Developments and Tests of Double-Sided Silicon Strip Detectors and Read-out Electronics for the Internal Tracking System of ALICE at LHC

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The internal-tracking-system (ITS) of the ALICE detector at LHC, consists of six concentrical barrels of silicon detectors. The outmost two layers are made of double-sided strip detectors (SSD). In the framework of a R&D, the characteristics and performances of these devices, manufactured by two different companies, associated with their designed read-out electronics, have been studied off- and in-beam at the SPS (CERN). The results are presented and discussed.

1. Introduction :

The ALICE experiment [1] is in preparation at LHC. It makes use of a complex apparatus aimed at the detection of hadrons and leptons emitted in the Pb + Pb collisions at ultra-relativistic energies. The most inner part (ITS), covering the $|\eta| \leq 0.9$ pseudo-rapidity region, is devoted to the dE/dx measurement and the tracking of the charged particles as well as the secondary-vertex reconstruction of the short-lived particles. It allows also the detection of low transverse-momentum particles.

The outmost two layers of the ITS have 39.1 and 43.6 cm radius, for a length of 45.1 and 50.4 cm, including 782 and 988 SSD, respectively. These sensors have been designed [2] as 75 x 42 mm^2 overall area, for a maximum thickness of 300 µm. They have 768 strips, about 25 - 40 µm wide, with a pitch of 95 µm, on each side. The strips are oriented with an angle of ±17.5 milliradians, depending on the side, with respect to the short-sized edge of the detector, i.e., a stereoscopic angle of 35 milliradians.

In the framework of R&D's currently in progress, we have ordered, from each of two manufacturers (Canberra and Eurysis Mesures), a pair of SSD's at the general specifications reported above, and studied their characteristics and performances [3] on a test-bench and a probe-station at IReS, as well as in-beam at the SPS at CERN. The resuts are presented and discussed in this contribution. All the detectors having performances globally comparable, typical results are given without detailed comparison.

2. Specific Characteristics of the SSD's :

The four SSD's, prepared at the general specifications given in the Introduction, have the following features. They are realised from a block of silicon of n-type and the strips obtained by p^+ and n^+ doping on the p and n side, respectively. Both sides are insulated by SiO_2 dielectric and the collected charges are read-out by capacitive coupling on aluminium strips (≥

1µm thick). All strip extremities have two pads, thus offering spare-bonding or flexible connection during tests. Each detector side is electrical, mechanical and chemical protected by passivation. There are no-floating strips and the noise is reduced on the n-side by p-spraying. The strips are polarised via punch through technics with a bias ring which is surrounded by a guard ring (≤ 1mm wide), so defining an effective area of 73 x 40 mm^2 for the SSD.

As the functioning and the performances of the SSD's are substantially dependent on the different capacitances characterising the detectors, approximate values of these latter have been requested at the time of the order [2]. However, they may vary with the resistivity of the silicon (≥ 6 kΩ.cm), the design technics and the manufacturing process. Consequently, they have been measured, after delivery, with a probe-station at IReS. The results are described in the next Section.

3. Test-bench and Probe-station Measurements :

The geometrical characteristics of the SSD's have been, first, measured by means of a probe-station and a binocular and were found nominal.

The coupling capacitor value (C_{cpl}) of the strips is typically found close to 200 pF and 220 pF for the p- and n-side, respectively, for most of the strips and detectors. The C_{cpl} over inter-strip capacitance (C_{is}) ratio has been imposed ≥ 20. Such a ratio minimises the crosstalk between the neighbouring strips which is strip-width dependent in a complicated manner. According to simulations giving C_{is} as a function of the width of the strips (for 95 µm pitch), it justifies a requested strip-width value of 25 - 40 µm. The bulk capacitance (C_b) was measured versus the bias voltage (V_b) to examine the full depletion voltage of the SSD, complete depletion is obtained for $V_b \geq 40$V. The bulk (i_b) and the guard-ring (i_{gr}) leakage currents were measured versus V_b. Both increase rapidly up to V_b ~25V then level off somewhat around 1.5 and 1.8µA between 30-60V. The strip leakage current (i_s) was measured to be ~ 1.9 nA, i.e., i_b /768. It may be concluded that the SSD's could be effectively operated at V_b<55V, thus limiting the risk of voltage break-down and SSD damage, and warranting an effective detector operation with acceptable leakage currents $i_s \leq 5$nA, $i_b \leq 5$µA and $i_{gr} \leq 5\mu$A. At last the number of dead strips was found less than10 for each side of all detectors.

