Low-lying positive- and negative-parity vibrational modes in ^{34}Mg region

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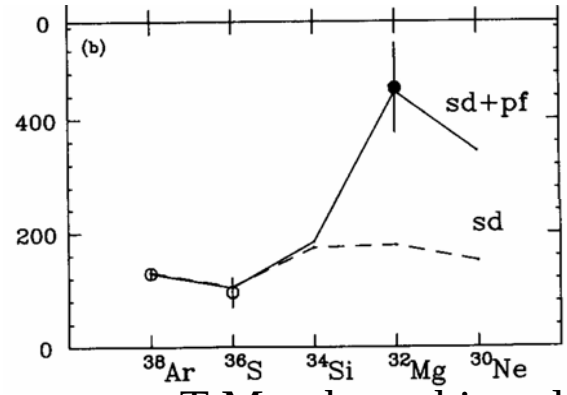
Shell inversion in neutron-rich Mg isotopes

J.A.Church et al.,PRC**72**, 054320 (2005)

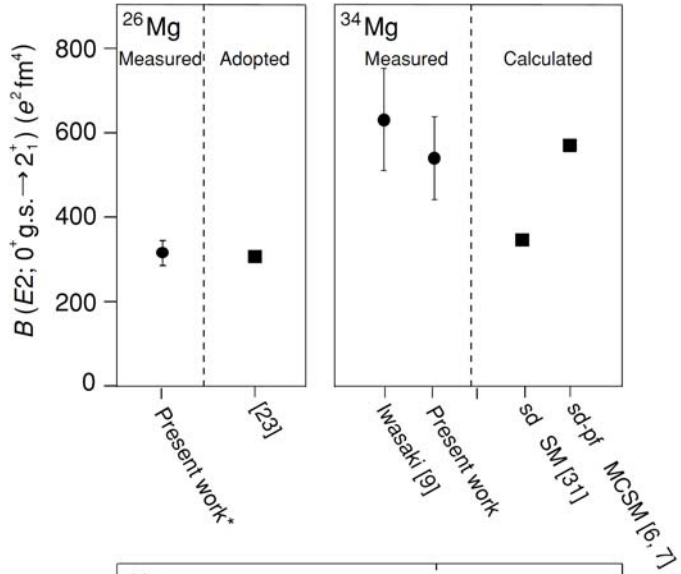
✓Low-lying 2^+ state: 885keV(^{32}Mg), 659keV(^{34}Mg)
✓Large B(E2;$0^+ \rightarrow 2^+$): 447e^2fm^4(^{32}Mg), 541e^2fm^4(^{34}Mg)

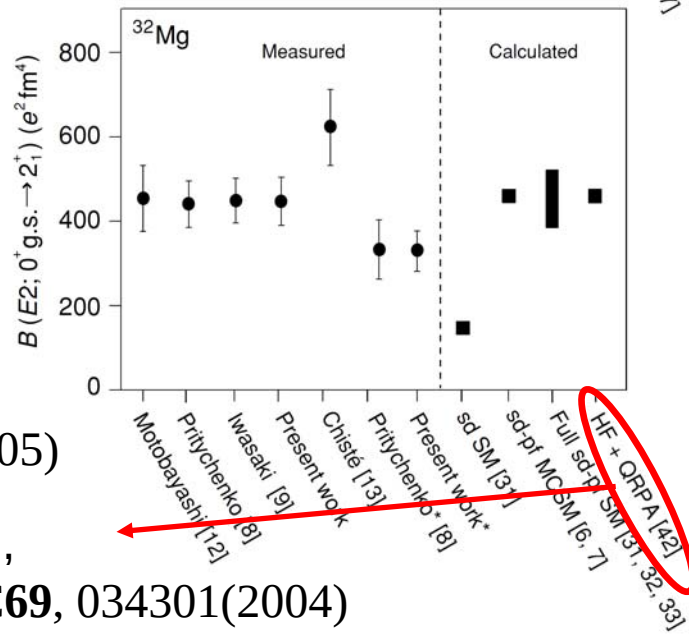
Breaking of N=20 spherical magic number

Shell inversion



T.Motobayashi et al.,PLB**346**, 9(1995)





cf. ^{31}Mg $I^\pi = \frac{1}{2}^+$ (g.s.) G.Neyens et al.,PRL**94**, 022501(2005)

Importance of pair correlation,
M.Yamagami and N.Van Giai, PRC**69**, 034301(2004)

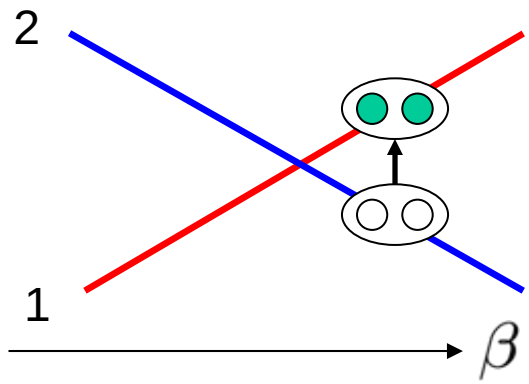
Soft mode of pair fluctuation

Soft $K=0^+$ mode in deformed nuclei

Two-level model (Bohr and Mottelson)

$$|0>=\frac{1}{\sqrt{a^2+b^2}}(a|\nu_1\overline{\nu_1}>+b|\nu_2\overline{\nu_2}>)$$

$$|0'>=\frac{1}{\sqrt{a^2+b^2}}(-b|\nu_1\overline{\nu_1}>+a|\nu_2\overline{\nu_2}>)$$



