CHARACTERIZATION FOR LOW DOSE PHOTON COUNTING CONE-BEAM CT

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Outline

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2- PIXSCAN Project
3- Thesis context
4- Characterization of X-ray source
5- Reconstruction Algorithms
6- Criteria of image quality
7- Conclusion

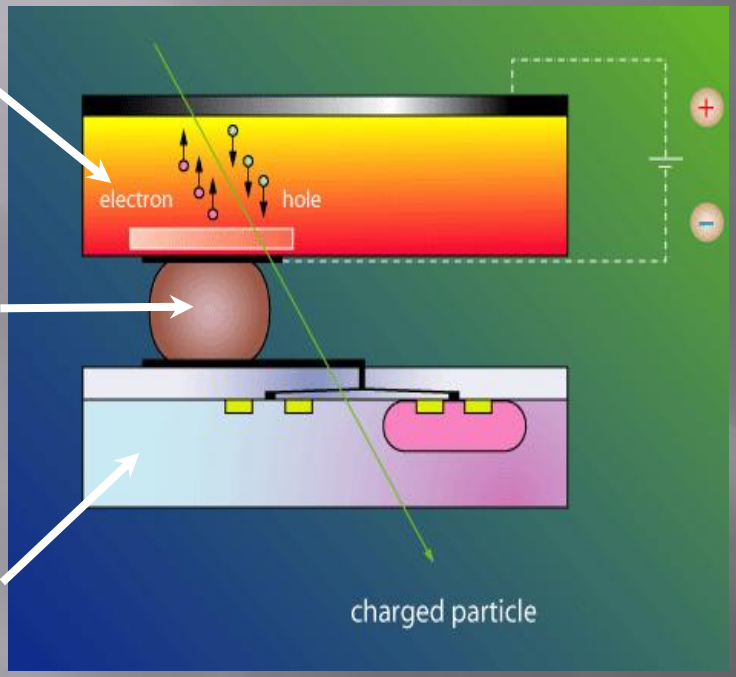
1-The XPAD3 new hybrid pixel camera

hybrid pixel

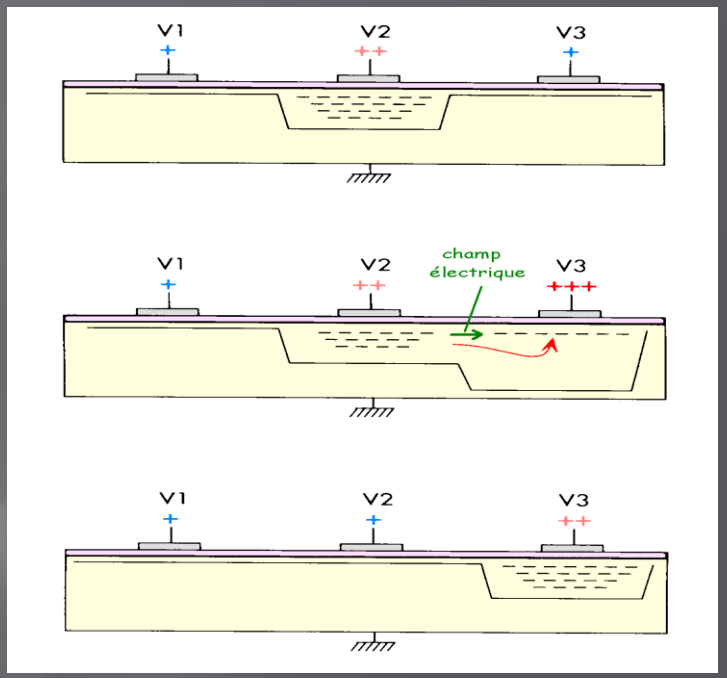
sensor
(Si or CdTe)

