Forward vertex detector upgrade for the PHENIX experiment at RHIC *

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Abstract A new forward vertex detector is under construction for the PHENIX experiment and will be installed in 2011. The device consists of two sets of four disks of silicon mini-strips and matches the acceptance of the existing muon detectors, and will provide precise vertex measurement for charged tracks. The forward vertex detector is designed to greatly enhance the heavy-flavor physics capabilities on PHENIX. The structure of the proposed device and its performance from Monte Carlo studies are presented.

Key words silicon detector, PHENIX

PACS 07.05.Tp, 07.05.Fb

1 Introduction

PHENIX (the Pioneering High Energy Nuclear Interaction eXperiment)[1] is an experiment that is running on the RHIC (the Relativistic Heavy Ion Collider)[2] at Brookhaven National Laboratory. By detecting the final particles from collisions of heavy ions at $\sqrt{S_{\rm NN}}$=200 GeV, PHENIX studies the attributes of QGP (Quark-Gluon-Plasma), a new state of matter that is believed to exist in the early stage of universe. The other physics goal of PHENIX is to study the spin structure of nucleons by colliding polarized protons at $\sqrt{S}$=200 GeV (up to 500 GeV). Since 2001, PHENIX has been running for eight years.

The PHENIX detector consists of a collection of detector, each of them performing a specific role in the measurement of results of a heavy ion collision. The detectors are grouped into two central arms and two muon arms. The central arms cover an acceptance of $-0.35< \eta <0.35$ on rapidity and 180° on φ direction, and are capable of measuring a variety of particles including pions, protons, kaons, deutrons, photons and electrons. The muon arms, including the muon trackers and muon identifiers, cover an acceptance of $1.2< |\eta| <2.4$ on rapidity and 360° on φ direction, and focus on the measurement of muon particles.

From the measurements of the large elliptic flow of light mesons and baryons and their large suppression at high transverse momentum $p_{\rm T}$ at RHIC[3], new degrees of freedom, characteristic of a deconfined QCD medium, has been convinced to drive the dynamics of nucleus-nucleus collisions. It has been recognized, however, that the potential of light quarks and gluons is quite limited for the characterization of the properties of the QGP medium. The next phase of the RHIC program calls for the precise determination of the density, temperature, opacity and viscosity by using some qualitatively new probes, such as heavy quarks.

Received 8 July 2008
* Supported by National Natural Science Foundation of China (10675004, 10375002) and Doctoral Fund of Ministry of Education of China

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The mesons with heavy quarks such as D (with c quark) or B (with b quark) mesons are short lived particles. Most of them decay into other stable particles like electrons or muons after flying a short distance, which is usually less than 1 mm for the typical heavy mesons produced at RHIC. However, the existing PHENIX detectors do not have the ability to separate these muon signals from background at the vertex position. More precise position measurement for charged tracks is necessary to identify the secondary vertex of muons that decay from heavy meson.

Two forward silicon vertex trackers (FVTX) are under construction for the PHENIX experiment that will directly identify and distinguish charm and beauty decays within the acceptance of the muon spectrometers. The FVTX will provide an essential coverage over a range of forward and backward rapidities ($1.2< |\eta| <2.4$). This rapidity range coverage will not only bring significantly larger acceptance to PHENIX, but also be critical for separating cold nuclear matter effects from QGP effects and for measuring the proton spin contributions over a significant fraction of the kinematic range of interest. Furthermore, the FVTX will greatly reduce background and improve the mass resolution for di-muon events[4].

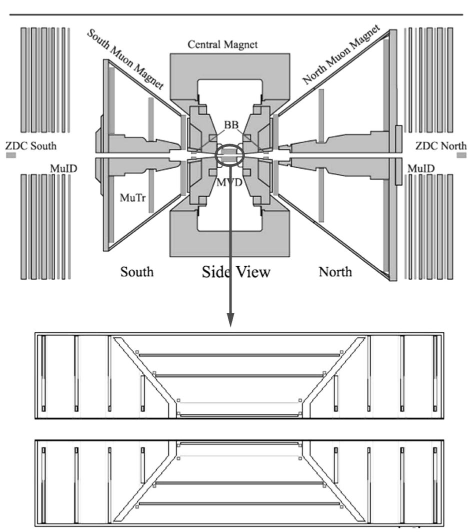

Fig. 1. Side view of the PHENIX detector and the silicon vertex trackers.

