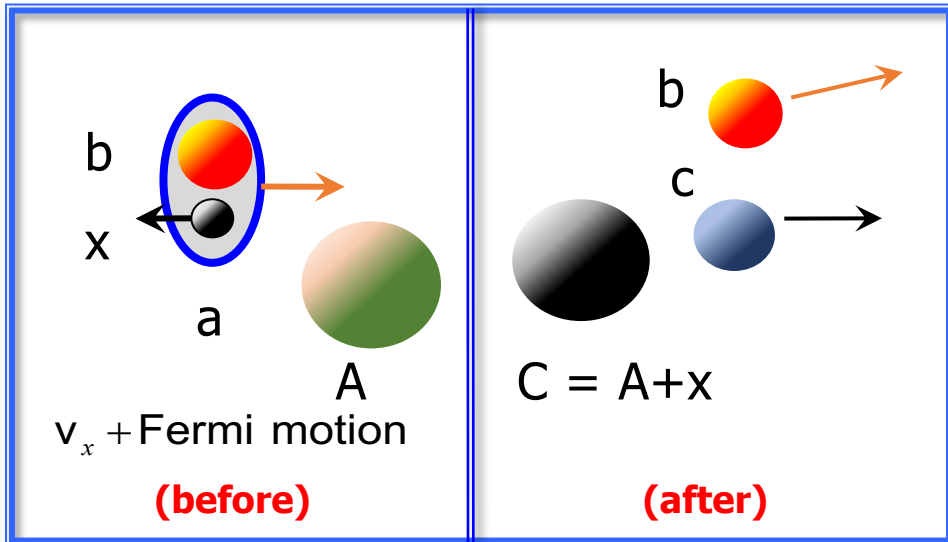


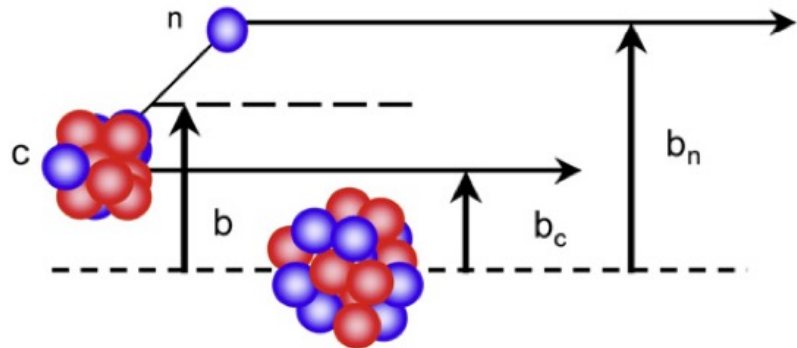
Indirect Methods in Nuclear Physics

Trojan horse method



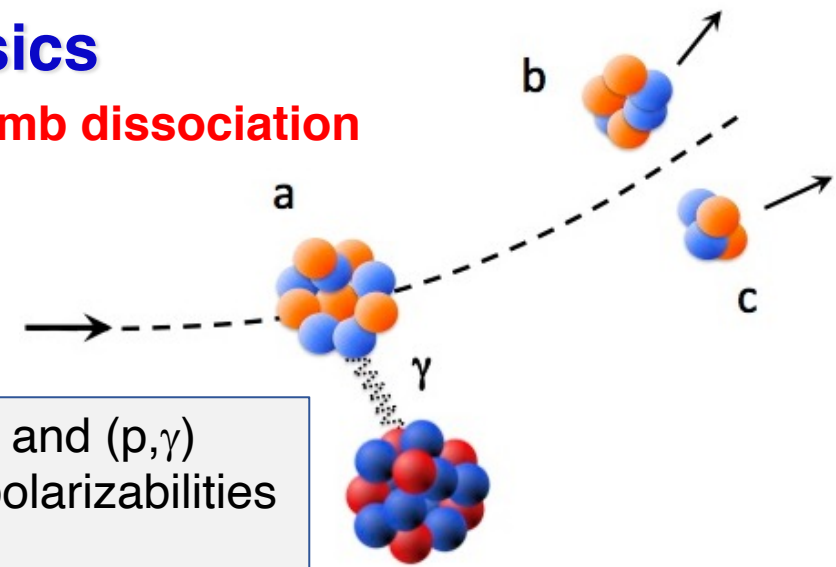
Applications to astrophysical $A + x \rightarrow C + c$ reactions

Knockout reactions

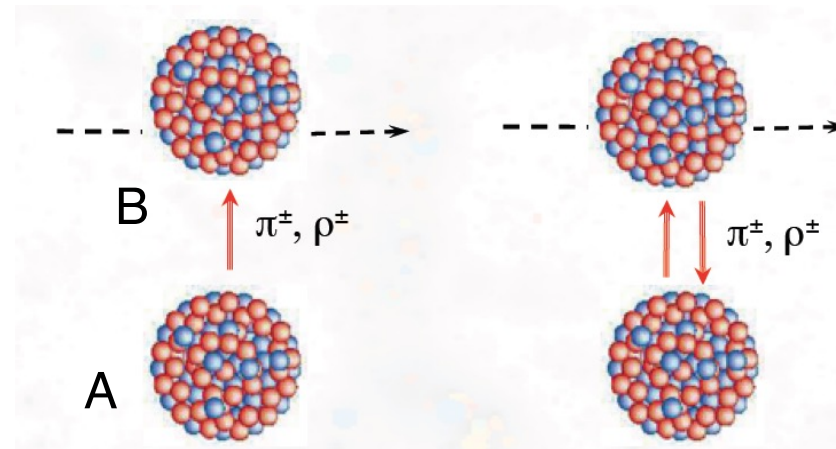


Probing distribution of single particle strength in nuclei

Coulomb dissociation



Charge exchange



Applications to electron capture and ν induced reactions in stars

One step

Two step
(meson exchange)

(\rightarrow double-beta decay)

Theory for indirect methods for NA

- **Optical potentials:** (a) parameter quantification analysis, (b) microscopic theory
- **Off-shellness:** On-shell energy/momentum of extracted information not well established for most reactions. I.e., extracted NA cross sections not the same as with free particles
- **Relativistic corrections,** 100 MeV/nucleon \sim 10% nucleon mass: (a) kinematics easy, (b) dynamics difficult because of retardation, simultaneity. Problem worsens at large E_{lab}
- **Quasi-free** processes not proved for most THM, knockout, transfer, or CE reactions
- **Multinucleon collisions** not well assessed in knockout, (p,2p) or CE reactions
-
- **Factorization** into structure and reaction parts not consistent (e.g., different interactions, eigen and scattering states obtained with different Hamiltonians)
- **Medium effects,** nuclear polarizabilities, coupled channels, too simplified
- **No statistical theory** exists for nuclear reactions in the nucleus-nucleus continuum