The ASACUSA scintillating fiber tracker: commissioning and characterisation.

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Abstract

The goal of the FAST (Fiber Antiproton Scintillating Tracker) detector is the measurement of the annihilation cross section of slow antiprotons in gaseous targets in the ASACUSA beam line at the Antiproton Decelerator (CERN). The tracker will allow to reconstruct the charged pion tracks to identify the annihilation vertices.

The detector, designed to cover a 50 cm long 15 cm radius cylindrical volume, consists of 2 axial and 4 stereo layers of scintillating fibers, readout by 42 multi-anode PMTs (64 channels each). 1 mm BCF-10 fibers have been used, for a total of 2688 readout channels. A custom designed electronic chain performs the signal amplification, discrimination and the digital sampling with a 640 MHz clock over a 800 ns gate.

To test the detector performance before the commissioning on the ASACUSA beam line a cosmic ray run with an external trigger system has been done, collecting a total of 10^5 events. This work will describe the operation of the FAST detector during the cosmic ray tests and the results of the track reconstruction analysis in terms of spatial and time resolution.

1 Introduction

A scintillating fiber tracker has been developed, in the framework of the ASACUSA experiment [1] at CERN, for the measurement of the annihilation cross sections of slow antiprotons (< 5 MeV) in gaseous targets. The intense antiproton beam (10^6 particles in a 30 ns bunch) provided by the Antiproton Decelerator [2] enters the mylar window and travels in the low pressure gas producing some tens of in-flight annihilations before reaching the end wall of

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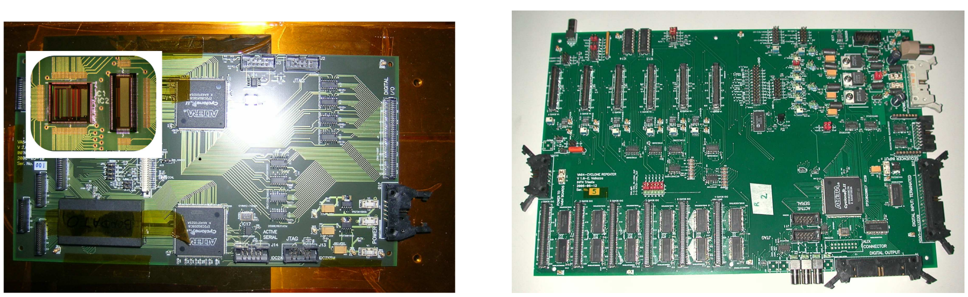
the vessel.
The detector has to track the annihilation charged pions to reconstruct and count the annihilation vertices. Scintillating fibers with multianode PMT readout allow to obtain the time resolution required to separate different events and a spatial resolution suitable for the wall annihilations rejection (∼1 cm), while keeping the number of channels relatively low.
The paper will describe the detector and electronics design, the cosmic ray test setup (section 2) and the results of the cosmic ray runs in terms of time resolution, cross talk, hit reconstruction capabilities and spatial resolution (section 3).

2 The detector and cosmic ray setup

The FAST tracker consists of 6 layers of scintillating fibers (BCF-10 by Bicron), 2 axial and 4 stereo, organized in two shells at 12 cm and 15 cm radius; fibers are grouped in 4-fiber bundles in order to improve efficiency and to reduce dead zones [3]. The scintillation light is readout by 42 multianode photomultipliers by Hamamatsu (H7546A, 64 channels) for a total of 2688 readout channels. The anode outputs are amplified, shaped ($\tau \sim 50$ ns) and discriminated by VLSI ASICs (VA64TAP2.1 and LS64 by IDEAS). The 64 discriminated signals are sent to a Cyclone II FPGA by Altera for time sampling in order to retrieve the time information of each hit. A 640 MHz sampling clock and a 512 bit/ch shift-register (for a 800 ns gate) are implemented in the Cyclone II FPGA [4].
Two full acquisition chains (128 channels) are hosted on the same frontend

