

Unified studies of structures and reactions by the Generalized Two-center Cluster model

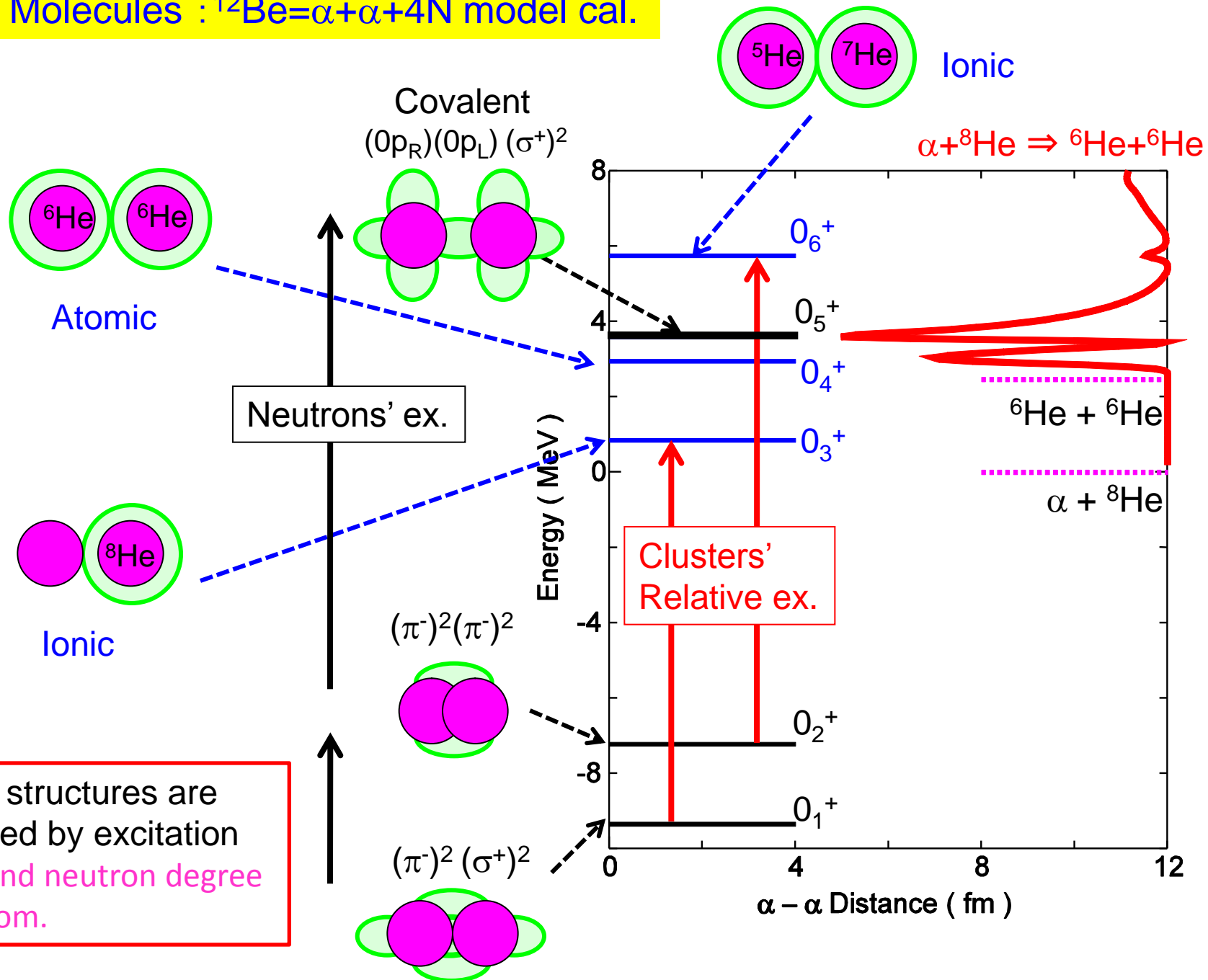
— Exotic structure changes and reaction dynamics —

