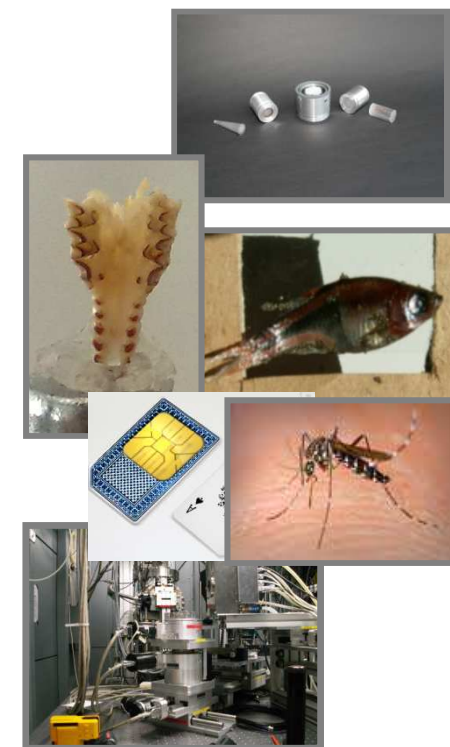
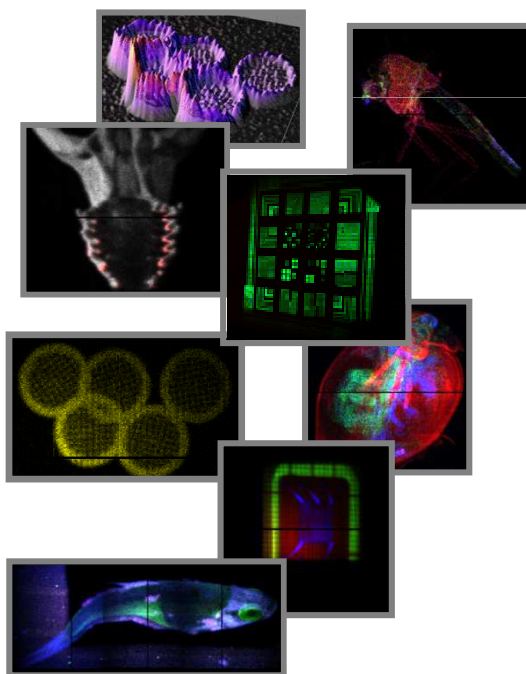


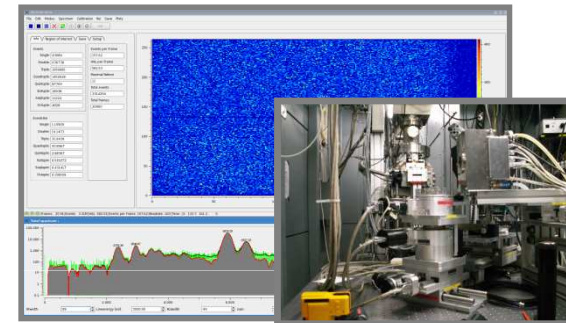
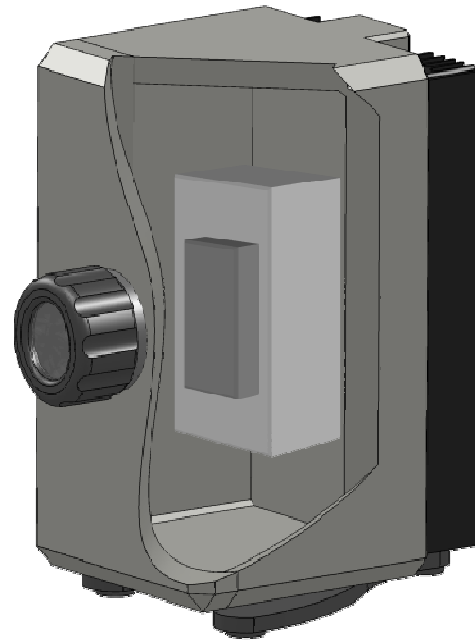
Experiences with the Color X-Ray Camera At the BAMline



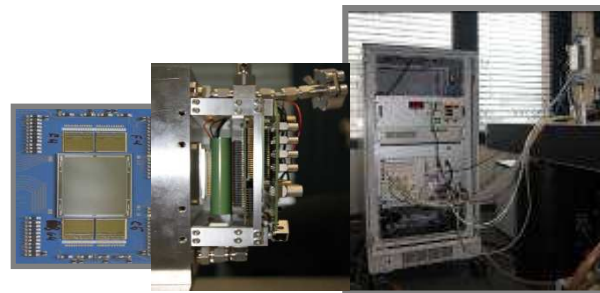


*Capillary Optics,
Measurements with
conventional X-ray
source*

Commercialisation



*Software and Experiments
at Synchrotron*



Sensor head with pn-CCD



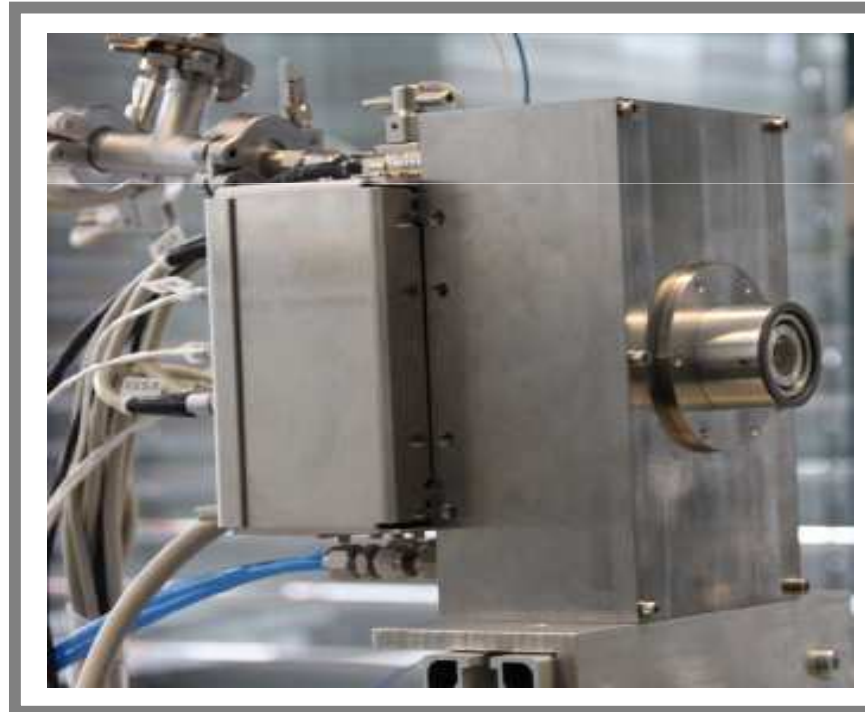
Overview



- **Components of the CXC**
- **Measurements in the laboratory**
- **Measurements at the synchrotron**
- **Beyond imaging**
- **Perspectives**
- **Conclusion**

Color X-ray Camera

combination of the energy resolution of a charge-coupled device (CCD) with capillary optics



Camera detector chip



Column-parallel, split frame readout pnCCD with frame store technique, 400 / 1000 Hz

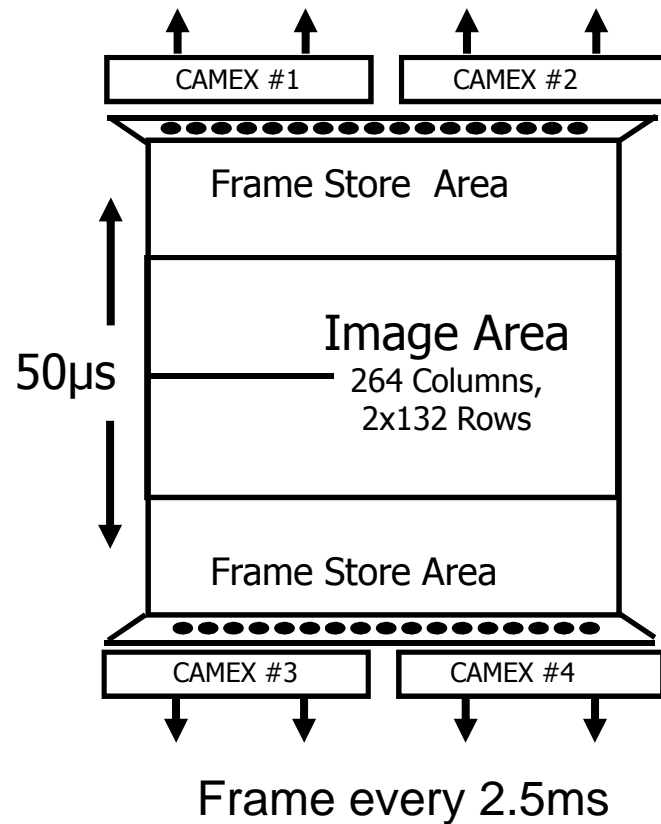


Image area	11,9 x12,3 mm²
Pixel size	(48 x 48) µm²
Number of pixels	69696
Pixel readout speed	28 MPixels/s
Frame rate	400 / 1000 Hz
Sensitive thickness	450 µm
Quantum efficiency	>95%@3-10keV, >30%@20keV
Readout noise	<3e⁻/Pixel
Charge transport efficiency	>0.9999

Camera detector chip



Column-parallel, split frame readout pnCCD with frame store technique, 400 / 1000 Hz

