Breast dosimetry in digital mammography and tomosynthesis

David R Dance

NCCPM, Royal Surrey County Hospital

United Kingdom

Outline

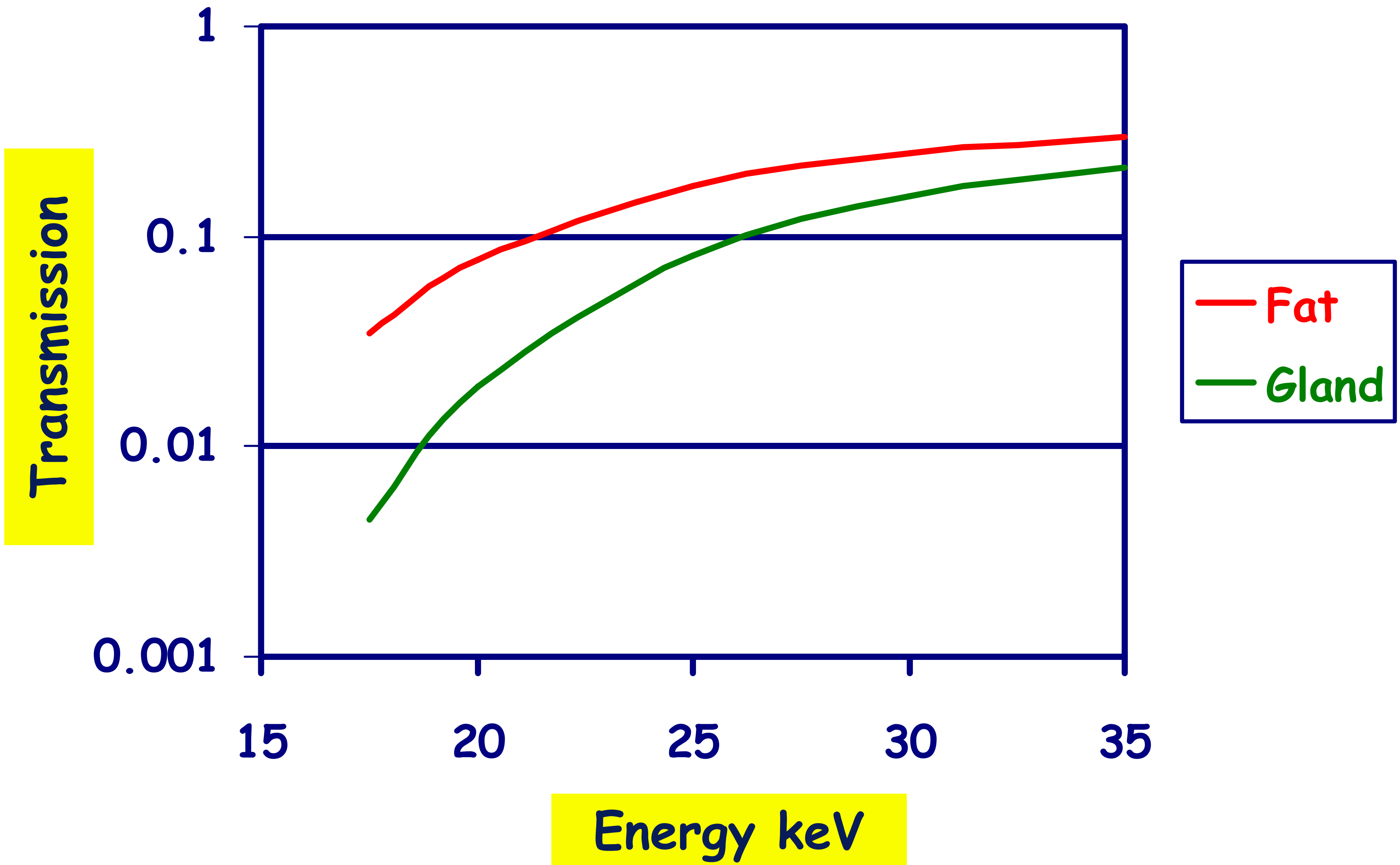
- Essentials of breast dosimetry in 2D
  - quantities
  - formalism
  - breast/PMMA equivalence
  - practical dosimetry using PMMA
  - practical patient dosimetry
- Extension for dosimetry for tomosynthesis (work in progress)

UK DOSE SURVEY 1981

- 5CM PHANTOM
- Entrance surface dose - TLD
- Dose range 0.9 to 45 mGy (!)

- kV range 24- 49 kV
- HVL range 0.2 mm Al to 1.7 mm Al

Transmission through 5 cm breast



In 1987 the ICRP 1987 recommended the use of

Average glandular dose (AGD)
(also known as mean glandular dose)

for breast dosimetry

Why?
Because it is these tissues that have the highest risk of radiation induced carcinogenesis.

Average glandular dose

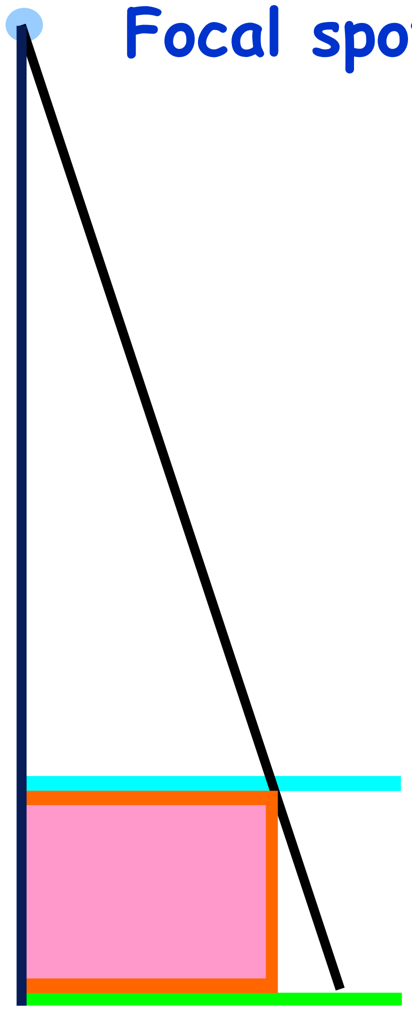
- Cannot measure **AGD** on patients
- Incident air kerma **K** (without backscatter) can be measured or estimated
- Need conversion coefficients which relate K to AGD

$$AGD = K\,g$$

- Used in: IPSM Report 59 1989 (UK)
  European Protocol 1996

Calculation of g using Monte Carlo model

(Dance 1990)

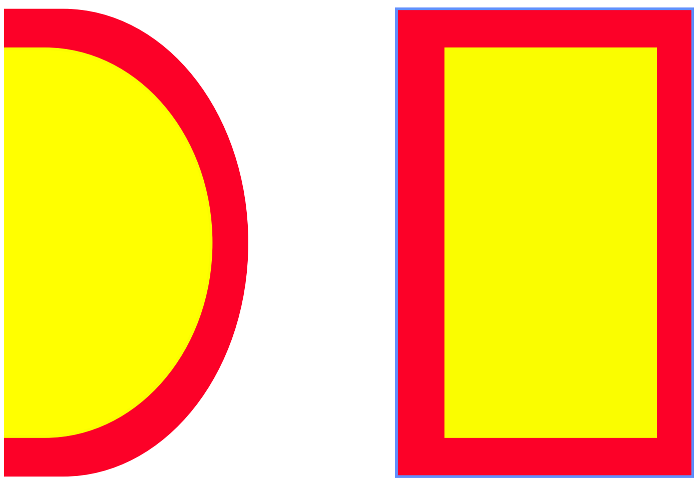


Calculate energy deposited in breast tissues

Simple breast model

CC projection

Hammerstein et al 1979



- 5 mm adipose shield region
- Central region with mixture of glandular and adipose tissues
- Fraction by weight of glandular tissue in central region is known as the glandularity

Hammerstein et al suggested the use of 50% glandularity for dosimetry

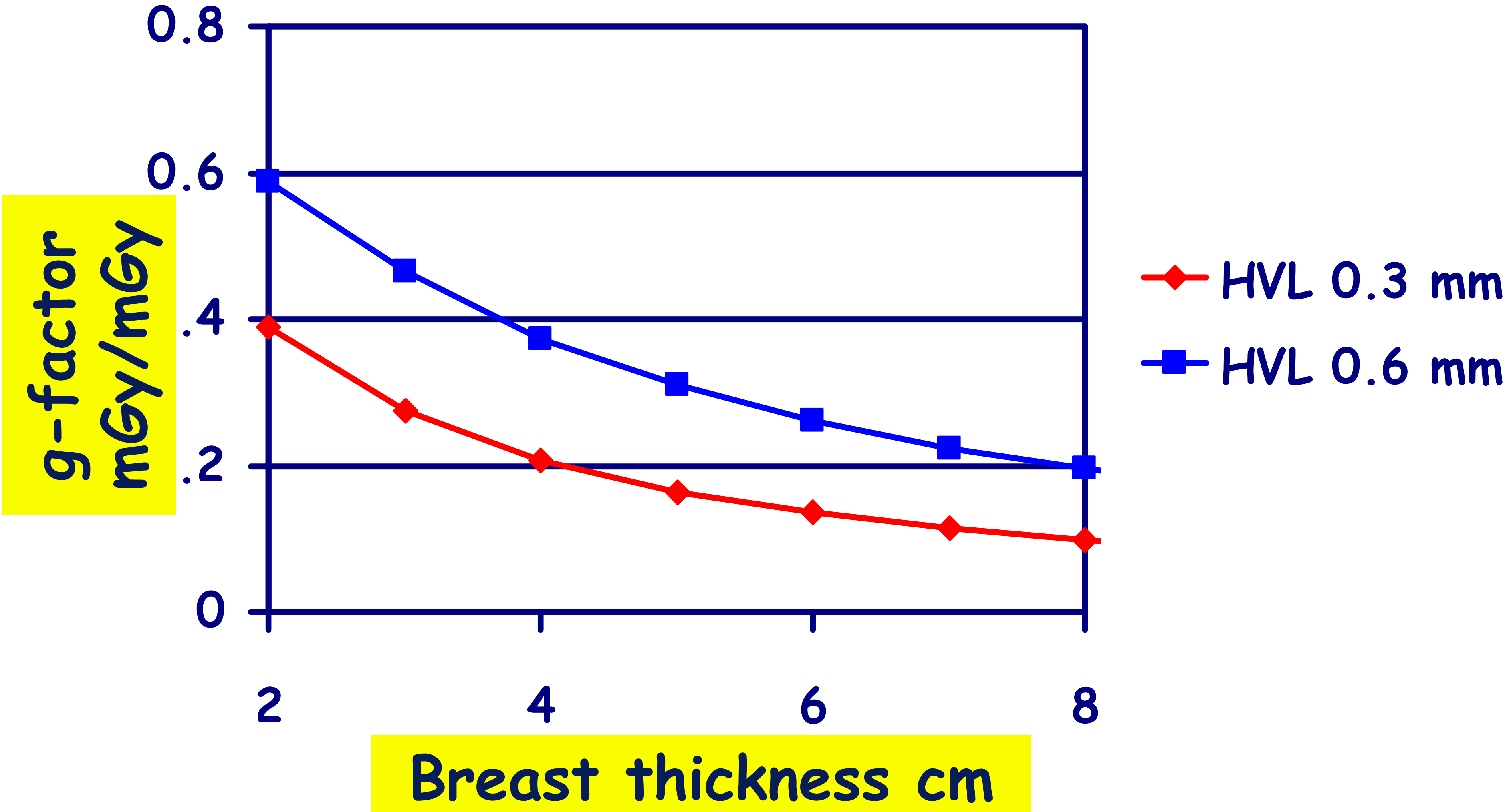
g-factors (AGD = Kg)

