Does Iodine CNRD Improve When Switching from Today's Energy Integrating CT to Tomorrow's Photon-Counting CT?

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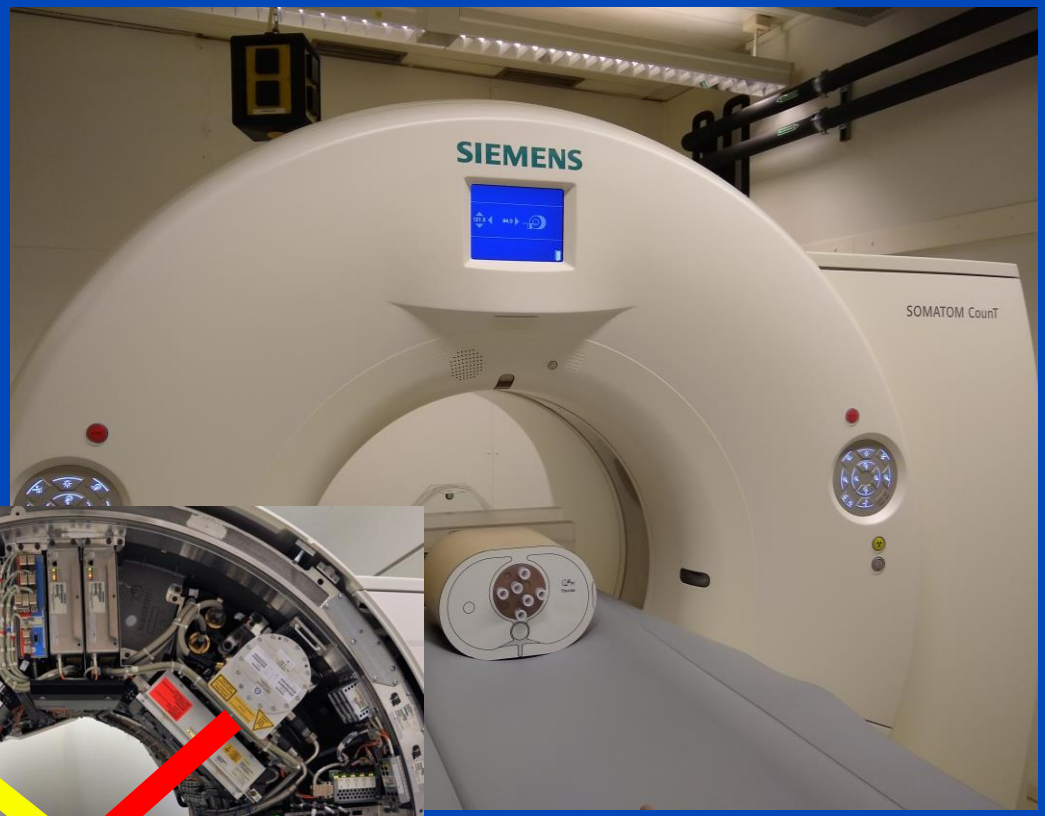
dkfz. DEUTSCHES KREBSFORSCHUNGSZENTRUM IN DER HELMHOLTZ-GEMEINSCHAFT

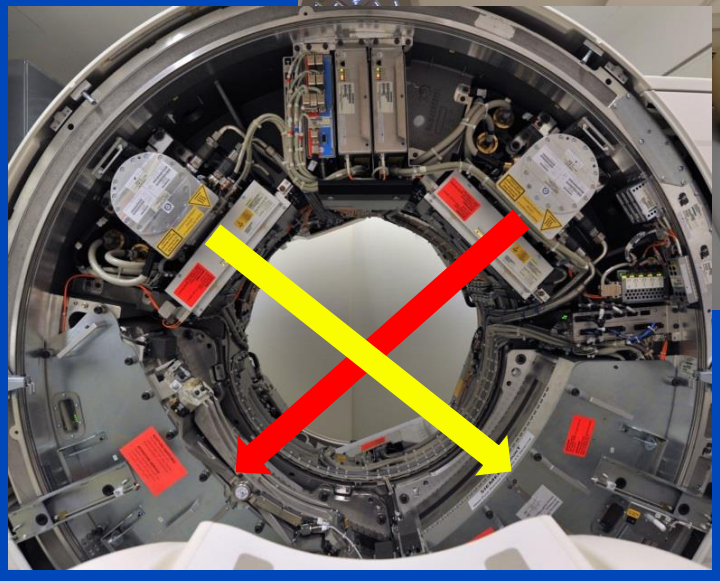
SOMATOM CounT CT @ DKFZ

Gantry from a clinical dual source scanner

A: conventional CT detector (50 cm FOV)

B: Photon counting detector (27.5 cm FOV)





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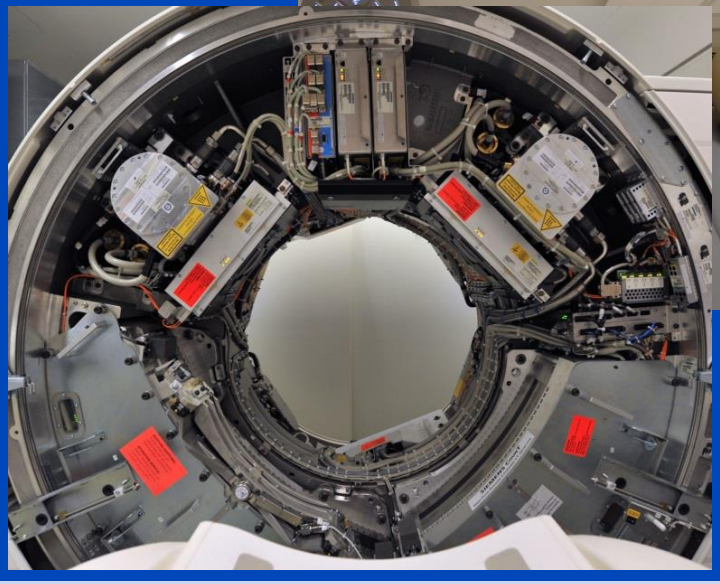

Prototype, not commercially available.

