Unbound exotic nuclei studied by projectile fragmentation

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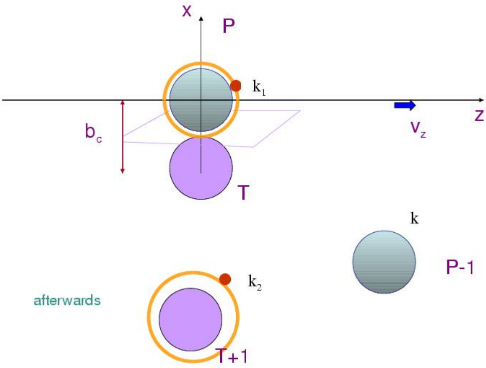
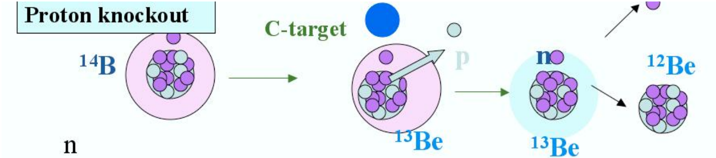
Plan of the Presentation

1. Reactions to study halo nuclei
   - Transfer to the continuum
   - Fragmentation reaction
2. Simple time dependent model
   - Inelastic excitation
   - General wave functions (asymptotic form)
   - Simple time dependent model
   - Comparison to the transfer to the continuum
   - Cross section.
   - Determination of the S-matrix.
   - Potential correction
3. Results
   - Comparison between time dependent and sudden approximation
   - Dependence on the binding energy of the initial state
   - Strength of every transition
   - Dependence on the scattering length of the final s-state
   - Add of a complex part to the potential

Transfer to the continuum reaction



Fragmentation reaction



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Transfer to the continuum

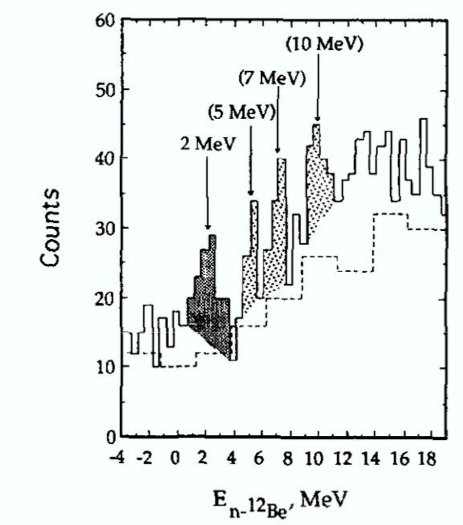

Figure: ^{12}Be (d,p) RIKEN (Korsheninnikov) (1995)

Fragmentation reaction.

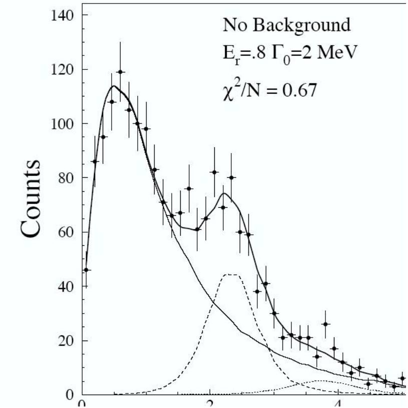

Figure: (a) LPC GANIL (Lecouey, Orr) (2002).

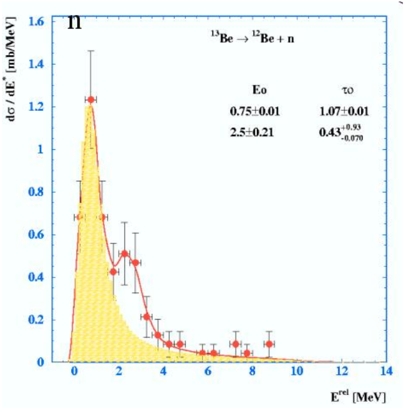

Figure: (b) GSI (U Datta Pramanik) (Surrey conference Jan.2005).

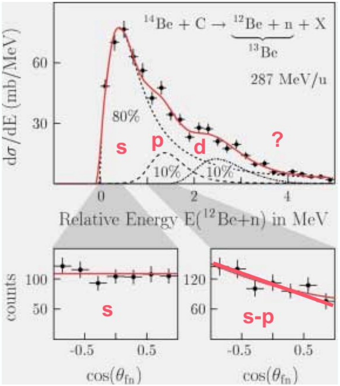

Figure: (a) GSI (Simon Nucl. Phys. A734 (2004) 323-326.

