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A portable telescope based on the ALIBAVA system for test beam studies

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ABSTRACT

A test beam telescope has been built using the ALIBAVA system to drive its data acquisition. The basic telescope planes consist of four XYT stations. Each station is built from a detector board with two strip sensors, mounted one in each side (strips crossing at 90°). The ensemble is coupled to an ALIBAVA daughter board. These stations act as reference frame and allow a precise track reconstruction. The system is triggered by the coincidence signal of the two scintillators located up and down stream. The telescope can hold several devices under tests. Each ALIBAVA daughter board is linked to its corresponding mother board. The system can hold up to 16 mother boards. A master board synchronizes and controls all the mother boards and collects their data. The off-line analysis software has been developed to study the charge collection, cluster width, tracking efficiency, resolution, etc., of the devices under test. Moreover, the built-in ALIBAVA TDC allows the analysis of the time profile of the device signal. The ALIBAVA telescope has been successfully operated in two test runs at the DESY and CERN-SPS beam lines.

1. Introduction

A test beam experiment is an ideal framework to characterize the properties of new sensing devices under development. In a test beam, one can collect a large amount of data under well controlled operational conditions. Though the beam parameters may depend on the energy range and the accelerator duty cycle, they are usually well determined (type of incident particles and their momentum, the spot size, the beam divergence and the number of particles per spill).

Nowadays, new types of silicon sensors for particle detection are being developed, specially in the experimental High Energy Physics field. Currently, ALICE [1], ATLAS [2], CMS [3] and LHCb [4] experiments at the CERN proton–proton LHC [5] collider are equipped with charged particle tracking systems based on silicon sensors, either using the pixel or strip technology. Many other experiments used silicon sensors in the past.

One of the problems that the existing silicon based tracking systems of the LHC experiments have to face is the radiation damage. The joint effect of the increase in the leakage current, depletion voltage and noise, together with the signal loss due to charge trapping, with the accumulated dose over the expected life time of the experiments will turn the current sensors unfunctional. There are plans to replace the current tracking systems of the LHC experiments with more radiation hard silicon sensors. That technology is currently being developed (see [6], and references therein).

Apart from testing the electrical properties of the new silicon sensor types (either irradiated or unirradiated), it is of utmost importance to test their tracking properties as well, as their particle detection efficiency and their spatial resolution will generally depend on the radiation dose.

When testing the sensors, it is important to have access to the signal each channel is collecting. Therefore an analogue readout is of great help. It is also important to perform the test under the right conditions (for instance, irradiated sensors must be kept cool) and to be able to test the resolution depending the incidence angle of the particles (therefore sensors must be mounted on rotating frames).

These and other issues are considered in the telescope that ALIBAVA Systems [7,8] have designed and built. This is a tracking telescope which allows to characterize the operating parameters of the devices under test in real operation conditions. As usually, the set-up of a test beam is laborious and time consuming. Thus,

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the ALIBAVA telescope has been conceived with the following functionalities:

- to allow easy handling and being portable,
- to minimize the set-up time,
- provide high resolution and high tracking (trigger) rate,
- with early feedback from analysis of the recorded data.

This paper presents the telescope hardware, sensors, mechanics and track reconstruction software as well as some preliminary results.

2. The ALIBAVA telescope hardware

The Alibava test beam telescope is a system able to reconstruct the track of the incident particles with reasonable precision and to determine the position of the beam particle interactions in a device under test (DUT) in order to test its tracking capabilities.

The telescope hardware is based on the existing ALIBAVA readout system. It has been developed to be able to host several ALIBAVA daughter and mother boards, so to install many tracking planes in the telescope. It is equipped with four reference tracking stations (hereafter called XYT stations). Each station consists of two 80–μm–pitch strip detectors mounted back to back on a daughterboard. Their strips run perpendicularly. So each station provides accurate track measurements in both directions. Each sensor has 128 strips which are connected to the Beetle readout chip [9] by micro-wire bonding using interposed metal-on-glass pitch adapters. The analog front-end pulse signal is sampled into the pipeline with the frequency of the Beetle chip (40 MHz) and it is proportional to the collected charge at the detector strip. The chip is configured by I2C protocol and the data and control signals are composed of 5 LVDS (Low-Voltage Differential Signalling) lines. The active area of each XYT station is $\approx 1 \times 1\ cm^2$. Each daughter board (either linked to an XYT station or to a DUT) is subsequently read by its corresponding mother board. The data acquisition system (DAQ) can hold up to 16 ALIBAVA mother boards. The whole system is controlled by a master board that synchronizes all the detector mother boards and collects the data. This master board is connected with a PC via a 100 M Ethernet link. The data acquisition software runs on the PC and sends all the commands and receives the data through that cable (Fig. 1).

