Empirical Dual Energy Beam Hardening Correction (EDEBHC) in Dual Energy Computed Tomography (DECT)

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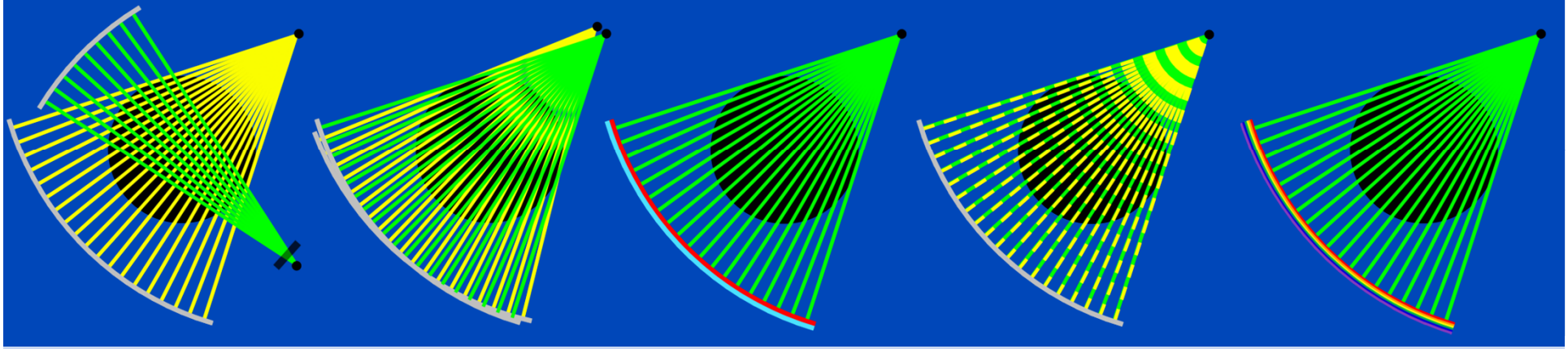
sirona. The Dental Company

