Microscopic description of temperature, pairing and deformation effects in nuclei

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IUF

Normal to superfluid (phase) transition in nuclei

Normal phase

Symmetric

Hot nucleus: T>Tc

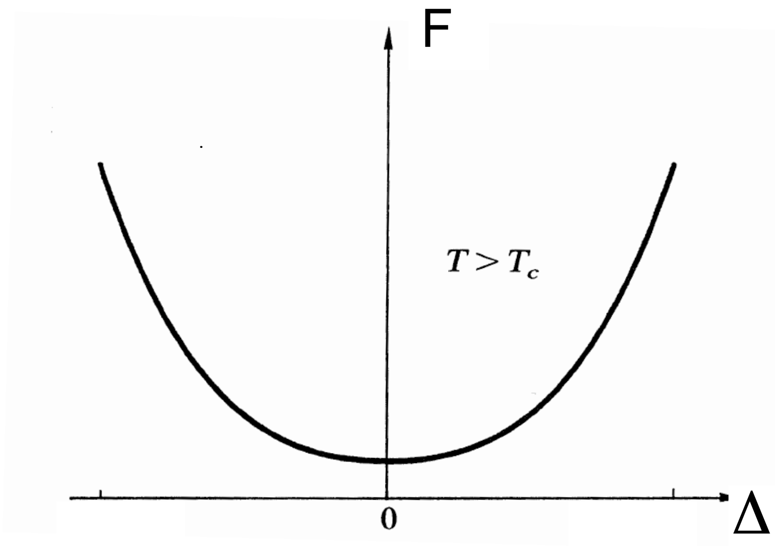
Superfluid phase

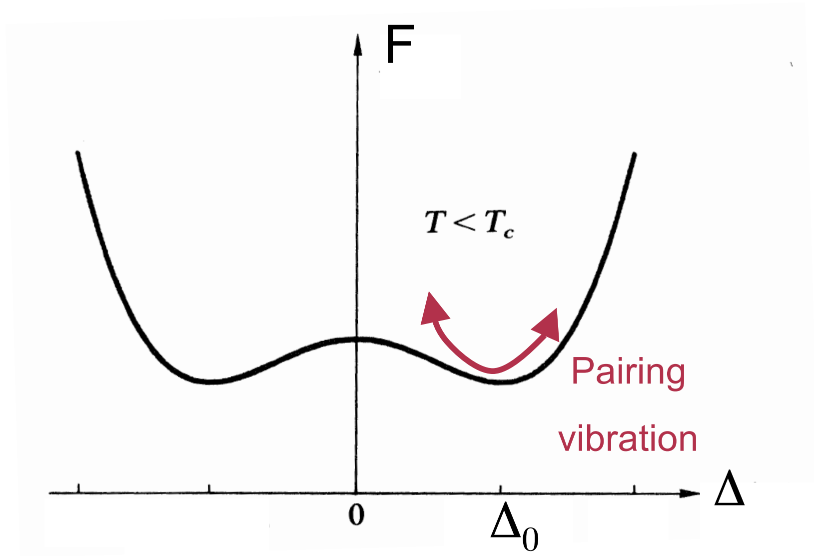
Spontaneous symmetry breaking

Nucleus: T<Tc

2[d] order phase transition

Δ pairing gap: order parameter





Finite temperature HFB

• **Goal:** describe the normal to superfluid transition in a self-consistent approach

A.L. Goodman NPA352 (81) 30

•**Method:** Grand canonical ensemble

Density matrix depends on Fermi-Dirac occ. $f_i = \frac{1}{1+e^{\beta E_i}}$

→ Same equation than HFB, except for the densities:

