Polarimetric performance of a multilayer CdTe spectro-imager for high-energy astrophysics

M. Moita[1], J. M. Maia[1,2], R. M. Curado da Silva[1], N. Auricchio[3], E. Caroli[3]

[1]LIP - Laboratório de Instrumentação e Física Experimental de Partículas, Departamento de Fisica da Universidade de Coimbra, Portugal
[2]Universidade da Beira Interior, Covilhã, Portugal
[3]INAF/IASF-Bologna, Via Gobetti 101, 40129 Bologna, Italy

Introduction

In the multi-messenger era, gamma-ray polarimetry may contribute to a wider understanding of gamma-ray transients associated to gravitational waves detection. Furthermore, allows a deep understanding of the physical processes, geometry and magnetic fields of sources such as pulsars, solar flares, active galactic nuclei or galactic black holes. Herein, we analysed the performances of a prototype in a 2 layers Compton configuration based on two CdTe spectro-imagers operated in coincidence. The two CdTe detectors have an anode segmented in 8´8 pixels (2 mm pitch) on 2 mm thick crystals. The detection system configuration will allow assessing the scattering polarimetric performance of a 3D spectro-imager by changing the distance between the two layers over the 100-600 keV energy range. These conclusions will be of fundamental importance for both high efficiency Laue lens telescope focal plane and all sky advanced Compton telescope design for next generation space mission. The polarimetric modulation factor was evaluated at distances between planes ranging from 8mm up to 16mm at different Compton scattering angles.

Compton Polarimetry

The Compton scattering process presents a dependence on polarization direction by the Klein-Nishima differential cross section for Compton scattering:

$$\frac{d\sigma_{KN,P}}{d\Omega} = \frac{r_0^2}{2}\left(\frac{E'}{E}\right)^2\left[\frac{E'}{E}+\frac{E}{E'}-2sin^2\theta cos^2\varphi\right]$$

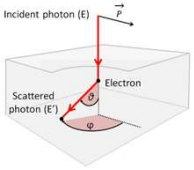


Fig. 1 – Schematic of Compton scattering of a polarized photon.

E – Energy of the incoming photon
E' – Energy of the scattered photon
r_0 – Classical electron radius
θ – Scattered angle
φ – azimuthal angle relative to the photon polarization plane

Dual Plane Polarimeter

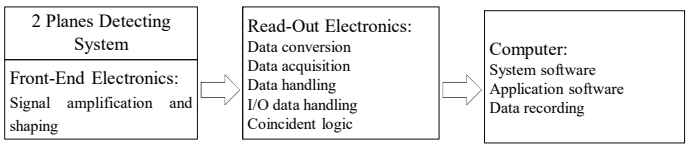


Fig. 2 – Schematic of the 2 planes detection system.

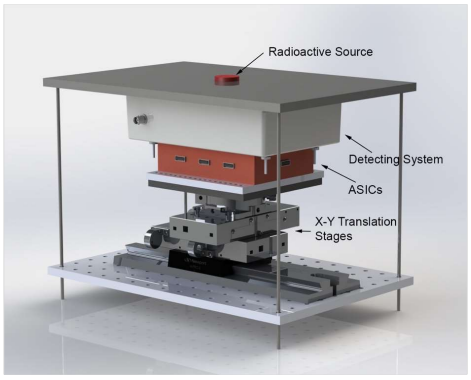


Fig. 3 - Opposite view of the beam pointing direction. It shows the beam entrance, the Dual Plane detector mounted to the 5-axis automated stage and the Ge detector in the end of the line.

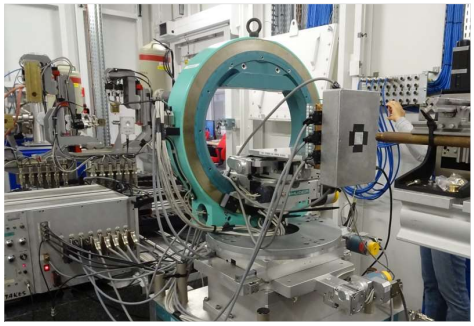


Fig. 4 - The Dual Plane Detector mounted on 5 axis automated stage. Is possible to see also the TAKES read out system.

ASTENA mission proposal

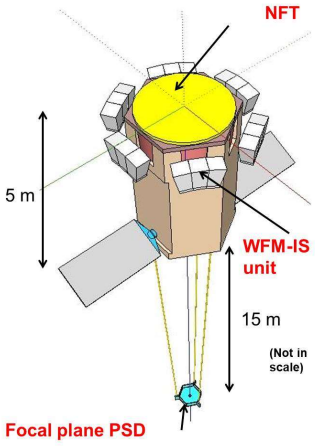


Fig. 6 - Configuration of the ASTENA mission concept in flight.

The Advanced Surveyor of Transient Events and Nuclear Astrophysics (ASTENA) consists of a Wide Field Monitor-Imaging Spectrometer (WFM-IS) working in the passband 2 keV – 20 MeV and a Narrow Field Telescope (NFT) in the passband 50 – 600 keV. The WFM-IS consists of 6 blocks of 3 detection units with two of them offset in one direction by ±20°. Each WFM-IS unit consists of an array of detection elements, each made of a scintillator bar (CsI(TI) or similar) 5 cm long, with an hexagonal cross section of about 75 ⟦mm⟧ ^2, viewed by two Silicon Drift Detectors (SDD) 0.45 mm thick, one on the top (side of entrance of the celestial photons) and other on the bottom. Thanks to its design, the WFM-IS is particularly suitable to be triggered by celestial transient events, like short and long (also low luminosity) GRBs, X–/gamma–ray counterparts of Gravitational Wave events, Tidal Disruption Events, etc, with 1 arcmin accuracy for prompt follow up with the NFT, measuring the prompt emission spectrum and the polarization status at high energies (>80 keV

Experimental Results

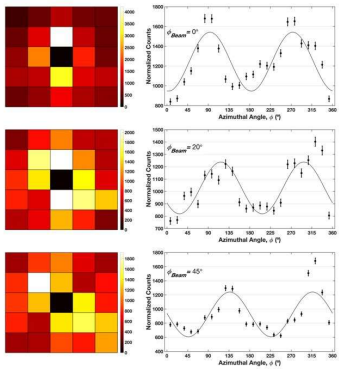
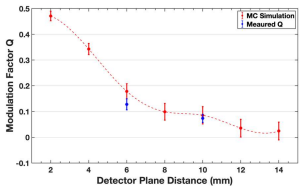


Fig. 5 - Number of double-events obtained inside a 15° radial bin, centred on the CdTe pixelized matrix for polarization angles of: 0°, 20° and 45°.



The modulation factor Q measured for 278 keV photons at two different distances between the detector planes compared with the simulation curve for modulation obtained for the full target distance range of the Dual Plane Detector system (2 – 14 mm).

Conclusion

In this work is presented a new detection configuration that is being developed for future high-energy astrophysics' missions. This configuration will allow to study and to assess the scattering polarimetric performance of a 3D spectro-imager and thereby while optimize parameters such as the distance between the two CdTe pixel detection layers over the 100-700 keV energy range. These results will be used to determine the final configuration of ASTENA mission proposal and further missions' based on multi-layer and 3D detection technology.

Contact
Miguel Moita
Laboratório de Instrumentação e Física Experimental de Partículas
Physic Department, University of Coimbra, Portugal
miguel.moita@coimbra.lip.pt

Acknowledgements
Fundação para a Ciência e Tecnologia for the Ph.D. scholarship grant PD/BD/105922/2014