Institut für Theoretische Physik I

4th Workshop on Nuclear Level Density and Gamma Strength

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Low-energy Electric and Magnetic Excitations Relevant to the Astrophysics

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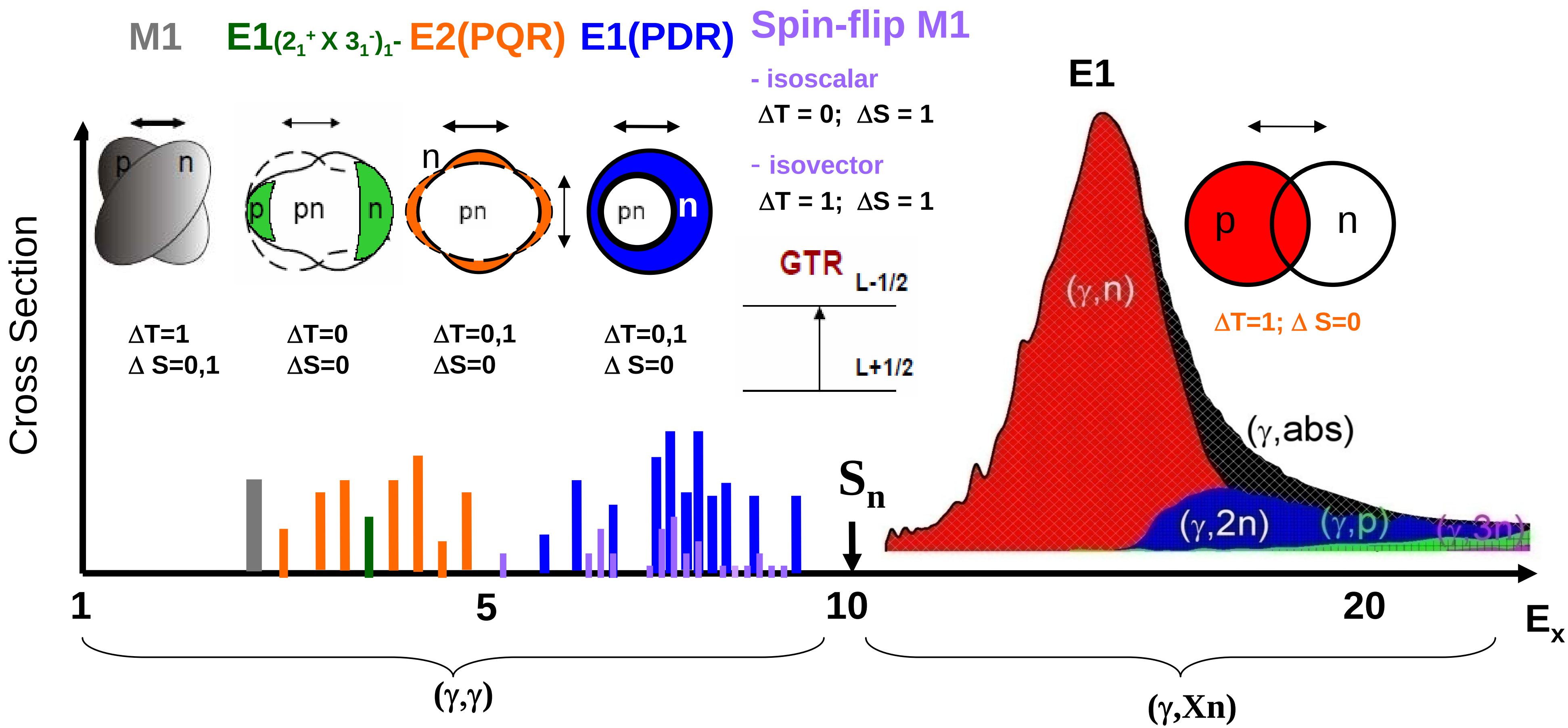
Sponsored by DFG and BMBF project 06GI9109

Characteristic Response of an Atomic Nucleus to EM Radiation

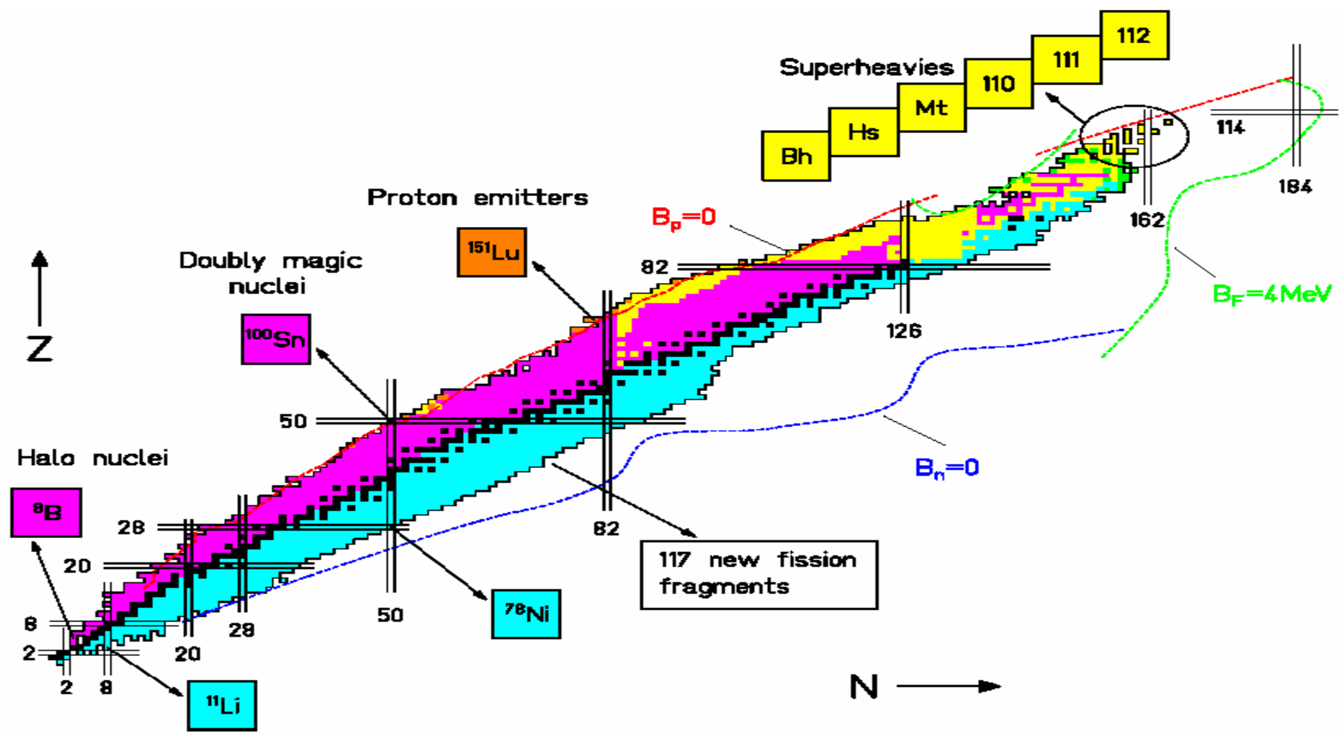


Moderate and Heavy nuclei :

- Orbital "Scissors" mode: E_x ~ 3 MeV, B(M1) ~ 3 μ_N^2
- Two Phonon Excitation: E_x ~ 4 MeV, B(E1) ~ 10^{-3} W.u.
- Pygmy Quadrupole Resonance: Ex ~ 2 - 5 MeV, B(E2) ~ 0.5 W.u.
- Pygmy Dipole Resonance: E_x ~ 6 - 9 MeV, B(E1) ~ 0.5 W.u.
- Spin-flip M1 excitations: E_x~ 4 - 12 MeV, B(E2) ~ 6 μ_N^2
- Giant Dipole Resonance: E_x ~ 10 - 20 MeV, B(E1) ~ 5 - 12 W.u.

Nucleosynthesis of Heavier Elements

Heavier elements (Z> 26-28) can be assembled within stars by a neutron capture processes.



s- process – slow neutron capture, low neutron densities

$(\sim 10^8 /cm^3)$

life time

$(\sim$ 1-10 years$)$

in explosive environments - Supernovae:

r – process - rapid neutron captures

ν – induced processes

rp – process - rapid proton captures

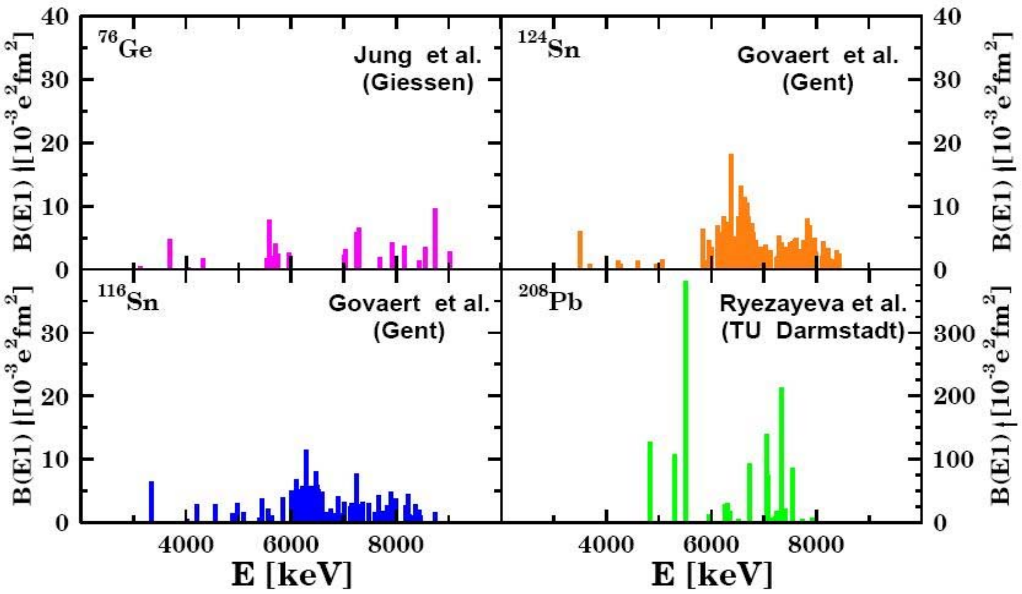
p-process (or γ-process) - photodisintegration of existing nuclei and ect…

Enhanced Dipole Strength

Observed strength in stable nuclei with moderate neutron excess (N > Z)

Below the neutron-separation energy (S_n ≈ 9 MeV)

1999 Govaert et al. PRC (γ,γ`)
2000 Hartmann et al., PRL (γ,γ`)
2002 A. Zilges et al., PLB (γ,γ`)
2002 Ryezayeva et al. PRL (γ,γ')
2004 Hartmann et al. PRL (γ,γ`)
2006 Savran et al. PRL (α,α' γ) and (γ
2006 Voltz et al. NPA (γ,γ`)
2008 Rusev et al. PRC (γ,γ`)
2008 Schwegner et al. PRC (γ,γ`)
2009 Savran et al. PRL (γ,γ`)
2011 Savran et al. PRC (γ,γ`)



PDR ≤ 1% of the Thomas-Reiche-Kuhn sum rule (S_{TRK} ~ NZ/A)

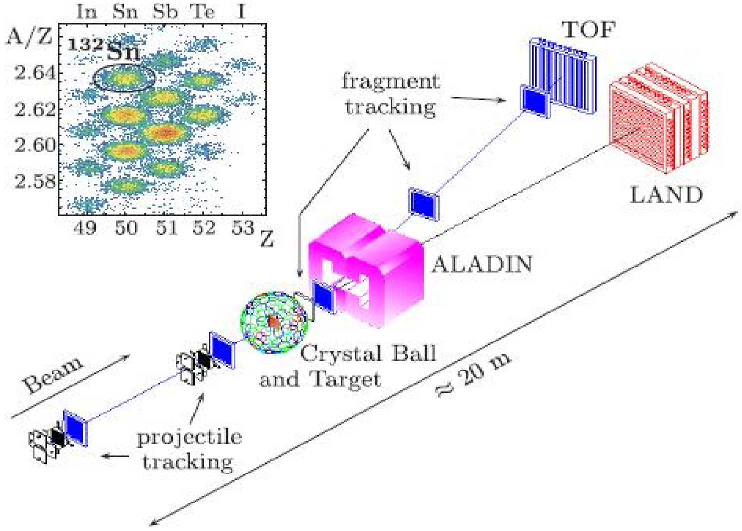
Enhanced Dipole Strength

Observed strength in unstable nuclei with neutron excess (N > Z)

Above the neutron separation energy: ~ 5 -7% of the EWSR

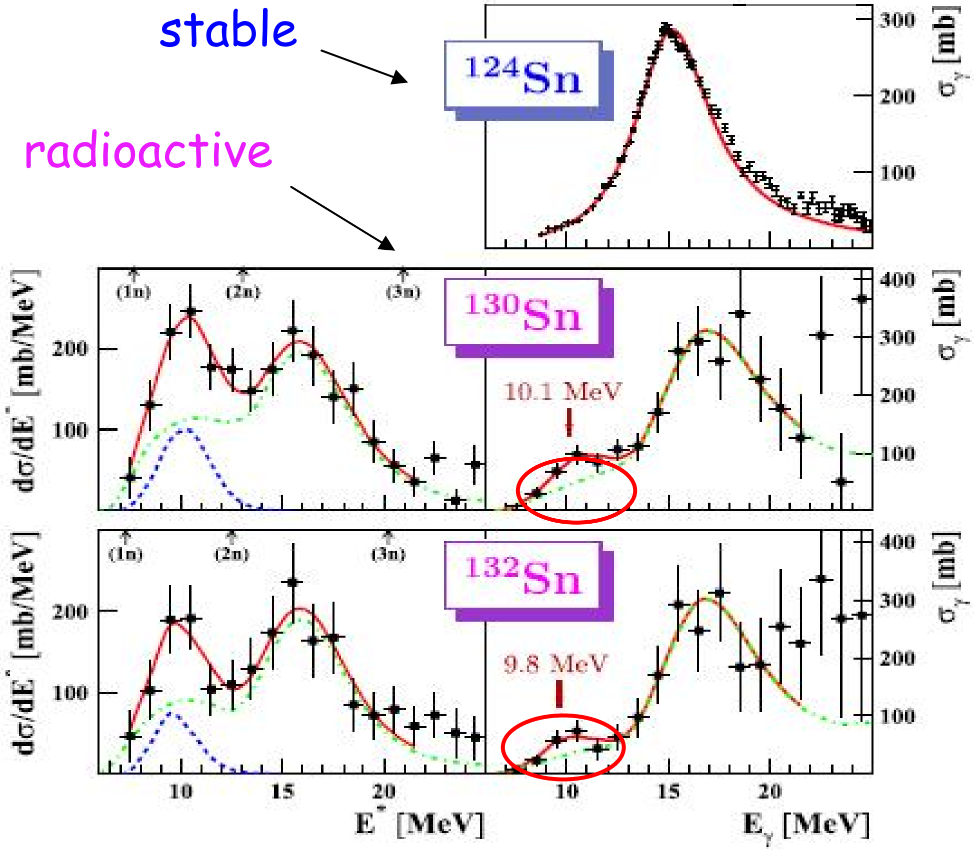
2005 Adrich et al. PRL (^{132}Sn, ^{9}Be)
2009 Wieland et al. PRL (^{68}Ni, ^{9}Be)
2008 Gibelin et al. PRL (^{26}Ne, ^{208}Pb)

