Partial Dynamical Symmetry and the Phonon Puzzle in Cd isotopes

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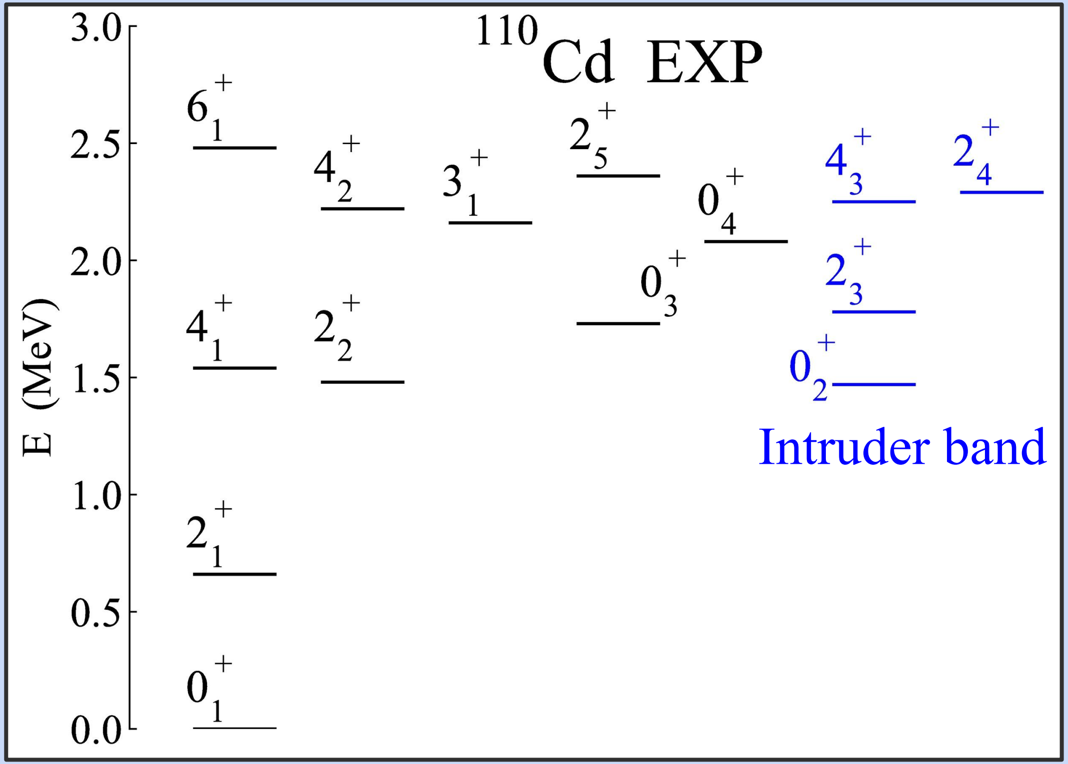
Introduction

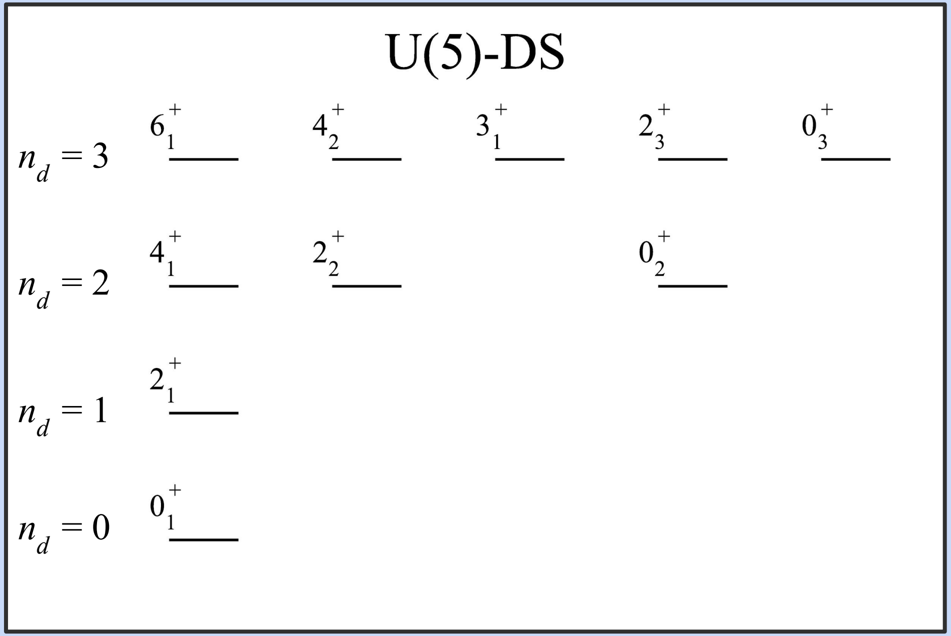
Cd isotopes - a prime example for a spherical nuclei.



Introduction

Spherical vibrator and γ-unstable deformed rotor

Spherical vibrator

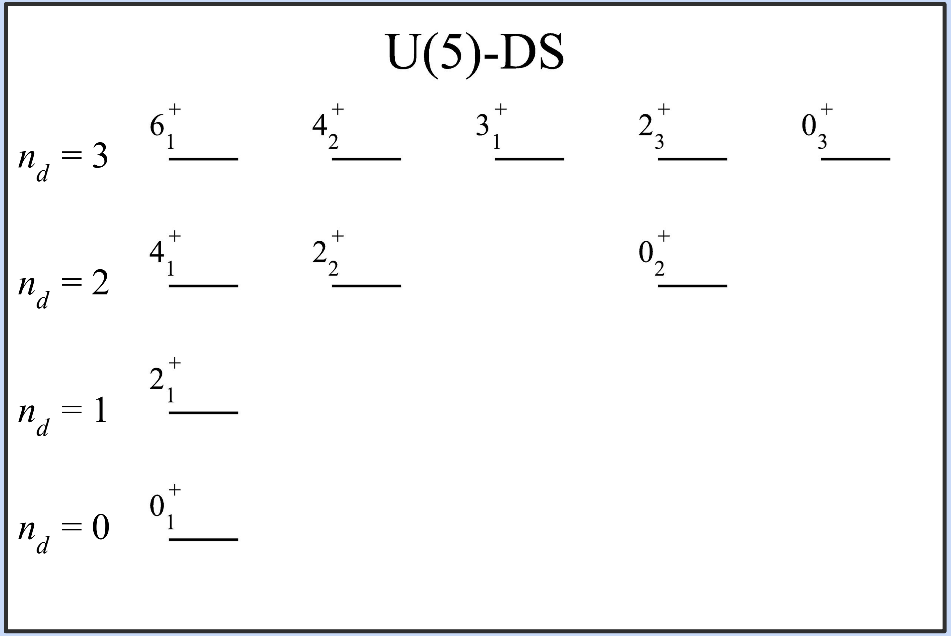


$$U(6) \supset U(5) \supset O(5) \supset O(3)$$

Introduction

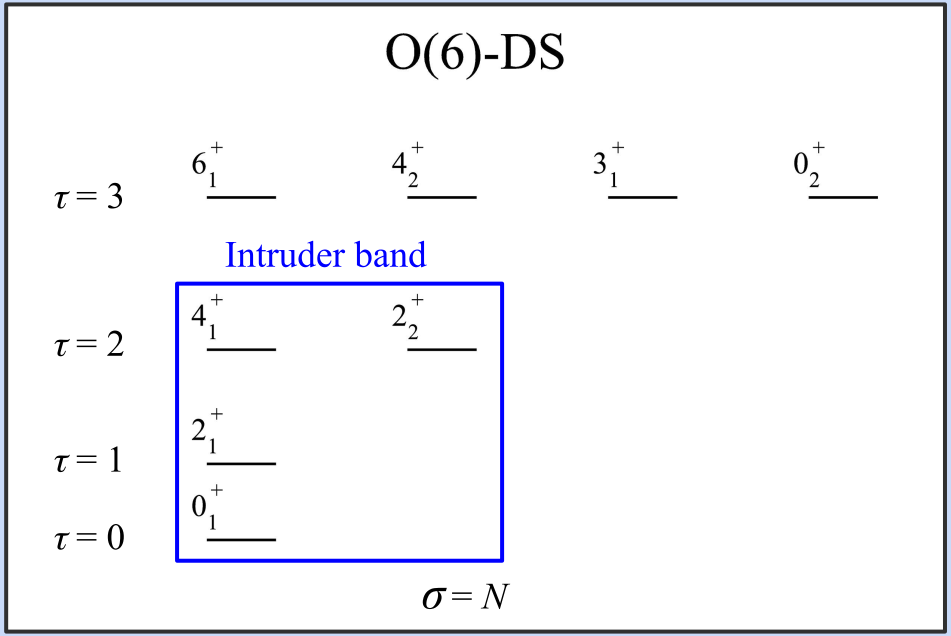
Spherical vibrator and γ-unstable deformed rotor

