A unified approach for nuclear excitations

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First Tsukuba-CCS-RIKEN joint
workshop on microscopic theories of
nuclear structure and dynamics

Nuclear Density Functional Theory (DFT)

$$E = \langle \Psi | \hat{H} | \Psi \rangle = \langle \Phi | \hat{H}_{eff} | \Phi \rangle = E[\hat{\rho}]$$

$|\Phi\rangle$ **Slater determinant** $\Leftrightarrow$ $\hat{\rho}$ **1-body density matrix**

- The Hohenberg-Kohn (HK) theorem guarantees that “the” exact functional exists but gives no clue on how to build it.
- One can start from a force V_{eff} and write $H_{eff} = T + V_{eff}$. E is the expectation value on a general Slater determinant.
- $\delta E = 0$ provides Hartree-Fock or Kohn-Sham (integro-)differential equations
- **Another possibility is to write directly the functional E[ρ] and fit the parameters to the data.**

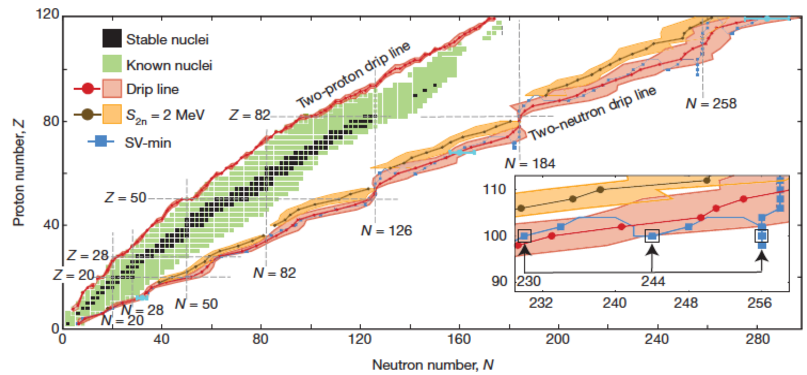
$E = a\rho^2 + \ldots$ (can become involved)

Modern functionals and their performance

- They are as “fundamental” as other models because of the **HK theorem**.
- They are applicable to almost the whole isotope chart and to excited states.

- Typical number of parameters ~ 10.
- Error on masses of the order of 1 MeV (can go further down).
- Trends of charge radii and deformations fairly well reproduced.
- Good description of excitations such as giant resonances, rotational bands.
- They can also be applied to β and ββ transitions.
- There is current interest in large amplitude motion, reactions etc.

(…)



J. Erler *et al.*, Nature 486, 509 (2012) - SEDF

A specific open questions is whether pairing is properly included in current EDFs (not only between equal particles but also between p and n).

H. Sagawa, C.L. Bai, GC, Phys. Scr. 91, 083011 (2016)

Beyond the simple DFT

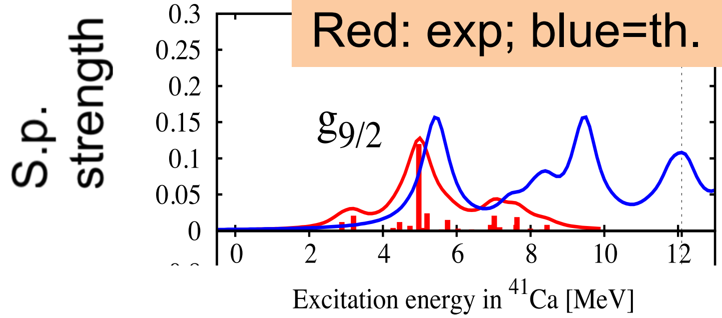
There are phenomena or observables that are **outside the DFT framework**.

The solution of the Kohn-Sham equations provides s.p. orbitals that are not the observed states in the A+1 or A-1 nuclei.

Single-particle strength

9/2$^+$ strength in ^{41}Ca.

Red: exp; blue=th.

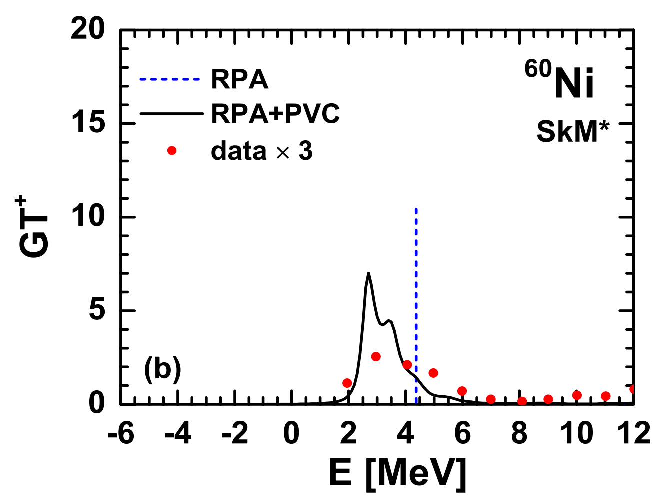


K. Mizuyama, GC, and E. Vigezzi, PRC 86, 034318 (2012).

Also for collective states, experiment shows broader and more fragmented states than the solution of DFT.

Multipole strength

Gamow-Teller strength in ^{60}Ni



Y. Niu *et al.*, PRC 85, 034314 (2012).

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Goal and strategy

- We would like to have an effective theory that is **based on s.p. and collective states that comes from DFT but also includes their mutual coupling.**

- It might be solved at given order.

- It should provide the fragmentation of states that characterizes the low-energy spectra, and the broad features in the giant resonance region.

Particle-vibration coupling (PVC) - I

In spherical nuclei this is the most effective way, if not the only one, to explain **fragmentation and widths** of single-particle and giant resonances in a consistent fashion. Valid both at the ~1 MeV and ~10 MeV scales.

In the following arrows will denote the particles (nucleon degrees of freedom) and wavy lines will denote the vibrations (or phonons – they are bosons).

HF or Kohn-Sham → Lowest-order coupling

RPA for vibrations → Lowest-order coupling

Use consistently the same Hamiltonian or EDF

Particle decays

γ decays

Correlation experiments

(…)

Particle-vibration coupling (PVC) - II

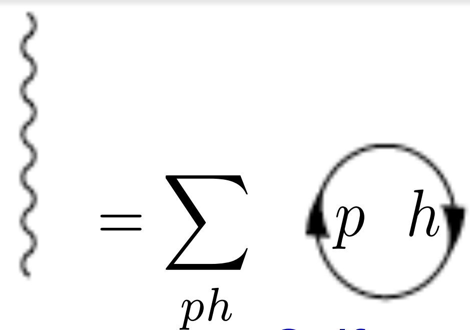
A formal description of the model can be given.
One starts from the Hedin's equations, that involve

$$G, \ \Sigma, \ W, \ \Pi, \ \Gamma$$

and performs a series of approximations.

HF states (Skyrme)
Both p and h^{-1}

Particle-Vibration Coupling (PVC).
M. Baldo *et al.*, J. Phys. G: Nucl. Part. Phys. 42 (2015) 085109.
Cf. I. Hamamoto, V. Soloviev *et al.*, V. Tselyaev, E. Litvinova *et al.* [...]



Self-consistent RPA
Sum of ph^{-1} "bubbles"

Focus

1. New model for odd-nuclei

HCM (Hybrid configuration mixing)

2. Extension of the model for GRs and β-decay: inclusion of T=1 and T=0 pairing

Q R P A + Q P V C (Quasiparticle Random Phase Approximation plus quasiparticle-vibration coupling)

Towards complete spectroscopy of odd nuclei

- There are several examples of spectra in which "particle" states (large spectroscopic factor in transfer reactions) co-exist with states made up with "particle plus core vibration" states (gamma decay similar to that of the core vibration).

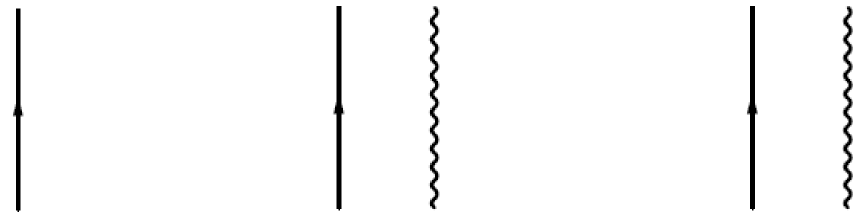
$$B(E\lambda, [j' \otimes \lambda]_j \to j') = B(E\lambda, \lambda \to 0)$$

- Could be a good playground for particle-vibration coupling models …

- … but in some cases particle-phonon states are instead 2p-1h, or 3p-2h states ("shell model-like" states).

Hybrid Configuration Mixing (HCM) model - I

We start from a **basis** made up with **particles** (or holes) around a core, and with **excitations** of the same core (RPA "phonons").

