Chapter 5

Inner Detectors

5.1 Silicon System Overview

The PHENIX experiment contains a set of detectors close to the collision point to provide event characterization, a centrality trigger, the collision vertex position along the beams and the time-of-flight start. The interaction detectors also measure fluctuations in the charged particle distributions. The detectors consist of a silicon detector subsystem comprising silicon strips and pads, and two arrays of beam-beam counters at either end of the experiment that measure the time-of-flight of forward particles. A combination of these detectors provides the event trigger, centrality trigger via multiplicity, and the vertex position at moderate resolution at the trigger level. The information derived from each detector type is summarized in Table 5.1.

Table 5.1: Capabilities of Interaction Detectors

Subsystem/ Coverage	TOF Start	Vertex	Multipl.	Central Trigger	$dN/d\eta$	Fluctuations
Beam-beam $\|\eta\| = 3.1 - 4$	σ <100 ps each tube	$\sigma \approx$ 1–2 cm For LVL-1 Trigger				
Si Strips $\|\eta\| \leq 2.5$		$\sigma < 2$ mm	yes	For LVL-1 Trigger	yes	$dN/d\eta$
Si Pads $\|\eta\| = 1.8 - 2.65$			yes	For LVL-1 Trigger	yes	$dN/d\eta$ $dN/d\phi$

The Silicon detector system has been changed since the pCDR to upgrade its capabilities while reducing the cost by integrating the role of multiplicity array and vertex detector into one system. The purpose of the detectors are:

1. To localize the vertex position along the beam axis to 2 mm at trigger Level 2 with high efficiency (> 90%), even for low multiplicity (p + p) events. This device will complement the beam counters and enable us to find a start time, t_0, for the time-of-flight measurement even if the beam counters are hit only on one side, as will happen sometimes in p + p or minimum bias p + A events.

2. To generate the on-line first level centrality trigger by measuring the total multiplicity.

3. To give $d^2N/d\eta d\phi$ over a large range on an event-by-event basis for fluctuation studies.

The silicon detector system, also called the "multiplicity/vertex detector" (MVD), is composed of two parts: two endcaps and two concentric central barrels. Figure 5.1 shows a schematic layout of the barrels and one of the two endcaps. Single-sided silicon strip detectors have been chosen because they offer ease of construction, reliability, and low cost in our compact, high granularity subsystem design. The central barrels have radii of 5 cm and 8 cm and a length of 64 cm, giving a single event coverage of 5 units in η about midrapidity for the inner barrel layer and 4 units for the outer layer. The variation of the vertex position along the beam (z) direction extends this reach for event-averaged quantities. The barrels are composed of 5 cm and 8 cm long strips for the inner and outer barrel, respectively, with a pitch of 200 μm, oriented perpendicularly to the beam. The disk-shaped endcaps, located at z positions of ± 35 cm, reach a pseudorapidity of 2.7 for an event occurring in the middle of the detector and are composed of pads ranging in size from approximately 2×2 mm^2 to 5×5 mm^2. The total silicon channel count is 43,008, including both pads and strips.

Vertex finding can be done with good efficiency using the hits in the central barrel for z positions up to ± 40 cm. This is approximately the $\pm 2\sigma$ length of the luminous region.

The multiplicity trigger is formed using an analog sum of charge deposited on the silicon detectors. Analog sums from the endcaps alone, and also from the central barrel, allow formation of multiplicity triggers from different ranges of pseudorapidity.

The beam-beam (BB) counters provide the start for the time-of-flight (TOF) subsystem and also the vertex position with moderate resolution. They consist of two arrays of Cherenkov counters with solid radiators and photomultiplier tube readout. The counters are clustered around the beam pipe outside the central magnet poles, and intercept particles at large rapidity. This detector sub system will utilize the same electronics as the TOF subsystem, as it provides an integral part of the TOF measurement for particle identification.

In the rest of Chapter 5, we present the MVD technical, performance, cost, and schedule details, followed by the same format for the BB arrays.

