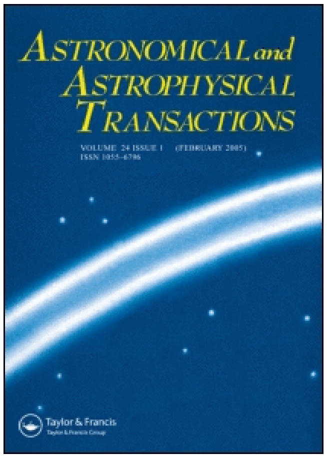

Astronomical & Astrophysical Transactions
The Journal of the Eurasian Astronomical Society
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713453505

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Online Publication Date: 01 December 2003
To cite this Article: Konobeevski, E. S., Mordovskoy, M. V. and Skorkin, V. M. (2003) 'The cosmic gamma-ray detector', Astronomical & Astrophysical Transactions, 22:6, 875 - 878
To link to this article: DOI: 10.1080/1055679031000153888
URL: http://dx.doi.org/10.1080/1055679031000153888

Astronomical and Astrophysical Transactions
Vol. 22, No. 6, December 2003, pp. 875–878

THE COSMIC GAMMA-RAY DETECTOR

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(Received 14 November 2002)

In this paper a compact large solid-angle photodetection system is proposed. This system was designed to measure spectrum of the gamma-ray bursts in the range from 20 MeV to 10 GeV with a resolution from 2 to 150 MeV.

Keywords: Spectrometer; Gamma-rays; Galaxy; Lead tungstate ($PbWO_4$)

Our knowledge of the inner Galaxy gamma-ray sky spectrum (Fig. 1) has increased during this last decade, principally because of the gamma-ray instruments on board the Compton Gamma Ray Observatory (see for example Battiston *et al.* (2000)).

The Compton Gamma Ray Observatory instruments are the imaging Compton telescope (COMPTEL) and the energetic gamma-ray experiment telescope (EGRET). COMPTEL was designed to conduct imaging surveys of the entire gamma-ray sky in the range from 0.8 to 30 MeV with a resolution of 0.1–1.5 MeV; it has a field of view of 64°, with a resolution of 1.7–4.4°. The purpose of COMPTEL was to focus on nuclear gamma-ray phenomena such as novae, supernovae and cosmic-ray-produced high-energy photons. EGRET was designed to conduct all-sky imaging surveys of the highest-energy phenomena, in the range from 20 MeV to 30 GeV (with a 20% resolution). It has a field of view of 20°, with a resolution of 0.3–10°. EGRET uses a neon–ethane spark chamber, which is based on the production of pairs by the incoming high-energy photons. It is used to study the unexplored Galaxy gamma-ray sky spectrum range from 20 to 100 MeV (Fig. 1). A compact large solid-angle photodetection system is proposed to conduct imaging surveys of the entire gamma-ray sky in the range from 20 MeV to 10 GeV. This system (the energetic photon spectrometer (EPHOS)) was designed to measure spectrum of the gamma-ray bursts with a resolution of 2–150 MeV. EPHOS consists of a scintillator detector array using lead tungstate ($PbWO_4$) crystals with a read-out obtained with fast photomultipliers. The density of $PbWO_4$ is $8.28\,g\,cm^{-3}$. The relevant advantages of $PbWO_4$ (see for example Menger *et al.* (1998)) are the short radiation length (0.89 cm) and fast timing (20 ns), which offers the possibility of efficient background suppression. The luminescence spectrum and the light yield of $PbWO_4$ are shown in Figures 2 and 3 respectively. The luminescence yield was determined by measuring the response to a ^{60}Co source ($E = 1.17$ and 1.33 MeV).

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ISSN 1055-6796 print; ISSN 1476-3540 online
DOI: 10.1080/1055679031000153888

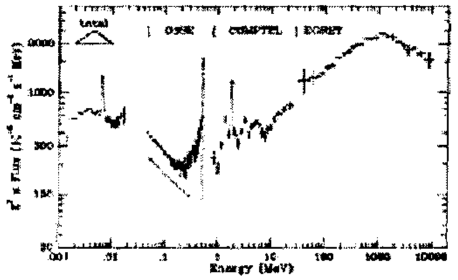

FIGURE 1 Inner Galaxy full X-ray and gamma-ray spectrum.

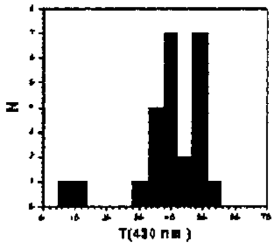

FIGURE 2 The luminescence spectrum of a $PbWO_4$ crystal.

A compact $PbWO_4$ scintillator provides good energy and time resolution for efficient multiphoton detection. $PbWO_4$ is the most appropriate scintillator material for the high-energy gamma-ray spectrometer. The energy resolution of $PbWO_4$ is shown in Figure 4.

