Particle number conserving approach to correlations

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Proton-neutron pairing & BCS

- 1964-1972 generalized BCS approaches

A.M. Lane, Nuclear Theory (1964) Benjamin, New York

A. Goswami, Nucl. Phys. 60 (1964) 228

P. Camiz, A. Covello and M. Jean, Nuovo Cimento 36 (1965) 663, ibid. B42 199

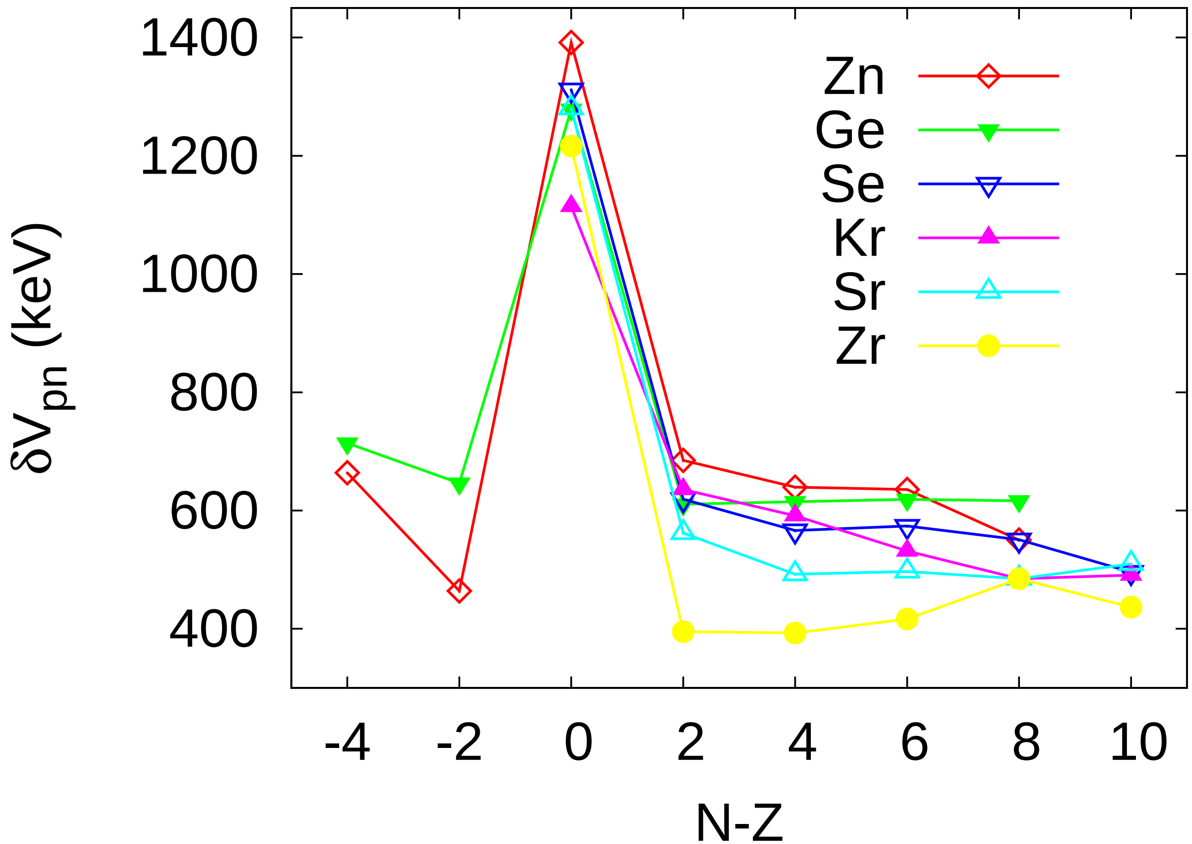
A. Goswami and L. Kisslinger, Phys. Rev. 140 (1965) B26

