Extensions of CEDFT relevant for SHN

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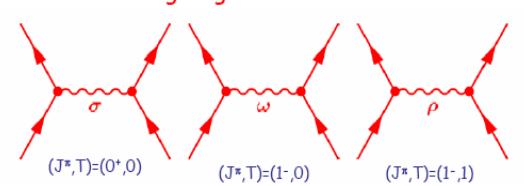
In Collaboration with P. Ring (Munich), V. Tselyaev (St. Petersburg)

Building blocks

I. Covarant energy density functional (CEDF) theory (P.Ring et al.)

The nuclear fields are obtained by coupling the nucleons through the exchange of effective mesons through an effective Lagrangian.



$S(\mathbf{r}) = g_\sigma \sigma(\mathbf{r})$ $\quad V(\mathbf{r}) = g_\omega \omega(\mathbf{r}) + g_\rho \vec{\tau}\vec{\rho}(\mathbf{r}) + eA(\mathbf{r})$

Sigma-meson: attractive scalar field

Omega-meson: short-range repulsive

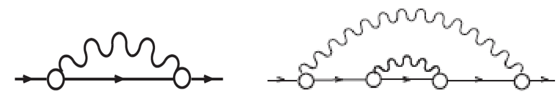
Rho-meson: isovector field

E[R] (7-9 parameters)

Self-consistent Extensions

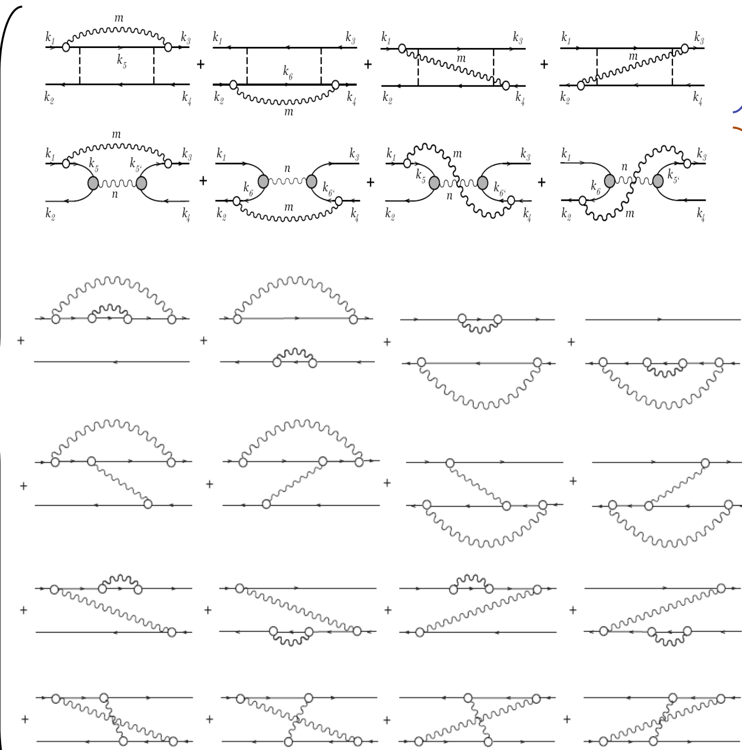
II. „Correlations“: Quasiparticle-vibration Coupling derived SC by field theory technique (Extensions of Landau-Migdal theory)

Single-particle motion:



Nuclear Response:

(Excitation spectra of collective and non-collective nature



40 years experience of several groups!

Last 3 years

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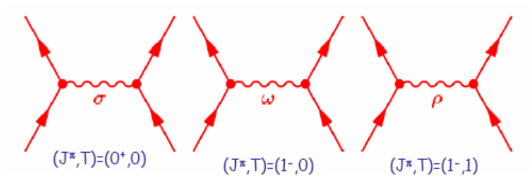

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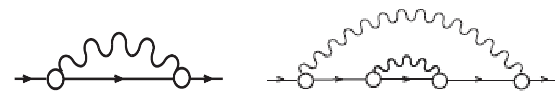

A. Bohr , B. Mottelson (idea)

V. G. Soloviev et al. (Dubna)

S. Kamerdzhiev, V. Tselyaev et al. (Obninsk)

G. Bertsch, P.-F. Bortignon, R. Broglia et al. (Milano)

Maxaux et al. (Brussels)

J. Speth et al. (Julich)

N. Van Giai et al. (Orsay)

P. Ring et al. (Munich)

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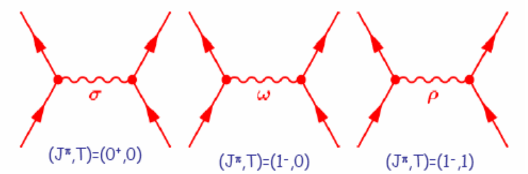

