Workshop on **Gamma Strength and Level Density in Nuclear Physics and Nuclear Technology**
Dresden-Rossendorf, 30 August – 3 September, 2010

Pygmy Resonances in Skin Nuclei

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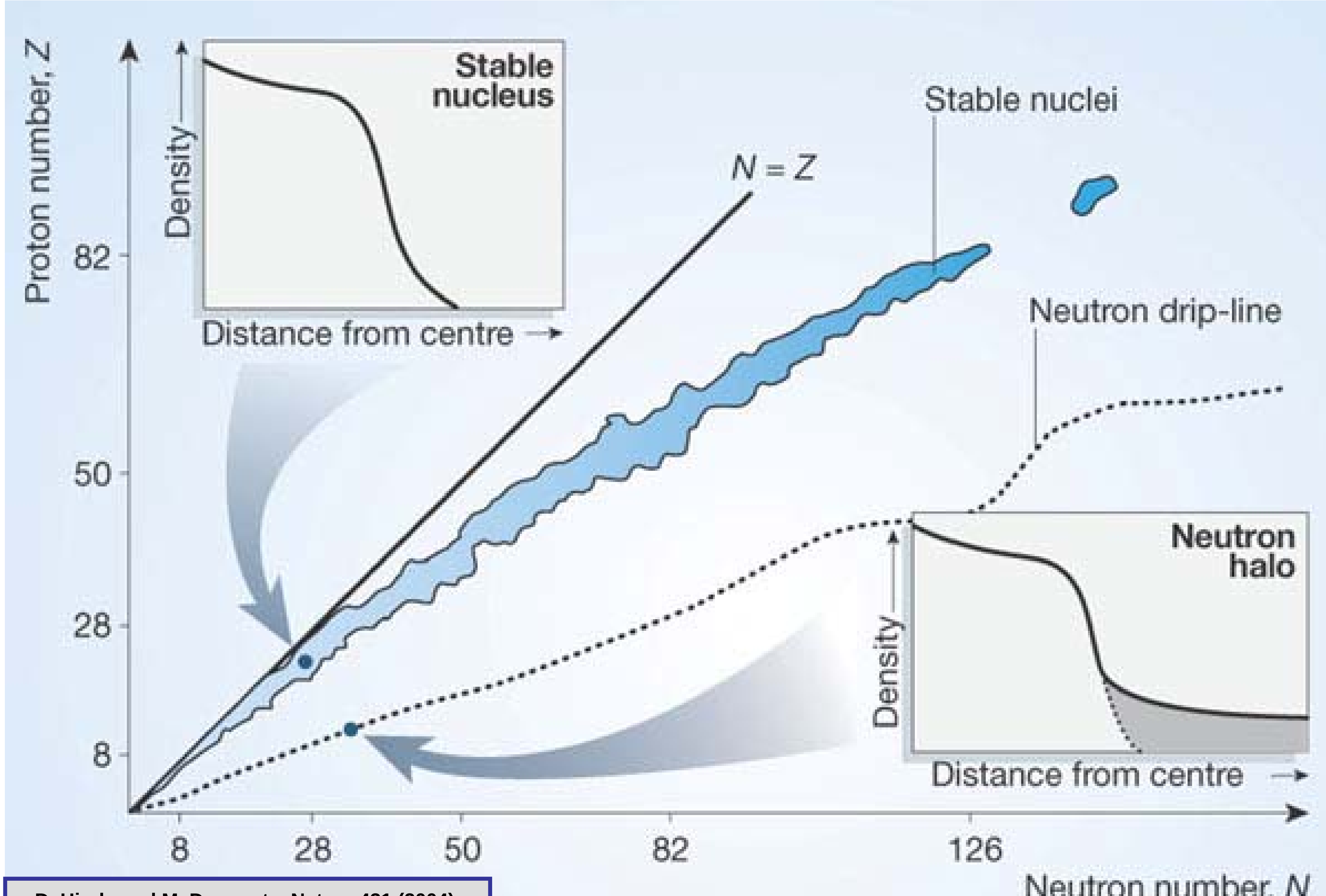
- A. Zilges, S. Volz
- U. Kneissl, M. Scheck
- Ch. Stoyanov, M. Grinberg, V. Ponomarev

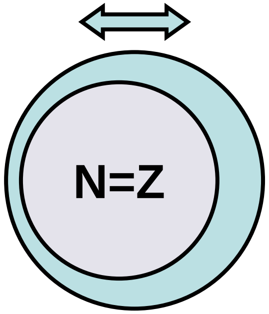
Nuclear Halos

Observation of halos in light nuclei : **Tanihata et al., Phys. Rev. Lett., 2676 (1985).**



D. Hinde and M. Dasgupta, Nature 431 (2004).

Skin Excitations



Oscillations of extra neutrons from the periphery vs. the isospin symmetric core Y. Suzuki et al., PTP 83 (1990) 180.
P. Isacker et al., PRC 45 (1992) R13.

Pygmy Resonances

Pygmy Dipole Resonance

Experiment

Stable nuclei : A. Zilges et al., PLB 542 (2002) 43.
Govaert et al., PRC 57 (1998) 2229.
N. Ryezayeva et al., PRL 89 (2002) 272502.

- Mostly of electric character
  A. Tonchev et al., PRL 104, 072501 (2010);
- Located below the particle emission threshold ;
- Up to 1% of EWSR

Unstable nuclei: A. Leistenschneider et al.,PRL 86 (2001) 5442.
E. Tryggestad et al., PLB 541 (2002) 52.
P. Adrich et al., PRL 95 (2005) 132501.

- Located closely above the particle emission threshold ;
- About 5-7% of EWSR

Theory

DFT
J. Chambers et al., PRC 50 (1994) R2671.

QPM
V. Ponomarev in PRL 89 (2002) 272502.
N. Tsoneva et al., PLB 586 (2004) 213.

QRPA-PC
D. Sarchi et al., PLB 601 (2004) 27.
G. Tertychny et al., Phys. Lett. B 647, 104 (2007).

RRPA and RQRPA
N. Paar et al., Rep. Prog. Phys. 70, 691 (2007).
J. Piekarewicz, PRC 73 (2006) 044325.

RQTBA
E. Litvinova, PRL 105, 022502 (2010).

Other Pygmy Resonances: N. Tsoneva, H. Lenske, PLB sub.

The Quasiparticle-Phonon Model

V. G. Soloviev: *Theory of Complex Nuclei* **(Pergamon Press, Oxford,1976)**

$$H = H_{MF} + H_M^{ph} + H_{SM}^{ph} + H_M^{pp}$$

$$H_{MF} = H_{sp} + H_{pair}$$

$$H_{res} = H_M^{ph} + H_{SM}^{ph} + H_M^{pp}$$

$$R^\lambda(r_1, r_2) = \kappa^\lambda R_\lambda(r_1) R_\lambda(r_2)$$

$$\kappa^\lambda = (\kappa^\lambda{}_0, \kappa^\lambda{}_1)$$

N. Tsoneva, H. Lenske, Ch. Stoyanov, Phys. Lett. B 586 (2004) 213
N. Tsoneva, H. Lenske, Phys. Rev. C 77 (2008) 024321

Phenomenological Density Functional Approach for Nuclear Ground States

The total binding energy can be expressed as an integral over an energy-density functional

$$B(A) = \sum_{q=p,n} \int d^3r \left(\tau_q(\rho) + E_{int}\right) + E_q^{pair}(k,\rho)$$

P. Hohlenberg, W. Kohn, Phys. Rev. 136 (1964) B864.
W. Kohn, L. J. Sham, Phys. Rev. 140 (1965) A 1133.

$$E_{int} = \frac{1}{2}\sum_q \rho_q U_q(\rho)$$

In terms of single-particle wave functions and occupancies the kinetic energy density, number and pairing densities are:

$$\tau_q = \sum_j v_{jq}^2 \frac{\hbar^2}{2M_q} |\vec{\nabla}\varphi_{jq}(\vec{r})|^2 \qquad \rho_q(\vec{r}) = \sum_j v_{jq}^2 |\varphi_{jq}(\vec{r})|^2 \qquad \kappa_q(\vec{r}) = \frac{1}{2}\sum_j v_{jq} u_{jq} |\varphi_{jq}(\vec{r})|^2$$

$$\left(-\frac{\hbar^2}{2M_q}\vec{\nabla}^2 + \Sigma_q(\vec{r}) - \eta_{jq}\right)\varphi(\vec{r}) = 0$$

$$\Sigma_q(\rho) = \frac{1}{2}\frac{\partial}{\partial\rho_q}_{|v_q^2} \sum_{q'} \rho_{q'} U_{q'}(\rho) \longrightarrow \Sigma_q(\rho) = U_q(\rho) + U_q^{(r)}(\rho)$$

For finite nucleus we can replace the integration over density by radial integrals

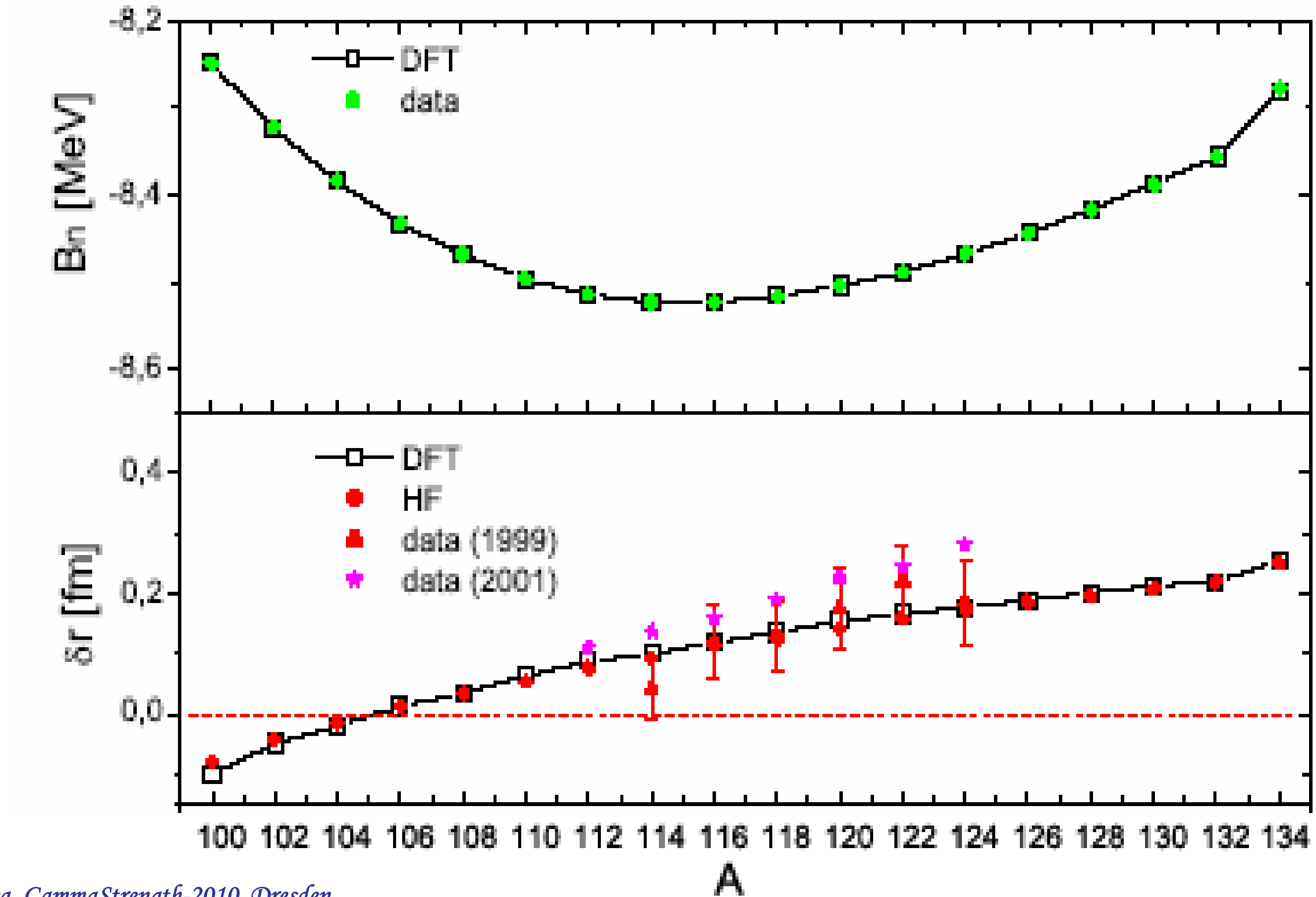
$$\rho(r)U_\alpha(r) = -2\int_r^\infty ds \frac{\partial\rho(s)}{\partial s} \boxed{\Sigma_\alpha(s)} \qquad U_{WS}(s)$$

where the density $\rho(r)$ is calculated self-consistently with wave functions from the effective potential $\Sigma_\alpha(r)$.
Hence, by means of these relations we are able to calculate B(A) for arbitrary phenomenological single-particle potential.