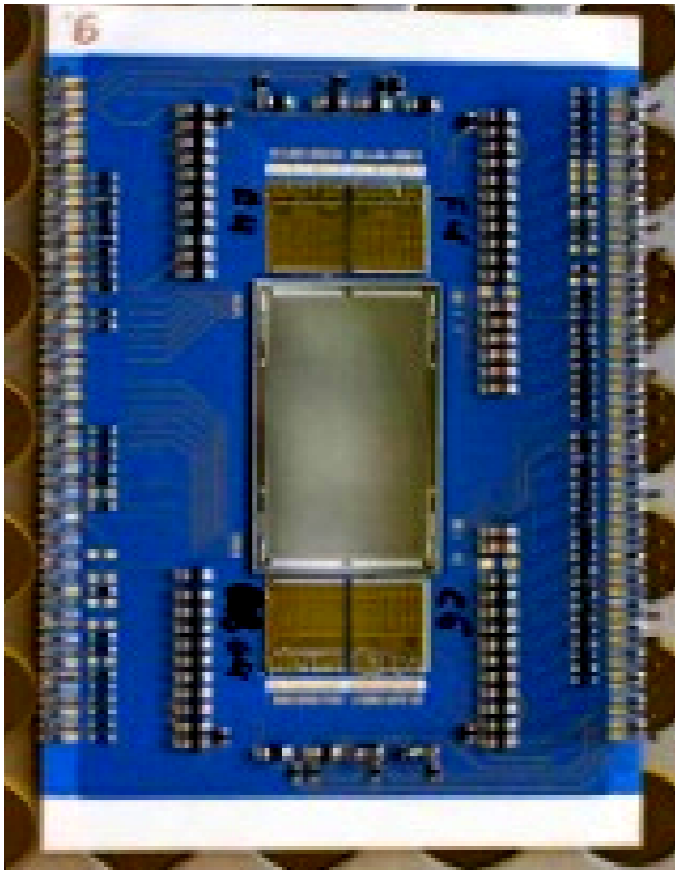
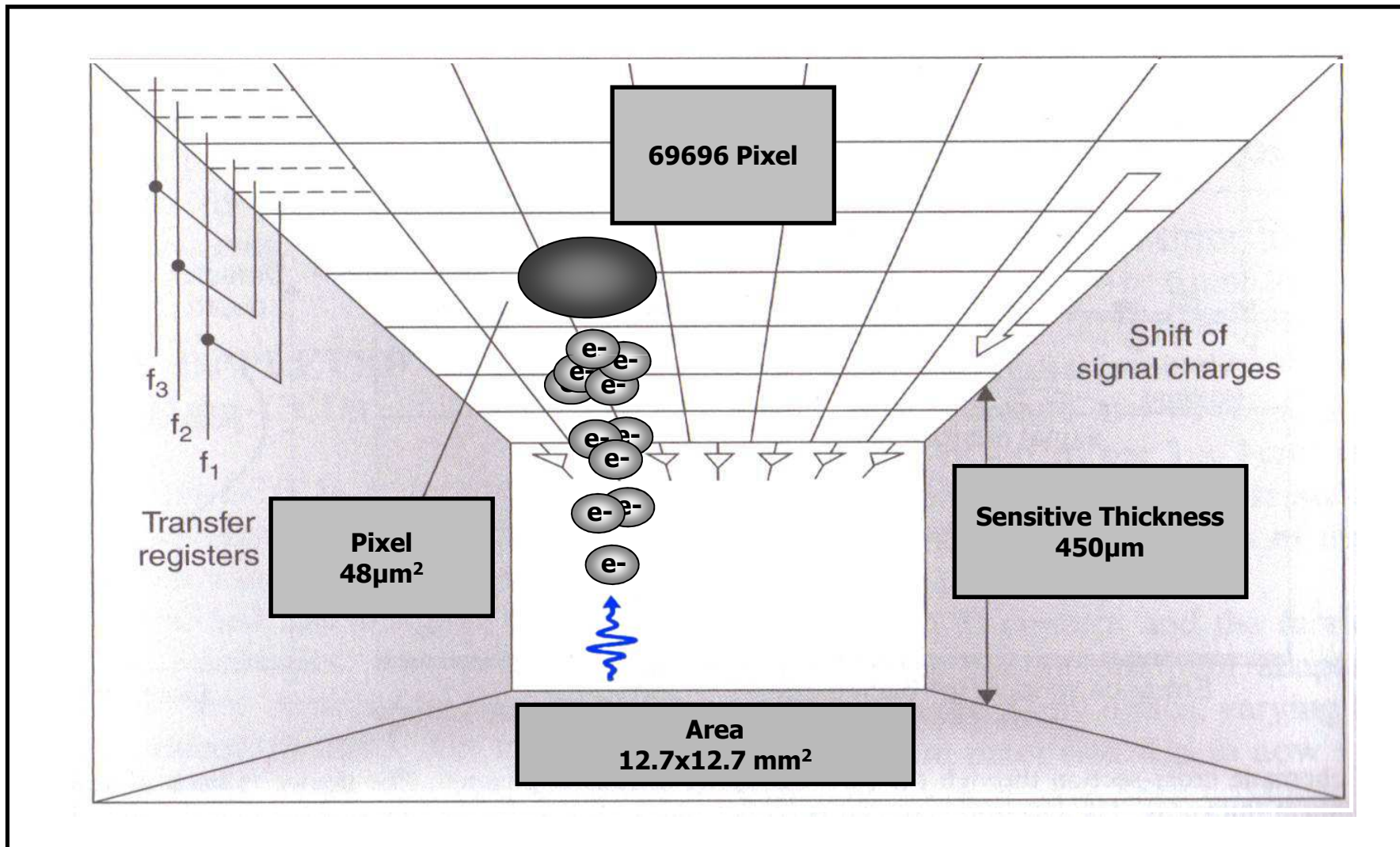


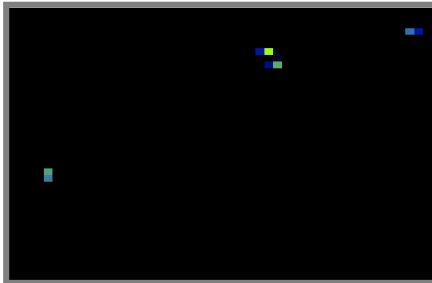
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Schematic view on the pnCCD

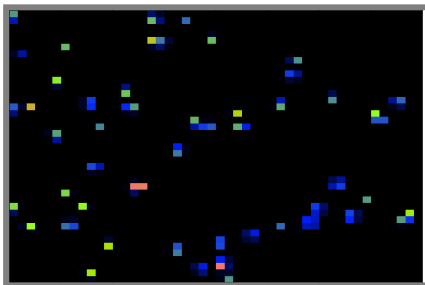


Eventanalysis

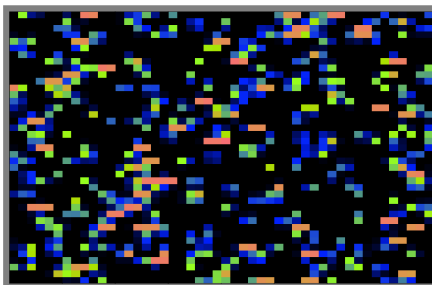
Not enough Photons



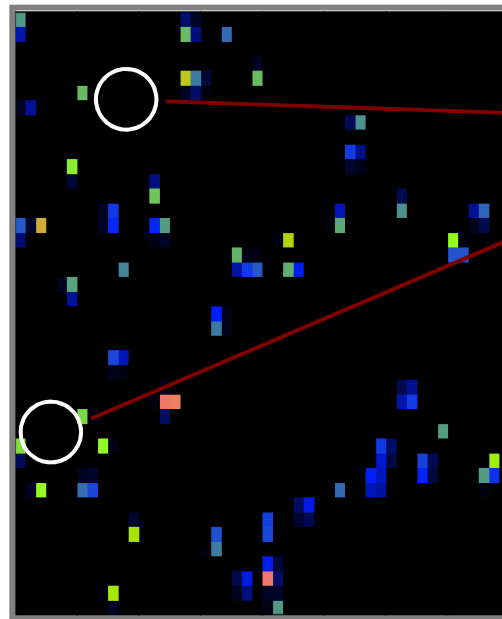
Good Illumination



Too much Photons

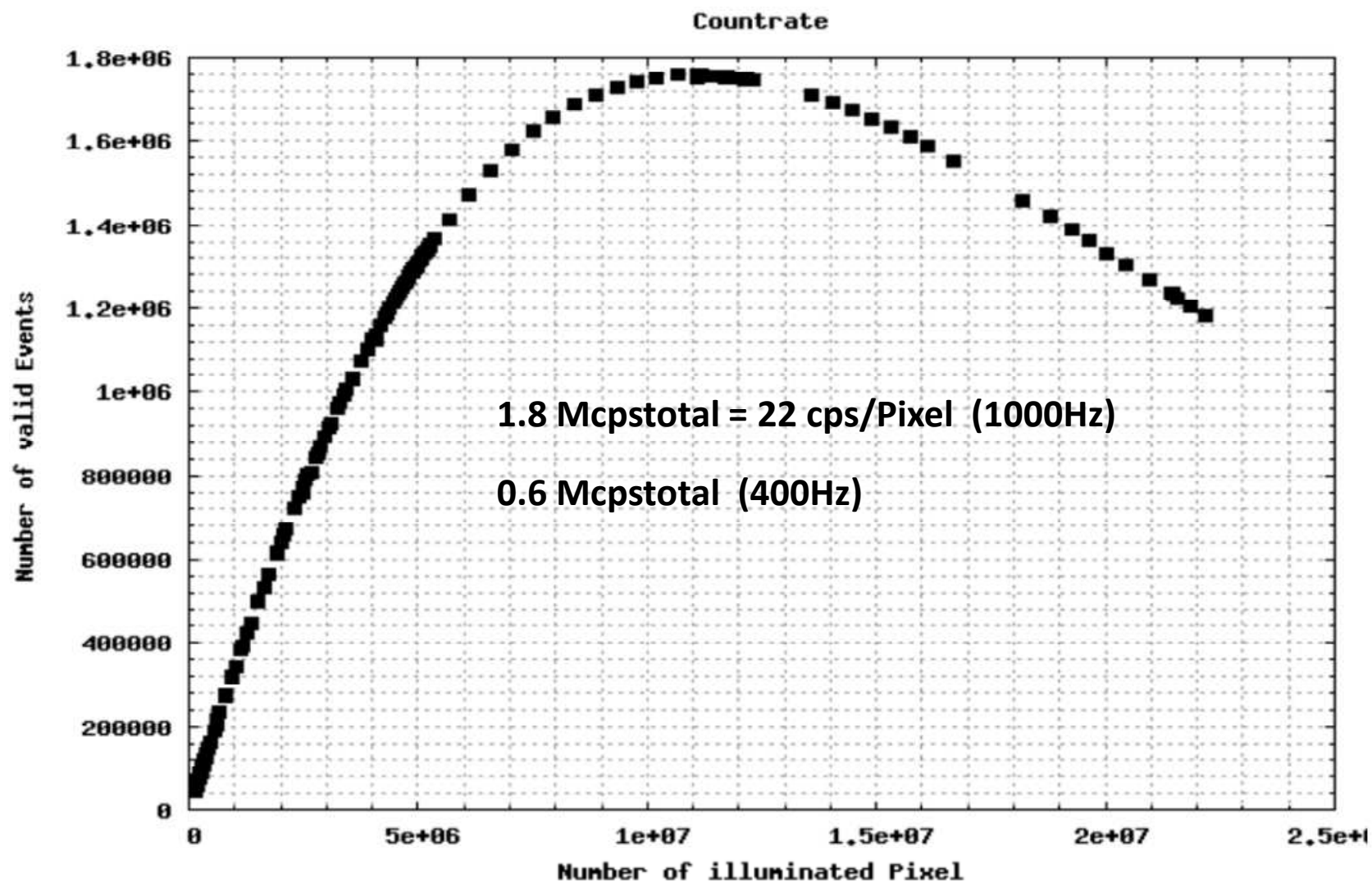


1. Common-Mode Correction
2. Dark-Frame Correction
3. Charge Transfer Efficiency / Gain Correction
4. Valid Photon: Energy and Position
5. Construction of Spectra



