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METROLOGY MEASUREMENTS ON A 64cm LONG SILICON MICROSTRIP DETECTOR

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-Technical report-

Abstract

A report is given on the results of metrology measurements performed by the L3-SMD group of Perugia on the first 64cm long Si microstrip detector which will be tested this summer at CERN. The detector consists of 8 identical silicon sensors which provide r-phi coordinates measurements. The coordinates of the 8 segments which form a 64cm long channel read-out line were measured. Data analysis showed two principal sources of nonlinearity: glueing and designing (which are contributing 41%, respectively 31.6%). The final 64cm long channel read-out line (6μm wide) has a maximum differences range from linearity of ±53μm.

Introduction

The purpose of this paper is to present the results of metrology measurements performed on the first manufactured 64cm long silicon microstrip ladder detector which will be used in the test beam this summer by the L3-SMD Group at CERN-Geneva. A presentation of the set-up used in this experiment will be done in a following paper.

The detector consists of 8 identical silicon sensors ladder mounted. Each sensor has 8cm length and 4cm width and contains 768 a.c. coupled microstrips. The strips pitch is 50μm, the length and width of strips being 77389μm and 6um respectively. The sensors are one side and strips orientation is longitudinal in order to read the R-Φ coordinate of the particles. Detailed description of the silicon sensors can be found in (1). At one end of the ladder there is one electronic subunit equipped with 5 Viking chips for data read-out (2). The strips from adjacent wafers were interconnected using wire bonding.

Metrology measurements data and bonding wire procedure

On each corner of sensors there is a reference cross. These crosses were used for sensors alignment during the glueing manufacturing of the ladder. Sensors numbering (from S1 to S8) starts from the electronic subunit and on each sensor coordinate measurements of the two crosses on the same long side was done as listed in Table 1. A reference system was previously defined (see Figure 1) using the first cross on S1 sensor and the last cross on S8 sensor for the X-axis definition. All following coordinate measurements were done in the L3-SMD clean room facility in Perugia, using the Mitutoyo BHN506 coordinate measuring machine, with 100x magnification objective. It was not necessary to measure also the other 16 crosses located on the other long side of detector, because the silicon processing technology of sensors is accurate to the micron level. As a consequence, all information regarding the alignement of the 8 sensors can be extracted measuring the cross coordinates on one side only.

A second set of measured coordinates is presented in Table 2 where, in the same reference system as above, we measured on each sensor the coordinates of the first strip (starting and ending points, at half strip width). These measurements were necessary in order to calculate the relative coordinates of the 8 segments which forms, after wire bonding, a read-out data channel line.

Two problems should be pointed out. These, as can be seen in the following section, influenced the linearity of the 64cm long read-out channel line.

The first is that, from design, the sensor has an even strips number (768) instead of having an odd one. This, combined with the double row layout pads for bonding make one long edge of sensor to start with an inner bonding strip while the opposite edge starts with an outer bonding strip. These asymmetry of sensors was not considered during detector glueing, so that the 8 sensors have mixed orientation (see arrows in Figure 1). Anyhow, the worst thing is that the strips positioning is not symmetrical with respect to the 4 reference crosses. On one long edge, the distance between the reference cross and the end of first strip is 1095μm while on the other long edge the same distance is 1145μm. An improved sensor design should avoid this asymmetry in strip positioning.

The second is that, also from design, one strip has different bonding pads terminations: at one end it has an inner bonding pad and on the other end it has an outer bonding pad. This end strip configuration can create some confusion during bonding, namely in defining the first bonded wire type (sometimes an inner one, othertimes an outer one). Also, as it was pointed elsewere (3) four rows of short bonding pads are very confusing while bonding and a large silicon area is lost. The best design, from wire bonding point of view, is to have only one inner and one outer rows long bonding pads. Anyhow, like in the previous case, the worst thing for such a mixing in bonding pad arrangement was the impossibility to wire bond strips with same number on adjacent sensors (it's not possible to bond an inner pad with an outer pad).

The wire bonding was done using a Hughes 2470-II Automatic Wire Bonder at the L3-SMD clean room facility at Perugia University, using 25μm AlSi1% wire. Because of the above mentioned problems, we list in Table 3 the shift introduced during the wire bonding, as the wire is passing from one sensor to the next, in a modulo(64) stips numbering convention. These data will be used in the next section to calculate the relative coordinates of the 8 segments which form a 64cm long channel read-out line.

Data analysis

Raw data presented above are used in the following to illustrate and understand some problems which have to be taken into account when such a very long ladder is manufactured.