N. Tsoneva, H. Lenske, PRC 77 (2008) 024321

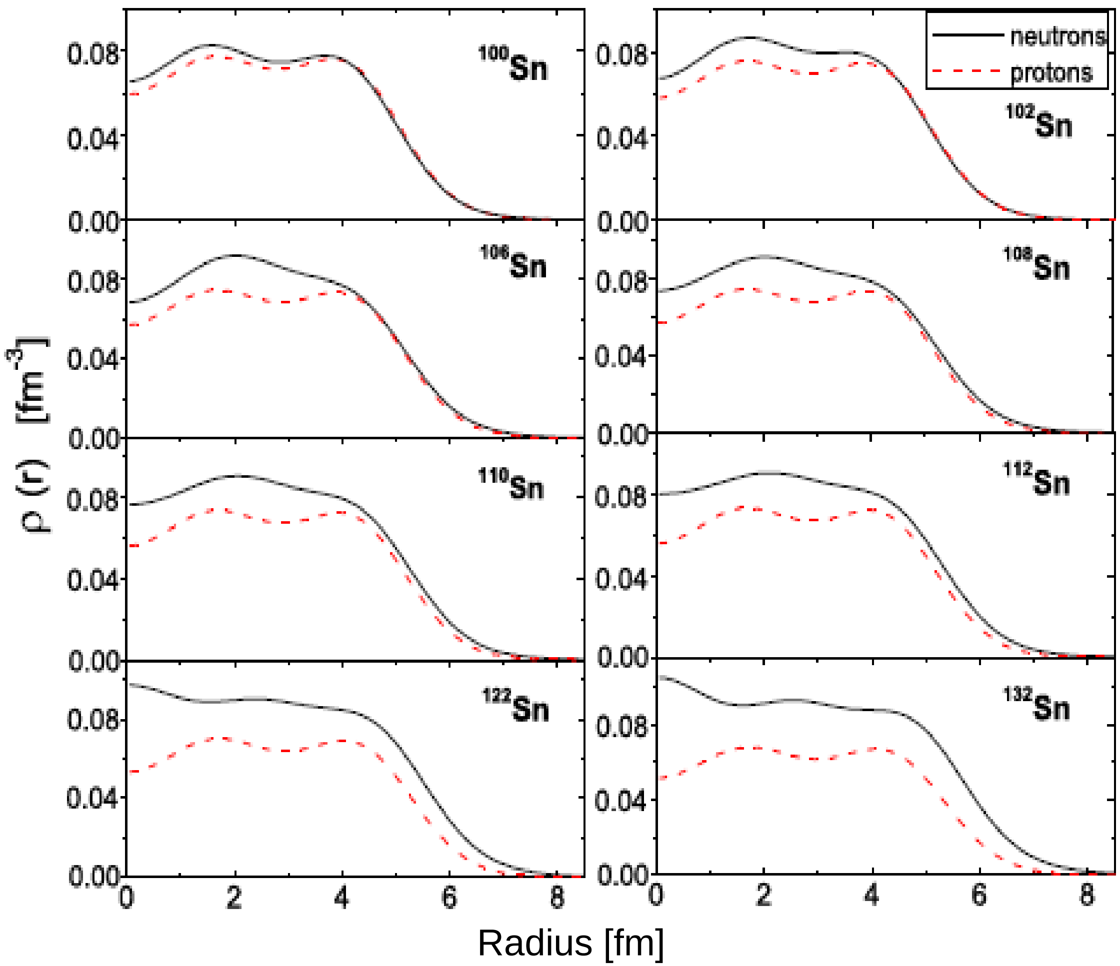
The Ground State

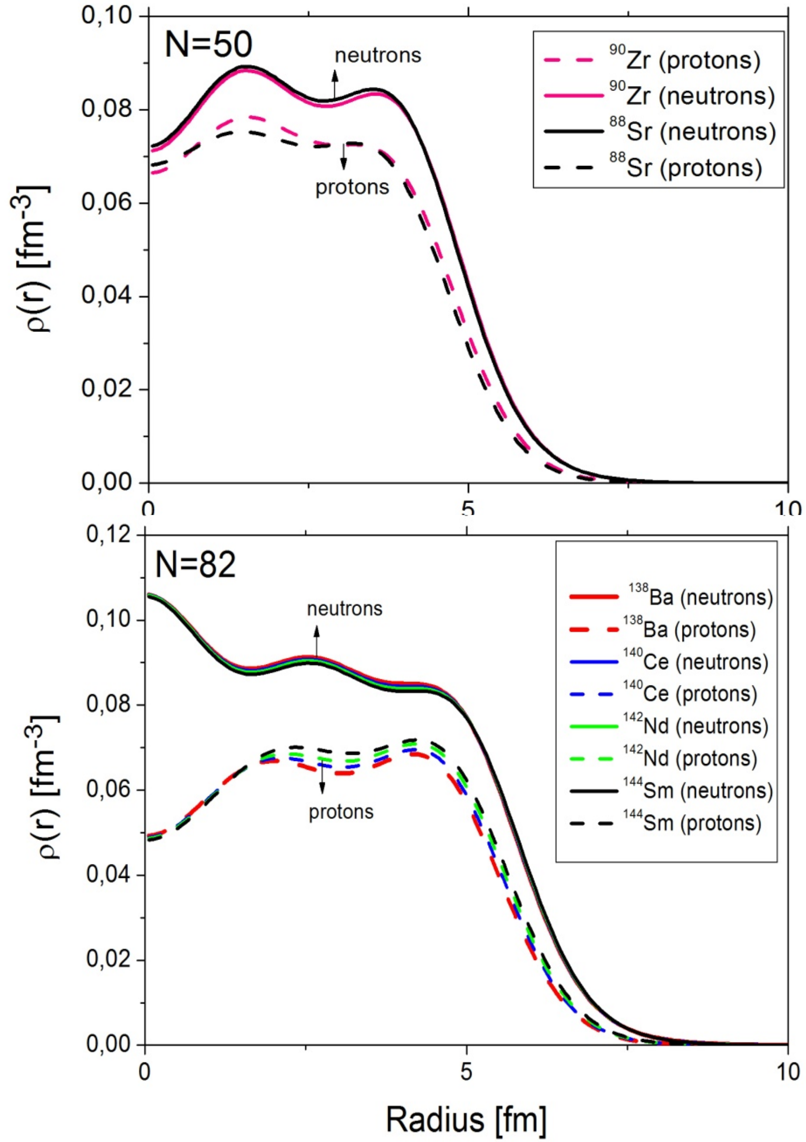
Binding energy and skin thickness $\delta r = \sqrt{< r^2 >_n} - \sqrt{< r^2 >_p}$



Calculations of Ground State Densities in Z=50, N=50 and N=82 Nuclei

$$\delta r = \sqrt{< r^2 >_n} - \sqrt{< r^2 >_p}$$





N. Tsoneva, H. Lenske, Phys. Rev. C 77 (2008) 024321
R. Schwengner et al., Phys. Rev. C 78 (2008) 064314

The Model Basis

V. G. Soloviev: Theory of Atomic Nuclei: *Quasiparticles and Phonons* (**Inst. Of Phys. Publ., Bristol, 1992)**

$$Q^{+}_{\lambda\mu i} = \frac{1}{2}\sum_{\tau}^{n,p}\sum_{jj'}\left\{\psi^{\lambda i}_{jj'}[\alpha^{+}_{j}\alpha^{+}_{j'}]_{\lambda\mu} - (-1)^{\lambda-\mu}\varphi^{\lambda i}_{jj'}[\alpha_{j'}\alpha_{j}]_{\lambda-\mu}\right\} \;,$$

$$a_{jm} = u_j\alpha_{jm} + (-)^{j-m}v_j\alpha^{+}_{j-m}$$

$$[Q_{\lambda\mu i}, Q^{+}_{\lambda'\mu' i'}] = \frac{\delta_{\lambda,\lambda'}\delta_{\mu,\mu'}\delta_{i,i'}}{2}\sum_{jj'}[\psi^{\lambda i}_{jj'}\psi^{\lambda i'}_{jj'} - \varphi^{\lambda i}_{jj'}\varphi^{\lambda i'}_{jj'}] - \sum_{\substack{jj'j_2\\ mm'm_2}}\alpha^{+}_{jm}\alpha_{j'm'}$$

$$\times\left\{\psi^{\lambda i}_{j'j_2}\psi^{\lambda' i'}_{jj_2}C^{\lambda\mu}_{j'm'j_2m_2}C^{\lambda'\mu'}_{jmj_2m_2} - (-)^{\lambda+\lambda'+\mu+\mu'}\varphi^{\lambda i}_{jj_2}\varphi^{\lambda' i'}_{j'j_2}C^{\lambda-\mu}_{jmj_2m_2}C^{\lambda'-\mu'}_{j'm'j_2m_2}\right\}$$

$$[H, Q^{+}_{\alpha}] = E_{\alpha}Q^{+}_{\alpha}$$

The Wave Function

$$\Psi_\nu(JM) = \Bigg\{ \sum_i R_i(J\nu) Q^+_{JMi} + \sum_{\substack{\lambda_1 i_1 \\ \lambda_2 i_2}} P^{\lambda_1 i_1}_{\lambda_2 i_2}(J\nu) \left[Q^+_{\lambda_1 \mu_1 i_1} \times Q^+_{\lambda_2 \mu_2 i_2} \right]_{JM}$$

$$+ \sum_{\substack{\lambda_1 i_1 \lambda_2 i_2 \\ \lambda_3 i_3 I}} T^{\lambda_1 i_1 \lambda_2 i_2 I}_{\lambda_3 i_3}(J\nu) \left[\left[Q^+_{\lambda_1 \mu_1 i_1} \otimes Q^+_{\lambda_2 \mu_2 i_2} \right]_{IK} \otimes Q^+_{\lambda_3 \mu_3 i_3} \right]_{JM} \Bigg\} \Psi_0$$

$$M(X\lambda\mu) = \sum_{\tau j j'} \frac{\langle j || X\lambda || j' \rangle}{\sqrt{2\lambda + 1}} \Bigg\{ \frac{u^{(\pm)}_{jj'}}{2} \sum_i \left(\psi^{\lambda i}_{jj'} + \varphi^{\lambda i}_{jj'} \right) \left(Q^\dagger_{\lambda \mu i} + (-)^{\lambda - \mu} Q_{\lambda - \mu i} \right)$$

$$+ v^{(\mp)}_{jj'} \sum_{mm'} C^{\lambda\mu}_{jmj'm'} (-)^{j' + m'} \alpha^\dagger_{j'm'} \alpha_{j' - m'} \Bigg\}$$

M. Grinberg, Ch. Stoyanov, Nucl. Phys. A. 573 (1994) 231

V. Ponomarev, Ch. Stoyanov, N. Tsoneva, M. Grinberg, Nucl. Phys. A 635 (1998) 470.

The Charge Transition Density

$$\rho(\vec{r}) = \langle \Psi_f \left| \delta(\vec{r} - \vec{r_k}) \right| \Psi_i \rangle$$

$$\rho(\vec{r}) = e \sum_{\lambda\mu} (-)^{\lambda} C^{J_f M_f}_{J_i M_i \lambda\mu} \rho_{\lambda}(\vec{r}) Y^{*}_{\lambda\mu}(\theta, \varphi)$$

In terms of QRPA phonons:

$$\boxed{\rho_{\lambda i}(\vec{r}) = \sum_{j \geq j'} \frac{1}{1 + \delta_{jj'}} \rho^{(\lambda)}_{jj'}(\vec{r}) g^{\lambda i}_{jj'} u_{jj'};}$$

$$\rho^{(\lambda)}_{jj'}(\vec{r}) = -\left[1 + (-)^{l+l'+\lambda}\right] (-)^{j+\lambda+1/2} \frac{\hat{j}\hat{j}'}{\hat{\lambda}\sqrt{4\pi}} \times$$

$$C^{\lambda 0}_{j\frac{1}{2}j'-\frac{1}{2}} R^{*}_{j}(\vec{r}) R_{j'}(\vec{r}),$$

$\hat{j} = \sqrt{2j+1}$; $g^{\lambda i}_{jj'} = \psi^{\lambda i}_{jj'} + \varphi^{\lambda i}_{jj'}$ and $u_{jj'} = u_j v_{j'} + u_{j'} v_j$