3. Detector box and telescope mechanics

The XYT stations count on a Detector Board (DB) with two strip detectors mounted at 90° in each side of the board. The DUTs can be mounted on a custom made detector board and, if necessary, placed inside a cooling box for irradiated sensor testing (Fig. 2).

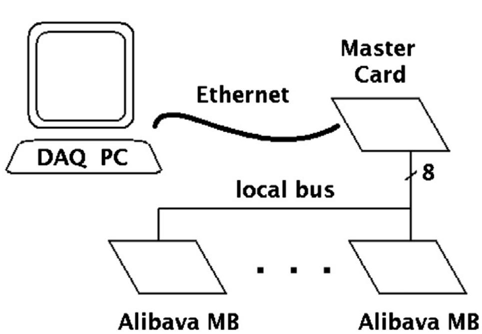

Fig. 1. Basic scheme of the telescope system connections between the DAQ PC and the master card, and between that and the mother boards (up to 16).

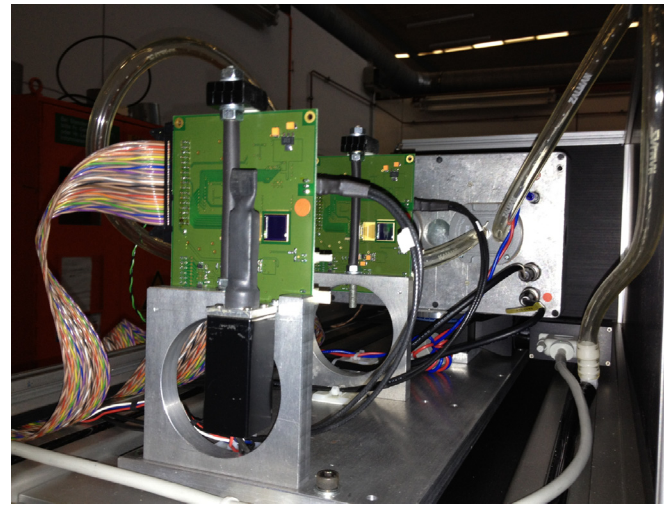

Fig. 2. Photograph of the telescope system. The front trigger scintillator, the first 2 XYT stations and the cold box for the DUT are displayed.

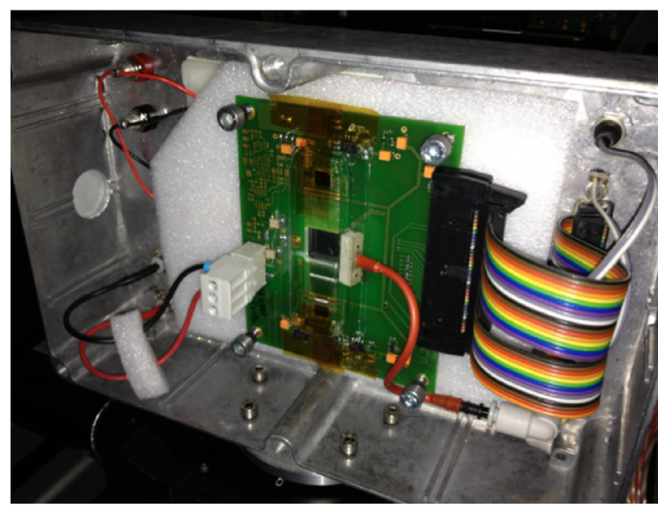

Fig. 3. The DUT mounted on its daughter board inside a cooling box.

The current DUT board has two Beetle chips facing each other to add the possibility to read out more channels in the same device. To cool down the detector, it is mounted on an aluminum radiator in contact with a Peltier device. The heat is evacuated by a closed water circuit. The prototype is installed in an aluminum crate with a protecting box (Fig. 3). This mechanical structure ensures an easy handling and minimizes the set-up time.

4. Data acquisition

The data acquisition is controlled by a PC connected to the master board via Ethernet. The master board manages and controls all the mother boards via the local data/address bus. It is also responsible to distribute the clock and trigger signals through the ALIBAVAs to make the system synchronous. The trigger is generated by two scintillators situated at each end of the telescope and the master board distributes the coincidence trigger to all mother boards. Each ALIBAVA mother board configures and communicates with the two Beetle chips of its XYT station. The Beetle chip is used to read out the detector's strips. This chip is a low noise ASIC with 128 input channels and a clock speed of 40 MHz. The radiation hard design can tolerate doses in