TEST OF A COMPACT SI-STRIP DETECTOR FOR THE FORWARD REGION IN DELPHI

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Abstract

The DELPHI detector will be upgraded by a new silicon detector in the very forward region to fulfil the physics demands of the LEP200 program. This detector will cover the angular region between 10° and 25° with respect to the beam pipe and will have a two dimensional readout. The severe space restrictions in this region lead us to develop a new arrangement of detectors and electronic hybrids. In beam tests the layout of the detectors was optimised. Special attention was given to the charge loss in intermediate strips for detectors with large strip pitch. Beam test results obtained with different detector layout, e.g. various implant widths, and different angle of the incident particles will be shown.

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1. Introduction

The DELPHI Very Forward Tracker (VFT) will be used to reconstruct particle trajectories in the very forward region of DELPHI, i.e. between 10° and 25° in polar angle. It consists of 2 layers of pixel detectors and 2 layers of ministrip silicon detectors [1]. Each ministrip detector layer is constructed out of 12 detector modules surrounding the beam pipe. They are inclined by 50° with respect to the beam axis. As the detector has to measure both azimuth and polar angle of the track, each module is assembled by gluing together two single-sided detectors with orthogonal strip orientation.

Due to the support material in the forward region of DELPHI the multiple scattering effect is dominating the reconstruction accuracy and only a rather moderate detector resolution is required. This argument together with the requirements of low construction costs and a very compact system suggested the use of silicon strip detectors with a large strip pitch.

2. Physics motivations

At LEP200 the processes with the largest cross sections ($q\bar{q}\gamma$, $\gamma\gamma$ channels) involve the forward region and thus it is very relevant to optimise the reconstruction in that region. Moreover the most interesting study at LEP200 will be the Higgs search, where the Higgs mass will be close to the Z^0 and $W^\pm$ mass. For this an increase in acceptance and hermeticity is fundamental. In particular for the channel $H^0 Z^0 \rightarrow jj\nu\nu$ the presence of the VFT substantially increases the efficiency and reduces the background.

In the search for charginos, the supersymmetric particles $\chi_1^\pm$ and $\chi_2^\pm$, the VFT increases the sensitivity by 30%. The sensitivity is defined as the minimal charginos production cross section giving a signal of at least 5σ . The minimal integrated luminosity to reach the 5σ level at LEP200 with the VFT is almost 1.8 times smaller than without it. Actually without the VFT the foreseen integrated luminosity is not sufficient to detect these particles. In this study the background is due to events badly reconstructed in the forward region and the VFT will give fundamental help in separating the signal from the background by reducing it by 40%.

In order to perform effective particle identification the Forward DELPHI Ring Imaging CHerenkov (RICH), relies on the prediction and measurement of the track parameters and its intersection with the radiators. The VFT can track particles before the Forward RICH allowing to increase the identification capabilities of pions, kaons and protons dramatically.

Since the VFT can track particles before any material of the DELPHI detector, the gain in efficiency to distinguish electrons and photons is up to 70%.

As we already stated at the beginning, the largest cross section at LEP200 is that of particle production due to the two-photon process and a large number of inclusive and exclusive reaction can be measured. The two photons are strongly boosted along the beam direction leading to a strongly forward peaked particle production yield. The detection efficiency rapidly grows with a small increase of the angular acceptance in the forward region.

3. The detector layout

The dimension of the prototype detectors are $5.2 \times 5.2 \text{ cm}^2$. Their thickness is $350 \text{ }\mu\text{m}$ and they carry 252 p^+ -implantation strips of $20 \text{ }\mu\text{m}$ width and 252 strips of $40 \text{ }\mu\text{m}$ width. The strip pitch is $100 \text{ }\mu\text{m}$, while the readout pitch is $200 \text{ }\mu\text{m}$. The AC-coupling is achieved by a 200 nm thick layer of SiO_2 between implant and readout lines. Signals generated on an intermediate strip are coupled via inherent strip-to-strip capacitance to the adjacent readout strips. The strips are connected via the channel resistance of a FOXFET (the Field OXide FET [2]) to the bias line. The advantage of this technique is first that the fabrication is very simple and second that we achieve very high dynamic values for the bias resistor (typical $150 \text{ M}\Omega$).

Since the space available inside the experiment is limited, we decided to glue the hybrids, produced in thick film technology, directly onto the surface of the silicon detector. The glue used was ARALDIT Standard (Ciba-Geigy). For the readout of the detector, we used the VIKING chip [3] specially produced for the use with silicon microstrip detectors. As the readout pitch of the detectors is $200 \text{ }\mu\text{m}$ and the input channel pitch of the chip is about $50 \text{ }\mu\text{m}$ we need a special interconnection piece (fan-in). This fan-in is produced on a thin ceramic substrate. The connecting lines are produced by photolithography. For each strip two bondings are needed: one from the detector to the fan-in and one from the fan-in to the chip. The fan-in is glued onto the hybrid. A sketch of a detector module is shown in fig.1.

4. Results from beam tests

Three detectors, spaced by 40 mm along the beam axis, were placed with parallel strip orientation on the top desk of a moving table. The table can be moved in both directions perpendicular to the beam and can be rotated along the vertical axis. This setup enabled the investigation of the detector performance at various track angles. The detectors were exposed to 7 GeV/c pions and protons in the T7 beam of the CERN PS accelerator complex.

The analogue signals from the VIKING chips were read out via repeater electronics and are digitised using a SIROCCO module [4].

