Imaging of phantoms and small animals with the AX-PET demonstrator

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The hardware of the AX-PET demonstrator and the main detector characteristics are described in detail in [1]. The contribution proposed for VCI 2013 goes far beyond this article. After a brief recapitulation of the detector design and the most important performance figures, we will discuss tomographic measurements. The two AX-PET modules are mounted on a mobile gantry set-up with a rotating support for the object to image. A number of PET phantoms, filled with positron emitting $^{18}$F in aqueous solution were imaged at the Small Animal PET Lab of the ETH Zurich and at the company Advanced Accelerator Applications, Saint Genis Pouilly, France. Dedicated image reconstruction software, based on an iterative MLEM (Maximum Likelihood Expectation Maximization) algorithm, was developed. These measurements proved high performance in terms of spatial resolution, contrast and uniformity over the entire field of view. Furthermore, various algorithms for treating Compton interactions in the crystal matrix could be tested. Fig. 1 shows an example of a reconstructed image of the resolution section of a NEMA mouse phantom. The smallest column with 1 mm diameter is clearly visible and reconstructed with an apparent diameter of 1.6 mm. Recently, another measurement campaign at the ETH Zurich permitted to image two rats and a mouse injected with $^{18}$F and the commonly used PET radiotracer FDG.

The axial concept is fully scalable (crystal and WLS strip dimensions, number of layers, etc.). Resolution, field of view and sensitivity can be adapted to the targeted application (small animal, brain, full body PET). Monte Carlo simulations are on the way to explore the ultimate performance of specific full ring detector designs. Currently, we concentrate our efforts on the extension of AX-PET towards a time-of-flight PET (TOF-PET): the precise measurement of the time difference of the two detected 511 keV photons is used to localize the annihilation point of the positron along the line of record: $\Delta r = c/2 \Delta t$. With a time resolution of the order 300 ps (FWHM), the annihilation point can be constrained to about 45 mm, which leads to significantly reduced noise and improved contrast in the reconstructed images. Ultimately, a TOF resolution in the 10 ps range, which is not in reach today, could make tomographic image reconstruction obsolete.

We will report about TOF-PET studies with the novel digital SiPM devices developed by Philips Digital Photon Counting. Two compact “digital” AX-PET modules have been built (4 crystals and 16 WLS strips each) and their performance in terms of energy, spatial and time resolution is being characterized. The excellent energy and spatial resolution of the analog AX-PET could be reproduced or even exceeded. Preliminary measurements (see Fig. 2) indicate that a TOF resolution well below 300 ps can be reached and demonstrate the possibility to extend the AX-PET concept by a powerful TOF component.

Fig. 1: Reconstructed resolution section of a NEMA mouse phantom. The diameters of the $^{18}$F filled columns are 1, 2, 3, 4 and 5 mm.

Fig. 2: Coincidence time resolution between two AX-PETs modules with digital SiPM readout.