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

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On behalf of the J-PET collaboration

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OBJECTIVE

Plastic-scintillator based PET detector

Proton beam therapy (PBT) range monitoring is required to fully exploit the advantages of proton beam in the clinic. In PBT the distribution of β+ emitters induced by a proton beam in patient can be detected by PET scanners, the emission distribution can be reconstructed and used for monitoring of the beam range.

The aim of this work is to study a feasibility of the J-PET technology for range verification in PBT.

IFJ PAN KRAKÓW

Krakow proton beam therapy centre

- Head and neck cancer patients treatment from Oct 2016
- ~200 patients treated in two Gantry rooms
- Eye treatment from 2010
- Proteus C-235 cyclotron
- Pencil beam scanning
- Eclipse TPS
- Dedicated QA protocols

MATERIALS AND METHODS

Plastic-scintillator based PET detector

Fig. 1.
2nd generation modular J-PET

A prototype of a diagnostic strip-based whole body PET scanner (J-PET) has been developed and tested at the Jagiellonian University in Krakow. [1] 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. A single detection module of the modular, 2nd generation strip-PET scanner (see **Fig. 1**) 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. 2**). They are read-out by fast on-board front-end electronics allowing excellent overall coincidence resolving time (CRT) of about 400 ps, which shows a significant improvement compared to the standard LSO-based PET scanners.

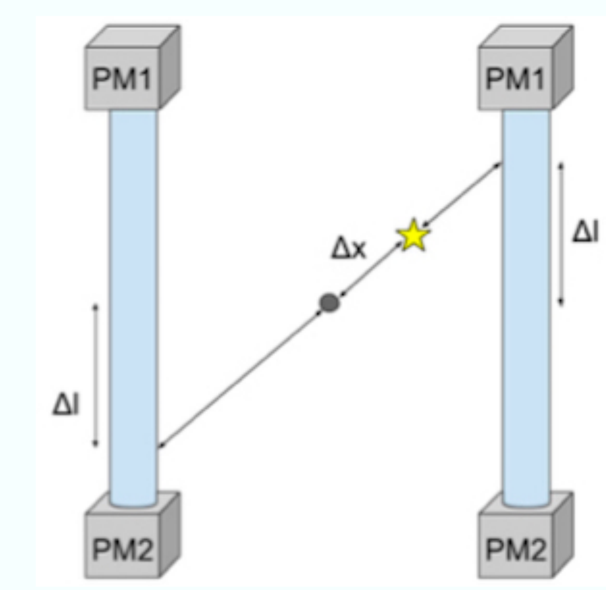


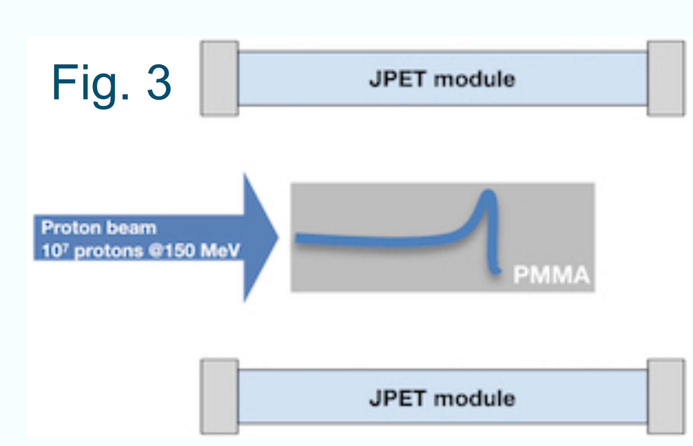
Fig. 2

Monte Carlo simulations

GATE Monte Carlo (MC) toolkit has been used to investigate the modular JPET system efficiency for detection of β+ annihilation back to back photons induced in PMMA target by a proton beam (see **Fig. 3**). Three barrel and three dual-head configurations (see **Fig. 4**; re-printed from [2]) of the modular system were investigated:

a) a single layer consisting of 24 modules (barrel)
b) a two layer consisting of 20 and 24 modules (barrel)
c) a three layers consisting of 20, 24 and 28 modules (barrel)
d) a single layer consisting of 10 modules (dual-head)
e) a two layer consisting of 20 and 24 modules (dual-head)
f) a three layers consisting of 20, 24 and 28 modules (dual-head)