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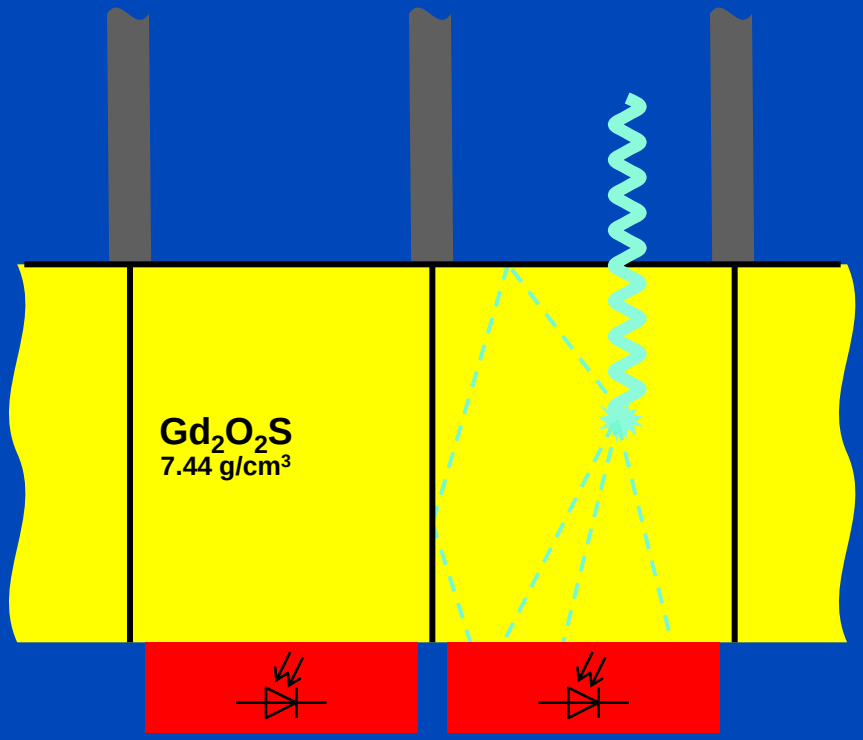
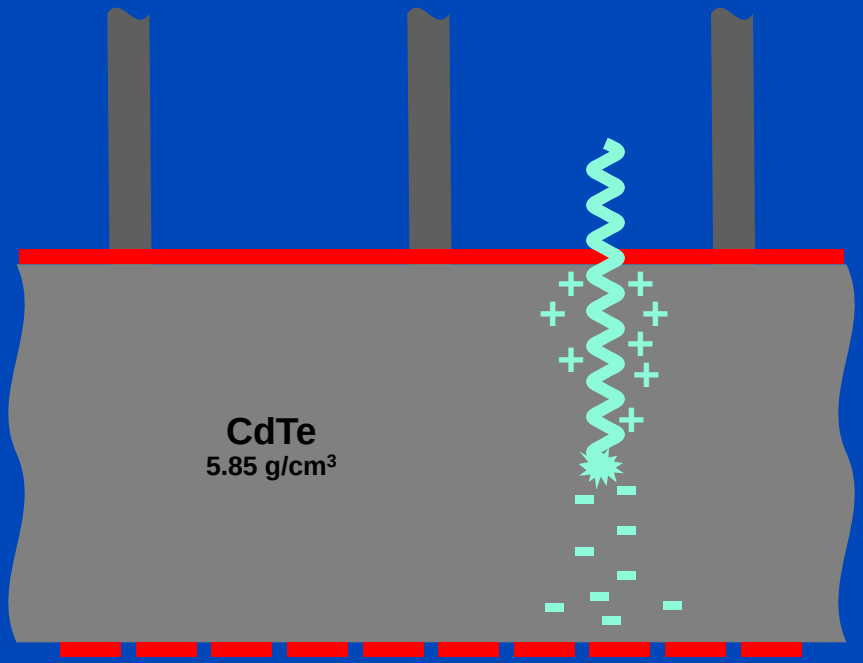
Photon-Counting CT

Counting Single Photons

Energy-Integrating (Today)

