



Quantitative radiology

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LETI ANNUAL REVIEW

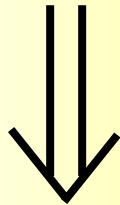
25 & 26 June 2002

Alpexpo - Grenoble France

MEDICAL IMAGING SESSION



- Digital radiographic detectors (Amorphous Silicon plates) designed to replace X-ray (analog) film in the near future
- Specific advantages of digital detectors VS film :
 - Linearity and dynamic
 - Reproducibility
 - Direct digital information and fast reading



Digital signal and image processing

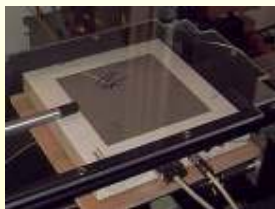
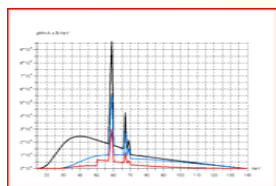
from qualitative information to quantitative information in radiology



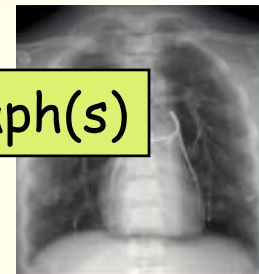
- Quantitative radiology : our approach
- Example of application : dual energy for bone densitometry and chest radiology
- Example of application : mammography
- Conclusion and future trends



Quantitative digital radiography approach



Raw digital radiograph(s)



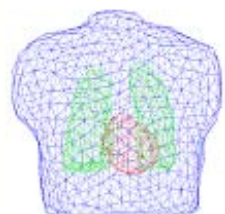
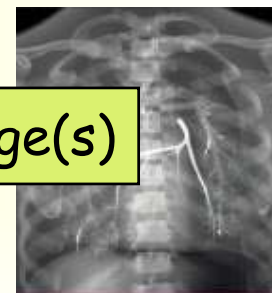
Acquisition
system
characteristics

Direct model
of radiograph
formation
process

Direct model
inversion



"Quantitative" image(s)



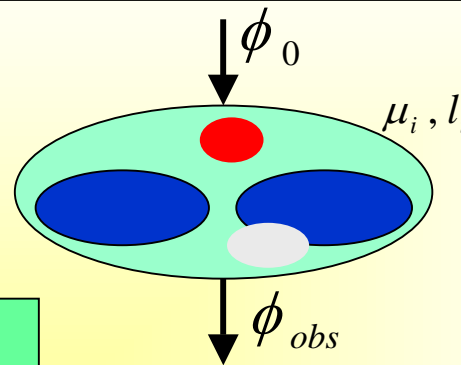
A priori on
observed object

$$\begin{cases} mes_L \approx \tau_b^L \cdot M_b + \tau_{st}^L \cdot M_{st} \\ mes_H \approx \tau_b^H \cdot M_b + \tau_{st}^H \cdot M_{st} \end{cases}$$

X-ray attenuation law :

$$\phi_{obs} = \phi_0 e^{-\sum_i \mu_i l_i}$$

Model



Acquisition (s)

A priori information
on the object, on the
acquisition device, ...

Quantitative parameters

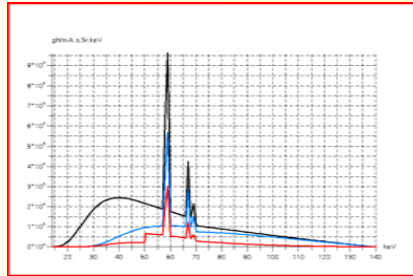
- μ_i : linear attenuation of material i
- l_i : thickness of material i
- ρ_i : density of material i
- Z_i : atomic number of material i



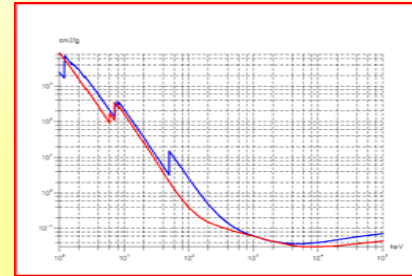
- Number of equations and number of unknowns
 - Large number of unknowns with a limited number of equations
- Technological limitations
 - Detector : linearity, S/N ratio, ...
 - X-ray source : stability of the X-ray flux
- Model limitations
 - Beam hardening
 - Scatter (at 100 keV, it can represent 4 times the direct flux)



