Iron Quantification in Dual-Source Dual-Energy Photon-Counting CT With Up To 4 Energy Bins

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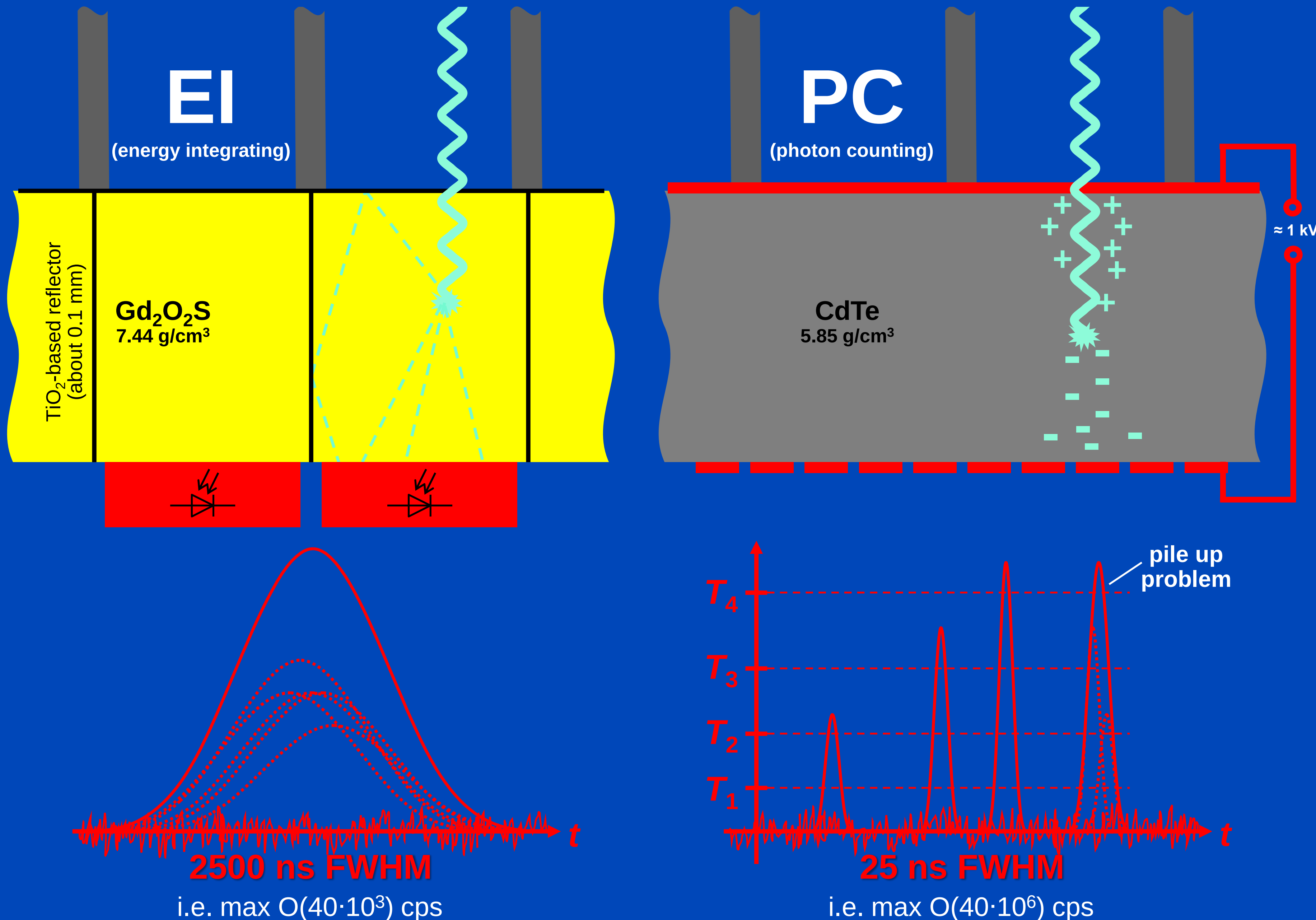
DEUTSCHES KREBSFORSCHUNGSZENTRUM IN DER HELMHOLTZ-GEMEINSCHAFT

Aim

To compare the performance of a dual-source dual-energy photon-counting CT system for iron imaging to a conventional dual-source energy-integrating CT.

