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Elliptic flow and the high p_T ridge in Au+Au collisions

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Abstract In this paper we look for correlations between intermediate p_T particle pairs and the v_2 of the remaining low p_T particles. We find that the shape of the flow vector distribution, which is calculated from all low p_T tracks, depends in a non-trivial way on the angular separation between the high p_T particle pairs in the event. Our analysis is based on 200 GeV Au+Au collisions measured with the STAR detector.

1 Introduction

Dihadron correlations are used in heavy-ion collisions to study the effect of jet-quenching and other interactions of jets with the medium created in the collision overlap zone [1, 2]. In non-central collisions, this overlap zone is not symmetric. The spatial asymmetry leads to large azimuthal anisotropies in momentum space resulting in high values of the second coefficient in the Fourier decomposition of the azimuthal distribution of produced particles with respect to reaction plane (v_2) [3–6]. Dihadron measurements from STAR have revealed a correlation structure which is narrow in the azimuthal angle difference ($\Delta\phi$) and broad in pseudorapidity difference ($\Delta\eta$), called the ridge [7–10]. This structure is unique to nucleus-nucleus collisions and its amplitude shows a non-monotonic rise with increase in collision centrality [11]. We search for a coupling between correlated jet or ridge pairs and the v_2 integrated over all low p_T particles.

2 Method and discussion

Our analysis is based on 16 million Au+Au events at 200 GeV center of mass energy measured with the STAR detector [12]. We select events with at least two tracks having $p_T > 2.0$ GeV/c and calculate the flow vector (q) to know if particles are produced in a preferential direction, which is calculated from $q_x = \Sigma\cos(2\phi_i)$ and $q_y = \Sigma\sin(2\phi_i)$ [13–15], where the sums run over all tracks having $p_T < 2.0$ GeV/c and ϕ_i is azimuthal angle of a track w.r.t. the reaction plane. The distribution of $|q|$ depends on the number of particles, v_2, and other correlations not related to v_2 [16]. If there are more than two tracks with $p_T > 2.0$ GeV/c, we select the leading and sub-leading tracks. This way we select one hadrons pair per event. This allows us to associate the $|q|$ of an event with the azimuthal separation of a high p_T pair. We investigate the modifications to $dN/d|q|$ for events with or without correlated high p_T pairs.

Figure 2.1 shows the distribution of the relative azimuthal angles between leading and sub-leading dihadron pairs with $p_T > 2.0$ GeV/c. If v_2 were the only source of correlations which is considered as background in the present analysis, then $dN/d\Delta\phi$ should have the following shape: $C(\Delta\phi) = b_0(1 + 2\langle v_2^{trig} v_2^{asso}\rangle\cos(2\Delta\phi))$, where v_2^{trig} and v_2^{asso} are the v_2 values respectively, for the leading and subleading particles. Other physical processes which can also contribute to correlations are particle decays, fragmentation of partons (jets), and HBT. Considering jet correlations prominent for high p_T dihadron pairs a two-component model is used to fit $dN/d\Delta\phi$: a "jet" component on top of a v_2 modulated "background" [1, 2, 17].

The next step of our analysis is to study $dN/d|q|$ for the events with high p_T pairs as a function of $\Delta\phi$ and $\Delta\eta$ of the high p_T pairs. If jets, the source of the correlations, interact with the medium, they may modify the v_2 of the event, changing the shape of $dN/d|q|$. Or alternatively, if the v_2 modulation in Fig. 2.1 is caused by the same space-momentum correlation that give rise to v_2, then this may result large values of v_2 [18]. This would also cause $dN/d|q|$ to depend on $\Delta\phi$ and/or $\Delta\eta$. Figure 2.2 shows average magnitude of flow vector ($\langle|q|\rangle$) vs. $\Delta\phi$ of the leading and sub-leading hadrons for either $|\Delta\eta| > 0.7$ or $|\Delta\eta| < 0.7$. We observe a non-trivial dependence on $\Delta\phi$. No prominent $\Delta\eta$

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dependence is seen in this figure. We also studied $\langle p_T \rangle$ vs. $\Delta\phi$ and find that within errors it is independent of the angle between the high p_T tracks.

