Deutsches Elektronen-Synchrotron
in der Helmholtz-Gemeinschaft

Investigation of Modified German 20th Century Coinage

Using Non-Destructive Synchrotron Radiation Techniques

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Overview

THE SETUP AT BEAMLINE G3

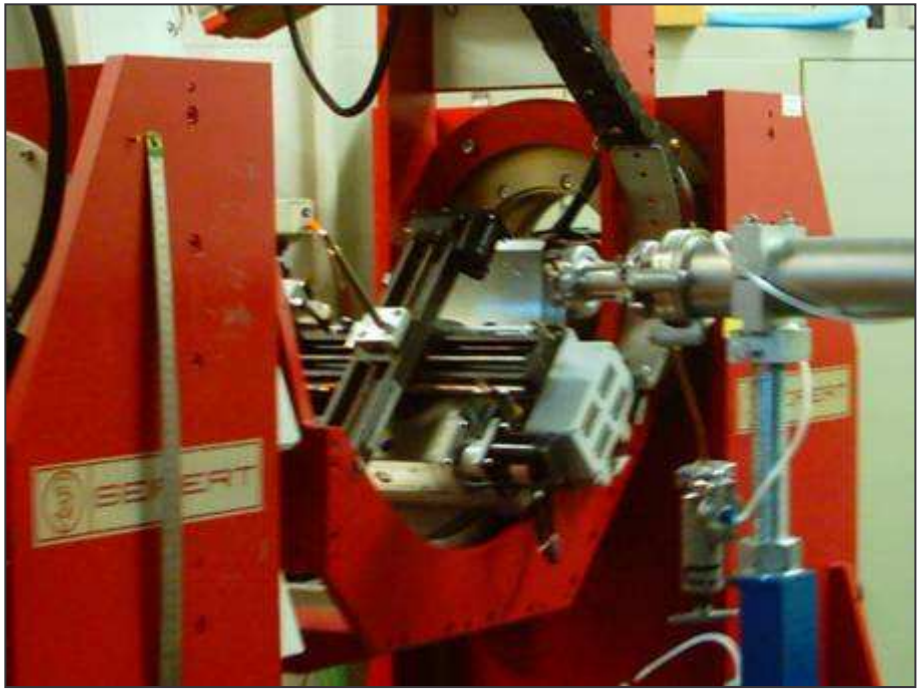
THE SAMPLE: NUMISMATICS IN A NUTSHELL

SPATIALLY-RESOLVED COMPOSITION-ANALYSIS: IMAGING X-RAY DIFFRACTION (IXRD) RESULTS

ALLOY COMPOSITION ANALYSIS: X-RAY FLUORESCENCE (XRF) RESULTS

DEPTH-RESOLVED COMPOSITION ANALYSIS: ENERGY VARIABLE X-RAY DIFFRACTION RESULTS

CONCLUSIONS



4-CIRCLE DIFFRACTOMETER AT BEAMLINE G3

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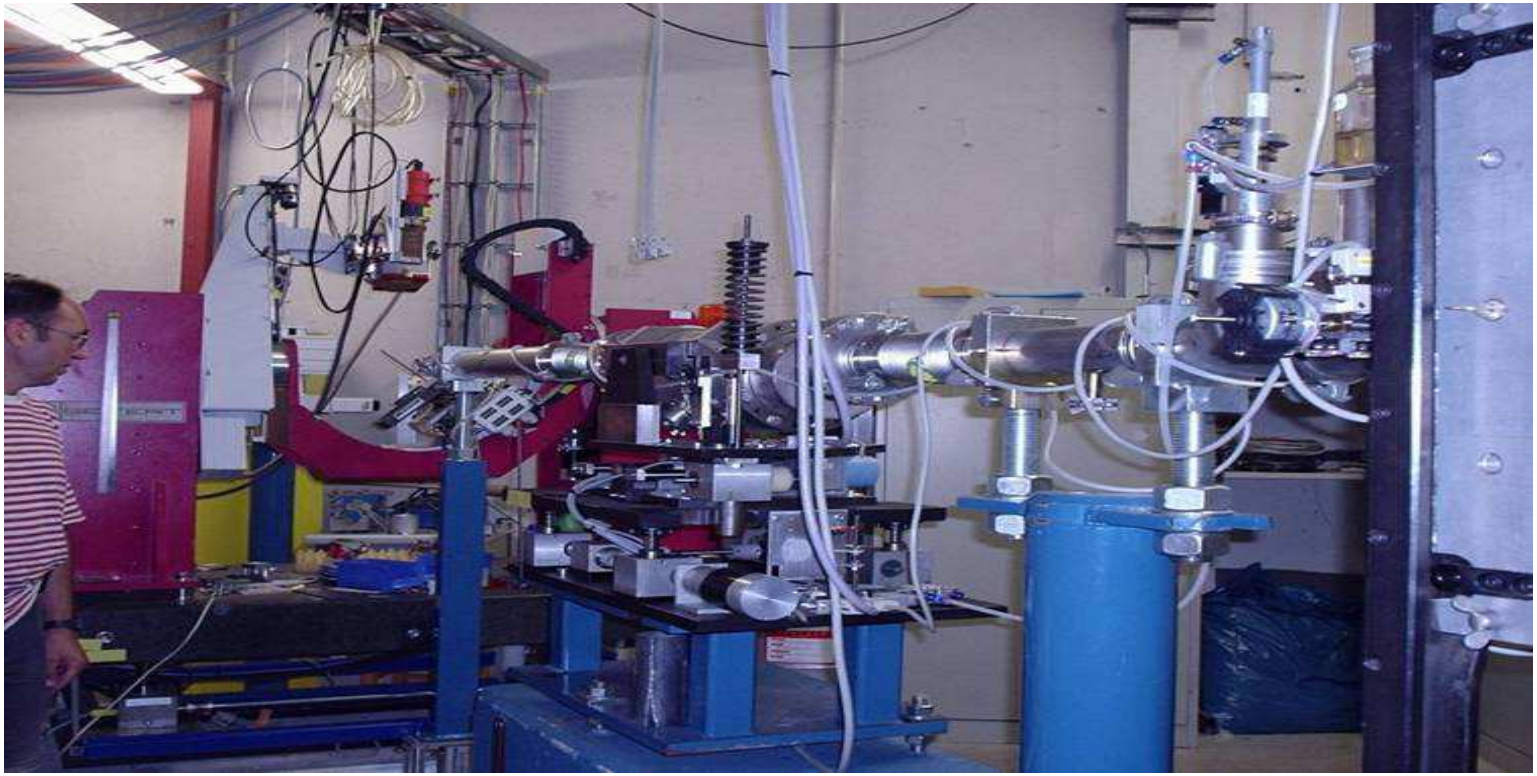
The Setup at Beamline G3

SHORT OVERVIEW OF THE BEAMLINE : Source: Doris (4.5 GeV)

Beam size: 2.8x1.1 mm (FWHM)
Divergence: 0.9x0.4 mrad FWHM Flux at the sample ~ 10^8 sec^{-1}