Bump-bonding

Electronic chip



CCD camera



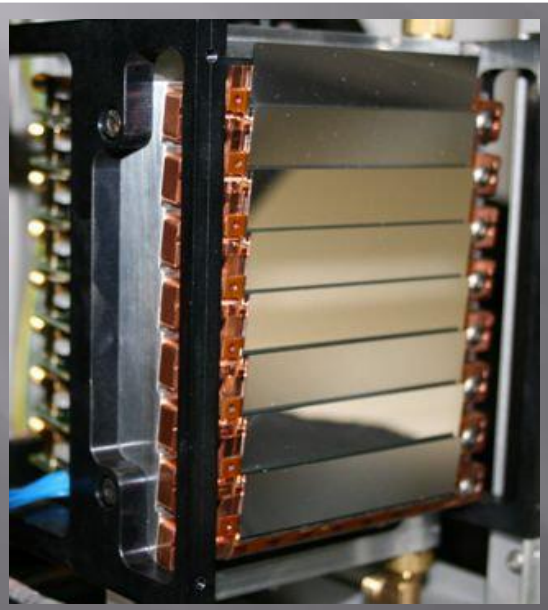
Fundamental difference with other detectors :
photon counting ! Not charge integration !

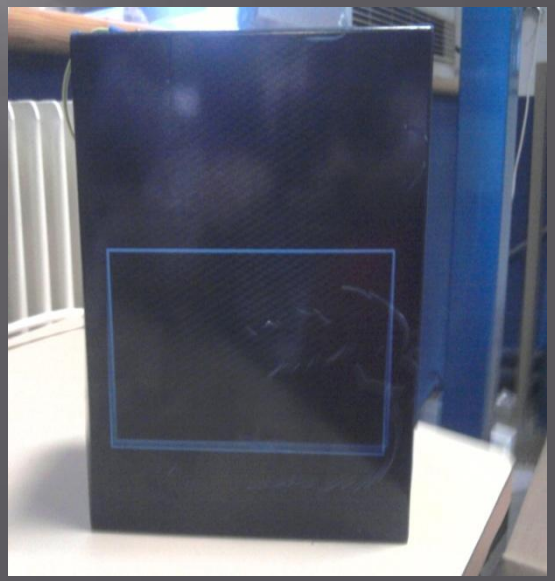
Existence of an energy threshold that enables counting.

No dark noise. → Pure poisson noise only.

