Di-neutron correlation and BCS-BEC crossover in the structure and decay of light neutron-rich nuclei

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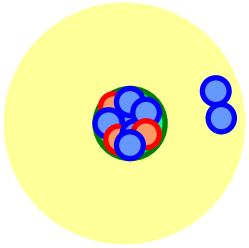

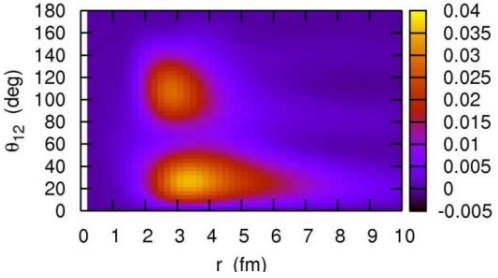

1. *Neutron-rich nuclei*
2. *Di-neutron correlation and BCS-BEC crossover*
3. *Two-neutron decay of ^{26}O*
4. *Summary*

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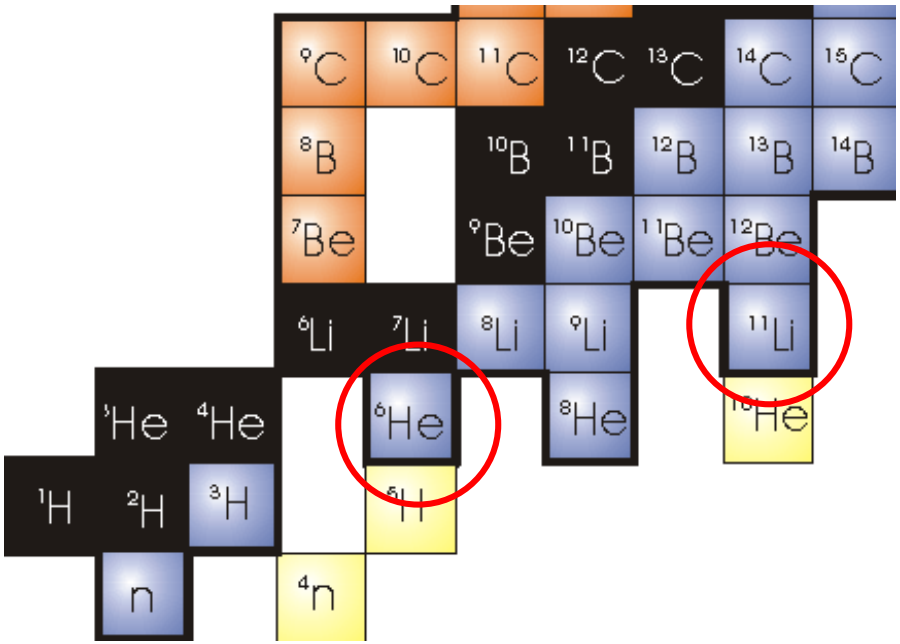
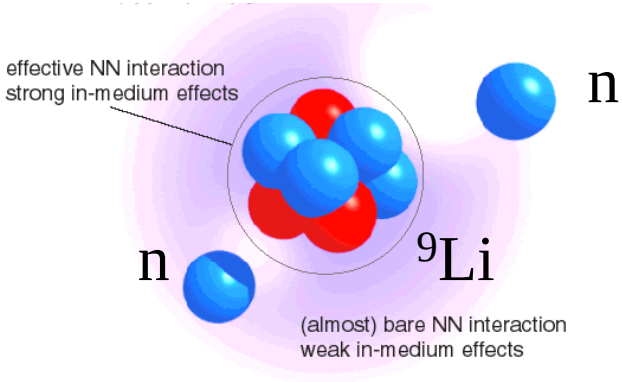
Introduction: neutron-rich nuclei



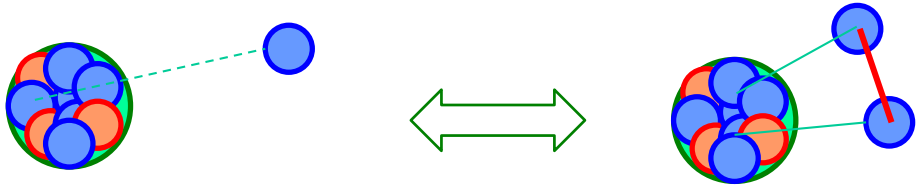
light neutron-rich nuclei
→ three-body structure