- Polychromaticity and beam hardening

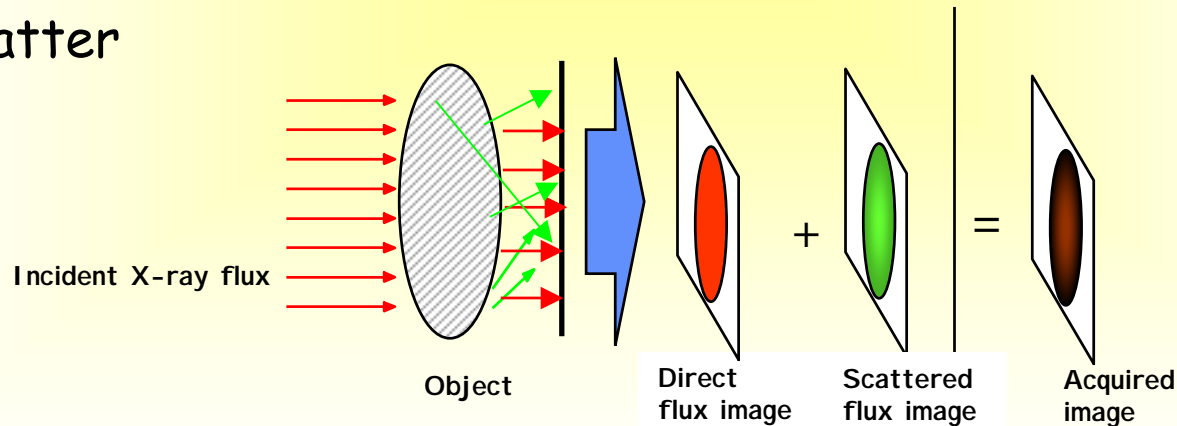


X-ray source spectra



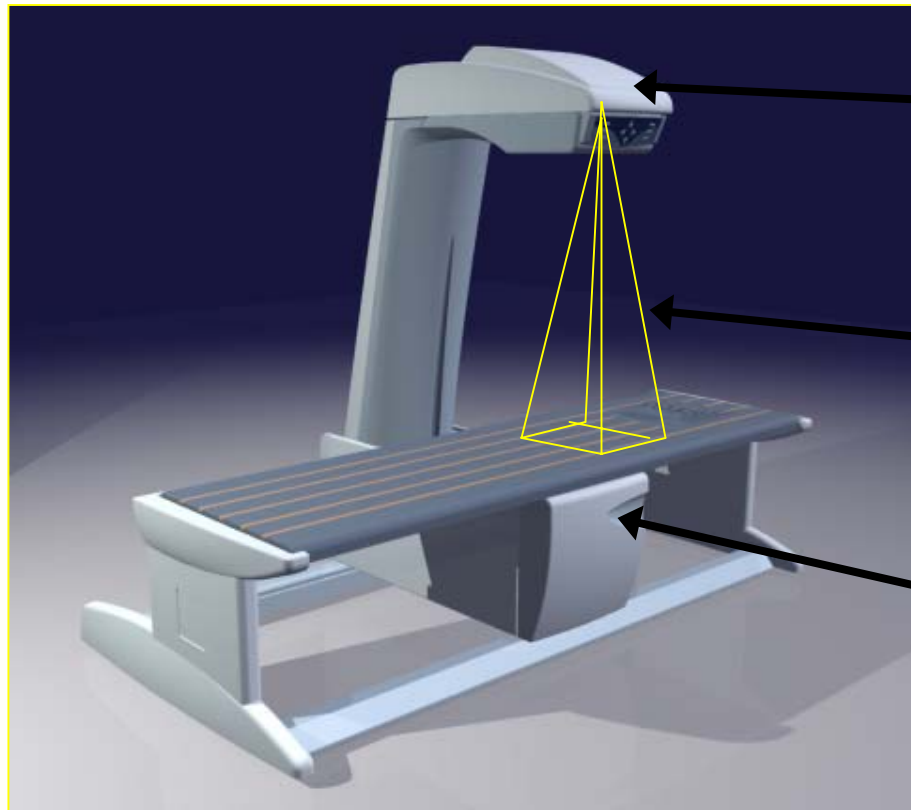
Linear attenuation of one material

- Scatter





Bone Densitometry using a digital flat panel



Pulsed X-ray generator

Cone-beam geometry

Digital flat detector

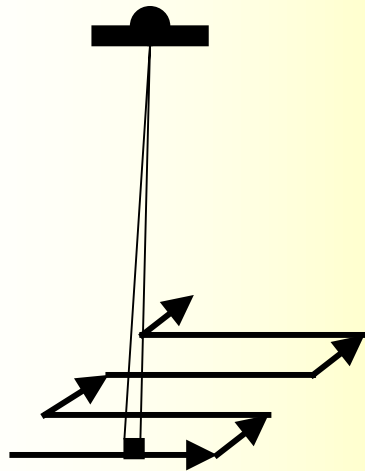
Lexxos system
from DMS

- Fast acquisition time : less than 1,5 s
- Quasi radiographic images : an open gate to a *new osteoporosis diagnosis*



