Pairing in dilute matter and in exotic nuclei

Q0. Do we have good ab initio description of Δ in typical systems?

Dilute uniform matter, stable nuclei

BCS-BEC crossover, small Cooper pair

Di-neutron correlation in n-rich nuclei

Q1. In which situations does the di-neutron correlation become prominent ?

Halo, skin, light /heavy, separation energy

Q2. What are theoretical measures of the di-neutron correlation ?

Coherence length? Short distance prob.?

Q3. Relation to the BCS-BEC in dilute matter?

Q4. What are experimental observables of the di-neutron correlation?

Exotic pairing

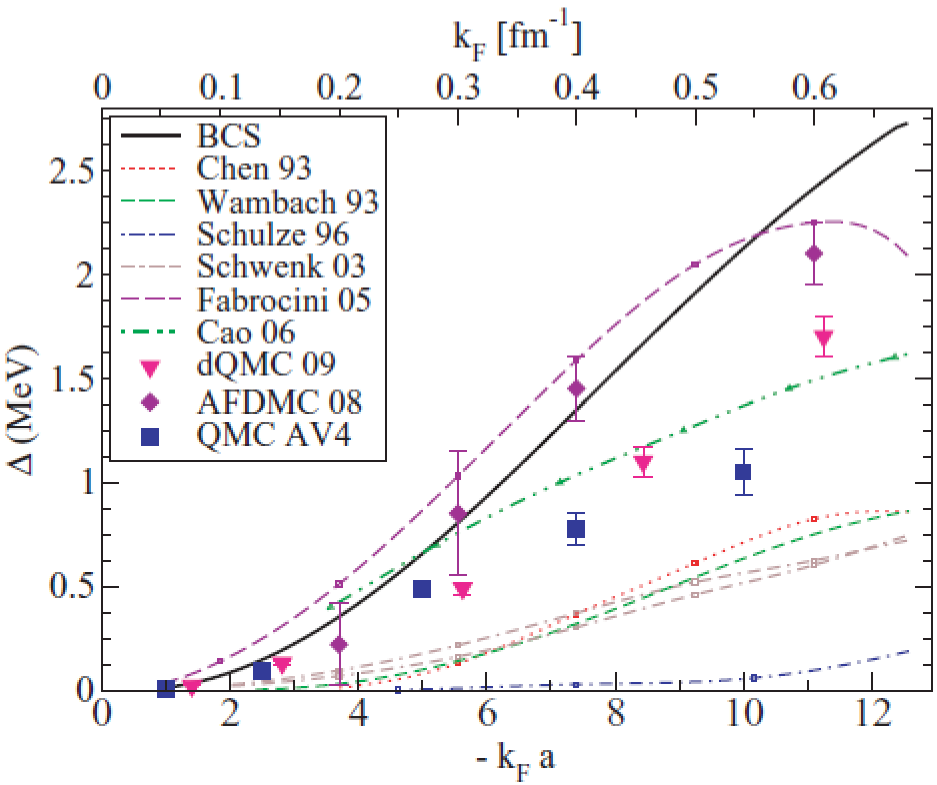
Q5. T=0 np-pairing ?

Q6. Its relation to quarteting & clusterization ?