Fig. 3



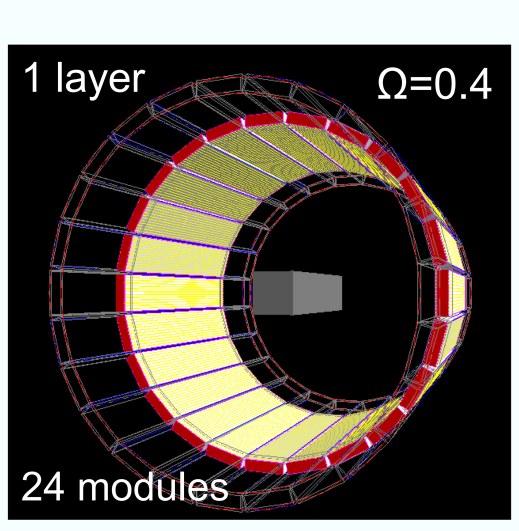


Fig. 4 (a)

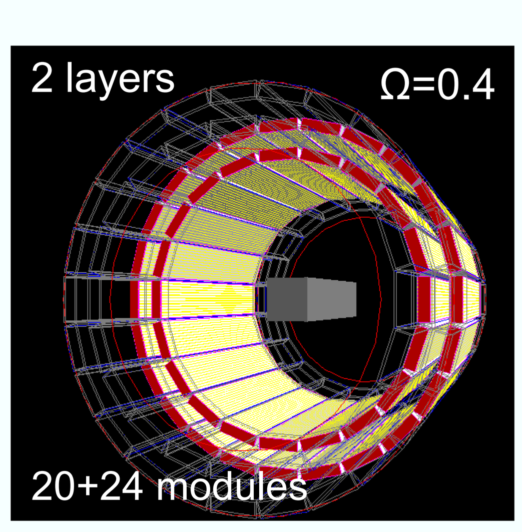


Fig. 4 (b)

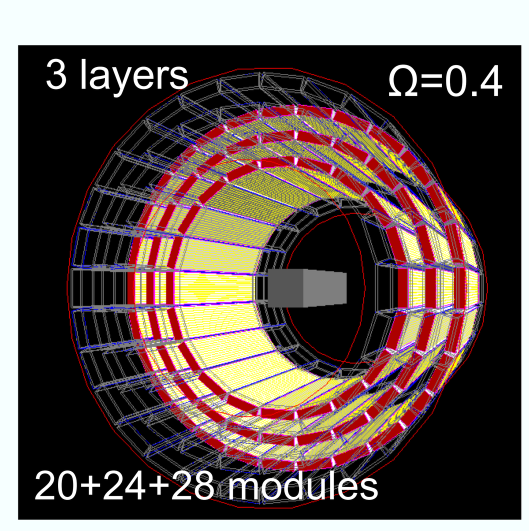


Fig. 4 (c)

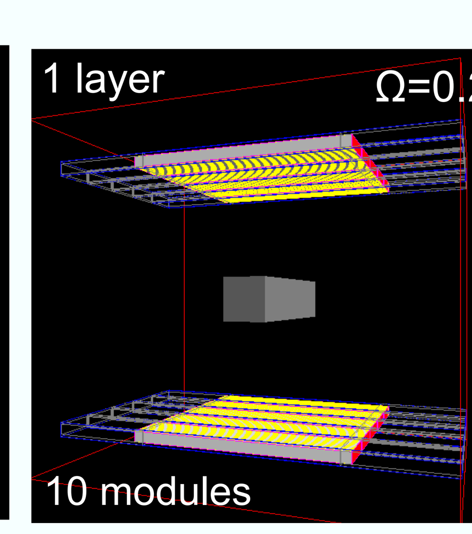


Fig. 4 (d)

