Available online at www.sciencedirect.com
ScienceDirect
Nuclear Instruments and Methods in Physics Research A 572 (2007) 495–497
NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A
www.elsevier.com/locate/nima

Technical features of the Time-of-Flight system for the PAMELA experiment in space

S. Russo[a,*], G. Barbarino[a], D. Campana[a], G. De Rosa[a], W. Menn[b], G. Osteria[a], M. Simon[b]

[a] *Dipartimento di Scienze Fisiche Universita' "Federico II" and INFN sez. di Napoli, 80126 Napoli, Italy*
[b] *Universitaet-GH Siegen, FB Physik, 57068 Siegen, Germany*

Available online 13 November 2006

Abstract

The PAMELA experiment is a space-borne apparatus devoted to the study of antiparticle component of cosmic rays. The Time-of-Flight (ToF) scintillator system allows both to distinguish electrons from antiprotons up to about 2 GeV and the measurement of the absolute charge of the particle. A read-out electronics with wide dynamic range and a time resolution better than 100 ps is requested. A fast trigger is also implemented.

PACS: 29.40.Mc; 07.87.+v

Keywords: Antimatter research; Electronics; Trigger; Time-of-Flight; Space-borne experiment

1. Introduction

A Payload for Antimatter Matter Exploration and Light-nuclei Astrophysics (PAMELA) [1] is a satellite-borne experiment scheduled to be launched at the middle of 2006 from Baikonur aboard of a Soyuz TM2 rocket. The primary goal of PAMELA is to measure both the energy spectrum of cosmic ray protons and electrons with a special care on their antiparticle counterparts and the search for nuclear antimatter covering wide energy range (50 MeV to 270 GeV) and with a sensitivity unreachable by previous similar experiments. PAMELA is built around a permanent magnet spectrometer equipped with double-sided silicon sensor tracker. The tracker is surrounded by a scintillator anticounter veto shield that will reject particles that do not pass cleanly through the acceptance of the tracker. Below the tracker there is a silicon–tungsten calorimeter, to allow topological discrimination between electromagnetic and hadronic showers. A scintillator telescope system will provide the primary trigger and Time-of-Flight (ToF) particle identification. This information integrated with the measurement of the trajectory length of the spectrometer gives the velocity β of the particle. In addition the energy loss in the counters determine the absolute value of charge z of the incident particles. A scintillator mounted beneath the calorimeter will provide an additional trigger for high-energy electrons. This is followed by a neutron detector system for selections of very high-energy electrons and positrons (up to 3 TeV).

2. The PAMELA ToF

The ToF system [2] is composed by three double planes of fast plastic scintillators read out by 48 photo-multiplier tubes (PMTs) mod. R5900 PMTs, manufactured by Hamamatsu Photonics. Several environmental and mechanical tests have been done to qualify these commercial PMTs for space-borne experiment.

The ToF and trigger electronics is a complex system made by nine boards. These are six Front-End (FE) boards, the DSP board and the two replicated trigger boards (one called "hot" and one called "cold"). The electronics must ensure low power consumption and good radiation hardness. To avoid single point failure and to guarantee at the best the reliability, a great effort has been made in the implementation of hardware and software redundancy.

*Corresponding author.
E-mail address: srusso@na.infn.it (S. Russo).

0168-9002/$ - see front matter © 2006 Elsevier B.V. All rights reserved.
doi:10.1016/j.nima.2006.10.154

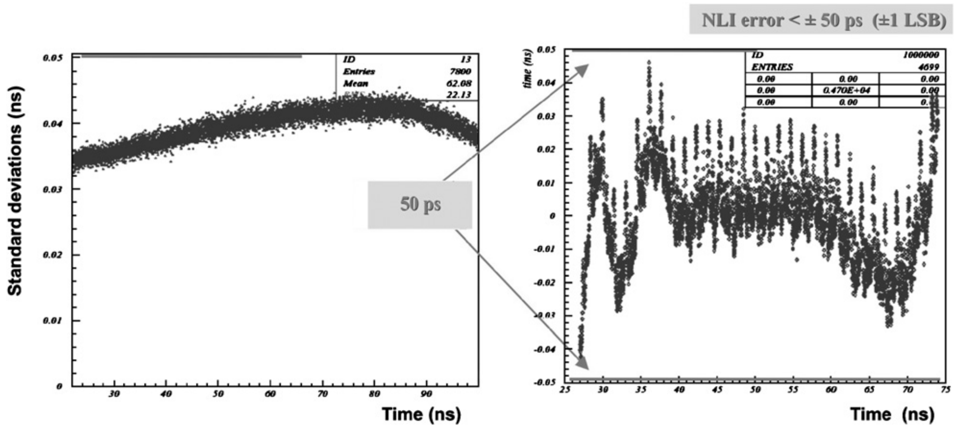

Fig. 1. Time resolution measurement results of the PAMELA FE boards.

