The new ALEPH Silicon Vertex Detector

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The new ALEPH Silicon Vertex Detector

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Abstract

The ALEPH collaboration, in view of the importance of effective vertex detection for the Higgs boson search at LEP 2, decided to upgrade the previous vertex detector. Main changes were an increased length (± 20 cm), a higher granularity for $r\phi$ view (50 μm), a new preamplifier (MX7 rad hard chip), a polymide (upilex) fan-out on z side to carry the signals from the strips to the front-end electronics outside the fiducial region reducing consequently the passive material in the central region by a factor of two. The detector, the running experience and its performance will be described.

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1. Introduction

The extensive study of the heavy flavour physics currently under way in the present generation of colliders made the Silicon Vertex Detectors the key tool to identify particles with heavy quarks (b,c). Tracks with the impact parameters in the 100 μm range are identified with high accuracy when extrapolated to the interaction point. Secondary vertices few mm apart from the interaction point are clearly distinguished. For an accurate track reconstruction in space it was decided to use double-sided silicon strip detectors arranged in a cylindrical two-layer detector with a coverage of $|\cos\theta| < 0.85$ for tracks to pass through at least the inner layer. The detector (VDET I) worked as expected during the LEP1 phase from 1991 until 1995.

The Higgs boson search at LEP2 increased the importance of effective vertex detection. The Aleph collaboration consequently decided to upgrade the previously installed VDET. Main features of the new vertex detector are

1. increased length ($\pm$ 20 cm), 6 detectors/face are used;
2. a polymide (upilex) fan-out is used on the z-side to carry the signals from the strips to the front-end electronics outside the active region; in this way the passive material is reduced by a factor of two;
3. the preamplifier chip used now is MX7 radiation hard;
4. the strip read-out pitch is 50 μm for r–ϕ view and 100 μm for the z view.

For an overall description of VDET I and a comparison between VDET I and VDET II, see Ref. [2].

2. Detector description

VDET II consists of 48 *modules* glued in 24 *faces* (Fig. 1) mounted in two concentric layers. The inner layer with 9 faces is located at an average radius of 6.3 cm while the outer layer with 15 faces is at a radius of 11 cm. Fig. 2 shows an overall view of the detector. Each module has three double-sided silicon strip detectors with dimensions $6.4 \times 5.3\,\mathrm{cm}^2$ each, the thickness is 300 μm. The design of the

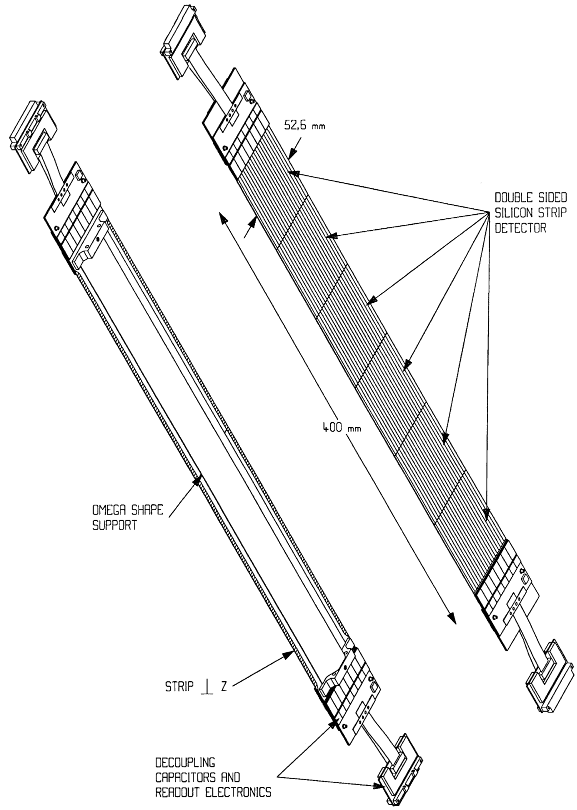

Fig. 1. VDET face.

