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Measurement of weak charged current structure in semileptonic b-hadron decays at the Z peak

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Nuclear Instruments and Methods in Physics Research A 360 (1995) 103–109

NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A

The L3 Silicon Microvertex Detector: installation and results on 1993 performance

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Abstract

The status of the Silicon Microvertex Detector (SMD) and its installation into the LEP-L3 experiment are presented, highlighting novel features and sophisticated techniques. Preliminary results based on 1993 data are given and compared with Monte Carlo predictions, to understand the detector performances and its tracking capabilities.

1. Introduction

Since March 1993, the Silicon Microvertex Detector (SMD) [1,2] is installed into the L3 experiment, enhancing its tracking capabilities [3], both in the $r-\phi$ and z projections.

This paper points out the characteristics and novel features of the detector. The 1993 and 1994 installations are briefly described. Preliminary results on detector performances and tracking capabilities are given in Section 4, and are compared with the expected Monte Carlo predictions and with the design parameters of the proposal.

SMD will play a crucial role [1,4] in both the high luminosity multi-bunch operating mode (HLEP) and at the LEP 200.

2. Design and construction

The SMD detector has been assembled in 1992/93 [5]. The SMD basic unit is a ladder, built with four silicon sensors. A total of 24 ladders are mounted on a 1 m long carbon fiber–Nomex honeycomb composite structure, arranged into two cylindrical layers of 12 ladders each (see Fig. 1). The inner layer has about 10% overlap between adjacent ladders, for alignment purposes. The outer layer has no overlap regions but each ladder has a 2° stereo angle rotation with respect to the interior ladders, to reduce combinatorial background in case of many particle events [1]. Each ladder is given mechanical rigidity by a carbon fiber Ω-shaped stiffener, glued on the $r-\phi$ side of the four silicon sensors.

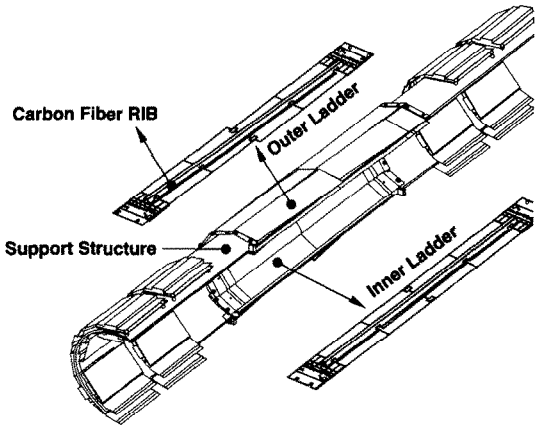

Fig. 1. Ladders on one half of the SMD support structure.

The active area of each ladder consists of four 300 μm thick double sided silicon sensors [6,7] which provide both $r-\phi$ and z coordinate for a 3-D measurement. The implantation strip pitch is 25/50 μm for strips parallel ($r-\phi$)/transverse (z) to the beam, respectively, while the readout pitches are 50 μm on the $r-\phi$ side and 150/200 μm on the central/forward region of the z side. Overall, about 73 000 readout channels are built into the detector, covering a polar angle range down to 22°.

A special ultra-thin flexible kapton router (minimum pitch of 35 μm) has been developed [8] to bring the z transverse strip signals to the ends of the ladder (Fig. 2). This greatly simplifies the heat removal and reduces the thermal gradient over the length of the detector because both $r-\phi$ and z front end readout electronics could be located at the ends of the ladder. In addition, the whole SMD is made quite transparent, about 1.2% X_0 at normal incidence, including 2 measuring layers and the supporting structure, again because only active elements are placed in the central region. Kapton proved to be a low cost, transparent (0.023% X_0), low cross talk (less than 3%) substrate to re-route transverse strip signals.

Silicon sensors are AC coupled to front and electronics by using an integrated capacitor chip (50 μm pitch; 150 pF/channel) [7]. A double diode protection has been added to avoid damage due to overvoltages of more than 16 V at the capacitor ends. Spikes like these can occur in the case of partial beam losses inside the detector. The capacitor chips are made of polysilicon layers on a quartz substrate.

Front end electronics is based on the SVX-H radiation hard chip developed at LBL [9], a charge sensitive preamplifier with a digital section to multiplex strip signals.