- g-factor is for 50% glandularity and varies with breast thickness.
- g-factors depend upon kV, anode material and filtration.

Simplification

- Tables of g-factor just based on HVL & breast thickness
- For spectra in use in 1990 worked within ± 5%

g-factors



0.8
0.6
.4
.2
0
g-factor
mGy/mGy
HVL 0.3 mm
HVL 0.6 mm
2
4
6
8
Breast thickness cm

Improved formulation in 2000

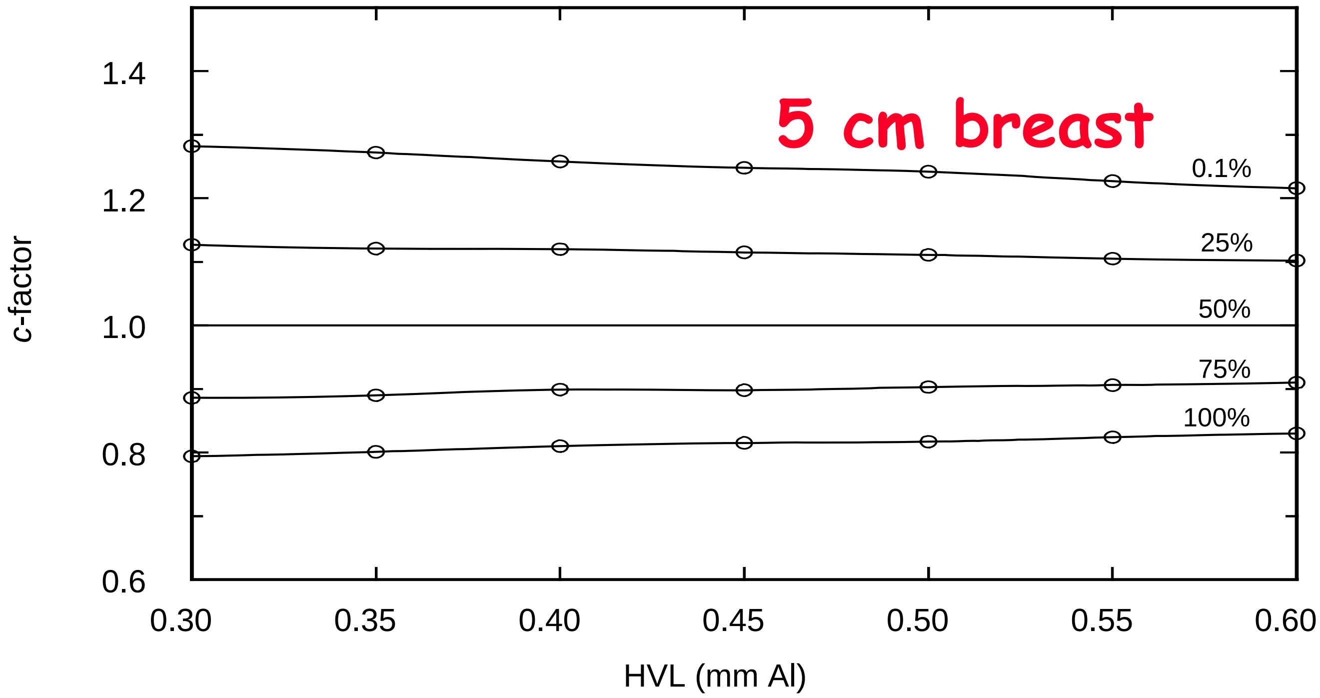
Dance et al 2000

- Real breasts don't all have 50% glandularity – factors calculated for 0.1-100%
- Wider range of spectra used

AGD = Kgcs

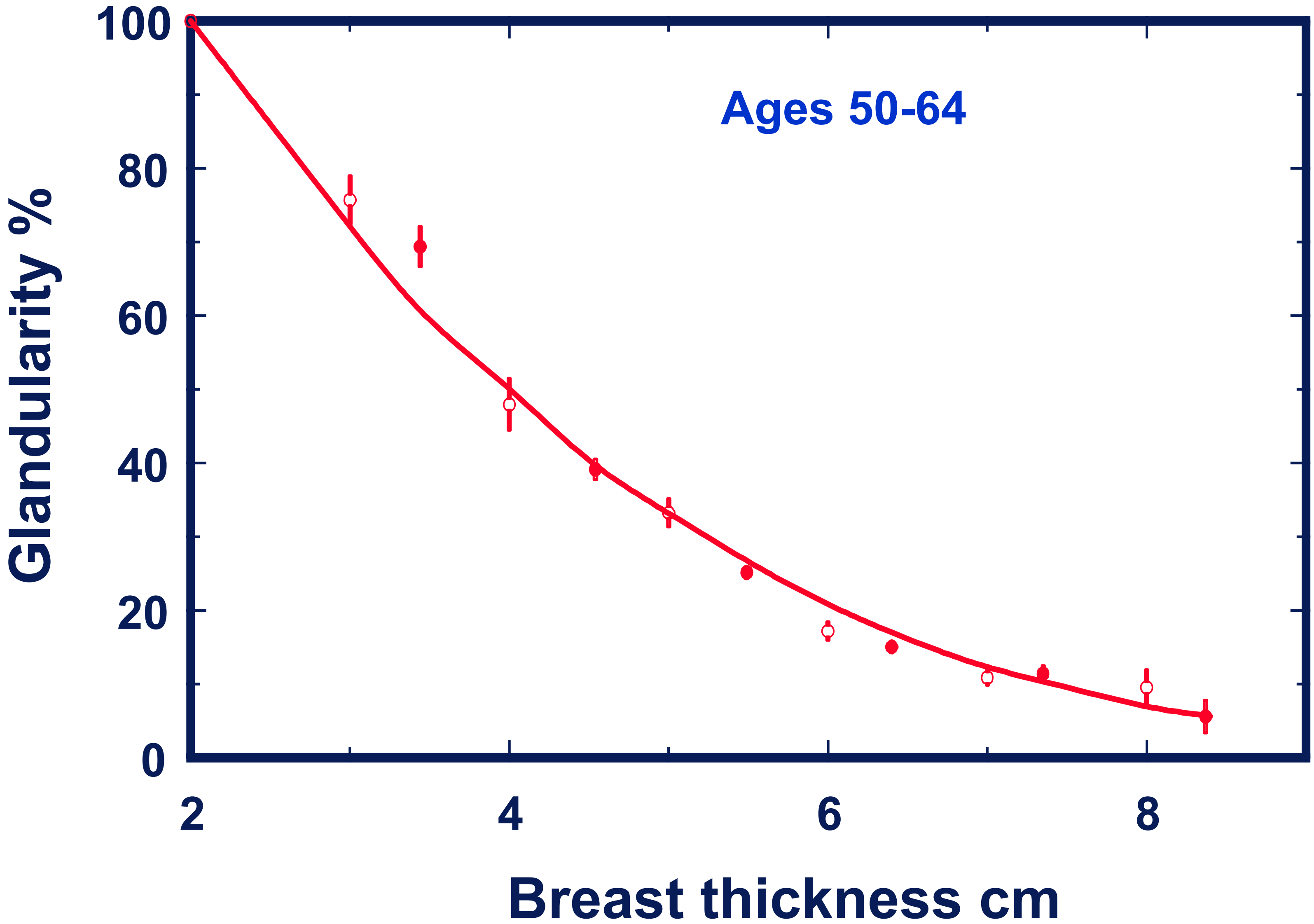
C-factors

Tabulated against HVL, breast thickness and glandularity



But what glandularity should be used?

