Investigation of γ-background affecting in-beam PET acquisition

K. Parodi[1], P. Crespo[1], W. Enghardt[1], T. Haberer[2], J. Pawelke[1] and D. Schardt [2]

[1]Forschungszentrum Rossendorf, Dresden; [2]GSI Darmstadt

The design study of the new generation in-beam PET scanner to be developed and installed at the dedicated ion beam tumour therapy facility of Heidelberg, Germany, demands a deep understanding of physical processes affecting in-beam PET acquisition. The current experience in the monitoring of carbon ion therapy at GSI Darmstadt shows that techniques well established in radiotracer imaging may fail in the non-conventional case of in-beam PET therapy monitoring. In fact the data acquired by the in-beam positron camera during particle extraction (spill) from the GSI synchrotron are corrupted by a high noise level. They are therefore discarded for tomographic reconstruction. Previous investigations have suggested the reason of high noise to be random concidences not properly corrected for during beam extraction. The standard random correction technique implemented by the manufacturer of our PET data acquisition system (CTI PET Systems, Knoxville, TN, USA) is based on subtraction of delayed (by 128 ns) from prompt coincidences. The failure of the correction during particle extraction is thought to be due to a non-stationary (in the sub-μs scale) γ-background originating from nuclear reactions induced by the beam and hence following the time microstructure of the carbon ions [1]. The time dependence may result in a reduction of delayed coincidences affecting the proper correction for the random coincidences detected in the prompt window. This conjecture has been supported by previous in-spill measurements of time correlation between the γ-rays produced in ^{12}C irradiation of organic matter and the synchrotron radiofrequency (RF) using a GSO scintillating crystal (2 cm radius and 2.5 cm thickness) coupled to a fast PMT [2]. In the presented experiment an improved electronics was set-up in order to add photon energy discrimination to the time information. A further record of the spill number was introduced in order to perform dynamic acquisition and establish the relationship between the single photons detected by the GSO crystal and the coincidences simultaneously recorded by the positron camera during particle extraction. The same experimental configuration of [2] was chosen. Monoenergetic carbon ion beams (energy: $88.83 - 426.11\,A$MeV, intensity: $1{\cdot}10^8 - 4{\cdot}10^6$ ions per 2 s spill) were completely stopped in blocks of PMMA ($C_5H_8O_2$) placed at the isocentre of the treatment unit in the middle of the positron camera field of view. The GSO detector was set perpendicular to the beam at the same distance (41 cm) as the positron camera heads from the isocentre. The experiment confirmed a time correlation of the γ-background seen by the in-beam PET scanner with the RF signal (Fig. 1) and hence with the previously measured ion beam microstructure [1]. The physical interpretation of the time distribution has been already discussed in [2]. The data analysis has addressed the comparison between (*i*) the calculated prompt and delayed coincidence rate induced by single γ-rays modulated in time according to the GSO data and (*ii*) the "beam-induced" (i.e. not related to β^+-activity) prompt and delayed rate extrapolated from the measured PET data. The rather good agreement (Fig. 2) supports the explanation of random correction failure due to a γ-background correlated in time with the beam microstructure. A more detailed analysis will be reported soon in a forthcoming paper. This work will be the basis for a new data acquisition concept for in-beam PET.

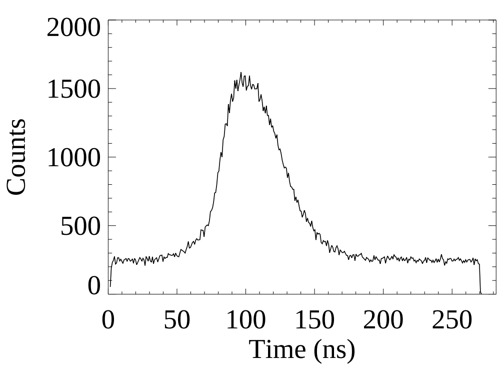

Figure 1: Time correlation with RF signal of photons detected by the GSO crystal in the $250 - 850$ keV energy window accepted by the positron camera during 500 spills of ^{12}C irradiation at 280.48 AMeV energy (RF period of 282.4 ns) and $8.5{\cdot}10^6$ ions/spill intensity.

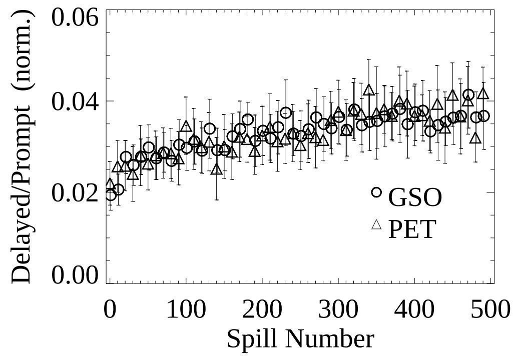

Figure 2: Ratio of the "beam-induced" delayed (d) and prompt (p) coincidence rate deduced from the GSO and PET data in dependence of the extracted spill for the same irradiation presented in Fig. 1. The d/p ratio from the GSO data was normalised to the average d/p value extracted from the PET data.

References

[1] K. Parodi et al., FZ Rossendorf, Wiss.-Tech. Ber. FZR-319 (2001) 97

[2] K. Parodi et al., FZ Rossendorf, Wiss.-Tech. Ber. FZR-341 (2002) 103