Noise in accelerated in-silico x-ray breast images: impact on the breast anatomy and the detector.

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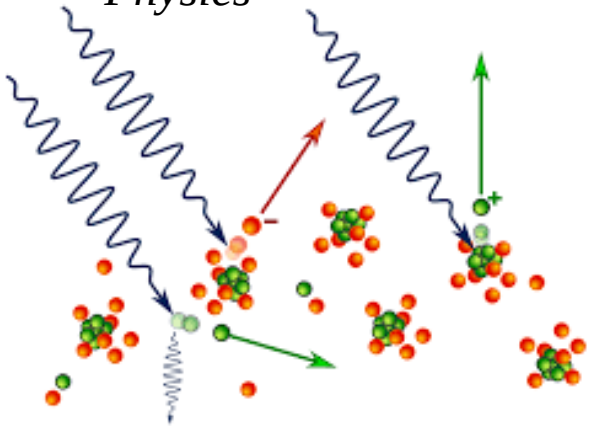
Virtual clinical trials in breast imaging for reduction of time and cost

Imaging apparatus

Patient cohort

In-silico replication

Physics



Medical Physics Research Laboratory

Istituto Nazionale di Fisica Nucleare

AGATA

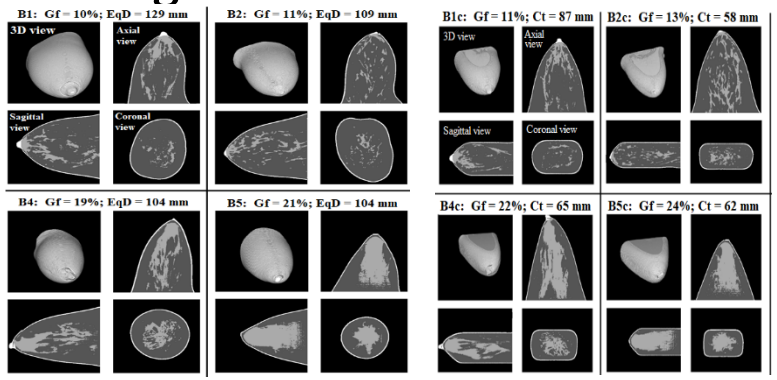
Advanced Geant4-based Application for in-silico clinical Trial in x-ray breAst imaging

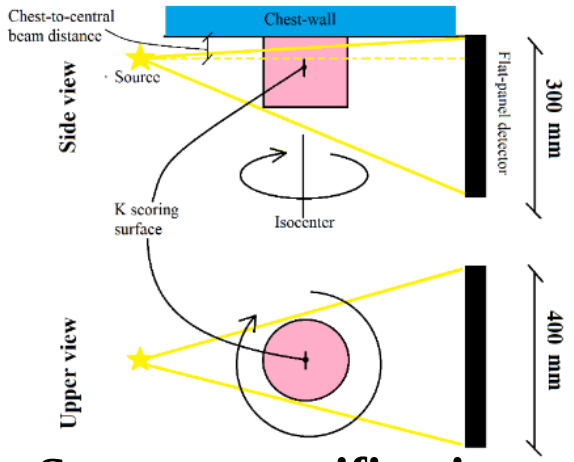
Monte Carlo based platform for the simulation of **mammography, DBT and BCT** exams relying on **patient derived breast phantoms**

