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The new double sided silicon microvertex detector for the L3 experiment

O. Adriani^h, J. Alcaraz^e, S. Ahlen^c, G. Ambrosi^{q,*}, A. Baschirotto^o, R. Battiston^q, A. Bay^j, G. Bencze^f, B. Bertucci^q, M. Biasini^q, G.M. Bilei^q, G.J. Bobbink^p, M. Bosetti^o, M.L. Brooks^l, J. Busenitz^b, W.J. Burger^j, C. Camps^a, M. Caria^q, G. Castelliniⁱ, A. Chen^r, T.E. Coan^l, V. Commichau^a, D. DiBitonto^b, P. Duinker^p, S. Easo^q, P. Extermann^j, E. Fiandrini^q, A. Gougas^k, K. Hangarter^a, C. Hauviller^e, A. Herve^e, S. Hou^r, I. Josa^e, J.S. Kapustinski^l, D. Kim^k, W.W. Kinnison^l, J. Kornis^d, V.R. Krastev^q, G. Landi^h, M. Lebeau^m, P. Lecomte^g, D.M. Lee^l, R. Leiste^t, W.T. Lin^r, W. Lohmann^t, R. Massetti^q, G.B. Mills^l, H. Nowak^t, G. Passaleva^{h,q}, T. Paul^k, M. Pauluzzi^q, S. Pensotti^o, P.G. Rancoita^o, M. Rattaggi^o, A. Rosch^t, A. Santocchia^q, M. Sachwitz^t, P. Schmitz^a, B. Schöneich^t, L. Servoli^q, G. Susinno^j, G. Terzi^o, J. Toth^f, G.M. Viertel^g, H. Vogt^t, S. Waldmeier^g, J. Wegmann^t, R. Weillⁿ, J. Xu^c, S.C. Yeh^s, B. Zhou^c

^a III. Physikalisches Institut, RWTH, Aachen, Germany

^b The University of Alabama, Tuscaloosa, USA

^c Boston University, Boston, USA

^d Physical Institute / Technical University, Budapest, Hungary

^e CERN, Geneva, Switzerland

^f RMKI / Res. Inst. for Part. and Nucl. Phys., Budapest, Hungary

^g ETH Zürich, Switzerland

^h INFN / Università di Firenze, Italy

ⁱ INFN / IROE Firenze, Italy

^j University of Geneva, Switzerland

^k Johns Hopkins University, Baltimore, USA

^l LANL, Los Alamos, USA

^m LAPP, Annecy, France

ⁿ University of Lausanne, Switzerland

^o INFN / Università di Milano, Italy

^p NIKHEF, Amsterdam, The Netherlands

^q INFN / Università di Perugia, Italy

^r NCU, Chung / Li, Taiwan

^s National Tsing Hua University, Hsinchu, Taiwan

^t DESY Zeuthen, Germany

The new technologies used in the construction of the L3 Silicon Microvertex Detector (SMD) at LEP are presented. The SMD consists of two cylindrical layers of double sided silicon sensors to provide very precise measurements of both $r\phi$ and z coordinates. In order to minimize the amount of material in the central region, a Kapton fanout has been developed to bring the signals of the z strips (transverse coordinate) to the end of the mechanical structure. To get rid of the leakage currents a new capacitor chip, with diode protection against overvoltages, has been designed and used. In addition, a solution based on optodecoupling has been adopted to read the silicon n-side strips operating at the bias voltage.

1. Introduction

To enhance the tracking capability of the L3 experiment at LEP [1] a silicon microvertex detector has been

built and installed and is now participating in the 1993 data taking at LEP.

The SMD is positioned in between the beam pipe and the outer tracker (TEC), as close as possible to the interaction point (see Fig. 1); thus the detector improves the efficiency and the purity of tagging short-lived particles (B and τ) because of the improved impact parameter mea-

* Corresponding author.

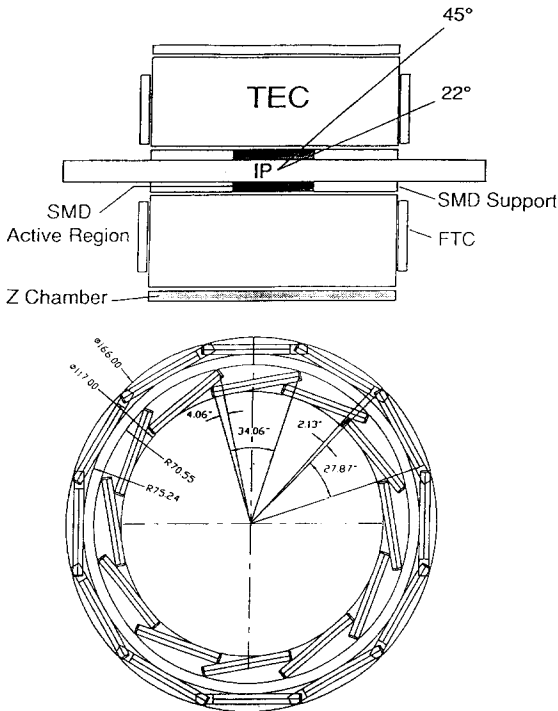


Fig. 1. SMD view in the L3 detector at LEP.