LAND-FRS collaboration at GSI



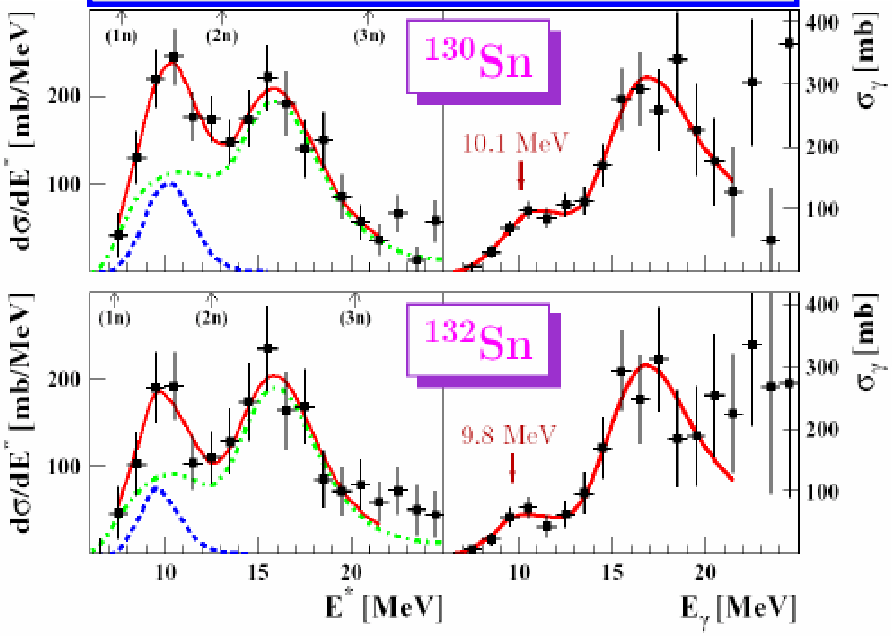
stable

radioactive

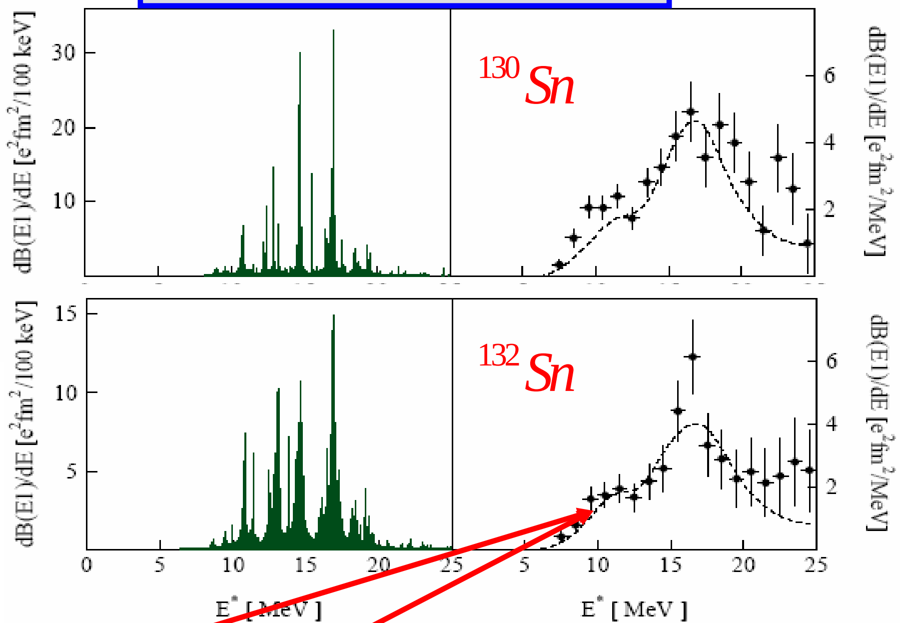


QPM calculations of excitation energies and integrated cross sections in ^{130,132}Sn in comparison with recent data / A. Klimkiewicz and the LAND-FRS collaboration, private communication/.*

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



QRPA and LAND-FRS data



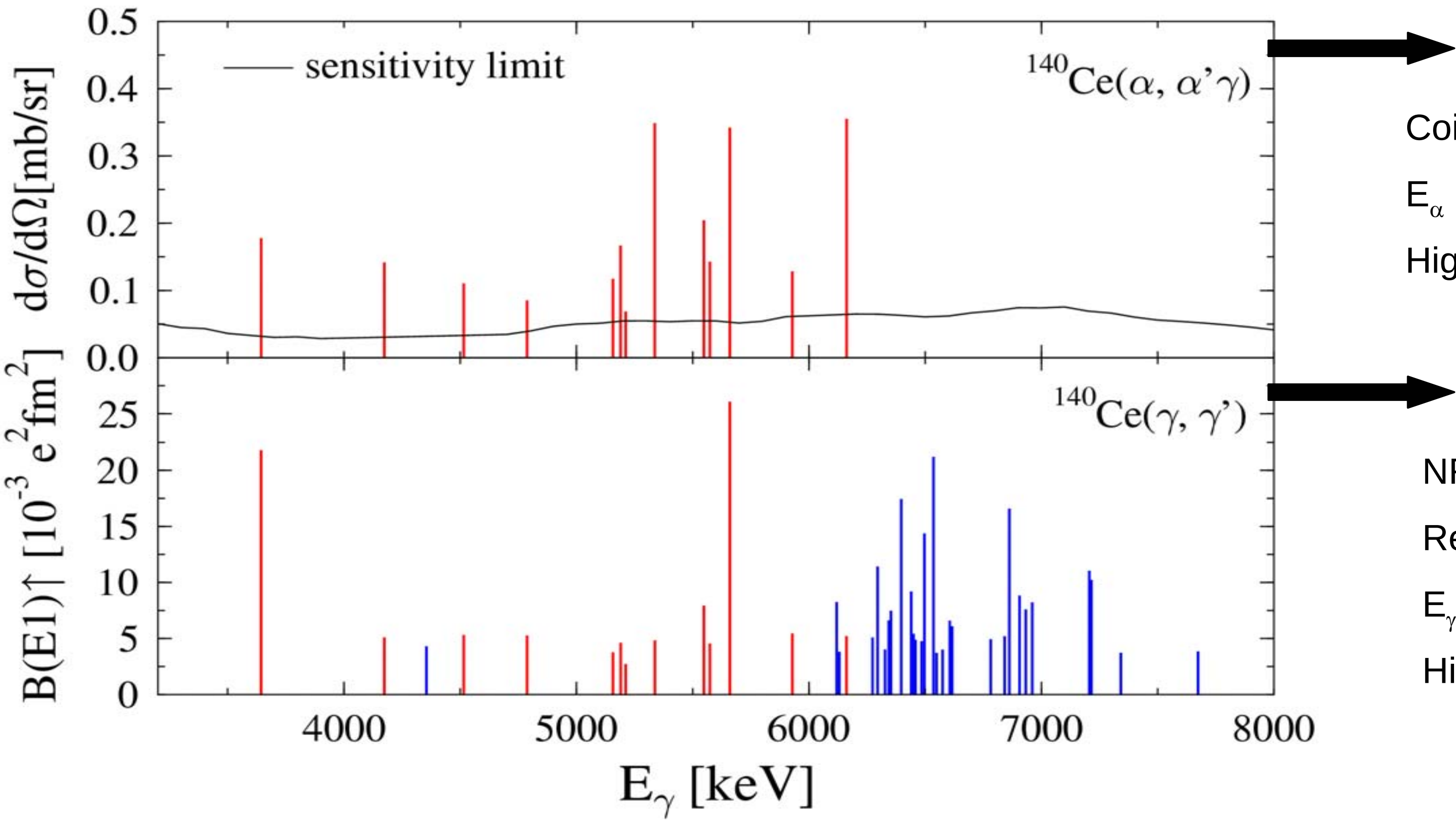
N. Tsoneva, H. Lenske, PRC 77 (2008) 024321

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.**

Splitting of the Pygmy Dipole Resonance. Mixed Isospin Character.

Complementary experiments with a-particles could provide deeper understanding of the PDR structure



KVI

Coincident experiment

E_α = 130 MeV

High energy resolution

TUD

NRF experiment

Real photons

E_γ = 4 - 8 MeV

High energy resolution

D. Savran et al. PRL, **97** 172505 (2006)

D. Savran et al. NIMA **564** 267 (2006)

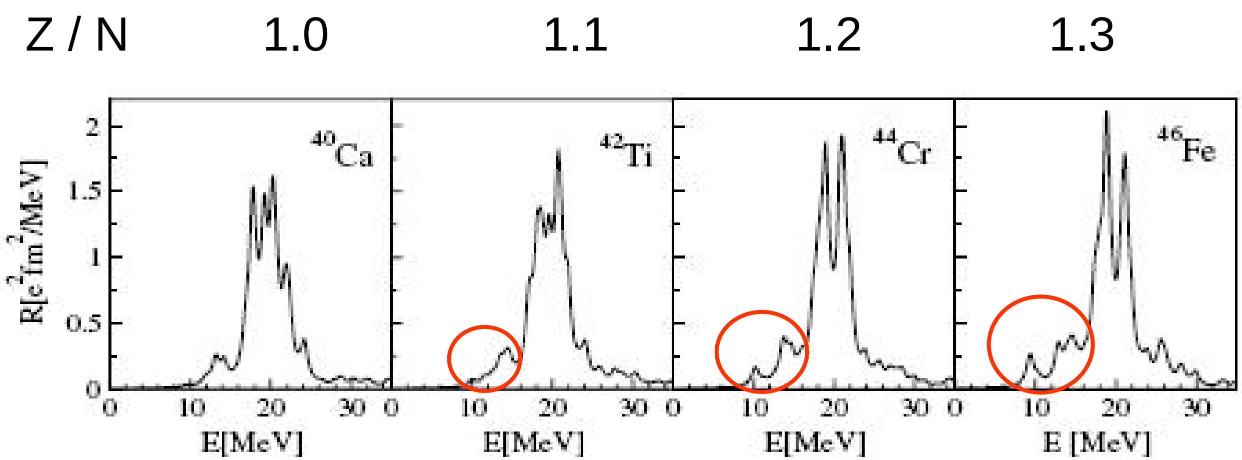
J. Endres et al. PRL **105**, 212503 (2010)

Talk of V. Derya

Enhanced Dipole Strength

Predicted in nuclei with proton excess (Z > N)

2005 N. Paar et al. PRL
2008 N. Tsoneva et al. PRC
2009 N. Paar et al. PRL



PDR is independent of the type of nucleon excess (neutron or proton)

=> Generic mode of excitation

Predicted pygmy quadruple resonance in charge-asymmetric nuclei (Sn isotopic chain)

2011 N. Tsoneva et al. PLB

The Quasiparticle-Phonon Model

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

$$H = H_{MF} + H_{res}$$

$$H_{MF} = H_{sp} + H_{pair} \qquad H_{res} = H_M^{ph} + H_{SM}^{ph} + H_M^{pp}$$

Nuclear Ground State

Single-Particle States

Phenomenological density functional approach based on a fully microscopic self-consistent Hartree-Fock-Bogoljubov (HFB) theory

Pairing and Quasiparticle States

BCS gap equation, solved separately for protons and neutrons

Residual Interaction

Separable Forces

$$V(r, r') = -\kappa_\lambda \upsilon_\lambda(r)\upsilon_\lambda(r')$$

$$V = -\frac{1}{2}\sum_{lm} \kappa_\lambda M^{+}_{\lambda\mu}(r) M_{\lambda\mu}$$

$$M_{\lambda\mu} = \sum_{j_1 j_2} \langle j_1 | \upsilon_\lambda Y_{lm}(\theta,\varphi) | j_2 \rangle a^{+}_{j_1} a_{j_2}$$

$$\kappa_\lambda = (\kappa^0_\lambda, \kappa^1_\lambda)$$

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

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

The total binding energy B(A) can be expressed as an integral over an energy-density functional

$$B(A) = \sum_{q=p,n} \int d^3r \left(\tau_q(\rho) + \frac{1}{2}\rho_q U_q(\rho) \right) + E_q^{pair}(k,\rho)$$

$$\rho_q = \sum_k v_{kq}^2 \left|\varphi_{kq}(\vec{r})\right|^2 \qquad \text{number density}$$

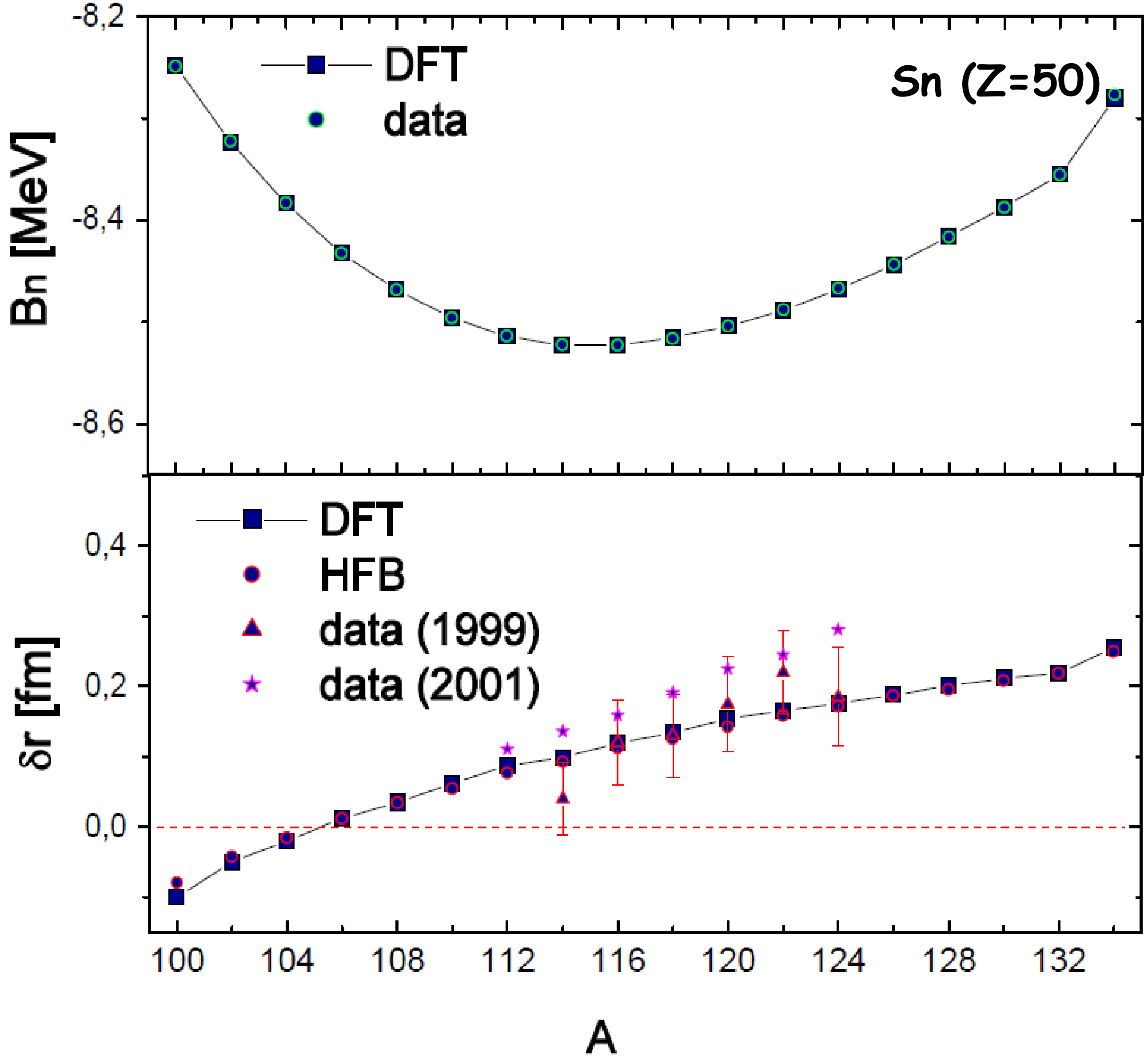
$$\tau_q = \sum_k v_{kq}^2 \left|\vec{\nabla}\varphi_{kq}(\vec{r})\right|^2 \qquad \text{kinetic density}$$

$$\kappa_q = \sum_k v_{kq} u_{kq} \left|\varphi_{kq}(\vec{r})\right|^2 \qquad \text{pairing density}$$

$$v_{kq}^2 = \frac{1}{2}\left(1 - \frac{e_q(k) - \lambda_q}{\sqrt{\left(e_q(k) - \lambda_q\right)^2 + \Delta_q(k)}} \right) \quad ; \quad v_{kq}^2 + u_{kq}^2 = 1$$

