Validation of the Small Animal Biospace Gamma Imager Model Using GATE Monte Carlo Simulations on the Grid

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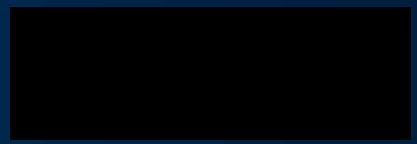

Inserm

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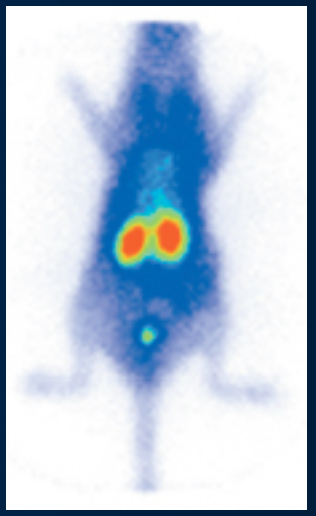
Introduction

Problem:

SPECT images have a poor quality



Idea:

Correction of the attenuation and the scattering from images

Key:

Modelling the detector and all the physical interactions

Solution:

Monte Carlo Simulations => accurate model [Buvat I., 2006]

Disadvantage:

Long computing time

Solution:

Grid computing [Breton V., 2003]

Outline

1) Introduction

2) Tools and Experiments
   - Monte Carlo Simulations toolkit
   - CiGri Grid
   - The small animal gamma camera model
   - Experimental set-up
   - Parallelization of the simulations
   - Validation of the camera model

3) Results

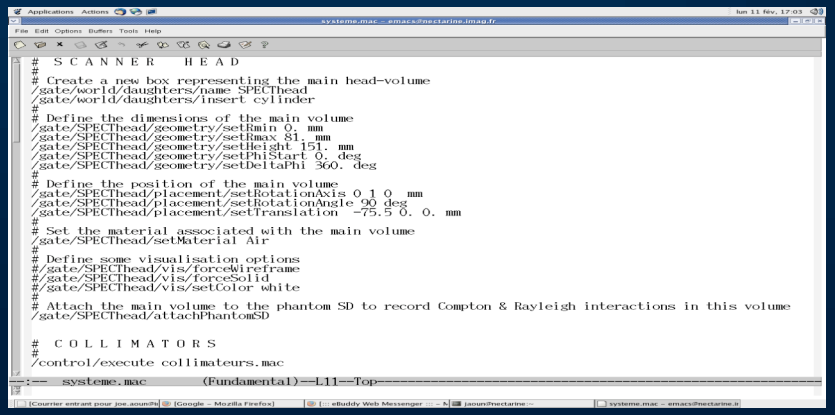
4) Conclusions and Perspectives

Monte Carlo Simulation toolkit : GATE

Geant4 **A**pplication for **T**omographic **E**mission

"**GATE: a simulation toolkit for PET and SPECT**",
S. Jan et al, ***Phys. Med. Biol.,*** 49 (2004) 4543-4561.

- based on GEANT4 : a standard simulation package for high energy physics
- open source and modifiable
- coded in C++ : more than 200 classes
- easy to use : simulations are defined and controlled by macros and scripts

