Does Dual Energy Dual Source CT with Energy-Selective Photon Counting Detectors Make Sense?

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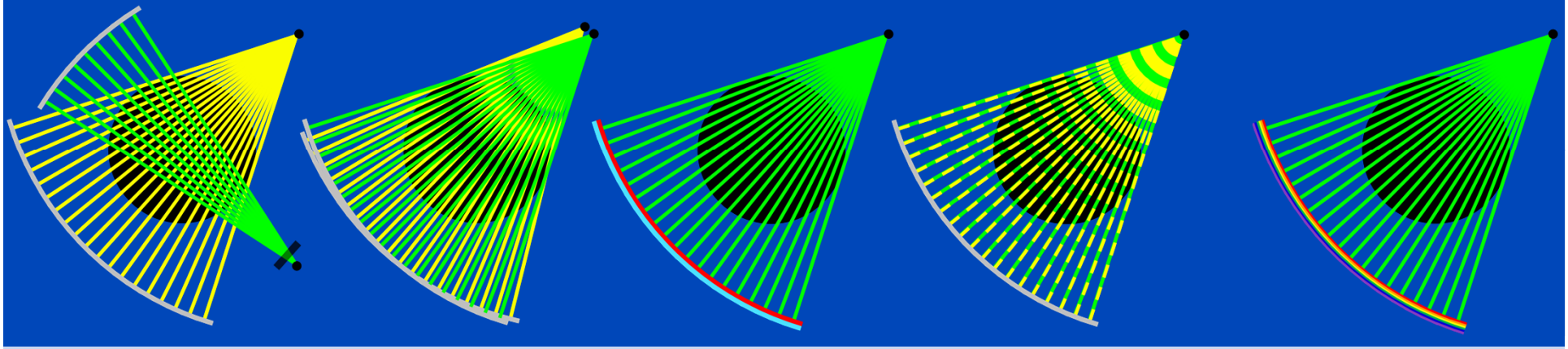
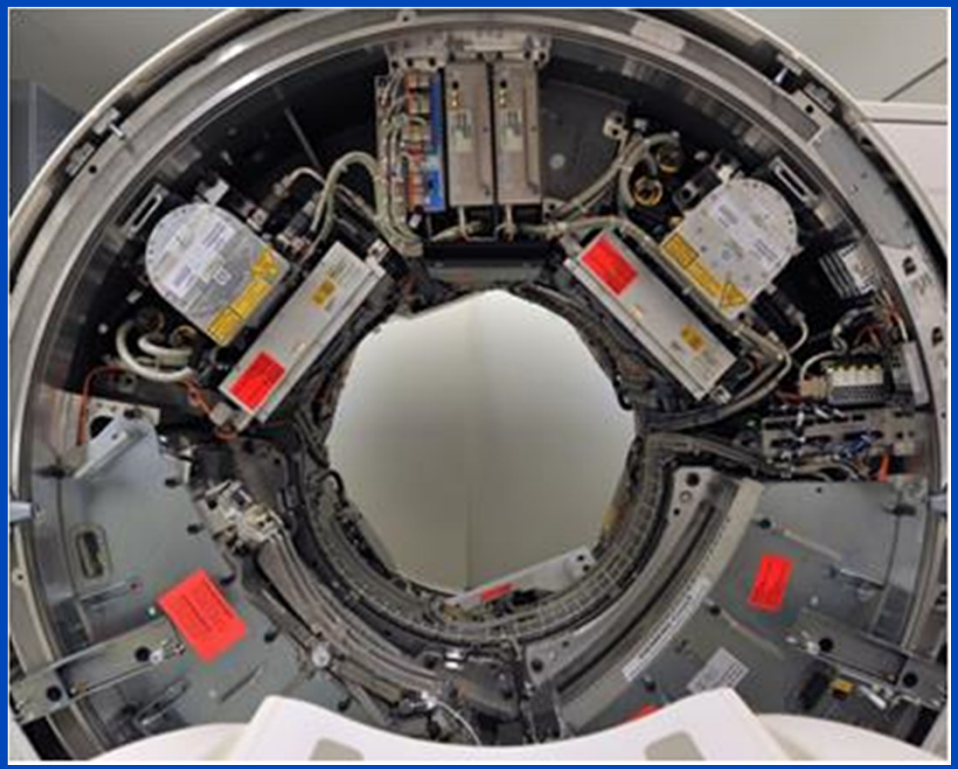
Energy-Resolved CT Technology

- **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





This photon-counting whole-body CT prototype, installed at the Mayo Clinic, is a DSCT system. However, it is restricted to run in single source mode.

