Comparison Between Pre-equilibrium Reaction Models.

Carla A. Soares Pompeia and Brett V. Carlson.

Instituto Tecnológico de Aeronáutica,

São José dos Campos.
Pre-equilibrium reactions

**When**

They occur when nucleons are emitted before the incident energy is distributed among the degrees of freedom of nucleus.

**Why**

They are important in nucleon-induced reactions with incident energy above 10 MeV. Fast reactors, ADS, proton therapy, ...

**How**

The commonly used semiclassical models that describe pre-equilibrium reaction are: The exciton model and the hybrid/HMS model.
Several characteristics...

The nucleons are distributed among single particle states.

The nucleons interact through two-body collisions, energy is conserved.

The Fermi energy lies between the last occupied level and the first unoccupied level of the nucleus in its ground state.

Particles and holes are called excitons.
Exciton Model

- freezes the hole at the Fermi energy;
- Assumes that the configuration with same number of excitons are in equilibrium;
- Makes use of the densities states and transition densities, which simplify the calculation.
Hybrid/HMS Model

- The transitions and emissions for each configuration are treated individually;
- The calculation are performed using Monte Carlo Method;
- For nucleon $^{40}\text{Ca}$ at 100 MeV, $10^9$ configurations versus 20 exciton numbers.
Natural Model

- The transitions and emissions for each configuration are treated individually;
- The calculation are performed using Monte Carlo Method;
- Transitions with same number of excitons are treated like the others.

configuration with $n$ excitons

particle emission

$n$ excitons

$n \pm 2$ excitons
Unified Microscopic Model

- Treat each configuration individually, as in the HMS model, but takes all transitions in account;
- Permits simulation of the conditions of the exciton model, HMS model and the natural model.
Energy spectrum of first and all emitted nucleons in nucleon +$^{40}$Ca at an incident energy of 100 MeV.
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Particle emission multiplicity as a function of incident energy in nucleon $^40\text{Ca}$.
Conclusion

- The results of the natural model are closer to the HMS ones than are the exciton model results;
- In spite of conceptual inconsistencies, the exciton model is not that bad an approximation;
- However, the natural results are distinct from the others. The transitions between configurations with the same exciton number should be taken into account correctly.