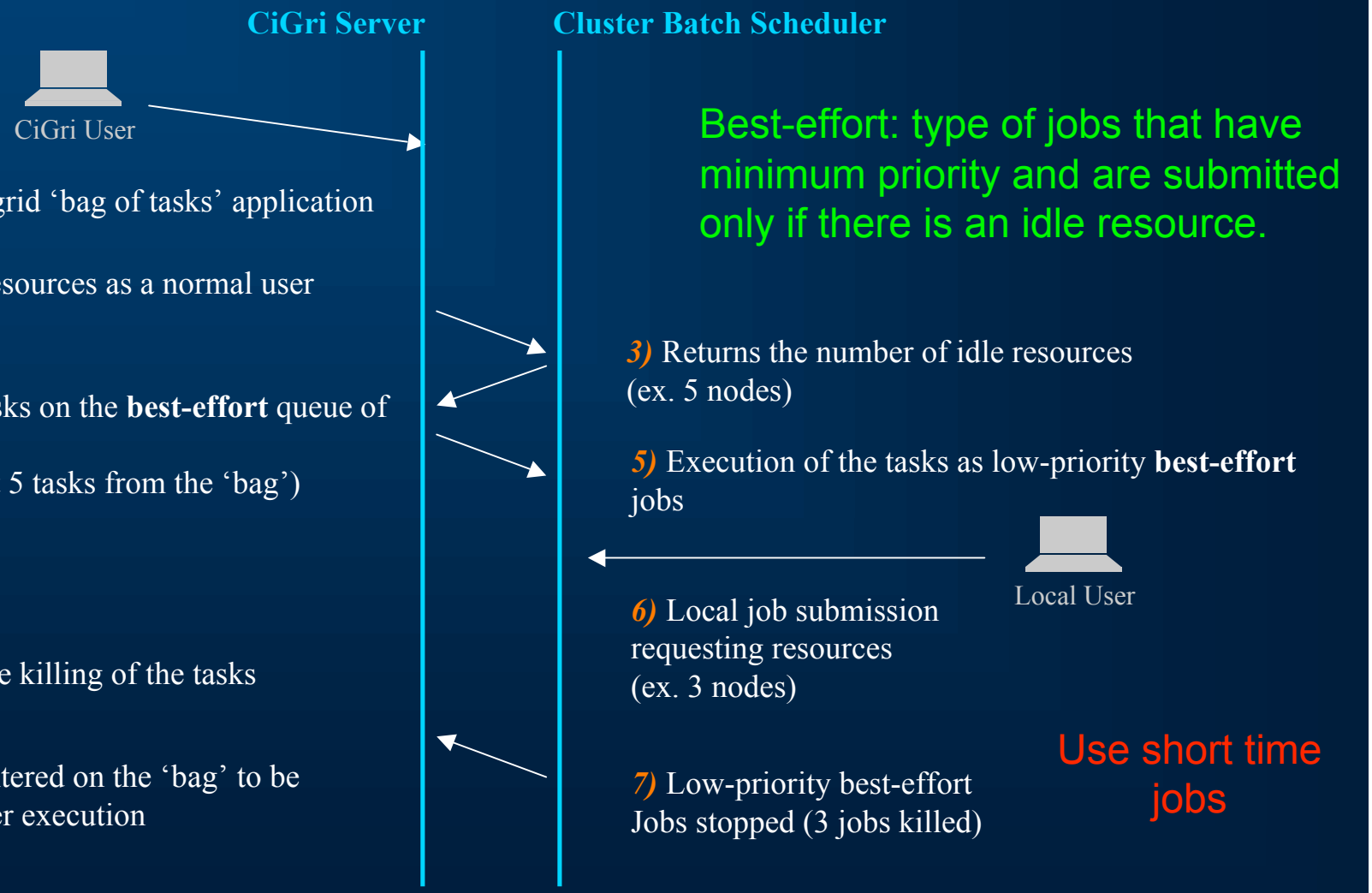


```
#  S C A N N E R    H E A D
#
# Create a new box representing the main head-volume
/gate/world/daughters/name SPECThead
/gate/world/daughters/insert cylinder
#
# Define the dimensions of the main volume
/gate/SPECThead/geometry/setRmin 0. mm
/gate/SPECThead/geometry/setRmax 81. mm
/gate/SPECThead/geometry/setHeight 151. mm
/gate/SPECThead/geometry/setPhiStart 0. deg
/gate/SPECThead/geometry/setDeltaPhi 360. deg
#
# Define the position of the main volume
/gate/SPECThead/placement/setRotationAxis 0 1 0  mm
/gate/SPECThead/placement/setRotationAngle 90 deg
/gate/SPECThead/placement/setTranslation  -75.5 0. 0. mm
#
# Set the material associated with the main volume
/gate/SPECThead/setMaterial Air
#
# Define some visualisation options
#/gate/SPECThead/vis/forceWireframe
#/gate/SPECThead/vis/forceSolid
#/gate/SPECThead/vis/setColor white
#
# Attach the main volume to the phantom SD to record Compton & Rayleigh interactions in this volume
/gate/SPECThead/attachPhantomSD


#  C O L L I M A T O R S
#
/control/execute collimateurs.mac
```

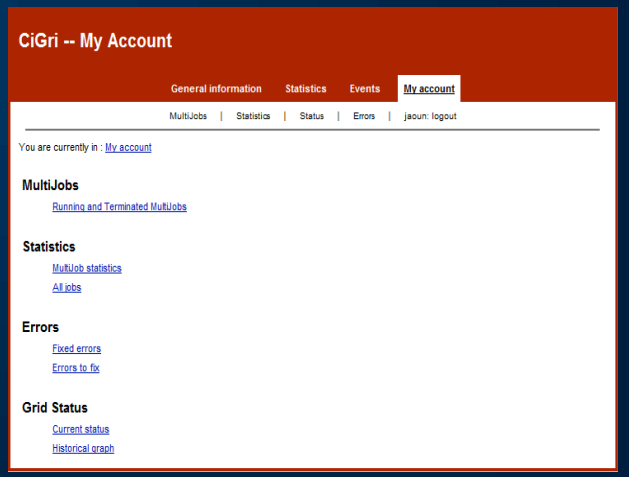
CIMENT Grid : CiGri

➡ Exploits the idle resources of the CIMENT clusters of the University of Grenoble



CiGri infrastructure

- Resource management system : OAR *(http://oar.imag.fr)*
- CiGri software: SQL database interacts with independent modules
  - scheduling jobs
  - submitting jobs
  - cluster synchronizing
  - monitoring jobs
  - collecting results
  - logging errors
  - killing jobs



- Accessible through a User Interface and monitored through a web portal

(https://ciment.imag.fr/cigri)

Submission of a job on CiGri

JDL

1. Macro_i
2. Status_i

Cluster 1

User Interface

Cluster 2

Output_i

Automatically collected

Cluster 3

GATE on CiGri

	Total		GATE availability (max)		GATE availability (average)	
	Clusters	CPUs	Clusters	CPUs	Clusters	CPUs
Day	11	886	7	430	7	125
Nights and Weekends	11	866	7	555	7	215

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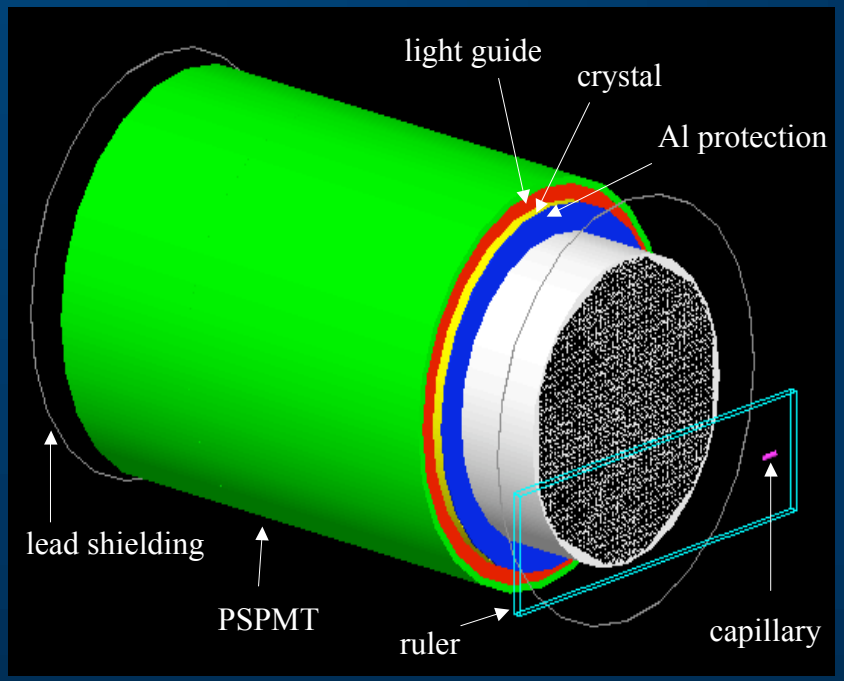
The Biospace small animal γ Imager model

