Relativistic approach to atomic nuclei including quasiparticle-vibration coupling

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Outline

- **Introduction:**
  Relativistic Nuclear Field Theory: connecting the scales of nuclear physics from Quantum Hadrodynamics to emergent collective phenomena

- **Formalism**

- **Applications to nuclear excitation modes:**

  - A few results in the particle-hole neutral channel

  - Response theory for spin-isospin excitations:
    Gamow-Teller transitions, beta-decay half-lives and the “quenching” problem

- **Conclusion & perspectives**

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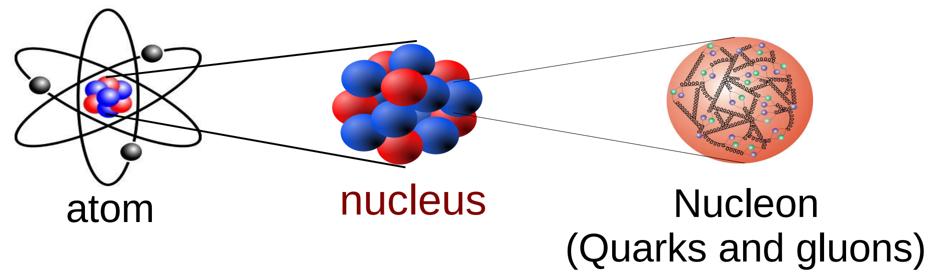
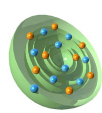
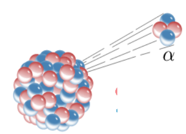
Atomic nucleus = challenging many-body system!

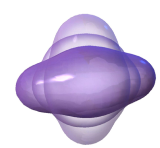
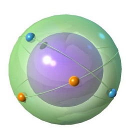


At the frontiers between microscopic & macroscopic worlds

- Exhibits generic properties of many-body systems:

  - shell structure
  - particle-decay and radiation
  - emergent collective phenomena
  - superfluidity

- Also has specific features and difficulties:
  - Two types of particles (neutrons & protons) which are not structureless
  - NN interaction unknown, existence of many-body forces...

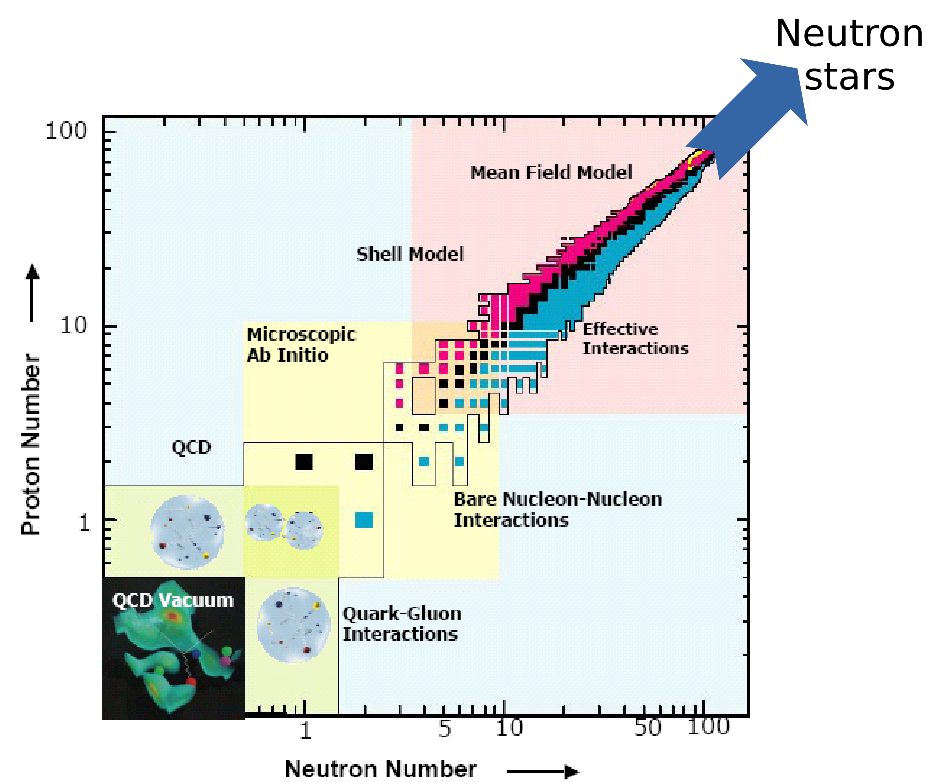
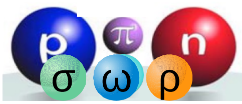


Figure: TRIUMF

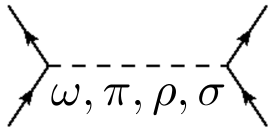
Relativistic Nuclear Field Theory: foundations

➡ Connects the scales from heavy mesons to the complex dynamics of heavy nuclei



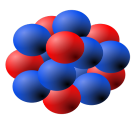
Mesons

$m_{\pi,\sigma,\omega,\rho}$ ~140-800 MeV



Walecka/Serot

Quantum Hadrodynamics (QHD)



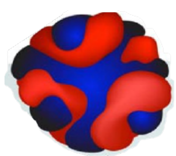
nucleons

S_n ~ 10 MeV

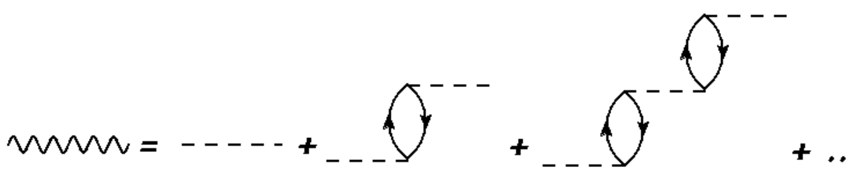
Ring

Bogoliubov/BCS /Gorkov

Relativistic mean-field + superfluidity



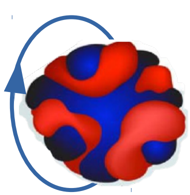
collective vibrations (phonons) ~ few MeV



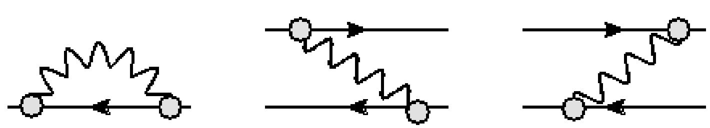
Ring

RRPA

(1p-1h)



nucleons & phonons



Argentina-Copenhagen -Milano...

Bohr-Mottelson

Nuclear Field theory – Particle-Vibration coupling

(2p-2h)

...

More correlations

self-consistent extensions of the Relativistic Mean-Field via Green function techniques

successive corrections in the single-particle motion and effective interaction

...

More correlations

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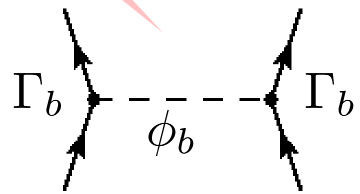
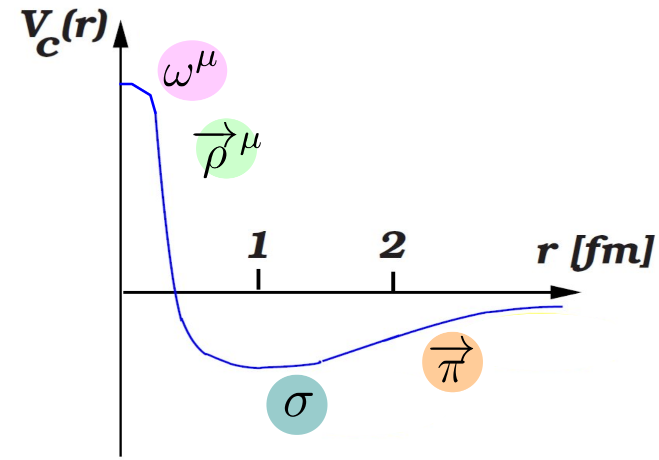
From QHD to relativistic mean field

★ Effective QHD Lagrangian:

$$\mathcal{L}_{eff} = \mathcal{L}_{Nucleons} + \mathcal{L}_{bosons} + \mathcal{L}_{int}$$





$$\phi_b = (\,\vec{\pi},\ \sigma,\ \omega^\mu,\ \vec{\rho}^{\,\mu},\ A^\mu)$$

$\vec{\pi}$: $(J^\pi = 0^-, T = 1)$

σ: $(0^+, 0)$

ω^μ: $(1^-, 0)$

$\vec{\rho}^{\,\mu}$: $(1^-, 1)$

$\Longrightarrow$ When both nucleons and mesons are quantized the equations of motion:

$$(i\gamma_\mu \partial^\mu - m - \sum_b \Gamma_b \phi_b)\psi = 0 \qquad \text{(Nucleons)}$$

$$(\Box + m_b^2)\phi_b = \mp \bar{\psi}\Gamma_b \psi \qquad \text{(Mesons)}$$

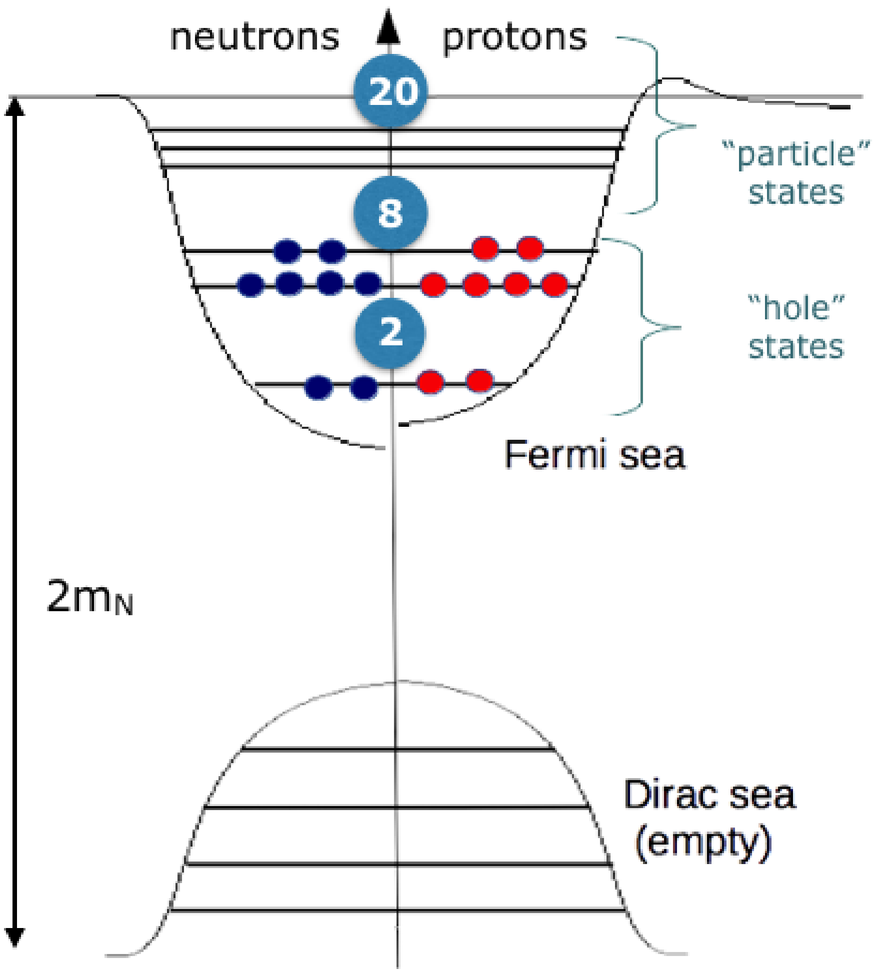
are very complicated to solve...

From QHD to relativistic mean field

★ Possible approximation: **Mean-field approximation** I.e. treat the bosons classically

$$\phi_b \to \langle \phi_b \rangle$$

⇉ the pion does not contribute in the ground state (would break parity)

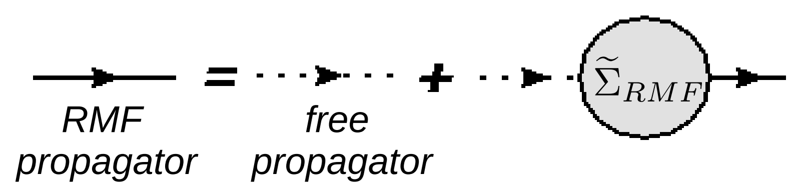


$\Longrightarrow$ EoM describe independent nucleons in classical meson fields:

$$(i\gamma_\mu \partial^\mu - m - \widetilde{\Sigma}_{RMF})\psi = 0 \quad \text{(Nucleons)}$$

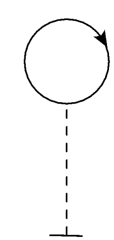
$$(-\Delta + m_b^2)\langle \phi_b \rangle = \mp \langle \bar{\psi} \Gamma_b \psi \rangle \quad \text{(Mesons)}$$

→ One-nucleon motion (propagator):



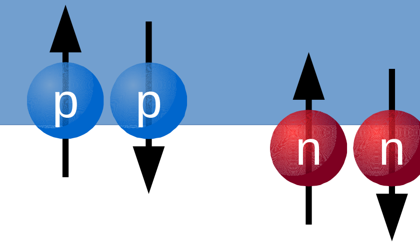
→ Static nucleonic self-energy:

$$\widetilde{\Sigma}_{RMF} = \sum_b \Gamma_b \langle \phi_b \rangle =$$



(Hartree)

From QHD to relativistic mean field



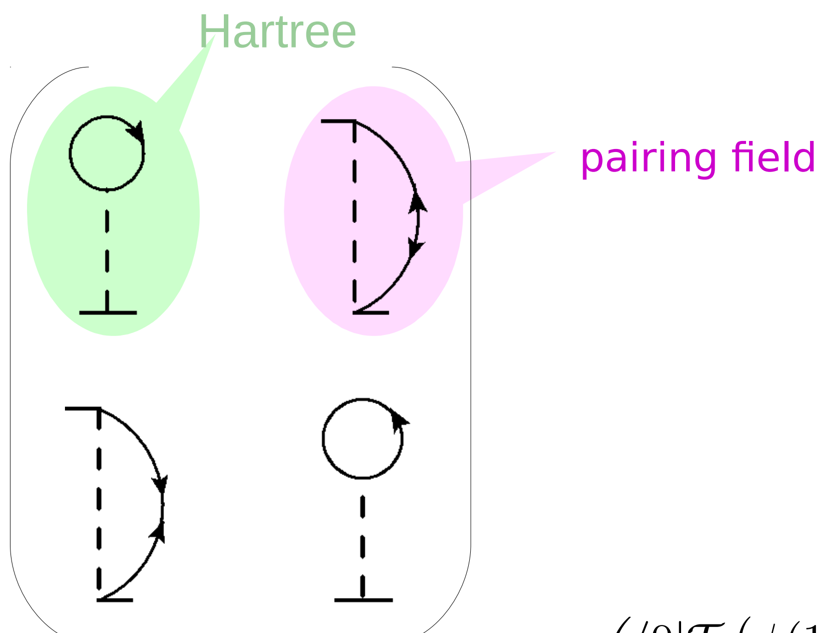
+ Superfluid pairing correlations in open-shell nuclei:

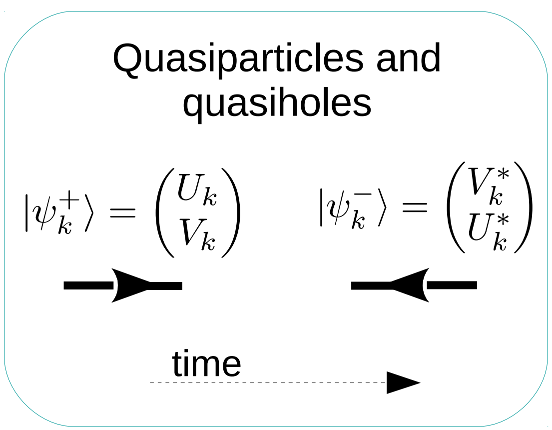
→ Introduce quasiparticles = superpositions of particles and holes (BCS/Bogoliubov)

$$\Rightarrow \begin{cases} (-\Delta + m_b^2)\langle\phi_b\rangle = \mp\langle V^T \beta \Gamma_b V^* \rangle & \text{(for bosons)} \\ \boldsymbol{\mathcal{H}_{RHB}|\psi_k^\eta\rangle = \eta E_k |\psi_k^\eta\rangle} \ , \ \eta = \pm 1 & \text{(for quasi-nucleons)} \end{cases}$$

· RHB self-energy:

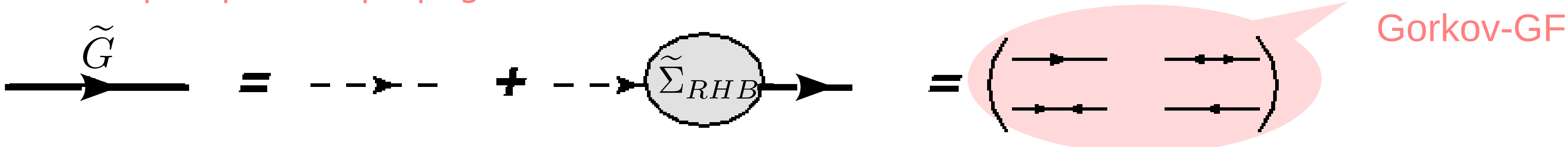
$$\widetilde{\Sigma}_{RHB} =$$



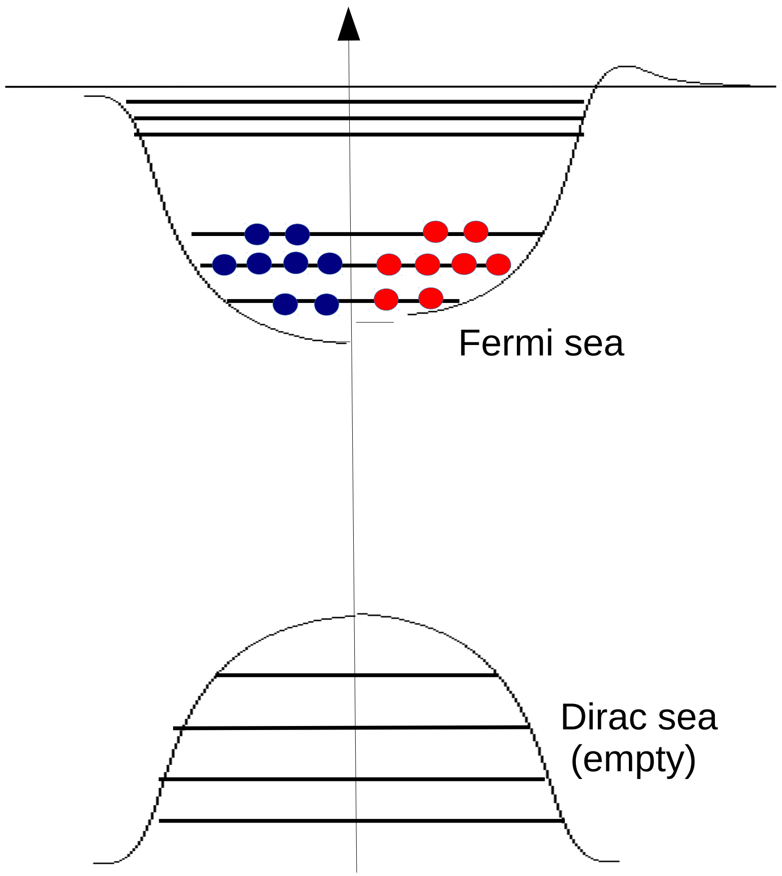


$$\begin{pmatrix} \langle 0|\mathcal{T}\left(\psi(1)\bar{\psi}(2)\right)|0\rangle & \langle 0|\mathcal{T}\left(\psi(1)\psi(2)\right)|0\rangle \\ \langle 0|\mathcal{T}\left(\bar{\psi}(1)\bar{\psi}(2)\right)|0\rangle & \langle 0|\mathcal{T}\left(\bar{\psi}(1)\psi(2)\right)|0\rangle \end{pmatrix}$$

→ RHB quasiparticle propagator:



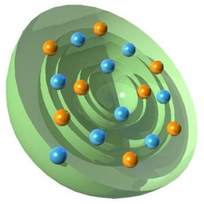
Going beyond mean-field: quasiparticles coupled to vibrations



Mean-field ground-state

= independent (quasi)particles

= 0-th order approximation



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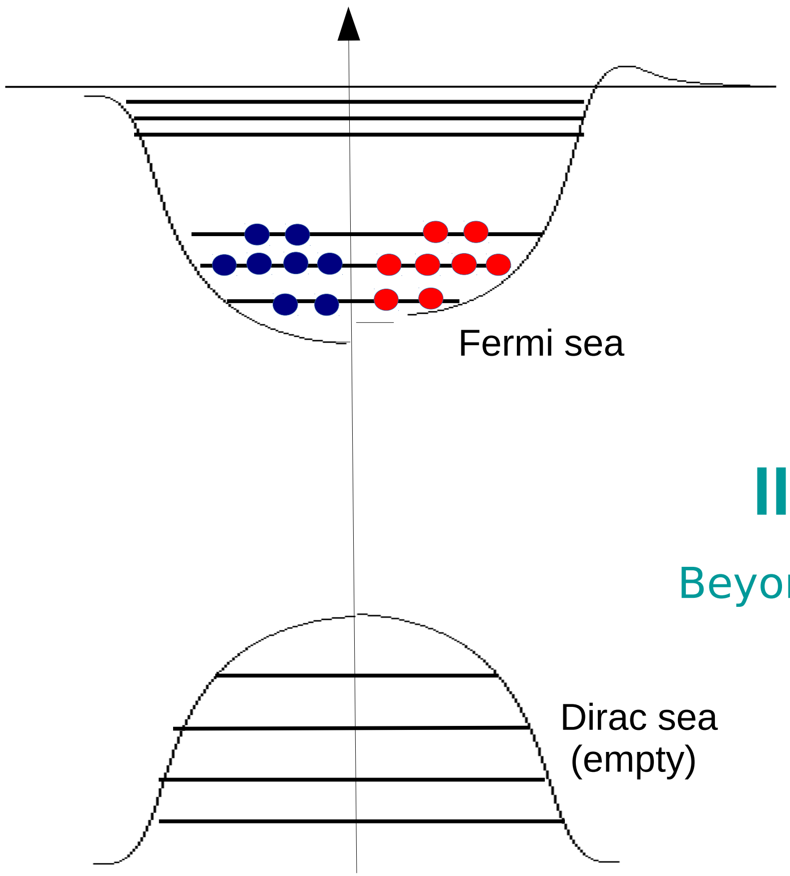
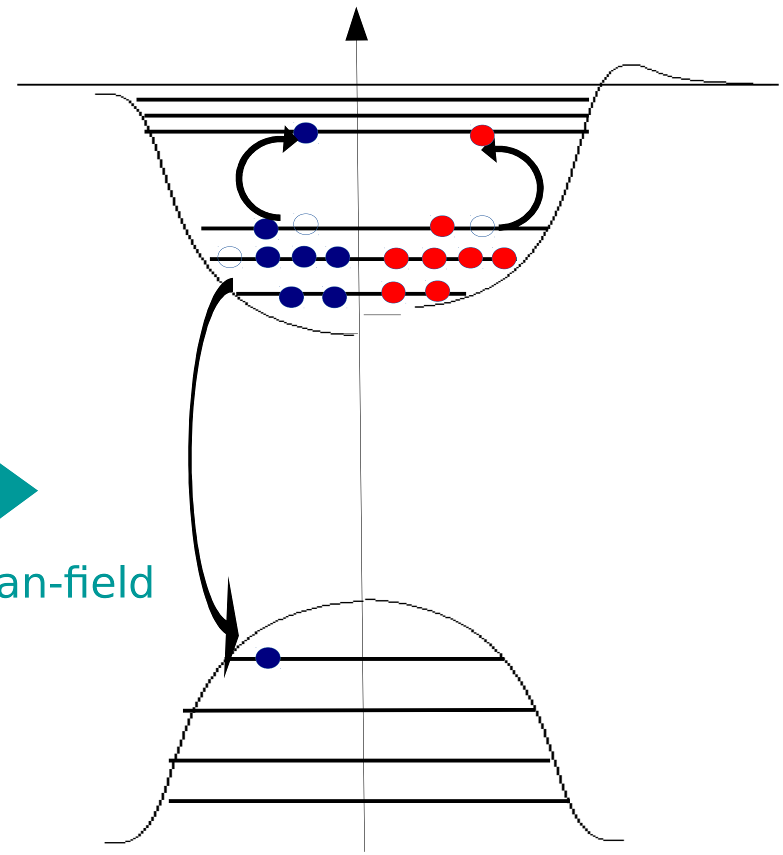