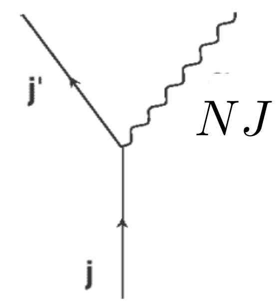


On this basis we **diagonalize the Hamiltonian** $H = H_0 + V,$

V_{Skyrme}

$$H_0 = \sum_{jm} \varepsilon_j a^\dagger_{jm} a_{jm} + \sum_{NJM} \hbar\omega_{NJ} \Gamma^\dagger_{NJM} \Gamma_{NJM},$$

$$V = \sum_{jmj'm'} \sum_{NJM} \frac{\langle j||V||j', NJ\rangle}{\hat{j}} a_{jm} \left[a^\dagger_{j'} \otimes \Gamma^\dagger_{NJ} \right]_{jm}$$



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Hybrid Configuration Mixing (HCM) model - II

- Some of the RPA phonons might be actually pure p-h states. Then, the states of our basis are 2p-1h**. In this sense they are not “vibrations” and the model cannot be considered “PVC”.**

- In this case Pauli principle violations can be important. **We correct for the non-orthonormality and overcompleteness of the basis by introducing the NORM matrix.**

$$n(j_1'n_1J_1, j_2'n_2J_2) = \delta(j_1', j_2')\delta(n_1, n_2)\delta(J_1, J_2) - \sum_{h_1}(-)^{J_1+J_2+j_1'+j_2'}\hat{J}_1\hat{J}_2 \left\{ \begin{array}{ccc} j_2' & j_{h_1} & J_1 \\ j_1' & j & J_2 \end{array} \right\} X^{(n_1J_1)}_{j_2'h_1} X^{(n_2J_2)}_{j_1'h_1}$$

This is the overlap between 1p-1 “phonon” states. The diagonal part reduces to 1 – $(2j+1)^{-1}$ in simple cases.

$$\mathcal{H} - E\mathcal{N} = 0$$

Basic equation (cf. SM and/or GCM)

$$\mathcal{H} - E\mathcal{N} = 0$$

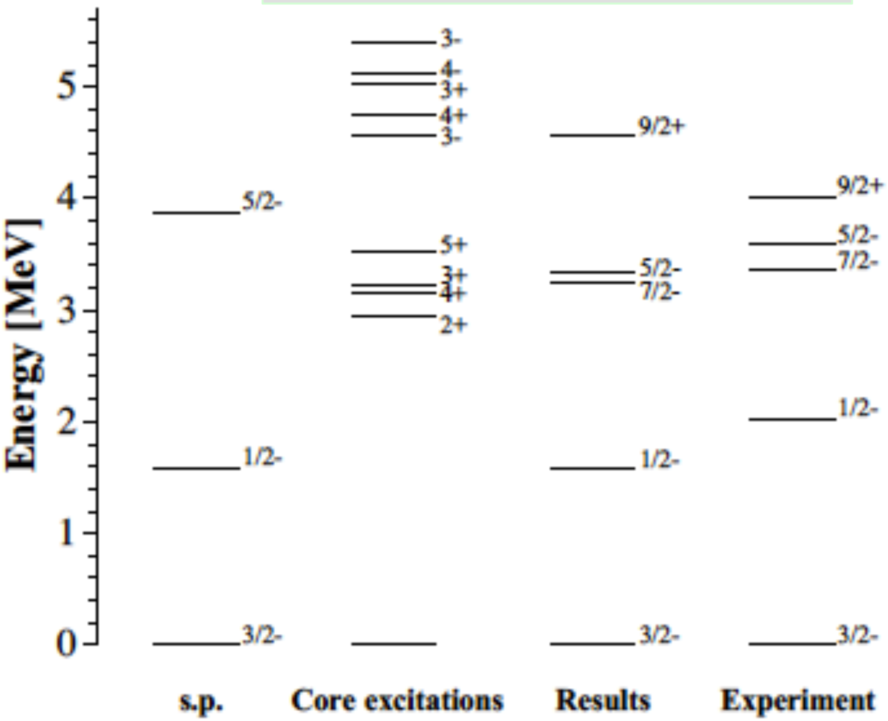
$$\mathcal{H} = \begin{pmatrix} \varepsilon_{n_1 lj} & 0 & \frac{\langle n_1 lj||V||n_1' l_1' j_1' N_1 J_1\rangle}{\hat{j}} & \frac{\langle n_1 lj||V||n_2' l_2' j_2' N_2 J_2\rangle}{\hat{j}} \\ 0 & \varepsilon_{n_2 lj} & \frac{\langle n_2 lj||V||n_1' l_1' j_1' N_1 J_1\rangle}{\hat{j}} & \frac{\langle n_2 lj||V||n_2' l_2' j_2' N_2 J_2\rangle}{\hat{j}} \\ \frac{\langle n_1 lj||V||n_1' l' j_1' N_1 J_1\rangle}{\hat{j}} & \frac{\langle n_2 lj||V||n_1' l' j_1' N_1 J_1\rangle}{\hat{j}} & \varepsilon_{n_1' l_1' j_1'} + \hbar\omega_{N_1 J_1} & 0 \\ \frac{\langle n_1 lj||V||n_2' j_2' N_2 J_2\rangle}{\hat{j}} & \frac{\langle n_2 lj||V||n_2' l' j_2' N_2 J_2\rangle}{\hat{j}} & 0 & \varepsilon_{n_2' l_2' j_2'} + \hbar\omega_{N_2 J_2} \end{pmatrix}$$

$$\mathcal{N} = \begin{pmatrix} 1 & 0 & \dots & 0 & 0 & \dots \\ 0 & 1 & \dots & 0 & 0 & \dots \\ \dots & \dots & \dots & \dots & \dots & \dots \\ 0 & 0 & \dots & n(j_1' n_1 J_1, j_1' n_1 J_1) & n(j_1' n_1 J_1, j_2' n_2 J_2) & \dots \\ 0 & 0 & \dots & n(j_2' n_2 J_2, j_1' n_1 J_1) & n(j_2' n_2 J_2, j_1' n_1 J_1) & \dots \\ \dots & \dots & \dots & \dots & \dots & \dots \end{pmatrix}$$

Results for ^{49}Ca

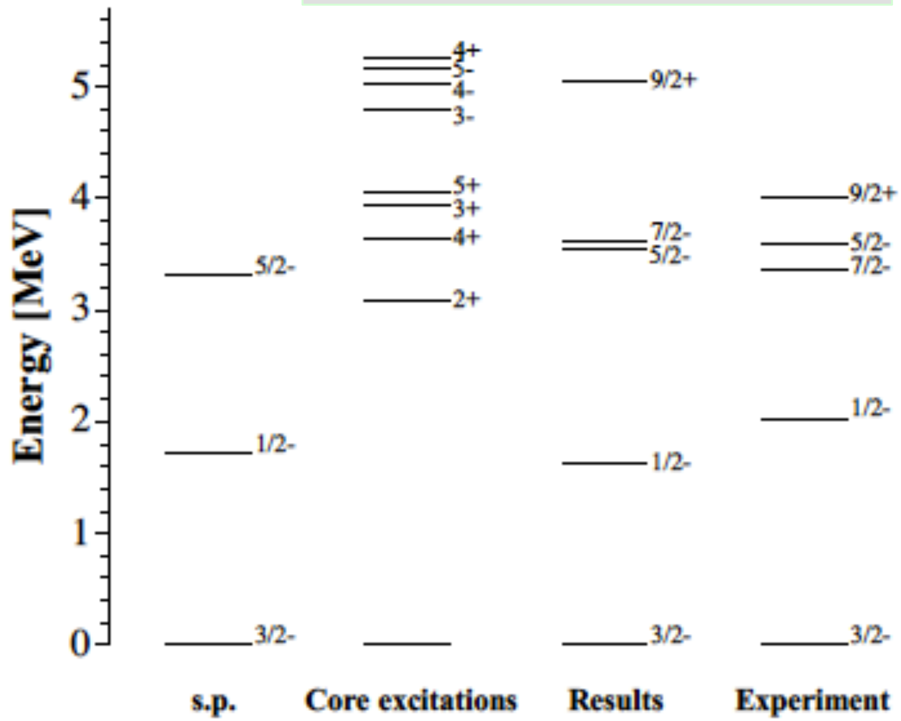
SkX

R.m.s. deviation th.-exp.: 0.429 MeV



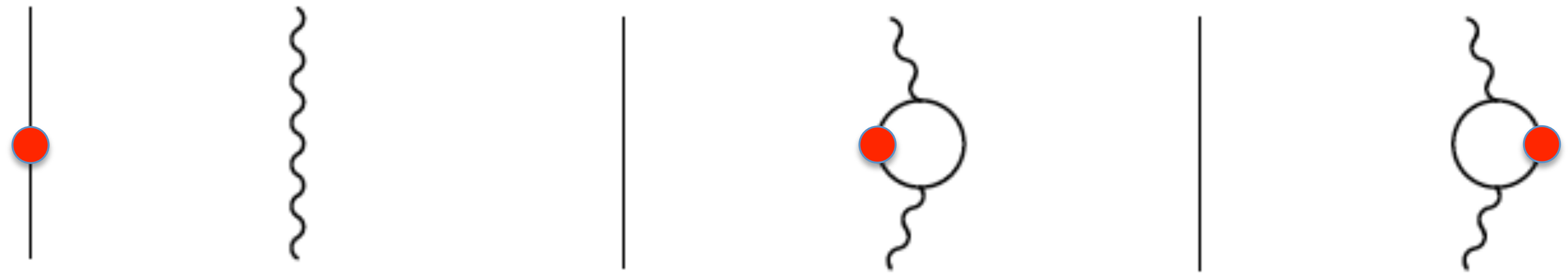
SLy5

R.m.s. deviation th.-exp.: 0.661 MeV



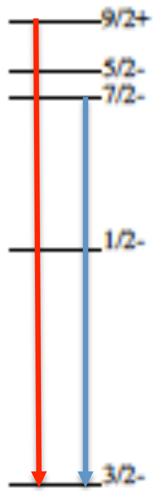
The spectrum is **more stretched** in theory than in experiment; nonetheless, <u>the **agreement is quite good**</u>.