The main aim of this study was to measure the influence of the implant width on the signal collection properties and the achievable spatial resolution. The impact of the strip implant width on the signal measured is manifold: first, together with the width of the metallization, it determines the value of the coupling capacitance between implant and amplifier input. In order to ensure a complete signal collection this capacitance has to be sufficiently high. Second, the interstrip capacitance is increased by having a wider implant (assuming a constant strip pitch), which means that the signal coupling between intermediate strips and readout strips can be influenced by the implant width. On the other hand an increase of the interstrip capacitance causes an increase of the total capacitance seen by the amplifier and therefore worsens the signal-to-noise ratio (S/N).

4.1 Charge Loss

In this section we present a comparison of the signal distributions measured on strips of $20 \text{ }\mu\text{m}$ and $40 \text{ }\mu\text{m}$ width, for hits on the readout strip (fig. 2a) and the intermediate strip (fig. 2b). All distributions are measured at a reverse bias voltage of 80 V . We obtain a most probable S/N ratio of 40 for hits with charge collection on a

readout strip, and 25 for hits where the charge is collected on an intermediate strip and the signal is capacitively coupled to the adjacent readout strips. For hits on a readout strip the distributions show no significant difference between 20 μm and 40 μm strip width, whereas the signal distribution measured on intermediate strips with 40 μm width is shifted to higher signals compared to the one measured on strips with 20 μm width. At full depletion we measure on the intermediate strip 58% and 64% of the total charge for 20 μm and 40 μm respectively.

A detector simulation using the simulation program SPICE confirms the measured values [5]. The simulation tells us to expect a ratio of 64% (72%) for 20 μm (40 μm) implant width between signals from hits on the intermediate strip and signals from hits on the readout strip. We interpret the signal loss for hits on the intermediate strips by the loss of signal to the back plane capacitance due to the rather small ratio between interstrip and back plane capacitance. The simulation shows that increasing the interstrip capacitance by even wider implant (60 μm) increases the signal measured on the intermediate strip by 6% only with respect to 40 μm . Additionally the noise increases due to the higher load capacitance. This noise increase has to be optimised against the signal gain. The signal measured on the readout strip does not change with the increase of strip width as the coupling capacitance at 20 μm width is already sufficiently high for the total charge to be collected.

4.2 Spatial resolution

Furthermore we analysed the impact of the strip width on the position finding algorithm and the achievable spatial resolution. In the events where charge division occurs and the cluster consists of more than one strip it is possible to determine the intersection point using the non-linear η -algorithm [6]. To estimate the spatial resolution, the difference of the hit position in detector 1 and 2 was plotted. This distribution includes an additional contribution from the beam divergence. From a 3-point straight line fit using all three detectors we estimate a beam divergence of 1.1 mrad. Unfolding this contribution yields a spatial resolution of 33 ± 4 μm for the detector part with 20 μm strips and 35 ± 4 μm for the part with 40 μm strips.

Our conclusion is that concerning the position finding and spatial resolution the strip width does not influence the performance of our detectors significantly, and emphasis is put on an increased charge collection efficiency.

4.3 Spatial resolution for inclined tracks

Due to the position of the VFT in the DELPHI detector, tracks passing the detectors will be inclined by an angle, of about $\theta = 30^\circ$. For the detectors measuring the ϕ coordinate, the track projection to the detector surface will be parallel to the strips, thus increasing the signal and S/N ratio. However, since the S/N ratio is already high enough, this should not influence the resolution. For the detectors measuring the r coordinate the track projection to the strip plane is orthogonal to the strips. The path length in silicon is $l = d/\cos\theta$ and its projection to the strip plane is $s = d\tan\theta$, where d is the detector thickness and θ the inclination angle. In our case s is ranging from 0 to 200 μm for a rotation angle of 0° to 30° respectively. Therefore we expect a cluster to contain between 1 and 3 strips depending on the incident angle. Fig. 3 shows the measured probability of the individual cluster width, i.e. the number of strips contained in a cluster for different rotation angle.

The angular dependence of the resolution was measured by rotating the setup around

the strip axis. The measurements were done for 0° , 10° , 20° and 30° . Inclined tracks were measured due to the setup in some of the detectors in the $20\text{ }\mu\text{m}$ and some in the $40\text{ }\mu\text{m}$ area. In the analysis we assume the same intrinsic resolutions for both strip widths.

The position of the hit is calculated using the η -algorithm for clusters containing more than one strip. When the entire signal is contained on a single strip the position of the strip was used as the cluster position. The obtained spatial resolution is presented in fig. 4 for different track angles. The resolution improves up to $18\text{ }\mu\text{m}$ at 20° . At this angle almost all clusters contain two strips which is the best condition for the η algorithm.

5. Conclusion

We have investigated the performance of large strip pitch detectors for the use in the DELPHI VFT detector. The electronic hybrids are glued on top of the silicon detectors. This allows to build a very compact tracking detector. A readout pitch of $200\text{ }\mu\text{m}$ with one intermediate strip is a very economical solution for strip detectors in the very forward region (and for large area detectors). The achieved S/N of 40 for hits on the readout strips and 25 for hits on the intermediate strips is sufficiently high. The spatial resolution is $35\text{ }\mu\text{m}$ for normal incident particles and improves to $18\text{ }\mu\text{m}$ for 20° incident angle. A larger strip width increases the signal from the intermediate strip due to the increase of the interstrip capacitance. The worsening of the overall S/N due to the larger total capacitance is negligible for slow electronics (integration time about $1.5\text{ }\mu\text{s}$).

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Fig. 1: Sketch of a detector module

Fig. 2: Signal distribution measured on the readout and intermediate strips with 20 μm and 40 μm strip width.

Fig.3: Measured probability for different cluster width at various track angle.

Fig. 4: Spatial resolution as a function of the incident angle.