3D dose distribution in two clinical digital breast tomosynthesis units: a phantom study

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“Mean” glandular dose as reference in X-ray breast imaging

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THE EFFECT OF DOSE HETEROGENEITY ON RADIATION RISK IN MEDICAL IMAGING

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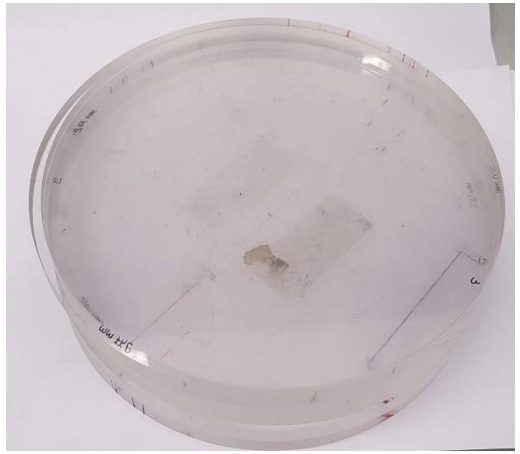
The current estimations of risk associated with medical imaging procedures rely on assessing the organ dose via direct measurements or simulation. The dose to each organ is assumed to be homogeneous. To take into account the differences in radiation sensitivities, the mean organ doses are weighted by a corresponding tissue-weighting coefficients provided by ICRP to calculate the effective dose, which has been used as a surrogate of radiation risk. However, those coefficients were derived under the assumption of a homogeneous dose distribution within each organ. That assumption is significantly violated in most medical-imaging procedures. In helical chest CT, for example, superficial organs (e.g. breasts) demonstrate a heterogeneous dose distribution, whereas organs on the peripheries of the irradiation field (e.g. liver) might possess a discontinuous dose profile. Projection radiography and mammography involve an even higher level of organ dose heterogeneity spanning up to two orders of magnitude. As such, mean dose or point measured dose values do not reflect the maximum energy deposited per unit volume of the organ. In this paper, the magnitude of the dose heterogeneity in both CT and projection X-ray imaging was reported, using Monte Carlo methods. The lung dose demonstrated factors of 1.7 and 2.2 difference between the mean and maximum dose for chest CT and radiography, respectively. The corresponding values for the liver were 1.9 and 3.5. For [illegible] and breast tomosynthesis, the difference between mean glandular dose and maximum [illegible] was 3.1. Risk models based on the mean dose were found to provide a reasonable reflection of cancer risk. However, for leukaemia, they were found to significantly under-represent the risk when the organ dose distribution is heterogeneous. A systematic study is needed to develop a risk model for heterogeneous dose distributions.

Layered breast phantoms

PMMA homogeneous phantom
5 circular slabs
Single slab thickness = 10 mm



BR 50/50 heterogeneous phantom
CIRS Phantom, BR3D mod. 020
Single slab thickness = 10 mm

DBT scanners and technique factors

Breast thickness (cm)	kVp	mAs
2	26	61.8
3	27	88.0
4	28	125.8
5	29	178.5

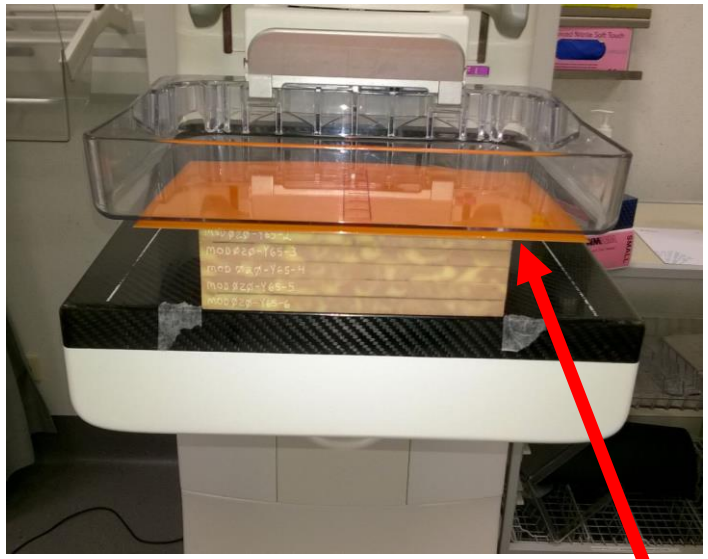
Siemens Mammomat Prime
Anode/filter: W/Rh
Scan angle: 50°
Source-detector distance: 65 cm

