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High-Energy Calibration of a BGO detector of the GLAST Burst Monitor

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Abstract. The understanding of the instrumental response of the GLAST Burst Monitor BGO detectors at energies above the energy range which is accessible by common laboratory radiation sources (< 4.43 MeV), is important, especially for the later cross-calibration with the LAT response in the overlap region between ~ 20 MeV to 30 MeV. In November 2006 the high-energy calibration of the GBM-BGO spare detector was performed at the small Van-de-Graaff accelerator at SLAC. High-energy gamma-rays from excited ^{8}Be* (14.6 MeV and 17.5 MeV) and ^{16}O* (6.1 MeV) were generated through (p, γ)-reactions by irradiating a LiF-target. For the calibration at lower energies radioactive sources were used. The results, including spectra, the energy/channel-relation and the dependence of energy resolution are presented.

Keywords: Instruments**: G**LAST, GBM; calibration
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CALIBRATION MEASUREMENTS & RESULTS

The NaI(Tl)- and BGO-detectors [1] of the GLAST Burst Monitor (GBM) [2] were extensively calibrated with radioactive sources in laboratory measurements [3]. In the energy range of the BGO-detectors from 150 keV to 30 MeV, common laboratory sources emitting γ-rays up to 4.43 MeV (here: ^{22}Na, ^{232}Th, the ^{40}K background line and ^{241}Am/^{9}Be) were used. At higher energies γ-rays can be generated by bremsstrahlung, like it was done for the LAT [4], by the use of Compton backscattering, which can be realized inside a storage-ring free electron laser (eg.: HIgS FELL facility [5]) or via (p,γ)-reactions as chosen in our case. For this purpose the small electrostatic Van-de-Graaff accelerator at SLAC, that produces a proton beam up to 350 keV, was reactivated, which was already used to verify the LAT photon effective area at the low end of the GLAST energy range (20 MeV) [6]. Its proton beam strikes a LiF target that terminates the end of the vacuum pipe (see Fig. 1.) and produces 6.1 MeV, 14.6 MeV, and 17.5 MeV gammas via the reactions:

$$p(\sim 340\,keV) + {}^{7}Li \rightarrow {}^{8}Be(1+)^{*} \rightarrow {}^{8}Be + \gamma\,(14.6\; or\; 17.5\,MeV) \tag{1}$$

$$p(340\,keV) + {}^{19}F \rightarrow {}^{16}O^{*} + \alpha \rightarrow {}^{16}O + \gamma\,(6.1\,MeV) \tag{2}$$

The highly excited 17.6 MeV state of ^{8}Be can be created by protons in a resonance capture process at 440 keV on ^{7}Li [see reaction (1)]. At lower energies, photons are still produced from the Breit-Wigner tail (Γ =12 keV [9]) of the ^{8}Be* resonance. A narrow γ-ray line at 17.5 MeV is produced by the transition to the ^{8}Be ground state, in which the quantum energy is determined by $h\nu = Q + \frac{7}{8} E_p$, with Q = 17.2 MeV as the energy available from the mass change and E_p = 340 keV the proton beam energy. The γ-ray line observed at 14.6 MeV, which corresponds to transitions to the first excited state of ^{8}Be, is broadened with respect to the experimental resolution, because of the short lifetime

