2012 :15th SESSION of ESMP

Lecture presented in Archamps (Salève Building) by :

Koos GELEIJNS (Leiden)

LEIDS UNIVERSITAIR MEDISCH CENTRUM

Overview of X-ray radiography

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LUMC

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Overview of X-ray radiography

X-ray physics

Radiography

Mammography

OrthoPanTomography / Cone-beam CT

Tomosynthesis

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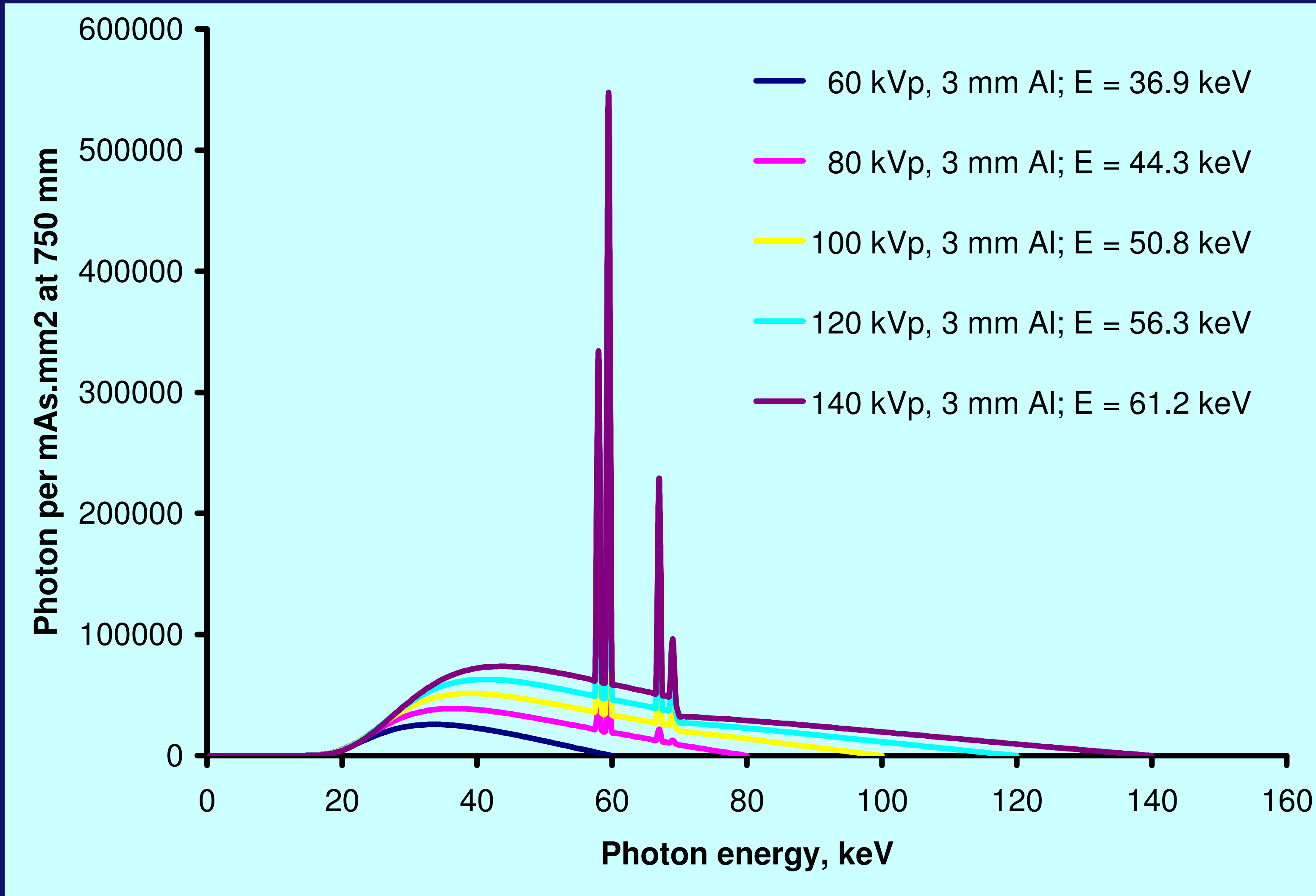
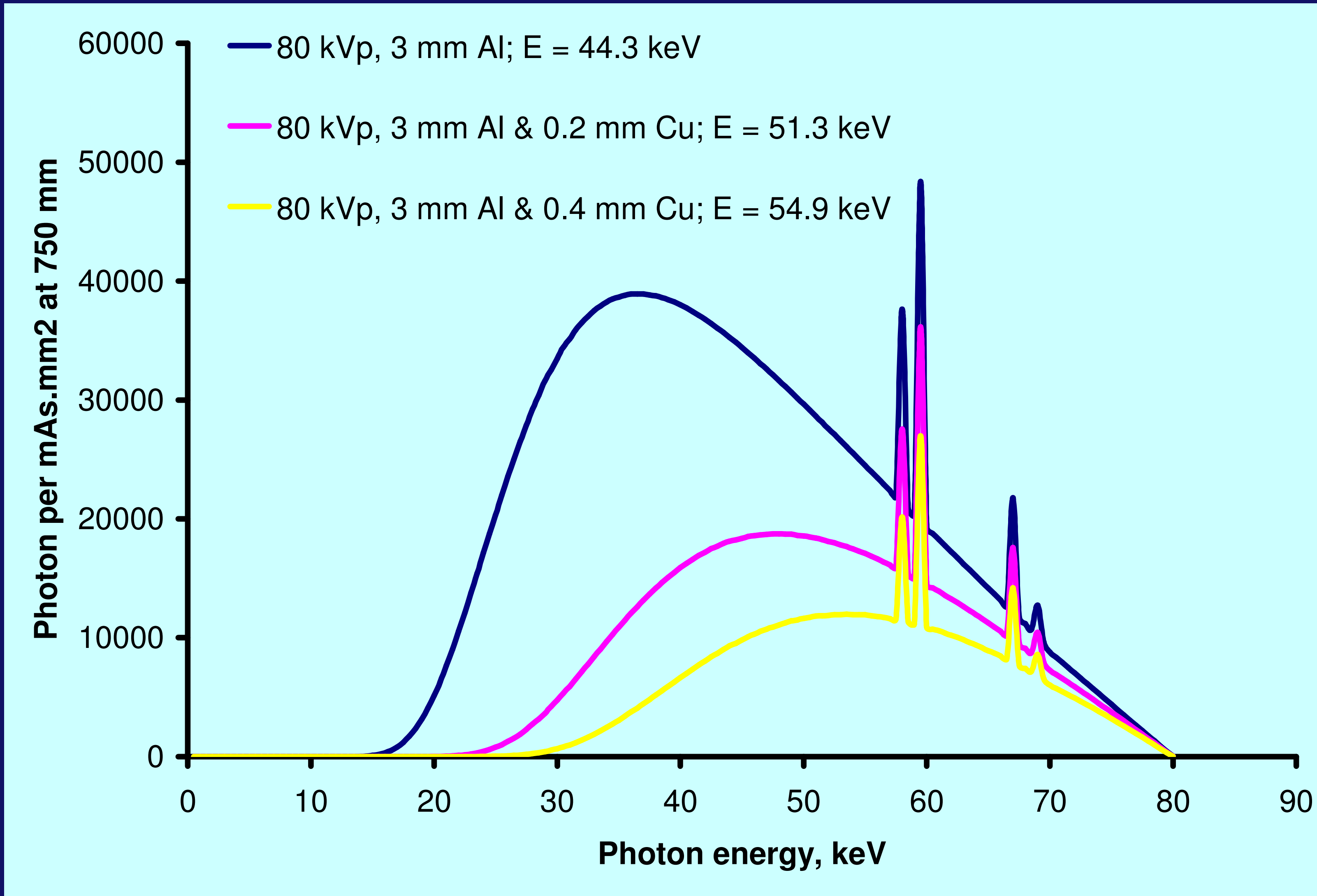
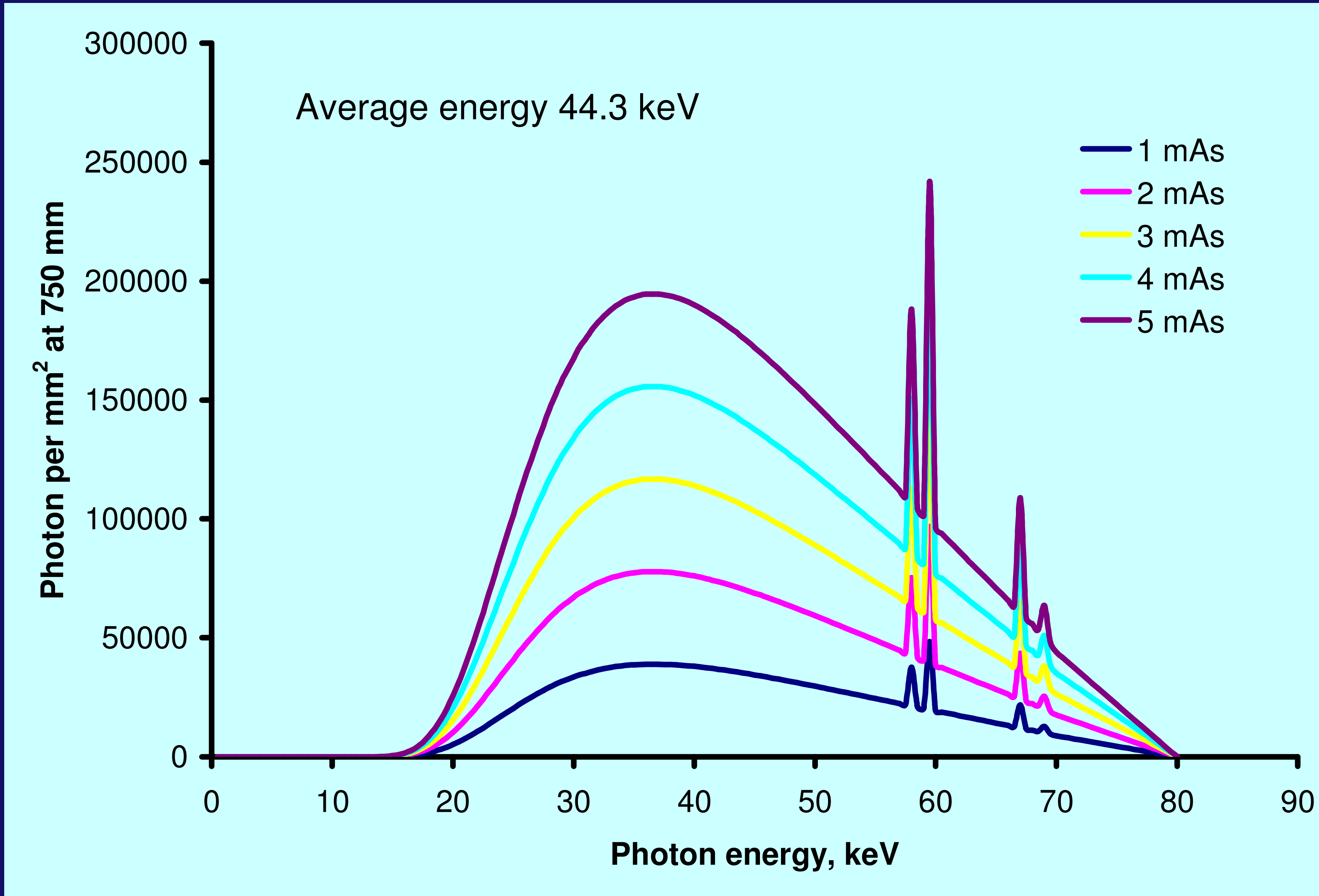
X-ray spectra at different tube voltages



X-ray spectra at different tube filtrations



X-ray spectra at different tube currents



X-ray spectra, what happens with "average photon energy (color)" and "intensity (brightness)"