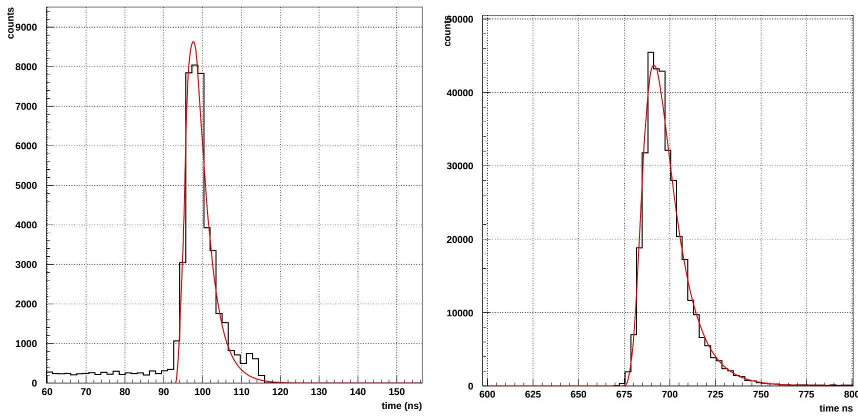


(a) (b)

Fig. 1. (a) One of the 21 frontend boards housing two ASIC chains (in the inset) and the ALTERA FPGAs. (b) The repeater board, controlling up to 6 frontend boards.

board (Fig. 1a). Four repeater boards (Fig. 1b) perform bias distribution, digital control of the frontend ASICs, digital I/O to the FPGAs, clock and trigger distribution and signal multiplexing for the analog readout. Up to 6 frontend boards can be controlled by one repeater.

A VME sequencer and four VME I/O registers provide the control of the repeater board and the digital data readout; the analog readout is accomplished by a SIROCCO [5] 12 bit flash ADC.
To test the detector behaviour before the commissioning on the ASACUSA



(a) (b)

Fig. 2. (a) Time dispersion for the single module setup; data are fitted with a Landau curve obtaining a FWHM of 5.24 ns. (b) Time dispersion for all the tracker channels; the computed FWHM is 19.2 ns.

beam line, a cosmic ray run has been performed, modifying the digital samplers on the front-end boards FPGAs to work in a common stop mode; this stop signal was provided by the delayed trigger signal. An analog readout mode has been implemented as well, using the trigger as the hold signal for the analog part of the ASICs. The trigger was provided by two 20×30 cm^2 plastic scintillators, placed above and below the tracker, in coincidence with a 10×10 cm^2 scintillator inserted inside the tracker itself. The event rate was around 0.1 Hz and data for different Z positions have been collected for a total of $\sim$ 10 days.

3 The detector performance

3.1 Time resolution measurements

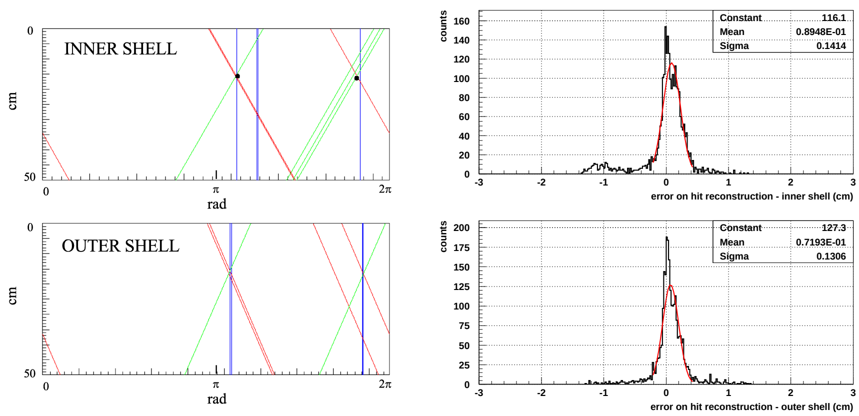
The time resolution has been evaluated using cosmic rays both on a single multianode module and on the whole tracker. The trigger system was provided by a 10×10×1 cm^3 scintillator with a known resolution of $\simeq$500 ps. The single module was tested in a small region in the fiber direction about 20 cm far from the PMT, while in the tracker case the trigger scintillator was placed inside, so that the whole sensible volume of the detector was involved.
The results are shown in Fig. 2: the single module shows a good time resolution

