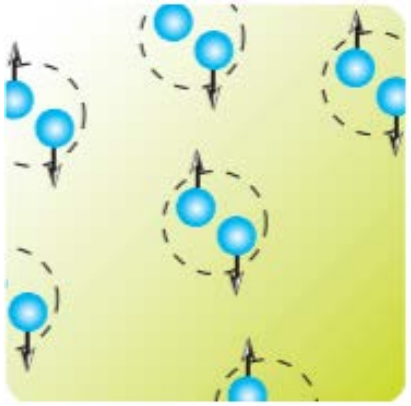
Momentum-space quasiparticle RPA calculation with Skyrme energy density functional for rotating weakly-bound nuclei

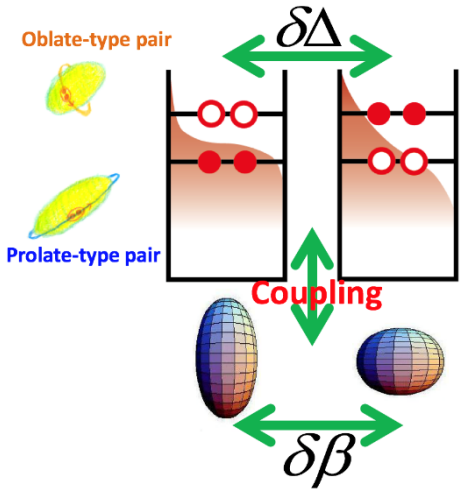
Masayuki Yamagami (*Univ. of Aizu, Japan*)

- Nuclear Physics -

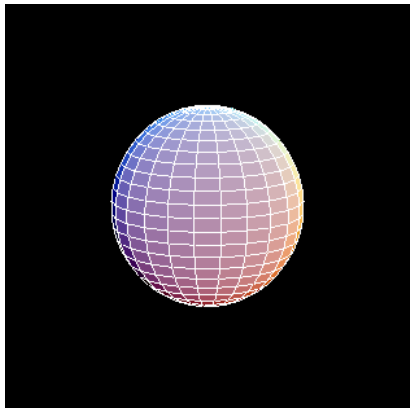
Pairing correlations



Pairing fluctuation



Quadrupole vib. ($K^\pi = 0^+$ mode)



New computer code *for exotic elementary excitations*

Elementary excitations

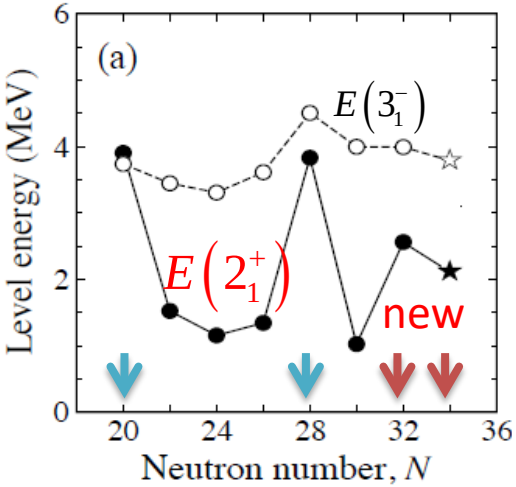
⇕ **Strongly associated**

Change of nuclear structure
Shell, Shape, Pairing, Rotation…

⇓ **As a comprehensive framework including these structure changes automatically**

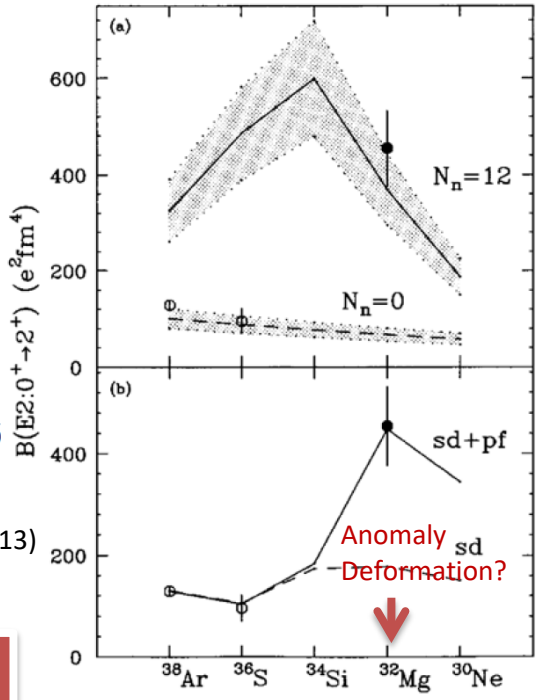
- **New computer code**
  Quasiparticle RPA *for rotating superfluid nuclei*
- **Application**
  Shape vibration induced by pairing fluctuation

New magic N=32,34 (Ca isotopes)



D. Steppenbeck et al,
J. Phys. Conf. Ser. 445 012012 (2013)

Vanishing N=20 (N=20 isotones)

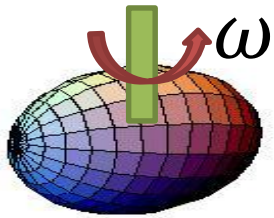


T. Motobayashi, *et al.*, PLB346, 9 (1995)

Pairing correlations

+

Deformation & Rotation



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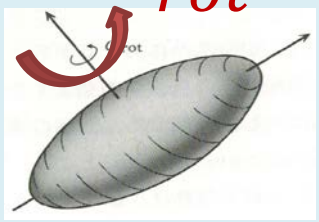
Exotic elementary Excitation??