Spherical vibrator



$$U(6) \supset U(5) \supset O(5) \supset O(3)$$

γ-unstable deformed rotor



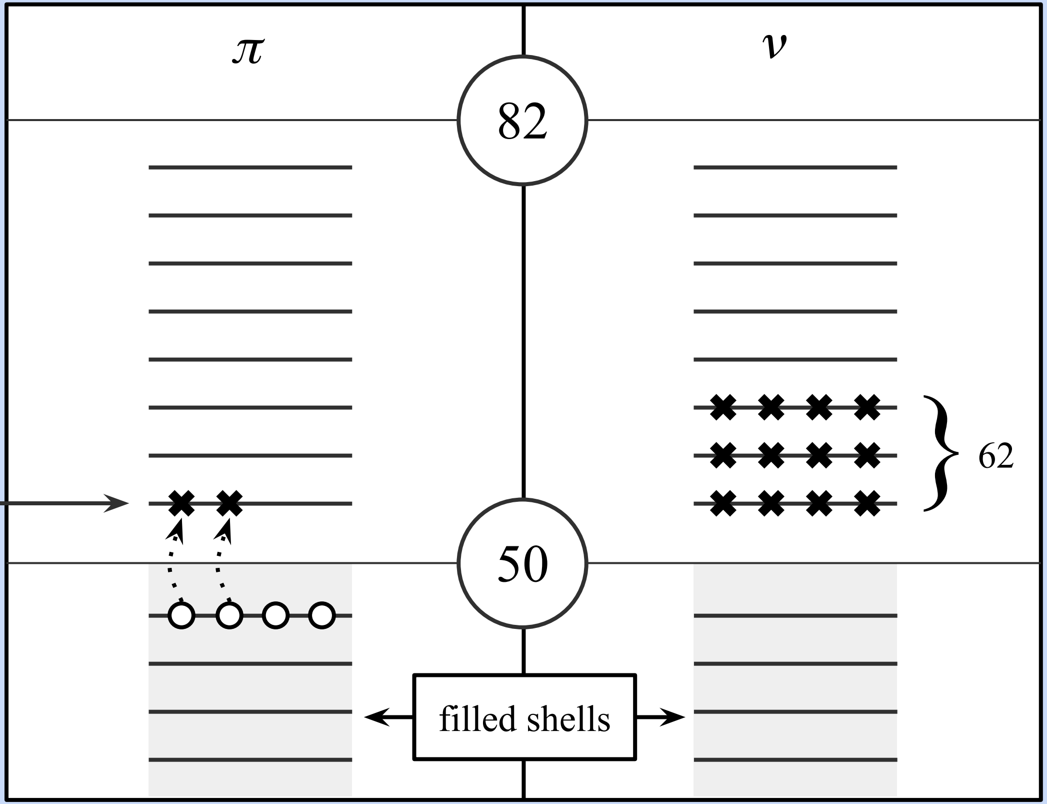
$$U(6) \supset O(6) \supset O(5) \supset O(3)$$

Introduction

Intruder states

$^{110}_{48}Cd_{62}$

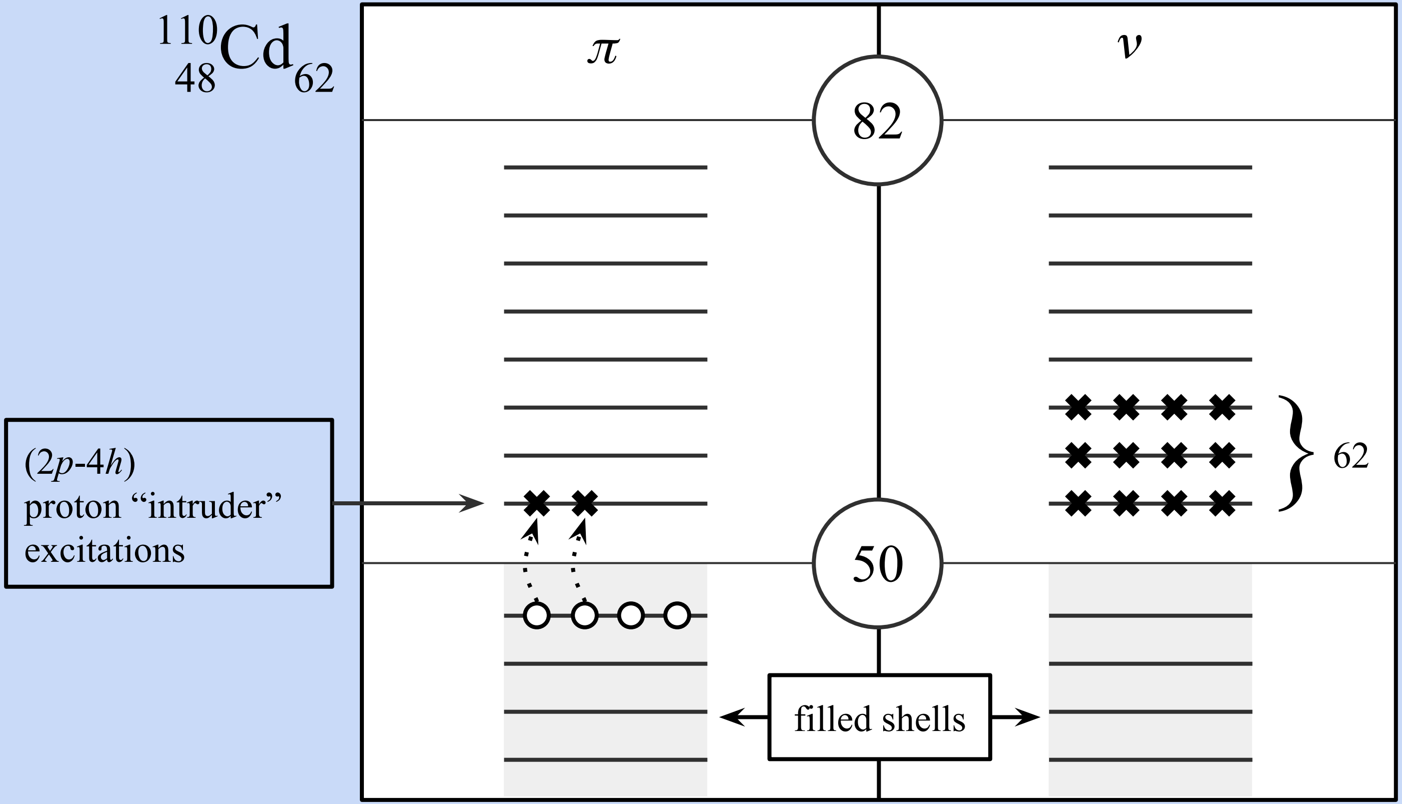
(2*p*-4*h*)
proton "intruder"
excitations



