Dose Reduction in Photon-Counting CT by Ultra-High Resolution Acquisitions Compared to Today's Iterative Reconstructions

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DEUTSCHES KREBSFORSCHUNGSZENTRUM IN DER HELMHOLTZ-GEMEINSCHAFT

Background and Aim

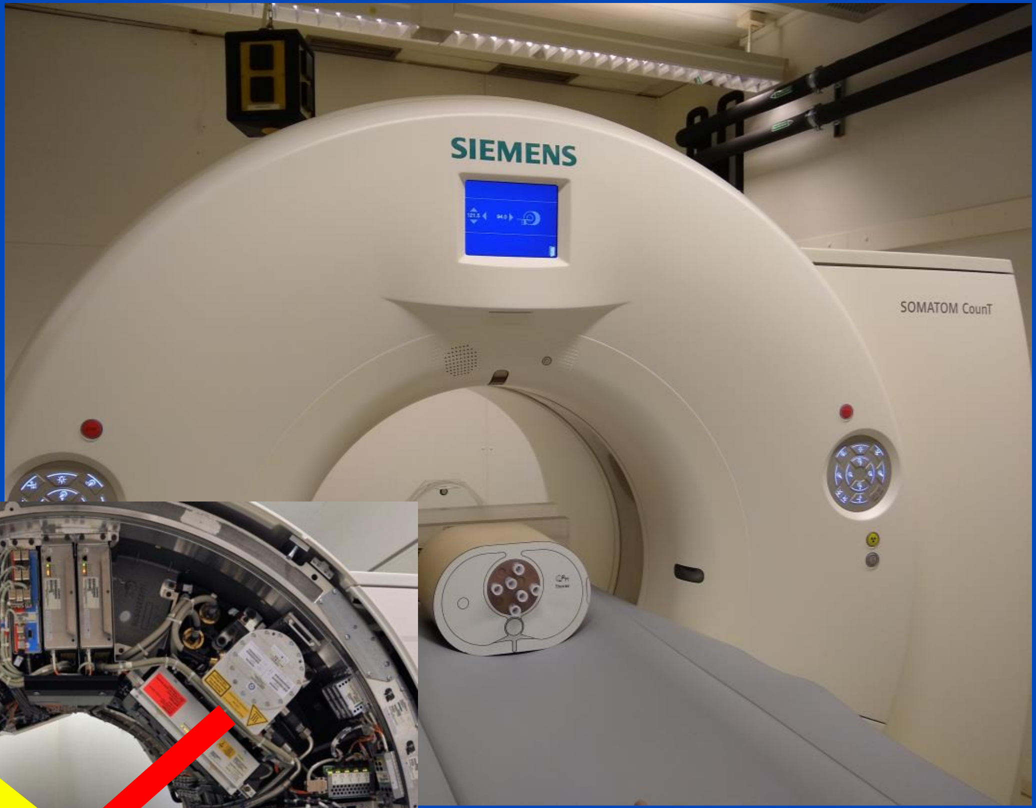
- Iterative reconstruction methods have proven to be a useful means to reduce administered radiation dose in today‘s energy-integrating CTs.
- Novel photon-counting detectors offer new ways to reduce radiation dose even since dedicated iterative reconstruction methods are not yet available.
- We aim at investigating the dose reduction that can be achieved by exploiting the favorable properties of photon-counting detectors using standard reconstructions.
- These results will be compared to the dose reductions achieved by today‘s iterative reconstructions applied to energy-integrating data.

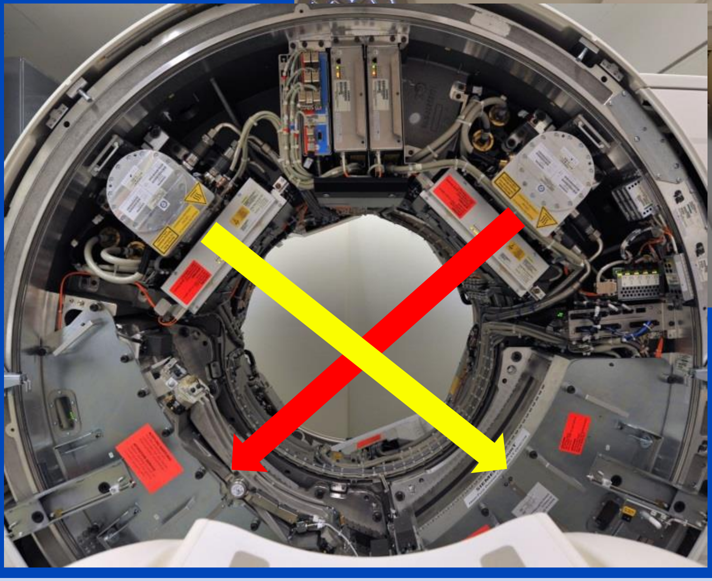
SOMATOM CounT CT @ DKFZ

Gantry from a clinical dual source scanner

A: conventional CT detector (50 cm FOV)

B: Photon counting detector (27.5 cm FOV)