H. Chen and A. Goswami, Phys. Lett. B24 (1967) 257

A.L. Goodman, G. Struble and A. Goswami, Phys. Lett. B26 (1968) 260

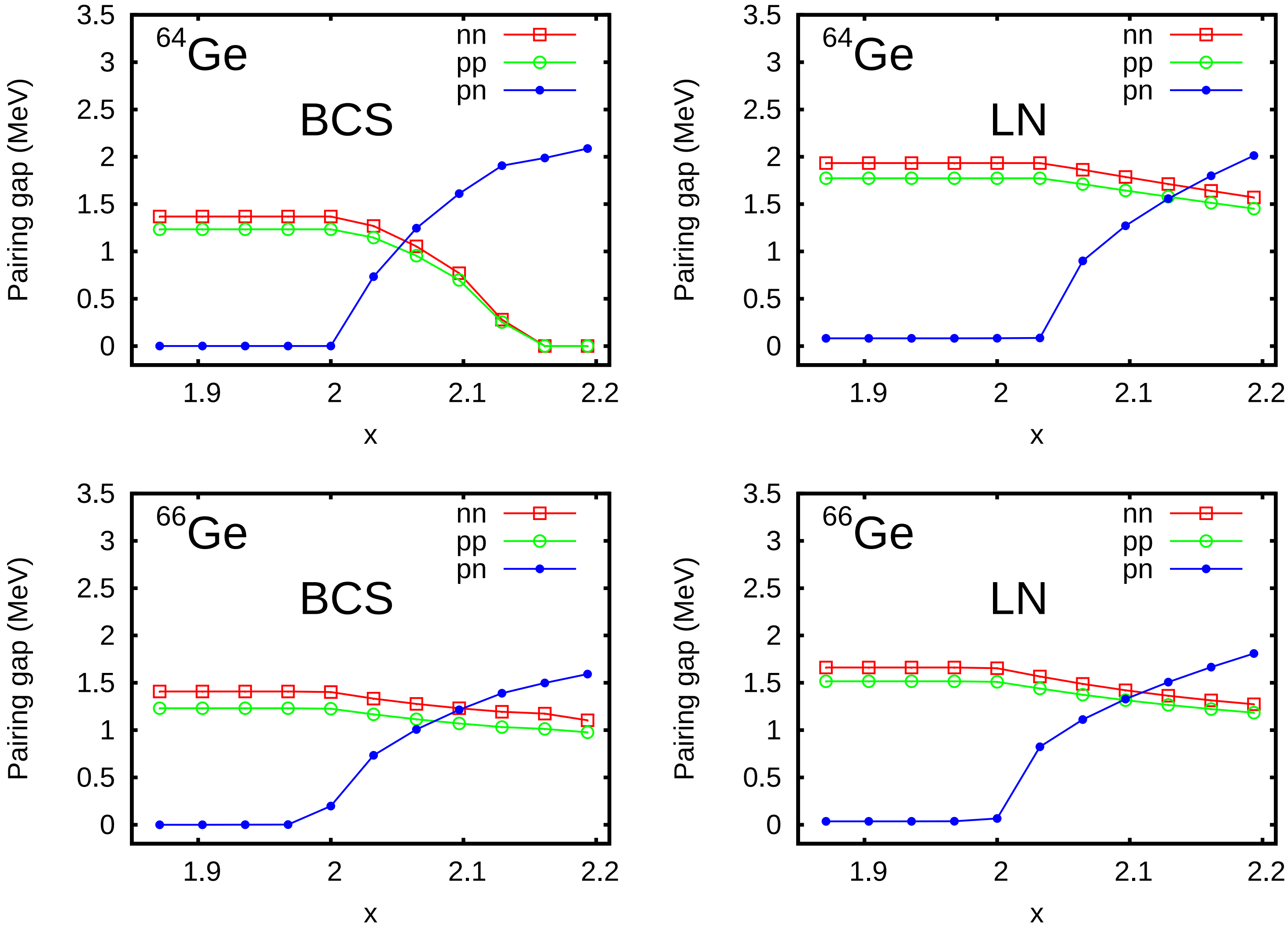
A.L. Goodman, Nucl. Phys. A186 (1972) 475.

Motivation



$$\delta V_{pn} = 0.25\left[(B(N,Z) - B(N-2,Z)) - (B(N,Z-2) - B(N-2,Z-2))\right]$$

BCS & pn-pairing



$$x = V(T=0)/V(T=1)$$

BCS

- Particle number and isospin non-conservation

$$
\begin{aligned}
|\mathrm{BCS}\rangle \;=\; \prod_k [& u_{k1p}u_{k2n} - u_{k2p}u_{k1n} \\
& + (v_{k1p}u_{k2n} - v^{\star}_{k2p}u_{k1n}) a_{kp}{}^{\dagger} a_{\bar{k}p}{}^{\dagger} \\
& + (v_{k2n}u_{k1p} - v^{\star}_{k1n}u_{k2p}) a_{kn}{}^{\dagger} a_{\bar{k}n}{}^{\dagger} \\
& + (v^{\star}_{k2p}u_{k1p} - v_{k1p}u_{k2p}) a_{kp}{}^{\dagger} a_{\bar{k}n}{}^{\dagger} \\
& + (v^{\star}_{k1n}u_{k2n} - v_{k2n}u_{k1n}) a_{\bar{k}p}{}^{\dagger} a_{kn}{}^{\dagger} \\
& + (v_{k1p}v_{k2n} - v^{\star}_{k1n}v^{\star}_{k2p}) a_{kp}{}^{\dagger} a_{kn}{}^{\dagger} a_{\bar{k}p}{}^{\dagger} a_{\bar{k}n}{}^{\dagger}] |0\rangle
\end{aligned}
$$