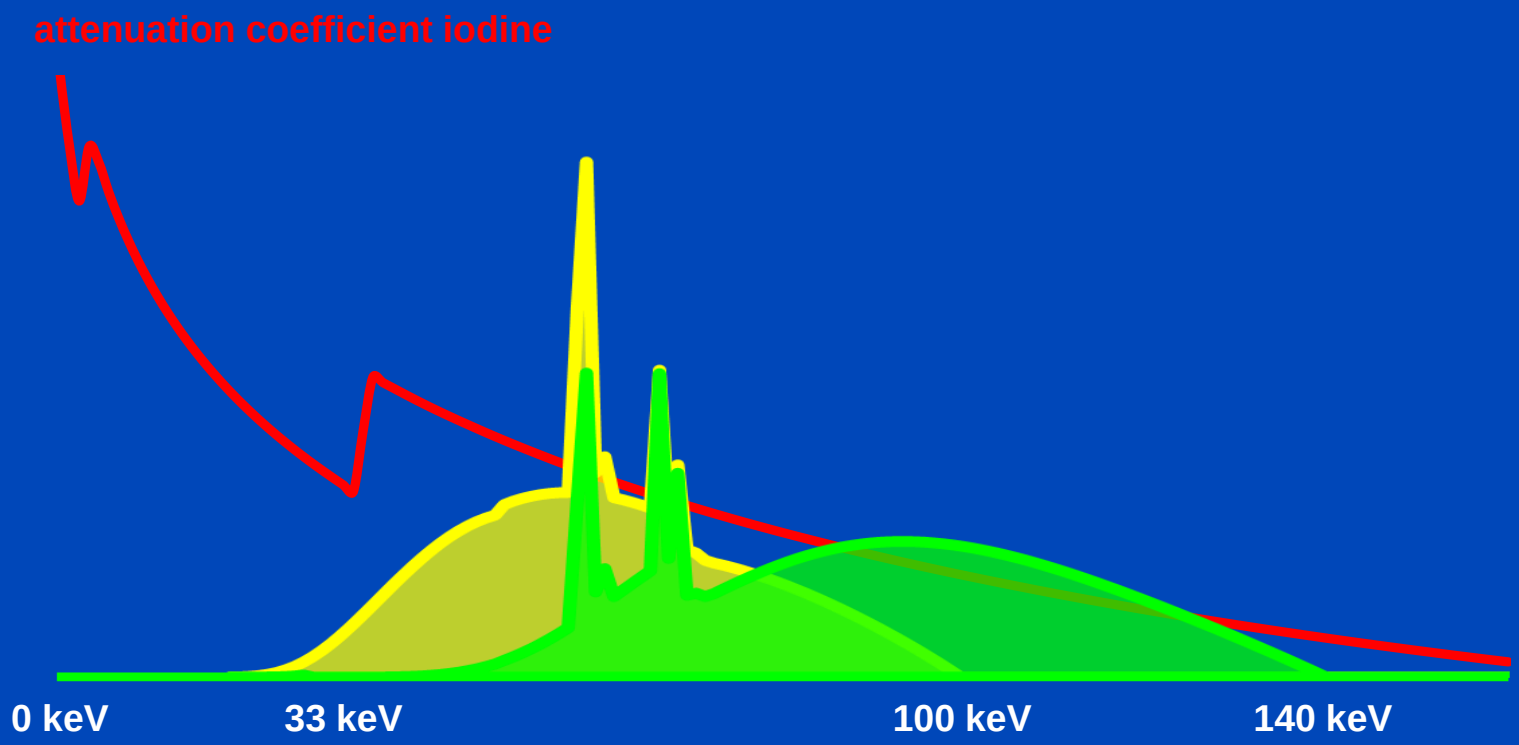


Photon-Counting (Future)



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

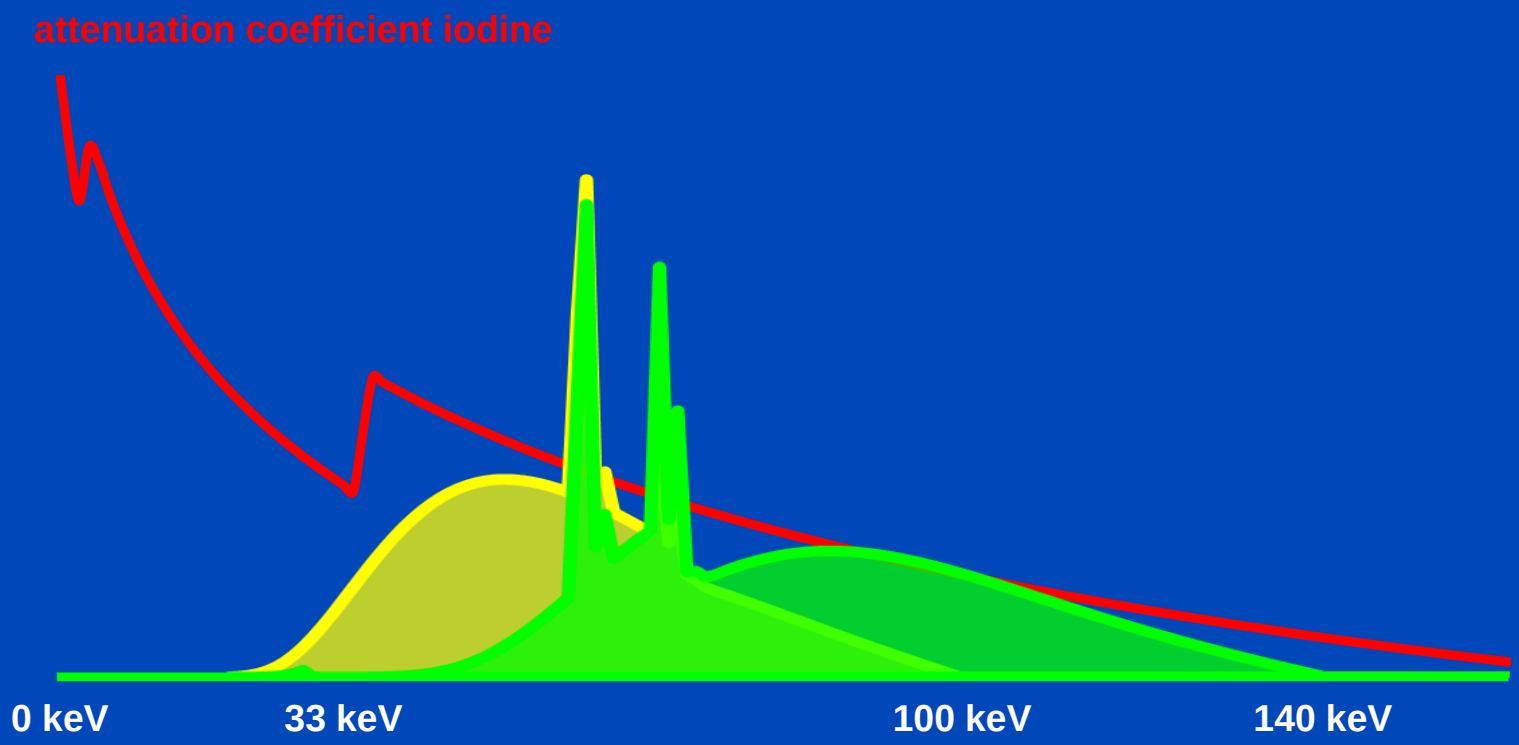
Energy Integrating
(Detected Spectra at 100 kV and 140 kV)