Another novel feature of SMD is the fiber optic transmission of the signals to the DAQ electronics allowing the optodecoupling of the SMD from the DAQ itself [10]. The optodecoupling provides a very effective way to minimize ground loop problems and to accomodate the electric

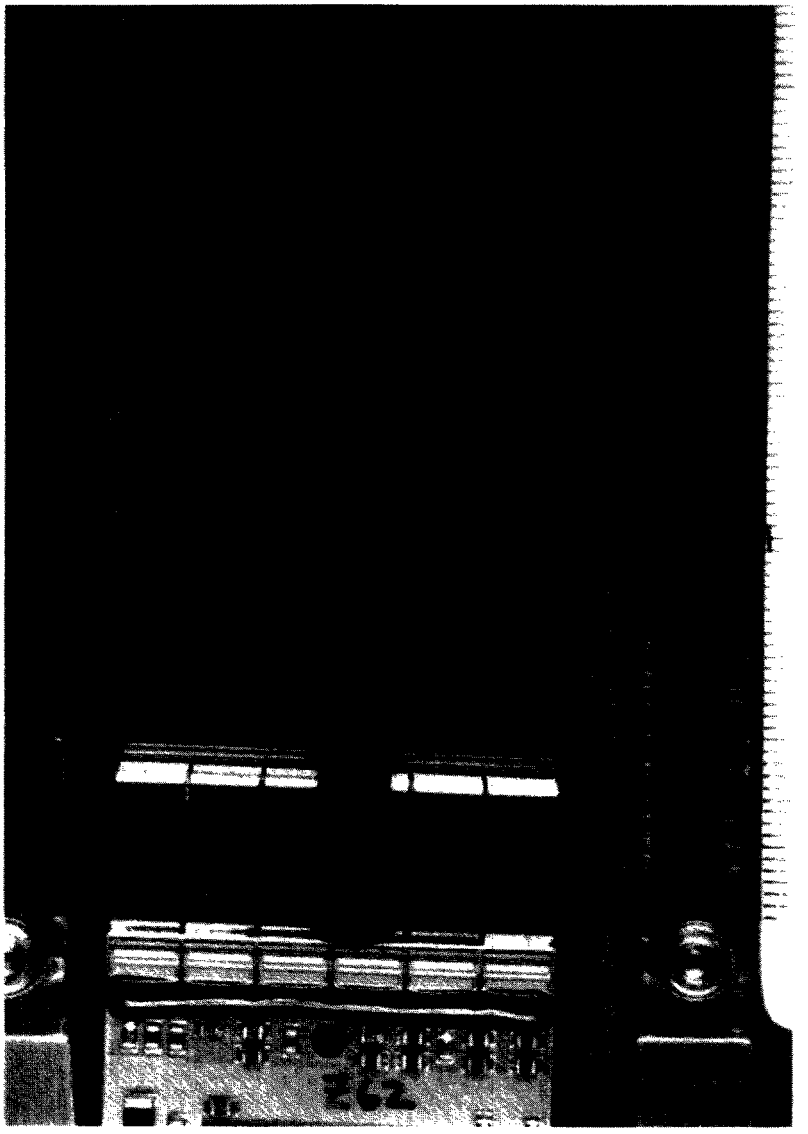

Fig. 2. Detailed view of the $r-\phi$ side of a ladder near the readout end, showing the carbon fiber stiffener.

potential difference between the two sides of the sensors (n-side strips and the corresponding front-end electronics operate at the bias voltage).

3. Installation

Installation is a critical task, because the 1 m long support structure has to be inserted between the TEC (time expansion drift chamber) and the smaller radius beam pipe, with tolerances of about ± 600 μm with respect to both the inner and the outer surfaces. One week is needed for SMD insertion. First installation was completed in March 1993. Fig. 3 shows the fully assembled detector.

During the installation, several problems had to be solved, mostly related to the tight installation tolerances. As a consequence, a fraction of the ladders were lost for readout. One major problem was that several 2 m long power and signal kapton cables, proved to be fragile to heavy manipulation and were damaged. Another fraction of ladders was lost because of wrong operation of the power supply system, which damaged 8 converter boards [1]

[1] The converters are custom boards installed on the same SMD support and containing voltage regulators and drivers for digital and analog control and data signals.