Higher Tamm-Dancoff Approximation

[1] *N. Pillet, P.Quentin and J. Libert, Nucl. Phys.* **A687** *(2002) 141.*

[2] *N. Pillet, PhD report, Bordeaux 1 University, 2002.*

[3] *T.L. Ha, PhD report, Bordeaux 1 University, 2004.*

$$\hat{H} = \hat{K} + \hat{V}$$

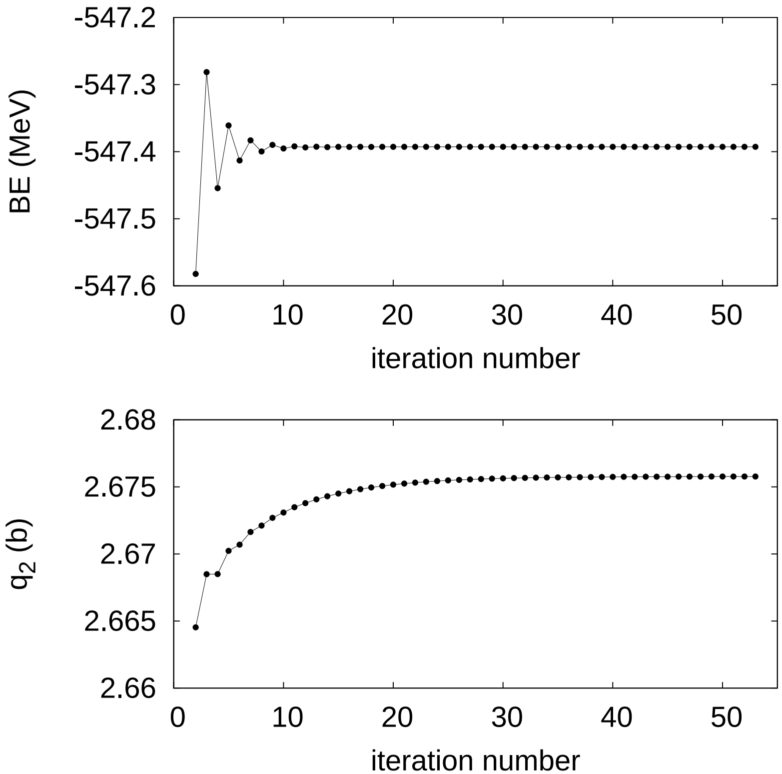
$$\hat{H}_{\mathrm{HF}}|\Psi_0\rangle = E_0|\Psi_0\rangle$$

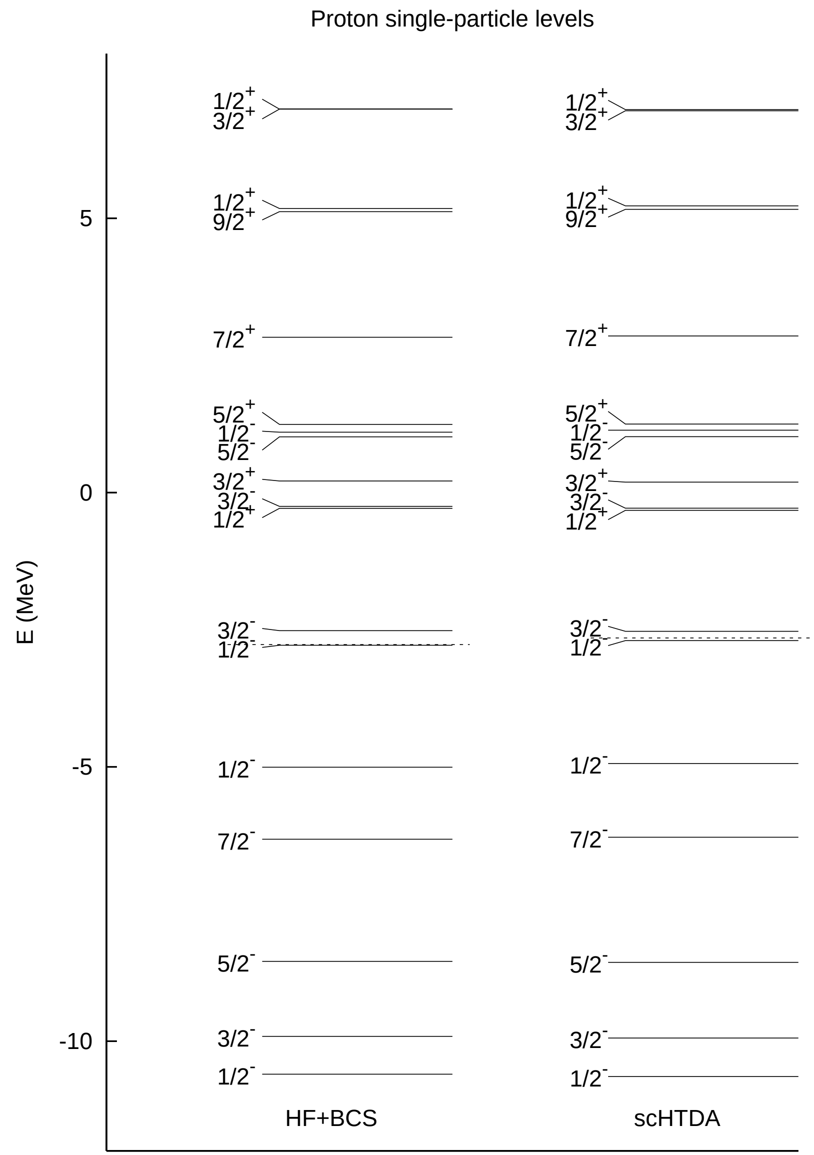
$$|\Psi\rangle = \chi_0|\Psi_0\rangle + \sum_{\mathrm{1p1h}} \chi_1|\Psi_1\rangle + \sum_{\mathrm{2p2h}} \chi_2|\Psi_2\rangle + \cdots$$

