# A silicon vertex tracker for PHENIX

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The PHENIX experiment will be upgraded with the Silicon Vertex Tracker (VTX). This new device will enhance the physics capabilities of PHENIX to explore the new hot and dense nuclear matter created in heavy ion collisions and proton spin structure in polarized proton-proton collisions. The vertex tracker will enable the direct measurement of heavy quark production by measuring the displaced vertex. We will build a four layer barrel detector, with two inner pixel sensors, two outer stripixel sensors, and mini-strip detectors at the end-cap region. This article will outline the physics capabilities of the new silicon tracker in the central region.

## 1. PHYSICS GOAL

The PHENIX experiment at the Relativistic Heavy Ion Collider (RHIC) accelerator complex at Brookhaven National Laboratory (BNL) has been exploring hot and dense nucler matter [1] and investigated the spin structure of protons [2].

In heavy ion collisions, heavy flavor quarks are produced by initial parton-parton scattering and penetrate the QGP. So they are expected to be a good probe to investigate the QGP. Also in polarized proton-proton collisions, open heavy flavor production will tag the initial gluons in the proton. The tagging heavy flavor quarks will enhance our physics capability. Also, good jet identification in $\gamma + jet$ events in $p$+$p$ will improve the measurement of gluon momentum fraction in protons.

## 2. REQUIREMENTS

In order to measure the heavy flavor displaced vertex, the resolution of distant closest approach (DCA) should be 40 $\mu$m, driven by $c\tau$ of 123 and 462 $\mu$m for $D^0$ and $B^0$, respectively. In addition, jet reconstruction by charged hadron tracks requires large acceptance. The VTX provides nearly full azimuthal coverage over $\mid \eta \mid < 1.2$ with good momentum resolution $\sigma(P)/P \sim 5\% \times P$. It will be able to operate under the following conditions: (1) high charged multiplicity in central Au-Au events, $dN/d\eta \mid_{\eta=0} = 687 \pm 37$ in the central rapidity region [3], (2) high radiation dose, which is estimated to be 100 kRad over 10 years of RHIC running time, (3) at high luminosity of $2 \times 10^{32}$ cm$^{-2}$s$^{-1}$ for polarized proton-proton run, data taking rate from the VTX detector should be 20 kHz,

*For the full list of PHENIX authors and acknowledgments, see appendix 'Collaborations' of this volume as required by other PHENIX subsystems, (4) material budget should be minimized in order to avoid multiple scattering for the DCA measurement and photon conversion for electron identification by outer detectors.

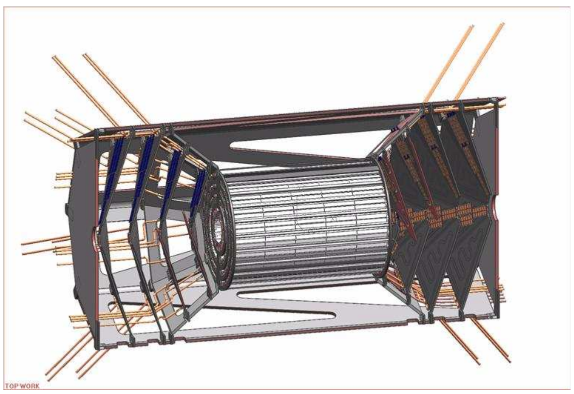

Figure 1. The PHENIX Vertex Tracker. The length and diameter are 80 cm and 40 cm, respectively.

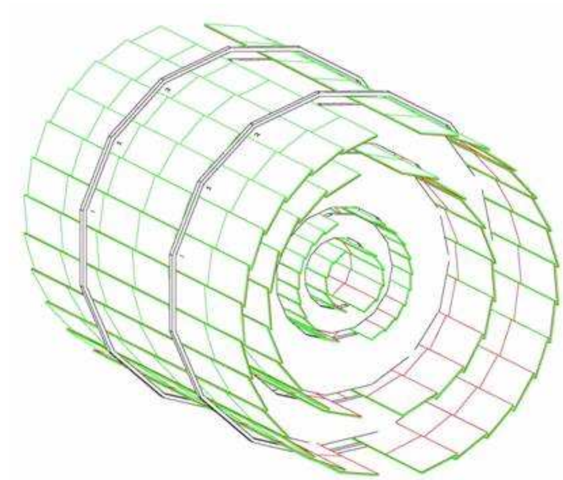

Figure 2. GEANT model of the barrel detectors.

## 3. DETECTOR

The PHENIX VTX consists of two regions, barrel and forward VTX, which cover $|\eta| < 1.2$ and $1.2 < |\eta| < 2.4$, respectively, as shown in Figure 1.

The forward detector has four layers of mini-strip silicon detector which overlap with the forward muon detectors [4]. The pixel size of the mini-strips is 50 $\mu$m in radial direction and 2.2 mm to 13 mm in $\phi$ direction. Signals will be read out by FERMILAB's PHX chips with 3 bit ADCs. There are a total of about 1.7M readout channels.

In order to avoid getting ghost hits due to the high charged particle multiplicity in central Au-Au collision, a true two dimensional readout pixel detector is used in the two inner layers. The outer two layers are stripixel detectors which are single sided 1+1 dimensional detectors. Figure 2 shows the GEANT model of barrel detectors. The radius of the beampipe will be 1.5 cm. The layers of sensors are at 2.5, 5.0, 10.0, and 14.0 cm. Table 1 describes the major design parameters of the barrel detectors. Since the magnetic field is parallel to the beam pipe and we are detecting particles in the central rapidity region, spatial resolution in $\phi$ is greater than in z. Thus the pixel size and strip pitch should be different in $\phi$ and z direction.

