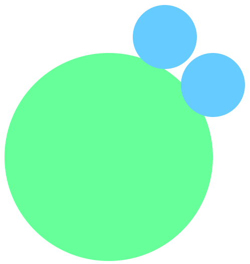
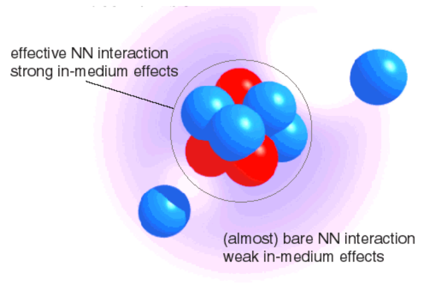
Di-neutron correlation in Borromean nuclei



K. Hagino (Tohoku University)
H. Sagawa (University of Aizu)



^{11}Li, ^{6}He

What is the spatial structure of valence neutrons?
Compact? Or Extended?

1. *Introduction: Di-neutron correlation*
2. *Three-body model for ^{11}Li and ^{6}He*
    - *Spatial structure (geometry) of valence neutrons*
    - *E1 strength*
3. *1-Dimensional 3-body model*
4. *Summary*

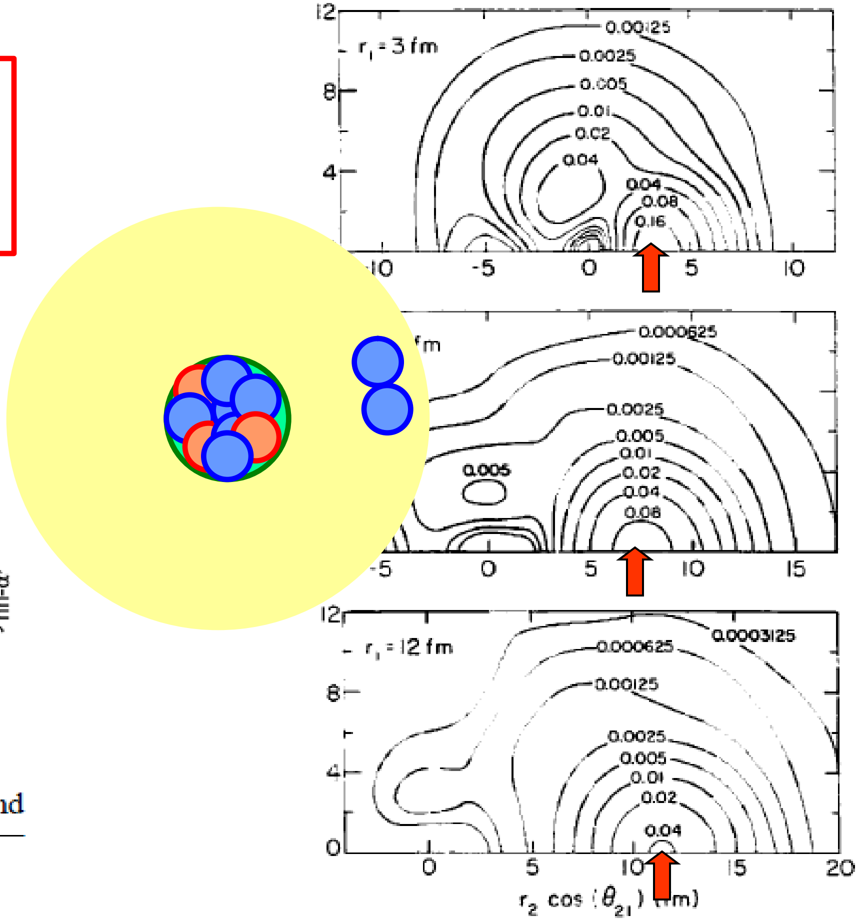
Borromean nuclei and Di-neutron correlation

Borromean nuclei: unique three-body systems

Three-body model calculations:

