PERFORMANCE OF NEUTRON DETECTOR AND BOTTOM TRIGGER SCINTILLATOR OF THE SPACE INSTRUMENT PAMELA

V. MALVEZZI FOR THE PAMELA COLLABORATION
INFN and University of Rome "Tor Vergata",
1, Via della Ricerca Scientifica,
I-00133, Rome, Italy
E-mail: valeria.malvezzi@roma2.infn.it

PAMELA (Payload for Antimatter Matter Exploration and Light-nuclei Astrophysics) is a satellite-borne experiment designed to study charged particles in the cosmic radiation over the largest energy range ever achieved. The apparatus is composed by a *magnetic spectrometer*, to determine the charge of the particles, an *electromagnetic calorimeter* and a *neutron detector* (ND), which perform the particle identification; in addition, an *anticoincidence system*, a *time of flight* (TOF) system and an additional *shower tail catcher scintillator* (S4) located below the calorimeter complement the instrument. The system composed by the electromagnetic calorimeter, the S4 and the ND will look for events with high energy release (more than 100 GeV) in the calorimeter, and with a larger field of view than that of PAMELA ($\sim$ 900 $cm^2 sr$). In this work we will show preliminary results concerning the performances of ND and S4 detectors coming from data collected during ground tests (January-May 2005) with PAMELA in final configuration.

1. Introduction

The final particles identification (i.e. positrons, electrons, antiprotons, protons, etc.) is provided by the combination of the calorimeter [1] and the neutron detector informations plus the velocity measurements from the ToF system at low momenta.
For high-energy particles, both electromagnetic and hadronic cascades, produced in our apparatus, cannot be fully contained in the calorimeter. Since neutrons are produced only by hadronic interactions, the neutron yield is $10 \div 20$ times larger in an hadronic cascade than in an electromagnetic one. Therefore, adding a neutron counter to our apparatus can improve the capabilities of the calorimeter to distinguish between primary electrons and hadrons [2], [3].
The main task of the Bottom Scintillator is to detect particles passing

through and then send the signal to the trigger system for elaborating the main trigger pulse.

S4 gives also information for lepton/hadron rejection. Infact, when the signal output detected by S4 corresponds to more then 10 minimum ionizing particles, this signal goes to the trigger system and its coincidence with the main trigger is the mark for the Neutron Detector to read out the data from its counters. Finally ,an additional task of the Bottom Scintillator is to play the role of trigger for detecting super high energy electrons coming from the lateral sides of the PAMELA apparatus, out of its field of view. Such electrons would produce a very high flux of neutrons in the Calorimeter and in the Neutron Detector. This task will be fulfilled by using a S4 signal exceeding the threshold of 200-300 minimum ionizing particles, due to the large number of secondaries produced by a particle with energy more then some hundreds of GeV.

2. The Neutron Detector and Bottom Scintillator instruments

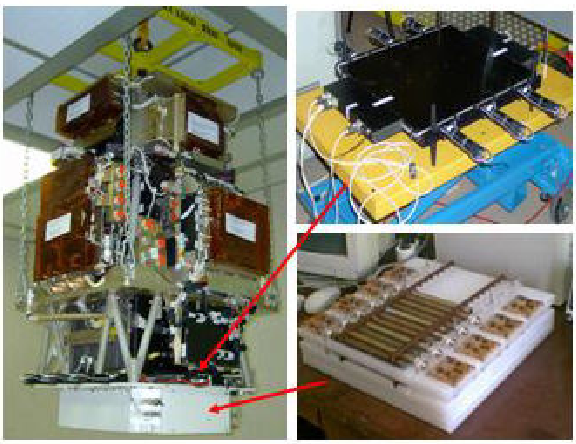

Figure 1. Left: view of the PAMELA flight Model. Right: [*top*] view of the bottom scintillator S4, [*bottom*] view of the neutron detector.

The main difficulty related to the detection of neutrons is that they have mass but no electrical charge. Because of this they cannot directly produce ionization in a detector, and therefore cannot be directly detected. This

means that neutron detectors must rely upon a conversion process where an incident neutron interacts with a nucleus to produce a secondary charged particle. These charged particles are then directly detected and from them the presence of neutrons is deduced.
The Neutron Detector is attached to the bottom of the PAMELA apparatus and is situated beneath the scintillation detector S4 (fig. 1). It is made of proportional counters, filled with ^3He, surrounded by a polyethylene moderator enveloped in a thin cadmium layer. The 36 counters are stacked in two planes of 18 counters each, oriented along the y-axis of the instrument. The size of the ND is $600 \times 550 \times 150\ mm^3$.
S4 has an area of $482 \times 482\ mm^2$ and a thickness of 10 mm; six PMTs are situated along the two opposite sides of the scintillator.

