2012 :15th SESSION of ESMP

Lecture presented in Archamps (Salève Building) by :

Elly CASTELLANO (London)

Physical principles of mammography

Elly Castellano

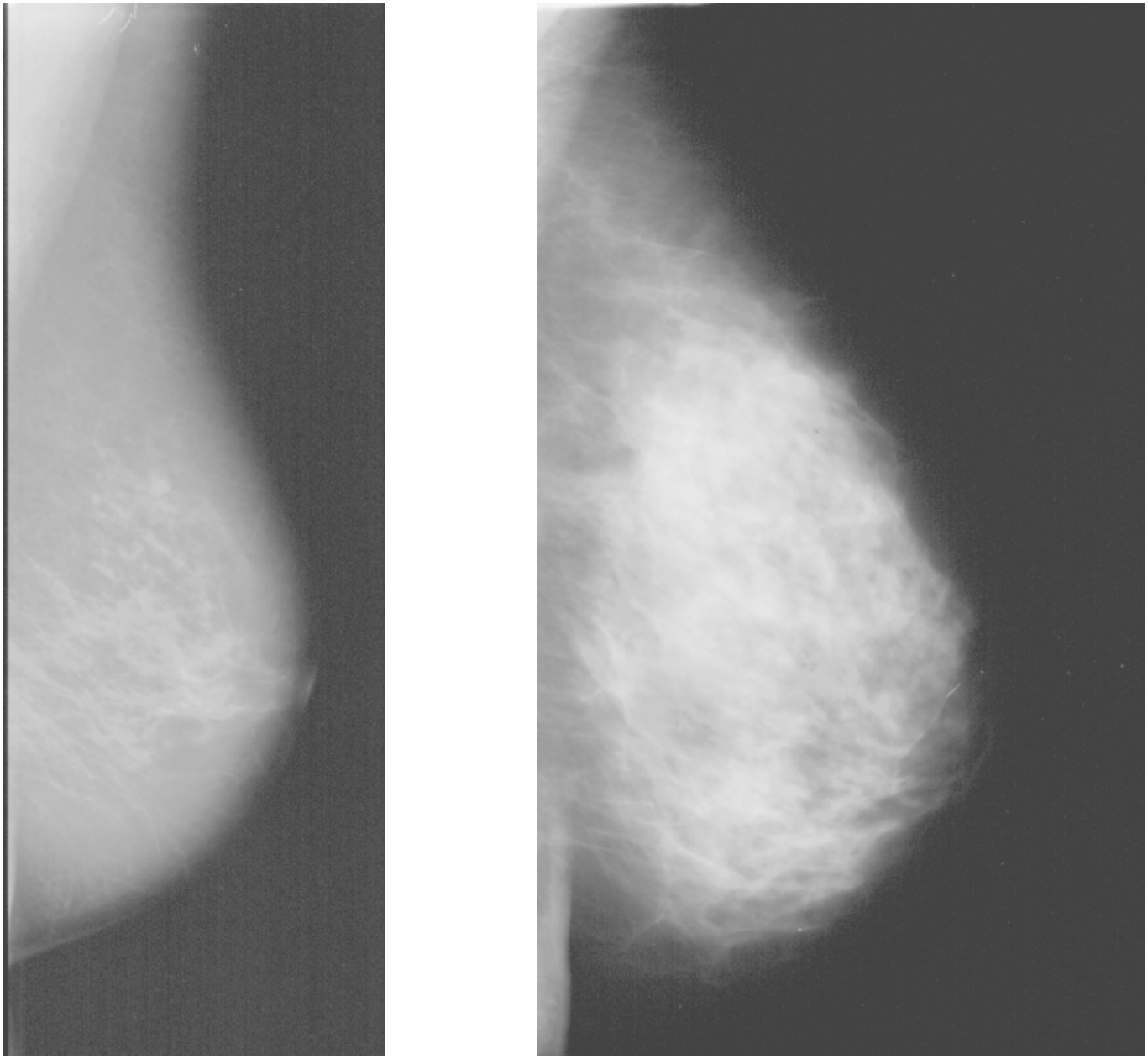
Royal Marsden Hospital
London, United Kingdom

Outline

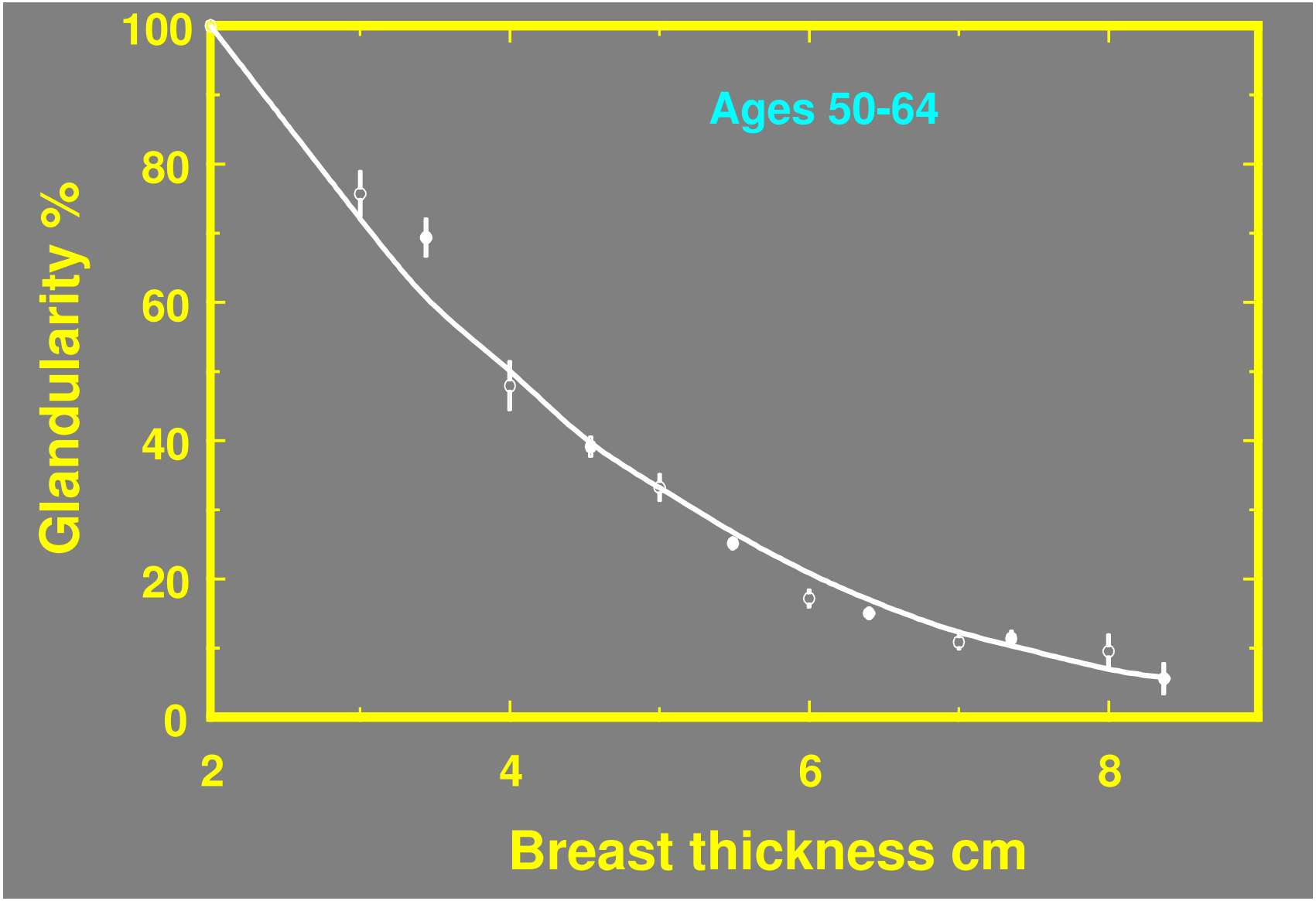
- Properties of the breast
- X-ray interactions
- Physical parameters
- System components

Compressed breast

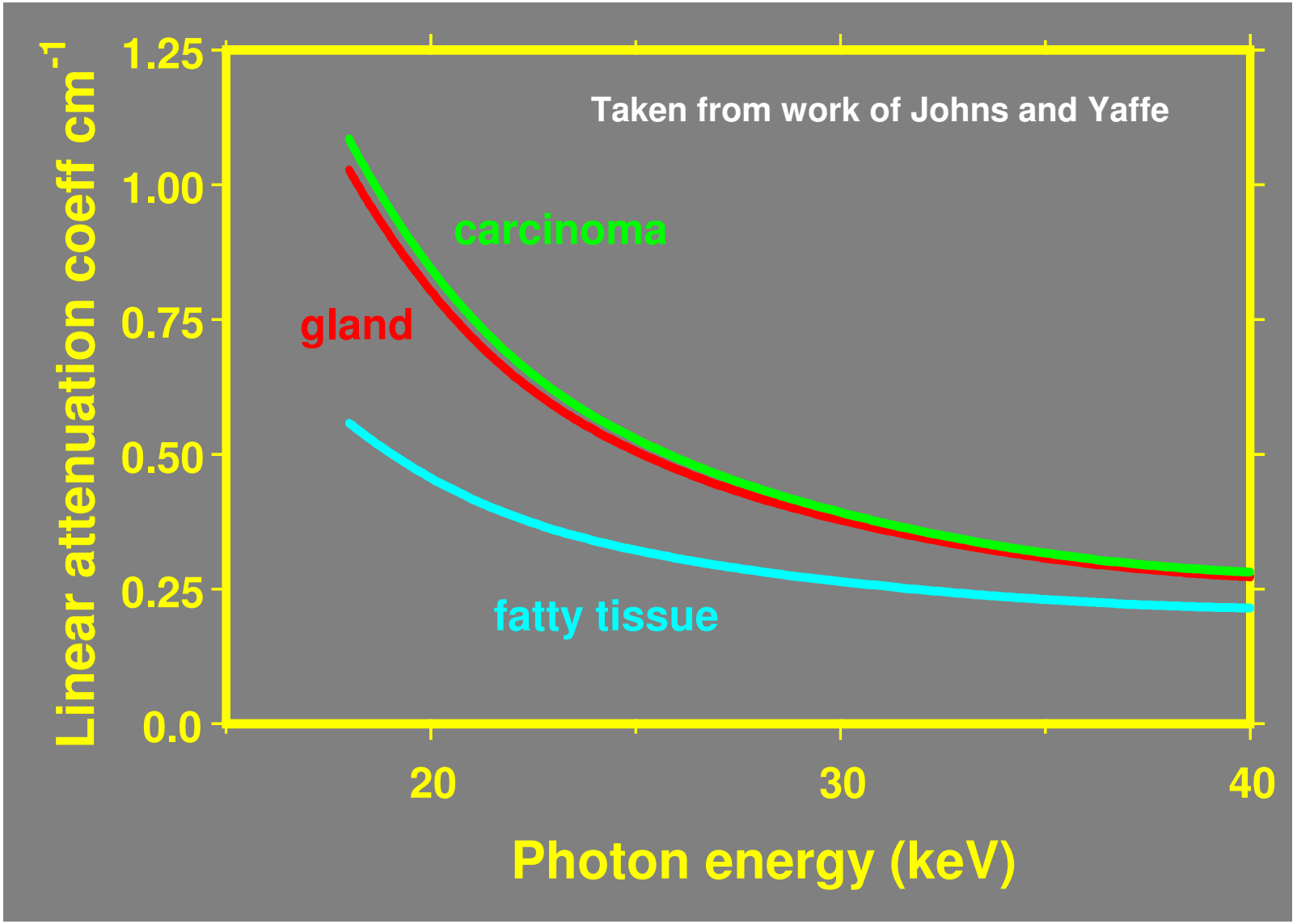
- Thickness 2 -11 cm
- Area 35 cm^2 - large
- Adipose/glandular tissues
- Calcifications



