PMT Simulation code optimization

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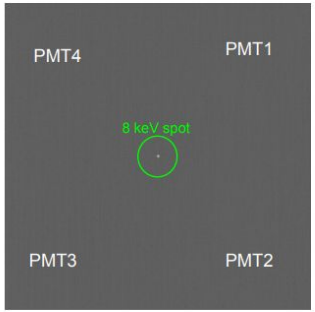
Introduction

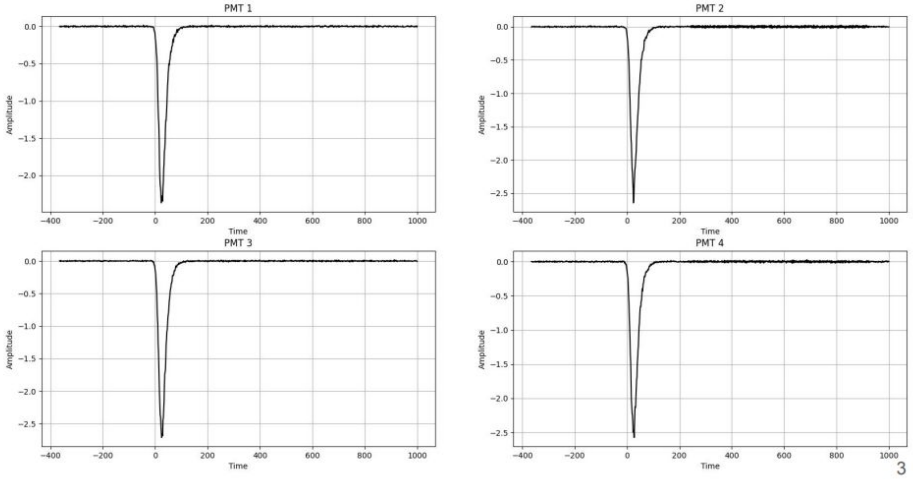
From Pietro Meloni's presentation (May 30, 2023)

Example 1 (8 keV ER spot at z = 450 mm)

Number of voxels is ~50k (it increases with z because of diffusion)

Each voxel contains ~1000 photons. It takes **6 hours** for one event.





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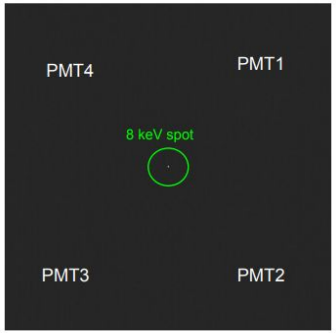
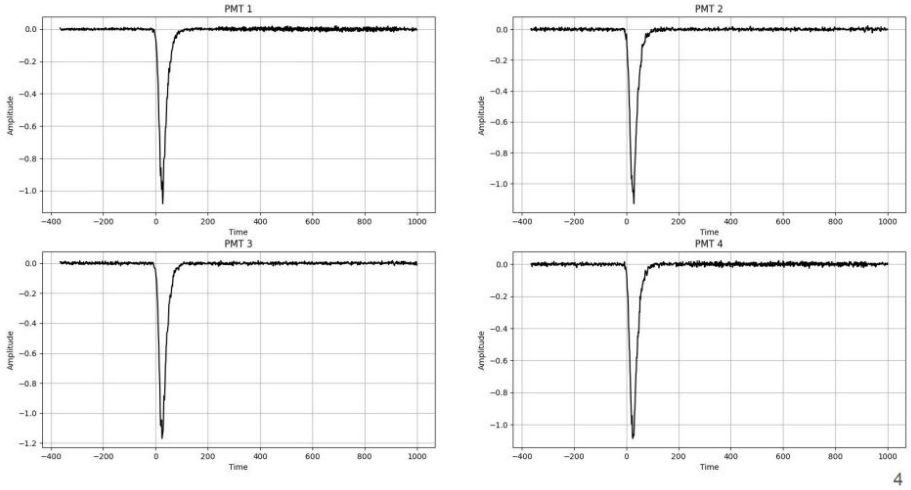
Introduction

From Pietro Meloni's presentation (May 30, 2023)

Example 2 (8 keV ER spot at z = 50 mm)

Number of voxels is ~10k (it increases with z because of diffusion)
Each voxel contains ~2000 photons. It takes **20 min** for one event.