$$\sum_i \chi_i^2 = 1$$

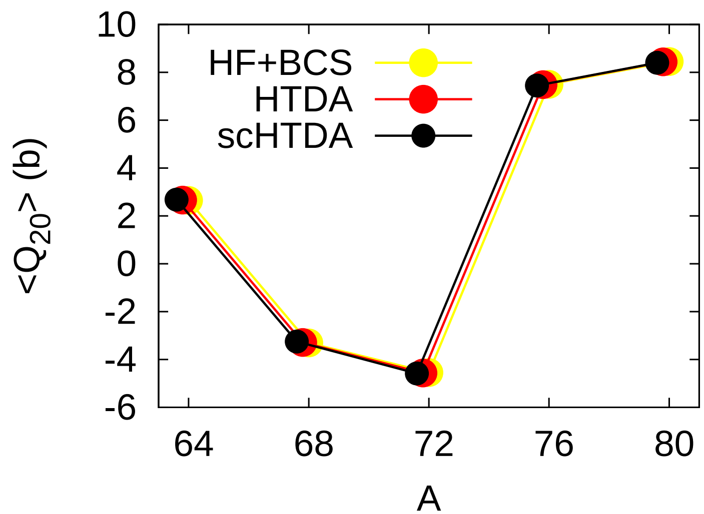
Self-consistency

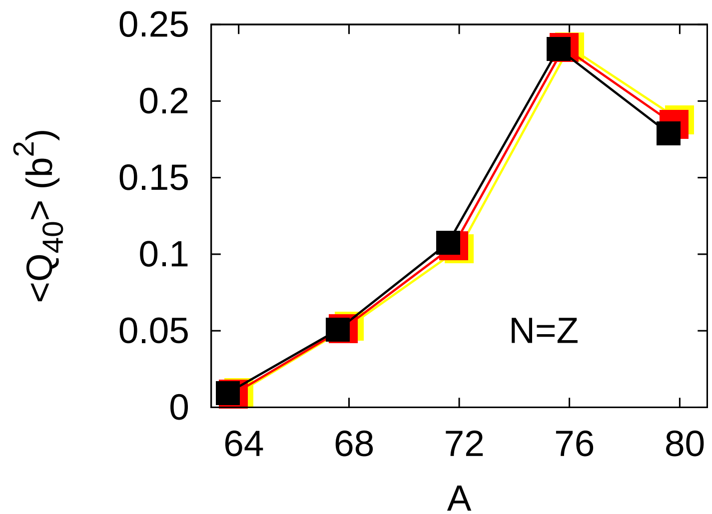
$$\langle i|\rho|j\rangle = \langle\Psi|a_j^\dagger a_i|\Psi\rangle$$





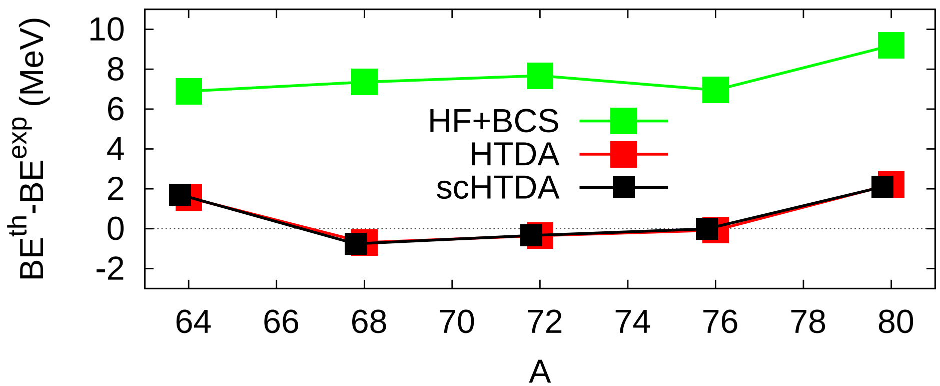
GS properties of $N = Z$ even-even nuclei





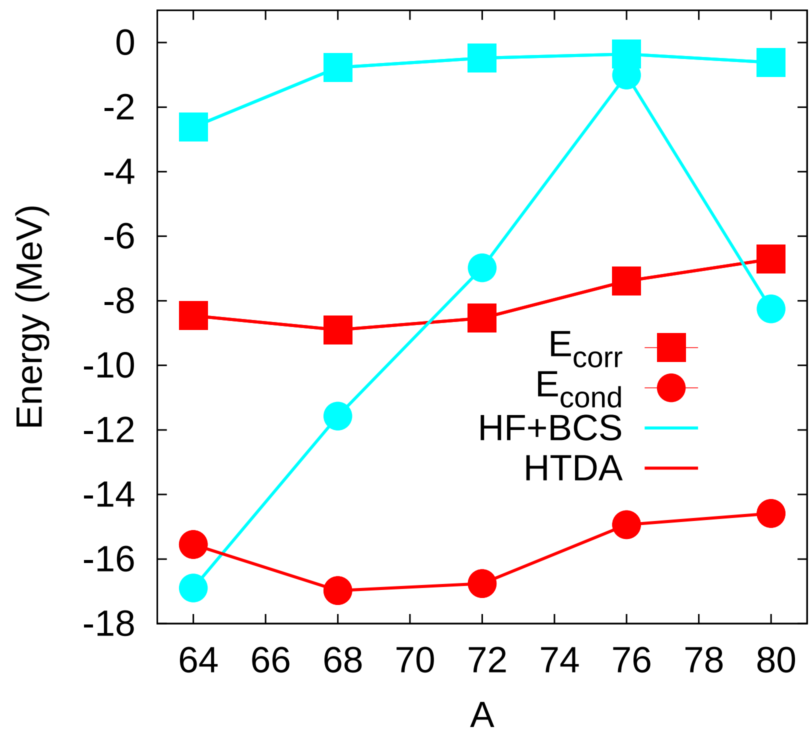
$$\hat{Q}_{20} = \int \mathrm{d}^3\boldsymbol{r}\rho(\boldsymbol{r})2r^2P_2(cos\theta) \qquad \hat{Q}_{40} = \int \mathrm{d}^3\boldsymbol{r}\rho(\boldsymbol{r})r^4Y_{40}(\theta)$$