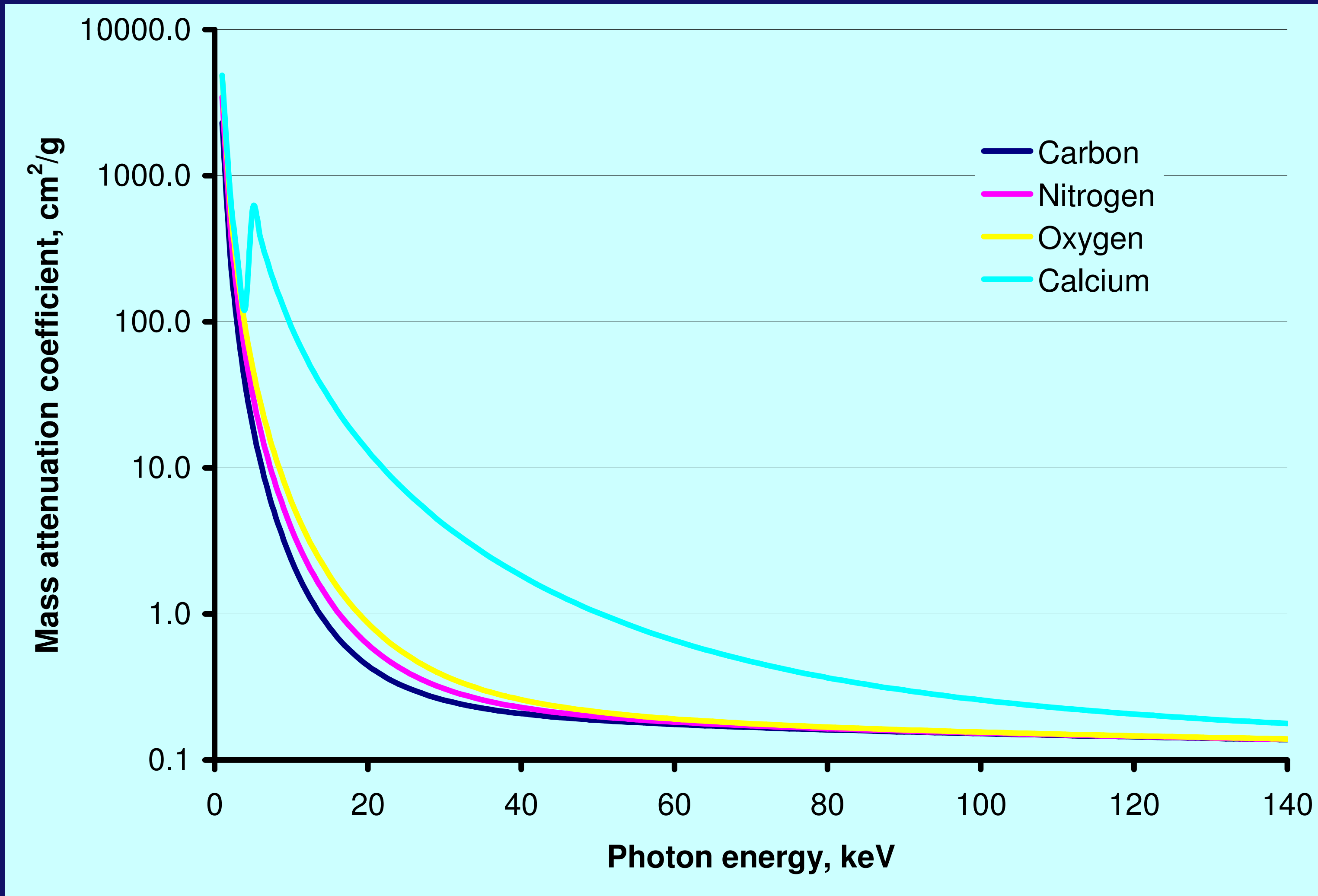
	Spectrum, average photon energy "color"	Spectrum, number photons per energy interval "brightness"
Tube voltage	↑	↑
Filtration	↑	↓
Tube current	no effect	↑

Attenuation of X-rays

- Interaction between X-rays and tissues generates an ‘X-ray shadow’
- Interaction mechanism:
  - Coherent scatter
  - Photo-electric effect
  - Compton effect
- Interaction depends on:
  - Thickness (cm)
  - Density (ρ ; g/cm^3)
  - Atomic composition (Z_{eff})

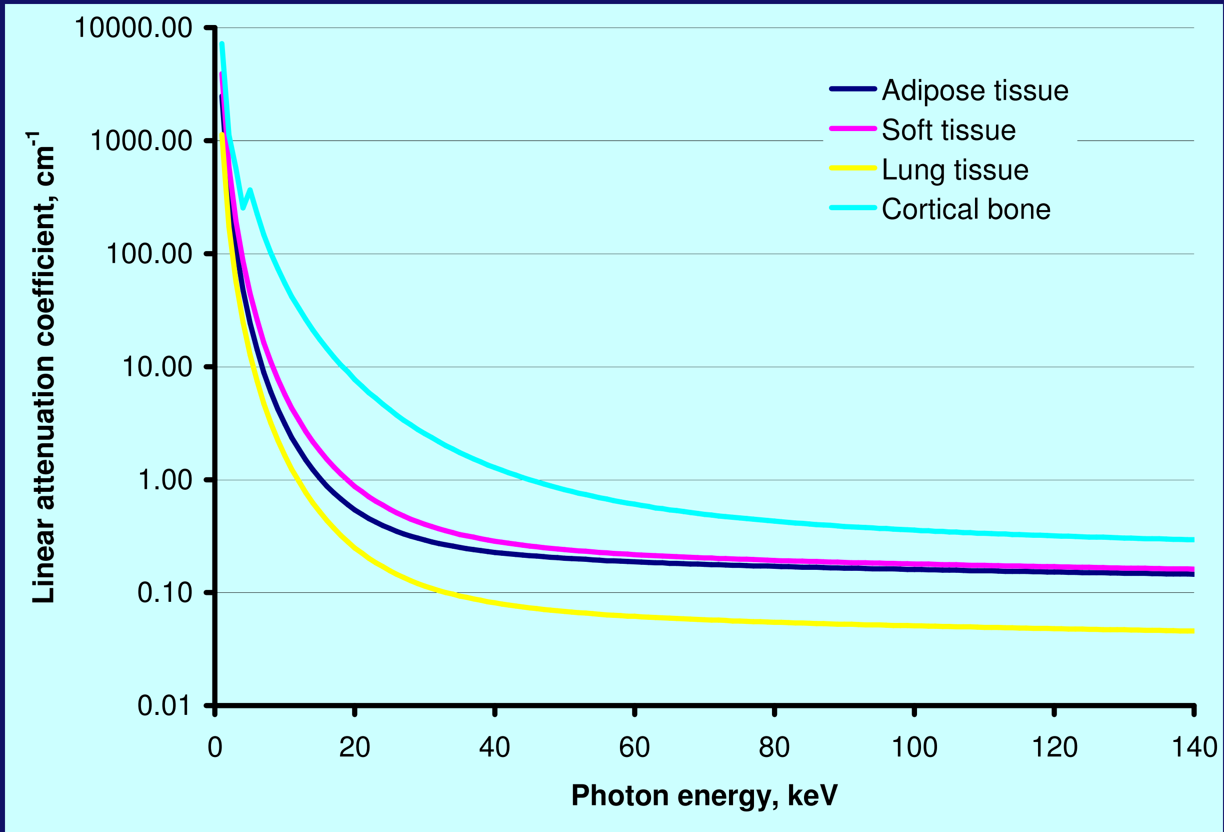
Note. Coherent scatter and compton effect generate scattered radiation

Interaction between X-rays and elements (substances)



Note: mass attenuation coefficient (μ / ρ)

Interaction between X-rays and tissues



Adipose tissue

ρ 0.95 / Z_{eff} 6.5

Soft tissue

ρ 1.06 / Z_{eff} 7.6

Lung tissue

ρ 0.30 / Z_{eff} 7.7

Bone

ρ 1.92 / Z_{eff} 11.9

Note: linear attenuation coefficient (μ) is a measure for attenuation per unit of tissue thickness: $I = e^{-\mu x}$

Note: ρ in g/cm³

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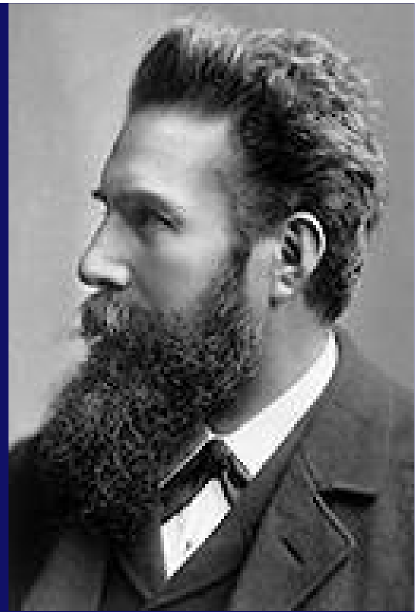

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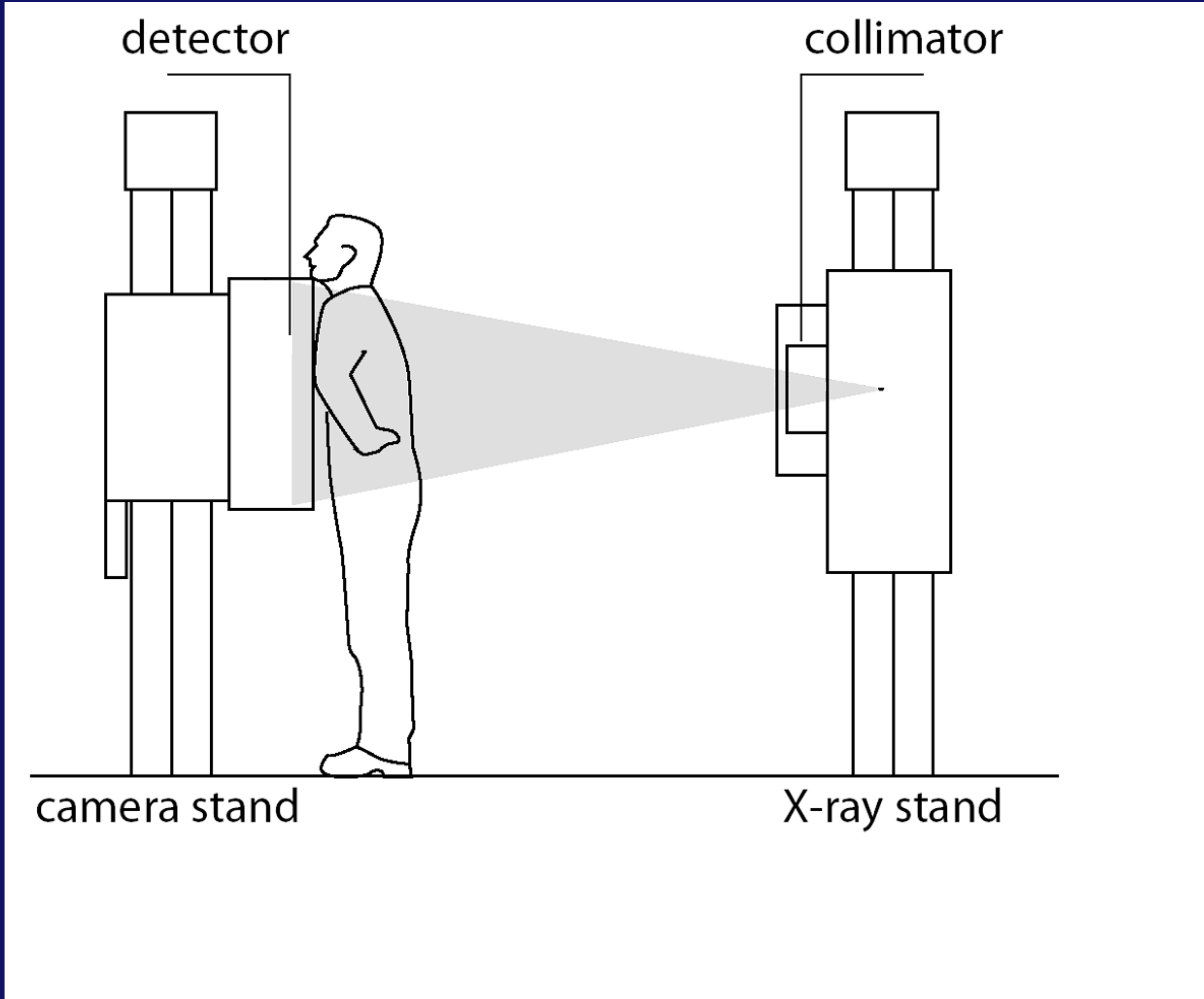
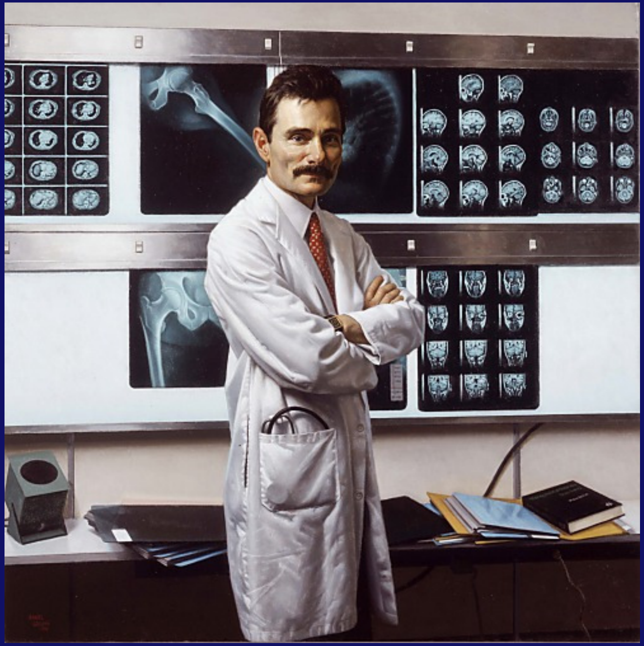
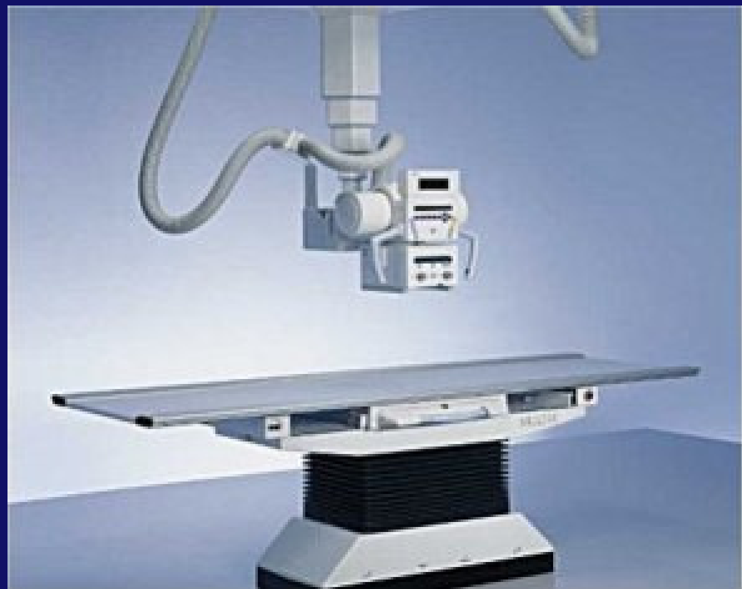
X-ray radiographs