$$\text{Signal}_{\text{EI}} = \int dE\, E\; N(E)$$

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

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



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

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

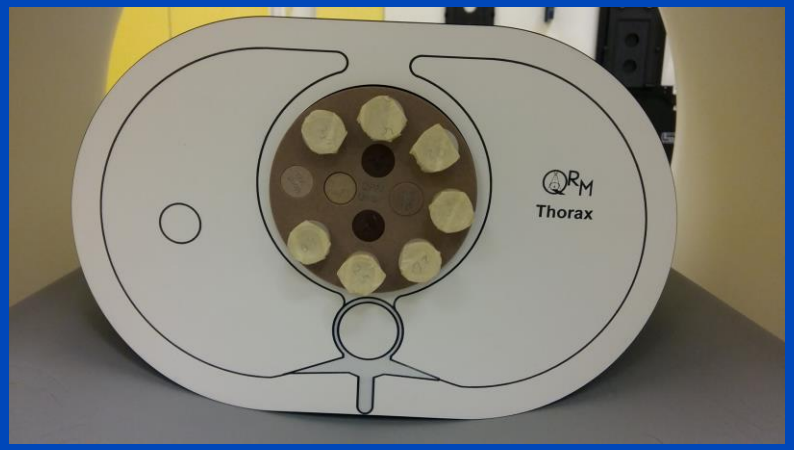
Aim

To evaluate the iodine CNRD improvements obtained with photon-counting (PC) CT compared to using a conventional energy-integrating (EI) CT detector.

Materials & Methods

Phantoms

- Anthropomorphic thorax and liver phantom
- Three different phantom sizes
  - Small (200 × 300 mm)
  - Medium (250 × 350 mm)
  - Large (300 × 400 mm)



Materials & Methods

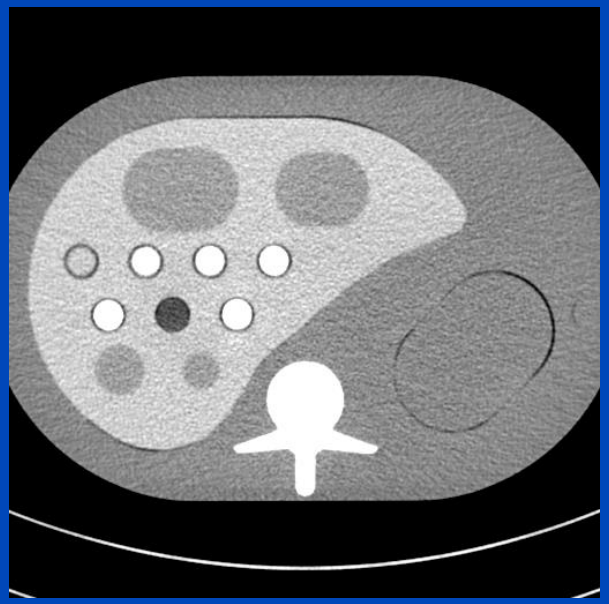
Image Acquisition and Reconstruction

- Images are acquired at **different tube voltages:**
  - 80 kV at 4.40 mGy ($CTDI_{vol\ 32\ cm}$) using 200 mAs_{eff}
  - 100 kV at 9.20 mGy ($CTDI_{vol\ 32\ cm}$) using 200 mAs_{eff}
  - 120 kV at 15.03 mGy ($CTDI_{vol\ 32\ cm}$) using 200 mAs_{eff}
  - 140 kV at 21.76 mGy ($CTDI_{vol\ 32\ cm}$) using 200 mAs_{eff}
- Pitch in all acquisitions was 0.6.
- Collimation for EI (32×0.6 mm) and PC (32×0.5 mm) was matched as close as possible, i.e. geometric efficiency is 80% vs. 82%
- Reconstruction is performed with **matched spatial resolution** using a D40f kernel onto a grid with a voxel spacing of 0.54 mm and a slice thickness of 1.2 mm.

