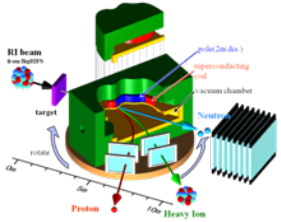


SAMURAI WS

Pygmy and giant resonances in neutron-rich nuclei

RIKEN NiSHiNA CENTER

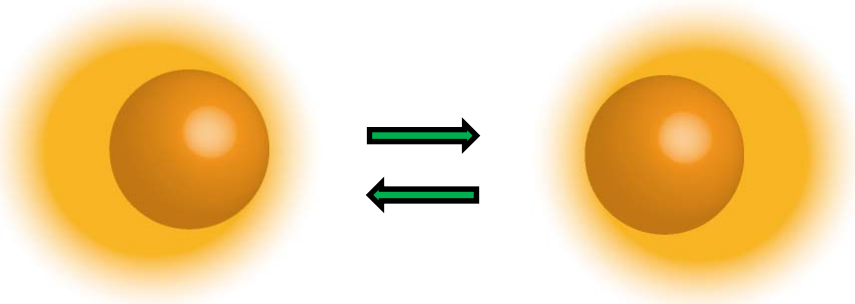
Kenichi Yoshida

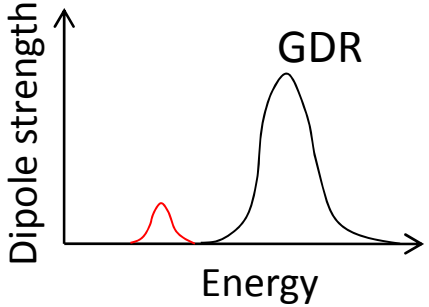
Collective modes unique to neutron-rich nuclei

Neutron excess

- ✓IS and IV mixing modes
- ✓Neutron-excitation dominant modes
- ✓Neutron-skin excitation modes

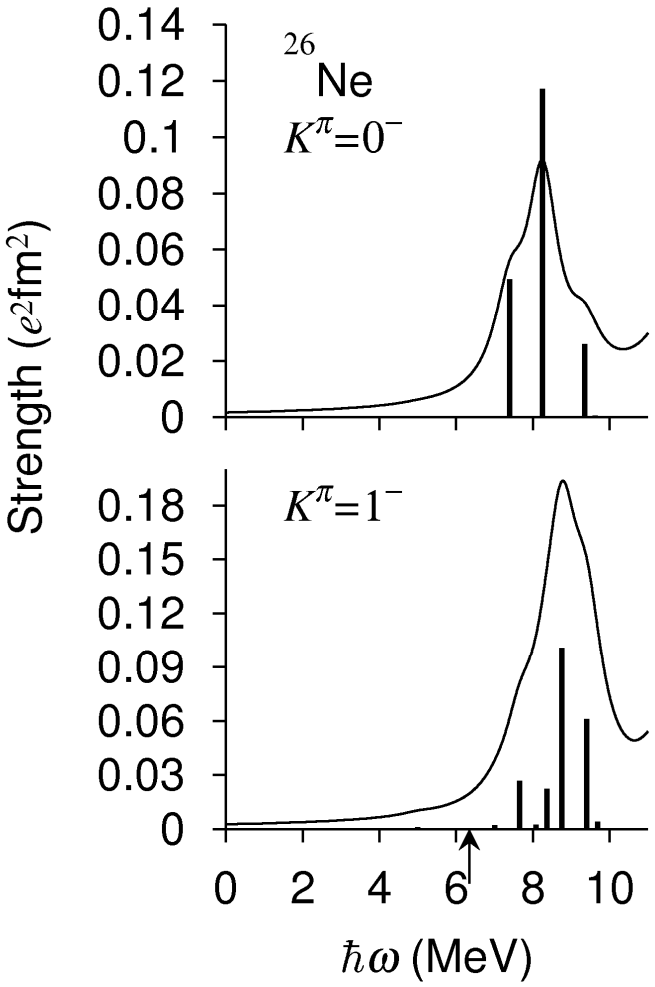
Soft dipole mode, Pygmy resonance



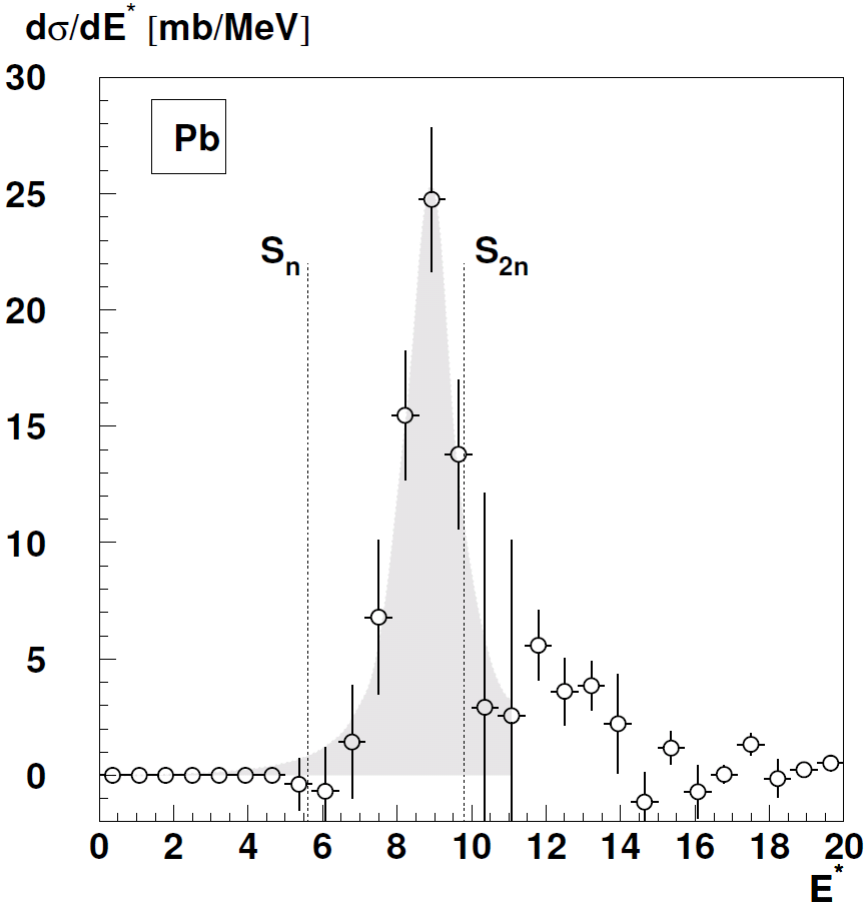


Pygmy resonance in ^{26}Ne

KY, N.V.Giai, PRC78(2008)014305



J.Gibelin *et al.*, PRL101(2008)212503



6% of the TRK sum rule (up to 10MeV)

Single-particle excitation is dominant: $\nu(2s_{1/2}^{-1}1p_{3/2})$

Decay pattern of pygmy resonance

J.Gibelin *et al.*, PRL101(2008)212503

TABLE I. Experimental neutron branching ratios for the structure at $E^* \sim 9$ MeV in ^{26}Ne to the ^{25}Ne states, compared to statistical decay calculations [26] for several multipolarities. We assumed that the reaction on ^{27}Al induces only $L = 2$ transitions, see text.

