Proton Beam Tests of Double-sided Silicon Strip Position Detectors

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1. Introduction

The silicon strip position detector has been developed and used in various areas due to its intrinsic high position resolution and fast speed of response for medical imaging sensors, radiation detectors, positioning detectors in space science and experimental particle physics. High technology, modern equipments and deep expertise are needed to design, develop and manufacture silicon sensor be top in quality.

We designed and fabricated the double-sided silicon position sensor in 5-inch fabrication line with high resistivity (> 5 kΩ·cm) N-type silicon wafer of 380 μm thick. The sensor fabrications were processed at the Electronic and Telecommunication Research Institute (ETRI). The front-end electronics and DAQ system were developed for signals readout from the silicon strip sensor with Va1Ta_3 chip [1] from IDEAS. We tested a performance of the double-sided silicon strip detector by using a 45 MeV proton beam from the MC-50 cyclotron at the Korea Institute of Radiological and Medical Science (KIRAMS) in Seoul and measured signal-to-noise ratios (SNR) of readout channels. We present preliminary results of the double-sided silicon strip detector performance with a proton beam.

2. Concepts of double-sided silicon strip sensor

The silicon sensor can be fully depleted by applied reverse bias voltage [2]. One of advantages of full depletion is that silicon bulk can be used as the active sensor volume. When charged particles pass through the silicon bulk, electron-hole pairs are produced and electrons are collected in n-side and holes are collected in p-side by the electric field. The principle of the strip detector is to divide a large area diode into narrow strips, each of which has a separate electronic readout channel. The position of the traversing charged particle is then given by the location of the strip showing the signal.

We have designed, developed, and tested a DC-coupled double-sided silicon strip sensor that provides two-dimensional position sensitivity. The manufactured double-sided silicon strip sensor has 512 channels on each side of the sensor and its size is 5.56 cm × 2.95 cm. The implant strips on one side of the layer are orthogonal to ones on the other side. In this way, one plane measures x and y coordinates of point, where ionizing particle goes through, on its two different sides. The p-side has two metal layers; one layer for the implantation strip and the other for the signal readout strip. The double-sided silicon strip sensor therefore is designed to have the double metal structures on the p-side and detail descriptions of the sensor can be found in Refs [3, 4].

3. Readout electronics of the silicon strip sensor

We developed VATA-Hybrid board, VATA-Interface board, VATA-Control board, VATA-Serial board and 64MHz FADC boards to read sensor signal out. Va1Ta_3 chip was used for the trigger purpose and output signal. The Va1Ta_3 chip mounted on VATA-Hybrid board has two different parts of specific characters. The one is called VA part which has analog signal output information of 128 channels. The other is TA part which makes trigger signal. Figure 1 is the architecture of the Va1Ta_3 front-end readout chip.

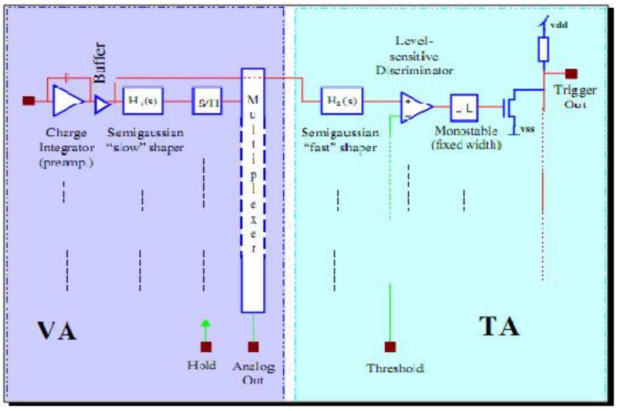

Figure 1. Va1Ta_3 chip from Gamma Medica-Ideas, Norway, has two different parts for self-trigger system [1].

Therefore, when the analog signals from the double-sided silicon strip sensor get into the Va1Ta_3, the signals go through two different systems and we have output signals from the VA part and trigger signals from the TA part. These two signals pass through 12 bit 64 MHz FADC board [5] and record into a personal computer. We analyze these data with C++ based analysis programs.

4. Measurement results

One of the figures of merit to characterize the sensor detector performance is the SNRs of detector readout channels. To measure the signal-to-noise of the detector, we used a 45 MeV proton beam at the KIRAMS in Seoul.