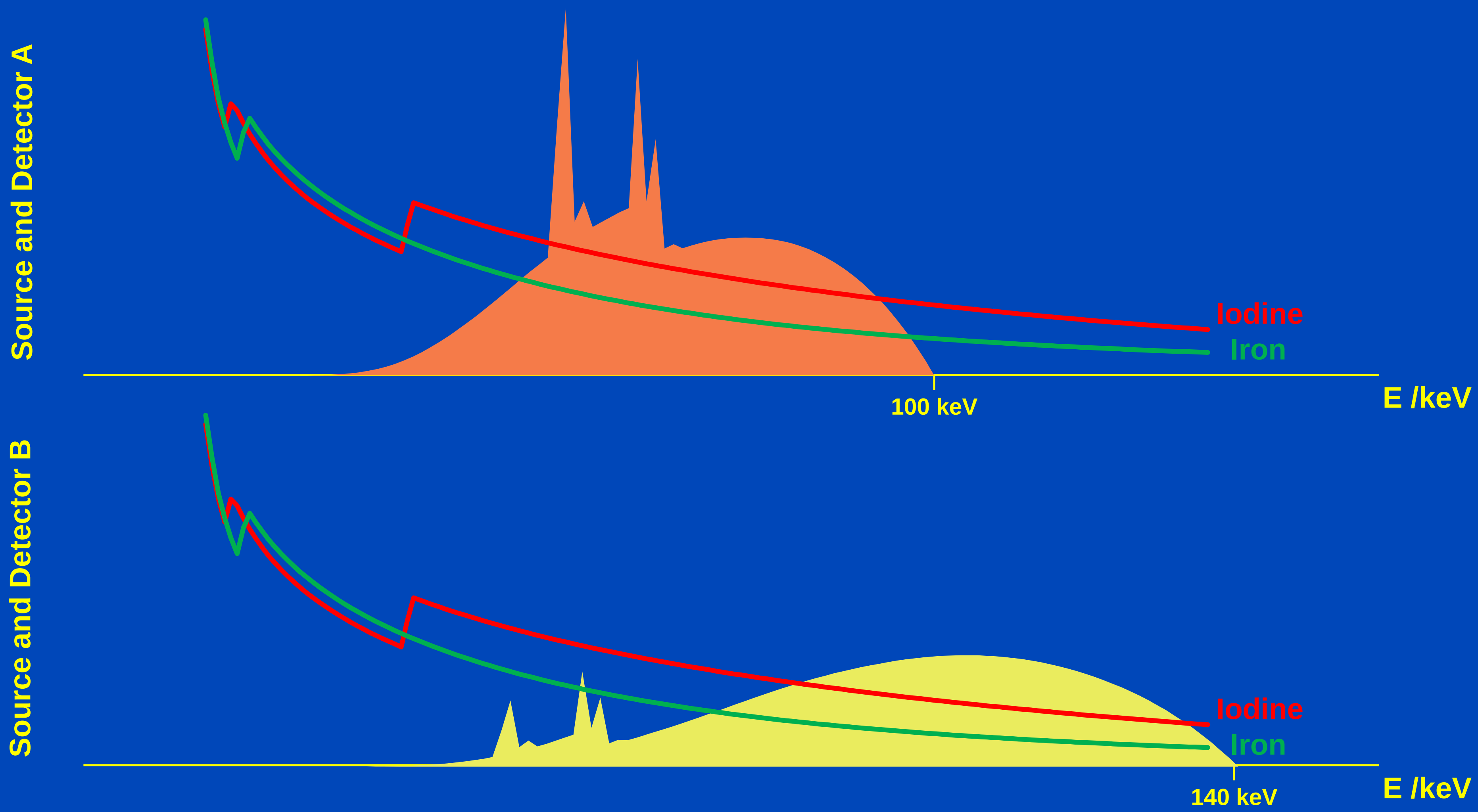
Indirect Conversion | Direct Conversion



Requirements for CT: up to 10^9 x-ray photon counts per second per mm². Hence, photon counting only achievable for direct converters.

Energy-Integrating Detector

100 kV / Sn 140 kV, 2 Spectra



Simulation: prefiltered spectra as seen after a 320 mm patient.