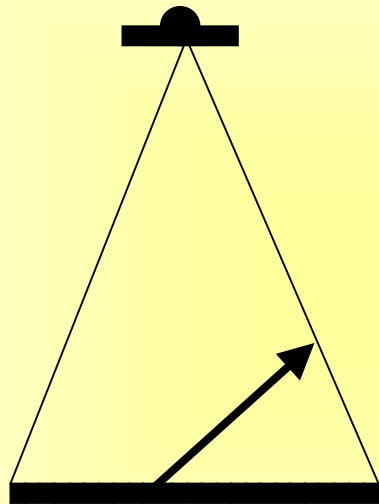
Scatter management in bone densitometry

Pencil beam



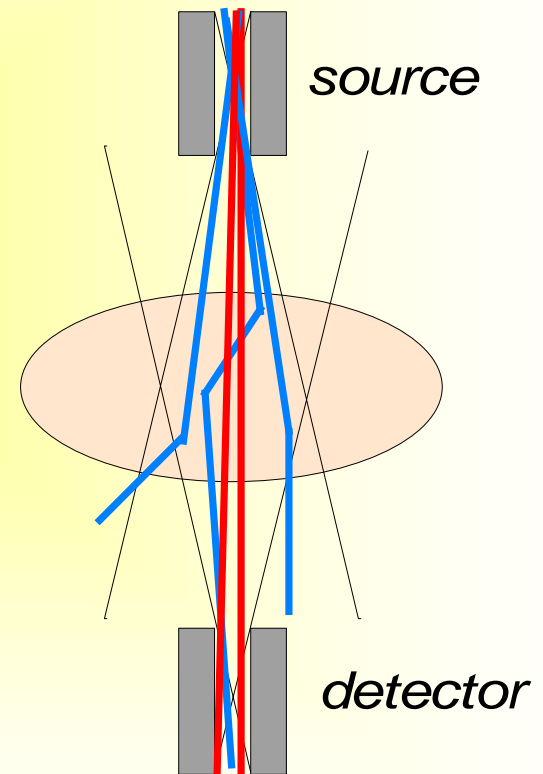
Lunar IQ
Norland XZ
Hologic 1000
DMS Challenger

Fan beam



Lunar Expert
Hologic 2000-4500W

Pencil- and fan-beam geometries reduce scatter from the patient by using collimation :



Bone Densitometry acquisition geometries

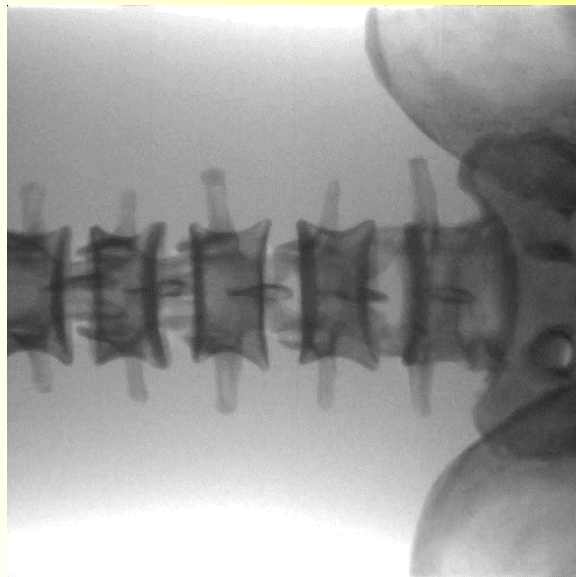


- Method relying on the use of an analytical model of scatter
- This model expresses scatter as a function of the acquired flux :

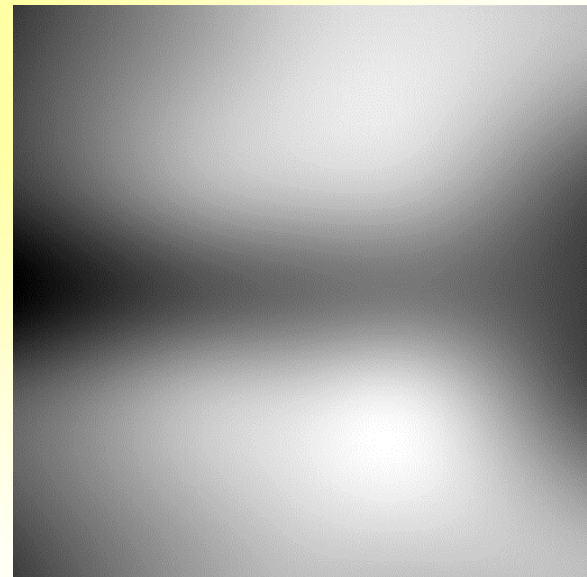
$$\phi_{total} = \phi_{direct} + F(\phi_{direct})$$

