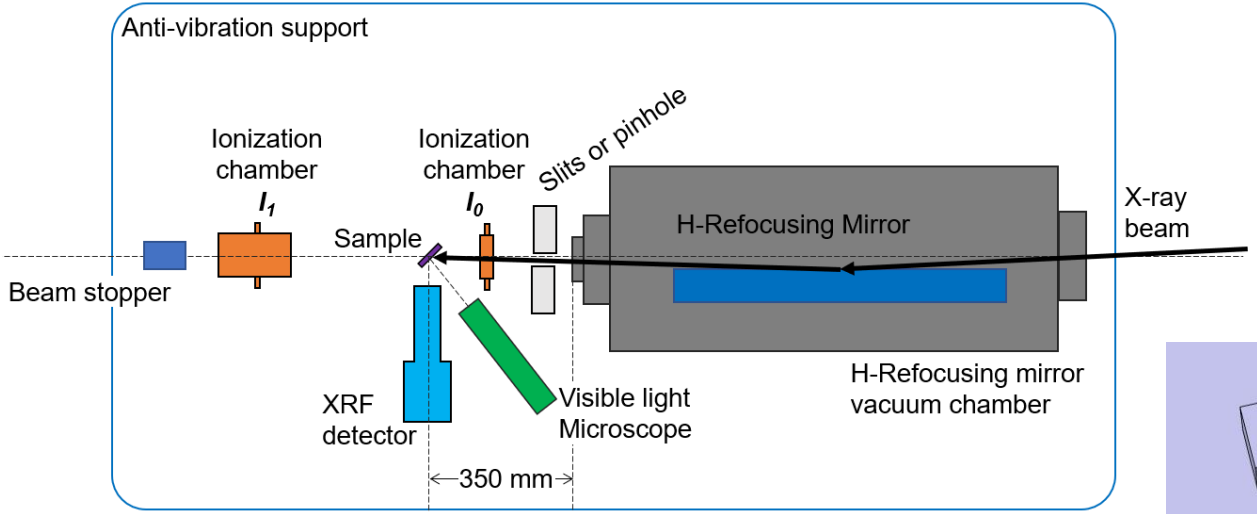
1 μm x 1 μm



50 μm x 50 μm

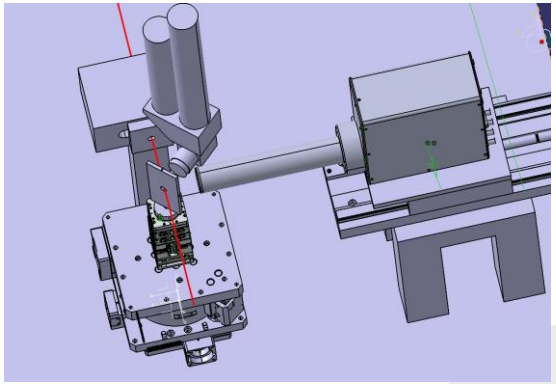
New μ-XRF beamline end station

In Air!



Schematic layout for day 1

In development

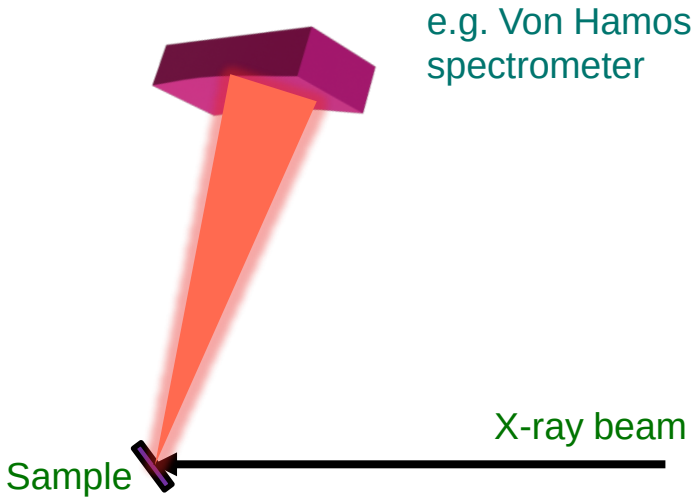


New μ-XRF beamline end station

Plenty space to grow:

- X-ray Emission Spectroscopy

- Multi-modal station



Sample environment:

- Cryogenic
- Controlled sample environment

→

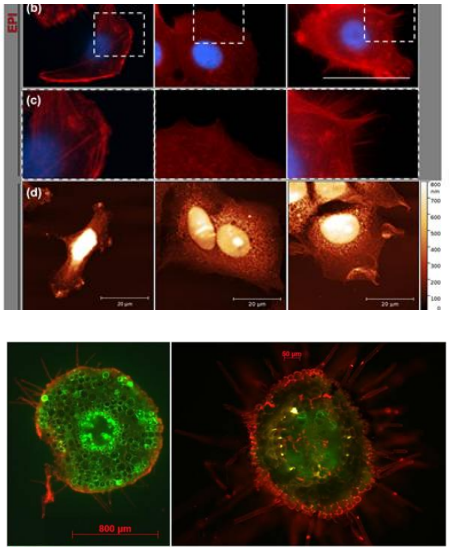
With **pulsed X-ray beams** (crab cavities), real-time chemical changes can be tracked, e. g. :

- **Battery cycling**, **corrosion**, **catalysis**, or **environmental exposure** studies.
- Operando environments with **fluid/gas cells**

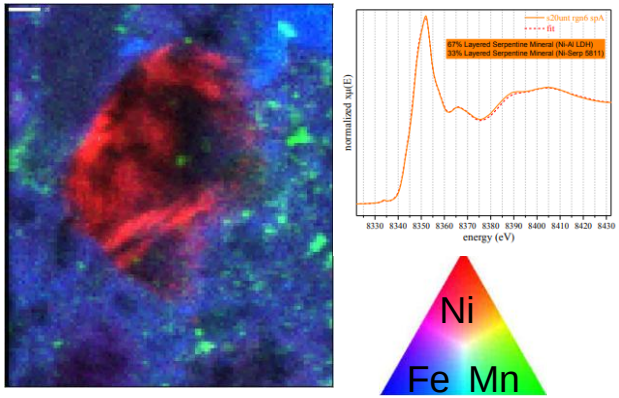
New opportunities

Elemental (XRF) and chemical (XANES) analysis with ***micrometric*** spatial resolution

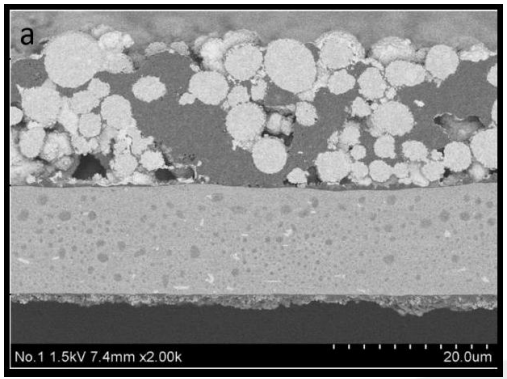
Life science



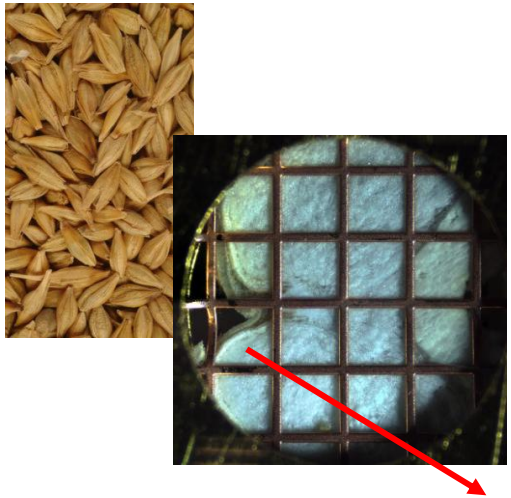
Environmental science
Cultural heritage



Materials science
Energy materials

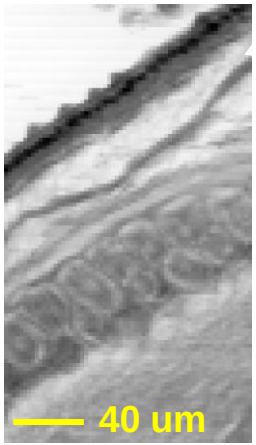


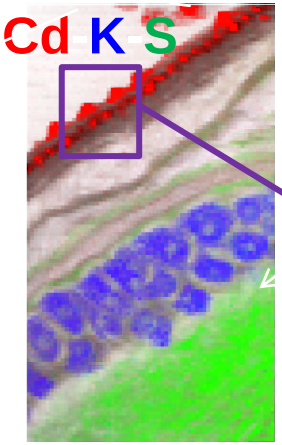
Life Sciences: metals toxicity in plants

