Measurement of D^0 meson elliptic anisotropy in Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV from STAR using the two-particle correlation method

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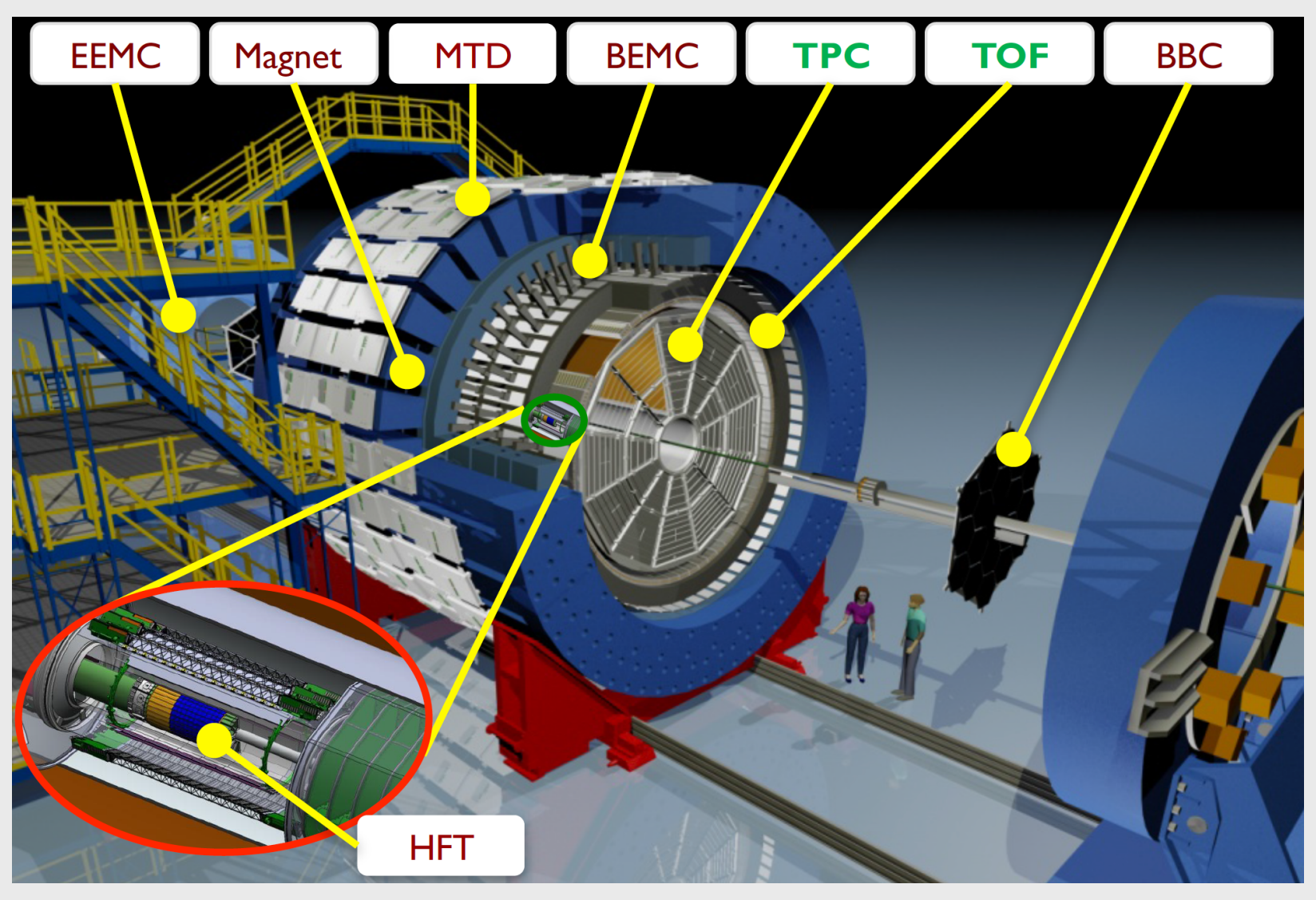
Abstract

The observed azimuthal anisotropies of light flavor hadrons suggest large partonic collectivity in the hot and dense medium created in relativistic heavy-ion collisions. Since heavy quark interactions with the medium may be different from light quark interactions, the measurements of heavy quark elliptic anisotropy is complementary to those of light quarks and can provide new insight in understanding the path length dependence of heavy quark energy loss in the medium and the degree of thermalization. In this poster, we present the STAR measurement of elliptic anisotropy (v_2) of D^0 in Au+Au collisions at $\sqrt{s_{NN}}$=200 GeV using the two-particle correlation method. The data were taken in the first year of physics running with the new STAR Heavy Flavor Tracker detector, which greatly improves open heavy flavor hadron measurements by the topological reconstruction of secondary decay vertices. The results are compared with theoretical predictions for D^0 meson anisotropy and other STAR published anisotropy measurement.

