Patienten-adaptierte Schwellwerteinstellungen für Optimalen Jodkontrast in einem Photonenzählenden Ganzkörper-CT

Patient-Specific Threshold Settings for Optimal Iodine Contrast in a Whole-Body Photon-Counting CT

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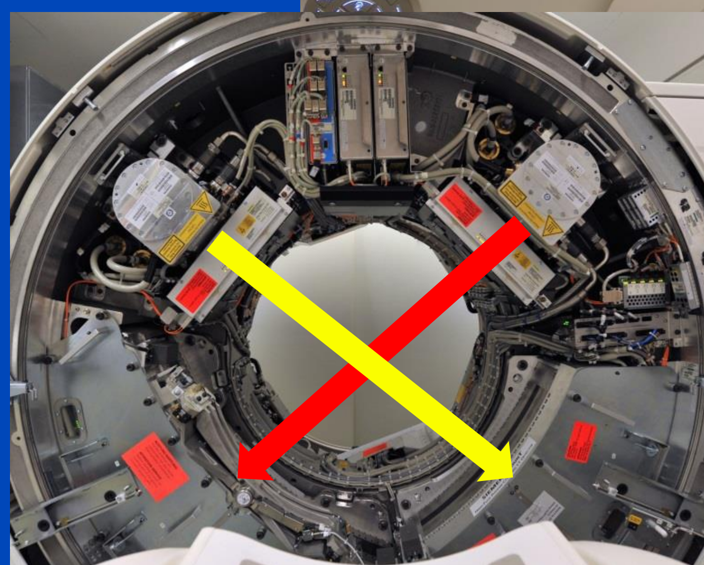
DEUTSCHES KREBSFORSCHUNGSZENTRUM IN DER HELMHOLTZ-GEMEINSCHAFT

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)

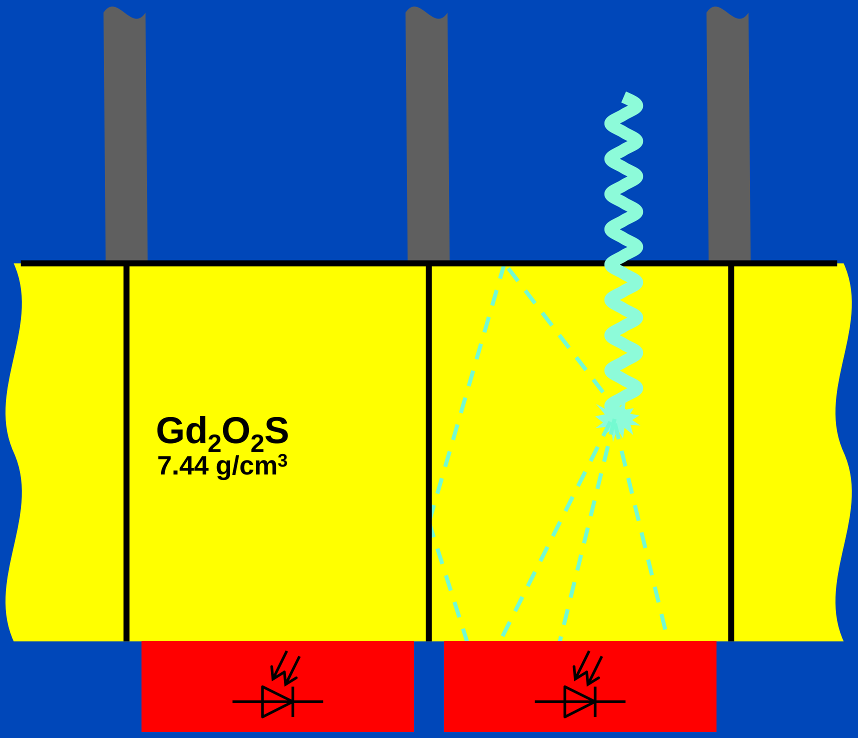


Siemens prototype, not commercially available.

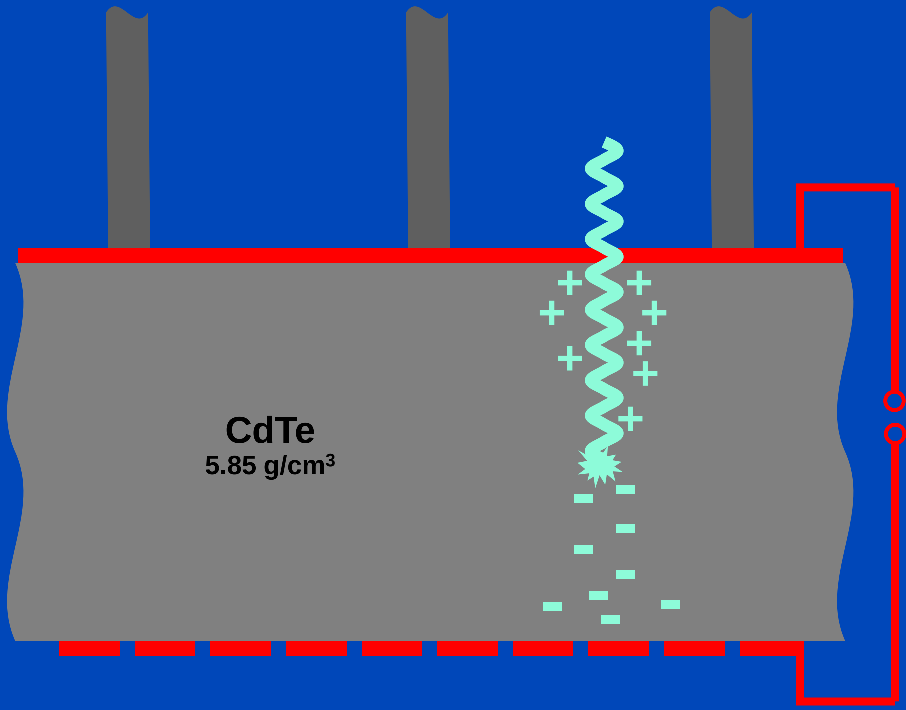
Photon-Counting CT

Counting Single Photons

Energy-Integrating (Today)