strong di-neutron correlation
in ^{11}Li and ^{6}He

$\rho_2(r_1, r_2, \theta_{12})$ for ^{11}Li



G.F. Bertsch, H. Esbensen,
Ann. of Phys., 209('91)327

$x^2 y^2 \rho_2(x, y)$ for ^{6}He

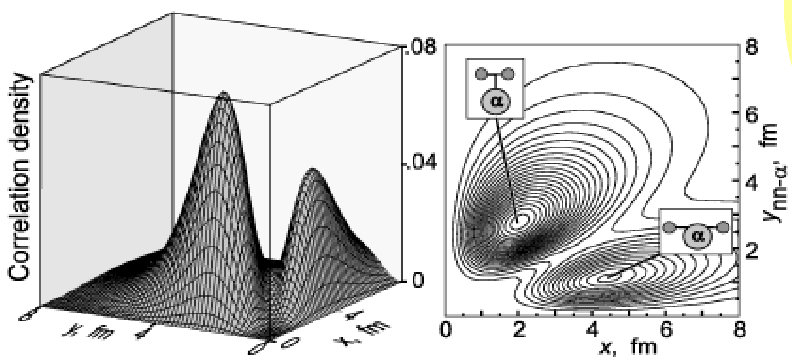


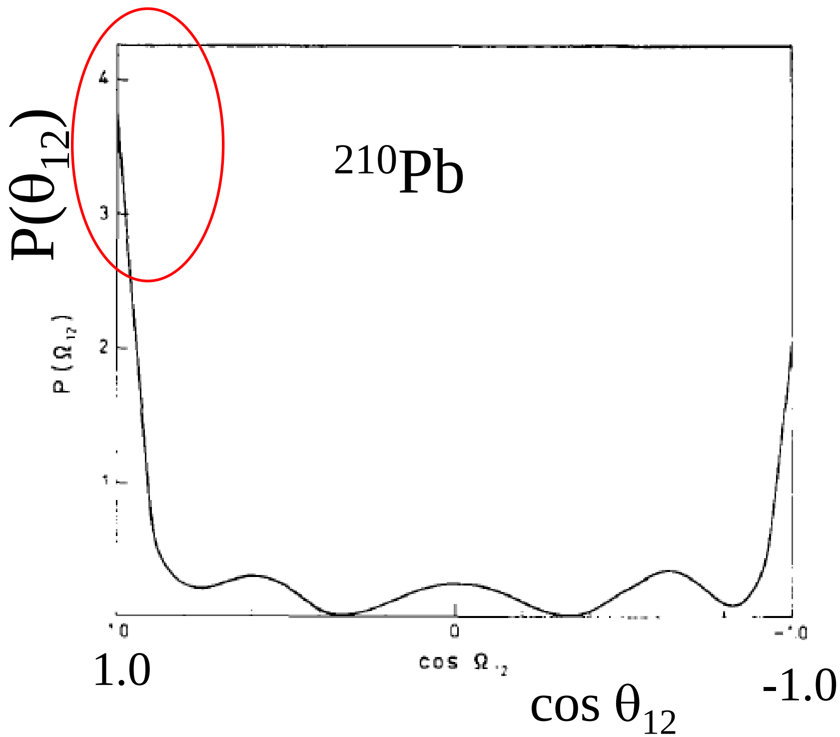
FIG. 1. Spatial correlation density plot for the 0^+ ground state of ^{6}He. Two components—di-neutron and cigarlike—are shown schematically.

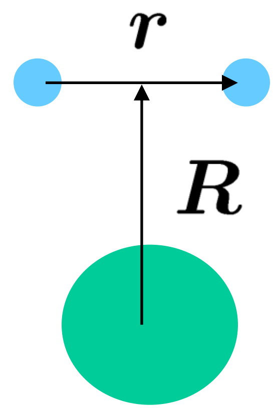
Yu.Ts. Oganessian, V.I. Zagrebaev,
and J.S. Vaagen, *PRL82('99)4996*
M.V. Zhukov et al., *Phys. Rep. 231('93)151*