Introduction

Intruder states

$^{110}_{48}Cd_{62}$



$N_\pi = 1,3$

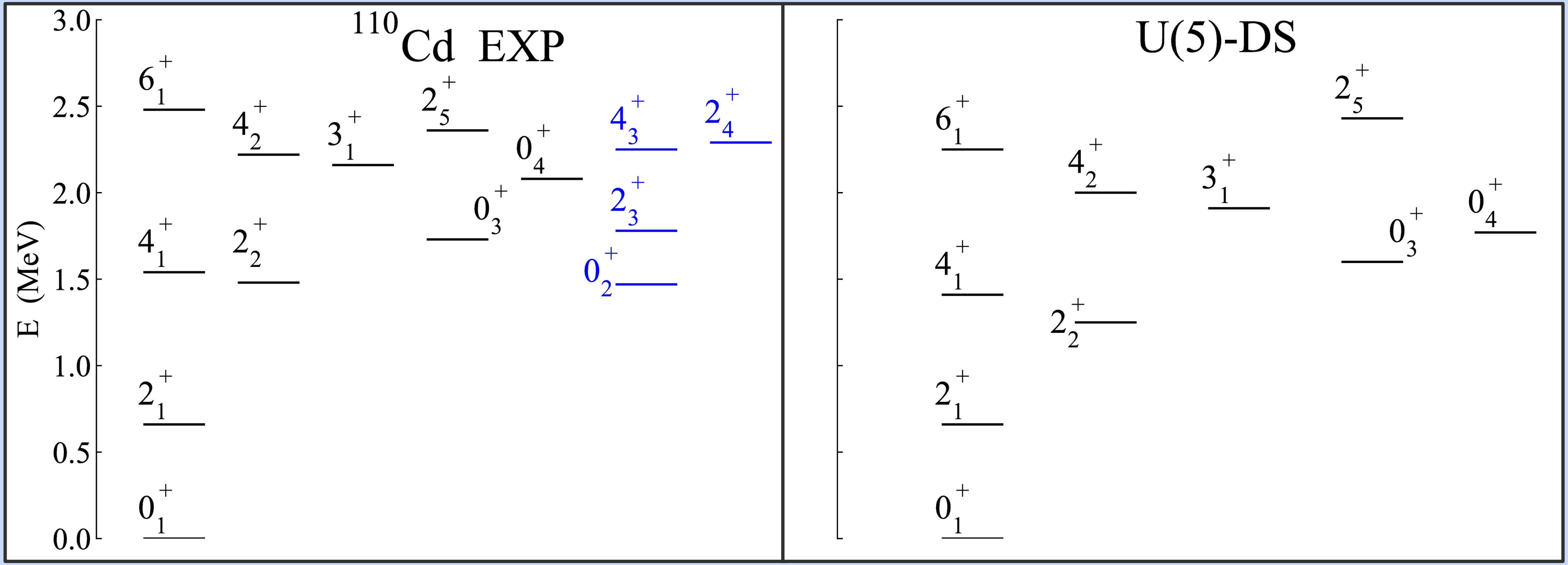
$N_\nu = 6$

$N = 7,9$

Introduction

The problem of ^{110}Cd

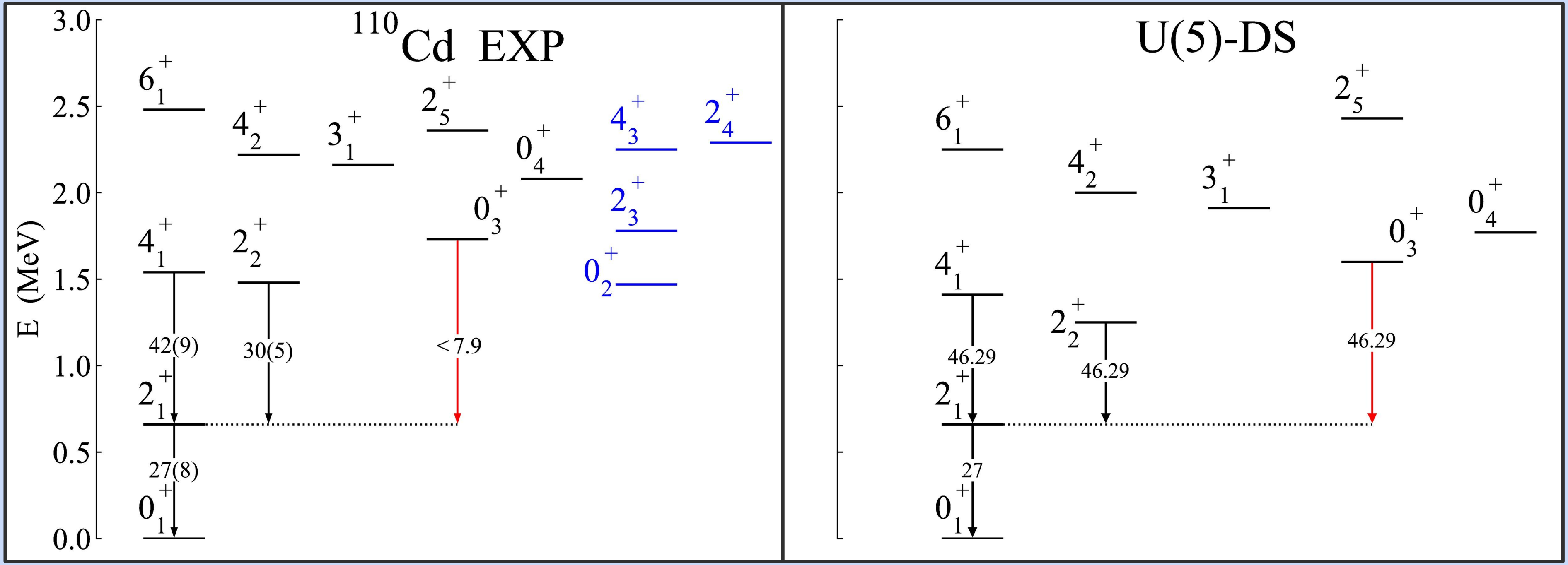
Normal-band



Additional U(5)-DS anharmonic terms

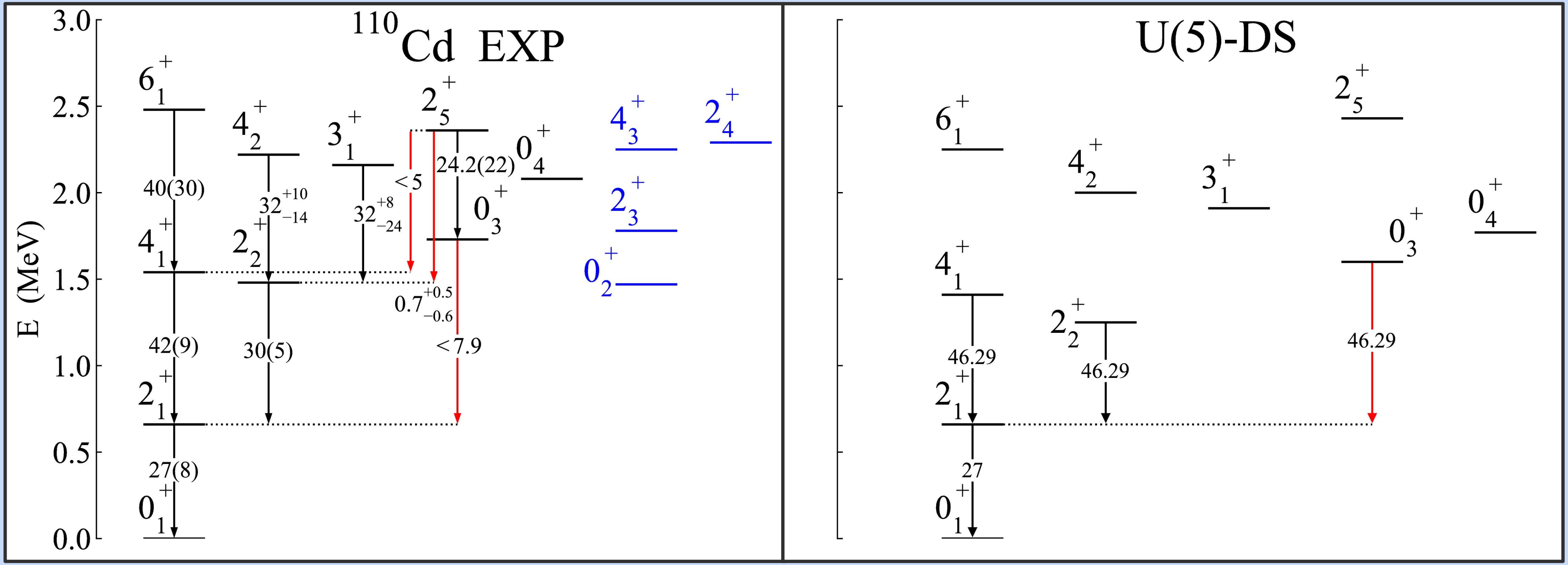
Introduction

The problem of ^{110}Cd



Introduction

The problem of ^{110}Cd



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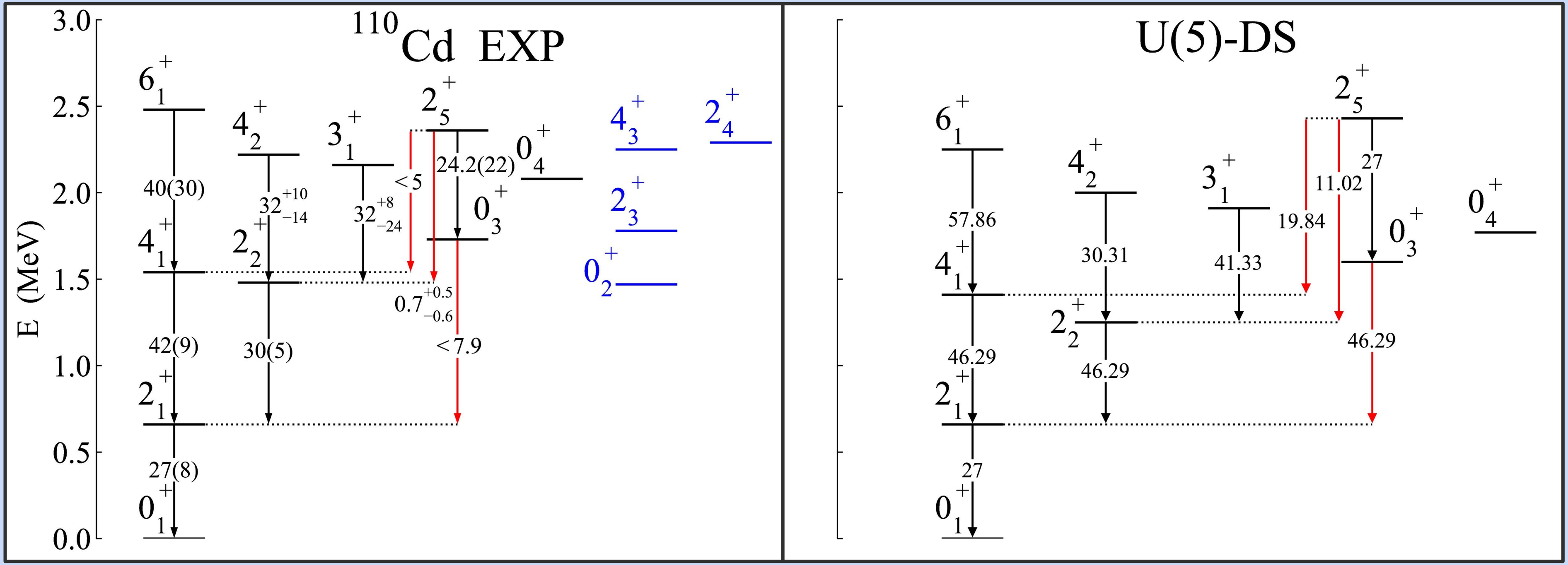
The problem of ^{110}Cd