QRPA Calculations on the Dipole Response in Sn Isotopes

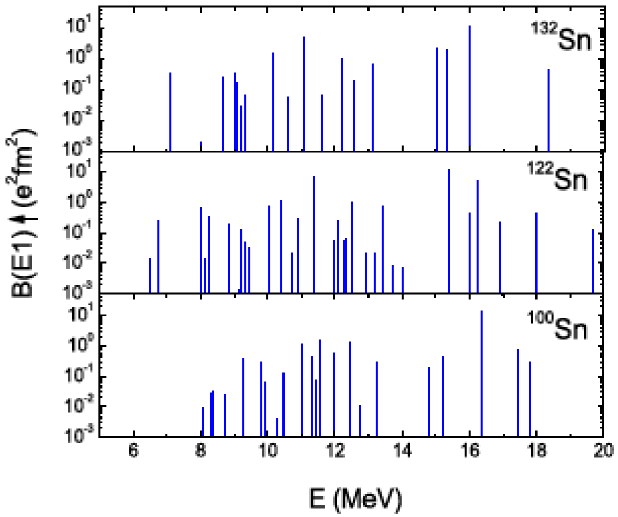
N. Tsoneva, H. Lenske, PRC 77 (2008) 024321

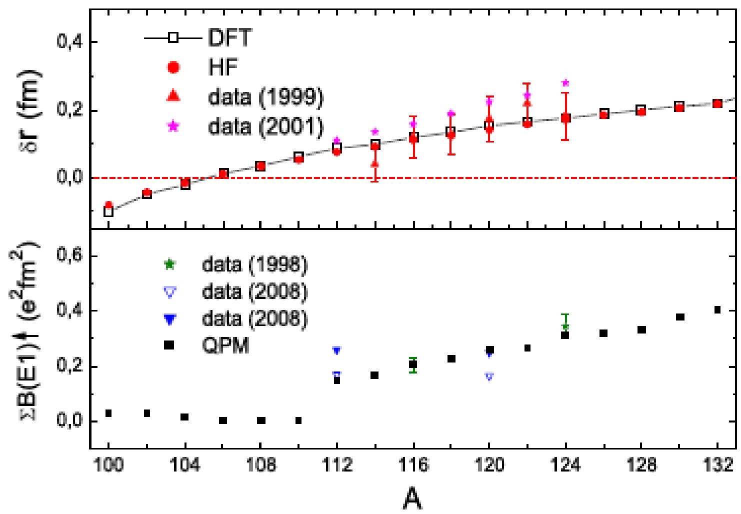
A connection between the total PDR strength and the neutron/proton skin thickness is observed

$$\delta r = \sqrt{< r^2 >_n} - \sqrt{< r^2 >_p}$$

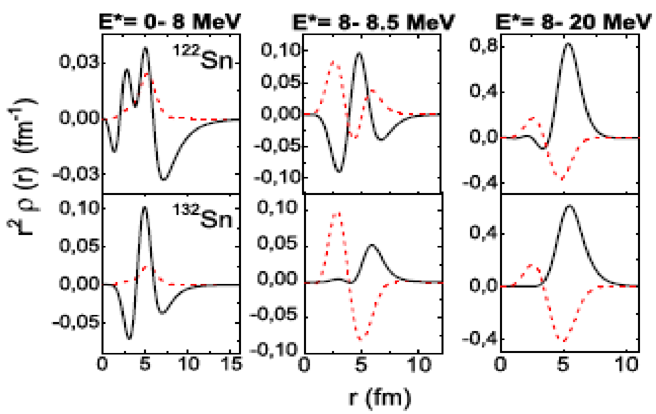
Neutron number increasing

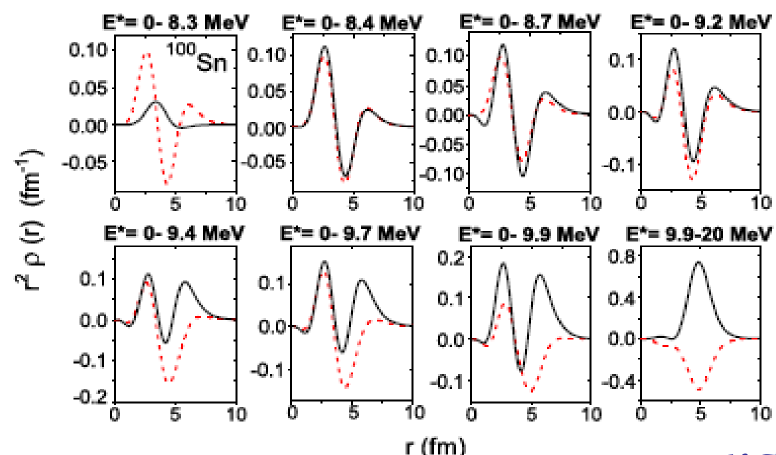
Neutron skin increasing





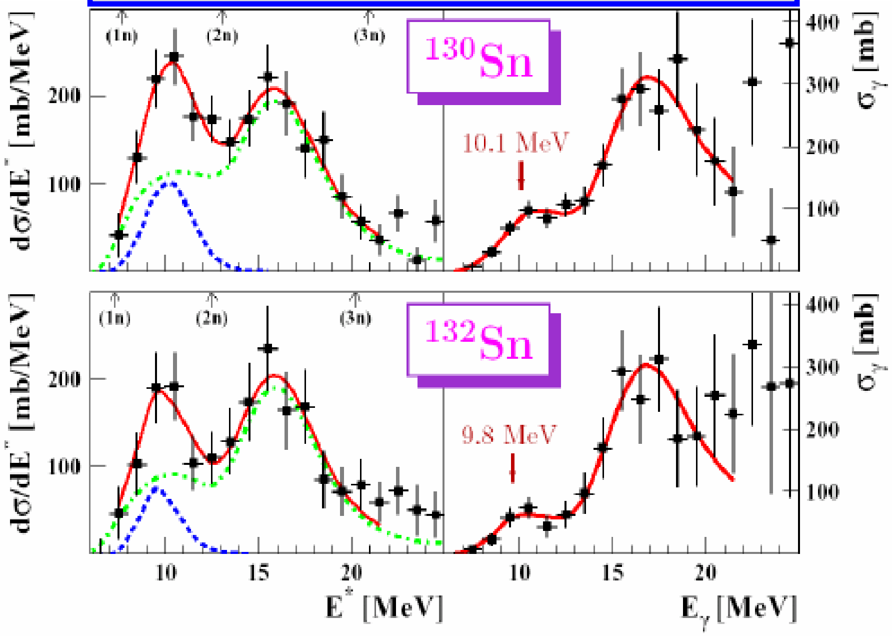
Exp. in Sn-116 and Sn-124:
K. Govaert et al,
Phys. Rev. C 57 (1998) 2229.
Exp. in Sn-112,Sn-120:
B. Ozel et al,
Nucl. Phys. A 778 (2007) 385.



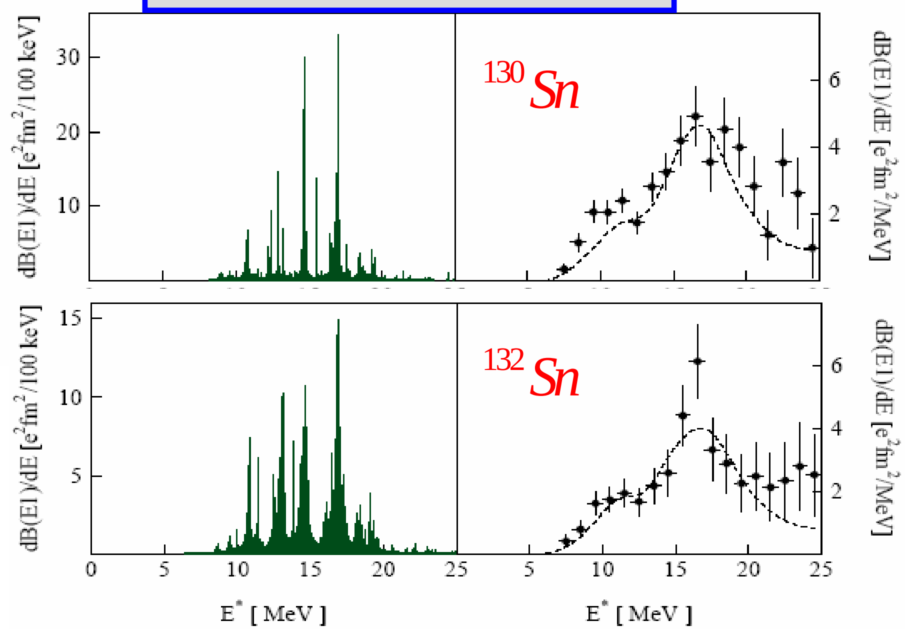


QPM calculations of excitation energies and integrated cross sections in $^{130,132}Sn$ in comparison with recent data / A. Klimkiewicz and the LAND-FRS collaboration, private communication/.*

Exp. (P. Adrich et al., PRL 95 (2005) 132501)



QRPA and LAND-FRS data



N. Tsoneva, H. Lenske, PRC 77 (2008) 024321

Nucl.	PDR (Energy region) QPM	$\langle E\rangle_{PDR}$ [MeV] QPM	$\int\sigma^{PDR}$ [mb MeV] QPM	E^{PDR}_{max} [MeV] Exp.	$\int\sigma^{PDR}$ [mb MeV] Exp.	E^{GDR}_{LET} [MeV] QPM	$\int\sigma^{GDR}_{LET}$ [mb MeV] QPM	E^{max}_{GDR} [MeV] Exp.	E^{max}_{GDR} [MeV] QPM	$\int\sigma^{GDR}$ [mb MeV] Exp.	$\int\sigma^{GDR}$ QPM
^{130}Sn	0-7.4	5.8	8.2	10.1(7)	130(55)	8-11	137.3	15.9(5)	16.	1930(300)*	1616
^{132}Sn	0-8	7.1	10.4	9.8(7)	75(57)	8-11	97.6	16.1(7)	16.1	1670(420)*	1518

*** The integration is taken up to 20 MeV.**

QRPA Calculations of the Total PDR Strength in N=82 and N=50 Isotones

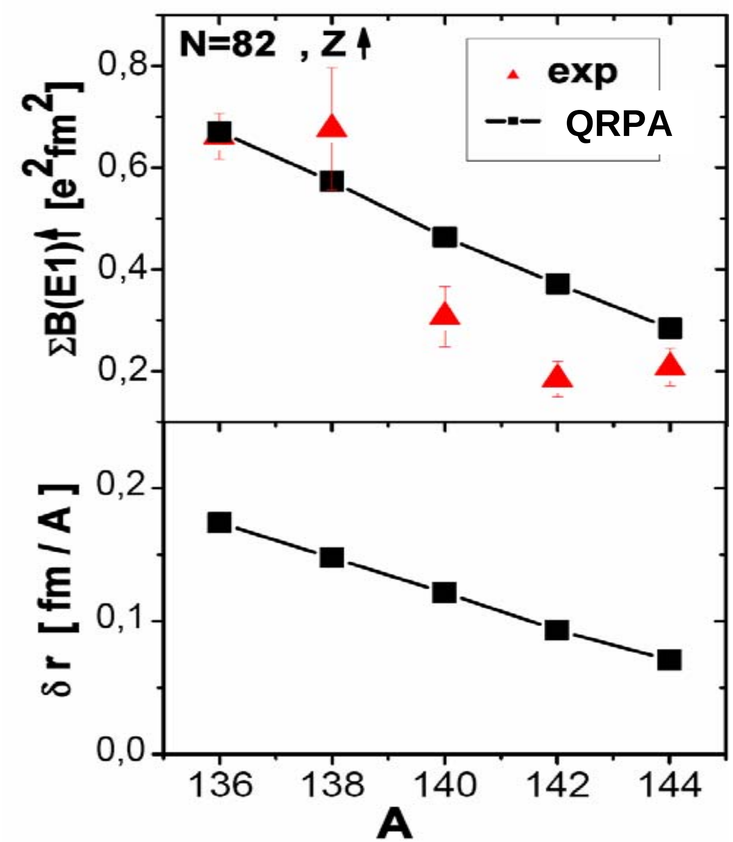
A connection between the total PDR strength and the neutron skin thickness is observed

Electron accelerator S-DALINAC, TU Darmstadt, Bremsstrahlung photons at 10 MeV.
S. Volz et al., Nucl. Phys. A, 779 (2006) 1-20;
D. Savran et al.,PRL 100, (2008) 232501

