Erkennbarkeit von Niedrigkontraststrukturen in der Photonenzählenden Ganzkörper Computertomographie – Eine Phantomstudie

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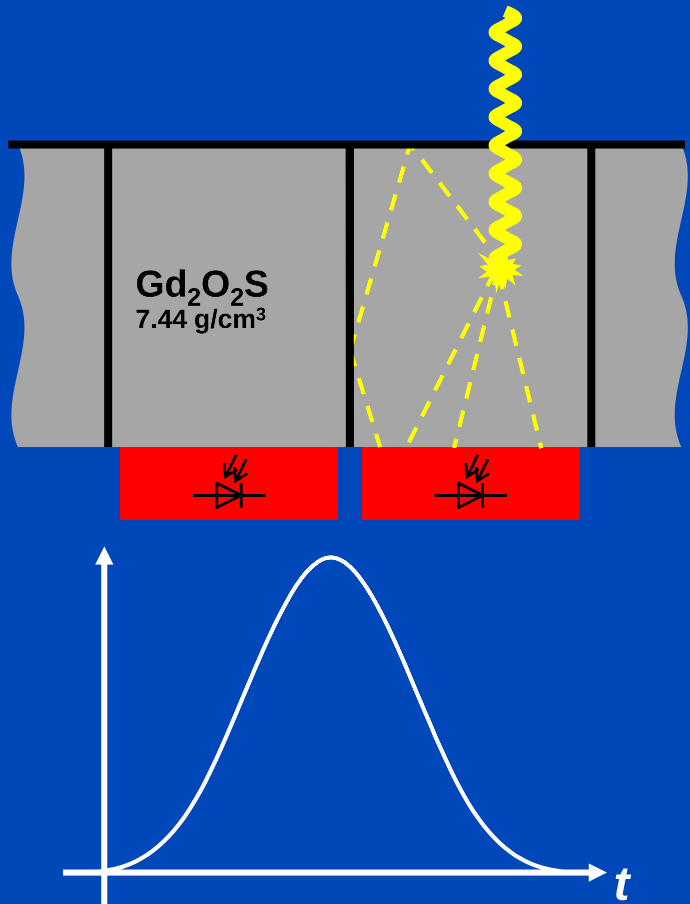
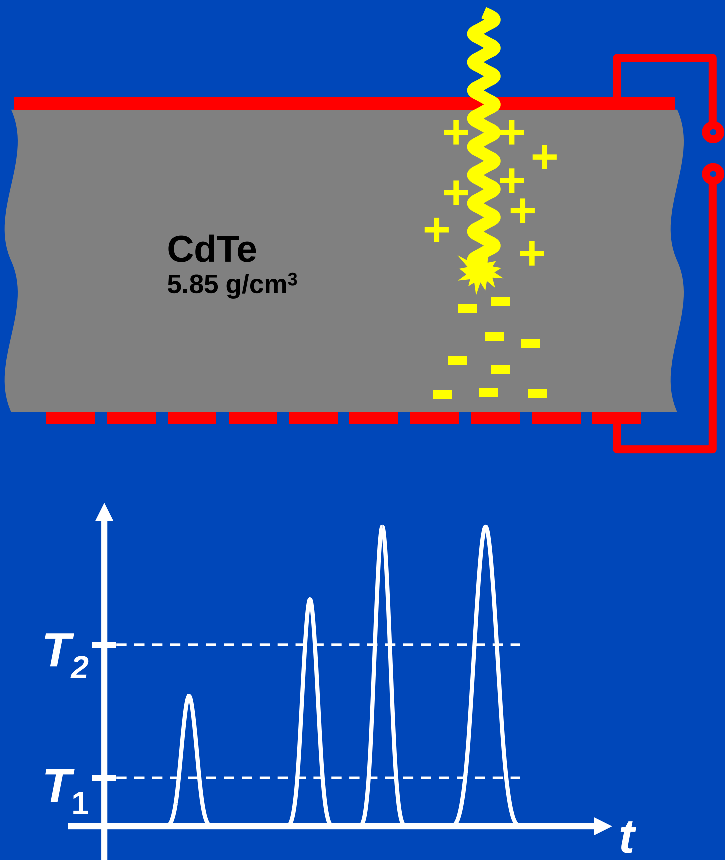
Detector Technologies