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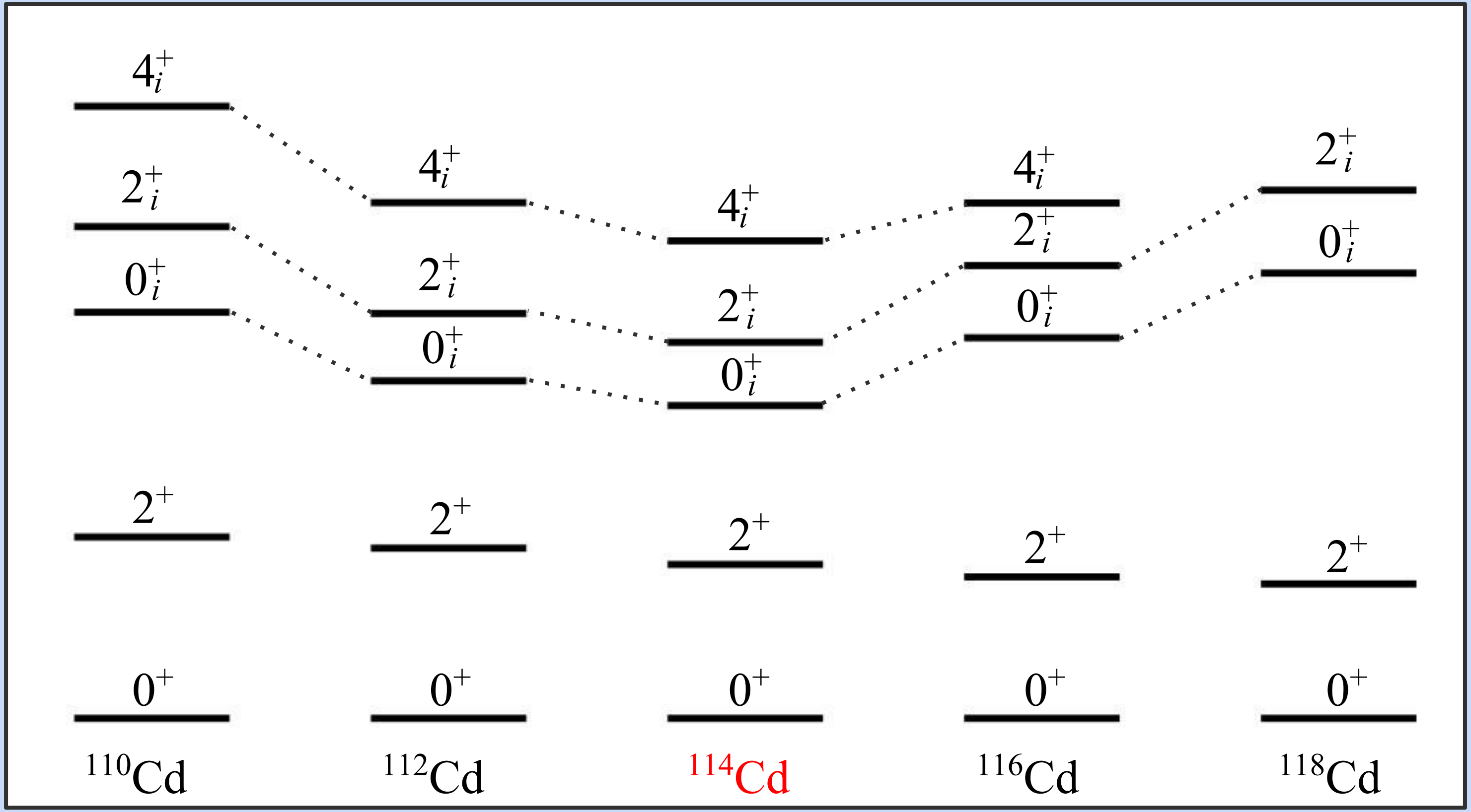
The problem of ^{110}Cd



Introduction

The problem of ^{110}Cd

- Strong mixing between normal and intruder bands

~~$B(E2;\ \text{3-phonon} \rightarrow \text{2-phonon})$~~

- Problem persists in $^{110\text{-}116}$Cd isotopes.

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Breakdown of the vibrational motion in the isotopes $^{110\text{-}116}$Cd

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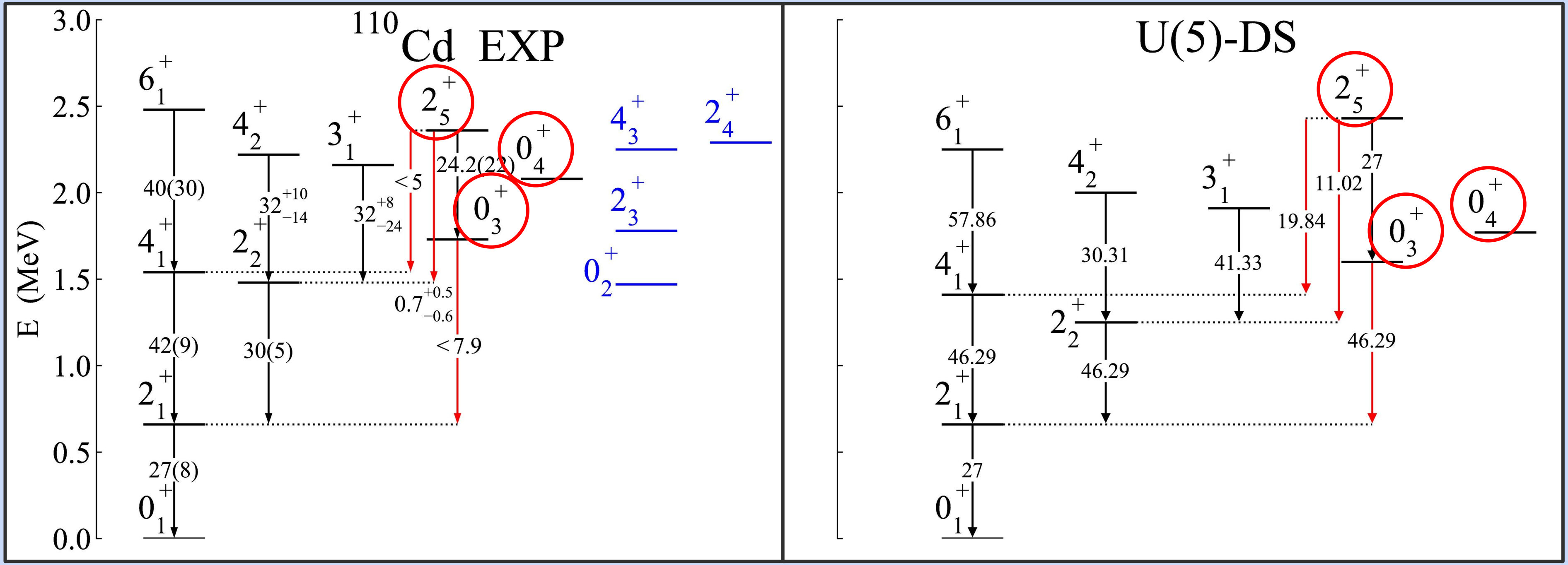
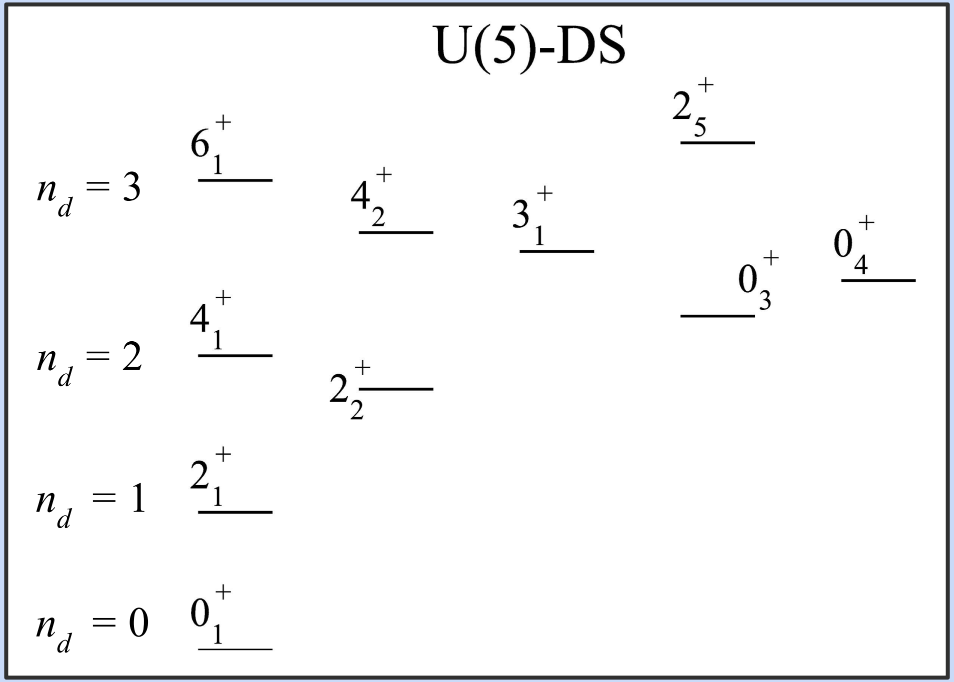
Breakdown of the vibrational motion in the isotopes $^{110\text{-}116}$Cd ?

