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**THE DESIGN OF THE L3 SILICON MICROVERTEX DETECTOR**

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**ABSTRACT**

An upgrade of the L3 central tracking system, a silicon microvertex detector (SMD), is described. The detector consists of two layers of silicon, each equipped for  $r$   $\phi$  and  $z$  readout with resolution  $\approx 6 \mu\text{m}$  and  $\approx 20 \mu\text{m}$  respectively. The SMD will provide full azimuthal coverage over the polar angular range  $22^\circ \leq \theta \leq 158^\circ$ . The total thickness is  $\approx 0.9\%$  of one radiation length.

## 1. - INTRODUCTION

As from the 1991 run, LEP is operating with a vacuum pipe of smaller radius (5.3 cm). This has opened up the possibility to install a silicon microstrip detector (SMD) to enhance the tracking capabilities of the L3 detector, both in  $r\phi$  and  $z$  projections. This upgrade has been approved and the detector will be installed for the 1993 running. The aim of this paper is to describe the main detector characteristics as they are and the expected impact on the tracking performances and physics capabilities of the L3 experiment [1.2]. As it will be described below, the SMD will significantly improve the analysing power of the L3 central detector on impact parameter momentum and  $z$  resolution as well as track reconstruction and jet identification capabilities.

## 2. - PHYSICS MOTIVATION

A silicon microvertex detector capable of reconstructing decay and primary vertices of particles of lifetimes down to  $10^{-13}$  s. will play a crucial role for the physics at both the LEP future options: the high luminosity multi-bunch operation and the high energy LEP 200.

When LEP will operate at the  $Z^0$  pole, with higher luminosity [3] (8 or more bunches), the SMD will provide a high efficiency (up to 30%) and purity (up to 80%)  $b$ -jet tagging for  $B$  meson related studies. The improvement on the  $z$ -coordinate and momentum reconstruction, thanks to the insertion of the SMD, will also be crucial for accurate measurement of the  $\tau$  polarisation asymmetry, by allowing a better charge determination and a cleaner identification.

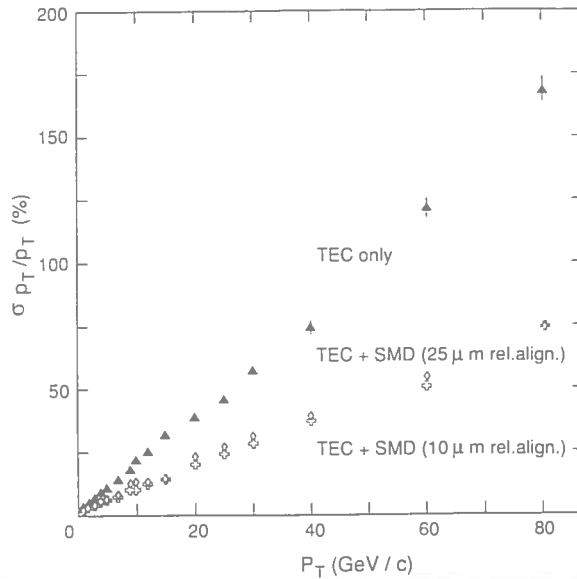
At LEP 200, a wide spectrum of interesting physics will be available [4.5]. In particular, the search for the Higgs boson will be effective in the range  $50 < M_{\text{Higgs}} < 90$  GeV. In this mass region the Higgs will mainly decay into the pair  $b\bar{b}$ : SMD will be a powerful tool to tag  $b$ -jets and then identify the associated final states. In the measurement of the  $W$  charge angular distribution, the SMD will allow a separation of the longitudinal and transverse components of the polarisation, over the full range of lepton momentum, by determining unambiguously the charge sign of the  $W$  in the largest possible polar angle region.

## 3. - PERFORMANCE OF THE L3 CENTRAL TRACKER WITH THE SMD

The SMD improves many aspects of the L3 tracking system [6]: transverse momentum resolution, impact parameter resolution,  $z$  coordinate measurement, track reconstruction in complex events. Here we report results based on a simulation performed assuming a two concentric layers, using GEANT and part of the L3 simulation package.