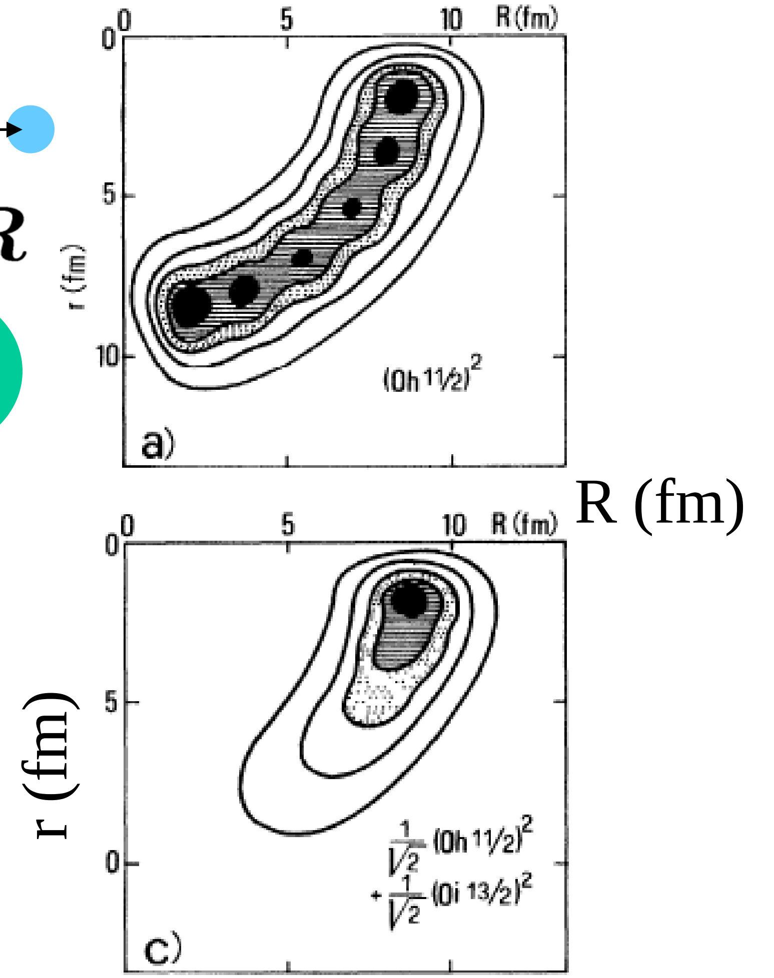
Borromean nuclei and Di-neutron correlation

Three-body model calculations:

strong di-neutron correlation
in ^{11}Li and ^{6}He







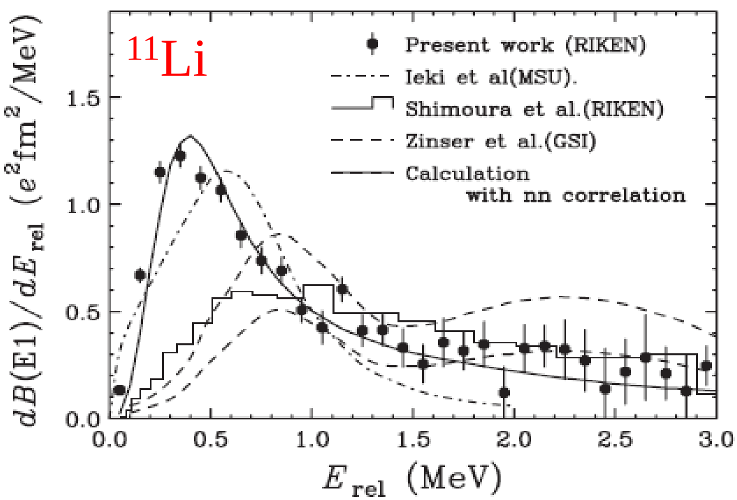
G.F. Bertsch, R.A. Broglia, and C. Riedel, NPA91('67)123

F. Catara, A. Insolia, E. Maglione, and A. Vitturi, PRC29('84)1091

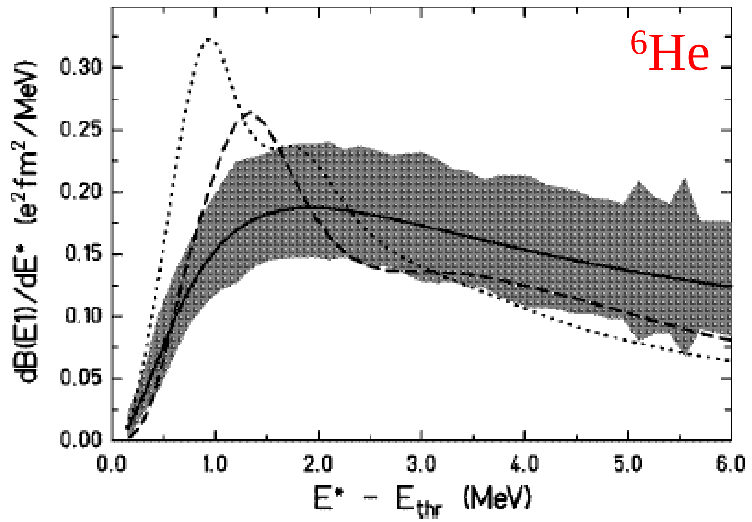
Remaining problem:

How to probe the strong dineutron correlation?

•Coulomb excitations?