Introduction

The problem of ^{110}Cd

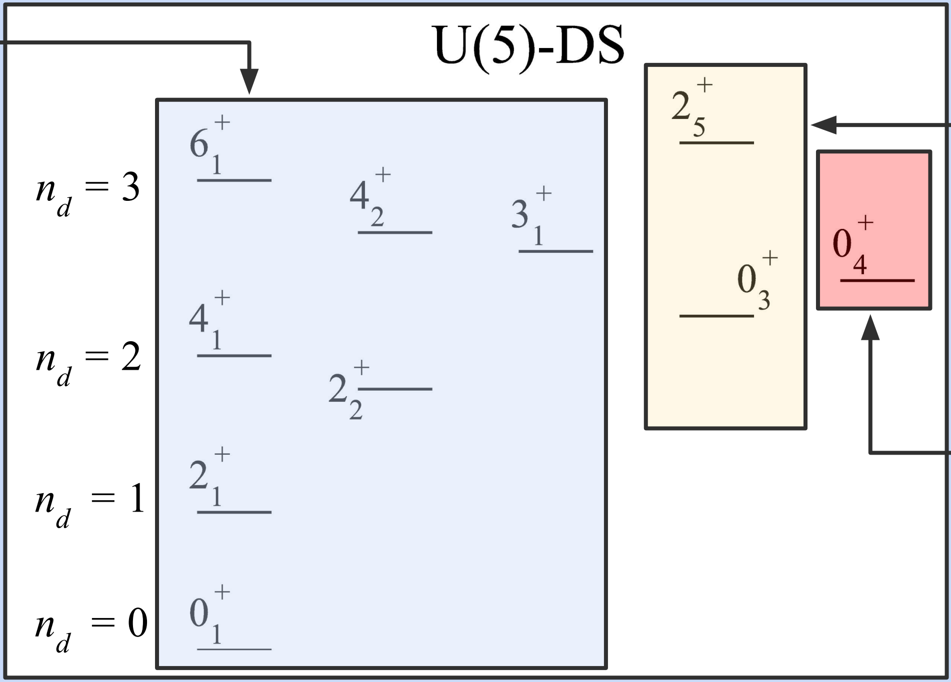


Classes of states



Classes of states

Class A:
$n_d = \tau = 0,1,2,3$
$(n_\Delta = 0)$



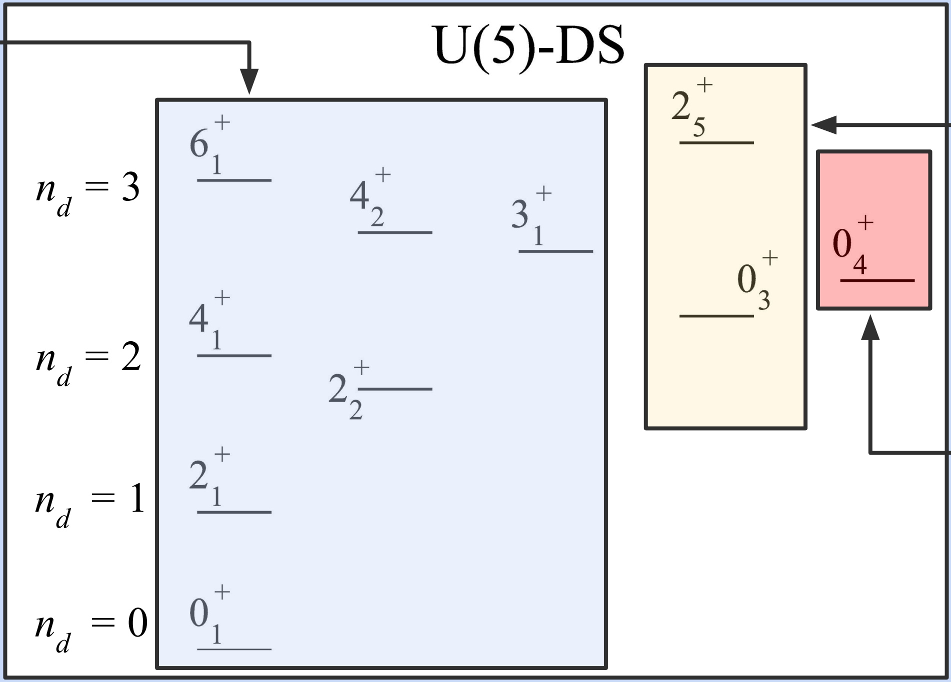
Class B:
$n_d = \tau + 2 = 2,3$
$(n_\Delta = 0)$

Class C:
$n_d = \tau = 3$
$(n_\Delta = 1)$

Classes of states

Class A:
$n_d = \tau = 0,1,2,3$
$(n_\Delta = 0)$

U(5)-PDS



Class B:
$n_d = \tau + 2 = 2,3$
$(n_\Delta = 0)$

Class C:
$n_d = \tau = 3$
$(n_\Delta = 1)$

U(5)-PDS Hamiltonian

- $$H^{\text{(normal)}}_{\text{U(5)-DS}} = \rho_1 n_d + \rho_2\, n_d(n_d - 1) + \rho_3[-C_{\text{O(5)}} + n_d(n_d + 3)] + \rho_4[C_{\text{O(3)}} - 6n_d]$$

- $$H^{\text{(normal)}}_{\text{PDS}} = H^{\text{(normal)}}_{\text{U(5)-DS}} + V_0$$

- $$V_0 = r_0\, G_0^\dagger G_0 + e_0(G_0^\dagger K_0 + K_0^\dagger G_0)$$

$$G_0^\dagger = [(d^\dagger d^\dagger)^{(2)} d^\dagger]^{(0)}$$

$$K_0^\dagger = s^\dagger (d^\dagger d^\dagger)^{(0)}$$

U(5)-PDS Hamiltonian

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- $V_0 = r_0\, G_0^\dagger G_0 + e_0(G_0^\dagger K_0 + K_0^\dagger G_0)$

  $V_0\, |[N], n_d = \tau, \tau\,, n_\Delta = 0\,, L\rangle = 0$

  Class A

$G_0^\dagger = [(d^\dagger d^\dagger)^{(2)} d^\dagger]^{(0)}$

$K_0^\dagger = s^\dagger (d^\dagger d^\dagger)^{(0)}$

U(5)-PDS Hamiltonian

- $H^{(\text{normal})}_{\text{U(5)-DS}} = \rho_1 n_d + \rho_2\, n_d(n_d - 1) + \rho_3[-C_{\text{O(5)}} + n_d(n_d + 3)]$
  $+ \rho_4[C_{\text{O(3)}} - 6n_d]$

- $H^{(\text{normal})}_{\text{PDS}} = H^{(\text{normal})}_{\text{U(5)-DS}} + V_0$

- $V_0 = r_0\, G_0^\dagger G_0 + e_0(G_0^\dagger K_0 + K_0^\dagger G_0)$

  $\Delta n_d = 0$ (for $r_0\, G_0^\dagger G_0$), $\Delta n_d = \pm 1$ (for $e_0(G_0^\dagger K_0 + K_0^\dagger G_0)$)

  $V_0 \,|[N], n_d = \tau, \tau, n_\Delta = 0, L\rangle = 0$

  Class A

$G_0^\dagger = [(d^\dagger d^\dagger)^{(2)} d^\dagger]^{(0)}$

$K_0^\dagger = s^\dagger (d^\dagger d^\dagger)^{(0)}$

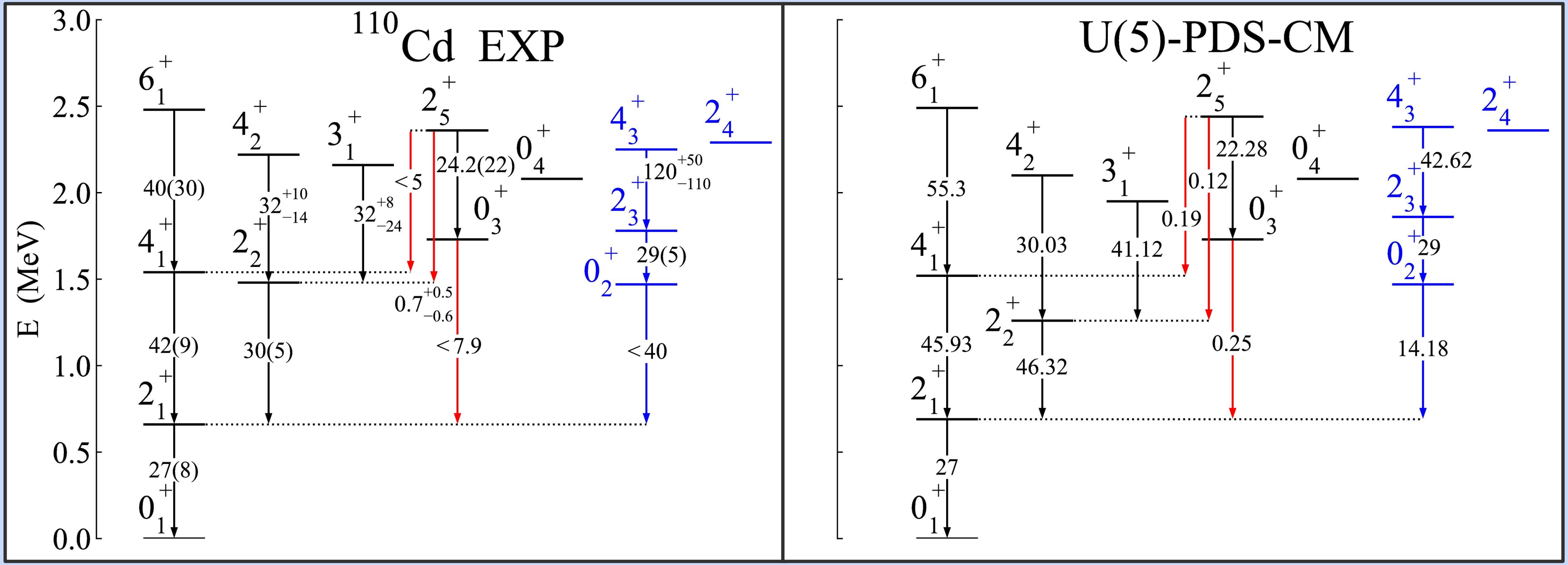
Hamiltonian: IBM-1-CM

- $H^{\text{(normal)}}_{\text{PDS}} = H^{\text{(normal)}}_{\text{U(5)-DS}} + V_0$ [*N*] irrep.

