Influence parameters in CT scanning

Pavel Müller

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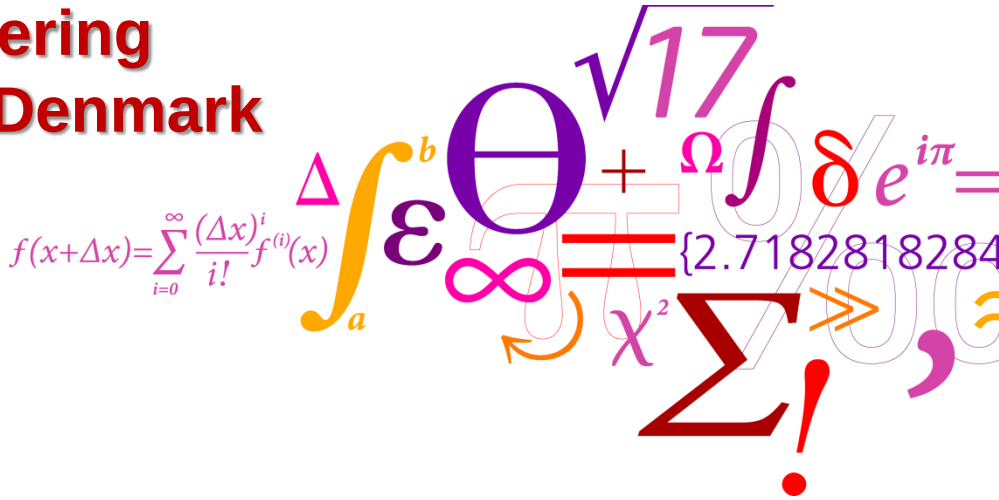
31st May 2011



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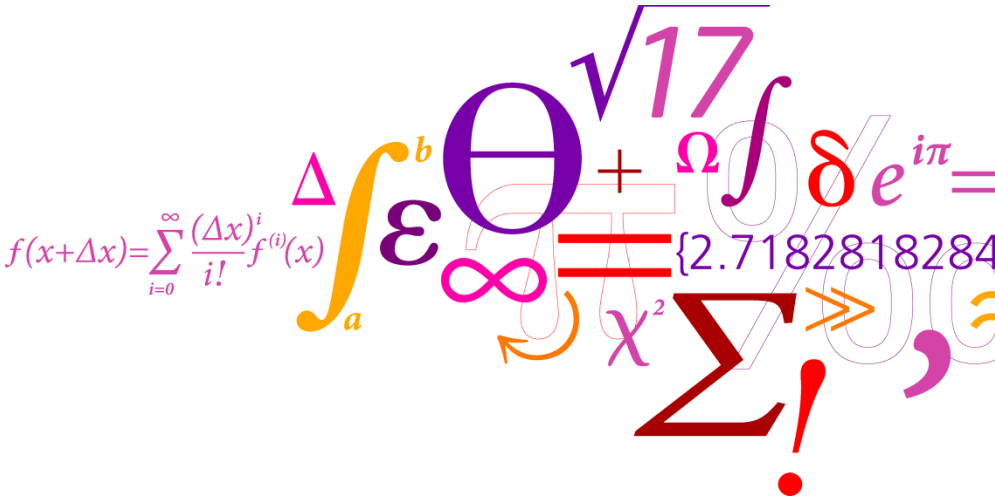
Outline

- Advantages, disadvantages and solutions
- Influence parameters in CT scanning
  - X-ray source
  - Rotary table
  - Threshold determination
  - Material composition
  - Magnification
- Conclusion



Advantages and disadvantages of CT

ADVANTAGES

- Non-destructive
- Short scanning time
- Volume data of high density
- Determination of inner and outer geometry

Disadvantages

- No accepted test procedures available so far
- Complex and numerous influence quantities affecting measurements
- Reduced measurement capability due to measurement errors (artefacts)
- Problem encountered when scanning multiple materials within one product
- Measurement uncertainty in many cases unknown (results are not traceable)

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- No accepted test
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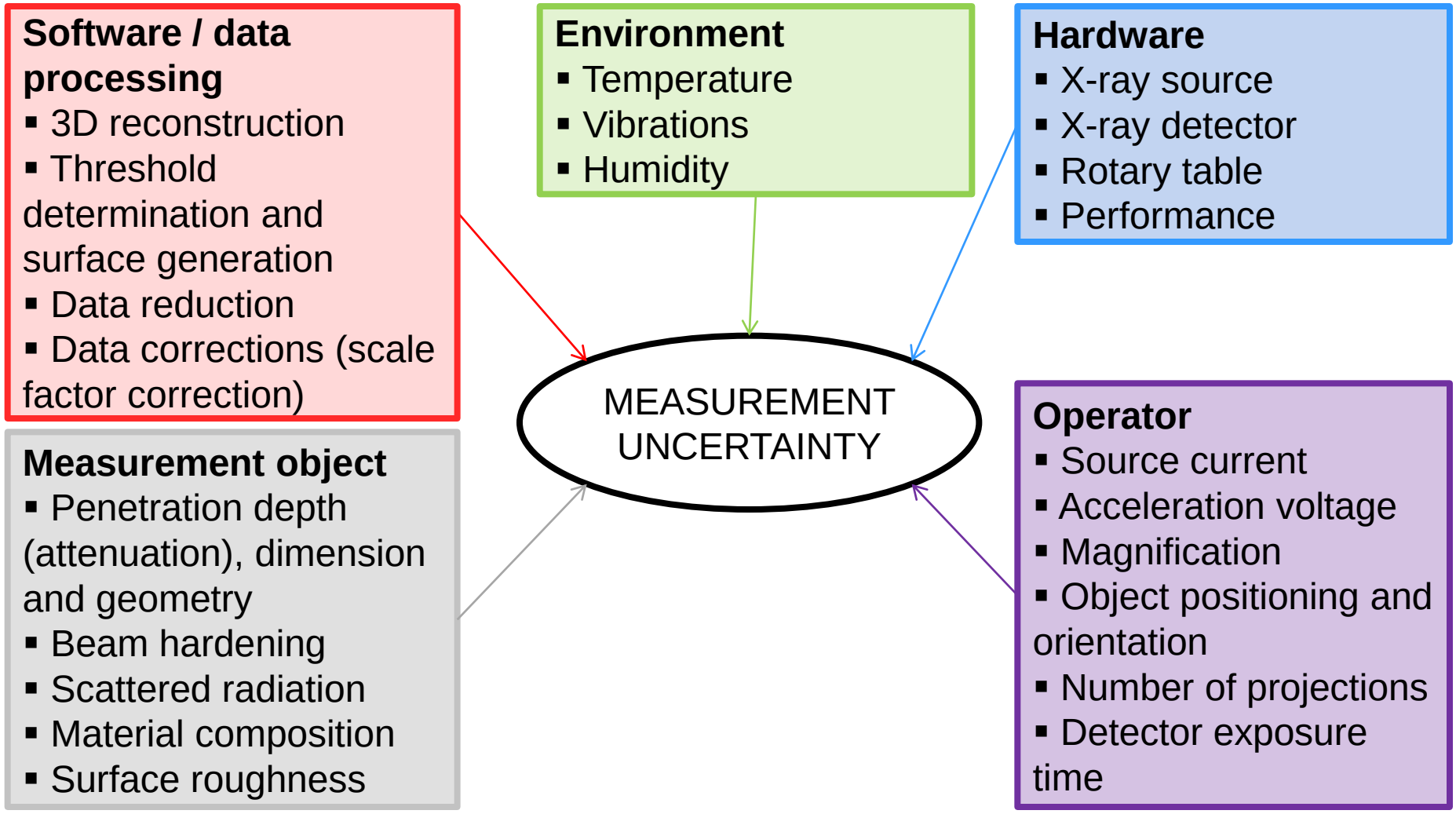
SOLUTIONS