Breast glandularity



S-factors

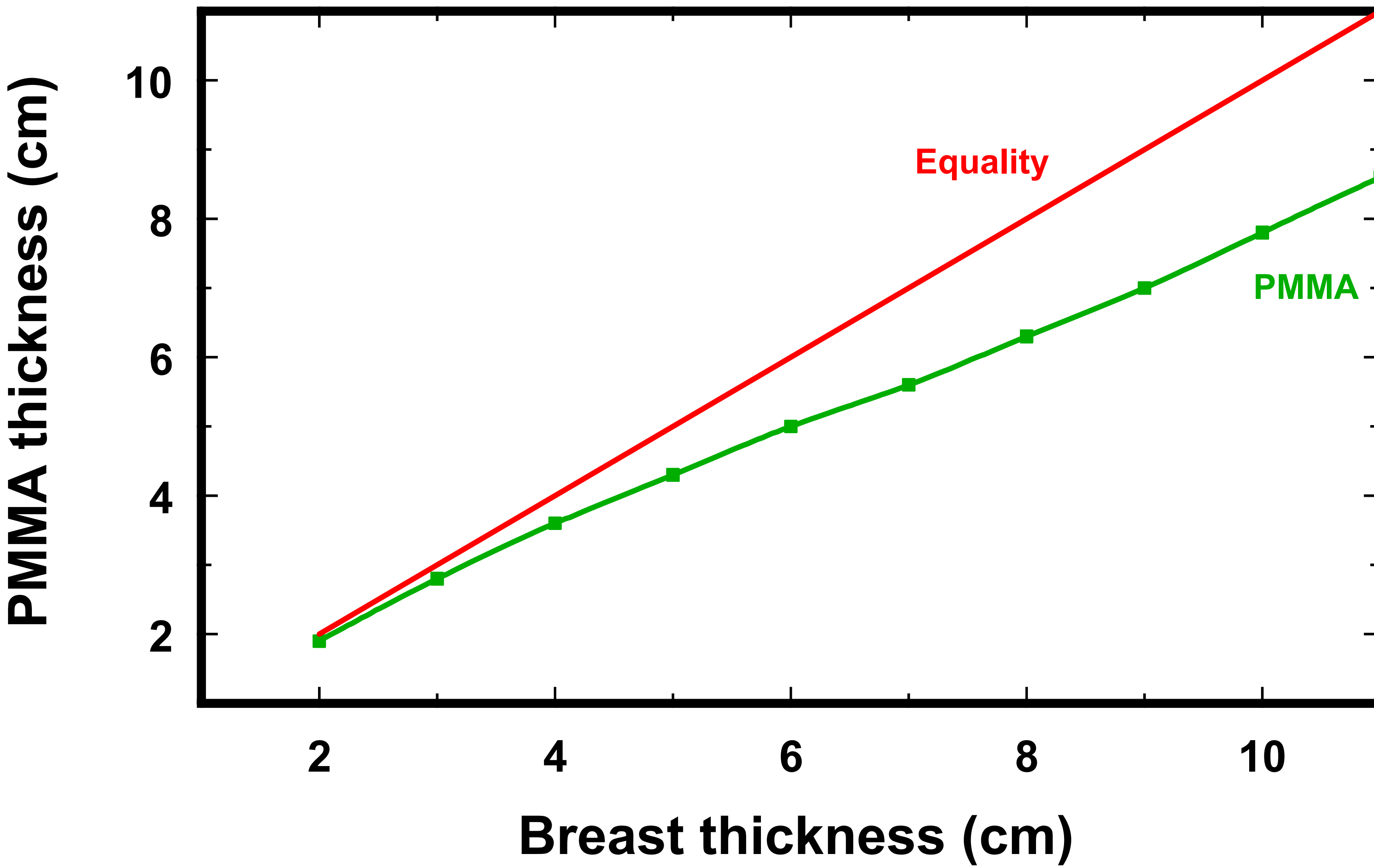
	S	Max Error
Mo/Mo	1.000	3.1%
Mo/Rh	1.017	2.2%
Rh/Rh	1.061	3.6%
Rh/Al	1.044	2.4%
W/Rh	1.042	2.1%
W/Ag	1.042	4.6%

“Standard breasts”

- For quality control and inter-system comparison need a simple phantom or phantoms
- Cheap and easily reproducible (PMMA)
- Should be approximately equivalent to typical compressed breast(s)

PMMA equivalence age 50-64

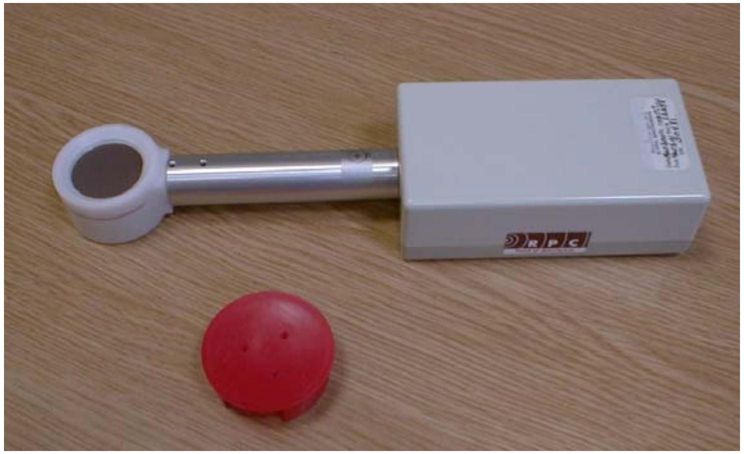
Dance et al, 2000



Practical dosimetry using blocks of PMMA

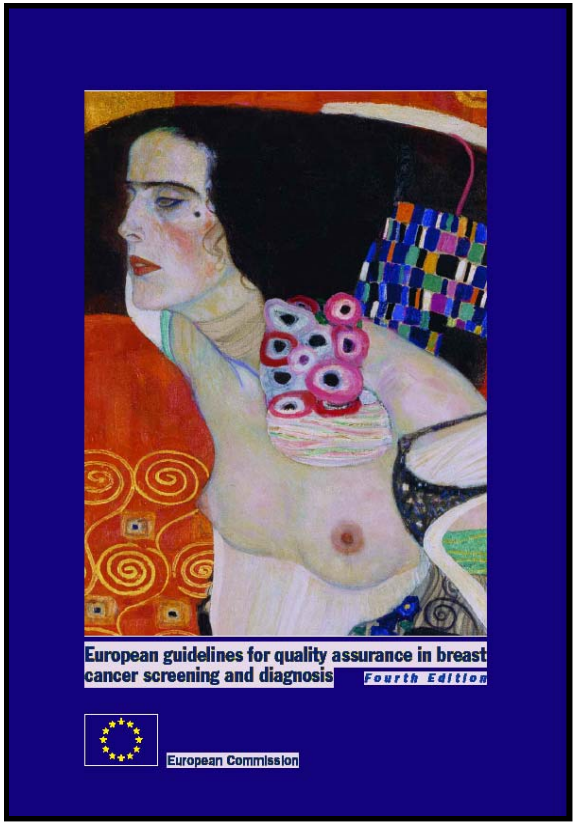
- Objective is to simulate exposure of 'standard breasts'

- Stage 1: determine exposure settings using blocks of PMMA
- Stage 2: determine incident air kerma from output measurement
- Stage 3: measure HVL
- Stage 3: calculate AGD
- Stage 4: review results



European guidelines

AGD = Kgcs



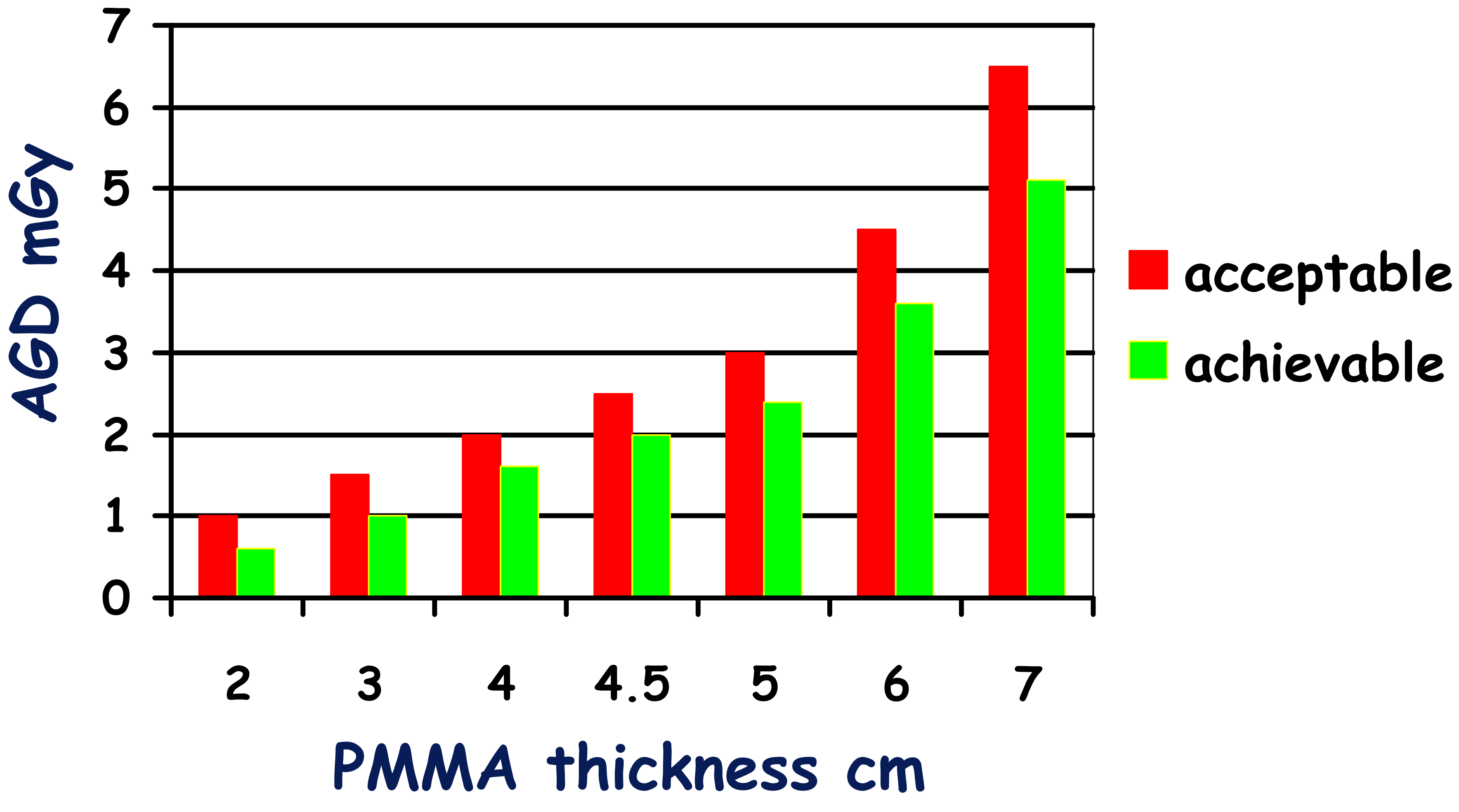
Tables A5.1 & A5.2

give g and c vs PMMA cm & HVL

Table A5.4

gives s

Stage 4: review results



Patient dosimetry

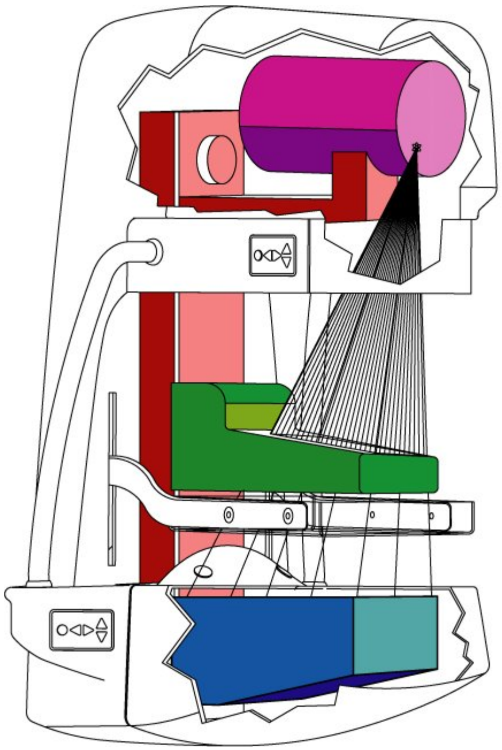
- Measure tube output and HVL with paddle in place
- Record exposure parameters for patient series (50 or more)
  - kV & target/filter
  - mAs
  - compressed breast thickness
- Calculate AGD