- $H^{\text{(intruder)}}_{\text{O(6)}} = \kappa\, Q(\chi=0) \cdot Q(\chi=0) + \Delta$ [*N*+2] irrep.

- $V^{(N,N+2)}_{\text{mix.}} = \alpha\, [(d^\dagger d^\dagger)^{(0)} + (s^\dagger)^2] + h.c.$ [*N*]⊕[*N*+2] irrep.

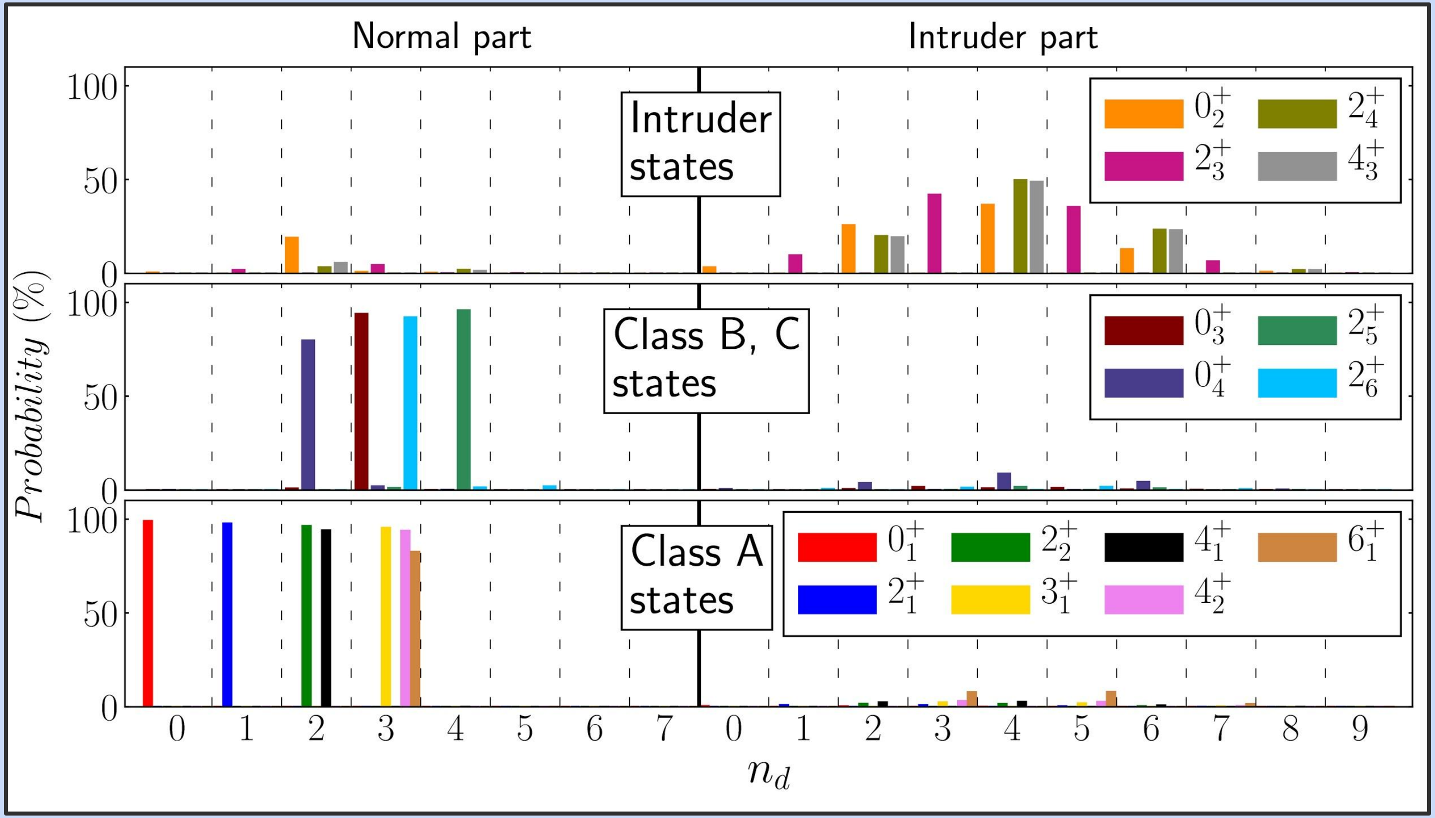
U(5)-PDS-CM



110Cd EXP
U(5)-PDS-CM
E (MeV)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
40(30)
42(9)
27(8)
30(5)
24.2(22)
< 5
< 7.9
< 40
29(5)
55.3
45.93
27
30.03
46.32
41.12
0.19
0.12
22.28
0.25
42.62
29
14.18