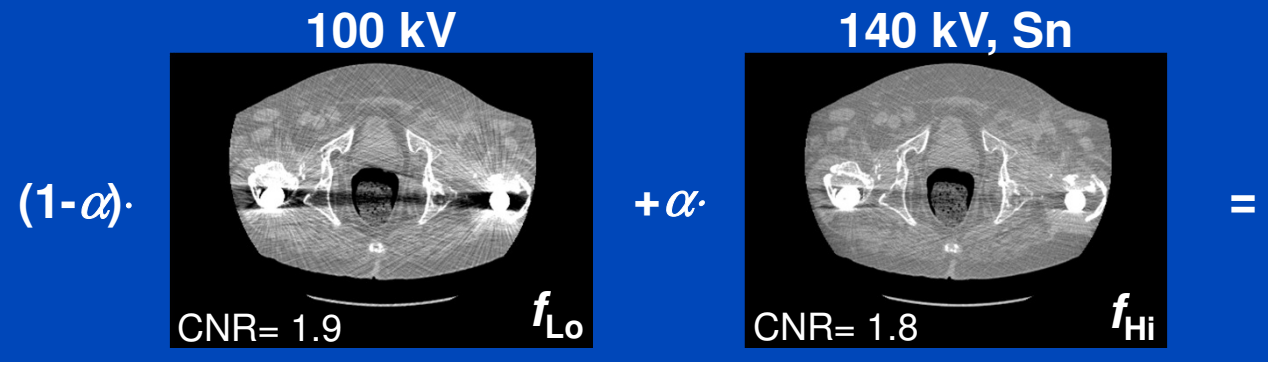
dkfz. DEUTSCHES KREBSFORSCHUNGSZENTRUM IN DER HELMHOLTZ-GEMEINSCHAFT

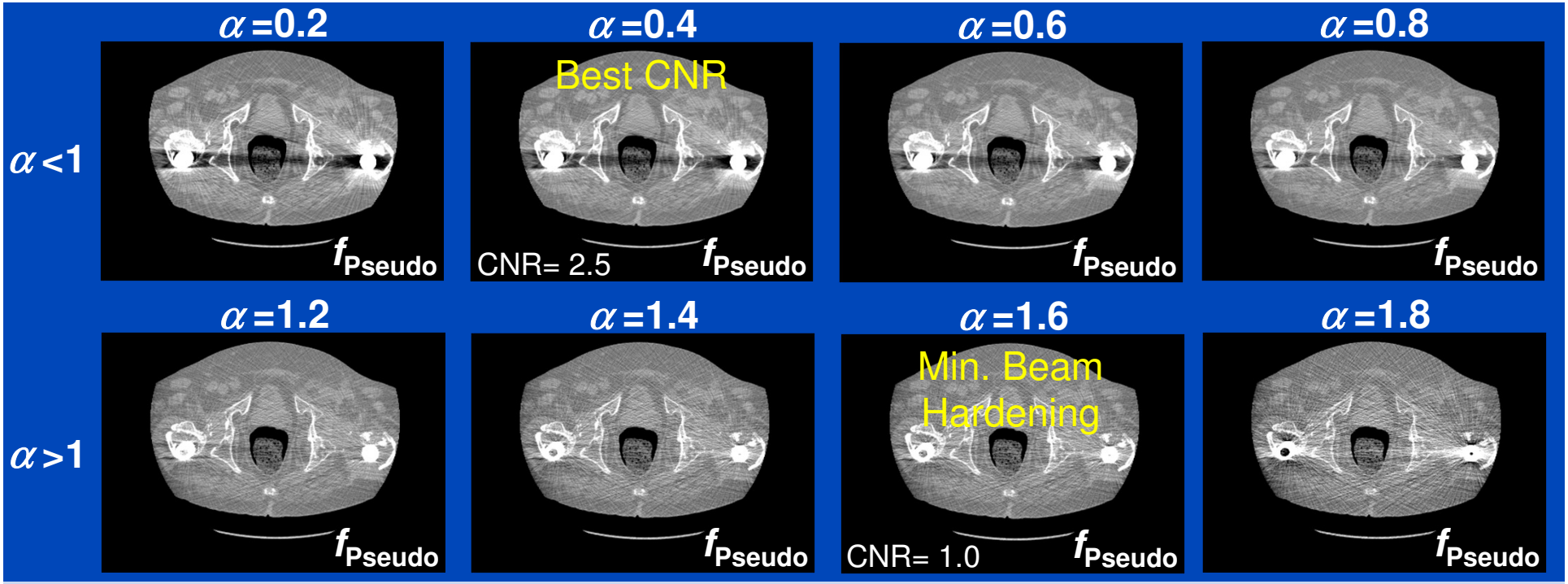
Energy-Resolved CT Technology

- **In the clinic:**
  - **Multiple scans at different spectra** — **mid-range**
  - **Dual source CT (DSCT), generations 2 and 3** — **high-end**
  - **Fast tube voltage switching** — **high-end**
  - **Dual layer sandwich detectors** — **high-end**
  - **Split filter** — **high-end**
- **First prototypes:**
  - **Photon counting detectors (two or more energy bins)** — **high-end**



From Pseudo Monochromatic Imaging to EDEBHC





C=0 HU; *W*=1000 HU

Material and Methods

Extension of Pseudo Monochromatic Imaging (α-Method)

- The simple α-weighting of two dual energy images is extended by higher order terms:

$$f_{\mathrm{EDEBHC}}(\alpha) \quad = \quad (1-\alpha) f_{10} + \alpha f_{01} + \sum_{ij} c_{ij}(\alpha) f_{ij}.$$

- α-value is selected by the physician.
- Basis images are generated using the DE-rawdata ($p_{\mathrm{Lo}}/p_{\mathrm{Hi}}$) by filtered backprojection:

$$\text{Basis images: } f_{ij} \quad = \quad X^{-1}\left(p^i_{\mathrm{Lo}} p^j_{\mathrm{Hi}}\right).$$

