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Evaluation of some features of the gamma camera using the software GATE

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Outline

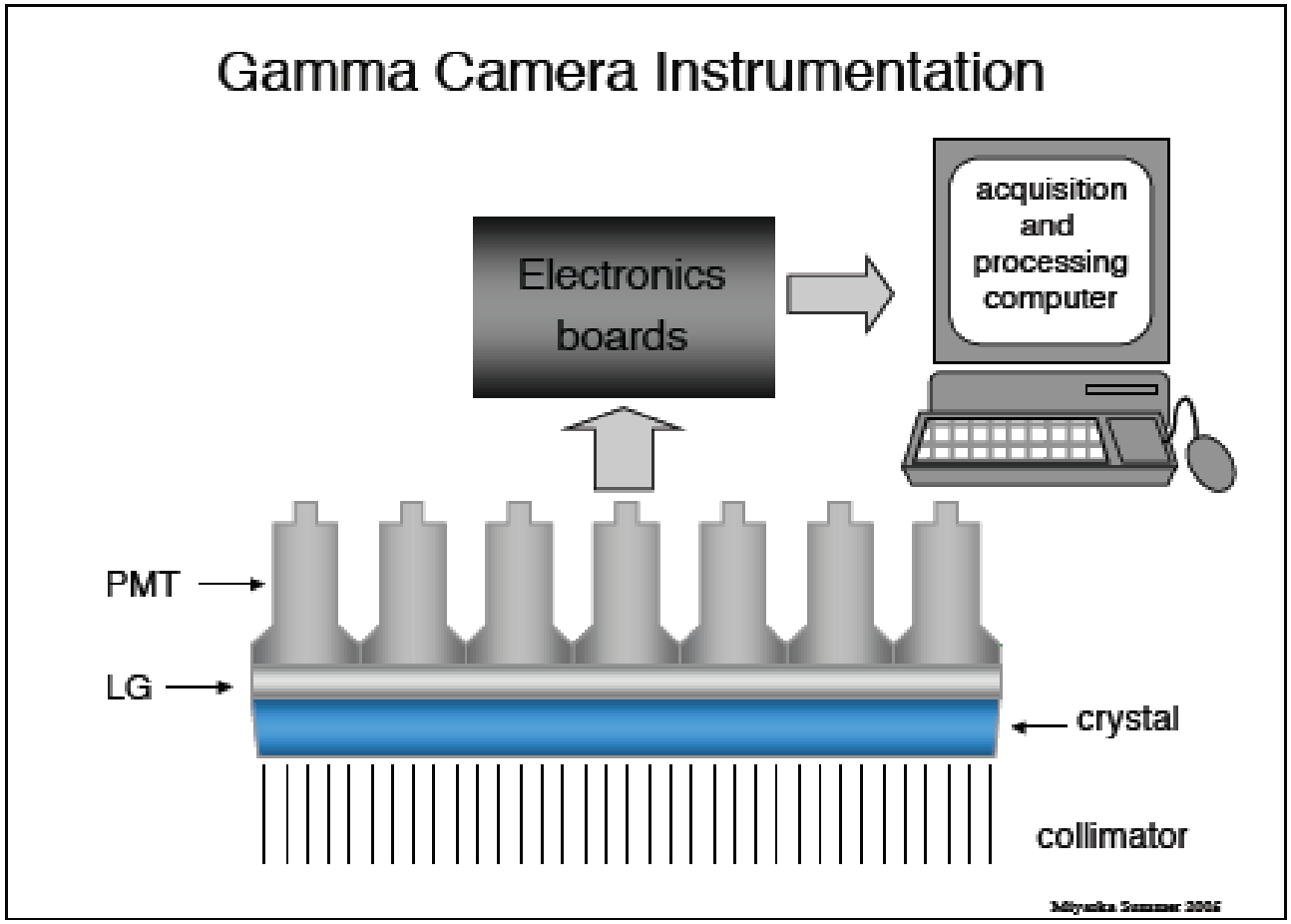
- Objectives
- Gamma camera
- Simulation of gamma ray detection
- Validating experiment
- Conclusion