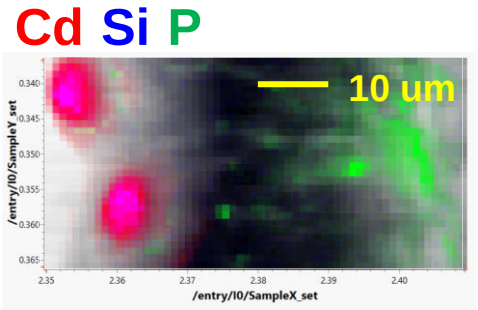


Localization of Cd
in barley grain

Localization and speciation at cellular level



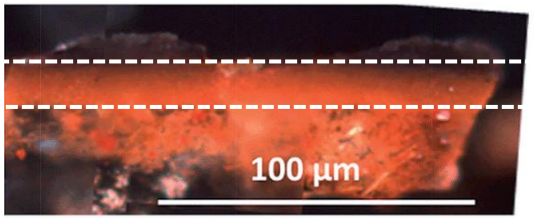


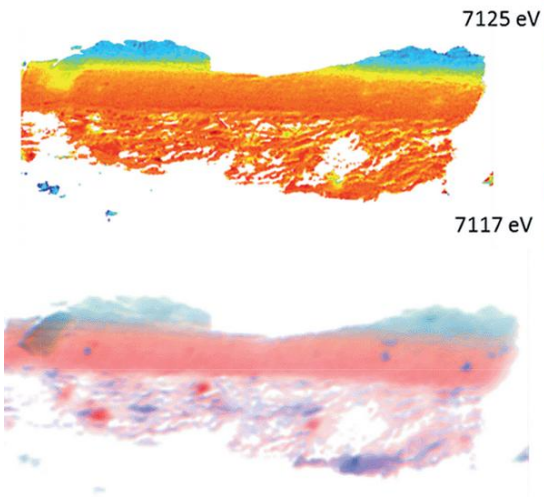


*Courtesy of K. Vogel Mikuš

Cultural heritage

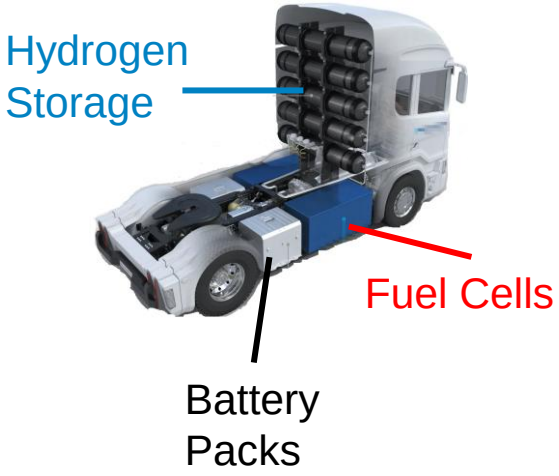
Attic Red-figure Hydria fragment
(about 460 B.C)

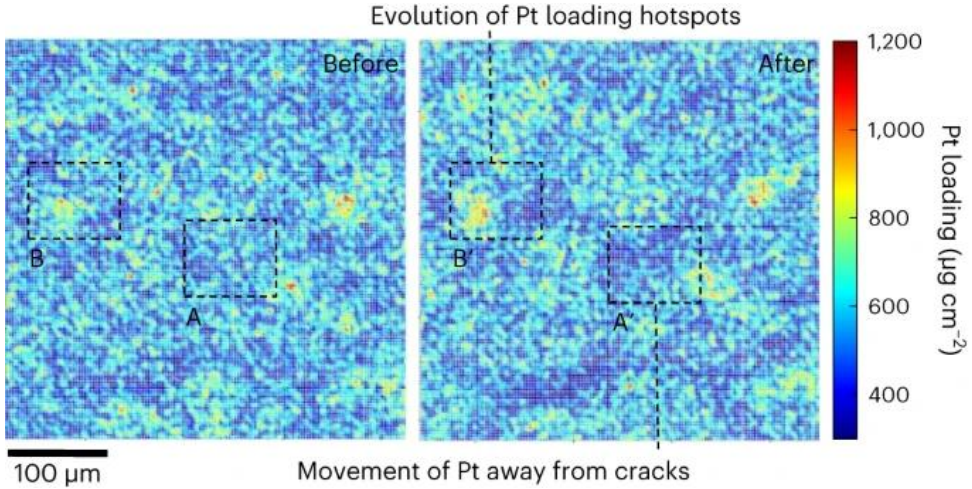




*I. Cianchetta et al. J. Anal. At. Spectrom., 2015, 30
https://doi.org/10.1039/C4JA00376D