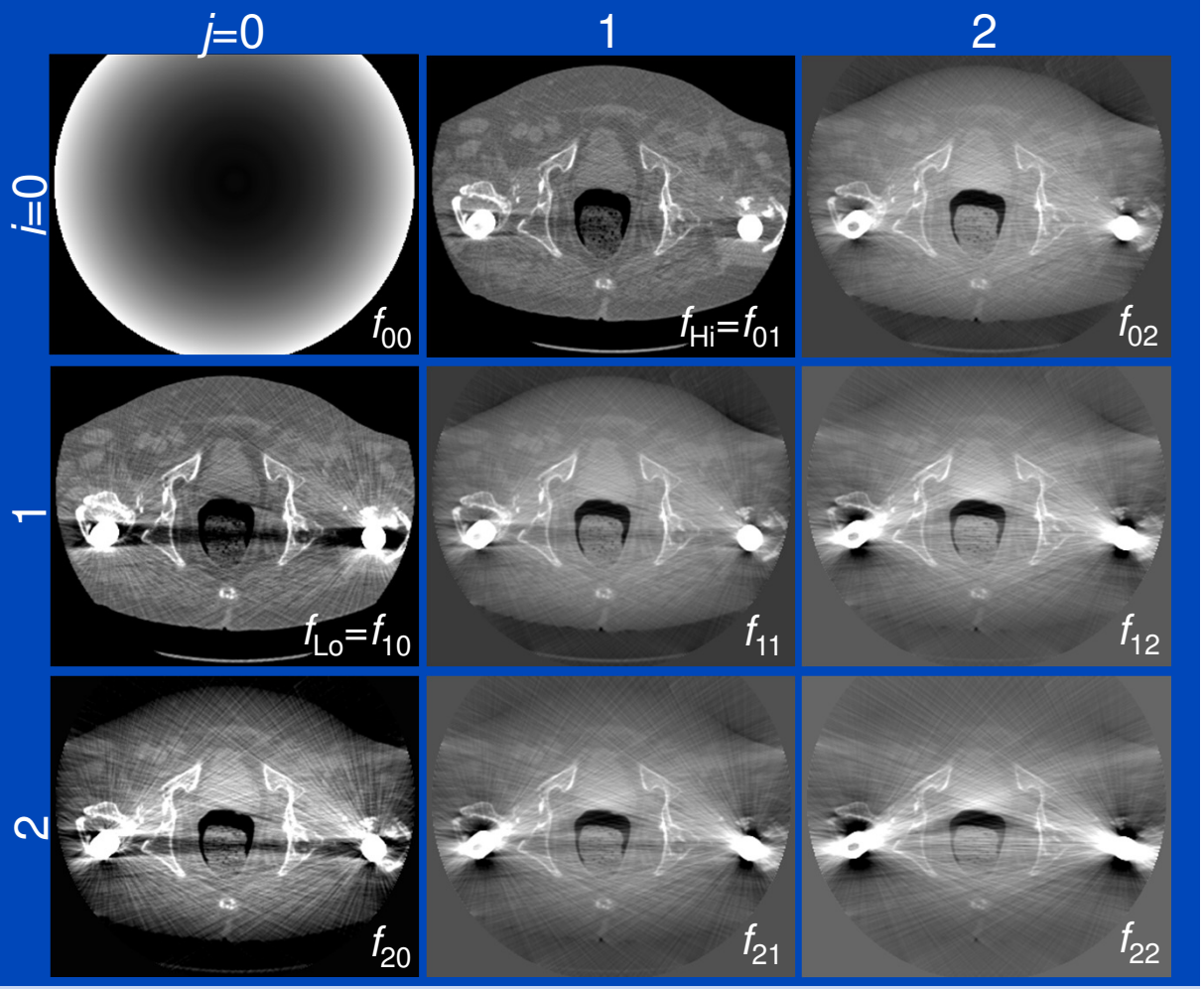
- The α-value is constant during optimization and serves as a pre-conditioner for a given contrast situation.

