A CDCC extension to microscopic three-cluster projectiles

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Outline

1. Introduction

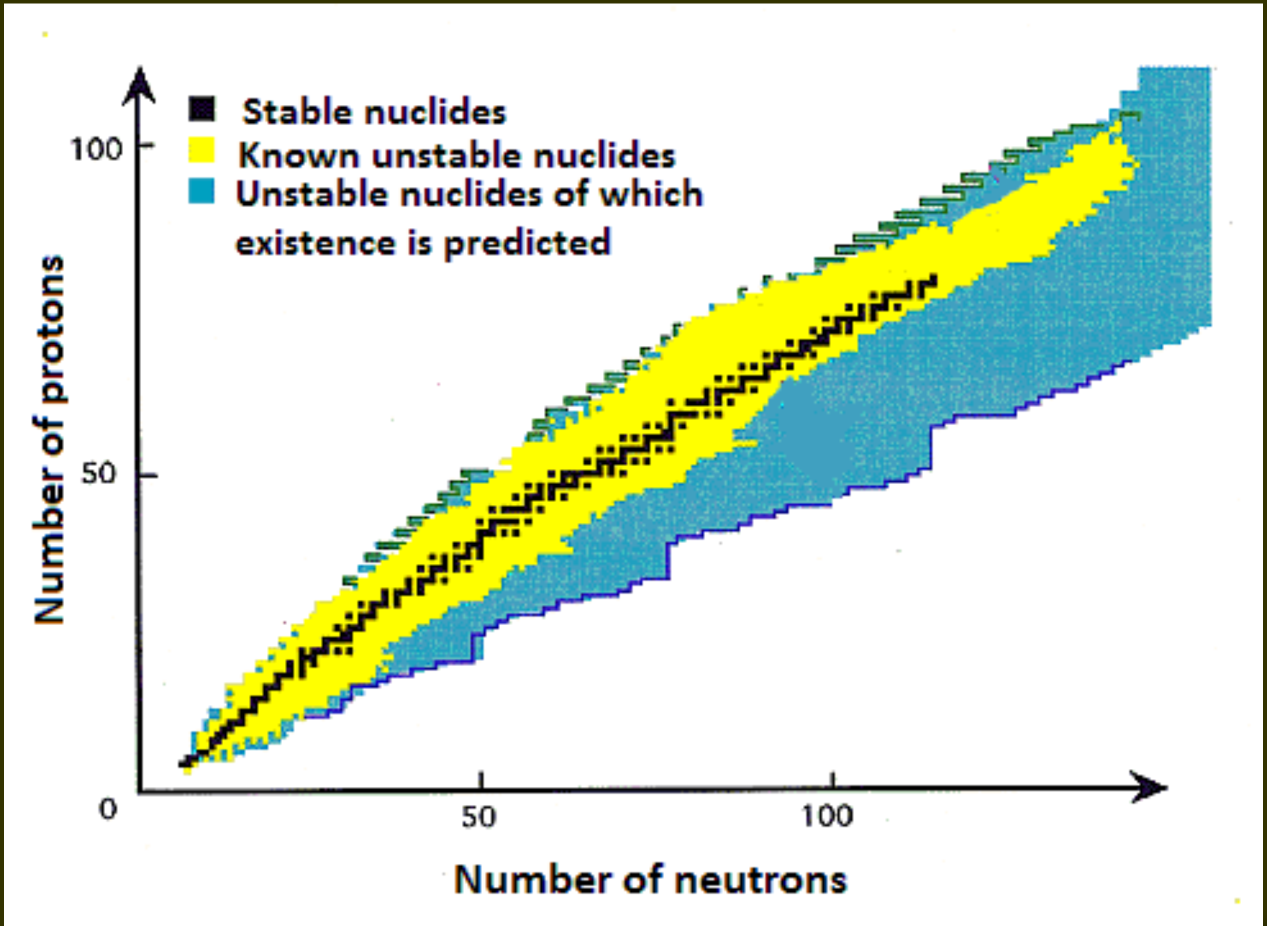
2. Microscopic CDCC method

3. Applications on the elastic scattering of the exotic nuclei