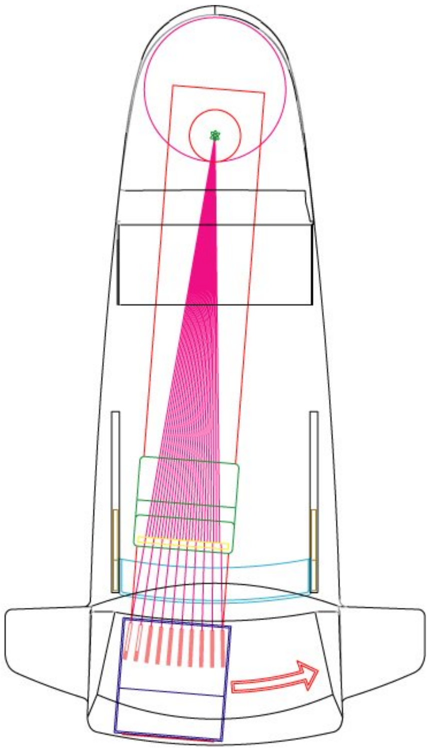
Dosimetry for breast tomosynthesis

- Work in progress
- Results from
  - Dance et al
  - Sechopoulos et al

- There are presently no European guidelines for dosimetry for breast tomosynthesis

Dose will depend on:





- Breast thickness, shape and glandularity
- Breast position in relation to edge of detector
- Central projection used: MLO or CC
- Radiation quality
- Tomographic motion:
  - projection angles
  - position of rotation axis
  - FFD

Possible methodology and formalism:

- Determine AGD for zero degree position using standard method for 2D imaging
- Apply formula to calculate dose for tomosynthesis.

AGD = K(0)gcs T

Possible formalism:

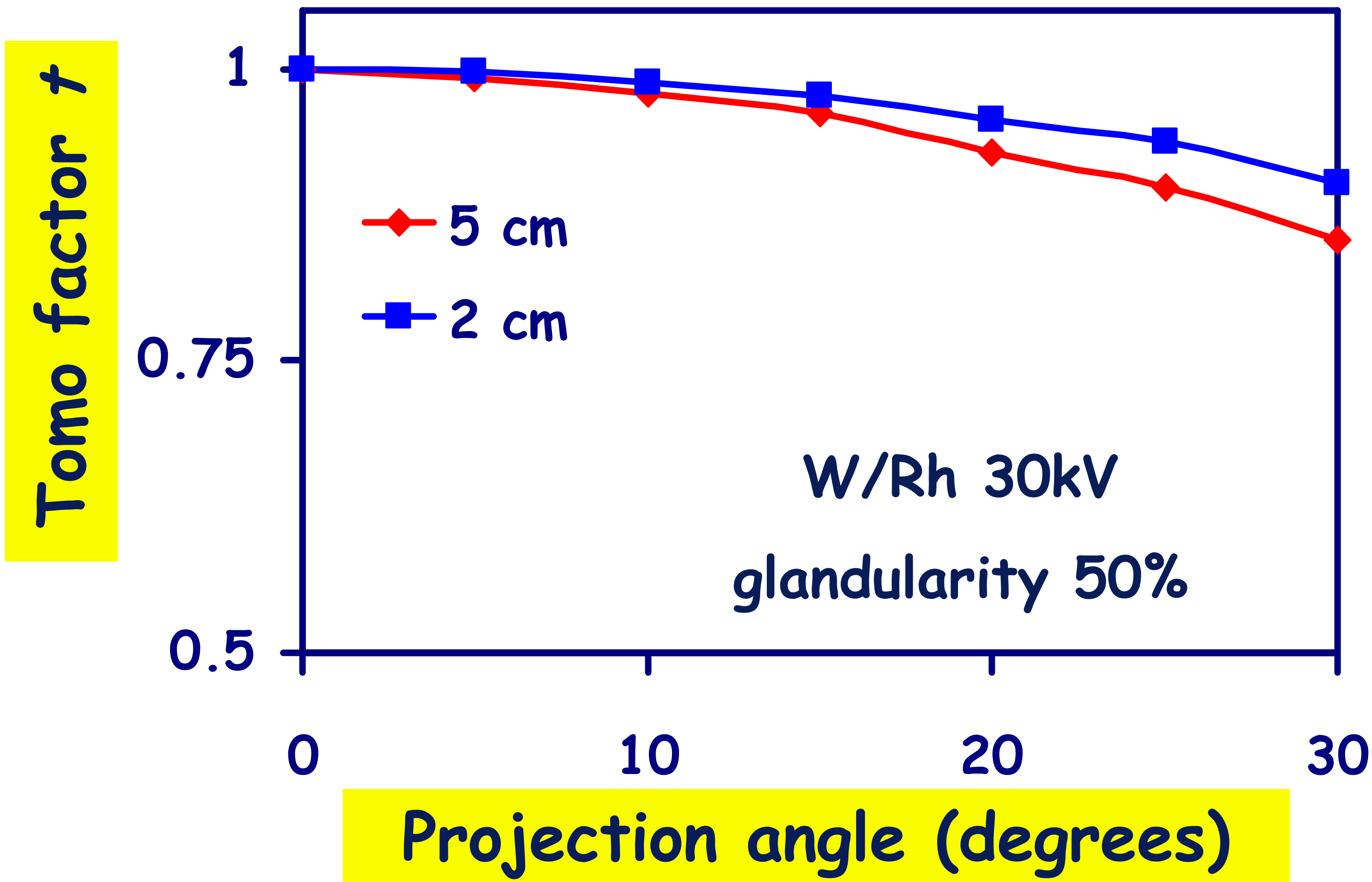
$$AGD = K(O)gcsT$$

$$T=\Sigma t(\Theta)$$

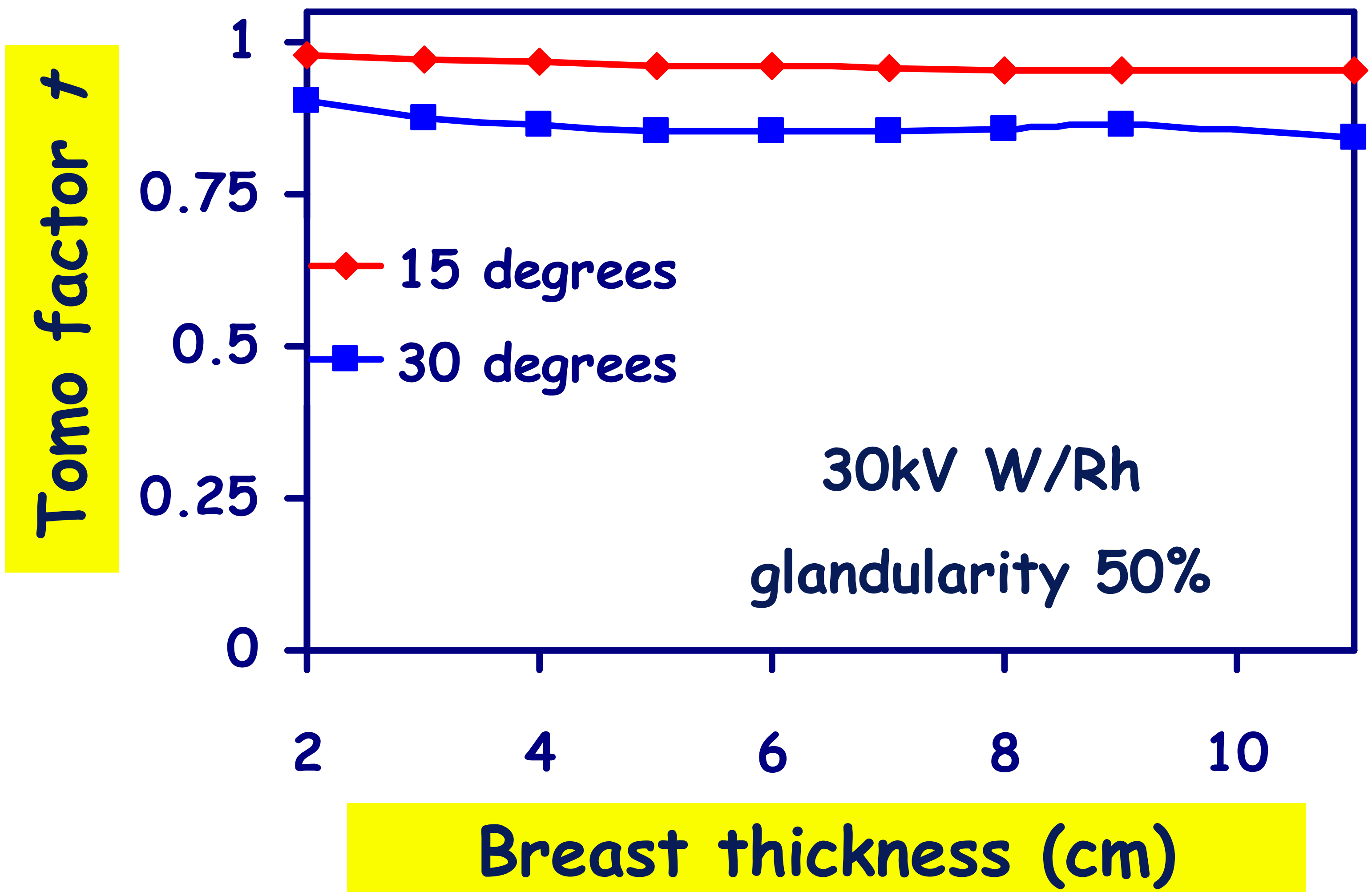
$$t(\Theta)=AGD(\Theta)/AGD(0)$$

BUT how does t(Θ) vary with all the various parameters?

