Usage of long axial crystals for PET applications: the AX-PET demonstrator and beyond

The usage of long and axially-oriented scintillator crystals for PET scanners has been shown by the AX-PET experiment to be a viable solution towards a parallax free PET system. The AX-PET is a fully operational PET demonstrator, based on axially arranged matrices of LYSO crystals (3x3x100 mm$^3$ each) and wavelength shifting strips. After extensive characterization measurements, the AX-PET has been used for the reconstruction of images of several phantoms and a few small animals (one mouse and two rats), filled and injected with F-18 based solutions.

The recent advent of digital SiPM (dSiPM) from Philips, with their compactness and high level of integration, combined with their excellent timing performance, opened interesting possibilities for future PET detectors and motivated the study of small scale prototypes modules of long crystals coupled to dSiPM. The same performance already achieved with the AX-PET has been demonstrated also by small scale setups with dSiPM readout. In addition, excellent coincidence timing resolution of $\sim 210$ ps have been achieved from dSiPM dual-sided readout 100 mm long LYSO bare crystals. In parallel, possibilities to reconstruct the axial coordinate from the dual-sided readout, by light sharing techniques, have been explored. A spatial resolution of $\sim 3$ mm FWHM, constant all along the length of the crystal, is obtained, with 100 mm long crystals with etched surfaces and ESR wrapping.

The present paper proposes a review of the AX-PET working principle and its main results, including the recent image reconstruction of small animals. The studies on 100 mm long, LYSO crystals readout on both sides by dSiPM, will also be presented, focusing both on the achieved timing performance (non-etched, bare crystals) and axial spatial resolution (etched and wrapped crystals).
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The usage of long axially oriented scintillator crystals for PET scanners has been demonstrated by the AX-PET experiment, as a viable solution towards a parallax free PET system. The AX-PET is a fully operational PET prototype, which - after extensive characterization measurements - has been used for the reconstruction of images of several phantoms and a few small animals (one mouse and two rats), filled and injected with F-18 water solutions.

The recent advent of digital SiPM (dSiPM) from Philips, with their compactness and high level of integration, combined with their excellent timing performance, opened interesting possibilities for future PET detectors and motivated the study of small scale prototypes modules of long crystals coupled to dSiPM. The same performance already achieved with the AX-PET have been demonstrated also with the digitally readout small scale setups. In addition, excellent coincidence timing resolution of \( \sim 210 \) ps have been achieved from dSiPM dual sided readout LYSO bare crystals. In parallel, possibilities to reconstruct the axial coordinate by light sharing techniques have been explored. A spatial resolution of \(~3\) mm FWHM is obtained, with 10 cm long dual sided readout crystals with etched surfaces, ESR wrapped, constant all along the length of the crystal.

The present paper proposes a review of the AX-PET working principle and results, with emphasis on the recent image reconstruction of small animals. The studies on dual-sided dSiPM readout, 10 cm long LYSO crystals will also be presented, focusing both on the timing performance (for the non-etched, bare crystals) and on the axial spatial resolution (with wrapped etched crystals).

Long axial crystals for PET applications: the AX-PET experiment and beyond

The usage of long axially oriented scintillator crystals for PET scanners has been demonstrated by the AX-PET experiment, as a viable solution towards a parallax free PET system.

The AX-PET is a fully operational PET demonstrator, consisting of two modules of 10 cm long LYSO scintillator crystals, individually readout by SiPM. Arrays of wavelength shifting strips (WLS), interleaved between the crystal layers, and individually coupled to SiPM, allow the measurement of the axial coordinate. Two AX-PET modules have been built and fully characterized with point-like Na-22 sources, demonstrating competitive performance in terms of energy (\( \Delta E/E \sim 12\% \), FWHM, at 511 keV) and spatial resolutions (\( \leq 2 \) mm, FWHM in all 3 coordinates over the complete field of view). Operated in coincidence on a dedicated gantry system, the two modules have been used for the reconstruction of images of several phantoms and few small animals (one mouse and two rats), filled and injected with F-18 water solutions.

The advent of digital SiPM (dSiPM) from Philips, with their compactness and high level of integration combined with the excellent timing performance, opens interesting possibilities for future PET detectors. Along this line, small scale prototype modules of the same detector components already adopted by the AX-PET (i.e. 10 cm long LYSO crystals and WLS) have been tested with dSiPM as photodetectors. The same performance already achieved by the AX-PET have been demonstrated also with the digital readout. In addition, competitive coincidence timing resolution of the order of 210 ps have been achieved by dual sided readout crystals.
The working principle of the AX-PET as well as its results will be presented, with emphasis on the recent small animal measurements campaign. Also the studies relative to small scale setups of long scintillator crystals dual-side readout by dSiPM will be presented, focusing both on the timing performance (for the non-etched crystals) and on the axial spatial resolution (with etched crystals).

The usage of long axially oriented scintillator crystals for PET scanners has been demonstrated by the AX-PET experiment, as a viable solution towards a parallax free PET system, where the compromise between good spatial resolution and good sensitivity (inherent to any radial geometry) is solved by the geometrical arrangement of the crystals.

Recently developed digital SiPM (from Philips) are promising alternative photodetectors

Such a matrix of crystals and WLS provides precise 3D localization of the photon interaction points, both for photoelectric absorption and for Compton scattering events. A dedicated image reconstruction software has been developed to cope with the peculiar geometry of the AX-PET. The recent small animals campaign concluded the measurements foreseen with the AX-PET demonstrator and proved the high performance of the detector and software involved. Parallel with the AX-PET final results, digital SiPM from Philips have been tested as a possible