JOINT INSTITUTE FOR NUCLEAR RESEARCH

BLTP Bogoliubov Laboratory of Theoretical Physics

Ground state correlations in odd-A nuclei

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Outline

Even-even nuclei

- Theory
- Occupation numbers
- Transition probabilities

Odd-even nuclei

- Theory
- Renormalized interaction strengths
- Transition probabilities and spectroscopic factors

Hamiltonian

$$H = \sum_{\tau}^{(n,p)} \{ \sum_{jm} (E_j - \lambda_\tau) a_{jm}^\dagger a_{jm} - \frac{1}{4} G_\tau^{(0)} : (P_0^\dagger P_0)^\tau :$$

$$- \frac{1}{2} \sum_{\lambda\mu} \kappa_\lambda : (M_{\lambda\mu}^\dagger M_{\lambda\mu}) : \}$$

$$H = \sum_{\tau}^{(n,p)} \{ \sum_{jm} (E_j - \lambda_\tau) a^\dagger_{jm} a_{jm} - \frac{1}{4} G^{(0)}_\tau : (P^\dagger_0 P_0)^\tau :$$

$$- \frac{1}{2} \sum_{\lambda\mu} \kappa_\lambda : (M^\dagger_{\lambda\mu} M_{\lambda\mu}) : \}$$

$$\alpha_{jm} = u_j a_{jm} - (-)^{j-m} v_j a^\dagger_{j-m}$$

$$\alpha_{jm} | qp \rangle = 0$$

$$\frac{1}{2} \sum_j (2j+1) \left\{ 1 - \frac{(E_j - \lambda)}{\sqrt{(E_j - \lambda)^2 + \Delta^2}} \right\} = n$$

$$\frac{G}{4} \sum_j \frac{2j+1}{\sqrt{(E_j - \lambda)^2 + \Delta^2}} = 1$$

Quasiparticles and Phonons

$$H = \sum_{\tau}^{(n,p)} \{ \sum_{jm} \varepsilon_j \alpha_{jm}^{\dagger} \alpha_{jm} - \frac{1}{2} \sum_{\lambda\mu} \kappa_{\lambda} : (M_{\lambda\mu}^{\dagger} M_{\lambda\mu}) : \}$$

$$A^{\dagger}(jj'|\lambda\mu) = \sum_{mm'} \langle jmj'm'|\lambda\mu\rangle \alpha_{jm}^{\dagger} \alpha_{j'm'}^{\dagger}$$

$$Q_{\lambda\mu i}^{\dagger} = \frac{1}{2} \sum_{jj'} [\psi_{jj'}^{\lambda i} A^{\dagger}(jj';\lambda\mu) - (-1)^{\lambda-\mu} \varphi_{jj'}^{\lambda i} A(jj';\lambda-\mu)]$$

$$Q_{\lambda\mu i}|ph\rangle = 0$$

EQPM-1

In RPA

$$\langle | \sum_m \alpha^\dagger_{jm} \alpha_{jm} | \rangle \approx 0$$

$$\frac{\kappa_\lambda}{2\lambda+1} \sum_{jj'} \frac{(f^\lambda_{jj'} u^+_{jj'})^2 (\varepsilon_j + \varepsilon_{j'})}{(\varepsilon_j + \varepsilon_{j'})^2 - \omega^2_{\lambda i}} = 1$$

In ERPA

$$\rho_j = \frac{1}{\sqrt{2j+1}} \sum_m \langle | \alpha^\dagger_{jm} \alpha_{jm} | \rangle$$

K. Hara, *Progr. Theor. Phys.* 32, 88 (1964)

In RPA

$$\langle|[Q_{\lambda\mu i}, Q^{\dagger}_{\lambda'\mu'i'}]|\rangle = \frac{1}{2}\delta_{\lambda\lambda'}\delta_{\mu\mu'}\sum_{jj'}(\psi^{\lambda i}_{jj'}\psi^{\lambda i'}_{jj'} - \varphi^{\lambda i}_{jj'}\varphi^{\lambda i'}_{jj'})$$