Motivation

- Produced by initial hard scatterings and receive influences throughout the whole evolution in heavy ion collisions.
- The charm quark flow is a unique tool to study the extent of thermalization of the bulk medium dominated by light quarks and gluons.
- At high p_T, D meson azimuthal anisotropy is sensitive to the path length dependence of charm quark energy loss in the medium, which offers new insights of heavy quark energy loss mechanisms.
- The two particle correlation method can apply eta gap between D meson candidate and reference hadrons which suppress non-flow effect effectively.

The Solenoidal Tracker at RHIC (STAR)



Main subdetectors used for this analysis are:

Time Projection Chamber (TPC)
- PID via energy loss dE/dx.
- Charged particle track and momentum reconstruction.

Heavy Flavor Tracker (HFT)
- HFT: Pixel detector + IST +SST.
- Provides high resolution space points (σ= 6.3μm for the innermost 2 layers).

Methodology

- **Definition of correlation v_2 :**

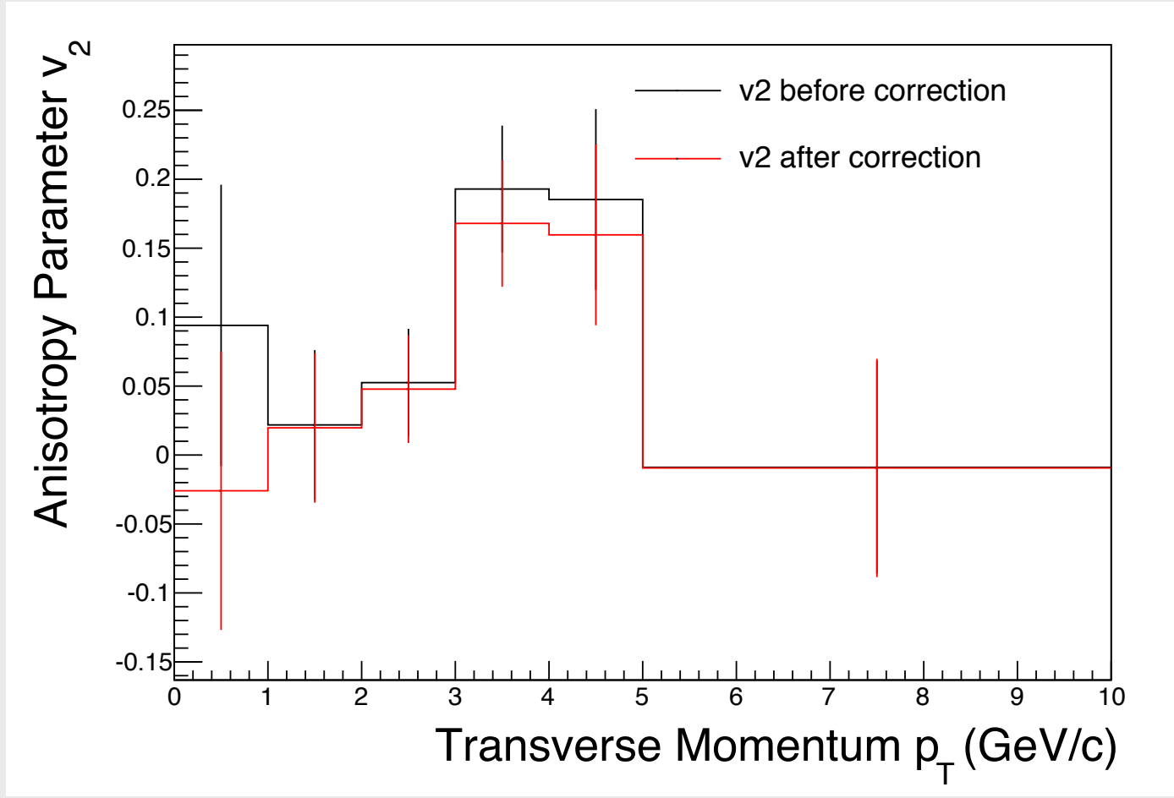
$$v_2^{D\bullet h} = <\cos(2\varphi_D - 2\varphi_h)>$$
$$\approx <\cos(2\varphi_D - 2\psi_{EP})> \bullet <\cos(2\varphi_{hadron} - 2\psi_{EP})>$$
$$= v_2^D \bullet v_2^h$$

The correlation of D meson and hadron is a product of anisotropy of D meson and hadron.