The MC simulation platform

INPUT

Digital Breast Phantoms





Scanner specifications

Monte Carlo based on GEANT4

OUTPUT

Dose distribution

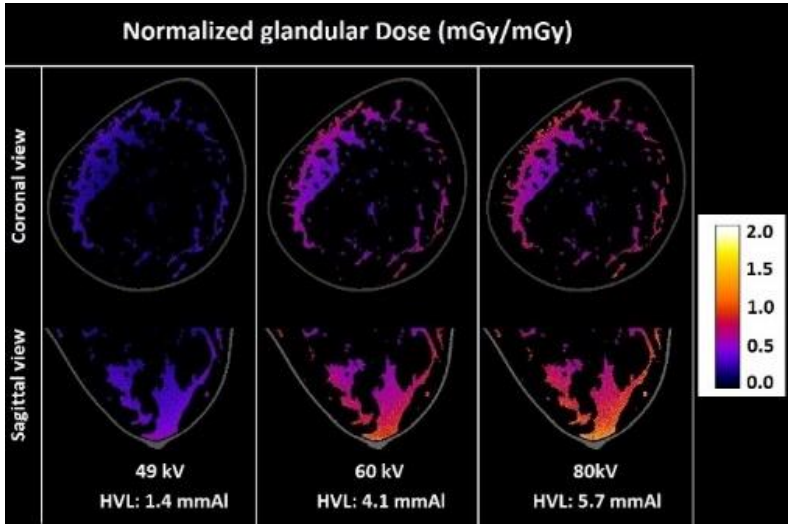
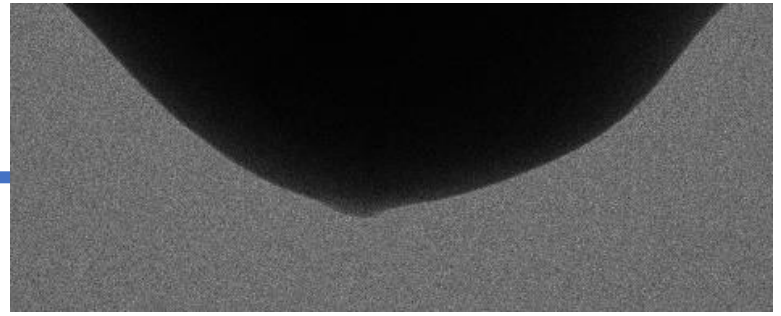
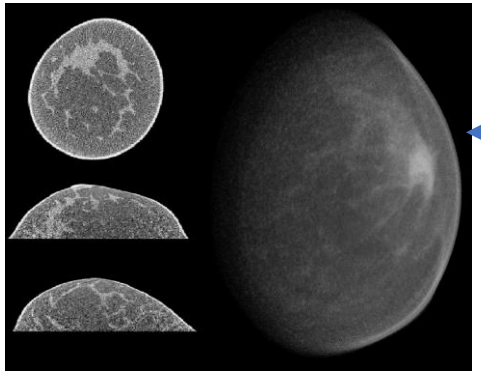