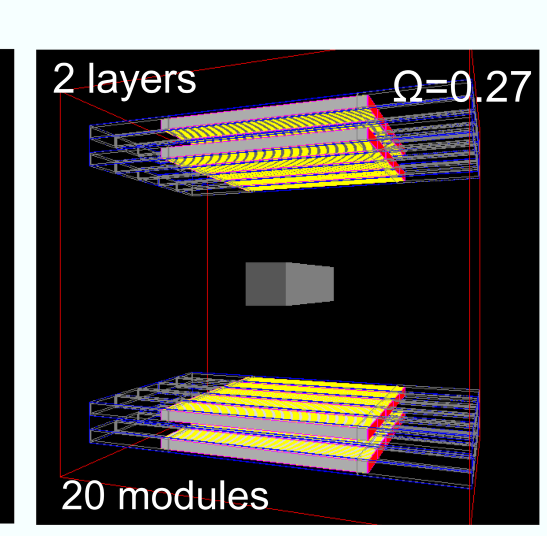


Fig. 4 (e)

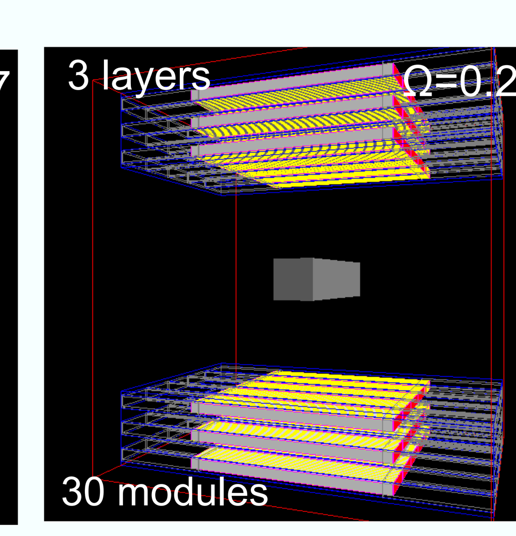


Fig. 4 (f)

RESULTS and CONCLUSION

The activity profile as a function of depth along the beam axis built from the transversally integrated signal along the phantom (blue) compared with the dose deposition profile (red; see **Fig. 5;** re-printed from [2]). The detection efficiency of the strips is about 10%. The efficiency of the system in the proton beam simulation increases quadratically with the number of detector layers. It ranges from 0.14% for single layer setup to 0.95% for three layers setup. **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.**

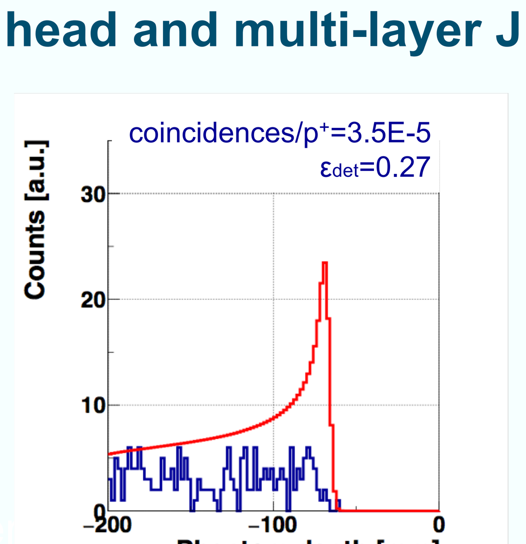


Fig. 5 (a)

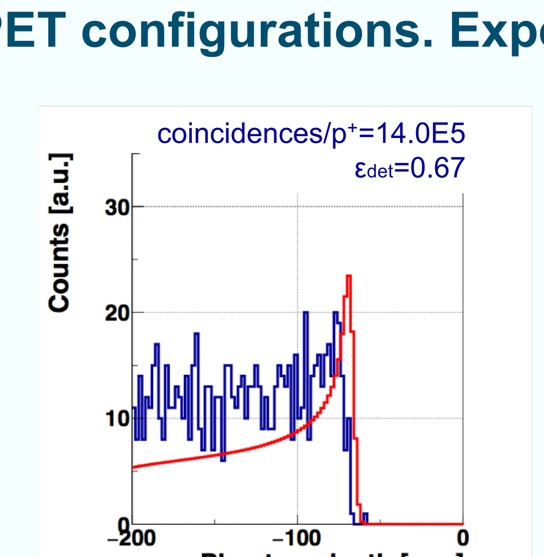


Fig. 5 (b)

