D^0 elliptic and triangular flow in Au+Au collisions at RHIC

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Abstract

Due to their large masses, heavy quarks are predominantly produced through initial hard scatterings in heavy-ion collisions. As such, they experience the entire evolution of the hot and dense medium created in such collisions and are expected to thermalize much more slowly than light flavor quarks.

For instance, the azimuthal anisotropy of charm quarks with respect to the reaction plane over a broad momentum range can provide insights into the degree of thermalization and the bulk properties of the system. Specifically at low transverse momenta we can examine the bulk properties in the strongly coupled regime. We present the STAR measurements of elliptic (v_2) and triangular flow (v_3) of D^0 mesons in Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV obtained from the first year of physics running with the new STAR Heavy Flavor Tracker.

Introduction: the physics of HFT

The studies of high energies collisions occurred RHIC are supposed to give insights about the nuclear matter at extreme temperatures and energy densities and describe the so-called Quark-Gluon Plasma [1,2].

Heavy quarks :

•Produced at the early stages of the collision in hard processes.

•Not affected by the chiral symmetry breaking.

•Study of their energy loss through the medium as well as their collective flow.

⇒sensitive probe to test medium characteristics (thermalization).

- HFT designed to detect heavy flavor through direct topological reconstruction of displaced vertices ⇒ need pointing resolution of ~60μm

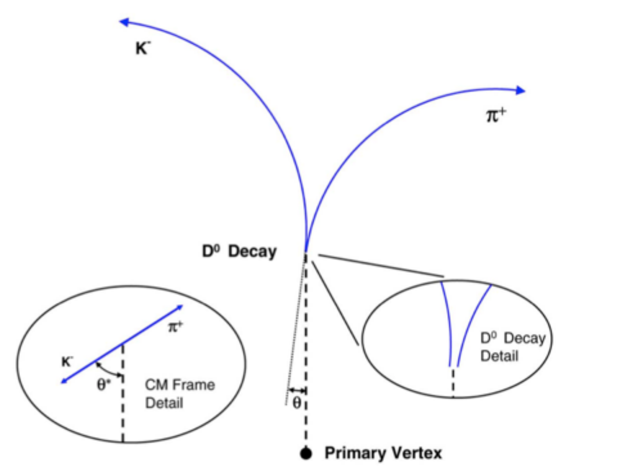

Figure 1: Illustration of D^0 production and subsequent decay at a secondary (displaced) vertex.

•D^0 → $K^-\pi^+$ BR = 3.83 %, cτ ~ 120 μm

•Λ_c → $p K^-\pi^+$ BR = 5.0 %, cτ ~ 60 μm

•B mesons → J/ψ + X or e + X cτ ~ 500 μm

D^0 Meson Signals and Efficiency Correction

- Using the HFT dramatically reduces combinatorial background.
- Over an order of magnitude improvement in measured significance compared to 2010/11 results using only TPC [3].
- This improvement is equivalent to roughly 200 billion events without the HFT.

Table 1: Comparison between the D^0 obtained from the combined 2010/11 datasets withtout the HFT vs. the result obtained with the HFT.

	w/o HFT	w HFT
	2010 + 2011	2014
# events(MB) analyzed	1.1 B	~900M
Significance per billion events	13	~220