Final ^{25}Ne state		Experiment			Statistical decay		
Energy (MeV)	J^π	Pb	Pb ($L = 1$)	Pb ($L = 2$) = Al	$L = 1$	$L = 2$	$L = 3$
0.0	$1/2^+$	$5^{+17}_{-5}\%$	$5^{+32}_{-5}\%$	$4^{+5}_{-4}\%$	40%	28%	22%
1.7 & 2.0	$5/2^+ + 3/2^+$	$66\% \pm 15\%$	$42\% \pm 30\%$	$95^{+5}_{-15}\%$	55%	67%	75%
3.3	$(3/2^-)$	$35\% \pm 9\%$	$60\% \pm 17\%$	$5^{+6}_{-5}\%$	5%	4%	3%

A striking feature of the observed decay pattern is the absence of decay to the ^{25}Ne GS, which is in contradiction with the predicted structure of the pygmy states. Indeed, it

Theoretical branching ratios, presently not available, are highly desirable for a more precise comparison. We note

Collective modes unique to neutron-rich nuclei

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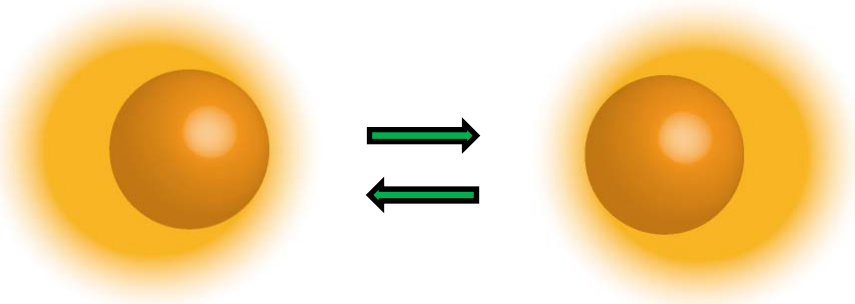
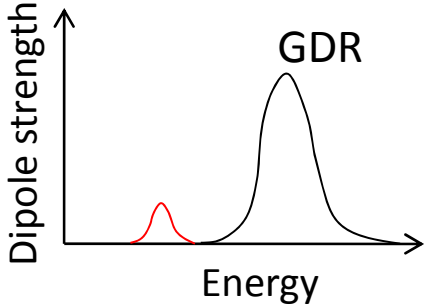
Soft dipole mode, Pygmy resonance





Deformation

Mixing of modes with different angular momenta

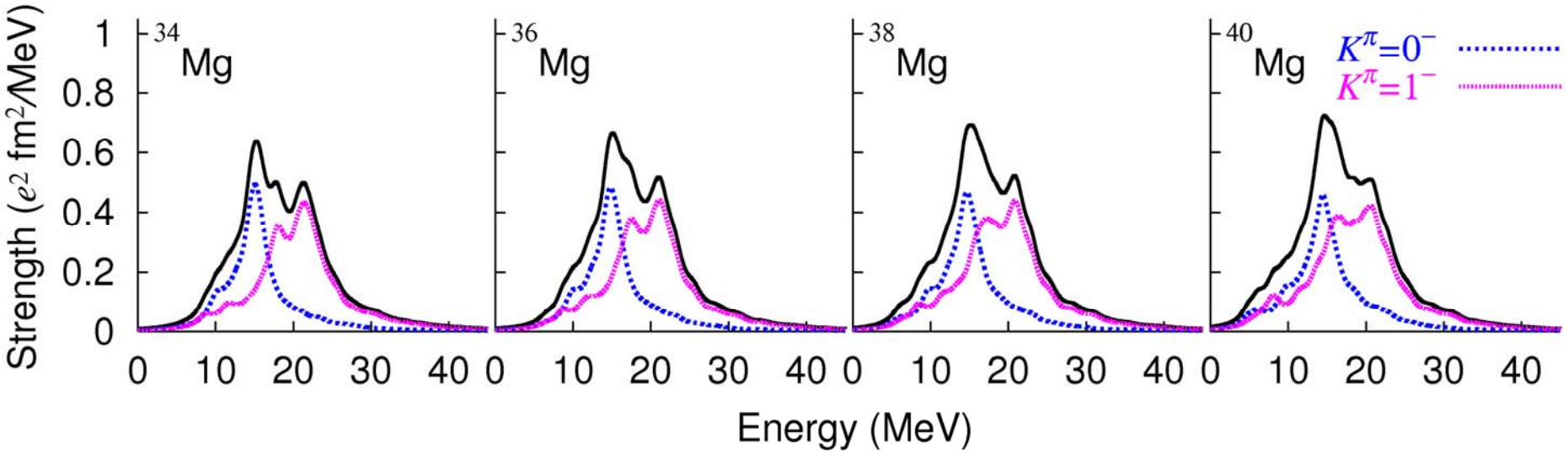
Pygmy resonance + collective octupole mode

A new kind of negative-parity excitation mode !?

IV dipole excitations in neutron-rich Mg isotopes

KY, PRC80(2009)044324

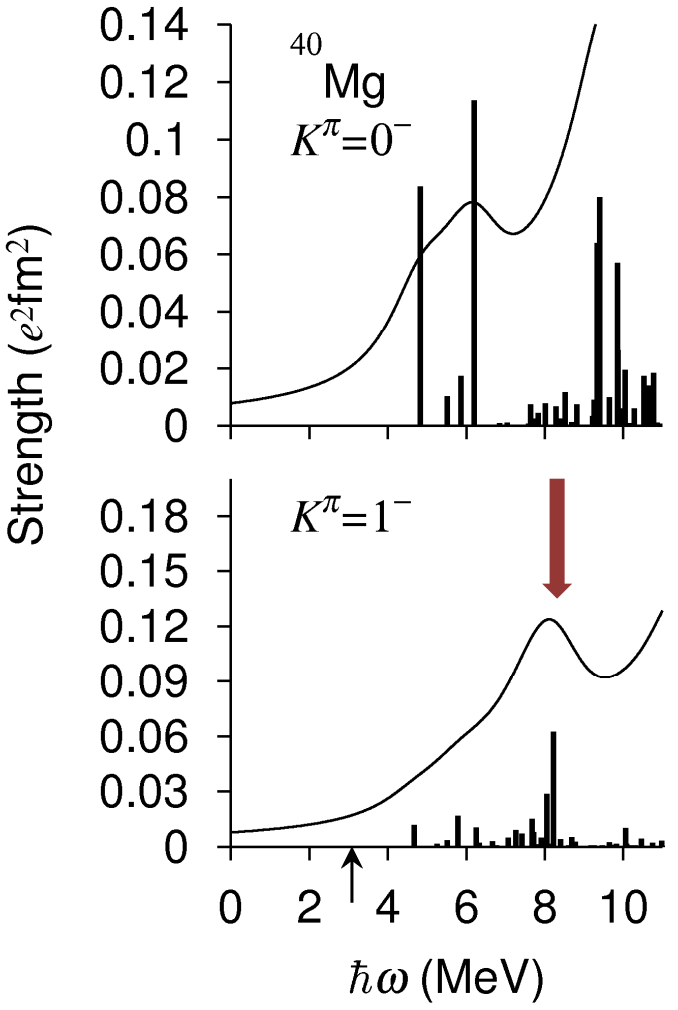
	^{34}Mg	^{36}Mg	^{38}Mg	^{40}Mg
$\beta_{2,n}$	0.35	0.31	0.29	0.28
$\beta_{2,p}$	0.41	0.39	0.38	0.36