(equation solved by a fixed point algorithm)

acquisition

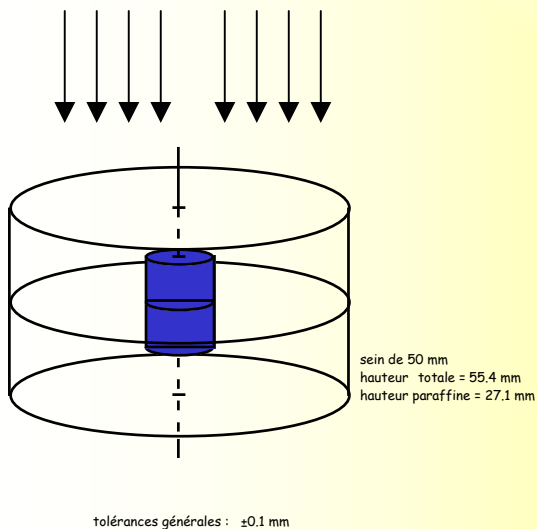


scatter

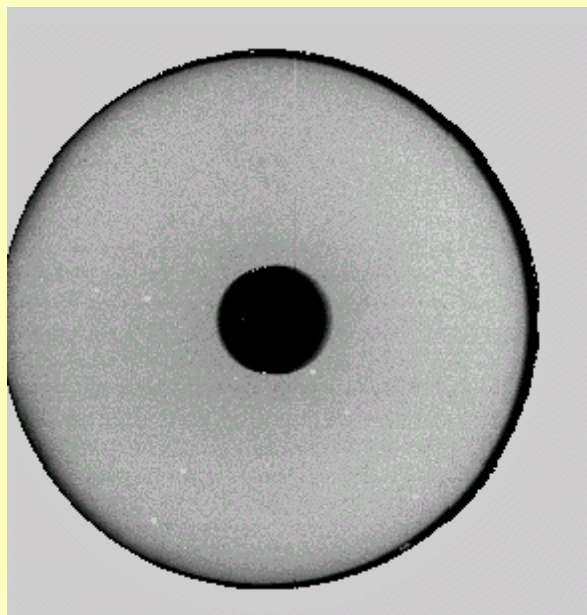




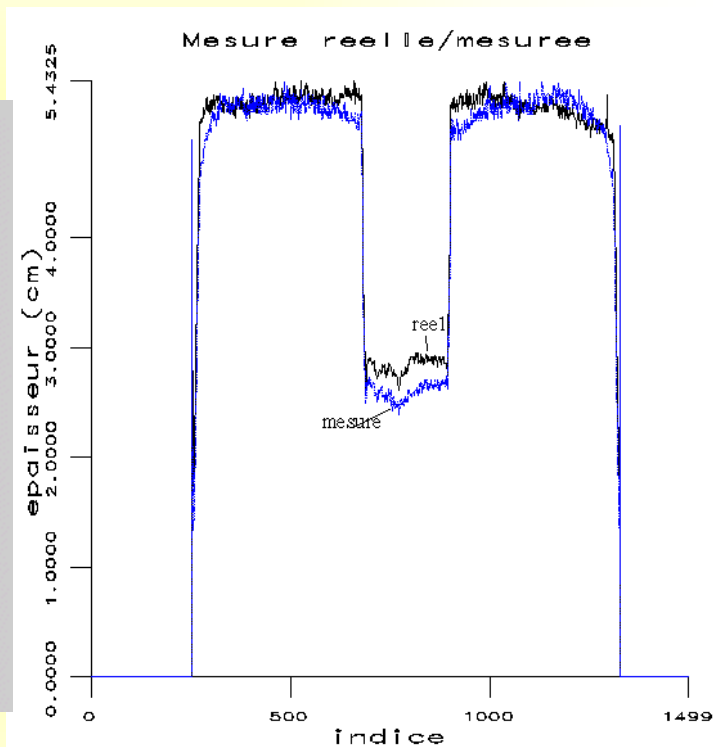
X-rays flux



Cylindrical object
(Plexiglas with paraffin)



