PRELIMINARY PERFORMANCE CHARACTERISTICS OF COMPTEL

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Abstract

COMPTEL - one of the four instruments on board NASA's Gamma-Ray Observatory GRO - has been exposed to gamma rays at various energies for calibration. First analysis of part of the calibration data confirms earlier predictions: Within a wide field-of-view of order 1 steradian (depending on special event selection criteria) the angular resolution was found to be 4.7° FWHM at 1.27 MeV and 2.7° FWHM at 4.4 MeV. The photopeak energy resolution at these energies is 8.8 % FWHM and 6.3 % FWHM, respectively. With these properties and its effective detection area, COMPTEL is an ideal instrument for surveying the entire sky and especially for mapping the galactic plane in the light of continuum and line emission at MeV-energies.

Introduction COMPTEL is one of the four gamma-ray instruments to be flown on NASA's Gamma-Ray Observatory GRO in 1990. Its energy range is 1 to 30 MeV. With its wide field-of-view of about 1 steradian and its angular resolution of a few degrees it is well suited to perform the first complete sky survey at MeV-energies, which is foreseen in the first year of the GRO-mission. From the second year onwards selected objects will be studied in more detail.

Instrument Description COMPTEL consists of two detector arrays, an upper one (D1) of 7 cells of liquid scintillator (NE 213), and a lower one of 14 NaI (Tl) crystals (D2). In the upper detector a gamma ray is first Compton scattered, and then the scattered gamma ray makes a second interaction in the lower detector. The locations and energy losses of both interactions are measured. The uncertainties in these parameters determine the energy and angular resolution of COMPTEL. Charged particle background is suppressed by anticoincidence signals from four veto domes of plastic scintillator surrounding both detectors. For a detailed instrument description see Schönfelder et al. (1984), Diehl (1988), and Ryan (1988).

Calibration The calibration of the fully integrated instrument with radioactive sources and γ-rays produced by nuclear interactions at a van de Graaf accelerator was performed from June to September 1987 at the Gesellschaft für Strahlenforschung at Neuherberg near München. The analysis of the calibration data is still in progress. Here preliminary results from a few radioactive source runs are presented (see Table 1).

Table 1: Radioactive Source Runs Analyzed

radioactive source	energy [MeV]	off-axis angles
Na^{22}	1.27	1°, 20°, 40°, 60°
Na^{24}	1.37 and 2.75	1°, 20°, 40°, 60°
Am^{241}/Be^{9}	4.43	1°, 20°, 40°, 60°

The radioactive sources were placed at distances of 8.0 to 8.5 m from the COMPTEL D1-detector. After each source run a background run was performed in which the radioactive source was blocked by a thick lead shield.

Preliminary Calibration Results

Energy Resolution The energy resolution of COMPTEL is determined by the energy resolutions of both detector assemblies. Fig. 1 displays the energy resolution of COMPTEL for γ-rays at 2.75 MeV and 4.43 MeV (after background subtraction). The two top spectra contain all events above the energy thresholds (50 keV in D1, and 500 keV in D2).