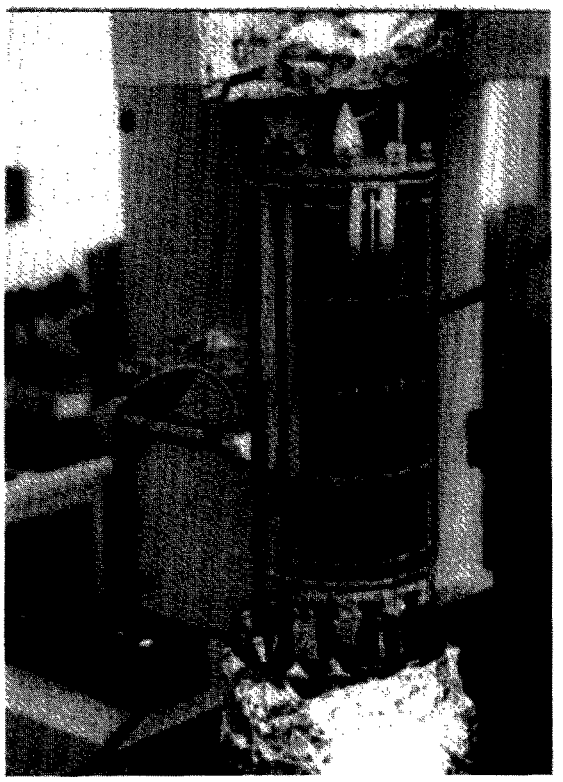

Fig. 3. The SMD positioned vertically on the metrology table.

installed on the SMD support. These damages particularly affected the number of ladders being read out. Each converter and its associated kapton cable correspond to about 1500 strips in our geometry. In addition, the equivalent of two ladders was damaged during metrology, of which one was replaced. As a consequence, about 50% of the detector was being read out during the 1993 run.

Finally, during 1993, only half of our electromagnetic shielding was installed, causing the overall grounding and shielding scheme of SMD not to be completed. Due to this, a new noise component, the so called "rib" effect, has shown up, and it will be discussed in the following section.

3.1. "Rib" effect

Silicon strips are often affected by a coherent noise whose rms is about the same for all channels. This is the so called common noise which makes all pedestals to go up and down together.

However, in our case a correlated noise with non-uniform rms appeared on the $r-\phi$ side only, during the 1993 run, due to the Ω-shaped carbon fiber rib. In correspondence with the stiffener feet, the coupling of the strips to the external e.m. noise is modified, differently from channel to channel. As a consequence, the correlated noise with significantly non-uniform rms appears. The sensor baseline

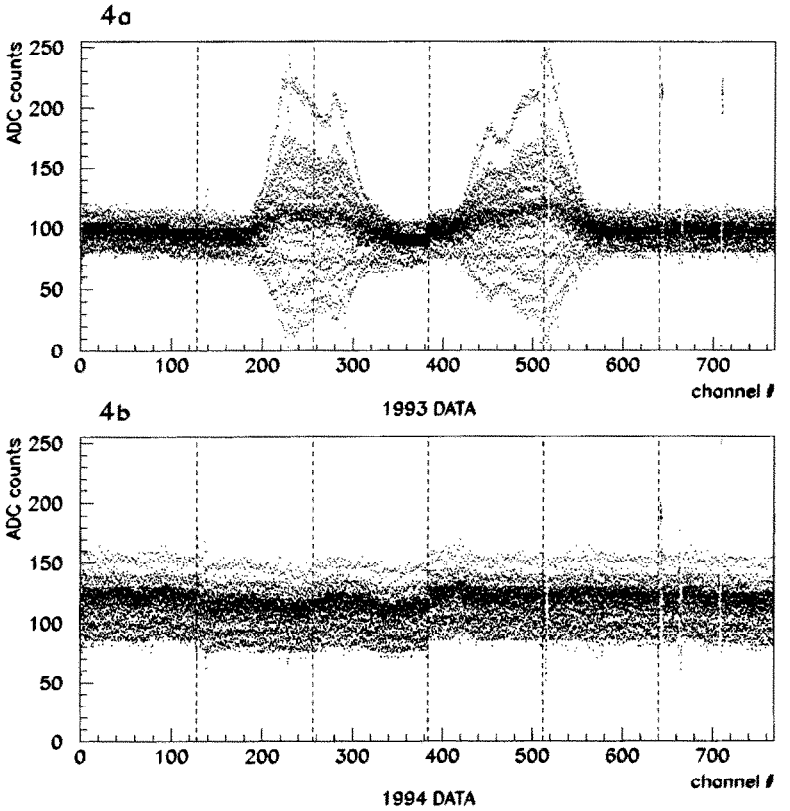

Fig. 4. Raw ADC data as a function of strip numbers, for several superimposed events and for the same ladder: (a) 1993 data; (b) 1994 data.