GS properties of $N = Z$ even-even nuclei



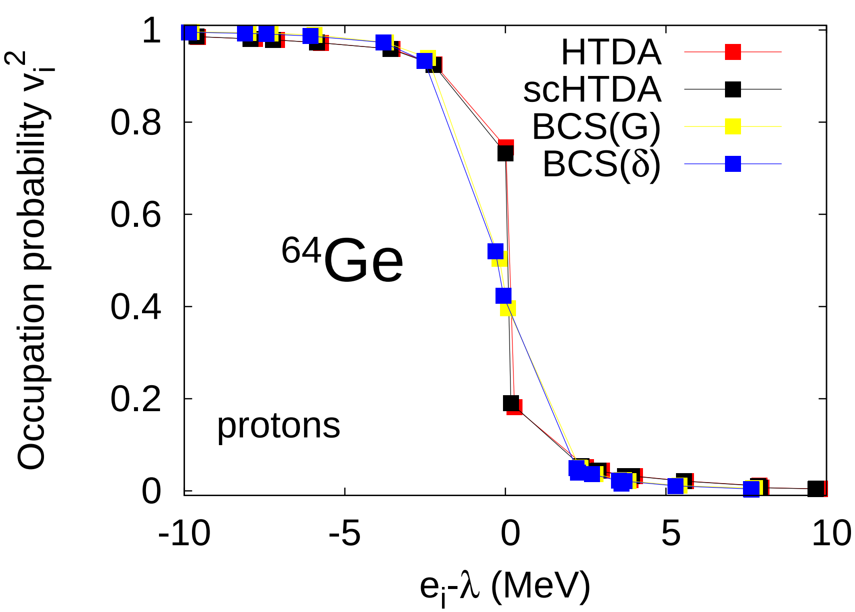
$$E_{\text{corr}} = \langle\Psi|\hat{H}|\Psi\rangle - \langle\Psi_0|\hat{H}|\Psi_0\rangle$$

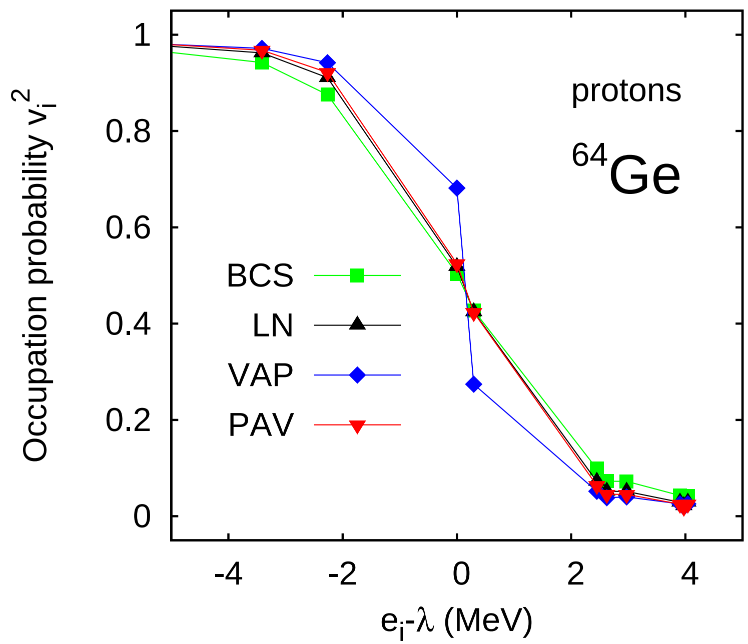
$$E_{\text{cond}} = E_{\text{corr}} - \sum_i \chi_i^2 E_i^{\text{p-h}}$$