T. Nakamura et al., PRL96('06)252502



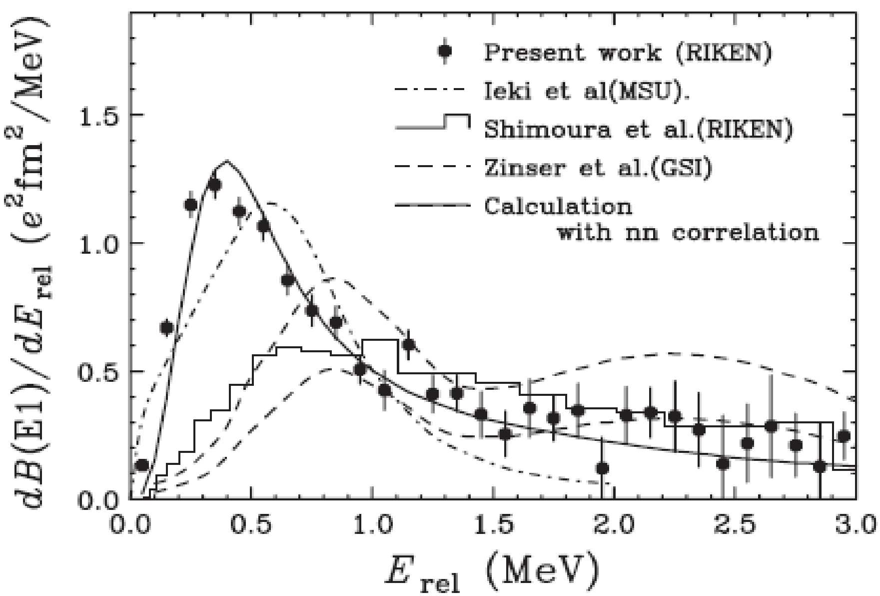
T. Aumann et al., PRC59('99)1252

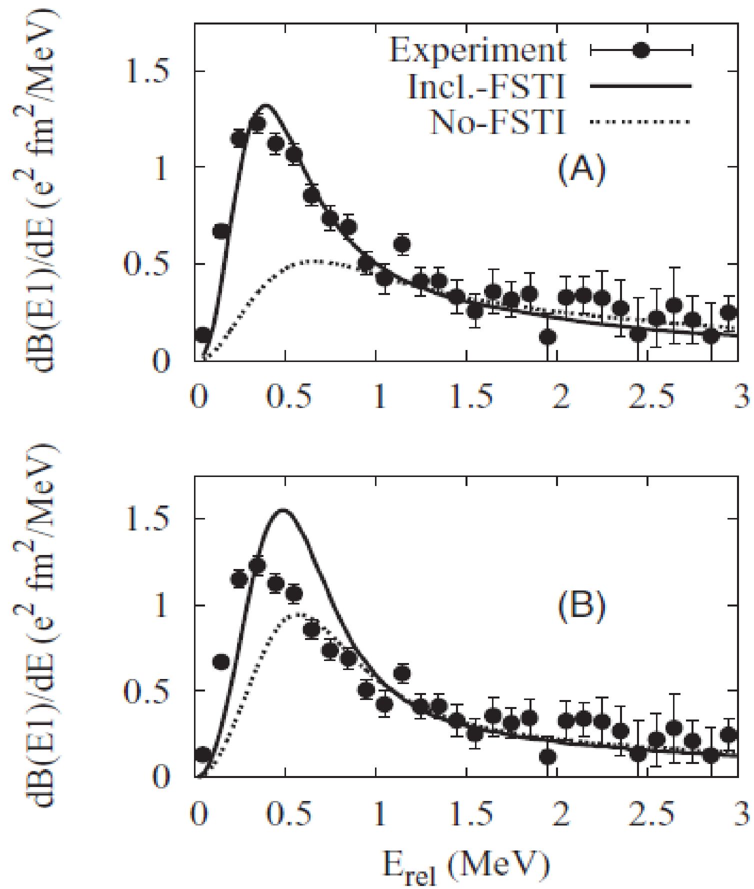
* (indirect) evidence for dineutron correlation

dineutron correlation in the ground state?

<u>Experimental evidence:</u> T. Nakamura et al., PRL96('06)252502

Recent Coulomb dissociation data of ^{11}Li





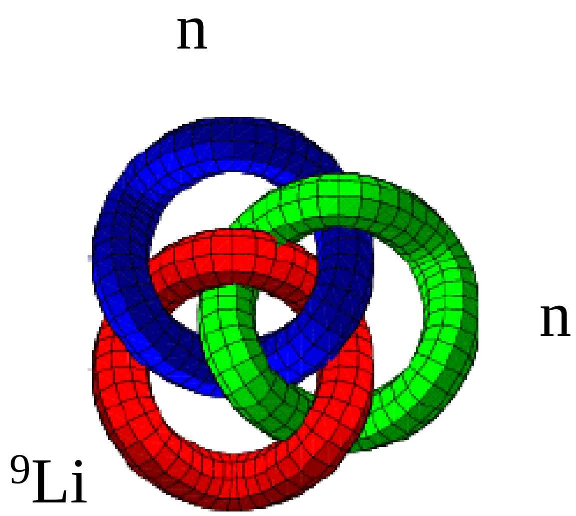
renewed interests in dineutron correlations in weakly bound nuclei