Energy materials: Fuel cells



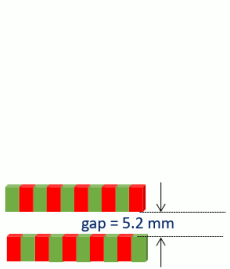


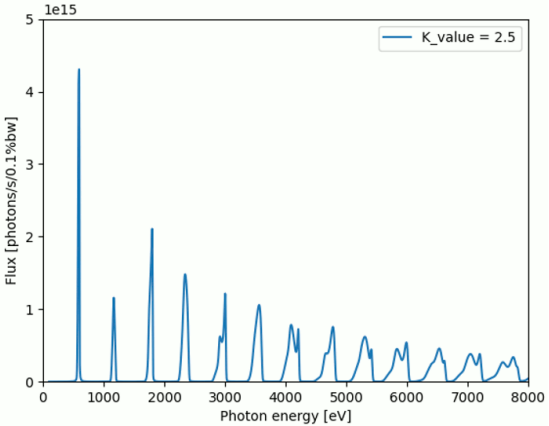
*K. Khedekar et al. *Revealing in-plane movement of platinum in polymer electrolyte fuel cells after heavy-duty vehicle lifetime*
Nature Catalysis volume 6, pages 676–686 (2023)
https://doi.org/10.1038/s41929-023-00993-6

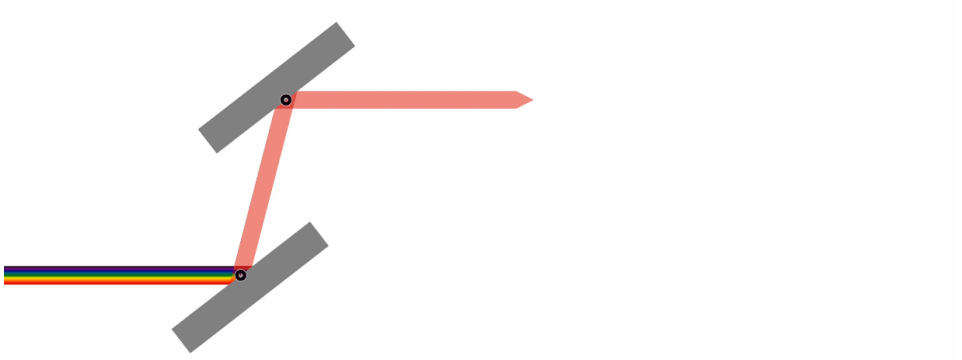
New challenges

Technical: Undulator - DCM Synchronization

Non-linear relationship between undulator gap and monochromator angle/energy leads to energy mismatch, intensity loss and beam inhomogeneity





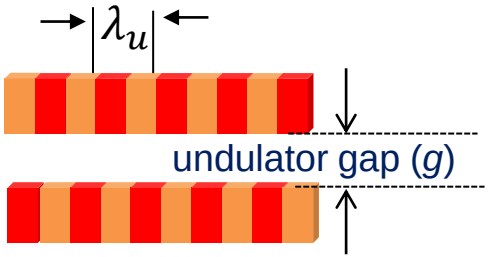


*https://www.synchrotronmovies.com/

Undulator - DCM Synchronization

$$E_n[\mathrm{eV}] = 9.496 \frac{n\mathcal{E}_e^2[\mathrm{GeV}]}{\lambda_u[\mathrm{m}]\left(1+\frac{K^2}{2}\right)}$$

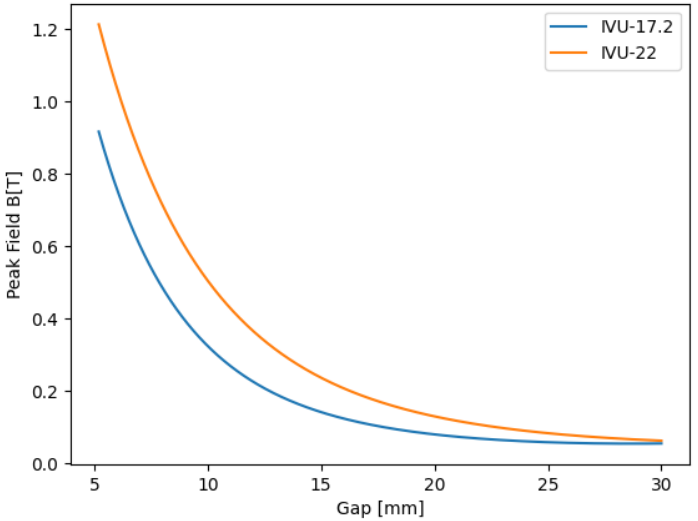
$$K = 0.934\, B[\mathrm{T}]\, \lambda_u[\mathrm{cm}]$$



