Laboratori Nazionali di Legnaro – INFN

Simulazione misure di laboratorio

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Outline

I. Introduction
II. Simulation advancements
III. Paper status

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I. **Introduction**
II. Simulation advancements
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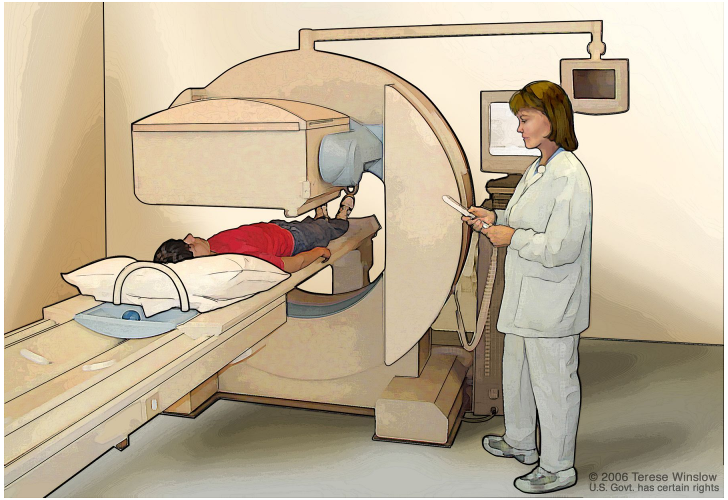
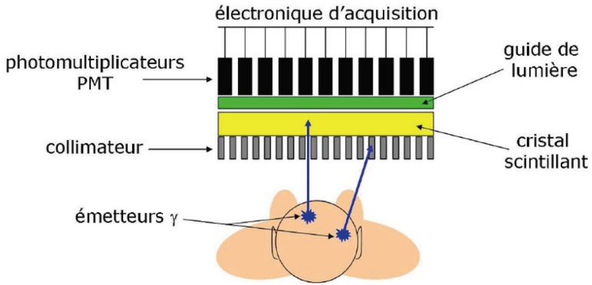
What is a gamma camera?

- device used to image gamma radiation emitting radioisotopes



Made by:
- collimator
- scintillating crystal
- optical photon detectors
- electronics



ISOLPHARM
SPES exotic beams for medicine

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		Year 1				Year 2				Year 3				Notes
		M3	M6	M9	M12	M15	M18	M21	M24	M27	M30	M33	M36	Required for
	WP3 - γ-Imaging													
MS3.0	Sizing of the detector components according to the required spatial resolution	→	●											MS3.1, MS3.2
MS3.1	Preliminary Monte Carlo simulations for detector design	→	○		●									MS3.2
MS3.2	Planar imaging detector construction for Ag-111 γ detection					→	○		●					MS3.3
MS3.3	Characterization and test of the planar system							→					●	

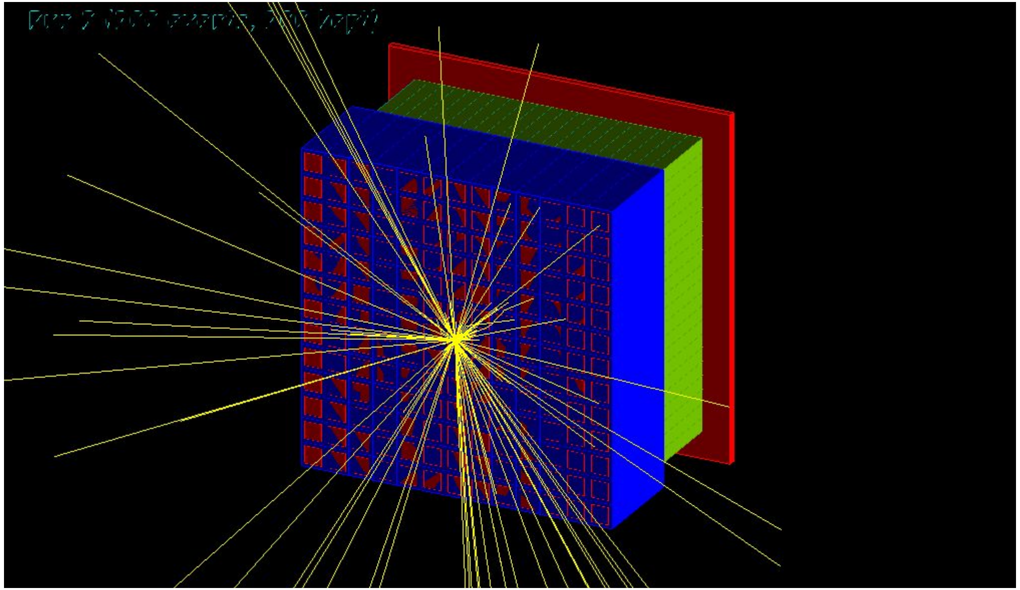
→	Activity started
○	Checkpoint (preliminary/partial results required to start other subsequent activities)
●	Milestone reached