   - ^{8}B
   - ^{8}Li

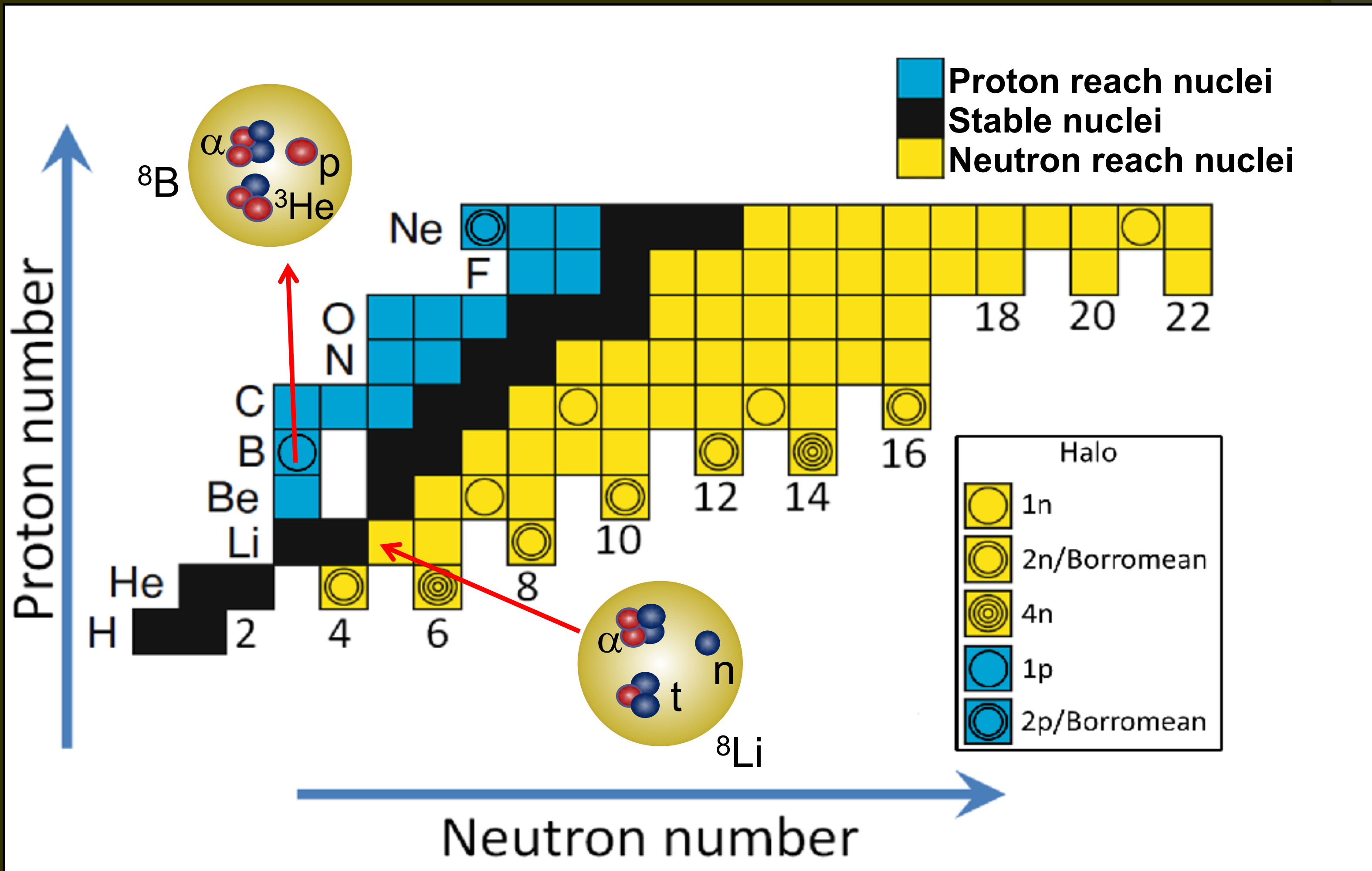
4. Conclusions

Chart of nuclides



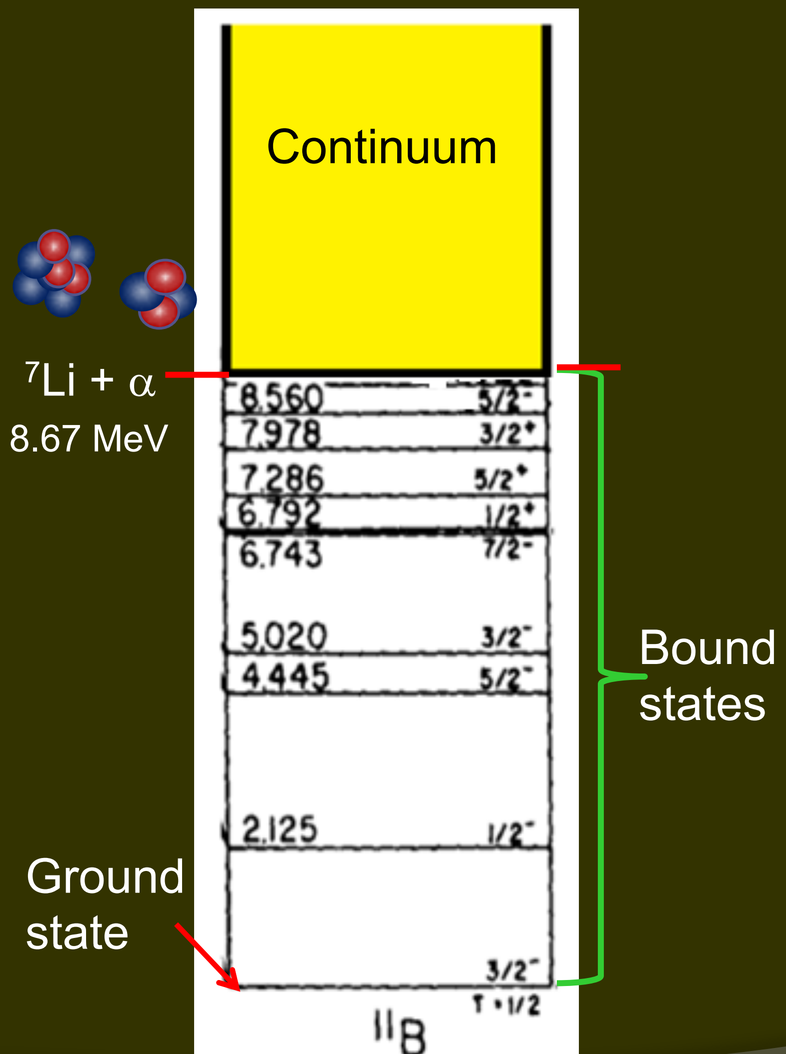
- Stable nuclei: Show up in nature; $\tau > 10^8$ yr.
- Unstable nuclei: $\tau < 1$ d.