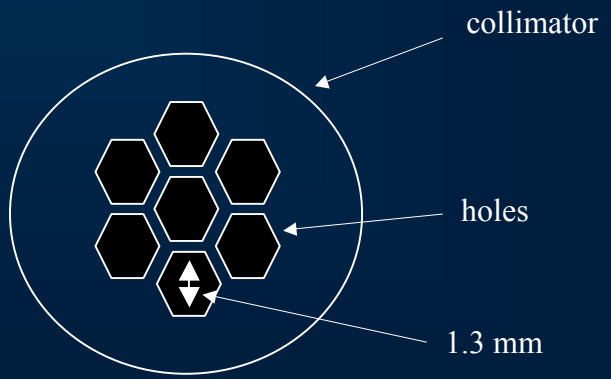


Circular field of view
D = 10 cm

Continuous NaI(Tl) crystal :
D = 12 cm & thickness = 4 mm

PSPMT = Photomultiplier modelled as a 2 mm glass entrance window and a 11 cm nickel backpart

LEHR parallel hole collimator with 35 mm thickness

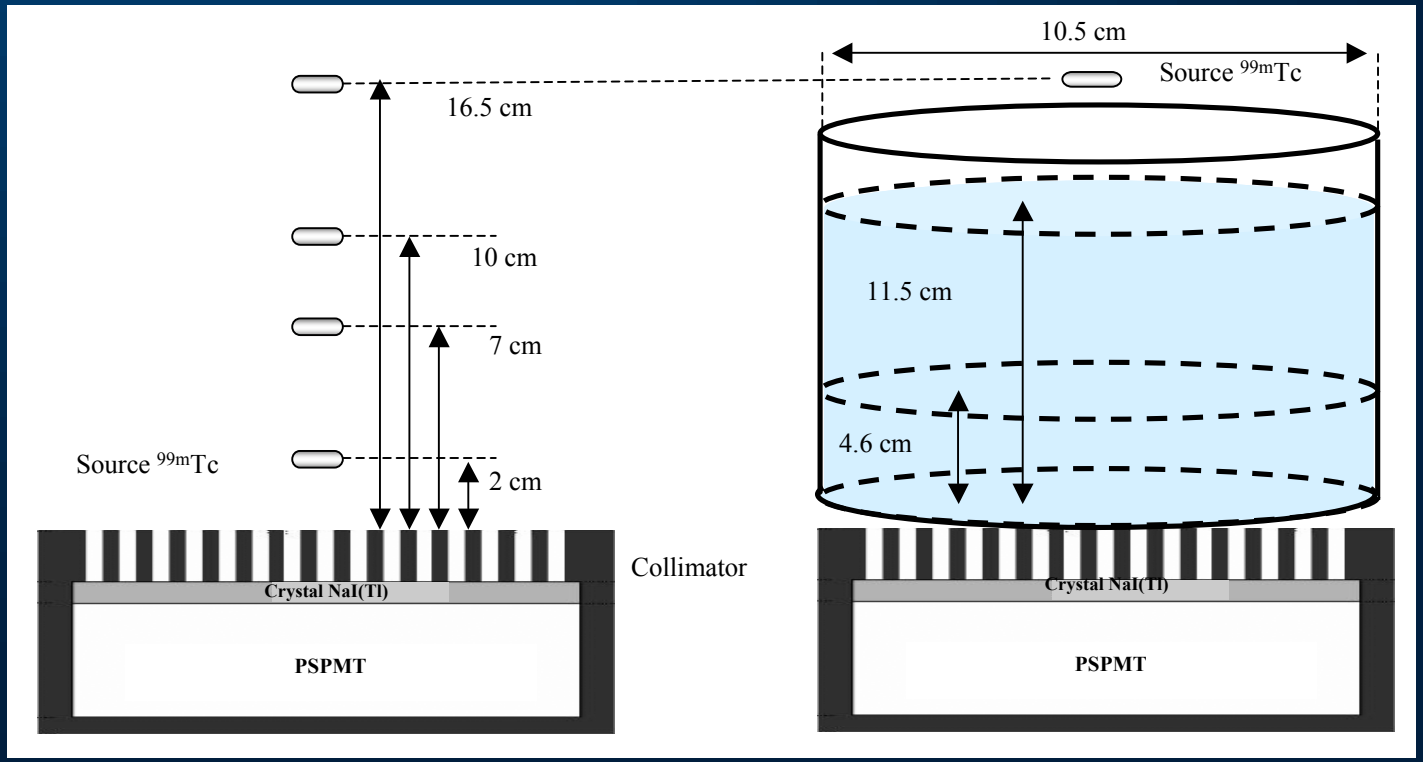


Septum thickness = 0.2 mm

Experimental set-up: Source in the center of the Field Of View

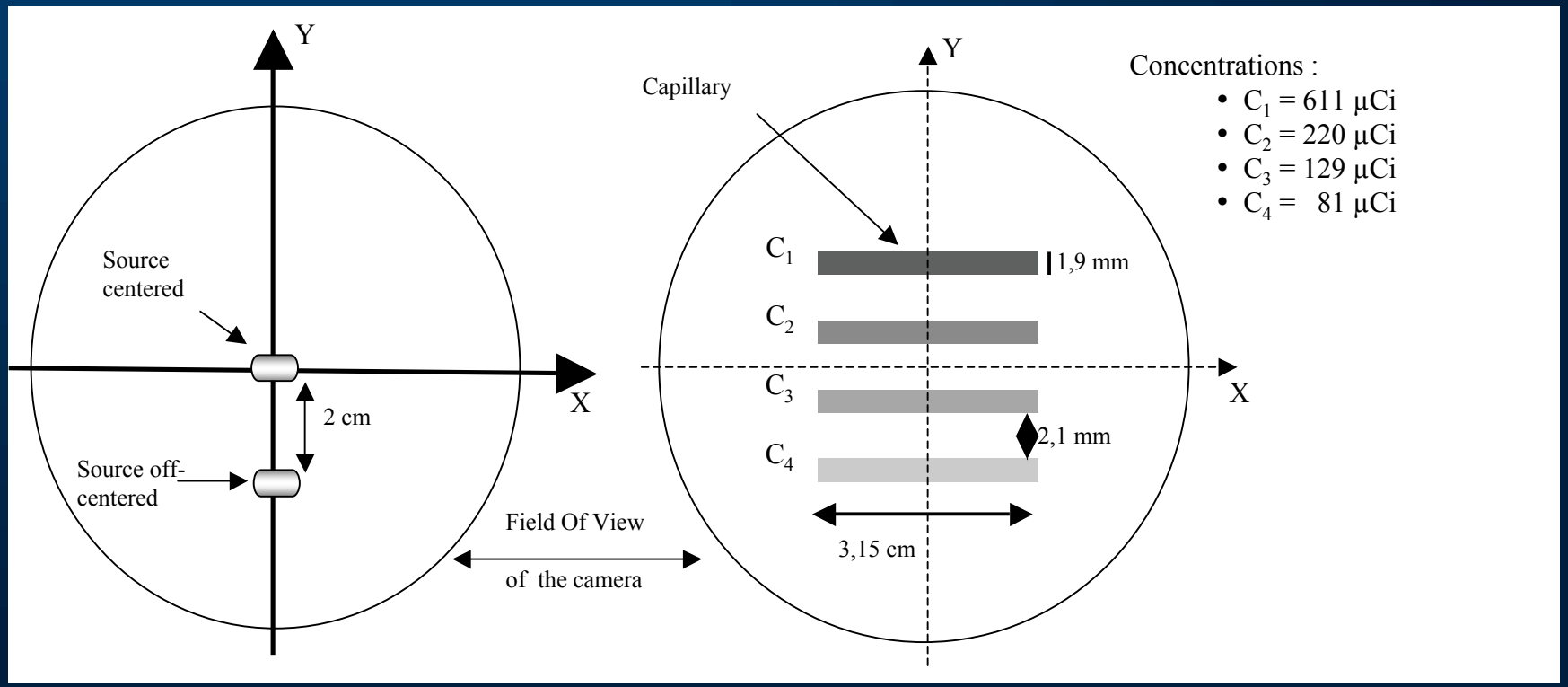
- The radioactive background measured first and subtracted from all the other measurements

Source placed at different distances from the camera in the air and above a beaker filled with water



Experimental set-up: Source 2 cm off-centered and image of a 4 capillaries phantom

