非束縛核 ^{8}C の 5体共鳴状態の構造

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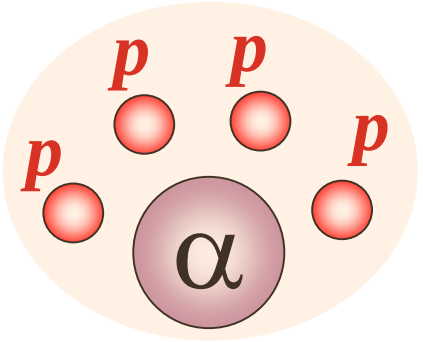
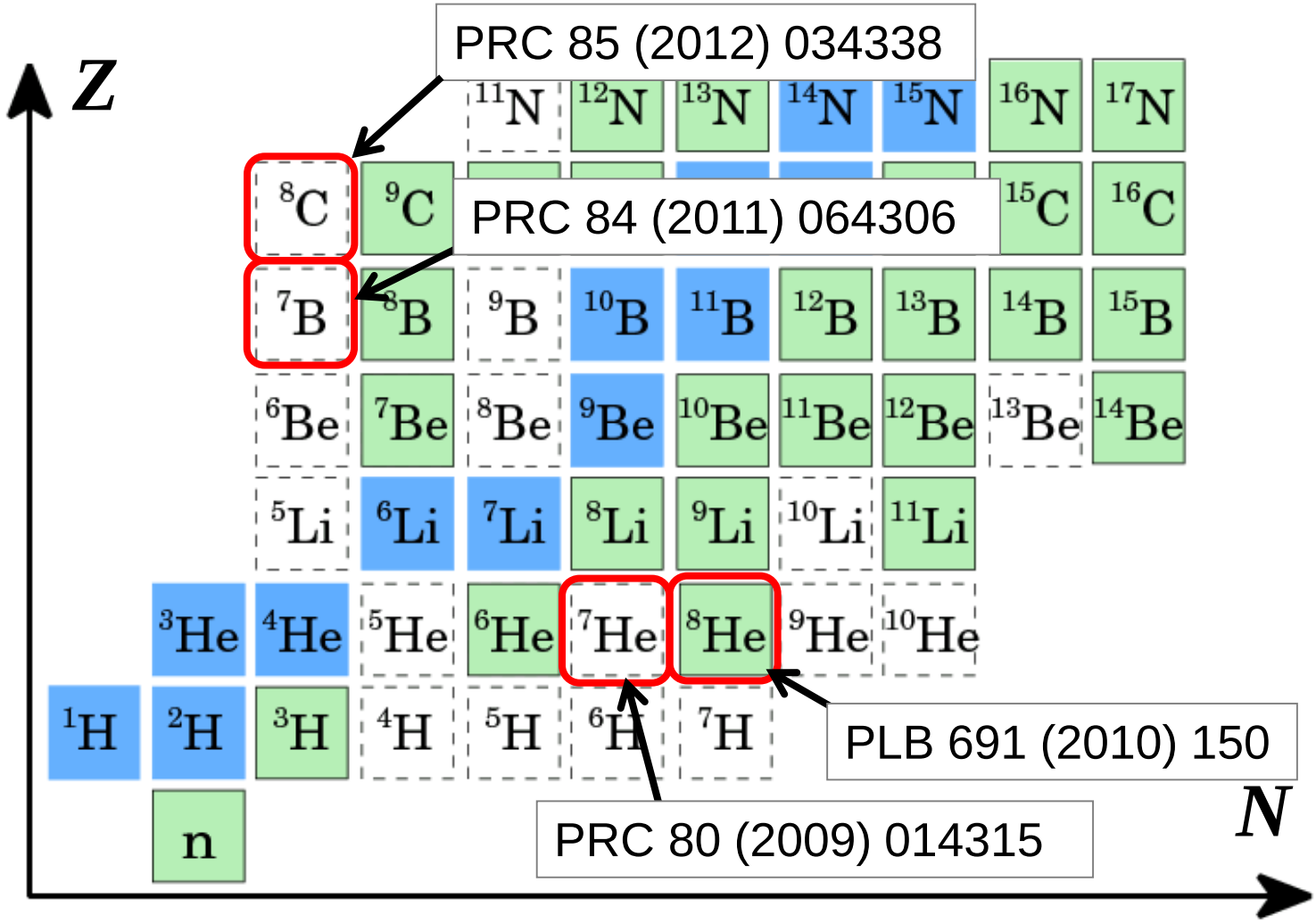


T. Myo, Y. Kikuchi, K. Kato
Physical Review C 85 (2012) 034338.

Why ^{8}C ?