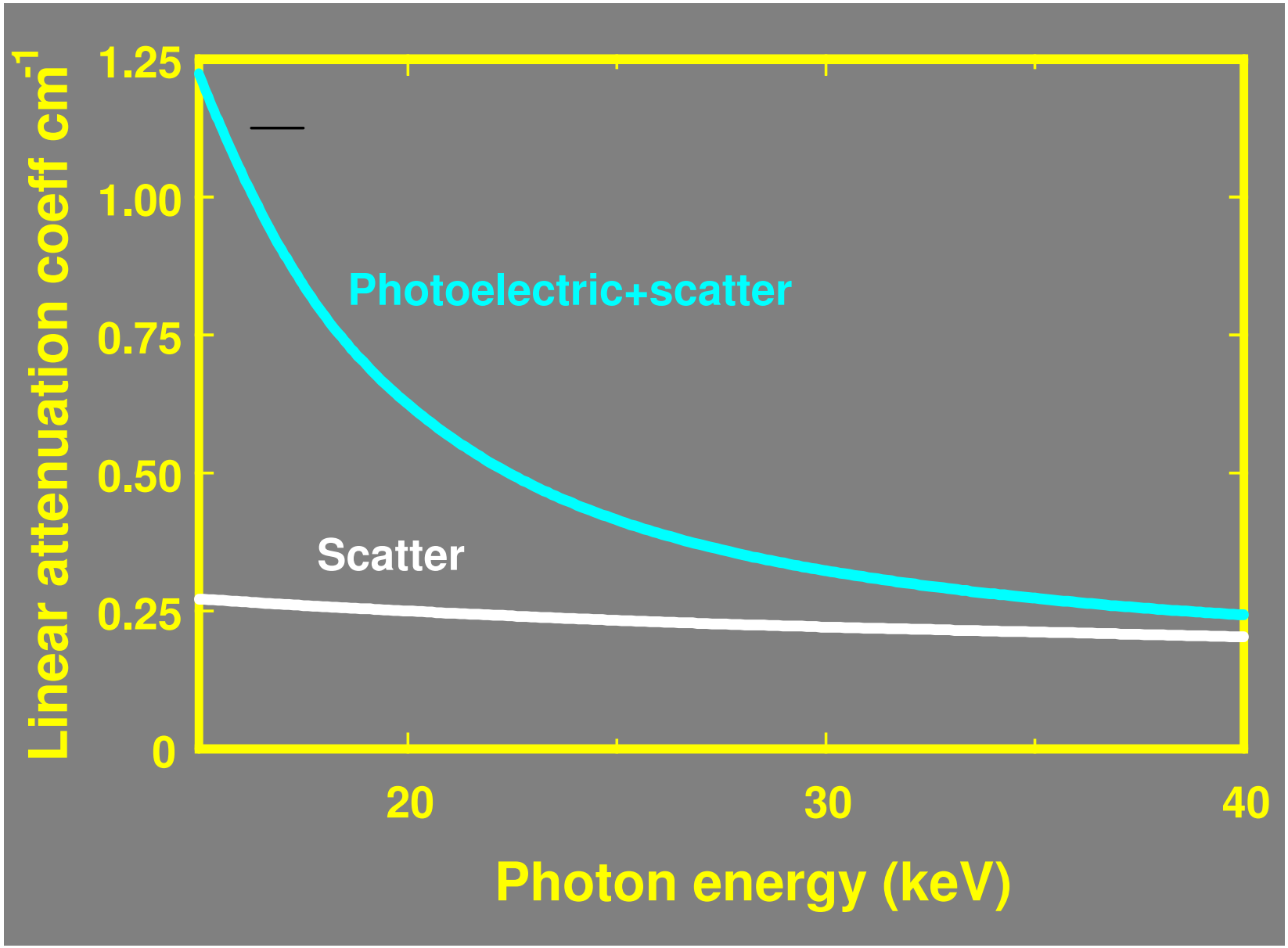
Breast glandularity



Linear attenuation coefficients

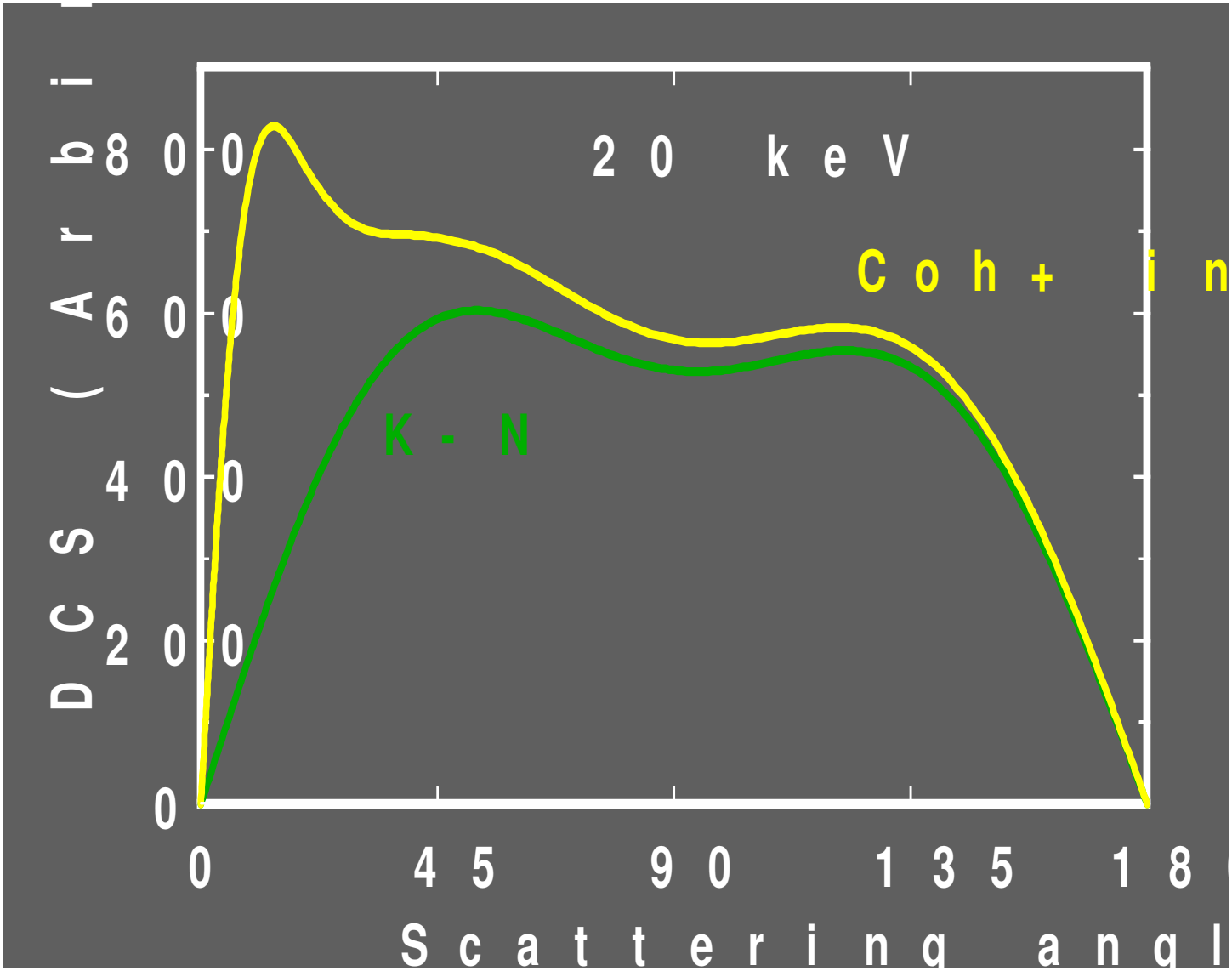


Interaction processes



Scatter processes

Shape of DCS



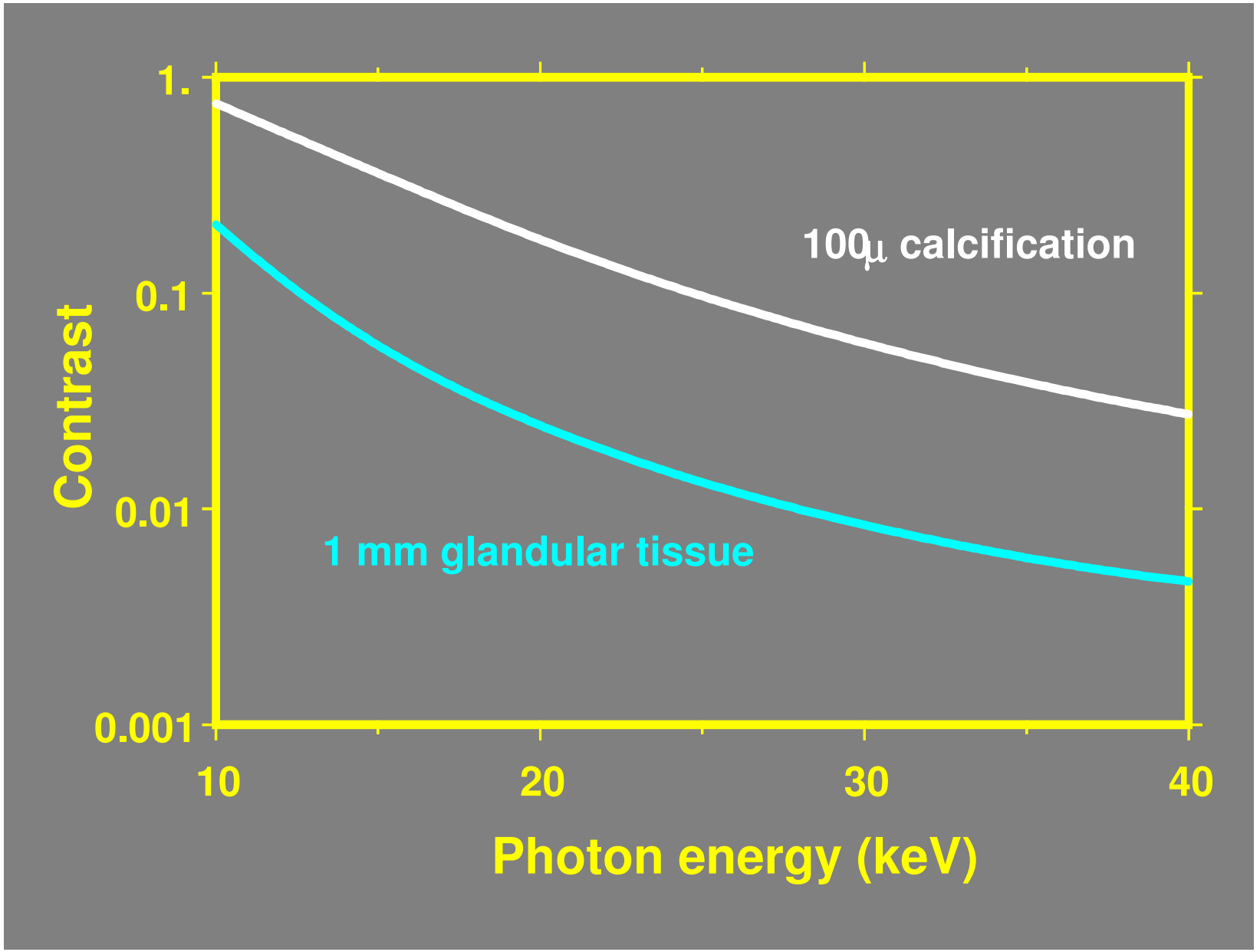
Mammography requirements

- Good contrast
- Good resolution
- Low dose
- Low noise
- Large dynamic range

Factors affecting contrast

- Object and background
- Transmitted X-ray spectrum