Scatter corrected image



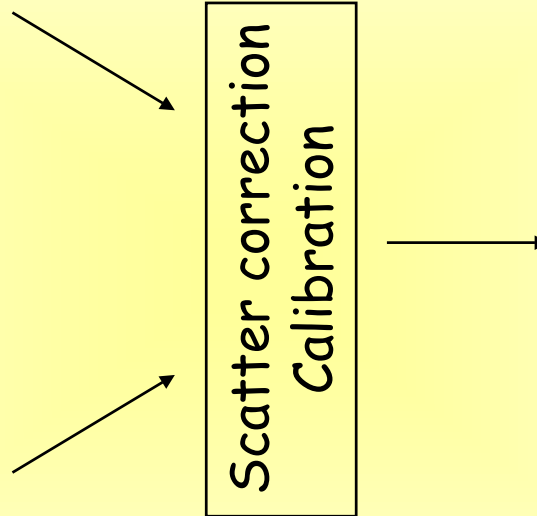


Bone densitometry results : spine

LE Acquisition



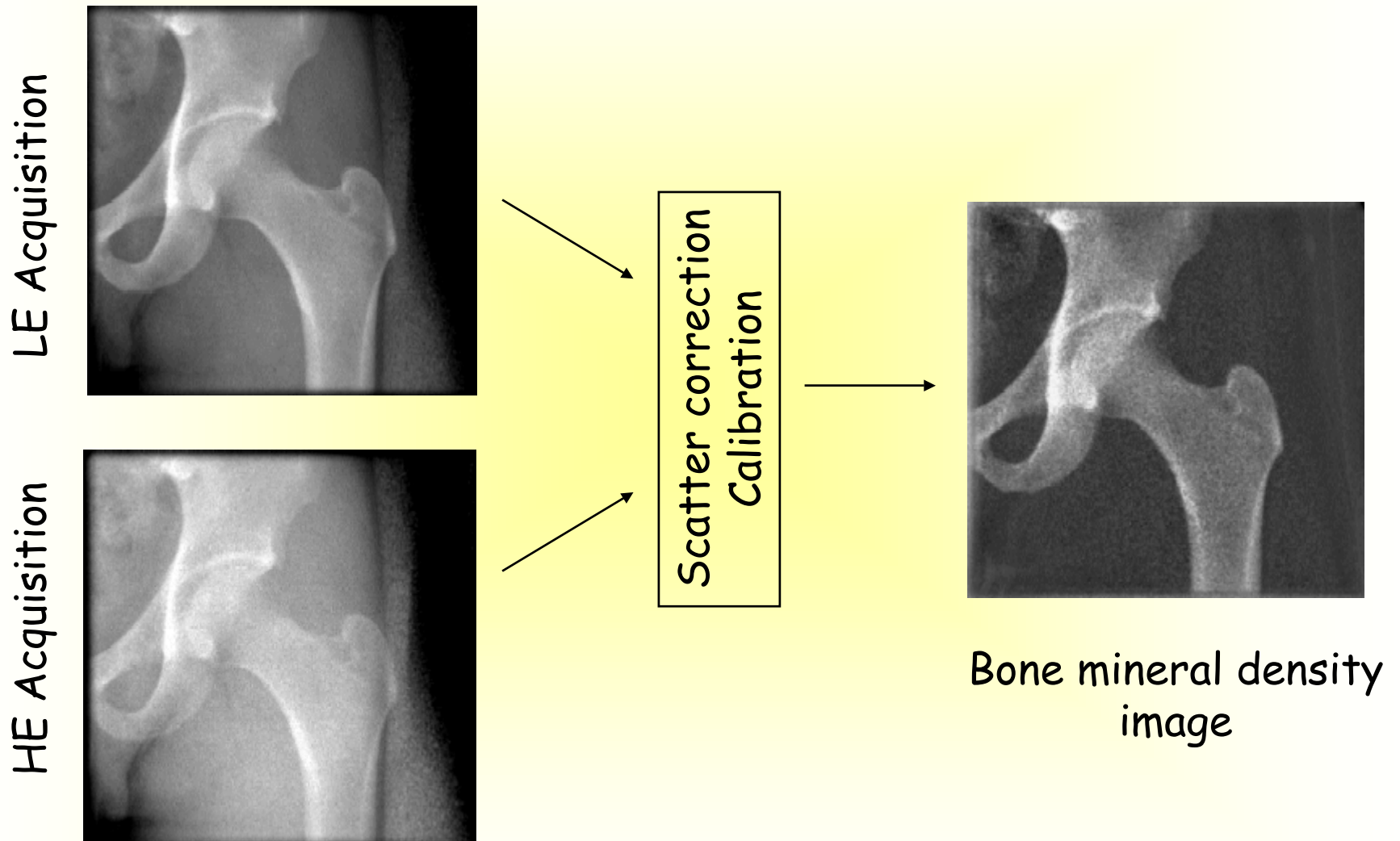
HE Acquisition



Bone mineral density
image



Bone densitometry results : hip





In standard mode

- AP lumbar spine 8-9 mSv
- Femoral neck 5 mSv

(For lumbar spine :

- Hologic QDR4500 (Fan Beam) 5-10 mSv
- Lunar Expert (Fan beam) 30-80 mSv)

	CV (%)
Lexxos	0.8
QDR 1000*	0.9
QDR 4500*	1.1

Reproducibility using 1g/cm² step(n=20)