In ERPA

$$\langle|[Q_{\lambda\mu i}, Q^{\dagger}_{\lambda'\mu'i'}]|\rangle =$$
$$= \frac{1}{2}\delta_{\lambda\lambda'}\delta_{\mu\mu'}\sum_{jj'}(1 - \rho_{jj'})(\psi^{\lambda i}_{jj'}\psi^{\lambda i'}_{jj'} - \varphi^{\lambda i}_{jj'}\varphi^{\lambda i'}_{jj'})$$

$$\rho_{jj'} = \rho_j + \rho_{j'}$$

EQPM-2

$$\frac{1}{2}\sum_j (2j+1)\left\{1-\frac{(1-2\rho_j)(E_j-\lambda)}{\sqrt{(E_j-\lambda)^2+\Delta^2}}\right\}=n$$

$$\frac{G}{4}\sum_j \frac{2j+1}{\sqrt{(E_j-\lambda)^2+\Delta^2}}(1-2\rho_j)=1$$

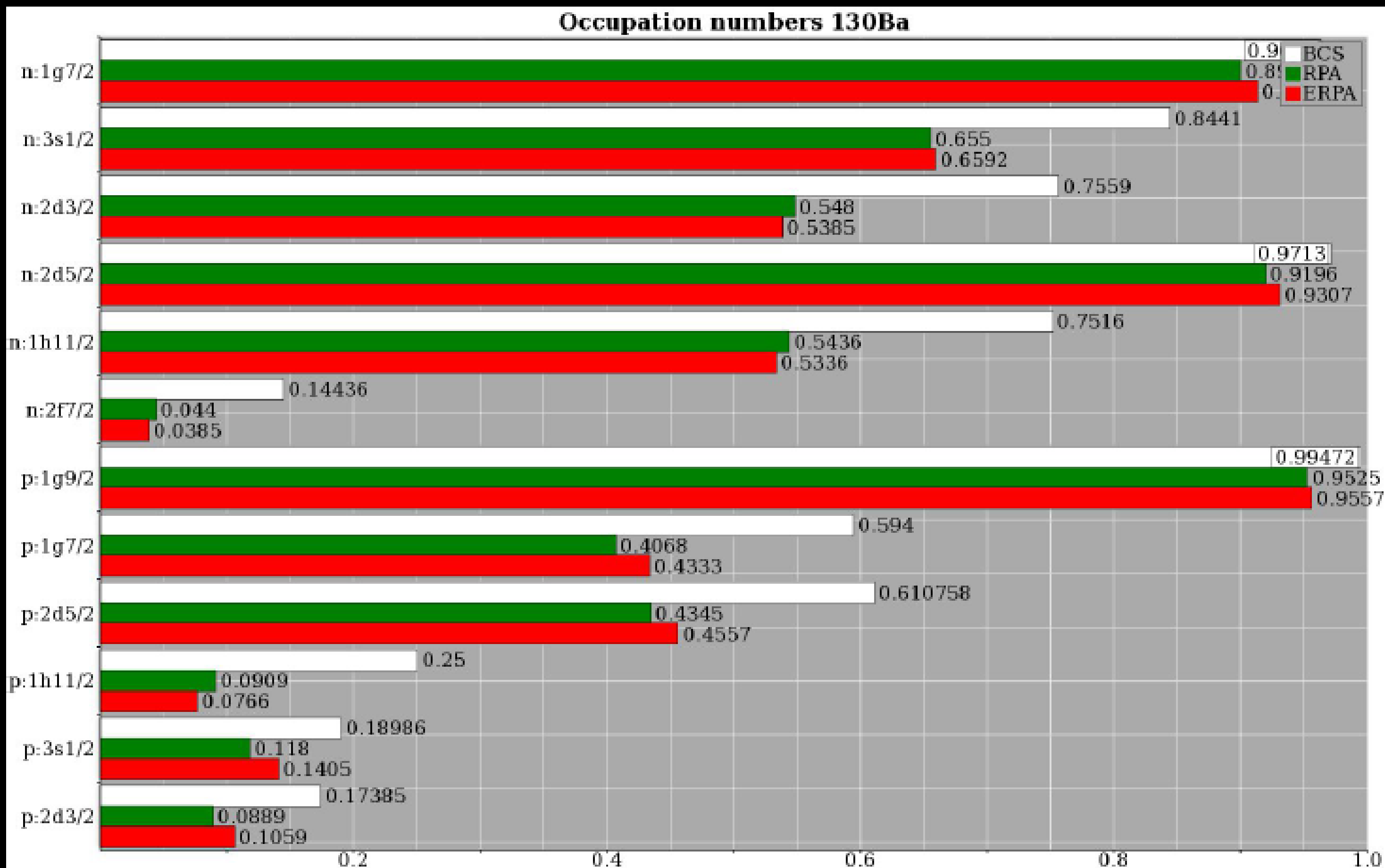
$$\frac{\kappa_\lambda}{2\lambda+1}\sum_{jj'}(1-\rho_{jj'})\frac{(f^\lambda_{jj'}u^+_{jj'})^2(\varepsilon_j+\varepsilon_{j'})}{(\varepsilon_j+\varepsilon_{j'})^2-\omega^2_{\lambda i}}=1$$

$$\sum_{jj'}(1-\rho_{jj'})[(\psi^{\lambda i}_{jj'})^2-(\varphi^{\lambda i}_{jj'})^2]=2$$

