Modeling Timescale of Equilibration in Dinuclear Systems

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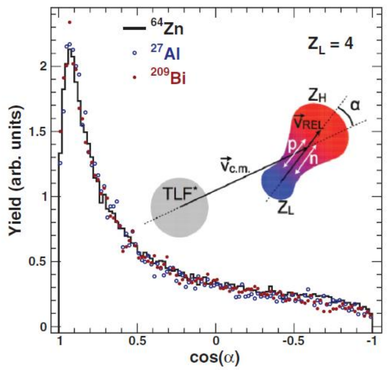
Introduction

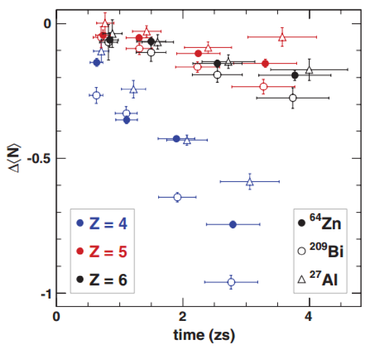
- The break-up and N/Z equilibration processes of dinuclear systems can be utilized to place constraints on the density dependence of the symmetry energy.
- In semi-peripheral heavy-ion collisions, the projectile and target can exchange charge, mass, and energy, creating two excited nuclei.
- The two excited nuclei formed are designated as projectile-like and target-like.
- A deformed projectile-like fragment (PLF) can undergo binary decay.
- The rotation of this decaying binary system can be used to probe the timescale of the N/Z equilibration of the system.

Previous Research

- The Indiana University research group measured the binary decay of PLF* fragments. From the rotation of the system, the timescale of the breakup and N/Z equilibration was extracted [1,2].
- Three different reactions were measured using a ^{64}Zn beam on ^{27}Al, ^{64}Zn, and ^{209}Bi targets.
- The projectile-like fragment decayed into two primary fragments, designated as Z_H for the heavier fragment and Z_L for the lighter fragment.
- To ensure that the projectile-like fragments studied were composed mainly of the initial projectile, they placed the constraint Z_H>11.
- The Z_L fragments examined were 4, 5, and 6.
- The angle between the center-of-mass velocity and the relative velocity of the two fragments, given here as α, is an important value for binary decay, giving the direction in which the Z_L fragment decays.
- When the Z_L fragment is emitted backward, the cos(α) = 1; when emitted forward, the cos(α) = -1.
- The research showed that the binary decay shows a preferential backwards decay with a strong peak just under 1.



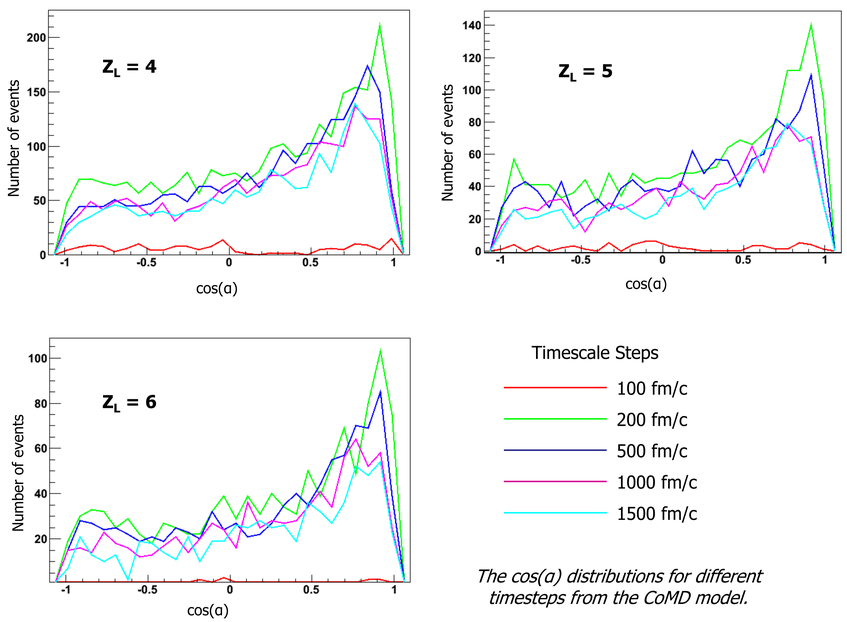
The cos(α) distribution for Z_L = 4. [1]



Average change in the neutron number for Z_L=4-6 as a function of the breakup time. [1]

Timescale Modeling

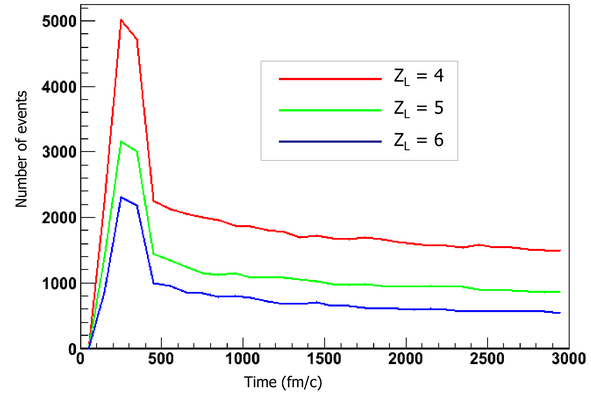
- The objective of this study was to use the Constrained Molecular Dynamics (CoMD) model to compare simulations to results from the IU group [1,2] on the complex PLF* binary decay process.
- The comparison will allow for a better understanding of the timescale of equilibration.
- To minimize computational time the 45 MeV/u ^{64}Zn + ^{64}Zn reaction was modeled.
- The experimental constraints, such as limiting Z_H to over 11 and investigating Z_L values of 4, 5, and 6 were also applied to the simulation.



The cos(α) distributions for different timesteps from the CoMD model.

- Similar to the experimental results, the CoMD data showed the cos(α) distribution to peak just under 1, though it did not show quite as strong a peak.
- At 100 fm/c, there are relatively few events that have binary decayed.
- The events at 100 fm/c that do occur did not show a preference to backwards decay and were instead distributed more evenly.
- At 200 fm/c, there is a large increase in the number of events measured, displaying the prominent peak at around cos(α) = 1.
- Time steps after 200 fm/c also show a peak at just under cos(α) = 1, though fewer binary decays are registered over time.

Timescale Modeling



Number of binary decays over time in the CoMD model.

- For all three Z_L values investigated, binary decay in the projectile-like fragment peaked at around 200 fm/c (0.66 zs).
- The results indicate that the binary decay occurs relatively quickly in most cases (< 500 fm/c).

Summary and Future Outlook

- We were able to demonstrate that the CoMD model produces the same trends for binary decay as found through the experiment.
- Additional statistical analysis, including the use of simulations with the ^{27}Al and ^{209}Bi targets, would provide further comparisons between the CoMD model and the experimental data obtained by the Indiana University research group.
- If the CoMD model proves to be a good representation of semi-peripheral collision and binary decay, we can examine the model to investigate the N/Z equilibration process and how it affects the density dependence of the nuclear symmetry energy.

References

[1] K. Brown et. al. Phys. Rev. C, **87**, 061601(R) (2013).
[2] S. Hudan et. al. Phys. Rev. C, **86**, 021603(R) (2013).

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