2023

Geant4 simulation of a gamma camera

MS3.1 – Preliminary Monte Carlo simulations for detector design

- source
- collimator
- scintillator
- SiPM
- ➢ output



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2024

Geant4 simulation of a gamma camera

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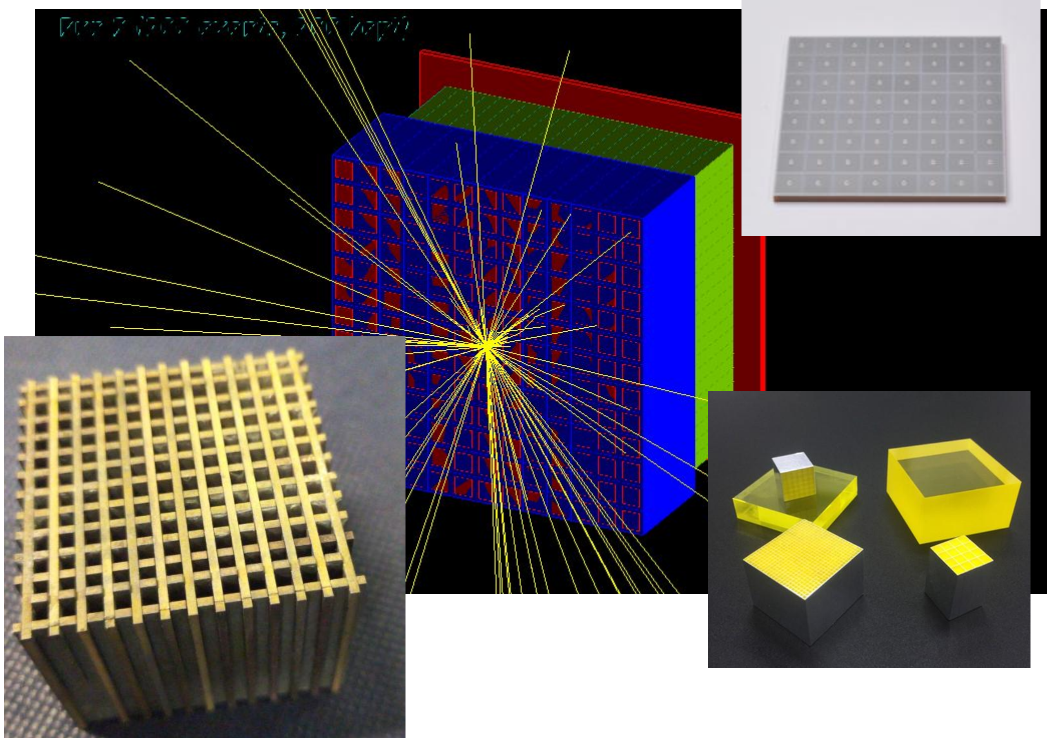
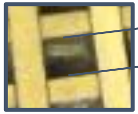
MS3.2 – Planar imaging detector construction for Ag-111 γ detection





holes
2 mm

septa
1 mm

		Year 1				Year 2				Year 3				Notes
		M3	M6	M9	M12	M15	M18	M21	M24	M27	M30	M33	M36	Required for
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2024