- Proton-rich unbound nucleus
  - ^{4}He-^{5}Li-^{6}Be-^{7}B-**^{8}C**, decay into α+4*p* 5-body system
- Experiments
  - Only the ground state is observed.
  - R. G. H. Robertson, S. Martin, W. R. Falk, D. Ingham, A. Djaloeis, Phys. Rev. Lett. **32**, 1207 (1974). **^{8}C & ^{20}Mg**
  - R. J. Charity et al., Phys. Rev. C 82, 041304(R) (2010). ^{9}C beam : ^{7}B, ^{8}B*, ^{8}C, ... @MSU
- **NO theory** describes ^{8}C resonances so far.
- Mirror symmetry of *p*-rich & *n*-rich unstable nuclei
  - ^{8}C vs. ^{8}He(*n*-skin) : Energy levels, Configurations ,...

Nuclear Chart



Mirror symmetry in A=7 & A=8

Method

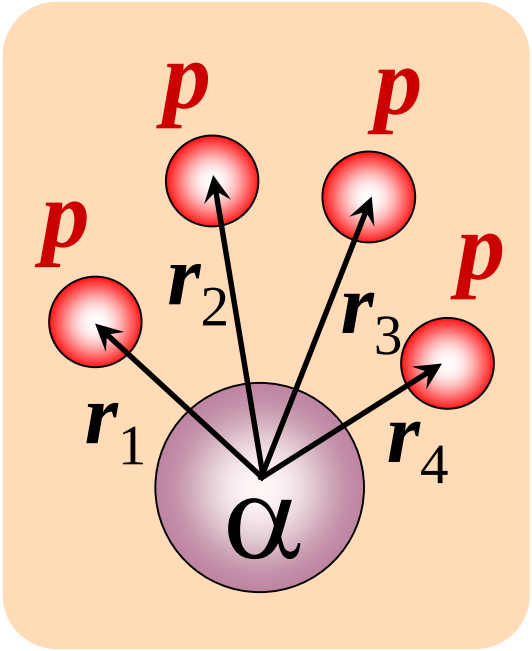
- Cluster Orbital Shell Model (COSM)
  - Include open channel effects.
    ^{8}C : ^{7}B+p, ^{6}Be+2p, ^{5}Li+3p, ^{4}He+4p
- Complex Scaling Method

$$\mathbf{r} \to \mathbf{r}e^{i\theta}, \quad \mathbf{k} \to \mathbf{k}e^{-i\theta}$$

  - Obtain <u>resonance w.f.</u> with correct boundary condition as **Gamow states**

$$E = E_r - i\Gamma/2$$

  - Give the continuum level density, ΔE
    - resonance+continuum, <u>Green's function</u>
    - strength function, Lippmann-Schwinger Eq., *T*-matrix



S. Aoyama, T. Myo, K. Kato, K. Ikeda, PTP116(2006)1 (review)

Kikuchi, Matsumoto et al. (Breakup)

Cluster Orbital Shell Model

- A-body System is obtained based on RGM equation

$$H(A) = H(^4\mathrm{He}) + H_{\mathrm{rel}}(N_V\, p) \qquad \Phi(^A\mathrm{He}) = \mathcal{A}\left\{\psi(^4\mathrm{He}) \cdot \sum_{i=1}^{N} C_i \cdot \chi_i(N_V\, p)\right\}$$

valence proton number

i : configuration index

$\psi(^4\mathrm{He})$: $(0s)^4$ ← No explicit tensor correlation

$\chi_i(N_V\, p) = \mathcal{A}\{\varphi_{i1}\varphi_{i2}\varphi_{i3}\varphi_{i4}\cdots\}$ $\varphi_i : L \le 2$, few-body method with Gaussian expansion

- Orthogonarity Condition Model (OCM) is applied.