^{11}Li = ^{9}Li + n + n

→ large radius

Borromean nuclei

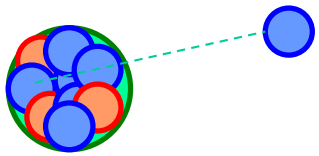


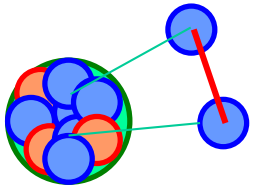
unbound bound

nn attraction

^{11}Li, ^{6}He

Borromean nuclei





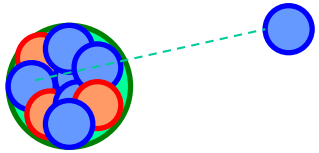
nn attraction

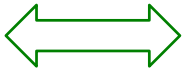
^{11}Li, ^{6}He

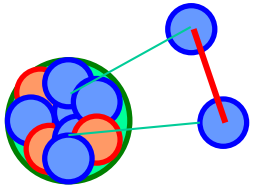
unbound

bound

three-body resonance





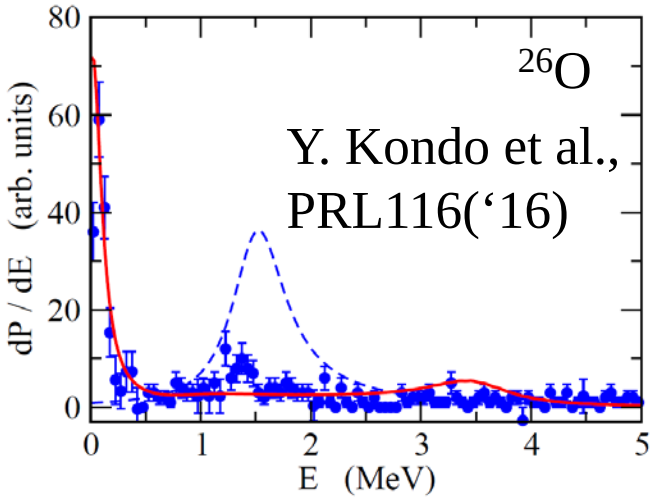


nn attraction

^{10}He, ^{13}Li, ^{16}Be, ^{26}O

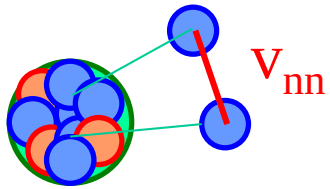
unbound

unbound, but nearly bound



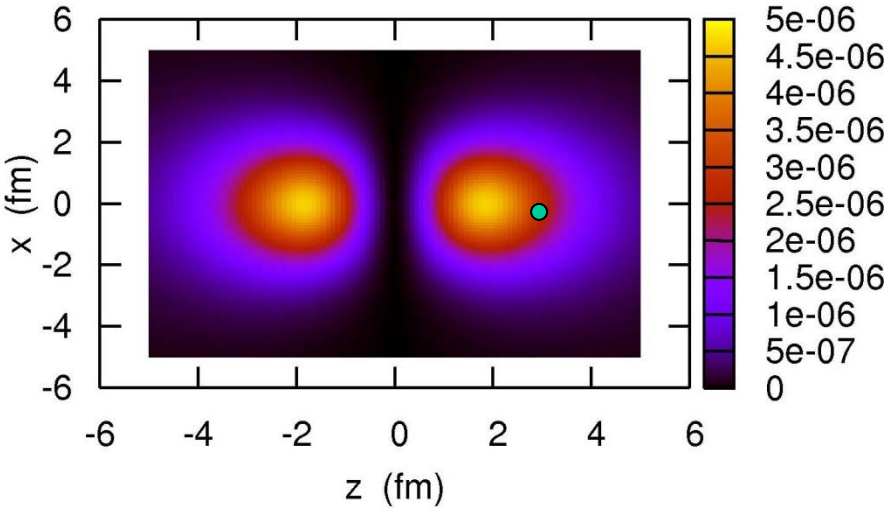
Role of nn correlation
in Borromean nuclei and
in the decay dynamics of unbound nuclei?

