Optimal design of detector thickness for dual-energy x-ray imaging

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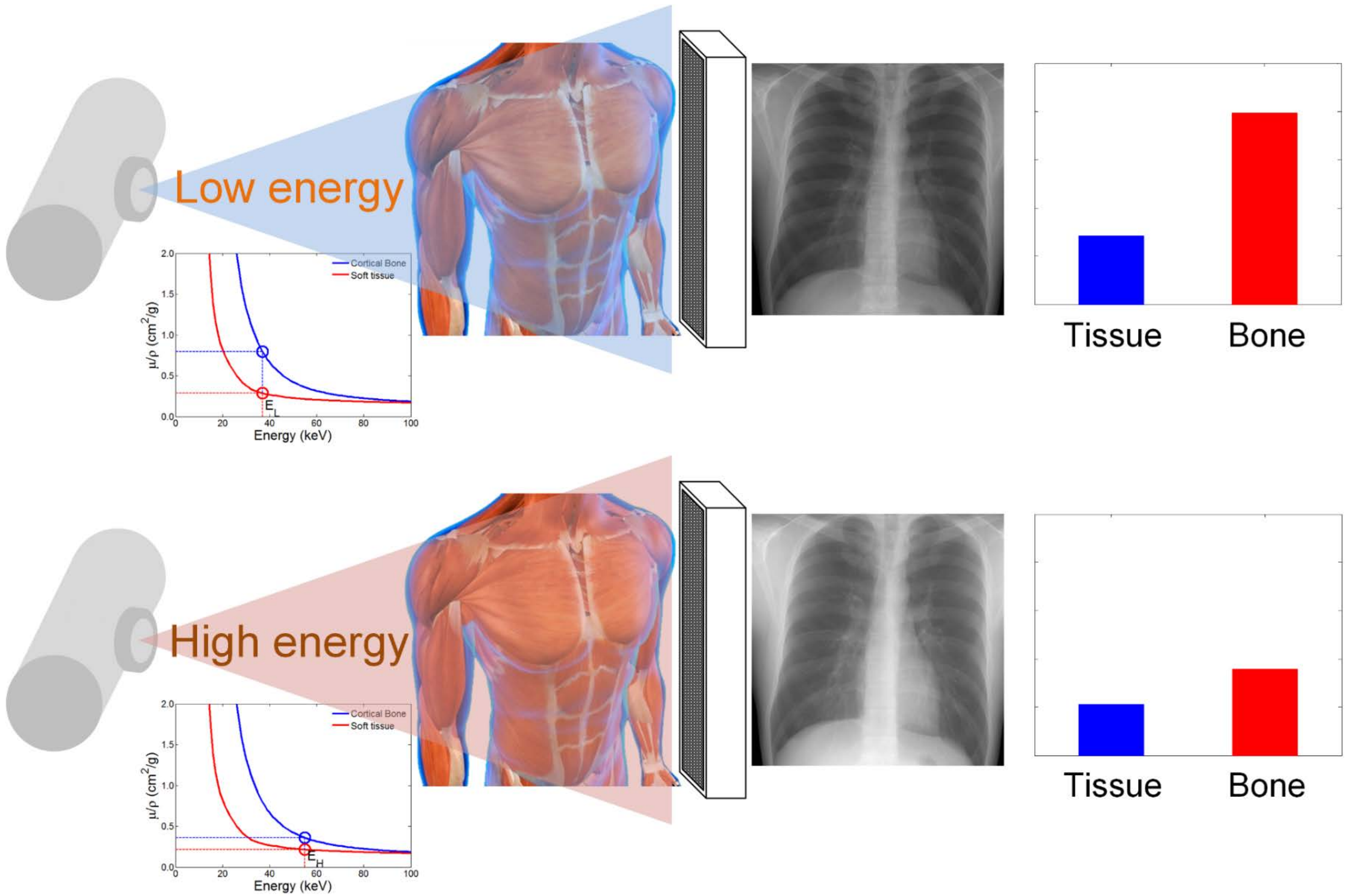
Dual-energy imaging