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The Setup at Beamline G3

- 4 Circle Diffractometer
- -90°<2θ<150°
- 0°<ω<150°
- 0°<χ<90°
- -180°<ψ<180°

- CCD-Detector With MicroChannel Plate (MCP)
- Allows spatially resolved diffractograms
- 1024 x 1024 pixels of 13 µm x 13 µm
- MCP-thickness 4 mm
- MCP-Channel diameter 10 µm

- NaI-Scintillation Counter
- Soller slits for collimation

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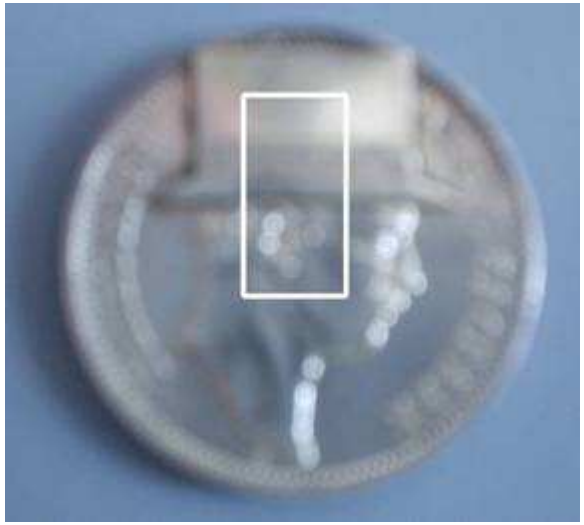
A Brief History of Spottmünzen

- Altered coins to express political views
- First appearances around 1450
- Coins circulate and reach a wide audience
- Coins show pictures of kings and popes to start from

Under investigation: 3 Reichsmark from 1903



A metal piece in the form of a hat was soldered onto King Friedrich August III's head, referring to the German idiom

"Den Hut nehmen" (taking one's hat)

which mocks the forced resignation of German nobility after World War I.