Photo courtesy of Siemens Healthcare, Forchheim, Germany.

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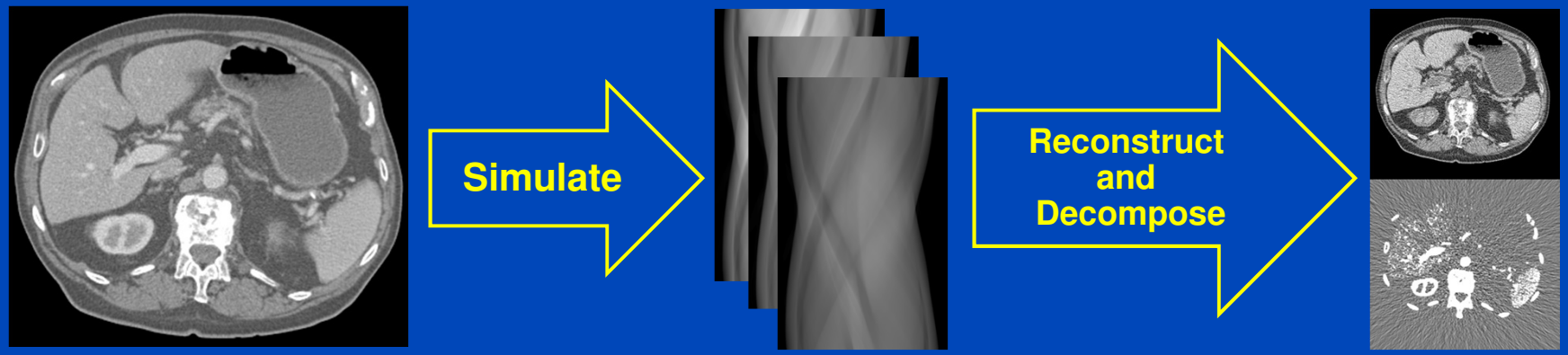
Simulations

- **Study typical dual energy CT (DECT) application:**
  - **Material decomposition: virtual non contrast (VNC) and iodine image**



- **Comparison of:**
  - **Dual source DECT techniques with energy integrating (EI) detectors**
  - **Energy-selective photon counting (PC) detectors**
- **Statistically optimal material decomposition[1]:**
  - **Constant contrast due to calibration**
  - **Constant patient dose in all cases (absorbed energy)**
  - **Noise minimization = CNRD maximization**

[1]S. Faby, S. Kuchenbecker, D. Simons, H.P. Schlemmer, M. Lell, and M. Kachelrieß. CT calibration and dose minimization in image-based material decomposition with energy-selective detectors. SPIE Medical Imaging 903318:1-12, April 2014.