Beyond mean-field

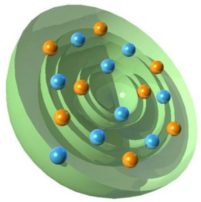


correlations

Mean-field ground-state

= independent (quasi)particles

= 0-th order approximation



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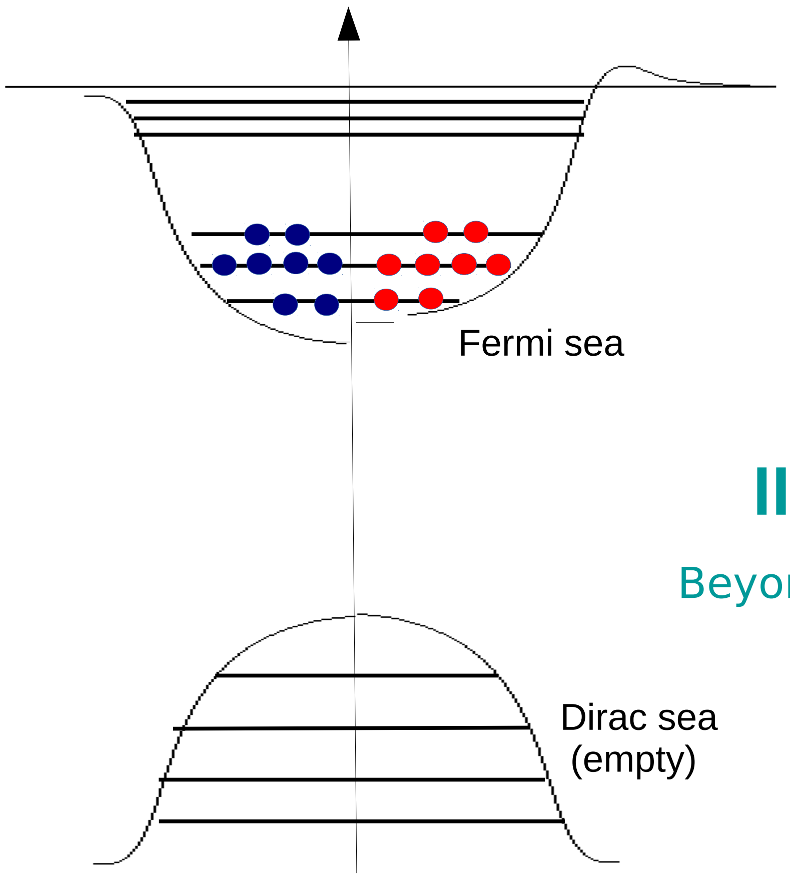
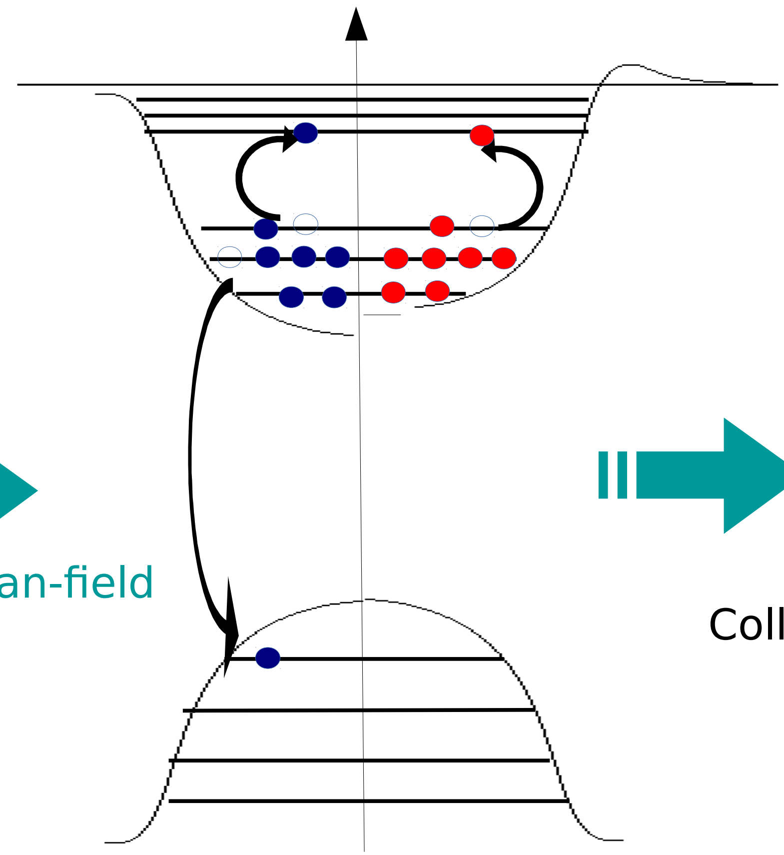
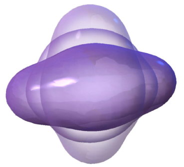


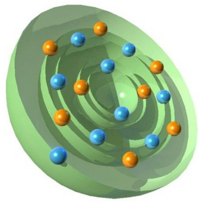
Beyond mean-field





Collective vibration
(phonon)

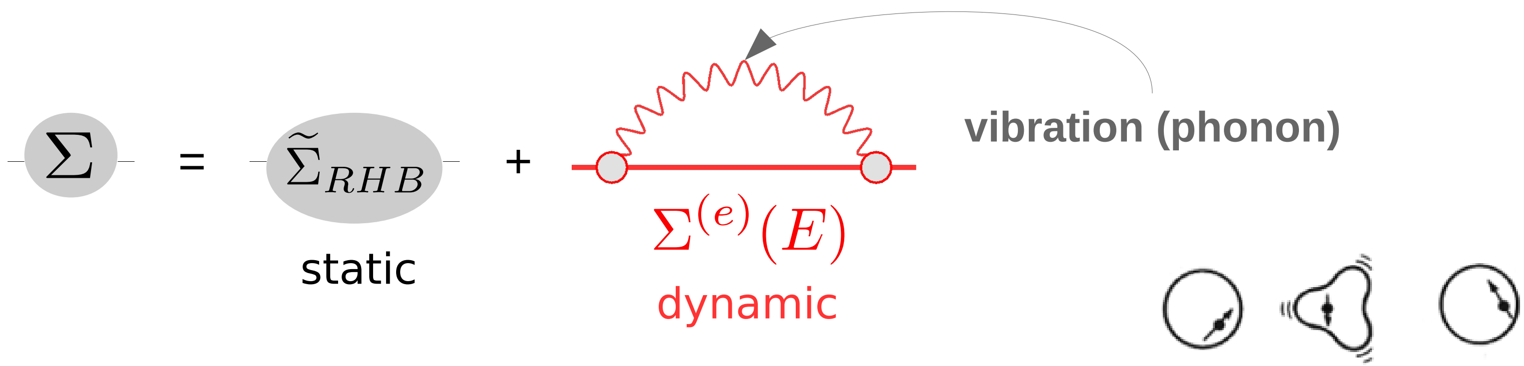
Mean-field ground-state
= independent (quasi)particles
= 0-th order approximation

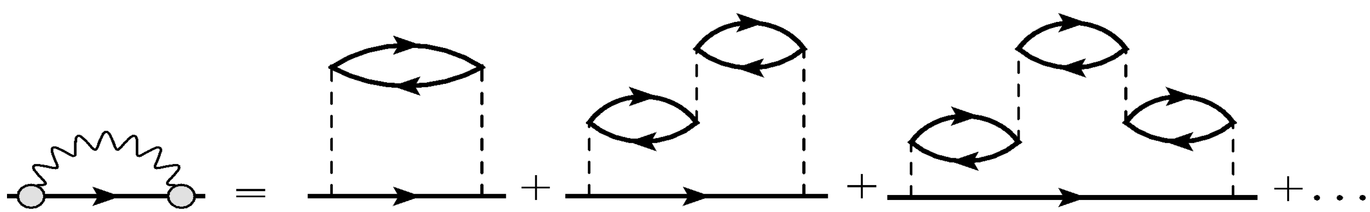


correlations

Going beyond mean-field: Quasiparticles coupled to vibrations

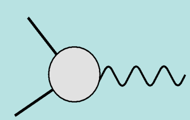
- Quasiparticle-Vibration Coupling (QVC) in the nucleonic self-energy:





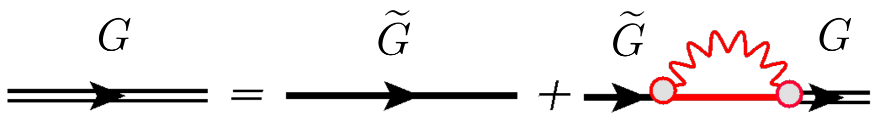
= ∞ serie of p-h excitations

→ Allows a non perturbative treatment of the NN interaction

→ New order parameter = QVC vertex 

Going beyond mean-field: Quasiparticles coupled to vibrations

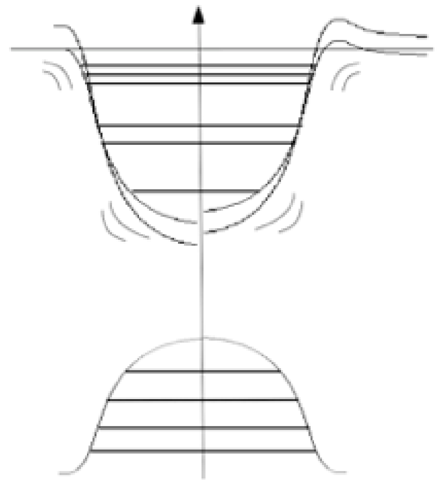
→ quasi-particle propagator:



$$G(E) = \left(\varepsilon - \mathcal{H}_{RHB} - \Sigma^{(e)}(E)\right)^{-1}$$

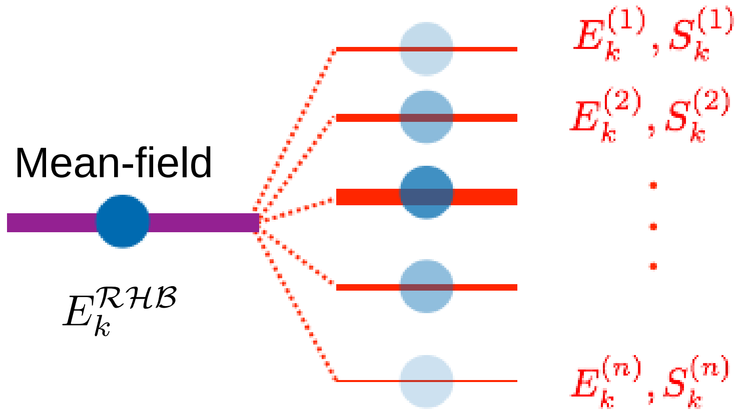
Introduces new poles

$$E_k^{(\nu)} = E_k^{\mathcal{RHB}} + \Sigma_k^{(e)}(E_k^{(\nu)})$$



$$\Sigma_{k_1 k_2}^{(e)\eta_1\eta_2}(\varepsilon) = \sum_{\eta=\pm 1} \sum_{k,\mu} \frac{\gamma_{\mu;k_1 k}^{\eta;\eta_1\eta}\, \gamma_{\mu;k_2 k}^{\eta;\eta_2\eta *}}{\varepsilon - \eta(E_k + \Omega_\mu - i\delta)}$$

→ fragmentation of single (quasi)particle states:



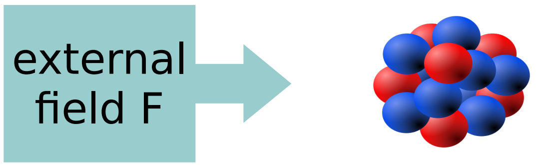
No more well defined (quasi)nucleons
on single (quasi)particle shells
→ fractional occupation numbers

$$E_k^{\mathcal{RHB}} = \sum_\nu S_k^{(\nu)} E_k^{(\nu)}$$

$$\sum_\nu S_k^{(\nu)} = 1$$

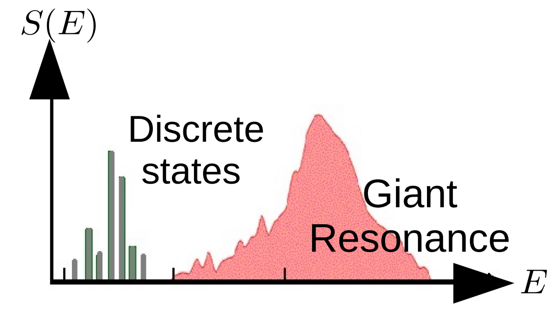
Excited states: nuclear response theory

- Response of the nucleus to an external field:

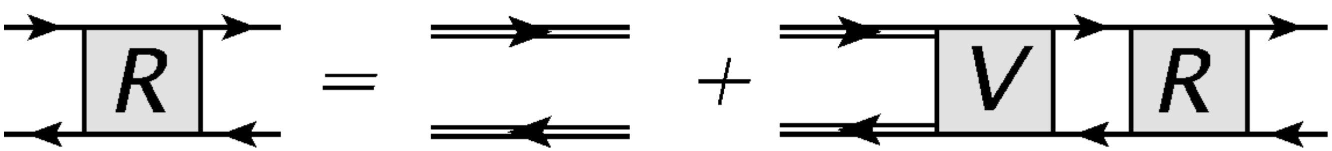


→ Transition strength:

$$S(E) = \sum_f |\langle \Psi_f | \hat{F} | \Psi_i \rangle|^2 \delta(E - E_f + E_i)$$
$$= -\frac{1}{\pi} \lim_{\Delta \to 0^+} \mathrm{Im}\, \langle \Psi_i | \hat{F}^\dagger R(E + i\Delta) \hat{F} | \Psi_i \rangle$$



Response function (2-body propagator)
solution of the Bethe-Salpeter equation (BSE)**:**

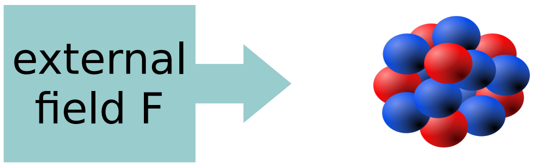


$$V = i \frac{\delta \Sigma}{\delta G}$$

effective interaction
induced by
the nuclear medium

Excited states: nuclear response theory

★ Response of the nucleus to an external field:



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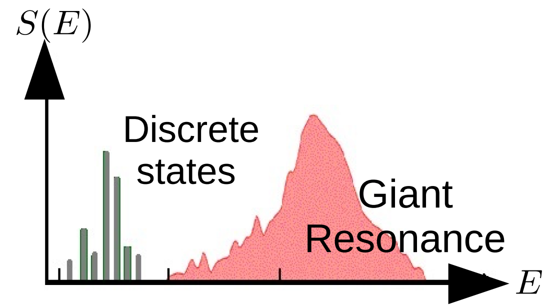

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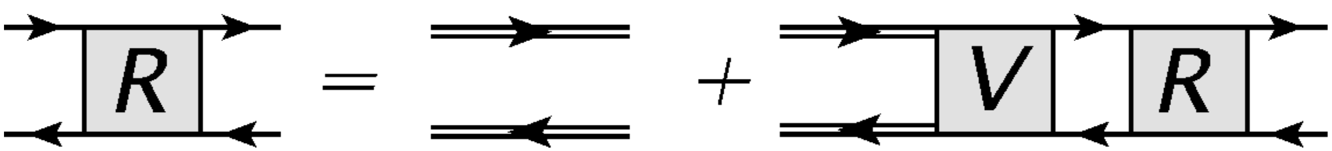
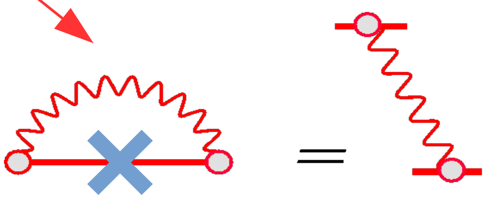


$$V = i\frac{\delta \Sigma}{\delta G}$$

effective interaction
induced by
the nuclear medium

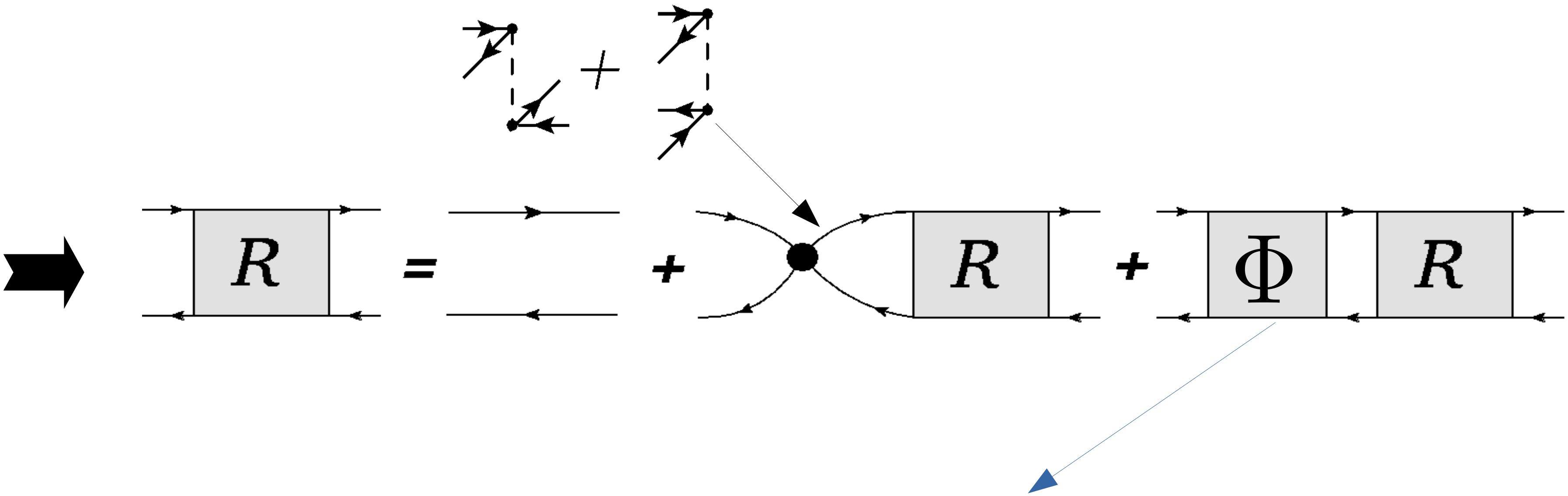
$$V(E) = i\frac{\delta \widetilde{\Sigma}_{RHB}}{\delta G} + i\frac{\delta \Sigma^e(E)}{\delta G}$$

Static meson
exchange
+ pairing

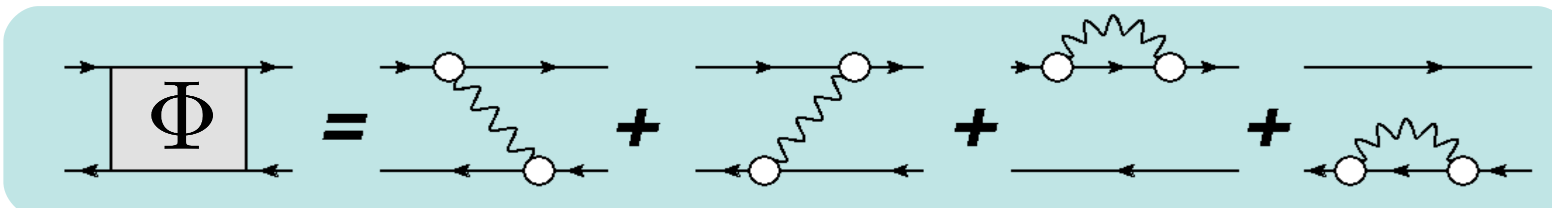


Energy-dependent
phonon exchange

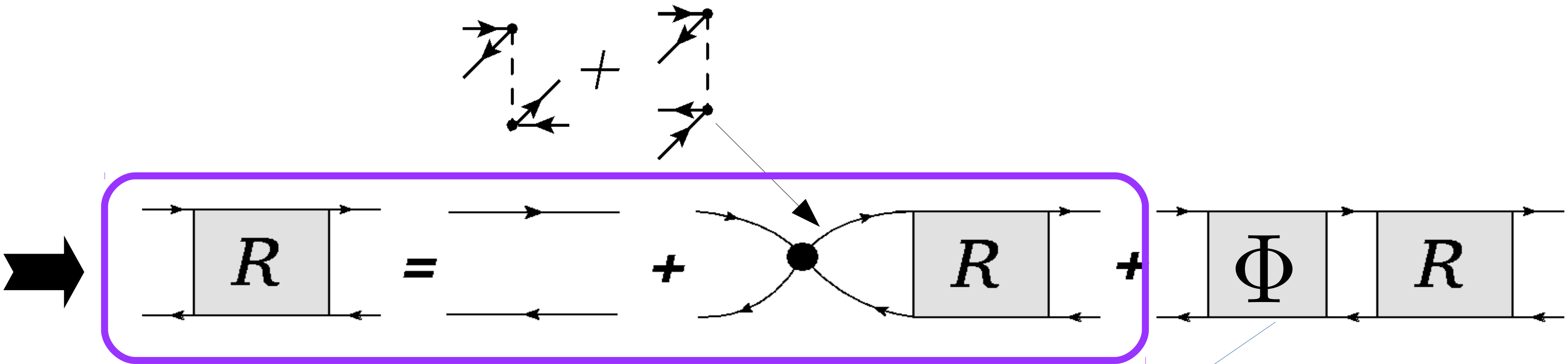
Excited states: nuclear response theory



Quasiparticle-Vibration Coupling amplitude:

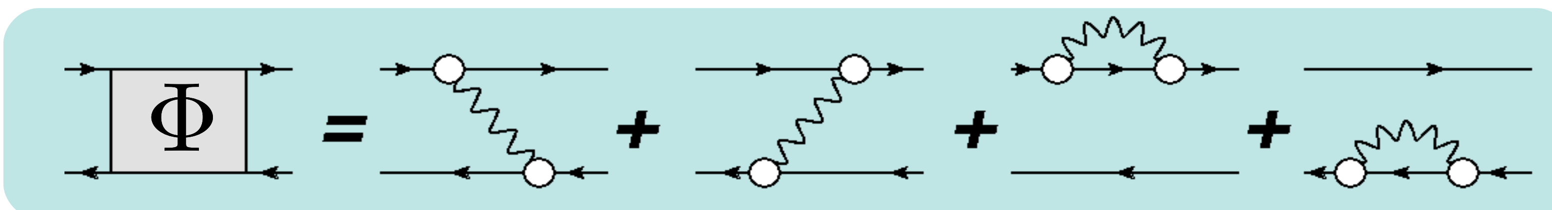


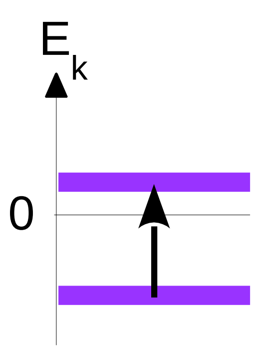
Excited states: nuclear response theory



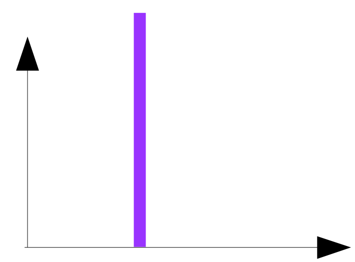
Relativistic Quasiparticle Random
Phase Approximation (RQRPA)

Quasiparticle-Vibration Coupling amplitude:





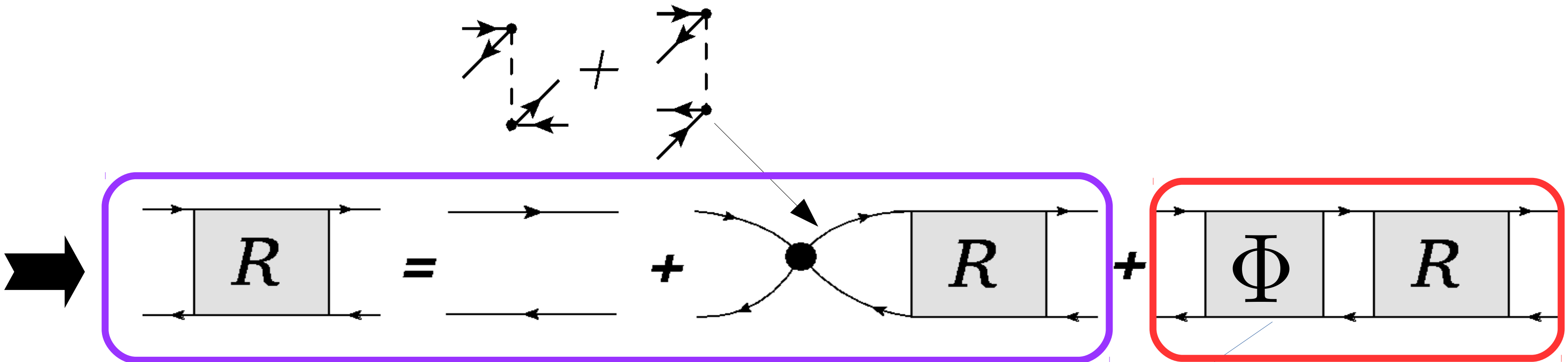
Single-particle states



Many-body states

1(q)p-1(q)h
configurations

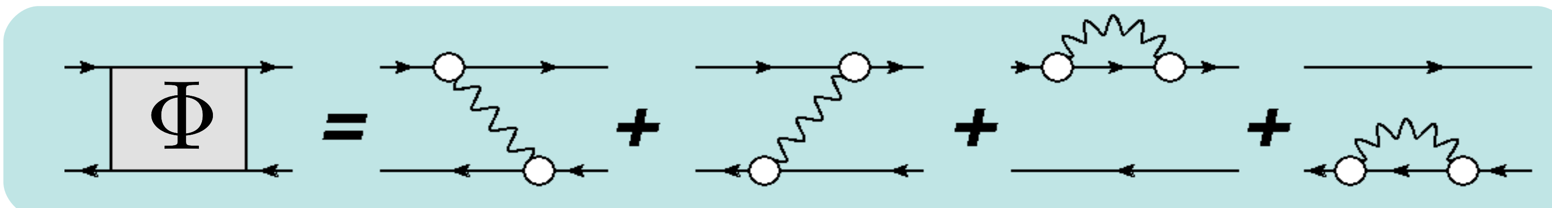
Excited states: nuclear response theory

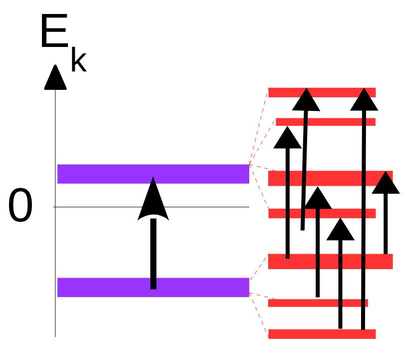


Relativistic Quasiparticle Random Phase Approximation (RQRPA)