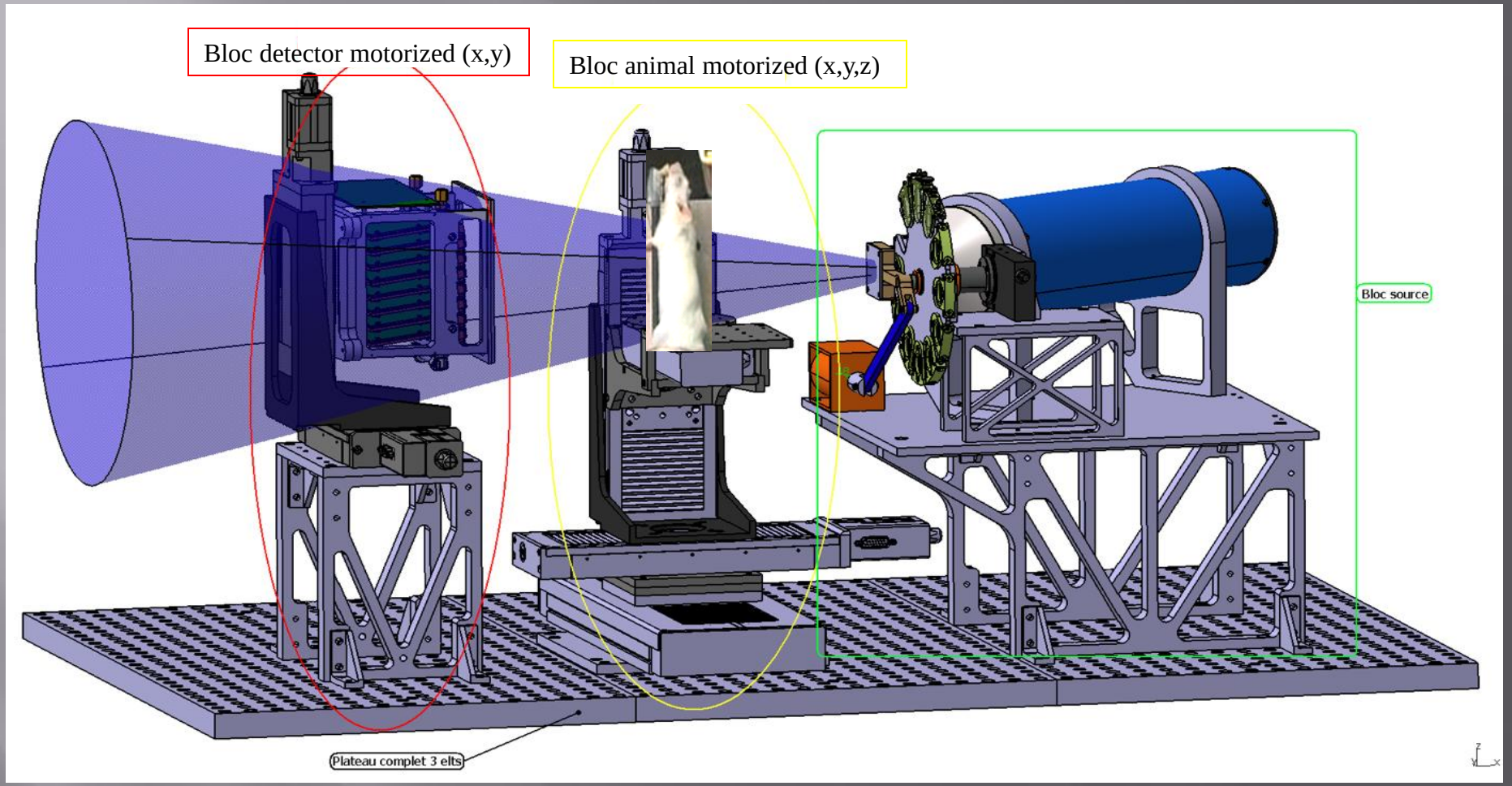
1-The XPAD3 new hybrid pixel camera

XPAD 3 hybrid pixel camera	CCD Camera
Photon counting mode	Charge integration mode
500 µm silicon sensor thickness	Gadox
560 x 960 pixels	4160 x 2080 (x1, x2, x4)
130 x 130 µm² pixel size	Effective pixel size 36 µm
78 x 75 mm² detector	201 x 190 mm²
Fast readout and data transfer up to 1000 frames/s (optical link and PCIExpress)	Max. Line/Frame Rate Up to 10fps binning dependent