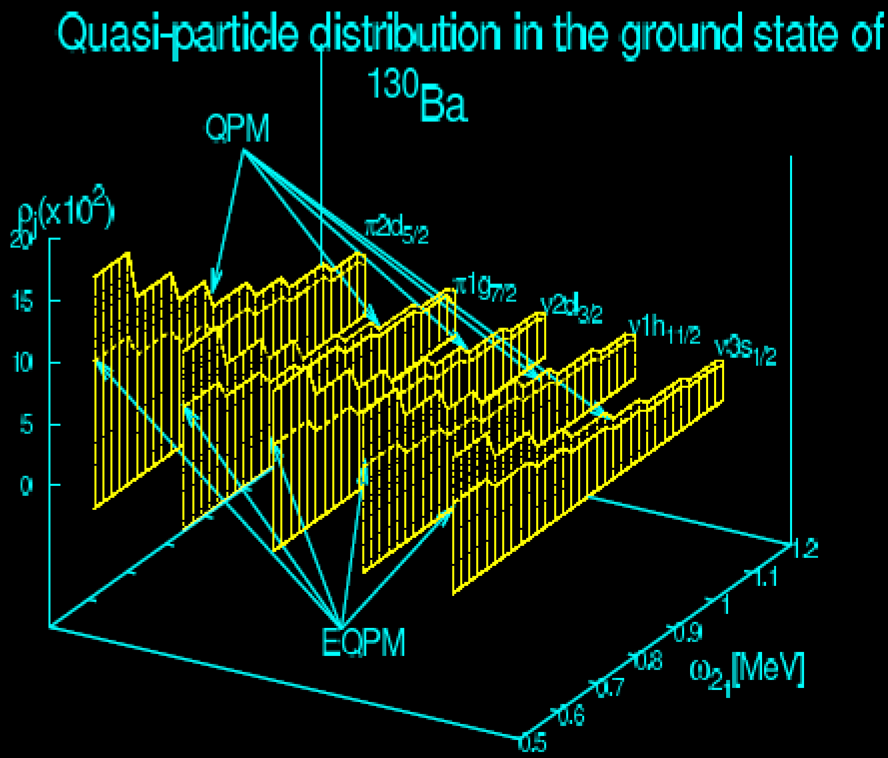
$$\rho_j=\frac{1}{2}\sum_{\lambda i j'}\frac{2\lambda+1}{2j+1}(1-\rho_{jj'})(\varphi^{\lambda i}_{jj'})^2$$

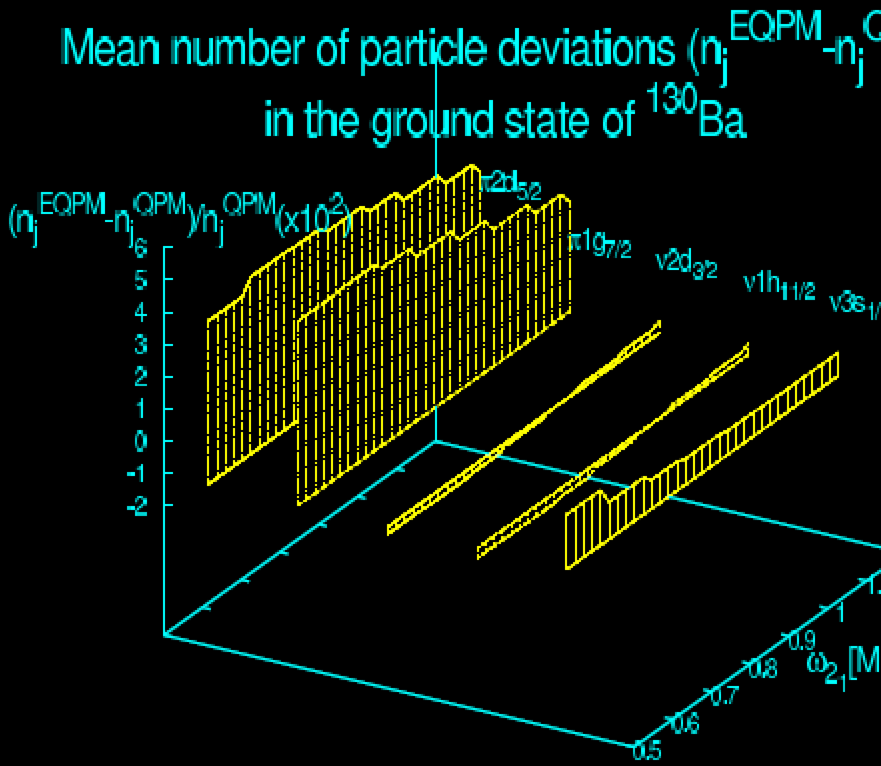
R.V. Jolos and W. Rybarska, Z. Physik A296 (1980) 73