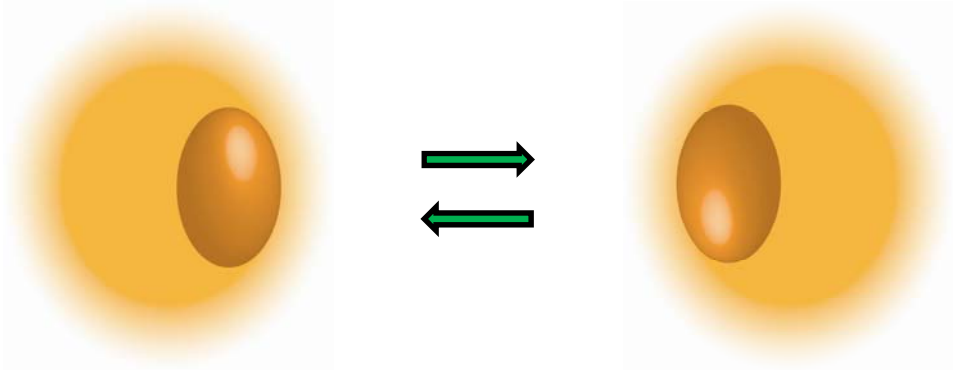


GDR: "K splitting" ⟹ good indicator of deformation

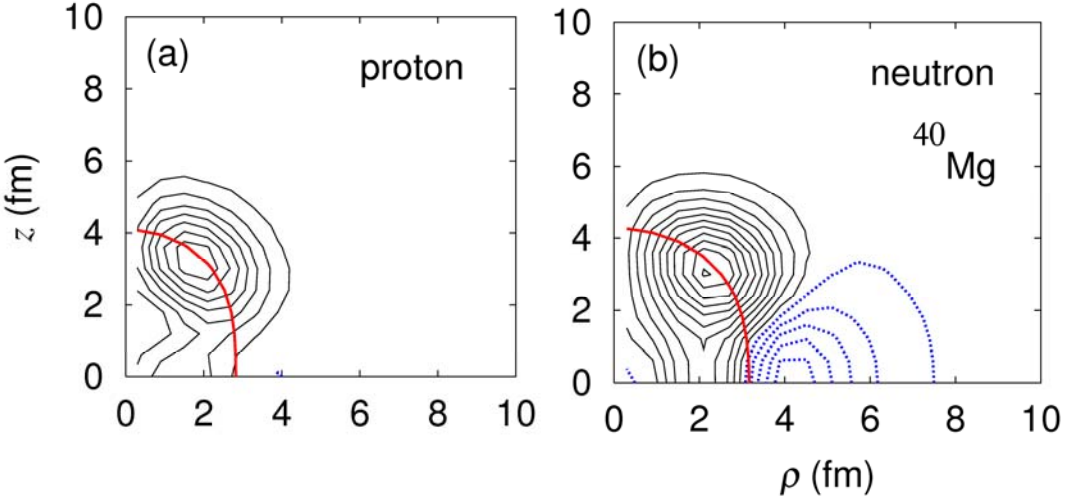
- Unique feature in neutron drip-line nuclei
  - ✓As approaching the drip line, the bump structure below 10MeV develops.

Pygmy mode in ^{40}Mg





Transition density (8.2 MeV)



Microscopic structure of pygmy mode in ^{40}Mg

At 8.22 MeV

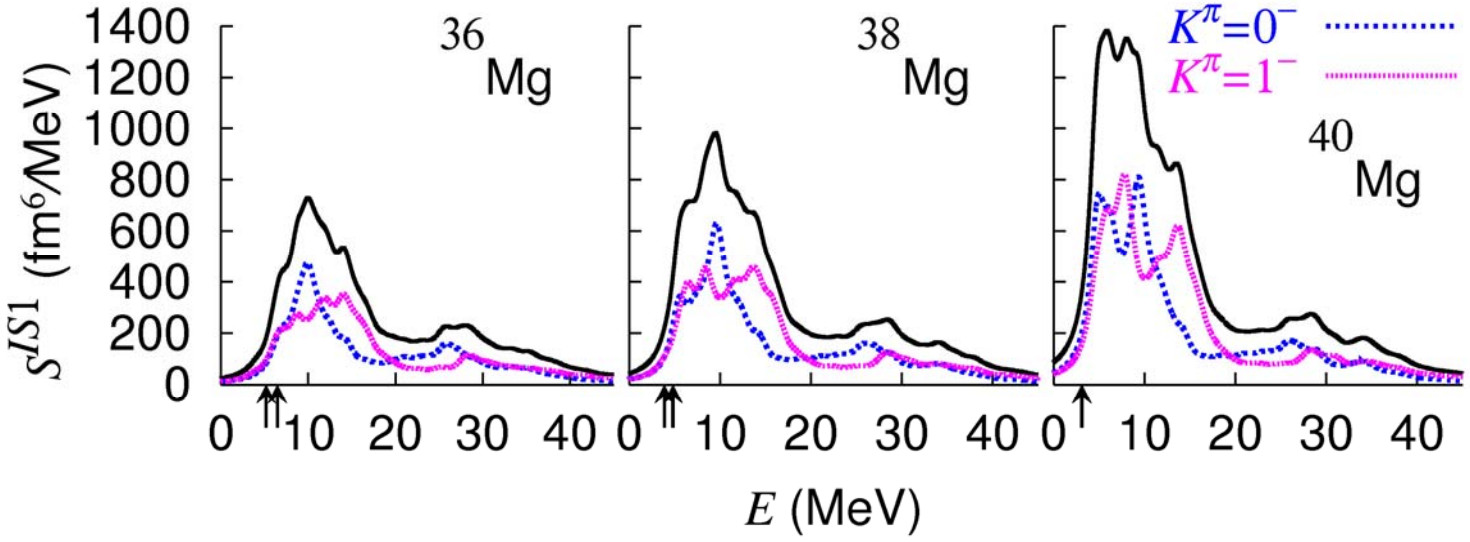
2qp excitations with $X^2 - Y^2 \geq 0.02$

	α	β	$E_\alpha + E_\beta$ (MeV)	$X^2_{\alpha\beta} - Y^2_{\alpha\beta}$	$D_{1,\alpha\beta}$ (e fm)	$O_{1,\alpha\beta}$ (fm^3)
(a)	$\nu[202]3/2$	$\nu[321]1/2$	8.28	0.289	0.164	−14.8
(b)	$\nu[200]1/2$	$\nu[312]3/2$	8.26	0.167	−0.190	10.5
(c)	$\nu[321]3/2$	$\nu[440]1/2$	7.49	0.062	0.054	29.7
(d)	$\nu[303]7/2$	$\nu[422]5/2$	7.92	0.050	0.059	3.82
(e)	$\nu[310]1/2$	$\nu 3/2^+$	7.96	0.037	0.159	16.4
(f)	$\nu[200]1/2$	$\nu[312]3/2$	9.04	0.034	0.011	−5.05
(g)	$\nu[200]1/2$	$\nu[310]1/2$	7.72	0.030	−0.053	−5.72
(h)	$\nu[303]7/2$	$\nu[413]5/2$	9.74	0.021	−0.087	10.7
(i)	$\nu[312]5/2$	$\nu[411]3/2$	6.91	0.020	0.073	23.4
(j)	$\nu[312]5/2$	$\nu 3/2^+$	8.97	0.020	0.106	−2.29

Generated by many 2qp excitations !