Electromagnetic transition probabilities



In the transition between two states made up with particle plus phonon, the electromagnetic operator (red dot) can act either on the particle or on the p and h that compose the phonon.

^{49}Ca: only few γ transitions are known and with a significant experimental error



	Theory SkX	Theory SLy5	Exp.
$B(E3, 9/2^+ \rightarrow 3/2^-)$	6.4	5.7	7.9 ± 2.0 W.u.
$B(E2, 7/2^- \rightarrow 3/2^-)$	1.4	1.0	0.05 ± 0.02 W.u.

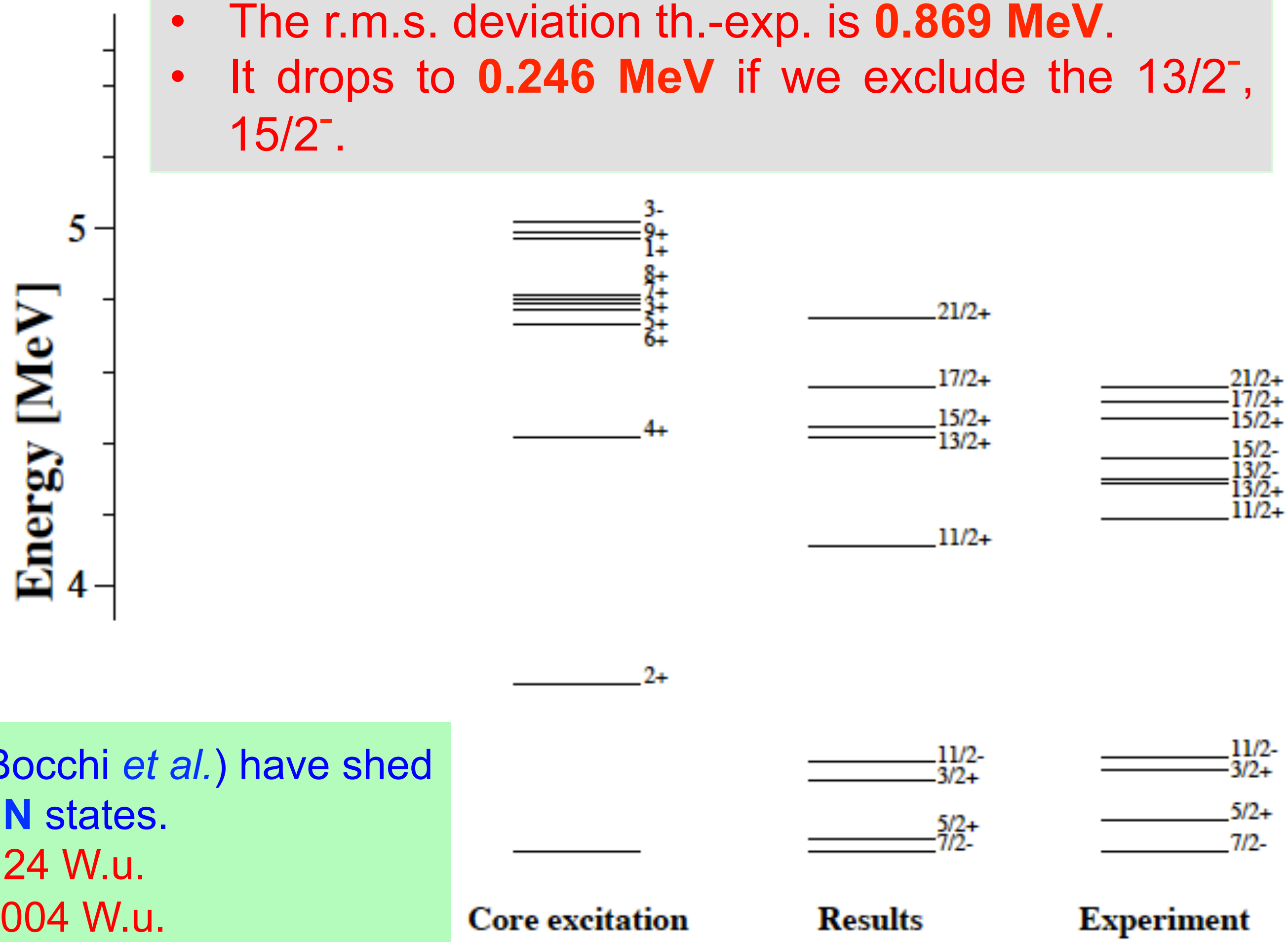
Results for ^{133}Sb

SkX

Only 2^+, 3^- and 4^+ core excitations are genuine "phonons". There are more core excitations in the model space, and they are 1p-1h (mainly $h_{11/2}^{-1}$-$f_{7/2}$). 6+ has 2-3 components.

The spectrum includes particle-phonon states as well as 2p-1h states.

- The r.m.s. deviation th.-exp. is **0.869 MeV**.
- It drops to **0.246 MeV** if we exclude the $13/2^-$, $15/2^-$.



- New measurements (G. Bocchi *et al.*) have shed light on some **HIGHER SPIN** states.
  B(M1, $15/2^+ \rightarrow 13/2^+$) = 0.24 W.u.
  B(M1, $13/2^+ \rightarrow 11/2^+$) = 0.004 W.u.
  (ratio = 60; theory provides a ratio of 20).

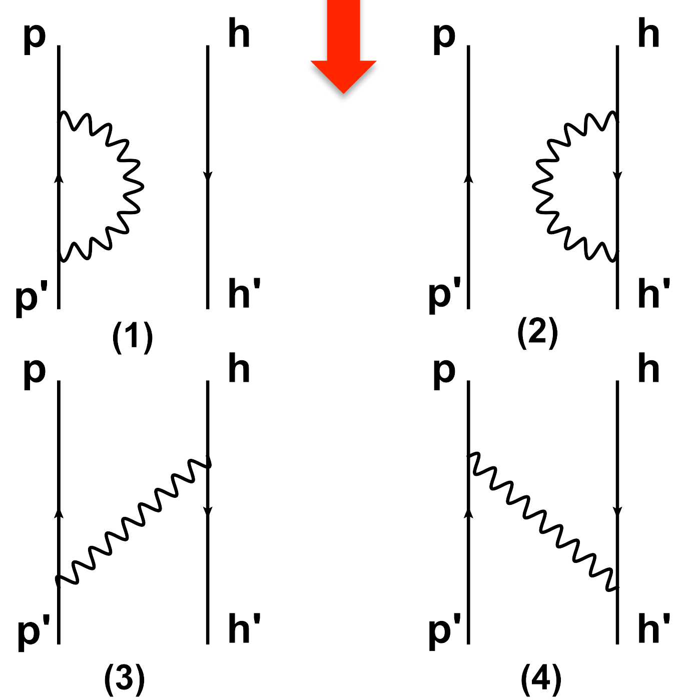
A similar model for resonances: RPA plus particle-vibration coupling

$$\begin{pmatrix} A+\Sigma(E) & B \\ -B & -A-\Sigma^*(-E) \end{pmatrix} \qquad \Sigma_{\mathrm{php'h'}}(E) = \sum_\alpha \frac{\langle ph|V|\alpha\rangle\langle\alpha|V|p'h'\rangle}{E-E_\alpha+i\eta}$$

One first solves self-consistent Hartree-Fock plus Random Phase Approximation (HF-RPA).

One adds the self-energy contribution (the state α is 1p-1h plus one phonon).

The scheme is known to be effective to produce the spreading width of GRs.