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

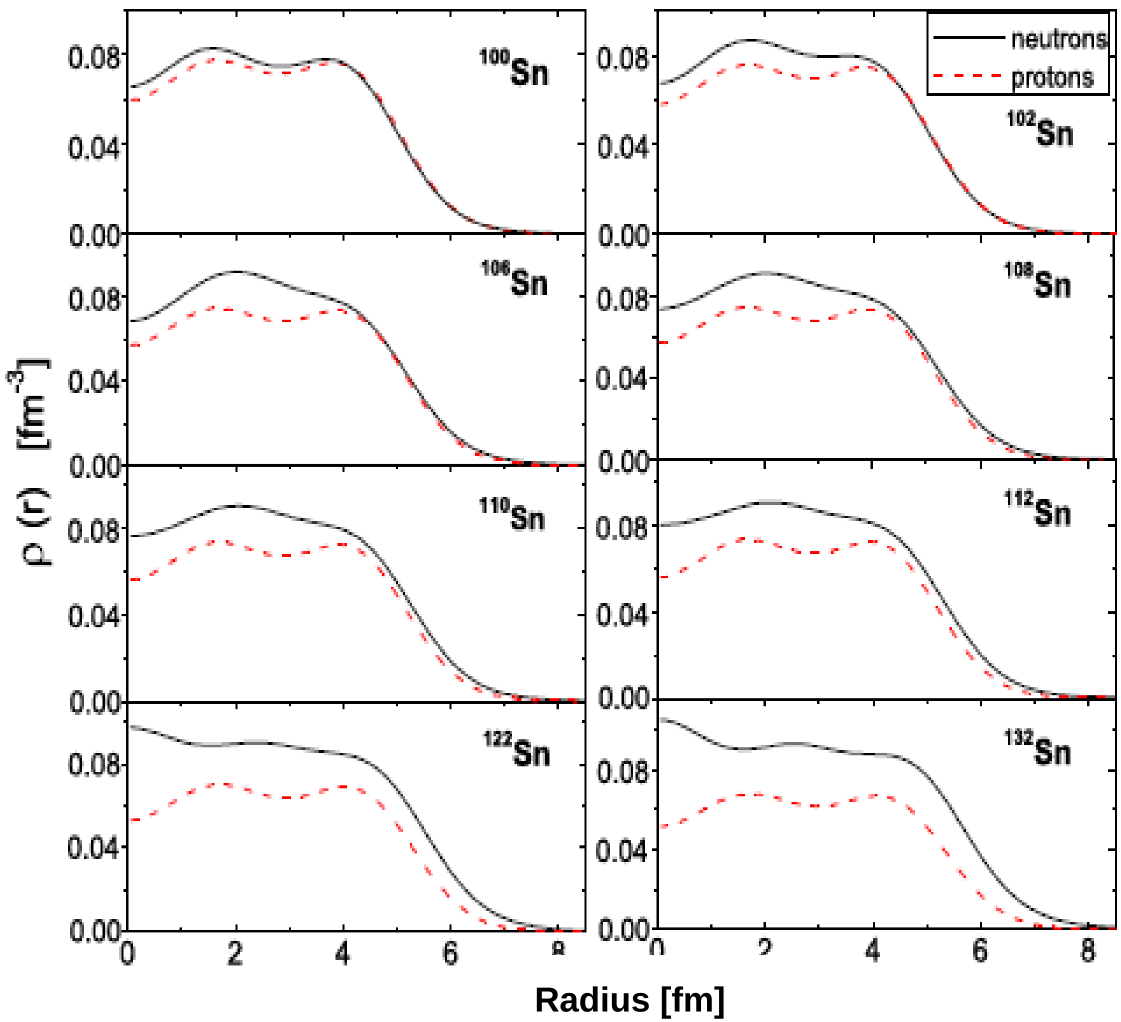
Binding Energy and Skin Thickness

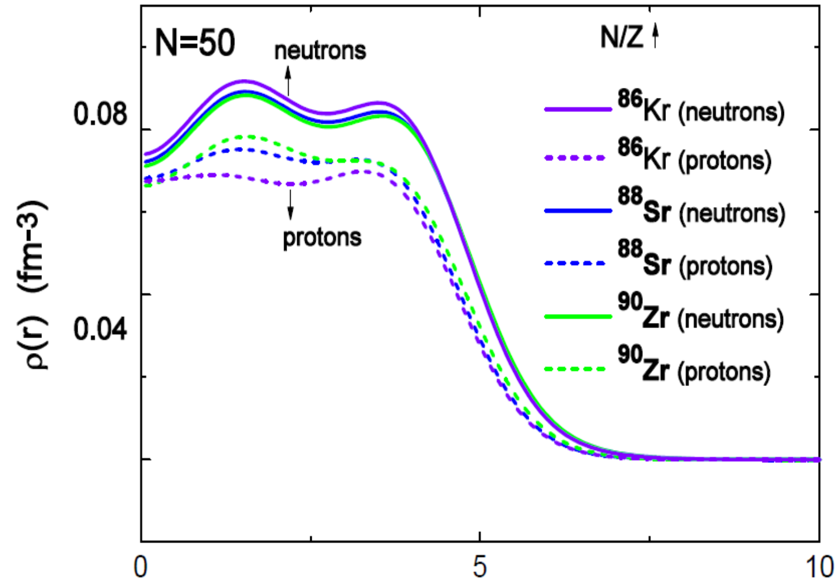


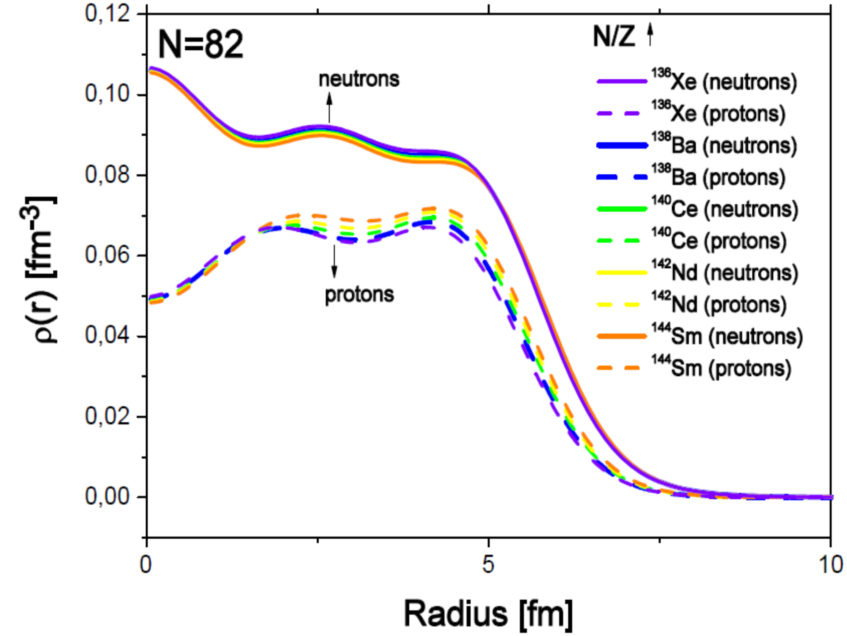
$$\delta r = \sqrt{< r^2 >_n} - \sqrt{< r^2 >_p}$$

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

$$\rho_q(r)=\frac{1}{4\pi r^2}\sum_{\alpha_q} v_{\alpha_q}^2 (2j_{\alpha_q}+1)R_{\alpha_q}^2(r)$$







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

The Excited States

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

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

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

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

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

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

The Wave Function

For even-even nucleus the QPM wave functions are a mixture of one-, two- and three-phonon components

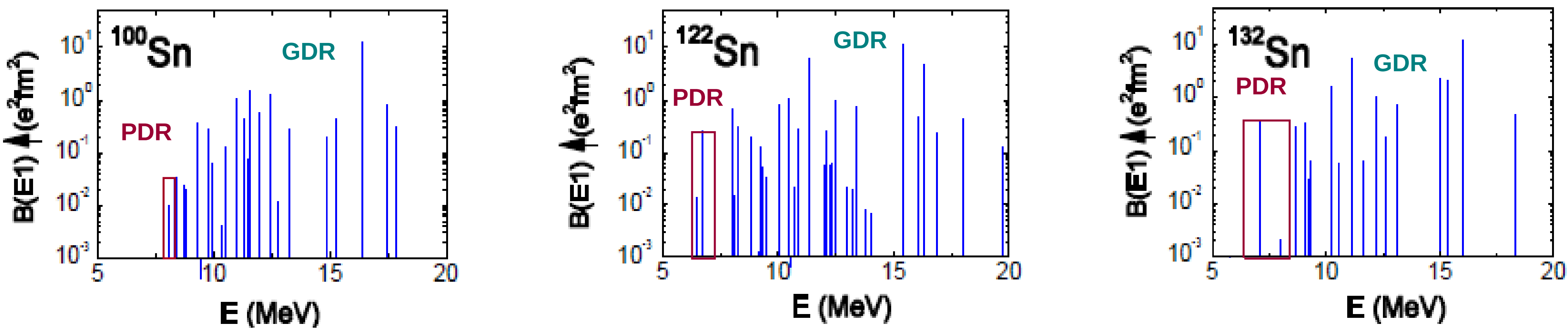
$$\Psi_\nu(JM) = \Bigg\{ \sum_i R_i(J\nu) Q^+_{JMi} + \sum_{\substack{\lambda_1 i_1 \\ \lambda_2 i_2}} P^{\lambda_1 i_1}_{\lambda_2 i_2}(J\nu) \left[Q^+_{\lambda_1 \mu_1 i_1} \times Q^+_{\lambda_2 \mu_2 i_2} \right]_{JM}$$

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

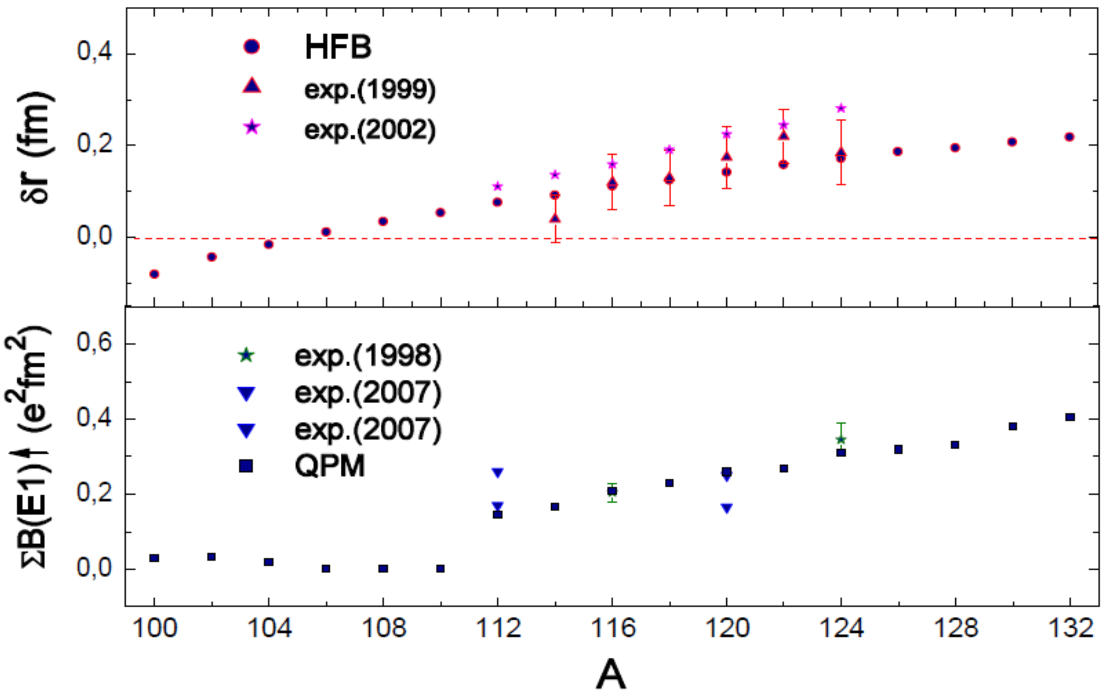
M. Grinberg, Ch. Stoyanov, Nucl. Phys. A. 573 (1994) 231

QRPA Calculations on the Dipole Response in Sn Isotopes

A connection between the total PDR strength and the neutron or proton skin



Skin Thickness and Electric Dipole Response



$$\delta r = \sqrt{\langle r_n^2 \rangle} - \sqrt{\langle r_p^2 \rangle},$$

$$\Delta_3 r^2 = \sum_i \langle 0 | \tau_{3i} r_i^2 | 0 \rangle,$$

Neutron number increasing (Z=50)
Neutron skin increasing

N. Tsoneva, H. Lenske, Ch. Stoyanov, Phys. Lett. B 586 (2004) 213

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

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

+ ground state pairing correlations

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

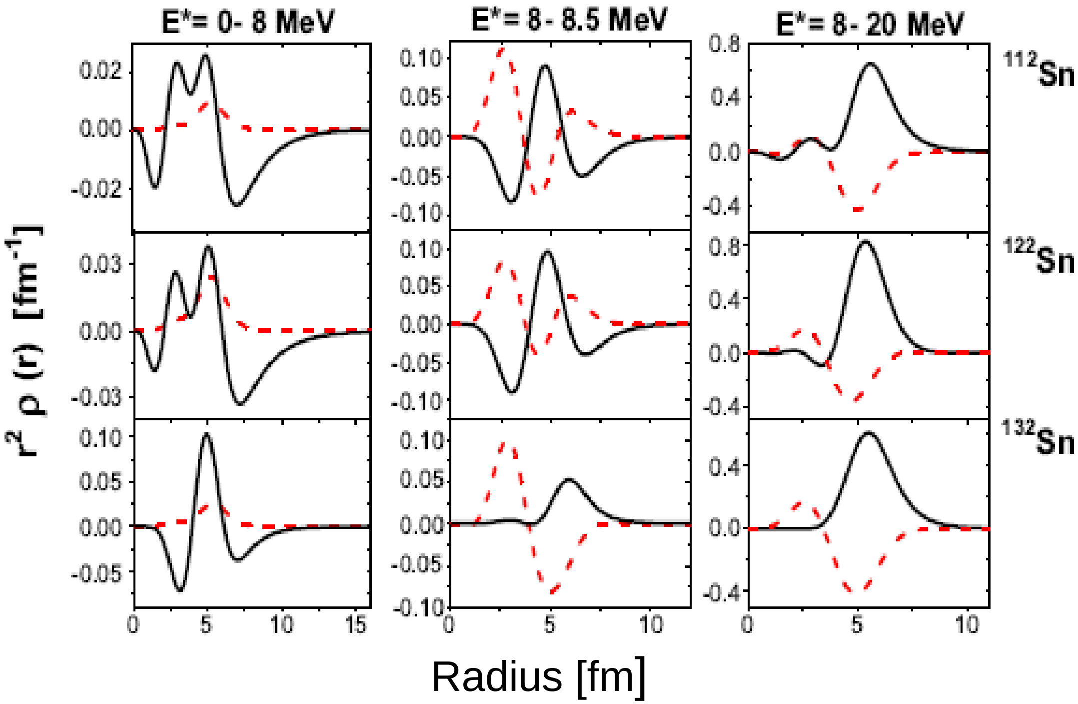
$$q_T = \frac{1}{2}(q_n + (-)^T q_p);$$

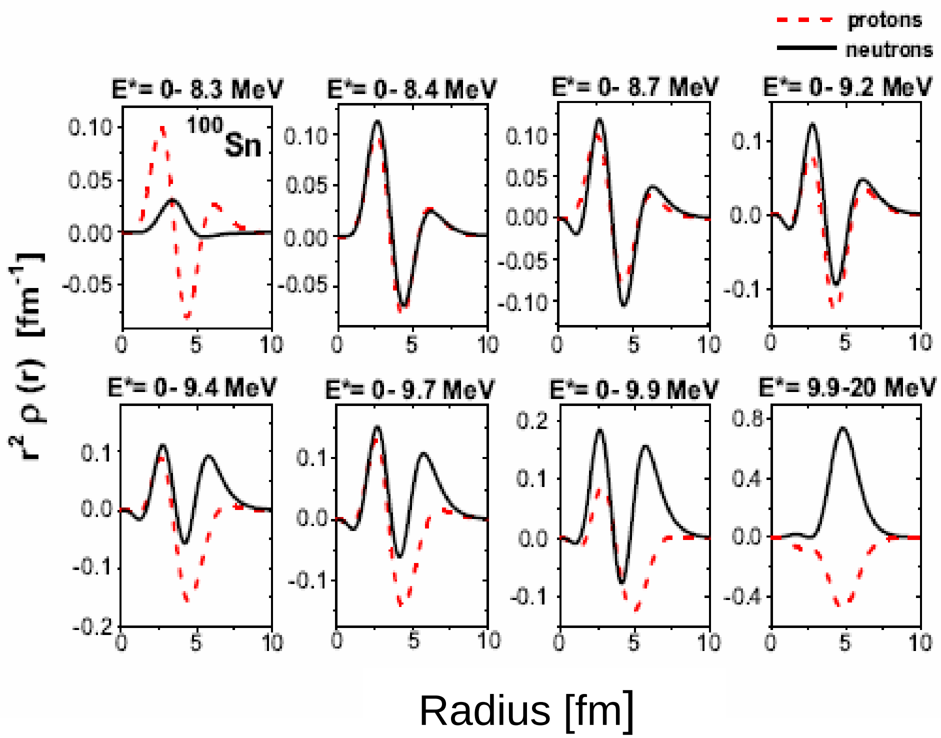
Dipole Transition Densities in Sn Isotopes