$$\rho = U^T f U^* + V^\dagger (1-f) V$$

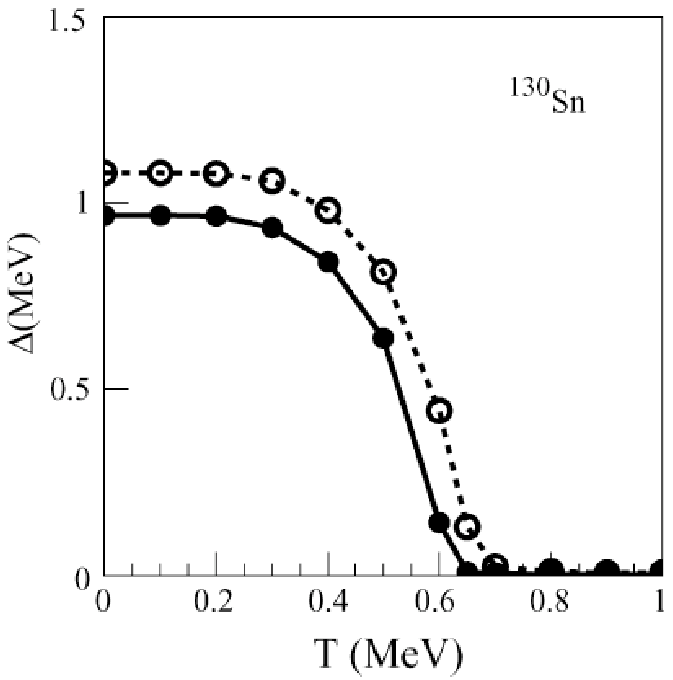
$$\kappa = U^T f V^* + V^\dagger (1-f) U$$

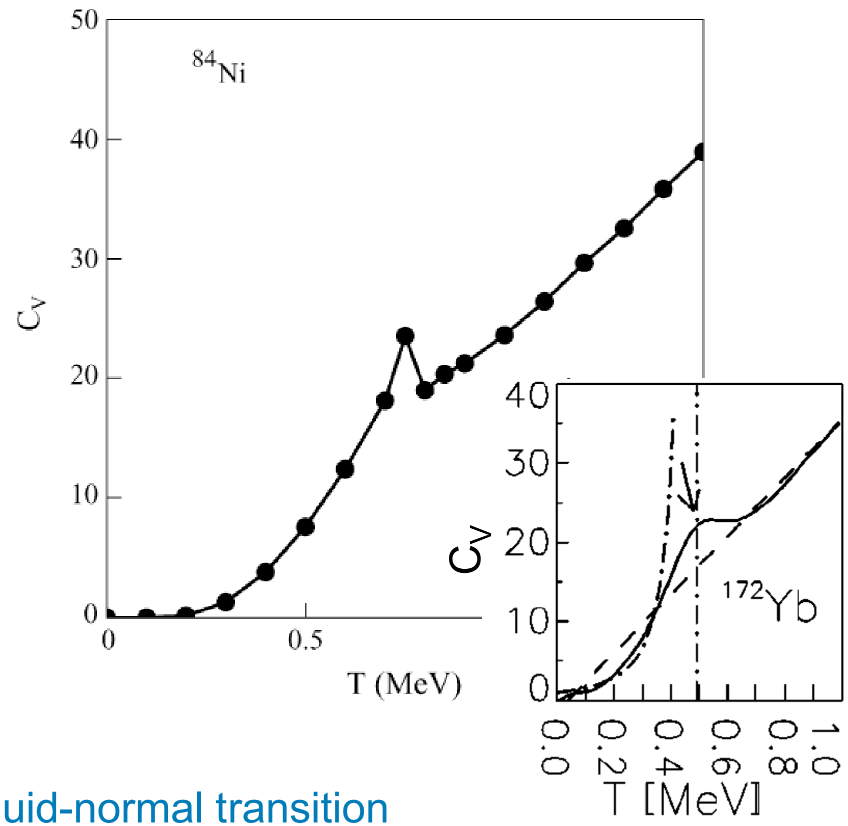
•Self consistent calculations:

Gogny: shape transition J.L. Egido, L.M. Robledo, V. Martin, PRL85 (00) 26

Skyrme: superfluid-normal transition E. Khan, N. Van Giai, N. Sandulescu, NPA789 (07) 94

Skyrme FT-HFB results





- Relevant description of the superfluid-normal transition
- Tc dependence on the volume/surface nature of the pairing interaction

Finite temperature QRPA

- **Goal:** compare Cv with measurements of excited states (Oslo group)

A. Schiller et al., PRC63 (01) 021306(R)

- **Method:** FT-QRPA coordinate space formalism with Fermi-Dirac terms

in the unperturbed Green function.

