

22/04/13

ZPF and Pauli principle at the basis of medium polarisation effects: self-energy, vertex corrections and induced interaction ①

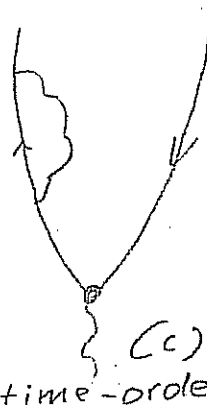
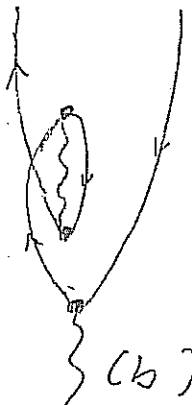
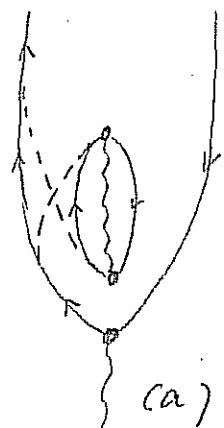
In keeping with a central objective of the formulation of quantum mechanics, namely that the ~~central~~<sup>basic</sup> concepts on which it is based relate directly to experiment, elementary modes of nuclear excitation (single-particle, collective vibrations and rotations), are solidly anchored on observation (inelastic and Coulomb excitations, one- and two-particle transfer reactions).

Of all quantal phenomena, zero point fluctuations (ZPF), <sup>closely connected with virtual state,</sup> are likely to be most representative of the essential differences existing between quantum and classical mechanics. In fact, ZPF are intimately connected with the complementary principle (Bohr), and thus with the indeterminacy (Heisenberg) and non-commutative (Born, Jordan) relations, and with the probabilistic interpretation (Born) of the (modulus squared) of the wavefunction. ~~These are the essential differences existing between quantum and classical mechanics.~~ of the wavefunctions, solution of Schrödinger's or Dirac's equations.

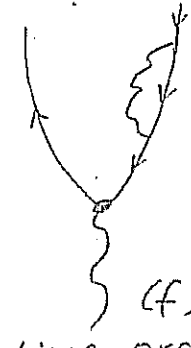
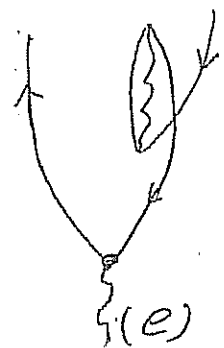
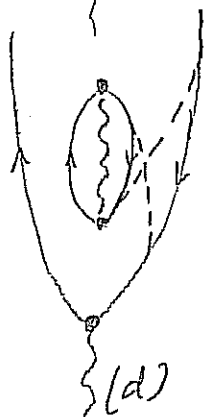
Pauli principle brings about essential modifications of the virtual fluctuations

of the many-body ~~system~~ system, 22/04/13 (2)  
modifications which are instrumental  
in the dressing and interweaving  
of the elementary modes of excita-  
tion (see Figs. A and B; ~~within~~ within  
~~the~~ the present context, see also  
J.R. Schrieffer, Theory of superconductivi-  
ty, Benjamin, N.Y (1964) p. 134).

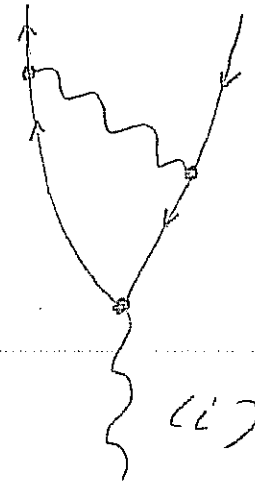
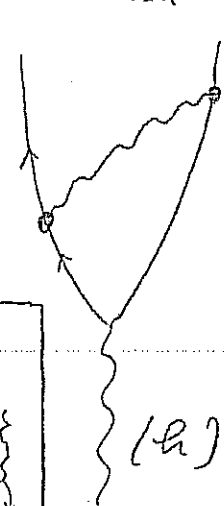
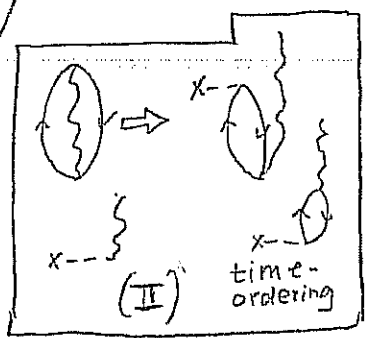
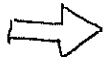
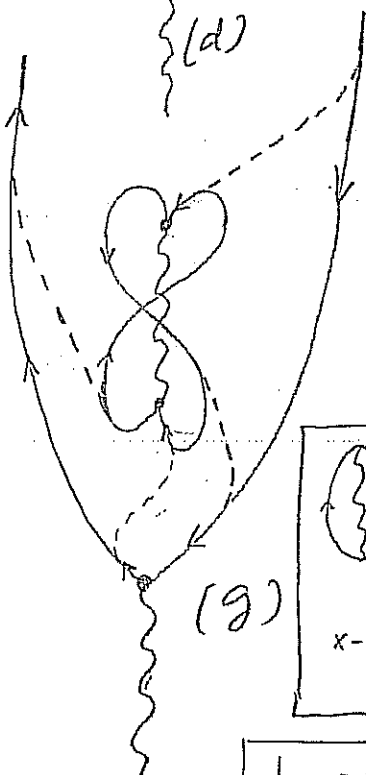
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time-ordering  
self-energy