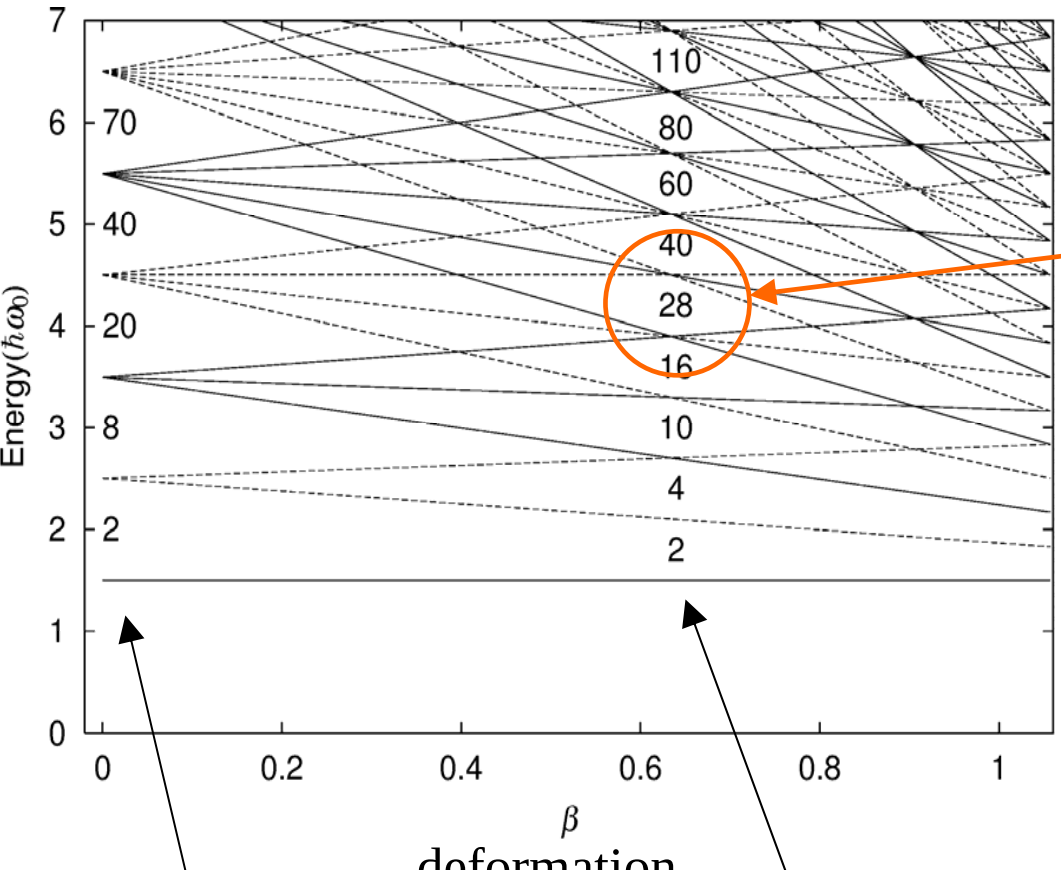
Transition matrix element

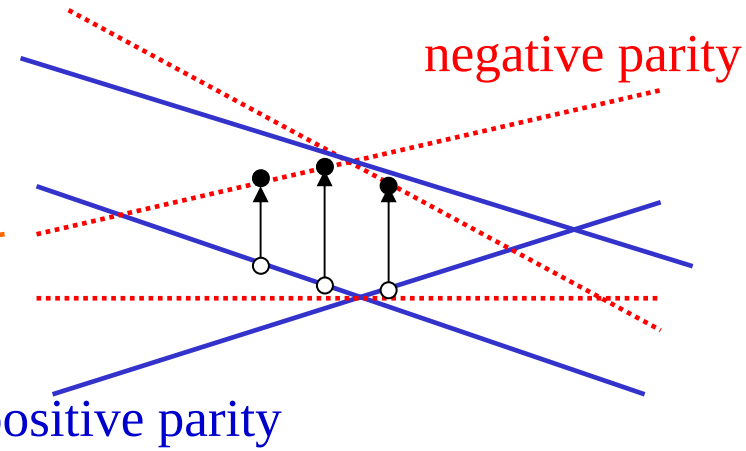
$$\Rightarrow \quad <0'|r^2Y_{20}|0>=\frac{2ab}{a^2+b^2}\left\{<\nu_2|r^2Y_{20}|\nu_2>-<\nu_1|r^2Y_{20}|\nu_1>\right\}$$

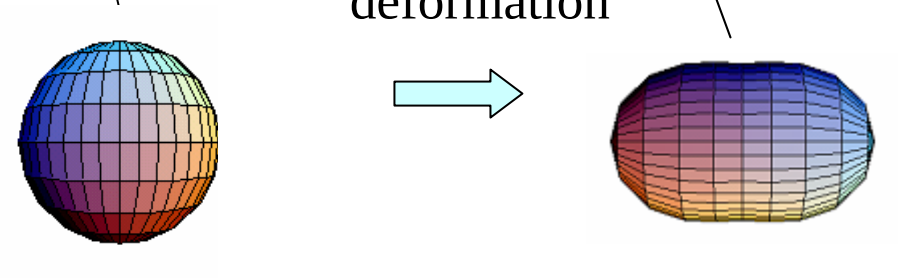
opposite sign

Enhancement

Soft octupole mode in largely deformed state





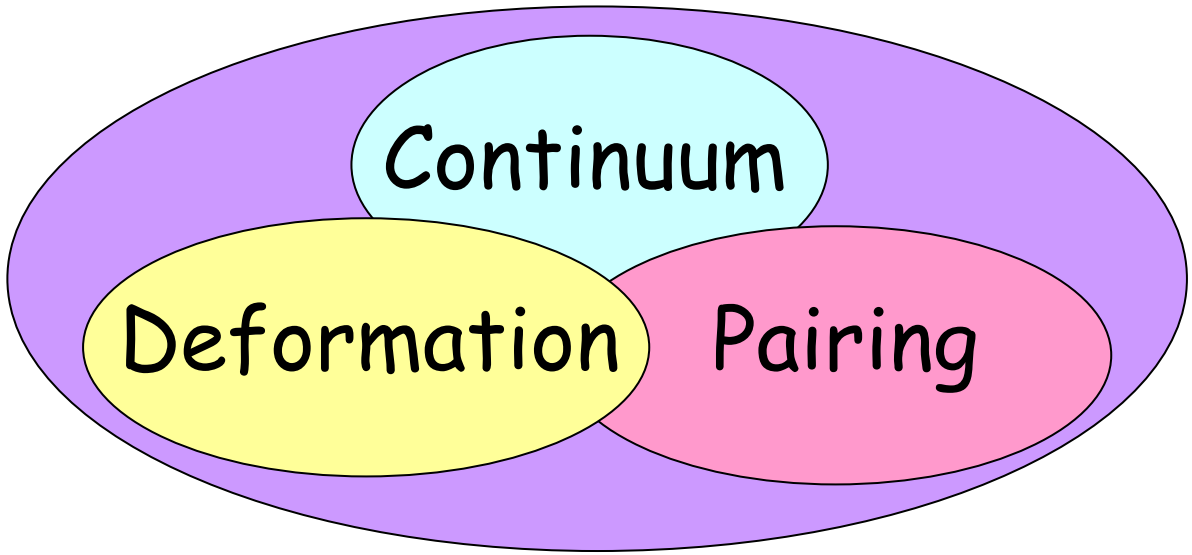


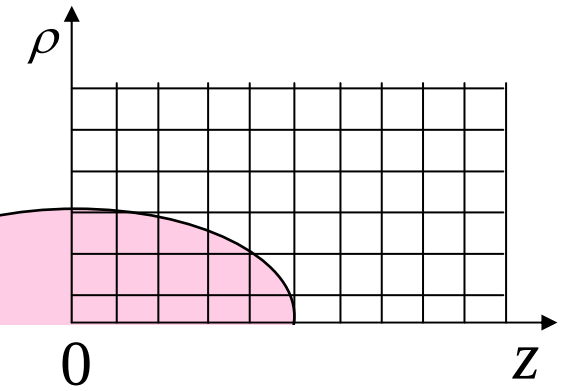
Soft negative parity vibrational modes (especially the octupole modes) are expected in largely deformed state.