Geant4 simulation of a gamma camera

MS3.3 – Detector characterization and test

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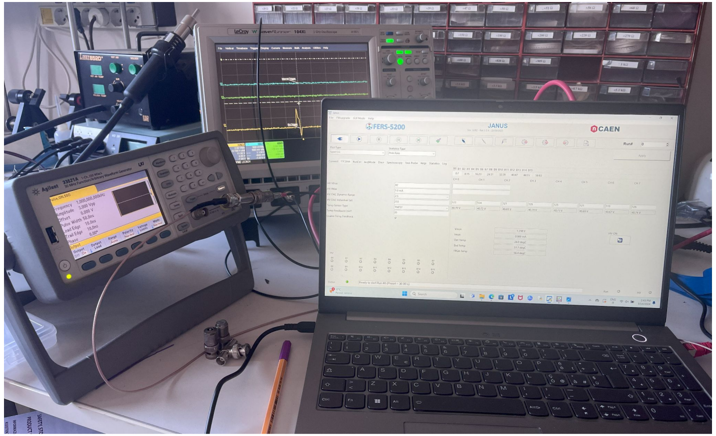
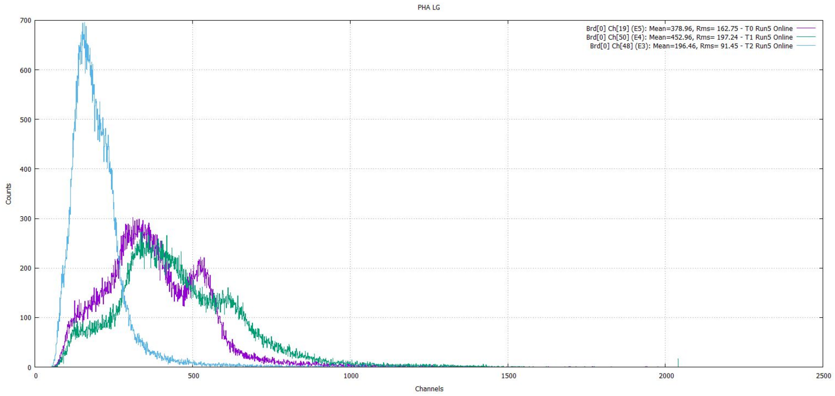
- Experiments were conducted at Bologna (S. Spadano and E. Borciani)
- Simulations can give a reference





Outline

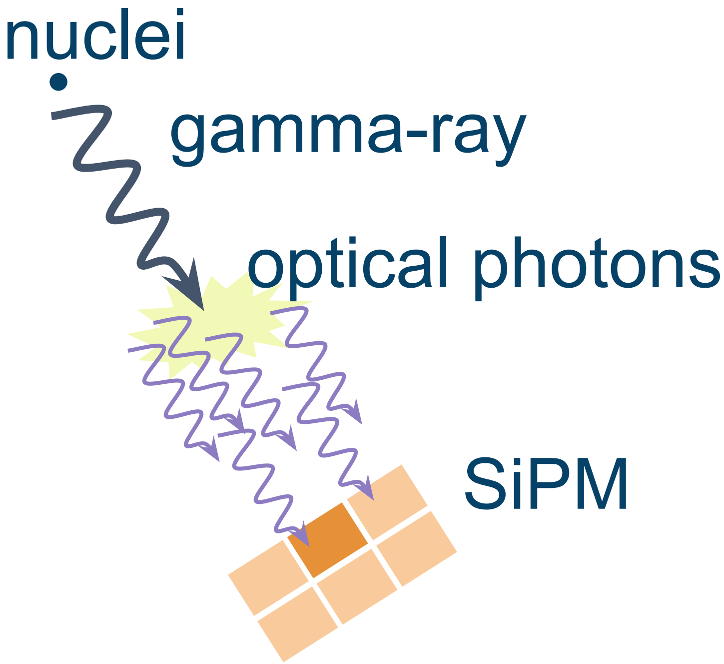
I. Introduction

II. **Simulation advancements**

III. Paper status

Output

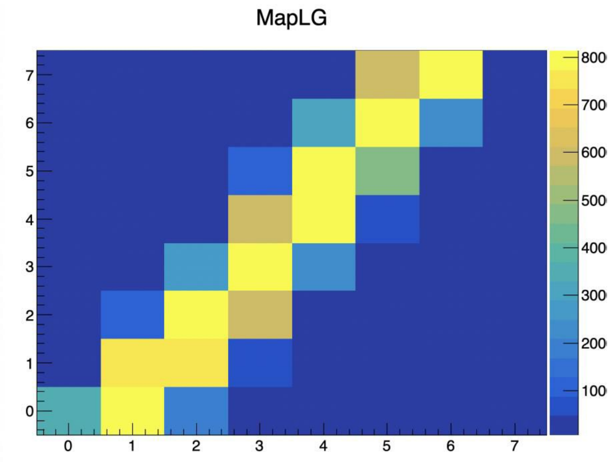
event	scintillator
ID 0	x, y, energy dep
ID 12	
ID 25	
…	
…	
…	
ID 976	
ID 987	