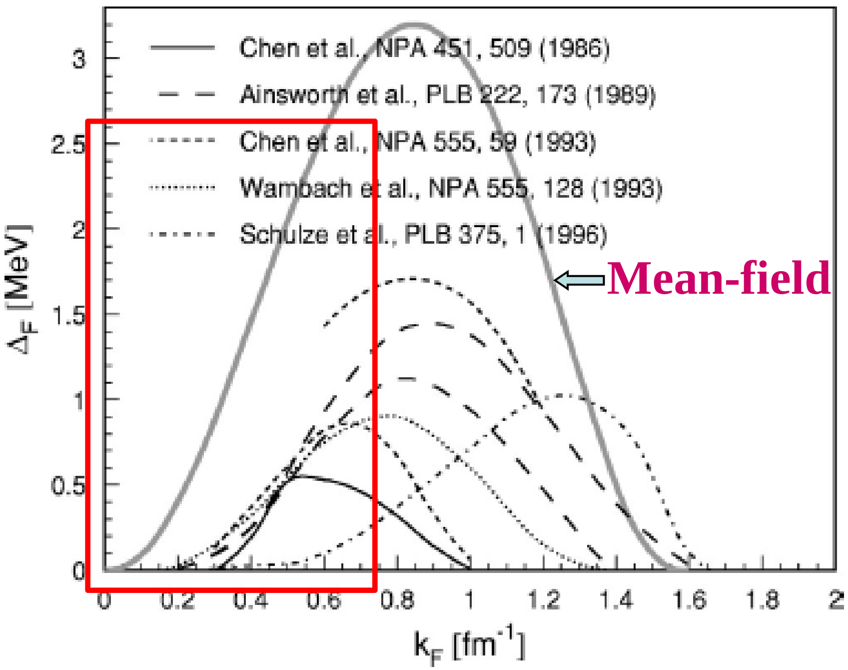
Q0. Do we have good ab initio description of Δ in simple systems?

pairing gap in dilute neutron matter

$\Delta = (1 \sim 0.5)\ \Delta_{\text{mean-field}}$ in recent calculations



Gezerlis & Carlson, PRC81 (2010)



Lombardo & Schulze 2001

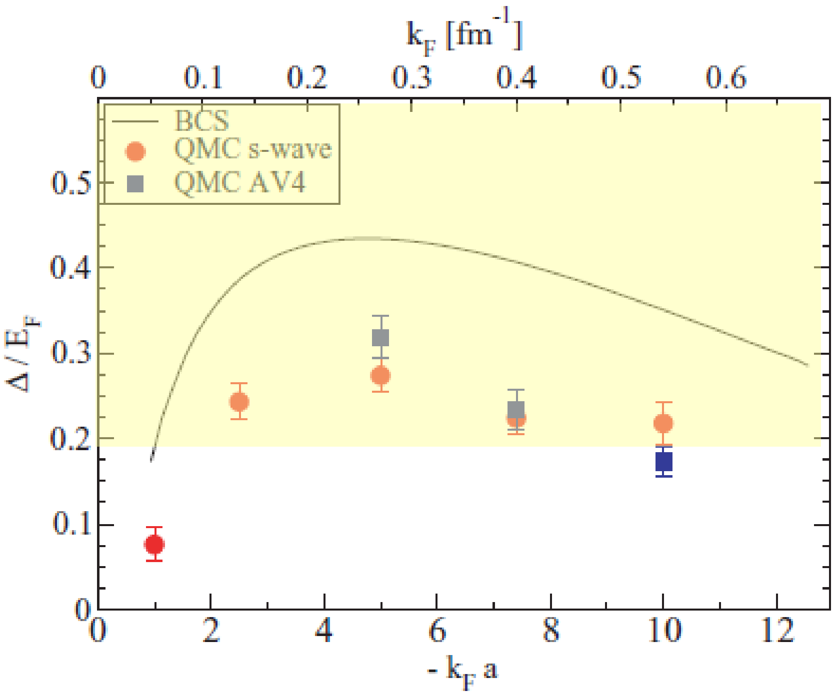
Strong coupling pairing in dilute matter & BCS-BEC crossover