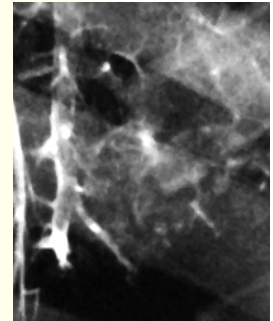


Dual-energy imaging : chest radiography example

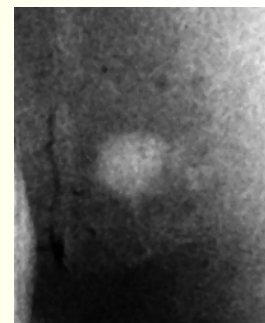
chest radiograph
dose level



bone image

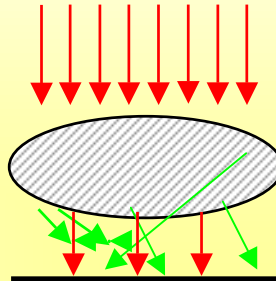
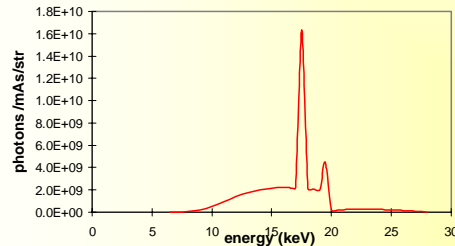