2-PIXSCAN Project



Complete system : 3 blocks

OXFORD Intruments X-ray tube

Target Voltage 10to 90kv, Target Current 1to 2 mA

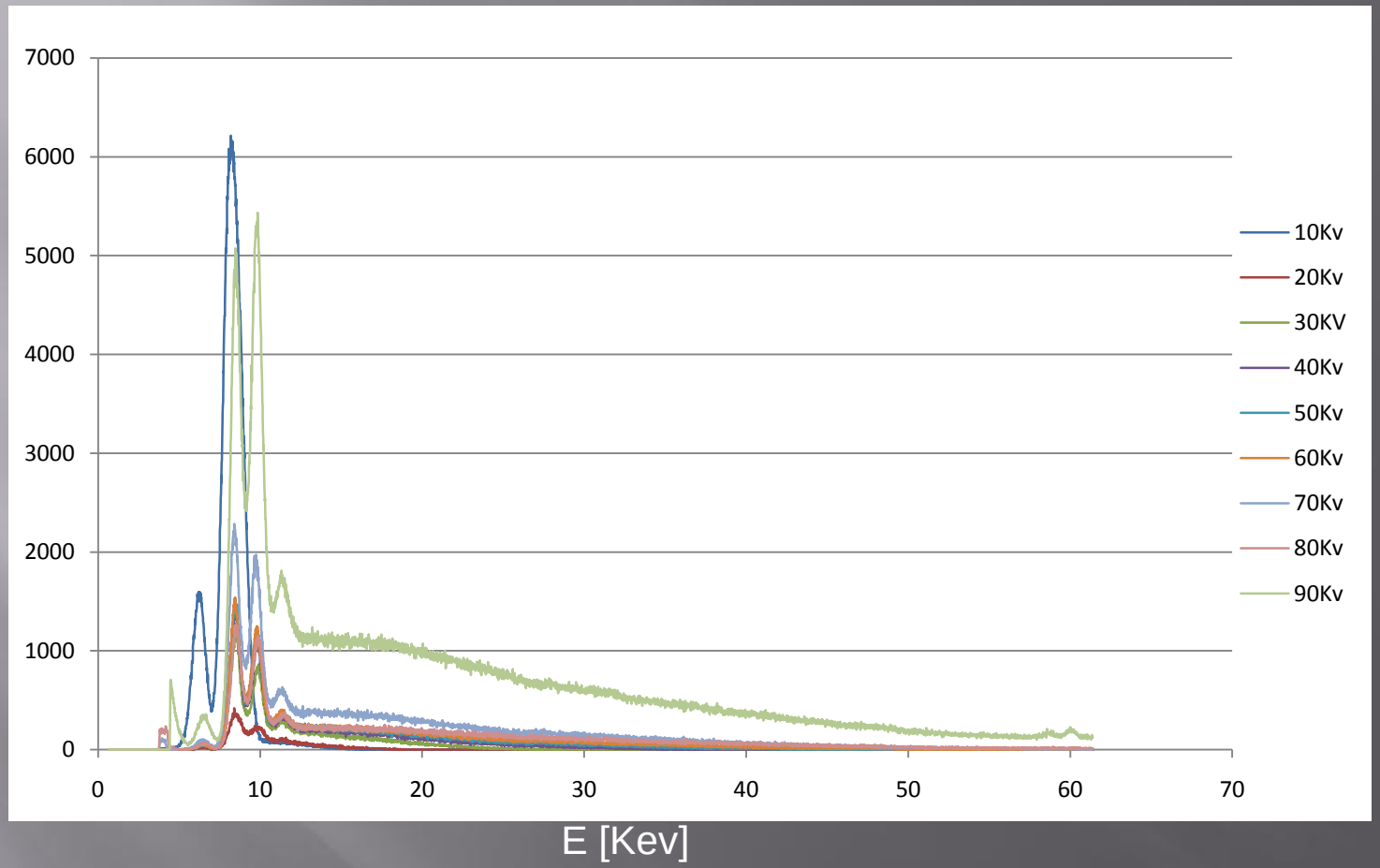
W target, 13 to40 µm focal spot size, 80 W, 33degrees Cone Angle

3-Thesis context

- Comparison of tomographic images reconstructed with the two cameras
- Asking the right questions
- Using the same techniques of reconstruction?
- Put them in the same conditions to the acquisition?
- Volume quality?