$$B[T] = a\, e^{b\frac{g}{\lambda_u}+c\left(\frac{g}{\lambda_u}\right)^2}$$

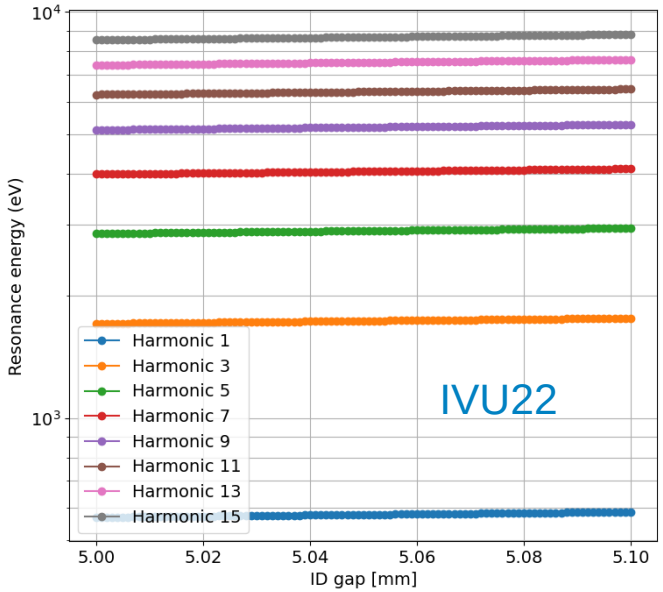
*From B. Diviacco: a =3.694, b=-5.068 and c=1.52

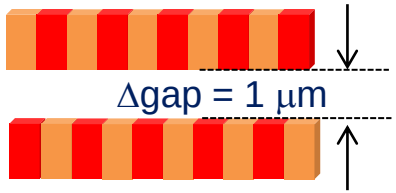
B field in function of undulator gap*:



$$E_{DCM} = \frac{hc}{2d\sin\theta}$$

Undulator - DCM Synchronization



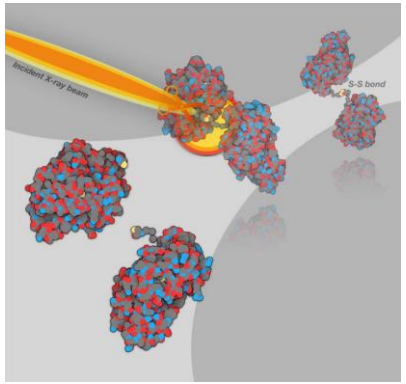


Average resonance energy change for 1 μm:

- 1st Harmonic: 0.2 eV
- 3rd Harmonic: 0.5 eV
- 5th Harmonic: 0.9 eV
- 7th Harmonic: 1.2 eV
- 9th Harmonic: 1.6 eV
- 11th Harmonic: 1.9 eV
- 13th Harmonic: 2.3 eV
- 15th Harmonic: 2.6 eV

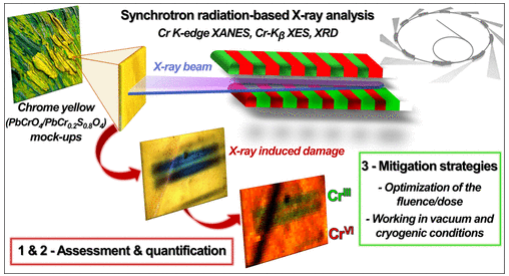
Force between the magnetic arrays → ~ kN/m

Radiation Damage



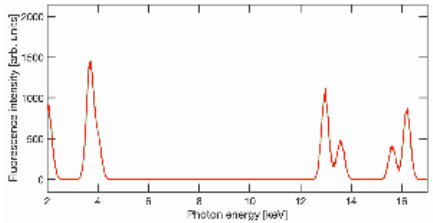
*Garman and Weik, *Radiation damage to biological samples: still a pertinent issue*
J. Synchrotron Rad. (2021). 28
roi.org/:10.1021/acs.analchem
.0c03251

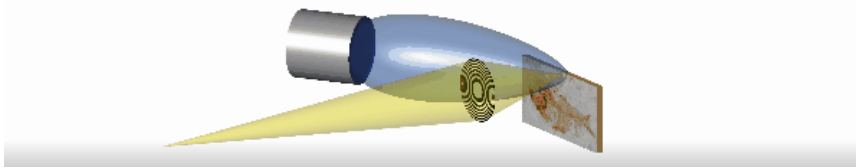
- Minimizing the exposure:
  - Enlarging the beam
  - Fast measurements (fly scans, optimized dwell time)
- Sample preparation:
  - Cryogenic sample supports



*L. Domico et al., *Damages Induced by Synchrotron Radiation-Based X-ray Microanalysis…,* Anal. Chem. 2020, 9
https://dx.doi.org/10.1021/acs.analchem.0c03251

