Simulations of the Strip-PET and the Matrix-PET detectors with the GATE package

Paweł Kowalski for the J-PET Collaboration

National Centre for Nuclear Research, Świerk Computing Centre, Otwock-Świerk

ABSTRACT

Novel PET systems (Strip-PET and Matrix-PET) based on plastic scintillators are developed by the J-PET collaboration. In order to optimize a geometrical configuration of built devices, advanced computer simulations must be performed. GATE (Geant4 Application for Tomographic Emission) is one of the best simulation packages allowing to cope with a complexity of multi-detector systems used in positron emission tomography.

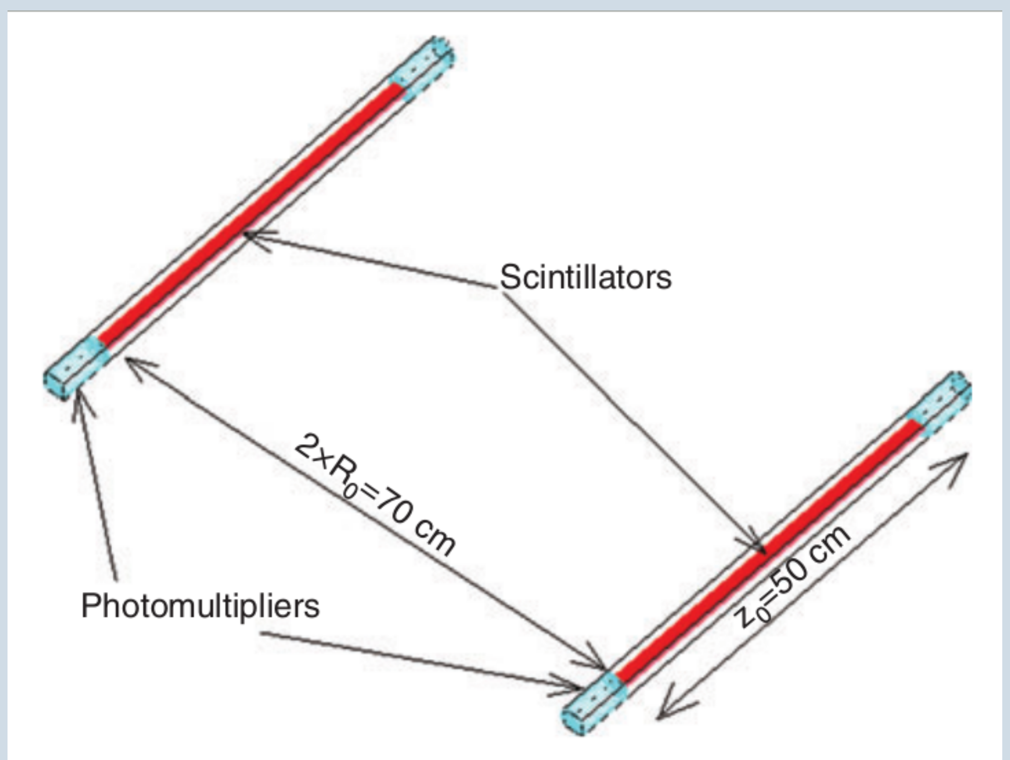
Simulations of the Strip-PET and the Matrix-PET detectors are performed in CIŚ cluster (Świerk Computing Centre at National Centre for Nuclear Research). The poster will include vizualisation of examples of results obtained so far.

1. GATE SOFTWARE

The GEANT4 Application for Tomographic Emission (GATE) [1] represents one of the most advanced specialized software packages for simulations of Positron Emission Tomography (PET) scanners. GEANT4 is a toolkit for simulation of the passage of particles through matter using Monte Carlo methods. Despite its complexity, GATE is easily configurable using script language.

2. SIMULATIONS OF THE STRIP-PET SYSTEM

The prototype Strip-PET [2] scanner is planned to be made of detectors placed on the lateral area of the cylinder with a diameter of 70 cm. The axis of each detector is parallel to the axis of the cylinder. Each detector is made of one strip of plastic scintillator and two photomultipliers attached to its ends.



Two-strip scanner was simulated and the map of efficiency of this system was determined. Because of the axial symmetry of the scanner, a two-strip module should reflect the main features of the full detector setup.

Fig. 1. Visualisation of the two-strip system

Rectangular region between the two strips may be divided into virtual pixels with size 0.5 cm x 0.5 cm. Map of efficiency may be defined as:

$$f_{acc}(x,z)=\frac{N_{acc}(x,z)}{N_{gen}(x,z)},$$

where (x,z) are coordinates of the center of the pixel, N_{gen} is the number of all annihilations generated in the pixel, and N_{acc} is the number of all events caused by the annihilations from the pixel (event means voltage signals in all four photomultipliers).