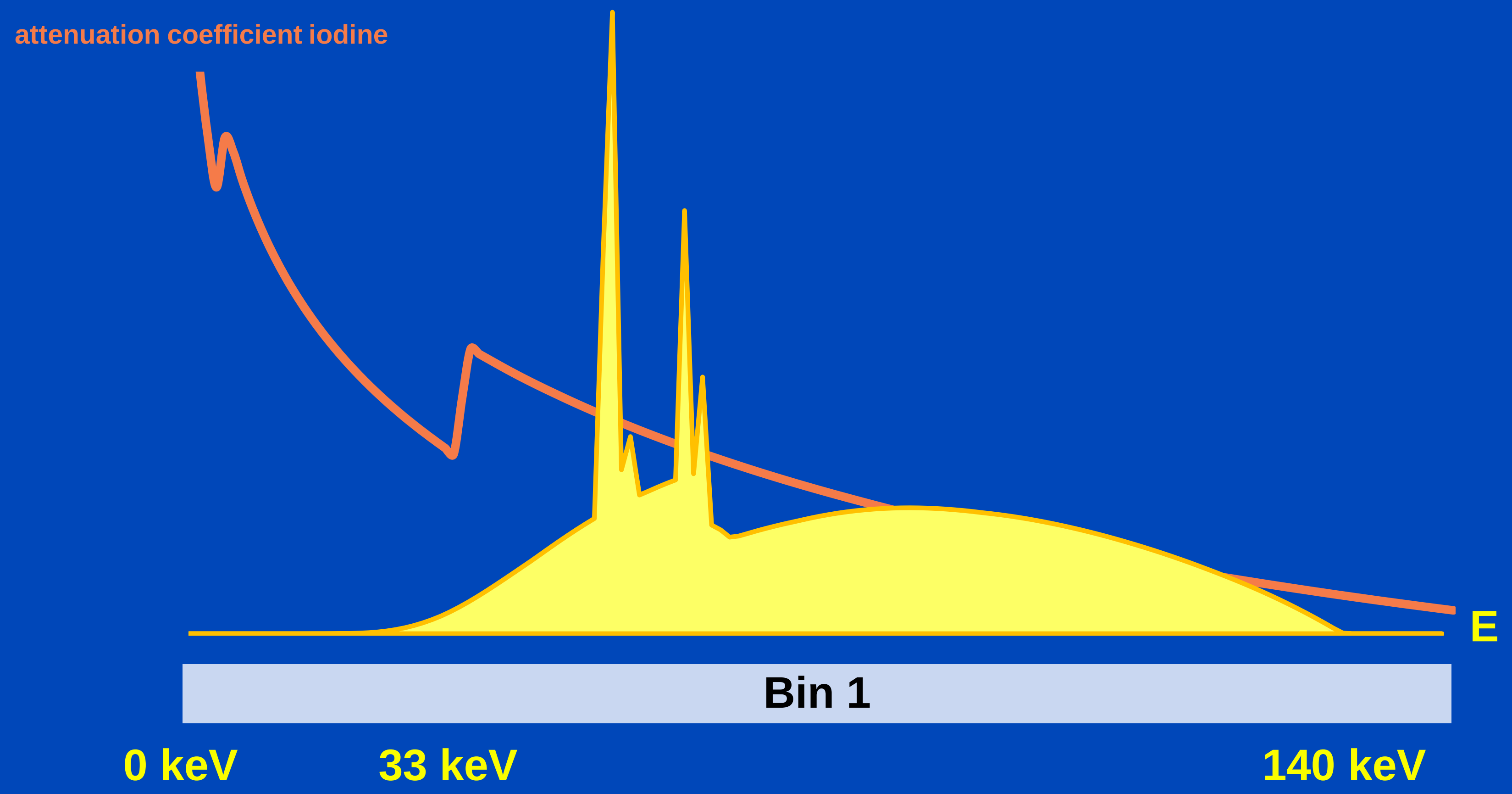
Photon-Counting (Future)



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

Photon-Counting CT

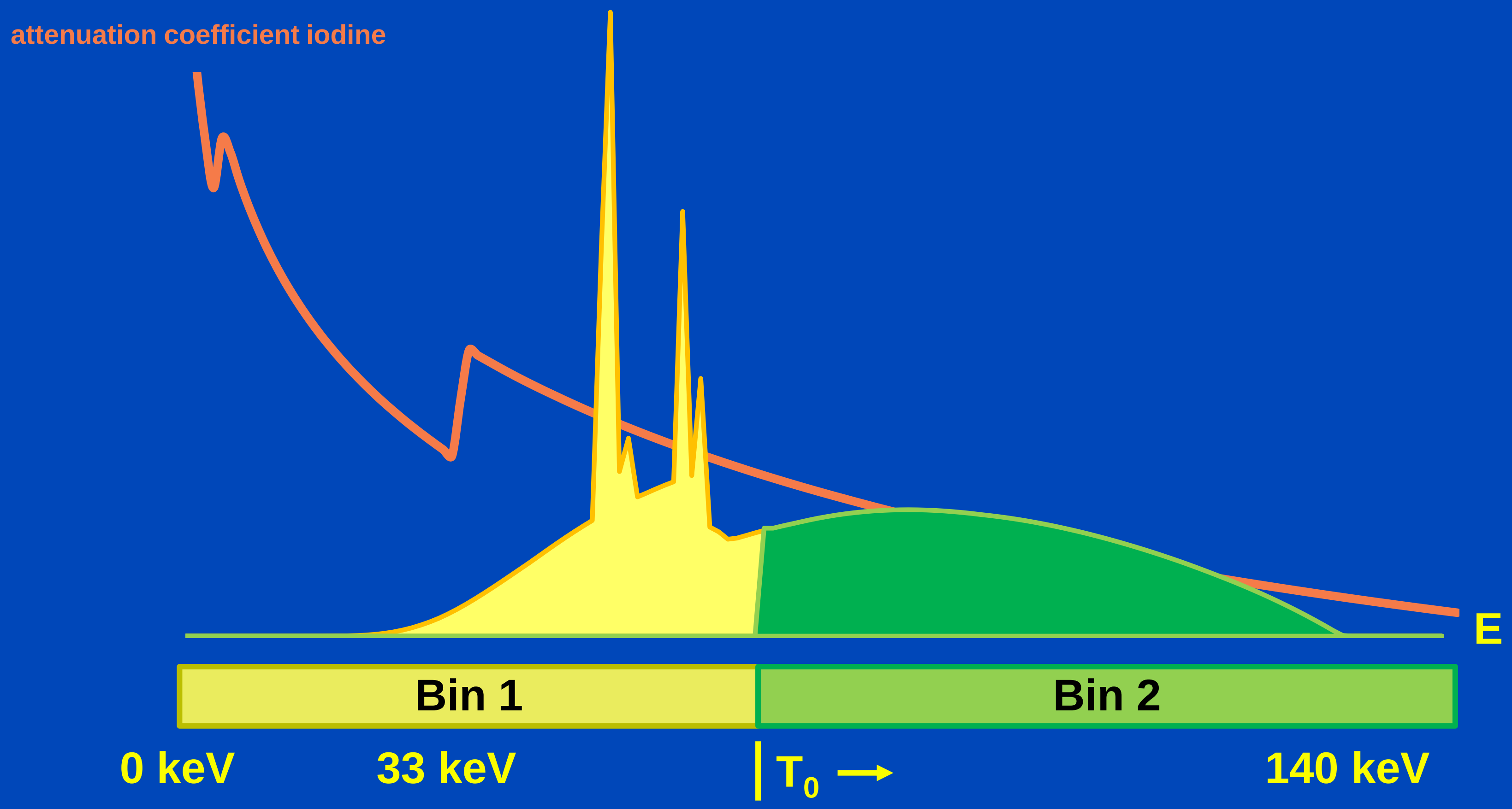
Spectral/Energy Information



Schematic 140 kV spectrum after 32 cm water.

