Dosimetry in breast computed tomography

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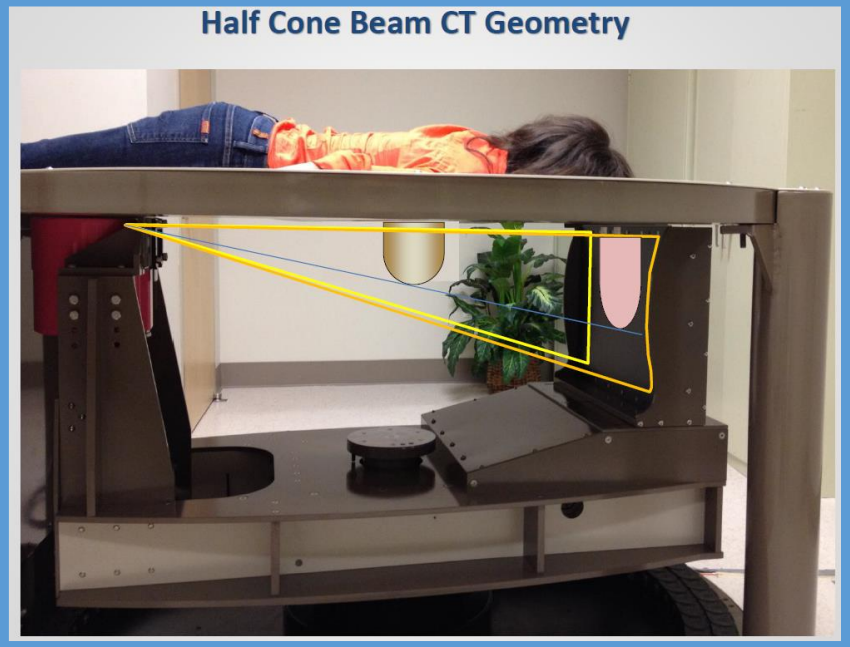
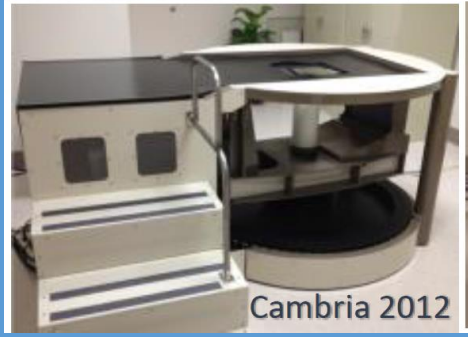


University of California Davis (Prof. J. M. Boone) 80 kVp

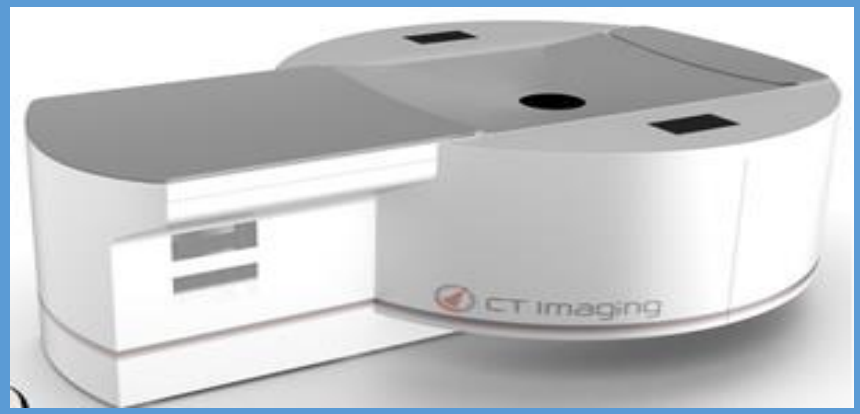


Phase-contrast breast microCT w/ SPECT (**University of Naples «Federico II»**) 60-120 kV

University of Rochester (Prof. R. Ning) **Koning Corp.** commercial scanner (FDA/EU approved for diagnostic imaging in combination with mammography, non contrast) 49 kVp

University of Massachusetts (Prof. A. Karellas) 70 kVp

University of Erlangen & CT Imaging (Prof. W. A. Kalender) Photon-counting detector 60 kVp



Dosimetry in dedicated breast CT

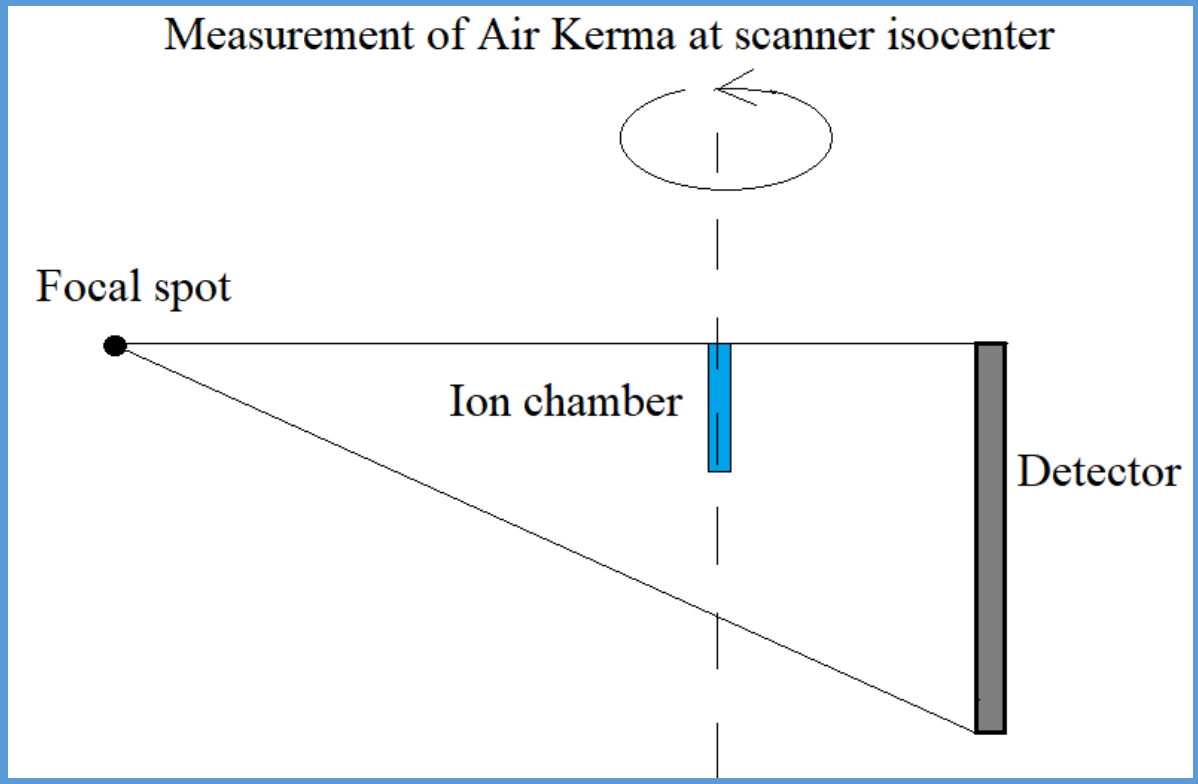
MGD = Mean Glandular Dose (mGy)