$$\sum_{i=1}^{N}\left\langle \chi_j \left| \sum_{k=1}^{N_V}\left(T_k + V_k^{cp}\right) + \sum_{k<l}^{N_V}\left(V_{kl}^{pp} + \frac{\vec{p}_i \cdot \vec{p}_j}{A_c m}\right)\right| \chi_i \right\rangle C_i = (E - E_{4\mathrm{He}})\, C_j$$

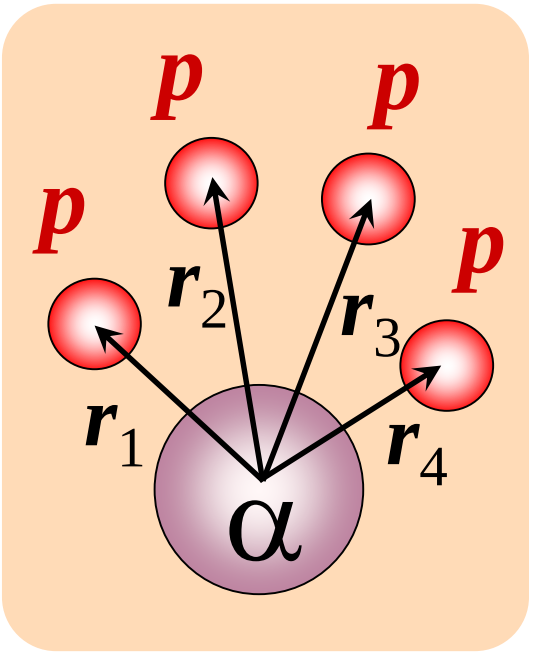
$\left\langle \varphi_i \middle| \phi_{\mathrm{PF}} \right\rangle = 0$: Remove Pauli Forbidden states (PF)

