Effects of momentum conservation on the analysis of anisotropic flow*

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We present a general method for taking into account correlations due to momentum conservation in the analysis of anisotropic flow. Momentum conservation mostly affects the first harmonic in azimuthal distributions, i.e., directed flow. It also modifies higher harmonics, for instance elliptic flow, when they are measured with respect to a first harmonic event plane.

In detail, the momentum conservation leads to two effects, whose magnitude is controlled by a parameter f which is roughly the square root of the fraction of all particles used in the estimate of the event plane. First, momentum conservation contributes to the correlation between a particle and the flow vector, proportionally to the parameter f. In addition, it affects the resolution of the event plane, although the effect is smaller, as it is quadratic in f. This second effect may also bias higher harmonics measured with respect to the first harmonic event plane. Note, however, that momentum conservation has no effect when elliptic flow is measured with respect to the second harmonic event plane. The correlation from momentum conservation vanishes if the detector acceptance is symmetric with respect to midrapidity.

The dimensionless quantity f is given by

$$f \equiv \langle w p_T \rangle_Q \sqrt{\frac{M}{\langle w^2 \rangle_Q N \langle p_T^2 \rangle}}, \tag{1}$$

and the subscript Q refers to those M particles used for the **Q**-vector (for which weight $w_i \neq 0$). If w is taken as $+1$ for particles detected in the forward hemisphere and -1 for the backward hemisphere, then $\langle w p_T \rangle_Q = (M_F \langle p_T \rangle_F - M_B \langle p_T \rangle_B)/M$, where F and B refer to particles used for the **Q**-vector from the forward and backward hemispheres, respectively, so that $M = M_F + M_B$. In this case the quantity $\langle w^2 \rangle_Q = 1$.

The correction to $\langle \cos(\phi - \Phi) \rangle$ is:

$$-\frac{p_T}{\sqrt{N \langle p_T^2 \rangle}} \frac{f}{\sqrt{1-f^2}} \frac{\sqrt{\pi}}{2} e^{-\chi^2/2} I_0(\chi^2/2), \tag{2}$$

where χ is the resolution parameter. It is worth noting that the Eq. (2) result depends on χ, expressing the effect of flow in reducing the correlation due to momentum conservation.

The resolution parameter of the subevent, $\chi_{\rm sub}$, can be extracted from the correlation between subevent planes by one of several methods. The correction for momentum conservation is an additive constant of order f^2. Finally, the relation between χ, and $\chi_{\rm sub}$, is:

$$\chi = \chi_{\rm sub} \sqrt{(2-f^2)/(1-f^2)}. \tag{3}$$

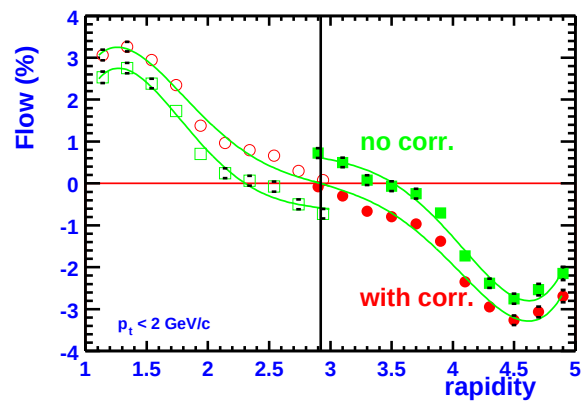

FIG. 1: NA49 results on directed flow as a function of rapidity for charged pions from minimum bias 158A GeV Pb + Pb. Shown are v_1 before (squares) and after (circles) correction for momentum conservation. Solid lines are polynomial fits. The open points have been reflected about midrapidity.

As an illustration, the method was applied [1] to the NA49 data in Pb+Pb collisions at 158 GeV per nucleon [2]. The increase in resolution due to momentum conservation is modest for this case, being less than 10%. However, Fig. 1 shows that the correction for the effect of momentum conservation on v_1 is indeed significant, roughly an absolute value of 1% in the whole rapidity range under study. The corrected correlation gives a directed flow vanishing at midrapidity within error bars, as it should. In fact, if one did not know N and $\langle p_T^2 \rangle$, one could force the data to go through zero at midrapidity as a way to evaluate this correction.

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