Material and Methods

Basis Images from Patient Measurement on a Siemens Definition Flash

$$\text{Basis images: } f_{ij} = X^{-1}\left(p^i_{\text{Lo}} p^j_{\text{Hi}}\right).$$

- **Beam hardening effects can be reproduced.**



C=0 HU; *W*=1000 HU

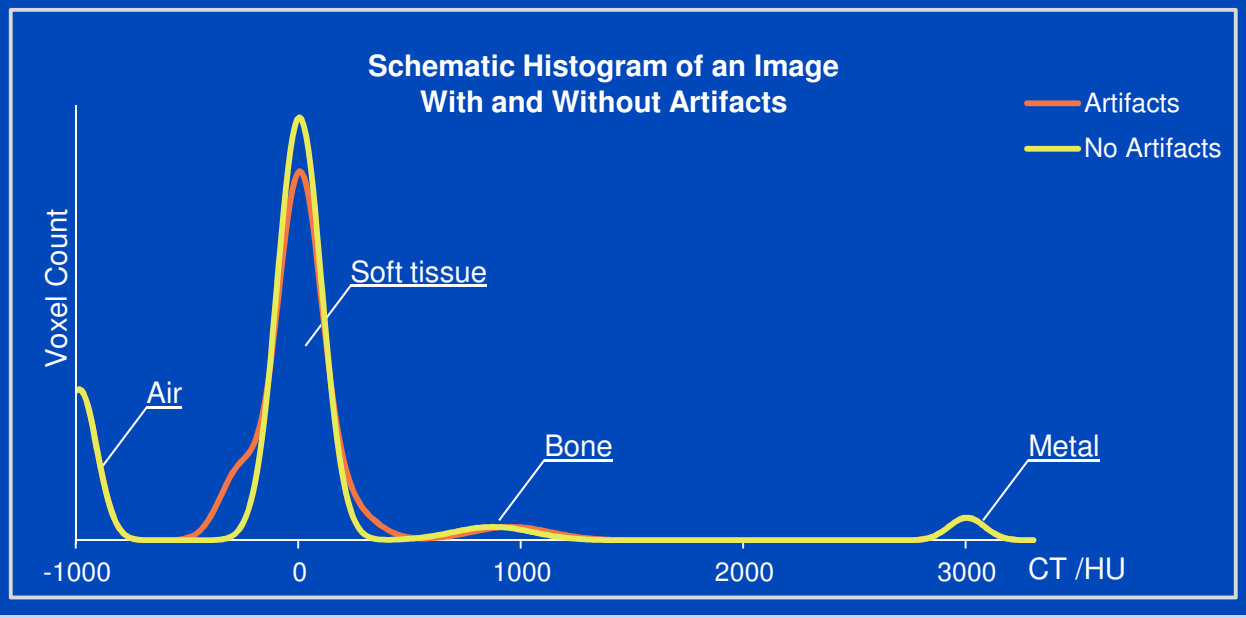
Material and Methods

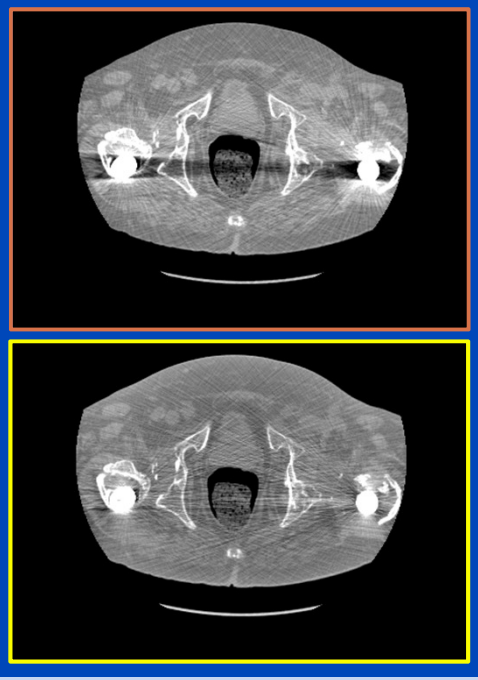
Cost Function

- **Entropy *H* of the image is used as cost function:**

$$\boldsymbol{c}(\alpha) = \underset{\boldsymbol{c}}{\operatorname{argmin}}\, H\left((1-\alpha)f_{10} + \alpha f_{01} + \sum c_{ij}(\alpha) f_{ij}\right).$$