silicon detectors is similar to the one used for VDET I [1] with strip pitch of 25 μm on the junction side (r–ϕ view) and 50 μm on the ohmic side (z view). Implanted p^+ strips between the n^+ strips on the ohmic side are used to block the electron accumulation layer present at the Si–SiO_2 interface. Guard rings surrounding the active region is used to bias the strips; on the junction side the punch-trough mechanism is used to provide the bias with the p^+ strips ending a few microns from the guard ring implant. On the ohmic side n^+ strips are biased taking advantage of the electron accumulation layer: the end of p^+ blocking strips is used to define a channel between the n^+ strips and the guard ring; the value of the bias resistor, determined by the length and the width of this low resistivity layer ($\sim$ 30 kΩ per square), is $R_{s-gr} = 12$–20 MΩ. The detectors are operated at a voltage slightly above the depletion value. One end of each module is

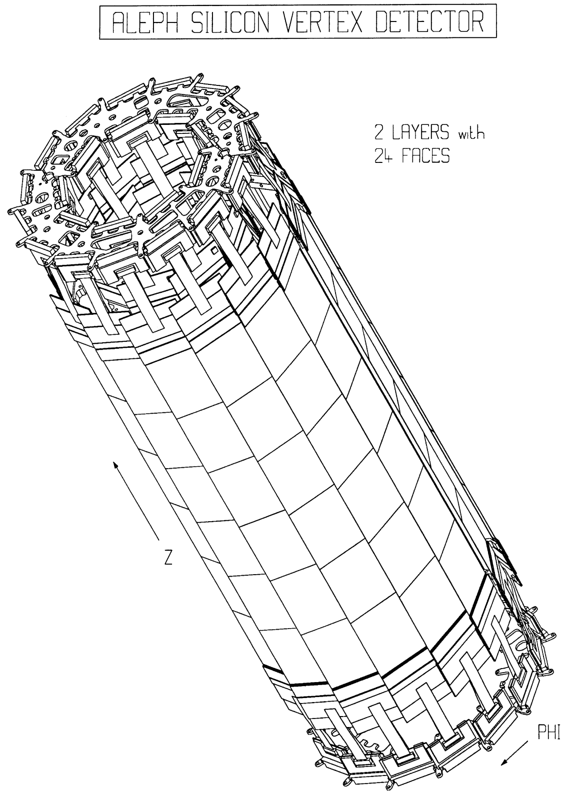

Fig. 2. VDET overall view.

equipped with two electronic hybrids, one for the z view and the other for the r–ϕ view. Each hybrid has eight radiation hard MX7 chip and associated decoupling capacitors with protection diodes. Each MX7 chip shifts out the signals from 128 strip channels and the 1024 channels of each view are output sequentially (every 2 μs) onto a single analog data line. Electronic chips are cooled with a gravity fed water distribution system and air flow is used to reduce temperature gradients along the detector. The total power dissipation is about 200 W. In the r–ϕ view 1021 strips are read-out while in the z view 960 strips are read-out with a total of 95088 for the complete detector. Table 1 summarizes the basic properties of the detectors.

3. Performance

The complete detector was installed in Aleph during the spring 1996; 16000 hadronic Z^0 decays were collected at the start of the run in July'96. These data have been used to study the performance of the detector; the signal/noise measured after the installation was similar to that obtained in the laboratory (Fig. 3). The face distortion problem found during the previous run in Novem-

Table 1
Properties of the ALEPH Silicon Detectors

Detector dimensions	52.6 mm × 65.4 mm	
Wafer thickness	300 μm	
Bulk resistivity	6–30 kΩ cm	
Depletion voltage	20–62 V	
	Junction side, $r\phi$-side	Ohmic side, z-side
Active area	51.0 mm × 63.92 mm	49.68 mm × 63.90 mm
p-strips (diodes)	2041	—
p-blocking strips	—	1280
n-strips	—	1279
(p/n) pitch	25 μm	50 μm
Strip length	63.92 mm	49.68 mm
Strip width	12 μm	12 μm
Readout pitch	50 μm	100 μm
Bond pad size	300 μm × 50 μm	300 μm × 50 μm