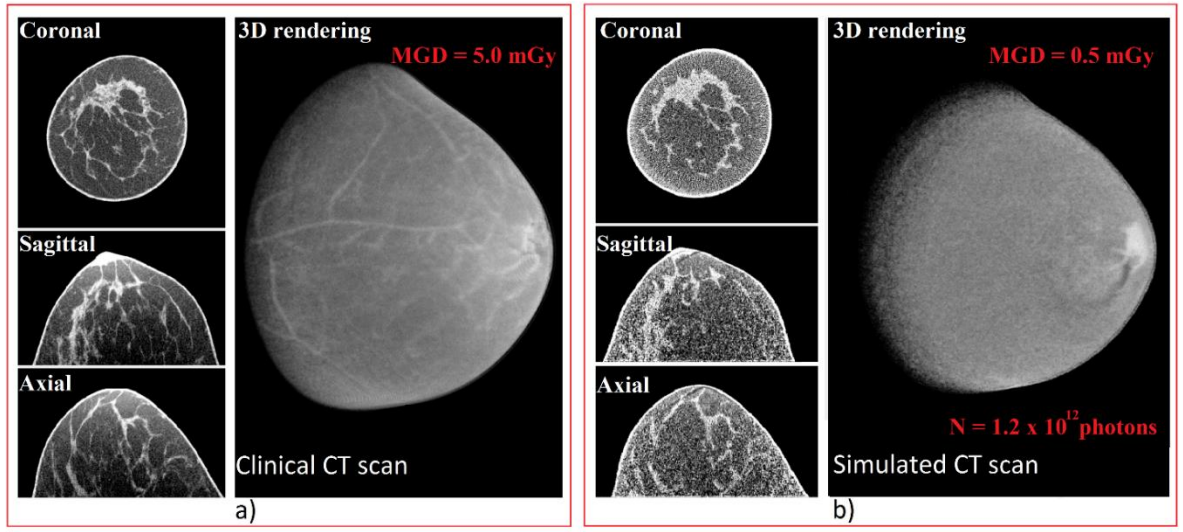
Image projections



Post processing

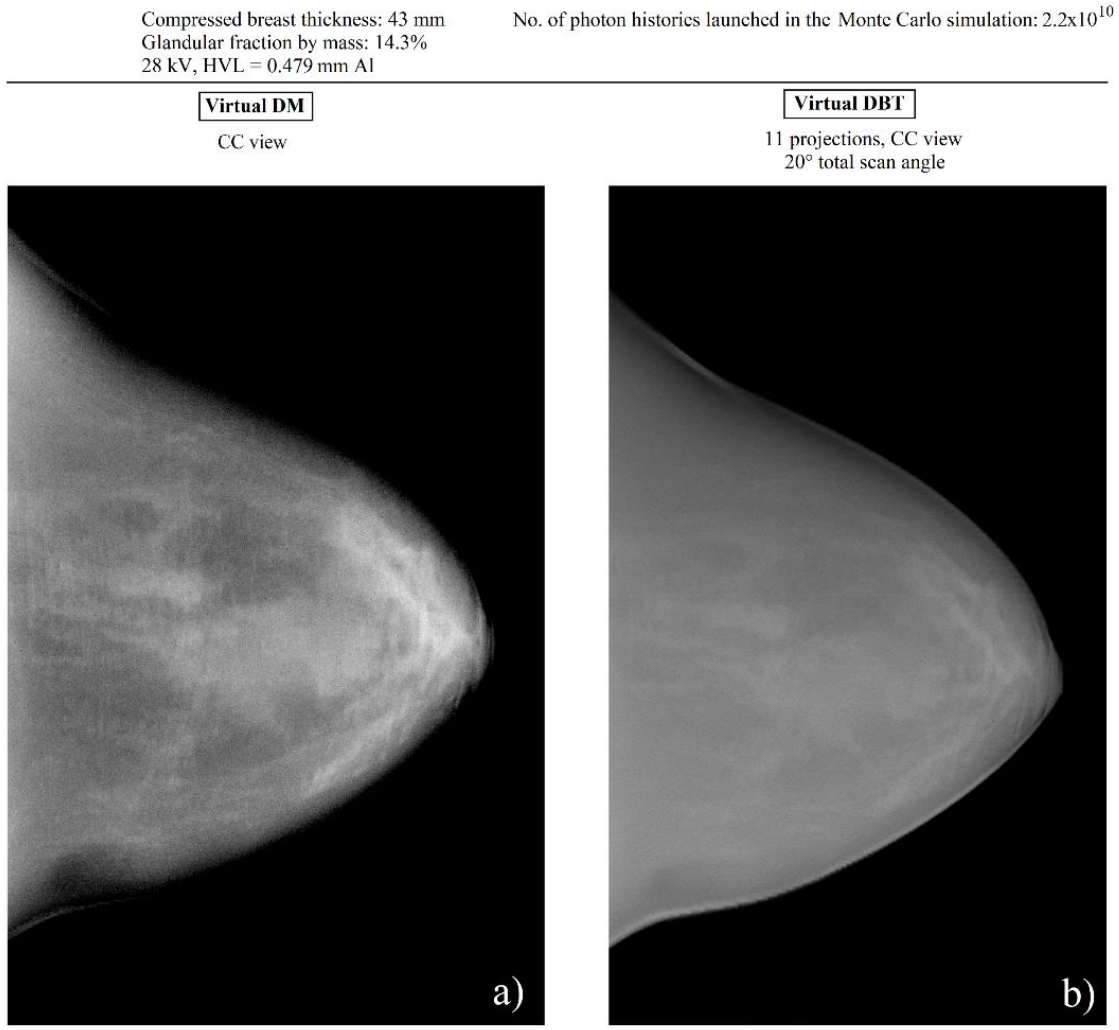


Use examples: technologies evalutions and comparison



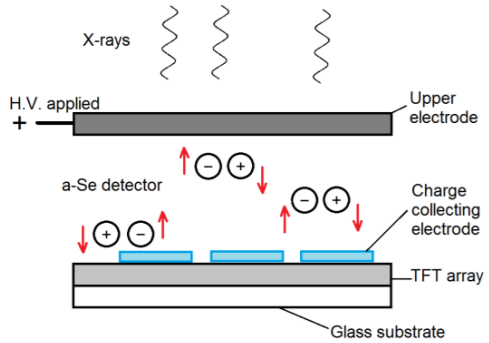
Comparison of clinical and simulated CT dataset
Multiscale structural similarity index between clinical and simulated CT datasets (perfect match MS-SSID = 1)

MS-SSID = 0.88
(good match, taking into account the different noise in the two CT datasets)



Detector model for realistic noise and spatial resolution

Simulated image – Dose deposit within a defined absorbed layer



In the AGATA platform the image is simulated as dose maps in the detector, which is modelled as an absorbing layer reflecting real geometries. This takes into account for the detector efficiency, Swank noise, poissonian noise and scatter. The inclusion of fluorescence implies also reduction of effficiency and spatial resolution, getting closer to relistic characteristics. The simulated image is then suitably post-proceessed.