Large scattering length **a=-18fm** for nn-attraction

"Large" pair gap vs. Fermi energy $\Delta/e_F > 0.2$ at low-densities

Monte-Carlo calculation

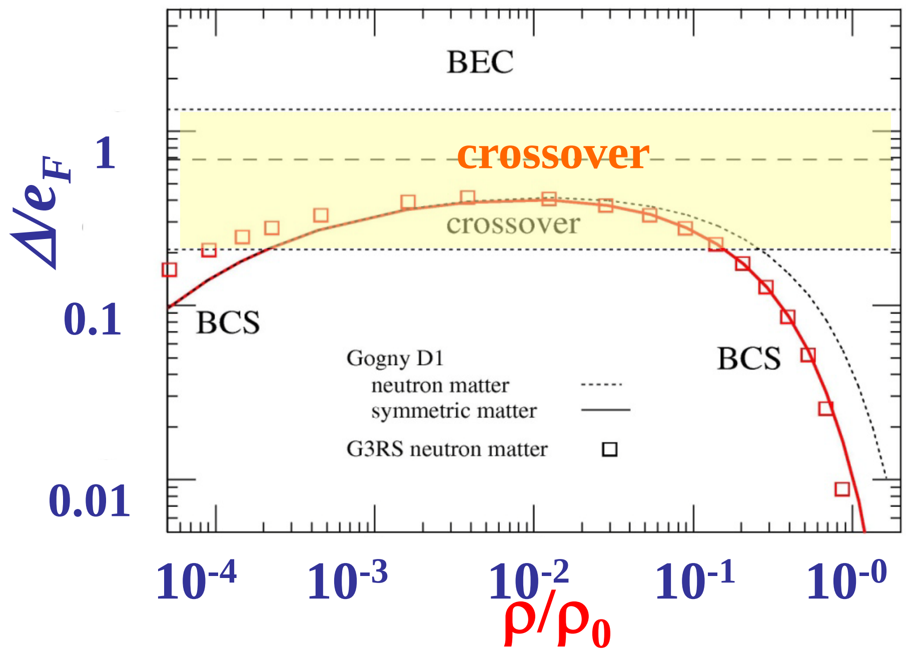
$\rho/\rho_0 = 10^{-3} \sim 0.5\times10^{-1}$



Gezerlis & Carlson, PRC81,025803 (2010)

Mean-field calculation (BCS approx.)

$\rho/\rho_0 = 10^{-4} \sim 2\times10^{-1}$

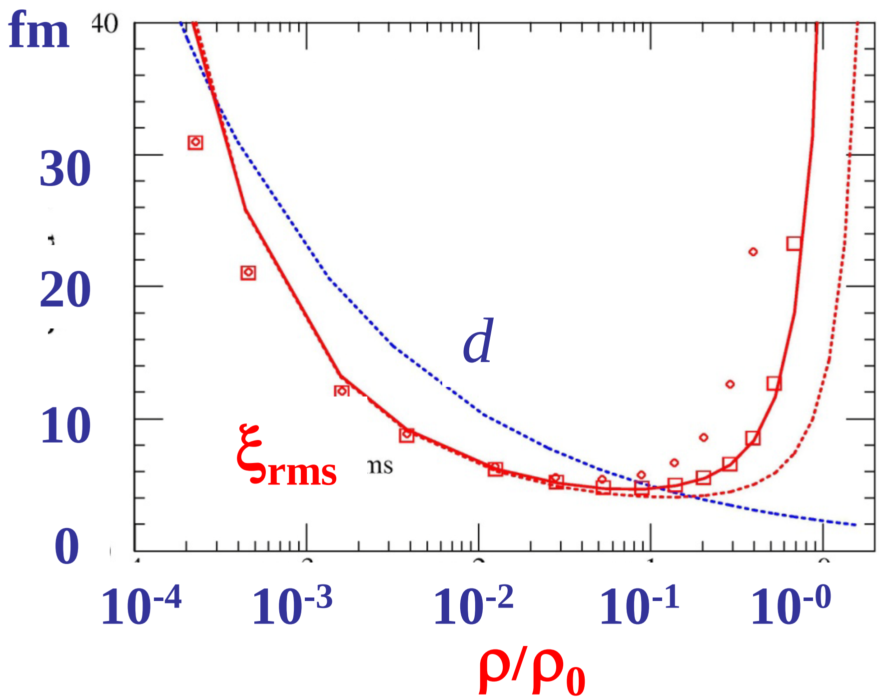


MM, PRC73,044309(2006)