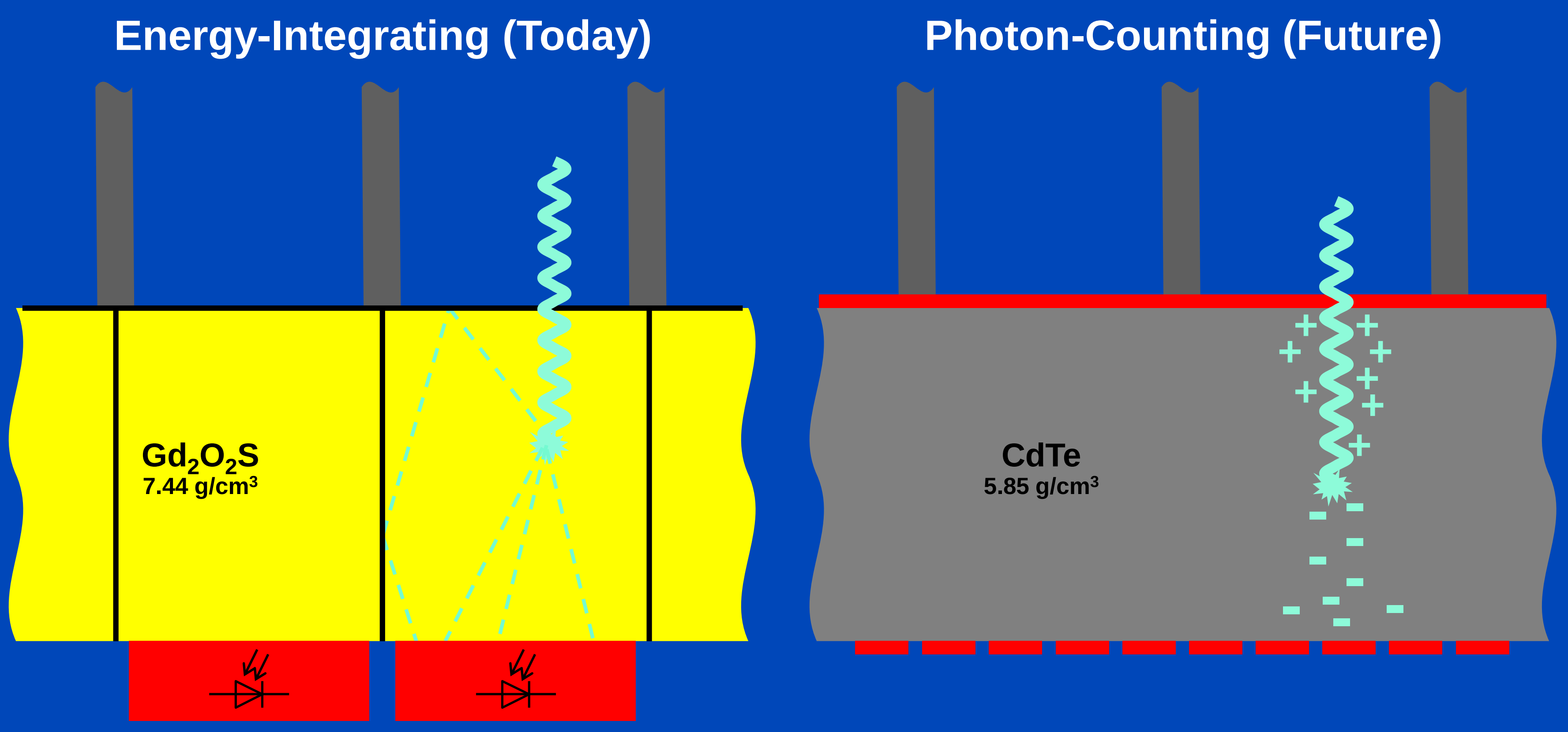




Prototype, not commercially available.

Photon-Counting CT

Counting Single Photons

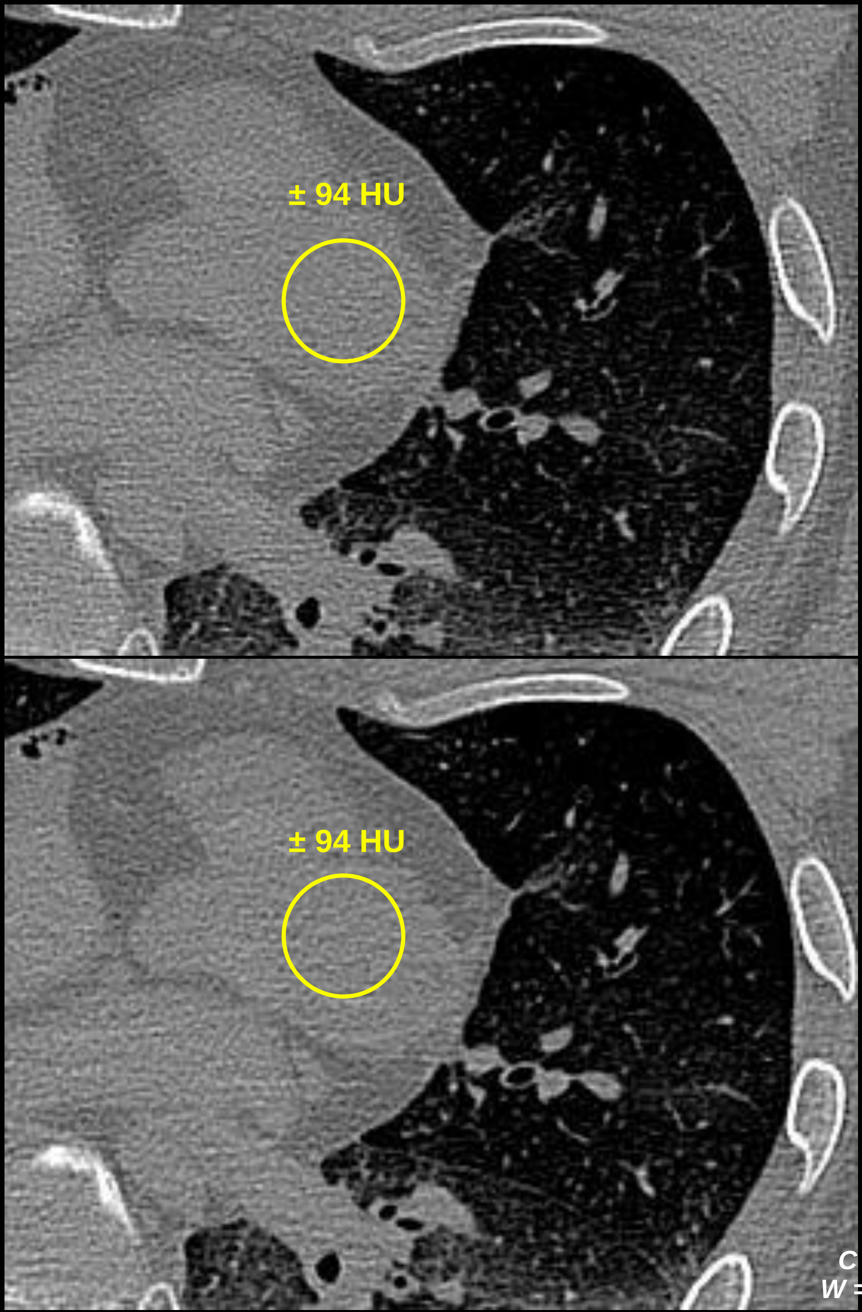


Requirements for CT: up to 10^9 x-ray photon counts per second per mm^2. Hence, photon counting only achievable for direct converters.