Occupation probability

$$v_i^2 = \rho_{ii}$$





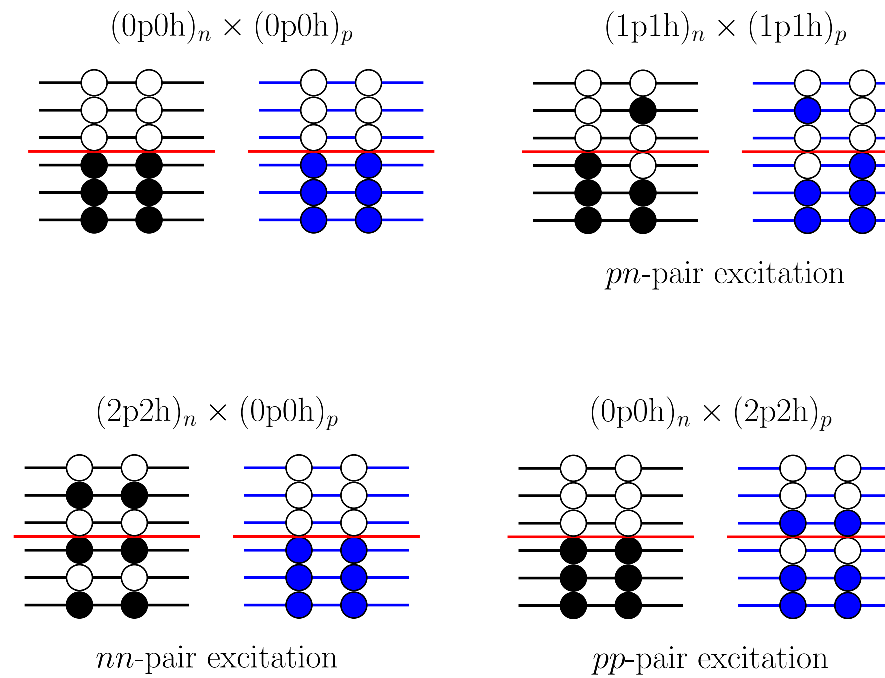
Composition of the correlated state

	neutrons			*protons*		
nucleus	*0p0h*	*1p1h*	*2p2h(pe)*	*0p0h*	*1p1h*	*2p2h(pe)*
^{62}Ge	67.8	$<$0.01	32.2 (30.0)	54.0	$<$0.01	46.0 (44.4)
^{64}Ge	52.8	$<$0.01	47.2 (45.85)	54.6	0.0	45.3(43.6)
^{66}Ge	61.0	$<$0.01	39.0 (36.6)	54.0	$<$0.01	46.0 (44.3)
^{68}Ge	41.7	0.03	58.2 (57.0)	60.3	$<$0.01	39.7 (38.0)

**pe-pair excitation*

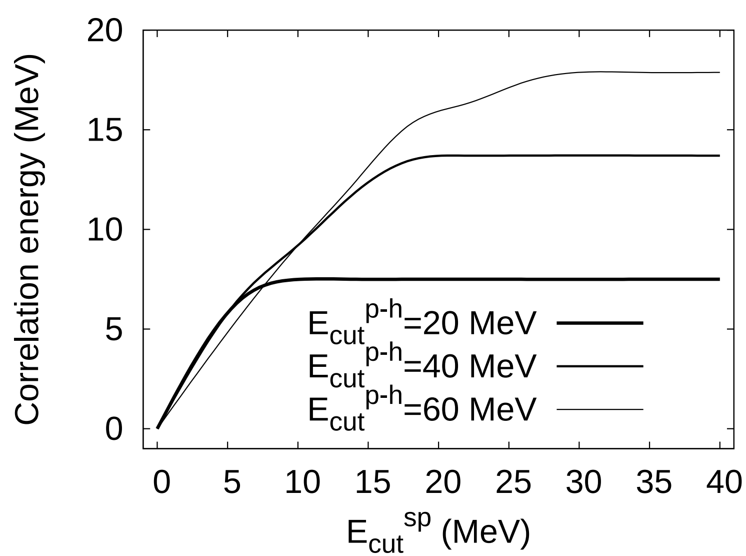
Proton-neutron pairing in HTDA method

$$
\begin{aligned}
|\Psi\rangle \quad &\equiv \quad |\Psi^n \otimes \Psi^p\rangle \\
&= \quad \chi_0 |\Psi_0^n \otimes \Psi_0^p\rangle \\
&+ \quad \sum_{(1\mathrm{p}1\mathrm{h})_n} \sum_{(1\mathrm{p}1\mathrm{h})_p} \chi_{11} |\Psi_1^n \otimes \Psi_1^p\rangle \\
&+ \quad \sum_{(2\mathrm{p}2\mathrm{h})_n} \chi_{20} |\Psi_2^n \otimes \Psi_0^p\rangle \\
&+ \quad \sum_{(2\mathrm{p}2\mathrm{h})_p} \chi_{02} |\Psi_0^n \otimes \Psi_2^p\rangle
\end{aligned}
$$