Di-neutron correlation and BCS-BEC crossover

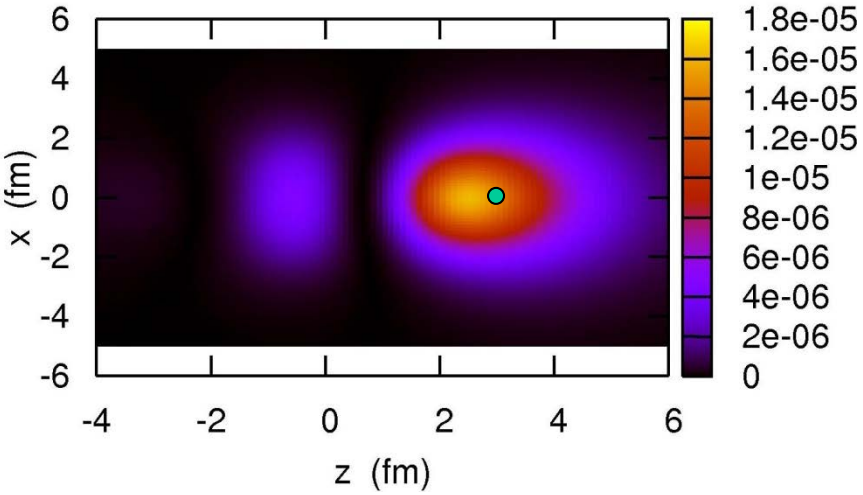


Three-body model calculations: $^{11}Li = {}^{9}Li + n + n$

without nn interaction $[(p_{1/2})^2]$



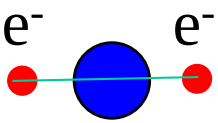
with nn interaction

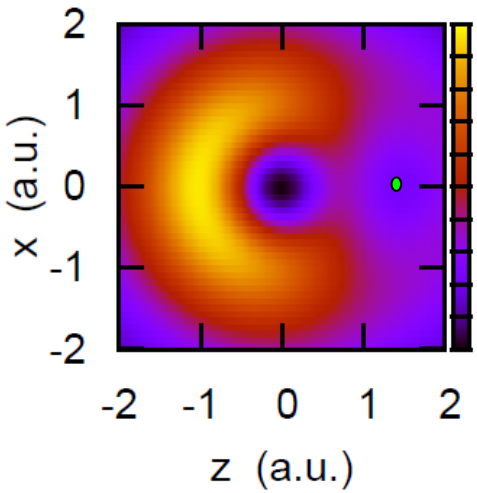


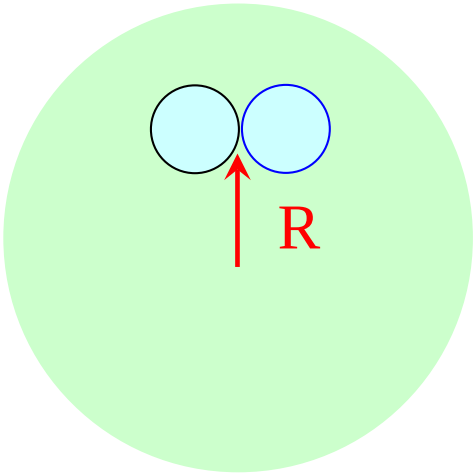
large asymmetry in density distribution **= di-neutron correlation**

cf. Coulomb hole in He atom

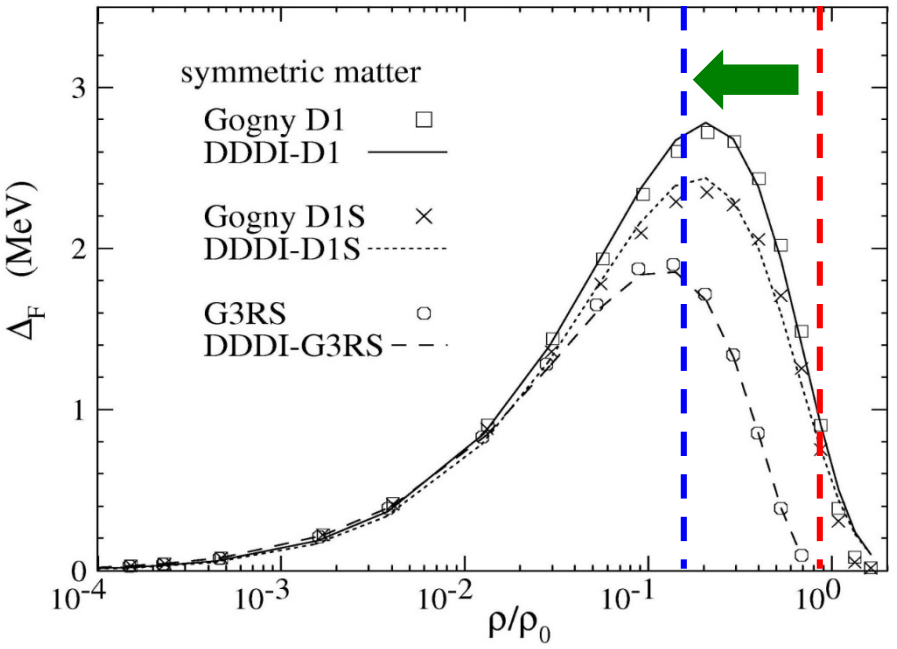
(He nucleus + e^- + e^-)





