Available online at www.sciencedirect.com
ScienceDirect
Nuclear Physics B (Proc. Suppl.) 215 (2011) 34–36
NUCLEAR PHYSICS B PROCEEDINGS SUPPLEMENTS
www.elsevier.com/locate/npbps

Performance of the AX-PET Demonstrator

P. Beltrame[a], E. Bolle[b] A. Braem[a], C. Casella[c*], E. Chesi[d], N. Clinthorne[e], R. De Leo[f], G. Dissertori[c], L. Djambazov[c], V. Fanti[a†], C. Joram[a], H. Kagan[d], W. Lustermann[c], F. Meddi[g], E. Nappi[f], F. Nessi-Tedaldi[c], J.F. Oliver[h], F. Pauss[c], M. Rafecas[h], D. Renker[i‡], A. Rudge[d], U. Ruotsalainen[j] D. Schinzel[c], T. Schneider[a], J. Séguinot[a], P. Solevi[h], S. Stapnes[b], U. Tuna[j], P. Weilhammer[d]

[a]CERN, PH Department, CH-1211 Geneva, Switzerland

[b]University of Oslo, NO-0317 Oslo, Norway

[c]ETH Zurich, CH-8092 Zurich, Switzerland

[d]Ohio State University, Columbus, Ohio 43210, USA

[e]University of Michigan, Ann Arbor, MI 48109, USA

[f]INFN Sezione di Bari, I-70122 Bari, Italy

[g]University of Rome "La Sapienza", I-00185 Rome, Italy

[h]IFIC (Universidad de Valencia / CSIC), E-46071 Valencia, Spain

[i]Paul Scherrer Institute, CH-5232 Villigen, Switzerland

[j]Tampere University of Technology, FI-33100 Tampere, Finland

The goal of the AX-PET project is to build and test a demonstrator for a high resolution, high sensitivity PET scanner, based on a novel geometrical concept of long axially oriented crystals. The demonstrator comprises two PET modules used in coincidence. The two modules have been constructed and characterized (both individually and in coincidence) in dedicated test setups, with point-like sources. Good performance in terms of energy, spatial and timing resolution have been demonstrated. First measurements with extended phantoms filled with FDG-radiotracers have been recently performed.

1. THE AX-PET PROJECT

The AX-PET (AXial Positron Emission Tomography) project introduces a novel geometrical concept for a PET scanner, based on matrices of long scintillator crystals, axially arranged in the tomograph. The concept of the experiment is described in detail in previous publications [1,2]. The detector module consists of a matrix of 48 long LYSO crystals[4] ($3\times3\times100$ mm^3 each), arranged in 6 layers. Behind each layer of crystals, an array of 26 wave length shifter (WLS) strips[5] is placed orthogonal to the crystals, for the measurement of the axial coordinate of the photon interaction point.

The aim of the AX-PET project is to build and characterize a demonstrator for a PET scanner. The demonstrator consists of two such modules, used in coincidence. In order to mimic the performance of a full scanner, the two modules are

*Corresponding author: Chiara.Casella@cern.ch
†On leave of absence from University and INFN Cagliari, Italy
‡Currently with Technical University München, Garching, Germany

[4]Prelude 420 ($Lu_{1.8}Y_{.2}SiO_5$:Ce), Saint Gobain.
[5]EJ-280-10x, ELJEN Technology.

0920-5632/$ – see front matter
doi:10.1016/j.nuclphysbps.2011.03.127

used in a gantry setup with a rotating source.

2. THE EXPERIMENTAL SETUP

The two modules have been assembled and individually characterized and calibrated with point-like sources in dedicated experimental setups at CERN. A ^{22}Na source (β^+ emitter; activity 0.9 MBq; 0.25 mm active diameter, embedded in a plexiglas disk) is placed between the module and a tagging scintillator coupled to a fast PMT. The coincidence between the module and the tagger is used to select the photons from the e^+ annihilation process. Tagging crystals of different size and geometry were available. Changing the tagger and the relative distance between tagger, source and module, two different configuration were tested: (a) uniform illumination of the module, for energy calibration and resolution measurements; (b) collimated beam spot on the module, for spatial resolution characterization and tests of response uniformity over different positions of the field of view (FOV).

A similar setup is used also with the two modules in coincidence. The two modules are mounted face to face (d = 15 cm) and the source is placed at several positions, inside and outside the FOV. As a last step, the two modules are mounted on the dedicated gantry setup. The gantry keeps one module on a fixed position and the second one on a movable arm ($\theta_{12} = 180° \pm 60°$), for the coverage of an extended FOV; in between, the source is placed on a rotating table.