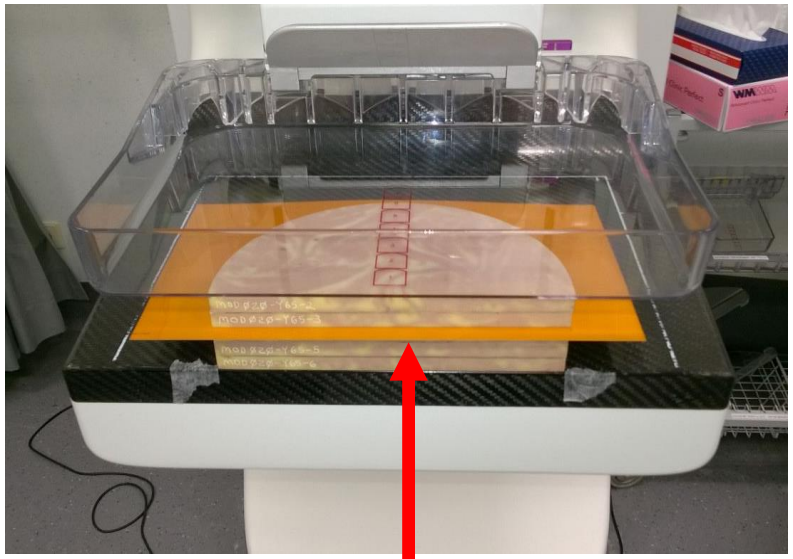
Breast thickness (cm)	kVp	mAs
2	26	39.0
3	28	41.0
4	29	53.0
5	31	59.0

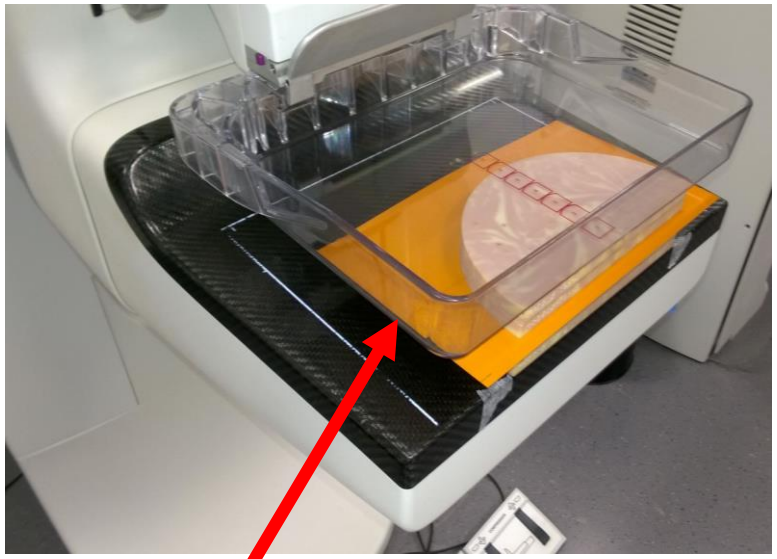
Hologic Selenia Dimensions
Anode/filter: W/Al
Scan angle: 15°
Source-detector distance: 70 cm