Approach

Sensitivity of soft vibrations on nuclear deformation

QRPA simultaneously taking into account





Directly solve HFB eq. in coordinate-space mesh-representation

H.O. basis ✗ Spatially extended structure

HFB + Deformed QRPA

Ground state

Coordinate-space HFB equation

Mean-field Deformed Woods-Saxon potential

Pair-field $v_{\mathrm{pair}}(\mathbf{r},\mathbf{r}') = V_0\left(1-\frac{\rho(\mathbf{r})}{\rho_0}\right)\delta(\mathbf{r}-\mathbf{r}')$

$V_0 = -450$ MeV fm^3

$E_{\mathrm{cutoff}} = 50$MeV

Excited state

QRPA equation in the AB matrix formulation

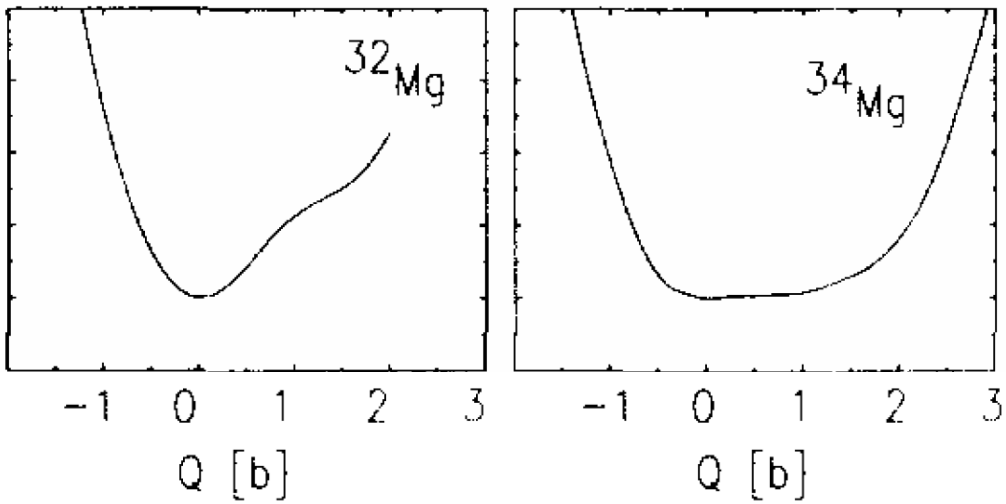
Residual interaction

p-h channel $v_{\mathrm{ph}}(\mathbf{r},\mathbf{r}') = \left[t_0(1+x_o P_\sigma) + \frac{t_3}{6}(1+x_3 P_\sigma)\rho(\mathbf{r})\right]\delta(\mathbf{r}-\mathbf{r}')$

p-p channel $v_{\mathrm{pp}}(\mathbf{r},\mathbf{r}') = V_0\left(1-\frac{\rho(\mathbf{r})}{\rho_0}\right)\delta(\mathbf{r}-\mathbf{r}')$

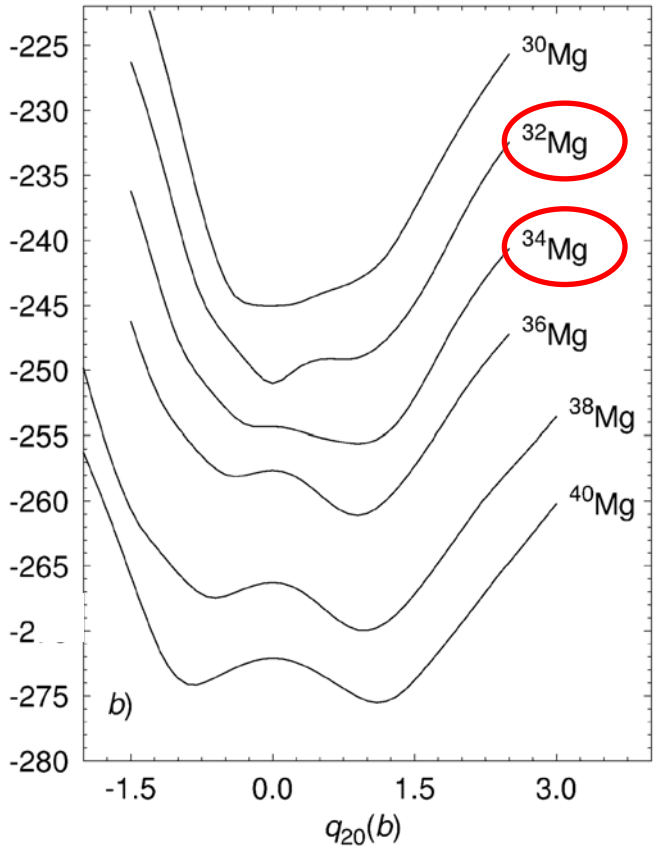
Deformation of ^{32}Mg and ^{34}Mg

Skyrme HFB calculation using SIII



J.Terasaki *et al.*,NPA621(1997)706

Gogny HFB calculation using D1S



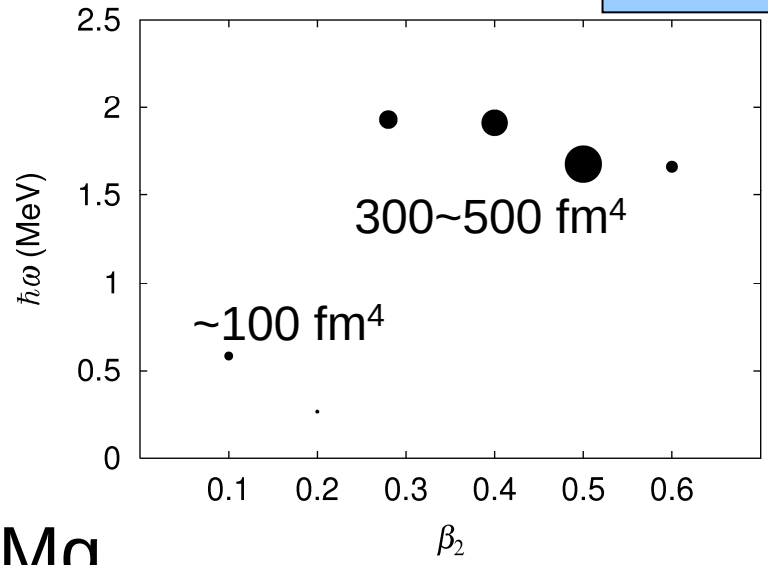
R. Rodríguez-Guzmán *et al.*, NPA709(2002)201

deformation dependence of low-lying modes ?