Quasiparticle RPA in rotating frame

Microscopic theory for ***vibrations*** *of* ***rotating superfluid nuclei***

Hartree-Fock-Bogoliubov eq. for rotating nuclei

$$\begin{pmatrix} h-\omega_{rot}j_x & \Delta \\ -\Delta^* & -h^*+\omega_{rot}j_x^* \end{pmatrix}\begin{pmatrix} U_k \\ V_k \end{pmatrix} = E_k \begin{pmatrix} U_k \\ V_k \end{pmatrix}$$



- **Triaxial shape** & **NO time-reversal symmetry**
- **Skyrme-EDF** + mixed type pairing force
- **Momentum space representation** (→ **next slide**)

Triaxial shape

QRPA matrix equation

$$\sum_{ll'}\begin{pmatrix} A_{kk'll'} & B_{kk'll'} \\ -B^*_{kk'll'} & -A^*_{kk'll'} \end{pmatrix}\begin{pmatrix} f^{(\lambda)}_{ll'} \\ g^{(\lambda)}_{ll'} \end{pmatrix} = E_\lambda \begin{pmatrix} f^{(\lambda)}_{kk'} \\ g^{(\lambda)}_{kk'} \end{pmatrix}$$

- **Residual interaction:**
  Landau-Migdal approximation of Skyrme interaction
- **Cutoff for two-quasiparticle energy** : $E_k + E_l < 40$ MeV

Momentum space representation (k-space)

Merit: Smaller model space than ***r***-space representation

e.g. **40 times smaller** for octupole vibrations of Superdeformed state in ^{40}Ca

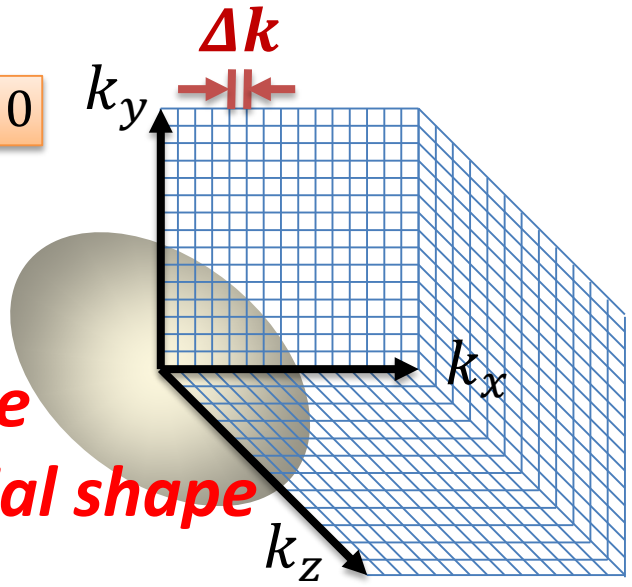
	Grid points N	Δk	$(\Delta k)^2 \propto \Delta\varepsilon_{sp}$
***k*-space rep.**	**560** $(0 \le k_x, k_y, k_z \le k_{max})$	**0.40 fm^{-1}**	**0.160 fm^{-2}**
r*-space rep.	**5625** $(0 \le x, y, z \le L_{box})$	**0.21 fm^{-1}**	**0.044 fm^{-2}**