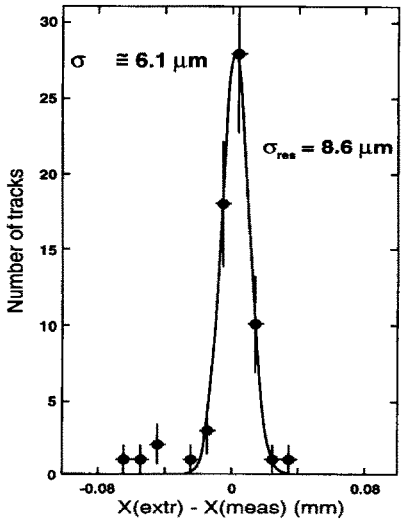

Fig. 5. Residual distribution for the $r-\phi$ coordinate; σ_{SMD} is obtained from σ_{Res} after correcting for the geometrical factor.

assumes that typical horn-like aspect, with similar shapes but non-uniform and different amplitude from event to event (see Fig. 4a). Hence, for the $r-\phi$ side the common noise subtraction is not implemented online and therefore no data suppression is possible. This "rib" effect is large and leads to a saturation of the AD converter in a non negligible fraction of the events, in correspondence to the strips in the rib region. The saturation of course decreases the efficiency of the detector.

The number of strips affected was about 15% of the total number of the SMD channels. For the 1993 run, SMD was already installed and it could not be reached anymore. Nevertheless the problem has been solved off-line by reading all the $r-\phi$ channels in raw mode and later applying a suitable algorithm to get rid of the rib effect. Correlation coefficients are defined between a channel and all the others to compute the horn shape which is then used to subtract the correlated noise event by event.

During 1994 shutdown, a hardware intervention was made to eliminate the "rib" effect (see Fig. 4b). The ribs were connected to the readout electronics ground potential, to minimize the sensitivity to the external e.m. noise. The readout electronics of the opposite ends of a ladder were brought to the same ground potential. In addition, the complete electromagnetic shielding was installed.

4. Performance in 1993

After an initial period of commissioning, SMD has been efficiently taking data since July 1993, during the

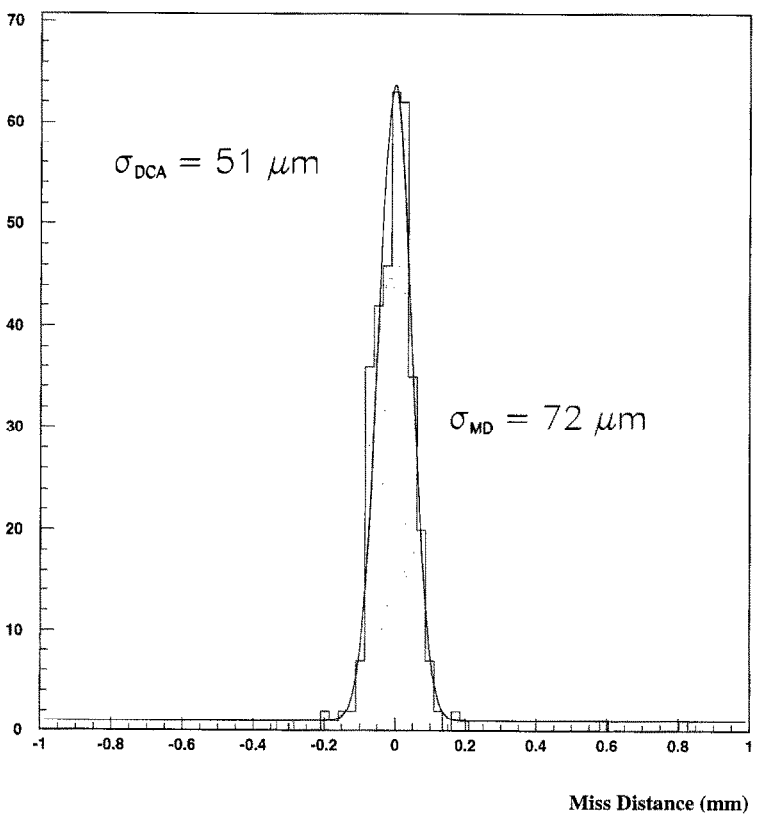

Fig. 6. Miss distance distribution for 45 GeV di-muons; σ_{DCA} is obtained from σ_{MD} after dividing by $\sqrt{2}$.