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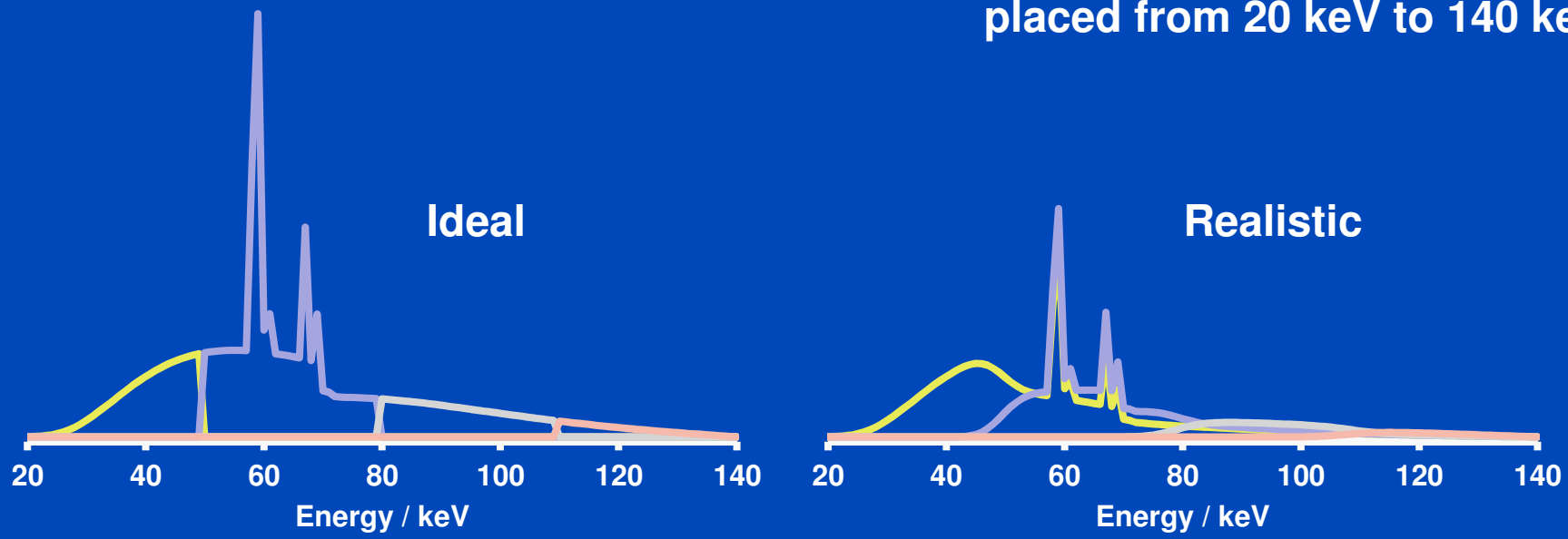
MECT Simulation

- Photon counting detector
- Energy bin spectra for $B = 4$, bin positions not optimized:

Energy bins equidistantly placed from 20 keV to 140 keV.



J. P. Schlomka, E. Roessl, R. Dorscheid, S. Dill, G. Martens, T. Istel, C. Bäumer, C. Herrmann, R. Steadman, G. Zeitler, A. Livne and R. Proksa, "Experimental feasibility of multi-energy photon-counting K-edge imaging in pre-clinical computed tomography," Phys. Med. Biol. 53, 4031-4047, 2008.