Previous measurements were repeated with the source 2 cm off-centered



Parallelization of the simulations

Optimization of the camera model: ~ 200 different models were tested

1 configuration → 1 big simulation → 1 billion emitted events → 30 billions random numbers

1 small simulation → 1 million emitted events → 30 millions random numbers → 10 minutes

Local CPU: Pentium IV, 3.2 GHz, 1 Go RAM

The Random number streams should be independent

[Reuillon R., 2008]

Output files of the simulations

1. Retrieved from CiGri
2. Merged into one file on a local CPU
3. Analyzed with the ROOT object oriented data analysis framework

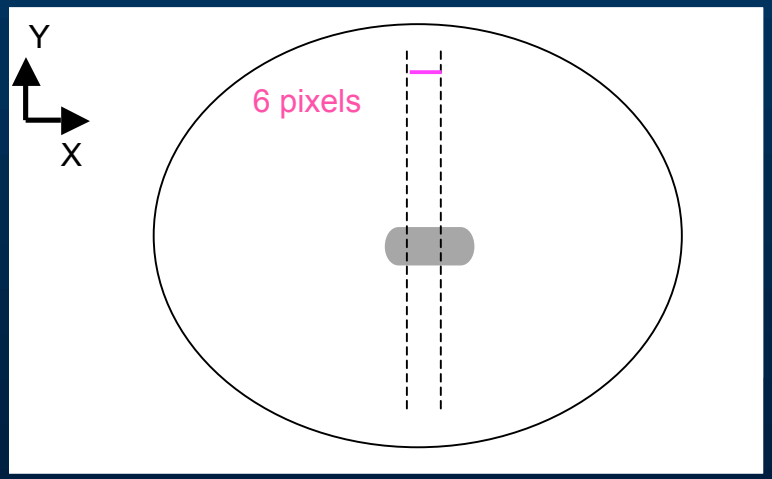
(http://root.cern.ch/)