Figure 2 presents the reference cross positions for the 8 sensors. It can be seen that the maximum difference between two crosses, along the whole ladder length is 96um (first cross on S4 and first cross on S7). The same difference but only inside one sensor does not exceed 44μm (on S7). Last value is also a measure of sensor tilting. Since the strips pitch is 50μm, a maximum acceptable value for this difference, within one sensor, can be considered to be 5μm or equivalent a tilting angle of 0.2 seconds. A least square interpolation line for all the 16 crosses shows a tilt angle of 7 seconds.

Figure 3 shows the variation of the distance between two adjacent sensors, measured as the distance between reference crosses. It can be seen that this parameter has a range of 106μm (between 295μm and 401μm), with a mean value of 340μm.

An indication of the quality of the measurements is given by Figure 4, where a reference distance, known to be precise to the micron level, is measured. This distance between two reference crosses from the same sensor shows a measurement error range of 5um (the mean value of calculated distance between two crosses on same sensor is 79073.75μm).

From the above analysis it can be concluded that alignment and glueing operations must be improved in order to improve the linearity of the 64cm long strip.

Continuing the metrology data analysis with the first strip positioning coordinates , Figure 5 shows these coordinates as a function of sensor number in the same manner as in Figure 2. It can be seen that the maximum difference between first strip coordinates along the whole ladder length is 170μm (again starting point of strip on S4 and also starting point of strip on S7). The maximum difference within one sensor is again 45μm (because of S7), which shows that the two measured data sets are consistent. The difference between 96μm on Figure 2 and 170μm on Figure 5 is due to the asymmetry of strips positioning with respect to the reference crosses. Because S2, S3, S4, S6 have different orientation as S1, S5, S7, S8 (see Figure 1), the two sensors groups are shifted one from the other with about 75μm, keeping the same relative position for sensors with the same orientation.

Figure 6 shows, like in Figure 3, the variation of the distance between two adjacent sensors, measured this time as the distance between strips end. It can be seen that this parameter is varying from 1980μm to 2085μm with a mean value of 2024μm. The range (105μm) is practical the same as the previous found (in Figure 3) (106μm) showing again the measurement consistency. This is outlined also in Figure 8 which plots, for the two measurements sets, the difference for the calculated distance between two adjacent sensors, as extracted from the correlation between Figures 3 and 6. The maximum range of 8um with a mean values of 0.2μm gives us again confidence in the measured raw data.

Figure 7, similar to Figure 4, presents the distribution measured of the strip lengths, which in fact should also be a well defined value affected only by measurement accuracy (the strip has a calculated mean value of 77338.625μm).

The final calculated relative coordinates of one read-out channel line 64cm length, obtained after wire bonding, is presented in Figure 9. Data from Table 3 were considered in this calculation. It can be seen that (because wire bonding was done connecting one strip from a sensor with the nearest one from the following sensor) the maximum variation in the 16 coordinates which forms a read-out channel line is reduced to 106μm, comparing with 170μm if strips with same numbers should be wire bonded. On the whole length of 640000μm those 106μm means a maximum tilt angle of 0.6 secconds.

Conclusions

Metrology measurements were done on the first 64cm long silicon microstrip ladder designed and manufactured by the L3-SMD Group to be tested this summer at CERN.

Measured data were analysed and the sources which affect the linearity of a 64cm long strip (6μm wide) were qualitatively and quantitatively discussed. It was found that the sensor glueing was contributing with 41% (+96μm, increasing the nonlinearity), the assimetry of strips positioning was contributing with 31.6% (+74μm, increasing the nonlinearity) and the jumping of strips during bonding (mainly because different pad termination of strips) was contributing with 27.4% (-64μm, decreasing the nonlinearity).

References

1. NCU R-Φ sensor, internal technical raport
2. O.Toker et al., Nucl. Instr. and Meth. A340 (1994) 572
3. C.Gingu, private communcations, L3-SMD Meeting, Geneva, 27/05/1994

Table 1

	X	Y
S1	0 79.074	0 -18
S2	79.401 158.472	-37 -33
S3	158.767 237.842	-23 -8
S4	238.204 317.278	-59 -36
S5	317.641 396.717	-25 -22
S6	397.052 476.126	-41 -37
S7	476.527 555.602	37 -7
S8	555.899 634.971	-3 0

Table 2

	X	Y
S1	846 78.233	-703 -721
S2	80.239 157.828	-813 -808
S3	159.608 236.998	-798 -784
S4	239.047 316.436	-834 -814
S5	318.485 395.874	-725 -726
S6	397.892 475.282	-817 -813
S7	477.367 554.756	-664 -709
S8	556.740 634.128	-704 -702