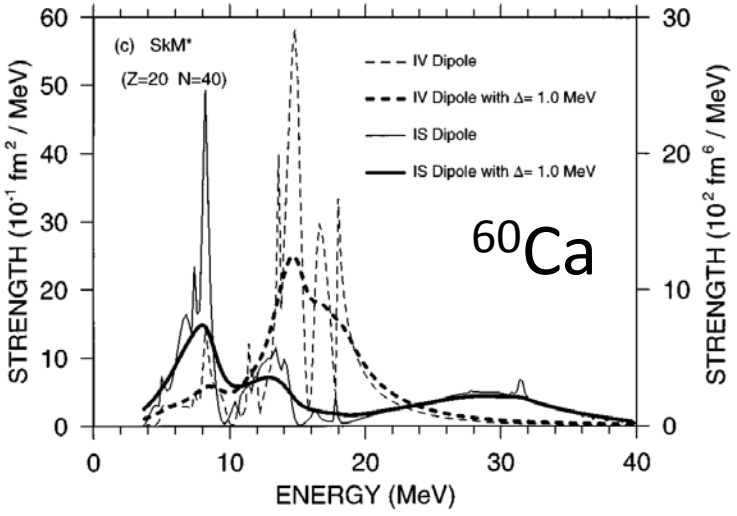
Isoscalar character of the pygmy mode

Responses for the compression dipole operator



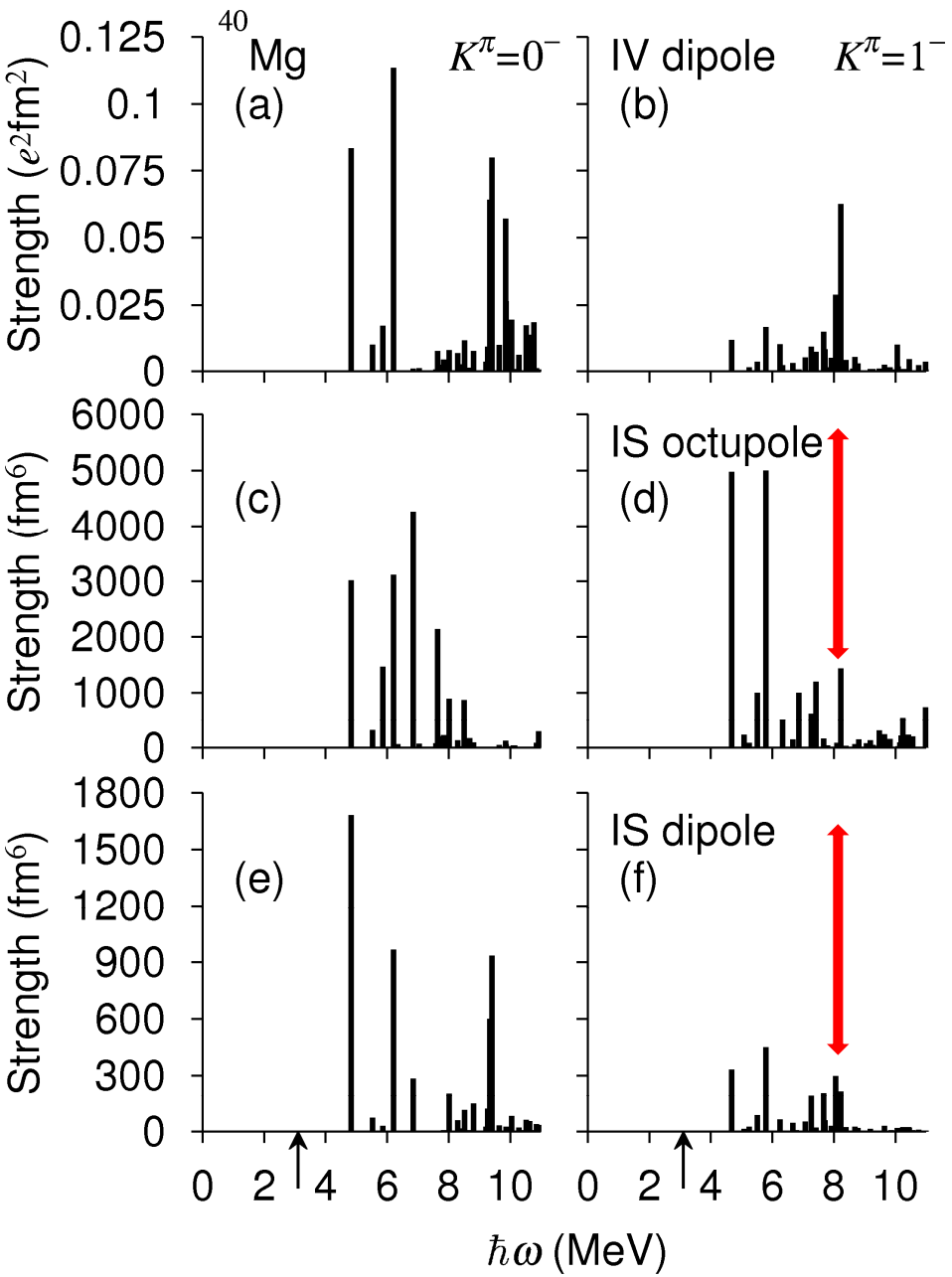
Tremendous enhancement of the transition strengths in the low-energy region

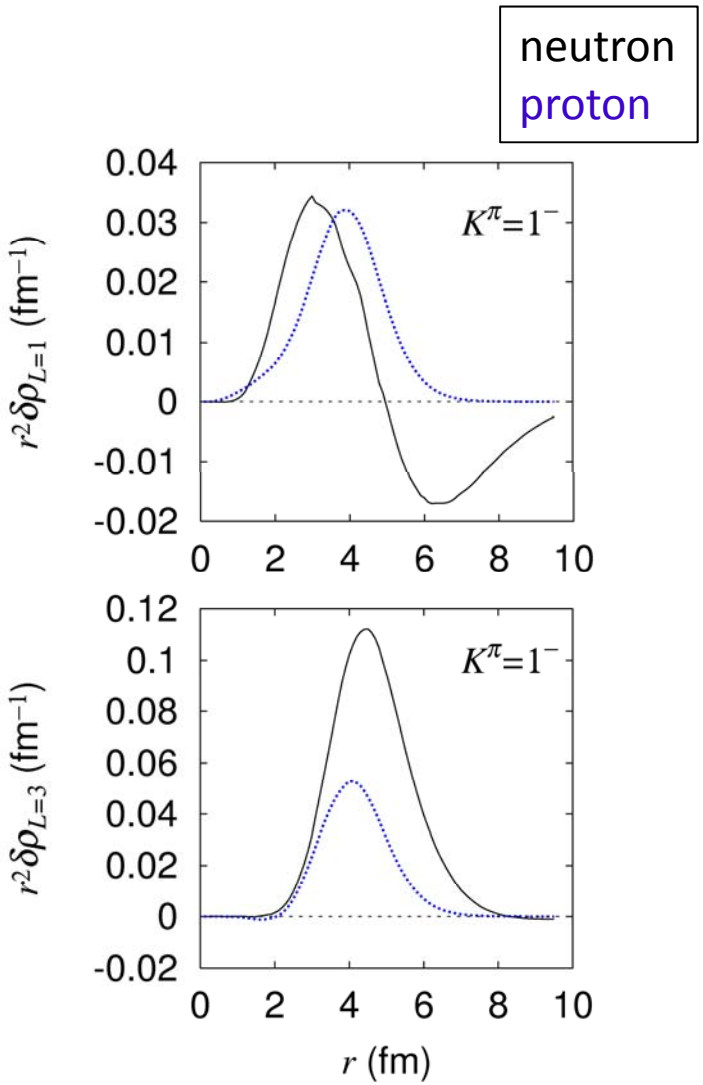
NEUTRON SKIN EFFECT (?)



I.Hamamoto, H.Sagawa, X.Z.Zhang, PRC57(1998)R1064

Mixing of different modes of excitation





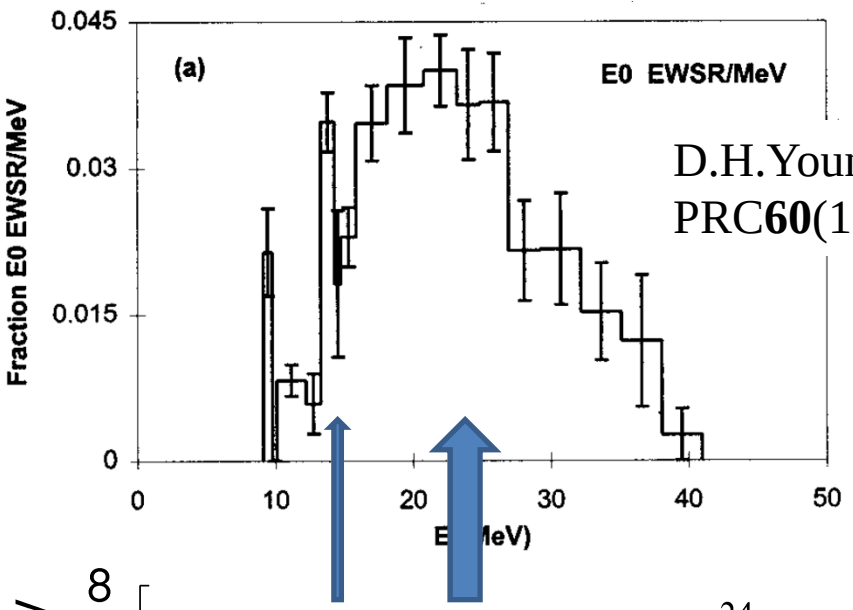
$$\delta\varrho_L(r) = \int d\cos\theta d\varphi \delta\varrho(\rho, z) Y^*_{LK}(\theta, \varphi)$$

