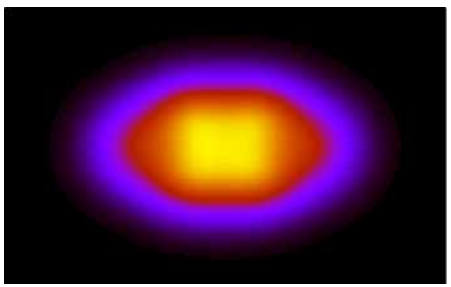
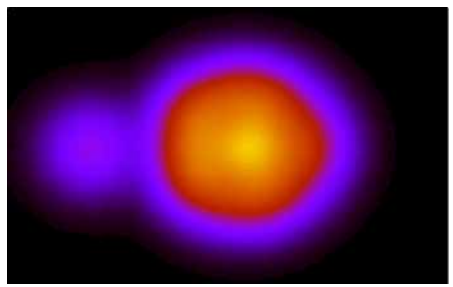
Coexistence of cluster structure and mean-field-type structure in medium-weight nuclei





TANIGUCHI, Yasutaka (Kyoto Univ.)

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HORIUCHI, Hisashi (Kyoto Univ.)

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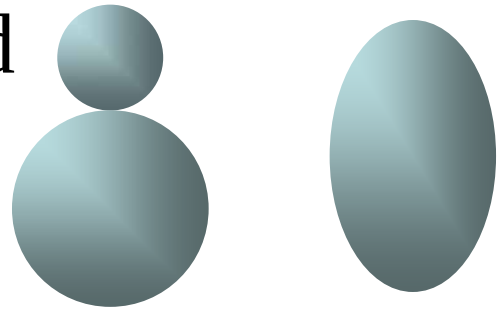
Introduction

Coexistence of cluster structure and mean-field-type structure in medium-weight nucleus.



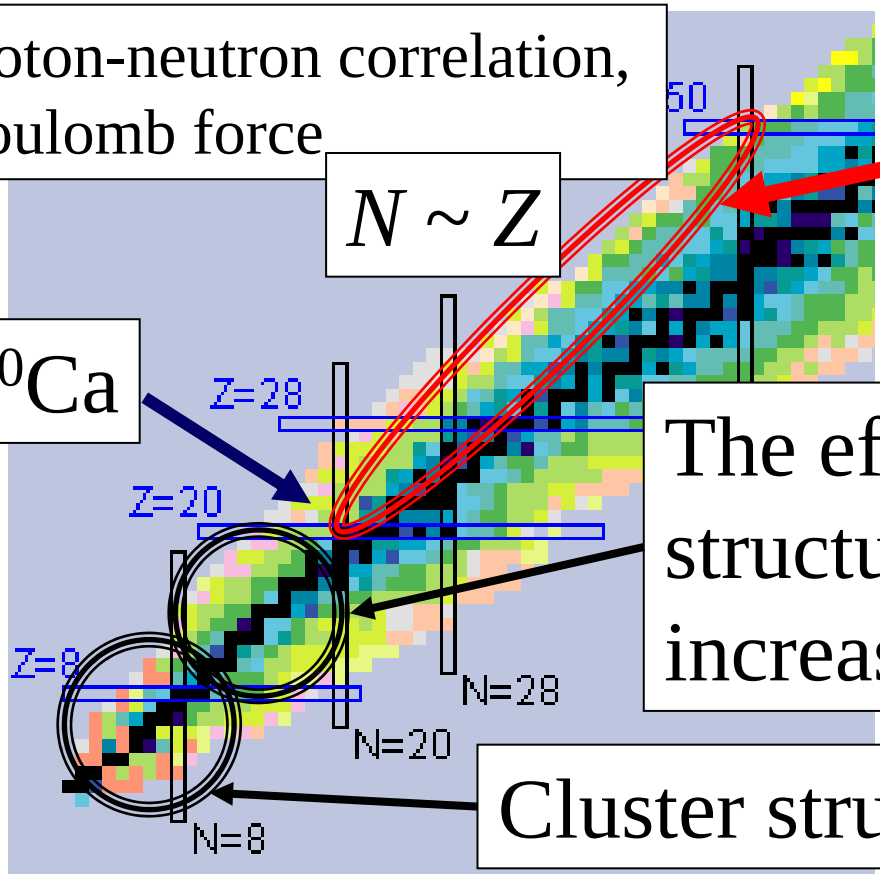
cluster mean-field-type

proton-neutron correlation, Coulomb force

$N \sim Z$

Are cluster structures important or not?

