Peripherality in inclusive nuclear breakup of halo nuclei

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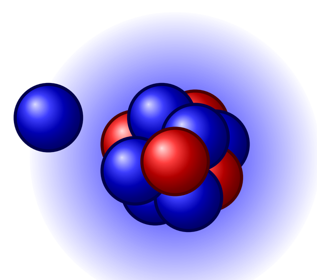
Motivation

Halo nuclei: nuclei near the dripline, presenting an exotic structure with large matter radius
→ Due to one or two loosely-bound neutrons
Seen as a compact core + one or two valence neutrons

Ex: $^{15}\text{C} \equiv {}^{14}\text{C} + n$
$^{11}\text{Be} \equiv {}^{10}\text{Be} + n$
$^{11}\text{Li} \equiv {}^{9}\text{Li} + n + n$



Short-lived:
→ Cannot be studied through spectroscopic methods
→ Studied through **reactions:**
elastic scattering, **breakup**,...

Inclusive breakup:

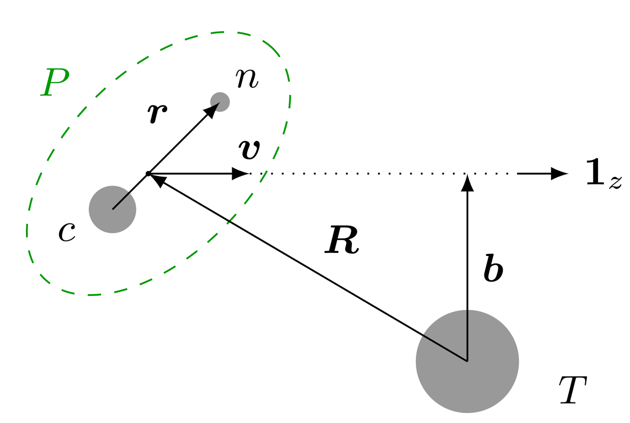
$^{15}\text{C} + {}^{9}\text{Be} \to {}^{14}\text{C} + X$ at 54*A* MeV [1]

Two contributions [2]: $\sigma_{\text{diff}} > \sigma_{\text{strip}}$
- **Diffractive breakup** (σ_{diff}): survival of n and ^{14}C
- Stripping (σ_{strip}): absorption of n by ^{9}Be

What do we probe with diffractive breakup?

Reaction model and description of the halo nucleus

- Two-body projectile (P): $P \equiv$ core (c) + neutron (n)
  Internal Hamiltonian: $h_{cn} = T_r + V_{cn}(r)$
  with V_{cn} an effective potential for c-n interaction
- Structureless target (T)
- P-T interactions: central optical potentials V_{cT} and V_{nT}



Three-body Schrödinger equation:

$$[T_R + h_{cn} + V_{cT}(\boldsymbol{R},\boldsymbol{r}) + V_{nT}(\boldsymbol{R},\boldsymbol{r})]\,\Psi(\boldsymbol{R},\boldsymbol{r}) = E\,\Psi(\boldsymbol{R},\boldsymbol{r})$$

with the initial condition $\Psi(\boldsymbol{R},\boldsymbol{r}) \underset{Z\to-\infty}{\longrightarrow} e^{ikZ+\cdots}\,\Phi_0(\boldsymbol{r})$, i.e., incoming P in its ground state Φ_0 with a velocity $v = \frac{\hbar k}{\mu_{cn}}$

1. Eikonal approximation: at high energy, the wavefunction ≈ plane wave [3]

$$\Psi(\boldsymbol{R},\boldsymbol{r}) = e^{ikZ}\,\widehat{\Psi}(\boldsymbol{R},\boldsymbol{r})\Phi_0(\boldsymbol{r}) \quad \text{with } |\Delta_{\mathbf{R}}\widehat{\Psi}| \ll k\left|\tfrac{\partial}{\partial Z}\widehat{\Psi}\right|$$