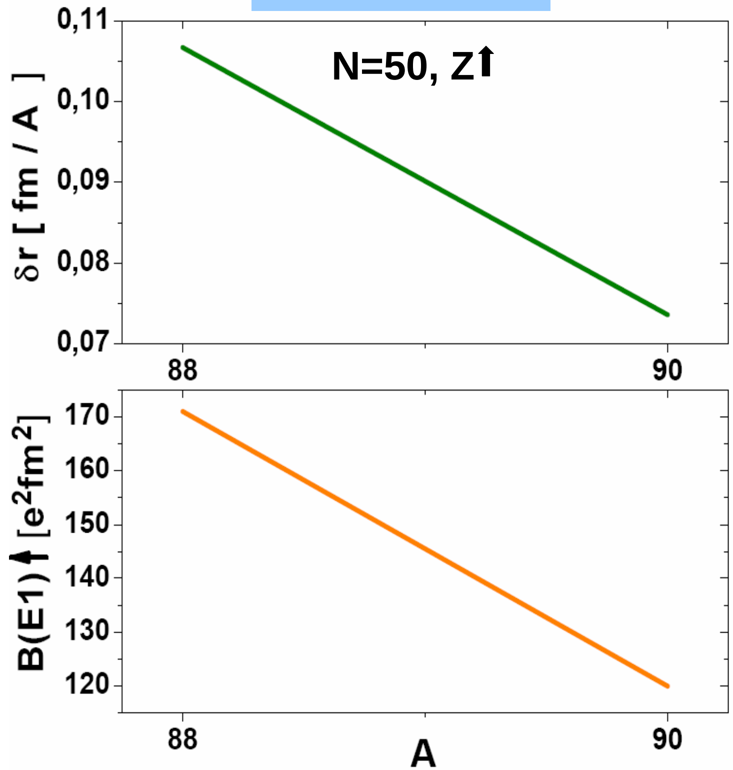
- **Proton number increasing**
- **Neutron skin decreasing**

$$\delta r = \sqrt{<r^2>_n} - \sqrt{<r^2>_p}$$

E*=0-8 MeV



E*=0-9 MeV



N. Tsoneva, GammaStrength-2010, Dresden

Skin Thickness and Electric Dipole Response

The skin thickness is defined as:

N. Tsoneva, H. Lenske, PRC 77, 024321 (2008)

$$\delta r = \sqrt{\langle r_n^2 \rangle} - \sqrt{\langle r_p^2 \rangle}, \quad \text{where} \quad \langle r_q^2 \rangle = \frac{1}{A_q} \int d^3 r\, r^2 \rho_q(\vec{r})$$

$$\Delta_3 r^2 = \sum_i \langle 0 | \tau_{3i} r_i^2 | 0 \rangle \qquad \tau_3 = \pm 1$$

The intrinsic nuclear dipole transition operator in laboratory coordinates:

$$\vec{D} = \sum_i \vec{r}_i \left(q_p \frac{1}{2}(1 - \tau_{3i}) + q_n \frac{1}{2}(1 + \tau_{3i}) \right); \quad q_T = \frac{1}{2}(q_n + (-)^T q_p)$$ isoscalar (T=0) and isovector (T=1) charges

$$\vec{x}_T = \sum_i \vec{r}_i (\tau_{3i})^T$$

$$\vec{D} = q_0 \vec{x}_0 + q_1 \vec{x}_1$$

The reduced isovector/isoscalar dipole transition moment and the dipole transition probability are :

$$\vec{M}_d^{(T)} = \langle 0 \| (\tau_3)^T \vec{r} \| d \rangle; \quad B_d(E1) = \left| q_0 \vec{M}_d^{(0)} + q_1 \vec{M}_d^{(1)} \right|^2$$

The isovector/isoscalar interference term :

$$\Re \sum_d \vec{M}_d^{(0)} \vec{M}_d^{(1)*} = \frac{1}{2 q_0 q_1} \left(\sum_d B_d(E1) - q_0^2 \sum_d \left| M_d^{(0)} \right|^2 - q_1^2 \sum_d \left| M_d^{(1)} \right|^2 \right)$$

In QRPA basis $|\alpha\rangle = |(ij)JM\rangle$

$$\frac{1}{2} \sum_d \vec{M}_d^{(0)} \cdot \vec{M}_d^{(1)*} = \boxed{\sum_{i,j} \vec{M}_{ij}^{(0)} \cdot \vec{M}_{ij}^{(1)*} v_i^2} - \sum_{i,j} \vec{M}_{ij}^{(0)} \cdot \vec{M}_{ij}^{(1)*} v_i^2 v_j^2 + \sum_{i,j} \vec{M}_{ij}^{(0)} \cdot \vec{M}_{ij}^{(1)*} u_i v_i u_j v_j$$

$$\Re \sum_{i,j} \vec{M}_{ij}^{(0)} \cdot \vec{M}_{ij}^{(1)*} v_i^2 = \sum_{i,j} < i|\vec{r}|j > \cdot < j|\tau_3 \vec{r}|i > v_i^2 = \boxed{\sum_i < i|\tau_3 r^2|i > v_i^2}$$

Skin Thickness and Electric Dipole Response

N. Tsoneva, H. Lenske, PRC 77, 024321 (2008)

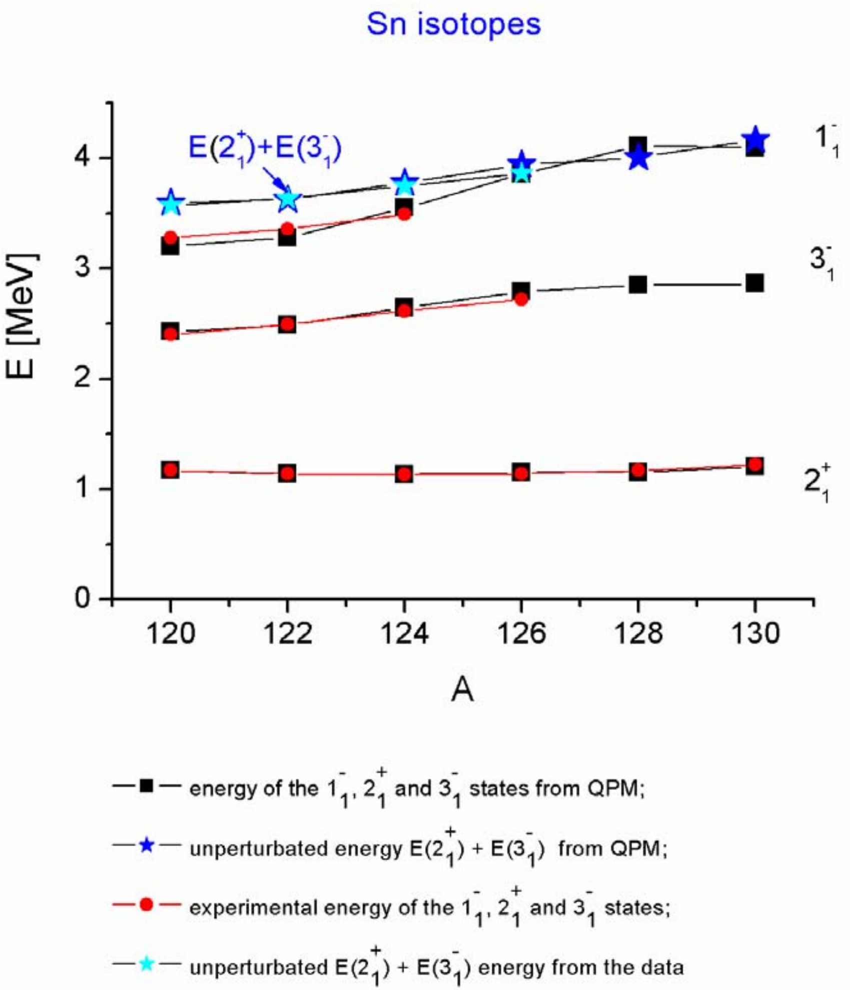
Relation between the non-energy weighted dipole sum rule and the skin measure:

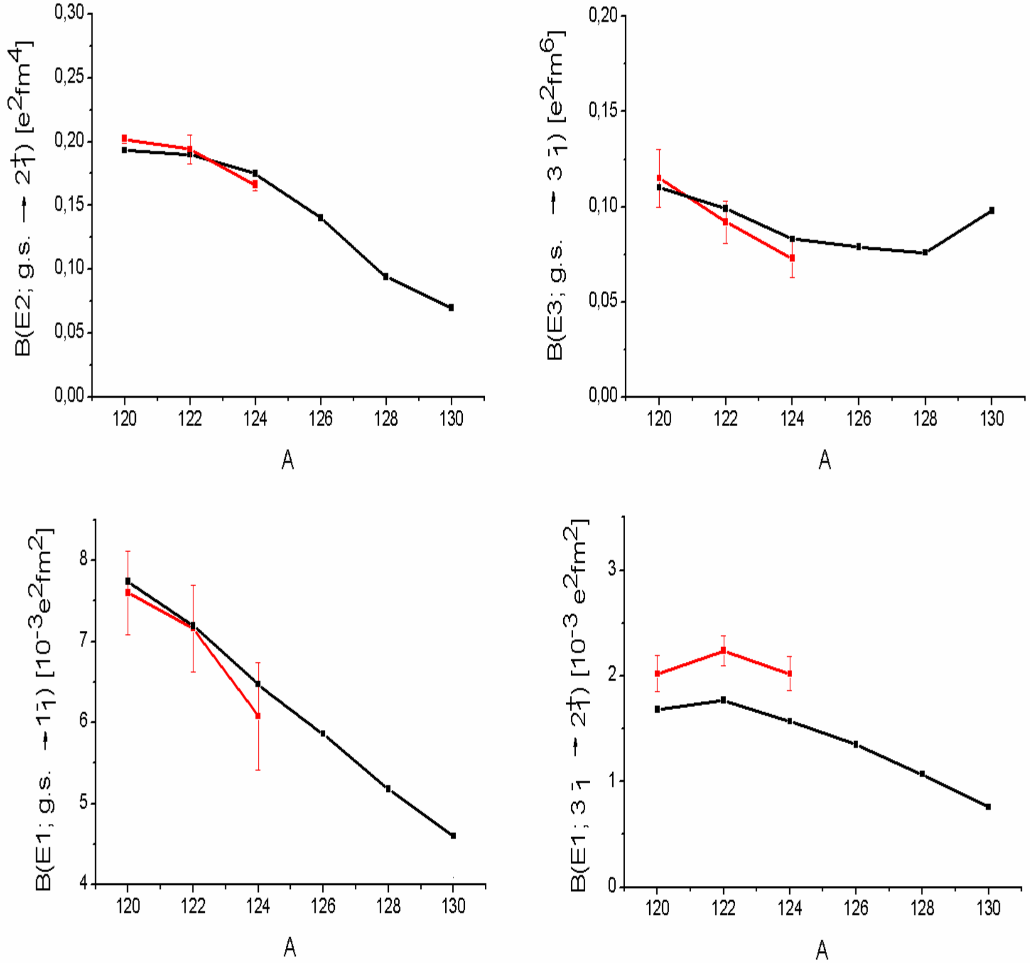
$$\Delta_3 r^2 = \frac{1}{4q_0 q_1}\left(\sum_d B_d(E1) - q_0^2 \sum_d \left|M_d^{(0)}\right|^2 - q_1^2 \sum_d \left|M_d^{(1)}\right|^2\right)$$

+ ground state pairing correlations

Two-phonon 1- states

U. Kneissl, N. Pietralla, and A. Zilges, J. Phys. G: Nucl.Part.Phys. **32,** R217 (2006)





The data are taken from J. Bryssinck et al., Phys. Rev. C59(1999)1930

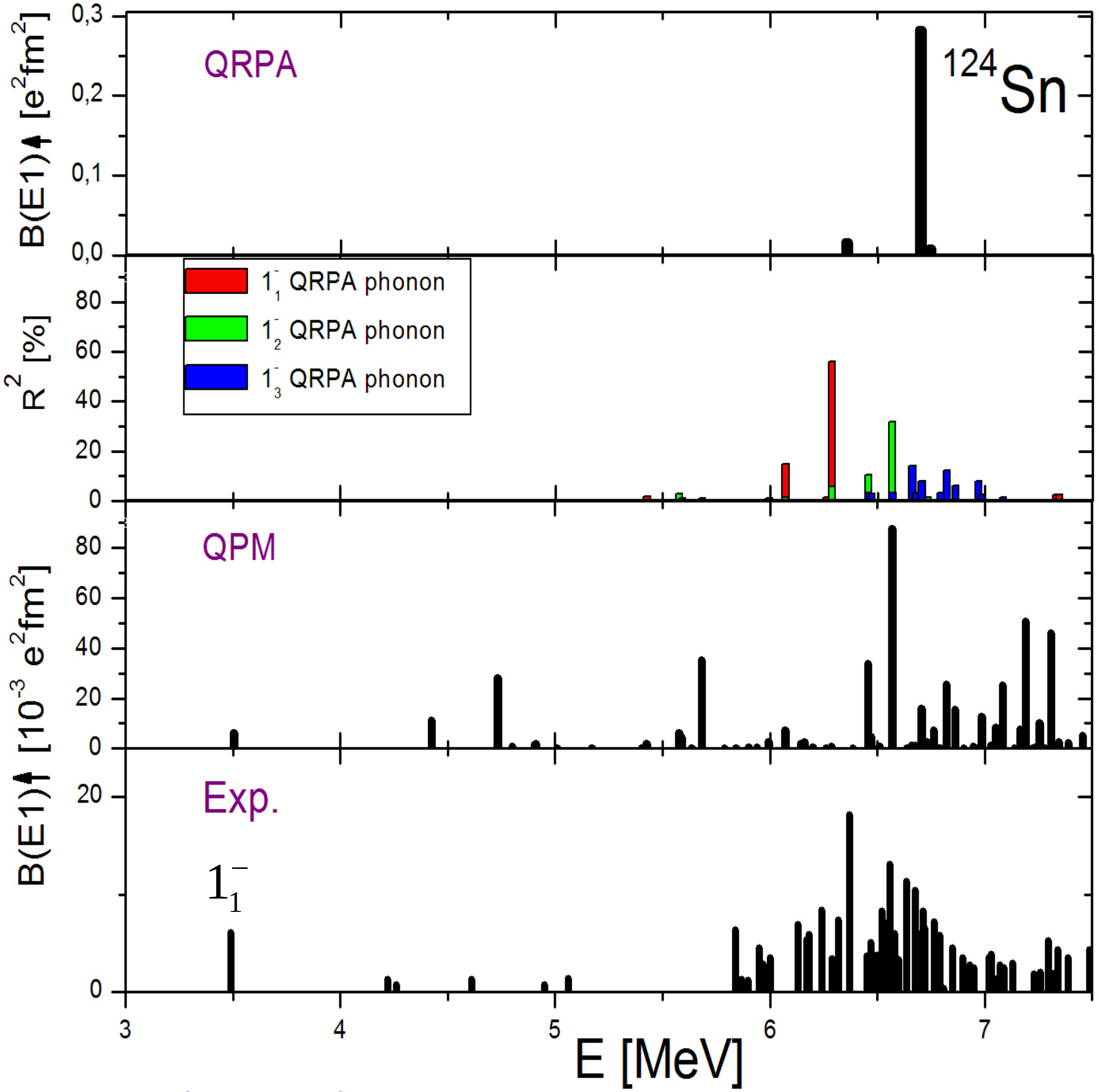
QPM results for the energies and B(E1), B(E2) and B(E3) transition probabilities of the first 1^-, 2^+ and 3^- states in Sn isotopes in comparison with experimental data.