Y. Suzuki, K. Ikeda, PRC38(1988)410, H. Masui, K. Kato, K. Ikeda, PRC73(2006)034318

Hamiltonian

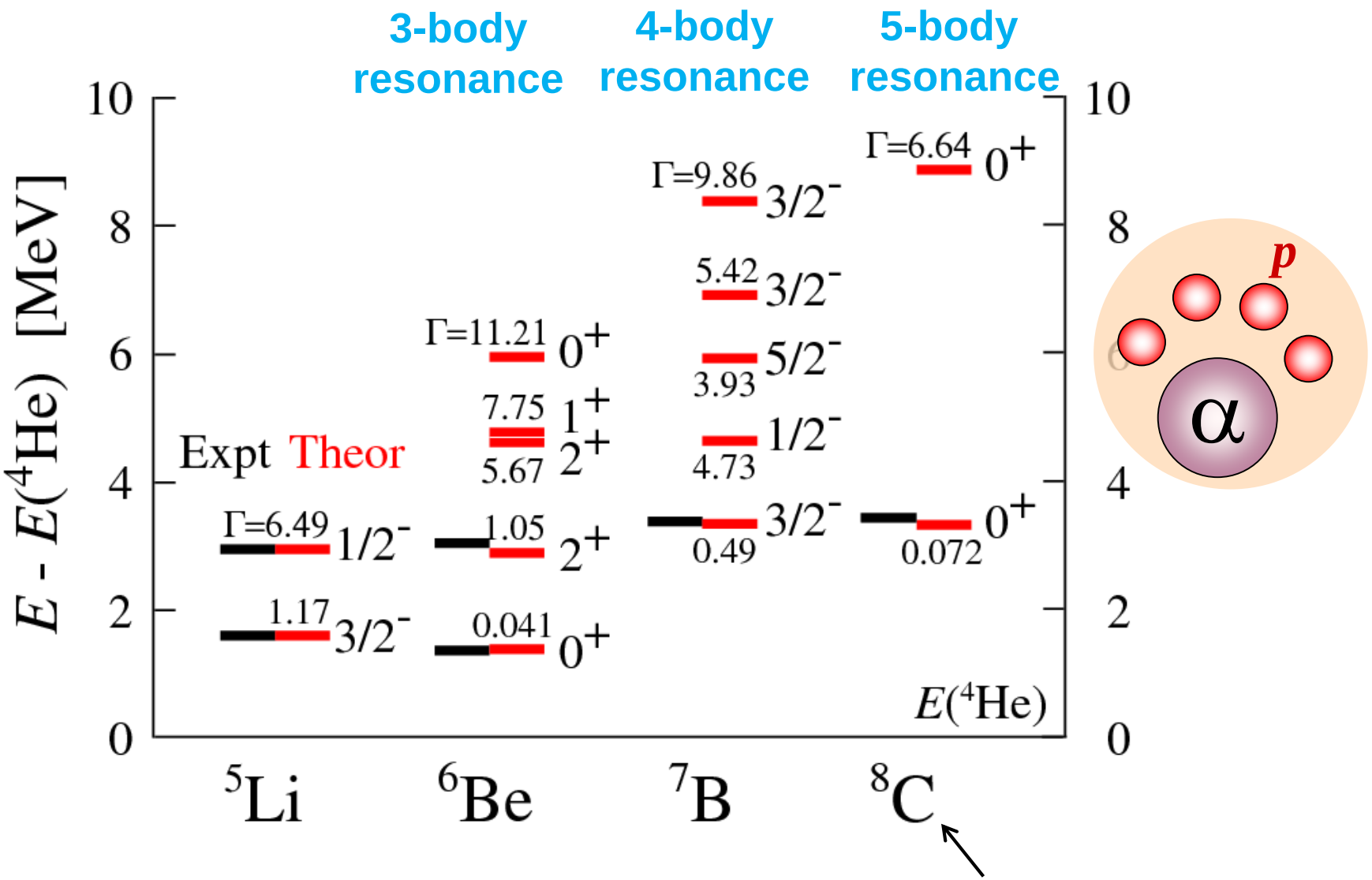
- $V_{\alpha p}$: microscopic KKNN potential + folded α-p Coulomb
  - s,p,d,f-waves of α-p scattering
- V_{pp} : Minnesota potential
  with slightly strengthened
  + p-p Coulomb