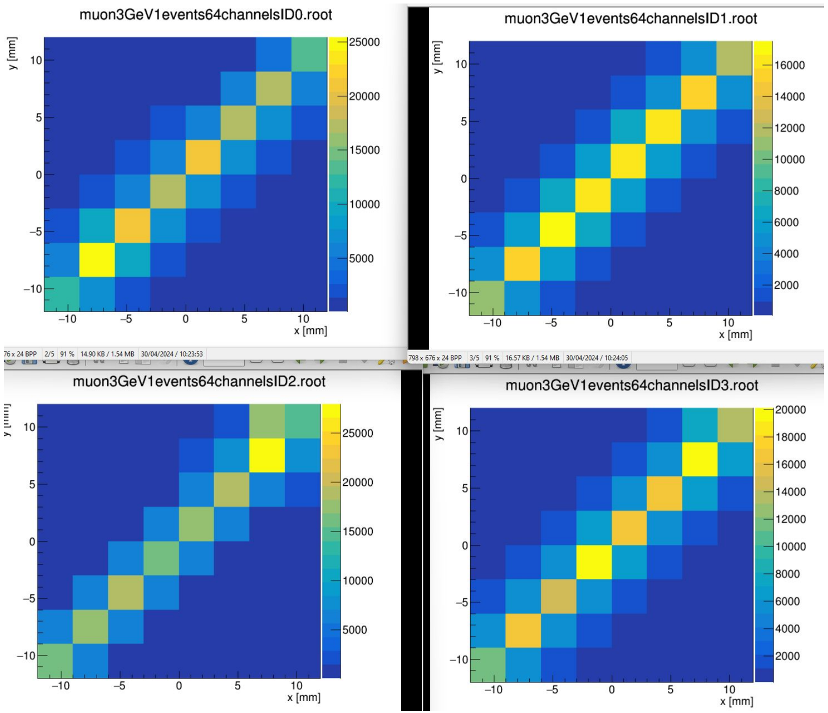
event	SiPM
ID 0	ix, iy, counts
ID 0	
…	
…	
ID 987	
ID 987	
ID 987	

Simulation muons

- (3 GeV) muon
- diagonal direction



Experiment

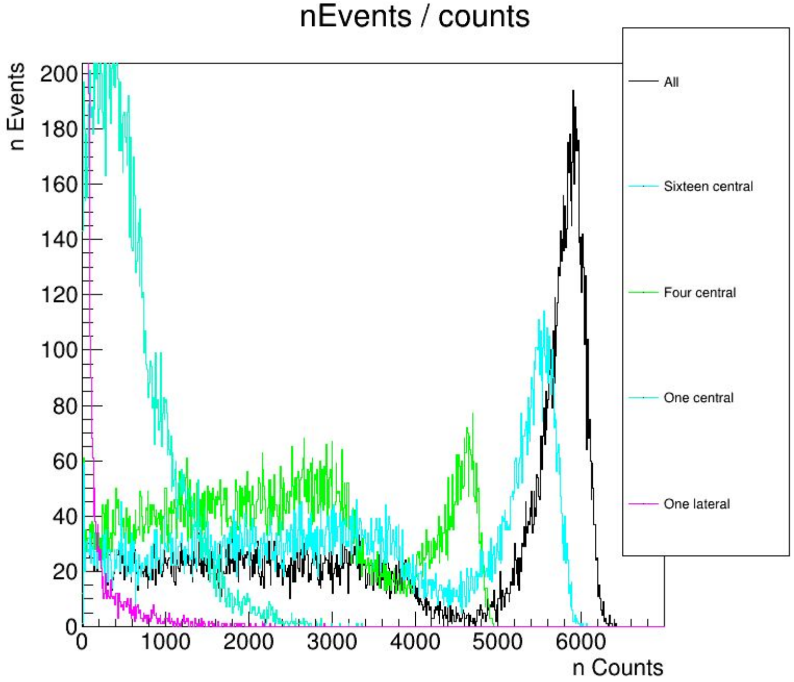


Simulations

Simulation for sealed sources

- Cs-137 source

x: 1	2	3	4	5	6	7	8	y
1-8							8-8	8
								7
		3-6	4-6	5-6	6-6			6
		3-5	4-5	5-5	6-5			5
		3-4	4-4	5-4	6-4			4
		3-3	4-3	5-3	6-3			3
								2
1-1							8-1	1