Nucl.	$J^{\pi}_{\nu'}$	Energy [MeV] Exp.	Energy [MeV] QPM	Trans. $E\lambda$	I^{π}_{ν}	$B(E1; I^{\pi}_{\nu} \rightarrow J^{\pi}_{\nu'})$ $[10^{-3}\ e^2fm^2]$, $B(E2; I^{\pi}_{\nu} \rightarrow J^{\pi}_{\nu'})$ $[10^{4}\ e^2fm^4]$, $B(E3; I^{\pi}_{\nu} \rightarrow J^{\pi}_{\nu'})$ $[10^{6}\ e^2fm^6]$ Exp.	QPM
^{120}Sn	2^+_1	1.171	1.171	E2	0^+_1	0.200(3)	0.193
				E1	3^-_1	2.02(17)	1.82
	3^-_1	2.401	2.424	E3	0^+_1	0.115(15)	0.110
	1^-_1	3.279	3.203	E1	0^+_1	7.60(51)	7.6
^{122}Sn	2^+_1	1.141	1.137	E2	0^+_1	0.194(11)	0.190
				E1	3^-_1	2.24(14)	2.06
	3^-_1	2.493	2.486	E3	0^+_1	0.092(10)	0.099
	1^-_1	3.359	3.281	E1	0^+_1	7.16(54)	7.02
^{124}Sn	2^+_1	1.132	1.133	E2	0^+_1	0.166(4)	0.174
				E1	3^-_1	2.02(16)	1.98
	3^-_1	2.614	2.645	E3	0^+_1	0.073(10)	0.087
	1^-_1	3.490	3.549	E1	0^+_1	6.08(66)	6.27
^{126}Sn	2^+_1	1.141	1.151	E2	0^+_1	-	0.140
				E1	3^-_1	-	1.74
	3^-_1	2.720	2.792	E3	0^+_1	-	0.079
	1^-_1	-	3.856	E1	0^+_1	-	5.8
^{128}Sn	2^+_1	1.168	1.154	E2	0^+_1	-	0.097
				E1	3^-_1	-	1.07
	3^-_1	-	2.849	E3	0^+_1	-	0.081
	1^-_1	-	4.115	E1	0^+_1	-	5.56
^{130}Sn	2^+_1	1.221	1.204	E2	0^+_1	-	0.066
				E1	3^-_1	-	1.11
	3^-_1	-	2.861	E3	0^+_1	-	0.098
	1^-_1	-	4.094	E1	0^+_1	-	5.53

N. Tsoneva, H. Lenske, Ch. Stoyanov, Phys. Lett. B 586 (2004) 213
N. Tsoneva, H. Lenske, Phys. Rev. C 77 (2008) 024321

QPM calculations in ^{124}Sn in Comparison with Experimental Data

K. Govaert et al., Phys. Rev. C 57 2229 (1998)
N. Tsoneva, H. Lenske, PRC 77, 024321 (2008)



Two-phonon 1_1^- state

$B(E1; g.s. \Rightarrow 1_1^-)_{QPM} = 6.06 \cdot 10^{-3} e^2 fm^2$

$B(E1; g.s. \Rightarrow 1_1^-)_{exp} = 6.08 \cdot 10^{-3} e^2 fm^2$

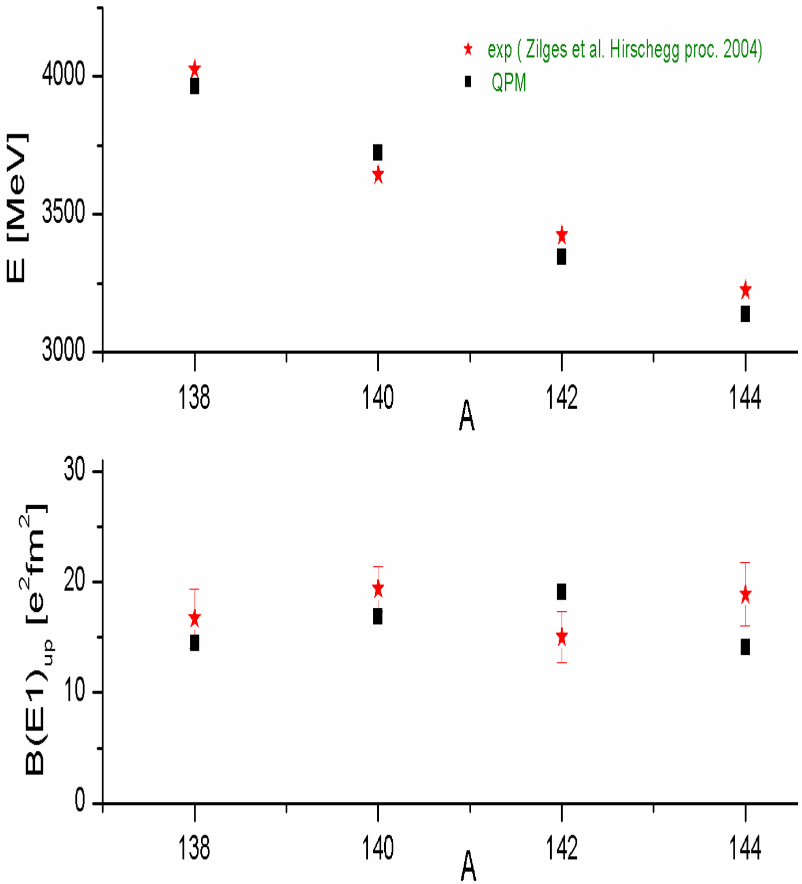
PDR strength E=5.7-7.5 MeV*

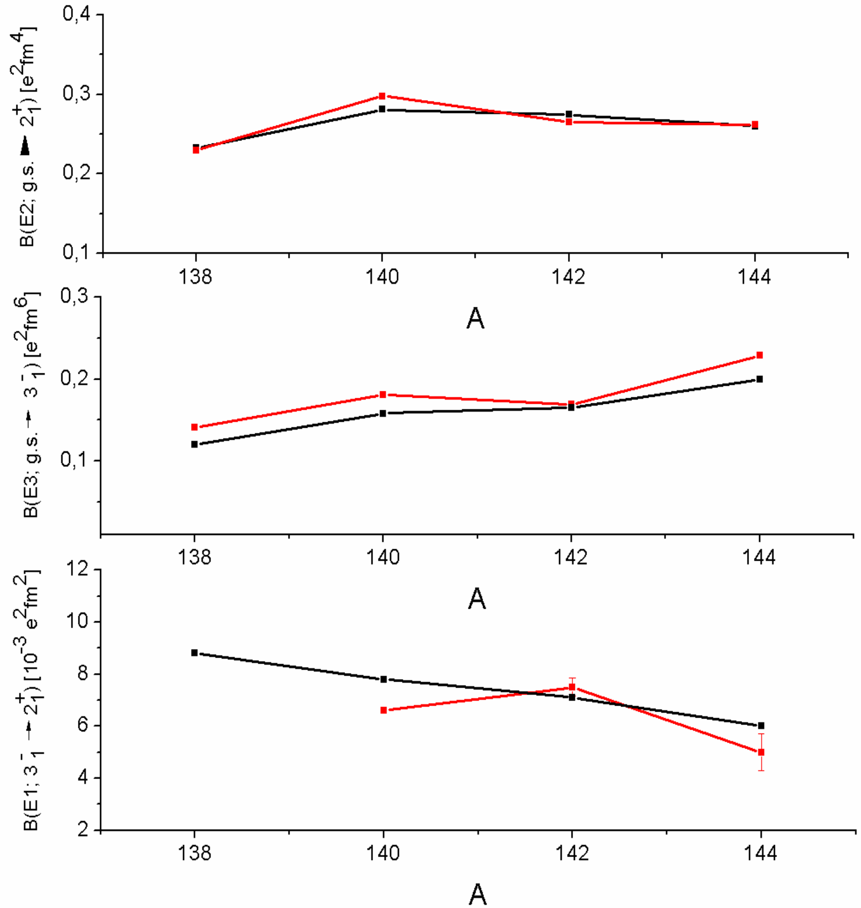
$$\sum_{QPM}^{PDR} B(E1)\uparrow = 0.324 \; e^2 fm^2$$

$$\sum_{QPM}^{PDR} B(E1)\uparrow = 0.345(43) \; e^2 fm^2$$

QPM Calculations on Energies and Transition Probabilities of the Two-Phonon 1- states Compared to Experimental data in N=82 isotones

S. Volz et al., Nucl. Phys. A, 779 (2006) 1-20.
D. Savran et al.,PRL 100, (2008) 232501.



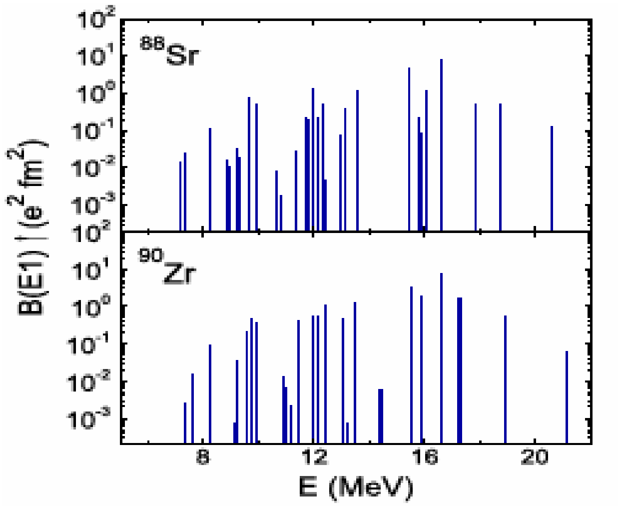


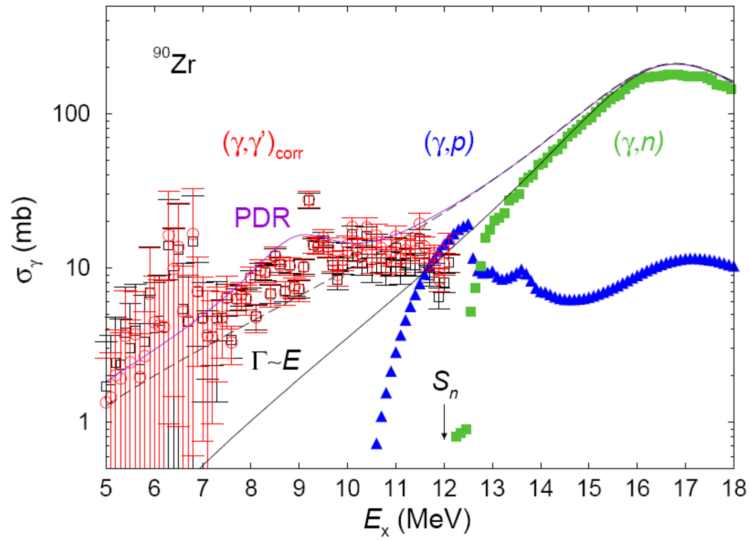
The data are taken from: S. Raman et al, At. Data Nucl. Data Tabl. 78 (2001) ;

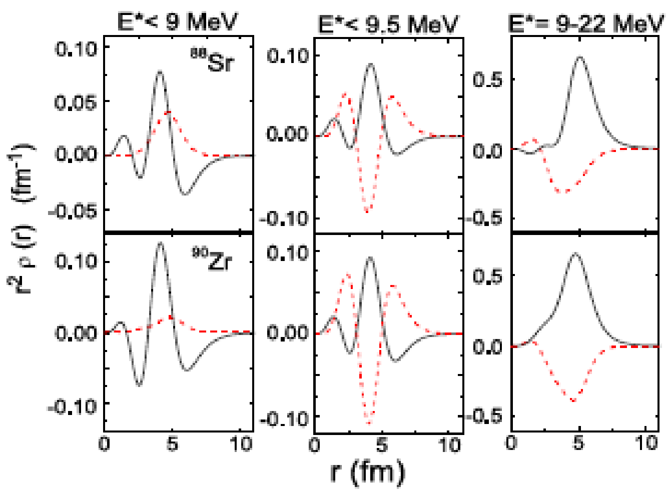
N. Pietralla, Phys. Rev. **C59** (1999) 2941.

