Mobile PET insert for simultaneous PET/MR imaging

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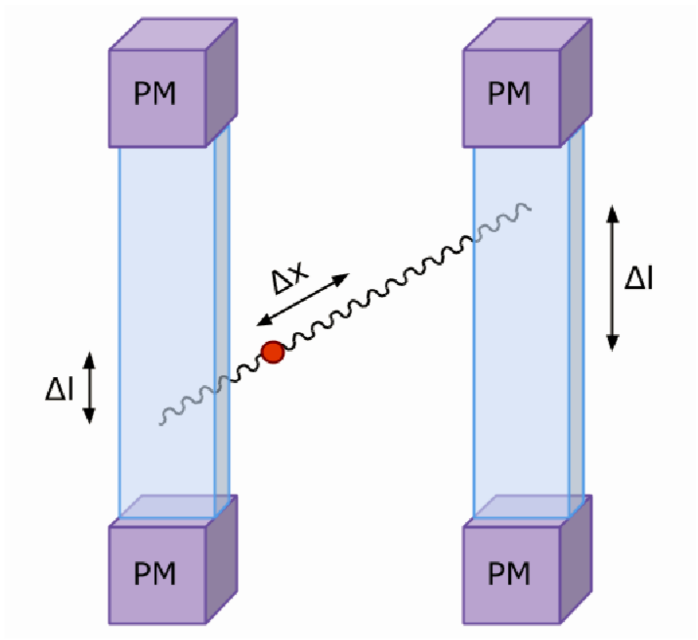
Introduction

Access to the anatomical and functional information about the human body interior is possible with various tomography techniques relying on the registration of radiation from the tissues and processing the collected data in the image or information on changes in the physico-chemical processes in the volume of interest. The purpose of the presented research is the development of the new type of device being a mobile (portable) and flexible (adaptable) PET scanner, which will play a role of an insert to the existing MR scanners, providing a unique worldwide solution for simultaneous (at the place and time) functional and anatomical PET-MRI imaging.

J-PET concept

Mobile PET insert device [1] is based on the J-PET scanner concept [2-8], consisting of individual detection modules, each build from a plastic scintillator strip connected optically at both ends with the array of the silicon photomultipliers which plays a role of light-to-electric signal converter. The determination of the point of annihilation along the direction of the gamma quanta propagation, is based on the time difference registered in various detection modules.



Hit position along the scintillator strip:

$$\Delta l = \frac{(t_2 - t_1)\cdot v}{2}$$

Annihilation point along the LOR:

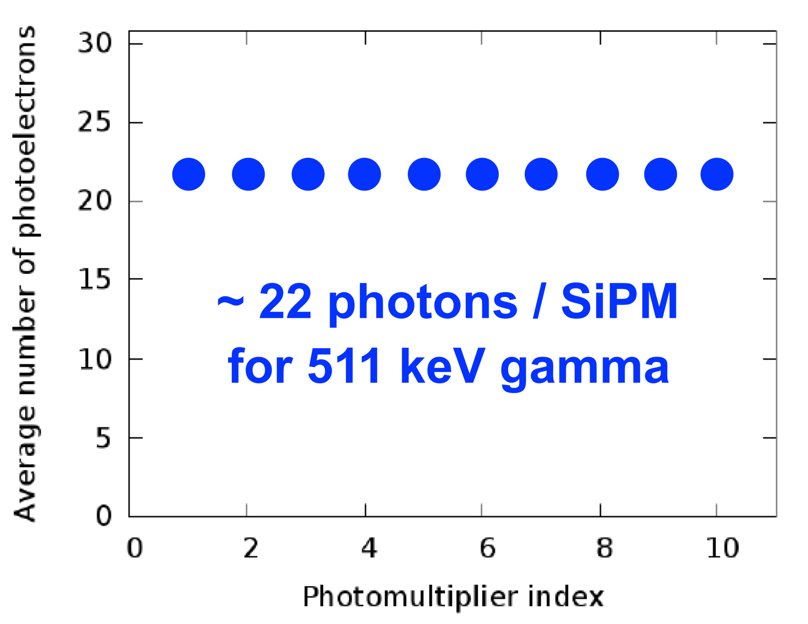
$$\Delta x = \frac{(t_l - t_r)\cdot c}{2}$$