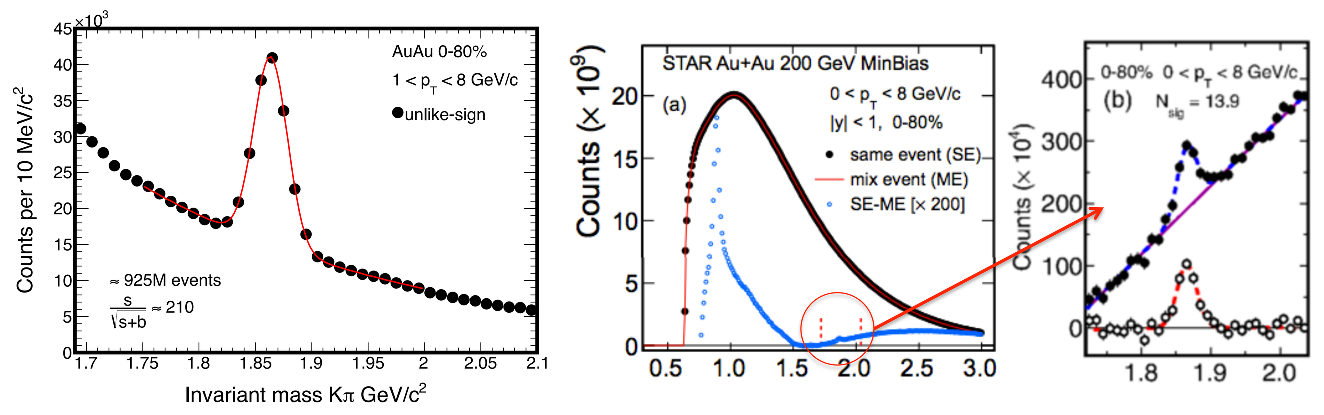

Figure 4: Left: D^0 signal obtained after applying HFT selection from roughly 700M events. Middle: D^0 candidates (black) form 2010/11 dataset without the HFT. Right: Zoomed in picture of D^0 signal.

STAR Experiment

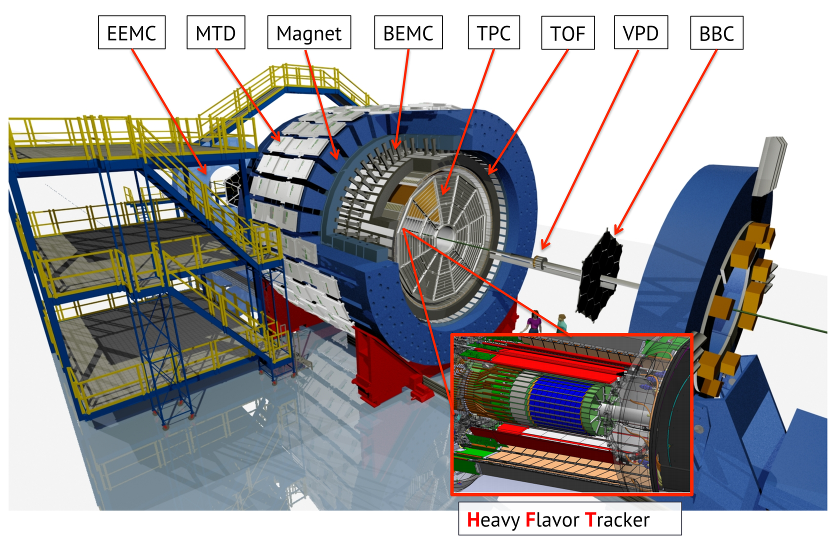

Figure 2: Schematic drawing of the STAR experiment showing the important detector assemblies as well as the location of the HFT.

The STAR HFT consists of three subassemblies with the purpose of gradually improving the track pointing resolution to be able to distinguish decay vertices.

- The existing **SSD** : a single layer of silicon strips detector located at a radius of 23 cm from the beam axis.
- **IST** : The Intermediate silicon tracker, a layer of single sided strips : it guides tracks from the SSD through PIXEL detector. It is composed of 24 liquid cooled ladders equipped with 6 silicon strip-pad sensors.
- **PIXEL** detector : The heart of this upgrade, the goal of this detector is to measure with great accuracy the track pointing resolution and to find secondary decays. It is made by 2 layers of 20.7 μm x 20.7 μm CMOS Active Pixel sensors [3].