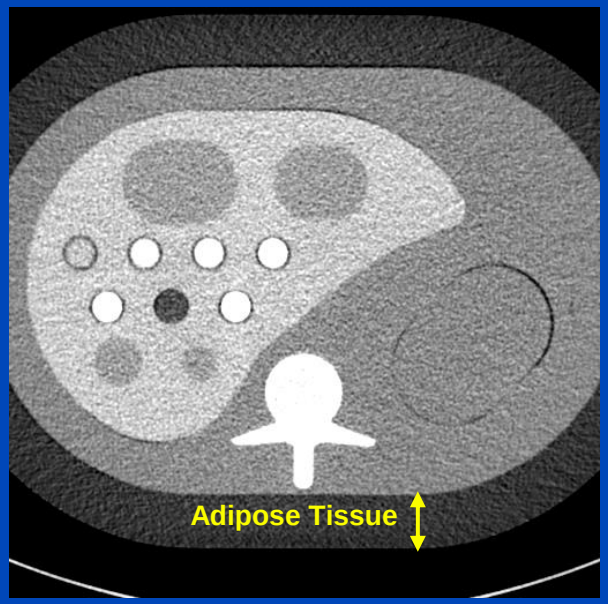
Materials & Methods

Reconstruction Examples @ 80 kV

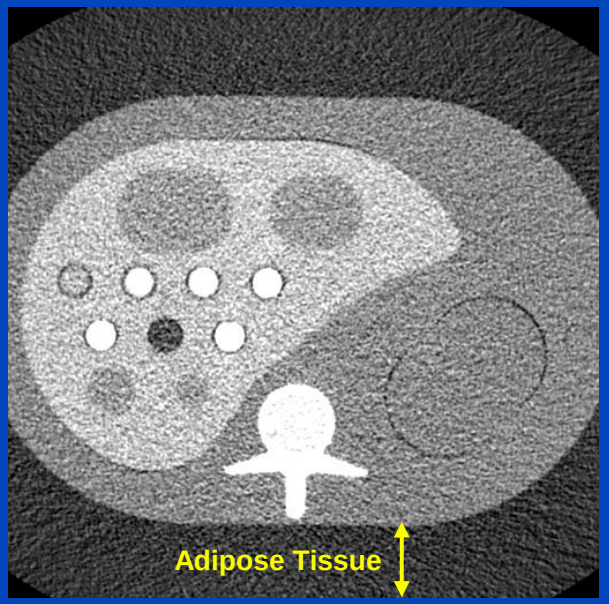
Small (200 × 300 mm)



Medium (250 × 350 mm)



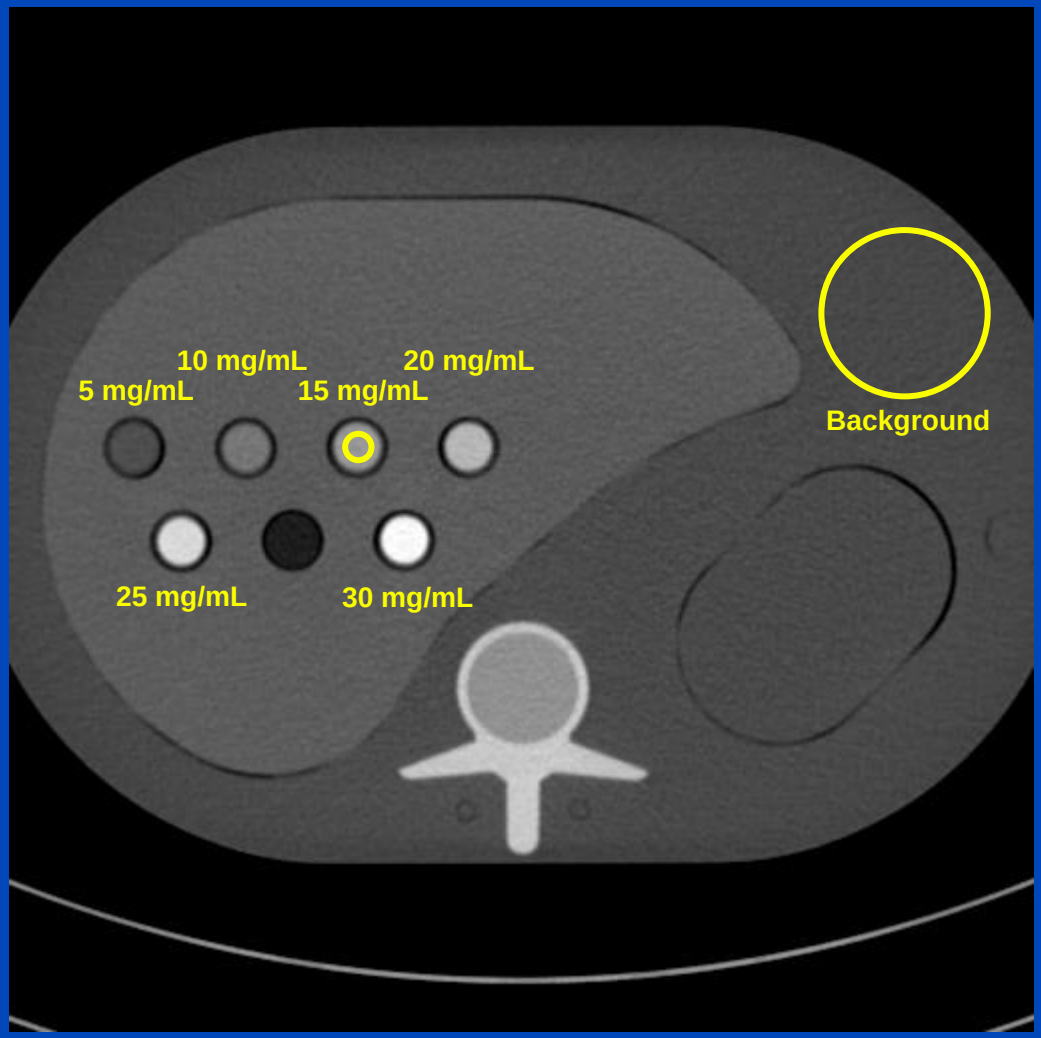
Large (300 × 400 mm)