Photon-Counting CT

Spectral/Energy Information



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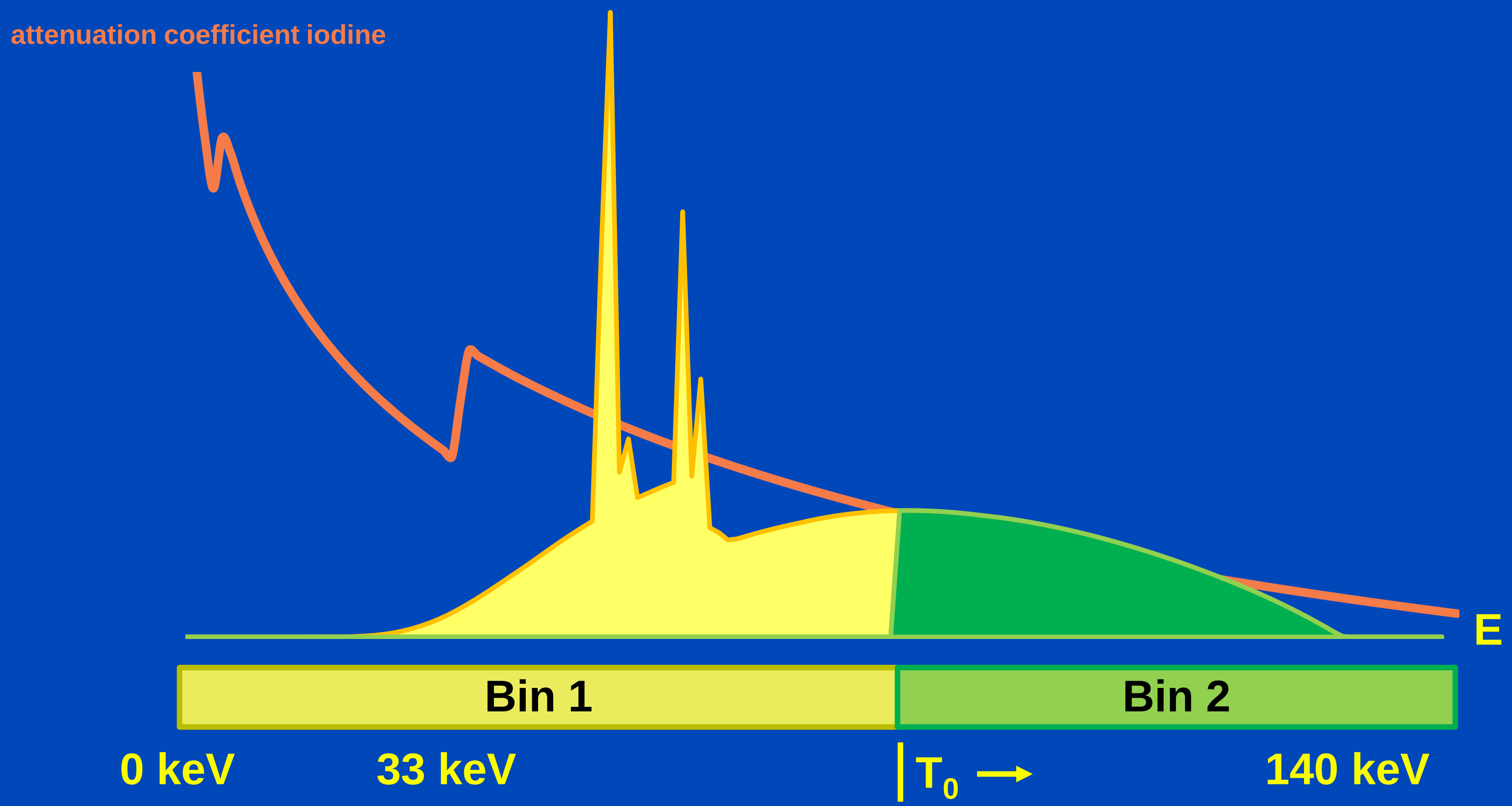
Photon-Counting CT

Spectral/Energy Information



Schematic 140 kV spectra after 32 cm water.

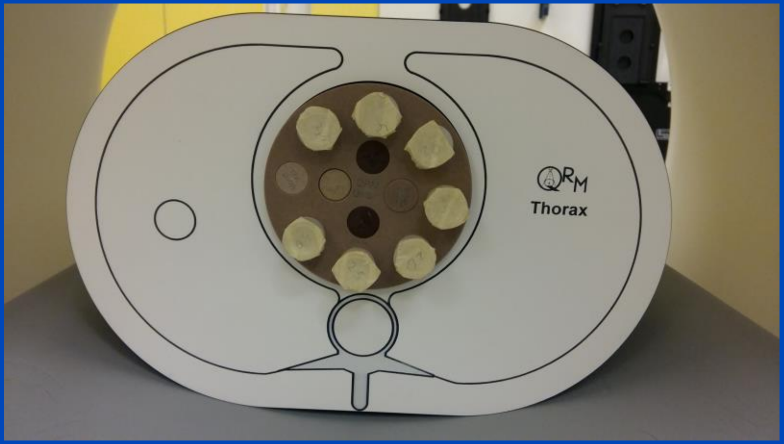
Aim

To evaluate iodine CNRD as function of threshold settings using a photon-counting (PC) detector compared to a conventional energy-integrating (EI) CT detector.