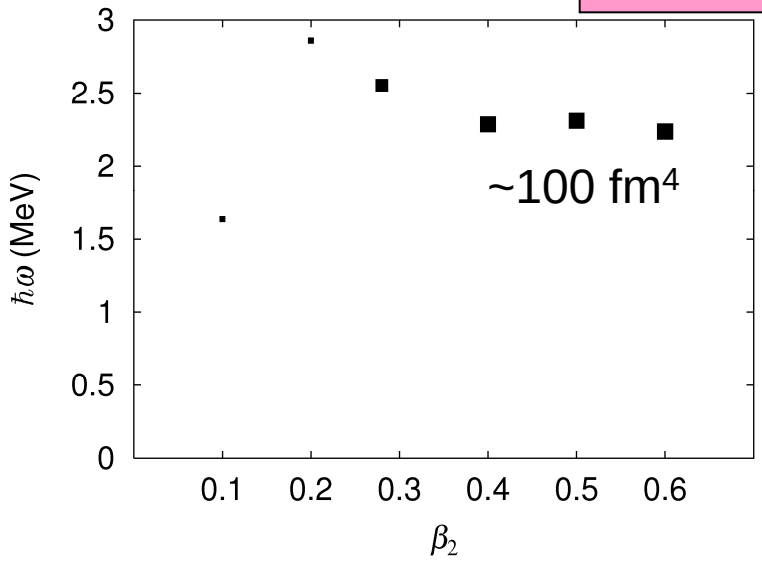
Deformation dependence ~ quadrupole vib.