*Both scanners are located at the Katholieke University of Leauven

Dose measurements via radiochromic films XRQA2 type

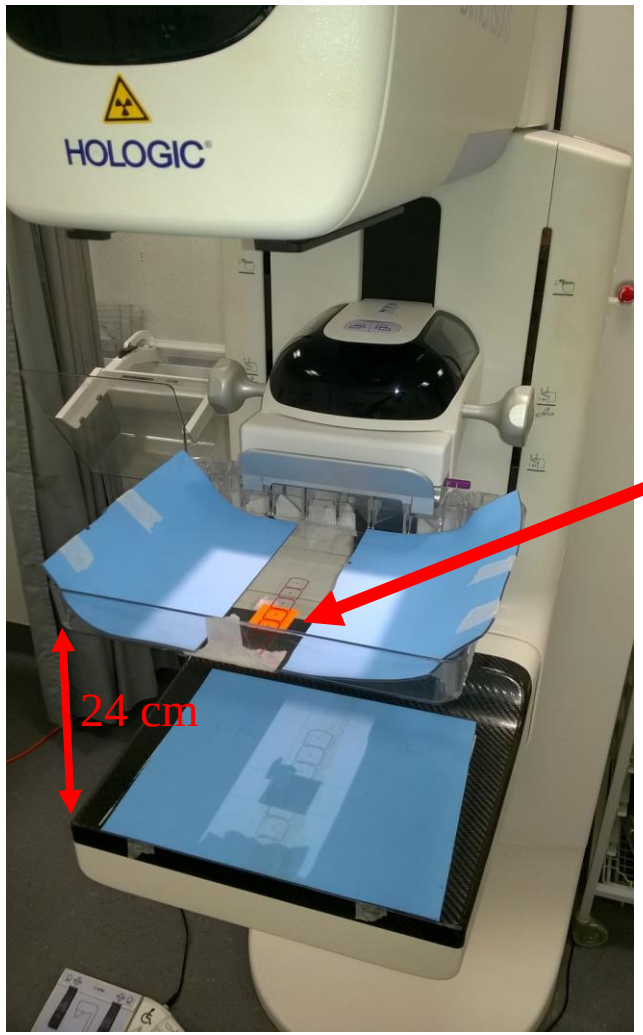




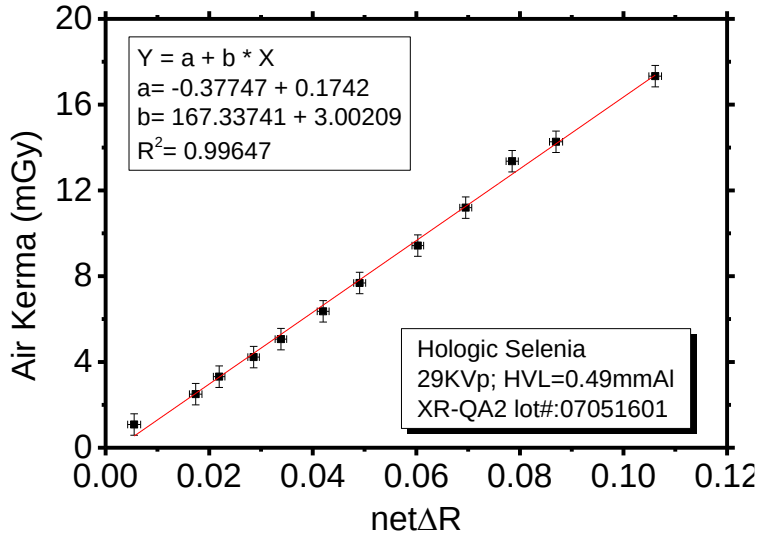


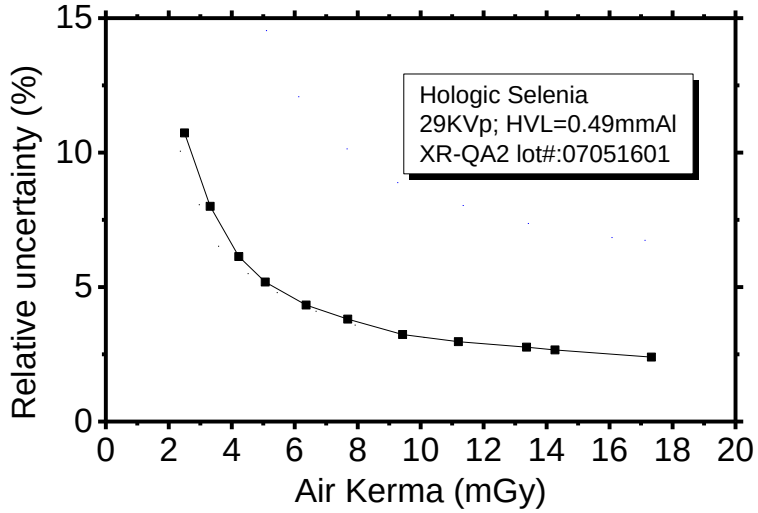
