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Response of the LAZIO-SiRad detector to low energy electrons

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LAZIO-SiRad, the Low Altitude Zone Ionization Observatory experiment, launched on February 28th 2005, started its operations on board the International Space Station in April 2005.
Lazio is a high performance cosmic ray detector able to measure and identify all particles traversing the apparatus separating nuclei from electrons/positrons in the energy range (10-100) MeV. It will record their time of arrival and their pitch angle under a $60\ cm^2 sr$ view.
In order to reach a significant technological goal, the apparatus include a new type of scintillator-based detector, such added for the first time to the set of space devices.
This paper will report and discuss the performances of the detector as resulting from a beam test with a low energy electron beam performed at the Frascati Beam Test Facility (BTF).

1. Introduction

LAZIO is a particle tracker which will be used to perform a number of low energy CR measurements, to characterize the ISS radiative environment, including the study of the correlation with anomalous phosphene (Light Flash) perception by astronauts and the study of the effect of different shielding materials.
An important aim of LAZIO is to be a technology demonstrator of a new kind of sensor capable of monitoring with high accuracy the short time stability of the energetic particles trapped in the Van Allen Belts, to investigate the possible correlation with precursor seismic activities.
The instrument is also equipped with a high precision low frequency magnetometer which will be used to measure the intensity and the variations of the magnetic field within the ISS. By this is possible to establish a correlation between the behavior of the magnetic field and the particle fluxes measurements. Lazio is therefore a CR spectrometer combined with a magnetometer.
This paper underlines the technological aspects of the mission, under the perspective of CR measurement: the spectrometer is equipped with an unpublished detector obtained by means of a solid state photomultipliers (SiPm) optically coupled with scintillator material and wavelength shifter. They represent the most important technological aspect of the CR side of the experiment and the main subject of this paper.

2. Description of the apparatus and Beam Test

The main body of the device is composed (Figure 1.(a)) by three Scintillator Detectors, *S1, S2* and *S3* equipped of Hamamatsu Photomultipliers, *T1* and *T2 composed planes* and four microstrip silicon views.
The scintillators are employed in measurement of the ionization energy loss *dE/dx* of the traversing charge particles and for charge information. The silicon microstrip detectors constitute the tracker part of Lazio. Their nominal spatial resolution is about 10μm in the upper p+ side and 30μm in the lower n+ side.
The *composed planes* are obtained by assembling scintillation detectors with SiPM. Each detector, *tile*, is a square device with 3 cm side and half cm thickness. A *Tile plane* is obtained by grouping of eight *tiles* agreeing with Figure 1.(b). The SiPM is relatively young and progressively developing photodetection technique [1][2], which allows obtaining the intrinsic gain for single photoelectron of the order of 10^6, value close to that of vacuum photomultipliers. Such a large gain, which confirms the name "*Photomultiplier"*, became achievable due to the fact that the SiPM operates in limited Geiger mode.
The *tile* construction is presented on Figure2. It consists of plastic scintillator 30×30×5 mm^3, wavelength sifter (WLS), mirror and SiPM. WLS is used for collection of photons which arise in scintillator, and shift the

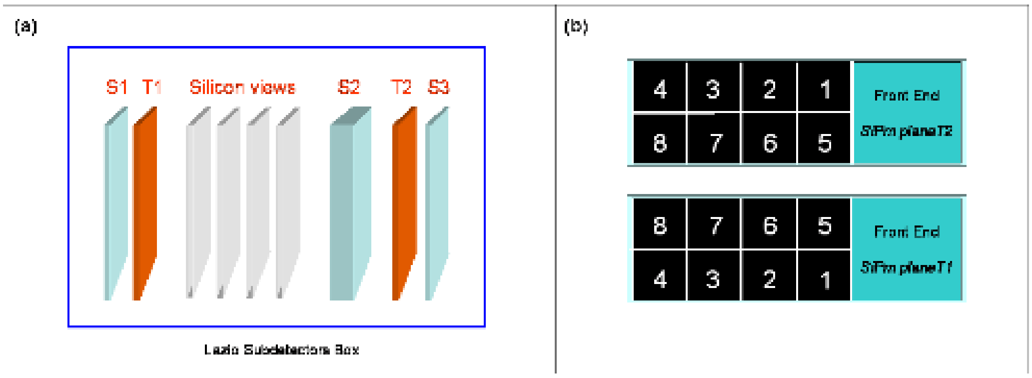

Figure 1. (a): Relative position of Lazio Subdetectors in the stack. (b): Section of SiPm composed planes *T1* and *T2*.