GMR in deformed nuclei

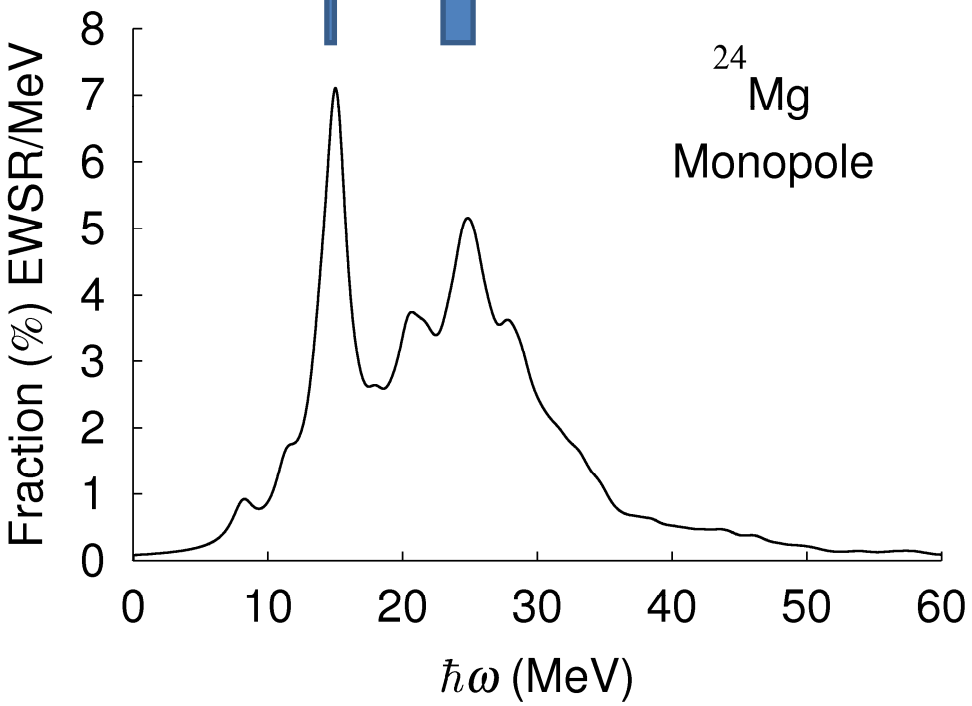
^{24}Mg

$$\beta_2(\nu) = 0.40$$
$$\beta_2(\pi) = 0.41$$

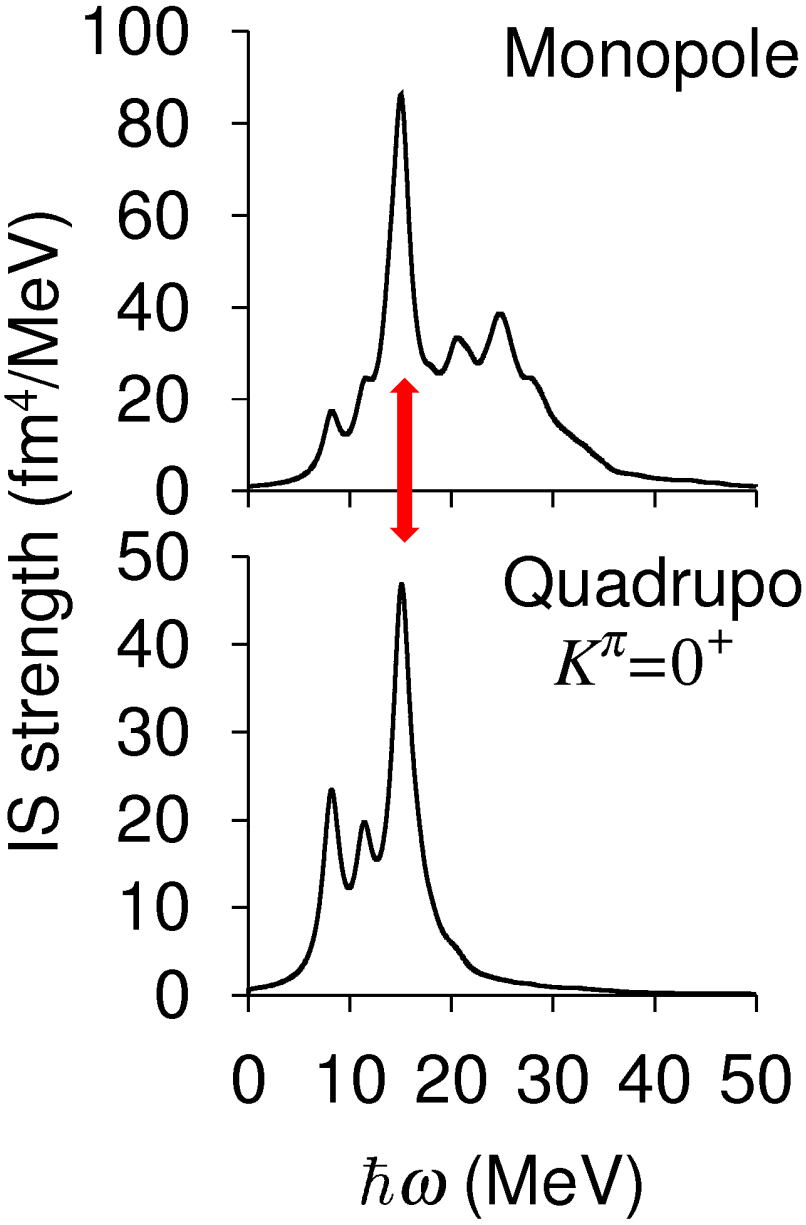
Prolately deformed



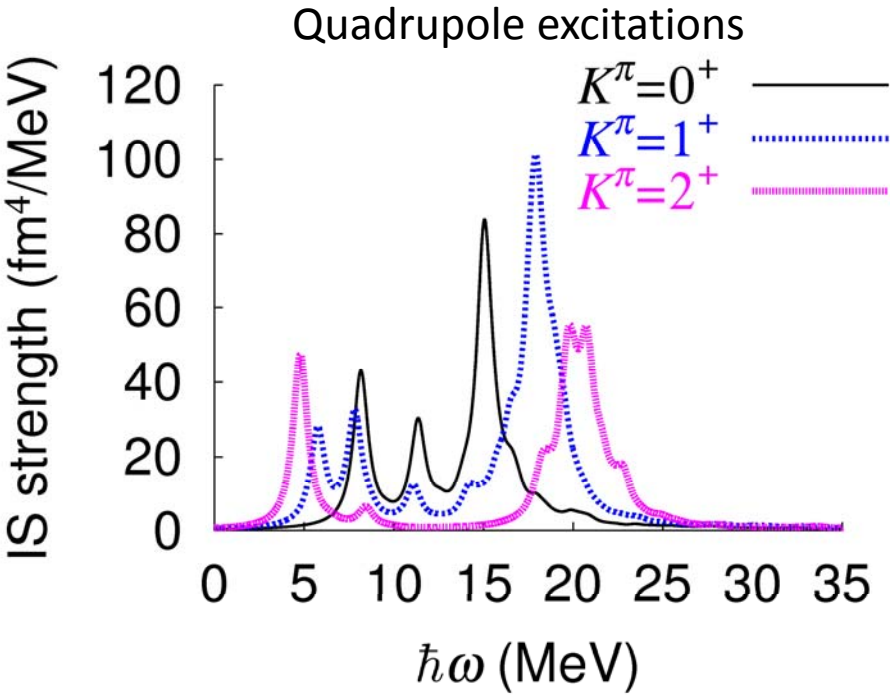
D.H.Youngblood *et al.*, PRC**60**(1999)014304