- Apply calibrated standards to correct measurement errors and achieve traceability
- Evaluate task specific measuring uncertainty
- Adopt experience from coordinate metrology to CT
- Perform tests to understand the influence of error sources

Influence parameters in CT scanning



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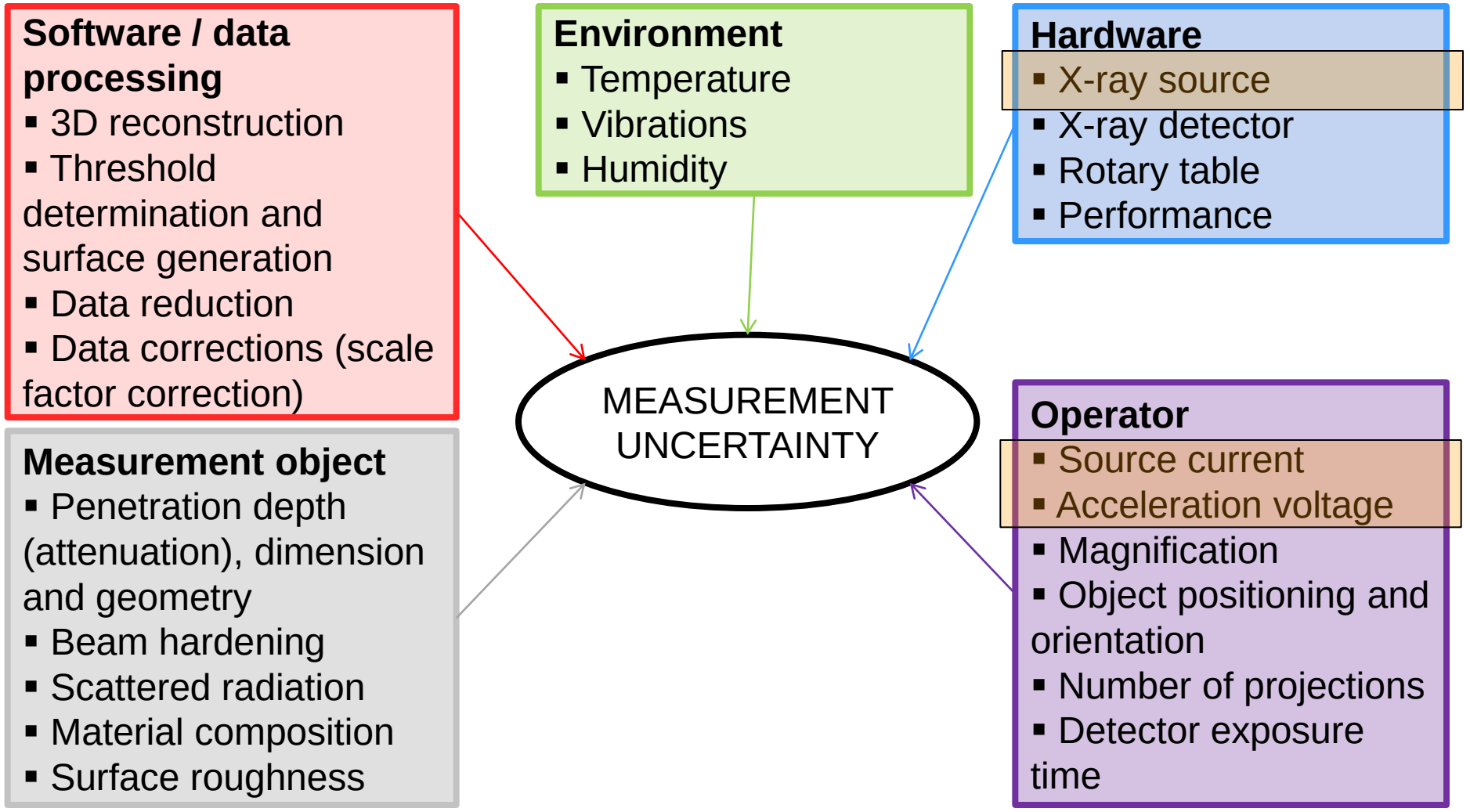
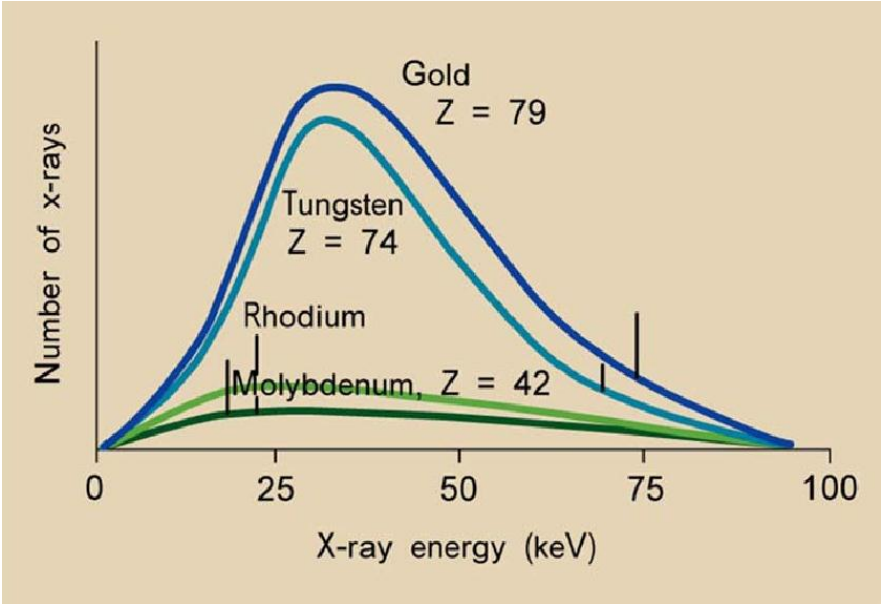


HARDWARE: X-ray source

X-ray source target material

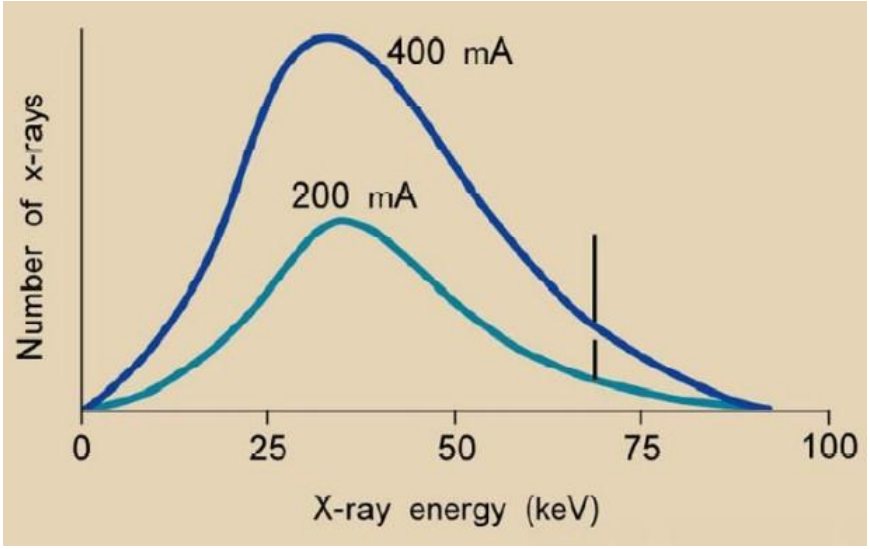
- Target characterized by material of different atomic number (Z)
- Z → X-ray spectrum → X-ray penetrative ability
- X-rays with higher energy penetrate more effectively
- High Z → reaching higher penetration (spectrum shifted towards high energy levels)