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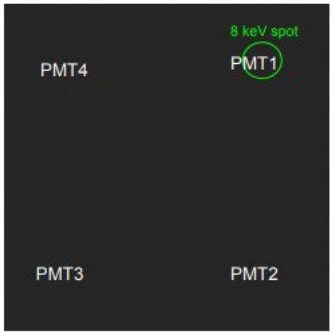
Introduction

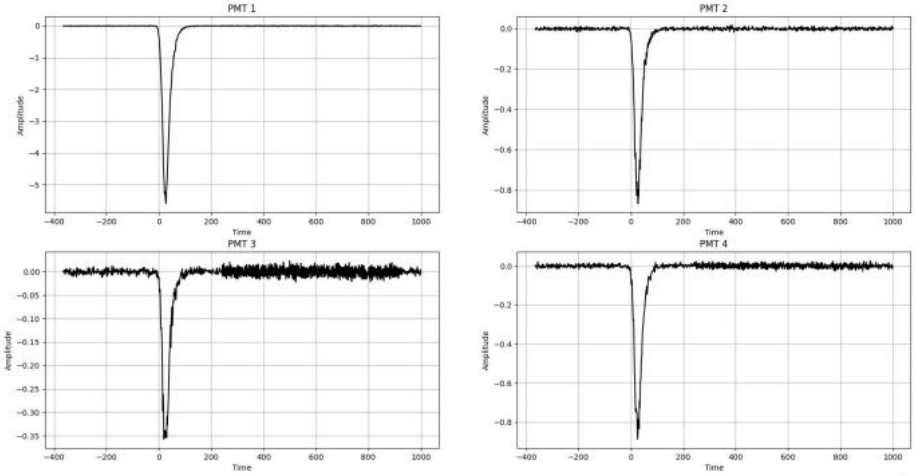
From Pietro Meloni's presentation (May 30, 2023)

Example 3 (non-centered 8 keV ER spot at z = 50 mm)

Number of voxels is ~10k

Each voxel contains ~2000 photons. It takes **20 min** for one event.





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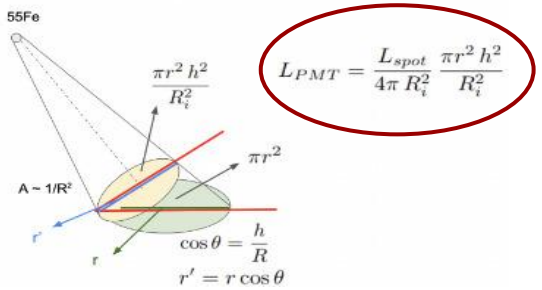
Code optimization

Proposed ideas to improve and speed up the code

- Use NumPy to vectorize the functions - **Signal generation** ✓
- Parallelize the generation of waveforms on each PMT - **Signal generation** ✓
- Use propagation photons equation - **Photon propagation**



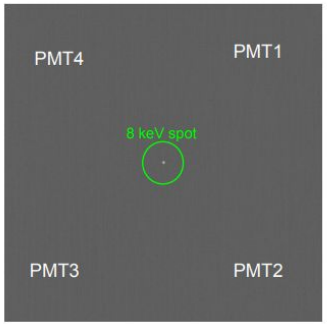
Fix issues and updates

- Old code was not considering the PMT quantum efficiency
- Noise covariance matrix updated (from corrected waveforms)

