DEVELOPMENTS ON Si DETECTORS

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ABSTRACT

The status of the art of the developments on Si detectors made in Pisa is described. Emphasis is put on the results of the tests performed in the laboratory and the application of double sided Si strip detectors in the LEP collider, including some preliminary results from the 1990 LEP run. In the meantime, some effort has been put in the development of pixel structures, several of which have already been built.

1.INTRODUCTION

The development of double-sided Si strip detectors has started in Pisa several years ago when small diodes 1 cm^2 have been fabricated to test the working principle. The basic idea to isolate n^+ strips in the ohmic side is to insert p^+ blocking strips between them, fig.1, ref 1; in this way the electron accumulation layer can be interrupted and the ohmic side segmentation can be used. Then 5x5 cm^2 detectors have been built to test the fabrication process for larger area devices.
By using the punch-through effect between two p^+ junctions, the juction side biasing scheme has been studied. A tuning of the ohmic side accumulation layer has been made by choosing a suitable pattern of p^+ blocking strips between bonding pads and guard ring. An external AC chip has been developed to prevent current going from the detector to the amplifier. These detectors have been installed as part of the ALEPH Si vertex detector for 1990 LEP running; the high spatial resolution of these devices improves the method of tagging decay vertices among the collision products of e^+e^- interactions.

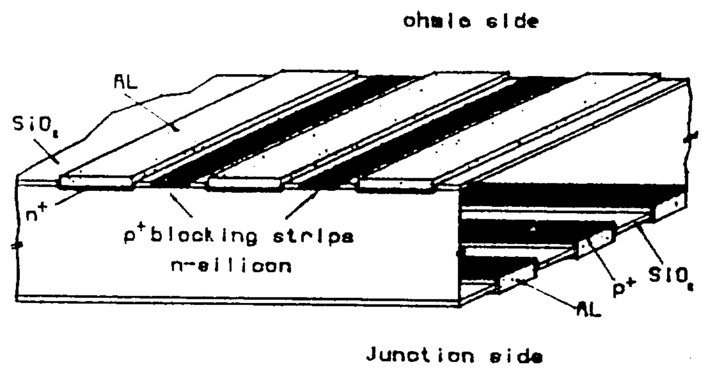

Fig.1: Schematic view of a double sided Si strip detector.

2.DOUBLE SIDED Si STRIP DETECTORS

The fabrication process of double sided Si strip detectors has been already described in detail elsewhere, ref.2; here I will give the main characteristics of the detectors. 4 " n-type high resistivity (>4 KΩ cm) 300 μm thick Si wafers from Wacker have been used, they were polished on both sides to allow precise processing steps. 5x5 cm ^{2} double sided Si strip detectors have been fabricated in the central region of the wafer, around this several test structures have been built to study the most significant parameters of the process.

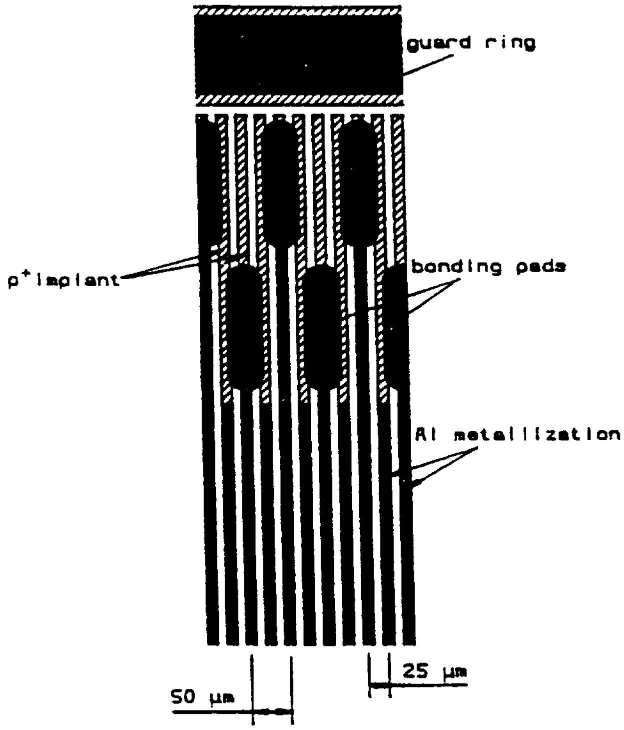

Fig.2: Strip pattern on the junction side.