Objectives

- The gamma camera is a very important device in the nuclear medicine departments
- Interest is to improve the functioning of this device and the image quality
- The aim of this work is to evaluate some characteristics of the gamma camera
- This issue will be realized by the simulation of a gamma ray detection via the gamma camera in static mode

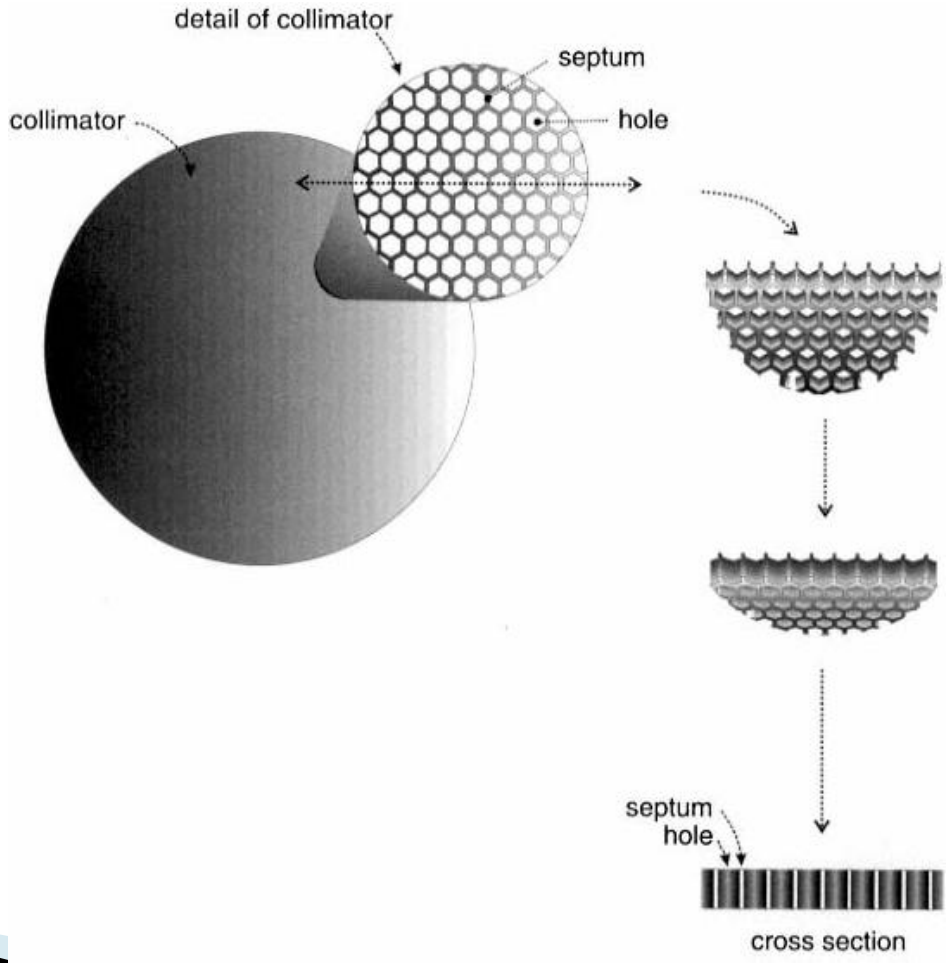
Gamma camera

- The gamma camera is composed of:

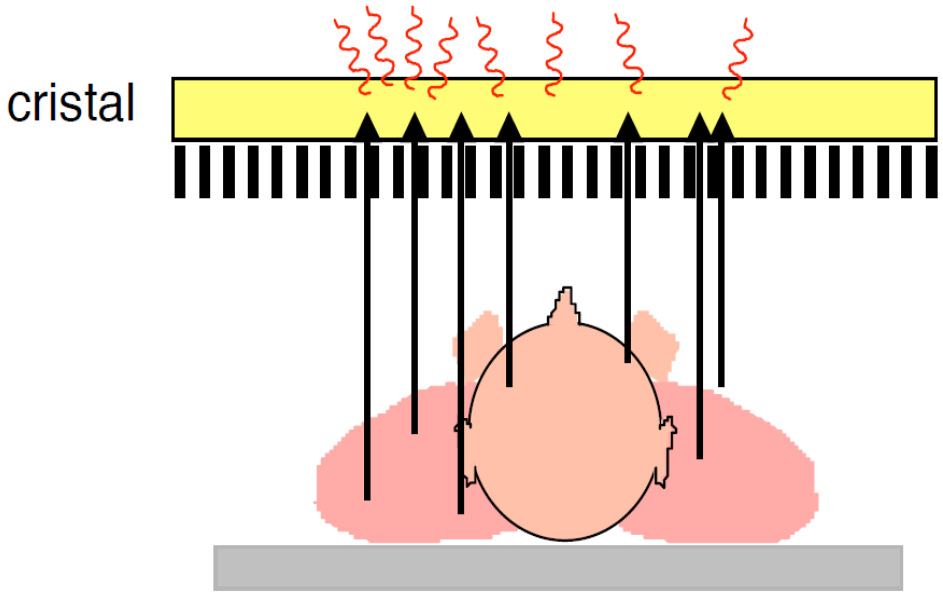


Gamma camera

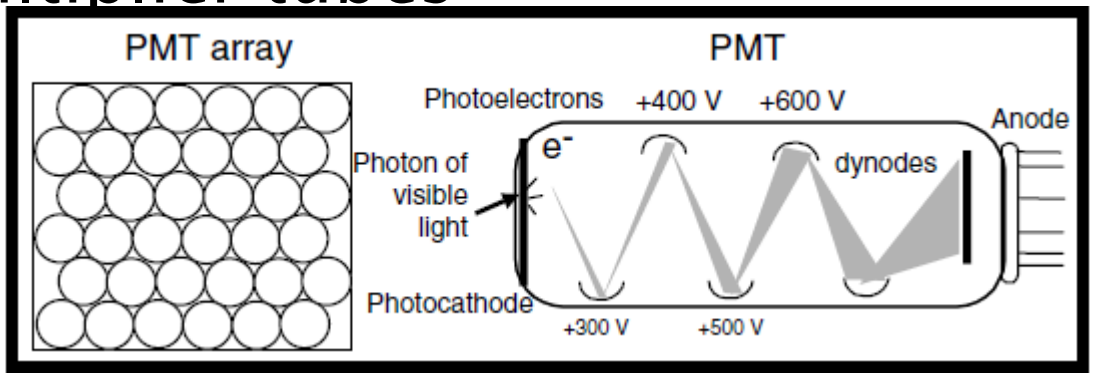
- Collimator

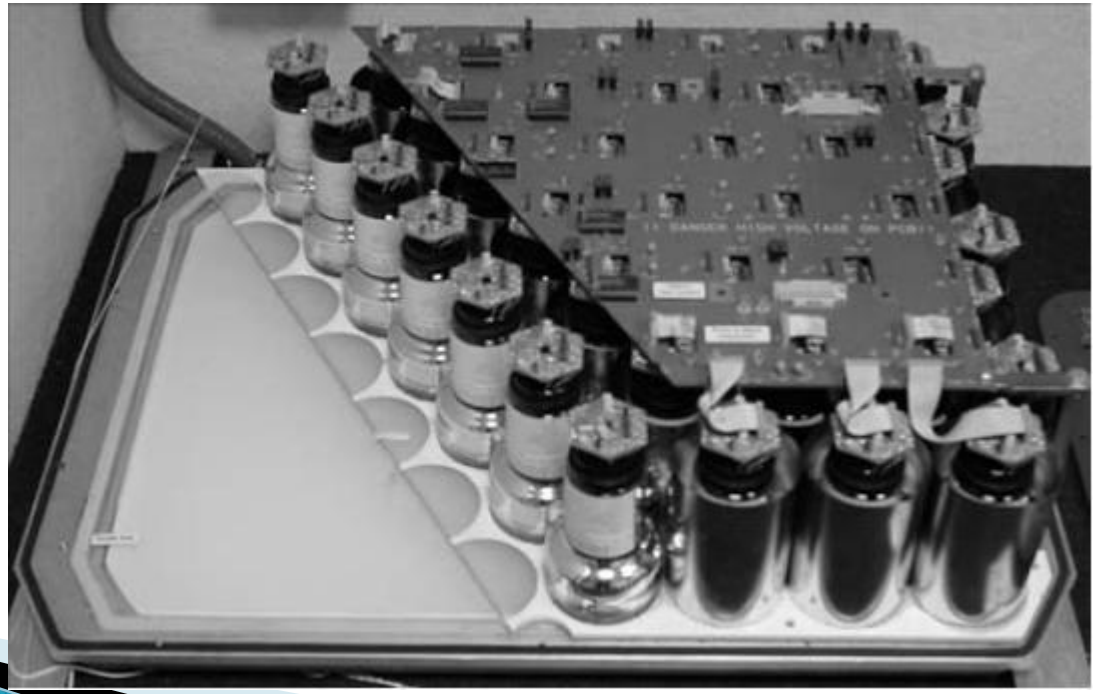


- Crystal



- Photomultiplier tubes





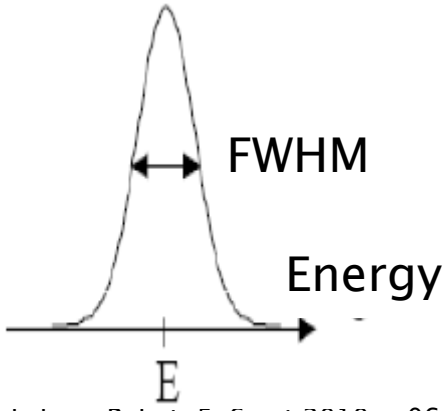
Gamma camera

- The characteristics of a gamma camera are
  - Spatial resolution: the minimum distance between two photons which the detector gives two distinguishable images

$$r_s = \sqrt{r_i^2 + r_c^2}$$

  - Energy resolution: the capacity of the detector to determine the accurate energy of a detected photon

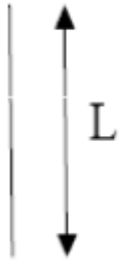
R(%)= (FWHM/E)*100



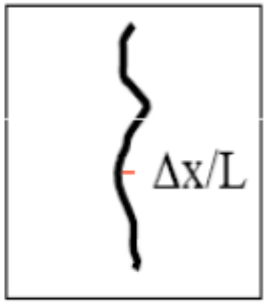