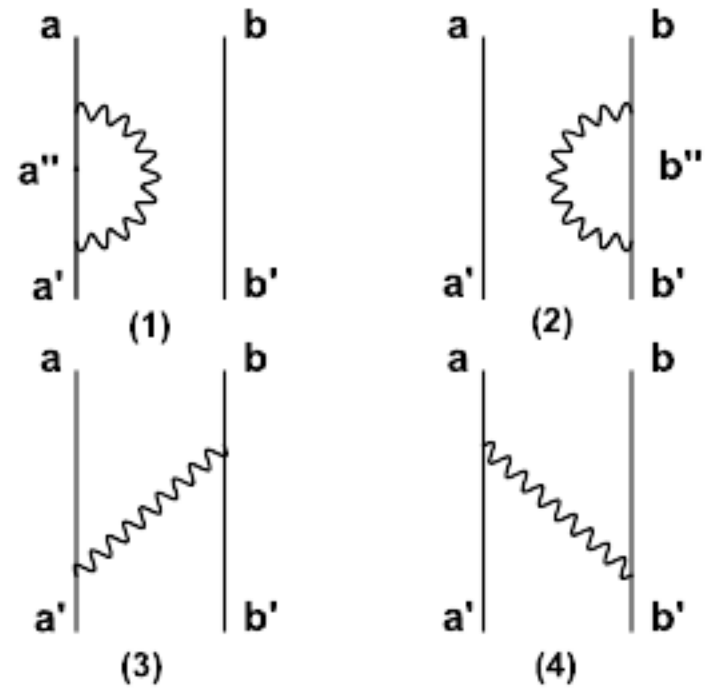


Extension to the case of open-shell nuclei

The basis is made up with states from **full HFB**. In the case of zero-range interactions, at a given cut-off for E_{qp} the pairing gap is fitted.

Phonons are from **quasi-particle RPA** (QRPA). We select the collective ones.

<u>The scheme is fully self-consistent also in the pairing channel.</u>



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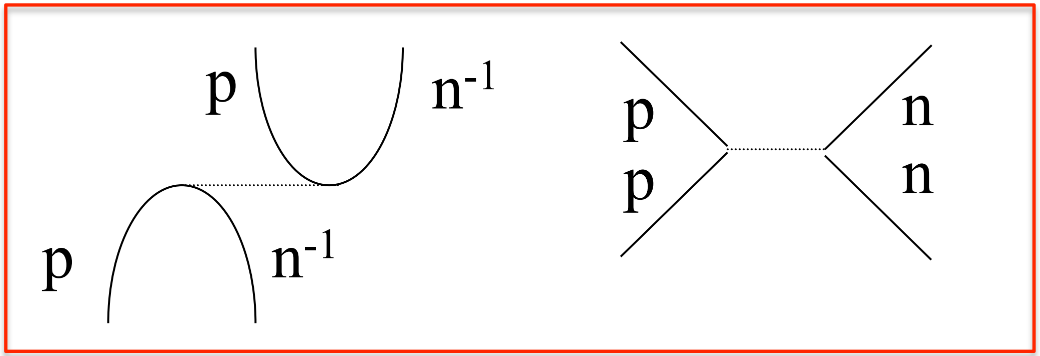
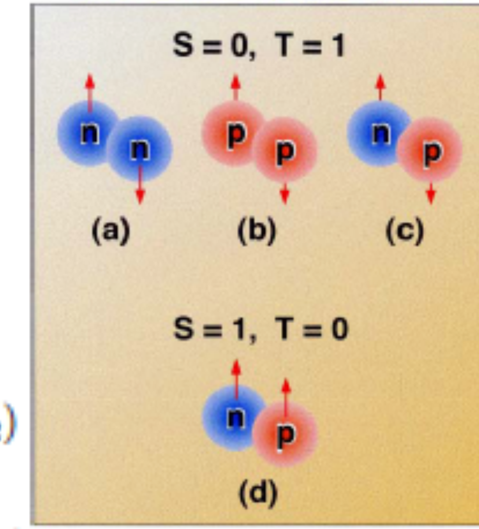




- p-h channel : Skyrme
- p-p channel : IS and IV pairing (cf. the talk by H. Sagawa)

$$V^{T=1}(\vec{r}_1,\vec{r}_2) = \hat{P}_s V_0 \delta(\vec{r}_1 - \vec{r}_2)$$

$$V^{T=0}(\vec{r}_1,\vec{r}_2) = \hat{P}_t f V_0 \delta(\vec{r}_1 - \vec{r}_2)$$

Test and performance of the model

- **Isospin invariance**: $V_{\rm C} = 0 \quad \Rightarrow \quad \left[H, \vec{T}\right] = 0 \quad \Rightarrow \quad E_{\rm IAS} = 0$

E_{IAS}(QRPA) = 280 keV, E_{IAS}(QRPA+QPVC) = 200 keV [^{78}Ni – SkM*]

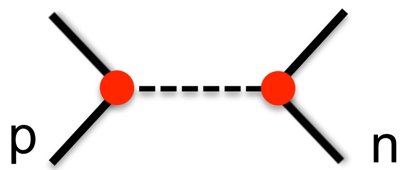
- **2^+ in ^{120}Sn:**

E_x = 1.42 MeV (exp. 1.17 MeV), B(E2) = 2632 e^2fm^4 (exp. 2016 e^2fm^4)

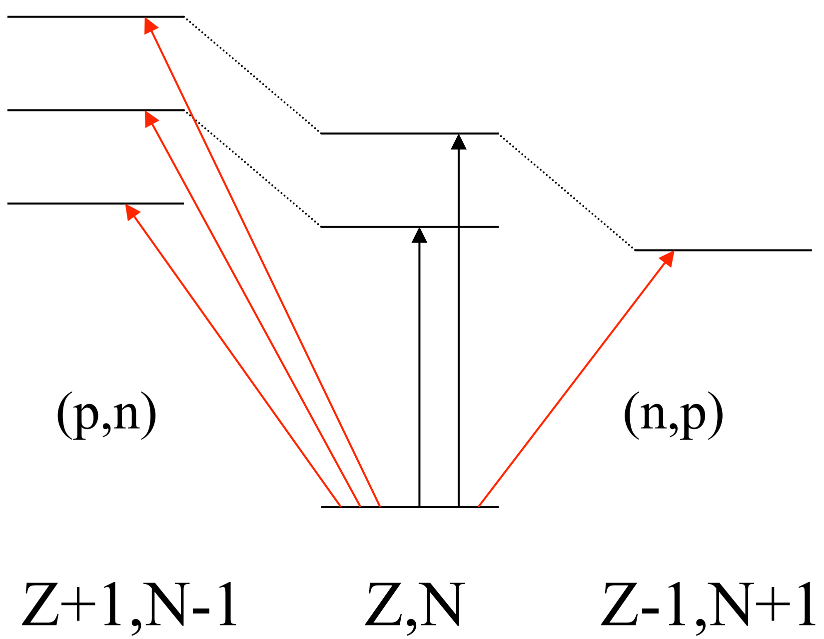
Charge-exchange transitions

- Some transitions may be inside the allowed β-decay window.
- However, most of them require external energy so that they are induced by charge-exchange reactions, like (p,n) or (^{3}He,t). **We look at GTR.**

The study of their properties can greatly improve our knowledge of the charge-changing part of H_{nucl} or $E[\rho]$.



At the same time the matrix elements of the transitions involved in double-β decays must be known to extract the neutrino mass (cf. J. Menéndez).



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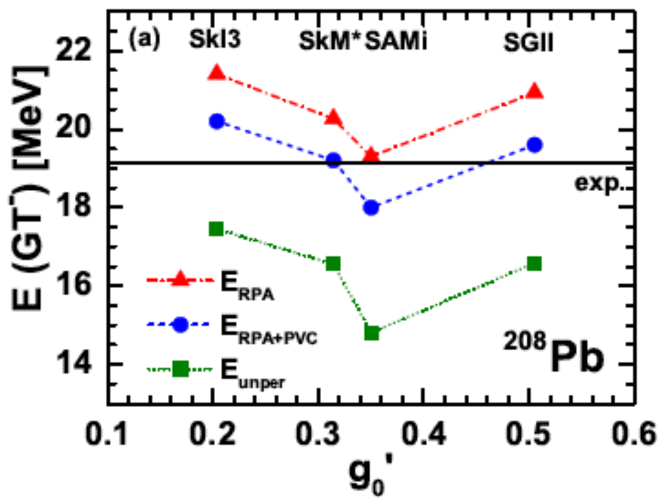
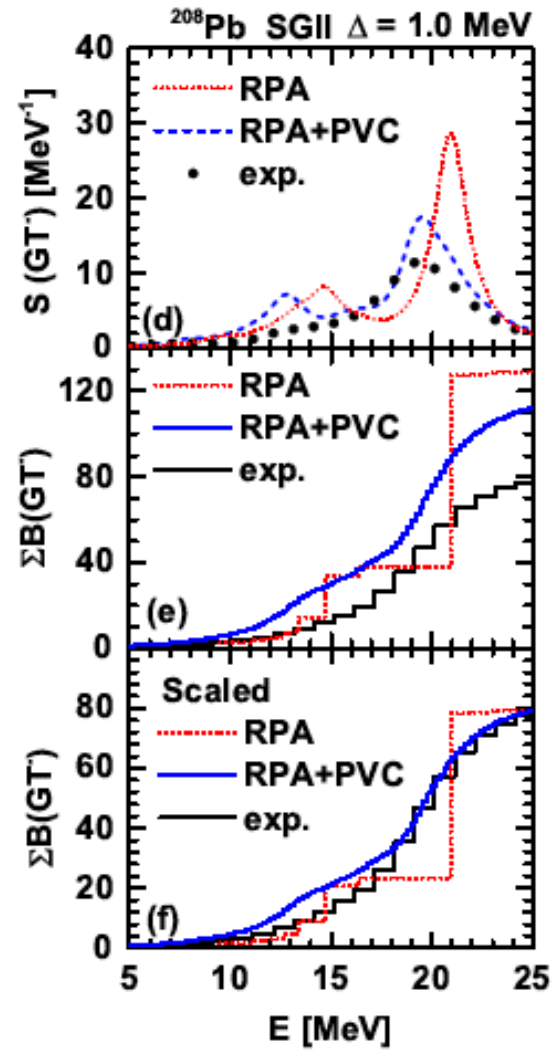
GTR in ^{208}Pb