The efficiency of the system depends on many geometrical (e.g. length of scintillator strips) and physical (e.g. depth of interaction) factors.

As one can see, the map of the efficiency is highly correlated with the geometry of the detector.

Results of simulations of two-strip system are described with details in [3].

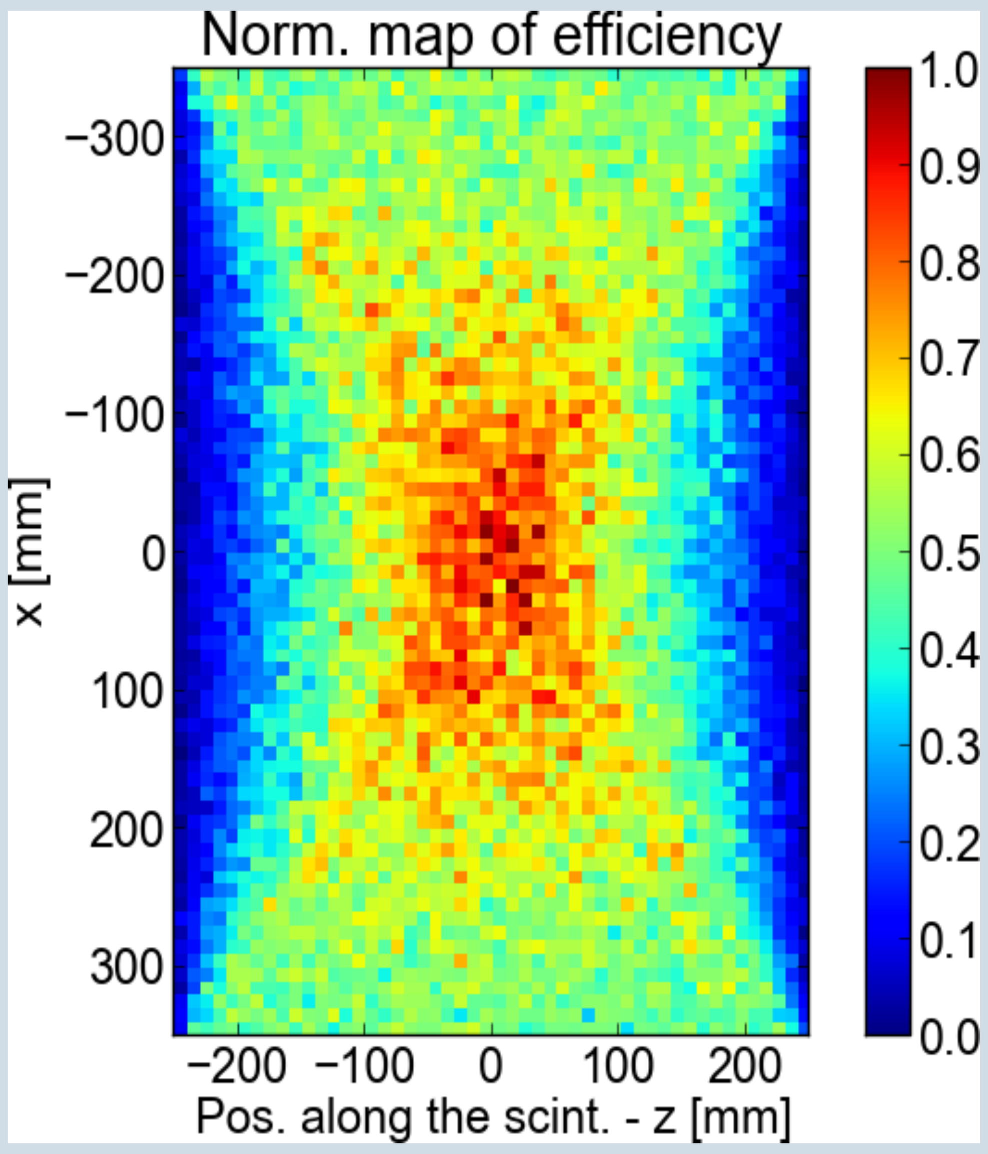


Fig. 2. Map of efficiency calculated using results obtained from GATE simulations

3. SIMULATIONS OF THE MATRIX-PET SYSTEM

The second novel PET system, which could be built of plastic scintillators is Matrix-PET [4]. In this scanner, four plastic plates would cover the whole body of the patient. Example configuration is shown in the figure 3.