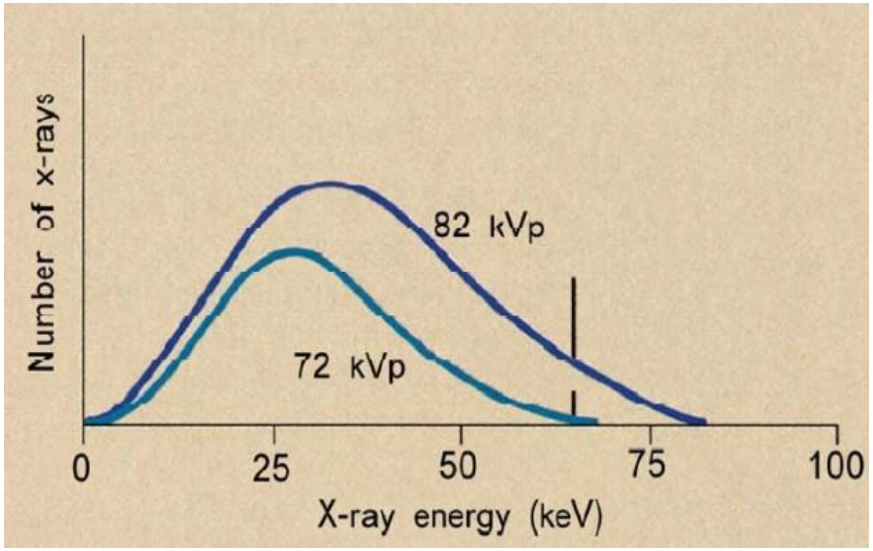


HARDWARE & OPERATOR: X-ray source

Source power (source current & acceleration voltage)

- **Current** → influence X-ray intensity (quantity or amount of radiation energy)
- **Voltage** → influence X-ray intensity (amount of X-rays) and energy distribution (quality=penetration power)
- Proper setup for current and voltage is needed → different for various materials, densities, geometries, sizes.

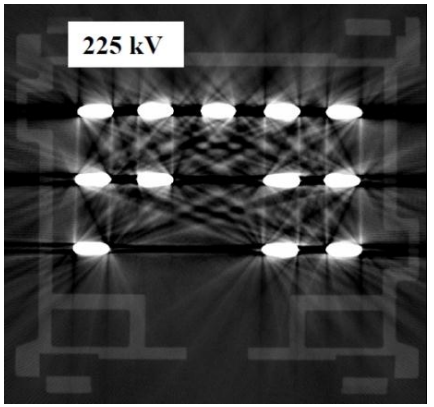


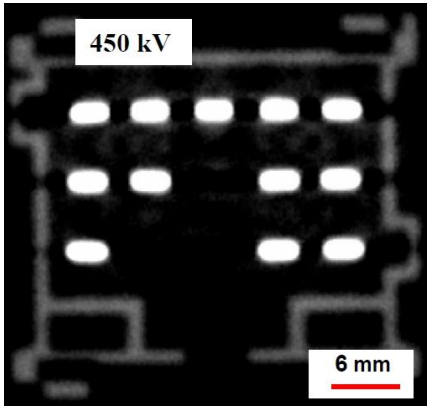


HARDWARE: X-ray source

225kV micro focus and 450kV macro focus within one CT system

- Tube voltage: 200kV and 300kV
- Specimen: Commercial plug
- Materials: Metallic pins, Polymeric housing





Results

- 450kV source → bigger parts to obtain overall image
- 225kV source → high resolution (level of detail) image due to small spot size (5-200µm)
- 450kV source → less artefacts, low resolution (spot size of 2.2mm)
- 225kV source → more artefacts around pins due to two materials with different att. coeff.

Kastner, J. et. al., 2006, *Advanced Applications of Computed Tomography by Combination of Different Methods*, *In: Proceedings of 9th European Congress on Non-Destructive Testing (ECNDT 2006)*.

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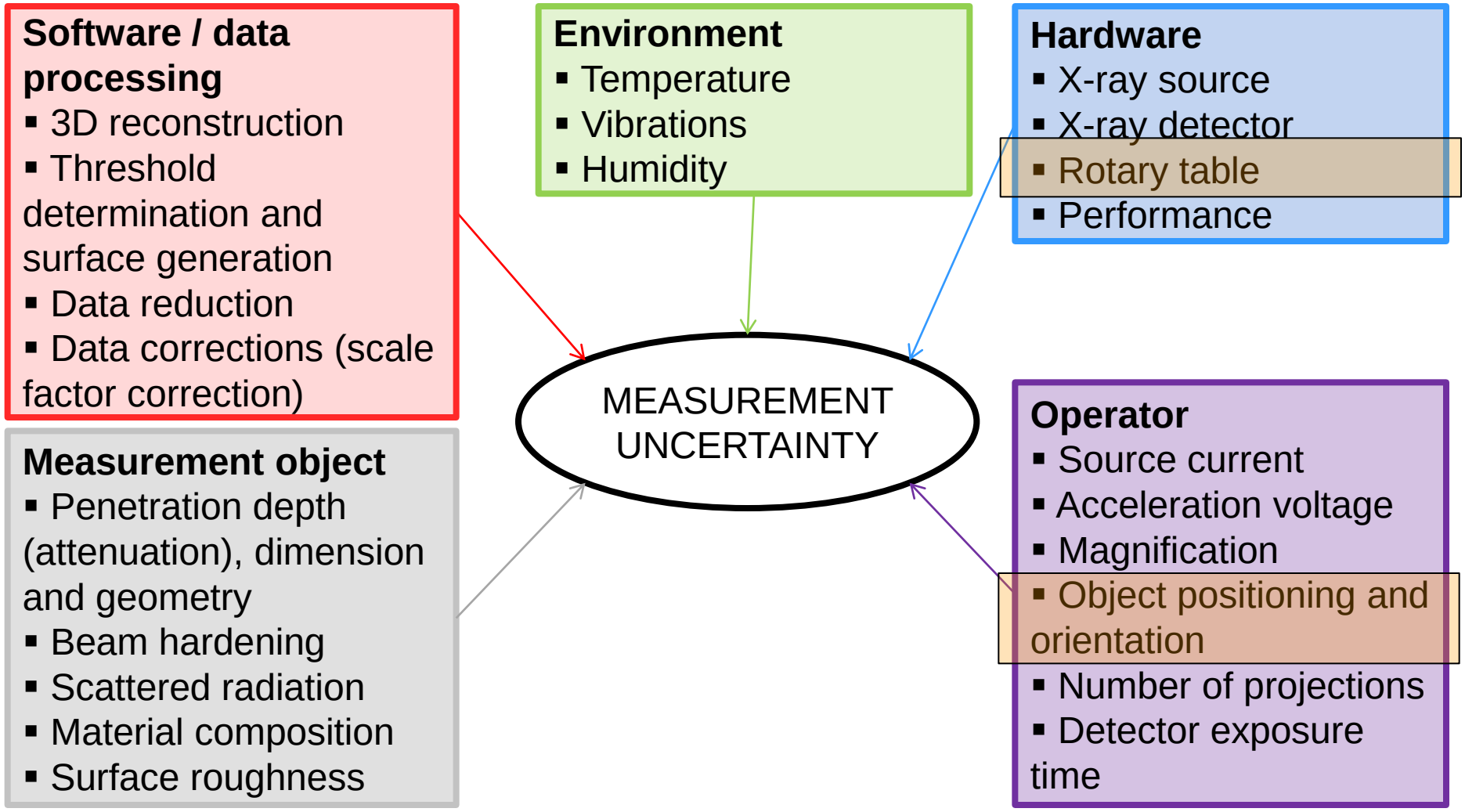
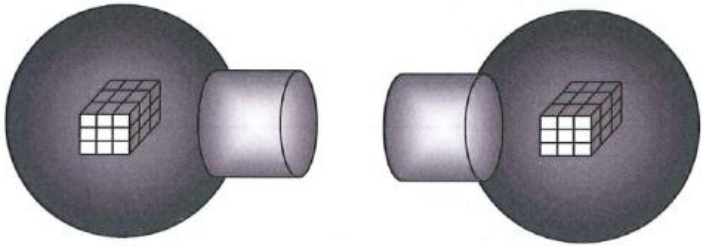