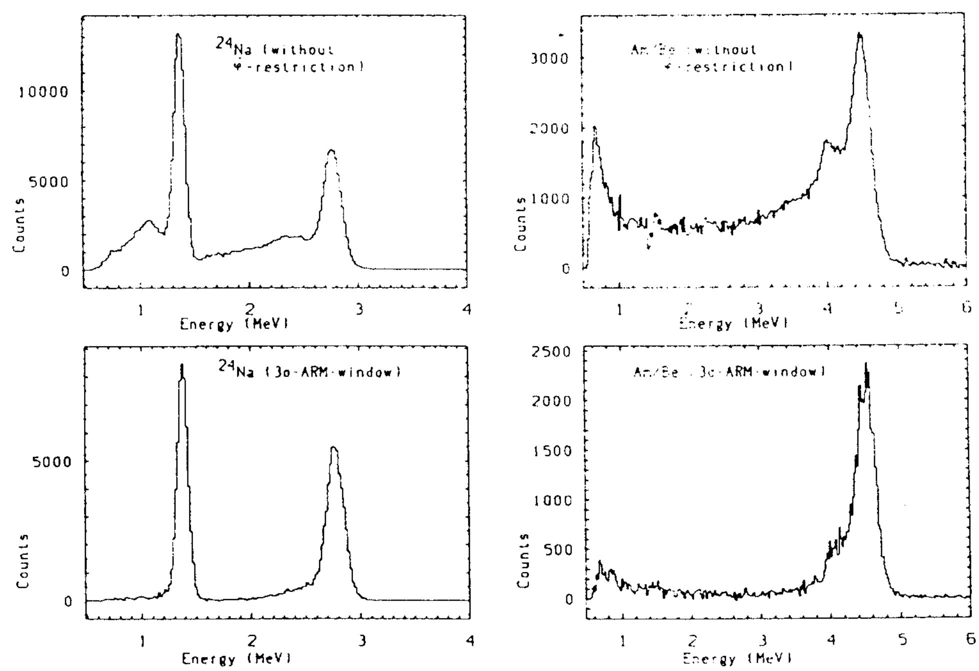

Fig. 1: Energy spectra obtained from γ-rays at 2.75 MeV and 4.43 MeV. (The term ARM-window is defined below).

The Compton tails in the energy spectra (resulting from incompletely absorbed events in D2) can be suppressed by applying event selection criteria, e.g. by limiting the Compton scatter angle $\bar{\varphi}$, which is derived from the measured energy losses, to small values (e.g. $\bar{\varphi} < 30°$), or by accepting only events whose event circles pass (within $\pm$ 1.5 σ) through the position of the radioactive source. By this latter event selection a nearly complete suppression of the Compton tail can be achieved as illustrated in the two bottom spectra of Fig. 1. This technique can be applied, if the position of a celestial γ-ray source is known. The photopeak energy resolutions of COMPTEL are summarized in Table 2.

Table 2: Energy and Angular Resolution of COMPTEL

Energy [MeV]	$\frac{\Delta E}{E}$ [FWHM]	ARM-width[FWHM]
1.27	8.8 %	4.74°
2.75	6.5 %	3.10°
4.46	6.3 %	2.71°

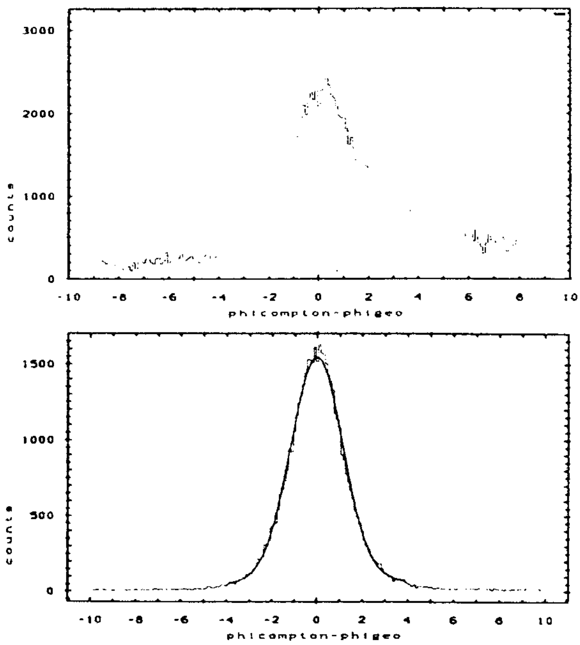

Fig. 2: ARM-distribution of 4.4 MeV γ-rays. Top: all events above thresholds accepted. Bottom: only photopeak-events (FWHM) accepted.

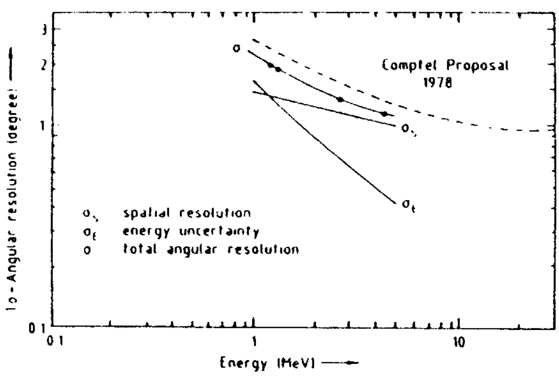

Fig. 3: 1 σ angular resolution of COMPTEL (ARM-width devided by 2.36) as a function of γ-ray energy.

Angular Resolution The angular resolution of COMPTEL is determined by two factors: first, by the uncertainty in the measurement of the direction of the scattered γ-ray, and second, by the uncertainty in the measurement of the energy deposits in D1 and D2, which define the derived Compton scatter angle $\bar{\varphi}$. An appropriate measure of the angular resolution is provided by the ARM-distribution (Angular Resolution Measure), which is displayed in Fig. 2 for 4.43 MeV γ-rays. Here on the abscissa the difference φ_{compt} - φ_{geo} is plotted, where $\varphi_{compt} = \bar{\varphi}$ is the Compton scatter angle as derived from the measured energy losses, whereas φ_{geo} is the geometric scatter angle, which is derived from the knowledge of the gamma-ray source position and from the location of the interactions in D1 and D2.

