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Nuclear Instruments and Methods in Physics Research A 518 (2004) 158–160
NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH
Section A
www.elsevier.com/locate/nima

The silicon microstrip detectors of the PAMELA experiment: simulation and test results

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Abstract

The PAMELA detector will fly at the beginning of 2004 on board the Russian satellite Resurs–DK for a 3-year mission designed to study mainly antiparticles in cosmic rays. The core of the apparatus is a magnetic spectrometer in which silicon microstrip detectors are employed. A dedicated simulation study, tuned on beam test data, is presented: it allows to determine the best position finding algorithm for different incidence angles.

PACS: 29.40.Gx; 29.40.Wk; 07.05.Tp

Keywords: Silicon microstrip detectors; Spatial resolution; Position finding algorithms

1. Introduction

The PAMELA apparatus [1] is designed to study mainly antiproton and positron fluxes in cosmic rays in a wide energy range and with high statistics: about 20,000 antiprotons in the energy range 0.08–190 GeV during a 3-year flight are expected. The telescope is composed of some detectors that provide particle identification. The spectrometer [2] is the core of the apparatus: it determines the momentum of charged particles that enter the angular aperture of the telescope, by measuring their curvature in the magnetic field produced by a permanent magnet. Tracking is provided by silicon microstrip detectors, that ensure a very precise reconstruction of the particles' impact point. They are double-sided detectors, 300 μm thick, whose main characteristics for junction and ohmic sides are listed in Table 1. The junction side determines the coordinate in the charged particles' bending direction.

2. Simulation of the detectors

A simulation of the detectors has been realized to better investigate their response to ionizing particles in the experimental conditions foreseen for the experiment. The simulation concerns both energy release in the silicon wafer (reproduced by the GEANT package) and collection of charge

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0168-9002/$ - see front matter
doi:10.1016/j.nima.2003.10.049

Table 1
Main characteristics of the silicon microstrip detectors (J = junction side, O = ohmic side)

	Strip pitch and type	Read-out pitch	p-stop	Integrated capacitors	Double metal
J	25.5 μm, p	51 μm		Yes	
O	67 μm, n	67 μm	One	Yes	Yes

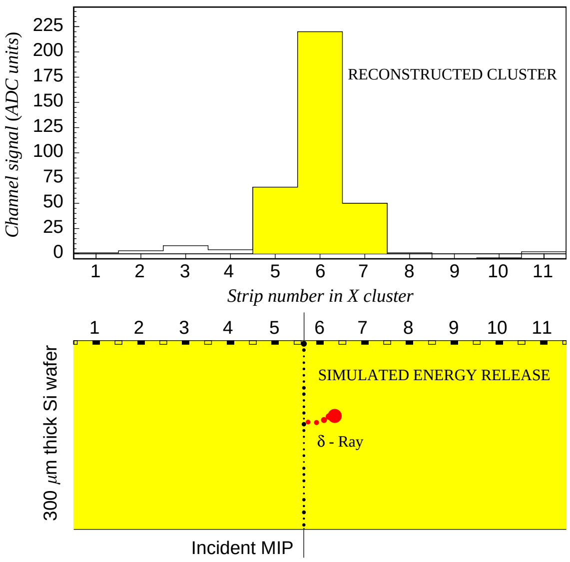

Fig. 1. A simulated event: charge generation and corresponding ADC signals.

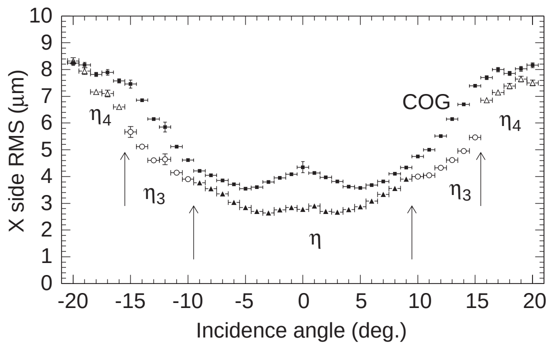

Fig. 2. Spatial resolution on the junction side as a function of the incidence angle.

carriers on the strips, after drift and diffusion in the material. Capacitive couplings among strips and the electronic noise observed for our detectors have also been introduced. Fig. 1 shows the charge generated in the silicon wafer along the track of a simulated high-energy proton (below) and the corresponding cluster signal arising in the readout (above). The collection on the strips of each point-like charge packet, generated by both the primary particle and the secondary energetic electrons allows to analyze the δ-ray effect on the cluster shape.

In the study of the spatial resolution, our starting point was the non-linear η algorithm [3]. This method involves only two strips in the determination of the best impact point: for this reason, it is suitable for orthogonal or slightly inclined tracks. The *distribution of spatial residuals*, which are defined as the difference between reconstructed impact point and true particle position, is equivalent to a similar distribution obtained for the data. Tails larger than in a Gaussian function are observed, due to energetic δ-rays that spread the energy release far from the particle incidence point. The spatial resolution of the detectors can be defined as the standard deviation of the distribution of residuals: it is about 3 μm on the junction side (thanks to a signal-to-noise ratio > 50) and about 12 μm on the ohmic side ($S/N \simeq 25$) for tracks perpendicular to the surface of the detector, values equivalent to those measured on beams [1]. For incidence angles up to 20°, corresponding to the angular aperture of the PAMELA telescope, generalizations to three (η_3) or four (η_4) strips of the η algorithm have been tested: they take into account the increase in the angle of the mean number of strips collecting the charge signal. Fig. 2 shows the resolution obtained on the junction side versus the particle's incidence angle: for each angular bin the best algorithm (among η, η_3 and η_4) is reported. The results of the Centre Of Gravity method [3] are included for comparison.

On the ohmic side the η algorithm gives the best resolution in all the entire angular range since the strip pitch is larger (67 μm) and the charge collection is limited to one or two strips for all the incidence angles.

3. Conclusions

The simulation of the detectors, combined with beam test data, allowed to determine the best position-finding algorithm for different incidence angles so as to fully exploit the characteristics of the sensors in a precise tracking of particles and antiparticles crossing the spectrometer.

References

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