Makoto Ito

Department of Pure and Applied Physics, Kansai University

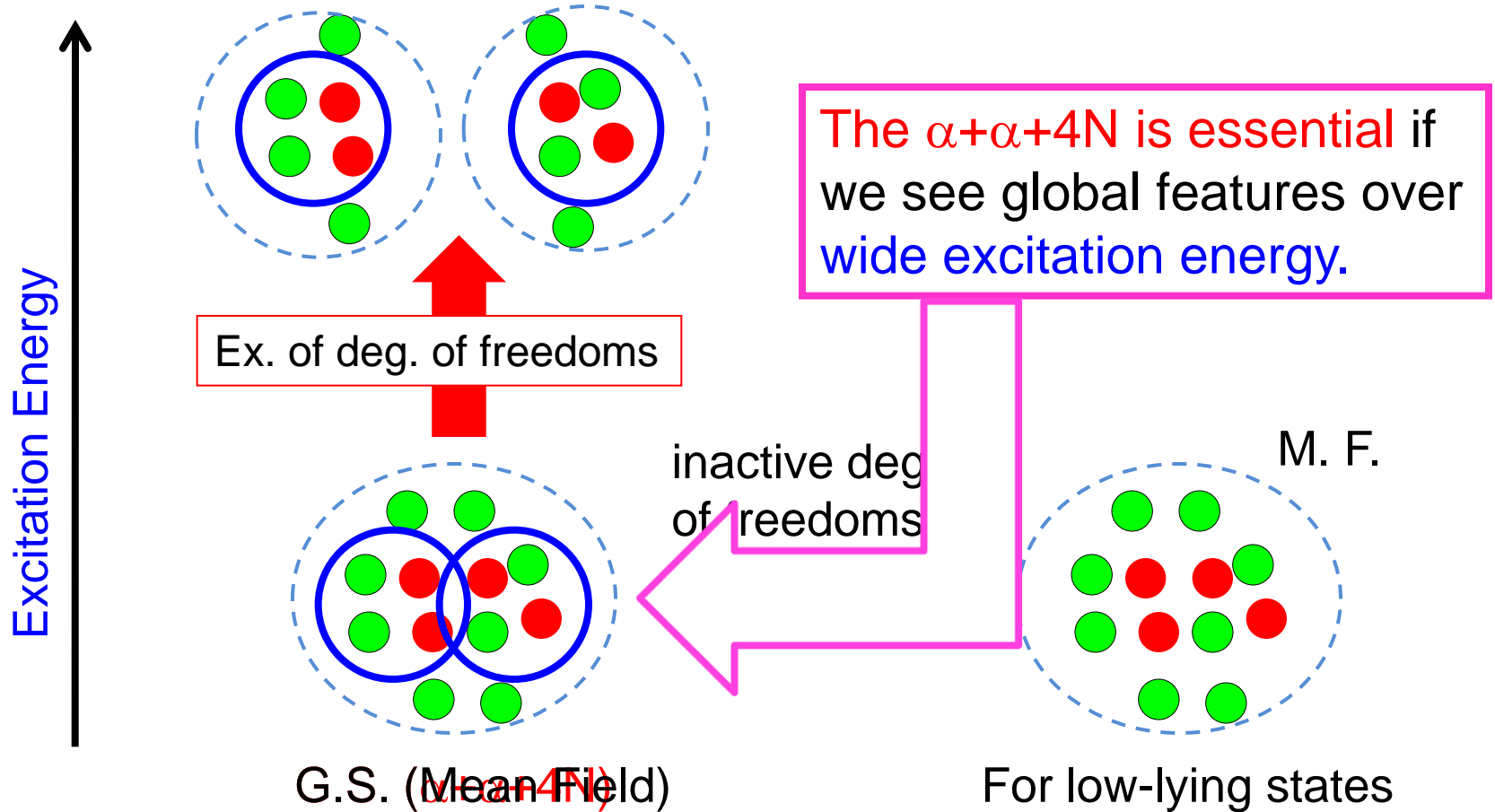
- I. Introductions : structures in ^{12}Be and $\alpha+^8\text{He}$ reactions
- II. Subjects of present studies
- III. Formulation
- IV. Systematic application to Be isotopes ($A=10, 12, 14, 16$)
- V. Discussion on low-energy reactions of neutron excess systems
- VI. Summary and feature studies

Femto Molecules : $^{12}\text{Be} = \alpha + \alpha + 4\text{N}$ model cal.



Various structures are generated by excitation of α - α and neutron degree of freedom.

What is an essential picture of a nucleus ?



Subjects

It is very important to investigate the global features of nuclei over wide excitation energy .

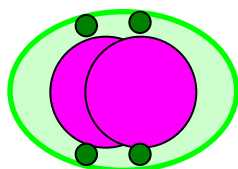
Analysis of Be isotopes are proceeding. \Rightarrow Today's report

Generalized Two-center Cluster Model (GTCCM)

M. Ito et al., PLB588(04), PLB636(06), PRL100(08)

$$^{12}\text{Be} = \alpha + \alpha + 4\text{N}$$

Mol. Orbit



Combine



α

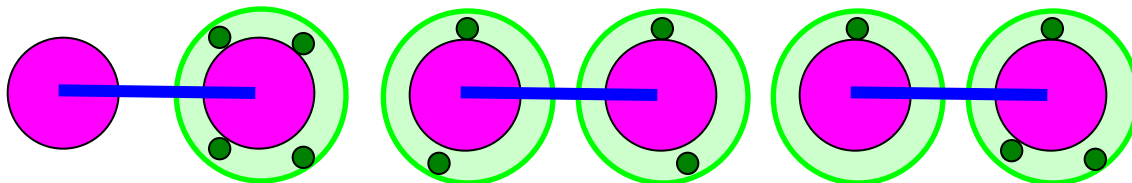
^8He

^6He

^6He

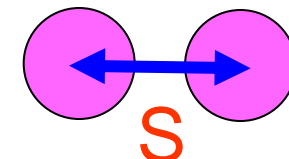
^5He

^7He



Combined model of mol. orbit and asymptotic channels

$$\Psi = c_1 \text{ (Mol. Orbit)} + c_2 \text{ (Mol. Orbit)} + c_3 \text{ (Mol. Orbit)} + \dots$$



$0P_i$ ($i=x,y,z$) coupled channel with atomic basis

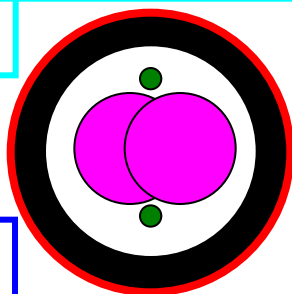
S, c_i : Variational PRM

Absorbing BC

Scattering BC

Tr. Density

Resonance PRM
PTP113 (05)



$-i W(R)$

$\alpha + ^8\text{He}$ Scattering
PRC78(R) (08)