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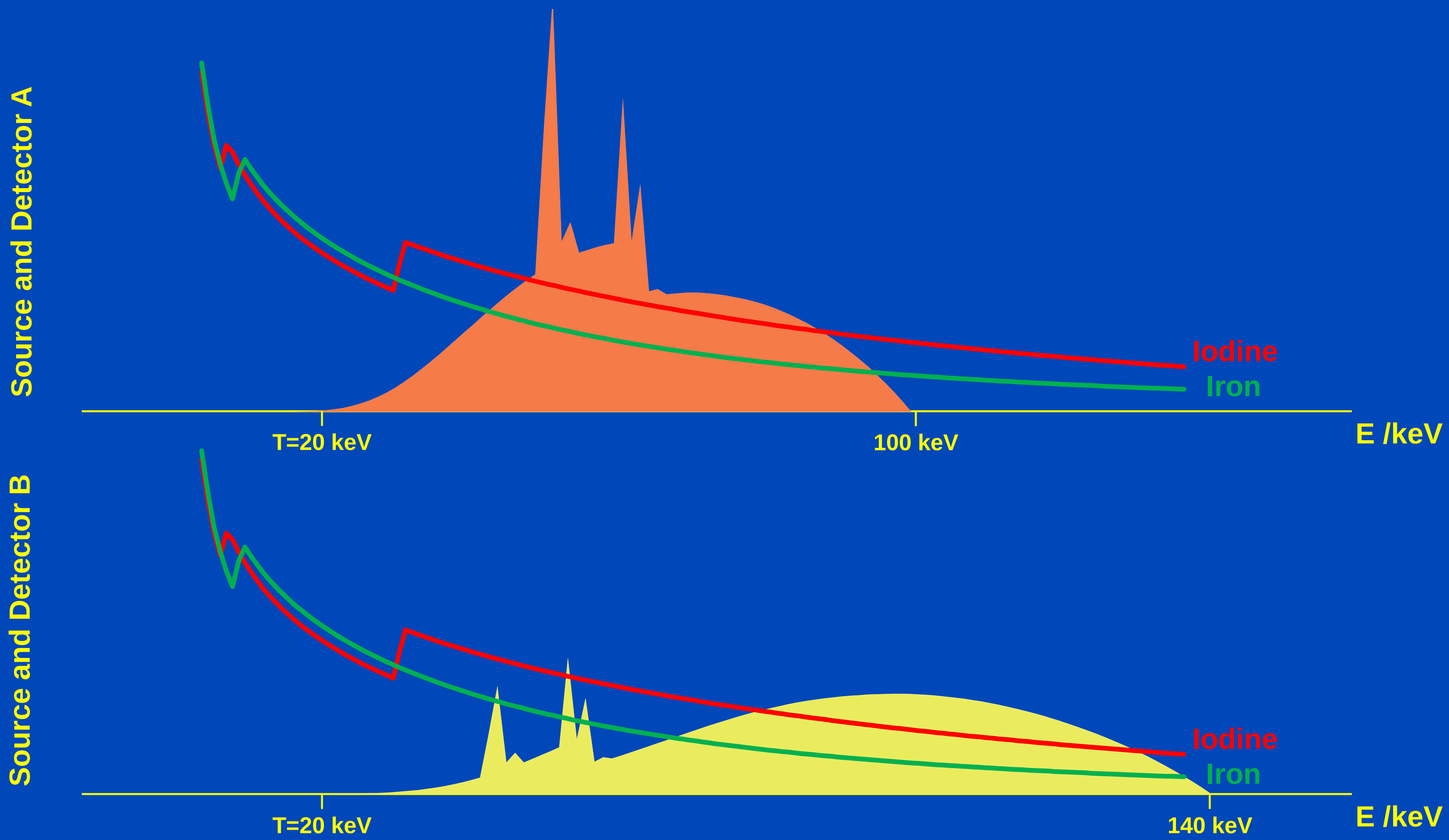
Photon-Counting Detector

100 kV / Sn 140 kV, 2 Spectra



Simulation: prefiltered spectra as seen after a 320 mm patient.