Full-energy peak is visible

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Simulation for sealed sources

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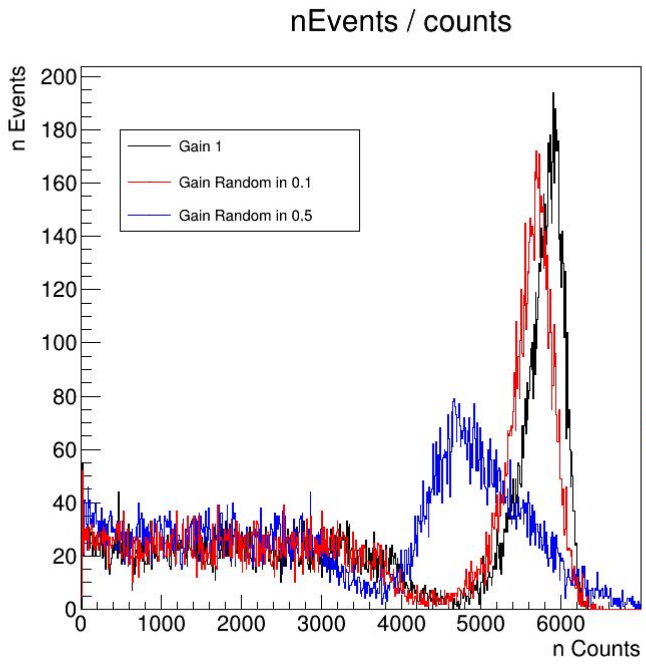
- Cs-137 source
- non-uniform gain matrix

```
// set gain matrix
cout << "Gain matrix" << endl;
TRandom *r1 = new TRandom();
const Float_t halfRandomWidth = 0.;
for (int iy=0; iy< nBinsX; iy++)
{
    for (int ix=0; ix< nBinsX; ix++)
    {
        gainMatrix[ix][iy] = 1.; // by default all pixels have the same gain
        gainMatrix[ix][iy] += r1->Uniform(-halfRandomWidth,halfRandomWidth);
        cout << TString::Format("%.2f\t",gainMatrix[ix][iy]);
    }
    cout << endl;
}
```



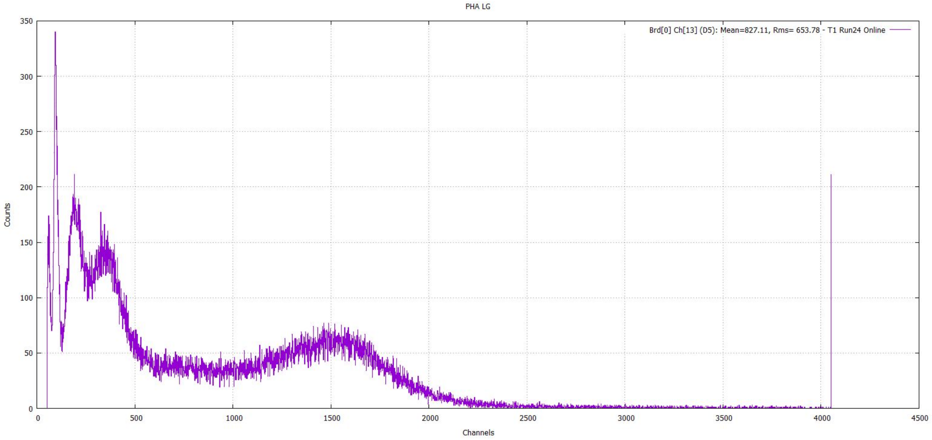
1.00	1.00	1.00					
1.00	1.00	1.00					
1.00	1.00	1.00					
1.00	1.00	1.00					
1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