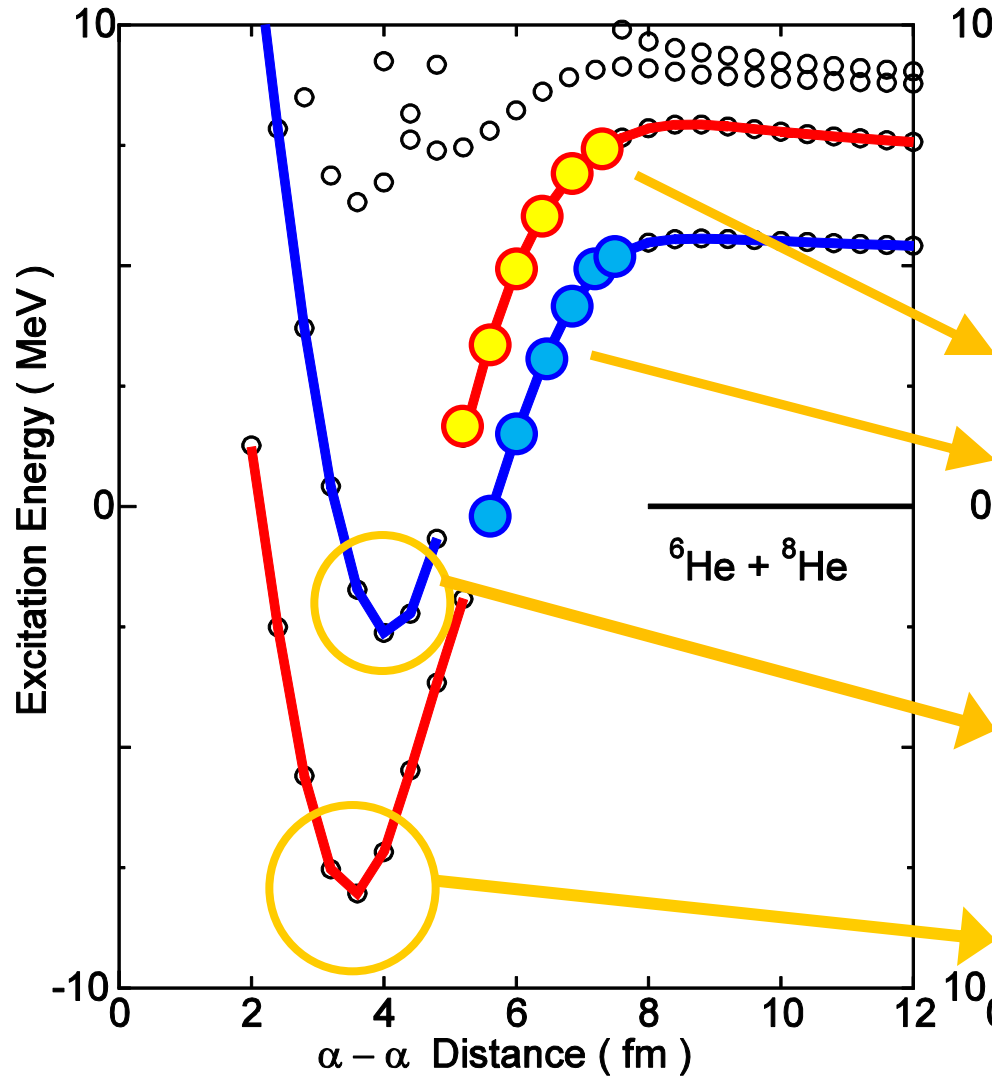
$$\langle \Psi_f | \rho | \Psi_i \rangle$$

$^{12}\text{Be}(0_1^+) \rightarrow ^{12}\text{Be}(0_{ex}^+)$
Monopole Transition

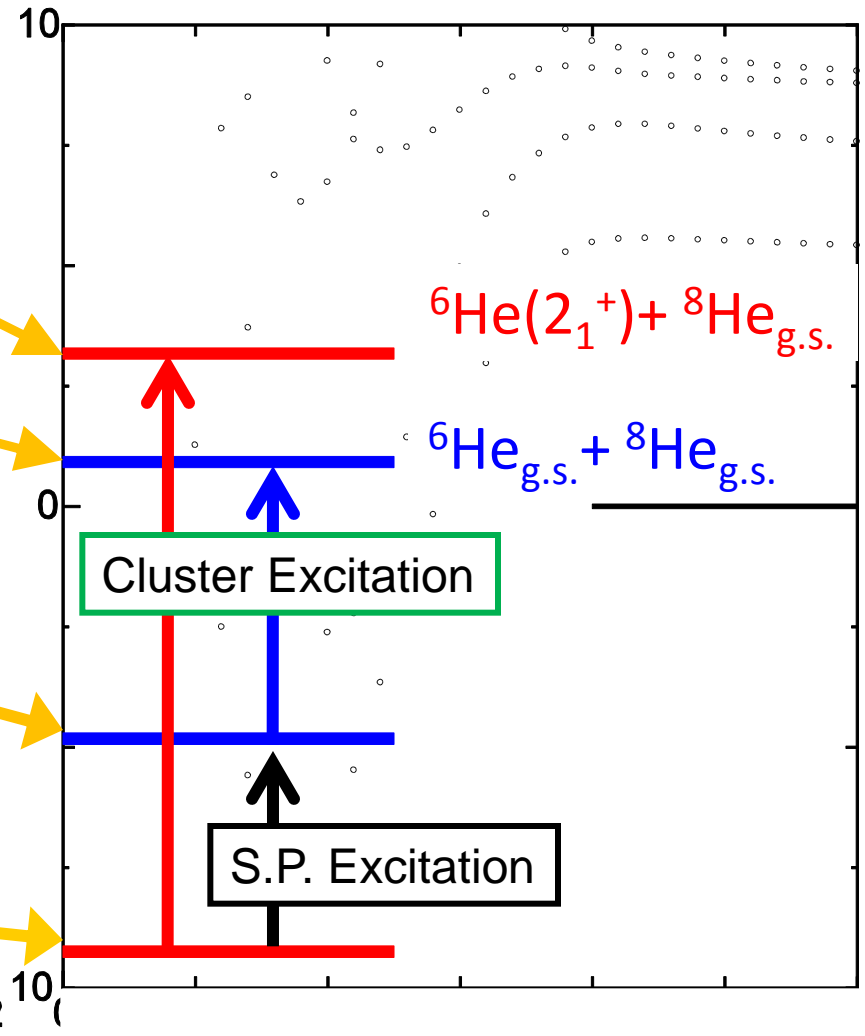
Results of $^{14}\text{Be} = \alpha + \alpha + 6\text{N}$ (62 channels)

(Scattering B.C. is important !!)