surement using the two precise points which are measured. This will also improve the momentum resolution because of the longer lever arm and the coordinate measurement of the particles along the beam direction.

2. Detector design

The SMD (see Fig. 2) consists of two cylindrical layers ≈ 6 cm and ≈ 8 cm radius from the beam line covering the azimuthal angle (ϕ) and $22^\circ \leq \theta \leq 158^\circ$ coverage. It allows two three-dimensional measurements of charged tracks. Each layer consists of 12 modules (ladders); the inner ones being partially overlapping ($\approx 5\%$) to allow alignment with tracks; the outer ones are not overlapping but have a 2° stereo rotation with respect to the inner ones to better resolve pattern recognition ambiguities. Each ladder is made of two double sided detectors with readouts through both ladders ends to optimize heat removal and to minimize the radiation thickness; the mechanical stability is ensured by a carbon fiber stiffener (0.2 mm thick, 14 mm profile width, 30 cm long) glued on the sensors p-side. The ladders are mounted on a carbon fiber support structure made of two cylindrical half shells 100 cm long, 3 mm thick. The hybrids at the ladder ends are water cooled.

The radiation length of carbon fiber is $X_0 = 24$ cm. The radiation thickness of the complete structure is 0.16% of X_0 . A description of the SMD design parameters is found in ref. [2]

3. The sensors

The sensors are produced by CSEM (Switzerland) based on a design developed at INFN Pisa [3]. The detectors are operated in capacitive charge partition mode. They are 7.04×3.84 cm² active area with 1536 strips on the p-side

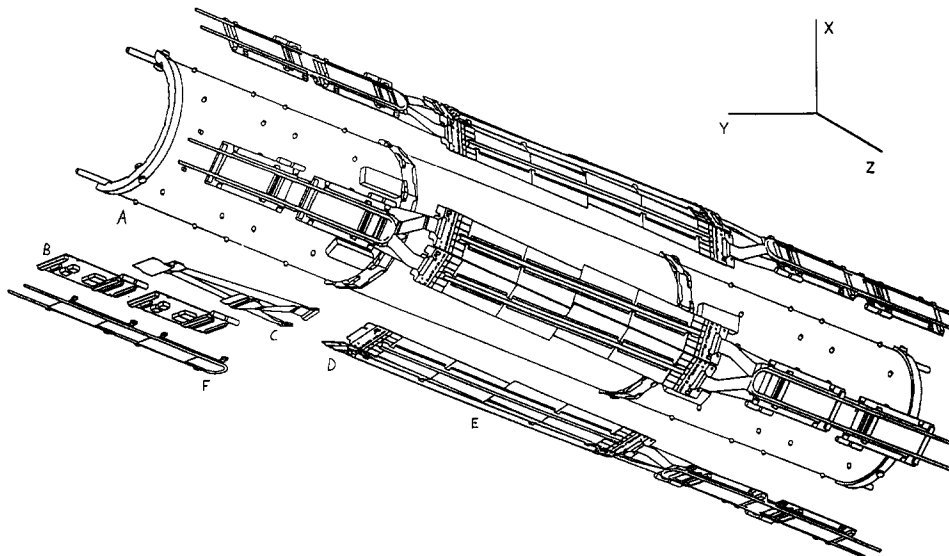


Fig. 2. SMD exploded view: A – support structure, B – converter boards, C – Kapton cables, D – hybrids with SVX-H, E – outer ladders, F – cooling system.