4. In-beam Tests of SSD's

The SSD's have been tested in-beam at the SPS with 120 GeV pions. The detectors were bonded to 12 (6 for each SSD-side) 128C read-out chips designed and developed in collaboration by the LEPSI and the IReS. These chips, described in previous papers [4, 5], are essentially characterised by 128 analog channels allowing shaping and amplification. They incorporate JTAG digital control, a pulse generator for test purpose, and run at very low power consumption (<340 µw/channel.The chips were mounted on a hybrid board and assembled with the SSD onto a test-structure [4]. This structure was placed on a spectrometer connected to a data acquisition system both previously described [6]. The spectrometer allows the tracking of the crossing particles with an accuracy of a few μm.

The residual fluctuation, around the chip-pedestal value, is considered as the noise value (n_i) characterising each SSD channel. The σ of their Gaussian distribution is typically of 540 e^- (one MiP has been taken equal to 25000 e^- in 300 μm of Si).

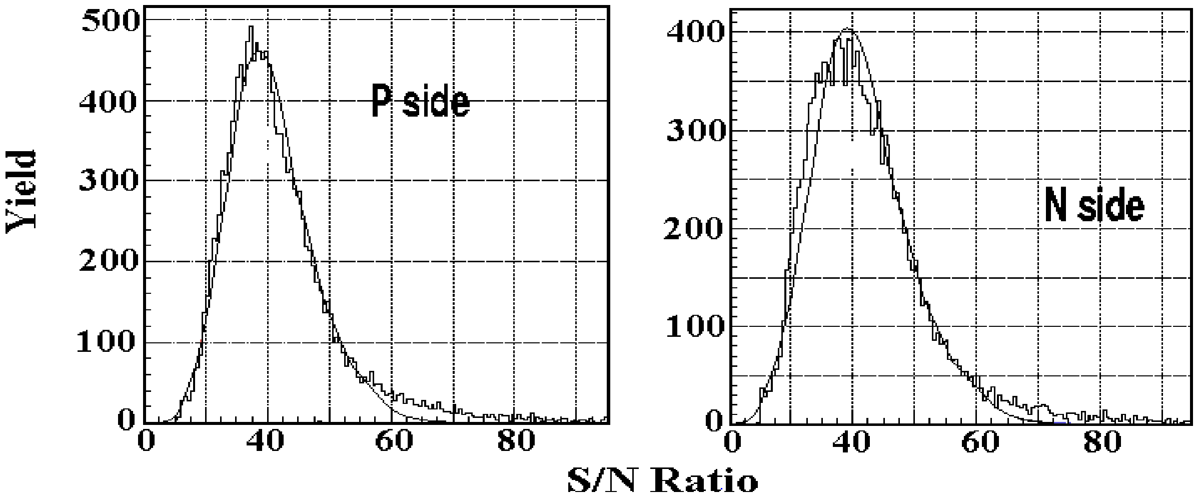
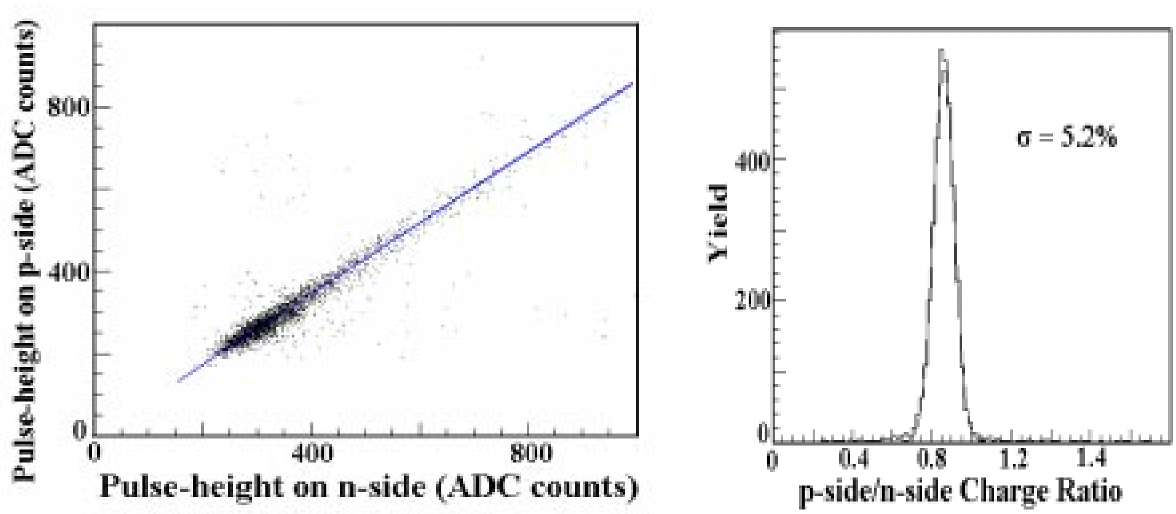


Figure 1. Signal to noise ratio disributions (histograms) for the two sides of a SSD, fitted to Landau distributions (curves).