HFT Performance

- The figure on the right shows the single track pointing resolution in the transverse (xy) and beam directions (z) for three particle species.
- The green line indicates the design goal for the subsystem for 750 MeV/c kaons.
- HFT exceeded the requirements, with a single track pointing resolution below 55 μm

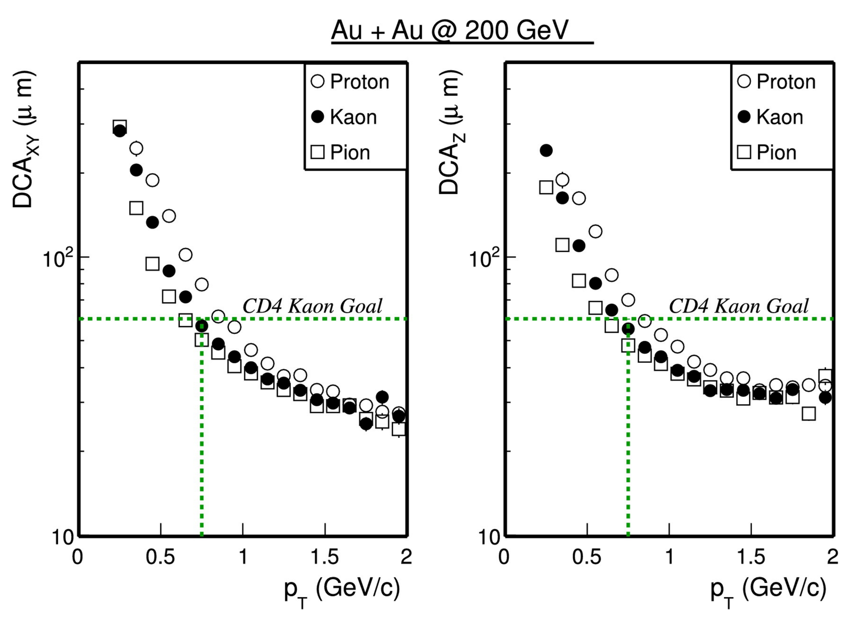

Figure 3: Single track pointing resolution in the xy (left) and z directions for protons, kaons and pions. The green line indicates the design goal for 750 MeV/c kaons.

Summary and Outlook

- Presented first results of charmed meson v_2 and v_3 using the HFT
- D^0 v_2 is non-zero for p_T > 1.0 GeV/c and appears to follow NCQ scaling in 0-40% central events
- Data favor model scenario where charm quarks flow
- D^0 v_3 is non-zero and described by model predictions. Indicates the importance fluctuations in initial conditions

2 billion events from Run16 to further improve precision will allow more thorough studies:

- Centrality dependence of D^0 v_2 and v_3
- Studies of charmed baryons (Λ_c)
- Long term: Bottom hadron flow and energy loss

