Study of Memory Effects in Dissipative Heavy-Ion Collisions

H.L. Yadav,[a,b] and K.C. Agarwal[b]

[a] *Research Centre for Nuclear Physics, Osaka University, Osaka, Japan*
[b] *Physics Department, Rajasthan University, Jaipur, India*

The dissipative heavy-ion reactions have been studied extensively both from the theoretical as well as experimental points of view covering a wide range of energies [1]. The main objective of this communication is to point out and emphasize the influence of memory effects on the observable quantities in the dissipative heavy-ion reactions. The calculations are carried out in terms of a macroscopic dynamical model within the framework of a multidimensional Fokker-Plank equation described in [2-4]. The multi-dimensional distribution function $f(q_i, p_i, t)$ is obtained by solving the Fokker-Plank equation given by

$$\frac{\partial f}{\partial t} + \sum_i \left[\frac{p_i}{m_i}\frac{\partial f}{\partial q_i} + \frac{\partial U_{dyn}}{\partial q_i}\frac{\partial f}{\partial p_i} \right] = -\sum_i \frac{\partial (v_i f)}{\partial p_i} + \sum_{ij} \frac{\partial^2 (D_{ij} f)}{\partial p_i \partial r_j} \tag{1}$$

Where p_i are the conjugate momenta of the collective coordinates q_i. For the collective coordinate we consider the position r and momentum p of the radial motion, angle θ and angular momentum l of rotation, deformation ϵ and mass asymmetry α. According to [2-3] the memory effect is treated through a time dependent dynamical potential,

$$U_{dyn}(\bar{q}) = U_{ad}(\bar{q})\,[1 - \chi(t)] + U_{diab}(\bar{q})\,\chi(t) \tag{2}$$

Where $\bar{q}$ denotes a set of collective coordinates, and the decay factor $\chi(t)$ describes a smooth transition from the diabatic potential U_{diab} to the adiabatic potential U_{ad} as described in detail in [4]. It is given by

$$\chi(t) = \exp\left\{ - \int_{-t_0}^{t} dt' \tau_{int}^{-1}(t') \right\} \tag{3}$$

Here the intrinsic equilibration time [5] is given by $\tau_{int} \simeq 2.10^{-22} s/E^*$ where E^* is the total excitation energy. The transport coefficients ni and D_{ij} are given by [3-4].

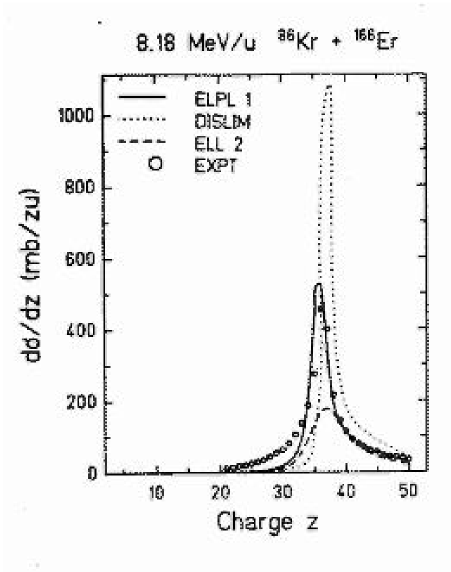
$$\nu_i = \nu_i^0 f_i(r, \epsilon) g_i(t) \quad \text{and} \quad D_{ij} = D_{ij}^0 f_{ij}(r, \epsilon) G_{ij}(t) \tag{4}$$

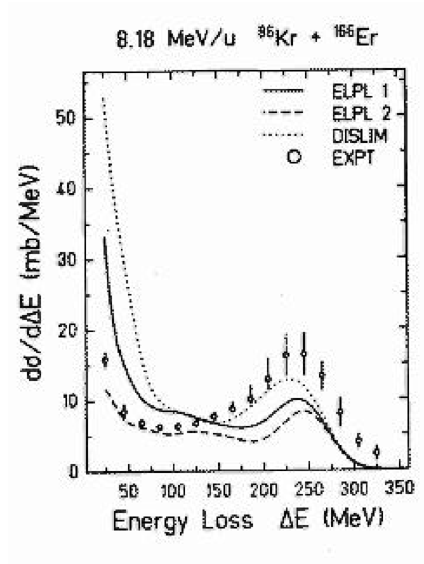
where f_i and G_{ij} are appropriate form fators [3-4], and the coefficients ν_i^0 and D_{ij}^0 are those used in ref. [3]. Three sets of calculation [4] have been carried out to study the memory effects:

(i) We use $(1 - \chi(t))$ for the factors g_i and G_{ij} to describe the elastoplastic process. The results are denoted by ELPL1.

(ii) In another set of calculations we remove the diabatic potential for the angular motion and the corresponding results have been marked by ELPL2.

(iii) In the third type of study no consideration is made for the diabatic potential and thus it describes the limit dissipative of the collision process. The results are designated as DISLIM.





In the figure below we have displayed the results of our study for the reaction $^{86}Kr(8.18\text{MeV}/u)+{}^{166}Er$ and that of $^{136}Xe+{}^{209}Bi$ for three different bombarding energies ($E_{lab} = 940$, 1130 and 1420 MeV) to show the energy dependence. For the $^{86}Kr + {}^{166}Er$ collision, the results for the angular distribution $\frac{d\sigma}{d\theta}$, charge distribution $\frac{d\sigma}{dZ}$ and energy distribution $\frac{d\sigma}{d\Delta E}$ have been shown along with the experimental data [6]. The calculated mean values of the deflection angle θ_{cm}, charge Z and energy loss ΔE have also been displayed. It is found that the elastoplastic limit ELPL1, in contrast to other two cases describes the experimental data more satisfactorily and provides convincing evidence for the memory effects in the dissipative heavy-ion collisions. Similar investigation for the $^{136}Xe + {}^{209}Bi$ reaction at three different bombarding energies corroborates our this conclusion as is evident from a comparison of the calculated energy cross-section with the experimental data [7] shown in the lowest part of the figure. In this figure each calculation has been done for two different cuts off in the initial impact parameter value used. In the first case, it corresponds to the dissipation energy ΔE. In the second case, it is obtained using the value of experimental cross-section. Once again the Elastoplastic limit ELPL1 is found to provide a satisfactory comparison with the experimental data and hence also a convincing signature for the memory effects.

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