Code optimization

Example 1 | Centered **|** 50k voxels, each voxel contains 1000 photons

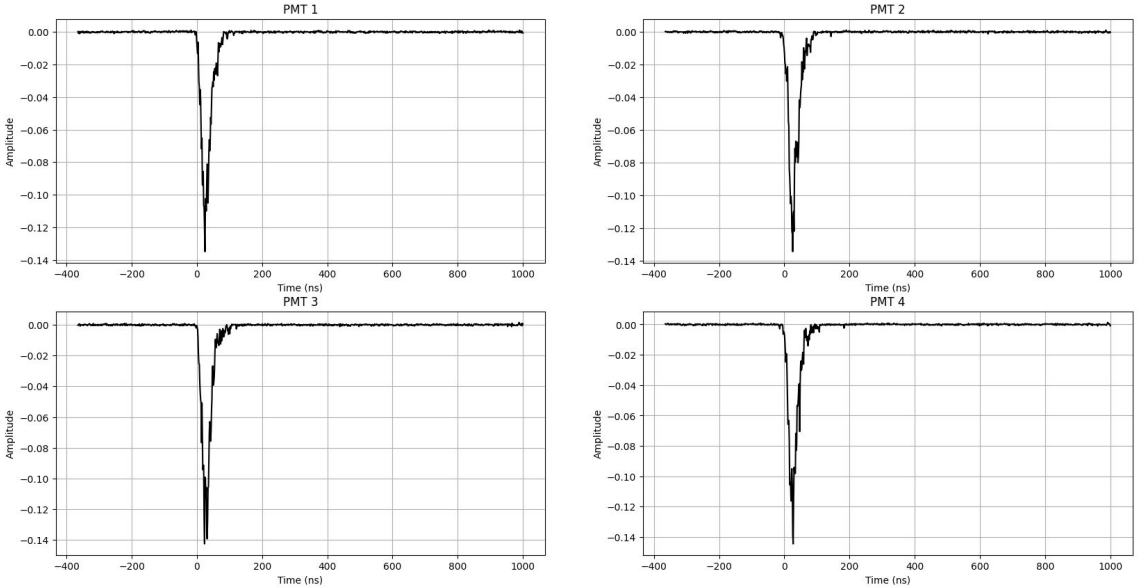
Implemented idea for signal generation: NumPy to vectorize the functions



