What do we actually probe in breakup reactions?

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Introduction

Breakup is a tool to study halo nuclei

Usually, SF extracted from $\sigma_{\rm bu}^{exp.}/\sigma_{\rm bu}^{th.}$
Is this valid?

Does breakup probe the whole wave function?
(isn't it peripheral?)
Is breakup sensitive to bound state only?
(role of continuum?)

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

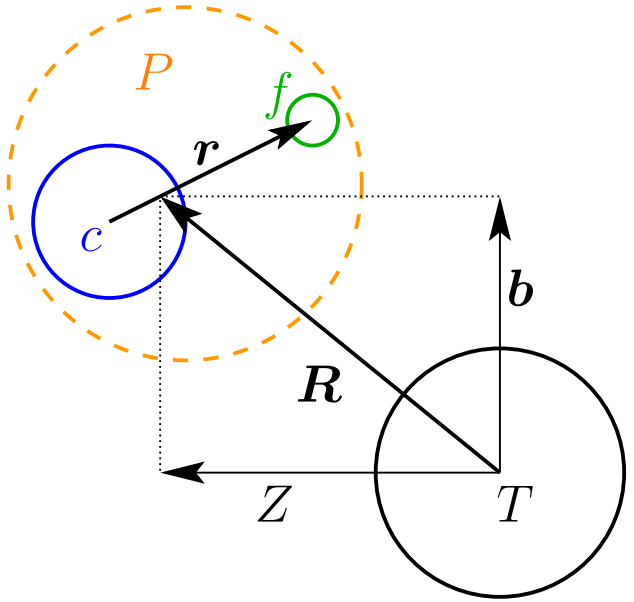
Model

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:

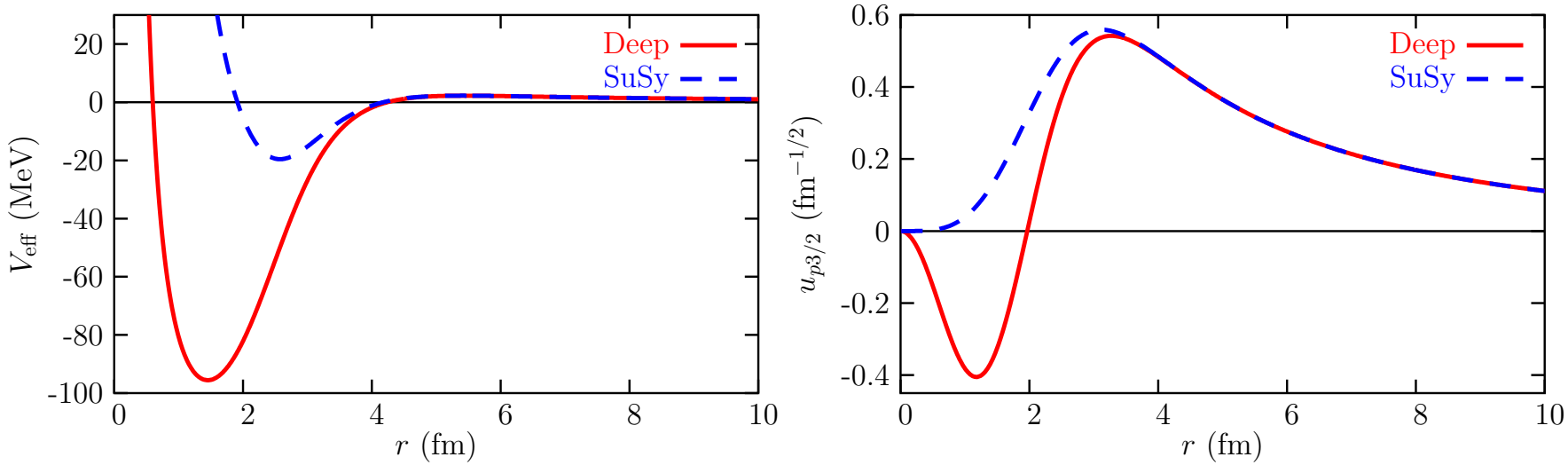
$$[T_R + H_0 + V_{cT} + V_{fT}]\,\Psi(\boldsymbol{R}, \boldsymbol{r}) = E_T \Psi(\boldsymbol{R}, \boldsymbol{r})$$