5.2 Silicon Detector Layout

5.2.1 Silicon Strip Detectors

The silicon barrels consist of 300-μm thick AC-coupled FOXFET (Field Oxide Field Effect Transistor) silicon wafers, with strips oriented perpendicular to the beams, as indicated in

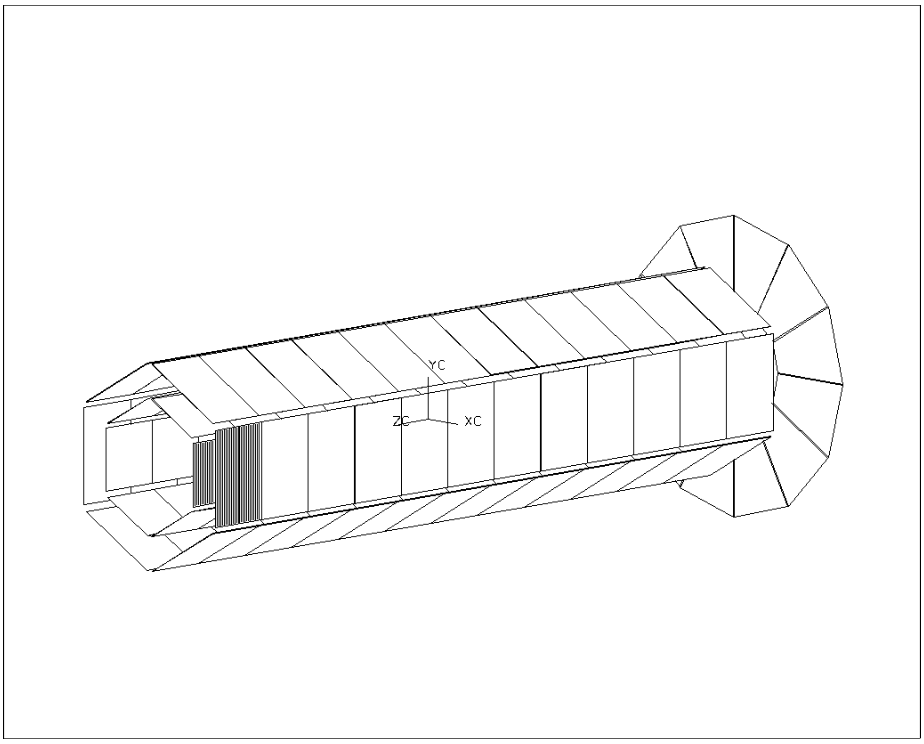

Figure 5.1: Layout of silicon detectors for multiplicity and vertex measurements.

Fig. 5.1. There are two sizes of detector wafer, which are fabricated from 4 in. silicon blanks. The inner (outer) barrel consists of detector wafers which are 5.3×5.0 (5.3×8.0) cm^2. The strip pitch on both detector sizes is 200 μm, yielding 256 channels per wafer. The total number of channels in the barrels is 36,864. The detector types, number of wafers, and channel counts are summarized in Table 5.2. The large pitch, which is acceptable in our application as we do not require precise track information from the silicon, greatly reduces the technical challenges of bonding detector wafers to front-end electronics and limits the channel count. The silicon detectors are arranged in azimuthal sectors consisting of 12 detector wafers along the beam (z) direction. There are six azimuthal sectors in each barrel.

The silicon barrels are designed to cover full azimuth, which is required for good vertex finding efficiency in low multiplicity collisions such as p + p or p + A. However, in the high multiplicity environment of central Au + Au collisions, it is possible that the additional conversion electrons from the silicon and electronics combined with the Dalitz electrons may raise the combinatorial background of electron pairs to an unacceptable level. We may opt to collect data for these collisions with only a subset of the azimuthal sectors. Two of the six azimuthal sectors fit in the region outside the electron arms. Full Monte Carlo studies of the background electrons arising in this geometry are underway using the PISA code, which allows simultaneous simulation of the silicon detector and electron arm subsystems and incorporates magnetic field effects, as described in Chapter 3. The current results,

Table 5.2: Silicon Detector Channel Count

Detector Type	Size (cm^2)	ϕ sectors	z sectors	Total Channels
Inner Barrel	5.3×5.0	6	12	18,432
Outer Barrel	5.3×8.0	6	12	18,432
End Cap	6.3×7.0	12	2	6144
Total				43,008

shown below, indicate that two azimuthal sectors should be acceptable in central Au + Au collisions, and that their vertex-finding capability is adequate, due to the large multiplicities in such events.

5.2.2 Silicon Pad Endcaps

The endcap detectors cover a pseudorapidity range between 1.8 and 2.65 on either side of the collision region for vertices at $z = 0$. Each endcap (see Fig. 5.1) is composed of 12 "sectors", each "sector" being manufactured from a single 4 in. silicon blank. The inner radius of each sector is 5 cm and the outer radius is 12 cm. The pads range in size from 2×2 mm^2 in the innermost ring to about 5×5 mm^2 in the outermost ring of pads, and are nearly square in shape. The azimuthal segmentation $\Delta\phi$ ranges from 2.3° to 2.5°. The dimensions were chosen such that the highest occupancies for central events are 0.35–0.46 for events with $dN_{ch}/d\eta = 1500$. The η segmentation is more than adequate for studies of fluctuations; the occupancy effects on fluctuation studies are discussed below. The azimuthal segmentation, along with the full azimuthal coverage makes it possible to do two-dimensional studies of fluctuations as well. The number of channels in the endcaps is 6144, as summarized in Table 5.1.