Materials & Methods

Phantoms

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



Materials & Methods

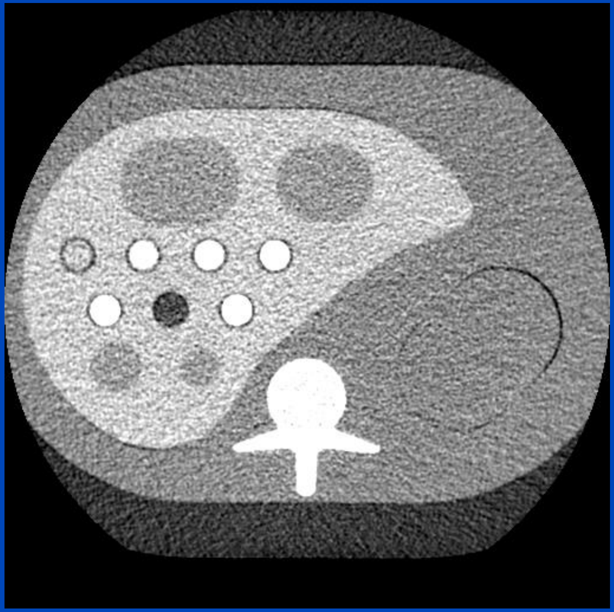
Image Acquisition and Reconstruction

- 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}
- However, in the following only reasonable combinations are considered:
  - 80 kV is used for the small patient
  - 100 kV is used for the medium patient
  - 140 kV is used for the large patient
- In case of the photon-counting detector, the thresholds were varied in the permissible range between 50 keV and 90 keV in steps of 5 keV.

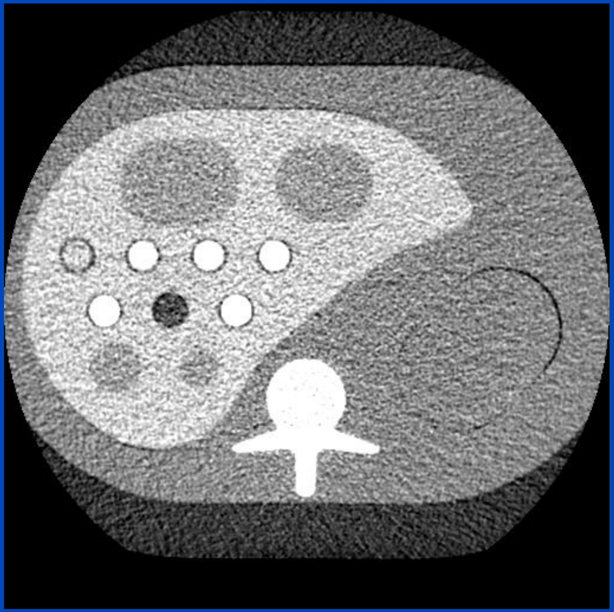
Materials & Methods

Example: 80 kV, Medium Phantom

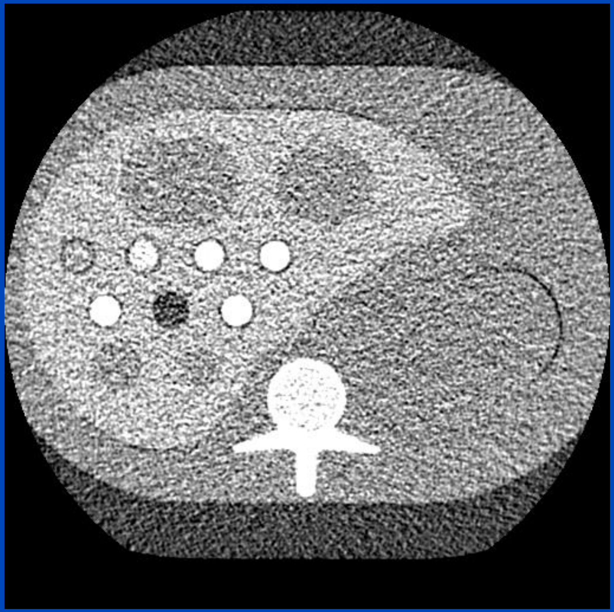
Complete Spectrum
(20 keV – 80 keV)



Bin 1
(20 keV – 50 keV)



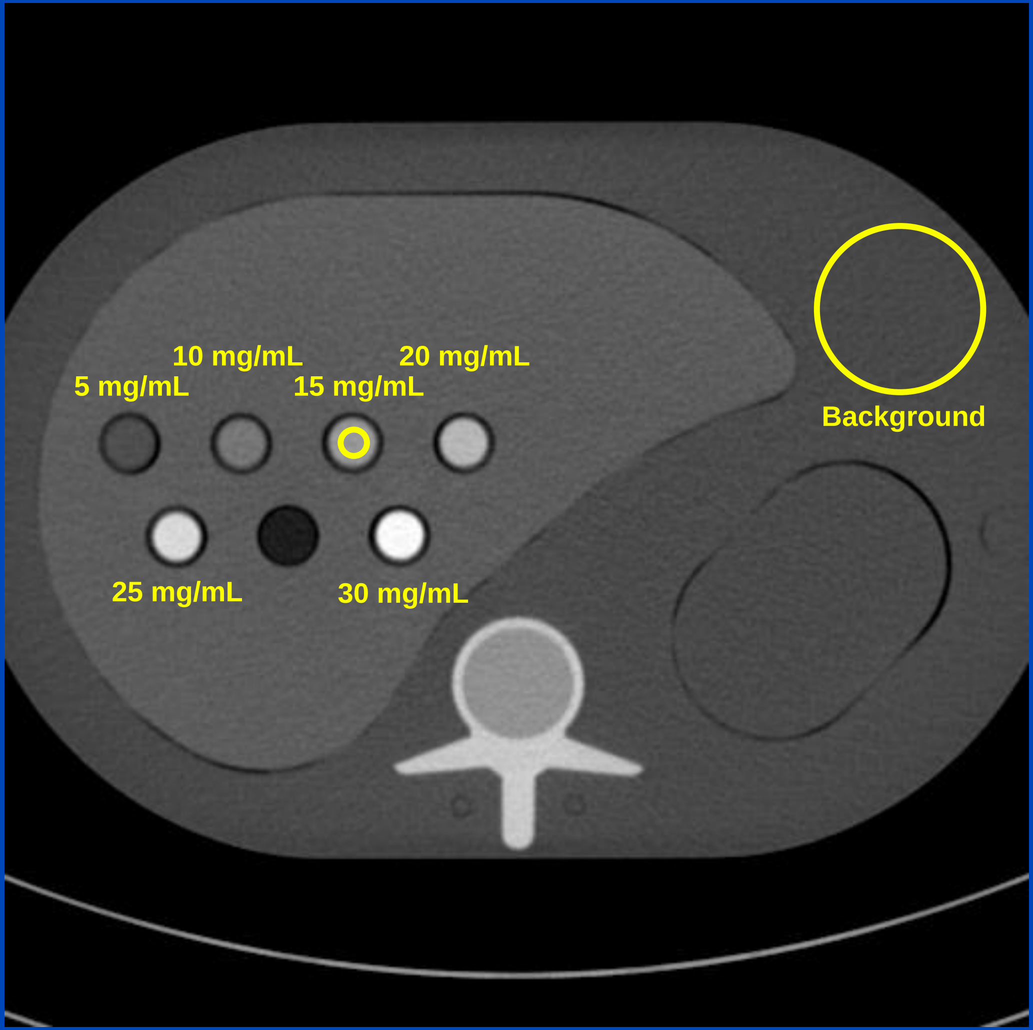
Bin 2
(50 keV – 80 keV)