D^0 elliptic and triangular flow

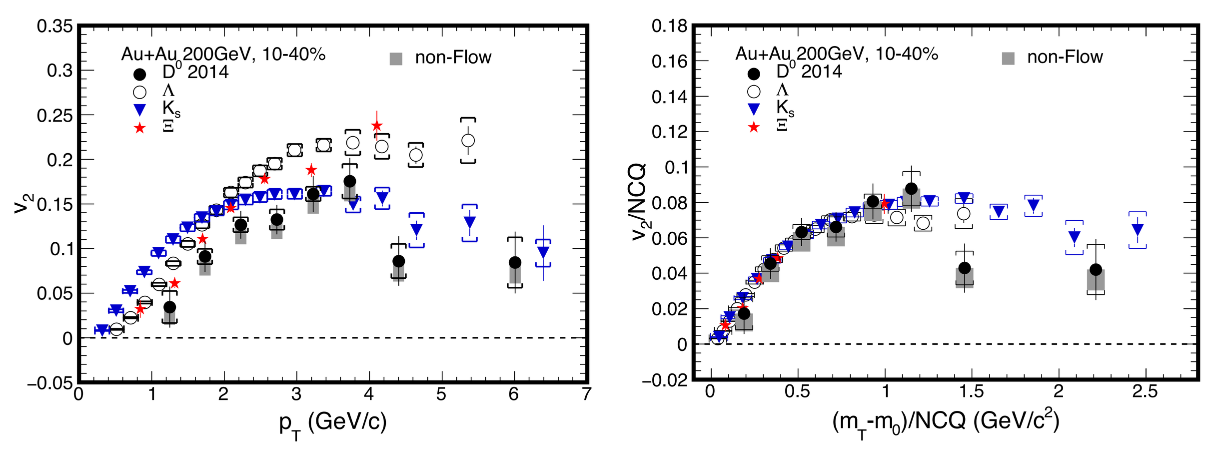

Figure 6: Left: D^0 elliptic flow (v_2) vs. transverse momentum in 10-40% central events compared other particle species. Right: v_2/NCQ (Number of Constituent Quarks) vs. (m_T-m_0)/NCQ with $m_T = \sqrt{p_T^2 + m_0^2}$)

Figure 6 (left) shows the v_2 vs. p_T for a series of particle species [4] in 10-40% central events.

- The D^0 is non-zero for p_T>1 Gev/c, a strong indication that charm is flowing.
- The right panel shows the v_2/NCQ(Number of Constituent Quarks) vs. (m_T-m_0)/NCQ with $m_T = \sqrt{p_T^2 + m_0^2}$.
- D^0 follows the same NCQ scaling as is observed for light species indicating the relevant degrees of freedom are the partons.

Figure 7 shows the D^0 R_{AA} and v_2 compared to a series of model calculations [5,6,7].

- Several models can describe both observables simultaneously
- Data favor scenarios where charm quarks flow.

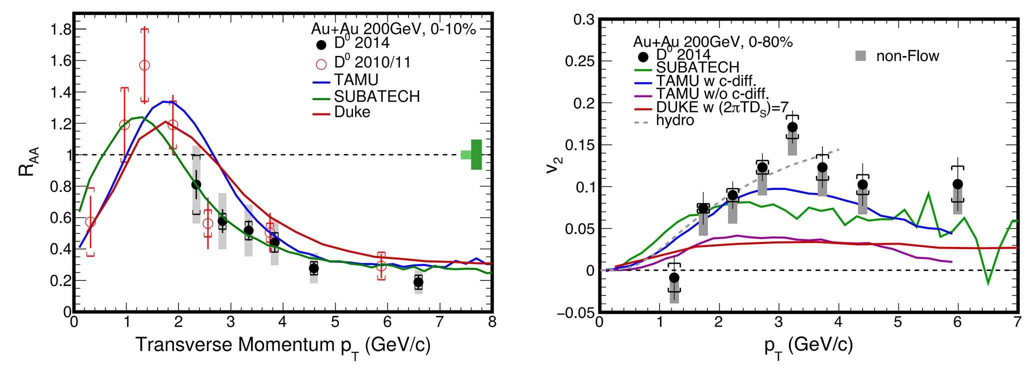

Figure 7: Comparison to a series of model calculations [] for both the D^0 nuclear modification factor (R_{AA}) and the elliptic flow (v_2).

Figure 8 shows the first measurement of D^0 triangular flow at RHIC.

- The model prediction includes charm interactions with the QGP medium and fluctuations in the initial conditions
- Model describes the data

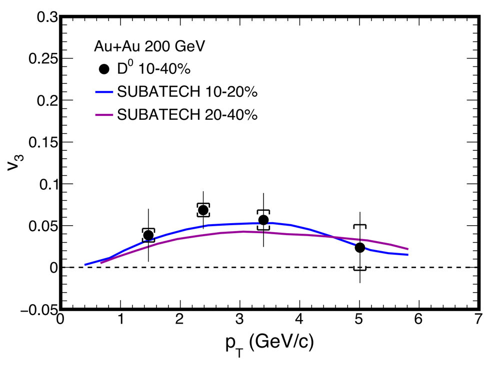

Figure 8: Triangular flow v_3 in 10-40% central events compared to model predictions in two centrality classes.

References

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