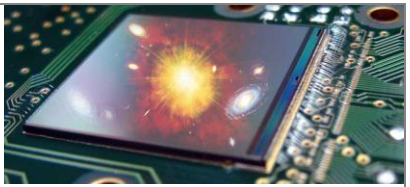


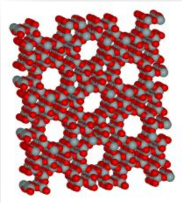
Single X ray detection with high sensitivity CMOS detectors

Mario BACHAALANY

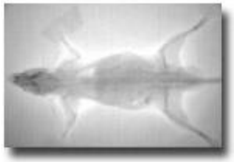
IPHC - CMOS Group

- X ray history and applications
- X ray application requirements
- How granular and fast detector gives better image
- CMOS modification and crystal coupling
- Experiment procedure and tools
- Results
- Next steps.....

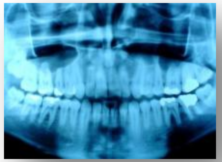
Tomography Imaging



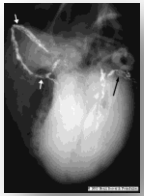
Crystallography



Small animal
Imaging



Dental Imaging



Cardiovascular Imaging

Wilhelm Conrad Roentgen

CT Scanner

X ray applications requirements

- High quality images (CCD detectors)
  - Dental Imaging
  - Crystallography
  - ....

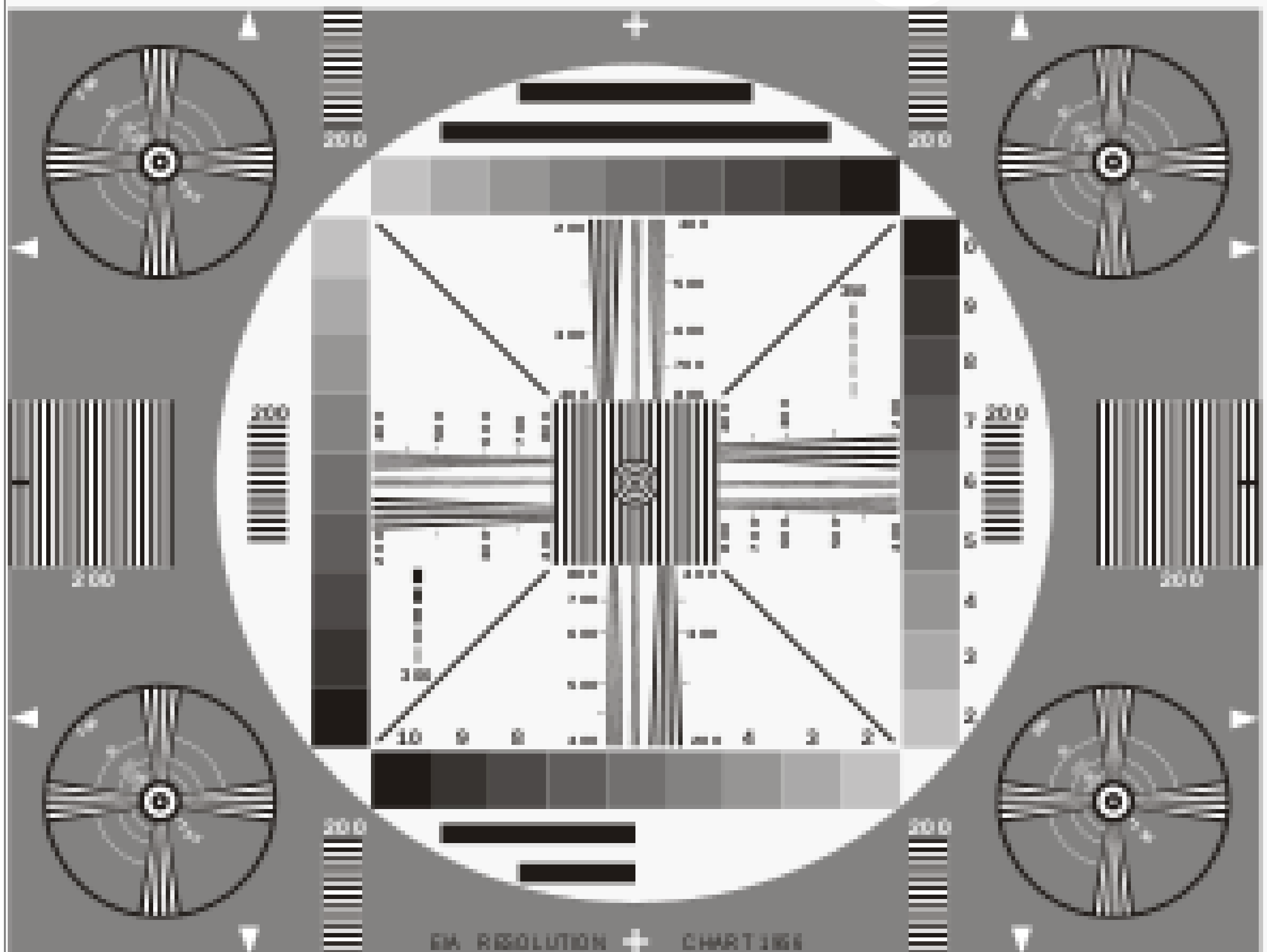
- Swift images (Hybrid detectors)
  - Cardiovascular Imaging
  - CT Scanner
  - Tomography Imaging
  - Small animal Imaging
  - .....

X ray applications requirements

- High quality images (CCD detectors)
  - Dental Imaging
  - Crystallography
  - ....
- Swift images (Hybrid detectors)
  - Cardiovascular Imaging
  - CT Scanner
  - Tomography Imaging
  - Small animal Imaging
  - .....