- Image receptor
- Scatter

Mammographic contrast



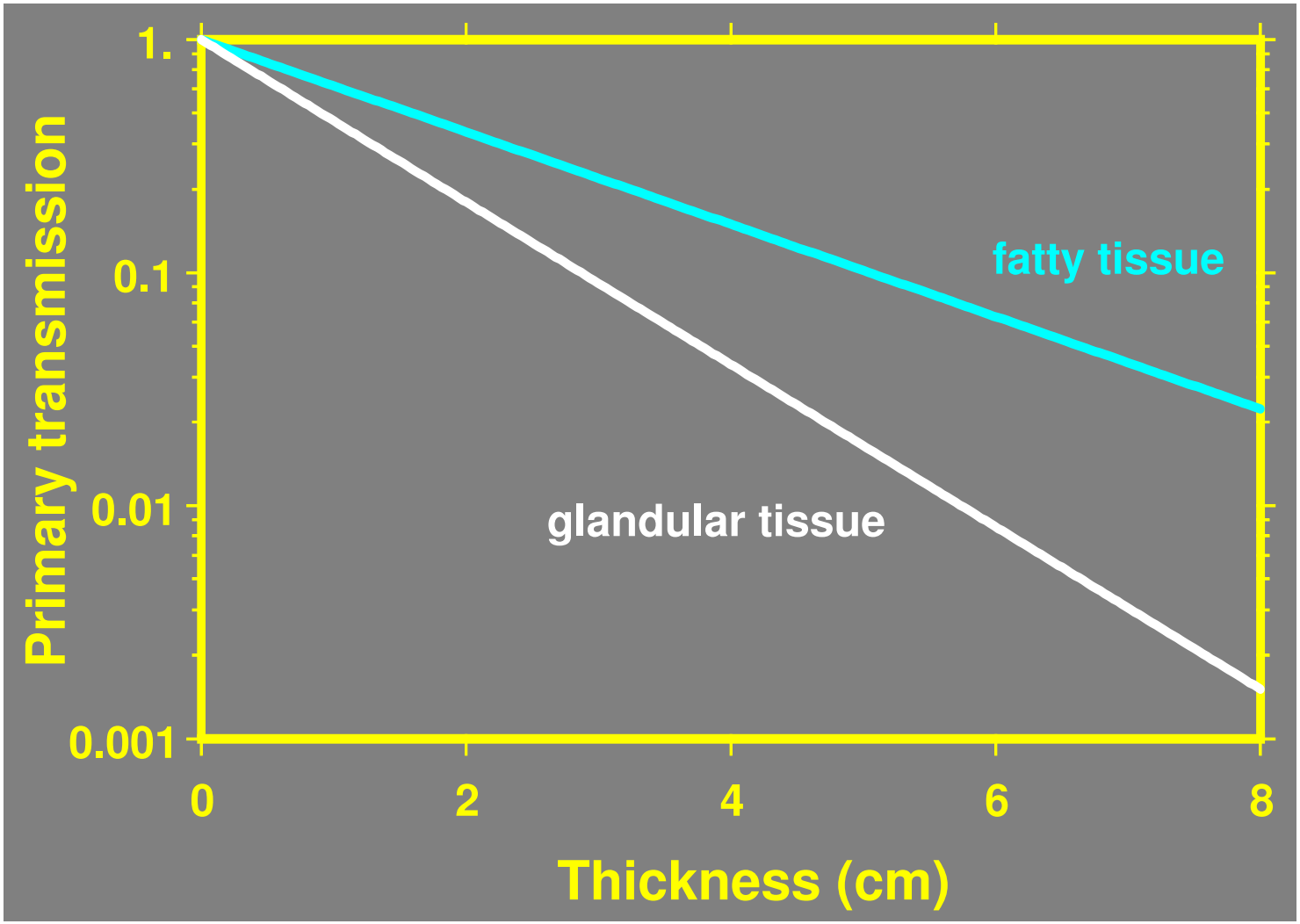
Factors affecting unsharpness

- Focal spot size
- Imaging geometry
- Receptor unsharpness
- Patient movement

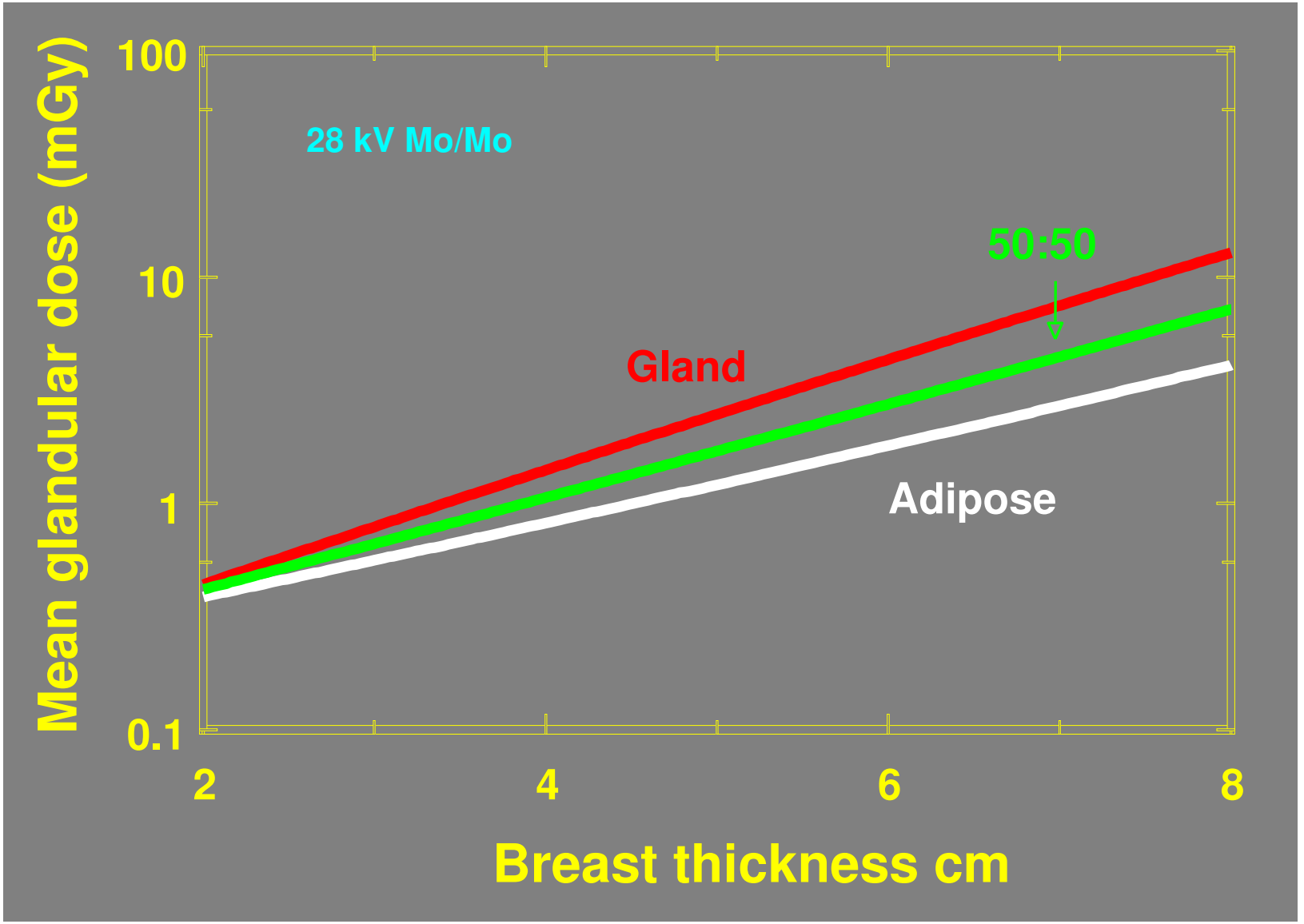
Factors affecting dose

- Breast thickness
- Breast composition
- Photon spectrum
- Receptor

Primary transmission through breast



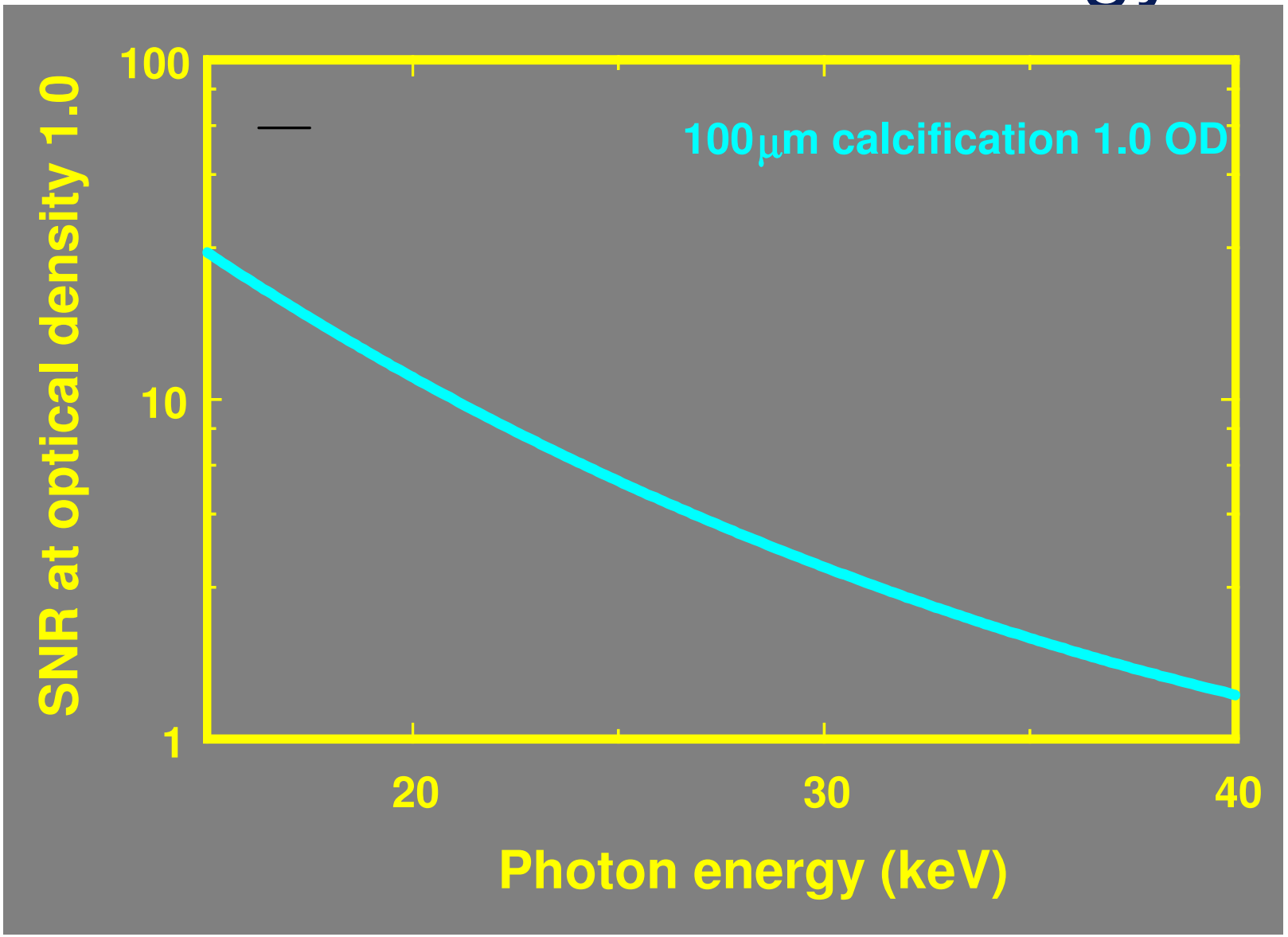