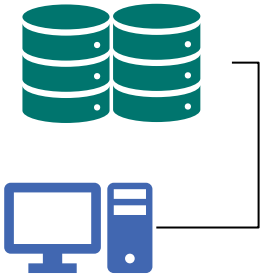
High flux, small spot sizes & fast measurements





Time per pixel, for example (0.5 μm x 0.5 μm) of 5 ms

- High data throughput
- Large data volume



Requires:

- Automated pipelines for spectral deconvolution and quantification

In addition: High beam and stage stability

*https://www.synchrotronmovies.com/

Summarizing

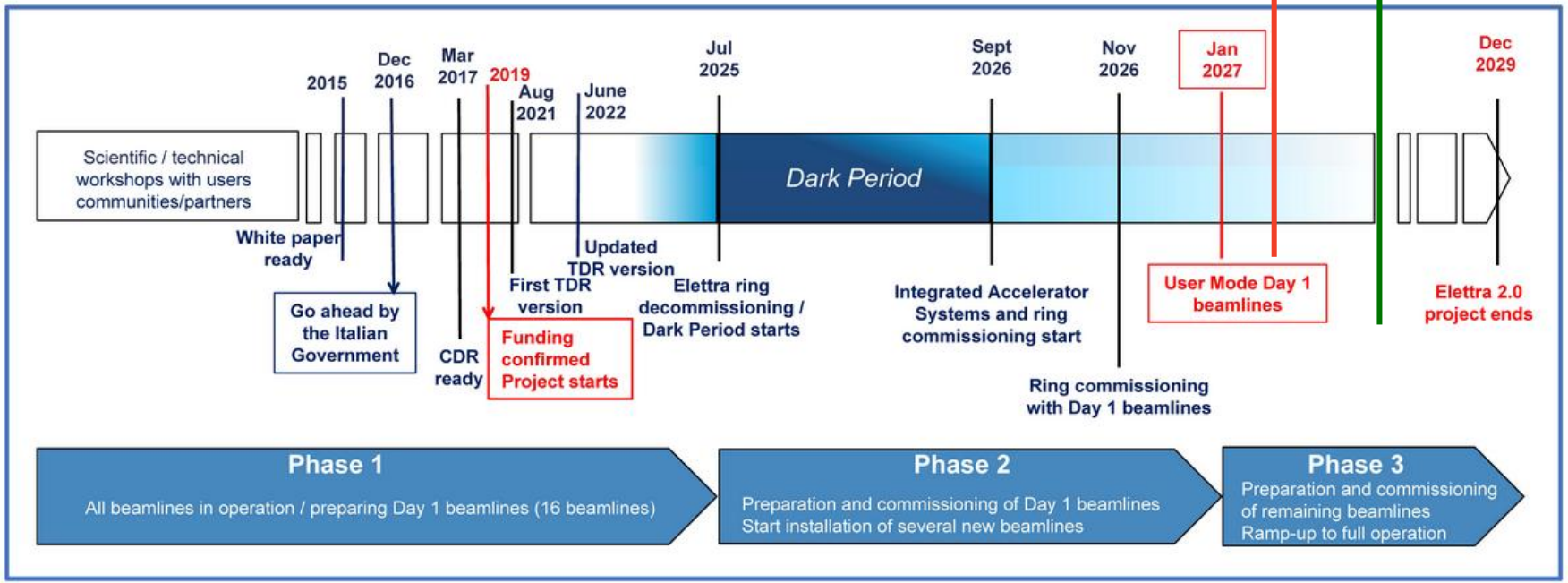
Aspect	Opportunity	Challenge
Spatial Resolution	Sub-micron elemental/chemical maps	Alignment precision, optics stability
Sensitivity	Trace element detection (ppm–ppb)	Detector saturation, calibration
Sample Environment	In situ/operando studies	Radiation damage, environmental control
Throughput	Fast scanning with high brilliance	Data volume, analysis speed
Applications	Biology, nanotech, art, geology, etc.	Sample prep, matrix effects

Elettra 2.0 timeline

μXRF Beamline:

Installation Begins Nov 2027

Starting Operation Aug 2028



Main people involved in this project


Giuliana Aquilanti*


Anna Bianco*


Ilaria Carlomagno


Roberta Totani


Matteo Altissimo


Lorenzo Raimondi*


Edoardo Busetto


Maurizio Polentarutti


Bruno Diviacco

Open position:
Senior scientist for the μXRF beamline at Elettra 2.0
Deadline: 26 June 2025
https://www.elettra.eu/about/careers.html?id=4254