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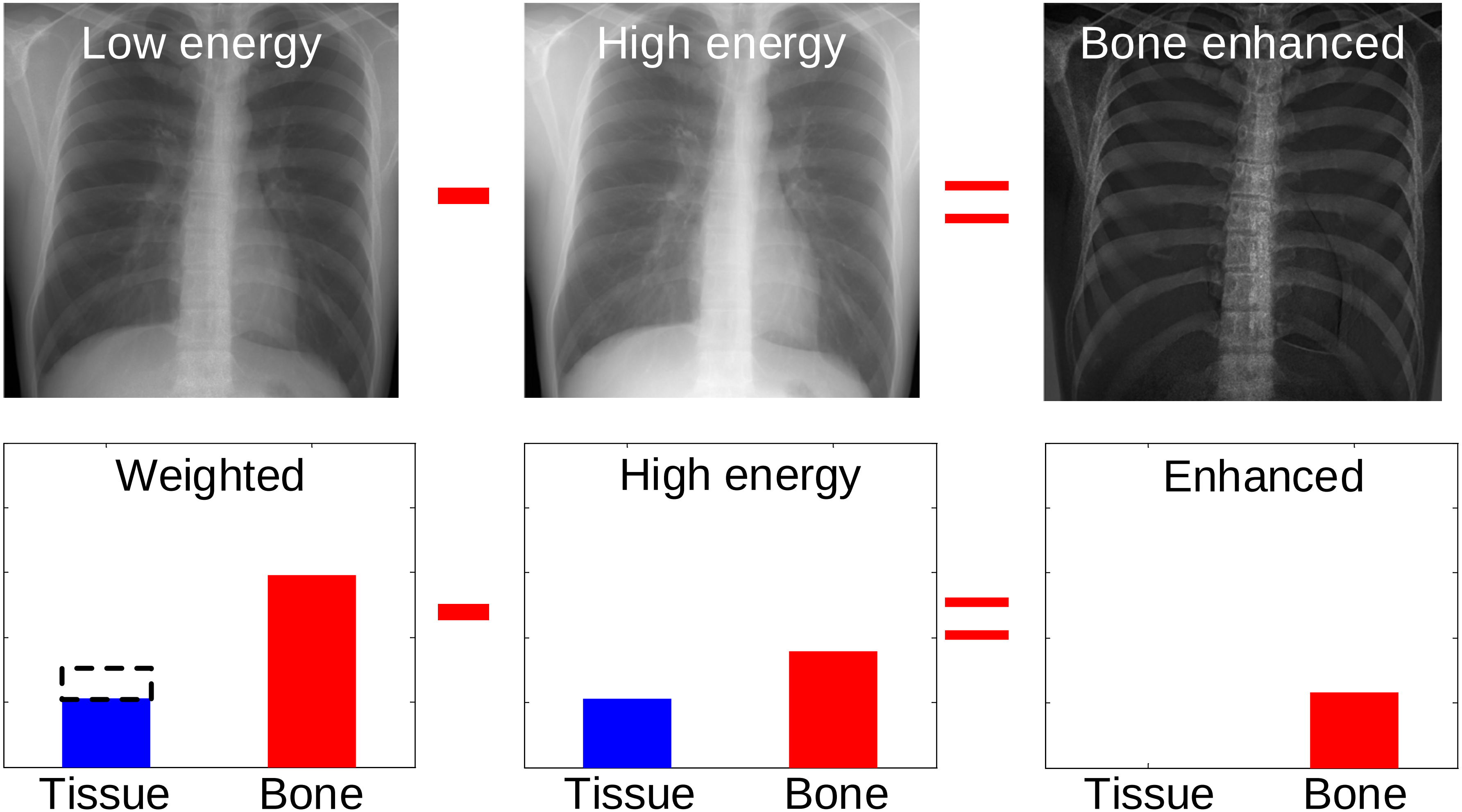
Dual-energy imaging



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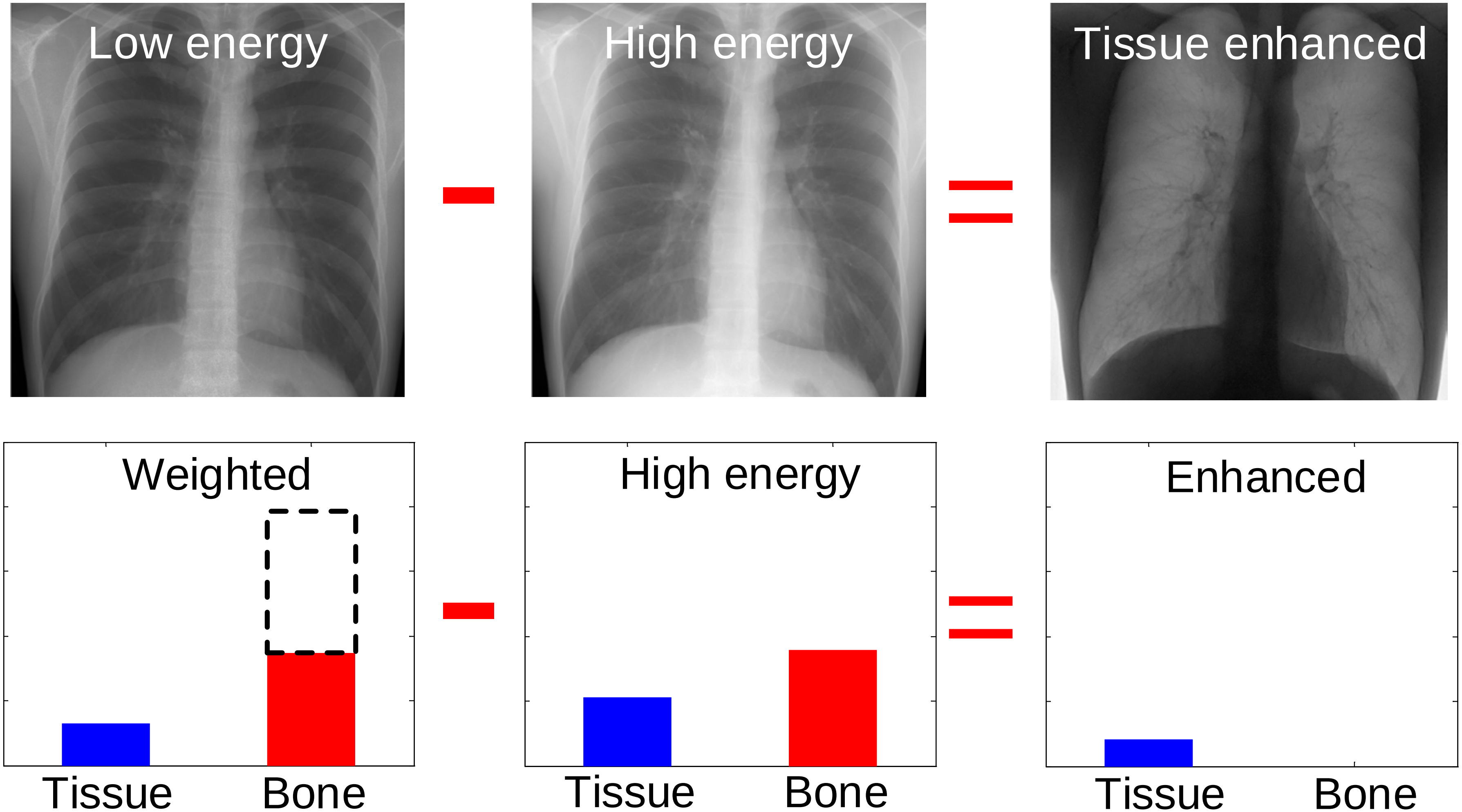
Dual-energy imaging