X-ray radiographs, film-screen radiography



Digital X-ray radiography



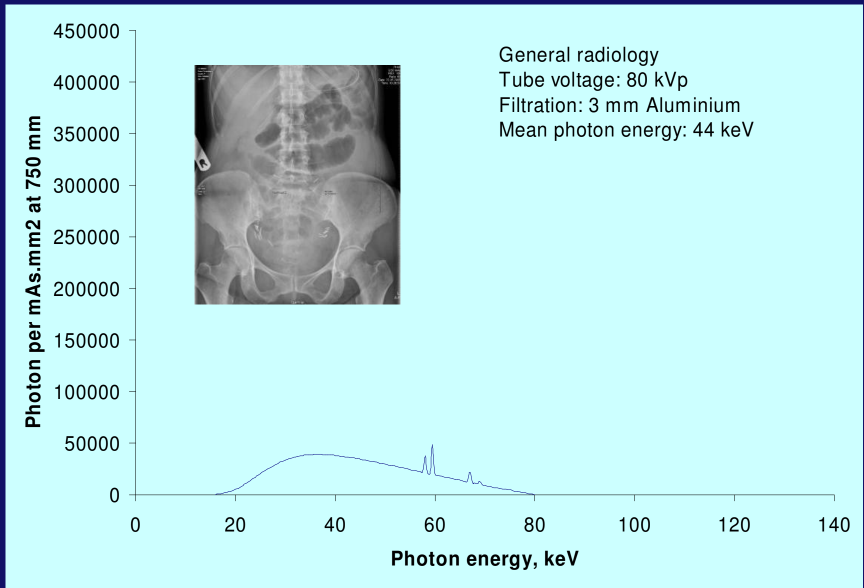
Soft-copy reading

Digital archiving and distribution

X-ray radiography

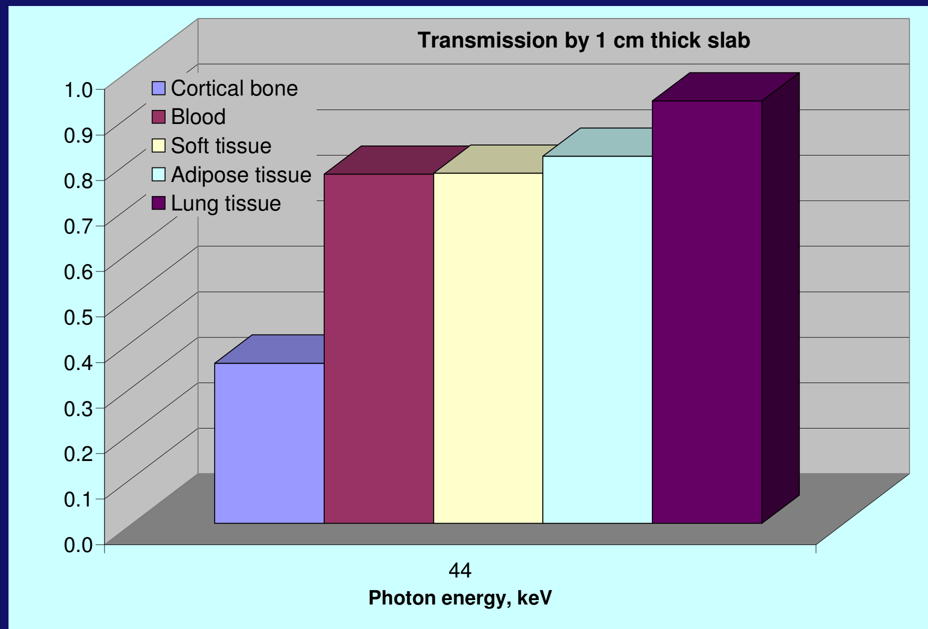
- Projection
- Static
- Tube voltage 50-90 kV