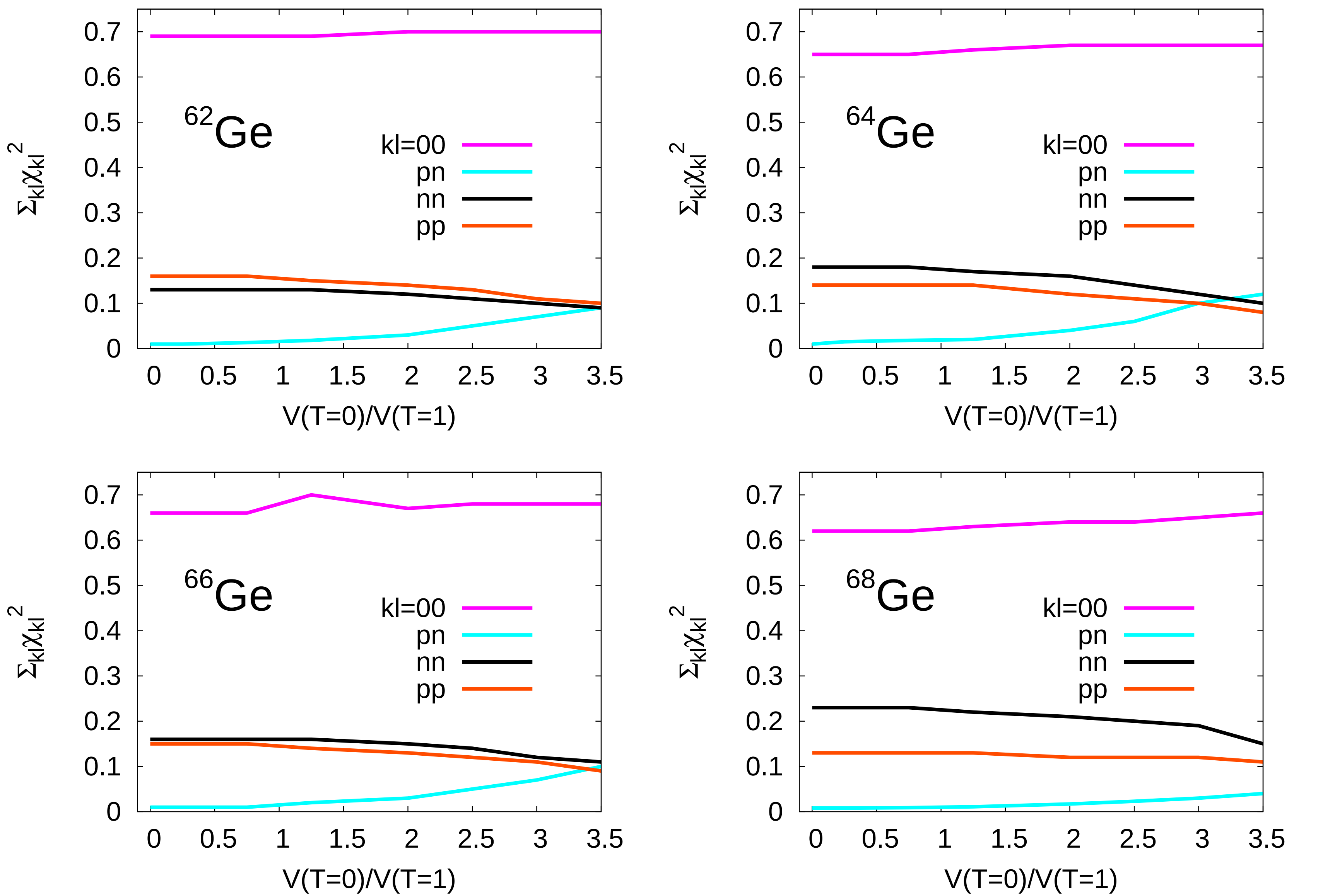


Model space: E_{cut}^{p-h}=50 MeV, E_{cut}^{sp}=30 MeV

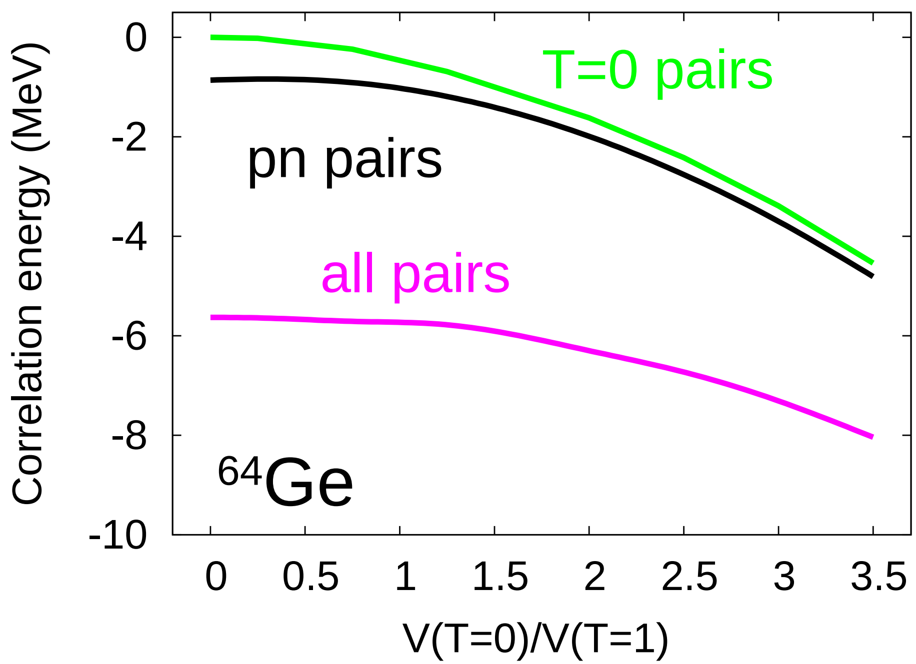
nucleus	*number of sp levels n/p*	*number of configurations*
^{62}Ge	*182/260*	*1822*
^{64}Ge	*220/214*	*1893*
^{66}Ge	*230/270*	*2432*
^{68}Ge	*234/216*	*2146*