Adiabatic surfaces ($J^\pi = 0^+$)



Energy level (B.S. approx.)



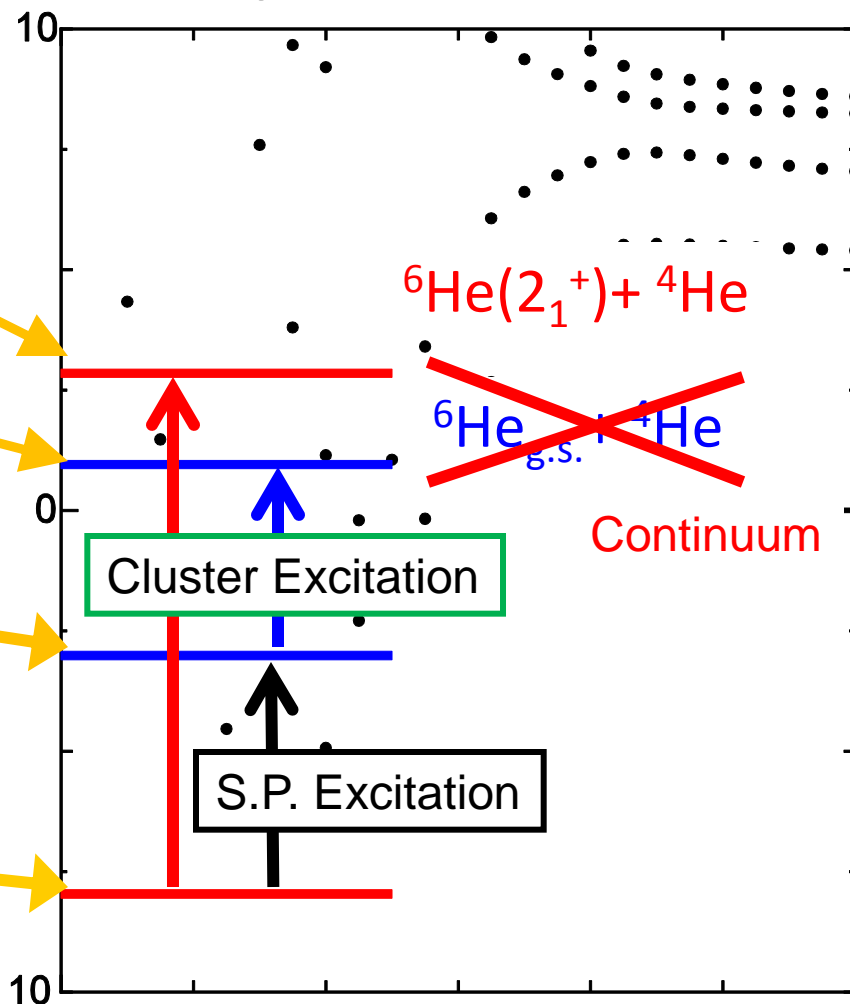
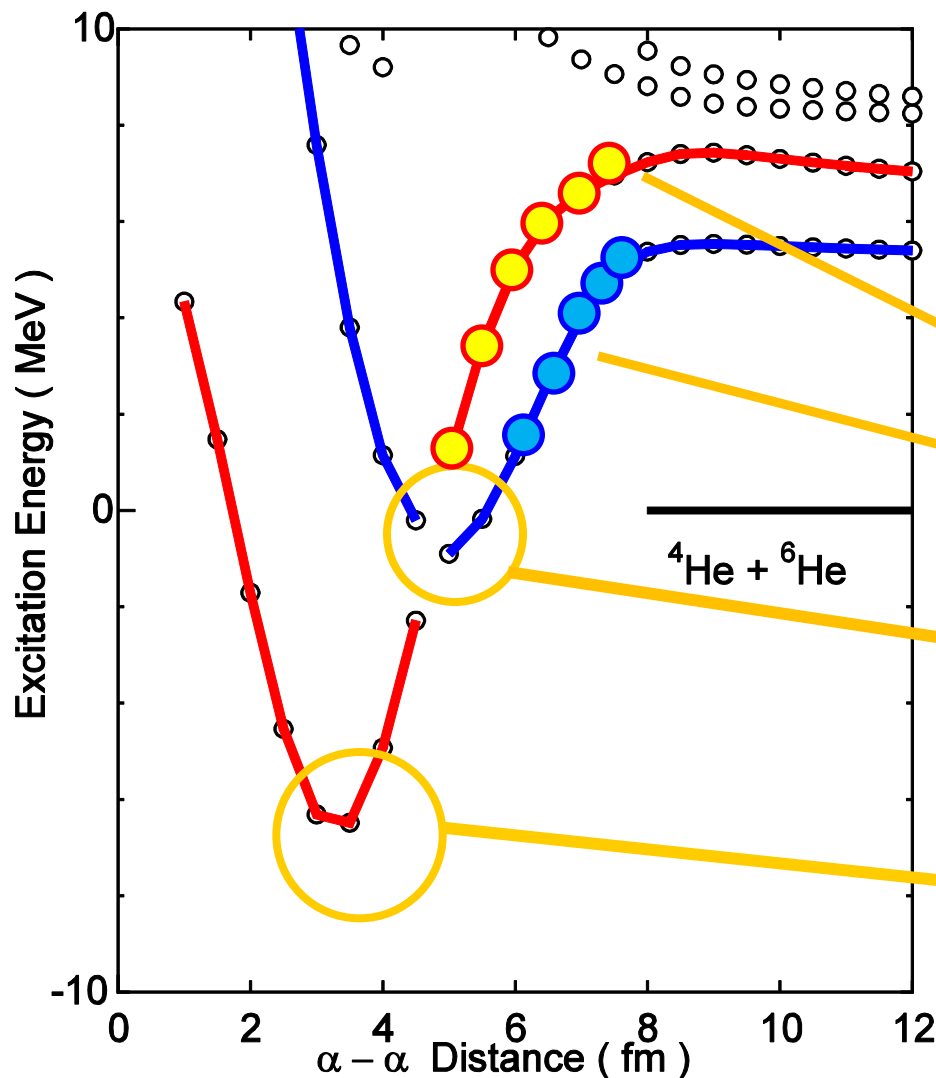
Results of $^{10}\text{Be} = \alpha + \alpha + 2\text{N}$ (8 channels)