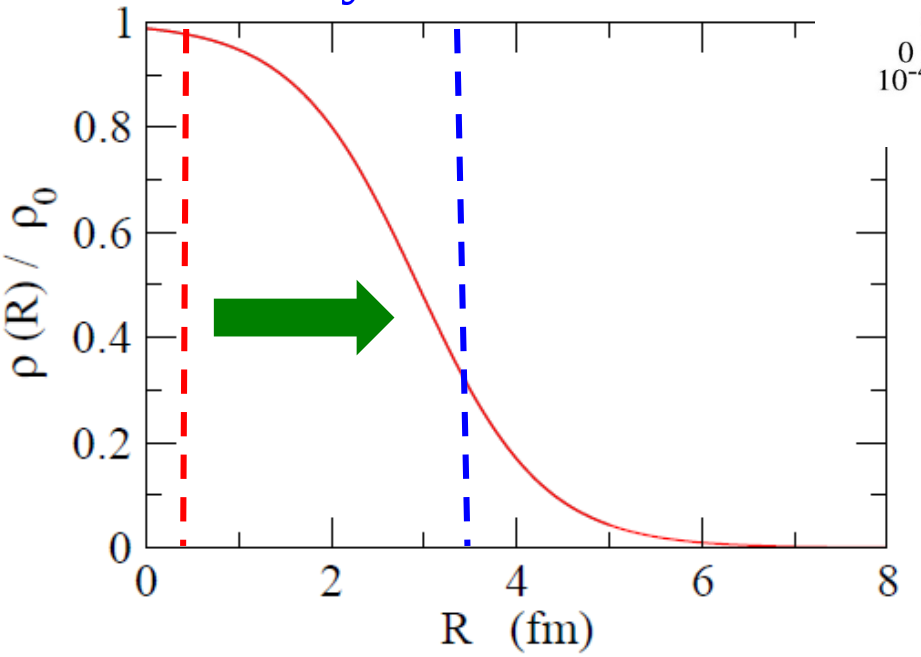


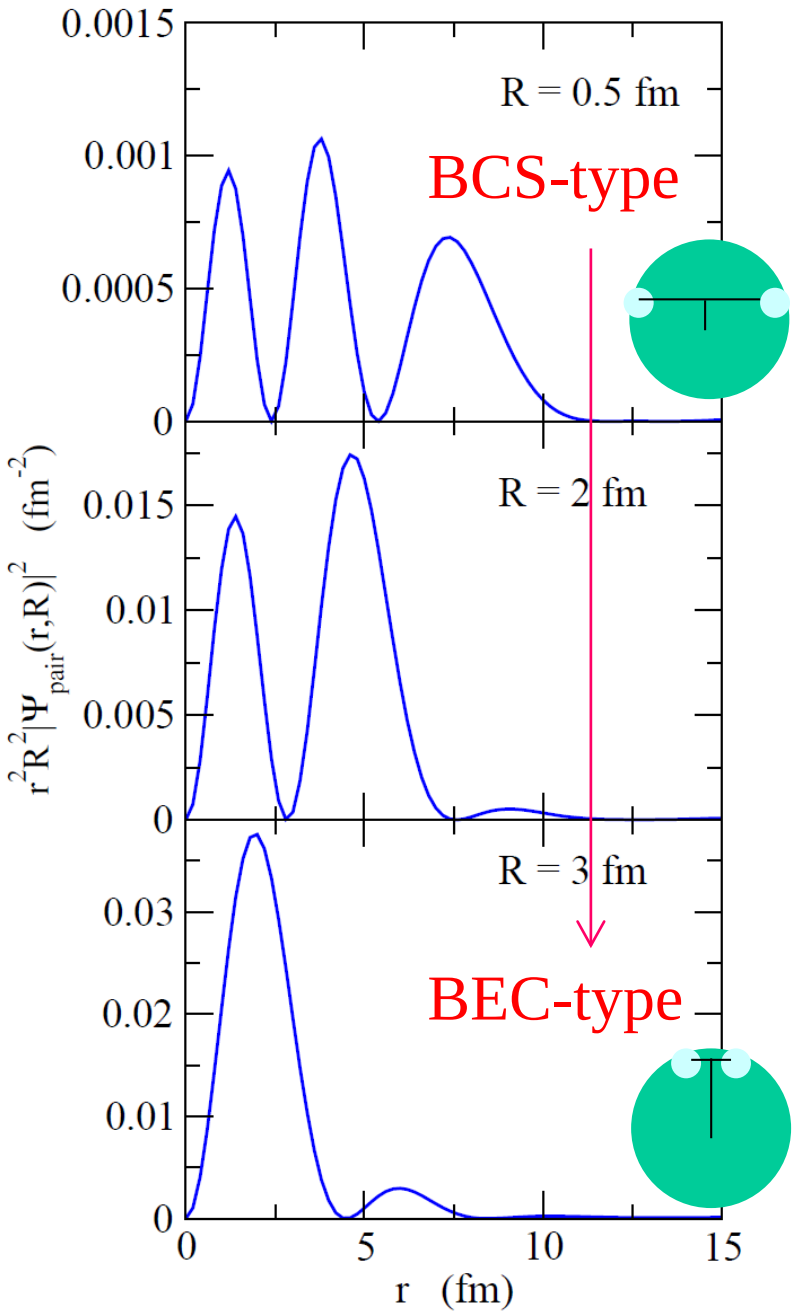
pairing gap in infinite nuclear matter

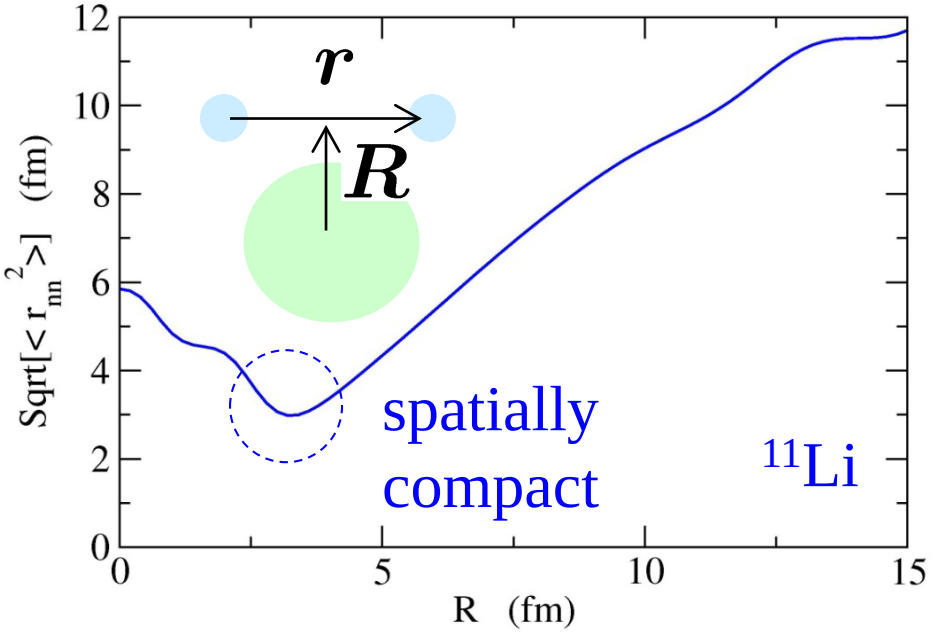


M. Matsuo, PRC73(’06)044309

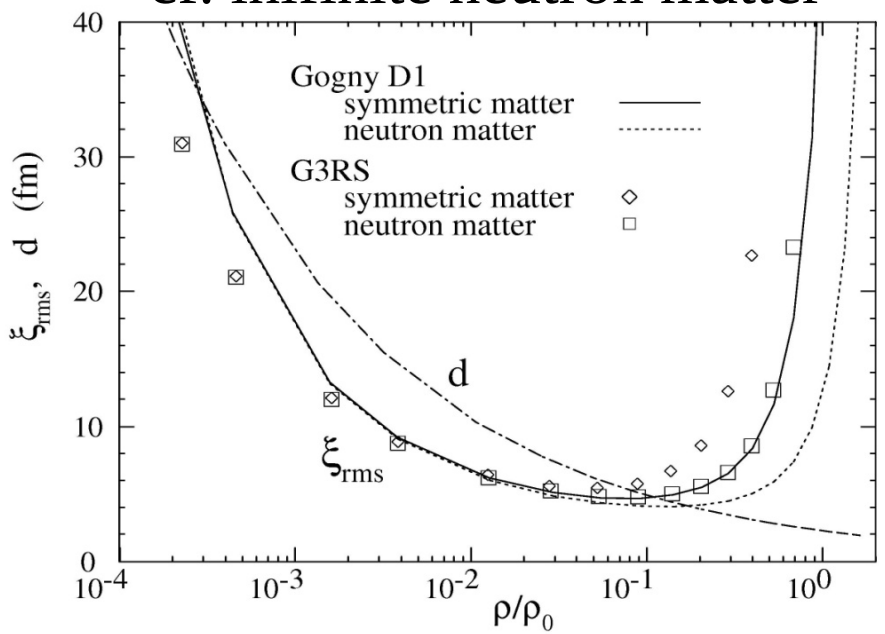
Density distribution







cf. inifinite neutron matter