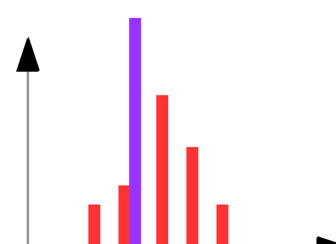
+ QVC

Quasiparticle-Vibration Coupling amplitude:





Single-particle states



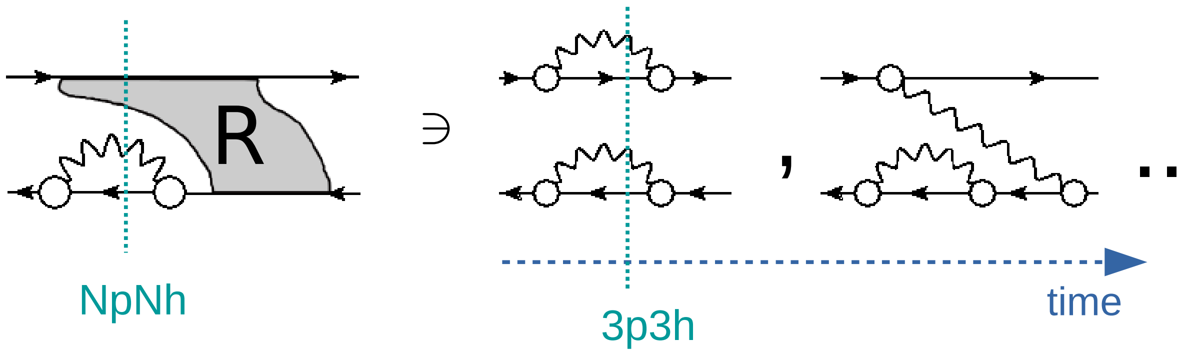
Many-body states

✔ spreading width

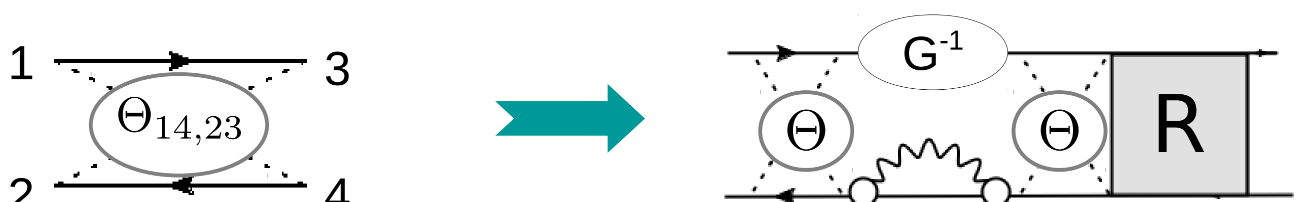
1(q)p-1(q)h ⊗ 1 phonon configurations

Excited states: nuclear response theory

Problem: Integration over all intermediate times ⇒ complicated BSE (integrations do not separate), appearance of NpNh configurations:

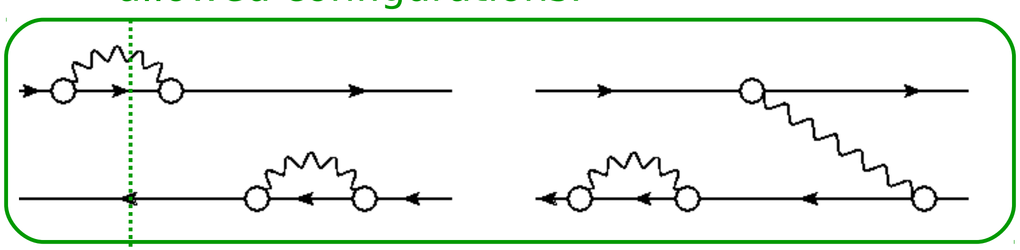


Solution: Time-Blocking Approximation [V.I. Tselyaev, Yad. Fiz. 50,1252 (1989)]



$$\Theta_{14,23} = \theta(t_4 - t_1)\theta(t_3 - t_2)$$

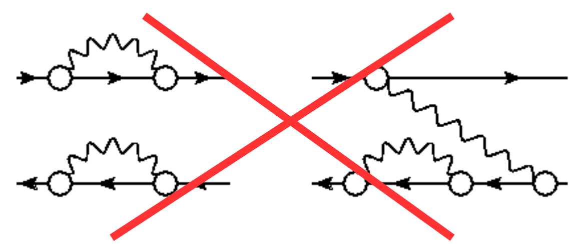
→ allowed configurations:



1(q)p-1(q)h ⊗ 1 phonon i.e. 2(q)p2(q)h

→ **spreading**

→ blocked configurations: 3(q)p-3(q)h, 4(q)p4(q)h...



... but can be included in a next step (under development)

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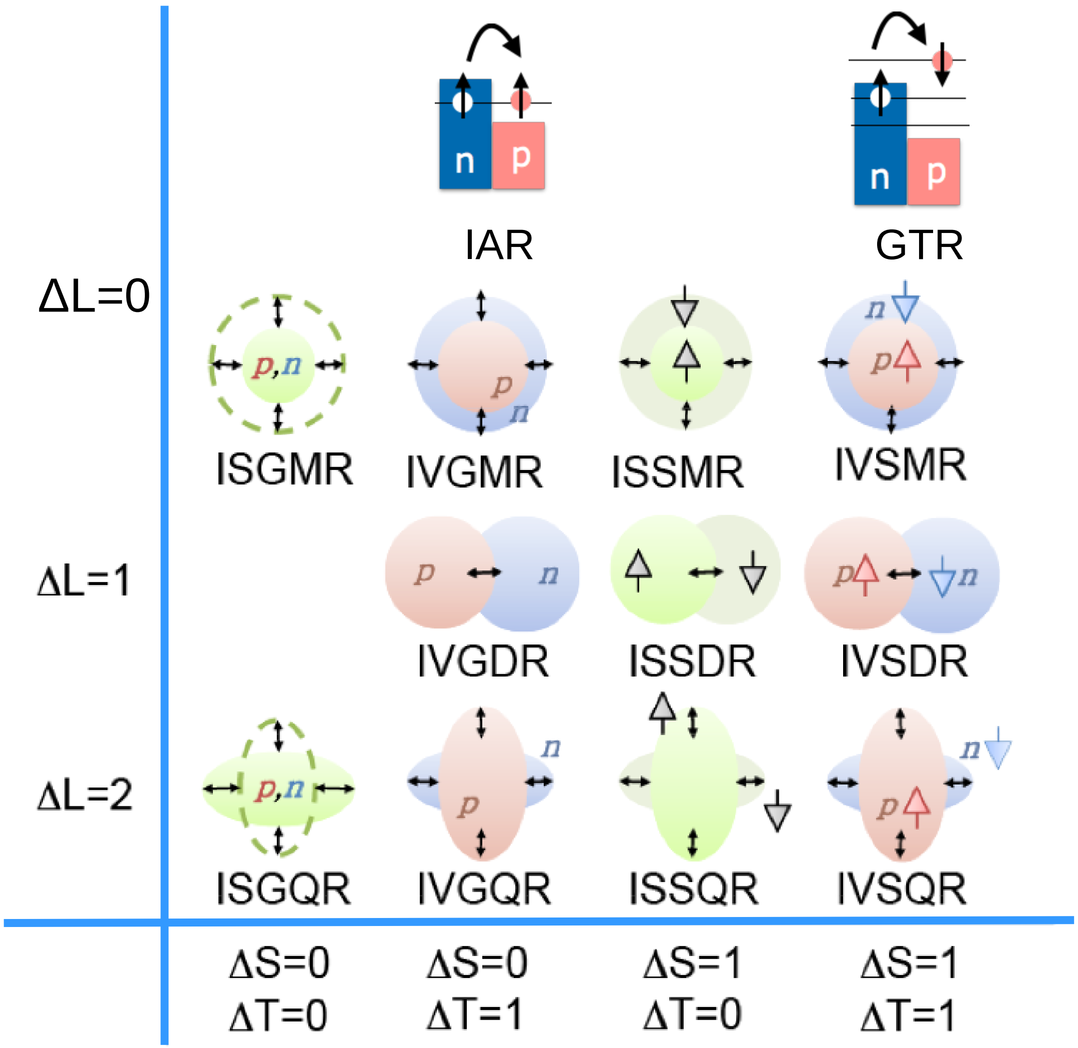
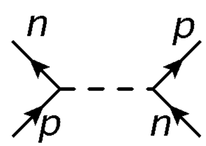
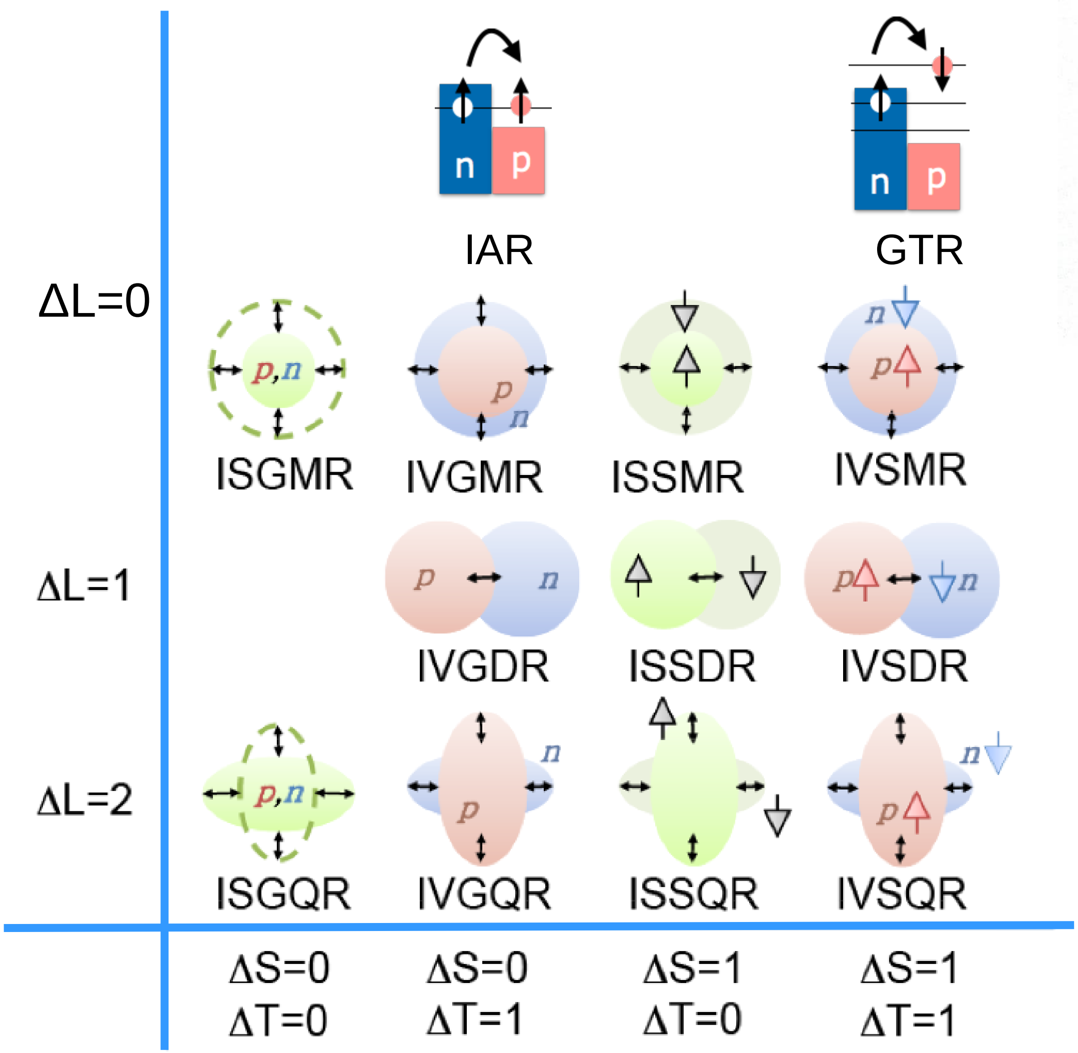
Nuclear vibrational motion and their applications



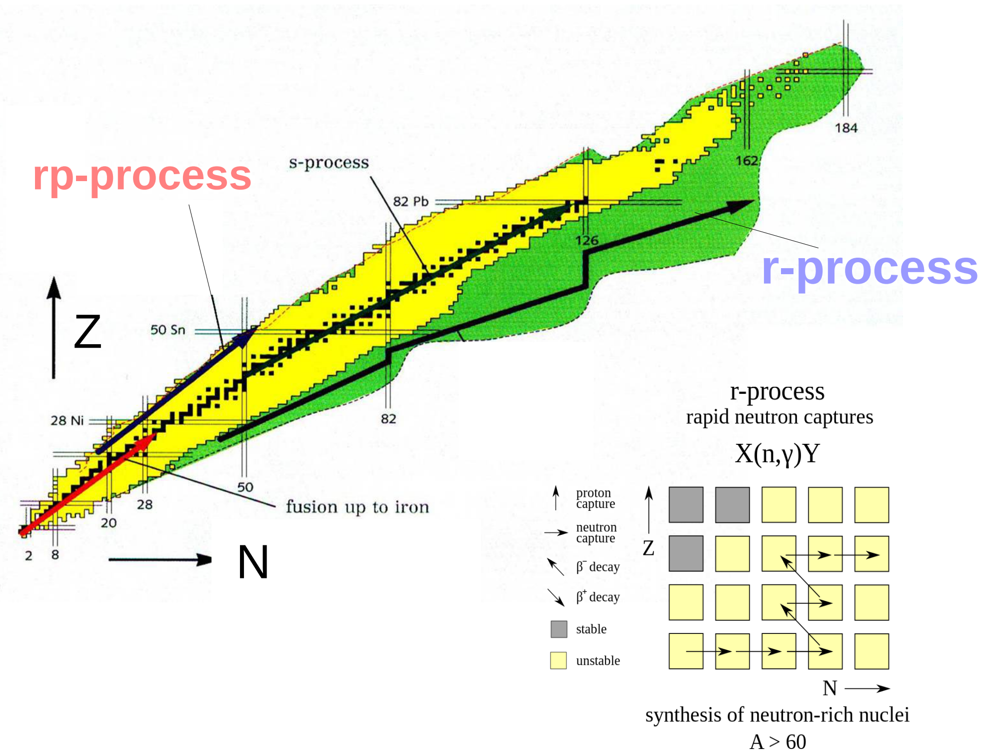
Nuclear vibrational motion and their applications

★ Channels of the nuclear interaction



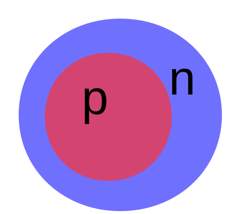


★ Astrophysics: (IAR,GTR,IVGDR...)



(IVGDR,GTR)

★ Neutron skin thickness
(IVGDR,IVSGDR...)



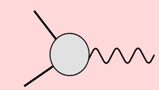
Numerical scheme

Inputs:
Meson parameters (<10)
+ pairing force (1-2)

Relativistic mean-field with pairing

(NL3 &
monopole pairing force)

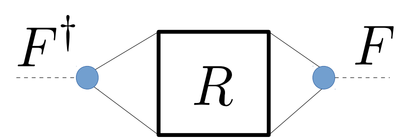
RQRPA
⇒ phonon spectrum and their coupling vertices



Phonons selected according to their T, J^π and energy

Typically: neutral (T=0) phonons with J^π =2+ → 6+, E_{max}=20-30 MeV

Solve BSE with RQTBA
for the response function
with given quantum numbers



external field

Strength distribution: $S(E) = -\frac{1}{\pi} \lim_{\Delta \to 0^+} \text{Im} \, \langle \Psi_i | \hat{F}^\dagger R(E + i\Delta) \hat{F} | \Psi_i \rangle$

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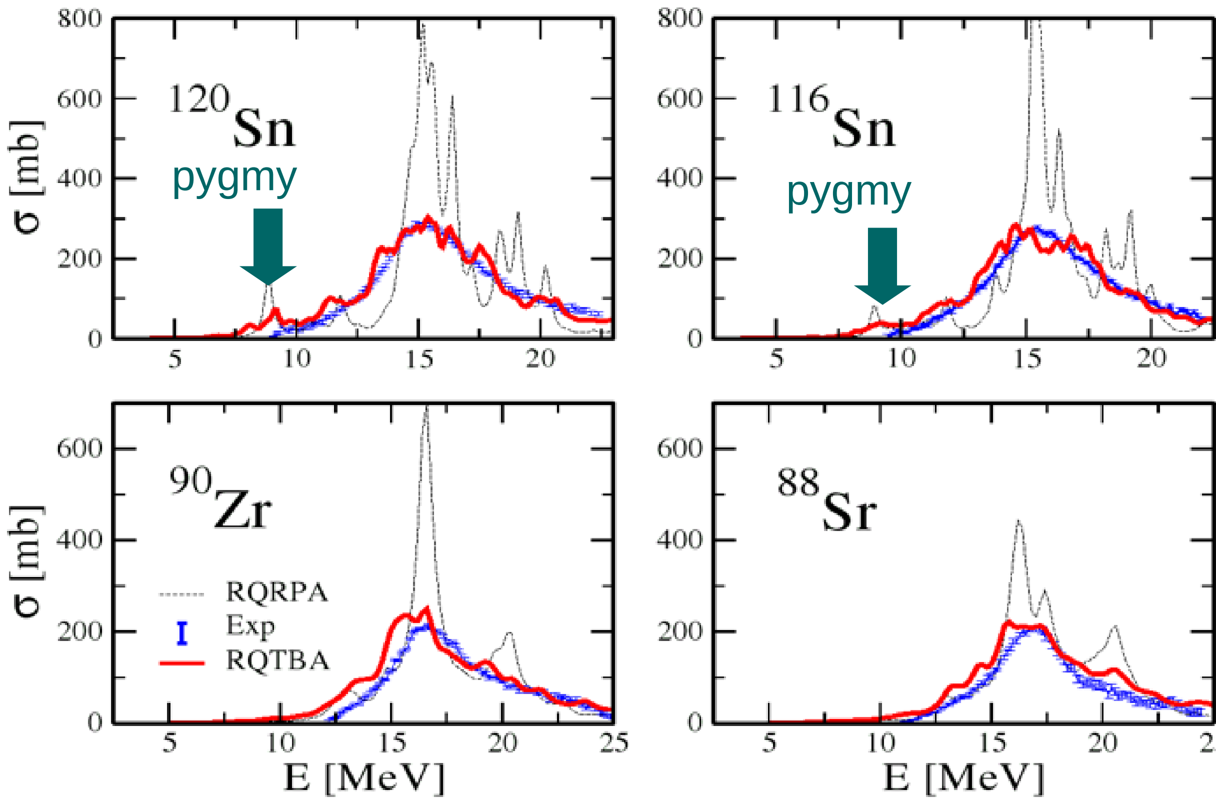
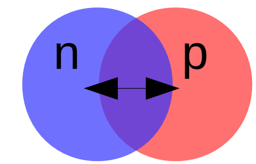
A few results in the ph neutral (ΔT_z=0) channel

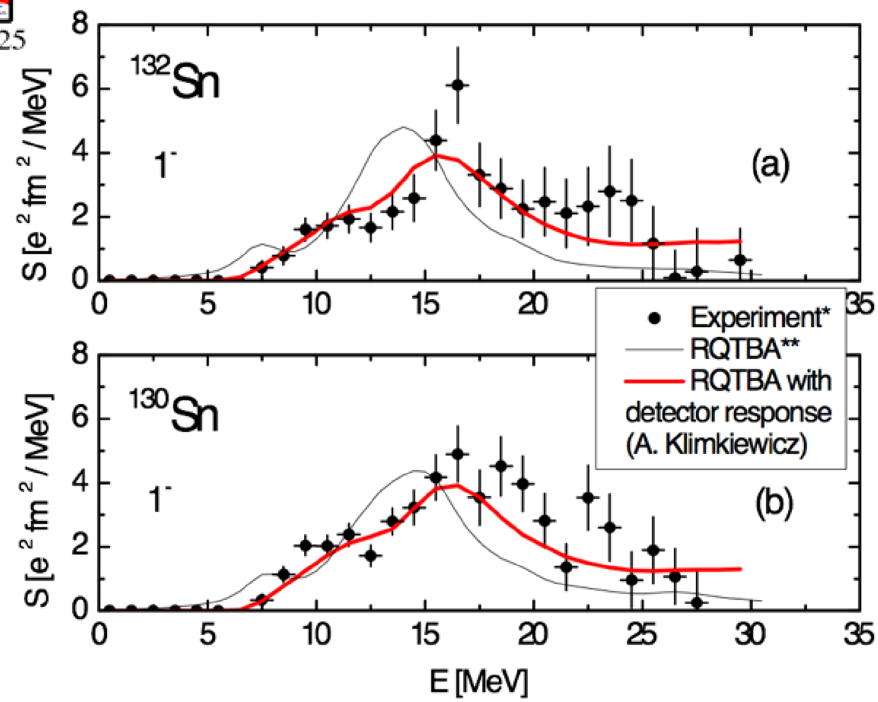




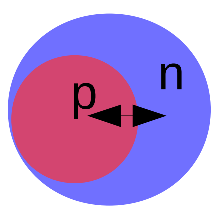
Test case: E1 (IVGDR)

Giant and pygmy resonances

Neutron-rich nuclei:

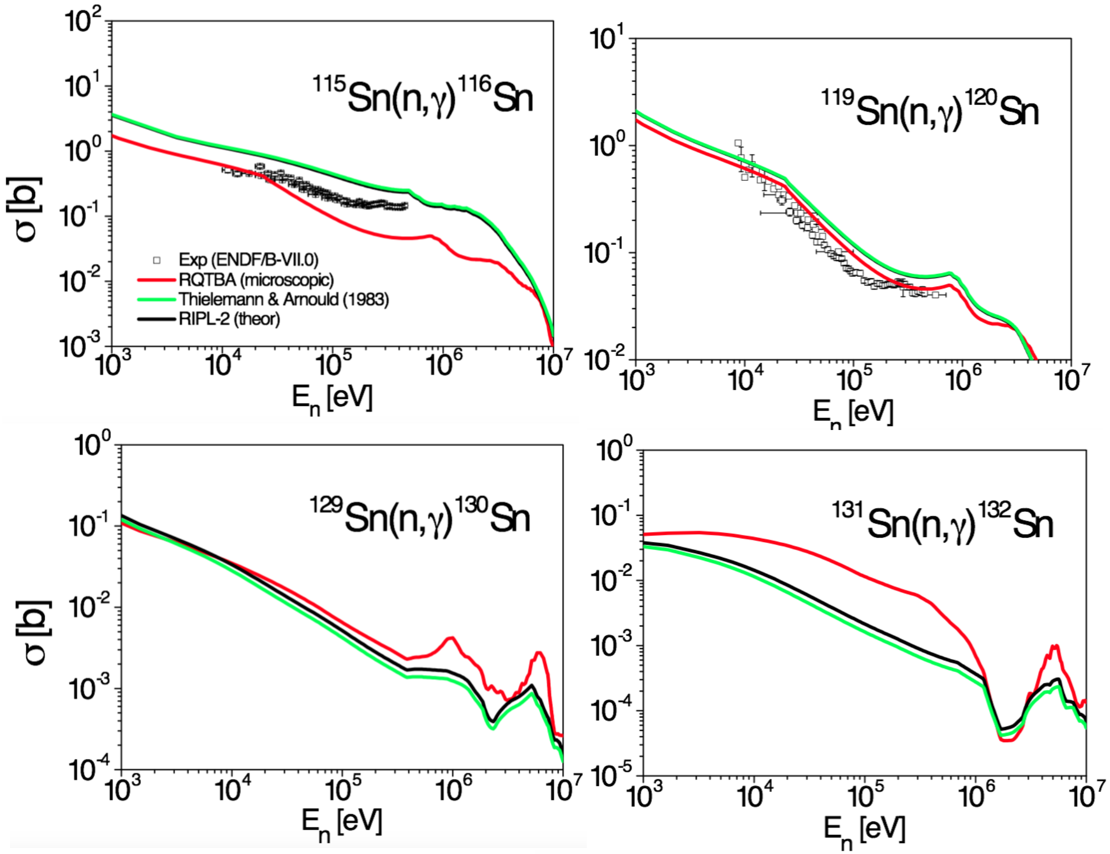


Pygmy Dipole Resonance (PDR):
Oscillation of the neutron skin against the core



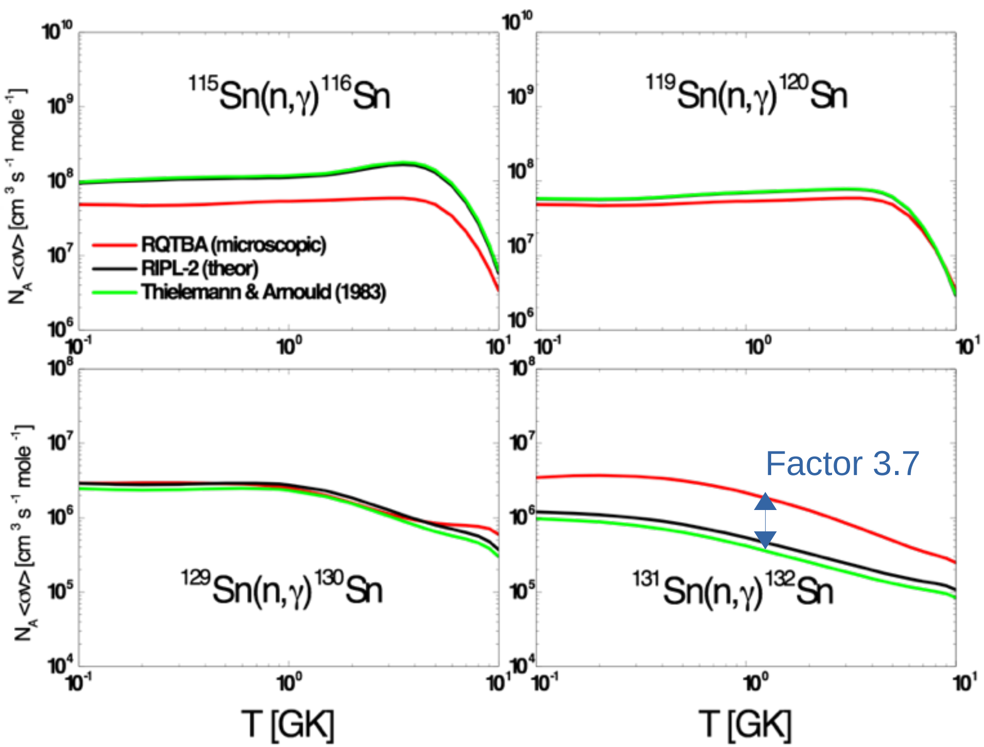
Litvinova, Ring, and Tselyaev, PRC 78, 014312 (2008)
Adrich et al., PRL 95, 132501 (2005)
Litvinova, Ring, Tselyaev, Langanke, PRC 79, 054312 (2009)