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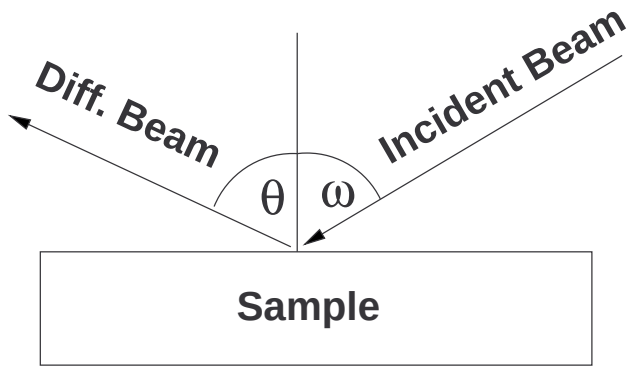
X-ray Diffraction Basics

Bragg Equation

$$n\lambda = 2d \sin\theta$$

Diffractometer Angles



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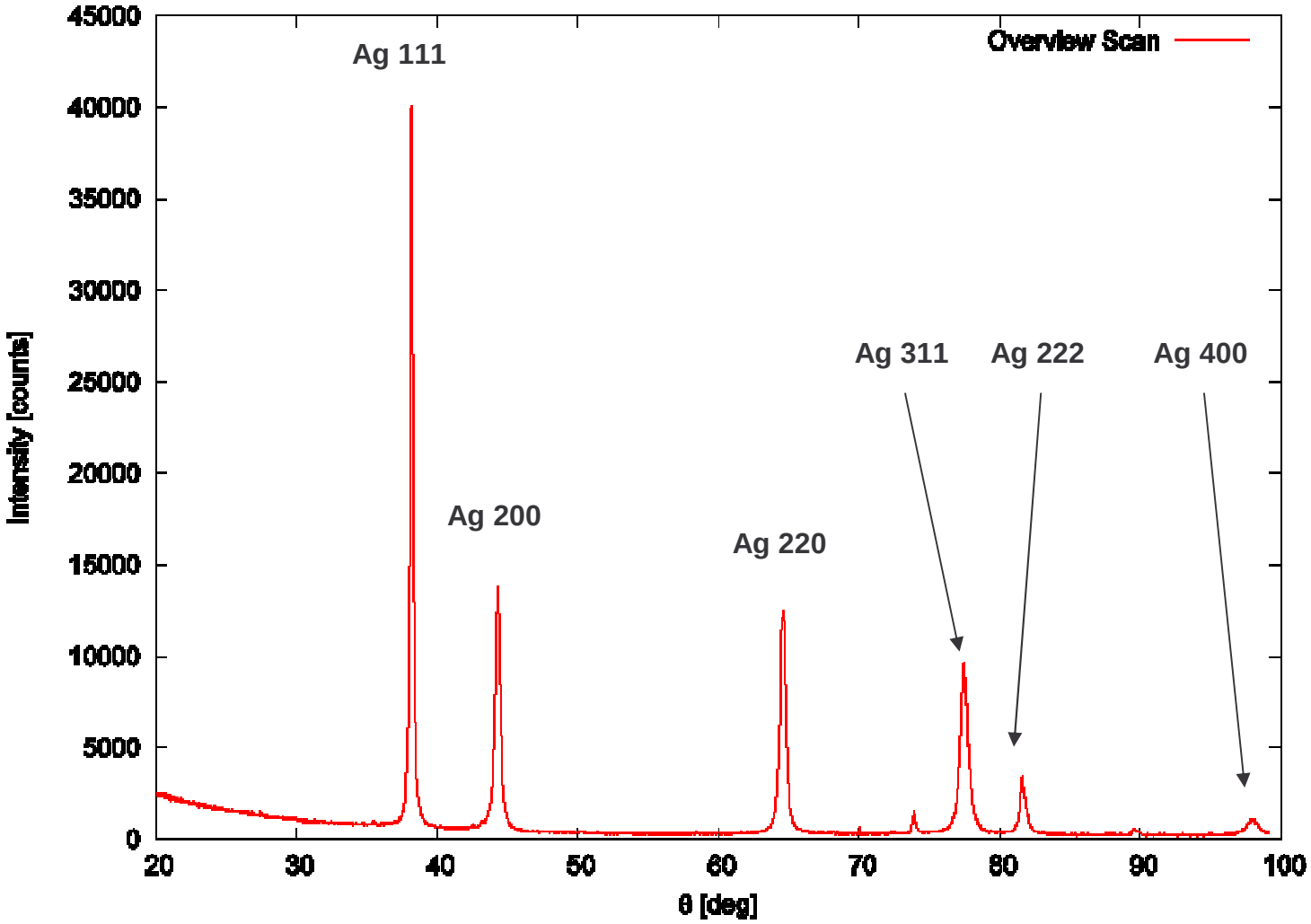
X-ray Diffraction results



