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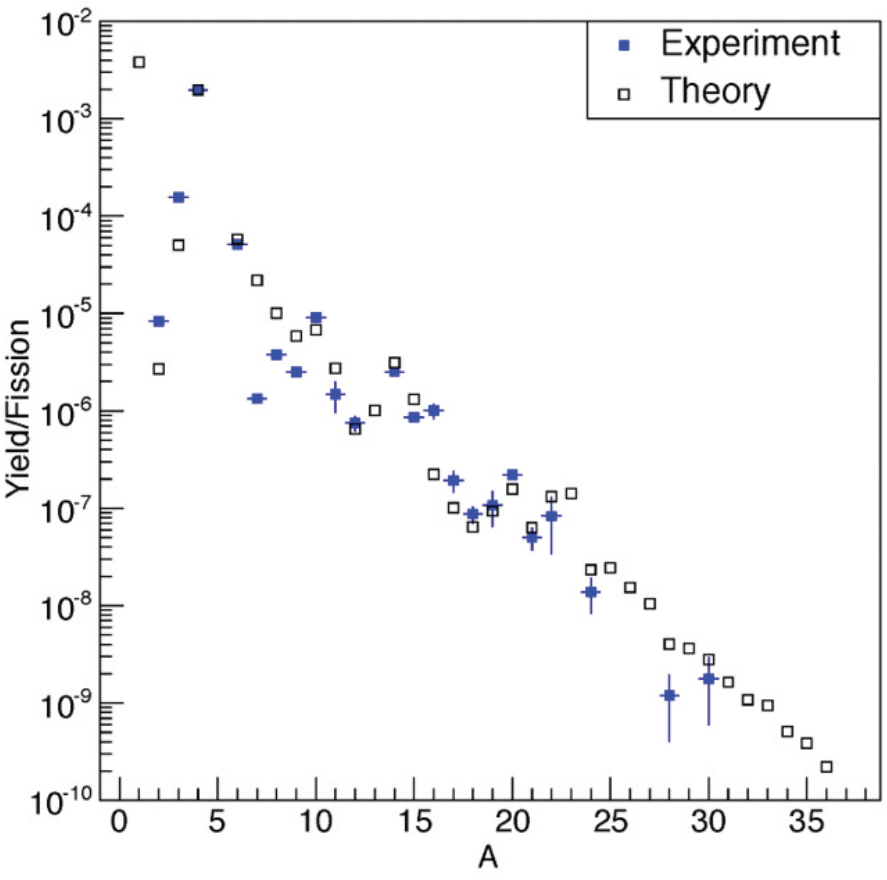
Nucleation and Cluster Formation as a Mechanism for Ternary Fission Fragment Production

Ternary fission fragment yields modeled as nucleation and time moderated chemical equilibrium in low-density nuclear matter

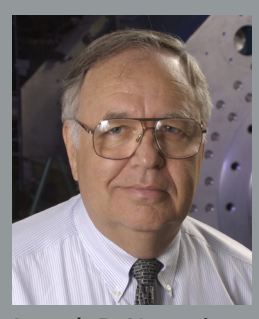
THE SCIENCE
Nuclear fission typically results in two major fragments. However, in a very small fraction of fission events, a third charged fragment is emitted. The third fragment may result from coalescing nucleons in the short-lived low-density region between the major fragments. The yield ratios of the ternary fragments are well described using a time moderated nuclear statistical equilibrium.

THE IMPACT
Clustering of nucleons at low density is a general property of nuclear systems. The low-density region between the major fission fragments presents a useful experimental system for understanding measurements of the neutron skin of nuclei and the nuclear pasta phase proposed for neutron stars and supernovae.

SUMMARY
In the fission of a heavy nucleus, a low-density region is formed between the two heavy products. A small fraction of fission events are accompanied by the emission of an energetic light particle from this region. Free nucleons in warm, low-density nuclear matter may coalesce to form fragments establishing a statistical equilibrium between free and bound nucleons. The fissioning system is short lived, however, and the coalescing nucleons may not reach equilibrium. Thus, we propose a nuclear statistical equilibrium (NSE) model in which the fragment production ratios are moderated by the time available to progress toward equilibrium.



Yield per fission event as a function of ternary fragment mass number (A). Solid points represent 241Pu(nth,f) experimental yields. Open data points are the product of nucleation moderated nuclear statistical equilibrium (NSE) model.



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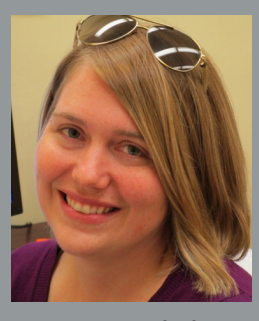

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PUBLICATIONS
S. Wuenschel, H. Zheng, K. Hagel, B. Meyer, M. Barbui, E.J. Kim, G. Ropke, and J.B. Natowitz, "Nucleation and cluster formation in low-density nucleonic matter: A mechanism for ternary fission," Phys. Rev. C 90, 011601R (2014).

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ABOUT THE CYCLOTRON INSTITUTE: *Dedicated in 1967, the Cyclotron Institute serves as the core of Texas A&M University's accelerator-based nuclear science and technology program. Affiliated faculty members from the Department of Chemistry and Department of Physics and Astronomy conduct nuclear physics- and chemistry-based research and radiation testing within a broad-based, globally recognized interdisciplinary platform supported by the United States Department of Energy (DOE) in conjunction with the State of Texas and the Welch Foundation. The facility is one of five DOE-designated Centers of Excellence and is home to one of only five K500 or larger superconducting cyclotrons worldwide.*