微視的多クラスター模型による ^{9}Be と ^{10}Be の励起状態の構造

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○ Motive

Study the Cluster or Molecular Structure among the excited states in ^{9}Be & ^{10}Be using the α+α+n and α+α+n+n model based on the microscopic multi-cluster model

○ Reference

^{9}Be	K.Arai *et al.*	PRC54(1996)132
	K.Arai *et al.*	PRC68(2003)014310
^{10}Be	Y.Ogawa *et al.*	NPA673(2000)122
	K.Arai	PRC69(2004)014309

- Model

- ^{9}Be ---- $\alpha+\alpha+n$ three-cluster model
- ^{10}Be ---- $\alpha+\alpha+n+n$

  four-cluster model

- Microscopic multi-cluster model according to the Resonating Group Method(RGM)

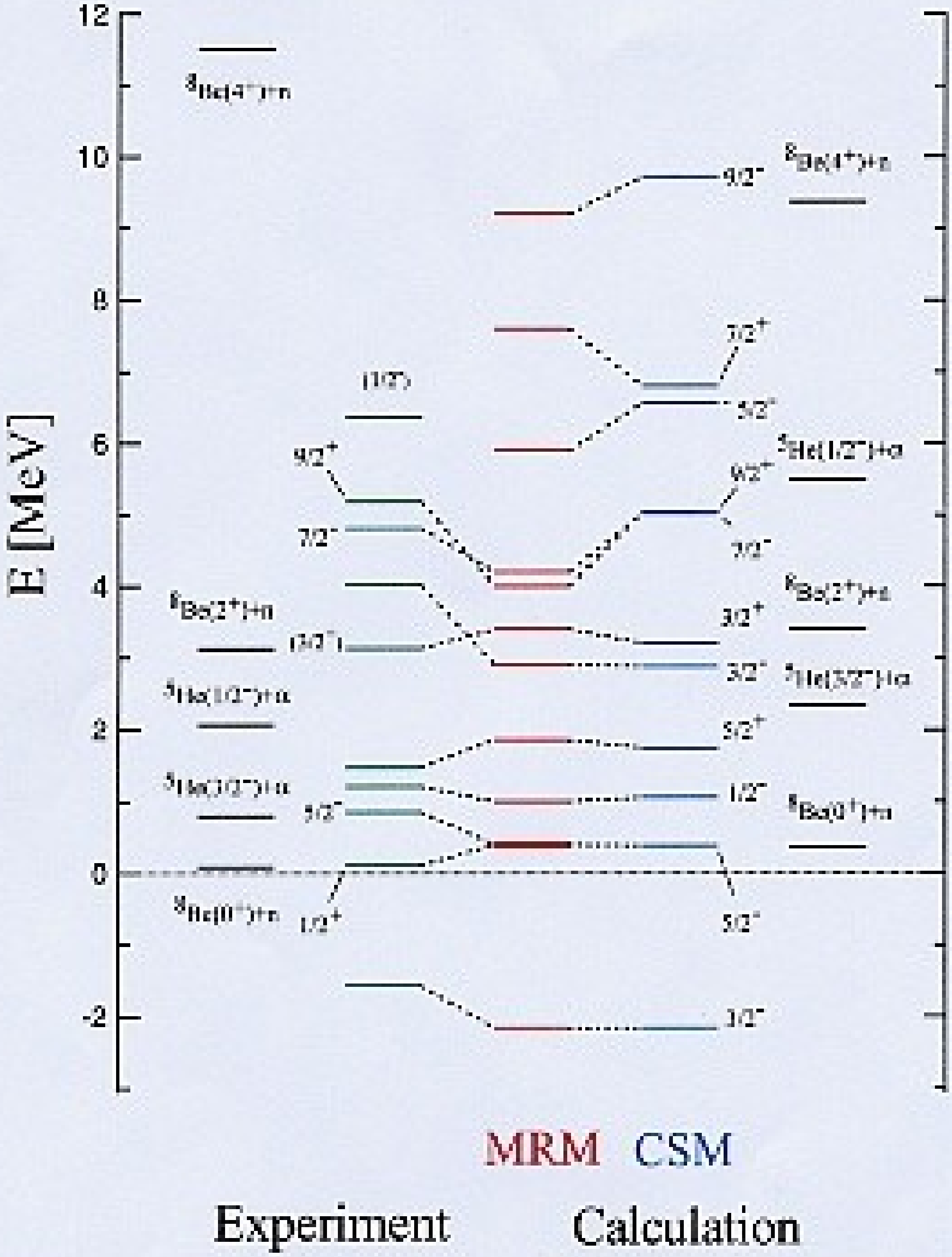
  Assumption of cluster structure
  W.F. satisfies Pauli principle exactly
  Employs the effective *N-N* interaction
  (Minnesota potential)

- Resonance state

Resonance parameters are determined by solving the two-body scattering problem by means of the Microscopic R-matrix Method(MRM).