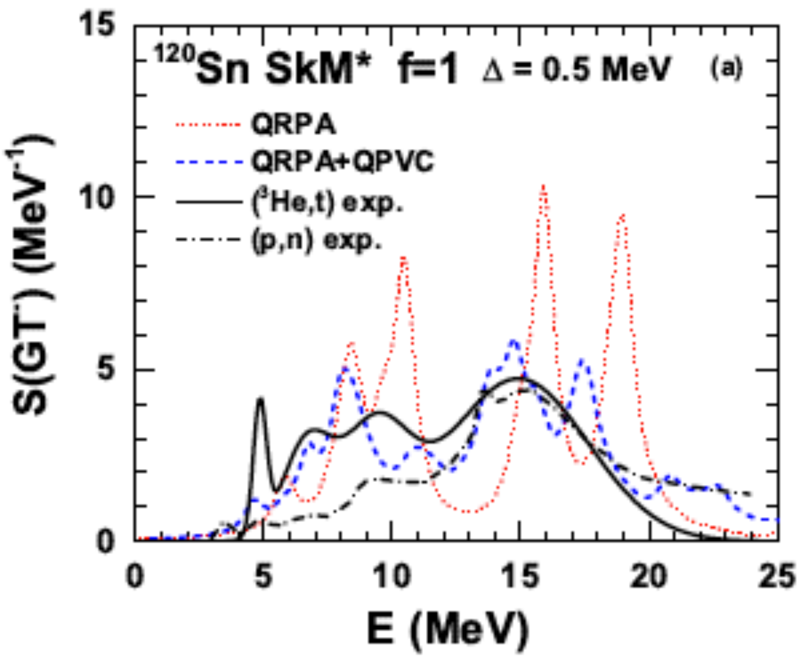
Y. Niu *et al.*, PRC 90, 054328 (2014).

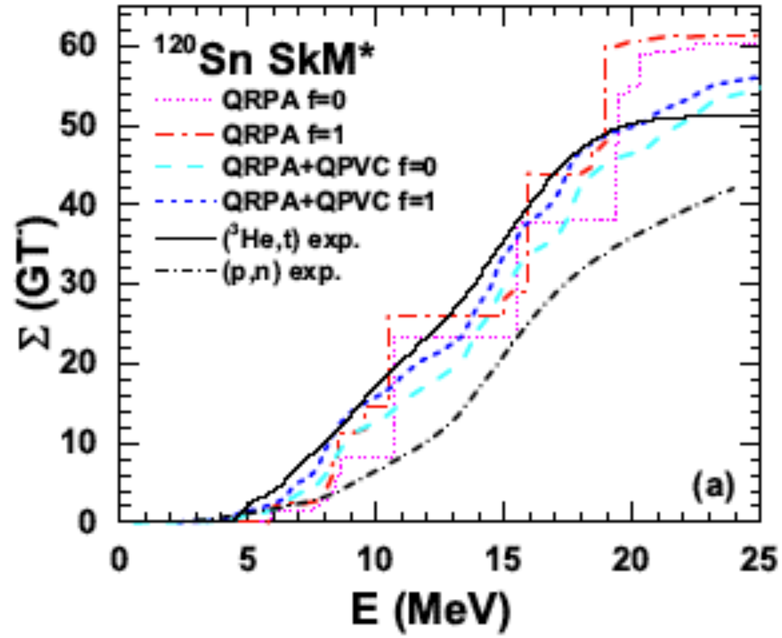




- The energy shift induced by PVC is very weakly interaction-dependent.
- The PVC calculations reproduce the lineshape of the GT response quite well.
- Part of the experimentally observed quenching is accounted for.

QRPA plus PVC: results for ^{120}Sn





- Theory reproduces the data in the high-energy GTR region.
- Not enough quenching.
- The effect of T=0 pairing is not large but it goes in the right direction of improving the agreement with experimental data.

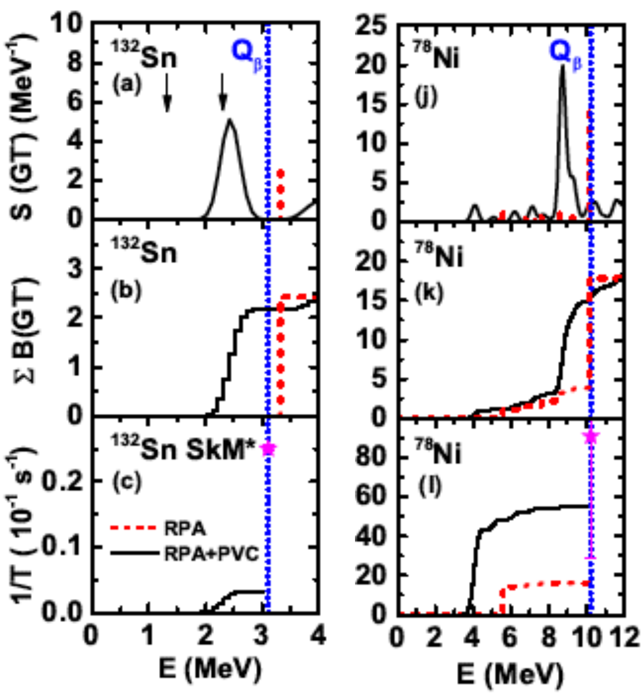
Particle-vibration effect on β-decay

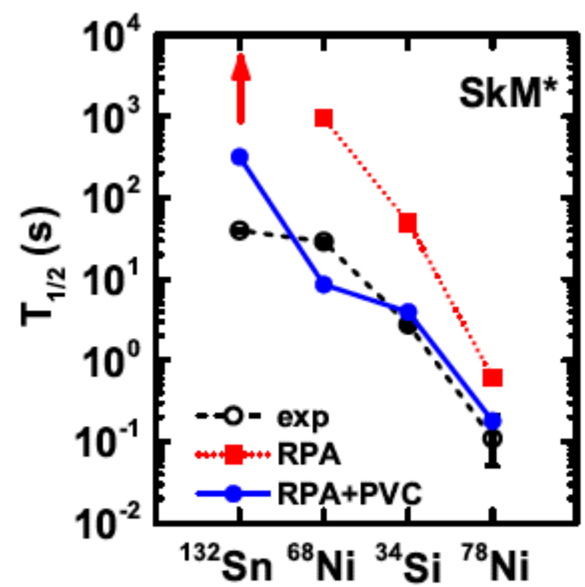
PVC can strongly affect the half-lives:

$$T_{1/2} = \frac{D}{g_A^2 \int_{E_c}^{Q_\beta} S(E) f(Z,E) dE}$$

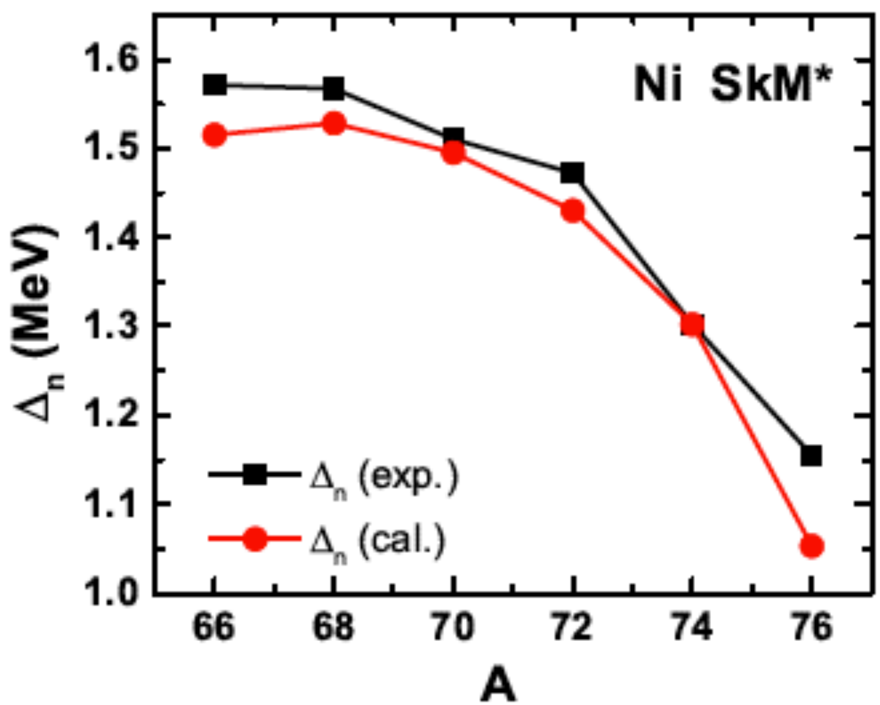
Its effect is to fragment and shift down the RPA peaks, so that there is more strength in the decay window. The effect is enhanced by the phase-space factor. We definitely improve agreement with experiment.