HARDWARE & OPERATOR: Rotary table & Positioning and orientation

- Effect of object position and orientation in the scan volume
- Measured/simulated distance between two spheres (3x3x3 voxel)
- Different positions and orientations
- Different ball bar sizes
- Condition: Object in the cone beam



Kumar, J. et. al., 2011, *Analysis of the effect of cone-beam geometry and test object configuration on the measurement accuracy of a computed tomography scanner used for dimensional measurement*, Measurement Science and Technology **22**, 15 pp., doi: 10.1088/0957-0233/22/3/035105

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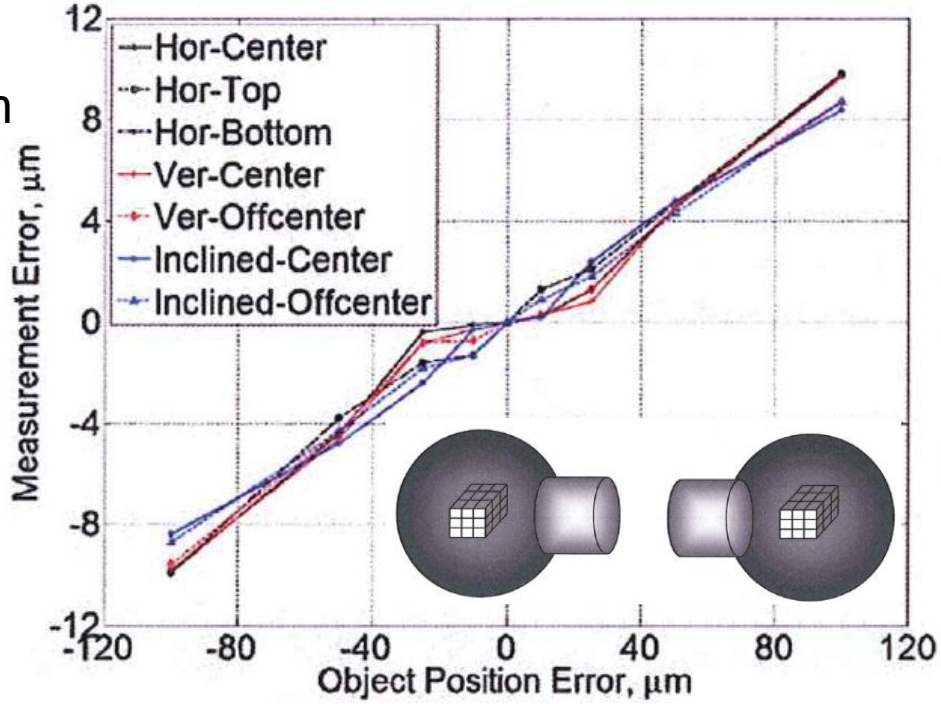

Results

- *Hypothesis*: No errors in the system → Object position and orientation do not have any signification effect on the measurement accuracy
- Errors in the system → Similar meas. errors at all object configur.

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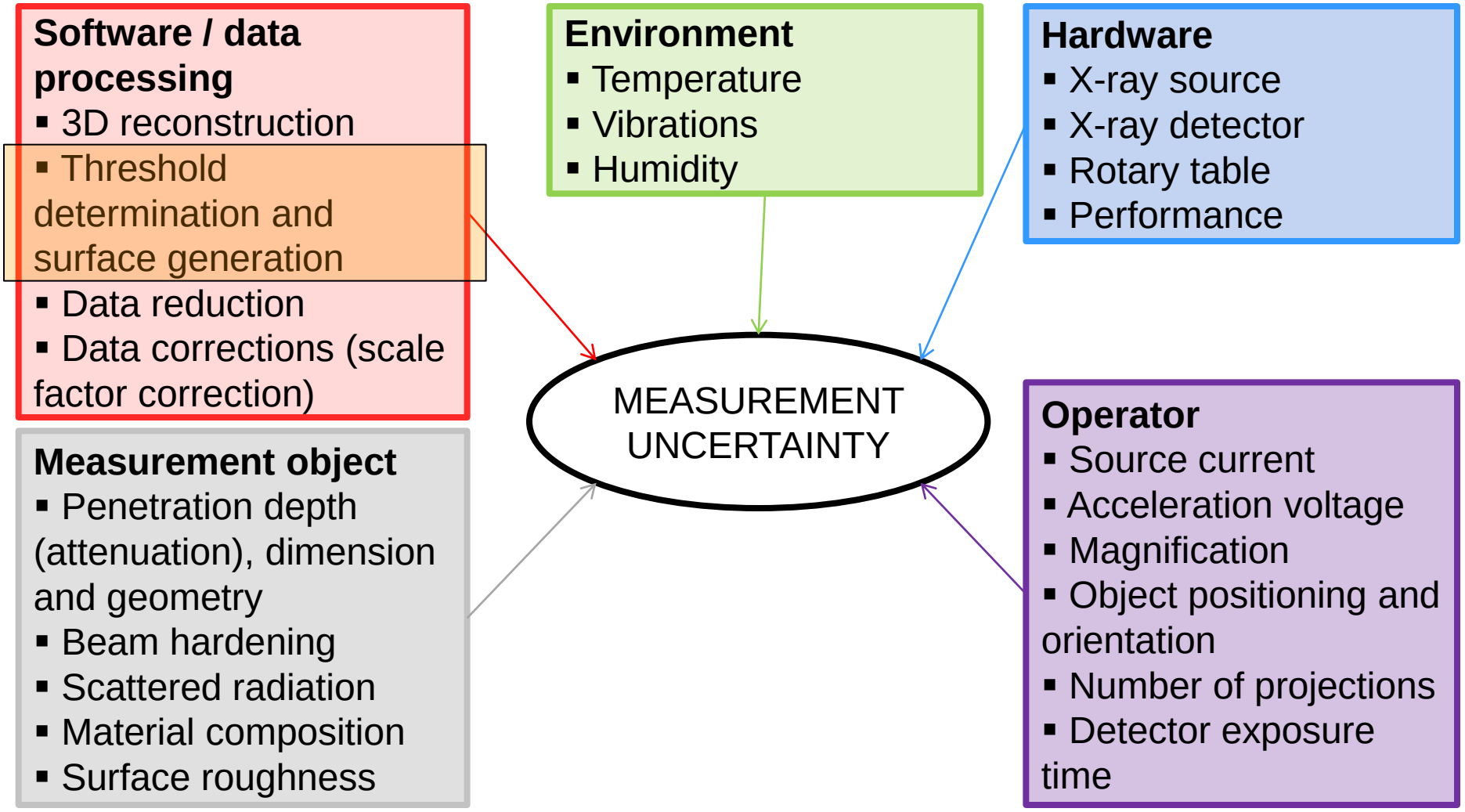
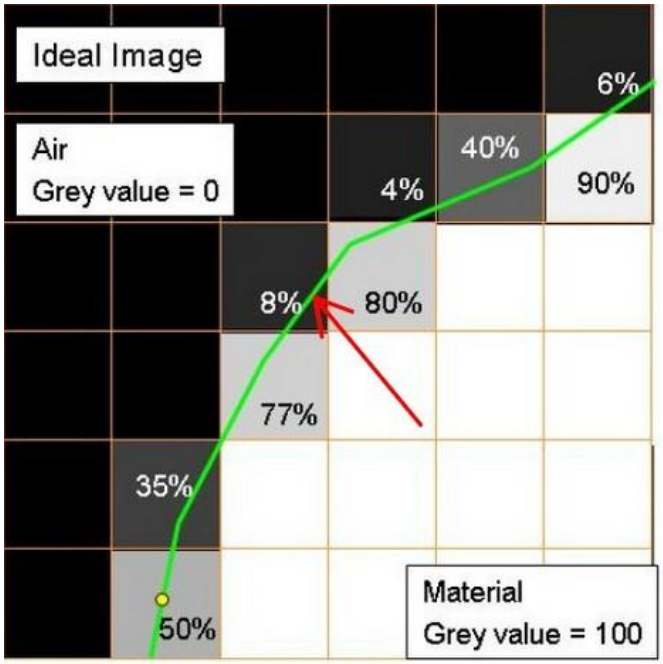
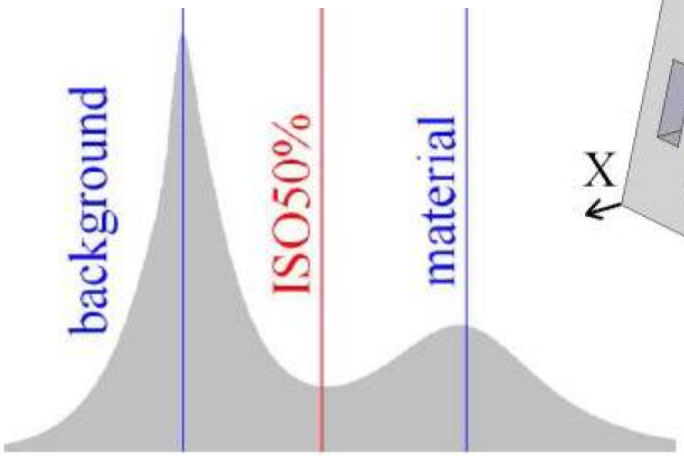
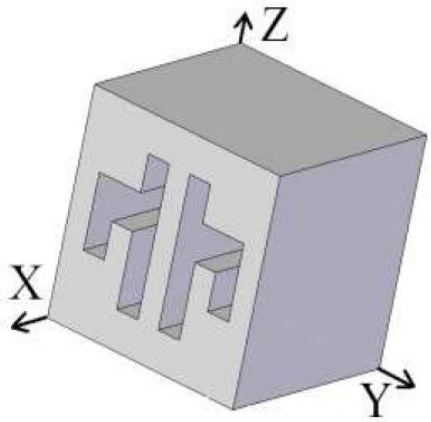