- $^{9}\text{Be} = \left[{}^{8}\text{Be}(0^{+},2^{+},4^{+}) + n \right] \oplus \left[{}^{5}\text{He}(1/2^{-},3/2^{-}) + \alpha \right]$
- $^{10}\text{Be} = \left[{}^{9}\text{Be}(3/2^{-},1/2^{+},5/2^{-}) + n \right] \oplus \left[{}^{6}\text{He}(0^{+},2^{+}) + \alpha \right]$

^{9}Be

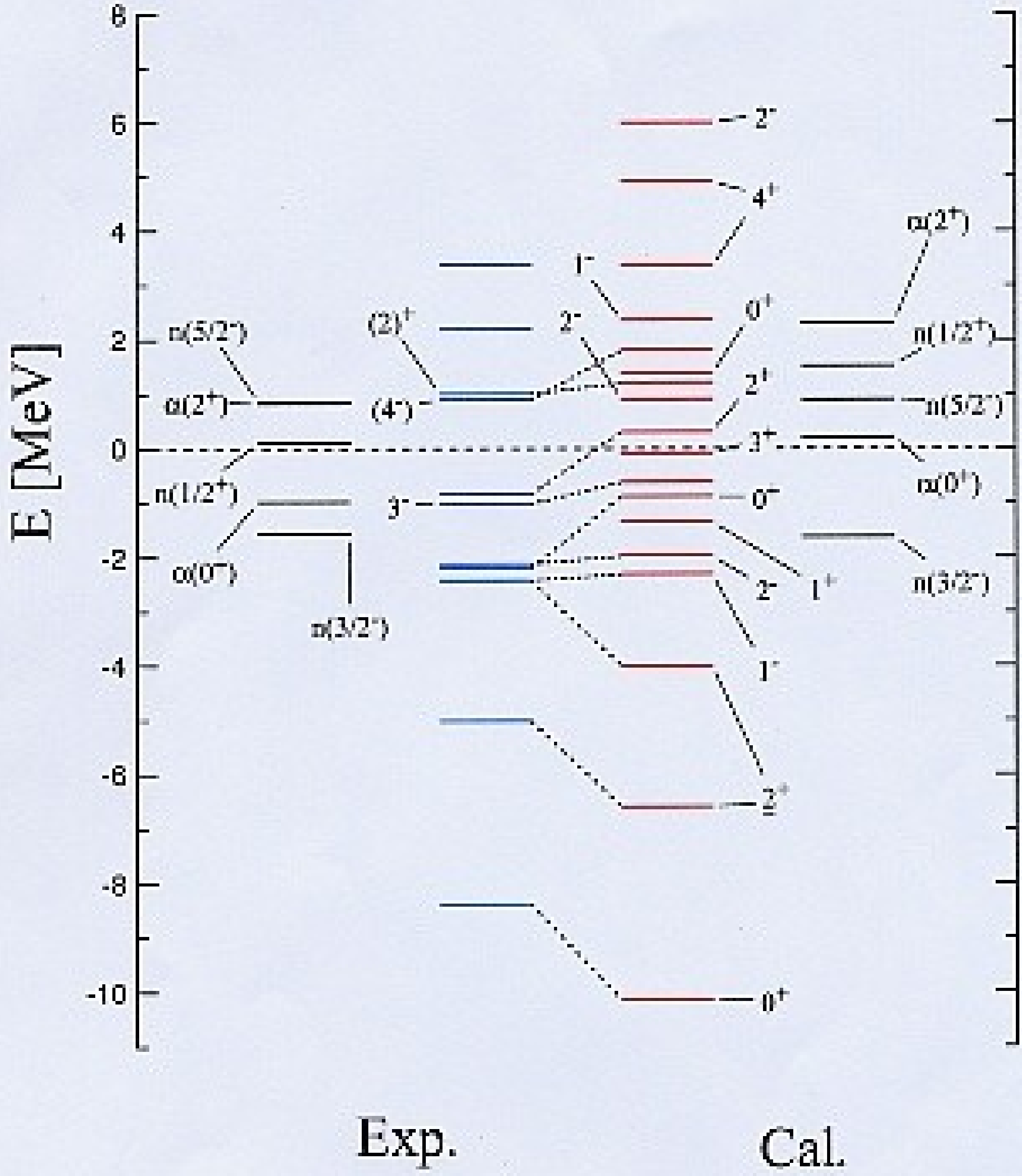


MRM --- Microscopic R-matrix method
(two-body scattering)

