Sensitivity of breakup calculations to projectile description

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Introduction

Halo nuclei are light exotic nuclei with large radius and small separation energy of one or two nucleons.
Seen as a core + loosely bound nucleon ($\equiv$ halo)

Breakup used to study halo nuclei

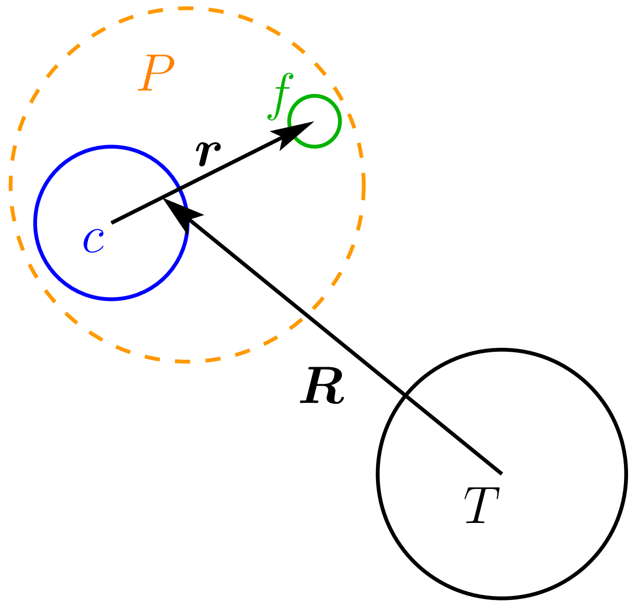
But, what can we actually learn from breakup?
What is the interplay between structure and reaction?
Can we extract SF, or ANC? influence of continuum?

- Test sensitivity to wave function parts
- Test sensitivity to phase shift

Model

Projectile (P) modelled as a two-body system:
core (c)+loosely bound nucleon (f) described by

$$H_0 = T_r + V_{cf}(\boldsymbol{r})$$



V_{cf} adjusted to reproduce
bound states and
some resonances

$V_{cT}, V_{fT} \equiv$ optical potentials

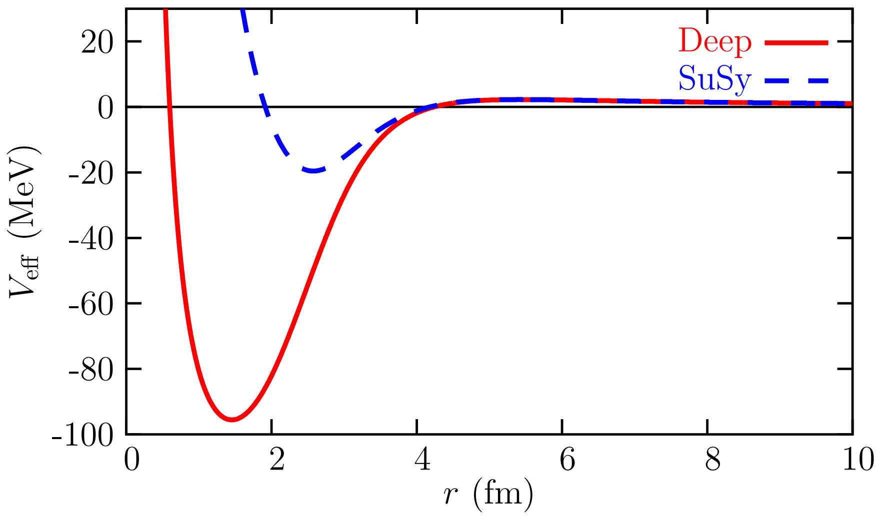
$\Rightarrow$breakup reduces to three-body scattering problem:

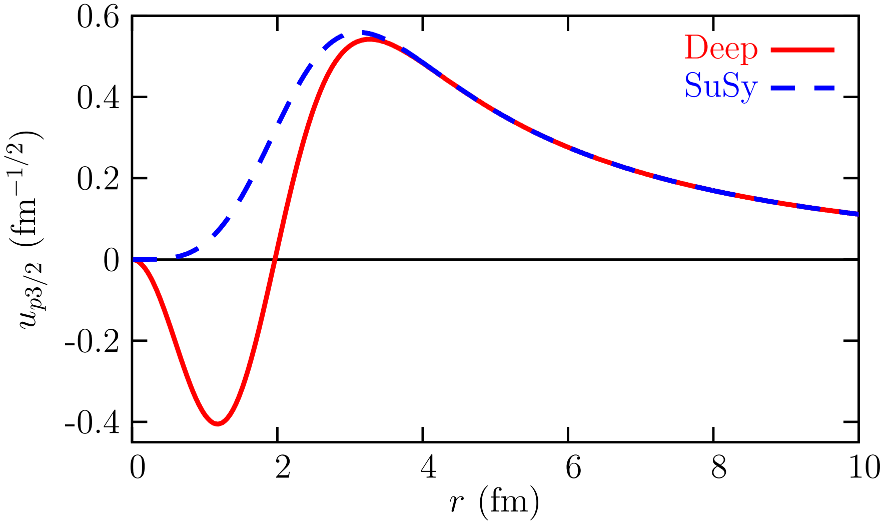
$$[T_R + H_0 + V_{cT} + V_{fT}]\,\Psi(\boldsymbol{R},\boldsymbol{r}) = E_T\Psi(\boldsymbol{R},\boldsymbol{r})$$