C/W=0 HU/400 HU

Materials & Methods

Regions of Interest



C/W=180 HU/600 HU

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):

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

Materials & Methods

CNRD Optimization – Bin Combination

- To optimize CNRD **in case of two bins**, we use an inverse variance weighting.
- In particular, weights for bin b are given as

$$w_b \propto \frac{C_b}{V_b}$$

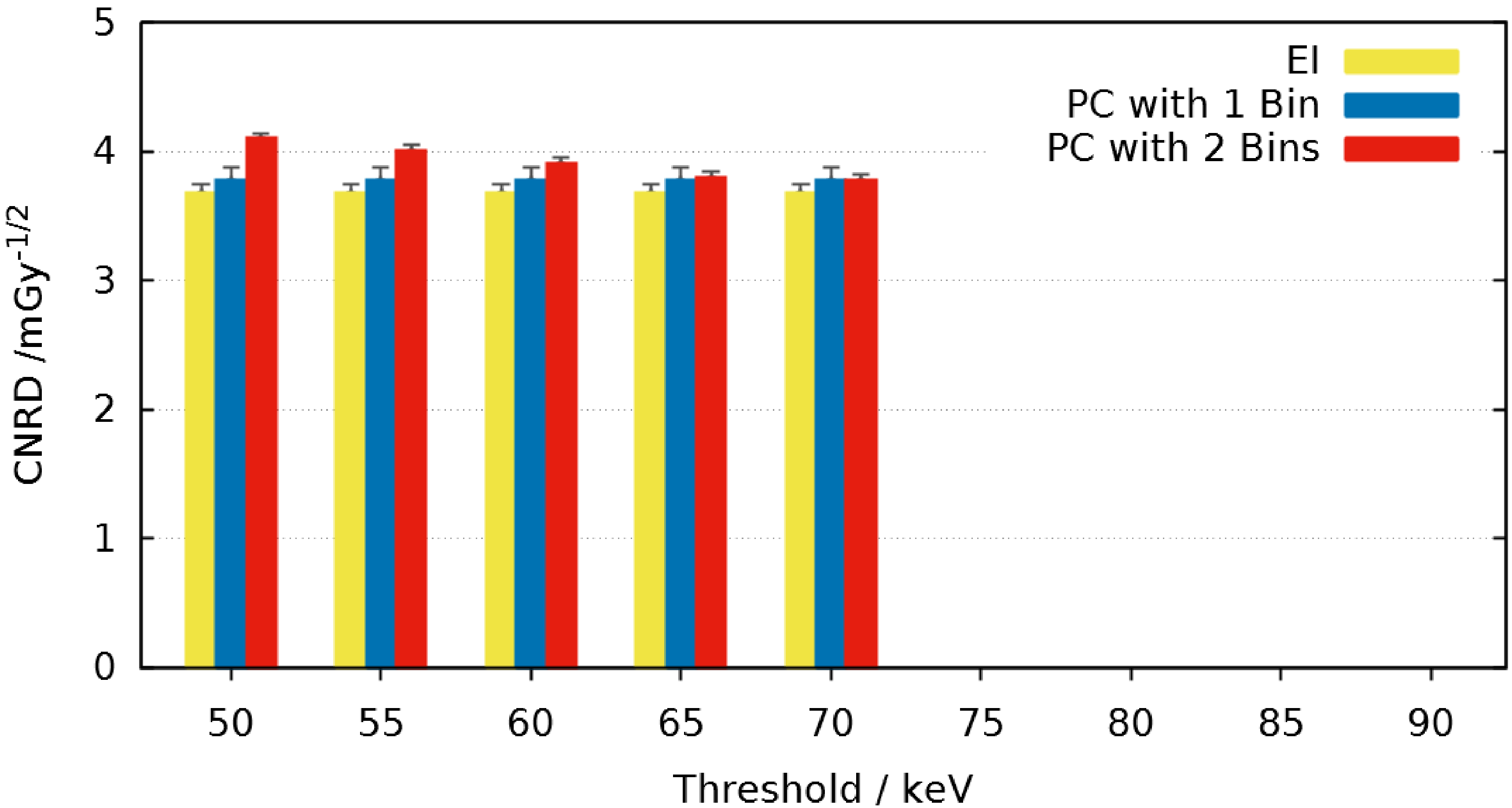
with C_b being the contrast in the respective bin image and V_b being the variance in the ROIs used to compute C_b.