CSM --- Three-body Complex Scaling method

Energy is given relative to $\alpha+\alpha+n$ threshold

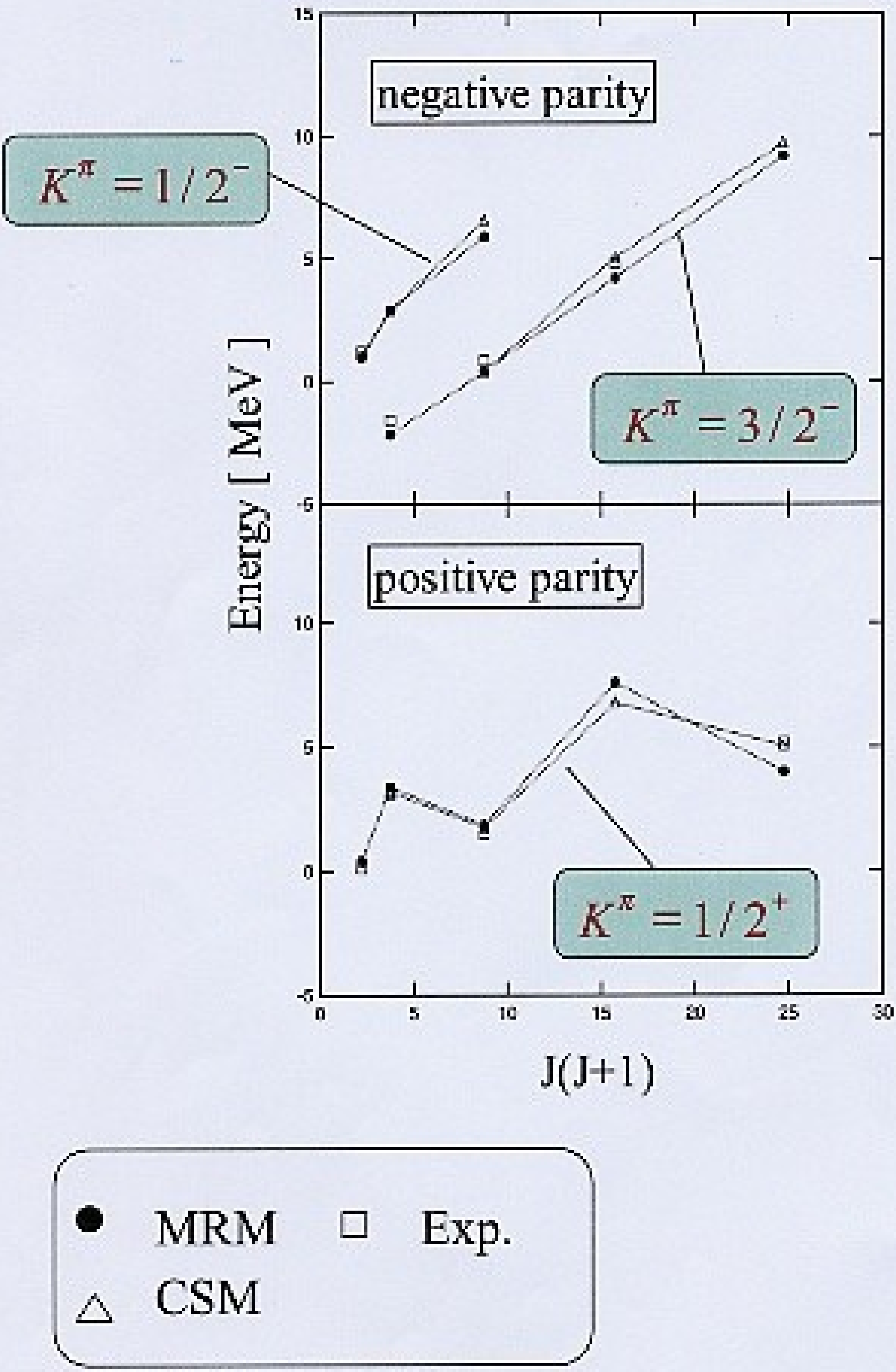
^{10}Be



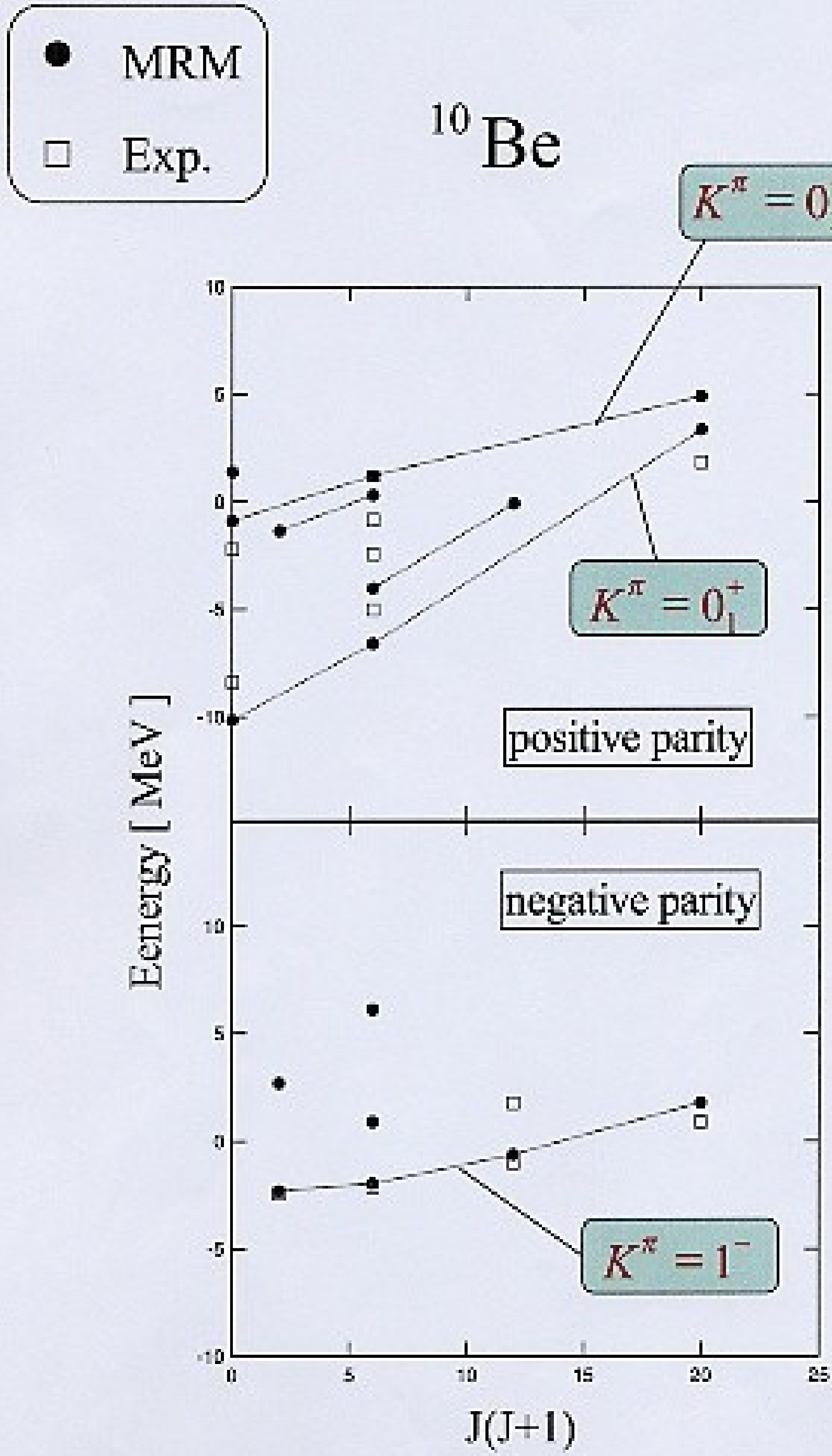
$$\alpha(J^{\pi})\rightarrow {}^{6}\mathrm{He}(J^{+})+\alpha, \quad n(J^{\pi})\rightarrow {}^{9}\mathrm{Be}(J^{+})+n$$