Our CMOS sensors has both

Sensor granularity



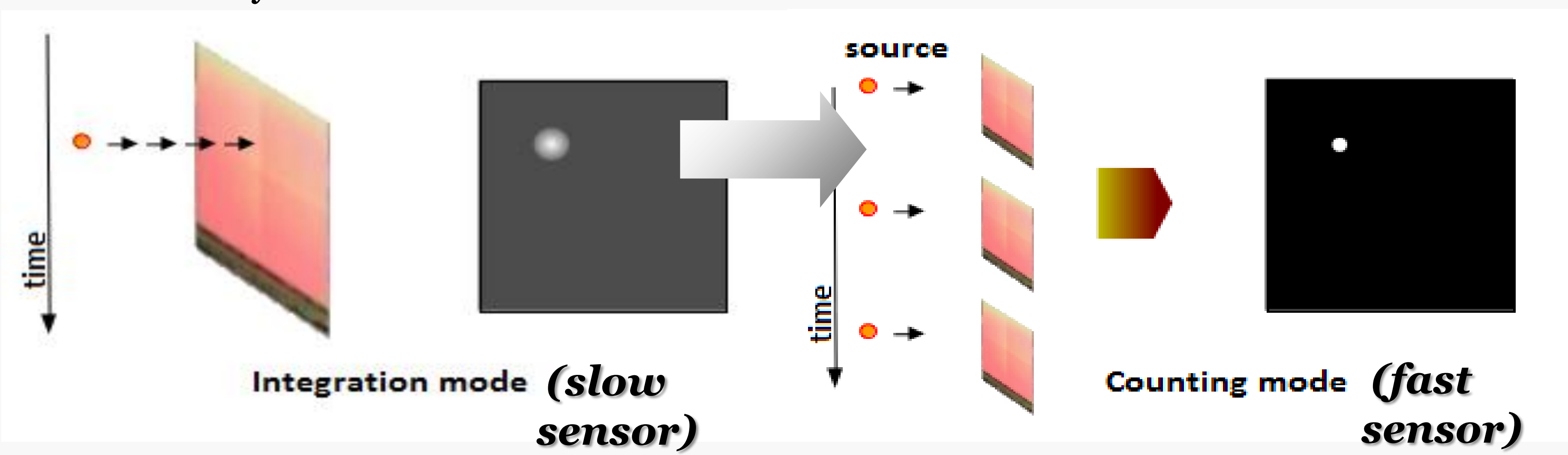
The **EIA 1956** resolution target was specifically designed to be used with television systems. The gradually expanding lines near the center are marked with periodic indications of the corresponding **spatial frequency.**

More granular means more details

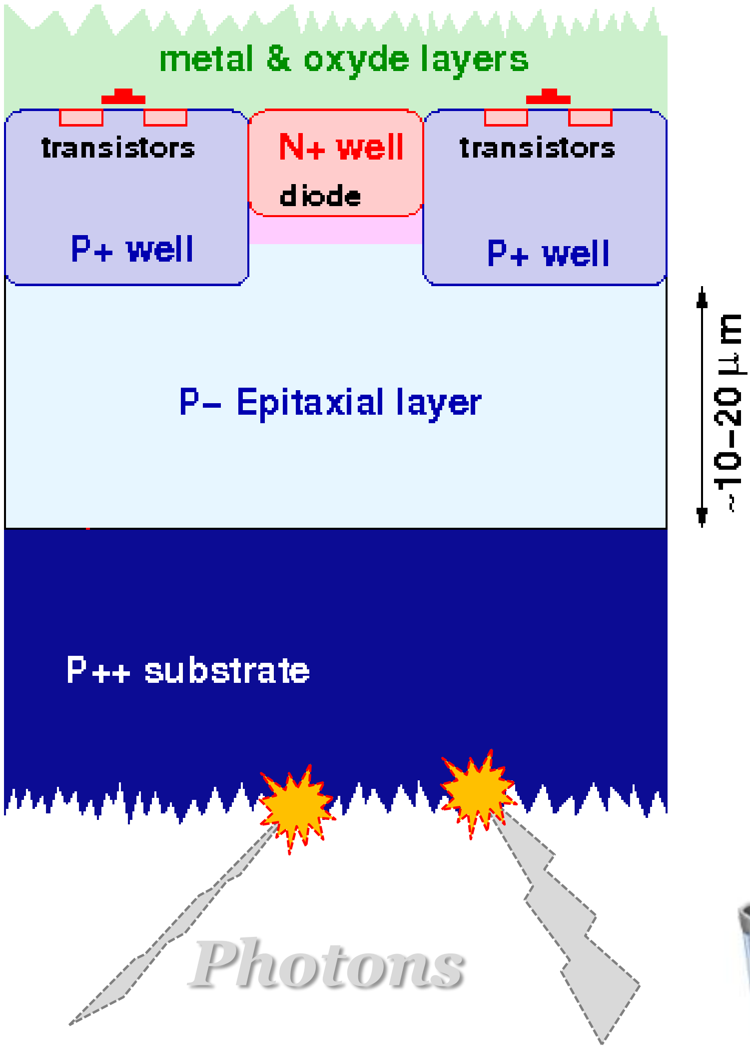
Fast sensors & imaging:

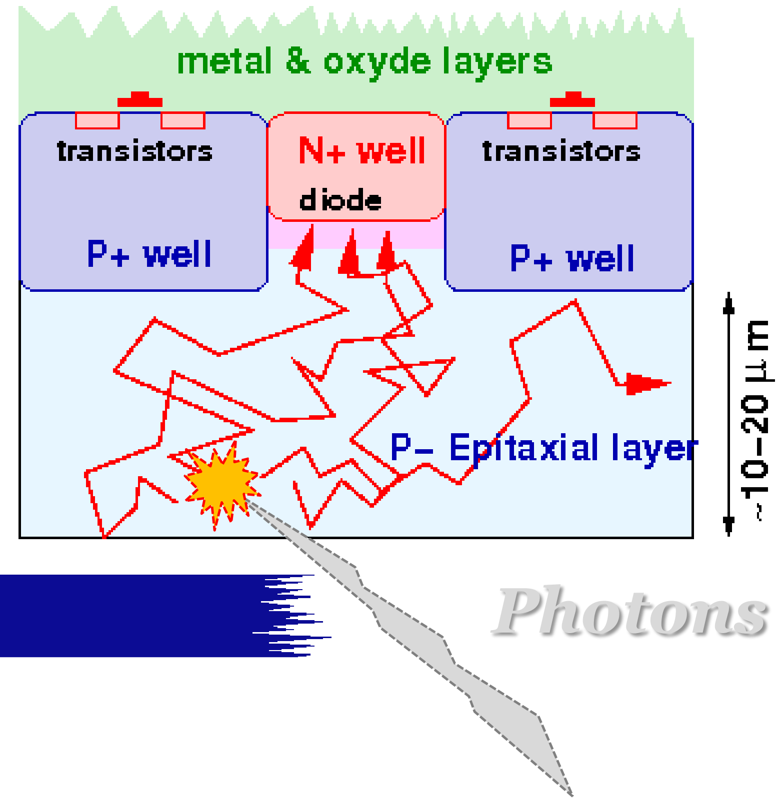
Benefits:

- Noise suppression, since noise fluctuations are filtered out and not integrated
- Improved image definition, quantitatively expressed by a better Modulation Transfer Function (MTF)
- Enhanced dynamic and resolution on intensity, because hits are counted individually