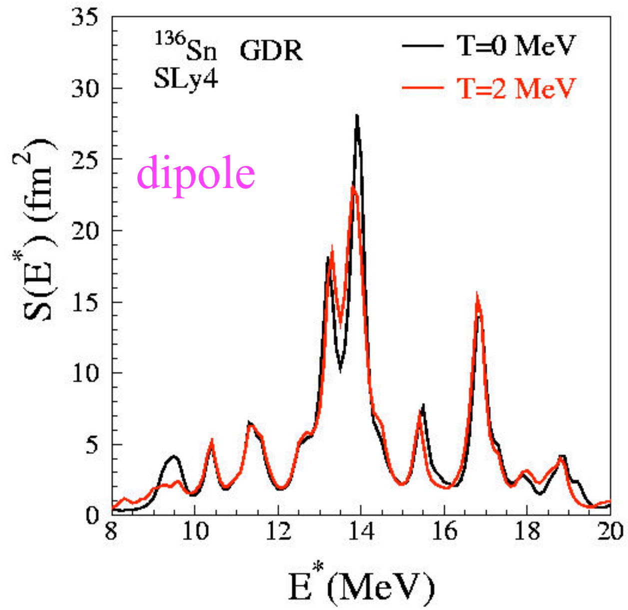
$$\mathbf{G} = (1 - \mathbf{G}_0\mathbf{V})^{-1}\,\mathbf{G}_0 = \mathbf{G}_0 + \mathbf{G}_0\mathbf{V}\mathbf{G}$$

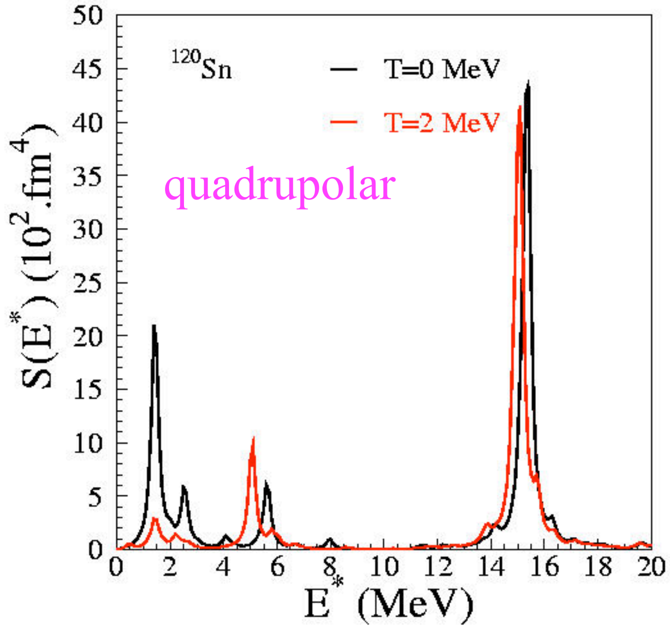
Residual interaction: $\mathbf{V}^{\alpha\beta}(\mathbf{r}\sigma, \mathbf{r}'\sigma') = \dfrac{\partial^2\mathcal{E}}{\partial\rho_\beta(\mathbf{r}'\sigma')\partial\rho_{\bar{\alpha}}(\mathbf{r}\sigma)}$