Coupling between the GMR and GQR

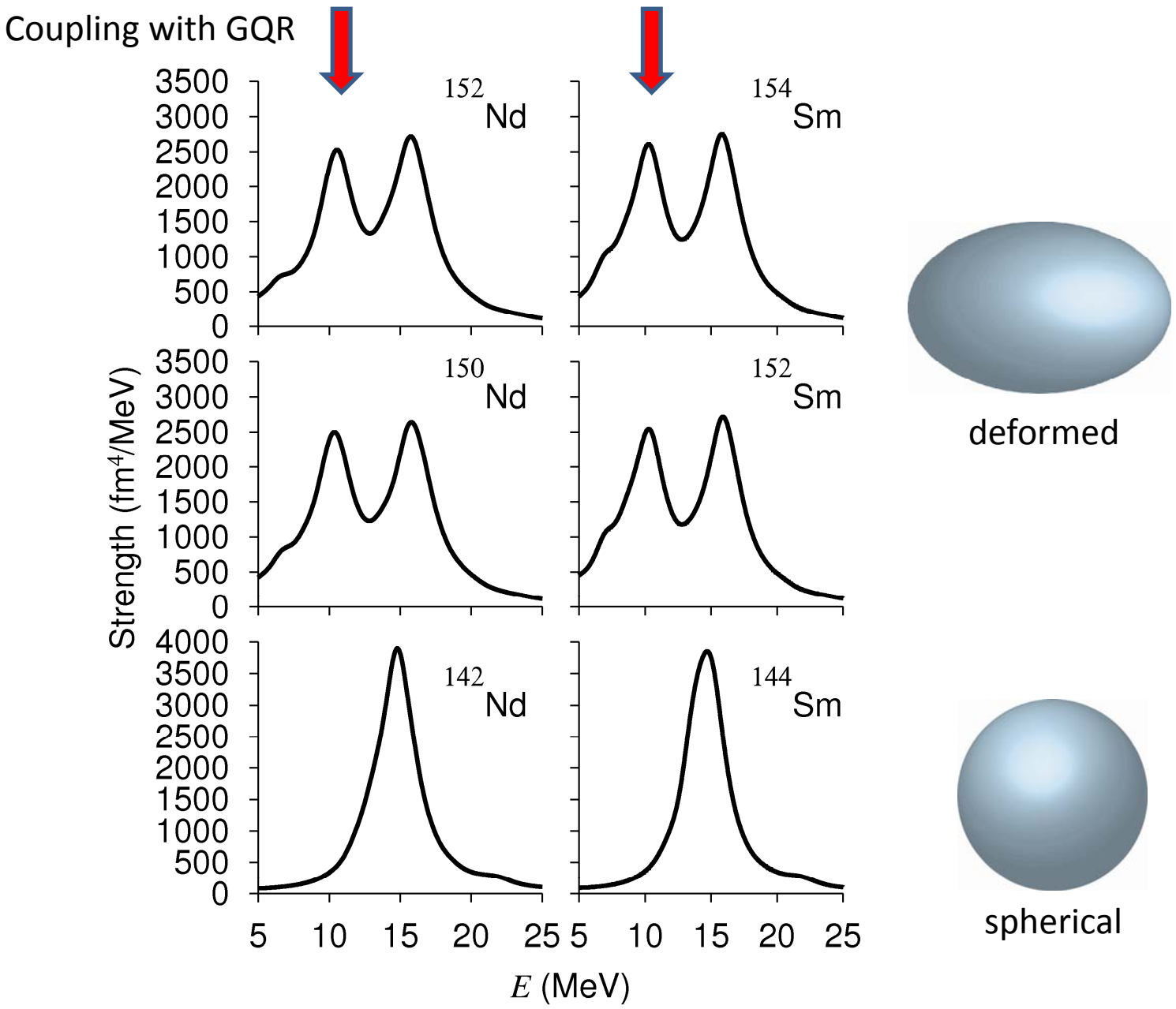


$$2\hbar\omega = 28\mathrm{MeV}$$
$$\sqrt{2}\hbar\omega = 20\mathrm{MeV}$$



KY, N.V.Giai, PRC78(2008)064316

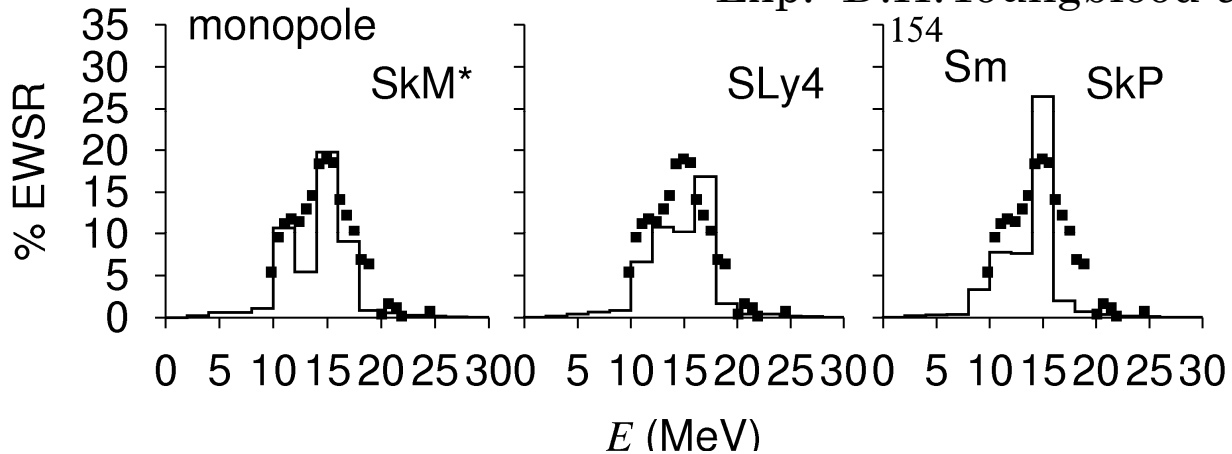