Table 3

shift	
S1	4 4
S2	3 3
S3	4 4
S4	3 3
S5	4 4
S6	3 3
S7	6 6
S8	5 5

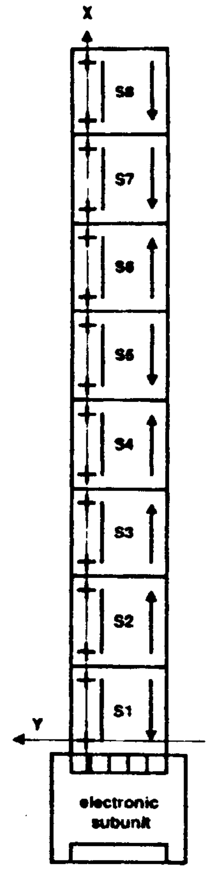

Figure 1.

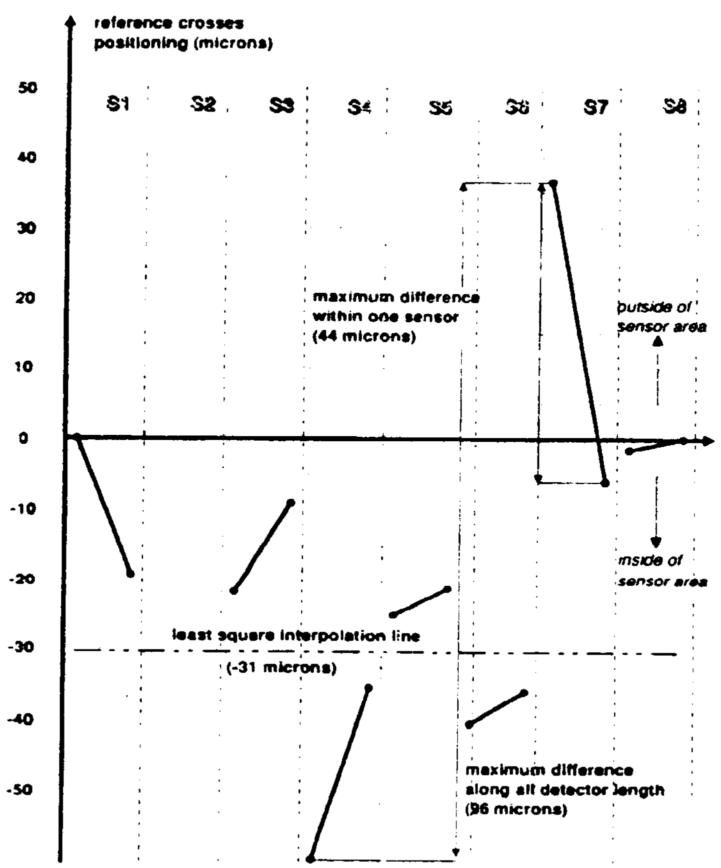

Figure 2. Reference crosses positioning

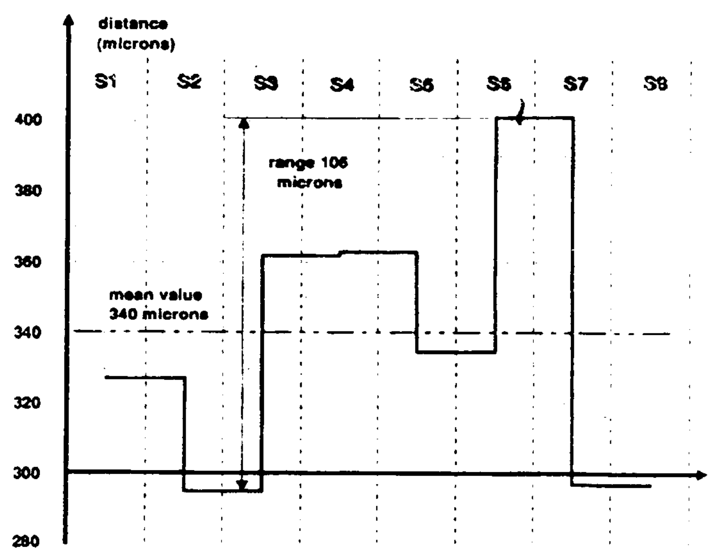

Figure 3. Distance between two adjacent sensors measured from cross to cross

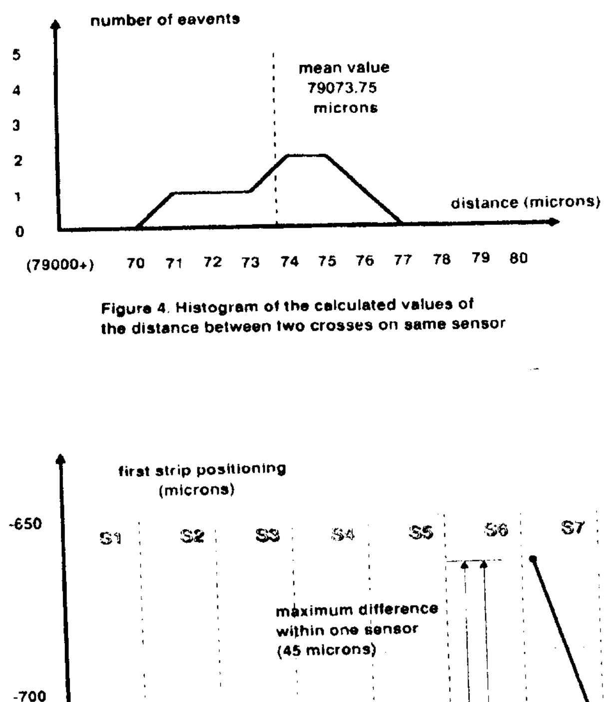

Figure 4. Histogram of the calculated values of the distance between two crosses on same sensor