Calibrated GafChromic films placed within the layered phantoms

GafChromic film calibration

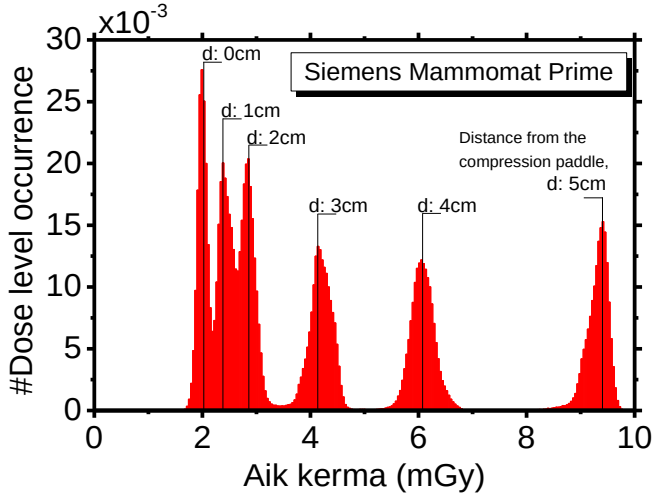


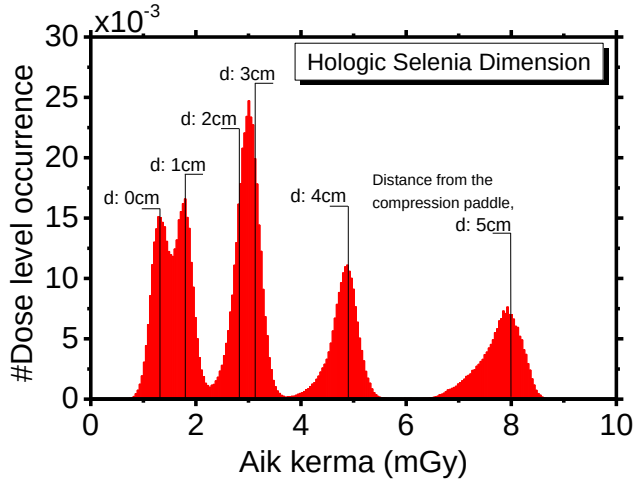
3×3 cm^2 GafChromic pieces irradiated at known exposure levels