DgN_{CT} = Normalized glandular dose coefficient in CT (mGy/mGy)

K = Air kerma at scanner isocenter (mGy) in a full rotation

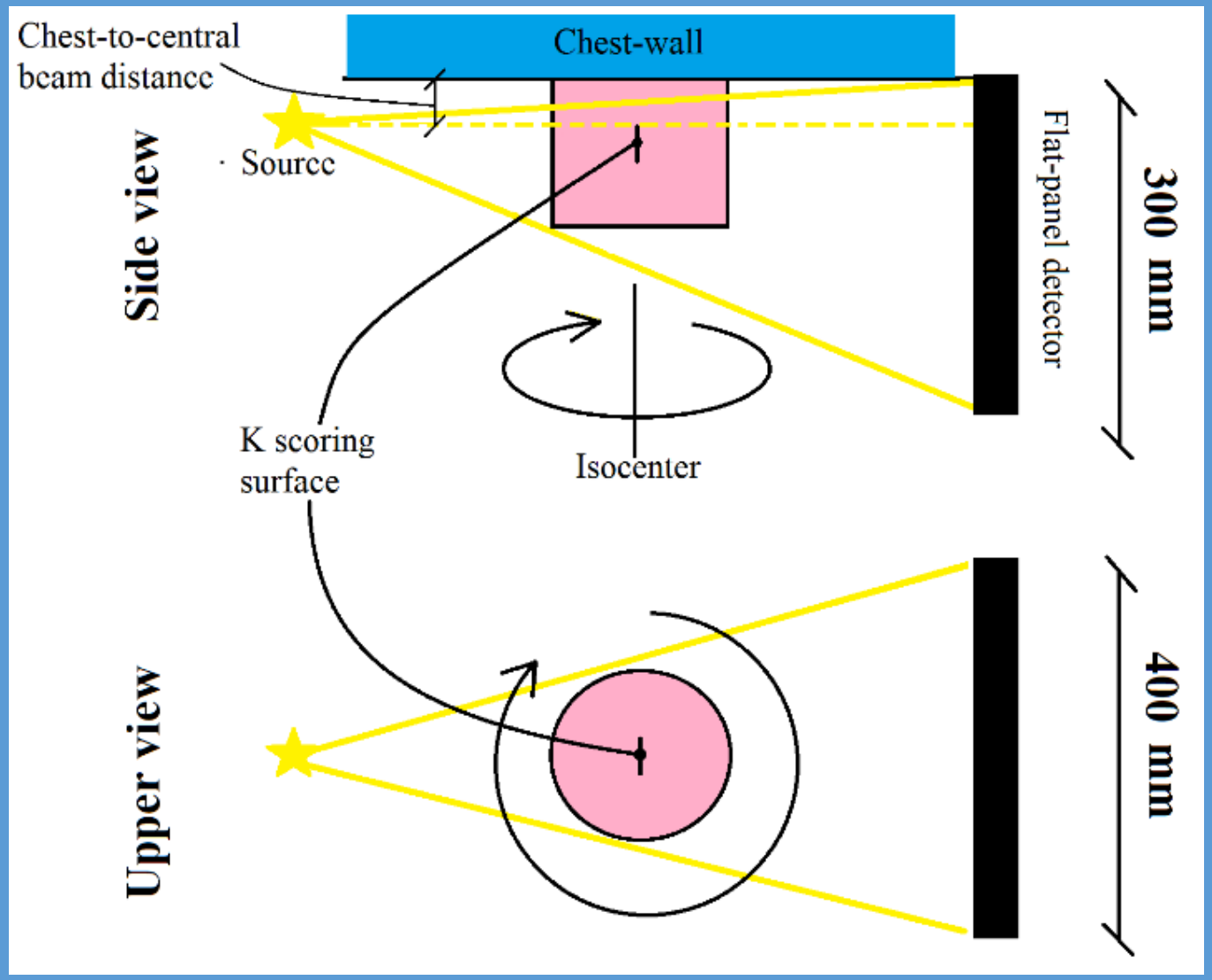
$$MGD = DgN_{CT} \times K$$

MAMMOGRAPHY:
Mean Glandular Dose
MGD = DgN x ESAK



Breast model and irradiation geometry

Homogeneous mixture adipose+glandular



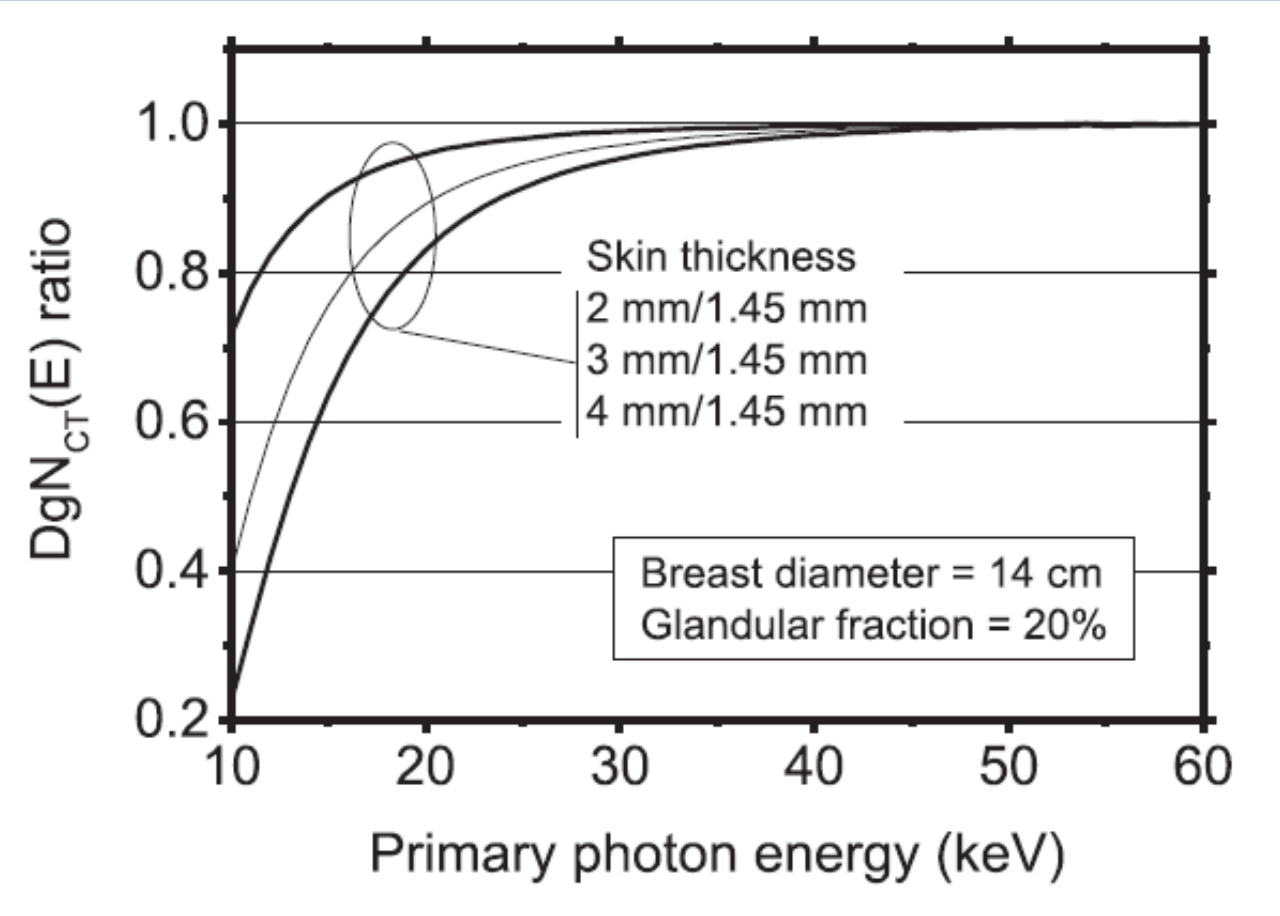
$$\mathrm{MGD} = \frac{\sum_i G_i(E) \times E_i^{dep}}{f_g \times W_b},$$