^{32}Mg

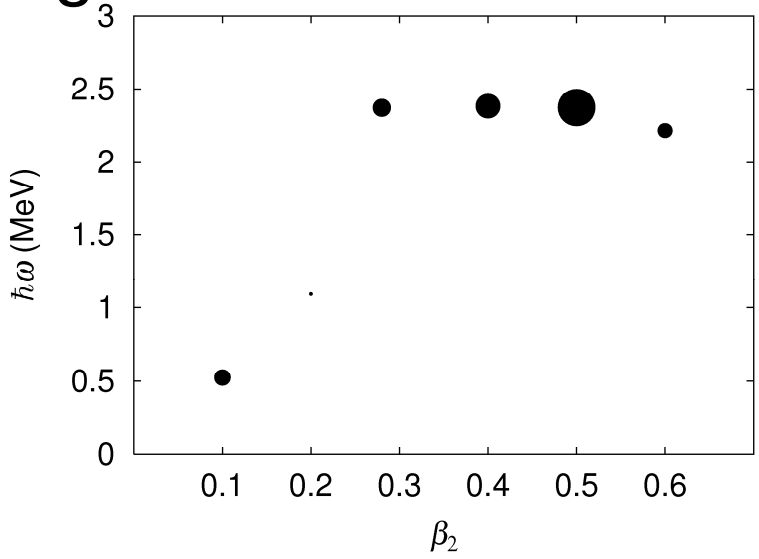
$K^\pi = 0^+$

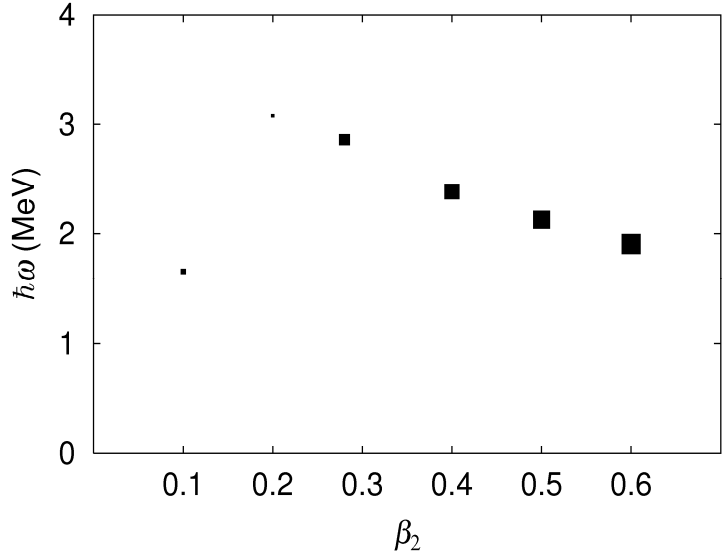


$K^\pi = 2^+$



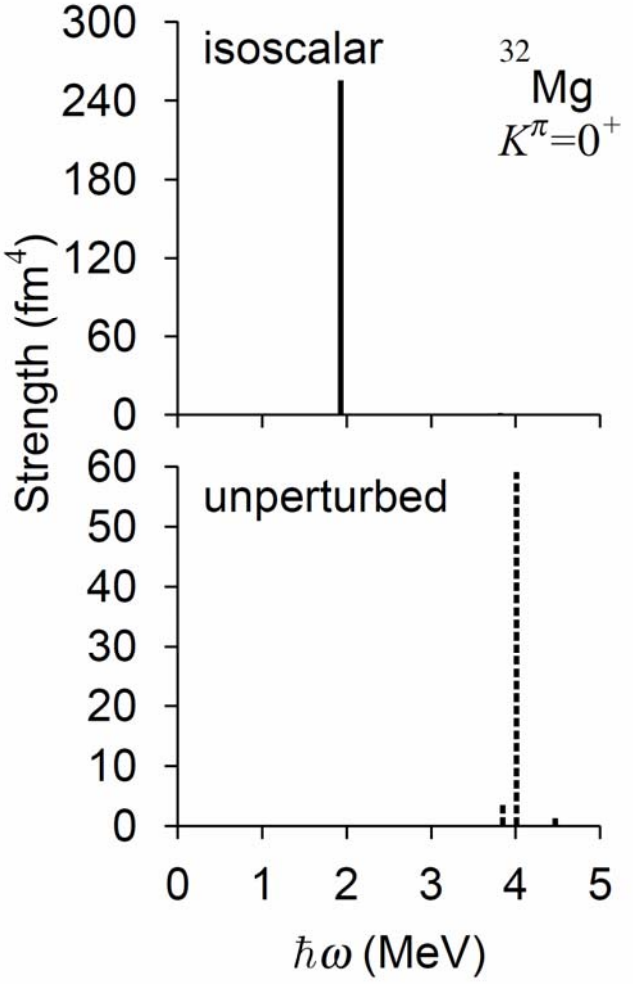
^{34}Mg

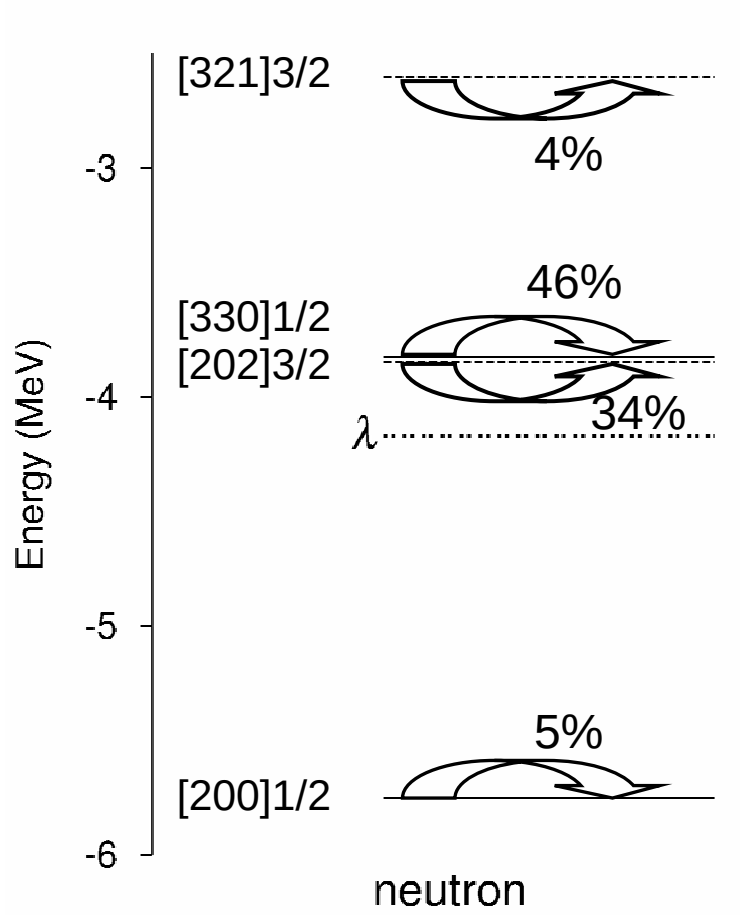


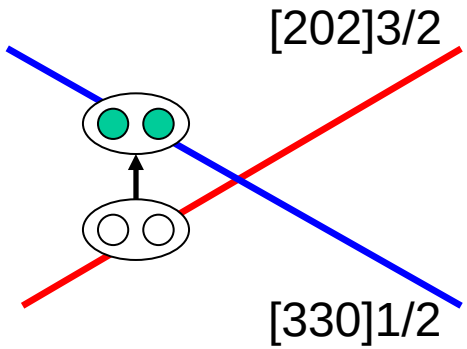


Structure of positive-parity vibrations

$\beta_2 = 0.28$



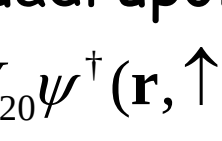




Pair fluctuation mode

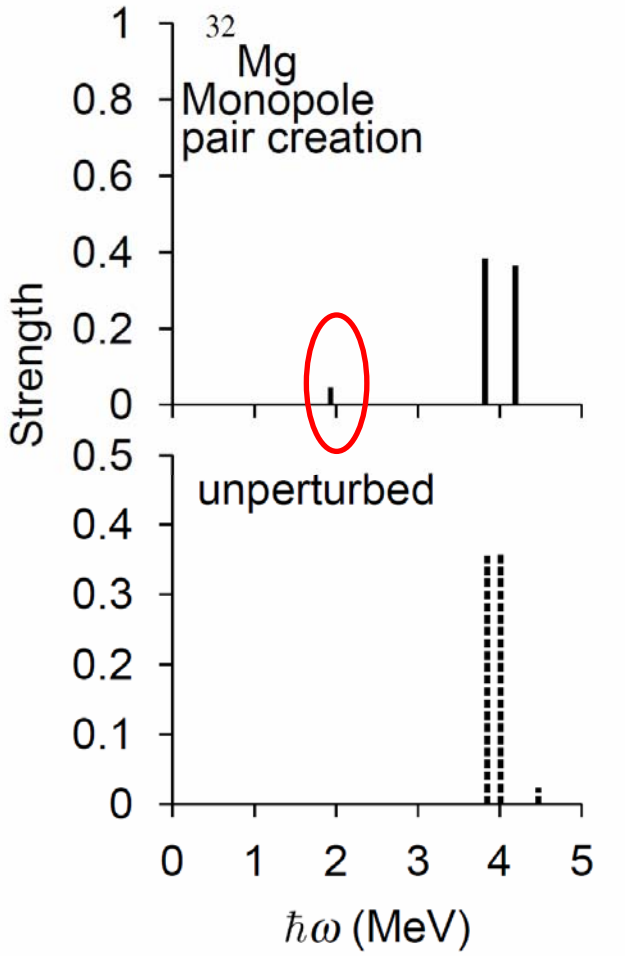
Monopole pairing

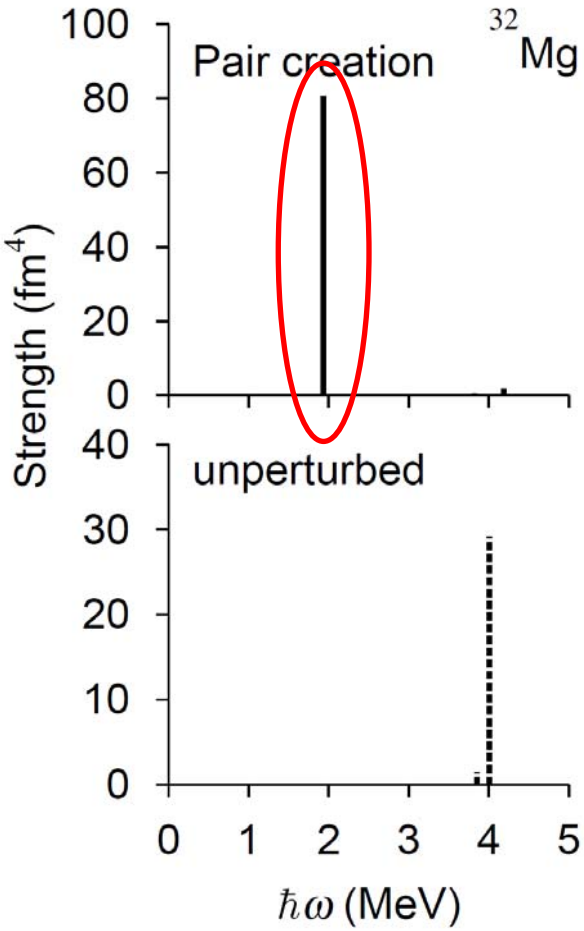
$$\int \psi^{\dagger}(\mathbf{r},\uparrow)\psi^{\dagger}(\mathbf{r},\downarrow)d\mathbf{r}$$



Quadrupole pairing

$$\int r^2 Y_{20}\psi^{\dagger}(\mathbf{r},\uparrow)\psi^{\dagger}(\mathbf{r},\downarrow)d\mathbf{r}$$