PhotonPropagation(): 14 min 58 sec

SignalSimulation(): 11 sec

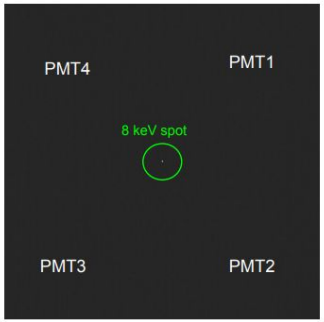
Before: **6 hours**

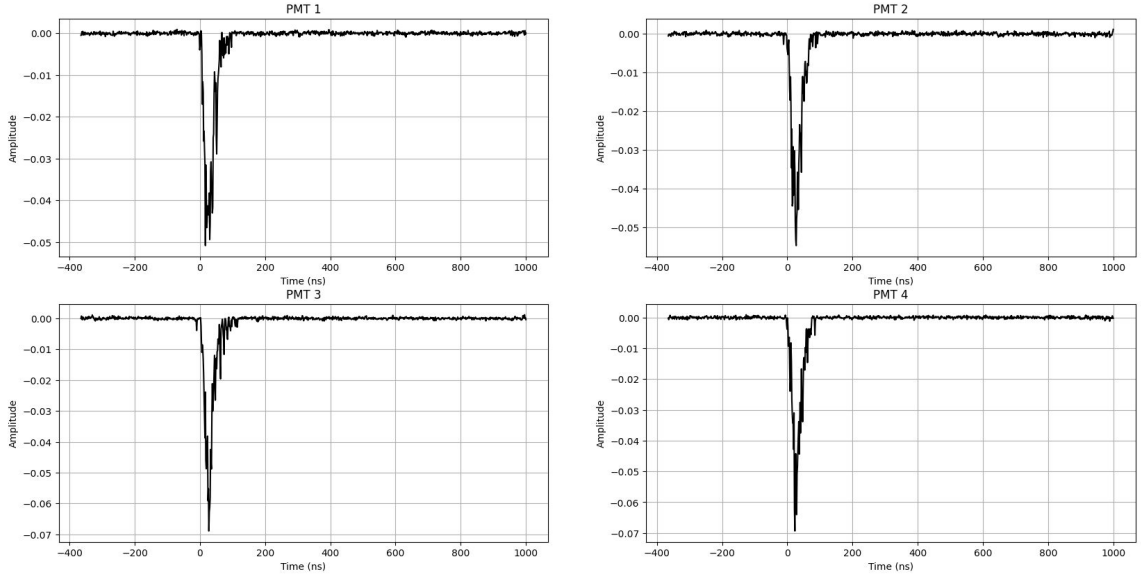


Code optimization

Example 2 | Centered **|** 10k voxels, each voxel contains 2000 photons

Implemented idea for signal generation: NumPy to vectorize the functions





PhotonPropagation(): 6 min

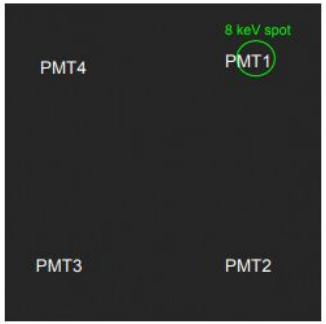
SignalSimulation(): 3 sec

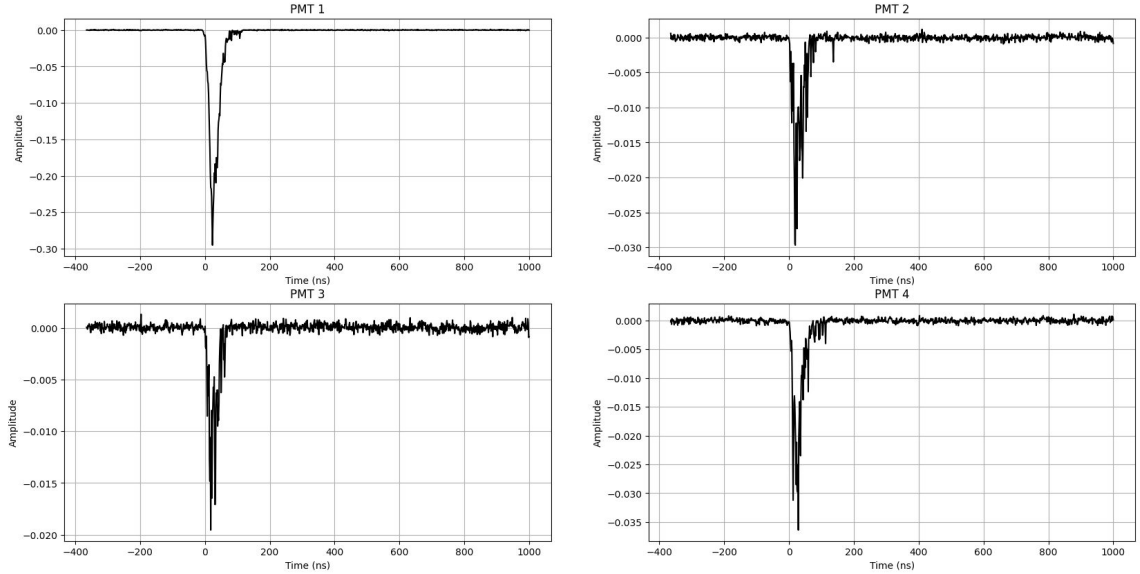
Before: **20 min**

Code optimization

Example 3 | non-centered **|** 10k voxels, each voxel contains 2000 photons

Implemented idea for signal generation: NumPy to vectorize the functions





PhotonPropagation(): 6 min

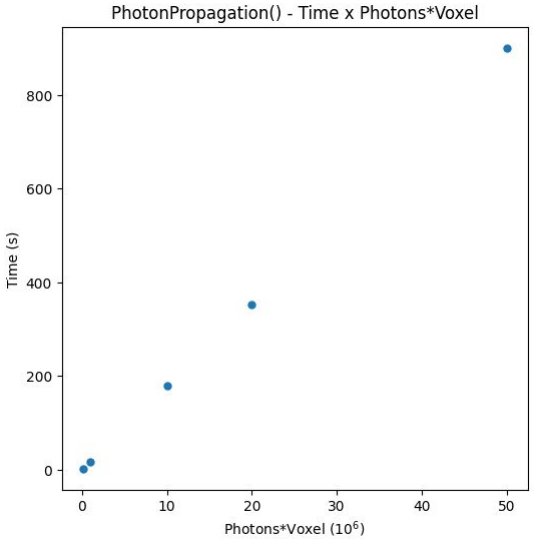
SignalSimulation(): 3 sec

Before: **20 min**

Code optimization

Analysis for different number of voxels and photons

Voxels	Photons/voxel	PhotonPropagation()	SignalSimulation()
100	1k	1.6 sec	0.08 sec
1k	1k	17.4 sec	0.32 sec
10k	1k	2 min 57 sec	2.3 sec
1k	100	1.6 sec	0.25 sec
1k	1k	19 sec	0.24 sec
