Title: First Results from the AX-PET Demonstrator

Summary:

The AX-PET collaboration is developing a novel PET camera concept with the scintillator crystals aligned along the z coordinate (patient’s axis) rather than in a radial configuration as in conventional scanners. The AX-PET concept allows the reconstruction of the two 511 keV annihilation photons in full 3D and avoids the parallax error inherent to radial geometries.

A full AX-PET detector will be composed of a number of modules arranged in a ring configuration as shown in Fig.1. In order to demonstrate the superior performance of such geometry in terms of both spatial resolution and sensitivity, a two-module prototype (demonstrator) is currently under construction. The two modules will be mounted on a rotating gantry and characterized in measurements with point sources and PET phantoms.

Each module of the AX-PET demonstrator is composed of six layers of eight LYSO crystals interleaved with six layers of 26 WLS (wavelength shifter) strips orthogonal to them, as shown in Fig.2 (left).

The crystals are 100 mm long and have a section 3 x 3 mm$^2$. The WLS strips are 40 mm long and have a rectangular section of 3 x 0.9 mm$^2$. Both crystals and strips are readout on one end with fast photo detectors (Geiger mode APDs of type Multi Pixel Photon Counters, MPPC, by Hamamatsu) and have a reflective coating on the opposite end. The optical principle is shown in Fig.2 (right). Part of the scintillation light produced by the interaction of 511 keV photons inside the crystal is totally reflected and detected by the MPPC at one end. The other part escapes and can be absorbed (and re-emitted at a different wave-length) by the WLS strips.
The axial geometry avoids parallax errors due to different depths of interaction of the photons in the crystals. In fact, for different depths, the interaction takes place in different crystals. Consequently, the spatial resolution is essentially uniform across the entire field of view. The possibility of reconstructing Compton events by tracking their interactions in the crystal matrix permits to improve the sensitivity of the device. Another advantage of this device is that, as both the LYSO crystals and the strips are readout with Geiger mode APDs, the detector is insensitive to magnetic fields and is therefore a priori suitable for a combined PET/MRI apparatus.

Status and prospects

A complete Monte Carlo simulation of the AX-PET demonstrator based on Geant4 and GATE software has been developed, as well as a dedicated reconstruction software package adapted to the axial geometry.

A pre-module (Fig. 3) with two LYSO-crystal rows and two WLS-strip rows has been built and tested, using the final electronics data acquisition chain which has been developed for this project. The signals from the MPPCs are fed through fast amplifiers into a 128 channel charge sensitive integrated circuit, VATAGP5 chip. The VATAGP5 operates in sparse mode and it is interfaced to a PC through a VME DAQ chain composed of two custom built electronics boards.

Figure 3: Layout of an AX-PET demonstrator module

The signals and address of the crystals give the energy information together with the x and y coordinates, while the WLS signals permit to reconstruct the z coordinate using the center of gravity method.

The first results obtained illuminating the pre-module with a $^{22}$Na source are very promising and confirm results which we have already achieved with smaller arrangements.

An energy resolution of 11.5% at 511 keV has been measured; the z coordinate has been reconstructed with 1.1 mm FWHM resolution. The Monte-Carlo code indicates that we can reconstruct Compton events with at least 60% efficiency and thus increase the sensitivity.

All hardware components have been procured and fully characterized. The two final modules, each composed by 48 crystals and 156 WLS strips are currently being assembled. We will report about the performance results of this system obtained with a $^{22}$Na point source (0.25 mm diameter).