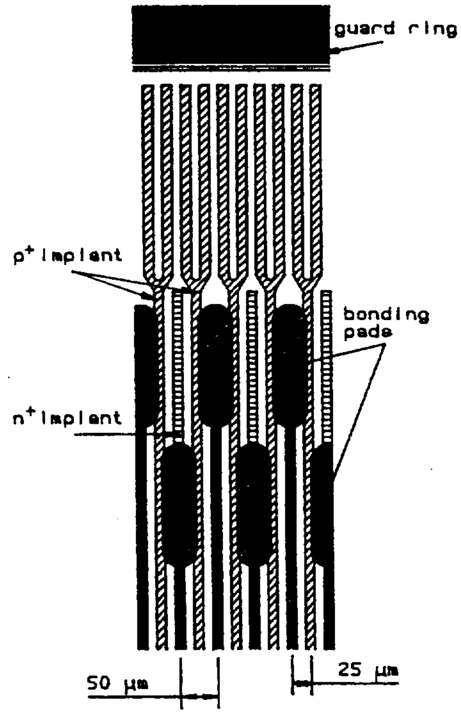

Fig.3: Strip pattern on the ohmic side.

On the junction side (p side) there are p^+ implanted strips with 25 μm pitch, and there are bonding pads every 50 μm, fig.2. Very high interstrip resistance (several GΩ) prevents the strips from floating and using properly the charge partition between them. To avoid this problem the punch-through effect between two close p^+ implants has been used to bias the strips: the distance between the guard ring and the p^+ strips is small (few microns) and such that the voltage difference between guard ring and strips is a few Volts and constant in equilibrium conditions.

On the ohmic side (n side) there are n^+ implant strips with 50 μm pitch interleaved with p^+ strips. The scheme to interrupt the electron accumulation layer and allow for individual strip readout has been widely studied in test structures; the effect of implant dose and geometry of the p^+ 'blocking strips' has been tuned. In particular a 'channel stop' is needed at the edge of the readout strips to prevent low resistance among the strips and the guard ring, fig.3.

Fig.4 shows a typical interstrip resistance as a function of the reverse bias voltage.

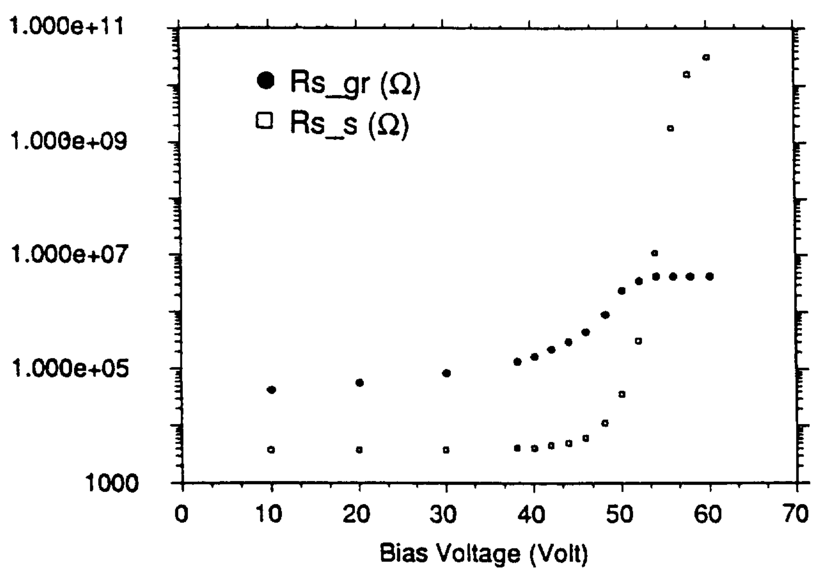

Fig.4: R_{S_s}, interstrip resistance on the ohmic side
R_{S_gr}, resistance between strips and guard ring.

The total leakage current of these detectors is in the range of few hundred nA, with this value measured at a bias voltage >1.5 times the depletion voltage. Fig. 5 shows the distribution of leakage current for all detectors produced so far: out of 120 detectors produced, 7 have a reverse current larger than 10 μA and are not shown in the plot. Detectors with leakage current above 2 μA are rejected. A scanning of the leakage current for each strip on the p-side is performed; if necessary the same scanning is done on the n-side to check for local problems. Typical strip leakage current is 100 pA, most detectors have no strips with I>10 nA. After cutting a stability test is done, the leakage current is monitored over several hours; detectors showing instabilities are rejected. After these selection criteria a yield of 75% is obtained.