Having observed a non-trivial dependence of $\langle |q| \rangle$ on $\Delta\phi$, our next attempt is to find v_2 for the events that had a correlated pair. We categorize the events in two classes i.e. (i) Ridge events: $|(\Delta\eta)| > 0.7$ and (ii) Ridge+jet events: $|(\Delta\eta)| < 0.7$. We calculate the q-distributions for the signal and background by dividing the near-side into two bins viz., bin 1: $\Delta\phi < 4\pi/20$ and bin 2: $4\pi/20 < \Delta\phi < 8\pi/20$ and by solving the following equations:

$$(S_1 + B_1)\frac{dN_1}{d|q|} = S_1\frac{dN_S}{d|q|} + B_1\frac{dN_B}{d|q|} \tag{2.1}$$

$$(S_2 + B_2)\frac{dN_2}{d|q|} = S_2\frac{dN_S}{d|q|} + B_2\frac{dN_B}{d|q|} \tag{2.2}$$

where S_1, S_2 are the number of events yielding a correlated pair in bin 1 and 2, respectively, B_1, B_2 are the number of events yielding un-correlated pair in bin 1 and 2, respectively, $\frac{dN_1}{d|q|}$ and $\frac{dN_2}{d|q|}$ are q-distributions for events corresponding to bin 1 ($\Delta\phi < 4\pi/20$) and 2 ($4\pi/20 < \Delta\phi < 8\pi/20$), respectively, $\frac{dN_S}{d|q|}$ and $\frac{dN_B}{d|q|}$ are the q-distributions for events giving correlated pair (signal) and uncorrelated pair (background). $\frac{dN_1}{d|q|}$ and $\frac{dN_2}{d|q|}$ are measured q-distributions, S_1, S_2, B_1 and B_2 are determined from the $dN/d\Delta\phi$ distributions by applying the two-component model. Now $\frac{dN_S}{d|q|}$ and $\frac{dN_B}{d|q|}$ can be determined solving the above equations. Elliptic flow is calculated by fitting the signal q-distributions ($\frac{dN_S}{d|q|}$) (Fig. 2.3) for ridge and ridge+jet events. Two parameters can be extracted from the q-distribution viz., $v_2\{q\}^2$ and σ^2_{dyn} which accounts for correlations that are not related to the reaction plane and the rms width of the v_2 distribution.

In Fig. 2.4, we report $v_2\{q\}$ for the event classes defined above. We use the ansatz that the near-side correlation con-

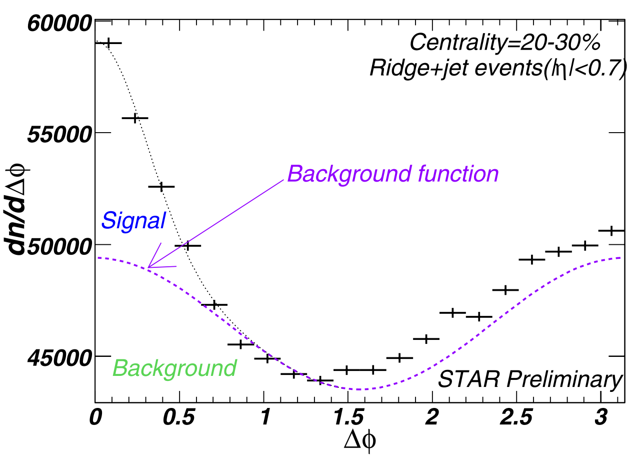

Fig. 2.1 $dN/d\Delta\phi$ for triggered events and the background function

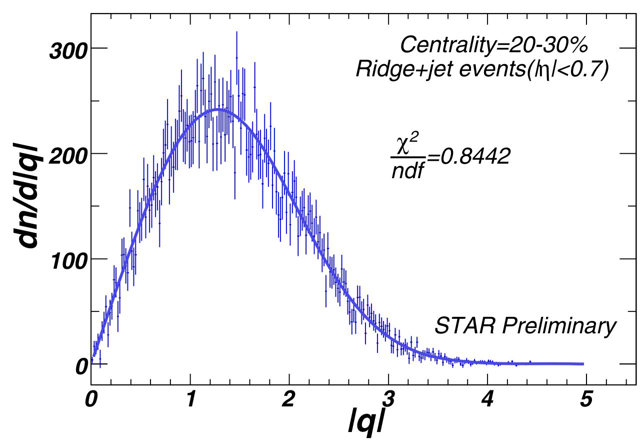

Fig. 2.3 q-vector distribution fit for events yielding correlated pair (signal)