2. Sudden approximation: $h_{cf} \approx \epsilon_0$ the energy of the ground state

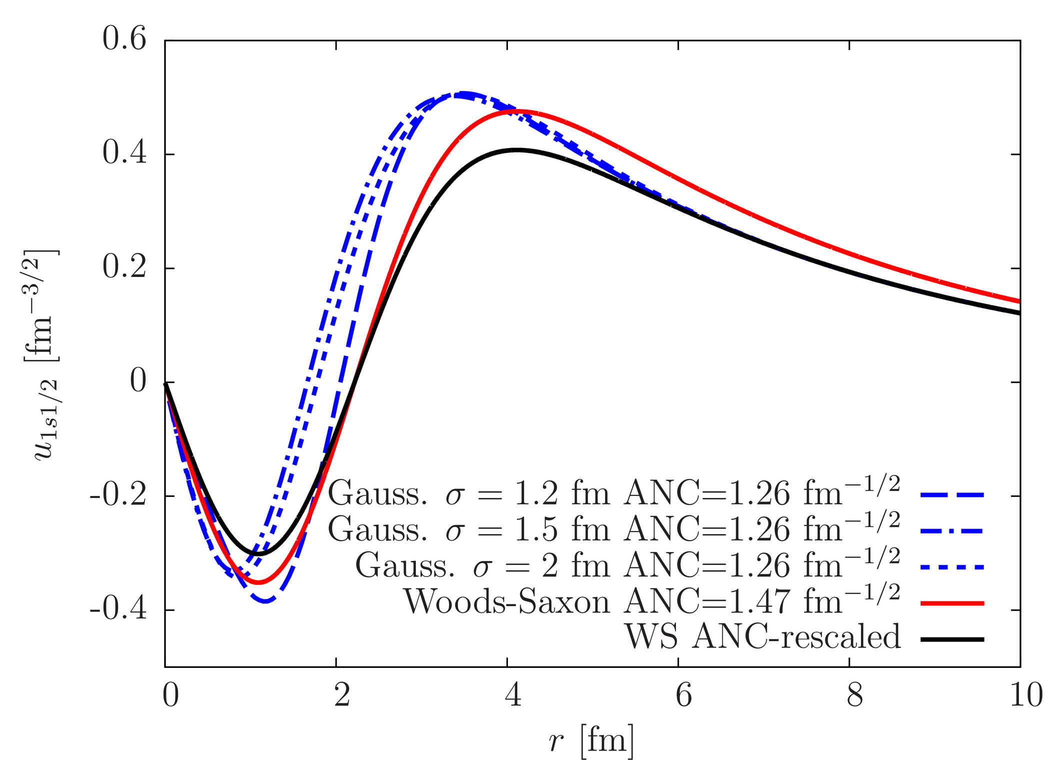
Solutions: $\Psi^{\text{eik}}(\boldsymbol{b},Z,\boldsymbol{r}) \underset{Z\to+\infty}{\longrightarrow} e^{ikZ}e^{i\chi(\boldsymbol{b},\boldsymbol{r})}\Phi_0(\boldsymbol{r})$, with $\chi(\boldsymbol{b},\boldsymbol{r}) = -\frac{1}{\hbar v}\int_{-\infty}^{+\infty}[V_{cT}(\boldsymbol{R}',\boldsymbol{r}) + V_{nT}(\boldsymbol{R}',\boldsymbol{r})]dZ'$