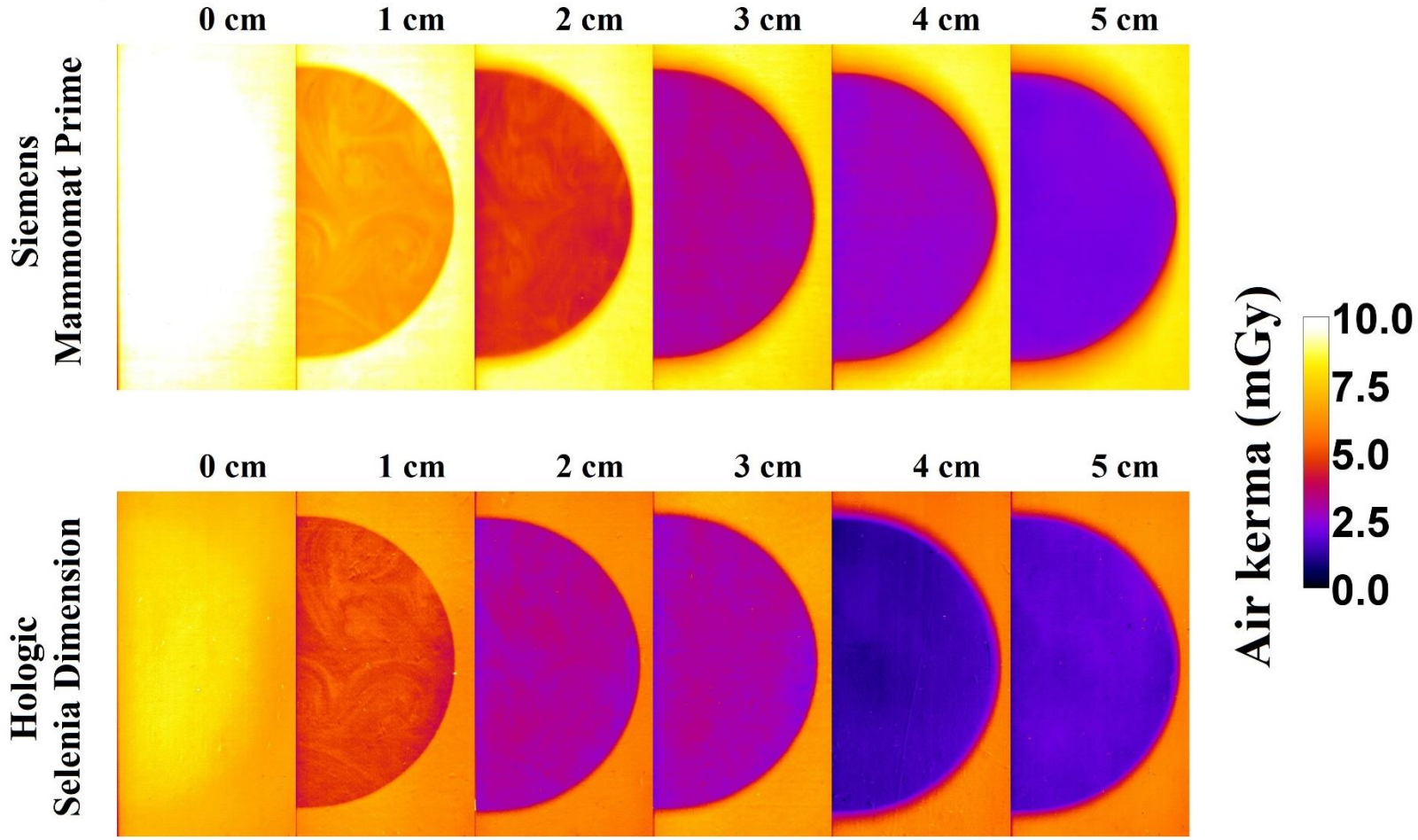




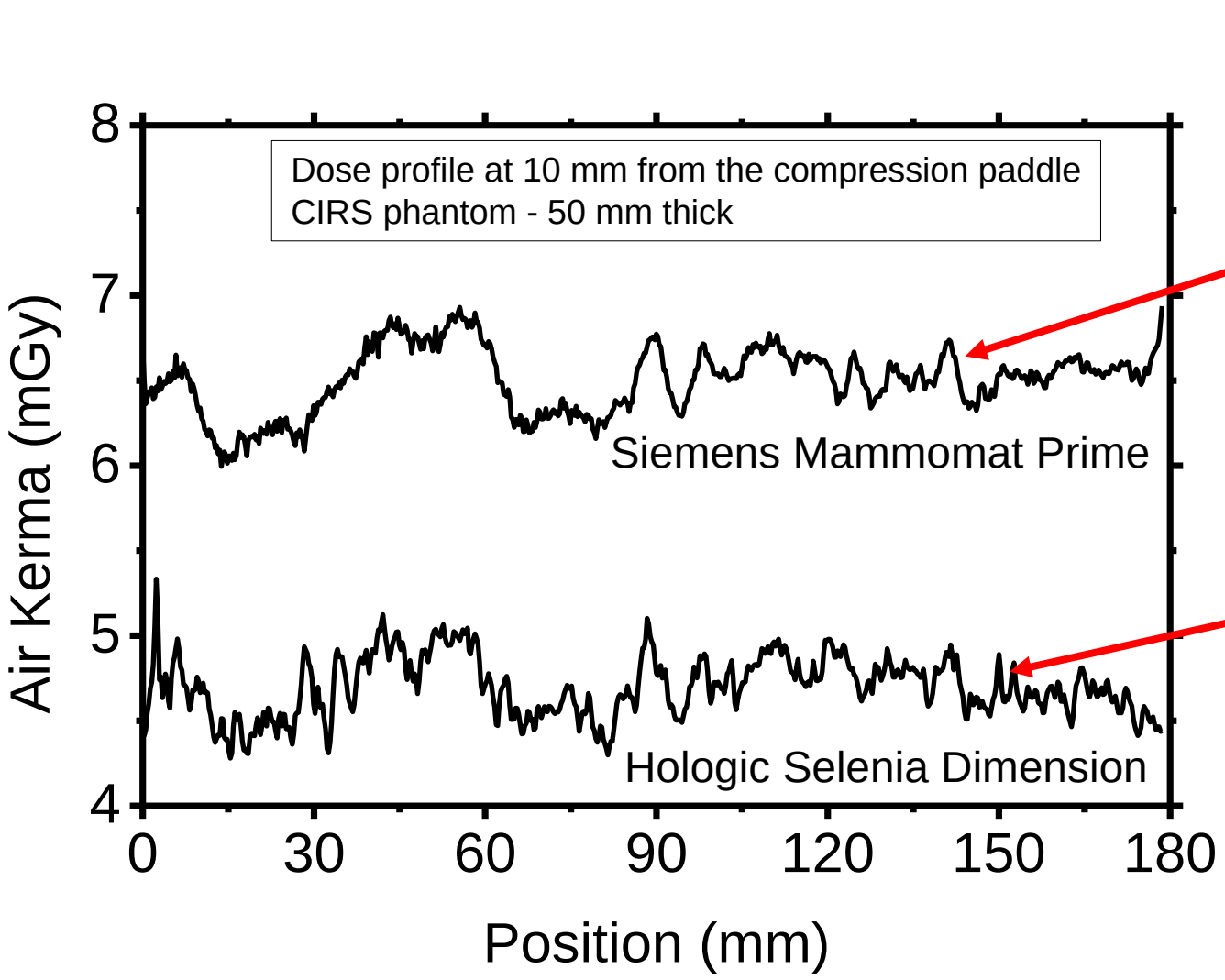
Dose map
CIRS phantom – 5 cm thick

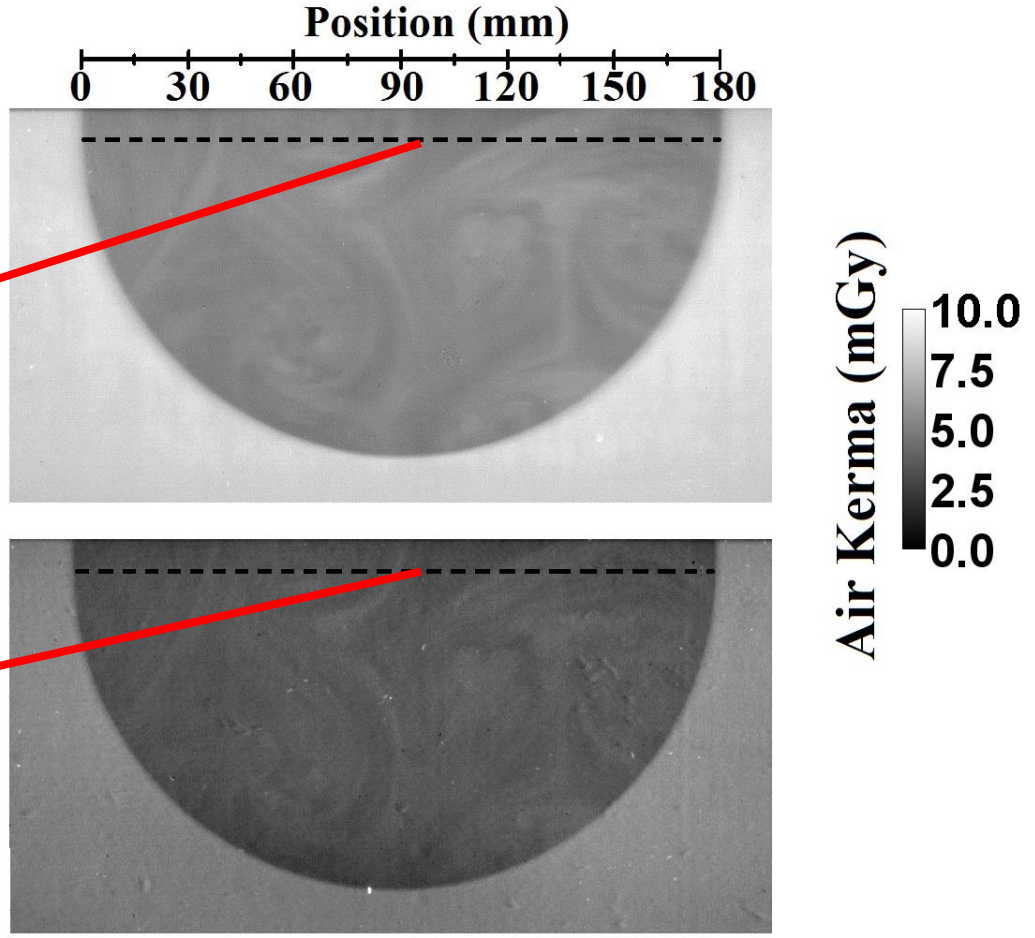




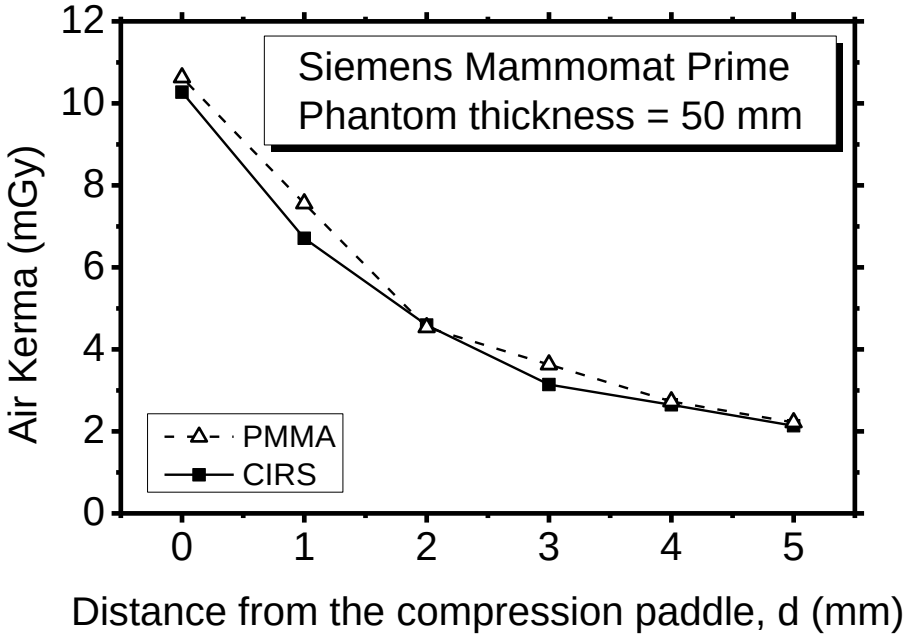