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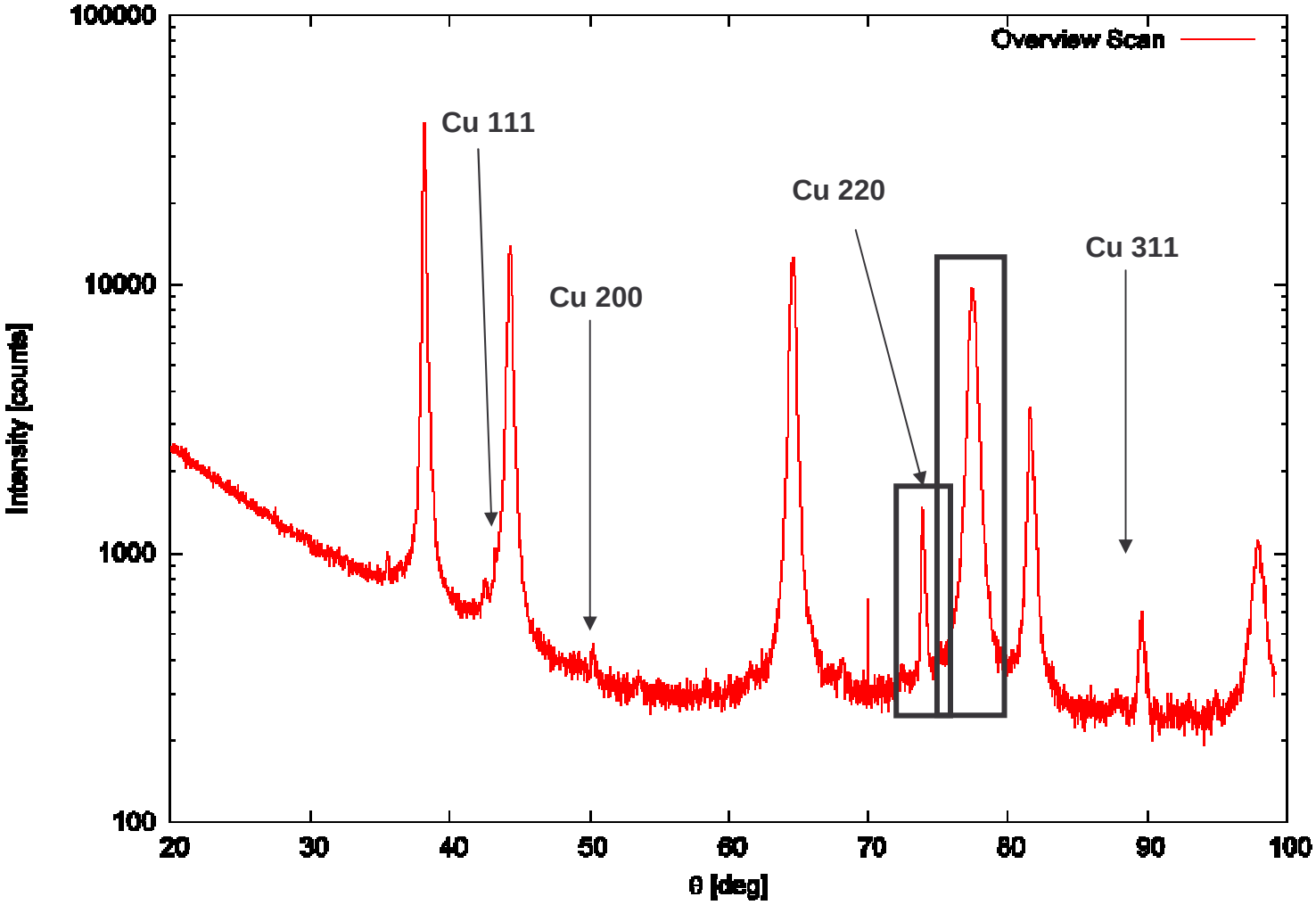
X-ray Diffraction results