Occupation numbers within BCS, QRPA, EQRPA



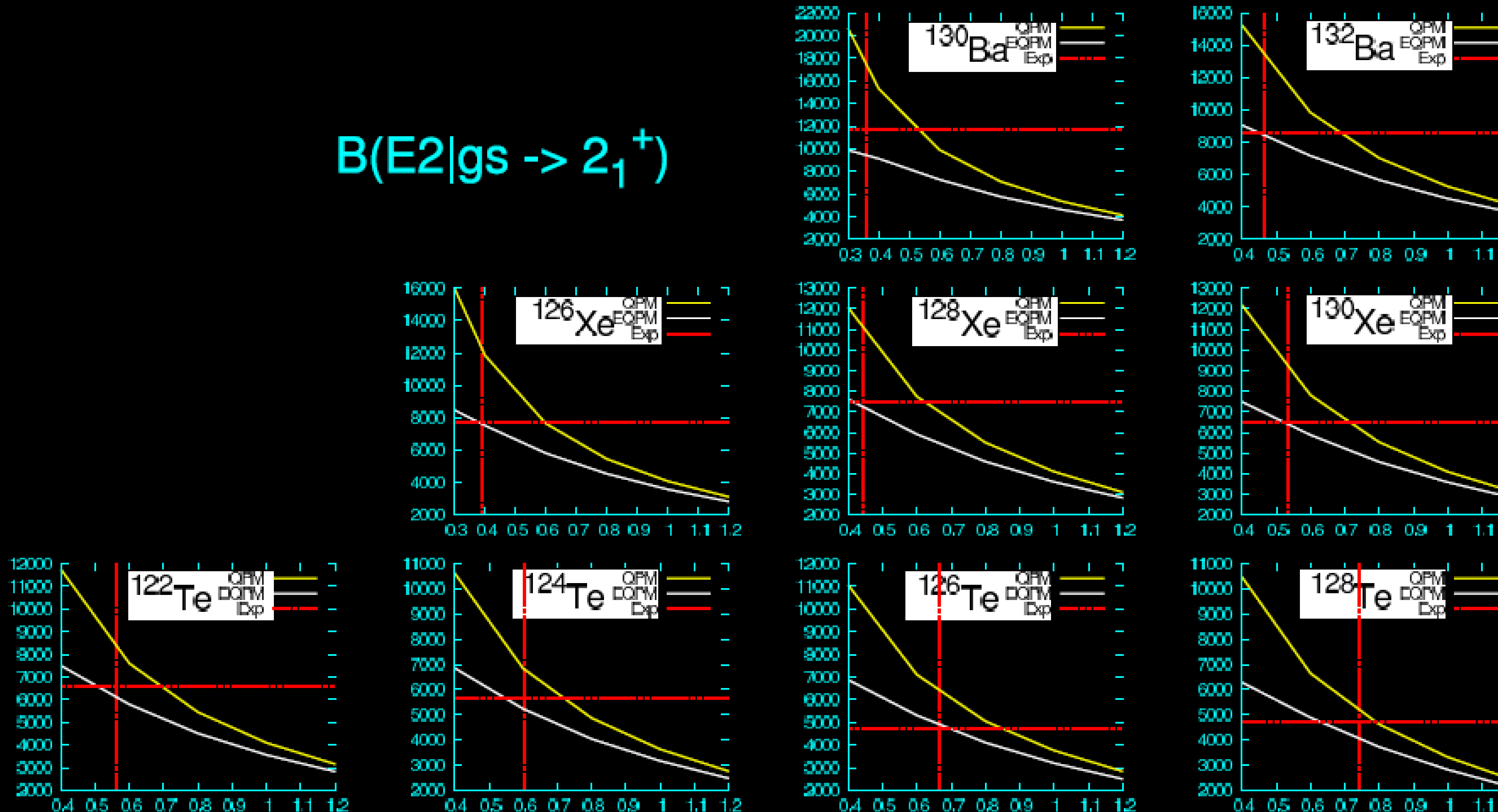
Occupation numbers





Transition probabilities in even-even nuclei

$B(E2|gs \to 2_1^+)$



$$B(E\lambda|g.s. \to \lambda_i) = \left[\frac{1}{2}\sum(1-\rho_{jj'})f^{\lambda}_{jj'}u^{+}_{jj'}g^{\lambda_i}_{jj'}\right]^2$$

Odd-even nuclei

$$\Psi_\nu(JM) = C_{J\nu}\alpha^\dagger_{JM} + \sum_{j\lambda i} D_j^{\lambda i}(J\nu)P^\dagger_{j\lambda i}(JM) - E_{J\nu}\tilde{\alpha}_{JM} - \sum_{j\lambda i} F_j^{\lambda i}(J\nu)\tilde{P}_{j\lambda i}(JM$$

