Measurements of J/ψ mesons from B meson decays with the PHENIX-VTX detector

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Heavy quarks, bottoms and charms, are a useful probe to study the properties of quark gluon plasma (QGP) created in high-energy heavy-ion collisions. Due to their large masses ($M_b \approx 4.2$ GeV/c^2 and $M_c \approx 1.3$ GeV/c^2), heavy quarks are dominantly produced via initial hard scattering between partons in the incoming nuclei. Since none of the heavy quarks can be created during space-time evolution of the QGP, the number of heavy quarks is fixed at the beginning of the collisions. However, the final state interactions of heavy quarks in the QGP such as energy loss and collective flow can modify the momentum and angular distribution of the heavy quarks.

The PHENIX experiment recently measured single electron yields from bottom and charm quark decays separately in Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV[1)] using the silicon vertex detector (VTX). VTX consists of four layers of silicon sensors covering $|\eta| < 1.2$ and almost 2π in azimuth. VTX provides a precise displaced tracking to measure the decay length of heavy flavor hadrons. We observed that bottom quarks were less suppressed than charm quarks at $3 < p_T < 4$ GeV/c and were similarly suppressed at high p_T.

J/ψ produced from B meson decay is a direct channel to measure the bottom production, and it is especially good for low p_T. All J/ψ are promptly produced at the collision vertex except for J/ψ from B decay, called non-prompt J/ψ, because of the decay length ($c\tau_{B^0} \approx 455 \mu m$). Therefore, we can separate non-prompt and prompt J/ψ by measuring their decay lengths.

The analysis is performed using data from $p+p$ and Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV recorded in 2015 and 2014. J/ψ is reconstructed by an unlike-sign di-electron pair. Electrons are identified using the ring-imaging Čerenkov detector and energy-momentum matching, where the energies and momenta are measured by the electromegnetic calorimeter and the drift chamber at the PHENIX central arm spectrometer, respectively. Electron tracks are associated with hits in VTX to remove the background tracks caused by photon conversions and Kaon decays. Figure 1 shows the invariant mass distributions of electron pairs in $p+p$ collisions. The red and blue histograms correspond to the unlike- and like-sign pairs, respectively. The like-sign distribution represents the combinatorial background qualitatively. In the distribution, the J/ψ signal is clearly seen and there is almost no background around the J/ψ mass region.

We then reconstruct the secondary vertex position of electron pair from the J/ψ decay and the collision vertex point using VTX. To identify non-prompt J/ψ, we calculate the pseudo proper time, X, which is defined as follows:

$$X = \frac{L_{xy} \cdot M_{J/\psi}}{p_{T\,J/\psi}}. \tag{1}$$

Here, L_{xy} is the length between the secondary vertex and the collision vertex projected in the direction of the momentum vector of J/ψ, and $M_{J/\psi}$ and $p_{T\,J/\psi}$ are the measured mass and p_T of the electron pairs, respectively. The kinematic relation of these variables is described in Fig. 2 (left). The pseudo proper time of J/ψ is an approximation of the decay length, $c\tau$, of B meson since the mass of J/ψ is close to that of the B meson. Figure 2 (right) shows the pseudo proper time distributions of simulated non-prompt and prompt J/ψ samples using PYTHIA and PHENIX detector simulation. These distributions are normalized to match their peaks in order to demonstrate the difference in the shape between non-prompt and prompt J/ψ. The non-prompt J/ψ has a longer tail on the positive side, which represents B meson decays far from the collision vertex, while the prompt J/ψ shows the symmetric shape caused by the detector resolution.

We are measuring the pseudo proper time of J/ψ using data from both $p+p$ and Au+Au collisions. These results will be published soon.

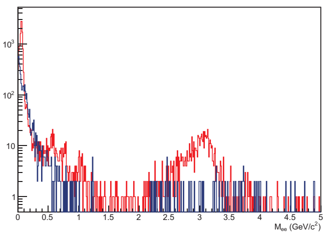

Fig. 1. Invariant mass of unlike sign(red) and like sign(blue) electron pairs.

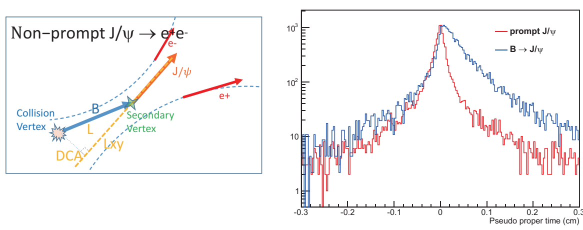

Fig. 2. (Left) Decay kinematics of non-prompt J/ψ. (Right) Pseudo proper time distribution of simulated non-prompt (blue) and prompt(red) J/ψ.

Reference

1) A. Adare *et al.*, Phys. Rev. C **93**, 034904 (2016).

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