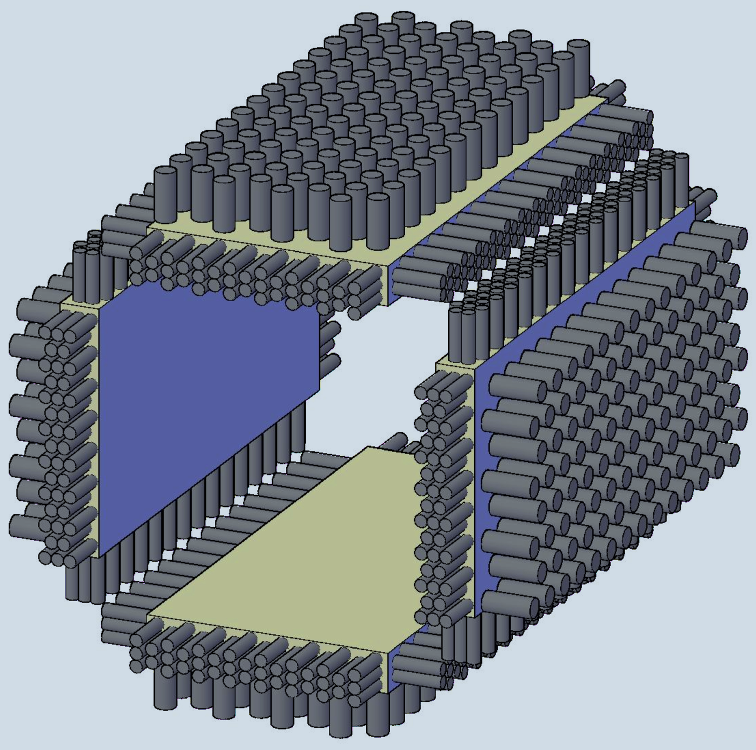


Fig. 3. Schematic view of possible arrangement of scintillation elements and photomultipliers of Matrix-PET scanner [4]

Single plate of Matrix-PET (figure 4) was simulated with GATE software. Size of plate was: 20 cm x 20 cm x 8 cm. Point source of optical photons (10 mln of photons generated) was placed in two positions: a) in te center of the plate, b) moved 7.5 cm from the center along the z axis. Results of simulation are presented in the figure 5.