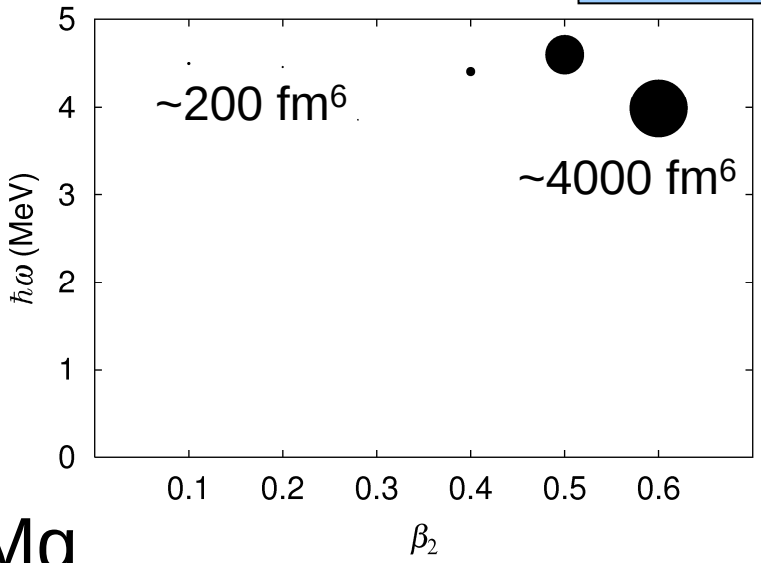




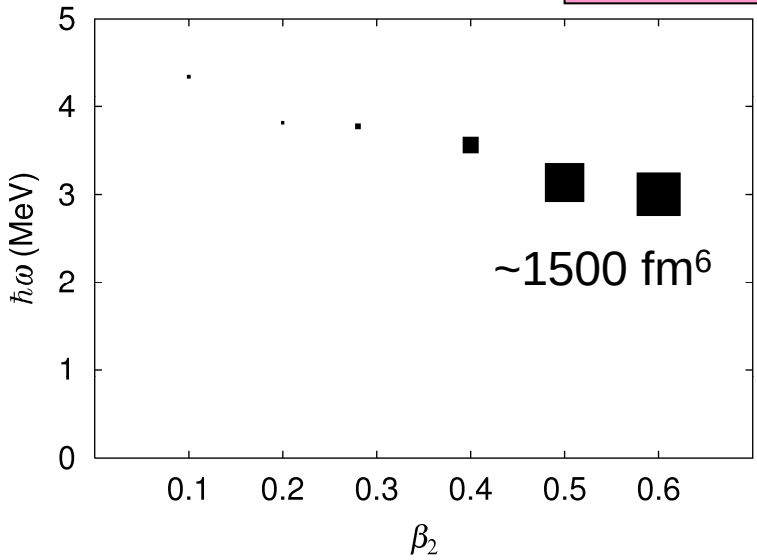
Deformation dependence ~ octupole vib.