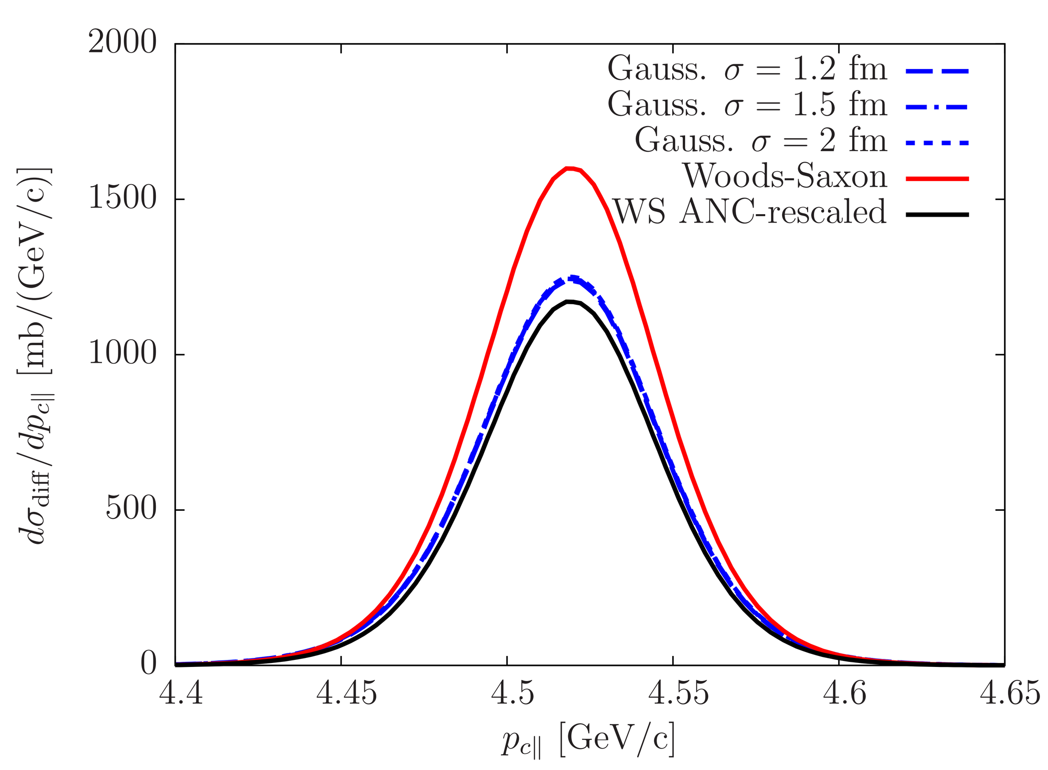
How sensitive are the observables to
① **projectile description?** Test with different V_{cn}
- Woods-Saxon potentials fitted to ϵ_0
- Gaussian potentials fitted to both ϵ_0 and ANC (normalisation of the tail of Φ_0) [4,5]

② **optical potentials?** Test with different V_{cT} and V_{nT}

① Sensitivity of diffractive breakup to ^{15}C description

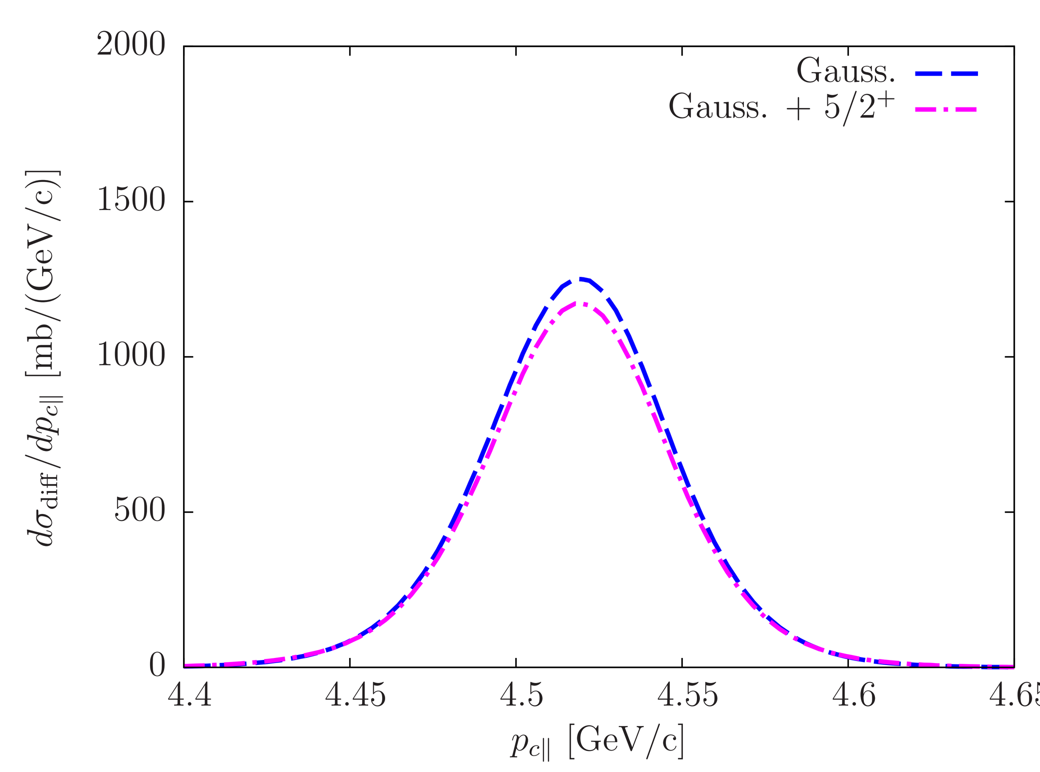
Wavefunction of the ground state $u_{1s1/2}$