Energy-Integrating Detector



Photon-Counting Detector

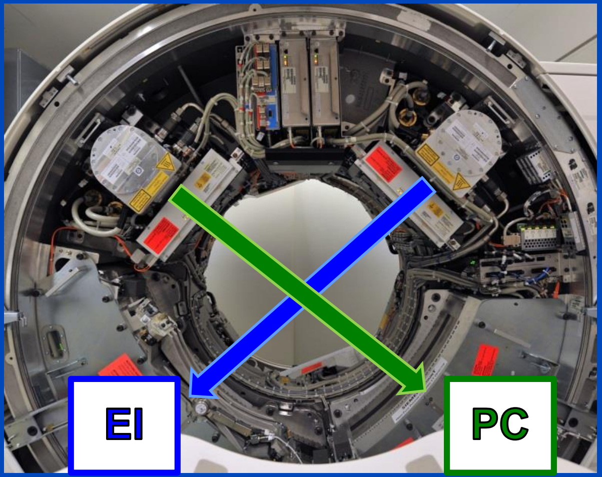


Systematic illustration of the operation principles of the different detectors

SOMATOM CounT CT at the DKFZ

Gantry from a clinical dual source scanner

- Conventional CT (EI) detector (50 cm FOV)
- Photon-counting (PC) detector (27.5 cm FOV)



Pixel size at the isocenter for different readout modes

PC-UHR Mode
0.25 mm pixel size

EI Detector
0.6 mm pixel size

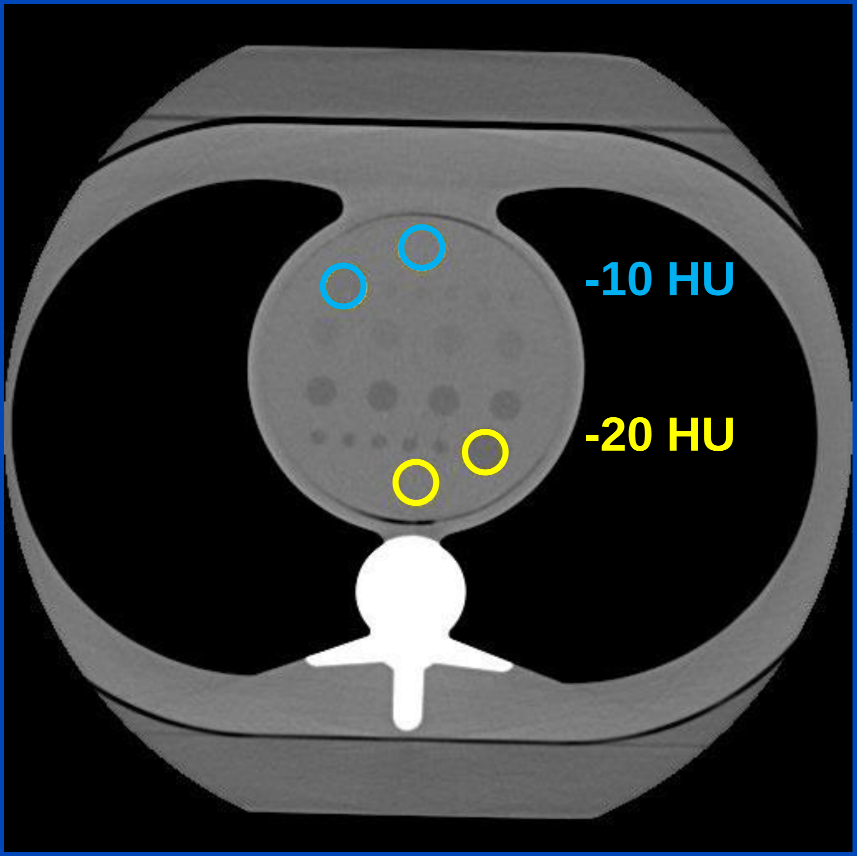
Contrast-to-Noise-Ratio (CNR)

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

$$\mathrm{CNR} = \frac{|\mu_{\mathrm{sig}} - \mu_{\mathrm{bg}}|}{\sqrt{\sigma^2_{\mathrm{sig}} + \sigma^2_{\mathrm{bg}}}}$$