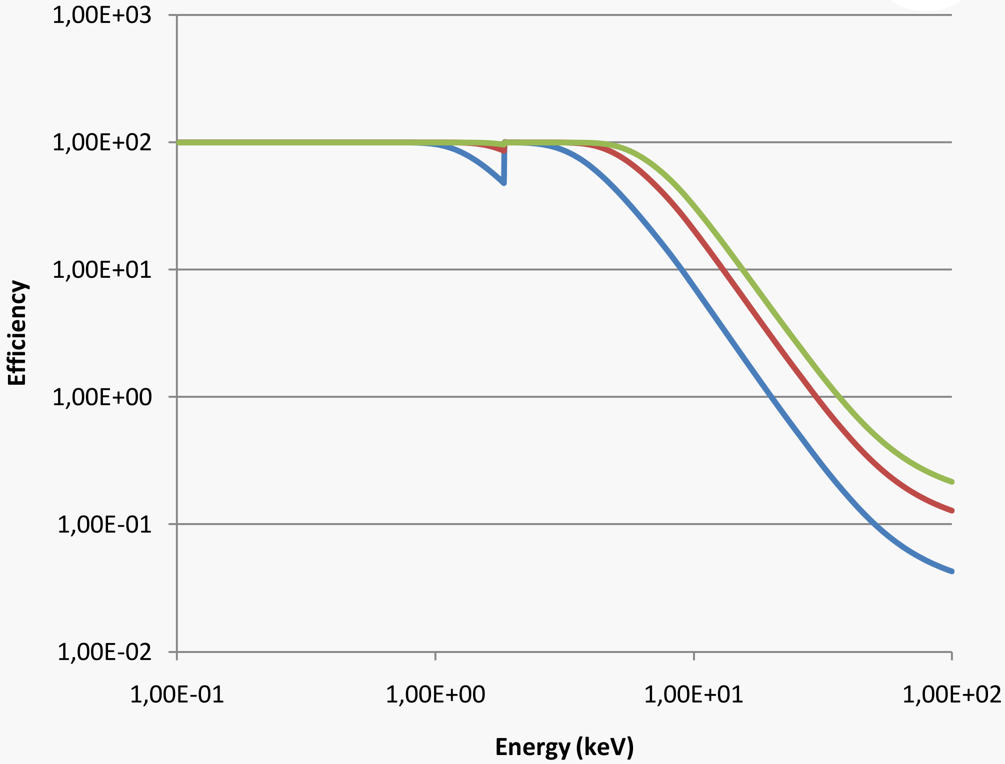
Back-thinned Process





This way the detector is more sensitive for photon detection.

CMOS sensitivity

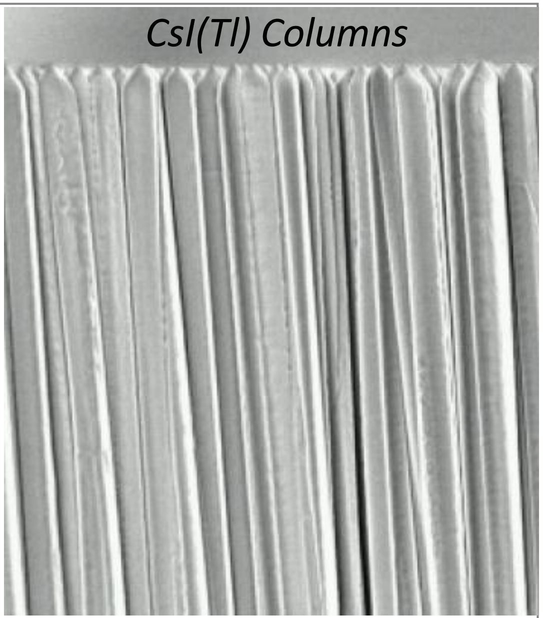


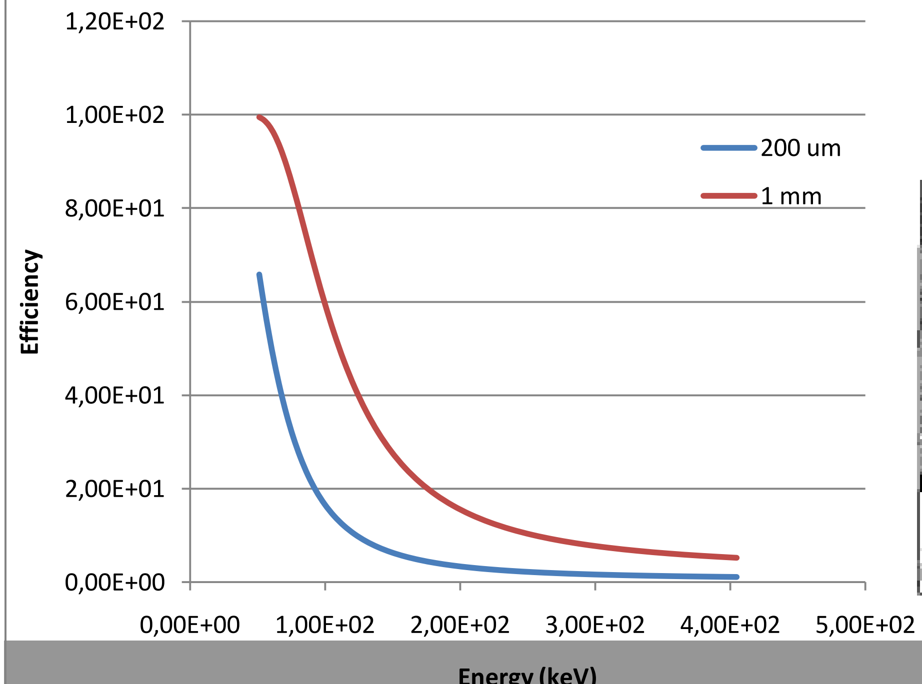
Back-thinned CMOS detectors are less sensitives for energies higher than 10keV.

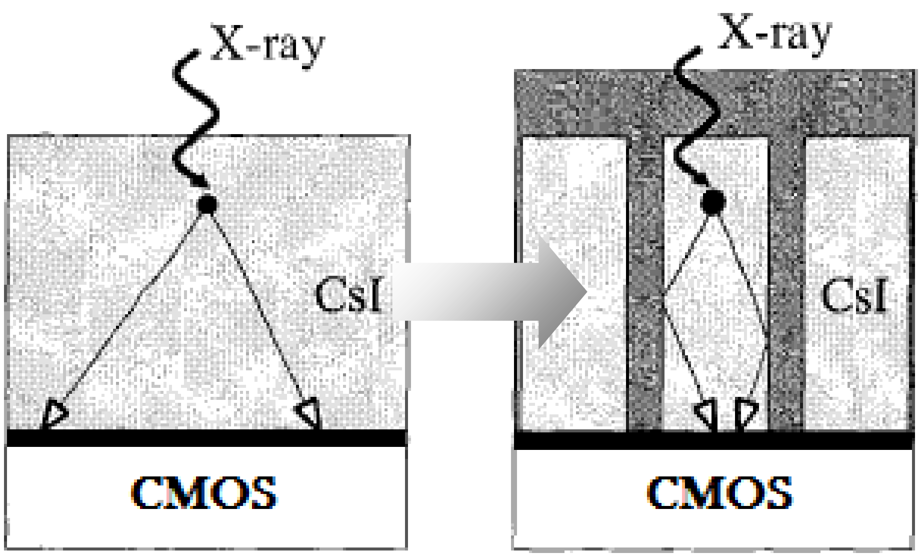
Use of scintillating crystal to convert x rays into visible light.