Acquisitions at same noise (Klein, Kachelrieß, Sawall et al. InvestRadiol:55(2), 2020)

EI, B70f

UHR, B70f



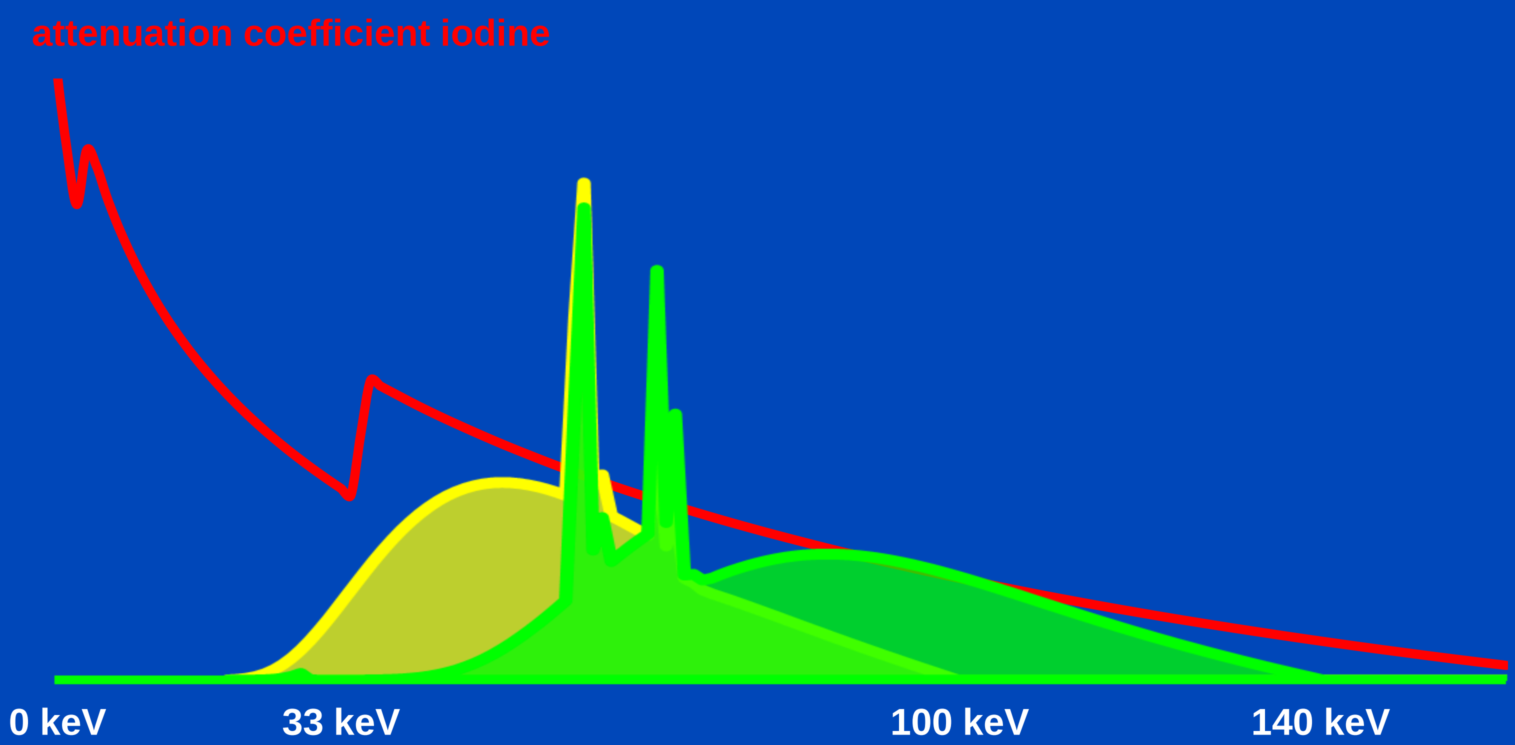
C = 50 HU
W = 1500 HU

Acquisition with EI:
- Tube voltage of 120 kV
- Tube current of 300 mAs
- Resulting dose of $\mathrm{CTDI}_{\mathrm{vol}\ 32\ \mathrm{cm}}$ = **22.6 mGy**

Acquisition with UHR:
- Tube voltage of 120 kV
- Tube current of 180 mAs
- Resulting dose of $\mathrm{CTDI}_{\mathrm{vol}\ 32\ \mathrm{cm}}$ = **14.6 mGy**

