Correlation between nuclear stopping and directed flow at intermediate energies

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Introduction

The major goal in heavy ion physics is to study the nuclear equation of state (NEOS) and also about the hot and dense nuclear matter. The various observables are used to study the NEOS in heavy ion collision at intermediate energy. Collective flow and nuclear stopping having a special status among all the observables. Various experimental and theoretical observations has been made about the study of collective flow and nuclear stopping in heavy ion collision. Collective flow is the phenomena which can be studied by "directed flow" which refers to azimuthal asymmetric emission of particles within the reaction plane and is given by [1]:

$$\langle p_x^{dir} \rangle = \frac{1}{A} \sum_{n=1}^{A} sgnY(i)p_x(i) \qquad (1)$$

where y(i) is the rapidity and p_x(i) is the momentum of i^{th} particle. The other is "elliptical flow" which is the squeeze out of the participant matter out of reaction plane. As a measure of the degree of stopping we use an observable dubbed varxz, the ratio of the variances of the transverse to that of the longitudinal rapidity distributions and is given by:

$$varxz = \frac{\sigma^2(x)}{\sigma^2(z)} \qquad (2)$$

For an isotropic thermal source varxz should be equal to unity [2]. Recently, Puri & coworkers [3] correlated the multifragmentation and global nuclear stopping. Fu *et al.* [4] calculated both radial flow and the degree of nuclear stopping using the reactions of Pb + Pb and Ni + Ni at an incident energy of 0.4, 0.8, and 1.2 GeV/nucleon. In present paper our aim is to study the complete systematic (system size dependences) of global stopping and directed flow and the correlation between these two observables for heavy ion reactions.

The Model

Calculations are carried out within the framework of Isospin dependent Quantum Molecular Dynamics (IQMD) [5] model, which is a modified version of QMD [6] model. The IQMD is a semi-classical model which describes the heavy-ion collisions on an event by event basis. For more details, see ref.[5].
In IQMD model, the centroid of each nucleon propagates under the classical equations of motion.

$$\frac{d\vec{r_i}}{dt} = \frac{dH}{d\vec{p_i}} \ ; \ \frac{d\vec{p_i}}{dt} = -\frac{dH}{d\vec{r_i}} \ . \qquad (3)$$

The H referring to the Hamiltonian reads as:

$$H = \sum_i \frac{p_i^2}{2m_i} + V^{ij}_{Yukawa} + V^{ij}_{Coul} + V^{ij}_{skyrme} + V^{ij}_{sym}. \qquad (4)$$

During the propagation, two nucleons are supposed to suffer a binary collision if the distance between their centroids

$$|r_i - r_j| \le \sqrt{\frac{\sigma_{tot}}{\pi}}, \sigma_{tot} = \sigma(\sqrt{s}, type), \qquad (5)$$

Results and Discussion

For the present analysis, simulations are carried out for the reactions of $^{40}_{20}Ca_{20} +^{40}_{20}$

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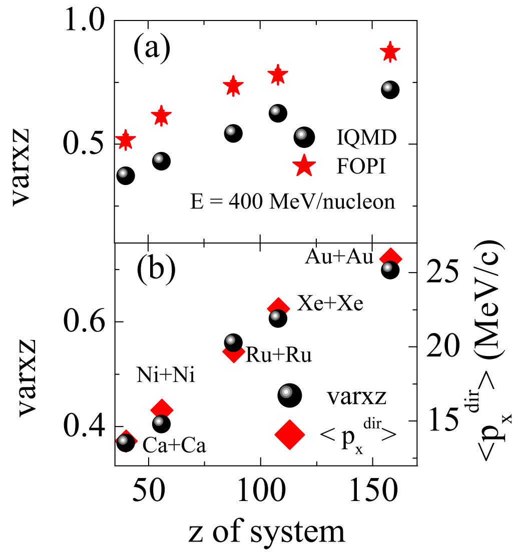

FIG. 1: System charge dependence of varxz [panel (a)] and correlation between varxz & p_x^{dir} [panel (b)]

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Ca_{20}, ${}^{58}_{28}Ni_{30} +^{58}_{28} Ni_{30}$, ${}^{101}_{44}Ru_{57} +^{101}_{44} Ru_{57}$, ${}^{132}_{54}Xe_{78} +^{132}_{54} Xe_{78}$ and ${}^{197}_{79}Au_{118} +^{197}_{79} Au_{118}$ at scaled impacct parameter $\hat{b}$ = b/b_{max} < 0.15, where $b_{max} = 1.12\ (A_P^{1/3} + A_T^{1/3})$ fm and A_P and A_T are the masses of projectile and target respectively.

To study the effect of system size dependence on the stopping observable varxz, we display in Fig.1 [panel (a)], the system charge dependence of varxz for central collision at an incident energy of 400 MeV/nucleon. It has been observed that, at the lower energy, there is no evident saturation as one goes from Ca+Ca, via Ni+Ni, Ru+Ru, Xe+Xe, all the way to Au+Au. Moreover, even for the central collisions the value of varxz is not unity. Which means that the system is not fully thermalized even for central collisions. Theoretical results are compared with the experimental findings of FOPI collaboration [2]. In [panel (b)], we dispaly the correlation between the varxz and $< p_x^{dir} >$. Both the parameters shows a linear relationship for each system and shows a positive slope. These observations are in agreement with Ref. [2].

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References

[1] A. D. Sood and R. K. Puri, Phys. Lett. B **594**, 260 (2004); E. Lehmann, A. Faessler, J. Zipprich, R. K. Puri, and S. W. Huang, Z. Phys. A **355**, 55 (1996).

[2] W. Reisdorf *et al.,* Phys. Rev. Lett. **92**, 232301 (2004).

[3] J. K. Dhawan, N. Dhiman, A. D. Sood, R. K. Puri, Phys. Rev. C **74**, 057901 (2006).

[4] F. Fu *et al.*, Phys. Lett. B **666**, 359 (2008).

[5] C. Hartnack *et. al.*, Eur. Phys. Journal A **1**, 151 (1998).

[6] J. Aichelin, Phys. Rep. **202**, 233 (1991).