Figure 4 summarizes the excellent energy resolutions for photons obtained for different $PbWO_4$ crystal integrating either over the total light output or over the fast component only. A significant improvement in the resolution can be deduced from the analysis of the single-crystal response measured below 200 MeV with tapered crystals. From the timing signal of the individual $PbWO_4$ crystal scintillator the intrinsic time resolution of 130 ps has been deduced. It even allows compact detector arrangements (length of flight path, 0.5 m) and sufficient particle–photon discrimination via a time-of-flight technique. The point of impact of the photon can be reconstructed from the shower distribution with an accuracy of (x or y) 1 mm. However, owing to thermal quenching at room temperature, one has to cope with a low luminescence yield, which can become the limiting factor at low energies. The temperature dependence of $PbWO_4$ light yield is shown in Figure 5.

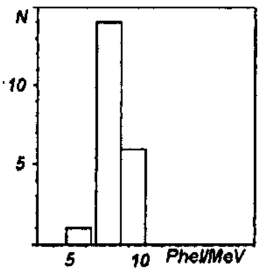

FIGURE 3 A light yield of $PbWO_4$ crystal.

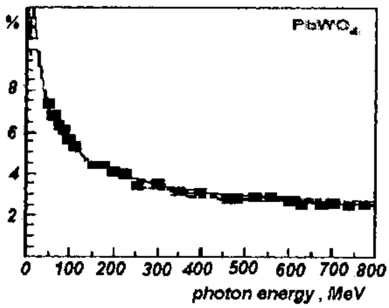

FIGURE 4 The energy resolution of $PbWO_4$.

EPHOS (Fig. 6) is an array of 200 scintillator detector based on $PbWO_4$ crystals. The EPHOS detectors were surrounded by anticoincidence shielding of plastic scintillators with photodiode read-out. It is offers the possibility of efficient charged-particle background suppression.

The EPHOS detector is made out of four $PbWO_4$ crystals of size 22 mm × 22 mm × 180 mm. A $PbWO_4$ crystal scintillator converts the energy of the photon into visible light, which is recorded by the fast photomultiplier FEU-175. The diameter of the photomultiplier photocathode is 20 mm. The construction of the EPHOS detector consisting of four $PbWO_4$ crystals is shown in Figure 7.

The detector is assembled from the photomultipliers and $PbWO_4$ crystals in common housing. The cooling element and copper heat exchanger are used to cool crystals. The $PbWO_4$ crystals are insulated from exterior heat. Two temperature sensors record the crystal temperature with an accuracy of 0.2–0.3 °C.

The operating temperature of detectors is required to be −20 °C. At this temperature the light output of crystal exceeds the similar parameter at ambient temperature by a factor of 2–3. The exit signal from photomultiplier is sent via a coaxial cable to a prestress low-noise amplifier, then to a final amplifier, to a delay and to the input of the analogue-to-digital converter in a common information-gathering system. The signals from the individual $PbWO_4$ crystal of detector are used to select information about the photon direction. EPHOS was designed to measure the spectrum of the gamma-ray bursts in the range from 20 MeV to 10 GeV with a resolution of 2–150 MeV. It has a field of view of π sr, with a resolution of 3–10°. The effective area of the EPHOS is 1500 cm^2 at 100 MeV. EPHOS uses $PbWO_4$ crystal scintillators as the active detection agent, converting the energy of the

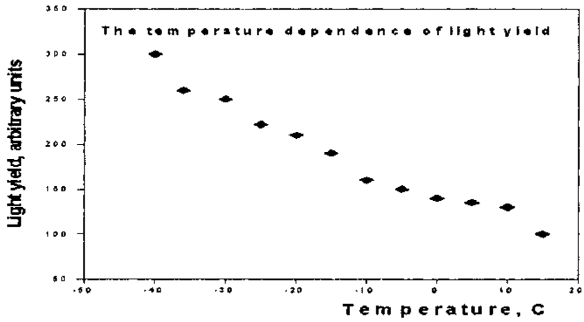

FIGURE 5 The temperature dependence of the $PbWO_4$ light yield.

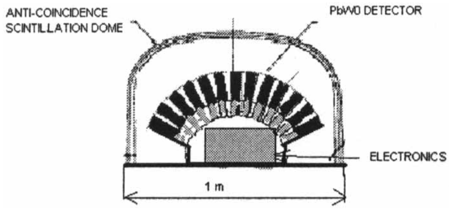

FIGURE 6 The construction of EPHOS.

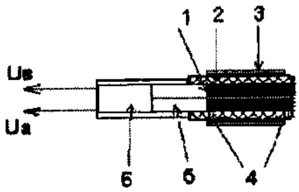

FIGURE 7 The construction of the EPHOS detector consisting of four $PbWO_4$ crystals: 1, $PbWO_4$ crystals; 2, copper heat exchanger; 3, cooling element; 4, temperature-sensing elements; 5, photomultiplier-175; 6, photomultiplier dividers.

photon into visible light, which is recorded by fast photomultipliers. The mass of EPHOS is about 700 kg, and the power consumption of EPHOS is 200 W. EPHOS was designed to be mounted on spacecraft. It continuously monitors the sky for bursts of gamma rays that last between 10 ms and 1000 s.

Acknowledgements

This work was supported by the Russian Foundation for Basic Research Project 01-02-17398.

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