Pixel value recovery – Pixel values are normalized to realistic scale

Spatial reolution tuning – Low-band gaussian filtering

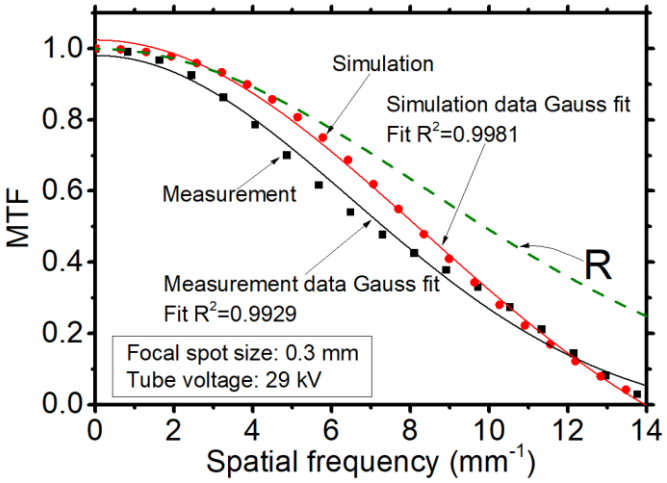
White additive noise inclusion – The power of the additive noise is evaluate by means of empirical studies

Detector model for realistic noise and spatial resolution

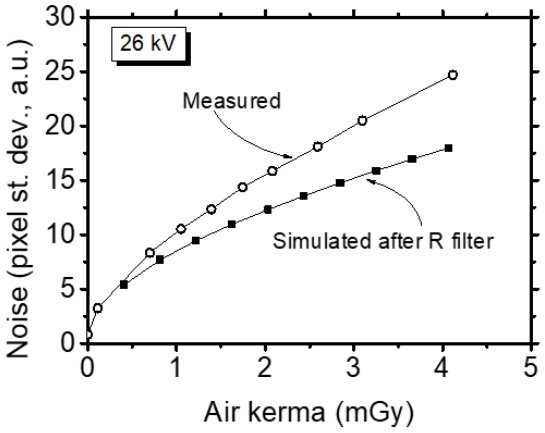
- Spatial resolution tuning

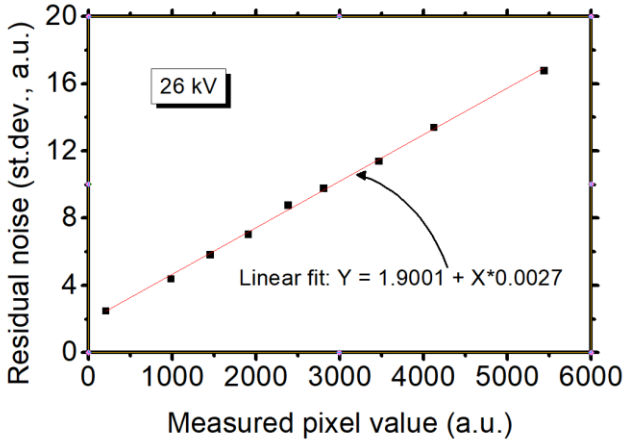
$$MTF_{Measured} = MTF_{Simulated} \cdot R$$

R is a low pass filter with Gaussian shape and standard deviation σ_R is related to the standard deviations of measured σ_M and simulated σ_S MTF as follows:



- Residual Additive White Gaussian Noise (AWGN)