Solved with Dynamical Eikonal [PRC 73, 024602 (06)]
and CDCC [Tostevin, F.M., Thompson, PRC 63, 024617 (01)]

SuSy transformations

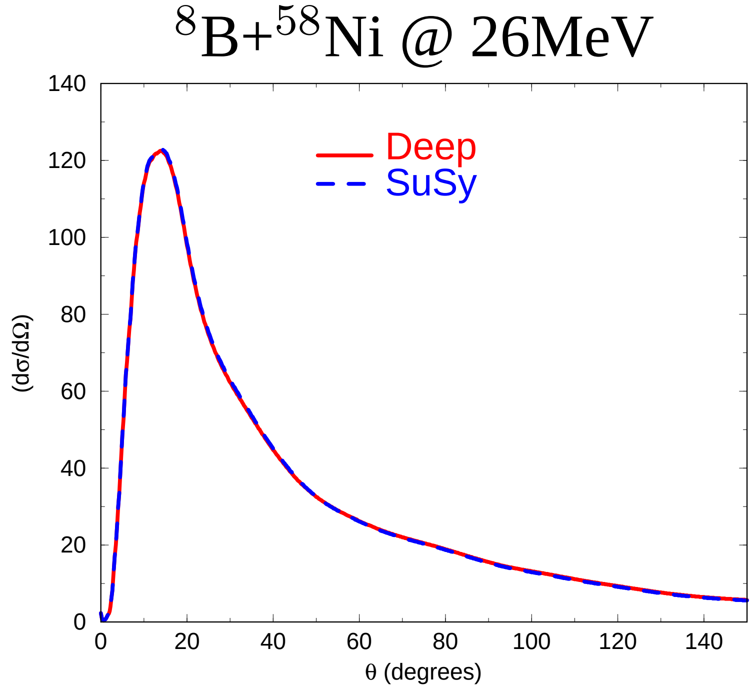
H_0, H_0' with different interior but same asymptotics obtained by SuSy transfo. [D. Baye PRL 58, 2738 (1987)]

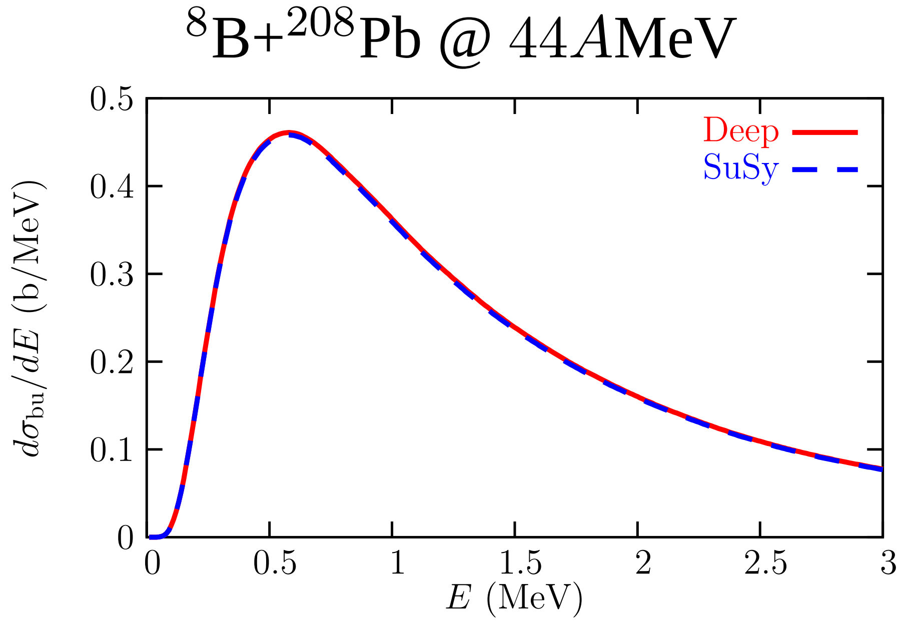




- Deep potential ⇒spurious deep bound state ⇒node in physical bound state
- Remove deep state by SuSy ⇒remove node but keep same asymptotics (ANC and phase shift)
- Analyse difference in $\sigma_{\rm bu}^{th}$ between deep vs SuSy