$$G(E) = \frac{f_g \times \frac{\mu_{en}}{\rho}(E)_g}{f_g \times \frac{\mu_{en}}{\rho}(E)_g + (1-f_g) \times \frac{\mu_{en}}{\rho}(E)_a}.$$

$$K = \sum_i \frac{E_i \times \frac{\mu_{en}}{\rho}(E_i)_{air}}{S \times cos\theta_i}$$

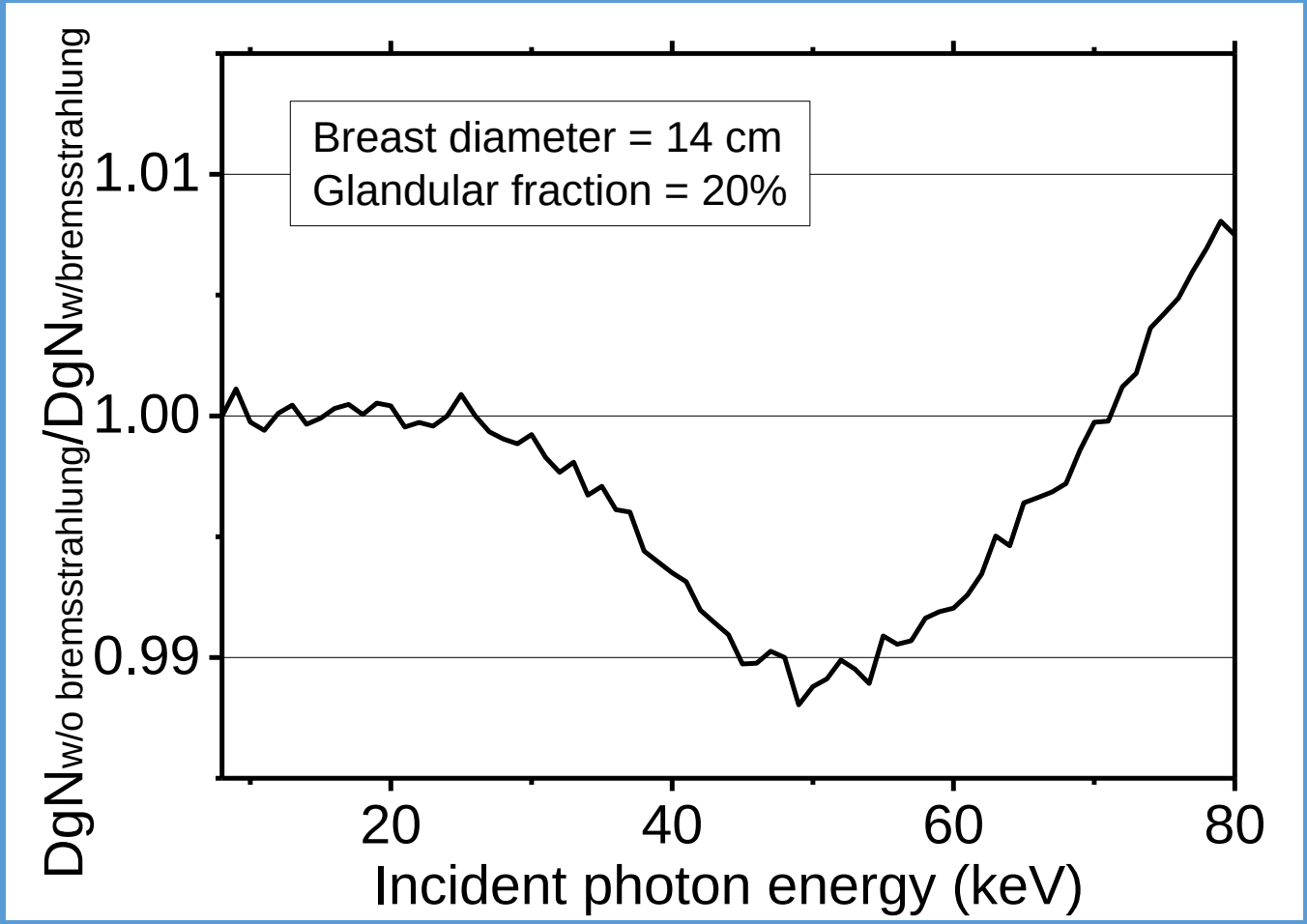
Energy range: 4.25 – 82.25 keV

Skin thickness influence on MGD



- Cylindrical breast
- Breast height = 1, 1.5, 2*breast radius
- Homogeneous adipose/glandular mix
- Skin thickness = 1.45 mm