soft tissue image



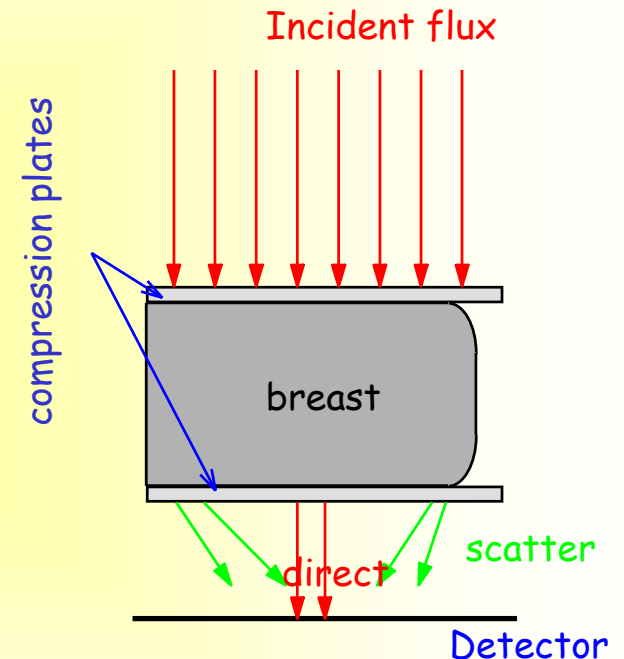


Radiograph formation process



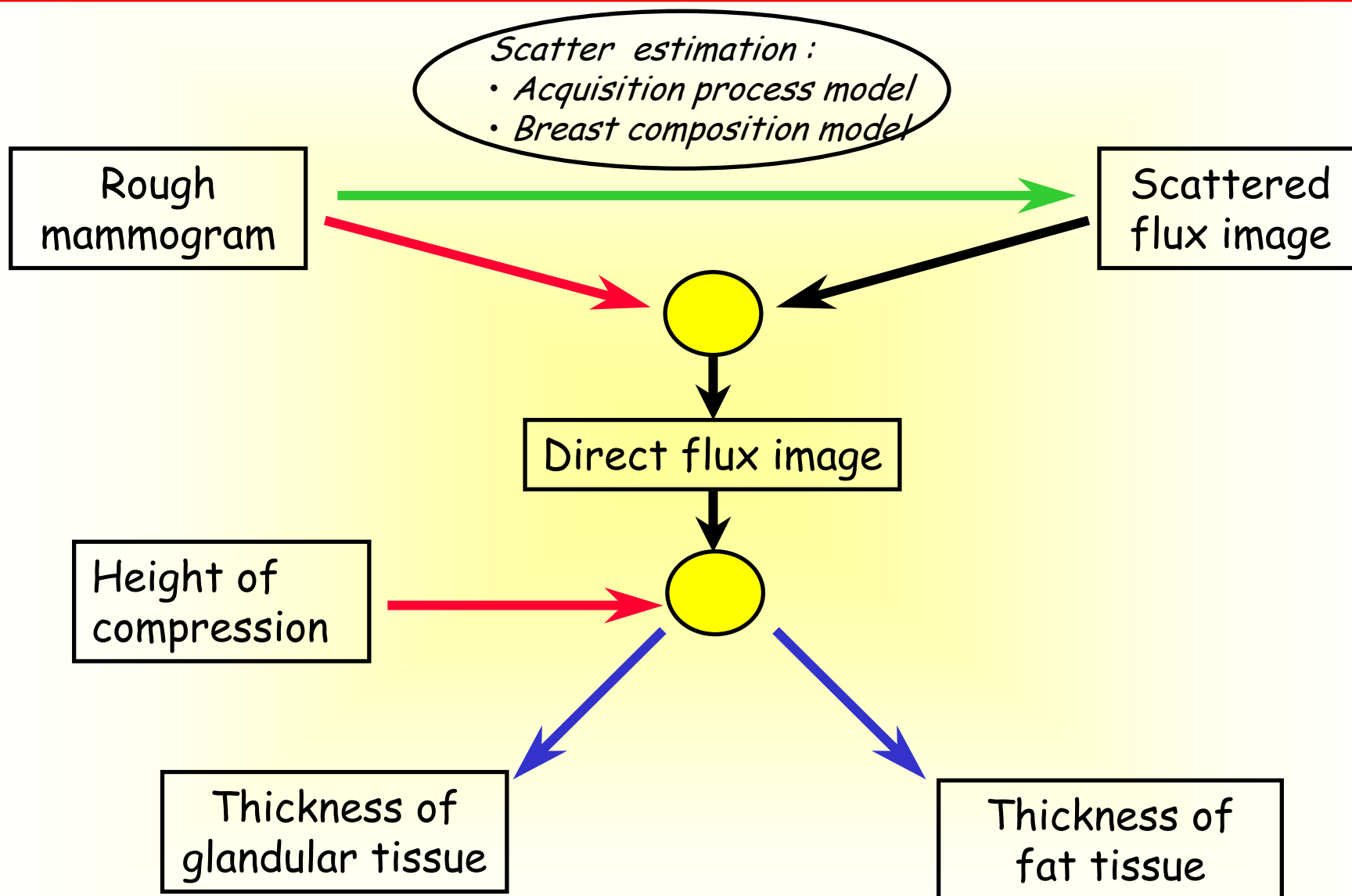
Prior

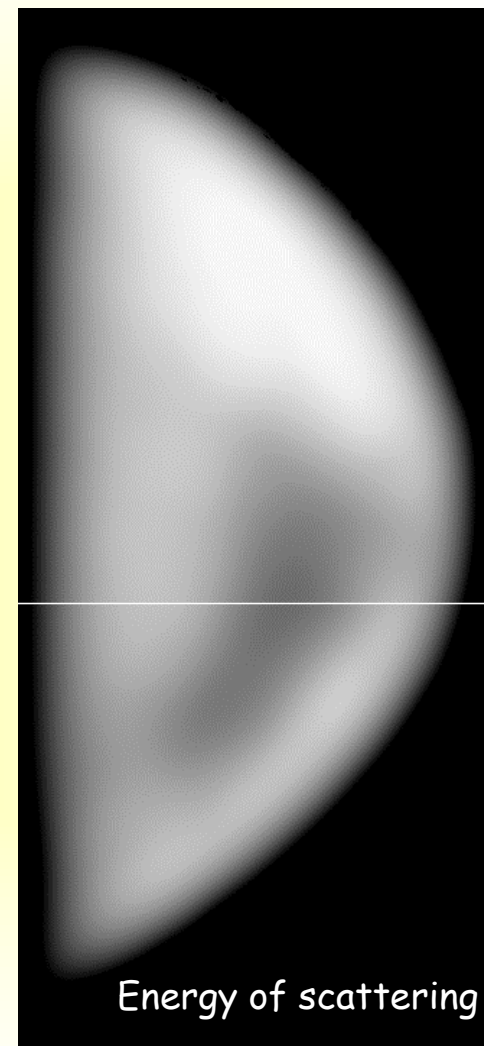
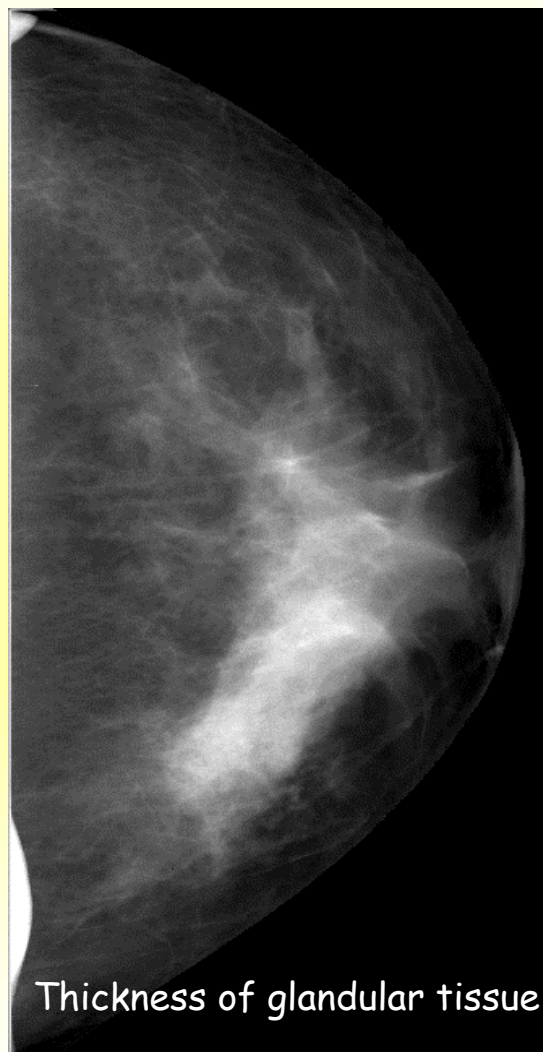
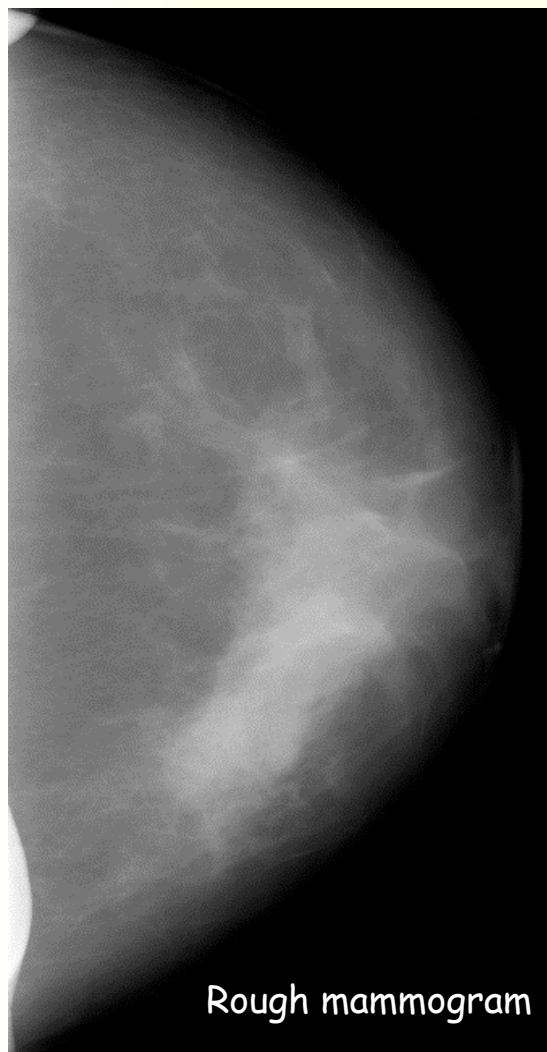
- *breast thickness* : height of compression
- *breast composition* :
 - ✓ glandular tissue
 - ✓ fat