Energy is given relative to the $\alpha+\alpha+n+n$ threshold

^{9}Be

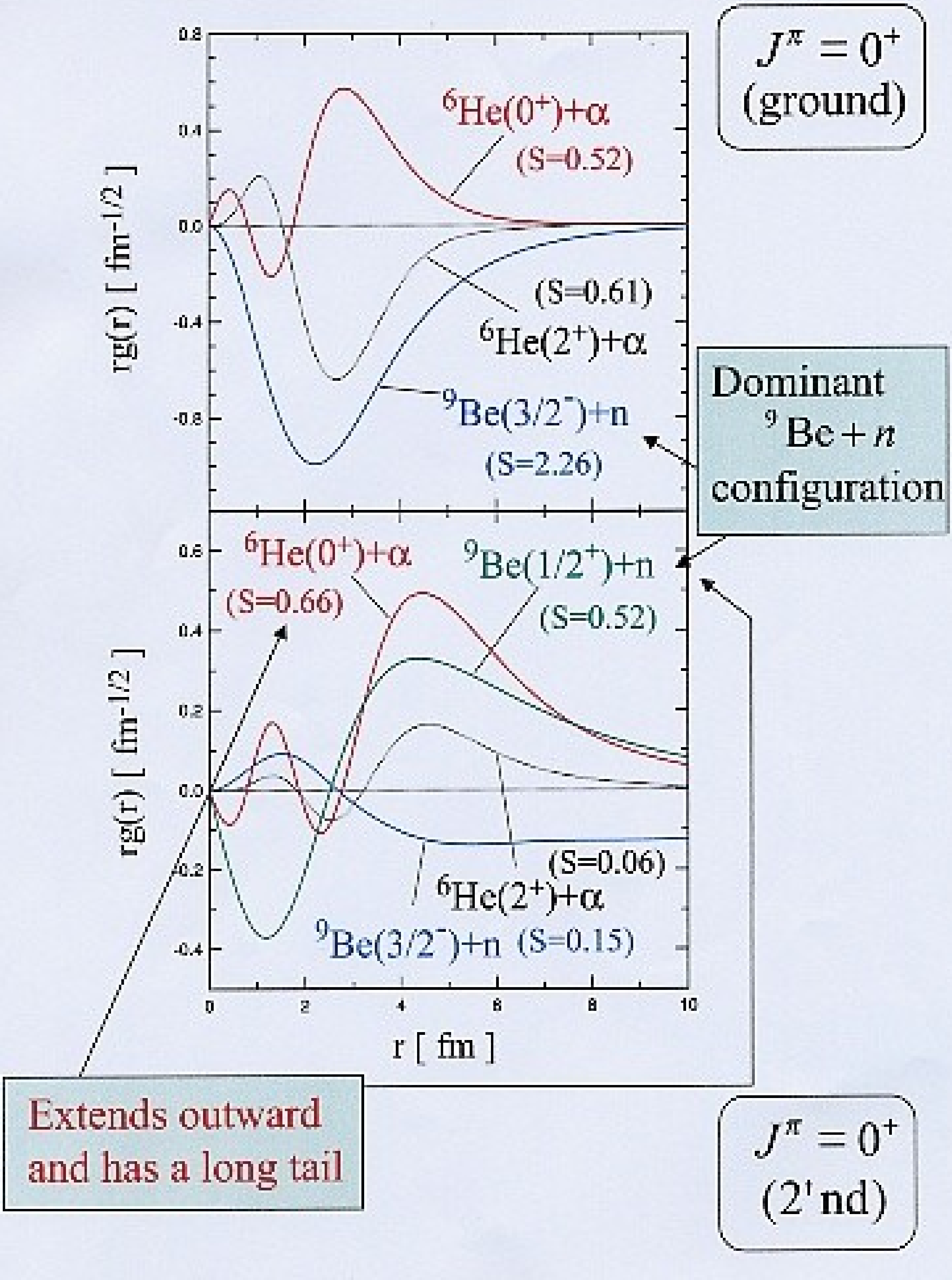


negative parity
positive parity
$K^{\pi}=1/2^{-}$
$K^{\pi}=3/2^{-}$
$K^{\pi}=1/2^{+}$
Energy [MeV]
J(J+1)
15
10
5
0
-5
0
5
10
15
20
25
30
MRM
Exp.
CSM