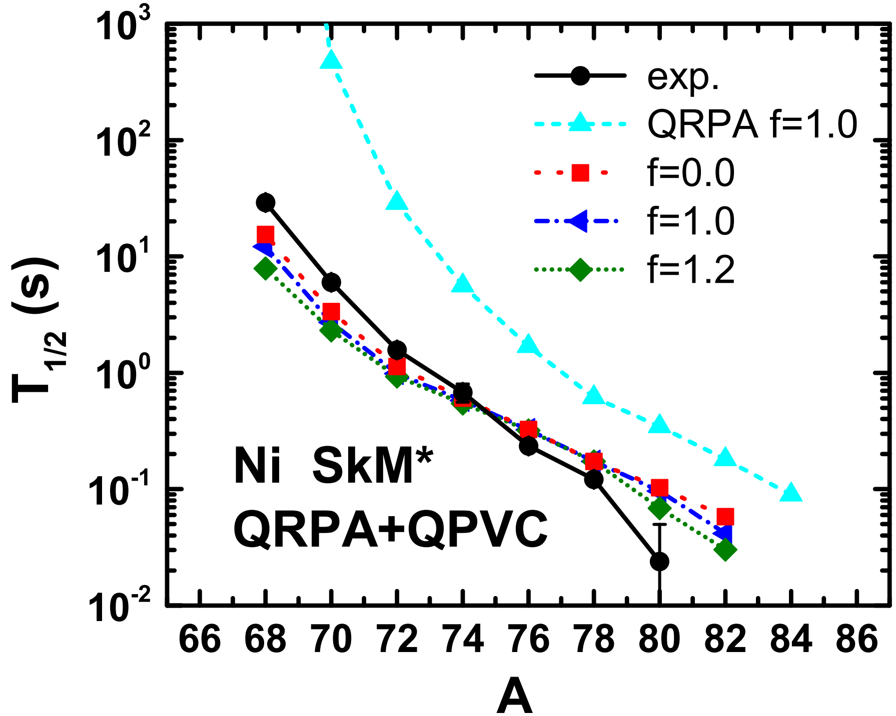
Y. Niu *et al.*, PRL 114, 142501 (2015).





The case of open-shell isotopes: ^{A}Ni





- The effect is confirmed in open-shell isotopes, where QRPA+QPVC provides much better agreement with experiment than simple QRPA.
- Weak sensitivity to T=0 pairing in this case.

β-decay of ^{100}Sn

Superallowed Gamow–Teller decay of the doubly magic nucleus ^{100}Sn

Nature 486, 341 (2012)

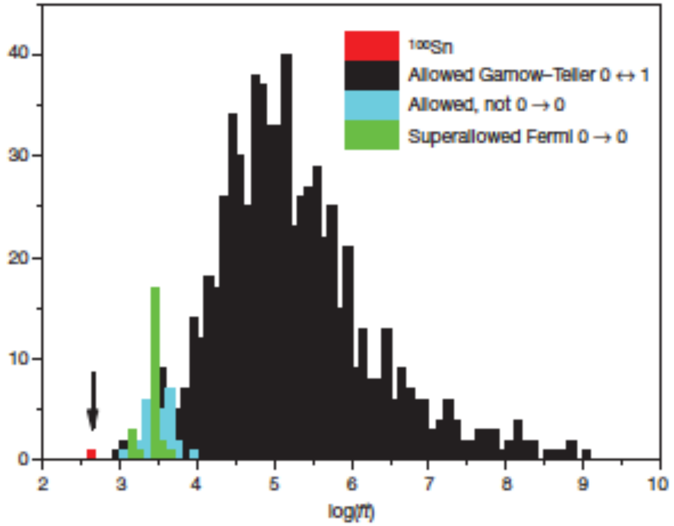


Figure 6 | Log(ft) values of allowed nuclear β-decays. Number distribution of log(ft) values for allowed β-transitions (obeying the selection rules). The data are from ref. 26. The values are for generally allowed Gamow–Teller transitions between 0^+ and 1^+ states (black), mixed Fermi/Gamow–Teller transitions (blue) and the well-established pure, superallowed Fermi transitions from 0^+ to 0^+ states (green). The decay of ^{100}Sn is unique because it has the smallest known log(ft) value (red) of any nuclear β-decay.

$t_{1/2}$	
RPA	17.41 s
RPA+PVC	4.18 s
Exp.	1.11 s

Co-workers

- **G. Bocchi**, P.F. Bortignon, M. Brenna, X. Roca-Maza, E. Vigezzi (University of Milano, Italy)
- **Y. Niu** (ELI, Magurele, Romania)
- J. Meng (PKU, Beijing, China)
- L. Cao (North China Electric Power University, Beijing, China)
- C.L. Bai (Chengdu, China)
- H. Sagawa (RIKEN, Japan)
- Z. Niu (iTHES, RIKEN, Japan)

Conclusions

- Density Functional Theory is a powerful framework to describe many properties of atomic nuclei.
- There are nonetheless properties outside the DFT framework, and we are interested in extending DFT in order to reproduce them.
- A clear physical case: states with mixed particle and phonon character in odd nuclei, with their electromagnetic transitions.
- We also have (Q)RPA+(Q)PVC for GRs.
- Applied to GTRs, our model accounts for most of the width and part of the quenching. It also improves significantly the description of β-decay. We now deal with open-shell systems.

Backup slides

Skyrme vs. relativistic functionals

Skyrme forces are widely used: they generate **LOCAL** functionals.

attraction

$$\hat{v}_{Sk}(\boldsymbol{r}_{12}) = t_0(1+x_0\hat{P}_\sigma)\delta(\boldsymbol{r}_{12}) + \frac{1}{2}t_1(1+x_1\hat{P}_\sigma)(\hat{\boldsymbol{k}}^{\dagger 2}\delta(\boldsymbol{r}_{12}) + \delta(\boldsymbol{r}_{12})\hat{\boldsymbol{k}}^2)$$
$$+ t_2(1+x_2\hat{P}_\sigma)\hat{\boldsymbol{k}}^\dagger \cdot \delta(\boldsymbol{r}_{12})\hat{\boldsymbol{k}} + \frac{1}{6}t_3(1+x_3\hat{P}_\sigma)\delta(\boldsymbol{r}_{12})\rho^\alpha\left(\frac{\boldsymbol{r}_1+\boldsymbol{r}_2}{2}\right)$$
$$+ iW_0(\hat{\boldsymbol{\sigma}}_1+\hat{\boldsymbol{\sigma}}_2)\cdot\hat{\boldsymbol{k}}^\dagger \times \delta(\boldsymbol{r}_{12})\hat{\boldsymbol{k}}.$$

short-range repulsion

In the covariant models the nucleons are described as Dirac particles that exchange effective mesons. One starts from Lagrangians.

$$\mathcal{L}_{int} = -\bar{\psi}\Gamma_\sigma\sigma\psi - \bar{\psi}\Gamma^\mu_\omega\omega_\mu\psi - \bar{\psi}\vec{\Gamma}^\mu_\rho\vec{\rho}_\mu\psi - \bar{\psi}\Gamma^\mu_e A_\mu\psi$$

$$\Gamma_\sigma = g_\sigma, \quad \Gamma^\mu_\omega = g_\omega\gamma^\mu, \quad \vec{\Gamma}^\mu_\rho = g_\rho\vec{\tau}\gamma^\mu, \quad \Gamma^\mu_e = e\frac{1-\tau_3}{2}\gamma^\mu$$

Fragmentation of s.p. strength

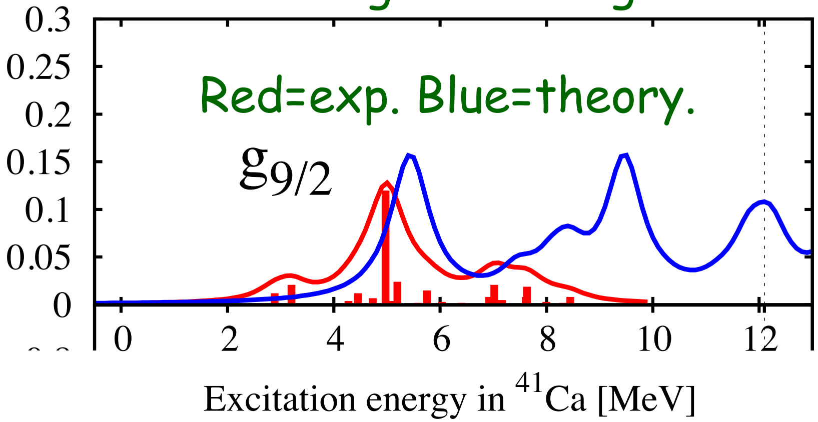
Dyson equation in coordinate space.