A few results in the ph neutral ($\Delta T_z=0$) channel



(n,γ) stellar reaction rates

Microscopic structure is important, especially when PDR is at the neutron threshold



Radiative neutron capture in the Hauser-Feshbach model:
standard Lorentzians vs microscopic structure

E. Litvinova et al., Nucl. Phys. A 823, 26 (2009).

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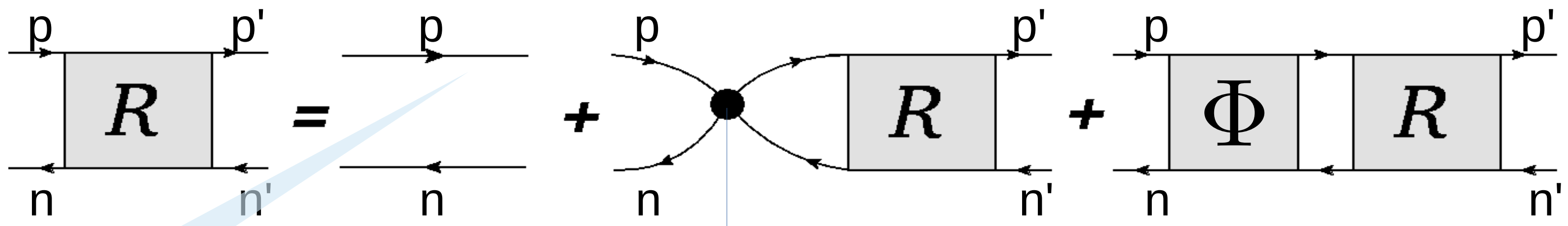
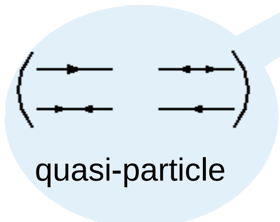
Response theory for isospin-transfer modes

★ Response in the ph proton-neutron channel:

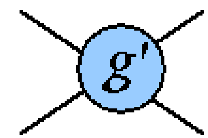




isovector interaction

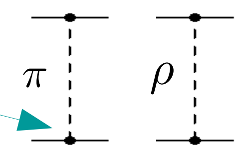
$$\widetilde{V} = V_\pi + V_\rho + V_{\delta\pi}$$

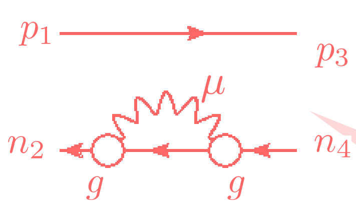
Landau-Migdal contact term

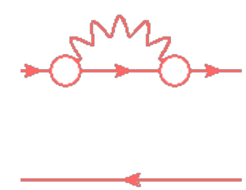


g' =0.6

free-space coupling constant



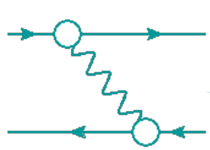


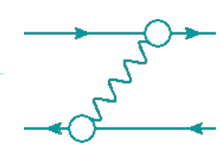


$$\Phi^{\eta}_{p_1 n_4, n_2 p_3}(\omega) =$$

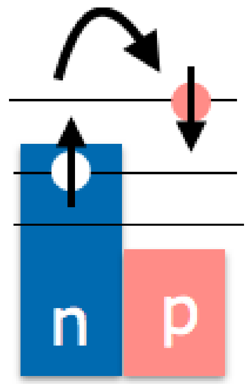
$$\sum_{\mu\xi} \delta_{\eta\xi} \left[\delta_{p_1 p_3} \sum_{n_6} \frac{g^{\eta;-\xi}_{\mu;n_6 n_2} g^{\eta;-\xi *}_{\mu;n_6 n_4}}{\eta\omega - E_{p_1} - E_{n_6} - \Omega_\mu} + \delta_{n_2 n_4} \sum_{p_5} \frac{g^{\eta;\xi}_{\mu;p_1 p_5} g^{\eta;\xi *}_{\mu;p_3 p_5}}{\eta\omega - E_{p_5} - E_{n_2} - \Omega_\mu} \right.$$

$$\left. - \frac{g^{\eta;\xi}_{\mu;p_1 p_3} g^{\eta;-\xi *}_{\mu;n_2 n_4}}{\eta\omega - E_{p_3} - E_{n_2} - \Omega_\mu} - \frac{g^{\eta;\xi *}_{\mu;p_1 p_3} g^{\eta;-\xi}_{\mu;n_4 n_2}}{\eta\omega - E_{p_1} - E_{n_4} - \Omega_\mu} \right]$$





Gamow-Teller transitions in Nickel isotopes (Ni → Cu)



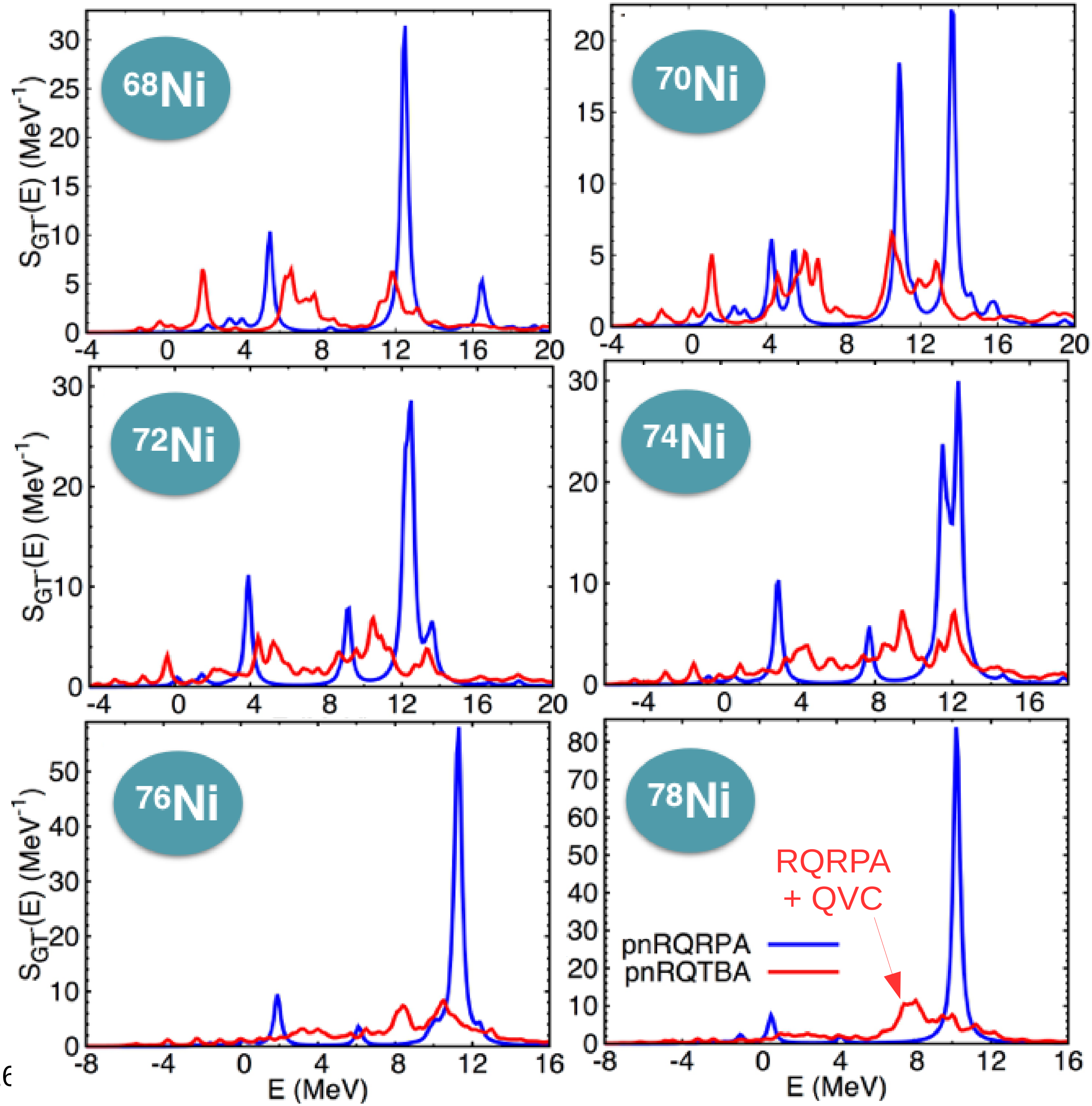
$$F_{GT^-} = \sum_n \begin{pmatrix} \sigma^i_{(n)} & 0 \\ 0 & \sigma^i_{(n)} \end{pmatrix} \tau_-^{(n)}$$

$$\Delta T_z = -1$$
$$\Delta S = 1$$
$$\Delta L = 0$$

QPVC brings fragmentation of the strength and distribution over a larger energy range

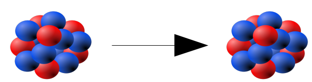
(Smearing Δ= 200 keV)

C. R. and E. Litvinova EPJA 52, 205 (2016



Low-energy GT strength and β-decay half-lives

Half-lives and low-energy strength:

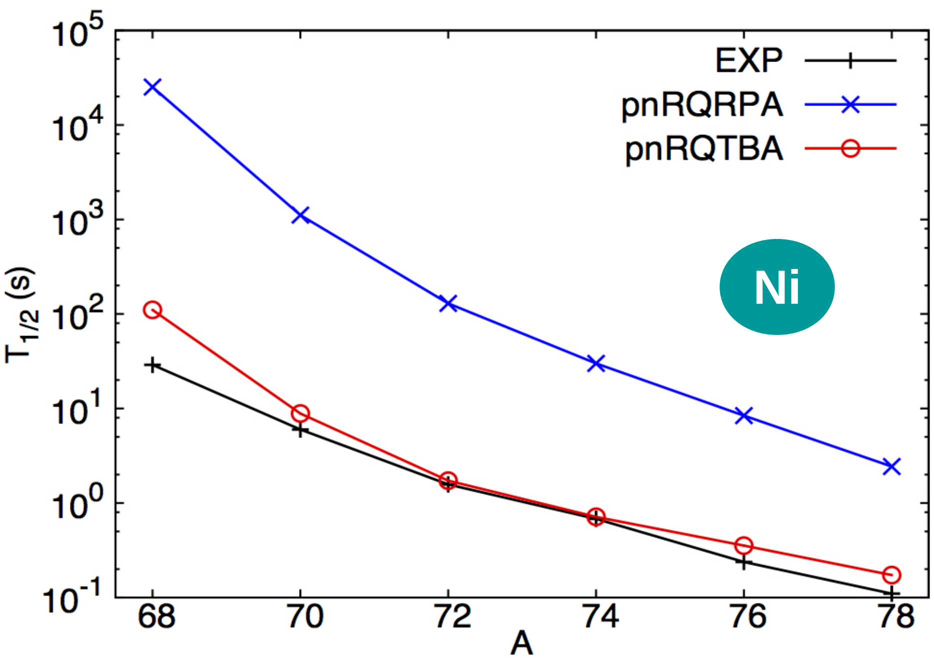


$$(Z,N) \longrightarrow (Z+1,N-1) + e^- + \bar{\nu}_e$$

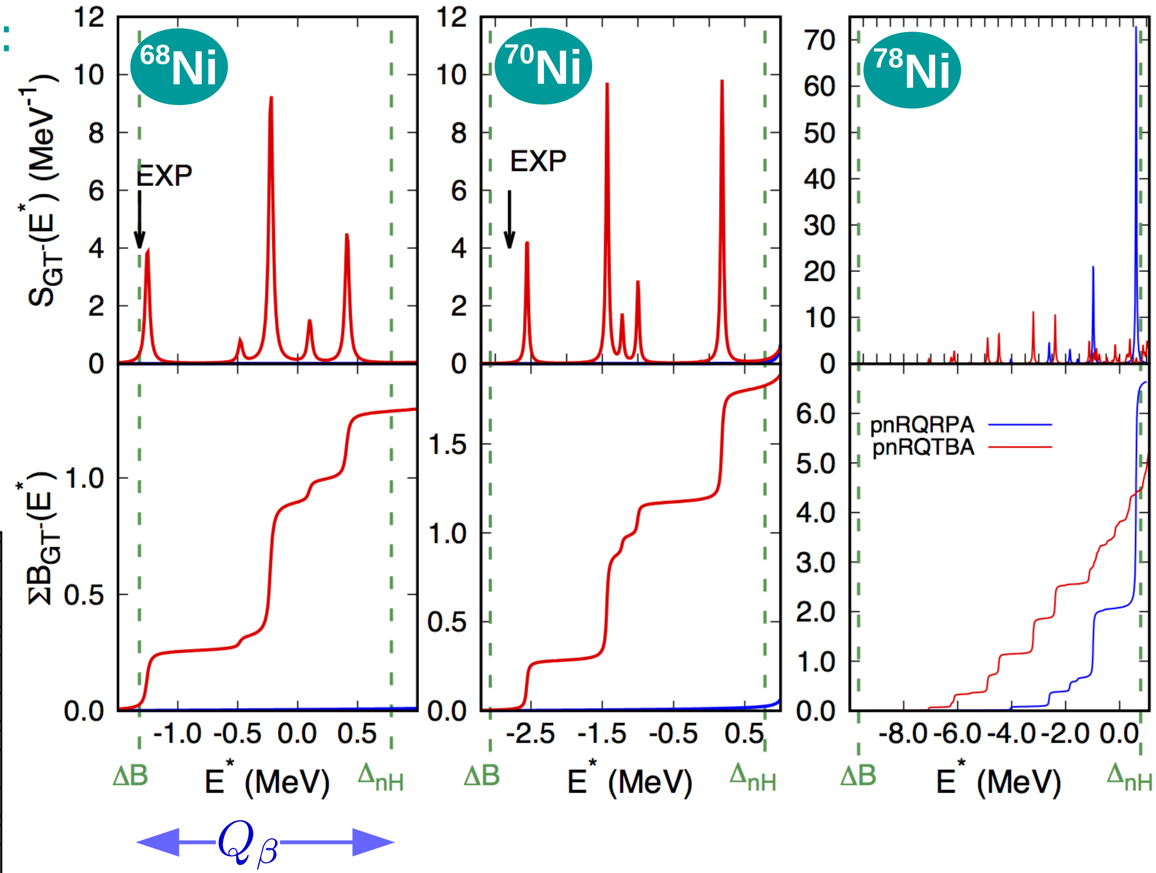
$$\frac{1}{T_{1/2}} = \frac{g_a^2}{D}\int^{Q_\beta} f(Z,Q_\beta - E)S(E)dE$$

With $g_a=1$

Leptonic phase-space factor



→ big improvement due to QVC!



- ^{68}Ni and ^{70}Ni : appearance of strength in the Q_β window due to QVC → finite lifetime
- ^{78}Ni: more strength with RQRPA but located at higher energies → smaller lifetime with QVC due to phase space factor

exp data from nndc.bnl.gov

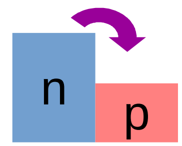
C.R. and E. Litvinova EPJA 52, 205 (2016).

Gamow-Teller transitions and the "quenching" problem

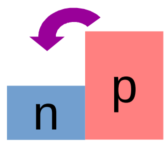
- "Quenching problem":

The observed GT strength (~up to the GR region) in nuclei is ~30-40% less than the model independent Ikeda sum rule: $S_{-} - S_{+} = 3(N-Z)$

$$S_{-} = \sum B(GT^{-})$$



$$S_{+} = \sum B(GT^{+})$$



$\Rightarrow$ some strength is pushed at high energies → possible mechanisms?

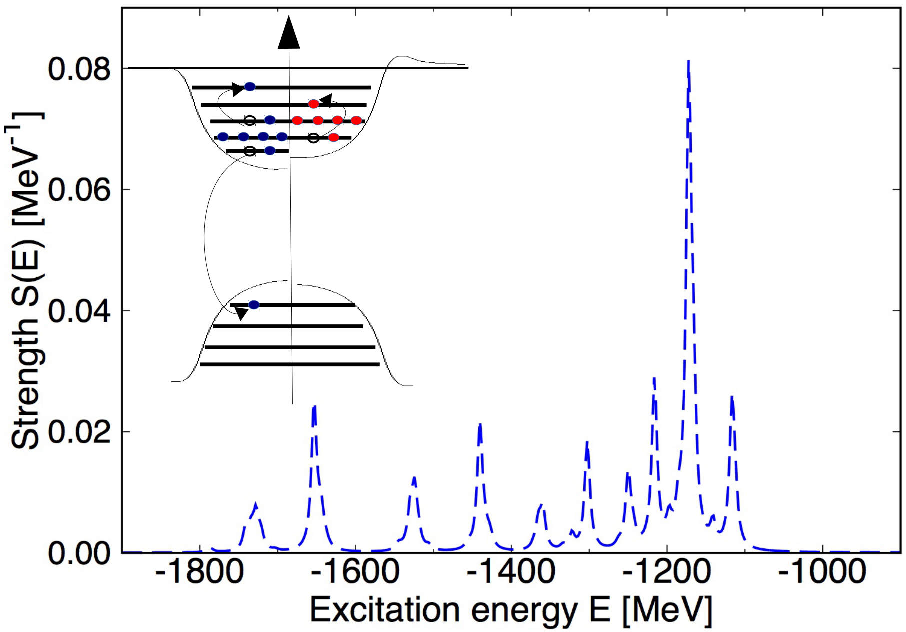
- Coupling of 1p1h to Δ baryon (believed to be small)
- Coupling of 1p1h to higher-order configurations such as 2p2h, 3p3h… (Believed to be the most important)

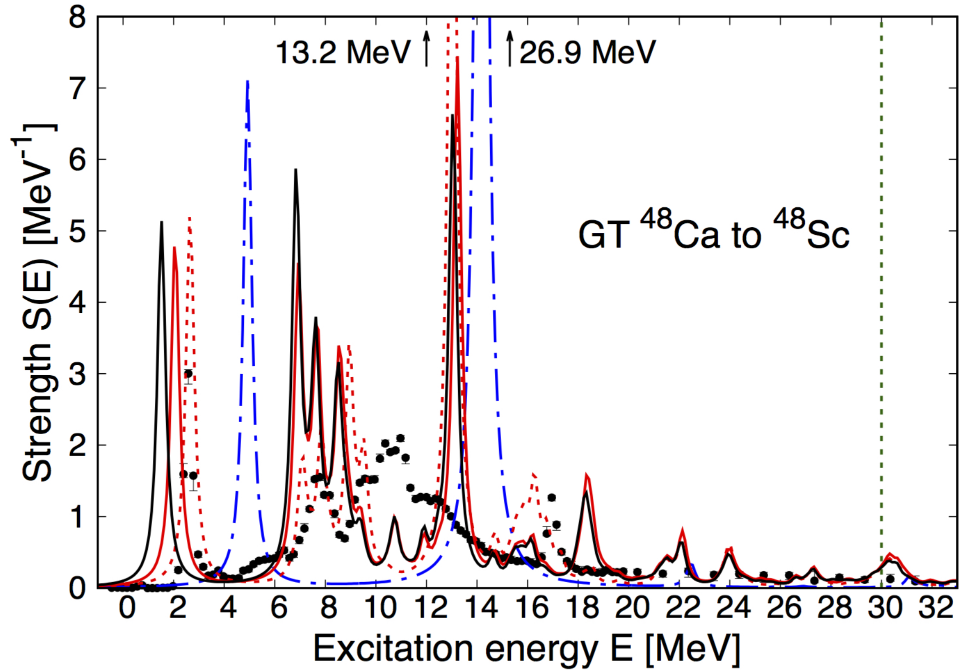
$\Rightarrow$ important to introduce complex configurations in large model spaces

At present with RNFT+TBA:

- 2(q)p-2(q)h configurations
- in an energy window from 30 MeV up to ~100 MeV in light or doubly magic nuclei

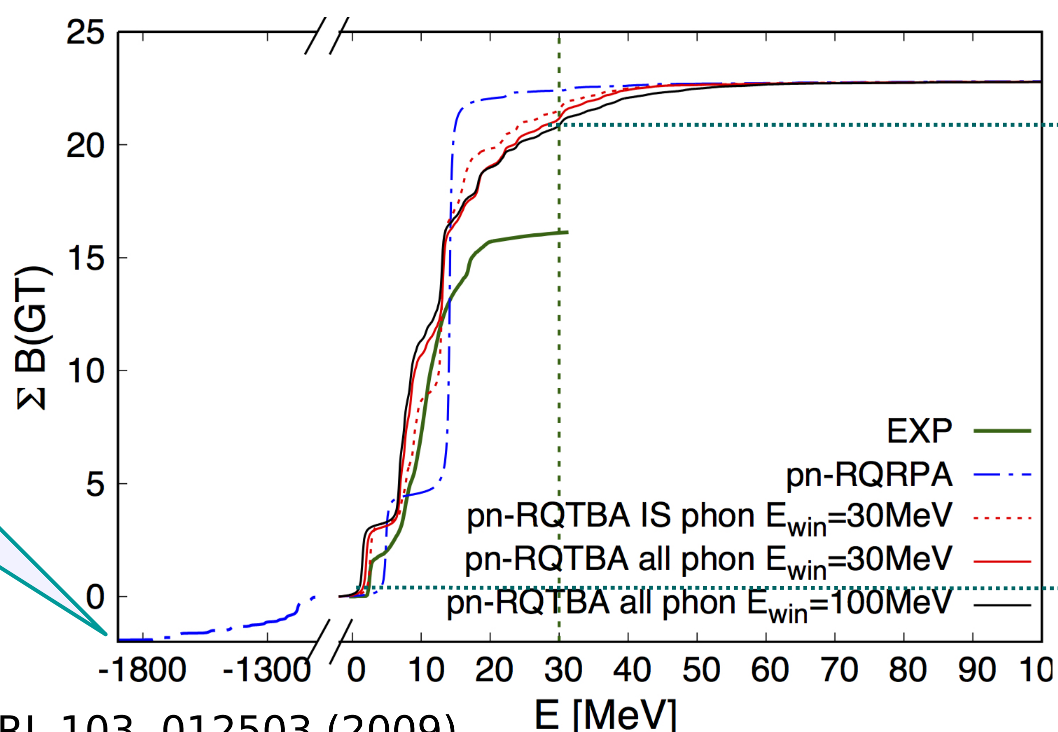
Gamow-Teller transitions and the “quenching” problem





+ transitions from the Fermi sea to the Dirac sea (~8%)

[N. Paar et al., PRC 69, 054303]



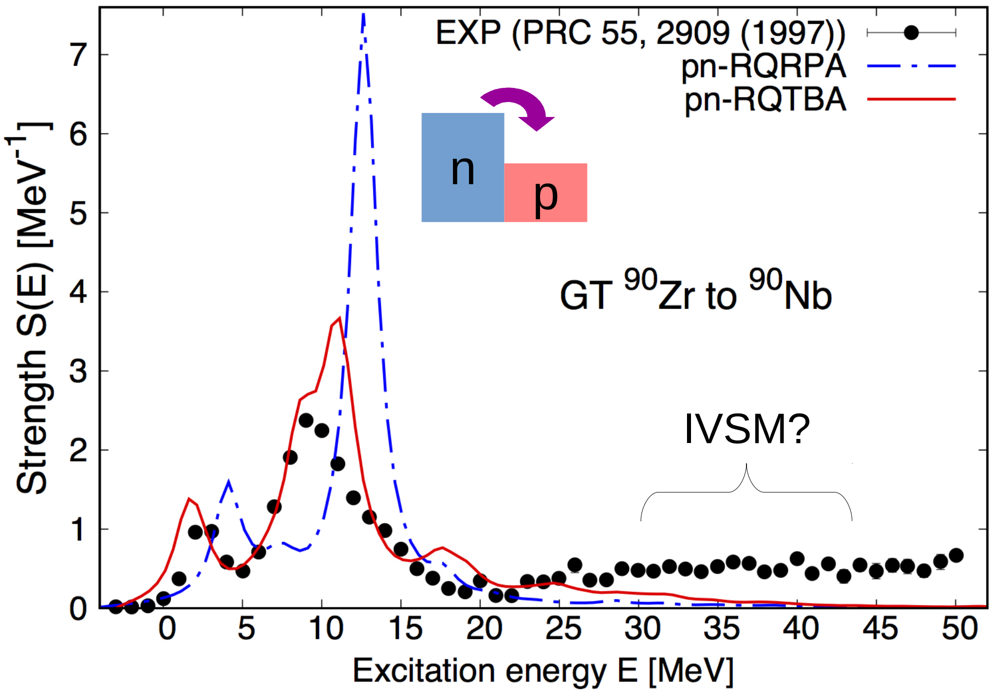
Up to 30 MeV: **~91%** (vs 98% in RQRPA) of the total GT_ strength

