Dynamic Pairing Effects on Low-Frequency Modes of Excitation in Deformed Mg Isotopes close to the Neutron Drip Line

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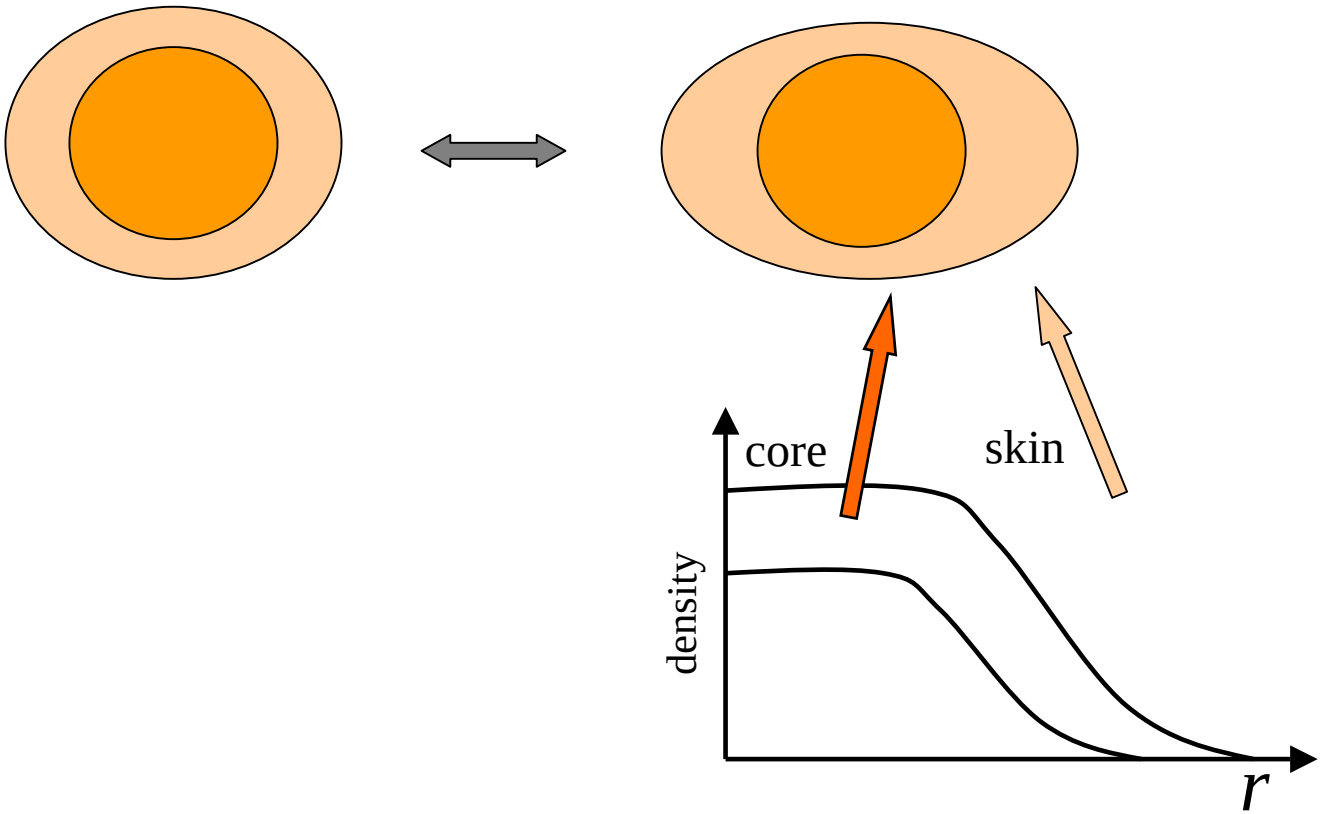
Low-lying modes unique to neutron-rich nuclei

Quadrupole vibration of neutron skin



Effect of Deformation ? Pairing ? Continuum ?

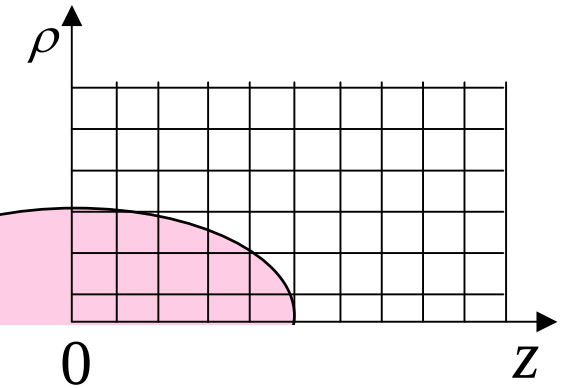
In deformed superfluid system close to the drip line → Soft $K=0^+$ mode ?