MRM
Exp.
^{10}Be
$K^\pi = 0_2^+$
$K^\pi = 0_1^+$
positive parity
negative parity
$K^\pi = 1^-$
Eenergy [MeV]
J(J+1)

^{10}Be g(r) : Reduced with amplitude into two-body decays



- The second 0^+ state in ^{10}Be has a large component of ^{6}He$(0^+)+\alpha$ which extends outward and has a long tail

⇨ Large ^{6}He $+\alpha$ clusering

⇨ $K^\pi = 0_2^+$ band ($J^\pi = 0_2^+,\ 2_4^+,\ 4_2^+$)

The ground $0^+ \Rightarrow {}^9\mathrm{Be}(3/2^-)\otimes \nu_{p_{3/2}}$ is dominant

The second $0^+ \Rightarrow {}^9\mathrm{Be}(1/2^+)\otimes \nu_{s_{1/2}}$ is dominant

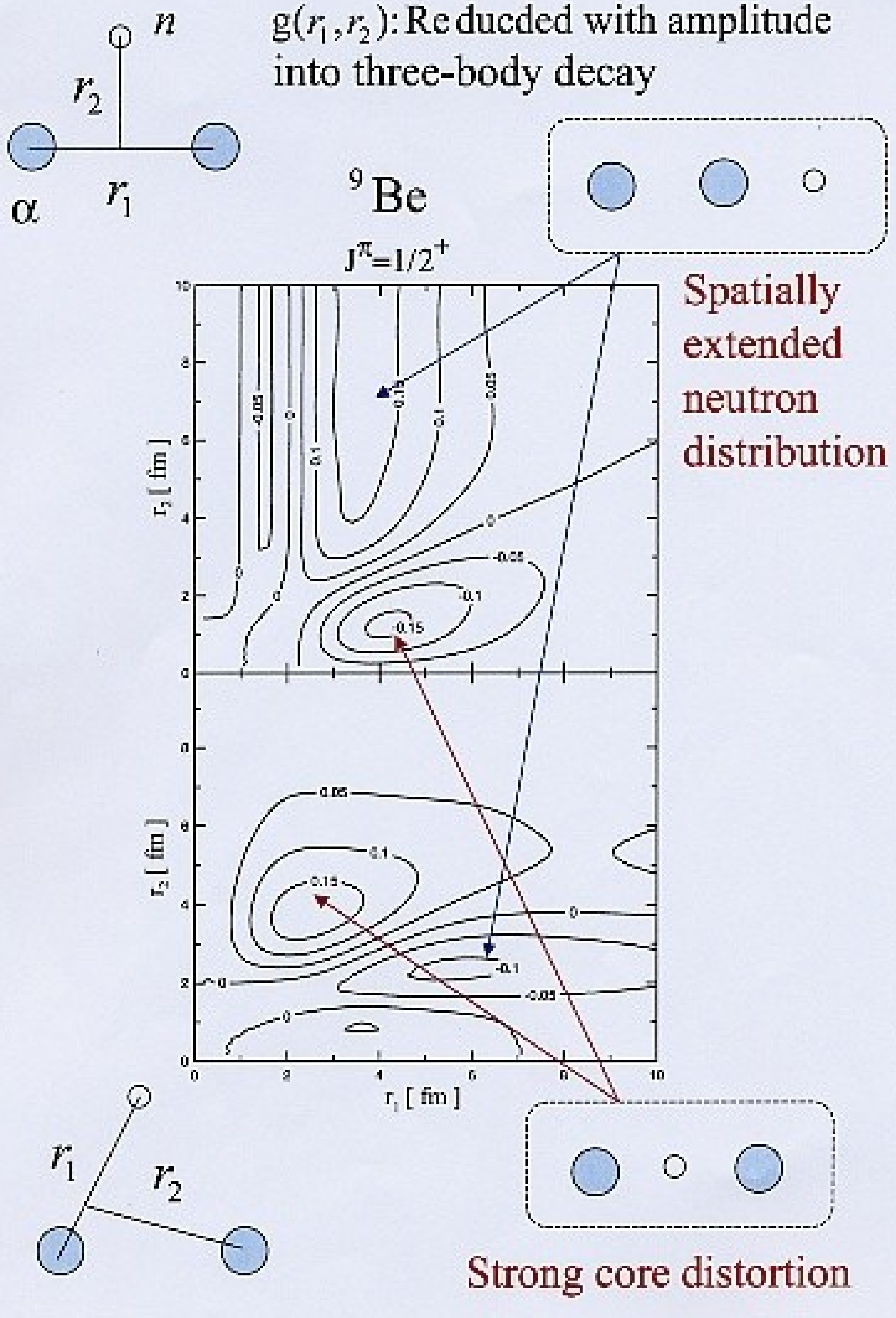
One more node in the second 0^+ state

⇨ Two neutrons excite into the $s_{1/2}$ shell in the 0_2^+ state ($2\hbar\Omega$ excitation)