If all events above threshold are accepted (no $\bar{\varphi}$-restriction), then the incompletely absorbed events in D2 cause an asymmetric distribution with an excess at positive (φ_{compt} - φ_{geo}) -values (see top of Fig. 2). If, instead, only photopeak events are accepted, then incompletely absorbed events are rejected and the resulting ARM-distribution is symmetric (bottom of Fig. 2).

Table 2 lists the widths of the ARM distributions of photopeak events as a function of energy. Fig. 3 illustrates, how much the spatial and the energy uncertainty contribute to the total angular resolution. The actual achieved resolution is slightly better than predicted in 1978 in the original COMPTEL-proposal.

Field-of-View The field-of-view of COMPTEL around its axis can be influenced by introducing restrictions to the derived scatter angle $\bar{\varphi}$. Also the energy thresholds in D1 and D2 affect the field-of-view.

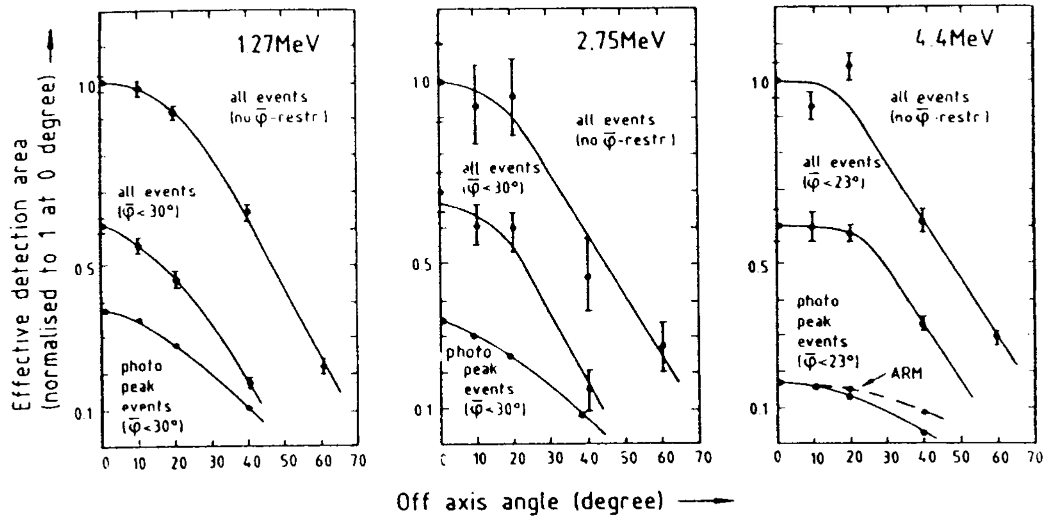

Fig. 4: Relative dependence of the effective detection area as a function of the off-axis angle (lines are for eye guidance only).

Fig. 4 displays the dependence of the relative effective detection area of COMPTEL with off-axis angle for 3 different γ-ray energies. The widest field-of-view is obtained, if no $\bar{\varphi}$-restriction is applied to the data (this case is used to normalize the distributions to 1 at vertical incidence). Though this analysis mode results in the highest effective detection area, the wide field-of-view will imply a significant background rate of atmospheric γ-rays from the earth horizon. The influence of the earth horizon can be reduced by introducing $\bar{\varphi}$-restrictions (e.g. $\bar{\varphi}$ < 30°), or by accepting only photopeak events or events within the FWHM-ARM-window. In all three cases the resulting energy and angular resolution of the telescope is improved, however, at the cost of a lower detection area. The actual choice of event parameter selection requires a case by case optimization.

Table 3: Absolute Detection Area

Energy [MeV]	Area [cm^2]
1.27	27.8
2.75	36.2
4.43	40.9

Absolute Detection Area The absolute detection areas for vertical incidence and no $\bar{\varphi}$-restriction (corresponding to the normalization factor 1 in Fig. 4) are listed in Table 3. The values were derived from radioactive source strengths provided by the suppliers (with an uncertainty of about 20 %). A confirmation of the quoted source strengths is in progress.

Conclusion With the results of this preliminary calibration analysis we have confirmed the basic characteristics which make COMPTEL well suited for imaging the sky in the 1 to 30 MeV region.

References

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