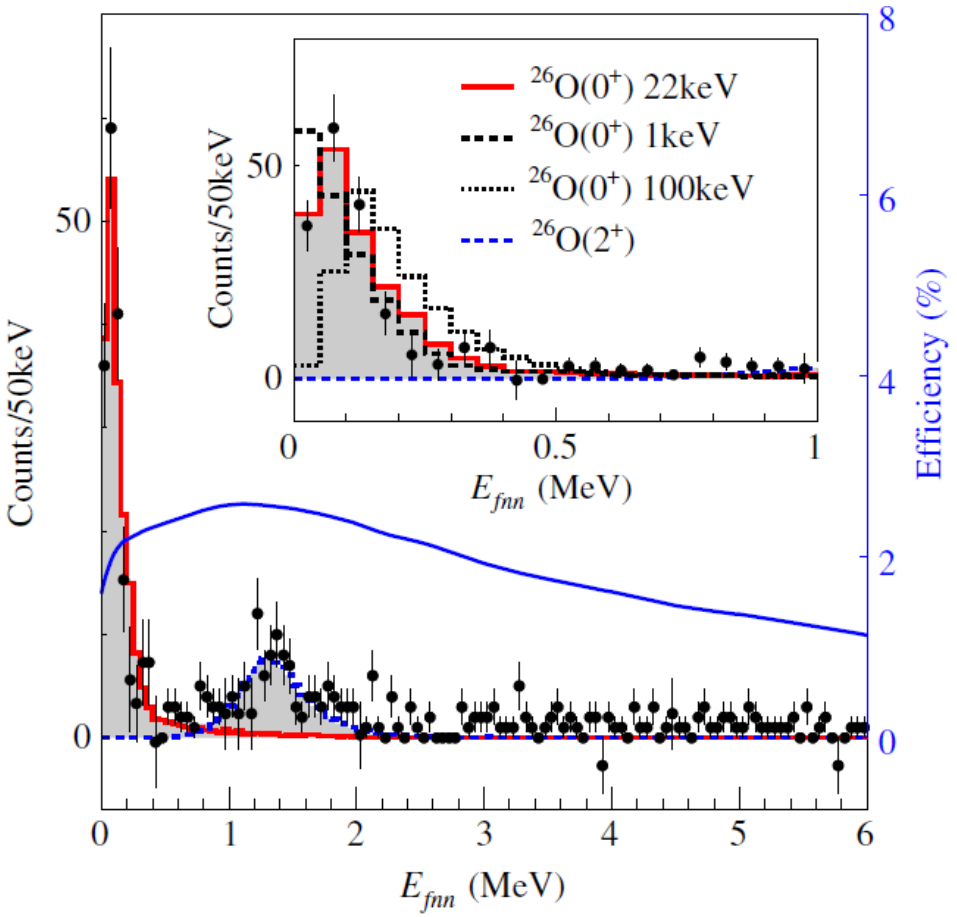


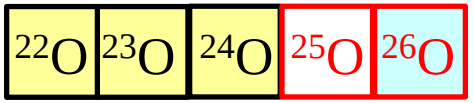
K.H. et al., PRL99 (’07) 022506

M. Matsuo, PRC73(’06)044309

Two-neutron decay of ^{26}O

Expt. : ^{27}F (201 MeV/u) + ^{9}Be → ^{26}O → ^{24}O + n + n





749 keV

^{25}O

2n decay

18 keV

^{24}O ^{26}O

(neutron drip line)