^{40}Ca

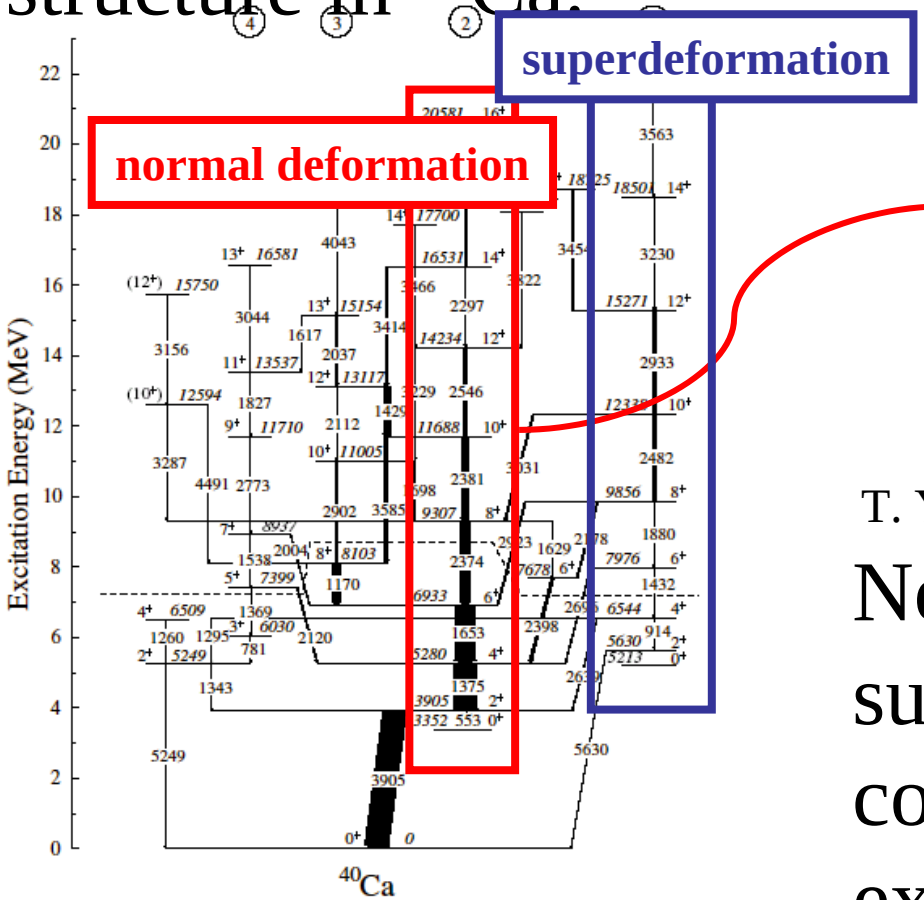


The effects of mean-field type structure to cluster structure are increasing

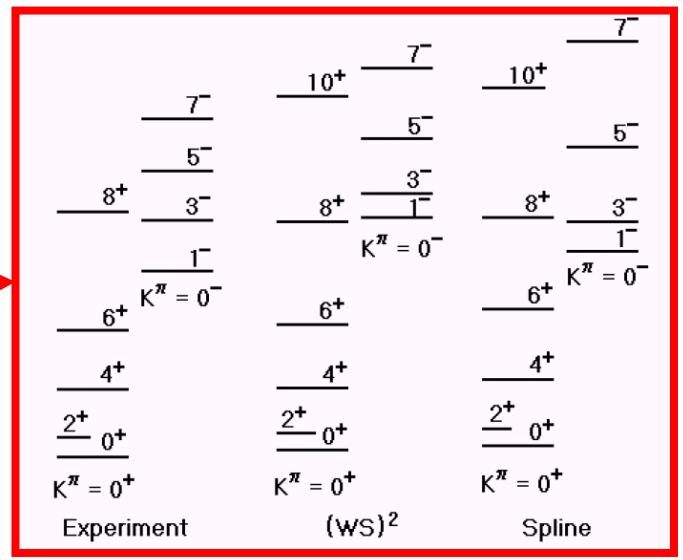
Cluster structures are well developed

Introduction

Coexistence of cluster structure and mean-field-type structure in ^{40}Ca.



E. Ideguchi et al, PRL **87** (2001), 222501



T. Yamaya et al, PTPS No. 132 (1998), Chap. 3

Normal deformed band was suggested to have α-^{36}Ar component theoretically and experimentally.

Framework
~AMD + GCM~

AMD wave function

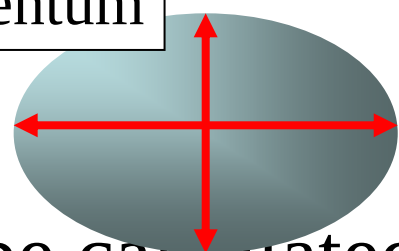
Slater determinant of deformed Gaussian wave packets (common width parameter).

GCM

Superposing basis wave functions, diagonalize Hamiltonian.

Basis wave functions are calculated by energy variation with *constraint*.