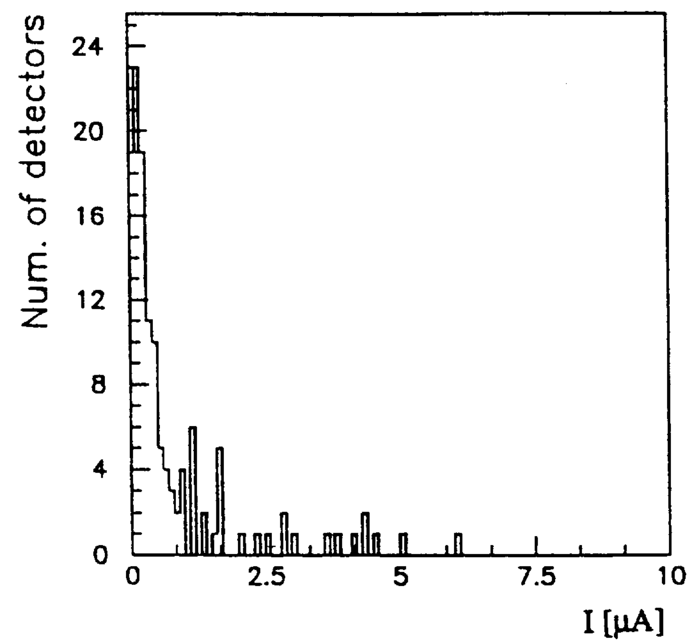

Fig.5: Distribution of the total leakage current for all detectors produced in the last two years.

3.VERTEX DETECTORS APPLICATION

These double sided Si strip detectors have been developed for the ALEPH vertex detector (VDET), ref.3; they have been installed as part of this detector for the LEP 1990 run, ref.4. Fig.6 shows a sketch of a 'face' made of two 'modules'.

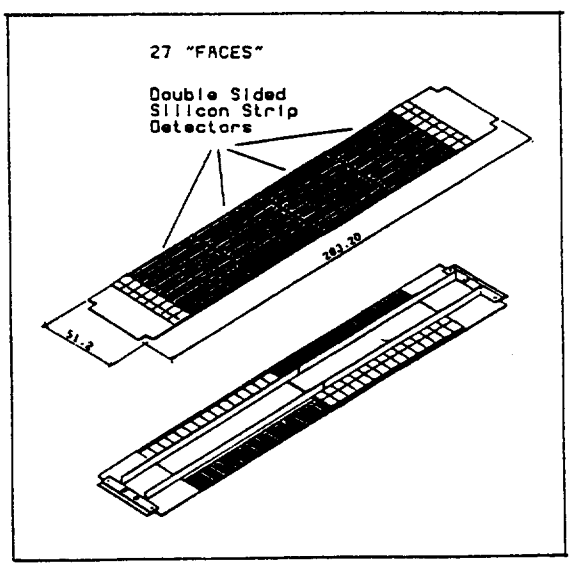

Fig.6: Sketch of one face: top, r-ϕ wiew up; bottom, r-z view up.

A module is the elementary unit of the detector, it consists of 2 double sided Si strip detectors and 2 ceramic fan-outs used as mechanical support and as support for the front-end electronics. To prevent saturation caused by leaky strips or different dc input levels in the charge sensitive preamplifier, a capacitive coupling between strips and preamplifier is used. An external AC chip has been built with capacitors (210 pF) made by double polisilicon; the pitch is 100 μm, same as the electronics; to reduce the stray capacitance a quartz substrate has been chosen. Before the installation in Aleph some modules were put in a test beam at Cern SPS; as a preliminary result a spatial resolution of 15 μm in the r-ϕ projection (100 μm readout pitch) and 24 μm in r-z projection (200 μm readout pitch) were obtained.