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

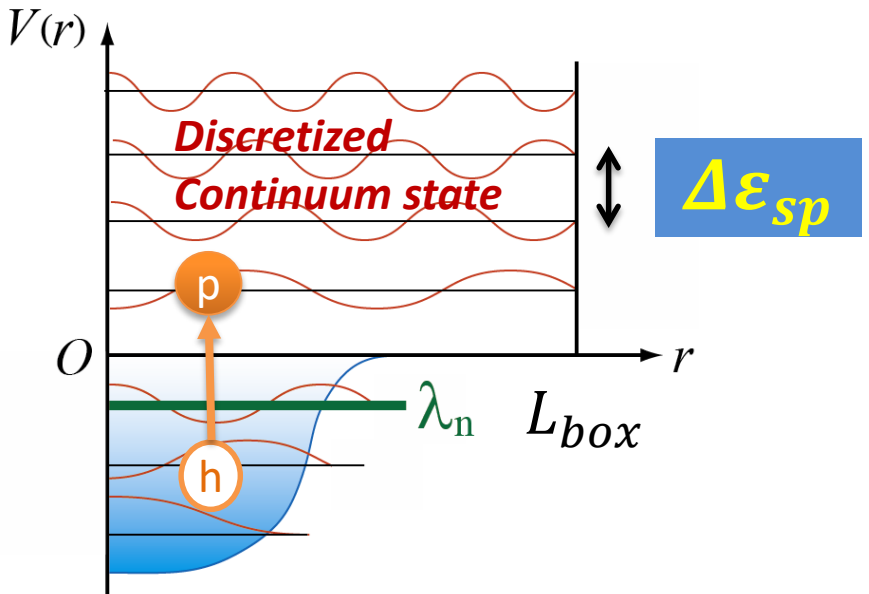
Smaller # of grid points

Smaller # of configurations

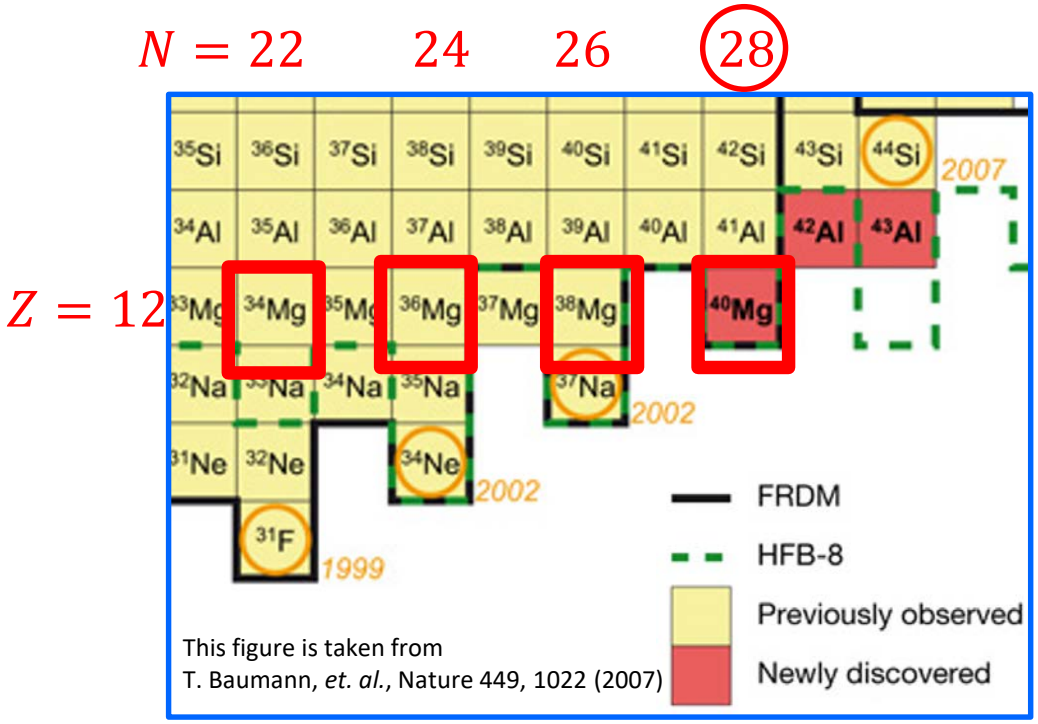
$k_x, k_y, k_z \ge 0$



1/8 space for triaxial shape



N-rich Mg isotopes: *Deformation and pairing*

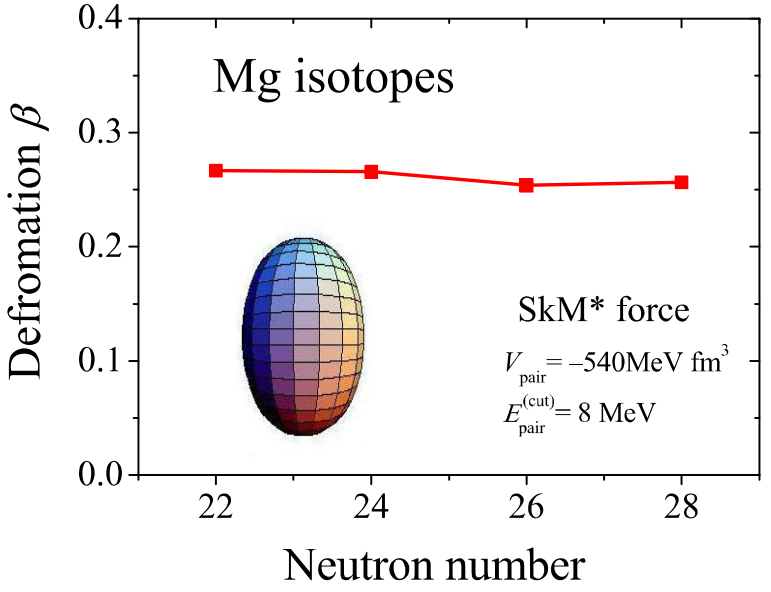


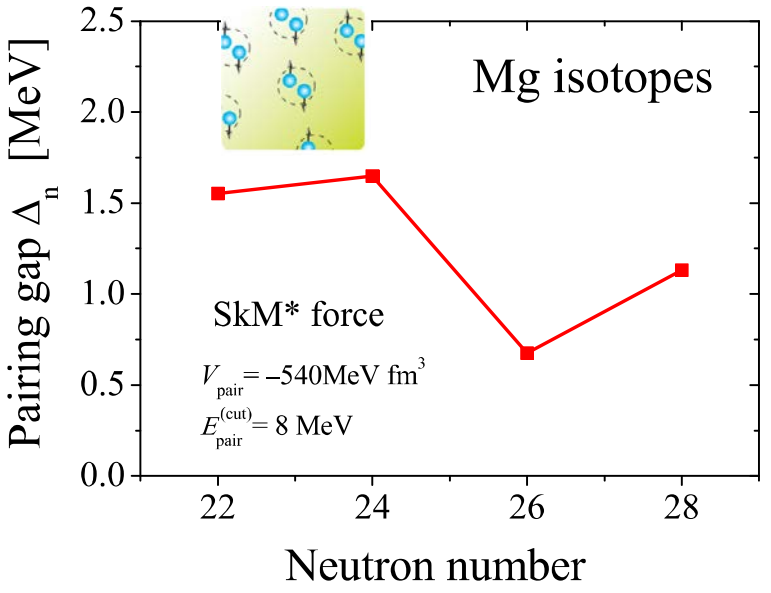
Experiment (E_{2^+},E_{4^+})