Peripherality of breakup reactions





No difference between deep and SuSy potentials

at low and intermediate energies, for various observables

(similar results on light targets)

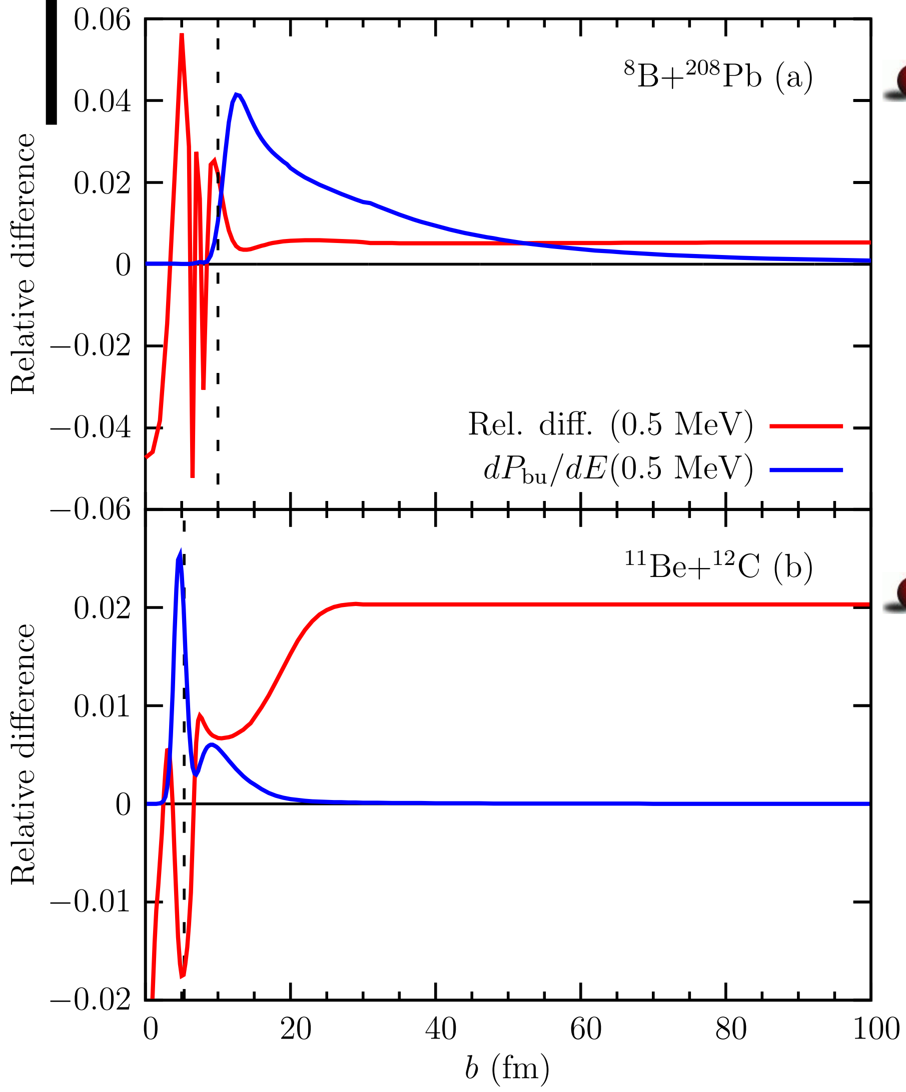
⇒breakup probes only asymptotics (ANC)

⇒not sensitive to whole normalisation (SF)

[P.C., F.M. Nunes, PRC 75, 054609 (2007)]

Projectile-target peripherality

Peripherality usualy refered to large P-T distances.