VAP: parity
VBP: angular momentum

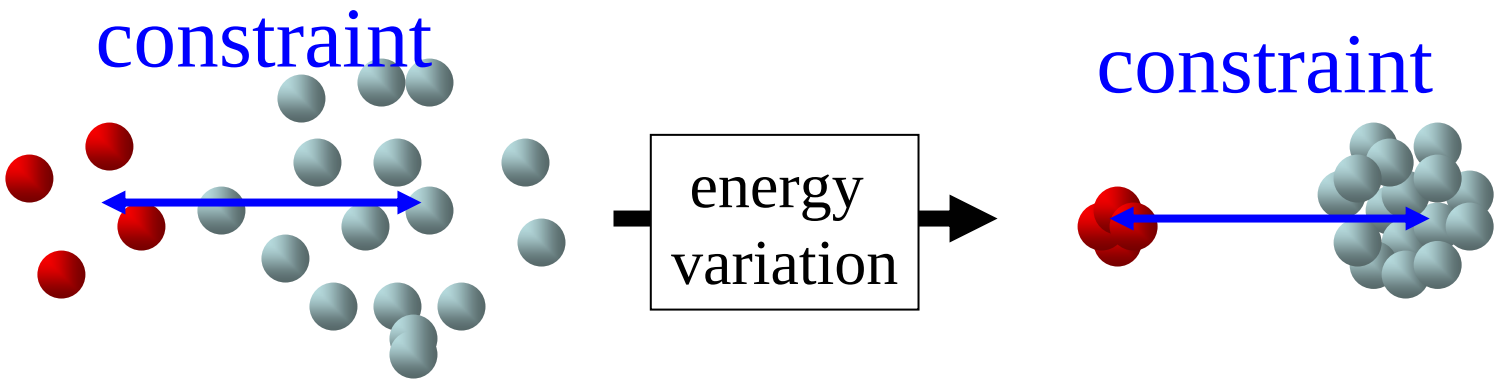


β-constraint: quadrupole parameter β

Mean-field-type structures tend to be calculated.

d-constraint: new constraint for clustering

d-constraint

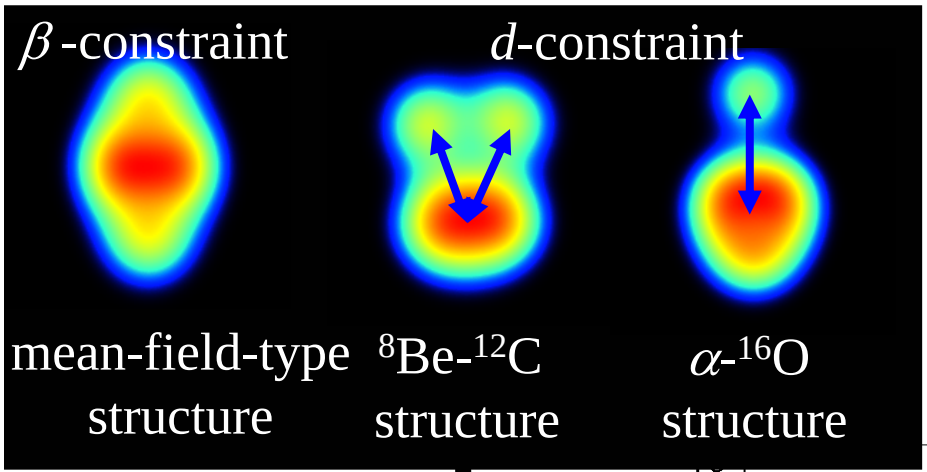


Constraint for the distance between the centers of masses of groups of nucleons corresponding to clusters.

Wave functions of each cluster are calculated as result of energy variation.

(Y. Taniguchi et al, Prog. Theor. Phys., **112** (2004), 475)

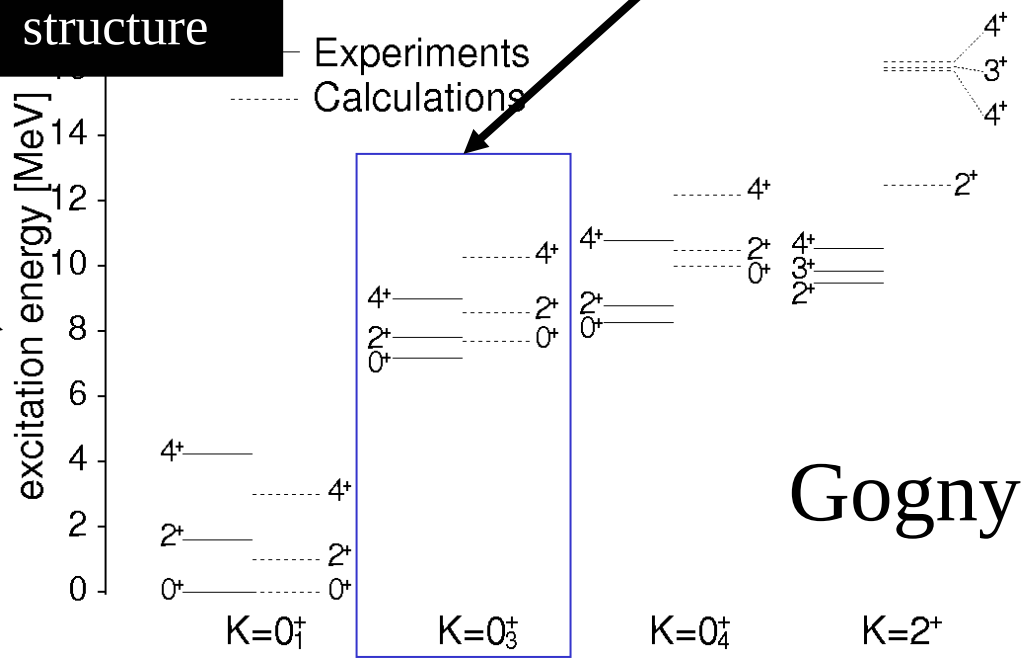
Result of ^{20}Ne



With *d*-constraint and β-constraint, this band is reproduced.