Gamma camera

- Sensitivity: defined by the ratio of the detected photons number and the global number of the photons emitted by the source

- Linearity: the capacity of the gamma camera of reproducing the exact shape of an object



Line source

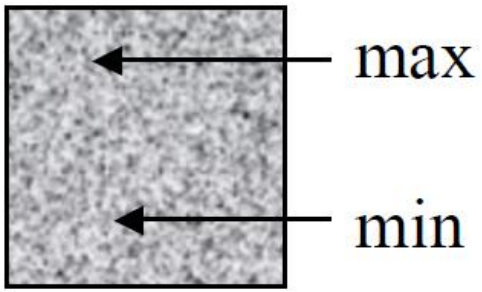


Resulted image

Gamma camera

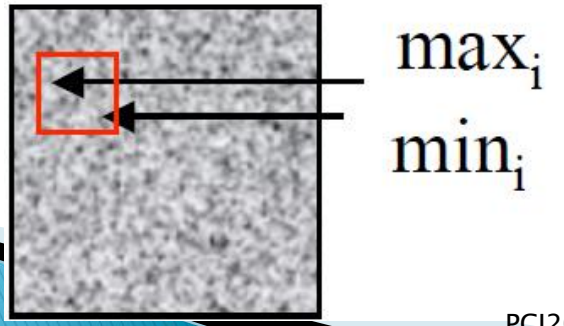
- Uniformity: the capacity of the gamma camera to give an homogeneous image for a uniform source
  - Integral uniformity

$$U=[(V_{max} - V_{min}) / (V_{max} + V_{min})]*100$$



  - Differential uniformity

$$U_d\ (\%) = [(Max\ \Delta V - Min\Delta V)/(Max\ \Delta V + Min\Delta V)]*100$$