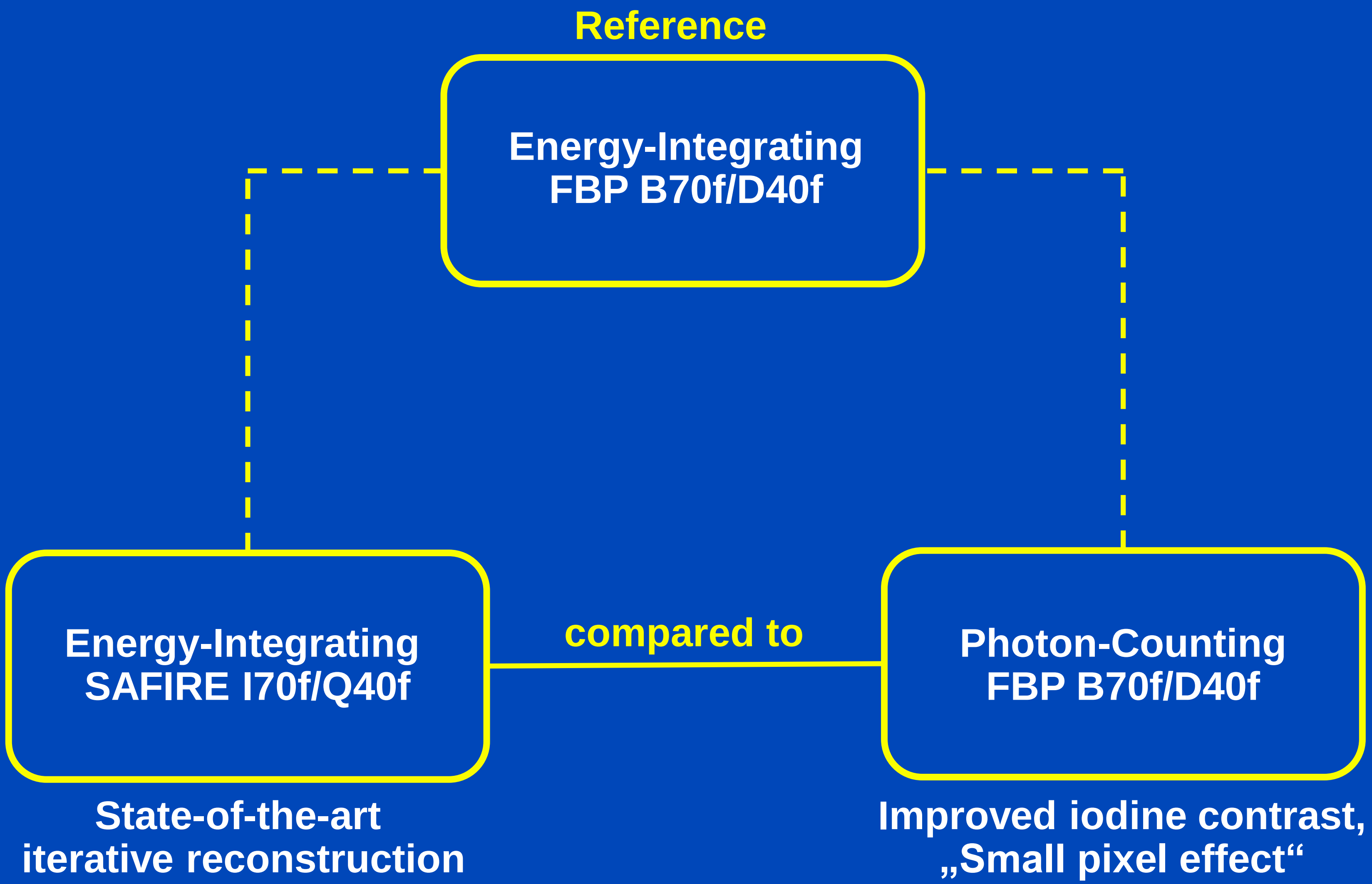
This is a 35% reduction in dose due to the “small pixel effect”!

Photon Counting
(Detected Spectra at 100 kV and 140 kV)



$$\mathrm{Signal}_{\mathrm{EI}} = \int dE\, E\; N(E) \qquad \mathrm{Signal}_{\mathrm{PC}} = \int dE\, 1\; N(E)$$

Spectra as seen after having passed a 32 cm water layer.

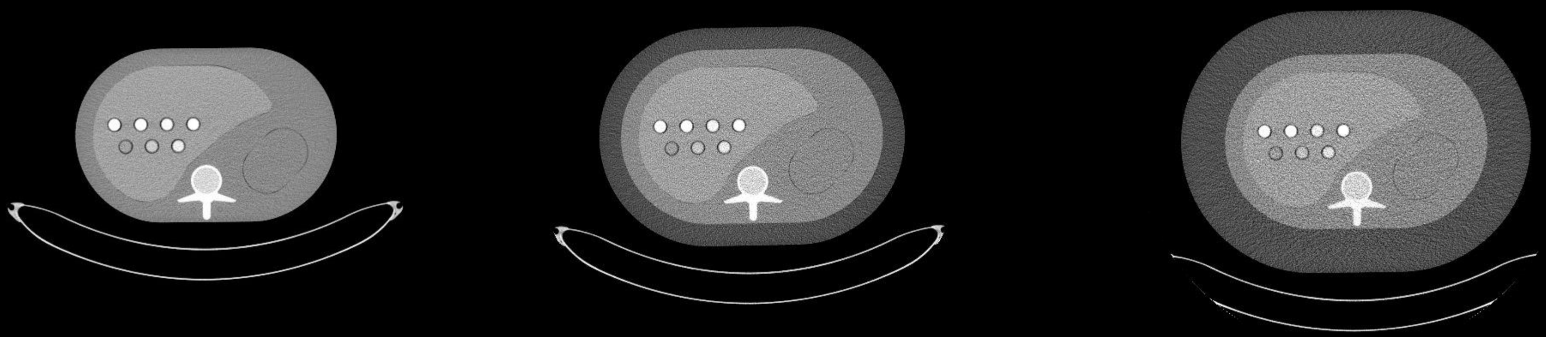

Reference
Energy-Integrating
FBP B70f/D40f
Energy-Integrating
SAFIRE I70f/Q40f
compared to
Photon-Counting
FBP B70f/D40f
State-of-the-art
iterative reconstruction
Improved iodine contrast,
„Small pixel effect“

Materials and Methods

- Images are acquired using a tube voltage of 120 kV using the EI and the PC detector in UHR mode.
- Reference EI data are reconstructed using weighted filtered backprojection (FBP).
- Further reconstructions of EI data are performed using SAFIRE strength 1-5.
- PC-UHR data are reconstructed using FBP.
- We consider two scenarios:
  - Bone imaging using sharp kernels (B70f, I70f)
  - Contrast enhanced imaging using quantitative kernels (D40f, Q40f)
- All data are reconstructed to a 512^2 matrix with a voxel size of 0.5 mm and a slice thickness of 0.75 mm.

Materials and Methods

- **Abdomen phantom of three different sizes (S, M, L) with iodine inserts of different concentrations**
  - **Small:** **20 cm × 30 cm**
  - **Medium:** **25 cm × 35 cm**
  - **Large:** **30 cm × 40 cm**
- **Additionally, a post-mortem CT angiography study is performed.**



Small Phantom **Medium Phantom** **Large Phantom**

***C* = 20 HU, *W* = 600 HU**

dkfz.