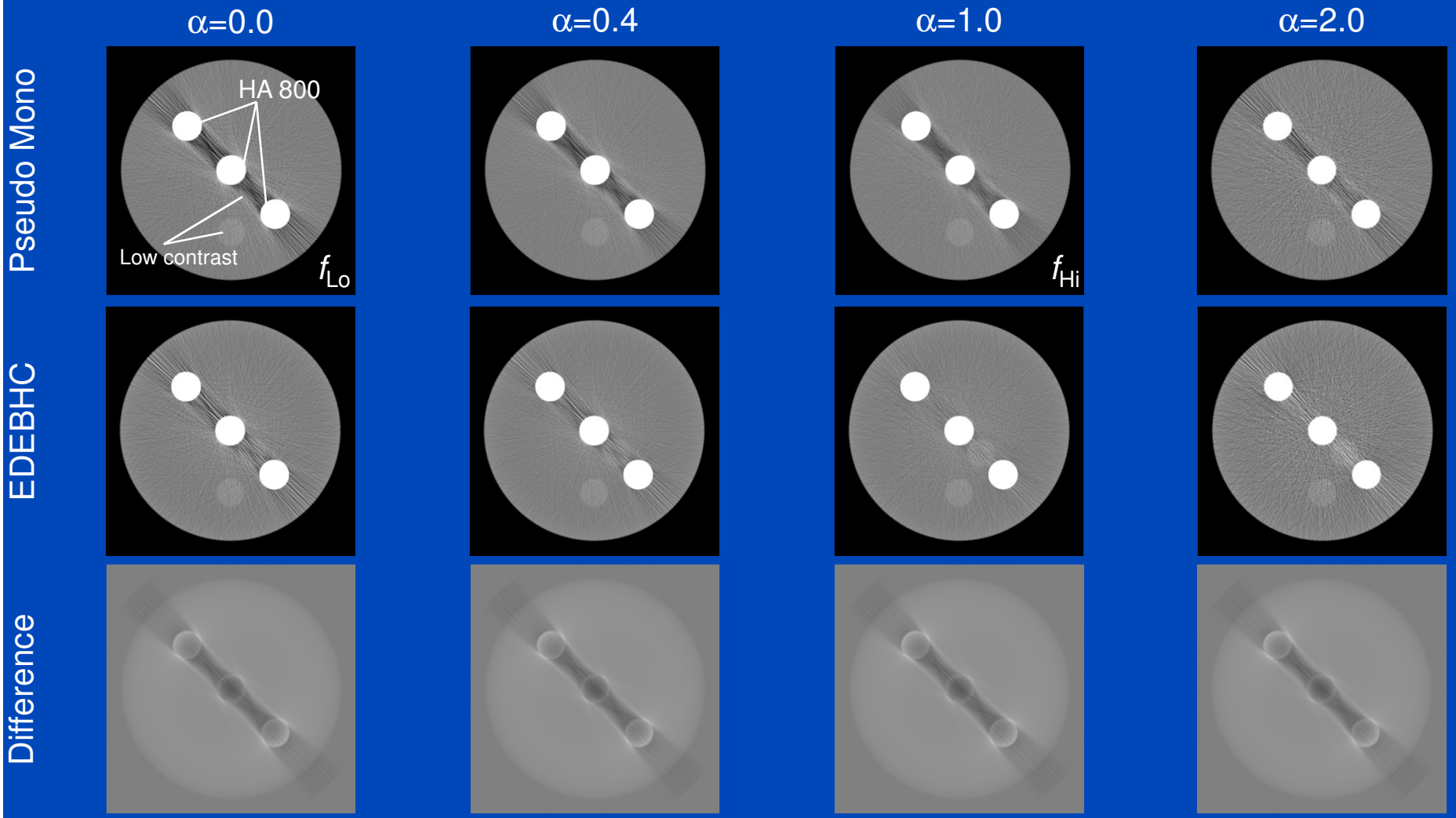
- **Beam hardening streaks lead to a broadening of the histogram peaks and therefore a minimization of the entropy indicates a reduction of artifacts.**