→ RQRPA strength naturally “quenched” due to complex configurations

But not enough... (exp: 71%)

EXP: K. Yako et al., PRL 103, 012503 (2009)

Gamow-Teller transitions and the "quenching" problem



GT strength only:

0-50 MeV:

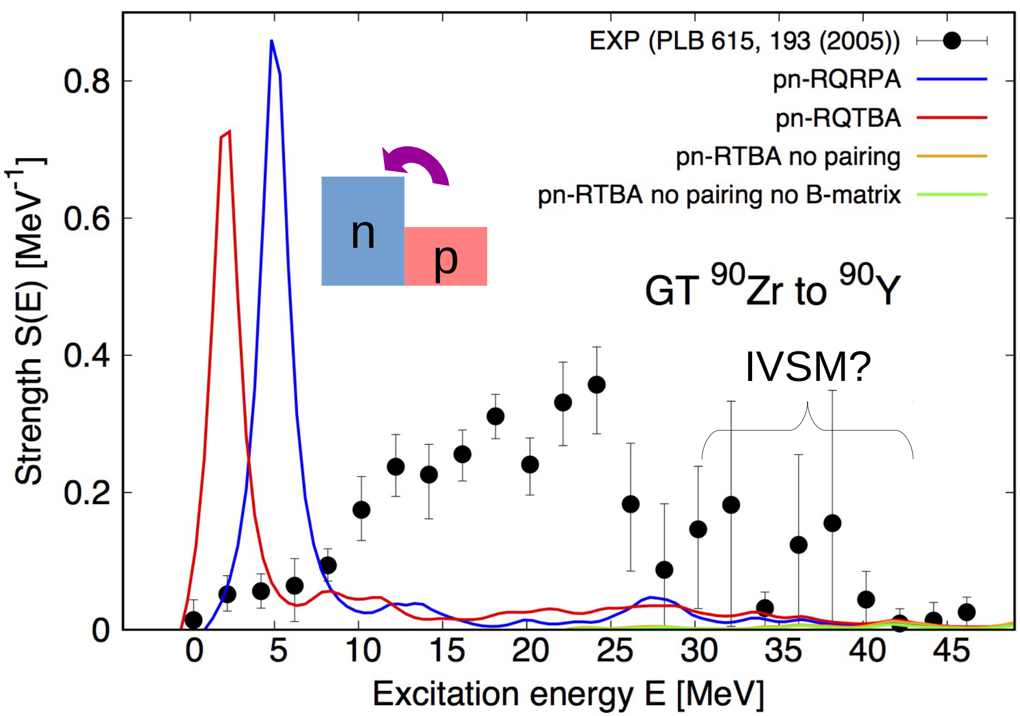
$$S_{-}^{EXP} \sim 29.3$$

$$S_{-}^{RQTBA} \sim 30.35$$

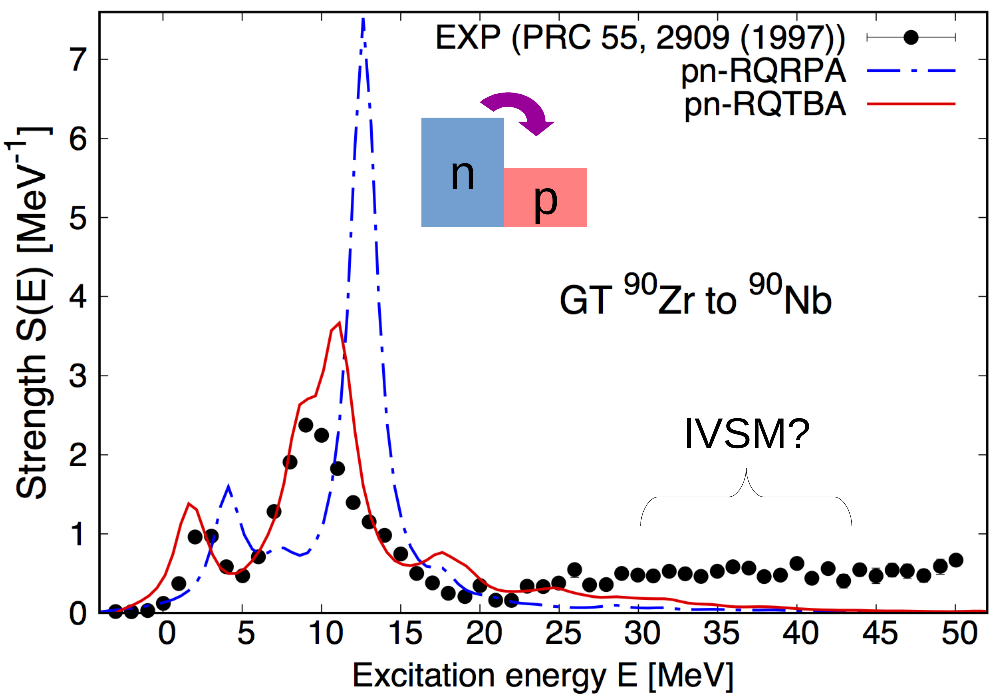
0-32 MeV:

$$S_{+}^{EXP} \sim 2.9$$

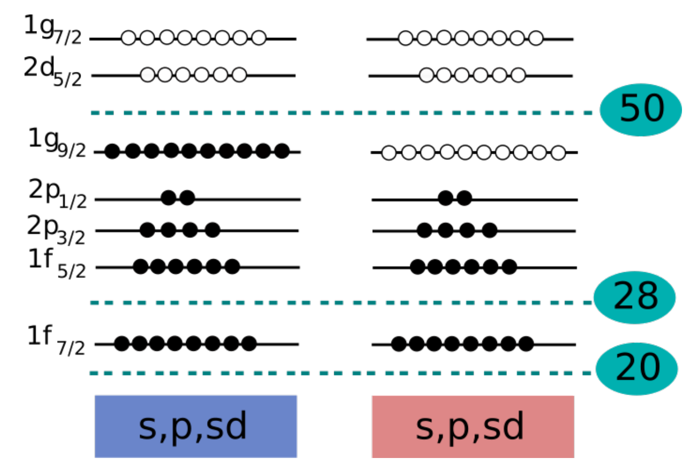
$$S_{+}^{RQTBA} \sim 2.54$$



Gamow-Teller transitions and the “quenching” problem



Schematic mean-field - no pairing:



Pauli-blocked

GT strength only:

0-50 MeV:

$$S_{-}^{EXP} \sim 29.3$$

$$S_{-}^{RQTBA} \sim 30.35$$

0-32 MeV:

$$S_{+}^{EXP} \sim 2.9$$

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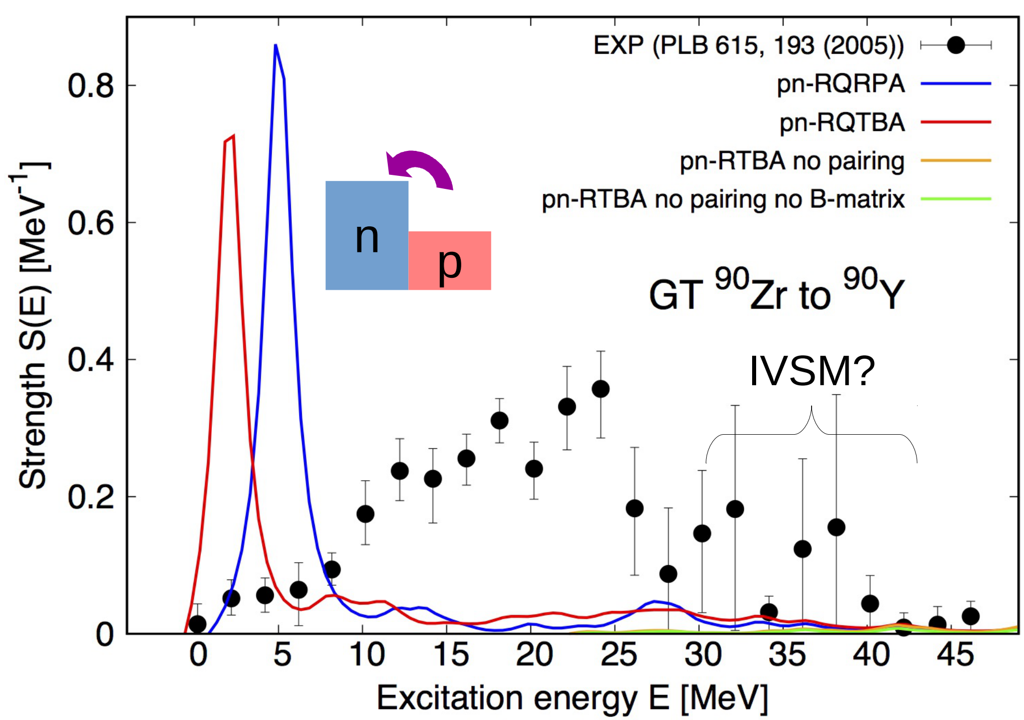
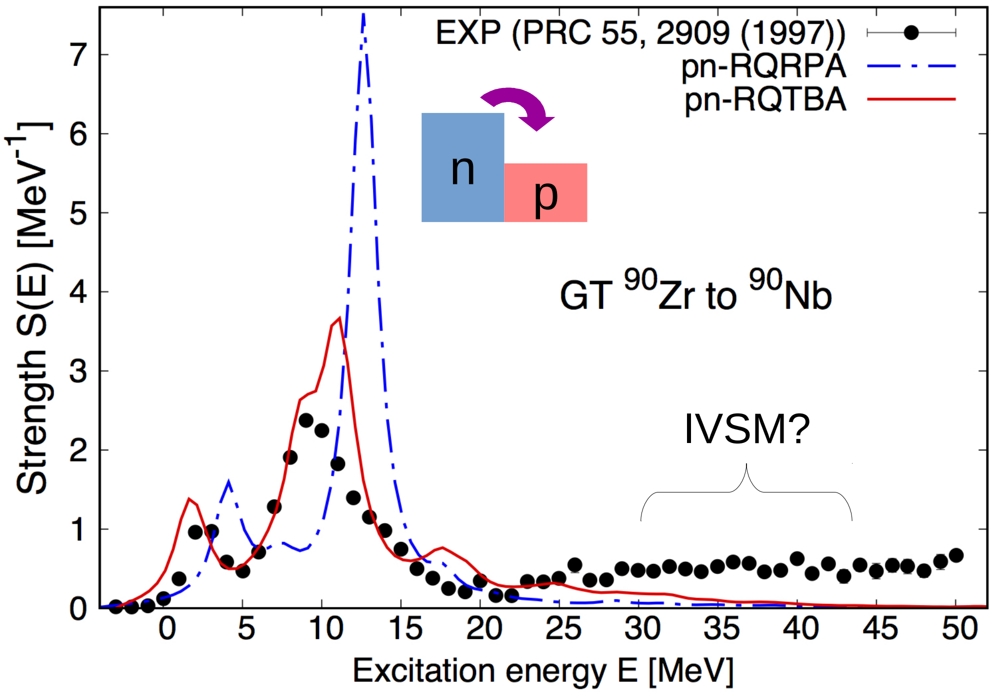
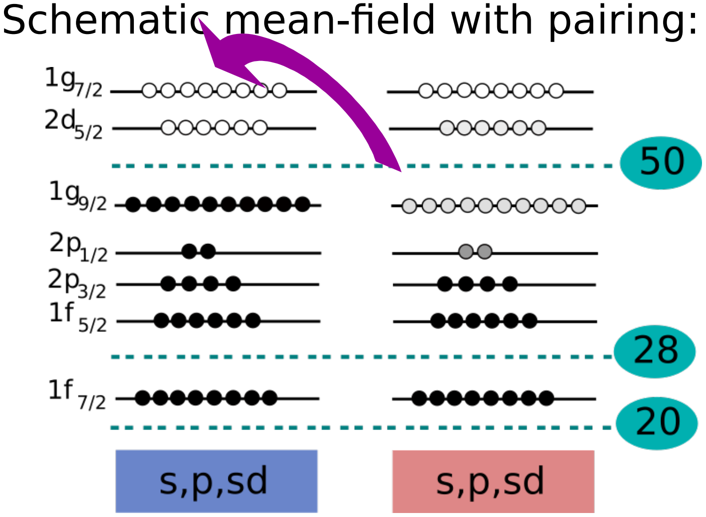


Gamow-Teller transitions and the "quenching" problem



Schematic mean-field with pairing:



GT strength in β$^+$ channel caused by ground-state correlations (pairing here). But need further fragmentation → GSC induced by QVC ?

GT strength only:

0-50 MeV:

$$S_{-}^{EXP} \sim 29.3$$

$$S_{-}^{RQTBA} \sim 30.35$$

0-32 MeV:

$$S_{+}^{EXP} \sim 2.9$$

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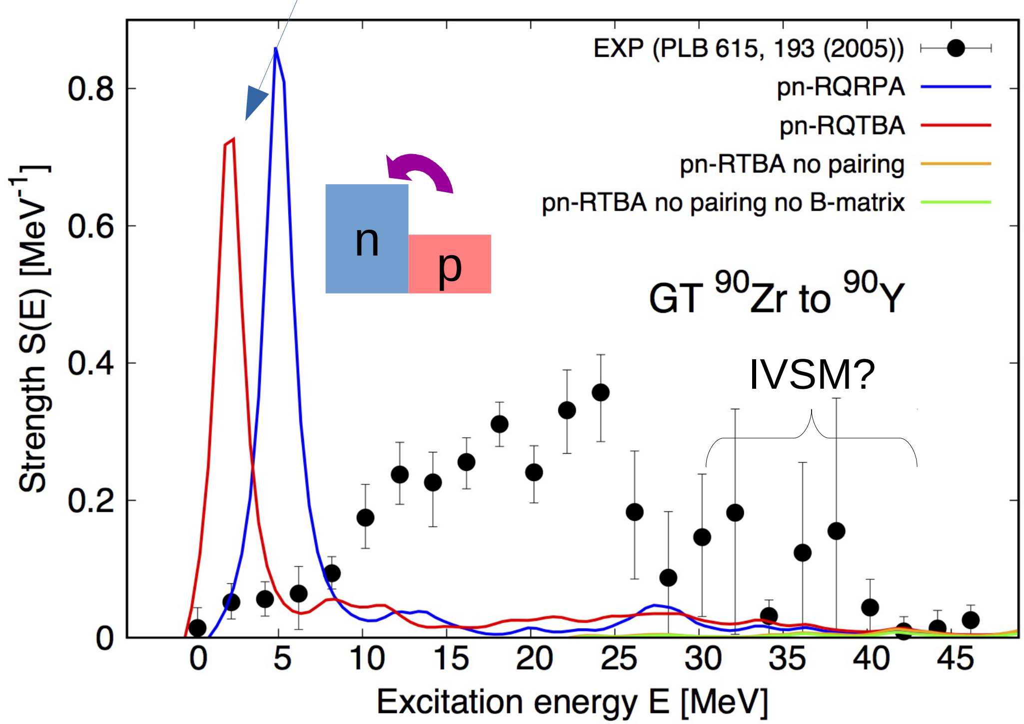
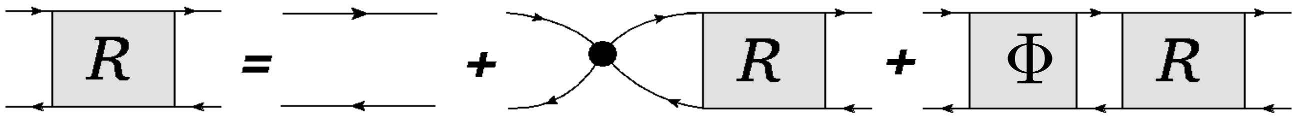
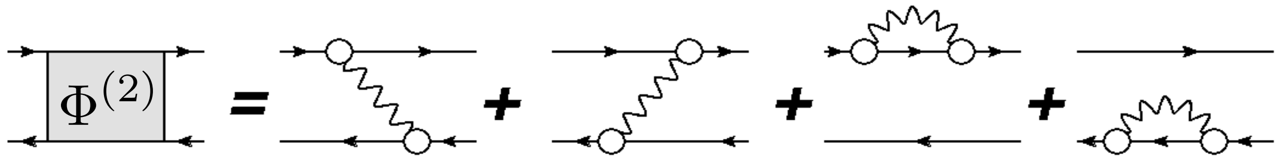


...Ongoing developments in the RNFT

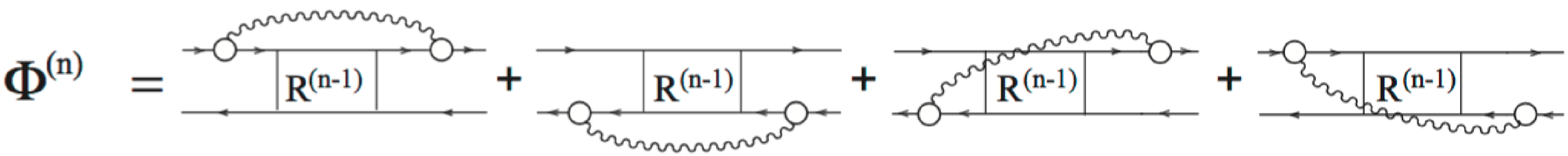
Inclusion of higher-order Np-Nh configurations in the response



RNFT +TBA:



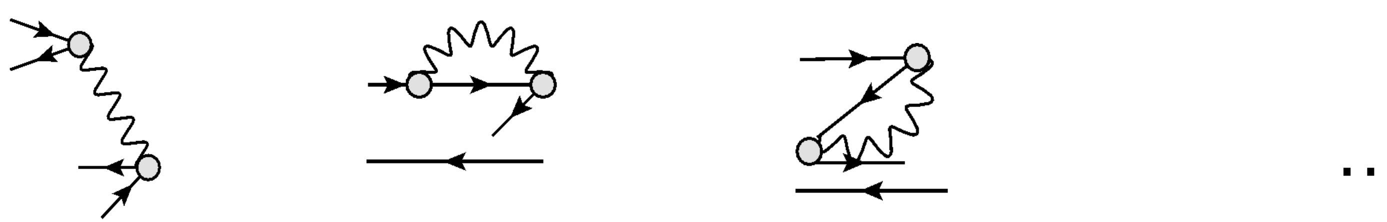
Extension:



E. Litvinova, Phys. Rev. C 91, 034332 (2015)

→ important for an accurate description of fine details of the transition strength

Ground-state correlations induced by QVC = backward going diagrams



→ important for e.g. (n,p) strength in neutron-rich nuclei / (p,n) strength in proton-rich nuclei

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Conclusion, perspectives

→ Conclusions:

- The RNFT is a powerful framework for the microscopic description of mid-mass to heavy nuclei, which allows the account for complex configurations of nucleons in a large model space.
- It has been quite successful in the description of neutral excitations.
- It appears promising in the spin-isospin channel (description of both the low-energy strength and overall distribution to higher excitation energy).
- However, in its present formulation (time-blocking approximation) it is often not sufficient.

→ Perspectives:

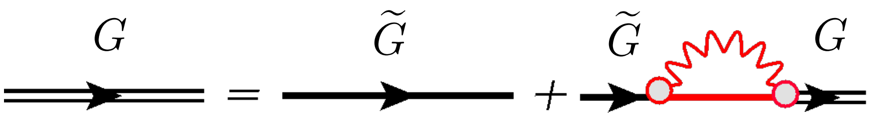
- Inclusion of higher-order configurations and ground-state correlations
- Application to double-charge exchange and double-beta decay ($2\nu\beta\beta$ and $0\nu\beta\beta$)
- Together with RNFT in the neutral channel, this framework provides a high-quality and consistent description of both phases of the r-process nucleosynthesis, (n,γ) and β-decay ⇒ implementation in astrophysical modeling
- Long-term goals: inclusion of the Fock term, start from bare interaction…
- Other ongoing developments at WMU: coupling to continuum and extension to finite temperature (Ph.D. of H. Wibowo), description of neutral pairing vibrations (Ph.D of I. Egorova)

Thank you!

This work is supported by US-NSF Grants PHY-1404343 and PHY-1204486

Next step beyond mean-field: Quasiparticles coupled to vibrations

→ quasi-particle propagator:

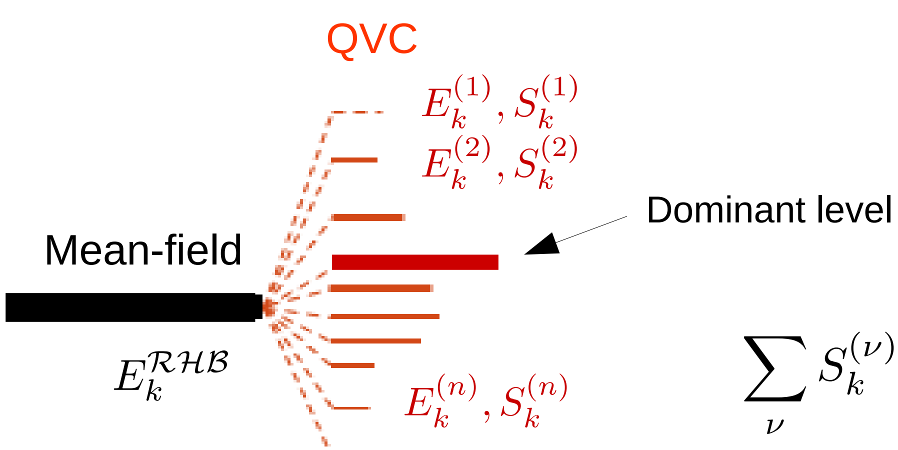


$$G(E) = \left(\varepsilon - \mathcal{H}_{RHB} - \Sigma^{(e)}(E)\right)^{-1}$$

Introduces new poles

$$E_k^{(\nu)} = E_k^{\mathcal{RHB}} + \Sigma_k^{(e)}(E_k^{(\nu)})$$

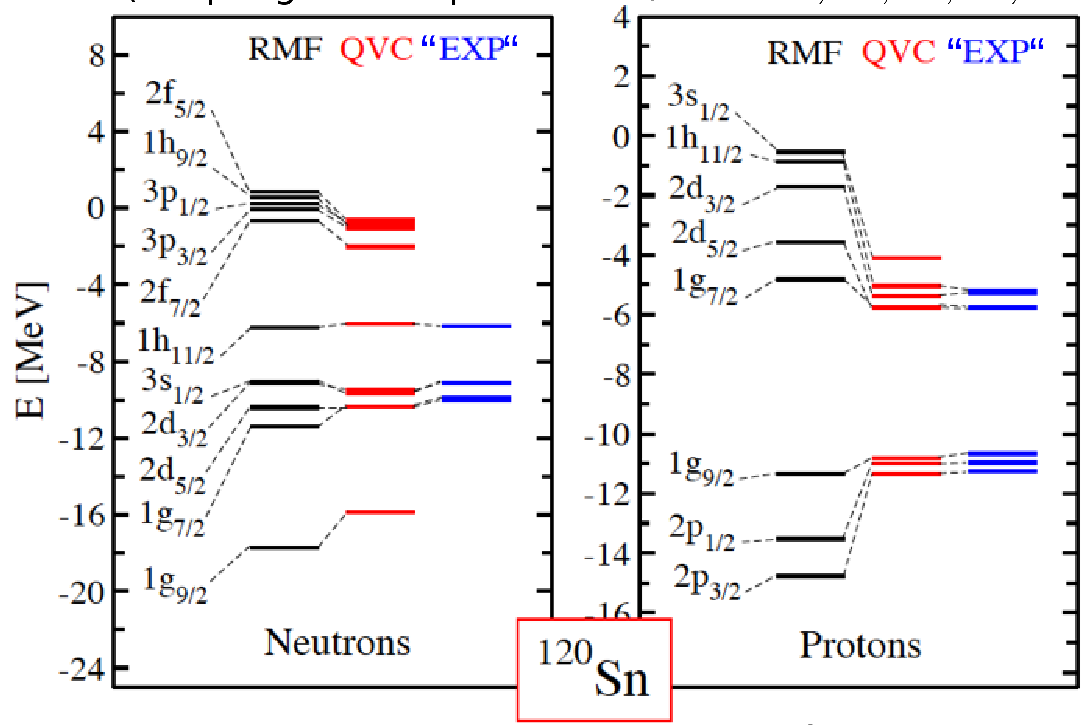
→ fragmentation of single (quasi)particle states:



$$\sum_\nu S_k^{(\nu)} = 1$$

Dominant level:

(coupling to T=0 phonons w/ $J^\pi = 2^+, 3^-, 4^+, 5^-, 6^+$)



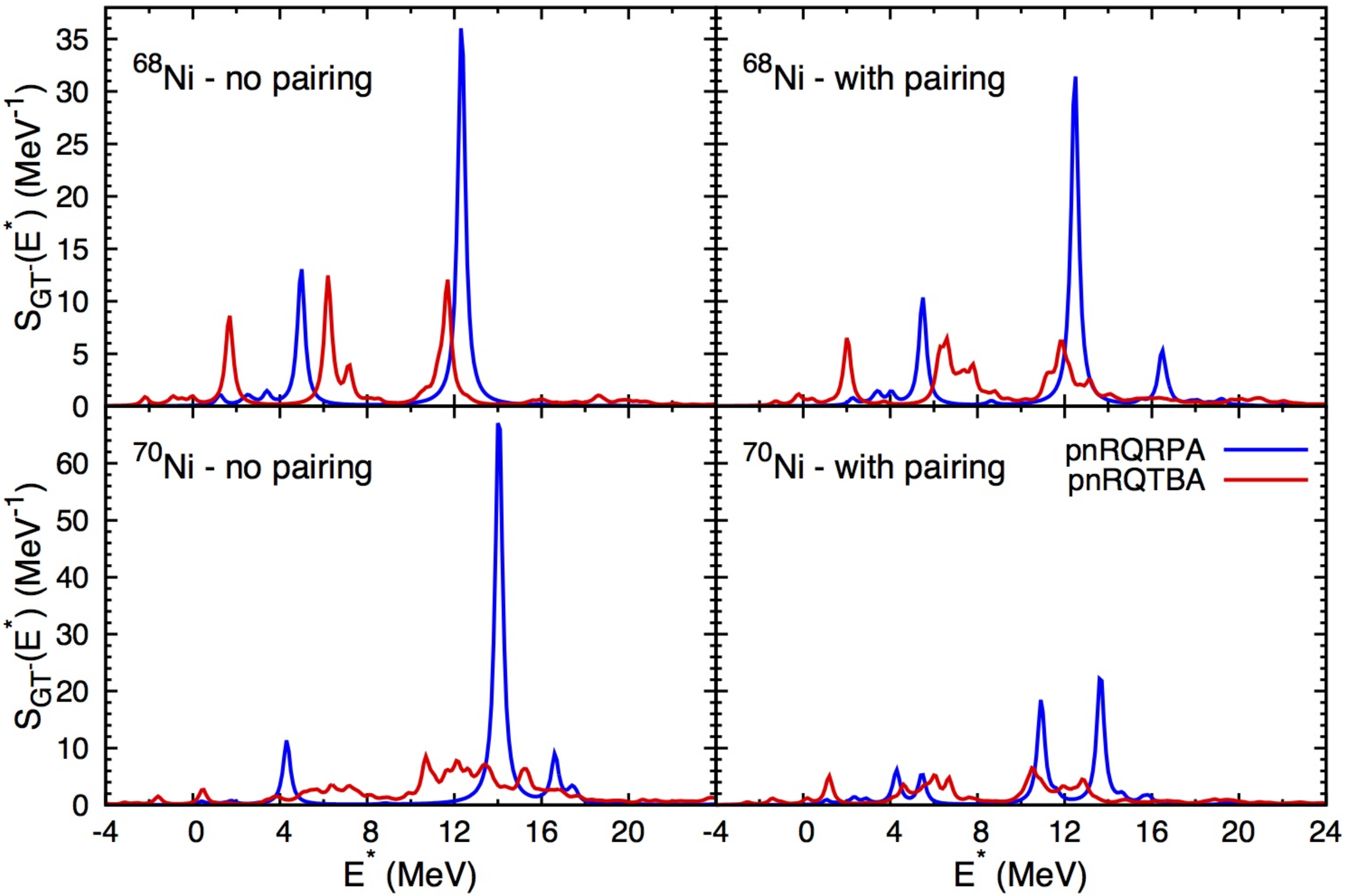
E. Litvinova, PRC 85, 021303(R) (2012)

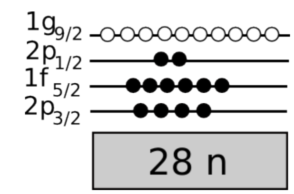
Spectroscopic factors in ^{120}Sn:

(nlj) ν	S^{th}	"S^{exp} "
$2d_{5/2}$	0.32	0.43
$1g_{7/2}$	0.40	0.60
$2d_{3/2}$	0.53	0.45
$3s_{1/2}$	0.43	0.32
$1h_{11/2}$	0.58	0.49
$2f_{7/2}$	0.31	0.35
$3p_{3/2}$	0.58	0.54

⚠ model dependence...

