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Silicon Strip Detector Processed on a 100 mm Silicon Wafer**

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**BEAM TEST RESULTS OF AN ION-IMPLANTED CAPACITIVELY COUPLED
SILICON STRIP DETECTOR PROCESSED ON A 100 mm SILICON WAFER**

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ABSTRACT

A capacitively coupled silicon strip detector with 50 μm readout pitch has been tested in a pion beam at CERN. The spatial resolution of the detector equipped with LSI readout chips was 4.9 μm and the most probable signal to single channel noise ratio was 31.

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1. INTRODUCTION

Silicon strip detectors are today currently used in high energy physics experiments, where a very good spatial resolution is needed. This paper describes beam test results of a capacitively coupled microstrip detector processed on a 100 mm silicon wafer. For the 100 mm wafers the effective processing area is almost double compared to the traditionally used 3 inch ones. This enables the design of detector systems with less inactive material and fewer electrical connections.

2. DESIGN OF THE STUDIED DETECTOR

The tested counter is a double sided silicon strip detector processed with integrated coupling capacitors, polysilicon resistors and an n-side field plate. The detector layout is presented in fig. 1. The active area of the counter is $19 \times 19 \text{ mm}^2$ and the thickness $380 \text{ }\mu\text{m}$. The strip pitch is $25 \text{ }\mu\text{m}$ on the p-side and $50 \text{ }\mu\text{m}$ on the n-side and the total number of strips is 1151. The detector was processed at the Technical Research Center of Finland. A more precise description of the design together with test results of electrical and beta source set-up measurements is given in [1].

Three 128 channel NMOS Microplex readout chips [2] were connected to both p- and n-side of the detector. The readout pitch is $50 \text{ }\mu\text{m}$ for both sides. From the laser and beta source studies [1] it was found out that the cluster distribution for the n-side was too wide to detect minimum ionizing particles. This report describes the results only from the p-side. Three different widths for the implant strips were used in the processing: 4, 5 and $7 \text{ }\mu\text{m}$. Some punch throughs were detected in the area of the narrowest strips and so the data from these strips was not used.

In the test a detector bias voltage of 150 V was used, the corresponding bias and guard ring current was $8 \text{ }\mu\text{A}$.

3. BEAM TEST SETUP

An optical bench with supports for five detector pairs (fig. 2) was set up for the beam test. The four counter pairs were used as a reference telescope and the two detectors to be analyzed, DS1 and DS2, were placed in the center of the bench. Test results for the other double-sided detector (DS1) are not described in this report. The strips of the detector plates were aligned with the horizontal and vertical axis with a precision better than 1 mrad.

A trigger signal for the readout system was supplied from three scintillators connected in coincidence. One $30 \times 30 \text{ mm}^2$ scintillator was placed just in front of the detectors and the two others ($30 \times 30 \text{ mm}^2$ and $10 \times 10 \text{ mm}^2$) at the exit of the setup. As reference detectors eight single-sided microstrip detectors were used. They were the same type as the ones in the DELPHI microvertex detector [3]: capacitively coupled with individually integrated polysilicon resistors for each diode, $25 \mu\text{m}$ pitch and $50 \mu\text{m}$ readout pitch, 640 strips each. These detectors were also equipped with NMOS Microplex readout chips.

The Data Acquisition System was run by a 68020 VME CPU under OS9 operating system. The VME system was connected to a CAMAC crate through a CAMAC-VME interface. The detectors were read out by using six separate SIROCCO [4] modules; one for each reference detector pair and one for both double-sided detectors. Data obtained was first stored on virtual disks on a Microvax through Ethernet and later copied onto tapes.

The beam was a pion beam with momentum higher than $200 \text{ GeV}/c$ so that multiple scattering was negligible.

4. DATA ANALYSIS AND RESULTS

4.1 Cluster analysis

For each trigger the raw pulse-height data from all the channels were written to tape. Neither the pedestal subtraction nor the zero suppression features of the SIROCCO were used. Pedestals, common-modes shifts and noise values were calculated in the off-line analysis of the data. The average noise of the studied DS2 detector was 5.2 ADC counts. Clusters were selected according to the following criteria. First a strip with signal to noise

ratio (S/N) higher than 4 was searched. Then all the neighbouring strips with S/N at least 2 were added into the cluster.

To study the clusters of the DS2 counter we used only events which had a reference track, defined by a hit on each of the 8 telescope detectors. The measured cluster multiplicity distribution is presented in fig. 3. The most probable number of strips in a cluster is 2, preferred for an accurate interpolation between strips. If it were larger the S/N of the cluster would be smaller, interfering the determination of the hit position. The corresponding cluster pulse-height distribution is shown in fig. 4. The most probable energy loss is 31 times the average noise of a single channel. Because of the good S/N value it is possible to distinguish the signal from the noise even without any reference track cut. This can clearly be seen in fig. 5 where the cluster S/N distribution is presented. Fig. 6 shows the charge partition within clusters which agrees well with the measured interstrip and amplifier input capacitances [1,2].

4.2 Spatial resolution

Hit positions were estimated using always the two largest signals in a cluster if possible. Only when both the neighbouring strips had a negative signal no interpolation was done. The obtained η -distribution ($\eta = PH(L)/(PH(L)+PH(R))$, where $PH(L)$ and $PH(R)$ are the pulse-heights in the left-hand and right-hand strips, respectively) for the studied DS2 detector is presented in fig. 7. The effect of the floating middle strip can be seen as an accumulation of charge in the middle of the two read-out strips. Because of the non-linearity look-up tables for interpolation were calculated assuming that the beam was equally distributed between strips. The table for the studied detector, derived from fig. 7 by using symmetrical integration, is shown in fig. 8.

After calculating the hit positions a straight line fit was performed through the planes of the reference detectors. Fitted tracks were accepted if their slope was less than 0.3 mrad and the maximum residue between the extrapolated track and the hit on each reference detector was smaller than 50 μm . After a preliminary analysis it was found out that the last horizontal detector did not have a satisfying beam profile. Therefore the p-side of the DS1 detector was used as a reference detector instead of the last horizontal one. Because the beam setup was optimized for the DS1 detector the studied one was not at the center of the bench and the removal of the last horizontal detector from the analysis made the setup even more unsymmetrical. Because of this the impact point error was dominated by the

performance of the DS1 and the second last horizontal detector. The calculated impact point error for the studied DS2 detector was 7.3 μm .

In fig. 9 the residual distribution of the tested DS2 detector with a Gaussian fit is presented, σ of the fit is 8.8 μm . This leads to a resolution of 4.9 μm after subtracting squarely the error of the predicted impact point.

4.3 Efficiency

For efficiency calculations the signals of three strips around the predicted impact point on the tested detector were studied. The probability to find a 4.5σ signal in one of the three strips was 0.996, this figure includes also the inefficiency of the electronics. No pedestal, noise etc. cuts were used when selecting the events.

5. CONCLUSIONS

A capacitively coupled silicon strip counter with 50 μm readout pitch has been tested in a pion beam. The obtained signal to noise ratio was 31 and the resolution using a Gaussian fit 4.9 μm . The efficiency of the counter was 0.996.

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Figure 1 Layout of the detector

Figure 2 Beam test setup

Figure 3 Cluster multiplicity distribution

Figure 4 Cluster pulse-height distribution

Figure 5 Cluster S/N distribution

Figure 6 Charge partition within clusters

Figure 7 η -distribution

Figure 8 Look-up table for interpolation

Figure 9 Residual distribution