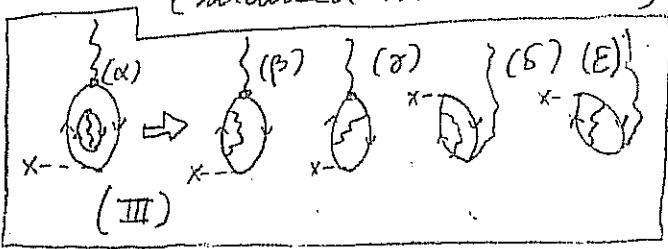


time-ordering  
self-energy



time-ordering

vertex correction  
(reduced interaction)



- ↑ particle
- ↓ hole (I)
- ⋈ (p-ph) vibration
- particle-(ph) vibr. vertex

Fig. A

Caption Fig. A

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(4)

Nuclear field theory (NFT) diagrams corresponding to the lowest order medium polarization effects renormalizing the properties of a particle-hole collective mode <sup>(curly line)</sup>, linear combination of particle-hole <sup>(up-going) - (down-going) arrowed lines</sup> excitations calculated within the random phase approximation (RPA) in of a bare interaction, and leading to the particle vibration coupling vertex (solid dot, see inset (I), bottom). The action of an external field on the zero point fluctuations (ZPF) of the vacuum (inset (II)), forces a virtual process to become real, leading to a collective vibration by annihilating a (virtual, spontaneous) particle-hole excitation (backwards going RPA amplitude) or, in the time ordered process, by creating a particle-hole excitation which eventually, through the particle-vibration coupling vertex, correlate into the collective (coherent state; forwards going amplitudes). Now, oyster-like diagrams associated with the vacuum ZPF can occur at any time (see inset III). Because the texture of the vacuum is permeated by symmetry rules (while one can violate <sup>conservation</sup> energy in a virtual state one cannot violate e.g. angular momentum or the Pauli principle), the process shown in the inset III (a) leads, through Pauli principle

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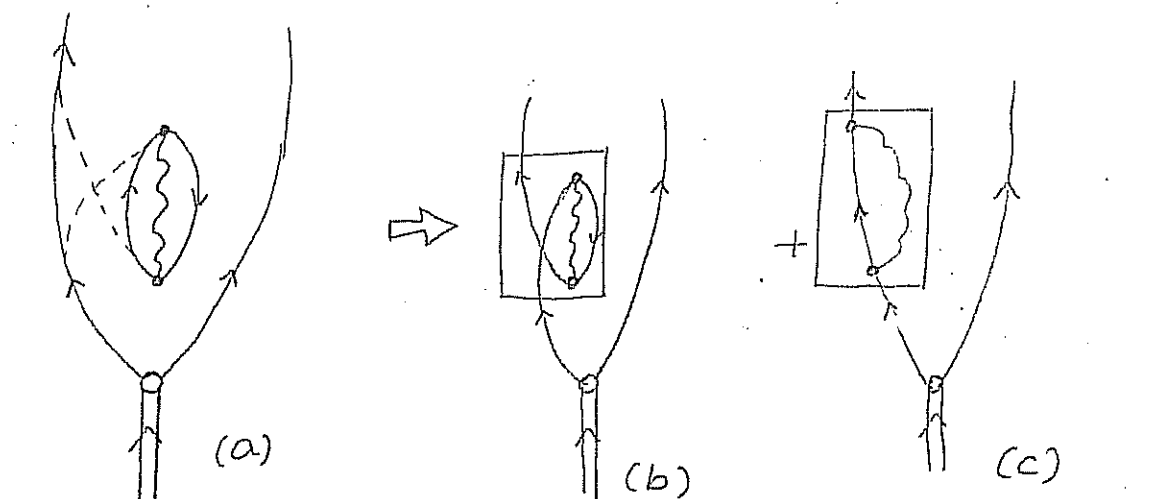
correcting processes (exchange of fermionic arrowed lines) to self-energy (inset III (β), (δ)) and vertex corrections (induced p-h interaction; inset III (γ), (ε)) processes. (5)