Validation of the γ Imager model

➡ Comparison of 4 parameters measured experimentally with the corresponding simulated data

Features of a gamma camera

- Energy spectra: events recorded in the whole FOV (40 – 186 keV)
- Sensitivity: Nb of detected events / Nb of emitted events
- Spatial Resolution: events recorded in the photopic window 126 – 154 keV



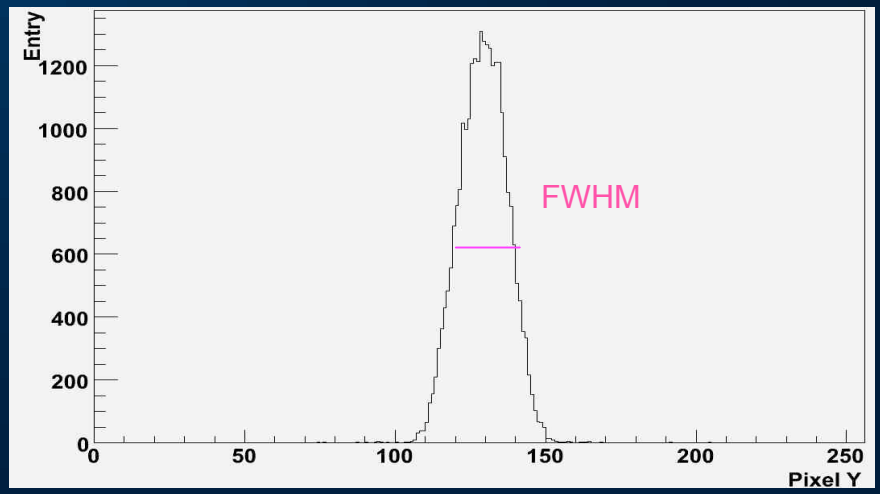


Image of a capillary phantom: a visual comparison of an inhomogeneous phantom

Outline

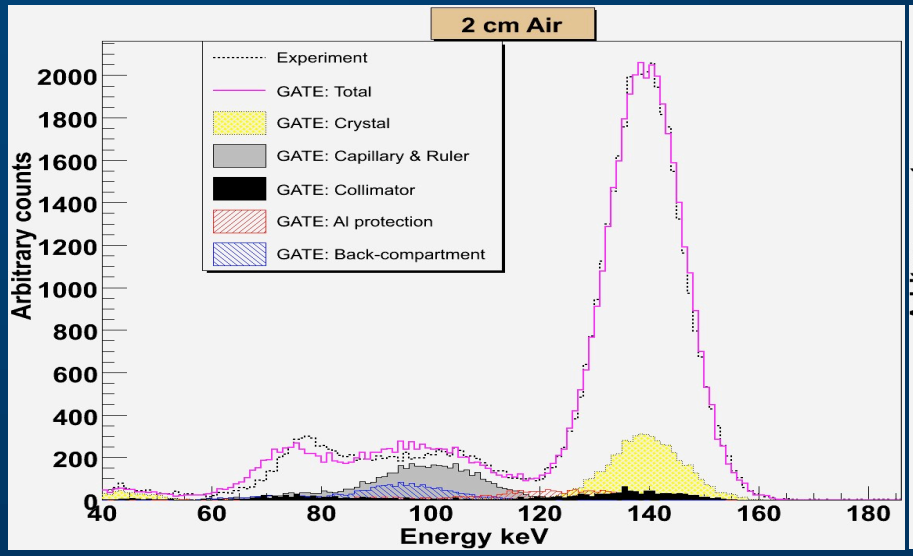
1) Introduction

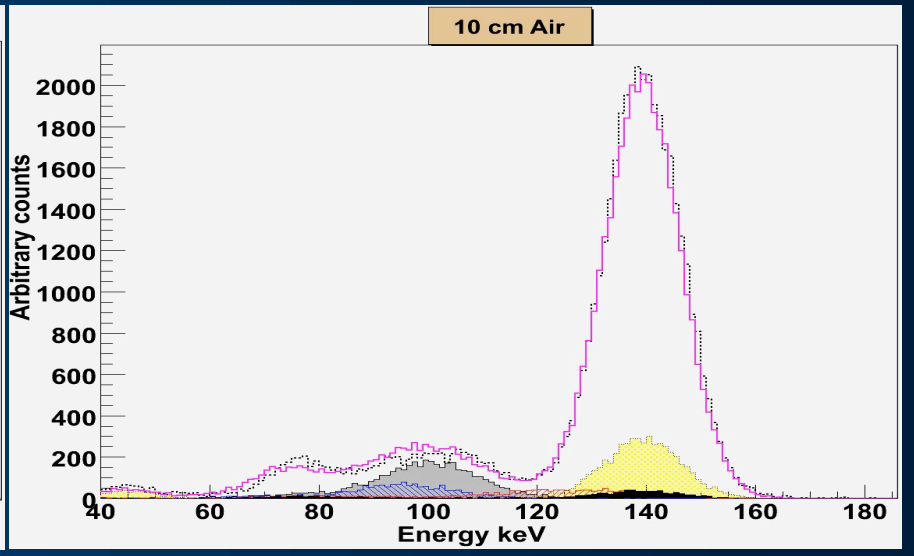
2) Tools and Experiments

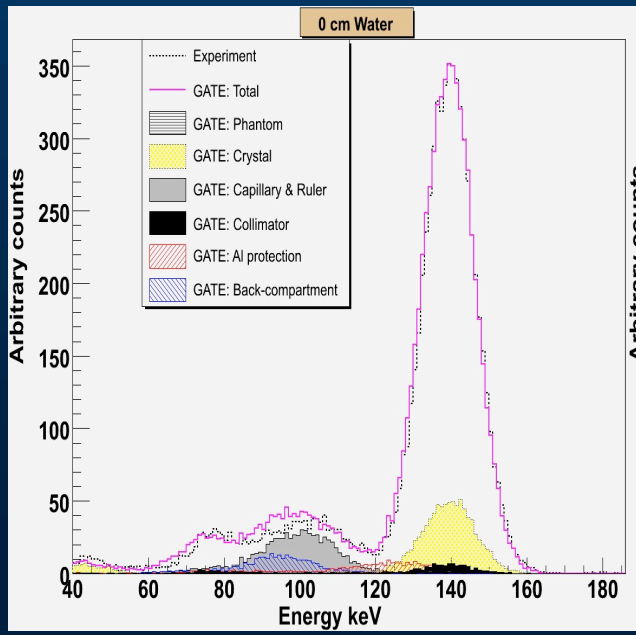
3) Results
   - Energy Spectra
   - Sensitivity
   - Spatial Resolution
   - Image of a capillary phantom
   - CiGri performance