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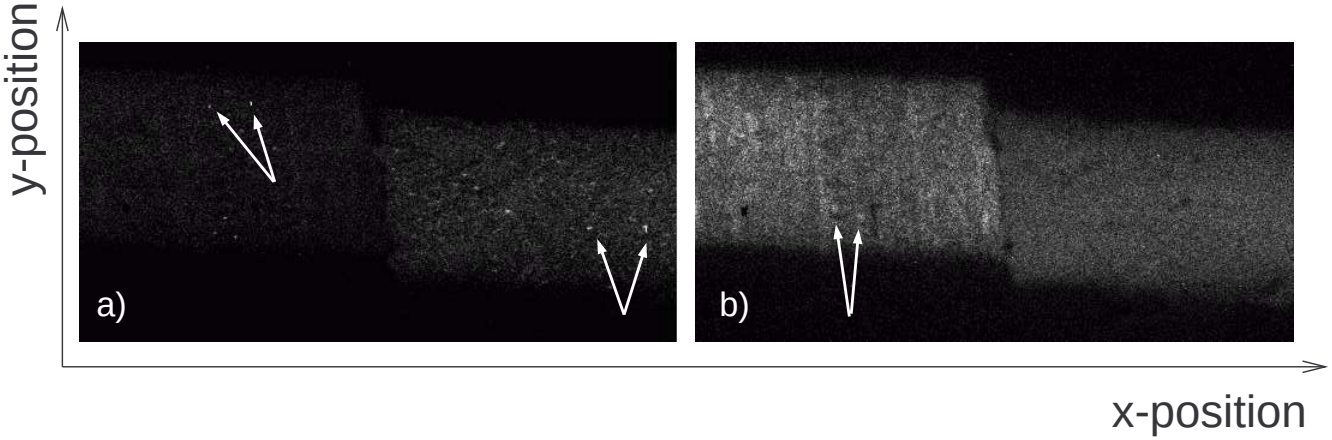
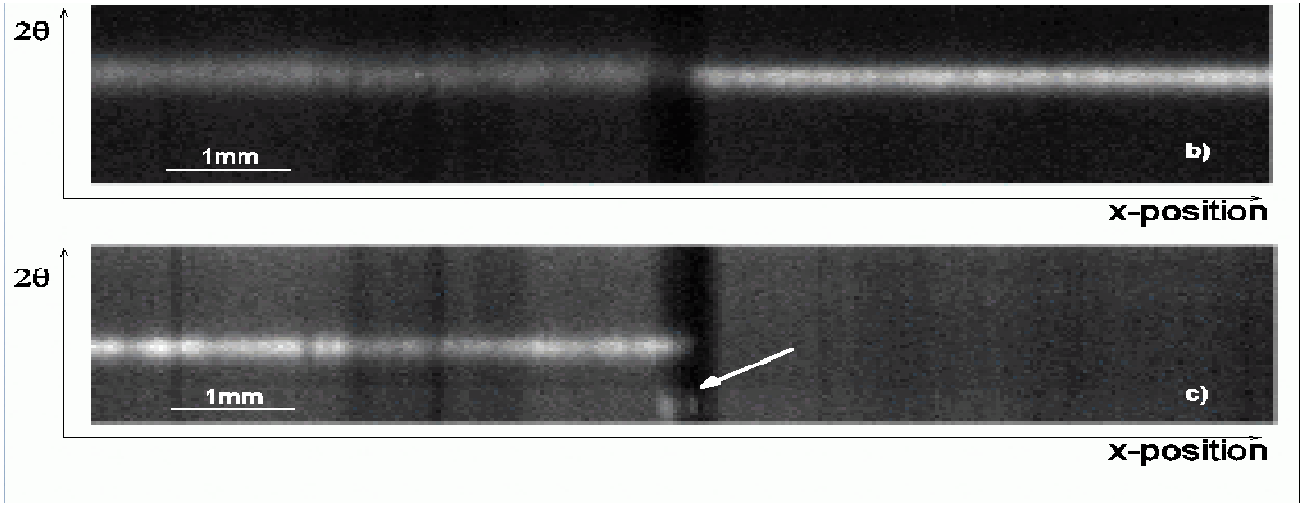
Imaging X-ray Diffraction

- The same principle as X-ray diffraction, but position resolved
- Problem: Big, 3-dimensional dataset: Intensity (x,y,θ)

