Flow Intensity Fields in Heavy Ion Collisions

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The extraction of information on the nuclear equation of state (EOS) from heavy ion collision data has proven to be a formidable task because microscopic simulations have shown that the collision dynamics depends in a complex way on the assumed density and momentum dependence of the mean fields, as well as on many (in-medium) cross sections for the ongoing elementary processes. Attempts to extract basic information from just sub-aspects of the data, such as 'sideflow' or 'elliptic flow' are plagued with ambiguities. To unravel the various only partially known aspects of the theoretical input, a complete set of experimental data should be available. This report shows the progress made by our Collaboration in the direction of obtaining the complete three-dimensional momentum distribution of all the particles emitted in heavy ion collisions in the SIS energy range. The example chosen refers to particles with charge $Z = 2$ emitted in 'half-overlap' collisions of Au on Au at 400A MeV. Emitted charged particles are known to have a momentum space distribution that can be described by $dN/u_t du_t dy d\phi = v_0\,[1{+}2v_1\cos(\phi){+}2v_2\cos(2\phi)]$, where u_t is the transverse 4-velocity, y the rapidity and ϕ the azimuth with respect to the reaction plane. The Fourier coefficients v_0, v_1 and v_2 are 2-dim. functions $v_i(y, u_t)$, i.e. neglecting the higher order coefficients, the third dimension (ϕ) is summarized at each point (y, u_t) by just three coefficients. Technically, we extract the three $v_i(y, u_t)$ coefficient fields from measurements of particle yields in the 4 quadrants subdividing the 2π range of ϕ. After some filtering to eliminate regions of distorted measurements (such as edge effects) and correcting for efficiency, we apply a locally varying biquadratic logarithmic fitting procedure that smoothens the data and fills the gaps in the acceptance. We deduce three intensity fields which are shown in Fig. 1. While the top panel shows the familiar ϕ-integrated two-dimensional invariant cross sections contours (they differ by a factor 1.5), the middle and lower panels show the complete sideflow and the elliptic flow *intensity* fields (on a linear equally binned scale). Obviously the flow intensity fields are highly correlated with the participant/spectator structure. In the middle panel the negative sign of the flow was suppressed in the backward hemisphere, in lower panel the background colour separates regions of out-of-plane emissions (near midrapidity) from those of in-plane emission. The full three-dimensional information allows one to look at the data also in rotated frames. Fig. 2 shows the modification of the average v_2 coefficient as a function of the rotation angle around the out-of-plane (y) axis in a longitudinal (rotated) rapidity bin -0.5 to +0.5. While such rotations do not introduce new information, they reveal the known interdependence of various forms of flow (side and elliptic flow). The *simultaneous* reproduction of all three intensity fields should be a challenge to future theoretical simulations and will help to unravel the theoretical unknowns.

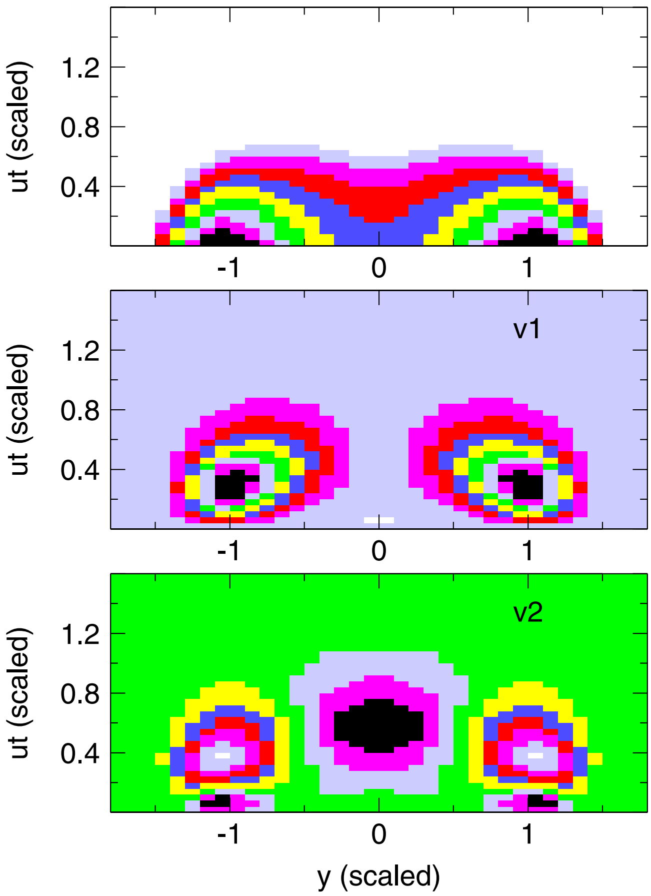

Fig. 1. Invariant cross sections for Z=2 particles emitted in semi-central collisions of Au+Au at 400 AMeV (upper panel) and the associated sideflow (middle panel) and elliptic flow intensity fields.

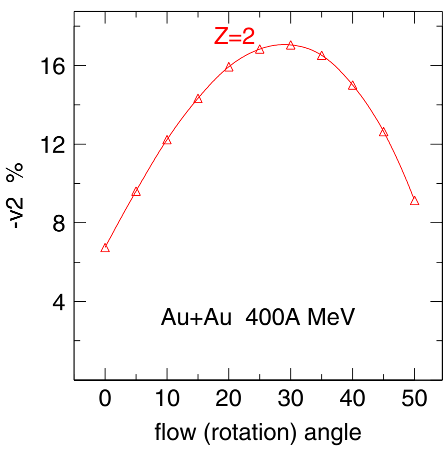

Fig. 2. Mid-rapidity elliptic flow ($-v_2$), deduced from the data in Fig.1, as function of flow axis angle.