

Systematics of stopping and its correlation to sideflow

W. Reisdorf, A. Andronic, A. Gobbi, O. N. Hartmann, N. Herrmann¹, K.D. Hildenbrand, Y.J. Kim, M. Kirejczyk, P. Koczoń, T. Kress, Y. Leifels, A. Schüttauf, Z. Tymiński
FOPI Collaboration, GSI Darmstadt, ¹ Universität Heidelberg

This report presents a rather complete systematics of stopping properties in heavy ion collisions at SIS energies, offering much needed data for comparison with state-of-the-art transport codes, our only hope to derive convincing information on the static and dynamic properties of colliding nuclear matter.

As a measure of the stopping power we present data for an observable dubbed $vartl$, the ratio of the variances of the transverse to that of the longitudinal (conventional) rapidity distributions. The distributions are *full event* observables: all emitted baryonic particles are added, weighted with their respective nuclear charges. The total charge accounted for represents typically 95% of the system charge or more, except for data below 150A MeV, where threshold effects prevent complete coverage of fragments with charge $Z > 6$. This limitation leads to an overestimate of $vartl$. Where necessary, bi-dimensional fitting procedures have been used [1] to interpolate and partially extrapolate the measured spectra. For thermal spectra, in the absence of flow, this ratio should be one. Flow may change $vartl$ however. Early, ideal hydrodynamics estimates [2] predict in this energy regime the phenomenon of *squeeze-out*, resulting, for central collisions, in preferred emission at polar (c.o.m.) angles of 90°: $vartl$ then becomes significantly larger than unity.

The upper-left panel of Fig. 1 shows excitation functions of $vartl$ for Au+Au and Ca+Ca in central collisions corresponding to reduced impact parameters $\hat{b} < 0.15$. Striking aspects of these data are

- a) the occurrence of a well defined 'maximal stopping' near 400A MeV and
- b) the failure of $vartl$ to ever reach values near or above unity even at the energy of maximal stopping.

Arguments speaking strongly in favour of interpreting $vartl < 1$ as evidence for partial transparency, rather than the dominance of longitudinal over transversal pressure gradients are:

- 1) the size dependence of $vartl$, upper right panel of the figure, which demonstrates that $vartl$ increases with the system size (apparently without reaching saturation);
- 2) the two lower panels of the figure show an impressive correlation of scaled directed sideflow p_{xdir} , both in the excitation functions and in the size dependence. In particular p_{xdir} is *positively* correlated with $vartl$.

The scaled directed flow is defined by p_{xdir}/u_{1cm} where $p_{xdir} = \sum sign(y)Zu_x / \sum Z$ (Z fragment charge, u_{1cm} c.o.m. projectile 4-velocity, u_x projection of the fragment 4-velocity on the reaction plane). The sum is over all measured particles, excluding pions, and y is the c.o.m. rapidity. The centrality corresponds to $\hat{b} = 0.3 - 0.4$ where sideflow is maximal.

The most natural explanation of the observed correlation is that sideflow, which is predominantly a spectator phenomenon [1], is resulting from the pressure gradient

between participant and spectator matter, which in turn grows with the degree of stopping. Our observation of partial transparency, which is confirmed by our isospin tracer experiments [3], has important consequences for the ongoing efforts to extract the Equation of State from heavy ion data, as well as for attempts to understand in-medium effects on mesonic particles, since the effective densities in the early phase of the reactions are expected to be strongly correlated to the degree of stopping.

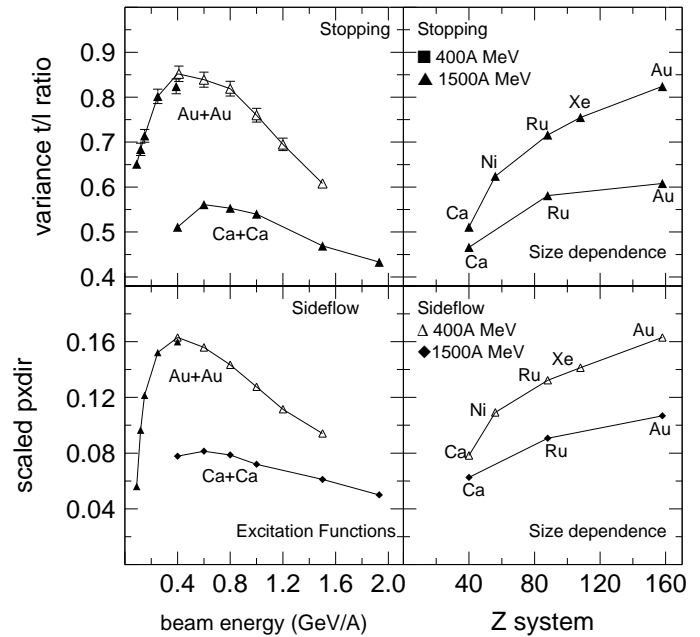


Fig. 1. Excitation functions (left) and size dependences (right) of the 'degree of stopping' (see text, upper panels) and global sideflow (lower panels). The Au on Au excitation functions represent a combination of two separate experiments (full, resp. open symbols).

References

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