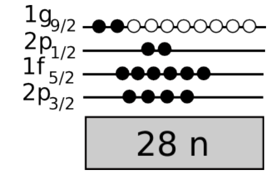
Effect of pairing correlations on the strength distribution:





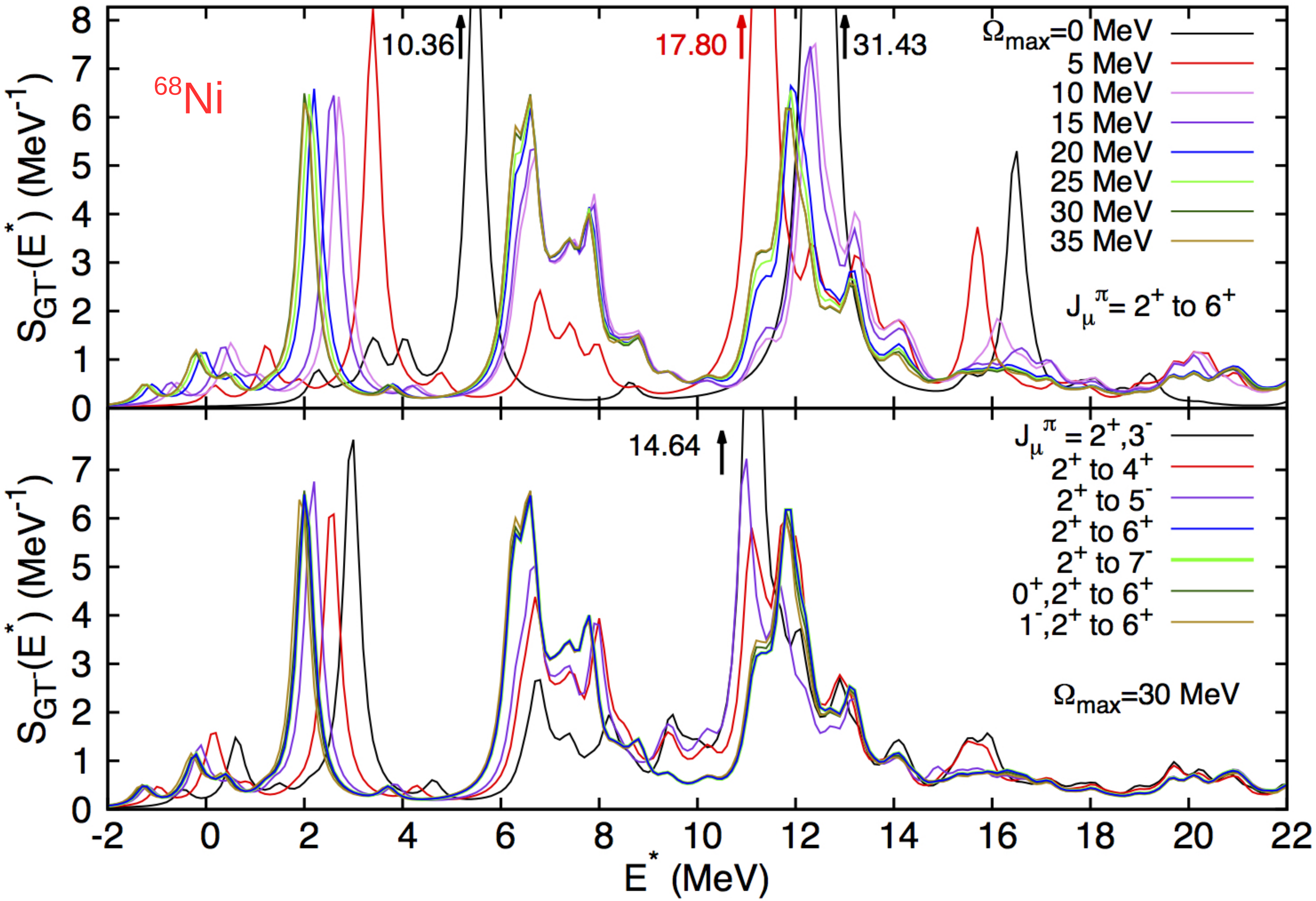
Pairing can bring fragmentation at the QRPA level (Landau damping)

QPVC brings spreading effects



Gamow-Teller transitions in Nickel isotopes (Ni → Cu)

Convergence of the strength according to the phonon spectrum (neutral phonons only):

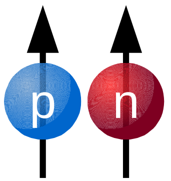


C. Robin and E. Litvinova EPJA 52, 205 (2016).

Low-energy GT strength and beta-decay half-lives

★ Problem with QRPA description: the beta-decay half-lives are systematically overestimated.

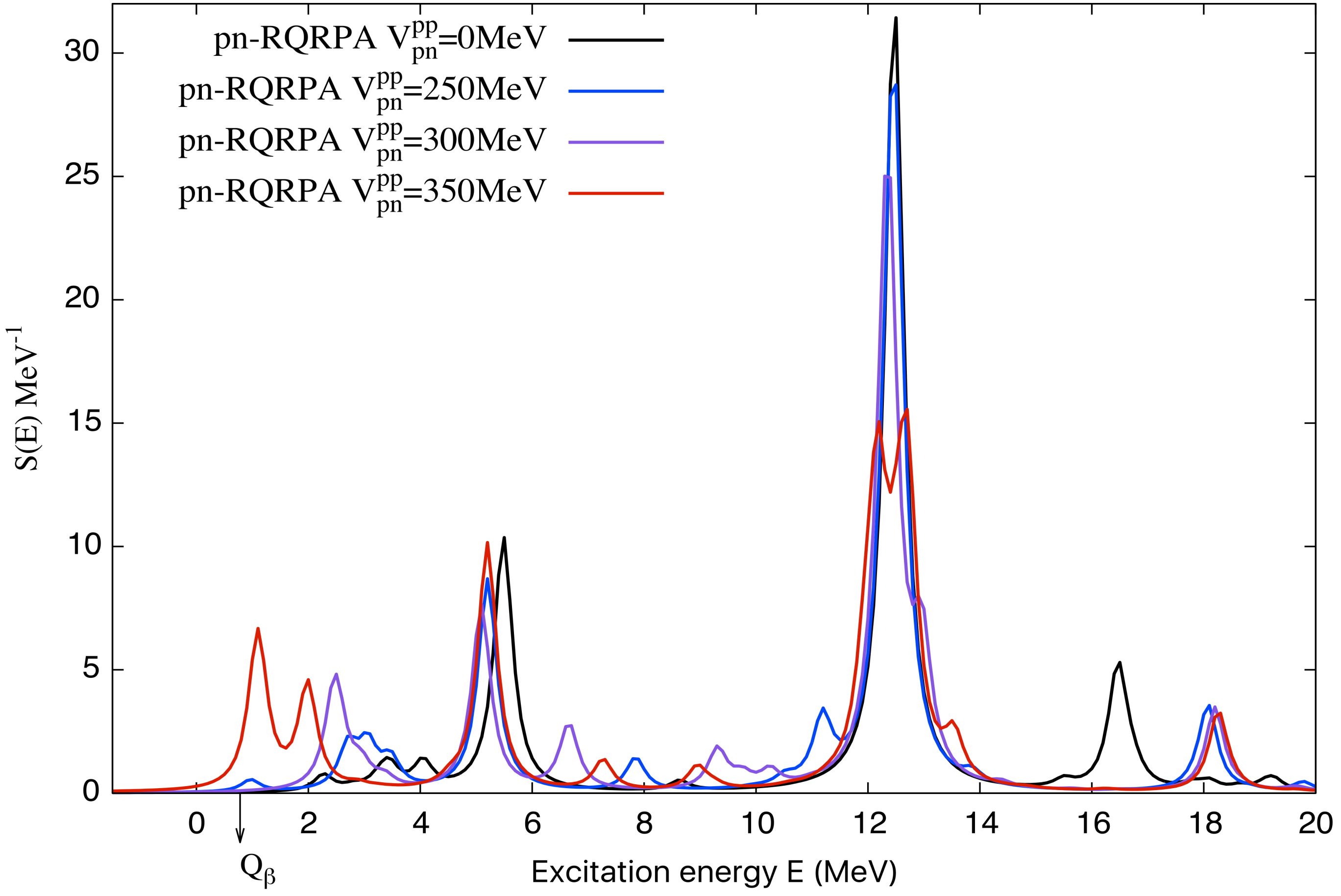
→ issue overcome by considering T=0 pn-pairing



But this type of pairing is not well understood
(no deuteron condensate → T=0 pairing is dynamic (?)...)
And not well constrained ...

→ often treated phenomenologically with an additional static pn residual interaction in the particle-particle channel.

→ Example in ^{68}Ni:

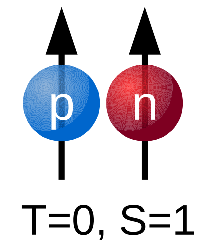


⇒ Lack of
predictive power

Low-energy GT strength and beta-decay half-lives

Problem with QRPA description: the beta-decay half-lives are systematically overestimated.

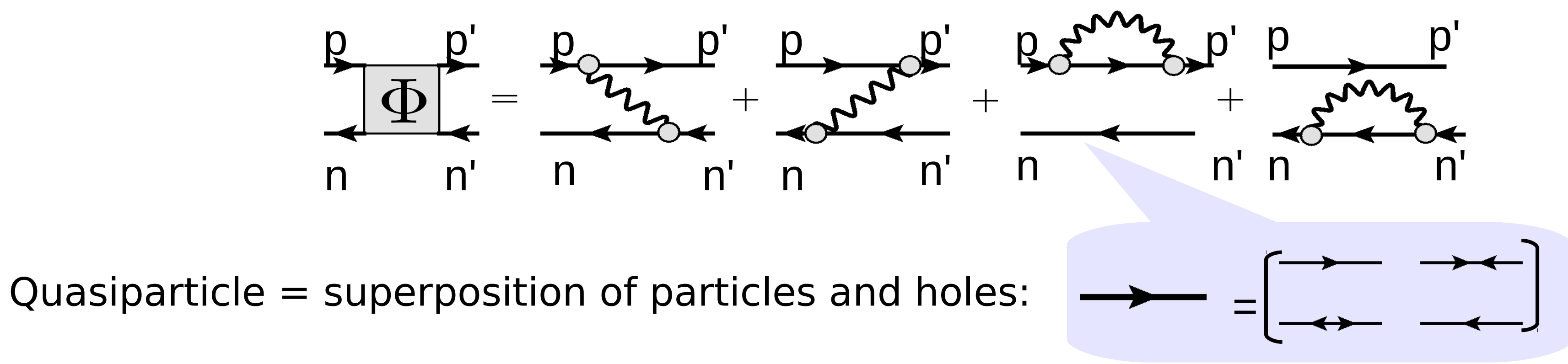
→ issue overcome by considering T=0 pn-pairing



But this type of pairing is not well understood
(no deuteron condensate → T=0 pairing is dynamic (?)...)
And not well constrained ...

→ often treated phenomenologically with an additional static pn residual interaction in the particle-particle channel.

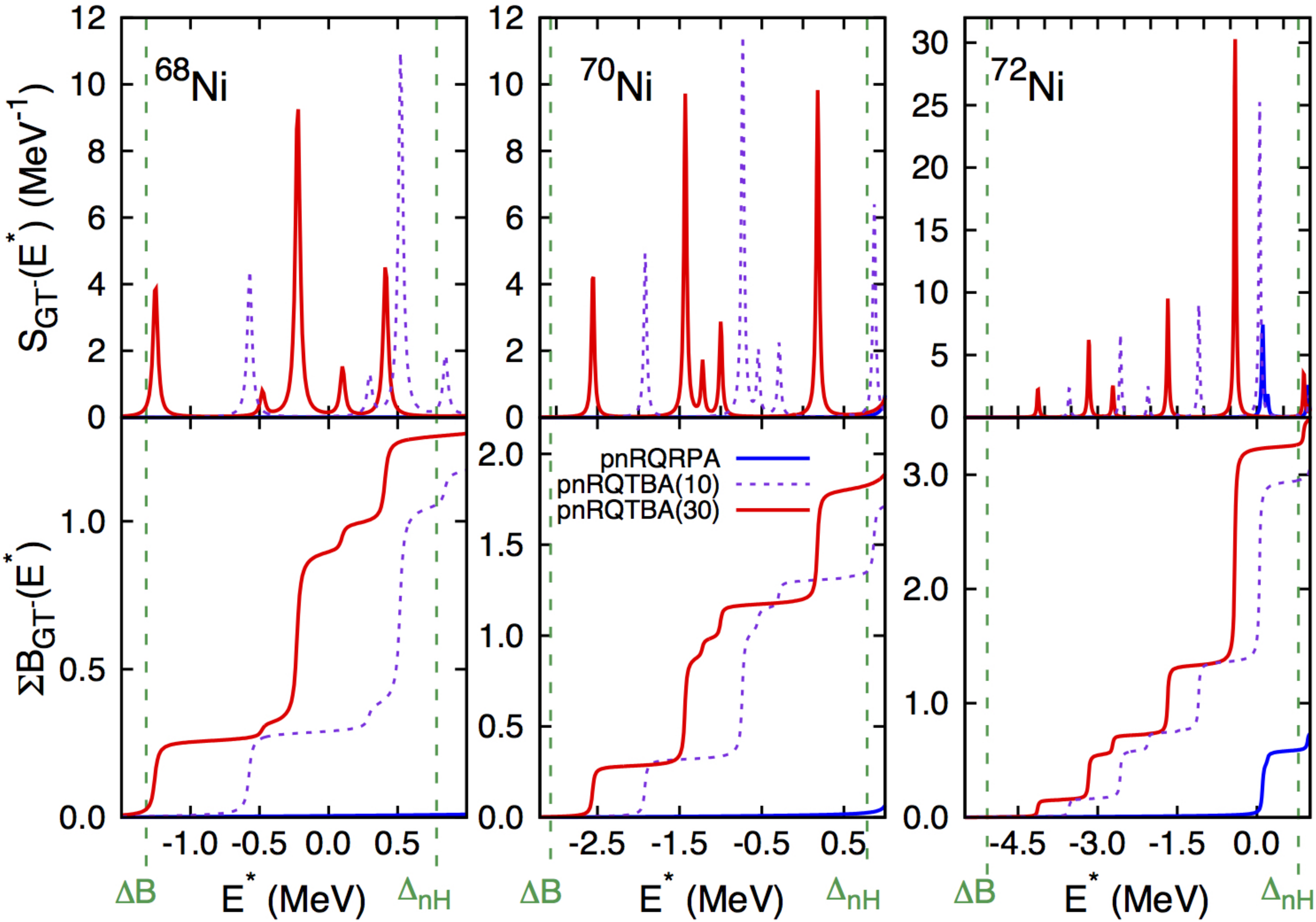
Goal: evaluate the effect of QVC on the half-lives and provide a possible microscopic mechanism for pn-pairing:



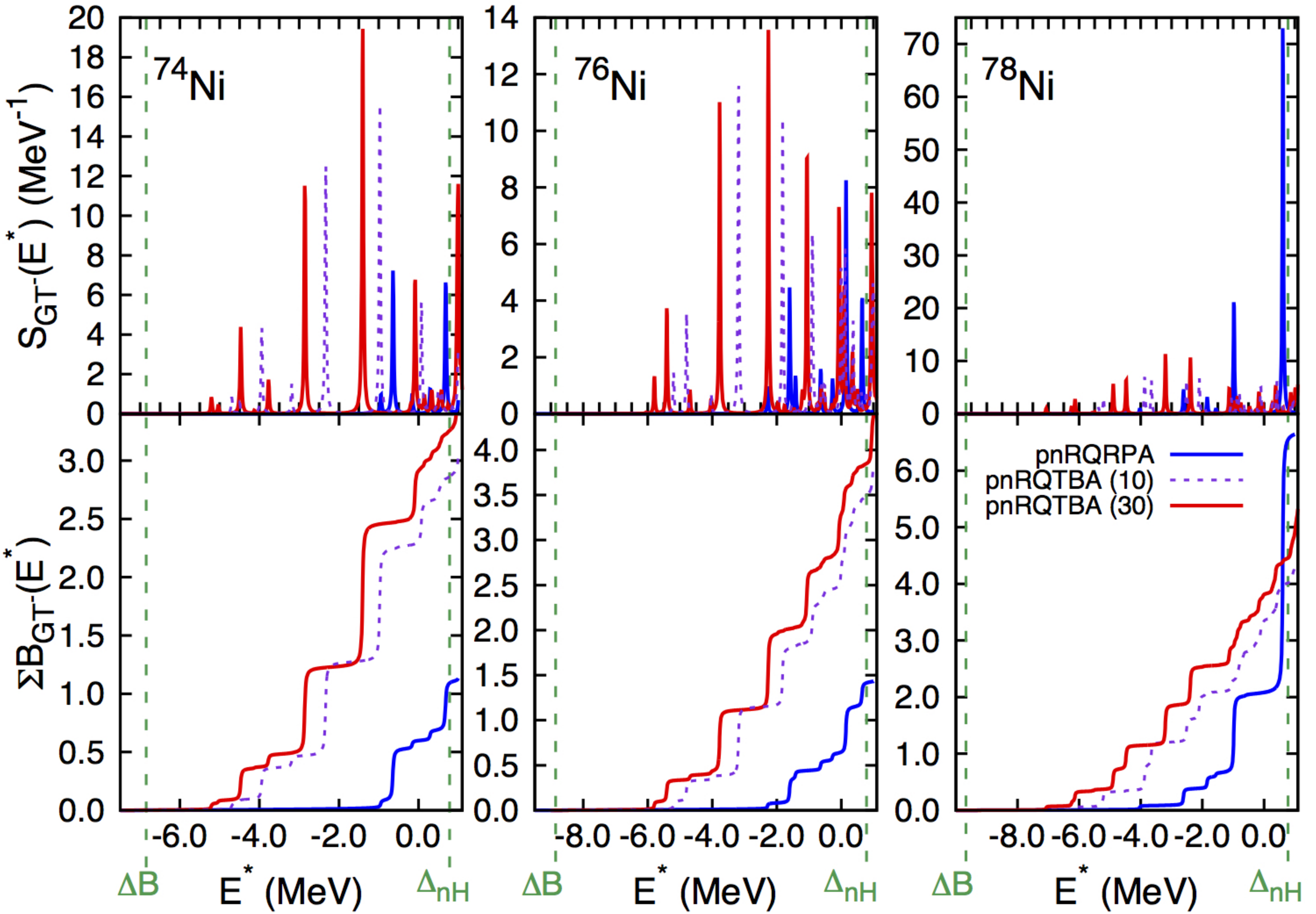
→ QVC generates a pn effective interaction in the particle-hole and particle-particle channels.