Advantages of the mobile PET insert

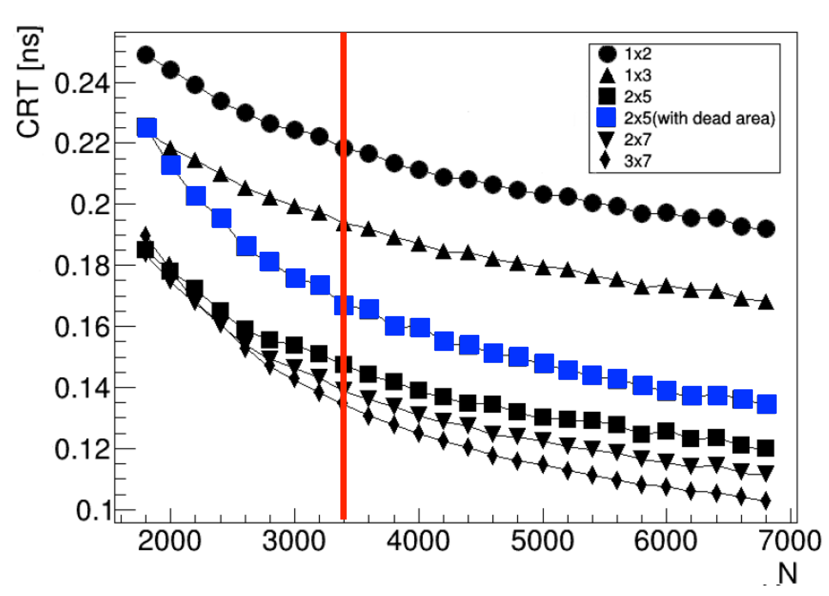
- Silicon photomultipliers are insensitive to the MR scanner magnetic field therefore mobile PET insert work will not be disturbed with the presence of high magnetic field.
- Small electronic elements will not cause the inhomogeneity of the magnetic field in the diagnosed volumes.
- Simultaneous PET/MR imaging will eliminate the possibility of artifacts in tomographic images due to e.g. patient movement, hindering the identification of potentially cancerous lesions.
- Proposed mobile PET insert will allow to use the existing MRI scanners currently held by hospitals, without interfering in their structure and parameters.
- Simultaneous PET/MR imaging will enable to shorten the patient examination, which will have positive influence on patient comfort.

Simulations results

We have performed MonteCarlo simulations to check and optimize the design of the readout array of the SiPM. The simulations have been performed assuming properties of the Hamamatsu silicon photomultipliers S12572-100P, with a photosensitive area of 0.3 cm x 0.3 cm, and the width of non-sensitive rim of 0.05 cm. The scintillator strip has dimensions of 0.7 cm x 1.9 cm x 30 cm.



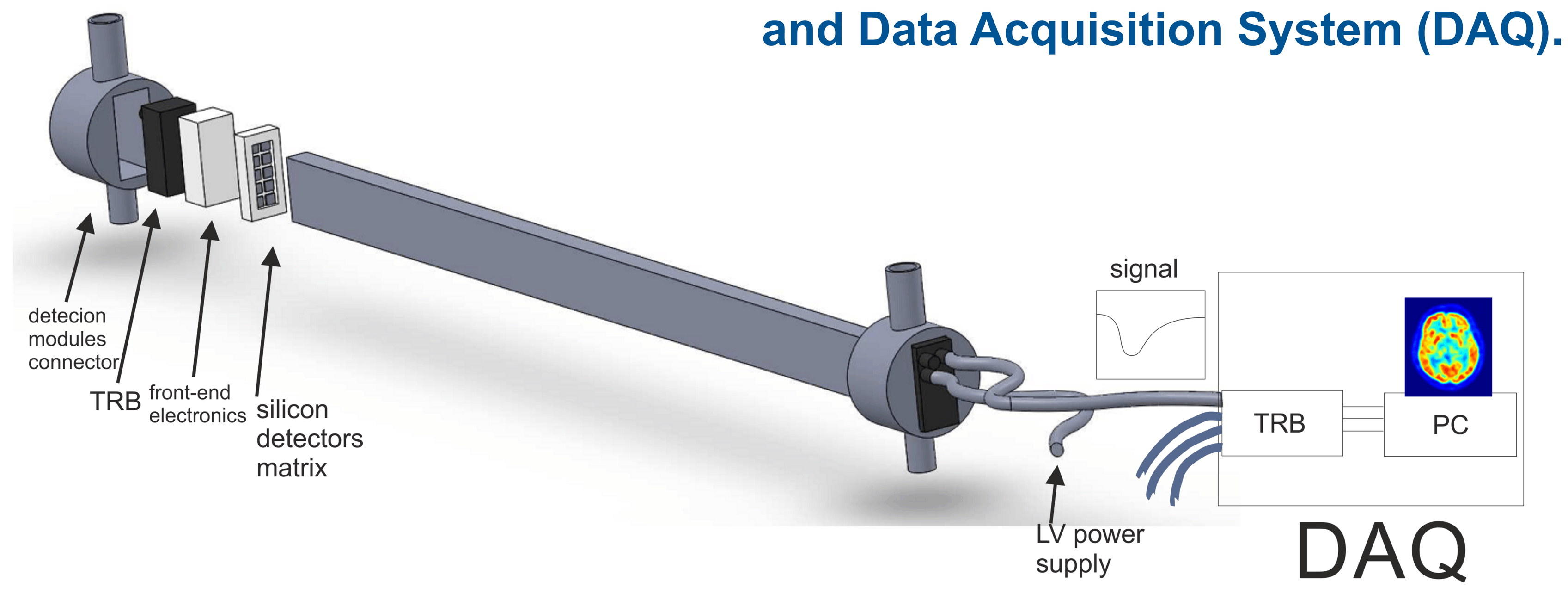
The average of 22 photoelectrons is detected by individual SiPM from the 511 keV gamma quanta.