3. On ground cosmic-ray acquisition

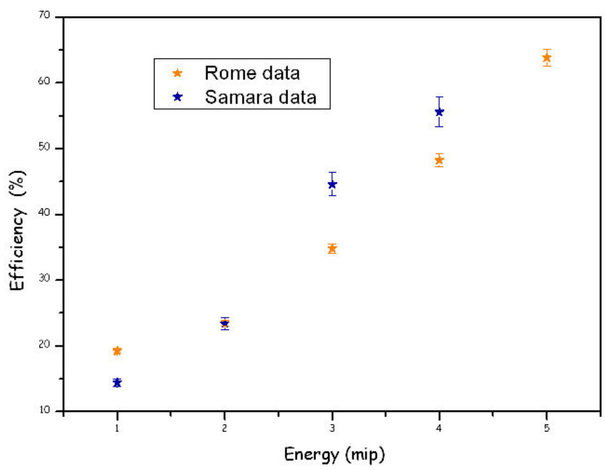

Figure 2. Efficiency of the scintillator S4 *vs.* the energy realeased in the last plane of the calorimiter.

During the assembling at the laboratories of the University of Rome "Tor Vergata" (Italy) and once PAMELA reached Samara (Russia) to be integrated inside the spacecraft, the system was tested with ground muons.

The first session of cosmic-ray acquisition started in Rome the 12th of February until 24th of March 2005; a total acquisition time of about 480 hours has been collected. In this time interval the "good" events collected by Neutron Detector and S4 were 286275 and 344071, respectively. The second session of cosmic-ray acquisition started in Samara the 12th of May 2005 until 24th of same month (acceptance test); a total acquisition time of about 140 hours has been collected. 132448 and 133884 of "good" events have been collected in this time interval by Neutron Detector and S4, respectively.
From data we have analyzed PAMELA ND and S4 response. About S4, the correct use of the three calibrations available for the detector have been cheeked together with the threshold value, useful when the instrument is in trigger.
To study the efficiency of the scintillator we selected the good (at least one track in TRK) events, interacting or not, releasing a positive amount of energy in the last calorimeter plane (plane 22, view X). The results are reported in figure 2. Both in Rome and in Samara data sample, the statistics for high energy is rather low, therefore it is not possible to study S4 efficiencies for energy released in Calo22x > 6 MIPs.
Concerning the ND performance, in figure 3 the acquisition rate of background neutrons for the two acquisition sessions are reported.
The red histograms correspond to the counting of the bottom half of the

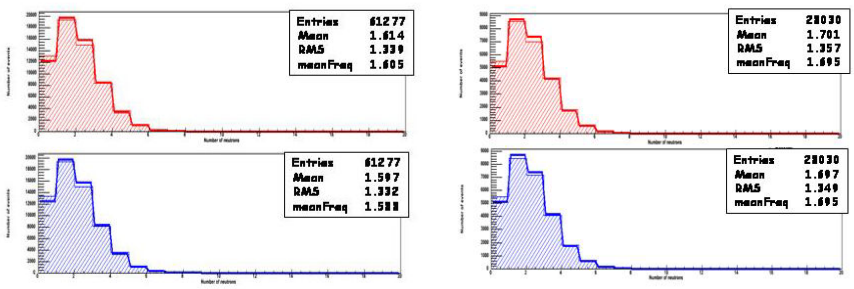

Figure 3. Acquisition rate of background neutrons for the two acquisition session in Rome (left) and Samara (right).

ND and the blue ones to the counting of the upper half of the ND. Each bin contains neutrons counted in 5s.

The behaviour of neutron detector with good interacting (applying CALO standard cuts) particles, both for Rome and Samara data, seems to be consistent with test beam data collected in September 2003 at CERN facility. Some differences exist due to the low particles energy collected on ground. Neutron distribution for straight particles is consistent with expectations (no neutrons produced).

4. Conclusion

Concerning S4, the threshold works in a good way when the detector is in trigger, and the efficiency increase with energy; this is important for trigger ND at high energy to discriminate positrons, protons and electrons.
About ND, background performance shows right behavior of the detector with an acquisition rate consistent with licterature, and the upper and lower part of the detector behave consistently.

References

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3. 50. Y.I. Stozhkov for PAMELA collaboration, *Int. J. Modern Phys. A* (2005).