- Exotic nuclei: Nuclei far from stability.

Chart of light nuclides

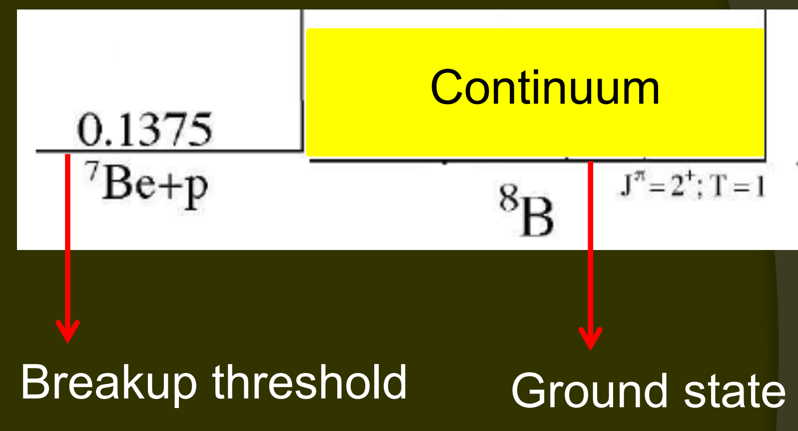


Weakly bound nuclei

Stable nucleus



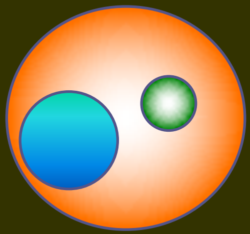
Weakly bound nucleus



Coupling with the continuum very important!

