Fermionic Molecular Dynamics
From Fusion to Multifragmentation

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A molecular dynamics picture is supposed to be adequate for the description of large fluctuations and correlations observed in heavy–ion collisions. But nucleons in nuclei cannot be localized enough so that classical physics is not applicable. Fermionic Molecular Dynamics (FMD) [1] includes two major properties of quantum mechanics: the Heisenberg uncertainty relation and the Pauli exclusion principle. The use of single–particle wave–packets in an antisymmetrized many–body state guarantees that neither the uncertainty principle nor the Pauli principle can be violated. Calculations have shown that FMD is able to describe ground states of light nuclei and reactions at low bombarding energies which exhibit large fluctuations [2].

In a second step we include short–range hard–core correlations into the antisymmetrized many–body state. With the previously used effective interactions (like Volkov V2) saturation of the binding energy in heavier nuclei cannot be achieved and collisions at higher energies turn out to be too transparent. First investigations of hard–core correlations on the two–body level already show that the binding energy of heavier nuclei (up to ^{40}Ca) saturates and that in reactions at higher energies the additional hard collisions between nucleons lead to much more stopping and faster equilibration.

In the figure below we demonstrate for the system ^{27}Al on ^{27}Al at b=5 fm that with increasing energy the collisions develop from fusion via incomplete fusion to fragmentation. For all three runs the initial intrinsic orientations and the impact parameter are kept fixed.

The single–particle density is shown in coordinate space integrated over z, with cuts at 0.9, 0.5, 0.1 and 0.001 of the maximum density. Crosses indicate the centres of the single–particle wave–packets.

The upper collision is for a lab energy of 4 AMeV. The system fuses and the momentum distribution (not shown) indicates that thermalization takes place. Due to the hard–core correlations the equilibrium is reached faster than with a softer interaction. At 800 fm/c, long time after the fusion occurred, an Alpha particle escapes.

The reaction in the second line with E=8 AMeV shows incomplete fusion. A ^{8}Be which originates from spectator matter (upper part of left nucleus) does not take part in the fusion and escapes to the right hand side carrying away momentum and angular momentum. Later on the ^{8}Be decays and the recoiling fused system equilibrates.

Fragmentation occurs in the last line. Here the two ^{27}Al collide at E=28 AMeV and break up into several fragments shortly after they merged. A more detailed analysis suggests that fragment formation happens rather early due to correlations which exist in the system before breakup.

References

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[2] J. Schnack, diploma thesis, GSI report GSI-93-21 (1993)