Photon and electron interactions

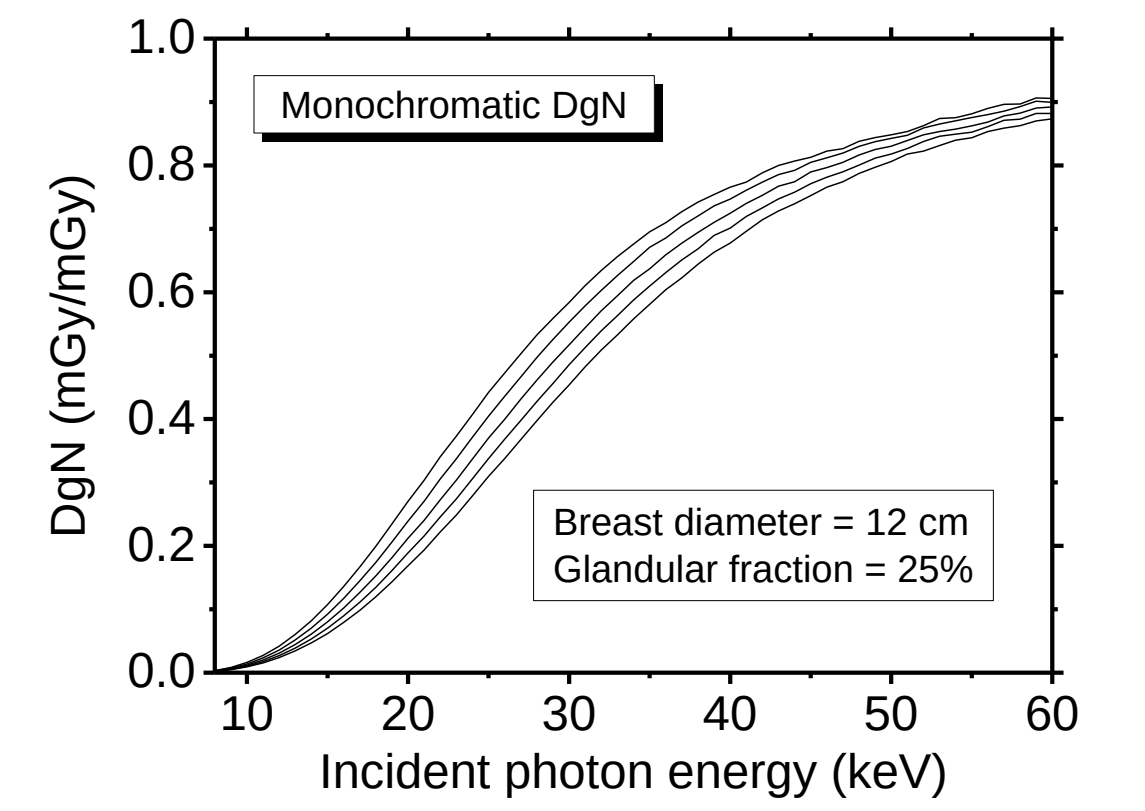


Simulated processes:

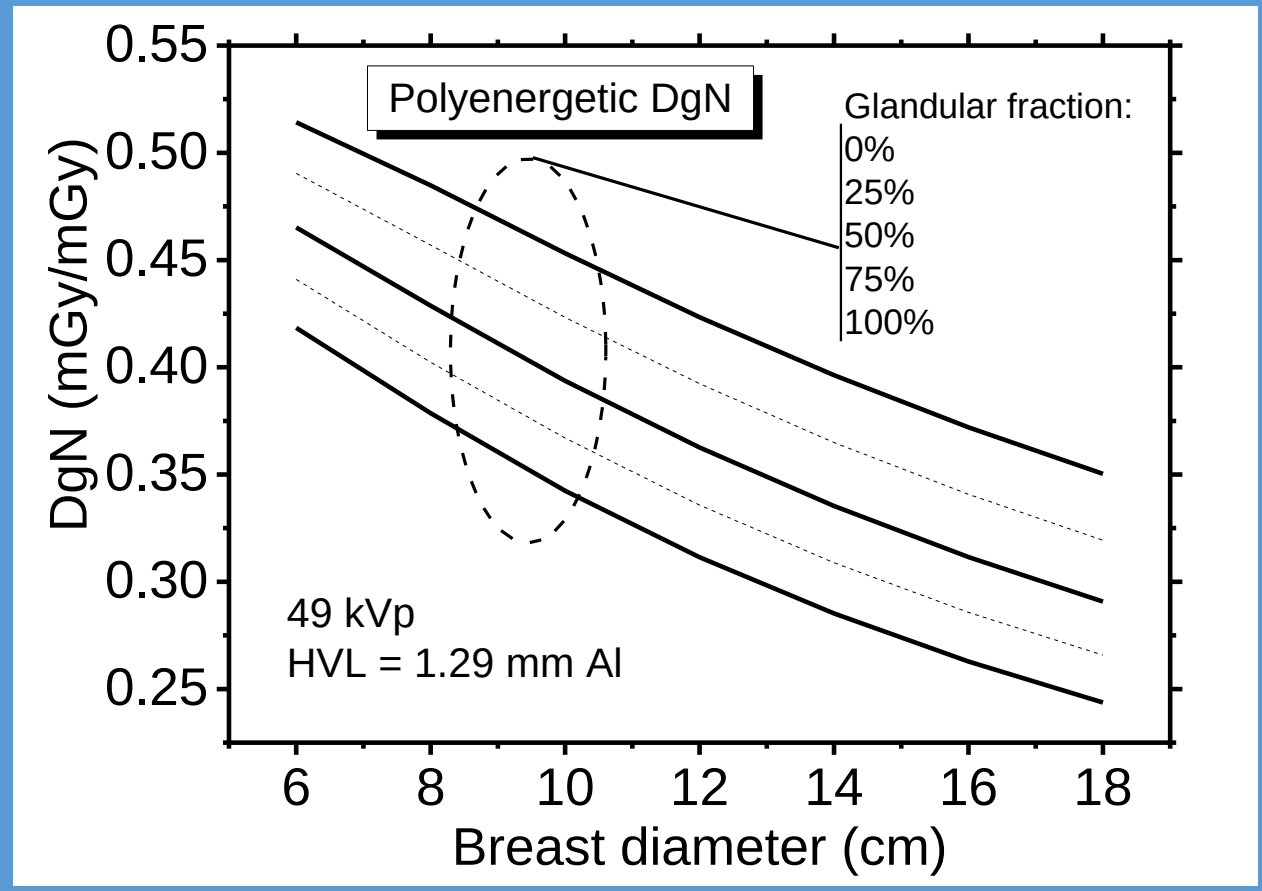
- Compton Scatter
- Rayleigh Scatter
- Photoelectric effect
- Bremsstrahlung