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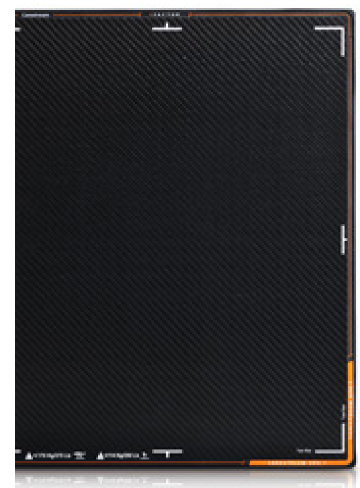
Motivation

- Commercial dua mploy a "single" of flat rent kV images



GE Healthcare
CsI:Tl
200 mg/cm^2

N. W. Marshall et al., "Quality control measurements for digital x-ray detectors," Phys. Med. Biol., Vol. 56, pp. 979-999, 2011

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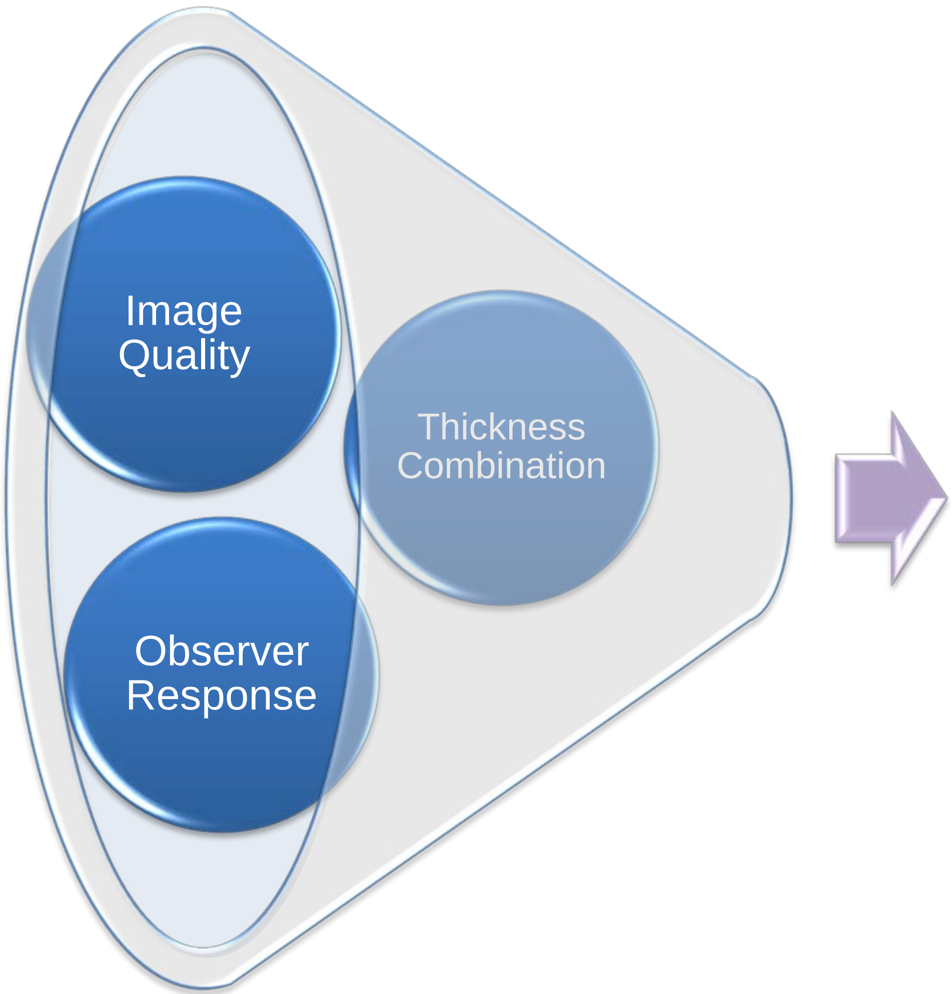
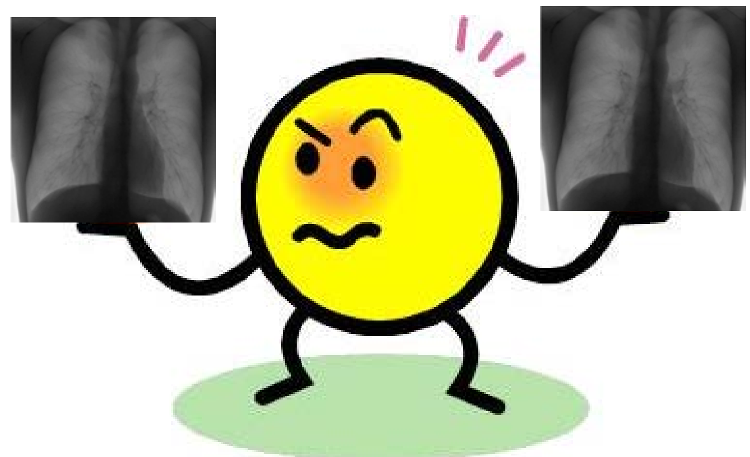
Strategy