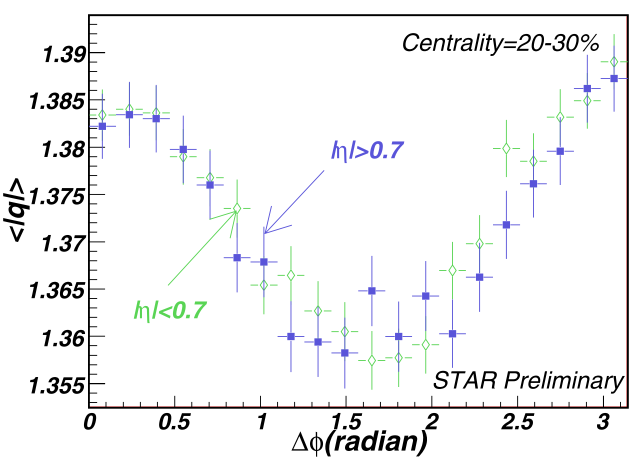

Fig. 2.2 Non-trivial behavior of $\langle q \rangle$ with $\Delta\phi$ for ridge and ridge+jet events

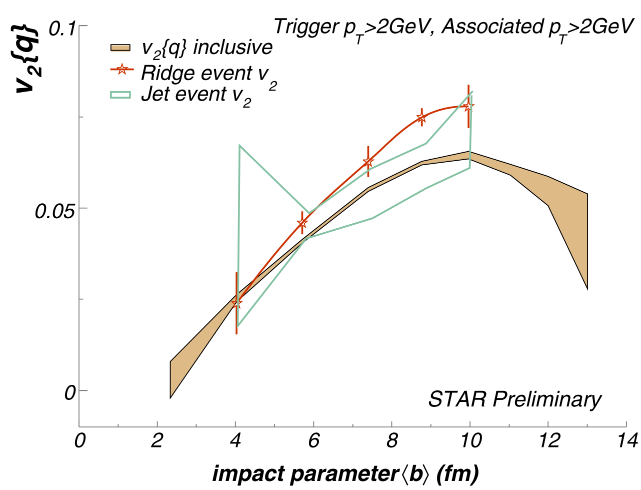

Fig. 2.4 Comparison of v_2 for jet signal with ridge signal

tains a jet part (narrow in $\Delta\phi$ and $\Delta\eta$) and a ridge part (narrow in $\Delta\phi$ but broad in $\Delta\eta$) [10]. By calculating the signal v_2 for ridge and ridge+jet events we can calculate v_2 for jet events as given below:

$$N^{ridge+jet} v_2^{ridge+jet} = N^{ridge} v_2^{ridge} + N^{jet} v_2^{jet} \tag{2.3}$$

$$N^{jet} = N^{ridge+jet} - N^{ridge}\ Acceptance\ factor \tag{2.4}$$

$$Acceptance\ factor = \frac{N^{ridge+jet(background)(\Delta\eta<0.7)}}{N^{ridge(background)(\Delta\eta>0.7)}} \tag{2.5}$$

$$v_2^{jet} = \frac{N^{ridge+jet}}{N^{jet}} v_2^{ridge+jet} - \frac{N^{ridge}}{N^{jet}} v_2^{ridge} \tag{2.6}$$

where N^{jet}, $N^{ridge+jet}$ and N^{ridge} are respectively the number of jet, ridge+jet and ridge events containing correlated high p_T pair.

The values of $v_2\{q\}$ vs. collision impact parameter b are presented in Fig. 2.4. $v_2\{q\}$ for the events that had a high p_T pair contributing to the ridge-like correlation exhibit a slightly larger $v_2\{q\}$ for non-central and peripheral collisions than those contributing a pair to the background. We also determine if the $v_2\{q\}$ values for events contributing pairs to the jet-like correlation and find that within the systematics uncertainties the values are consistent with v_2 from inclusive events, however this aspect is under investigation.

3 Summary

We have developed an analysis to search for jet interactions with the medium and/or possible effects linking the high p_T ridge correlation to v_2. The latter could occur if the same physics mechanism underlies both phenomena as proposed in several references [19–22]. By selecting one high-p_T pair per event and the two component model, we find that $v_2\{q\}$ calculated from $dN/d|q|$ for events yielding pairs in the ridge is slightly larger v_2 for non-central and peripheral collisions than those events yielding high p_T pairs in the background.

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