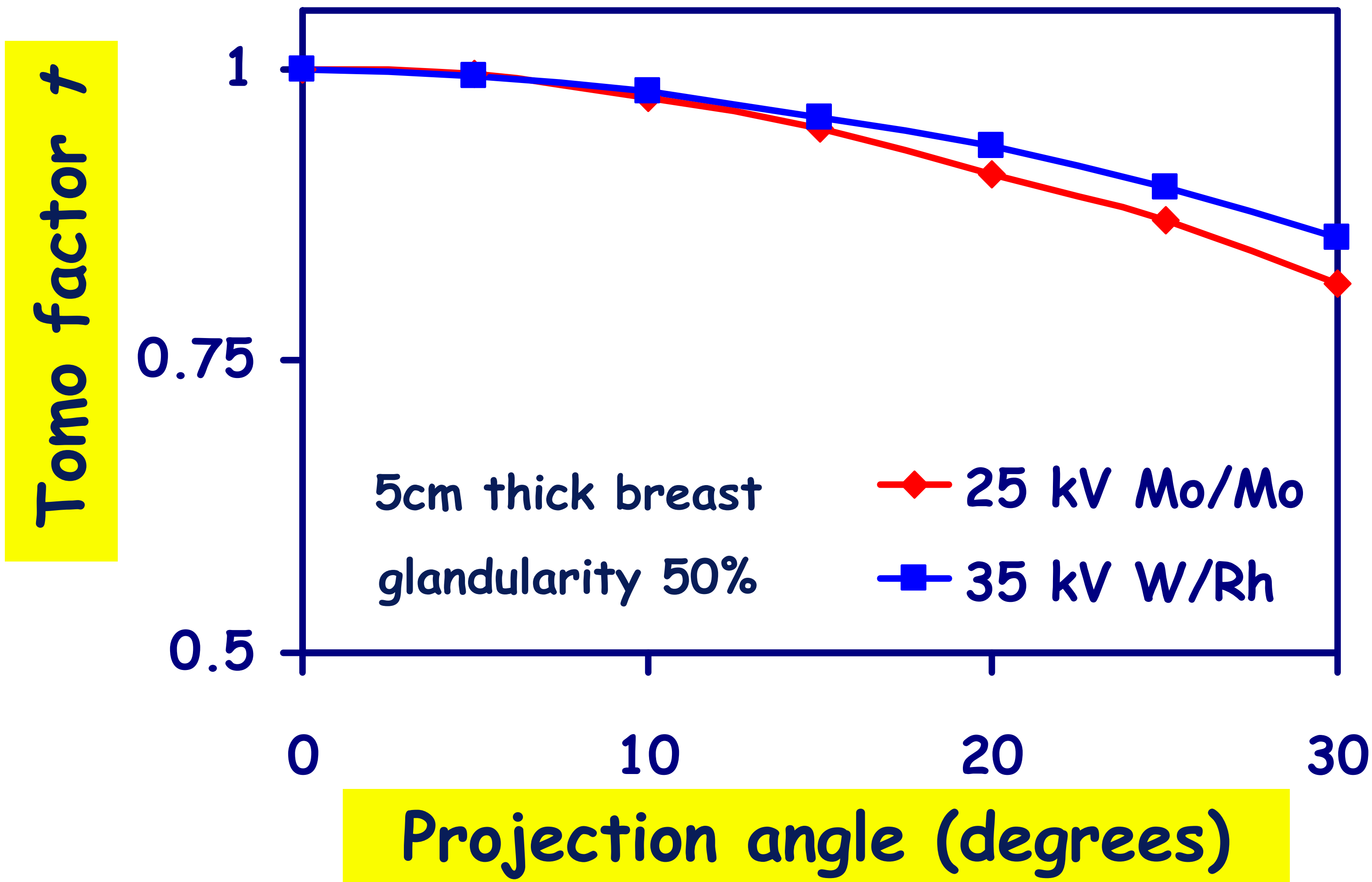
Dependence of t(Θ) on projection angle (CC view)



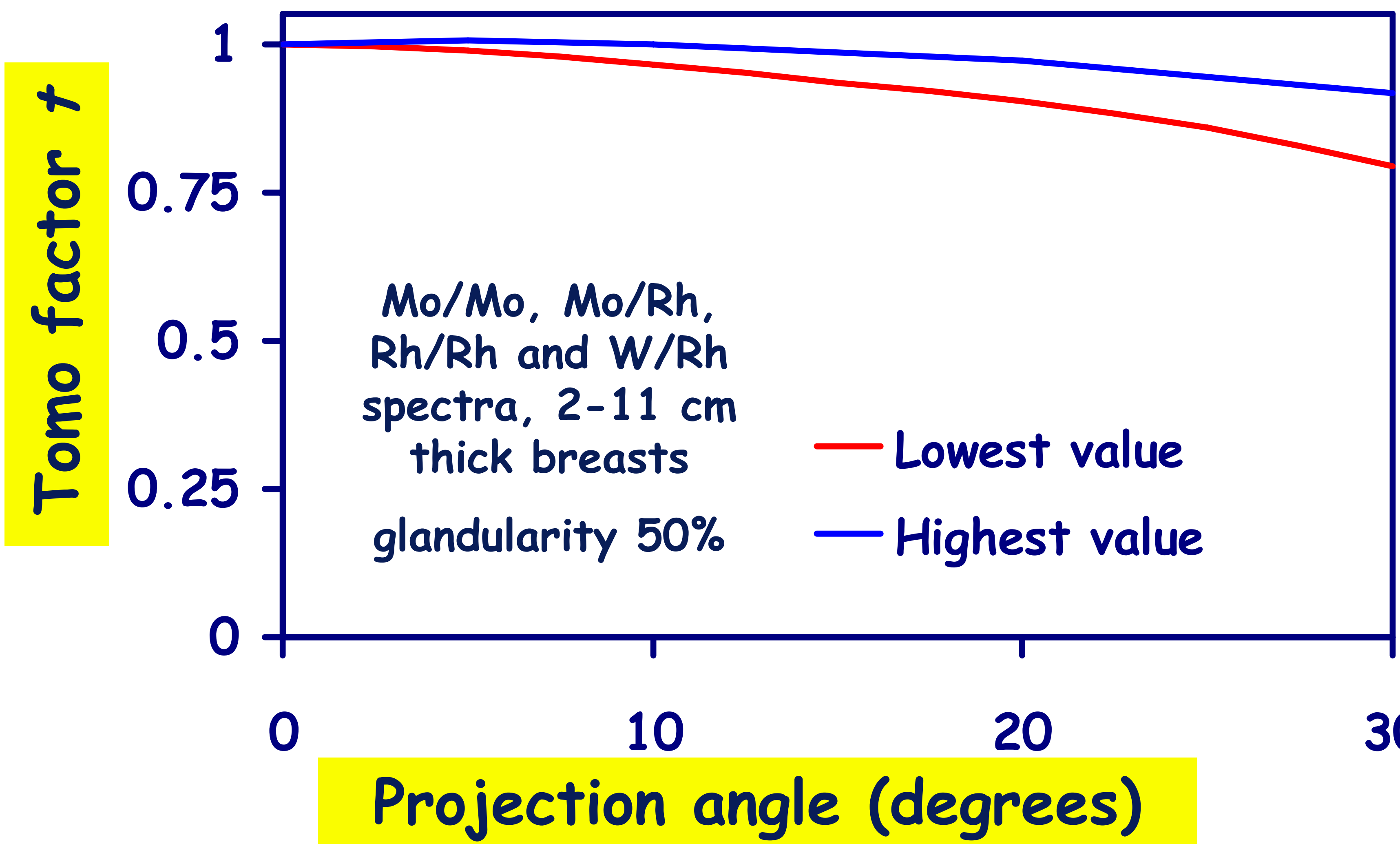
Dependence of t(Θ) on breast thickness (CC view)