- The resulting CNR is

$$\mathrm{CNR}^2 = \frac{\left(\sum_b w_b C_b\right)^2}{\sum_b w_b^2 V_b}$$

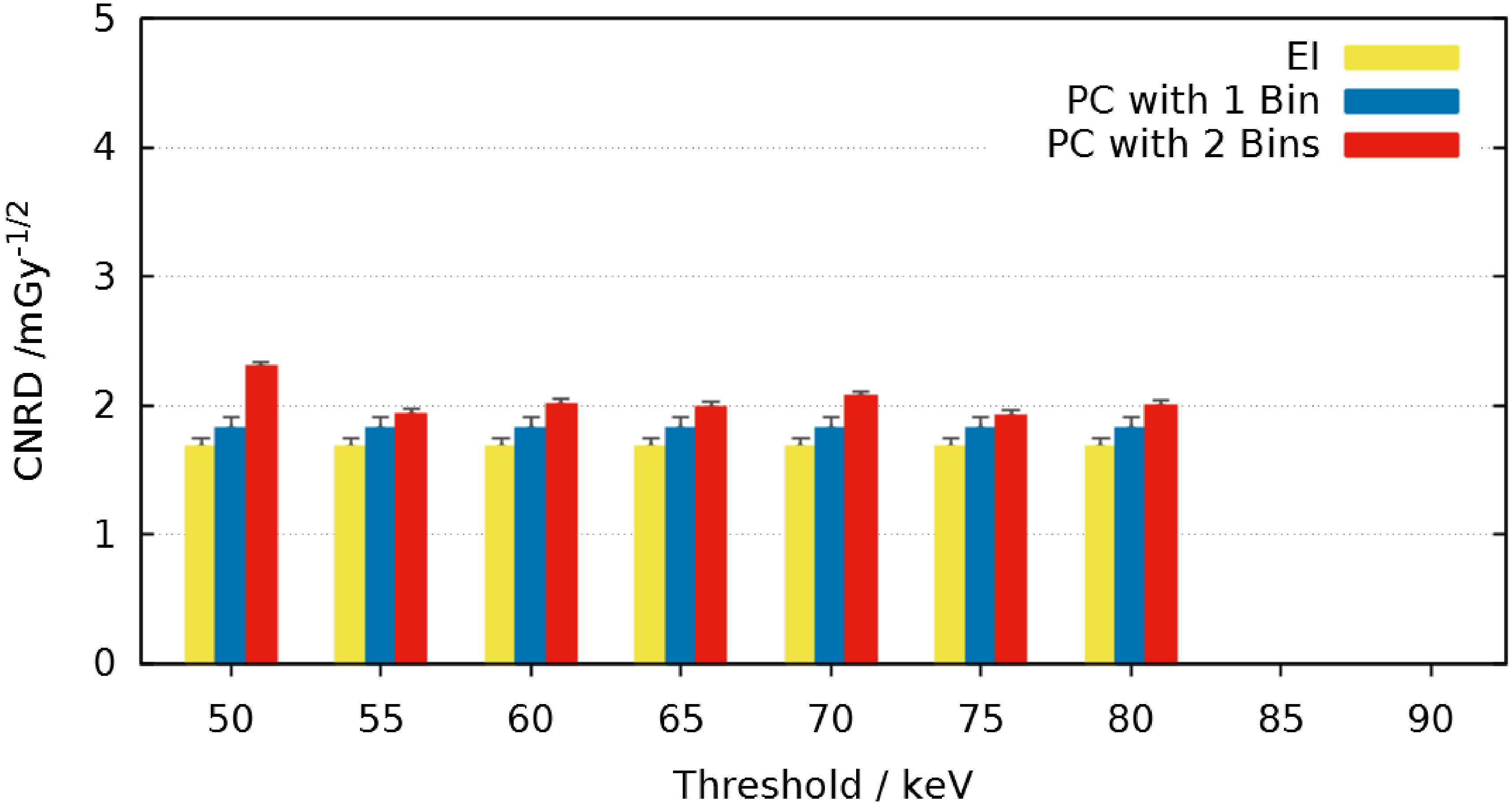
CNRD

Small Phantom @ 80 kV



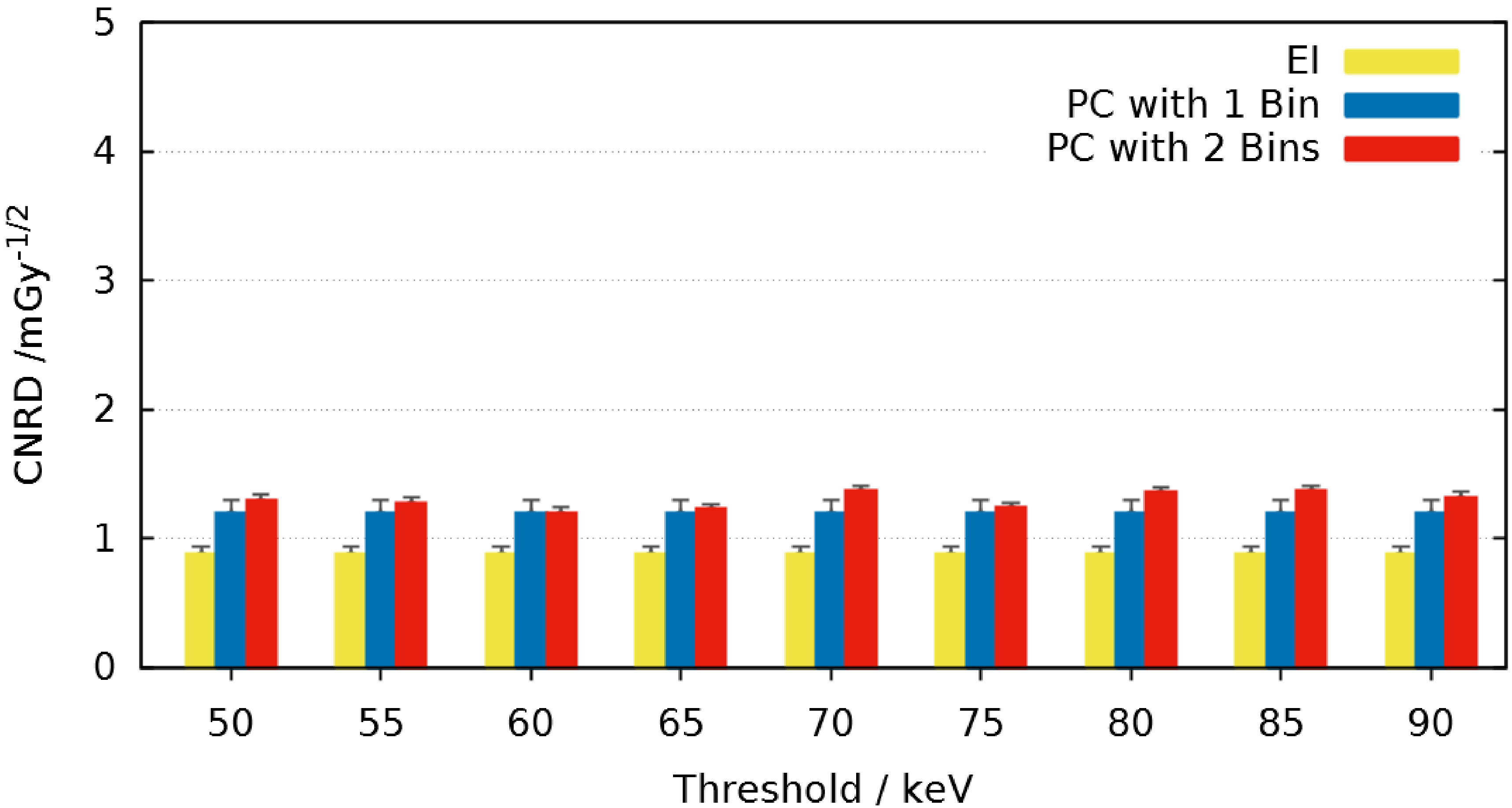
CNRD

Medium Phantom @ 100 kV



CNRD

Large Phantom @ 140 kV



Summary & Conclusion

- The photon-counting detector is always superior to the energy-integrating detector in terms of iodine CNRD.
- This finding holds for all considered threshold settings, all tube voltages and all phantom sizes.
- In doubt, one may use a threshold of 50 keV.
- The threshold settings pose an additional degree of freedom and might be used in future applications.