- Normalization to dose

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

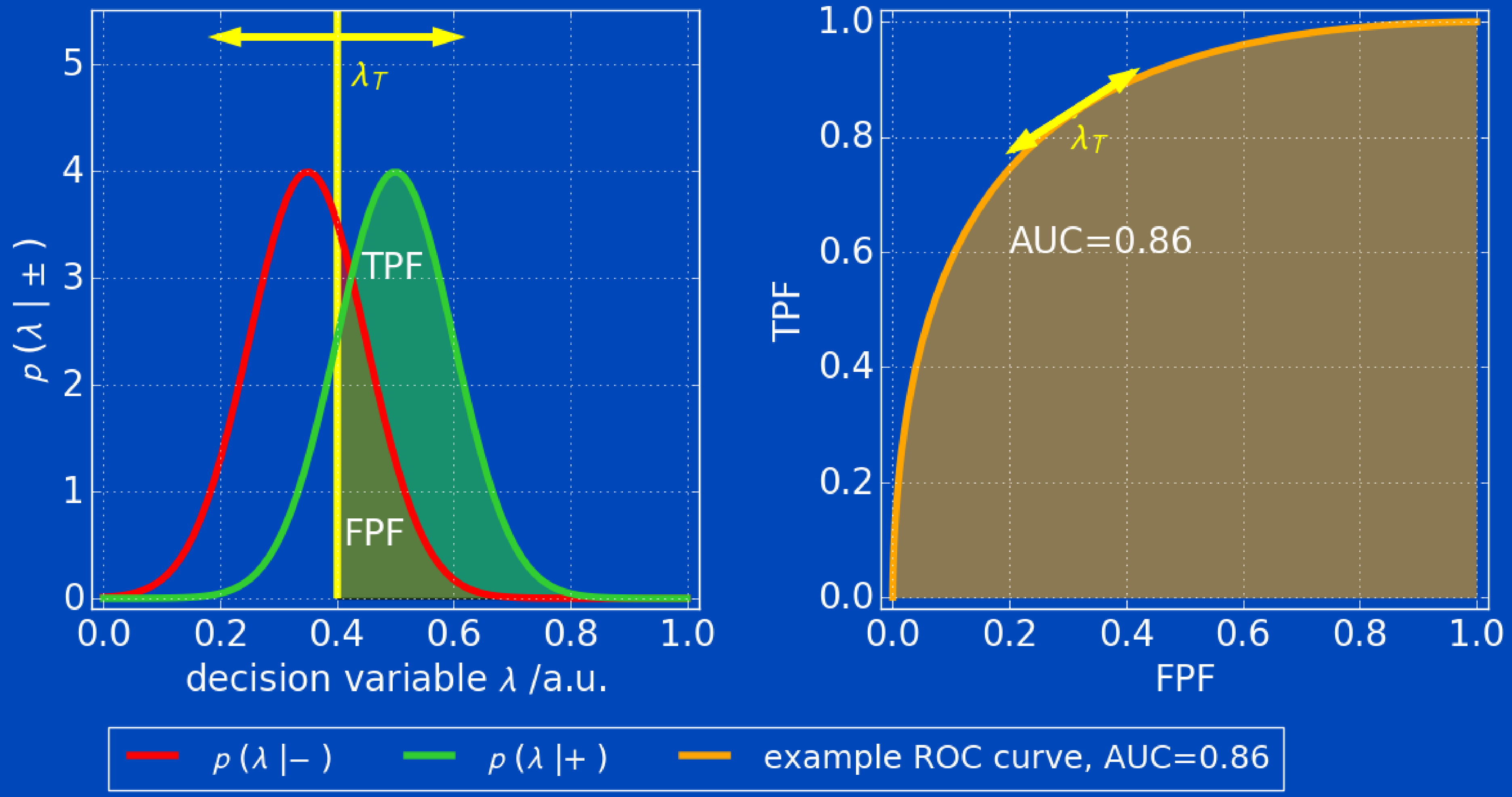


Regions of interest for CNR, M-phantom (PC); *C* = 40 HU, *W* = 300 HU

Model Observer

- Used to determine image quality
- Evaluated by the performance of an *“observer”* on a specific task
- Studies with human observers are very time consuming → **use mathematical model observers**
- Consider a binary detection problem i.e. “*Is a lesion in the image present?”*
- Calculation of a response or decision variable $\lambda(\boldsymbol{f})$
- A high value indicates a high confidence that the signal or lesion is present.