H. Esbensen, K. Hagino, P. Mueller, and H. Sagawa, PRC76('07)024302

c.f. M. Matsuo et al., PRC71('05)064326
PRC73('06)044309

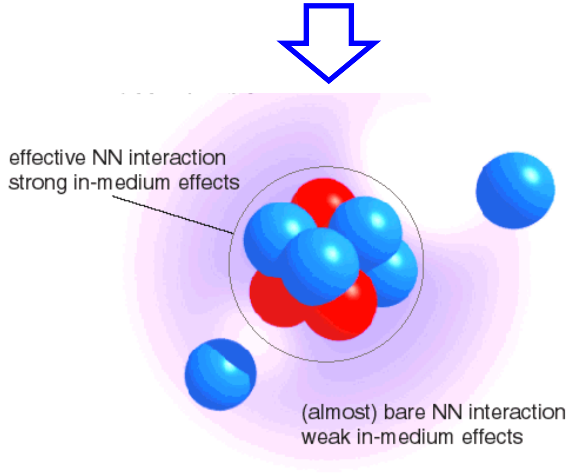
Remaining problems

- spatial structure of dineutron (cf. a large pair coherence length?)
- dineutron correlation in heavy nuclei?
- E1 excitations?
- Pair transfer?



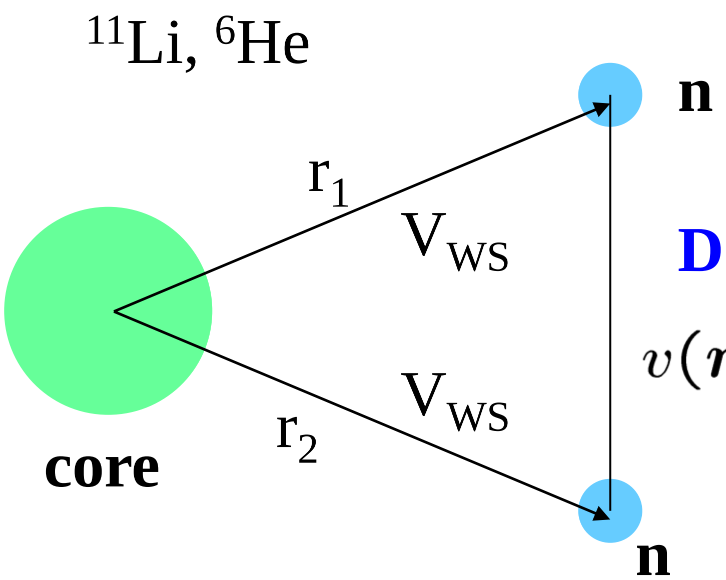
What is the spatial structure of the valence neutrons?

To what extent is this picture correct?



Three-body model with density-dependent delta force

G.F. Bertsch and H. Esbensen,
Ann. of Phys. 209('91)327
H. Esbensen, G.F. Bertsch, K. Hencken,
Phys. Rev. C56('99)3054