Events [Pixel]	[%]
1	1.1
2	19.2
3	32.2
4	43.6
5	2.6
6	0.6
7	0.4
8	0.2

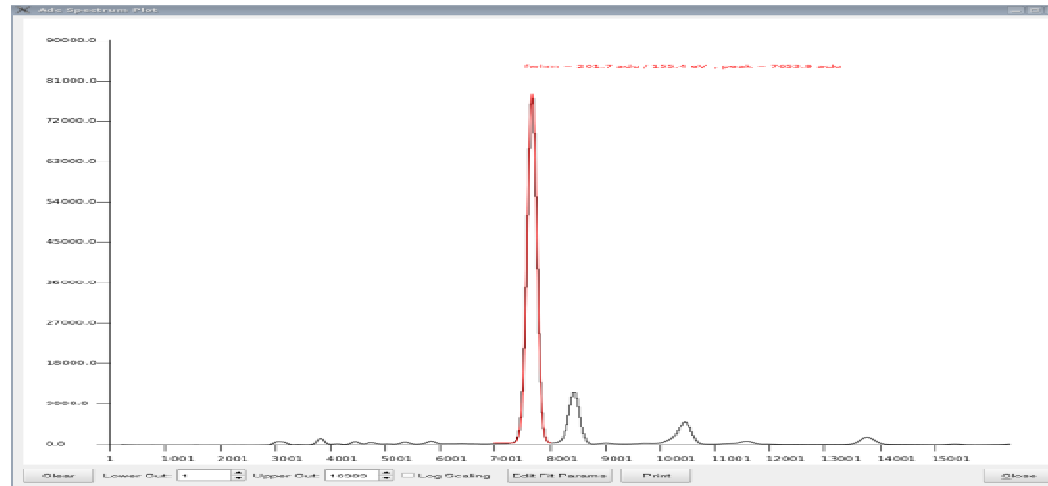
Count rate



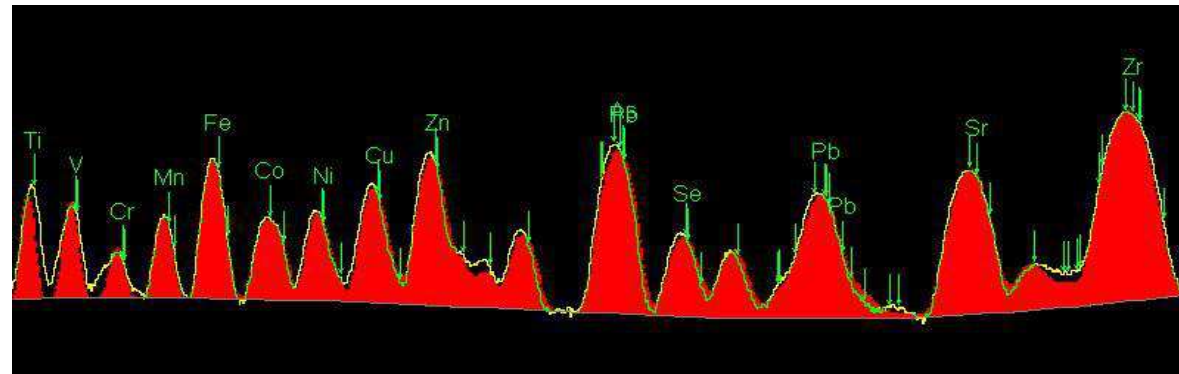
Spectra



Mn Foil:
FWHM 153 eV
 $T_{\text{CCD}} = -27^{\circ}\text{C}$

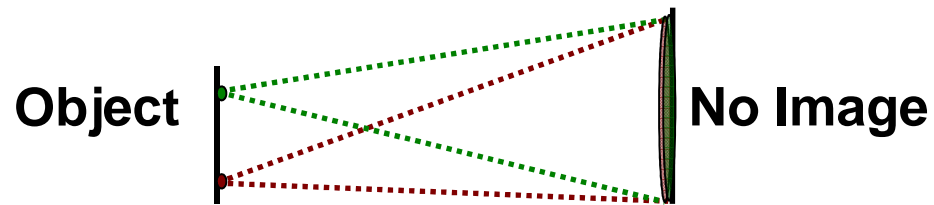


Standard BAM S005A

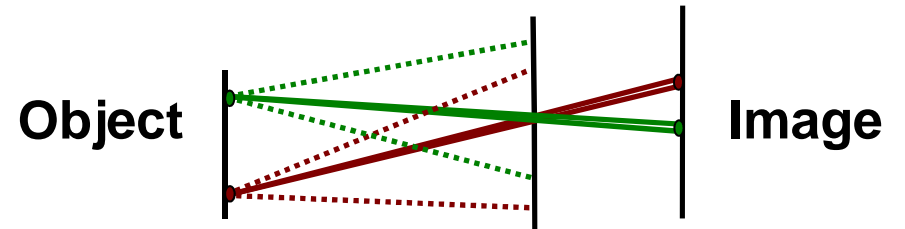


Copper(II)-oxid 112 mg/kg -> MDL better than 1ppm
NIST SRM613 ~ 30 ppm / pixel in 1000s

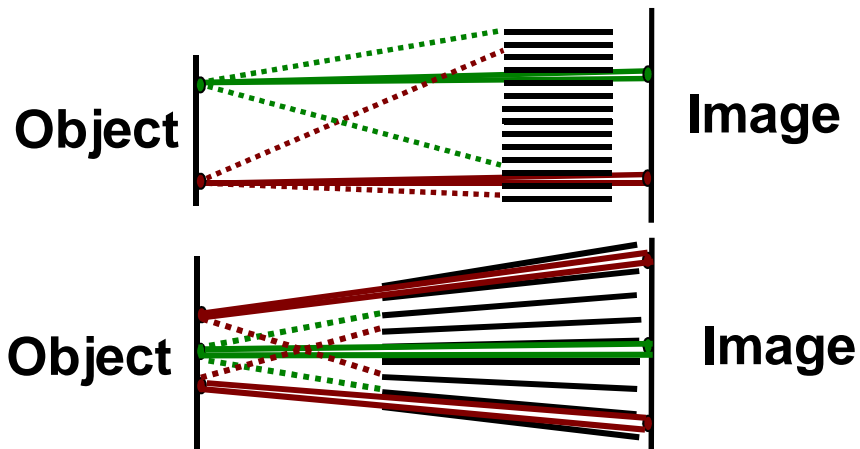
Without



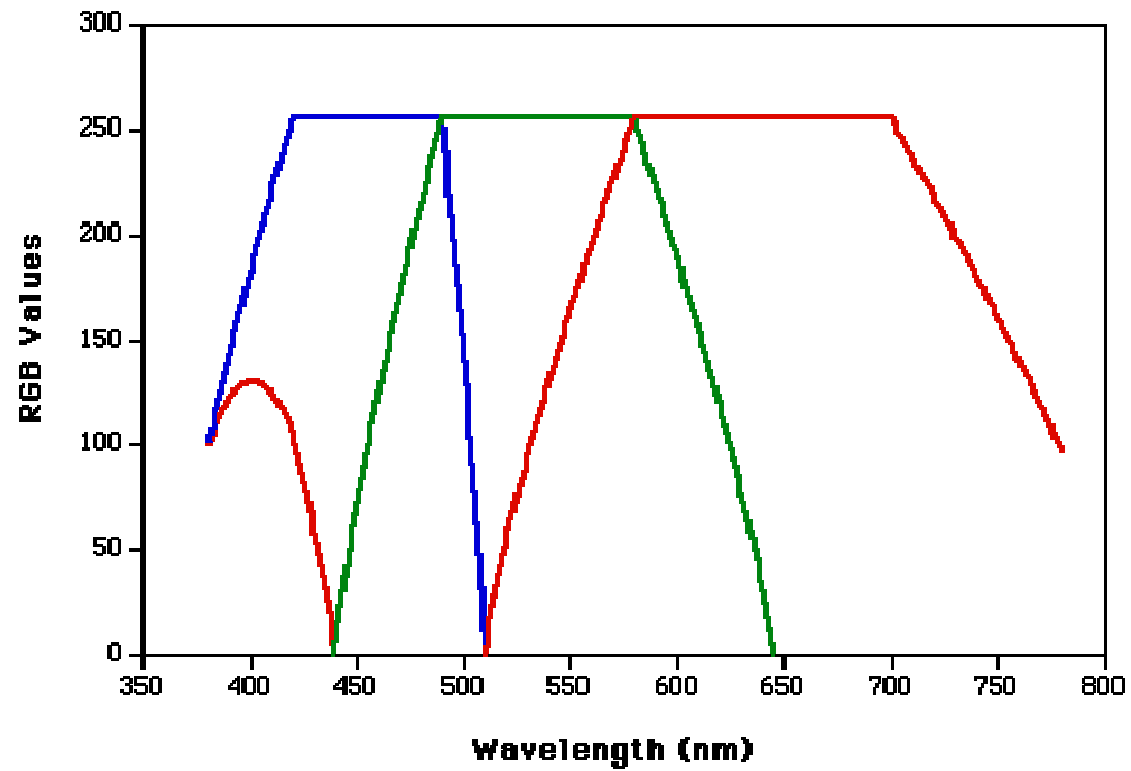
Pinhole (Camera Obscura)