X-ray spectrum (80 kV) & transmission

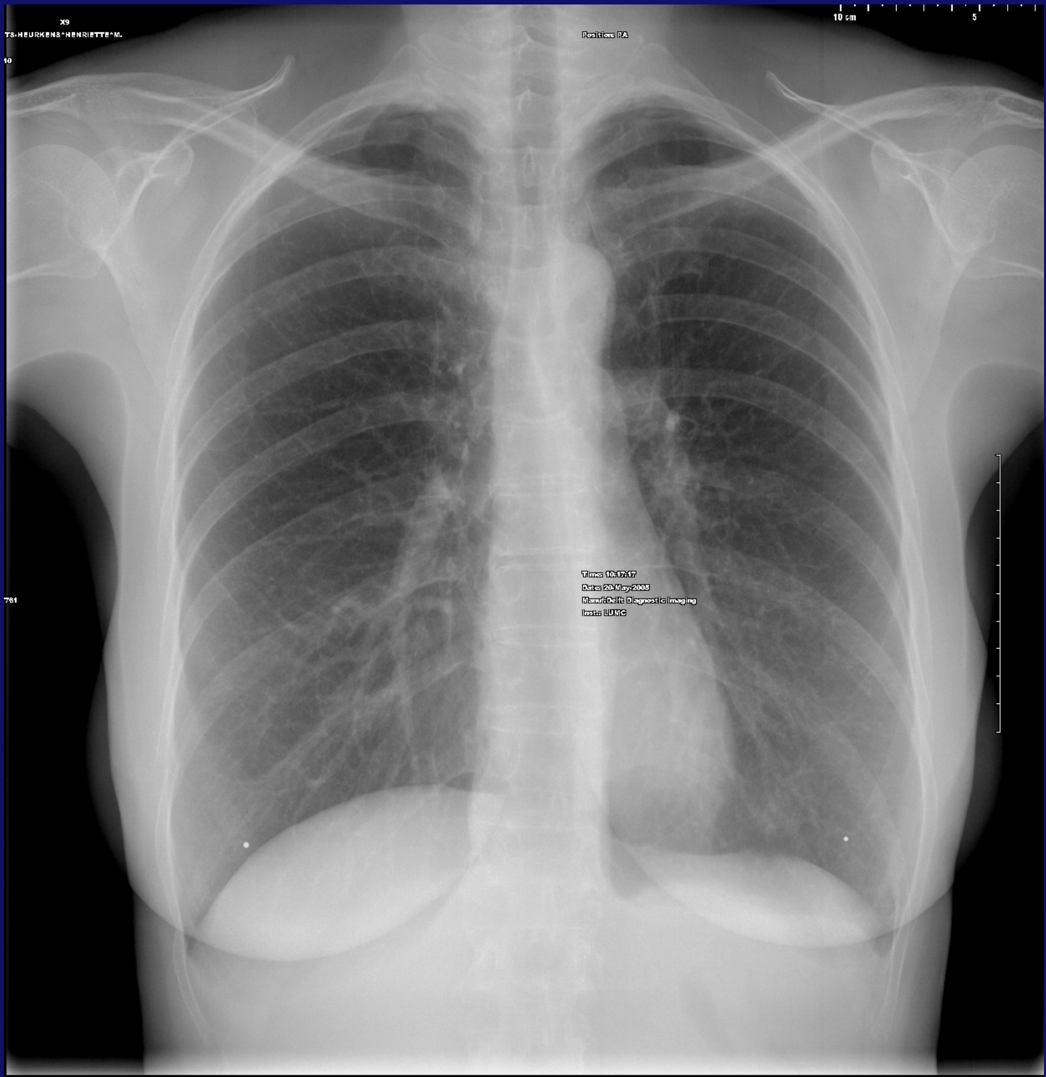


Transmission		
Low	Normal	High

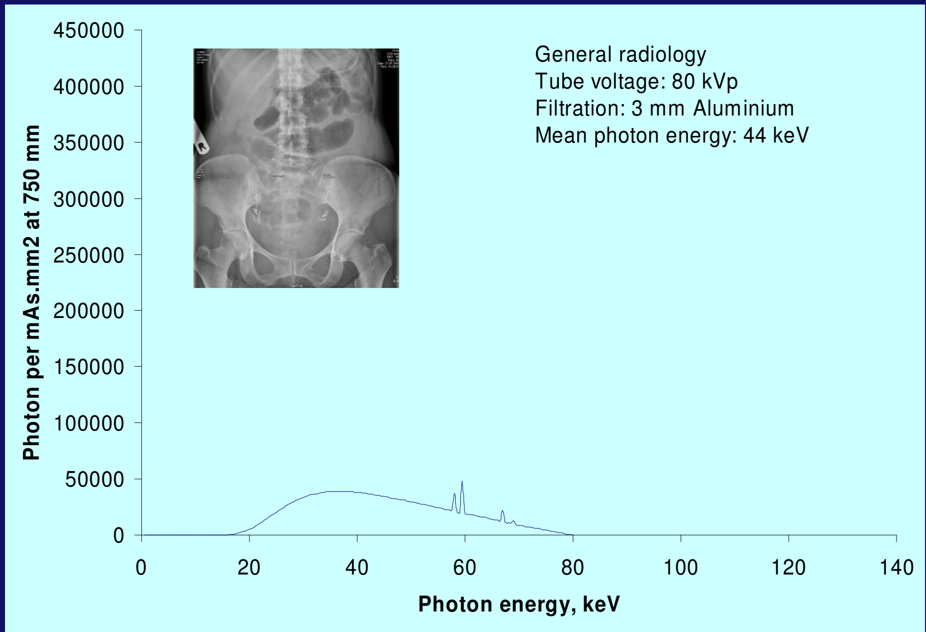
Contrast		
Low	Normal	High



Chest radiography: high tube voltage & copper filter

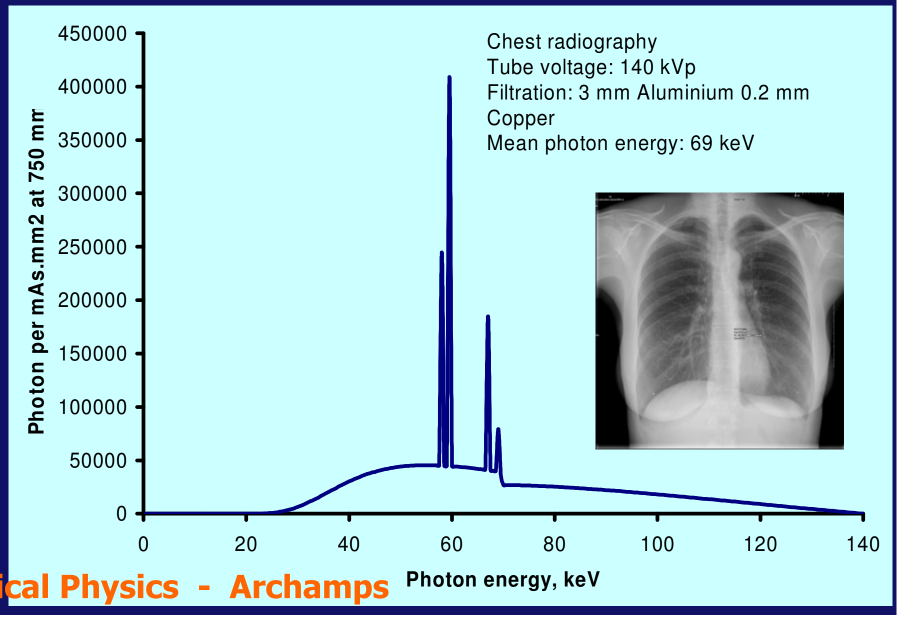


X-ray spectrum: general radiology vs chest radiology

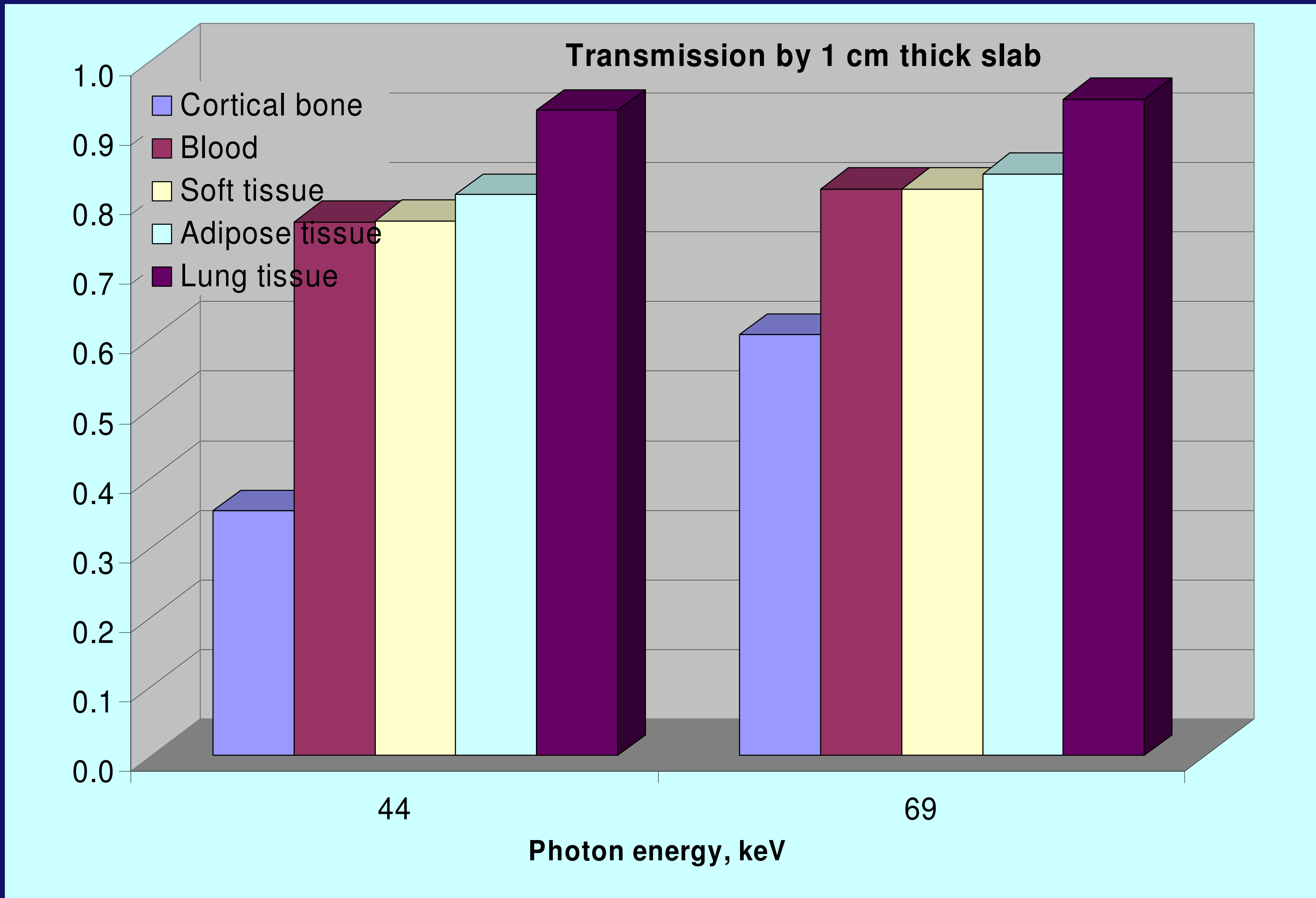


Transmission		
Low	Normal	High

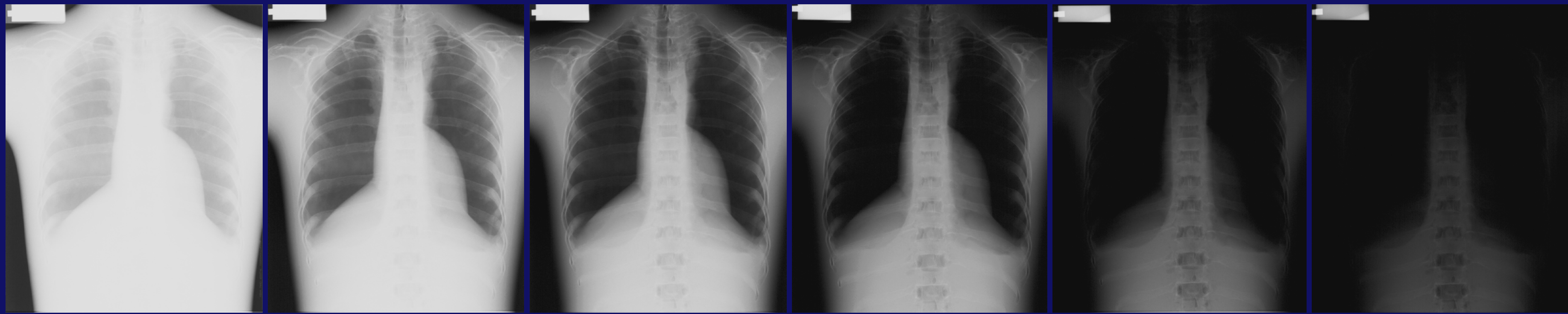
Contrast		
Low	Normal	High



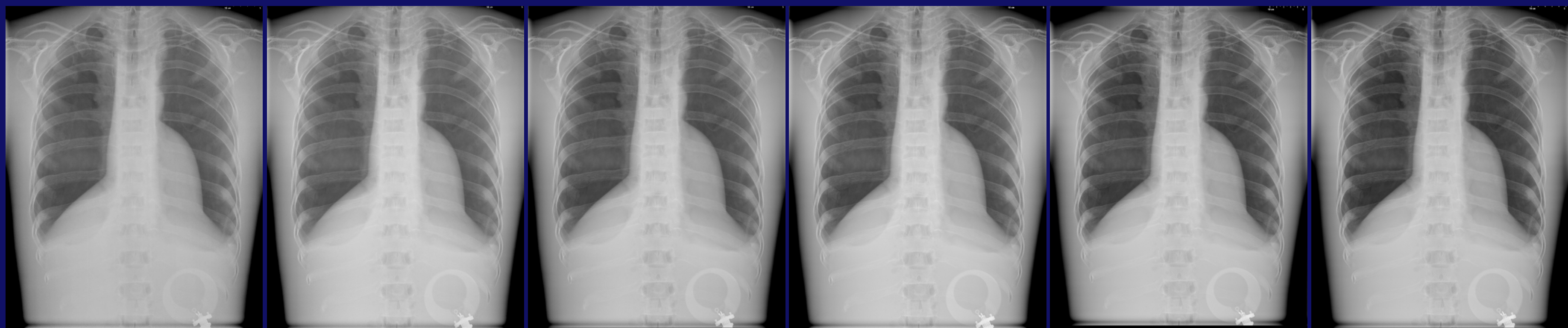
Transmission: general radiology vs chest radiology



Relative intensity (mAs)

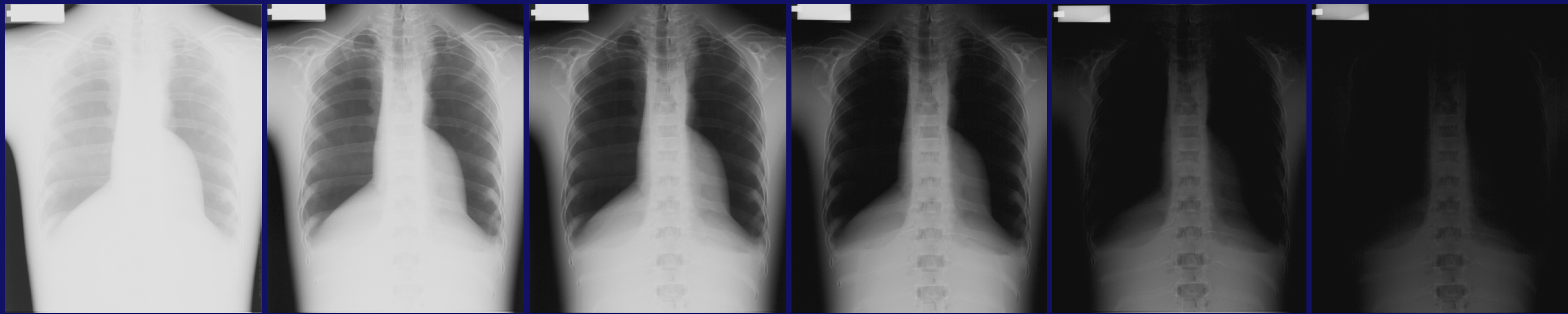


25% 50% 100% 150% 225% 300%

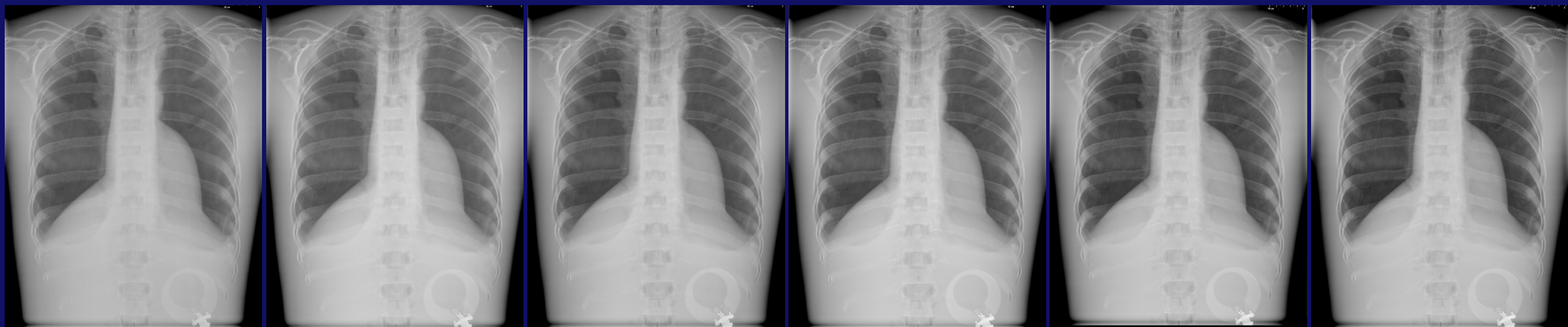


Differences in intensity (mAs)