Solved with Dynamical Eikonal Approximation

[Goldstein, Baye, P.C. PRC 73, 024602 (2006)] and CDCC

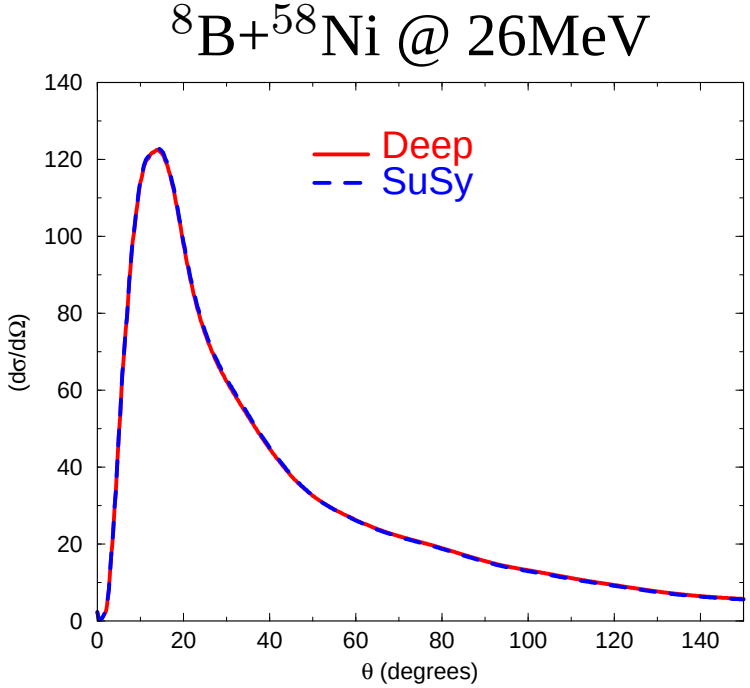
Sensitivity to bound-state

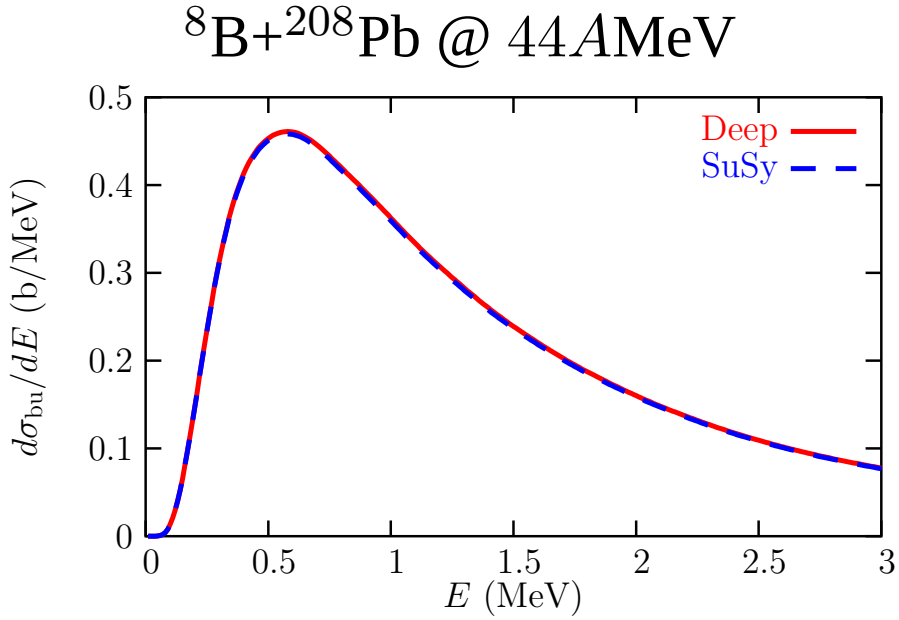
Use 2 H_0 with different interior but same asymptotics obtained by SuSy transfo. [D. Baye PRL 58, 2738 (1987)]