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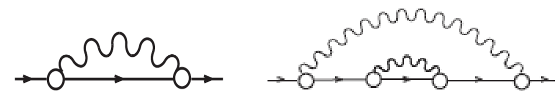

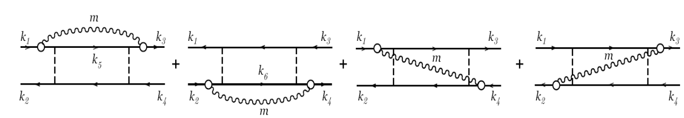

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G. Bertsch, P.-F. Bortignon, R. Broglia et al. (Milano)

J. Speth et al. (Julich)

E. Litvinova, V. Tselyaev, PRC (2007):
Generalized to superfluid nuclei,
Implemented numerically including continuum

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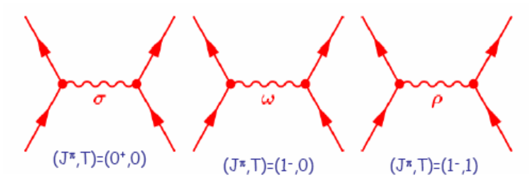

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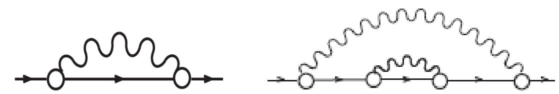

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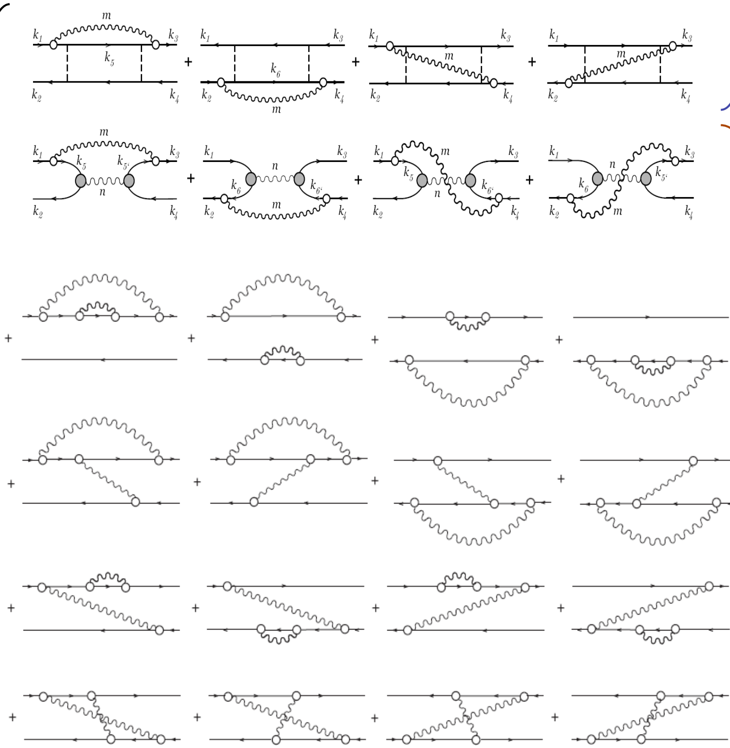