QRPA calculation simultaneously taking into account

Deformation

Pairing → Deformed HFB

Continuum → Box discretization



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

→ First results of such a calculation

Investigation of deformed neutron-rich nuclei

Ground state

Coordinate-space HFB equation

Mean-field Deformed Woods-Saxon potential

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

$V_0 = -450 \text{ MeV fm}^3$

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

Excited state

QRPA equation in the AB matrix formulation

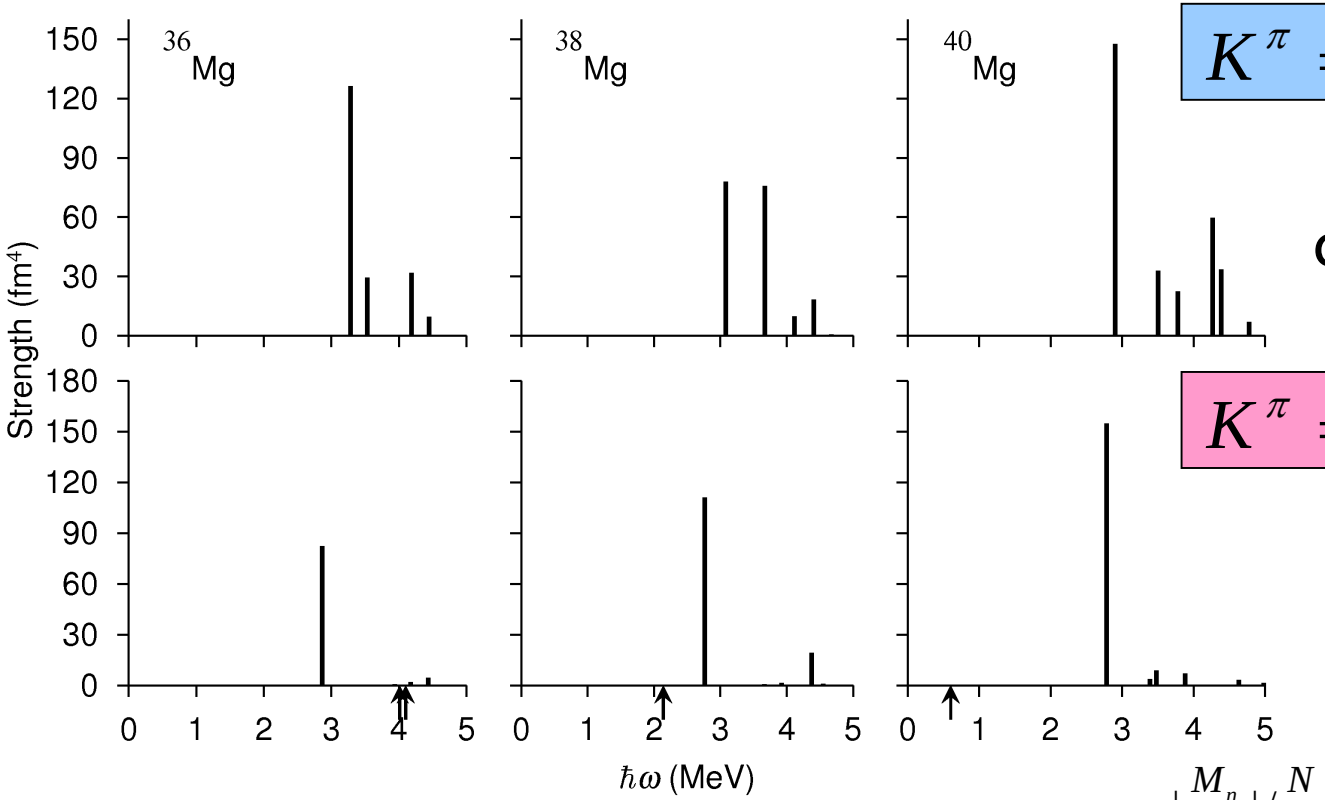
Residual interaction

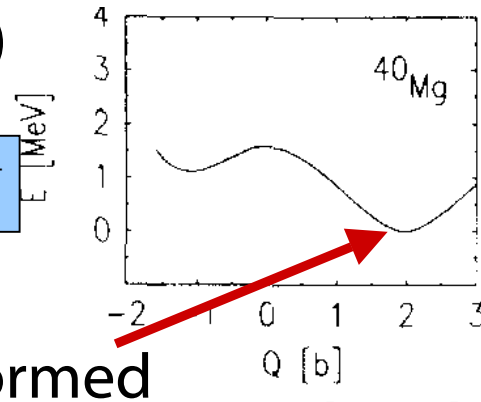
p-h channel $v_{\text{ph}}(\mathbf{r},\mathbf{r}') = [t_0(1+x_o P_\sigma) + \frac{t_3}{6}(1+x_3 P_\sigma)\rho(\mathbf{r})]\delta(\mathbf{r}-\mathbf{r}')$

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

Low-frequency quadrupole vibrations in deformed Mg isotopes close to the drip line