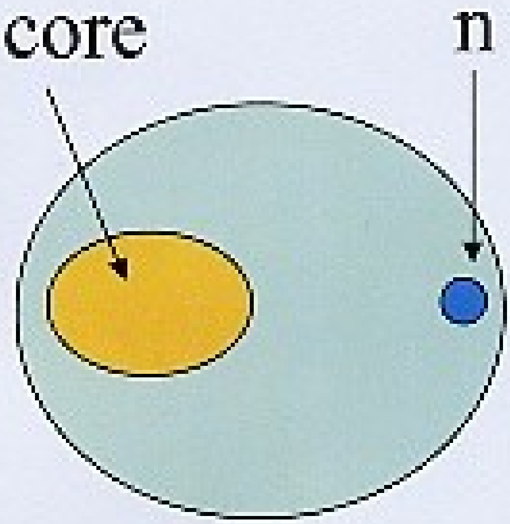
- Three competing configuration is required to reproduce this intruder 0_2^+ state

  - One of them produce the spatially extended neutron distribution outside ^{8}Be core

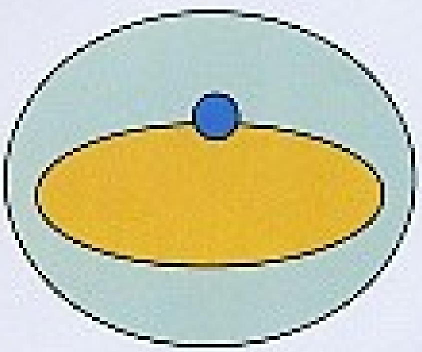
  - Another of them has a quite strong core deformation or distortion induced by the the valence neutron and this lowers the $s_{1/2}$ orbit in ^{10}Be


g(r1,r2): Reducded with amplitude into three-body decay
n
r2
α
r1
9 Be
Jπ=1/2+
Spatially extended neutron distribution
r2 [fm]
r1 [fm]
-0.05
0
-0.1
-0.15
0.1
0.15
0.05
r1
r2
Strong core distortion

- ***Two competing configurations*** are quite essential to reproduce the anomalous $1/2^+$ state in ^{9}Be

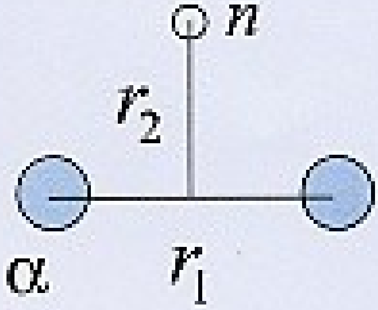


Valence neutron produces the spatially extended neutron distribution outside core and long neutron tail like the neutron halo if this state is a bound state



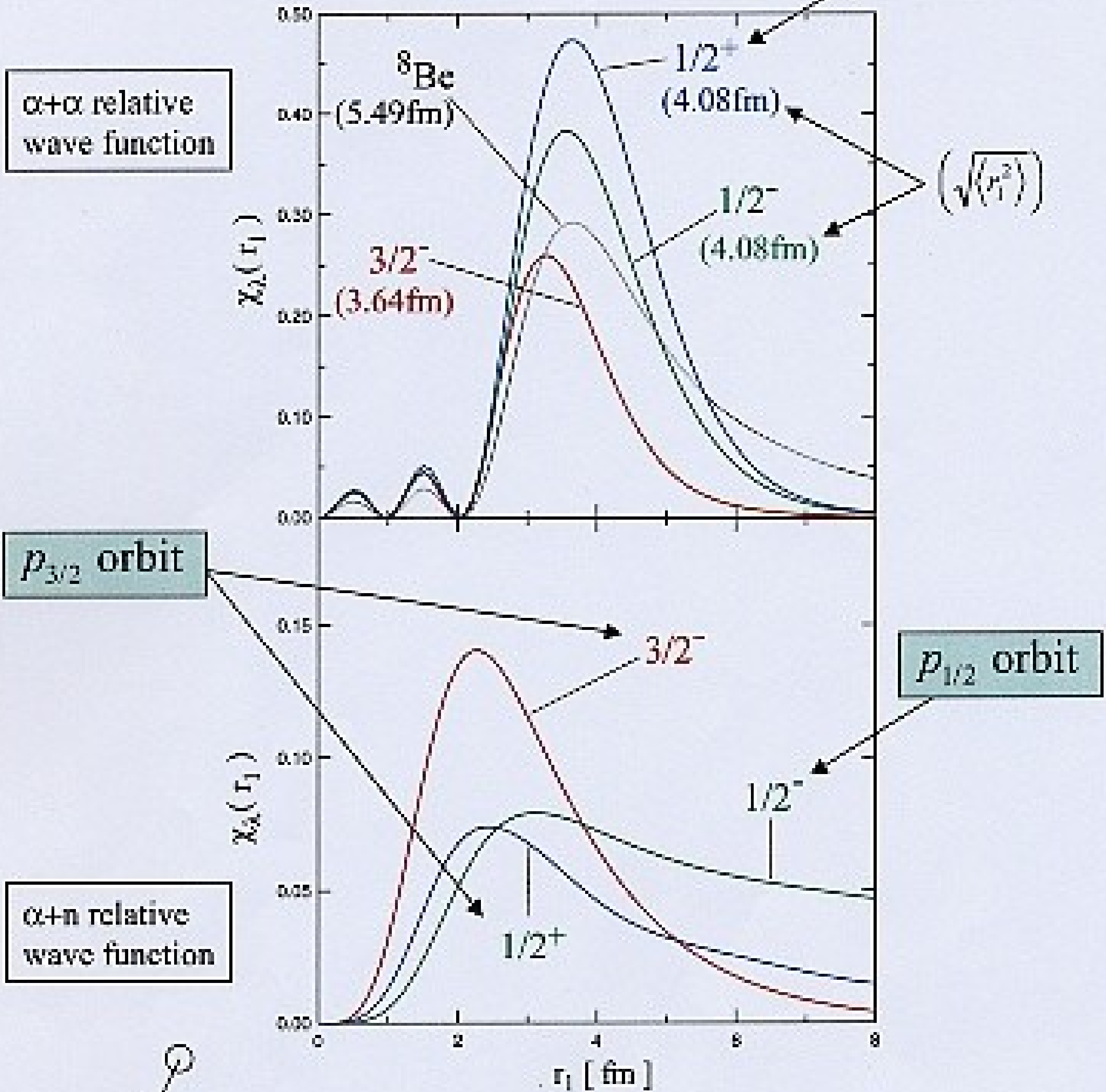
Valence neutron stays near or inside the core and induces the strong core distortion(deformation) which lowers the energy and causes the parity inversion in ^{9}Be