CsI(Tl) caracteristics:

- Creates~54 photons/keV
- Energy of created photons ~2.3eV
- Wavelength~540nm
- A matrix of thin column crystals with ~2um large.

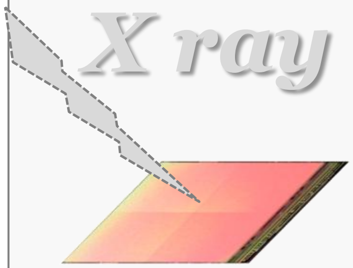






Experiment

Procedure

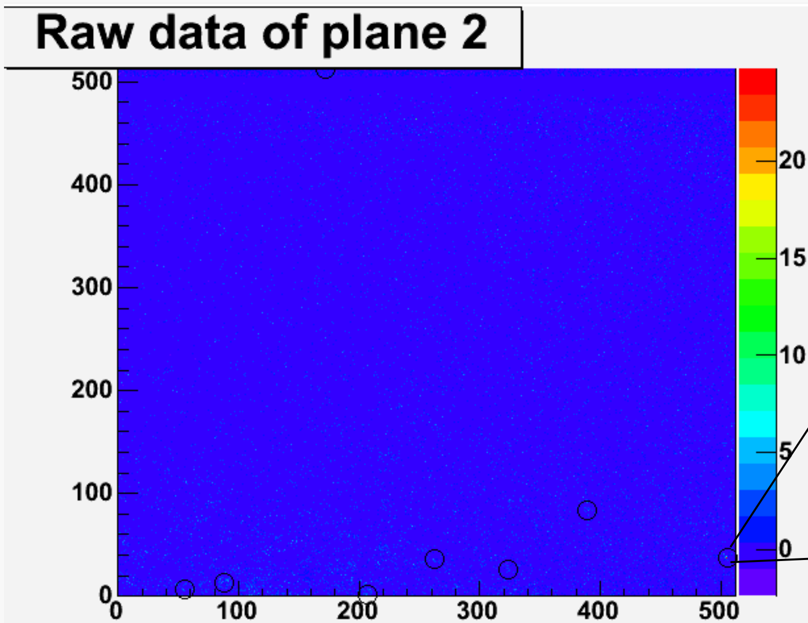


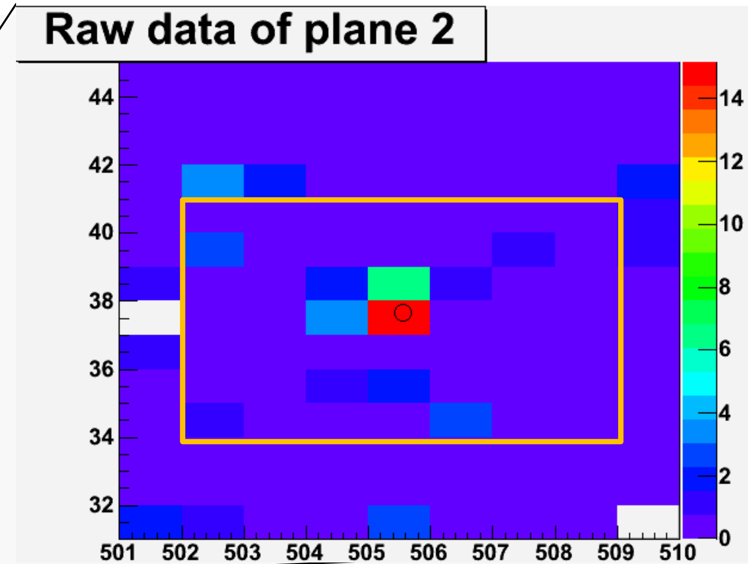
Auxiliary Card

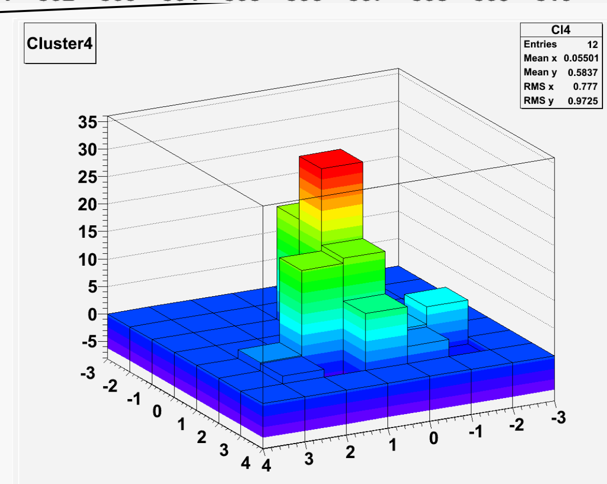
TNT or Imager Card

Detection of an x ray → ***Amplification*** → ***Digitization and processing*** → ***Saving and analyzing***

What's a cluster?!



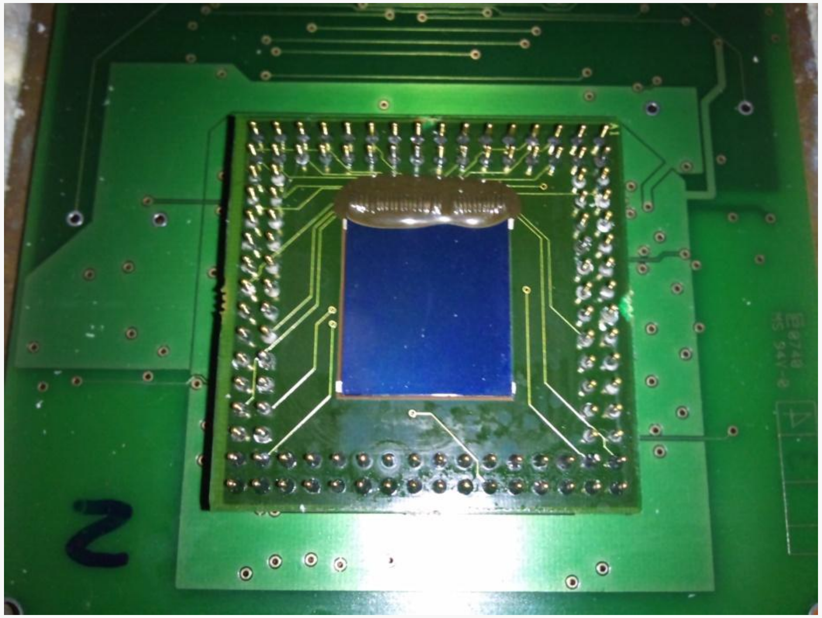




The reconstructed position of the impact is the position of the center of gravity of all the pixels of that cluster

