THE ANTICOINCIDENCE SHIELD OF THE PAMELA SATELLITE EXPERIMENT

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The PAMELA experiment consists of a magnetic spectrometer, a transition radiation detector, an electromagnetic imaging calorimeter with a shower-tail catcher and a scintillator-based time-of-flight system. It will be launched late 2002 / early 2003. The spectrometer is surrounded by a scintillator-based anticoincidence system consisting of four lateral and one top anticounter which will help in discriminating against out-of-acceptance triggers. A simulation study has been made to determine how backscattering from the calorimeter affects the capability to reject background events.

1 Introduction

When launched, PAMELA[1] will be the most complex particle detector system ever operated in space. As shown in figure 1, PAMELA is built around a tracking system comprising 6 planes of double-sided silicon detectors placed within the bore of a 0.4T permanent magnet. Above the tracker is a transition radiation detector (TRD) which provides electron-hadron discrimination. The TRD is built up from 9 planes of Xe/CO2 filled straw tubes interleaved with carbon fibre radiators. Below the tracker is an electromagnetic imaging calorimeter constructed from 22 layers of single-sided silicon detectors interspersed with 21 layers of tungsten absorbers. The total depth of the calorimeter is 16 radiation lengths. A scintillator-based shower-tail catcher sits below the calorimeter. Three planes of time-of-flight are scintillator placed atop the TRD and above and below the tracker. This paper concerns the anticoincidence system which completely covers the lateral sides of the tracker and defines the acceptance at the tracker's entrance. The PAMELA subdetectors will be assembled together and tested as a system in Rome during Summer 2002 prior to integration with a pressure vessel attached to a Resurs DK satellite at the TsSKB Progress company in Samara and subsequent transport to Baikonaur for launch in late 2002 / early 2003. The satellite will execute an elliptical polar orbit (70.4°) at an altitude varying between 300km and 600km. The minimum mission length is two years.

The first level trigger in PAMELA is given by a coincidental energy deposit in the three time-of-flight scintillators. Down-going particles can subsequently be selected using time-of-flight information and the pulse height from the scintillators gives information about the absolute value of the charge. The tracking system is used to determine the momentum and the sign of the charge of the particles and the combined information from the TRD and calorimeter gives excellent lepton hadron separation. At lower energies (<1 GeV for protons) particles can also be identified directly from time-of-flight measurements. Before a candidate event is selected, the activity in the anticoincidence system is checked. No activity means that the particle has cleanly entered and traversed the acceptance of the tracker. The top anticounter also provides an additional line of defence against particles produced in local interactions in the pressure vessel housing PAMELA.

In the next section, the anticounter system is described in more detail. In the final section a trigger rate simulation which focuses on a description of the 'self-veto' problem (when backscattered particles from the calorimeter can fake a signal in the anticounters) is presented.

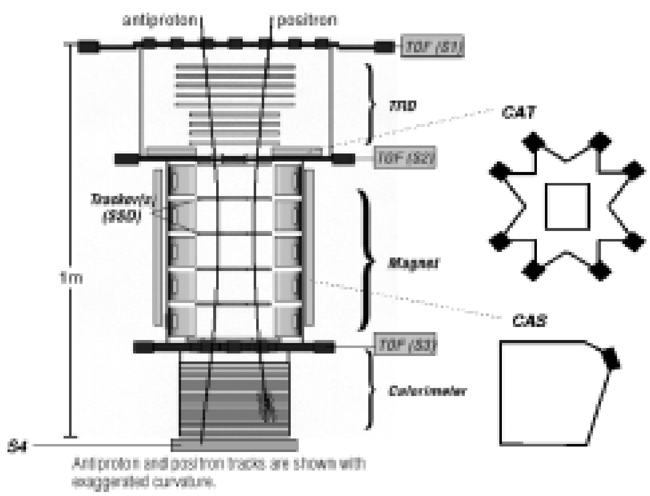

Figure 1. Schematic picture of the PAMELA experiment. To the right the approximate shapes of the CAT and CAS anticounters are shown.

2 The Anticounter System

The anticounter (AC) system comprises of a top detector, CAT, and 4 identical side detectors, CAS. The geometry of the detectors is shown in figure 1. Each detector is made from a sheet of 8mm thick Bicron BC-448M plastic scintillator read out by Hamamatsu R5900U photomultiplier tubes. The photomultipliers are joined to the scintillators with 7mm thick silicone 'cookies'. The scintillators are wrapped first in reflective layers of Dupont Tyvek and then opaque Dupont Tedlar.

A high voltage divider is located directly behind each PMT. Signals from the 16 PMT's are fed to an analogue front-end which includes an integration / amplification stage and a discriminator. Discriminated pulses are retimed to be 100ns long and fed into a 32 bit shift register implemented in an antifuse FPGA clocked at 25MHz. The PAMELA trigger is used to gate the clock such that AC pulses in time with the trigger appear in the centre of the shift register. The FPGA is interfaced to the PAMELA DAQ system through a DSP which builds the anticounter events and performs calibrations and general housekeeping tasks. The calibration system is based upon LEDs mounted within each anticounter.