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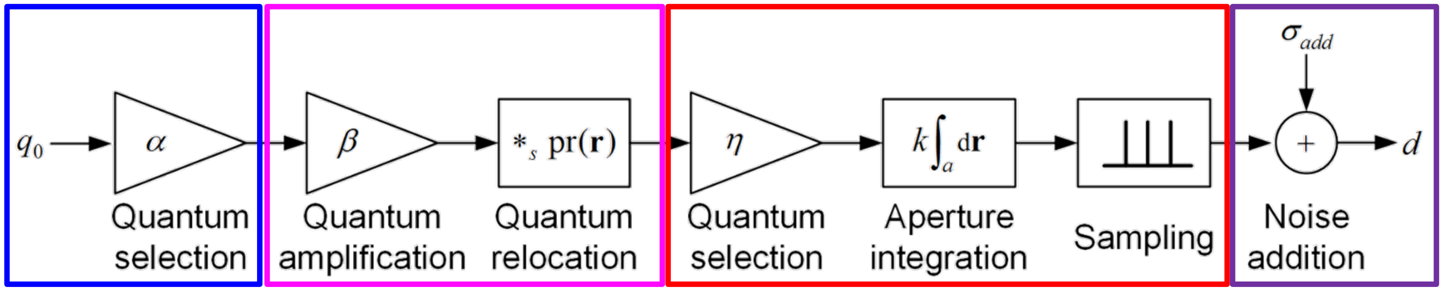
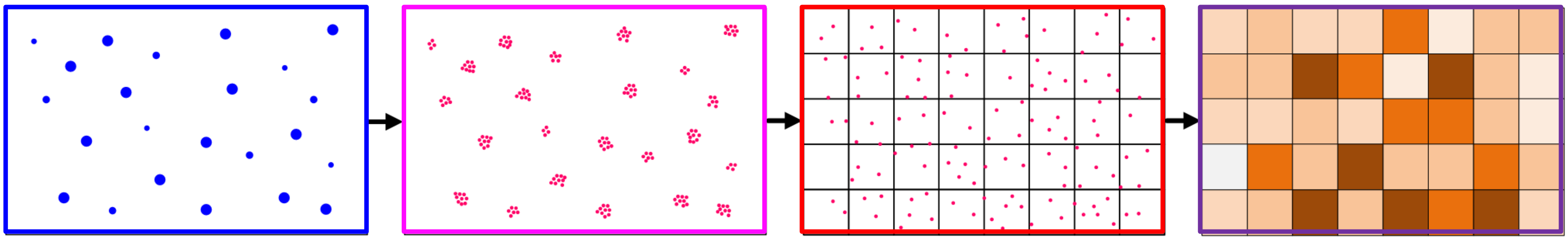
Modeling

- A simple cascaded-systems model describing the signal and noise propagation in an indirect flat-panel detector





$$S'(u,v) = \frac{1}{\bar{q}_0}\left[\frac{1}{\gamma\bar{g}} + \frac{\sum_{i=0}^{\infty}\sum_{j=0}^{\infty} T^2\left(u \pm \frac{i}{p}, v \pm \frac{j}{p}\right)}{\alpha}\left(\frac{1}{I} - \frac{1}{\beta}\right)\right] + \frac{p^2\sigma_{add}^2}{\bar{q}_0\bar{g}^2}$$

$$NEQ(u,v) = \frac{T^2(u,v)}{S'(u,v)}$$

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Modeling

- The DQE in DE images may be expressed in the conventional DQE form:

$$T'_{DE}(u,v) = \left[\frac{w^2\bar{q}_H}{\bar{q}_L + w^2\bar{q}_H}T_L^2(u,v) + \frac{\bar{q}_L}{\bar{q}_L + w^2\bar{q}_H}T_H^2(u,v)\right]^{1/2}$$