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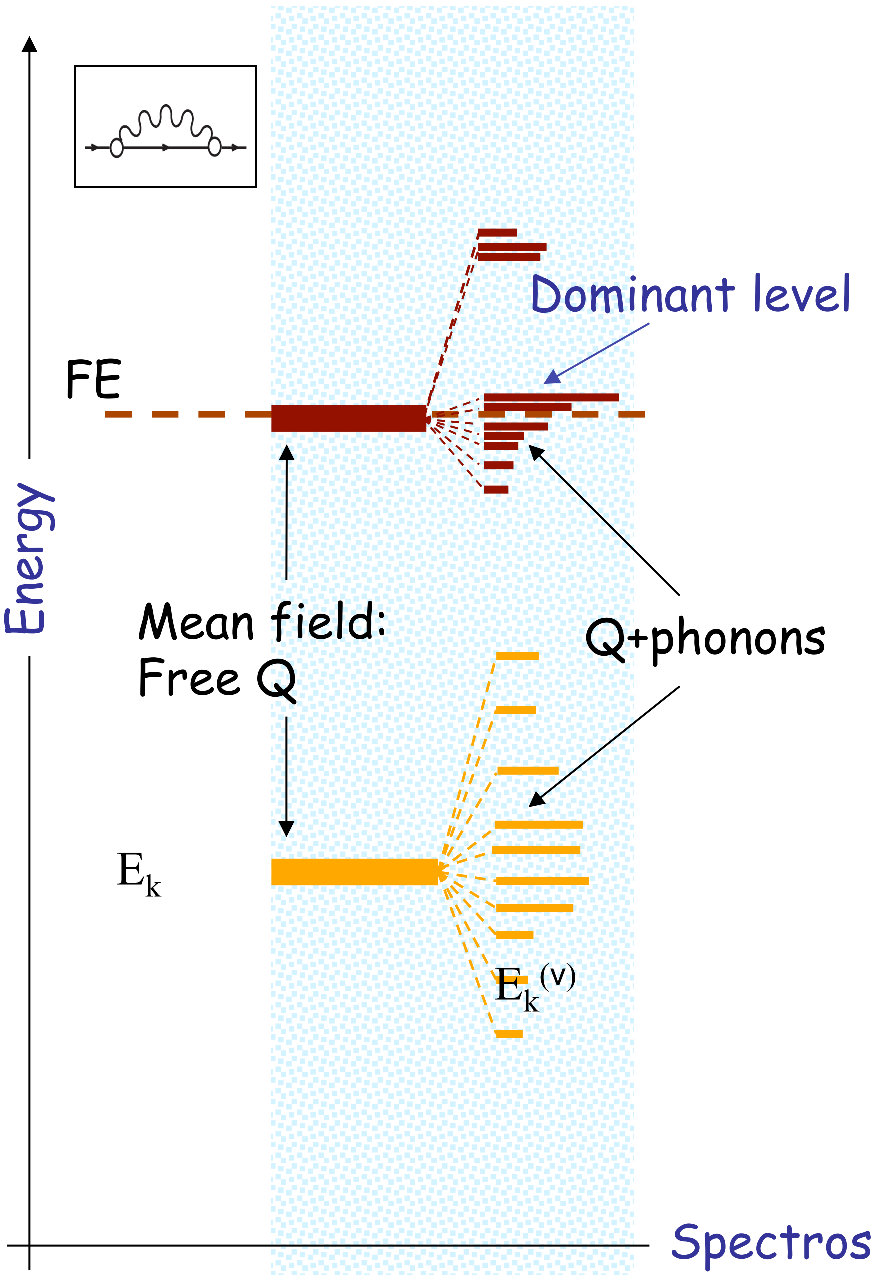
Last 3 years

~ 30 publications since 2006

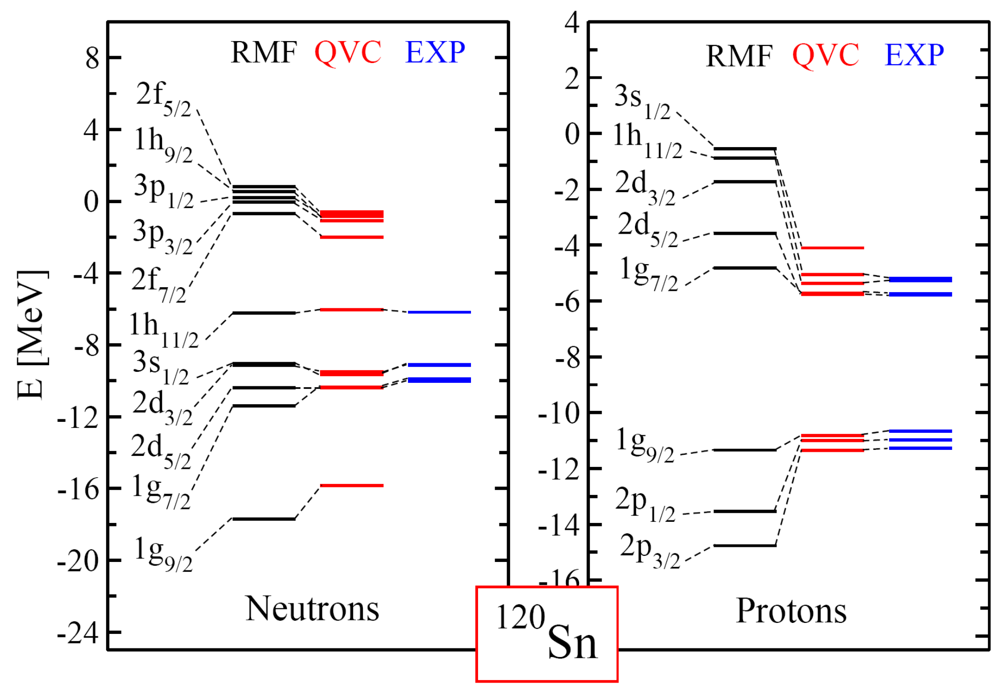
Quasiparticle-vibration coupling:
Pairing correlations of the superfluid type + coupling to phonons



Dominant single-quasiparticle levels: (spherical)