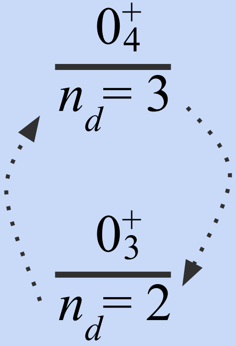
U(5)-PDS-CM

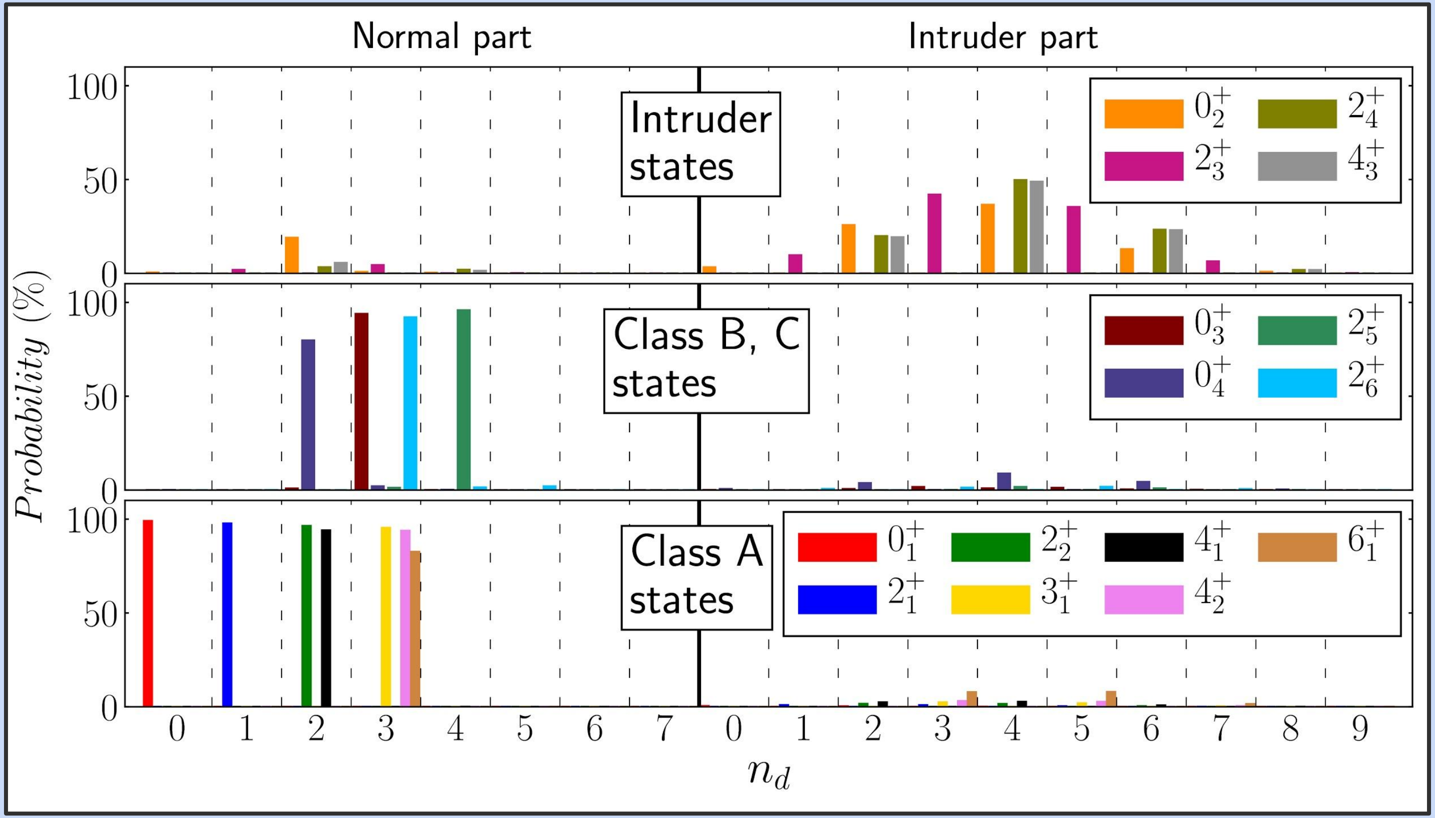
U(5) decomposition



U(5)-PDS-CM

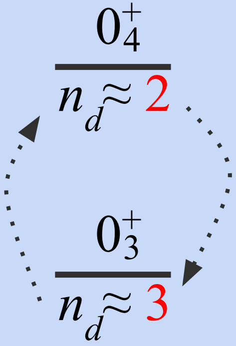
U(5) decomposition

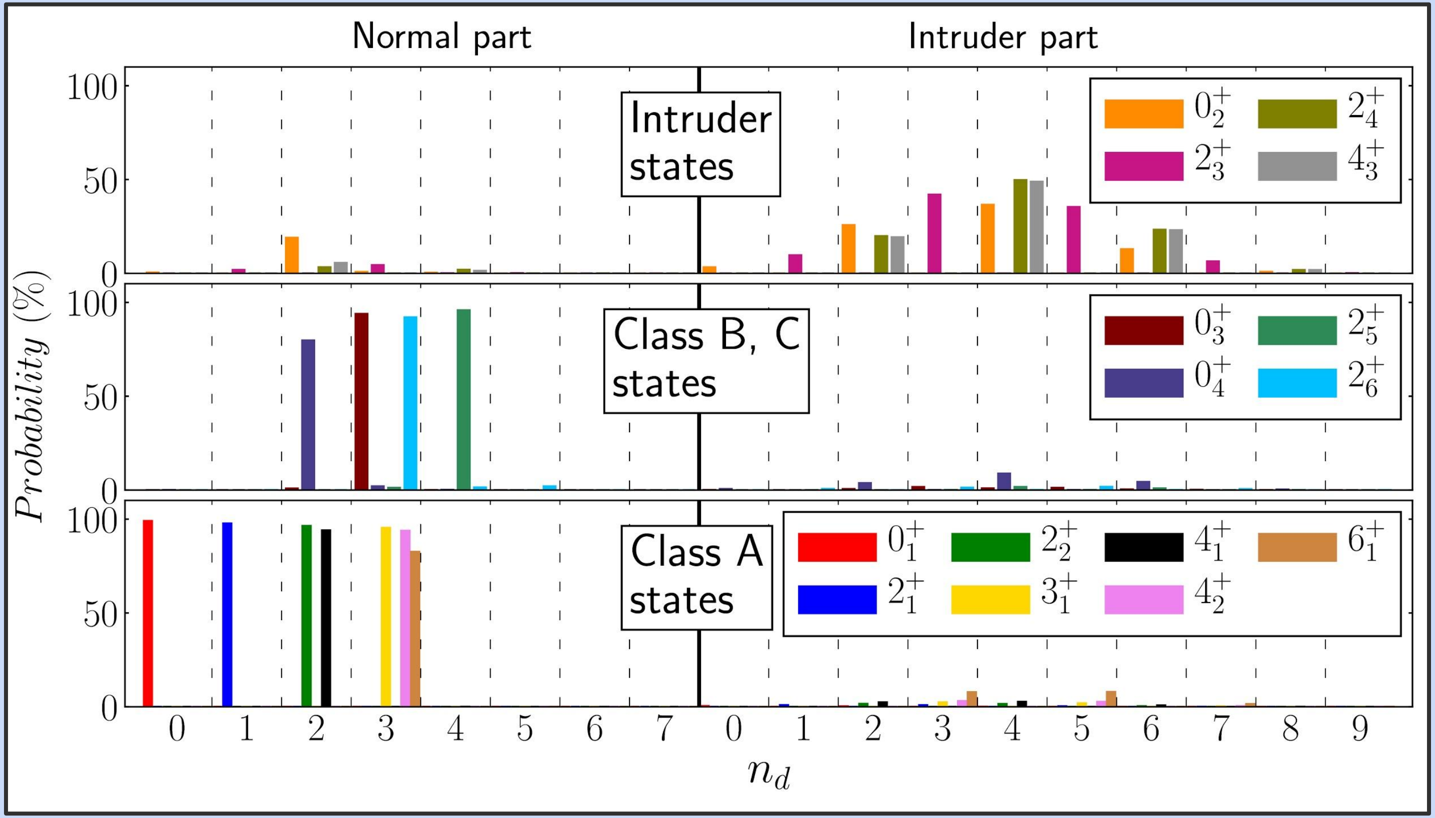




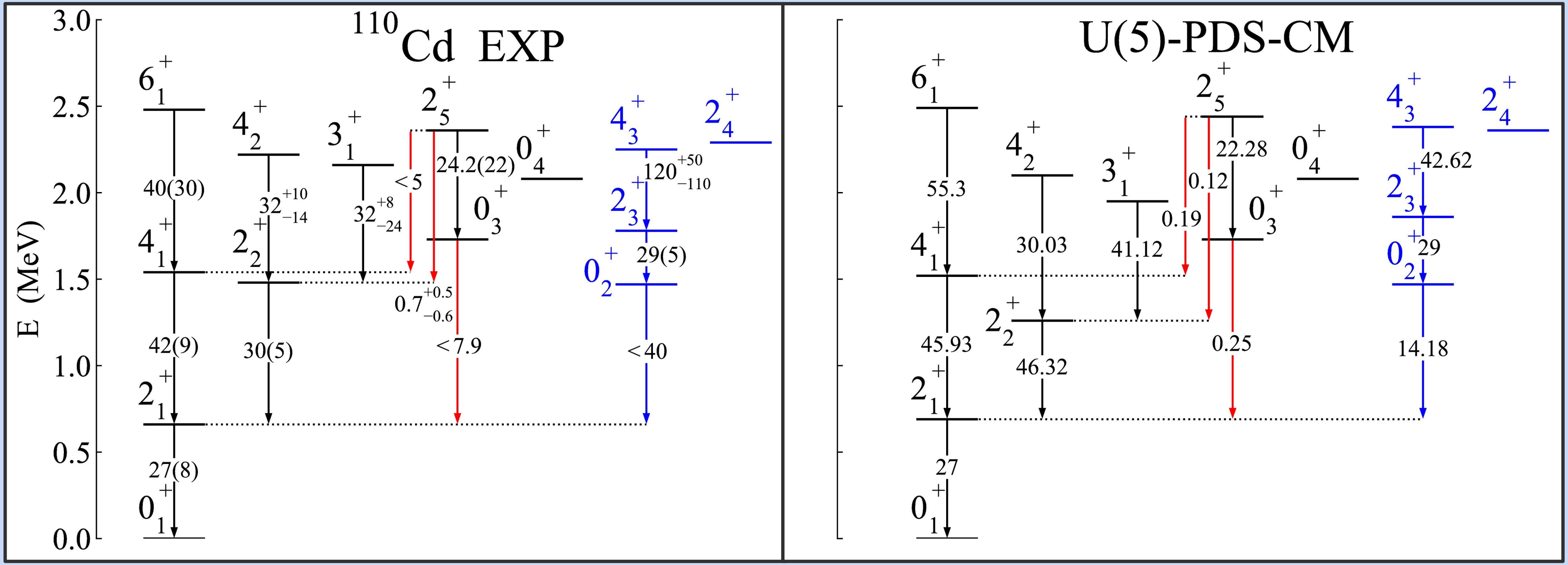
U(5)-PDS-CM

U(5) decomposition





U(5)-PDS-CM



E (MeV)
3.0
2.5
2.0
1.5
1.0
0.5
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110Cd EXP
40(30)
42(9)
27(8)
30(5)
32+10−14
32+8−24
< 5
24.2(22)
0.7+0.5−0.6
< 7.9
120+50−110
29(5)
< 40
U(5)-PDS-CM
55.3
45.93
27
30.03
46.32
41.12
0.19
0.12
22.28
0.25
42.62
29