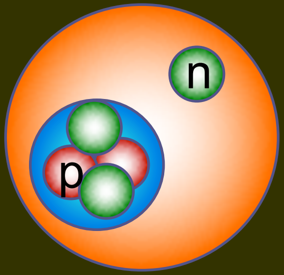
Cluster models

Non-microscopic



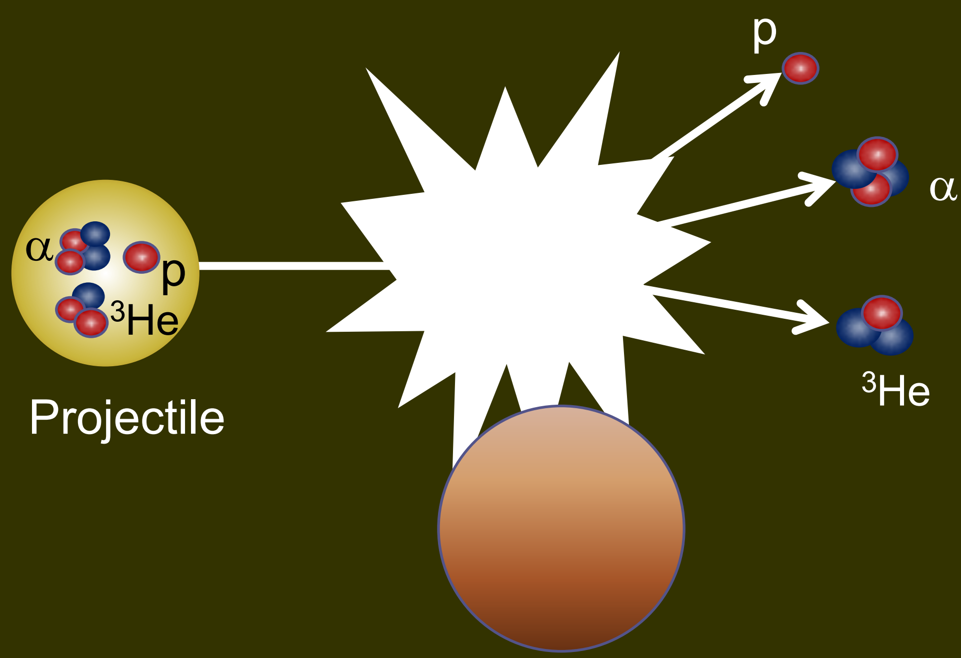
- Nucleus-nucleus interaction: In many cases not very well known.
- Antisymmetrization effects are simulated by a suitable choice of nucleus-nucleus potentials.

Microscopic



- Nucleon-nucleon interactions.
- The Pauli principleis exactly taken into account.
- Number of bodies increase: More difficult calculations.

Describing exotic nuclei



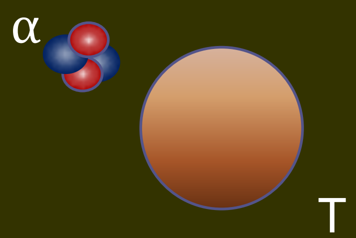
• Exotic nuclei are studied experimentally and theoretically through reactions (mostly breakup). Elastic are the starting point.

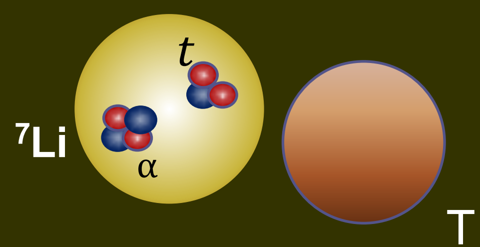
• An accurate description of the wave function of the projectile is needed into the reaction model.

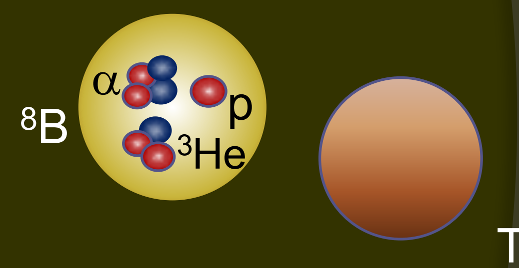
Describing exotic nuclei

• Including a microscopic cluster description of exotic nuclei into reaction models is a current area of research: (mixing structure and reaction models):

Elastic scattering







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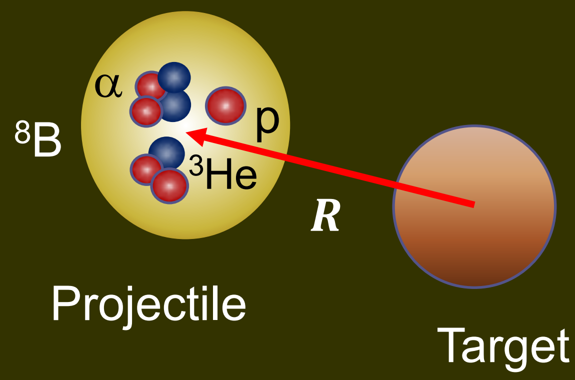
P. Descouvemont,
Current.

Continuum discretized coupled channels (CDCC) method



We wish to solve the Schrödinger Eq.

$$\mathrm{H_{PT}}\Phi(\xi_P, \boldsymbol{R}) = E_T \Phi(\xi_P, \boldsymbol{R}),$$

with

$$H_{PT} = T_R + H_P(\xi_P) + V_{PT}(\xi_P, \boldsymbol{R}).$$

$T_R \rightarrow$ P-T relative kinetic energy,

$$V_{PT} = \sum_{i=1}^{8} V_{iT}(\xi_P, \boldsymbol{R}),$$

$\rightarrow$ P-T Potential

$$V_{iT}(\xi_P, \boldsymbol{R}) = \underbrace{V_{iT}^{N}(\xi_P, \boldsymbol{R})}_{\text{Nuclear Nucleon-Target}} + \underbrace{V_{iT}^{C}(\xi_P, \boldsymbol{R})}_{\text{Coulomb Nucleon-Target}},$$