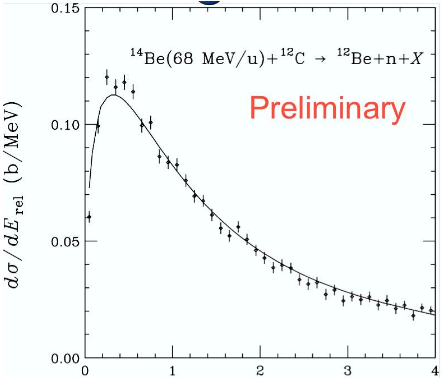

Figure: (b) RIKEN (Nakamura)(ECT* 2004)unpublished.

Inelastic excitation.

Inelastic-like excitations can be described by the first order time dependent perturbation theory amplitude:

$$A_{fi} = \frac{1}{i\hbar}\int_{-\infty}^{\infty} dt \langle \psi_f(t)|V_2(\mathbf{r})|\psi_i(t)\rangle$$

In order to obtain a simple analytical formula we consider the special case in which $V_2(r) = v_2\delta(x)\delta(y)\delta(z)$.

$$A_{fi} = \frac{v_2}{i\hbar v}\int_{-\infty}^{\infty} dz\ \psi_f^*(b_c, 0, z)\psi_i(b_c, 0, z)e^{iqz}$$

$\otimes$

General wave functions (asymptotic form).

For the initial state:

$$\psi_i(b_c, 0, z) = -C_i i^l \gamma h^{(1)}_{l_i}(i\gamma r) P_{l_i}(z/r).$$

For the final continuum state:

$$\psi_f(b_c, 0, z) = C_f k \frac{i}{2}(h^{(+)}_{l_f}(kr) - S_{l_f} h^{(-)}_{l_f}(kr)) P_{l_f}(z/r).$$

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Simple time dependent model.

$$A_{fi} = \frac{v_2}{i\hbar v}\int_{-\infty}^{\infty} dz\ \psi_f^*(b_c,0,z)\psi_i(b_c,0,z)e^{iqz}$$

$$I(k,q) = I_R + iI_I = |I|e^{i\alpha}$$

$$\bar{S} = Se^{2i\alpha} = e^{2i(\delta+\alpha)}$$

$$|A_{fi}|^2 = C^2|I|^2|1-\bar{S}|^2.$$

Comparison to the transfer to the continuum.

Fragmentation:

$$\frac{dP_{in}}{d\varepsilon_f} = \frac{2}{\pi}\frac{v_2^2}{\hbar^2 v^2} C_i^2 \frac{m}{\hbar^2 k} \Sigma_{l_f}(2l_f+1)|1-\bar{S}_{l_f}|^2 |I_{l_f}|^2.$$

Transfer:

$$\frac{dP_t(b_c)}{d\varepsilon_f} \approx \frac{4\pi}{k^2}\Sigma_{l_f}(2l_f+1)|1-S_{l_f}|^2 B_{l_f,l_i}$$

(*G. Blanchon, A. Bonaccorso and N. Vinh Mau, Nucl. Phys. A739 (2004) 259.*) ⊗

Cross section.

$$\frac{d\sigma}{d\varepsilon_f} = C^2 S \int_0^\infty d\mathbf{b_c} \frac{dP_{in}(b_c)}{d\varepsilon_f} P_{ct}(b_c),$$

The core survival probability:

$$P_{ct}(b_c) = |S_{ct}|^2$$

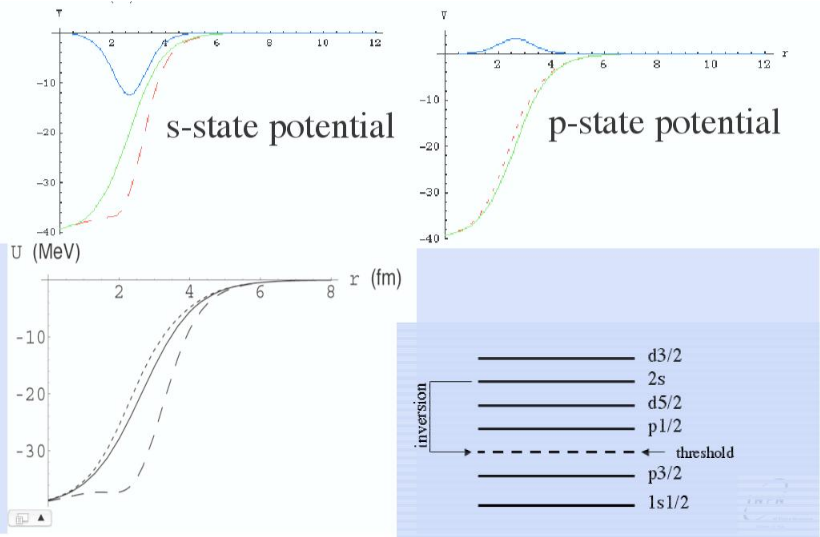
$\otimes$

Determination of the S-matrix.