Fit $E(^6\mathrm{He}_{\mathrm{GS}})$ with αnn



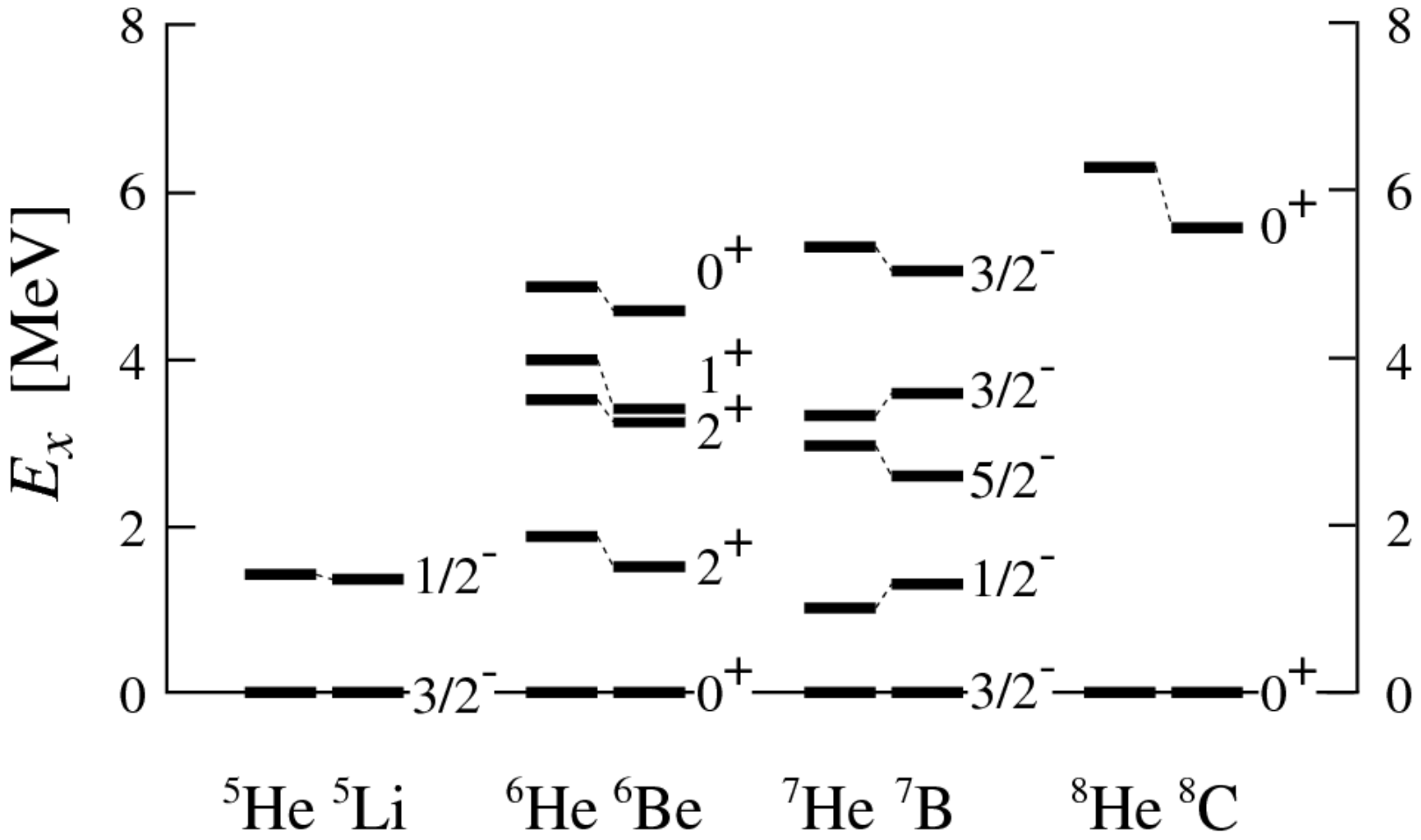
A. Csoto, PRC48(1993)165.
K. Arai, Y. Suzuki and R.G. Lovas, PRC59(1999)1432.
TM, S. Aoyama, K. Kato, K. Ikeda, PRC63(2001)054313.
TM K. Kato, K. Ikeda, PTP113(2005)763.

