PREFLIGHT TESTS OF THE MASCO TELESCOPE


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ABSTRACT

We present some of the preflight tests carried out with the MASCO balloon-borne imaging gamma ray experiment in order to test the detector system and associated electronics employed by the telescope. The detector system is composed by a 41 cm-diameter, 5 cm-thick NaI(Tl) crystal surrounded by plastic scintillators on the top and on the sides, for shielding. A similar NaI(Tl) is used at the bottom with the same purpose. The imaging device capability is provided by an extended 19x19 MURA-based coded mask placed 305 cm away from the detector plane which is mounted in such a way that it becomes an antimask with a 90 degree rotation. The tests determined the position sensitive detector diameter to be approximately 24 cm and showed that it is possible to do imaging in a fully coded circular (14.2 degree-diameter) field of view with a positioning power of 4.5 arcminutes for a 5 cr source. The measured energy resolution was about 10% at 662 keV and the spatial resolution was approximately 10 mm at 100 keV. We have made a series of laboratory images using a 320 mCi $^{137}$Cs radioactive source to test the effectiveness of the mask-antimask subtraction technique and obtained a 60% improvement in signal-to-noise ratio of the images. Temperature tests of the on board electronics were carried out and the results of the peak detector circuits tests are presented.

INTRODUCTION

The MASCO (which stands for MÁScara COdificada - Portuguese for Coded Mask) telescope (Villela et al., 1995) is a balloon-borne instrument designed to obtain images of the sky in the energy range of 50 keV to 1.8 MeV with an angular resolution of 14 arcmin in a circular field of view of ~14°. The detector system consists in a 41 cm-diameter, 5 cm-thick NaI(Tl) crystal coupled to 19 photomultipliers tubes (PMTs). The active anticoincidence system is composed by plastic scintillators (POPOP, PPO) on the sides and by a NaI(Tl) crystal at the bottom. A 3 mm-thick plastic scintillator, viewed by 3 PMTs, is placed in front of the detector for charged particle veto. The lateral shielding is made out of 12 1 m-high, 15 cm-thick modules, each one viewed by one PMT. The imaging device is a 19x19 element square MURA-based (Gottesman and Fenimore, 1989) extended mask, which becomes an antimask by a 90 degree rotation (but one element in each pattern). The mask is mounted in a single piece mask-antimask configuration, and it can either rotate 90° to become antimask or be driven at constant rotation to permit mask and antimask observations to eliminate source ambiguities. The pulses generated by the 19 PMTs are sent to a resistor network which generates 4 analog signals that provide the events' positions on the detector. A fifth analog signal line is used to provide the energy information.

The data acquisition system, which is based on a 66 MHz 486 VME-bus industrial PC computer, was designed to handle the signals generated by the MASCO detector system, composed by the main detector and the active shielding. The experiment energy range of 50 keV to 1.8 MeV is divided in two bands: one from 50 keV to 300 keV and another from 300 keV to 1.8 MeV. The data acquisition system converts the pulses generated by the PMTs.
into digital words and make the data available for analysis, including a time tag associated with each event. It supports average counting rates up to 4000 events/s. Five peak detector circuits were specially designed to accommodate the dynamic range of the input pulses. They use 12 bit analog-to-digital converters (ADCs) for simultaneous conversion of 10 analog channels. The ADC dynamic range is 0 V to 5 V. The maximum time conversion is 15 μs. A 64 kwords (16 bit word) double buffer is used for random events storage allowing a dead time of 25 μs. For a 20 hour flight approximately 605 MBytes of data will be generated. The data will stored on board and parts of them will be sent to ground via telemetry. The telemetry downlink rate is 96 kbps.

TESTS

Several tests were carried out with the detector system in order to simulate its performance during the flights. The first test was conducted with the data acquisition system. In order to check the peak detector circuits behavior in ambient conditions close to that of their operation at balloon altitudes, we have performed several temperature tests with them. The tests consisted in measuring the circuits' responses to different temperatures and were conducted following a typical temperature profile expected inside the electronics bay in a balloon flight. Several input signal levels were selected through the use of a calibrated attenuator, covering the entire dynamic range of the circuits, as a function of the temperature profile. The input and output readouts were measured with a 4096 channel pulse height analyzer. The observed results showed that the peak detector circuits have the lowest variation, as a function of the temperature, for low amplitude signals. These variations do not jeopardize the functioning of the whole detector system. Figure 1 shows the results of the temperature tests for one of the five peak detector circuits, corresponding to 4 output values.

![Figure 1 - Channel drift (in a multichannel analyzer) of one of the peak detector circuits for 4 attenuation values of the input signal. The temperature dependence is less critical for the highest attenuations (10 dB and 14 dB).](image)
The second test consisted in determining the positions of the gamma ray events occurring in the detector and to test
the ability of the detector system to do imaging. First, the useful position-sensitive area of the detector was
measured; as a consequence of the distribution of the 19 PMTs on the detector, the detector spatial resolution is
degraded for radii greater than ~12 cm. The spatial resolution is ~10 mm at 100 keV. Energy spectra of a
collimated 320 mCi $^{137}$Cs (662 keV line) radioactive source provided an energy resolution of ~10%. Figure 2 shows
the measured laboratory background in the detector plane for ~6 hours integration time. One can see the increase
in the recorded counts towards the edge of the detector, which is due to the position-dependent background
systematics and degradation of the detector spatial resolution for radii greater than ~12 cm.

![Fig. 2: Uncorrected laboratory background count distribution over the detector surface. The two-
dimensional histogram samples the surface at 1/4 the mask cell size.](image)

Figure 3 shows a shadowgram obtained, after flat-field procedure, with a 2-hour illumination of the detector by the
$^{137}$Cs source. The area shown corresponds to the complete central MURA pattern of the mask, which is an area of
23.75 cm x 23.75 cm.

![Fig. 3 – The central part of the mask (a) is shown on the central region of detector surface (b) during the preflight
tests of the MASCÔ telescope.](image)
Laboratory images were among the crucial tests performed as they would reveal the ability of the detector system to do imaging. The imaging tests were done with the mask placed 3 m away from the detector plane and a $^{137}$Cs source placed 68 m away from the detector. A 16 hour integration time “flat-field” was performed with the same source placed 20 m from the detector without the use of the mask in order to get an uniform exposure. We have made images using the system in the mask and antimask configurations. An image obtained in the mask configuration resulted in a signal-to-noise ratio (SNR) of 14.8. With the use of the subtractive mask-antimask technique, i.e., using images obtained with the system in mask and antimask configurations, we have obtained an image with a SNR of 23.7, which corresponds to a 60% improvement in quality over the image obtained with the system in the mask configuration only. Figure 4 shows an image obtained with the mask-antimask technique.

![Image of a laboratory image of a $^{137}$Cs source]

CONCLUSION

The tests carried out with the detector system of the MASCO telescope showed that it can perform well during the flights. The ability of the MASCO telescope to do imaging has been tested, especially the mask-antimask imaging method, which was shown to be an effective way to improve up to 60% the signal-to-noise ratio of the images. The temperature tests of the on board electronics showed that the system can function well at balloon altitude conditions. The experiment has a high-angular resolution of ~14 arcminutes with a 4.5 arcminute location power for a 5 σ point source, which makes it very appropriate to perform observations of the Galactic Center region, which will be its first target.

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REFERENCES