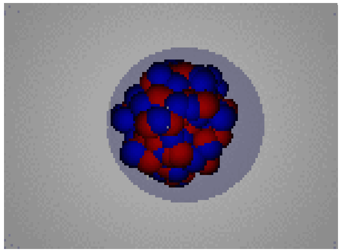
N.Tsoneva, H. Lenske, PRC 77 (2008) 024321

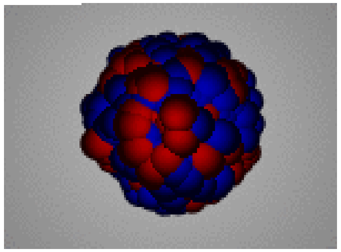
Transition densities are directly related to nuclear response functions

$$\delta\rho^{T}(\vec{r}) = \sum_{j_1 j_2;\lambda\mu} [i^{\lambda} Y_{\lambda\mu}(\hat{r})]^{\dagger} \rho^{\lambda T}_{j_1 j_2}(r) [a^{+}_{j_1} a_{j_2}]_{\lambda\mu}.$$







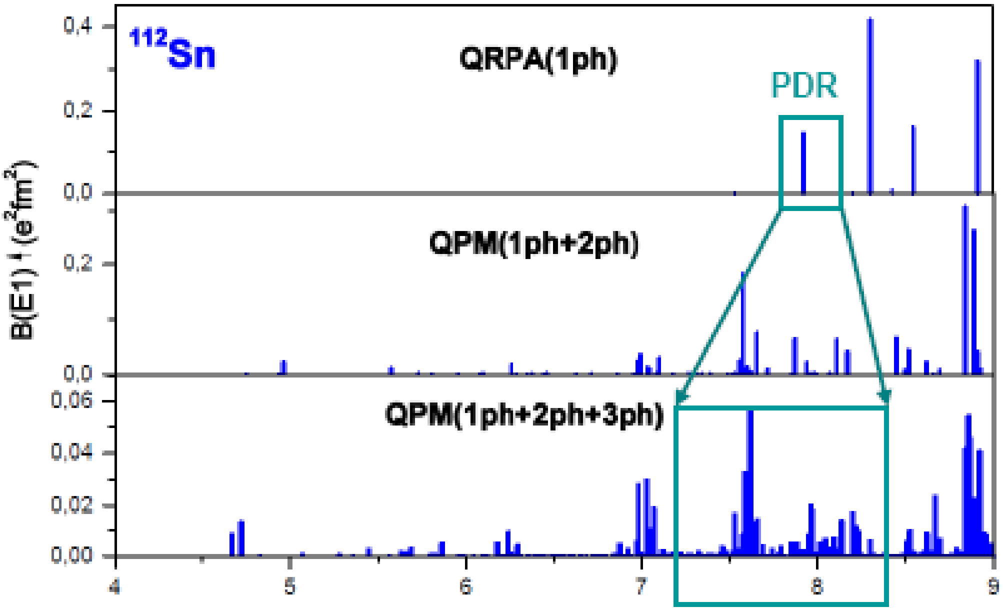


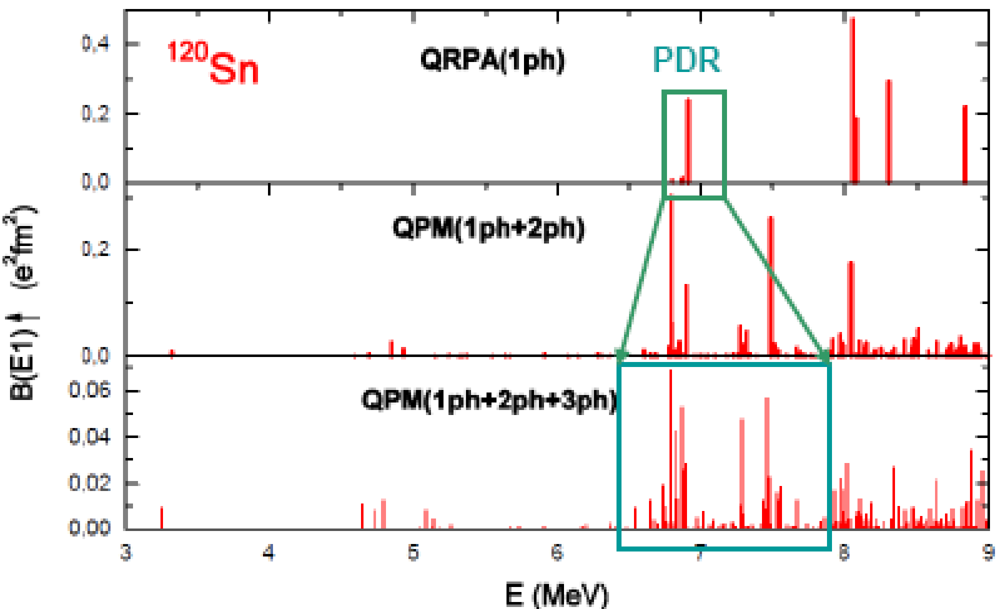
Multiphonon Calculations of E1 Transitions in $^{112,120}Sn$

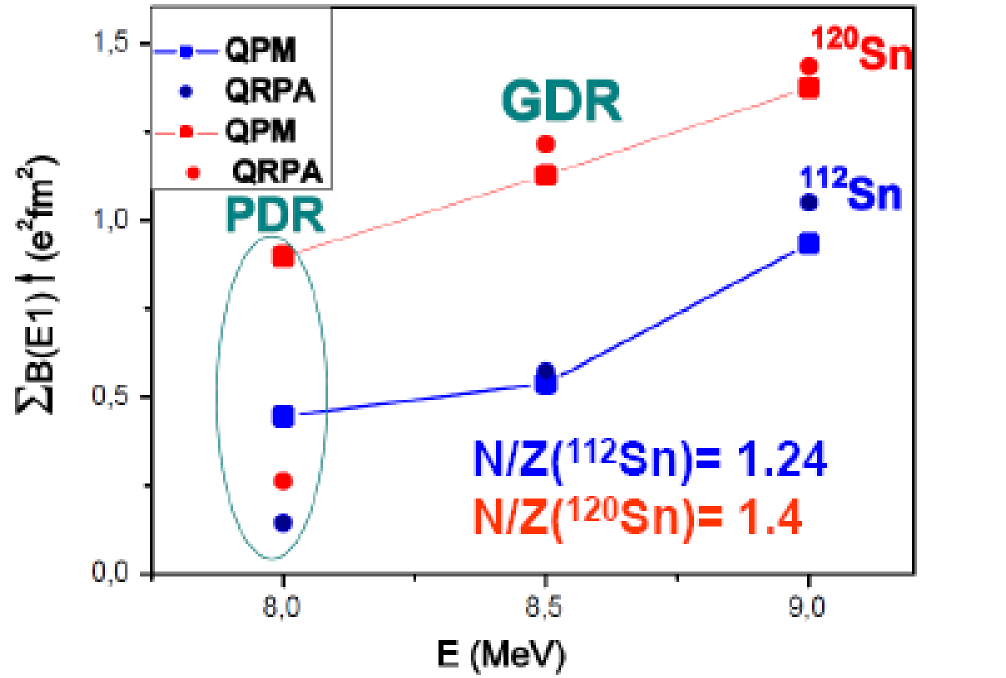
$$\langle Q_{\lambda_N i_N} \ldots Q_{\lambda_2 i_2} Q_{\lambda_1 i_1} \| M(E\lambda) \| Q^{+}_{\lambda i} Q^{+}_{\lambda_1 i_1} Q^{+}_{\lambda_2 i_2} \ldots Q^{+}_{\lambda_N i_N} \rangle \neq 0 \quad \text{QRPA}$$

$$M(E(M))_{\lambda\mu} = M^{Ph} + M^{QPh}(E(M))_{\lambda\mu} \quad \text{QPM}$$

$$\approx [\alpha^{+}_{j} \otimes \alpha^{+}_{j'}]$$







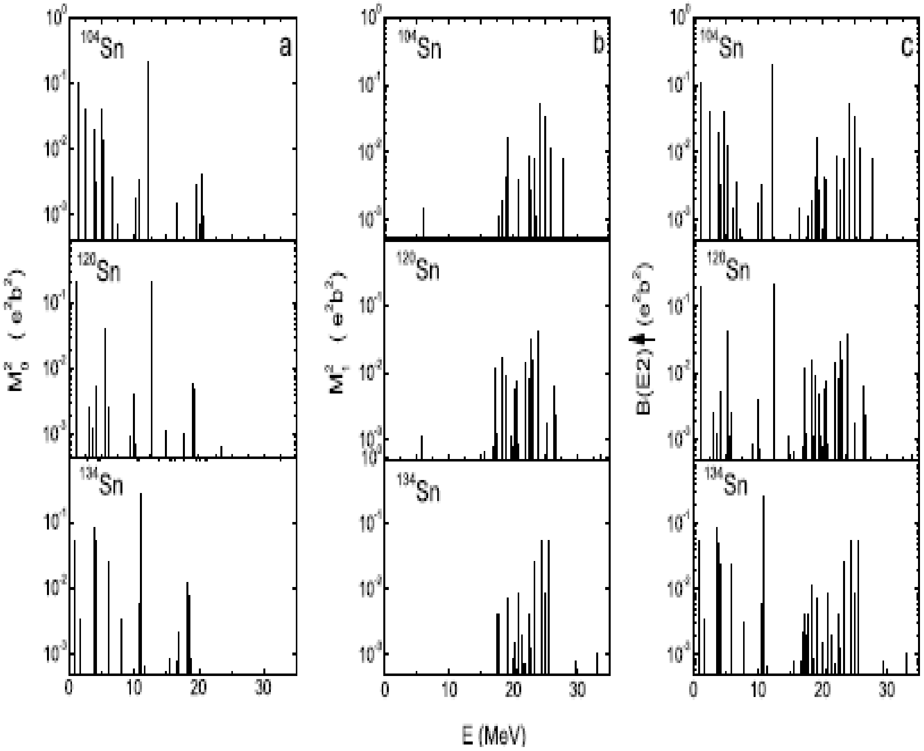
GDR (E*>8MeV) (1ph)
PDR (1ph+2ph+3ph)

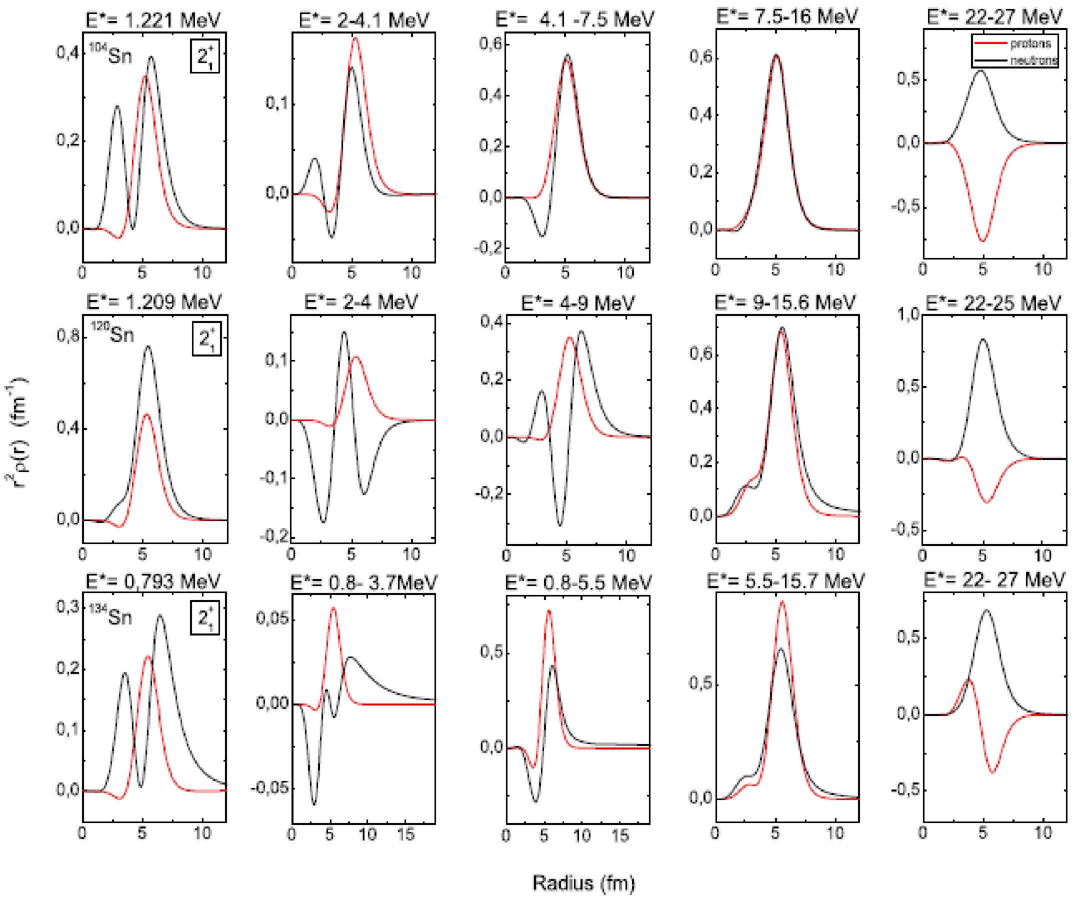
QRPA Calculations of Isoscalar and Isovector Quadrupole States with energies up to 35 MeV in Sn Isotopes

N. Tsoneva, H. Lenske, Phys. Lett. B 695 (2011) 174

A Signature of a Pygmy Quadrupole Resonance

$$M_I(2^+) \approx \langle 2^+ \| \sum_k^A r_k^2 Y_{2\mu}(\Omega_k)(\tau_3)^I \| \mathrm{g.s.} \rangle$$





QRPA Calculations of Low-Energy 2^+ States Related to PQR

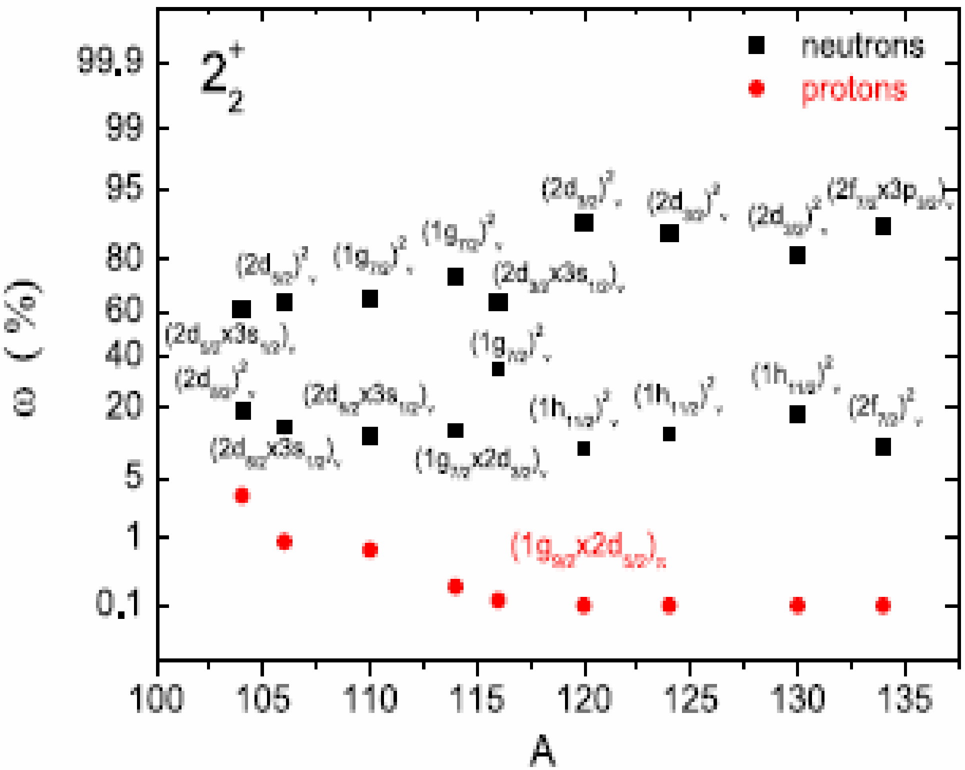
N. Tsoneva and H. Lenske, Phys. Lett. B 695 (2011) 174

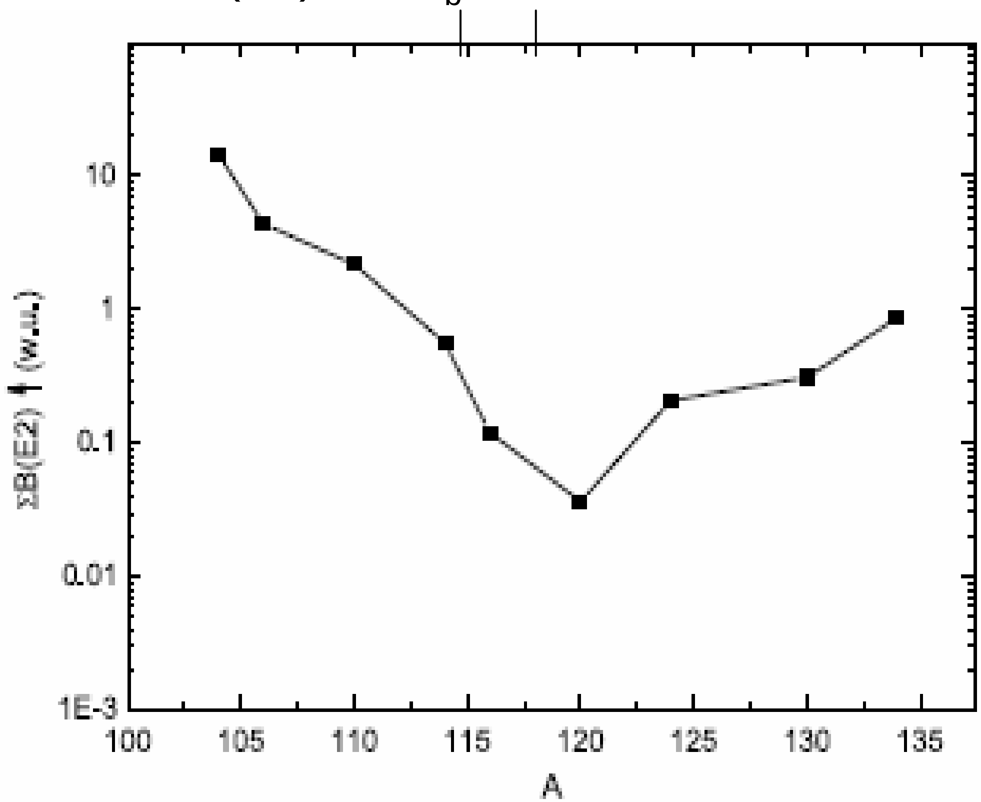
Pygmy quadrupole resonance is a genuine mode!