Capillary Optic

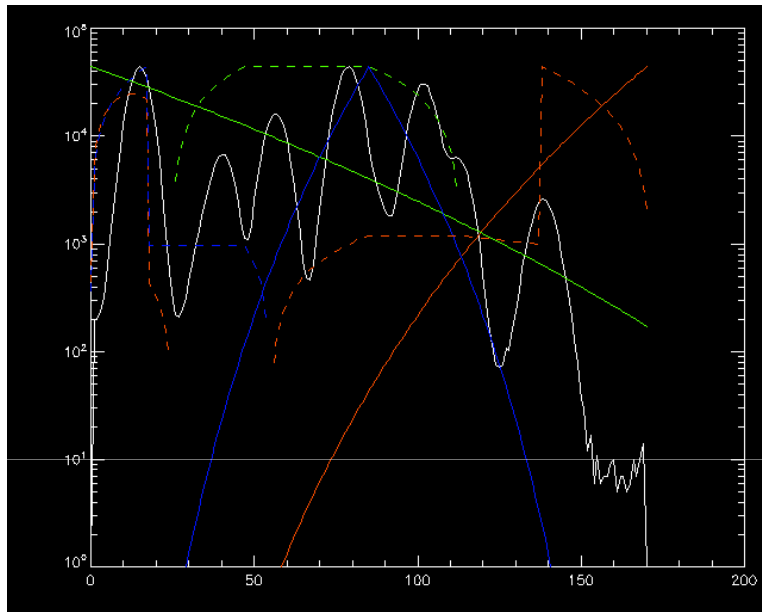


Color for the Camera

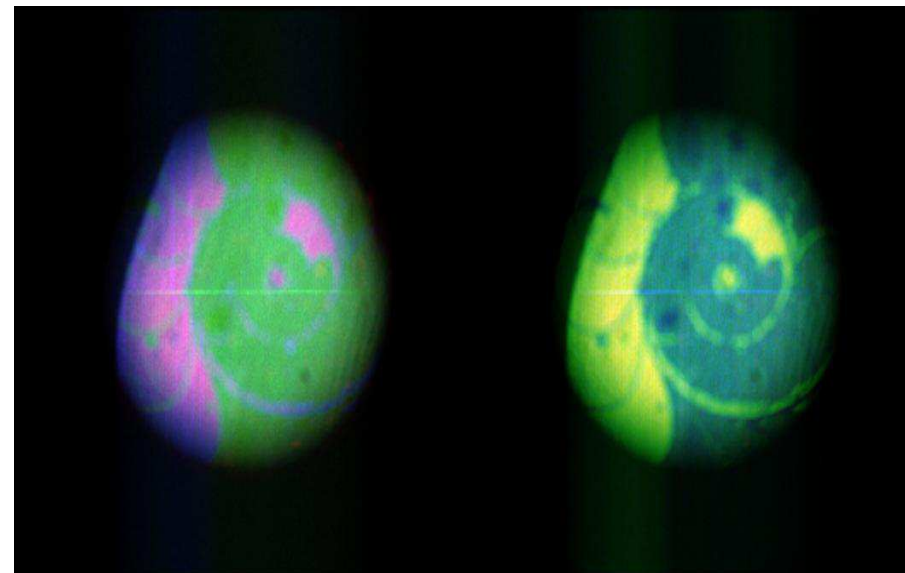


Visible Light -> RGB

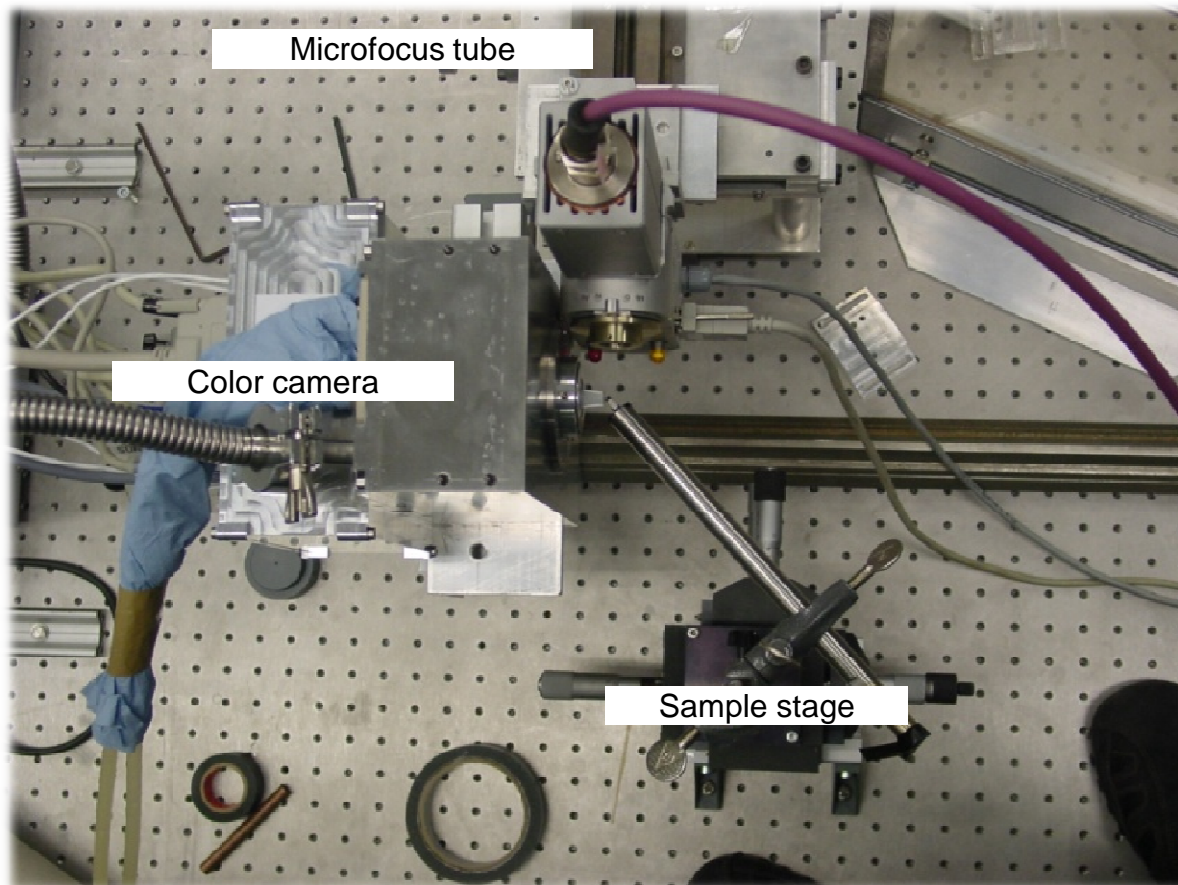
Colour for the Camera



- Fast Visualization
- Parameter Reduction

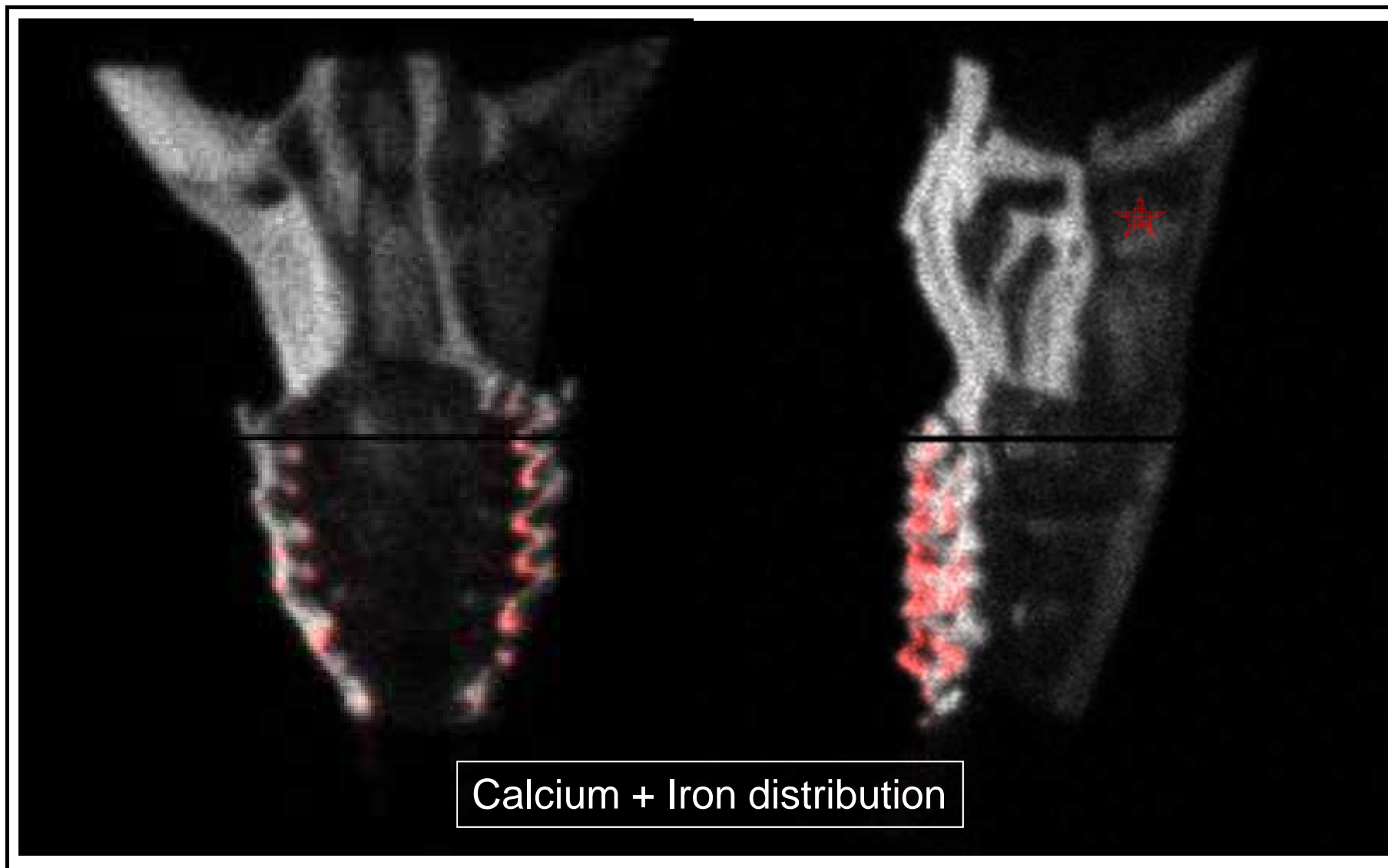


Laboratory setup



Head of a red tooth sore
1:1 capillary
Source: Rh-Microfocus tube
($U=40\text{keV}$, $I=700\mu\text{A}$)
Measurement time: 60min

30 Watt Microfocus Rh source, 1hour
50 ms / Pixel



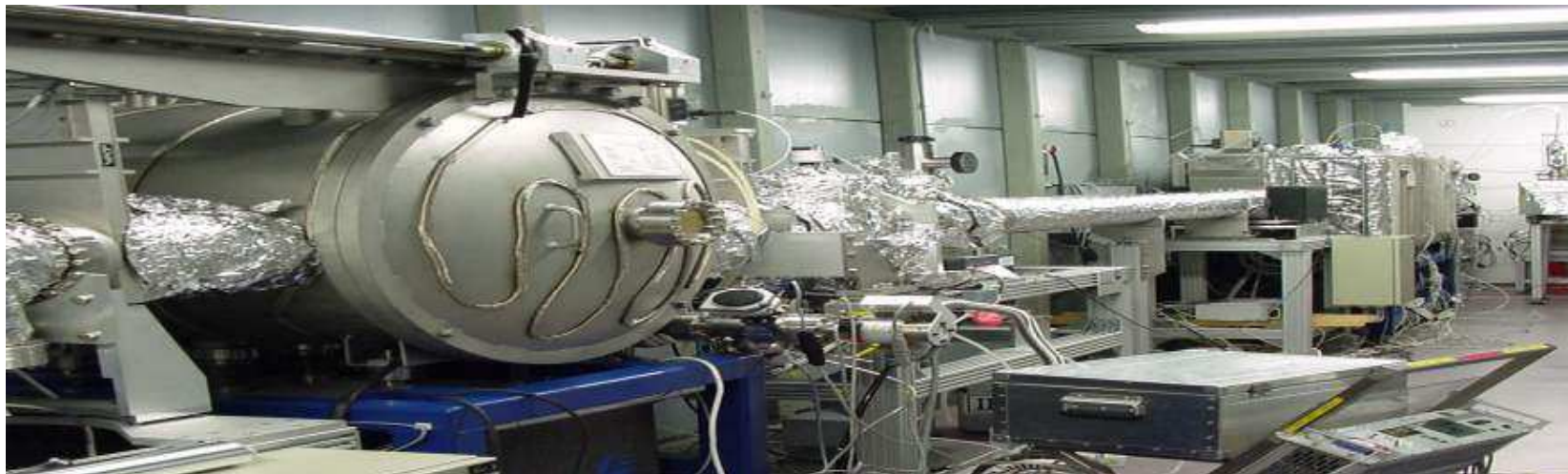
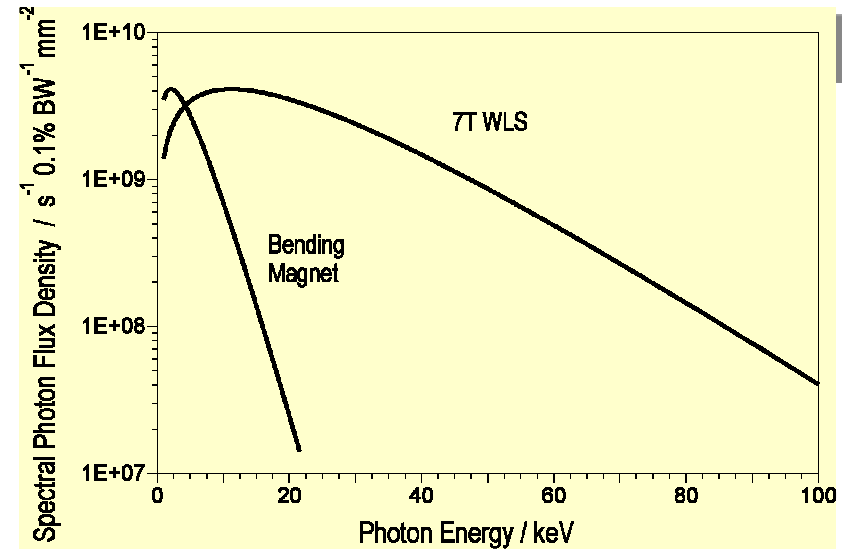
Layout of the BAMline



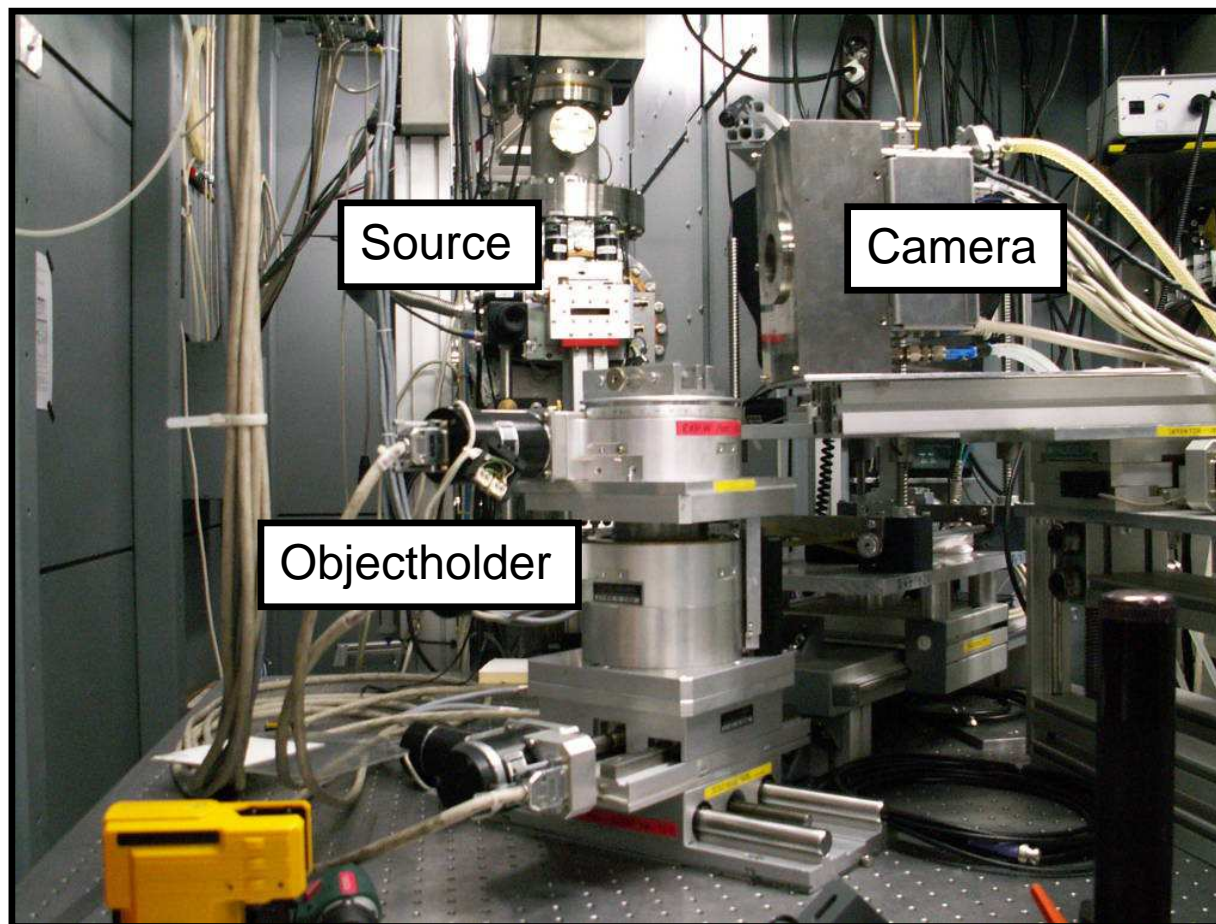
**Double crystal
monochromator**
 $E/\Delta E \sim 10^3$