Mean glandular dose

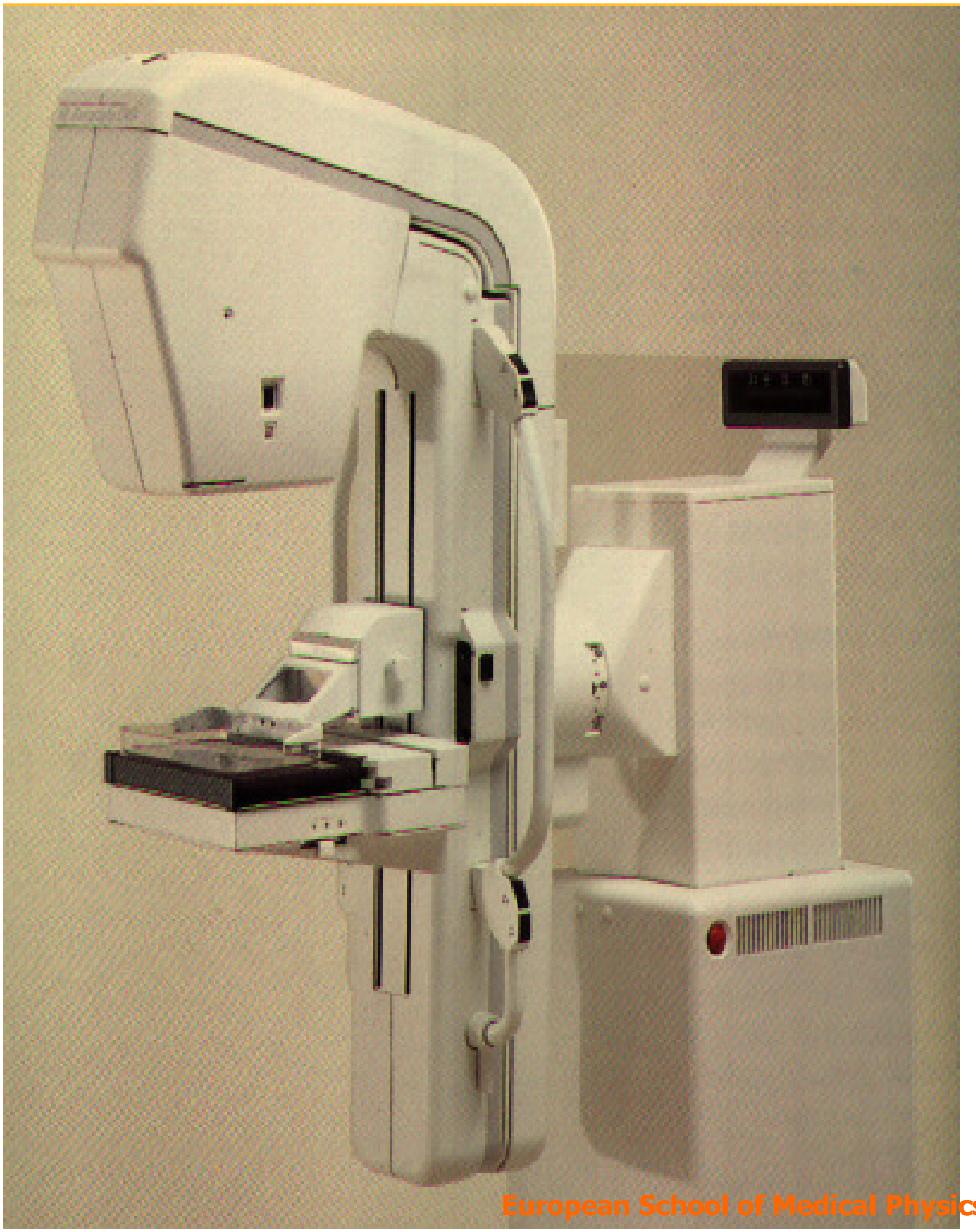


Factors affecting noise

- Quantum mottle
- Light photons
- Screen structure
- Film granularity

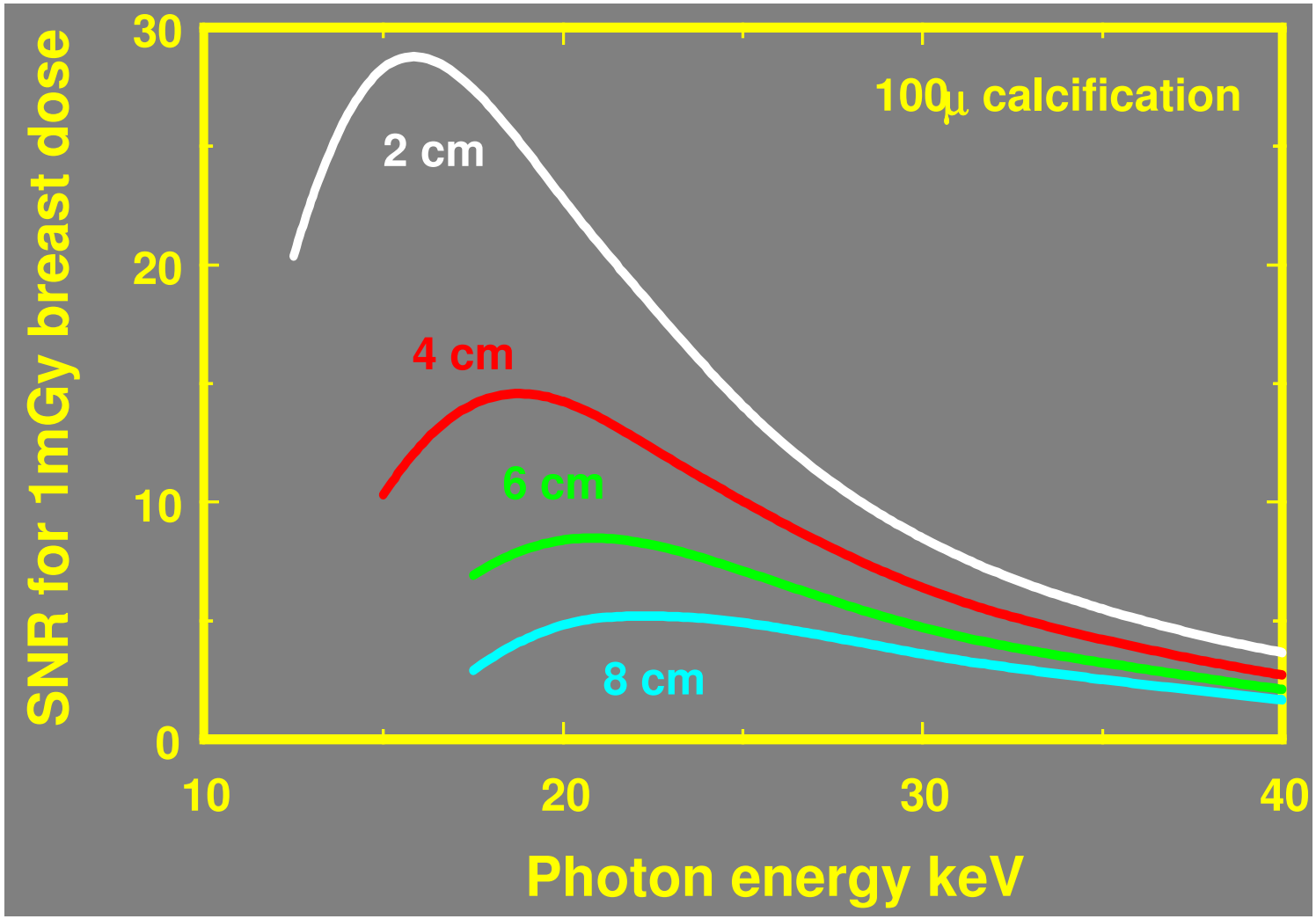
Quantum mottle vs energy



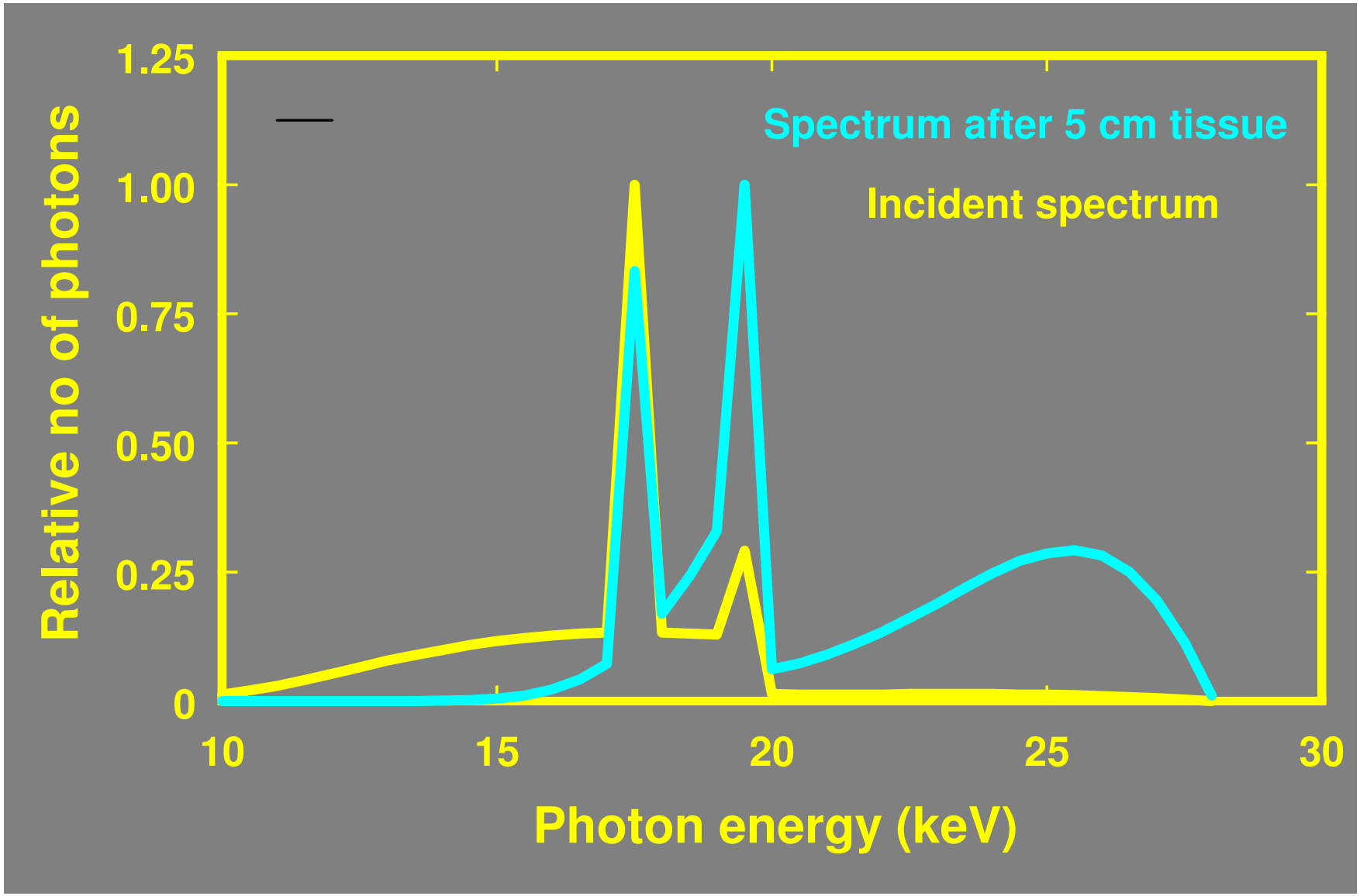


Mammographic X-ray set

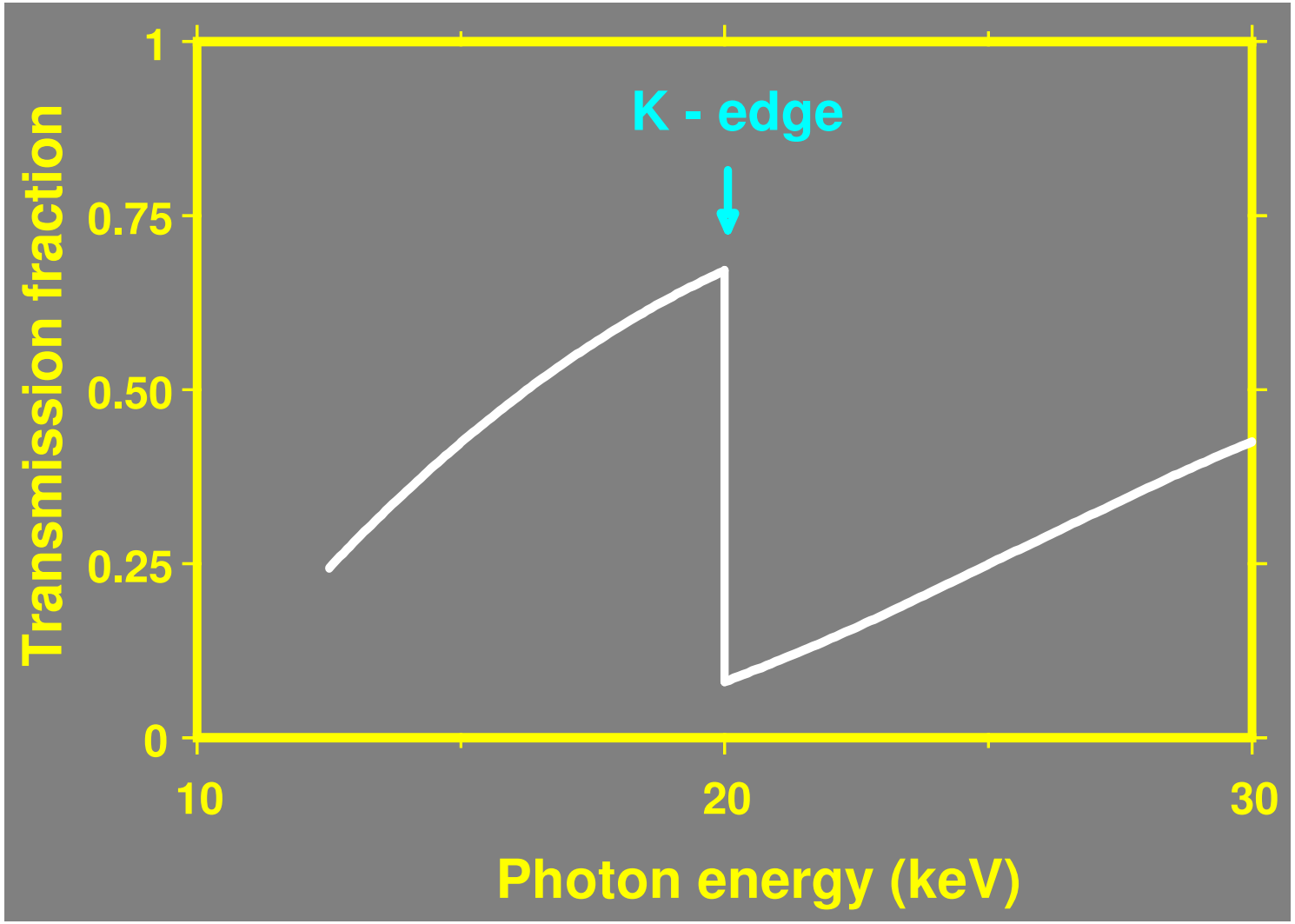
Optimal energies for mammography



Mo/Mo spectra