Y. Kondo et al., PRL116('16)102503

→ E_{decay} = 18 +/- 3 +/- 4 keV

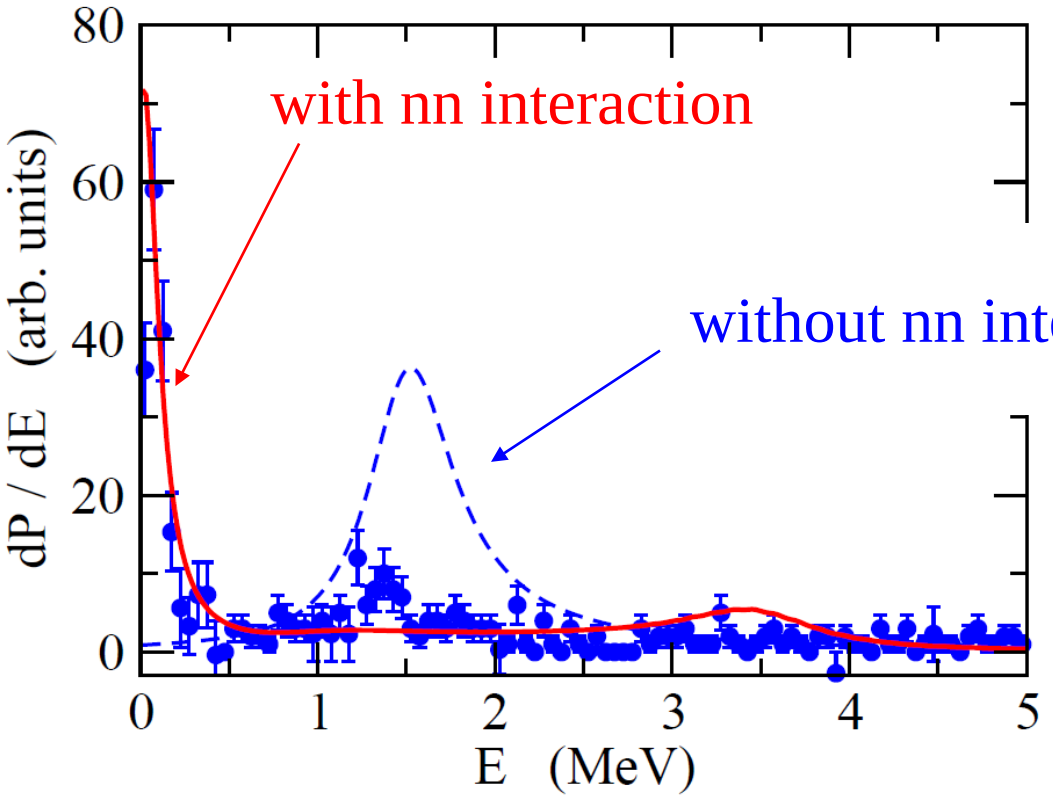
3-body model analysis for ^{26}O decay

K.H. and H. Sagawa,
- PRC89 (‘14) 014331
- PRC93(‘16)034330

Expt. : ^{27}F (201 MeV/u) + ^{9}Be → ^{26}O → ^{24}O + n + n

$$\frac{dP}{dE} = \int dE' |\langle \Psi_{E'} | \Phi_{\rm ref} \rangle|^2 \, \delta(E - E') = \frac{1}{\pi} \Im \langle \Phi_{\rm ref} | \frac{1}{H - E - i\eta} | \Phi_{\rm ref} \rangle$$

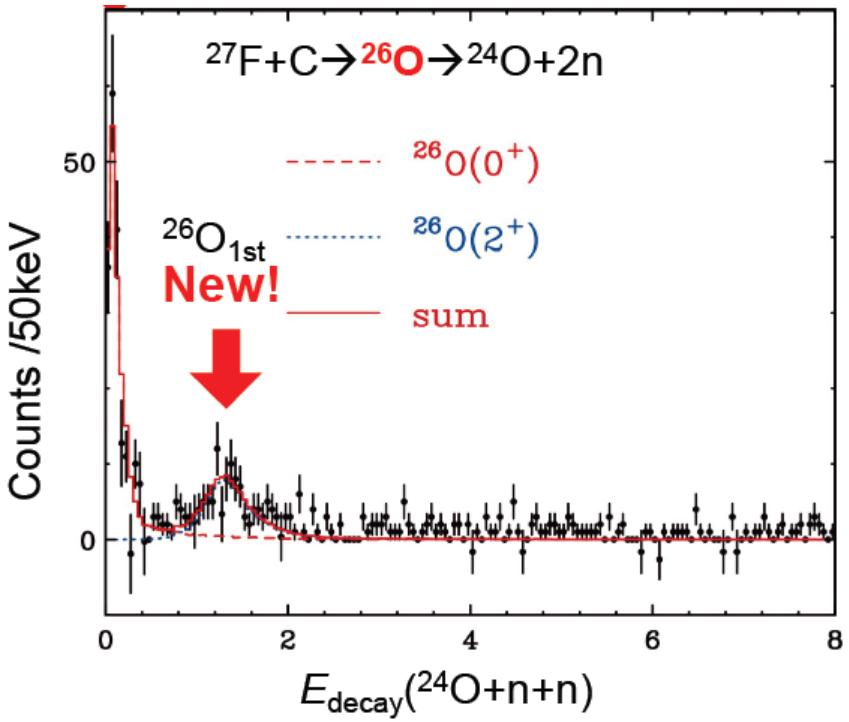
continuum dynamics, FSI



cf. $e_{1d3/2}(^{25}O)$
= 0.749 MeV

2^+ state in ^{26}O

a prominent second peak
at E = 1.28 $^{+0.11}_{-0.08}$ MeV



Y. Kondo et al.,
PRL116(’16)102503

three-body model calculation:

(MeV)