$$NEQ_{DE}(u,v) = \frac{T'^2_{DE}(u,v)}{S'_{DE}(u,v)}$$

$$S'_{DE}(u,v) = w^2 S'_L(u,v) + S'_H(u,v)$$

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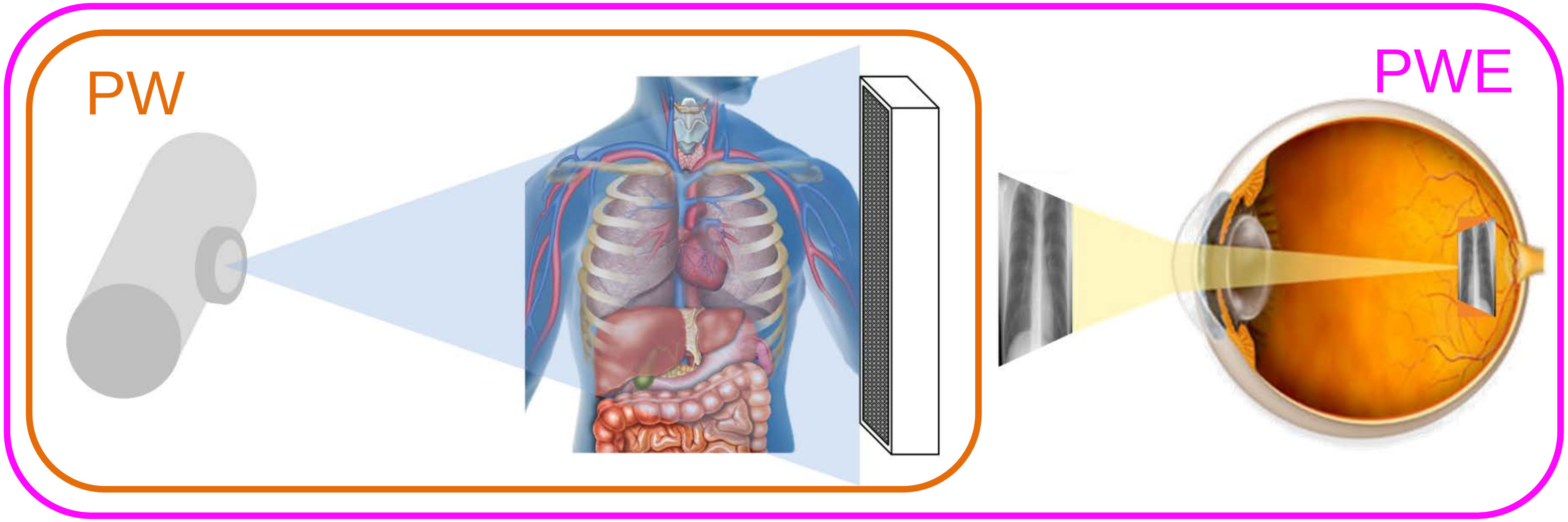
Detectability index



- Detectability index for the prewhitening matched filter observer model

$$d'_{PW} = \iint \frac{\{T^2(u,v)W(u,v)\}}{S'(u,v)} \mathrm{d}u\mathrm{d}v$$

- To include a human eye filter and internal noise

$$d'_{PWE} = \iint \frac{E^2(u,v)\{T^2(u,v)W(u,v)\}}{E^2(u,v)S'(u,v) + N_{int}} \mathrm{d}u\mathrm{d}v$$

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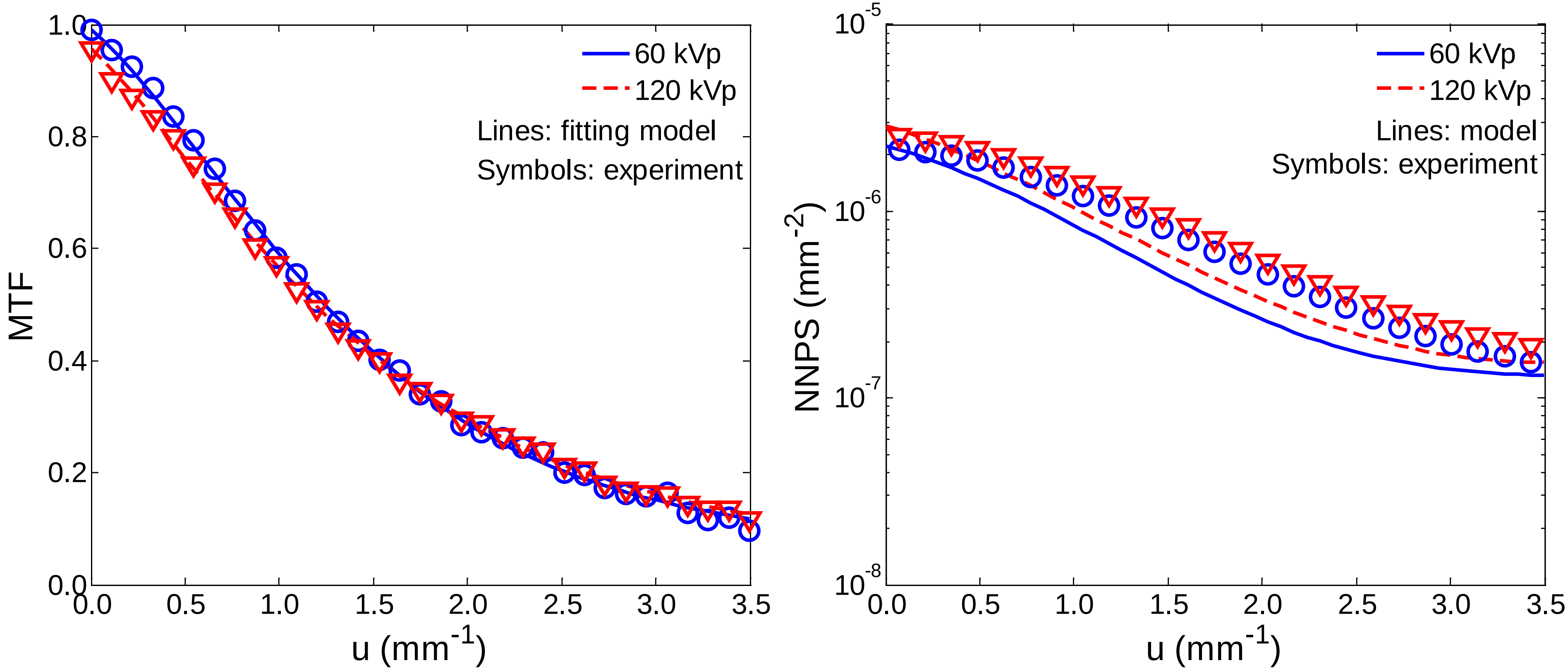
Validation

- Validation between measured in CsI/a-Si detector and CSA model
- 60 kVp + (13.5 + 2.5) mmAl / 120 kVp + (23.0 + 4.5) mmAl + 0.3 mmCu