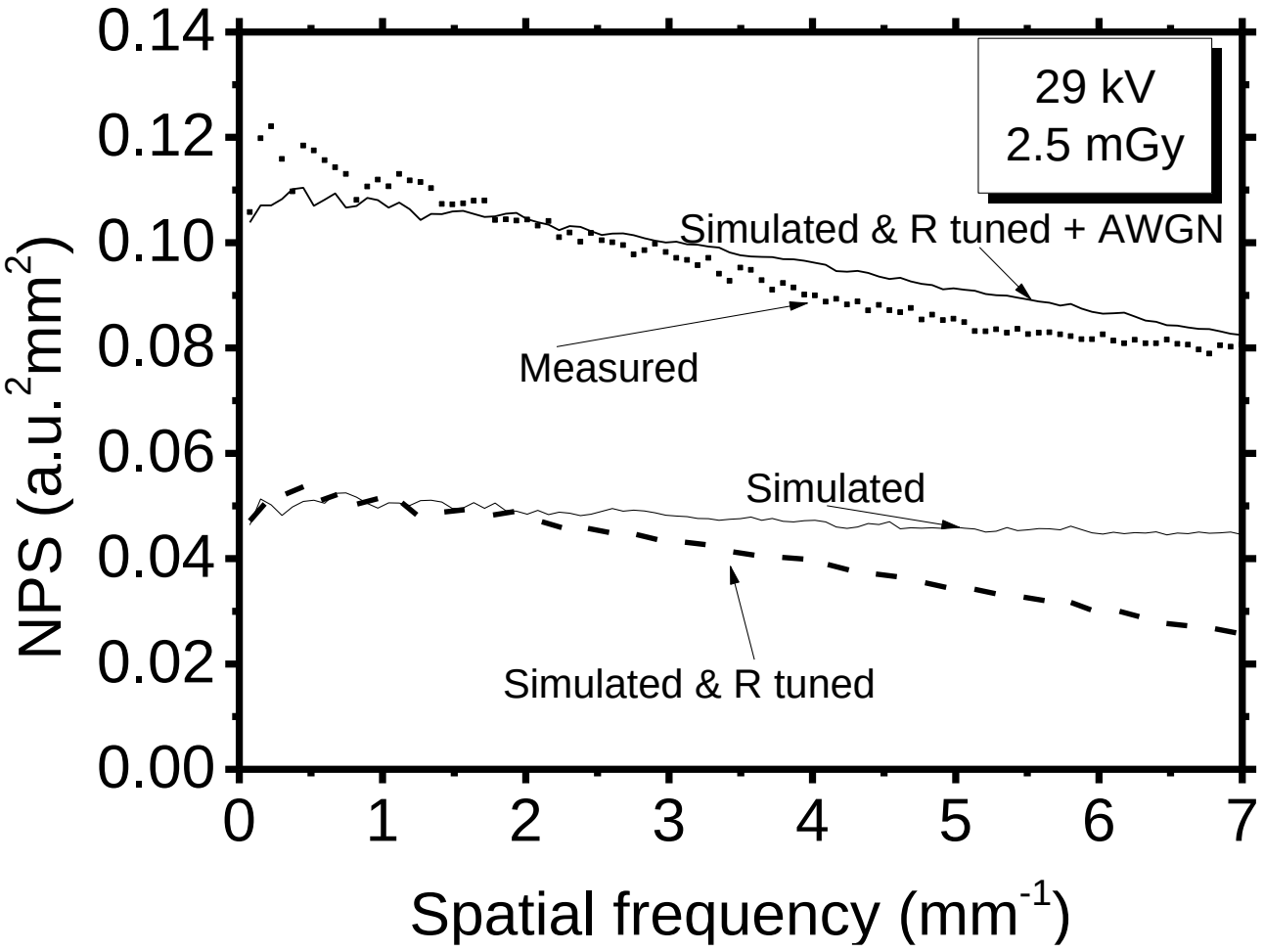




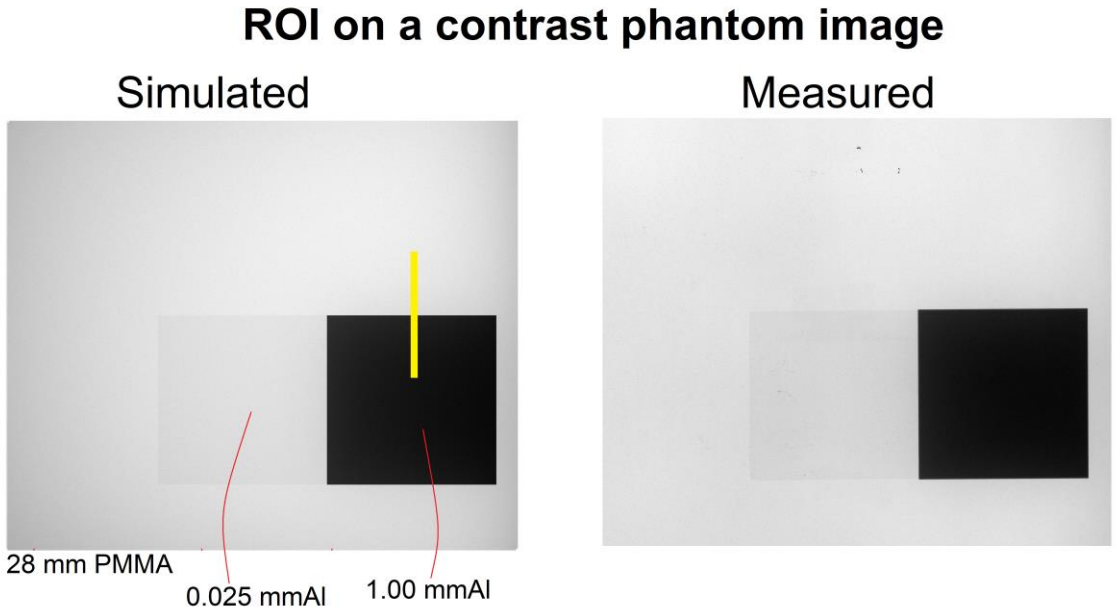
$$\sigma_{residual} = \sqrt{\sigma_M^2 - \sigma_S^2}$$

