Contribution ID: **82**

Type: **Contributed Talk**

Theoretical description of direct nuclear reactions in the FRIB era

Friday, 28 November 2025 12:05 (15 minutes)

Nuclear reactions play a critical role in probing the properties of atomic nuclei, production of elements in astrophysical environments, as well as national security applications. For example, a class of reactions known as 'transfer reactions' are useful in determining spins, parities, and spectroscopic factors for specific nuclear states. In particular, deuteron-induced transfer reactions on rare isotopes have been used to probe single-particle levels of nuclei as well as to indirectly infer neutron-capture rates needed to simulate the synthesis of heavy elements in cataclysmic astrophysical events. Since the observables measured in reaction experiments are cross sections, extracting structure properties as well as the relevant neutron-capture rates requires reliable descriptions of the reaction dynamics. In light of reaction measurements taking place in rare isotope facilities around the world and in anticipation of the large influx of data from FRIB, theories that are suitable for the description of reactions involving exotic nuclei are needed. Using the example of deuteron-induced reactions, I will discuss the importance of a dependable reaction theory for translating experimental measurements into the desired nuclear information. I will also discuss advances in the three-body (neutron + proton + nucleus) description of such reactions as well as ab initio approaches that seek a solution of the many-body scattering problem, starting from nucleon-nucleon potentials derived from chiral effective field theory. Finally, I will give my perspective on efforts to construct predictive reaction theories that can be reliably applied to exotic isotopes by focusing on integrating few-body reaction dynamics with ab initio methods.

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Session Classification: Session 14

Track Classification: Nuclear Structure, Reactions and Dynamics