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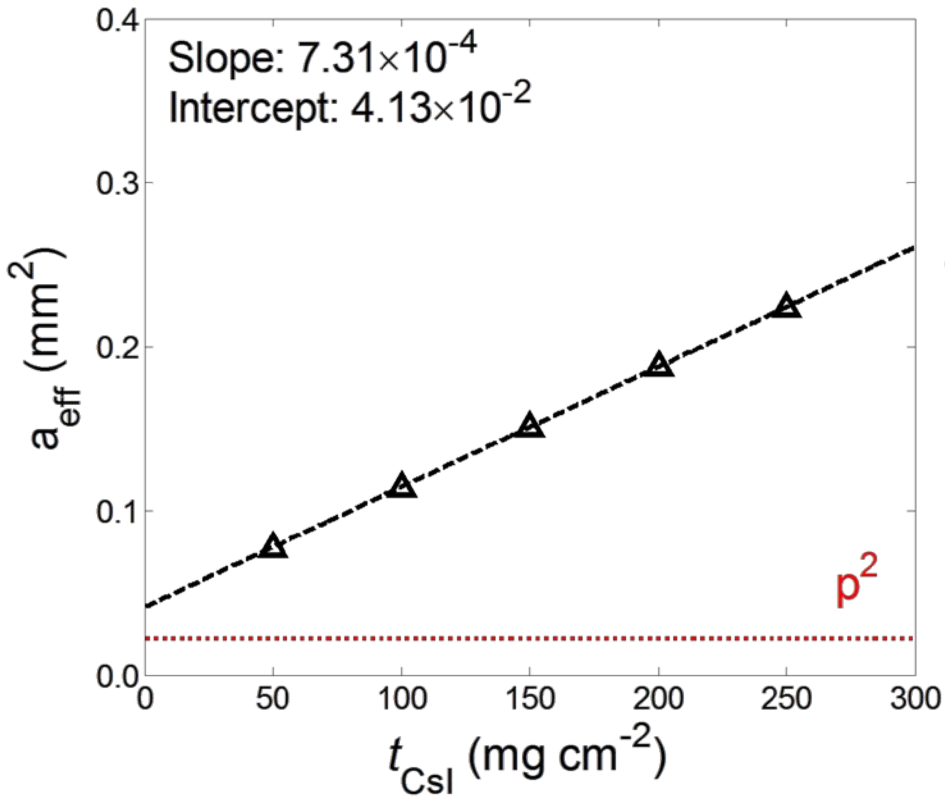
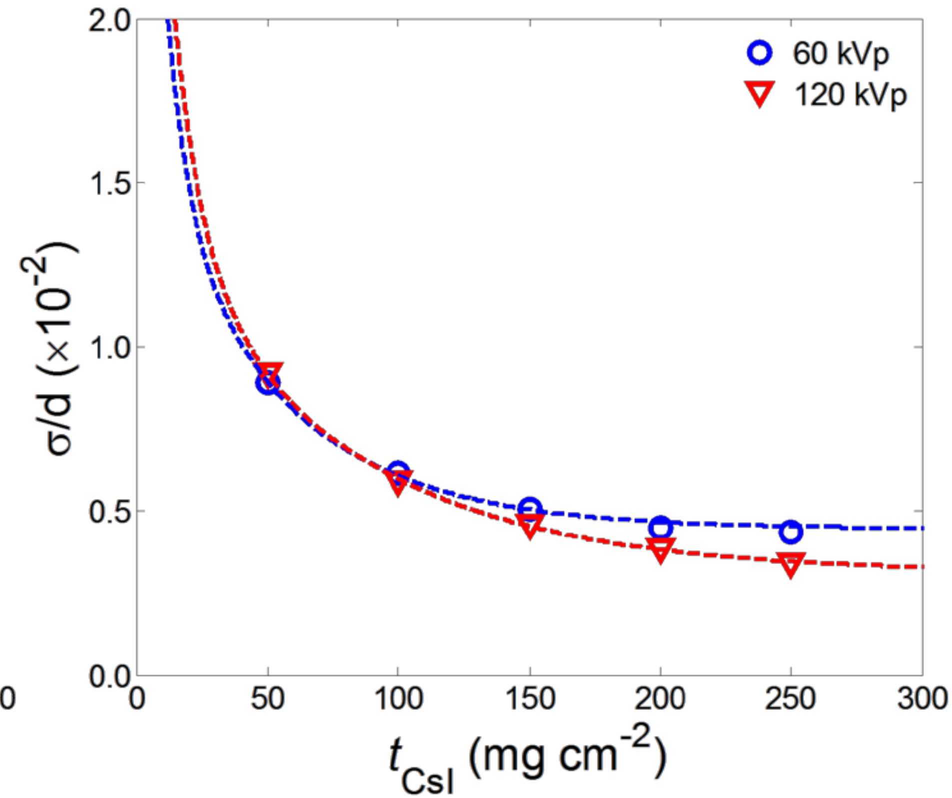
Theoretical performance

- Calculation results of hypothetical detector performances using the cascaded-systems model
  - $a_{eff} = \left[2\pi \int_0^\infty T(f)\mathrm{d}f\right]^{-1}$, $\sigma/\bar{d} \sim \left(\bar{q}_0 a_{eff} \alpha I\right)^{-1/2}$