Contrast-to-Noise Ratio (CNR)

- **By selecting two ROIs, the CNR can be calculated using**

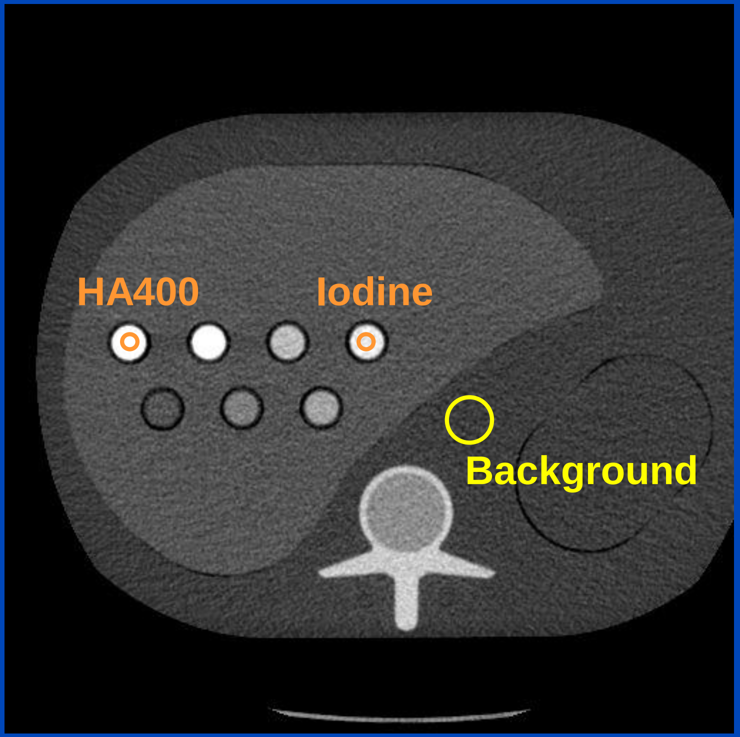
$$\mathrm{CNR} = \frac{|\mu_1 - \mu_2|}{\sqrt{\sigma_1^2 + \sigma_2^2}}$$

- **Normalization to dose D:**

$$\mathrm{CNRD} = \frac{\mathrm{CNR}}{\sqrt{\mathrm{D}}}$$

- **The potential x-ray dose reduction can be calculated by**

$$\text{Dose Reduction} = 1 - \frac{\mathrm{CNRD}^2_{\mathrm{Ref}}}{\mathrm{CNRD}^2_{\mathrm{PC}}}$$



C = 200 HU, W = 600 HU

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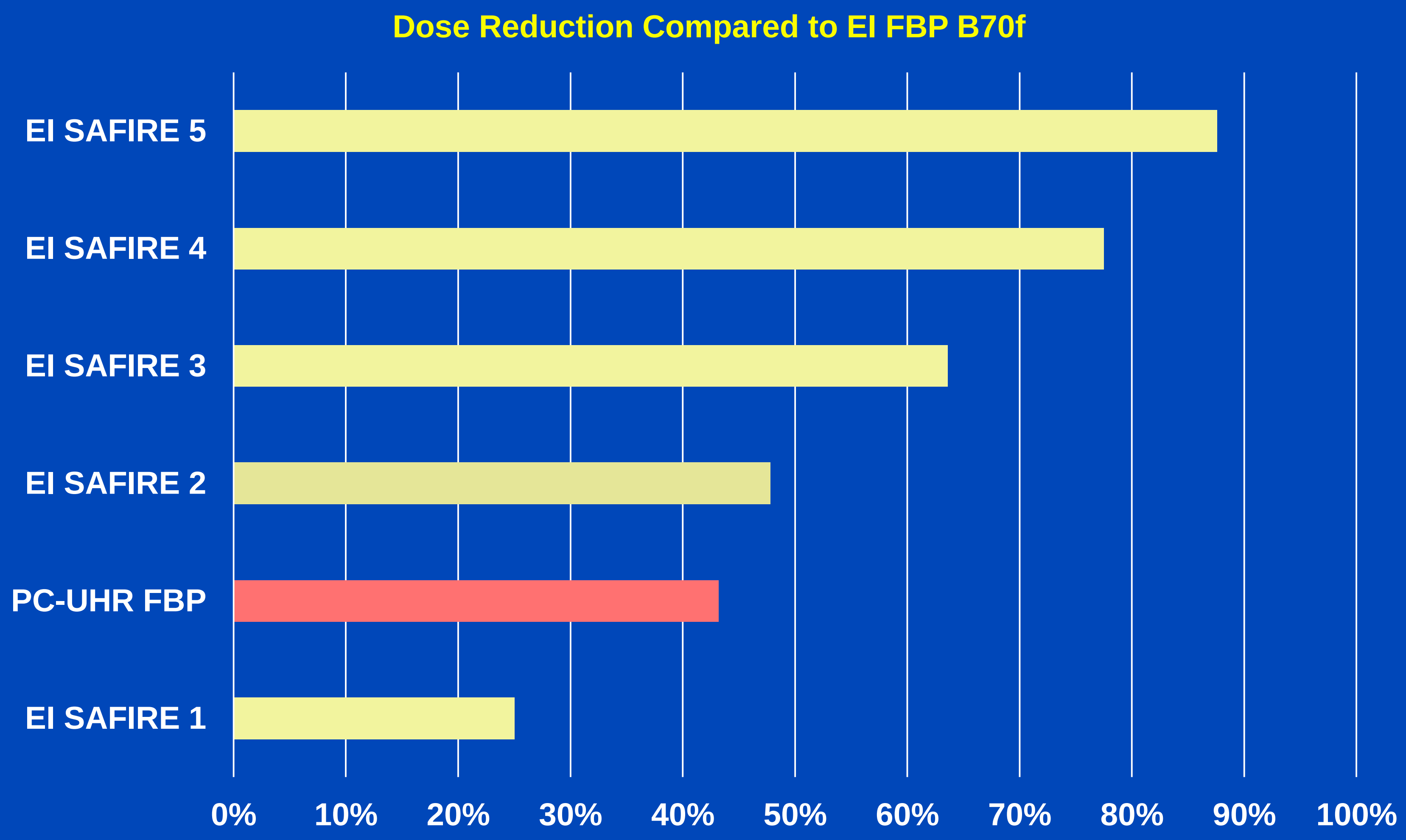
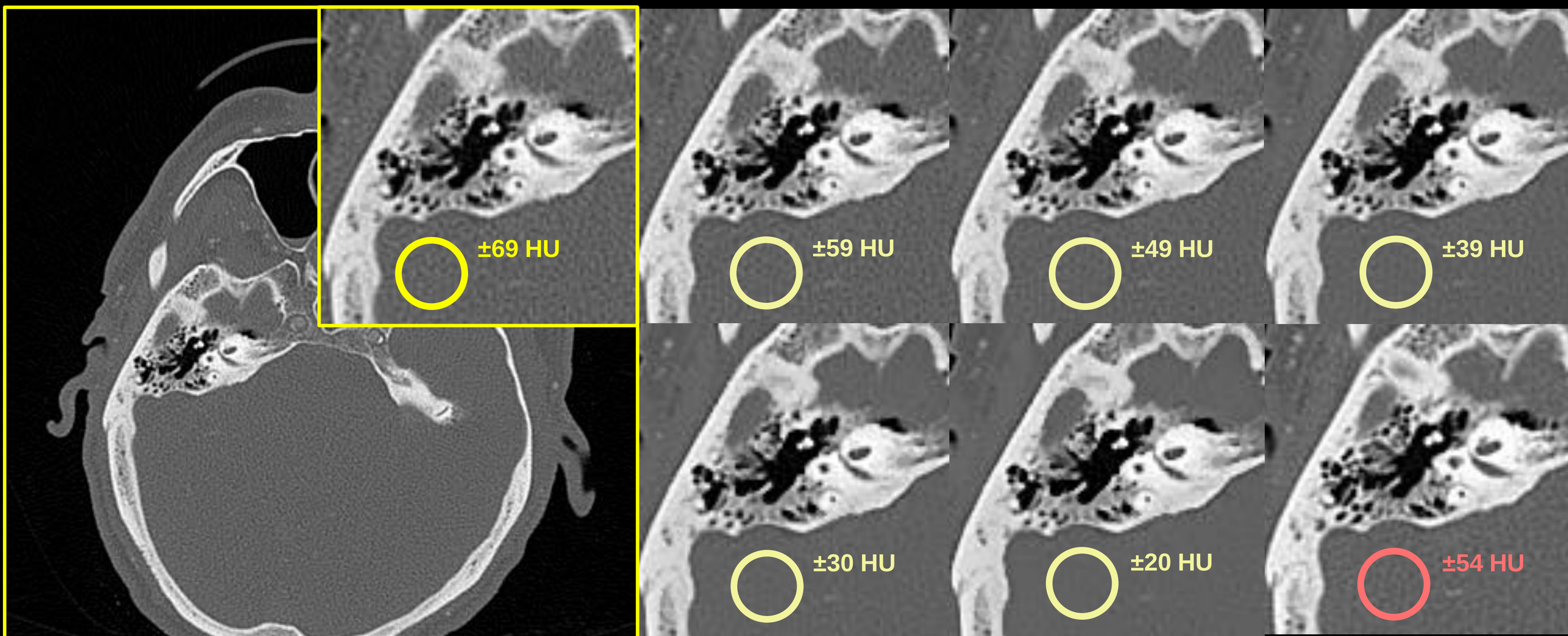
Bone Imaging

