2- 26 Effect on Transverse Flow Definition from Different Reaction Mechanisms in AMD and CoMD — Semi-transparency

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In general, the definition of the transverse flow can be classified into the slope flow[1] and the average flow[2] in the certain mid-rapidity region. For a given type of isotope with mass number A, these two definitions are, respectively, expressed as

$$F_{\mathrm{slope}} = \frac{1}{A}\frac{\mathrm{d}P_x}{\mathrm{d}Y^{\mathrm{c.m.}}}|Y^{\mathrm{c.m.}}=0 \quad ,$$

$$F_{\mathrm{avg.}} = \frac{1}{N}\sum_{i=1}^{N}\mathrm{sign}\{Y^{\mathrm{c.m.}}(i)\}\cdot\frac{P_x(i)}{A} \quad ,$$

where $Y^{\mathrm{c.m.}}(i)$ and $P_x^{\mathrm{c.m.}}(i)$ are, respectively, the total energy and longitudinal momentum in the center of mass frame. For convenience in the following discussions, reduced rapidity is introduced as $Y_{\mathrm{red}} = Y^{\mathrm{c.m.}}/\ Y^{\mathrm{c.m.}}_{\mathrm{proj}}$, where $Y^{\mathrm{c.m.}}_{\mathrm{proj}}$ is the center-of-mass rapidity of the projectile[2], so that the projectile (or target) has Y_{red} = 1 (or -1) and the mid-rapidity region is assigned around Y_{red} = 0. Therefore in our analysis, the flow was quantified by focusing on the $Y_{\mathrm{red}}\approx 0$ region. For easy discussions, flow from both definitions are written as F_{slope} and $F_{\mathrm{avg.}}$, respectively.

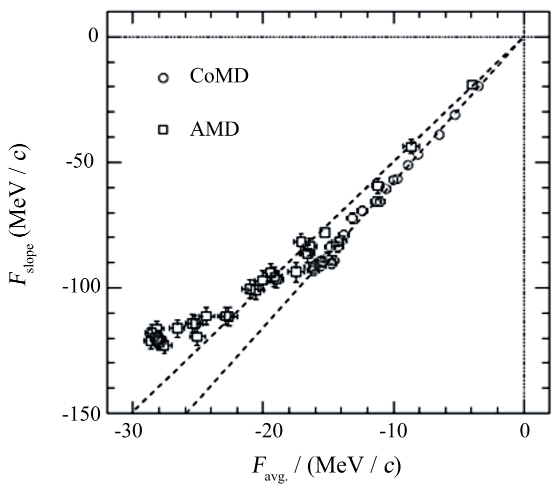

Fig. 1 Extracted F_{slope} vs $F_{\mathrm{avg.}}$ from AMD (open squares) and CoMD (open circles). The data points represent the flow from $A = 1 \sim 30$ particles. The dashed lines are for guiding the eyes.

In Fig. 1, the extracted F_{slope} is plotted as a function of $F_{\mathrm{avg.}}$ for both AMD and CoMD. $F_{\mathrm{avg.}}$ is determined in the rapidity window of Y_{red} = (-0.4,0.4). For easy comparison, the particles with $A = 1 \sim 30$, whose flow shows monotone decreasing trend as A increases, is taken into account. The linear relationship between F_{slope} and $F_{\mathrm{avg.}}$ demonstrates the consistency of these two definitions. However a slight deviation of linear relationships, $F^{\mathrm{AMD}}_{\mathrm{slope}} = (5.0\pm0.1)\times F^{\mathrm{AMD}}_{\mathrm{avg.}}$ and $F^{\mathrm{CoMD}}_{\mathrm{slope}} = (5.7\pm0.1)\times F^{\mathrm{CoMD}}_{\mathrm{avg.}}$ is obtained.

Before discussing, In Fig. 2, normalized rapidity distributions from AMD and CoMD are compared, for instance, rapidity of A= 1, 4, 12, 20, 30, 40 is chosen. From Fig. 2, one can observe the different patterns of rapidity predicted by AMD and CoMD. On one hand in CoMD case, the shapes of Y_{red} for the fragments with various mass all appear roughly "Gaussian-like", except for that the broadenings of the peak decrease with the increase of A. This gradual diminution of the broadening is due to two reasons as explained below: one reason is the decrease of the thermal momentum contributions on Y_{red} as A increases because of the mass dependence of the thermal motion; the other one is the limitation of the momentum conservation. The momentum per nucleon of heavy fragments cannot be too large. On the other hand, AMD rapidity distributes differently, like for A=1 fragments, the distribution shapes "Gaussian-like", whereas the projectile-like (PL) and target-like (TL) components tend to separate as A increases. Finally, very tiny amount of large fragments fall into the mid-rapidity bins. The comparison of the rapidity distributions between AMD and CoMD indicates that in the collision of CoMD, projectile and target prefer to compounding and then stopping in the origin of Y_{red}, whereas AMD predicts the nucleons in projectiles and targets have more semi-transparency.