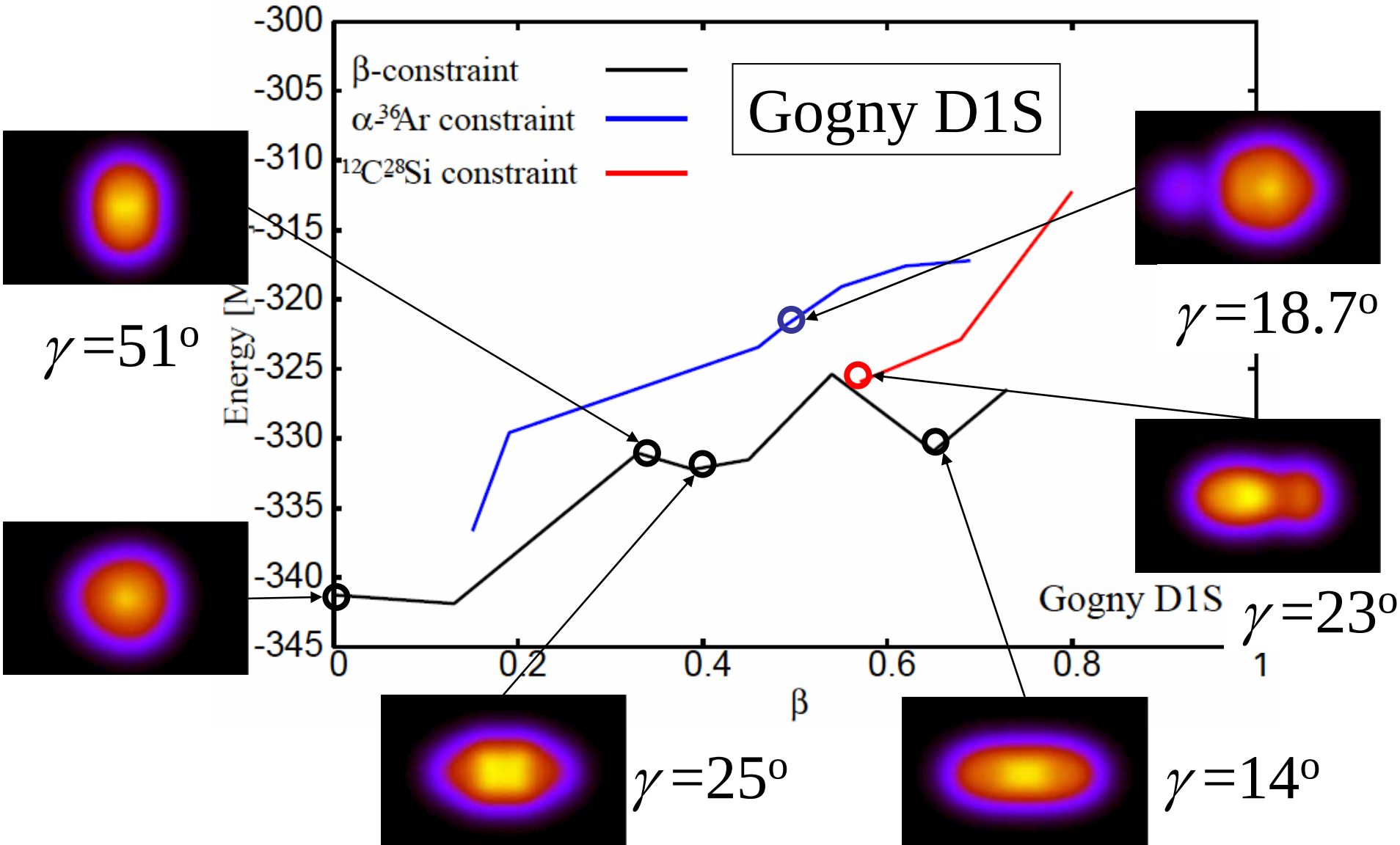
GCM

^{8}Be-^{12}C structure wave functions are calculated with *d*-constraint.

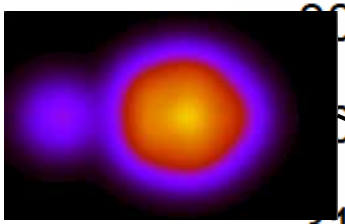


(Y. Taniguchi et al, Prog. Theor. Phys., **112** (2004), 475)