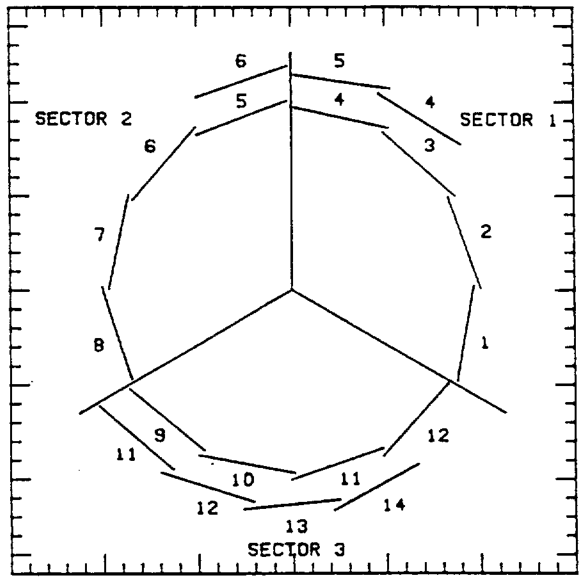

Fig.7: Faces installed in Aleph for 1990 LEP run.

19 faces were installed in Aleph in Feb '90, fig.7; 150 K hadronic Z^0 were collected with VDET by the end of the run. After a crude alignment, a preliminary exercise in the impact parameter has been made: the primary vertex is calculated on an event by event basis, then the tracks hitting the vertex detector are forced to pass trough the corresponding VDET hit keeping the same momentum p as determined by TPC. In these conditions the impact parameter resolution in the r-ϕ plane for $p>p_0$ is shown in fig.8.

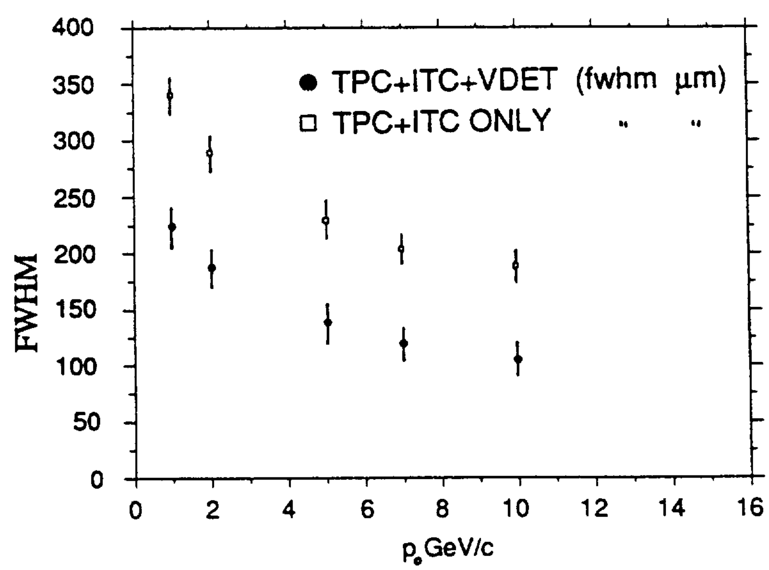

Fig. 8: Impact parameter resolution in r-ϕ plane for $p>p_0$

4. PIXEL DEVICES

For the next generation of high luminosity hadron colliders (SSC, LHC), events with highly collimated tracks inside jets can prevent the use of double sided Si strip detectors; in fact space ambiguities due to multiple hits in the same wafer can be left unresolved, if the signal to noise ratio is too small there is no way to use the pulse height correlation between the two projections to solve this kind of ambiguity. If a Si pixel device is used a true 2-dimensional space information can be provided. The time ambiguity has also to be solved: events rate approching 100 MHz are foreseen, up to now no electronics work in this range. The problem is to store the information of interested pixels in a pipeline until a decision about the interest of the event has been taken. The first level trigger may arrive .5 μsec after the event, in this case a pipeline of 50 events is required.
The last problem is the high radiation level in the next hadron colliders where a flux of fast neutrons of 10^{13} n/cm^2 at $L = 10^{33}$ cm^{-2} sec^{-1}, r=10 cm, is expected. Several linear (100 μm pitch) and square (380 μm pitch) arrays of pixels have been built to test combined low capacitance detectors and suitable electronics. These structues will then be irradiated to study the effect of high level radiation doses.

5. CONCLUSIONS

After several years of development, the double side readout Si strip detectors can now be fabricated with high level of reliability. The first results in the Aleph Si vertex detector show that they are suitable devices to cope with the requirements of vertex detectors in general. Tests have to be done to understand the radiation resistance of these detectors and eventually improve it. The effort in understanding how the sensitive element area reduction can improve the use of Si detectors in the next generation of high luminosity hadron colliders has started.

REFERENCES

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