Tests on Hologic Selenia Dimension DM/DBT scanner

Noise power spectrum



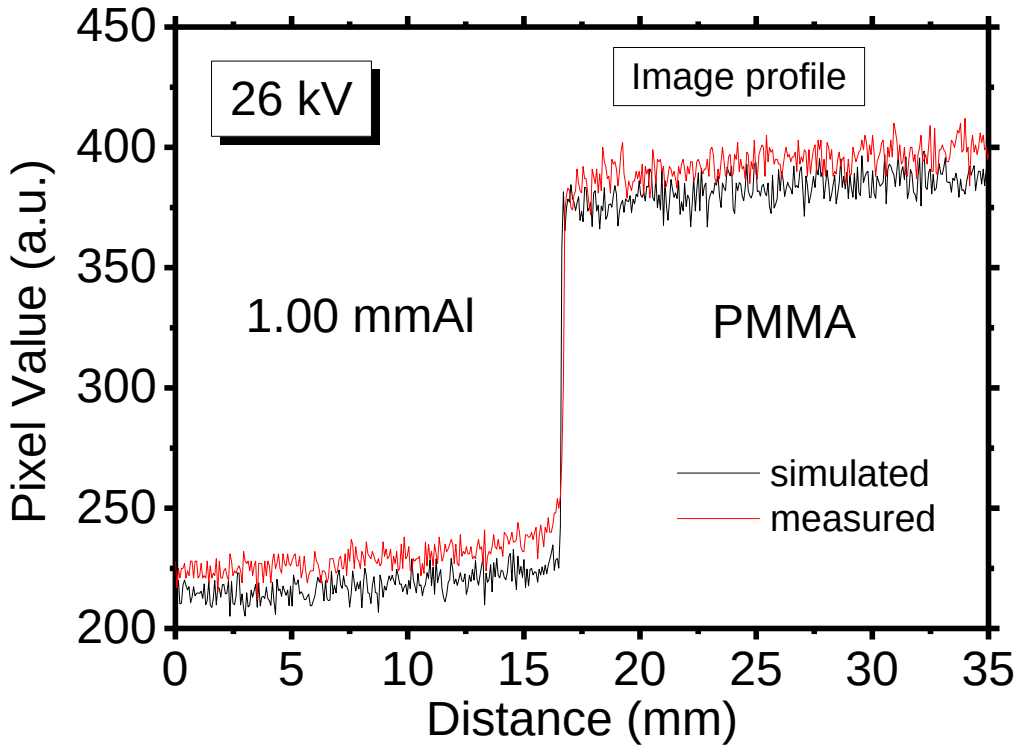
A phantom test



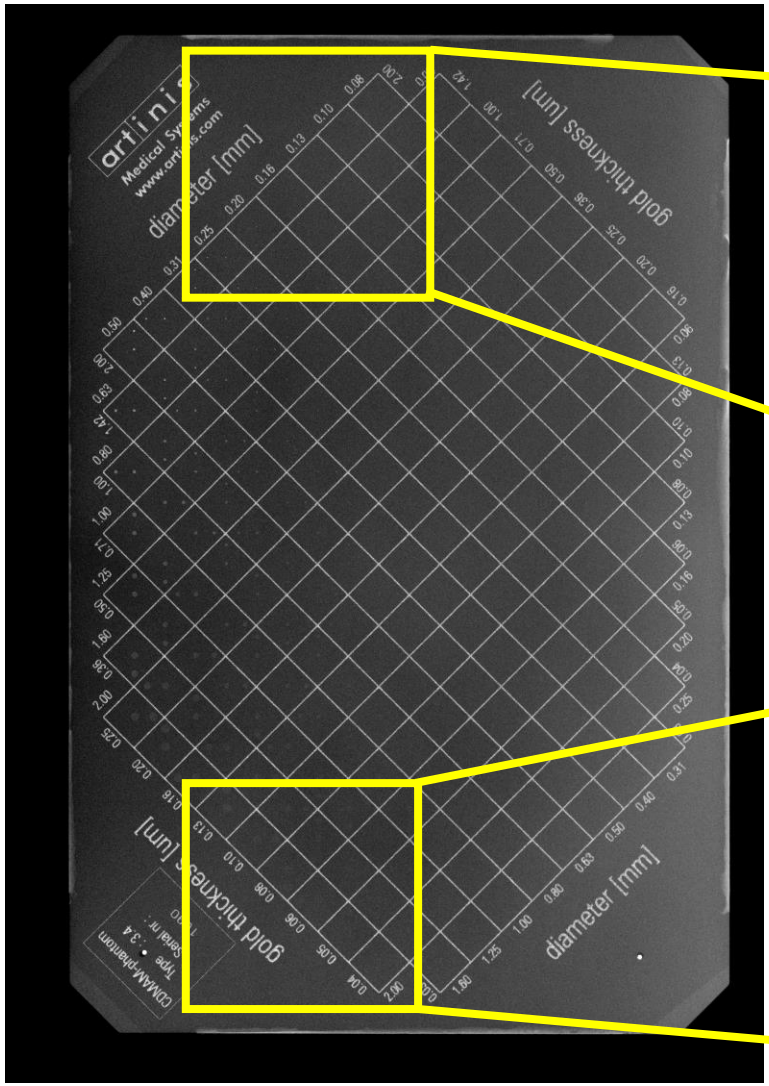
$CNR_{PMMA\text{-}1mmAl}$

Simulated = 23.0

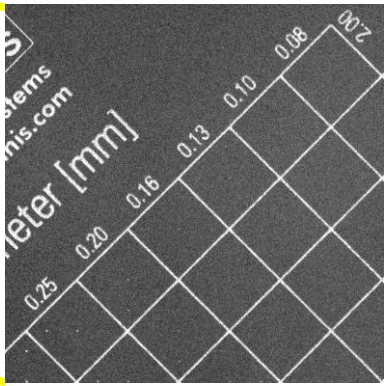
Measured = 26.0



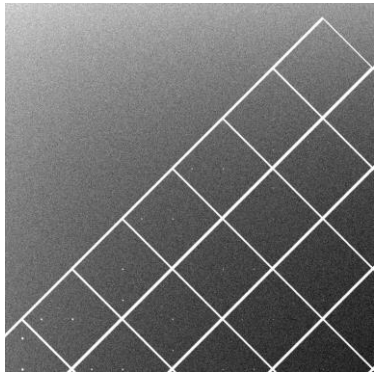
A CDMAMA test



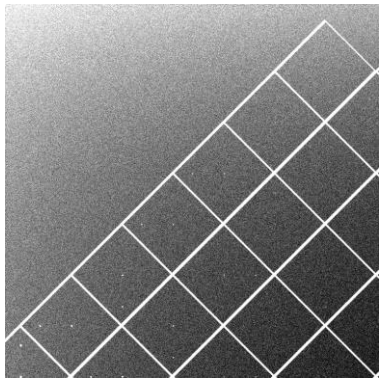
Measurement



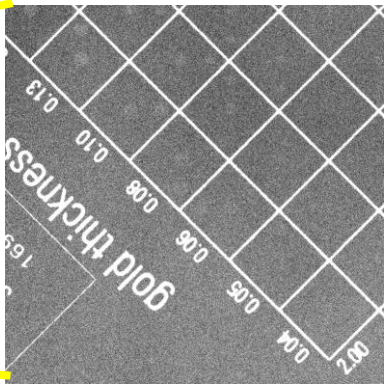