B(M1) to the first symmetric $2_1^+ \sim 10^{-2}\mu_N^2$

B(E2) increases with the neutron number,

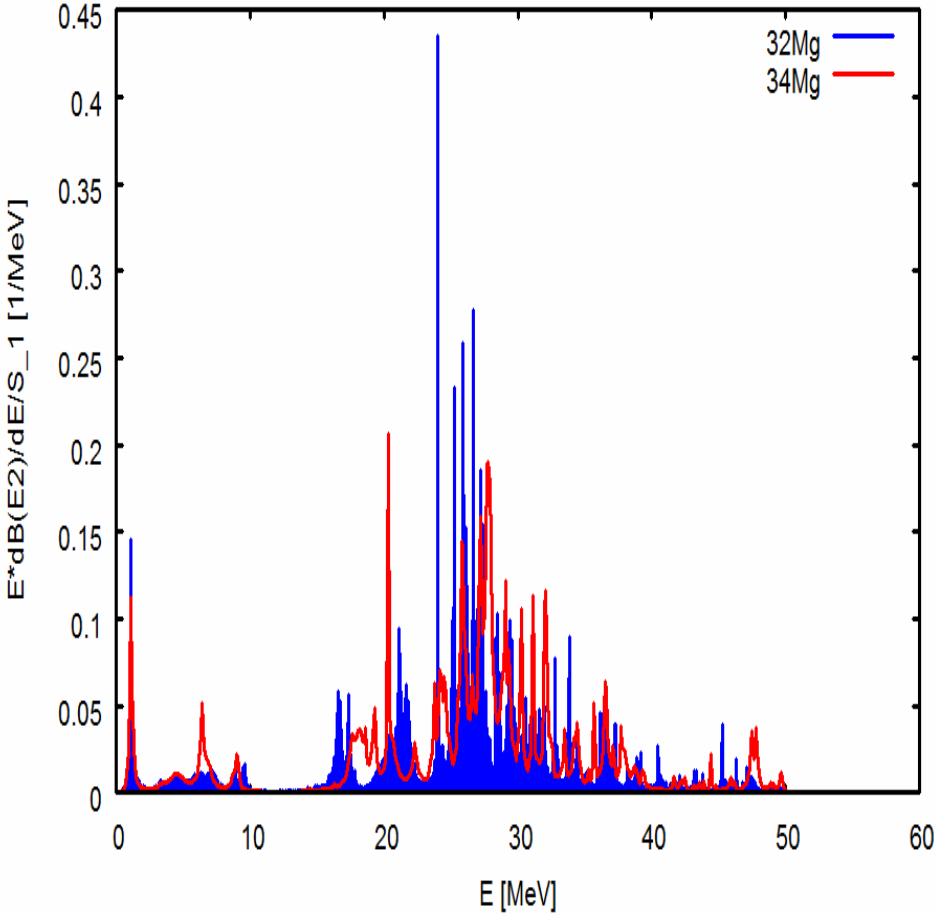
$B(E2) \sim 1/\varepsilon_b^{\ 2}$

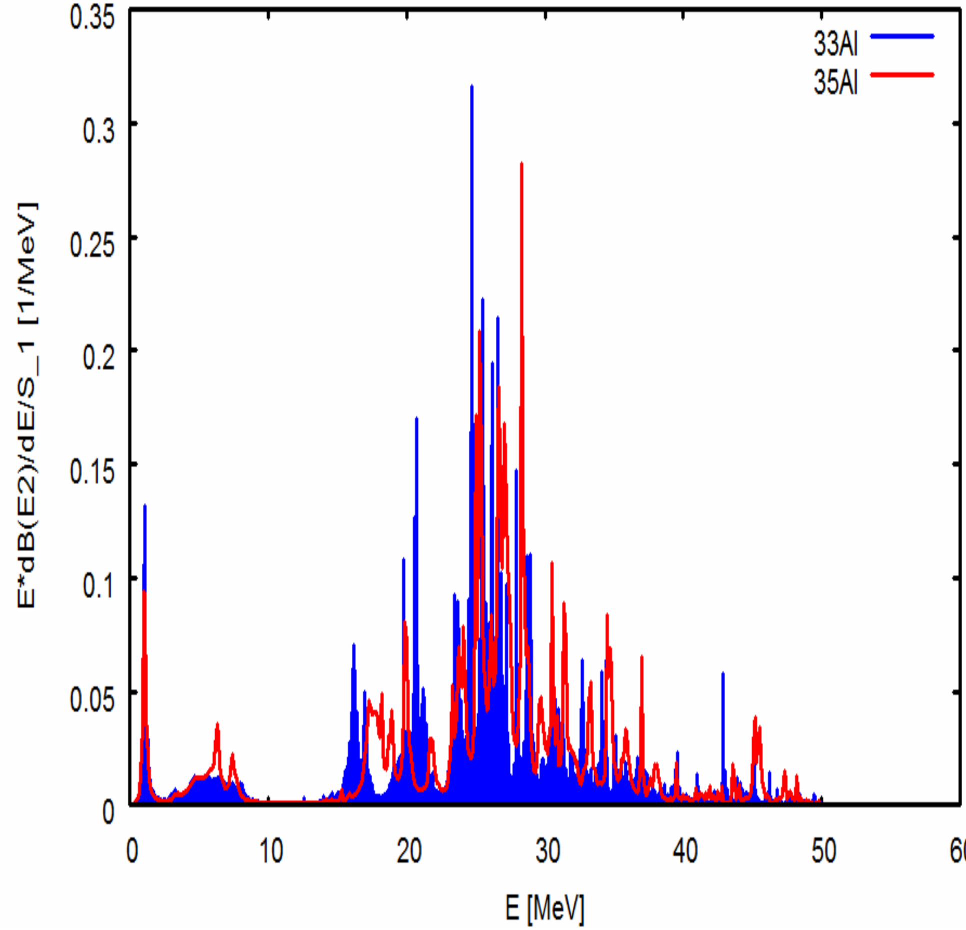




A change in the E_b of the $g_{9/2}$ which is the proton Fermi level in Sn isotopes when approaching the N=Z limit.
E_b= -12.88 MeV in ^{134}Sn ; E_b=-7.20 MeV in ^{104}Sn

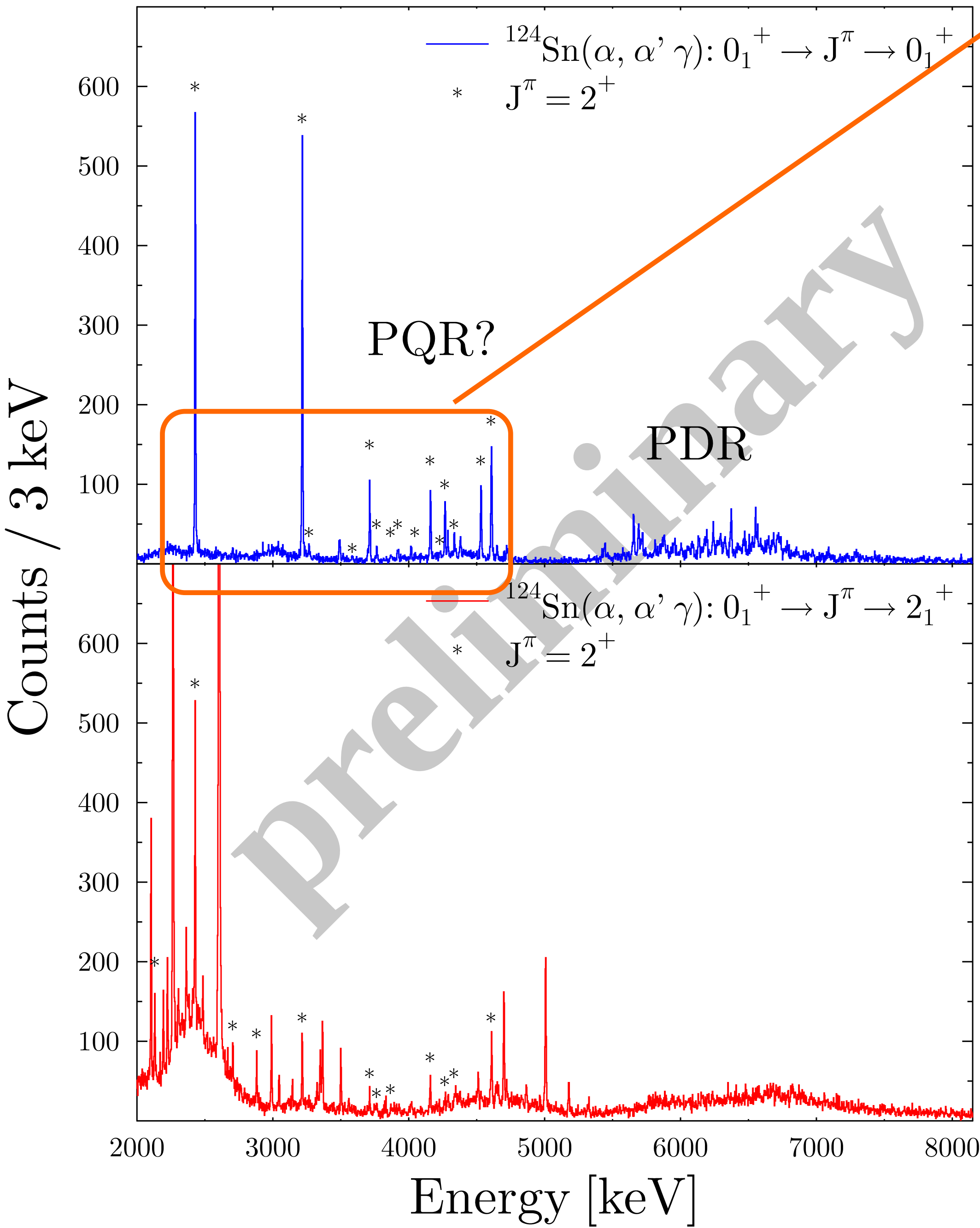
B(E2) in ^{32}Mg/^{34}Mg and ^{33}Al/^{35}Al (QRPA): Spectral Distribution normalized to EWSR

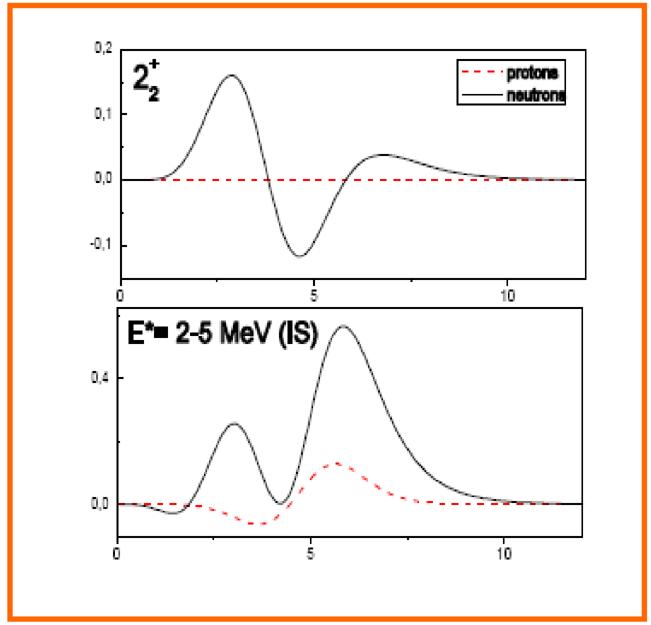




M. Spieker, J. Endres, A. Zilges, Universität zu Köln

N.T., QPM calculations





The First High-Sensitivity Investigation of the Electric Character of the Pygmy Dipole Resonance

PRL 104, 072501 (2010) PHYSICAL REVIEW LETTERS week ending 19 FEBRUARY 2010

Spectral Structure of the Pygmy Dipole Resonance

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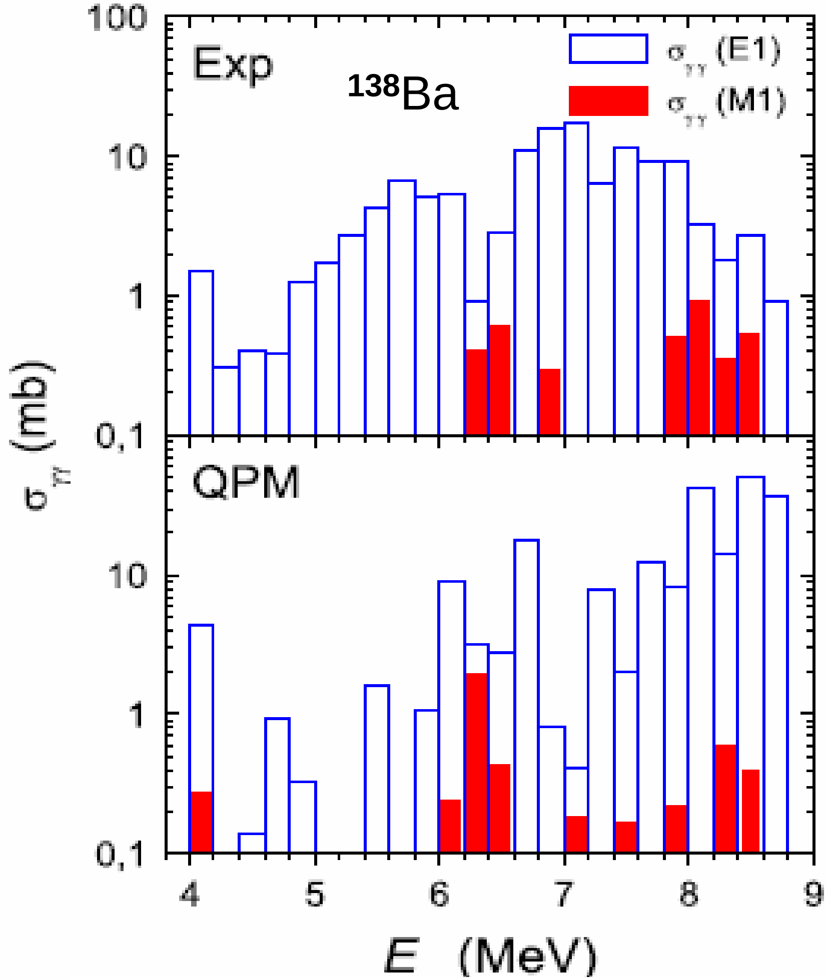
(Received 23 July 2009; published 18 February 2010)

High-sensitivity studies of $E1$ and $M1$ transitions observed in the reaction $^{138}\mathrm{Ba}(\vec{\gamma}, \gamma')$ at energies below the one-neutron separation energy have been performed using the nearly monoenergetic and 100% linearly polarized photon beams of the HI$\vec{\gamma}$S facility. The electric dipole character of the so-called "pygmy" dipole resonance was experimentally verified for excitations from 4.0 to 8.6 MeV. The fine structure of the $M1$ "spin-flip" mode was observed for the first time in $N = 82$ nuclei.