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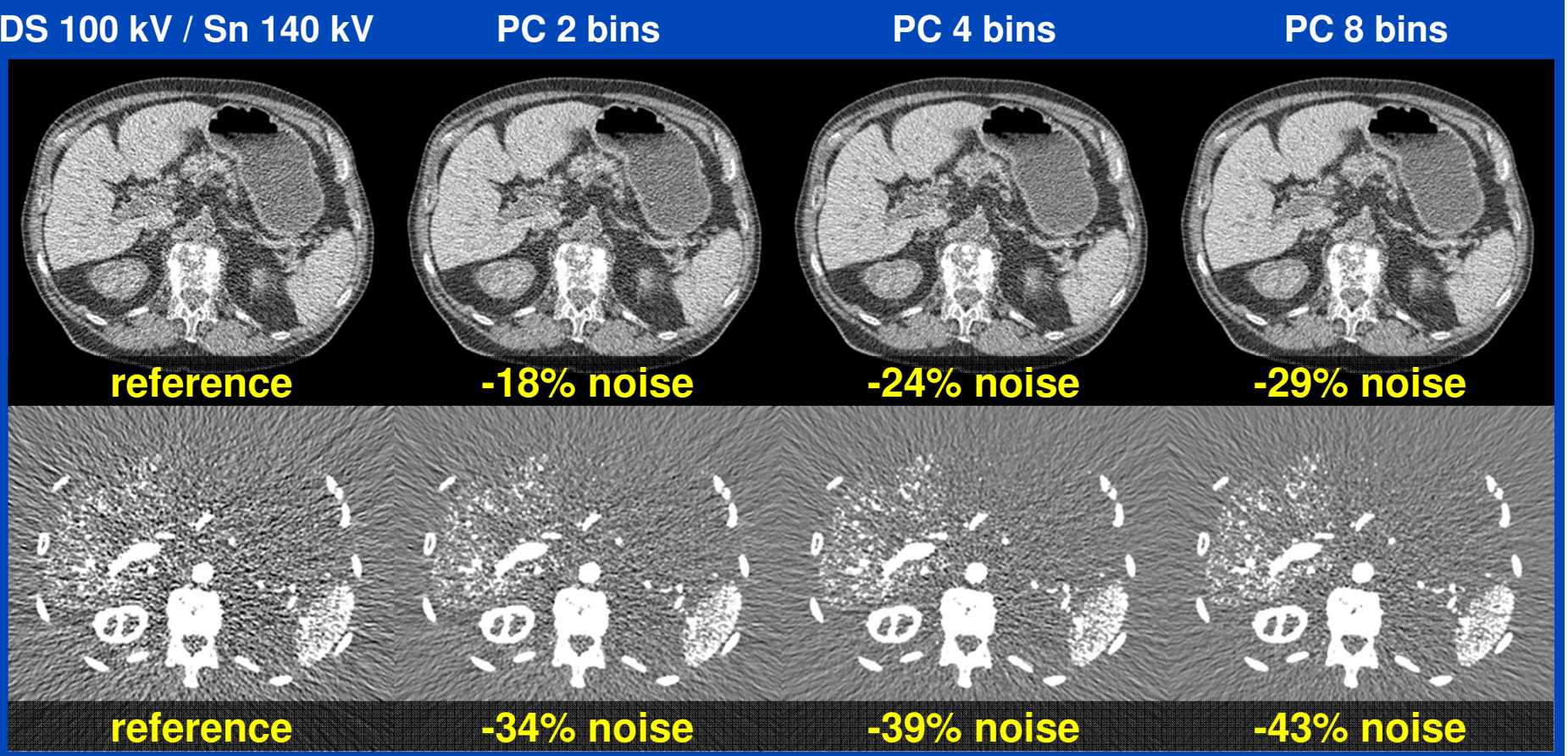
Results – PC (Ideal Model)



For details regarding the material decomposition method see Faby et al., SPIE 2014.

Water: C = 0 HU / W = 400 HU
Iodine: C = 0 mg/mL / W = 6 mg/mL

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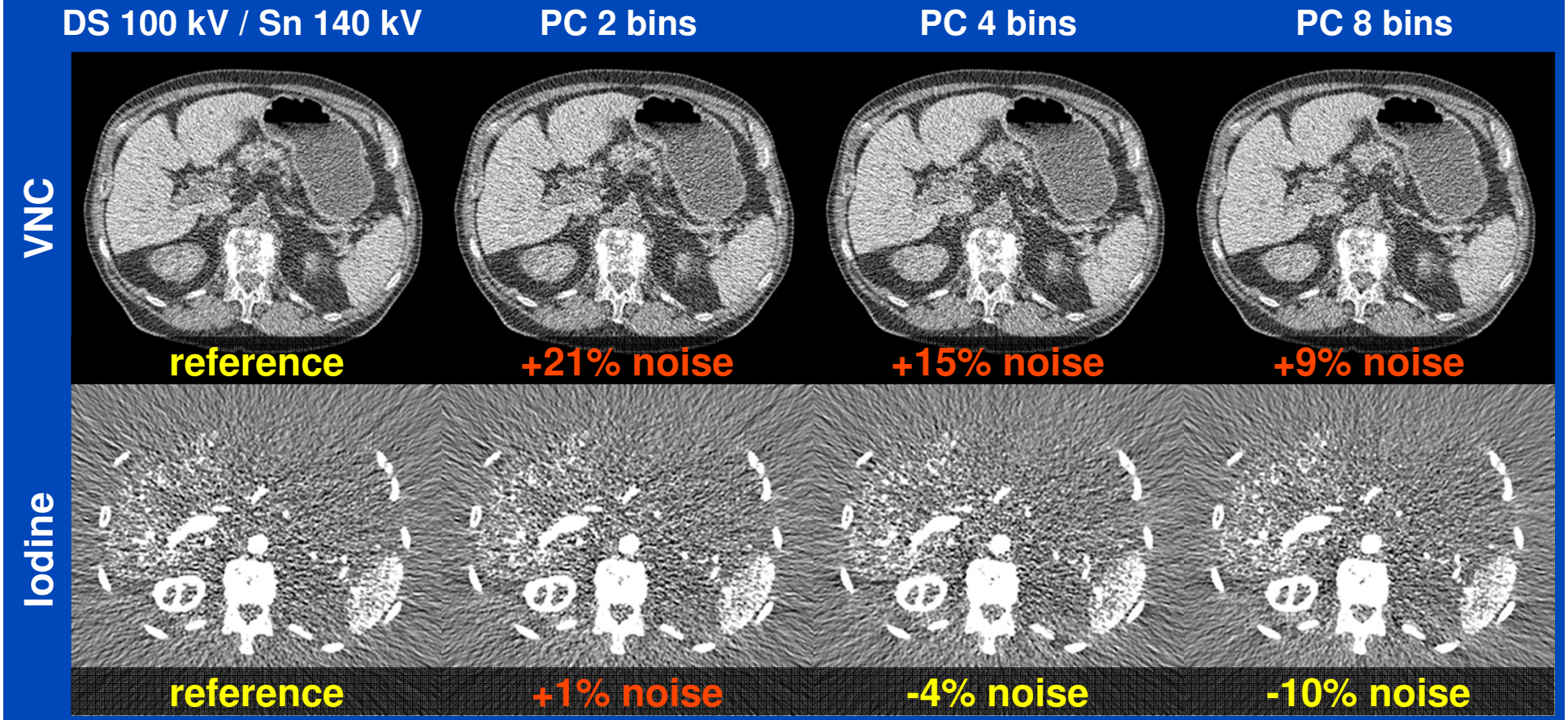
Results – PC (Realistic Model)



