# Study of interstrip gap effects and efficiency for full energy detection of Double Sided Silicon Strip Detectors

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**Abstract.**
In this work is reported a study on the response of double sided silicon strip detectors. In order to investigate the effect of the electrode segmentation on the detector response, two experiments were performed aimed to measure the efficiency for full energy detection. Results show that the efficiency for full energy detection, that is directly related to effective width of the inter-strip region, varies with both detected ion energy and bias voltage. The experimental results are qualitatively reproduced by a simplified model based on the Shockley-Ramo-Gunn framework.

## 1. Introduction

Double Sided Silicon Strip Detectors (DSSSDs) are widely used in high energy and in nuclear physics studies. Their high granularity and their large area make them very suitable to perform, for example, accurate measurements of angular distributions and to study reactions where coincidences between more particles are requested. It is known that the segmentation of the electrodes affects the signal formation for particles whose trajectory crosses an interstrip region [1, 2, 3, 4, 5, 6]. In particular phenomena such as charge sharing and opposite polarity signals can occur. Such phenomena make the efficiency for full energy detection for DSSSDs lower than 100% as one can expect from a single pad detector. Therefore, for the analysis of data obtained by using DSSSDs, it is very important to select the events with the correct full energy and reject interstrip events.

We performed a systematic characterization of the dependence of DSSSDs inter-strip effects on the incident ion type, energy, and polarization voltage. Studies to identify an appropriate

selection procedure of events which allows to maximize the efficiency for the full energy reconstruction have also been performed [2]. Moreover, systematic measurements of the effective width of the inter-strip gap were performed by scanning the front and back inter-strip regions using proton micro-beams at different energies and for different detector bias [1].
In the present paper the results concerning a DSSSD 1000 $\mu$m thick will be discussed. The DSSSD under study is the model W1, manufactured by Micron Semiconductor Ltd. It has an active area of 50×50 mm$^2$, each electrode is divided into 16 parallel strips, and strips of the front and back side are perpendicular each other. Each strip is 3 mm wide and they are separated by a 100 $\mu$m wide $SiO_2$ layer that in the following is called interstrip.

## 2. Measurements of full energy detection efficiency

A first experiment was performed at the Laboratori Nazionali del Sud, Catania, by using $^7$Li and $^{16}$O Tandem beams. The low intensity ( 100 pps) ion beams at energies between 10 and 50 MeV, were directly sent onto the 1000 $\mu$m thick DSSSD placed at 0° with respect to the beam direction. The aim was to study the dependence of the interstrip effects on the beam energy, the ion species and polarization voltages. Moreover the use of a mono-energetic beam allow to easily find a selection procedure of the full energy events.

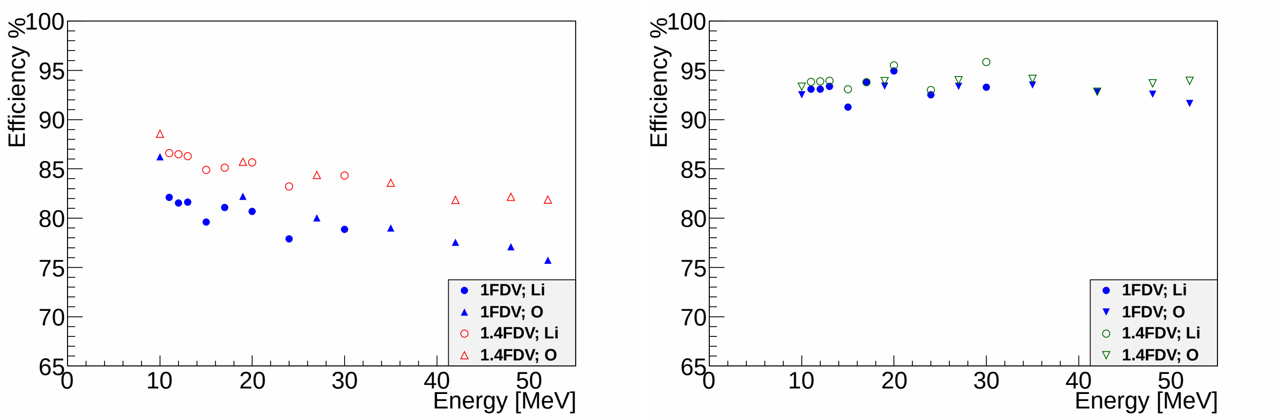


**Figure 1.** Efficiency for full energy detection as a function of the beam energy, for two different bias voltages applied to the detector. In the left panel is shown the efficiency obtained imposing the condition $E_{front} \approx E_{back}$, the continuous line corresponds to the efficiency for the full energy detection calculated using the geometrical interstrip width; in the right panel is shown the efficiency obtained recovering the back interstrip events. See the text for more details.

We observed that not all the particles impinging on the DSSSD are detected with the full energy. In fact particles whose trajectory crosses an interstrip region give rise to signals with a lower amplitude or with an opposite polarity. We divided those events in two classes corresponding to particles crossing the back or the front inter-strip region. For back inter-strip events summing the signals from the two adjacent strips those signals we obtain a full energy signal. Also for front inter-strip events two adjacent front strips give signals, but in this case one of them can have an opposite polarity and the sum of the two signals does not give a full energy signal.