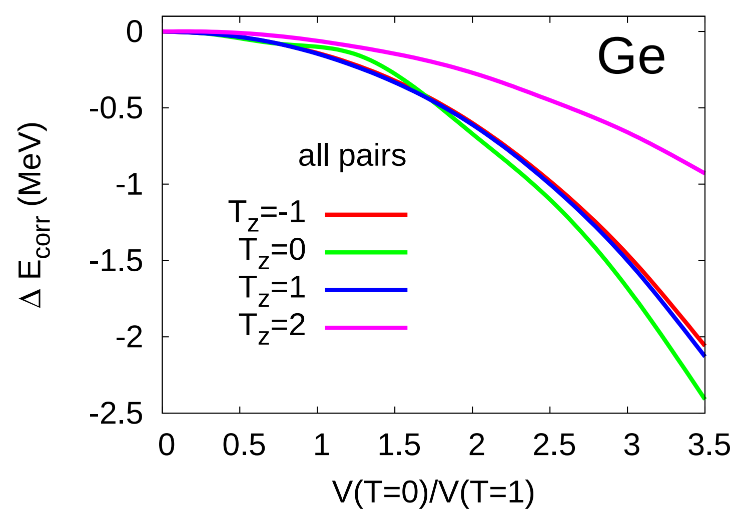


GS wave function decomposition



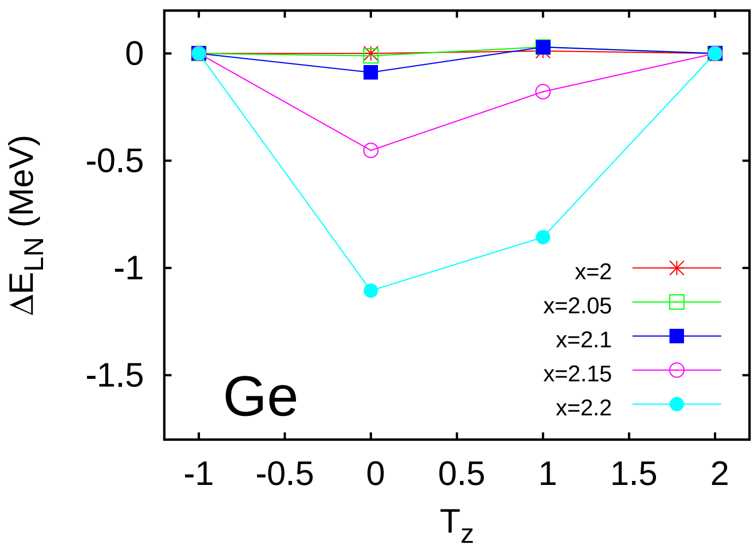
Correlation energy



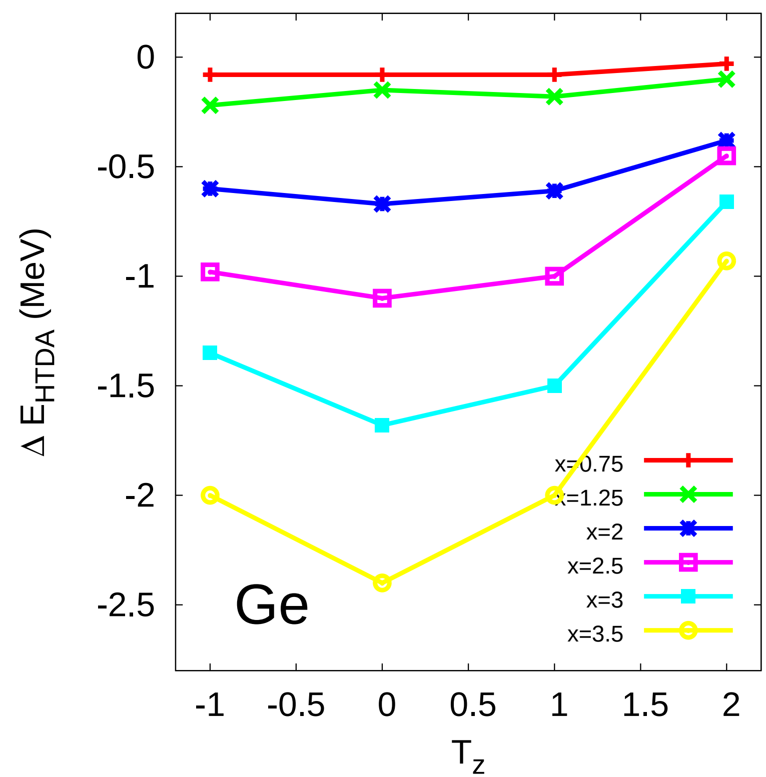


Wigner energy

Lipkin-Nogami



HTDA



$$
\begin{aligned}
\Delta E &= E(x) - E(x=0) \\
x &= V(T=0)/V(T=1)
\end{aligned}
$$

Summary & outlook

- We have applied an approach conserving particle number and isospin to describe pn pairing;
- The qualitative description of isoscalar pairing is similar to that of BCS+LN method;

- α clustering
  low lying collective states
  isomeric states
  β-decay rates