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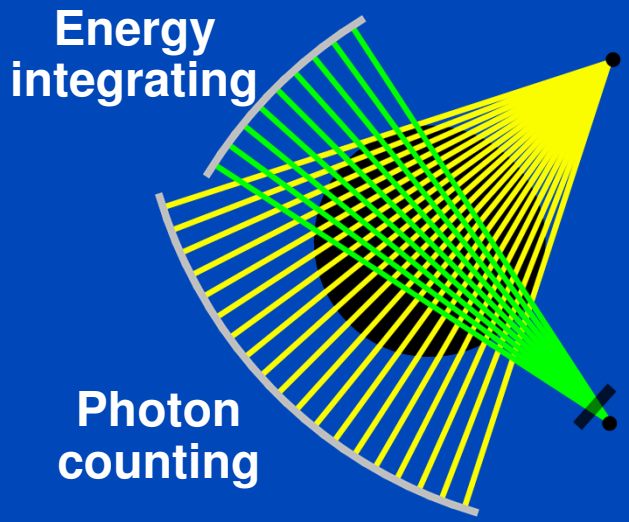
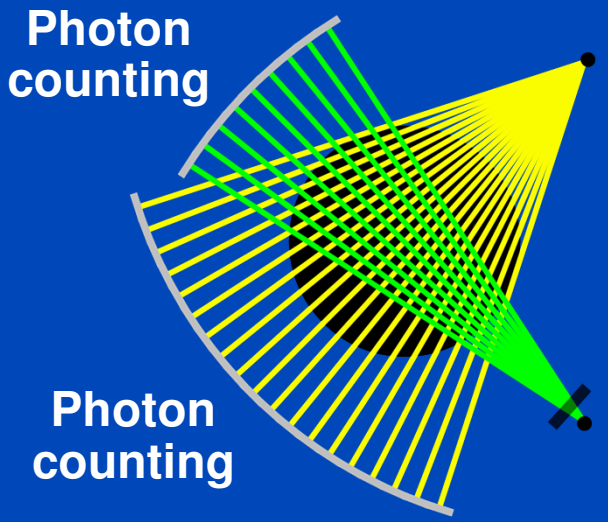
PC/EI and PC/PC DSCT Concepts