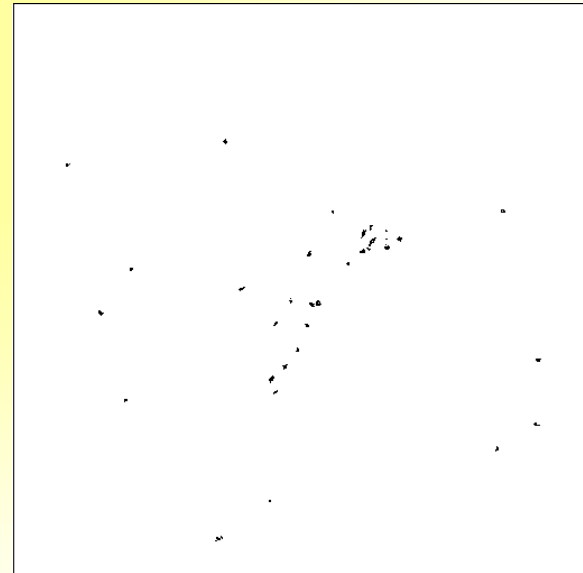
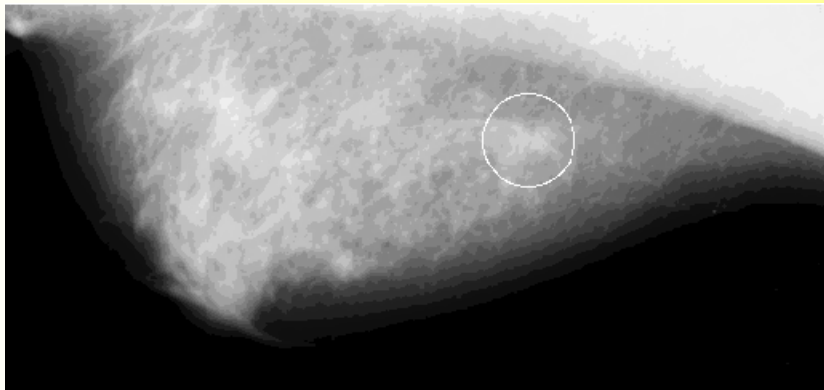
Processing steps in mammography







- Provides quantitative information improving diagnosis
- Improves CAD performances





- Thanks to advantages provided by digital detectors and physical based processing, in radiology, its possible :
 - To enhance information
 - To quantify information
 - To provide new information
- An open gate to :
 - Improved diagnosis information from digital radiographs
 - New applications with digital detectors