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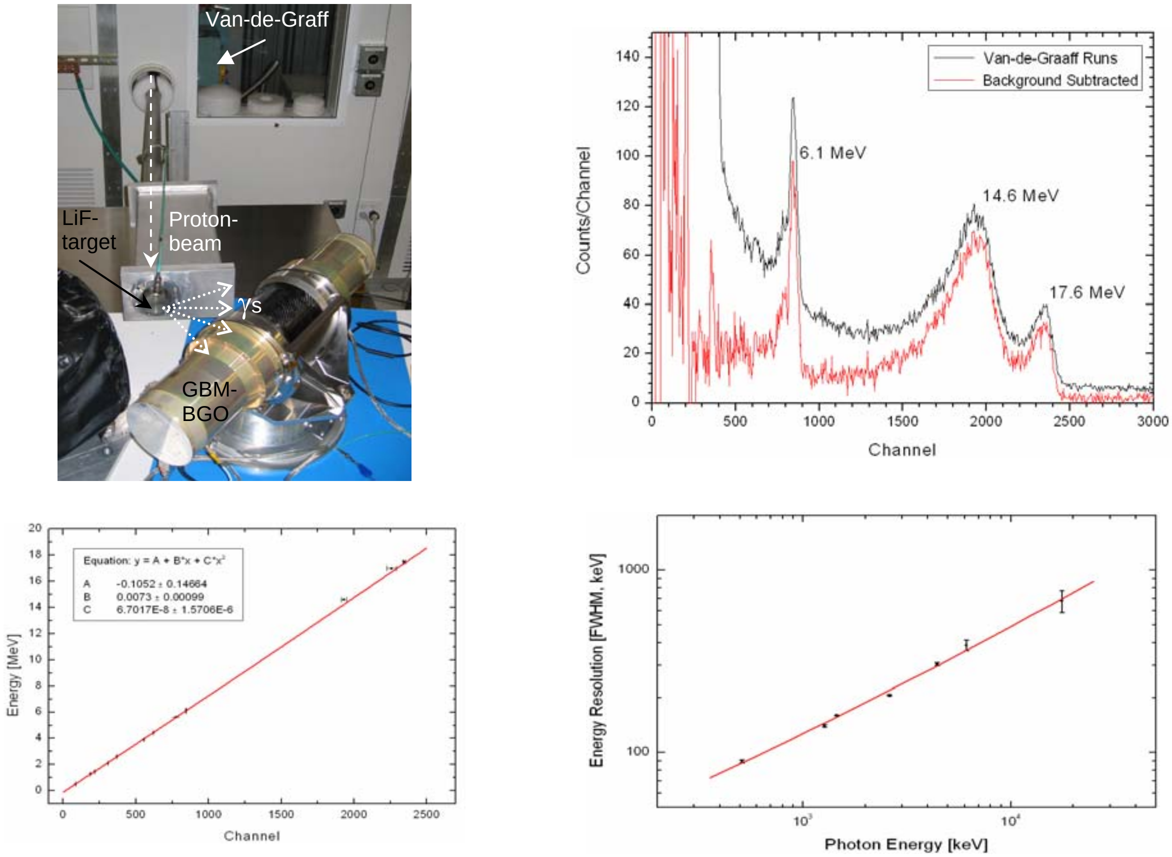

FIGURE 1. Upper left: Setup of the GBM-BGO detector at the SLAC Van-de-Graff accelerator. Upper right: Summed spectrum of all Van-de-Graff runs, showing the prominent γ-ray lines of the (p,γ)-reactions (1) and (2). Lower left: Energy to channel calibration. Lower right: Dependence of the energy resolution (FWHM).

of the state against decay into two alpha-particles. In the resonant case an isotropic flux with a 17.5 MeV/14.6 MeV line intensity ratio of 2:1 is expected [7]. The nonresonant case (eg. for proton energies of ~ 1.15 MeV [8]) is strongly anisotropic and different for the two γ-ray components. When the narrow (Γ =3.2 keV [9]) ^{16}O* resonance at 340 keV is hit, 6.1 MeV γ-rays are generated [see reaction (2)].

The GBM BGO spare detector was placed as close as possible to the LiF-target (Fig. 1, upper left), in order to guarantee a maximized flux of the generated γ-rays, and at an angle of ~45°, with respect to the proton-beam line. The peaks in the high energy-spectrum shown (Fig. 1, upper right) were fitted by accounting for the 511 keV single escape peaks. The photo- to escape-peak ratio was fixed with the help of simulations performed especially for this geometry (single BGO crystal, fan-shaped γ-rays emission region emerging from the location of the LiF-target.). Due to the fact, that the 14.6 MeV line is intrinsically broadened it couldn't be added to the dependence of the energy resolution (Fig. 1, lower right). The energy/cannel relation was best fit by a parabolic function (Fig. 1, lower left). In contrast to the expectations (see above) the measured ratio of the 17.5/14.6 MeV line flux is ~ 1:5, which is not yet understood. The flux ratio was found to be constant when moving the BGO detector to the 0° position.

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