Background rejection efficiency of the anti-coincidence system of the High Energy Detector of New Hard X-ray Mission

E. Strazzeri[1], M. Giorgini[2], T. Mineo[1], A. Giuliani[2], E. Perinati[3], A. Chen[2], A. Tiengo[2], O. Catalano[1], F. Gastaldello[2], M. Rossetti[2], N. La Palombara[2], S. Mereghetti[2]

1 INAF-Istituto di Astrofisica Spaziale e Fisica Cosmica Palermo

2 INAF- INAF-Istituto di Astrofisica Spaziale e Fisica Cosmica Milano

3 Institute for Astronomy and Astrophysics of the University of Tübingen

Contact: **strazzeri@ifc.inaf.it**

Abstract

The NHXM (New Hard X-ray Mission) observatory is a medium size mission designed to observe X-ray emission in the range 0.5 keV-80 keV range with high spatial and spectral resolution, together with a sensitive X-ray imaging polarimetric capability. The mission, submitted to the 2010 ESA Cosmic Vision call, has the main scientific objective of studying the physics of accretion in black holes and of particle acceleration mechanism for different sources. The spectral-imaging camera includes a High Energy Detector (HED) sensitive in the 7 keV-120 keV band surrounded by an Anti-Coincidence (AC) system conceived to reduce the particles and gamma rays background. In this poster, we present a set of simulation results on the AC system, performed with GEANT4, in order to investigate the rejection efficiency, at different energy thresholds, for different inorganic scintillators crystals.

Introduction

The New Hard X-ray Mission (NHXM) is a medium size mission, submitted to the 2010 ESA Cosmic Vision call, designed to observe the X-rays sky in the range 0.5 keV-80 keV producing simultaneously images with high spatial resolution, spectra with E/DE<60 and maps of the polarization degree and angle of the emitted radiation (Tagliaferri et al., SPIE 7732 (2010) 773217). The payload is composed by three identical spectral-imaging focusing telescopes, one X-ray polarimeter and a Wide Field X-Ray Monitor, sensitive in the band 2 keV-50 keV, for the detection of high variable sources (e.g. GRB, soft-Gamma Ray repeaters, transient sources like CV, novae, binary sources, or relativistically boosted blazars).
The NHXM is qualified to provide a real breakthrough on a number of hot astrophysical topics and to open a brand new window for the understanding of the accreting non-thermal sources.
In particular, the main scientific objectives of NHXM are based on: i) censing the black holes in the Universe and probing the physics of accretion in the most diverse conditions; ii) investigating the particle acceleration mechanism and the effects of radiative transfer in highly magnetized plasmas and strong gravitational fields. The satellite is designed for a Low Equatorial Orbit (LEO) similar to the one of two very successful hard-X ray missions, BeppoSAX and Swift (a circular nearly equatorial (inclination <5°) orbit at 600 km mean altitude) that allows for a very low and stable background count rate.

Table 1: ***NHXM scientific requirements***

Parameter	Value
Energy band	0.3 keV – 80 keV
FOV (at 30 keV)	≥ 12 arcmin
On-axis sensitivity	≤ 10^{-14} c.g.s.(~0.5 μCrab), 10keV-40 keV (3s, 1Ms, PL-G=1.6)
On-axis effective area	≥ 300 cm^2 at 0.5 keV ≥ 1000 cm^2 in the range 2 keV-8 keV ≥ 350 (500) cm^2 at 30 keV ≥ 100 cm^2 at 70 keV
LED background	< 1×10^{-3} cts s^{-1} cm^{-2} keV^{-1}
HED background	< 2×10^{-4} cts s^{-1} cm^{-2} keV^{-1}
Angular resolution (HEW)	≤ 15″ E<10 keV ≤ 20″ E<30 keV
E/DE	40-50 at 6 keV 60 at 60 keV
Polarisation sensitivity	9.7% MDP in 100 ks for 1 mCrab (2 keV-10 keV) 1.8 mCrab (6 keV-35 keV)
Wide Field X-RayMonitor	2 mCrab in 50 ks at 5 s (2 keV-50 keV); triggering on a 0.5 Crab source in 1 s, providing the position in < 1 min, FOV= 2.9 sr partially coded, 0.5 sr fully coded
Absol. pointing reconstr.	3″ (radius 90%)

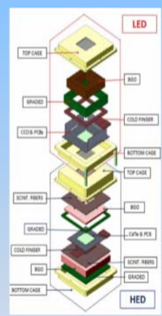

Figure 1: Exploded view of the LED and HED modules

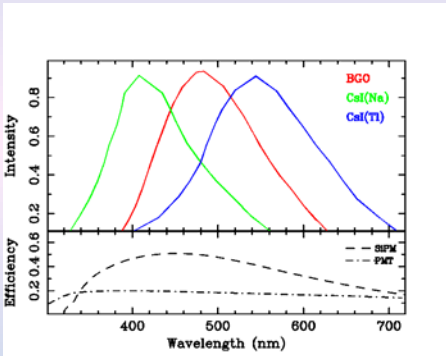

Figure 2: Top panel : the emission spectra of the BGO (red line), CsI(Na)(green line) and CsI(Tl) (blue line).
Bottom panel : the PMT and SiPM efficiency.