^{32}Mg: S.Takeuchi, *et al.*, Phys.Rev. C79, 054319 (2009)

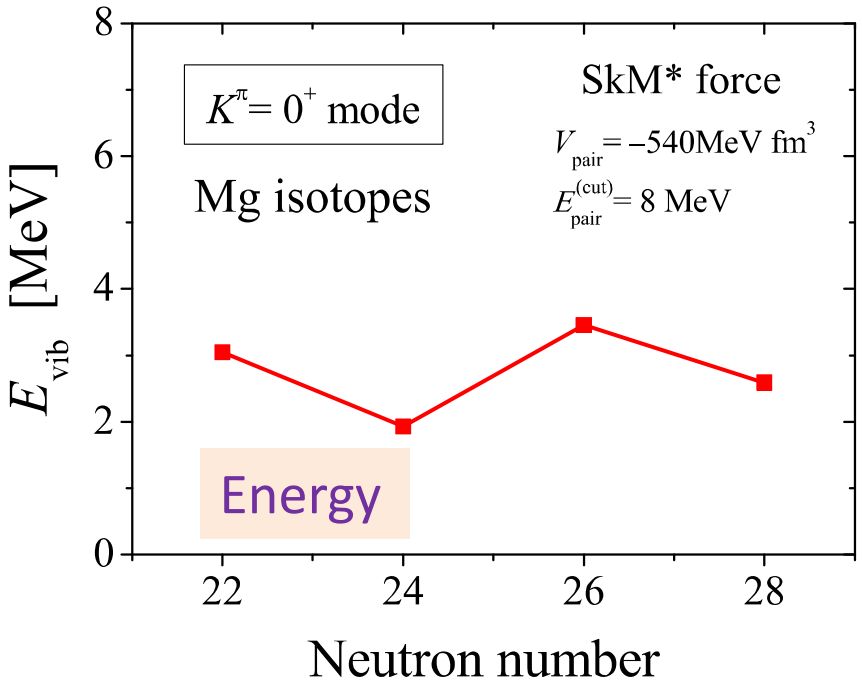
$^{34\text{-}38}$Mg: P.Doornenbal, *et al.*, Phys.Rev.Lett., 111, 212502 (2013)

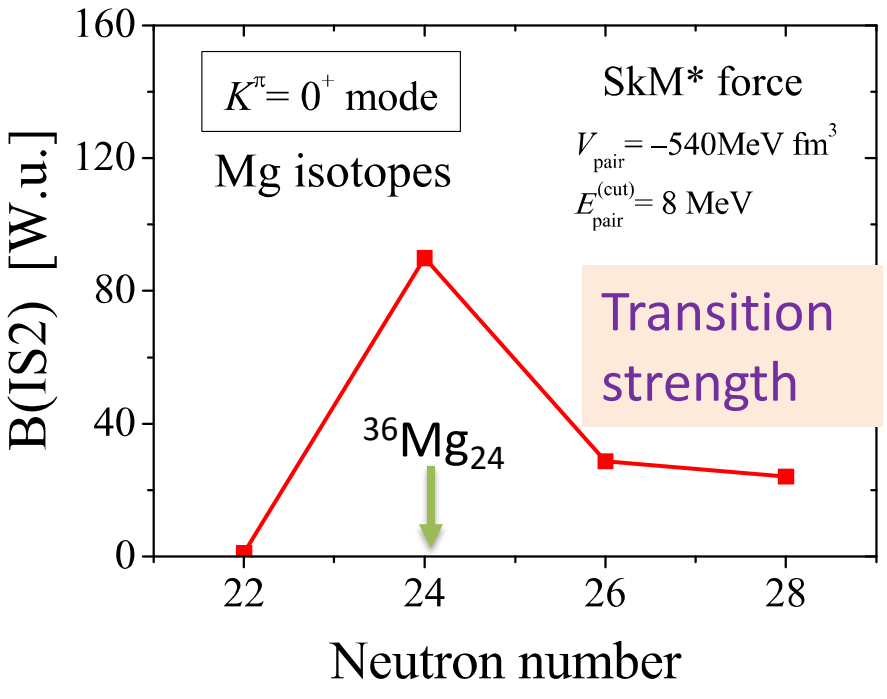
	E_{4^+}/E_{2^+} (Shape *Suggested*)	Theory
^{34}Mg	3.13 (Deformed)	Deformed
^{36}Mg	3.06 (Deformed)	Deformed
^{38}Mg	3.07 (Deformed)	Deformed
^{40}Mg	?	Deformed