^{32}Mg

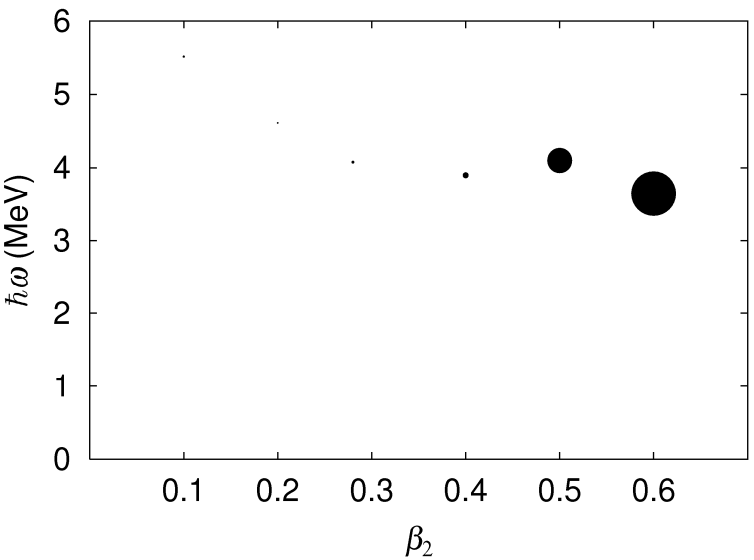
$K^\pi = 0^-$

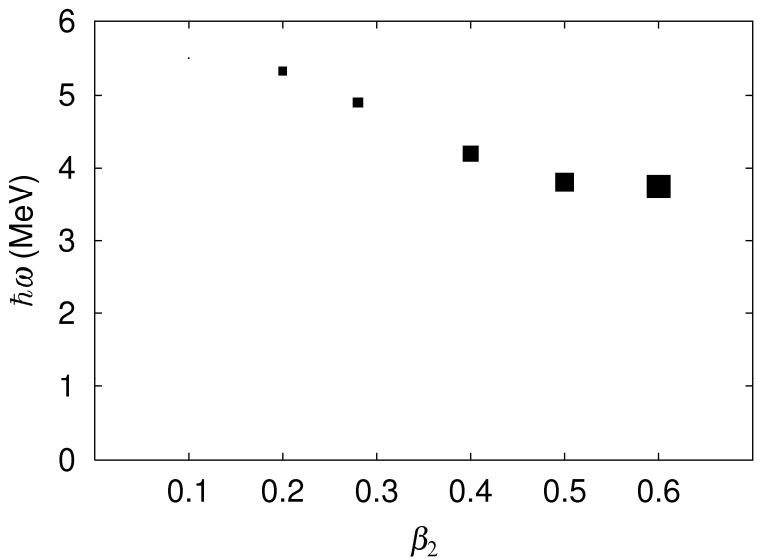


$K^\pi = 1^-$



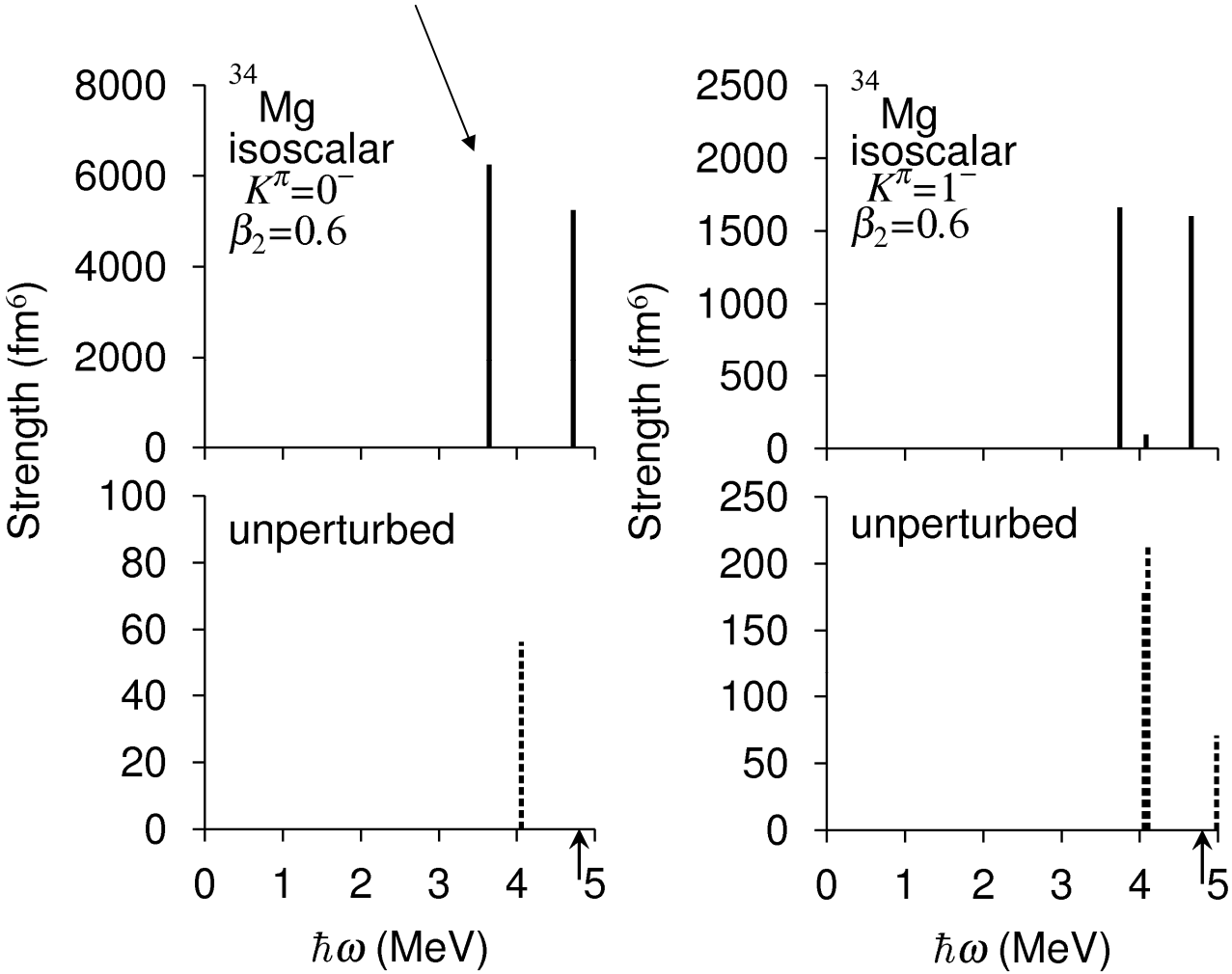
^{34}Mg





Negative-parity vibrations

B(IS3)=6250 fm^6, B(E3)=722 e^{2}fm^6



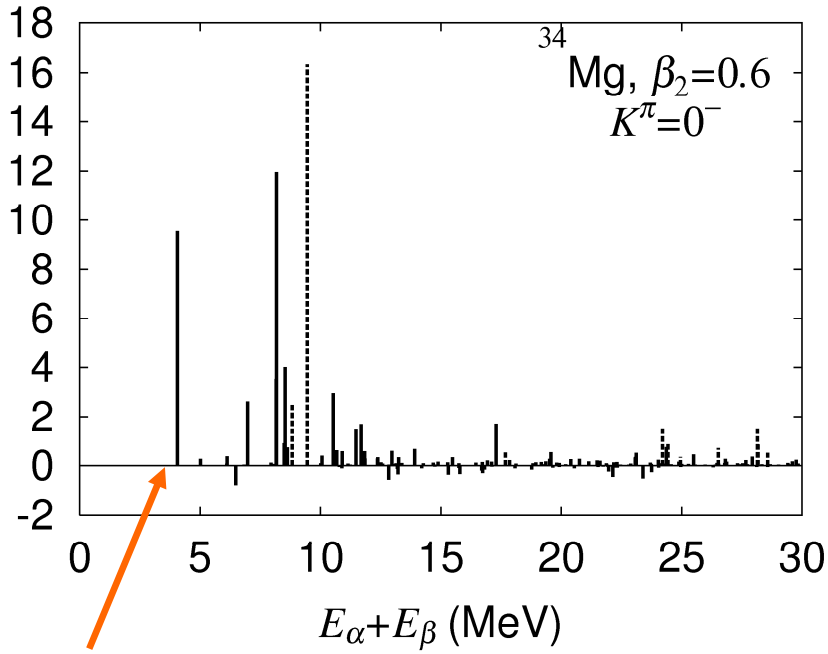
(1W.u.=60fm^6)

Quite enhanced transition strengths 30~100 W.u. (intrinsic)

Structure of K=0⁻ modes

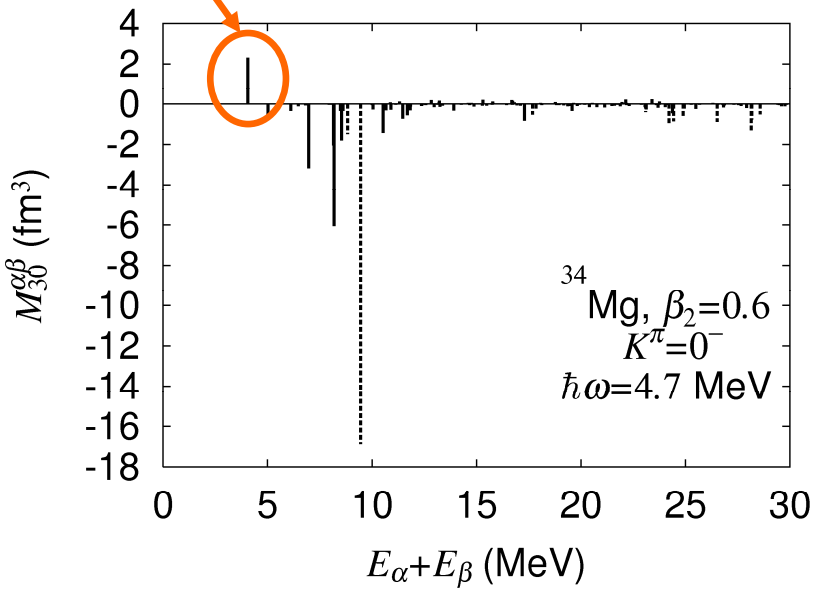
Transition matrix element

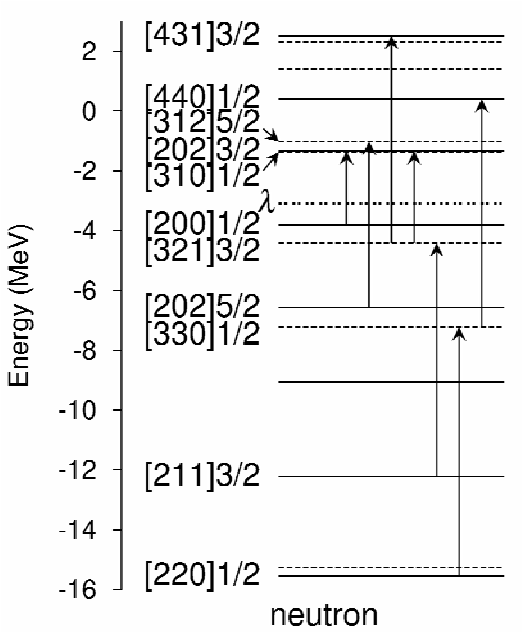
$$\langle RPA|\hat{Q}_{30}|0\rangle = \sum_{\alpha\ \beta} M_{30}^{\alpha\ \beta}$$