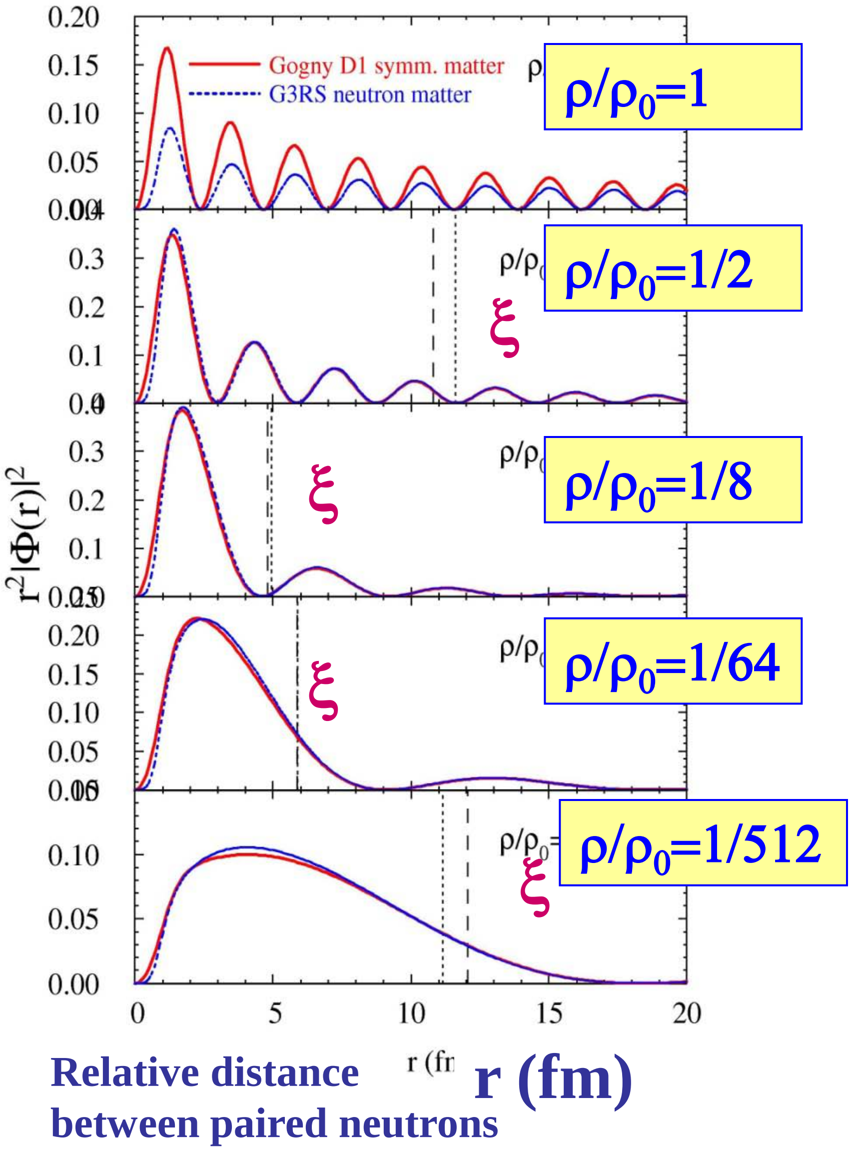
Q3. How can we relate the di-neutron correlation to the BCS-BEC in dilute matter?
How do we learn the pairing in dilute matter

BCS calculation using A bare force (G3RS)
Gogny force (D1)

Neutron pairing gap



Cooper pair wave function



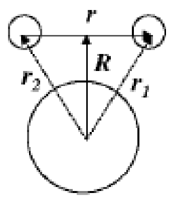
Pair wave function has large amplitude at short relative distances r∼2-3 fm

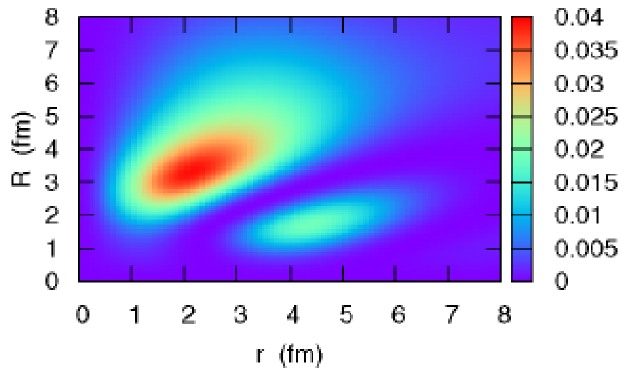
MM, PRC73,044309(2006)
Margueron et al, PRC77,054309(2008)