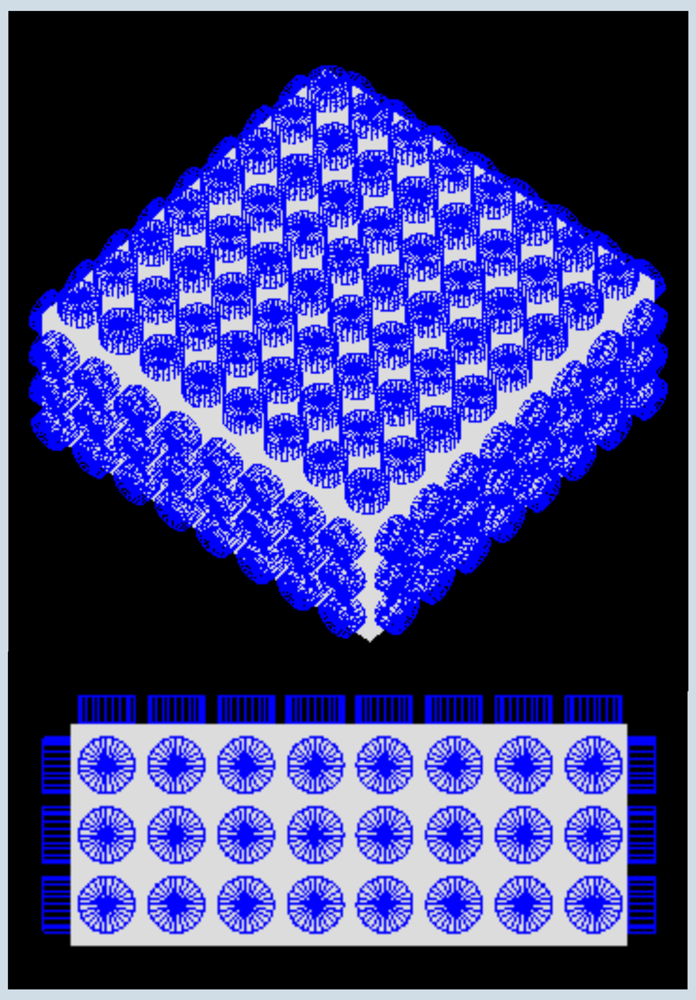


Fig. 4. Visualisation of the single plate from GATE

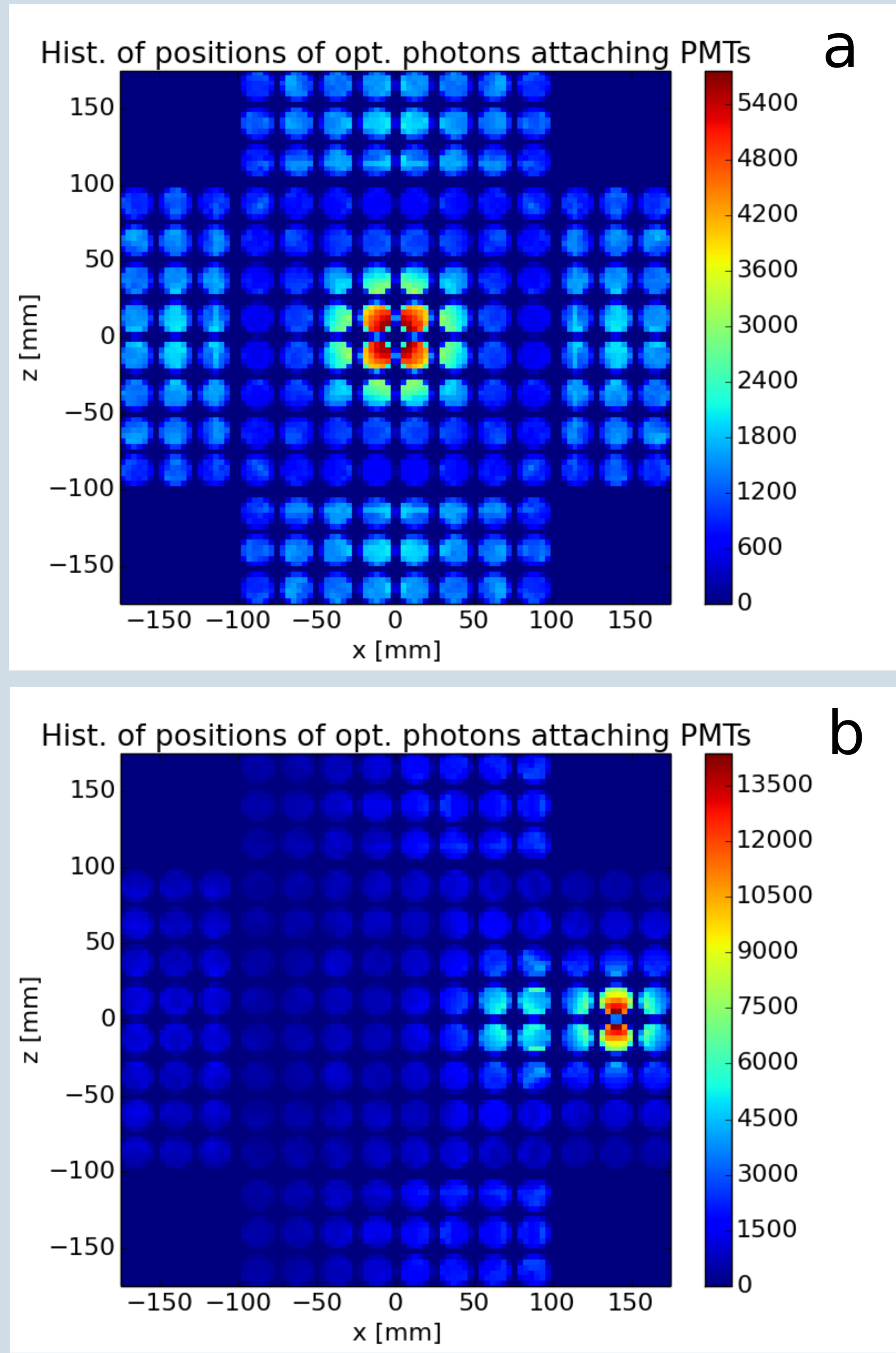


Fig. 5. Number of optical photons detected by the photomultipliers presented on the net of the cuboid: a) source in the center of the plate, b) source moved along the z axis

Number of photons detected in each photomultiplier translates into the amplitudes of the measured signals. Distribution of amplitudes may be used to reconstruct the point of interaction of gamma quanta and finally for reconstruction of the point of positron annihilation, which is the base of all PET systems.

REFERENCES

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