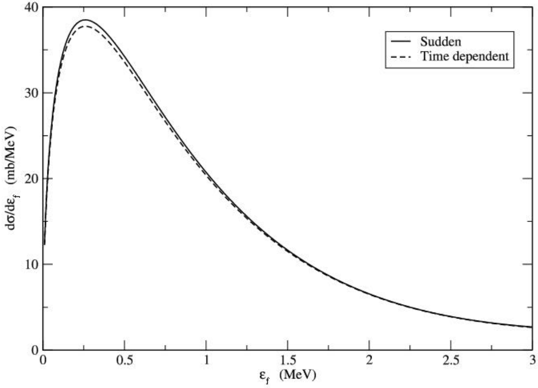
$$
\begin{aligned}
h &= t + U. \\
U(r) &= V_{WS} + \delta V. \\
\delta V(r) &= 16\alpha e^{2(r-R)/a}/(1+e^{(r-R)/a})^4.
\end{aligned}
$$

V_{WS} = Woods-Saxon potential plus spin-orbit. δV = correction which originates from particle-vibration couplings.
(N. Vinh Mau and J. C. Pacheco, Nucl. Phys. A607 (1996) 163.) ⊗

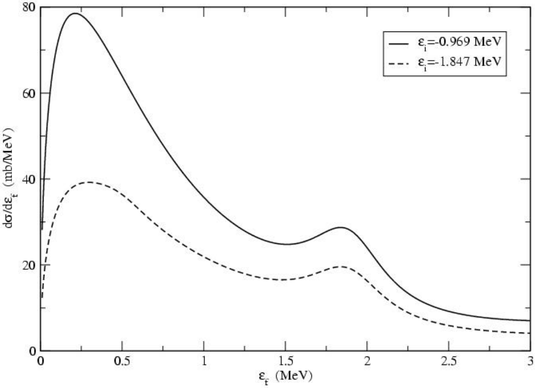
Potential correction.



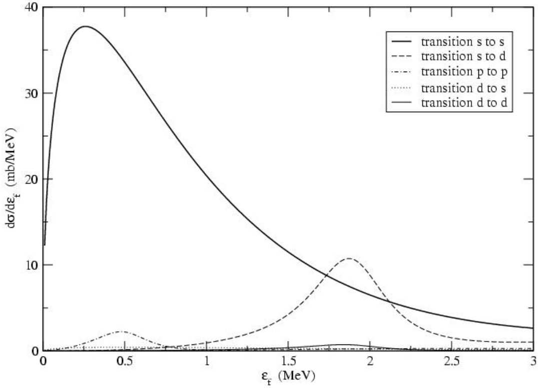
Comparison between time dependent and sudden approximation.



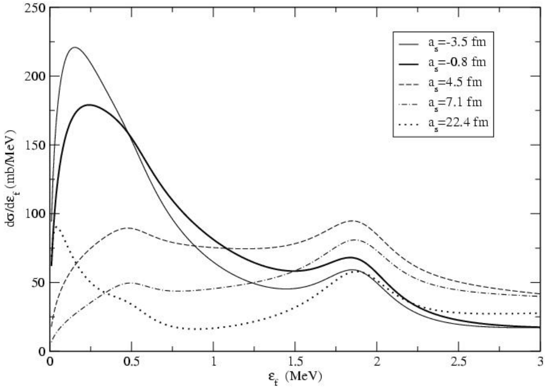
Dependence on the binding energy of the initial state.



Strength of every transition.



Dependence on the scattering length of the final s-state.



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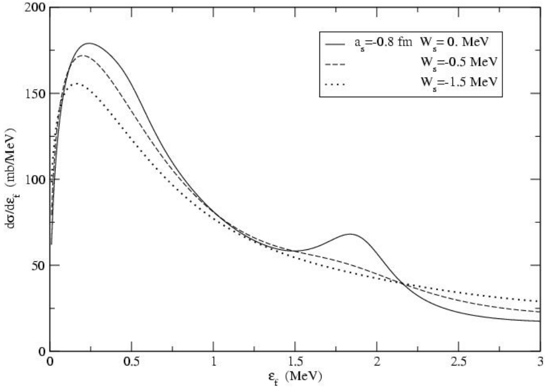
Introduction of an imaginary part to the potential.



Conclusions and outlooks

- ^{13}Be is a signature of the halo state of the neutron.
- Possibility to use s resonances.
- One or two step calculation.

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