K=0 mode of quadrupole vibrational excitation



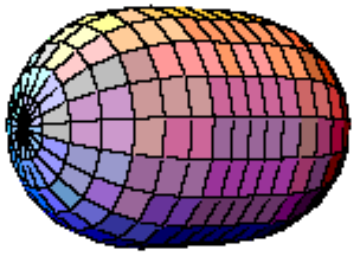


E_{vib}

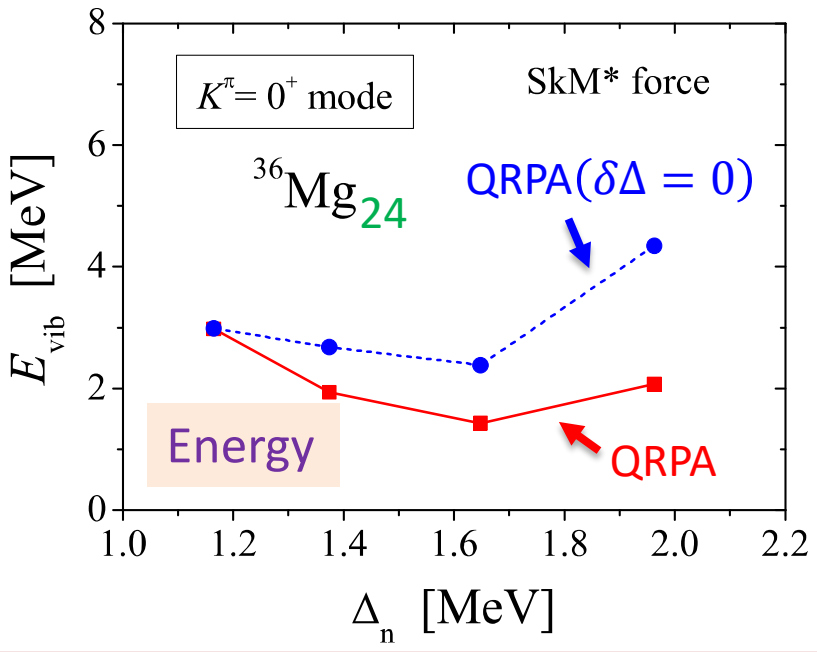
0

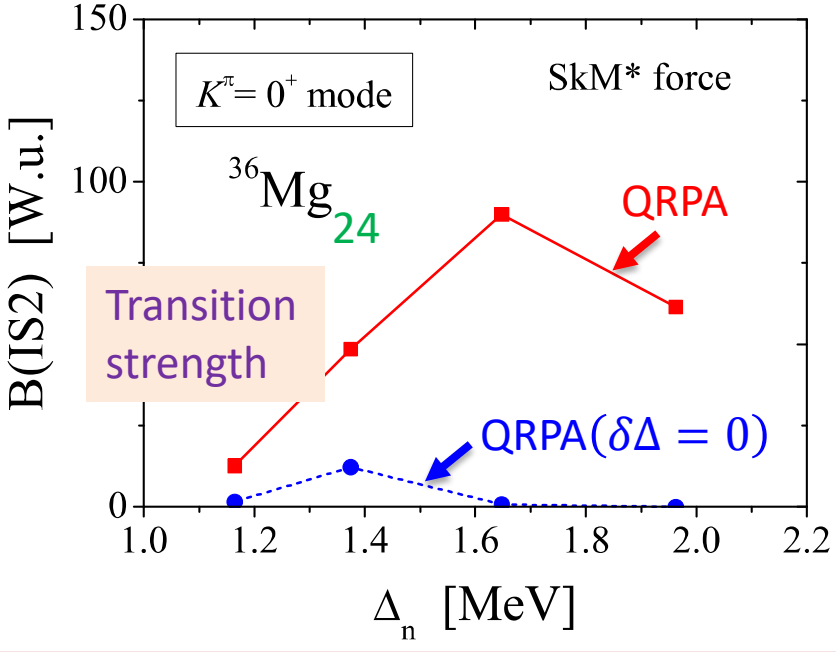
$$B(IS2) = |\langle vib|r^2 Y_{20}|0\rangle|^2$$