Proton-rich side : ^{4}He+4*p*



Charity et al. PRC84(2011)014320.
TUNL Nuclear Data Evaluation

Mirror Symmetry



- Good symmetry

Configuration weights of ^{8}C, ^{8}He

G.S.

0p0h

	^{8}C (4p)	^{8}He (4n)
$(p_{3/2})^4$	**0.88**	**0.86**
$(p_{3/2})^2(p_{1/2})^2$	0.06	0.07
$(p_{3/2})^2(d_{5/2})^2$	0.04	0.04

0^+_2

2p2h

	^{8}C (4p)	^{8}He (4n)
$(p_{3/2})^4$	0.04	0.02
$(p_{3/2})^2(p_{1/2})^2$	**0.93**	**0.97**
$(p_{3/2})^2(d_{3/2})^2$	0.02	0.02

- Good symmetry between ^{8}C & ^{8}He

Continuum effect in ^{8}C (r_p< 6 fm)

G.S.

0p0h

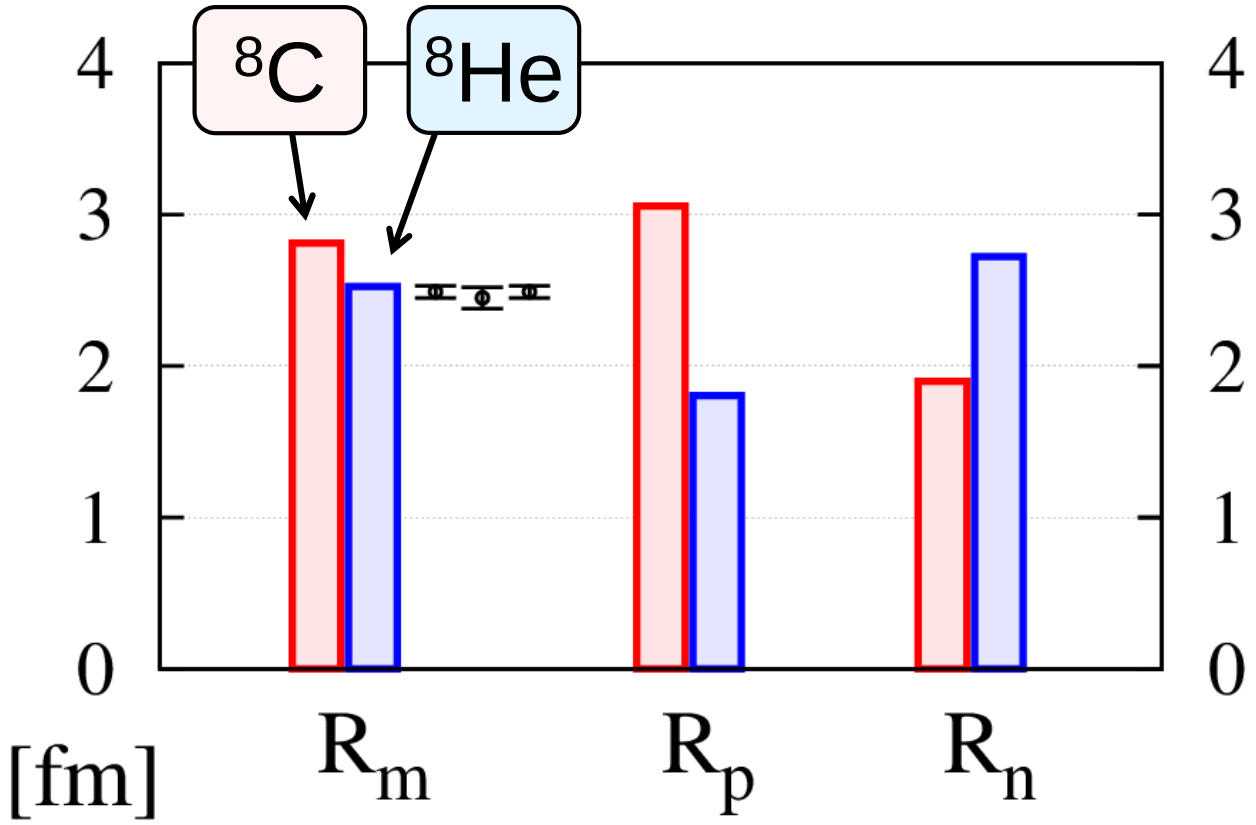
	Full	No continuum
$(p_{3/2})^4$	**0.88**	**0.85**
$(p_{3/2})^2(p_{1/2})^2$	0.06	0.07
$(p_{3/2})^2(d_{5/2})^2$	0.04	0.04

0^+_2

2p2h

	Full	No continuum
$(p_{3/2})^4$	0.04	0.05
$(p_{3/2})^2(p_{1/2})^2$	**0.93**	**0.80**
$(p_{3/2})^2(1s_{1/2})^2$	–0.01	0.09
$(p_{3/2})^2(d_{3/2})^2$	0.02	0.01
$(p_{3/2})^2(d_{5/2})^2$	0.00	0.00