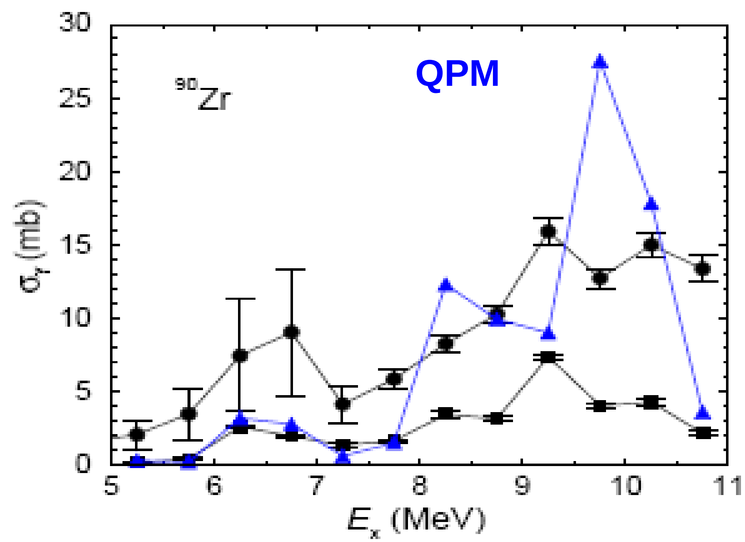
QPM Calculations of Dipole Photoabsorption Cross Section in ^{90}Zr in comparison with Experimental Data Obtained from Inelastic Photon Scattering (ELBE-Rossendorf)

R. Schwengner et al, Phys. Rev. C 78 (2008) 064314









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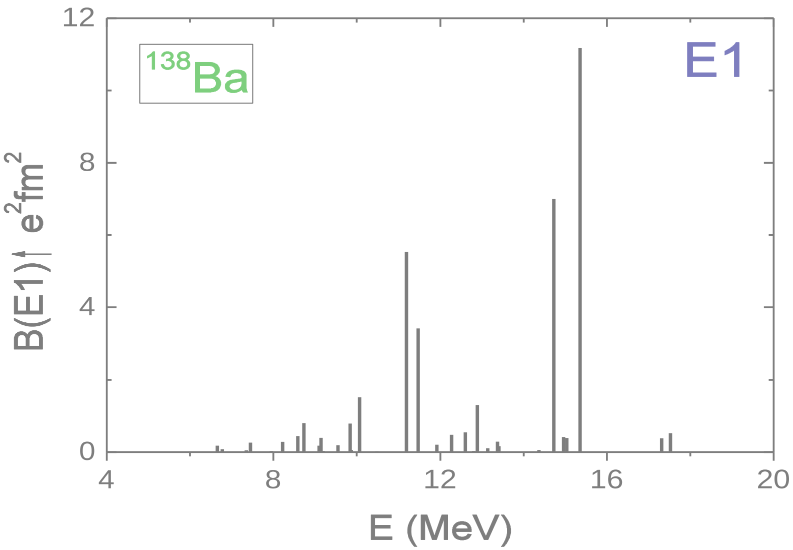
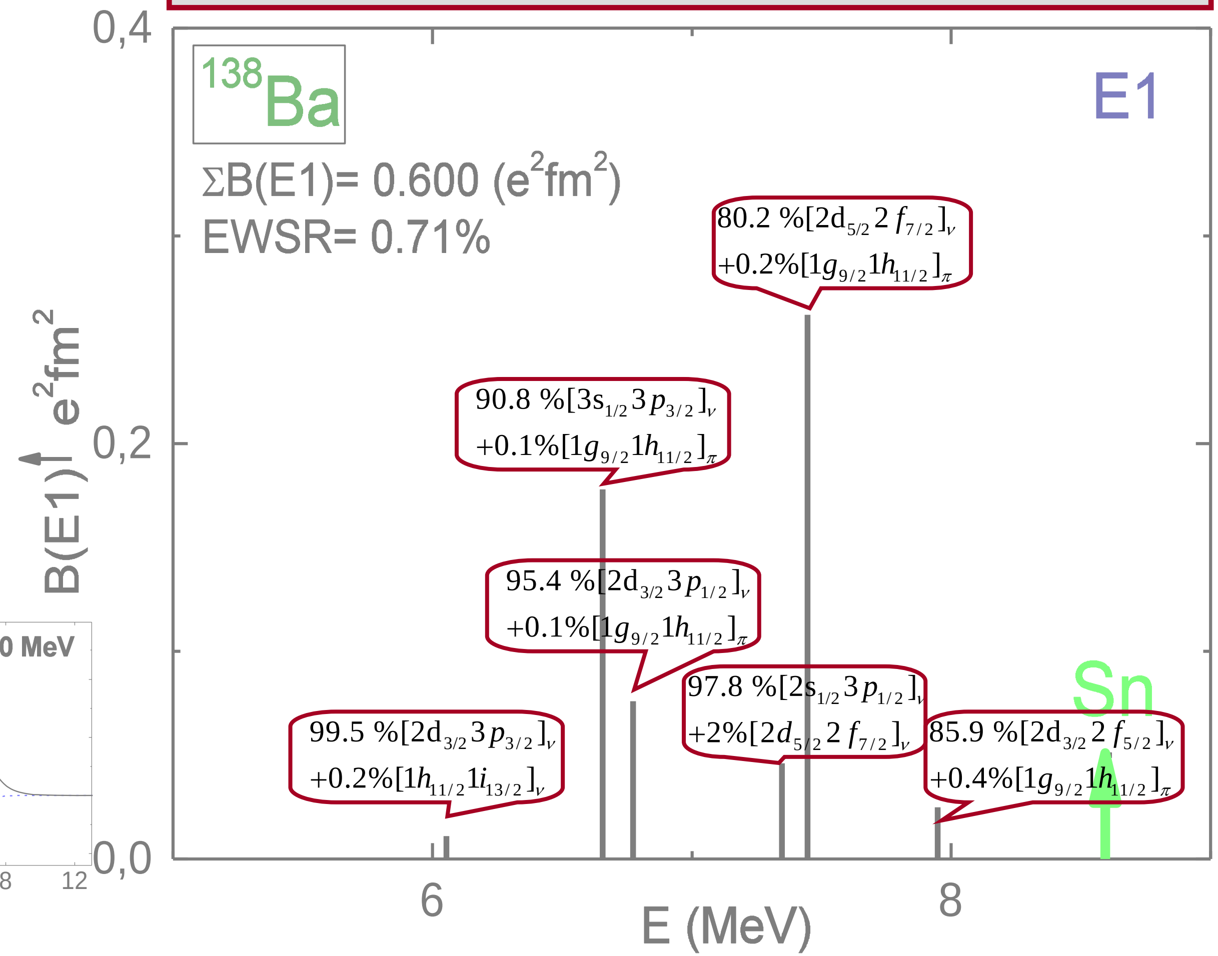
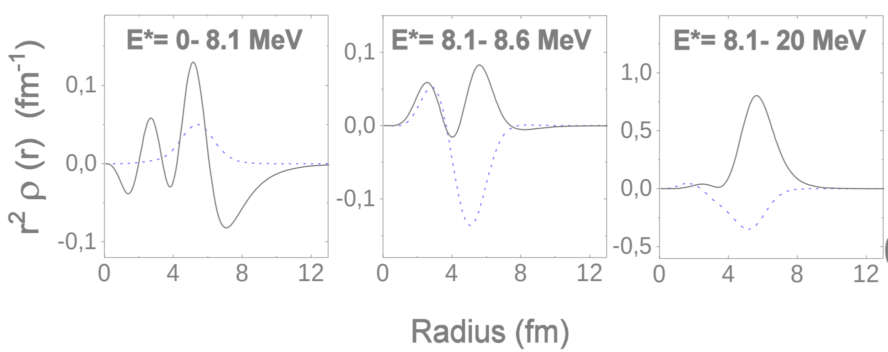
QRPA Calculations of 1^- States in ^{138}Ba

Phys. Rev. Lett. 104, 072501 (2010)