(Scattering B.C. is imposed.)

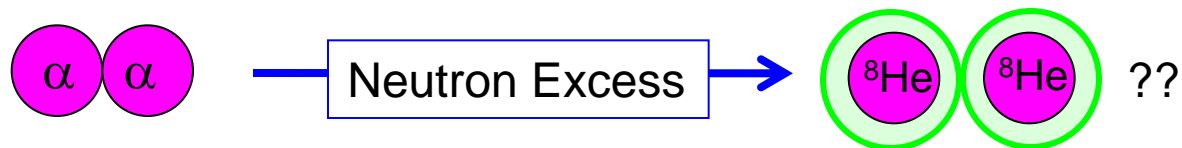
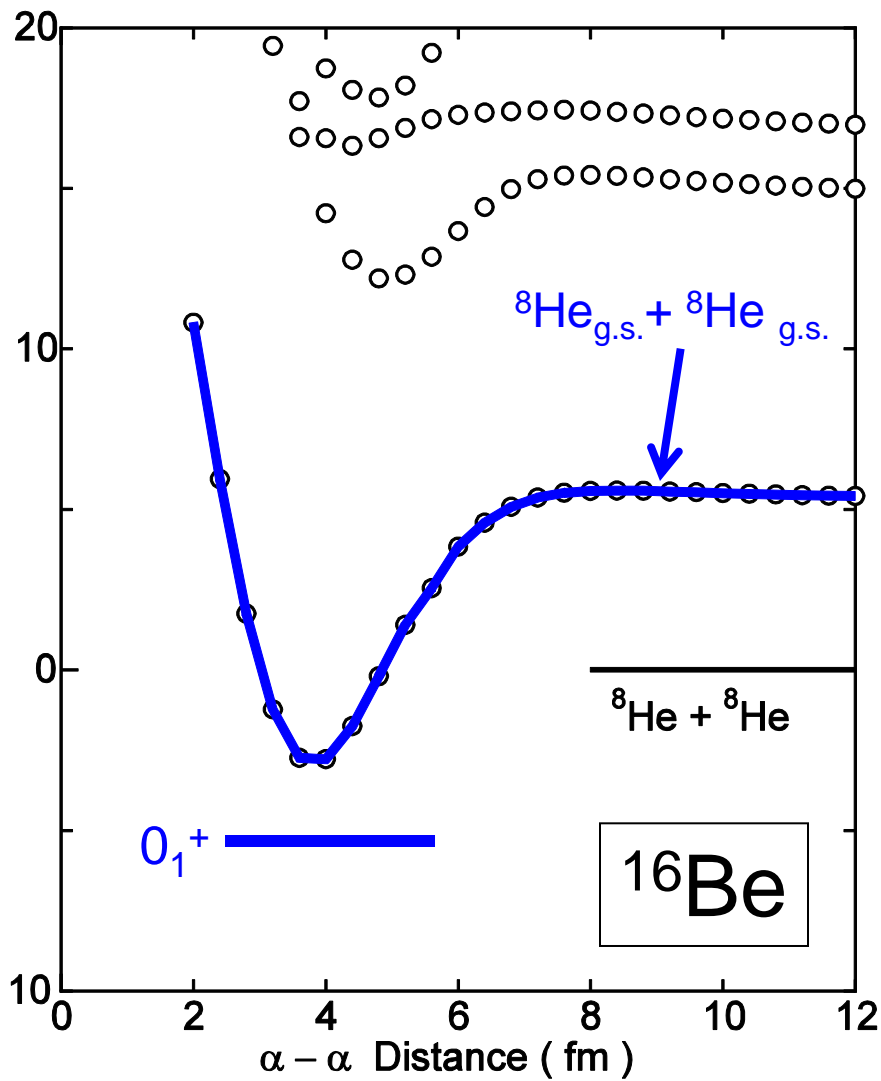
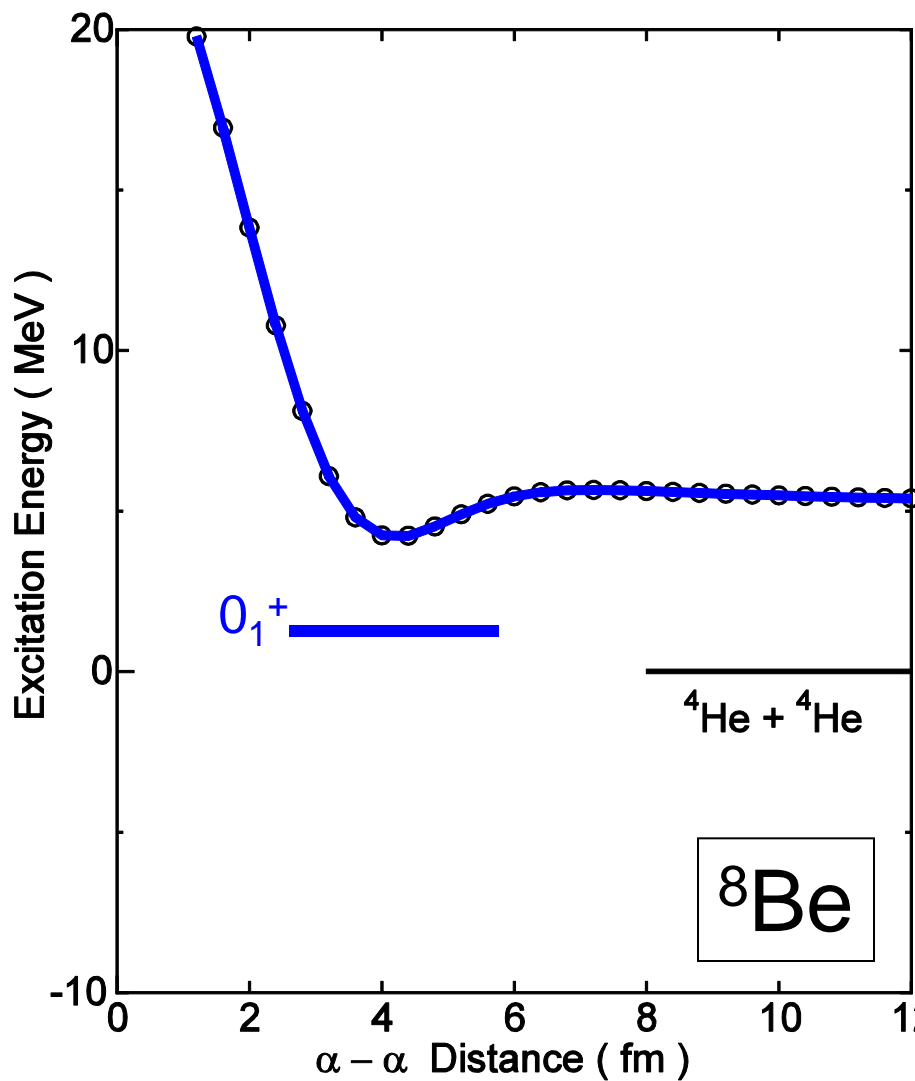
Similar structure to ^{14}Be