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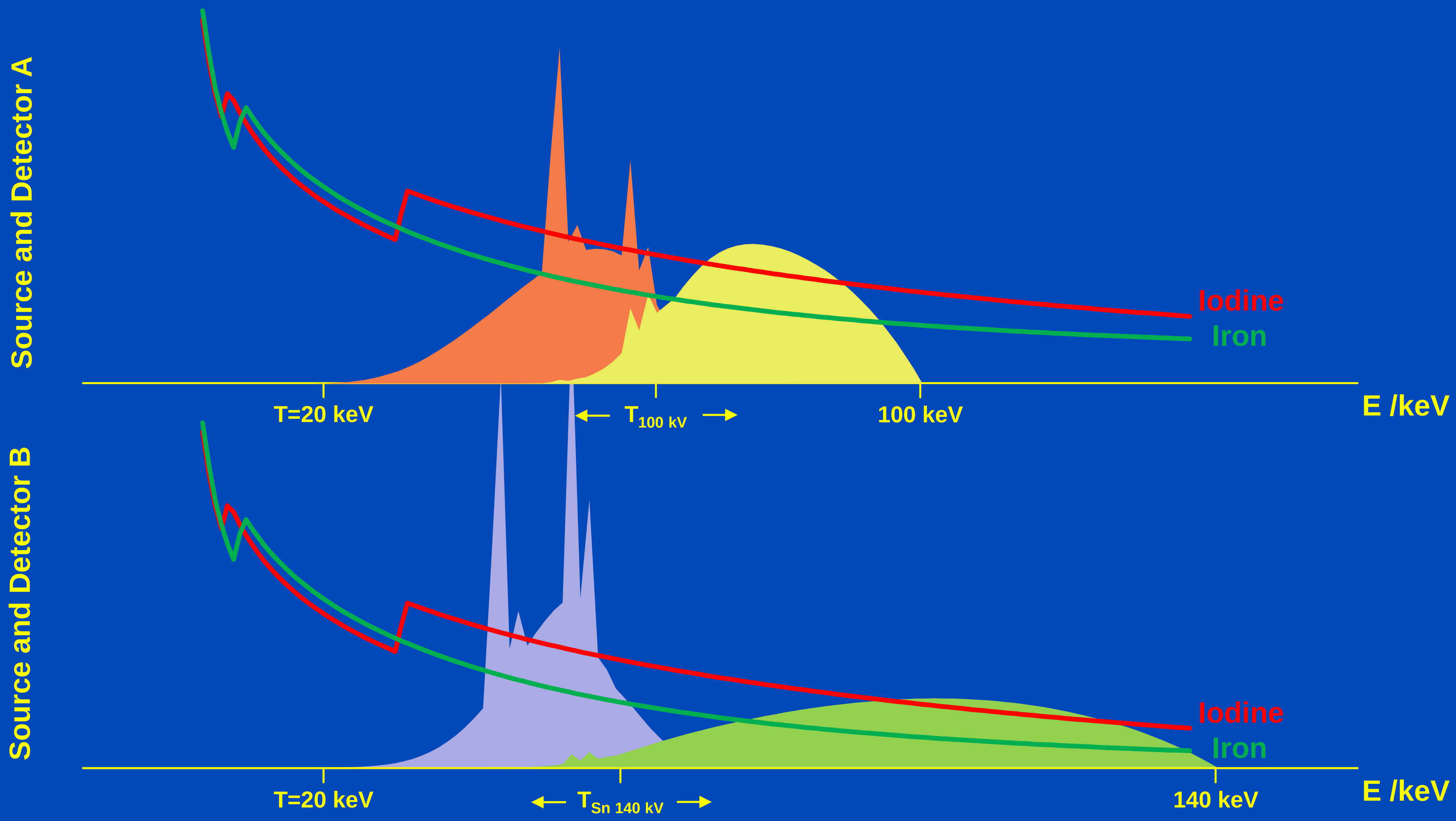
Photon-Counting Detector

100 kV / Sn 140 kV, 4 Spectra



Simulation: prefiltered spectra as seen after a 320 mm patient.