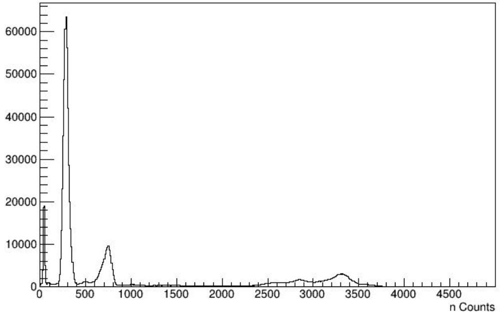
0.93	0.98	1.06	0.95	0.94	0.93	1.06	0.94
1.07	1.02	1.00	1.08	0.98	1.10	1.06	0.91
1.07	0.98	0.91	0.91	1.07	1.00	1.04	0.97
1.09	0.95	0.93	0.90	0.92	1.09	1.06	0.94
1.02	1.07	0.95	0.97	0.99	1.07	1.04	0.94
0.90	0.99	1.02	1.09	0.93	1.09	1.00	0.99
1.00	1.10	1.09	0.91	1.09	1.05	1.10	0.98
0.92	0.92	1.01	0.94	0.93	1.06	0.95	1.06

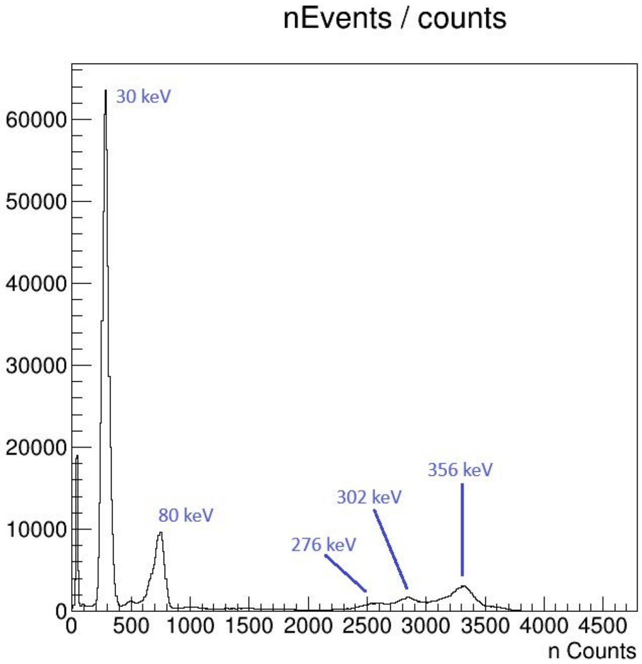
0.65	0.92	1.29	0.75	0.69	0.67	1.28	0.72
1.36	1.10	0.99	1.39	0.88	1.49	1.28	0.54
1.35	0.89	0.53	0.55	1.35	1.02	1.21	0.83
1.43	0.74	0.65	0.52	0.62	1.44	1.28	0.70
1.09	1.35	0.75	0.85	0.97	1.34	1.18	0.72
0.51	0.96	1.09	1.43	0.65	1.45	1.00	0.94
0.98	1.49	1.46	0.55	1.45	1.23	1.48	0.88
0.59	0.59	1.06	0.71	0.64	1.28	0.74	1.28

Simulation for sealed sources

- Ba-133 source







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ISOLPHARM SPES exotic beams for medicine

Paper

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1. Introduction
    a. ISOLPHARM project and ADMIRAL experiment
2. Material and Methods
    a. Description of collimator, scintillator and SiPM
    b. MOBY
    c. Geant4: physics lists used, setup
    d. Experimental setup
3. Results
    a. Comparison with experimental data
    b. Study of the SNR (tumor over background) varying tumor activity and position in the body
4. Conclusion
    a. Expected detector sensitivity and resolution

Design of a gamma camera for Ag-111 imaging within the ISOLPHARM project

Introduction

Targeted Radionuclide Therapy (TRT) is an emerging technique that is being used as treatment for cancer. TRT uses drugs labeled with radionuclides to deliver a specific ionizing radiation in the targeted lesion. Radionuclides of medical interest are typically supplied by cyclotrons or nuclear research reactors. The ISOLPHARM project is planning to use the ISOL facility SPES at INFN-LNL to produce neutron-rich radionuclides. One isotope that can be produced with relatively great amounts is Ag-111, it is both a β emitter and a γ emitter therefore is promising for theranostic applications.