$K = 0$

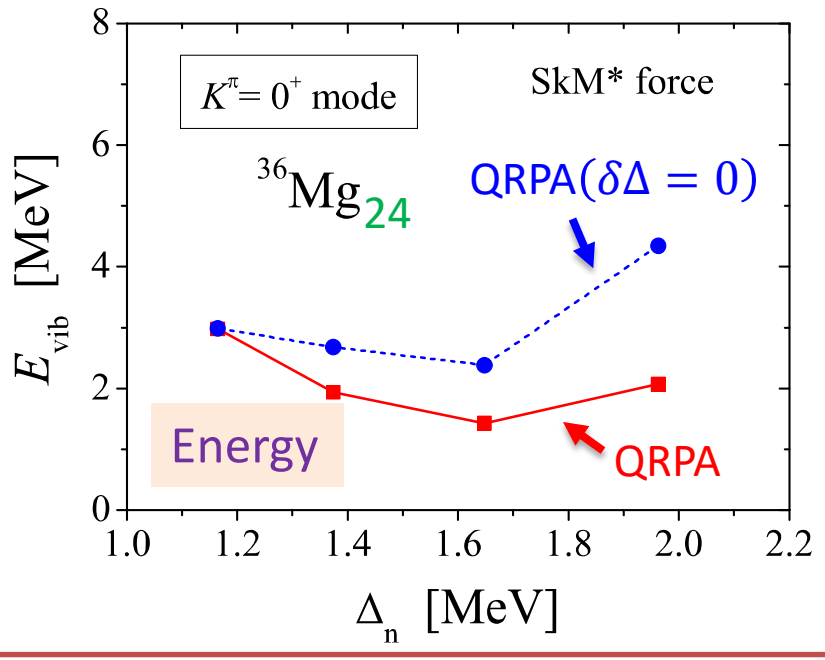


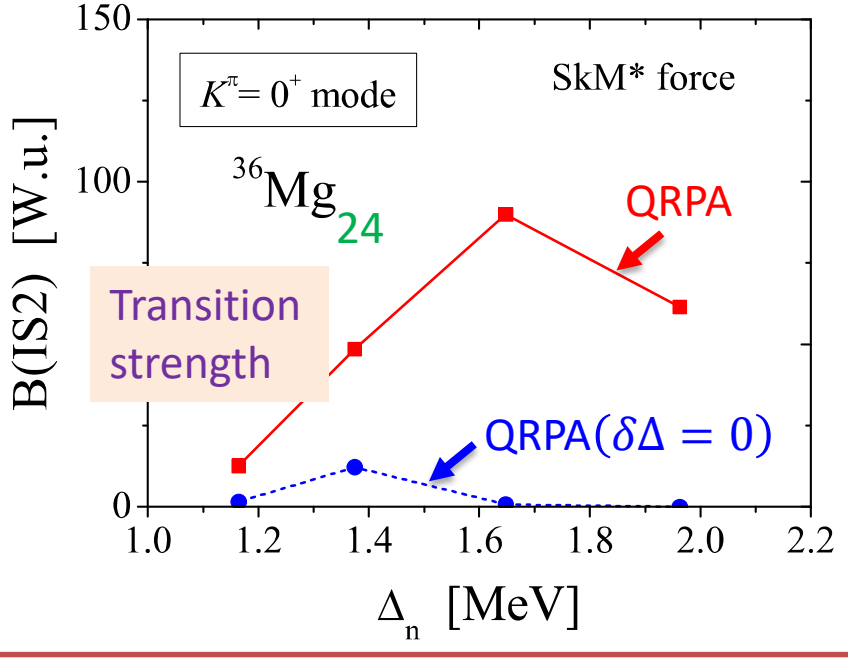
Pairing dependence in ^{36}Mg (N=24)