Monoenergetic and Polyenergetic DgN_{CT}

Homogeneous mixture adipose+glandular

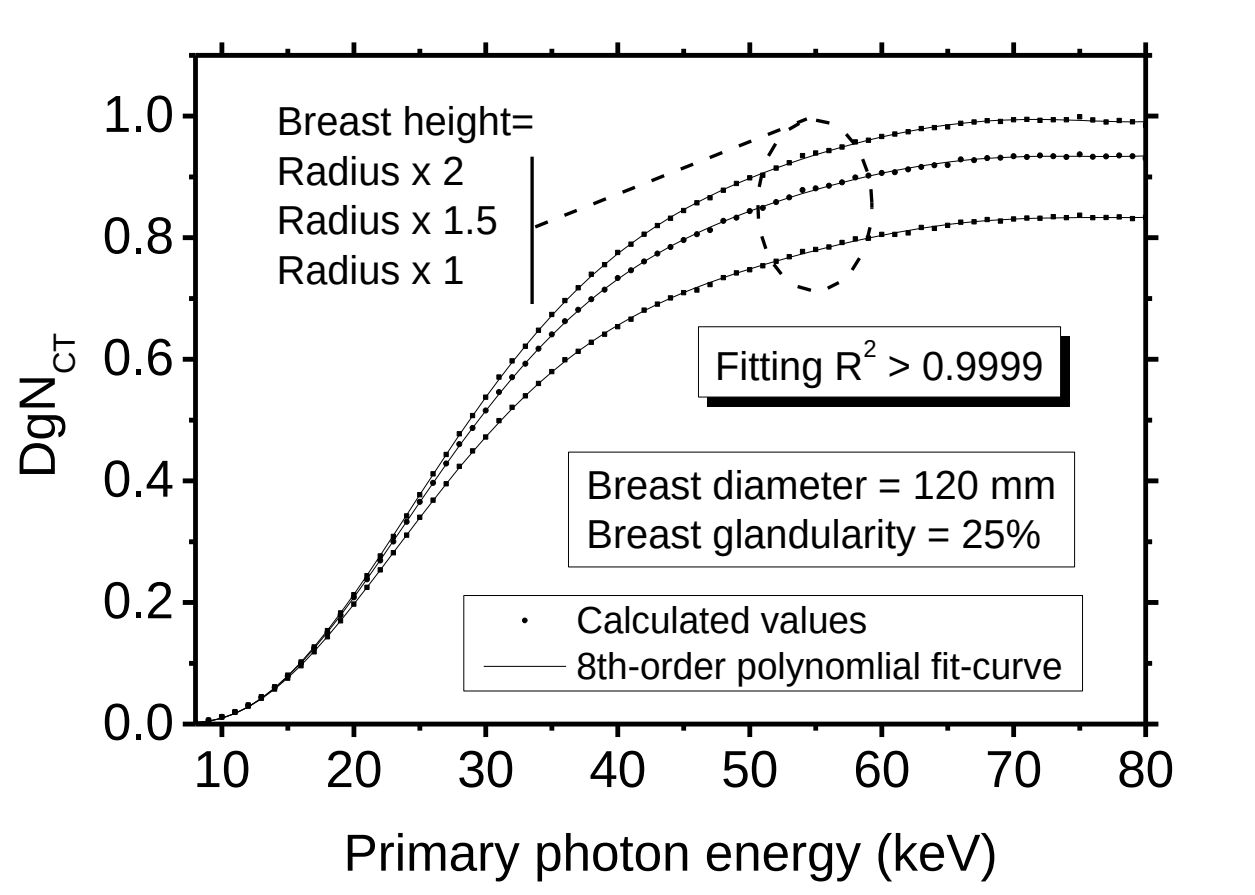


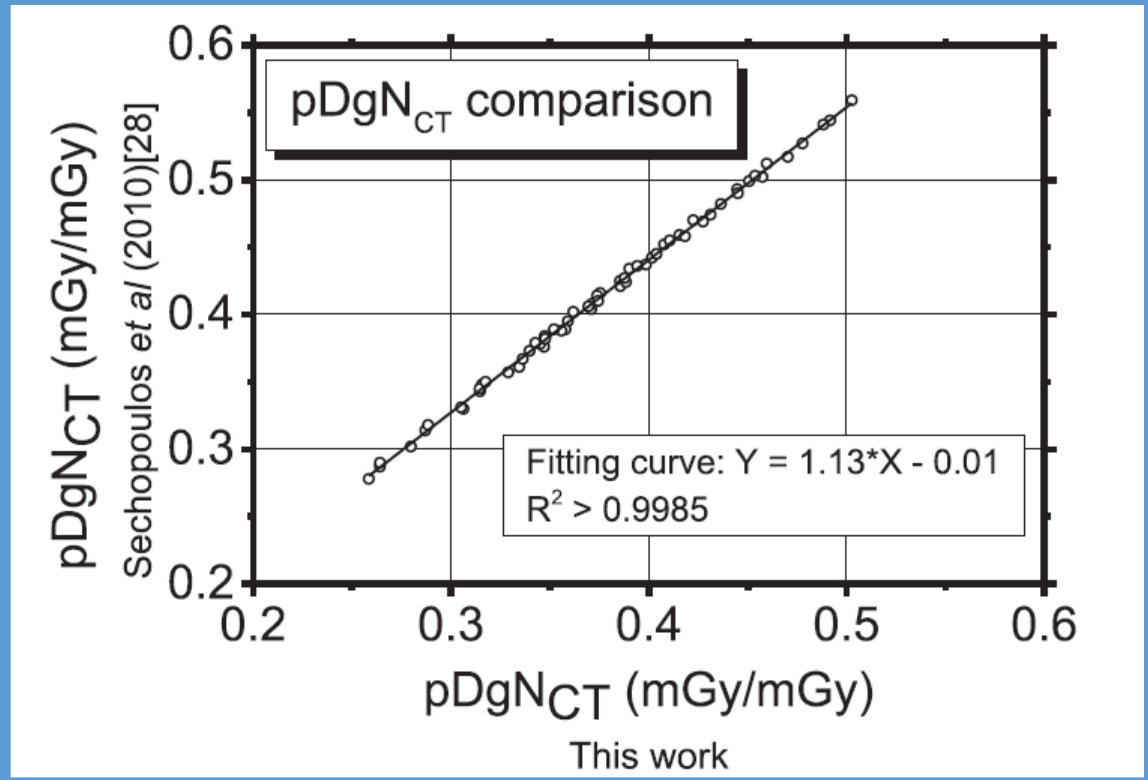
$$\mathrm{pDgN_{CT}} = \frac{\sum_{E_{min}}^{E_{max}} \Phi(E) \times \vartheta(E) \times \mathrm{DgN}(E) \times \Delta E}{\sum_{E_{min}}^{E_{max}} \Phi(E) \times \vartheta(E) \times \Delta E}$$



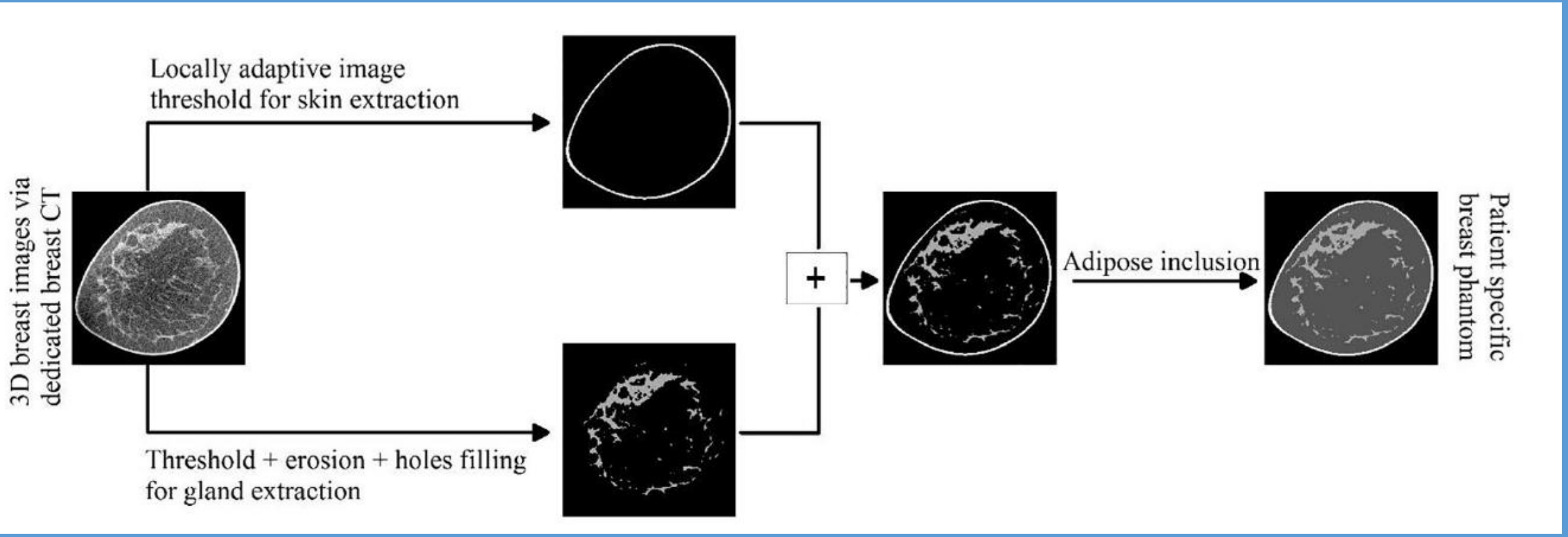
Interpolated data for monoenergetic DgN_{CT}