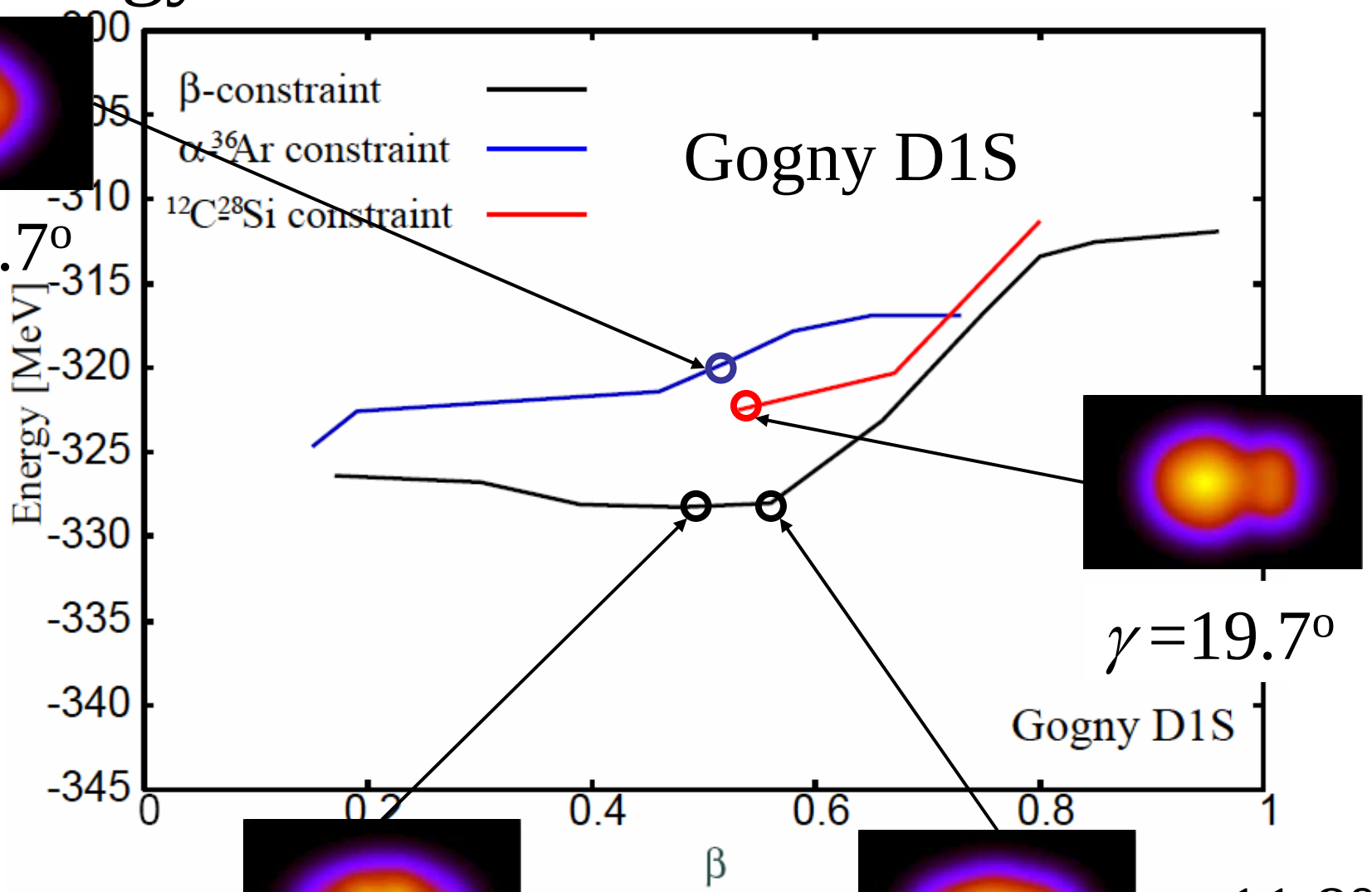
Energy curves of $J^{\pi}=0^{+}$ states of ^{40}Ca



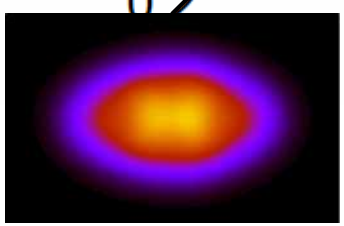
Energy curves of $J^{\pi}=1^{-}$ states of ^{40}Ca