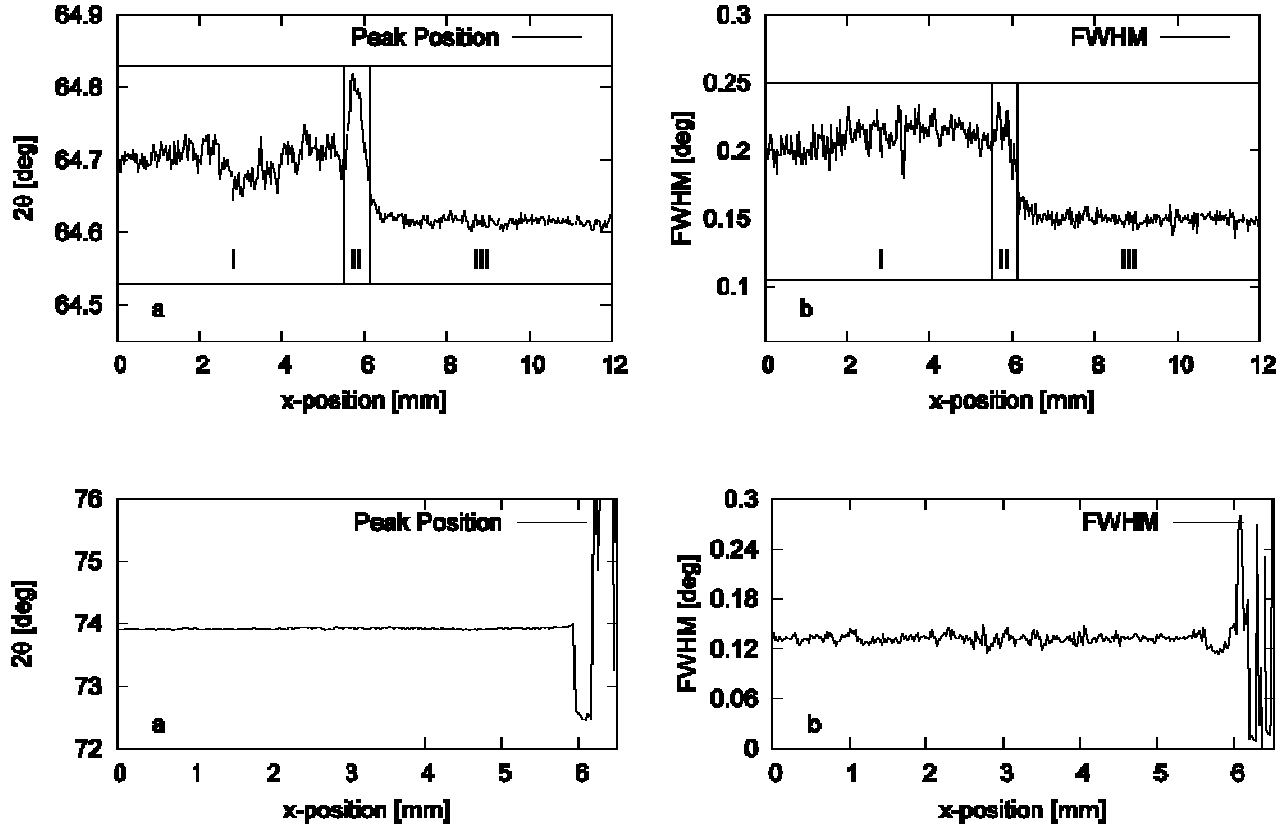


- Solution: Integration in ‘uninteresting’ y-direction

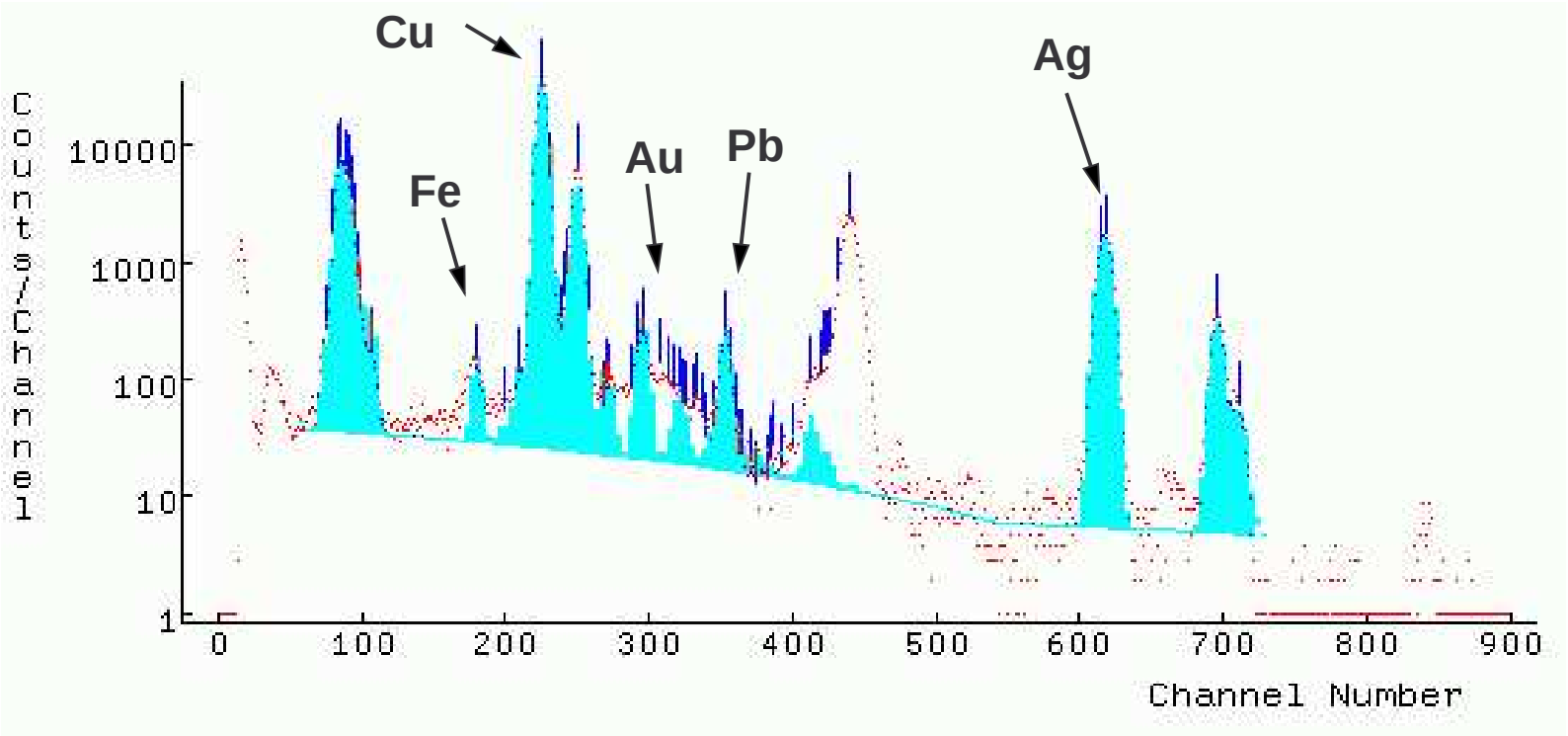


Imaging X-ray Diffraction (contd.)

- IXRD allows for quick determination of spatial distribution of crystallographic Phases



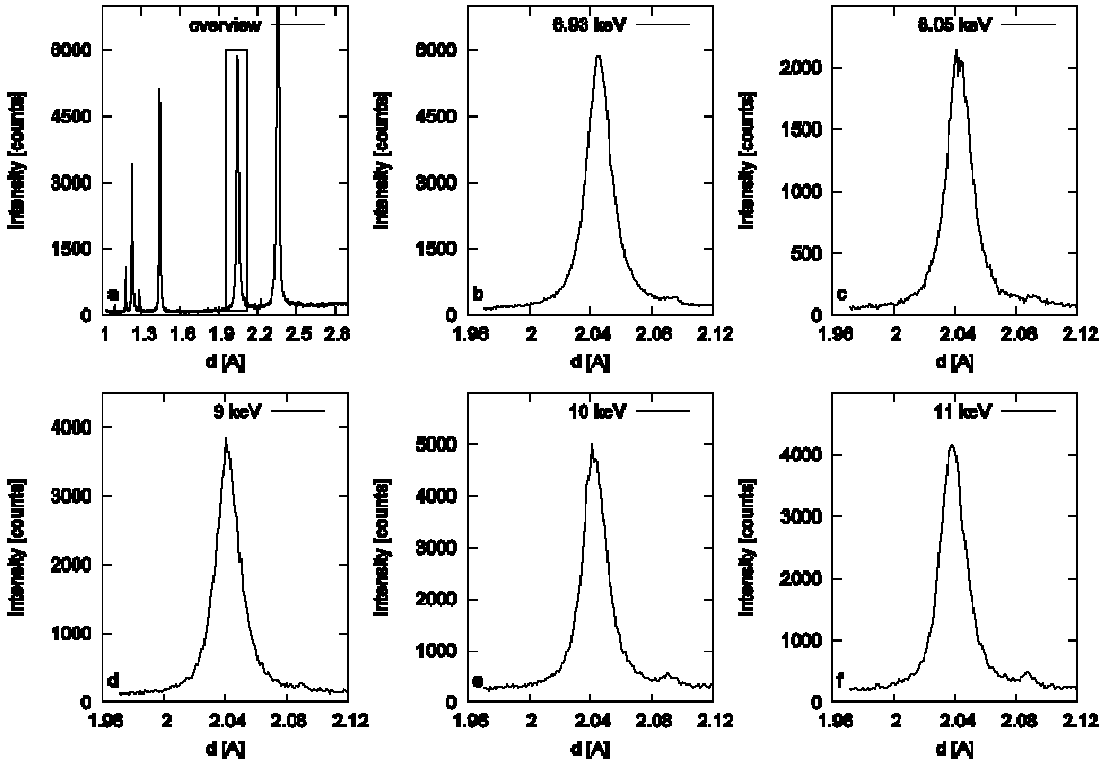
X-ray Fluorescence Analysis



- XRF allows to detect small traces of elements
- Different concentrations of gold and iron proof that coin and hat were made from different alloys

Energy Variable X-ray Diffraction

- Varying the beam energy allows for different penetration depths
- With deeper penetration depths, the copper peaks grow in intensity
- Thickness of Silver layer can be computed