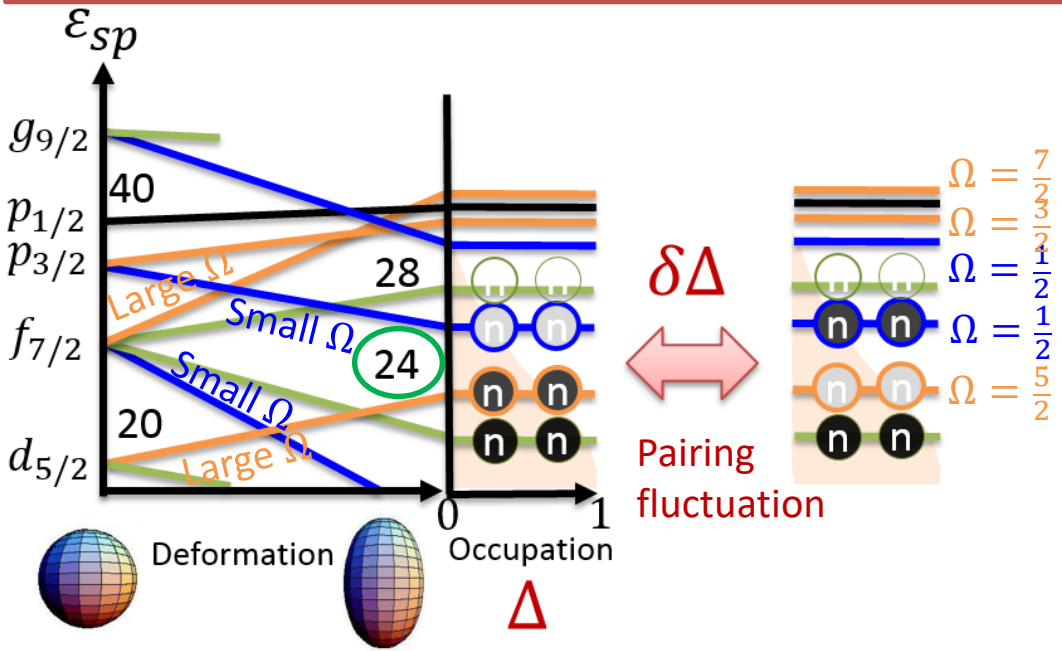


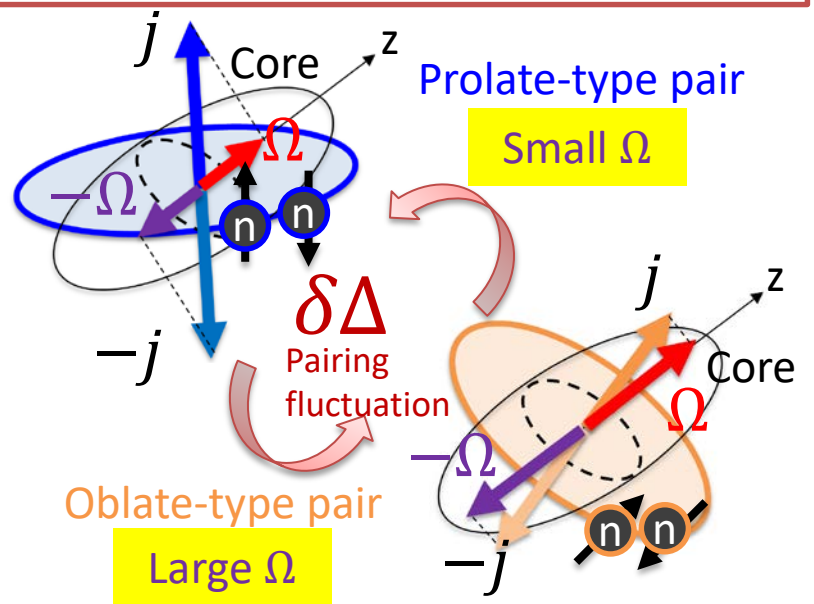


Pairing dependence in ^{36}Mg (N=24)



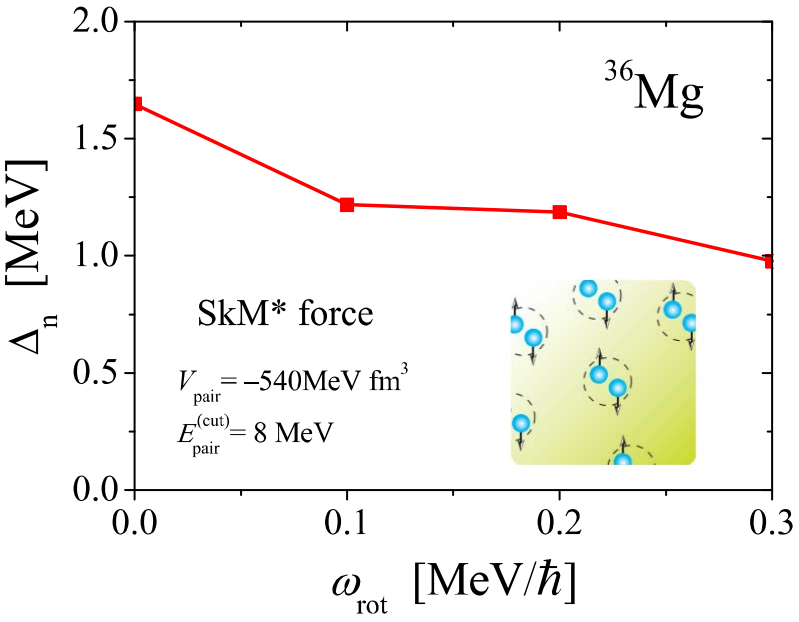






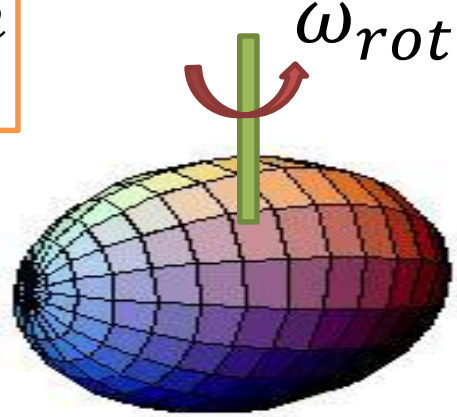
See also K.Yoshida, M.Y., PRC77, 044312 (2008)