ISGMR in the rare-earth nuclei



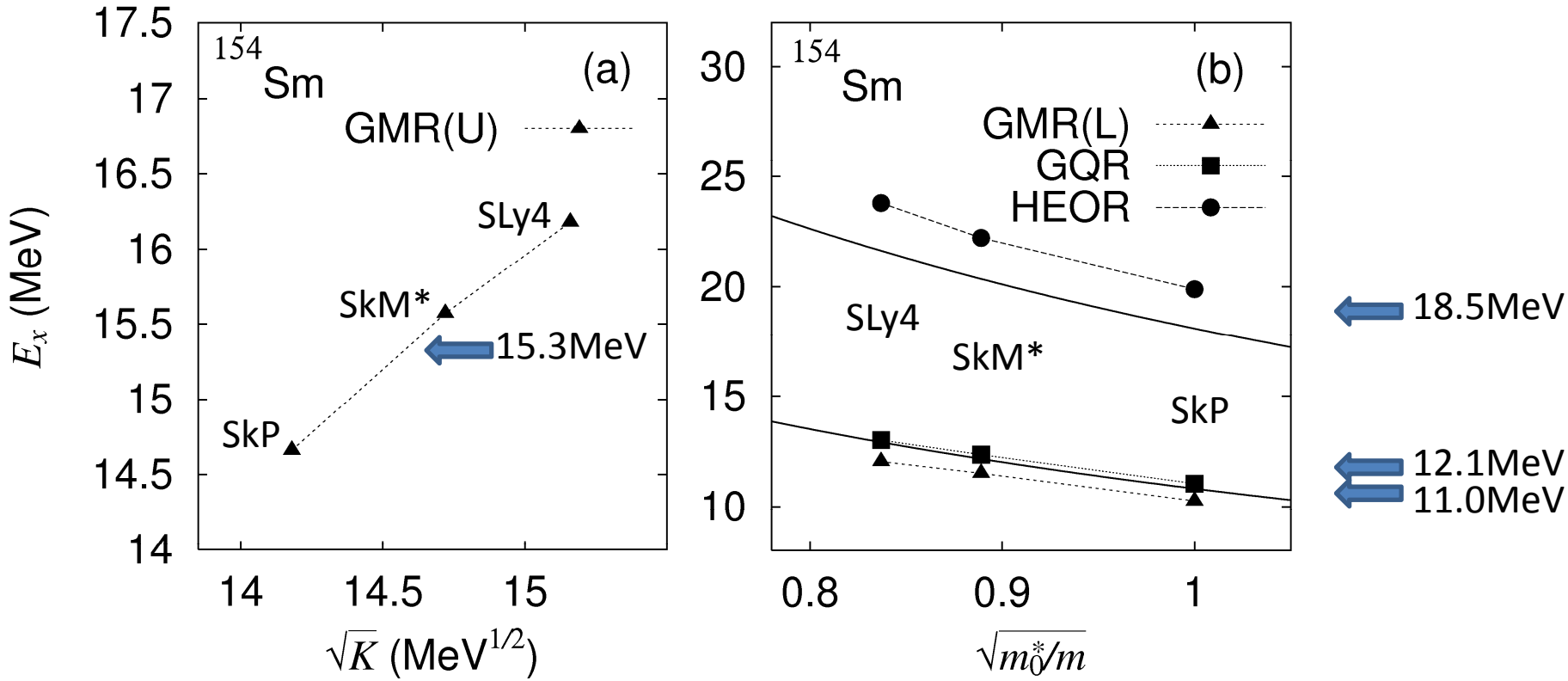
GRs and matter properties

ISGMR

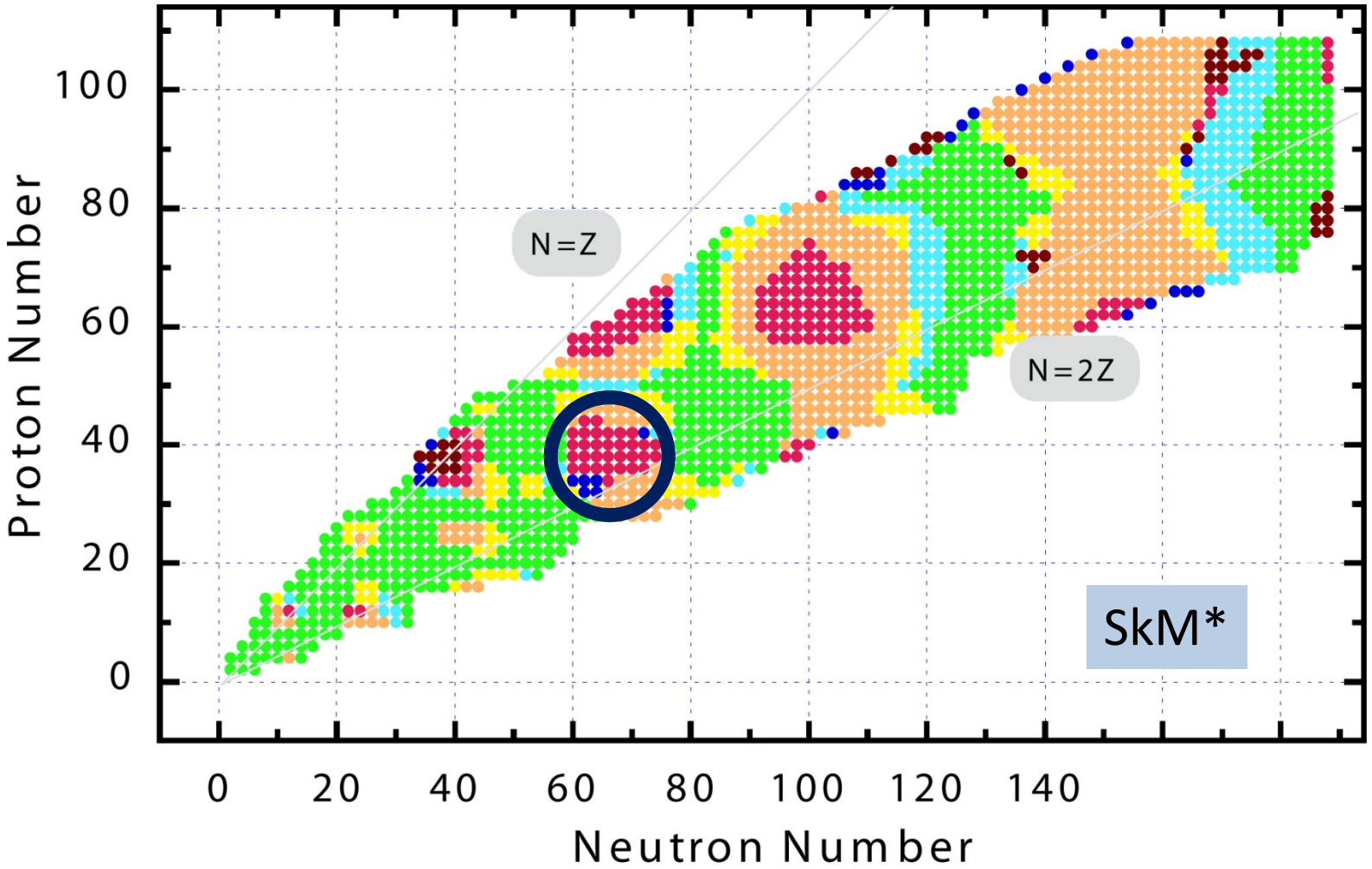
Exp.: D.H.Youngblood *et al.*,PRC69(2004)034315