The first ones are detailed in graphs (a)-(f), while the second ones in graphs (g)-(i).

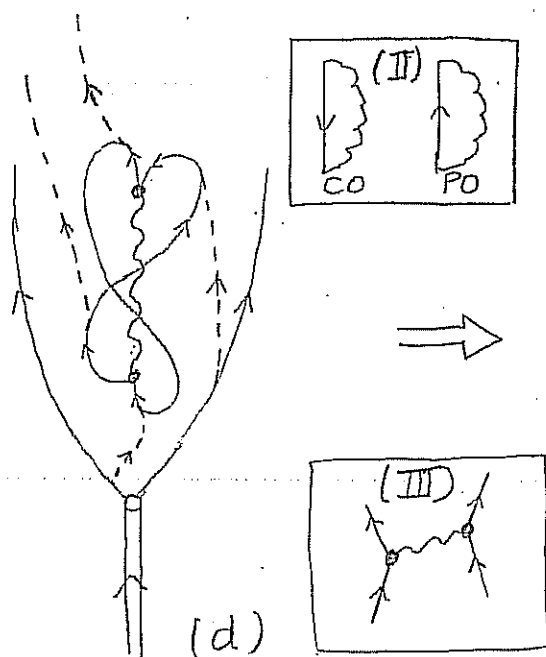
In keeping with the fact that the vibrational states can be viewed as a coherent state exhausting a large fraction of the EWSR (e.g. a Giant Resonance) for which the

associated uncertainty relations in momentum and coordinate fulfill the absolute minimum consistent with quantum mechanics ( $\Delta\alpha_{\lambda\mu} \Delta\pi_{\lambda\mu} = \hbar/2$ ,  $\alpha_{\lambda\mu} = (\hbar\omega_\lambda/2C_\lambda)^{1/2} (\pi_{\lambda\mu}^\dagger + \pi_{\lambda\mu})$ )

being the (harmonic) collective coordinate,  $\pi_{\lambda\mu}$  being the conjugate momentum; cf. e.g. R. Glauber, in Proceedings of the International School of Physics E. Fermi on Quantum Optics, course XLII, ed. R. Glauber, Ac. Press, N.Y. (1969) p. 15), there is a strong cancellation between the contribution of self-energy and vertex correction diagrams (P.F. Bortignon and R.A. Broglia, Nucl. Phys., ), implying small anharmonicity and long lifetimes ( $\Gamma/E \ll 1$ , where  $\Gamma$  is the width and  $E$  the centroid of the mode  $|\lambda\mu\rangle = \pi_{\lambda\mu}^\dagger |0\rangle$ ,  $(\hbar\omega_\lambda/2C_\lambda)^{1/2}$  being the 2.P.F amplitude (cf. e.g. Brink and Broglia, Nuclear Superfluidity, pp 185, 298)



time ordering,  
self-energy.



time ordering  
vertex correction  
(induced interaction)

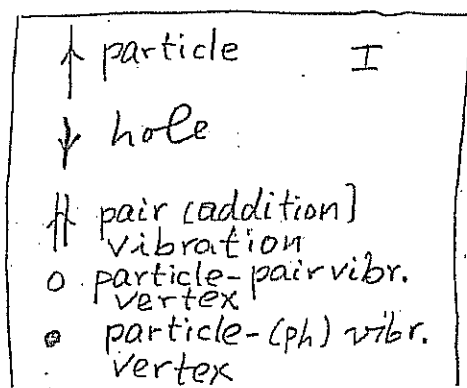


FIG. B

Caption Fig. B

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Pauli effects associated (p-r)  $\pm$  PF dressing  
pairing vibrational modes (see inset  
bottom left) in terms of self-energy  
(graphs (a) - (c); correlation (CO) and pola-  
rization (PO) diagrams, inset II) and  
vertex correction (graph (d) - (f);  
induced particle-particle interaction,  
inset (III)) processes.