Simulations

The study of the AC detector efficiency with the proposed configuration has been performed by means of GEANT4 that include the detailed description of the HED and AC geometry as showed in Fig.1. An empty Al box for the LED camera is also taken into account together with the cage for the CsI(Tl) and CsI(Na) scintillators. The light collection from the scintillator is performed with two PMT of size 35x16 mm^2 each and with 12 SiPMs with a similar collecting area.
The energy deposited in the scintillators, as provided by GEANT4, is converted into UV photons with the factor quoted in Table 2 and the spectra shown in Fig.2.
To evaluate the light collected by the PMTs, it has been performed an *ad-hoc* simulation that assumes a reflection from the scintillator walls of 97% and follows the randomly generated photons inside the scintillator up to their detection or absorption. It has been found that the collected light is proportional to the ratio of the covered PMT or SiPMs area to the total scintillator surface. The input charged particles (p,e^-,e^+), with rate values indicated inTable 3 and energies in the range 30 MeV-100 GeV, has been generated in a 4π solid angle with isotropic angular distribution and the following energy distribution (Mizuno et al., ApJ 614 (2004) 1113):

PROTONS

$$\begin{cases} \Phi_{TOT} = 0.1 \cdot \left(E/_{0.1}\right)^{-1.0} & E < 100\ MeV \\ \Phi_{TOT} = 0.1 \cdot \left(E/_{0.1}\right)^{-0.87} & 100\ MeV < E < 600\ MeV \\ \Phi_{TOT} = 0.02 \cdot \left(E/_{0.6}\right)^{-2.53} & 600\ MeV < E < 8800\ MeV \end{cases}$$

ELECTRONS POSITRONS

$$\begin{cases} \Phi_{TOT} = 0.3 \cdot \left(E/_{0.1}\right)^{-1.0} & E \leq 100\ MeV \\ \Phi_{TOT} = 0.3 \cdot \left(E/_{0.1}\right)^{-2.7} & E > 100\ MeV \\ \Phi_{TOT} = 0.3 \cdot \left(E/_{0.1}\right)^{-2.7} + 0.113 \cdot E^{-2.6} & E \geq 8800\ MeV \end{cases}$$

The simulated input particles are 24 10^6 protons, 6 10^6 electrons and 7 10^6 positrons. For each incident particle there are about 1500 events in the range 7 keV-100 keV of the residual spectra. A threshold of 5 and 15 photoelectrons for the PMT and SiPM, respectively, is applied to trigger events in AC system. The corresponding thresholds for the energy deposited in the three scintillators are shown in Table 4, where also the total residual rates in the energy range 7 keV-100 keV are indicated.

Table 3. Rate of the input charged particle spectra

Primary Particle	Rate [ct cm^2s^{-1}]
Protons	0.32
Electrons	0.08
Positrons	0.13

Table 2. Light yield for the three scintillators

Scintillator	Light Yield
BGO	10
CsI(Tl)	54
CsI(Na)	41

Table 4. Rate of the input charged particle spectra

Scintillator	Threshold (keV)		Residual bkg in the range 7 keV-100 keV (ph cm^{-2} s^{-1} keV^{-1})			
	PMT	SiPM	PMT		SiPM	
BGO	90	110	7.4±0.2e-5	(2.4±0.1e-5 protons) (2.1±0.1e-5 electrons) (2.9±0.1e-5 positrons)	7.5±0.2e-5	(2.4±0.1e-5 protons) (2.1±0.1e-5 electrons) (3.0±0.1e-5 positrons)
CsI(Tl)	20	25	6.6±0.2e-5	(2.0±0.1e-5 protons) (1.8±0.1e-5 electrons) (2.8±0.1e-5 positrons)	6.7±0.2e-5	(2.1±0.1e-5 protons) (1.8±0.1e-5 electrons) (2.8±0.1e-5 positrons)
CsI(Na)	20	25	7.1±0.2e-5	(2.3±0.1e-5 protons) (1.9±0.1e-5 electrons) (2.9±0.1e-5 positrons)	7.0±0.2e-5	(2.1±0.1e-5 protons) (1.9±0.1e-5 electrons) (3.0±0.1e-5 positrons)

Conclusions

The three investigated scintillators give an equivalent rejection efficiency for the considered charged particles, although the CsI are less efficient. However, their different energy threshold and density (7.13 g/cm3 for BGO and 4.51 g/cm3 for CsI) can produce different rejection efficiency for photons so that further simulations are required to evaluate these effects, considering that in LEO orbit the contribution of photons to the residual background is not negligible. The SiPM has a quantum efficiency higher than the PMT one, however its high electronic background converts to a higher energy threshold, with similar results for the particle residual background in the HED.