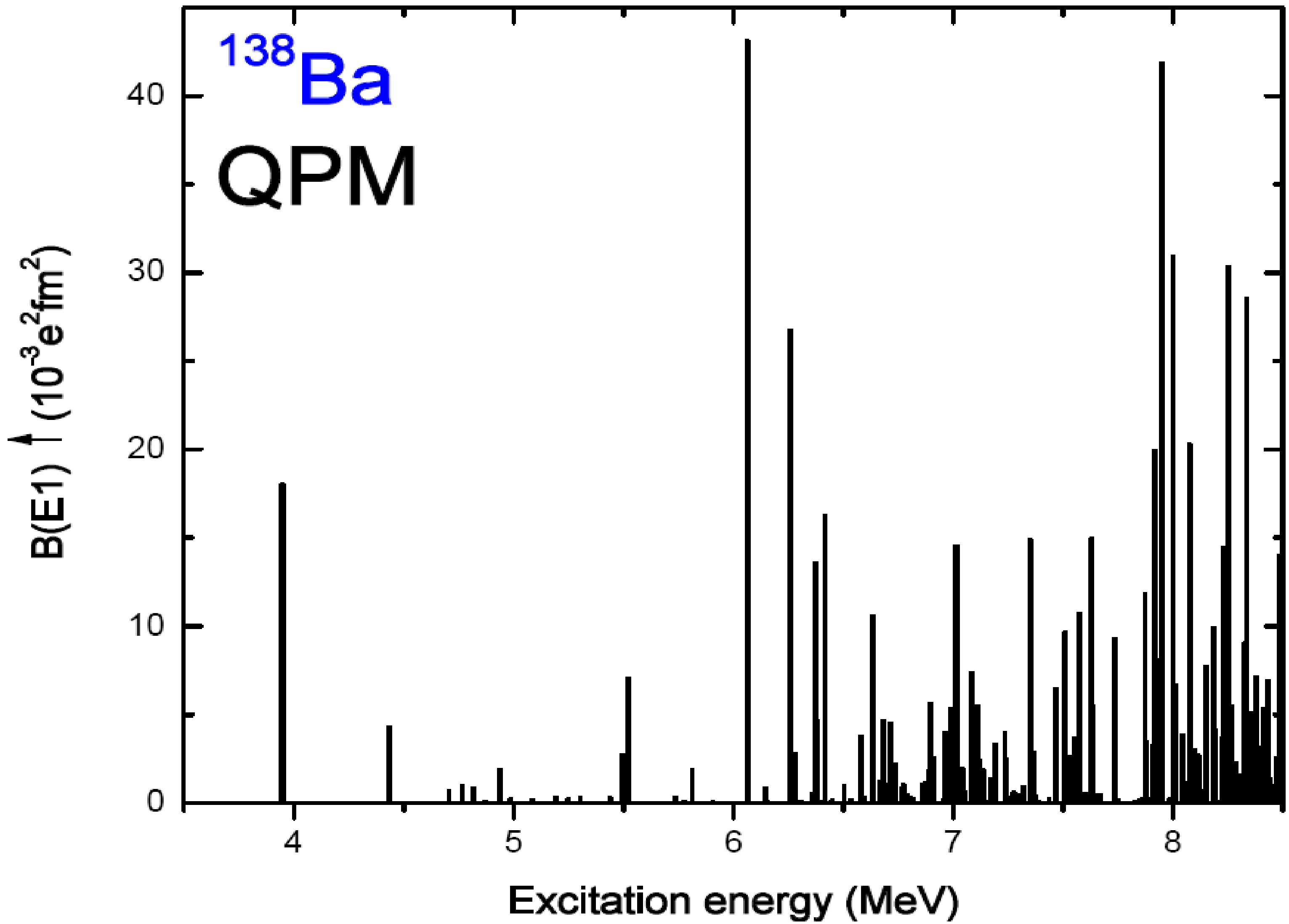


Low-energy E1 strength related to neutron skin



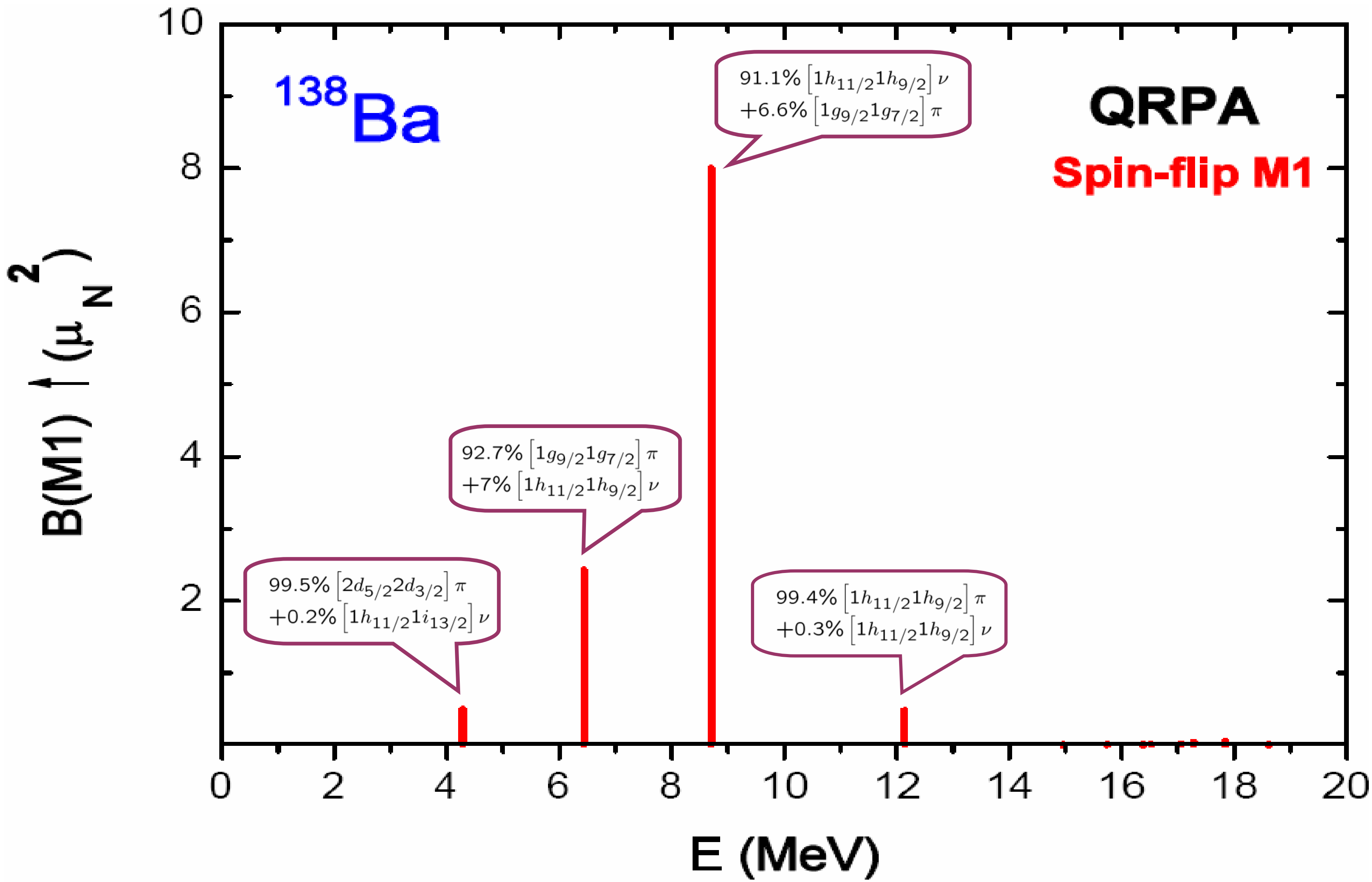


QPM Calculations of E1 Strength in ^{138}Ba



Are There Other than E1 Dipole Excitations in the PDR Region ?

QRPA Calculations of 1^+ States in ^{138}Ba



Parity Measurements with Polarized Photon Beams of Low-energy Dipole Excitations in ^{138}Ba $(\vec{\gamma}, \gamma')$ at HIGS, Duke, USA

Phys. Rev. Lett. 104, 072501 (2010)

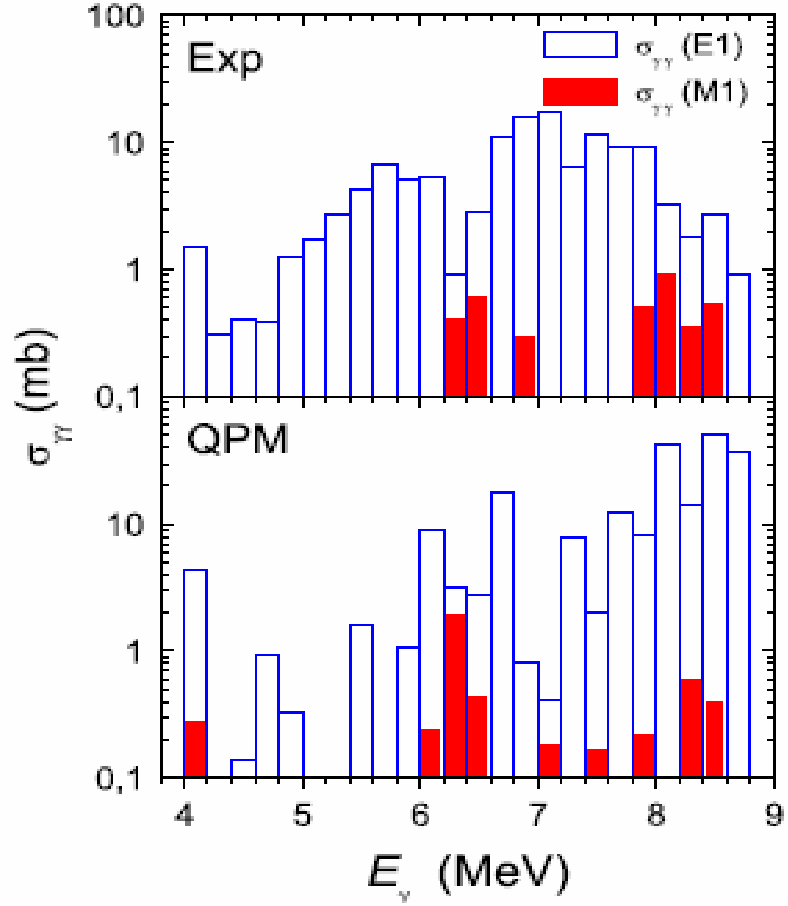
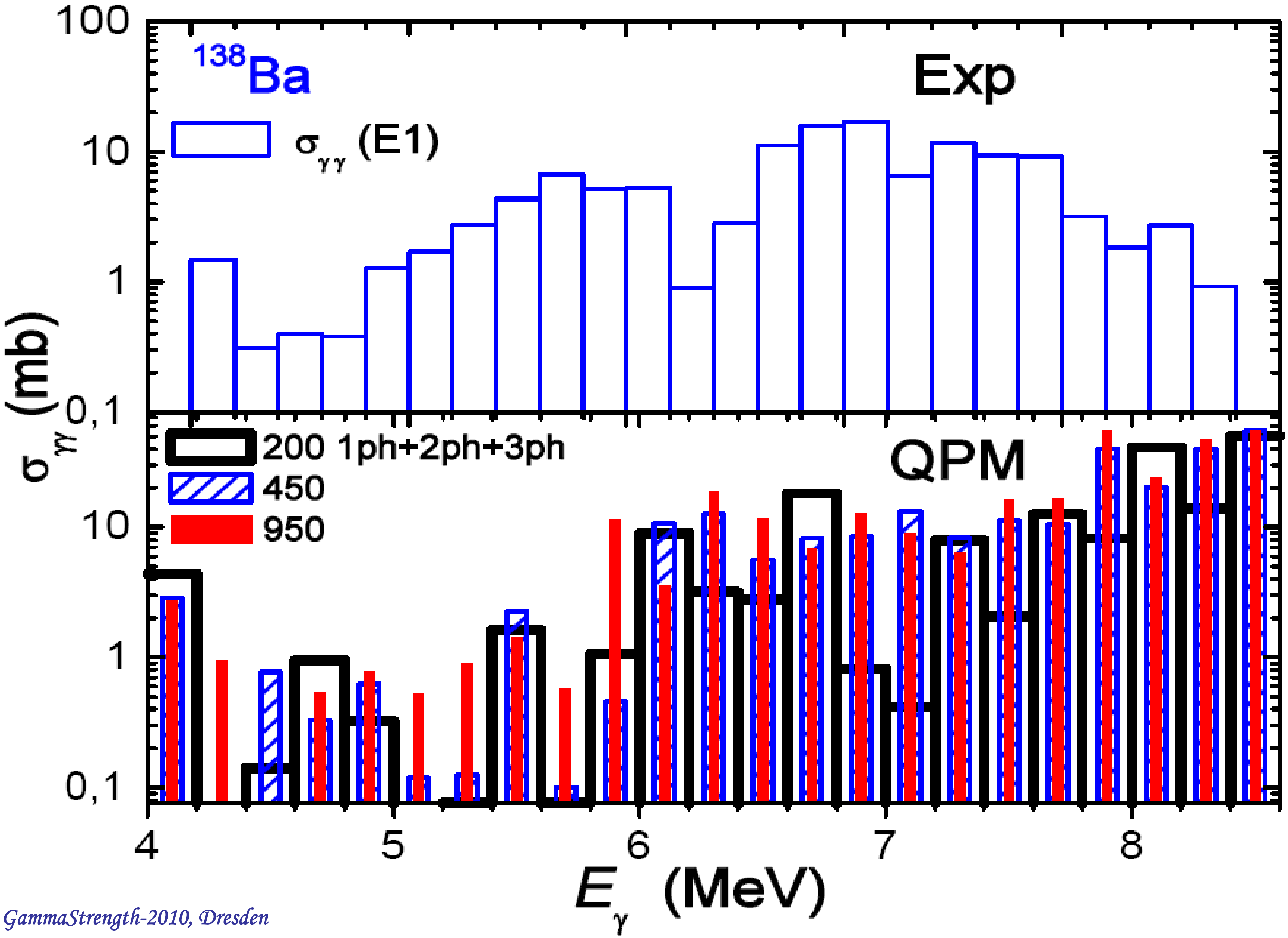


TABLE I. $E1$ and $M1$ parameters deduced in ^{138}Ba below the neutron-separation energy in comparison with the QPM calculations.

	$\langle E_{E1}\rangle$ [MeV]	$\Sigma B(E1)\uparrow [e^2\,\mathrm{fm}^2]$	$\langle E_{M1}\rangle$ [MeV]	$\Sigma B(M1)\uparrow [\mu_N^2]$	EWSR_{E1} [%]
Experimental	6.7	0.96(18)	6.9	2.5(6)	1.3
QPM	7.3	1.22	6.9[a]	2.9[a]	1.8

[a] $4.1\ \mathrm{MeV} < E^* < 8.5\ \mathrm{MeV}$.