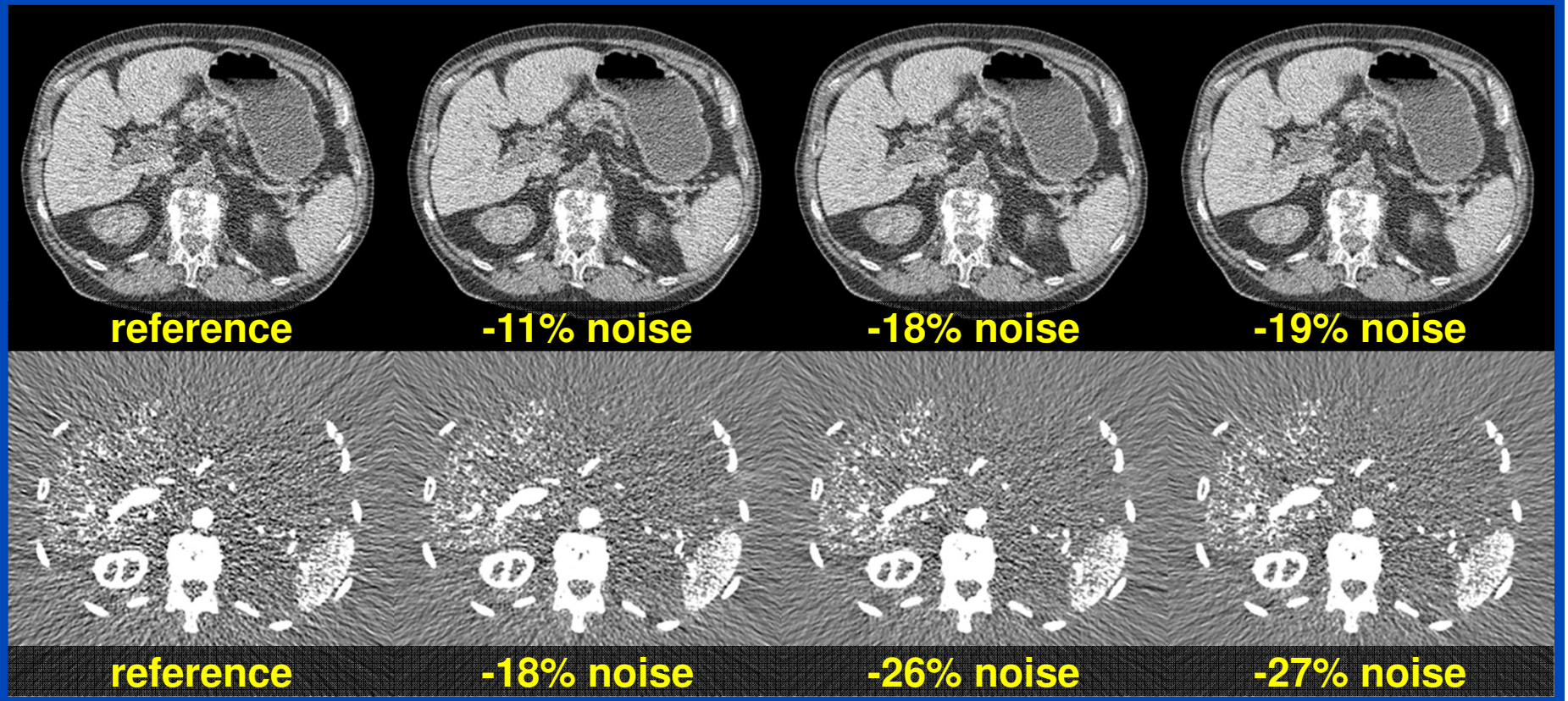
- Improve PC detector performance using DSCT
- Replace low spectrum EI detector by PC detector
- Replace both EI detectors by PC detectors





Results – PC/EI (Realistic PC Model)