Radial properties of ^{8}C, ^{8}He – **G.S.** –

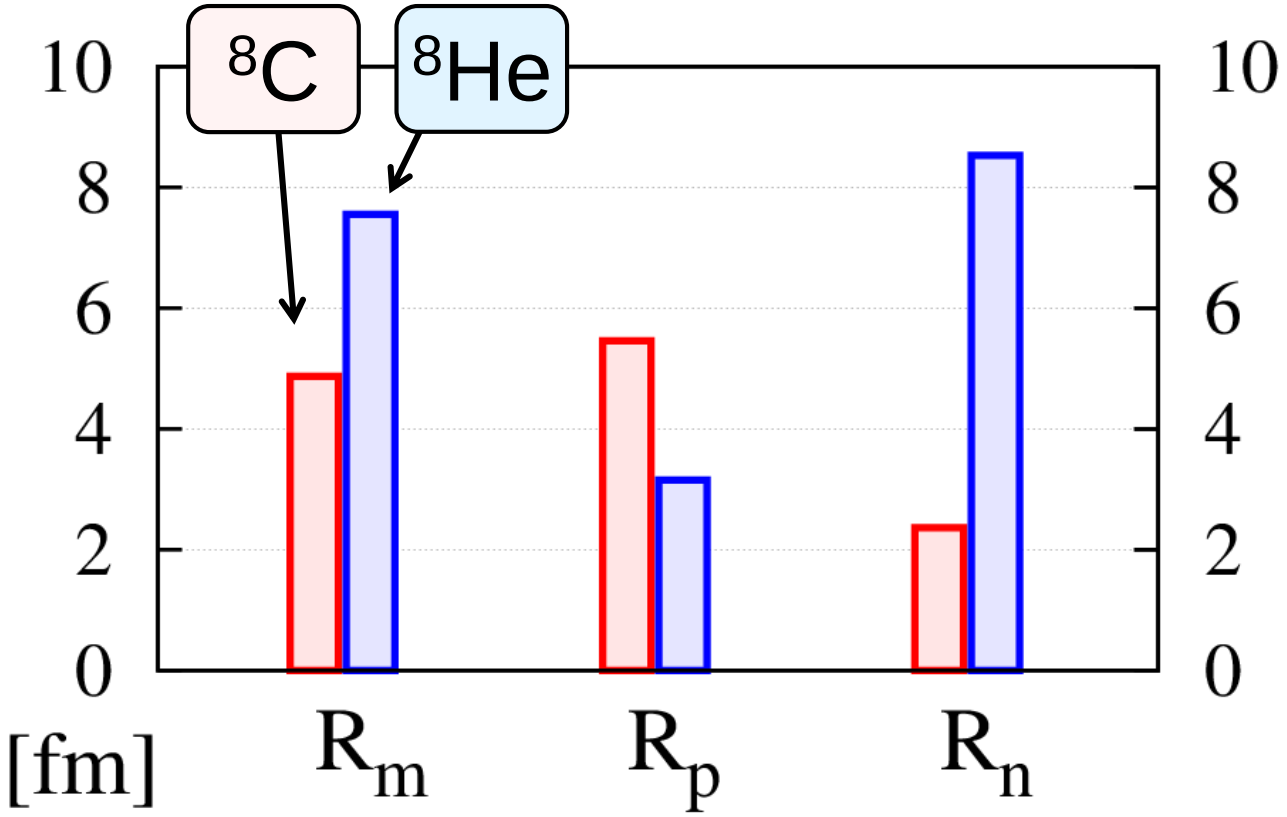


<u>10%-15% increase</u> due to Coulomb repulsion

cf. ^{6}Be-^{6}He, 20% increase
(2p) (2n)

I. Tanihata et al., PLB289('92)261
G. D. Alkhazov et al., PRL78('97)2313
O. A. Kiselev et al., EPJA 25, Suppl. 1('05)215

Radial properties of ^{8}C, ^{8}He – $\mathbf{0^+_2}$ –



<u>30% decrease</u> due to Coulomb barrier

$\mathbf{0^+_2}$

^{8}C	$(E_r\,,\,\Gamma)$ = (8.9, 6.4)	(MeV)
^{8}He	$(E_r\,,\,\Gamma)$ = (3.1, 3.2)	comparable

Summary

^{8}C

- Proton-rich, five-body unbound nucleus
- α+4*p* with COSM + complex scaling
- Mirror symmetry between ^{8}C & ^{8}He
  - Configurations show good symmetry.
  - Continuum effect is large in 2nd 0^{+}.
  - Radius shows different behavior due to $\underline{V_{\text{Coulomb}}}$

GS : $R(^{8}\text{C}) > R(^{8}\text{He})$, 0^{+}_{2} : $R(^{8}\text{C}) < R(^{8}\text{He})$

Five-body resonances of ^{8}C using the complex scaling method

T. Myo, Y. Kikuchi, K. Kato Phys. Rev. C 85 (2012) 034338, 87 (2013) 049902(E).

Continuum effect in ^{8}He (r_n< 6 fm)

G.S.