DOI: 10.1103/PhysRevLett.104.072501 PACS numbers: 21.10.Hw, 21.60.−n, 23.20.En, 24.70.+s

Parity Measurements with Polarized Photon Beams of Low-energy Dipole Excitations at HIγS, Duke University

A. Tonchev et al., Phys. Rev. Lett. 104, 072501 (2010)



$\sigma_{\gamma\gamma}(M1)/\sigma_{\gamma\gamma}(E1)$ **~ 3%**

- First systematic spin and parity measurements and the QPM calculations ^{138}Ba verified for the first time that the observed dipole strength from 4~MeV to particle separation energy is predominantly electric dipole in nature and it could be related to pygmy dipole resonance and neutron skin oscillations.
- The fine structure of the M1 spin-flip mode was observed and theoretically described for the first time in N = 82 nuclei.
- Separation of the PDR to isoscalar and isovector. Interplay between the GDR and the PDR at higher energies. As the excitation energy increases, the isovector contribution to the dipole strength exponentially increases due to the left tail of the GDR.

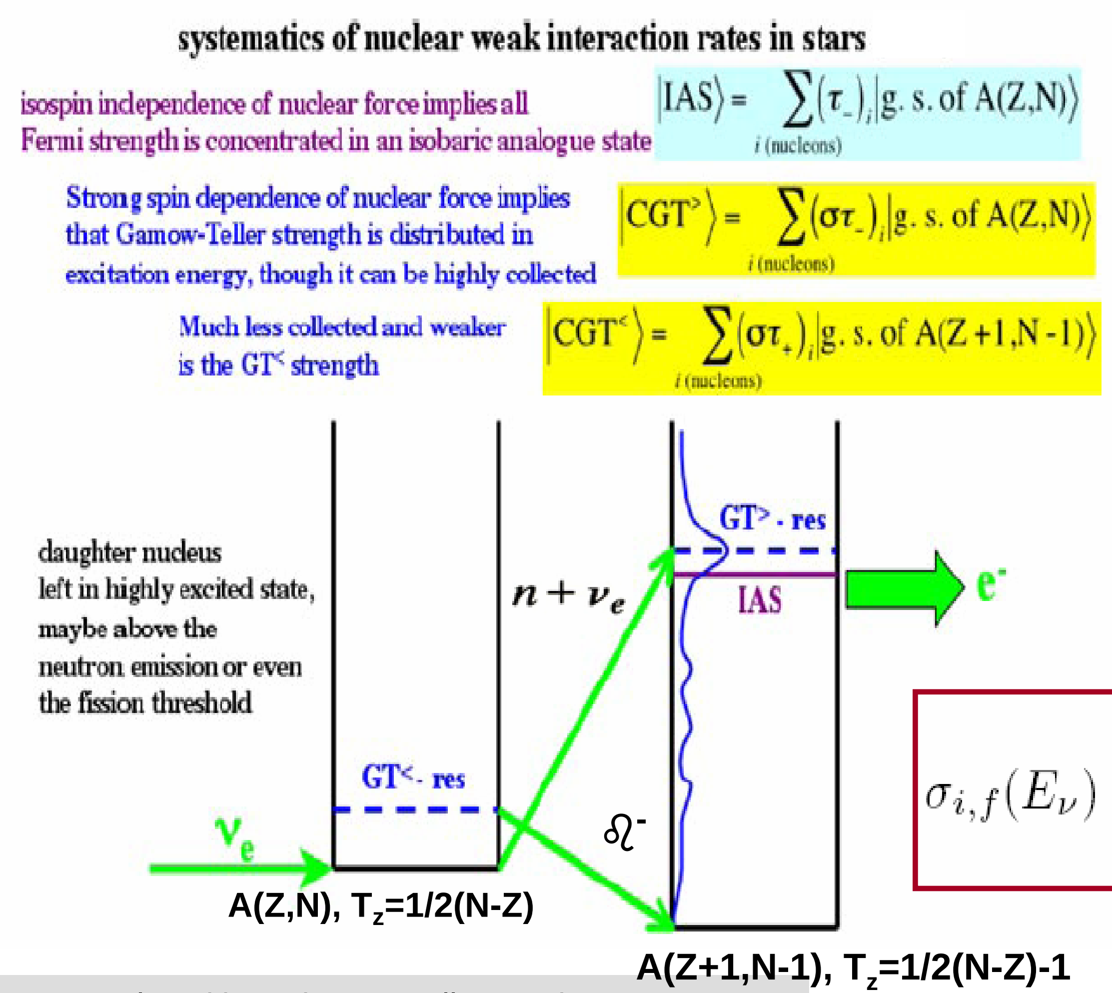
TABLE I. $E1$ and $M1$ parameters deduced in ^{138}Ba below the neutron-separation energy in comparison with the QPM calculations.

	$\langle E_{E1}\rangle$ [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 MeV < E^* < 8.5 MeV.

Supernova neutrino-nucleus astrophysics

Precision data on M1 strength distributions supply to a large extent the required information on the nuclear Gamow-Teller (GT) Resonance which determines the inelastic neutrono-nucleus cross sections.



The inelastic neutrono-nucleus cross section might be relevant to several aspects in supernova physics

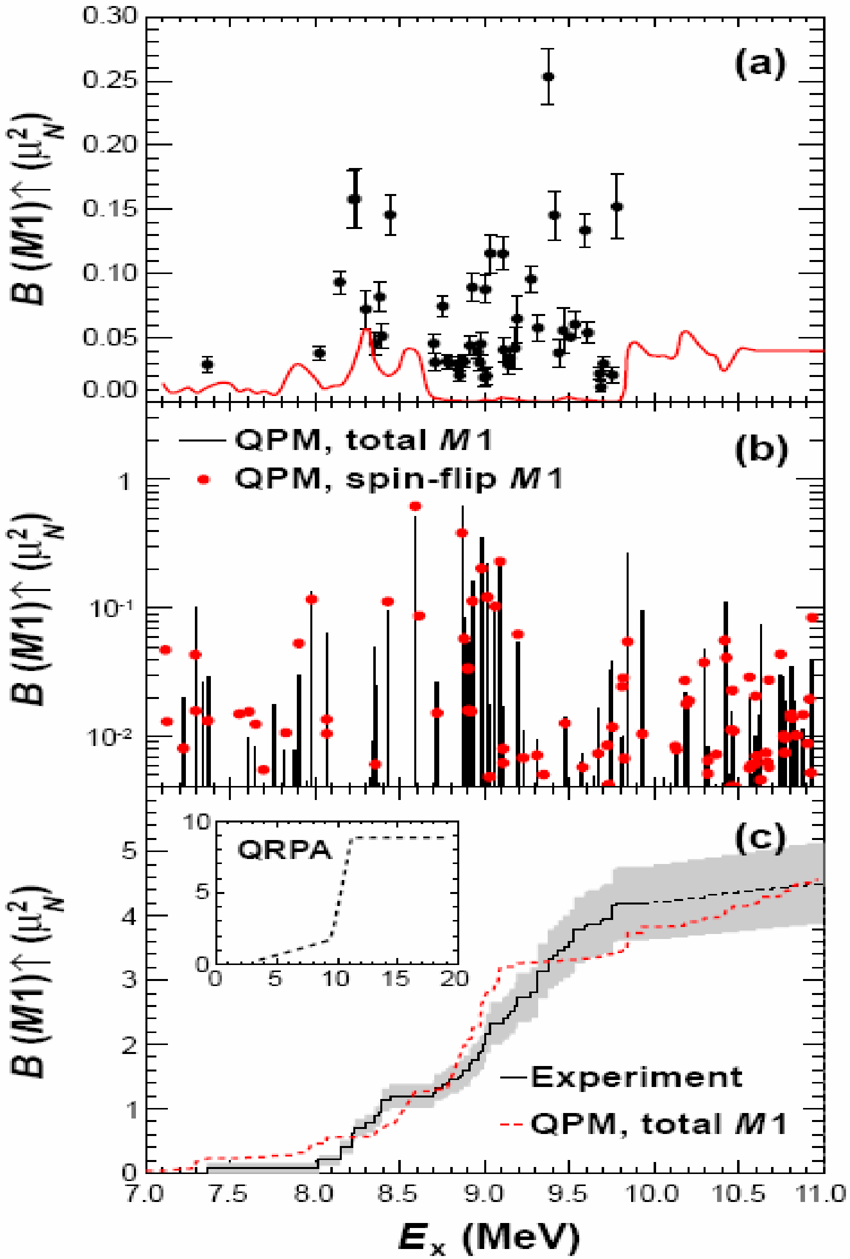
- for the termalization during the collapse phase;
- for the revival of the stalled shock in the delayed explosion mechanism;
- for explosive nucleosynthesis.

$$\sigma_{i,f}(E_\nu) = \frac{G_F^2 g_A^2}{\pi(2J_i+1)}(E_\nu - \omega)^2 |\langle f|| \sum_k \boldsymbol{\sigma}(k)\boldsymbol{t}(k)||i\rangle|^2,$$

A. B. Balantekin and G. M. Fuller, J. Phys. G: Nucl. Part. Phys. **29**, 2513 (2003).
K. Langanke et al., Phys. Rev. Lett. **93** (2004) 202501

Fine Structure of the Giant M1 Resonance in ^{90}Zr

Spin and Parity Determination at HIγS, Duke University



G. Rusev, N. Tsoneva, F. Dönau, S. Frauendorf, R. Schwengner, A. P. Tonchev, A. S. Adekola, S. L. Hammond, J. H. Kelley, E. Kwan, H. Lenske, W. Tornow, and A. Wagner

Phys. Rev. Lett. 110, 022503 – Published 9 January 2013

- Explaining the fragmentation pattern and the dynamics of the ‘quenching’ means to understand the coupling of the 2-QP doorway states to many-QP configurations

- Multi-particle multi-hole effects increase strongly the orbital part of the magnetic moment which is an interesting result not reported before.
The effect is estimated to account for about 22% of the total M1 strength below the threshold.

- Theory and experiment are in a very good agreement on the values of total measured M1 strength at E*=7-11 MeV and its centroid energy

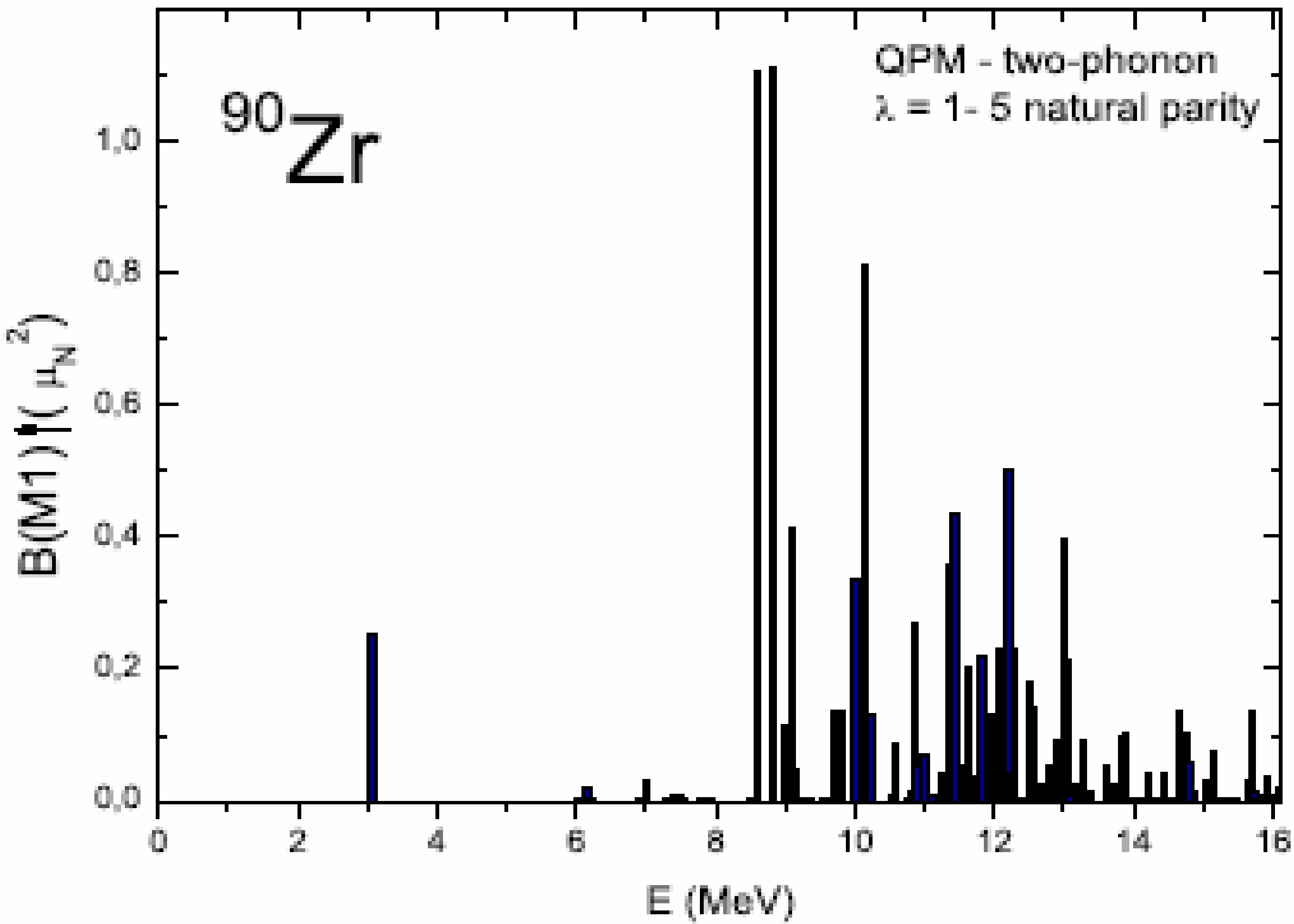
$\Sigma B(M1)_{Exp.}\uparrow = 4.5\,(6)\ \mu_N^2$ $\Sigma B(M1)_{QPM.}\uparrow = 4.6\ \mu_N^2$

$E^{c.m.}_{Exp.} = 9.0$ MeV $E^{c.m.}_{QPM} = 9.1$ MeV

$g^s_{eff} = 0.8\ g^s_{bare}$

QPM Predictions of M1 Strength around the Neutron Threshold

recently confirmed in (p, p‘) experiment (C. Iwamoto et al., Phys. Rev. Lett. 108, 262501 (2012))



Investgations of (γ,n) Reactions to Probe the s-Process Branching

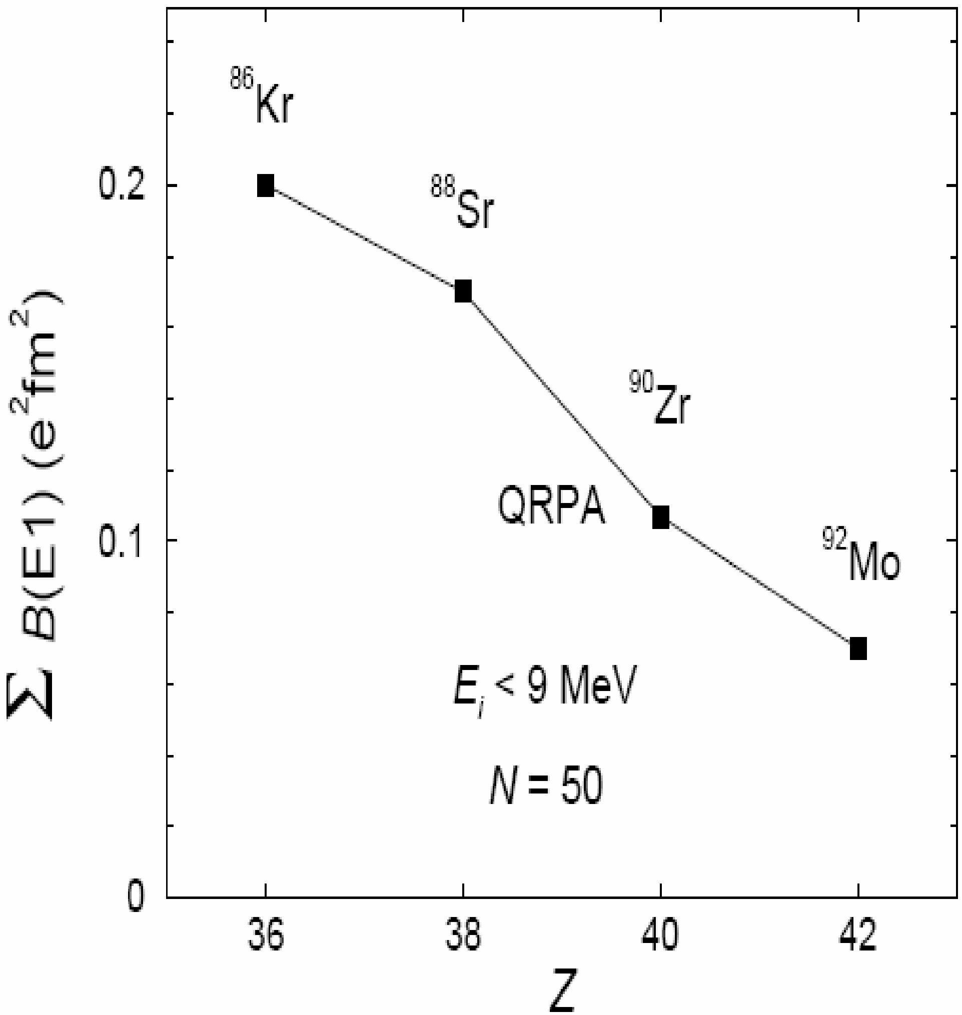
Stars with masses $\lesssim 8\ M_\odot$ become Asymptotic Giant Branch (AGB) stars during their final evolutionary stage. They are predicted to be the source of about half of all elements beyond iron in the Galaxy.

