PHENIX Silicon Vertex Tracker upgrade

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Abstract

The PHENIX experiment is planning to make a new silicon vertex tracker (VTX) for detector upgrade to enhance the capability of detecting open heavy flavors. In this paper, conceptual design of VTX and physics programs with VTX are introduced and then current R&D activities in PHENIX are presented.

Key words: PHENIX, Upgrade, Silicon Vertex Detector, Microstrip, Pixel
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1 Introduction

The PHENIX experiment [1] at the Relativistic Heavy Ion Collider (RHIC) in Brookhaven National Laboratory has been operational since 2000 and has produced many fruitful results. PHENIX has two major physics goals, namely, the study of hot and dense matters created in high-energy heavy ion collisions and the measurement of spin structure of proton with polarized proton collisions.

In both of these programs, measurement of open heavy flavors becomes more and more important. In heavy ion collisions, for example, energy loss of heavy quarks is a key measurement to identify the nature of observed suppression of high-p_T particles [2]. However, the ability to detect open heavy flavors by the existing PHENIX baseline detectors is limited to inclusive measurements of electrons and muons, and such measurements suffer from severe backgrounds (see Ref. [3] for example). If we can measure the displaced vertex in the decay of heavy quarks, it greatly enhances the capability. Therefore, we proposed [4] a new silicon vertex tracker (VTX) as a major upgrade of the PHENIX detector.

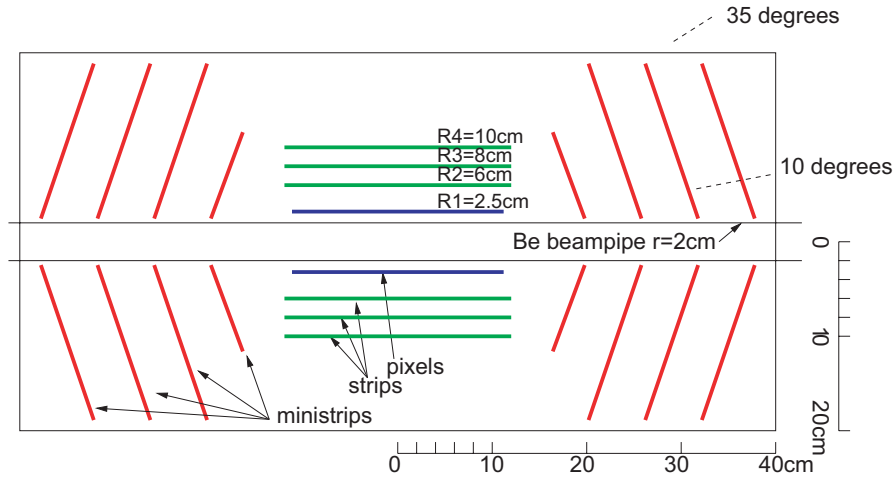

Fig. 1. A schematic drawing of proposed VTX. Rough layout of the barrel and endcap layers are shown.

2 Overview of the silicon vertex tracker

VTX consists of four layers of barrel silicon detectors which covers $|\eta| < 1.2$ and four layers of endcap detectors ($1.2 < |\eta| < 2.4$), as shown in Fig. 1. We use hybrid pixel detector technique developed by the ALICE collaboration [5] for the first layer of the barrel part; the outer three layers are covered by a novel single-sided silicon strip detector which is under development (see below). The technical option for the endcap layers is still preliminary; we are planning to use mini-strips of 50 μm wide (in the r direction) and 2.2 mm (innermost strip) to 11.6 mm (outermost strip) long in the ϕ direction.

With VTX, we expect following physics will be in reach. In heavy ion collisions, accurate charm measurements will not only help to understand the nature of the suppression of high-p_T particles but give a firm baseline to quantify suppression or possible enhancement of J/ψ. In polarized proton collisions, heavy quark production is an excellent tool to measure gluon polarization in wide kinematic range, especially at small Bjorken x (see Fig. 2). VTX also helps gluon polarization measurement with direct photons by giving the axis of jet which is expected in the other side of the photon. The same measurements give parton structure of nuclei in pA collisions so that the gluon shadowing can be studied over broad x range. More details about the physics motivations with VTX are described in Ref. [4].