1.498 ---------- $(d_{3/2})^2$

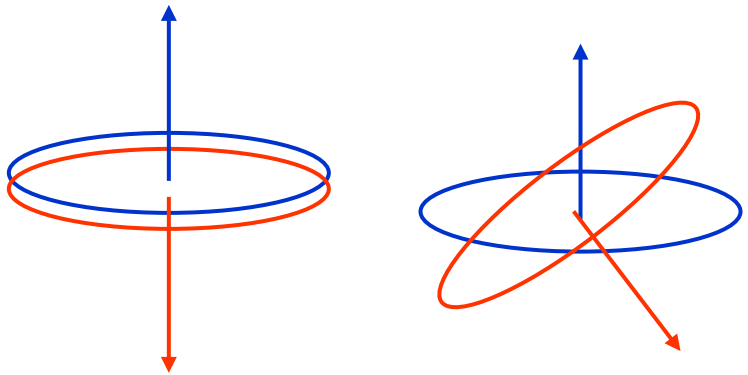
1.282 ———— 2^+

Γ = 0.12 MeV

0.018 ———— 0^+

K.H. and H. Sagawa,
PRC90(‘14)027303; PRC93(‘16)034330.

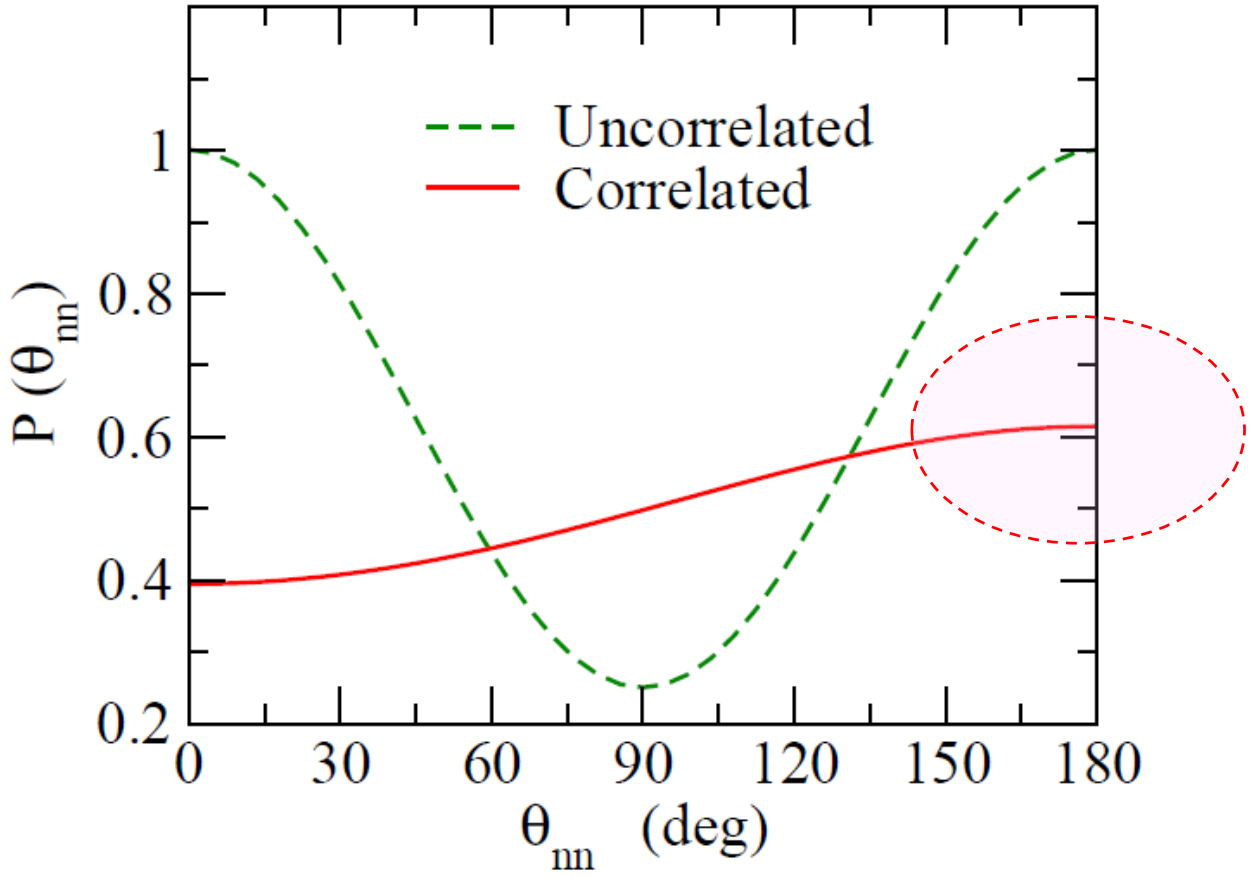
I=0 pair $\quad$ $I \neq 0$ pair



Angular correlations of two emitted neutrons

$$P(\theta) \sim |\langle \boldsymbol{k}_1 \boldsymbol{k}_2 | \Psi_{\mathrm{3bd}}(E) \rangle|^2$$