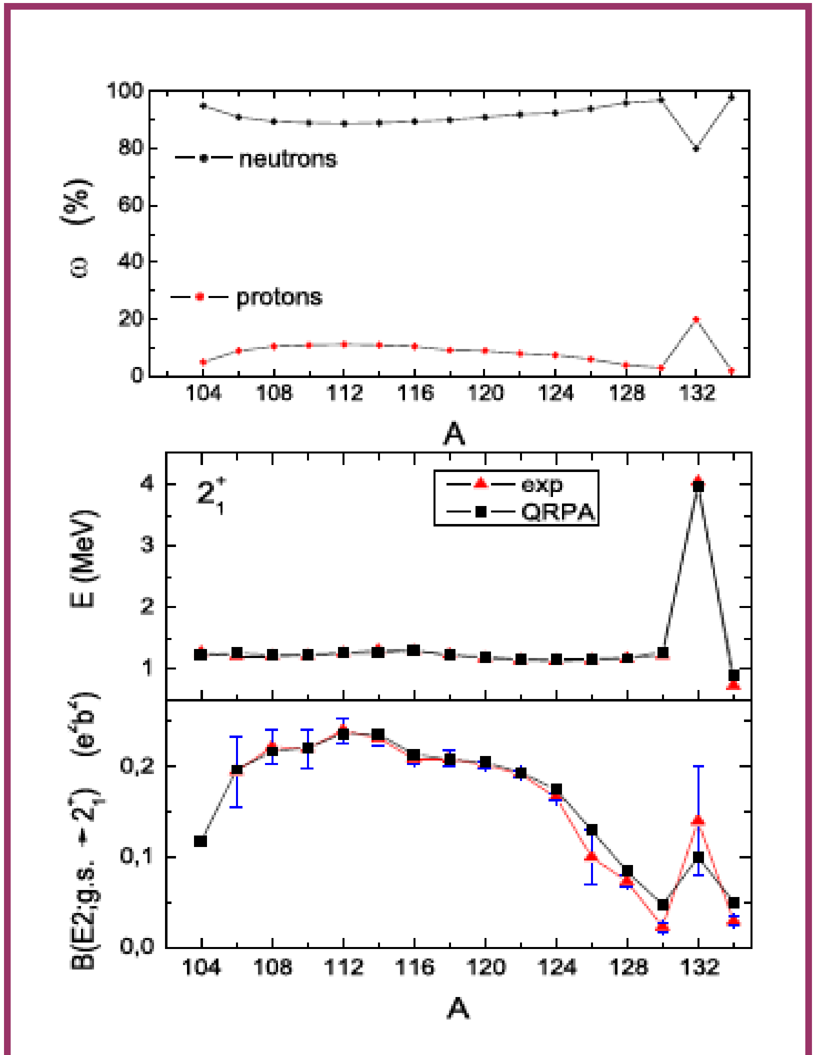
QPM Calculations of 1⁻ States within Different Phonon Spaces

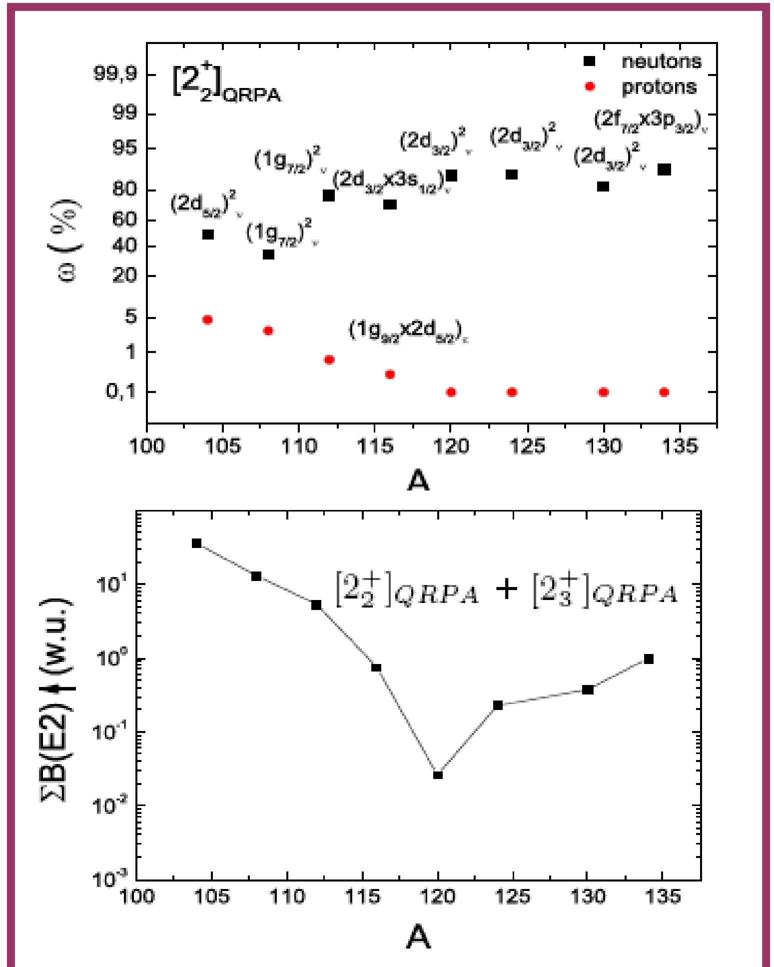


N. Tsoneva, GammaStrength-2010, Dresden

Low-Energy Quadrupole Excitations in Sn Nuclei

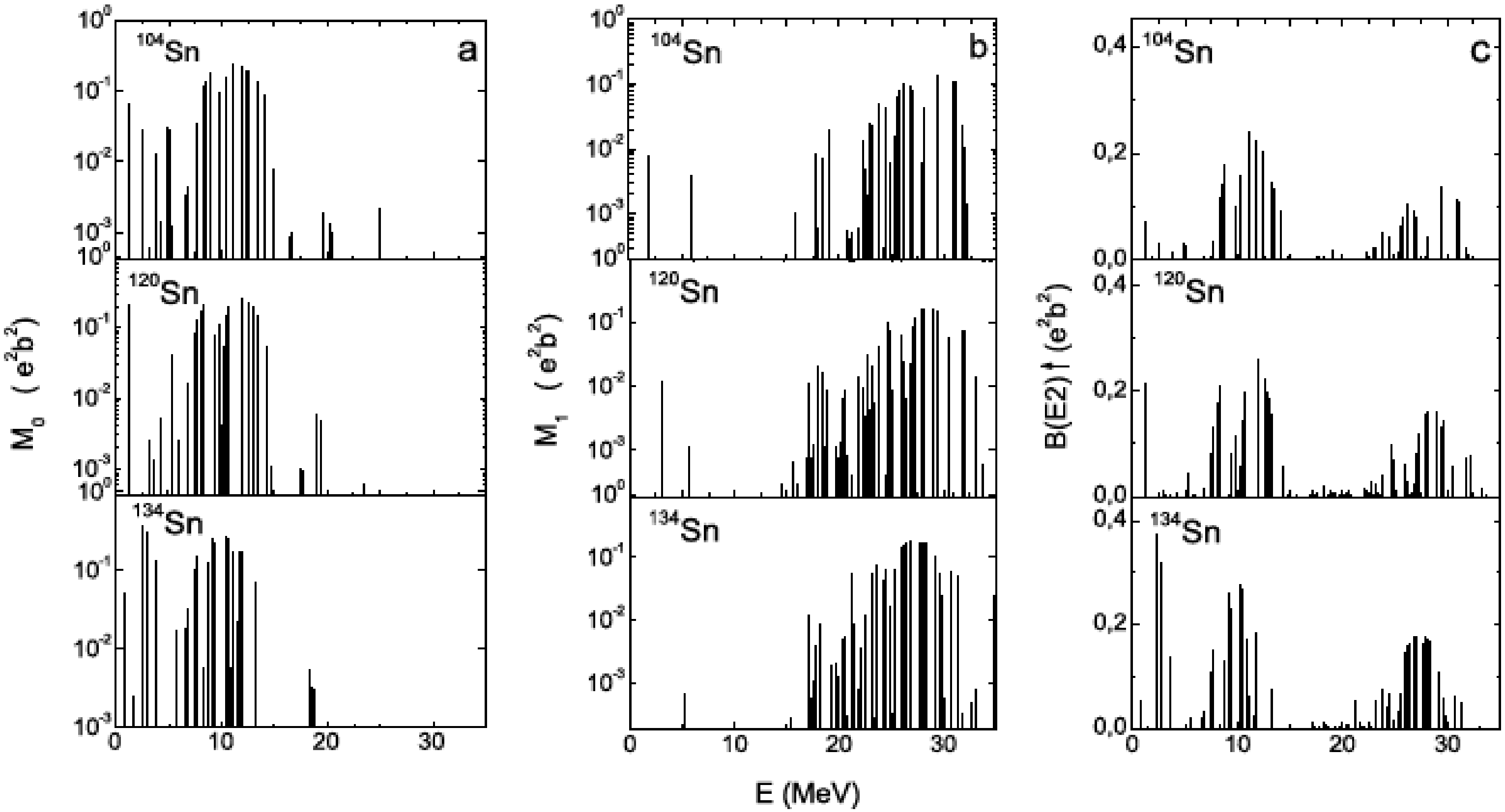
$$\omega_{j_1 j_2}(\lambda\mu i) = \sum(|\psi^{\lambda\mu i}_{j_1 j_2}|^2 - |\varphi^{\lambda\mu i}_{j_1 j_2}|^2) * 100(\%)$$





Isoscalar and isovector quadrupole states in Sn nuclei

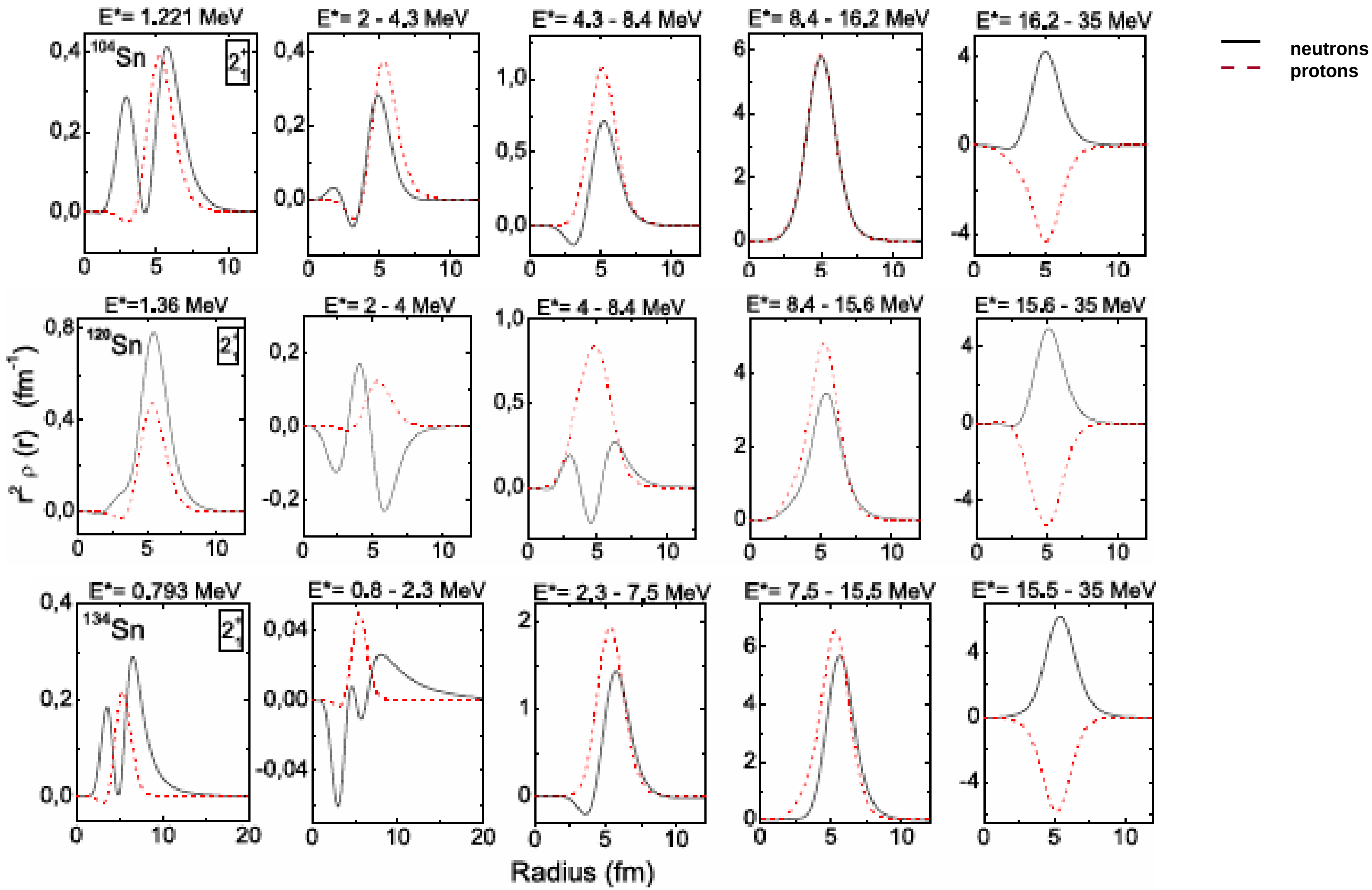
$$M_{0(1)}(2^+) \approx \left| \left\langle 2^+ \left\| \sum_k^p r_k^2 Y_{2\mu}(\Omega_k) \pm \sum_k^n r_k^2 Y_{2\mu}(\Omega_k) \right\| g.s. \right\rangle \right|^2$$



QRPA Calculations of Isoscalar and Isovector Quadrupole States in Sn Isotopes

A Possible Signature of a Pygmy Quadrupole Resonance

N. Tsoneva, H. Lenske, PLB submitted, arXiv:0910.3487 [nucl-th]



Conclusions

- *A correlation between the total PDR strength and the neutron-to-proton ratio N=Z defining the size of the neutron or proton skin.*

- *The PDR is independent of the type of nucleon excess.*

- *Investigations the assumption that the low-energy dipole strength in N=82 should be related mostly to E1 strength. Even though, in order to determine the pure dipole strength associated with PDR and neutron skin phenomenon , the magnetic contribution must be identified and subtracted.*

- *B(E2) transitions of low-energy mixed-symmetry 2^+ states in Sn isotopes are found correlated with the number of the excess nucleons. These states are clustered in a confined energy region and may be considered forming a Pygmy Quadrupole Resonance.*

- *Furthermore, the correlation of the Pygmy Quadrupole Resonance strength with the neutron (proton) skin thickness manifests itself via a transition from a neutron PQR to a proton PQR in ^{104}Sn, the mass region where the neutron skin reverses into a proton skin.*