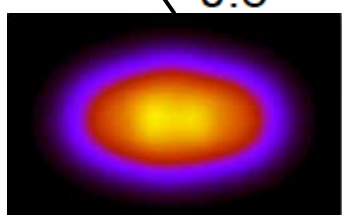
$\gamma=17.7^{o}$



$\gamma=19.7^{o}$

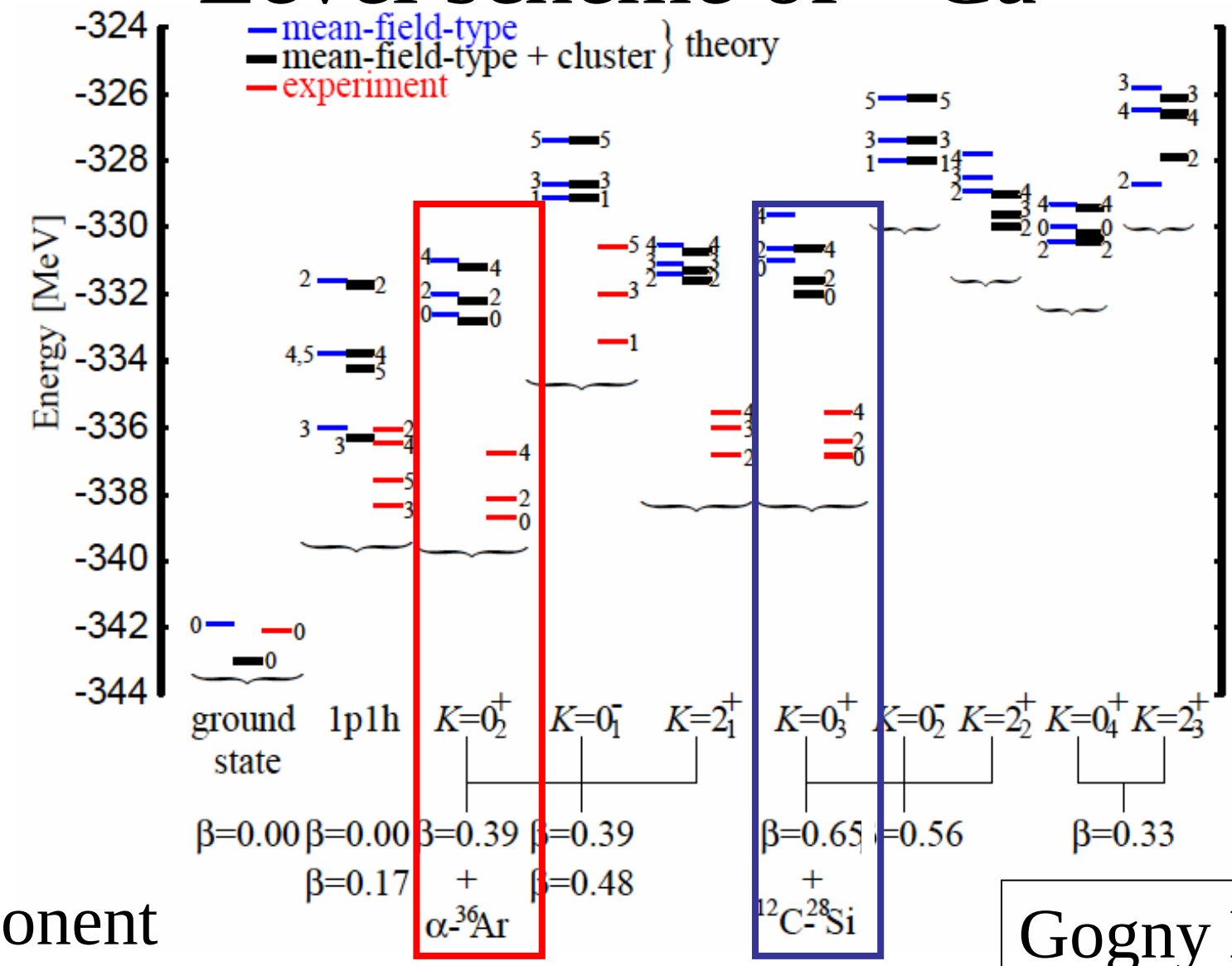


$\gamma=17.3^{o}$



$\gamma=11.8^{o}$

Level scheme of ^{40}Ca



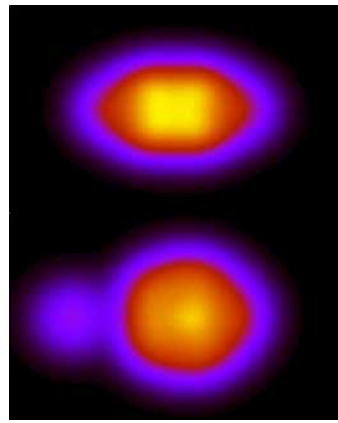
main component

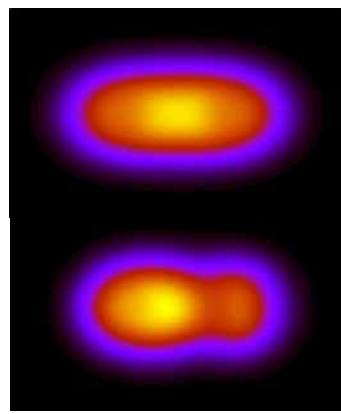
Gogny D1S

Discussion