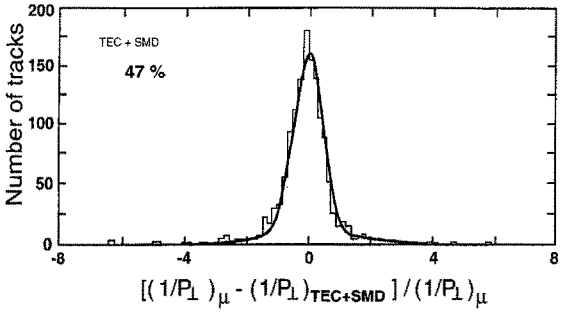

Fig. 7. Transverse momentum resolution for 45 GeV muons.

1993 LEP run. Due to the small number of ladders being read out, available statistics is limited and the local alignment is difficult. The 1993 data was useful to develope off-line programs, to understand detector performances and to compare them with the Monte Carlo predictions.

$Z^0 \rightarrow \mu^+\mu^-$ events are used, in the central part of the L3 detector. SMD is globally aligned to the outer detectors.

SMD instrinsic resolution is evaluated applying an acollinearity cut to use the di-muons as a single straight track. At least 2 SMD points define a track. Residuals are taken as the difference between the extrapolated point on another SMD plane and the hit point found on that same plane (Fig. 5). After unfolding the geometrical factor, an intrinsic resolution of 6.1 μm on the $r-\phi$ coordinate is obtained which is compatible with the test beam results [11].

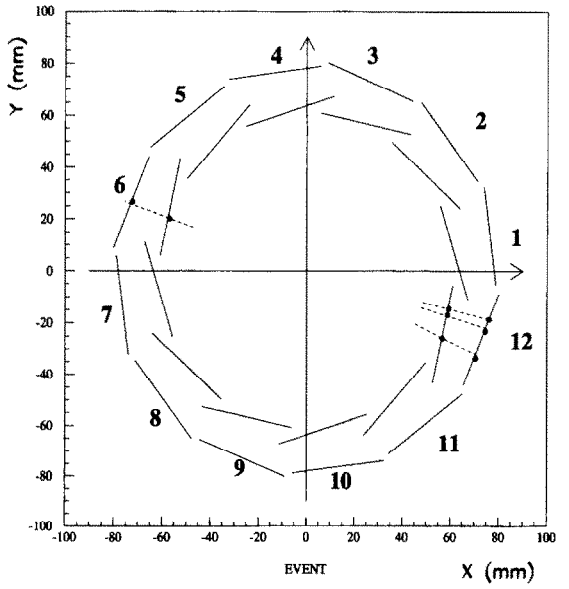

Fig. 8. A $\tau^+\tau^-$ event from 1994 data showing TEC extrapolated tracks (dashed lines) and SMD hits (dots).

From the miss distance distribution, calculated at the interaction point (Fig. 6), we derive a distance of closest approach (DCA) resolution of 51 μm which is compatible with the Monte Carlo predictions [4], taking into account the present TEC calibration accuracy and the current alignment uncertainty (estimated to be of the order of few tens of microns).

We obtain a p_t resolution at 45 GeV of 47% (Fig. 7) compatible with the Monte Carlo prediction of 42% [4], about 1.7 better than with TEC alone.

After 1994 installation, 98% of the detector is working and taking data. It is now possible to look at multiple track events: Fig. 8 shows a typical $\tau\tau$ event, with one τ decaying to one charged track and the other τ to three charged tracks. The lines correspond to TEC extrapolated tracks while the dots represent SMD hits.

5. Conclusion

SMD has been installed for the first time in 1993. Problems encountered in this delicate process have been understood and solved. SMD design resolution has been reached. DCA resolution is in agreement with the Monte Carlo predictions given the current alignment and TEC calibration level. Transverse momentum resolution is close to the predicted value and already a factor 1.7 better than with TEC alone. We can therefore conclude that the part of SMD which was read out during the 1993 run was performing as expected.

In 1994 improved insertion tools and more robust readout kapton cables avoided damages during the installation. Electromagnetic shielding has been completed and the "rib" problem understood. SMD is now debugged and fully operational. With the complete coverage now available, we are ready for physics analysis with 1994 data.

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