SOFTWARE: Threshold determination

- Threshold value is a parameter for accurate image segmentation and surface data determination by indentifying edges inside the voxel
- Threshold value can be determined by measuring reference objects (e.g. cactus step-gauge)
- Widely used ISO-50 (AVG between gray values for air and material)







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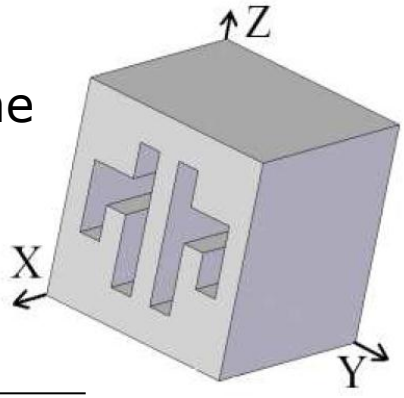
Results

- Measurements performed on the planes between flat surfaces of cactus
- Using ISO-50 → edge often shifted with respect to the real material edge
- Al casting → threshold too small (~40%, i.e. closer to the air gray values)
- Steel & ZrO_2 → threshold too large (~85%, i.e. closer to the material gray values)



Kiekens, K. et. al., 2010, *A test object for calibration and accuracy assessment in X-ray CT metrology*, 10th International Symposium on Measurement and Quality Control, pp. 5-9

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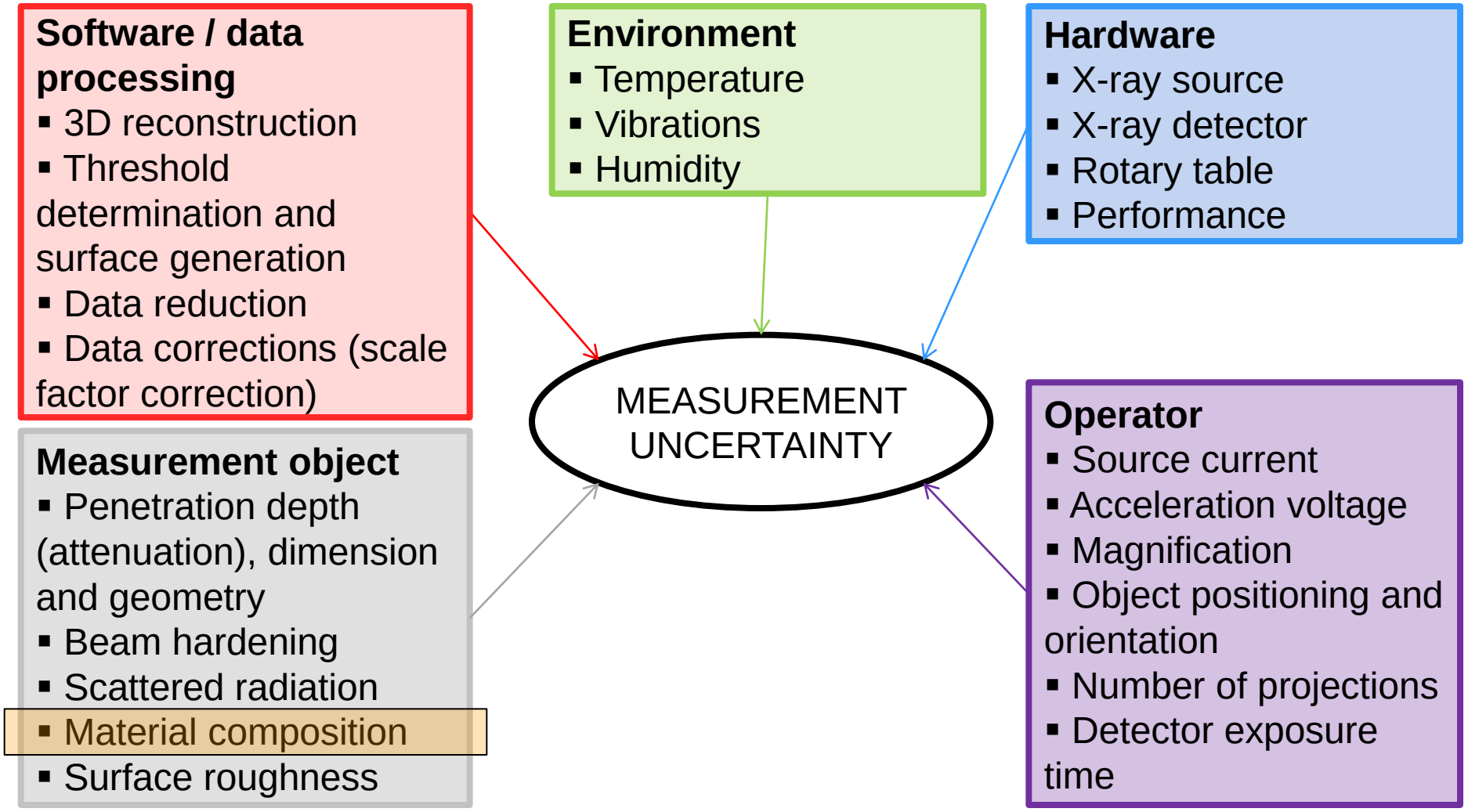
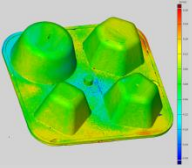
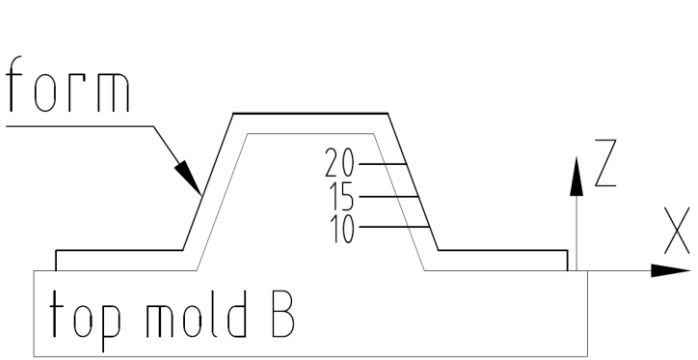
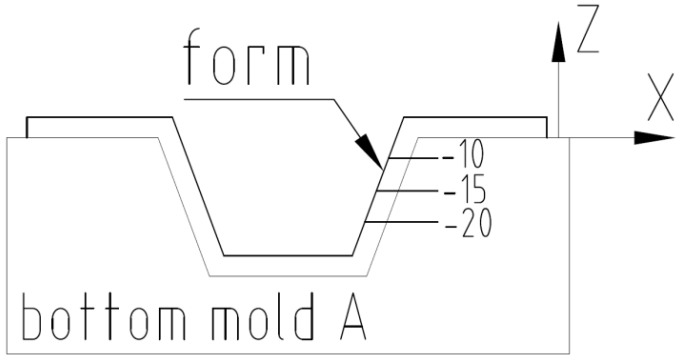




