Multifragmentation in Fermionic Molecular Dynamics

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Fermionic Molecular Dynamics (FMD) predicts a clear first–order liquid–gas phase transiton even for rather small nuclear systems [1]. But the time which FMD needs to achieve global equilibrium at a given temperature or excitation energy in the coexistence phase, is much longer than typical reaction times. On the other hand, the same model shows on a short time scale fragmentation in collisions of nuclei [2,3]. In the first row of the figure a typical result of a collision with $E_{LAB} = 35A$MeV and $b = 2.75$ fm is depicted in terms of a density contour plot.The excited system formed at 120 fm/c with $E^*/A \approx 8$ MeV clearly breaks up into several fragments. By only looking at one–body distributions in coordinate and momentum space it is difficult to decide how much the system has been randomized before breakup.

Therefore, we create a randomized system by hand and study its time evolution in the framework of FMD. For that, in the ground state of ^{56}Fe, the mean positions of the wave packets are randomly displaced such that an excitation energy of $E^*/A = 9.7$ MeV is reached. In the second row one sees that now FMD does not predict multifragmentation but rather an evaporation residue. At the initial time the density differs very little from the groundstate density but due to the randomization of the positions which has destroyed the many–body correlations in the ground state the nucleons acquire high momentum components and begin to evaporate. The crosses indicate the mean positions of the packets. A cross which is not surrounded by density contour lines implies that the wave packet has already spread out so far that the density, even in the maximum, has fallen below the last contour. These are unbound nucleons. At 300 fm/c many nucleons have left the original Fe nucleus and only a small evaporation residue is left.

In the third row an excitation energy of $E^*/A = 10$ MeV is created by shrinking all mean positions by a factor of 0.6 and adding only small random displacements. This way the nucleus is compressed but correlations are not completely destroyed. The not astonishing result is that one sees multifragmentation with the initial structure of the Fe nucleus surviving to a large extent.

All three cases have excitation energies in the coexistence region of the first order phase transiton. As has been shown in [1] the FMD model predicts that for low pressure it ranges from about $E^*/A = 5$ to 11 MeV per particle.

These results indicate that a non–thermal situation like in a collision might actually be very helpful in getting the nucleus beyond the barrier for multifragmentation, which exists in the equilibrium potential–energy surface, much faster than a quasi–static equilibrium evolution. A non–equilibrium system, which drives towards equilibrium, can feed into all parts of the coexistence region in the phase diagram, ranging from a situation with small E^* where a large fraction of the particles is in clusters (liquid) and few are in the vapour to the high excitation side with smaller fragments and many unbound nucleons (vapour).

[1] J. Schnack, H. Feldmeier: Phys. Lett. B 409 (1997) 6

[2] H. Feldmeier, J. Schnack: Advances in Nuclear Dynamics 3, p. 83-90, Plenum Publishing Corp., NY (1997)

[3] H. Feldmeier, T. Neff, R. Roth, J. Schnack: Proc. Int. Symp. Innovative Computational Methods in Nuclear Many Problems, Osaka (1997)

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