3. ACHIEVED PERFORMANCE

Figure 1 shows the typical results in terms of energy resolution achieved in one AX-PET module. A mean energy resolution of 11.6% FWHM (at 511 keV) - averaged over the 48 crystals of the module - is obtained. Also, a good uniformity among different crystals is observed. From the two modules coincidence data (with point-like source), an estimate of the spatial resolution in the axial direction can be obtained. Figure 2 shows a geometrical drawing of the lines of response for 100 coincidence events of a typical run and their intersection with the central plane. This

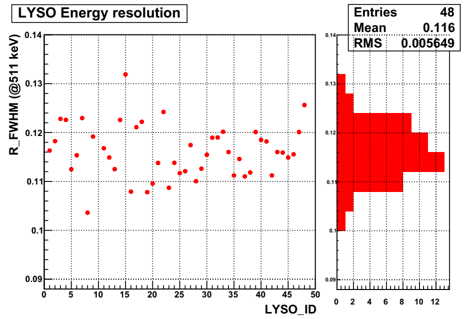

Figure 1. Energy resolution (FWHM) at 511 keV, for the 48 crystals belonging to one AX-PET module. Similar results are achieved for the second module.

latter distribution results in an intrinsic axial resolution of 1.35 mm FWHM, once the contributions coming from the physics of the e^+ annihilation - finite positron range and non collinearity of the two emitted photons - are subtracted [3]. Figure 3 shows finally the timing performance obtained in the two modules coincidence, which would allow for a small coincidence window of a few ns.

4. PHANTOMS MEASUREMENTS

A first measurement campaign with phantoms filled with FDG radiotracer has been recently carried out (April 2010) at the ETH Radiopharmaceutical Insitute[6], Zurich. Different phantoms (capillaries, mouse-like and micro-Derenzo phantoms) were filled with different initial activities of FDG (max 30 MBq) and coincidence data were acquired, with the two modules in a fixed position and the source rotating, from 0 to 180 degrees in steps of 10 degrees each.

The reconstruction algorithm is an iterative reconstruction method (MLEM, Maximum Likelihood Expectation Maximisation), based on a system matrix which models the geometry of the modules. The system matrix is computed with multi-ray tracing technique, also including crystal attenuation and penetration effects. Although

[6] www.pharma.ethz.ch/institute_groups/radiopharmaceutical_science

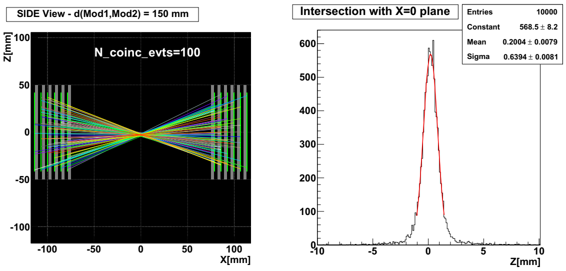

Figure 2. Left: Drawing of lines of response i.e. lines connecting - event by event - the interaction points measured in the 2 modules, when they are used in coincidence with the ^{22}Na source in the middle. Right: Their intersection with the central plane ($x = 0$). The σ of this distribution (estimate of the achieved axial resolution) includes intrinsic resolution, positron range and non collinearity contributions.

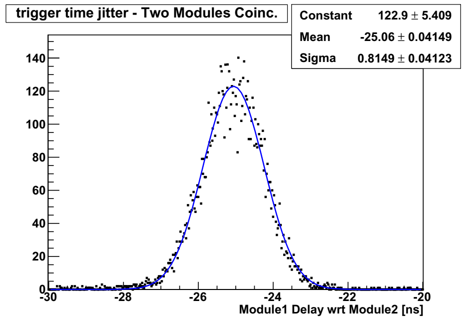

Figure 3. Time jitter of one AX-PET module with respect to the other, when they are used in coincidence.

still preliminary, images from the phantoms data have been successfully reconstructed. An example is shown in Figure 4.

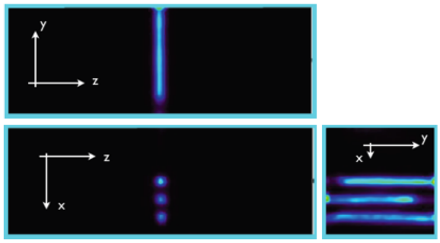

Figure 4. Preliminary reconstructed images (in sagittal, coronal and transverse plane) of a 3 capillaries phantom filled with FDG radiotracer. The capillaries are 30 mm long, with an inner diameter of 1.4 mm. The pitch is 5 mm. The apparent differences in the length of the 3 capillaries in the reconstructed image is due to air bubbles. The system matrix used for this image maps a FOV of 30×30×83 voxels, each voxel being 1 mm^3.

5. CONCLUSIONS AND OUTLOOK

The two modules for the AX-PET demonstrator have been assembled and fully characterized. The achieved performance, in terms of energy, timing and spatial resolution are competitive with state of the art PET instruments. The first measurements with extended objects (different phantoms filled with FDG radiotracer) have been performed, and the first preliminary reconstructed images are available. Improvements of the quality of the reconstructed images are currently ongoing. A second measurements campaign with phantoms - including the extended FOV coverage - is also planned in the upcoming months.

6. ACKNOWLEDGEMENTS

We are grateful to the ETH Institute of Pharmaceutical Sciences, Animal Imaging Center - PET, in Zurich, for the phantom measurements campaing. In particular we would like to thank Prof. August Schubiger, Prof. Simon M. Ametamey, PD Stefanie D. Kramer and their entire team. We also thank the various technicians at CERN and ETH who strongly contributed to the progress of the project.

REFERENCES

1. J. Seguinot et al., Il Nuovo Cimento C 29 (04) (2006) 429.
2. A. Braem et al., NIM A 580 (2007) 1513.
3. S. E. Derenzo, IEEE Trans Nucl Sci (1986) NS-33: 565-569.