CHAPTER 10: SUMMARY, CONCLUSIONS & PROSPECTS

Over the last two decades, silicon detectors have become one of the standard tools for experimental physics. Presently, a large variety of Silicon detectors are in use in high-energy and heavy-ion experiments. New designs are constantly being developed and tested in the experimental environment. In parallel, the associated front-end electronics have become smaller and faster further improving the geometry for tracking detectors. The SVT detectors and electronics described in this thesis are good examples for the most recent achievements in trying to optimize the detector/electronics system required for high precision experiments

Tracking detectors in fixed target and collider experiments require large detection area with high position resolution. Traditional position sensing Silicon detectors such as microstrip or pixel detectors can provide relatively large coverage and good position resolution, however, the number of readout channels increases proportionally with the detector area. Silicon Drift Detectors provide unambiguous two-dimensional position information, with a pseudo one-dimensional readout thus reducing the amount of electronics considerably. In addition, low anode input capacitance allows the precise measurement of low energy signals, such as MIP particles. The high spatial resolution with cost effective granularity makes these devices ideal as tracking detectors. Figure 10.1 shows the area coverage of vertex and tracking detectors according to the main technologies developed in the last two decades. Silicon Drift Detectors have comparable area coverage to the Active pixel detectors and the CCD based detectors, however, the number of readout channels is an order of magnitude smaller. Compared to Microstrip detectors, the Silicon Drift Detectors have the advantage of no ambiguity in the position information, which facilitates two-dimensional tracking with a single layer detector. The next few decades of fundamental physics research will show whether Silicon Drift technology can compete with more established Silicon Strip and pixel detectors.

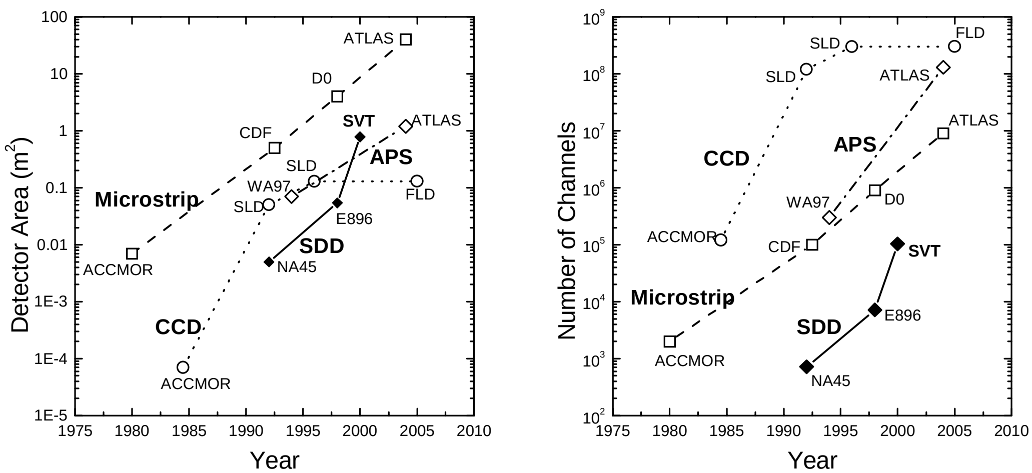

Figure 10.1: *Time development of area coverage and number of channels of the leading-edge vertex tracking detectors, according to the main technologies: Microstrip, Charged-Coupled Devices, Active Pixel Sensors and Silicon Drift Detectors.*

As a first step towards an integrated tracking system, based on silicon detectors, a large area Silicon Drift Detector was developed for the STAR/SVT experiment. The final detector design exhibits a minimized inactive area in order to maximize tracking efficiency. The focusing region was optimized to improve charge collection. In the development of the final design, the aim was not only to optimize the detector performance, but also to make the detector sufficiently robust to increase production yield. Tests in the laboratory, such as laser drift curves and anode leakage current measurements show that the detector exhibits excellent position resolution and low noise levels. To monitor and calibrate the drift velocity, charge injection structures were implemented on the detector. Different charge injection methods were tried and have shown different response. The MOS type injection was chosen for the final design, due to its satisfactory response without introducing any additional current into the detector.

15 Silicon Drift Detectors were assembled and used as a tracking device in the heavy-ion BNL/AGS-E896 experiment. Preliminary analysis results show good detector performance, low noise levels, and no evidence of charge recombination. The good agreement between the hit occupancy on the detector and simulation results indicates no hit inefficiency. The broad range of the integrated charge spectrum shows that the detector and its corresponding front-end electronics have a good dynamic range, being capable of measuring particles hits via charge deposition from a MIP to over 20 MIP's. The total number of dead channels in the E896 array was around 1%, 80 anodes out of 7200, which is below the SVT requirement of a maximum of 2% bad channels. Magnetic field studies show that the SDD's operate satisfactory in a large magnetic field environment. A decrease of the drift velocity due to the magneto-resistance effect was observed and parameterized.

Large scale fabrication of detectors has started aiming to produce at least 250 "good" detectors for the SVT. Due to the large quantity of wafers and the high quality requirements of the SVT, a non-destructive testing procedure was developed to characterize and select the wafers to be used in the SVT.

Aside from the application in particle physics, Silicon Drift Detectors can potentially be used in a wide variety of different areas such as in X-ray spectroscopy, applied science and imaging. Detector technology is a very exciting area, where new ideas arise every day, always aiming to improve detection capabilities and efficiency or discovering new applications for these detectors, all to supply the extremely demanding urge of experimental physics to pursue new discoveries. Physics theories have become considerably complex so that experiments have to be very specific and specialized, however, detectors should be made as general as possible, in order to be open for new physics discoveries and to be usable in many different applications.

This thesis documents the complete history of the STAR Silicon Drift detector development from the late stages of design considerations to the final detector, ready for mass production. It details the specifics of the final design, the main reasons that led to the final design and it documents the tests that were developed to determine the quality of a drift detector. It finally demonstrates the first application of drift detectors in a tracking device. The first set of physics results, in terms of particle multiplicity and charge deposition were successfully compared with simulations that are known to describe the physics of Relativistic Heavy Ion collisions quite well. In addition, those measurements were used to draw further conclusions on the detector performance in terms of hit efficiency, charge collection efficiency, dynamic range, and application of drift detectors in strong magnetic fields. Based on all the results shown here, we conclude that our goal to design a reliable new tracking device based on Silicon Drift Detectors has been achieved and that the relevant physics in future Heavy Ion Collider experiments, starting with STAR, is well within reach of the developed technology.