$$P^\dagger_{j\lambda i}(JM) = [\alpha^\dagger_j Q^\dagger_{\lambda i}]_{JM}$$

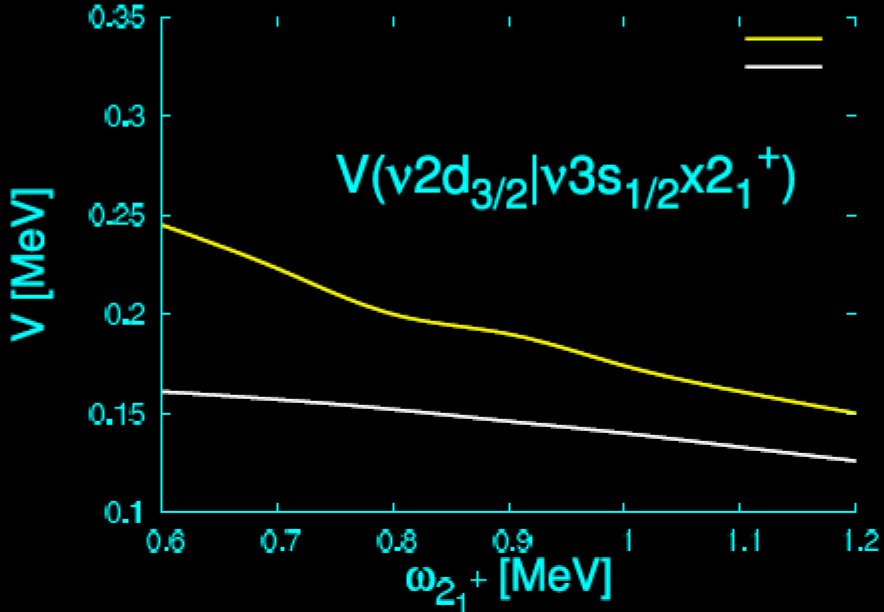
$$\begin{pmatrix} \varepsilon_J & V(Jj'\lambda' i') & 0 & -W(Jj'\lambda' i') \\ V(Jj\lambda i) & K_J(j\lambda i|j'\lambda' i') & W(Jj\lambda i) & 0 \\ 0 & W(Jj'\lambda' i') & -\varepsilon_J & -V(Jj'\lambda' i') \\ -W(Jj\lambda i) & 0 & -V(Jj\lambda i) & -K_J(j\lambda i|j'\lambda' i') \end{pmatrix} \begin{pmatrix} C_{J\nu} \\ D_{j'\lambda' i'}(J\nu) \\ -E_{J\nu} \\ -F_{j'\lambda' i'}(J\nu) \end{pmatrix}$$

