PV-0480 Plastic-scintillator based PET detector for proton beam therapy range monitoring: preliminary study

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Purpose or Objective

Proton beam therapy (PBT) range monitoring is required to fully exploit the advantages of a proton beam in the clinic. In PBT the distribution of beta+ emitters induced by a proton beam in a patient can be detected by PET scanners, the emission distribution can be reconstructed and used for monitoring of the beam range. A prototype of a diagnostic strip-based whole-body PET scanner (J-PET) has been developed and tested at the Jagiellonian University in Krakow (Moskal et al. Phys. Med. Biol. 61 (2016) 2025-2047). The advantages of the system over commercial PET scanners is that it increases the geometrical acceptance and facilitates integration in the treatment room, off-line or in the treatment position. The aim of this work is to study a feasibility of the J-PET technology for range verification in PBT.

Material and Methods

A single detection module of the strip-PET scanner is constructed out of thirteen 50-cm long organic scintillator strips. The light pulses produced in a strip by gamma quanta are propagated to its edges and converted into electrical signals by silicon photomultipliers (see Fig. 1). They are read-out by fast on-board front-end electronics allowing excellent overall coincidence resolving time (CRT) of about 300 ps, which shows a significant improvement compared to the standard LSO-based PET scanners. Three different configurations of the modular system were investigated: (i) a single layer consisting of 24 modules, (ii) a two-layer consisting of 20 and 24 modules, and (iii) three-layer consisting of 20, 24 and 28 modules. GATE Monte Carlo (MC) toolkit has been used to investigate the modular JPET system efficiency for detection of beta+ annihilation back to back photons induced in PMMA target by a proton beam (see Fig. 2). A MC based comparison of a J-PET based dual head system consisting of 2x5 modules configured as two opposing heads with the clinically operated inter-spill dual-head PET system installed at CNAO (V. Ferrero et al. Sci. Rep. 8:4100 2018) has been performed.

Fig. 1.

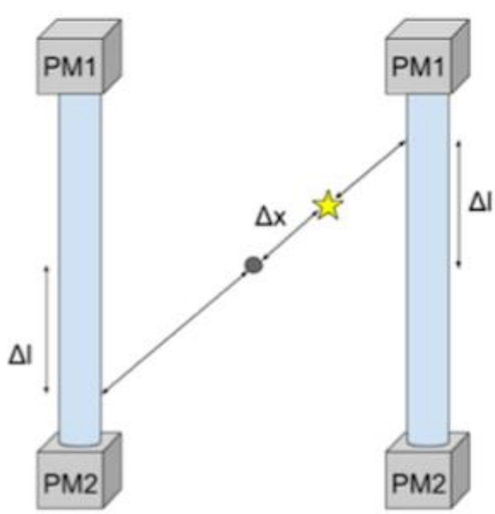
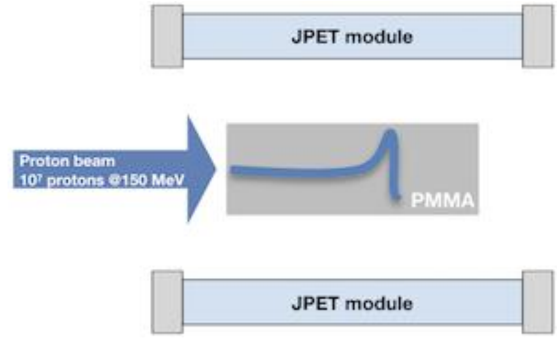


Fig. 2.



Results

The efficiency of the system in the proton beam simulation increases quadratically with the number of detector layers. It ranges from 0.12% for single layer setup to 0.75% for three-layer setup. Detected coincidences per primary proton for the single layer, two and three layer modular JPET configurations is 4.0*10^(-5), 1.3*10^(-4) and 2.5*10^(-4), respectively. The comparison of the dual head JPET and PET system installed at CNAO reveals comparable results.

Conclusion

Performed simulations suggest the signal obtained with the J-PET detector technology during proton beam therapy is sufficient for range monitoring. The results revealed that inter-spill beam range monitoring is achievable with both, dual-head and multi-layer JPET configurations. Experimental verification of the performed simulations is planned.