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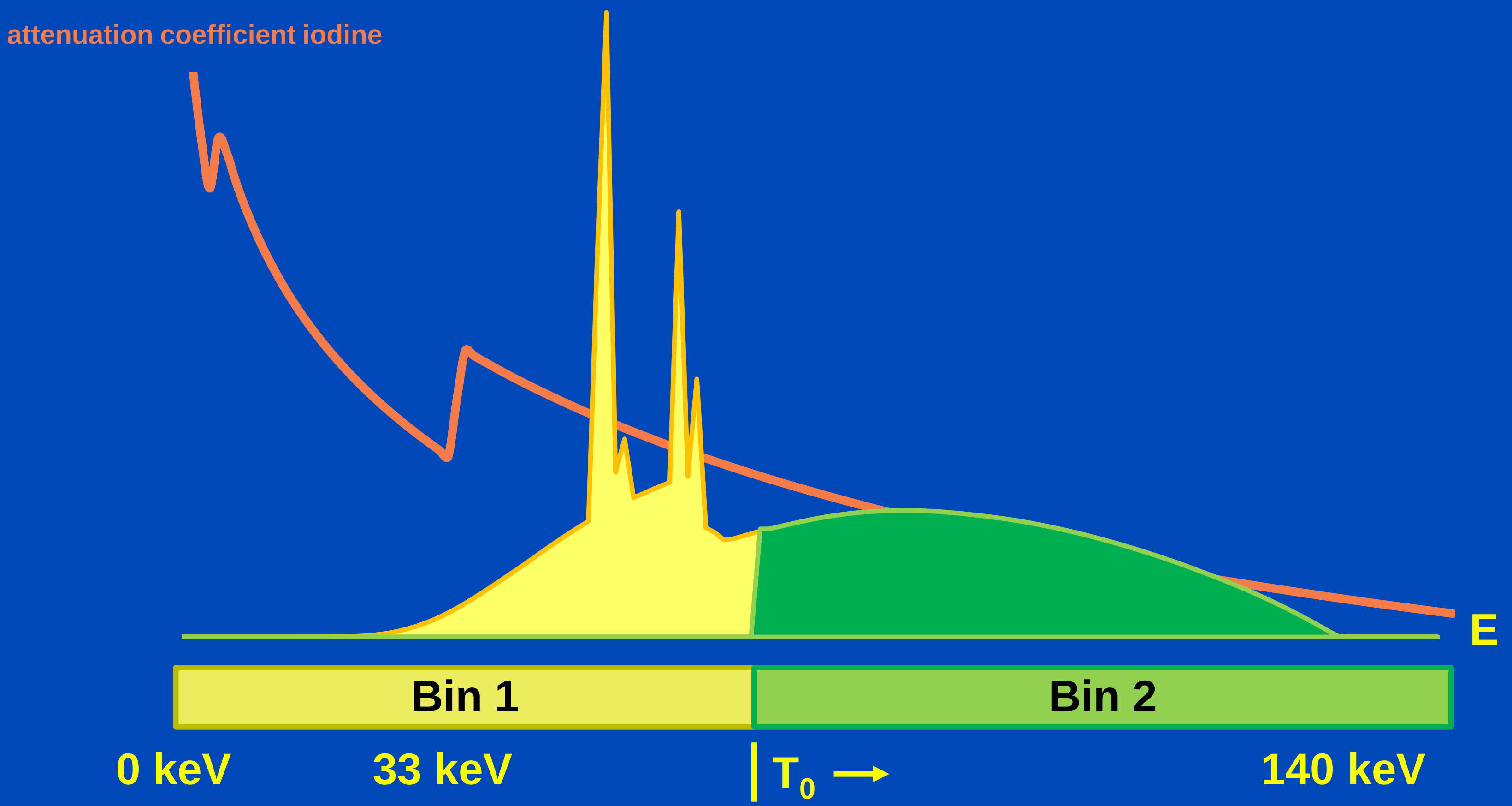
What‘s next?