* No longer @Elettra

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Trieste

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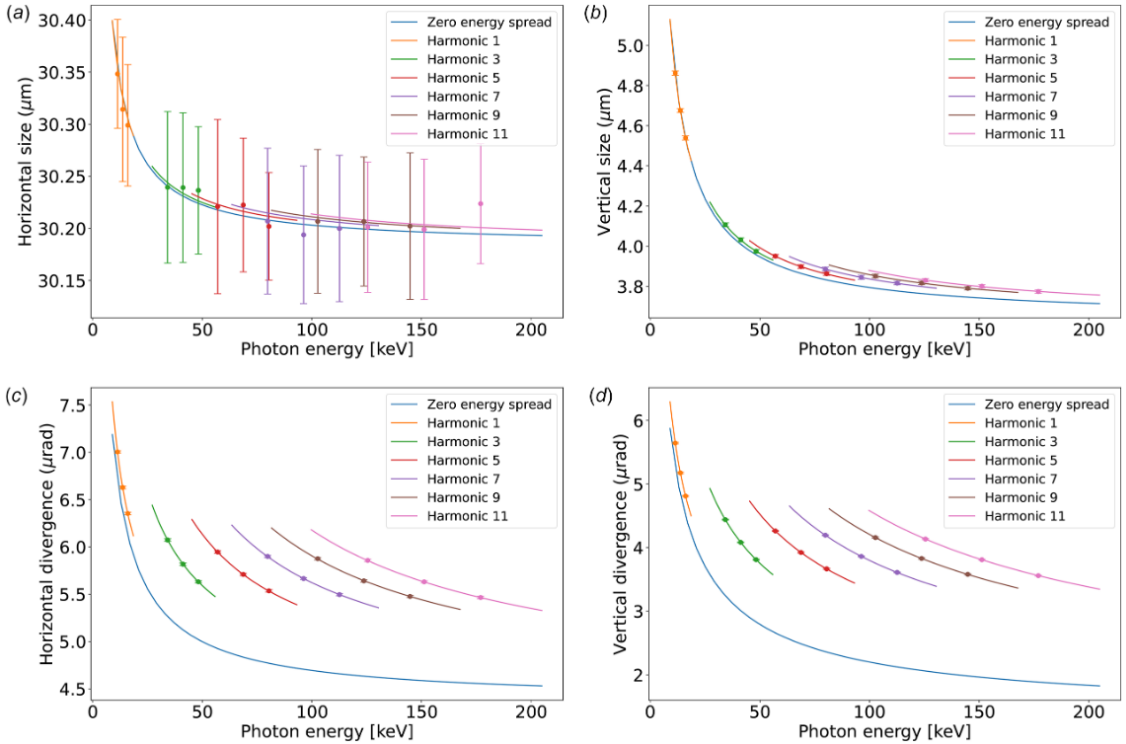
Elettra Sincrotrone Trieste

Extra slides

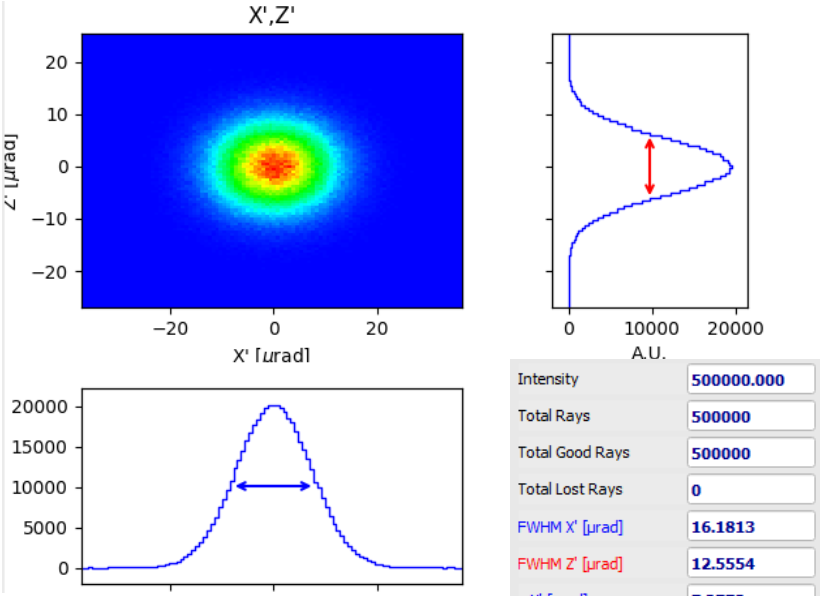


*M. Sanchez del Rio and J. Reyes-Herrera, *Modelling undulators in ray tracing simulations* J. Synchrotron Rad. (2025). 32, 340 https://doi.org/10.1107/S1600577525000190