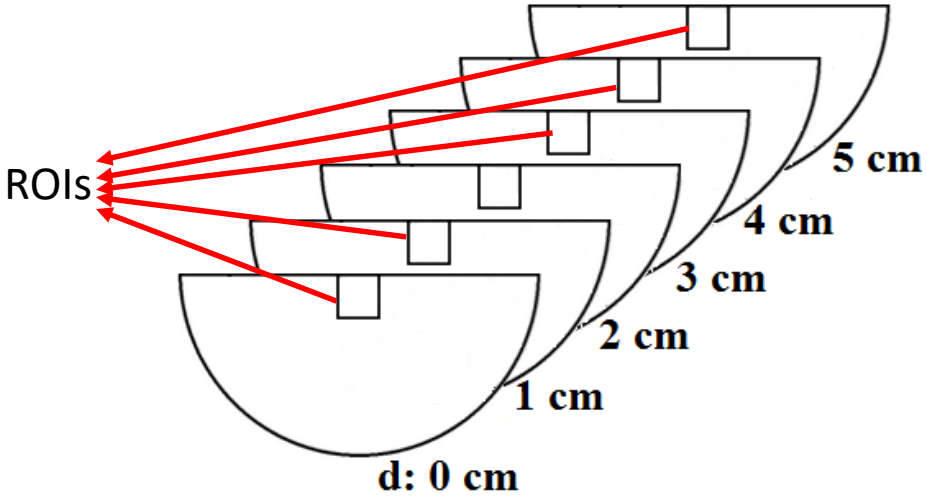
In-plane Dose Profile

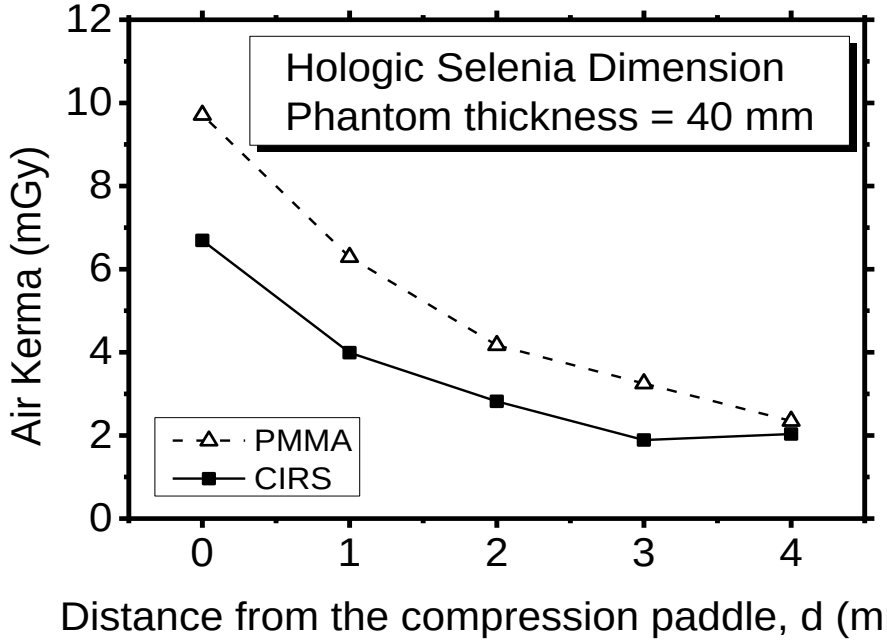




Vertical Dose Profile







Conclusion

1) We measured, via GafChromic films XR-QA2 type, dose distributions (dose map) within two breast phantoms for two clinical DBT scanners;

2) We showd the differences between the measured dose and dose distributions which depend on the scanner protocol and spectrum;

3) We have been developing a Monte Carlo code for dose estimated in DBT and it will be validated vs measurement data presented in this work.

Thank you!!!

Any questions?

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