4- Characterization of X-ray source

Energy spectrum of the X-ray source OXFORD Instruments

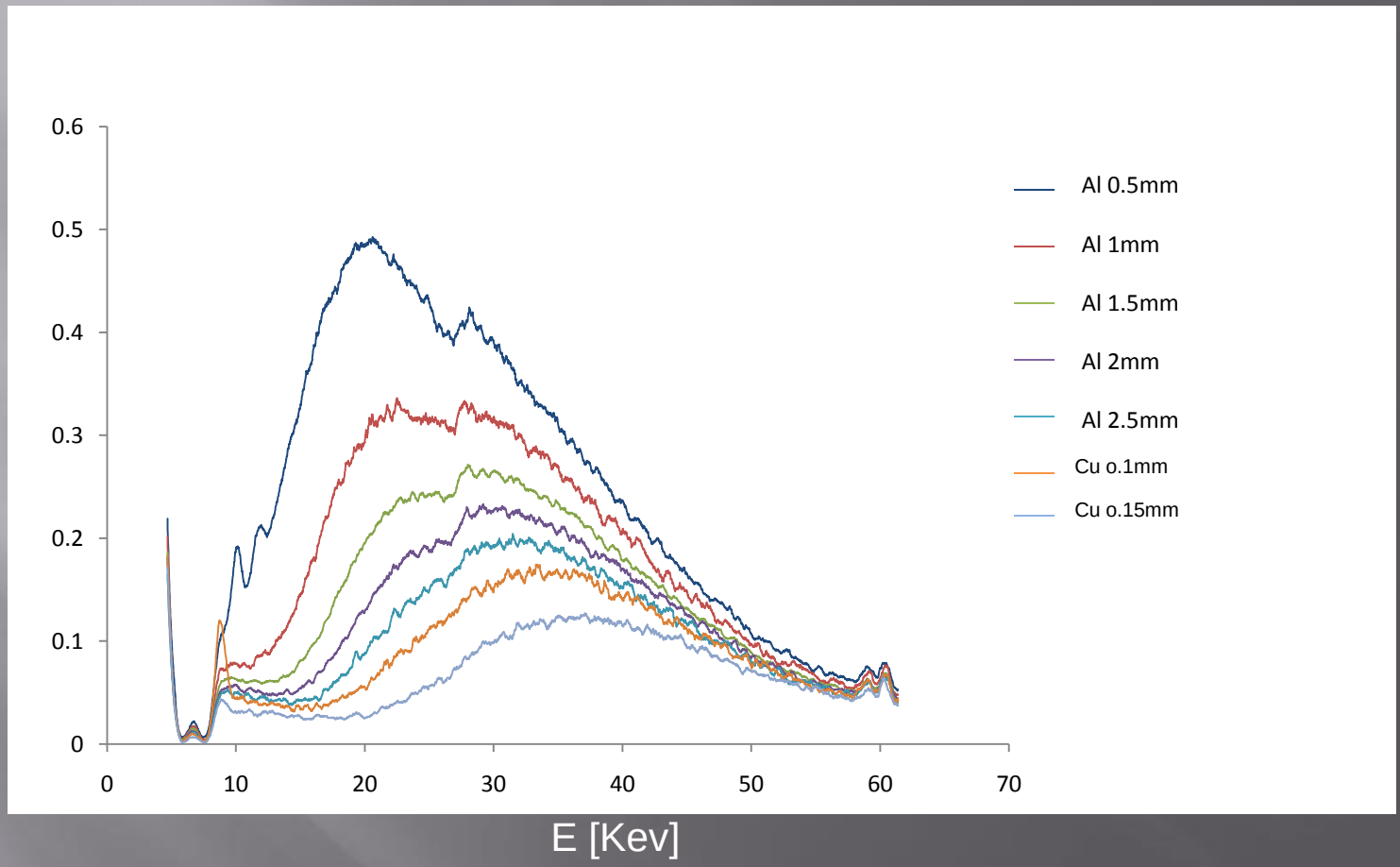


- CdTe-100T γ/x-ray detector (3×3×3mm³)
- Power supply & amplifier
- Collimator kit: Collimator housing , 7 Tungsten collimator discs (25µm – 2mm hole)

- Laser
- Mounting system
- Acquisition software: Spectrum Techniques UCS30
- 10min acquisition