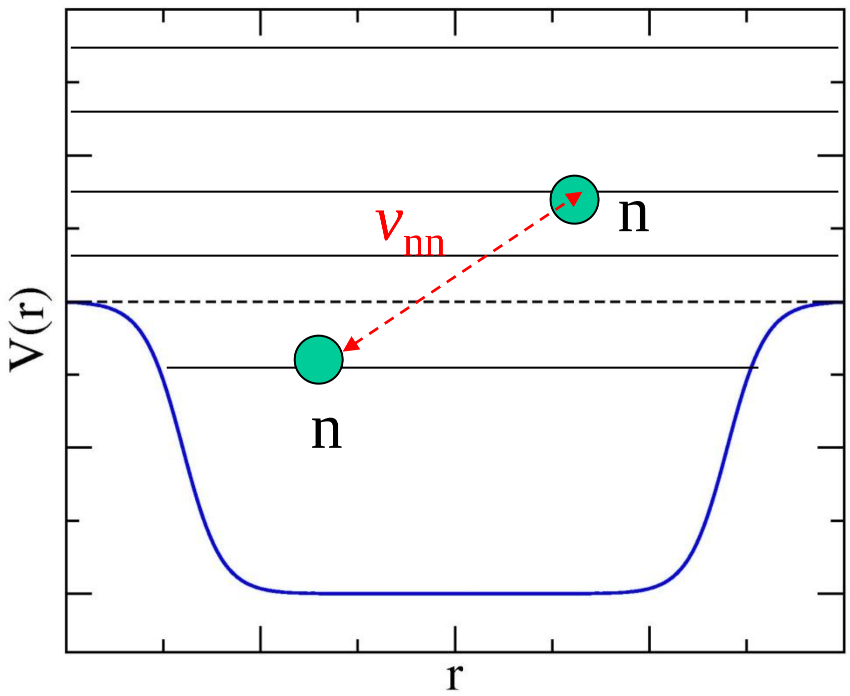


Density-dependent delta-force

$$
\begin{aligned}
v(\boldsymbol{r}_1, \boldsymbol{r}_2) &= v_0(1 + \alpha\rho(r)) \\
&\quad \times \delta(\boldsymbol{r}_1 - \boldsymbol{r}_2)
\end{aligned}
$$

$$
\boxed{H = \frac{\boldsymbol{p}_1^2}{2m} + \frac{\boldsymbol{p}_2^2}{2m} + V_{nC}(r_1) + V_{nC}(r_2) + V_{nn} + \frac{(\boldsymbol{p}_1 + \boldsymbol{p}_2)^2}{2A_c m}}
$$

$$H = \frac{\boldsymbol{p}_1^2}{2m} + \frac{\boldsymbol{p}_2^2}{2m} + V_{nC}(r_1) + V_{nC}(r_2) + V_{nn} + \frac{(\boldsymbol{p}_1 + \boldsymbol{p}_2)^2}{2A_c m}$$



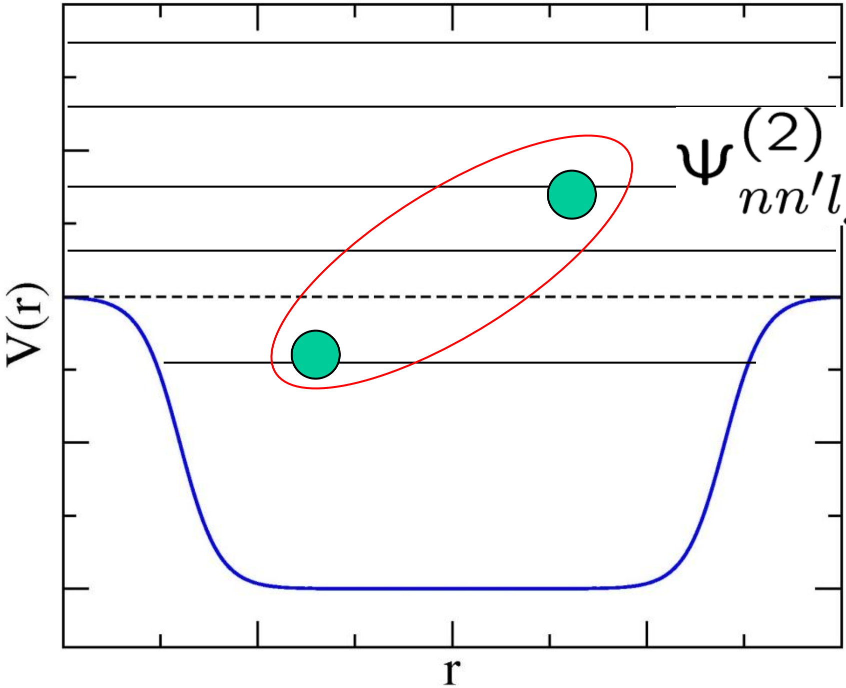
continuum states:
discretized in a large box

$$V_{nn}(\boldsymbol{r}_1, \boldsymbol{r}_2) = \delta(\boldsymbol{r}_1 - \boldsymbol{r}_2)\left(v_0 + \frac{v_\rho}{1 + \exp[(r_1 - R_\rho)/a_\rho]}\right)$$

- ✓ contact interaction
- ✓ v_0: free n-n
- ✓ density dependent term: medium many-body effects

$$H = \frac{\boldsymbol{p}_1^2}{2m} + \frac{\boldsymbol{p}_2^2}{2m} + V_{nC}(r_1) + V_{nC}(r_2) + V_{nn} + \frac{(\boldsymbol{p}_1 + \boldsymbol{p}_2)^2}{2A_c m}$$

$$\boxed{\Psi_{gs}(\boldsymbol{r}, \boldsymbol{r}') = \mathcal{A} \sum_{nn'lj} \alpha_{nn'lj} \, \Psi^{(2)}_{nn'lj}(\boldsymbol{r}, \boldsymbol{r}')}$$



