Optimum detector arrangements for in-beam PET with direct time-of-flight*

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Due to its effectiveness in monitoring highly tumour-conformed charged hadron therapy, in-beam positron emission tomography (in-beam PET [1]) is strongly desirable at charged hadron facilities under construction [2] or planning [3]. We present, therefore, optimized arrangements of the γ-ray detectors for next-generation in-beam PET scanners. A versatile, fully 3D, maximum likelihood expectation maximization (MLEM) algorithm coupled to a simulation routine was applied to several high-resolution closed-ring or dual-head tomographs. In order to evaluate the quality of images obtained with several camera configurations in real therapeutic situations, β^+-activity distributions calculated from a treatment plan with the PosGen Monte-Carlo code [4] were considered. Results regarding the optimisation of in-beam PET for monitoring head-and-neck irradiation can be found in [5, 6, 7]. Here we refrain to the more challenging situation, due to the large image volume, of monitoring the irradiation of the pelvis.

Fig. 1 depicts the positioning strategy for monitoring irradiation of the pelvis with in-beam PET and Fig. 2 shows the corresponding reconstructed images obtained without (top and middle rows) and with (bottom) time-of-flight (TOF) capable detectors. The sagittal views in Fig. 2 show the rectum of the patient, a radiosensitive organ, lying adjacent to the irradiated tumour and, therefore, elucidate how in-beam PET monitoring brings important information to the radiooncologist. Clearly, the closed-ring detector configuration (top row) yields the best images and its implementation feasibility is discussed in [5, 6]. Although the field of view of the dual-head tomograph with $\phi = 46\,^\circ$ (middle row) covers the irradiated volume completely, the corresponding reconstructed images contain less information due to the image degradation arising from the gaps between the two detector heads [5, 6]. This degradation is refrained [5, 7] if TOF-capable detectors with sufficiently good coincidence time resolution are used (bottom row).

In summary, in-beam PET monitoring of large fields benefits most from a closed-ring tomograph if ultra-fast TOF-capable detectors are not available at large production scales. A non-TOF dual-head tomograph with $\phi = 46^\circ$ yields satisfactory results for monitoring head-and-neck irradiation due to the smaller target volume (not shown).

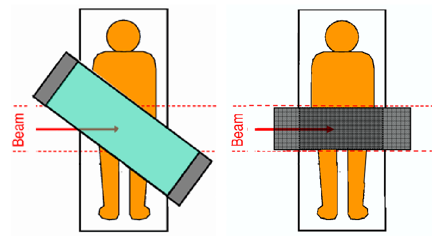

Figure 1: Patient positioning with closed-ring (left) and dual-head (right) tomographs for pelvis irradiation.

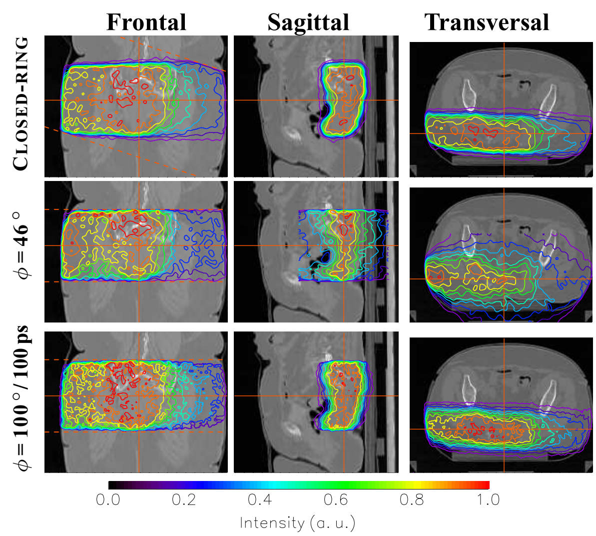

Figure 2: Reconstructions of a realistic pelvis irradiation (simulation). The angle ϕ (dual-head scanners only) is formed between the edge of the top and bottom detector heads with the isocenter of the tomograph. Top and middle rows obtained without TOF-capable detectors and MLEM reconstruction. Bottom row with detectors yielding 100 ps FWHM coincidence time resolution and with an ultra-fast, real-time direct-TOF algorithm.

References

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