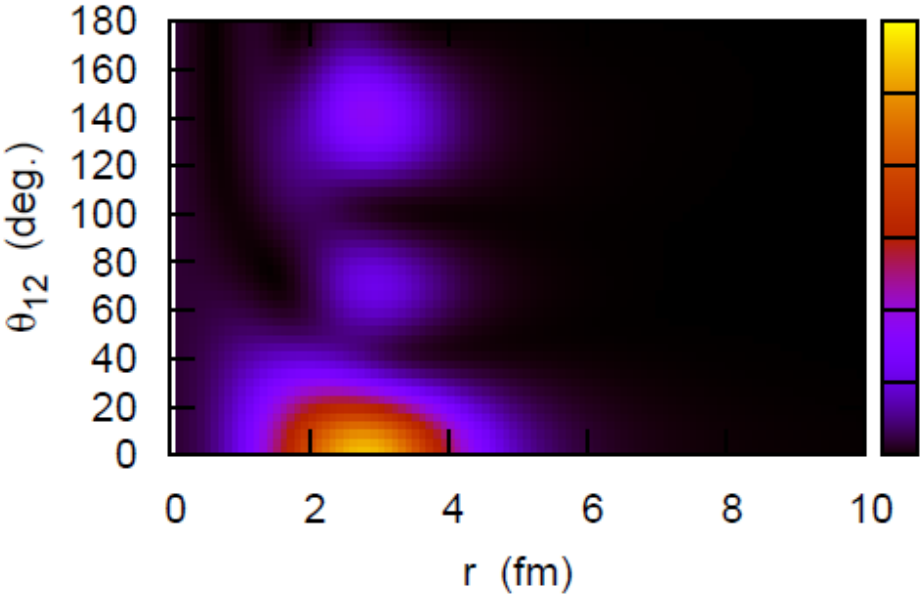
K.H. and H. Sagawa,
PRC89 (‘14) 014331;
PRC93 (‘16) 034330

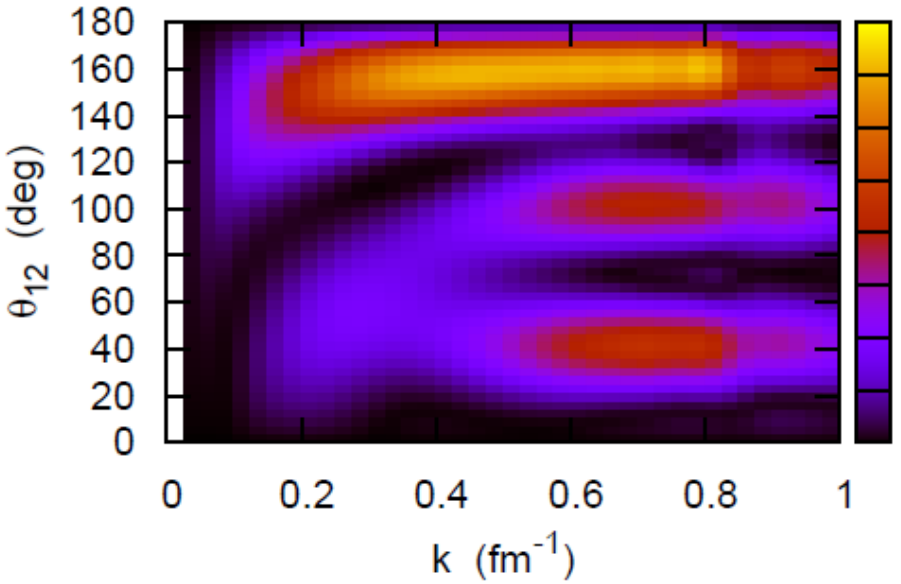


correlation → enhancement of back-to-back emissions

Two-particle density in the bound state approximation

r-space $\rho(r, r, \theta)$ → Fourier transform → *p*-space $8\pi^2 k^4 \sin\theta \cdot \rho(k, k, \theta)$





$(d_{3/2})^2$: 66.1%
$(f_{7/2})^2$: 18.3%
$(p_{3/2})^2$: 10.5%
$(s_{1/2})^2$: 0.59%
rms radius = 3.39 +/- 0.11 fm

dineutron correlation

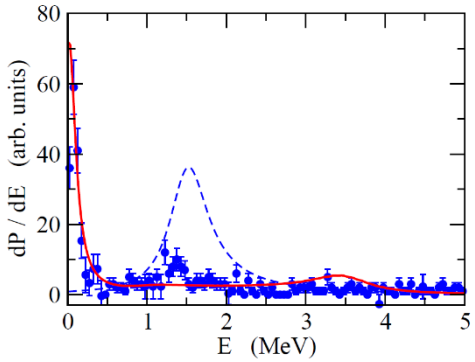
↕

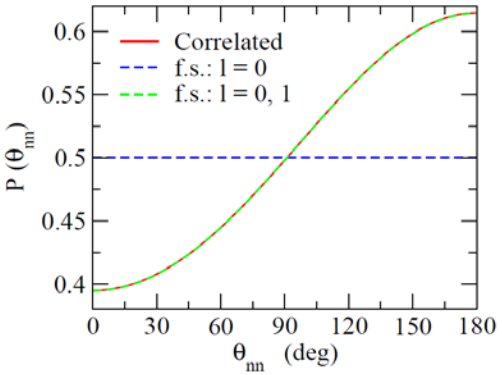
enhancement of large opening angles

Summary

Three-body model for light neutron-rich nuclei

- Borromean nuclei
  - ✓ di-neutron correlation
  - ✓ similarity to BCS-BEC crossover phenomenon
- 2n emission decay of ^{26}O
  - ✓ Decay energy spectrum: strong low-energy peak
  - ✓ 2^+ energy
  - ✓ Angular distributions: enhanced back-to-back emission
    ⟷ dineutron correlation





- A challenge: extension to five-body model cf. ^{28}O → NSMAT