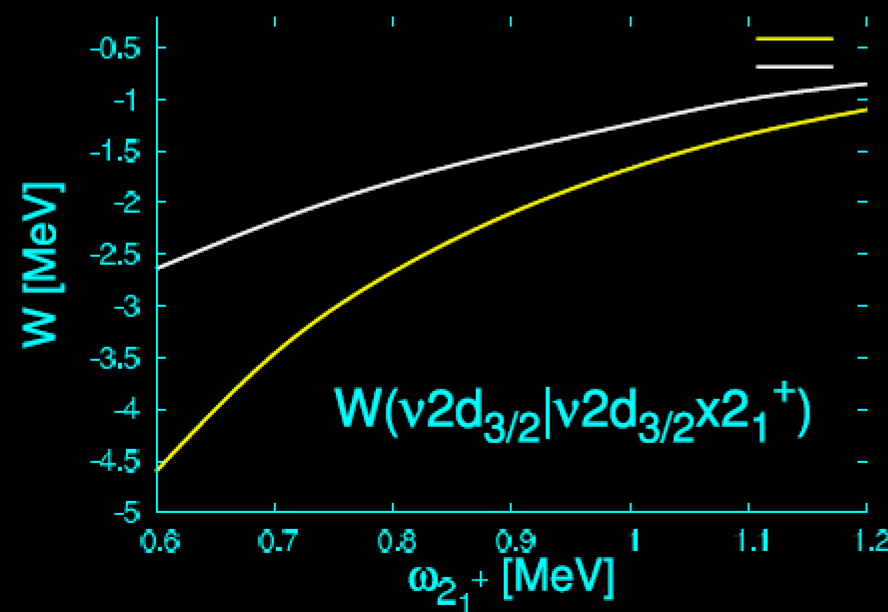
$$= \eta_{J\nu} \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1-\mathcal{L}^*(Jj\lambda i) & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1-\mathcal{L}^*(Jj\lambda i) \end{pmatrix} \begin{pmatrix} C_{J\nu} \\ D_{j'\lambda' i'}(J\nu) \\ -E_{J\nu} \\ -F_{j'\lambda' i'}(J\nu) \end{pmatrix}$$

$$V(Jj\lambda i) = \langle|\{[\alpha_{JM}, H], P^{\dagger}_{j\lambda i}\}|\rangle =$$
$$= -\frac{1}{\sqrt{2}}[1 - \rho_j + \mathcal{L}^*(Jj\lambda i)]\Gamma(Jj\lambda i),$$
$$W(Jj\lambda i) = \langle|\{[\alpha^{\dagger}_{JM}, H], \tilde{P}^{\dagger}_{j\lambda i}\}|\rangle =$$
$$= \frac{\pi_\lambda}{\pi_J}\varepsilon_J \rho_j \varphi^{\lambda i}_{Jj} - \frac{1}{4}[1 - \rho_j + \mathcal{L}^*(Jj\lambda i)]\frac{\pi_\lambda}{\pi_J}\sum_{i_1}\mathcal{A}(\lambda i_1 i)\varphi^{\lambda i_1}_{Jj},$$
$$K_J(j\lambda i|j'\lambda' i') = \frac{1}{2}[I_J(j\lambda i|j'\lambda' i') + I_J(j'\lambda' i'|j\lambda i)] =$$
$$= \delta_{jj'}\delta_{\lambda\lambda'}\delta_{ii'}[1 - \rho_j + \mathcal{L}^*(Jj\lambda i)](\varepsilon_j + w_{\lambda i})$$
$$- \delta_{jj'}\delta_{\lambda\lambda'}\delta_{ii'}(1 + \mathcal{L}(Jj\lambda i))\frac{1}{4}\sum_{\imath_1}\mathcal{A}(\lambda i i_1)\mathcal{L}^*_{J|j}(j\lambda i|j\lambda i_1)$$