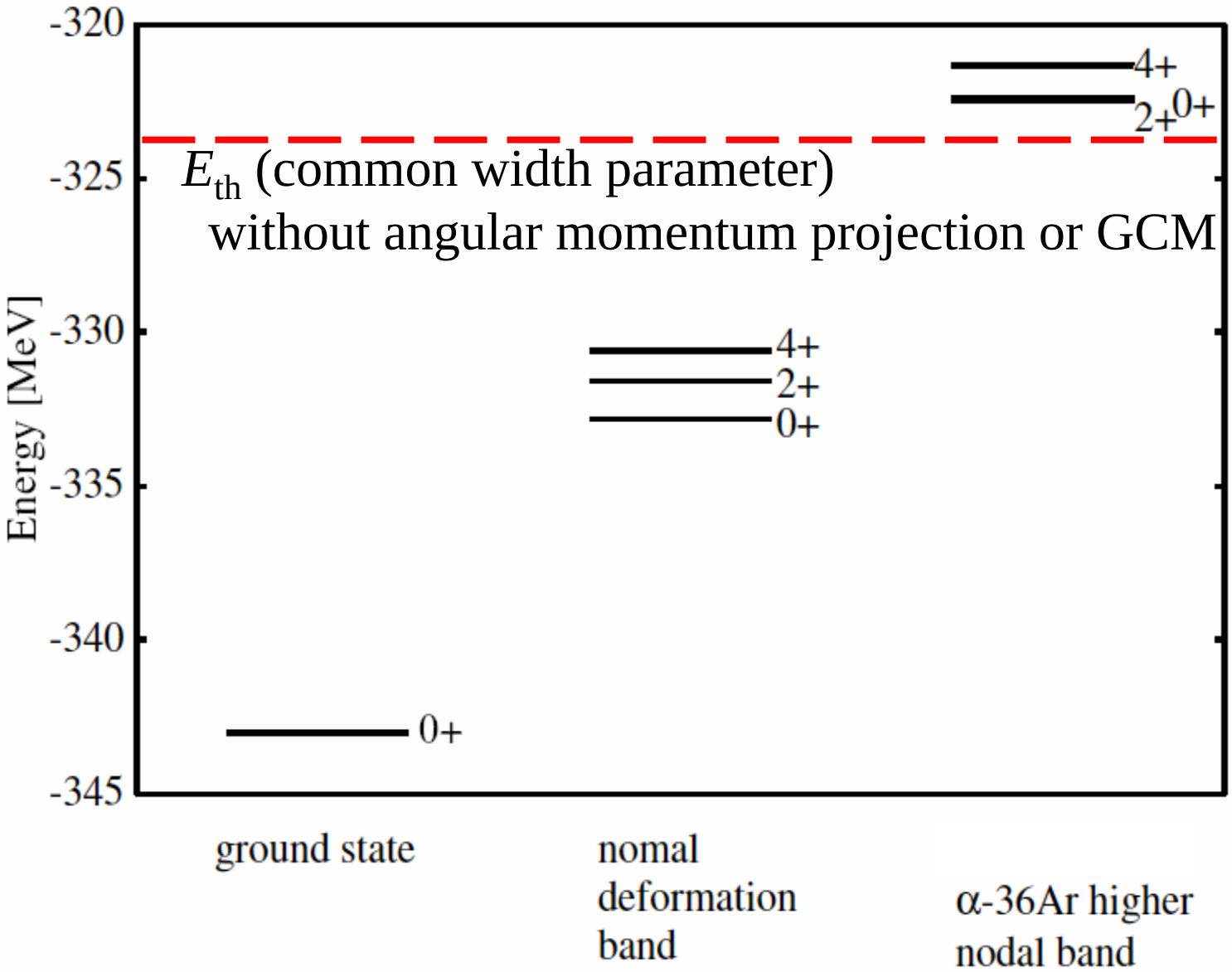
Cluster structure component

K^π	J^π	configuration	$\lvert\text{overlap}\rvert^2$ [%]
0_2^+	0^+	α-^{36}Ar	31
(ND)	2^+		37
	4^+		38
2_1^+	2^+	α-^{36}Ar	41
(ND)	3^+		38
	4^+		40
0_3^+	0^+	^{12}C-^{28}Si	61
(SD)	2^+		61
	4^+		60
2_2^+	2^+	^{12}C-^{28}Si	62
(SD)	3^+		62
	4^+		63

