The ToF and Trigger systems of the PAMELA experiment: Performances of the Flight Model

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A time-of–flight scintillator system has been developed for the Pamela satellite-borne cosmic ray experiment. The Pamela main scientific goal is the measurement of the fluxes of antiprotons and positrons in cosmic rays over the large energy ranges of respectively 80 MeV-190 GeV and 50 MeV-270 GeV.
The installation of the apparatus on board the Russian satellite Resurs DK1 is now in progress, the launch is scheduled for the late 2005. The TOF system will provide the fast trigger to the experiment, the rejection of albedo particles and the possibility to distinguish electrons from anti-protons up to about 1.5 GeV. The performances of the ToF and Trigger flight model systems measured using cosmic rays before the delivery for the final integration in Russia are described.

1. Introduction

The assembling of the Pamela [1] Flight model in the clean rooms of the Rome University "Tor Vergata" has been completed at the end of March 2005. On March 29th the apparatus has been carried to the TsSKB-Progress of Samara in Russia for the integration with the satellite. For several weeks before the leaving for the Russia and for two weeks after the arrival in Samara the apparatus was tested in the flight configuration acquiring several hundreds of thousand of cosmic muons.
During the test different settings for the various detector elements were tested in order to verify the behavior of the apparatus in all the possible configurations. In particular for what concern the Trigger and Time of flight systems, all the different trigger configurations were successfully tested and the performances of the ToF were tested for different values of High Voltage and threshold. In the next sections the preliminary results of these measurements will be presented and compared with the results obtained on the various system elements during the qualification test.

2. ToF system description

The ToF system [2] is made of 6 layers of fast plastic scintillators arranged in three planes (S1, S2 and S3), with alternate layers placed orthogonal to each other. The dimensions of the layers are dictated by the projected trajectories of charged particles passing through the spectrometer. The overall sensitive area of each of the two layers of S1 is 330x408 mm^2, the first layer is divided in 8 strips while the second layer is divided in 6 strips. The overall sensitive area of the remain planes S2 and S3 is 150x180 mm^2 segmented respectively in 2 by 2 and 3 by 3 strips. The thickness of the S1 and S3 layers is 7 mm while the layers of S2 are only 5mm thick. The total number of scintillator paddles is 24. Both ends of each scintillator paddle are glued to a one-piece adiabatic UV-transparent Plexiglas light guide. This is in turn mechanically coupled to a PMT by means of optical pads. Scintillators and light-guides are wrapped in a 25 mm thin Mylar foil. The S3 plane is housed directly in the base plate of PAMELA and kept in place by a set of steel frames. The other two planes are enclosed in light-proof boxes.
The chosen plastic scintillator is the BICRON BC-404 which has a pulse rise time of 0.7 ns, a decay time of 1.8 ns and an attenuation length of 160 cm. Strip widths have been chosen to match the exit areas of the

scintillators to the 3.24 cm^2 active areas of the PMTs. The readout electronics of the ToF system is composed of nine boards (6U VME). Six Front End boards perform the time and charge digitization of the 48 PMT pulses of the PAMELA ToF. Data from these are collected by a DSP board through serial links and, after digital processing, transferred to the main data acquisition system.

3. Trigger system description

The trigger board [3] receives the 48 signals from ToF system for the main trigger and about 7 signals from other subsystems able to generate auto-trigger for particular events. To guarantee synchronization of the data acquisition, the trigger board manages the busy lines coming from each of the PAMELA subsystem for a total of 20 busy lines. All the input and output lines are in the LVDS standard. About 60 rate counters, dead/live time counters and the logic to generate calibration pulse sequences for different subsystems of the apparatus are also implemented on the board. The logic is distributed on 9 Actel 54SX32A FPGAs.
Control masks select trigger types and allow the selection of failed (noisy or dead) ToF channels.
The pattern of the fired channels is generated for each trigger. A DSP (ADSP 2187L) is used to manage the data structure organization and to monitor the rate counters of the ToF channels and other subsystems.

4. Qualification tests

Several qualification tests were performed on each element of the two systems in order to reach maximum reliability and best performances. Vibration and environmental tests were performed on different models of the system to evaluate its behaviour during the launch and the flight. Accurate selection of scintillator paddles, light guides and PMT was achieved analysing result of several measurements in different experimental setup. In particular, the intrinsic time resolution and the charge distribution of each ToF paddle was measured placing the paddles on top of a drift chamber (DC) and comparing the impact point reconstruction done by the scintillator with the one obtained by the DC. Since the DC can reconstruct the tracks of ionizing particles passing through its sensitive volume with a precision of 300 mm, its contribution to the error can be considerate negligible. In table 1 we summarize the final results of these measurements for the different layers before and after the time-walk correction.

Table 1. Mean values of the time resolution for the different layers of the ToF system

Paddle ID	Before Correction (ps)	After Correction (ps)
<S11 >	145	125
<S12>	150	135
<S21>	145	125
<S22>	166	144
<S31>	122	110
<S32>	134	116

5. Flight model tests

The measure of the performance of the ToF system and trigger in the real flight configuration was possible only during the final assembling phase of Pamela apparatus in Rome when all subsystems were integrated, cabled and supplied with 'flight' low and high voltage power supplies. In this conditions cosmic muons were

acquired using the ToF scintillators and trigger board in order respectively to detect the particles passing through the apparatus and to trigger and to manage the data acquisition.

Data was taken in different working conditions relative both to the HV values as well as to the threshold values of the ToF system in order to evaluate the trigger efficiency and the time resolution as function of the working condition.