4- Characterization of X-ray source

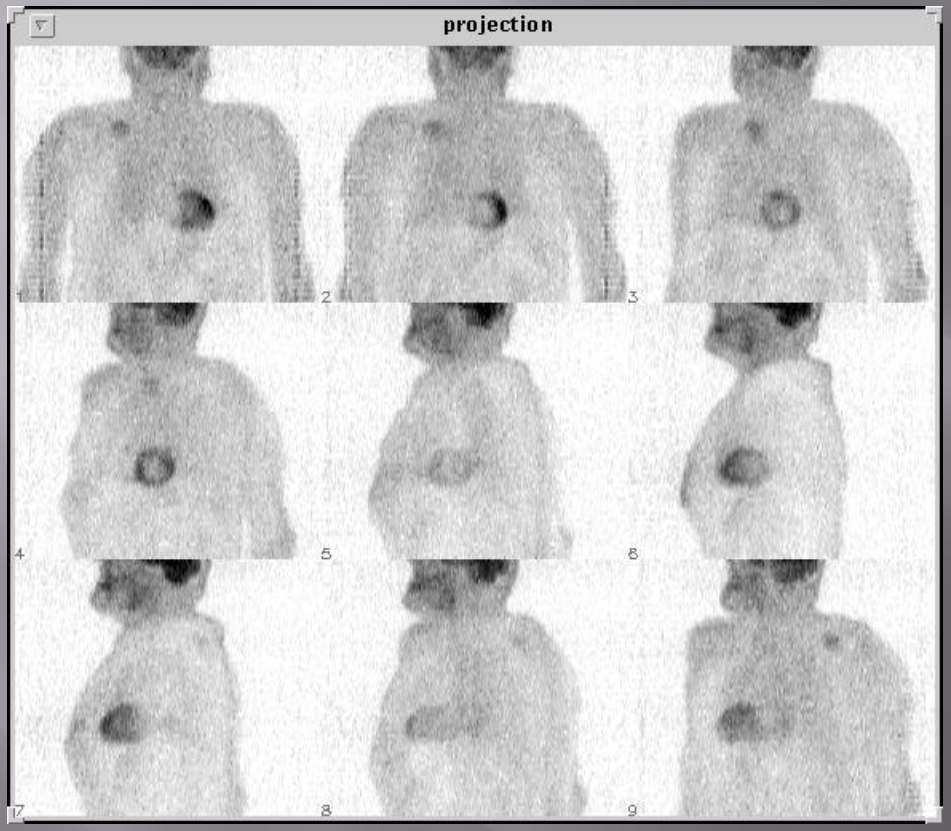
Measurements of spectra with different filters



- Measurements performed with Al thicknesses of 0.5mm to 2.5mm (90Kv)
- Hardening of the spectrum to high energies

5- Reconstruction algorithms
X ray Computed Tomography

Sinogramme



Same object seen under many different angles provides different projections.

By combining information from all the projections, we can get the 3D object.

X photons interact with matter.

5- Algorithms

a) FDK

- Feldkamp, Davis, Kress (FDK)
- Analytical method
- Filtering projections (1D) ⇒ back-projection of filtered projections

b) SART and ML-EM

- **-** Algebraic and iterative methods

Model : Af = p

with **p** projections, **f** volumic function to estimate, and **A** system matrix.

The solution is provided by the pseudo inverse matrix of **A.**

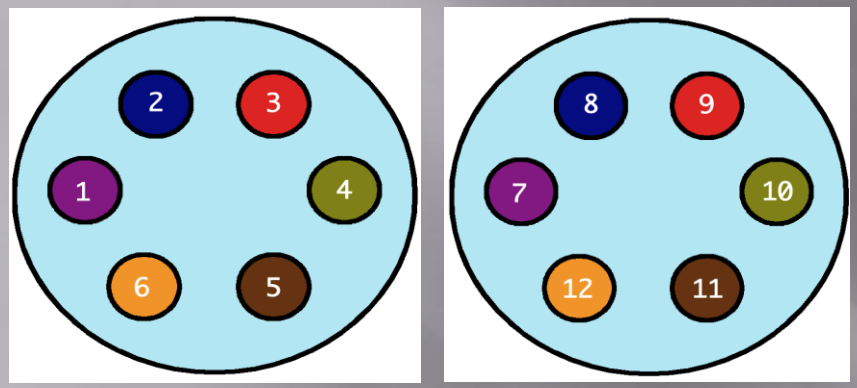
- - Simultaneous Algebraic Reconstruction Tomography (SART, extension of ART algorithm) algorithm.

- - Maximum Likelihood Expectation-Maximization (MLEM) algorithm.

5- 2 Simulation

- Tests have been performed on a simulated phantom with the software GATE.