- **Acceptance Correction:**

Fix the non-uniform acceptance by subtracting the red terms
ref. PhysRevC.83.044913

$$v_2^{D\bullet h} = <\cos(2\varphi_D - 2\varphi_h)> - <\cos(2\varphi_D)>\bullet<\cos(2\varphi_h)> + <\sin(2\varphi_D)>\bullet<\sin(2\varphi_h)>$$



- **Reference Hadron v_2:**

$$<\cos(2\varphi_{h1} - 2\varphi_{h2})> = (v_2^h)^2$$

Using the same method, the correlation of hadron1 and hadron2 is the square of hadron v_2

- **Calculate D meson v_2:**

$$v_2^D = \frac{\sum_{centrality} (N_{D-hadron} \bullet \cos(2\varphi_D - 2\varphi_{hadron}) \bullet \frac{1}{\varepsilon_{trigger}})}{\sum_{centrality} (v_2^{hadron}(centrality) \bullet N_{D-hadron} \bullet \frac{1}{\varepsilon_{trigger}})}$$

- $\varepsilon_{trigger}$: trigger efficiency
- $N_{D\text{-}hadron}$: number of D-hadron pair in different centrality
- The hadron v_2 is weighted by the number of D-hadron pair
- Calculate D meson v_2 in different D meson p_T bins.

D^0 v_2 calculation

- **Equation for background extraction :**

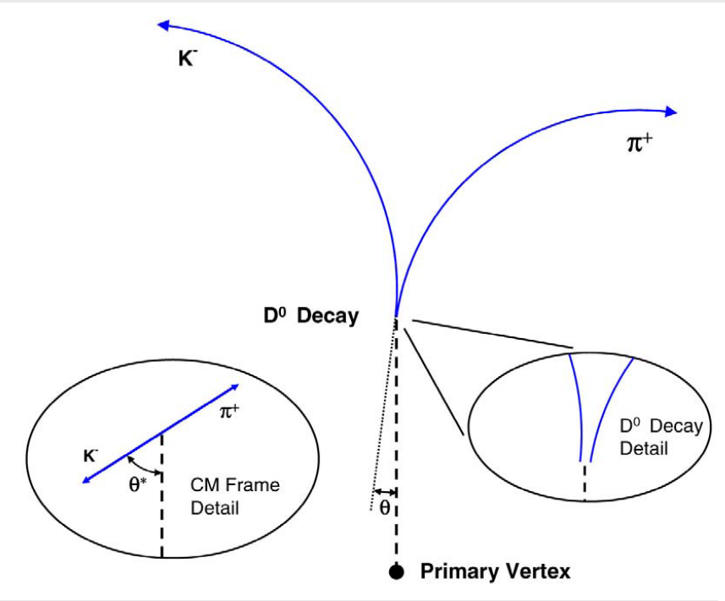
$$N_{cand} = N_{signal} + N_{bkg} \Rightarrow \frac{dN_{cand}}{d\varphi} = \frac{dN_{signal}}{d\varphi} + \frac{dN_{bkg}}{d\varphi}$$
$$N_{cand}[1 + 2v_2^{cand}\cos(2\varphi)] =$$
$$N_{signal}[1 + 2v_2^{signal}\cos(2\varphi)] + N_{bkg}[1 + 2v_2^{bkg}\cos(2\varphi)]$$

$$v_2^{signal} = \frac{N_{cand} \bullet v_2^{cand} - N_{bkg} \bullet v_2^{bkg}}{N_{signal}}$$

- **Candidate and background sample :**
  - **Candidate:** unlike-sign pair in (-3σ,3σ)
  - **Background:** average of following:
    - like-sign pair in (-3σ,3σ)
    - like-sign pair in (±4σ,±9σ)
    - unlike-sign pair in (±4σ,±9σ)
  - N_{cand}: Integral in (-3σ,3σ)
  - N_{signal} and N_{bkg} : Calculate from fitting function
  - σ is square root of variance from Gaussian

