# Comparison of Methods of Elliptic Flow Analysis [1]

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In a study of methods of elliptic flow analysis we have compared the results of seven methods. The data come from the reaction Au + Au at $\sqrt{s_{\mathrm{NN}}} = 200$ GeV. The STAR detector main time projection chamber (TPC) was used in the analysis of two million events.

*Methods*— The standard method correlates each particle with the event plane determined from the full event minus the particle of interest. Since the event plane is only an approximation to the true reaction plane, one has to correct for this smearing by dividing the observed correlation by the event plane resolution, which is the correlation of the event plane with the reaction plane. The event plane resolution is always less than one, and thus dividing by it raises the flow values. To make this correction the full event is divided up into two subevents (a,b), and the square root of the correlation of the subevent planes is the subevent plane resolution. The full event plane resolution is then obtained using the equations which describe the variation of the resolution with multiplicity.

The scalar product method is a simpler variation of this method which weights events with the magnitude of the flow vector $Q$:

$$v_n(\eta, p_t) = \frac{\langle Q_n u^*_{n,i}(\eta, p_t)\rangle}{2\sqrt{\langle Q^a_n Q^{b*}_n\rangle}}, \tag{1}$$

where $u_{n,i}$ is the unit vector of the $i^{th}$ particle. If $Q_n$ is replaced by its unit vector, the above reduces to the standard method.

The cumulant method has been well described and previously used for the analysis of STAR data. The $N$-particle cumulant result is designated $v_n\{N\}$.

There are also several subevent methods where each particle is correlated with the event plane of the other subevent. If the subevents are produced randomly, we will call this the random subs method. If the particles are sorted according to their pseudorapidity, we will call it the eta subs method. In these methods, since only half the particles are used for the event plane, the statistical errors are approximately $\sqrt{2}$ larger, but autocorrelations do not have to be removed since the particle of interest is not in the other subevent.

Another method involves fitting the distribution of the lengths of the flow vectors normalized by the square root of the multiplicity:

$$q_n = Q_n/\sqrt{M} \tag{2}$$

$$\frac{dP}{q_n dq_n} = \frac{1}{\sigma_n^2} e^{-\frac{v_n^2 M + q_n^2}{2\sigma_n^2}} I_0\left(\frac{q_n v_n \sqrt{M}}{\sigma_n^2}\right), \tag{3}$$

where $I_0$ is the modified Bessel function and

$$\sigma_n^2 = 0.5(1 + g_n). \tag{4}$$

Nonflow effects are fit with the parameter $g_n$.

*Results*— To make a precise comparison of the various methods we have calculated $v_2$ integrated over $p_t$ and $\eta$, and plotted it vs. centrality in the Fig. To make the comparison valid we have used the same events and the same cuts. To expand the scale we have plotted the ratio to the standard method.

The results fall generally into two bands: those for two-particle correlations methods, and those for multi-particle methods. The difference is due either to the decreased sensitivity of the multi-particle methods to nonflow effects, or to their increased sensitivity to fluctuation effects. It appears that either nonflow or fluctuations can explain the two bands in the Fig., and most probably it is some of both. Since nonflow effects and fluctuations raise the two-particle correlation values, and fluctuations lower the multi-particle correlation values, the "truth" must lie between the lower band and the mean of the two bands. At the moment we can only take the difference of the bands as an estimate of the systematic error.

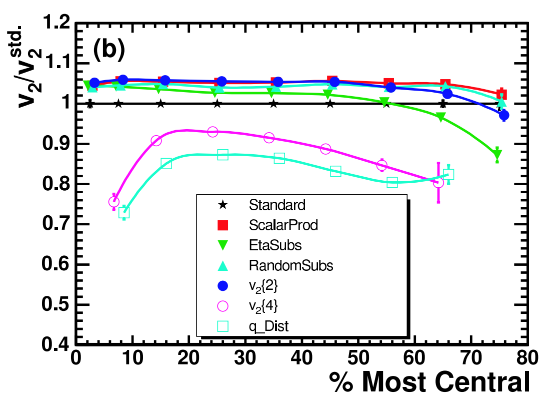


FIG. 1: Charged hadron $v_2$ integrated over $p_t$ and $\eta$ vs. centrality for the various methods. The ratio of $v_2$ to the standard method $v_2$ is shown.

[1] J. Adams et al., *arXiv* nucl-ex/0409033, Phys. Rev. C. **to be published** (2005).