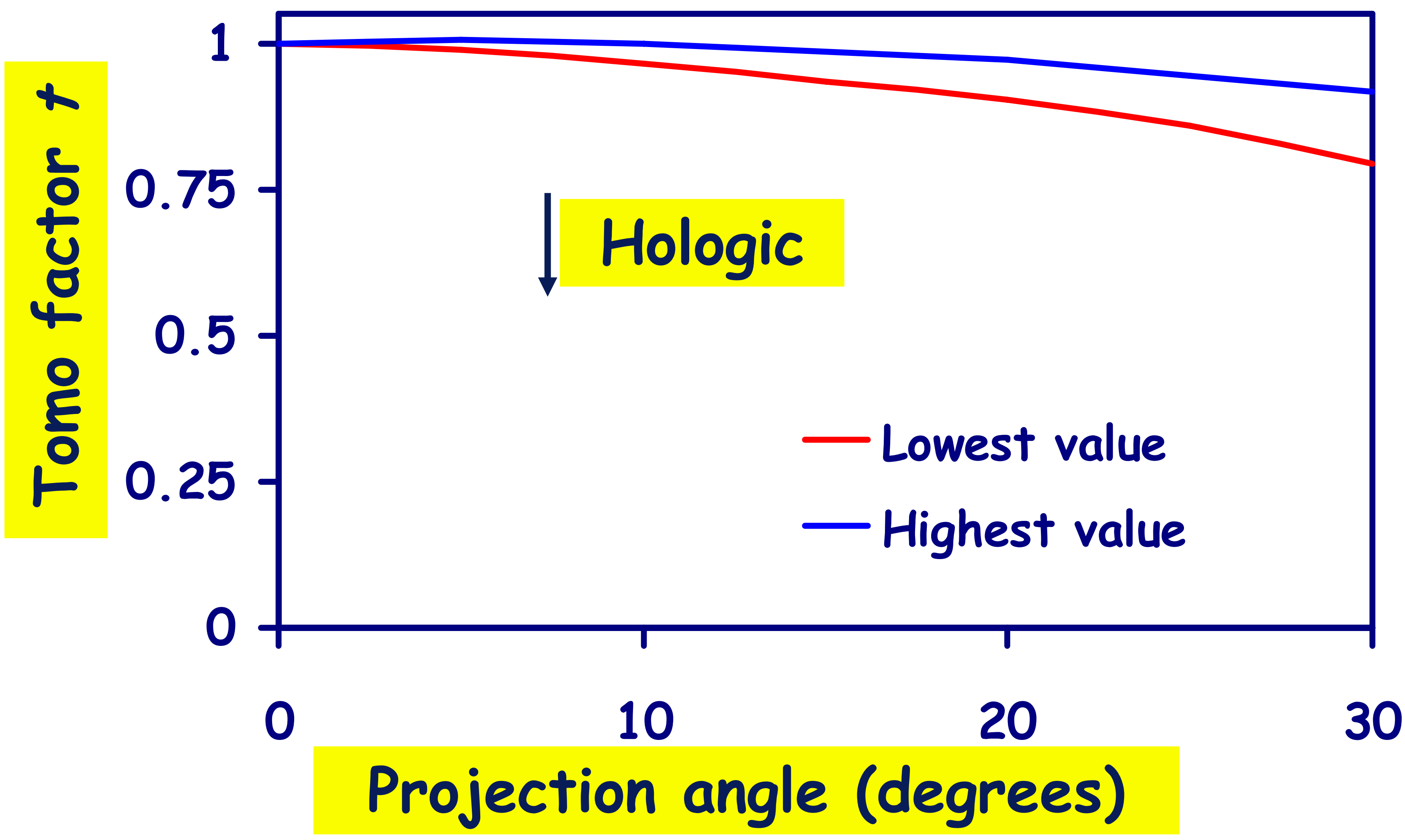
Dependence of t(Θ) on X-ray spectrum (CC view)



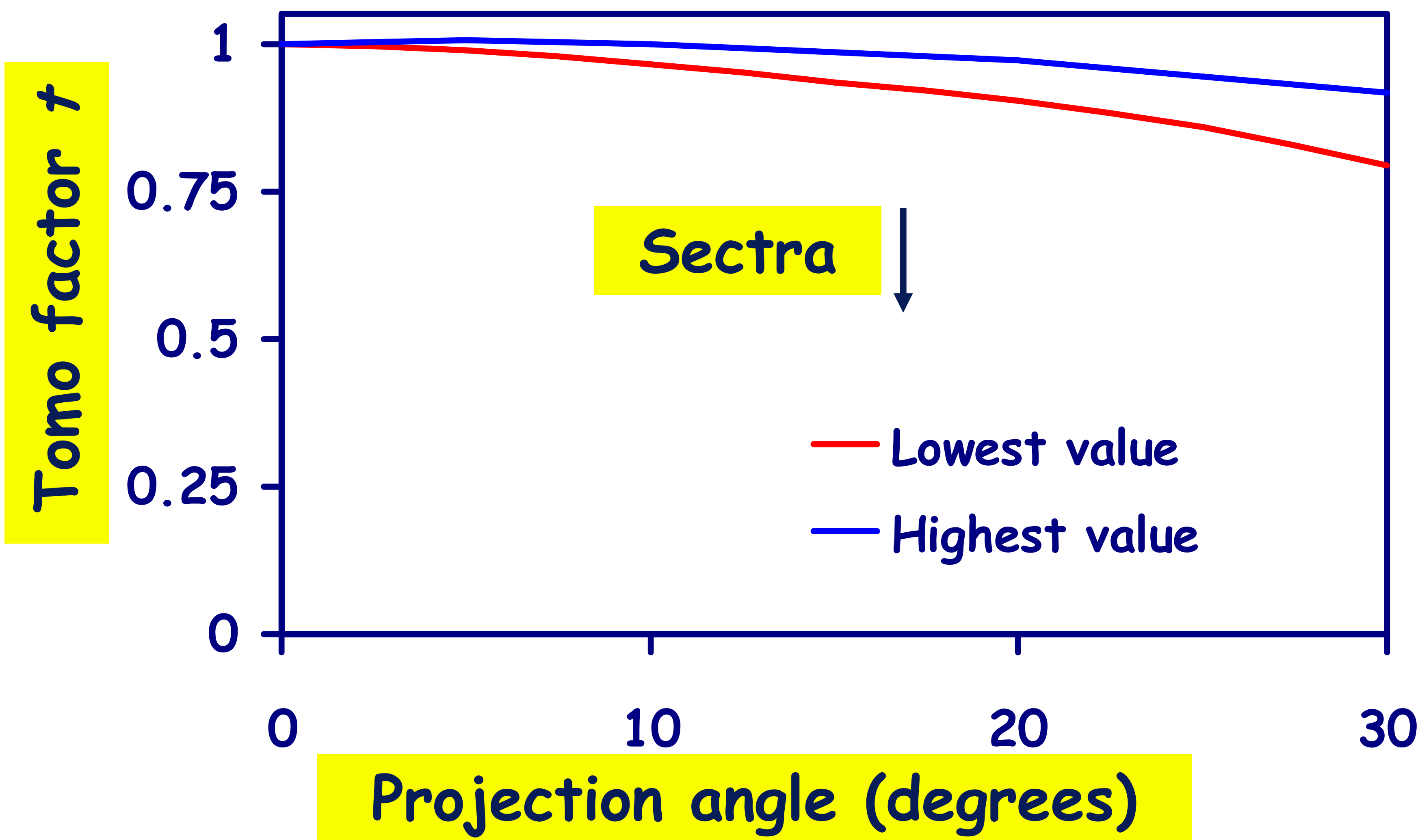
Overall variation of t(Θ) (CC view)



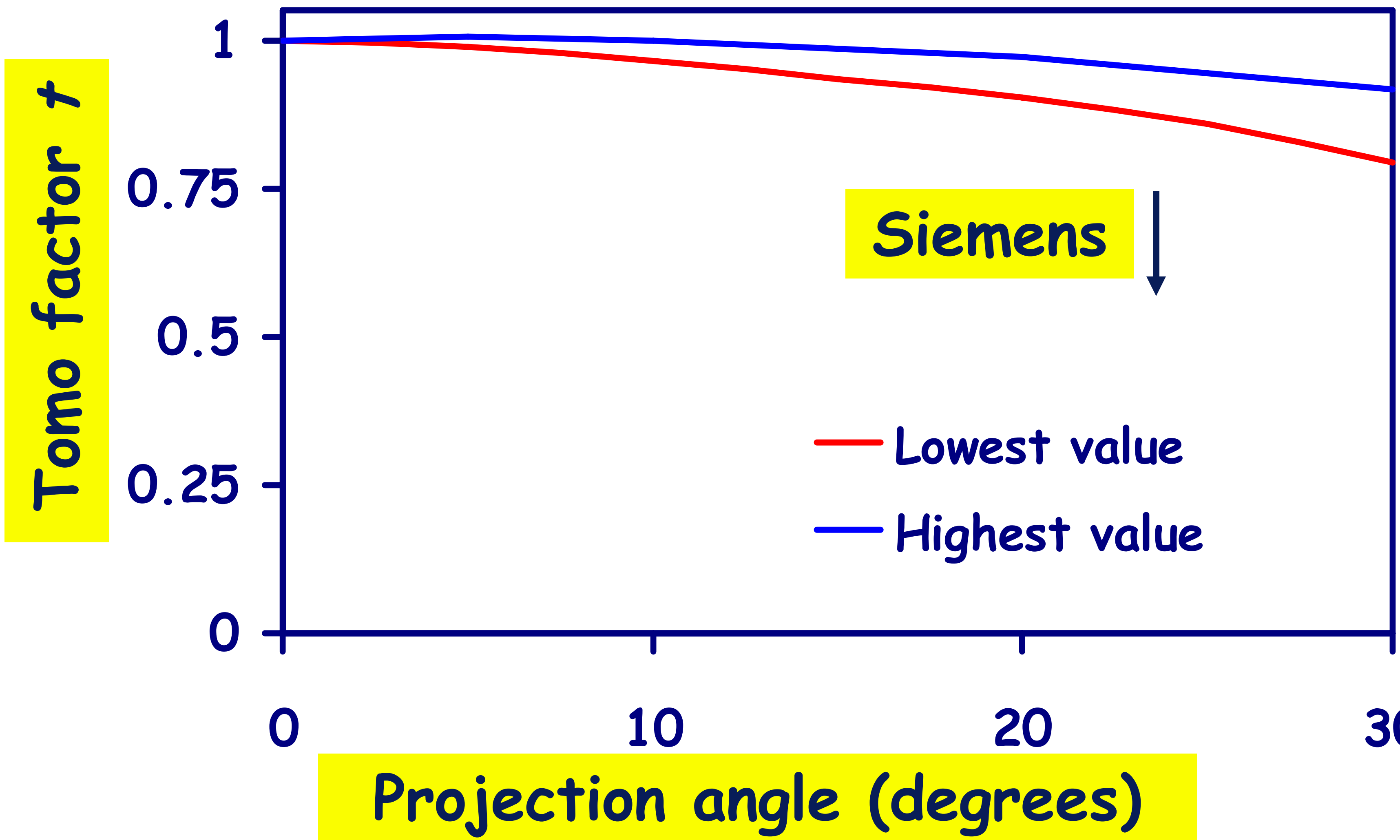
Overall variation of t(Θ) (CC view)