C/W=0 HU/400HU

Materials & Methods

Regions of Interest



C/W=180 HU/600HU

Materials & Methods

CNRD Computations

- **The contrast-to-noise ratio (CNR) could be used as a figure of merit:**

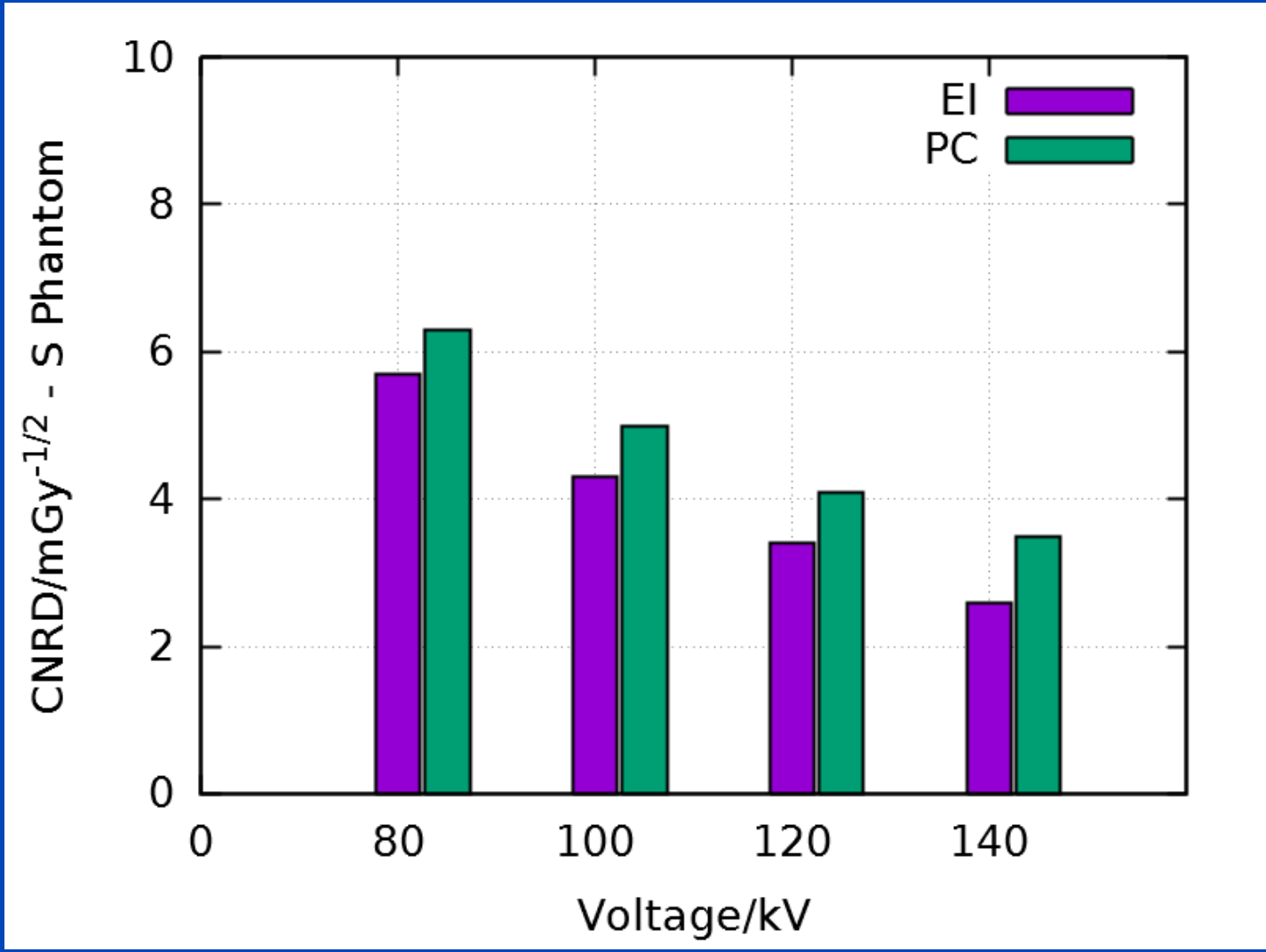
$$\mathrm{CNR} = \frac{\mathrm{Contrast}}{\mathrm{Noise}} = \frac{|\mu_{\mathrm{ROI\ 1}} - \mu_{\mathrm{ROI\ 2}}|}{\sqrt{\sigma^2_{\mathrm{ROI\ 1}} + \sigma^2_{\mathrm{ROI\ 2}}}}$$

- **To account for different tube voltages and different dose levels we rather use the dose-normalized CNR (CNRD):**

$$\mathrm{CNRD} = \frac{\mathrm{Contrast}}{\mathrm{Noise} \cdot \sqrt{\mathrm{Dose}}} = \frac{\mathrm{CNR}}{\sqrt{\mathrm{Dose}}}$$