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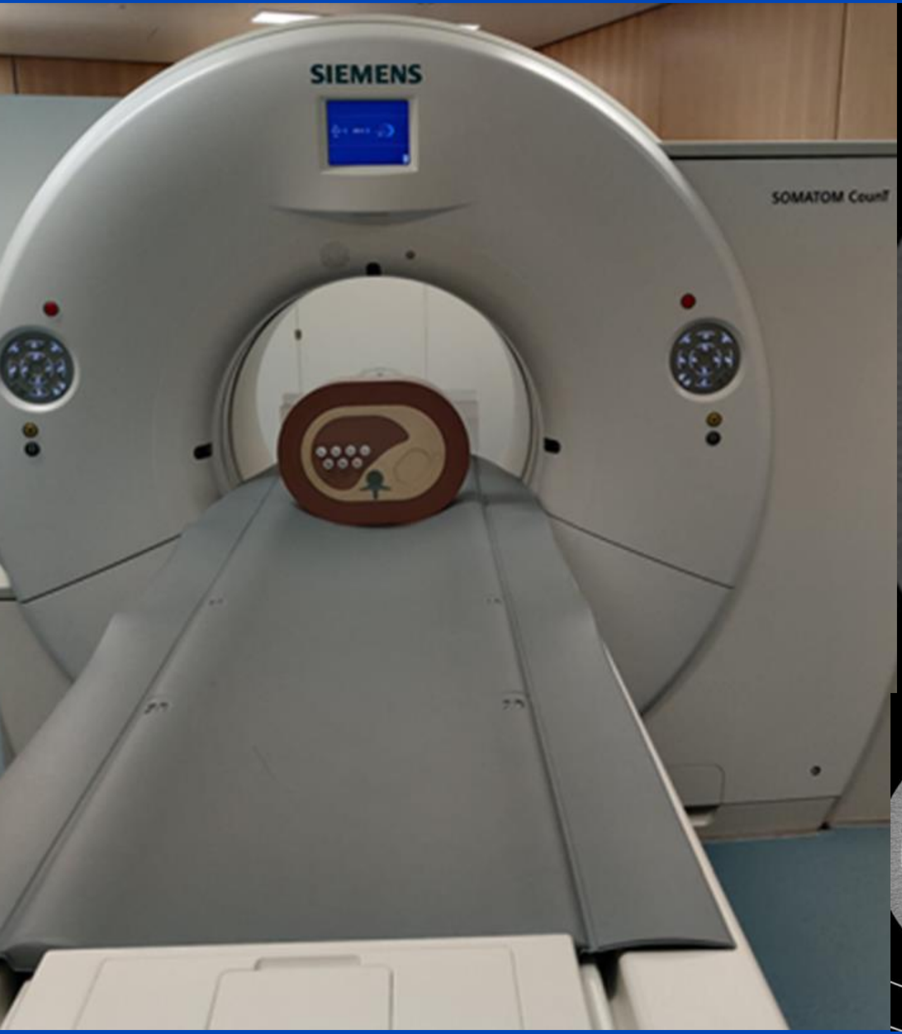
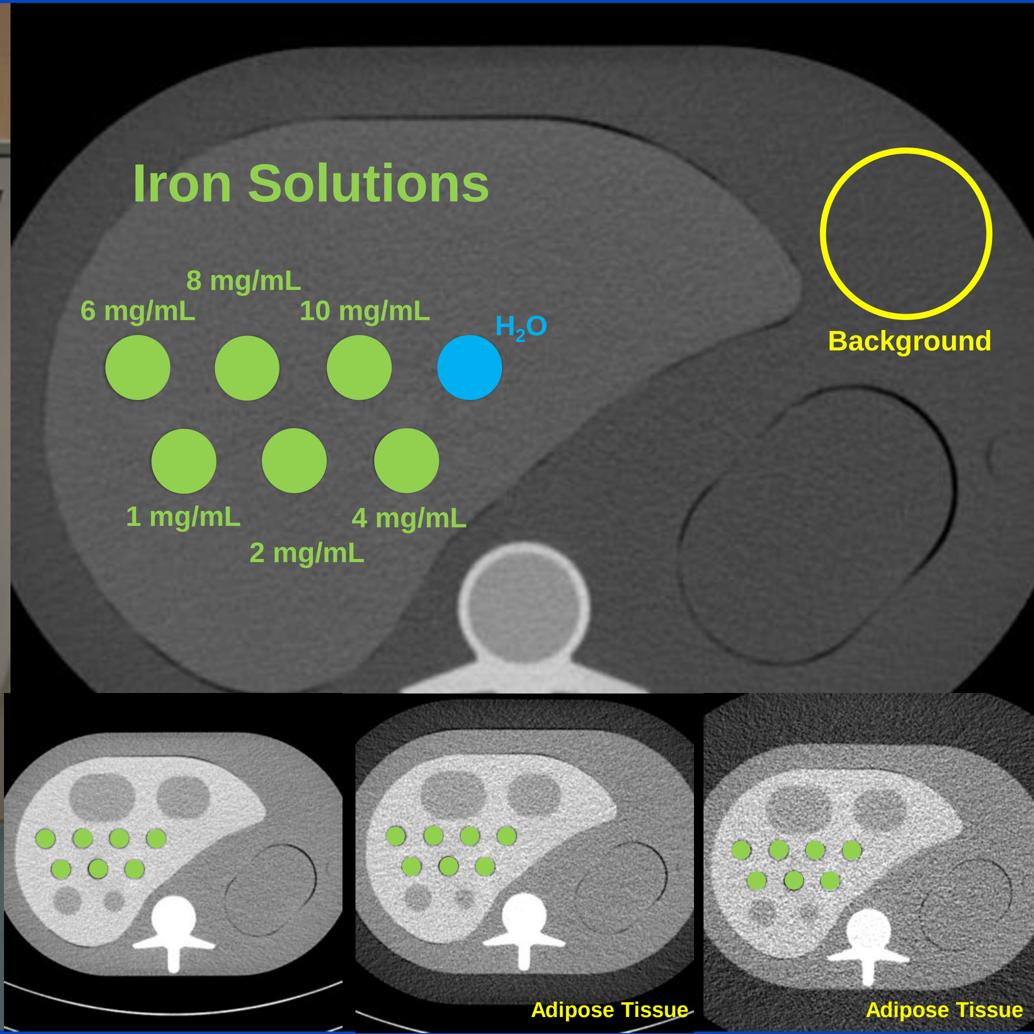
Materials and Methods