Adiabatic surfaces ($J^\pi = 0^+$)

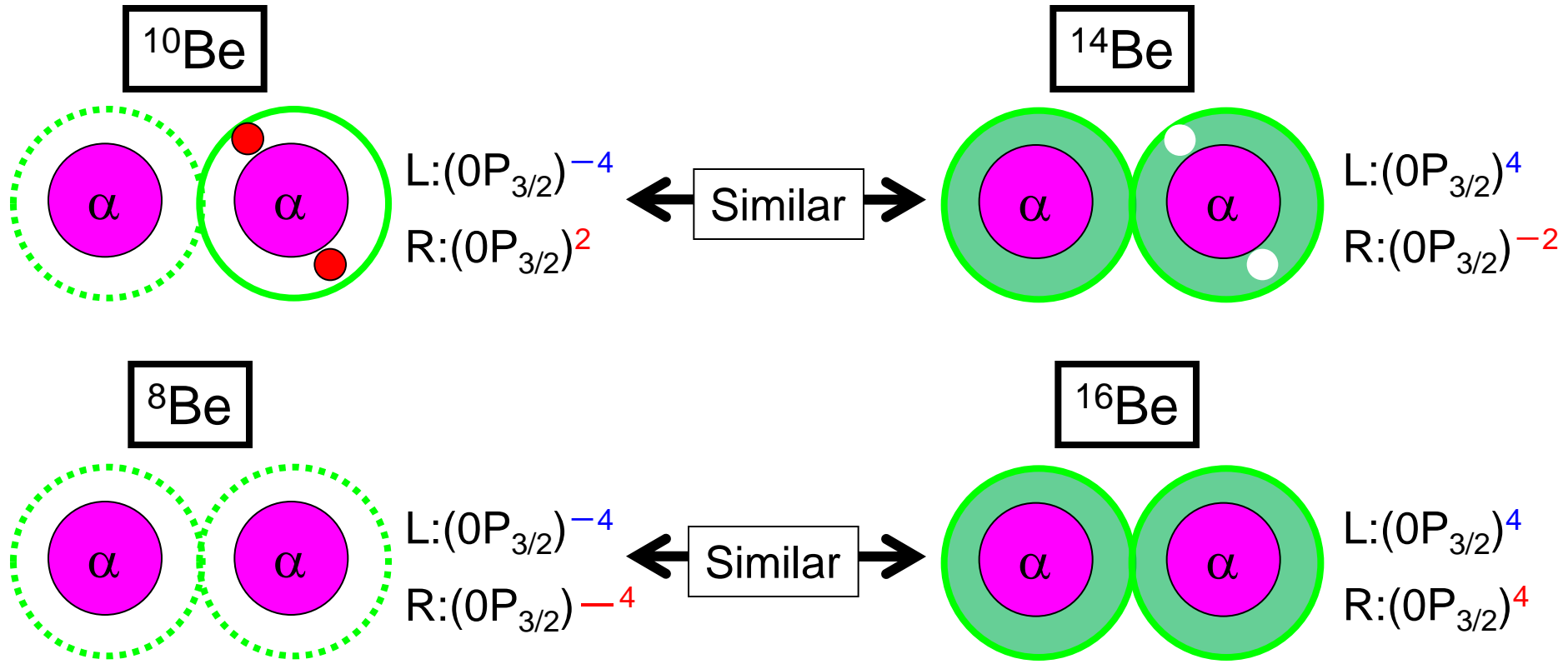
Energy level (B.S. approx.)