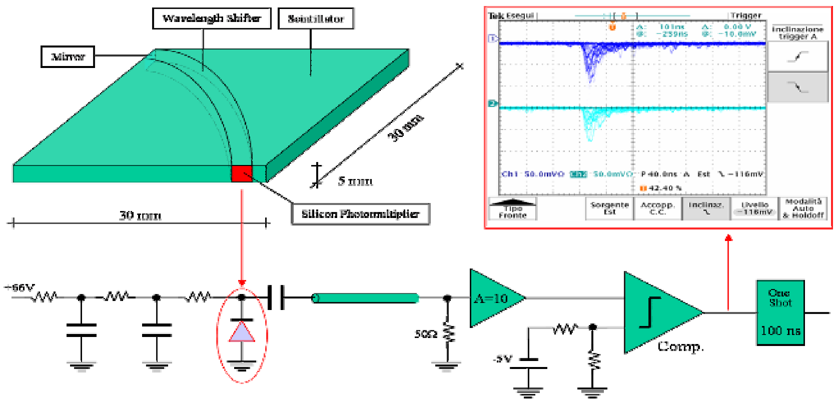

Figure 2. SiPm pictorial view, Front End electronic channel scheme and example of analog oscilloscope parallel acquisition of two *tiles.*

maximum spectrum from blue to green field. Mirror at the end of WLS allow increasing the photon number of about 1.5 times. The single Front End electronic channel is presented on Figure2.
In the Beam Test session were carried a debug&optimization operations and the calibration of the apparatus. In the former we supplied the data acquisition with NIM and Camac electronics controlled by a LabView based software. The final calibration, otherwise, was carried in the full Flight configuration. Analog and Digital signals were acquired directly from the Front End of the scintillators; the path of each TTL signal is converted into a NIM signal, split and sent to the acquisition and control peripheral units. The Analog signals are sent to the peripherals with proper delay.
The Front End electronics of the scintillators and *tiles* was subject of troubleshooting operations in order to set the best discriminator thresholds. During the Beam Data Acquisition the trigger was a 150ns logic signal provided by the accelerator acquisition system.
LAZIO was calibrated in December 2004 at DAFNE Beam-Test Facility (BTF) in Frascati (Rome), at National Laboratories (LNF) of Nuclear Physics National Institute (INFN). This is a beam transfer line which has been designed in order to optimize the operation mode in which single electrons are stochastically produced for detector calibration purposes.
The measurements were done using the electron beam characteristics (25-750)MeV @ 50Hz with a current of 1 to 8 particles/pulse, (1-10)ns pulse duration, 1 KHz max electronic rate and 10^3 particles/s of allowed current. The Beam Spot minimal size was σ_{xy} ~2mm.
Data acquisition involved a beam calorimeter which provided information about the beam energy distribution. Selecting the multiplicity-dependent event as showed in Figure 3, it was possible to fix the low energy limit of detectors; this depends also on the discriminator thresholds and power voltages. By tuning these variables an optimization of the sensitive energy range of the apparatus is obtained. These data show the Read Out of a relatively high efficiency *tiles* and, weighty, the linear answer of the device with particle multiplicity. The time fitting operations were performed using a Beam Trigger as a *gate* for the ADC, therefore not external scintillator system was required apart of the Beam Profiler dedicated to the beam control line. The measures performed with 500MeV@50Hz electrons were about Subdetectors Resolution, Light Counting Attenuation vs. Distance of the impinging point in the scintillators; voltages and energy behavior of *tiles* was observed; the Relative Detector Efficiency was calculated performing normalization to the BTF Calorimeter Counting and to the Relative and Global Trigger System agreeing with next relation, where G is the geometrical factor, φ the particle flux and N_k the counting performed by the detector k.

