Charm reconstruction using a micro-vertexing technique and STAR silicon vertex detectors

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Introduction

The energy loss measurements of heavy quarks are a unique probe of the hot and dense medium created in the heavy ion collisions at RHIC[1]. Most of the heavy flavor measurements at RHIC are done through the semi-leptonic decay channel. Since both charm and bottom contribute to the non-photonic electron spectrum, the relative yield of charm and bottom are highly uncertain in such measurements. A direct measurement of charm can resolve this ambiguity.

We present a micro-vertexing method for the direct reconstruction of the $D^0(\bar{D^0})$ meson through the decay channel $D^0(\bar{D^0}) \rightarrow K^{\mp}\pi^{\pm}$ using STAR silicon vertex detectors. This method uses a kinematically constrained secondary vertex fit and other track cuts to reduce combinatorial background. Results of $D^0(\bar{D^0})$ measurements in Au+Au data at $\sqrt{s_{NN}}$ = 200 GeV are presented.

STAR Experiment

The STAR experiment is a large detector placed at one of the collision points of RHIC. STAR has used in the past a silicon detector ensemble, consisting of a 3-layer Silicon Vertex Detector (SVT) using the silicon drift sensors, and a one-layer Silicon Strip Detector (SSD) using double sided micro-strip sensors. Silicon vertex detector was mainly designed to improve reconstruction of strange particles as well as to extend their acceptance to low transverse momentum. Later, these detectors have been used to study decays of charmed mesons. We use track hit information from the silicon detector together with TPC for the required impact parameter (DCA) resolution. At 1 GeV, the pointing resolution to the interaction point is $\sim 250\ \mu$m with track hits on all four silicon layers. Table.1 gives the transverse DCA resolution at 1 GeV for increasing silicon hits requirement on track.

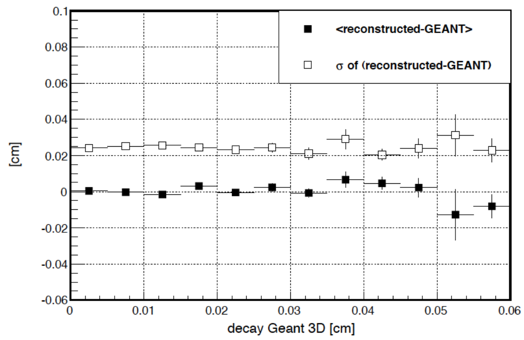

FIG. 1: Difference between L_{reco} and L_{MC} as a function of p_T.

TABLE I: Transverse DCA resolution with number of silicon points fitted to track.

Silicon Hits	$\sigma_{XY}{}^a$ (μm)	$\sigma_Z{}^a$ (μm)
0 (TPC only)	3327	2918
1 (TPC + SSD)	957	1528
2 (TPC + SSD + SVT)	382	540
3 (TPC + SSD + SVT)	296	383
4 (TPC + SSD + SVT)	280	344

[a]at 1 GeV.

Constrained Secondary Vertex Fit

Micro-vertexing is the process of reconstructing the secondary vertex through a fit to the D^0 daughter tracks. Since the decay of D^0

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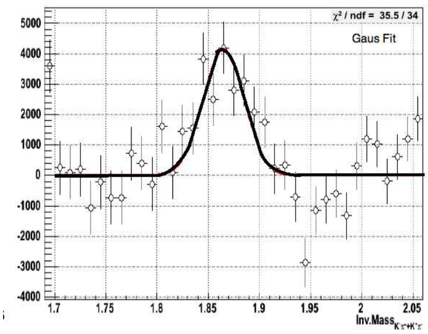

FIG. 2: Gaussian fitted D^0 invariant mass

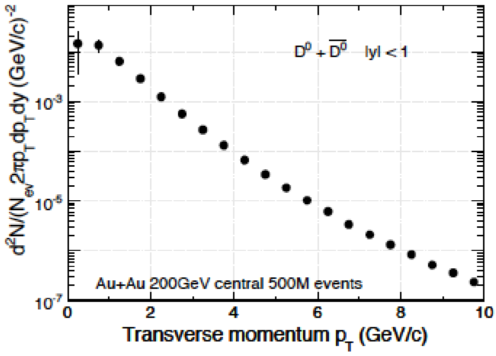

FIG. 3: Projected spectra measurement of HFT

($c\tau \sim 123\mu$m) occurs before the tracking detectors, secondary vertexing has to be done using the identified daughter tracks (K and π). In order to have precision secondary vertexing, we use full track/error information close to the interaction vertex. A plot of the difference between reconstructed(L_{reco}) and Monte Carlo(L_{MC}) decay length and its resolution (Fig. 1) shows that the reconstructed parameters behaves as expected within the current detector resolution.

The constrained vertex fit method gives more than a factor two better secondary vertex resolution for the high p_T D^0s compared to traditional helix swimming methods. Microvertexing also involves calculation of different variables associated with the reconstructed secondary vertex. A cut on these variables can reduce the background appreciably, given the marginal resolution of the detectors.

Results and Future in STAR

A preliminary invariant mass of D^0 from 35 million Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV is shown in Fig. 2. This is done after fitting a third order polynomial to the background and subtracting it off from the total yield (signal + background). The signal is then fitted with a gaussian function. An estimated ratio of $D^0/\bar{D}^0$ is estimated to be 1.18±0.24(stat.). This ratio is compatible with a vanishing baryo-chemical potential at RHIC. Additional combinatorial background reconstruction methods are needed to further understand the systematics of the charmed meson signals.

The method developed is a baseline for analyses using the future Heavy Flavor Tracker (HFT) of STAR. HFT is designed for exclusive charm measurements in STAR. It is a microvertexing detector using active pixel sensors and silicon strip technology and can measure neutral and charged particles with displaced vertices of 100 μm or less from the primary vertex. HFT will replace the decommissioned SVT. The HFT consists of two subdetectors: a silicon pixel detector (PIXEL) and an intermediate silicon tracker (IST). Both these detectors lie inside the radial location of the SSD. The SSD-IST-PIXEL detector serves the purpose of graded resolution from the TPC to the interaction point.

The HFT can measure all major charm carrying particles. It can extend the p_T reach and measure spectra (fig.3) and cross section with great accuracy. Thus HFT can conclusively study flow and energy loss of heavy flavor particles[2].

References

[1] Heavy-quark calorimetry of QCD matter, **Phys. Lett. B 519, 199 (2001)**.

[2] Heavy Flavor Tracker (HFT): A new inner tracking device at STAR. **Nucl. Phys. A 830, 636c (2009)**.