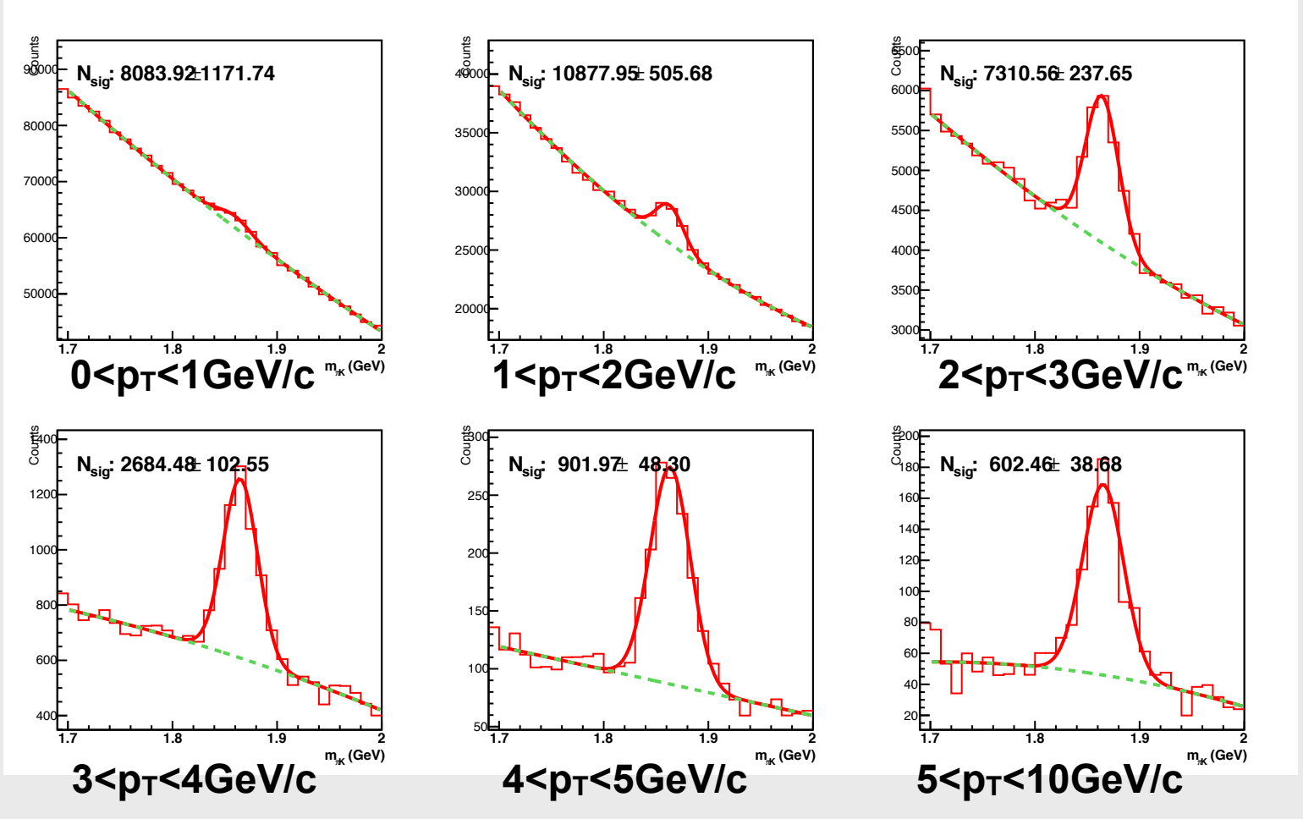
D^0 meson Reconstruction

- **Trigger and event selection:**
  - Trigger: minimum bias trigger
  - $|Vz_{primary\ vertex}| < 6$ cm
  - $|Vz_{primary\ vertex} - Vz_{vpd}| < 3$ cm
- **Topological cut definition**
  - **DCA(K,π)**: The distance of closest approach (DCA) between Kaon track and π track
  - **Decay Length**: the distance between primary vertex to the reconstructed D^0 decay vertex.
  - **DCA(V0,PV)**: The DCA between reconstructed D^0 track to primary vertex. (= decay length x sin(θ))