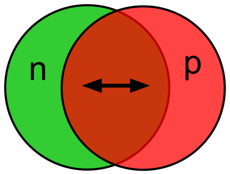
Open shell

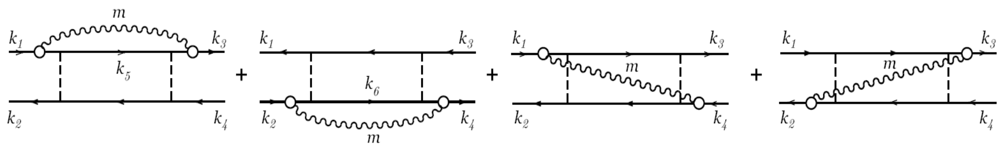
Closed shell

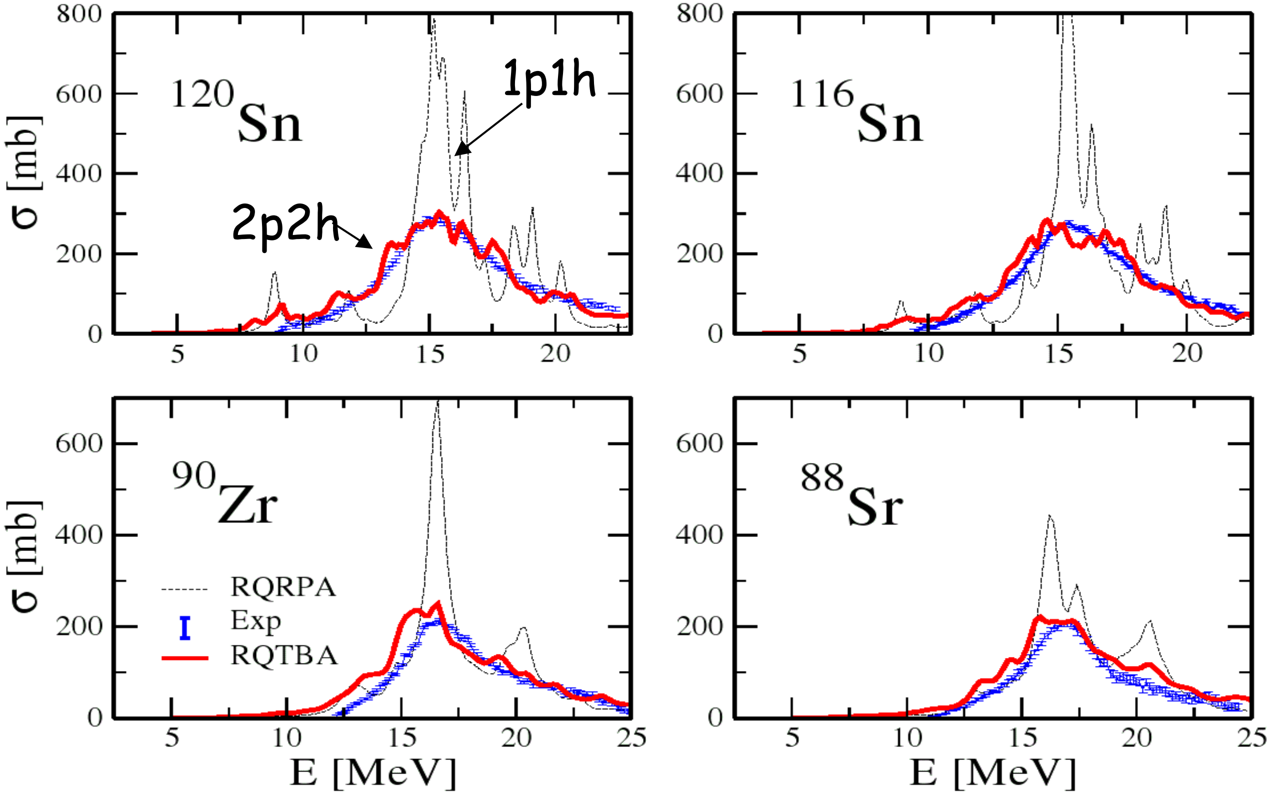


E.L., PRC 85, 021303(R)(2012)

Damping of Giant Dipole Resonance: Beyond relativistic QRPA







Many successful applications to various types of giant resonances

From spreading widths - to transport coefficients?

