Part II

Requirements

Chapter 3

Executive Summary

Last Updated: 15 June 1995

The purpose of the SVT is to extend STAR tracking to the lowest achievable momenta and to identify short lived particles decaying before they reach the inner layers of the TPC. The SVT therefore needs to be as close as possible to the primary vertex while maintaining a reasonable radial coverage. It must also have an excellent position resolution to permit accurate tracking and vertexing and it should be as light a mass as achievable to minimize scattering of particles, gamma-ray conversion and the generation of background within the detector. In addition, the detector must also handle large occupancy although the number of electronic channels should be limited to minimize the cost. Semi-conductor drift detector technology has been shown to permit excellent spatial resolution, to handle quite large particle occupancy and to require a small fraction of the number of electronic channels of an equivalent spatial resolution pixel detector. The inherent slow readout time of semi-conductor drift detectors is still a factor of 10 smaller than the TPC drift time and therefore does not impose any limitations on the experiment. Solid state drift detectors appear to be the optimal technology for a STAR microvertex detector. Table I gives summary information for the SVT.

Table I: *Description of the proposed Silicon Vertex Tracker for STAR.*

Silicon Vertex Tracker	
length (active area)	42 cm (max.)
Inner Barrel (radial distance)	5.97 cm
Middle Barrel (radial distance)	10.16 cm
Outer Barrel (radial distance)	14.91 cm
Thickness of wafer (SDD)	300 μm
Total Thickness	900 μm $\sim$ 0.9% X_o
Number of wafers	216
Inner Barrel	32 (8$\times$4)
Middle Barrel	72 (12$\times$6)
Outer Barrel	112 (16$\times$7)
Diameter of wafer (SDD)	10.16 cm = 4 in
Length of wafer (SDD)	6 cm
Width of wafer (SDD)	6 cm
Drift Length of wafer	3 cm
Average Drift Time	3 μs
Time Samples	128
Sampling Rate	27 MHz
Anode Pitch	250 μm
Number of Channels	103680
Position Resolution	$<$ 25 μm

Chapter 4

Geometry

Last Updated: date

4.1 Location

Requirement:
Placed near the collision vertex.

Justification:
One purpose of the SVT is to identify production of multi-strange and short-lived neutral particles through observation of their decay modes. In order to do this it is necessary to identify secondary vertices. This implies that the detector must have excellent position resolution *as well as be* very close to the collision vertex.

Status:
The SVT design as specified in **Chapter 22** has 3 layers of SDDs positioned between 6 – 15 cm from the beam axis (see Table I).

4.2 Shape and Pseudorapidity Coverage

Requirement:
Cylindrical symmetry with full azimuthal coverage and a large pseudorapidity coverage about midrapidity.

Justification:
One purpose of STAR is to study global observables for relativistic Au + Au central collisions. One variable in these studies will be pseudorapidity. Fluctuations and

statistics are also very important for the event-by-event physics to be done by STAR, and such studies require the largest possible pseudorapidity coverage. The TPC is designed to do full tracking for the pseudorapidity range $-1 \geq \eta \leq 1$ and full azimuthal coverage. Since the SVT is to complement and enhance data taken with the TPC, it is clear that the same pseudorapidity region should be covered if possible. In addition, the new physics provided by the SVT alone will have very small cross sections so that the largest pseudorapidity coverage possible should be implemented.

Status:
The SVT design (see Table I) provides full azimuthal coverage for $-1 \geq \eta \leq 1$. See also **Chapter 22**.

4.3 Number of Layers

Requirement:
A minimum of three layer is required for the SVT.

Justification:
A minimum of three space points is required to determine track parameters when the track is in a uniform magnetic field.

Status:
The SVT design as specified in **Chapter 22** contains 3 concentric barrels of SDDs (see Table I).

Chapter 5

Performance

Last Updated: date

5.1 Particles Detected

Requirement:
The SVT must detect charged particles from minimum ionizing to 20 $\times$ minimum ionizing.