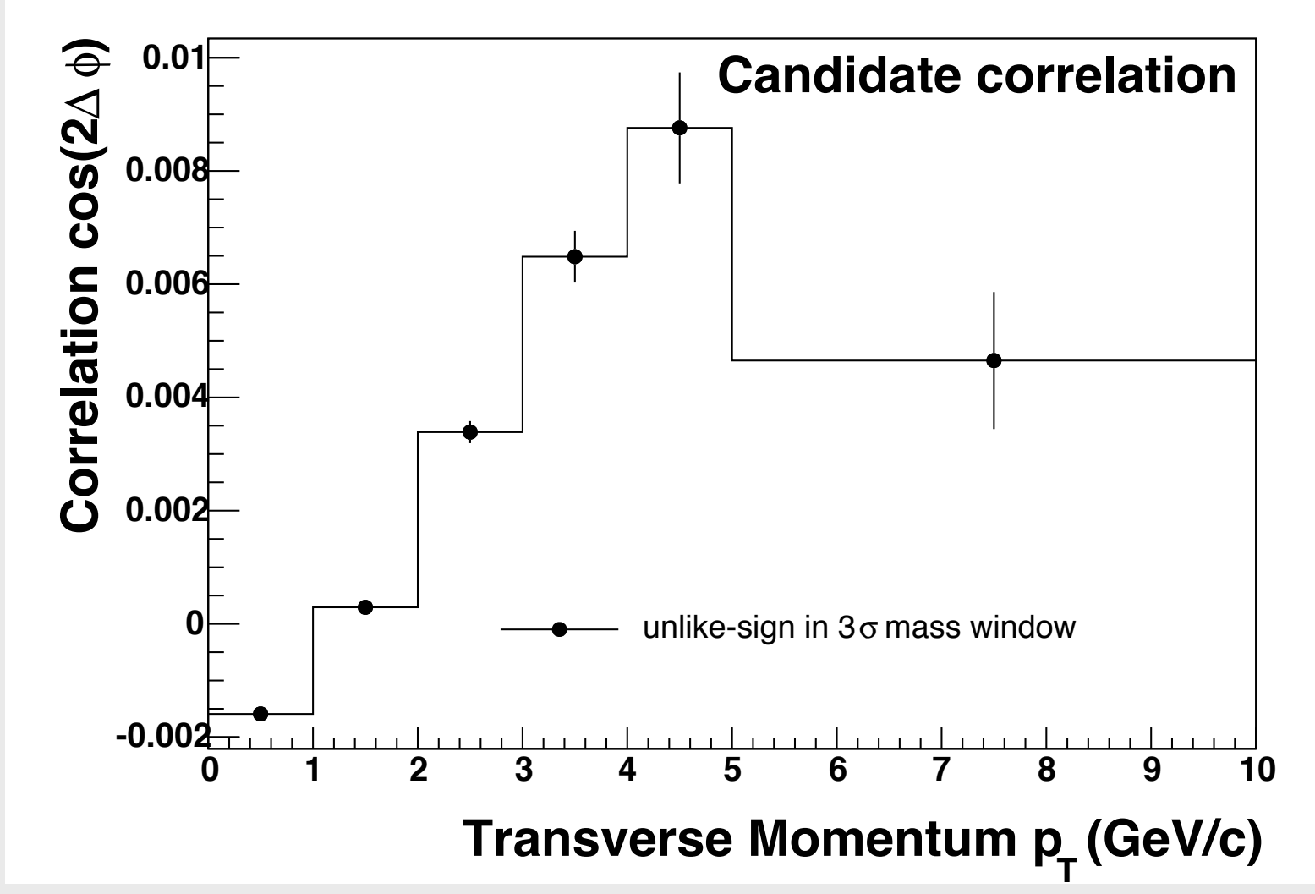
cuts \ $D^0 p_T$ (GeV/c)	0-1	1-2	2-3	3-5	5-10
decay length (μm)	145	181	212	247	259
DCA(K,π)(μm)	84	66	57	50	60
DCA(K,PV)(μm)	103	91	95	79	58
DCA(π,PV)(μm)	110	111	86	81	62
DCA($V0,PV$)(μm)	61	49	38	38	40

- **Reference hadron selection:**
  - $0.2 < p_T < 2$ GeV/c
  - |eta| < 1.0
  - DCA < 2 cm
  - Fitting hits in TPC > 20
  - (#Fit points/#possible points) in TPC > 0.52
- **Kaon and π selection:**
  - $p_T > 0.6$ GeV/c
  - Fitting hits in TPC > 20
  - Fitting possibility in TPC > 0.52
  - at least one hit in every layer of PXL and IST
  - $|n\sigma_{Pion}| < 3.0$; $|n\sigma_{Kaon}| < 2.0$. For dE/dx in TPC