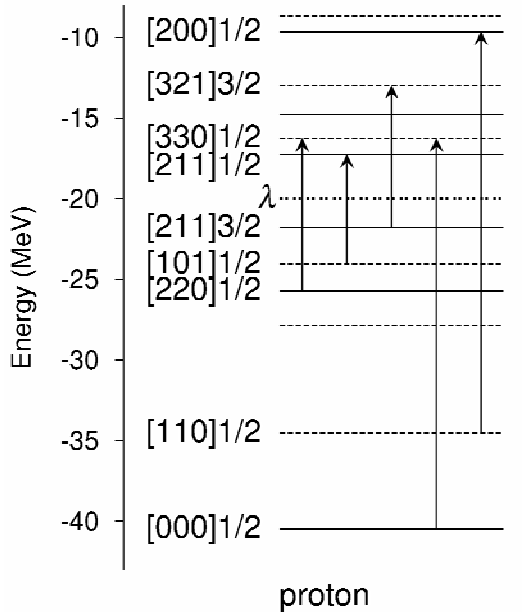


neutron:[200]1/2→[310]1/2

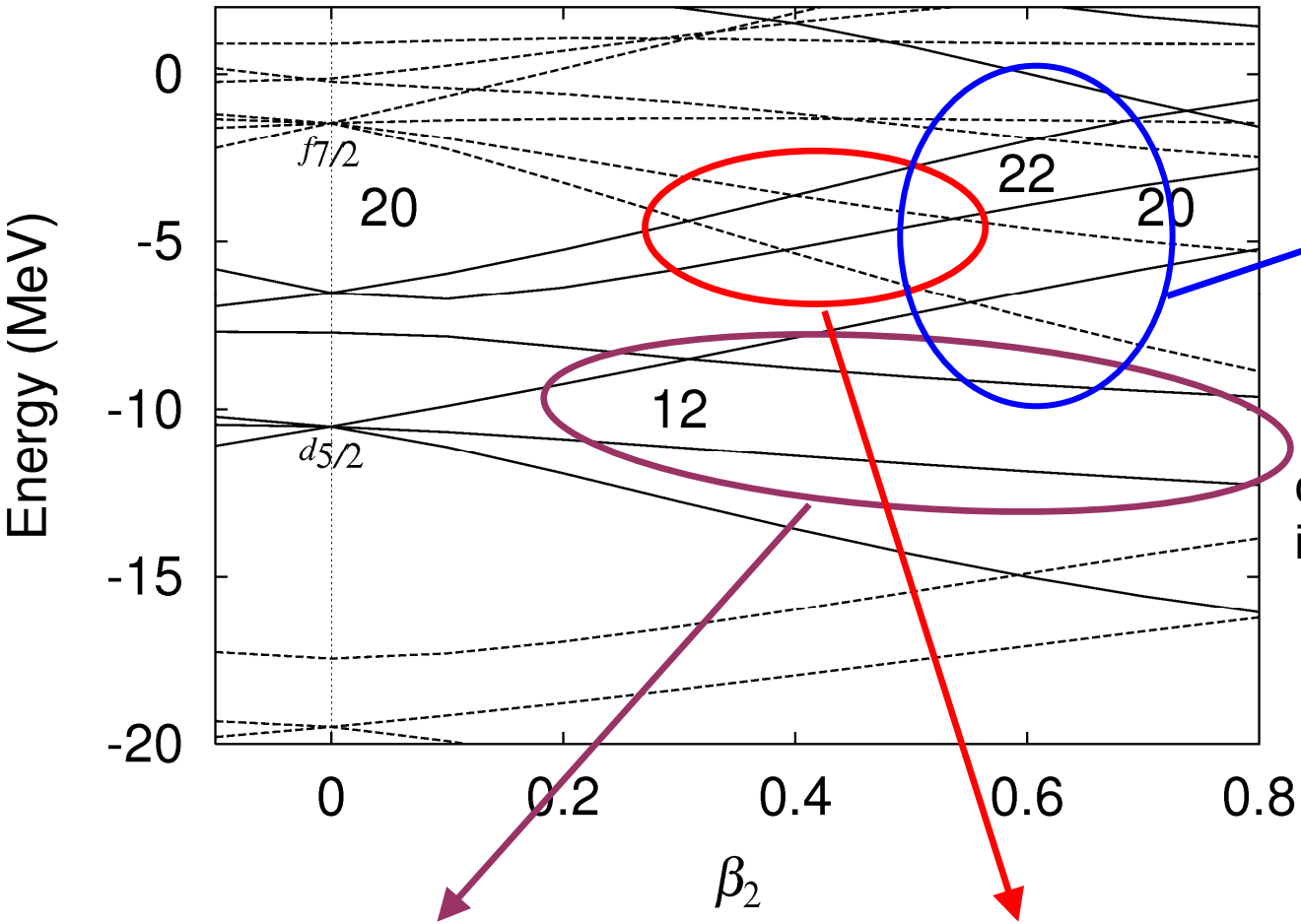
Out of phase







Deformation dependence of low-lying modes



Soft octupole vib.

associated with SD shell structure

cf. Soft K=0$^-$ and 1$^-$ modes in SD state in ^{40}Ca and ^{44}Ti

T.Inakura et al., NPA768(2006)61

Gamma vibration

Excitation of protons Z=12

Pair fluctuation

Soft K=0$^+$ mode

Summary

- ✓Normal deformed states in ^{32}Mg, ^{34}Mg
  - ✓Soft $K=0^+$ mode
    - Pairing vibration
    - Quadrupole pairing
  - ✓Gamma vibrational mode
    - Coherent motion of protons and neutrons
- ✓Superdeformed states in ^{32}Mg, ^{34}Mg
  - ✓Low-lying $K=0^-$, 1^- states
    - Very large transition strengths
      - 2q.p. excitations near the Fermi level
      - Excitations from deeply bound to weakly bound state

Soft octupole vibrational mode

good indicator of large deformation of n-rich Mg isotopes

Grand state property

^{32}Mg

	0.1	0.2	0.28	0.4	0.5	0.6
Δ_n	1.15	1.50	1.64	1.63	1.55	1.48
Δ_p	0.65	0.11	0.0	0.0	0.0	0.0
λ_n	-4.06	-4.09	-4.17	-4.31	-4.31	-4.21
λ_p	-17.6	-17.4	-17.0	-17.0	-17.5	17.0
$\sqrt{\langle r^2 \rangle_n}$	3.44	3.47	3.50	3.56	3.61	3.66
$\sqrt{\langle r^2 \rangle_p}$	2.99	3.01	3.03	3.07	3.11	3.15