$$\Sigma =$$

$$G = G^0 + G^0 \Sigma G$$

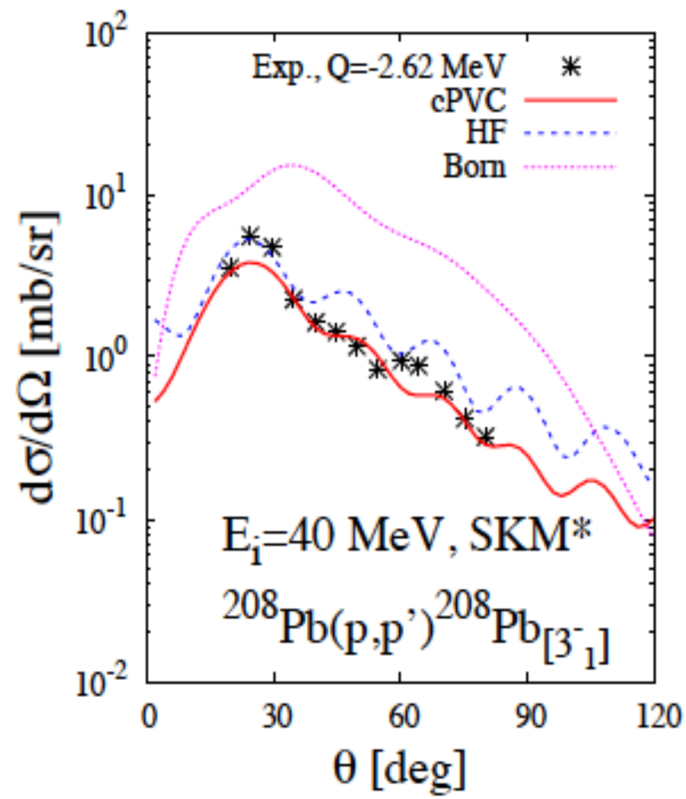
$$S = -\frac{1}{\pi}\int d^3r\ G(\vec{r},\vec{r};\omega)$$

Y-axis: g9/2 strength in ^{41}Ca



K. Mizuyama, GC, and E. Vigezzi, PRC 86, 034318 (2012).

APPLICATION TO SCATTERING
Courtesy: K. Mizuyama



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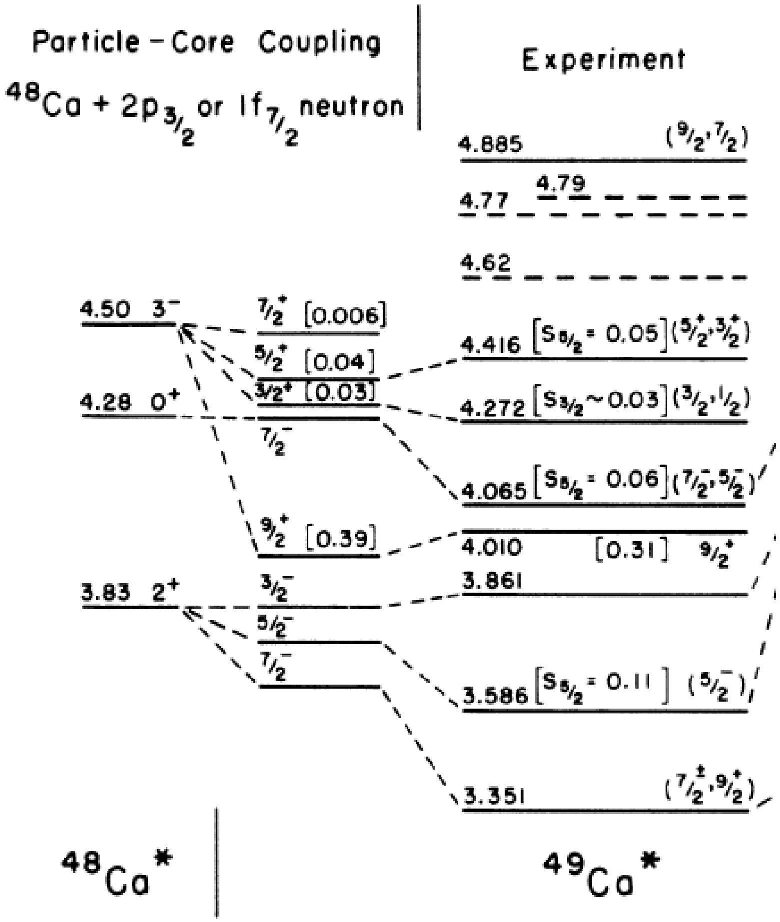
States from (d,p) on ^{48}Ca.

T.R. Canada *et al.*, Phys. Rev. C4, 471 (1971)

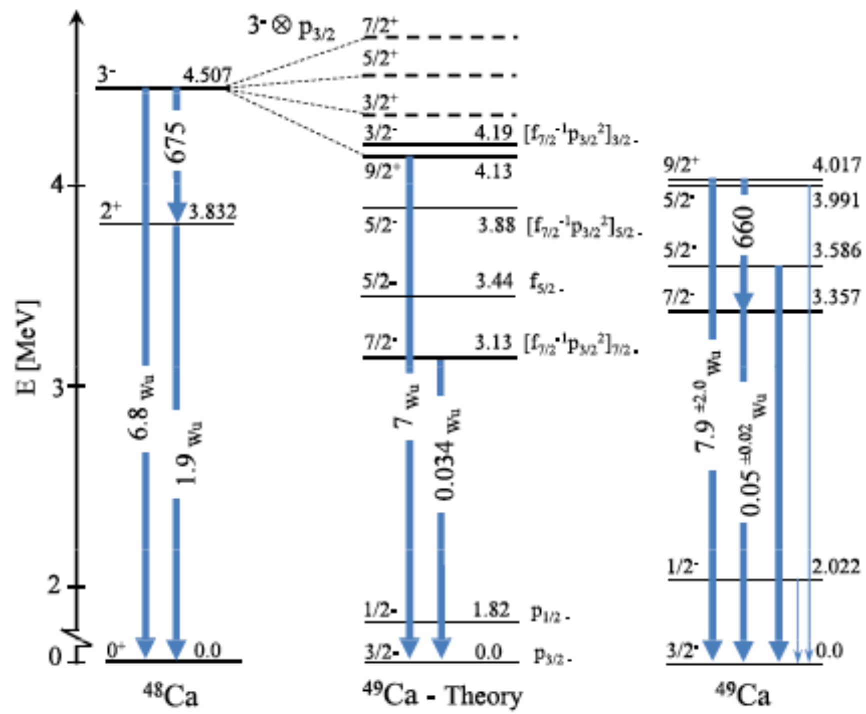
Neutrons plus a ^{48}Ca vibration ?



^{64}Ni+^{48}Ca (5.7 MeV/u) performed at LNL recently.

The angular momenta have been found to be aligned <u>perpendicular</u> to the reaction plane. <u>Spin</u> and lifetimes extracted.

D. Montanari *et al.*, Phys. Lett. B 697, 288 (2011)



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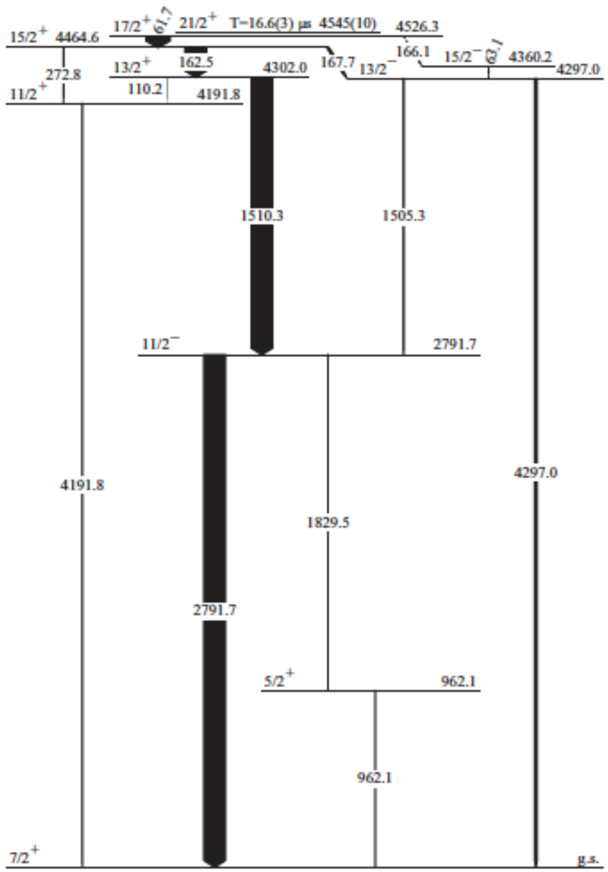
Spectroscopy of ^{133}Sb (^{132}Sn + p)

- Despite the importance of the region around ^{132}Sn, the information about **low-lying states of neighbouring nuclei** need still be completed.