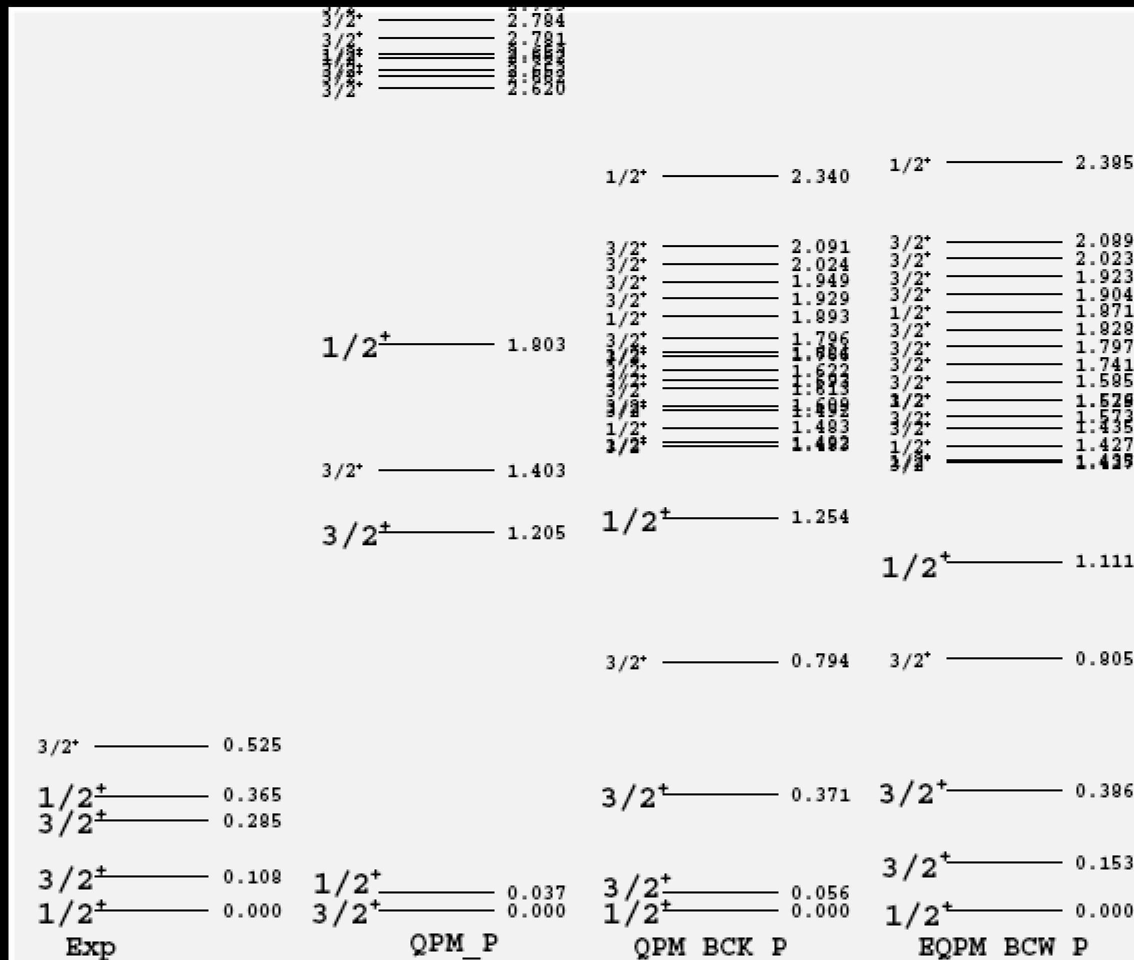
Interaction strengths

^{131}Ba

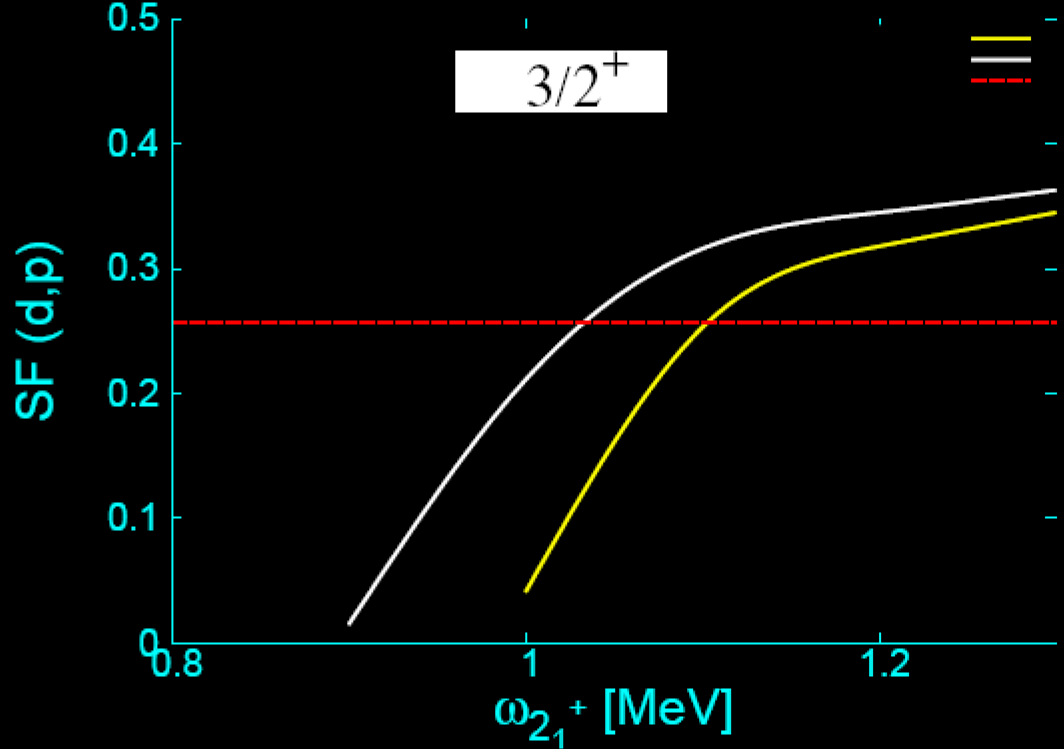




Spectrum (^{131}Ba) @ $\omega_{2_1^+} = 1$ MeV



Spectroscopic factors



Nuclide	Exp	$\omega_{2_1^+}$, QPM_BCW_P	$\omega_{2_1^+}$, EQPM_BCW_P
^{123}Te	0.5	1.4	1.3
^{125}Te	0.46	1.5	1.3
^{127}Te	0.38	1.5	1.35

Transition probabilities in odd-even nuclei

$$B(E\lambda; J_1\nu_1 \to J_2\nu_2) = \frac{1}{\pi_{J_1}^2}\left[\sum_i U(J_1\nu_1 J_2\nu_2\lambda i)\sqrt{B(E\lambda; g.s. \to$$

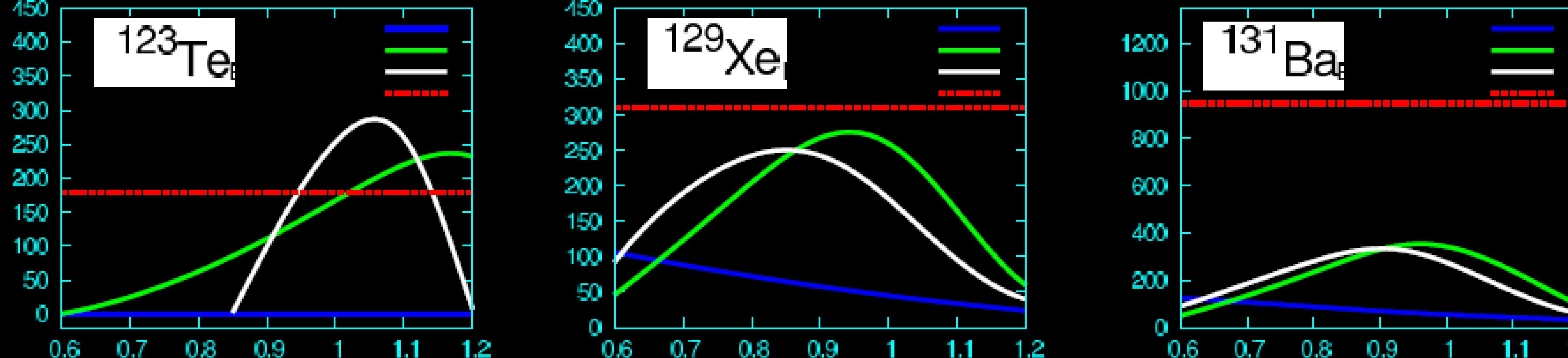
$$\approx \frac{1}{\pi_{J_1}^2} U^2(J_1\nu_1 J_2\nu_2\lambda 1) B_{even}(E\lambda; g.s. \to \lambda_1).$$

$$U(J_1\nu_1 J_2\nu_2\lambda i) =$$

$$= \frac{\pi_{J_1}}{\pi_\lambda}[C_{J_2\nu_2} D_{J_2\lambda i}(J_1\nu_1) - E_{J_2\nu_2} F_{J_2\lambda i}(J_1\nu_1)][1 + L(J_1 J_2 \lambda i)] +$$

$$(-)^{J_1 - J_2 + \lambda}\frac{\pi_{J_2}}{\pi_\lambda}[C_{J_1\nu_1} D_{J_1\lambda i}(J_2\nu_2) - E_{J_1\nu_1} F_{J_1\lambda i}(J_2\nu_2)][1 + L(J_2 J$$

$B(E2|3/2^+ \rightarrow 1/2^+)$



Summary

- Renormalized qp-ph interaction strengths have been derived using the Extended Boson Approximation within a 1ph model
- Some effects due to the qp-ph interaction weakening have been presented - spectroscopic factors, transition probabilities and spectra
- The results of the numerical calculations indicate an overall improved agreement with the experiment

Thank you for your attention!