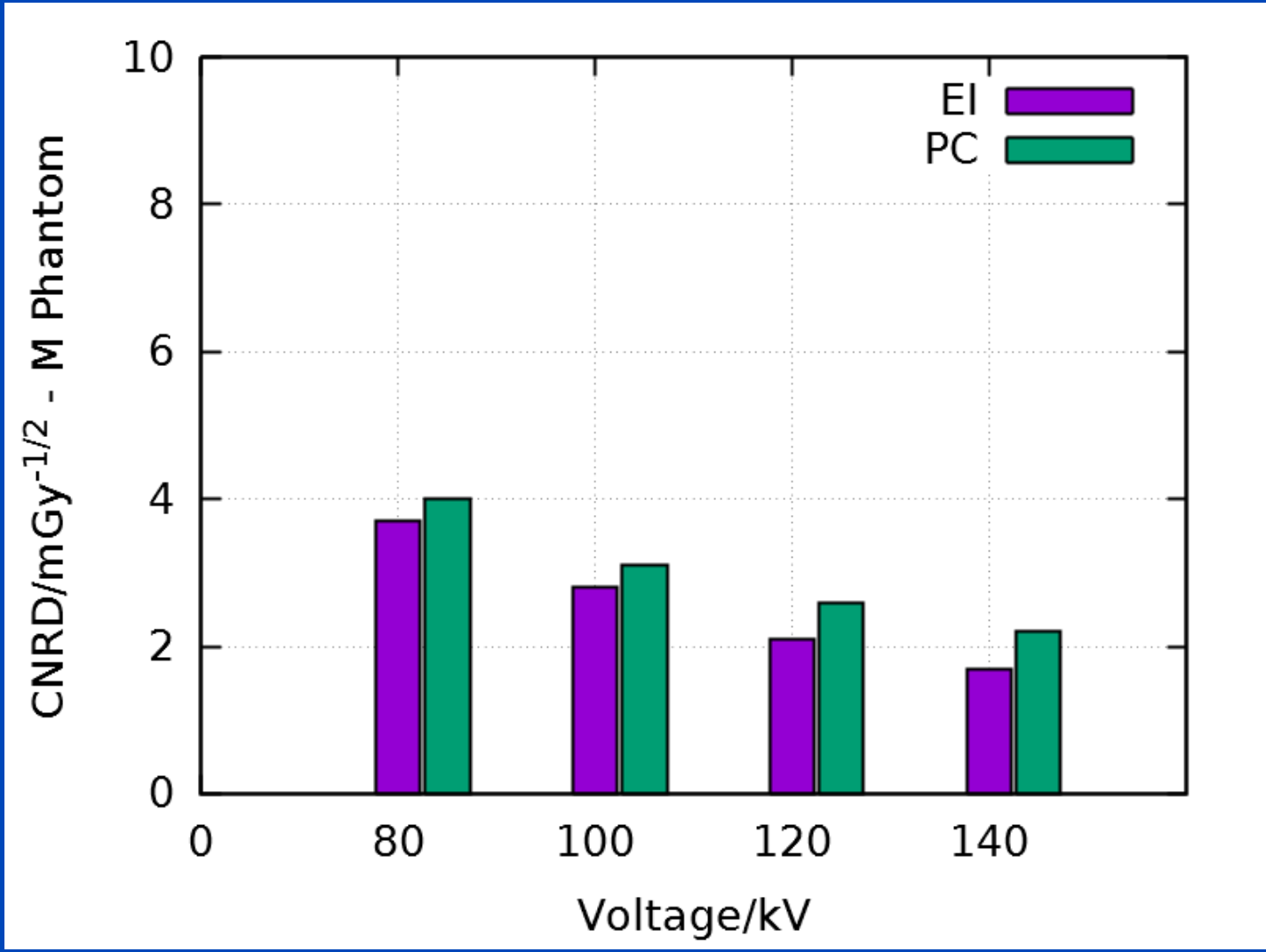
Results

CNRD – Small Phantom



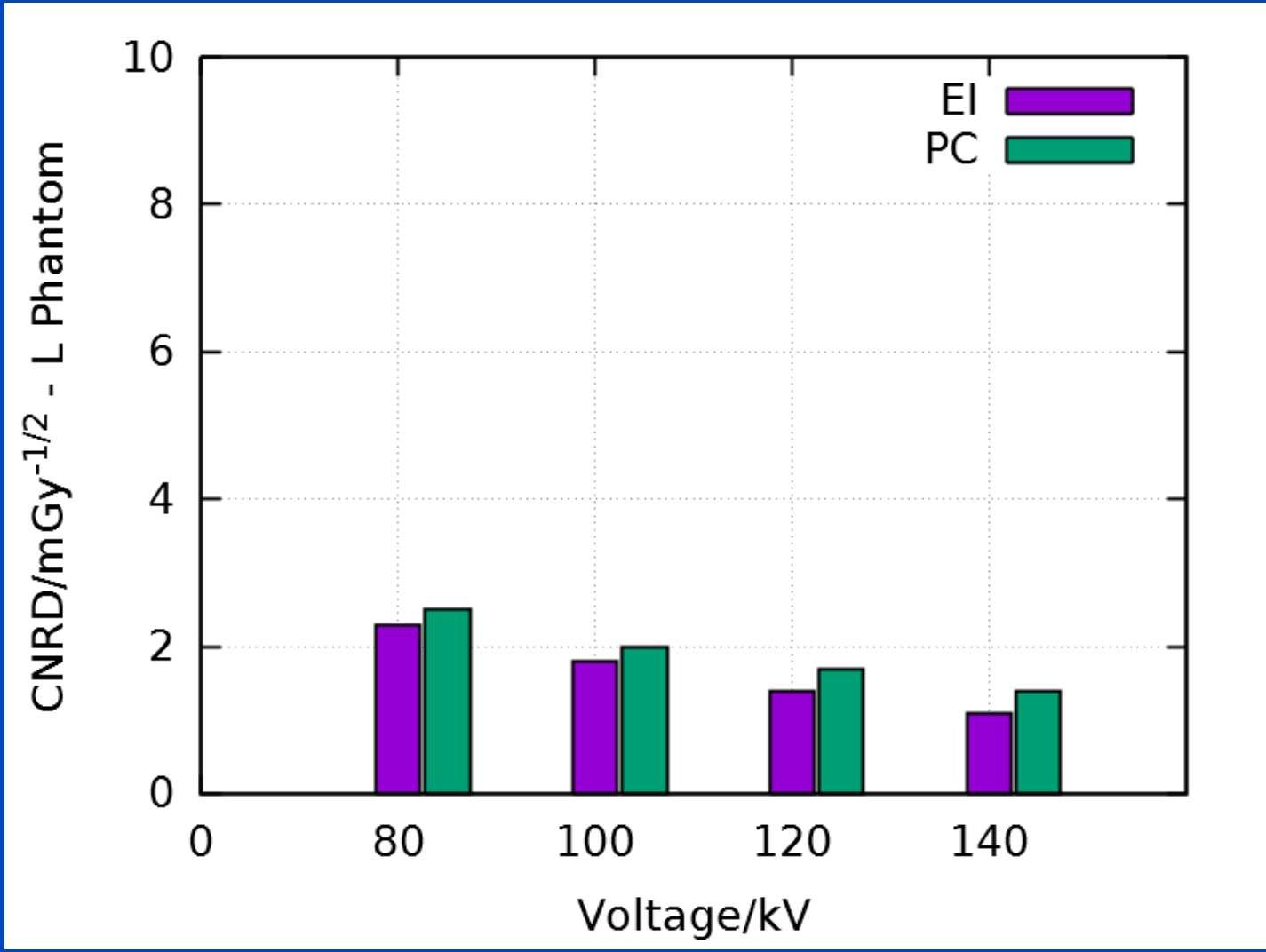
Results

CNRD – Medium Phantom



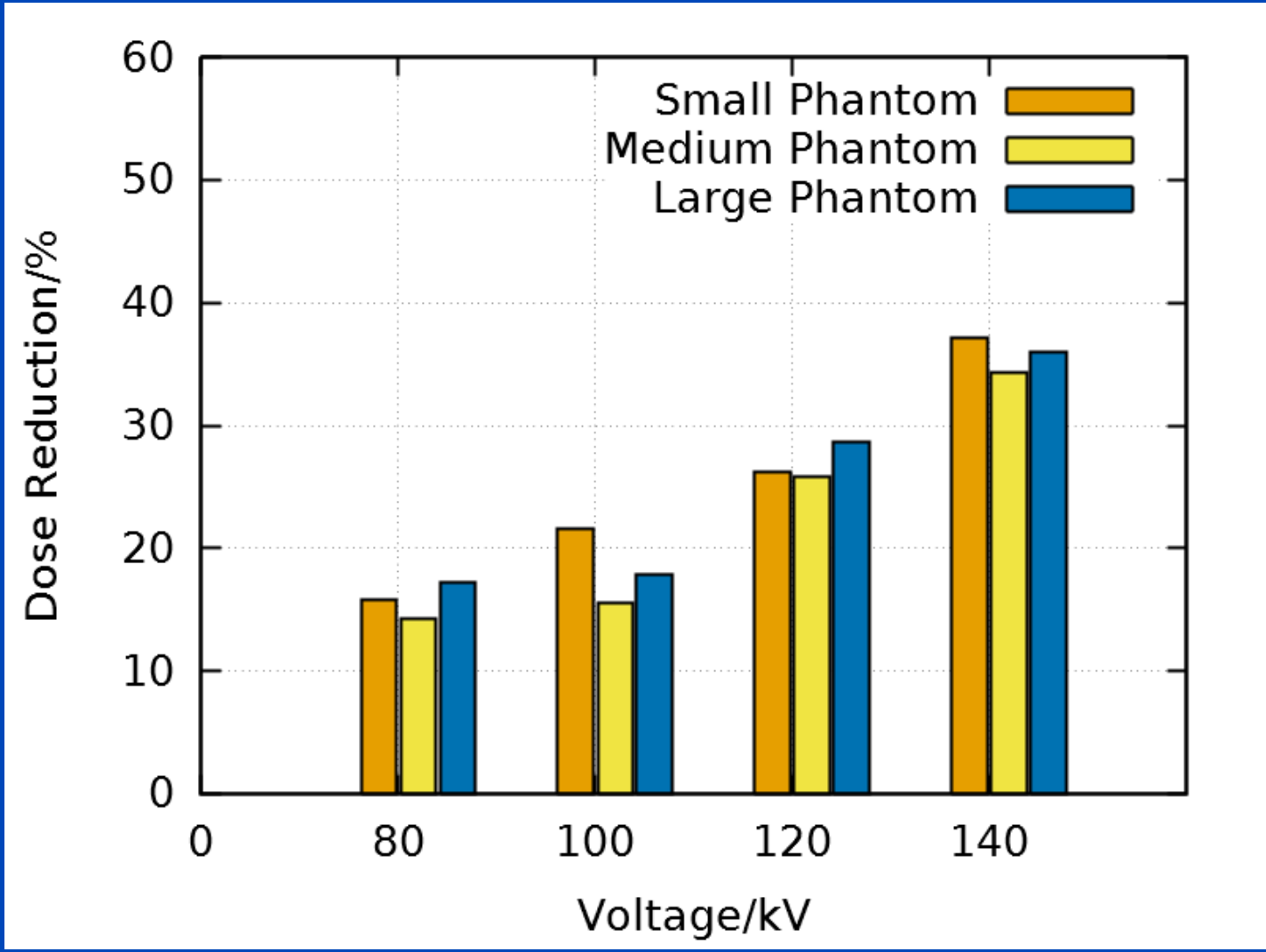
Results

CNRD – Large Phantom



PC vs. EI

Potential Dose Reduction



PC vs. EI

… in Numbers

Tube Voltage /kV	Small	Medium	Large	Average over all Phantoms
Relative CNRD Improvement				
80	9.0%	7.9%	9.9%	**8.9**%
100	12.9%	8.8%	10.4%	**10.7**%
120	16.4%	16.1%	18.3%	**16.9**%
140	26.0%	23.4%	25.0%	**24.8**%
Potential Dose Reduction				
80	15.8%	14.2%	17.2%	**15.7**%
100	21.6%	15.6%	17.9%	**18.4**%
120	26.2%	25.8%	28.6%	**26.9**%
140	37.1%	34.3%	36.0%	**35.8**%

Summary & Conclusion

- **Iodine-CNRD in the PC system is superior compared to the EI system.**
- **In particular, CNRD improvements between 7% and 27% are observed.**
- **The improvements correspond to potential radiation dose reductions between 12% and 38%.**
- **Imaging using a PC detector seems particularly promising for small patients at low tube voltages and for measurements at 140 kV.**

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- **Imaging using a PC detector seems particularly promising for small patients at low tube voltages and for measurements at 140 kV.**

Iodine CNRD will improve when switching from today‘s energy-integrating CT to tomorrow‘s photon-counting CT.

Thank You!

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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.