MIMOSA 5 (test sensor)

- 1024x 1024 pixels
  - 4 x 512x512 sub matrices
- Each pixel 17x17um²
- 303mm² of sensitive area
- 14um epitaxial layer
- 20 frames/sec



Tools

- MIMOSA 5 Sensor

- Cluster size: 5x5

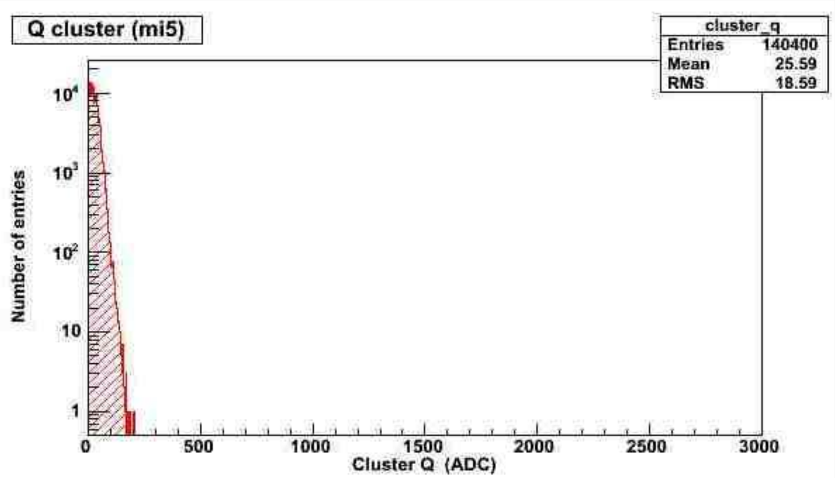
- Source Co57 which emits x rays of 122keV (87%) and 136keV (11%) posée sur la matrice d’étude

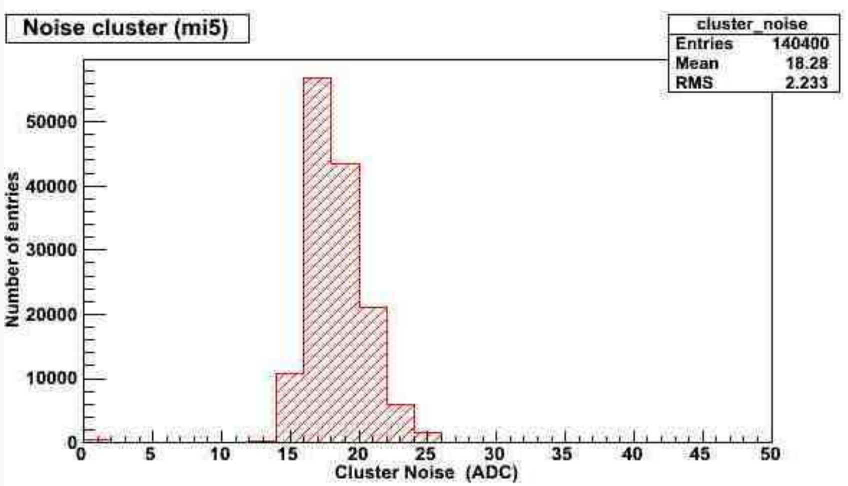
- ‘Imager’ Card for analysing and processing.

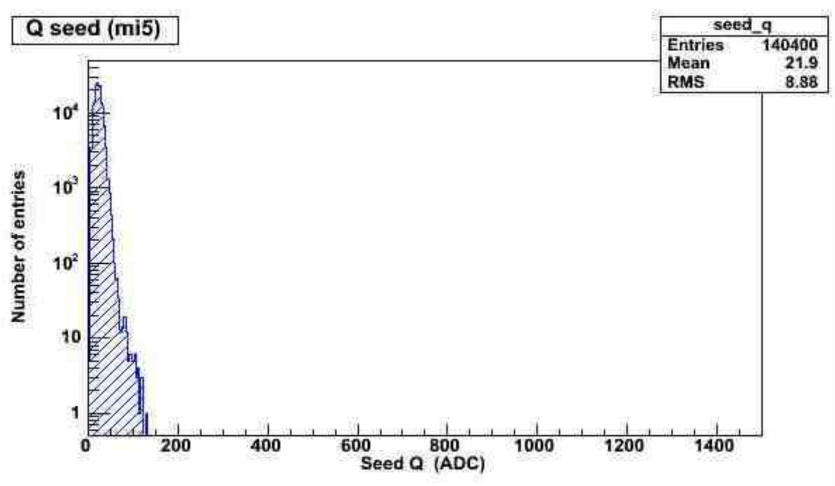
- Experiment done at 0°c (coolant temperature)

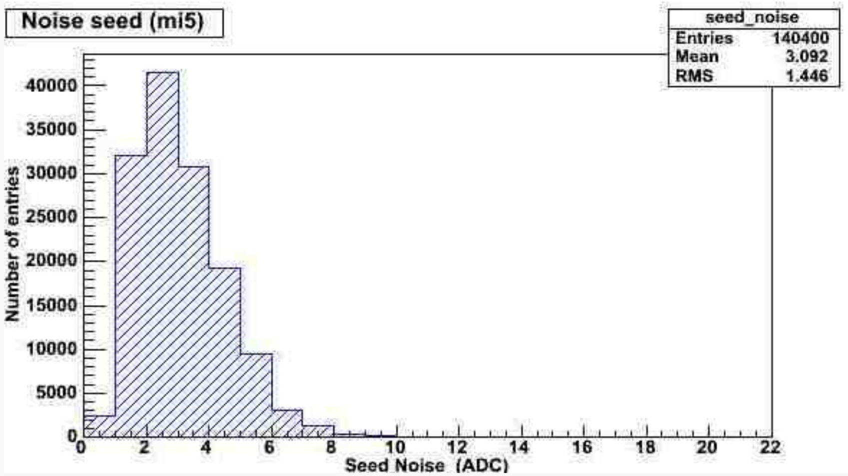
Noise Run (without source)