2 Forward vertex detector design

The forward vertex detector system is composed of two identical endcap sections, one in front of the north muon spectrometer and the other in front of the south muon spectrometer. Each endcap has four disks that contain 48 individual wedge shaped towers mounted on a carbon composite support substrate. Each wedge supports silicon sensors with readout chips wire bonded to the sensors. The technology for the sensors will be p-n detectors with 75 μm width oriented strips. Every individual strips fan out from the center of the 7.5 deg wedge (Fig. 2). The strips nearest the beam pipe at a radius of 4.5 cm are 2.9 mm long in the φ coordinate, and are about 11.2 mm long at the largest radius of 17 cm. The total number of readout strips in each endcap is about 553,000. The FPHX chips for the sensors on each edge are connected to a flexible bus that takes the data to the outer radius of the wedge[4].

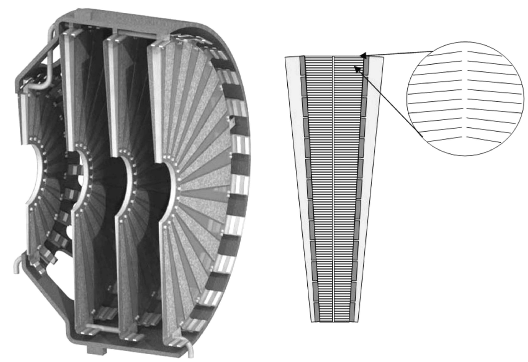

Fig. 2. Structure of the forward vertex detector (one endcap) and strips on each sensor.

3 Performance simulation

The FVTX detector sensitive and non-sensitive volumes have been simulated in the PHENIX GEANT3 based framework. Detector geometry is described to strip level. The simulation includes a full digitization of the Monte Carlo hits on silicon strips. Cluster finding on strips which belong to one hit is performed, and a centroid fit is applied to each cluster. When the centroid positions of the clusters are determined, a Kalman Filter track fit is made to pick up one set of parameters which will be further used to project the track to the event vertex and to extract the Distance of Closest Approach (DCA) of the track to the primary vertex. This DCA value can be used to discriminate the tracks originating from the primary vertex (mostly from background) and the tracks coming from a displaced secondary vertex (from heavy meson decay). Fig. 3 shows the DCA resolution on r and φ directions at different momentum. For

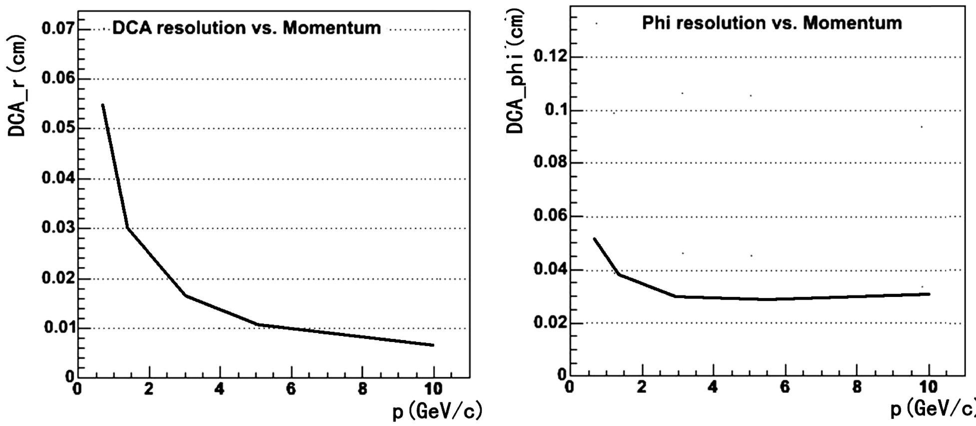

Fig. 3. Simulation result of the FVTX's DCA resolution at different momentum on r and φ direction.

particles with momentum larger than 5 GeV/c, position resolution is about 100 μm on r direction and about 300 μm on φ direction.

4 Summary

The Forward Vertex Silicon Detector is under construction for the PHENIX experiment and will be installed in 2011. The concept design of the detector is introduced. GEANT3 based simulation shows that the position resolution of the new detector for a secondary vertex can be 100 μm on r direction, which will greatly enhance the heavy-flavor physics capabilities on PHENIX.

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