Justification:
This is the range expected based on output from event generators such as FRITIOF.

Status:
The SVT design as specified in **Chapter 22** allows a dynamic range of 40:1.

5.2 Momentum Range

Requirement:
Pions with initial transverse momenta of 50 MeV/c (within $|\eta| \leq 1$) must penetrate all 3 layers of the SVT.

Justification:
The TPC momentum cut off is about 150 MeV/c. A 50 MeV/c lower limit gives a significant enhancement to STAR's capabilities.

Status:

The SVT design as specified in **Chapter 22** will detect pions of momenta 50 MeV/c.

5.3 Occupancy

Requirement:

Occupancy in the first layer of the SVT should be less than 3.5% for central Au + Au events (FRITIOF).

Justification:

Large occupancy will affect quantities such as efficiencies for tracking, track matching efficiencies, momentum resolution, particle identification, and two two-track resolution. This in turn will affect the quality of the physics produced by the experiment. Simulations for the SVT have shown that for a central Au + Au (FRITIOF) event the inner layer average occupancy is about 3.5% and that this occupancy does not degrade the performance of the detector.

5.4 Position Resolution

Requirement:

The overall experimental position resolution provided by the SVT should be < 25 μm for both transverse directions.

Justification:

The fundamental requirement for a vertex detector is excellent position resolution. Silicon drift detectors have been developed with intrinsic position resolution of 10 μm for both transverse directions. Position resolution determines the ultimate accuracy of secondary vertex finding, two-track resolution, momentum resolution, and efficiencies. Simulations have shown that a position resolution of 25 μm is adequate for the SVT.

Status:

STAR has a large SDD Research and Development program that is producing prototype SDDs with such position resolution.

5.5 2-Track Resolution

Requirement:
Two track resolution of 300 μm

Justification:
The ability to do HBT physics requires excellent two track resolution since the two particle correlation function is most sensitive to source size for small values of relative momentum.

Status:
SVT simulations have shown that the same position resolution achieved for a single track is achieved for two tracks for track separation > 300 μm.

5.6 Radiation Length, Multiple Coulomb Scattering, Energy-Loss

Requirement:
The average radiation length for all SVT material between the beam line and the full tracking region of the TPC should be 3.5% or less. Multiple Coulomb scattering and energy-loss should not degrade the performance of the SVT.

Justification:
A low-mass SVT allows the detection and tracking of charged particles to smaller momenta than possible with the TPC. Multiple Coulomb scattering and energy loss effects are directly proportional to the amount of mass particles traverse. These effects, in turn, affect position resolution and the quality of particle identification, tracking precision and track matching efficiencies.

Status:
The present SVT design leads to an average radiation length of 3.5%. The low momentum cutoff for tracking and particle identification is extended down to 50 MeV/c.

Chapter 6

Effect on Other STAR Detectors

Last Updated: date

Requirement:
The SVT should not degrade the performance of other STAR detectors. The SVT should enhance the performance of the TPC in the region of overlap.

Justification:
The TPC is the baseline detector and the SVT should not affect its performance in the stand-alone mode of operation. However, when the SVT is operated together with the TPC, for the region where tracking and particle identification can be done in both detectors, the global TPC-SVT performance will be much improved (tracking, efficiency, momentum determination, and particle identification).

Status:
The present SVT design leads to a global TPC–SVT performance that is much better than that expected for the TPC alone.

Chapter 7

Electronics

Last Updated: date

7.1 Pulse Preamplification and Shaping

Requirement:
Electronics near the silicon drift detectors are required for preamplification and shaping of the signals from the anodes. These electronics must handle the dynamic range (20:1) of signals produced by the particles of interest.

Justification:
Preamplification and pulse shaping is the first stage of electronically processing the data from silicon detectors. The signals from such detectors are small (a few mV) and effort must always be made to place the initial electronics as close as possible to the detector. Minimum requirements for satisfactory performance of the electronics must be explicitly stated. Simulation studies determine the effects of signal to noise, cross talk, etc., on the final information extracted from the detector.

