Silicon Drift detectors are nowadays being used in ultrarelativistic heavy-ion experiments at CERN-SPS to detect charged particles at midrapidity. For 158 A GeV Pb+Pb central collisions particle density in most populated part of detector reaches up to 100 particles/cm². For reliable interpretation of detector data it is thus necessary to analyze in detail effects of high particle occupancy on detector efficiency and precision of hit position reconstruction.

1 Silicon Drift Detectors

Silicon Drift detectors (SDDs) are two dimensional position sensitive detectors of charged particles where one of the particle’s hit coordinates is deduced from a drift time of the generated electron cloud in fully depleted bulk of the detector. Second coordinate of the hit is determined from partition of generated charge between segmented anodes. One advantage of the SDDs is that two dimensional information on hit coordinates can be obtained using just a one dimensional readout electronics. Second advantage is their very high position resolution reaching \( \approx 20 \) \( \mu \)m in both dimensions.

Principle of the Silicon Drift Detector was first described and implemented by Gatti and Rehak [1]. Ionizing particles and soft X-rays produce during their passage through the detector electron-hole pairs. For the case of Minimum Ionizing Particles (MIPs) passing through 300 \( \mu \)m thick Si-wafer about 25 000 of electron-hole pairs are generated. Full depletion of the detector bulk is accomplished by suitably chosen electrical field applied on reverse biased rectifying P-N junctions placed on both sides of the detector wafer. While electric field attracts holes to the closest P junction, electrons within few tenths of ns move to the center of wafer and drift over distances up to 35 mm towards collecting anodes. Since anode capacitance is very low (\( \approx 400 \) fF) introduced noise is also very low. Thus a high charge sensitivity of the detector is guaranteed.

Due to their high position resolution SDDs are nowadays used as tracking and charged particle multiplicity detectors in high multiplicity environment which is encountered in experiments with ultra-relativistic heavy ions. Depending on their implementation these detectors appear in different geometries. In fixed target experiments CERES [4] and WA98 on the SPS accelerator at CERN [3] they have usually a radial form. They will constitute a substantial part of future tracking systems of next generation of ultrarelativistic heavy ion experiments ALICE [2] (at CERN-LHC) and STAR (at BNL-RHIC).
2 Signal formation in SDD

2.1 Dynamics of charge transport in SDD

Passage of the minimum ionizing particle generates in 300 $\mu$m N-type Silicon on average 25000 electron-hole pairs along the particle track. This value fluctuates obeying the Landau distribution. Generated holes are collected on nearest P-N junctions, electrons drift rapidly towards the center of Silicon wafer. Within 30 ns electrons form a cloud in the center of the wafer and drift in the constant electrical field towards the anode. Evolution of the initial charge distribution is determined by diffusion and repulsion of electrons and by geometry of the drift field [6]. In the case of the radial SDD the drift field has radial symmetry and due to this fact dimensions of the charge distribution in tangential direction are magnified by factor $r_A/r_h$, where $r_A$ is diameter of the anode and $r_h$ is a diameter of the particle hit.

The drift speed of electrons is determined by relation

$$v_{dr}(r) = \mu \cdot E(r),$$

where $\mu$ is electron mobility and $E(r)$ is a local electrical field. In the ideal case of constant electrical field we obtain the constant drift speed. In reality the electrical field can vary due to defects in high voltage distribution or near calibration charge injection structures which must be polarized in a different way than the regular drift strip junctions. Due to this field variation also the drift speed changes locally. In this case special position reconstruction algorithm must be used otherwise we obtain artificial structures in radial particle distributions. Radial density of particles corresponds to local drift speed because

$$\frac{dN_{ch}}{dt} = \frac{dN_{ch}}{dr} \frac{dr}{dt} = \frac{dN_{ch}}{dr} v_{dr}(r)$$

and if we assume, during the position reconstruction, constant drift speed, local increase of drift speed corresponds to increase in reconstructed radial particle distribution.

After the drift in the center of detector wafer electrons are finally near anode deflected towards the anode $N^+$ contact. Anodes of radial SDDs are interlaced so that even signals produced by hits near anode are registrated on two anodes. This charge splitting can be used for precise determination of azimuthal position of the particle hit if we calculate the center of mass of registrated charge.

During the drift approx 2% of generated charge is lost in recombination processes or trapped on 1 cm of drift [7].

2.2 Influence of readout electronics on detector performance

Speed and noise of the readout electronic chain are parameters determining widely detector performance. Noise level determines the zero suppression threshold. It's influence on reconstruction of deposited charge will be described below. Shaping time of the preamplifier-shaper determines together with drift speed the whole