$\Psi^{(2)}_{nn'lj}(\boldsymbol{r}, \boldsymbol{r}')$

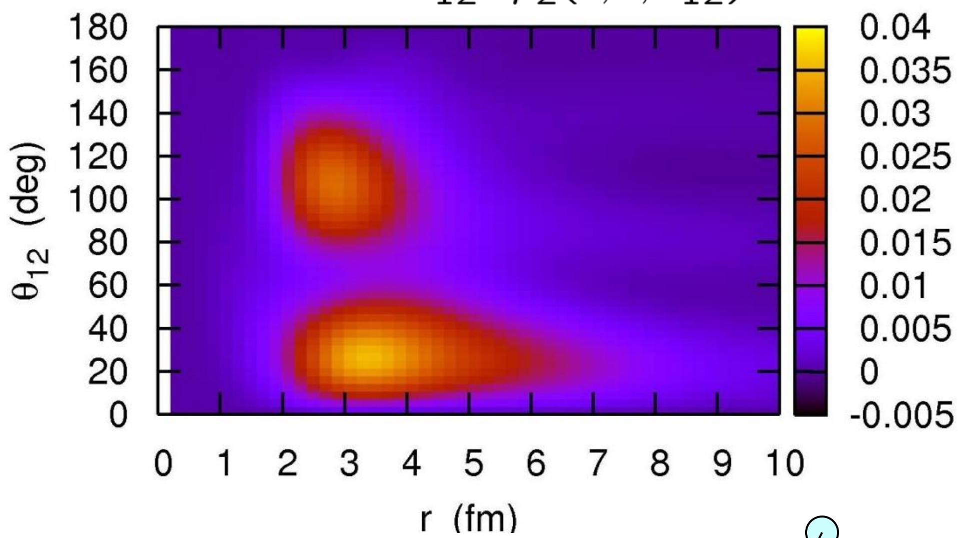
uncorrelated basis

⇩

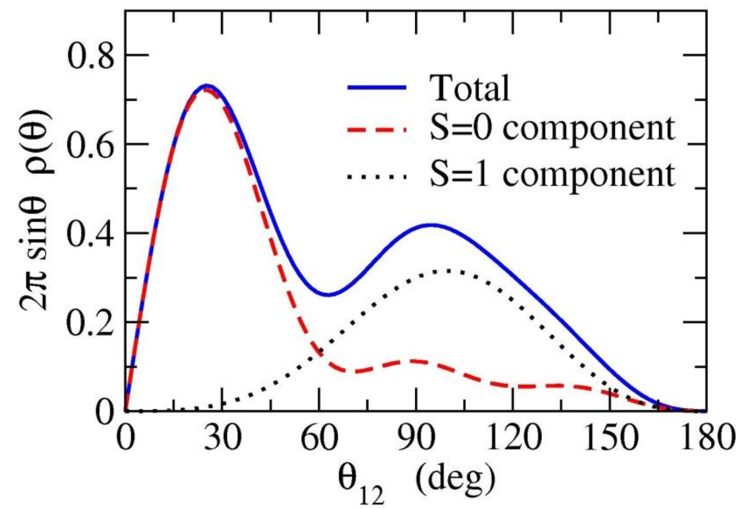
diagonalization of Hamiltonian matrix
(~ 1500 dimensions)