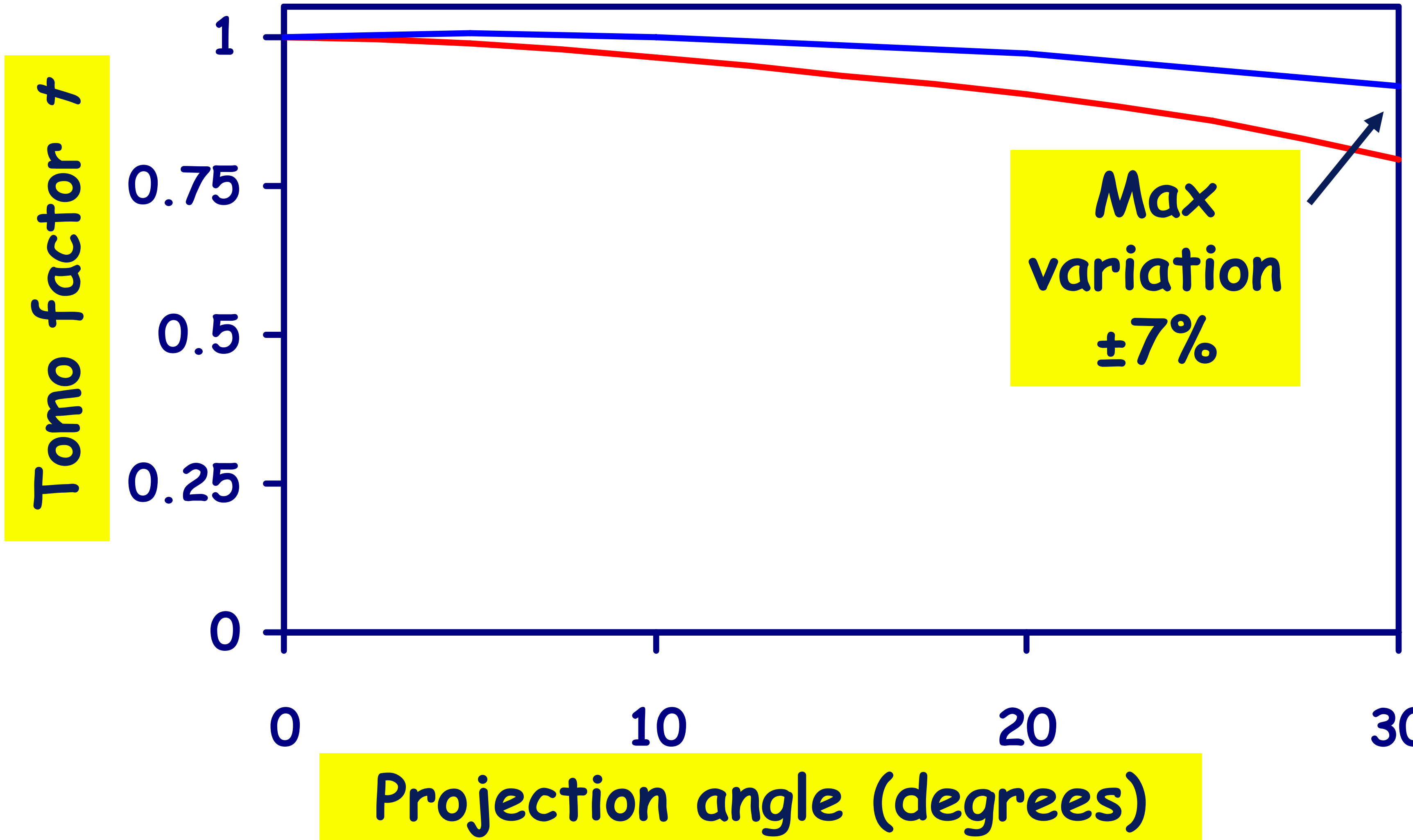
Overall variation of t(Θ) (CC view)



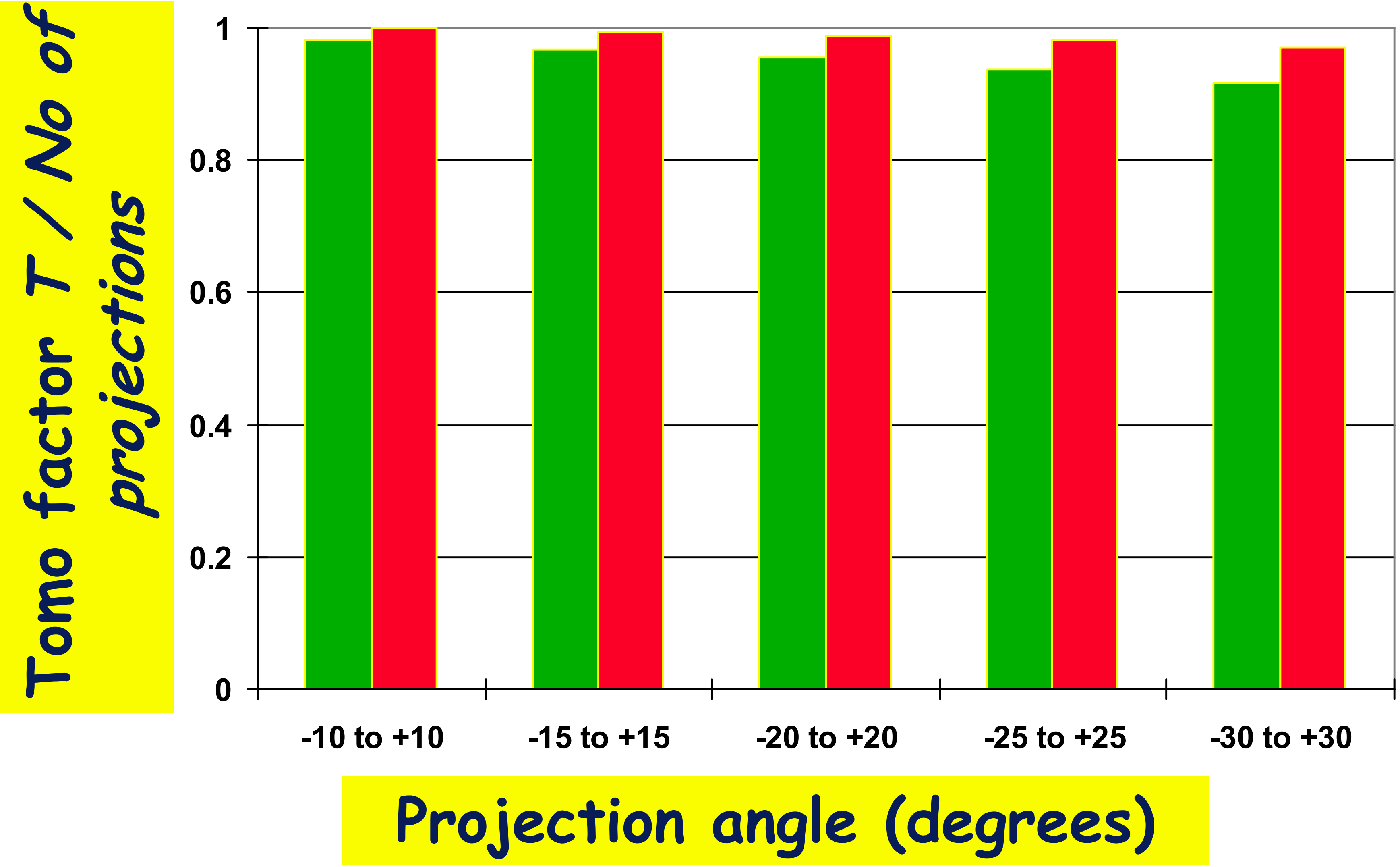
Overall variation of t(Θ) (CC view)



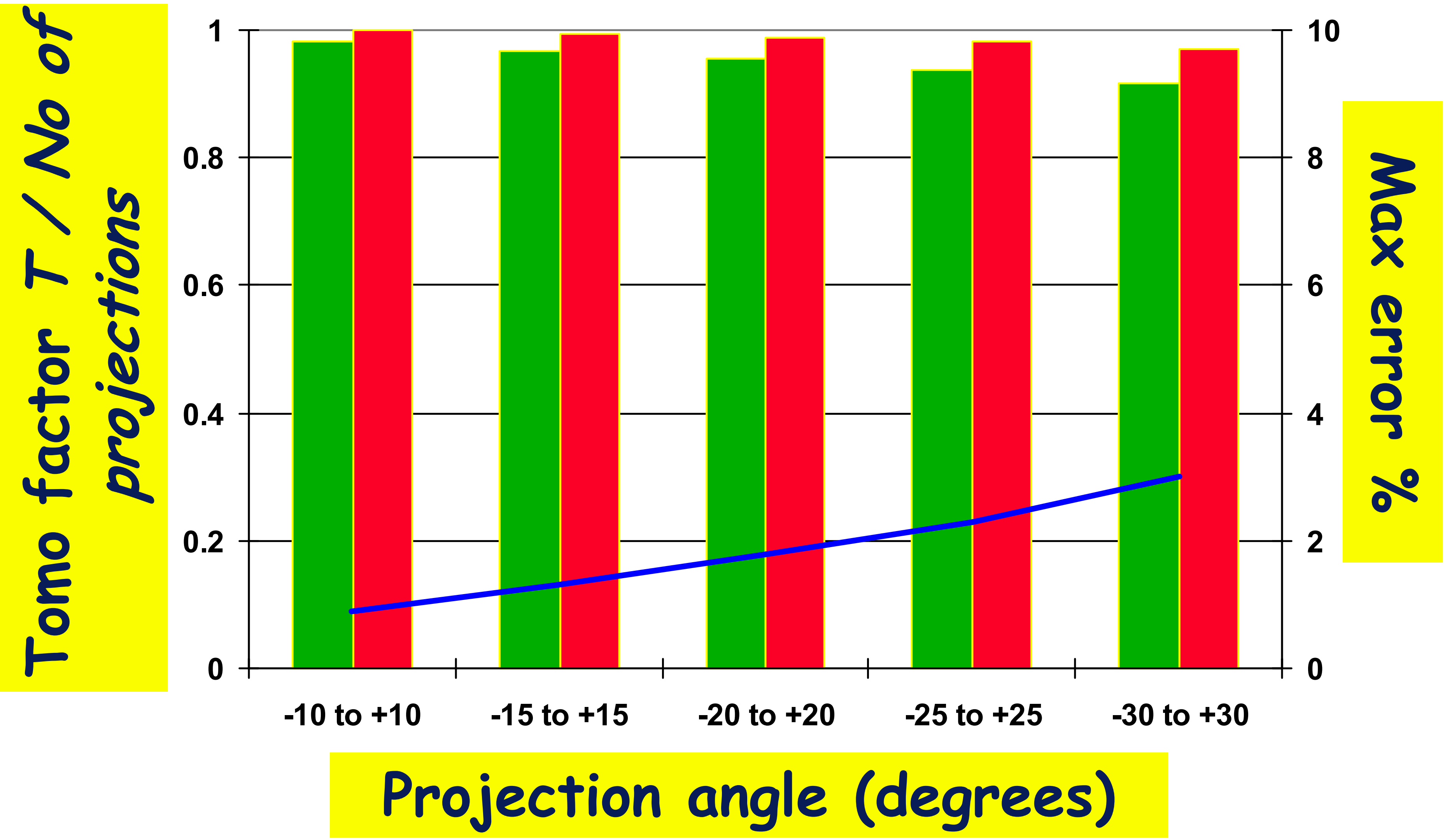
Overall variation of t(Θ) (CC view)