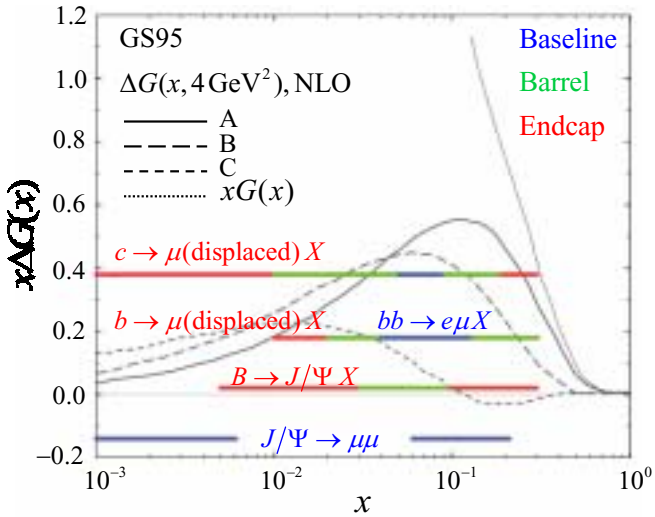

Fig. 2. Expected x range for different channels used to extract the gluon spin structure function in proton. The curves show various estimates of the expected gluon polarization.

3 Present R&D efforts and plans

Various R&D are actively ongoing for each subsystem. For the pixel layer, we are working with the ALICE [5] and NA60 [6] collaborations and have accumulated expertise on the ALICE pixel hybrid system. Mostly, we will use the same techniques developed by ALICE, with some modifications for faster readout (257 μs/event for ALICE and < 40 μs/event for PHENIX). For this goal, we are working on modification of the readout controller (pilot chip) and the data bus.

For the strip layers, we are developing a novel "stripixel" sensor with BNL Instrumentation Division [7–9]. The concept of the stipixel sensor is shown in Fig. 3. This allows two-dimensional position sensitivity with single-sided sensors by charge sharing between the two interleaved electrodes in one pixel. One electrode is DC-coupled to the horizontal readout line, x-strip, in the first aluminium layer, and is used to give vertical position. In the same way, the other consistitutes the u-strip (diagonal strip) in the second metal layer. The two aluminium layers are separated by a polyimide layer so that the x and u strips are independent.

The first prototype stripixel sensors for PHENIX were produced in 2002. The sensors have a size of 34.3 mm $\times$ 64.6 mm with thicknesses of 400 μm and 250 μm, and have two active areas of 30.7 mm $\times$ 30.0 mm each, composed of 384$\times$2 strips with 80 μm pitch. The strip capacitance was about 10 pF at 80 V, where full depeletion is achieved. The leakage current was as low as a few nA up to a bias voltage of 400 V.

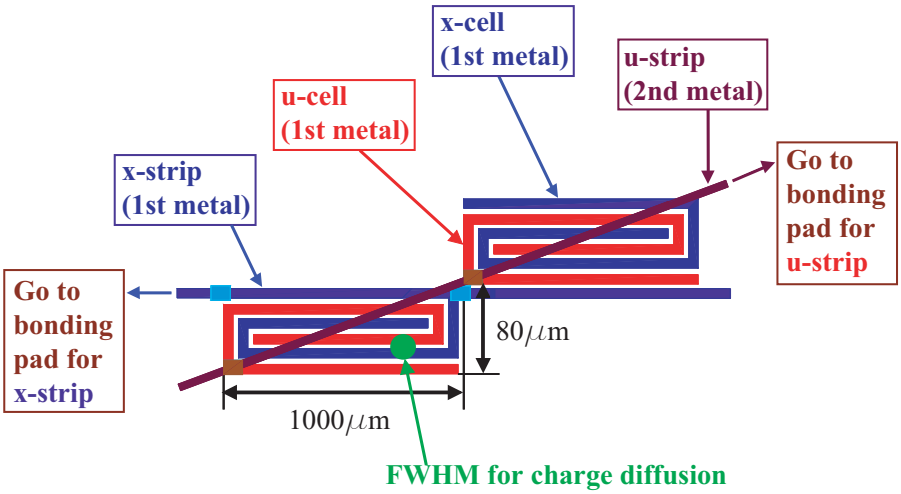

Fig. 3. The stripixel detector concept (not to scale). Only two diagonally adjacent pixels are shown.