The first step, in the analysis, consists of searching the strips having a s_i/n_i ratio exceeding a limit L_1 chosen by the user, L_1 is taken large to identify the strip clearly fired. The next step consists of repeating the operation for the neighbouring strips with another limit $L_2<L_1$. All these strips define a cluster of n_s strips, typically, n_s =1.6. These L values, used throughout the analysis, have been optimised from a recurrent analysis implying a detection efficiency of



99%.

Figure 2. Charge matching in a SSD ; on the left part the pulse-height on the n-side is plotted against that on the p-side, on the right part the ratio of collected charge on the p- over the n-side is displayed, the measured distribution (histogram) is fitted to a Gaussian (curve) for which σ = 5.2%.

Once a cluster of strips has been determined, a signal and a noise value are currently calculated

as $S=\Sigma s_i$ and $N=\Sigma n_i/n_s$, respectively, for these clusters. An example of S/N, measured for the two sides of a SSD, is shown in Figure 1. The distributions are Landau shaped, and exhibit a maximum around S/N~40 for each side.One virtue of a double-sided SSD is to allow the correlation of charges collected on the two sides, thus lowering multi-hit ambiguities. An example of this charge matching is presented in Figure 2, it corresponds precisely to the case shown in Figure 1. The pulseheight of the p-side is plotted versus that of the n-side in the left part of the figure, while the right part shows the distribution of the ratio p-side/n-side pulseheight. The standard deviation σ of the Gaussian fitting the measured distribution is equal to 5.2%, it is typical of all the tested SSD's.

The spatial resolution may be calculated from the residual difference between the measured position of the hit on both sides of the SSD and that determined from the tracking offered by the spectrometer. It should be kept in mind, that due to the stereoscopic angle, the hit position

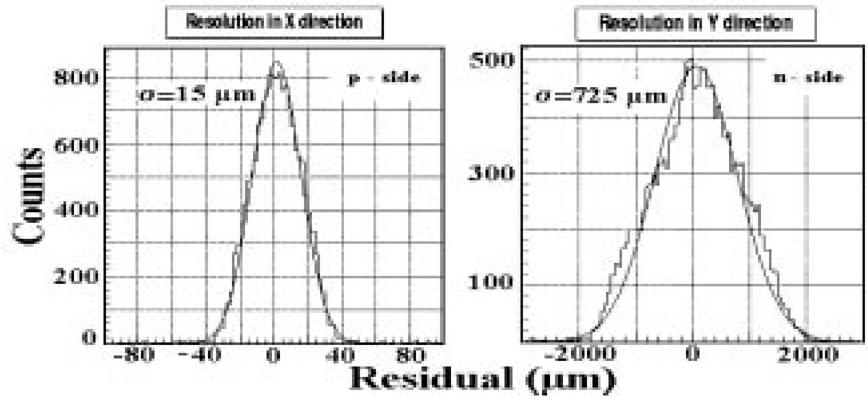


Figure 3. Calculated residual distributions (histograms) in the *x* direction (left) and in the *y* direction (right), the distributions are fitted to Gaussians (curves).

is initially determined in a (*u*, *v*) referential, rotated by 17.5 milliradians with respect to (*x, y*). The residuals x (orthogonal to the beam axis) and y (parrallel to the beam axis in ALICE) are shown in Figure 3 (coherent with figures 1 and 2) for the p- and n-side of a SSD. They are typically of 15 μm in the *x*(rφ) direction, and of ~ 750 μm in the *y* (*z*) direction.

5. Conclusion :

Four double-sided SSD's, from two different manufacturers, associated with read-out chips, all prepared at the general ALICE specifications, have been tested off- and in-beam.. The performances of these modules satisfy the ALICE requirements and indicate that the fixed milestone has been fulfilled. On this basis, 320 modules are going to be produced and assembled in the near future, to build an outer layer of double-sided SSD's (7), around the SVT of the STAR detector.

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