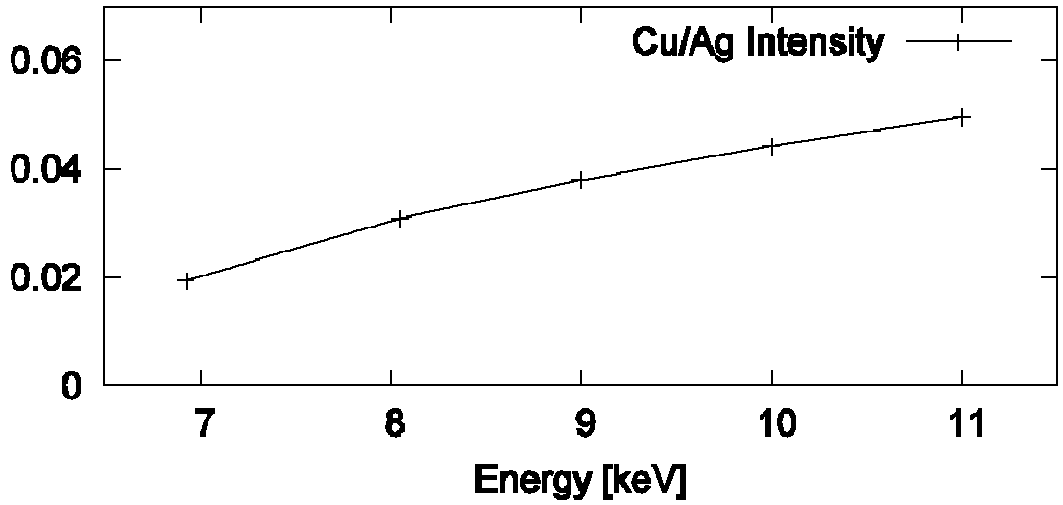
Beam attenuation

$$I = I_o \cdot e^{-\frac{\mu}{\rho}\rho \cdot l}$$

Layer thickness

$$t = \frac{\ln\left(\frac{I_i}{I_j}\right) \cdot \cos(\theta)}{2\rho \cdot \left(\mu_j - \mu_i\right)}$$

Energy Variable X-ray Diffraction



Computed Layer thickness: 1.86 microns +- 90 nm

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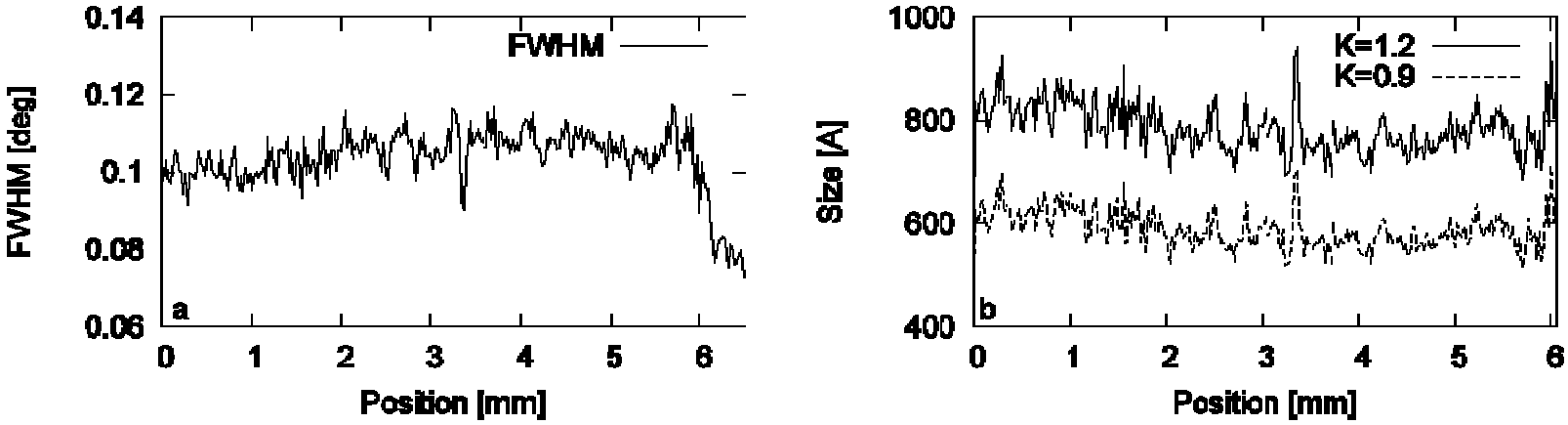
Computation of Crystallite Thickness

- Crystallite Thickness can be computed position-resolved from FWHM of IXRD-results via Scherrer-equation

$$\tau = \frac{K\lambda}{\left(B_{FWHM} - B_{instrumental}\right)\cdot\cos\left(\theta\right)}$$



Crystallites are smaller than layer thickness ->
No contradiction

Conclusion

- Synchrotron Radiation methods offer a wide range of techniques for material research

- Spatial Composition of the coin could be derived
- Alloy composition can be investigated in detail

- The presented methods are non-destructive
- The instrumentation is suited for large samples

Good features for archaeological research

Questions and Comments