Energy spectre



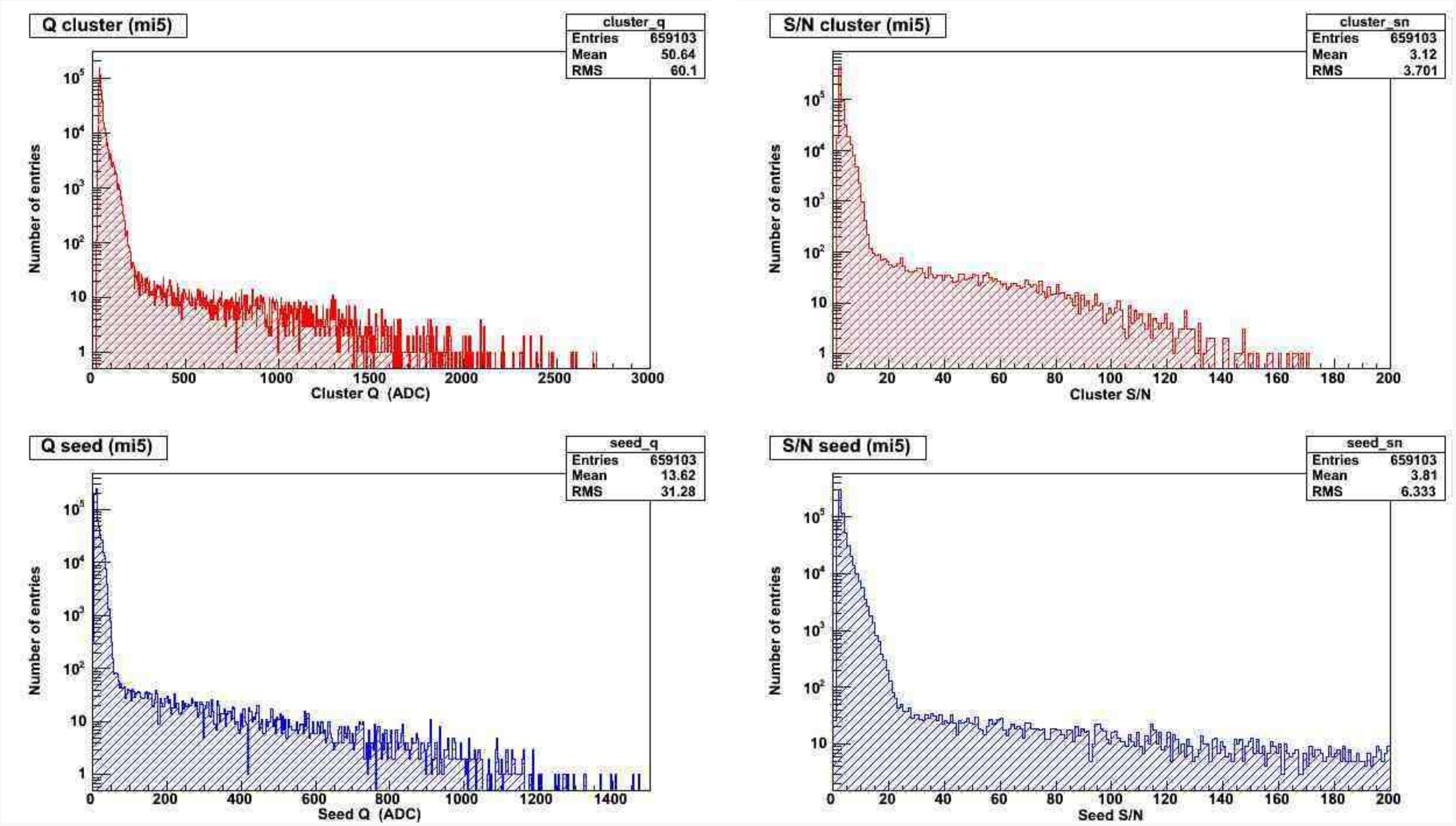






Results without filtering

Energy spectre



No obvious peak => Traditional thresholds are useless!!

Addition of a new filter

if S/N of pixel > seed threshold => We construct a cluster based on this seed

Creation of a cluster from a noisy pixel

3	1	2
-1	5	-3
1	-2	0

We have 2 pixels which have S/N > 2

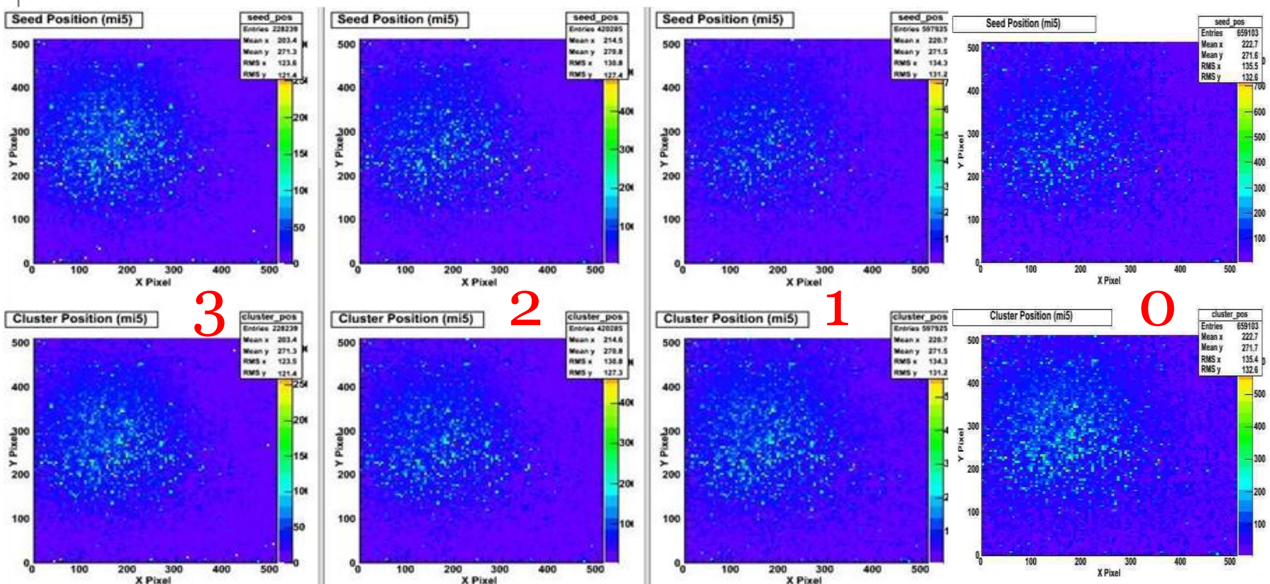
Creation of a cluster a from a true signal