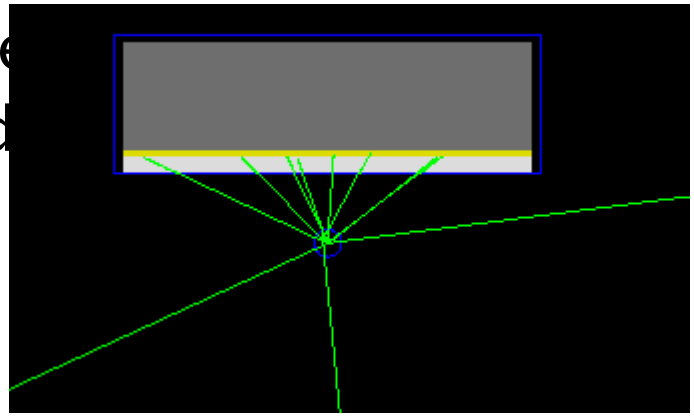


$$\Delta V = max_i - min_i$$

Simulation of a gamma ray detection

- The objective is to evaluate the energy resolution, the sensitivity and the spatial resolution of the gamma camera

- Simulation of a gamma ray detection by the gamma camera
  - GATE software
  - Data provided

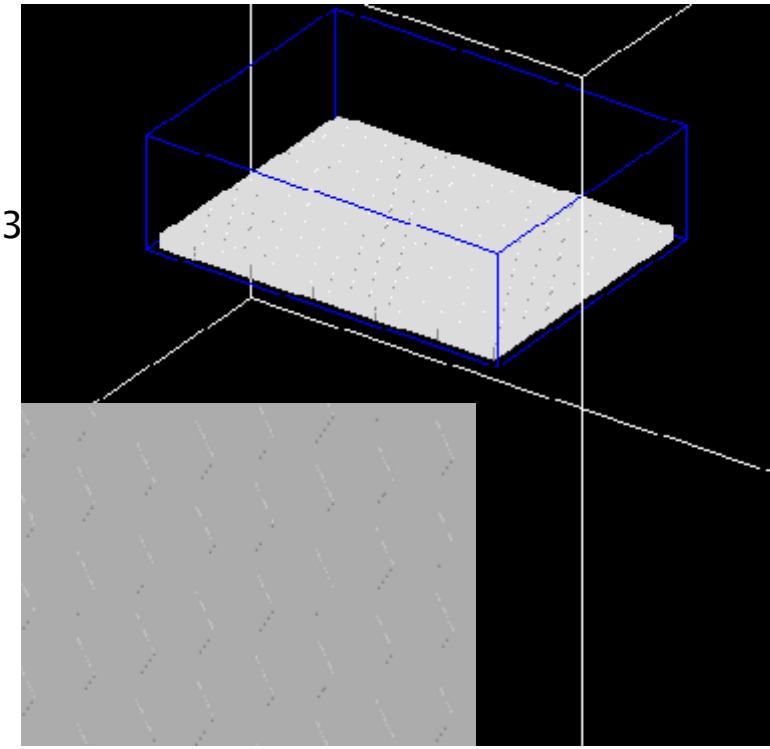


GATE

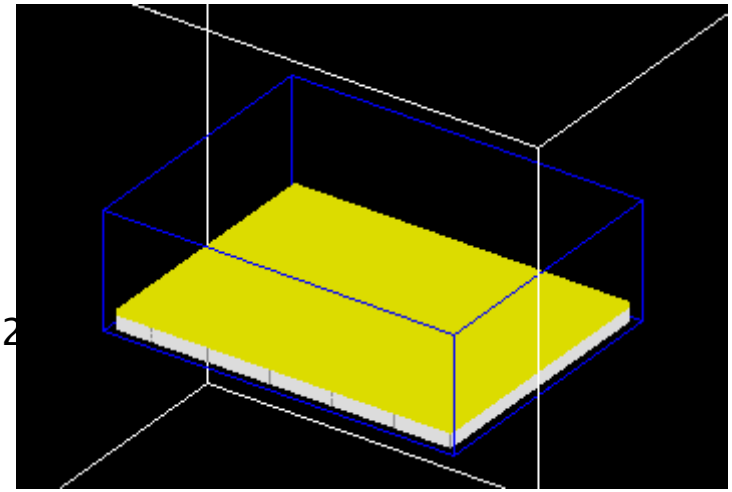
- GATE=GEANT4 Application in Tomographic Emission
- Open source software
- Allows the simulation of the devices using tomographic emission (PET and SPECT)
- Managed the time and mouvement of the devices component (rotation, translation …)
- Easy use of its scripts

SPECT

- The characteristics used for the simulation:
  - Single head SPECT gamma camera, Siemens e.cam