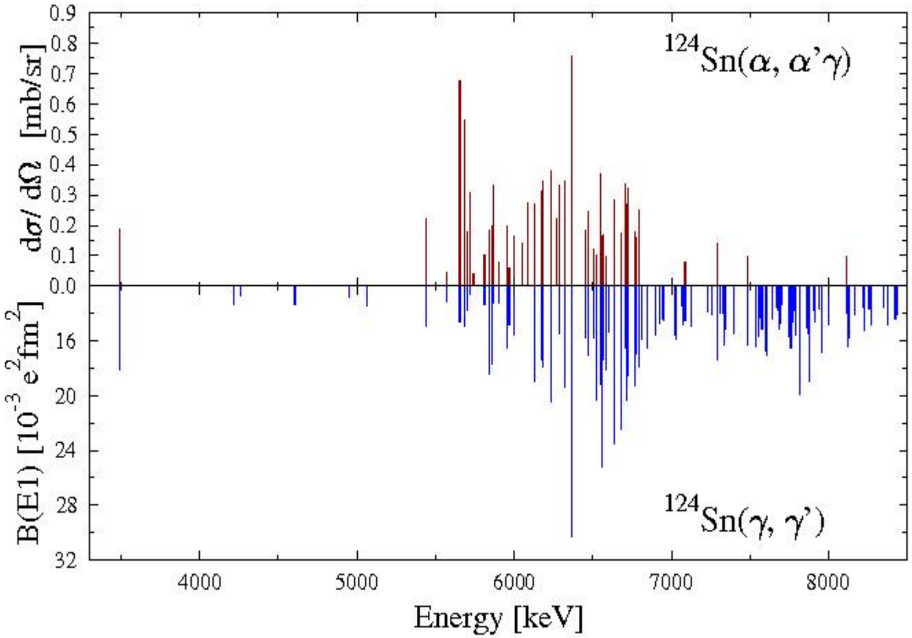
Other ingredients for reaction theory?

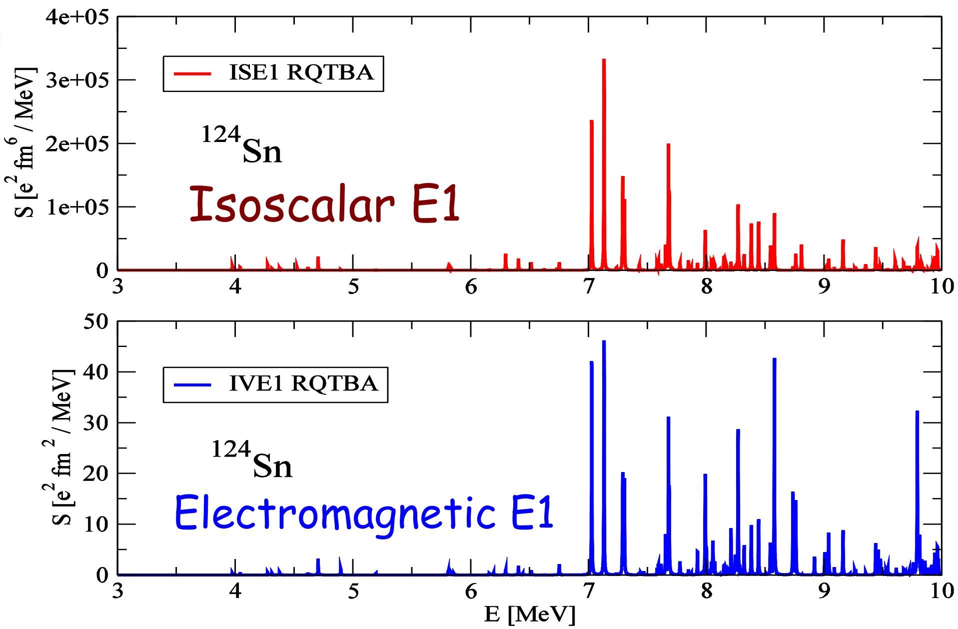
E. Litvinova, P. Ring, and V.Tselyaev, Phys. Rev. C 78, 014312 (2008)

Isospin structure of low-lying dypole strength

Experiment:
J. Endres, D. Savran, A. Zilges et al.

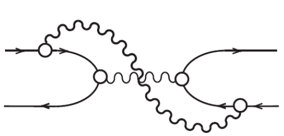
Theory: Relativistic quasiparticle time blocking approximation