Adiabatic Energy surfaces of ${}^8\text{Be}$ and ${}^{16}\text{Be}$ ($J^\pi=0^+$)



Systematics based on the Cluster Picture



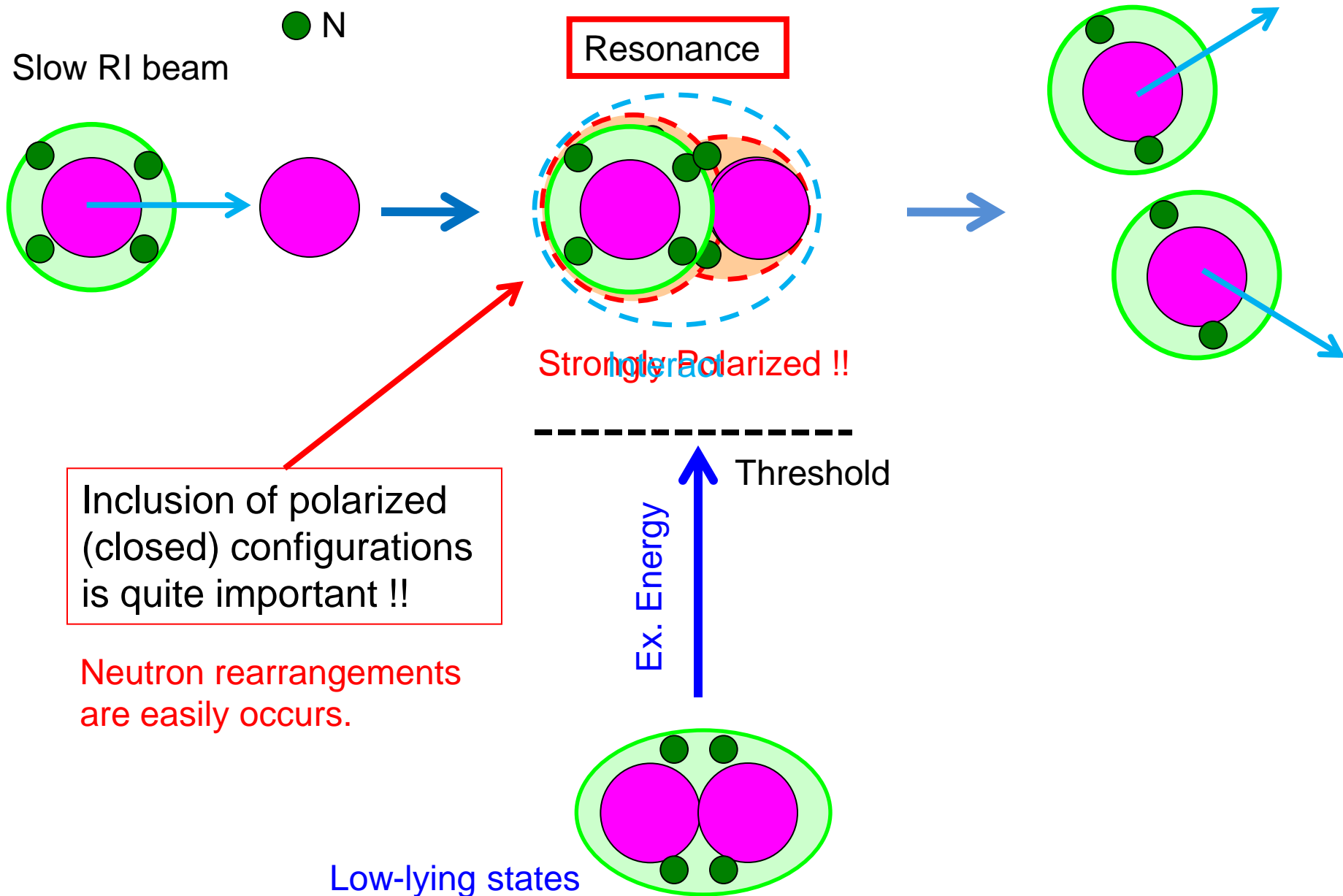
We are now analyzing wave functions.

Special feature in ^{12}Be

$^{12}\text{Be} = ^6\text{He} + ^6\text{He}$, $\alpha + ^8\text{He}$ is a **self conjugate** when atomic p-h are exchanged.

⇒ This is a special nucleus in even Be isotopes

Key points of theoretical studies for nucleosynthesis



Effect of Closed compound states in $\alpha+{}^8\text{He} \Rightarrow {}^6\text{He}+{}^6\text{He}$ in ${}^{12}\text{Be}$

$$\Psi = \phi(\alpha+{}^8\text{He}) + \underbrace{\phi({}^6\text{He}+{}^6\text{He})}_{\text{Dotted curves (Open)}} + \Omega(38\text{config.})$$