	EI 2 Spectra	PC 2 Spectra/Bins	PC 4 Spectra/Bins
Detector Type	Energy Integrating	Photon Counting	Photon Counting
Number of detected spectra	2	2	4
Thresholds for 80 kV/100 kV	- -	T_1 = 20 keV -	T_1 = 20 keV T_2 = 50 to 90 keV
Thresholds for Sn 140 kV	- -	T_1 = 20 keV -	T_1 = 20 keV T_2 = 50 to 90 keV
Tube voltage	80 kV / Sn 140 kV or 100 kV / Sn 140 kV		
Tube current	398 mAs / 154 mAs or 193 mAs / 149 mAs		
CTDI	15 mGy		

Materials & Methods

Scanner and Phantom with Iron Solutions





Top: *C* = 180 HU, *W* = 600 HU. Bottom: *C* = –50 HU, *W* = 400 HU

Materials & Methods

Material Decomposition

- Material decomposition is performed in image domain using a previously published algorithm[1].
- If the number of measurements equals the number of desired material maps, the method inverts the corresponding system of equations.
- If there are more measurements than desired material maps, the method performs an statistically optimal weighting of all bins to minimize image noise.

[1]Faby, Sawall, Kachelrieß et al. Performance of today's dual energy CT and future multi energy CT in virtual non-contrast imaging and in iodine quantification: A simulation study. Medical Physics, 42, 4349–4366, 2015.

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Materials & Methods

Figures of Merit

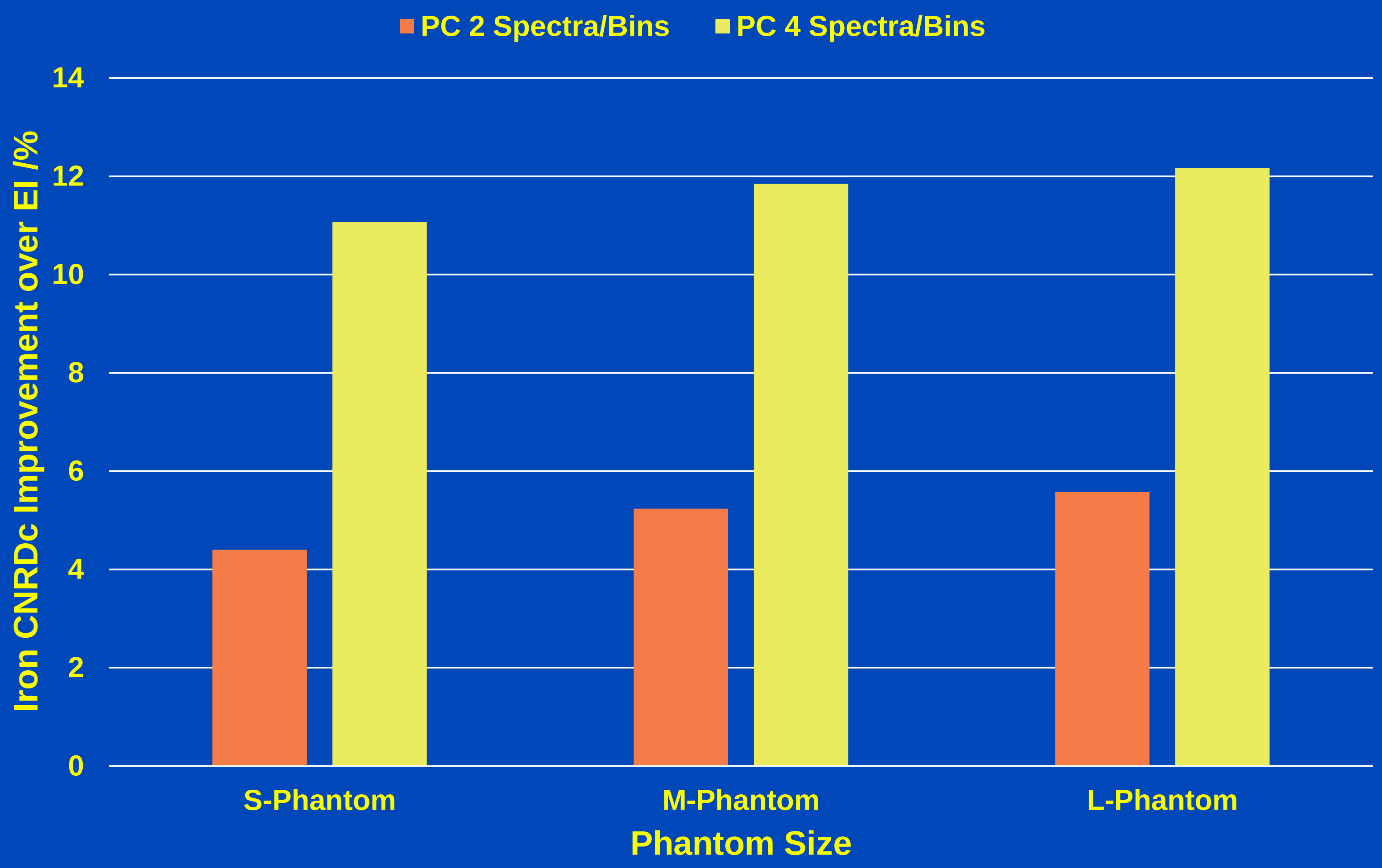
- Image quality of iron material maps can be quantified using the dose-normalized CNR (CNRD).
- We further normalize for iron concentration:

$$CNRDc = \frac{CNRD}{c}$$

- For evaluation, we report the CNRDc improvement of photon-counting measurements over energy-integrating ones.

Results

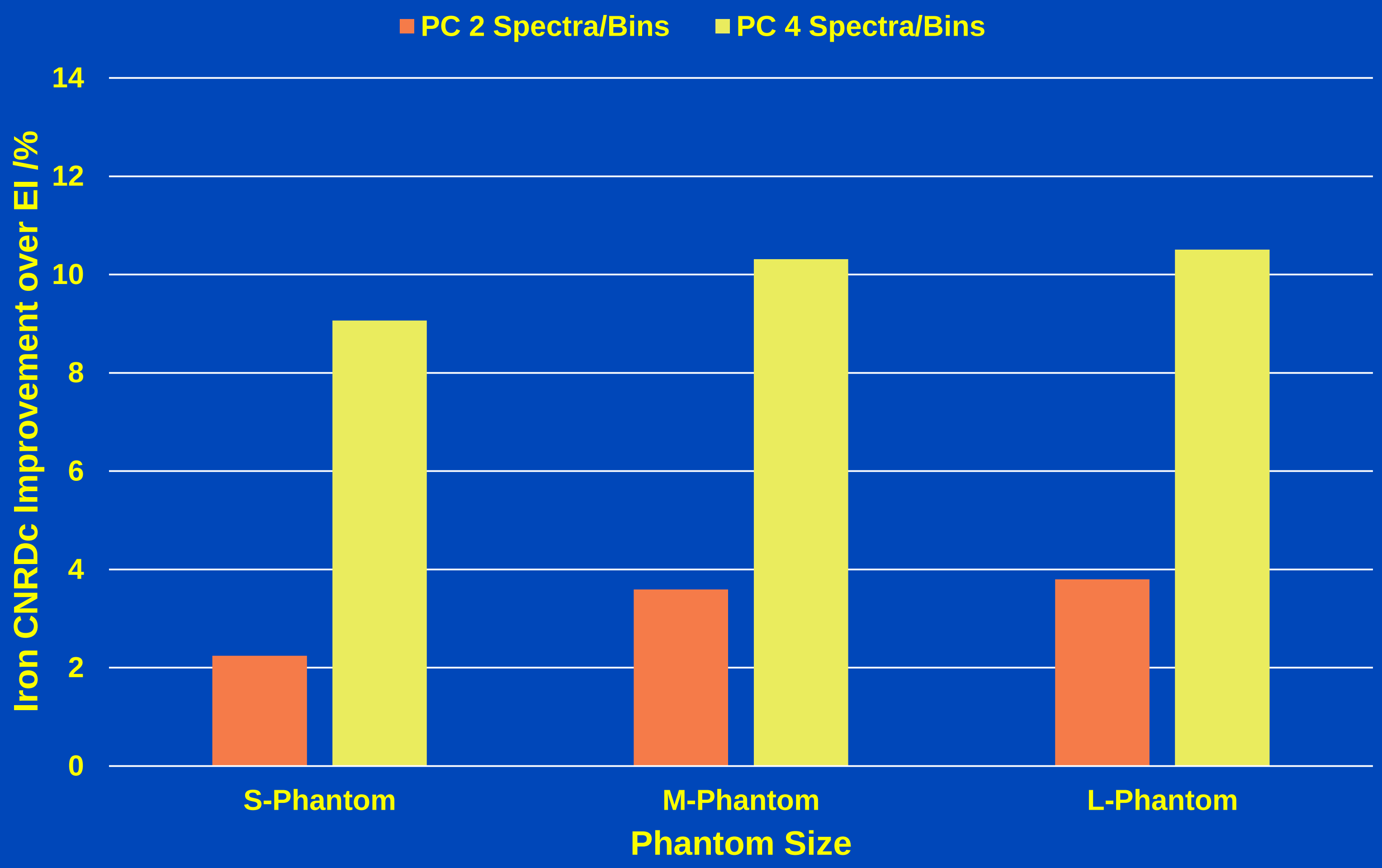
80 kV / Sn 140 kV



The results using 4 spectra were obtained using optimal threshold settings.

Results

100 kV / Sn 140 kV



The results using 4 spectra were obtained using optimal threshold settings.

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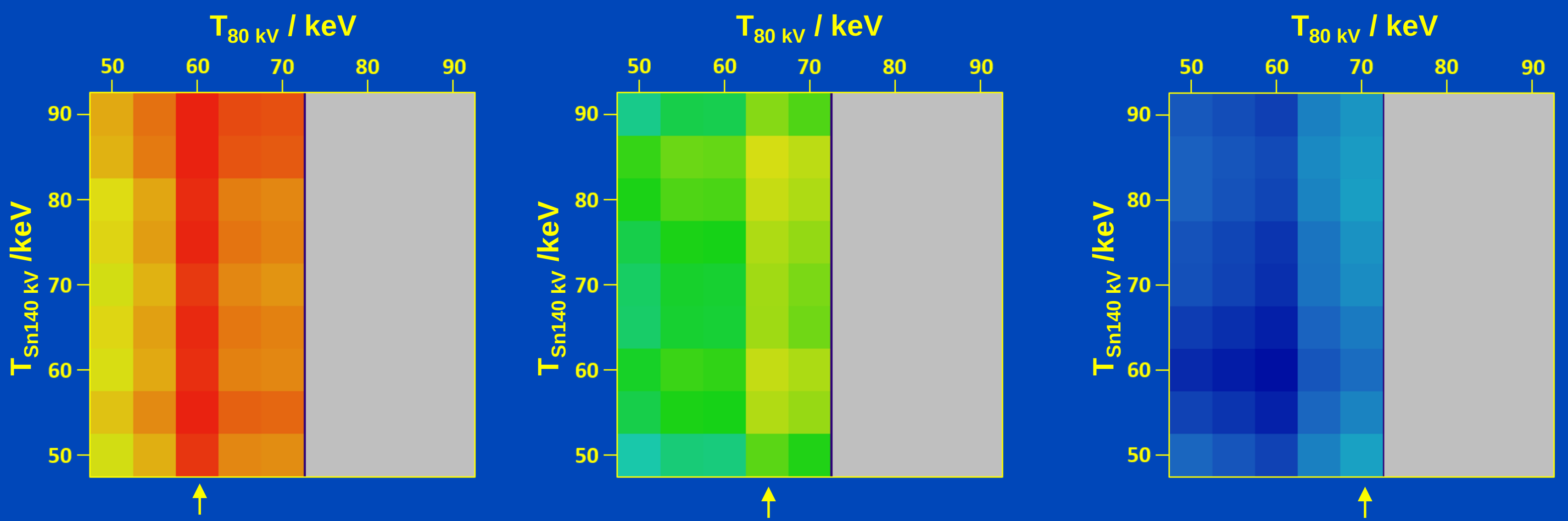
Results

4 Spectra/Bins, 80 kV / Sn 140 kV

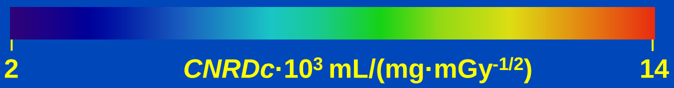
S-Phantom | M-Phantom | L-Phantom



Optimum @ $T_{80\ kV}$ = 60 keV

Optimum @ $T_{80\ kV}$ = 65 keV

Optimum @ $T_{80\ kV}$ = 70 keV



Summary & Conclusions

- Dual-source dual-energy PCCT provides a higher iron CNRDc for all investigated protocols compared to EI.
- 4 spectra/bins allow for an additional improvement of CNRDc.
- However, the results do not show a dependence on the threshold $T_{Sn140\ kV}$.
- This is most likely caused by the fact that the iron k-edge is at 7.1 keV.

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.