  - Collimator
    - A parallel hole collimator:
    - Dimensions: 59.1x44.5x2.405 cm^3
    - Hole's shape: hexagon
    - Hole's diameter: 1.11mm
    - Septum's thickness: 0.16 mm



SPECT

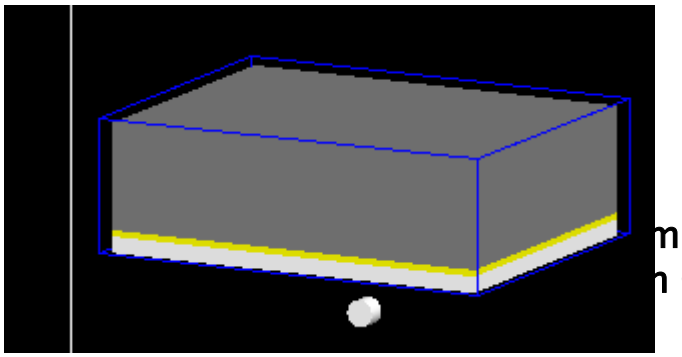


- Crystal:
  - Crystal type: NaI
  - Crystal thickness: 0.95 cm (3/8”)
  - Crystal dimensions: 59.1x44.5 cm^2
- System Spatial resolution: 7.4 mm
- Energy resolution: 9.9%

Phantom

- A cylindrical phantom filled of water
- Dimensions:
  - Radius: 2cm
  - Height: 3cm
- Distance from the SPECT head surface: 10 cm
- In GATE:

/gate
/gate
/gate
/gate
/gate
/gate
/gate



m
n 0. -19.975 0 cm

Source

- 99 metastable technetium: ^{99m}Tc
- Gamma rays emission, 140 kev
- Short half life: 6 hours
- Very used in the nuclear medicine explorations