**Double multilayer
monochromator**
 $E/\Delta E \sim 40$

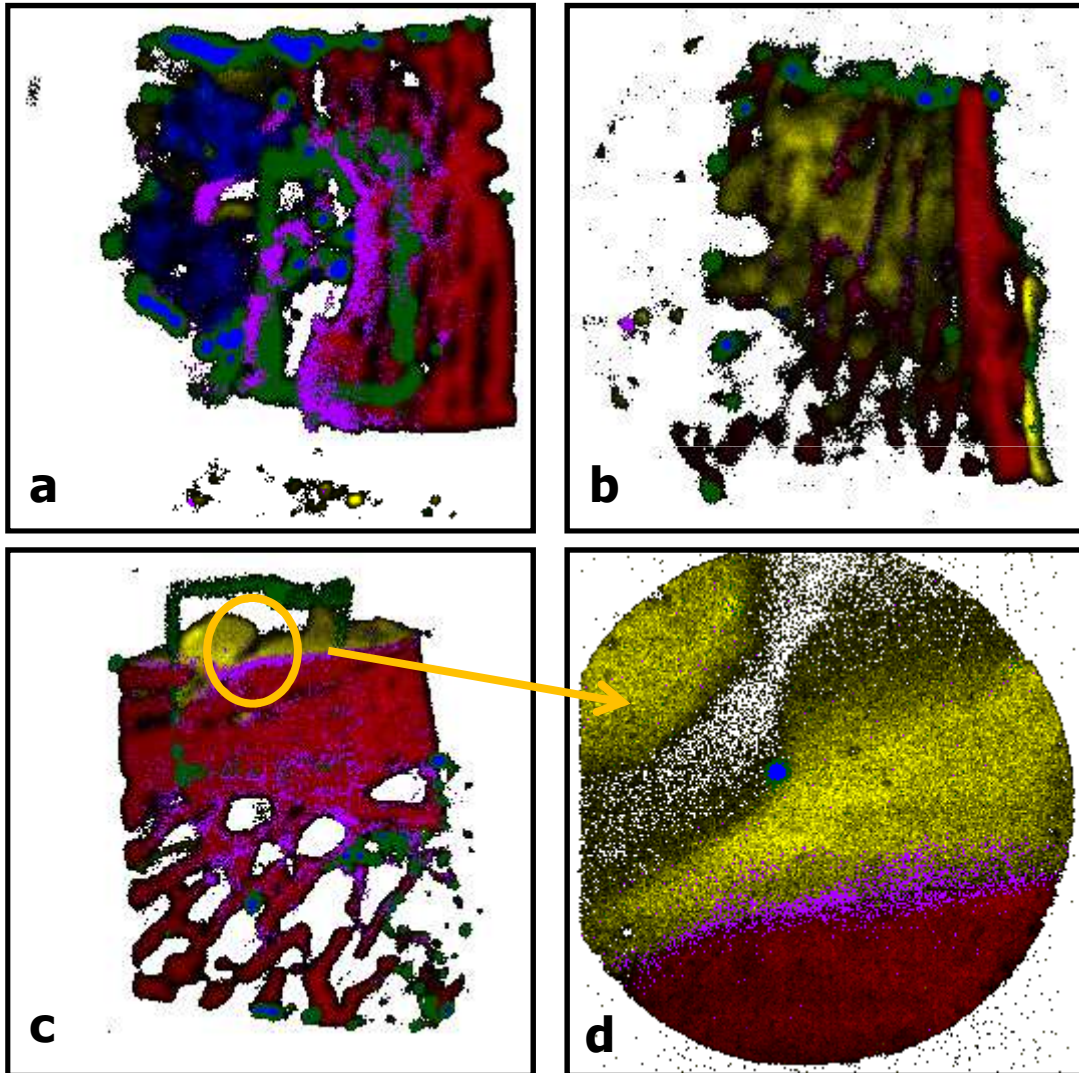
Wavelength shifter
Stability: 0.01%
**Homogeneity: 0.02% (± 1
mrad)**



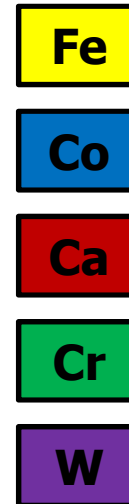
XRF setup at the BAMline



Medical Science: Steel implantat in bone



40 Minutes,
a-c) 50 μm 1:1 Optics
d) 8 μm 1:6 Optics



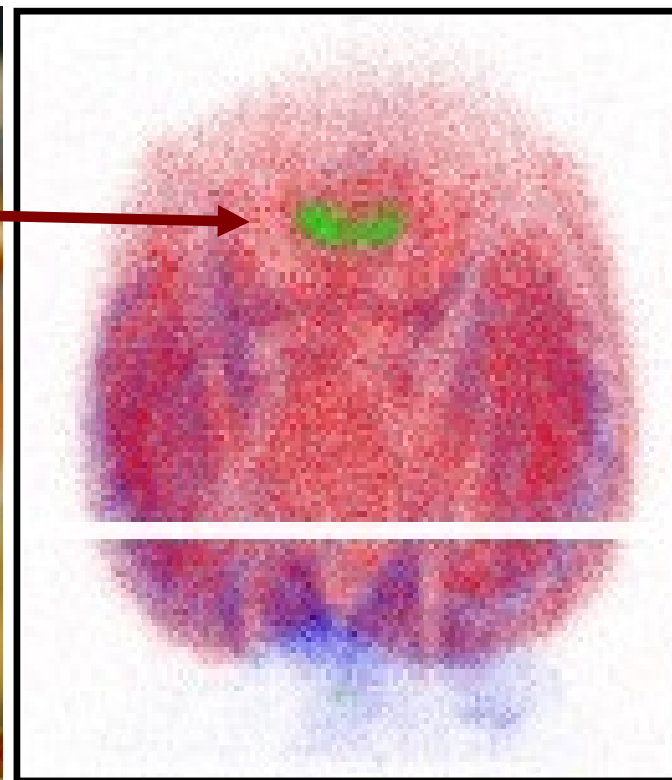
Biological samples



HZB Helmholtz
Zentrum Berlin

M. Kühbacher

Ocelli (**Fe**)

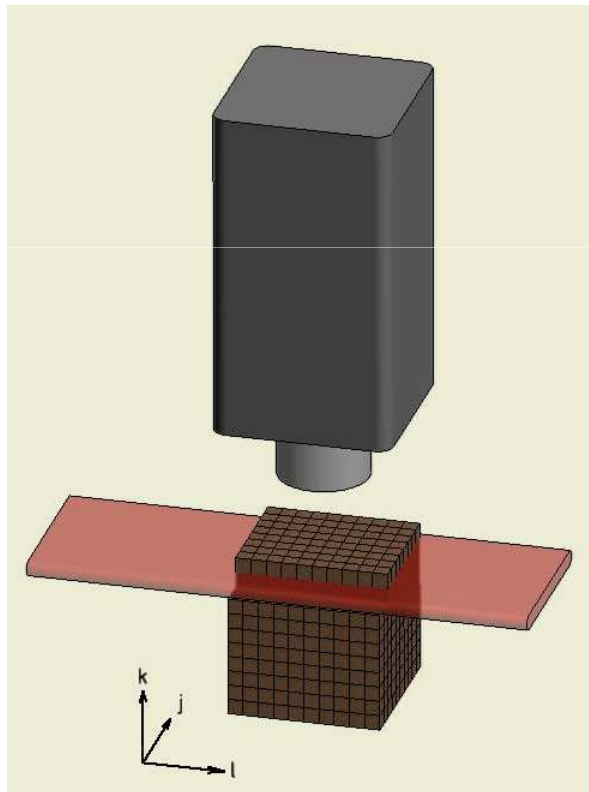




3D

Slicing

With a broad and flat beam a slice is cut out from the volume to be examined

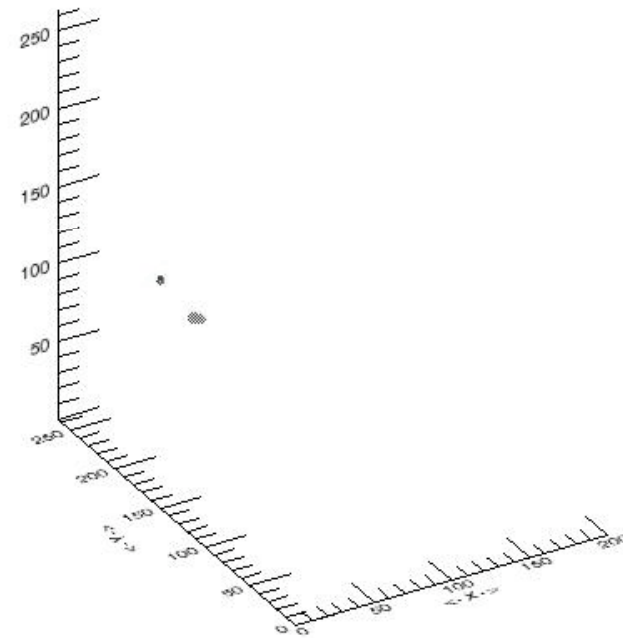


Slicing



Scatter

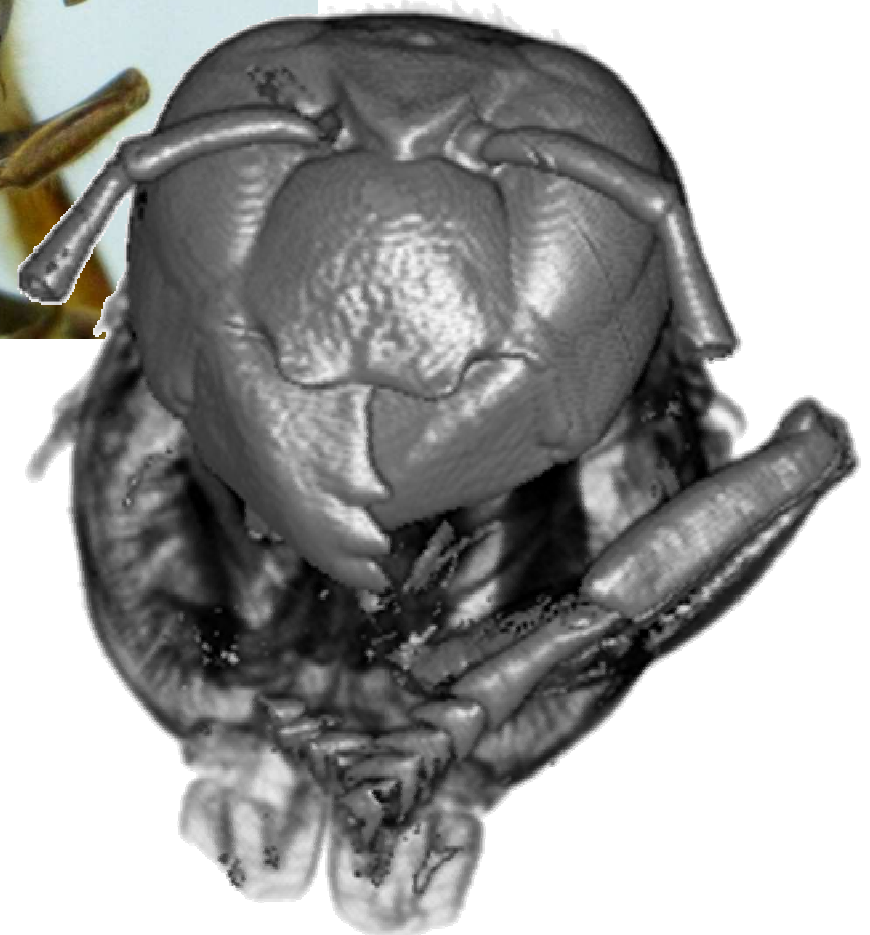
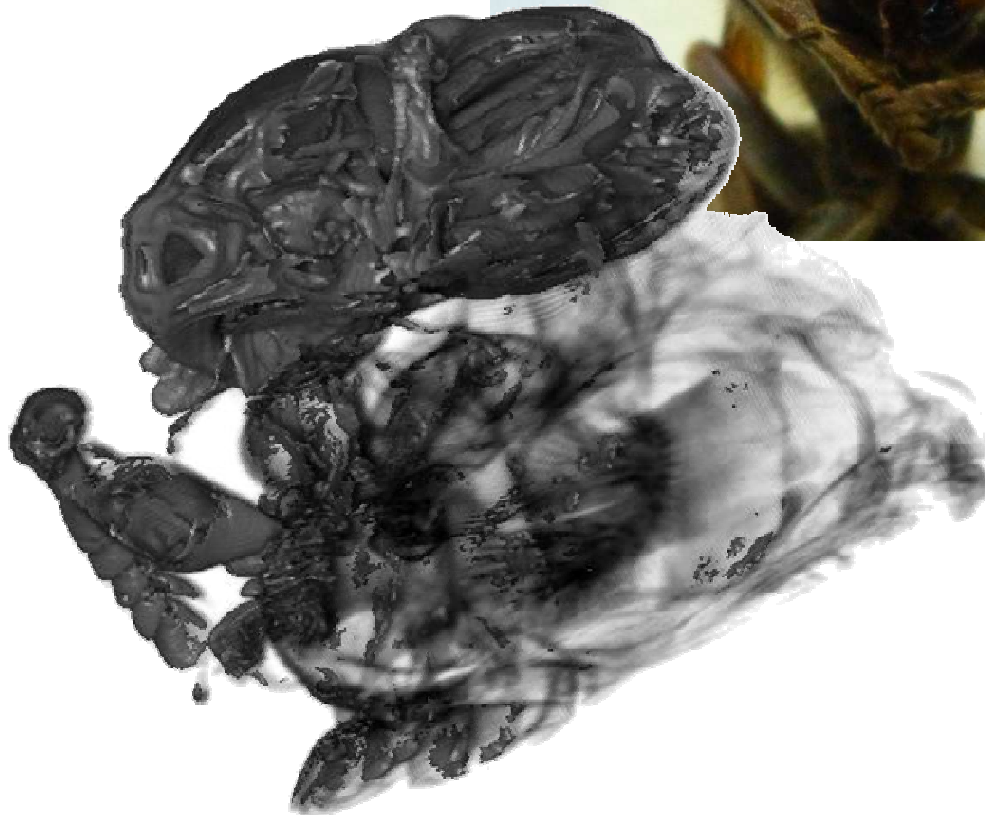
Fe