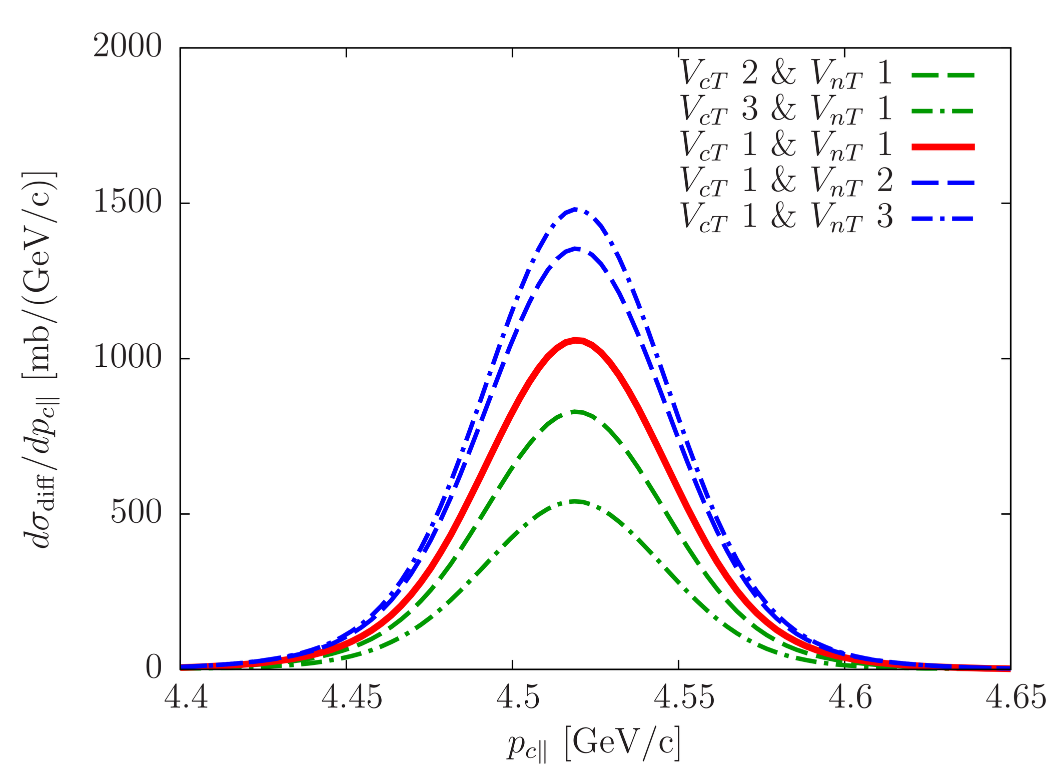
⇒ **Peripheral:** mostly sensitive to the asymptotic behaviour of the ground-state wavefunction

Including the excited bound state $5/2^+$



Interaction in the d-wave → non-zero d phase shifts in the continuum
⇒ **Non-negligible effect of the first excited state**

② Effect of the optical potentials



⇒ **Strongly dependent on the optical potentials**

Conclusions and prospects

Main contribution to inclusive breakup is **diffractive breakup** which

① is **peripheral:** insensitive to the inner part of the wavefunctions
⇒ we can only probe the asymptotic part of the wavefunctions
should **include the excited bound states** (and known resonances?)

② is **very sensitive to the choice of the optical potentials**
→ more realistic description within the Optical Limit Approximation of Glauber?

⇒ **Next step: extension of this analysis to stripping**

References

[1] J. A. Tostevin *et al.*, Phys. Rev. C **66**, 024607 (2002).
[2] M. S. Hussein and K. W. McVoy, Nucl. Phys. A **445**, 124 (1985).
[3] R. J. Glauber, *High energy collision theory*, Lecture in theoretical physics, (1959).
[4] H.-W. Hammer, C. Ji and D. R. Phillips, J. Phys. G. **44**, 103002 (2017).
[5] L. Moschini, Poster to the 57th International Winter Meeting on Nuclear Physics (2019).

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