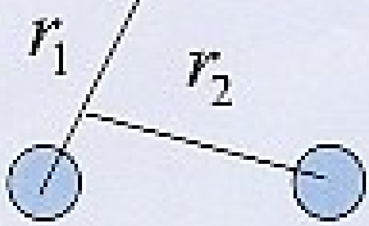
In both configuration, the valence neutron motion appears to be consistent with the σ orbit picture in the molecular orbital method



^{9}Be

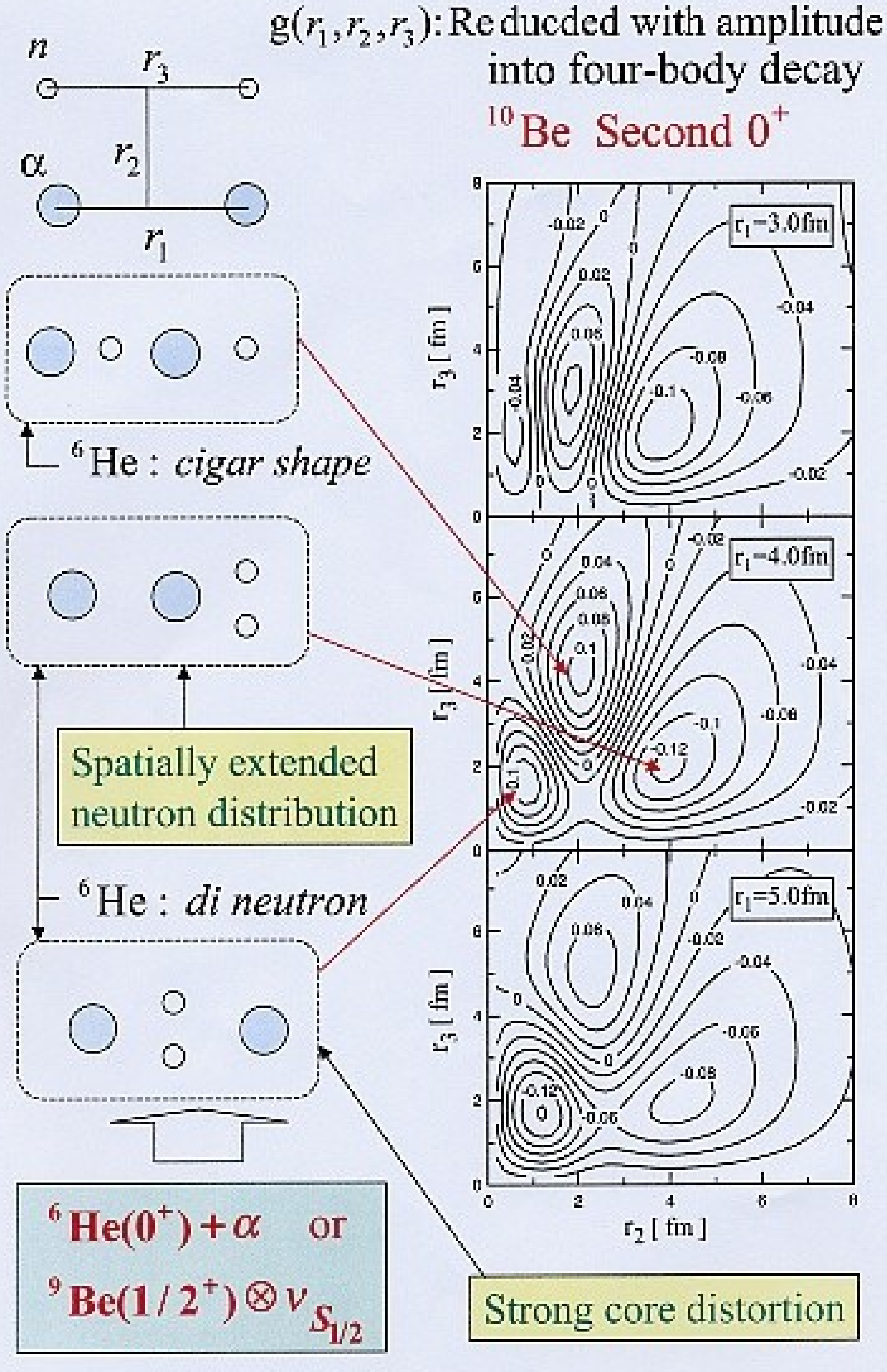
Larger α+α clustering



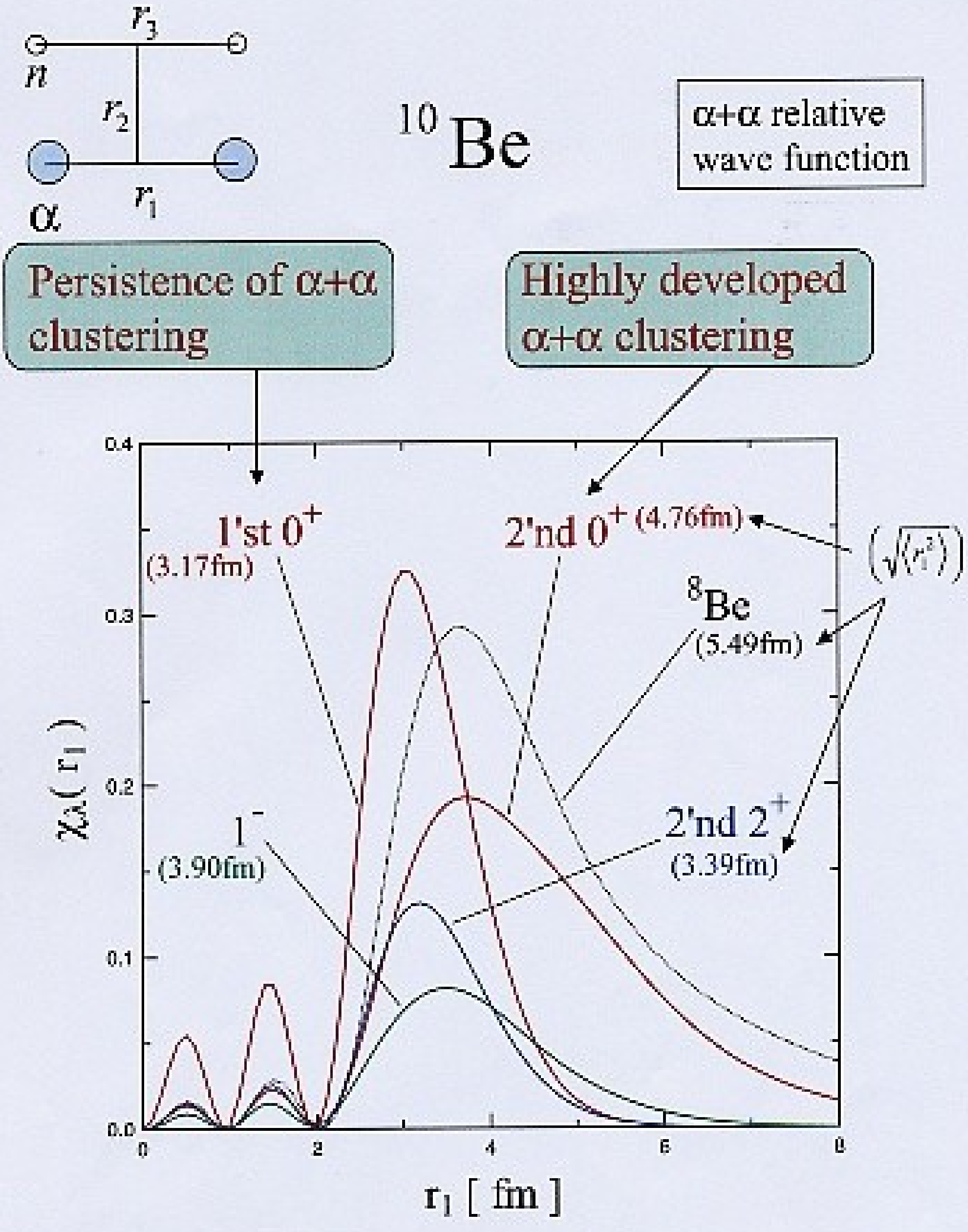


$$\chi_\lambda(r_1) = \int dr_2\, r_1^2 r_2^2 \left|g_\lambda(r_1, r_2)\right|^2$$

$$\langle r_1^2 \rangle = \int dr_1 \chi_\lambda^2(r_1) r_1^2 \,/ \int dr_1 \chi_\lambda^2(r_1)$$



g(r1, r2, r3): Reducded with amplitude into four-body decay
10Be Second 0+
n
r3
α
r2
r1
6He : cigar shape
Spatially extended neutron distribution
6He : di neutron
6He(0+) + α or
9Be(1/2+) ⊗ ν s1/2
Strong core distortion
r1=3.0fm
r1=4.0fm
r1=5.0fm
r3 [fm]
r2 [fm]



$$\chi_\lambda(r_1) = \int dr_2 dr_3\, r_1^2 r_2^2 r_3^2 \left|g_\lambda(r_1, r_2, r_3)\right|^2$$

$$\langle r_1^2 \rangle = \int dr_1 \chi_\lambda^2(r_1) r_1^2 \,/ \int dr_1 \chi_\lambda^2(r_1)$$

Summary

- **Second 0^+ state in ^{10}Be**

  has a large $^{6}He(0^+) + \alpha$ clustering

  and appears to produce $K^\pi = 0_2^+$ band.

  This state is dominated

  by $2\hbar\Omega$ excitation.

  (two neutrons excite into the $s_{1/2}$ shell)

- **$1/2^+$ state in ^{9}Be and 0_2^+ state in ^{10}Be**

  are given by ***TWO*** and ***THREE*** competing configurations respectively.

  One of them produce *a spatially extended neutron distribution* outside the core and another has *a strong core distortion* induced by the valence neutron.

  The valence neutrons motion seems to be like the ***σ-orbit*** in the molecular orbital method