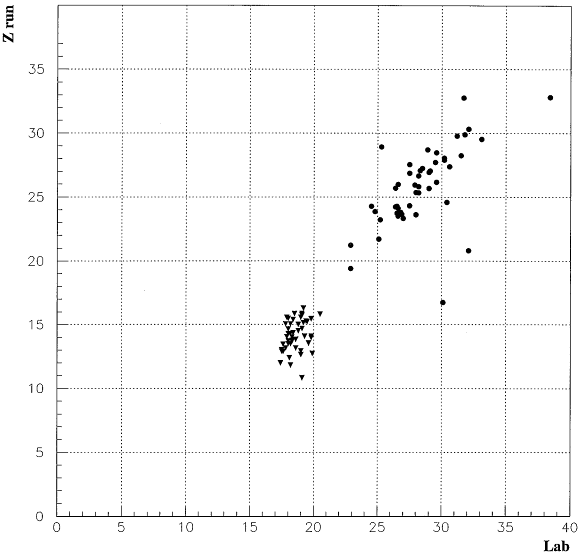

Fig. 3. Comparison of signal to noise ratio from laboratory measurements with that from Z^0 run data (June '96). Points are plotted for all 48 VDET II modules: triangles for z view and circles for the r–ϕ view.

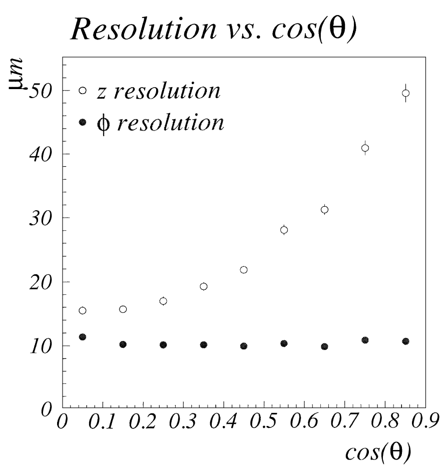

Fig. 4. VDET resolution measured from tracks with three hits in the overlaps.

ber '95 [2], was solved by reinforcing the kevlar support that holds the two modules in a face with a similar carbon fibre omega beam support glued on top of the kevlar one. The distortions as measured by a laser position monitoring system [3] are now below 5 μm. Z^0 data have been used to align the detector. An alignment precision better than the intrinsic resolution of the detector itself was reached by using the measurements of the wafer relative positions within a face done after fabrication and constraining tracks, in events without secondary vertices, to come from the same primary vertex. The resolution is measured from tracks passing through the overlap regions where two hits are used to predict the position of the third hit. The resolution as a function of $\cos\theta$ is shown in Fig. 4. The average efficiency to find a cluster on one side when a cluster is found on the other side is 95% for r–ϕ view and 93% for z view. The performance of VDET II is summarized in Table 2.

Table 2
Summary of VDET II performance

	z side	r–ϕ side
Physical strip pitch	50 μm	25 μm
Number of physical strips per wafer	1279	2041
Readout strip pitch	100 μm	50 μm
Number of readout strips per wafer	640	1021
Number of readout strips per module	960	1021
Signal/noise (90°)	18	31
Resolution (90°)	15 μm	10 μm

4. Conclusion

A new Silicon Vertex Detector has been installed in ALEPH for LEP2 operations. The discovery potential for the Higgs search has been increased by extending the angular coverage and by reducing the material in the tracking volume. In the r–ϕ view the granularity has been increased by using 50 μm read-out strip pitch. The device is performing as expected with a mechanical stability better than 5 μm. The spatial resolution obtained is 10 μm on the r–ϕ side and 15 μm on the z side.

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