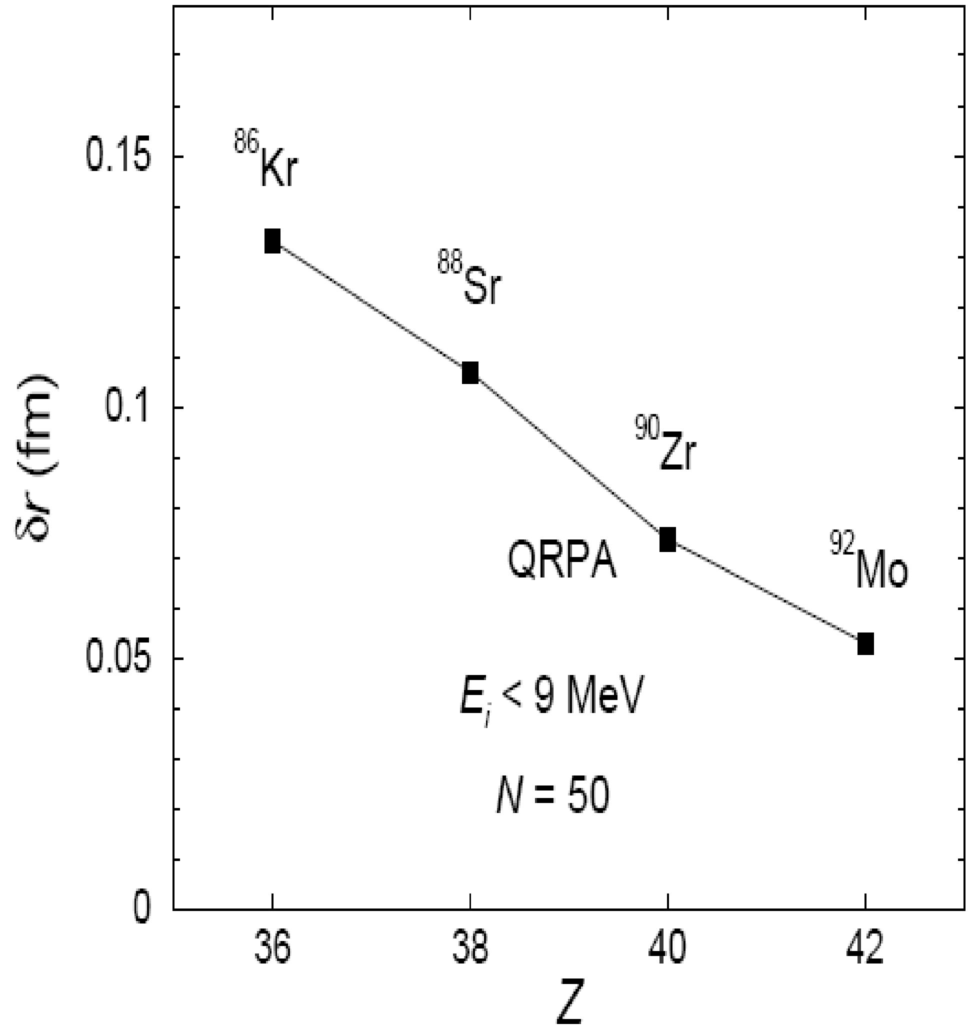
These elements are produced in AGB stars via slow neutron capture (the s-process), which operates at relatively low neutron densities.

Under such conditions most short-lived radioactive nuclei reached by the s-process β-decay rather than undergoing a neutron capture.

When the s-process reaches longer-lived radioactive nuclei, however, neutron capture may compete with the β-decay, giving rise to s-process branching.

First systematic studies of the PDR in N=50 isotones

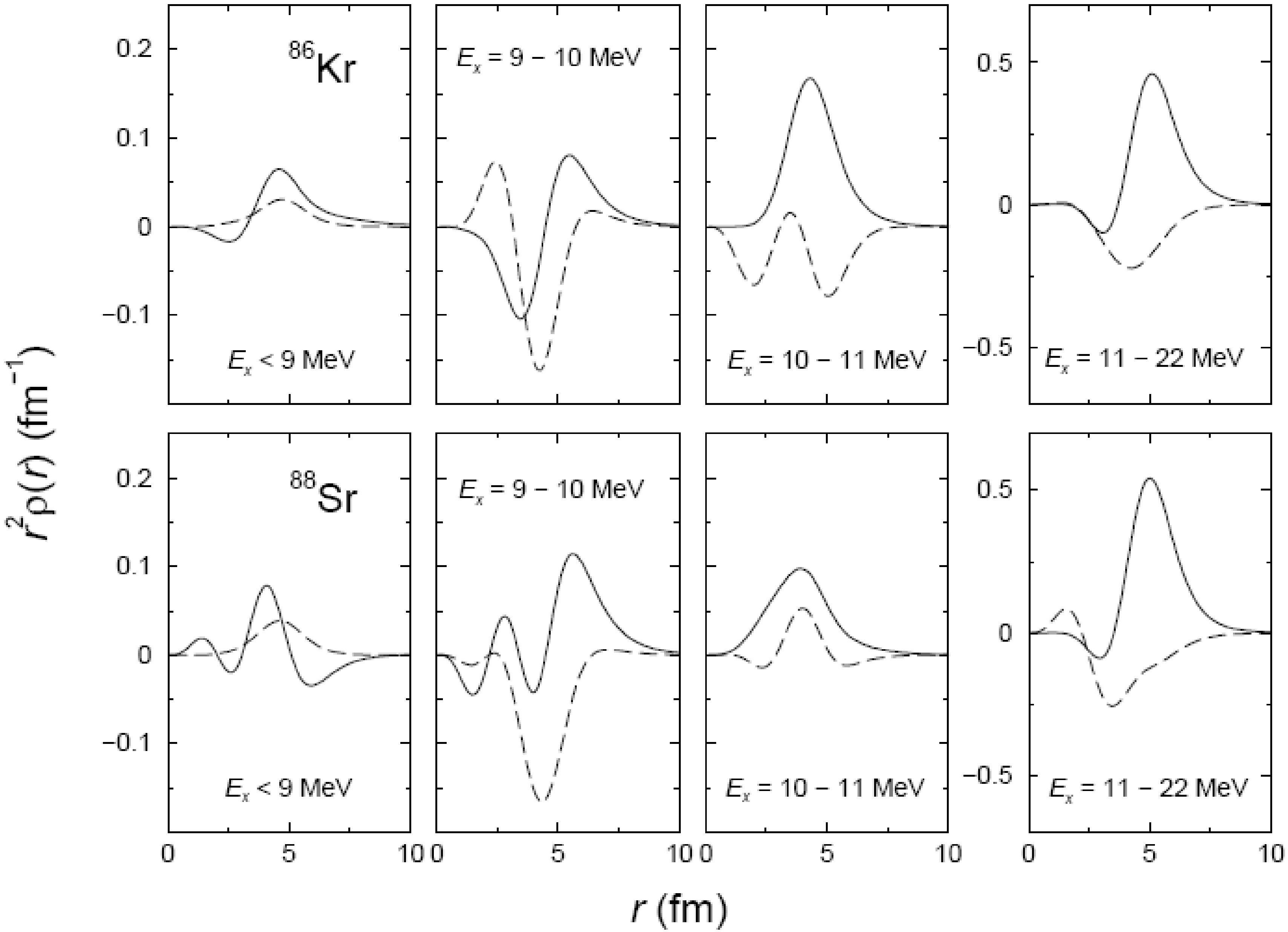




R. Schwengner, R. Massarczyk, G. Rusev, N. Tsoneva, D. Bemmerer, R. Beyer, R. Hannaske, A. R. Junghans, J. H. Kelley, E. Kwan, H. Lenske, M. Marta, R. Raut, K. D. Schilling, A. Tonchev, W. Tornow, and A. Wagner

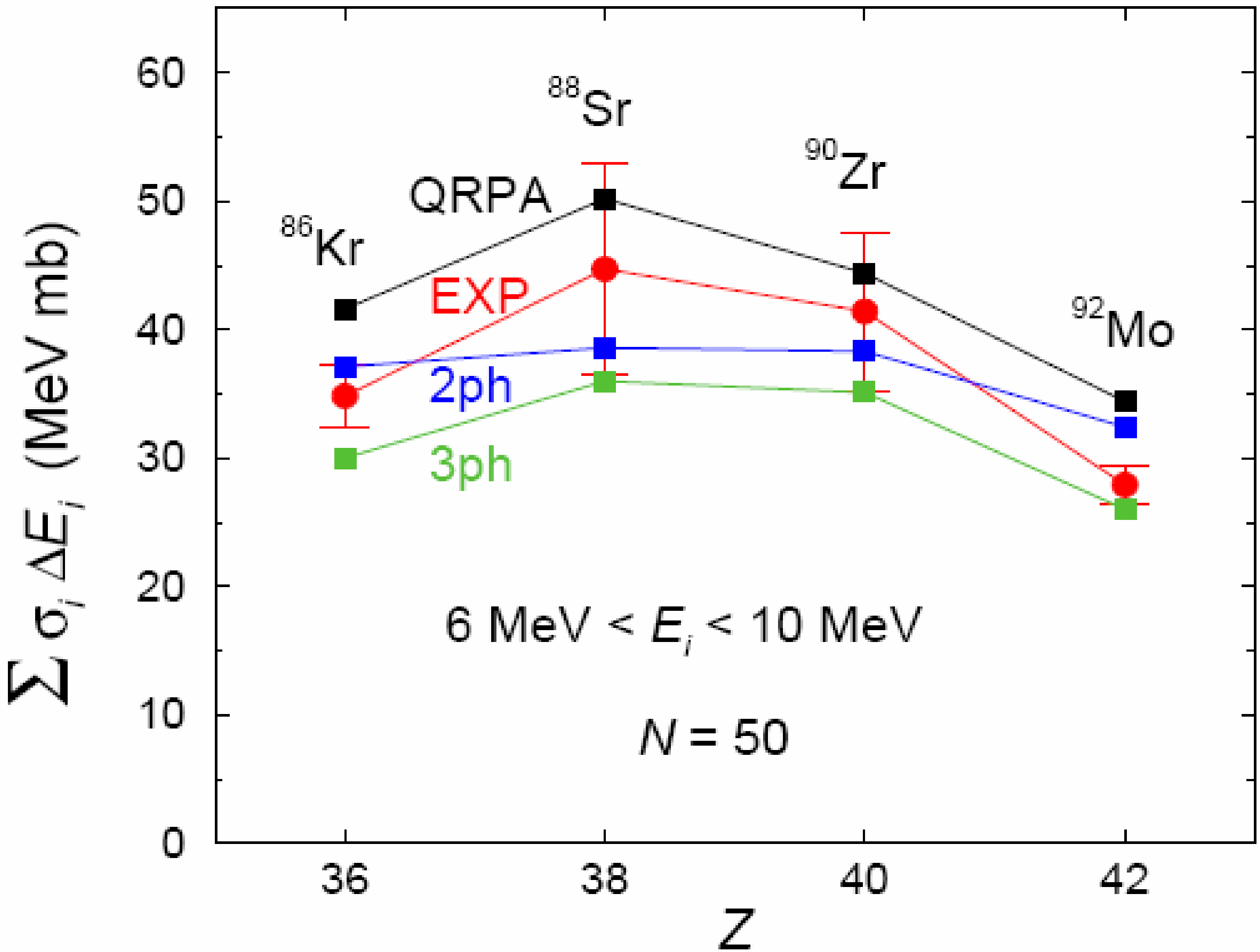
Phys. Rev. C 87, 024306 – Published 8 February 2013

QRPA Dipole proton (dashed line) and neutron (solid line) transition densities in N=50 isotones



Phys. Rev. C 87, 024306, 2013

First systematic studies of dipole strength of N=50 isotones and the nucleus ^{86}Kr was studied in QPM and in photon-scattering experiments using bremsstrahlung produced with electron beams of energies of 7.9 and 11.2 MeV delivered by the linear accelerator ELBE and using quasi-monoenergetic γ - rays of 10 energies within the range from 4.7 to 9.3 MeV delivered by the HIγS facility.

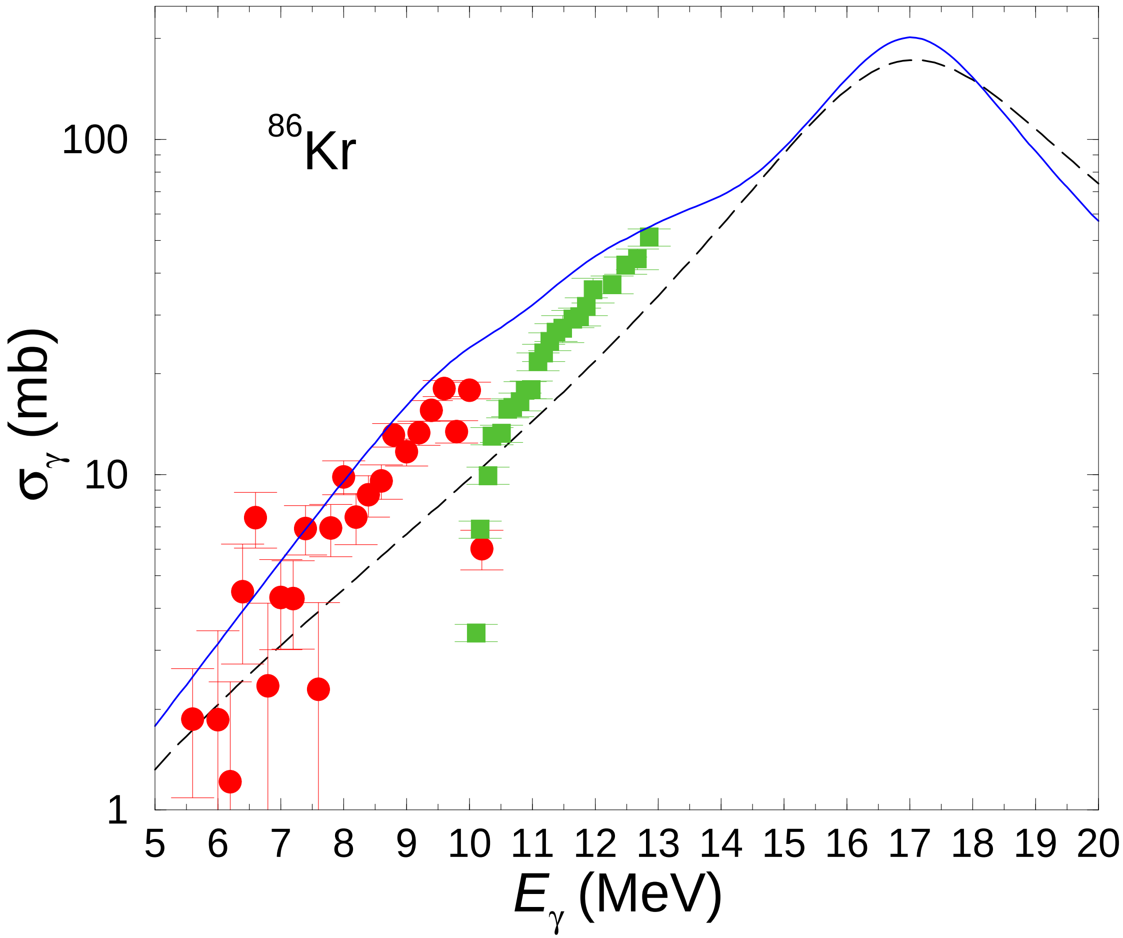


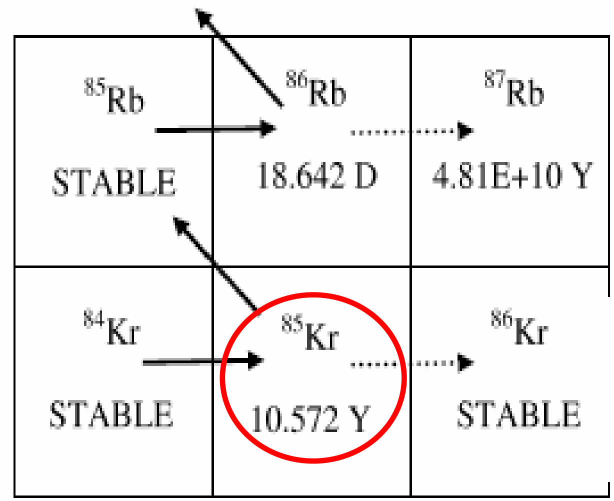
Phys. Rev. C 87, 024306, 2013

Cross-Section measurements of the ^{86}Kr(γ,n) Reaction to Probe the S-Process Branching at ^{85}Kr

R. Schwengner et al., Phys. Rev. C 87, 024306, 2013

A way to investigate **^{85}Kr branching point and the s-process:**
Because of the long half-life, the ^{85}Kr ground state is a branching point and thus a bridge for the production of ^{86}Kr at elevated neutron densities.