Q1. In which situations does the di-neutron correlation become prominent ?
Halo, skin, light /heavy, separation energy

1. 2n-halo nuclei e.g. 11Li

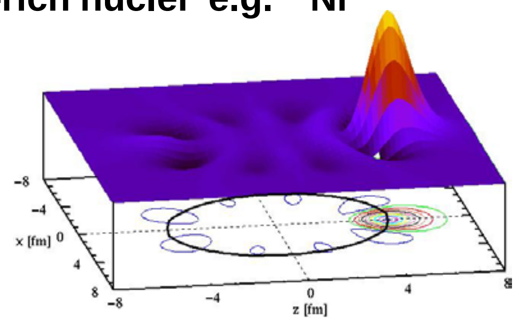
G.F.Bertsch, H.Esbensen, Ann. Phys. 209(1991) 327





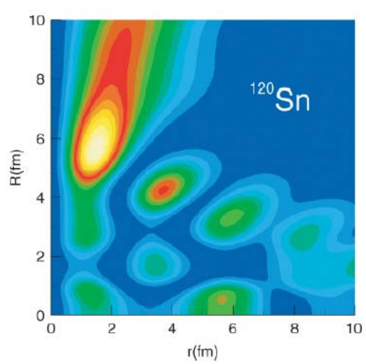
Hagino, Sagawa, Carbonell, Schuck, PRL99, 022506(2007)

2. Heavy n-rich nuclei e.g. ^{84}Ni



Matsuo, Mizuyama, Serizawa PRC71,064326(2005)

3. Heavy stable nuclei



e.g. ^{18}O , ^{210}Pb, (alpha in 212Pb)

Ibarra et al. NPA288, 397 (1977)
Janouch & Liotta PRC27,896 (1983)

etc

e.g. ^{120}Sn

Pillet, Sandulescu, Schuck, PRC76, 024310 (2007)

4. Slab, Semi-infinite matter

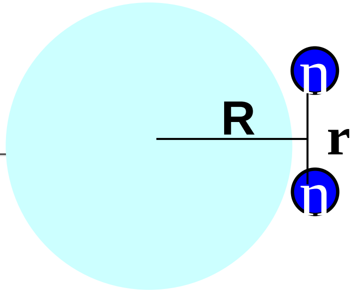
Kanada-Enyo, et al, PRC79,054305(2009)
Pankratov, et al. PRC79, 024309 (2009)