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

Peripherality of breakup reactions





No difference between deep and SuSy potentials

at low and intermediate energies

for energy and angular distributions

similar results on light targets

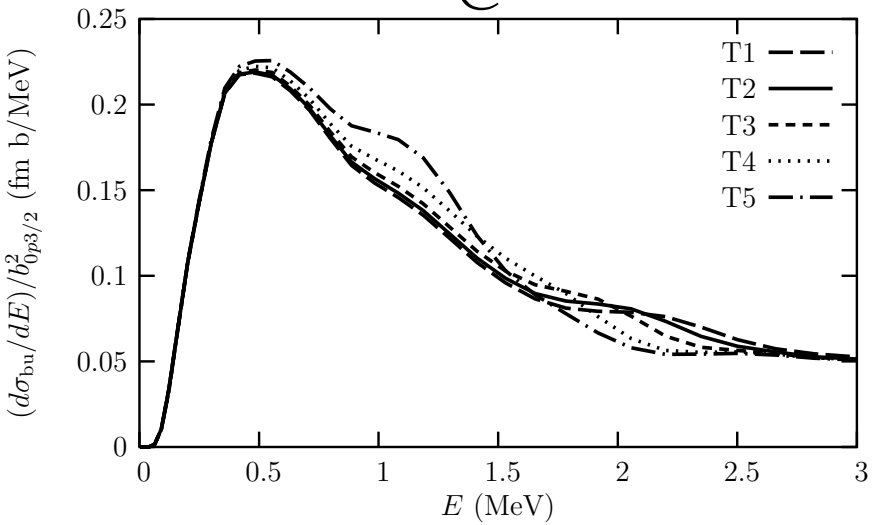
⇒breakup probes only asymptotics (ANC)