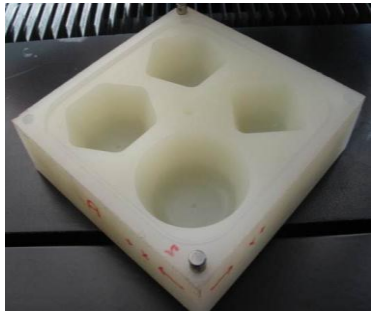
MEASUREMENT OBJECT: Material composition

- Geometrical measurements on silicone rubber
- Measurand: Cone diameter at 3 given heights
- Calculation of measuring uncertainty using GUM



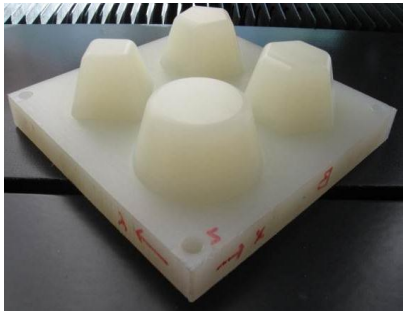


Polyamide

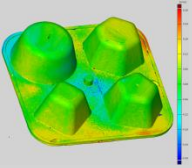


Silicone rubber

Polyamide

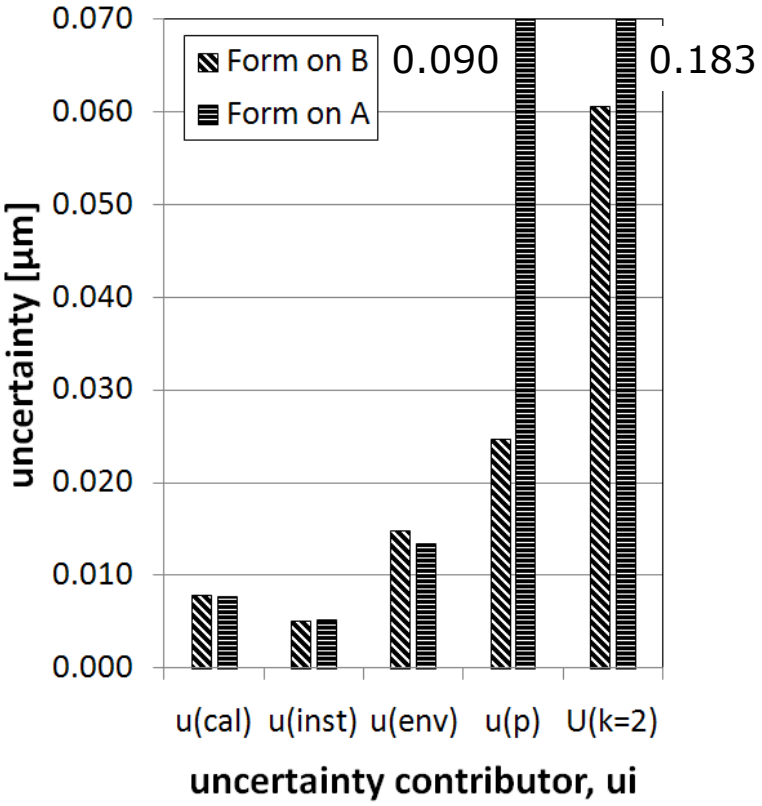


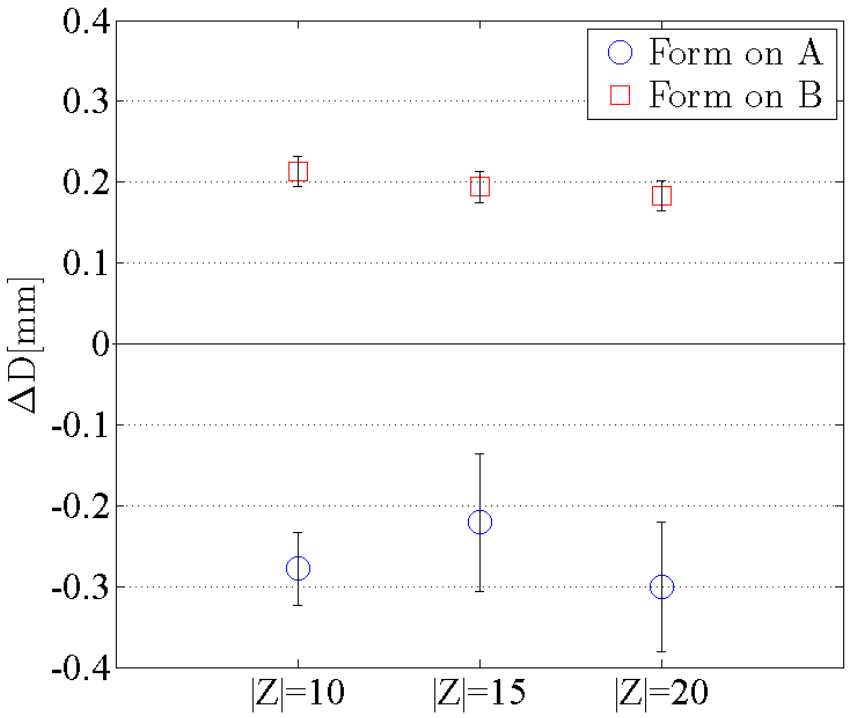
Müller, P. et. al., 2011, *Geometrical metrology on silicone rubber by computed tomography*, In: Proceedings of the 11th euspen International Conference, Como, Italy, pp. 243-246