Ca

Zn

Slicing



Beyond Imaging

-

Double Dispersive X - Ray Fluorescence

Platinum in Gold

PGE are important for provenance



The gold and platinum lines are overlapping

Excitation below the Au edge induces Raman scattering

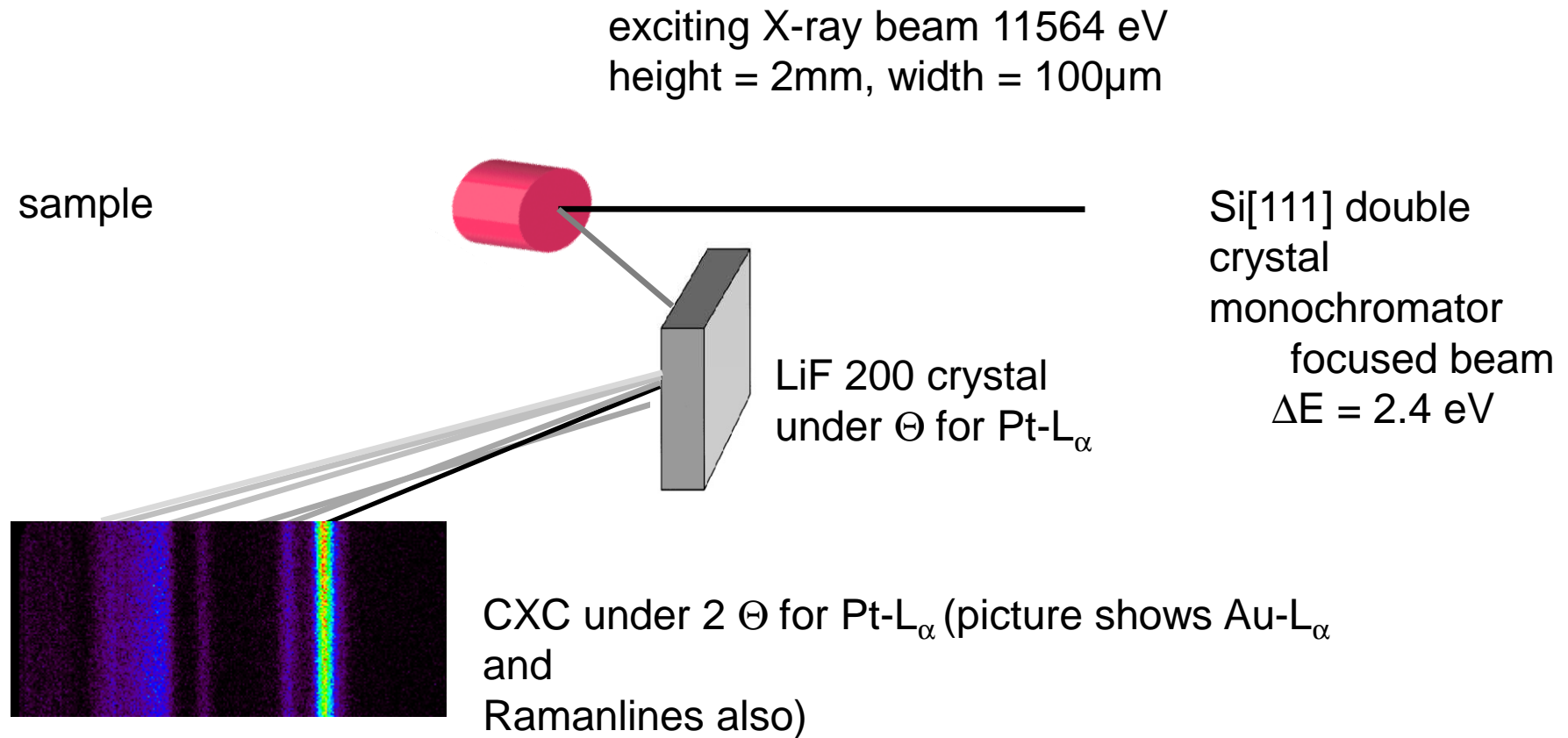


Three Approaches with Energy Dispersive Setup:

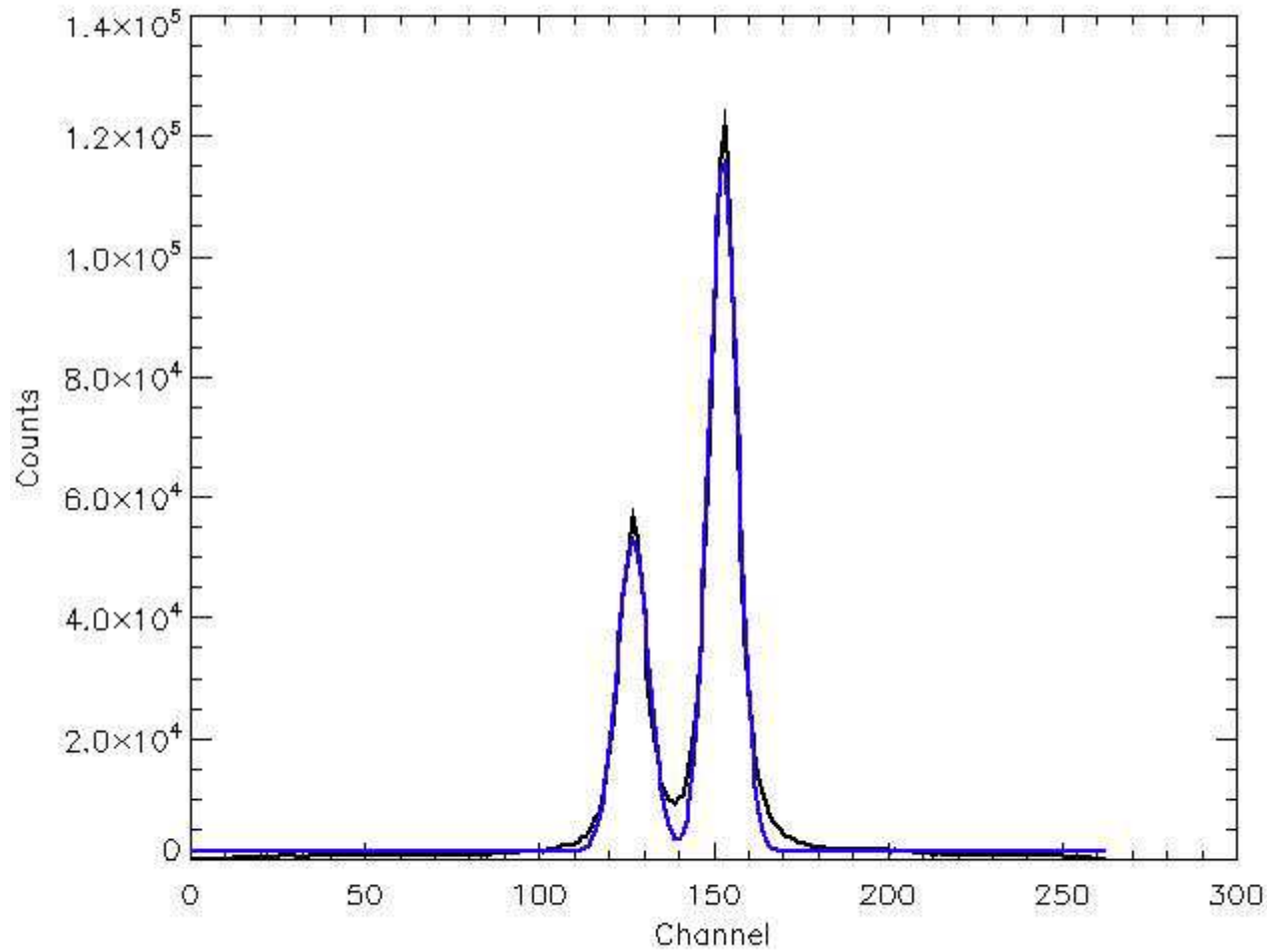
1. Excitation above and below the Pt L-edge
2. K-edge
3. Difference to pure gold