K-edge filter - 30 micron Mo

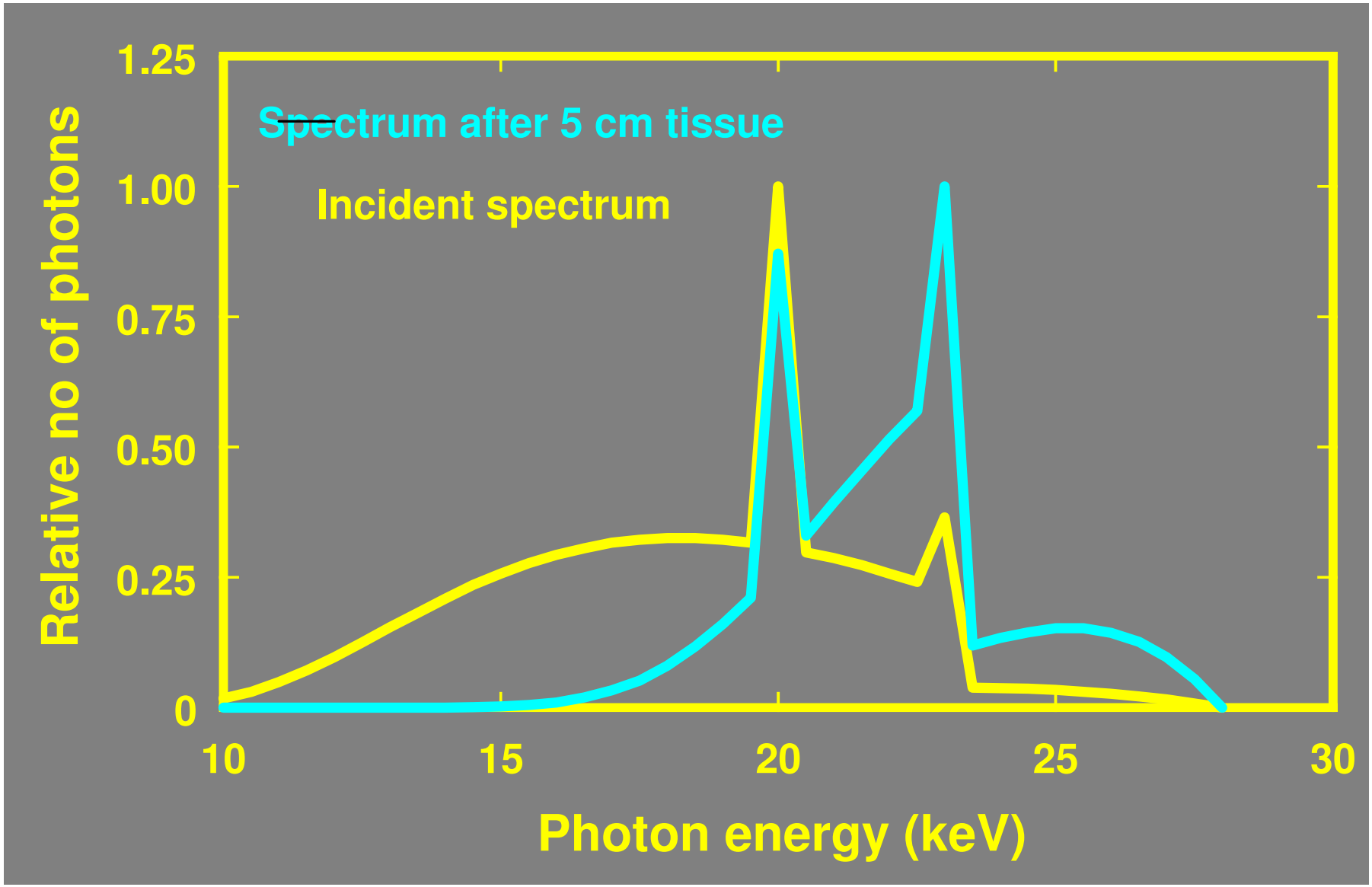


K-edges

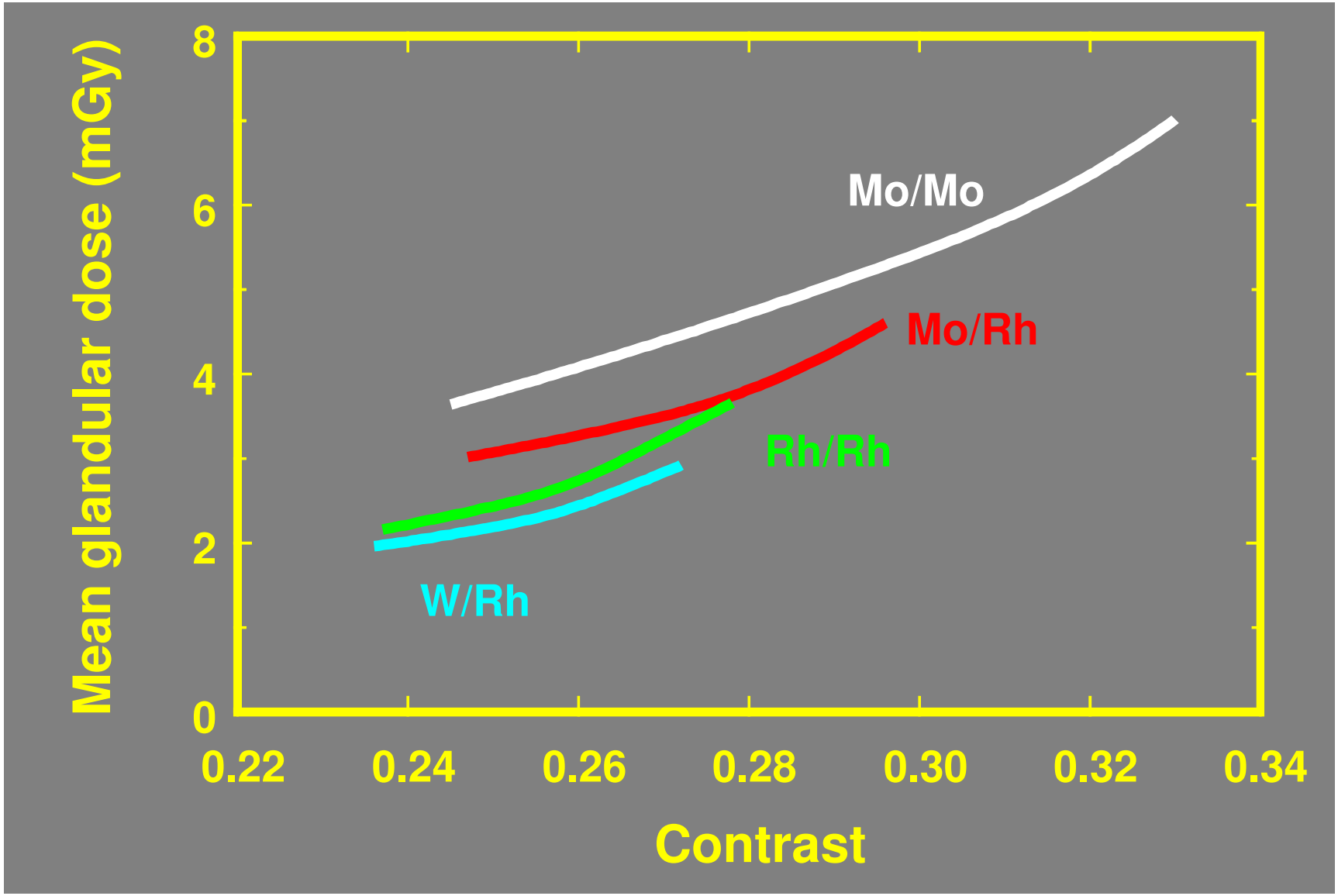
Mo 20.0 keV

Rh 23.3 keV

Rh/Rh spectra



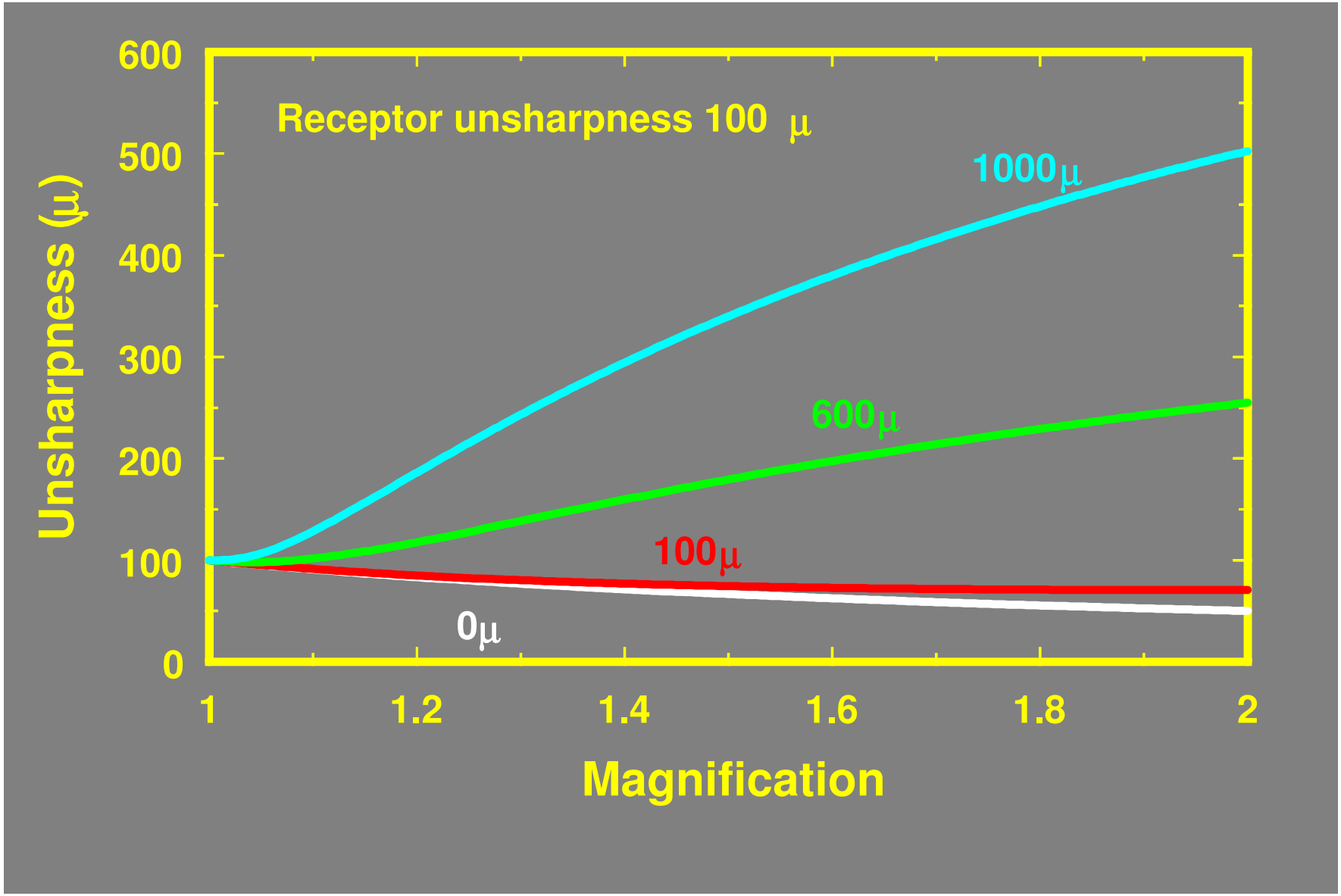
8cm breast 10% glandularity



Spectra for screen/film mammography

- Cannot match Mo/Mo for high contrast
- Other spectra offer dose savings at lower contrast
- Optimum spectrum varies with breast thickness and glandularity