Conventional film-screen chest radiography



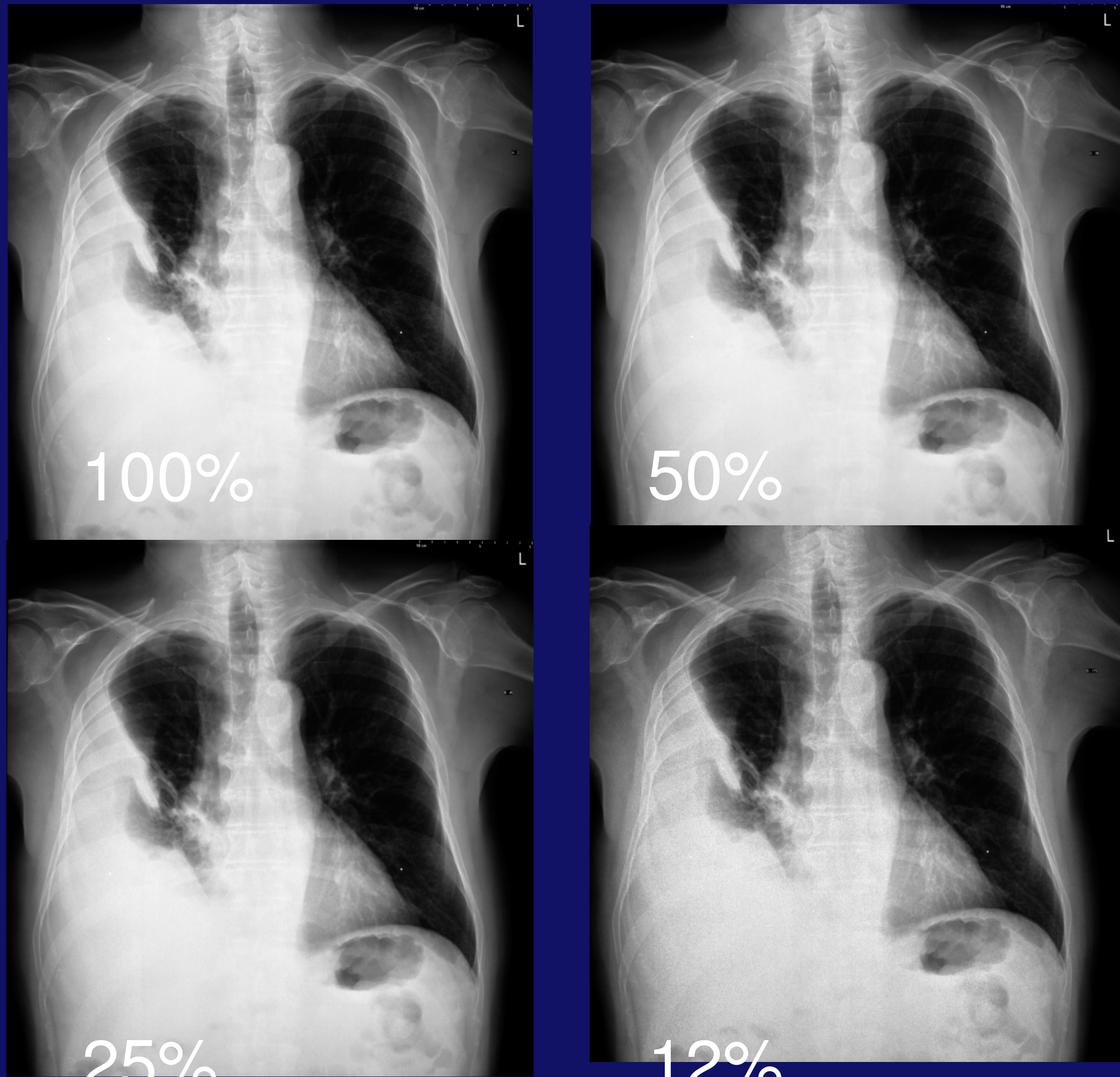
25% 50% 100% 150% 225% 300%



Digital chest radiography

Dose and image quality: digital systems "optical density" is constant

Dose-reduction and diagnosis



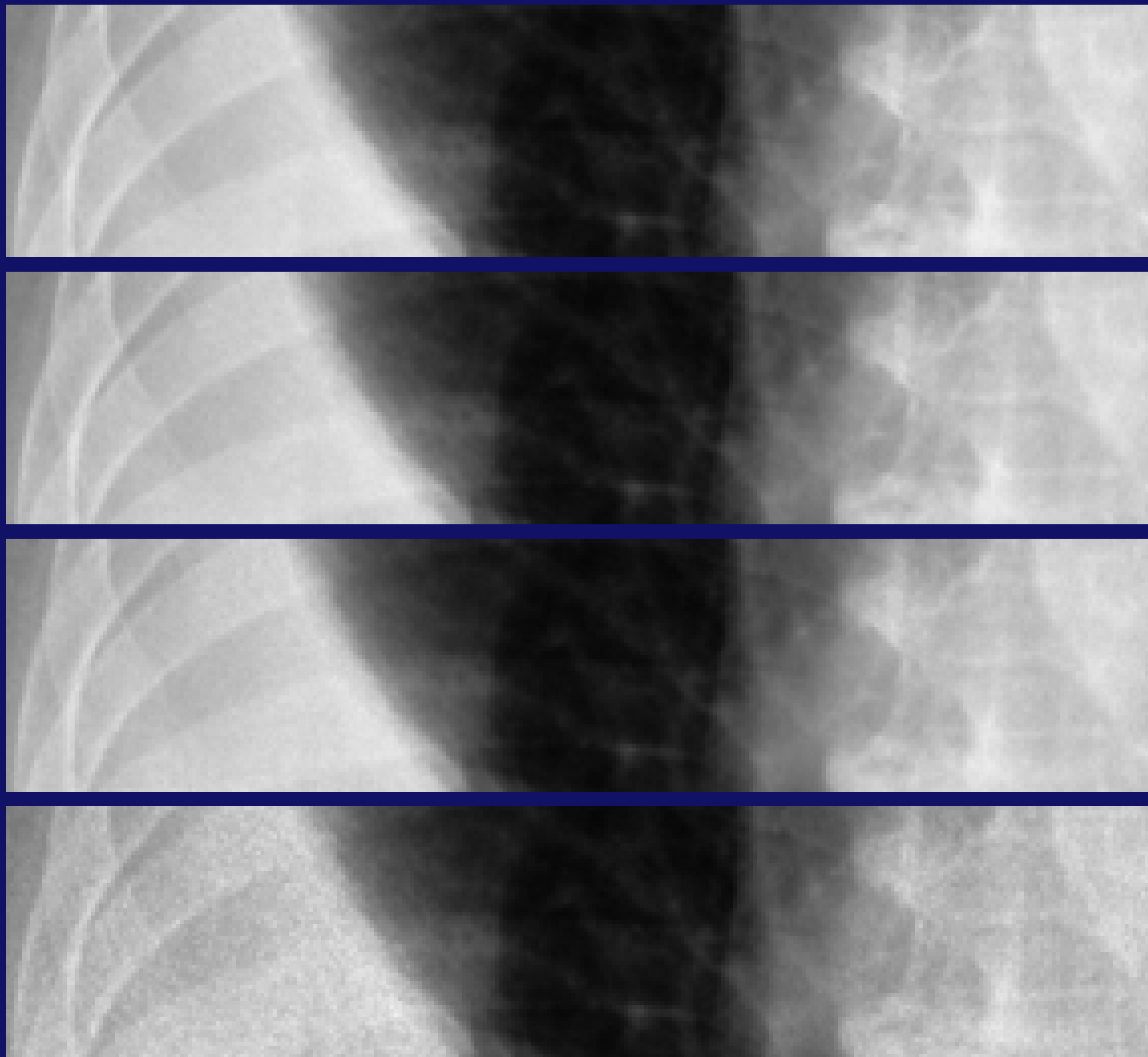
Digital: intensity (mAs) has impact on noise