Isoscalar quadrupole transition strengths (intrinsic)





deformed

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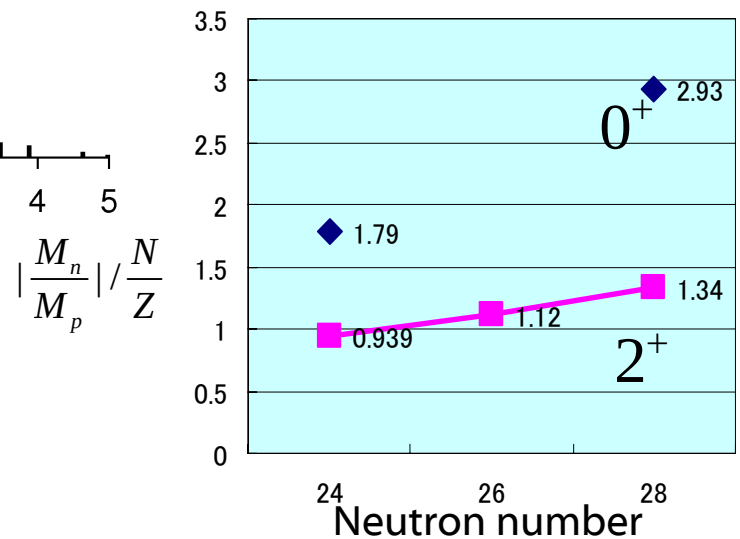
HFB, SIII