5.1 Efficiency measurement

The efficiency of single paddle was evaluated using a set of perfectly reconstructed tracks pointing in the paddle. The tracks selection criteria requires a good reconstructed track from the tracker in agreement with the position of the track as reconstructed from the timing information of the ToF in the planes different from the one under study.

The paddle length is divided into 10 intervals and for each of the interval the ratio between "track inside" events and valid signal from PMT is evaluated. As shown in Fig. 1 for the plane S3, the efficiency is good also for the intervals far from the PMT. The results are similar for other planes, slightly worse for the longer paddles of S1, but as expected they depend strongly from the operational conditions of the system. Comparing the results obtained in different working condition was possible to exclude some of the configurations tested.
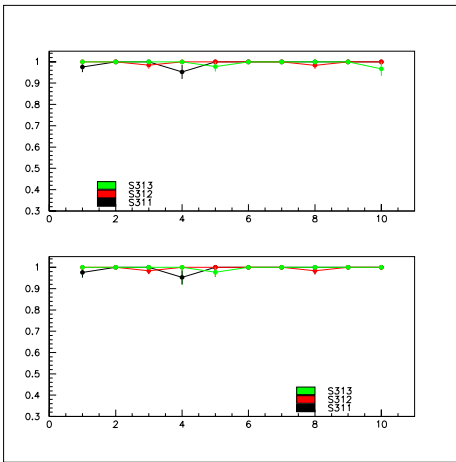

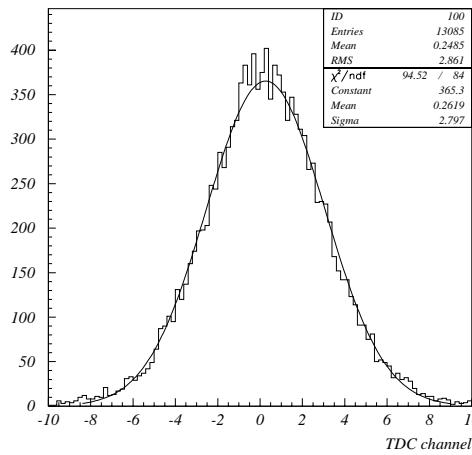**Figure 1.** Efficiency of the two layers of the plane S3 as function of the distance from the PMT

Figure 2. Time resolution in unit of 50 ps for a S2 paddle

5.2 Time resolution measurements

In order to obtain a first evaluation of the time resolution of the single paddle we adopt a procedure similar to the one used for the qualification test. The position of the track along the paddle as measured from the tracker is compared to the one obtained from the difference of the TDC value associated to the two PMT's of the paddle plotting the last as function of the first. Assuming negligible the uncertain due to the tracker the distribution of the residuals give us the time resolution of the paddle.

Fig. 2 shows the result for a paddle of S2. In this analysis we didn't apply any correction to the data so the results obtained should be compared with the one shown in the first column of table 1. These preliminary results show a general worsening of the performances respect to the one obtained in the qualification test.

Respect to the values shown in table 1 the time resolution measured is roughly 20% worse for the paddles of S1 and S3 and less then 10% worse for the paddles of S2.

The evaluation of the β resolution requires a more accurate analysis of the data which is still in progress. In fig. 3 however we show the very preliminary distribution of β measured on a small fraction of cosmic muons sample acquired in Rome. The distribution is the weighted mean of the 4 independent beta measurements between the layers S11-S31, S12-S32, S21-S31, S22-S32. In Fig. 3 is also shown the plot of the beta as function of the rigidity in GV of the particles as measured by the spectrometer.
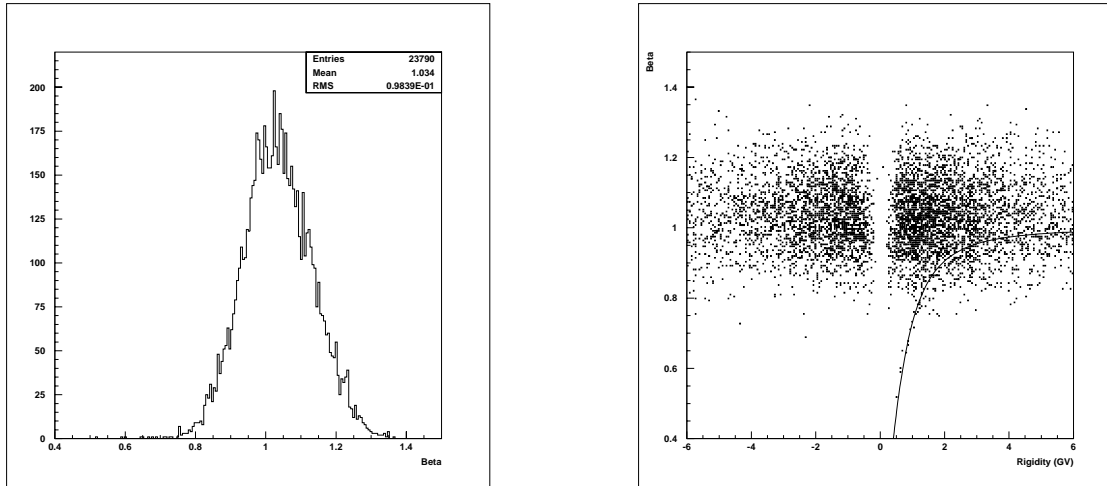

Figure 3. Preliminary Beta distribution and Beta vs rigidity plot.

6. Conclusions

The preliminary analysis of the 'ground' data of Pamela Trigger and ToF systems shows that systems work as expected. A little worsening of the performance of the ToF respect to the results of the qualification test is observed. Studies are in progress to better understand this effect. In any case these preliminary results makes us confident on the possibility to reach with these systems all the Pamela scientific goals.

7. Acknowledgements

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References

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