M-Phantom



Bone Imaging

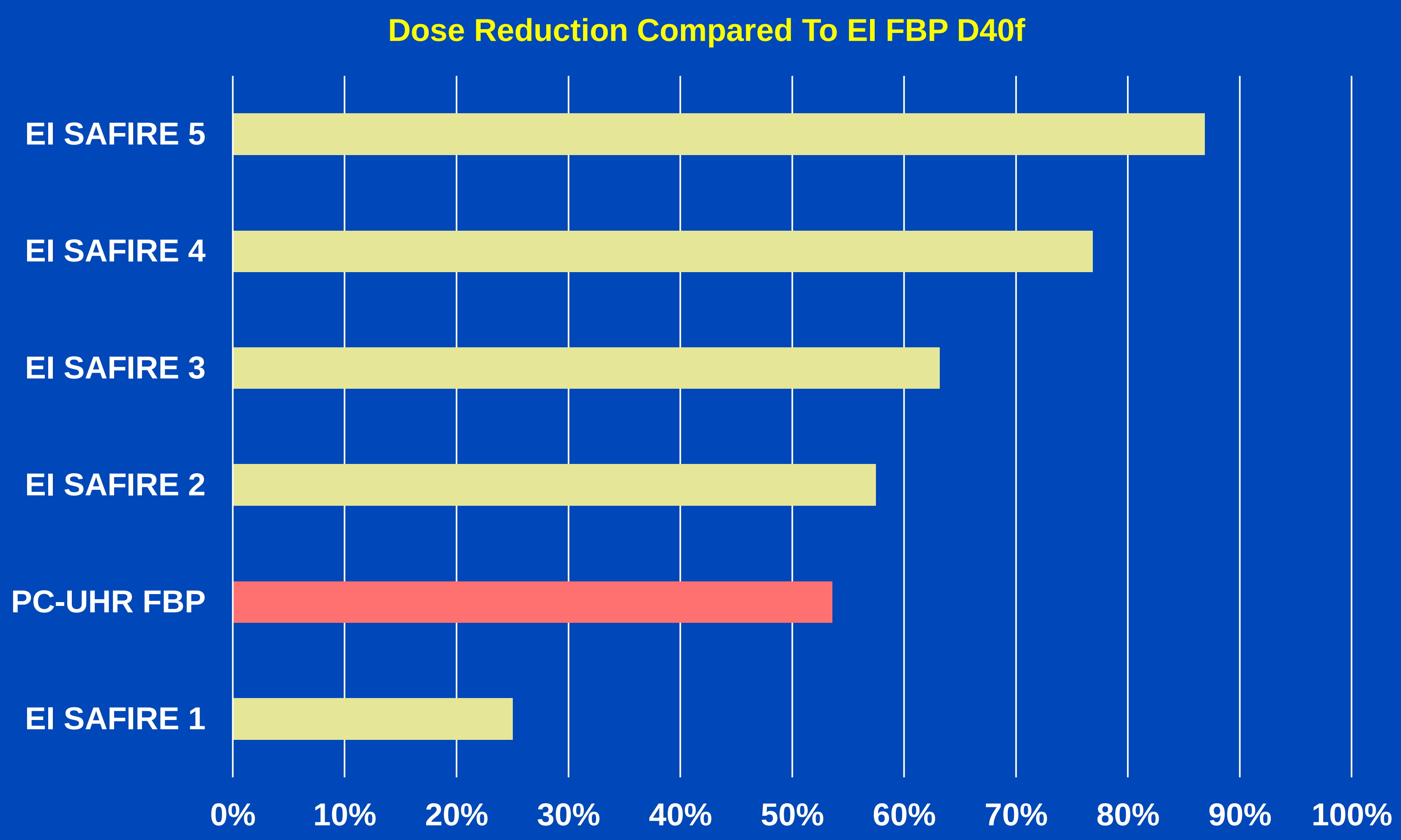
Post-Mortem CT Example (B70f/I70f)