Results

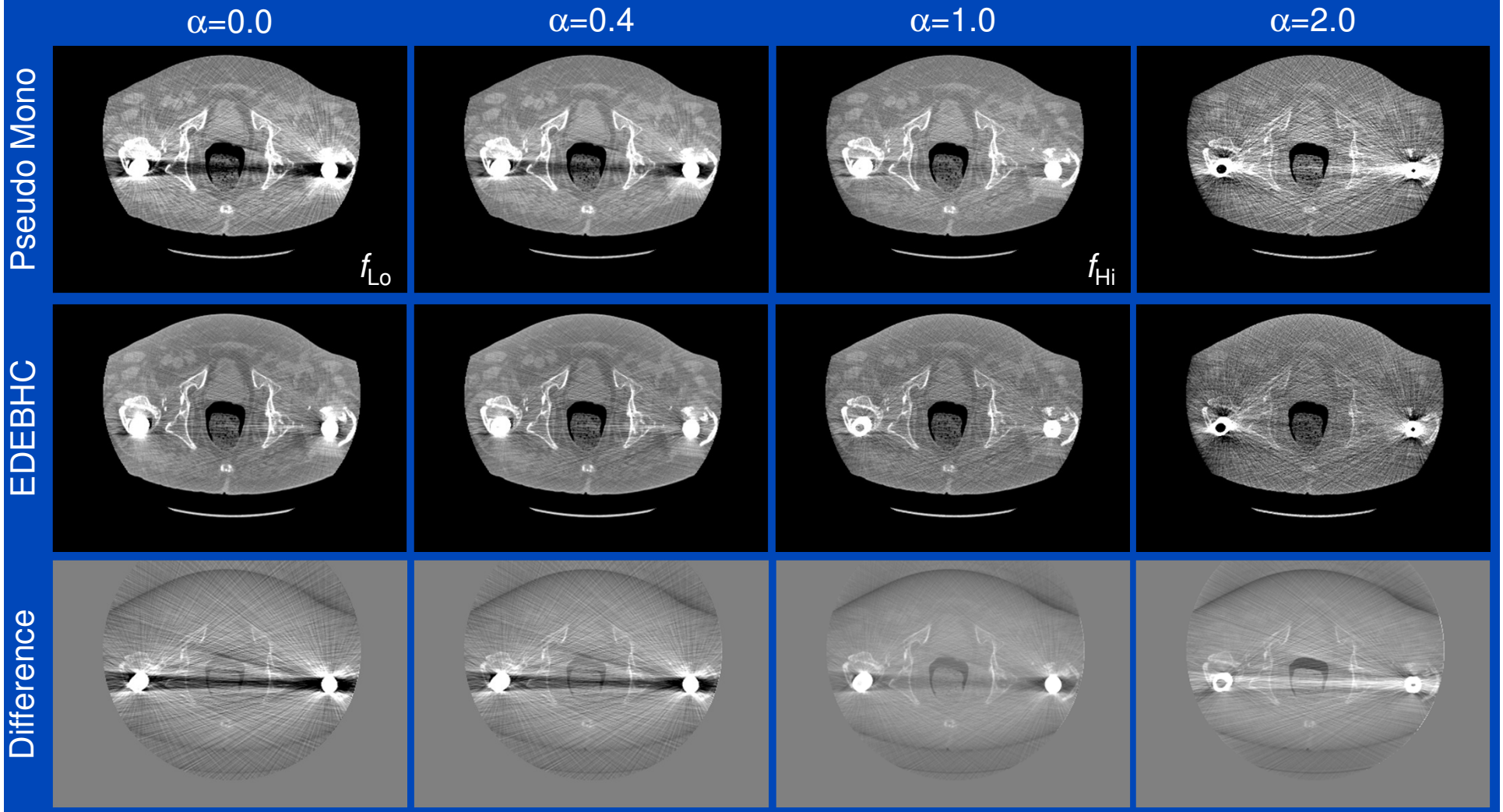
Simulation of a Disk Phantom



C=0 HU; *W*=1000 HU

Results

Patient Measurement



C=0 HU; *W*=1000 HU

Conclusion

- EDEBHC provides images with reduced beam hardening for an infinite number of contrast situations.
- EDEBHC can deal with scatter and does not rely on any pre-calibration steps.

Thank You!

This presentation will soon be available at www.dkfz.de/ct.

Parts of the reconstruction software RayConStruct-IR were provided by RayConStruct® GmbH, Nürnberg, Germany.