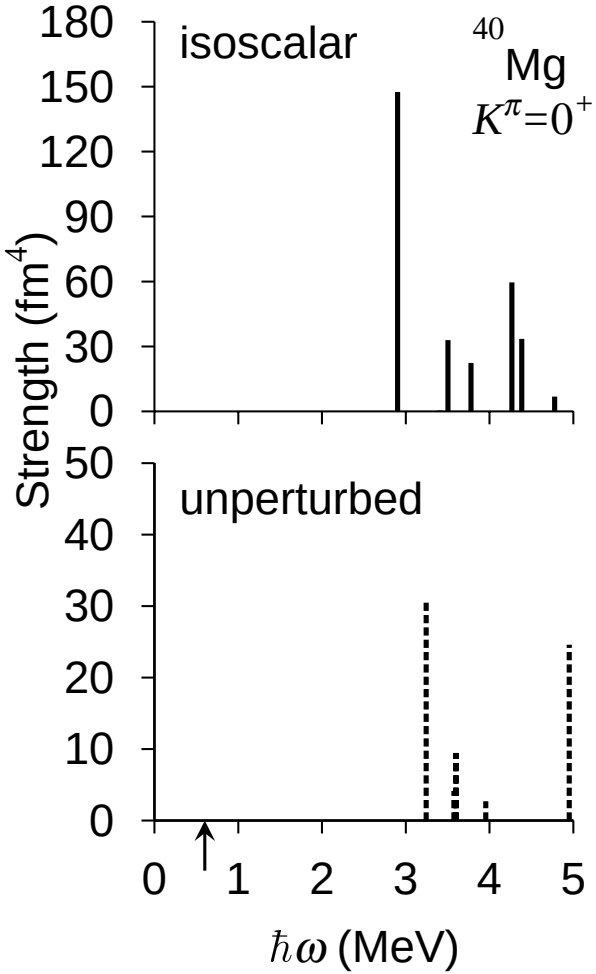


Neutron number increasing

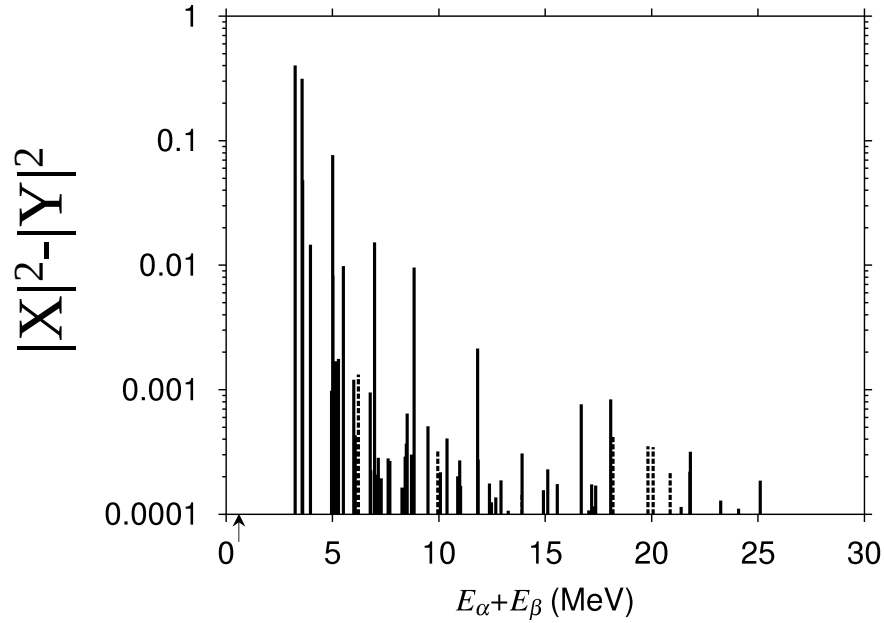
Enhancement of neutron excitation

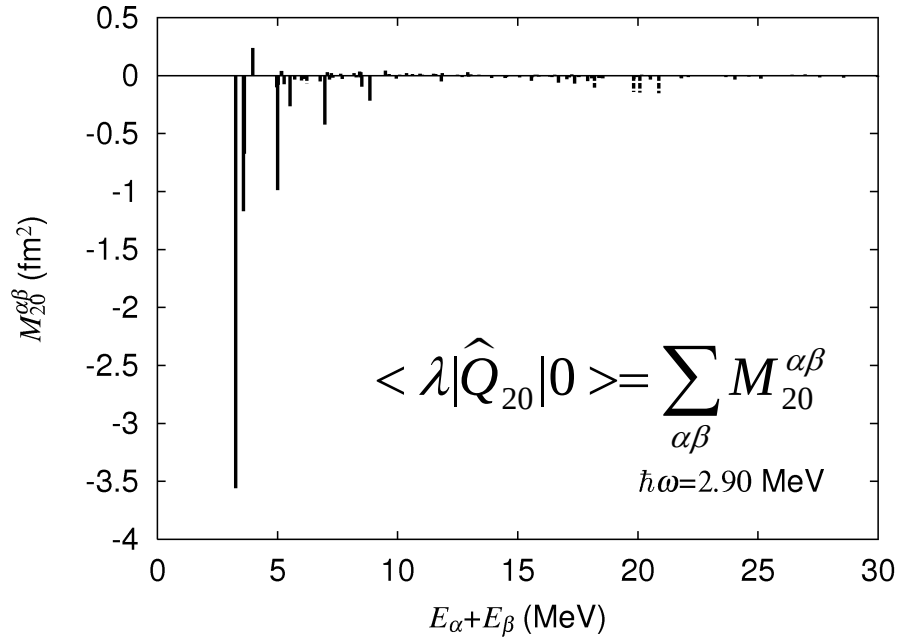
Soft K=0⁺ mode in deformed ^{40}Mg

$$\left|\frac{M_n}{M_p}\right| \Big/ \frac{N}{Z} = \frac{6.78}{2.33} = 2.9$$



1 W.u.=8.13 fm^4



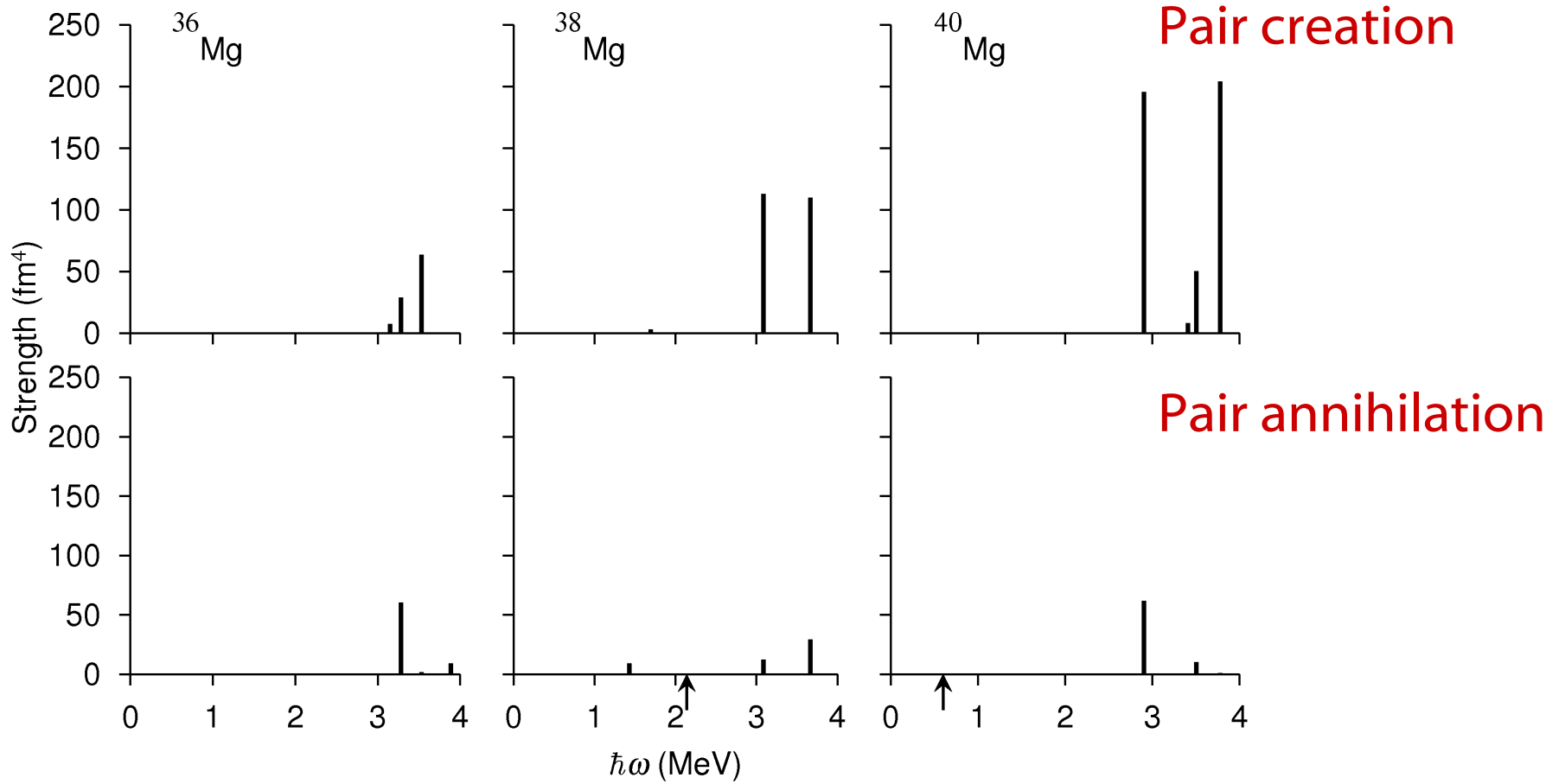