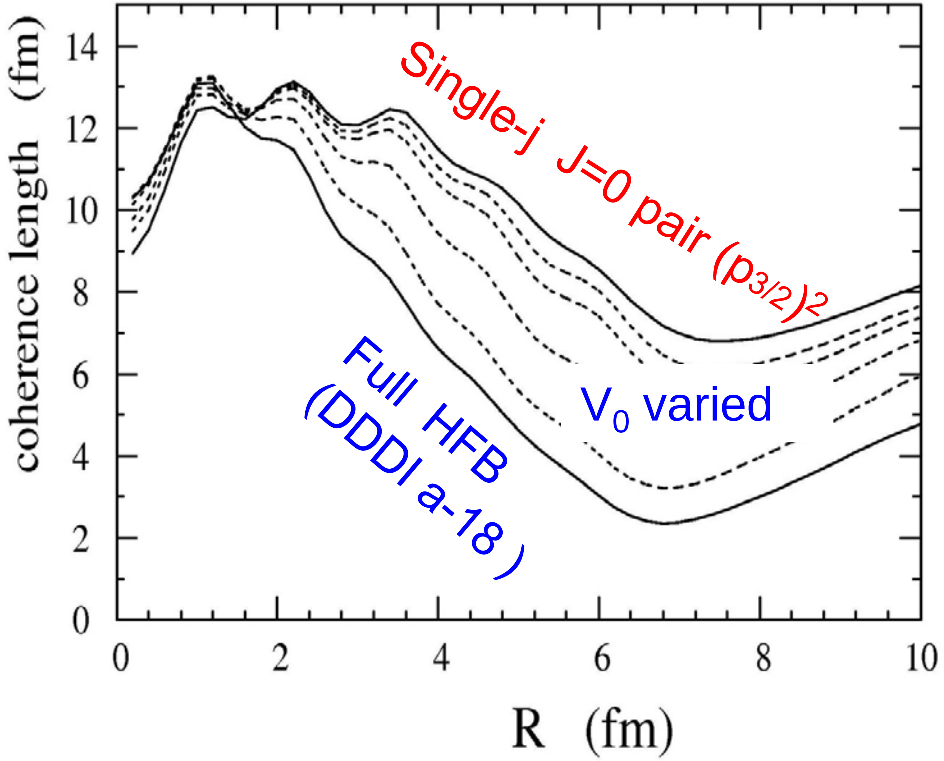
Q2. What are (theoretical) measures of the di-neutron correlation ?

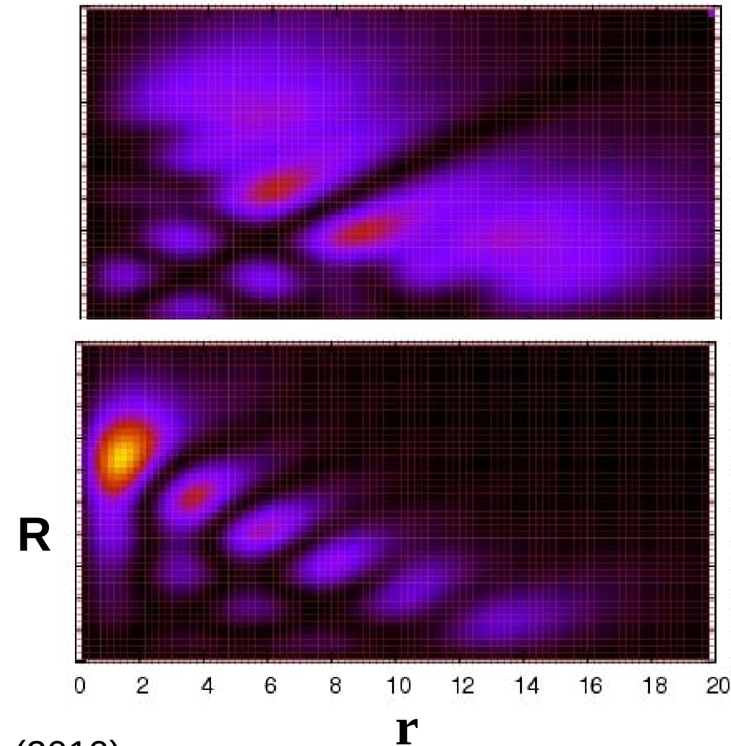
Rms radius of 'Cooper pair' as a function of R

^{142}Sn

$$\xi = \langle r^2 \rangle = \frac{\int r^2 P_c(R,r)dr}{\int P_c(R,r)dr}$$







It is influenced by geometrical effect of finite volume

[1] Pillet, Sandulescu, Schuck, Berger, PRC81 (2010)

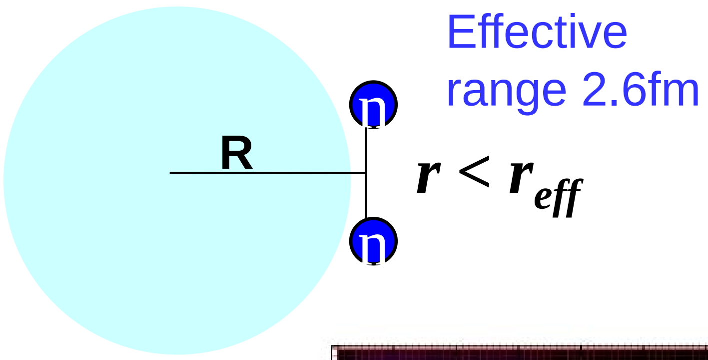
And also by the surface spatial correlation (especially in halo).