T≠ 0

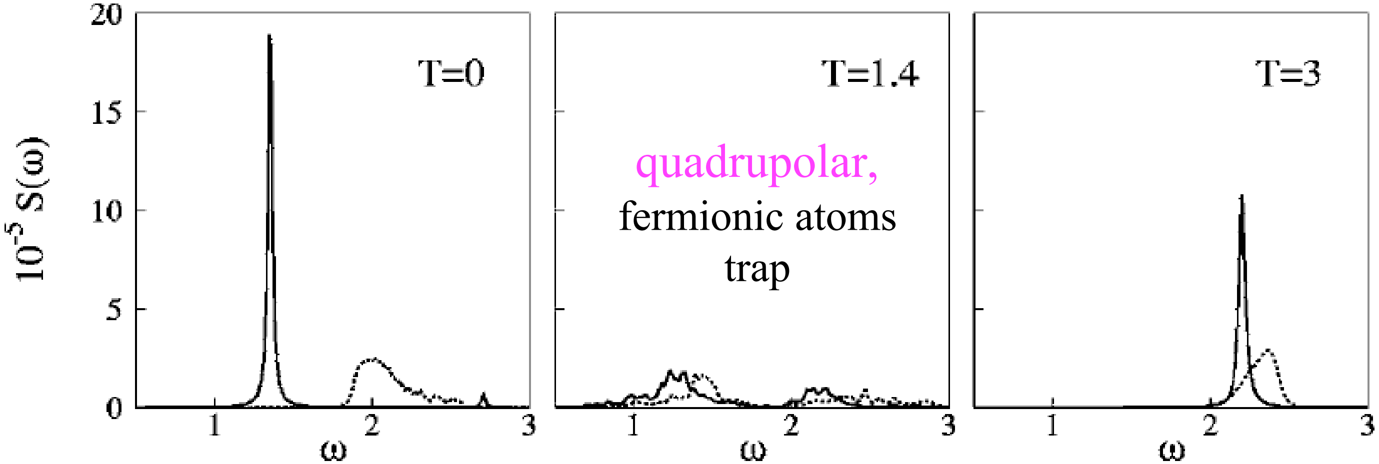
$$G_0^{11}(1,1';\omega) = \sum_{ij}\left[\frac{U_i^*(1)U_j(1)U_j^*(1')U_i(1')}{\hbar\omega + i\eta + E_i - E_j}(f_i - f_j) + \frac{U_i^*(1)U_j(1)V_i(1')V_j^*(1')}{\hbar\omega + i\eta + E_i - E_j}(f_j - f_i)\right.$$
$$+\frac{V_i(1)V_j^*(1)V_j(1')V_i^*(1')}{\hbar\omega + i\eta - E_i + E_j}(f_j - f_i) + \frac{V_i(1)V_j^*(1)U_j^*(1')U_i(1')}{\hbar\omega + i\eta - E_i + E_j}(f_i - f_j)$$
$$\left.+\frac{V_i(1)U_j(1)\left[U_j^*(1')V_i^*(1')\right]}{\hbar\omega + i\eta - E_i - E_j}(1 - f_i - f_j) + \frac{U_i^*(1)V_j^*(1)\left[V_j(1')U_i^*(1')\right]}{\hbar\omega + i\eta + E_i + E_j}(f_i + f_j - 1)\right]$$