Outlook

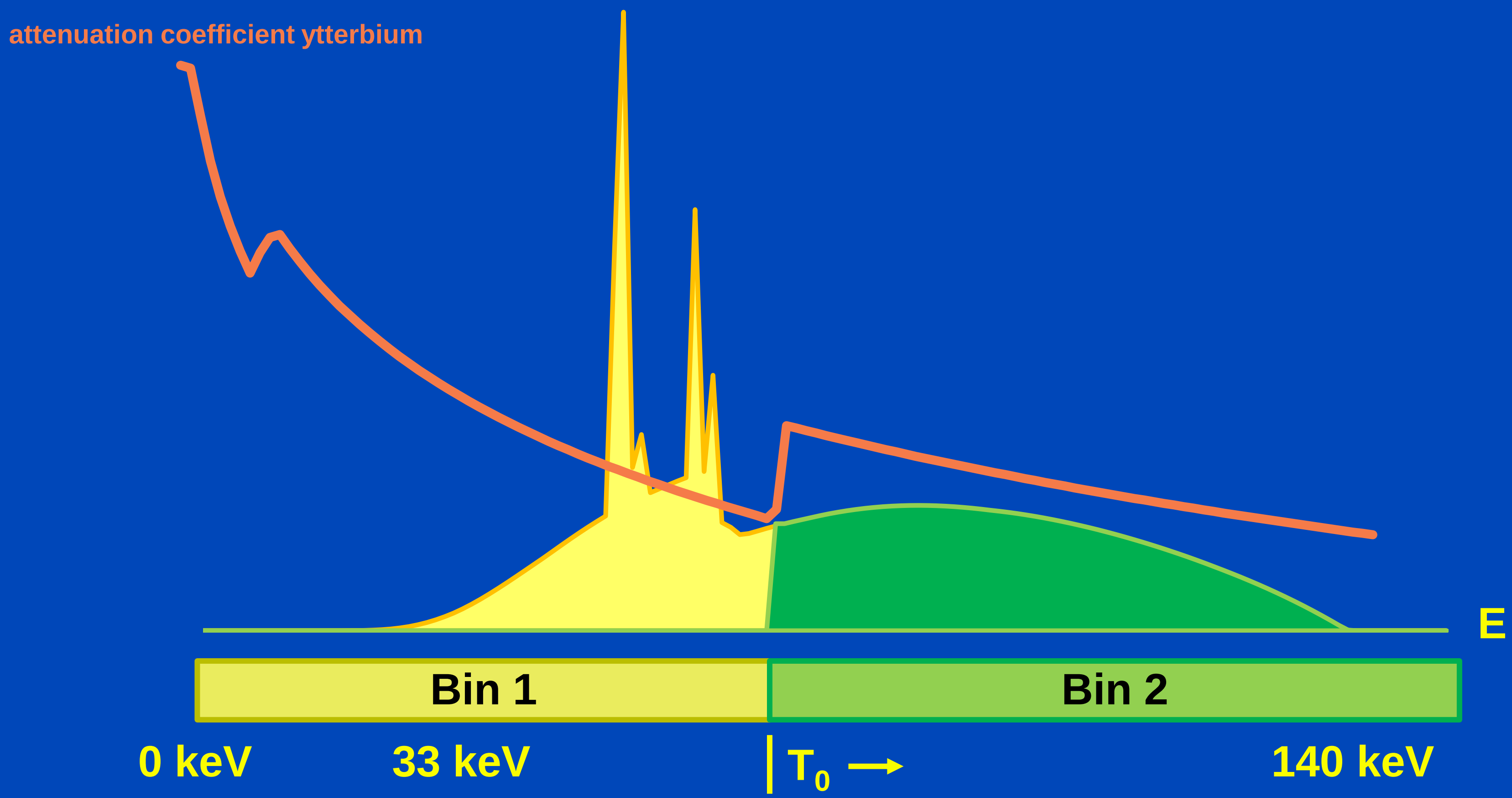
k-Edge Imaging



Schematic 140 kV spectra after 32 cm water.

Outlook

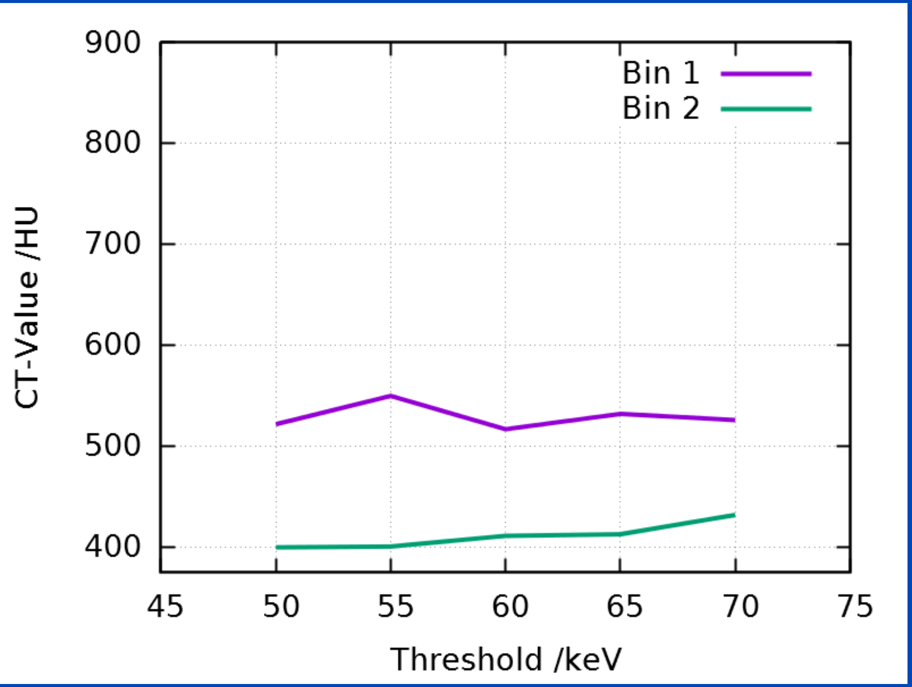
k-Edge Imaging



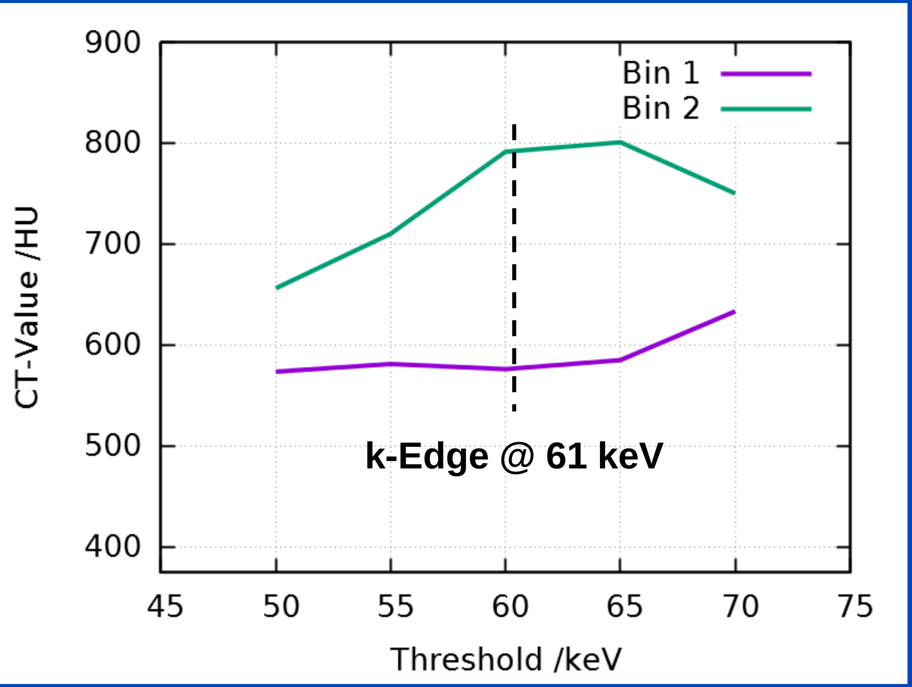
Schematic 140 kV spectra after 32 cm water.

Outlook
k-Edge Imaging

Iodine



Ytterbium



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- The photon-counting detector is always superior to the energy-integrating detector in terms of iodine CNRD.
- This finding holds for all considered threshold settings, all tube voltages and all phantom sizes.
- In doubt, one may use a threshold of 50 keV.
- The threshold settings pose an additional degree of freedom and might be used in future applications.
- Clinical k-edge imaging seems within reach.
- However, novel contrast agents are required.

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.