Unsharpness combinations



Focal spot sizes and geometry

- Contact mammography
  - focal spot size 0.3 mm (measured)
  - focus film distance 65 cm
  - minimize gap between breast and receptor
- Magnification mammography
  - focal spot size 0.15 mm (measured)

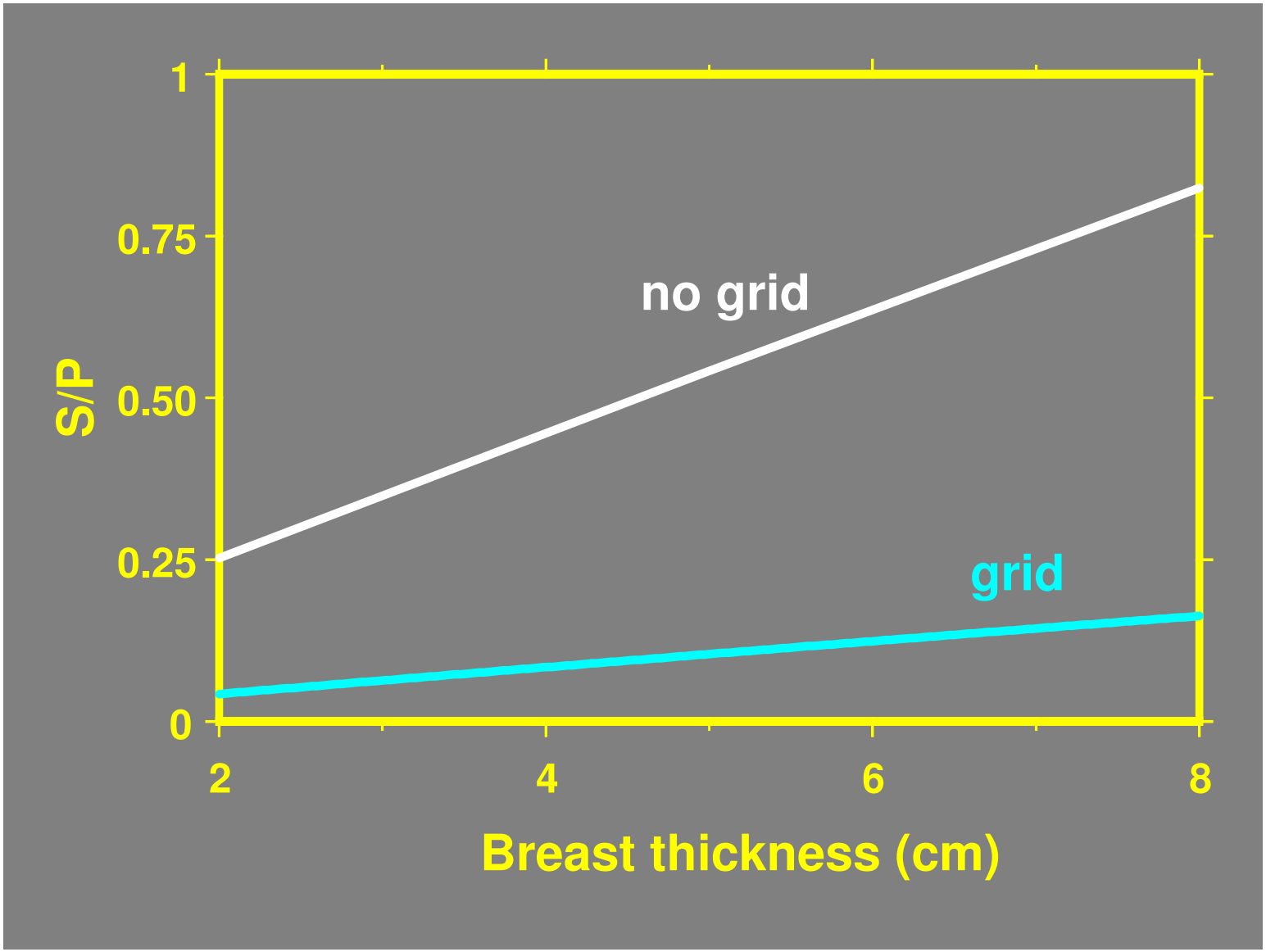
Breast compression

- Reduced dose
- Reduced scatter
- Improved contrast
- Improved unsharpness
- Reduced dynamic range
- Improved visualisation

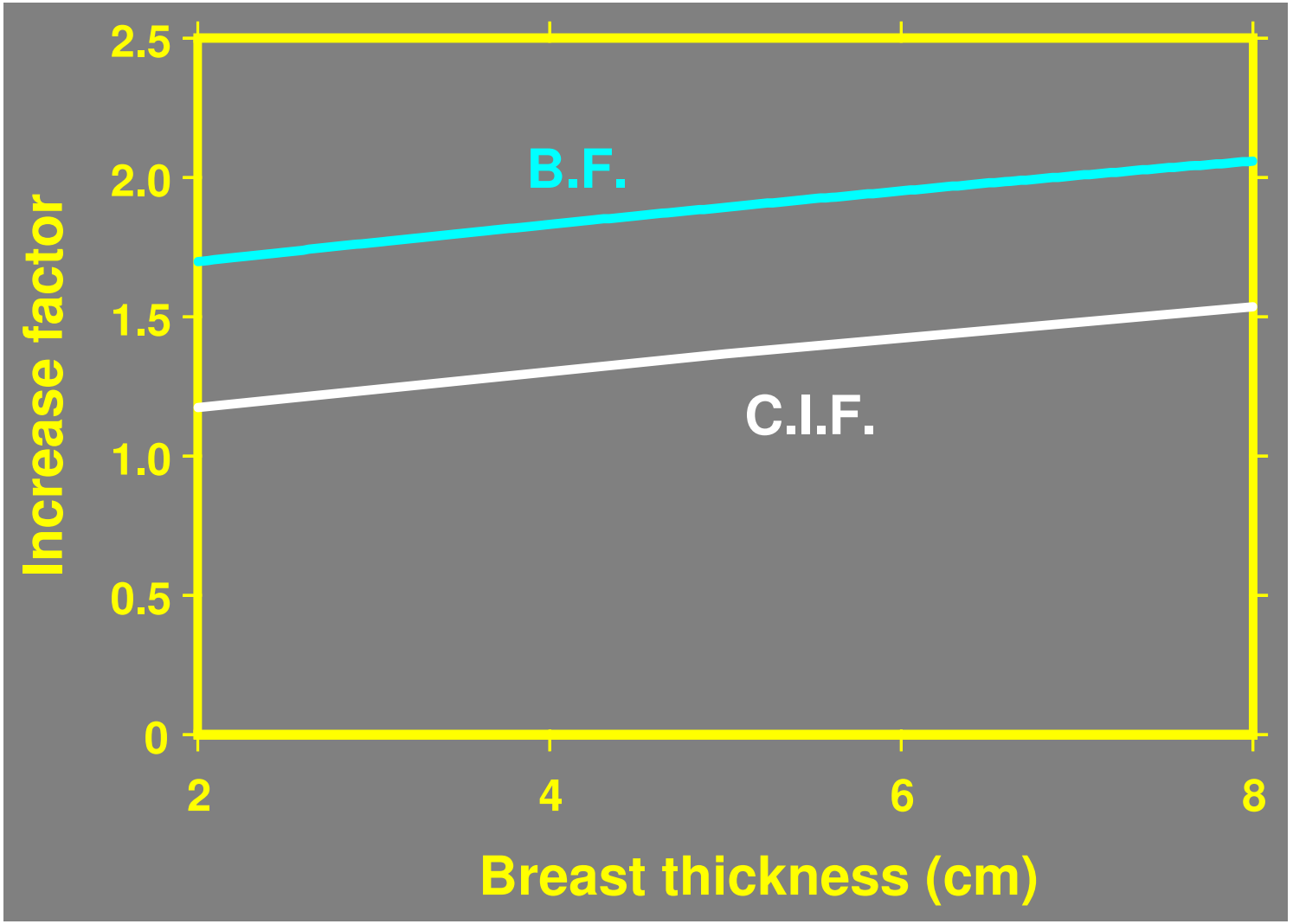
Contrast degradation factor

$$CDF = \frac{1}{1 + S/P}$$

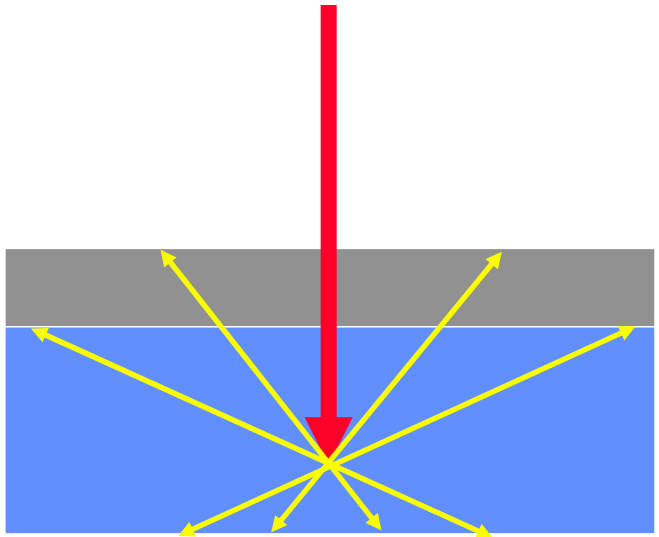
Scatter to primary ratio



CIF and BF


2.5
2.0
1.5
1.0
0.5
0
Increase factor
B.F.
C.I.F.
2
4
6
8
Breast thickness (cm)

Screen-film receptor

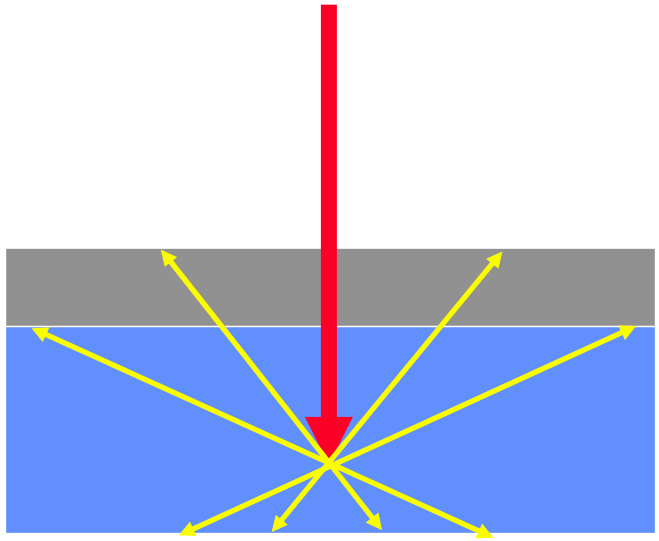


film

screen

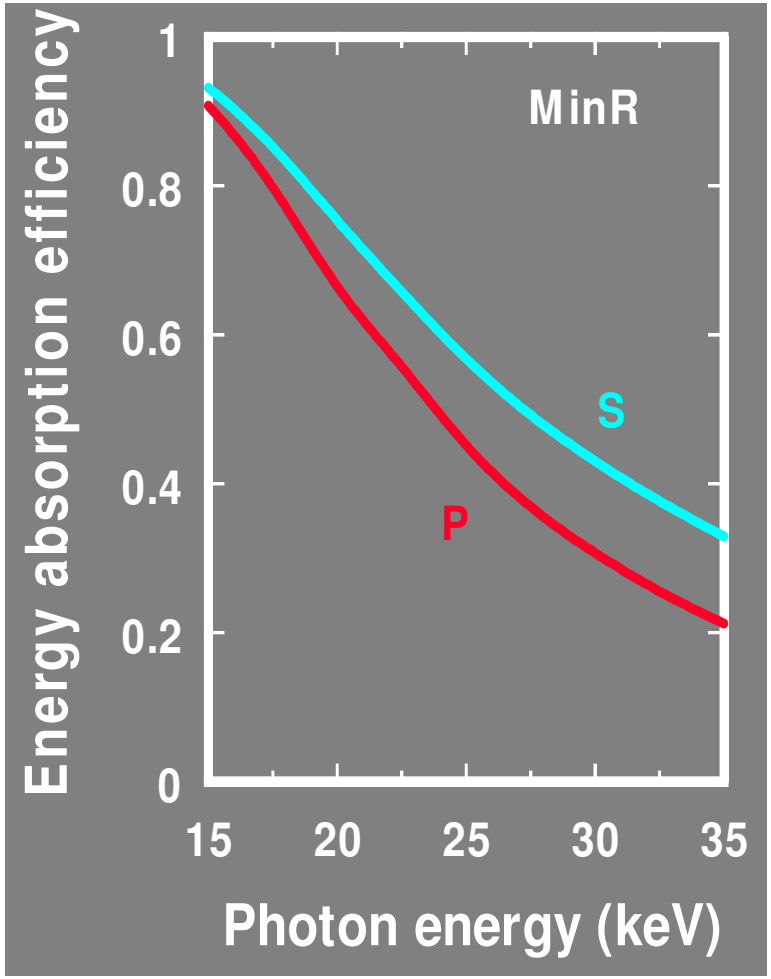
Factors affecting speed of the screen-film receptor