Source

- Activity used : 37 MBq
- Energy window: 15%
- In GATE:

```
/gate/source/addSource SourceConfinement
/gate/source/SourceConfinement/gps/type Volume
/gate/sou                                ylinder
/gate/sou    urceConfinement/gps/        mm
/gate/sou    urceConfinement/gps/        m
/gate/sou    urceConfinement/gps/        -19.975 0. cm
/gate/sou                                gamma
/gate/sou                                40. keV
/gate/sou                                fLife 21600 s
/gate/sou                                001 Ci
/gate/sou                                iso
/gate/source/SourceConfinement/gps/mintheta 0. deg
/gate/source/SourceConfinement/gps/maxtheta 180. deg
/gate/source/SourceConfinement/gps/minphi 0. deg
/gate/source/SourceConfinement/gps/maxphi 360. deg
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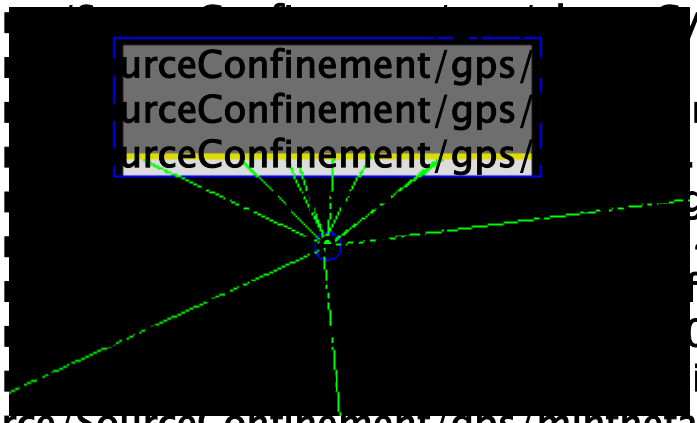

Result of the simulation

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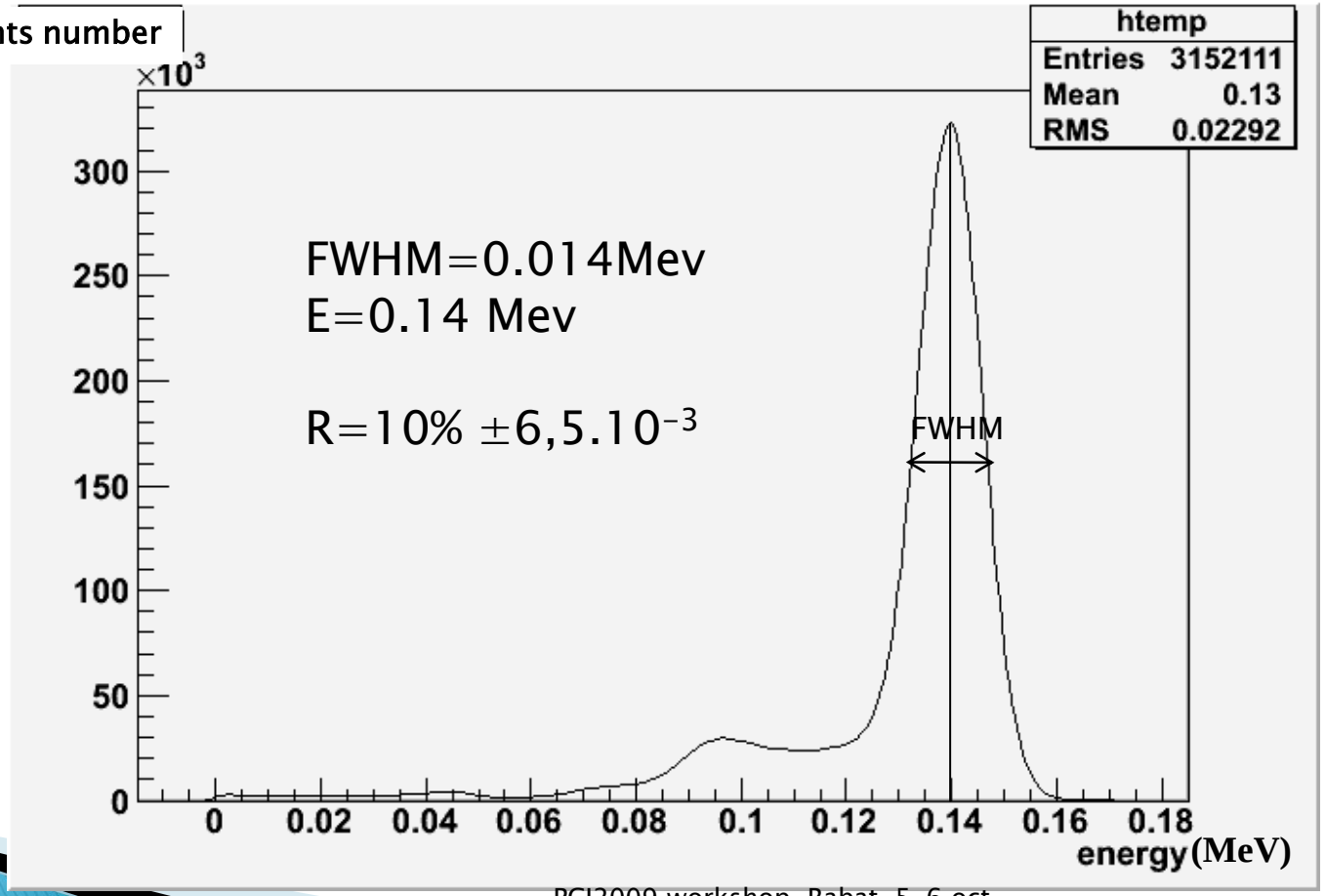
Energy resolution

- Energy spectrum



The validating experiment

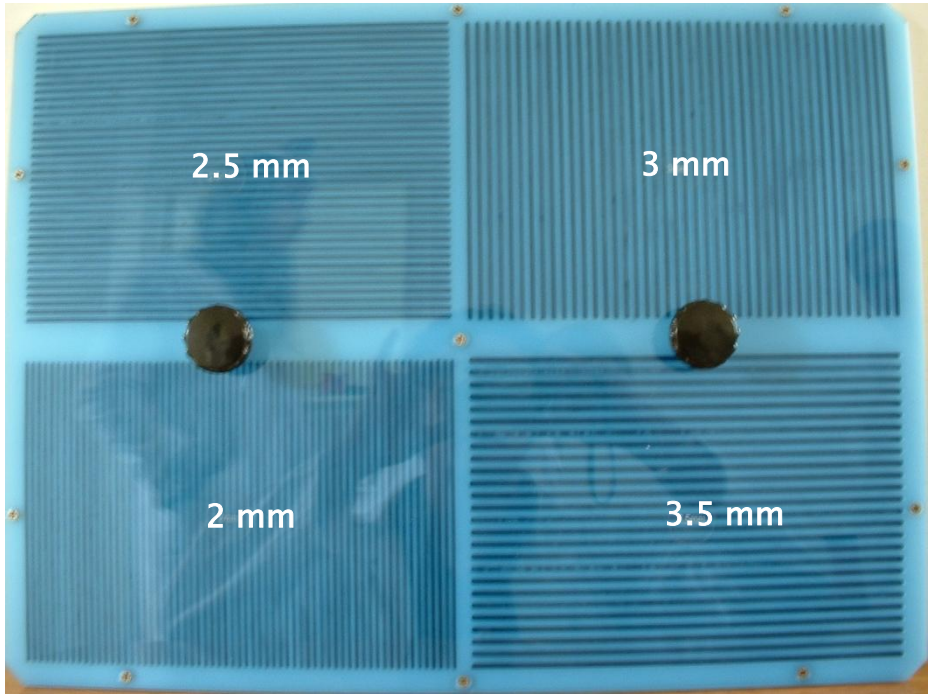
- The objective of this experiment is to validate the simulation results
- Applied to the gamma camera of nuclear medicine department of Ibn Sina hospital

Experiment steps

- Step 1 (before the manipulation)
  - Make some quality control:
    - Peaking: verifying the energy spectrum, and the offset of the technetium energy peak
    - Tuning: automatic adjustment of the PMTs gain
    - Uniformity quality control: verification of the image homogeneity

- Step 2 (sensitivity)
  - The aim of this test is to verify the gamma camera response to radionucleide source of known activity
  - The sensitivity is determined by the ratio of the detected counts per second (cps) per unit activity in the source
  - Source of 37 MBq
  - Distance source-face of the SPECT head: 10 cm
  - Time of acquisition: 100 s

- Step 3 (spatial resolution)
  - For this test we'll use a quandrant bar phantom



- A source of: 37 MBq
- A preset count 6.10^6
- The phantom is positioned between the source and SPECT head
- The spatial resolution is calculated using the formula:

$$FWHM = 1.75 \times B$$

B= the width of the smallest bar that can be visualized

Conclusion

- The result of the simulation for the energy resolution (10%) match with the value given by the constructor (9.9%)
- The experiment will be done in the futur
- The next steps:
  - Evaluate the spatial resolution and the sensitivity
  - To validate the simulation results for the gamma camera in the tomographic mode

Thank you