Model Observer – ROC Curve

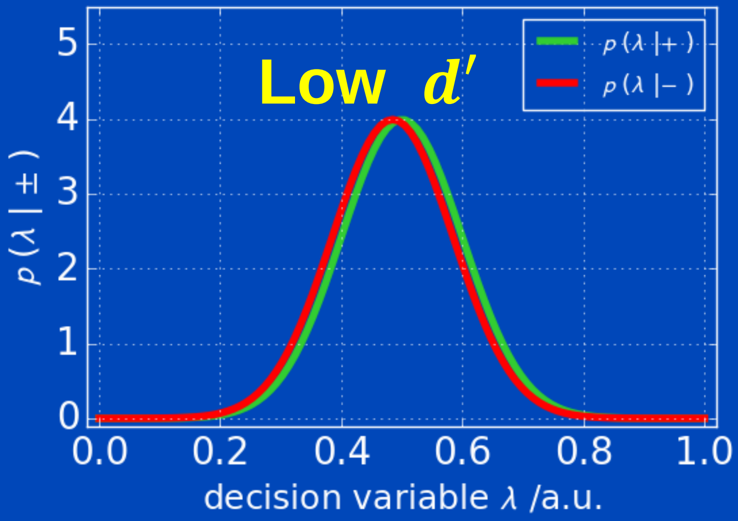


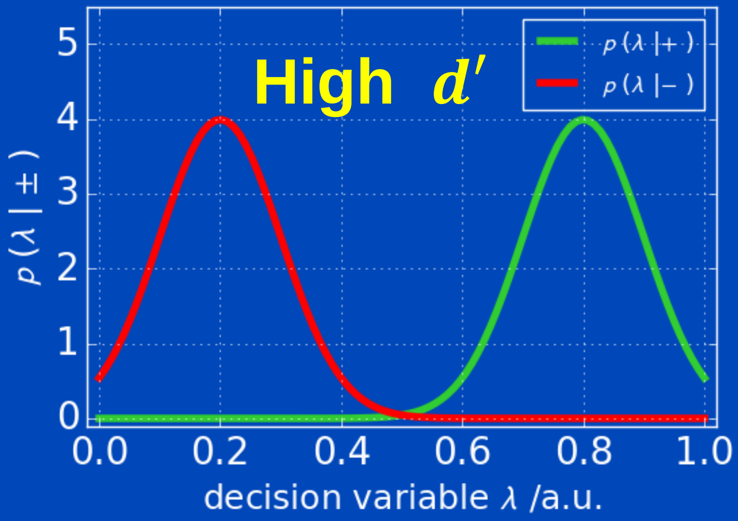
Probability density function of the observer response, for signal present $p(\lambda|+)$ and signal absent $p(\lambda|-)$ images, and the corresponding ROC curve

Model Observer – AUC and d'

- AUC, d' are global figures of merit and do not depend on a specific decision threshold λ_T.
- Detectability d' broadly describes how well both distributions are separated:

$$d' = \frac{\overline{\lambda_+} - \overline{\lambda_-}}{\sqrt{\frac{1}{2}(\sigma_+^2 + \sigma_-^2)}}$$





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Model Observer – AUC and d'

- AUC, d' are global figures of merit and do not depend on a specific decision threshold λ_T
- d' is related to AUC by:

$$\text{AUC} = \frac{1}{2}\left(1 + \text{erf}\left(\frac{d'}{2}\right)\right)$$

- With:

$$\text{erf}(x) = \frac{2}{\sqrt{\pi}} \int_0^x dt\; e^{-t^2}$$

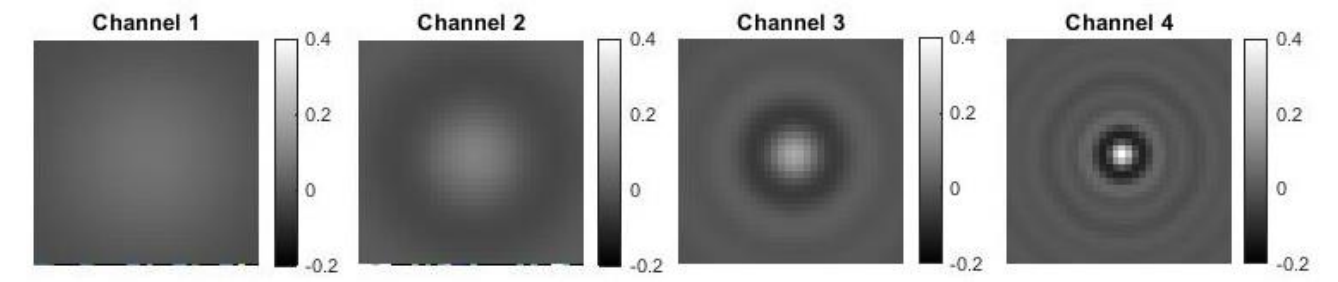
Model Observer
Channelized Hotelling Observer (CHO)

- Consider a SKE / BKE binary task
  → **determine if a lesion is present in a noisy image**
- Channel filters are included to reduce dimensionality

$$\boldsymbol{v} = \mathcal{U}^T \boldsymbol{f}$$

- With $\mathcal{U}$ channel matrix, $\boldsymbol{v}$ channelized images, $\boldsymbol{f}$ images and $\mathcal{S}$ the covariance matrix
- The decision variable for the CHO is given by:

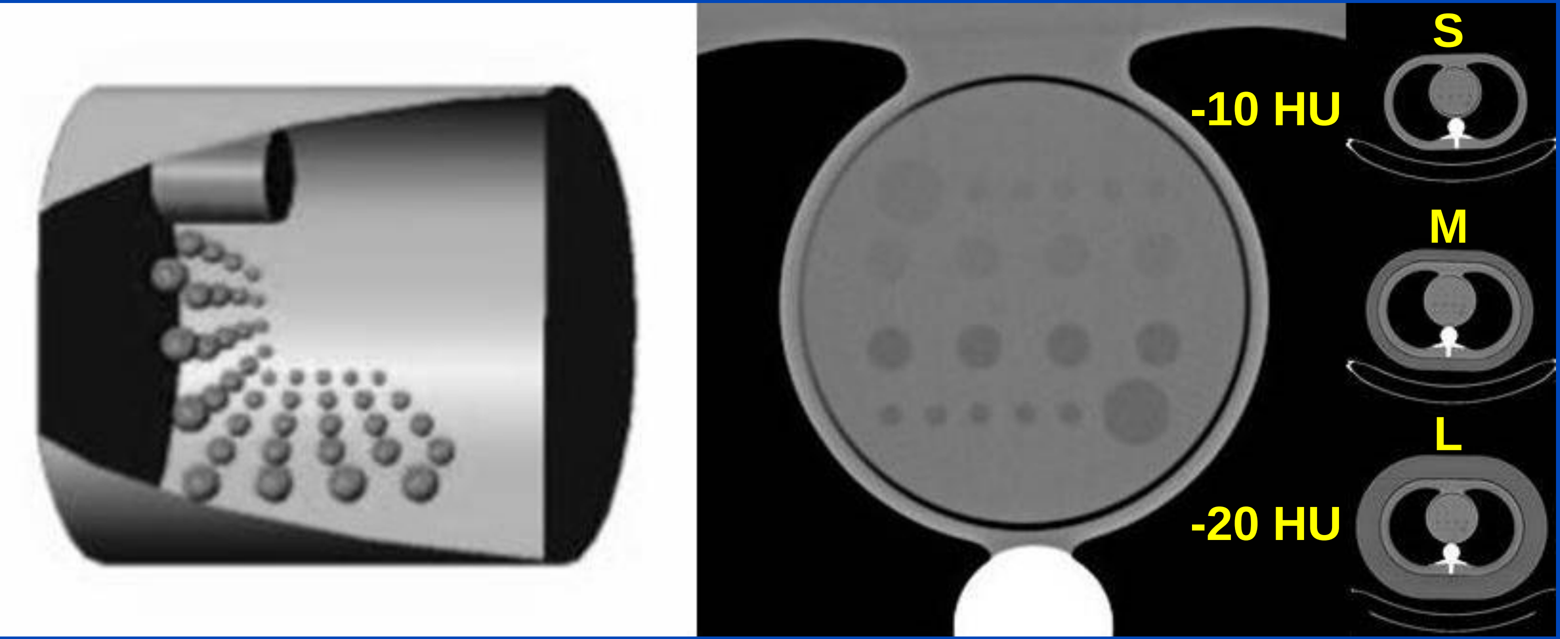
$$\lambda(\boldsymbol{v}) = \left(\overline{\boldsymbol{v}^+} - \overline{\boldsymbol{v}^-}\right)^T \mathcal{S}^{-1} \boldsymbol{v}$$



