# Effect of nuclear compressibility on the fragmentation in peripheral Au+Au collisions at 35 AMeV

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## Introduction

The heavy-ion collisions in intermediate energy regime can provide important clues about the nature of baryonic matter equation of state (EoS) with nucleon density varying between 1/3 and 3 times the saturation density $\varrho_o (= 0.17 \ fm^{-3})$ of cold nuclei [1]. At higher bombarding energies, momentum dependence of *n-n* interaction as well as in-medium scattering cross-section affect considerably the phenomenon of collective flow and multifragmentation [2, 3]. In Fermi energy domain, fragmentation of hot nucleus has been given attention in recent times [4], where *quantum molecular dynamics* (QMD) model coupled with advanced clustering subroutine namely *simulated annealing clusterization algorithm (SACA)* is reported to explain the $^{16}O + ^{80}Br$ fragmentation data at incident energies $T_{lab}$=50-200 AMeV. For the present work, we aim to address the problem of nuclear EoS by studying the fragmentation in peripheral Au+Au collisions at $T_{lab} = 35$ AMeV employing a soft EoS ($\kappa = 200 MeV$) and a hard Eos ($\kappa = 380 MeV$).

## The Model

To generate the phase space of nucleons and see the effect of different nuclear compressibilities, we employ quantum molecular dynamics (QMD) model [5]. In this model, phase space

of nucleons is calculated via Hamilton's equations of motion:

$$\dot{\mathbf{p}}_i = -\{\mathbf{r}_i, \mathcal{H}\}, \qquad (1)$$
$$\dot{\mathbf{r}}_i = \{\mathbf{p}_i, \mathcal{H}\}. \qquad (2)$$

Here $\mathcal{H}$ is the total Hamiltonian of the system of $A_P + A_T$ nucleons. These equations are solved after fixed time interval $\triangle t$ chosen to be very small.

The phase space of nucleons is clusterized using improvised version of *SACA* [6] labeled as *SACA (2.1)* where binding energy of each cluster $\zeta_f$ is checked to be greater than $E_{bind}$ given as

$$E_{bind} = a_v A_f - a_s A_f^{2/3} - a_c \frac{Z_f(A_f-1)}{A_f^{1/3}} -$$

$$a_{sym} \frac{(A_f - 2Z_f)^2}{A_f}(\pm, 0) \ a_p \frac{(1 - e^{-A_f/30})}{A_f^{1/2}}, \quad (3)$$

with $A_f$ and $Z_f$ as mass and charge of a cluster. The last term (*i.e.* pairing energy term) is taken to be +ve for even-even nuclei, -ve for odd-odd nuclei and zero for odd $A_f$ nuclei.

## Results and Discussion

We display in Fig. 1, the calculations with soft and hard equations of state for Au(35 AMeV)+Au collisions at reduced impact parameters $\hat{b} = 0.55$ and 0.85, respectively. One obtains a clear difference in the fragment observables due to choice of nuclear compressibility. Asymptotic size of $A^{max}$ and multiplicity of heavier clusters $[3 \leq Z \leq 80]$ saturate as early as 100 fm/c when system has just

evolved from violent phase. With soft EoS, a larger number of heavier fragments are produced, thereby, decreasing the size of $A^{max}$, while hard $n$-$n$ collisions result into emission of free nucleons mostly. Earlier recognition of cluster configuration suggest that $SACA$ $(2.1)$ is well suited for the study of heavy ion reactions in low energy regime. Next, we turn to comparison of model calculations for the multiplicity of fragments $[3 \leq Z \leq 80]$ obtained from decay of spectator matter moving in forward direction with rapidity $y > 0.5 \; y_{beam}$ in the c.m. frame with experimental data taken with Miniball-Multics array [7]. Figure 2 depicts the results of QMD simulations for soft and hard interactions at 100 fm/c as a function of reduced impact parameter $b/b_{max}$. The mean multiplicity of fragments falls with increase in the impact parameter. This can be understood in terms of lesser transfer of energy from hot participant zone to spectator region at peripheral geometries. One can clearly see that soft EoS accurately reproduces the experimental trend of fragment multiplicity as a function of impact parameter. The hard EoS on the contrary, seems too explosive to explain the data.

This study shows that $SACA$ $(2.1)$ can well describe the early dynamics of reactions at low energy. The predictions with QMD model for the fragment yield in peripheral Au+Au collisions favor *soft* nature of baryonic matter [8].

**References**

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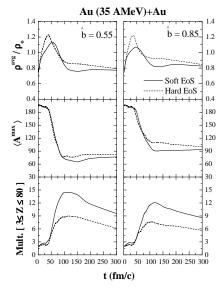[6] Y. K. Vermani *et al.*, J. Phys. G: Nucl. and Part. Phys. **37**, 015105 (2010).

FIG. 1: The time evolution of mean nucleon density $\rho^{avg}$ (top), size of heaviest fragment $A^{max}$ (middle), and multiplicity of fragments with charge $3 \leq Z \leq 80$ (bottom).
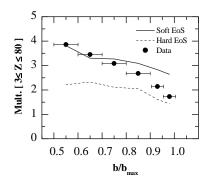


FIG. 2: The impact parameter dependence of multiplicity of fragments with charge $3 \leq Z \leq 80$ obtained with a 'soft' EoS (solid line) and a 'hard' EoS (dashed line) in Au(35 AMeV)+Au collision. Filled circles depict the experimental data points [7] (Preliminary Results).

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