ELSEVIER

ALIBAVA Silicon Microstrip Readout System for Educational Purposes

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Abstract

The ALIBAVA is a compact and portable system for characterization of silicon microstrip radiation detectors. Actually, the ALIBAVA system is conceived to easily characterize multichannel semiconductor detectors, providing high sensitivity to low signals and high speed. The front-end electronics is based on a low noise ASIC with 128 input channels. Beyond its scientific and sensor R&D applications, the system can also be used in instrumentation lectures at the university teaching laboratories. New features of the system makes it more suitable for its handling by undergraduate and postgraduate students, who will greatly benefit in their instruction by using this system to learn about the properties of microstrip sensors and signal formation in those devices.

Keywords: , Readout system, Silicon sensors, Charge collection

1. Introduction

The ALIBAVA system [1] is conceived to easily characterize multichannel semiconductor detectors, providing high sensitivity to low signals and high speed. The front-end electronics is based on a low noise ASIC with 128 input channels and a clock speed of 40MHz. The ALIBAVA readout system is compact, portable and a powerful tool that allows researchers to study the properties of their sensors, some recent applications of the system are presented in references [2]-[5]. The system is typically used to test microstrip sensors with variable interstrip distance by laser, radioactive source or particle beam. The development was supported by CERN-RD50. Over 30 particle physics institutes in Europe and USA use the system.

EASY (Educational ALIBAVA System) is the new version of the ALIBAVA system. Beyond its scientific and sensor R&D applications, the new system has been adapted to be used in instrumentation lectures at the university teaching laboratories. The EASY system makes it more suitable for handling by undergraduate

and postgraduate students, following lectures on radiation detection instrumentation. The set-up is ideal for making basic or complex experiments with silicon microstrip detectors similar to the ones performed in the actual research field, in facilities like CERN (LHC), DESY, FERMILAB, Synchrotrons, etc, using a radioactive source or a laser to inject charge.

2. Educational ALIBAVA system

The main components of the system are a Mother Board and a Detector Board. The Detector Board contains one Beetle readout chip as well as the circuitry necessary to connect the Beetle chip [6] with the motherboard. The Beetle is a radiation hard read-out chip developed for the LHCb experiment with 128 channels, consisting of a low-noise charge-sensitive preamplifier, an active CR-RC pulse shaper and a buffer. Each channel is sampled with a 40MHz frequency into an analogue pipeline (maximum programmable latency of $4\mu s$). The analogue signal from each channel is readout from the chip.

Pitch adaptors and a detector board are used to interface the sensor. The sensor is a P-on-N microstrip silicon sensor of 128 channels with pitch 160 μm, thickness of 300 μm, polysilicon biasing resistors and AC coupled. The depletion voltage of the sensor is less than 60 Volts and the leakage current at depletion voltage below 10 nA/strip. Together with the sensor, the daughterboard includes a diode below the sensor that provides an external trigger for the measurements with radioactive source.

The Mother Board is intended to process and digitize the analogue data that come from the analogue readout chip. It also processes the trigger input signal of the diode in case of radioactive source setup or it generates an output trigger signal if a laser setup is used. Moreover, it controls the whole system and it communicates with the PC software via USB 2.0 interface, using a FPGA with an embedded processor and custom logic. The Mother Board also generates the power for the Detector Board as weel as HV for the silicon sensor. A specific software controls the whole system and processes the data acquired by the detectors in order to store it in an adequate format. This format is compatible with software used for further data analysis. With this software the system can be configured and calibrated. Acquisitions with a laser setup or a radioactive source setup can be carried out as well to demonstrate and visualize the operating principles of the silicon strip detector. The system is Plug and Play and can be used with Windows, Linux and Mac Os.

3. Experiments with EASY

This simple electronic equipment establishes the basis for an affordable and complete set of student laboratory experiments, illustrating the operation of a silicon microstrip detector with high speed readout electronics. The students can be introduced from very simple concepts to the more complex studies. Here we summarize some examples of suggested exercises.

3.1. Signal and Noise

The students will be introduced to the concepts of pedestals, noise, cluster size and signal to noise ratio (SNR). This is an important aspect from the operational point of view to distinguish the genuine signals from the electronics noise. The system allows changing the SNR and the number of neighbor channels in the cluster formation. The total noise of the system is measured as an equivalent noise charge (ENC) at the input of the amplifier. The student can measure the dependency of mean noise with the reverse voltage or with the temperature, learning their effects in the total ENC through the sensor capacitance, leak current, etc.

