Gated phantom irradiation for 4D in-beam and 4D off-beam PET comparison*

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Introduction

Treatment of intra-fractional moving tumours in the thorax and upper abdominal region using ion beams requires motion compensated beam delivery [1] but also reliable dose monitoring. Positron emission tomography (PET) can be applied to image the autoactivation occuring along the beam path during irradiation and it has turned out that PET delivers valuable information when evaluating the radiation induced activity in static targets. Depending on the available scanner type the PET measurement is carried out with a double-head scanner during irradiation (in-beam), immediatly afterwards with a scanner inside the treatment room (in-room) or with a conventional full-ring scanner in close vicinity to the treatment room (off-beam) [2]. Since 2008 a lot of experience was gained from time-resolved (4D) in-beam PET measurements with moving phantoms using the double-head PET scanner BASTEI at the former medical beam line at GSI [3].

Materials and Methods

Since there is no in-beam PET installation in clinical operation it has to be validated whether gained knowledge coincides with experiences collected at existing off-beam PET installations. Therefore, first phantom experiments with 4D PET measurements were performed under almost equal conditions at GSI and the Heidelberg Ion-Beam Therapy Center (HIT). Same motion system (commercial motion table QUASAR) and targets (made of polymethyl methacrylate) were used at both installations. A rather simple ^{12}C treatment plan including only two adjacent energies and horizontal pencil-beam scanning was delivered within a 50% amplitude gating window regarding the ± 10 mm target elongation of a $\cos^4$-motion pattern. The quite complex target geometry induced well defined range variations that have to be reproduced in the PET images. Measurements performed at GSI where reconstructed with an in-house 4D reconstruction algorithm [4] concerning in-beam (irradiation + 40 s) and in-room (1–4 min after irradiation end) time regime. Off-beam measurements at HIT started about 7 min after irradiation due to target transport to the scanner but lasted then 30 min.

Results

Reconstructed activity distributions from measurements with a static and a moving target performed at GSI are shown as color coded distribution with additional contour plot in figure 1. Range modifications are well detectable in the scanner midplane after 4D reconstruction but resolution in perpendicular direction suffers from limited angle artefacts. Detailed comparison of counting statistics and resultig image quality for 4D in-beam and 4D off-beam PET measurements at the different facilities will follow soon.

References

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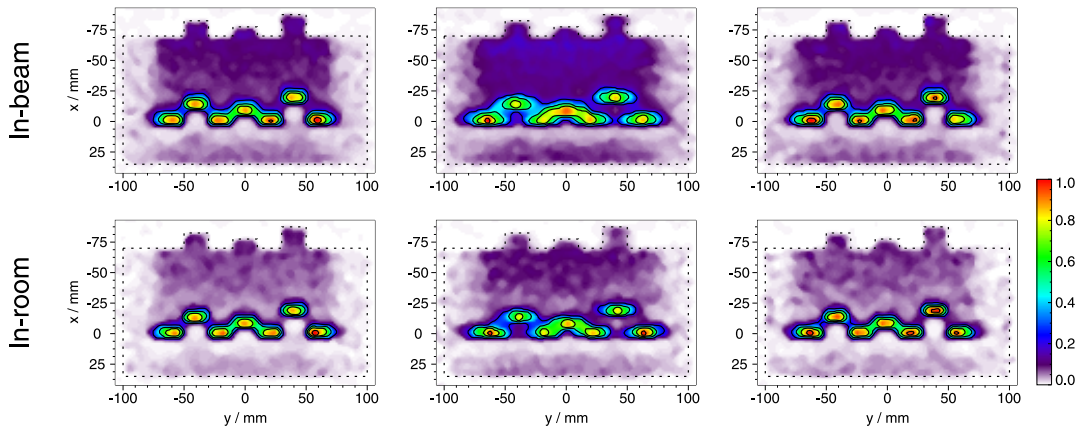

Figure 1: Reconstructed activity distributions in the irradiated phantom (dotted contour) shown for the midplane between detector heads. Images are shown for a static target (left), a moving traget without motion consideration during reconstruction (middle) and performing correct 4D reconstruction, in each case for in-beam and in-room time regime. Beam direction was along the x-axis and motion parallel to the y-axis.