of 5.24 ns (FWHM). The difference in the lengths of the fibers and the trigger cables accounts for the overall resolution degradation at 19.2 ns.

3.2 Hit reconstruction and resolution

Fig. 3a presents a 2D projection of the tracker shells for a detected cosmic ray, while Fig. 3b shows the quality of the reconstructed hits, expressed as the difference between the position of the intersection of the stereo layers and the axial layer hit. The differences are consistent with the readout pitch and the estimated errors on the fiber positioning in space.

In Fig. 3a active fibers far from the crossing points are due to optical cross



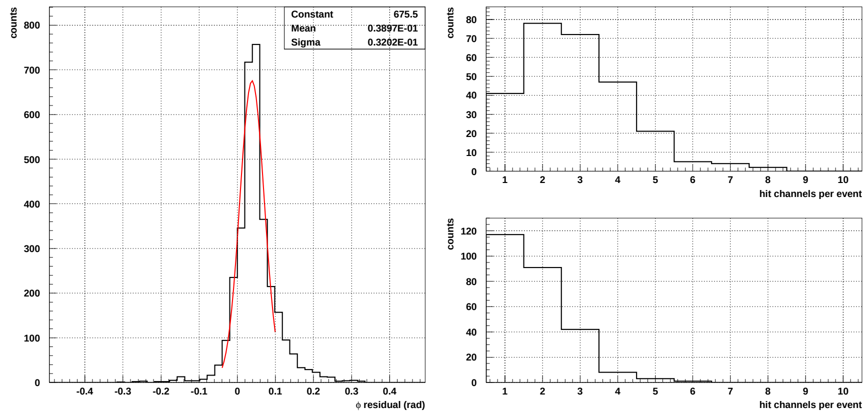
(a) (b)

Fig. 3. (a) 2D representation of the 2 shells of the tracker crossed by a cosmic ray; 0 and 2π positions correspond to the top of the cylinders. (b) Error on the hit recostruction (see text).

talk effects on the PMT windows; these effects make the reconstruction of the hit position difficult and less precise, as shown in Fig. 4a, where the residuals for the inner shell are greater than expected. The main cause of the cross talk effect has been identified in the poor quality of the mechanical alignment of the PMT with respect to the fiber mask; Fig. 4b shows that a finer alignment obtained with the help of a LED pulser can reduce the cross talk to an acceptable level. The alignment of the 42 PMTs is ongoing and a new cosmic ray run is foreseen.

4 Conclusions

A cosmic ray test of the FAST scintillating fiber tracker has been done to qualify the detector and electronics performances. The whole acquisition system



(a) (b)

Fig. 4. (a) ϕ residuals for the inner shell; the 2 reconstructed hits on the outer layer have been used to project the track. The readout pitch is $\simeq$0.02 rad. (b) Number of hits per cosmic ray on a single MA-PMT before and after the LED alignment; a part of the 2 hit events are intrinsic, given the partial superposition of nearby channels.

showed a very stable behaviour during the 10 days of the run. The time resolution of the detector has been measured to be within the design specifications. Evidences of cross talk at the fiber-PMT interface have been found; the effect is a broadening of the spatial resolution and a reduced efficiency on the hit reconstruction. A solution to this problem has been identified and tested on a single module and is being implemented on the whole tracker. A new cosmic ray run is foreseen to verify the improvement on the detector performances before the 2007 data taking period.

References

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