3 Trigger Rate Simulation

A first level trigger can include both 'good' triggers, i.e. particles entering and traversing the tracker acceptance which reach the calorimeter without interacting on the way, and 'false' triggers, i.e. particles hitting the experiment from outside the acceptance or interacting with the inside of the tracker cavity. To examine the performance of the AC system in-orbit a simulation study has been performed using a proton spectrum[2] for the polar region of the orbit where the flux is largest due to the negligible geomagnetic cut-off. Protons make up the largest part of the cosmic radiation ($\sim$90%) and the polar flux will be approximately 8 times larger than the equatorial flux.

A first level trigger rate of 24Hz is predicted with 'good' triggers contributing 7Hz and 17Hz coming from 'false' triggers. The dominant part of the 'false' triggers are produced by particles hitting the experiment from above, but a non-neglible amount is also produced due to particles hitting the experiment from the sides and from below. Figure 2 shows the dependence of the 'false' triggers on the kinetic energy of the incoming particle.

By using the AC system in a second level trigger one could reduce this background from 17Hz to 5Hz with the condition that a level one trigger ($>$0.25 mip deposited in each ToF scintillator) is not accompanied by signal

(> 0.5 mip) in any of the AC detectors, where 1 mip is the energy deposited by a minimum ionizing particle passing through the scintillator. This is shown by the dashed line in figure 2.

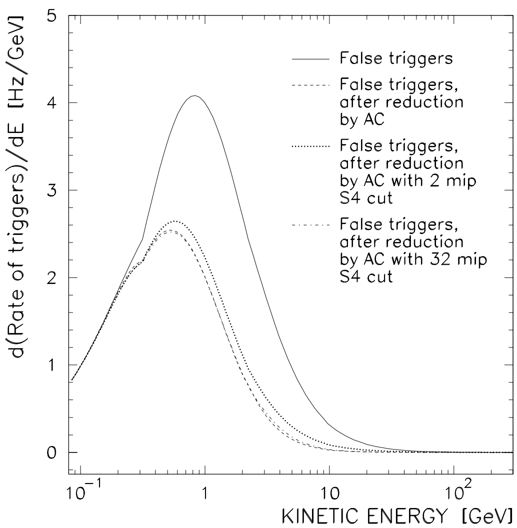

Figure 2. Differential trigger rates as function of the kinetic energy of the incoming particle.

An event where a particle passes cleanly through the spectrometer can still give rise to an AC signal due to backscattered particles produced in the calorimeter. Using the AC system to reject 'false' triggers in this simple way could therefore result in loss of 'good' events. As shown in figure 3 the fraction of rejected 'good' triggers increases with the energy of the incident particles- as expected for backscattering. This is undesirable since more than 20% of the physically interesting[3] high energy (>30 GeV) events are lost.

For the purpose of this study, the energy leakage from the bottom of the calorimeter was used to provide a variable sensitive to the energy of the incident particle. A revised AC veto signal can then be formed, i.e.: signal in AC and no activity in S4 above a predefined cut-off. A range of cut-offs were investigated from 0-32 mip. In figure 3 the fraction of rejected 'good' triggers is plotted for the following three cases: only AC, energy deposited in S4 (E_{S4}) <2 mip and E_{S4} <32 mip. As seen in this figure the fraction of lost

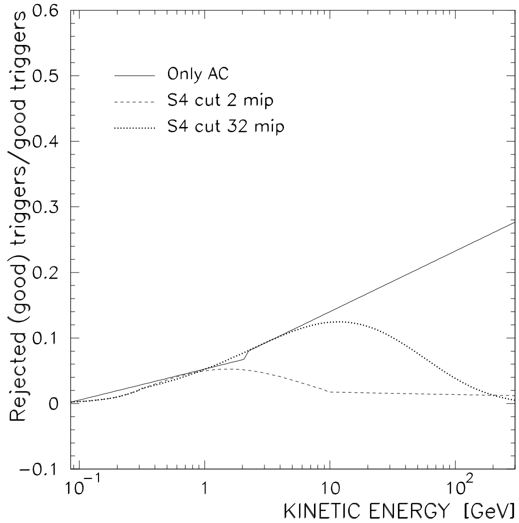

Figure 3. Fraction of 'good' triggers lost due to backscattering as function of the kinetic energy of the incoming particle.

'good' events is greatly reduced (especially at higher energies) by using the S4 signal.

The resulting trigger rate shown, in figure 2, is 7Hz (5Hz) for a 2 mip (32 mip) cut on the energy deposited in S4.

In summary, the AC system in combination with the S4 detector is able to help reduce the 'false' trigger rate by at least 60% without losing any significant part of the 'good' events. A more refined study is currently being conducted using calorimeter information instead of S4.

References

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2. P. Papini *et al, Il Nuovo Cimento* **19**, 367 (1996)
3. M. Boezio *et al, Nucl. Instr. and Meth.* A **471**, 184 (2001)