The performance of the sensors was tested on testboards using VA2 chips. A ^{90}Sr β-source and a test beam at T1 beam line of KEK-PS were used to evaluate the signal-to-noise (S/N) ratio, the detection efficiency, charge sharing between x and u strips, and the position resolution. The S/N ratio for minimum ionizing particle was about 17 and 9 for the 400 μm and 250 μm thick sensors, respectively. It is noted that the noise level was ~ 3 times worse than expected for VA2 chips with 10 pF load, and that the operation conditions are still to be improved. Reflecting the difference of the S/N ratio, the detection efficiency was satisfactory for 400 μm thick sensors ($\sim$97%), while it was poor ($\sim$60%) for 250 μm sensors. Position resolution was obtained to be $\sigma_x \simeq 23$ μm for x strips and $\sigma_u \simeq 31$ μm for u strips, after subtracting multiple scattering effect. These results are in good agreement with the expectations.

We used an asymmetry parameter, $A_Q = (Q_x - Q_u)/(Q_x + Q_u)$, where Q_x and Q_u are collected charges in x and u strip, respectively, to characterize charge sharing property. When the beam axis is perpendicular to the sensor plane (tilt angle $\theta = 0°$), there are two peaks at $A_Q \sim \pm 0.2$ in the A_Q distribution, while only one peak is observed when the sensor is tilted by 15 degree or more (see Fig. 4). These results show stripixel principle is working quite well; even when the sensor is perpendicular to the beam, we expect that use of finer structure improves the charge asymmetry distribution drastically. In order to verify this expectation, we are developing the second prototype sensors with a finer pitch (13 μm $\rightarrow$ 8 μm).

For the readout of strip detectors, our plan is to use the SVX4 chips [10]. We are developing adaptor boards to implement SVX4 chips into the PHENIX DAQ system and to take a matching between the stripixel sensor and SVX4

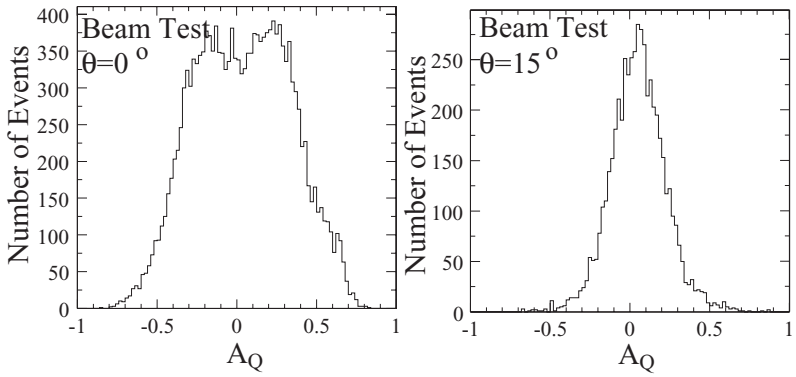

Fig. 4. Distribution of charge asymmetry parameter (A_Q) for tilt angles (θ) of 0 and 15 degrees.

(pitch conversion, DC-AC coupling conversion etc.).

4 Summary and prospects

PHENIX is constructing a new silicon vertex detector, VTX, to enhance its physics capabilities. Various R&D efforts are ongoing, including the development of new stripixel sensor. Construction of the barrel detectors will start by 2005 and will be finished by 2007. R&D for the endcap detectors will start soon and installation is expected to be done by 2008.

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