Homogeneous mixture adipose+glandular



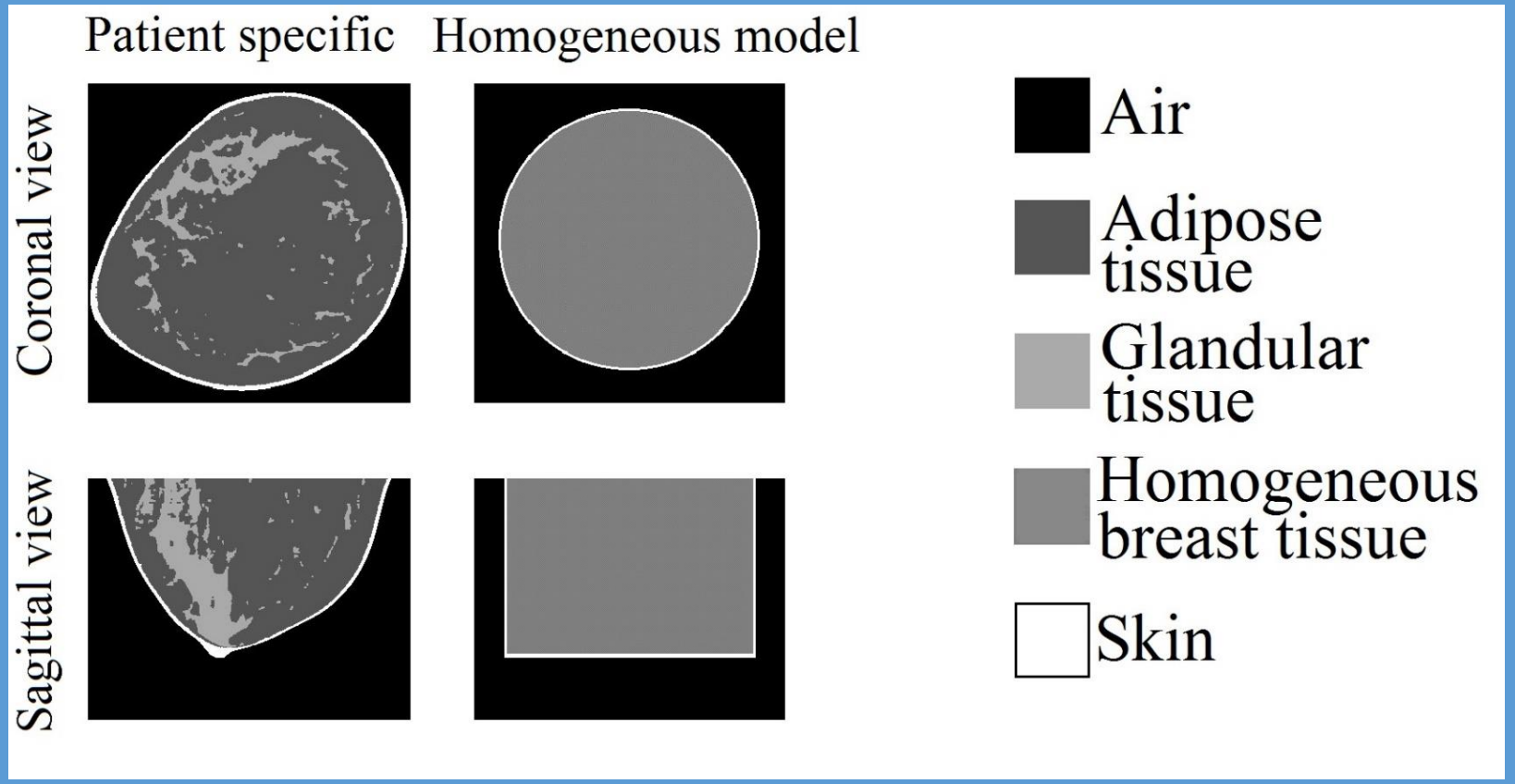


Patient specific breast phantoms



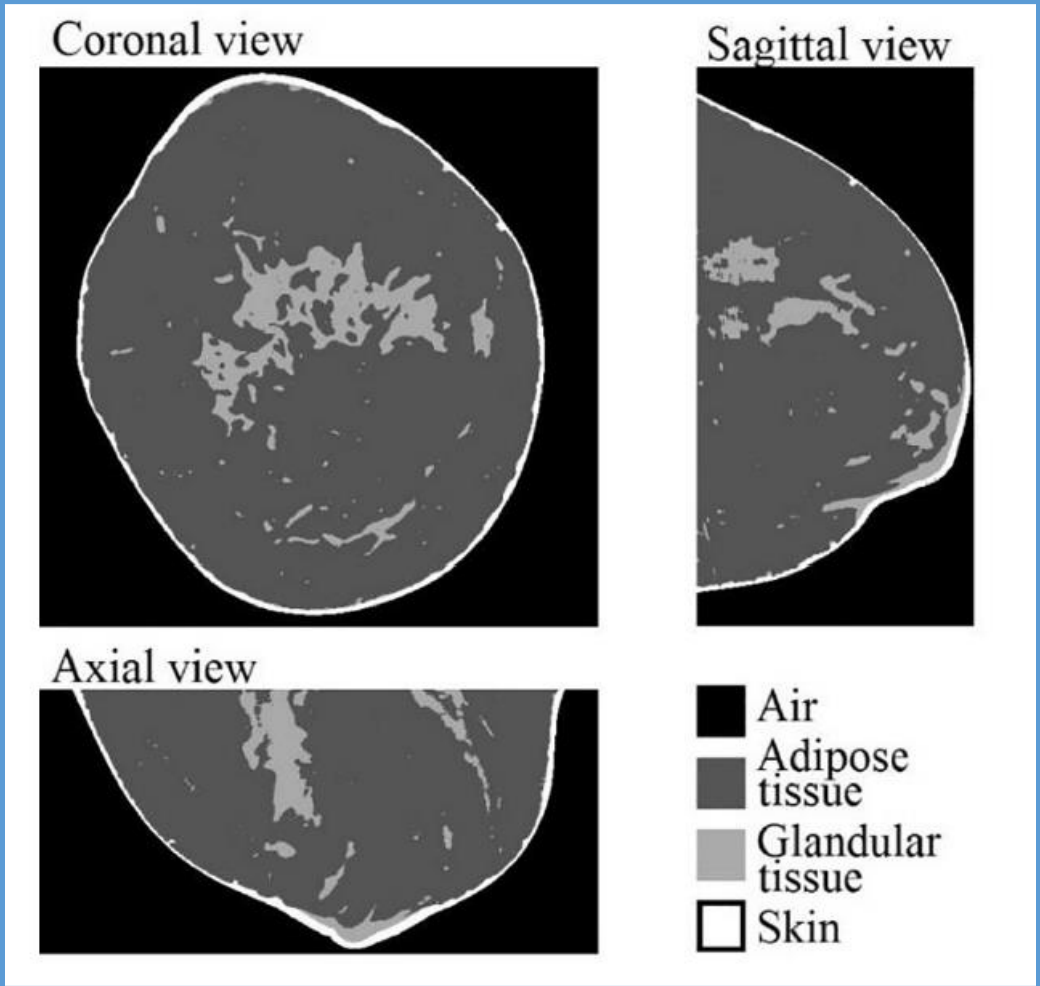
Simple model vs patient specific breast phantoms