MEASUREMENT OBJECT: Material composition

$$U_{CT} = k \cdot \sqrt{u_{cal}^2 + u_{inst}^2 + u_p^2 + u_{env}^2}$$





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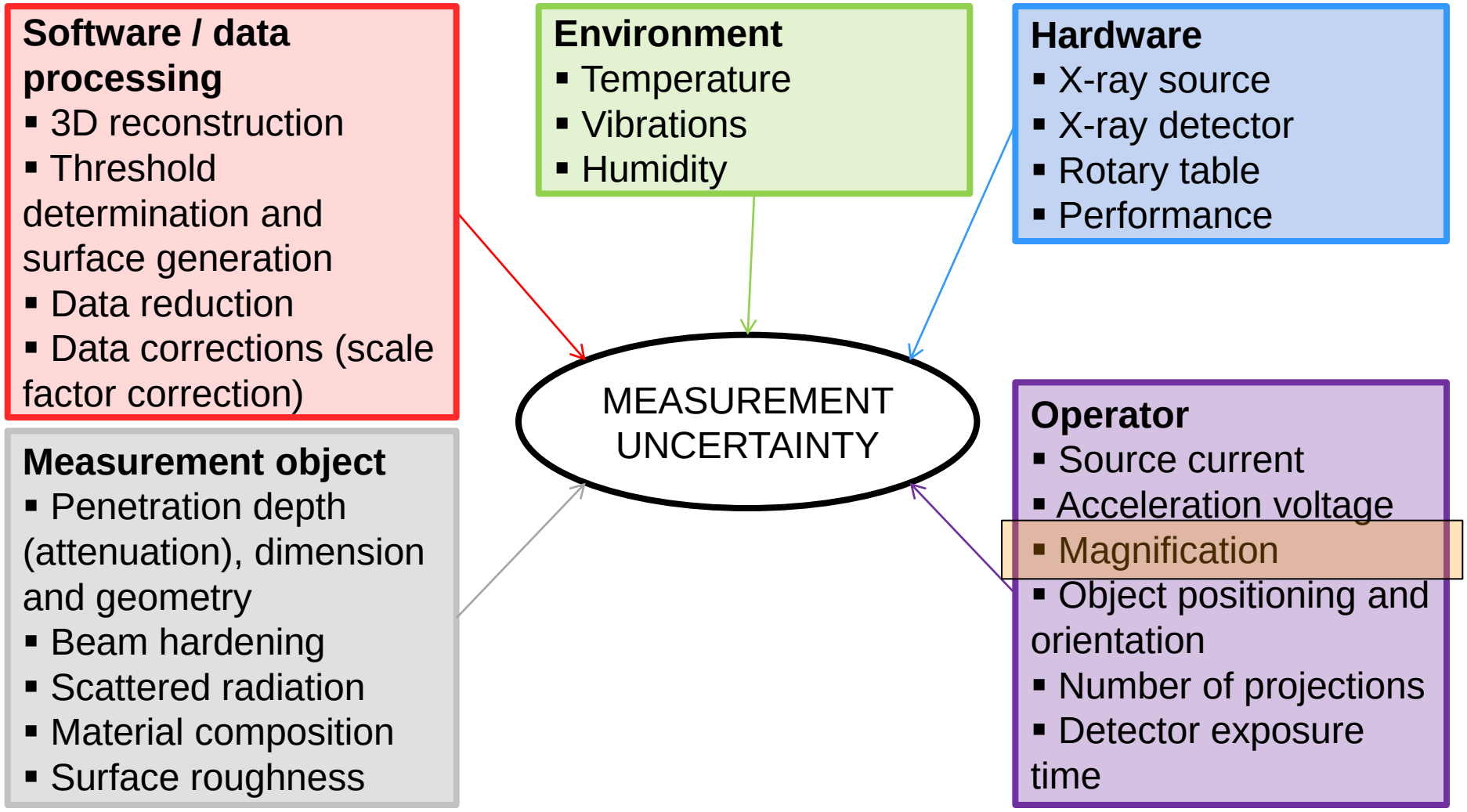
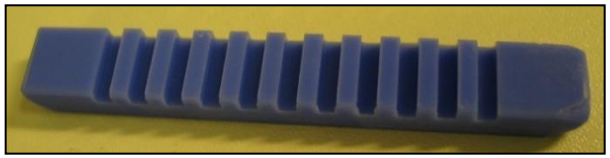
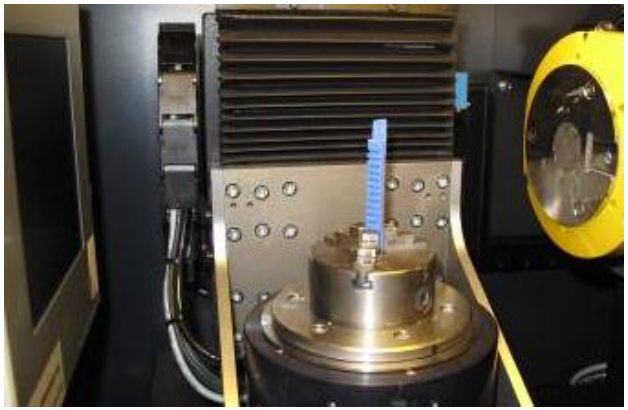


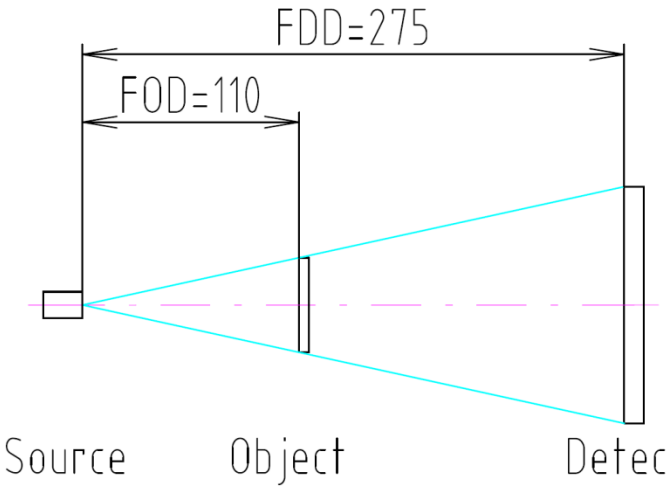
OPERATOR: Magnification

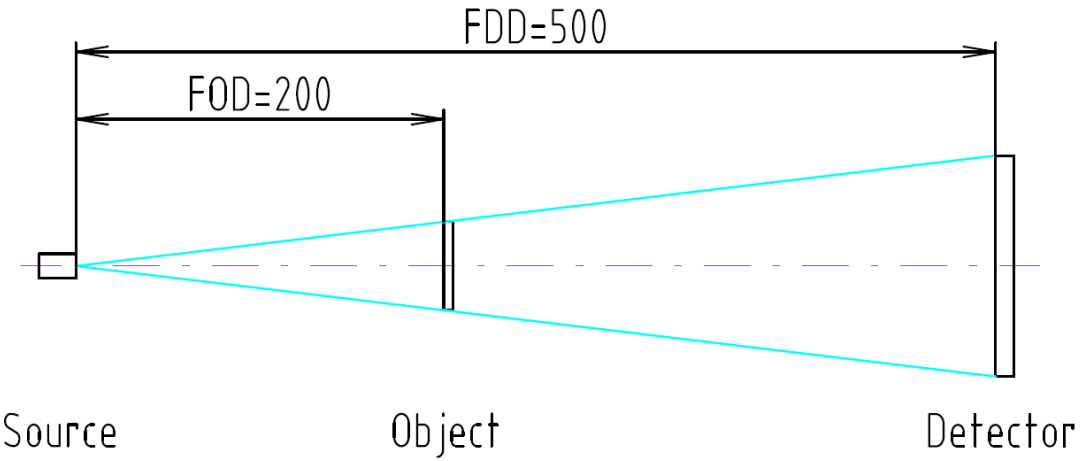


- 42mm replica step gauge
- Evaluation of *E* according to VDI/VDE 2617-6.2
- 4 incremental dist. measured unidirectionally
- E=Lm-Lc+PS±PF

Parameter	Setup 1	Setup 2	Setup 3
Magnif. [x]	2.5	2.5	1.667
FDD [mm]	275	500	500
VS [µm]	20	20	30







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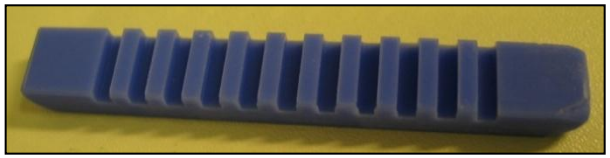