	$\beta_2(\nu)$	$\beta_2(\pi)$
SkM*	0.30	0.33
SLy4	0.30	0.33
SkP	0.28	0.30



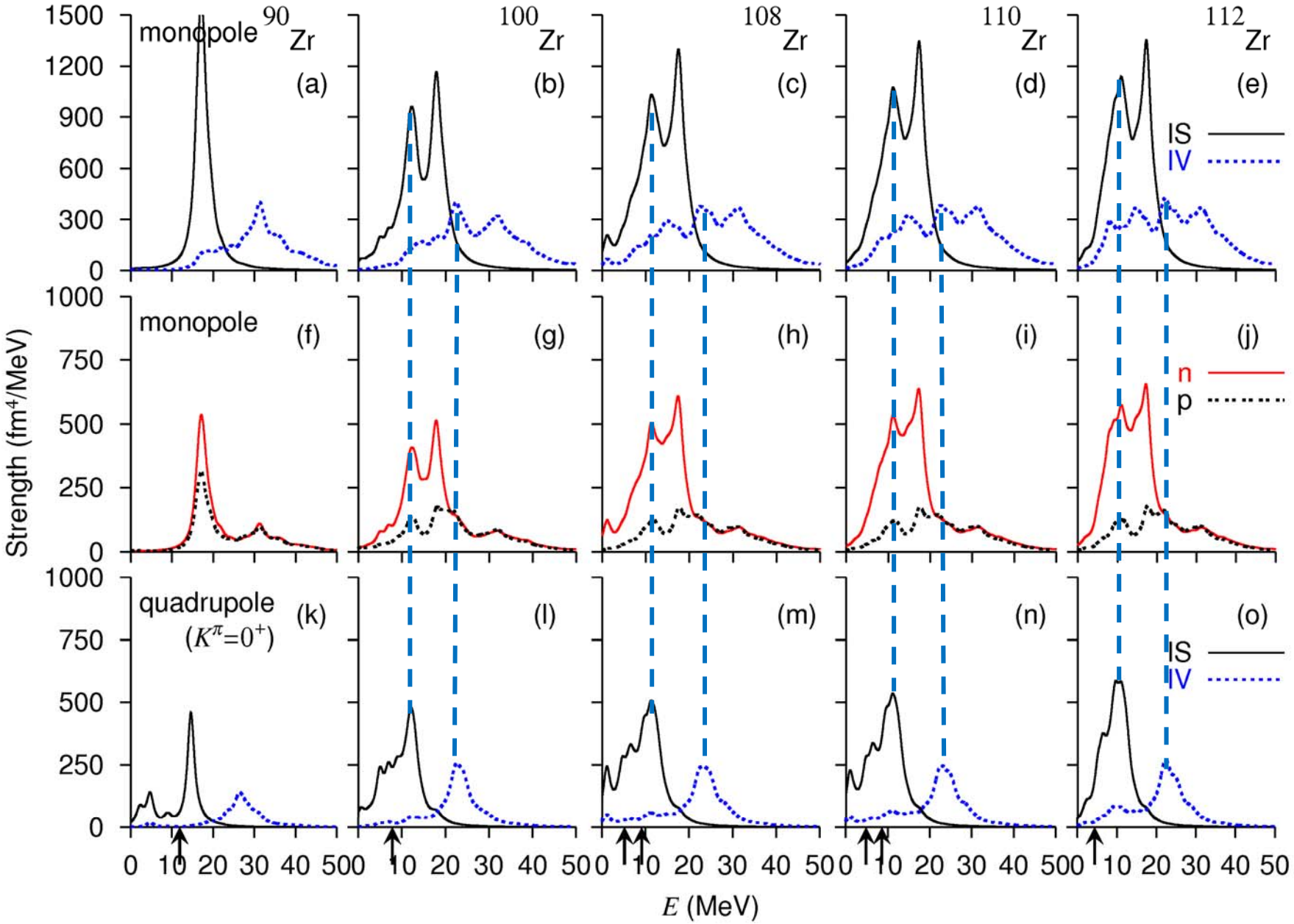
Deformation in Zr isotopes



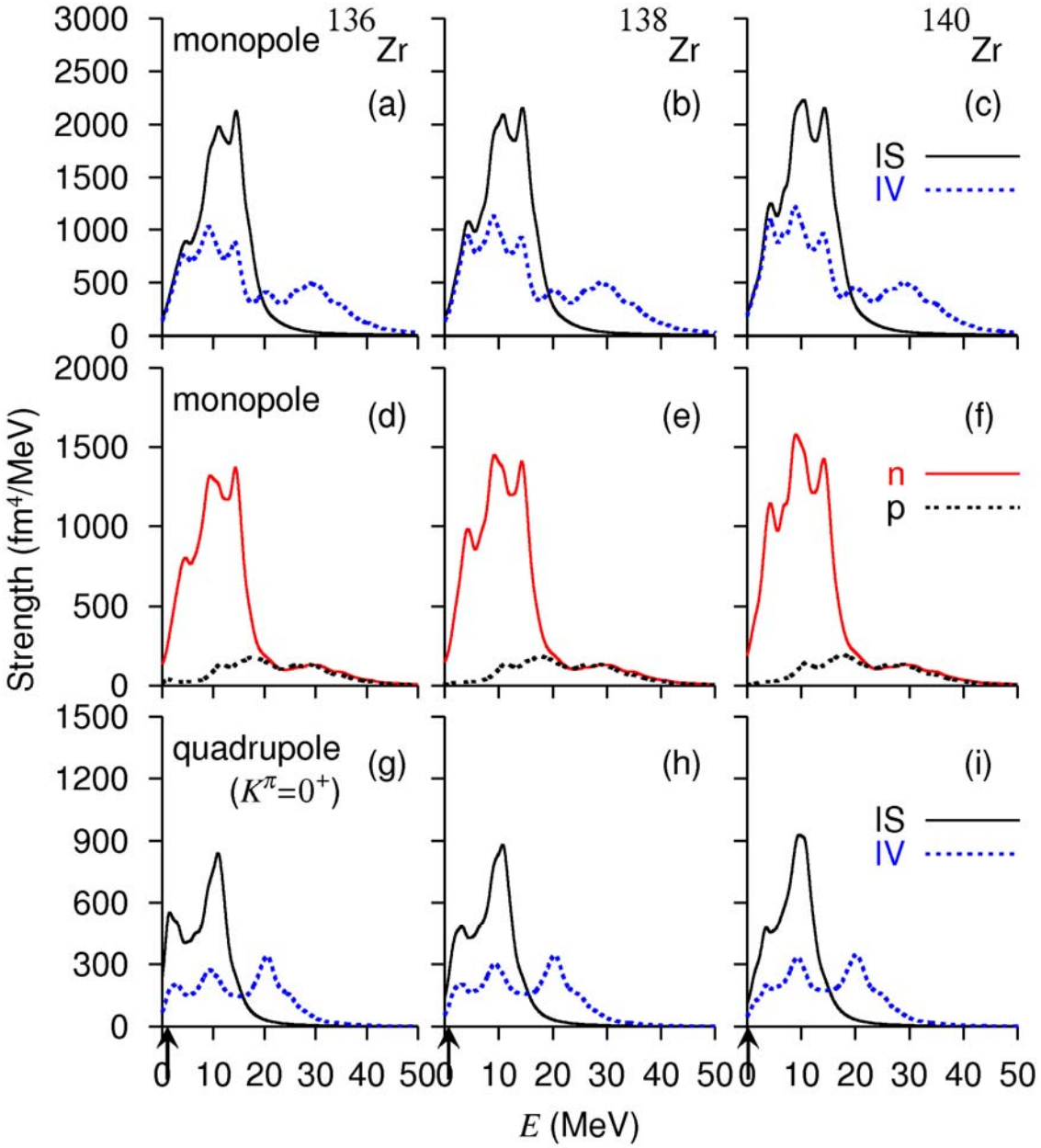
M.V. Stoitsov *et al.*, Phys. Rev. C68(2003) 054312

Strong deformation in Zr isotopes around N=70

Effects deformation and neutron excess on GMR



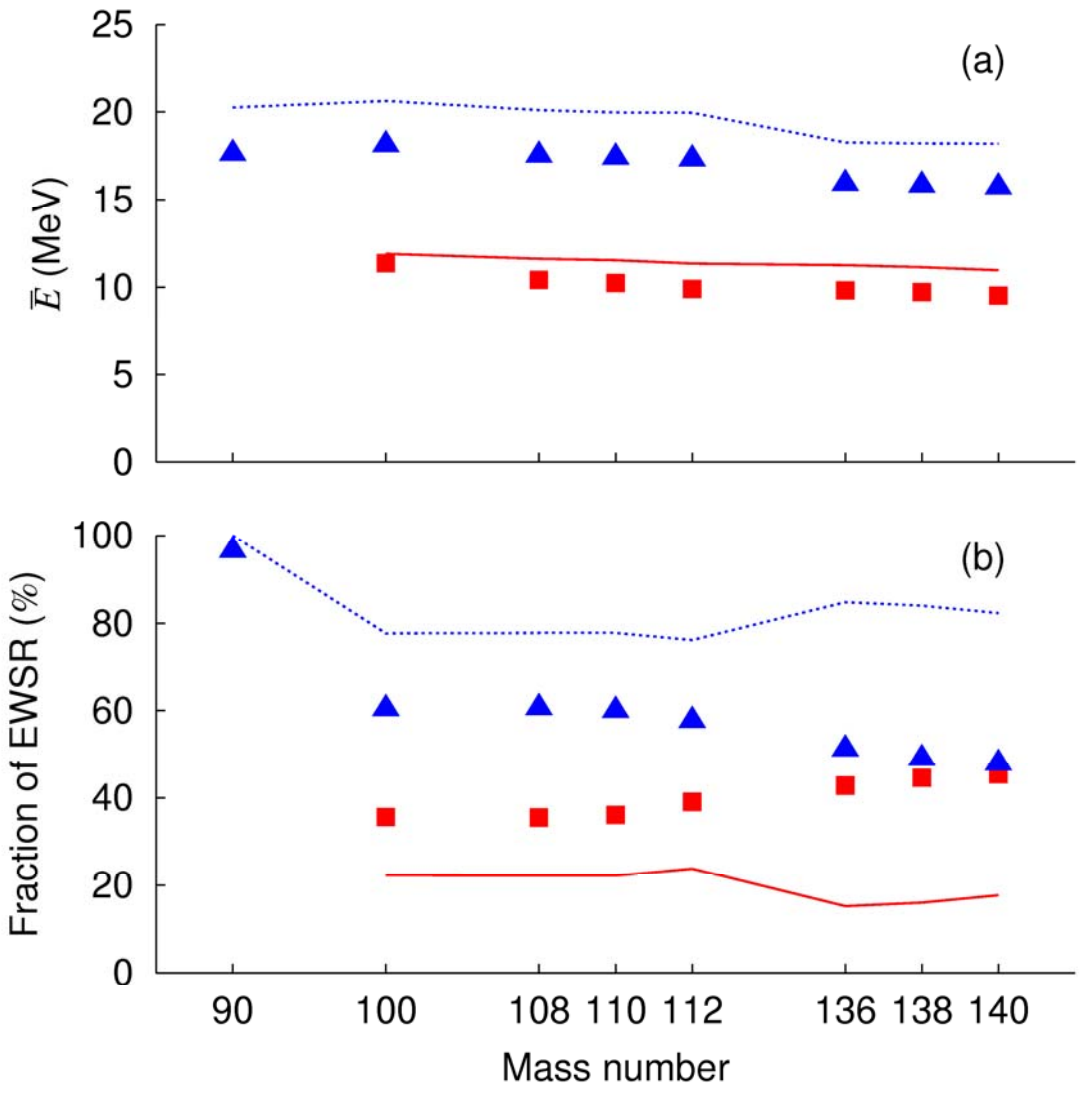
GMR in deformed drip-line nuclei



KY, PRC82(2010)034324

- ✓Excitation of neutrons
- ✓Threshold strength

Effect of neutron excess



Mean energy: $\bar{E} = \frac{m_1}{m_0}$

Solid (dotted) lines: Scaling model

S.Nishizaki, K.Andō, PTP**73**(1985)889

Concentration of the strengths in the low energy region

Summary

➢Collectivity of the pygmy resonance, and the condition for its emergence

Not yet known

✓Systematic investigation
✓Microscopic structure

☐Pygmy resonance in the deformed Mg isotopes

IV dipole + IS octupole + IS compression dipole

☐Giant monopole resonance

Deformation: coupling with the GQR

Neutron excess: enhancement of the low-lying strength