$\xi_P \rightarrow$ Internal coordinates of the projectile

$H_P(\xi_P) \rightarrow$ Internal Hamiltonian of the projectile

$\Psi_i\,(\xi_P) \rightarrow$ State of the projectile

Continuum discretized coupled channels (CDCC) method

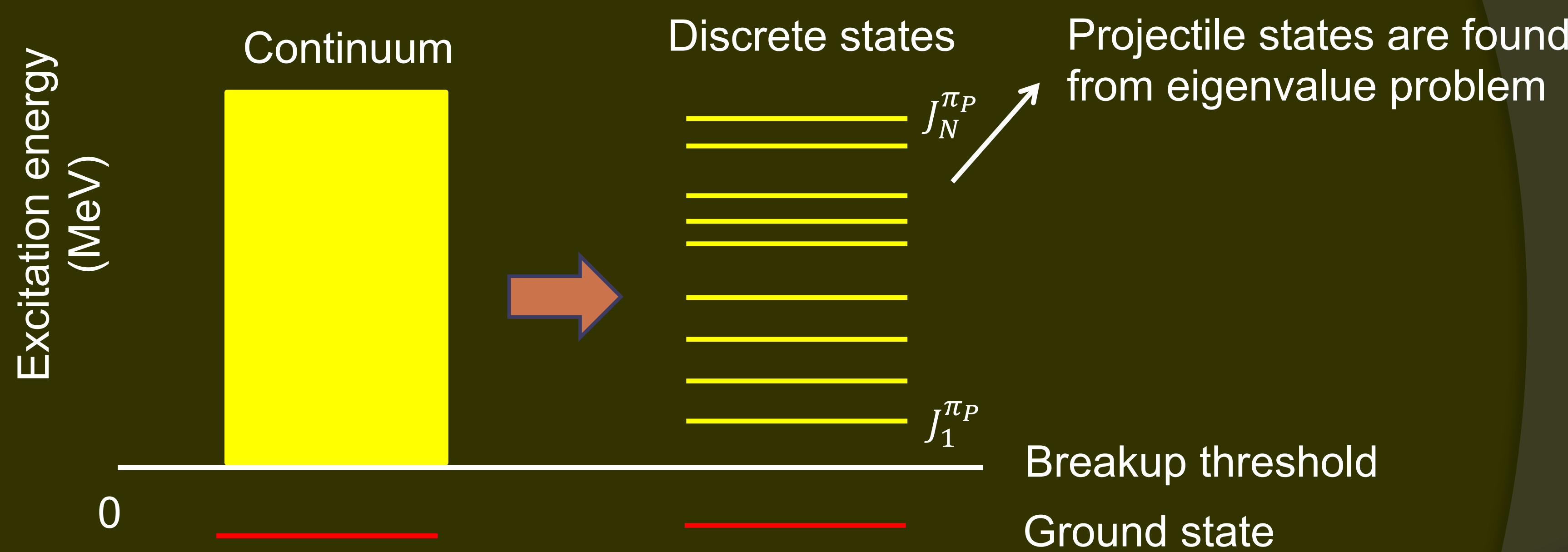
In the CDCC method the total wave function is expanded in the eingefunctions of the projectile $\Psi_i\,(\xi_P)$

$$\boxed{\Phi(\xi_P, \boldsymbol{R}) = \sum_i \Psi_i\,(\xi_P)\chi_i(\xi_P, \boldsymbol{R})}$$

To get

$$\underbrace{\left[-\frac{h^2}{2\mu_{PT}}\nabla^2 + V_{cc}(\boldsymbol{R}) - (E - \epsilon_c)\right]\chi_c(\boldsymbol{R}) = \sum_{c\prime\neq c} V_{c'c}(\boldsymbol{R})\chi_{c\prime}(\boldsymbol{R})}_{\textbf{CDCC system of equations}}$$

Continuum discretized coupled channels (CDCC) method



Microscopic model of the projectile

Projectile

The Schrödinger equation of the projectile

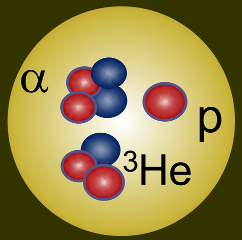
$$H_P \Psi_i^{J_P M_P \pi_P}(\xi_p) = \epsilon_i \Psi_i^{J_P M_P \pi_P}(\xi_P),$$