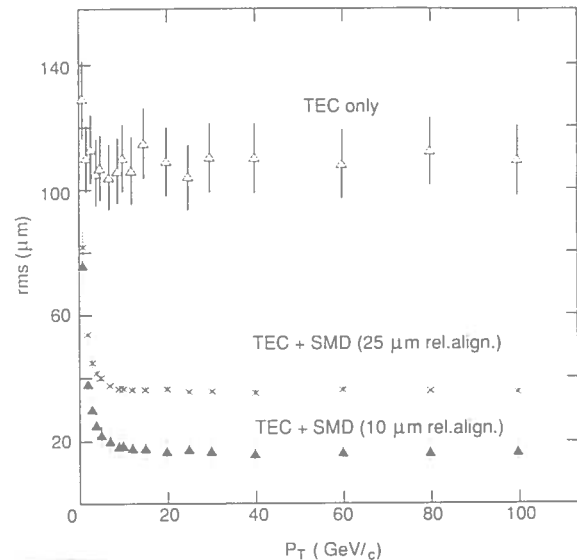
To evaluate the improvement on transverse momentum resolution, we have simulated single muons with momenta ranging from 1 to 100 GeV/c. In fig. 1 we report the results for  $\theta=90^\circ$ ; however, a similar behaviour is observed if one integrates over the whole polar angle region covered by the SMD. A remarkable improvement in resolution is seen (up to a factor 2.2 at high  $p_T$ ) by comparing the  $p_T$  resolution obtained with TEC (the high resolution time expansion chamber) alone with TEC + SMD. With the SMD it is therefore possible to measure the charge of a single particle (at the  $2\sigma$  level) up to  $\approx 80$  GeV/c of  $p_T$ . The gain in impact parameter resolution, has been evaluated in the  $r\phi$  plane for single muons in the whole  $\phi$  and  $\theta$  regions covered by the SMD; the results are shown in fig. 2 for  $\theta = 90^\circ$  in the case TEC + SMD

and TEC alone, assuming either a 10  $\mu\text{m}$ , or a 25  $\mu\text{m}$  point resolution, to account for an estimated accuracy on the TEC-SMD relative alignment. In the latter case the improvement is a factor of about four for  $p_T > 3 \text{ GeV}/c$ .



**FIG. 1** – Momentum resolution for single  $e$  ( $\theta = 90^\circ$ ).

**FIG. 2** – Impact parameter resolution for single  $\mu$  ( $\theta = 90^\circ$ ,  $B = 0.51 \text{ T}$ ).



#### 4. – SMD DESIGN PARAMETERS

The measurement of the  $z$  coordinate is an important feature of the L3 SMD. For this reason a very appealing sensor choice is the double sided design pioneered by the LSD Pisa-INFN group for the Aleph experiment [7.8]. Given the constraints on space between the smaller beam pipe and the TEC, the SMD present design consists of two layers of 11 and 13 ladders (fig. 3) at about 6 and 8 cm respectively. Each ladder (fig. 4), consists of 4 rectangular double-sided  $n$ -type high resistivity silicon detectors, 300  $\mu\text{m}$  thick, of 7 X 4  $\text{cm}^2$  each. The  $p$ -strips on the junction side ( $r \phi$  coordinate) are parallel to the beam, the  $n$ -strips on the ohmic one ( $z$  coordinate) are orthogonal.