$$<\lambda|\hat{Q}_{20}|0> = \sum_{\alpha\beta} M_{20}^{\alpha\beta}$$

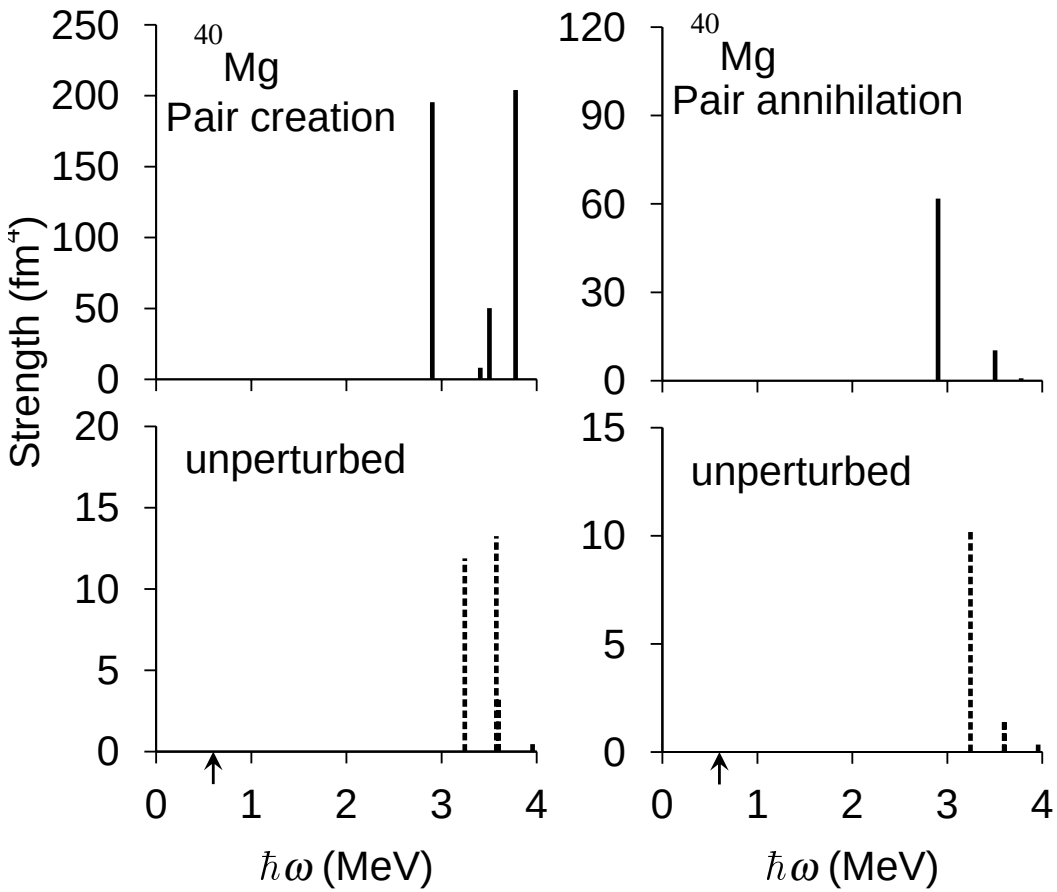
Two-neutron pair transition strengths

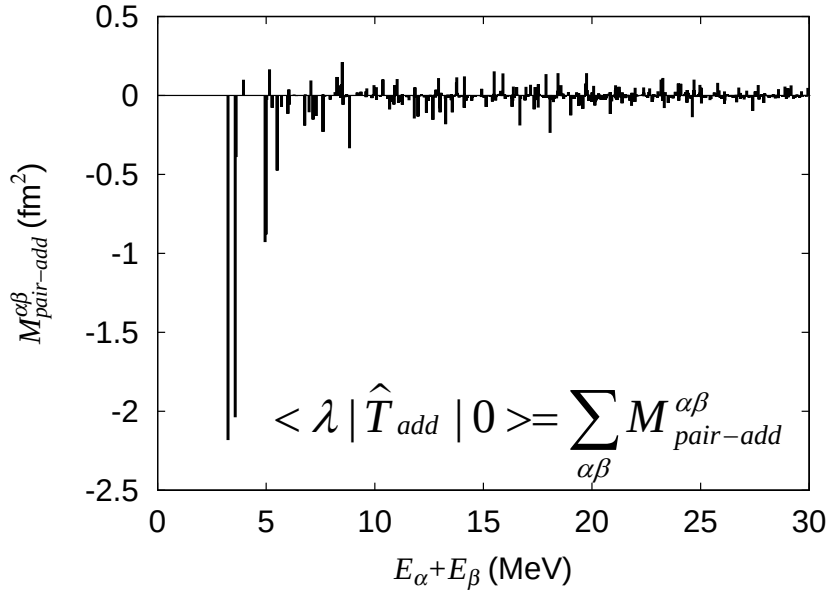
$$\hat{T}_{add} = \int d\mathbf{r} r^2 Y_{20} \psi^+(\mathbf{r},\uparrow)\psi^+(\mathbf{r},\downarrow) \;, \quad \hat{T}_{rem} = \int d\mathbf{r} r^2 Y_{20} \psi(\mathbf{r},\downarrow)\psi(\mathbf{r},\uparrow)$$