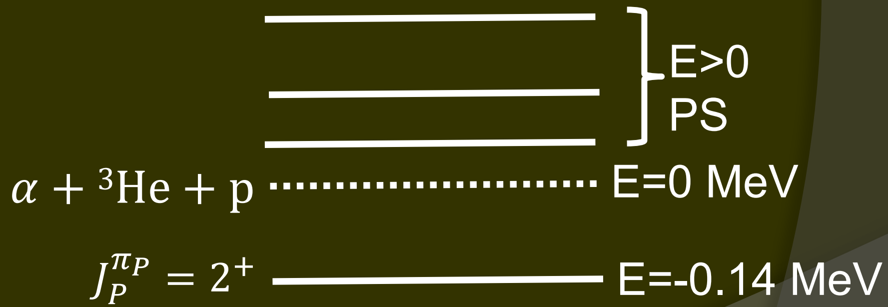
is obtained from Slater determinants

for

$\epsilon_i < 0$, Bound states
$\epsilon_i > 0$, Pseudostates
(Aprox. Continuum)

^{8}B





Characteristics of the microscopic CDCC model*

- ☺ High predictive power:

  Wave functions of the projectile→ nucleon-nucleon interactions

- ☺ The model is based on:

  Nucleon-Target interactions (large known set available)

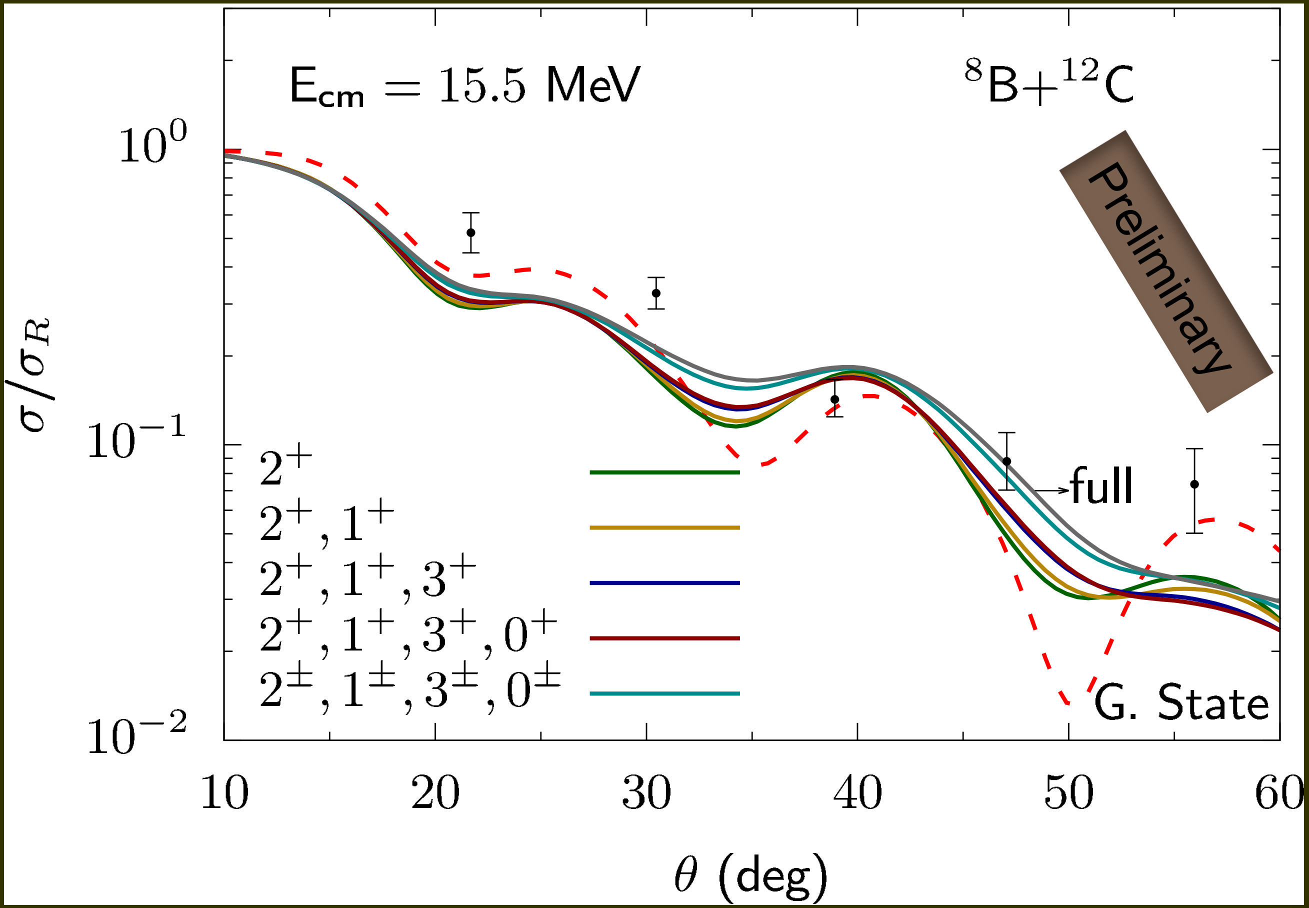
  (nucleus-nucleus interactions unknown in many cases)

- ☺ Influence of continuum states on reactions.