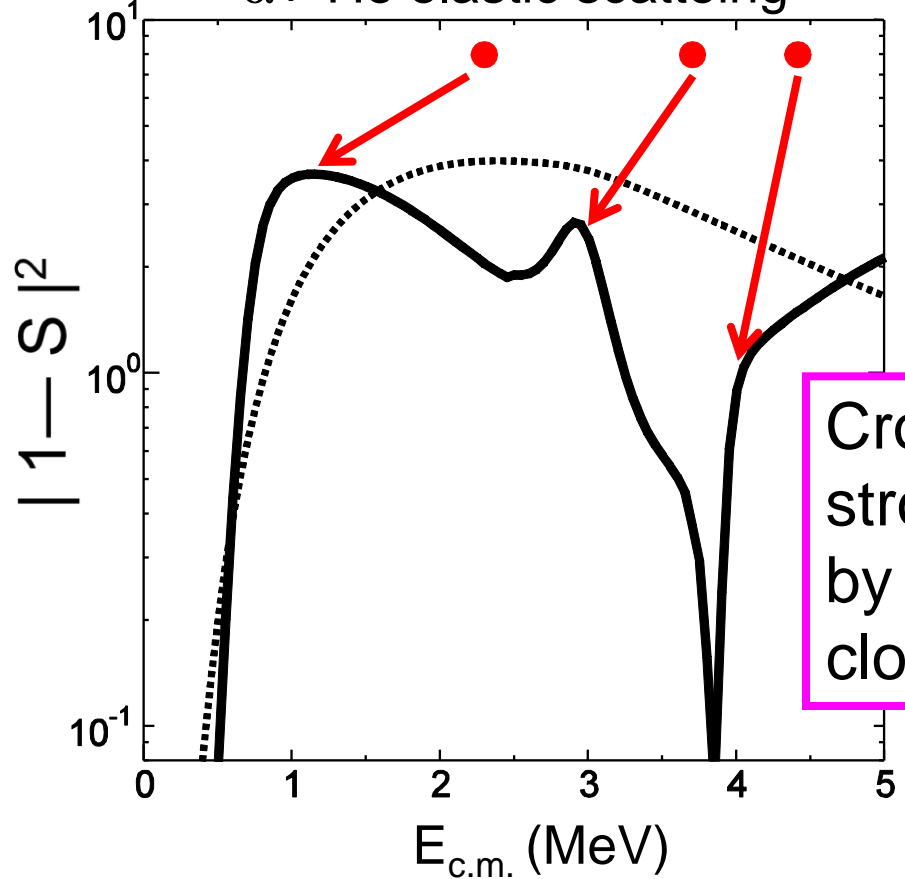


Dotted curves (Open)

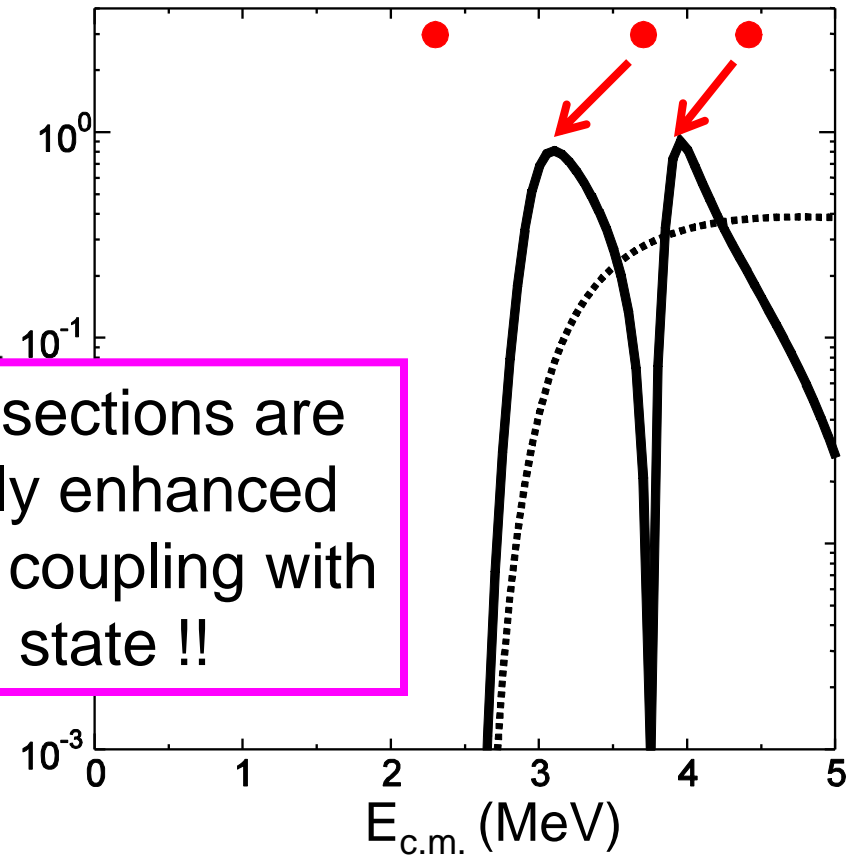
Red circles (Closed)

Solid curves

$\alpha+{}^8\text{He}$ elastic scattering



$\alpha+{}^8\text{He} \rightarrow {}^6\text{He}+{}^6\text{He}$



Cross sections are strongly enhanced by the coupling with closed state !!

Subjects of our studies

Investigations of **global features of nuclear structures** over wide energy region

Studies on Be isotopes

1. Ground states should be consider as **a hybrid of clusters and excess neutrons**.
2. Various structures appears by the excitation **of two deg. of freedoms**.
3. Neutron rearrangements easily occurs in reaction process.

- M. I., N. Itagaki, H.Sakurai, K. Ikeda, PRL 100, 182502 (2008).
- M. I., N. Itagaki, PRC78, 011602(R) (2008).
- M. I., N. Itagaki, Phys. Rev. Focus Vol.22, Story4 (2008).

Feature studies

Hybrid of α -cluster and excess neutrons is rather natural because of ${}^8\text{Be}=\alpha+\alpha$.

Studies on sd-shell nuclei ($\text{O}=\alpha+\text{C}+\text{XN}$, $\text{Ne}=\alpha+\text{O}+\text{XN}$) is very interesting.