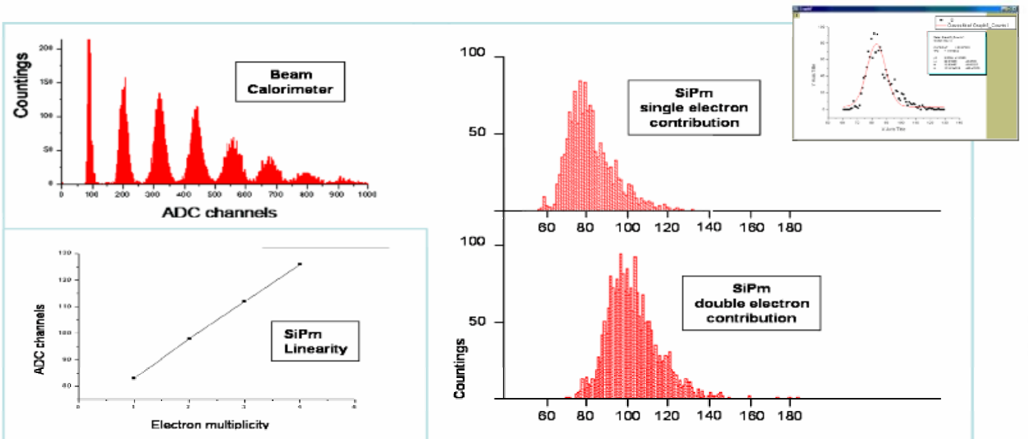

Figure 3. Parallel acquisition of Beam calorimeter and SiPm detectors; multiplicity information are taken from the calorimeter (top-left). Response of a *tile* to single and double electron contribution are showed in the right side; in the bottom-right side the linear behaviour of the device is plotted against the number of passing electrons.

$$Eff(T) = \frac{G\phi\, N_{S1} \cdot N_T \cdot N_{S2}}{G\phi\, N_{S1} \cdot N_{S2}}$$

The counting of the trigger *S1 · S2* is about 99.6% of the total number of events detected by calorimeter. *T1* (*T2*) planes show 87.3% (79.3%) and 87.0% (85.3%) efficiency relative to trigger and calorimeter respectively. Finally in Figure 4 is plotted the result of a preliminary analysis of space data together with the answer of a single *tile* at spamming (6 mm pitch) with 500 MeV electrons. The latter show a resolution adequate to recognize different multiplicity contribution and a very satisfactory attenuation. This is because the answer does not depend on the particle impact point position, within a limit of 5%.
The count rate of the Lazio trigger *S1·T1·S2* and *S1·S2* have the same time trend and reflect the latitude particle fluxes dependence. The differences in amplitude are due to different geometrical factors of corresponding detector sets. The picture demonstrates that scintillation detectors with Hamamatsu photomultipliers and specially Silicon Photomultipliers are working in space as expected. The analysis of the single tile efficiency in space will be estimate later, by means of the silicon microstrip detector information.

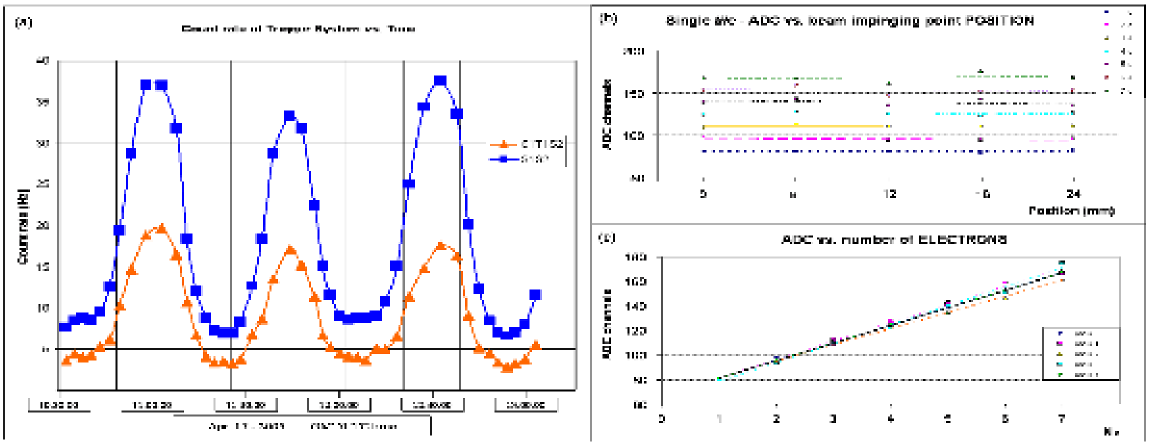

Figure 4. (a) Preliminary view of ISS data: the latitude effect is clear. (b) Spamming on single *tile* with 500 MeV electrons; (c) plot of a single *tile* answer vs. multiplicity of passing particles.

4. Conclusions

Nevertheless the *tiles* efficiency appear relatively small in respect to the traditional scintillators, it was a very encouraging result in the perspective of future improvement. We maximized the performances of *tiles* by means of Lazio Beam Test and they are currently subject of technological analysis. They might be used in forthcoming development of experiments PAMELA2 and ALTEA2.

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