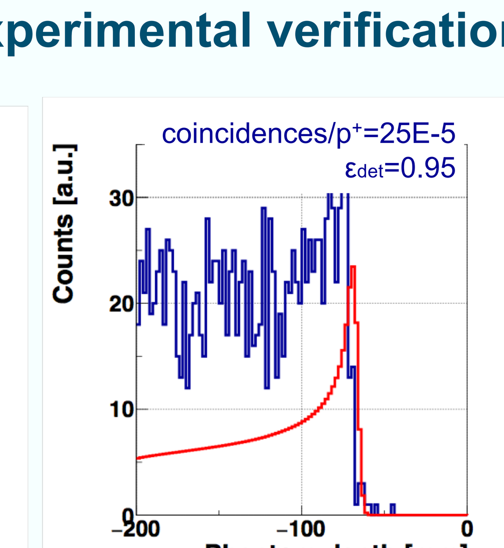
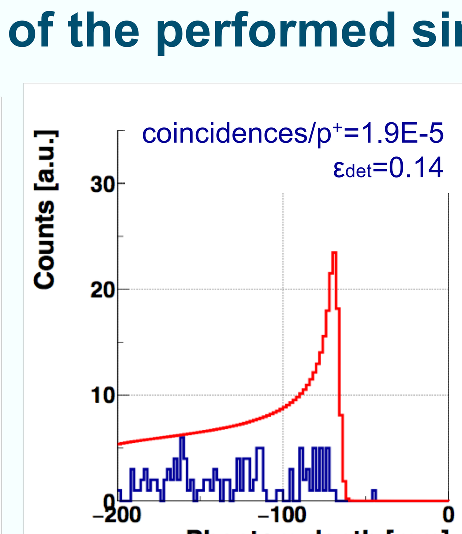


Fig. 5 (c)



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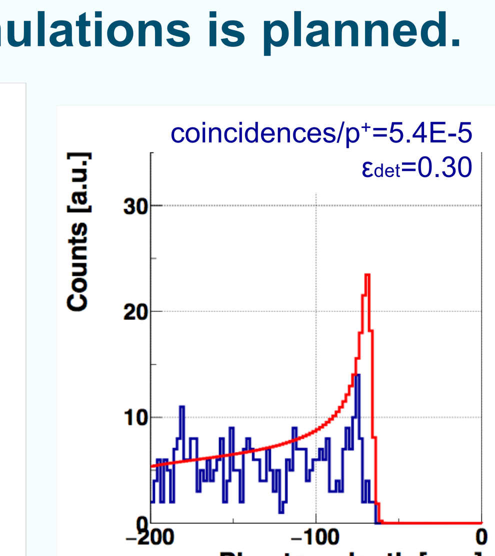

Fig. 5 (e)

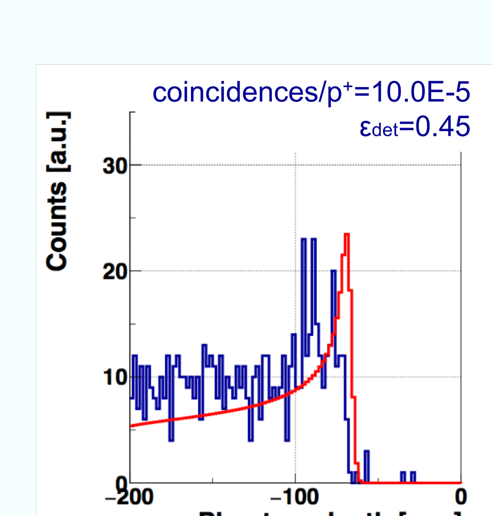

Fig. 5 (f)

Literature:

[1] Moskal et al. Phys. Med. Biol. 61 (2016) 2025-2047,
Moskal et al. Phys. Med. Biol. 64 (2019) 055017

[2] Rucinski et al. 2018, proceeding of IEEE Nuclear Science Symposium and Medical Imaging Conference (NSS/MIC)

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