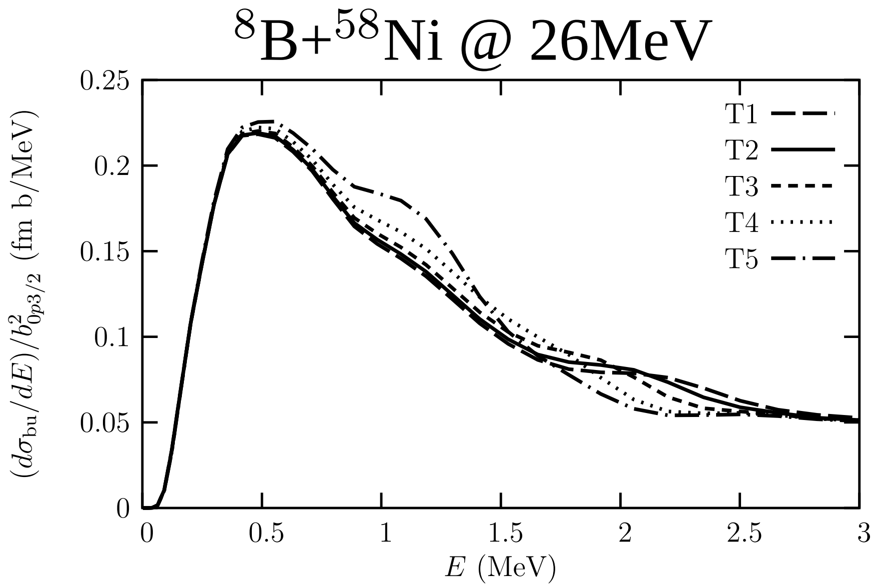


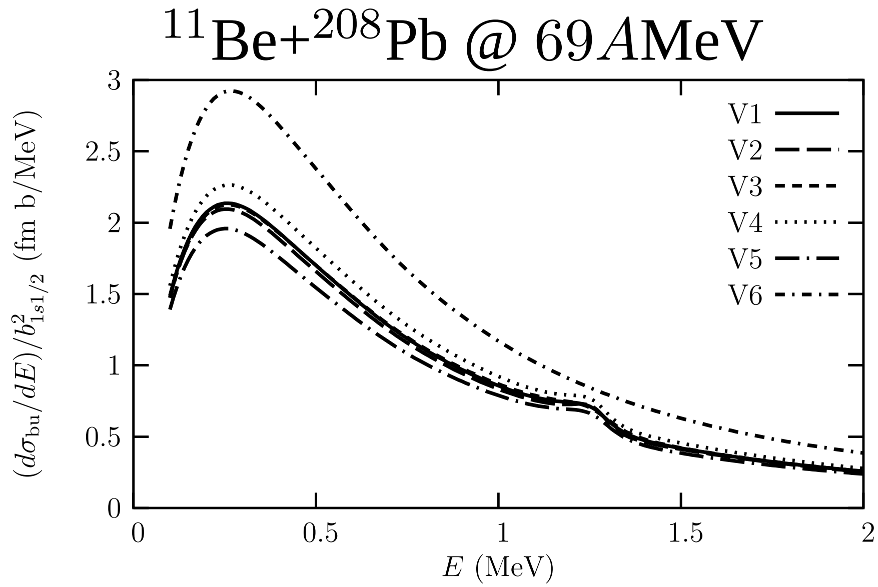
- Coulomb breakup:
  - P_{bu} significant: $b > 10$fm $\Rightarrow$peripheral in R_{PT}
  - Relative difference small $\Rightarrow$peripheral in r_{cf}
- Nuclear breakup:
  - P_{bu} significant: $b < 20$fm $\Rightarrow$surface peaked in R_{PT}
  - Relative diff. still small $\Rightarrow$still peripheral in r_{cf}

$\Rightarrow$Both peripheralities not directly related

Sensitivity to continuum description

Breakup calculations of ^{8}B, ^{11}Be with various V_{cf}





$\sigma_{\rm bu}/{\rm ANC}^2 \Rightarrow$ differences due to continuum:

- unfitted $p1/2$ resonance in ^{8}B
- non-resonant $p3/2$ phase shift in ^{11}Be