100%

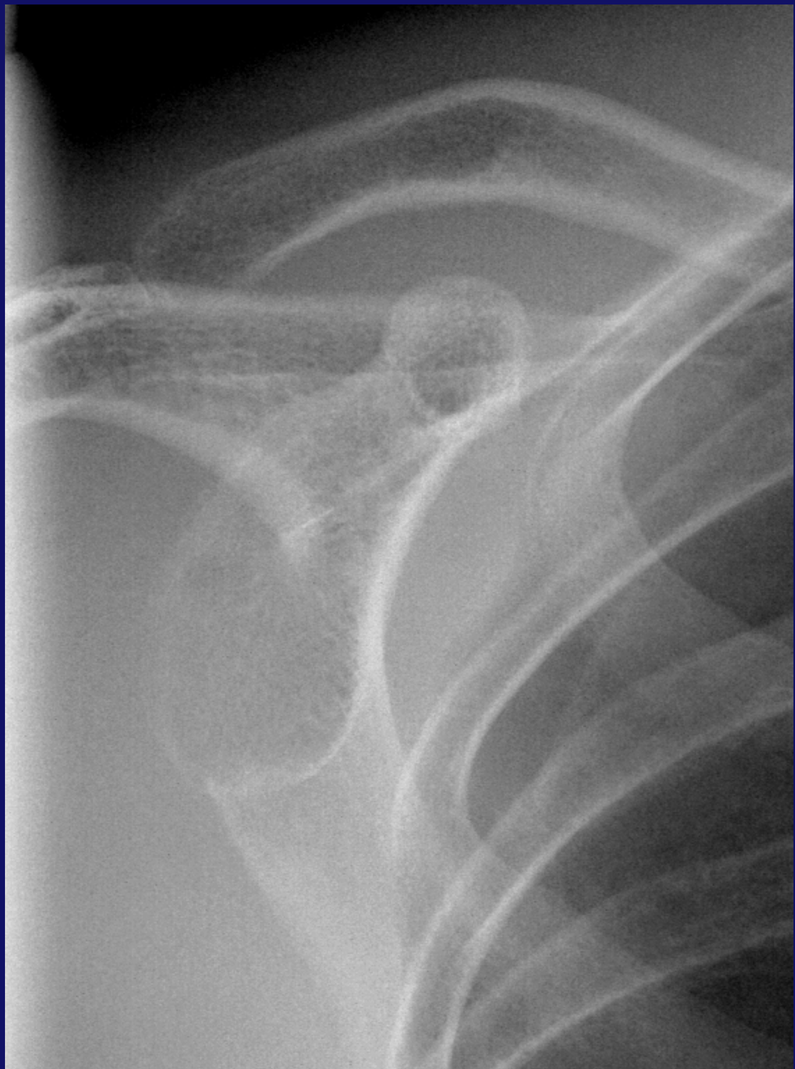
50%

25%

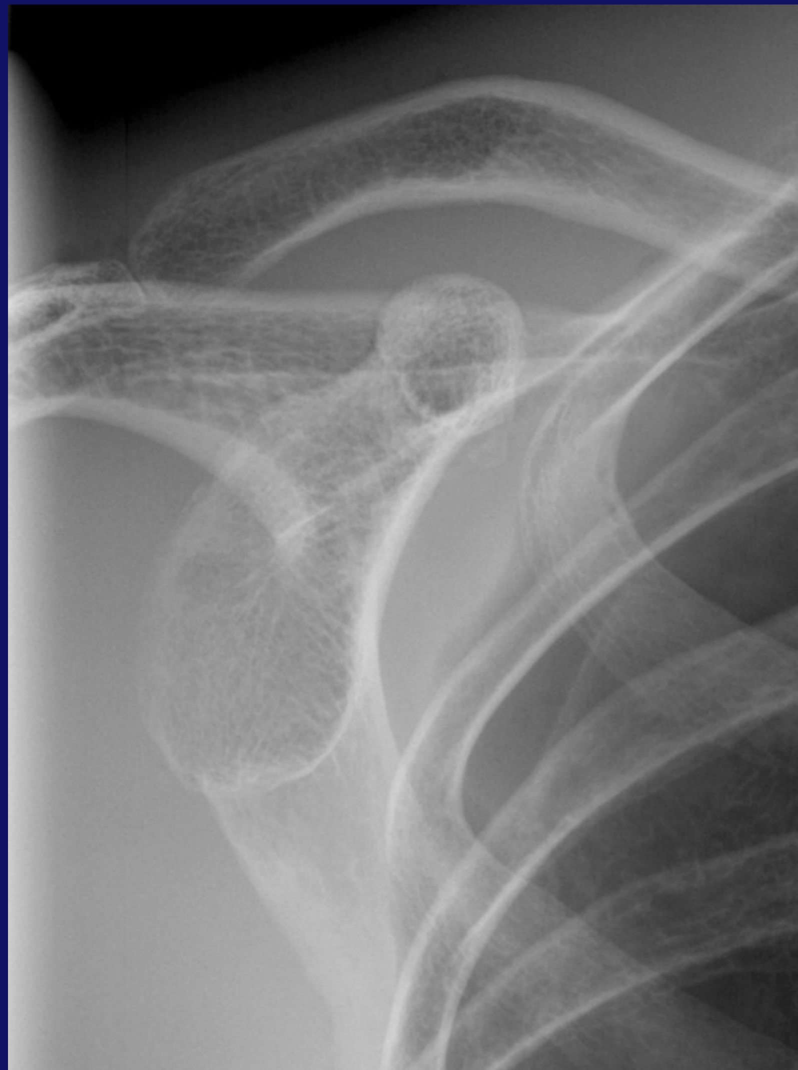
12%



Digital: intensity (mAs) has impact on noise



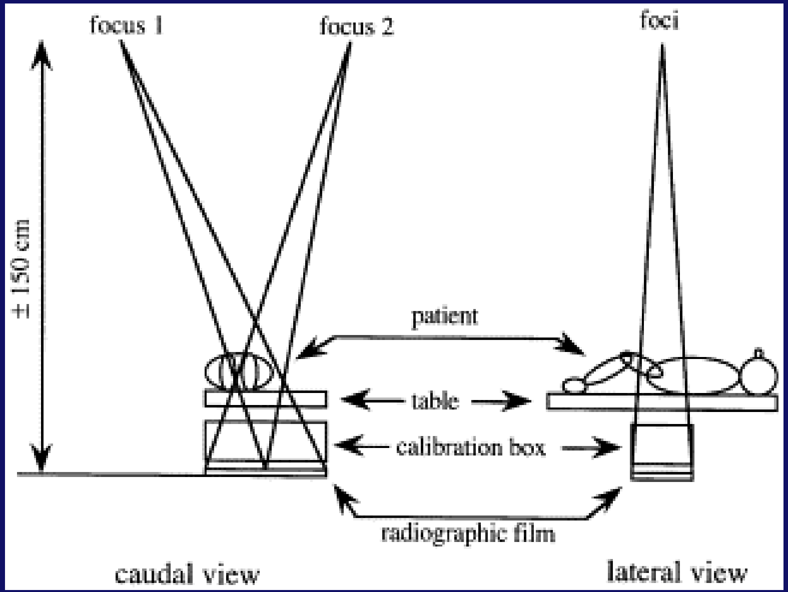
Low intensity



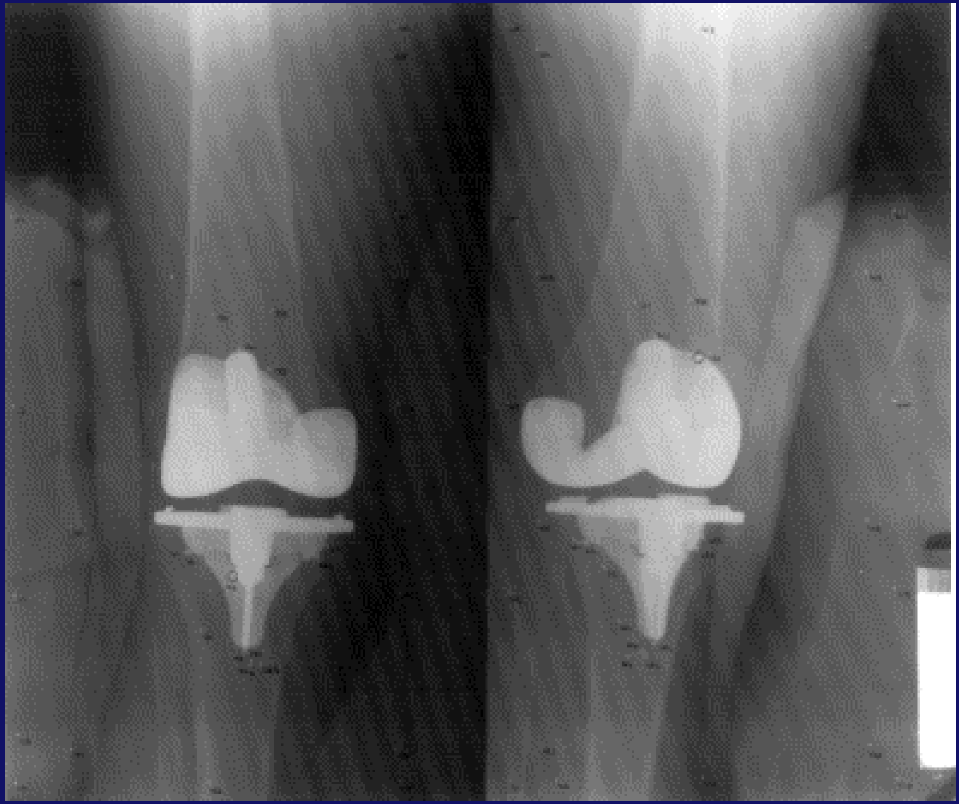
High intensity

Roentgen Stereophotogrammetric Analysis (RSA)

At the Leiden University Medical Center an RSA-based technique was developed and used to measure the micromotion of hip-, knee-, and elbow-prostheses.

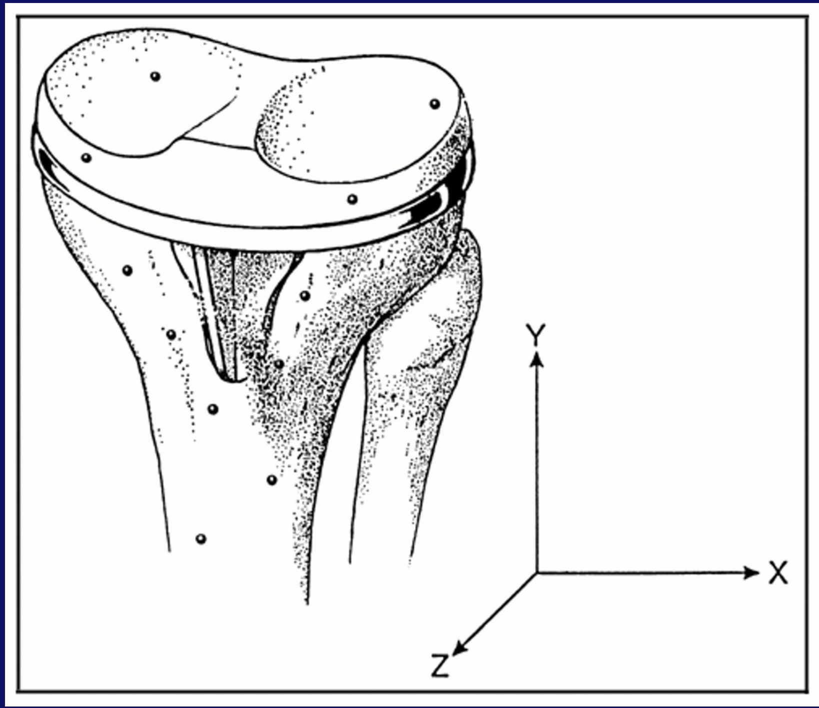


A schematic drawing of the stereo X-ray setup for the exposure of the left and right parts of the radiograph, needed for the RSA procedure. A calibration box with fiducial markers is used.

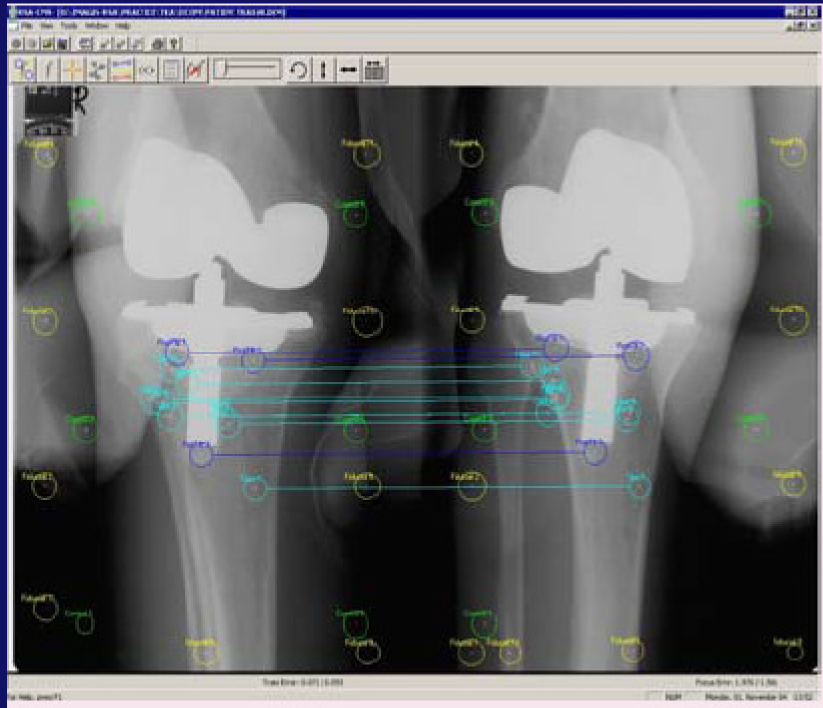


A RSA stereo-radiograph of the Interax total knee prosthesis. A large number of calibration markers, bone markers, and prosthetic markers are clearly visible in the radiograph.

Roentgen Stereophotogrammetric Analysis (RSA)



Drawing showing the general locations of the tantalum-ball markers (circles) in the left tibia and in the tibial polyethylene bearing insert.



Analyzed RSA radiograph of a knee

The maximum errors in the computed translation and rotation were 0.11 mm and 0.24°