Status:
A preamp and shaping amplifier (PASA) has been under design for several years. The design specifications are given in **Chapter 23**. A dynamic range of 40:1 is specified to give headroom.

7.2 Time Sampling

Requirement:

Electronics are required to time sample the preamplified and shaped signals from the SDDs. The sampling must be done such that the intrinsic position resolution obtained from analysis of the time samples permits < 10 μm position resolution.

Justification:
The time dependence of the signals from the SDD anodes is related through the SDD drift times to position.

Status:
Switch Capacitor Arrays (SCAs) (see **Chapter 23**) have been designed to provide this functionality. They are 128 time bins deep and operate at a frequency of 27 MHz. Simuilations show that the combined PASA – SCA system will perform such that the intrinsic position resolution is about 10 μm for minimum ionizing particles and SDDs of the current design.

7.3 Multiplexing

Requirement:
Minimize the number of conductors needed to take the SCA information off the detector by multiplexing signals. The system should have enough band width to pass 100 events/sec to the Readout Electronics.

Justification:
The total number of anodes of the SDDs comprising the SVT is over 100,000. It is not practical nor economical to deal with this many electrical connections to bring data off the detector. Instead a multiplexing scheme must be developed to substantially reduce the number of conductors needed. The baseline calls for a maximum event rate of 100 events/sec into DAQ.

Status:
For the present design the multiplexing is 240:1. Specifications are provided in **Chapter 23**.

7.4 Readout/Timing and Control

Requirement:
Electronics are required outside the active volume of the detector, but as close as possible to the SVT (a few meters away), to perform the following functions:

(1) timing and control of SCA readout, (2) receive the multiplexed analog signals from the SDDs and perform analog to digital conversion, (3) send data to data acquisition, (4), receive, interpret, and act on information provided by Trigger Electronics, and interact with a Controls system that must be designed for monitoring, readout board configuring, testing, etc. The Readout Electronics must be able to process and send digitized data to DAQ at 100 events/sec.

Justification:
The data must be taken off the detector, digitized, and sent to DAQ. DAQ is designed to receive 100 events/sec.

Status:
A prototype Readout Board has been designed and is under construction.

Chapter 8

Interfaces

Last Updated: date

Requirement:
The SVT subsystem must have interfaces to Trigger, DAQ, and Controls.

Justification:
These are the interfaces used for the TPC. The SVT will use the same kind of interfaces.

Chapter 9

Data Acquisition

Last Updated: date

Requirement:
A data acquisition system capable of receiving data at 100 events/sec.

Justification:
The STAR DAQ Requirements specify a maximum event rate into DAQ of 100 events/sec.

Status:
SVT DAQ requirements are contained in the STAR DAQ Requirements Document. The SVT DAQ requirements are essentially the same as those for the TPC.

Chapter 10

Hardware Controls

Last Updated: date

Requirement:
Temperature monitors, voltage monitors, current monitors, and position monitors must be used to insure the validity of the data. Controls for detector configuration, setting voltages, setpoints, etc. are required.

Justification:
The monitoring of voltages and currents insures that the proper power is being provided the electronics. Temperature gradients across the SDDs lead to non-linearities in SDD response. The SDD drift velocity is temperature dependent. Voltages and set points always have to be changed during experiments.