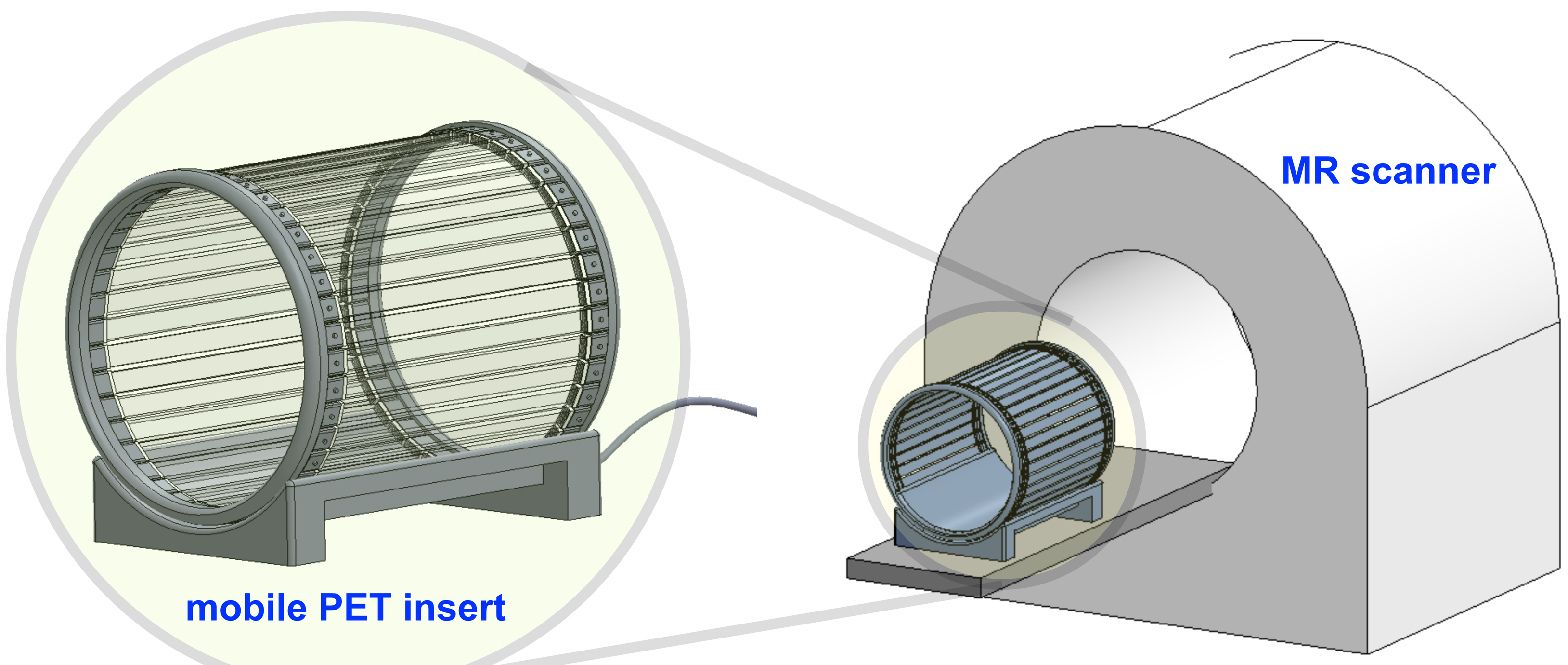
The (2 x 5) SiPM configuration covers area about 68% of the end of scintillator. The CRT ~ 0.170 ns.