FT-QRPA results





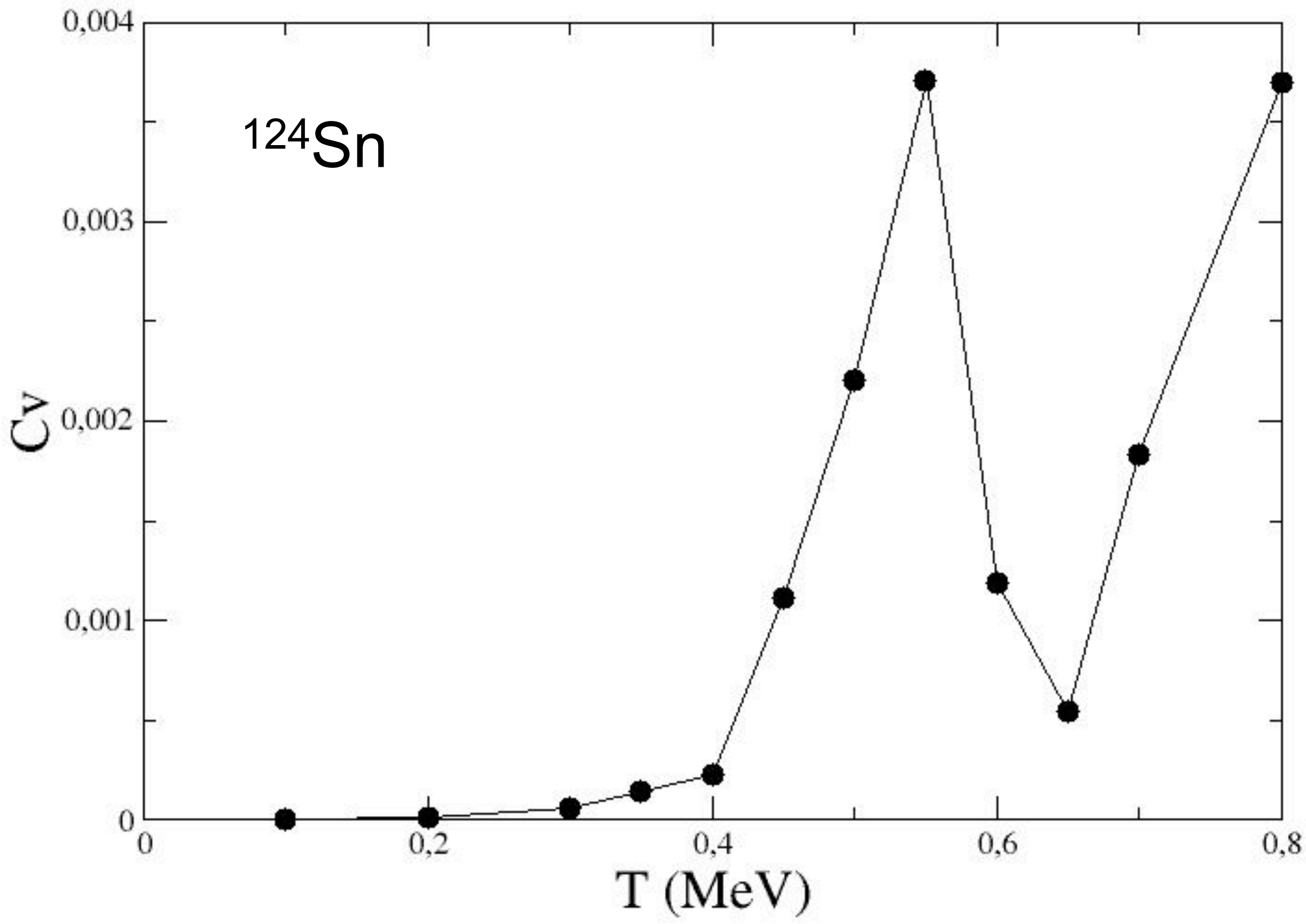
E. Khan, Nguyen Van Giai, M. Grasso, NPA731 (04) 311



M. Grasso, E. Khan, M. Urban, PRA72 (05) 043617

Cv calculations

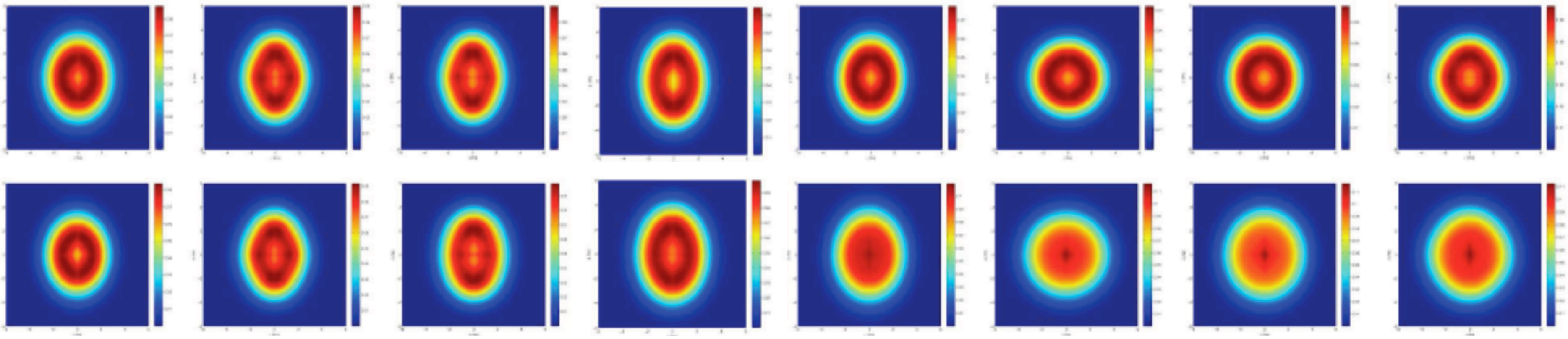
- **Method**: calculate all possible J^π QRPA responses below 5 MeV: 0+ to10+
- Cv from S: $S = -\sum_i (2j_i+1)(f_i ln f_i + (1-f_i) ln(1-f_i))$