First plane of balls Second plane of balls



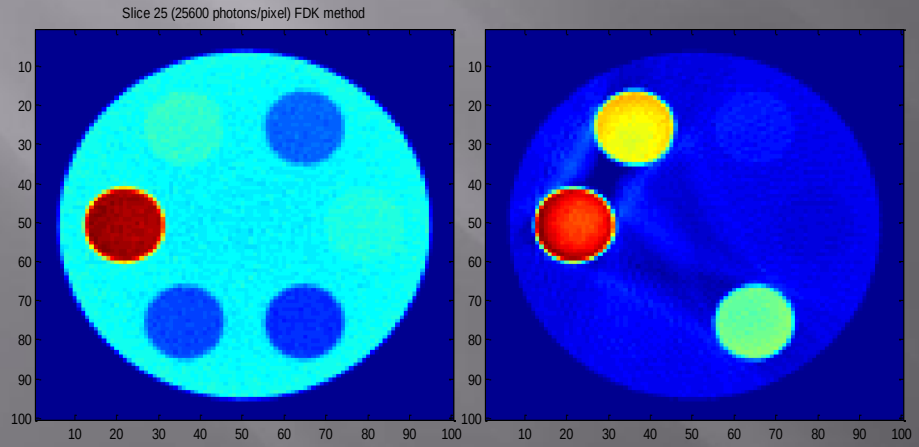
Two horizontal planes of the cylindrical simulated phantom, with different density balls.

Simulations have been performed with :
-Acquired projections of size 100 x 100 pixels, 360 projections.
- A reconstructed volume of 100 x 100 x 100 pixels.
-Activity (Photons/pixels) ranging from 100 to 25600.

1: IomeronInj, 2: Polystyrène, 3: LungMoby, 4: Brain, 5: Adipose; 6: Blood.

7: RibBone, 8: Liver, 9: SpineBone,10: Carbon 11: Cartilage,12: Skull,

First plane of balls Second plane of balls



FDK method 25600 photons /pixel

6-Criteria of image quality

For all calculations: Image to 25,600 photons / pixel is considered as reference image.

a) PSNR (Peak Signal to Noise Ratio)

$$PSNR = 20\log_{10}\left(\max(I_{ref})/MSE(I_{ref}-I_{rec}) \right)$$

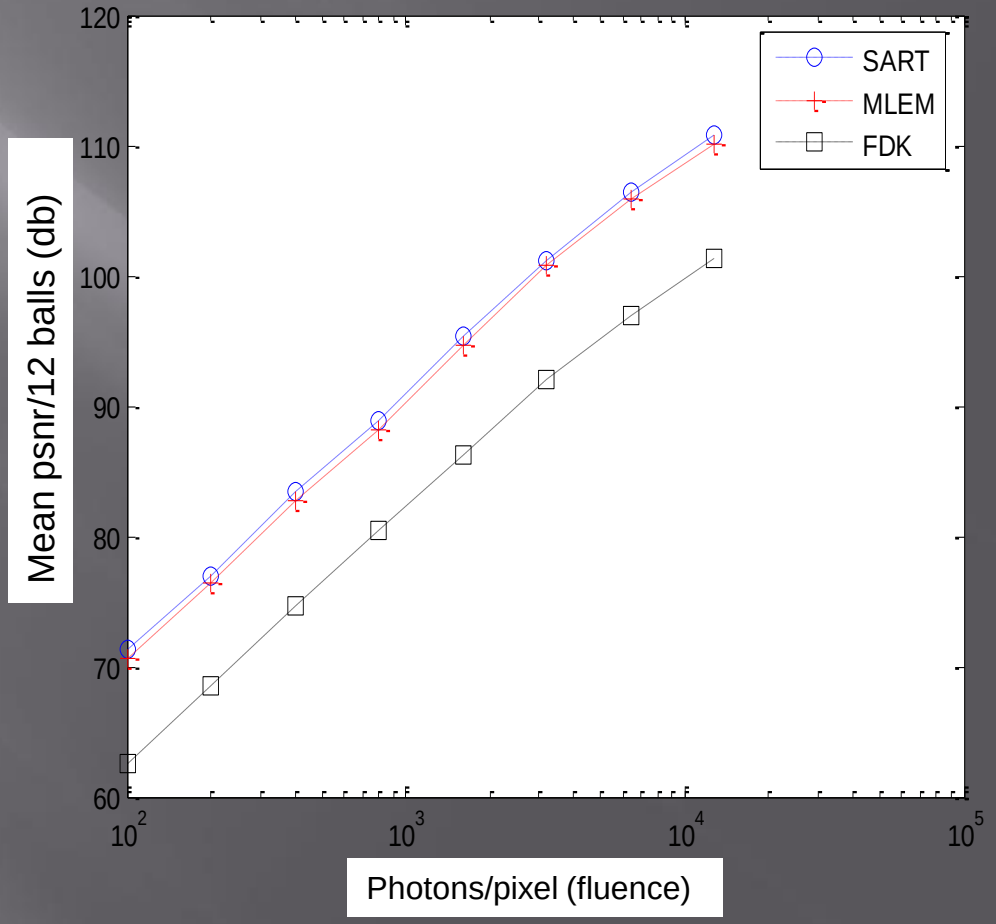
-Superiority of iterative methods according to PSNR criteria.