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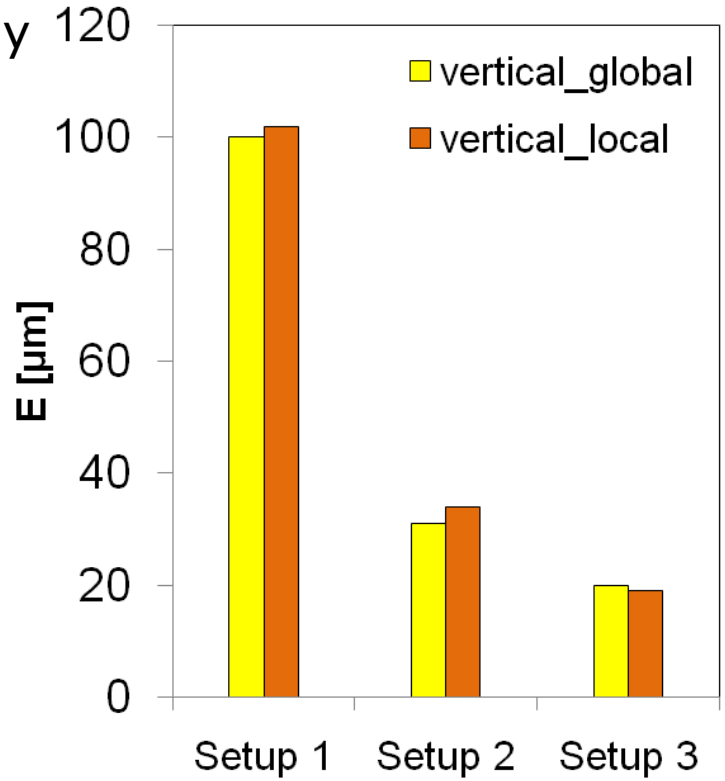

Results

- Higher magnification doesn't assure best accuracy → noise at the borders
  → blurring

Cantatore, A. et. al., 2011, *Verification of a CT scanner using a miniature step gauge*, In: Proceedings of the 11th euspen International Conference, Como, Italy, pp. 46-49

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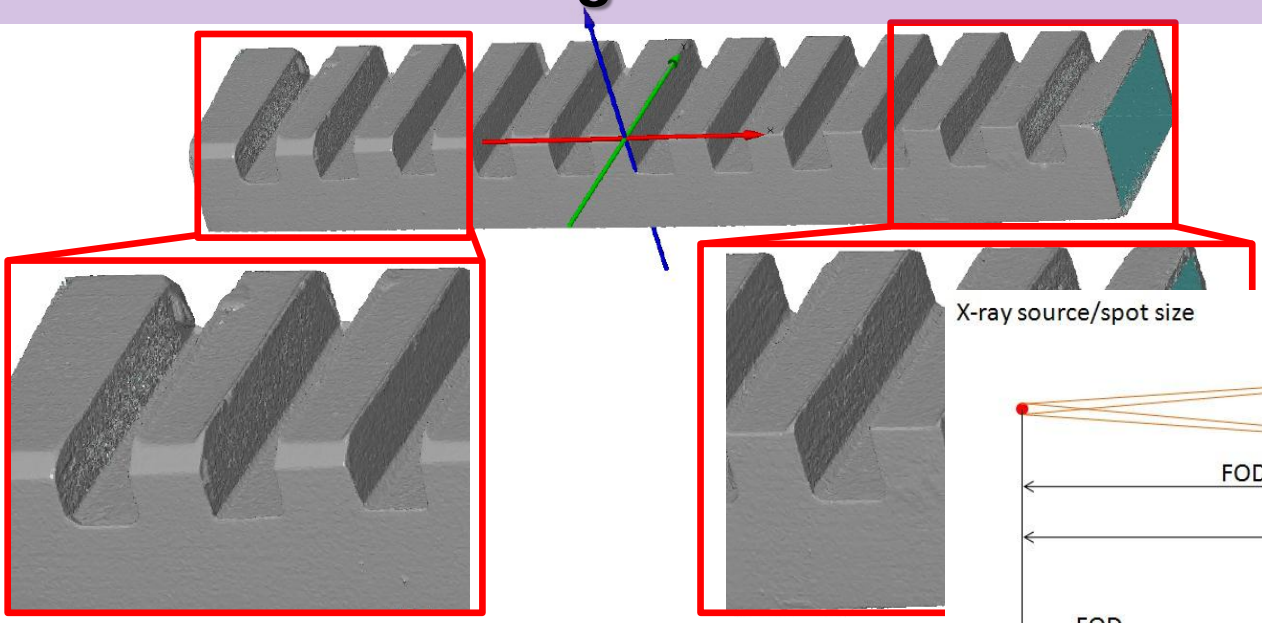
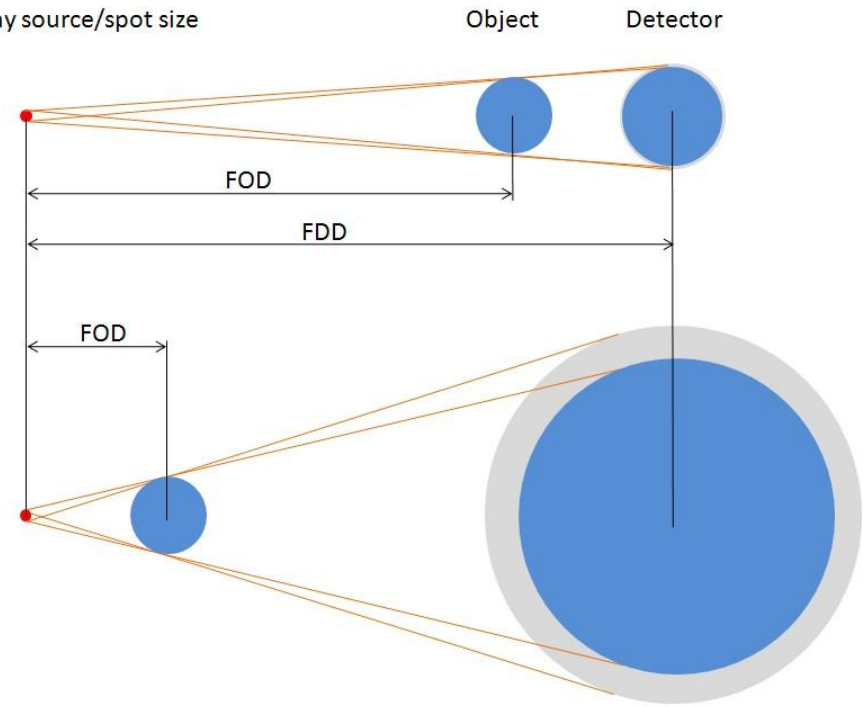


Noise at the borders

Blurring



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Conclusions

- CT scanning is a powerful tool for dimensional measurements.

- Numerous influence quantities influence the scanned data and these have to be further corrected to obtain reliable results.

- In order to fully understand the influence factors, tests should be performed to support knowledge on CT scanning.

Thank you for your attention

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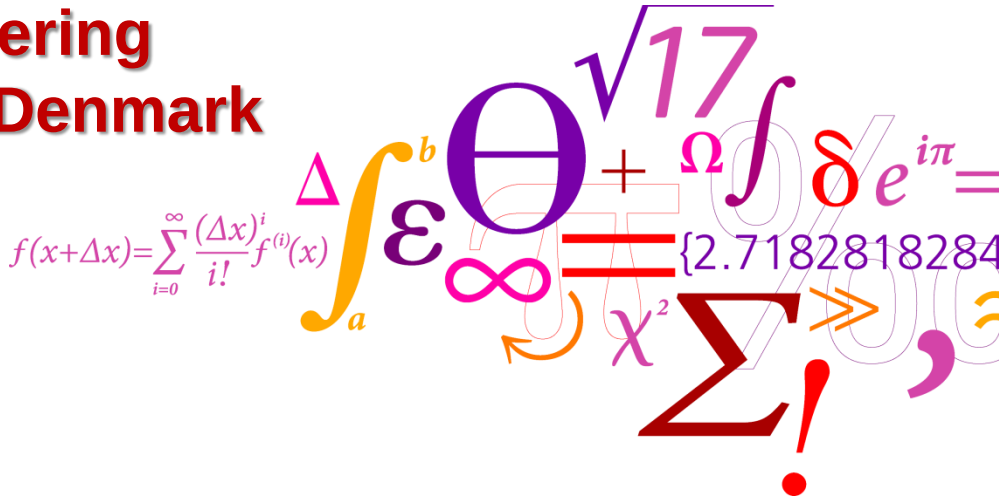

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