1k	10k	3 min 3 sec	0.33 sec



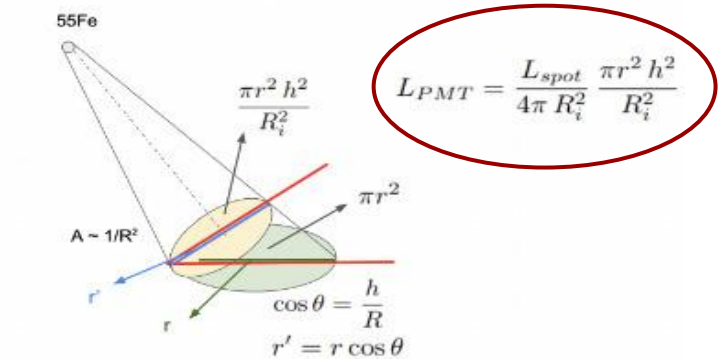
Results

Optimization results

- **Signal generation -** Optimized ✓
- **Photon propagation -** In progress
  - Created a module to calculate PMT hits using the photon prop. equation

Next steps

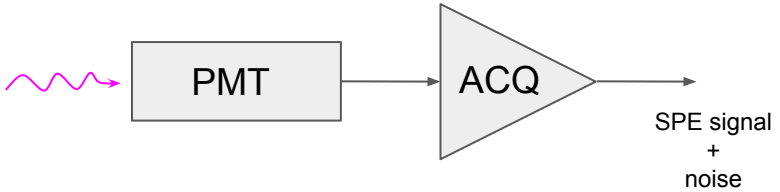
- Finish photon propagation optimization
- Add the code modifications to the digitization repository



PMT signal characterization (match between LED and Experiment setups?)

- PMT signal simulation is based on the SPE response (ACQ board included)
  - ACQ bandwidth is an important parameter

Different bandwidth might change SPE shape and amplitude distribution

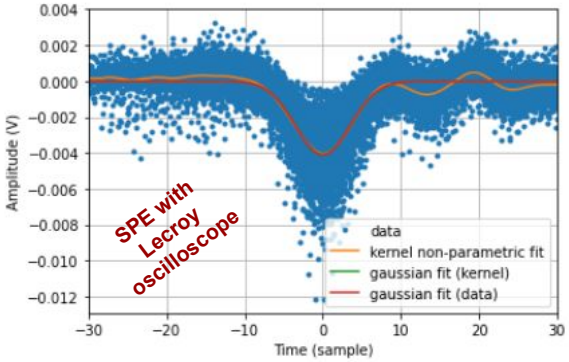


- SPE signal acquisition setup: LED
  - PMT: R7378A (Hamamatsu)
  - Sampling Rate: 5 GS/s (0.2 ns)
  - Bandwidth: ??

Lecroy oscilloscope

- Experiment setup:
  - PMT: R7378A (Hamamatsu)
  - Sampling Rate: 750 MS/s (1.33 ns)
  - Bandwidth:
    - Analog inputs 500 Mhz ??

V1742 5, 2.5, 1 GS/s and 0.75 GS/s



Rising time ~1.5 ns
(datasheet)