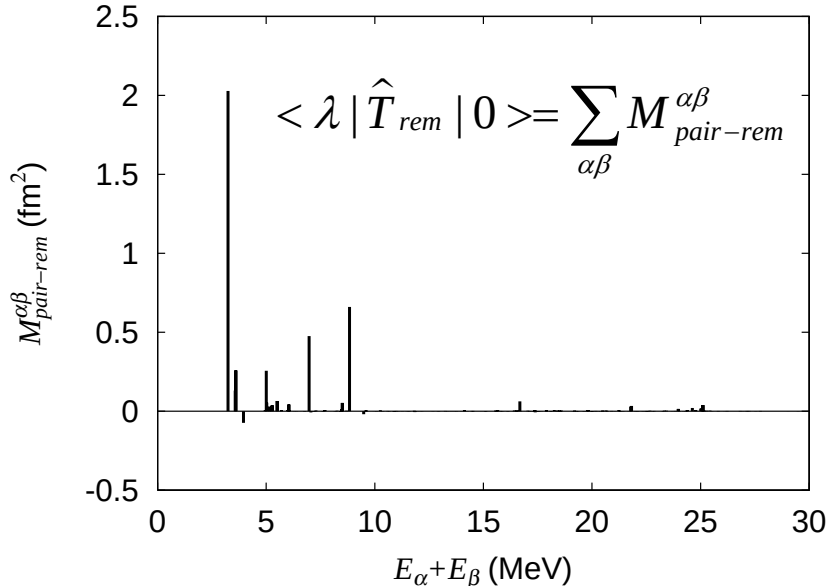
$$|<\lambda|\hat{T}|0>|^2$$



Pair creation/annihilation in ^{40}Mg







Mechanism for generation of soft K=0$^+$ mode

Collective both in p-h and in p-p channel

How to generate the coherent mode?

Why are the transition strengths large ? ~ 10-20 W.u. (intrinsic)