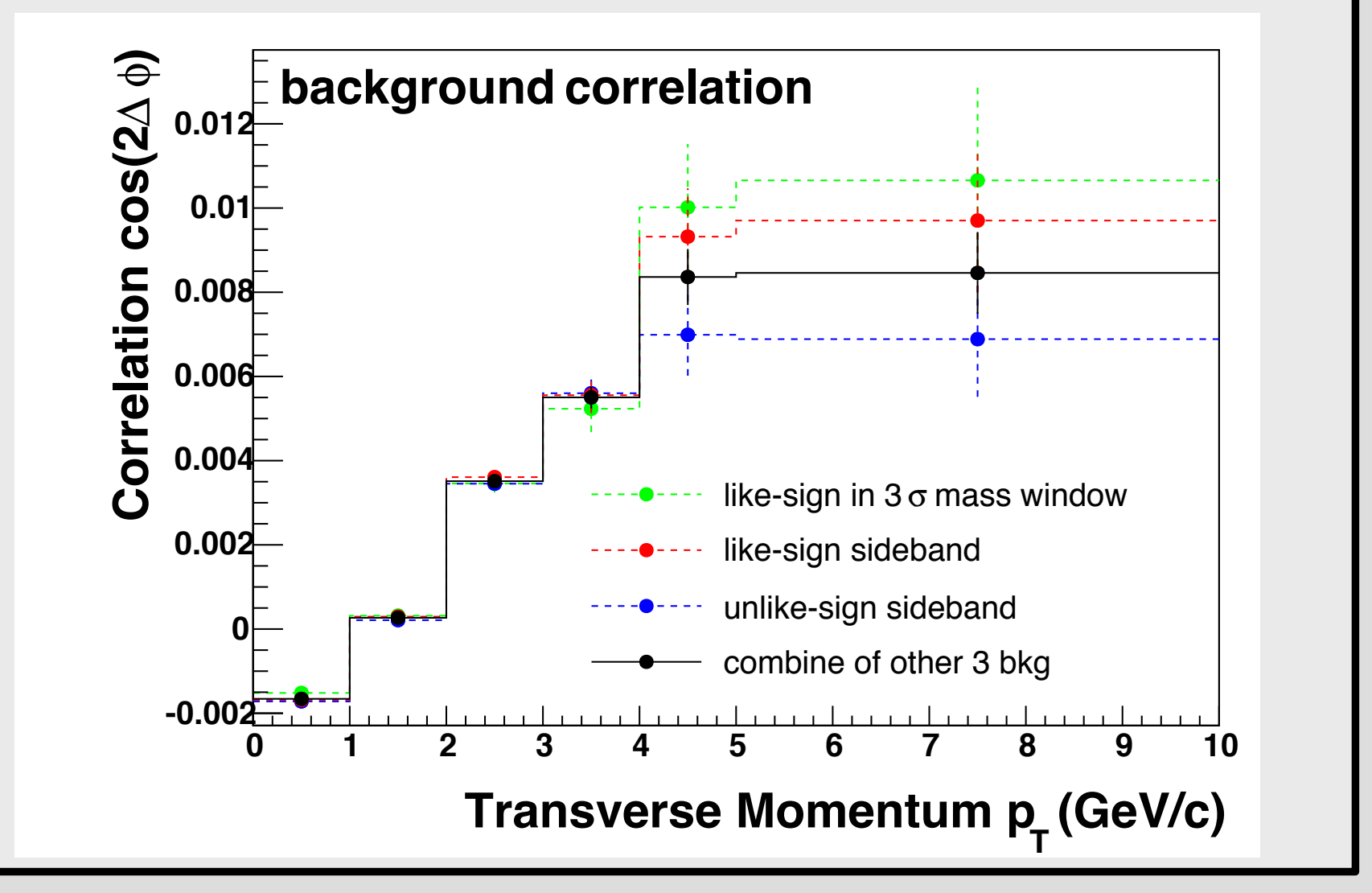


Candidate and Background correlation

- Candidate v_2 comes from unlike-sign pairs.



- Background v_2 is a combination of 3 different methods.