0p0h

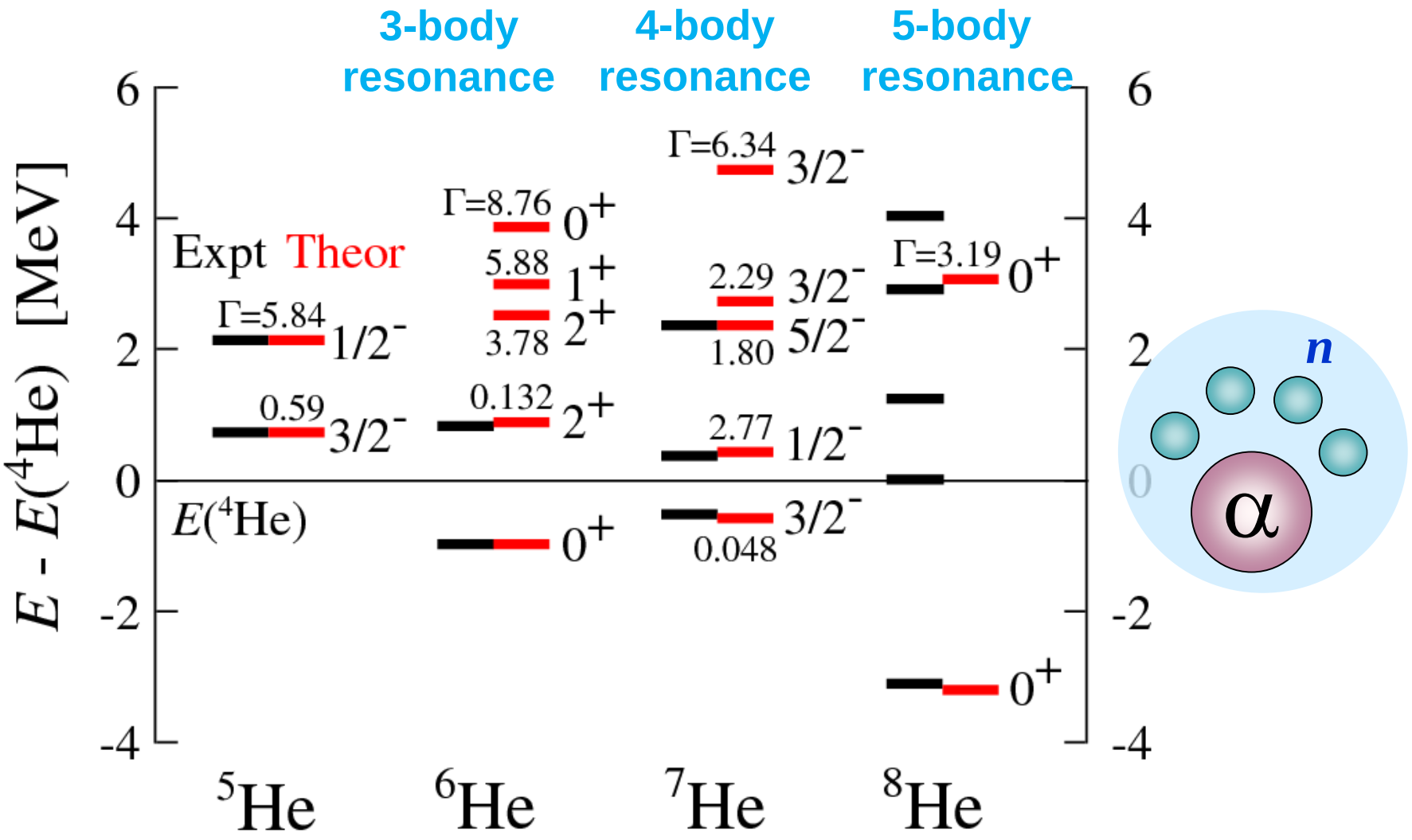
	Full	**No continuum**
$(p_{3/2})^4$	**0.86**	**0.86**
$(p_{3/2})^2(p_{1/2})^2$	0.07	0.07
$(p_{3/2})^2(d_{5/2})^2$	0.04	0.04

0^+_2

2p2h

	Full	**No continuum**
$(p_{3/2})^4$	0.02	0.07
$(p_{3/2})^2(p_{1/2})^2$	**0.97**	**0.81**
$(p_{3/2})^2(1s_{1/2})^2$	–0.01	0.04
$(p_{3/2})^2(d_{3/2})^2$	0.02	0.02
$(p_{3/2})^2(d_{5/2})^2$	0.00	0.01

He isotopes : Expt vs. Complex Scaling



TM, K.Kato, K.Ikeda PRC76('07)054309
TM, R.Ando, K.Kato PRC80('09)014315

TM, R.Ando, K.Kato, PLB691('10)150
TUNL Nuclear Data Evaluation