3.2. Passage of particles through matter

The signal formation in the silicon sensor is due to the ionizing energy loss of the incident particles. One can study the charge deposition of a mip using a Sr90 β source. The system allows the reconstruction of the pulse shape by measuring the signal as a function of the time between the trigger signal and the periodic readout signal that takes place every 25ns. The trigger signal is provided by a diode located below the microstrip detector. The parameters of the chip has been fixed to modulate the pulse shape and to obtain the maximum of the signal within the time window of the system.
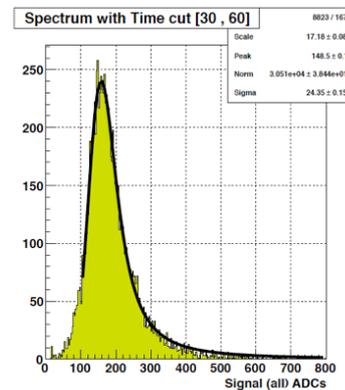

Figure 1: Charge deposition of a mip (Sr90 β source).

The analysis software allows defining the time interval where the signal has its maximum to calculate the charge deposition. Since the interactions between charged particles and the semiconductors are statistical in nature, the total energy deposited by each particle will vary. However, the energy distribution produced over a large number of events is predictable and follows a Landau distribution as shown in figure 1. From the previous distribution one can obtain the mean charge deposition and by fitting the Landau function the most probable charge deposition (MPC) of a mip particle in ADC counts units. The system provides self-calibration to obtain the charge deposition in electrons.

3.3. Charge collection, depletion voltage and electric field

The incident particle creates electron-hole pairs all along its pass through the sensor bulk. But only those

pairs created in the depletion region contribute to the signal thanks to the electric field, which drifts them away. Therefore the signal depends on the size of the depletion region. The students will be introduced in the concept of Charge Collection Efficiency (CCE) and its correlation with the depletion voltage. CCE could be evaluated using a 90Sr β source or an infrared laser ray. Using 90Sr β source for each reverse voltage one can obtain directly the charge collected (figure 2). Using infrared laser, an arbitrary charge is injected, however a posterior calibration could be appled; the advantage of using a laser source is the higher rate of the data acquisition.
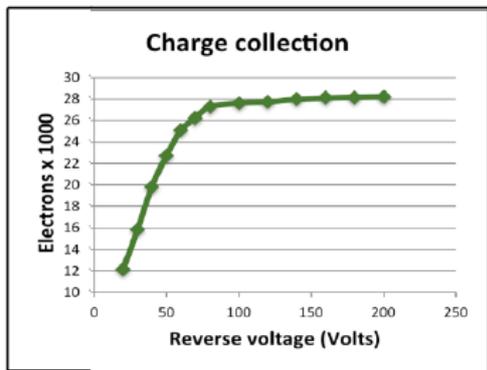

Figure 2: Charge collection variation with the reverse voltage for a mip (Sr90 β source) in a 300 μm thick strip detector.

Figure 2 can be used to define the Effective Depletion Voltage (EDV) as the reverse voltage at which the CCE reaches 80% of the maximum Charge Collection value to be compare with the nominal depletion voltage provide with the sensor characterization (obtained by bulk capacitance measurement).

3.4. Strip structure, charge sharing and position resolution

The EASY system includes a 980 nm pulsed laser with optical fibre output connected to micro-positioners to focus the laser and move the injected charge around the detector. The laser signal can be moved perpendicular to the strip direction to study to structure the strips (figure 3) . Depending on the incidence point, the charge collected can be shared between adjacent strips. Students can investigate the effect of charge sharing in the position resolution of an microstrip detectors.
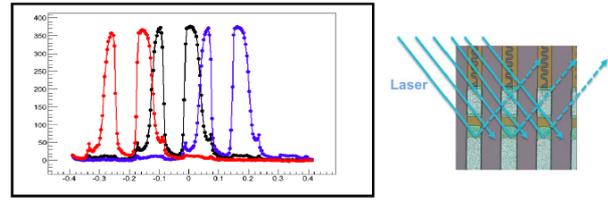

Figure 3: Charge collected in three adjacent strips when laser is moved perpendicular to them. The laser light is reflected on the aluminium of the strips, while the charge is sharing between contiguous strips when laser light hits in the inter strips zone. On the right, a sketch of the laser incidence and reflexion on the strips.

4. Conclusions

EASY is the new version of the ALIBAVA system, a compact and portable system for characterization of silicon microstrip radiation detectors. ALIBAVA system is adapted to be used in instrumentation lectures at the university teaching laboratories. The EASY system makes it more suitable for handling by undergraduate and postgraduate students. The system can be configured to work with laser light or radioactive sources. The set-up is ideal for making basic or complex experiments.

5. Acknowledgment

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