Elliptic Flow from Au+Au Collisions at \( \sqrt{s_{NN}} = 200 \text{ GeV} \)

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Abstract.
This paper presents results of elliptic flow measurements at moderate high transverse momentum in Au+Au collisions using the STAR detector at RHIC. Sizable \( v_2 \) is found up to 7 GeV/c in transverse momentum. Non-flow effects are discussed comparing correlations in p+p collisions and Au+Au collisions. \( v_2 \) from two-, four- and six-particle cumulant are shown and discussed.

INTRODUCTION

The azimuthal anisotropy of produced particles at large transverse momentum in non-central heavy ion collisions is one of several promising observables for probing the early partonic phase \([1, 2]\), and in particular, this phenomenon can provide insights into partonic energy loss in the relevant medium \([3]\). Partonic energy loss increases systematically with increasing initial medium density and thus provides an important constraint on the initial parton densities. At moderate to large transverse momentum, the jet fragmentation process introduces a genuine correlation among fragmentation products, which is expected to be the dominant non-flow source \([4]\) that can complicate the interpretation of flow analyzes that are based on two-particle correlations \([5]\). In order to investigate further the systematic uncertainties due to non-flow, comparison of azimuthal correlations is made between Au+Au and p+p collisions, in which only non-flow is expected to occur. Additionally, non-flow contributions to four-particle correlations, which are expected to be small \([6]\), are investigated through comparison to six-particle correlations.

RESULTS

The left plot of figure 1 shows \( v_2 \) from the event plane (RP) and two- and four-particle cumulant \((v_2 \{2\} \text{ and } v_2 \{4\})\) methods. The difference between the RP and \( v_2 \{2\} \) methods may originate from the analytical extrapolation of event plane resolution from sub-events to full events. The difference between four-particle cumulant \( v_2 \) and the other two methods could be partially explained by non-flow effects and partially explained by the fluctuation of \( v_2 \) itself \([7]\), but in either cases, 4-particle cumulant method gives a lower limit on \( v_2 \). From the plot we can see that in middle central events at \( \sqrt{s_{NN}} = 200 \text{ GeV} \), significant \( v_2 \) is found up to 7 GeV/c, which is the region where fragments of high \( p_t \) partons can be disentangled from the soft hydrodynamics component. The mea-
surement will provide an important constraint on the initial parton densities in a "jet quenching" picture \[3\]. The finite $v_2\{4\}$ at high $p_t$ seen in the figure demonstrates that $v_2$ is predominantly due to correlations relative to the the reaction plane rather than the intra-correlations of jet fragments \[3\]."

\[\] 

**FIGURE 1.** Left : $v_2$ as a function of transverse momentum from event plane method (circles), two-particle cumulant method (triangles) and four-particle cumulant method (stars). Right : Two-particle correlation in p+p (circles) and Au + Au (solid dots). $Q_{\text{sub}}$, which is the $Q$ vector from randomly divided sub-events, is used in making this plot.

The four-particle cumulant $v_2$ analysis requires large statistics thus has limited power in terms of separation of non-flow effects at high $p_t$ with currently available data. In order to get an insight to the problem, we can separate the two-particle correlation in Au+Au collisions as

$$
\langle u_D Q^{*}\rangle_{AA} = M^{AA} v_{DI} + M^{AA} \delta_{DI}^{AA},
$$

where $Q = \sum u_j$, $u_j = e^{2i\theta_j}$. $v_D$ is differential flow and $v_I$ is the integrated flow for particles used to define $Q$. $\delta_{DI}^{AA}$ is the two-particle non-flow correlation in Au+Au collisions and can be approximated to

$$
\frac{\delta_{DI}^{PP}}{N_{\text{collision}}} \approx \frac{\delta_{DI}^{PP} M^{PP}}{M^{AA}} = \frac{\langle u_D Q^{*}\rangle_{PP}}{M^{AA}}. 
$$

$M^{AA}$ and $M^{PP}$ are multiplicities for Au+Au collisions and p+p collisions, respectively.

Here we have made assumptions, which are not necessarily true, about the similarity of non-flow for both p+p and Au+Au collisions, but this comparison is a very useful supplement to what is learned from four-particle cumulant studies. Rearranging terms, we have

$$
\langle u_D Q^{*}\rangle_{AA} = M^{AA} v_{DI} + \langle u_D Q^{*}\rangle_{PP}. 
$$

The right plot of figure 1 shows that the correlations have similar magnitude in p+p and the most central and peripheral Au+Au collisions, indicating that non-flow may dominate the correlations for these centrality classes. The correlations for mid-central Au+Au collisions are much stronger than those seen in p+p, so that true flow effects may dominate in this case.

In four-particle cumulant analysis, contributions of non-flow effect from four-particle correlations remains although non-flow from two-particle correlations are removed. To remove 4th order non-flow effect one needs to go to higher order cumulants. However this effect was expected to be small \[6\] and indeed confirmed by Figure 2.
FIGURE 2. \(v_2\) from two-(stars), four-(crosses) and six-(triangles) particle correlation, versus cross section at \(\sqrt{s_{NN}} = 200\) GeV. There is an overall 10% downward systematical uncertainty due to low \(p_t\) background contaminations in STAR detector.

\(v_2\{4\}\) and \(v_2\{6\}\) overlays on the top of each other very well, indicating that non-flow from four-particle correlation, which is shown by the difference between \(v_2\{4\}\) and \(v_2\{6\}\), is negligible.

**SUMMARY**

Sizable \(v_2\) is found up to 7 GeV/c in \(p_t\) in Au + Au collisions at \(\sqrt{s_{NN}} = 200\) GeV. Non-flow effect could be dominant at high \(p_t\) in peripheral and central events. Non-flow from pure four-particle correlation is negligible.

**ACKNOWLEDGMENT**

I thank S. Voloshin, K. Filimonov, A. Poskanzer and R. Snellings for their contributions.

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