Chapter 11

Mechanical

Last Updated: date

11.1 Support Structure

Requirement:
statement of requirement

Justification:
statement of justification

11.2 Cooling System

Requirement:
statement of requirement

Justification:
statement of justification

11.3 Assembly

Requirement:
statement of requirement

Justification:
statement of justification

11.4 Installation

Requirement:
statement of requirement

Justification:
statement of justification

11.5 Alignment/Position

Requirement:
statement of requirement

Justification:
statement of justification

Chapter 12

Integration

Last Updated: date

12.1 Space

Requirement:
statement of requirement

Justification:
statement of justification

12.2 SVT–Water/Air

Requirement:
statement of requirement

Justification:
statement of justification

12.3 SVT–TPC

Requirement:
statement of requirement

Justification:
statement of justification

Chapter 13

Software

Last Updated: date

13.1 On-Line Software

Requirement:
Develop all software required for on-line data acquisition. This software must include interface software when required (e.g., software to download software to embedded processors). Specifically, develop software for the following tasks: setting up and configuring the SVT, SVT SVT data acquisition modes, L3 Trigger, data acquisition, event building, run control, quality control, monitor, diagnostics, alarm/safety, calibration/alignment, on-line analysis, on-line event display, and job control.

Justification:
STAR and the SVT are flexible systems whose components require careful set up and configuring. The hardware associated with the SVT must be controlled and monitored. Safety/alarm systems are necessary to protect personnel and equipment. A successful experiment of the complexity of STAR requires on-line quality control, monitoring, and diagnostics. It will be necessary to do careful calibration/alignment as well as some data analysis on-line to insure that the SVT is working properly. Each of the above is most effectively done through use of state-of-the-art software. In addition, because of the complexity of these competing on-line tasks, job control software is needed to schedule tasks and priorities.

13.2 Off-Line Software

Requirement:

Develop all SVT-related software that is required for SVT design and simulations. Develop off-line calibration/alignment software. Develop software required for event reconstruction and data analysis. Develop software for physics analysis.

Justification:
The SVT is distinct from the TPC and the other STAR subdetectors. The SDD's are novel silicon detectors and the design work must be done carefully. The performance of the SVT must be evaluated through a vigorous program of STAR simulations where the SVT is present. The ability of the SVT to enhance STAR's event reconstruction capabilities must be demonstrated. It must be demonstrated that the SVT is capable, in principle, of making the measurements discussed in the **Introduction**. The data must be analyzed off-line to search for new physics.

13.3 Infrastructure Software

Requirement:
Develop software for Data Management and Calibration Management. Document all SVT software used by STAR.

Justification:
An experiment of the complexity of STAR with an SVT requires very careful attention to the **Software Infrastructure**. The experiment will be successful only if very special attention is given to the management of all data. Because of the large number of people at different institutions who will work on different SVT software tasks, and because people will be leaving and joining the effort over the years, it is particularly important to generate good documentation for the software.

Chapter 14

Feasibility

Last Updated: date

Requirement:
It must be demonstrated that it is technically feasible to build the SVT.

Justification:
Large area SDDs are new technology and it has to be demonstrated that they can be mass-produced. Integrating many hundred SDDs into a compact device is no trivial task. In particular, the front-end electronics (PASA and SCA) need to be compact and carefully designed.

Status:
An SVT Research and Development program has been underway for several years, and a systems test will be done during Spring 1996 using prototypes of the components that are critical for establishing that it is technically feasible to build the SVT. A detailed System Test Requirements Document has been written.

Chapter 15

Affordability

Requirement:
Last Updated: date

An estimate of the final cost of the SVT should be kept as up to date as possible.

Justification:
It makes no sense to design something that is too expensive to build.

Status:
A cost estimate for the SVT is given in **Part VII**.

Chapter 16

Safety

Last Updated: date

Requirement:
Safety considerations must be kept in mind during all phases of the SVT project. All relevant safety codes and regulations will be observed.

Justification:
No one should be injured in working on the SVT. Equipment should be interlocked based on safety concerns for both people and equipment. Protecting the SVT from damage is a primary concern.

Chapter 17

Planning and Schedule

Last Updated: date

Requirement:
A well thought out plan and schedule must be made for the SVT project.

Justification:
All large projects are very complex, utilize considerable manpower, are expensive, and take a long time. Successful execution and completion of such projects require planning and scheduling.

Status:
Schedules are provided in **Part VII**.