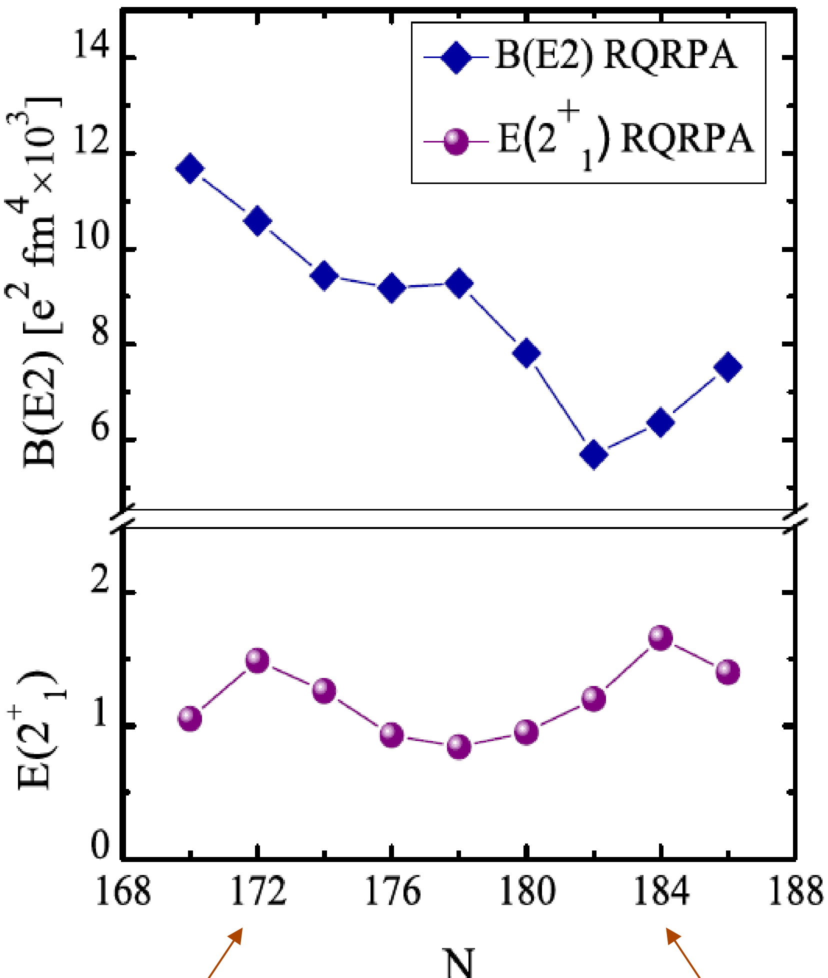
J. Endres, E. Litvinova, D. Savran et al., PRL 105, 212503 (2010)