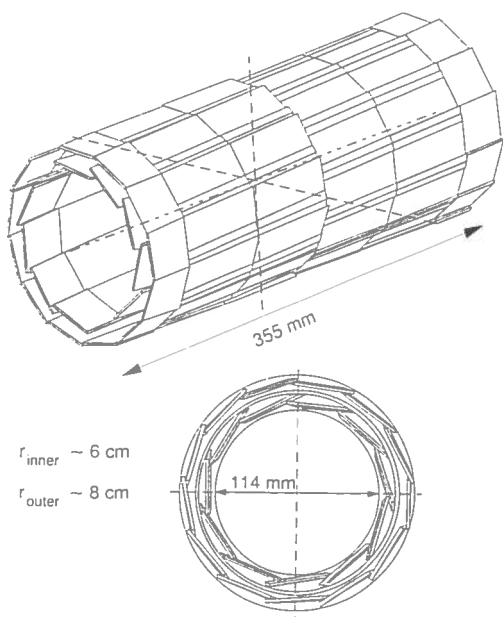


FIG. 3 – Sketch of SMD assembly

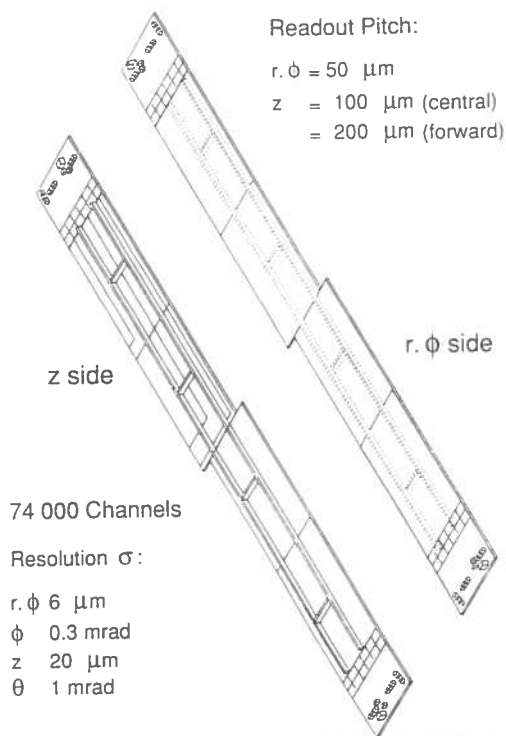


FIG. 4 – Conceptual ladder design

A sensor strip pitch of  $25 \mu\text{m}$  gives satisfactory resolution [10], which, with the chosen readout pitch ( $50 \mu\text{m}$  in  $r \phi$ ,  $150$  and  $200 \mu\text{m}$  in  $z$  respectively for the central and the forward sensors): we expect a single track resolution of  $6 \mu\text{m}$  in  $r \phi$  and, at worst, of  $20\text{--}25 \mu\text{m}$  in  $z$ .

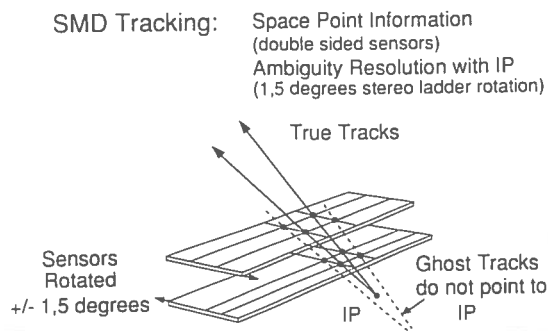
These double-sided sensors are ac-coupled to the readout preamplifiers through coupling capacitors on a quartz substrate [9].

Heat dissipation studies, performed at Los Alamos National Laboratory, have indicated that, in order to keep thermal gradients to an acceptable level, all the readout electronics should be located at the ladder ends. Therefore the  $z$  strips need a special fanout circuit, presently under design, to bring the  $z$  signals to the two ladder ends: it will consist of a thin aluminum layer on a silicon (or kapton) substrate. The total number of channels of the detector is therefore  $\approx 74000$ .

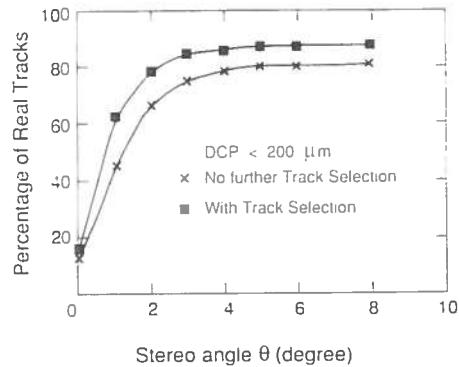
An alternative solution, making use of two single side sensors glued together, is presently being investigated by the HEP group in Taiwan.