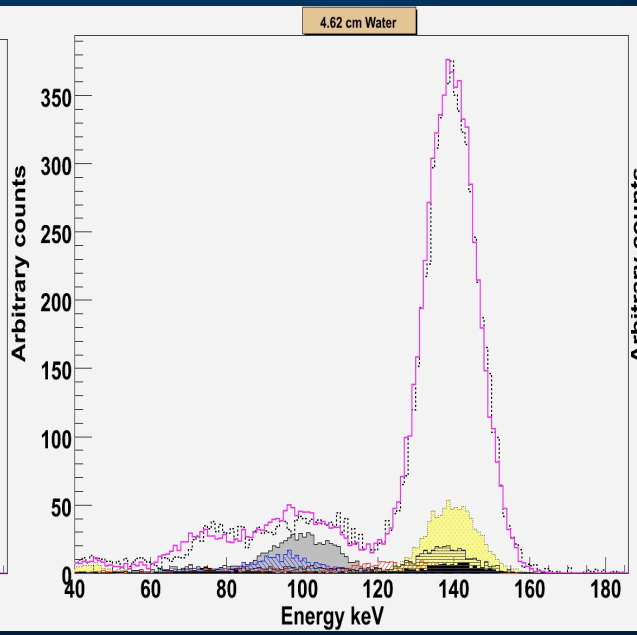
4) Conclusions and Perspectives

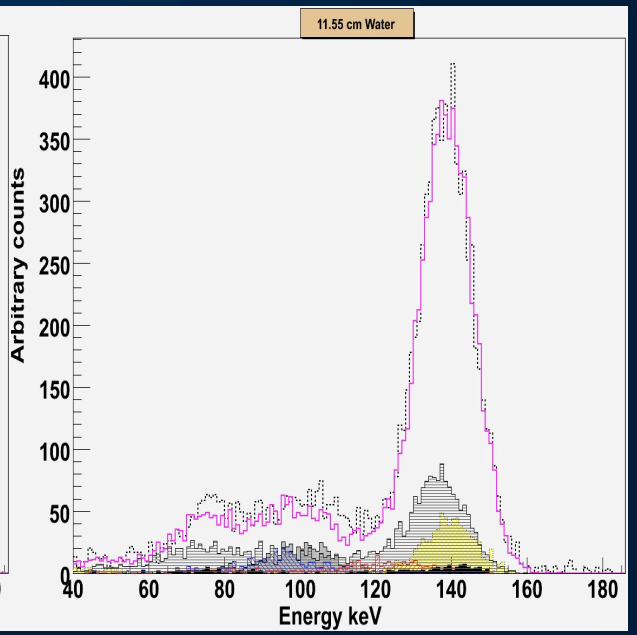
Energy Spectra



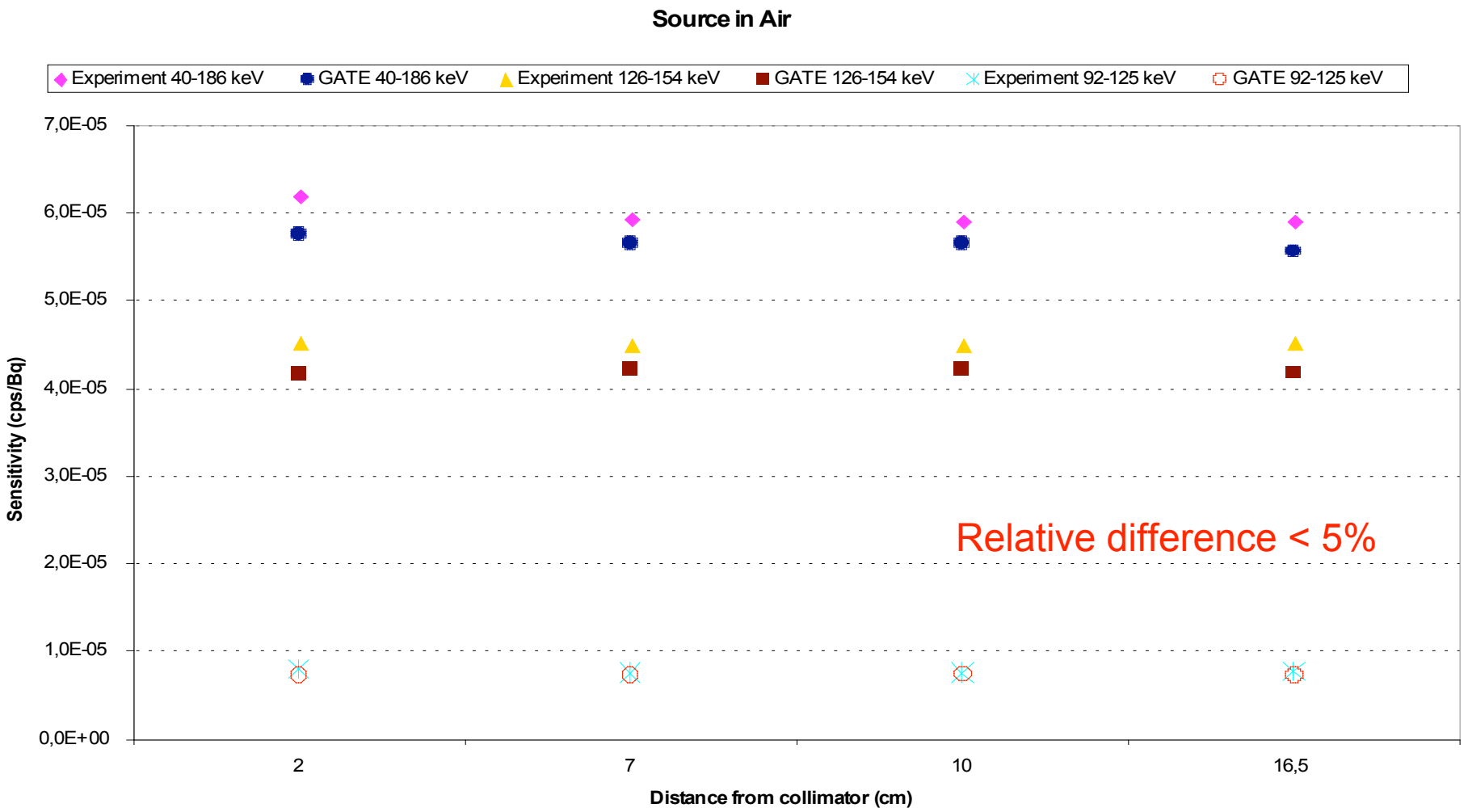




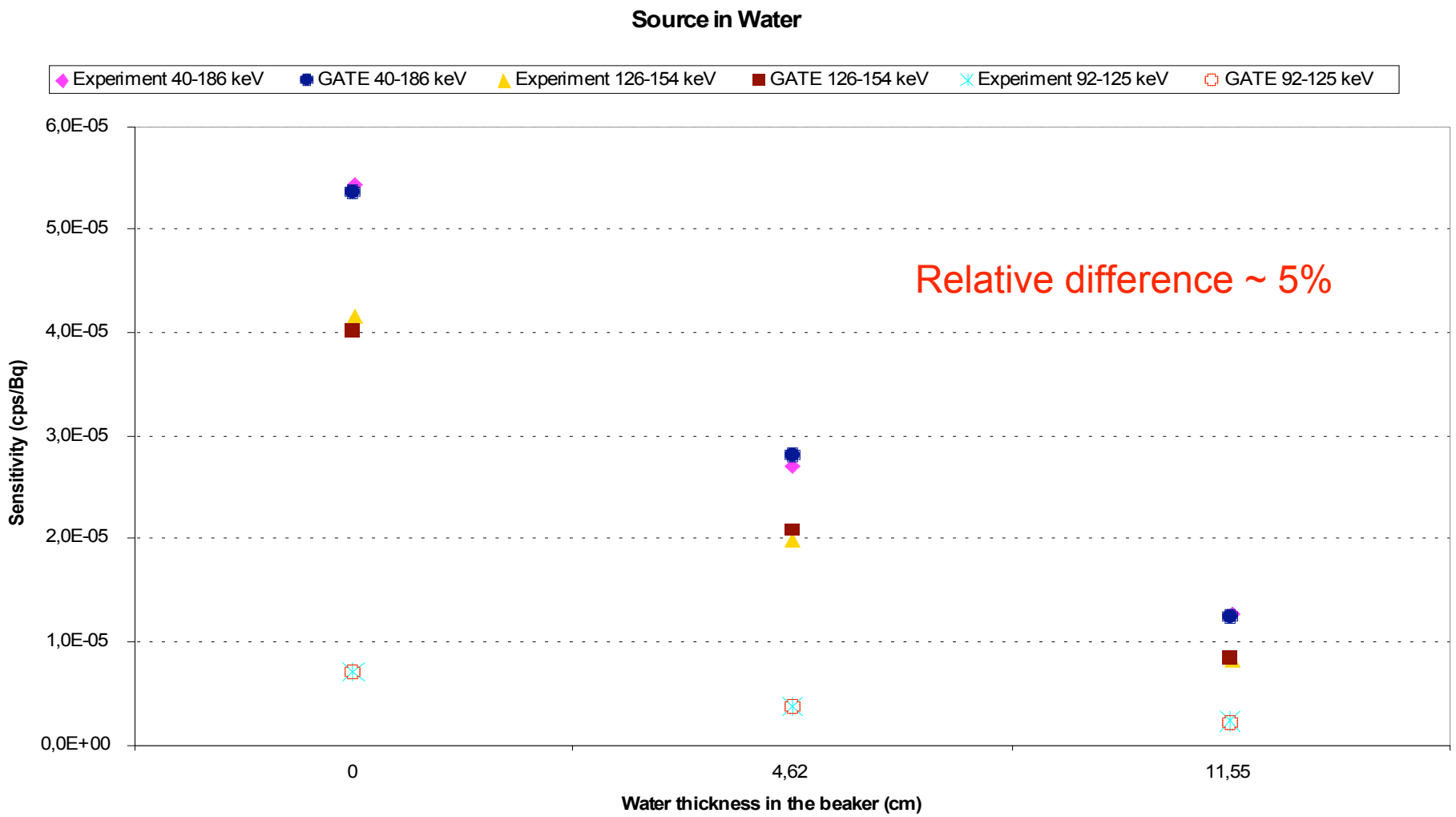




Sensitivity in Air



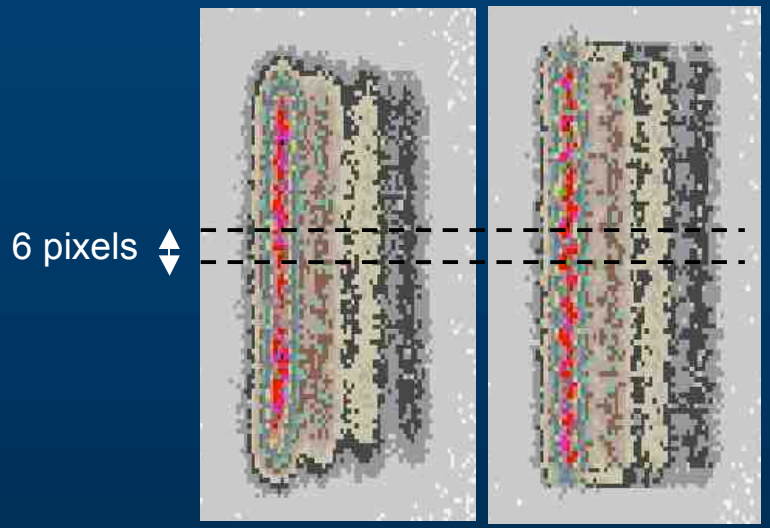
Sensitivity with the Beaker



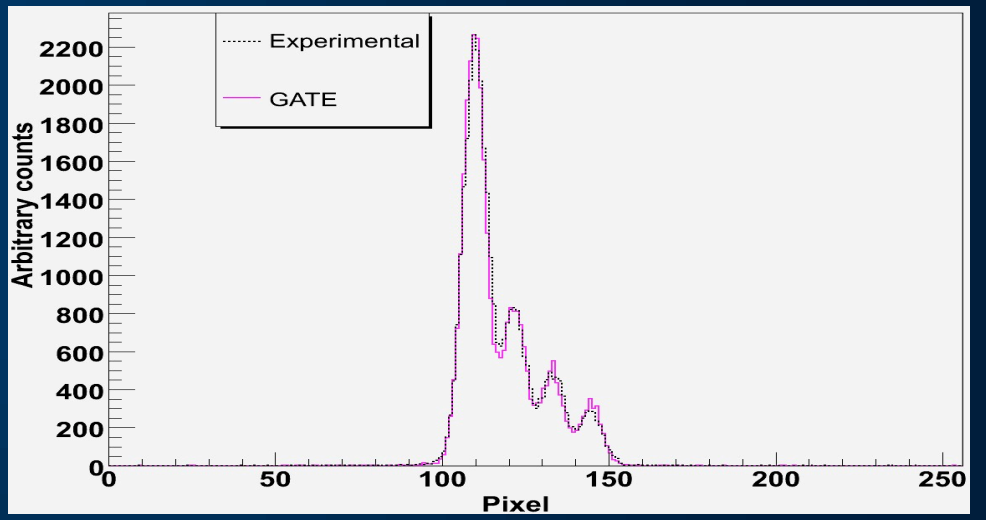
Spatial Resolution

Distance source-collimator (water thickness)	Centered Source			Off-centered Source		
	Experimental FWHM (mm)	Simulated FWHM (mm)	Difference (%)	Experimental FWHM (mm)	Simulated FWHM (mm)	Difference (%)
2 cm	3.34	3.22	3.64	3.58	3.20	10.5
7 cm	4.53	4.54	1.89	4.75	4.53	4.49
10 cm	5.32	5.40	1.47	5.61	5.39	3.95
16.5 cm	7.25	7.34	1.30	7.64	7.37	3.49
16.5 cm (0 cm water)	7.27	7.39	1.63	7.63	7.38	3.32