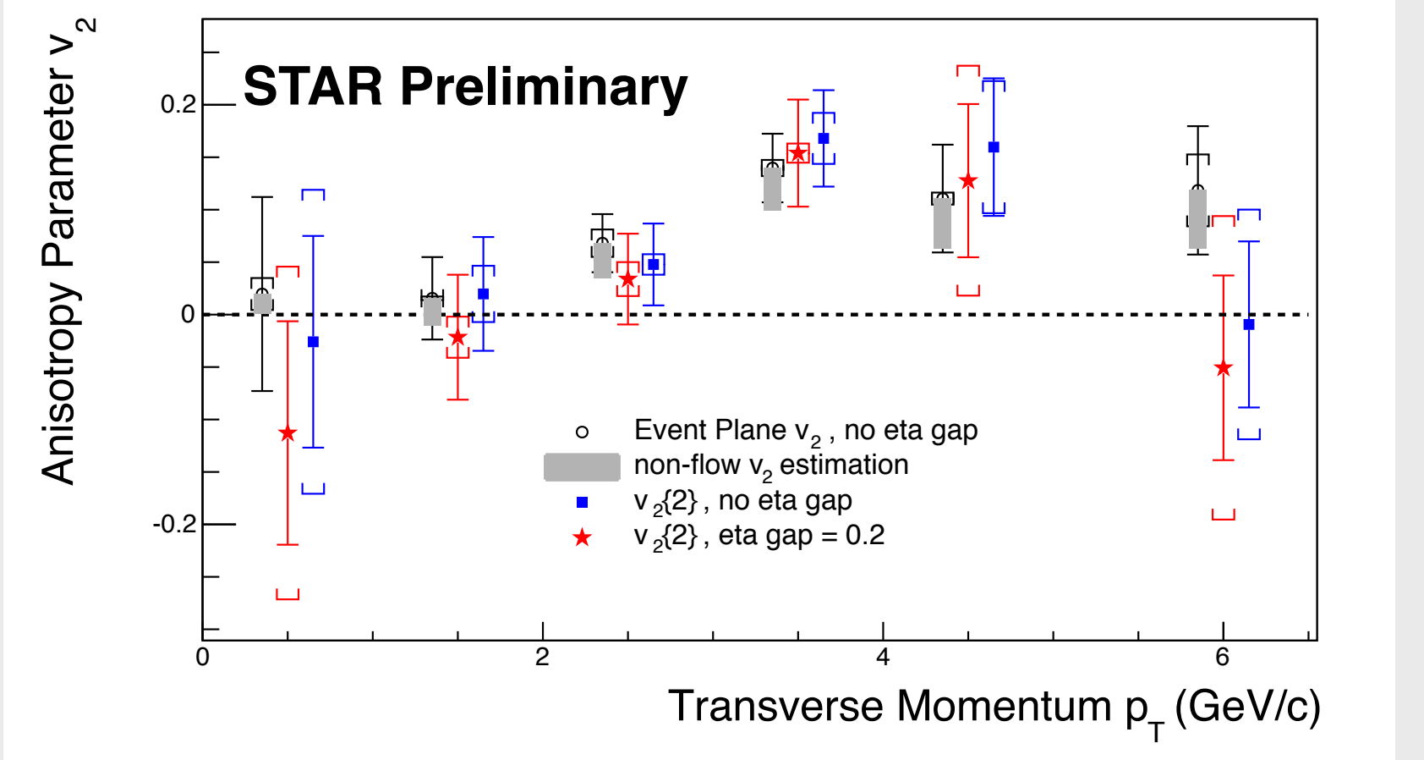
Systematic Uncertainty

Two systematic uncertainties:
- **Yield error**: using exponential to fit background as reference.
- **Background v_2 uncertainty**: The biggest difference between these three bands to default v_2.

p_T bin (GeV/c)	D^0 v_2 with stat.	Yield Error	Bkgd Error
0-1	−0.026±0.101	±0.000	±0.145
1-2	0.020±0.054	±0.000	±0.027
2-3	0.048±0.039	±0.000	±0.010
3-4	0.168±0.046	±0.001	±0.024
4-5	0.160±0.066	±0.001	±0.063
5-10	−0.009±0.079	±0.011	±0.109

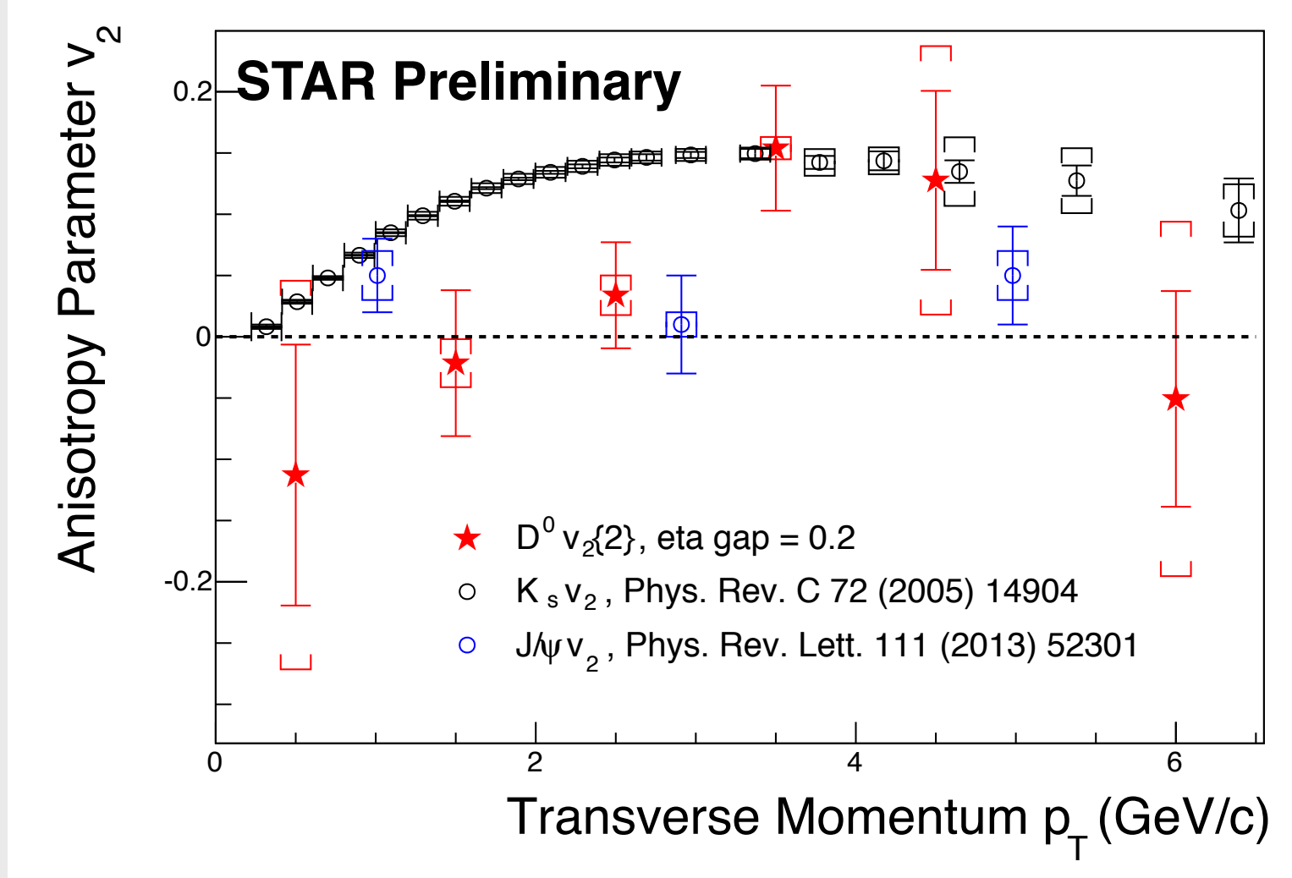
Results

- Consistent with event plane method
- Two particle correlation method can apply eta gap between D meson and reference hadrons.
- Eta gap suppresses non-flow effect