A case study



In this specific case the MGD calculated with the homogeneous cylindrical model is 21% lower than the one calculated with the patient specific phantom (49 kVp; W/Al)

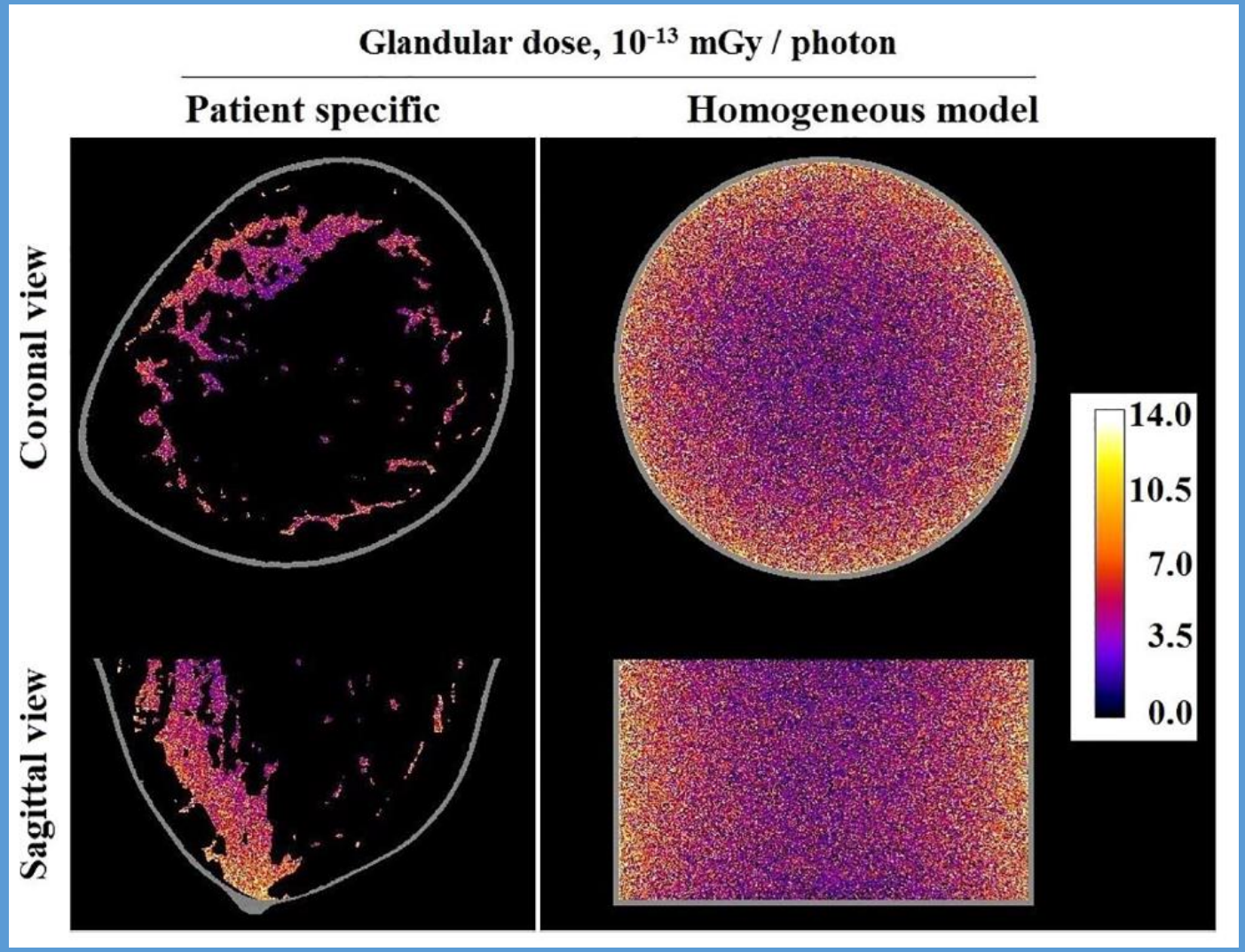
DgN_{CT} coefficients assessment

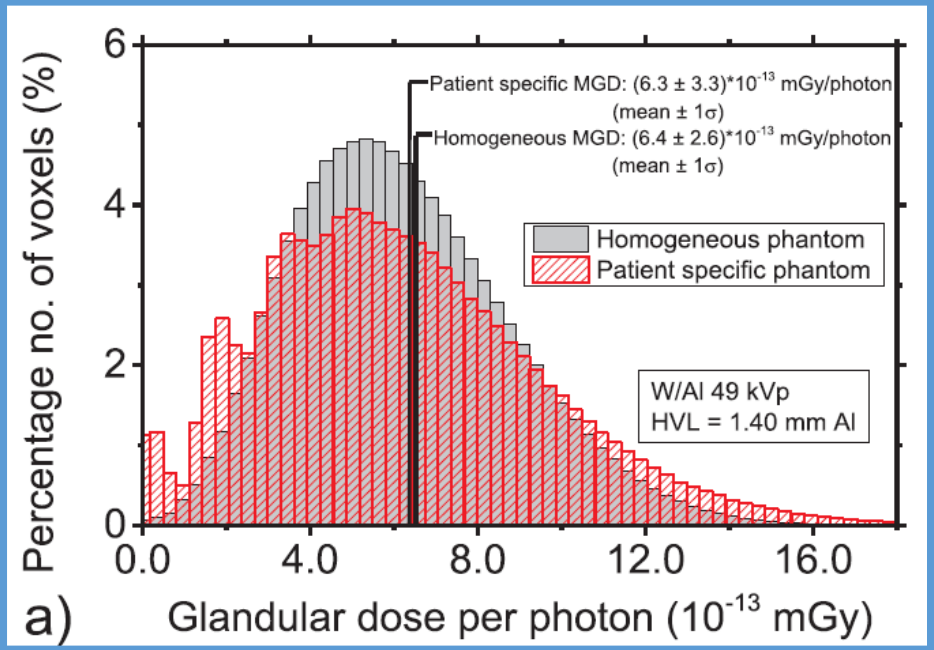


20 segmented 3D images*
of 20 different breasts

	Mean	Std	Min	Max
Glandular fraction (%)	28.0	22.6	4.9	76.0
Diameter (cm)	11.2	2.1	6.4	14.6