Four square spatial-domain channels

Phantom Measurements

- Tube voltage: 120 kV, 140 kV
- Effective tube current: 80 mAs, 120 mAs, 180 mAs, 240 mAs
- Pitch: 0.5
- Reconstructed with FBP, B40f (smooth) and B70f (sharp)



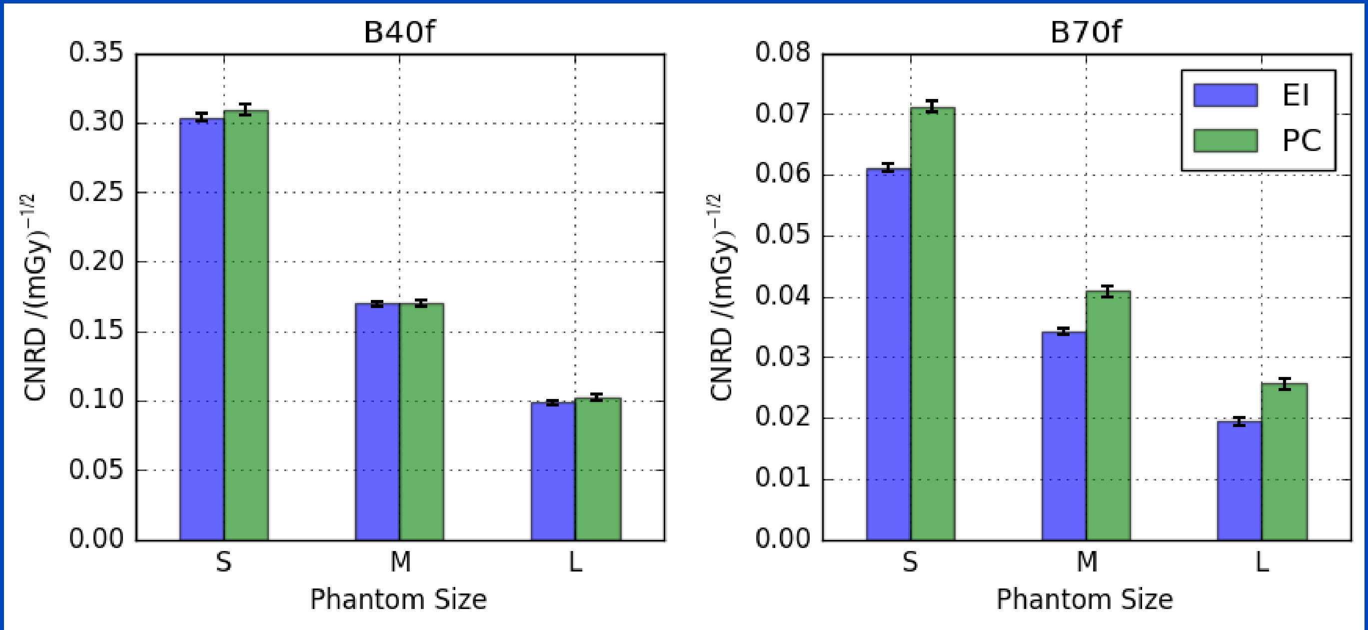
20 cm × 30 cm

25 cm × 35 cm

30 cm × 40 cm

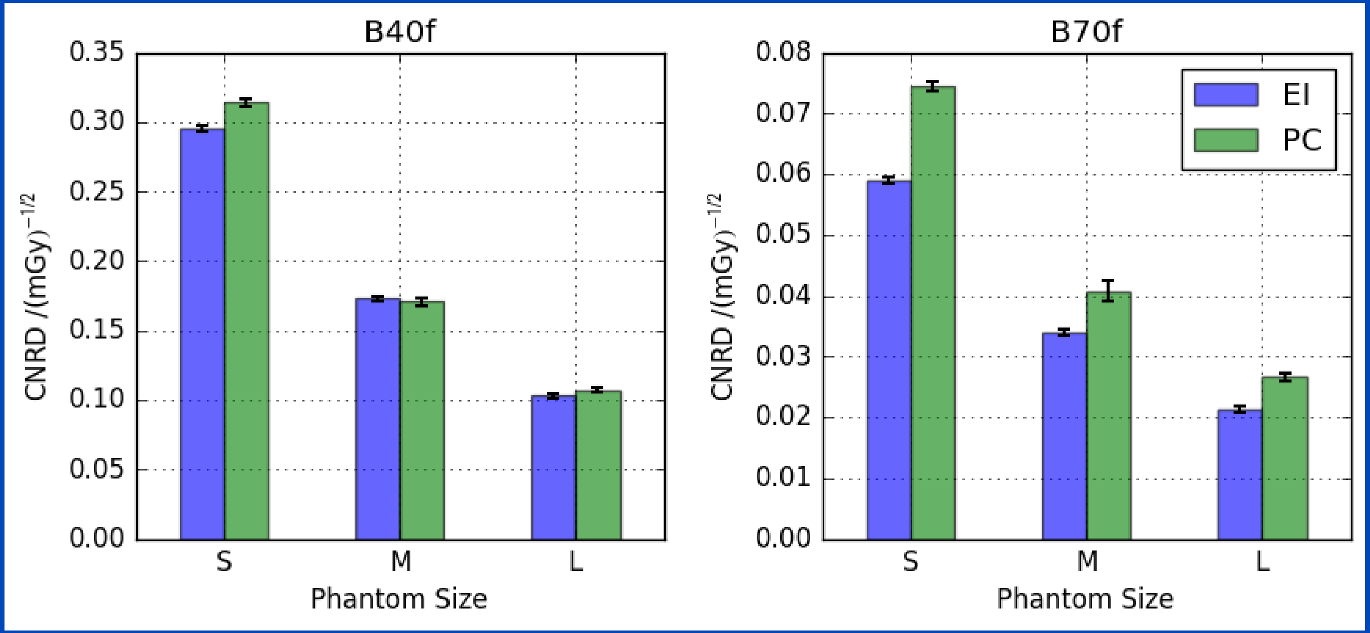
Phantoms used in this study, C = 40 HU, W = 300 HU

CNRD Improvement of PC at 120 kV



Phantom Size	Relative CNRD Difference PC vs. EI	
	B40f / %	B70f / %
S	1.8 ± 1.6	16.5 ± 1.9
M	0.4 ± 2.0	19 ± 3
L	4 ± 3	32 ± 7

CNRD Improvement of PC at 140 kV

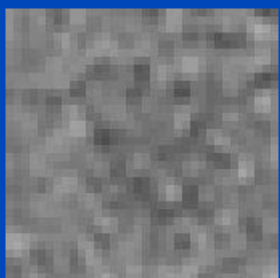


Phantom Size	Relative CNRD Difference PC vs. EI	
	B40f / %	**B70f / %**
S	**6.4 ± 1.3**	**26.3 ± 1.7**
M	**-1.4 ± 1.9**	**20 ± 5**
L	**4.0 ± 2.5**	**25 ± 4**