The double-sided silicon strip sensor and readout electronics were assembled in an aluminum light-tight box to shield light and reduce the electromagnetic interference. Figure 2 is a schematic diagram of the experimental setup for the SNR measurement of the silicon strip detector with a 45 MeV proton beam.

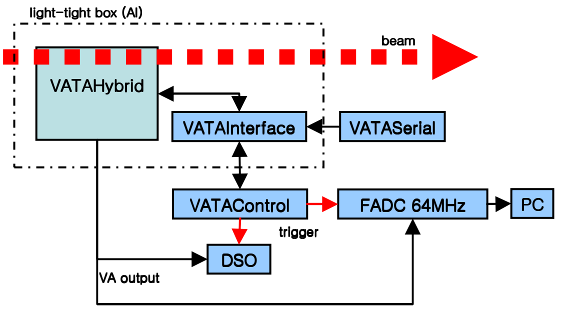

Figure 2. This schematic shows experimental setup for proton beam test of the silicon strip detector.

The silicon strip sensor assembly was placed from the proton beam line to avoid sensor damage due to high beam flux and located in off-axis from the beam line. The distance between the beam line axis and the sensor is about 20.0 cm.

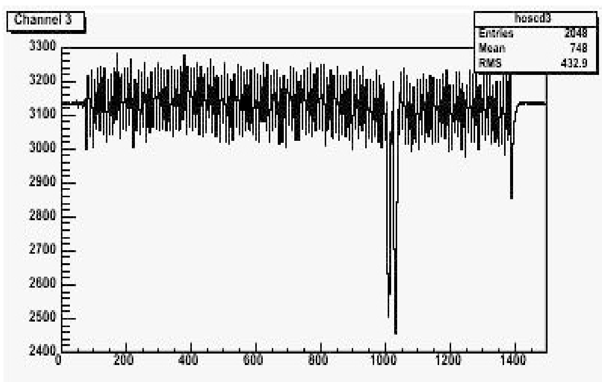

Figure 3. Proton induced signals with charge-sharing.

The measurement of single triggered event is shown in Fig. 3. The peaks in the negative direction of the distribution are the proton induced signals but it shows that there are a number of charge-sharing between closely neighboring sensor strips.

Figure 4 is the ADC distribution of a sensor channel. The coherent noises were not subtracted and charge sharing correction was not taken cared. A Gaussian and Landau-Gaussian convolution functions were used to fit the pedestal and signal distributions, respectively. The SNR is expected to be around 10 after the coherent noises and consideration of charge sharing, and detail analysis is in progress.

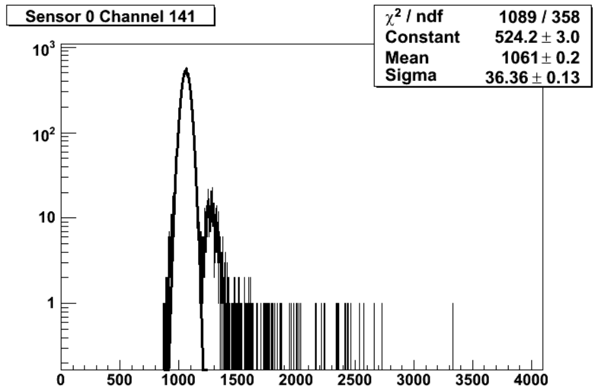

Figure4. ADC distribution of a single strip channel by using a proton beam. The dominant peak is due to pedestal and lower peak is the signal.

5. Summary

The double-sided silicon strip sensor was designed and manufactured on the 5-inch fabrication line and fabricated at ETRI. We developed readout electronics using the Va1Ta_3 chip which is a significantly upgraded version of the VA1 with added trigger functionality.

The silicon sensor and the readout electronics were placed in the light-tight box and the detector was placed in off-axis from the 45 MeV proton beam line at KIRAMS. We measured the SNR level of the double-sided silicon strip detector with the proton beam. The preliminary measurement result showed the SNRs of the channels to be expected around 10.

We think the dominant noise source come from the electronics and revision of the PCB layout is also in progress.

REFERENCES

[1] Va1Ta_3 Datasheet V0R1, http://www.ideas.no.
[2] G. Lutz, Semiconductor Radiation Detector, Springer, New York, pp. 100-102, 1999.
[3] D. H. Kah et al., Nucl. Instr. and Meth. A 579 (2007) 745
[4] H. Park et al., J. Korean Phys. Soc. 49 (2006) 1401
[5] FADC64 firmware, http://www.noticekorea.com.