Simulated raw



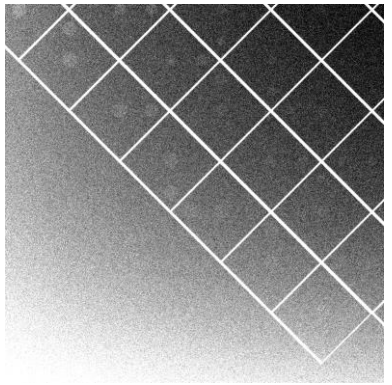
Simulated R-tuned + AWGN



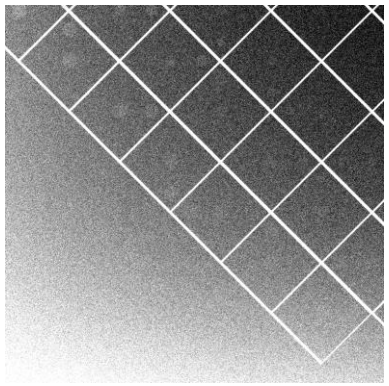
Measurement



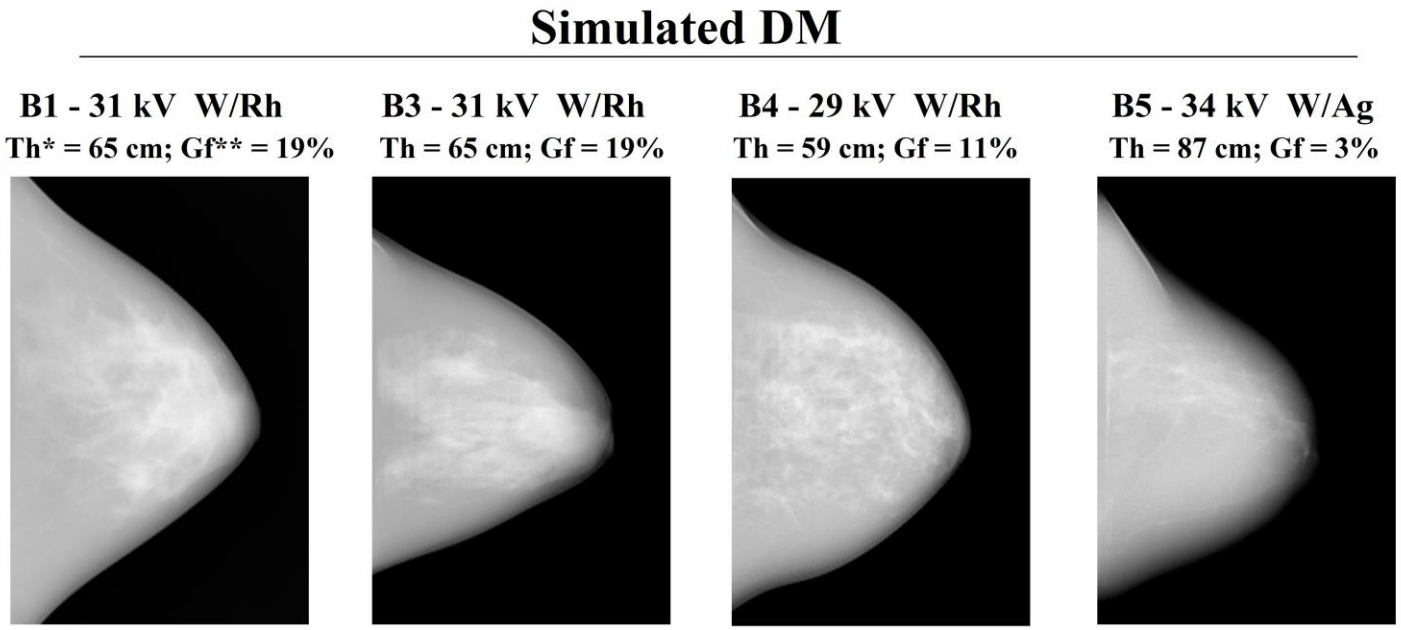
Simulated raw

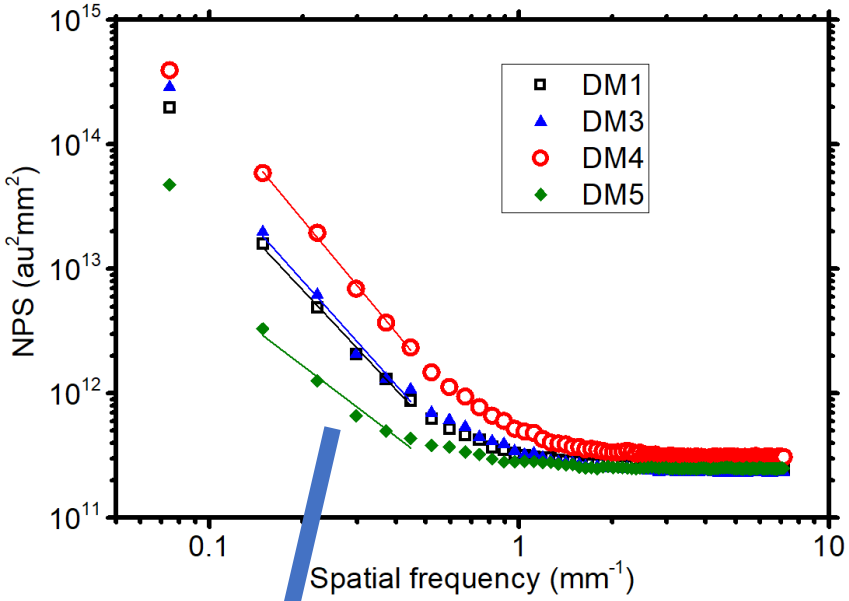


Simulated R-tuned + AWGN



Anatomical noise in simulated images





Phantom name	β
B1	2.7 ± 0.1
B3	2.8 ± 0.2
B4	3.0 ± 0.1
B5	1.9 ± 0.2

Conclusions

- ✓ We presented an empirical method for tuning spatial resolution and noise in Geant4 simulated images for tuning characteristics toward realistic ones
- ✓ Phantom tests showed the appropriateness of the proposed methodology
- ✓ Anatomical noise in simulated mammograms resulted similar to that of that evaluated on patient images

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Thanks for the attention!!!

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