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# Study of energy dissipation in heavy ion collisions

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## Introduction

The heavy ion collision is the only way to produce and study hot and dense, strongly interacting nuclear matter [1]. At the collision point, the two nuclei fuse together to form thermally excited nuclear matter[2]. The rise in temperature and density of the nuclear matter depends upon various initial parameters such as incident energy, impact parameter, mass, isospin-asymmetry etc. The nuclear matter can exist in three different phases depending upon the temperature and density. At low temperature and low densities, liquid phase exists. At low temperature and high densities, we have condensed phase of the nuclear matter. At the extremes of temperature and density, quark gluon plasma (QGP) exists. At high temperature and low densities, hadron gas phase is exists which can be achieved through the heavy ion collisions at intermediate energies.

In the reaction dynamics of the heavy ion collisions, when the projectile and target move towards each other with some incident energy, they create a highly dense zone which is called participant zone or fire ball [3]. This fireball is an object of interest since its formation is governed by the density achieved in the violent phase of collision due to the initial energy provided to the nuclear system of projectile and target nucleons. In this paper, an attempt has been made to study the amount of energy acquired or hold and energy dissipated in heavy ion collisions at intermediate energies using isospin dependent quantum molecular dynamics (IQMD) model.

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## Model

The Isospin quantum molecular dynamics (IQMD) [4, 5] model treats different charge states of nucleons, deltas and pions explicitly. The nucleons are primarily initialized in a sphere of radius in accordance with the liquid drop model (LDM) [6] i.e. isospin independent. The hadrons propagate using Hamilton equations of motion:

$$\begin{aligned} \langle\ H\ \rangle\ &=\ \langle\ T\ \rangle + \langle\ V\ \rangle \\ &=\ \sum_i \frac{p_i^2}{2m_i} + \sum_i \sum_{j>i} \int f_i(\vec{r},\vec{p},t) V^{ij}(\vec{r}',\vec{r}) \\ &\quad \times f_j(\vec{r}',\vec{p}',t) d\vec{r} d\vec{r}' d\vec{p} d\vec{p}'. \end{aligned} \tag{1}$$

The nucleons of the target and projectile interact by two- and three-body Skyrme forces, Yukawa potential and Coulomb interactions. A symmetry potential between protons and neutrons corresponding to the Bethe-Weizsacker mass formula has also been included. In addition, Pauli blocking (of the final state) of baryons is taken into account by checking the phase space densities of the final states.

## Results and discussion

The IQMD simulations have been carried out for the symmetric reaction of $^{56}$Ni+$^{56}$Ni at an incident energy of 50 MeV/n. The reaction is followed till 200 fm/c. The left panels of Fig. [1] display the time evolution of energy dissipated $E_{diss}$ (upper) and energy hold $E_{hold}$ by the nuclear matter. On the other hand, the right panels represents the time evolution of number of nucleons which dissipated the energy from 50 MeV $N_{diss}$ (upper) and gained the energy above 50 MeV $N_{gain}$ (lower) during the reaction dynamics. It can be seen from the figure that in the collision dynamics, the system first gain the energy up to 40 MeV/n and dissipate only 10 MeV/n energy around 10-20 fm/c. After that, the nuclear system suddenly dissipate the large amount of energy $\sim$ 35 MeV/n up to 100 fm/c. At this time, the amount of energy hold by the system is around 15 MeV/n. This dissipated energy (or hold energy) of the nuclear system saturates at 200 fm/c.

The total number of nucleon in the system is 112 for the reaction studied in the present work and the initial energy provided to each nucleon is 50 MeV. However, during the collision process, some nucleon will gain the energy and some will lose. One can observe from the figure that the $N_{diss}$ decreases around 10-20 fm/c and suddenly this count increases to 110 at 50 fm/c an remain constant.

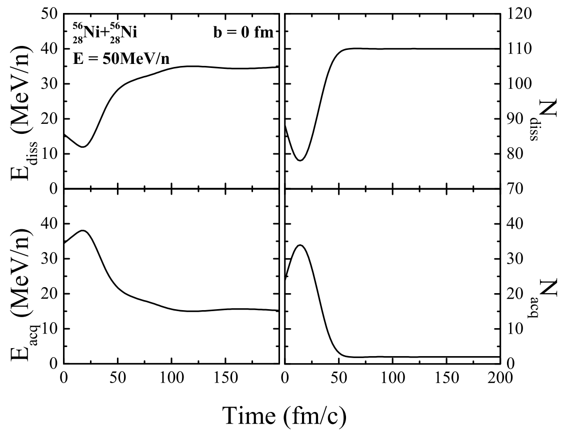


FIG. 1: Time evolution of energy dissipation (upper left panel), energy acquired (lower left panel), number of particles dissipating the energy (upper right panel) and acquiring the energy (lower right panel) for the reaction of $^{56}$Ni+$^{56}$N$atincidentenergyof50MeV/n$

## Conclusions and Outlook

In summary, we have studied the energy dissipation by the nuclear system at 50 MeV/n for head-on collisios. It has been concluded that the participant zone (fire ball) forming around 10-20 fm/c, is definitely having high energy, but not greater than the energy applied i.e. always less than 50 MeV/n. The number of particles dissipating the energy suddenly (10-20 fm/c) are responsible for the out burst of the fire ball. From the starting of the collision to the freeze out time, there is continues dissipation in amount of energy that might spread in the form of photons or gamma rays. The further calculations in this direction are under process.

## References

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