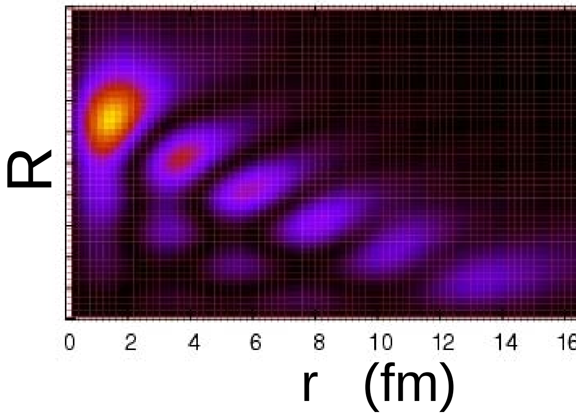
[2] Hagino et al J Phys.G37 (2010)

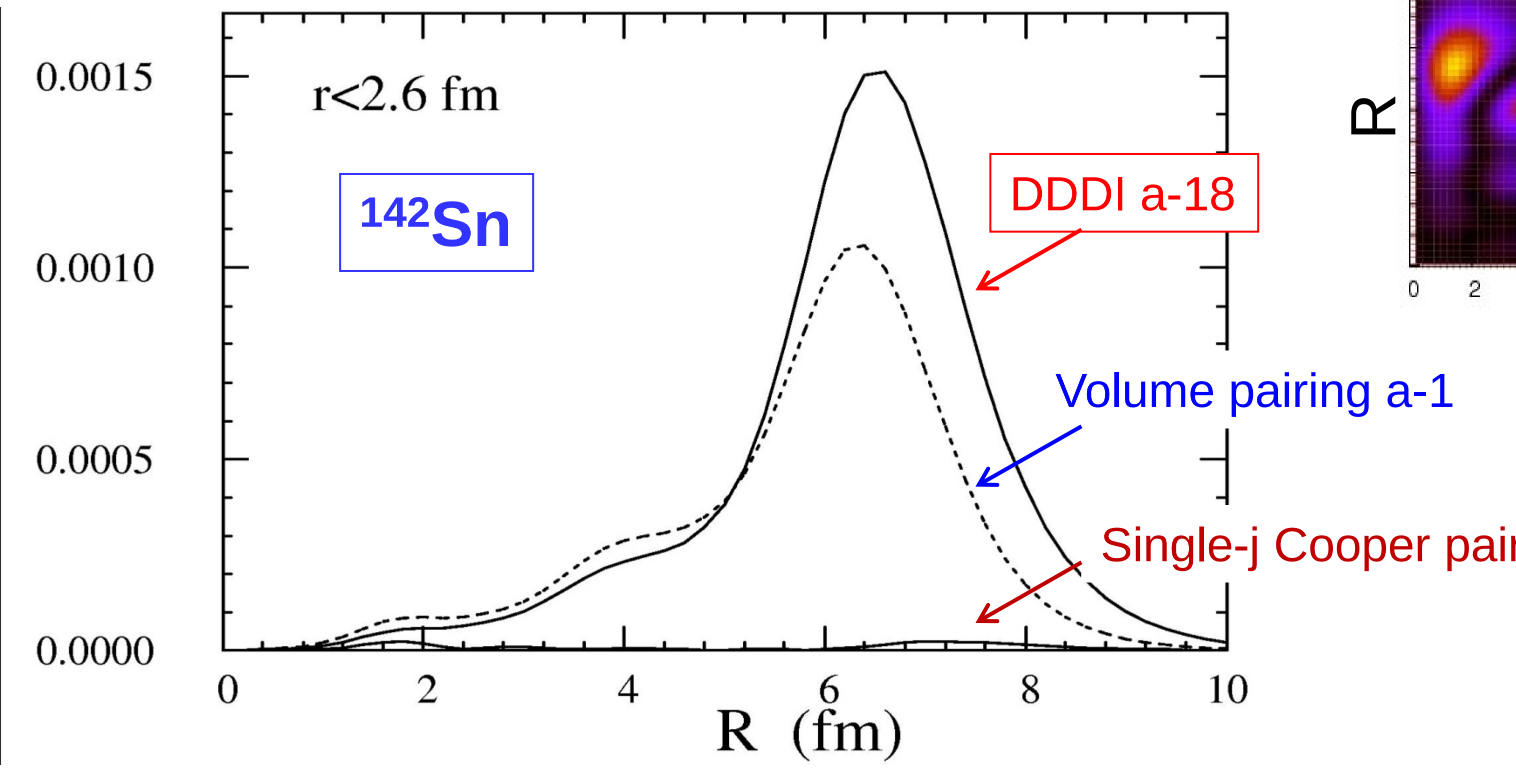
Pair contact probability $r < 2.6$ fm

Probability of pair at short relative distances within the interaction range

$$p(R) = \int_0^{r_{eff}} P_c(R, r)\,dr$$

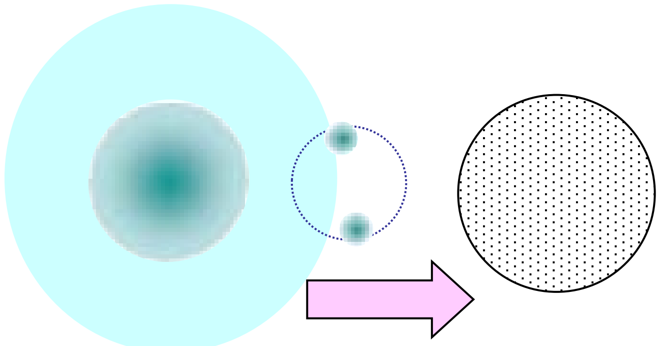




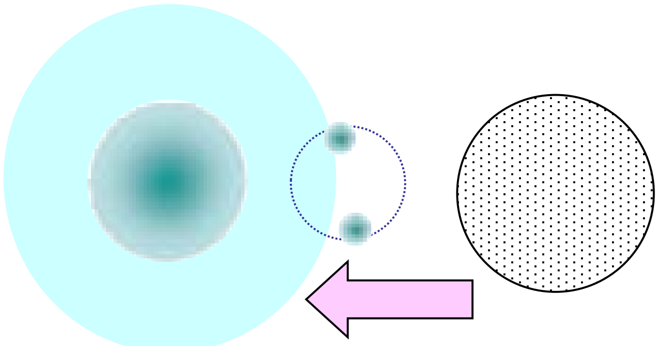


Q4. What are (experimental) observables of the di-neutron correlation?

Pair transfers in neutron-rich nuclei



Pair removal



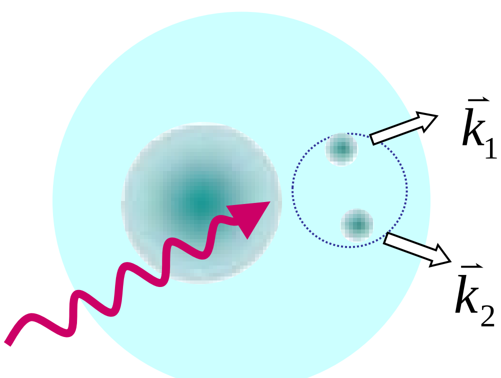
Pair addition

132Sn~140Sn **precursory 0^+_2**

142Sn~ **enhanced 0^+_2 transfer**

Shimoyama's presentation on Oct.24

2n break-up through soft dipole excitation in nuclei near n-drip line



2n correlation ??

^{11}Li, ^{6}He, etc.

Hagino et al., PRC80, 031301 (2009)

Kikuchi et al., PRC81, 044308 (2010)