To fully exploit the imaging potential of Ag-111, it is necessary to use a device that is tailored for its gamma-ray radiation. Therefore, in the three years of ADMIRAL experiment the third work package (WP3) will be devoted to the development of such a device. High spatial resolution (< 4 mm) is required for small animal imaging when using a single photon emitting radionuclide such as Ag-111 (Yamamoto2016). It is possible to achieve an even better resolution and organ-specific activity uptake by performing ex-vivo studies. On the other hand, using a gamma camera does not require the sacrifice of the small animal thus allowing to study the evolution in time of the biodistribution (Weber1999).

Material and Methods

System elements

The gamma camera that is under construction is represented in Figure 1 and comprehends: collimator, scintillator, SiPM, readout electronics.

■ ■ ■

Outline

I. Introduction
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IV. **Future perspectives**

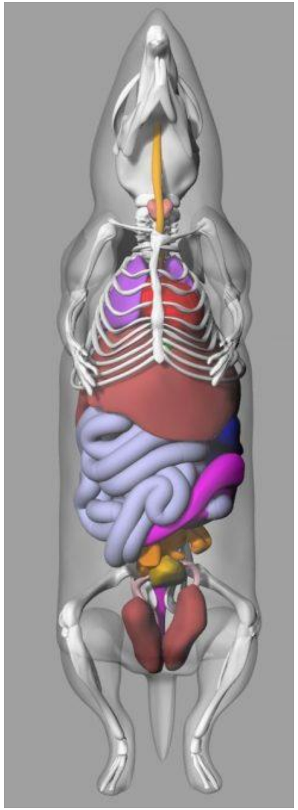
Future steps

- **optimize** the code according to the experimental needs
- **support** the detector construction:
    - study collimator dimensions effects
    - study source distance effects
    - …
- **predict** and **analyze** experimental data
- **write** the paper regarding the simulations

Thanks for the attention

Backup

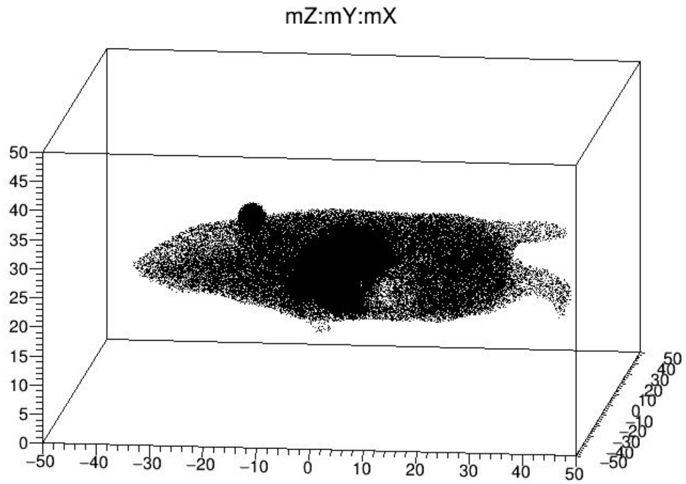
MOBY background



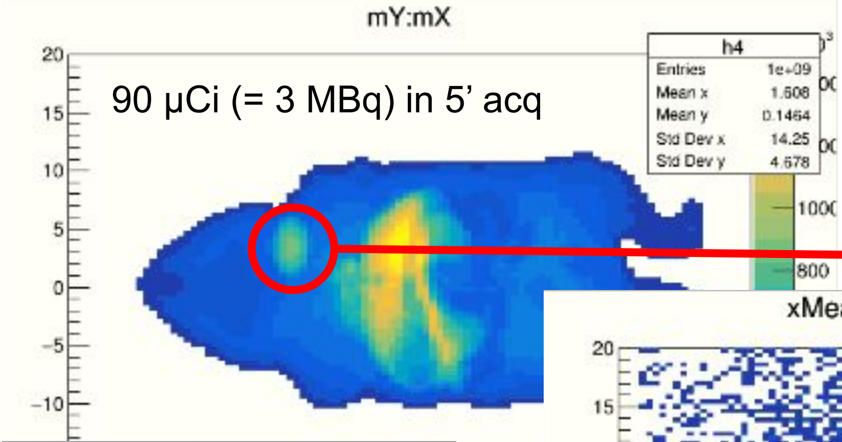
- MOBY is provides **highly detailed anatomies** for a laboratory mouse
- Parameterized models for the beating heart and respiratory **motions**
- **Voxelized** versions of the phantoms can be derived