-Linear increasing of PSNR as a function of dose.

-Significant criterion, but not enough

-Only averaged the image

-This measure does not reflect the human perception



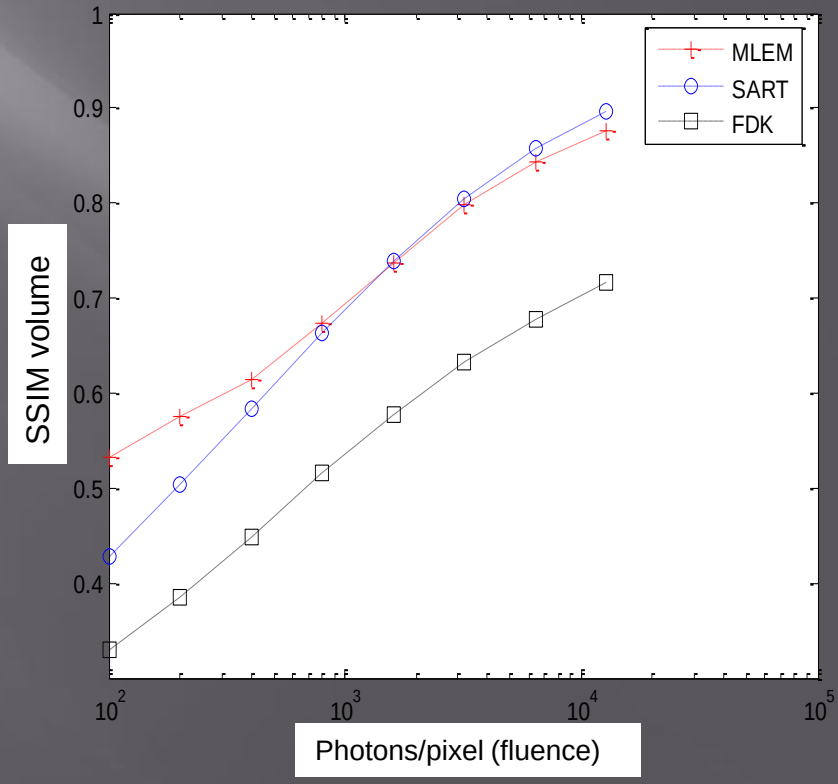
6-Criteria of image quality
b)SS_SSIM (Single Scale Sturctural Similarity)

- The general form of the Structural Similarity (SSIM) index between signal I_{ref} and I_{rec} is defined as:

$$SSIM(I_{ref}, I_{rec}) = \frac{(2\mu_{I_{ref}}\mu_{I_{rec}} + C_1)(2\sigma(I_{ref} - I_{rec}) + C_2)}{(\mu_{I_{ref}}^2 + \mu_{I_{rec}}^2 + C_1)(\sigma_{I_{ref}}^2 + \sigma_{I_{rec}}^2 + C_2)}$$

Apply the SSIM indexing algorithm for image quality assessment using a sliding window approach.

-Results almost identical with SART and MLEM.
-MLEM and SART better than FDK
-Linear increasing of SS_SSIM as a function of dose



7-Conclusion

- Iterative methods have shown their superiority on Fourier-based method.

- The quality of reconstructed images depends on the dose and on the density of the tissue concerned.

- The quality of reconstructed images linearly depends on the dose.
- Finding the right filters to perform specific experiments.
- Apply techniques to real data.
- Install the CCD camera in the PIXSCAN
- Study of the CCD camera

Thank you for your attention