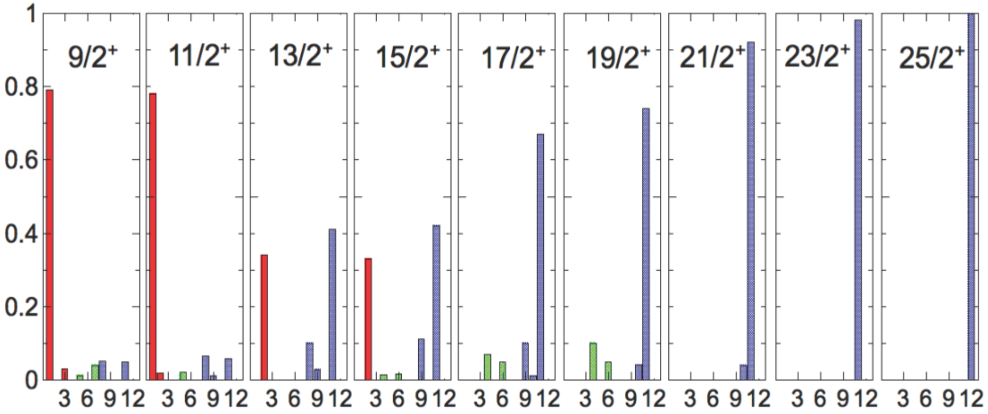
W. Urban *et al.*, PRC 79, 037304 (2009)



- Recently new measurements (G. Bocchi *et al.*) have shed light on some **HIGHER SPIN** states (up tp 25/2$^+$).
  B(M1, 15/2$^+$→13/2$^+$) = 0.24 W.u.
  B(M1, 13/2$^+$→11/2$^+$) = 0.004 W.u.
  (ratio = 60; theory provides a ratio of 20).

- The odd proton is $g_{7/2}$. Low spin states may come from coupling to 2$^+$, 3$^-$, 4$^+$ phonons. High spin states can only come from $g_{7/2}$ coupled to $h_{11/2}^{-1}$ $f_{7/2}$ neutron p-h states.

Electromagnetic transitions and the mutable nature of the wavefunction



red: $\pi g_{9/2} \otimes 2^+, 4^+$

blue: $\pi g_{9/2}\ \nu h^{-1}_{11/2}\ \nu f_{7/2}$

This nature is reflected in the M1 transition probabilities.

The wave functions of $15/2^+$ and $13/2^+$ are dominated by $g_{9/2}$, $h_{11/2}^{-1}$ $f_{7/2}$, so the B(M1) transition is made up with s.p. amplitudes. $B(M1)_{th}$ = 0.021 W.u.

In the case of the transition $13/2^+ \rightarrow 11/2^+$, the final state has phonon component so there is a mismatch in the components and B(M1) is quenched, $B(M1)_{th}$ = 0.001 W.u. Ratio = 20.

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Microscopic content of the states

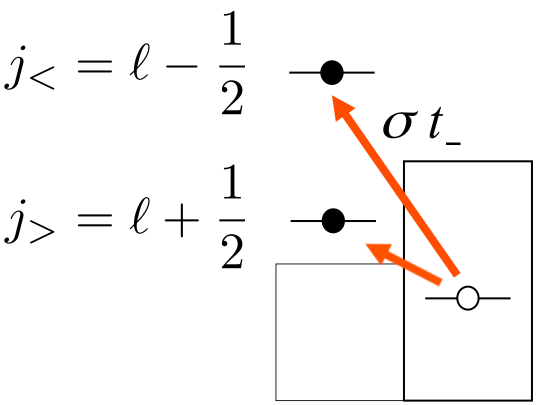
	EXP.	Calculation with 2^+, 3^-, 4^+	All excitations below 5.5 MeV included
$9/2^+$	4.027	3.84 $[\pi g_{7/2} \otimes 2^+ \ (0.82)]$	4.08 $[\pi g_{7/2} \otimes 2^+ \ (0.80)]$
$11/2^+$	4.192	3.82 $[\pi g_{7/2} \otimes 2^+ \ (0.74)]$	4.11 $[\pi g_{7/2} \otimes 2^+ \ (0.78)]$
$13/2^+$	4.302	4.66 $[\pi g_{7/2} \otimes 4^+ \ (1.00)]$	4.44 $[\pi g_{7/2} \nu h^{-1}_{11/2} \nu f_{7/2} \ (0.40)]$
$15/2^+$	4.464	4.37 $[\pi g_{7/2} \otimes 4^+ \ (0.98)]$	4.45 $[\pi g_{7/2} \nu h^{-1}_{11/2} \nu f_{7/2} \ (0.40)]$
$17/2^+$	4.526		4.58 $[\pi g_{7/2} \nu h^{-1}_{11/2} \nu f_{7/2} \ (0.66)]$
$19/2^+$	4.539		4.64 $[\pi g_{7/2} \nu h^{-1}_{11/2} \nu f_{7/2} \ (0.73)]$
$21/2^+$	4.545		4.76 $[\pi g_{7/2} \nu h^{-1}_{11/2} \nu f_{7/2} \ (0.92)]$
$23/2^+$	4.753		4.83 $[\pi g_{7/2} \nu h^{-1}_{11/2} \nu f_{7/2} \ (0.98)]$
$25/2^+$	4.844		5.11 $[\pi g_{7/2} \nu h^{-1}_{11/2} \nu f_{7/2} \ (1.00)]$

Different kinds of excitations in ^{132}Sn

	Energy		Transition strength		Main components
	Exp.	Theory (RPA)	Exp.	Theory (RPA)	Theory (RPA)
2^+	4.041	3.87	7	4.75	$\nu h_{11/2}^{-1} f_{7/2}$ (0.56), $\pi g_{9/2}^{-1} d_{5/2}$ (0.19), $\pi g_{9/2}^{-1} g_{7/2}$ (0.14)
3^-	4.352	5.02	> 7.1	9.91	$\nu s_{1/2}^{-1} f_{7/2}$ (0.40), $\nu d_{3/2}^{-1} f_{7/2}$ (0.12), $\pi p_{1/2}^{-1} g_{7/2}$ (0.12)
4^+	4.416	4.46	4.42	5.10	$\nu h_{11/2}^{-1} f_{7/2}$ (0.63), $\pi g_{9/2}^{-1} g_{7/2}$ (0.21)
6^+	4.716	4.73		1.65	$\nu h_{11/2}^{-1} f_{7/2}$ (0.86), $\pi g_{9/2}^{-1} g_{7/2}$ (0.11)
4^-	4.831	5.68		0.16	$\nu s_{1/2}^{-1} f_{7/2}$ (0.91)
8^+	4.848	4.80		0.28	$\nu h_{11/2}^{-1} f_{7/2}$ (0.98)
5^+	4.885	4.77		0.61	$\nu h_{11/2}^{-1} f_{7/2}$ (0.99)
7^+	4.942	4.80		0.81	$\nu h_{11/2}^{-1} f_{7/2}$ (0.98)
5^-	4.919	5.98		0.96	$\nu d_{3/2}^{-1} f_{7/2}$ (0.96)
(9^+)	5.280	4.99		0.16	$\nu h_{11/2}^{-1} f_{7/2}$ (0.99)
2^-		5.44		1.77	$\nu d_{3/2}^{-1} f_{7/2}$ (0.79)

One should contrast real phonons with pure p-h states.

The Gamow-Teller resonance



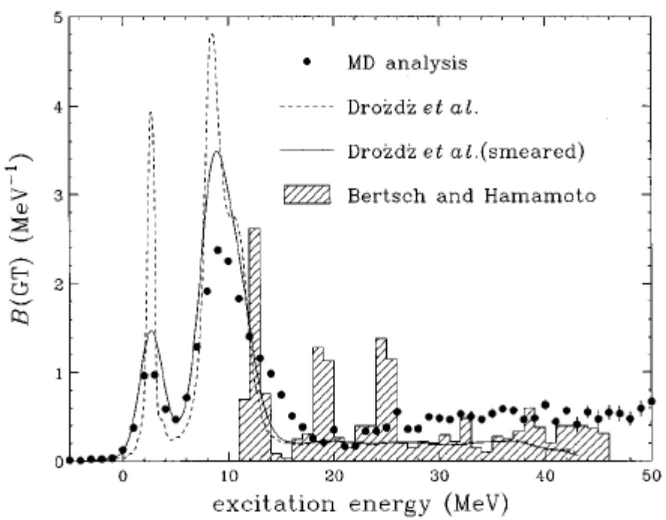
$j_>$

$\varepsilon_{\rm ph}^{(II)}, \varepsilon_{\rm ph}^{(I)}$ Highest and lowest particle-hole transitions in the picture

$$\varepsilon_{\rm ph}^{(II)} - \varepsilon_{\rm ph}^{(I)} = \varepsilon_{j_<} - \varepsilon_{j_>}$$

Unperturbed GT energy related to the spin-orbit splitting

$$\hbar\omega \approx \varepsilon_{\rm ph} + \langle V_{\rm res} \rangle$$



RPA GT energy related also to V in στ channel

Osterfeld, 1992:
Using empirical Woods-Saxon s.p. energies, the GT energy is claimed to determine g_0'

$$V_{\rm res} = g_0' \delta(\vec{r}_1 - \vec{r}_2)\sigma_1\sigma_2\tau_1\tau_2$$

We want to go beyond the empirical description.