2.1. FE boards

Each FE board receives the analog signals coming from eight PMTs. In the time section of FE board, each anode line is coupled to a fast discriminator. The output signal is sent to the trigger board and to a double-ramp Time-to-Amplitude-to-Time converter (TAT). To minimize the time-walk effect, a double threshold discriminator technique has been employed: the lower threshold has to be chosen for the time measurements, while the higher threshold selects between real signals and noise. These two thresholds are settable by remote through two DACs. To improve the time resolution a double-ramp time expander has been implemented. The arrival of the PMT pulse produces the start of the fast ramp, while the trigger signal (COMMON STOP) starts the slow ramp. Such device is realized by charging at constant current a capacitor until a stop signal arrives. Then the capacitor is slowly discharged with a much lower constant current. This discharging time is measured by a Time-to-Digital Converter (TDC) clocked at 100 MHz. In our case the expansion factor is 200 and the intrinsic time resolution of our electronics is 50 ps. Using the same double-ramp technique a J-FET charges up a capacitor at a voltage proportional to the value of the input PMT signal. The capacitor is linearly discharged with a constant current source. Clearly, the discharge time is once again proportional to capacitor voltage, and therefore to PMT total charge. Likewise in the time section the discharge time is measured with the TDC.

3. Results

3.1. Qualification tests

The performances of the ToF and trigger electronics has been subject to extensive test. The time resolution and integral non-linearity of the flight model of the FE boards have been measured with an AGILENT 81132 pulse generator (RMS jitter of the time base $= 15\,\text{ps} \pm 0.001\%$ of the delay). The results, shown in Fig. 1, fully satisfy the design specifications. The measured time resolution is better than 50 ps.

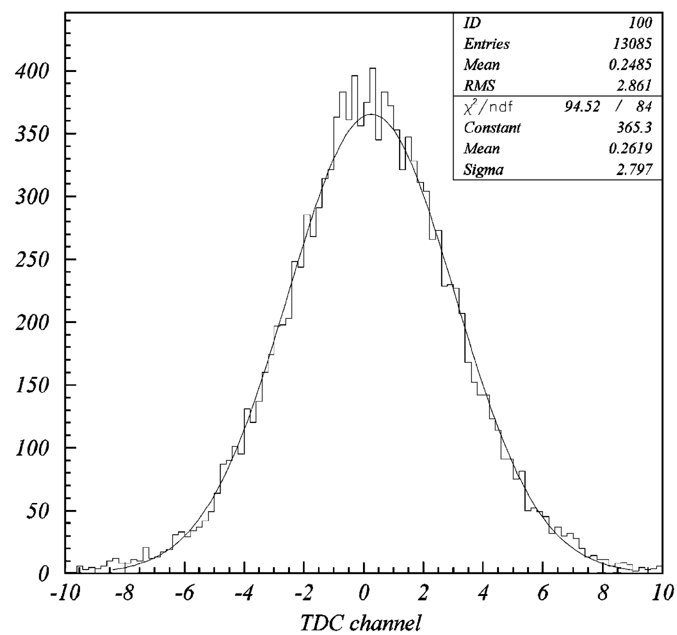

Fig. 2. Time resolution in units of 50 ps for S2 paddle.

3.2. Flight model tests

In order to obtain a first evaluation of the time resolution of the single counter we adopt the following procedure: the position of the track along the counter measured from the tracker is compared to the one obtained from the difference of the TDC value associated to the two sides of the PMT counter. Plotting the last as function of the first and assuming negligible the uncertainty due to the tracker, the distribution of the residuals gives us the time resolution of the counter. Fig. 2 shows the result for a paddle of S2.

References

[1] O. Adriani, et al., IEEE Trans. Nucl. Sci. NS-51 (3) (2004) 854.
[2] G. Osteria, et al., Nucl. Instr. Meth. A 535 (2004).