$\Rightarrow$Breakup probes both bound and scattering states

Peripheral $\Rightarrow$ANC and phase shift

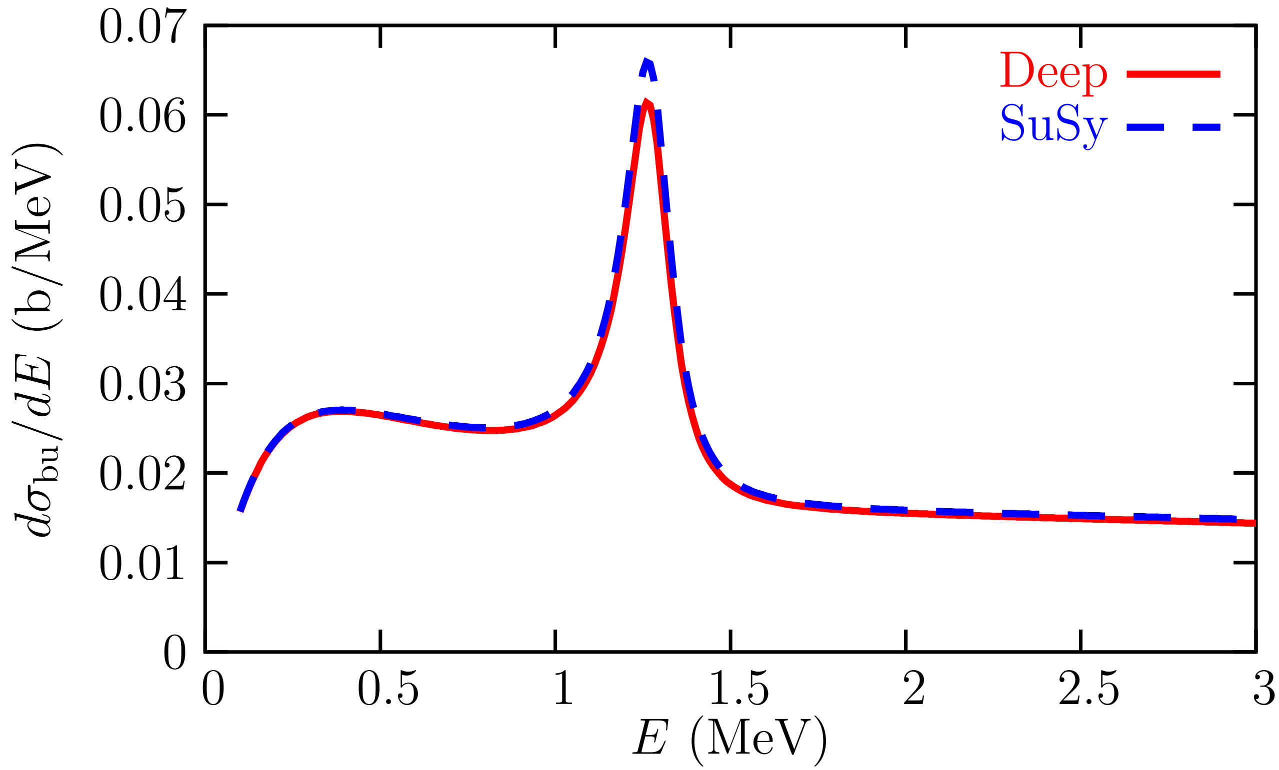
[P.C., F. M. Nunes, PRC 73, 014615 (2006)]

Conclusion

- Breakup used to study halo nuclei
- To test peripherality, we compute $\sigma_{\rm bu}^{th}$ with two H_0 obtained by SuSy that differ only in the interior
- Calculations done at low/intermediate energies, heavy/light targets, many observables studied
- Breakup probes the tail of wave functions (ANC)
  $\Rightarrow$not sensitive to total normalisation (SF)
- Breakup is sensitive to projectile continuum
  $\Rightarrow$needs to be constrained
  $\Rightarrow$need of scattering data

Support from the NSF & NSERC is acknowleged

^{11}Be on C at $67A$MeV



Test peripherality on light target (nuclear dominated)

No difference between deep and SuSy

⇒even on light target, breakup is peripheral

⇒breakup probes ANC

SF vs ANC

Actual wave function contains various configurations:

$$\Psi(\boldsymbol{r}) = S_0 \Phi_0(\boldsymbol{r}) + \ldots$$

If only Φ_0 contributes to breakup $\sigma_{\rm bu} \propto S_0^2 = \rm SF$

But if breakup probes only the tail

since $\Phi_0 \underset{r\to\infty}{\longrightarrow} b e^{-\kappa r}$

$\Rightarrow \sigma_{\rm bu} \propto (bS_0)^2 = \rm ANC^2$

But ANC can be useful

Unfortunately continuum plays along...

SuSy transformations

Transformations of a potential that remove ground state without altering remaining spectrum.
Preserve asymptotics, i.e. phase shifts in continuum and ANC of bound states.

Baye, Phys. Rev. Lett. 58, 2738 ('87); J. Phys. A 20, 5529 ('87)

$$V_2^{lj} = V_0^{lj} - 2\frac{d^2}{dr^2}\ln\int_0^r |u_{lj}^0(r')|^2 dr',$$

where u_{lj}^0 is the wave function of the removed state

⇒potential modified only in the range of u_{lj}^0
wave functions modified accordingly

⇒preserve ANC and δ_{lj}