E. Khan, N. Sandulescu, Nguyen Van Giai, in prep.

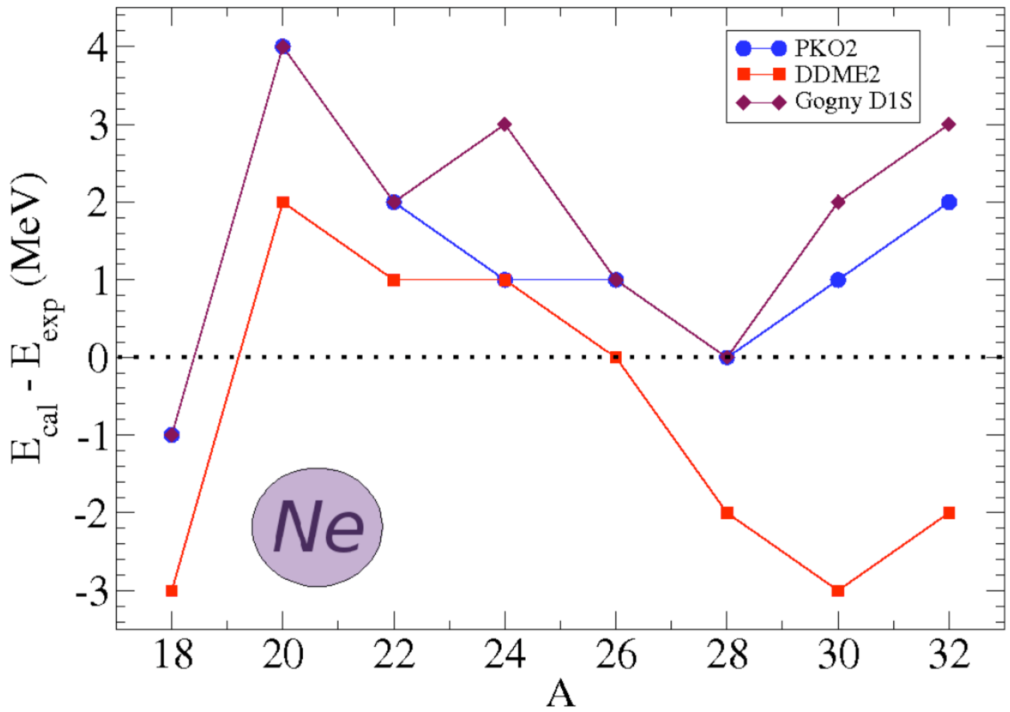
Ne isotope

Relativistic deformed HFB



18 20 22 24 26 28 30 32

- Axially symmetric RHFB model
- Fock term included
- DD coupling constants



Jean-Paul Ebran, PhD (Orsay, 2010)

Conclusion

• FT-HFB is a appropriate tool to describe superfluid-normal transition

• EDF only parameter, allows to probe the surface/volume nature of the pairing force

• Specific heat of nuclei (compare with exp data): FT QRPA calculations provides the excited energy spectrum

•Relativistic HFB in axial symmetry available