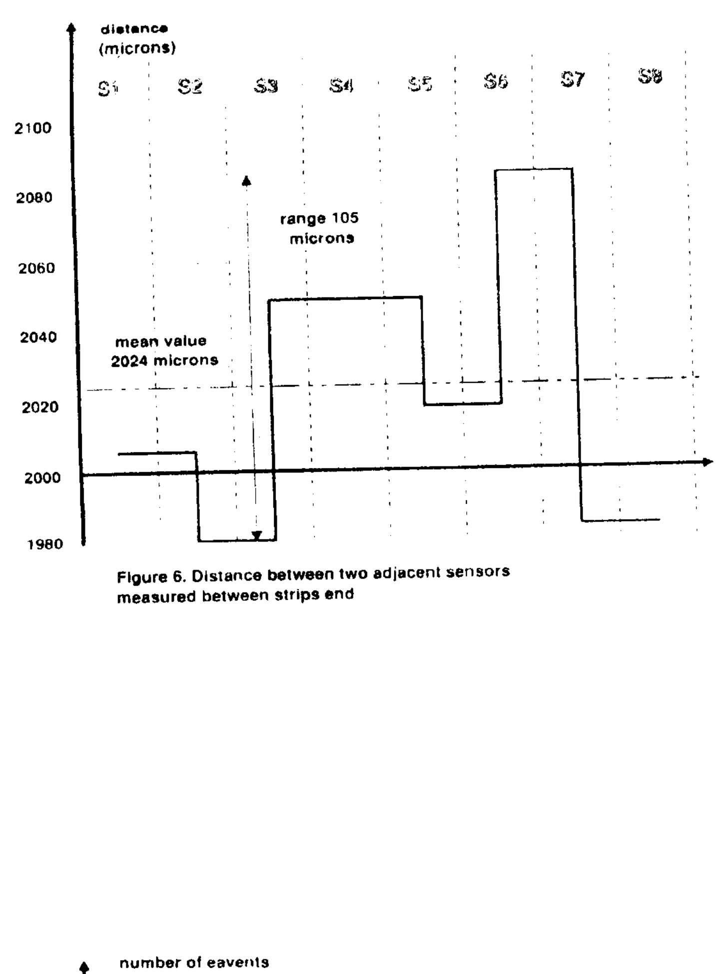

Figure 6. Distance between two adjacent sensors measured between strips end

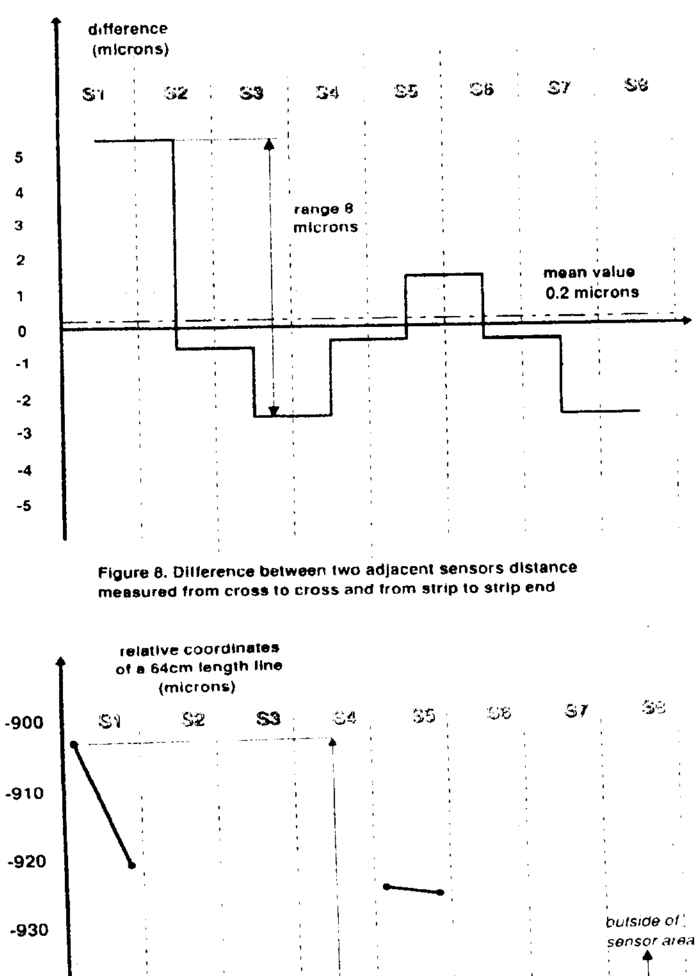

Figure 8. Difference between two adjacent sensors distance measured from cross to cross and from strip to strip end