- ☺ Non free parameter.

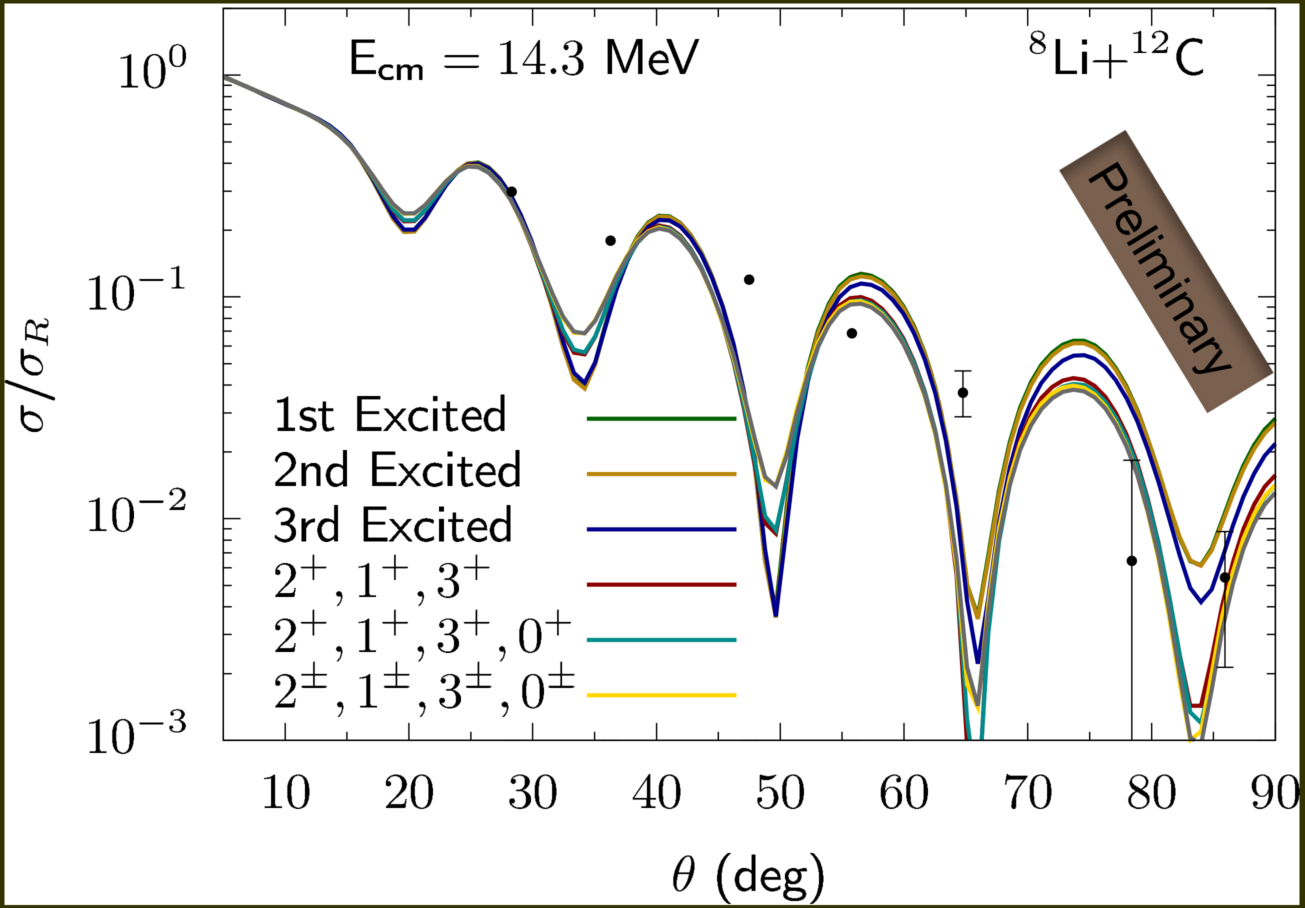
* P. Descouvemont and M. Hussein, Phys. Rev. Lett. 111 (2013) 082701.