E. Litvinova, P.Ring, V.Tselyaev, PRL 105, 02252 (2010)
(two-phonon diagrams included)



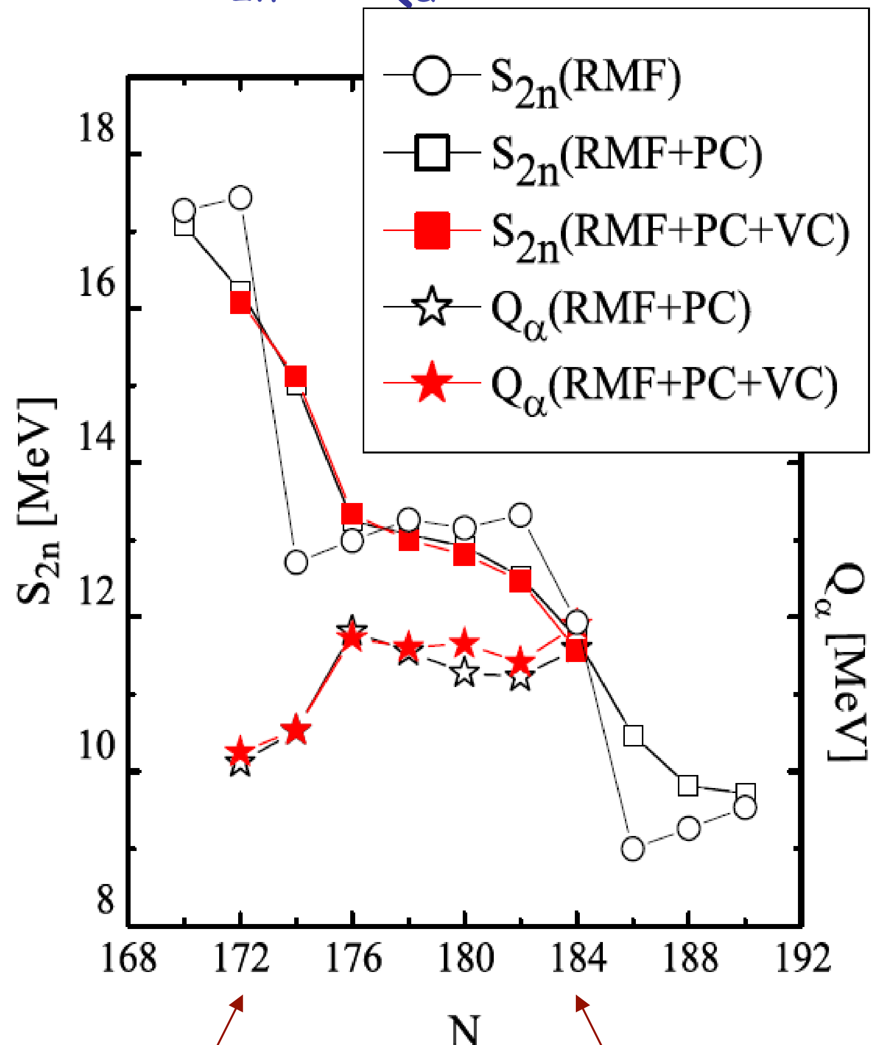
Structure studies for Z = 120

Lowest 2+ states



without QVC

S_{2n} & Q_α

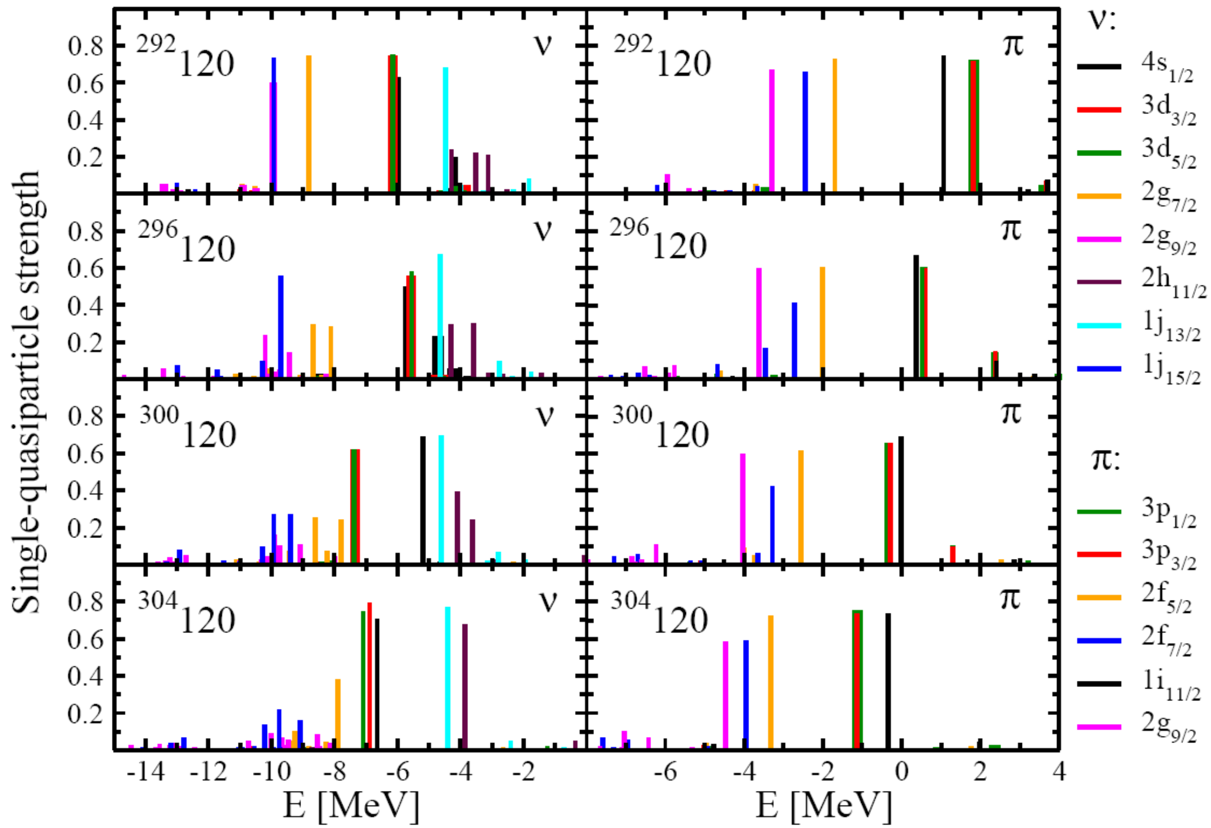


Shell evolution in superheavy Z = 120 isotopes: Quasiparticle-vibration coupling (QVC) in a relativistic framework

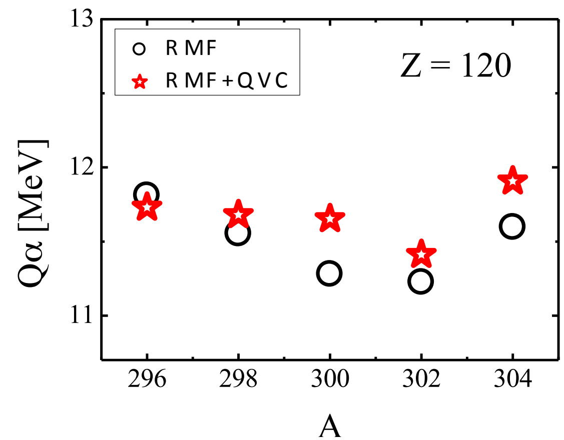
1. Relativistic Mean Field: spherical minima
2. π: collapse of pairing, clear shell gap
3. ν: survival of pairing coexisting with the shell gap
4. Very soft nuclei: large amount of low-lying collective vibrational modes (~100 phonons below 15 MeV)