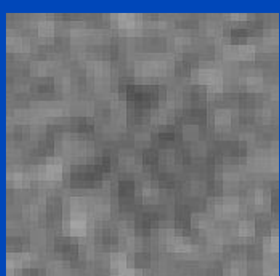
Results Detectability

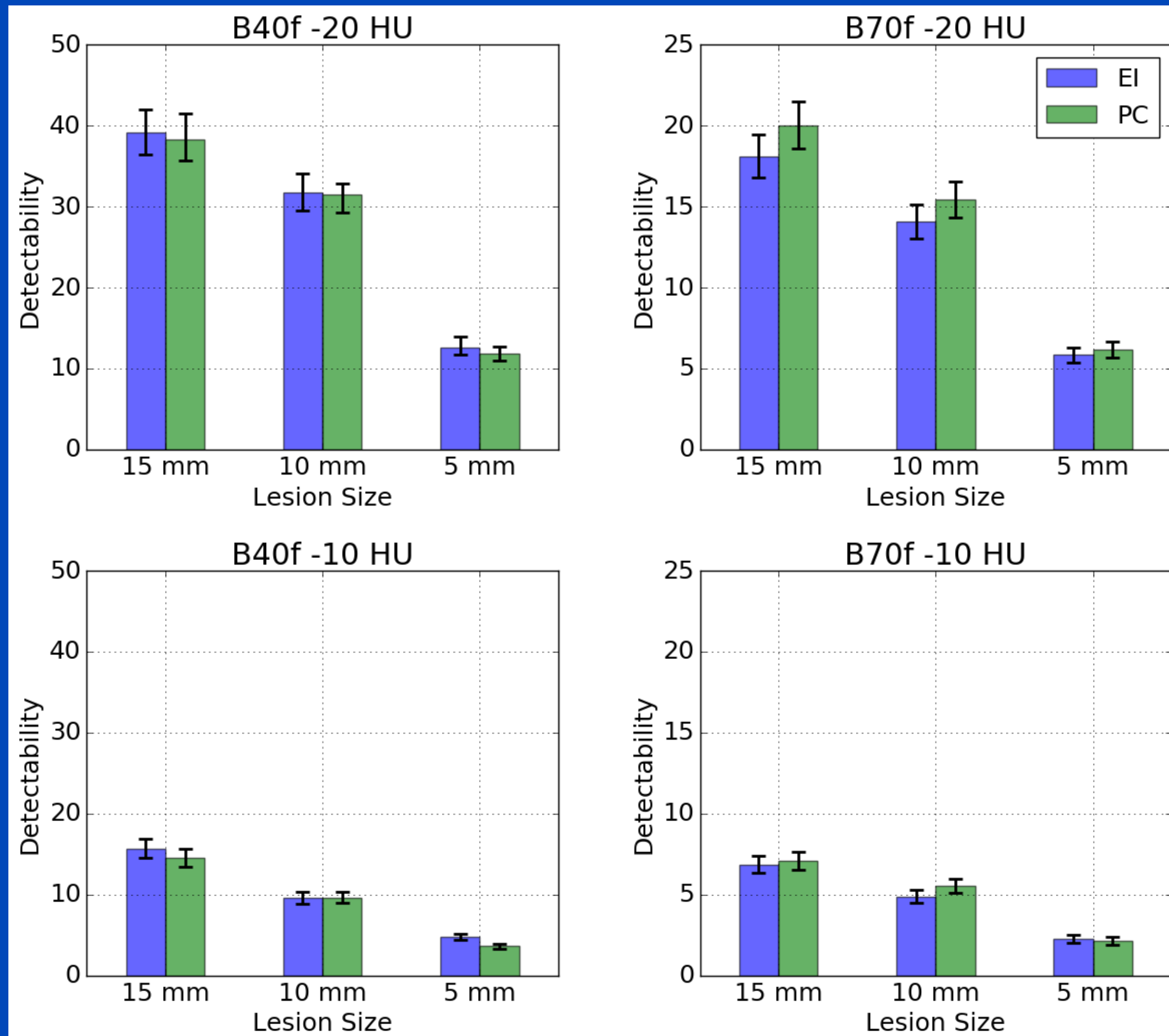
B40f

EI



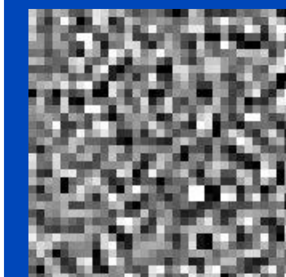
PC



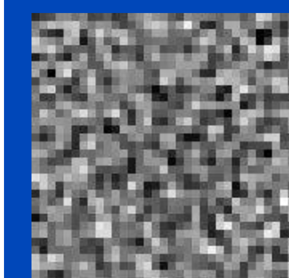


B70f

EI



PC



Images of the -20 HU / 10 mm lesion *C* = 40 HU, *W* = 300 HU

Conclusion

- The same detectability of low contrast lesions is achievable for the PC with less dose compared to the EI.
- Alternatively, the usage of sharper reconstruction kernels allows better detectability of small lesions, due to lower noise of the PC at higher spatial resolution.

Thank You !

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Job opportunities through DKFZ's international PhD or Postdoctoral Fellowship programs (marc.kachelriess@dkfz.de).