→ QVC can provide an underlying mechanism for dynamical proton-neutron pairing

Gamow-Teller resonance in Nickel

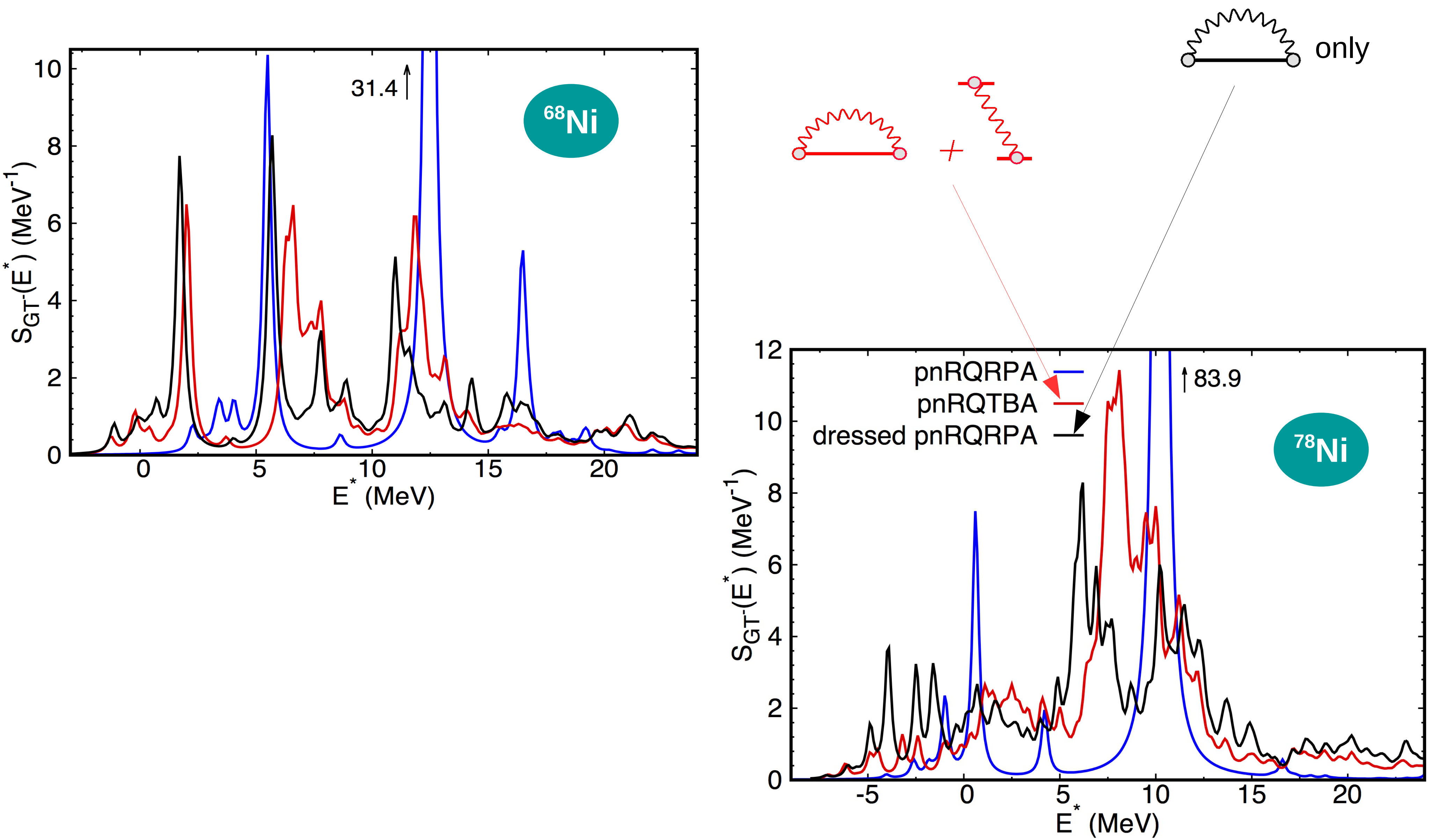


Gamow-Teller resonance in Nickel

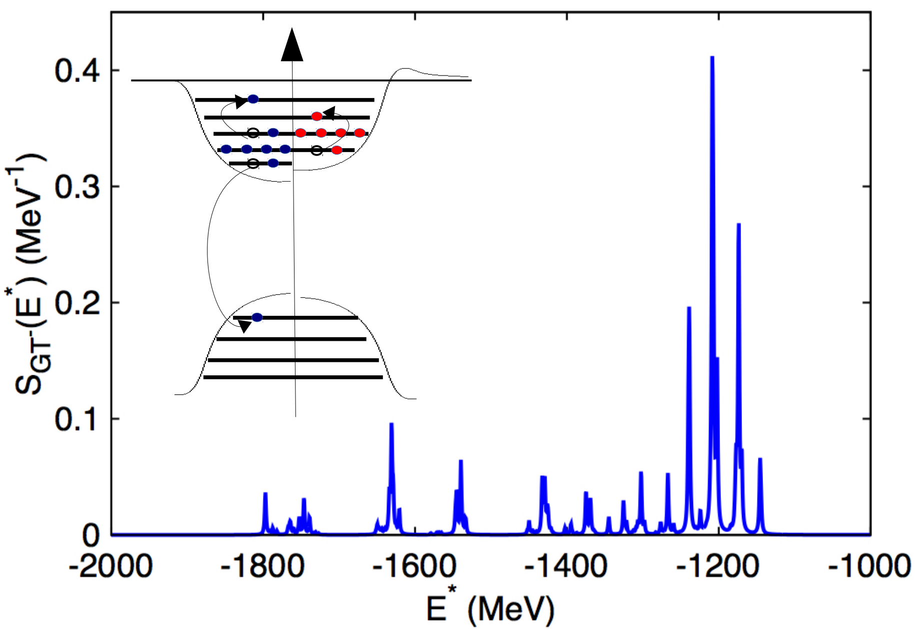


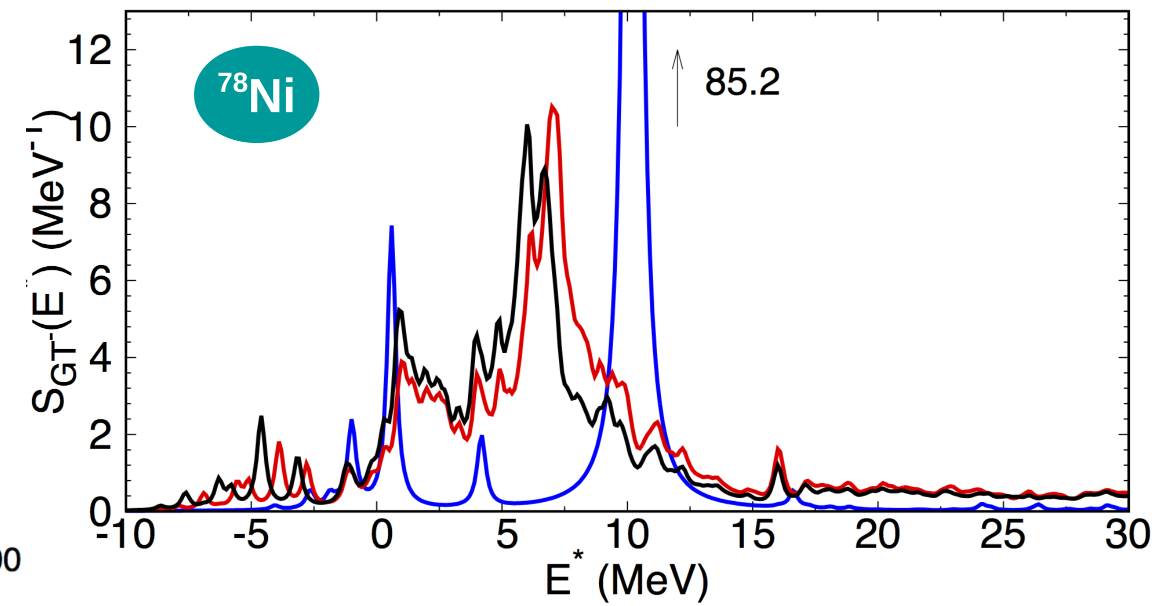
Gamow-Teller transitions in Nickel isotopes (Ni → Cu)

- Effect of phonon-exchange interaction vs self-energy insertions:



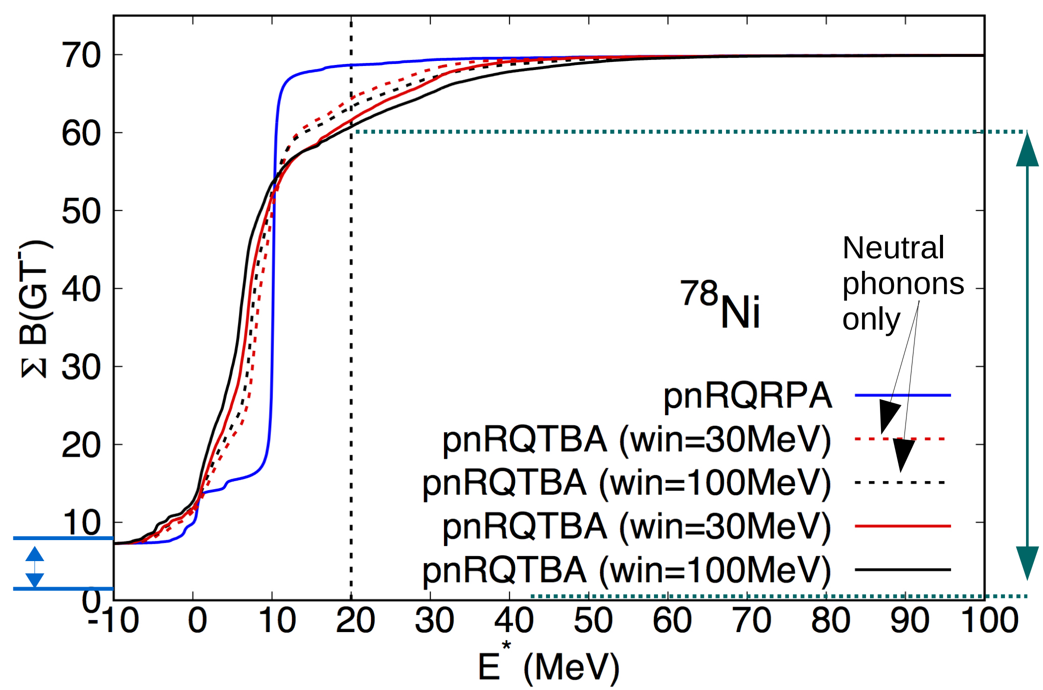
Gamow-Teller transitions and the “quenching” problem





+ transitions from the Fermi sea to the Dirac sea (~10%)

[N. Paar et al., PRC 69, 054303]

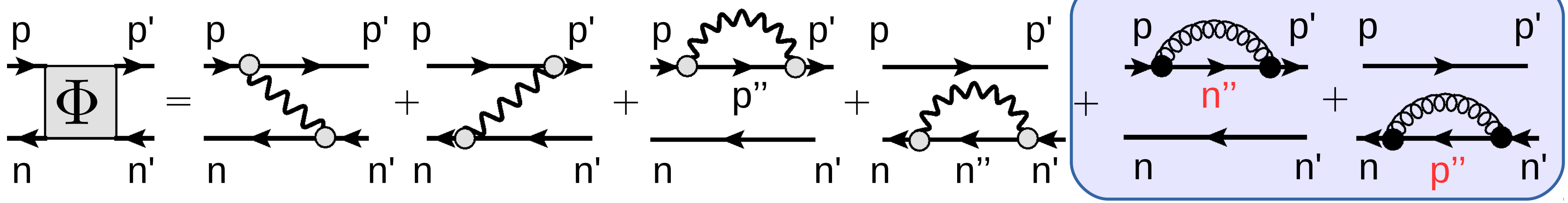


Up to the GR region: **~81%** (vs 97% in RQRPA) of the total GT_ strength

→ RQRPA strength naturally “quenched” due to complex configurations

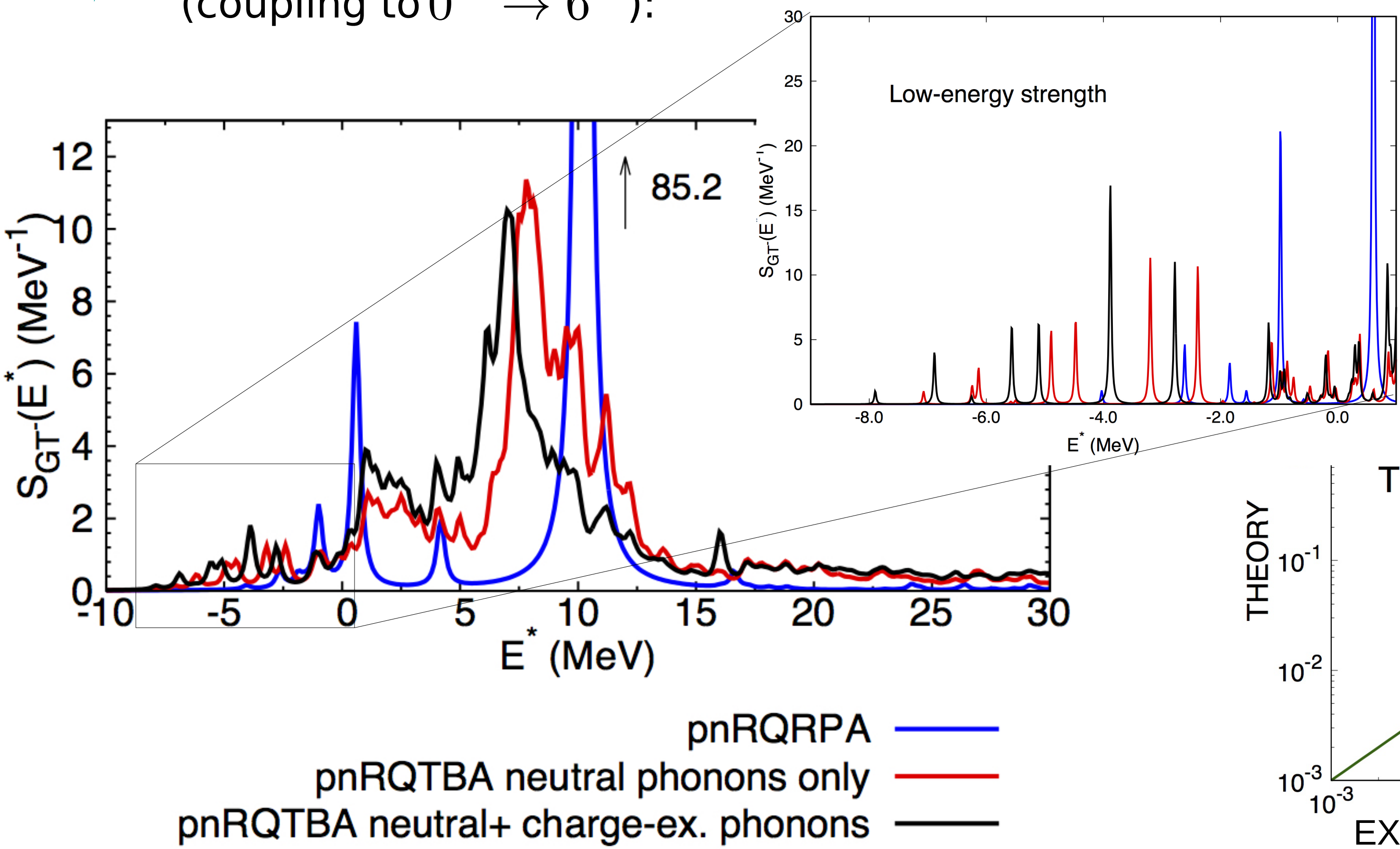
New-developments: coupling to charge-exchange phonons

Existence of low-energy isospin-flip modes which can couple to single-nucleon degrees of freedom → additional terms in the effective interaction:

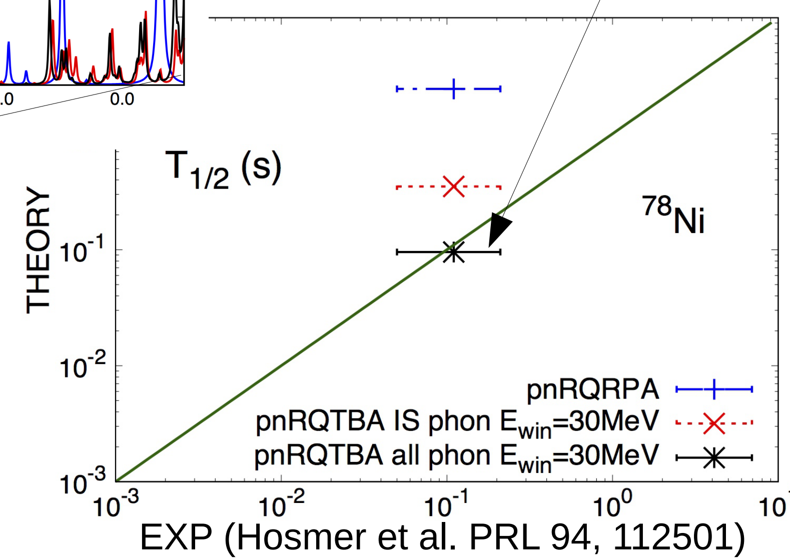


(No extra phonon-exchange term because of charge conservation)

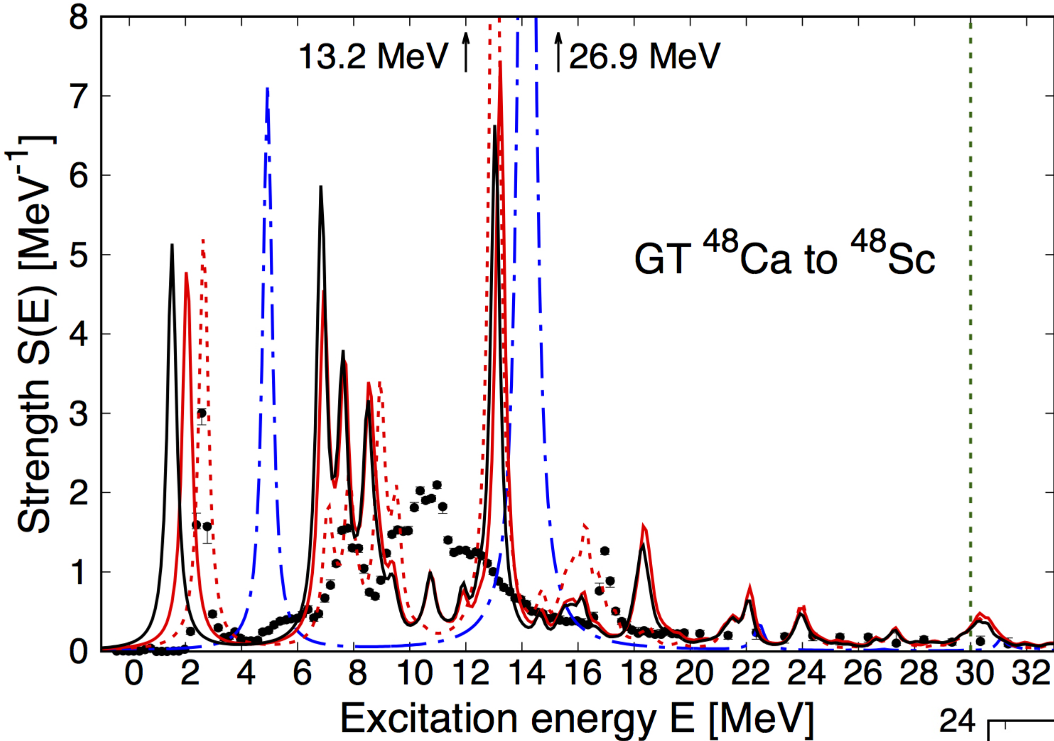
Effect on the nuclear response in ^{78}Ni:
(coupling to $0^{\pm} \rightarrow 6^{\pm}$):



Additional decrease of the half-life



Gamow-Teller transitions and the "quenching" problem



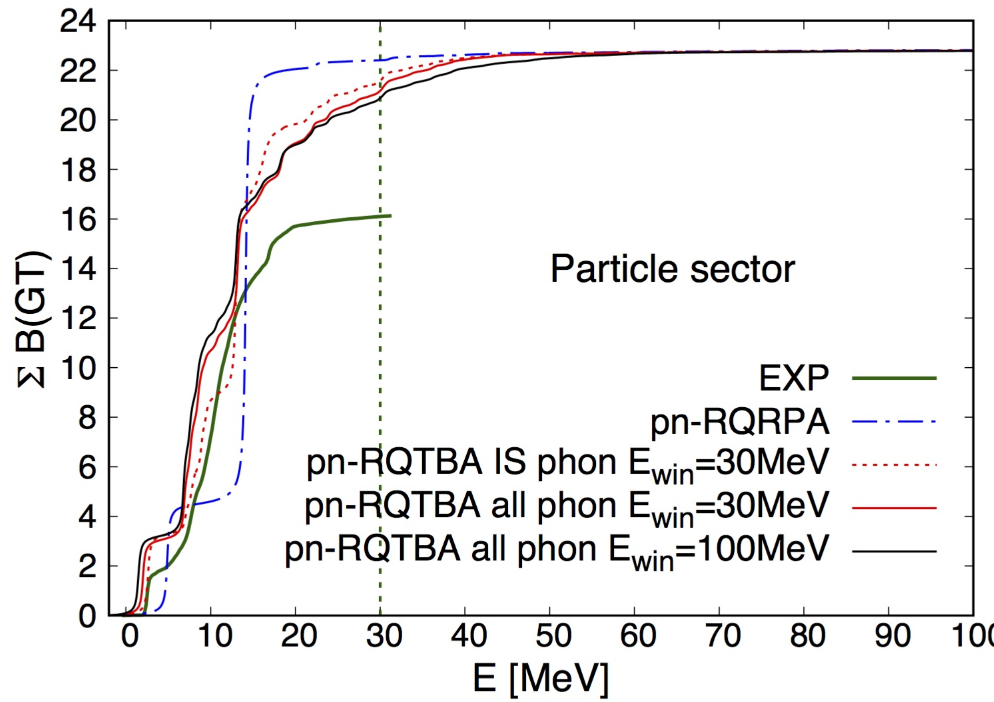
with QVC:

- more detailed description of the transition strength due to 2p-2h configurations
- "quenching" of the RPA strength in the experimental energy window due to fragmentation and redistribution

But not enough...

At 30 MeV:

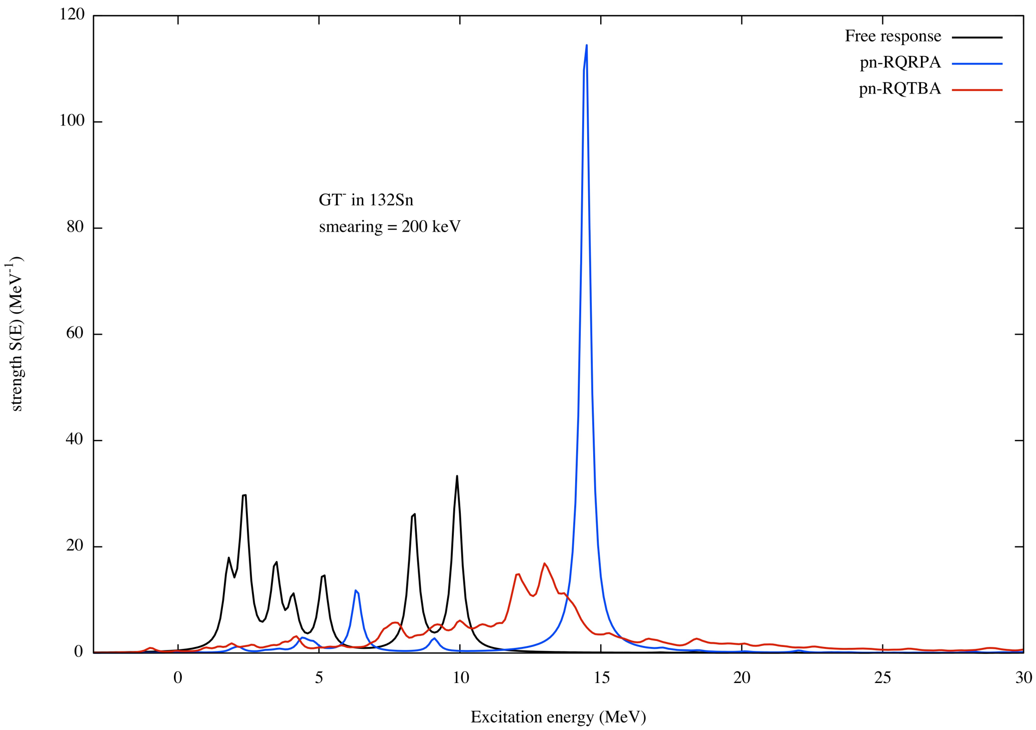
- RQRPA: quasi-saturated (98%)
- RQTBA: 91%
- Exp: ~71%

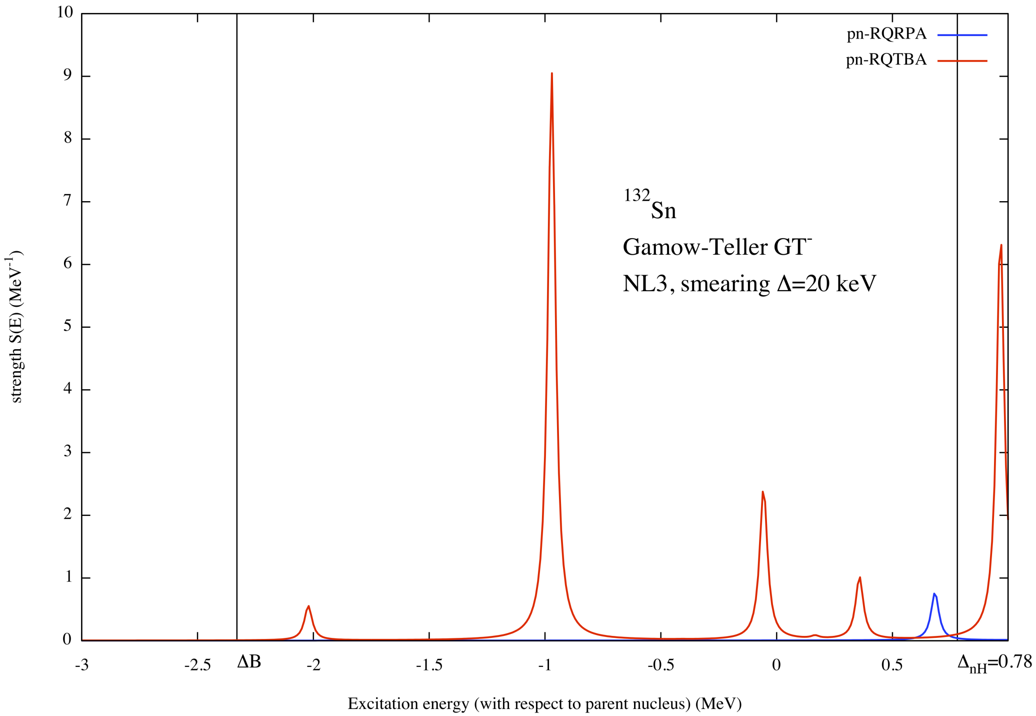


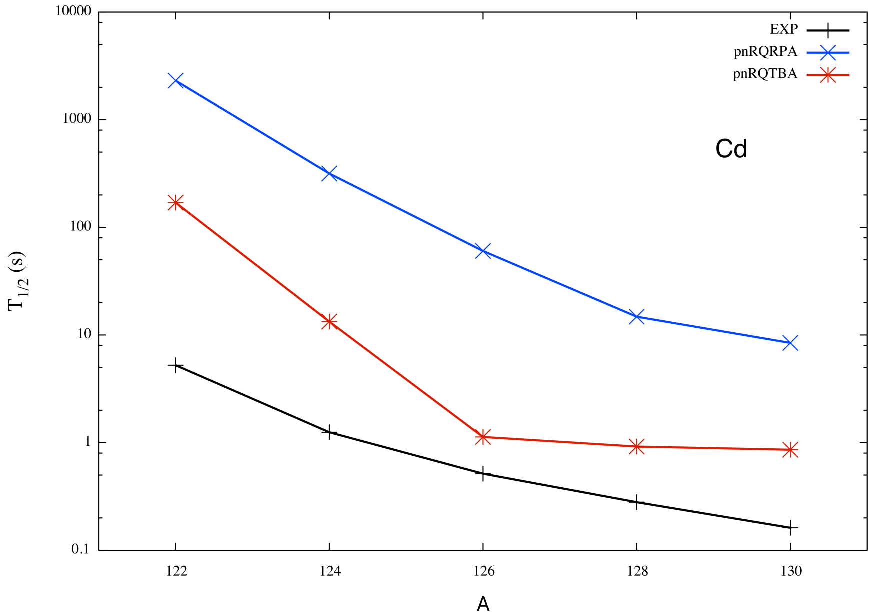
100% ?

