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.
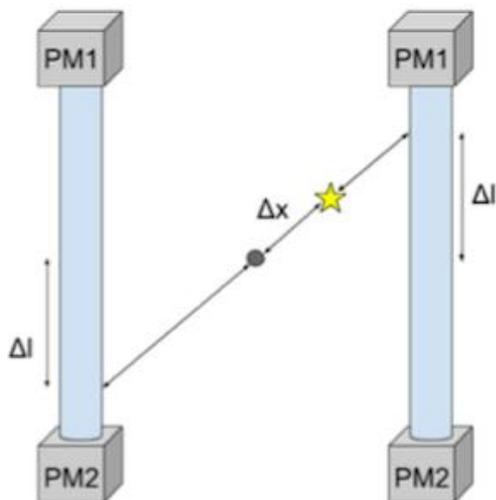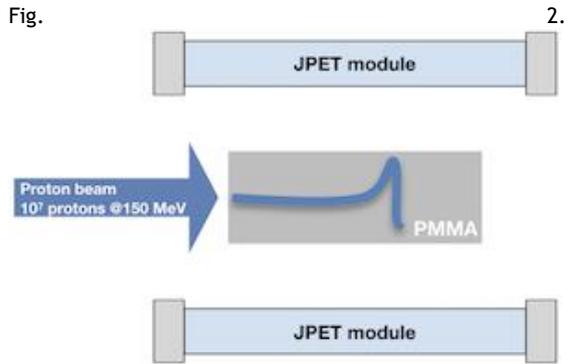
Fig. 2.

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.

Fig. 1.