Effect of rotation in ^{36}Mg

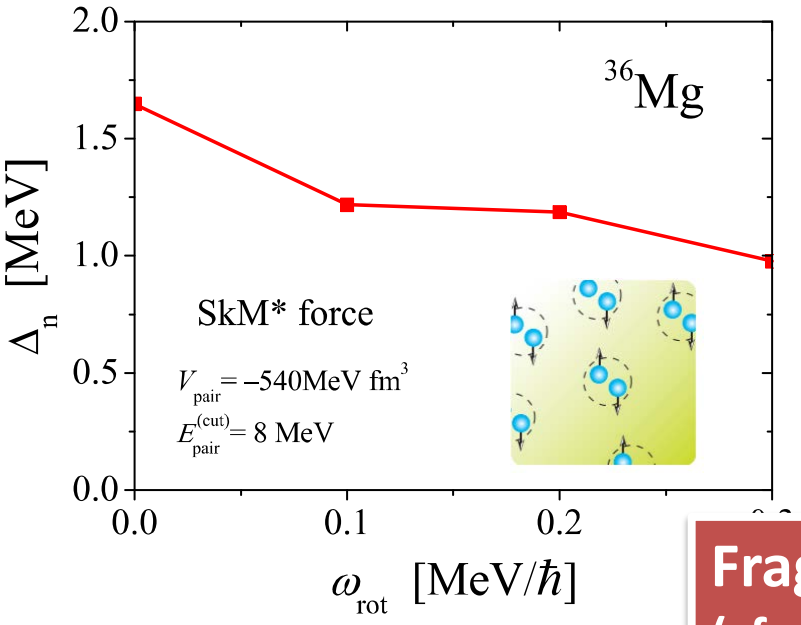


$$\omega_{rot} \lesssim 0.3\ \mathrm{MeV}/\hbar$$
$$I_{coll} \lesssim 4\hbar$$

Breaking of
time-reversal symmetry

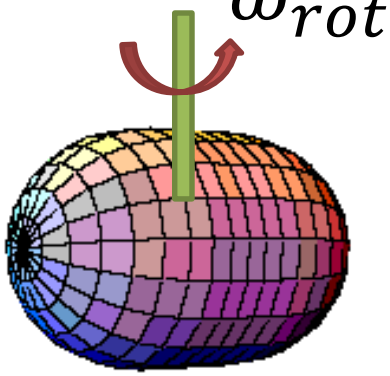


Effect of rotation in ^{36}Mg

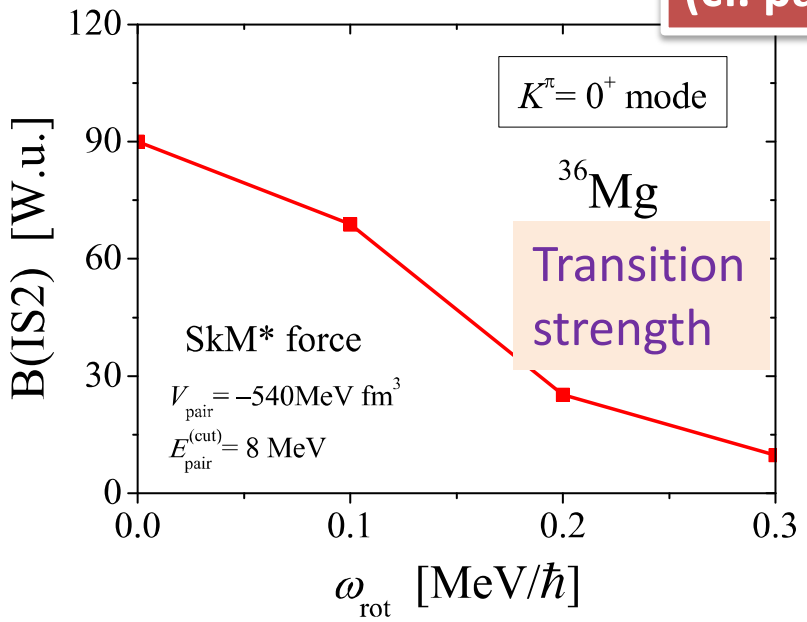


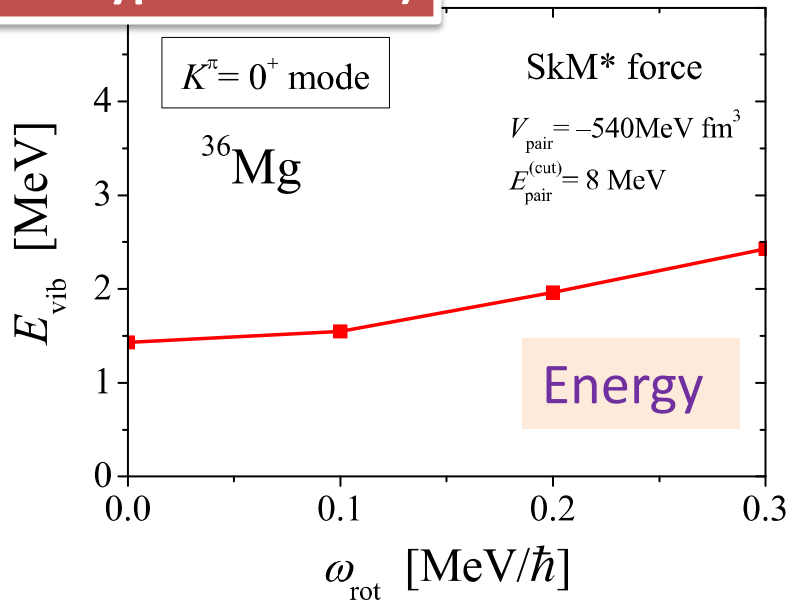
$\omega_{rot} \lesssim 0.3$ MeV/$\hbar$
$I_{coll} \lesssim 4\hbar$

Breaking of
time-reversal symmetry



Fragile excitation!
(cf. particle-hole type vibration)





Summary

New code:

Quasiparticle RPA in rotating frame

- Microscopic theory for *vibrations of rotating superfluid nuclei* -

- **Skyrme-EDF** (we expect the predictive power)
- **Triaxial shape & NO time-reversal symmetry** (comprehensive tool)
- **Momentum space representation** (suitable for unstable nuclei)

Application:

***K*=0 mode of quadrupole vibrational excitation in n-rich Mg**

- **Pairing fluctuation is essential**
- **Strong sensitivity to rotation**

  → Necessity of microscopic theory ***such as QRPA in rotating frame***

Future development:

1) Heavier mass regions, 2) Extension to large-amplitude motions,…