16.5 cm (4.62 cm water)	7.26	7.32	0.91	7.62	7.26	4.69
16.5 cm (11.55 cm water)	7.58	7.65	0.91	7.83	7.61	2.85

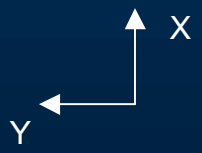
Image of the capillary Phantom



Experiment GATE



6 pixels profile



CiGri performance

	1 simulation (1000 jobs)	200 simulations	Gain	Resubmission percentage (%)
Local CPU Pentium IV, 3.2 GHz, 1 Go RAM	167 h	1392 days (~ 4 years)	1	0
CiGri – day	4 h	37 days	42	16.9
CiGri – nights and weekends	2.5 h	21 days	67	10.2
CiGri – estimated average	3 h	25 days	56	13.4

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Conclusions

- GATE was able to accurately model the Biospace ɣ Imager.

- Computing grid = indispensable tool in the field of nuclear medical imaging

=> Deployment of large scale computations and reducing considerably the elapsed time.

=> Getting more accurate statistical results by increasing the number of tests.

Perspectives

- **F**ully **3D** **M**onte **C**arlo reconstruction method [El Bitar Z., 2006].
  - Using the camera model => investigating new algorithms such as an iterative reconstruction algorithm
  - Fully 3D Monte Carlo => Huge matrices => compression

- Increasing the number of CPUs
  - by adding gradually new clusters of the University of Lyon
  - By using the European grid EGEE *(http://public.eu-egee.org/)*

- Improving CiGri performance

  Current efforts are focused on "check-pointing" to allow execution of longer jobs that can be restored in case of a best-effort kill.

Thank You for your attention !!