C=400 HU, *W*=2800 HU

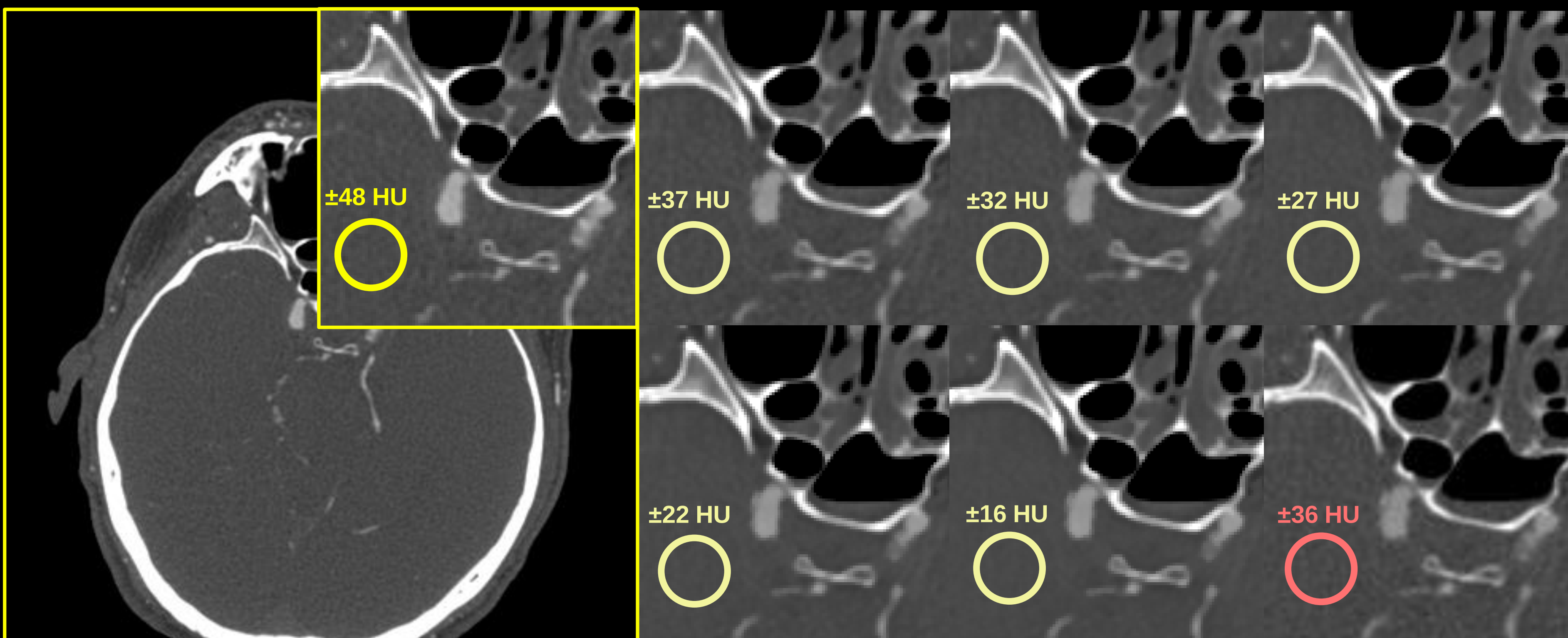
Contrast Enhanced Imaging

M-Phantom



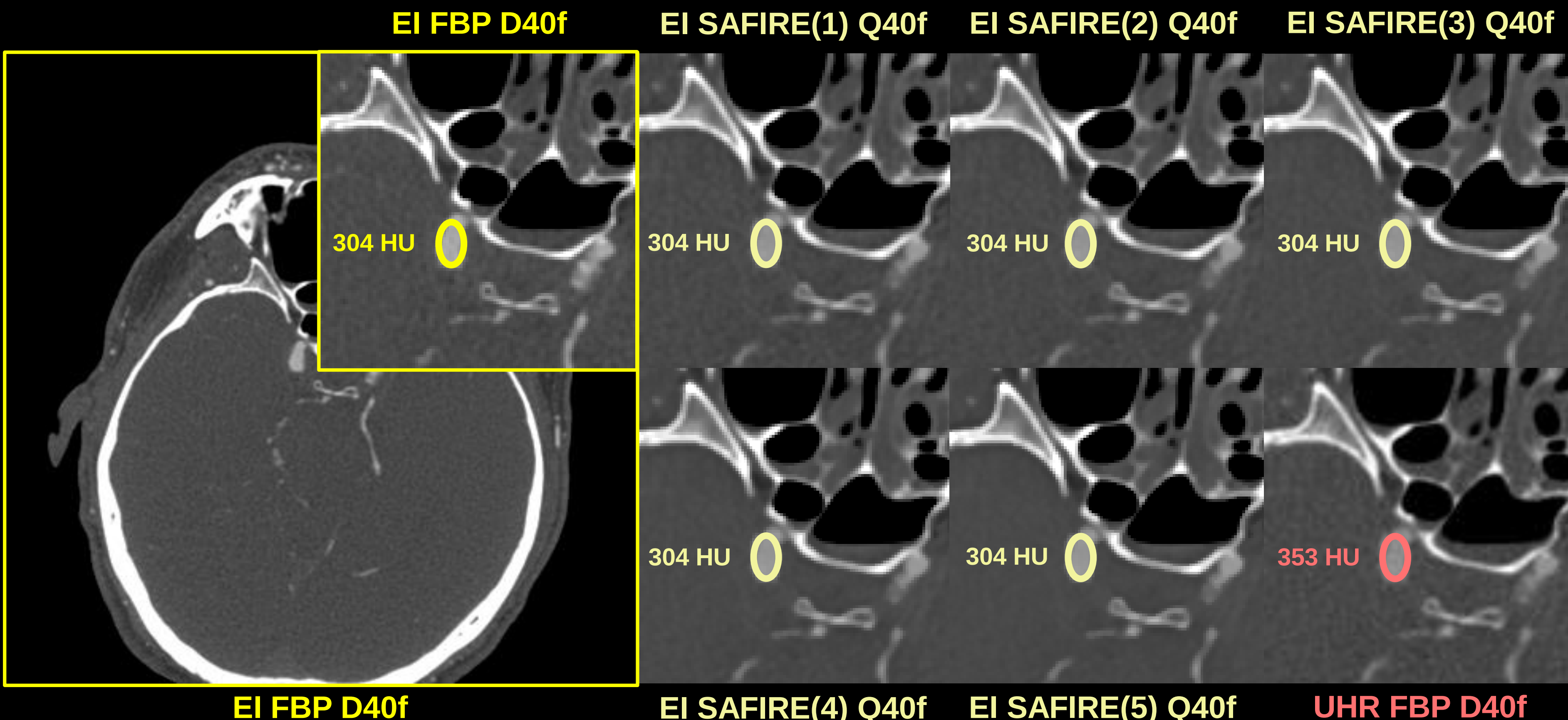
Contrast Enhanced Imaging

Post-Mortem CT Angiography Example (D40f/Q40f)



Contrast Enhanced Imaging

Post-Mortem CT Angiography Example (D40f/Q40f)

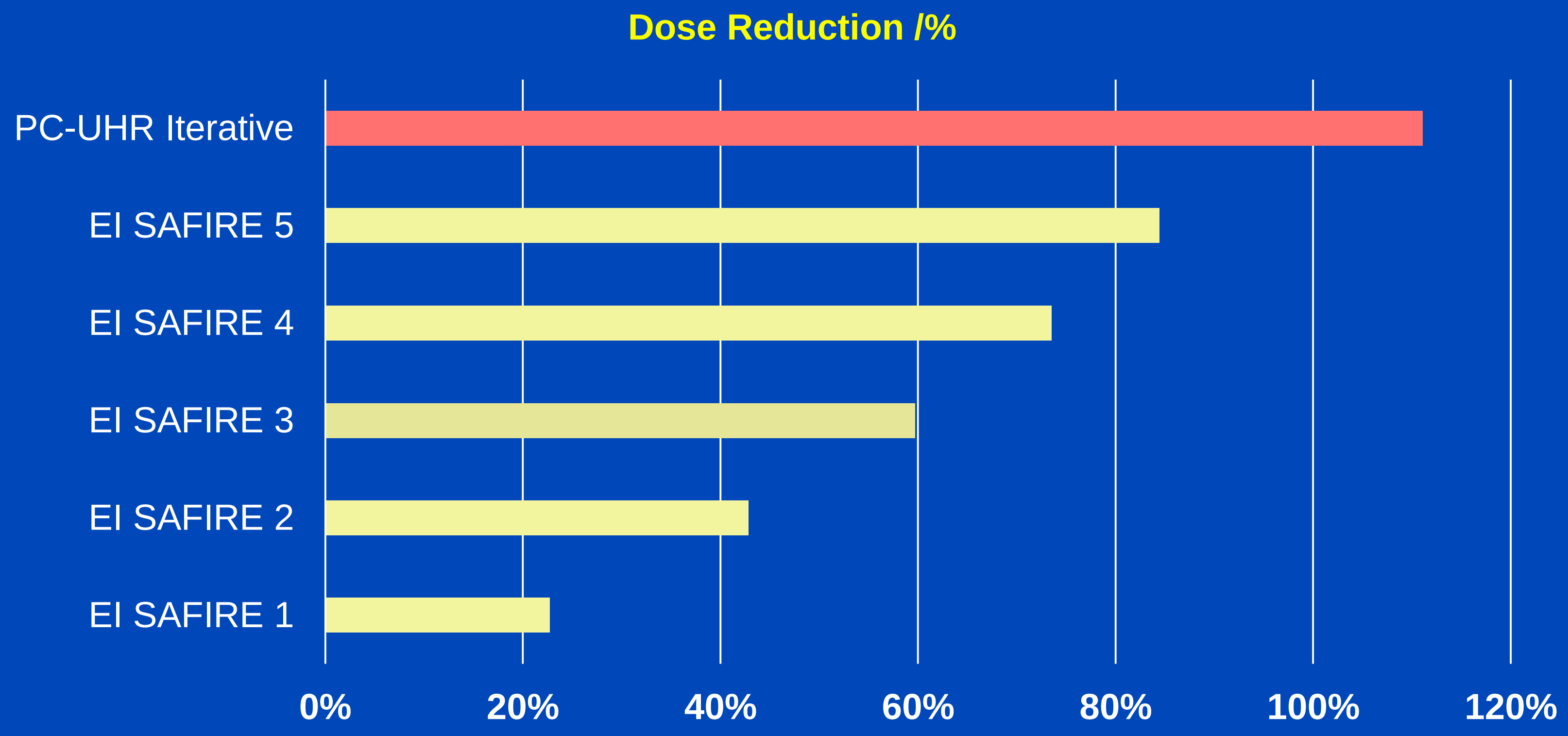


Summary & Conclusion

- PC-UHR acquisitions combined with the improved iodine contrast allow for a dose reduction similar to state-of-the-art iterative reconstructions.
- These results hold for all investigated phantom sizes and were verified in a post-mortem CT angiography study.

Outlook?

- **Further dose reductions will be achieved by combining acquisitions using small pixels with dedicated iterative image reconstruction methods.**



Thank You!

This presentation will soon be available at www.dkfz.de/ct.
Job opportunities through DKFZ's international Fellowship programs (marc.kachelriess@dkfz.de).
Parts of the reconstruction software were provided by RayConStruct® GmbH, Nürnberg, Germany.