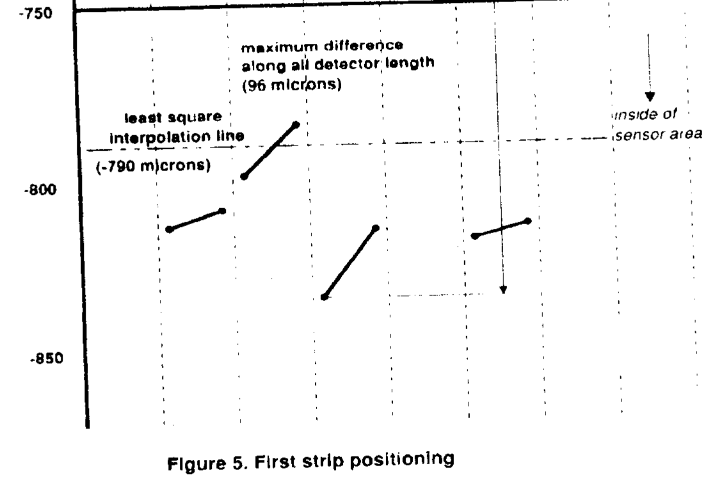

Figure 5. First strip positioning

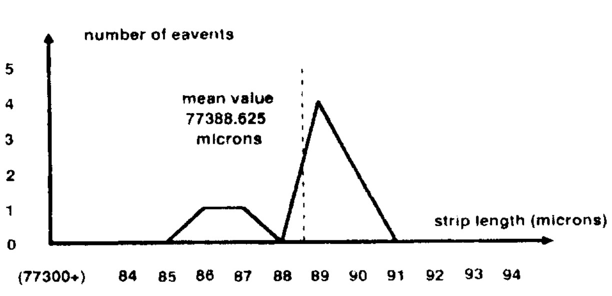

Figure 7. Histogram of the calculated values of strip length

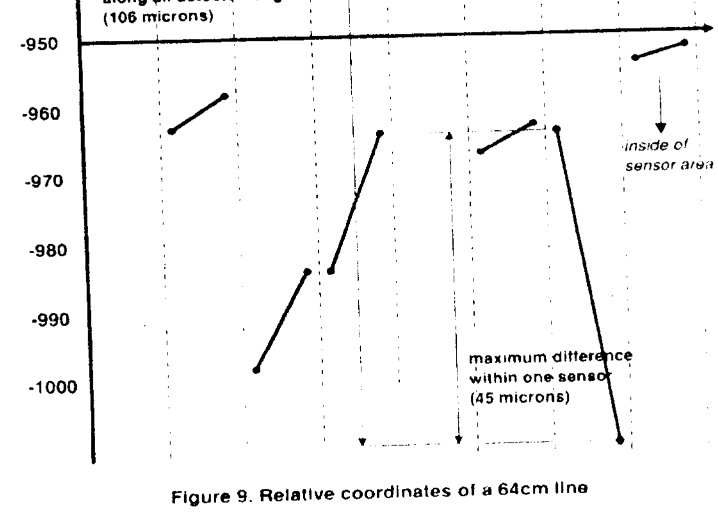

Figure 9. Relative coordinates of a 64cm line