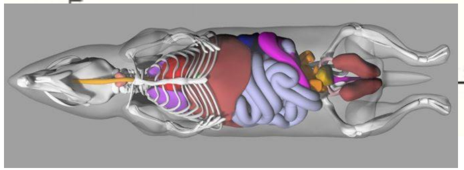
https://cvit.duke.edu/resource/moby-roby-phantoms/

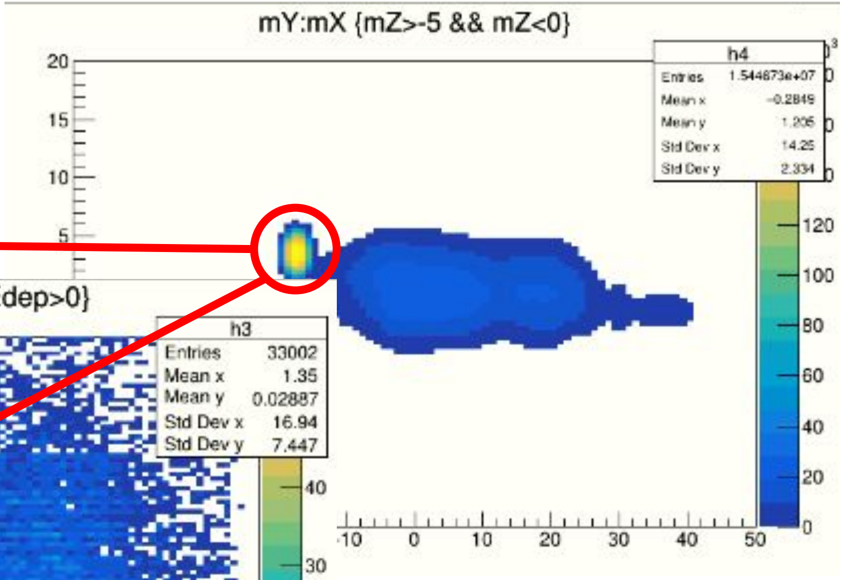
attenuation + activity

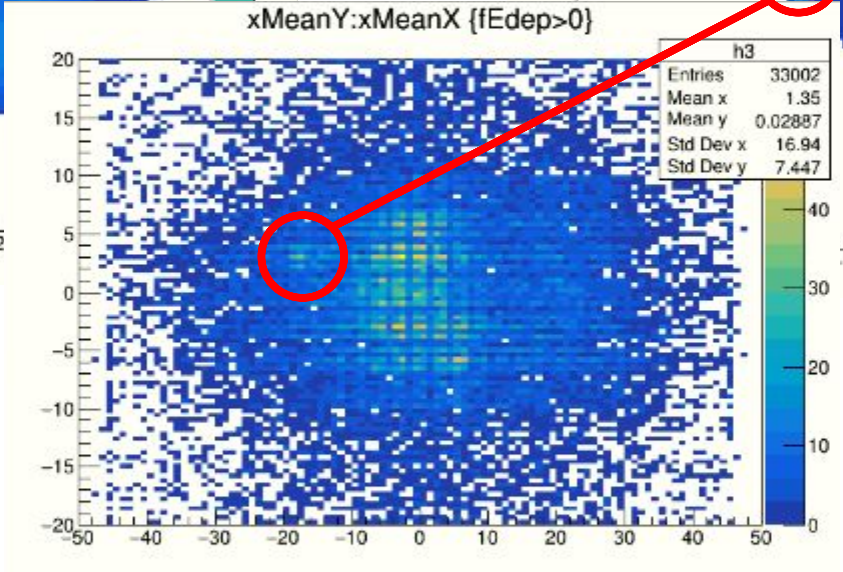


Simulation with MOBY









Previous experiments in-vivo used 6 MBq of Ga-68

Simulation for sealed sources

- Ba-133 source