The pixel sensor [5] is $p^+$-in-n structure and it is 200 $\mu$m thick. A cell is defined by the $p^+$ implants on one side of the n-type silicon. The cell size is 50 $\mu$m ($\phi$) $\times$ 425 $\mu$m (z). Each sensor has $256 \times 32$ cells in a $1.28 \times 1.36$ cm$^2$ area and four sensors compose a

Table 1
Major parameters of Barrel detectors

| Sensors | pixel | | stripixel | |
|---|---|---|---|---|
| Layer | R1 | R2 | R3 | R4 |
| r (cm) | 2.5 | 5.0 | 10.0 | 14.0 |
| z (cm) | 21.8 | 21.8 | 31.8 | 38.2 |
| Readout Channel | 1,310,720 | 2,621,440 | 138,240 | 239,616 |
| Sensor size (cm) | 1.28 ($\phi$) $\times$ 1.26 (Z) | | 3.43 ($\phi$)$\times$ 6.36 (Z) | |
| Channel Size | 50 $\mu$m ($\phi$)$\times$ 425 $\mu$m (Z) | | 80 $\mu$m ($\phi$) $\times$ 3cm (Z) | |
| Radiation length | 1.2 % | | 2.0 % | |
| Occupancy | 0.53 % | 0.16 % | 4.5 % ($\phi$)<br>2.5 % ($\phi$) | 4.7 % (u)<br>2.7 % (u) |

sensor chip. Every pixel sensor is connected by bump-bonding to the matching readout electronics [6] of a readout chip, which contains preamplifiers and discriminators for each individual cell and digital FIFO for readout. In addition, all signals are OR-d in a single sensor and a FAST-OR trigger is generated. These hybrids of sensors and readout chips are mounted on a carbon-carbon composite support frame and connected to an Al-Kapton bus [7], which is glued on the top of the sensor hybrids, by wire bonding. The Al-Kapton bus connects to a SPIRO board, which multiplexes the digitized signals and FAST-OR trigger signals from the readout chips and transfers the to the front end module (FEM) via 1.6 Gbps optical links. The FEM receives these signals and feeds the into the PHENIX DAQ system [8].

The stripixel sensor [9] has strips of finely segmented (80 $\mu$m $\times$ 1000 $\mu$m) pixels. Each pixel has two spiral shaped electrodes that collect the charge produced by an ionizing particle. Each pixel is connected along the ($\phi$) direction and along the direction $u$ which is tilted by 4.6 degrees w.r.t. the $\phi$-strip. Thus it provides stereoscopic $\phi$-$u$ readout and therefore two dimensional information on a single sided sensor. The sensor is 500 $\mu$m thick. Resolution of the stripixel sensors was measured in a test beam, the obtained value of 23-25 $\mu$m agrees with expectations from the pitch of strips, which is $80/\sqrt{12}$ $\mu$m [10]. Signals from $\phi$ and $u$ strips are fed to the SVX4 chips which are developed in FERMILAB [11], then they are amplified and buffered in analog FIFO. If an event is triggered, they are digitized with an 8 bit ADC and read out.

The PHENIX VTX will be built and installed in 2009 with possible early partial implementation.

## 4. EXPECTED PERFORMANCE

The DCA resolution is estimated by GEANT simulations and the PHENIX track reconstruction program (Figure 3). Narrower peak comes from primary collision vertex, the wider peak from $D^0$ decay. Resolution is sufficient to distinguish $D^0$ decays from the primary vertex, as well as to distinguish $D^0$ from $B^0$. Jet reconstruction will improve the gluon polarization measurement in polarized proton-proton collisions. Figure 4 shows the correlation between the reconstructed and true $x$ values of the gluon in a $\gamma$ + jet event.

The radiation length of current design and hit occupancy in central Au-Au collisions at $\sqrt{s_{NN}} = 200$ GeV are shown in Table 1: they will satisfy our requirements.

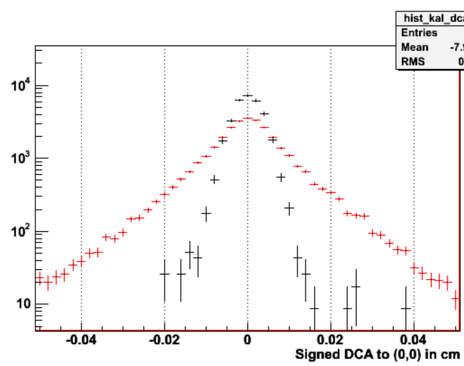


Figure 3. DCA estimated by GEANT simulation.

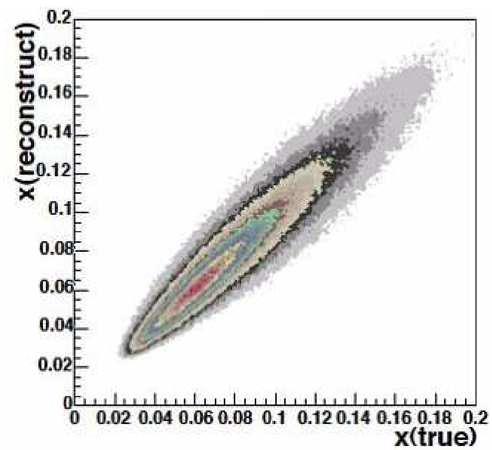


Figure 4. Correlation between reconstructed and true $x$-value of the gluon in a $\gamma$ + jet event.

## 5. CONCLUSION

The PHENIX experiment will be upgraded with a silicon vertex tracker (VTX), which will be able to tag heavy-flavor quark production in both heavy ion and polarized proton-proton collisions, and will expand our physics capabilities. The design has the required DCA resolution in the high charged track multiplicity environment.

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