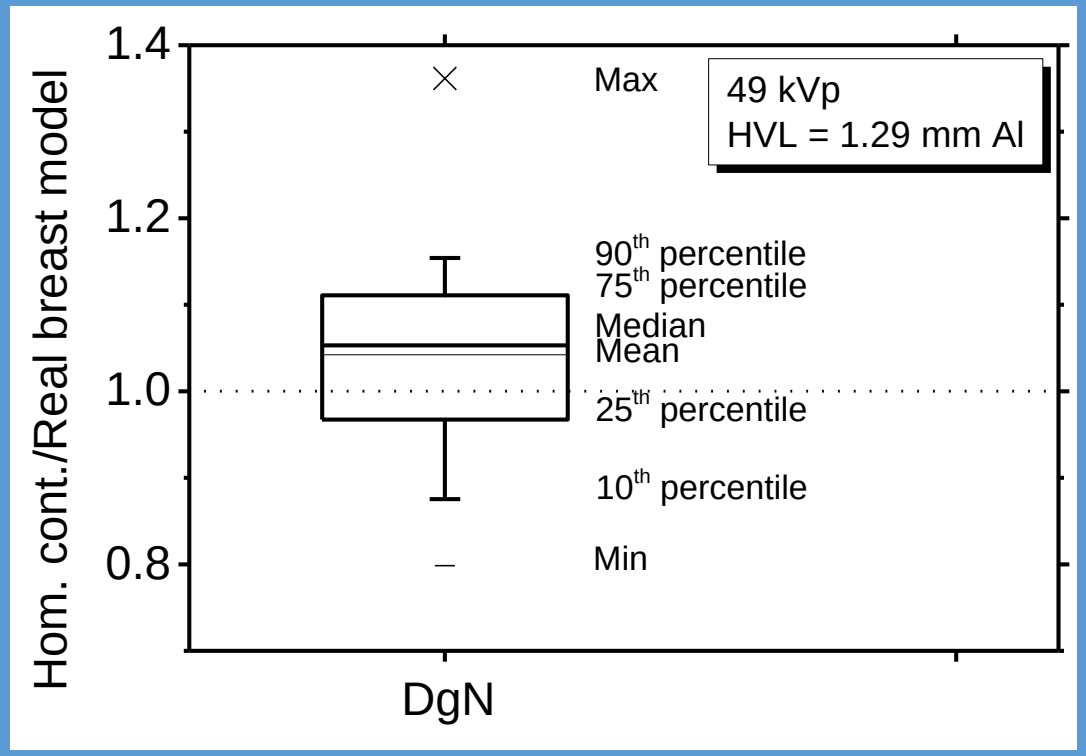
*by courtesy of Prof. Ioannis Sechopoulos - Radboud UMC – Nijmegen (NL)





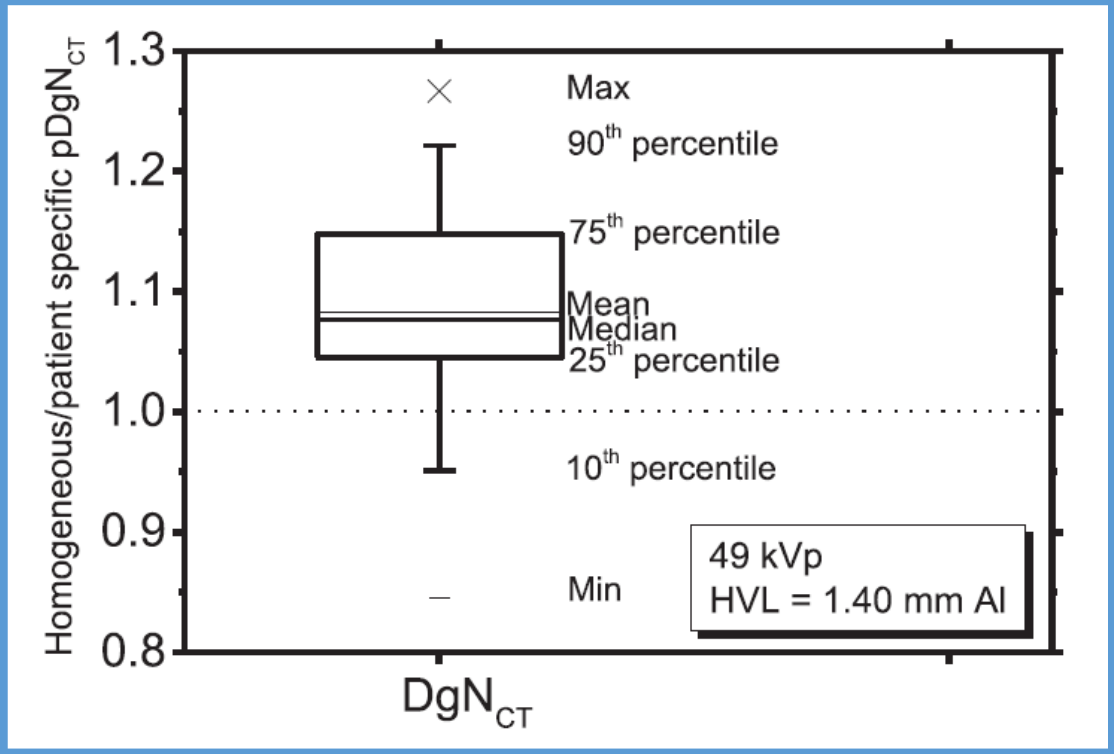
Glandular dose distribution within a patient specific heterogeneous breast (left) and within a homogeneous cylindrical breast model (right). The grey lines indicate the skin boundary. The coronal slice was selected at 2.1mm from the chest wall and the sagittal slice is at the mid-breast. Simulated beam quality: 49 kVp, HVL=1.40mm Al.

DgN_{CT} coefficients assessment



Mean = 1.04
Std. Dev. = 0.13
Min = 0.80
Max = 1.36

Mean = 1.08
Std. Dev. = 0.10
Min = 0.85
Max = 1.27



Conclusions

- Homogeneous and heterogeneous breast models for MGD evaluation in breast CT have been presented, with 1.45 mm skin thickness
- Monoenergetic and polyenergetic DgN coefficients have been provided up to 80 keV with Geant4 MC simulations
- MGD estimates differ by less than 8%, on average, with respect to a patient specific breast model (min -15%, max +27% difference) (49 kVp, HVL 1.4 mmAl)

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