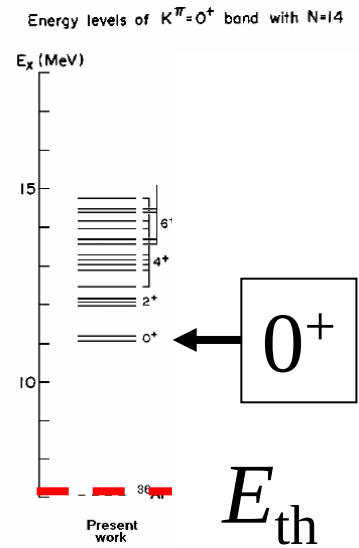




α-^{36}Ar higher-nodal band

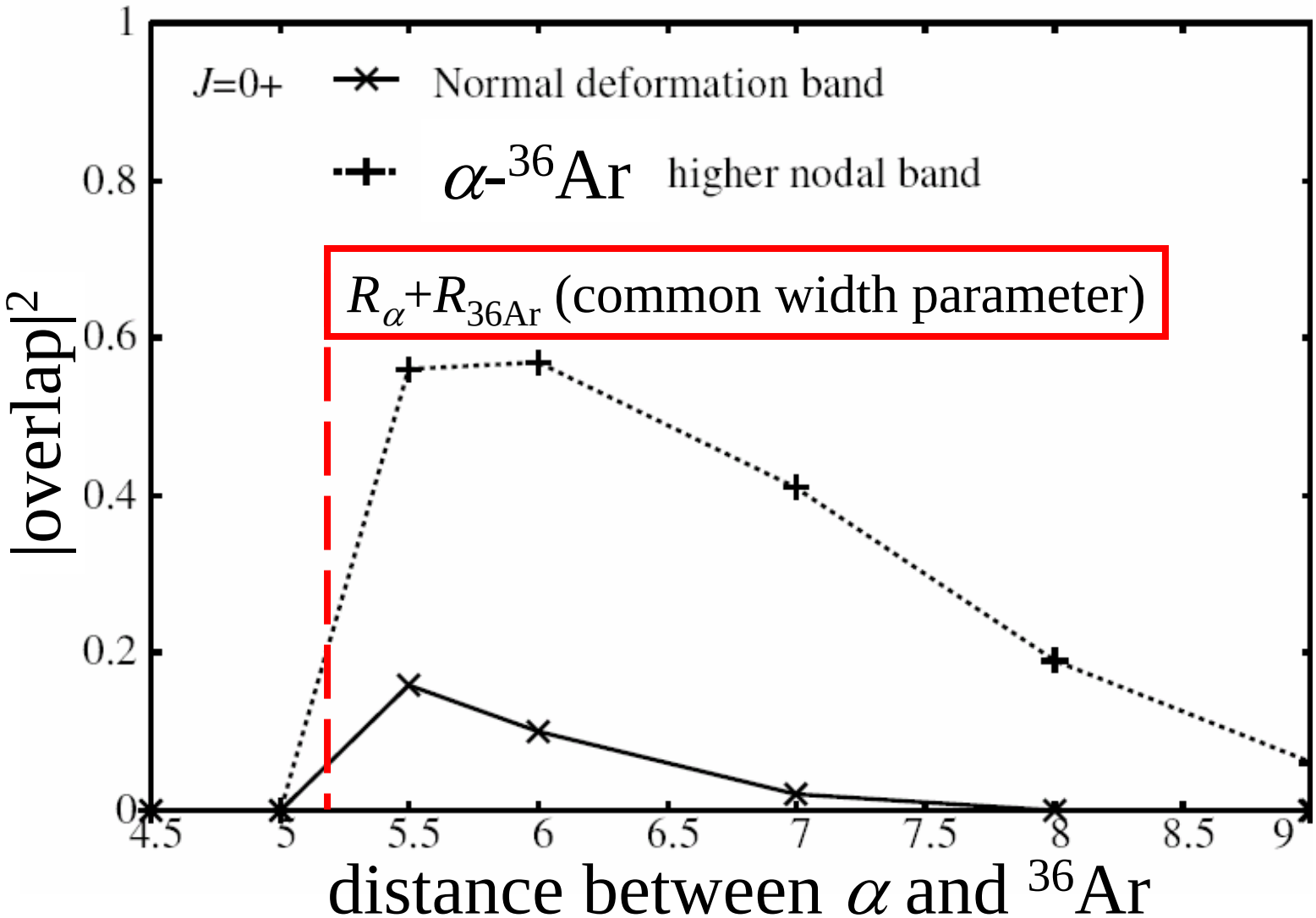


experiment



T. Yamaya et al,
PTPS No. 132 (1998),
Chap. 3

α-^{36}Ar component

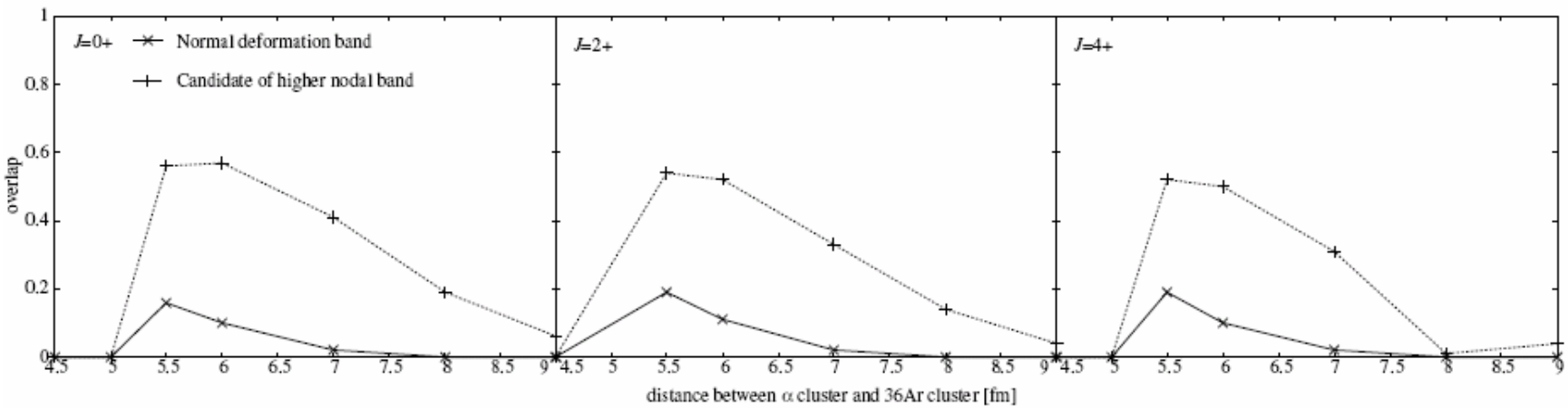


Summary

1. New constraint, *d*-constraint, works well to calculate cluster structure wave functions.
2. As for ^{20}Ne, ^{8}Be-^{12}C cluster structure is calculated with *d*-constraint. Using ^{8}Be-^{12}C, α-^{16}O and mean-field-type wave functions as GCM basis, $K^{\pi}=0_3^+$ band is reproduced.
3. As for ^{40}Ca, normal deformed bands ($K^{\pi}=0_2^+$ and $2_1^{+)}$ have 30-40% of α-^{36}Ar cluster structure component as suggested theoretically and experimentally. Superdeformed bands ($K^{\pi}=0_3^+$ and $2_2^{+)}$ have 60% of ^{12}C-^{28}Si cluster structure component.
4. Excitation energies of ^{40}Ca are too high.
    1. Calculate using Skyrme force (SLy7).
    2. Superpose more basis.
    3. Expand AMD wave function to have different wave packets width parameters.

α-^{36}Ar component

0^+ 2^+ 4^+



Details of wave functions

wave function	energy [MeV]	LS energy [MeV]	β	γ [rad]
$\beta = 0.00$	-340.8	-0.1	0.00	—
$\beta = 0.39$	-326.7	-18.4	0.39	0.44
$\beta = 0.65$	-321.0	-33.5	0.65	0.24
α-^{36}Ar = 5.0 fm	-317.9	-9.0	0.19	0.03
α-^{36}Ar = 5.5 fm	-316.0	-12.2	0.46	0.35
^{12}C-^{28}Si = 4.0 fm	-316.6	-34.6	0.57	0.40

projected to positive parity