Using the Energy Dispersion

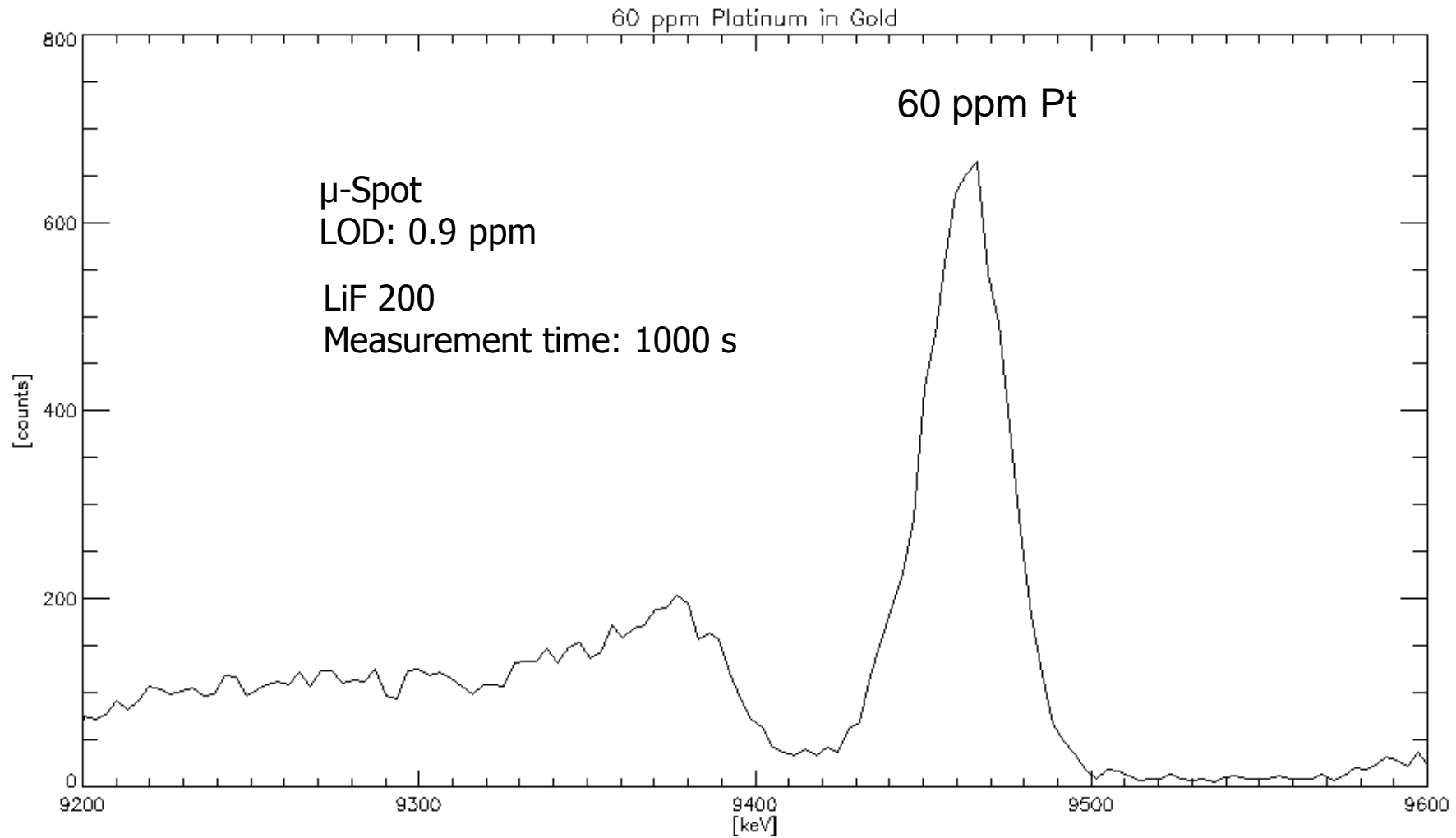


Second Order / Cu



Beamsize/mm	Counts K1	FWHM / eV	Time	CPS
1	1221405	7.7	00:05:08	4071.35

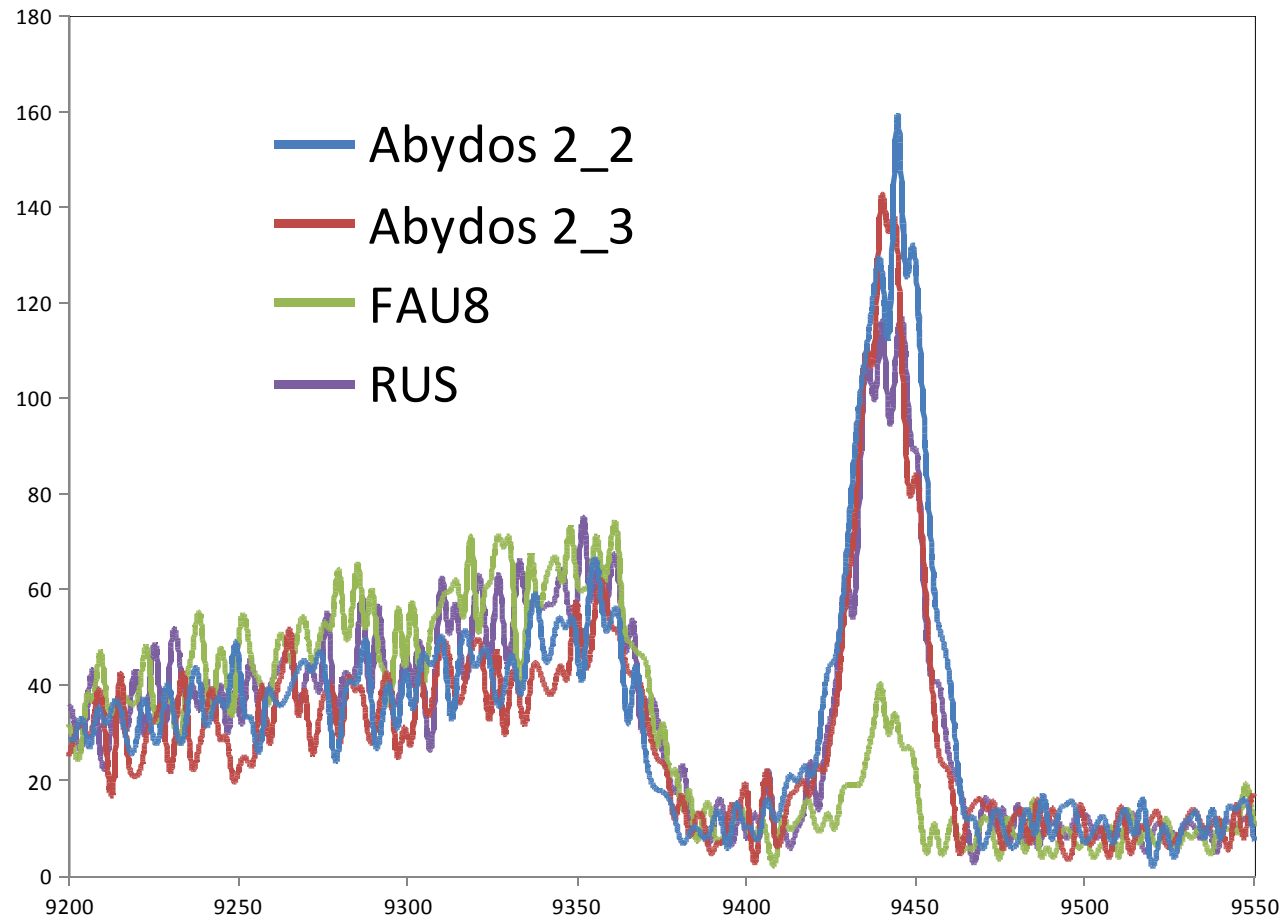
Best Result Pt



Applications

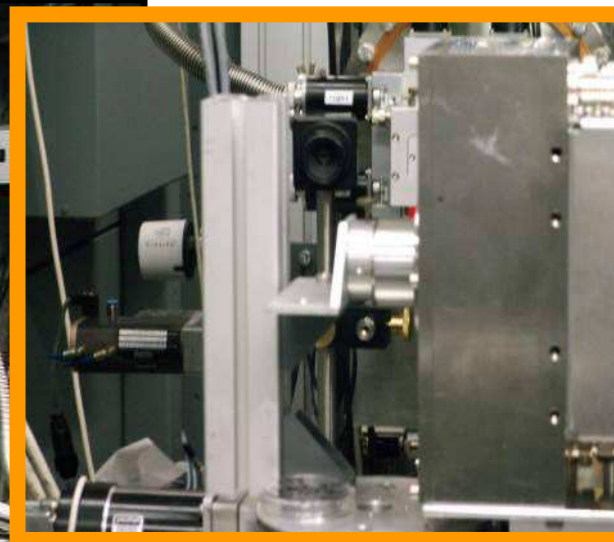
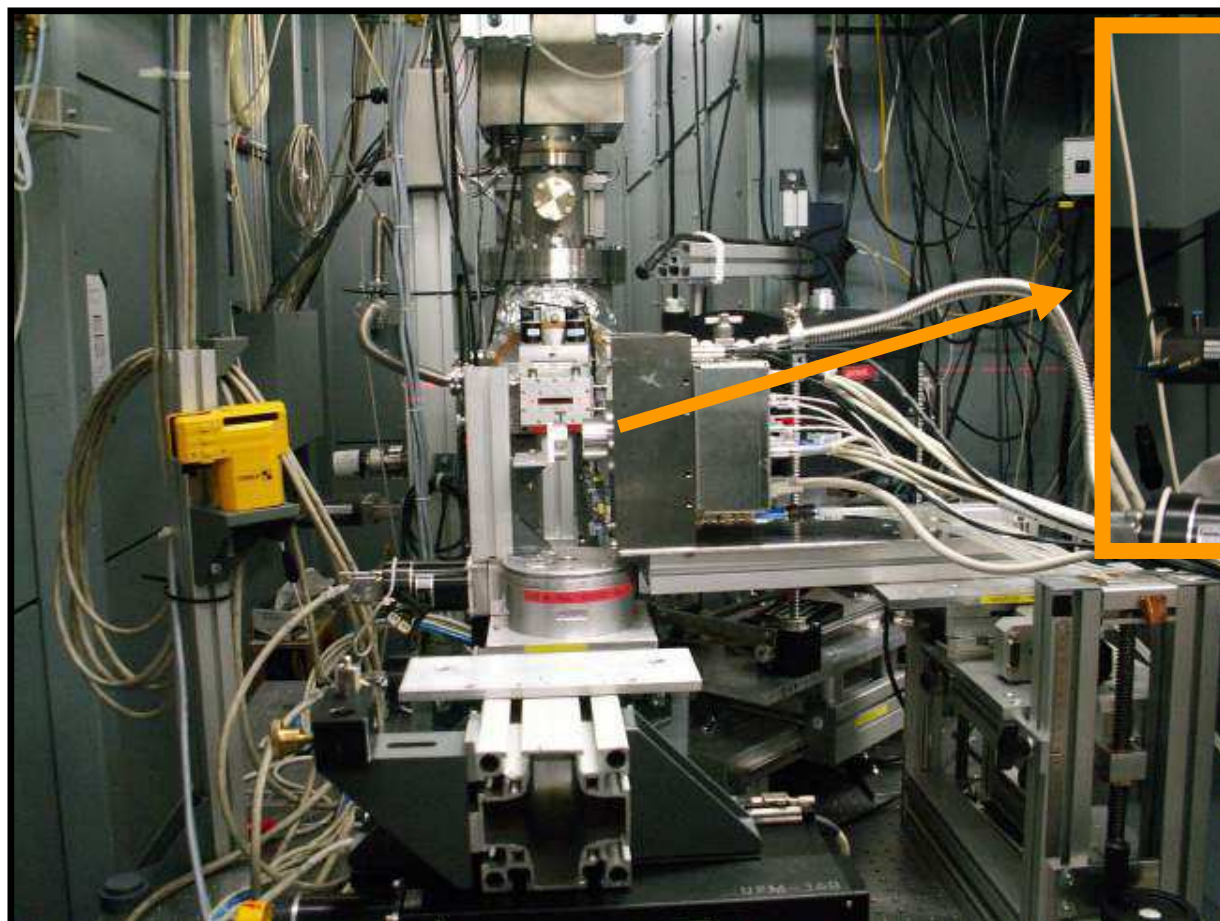


Gold from Egypt ...