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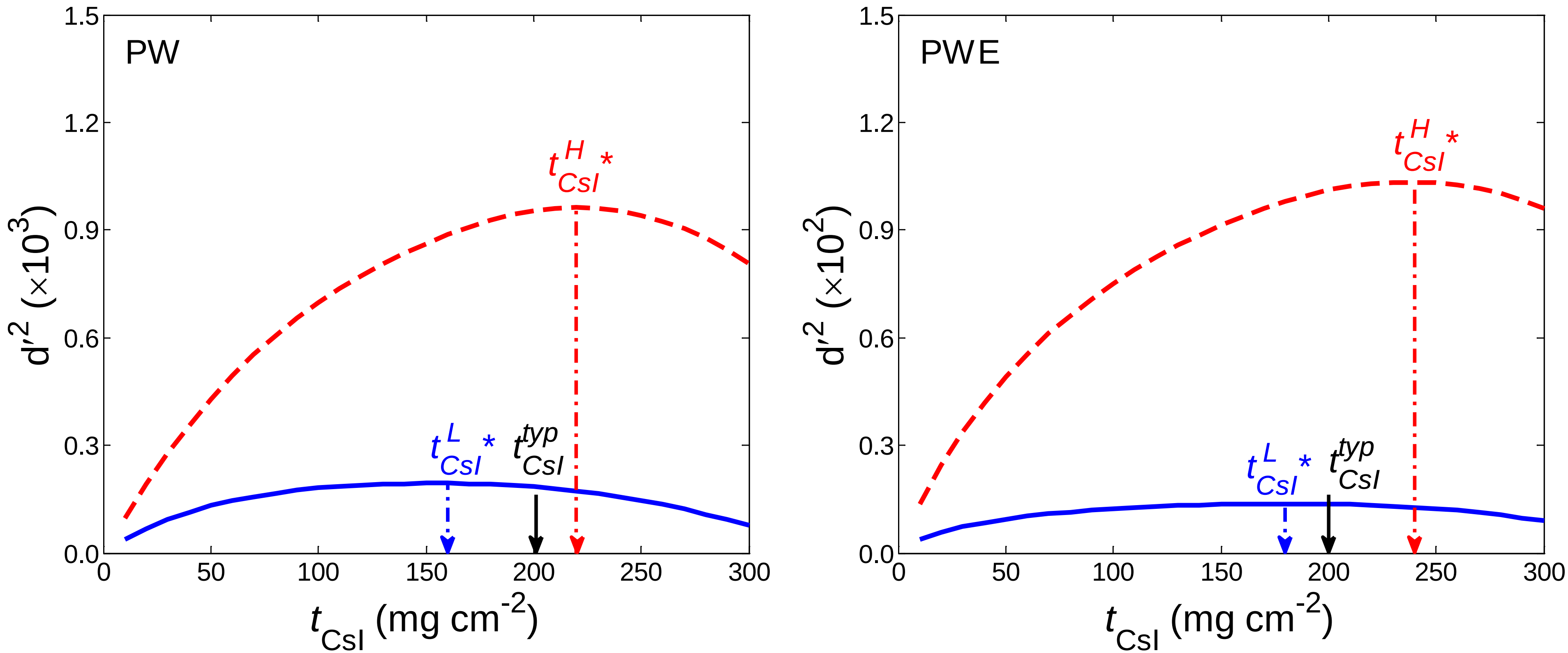
Detectability index

- Detectability indexes of conventional radiography
  - In the detectability index for the PW model, the typical CsI thickness (i.e., $t_{CsI}^{typ} = 200\ mg\ cm^{-2}$) is located between the respective optimal CsI thicknesses calculated for low and high-kVp spectra



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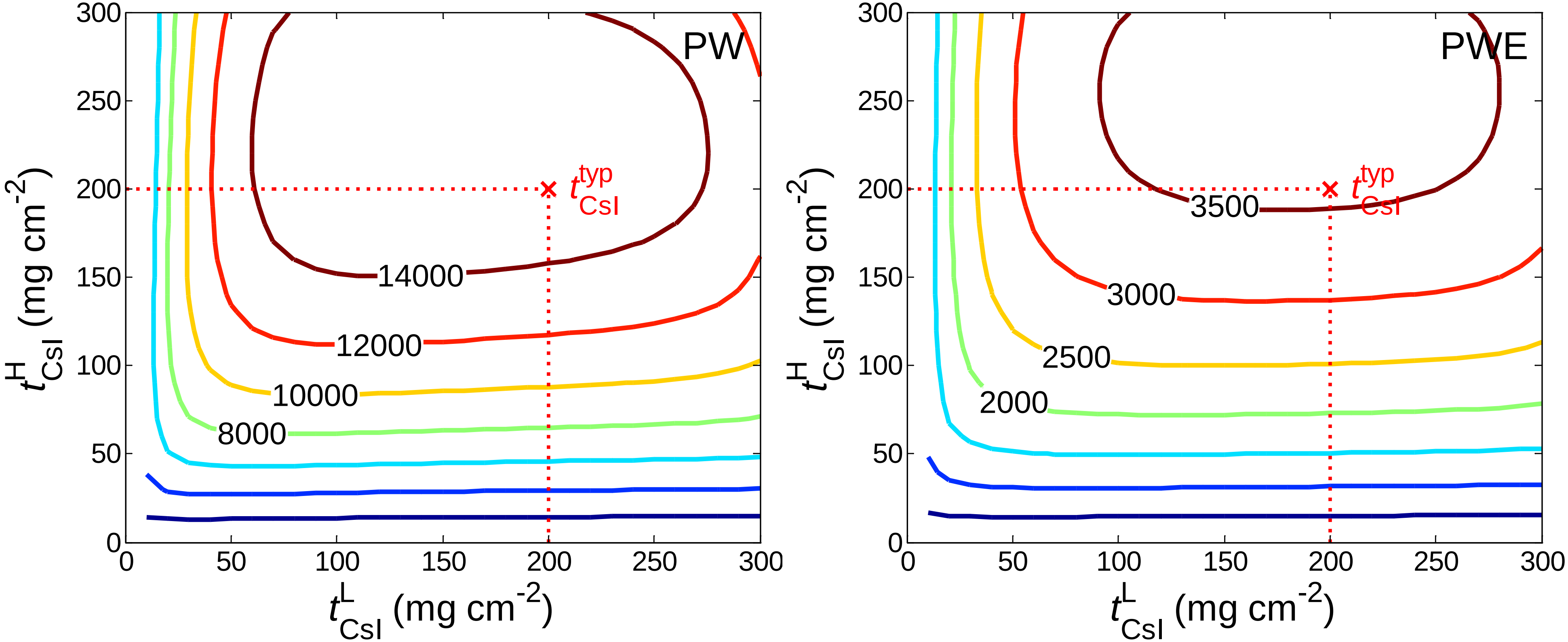
Detectability index