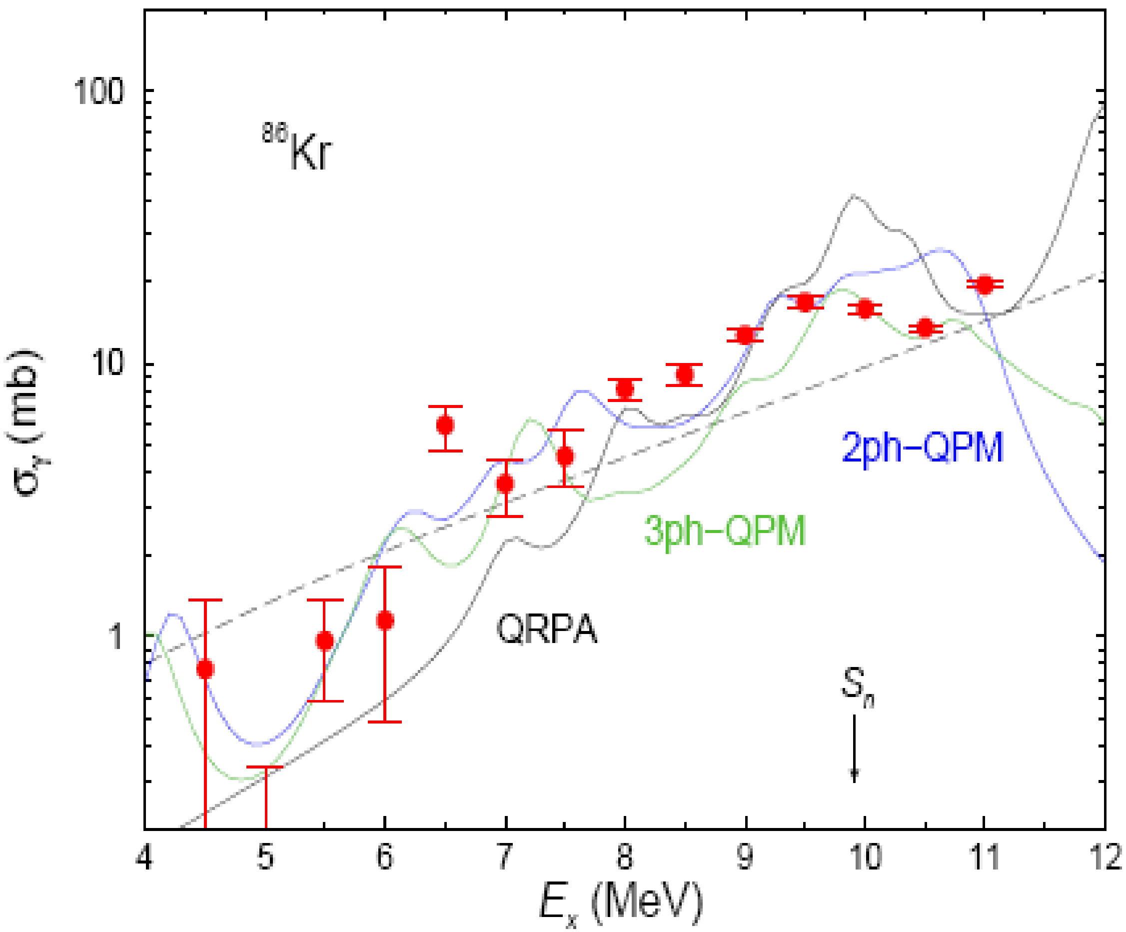


Part of the nuclear chart illustrating the s-process branching point at ^{85}Kr and ^{86}Rb. The solid arrows represent the usual s-process path while the dotted ones are the alternate s-process paths from branching.

R. Raut et al., sub. PRL

Total photoabsorption cross section of ^{86}Kr including (γ,γ') (red circles) compared with results of QRPA (black line), 2-phonon QPM (blue line), 3-phonon QPM (green line) calculations.

The QRPA and QPM solutions were folded with Lorentz curves of 0.5 MeV width.



•The QPM calculations for ^{86}Kr show enhanced low-energy dipole strength in the energy region from 6 to 10 MeV.

•Of special importance are the states at about 6 to 7.5 MeV whose structure is dominated by neutron components and their transition strengths are directly related to the size of a neutron skin.

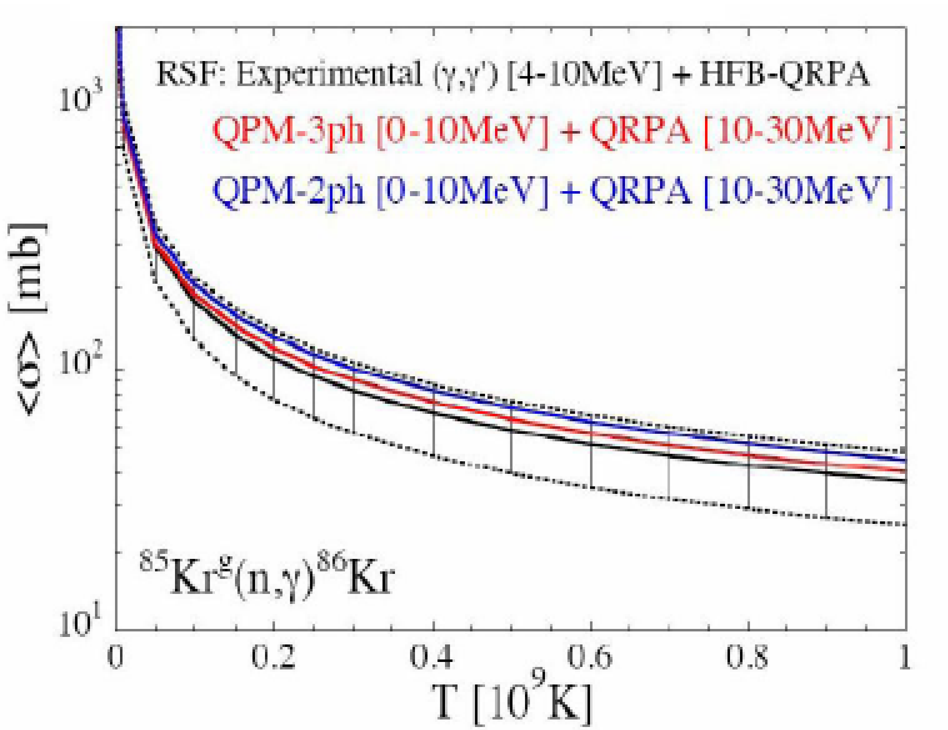
R. Schwengner, R. Massarczyk, G. Rusev, N. Tsoneva, D. Bemmerer, R. Beyer, R. Hannaske, A. R. Junghans, J. H. Kelley, E. Kwan, H. Lenske, M. Marta, R. Raut, K. D. Schilling, A. Tonchev, W. Tornow, and A. Wagner, **Phys. Rev. C 87, 024306, 2013.**

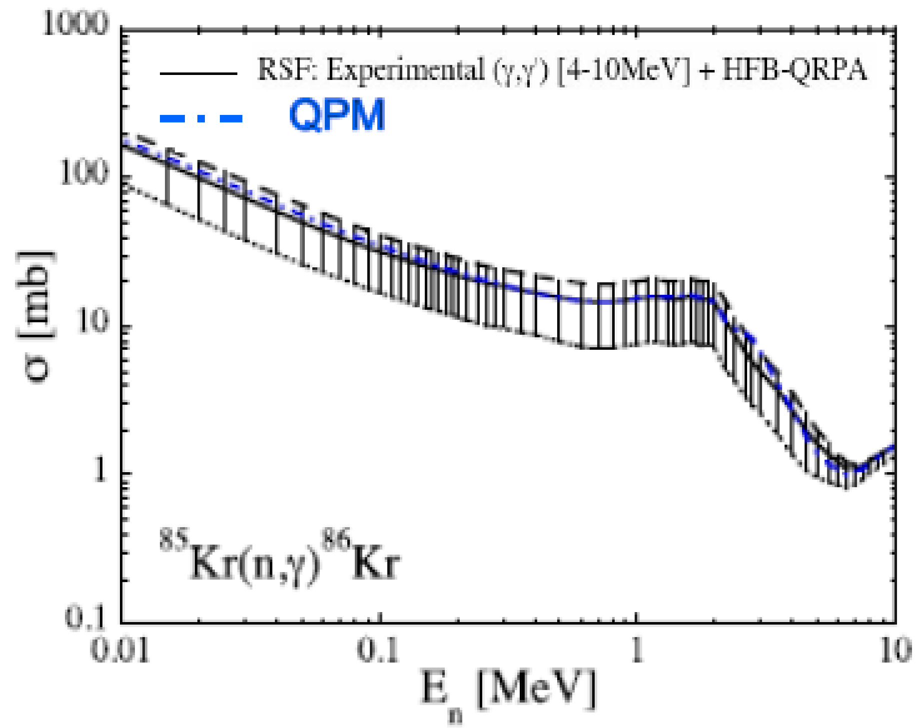
Total cross section of $^{85}Kr^{g}(n,\gamma)^{86}Kr$ reaction

Neutron capture cross sections onbranching point nuclei can be derived from probing the (γ,n) photodisintegration cross section of the neighbouring stable nucleus.

$$T_\gamma \sim \int_0^{E^*} \rho \; f_{E1}(E^* - \epsilon)\; d\epsilon$$

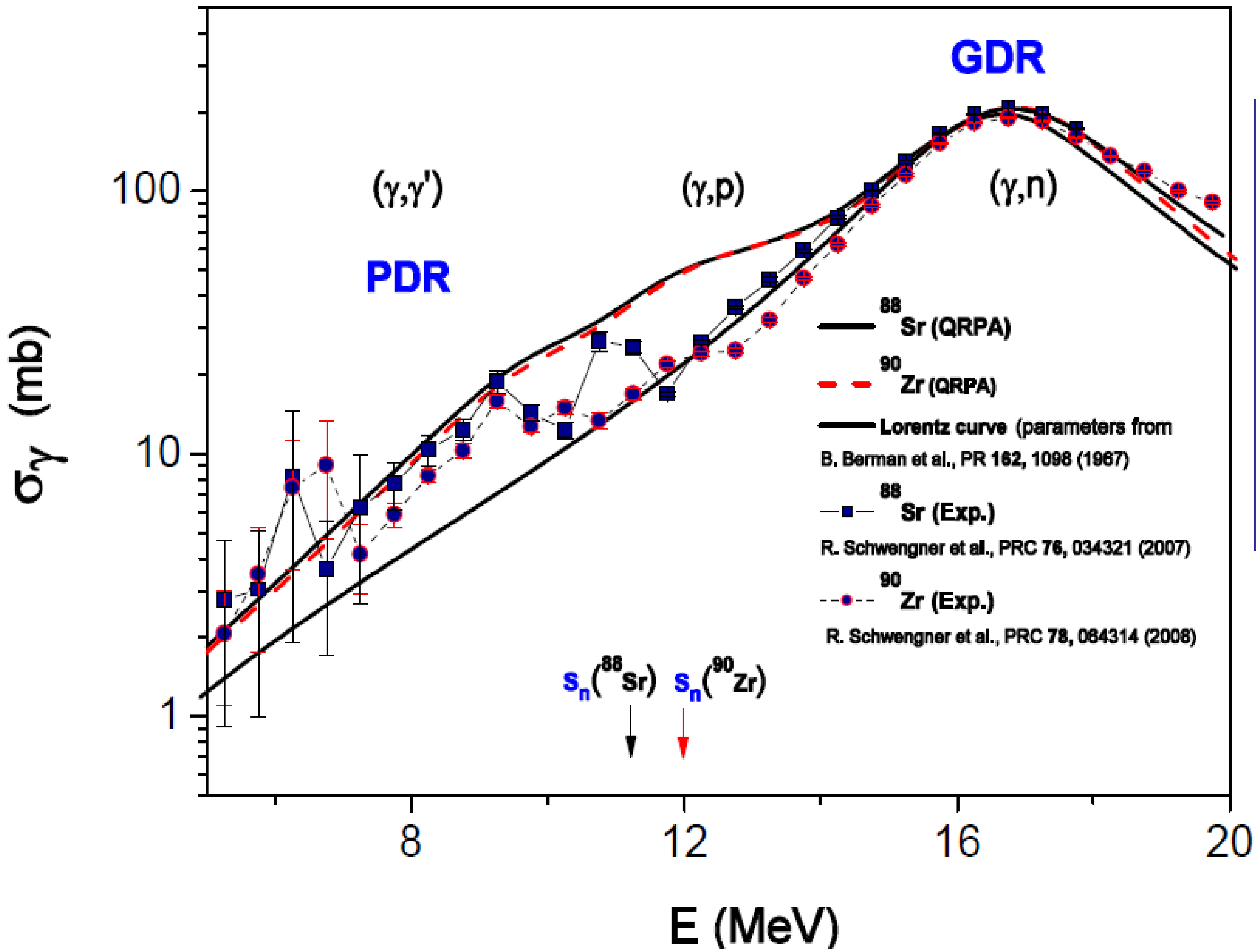
R. Raut et al., sub. to PRL





in collaboration with S. Goriely

The Astrophysical Importance of the Pygmy Resonances



The present analysis shows that standard strength functions currently used for the calculation of cross sections in codes based on statistical reaction models do not describe the dipole-strength distribution below the (γ,n) threshold correctly.

Conclusions

- PDR is a common feature of skin nuclei and independent of the type of nucleon excess which strength is correlated with the size of the neutron or proton skin .

- Physically, the PDR is a sequence of non-collective s.p. excitations related to the least bound neutrons or protons forming the nuclear skin. These excitations contribute substantially to the experimentally observed enhanced low-energy E1 strengths which are of genuine importance for n-capture cross sections and nucleosynthesis of heavier elements.

- QRPA is not sufficient to interprete the experimentally observed low-energy dipole strengths. Multiphonon approaches accounting for the fragmentation process of 2QP doorway states are needed.

- Higher order multipole excitations related to neutron or proton skin oscillations theoretically predicted- Pygmy Quadrupole Resonance. Recent experimental evidences for 124Sn found

- The fine structure of the M1 resonance could be explained as a composition of spin-flip and orbital excitations related to multi-phonon structures.

  Explaining the fine structure of the M1 resonance and the dynamics of the quenching means to understand the coupling of the 2QP doorway states to many-QP configurations. Relevance to inelastic ν-induced processes for astrophysics.