SF extracted from measurements are questionable

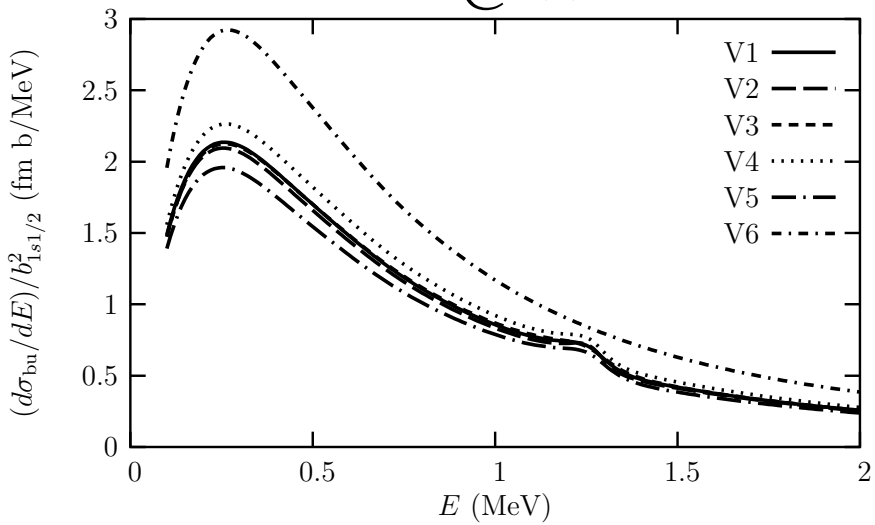
Sensitivity to continuum description

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

^{8}B+^{58}Ni @ 26MeV



^{11}Be+^{208}Pb @ 69AMeV



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

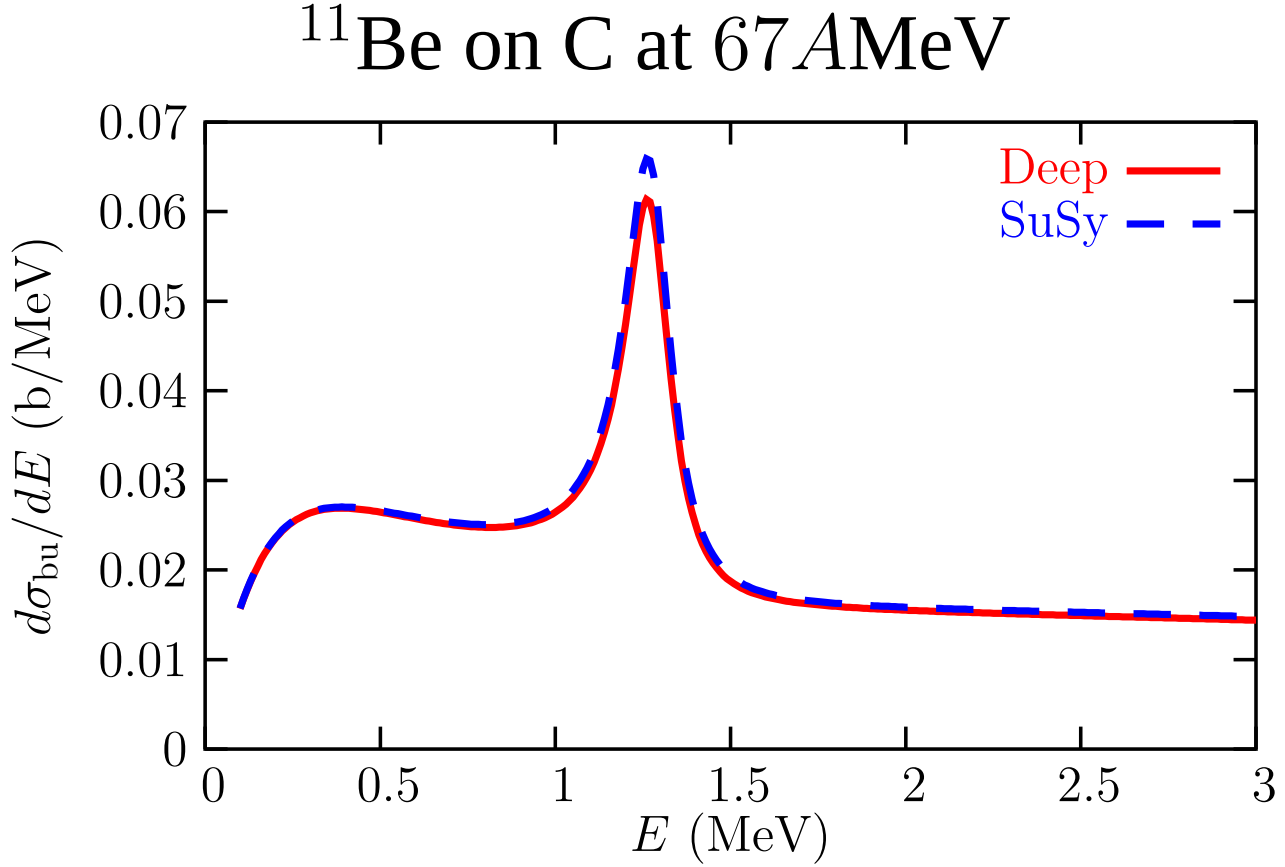
P.C., F. M. Nunes, PRC 73, 014615 (2006)

Conclusion

- Breakup is a tool 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
- No difference between deep and Susy
  $\Rightarrow$breakup probes only the tail of wave functions of both bound and continuum states
  $\Rightarrow$calculations sensitive to ANC and phase shift
- This is true for low/intermediate energies, many observables, heavy/light targets

$\Rightarrow$Attention when analysing measurements:
SF obtained from breakup are questionable

And on light target...



Test peripherality on light target (nuclear dominated)

No difference between deep and SuSy

$\Rightarrow$even on light target, breakup is peripheral

$\Rightarrow$breakup probes ANC

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

$\Rightarrow$potential modified only in the range of u_{lj}^0

wave functions modified accordingly

$\Rightarrow$preserve ANC and δ_{lj}