Halo nuclei

- Very neutron-rich nuclei that exhibit a large matter radius and a low separation energy of one or two neutrons.
- Seen as a core surrounded by one or two loosely-bound neutrons which form a sort of halo.
- Examples: $^{11}\text{Be}$, $^{13}\text{C}$ (one-neutron halo), $^{14}\text{Be}$, $^{15}\text{Li}$ (two-neutron halo)
- Studied through reactions (e.g., elastic scattering, breakup, ...)
  - need an accurate theoretical description of those reactions and/or observable insensitive to reaction process.

Angular distributions

Angular distributions for elastic scattering and breakup are very similar [1].
- projectile scattered similarly whether bound or broken up
This can be explained within the Recoil Excitation and Breakup model [2], which
- assumes an adiabatic treatment of the projectile excitation
- neglects the interaction $V_{EF}$ between the halo neutron and the target
  - excitation and breakup of the projectile due to the recoil of the core.

REB predicts for elastic scattering

$$\frac{d\sigma}{d\Omega} = |F_{\text{EL}}|^2 \left|\frac{d\sigma}{d\Omega}\right|_{pt}$$ (1)

with $F_{\text{EL}} = \int \Phi_{\text{EL}}(Q - \mathbf{r}) d\mathbf{r}$
  - where $Q \propto (\mathbf{K} - \mathbf{K}')$
  - form factor $\propto$ scattering of a pointlike nucleus

Similarly for breakup

$$\frac{d\sigma}{dE_{\text{kin}}} = |F_{\text{EL}}|^2 \left|\frac{d\sigma}{dE_{\text{kin}}}\right|_{pt}$$ (2)

with $|F_{\text{EL}}|^2 = \sum_{\text{jm}} \left| \int \Phi_{\text{EL}}(E) \Phi_{\text{EL}}(Q - \mathbf{r}) d\mathbf{r} \right|^2$

This explains the similarities in angular distributions and provides the ratio idea.

No dependence on target

Similar ratios for $\text{ConWells}$ and $\text{nucleus}$ dominated collisions
  - independent of the reaction process

Ratio Idea

Following (1) and (2),

$$\frac{d\sigma_{\text{EL}}}{dE_{\text{kin}}} = \frac{|F_{\text{EL}}(Q)|^2}{|F_{\text{EL}}(Q')|^2}$$ (3)

- independent of reaction process
- probes only nuclear structure
- no need for normalising experimental cross sections

Test within the Dynamical Eikonal Approximation [4], which includes the projectile dynamics and $V_{EF}$

We use $d\sigma_{\text{EL}}/d\sigma_{\text{BT}} = |F_{\text{EL}}|^2$

$$\frac{|d\sigma_{\text{EL}}/dE_{\text{kin}}|}{|d\sigma_{\text{BT}}/dE_{\text{kin}}|} = \frac{|F_{\text{EL}}(Q)|^2}{|F_{\text{EL}}(Q')|^2}$$

Angular distributions for breakup and all processes are compared to their ratio and its prediction $|F_{\text{EL}}(Q)|^2$ [4]
- Ratio removes most angular dependence
- DRA ratio in excellent agreement with REB $|F_{\text{EL}}|^2$

Sensitivity to projectile structure

Ratio sensitive to projectile binding energy in both shape and magnitude

Ratio is also sensitive to details of the radial wave function [4]

Conclusion & Outlook

- Ratio of angular distributions provides a reaction-independent observable to study halo nuclei.
- Sensitive to binding energy, partial-wave configuration and radial wave function
- Can it be extended to two-neutron halos and/or proton halos?
- Can we obtain information about spectroscopic factors?

References