- Detectability indexes of dual-energy radiography
  - For the PW model, the optimal t_{CsI} for dual-energy imaging ranges $\sim 120 - 250\ mg\ cm^{-2}$ for the low-kVp spectrum whereas it ranges for $\sim 230 - 300\ mg\ cm^{-2}$ or thicker for the high-kVp spectrum



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Conclusion

- The optimal CsI thickness for dual-energy chest imaging has been theoretically investigated by evaluating prewhitening observer model detectability indexes
- To evaluate the PW and PWE detectability indexes, dual-energy fluence and MTF have been reviewed compared to the conventional descriptions
- From the calculation results, the typical CsI thickness of 200 $\mathrm{mg\,cm^{-2}}$ is placed in the optimal extent with the PWE model, whereas the PW model requires a larger CsI thickness for better detectability performance
- Although t_{CsI}^{typ} does not much depart from the optimal ranges, the t_{CsI} larger than t_{CsI}^{typ} is preferred for a better dual-energy imaging performance
- It is worth to note that the absolute values of detectability indexes obtained for dual-energy radiography are higher than those for conventional radiography

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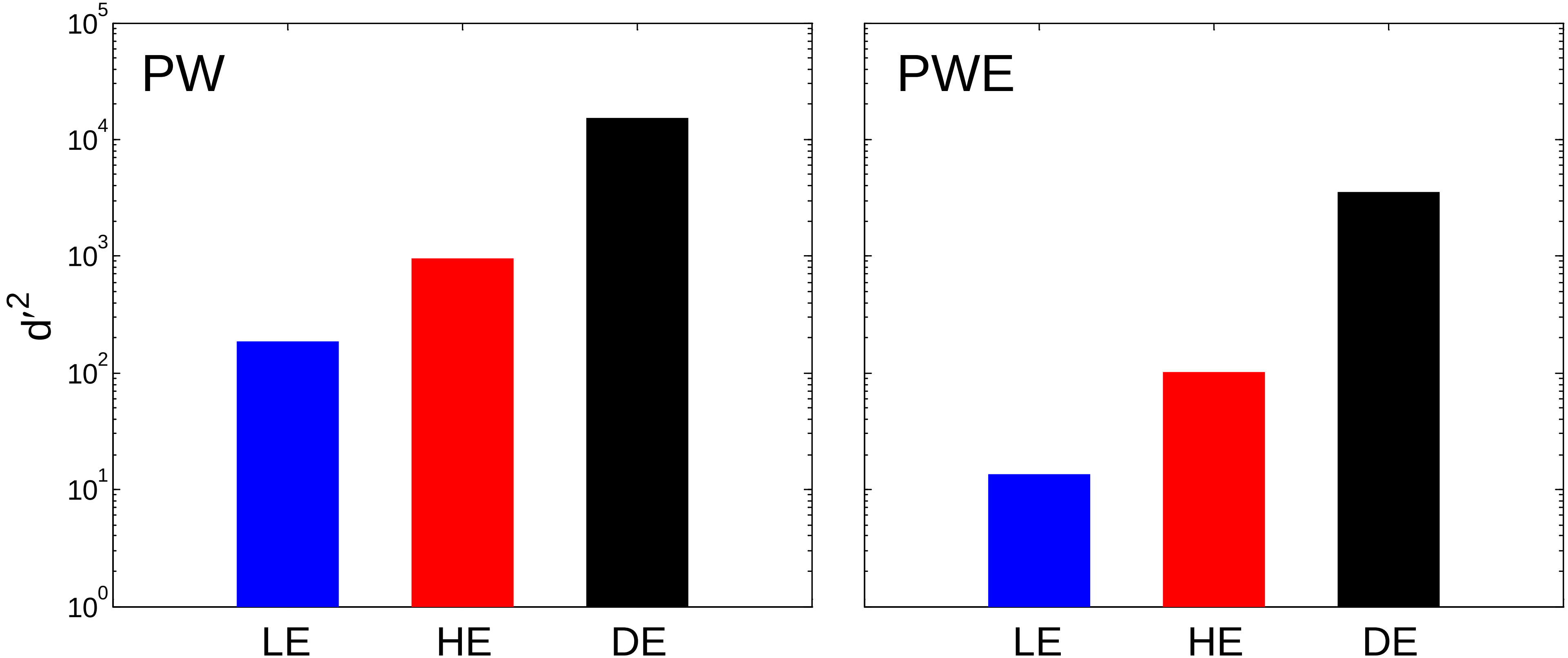
Detectability index



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