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Performance on test beam of the L3 double-sided silicon microstrip detector

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Two modules of the L3 Silicon Microvertex Detector (SMD) have been tested on beam. The active area of the modules consists of double sided silicon microstrip detectors; the implantation pitch is 25 μm and 50 μm in the junction and ohmic side, respectively. The detectors are read out by a VLSI radiation hard amplifier (SVX-H). The position resolution, with a readout pitch of 50 μm and 200 μm for the two sides, is determined to be 7.0 μm and 14.3 μm . A signal to noise ratio ≥ 16 and a detection efficiency $\geq 99\%$ are measured for both sides.

1. Introduction

The Silicon Microvertex Detector (SMD) has been installed inside the L3 experiment to improve the performance of its tracking system, in the study of short lived particles produced in e^+e^- collisions at Z mass. The use of double sided silicon microstrip detectors allows a three

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Fig. 1. Half ladder side view.

dimensional position measurement, minimizing the multiple Coulomb scattering with respect to the outer L3 detectors [1].

In this paper we report about a beam test of a prototype including all the components of the system. In section 2 we describe the main characteristics of the silicon detectors and of the readout system and we present the results of the analysis of the data taken in section 3. The conclusions are given in section 4.

2. Design

The basic module of the SMD ("ladder") is made of two electrically independent units ("half ladders"): the active area of each half ladder consists of two double sided silicon microstrip sensors, produced by CSEM [2], on a design developed by INFN Pisa [3].

They are built from an n-doped silicon crystal, with high resistivity ($\rho_n > 6 \text{ k}\Omega \text{ cm}$) and a thickness of $300 \mu\text{m}$. The junction side is divided into 1537 p^+ strips, with a pitch of $25 \mu\text{m}$, while the ohmic side consists of 1409 n^+ strips, with a pitch of $50 \mu\text{m}$; the active area of the sensor is $7.04 \times 3.84 \text{ cm}^2$. The p and n side are used in SMD for $r\phi$ and z coordinate measurement, respectively.

The sensors are read out with a pitch of $50 \mu\text{m}$ on the $r\phi$ side and $150/200 \mu\text{m}$ on the central/forward region of the z side. In order to AC couple the sensors to the readout electronics, a special capacitor chip (capacitance value 150 pF) is used [2]. The two detectors of each half ladder are read out by two hybrids (one per each side), each equipped with 6 SVX-H chips, VLSI radiation hard chips developed at LBL [4].

In order to keep the electronics at the half ladder end, a $50 \mu\text{m}$ thick Kapton cable with L-shaped copper strips is used to route the signals from the z side strips to the preamplifiers [5]. This allows one to minimize the material in the active area and to optimize the heat removal. Fig. 1 shows the side view of a half ladder.

After passing through an intermediate converter board, signals are digitized and optically decoupled by a special optical board [6]. Data are then sent through optical fibers to a fast Data Reduction Processor [7]; the synchronization and the timing of the system is achieved by a special Sequencer module [8].

3. The beam test

Two half ladders were tested in the summer of 1992 in a charged pion beam at CERN. This gave the opportunity to test the full readout chain, from sensor to data acquisition, for the first time. Fig. 2 shows the detectors placed on a support structure. Two sets of single sided silicon sensors were used to define the trajectory of the particles. Scintillators were used to define the trigger. A VAX cluster controlled the data acquisition operation.

A total of about 2×10^5 events were collected. The aim of the analysis of the data has been:

- determination of the signal to noise ratio for the half ladders;
- measurement of the intrinsic position resolution of the detector;
- determination of the detection efficiency;
- evaluation of correlation between the charge collected by the two sides for the same track.

In addition to the uncorrelated noise of each channel (σ_{PED_j}), a coherent noise (CM^i), constant over a single SVX, was observed. So the pedestal value for each channel (PED_j) and the fluctuations were determined by the following expressions:

$$\text{PED}_j = \sum_{i=1}^N \frac{\text{RAW}_j^i}{N},$$

$$\text{CM}^i = \sum_{j=1}^{128} \frac{(\text{RAW}_j^i - \text{PED}_j)}{128},$$

$$\sigma_{\text{PED}_j} = \sqrt{\sum_{i=1}^N \frac{(\text{RAW}_j^i - \text{PED}_j - \text{CM}^i)^2}{N-1}}.$$

These quantities were first calculated over a group of at

Fig. 2. Beam test setup.

Fig. 3. Cluster charge distribution for $r\phi$ (a) and z (b) side.

least 100 events without beam and then updated to take into account long range drift [9]. After excluding noisy and dead channels, the distributions of the common mode noise per each SVX and the uncorrelated noise per each channel were determined.

The Gaussian behaviour of the uncorrelated noise was found to be very good, so that a cluster candidate could be defined as a group of continuous strips with a charge $Q > 2\sigma_{\text{PED}}$, of which at least one has a charge $Q > 3\sigma_{\text{PED}}$. The charge and the noise of these candidates were defined as the sum of the charge and the square root of the quadratic sum of the σ_{PED} over the channels of the cluster, respectively. The distributions of the charge of the clusters for the two sides are shown in Fig. 3; the dashed line corresponds to the noise, which was cut requiring $Q_{\text{CLUS}}/\sigma_{\text{CLUS}}$ to be greater than 6 or 5, for the $r\phi$ and z side, respectively.

The signal to noise ratio was defined as the ratio between the most probable value of the cluster charge and the average value of σ_{PED} . The values obtained for this quantity are 17 and 16 for the $r\phi$ and z side, respectively.

One of the most interesting features of the double sided detectors is the possibility of correlating the charge collected on the two sides. Fig. 4 shows a scatter plot of the cluster charge on the two sides of the same detector, revealing a good correlation between the two quantities ($\sigma_{\text{cor}} = 19\%$).

The reference detectors were used to define the particle trajectories and thus to align the half ladders: the residue distributions for the two sides of the detector are shown in Fig. 5. The width of these distributions is determined by both the intrinsic detector resolution and the tracking error due to the resolution of the reference detectors. Unfolding this last contribution, the spatial resolution of the SMD detectors was determined to be $7.0 \mu\text{m}$ and $14.3 \mu\text{m}$ for the $r\phi$ and z side, respectively.

For the definition of detection efficiency we considered a particle detected if one of the four strips around the track intersection point had a charge larger than five times the sigma of the pedestal, or two strips out of the four had a

Fig. 4. Two sides charge correlation.

Fig. 5. Residue distribution for $r\phi$ (a) and z (b) side.

charge larger than three times the sigma of the pedestal; with this definition an efficiency of 99.9% and 99.3% was measured for the two sides.

4. Conclusion

A prototype of the L3 silicon microvertex detector was tested on beam. In this paper we have presented the following results:

- a signal to noise ratio ≥ 16 for both sides;
- a position resolution of about $7 \mu\text{m}$ for the $r\phi$ side and $14 \mu\text{m}$ for the z side;
- a detection efficiency $\geq 99\%$ for both sides;
- a good charge correlation between the two sides of the same sensor ($\sigma_{\text{cor}} = 19\%$).

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