- Composition and thickness of screen
- Photon spectrum
- Light output
- Film response
- Film processing
- Reciprocity failure



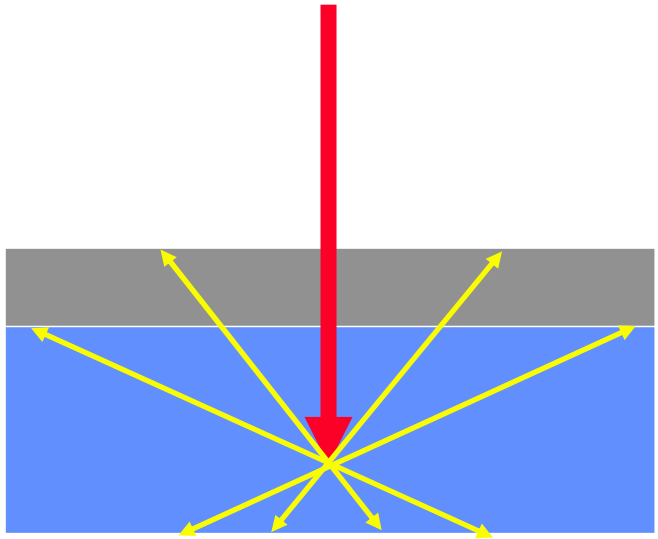
MinR properties

- Rare earth
- Gd_2O_2S phosphor
- K-edge 50.2 keV
- Green light (2.4 eV)
- Light eff. 15%
- 20 keV photon gives 1200 light photons

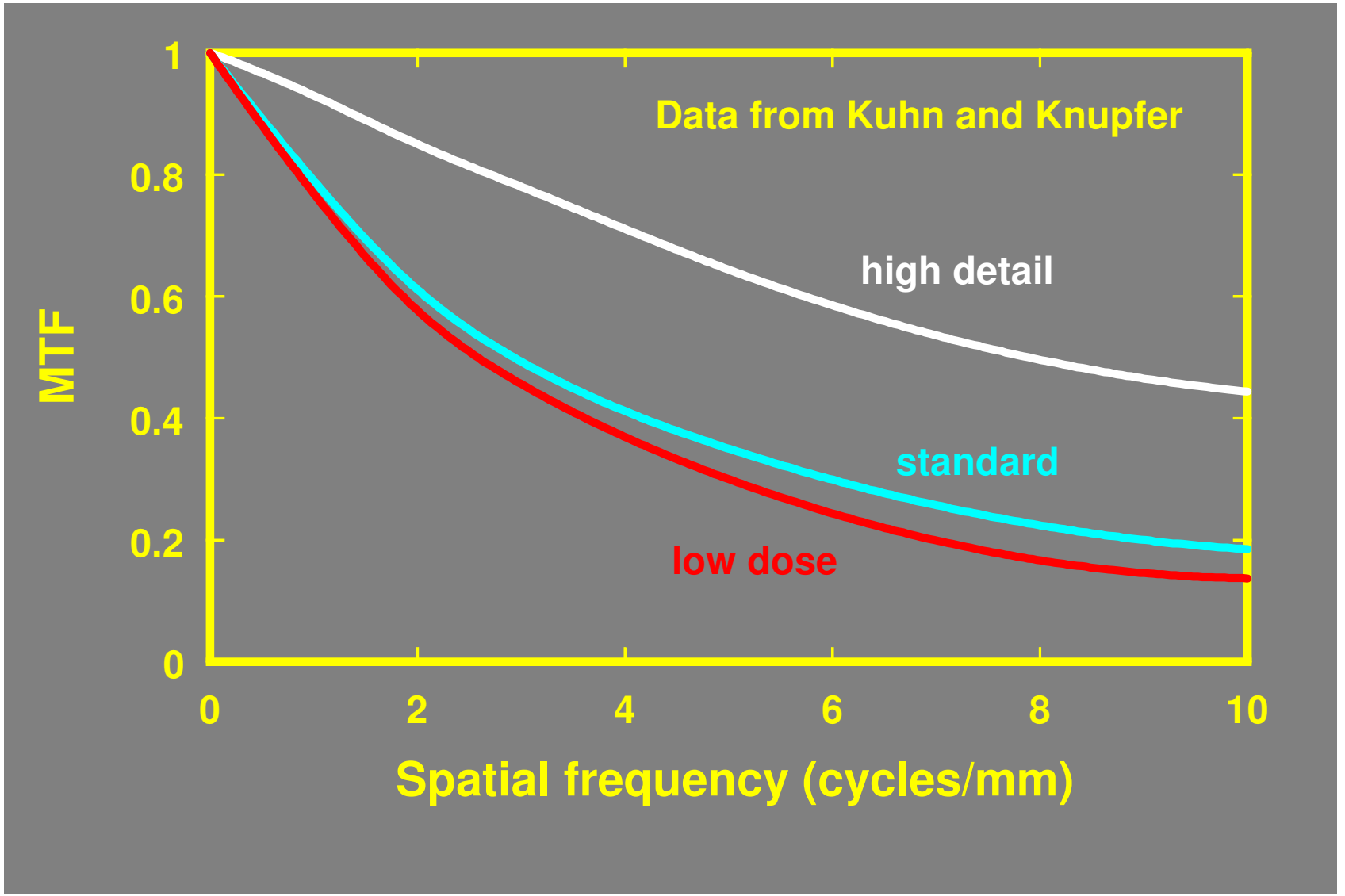


Receptor unsharpness

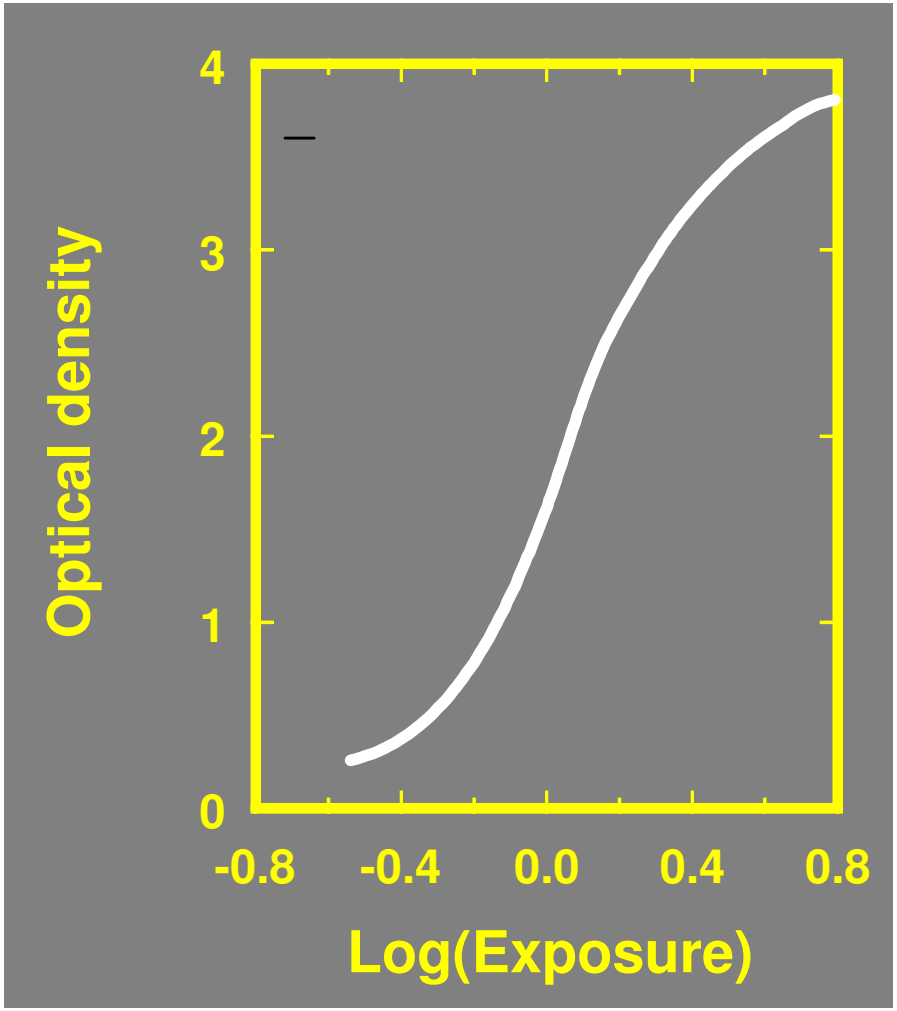
- Light spread
  Screen thickness
  Incident photon spectrum
  Absorptive dyes
  (Cross-over)