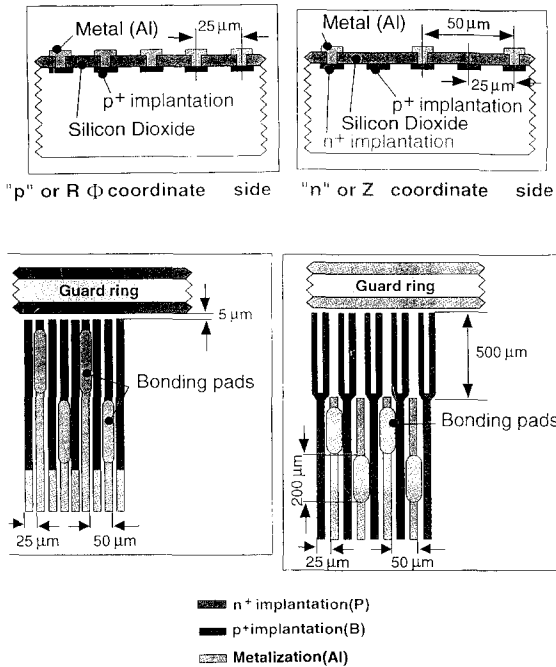


Fig. 3. Double sided sensors masks.

and 1409 on the z-side, 300 μm thick. The p-strips (diodes) parallel to the beam ($r\phi$ coordinate) and the n-strips orthogonal to it (z coordinate) have a pitch, respectively, of 25 μm and 50 μm, while the readout pitch is 50 μm on the $r\phi$ side and 150/200 μm on the central/forward-backward region of the z side, so that the total number of readout channels is 73728 (see Fig. 3). The active areas are surrounded by guard-rings (doubled on the $r\phi$ side), which are resistively coupled to the strips both on the p and n sides, by punchthrough and surface accumulation layer channeling, respectively. Many electrical test have been made on each sensor before the installation and some acceptance criteria have been applied to accept sensors: (i) guard-ring current $< 2 \mu\text{A}$ at 1.5 times $V_{\text{depletion}}$; (ii) no more than two p-strips with a current $> 50 \text{ nA}$; and (iii) no more than two p-strips in short-circuit.

More than 200 sensors have been produced and tested with a total yield of $\approx 75\%$.

4. Electronic readout chain

In the following section we outline the main features of the electronic readout chain.

To read out the transverse coordinate, a special thin cable has been developed. It consists of a low mass Kapton cable 50 μm thick, glued to the ladder n-side, with L-shaped copper strips. The input pitch matches the n-side

readout pitch (150 μm and 200 μm in the central regions, respectively) and the output one matches the readout chip pitch (48 μm) [4]. For the front-end electronics we used the SVX-H (radiation hard) chip which has been developed for the CDF experiment [5] and used for the first time in SMD with double-sided detectors and in large quantity. Each chip contains 128 charge amplifiers with a gain of 15 mV/fC, each followed by sample and hold, threshold storage, comparator and latch stages. Digital circuitry to control the serial multiplexed readout allows various readout modes.

The chips are glued onto hybrid circuits and the amplifier inputs are AC coupled to the strips through integrated

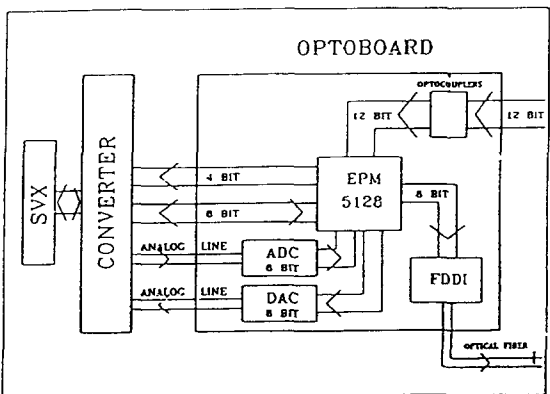
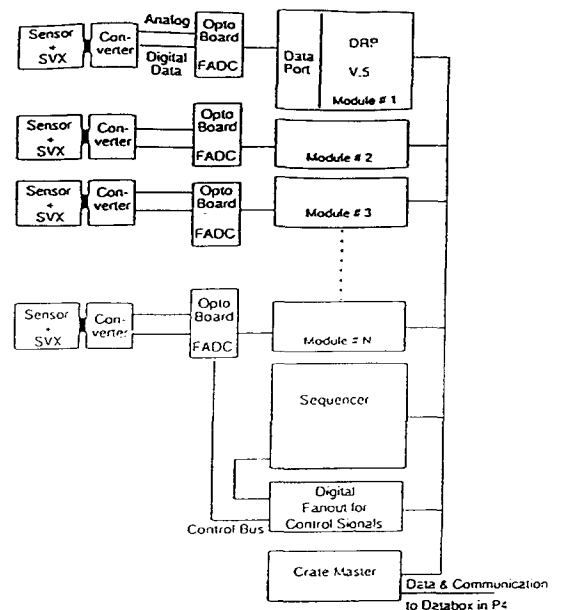


Fig. 4. Block diagram of readout system and of the optoboard.

capacitors (150 pF) chips, containing diode protection against breakdown due to overvoltages [6].