PC 100 kV / EI Sn 140 kV



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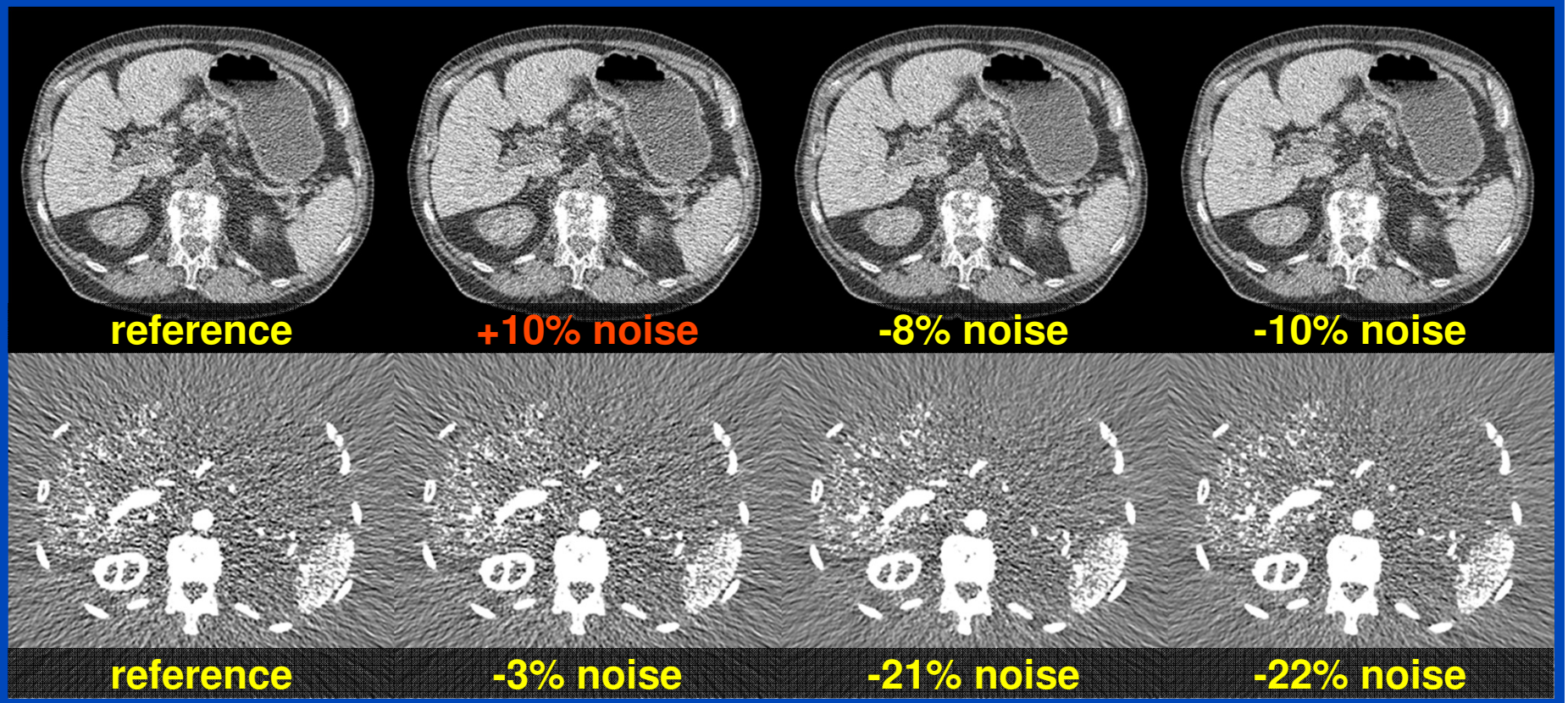
Results – PC/PC (Realistic PC Model)

PC 100 kV / PC Sn 140 kV



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Why is the PC/EI combination better than the PC/PC combination?

Different intrinsic x-ray photon energy weighting of the two detector technologies

Detector signal for energy bin *b*:

$$S_b = \int dE\, \boldsymbol{s(E)} N_{0,b}(E) e^{-p\psi(E)}$$

Detector sensitivity *s*(*E*):

Photon counting:

$$s(E) = 1$$

Photon counts

Energy integrating:

$$s(E) \propto E$$

Scintillator light output

Conclusion

- **Single source CT photon counting:**
  - **Ideal PC detector: Superior performance than DS DECT at 100 kV / Sn 140 kV.**
  - **Realistic PC detector: Inferior performance than DS DECT at 100 kV / Sn 140 kV.**
- **Dual source CT with one or two photon counters:**
  - **Significantly improves performance for realistic PC detector.**
  - **PC/EI combination may be an option for realistic PC detectors.**
- **Similar findings apply to 3rd generation DSCT running at 90 kV / Sn 150 kV.**

Thank You!

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

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