Mobile PET insert design

The individual detection module consisting of scintillator strip and array of silicone photomultipliers connected to Front-End-Electronics and Data Acquisition System (DAQ).

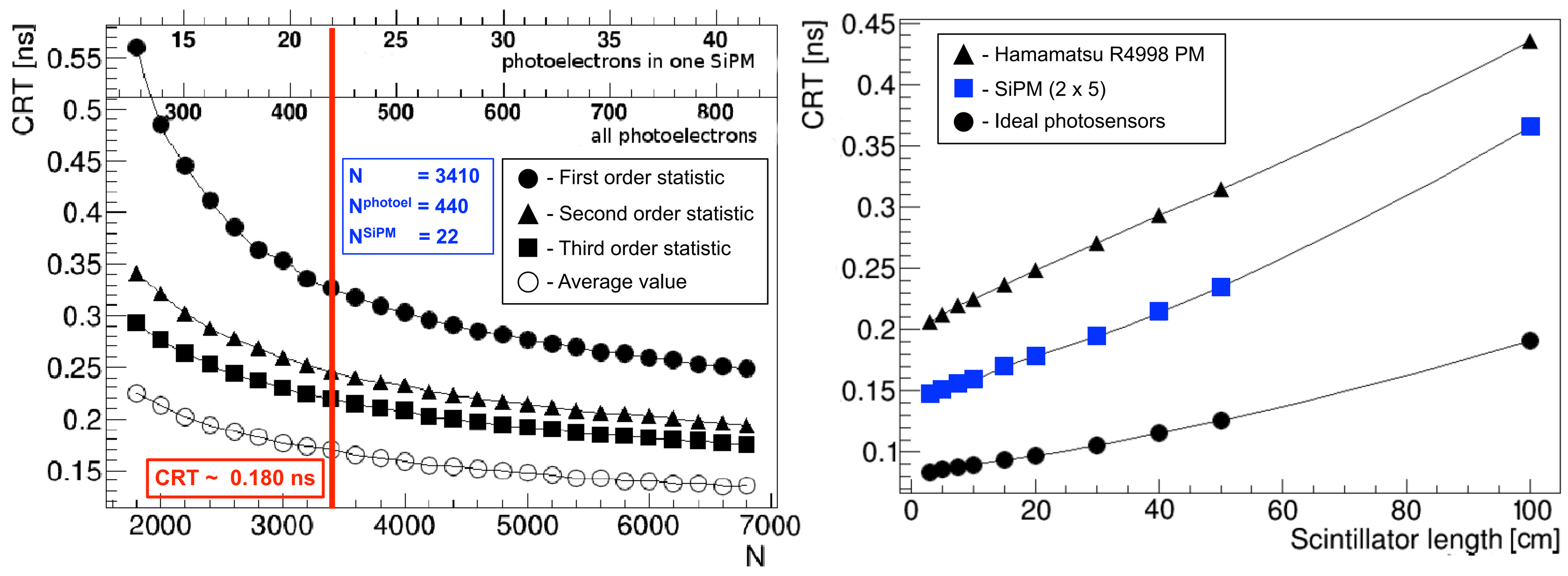


(left) Visualization of the mobile PET insert consisting of 60 individual detection modules (scintillator and silicon photomultipliers end-caps), *(right)* and the usage of the PET insert together with the MR scanner.



Summary and outlook

- The time resolution may be significantly improved by recording individual timestamps of photons arriving to the scintillator edge using the silicon photomultipliers array (SiPM).
- For the SiPM arranged into a 2 x 5 arrays at two ends of the scintillator strip CRT ranges from 0.170 - 0.365 ns when extending an axial field-of-view (FOV) from 15 cm to 100 cm, which corresponds to the axial position resolution from 1.4 cm - 3.1 cm (FWHM).



- The laboratory tests of the single strip with the array in the 2 x 5 SiPM configuration has started.
- As a next step the test of a single detection module will be performed in the diagnostic chamber of the MR scanner to check the signal quality and electronic performance in the presence of the magnetic field.

Bibliography

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Acknowledgment

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