The output SVX signals are sent via an intermediate Converter board to a special optically decoupled system (Optoboard and Optoreceivers) (see Fig. 4) [7]. The analog signals coming from SVX are digitized on-board via an 8-bit 40 MHz flash ADC [8] and are sent to the DAQ via multimode optical fibers. In this way there are no electrical connections between DAQ and the front-end electronics, thus they may be kept at any (reasonable) voltage difference; in addition the detectors are biased using a special floating power supply [9]. A high stability 8-bit DAC [10] generates signals to calibrate the SVXs.

The optical boards are placed 10 m away from the detector; differential drivers/receivers are used to drive analog and digital signals between Converters and Optoboards. On the DAQ side, a set of VME fast Data Reduction Processors (DRP) [11] are used to receive signals from Optoreceivers, to reduce the amount of data for processing [12] and to transfer them to the L3 data stream. The synchronization of the readout to the external trigger is achieved by a Sequencer [13] which generates bit patterns, necessary to start and synchronize the multiplexed readout of SVX to the DRPs.

5. Position monitoring

Two position-sensitive systems monitor the relative position of SMD with respect to the TEC. The first one is a capacitive displacement monitoring system. Capacitive sensors on the SMD support are coupled to ground targets on the inner wall of the TEC. They are sensitive to (r, ϕ) and (r, z) displacements. The expected long-term resolution is $< 10 \mu\text{m}$. The second system is a laser-based system. Infrared laser pulses are transported by an optical fiber to a focusing lens rigidly attached on the inner TEC wall. The laser light illuminates the detector outer layer at different angles and the output signal is read out through the standard DAQ. In this way, azimuthal and radial displacements may be measured with a precision of a few microns.

6. Conclusion

This paper describes the innovative aspects of the L3/SMD: low mass readout Kapton cable, optodecoupling of front-end electronic and a large number of SVX-H chips coupled to double sided detectors. The various components

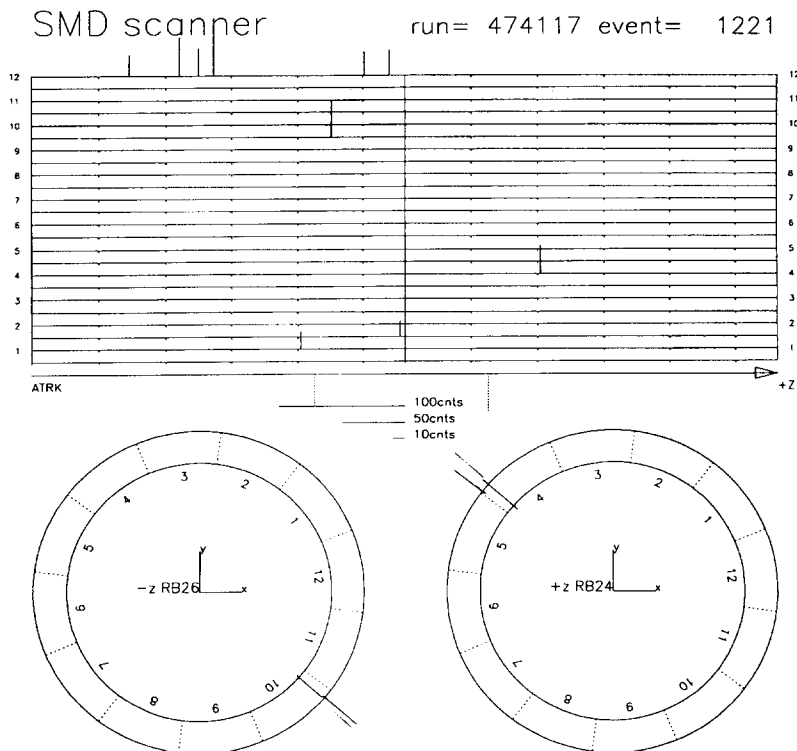


Fig. 5. Display of an event in the z (upper) and $r\phi$ (lower) projections: hits due to a MIP are seen in sector 10 and sector 4 both in inner and outer layers and both in z - and $r\phi$ -side. The corresponding TEC track position is shown as dotted line.

mentioned in the paper have been investigated in a test beam described by a presentation in this conference [14]. The SMD detector has been installed inside L3 on March 1993. The commissioning of the detector is completed and data are regularly logged to tape (see Fig. 5). Debugging and understanding of detector performance are in progress.

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