EXP: K. Yako et al, PRL 103, 012503 (2009)

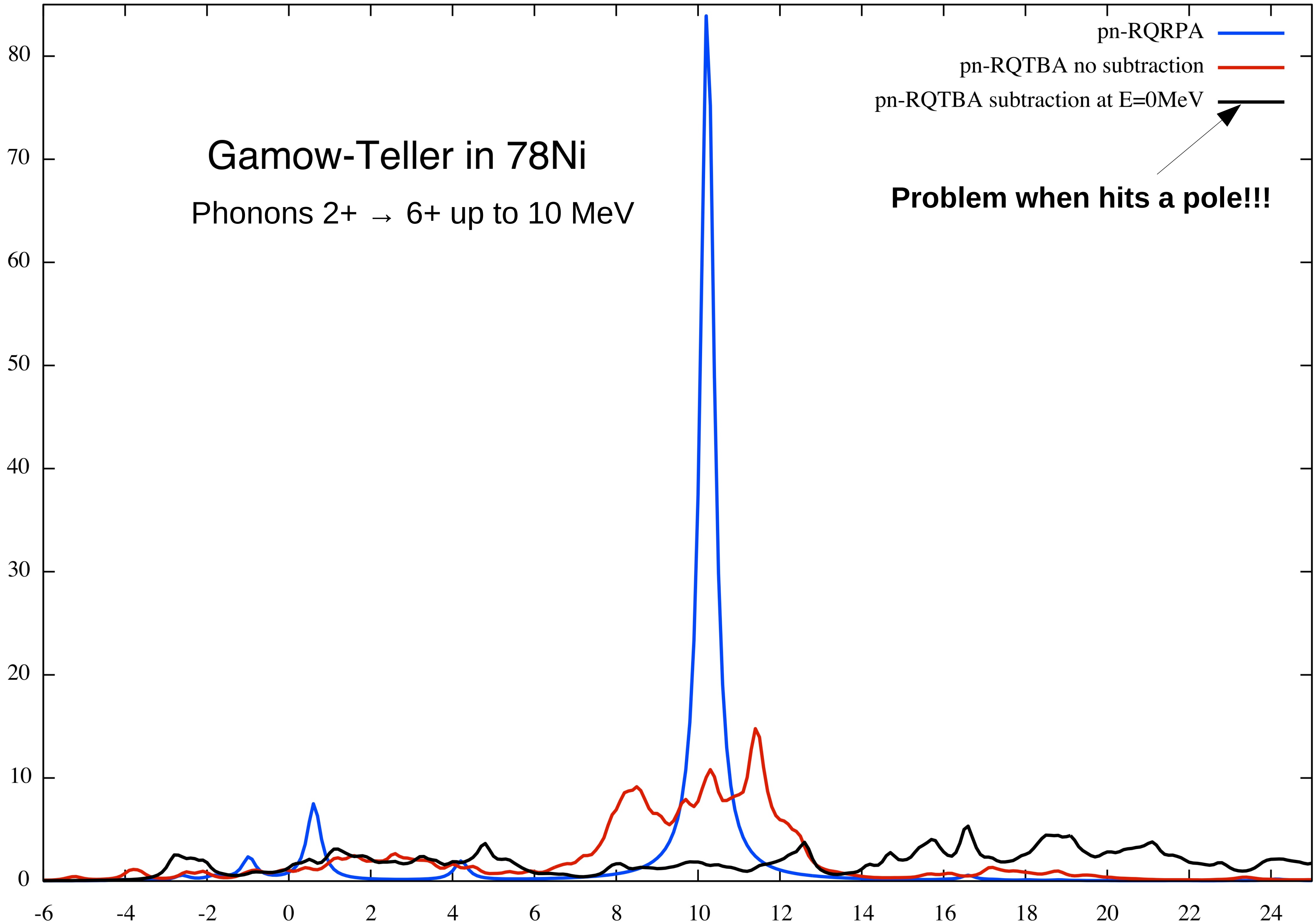
Other GT strengths and beta-decay half-lives



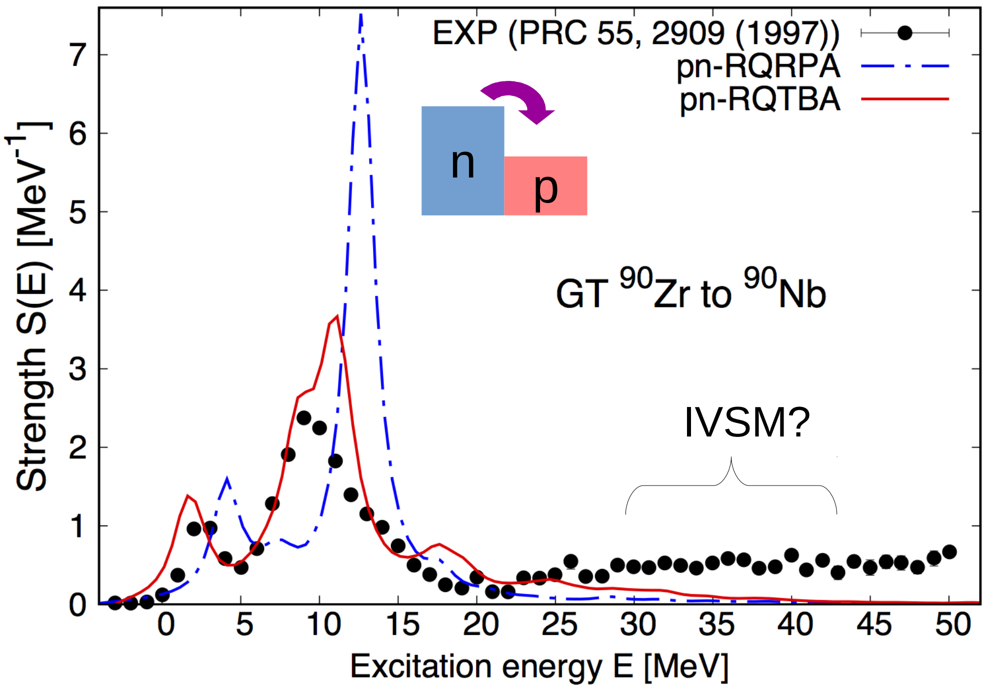


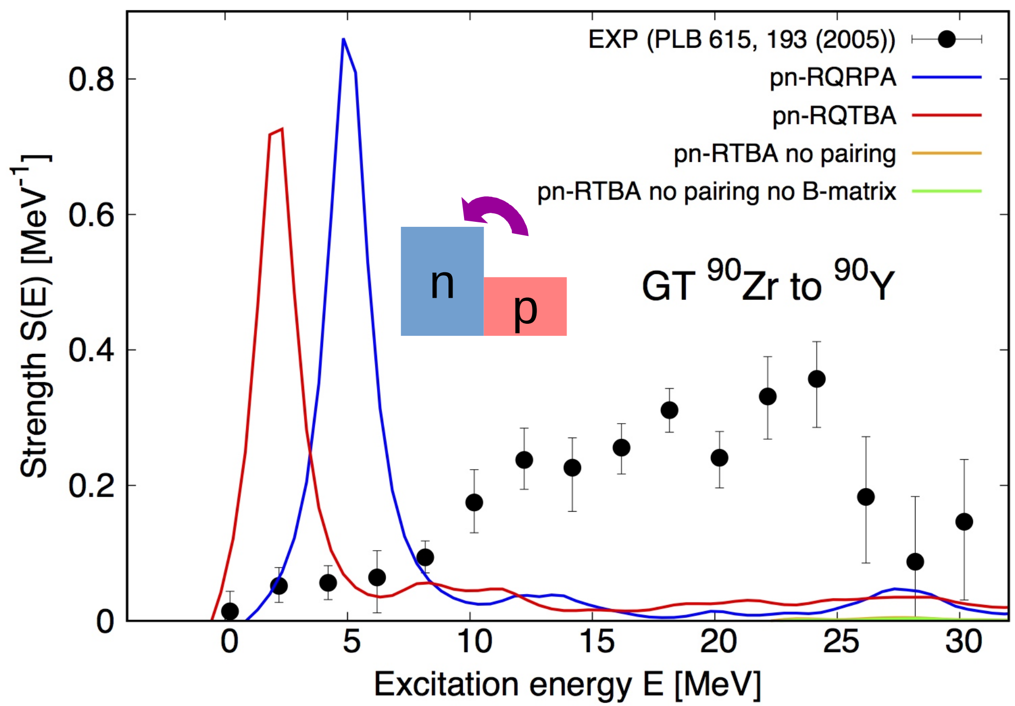


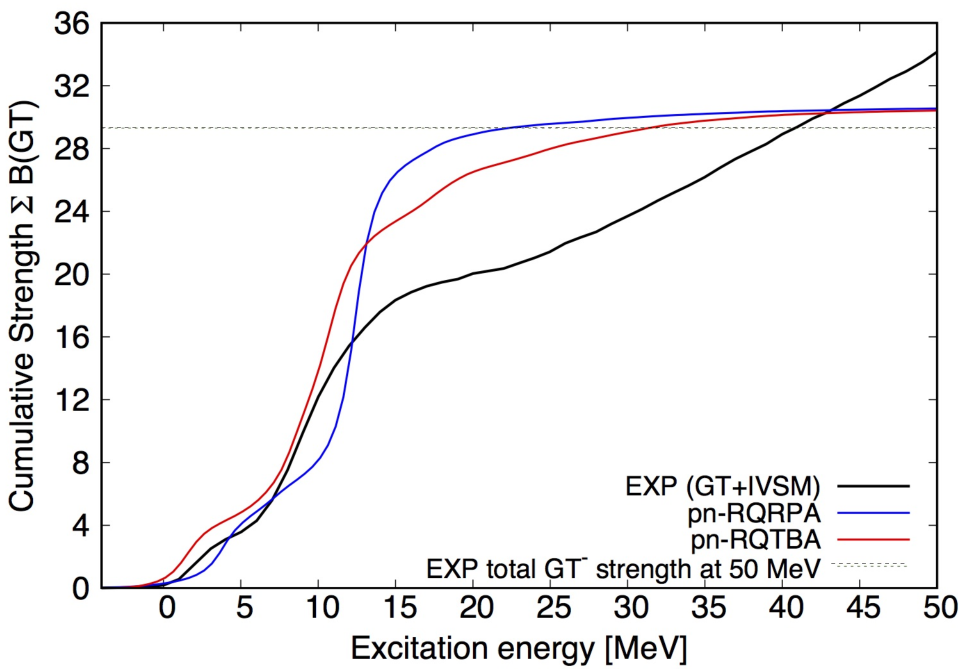
Gamow-Teller in ^{78}Ni

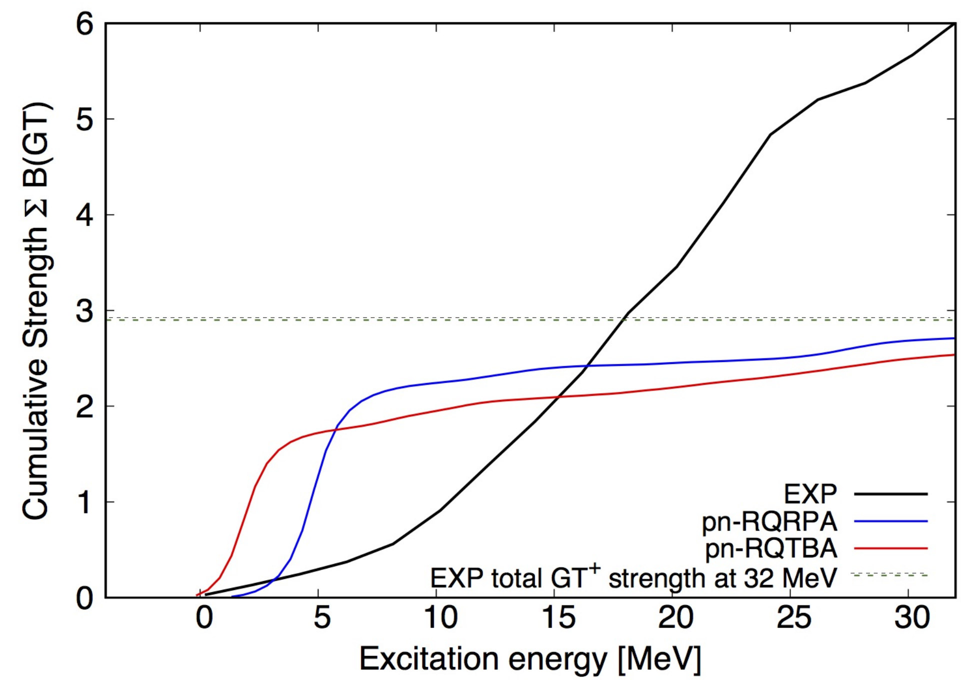


Gamow-Teller transitions and the “quenching” problem



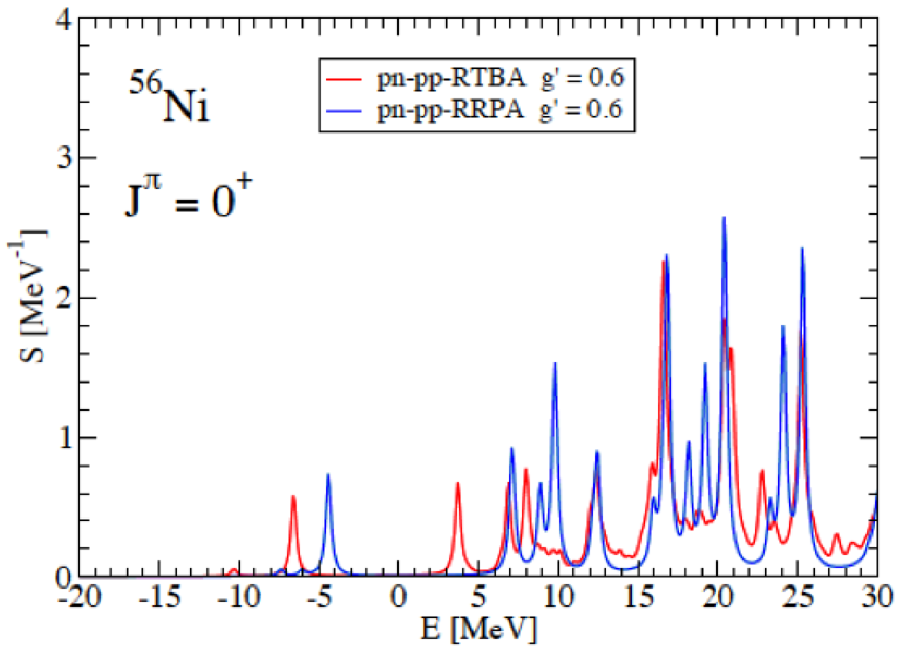


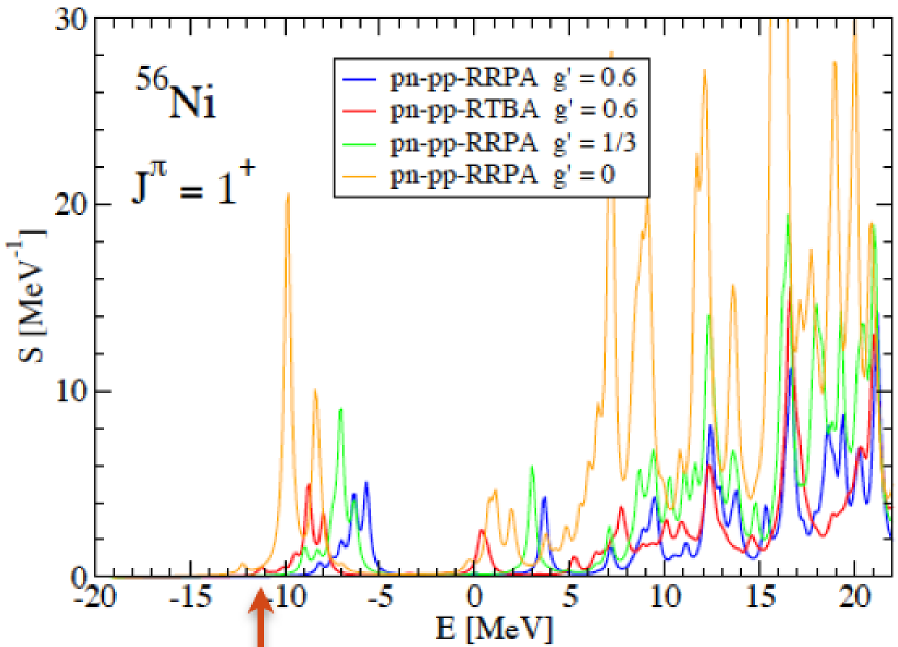




Response in proton-neutron particle-particle (deuteron transfer) channel: quest for deuteron condensate and pn-pairing

$^{56}Ni \rightarrow {}^{58}Cu$



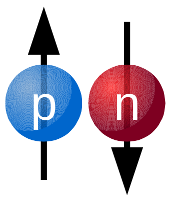


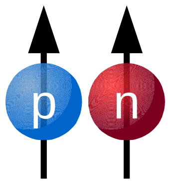
Ground state of 58Cu (odd-odd)

E.L., C. Robin, I. Egorova, arXiv:1612:09182

- *Spectra of odd-odd nuclei including their ground states can be calculated in pn-pp-RTBA*
- *Presently in medium-mass N=Z nuclei no deuteron condensate is found at realistic values of g', but the low-lying excitation modes are collective and can mediate T=1 and T=0 proton-neutron dynamical pairing*

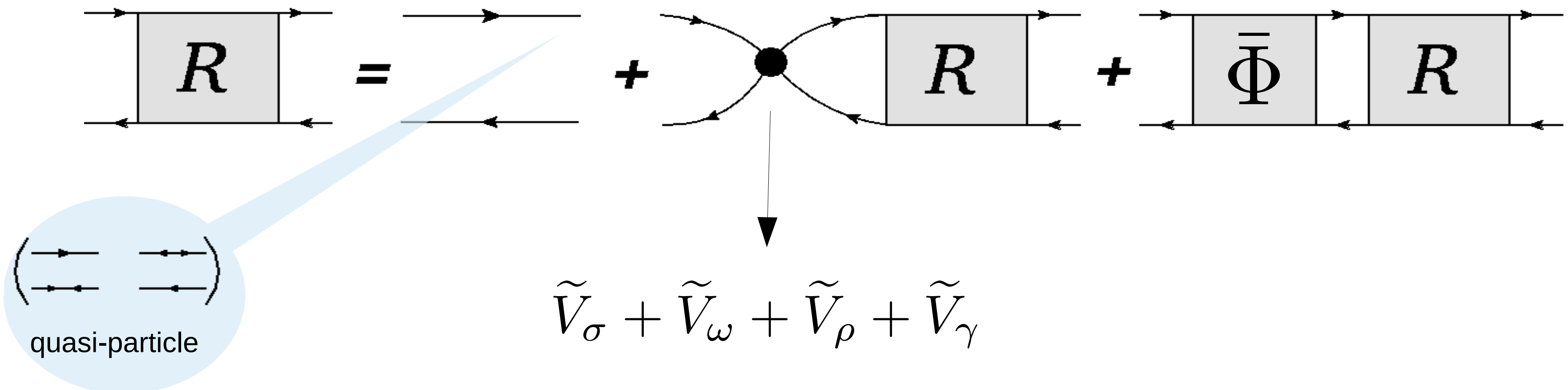
Work in progress



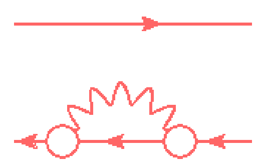


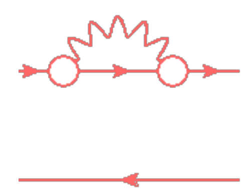
A few results in the ph neutral (ΔT_z=0) channel

- Response in the neutral ph channel:

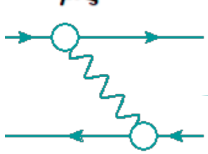


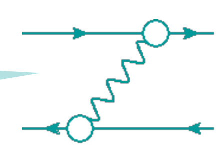
$$\widetilde{V}_\sigma + \widetilde{V}_\omega + \widetilde{V}_\rho + \widetilde{V}_\gamma$$





$$\Phi^{\eta}_{k_1 k_4, k_2 k_3}(\omega) = \sum_{\mu\xi} \delta_{\eta\xi} \Bigg[\delta_{k_1 k_3} \sum_{k_6} \frac{\gamma^{\eta;-\xi}_{\mu;k_6 k_2} \gamma^{\eta;-\xi*}_{\mu;k_6 k_4}}{\eta\omega - E_{k_1} - E_{k_6} - \Omega_\mu} + \delta_{k_2 k_4} \sum_{k_5} \frac{\gamma^{\eta;\xi}_{\mu;k_1 k_5} \gamma^{\eta;\xi*}_{\mu;k_3 k_5}}{\eta\omega - E_{k_5} - E_{k_2} - \Omega_\mu}$$
$$- \left(\frac{\gamma^{\eta;\xi}_{\mu;k_1 k_3} \gamma^{\eta;-\xi*}_{\mu;k_2 k_4}}{\eta\omega - E_{k_3} - E_{k_2} - \Omega_\mu} + \frac{\gamma^{\eta;\xi*}_{\mu;k_3 k_1} \gamma^{\eta;-\xi}_{\mu;k_4 k_2}}{\eta\omega - E_{k_1} - E_{k_4} - \Omega_\mu} \right) \Bigg];$$





The role of the low-lying dipole strength (pygmy dipole resonance)

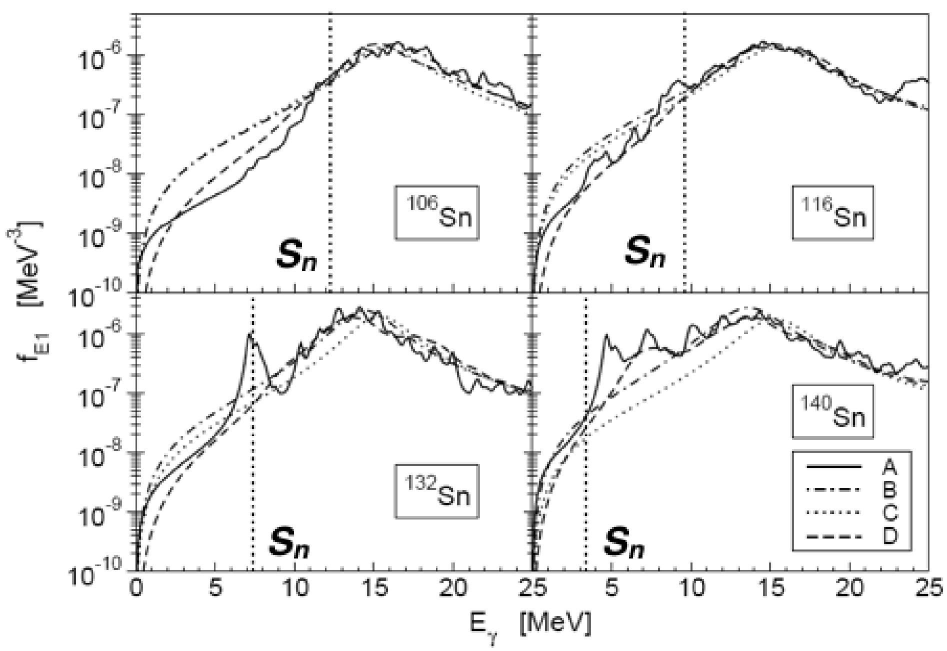
Microscopic strength and conventional GDR parametrizations

A ——— *RQTBA*

B —·—·—·— *Lorentzian fit to RQTBA*

C ········ *Lorentzian fit to Exp.: J.J. Cowan, F.-K. Thielemann, J.W. Truran, Phys. Rep. 208, 267 (1991)*

D - - - - - *Skyrme+QRPA, S. Gorieli, E. Khan, NPA 706, 217 (2002)*

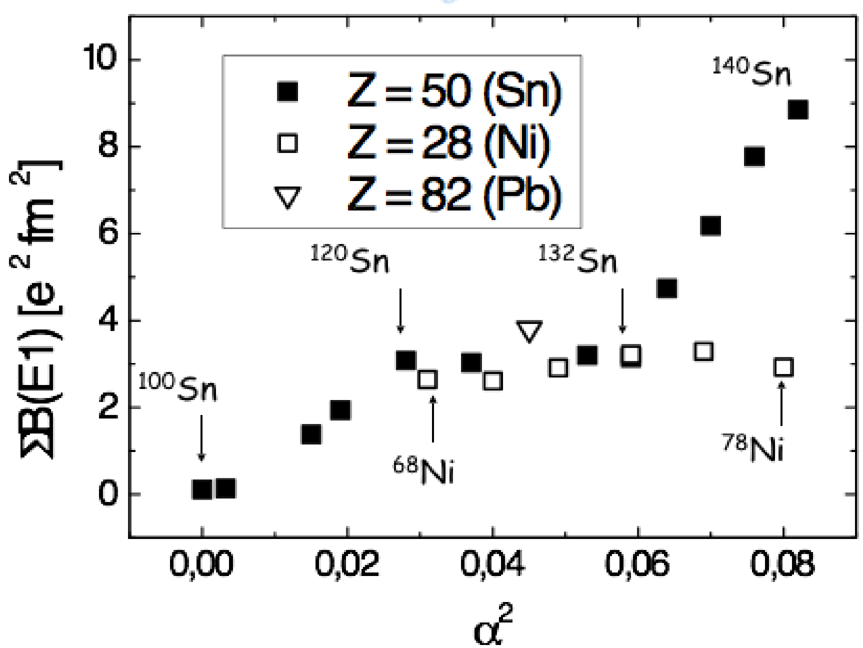


E. L., H.P. Loens, K. Langanke et al., Nucl. Phys. A 823, 26 (2009)

Total PDR strength vs asymmetry parameter α:

$\alpha = (N-Z)/A$

RQTBA systematics: nearly linear dependence on α with deviations around shell closures with intruder orbits



E. L., P. Ring, V. Tselyaev, K. Langanke, Phys. Rev. C 79, 054312 (2009)