In the present L3 configuration, there is a need of resolving the  $> 1$  track ambiguities, already at the SMD level. For this purpose, the inner and outer ladders will have a relative stereo rotation of about  $3^\circ$  with respect to each other, on an axis normal to the strip plane. Without this rotation, in fact, the number of combinatorial background tracks, i.e. the fake tracks which are reconstructed by associating hits in the different layers ("ghost" tracks, see fig. 5), is large, due to the relatively simple SMD geometry and to the absence of other precise space points close enough. With stereo layers, the  $z$  and the  $r \phi$  informations from each double sided sensor, can be associated and the ambiguity resolved. To investigate the effectiveness of this geometry, a sample of  $u$ -jets has been generated and all possible tracks reconstructed: those missing the vertex by more than  $200 \mu\text{m}$  were rejected. The fraction of real tracks reconstructed over the total

is below 20%, for the case of  $0^0$  rotation (see fig. 6), reaching the limit  $\geq 80\%$  for the  $2^0$  relative angle.



**FIG. 5** – Stereo relative rotation of the SMD ladders.



**FIG. 6** – Purity of reconstructed tracks vs stereo angle. DCP (distance of closest approach) is used for a loose vertex selection.

This result imposes further constraints on the ladders arrangement, beyond the space requirements imposed by the beam pipe and by TEC. One should try to reduce the  $\phi$  segmentation, in order to have a small number of detectors to assemble and should follow the modularity of the readout preamplifier, the SVX [10] VLSI chips. A SVX chip has 128 channels at  $50 \mu\text{m}$  pitch in  $r \phi$ , corresponding to a 6.4 mm width. For mechanical constraints, the maximum stereo relative angle is  $\pm 1.5^0$ : this is the limit if one wants to avoid building different type of ladders. Each ladder structure contains two opposing identical half ladders, glued together in the middle and bonded to the far ends to a hybrid circuit which carries SVX circuitry, readout bus and bias circuitry.

#### 4.1. – MECHANICS

The present mechanical design foresees therefore a rotation of  $+ 1.5^0$  for the inner layer and  $- 1.5^0$  for the outer one. The ladders are mounted on a carbon fiber composite structure which, at the same time, is rigid and light. Given the number of channels in the system, the total power generated is  $\approx 150 \text{ W}$ .

A crucial item for a high precision microvertex detector, is the precise knowledge of the geometrical parameters, at the few microns level. For that, it has been foreseen a very accurate survey of the individual structure before the assembly and continuous monitor for the stability during operation in L3.

During assembly, the ladder position and orientation are mapped with a high precision device with an accuracy on the physical dimensions of  $5\text{--}6 \mu\text{m}$ .

The relative position of SMD with respect to the other L3 subdetectors, can be determined by offline alignment, expecting a  $\approx 10 \mu\text{m}$  accuracy. In addition one can benefit of a 3 mm overlapping ( $\approx 8\%$ ) of each ladder with its neighbouring ones.

The stability monitoring can be realised with a capacitive readout system using capacitor probes which have been proven to successfully monitor  $\approx 1 \mu\text{m}$  for radial displacements and  $\approx 5\text{--}7 \mu\text{m}$  for lateral displacements [11].

## 4.2. - ELECTRONICS

The readout scheme includes per each half-ladder 12 SVX-H chips developed at LBL for the CDF experiment. The chip comprises an analog and a digital section and it contains 128 channels of low noise charge sensitive amplifiers. The chip has a logic which allows the realisation of three different readout modes: full readout, sparse scan only of fired strips, sparse scan also of neighbouring ones.

Four types of modules are needed for control and readout: a converter (transceiver), a digitizer, a sequencer and a fanout module. The DAQ will be a modification of the existing TEC FADC/DRP VME module [6].

## 5. - CONCLUSION

We have described the design of a silicon microvertex detector which is being built for the L3 experiment. The studies performed shows that this detector will substantially improve the L3 tracking performances, playing a crucial role for the future LEP runs.

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