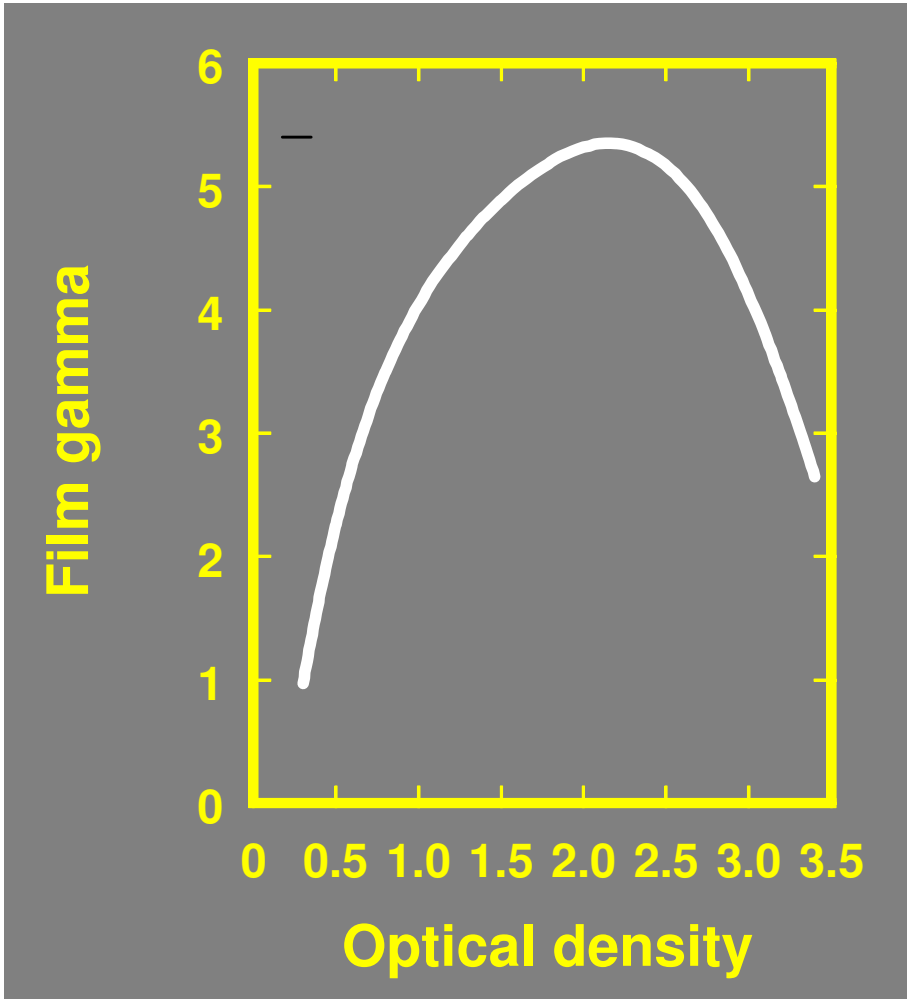


Modulation transfer functions

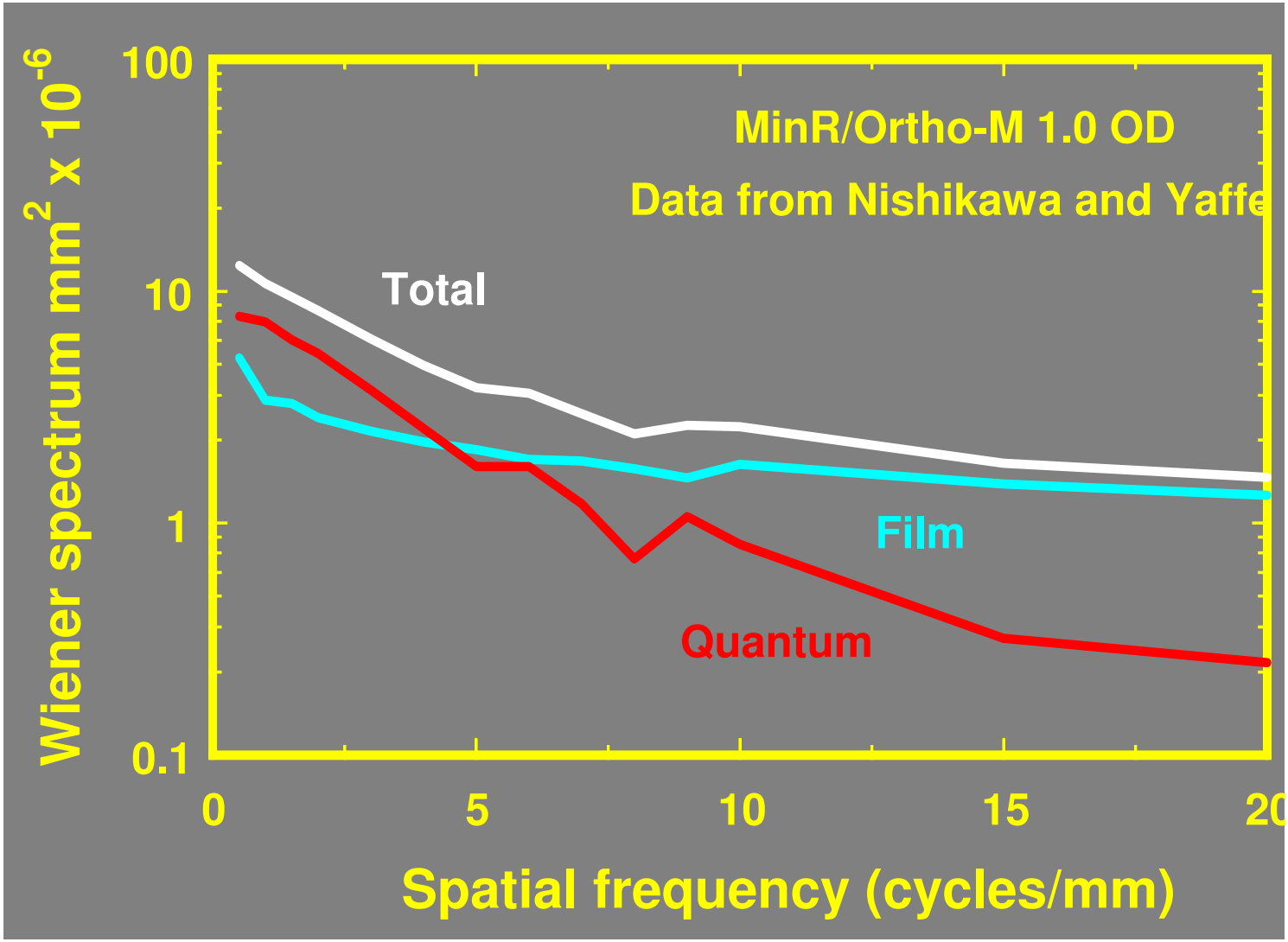


Film characteristic and gamma





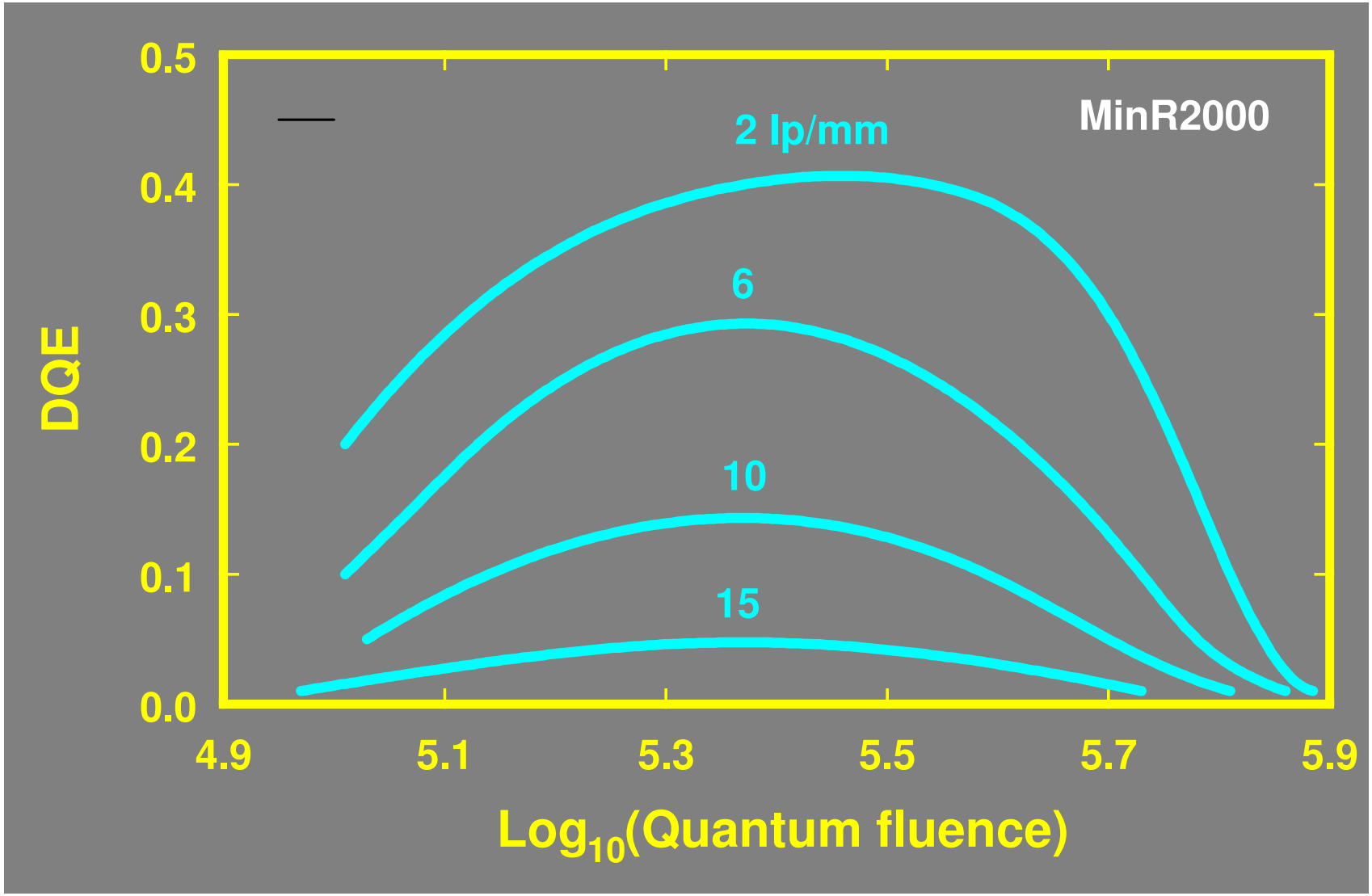
Wiener spectra



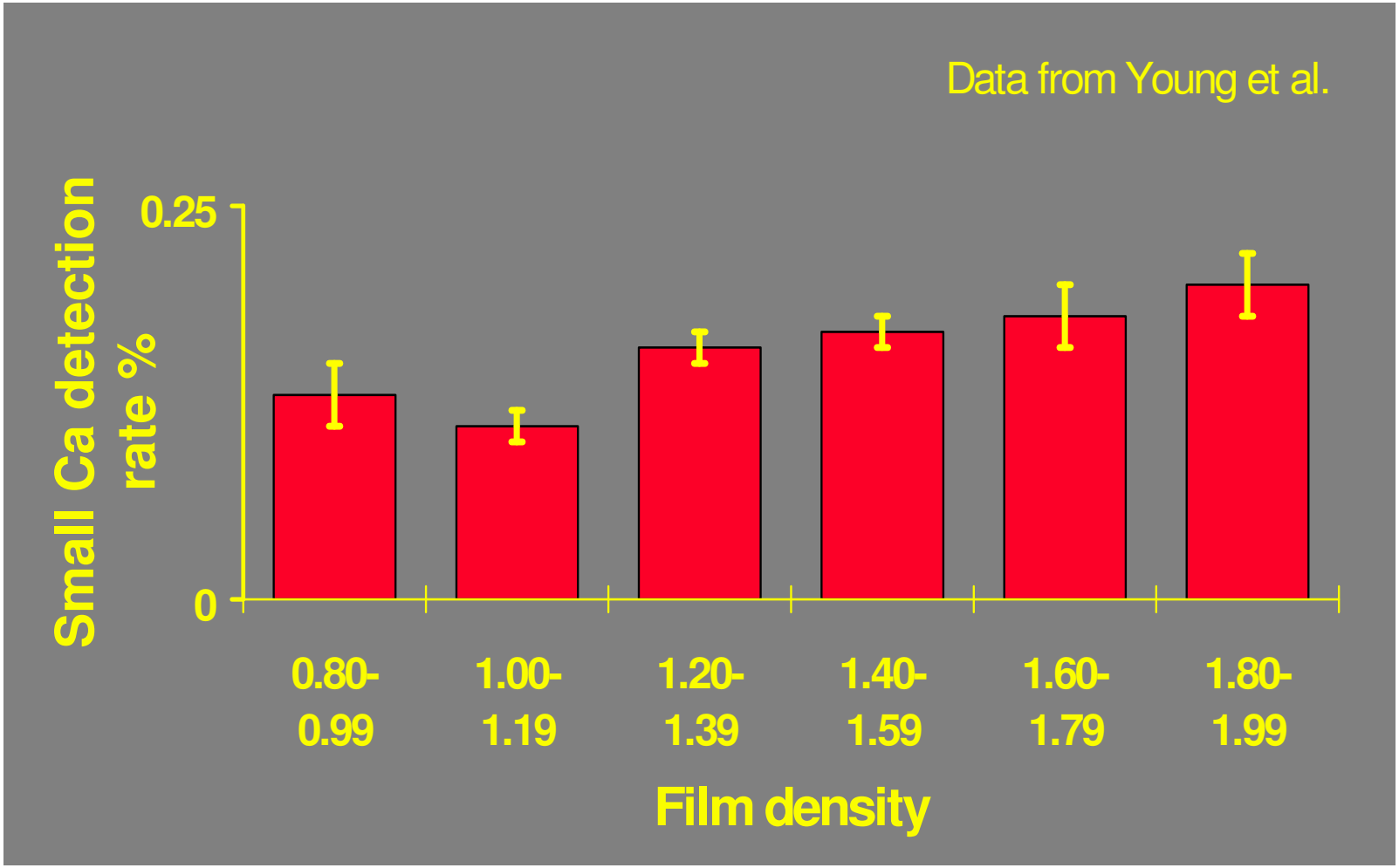
$$DQE = \left(\frac{SNR_{out}}{SNR_{in}} \right)^2$$

Detective quantum efficiency

DQE


0.5
0.4
0.3
0.2
0.1
0.0
DQE
2 lp/mm
MinR2000
6
10
15
4.9
5.1
5.3
5.5
5.7
5.9
Log10(Quantum fluence)

Optical densities in mammography



Conclusions

- Mammographic image quality and dose have improved considerably since the early ‘80s

  BUT

- There is still much room for improvement !

We still need ...

- Improved receptor
- Improved X-ray spectra
- Improved SNR variation over image