2	3	1
3	5	4
1	2	1

We have 4 pixels which have S/N > 2

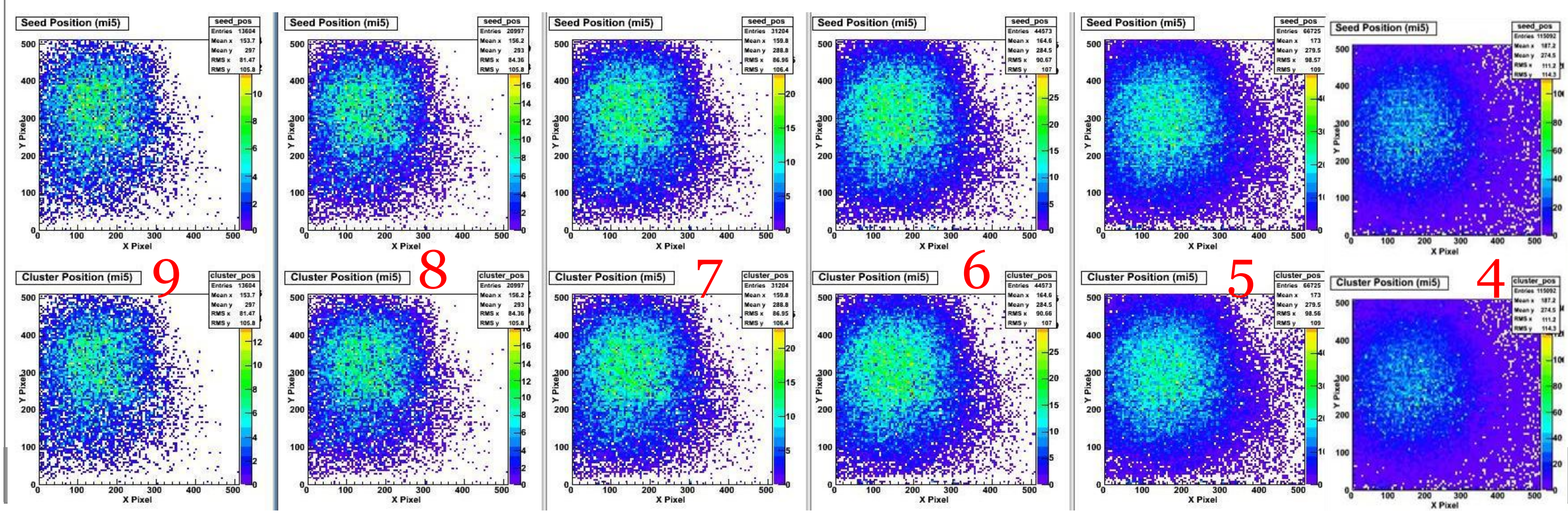
Picking clusters depend on the number of pixels which have S/N >2