Two key points

Pair correlation

Effect of dynamical pairing

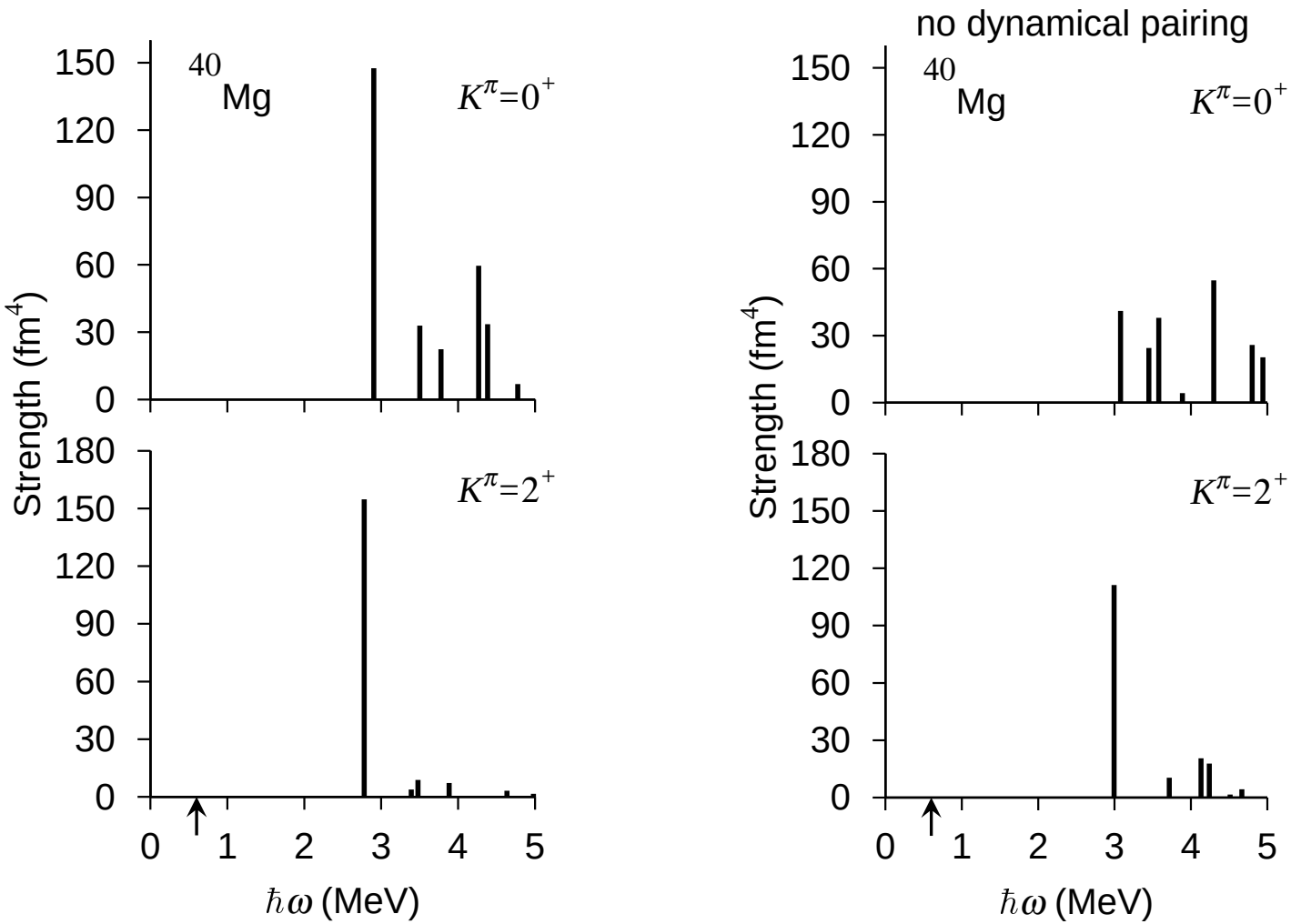
Weakly bound system

Spatial structure of quasiparticle wave functions

Dynamical pairing

Superposition of p-h, p-p and h-h vibrations

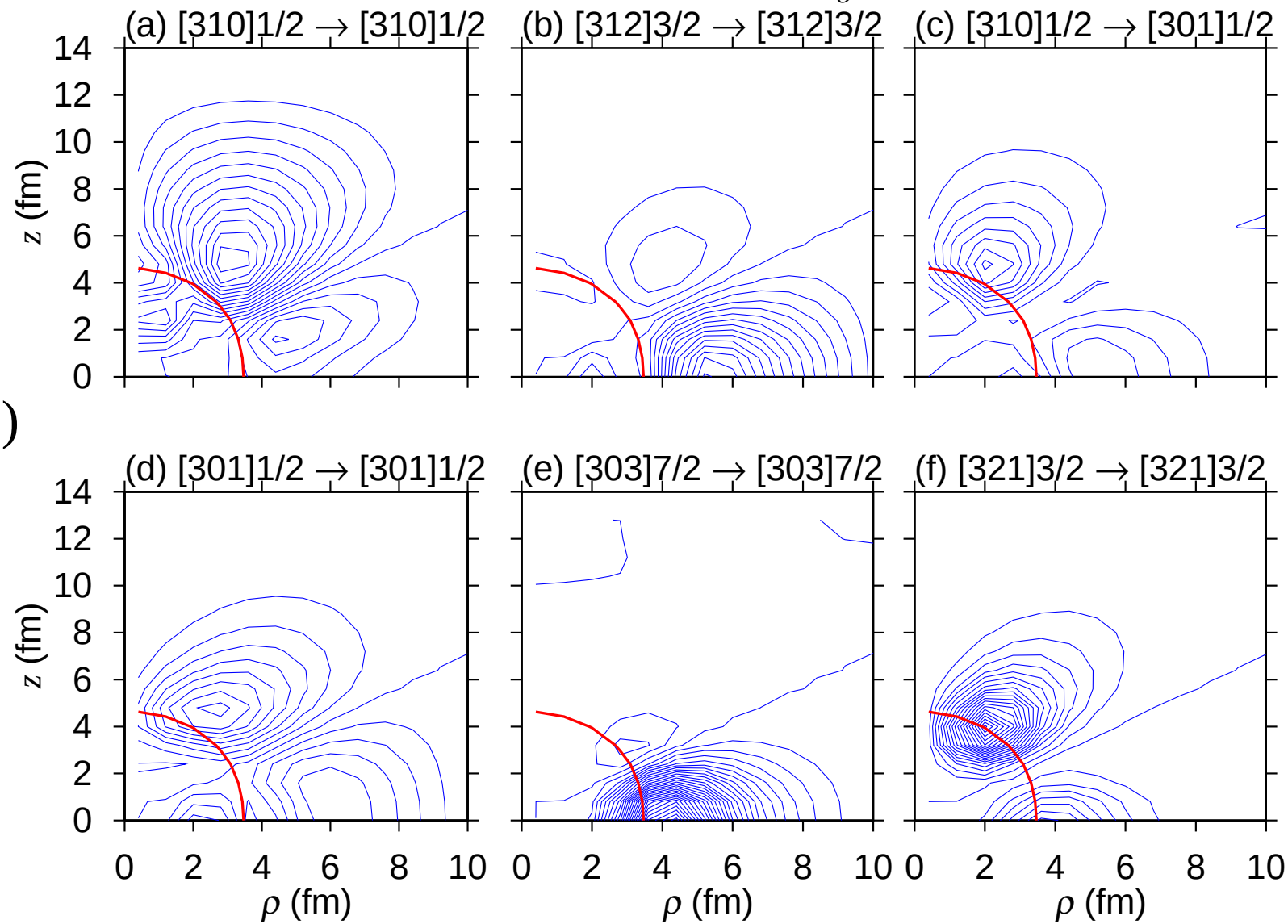
Generation of the coherence



Spatial structure of 2qp excitations (p-h channel)

$$< \alpha | \widehat{Q}_{20} | \beta > \equiv \int d\rho dz Q_{20}^{\alpha\beta}(\rho, z) \qquad \widehat{Q}_{20} = \sum_{\sigma} \int d\mathbf{r} r^2 Y_{20} \psi^{+}(\mathbf{r}, \sigma) \psi(\mathbf{r}, \sigma)$$