... Results at the SR2A in Paris

XRF setup at the BAMline

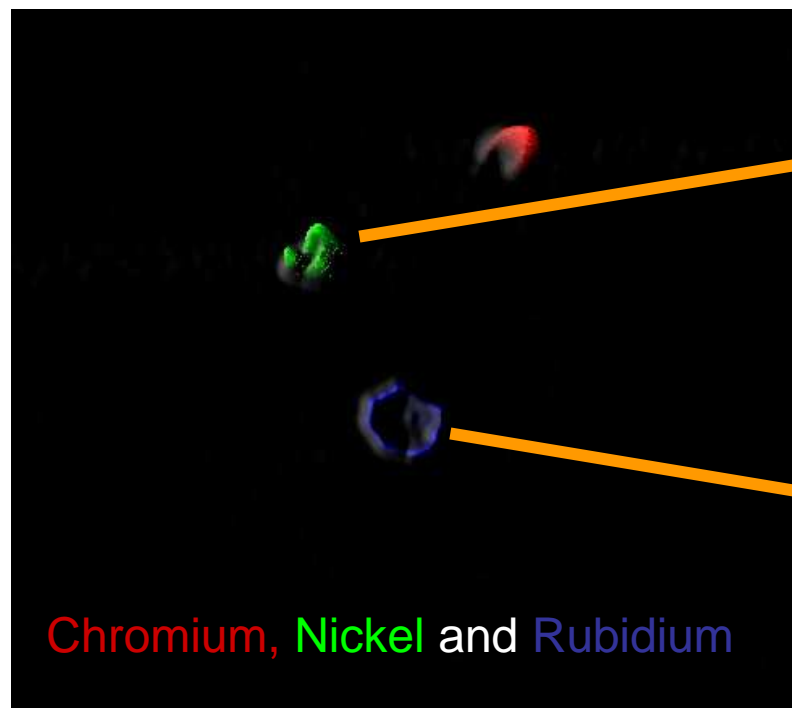


TXRF setup

Measurements under very flat angle, camera 90°

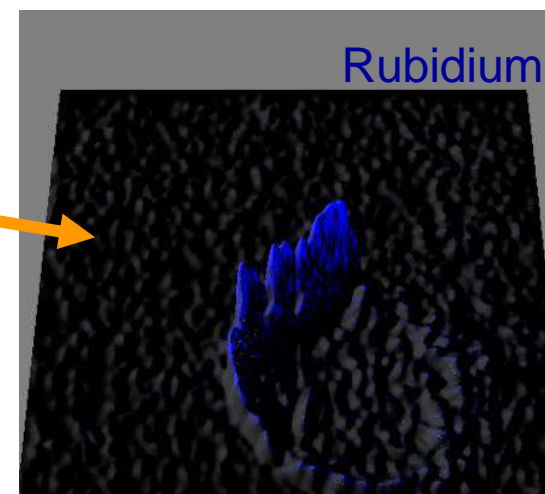
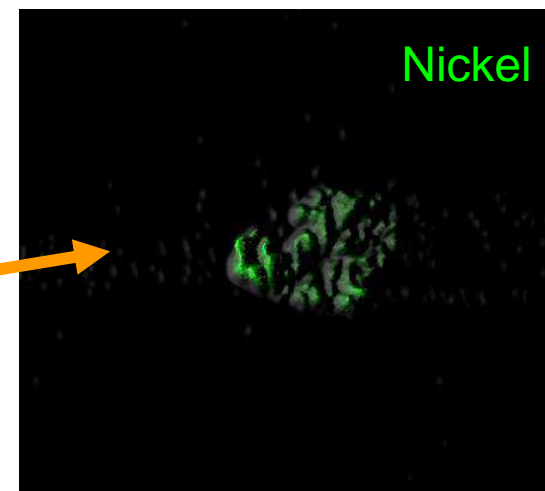
A. Berger
A. Kühn

Drying of drops



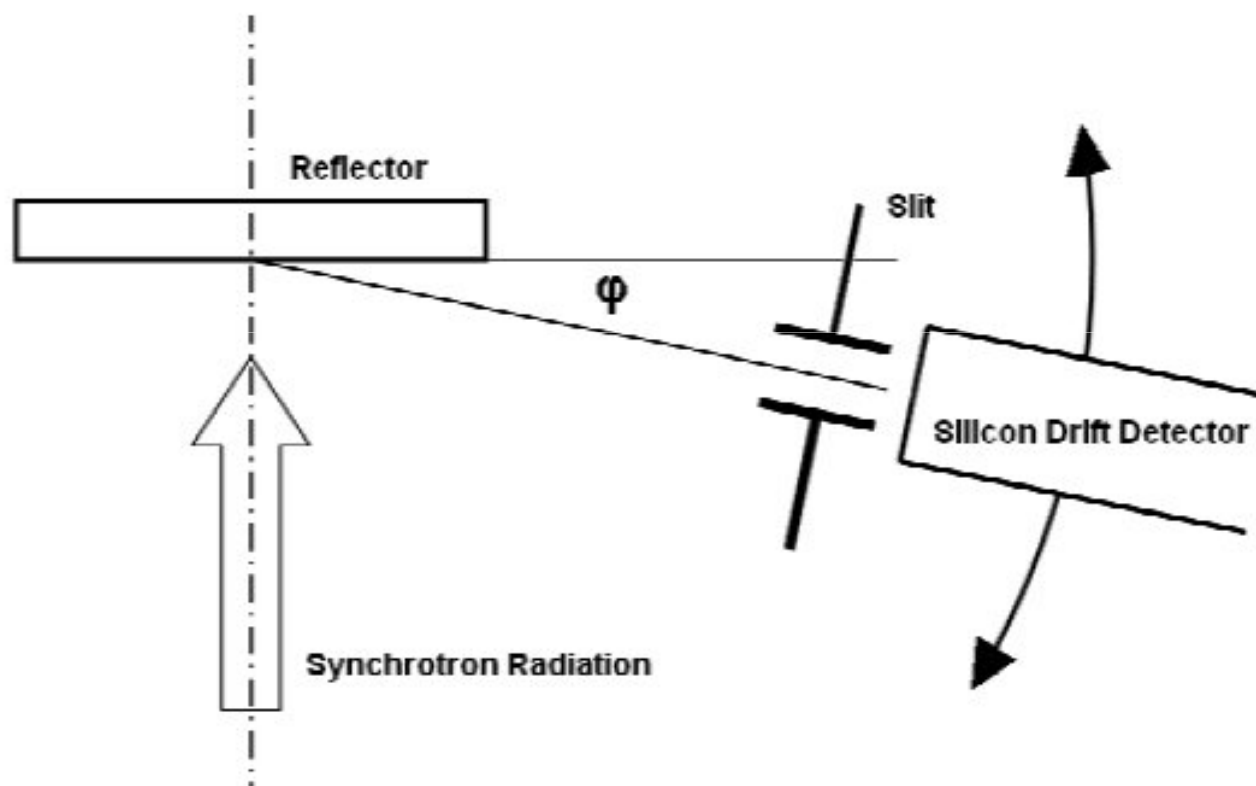
Drops (1000 nanogramm),
Exposure time 15 minutes

Magnification
with 1:3
capillary



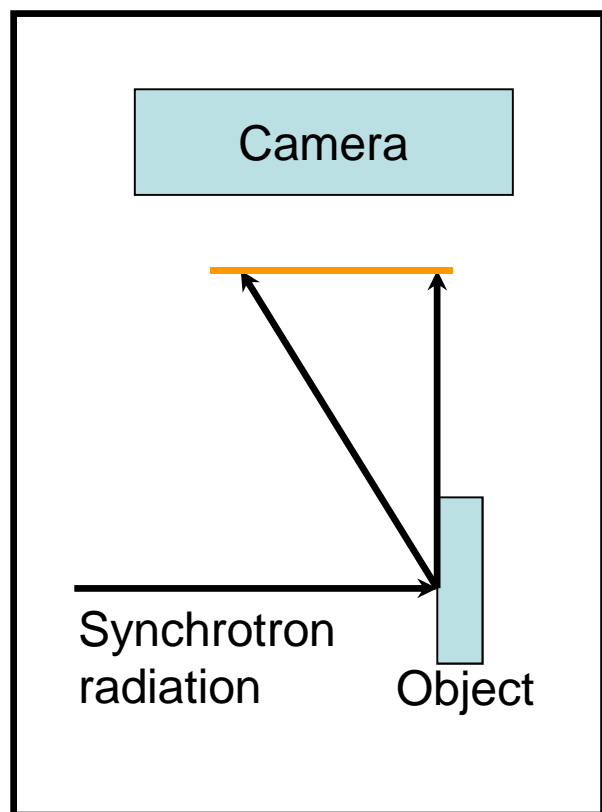
Grazing Exit GEXA

G. Pepponi

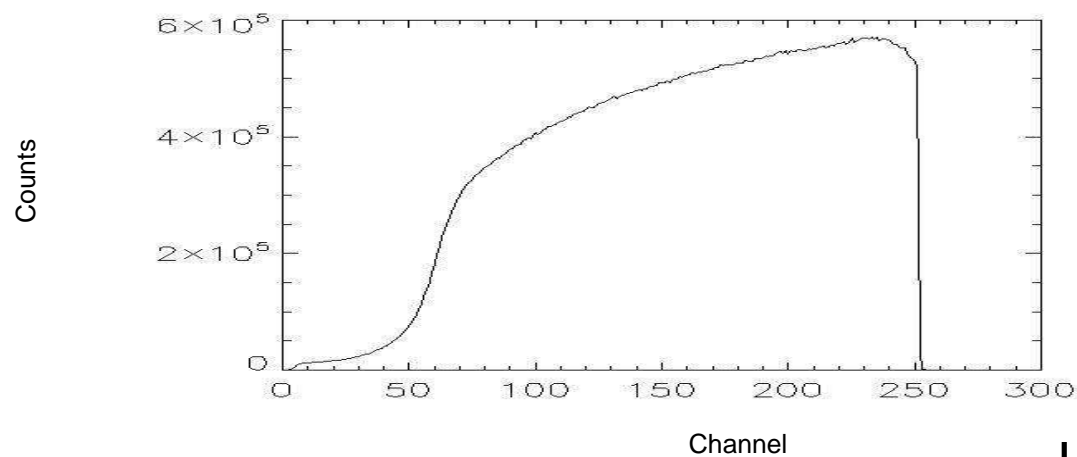
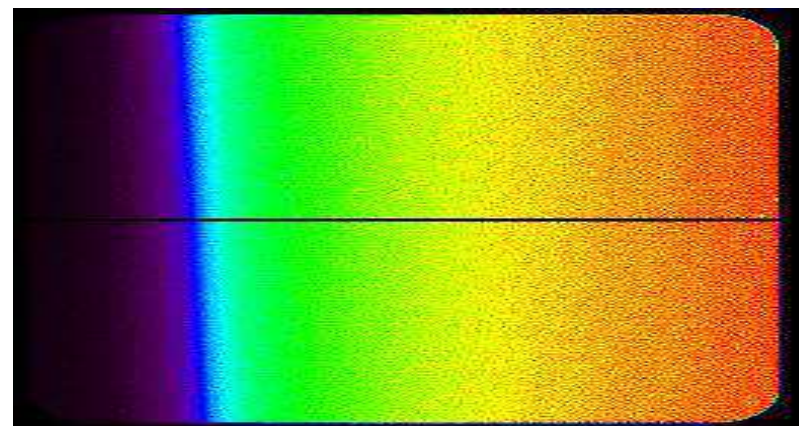


THIN FILM CHARACTERIZATION

Grazing Exit GEXA

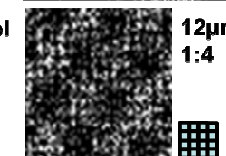
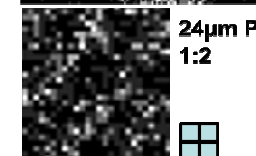
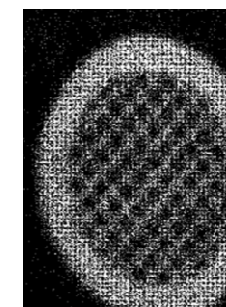
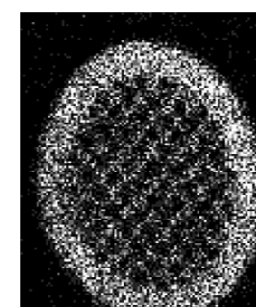
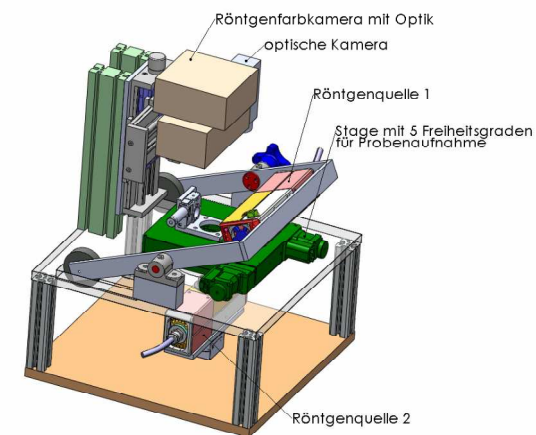
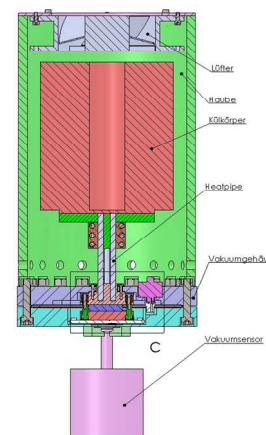


Hf on Si



Outlook

- Push resolution (subpixel, optics)
- Higher frame rates (more events per second)
- Table-Top-Detector Device (no pump, air cooling)
- Laboratory setup of an XRF-Microscope
- Experiments
- Software development



Thank you for your attention!