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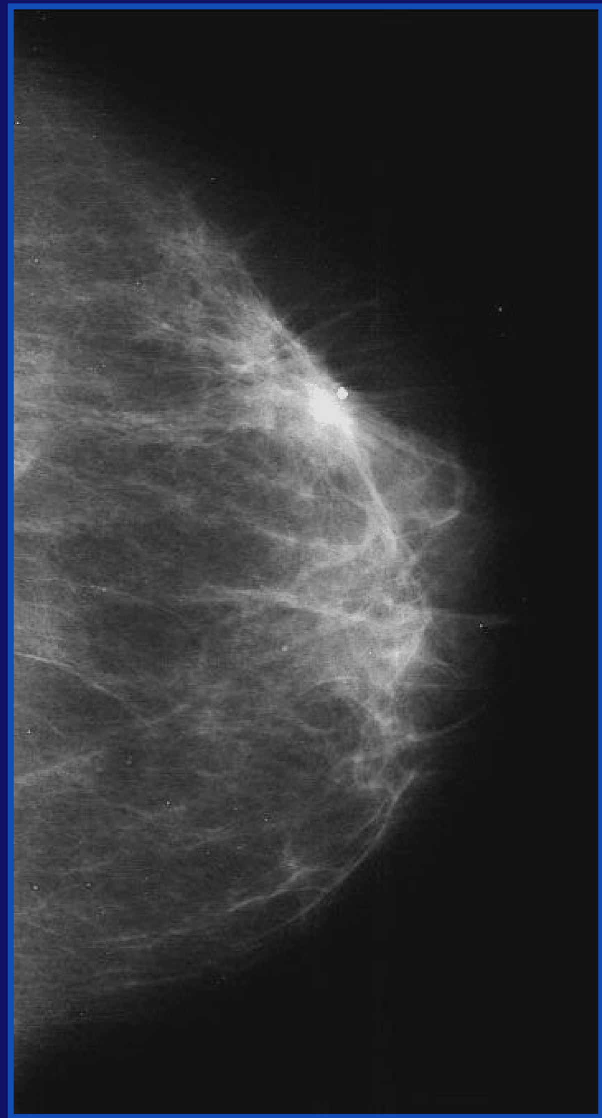
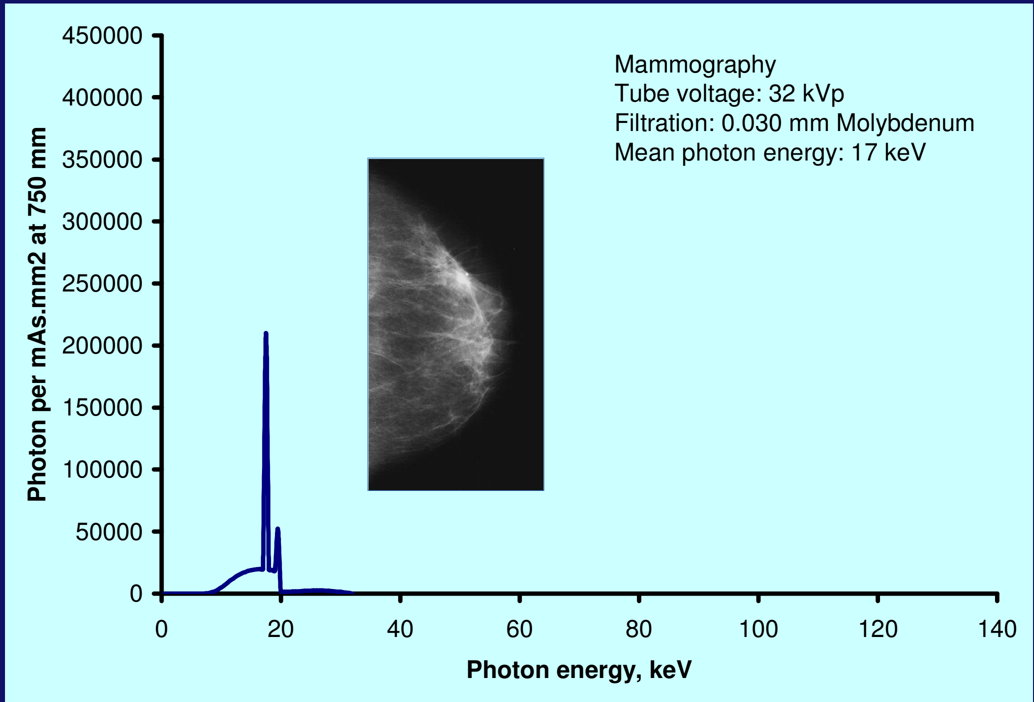
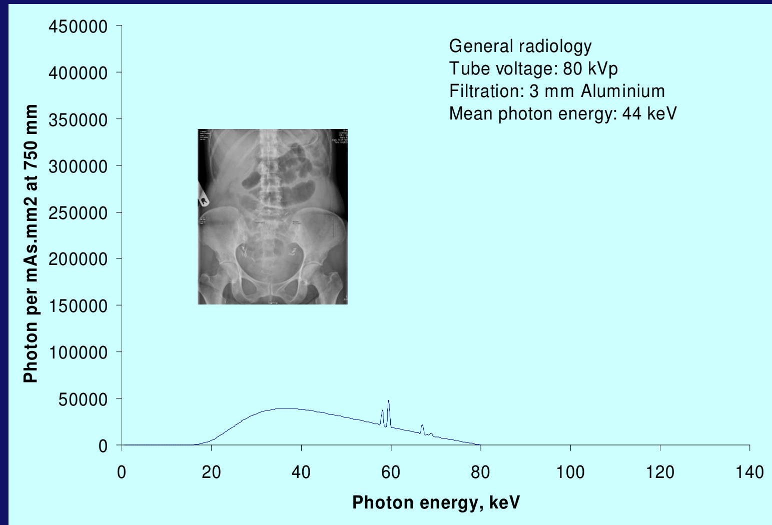
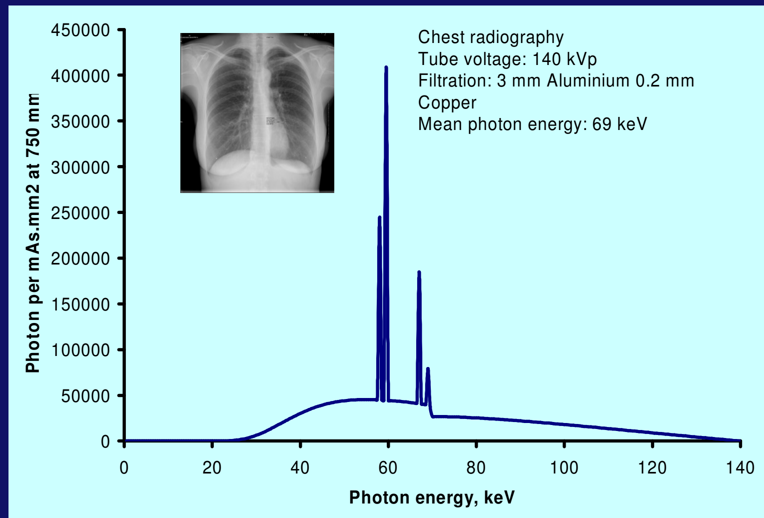


X-ray spectrum mammography: very low X-ray energy







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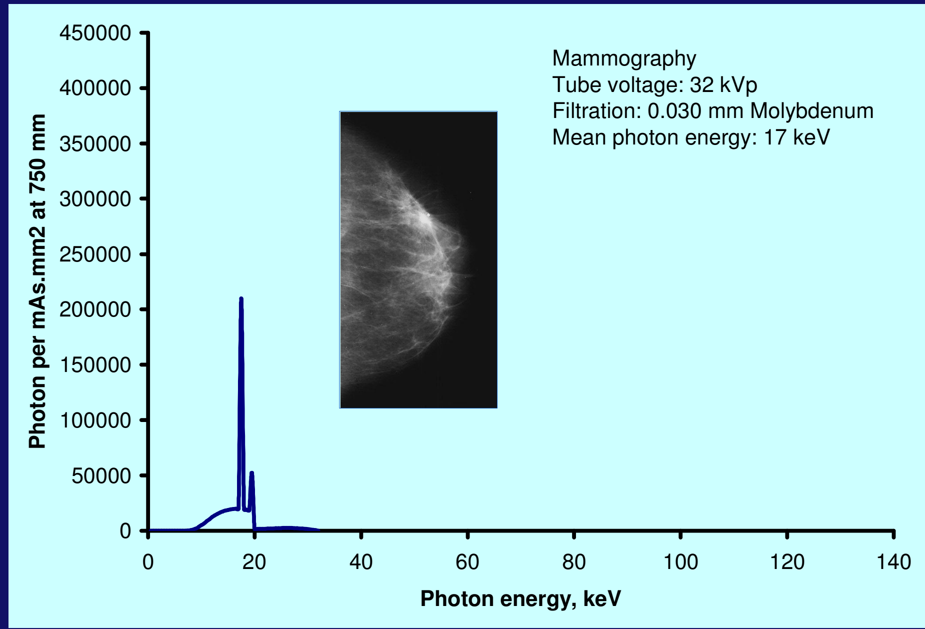
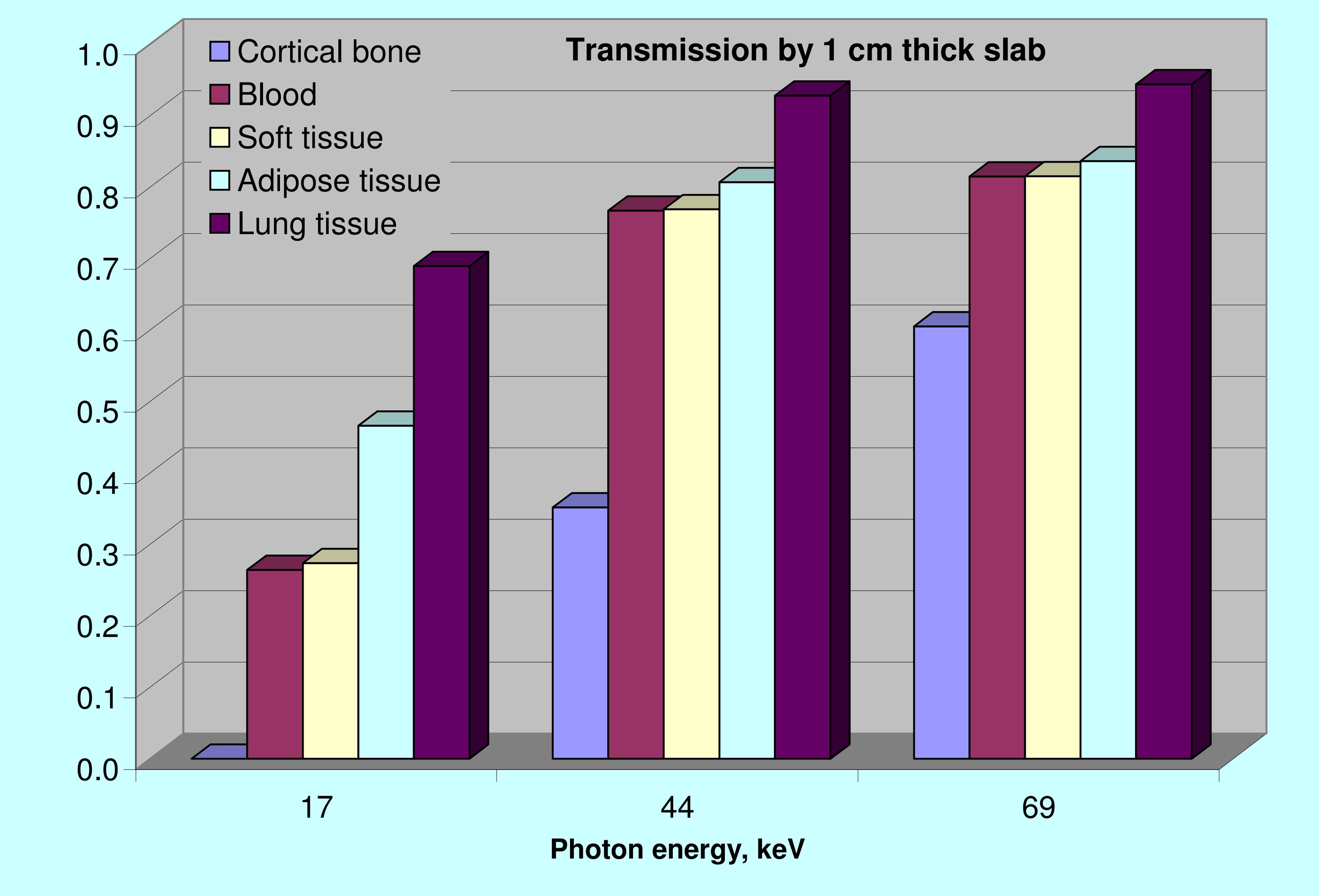


Transmission		
Low	Normal	High

Contrast		
Low	Normal	High


Transmission by 1 cm thick slab
Cortical bone
Blood
Soft tissue
Adipose tissue
Lung tissue
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
17
44
69
Photon energy, keV

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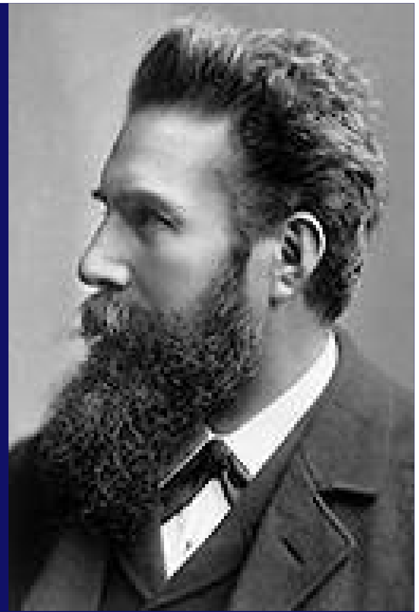

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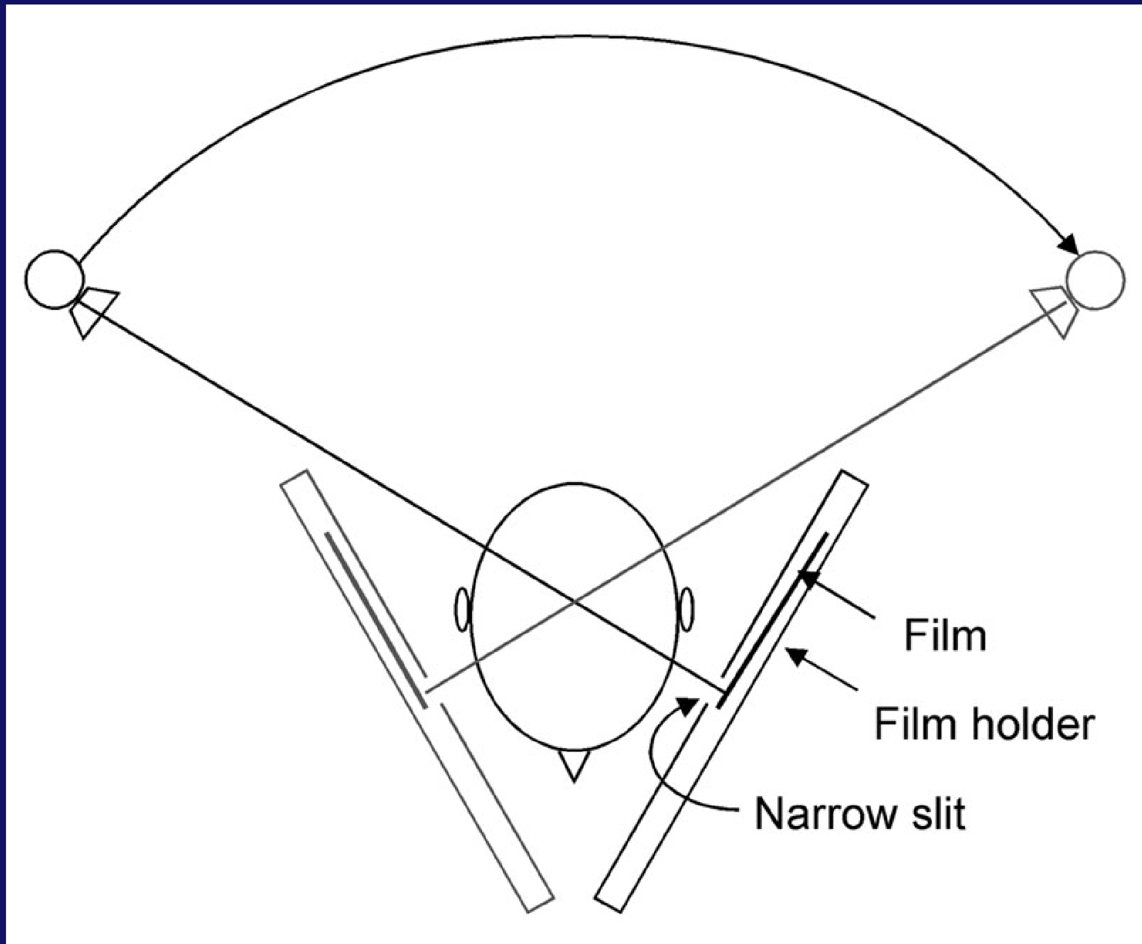
OrthoPanTomography (OPG)