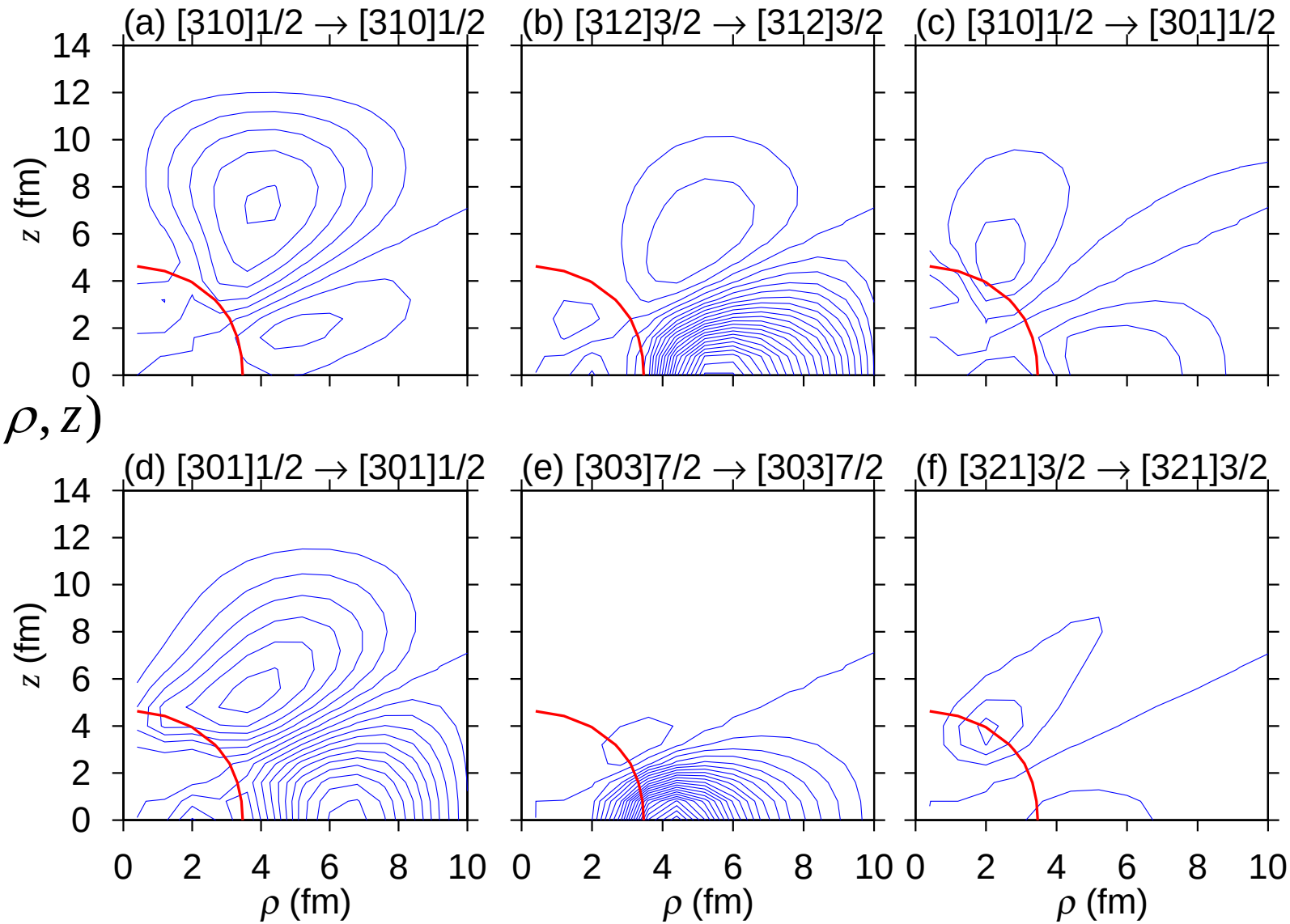
$Q_{20}^{\alpha\beta}(\rho, z)$



Spatial structure of 2qp excitations (p-p, h-h channel)

$$< \alpha\beta | \hat{T} | 0 > \equiv \int d\rho dz Q^{\alpha\beta}_{pair-add}(\rho, z) \qquad \hat{T} = \int d\mathbf{r} r^2 Y_{20} \psi^+(\mathbf{r}, \uparrow) \psi^+(\mathbf{r}, \downarrow)$$

$Q^{\alpha\beta}_{pair-add}(\rho, z)$



Summary

We have investigated properties of excitation modes in deformed Mg isotopes close to the neutron drip line.

Deformed QRPA calculation based on coordinate-space HFB including the continuum

We have obtained soft $K=0^+$ and 2^+ modes in $^{36\text{-}40}$Mg.

Spatial extension of two-quasiparticle wave functions

⇨ Large transition strengths

Coupling between quadrupole vib. and pairing vib.

Similar spatial structure of quasiparticle w.f. near the Fermi level

⇨ Generating coherent mode

$K=0^+$ mode is particularly sensitive to the dynamical pairing.

⇨ Good indicator of pair correlation in deformed drip-line nuclei