Source

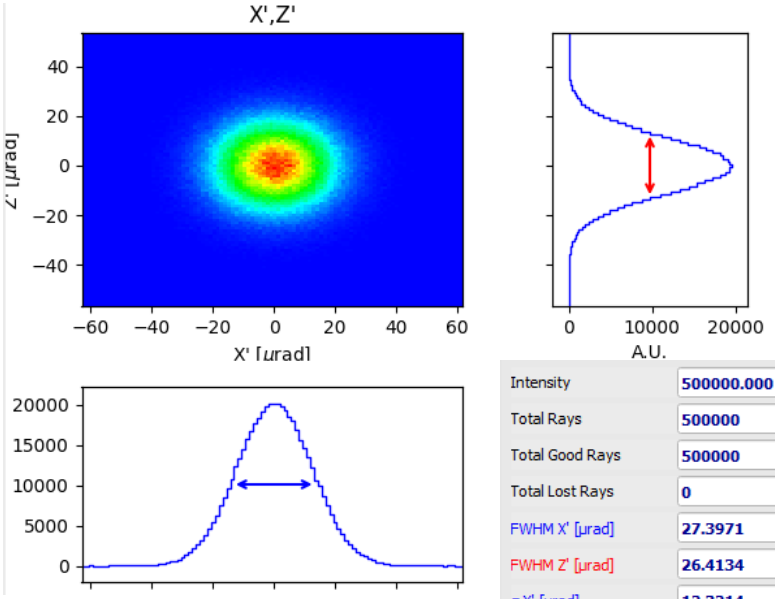
Undulator Gaussian - 12 keV 11th harmonic

$\delta_\varepsilon = 0$



Intensity	500000.000
Total Rays	500000
Total Good Rays	500000
Total Lost Rays	0
FWHM X' [µrad]	16.1813
FWHM Z' [µrad]	12.5554
σ X' [µrad]	7.2772
σ Z' [µrad]	5.3714
centroid X' [µrad]	0.0208
centroid Z' [µrad]	0.0076

$\delta_\varepsilon = 0.000934$

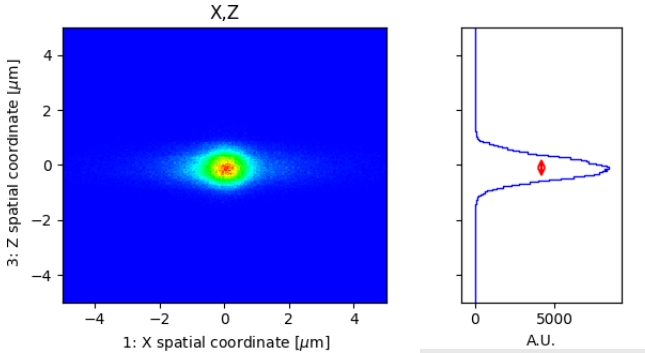


Intensity	500000.000
Total Rays	500000
Total Good Rays	500000
Total Lost Rays	0
FWHM X' [µrad]	27.3971
FWHM Z' [µrad]	26.4134
σ X' [µrad]	12.3214
σ Z' [µrad]	11.3002
centroid X' [µrad]	0.0352
centroid Z' [µrad]	0.0159

Sample

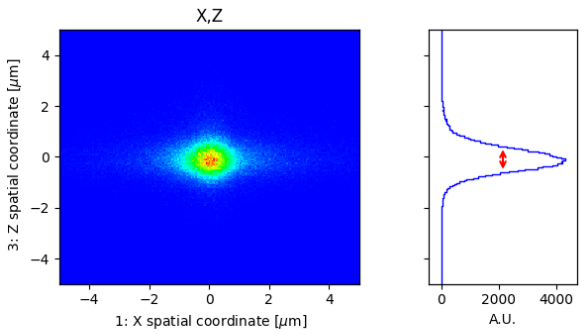
Undulator Gaussian - 12 keV 11th harmonic

$\delta_\varepsilon = 0$



Intensity	149607.971
Total Rays	500000
Total Good Rays	203265
Total Lost Rays	296735
FWHM 1: X spatial coor	1.1443
FWHM 3: Z spatial coor	0.8955
σ 1: X spatial coordinat	1.1227
σ 3: Z spatial coordinat	0.4102
centroid 1: X spatial coc	0.0236
centroid 3: Z spatial coc	-0.0938

$\delta_\varepsilon = 0.000934$



Intensity	89444.700
Total Rays	500000
Total Good Rays	121617
Total Lost Rays	378383
FWHM 1: X spatial coor	1.1443
FWHM 3: Z spatial coor	0.9950
σ 1: X spatial coordinat	1.1993
σ 3: Z spatial coordinat	0.5772
centroid 1: X spatial coc	0.0340
centroid 3: Z spatial coc	-0.0616