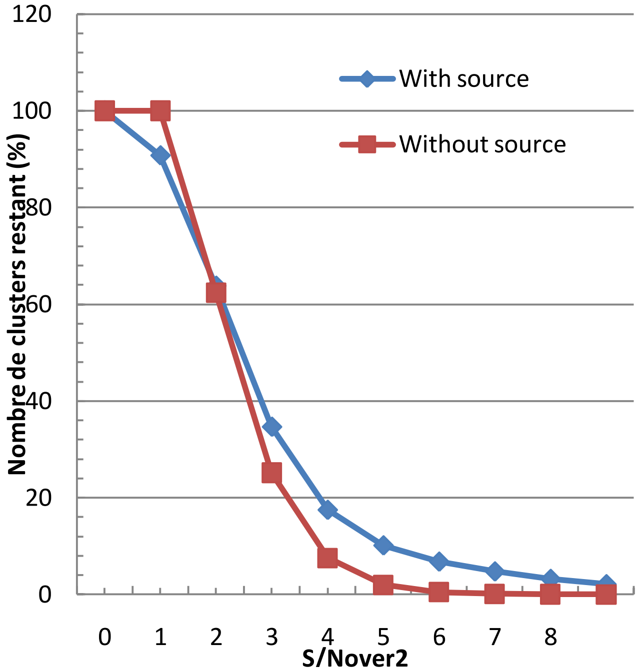
Filter effect on a run with source

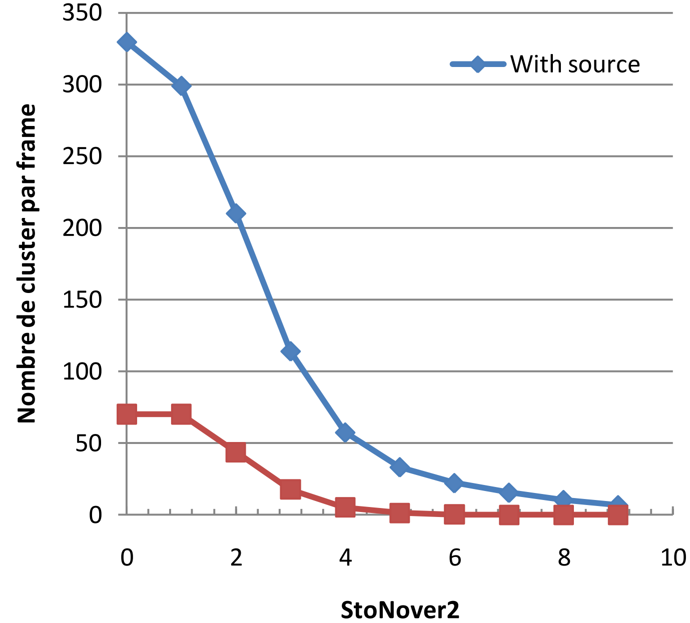


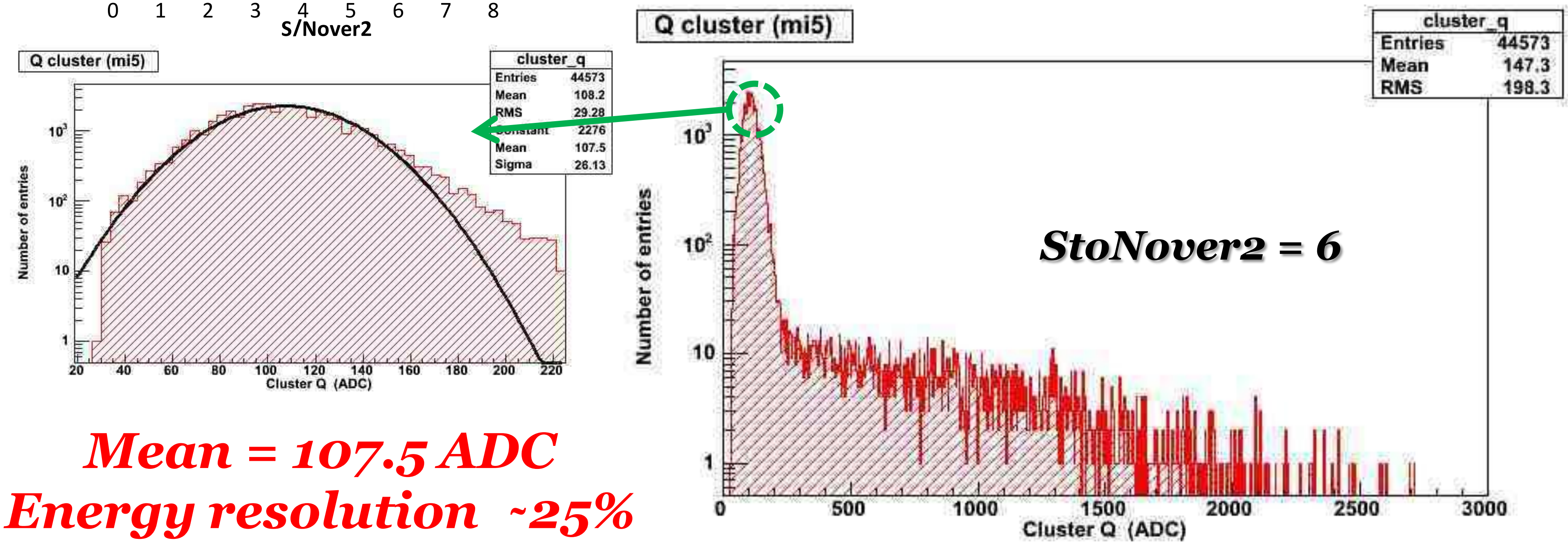
Better borders

Better contrast









Mean = 107.5 ADC

Energy resolution ~25%

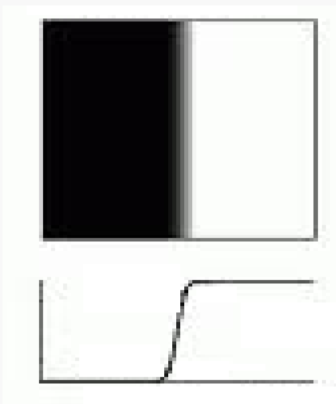
Spatial Frequency (MTF)

- HEP guys use PSF (Point Spread Function)
  - 2D gaussian
  - Resolution is represented by σ (in distance unit).

- Imaging guys use MTF (Modulation Transfer Function)
  - Fourier Transformation of PSF (in 2D)or
  - Fourier Transformation of LSF (Line Spread Function)
  - Resolution is represented by sigma (Line Pairs per unit distance ‘Lp/mm’)

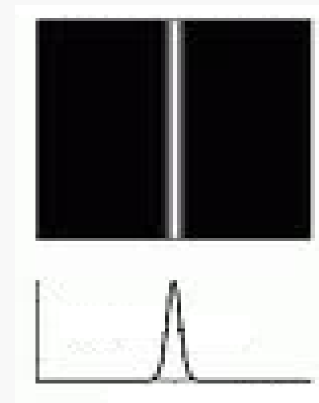
Edge Response Function(ERF)

- the edge response is how the system responds to a sharp straight discontinuity (an edge).



ERF

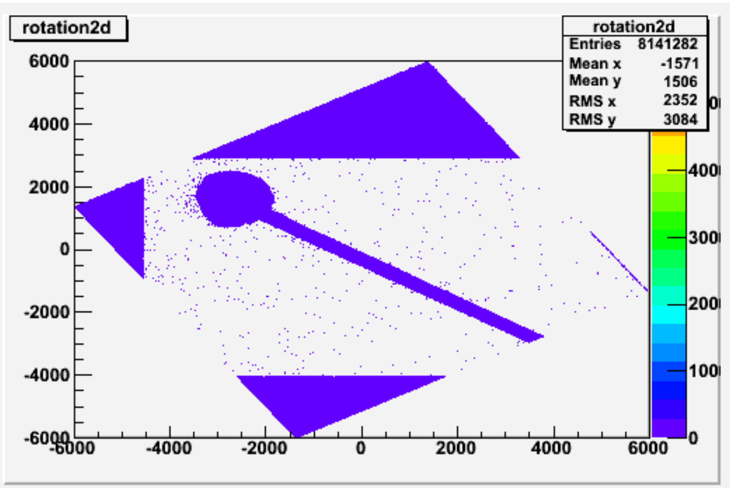
$$\frac{\partial(ERF)}{\partial x}$$



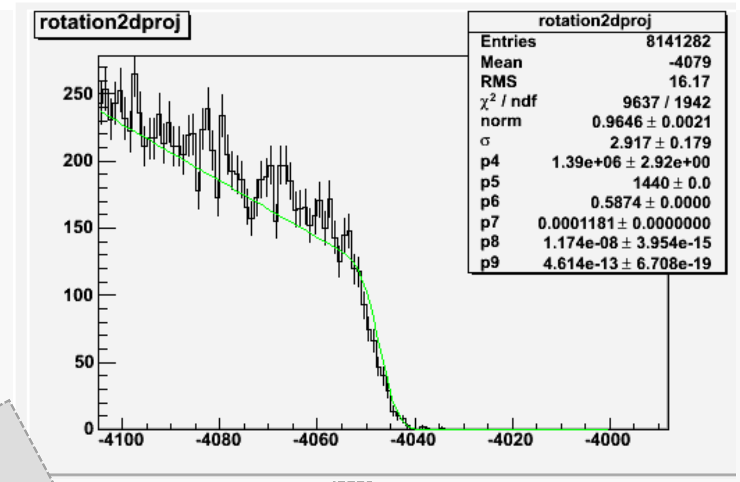
LSF

- Since a line is the derivative (or first difference) of an edge, the LSF is the derivative (or first difference) of the edge response.

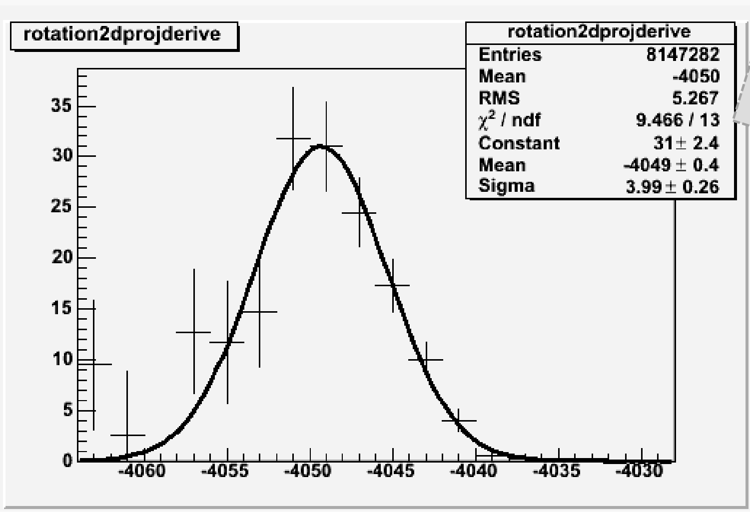
Resolution Results (With Fe55 without crystal)



Choose side and project it



Derive histogram



Sigma within ERF = 2.9 ± 0.18 μm

Sigma within LSF = 4 ± 0.26 μm

Next steps

- Represent the resolution using MTF function
- Find the spacial resolution of the system with crystal
- Deeper study on energy resolution
- Do the same work but with a more reliable sensor
- …

Thank you for your listening!!