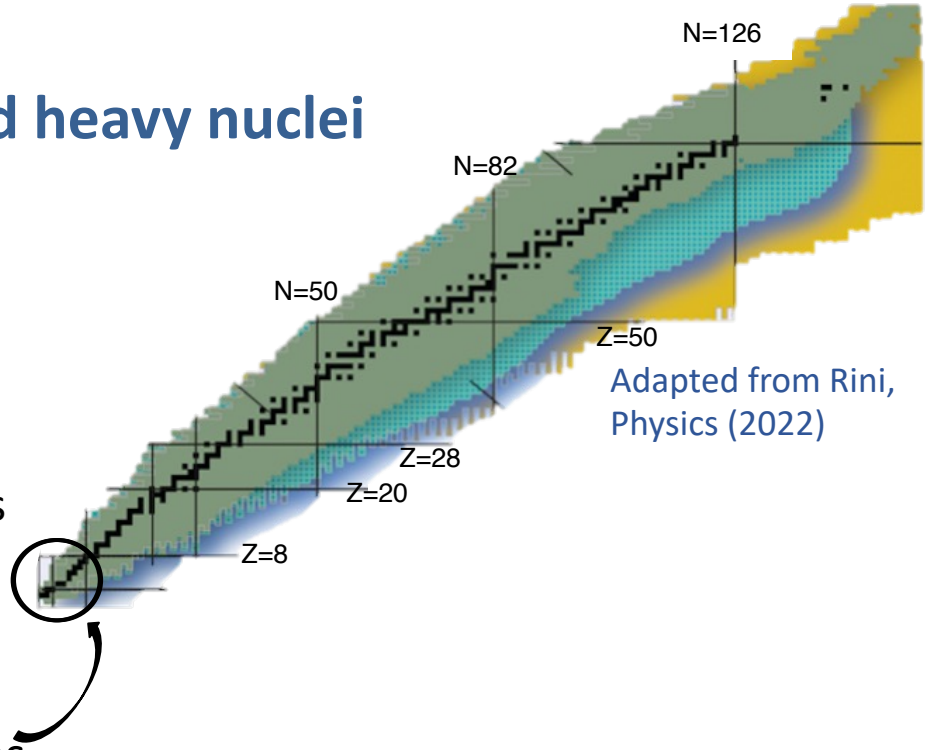
Integrated structure & reaction theory for medium-mass and heavy nuclei



Adapted from Rini, Physics (2022)

- We need to predict reactions involving nuclei across the isotopic chart
  - guide experiments, which in turn provide stringent tests for theory
  - study evolution of shell structure, deformation, collective excitation modes
  - generate inputs for astrophysical simulations, which in turn provide insights into stellar evolution, origin of elements
  - complement measurements to populate databases for applications
- For light nuclei we have seen substantial progress with RGM approaches
  - Treat structure and reactions simultaneously, account for correlations
  - Consistent use of interactions based on χEFT
  - Symmetry-adapted bases provide path forward to medium-mass nuclei
- For heavier nuclei we ignore the internal structure of the interacting nuclei
  - Focus on improving reaction mechanisms: transfer, inelastic scattering, breakup
  - Include higher-order reaction processes: multi-step, coupled-channels, breakup-fusion, etc.

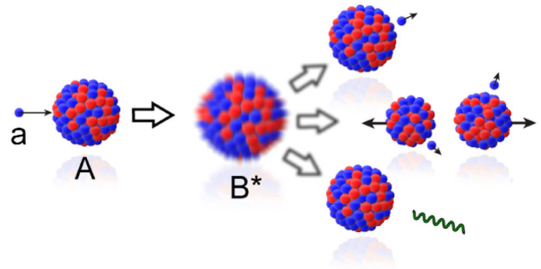
We need to take advantage of state-of-the-art structure theories to improve reaction descriptions!

Jutta Escher, escher1@llnl.gov

Integrated structure & reaction theory for medium-mass and heavy nuclei

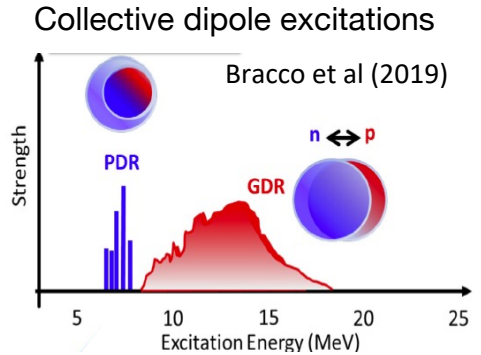
- Advanced structure models
  - Shell model, SA shell model
  - Beyond-mean-field approaches (QPA, QRPA, CRPA, RRPA)
- Competent reaction theory
  - R-matrix
  - Direct: DWBA, ADWA, coupled-channels
  - Statistical: Hauser-Feshbach
- We need to go beyond 'competent'
  - Develop reaction theory that can connect to multiple structure models
  - Identify shortcomings in structure, reaction, or experiment; UQ
  - Close connection to experiment
  - Training workforce in structure, reactions

Statistical Hauser-Feshbach (HF) reactions



- Replace disjoint mix of phenomenological structure models by microscopic inputs
- Develop criteria for estimating the limits of validity of HF
- Develop prescriptions for compound reactions proceeding through weakly-overlapping resonances; bridge to HF
- Treatment of direct/semi-direct contributions to HF
- Deploy ML/AI tools and assess uncertainties

Direct inelastic scattering



Develop inelastic scattering framework to address multiple needs:

- Charged-particle inelastic scattering provides insights into collective structures, exotic modes
- Nuclear data evaluations have incomplete neutron inelastic scattering information
- Charged-particle inelastic scattering serves as a 'surrogate reaction' and allows indirect access to unknown cross sections
  - Capture reactions on unstable nuclei for astrophysics
  - (n,n'), (n,2n), (n,f) reactions for nuclear data evaluations

We need to combine state-of-the-art structure approaches with reaction theory to achieve microscopic reaction predictions

Jutta Escher, escher1@llnl.gov