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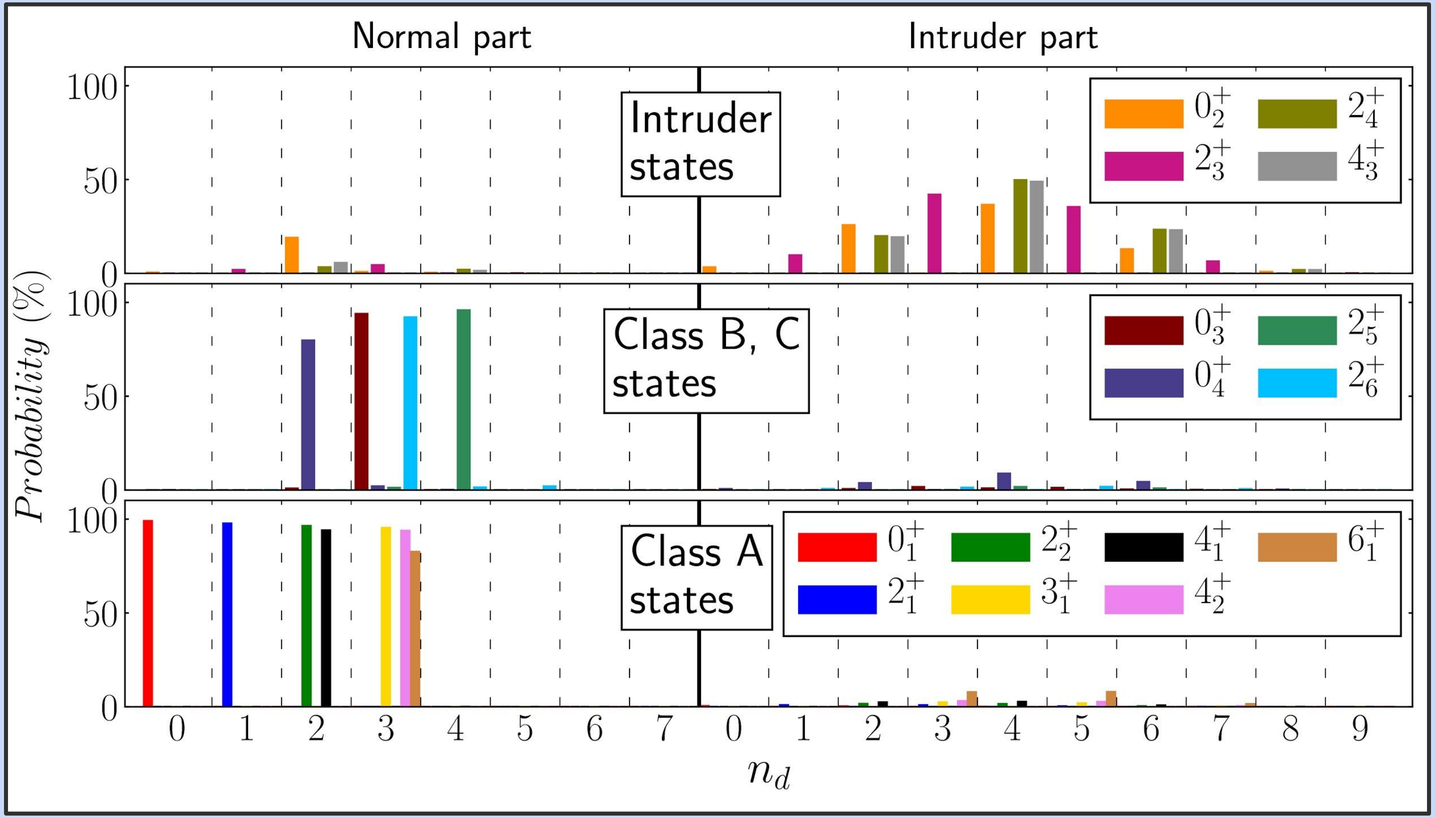
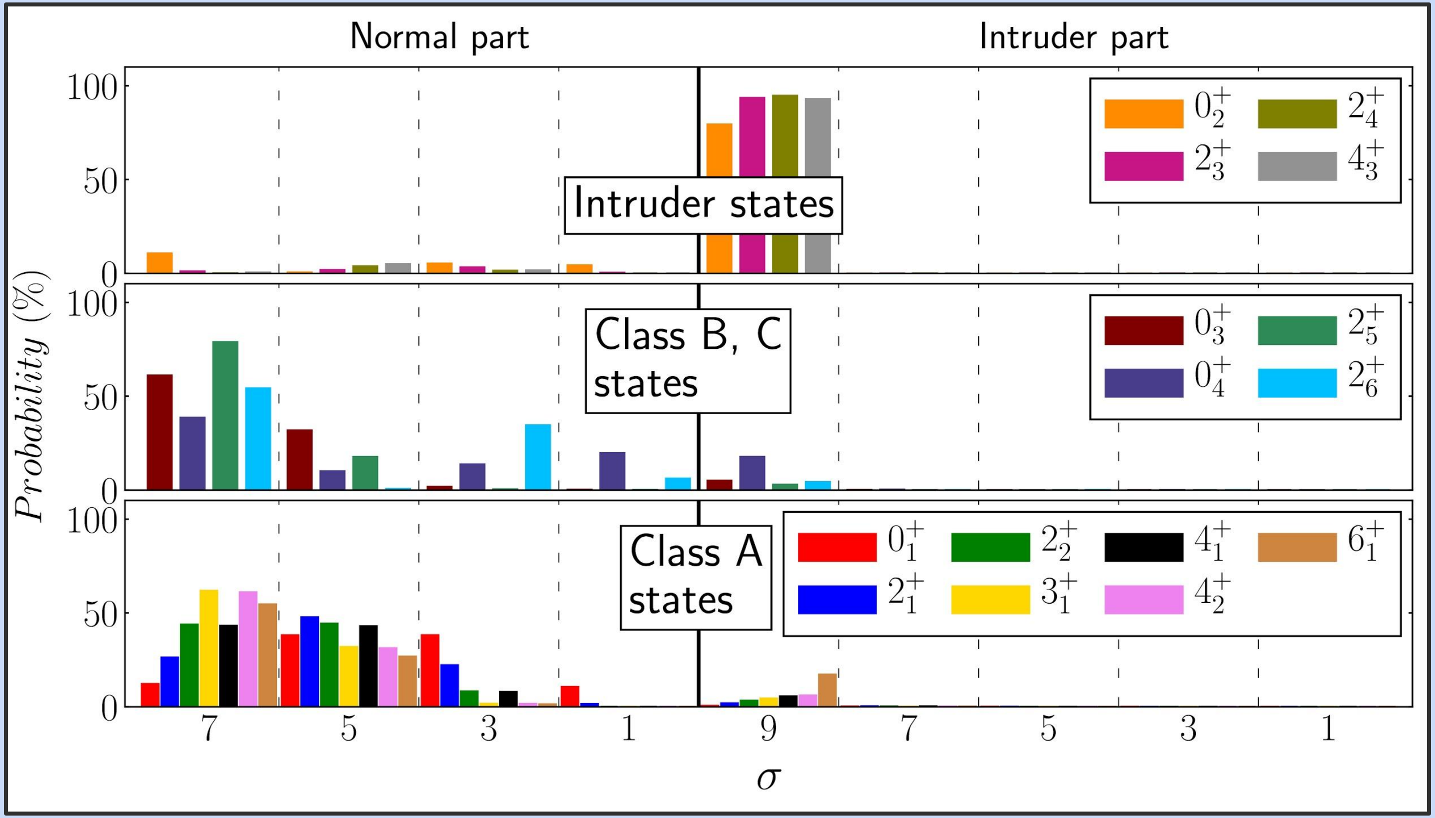
U(5)-PDS-CM

U(5) decomposition

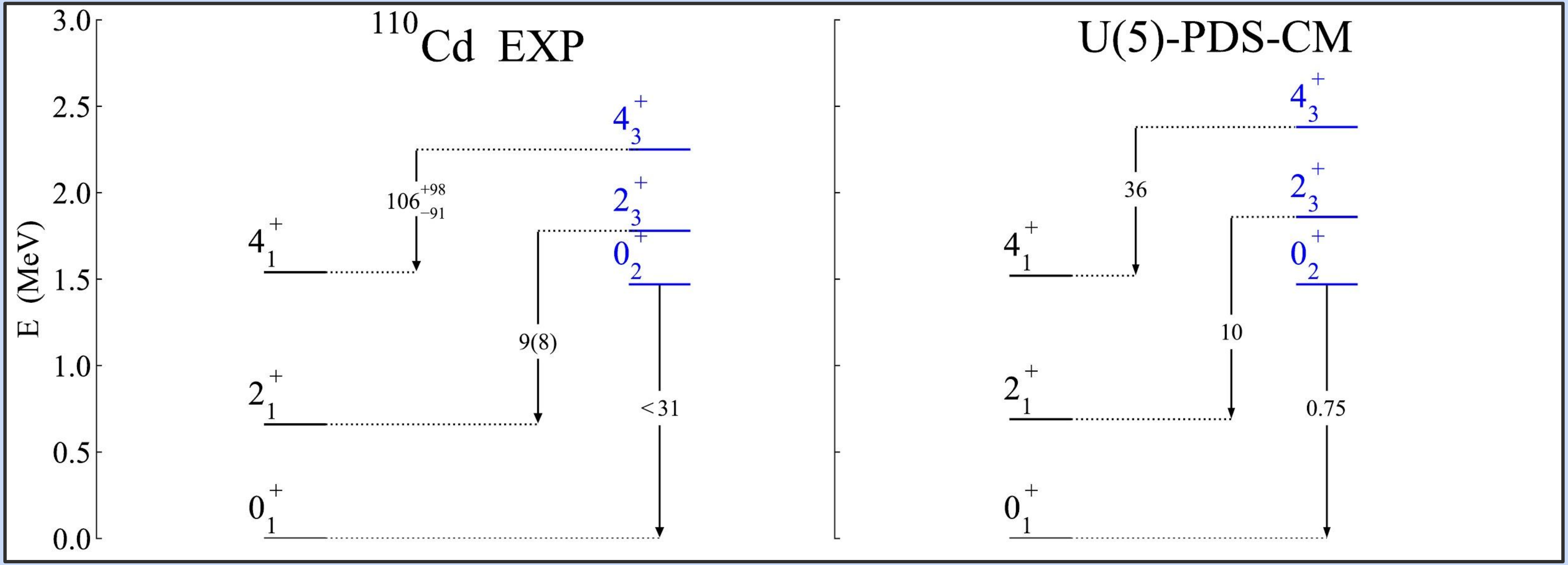


U(5)-PDS-CM
O(6) decomposition



U(5)-PDS-CM

E0 transitions



$$T^{(E0)} = (e_n N + e_p Z)\,\eta\,(n_d^{(N)} + n_d^{(N+2)})$$

Summary

- Reproduced problematic *E2* transitions

  (new interpretation for the “Phonon Puzzle”).

- Class A states are approximately pure U(5)-DS (use of U(5)-PDS).

- Mixing with the intruder band is weak (mainly phonons mixing).

- Outlook: ^{112}Cd, ^{114}Cd, ^{116}Cd ? Preliminary results for ^{112}Cd seem promising!

Thank you