One of the important design considerations was that the silicon layout allow the same hybrid electronics to be used for both the barrel and the endcaps. The pads are connected to the electronics located on the outer perimeter of the endcap via kapton cables. As in the barrel, one detector wafer is connected to each hybrid; more details on the cabling are given below. The barrel and endcap detectors also share an overall support structure, cooling scheme, trigger and readout electronics design.

5.3 Mechanical

5.3.1 Overall Support Structure

The support structure for the MVD uses minimum material to avoid creating background electrons from photon conversions, yet has very high rigidity to keep the silicon detector sectors located with respect to one another. Furthermore, the support structure must have a very small coefficient of thermal expansion. Consequently, we have chosen to fabricate

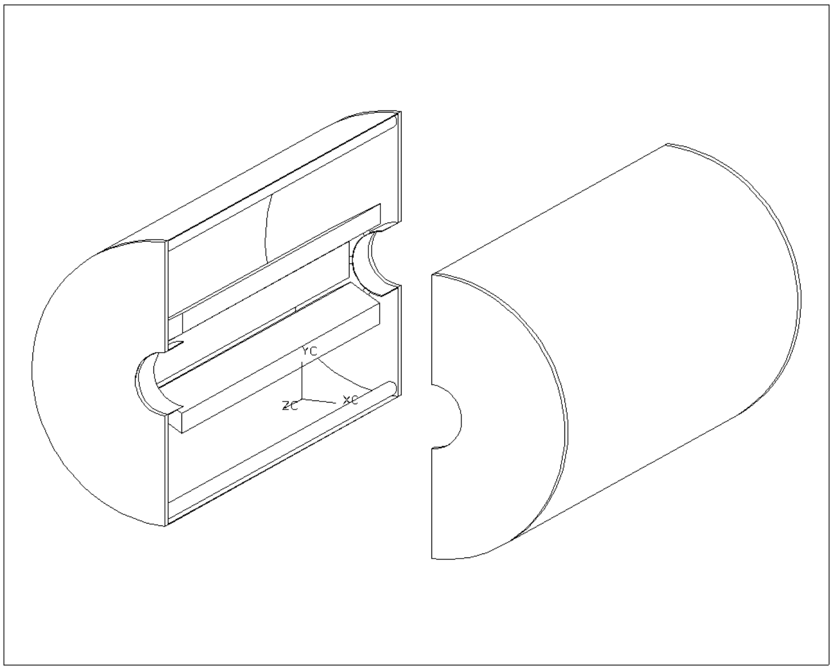

Figure 5.2: Cutaway view of the silicon support/enclosure half-cylinders.

the main structural elements of the MVD support from a graphite fiber resin matrix. This graphite composite system is similar to that being developed to support the SDC central tracker [1]. The SDC leading resin candidate is a cyanate ester, which has low moisture absorption and thus low variation with humidity level. This material exhibits a high stiffness to weight ratio as well as a large effective radiation length of 25 cm.

The support structure uses struts which are thin tube-shaped elements made by the heat-curing of wrapped B-Staged graphite cloth. The cross section of the tube approximately 1 in. in diameter, with the thinnest wall thickness consistent with adequate structural strength.

The MVD is contained in two half cylinders, each half cylinder being composed of graphite-composite emdplates and three of the struts described above. This separation into half cylinders is necessary to allow installation of the detectors around the beam pipe. The endplates provide vertical structural support, locate the struts, and support the silicon pad motherboards and other associated electronics. Upon installation into PHENIX, the endplates are bolted together to provide a single cylinder. Figure 5.2 shows the half cylinders separated, and illustrates the location of two of the three struts at the top and bottom. The third strut is located at an azimuthal angle of 116.5° below the top strut and is not visible in the drawing. The location of the struts keeps them out of the aperture of the electron arms, and allows them to be used to support the hybrid electronics circuits for the silicon strip detector readout. Note that the full barrels use the top and third struts for hybrid circuit support. The lower struts will be used for hybrid support should we run with only two azimuthal sectors for central Au + Au collisions.