Therefore, the use of such detectors, requires a procedure to select the correct full energy events rejecting the others. A common way to select the full energy events with DSSSDs is to compare the energy measured by the front side $E_{front}$ with the one measured by the back side

$E_{back}$ by imposing $E_{front} \approx E_{back}$, within a given tolerance. By applying this selection to our data we found that the obtained efficiency is slightly dependent on the energy and on the bias applied on the detector as shown in the left panel of Fig. 1 Moreover the efficiency is lower than the one extracted from the geometrical interstrip width. By remembering that for back inter-strip events just charge sharing phenomena with out any charge loss occurs, we proposed another events selection. In this case the energy measured by the front strips is compared to the sum of the energy of two adjacent back strips. In this way all the back inter-strip events are recovered increasing the efficiency and removing the dependence on energy and on bias as shown in right panel of Fig. 1 [2]. The average value of the efficiency for full energy detection is ~94%. The corresponding value of the inter-strip width is larger than the geometrical one.

## 3. Measurements of the effective inter-strip width

Since the efficiency for full energy detection is directly related with the effective inter-strip width, we performed a second experiment with the aim to have a direct measurements of the effective interstrip width for different operating conditions of the detector. The experiment was performed at the Ruder Bošković Institute in Zagreb using the local microbeam facility. The advantage to use a microbeam is that it is possible to know the position of the impinging particle with a precision of few $\mu$m. For each particle impinging on the detector the following information were recorded: the coordinates (x, y) corresponding to the horizontal and the vertical beam position inside the scanning area and the energy signals from all the front and back strips. Proton microbeams of 1.7 and 6 MeV at low intensity (~ 100 pps) were used to irradiate the DSSSD. For each beam energy the measurements were repeated for bias voltages equal to 0.5, 1 and 1.5 times the full depletion voltage (FDV).

In the left panel of fig. 2 is shown the measured energy as a function of the impact position of

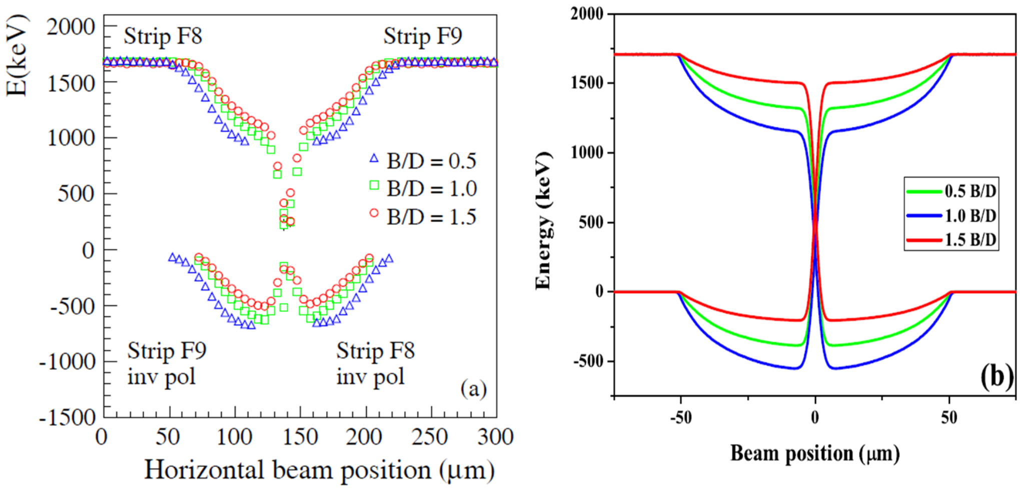


**Figure 2.** Energy as function of position for proton of 1.7 MeV for three different bias voltages. On the left panel are shown experimental data refering to a front interstrip region, on the right panel are shown data coming from simulations (fro more information see the text). B/D indicates the ratio between the applied bias and the full depletion voltage.

the incident proton. From the plot it is possible to distinguish clearly the strip and interstrip regions. When the beam is on one strip the full charge is collected by that strip, as the beam moves over the edge there is a region where both the adjacent strips produce signals that have an amplitude lower than the full energy and that can have opposite polarity. As the beam moves on the next strip the charge is entirely collected by that strip.

In the right side of figure 2 we show the result of a simplified simulation, based on the Shockley-Ramo-Gunn framework, is reported. By assuming a build up of positive charge at the oxide interface in the front inter-strip and of negative charge at the oxide interface in the back inter-strip a satisfactory qualitative reproduction of all the observed inter-strip effects has been obtained [1].

## 4. Summary and conclusions

A systematic study of the dependence of Double Sided Silicon Strip Detectors inter-strip effects on the incident ion type, energy, and polarization voltage was performed. A first measurement was performed by mean of $^{7}$Li and $^{16}$O beams at different energies, showing that the efficiency for full energy detection depends on the energy and type of the detected ion and on the applied bias voltage. A new selection procedure of events that maximize the efficiency for the full energy reconstruction and remove the cited dependences has been proposed. In a second test, direct measurements of the effective width of the interstrip region were performed by mean of a proton micro-beams at different energies and for different detector bias. Results confirmed that both front and back effective inter-strip widths, which are related to the efficacy for full energy detection, can be much larger than the nominal geometric width of the $SiO_2$ zone and depend on the operating conditions. The experimental observations were qualitatively interpreted and described by simplified simulations based on the Shockley-Ramo-Gunn framework. Therefore, for those experiments aiming at an accurate measurements of absolute cross-sections, especially if two or more DSSSD are used in coincidence, efficiency for full energy detection cannot be deduced from the geometric inter-strip width but a characterization of the used DSSSDs is required.

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