Elastic scattering of $^{8}B+^{12}C$



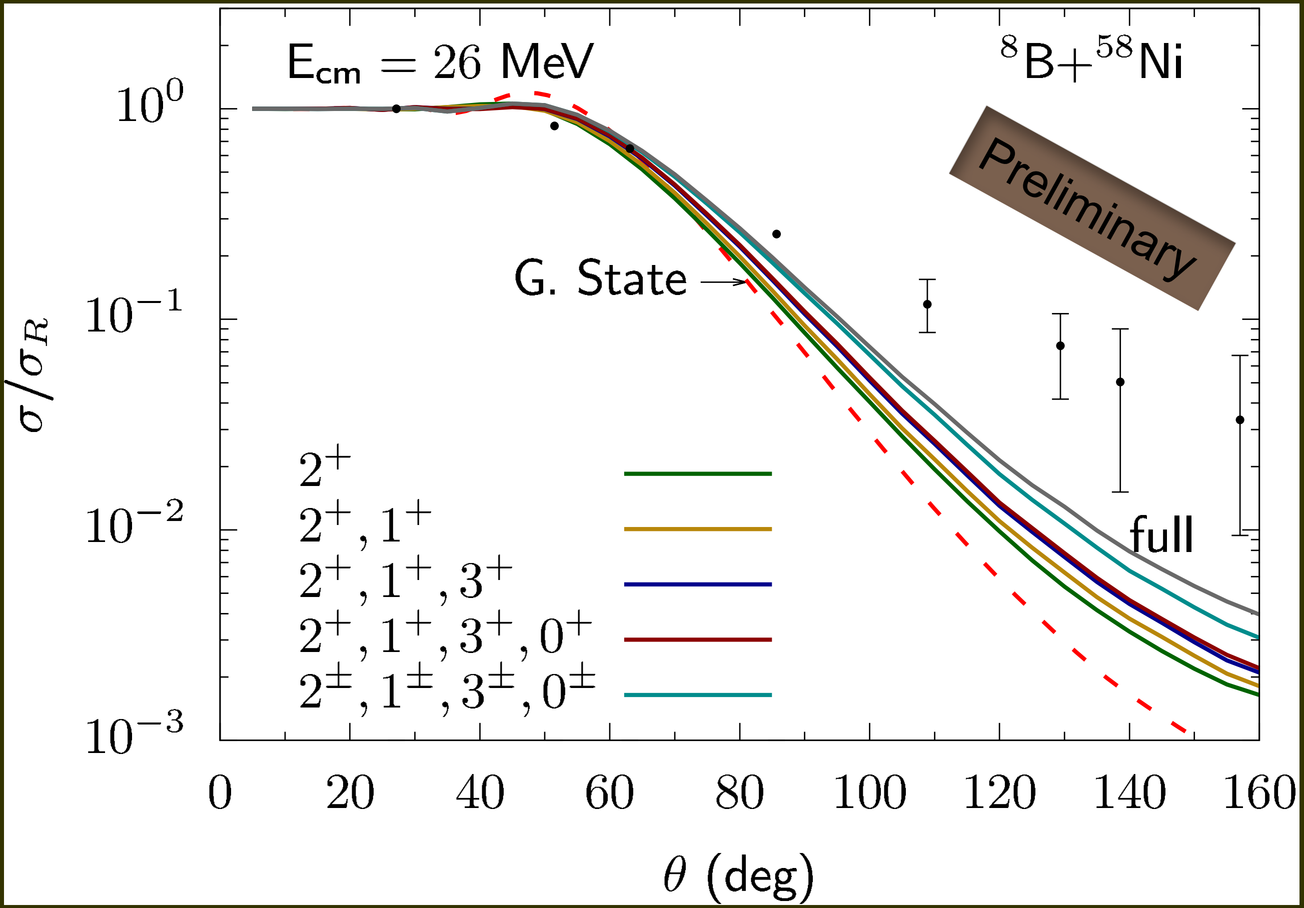
- Fair agreement with experimental data (no fitting parameters).
- Influence of continuum states on the elastic scattering.

Elastic scattering of $^{8}Li+^{12}C$



- Fair agreement with experimental data (no fitting parameters).
- Influence of continuum states on the elastic scattering.

Elastic scattering of $^{8}B+^{58}Ni$



- ❖ Slow convergence (time consuming calculations!).
- ❖ Influence of continuum states on the elastic scattering.

Conclusions and Remarks

- We introduce a precise microscopic wave function of the projectile (microscopic three-cluster model) to study the elastic scattering of ^8B and ^8Li.
- We observe an influence of continuum states on the elastic scattering of the studied projectiles.
- We get a fair agreement with the experimental data without any adjustable parameter.
- We can predict cross sections to be further measured.

Thank you for your attention