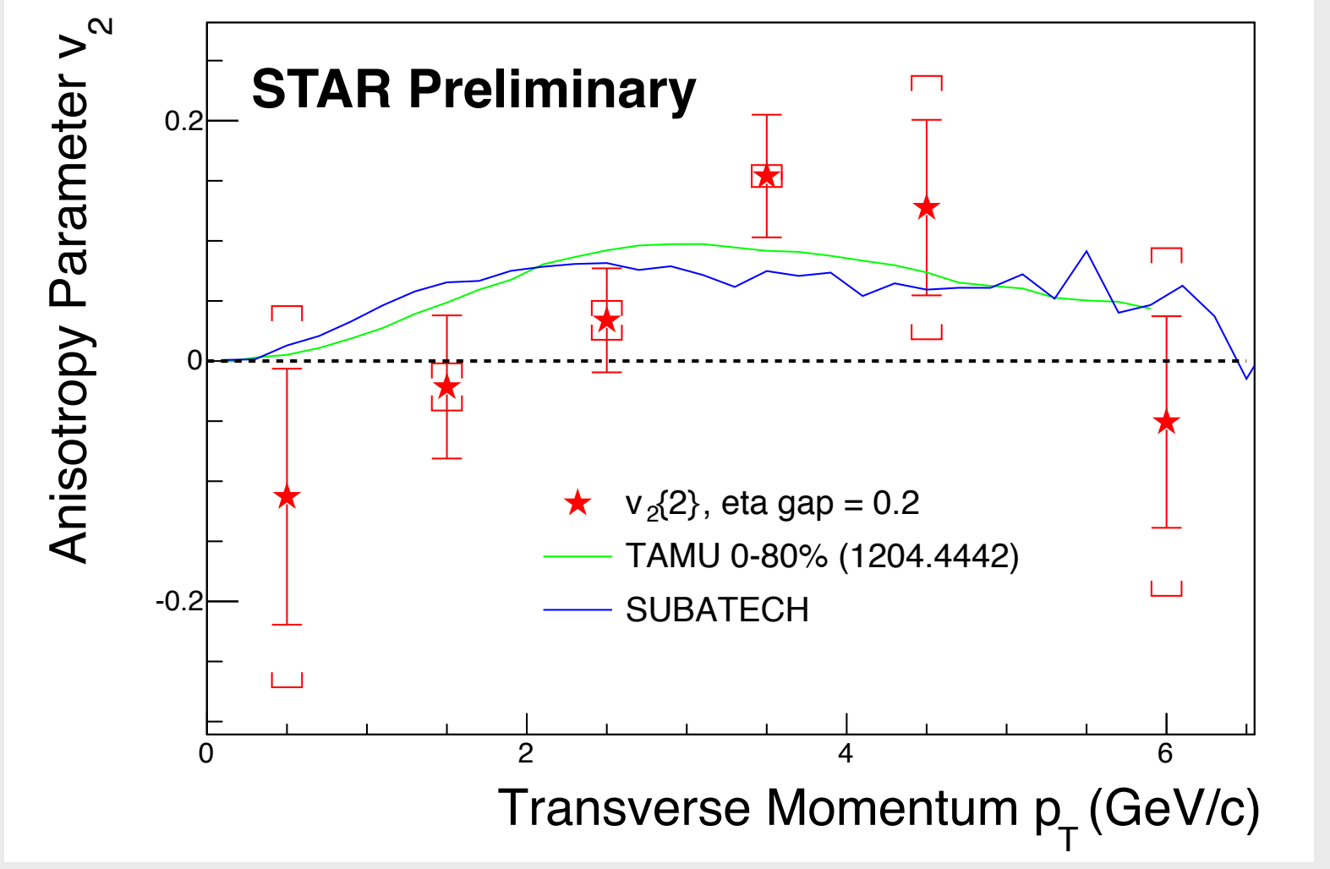


Discussion

D^0 v_2 compared with K_s and J/Ψ v_2 measurement



Data compared to theoretical predictions, which has no effect of non-flow.



Conclusion

- Two-particle correlation method v_2 is consistent with event plane method.
- D^0 v_2 is finite for $p_T > 3.0$ GeV/c and lower than light hadrons for $p_T < 3.0$ GeV/c.
- Good agreement between theoretical predictions and experimental results.

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The STAR Collaboration: http://drupal.star.bnl.gov/STAR/presentations

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