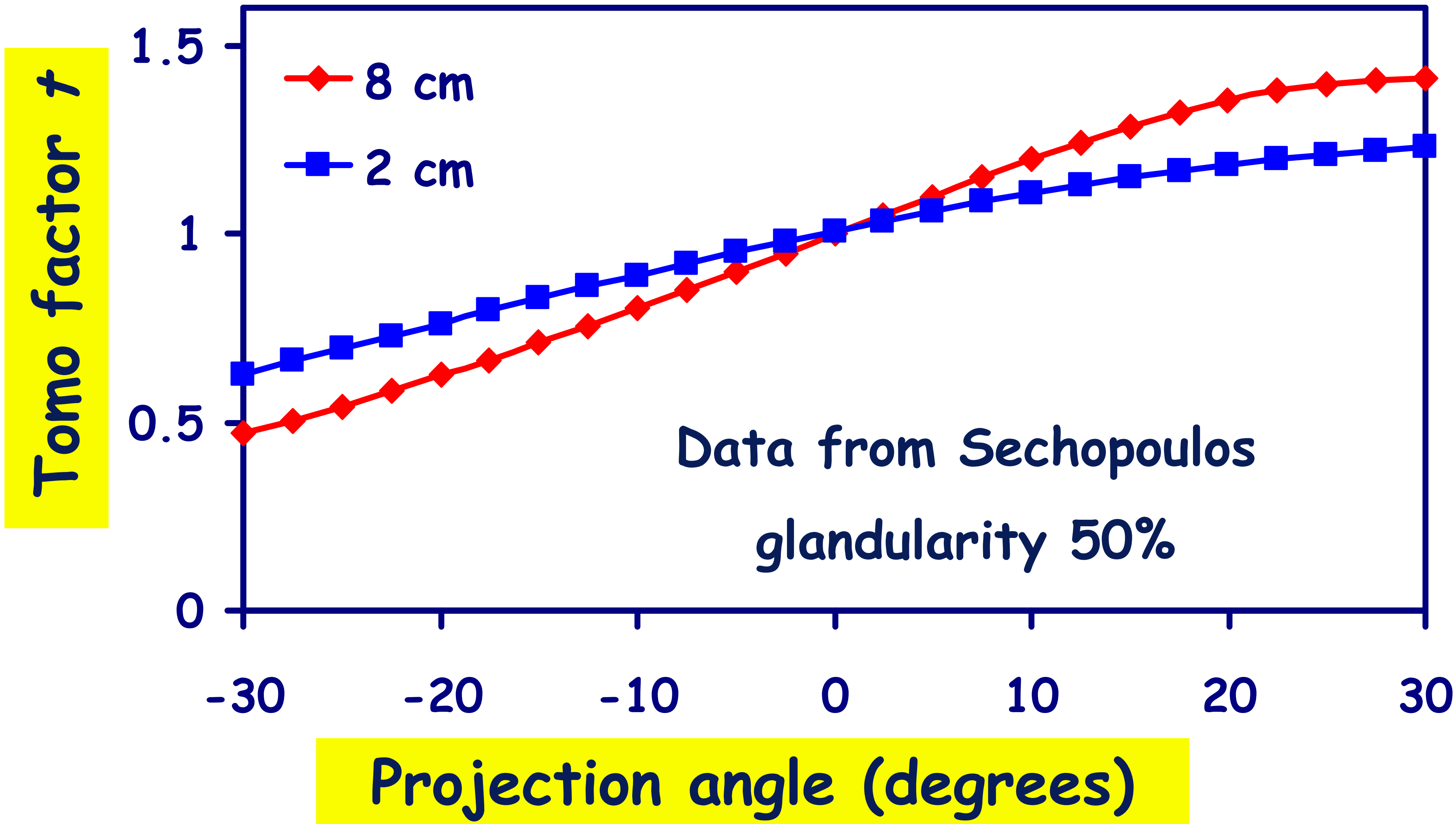
Overall variation of T with angular range (CC view)



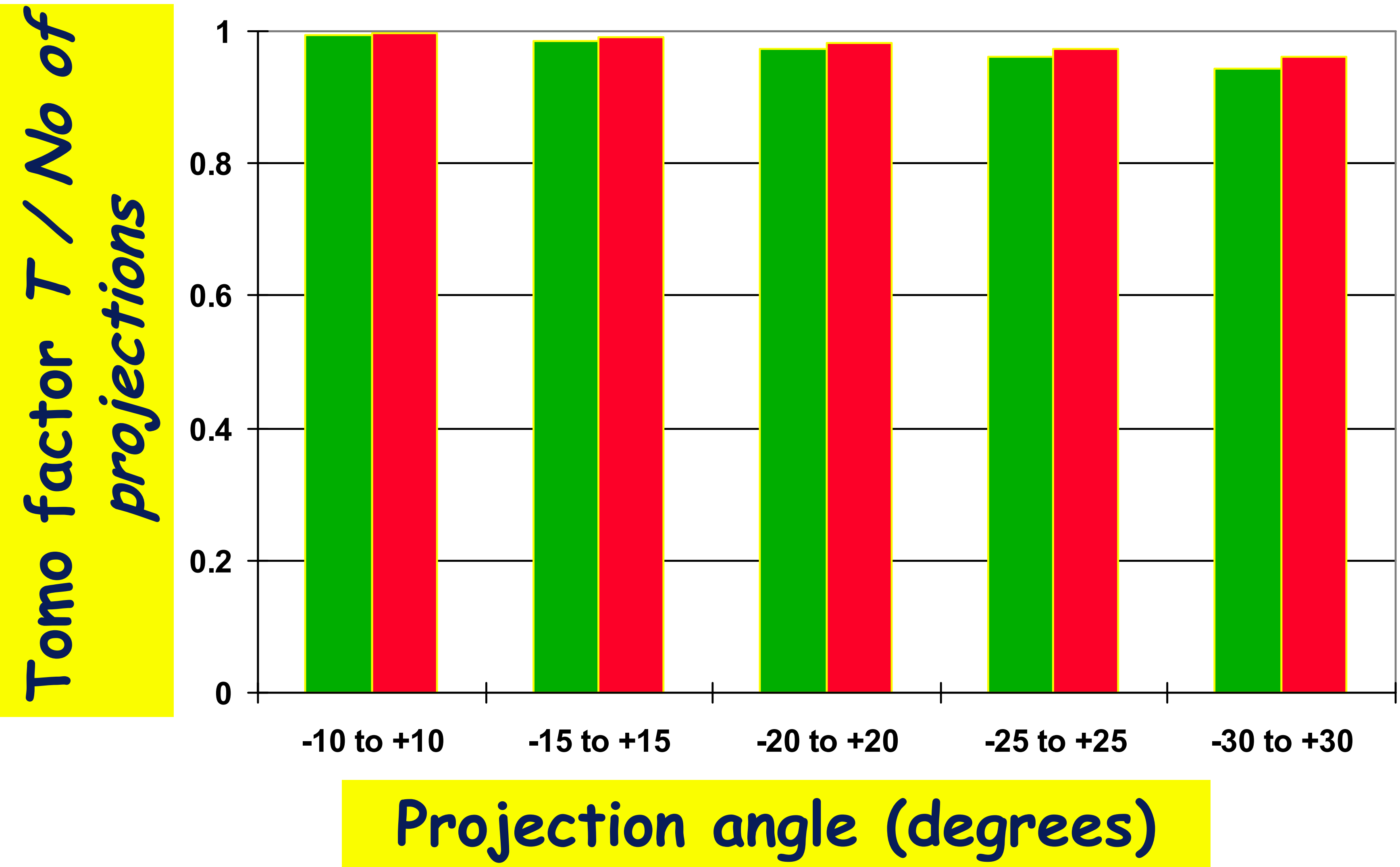
Overall variation of T with angular range (CC view)



Dependence of t(Θ) on projection angle (MLO view)



Overall variation of T with angular range (MLO view)



Conclusions for dosimetry for tomosynthesis

1. The formalism for 2D can be extended to tomosynthesis by the use of a further factor T, which can be tabulated against the angular range used. T is close to 1

2. If different weights are given for each angle, individual factors t(Θ) must be used

3. Different factors may be needed for breasts of different compressed areas and for different projections.

4. The dose is affected by the position of the breast on the breast support plate.

What is the dose for breast tomosynthesis?

$$AGD = K(0)gcs\ T$$

1. The value of T is close to 1
2. The AGD will thus be similar to that for digital mammography if the same total mAs is used.
3. Actual values of AGD depend upon the exposure parameters chosen by the manufacturer, and these vary.
4. Can expect the total dose for the examination to be similar to that for standard digital mammography

Finally...

- Breast dosimetry important part QC
- Careful measurement is essential in accordance with procedures in the European Guidelines.
- Remember that all dosimetry is for very simple models of the breast. In real breasts, the distribution of glandular tissue will be different as will the AGD.

Acknowledgements

Thank you to colleagues at NCCPM for provision of data and images and the EU Sixth Framework Programme for funding (HighRex project)