This semi-transparency may be originated from the different treatments to the fragmentation process in the collisions. As well known that as dealing with Pauli blocking, CoMD forces the average occupation numbers f_i (for a nucleons) to satisfy the condition f_i <1 at each time step; for AMD, the the wave packets of nucleons are antisymmetized and this antisymmetrization implies in the evolution. Pauli principle will be satisfied automatically. However many n-n collisions are blocked, resulting in that the projectile and the target pass through each other for both central and peripheral collisions[3]. In this paper, AMD-V code is utilized and as discussed in Ref.[3], the technique of wave packet splitting, which allows the projectile and the target to compound easily and enables the breakup of the system into small pieces, has been introduced in stochastic two-nucleon collisions in this version. After adjusting the strength of wave packet splitting, experimental data[4] is better reproduced, rather than the AMD calculations without it. Even so, further research is needed before a conclusion, because the appropriate strength seems to depend on the size of the system and/or the incident energy, and the most important is CoMD-II can very well reproduces this data as well, even without any antisymmetrization or wave packet splitting. Since the aim of this section is to clarify the flow mechanism, both results are allowed for in the further flow analysis.

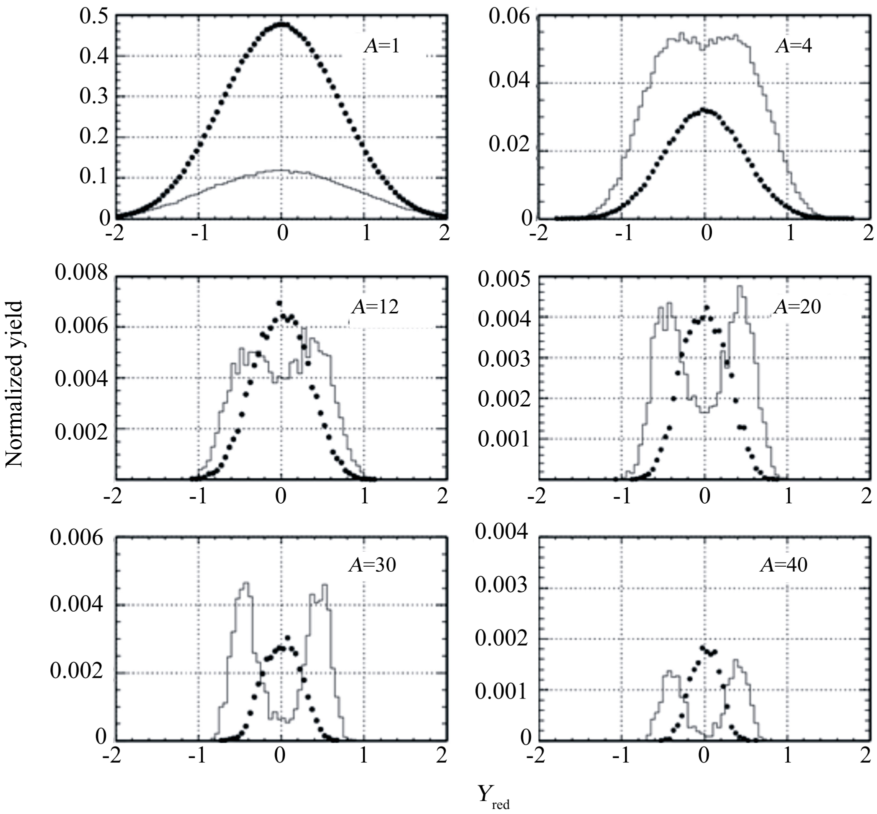

Fig. 2 (color online) Normalized rapidity distributions from AMD (lines) and CoMD (dots) for A=1, 4, 12, 20, 30 and 40.

Thus if $F_{\mathrm{avg.}}$ definition is employed, the weight distribution of P_x/A is important while extracting $F_{\mathrm{avg.}}$. Yet the weight is determined by the rapidity distribution. Taking CoMD as an example, as a consequence of the "Gaussian-like" distribution, the weight of P_x/A with large absolute values decreases from $Y_{\mathrm{red}}= 0$ to $Y_{\mathrm{red}} > 0$. This fact can interpret the result shown in Fig. 1, that for "uniform-like" rapidity distribution in AMD, large P_x/A contributes more while averaging P_x/A, compared with that of CoMD. Therefore under the assumption of the invariance of F_{slope}, the ratio of AMD, $F^{\mathrm{AMD}}_{\mathrm{slope}}/F^{\mathrm{AMD}}_{\mathrm{avg.}}$ will be smaller than $F^{\mathrm{CoMD}}_{\mathrm{slope}}/F^{\mathrm{CoMD}}_{\mathrm{avg.}}$ of CoMD due to the enhancement of $F^{\mathrm{AMD}}_{\mathrm{avg.}}$. Additionally the some squares in Fig. 1 locate off the fitting line in the large flow region. This is because the distribution in mid-rapidity region for AMD changes slightly depending on the particle mass. Strictly speaking, the mid-rapidity region of AMD distributes from "$\cap$" to "$\cup$" with the increase of A from $A = 1$ to $A = 30$. As a consequence, $F^{\mathrm{AMD}}_{\mathrm{avg.}}$ from light particles will be more enhanced, compared with those from the heavy ones.

References

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