Vibration corrections to binding energy (RQRPA)

$$E_{VC} = -\sum_{\mu} \Omega_{\mu} \sum_{k_1 k_2} |Y^{\mu}_{k_1 k_2}|^2$$



Vibration corrections to α-decay Q-values



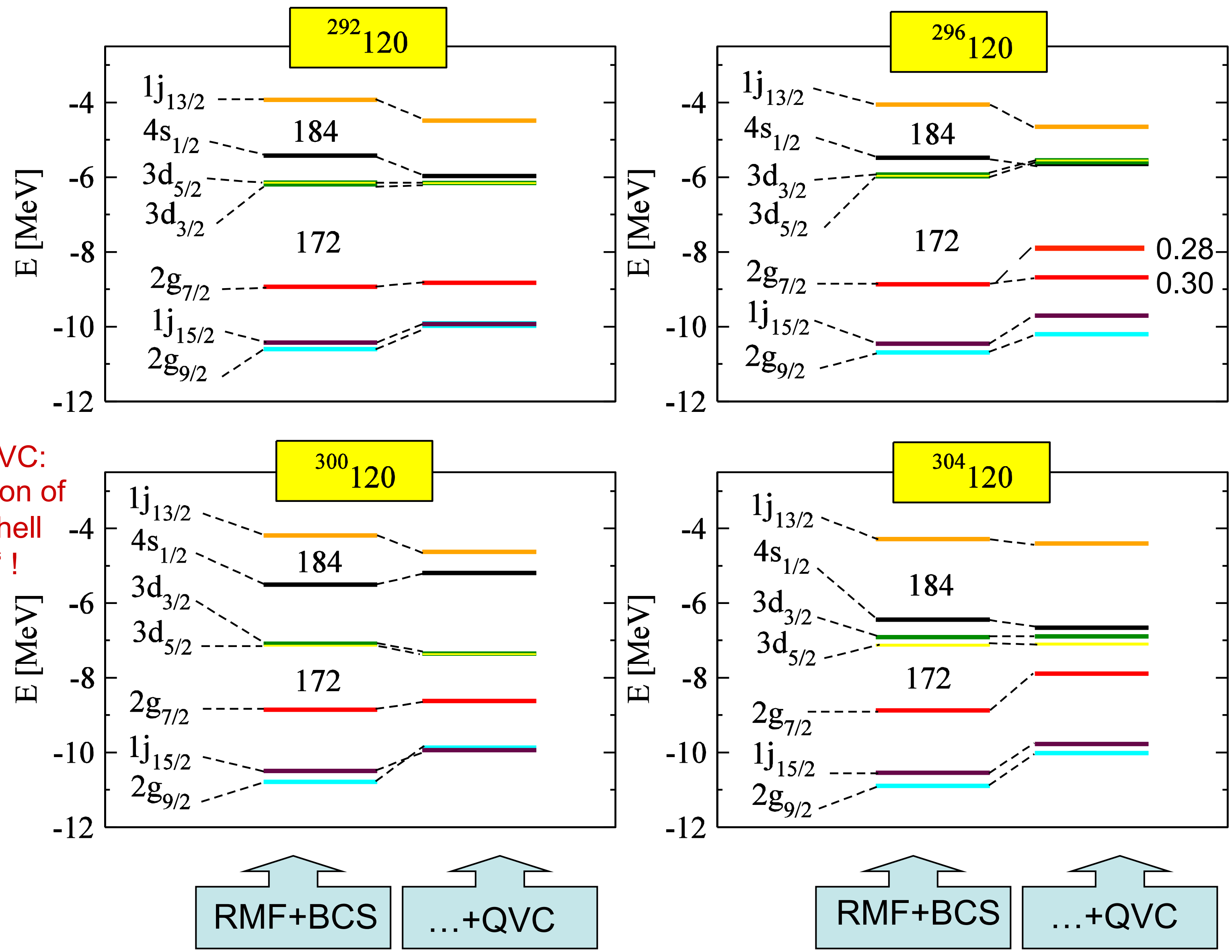
Vibrational corrections:

1. Impact on the shell gaps
2. Smearing out the shell effects

Shell stabilization & vibration stabilization/destabilization (?)

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

Dominant neutron states in Z = 120



Comparable Spectroscopic strengths

PC+QVC: Formation of the „shell gap“ !

Outlook

- The concept „CEDF + vibrational correlations": only ~ 4 years of experience, but many successful applications to nuclear structure.

- Provides collective excitations, single-quasiparticle structure. Nuclear response function (includes damping mechanisms microscopically) can (potentially) help for description of fusion dynamics.

- Coupling to rotational degrees of freedom: an extension to deformed case is in progress. CEDFT is already working very well in SH mass region at the mean field level for fission barriers (A. Afanasjev), alpha-decay Q-values (G. Lalazissis), as GCM for low-lying states (T. Niksic, V. Prassa, D. Vretenar) etc., so we expect only improvements.

- The approach is stable, microscopic, self-consistent, universal (8 universal parameters), the correlations are taken into account by the diagrams. There are 100's of diagrams, but the basic techniques are well developed.

- Room for improvements: next-order diagrams for fine effects, „better" functionals.