About 70-80 kVp

OrthoPanTomografie (OPG): rotation, slit

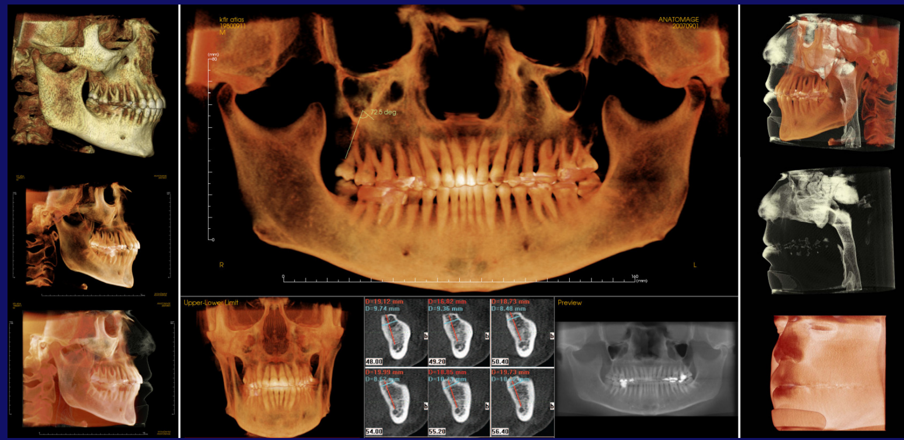


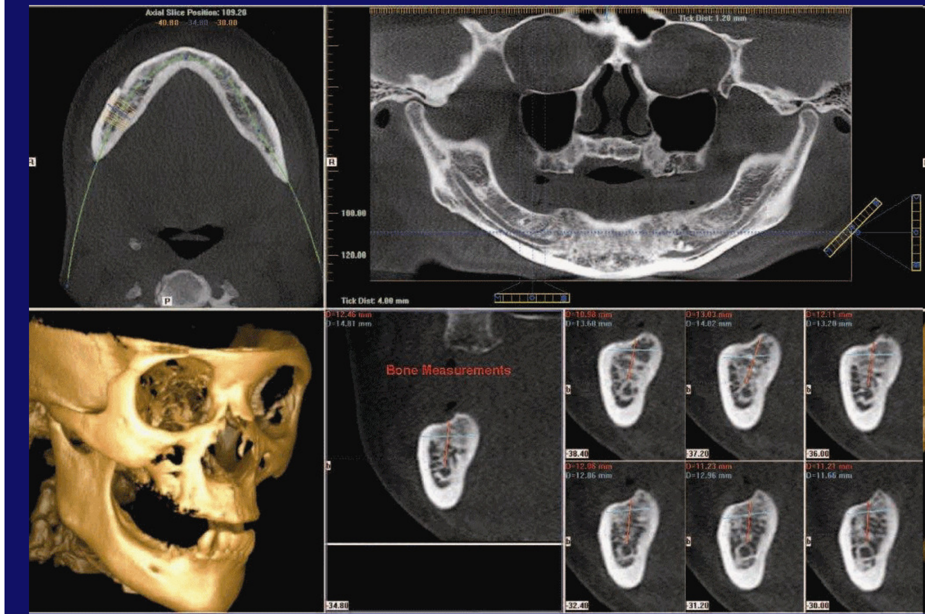
OrthoPanTomography (OPG)

PRINCIPLES AND TECHNIQUES

The basic principle of panoramic radiography is identical to conventional tomography. The X-ray tube and cassette holder are linked at a fixed distance of 50–70 cm and both rotate around the head during the exposure. The cassette moves in the same direction as the X-ray beam but at a slower speed. The correct film speed ensures that one curved plane is in focus: the image layer. Structures outside the image layer are blurred and distorted. The image layer is commonly 10–30 mm thick and includes the entire width of the jaw.

Cone-beam CT for dental applications





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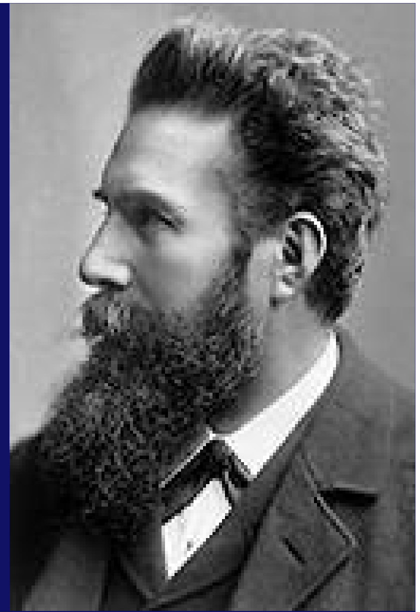

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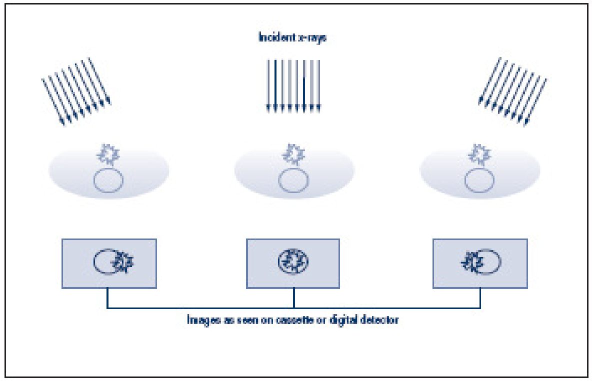
Breast tomosynthesis

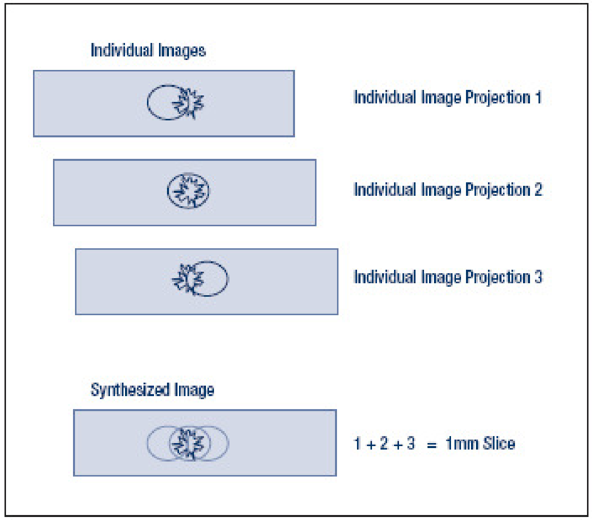
Selenia Dimensions™ Breast Tomosynthesis System*

Figure 1: Tomosynthesis Can Reduce or Eliminate Tissue Overlap



With tomosynthesis imaging, images acquired from different angles separate structures at differing heights. Conventional mammography would acquire only the central image

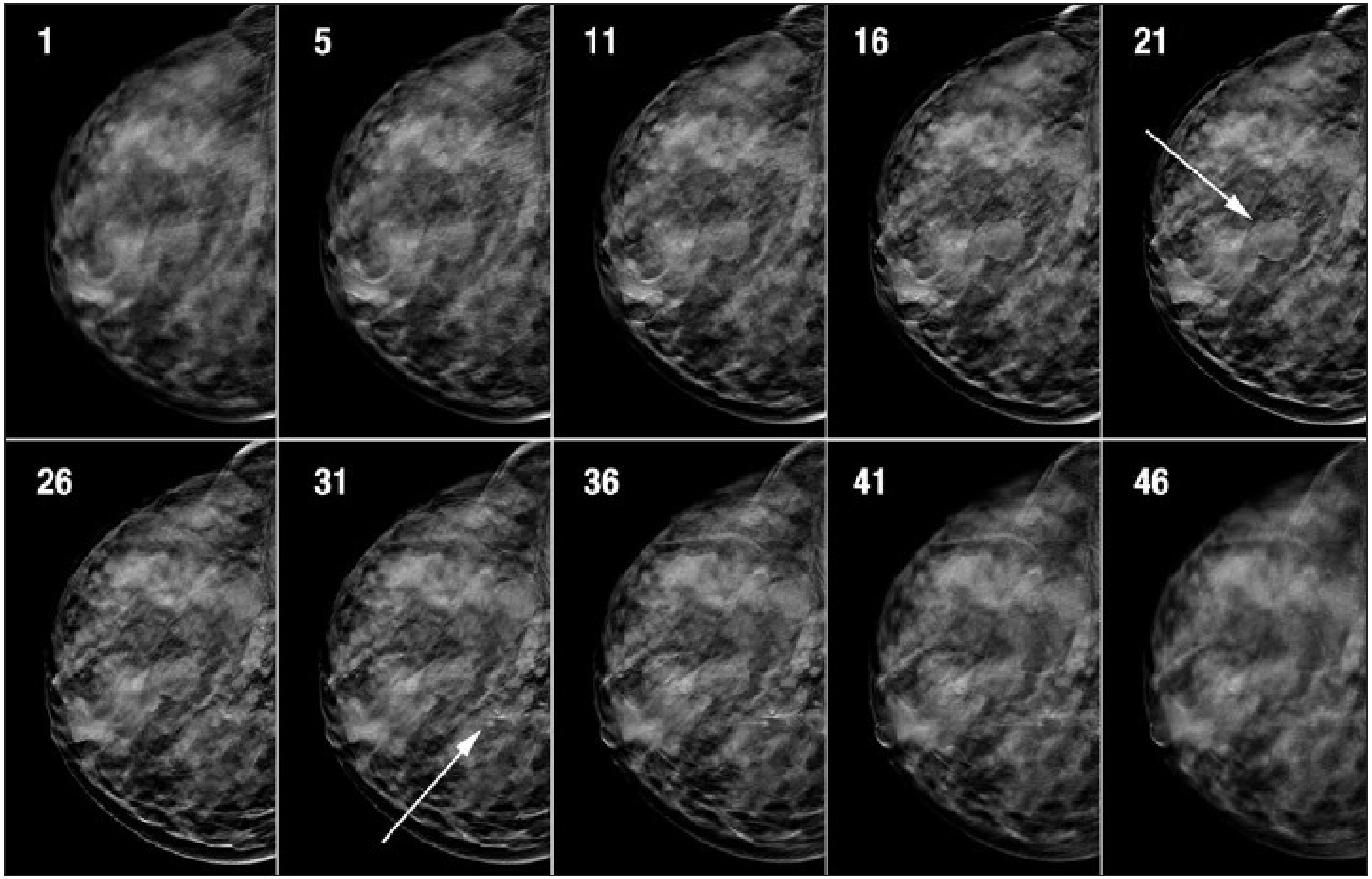
Figure 2: Tomosynthesis Enhances Objects at a Given Height



By shifting and adding the acquired projections, 3-D imaging increases the visibility of objects by blurring out objects from other heights

Breast tomosynthesis

Figure 5: Reconstructed Tomosynthesis Slices



Reconstructed tomosynthesis slices through the breast from breast platform up to compression paddle reveal objects lying at differing heights in the breast, such as cysts and calcifications shown by arrows