Two-particle density for the ground state of ^{11}Li and ^{6}He

^{11}Li

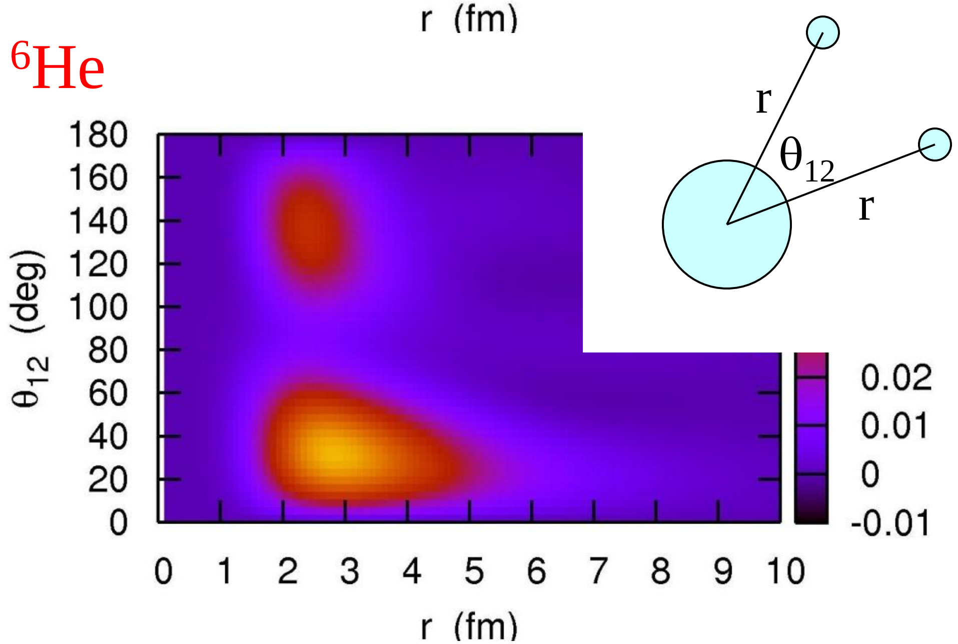


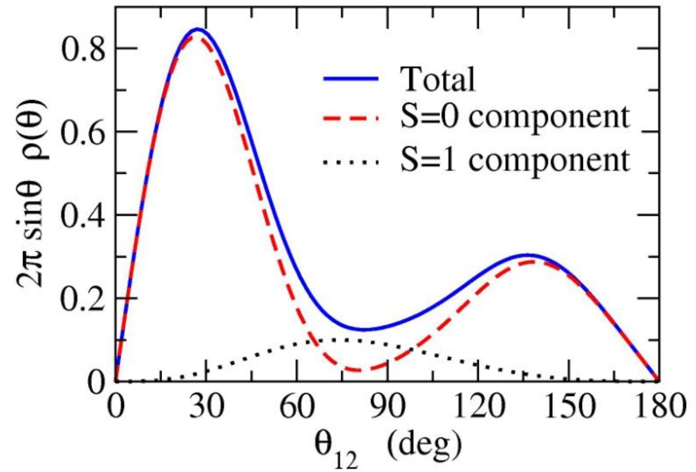
strong di-neutron correlation



$$\langle\theta_{12}\rangle = 65.29 \quad \text{deg.}$$

^{6}He





$$\langle\theta_{12}\rangle = 66.33 \quad \text{deg.}$$

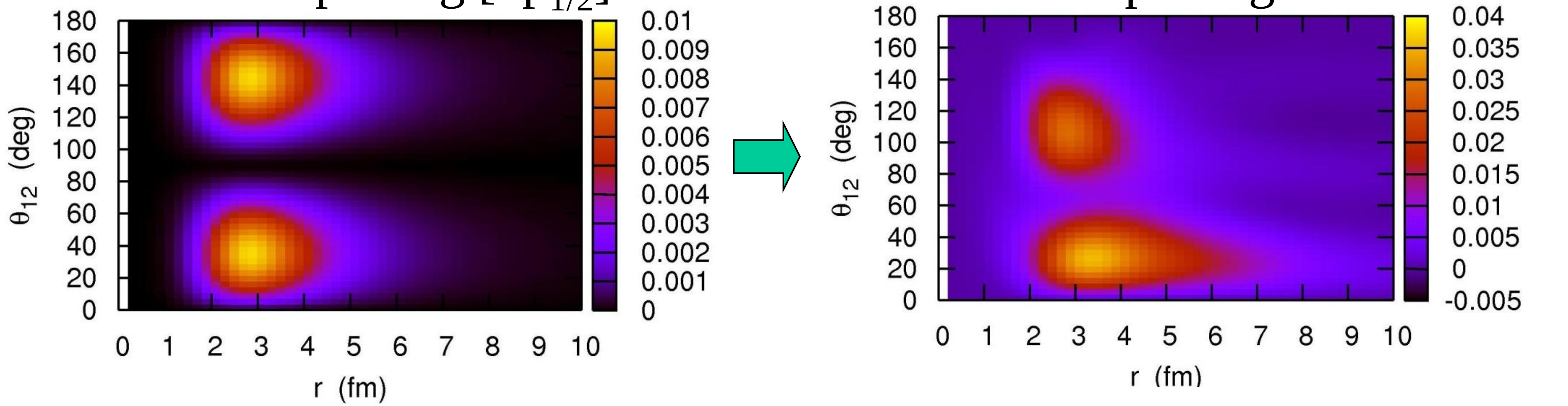
K.H. and H. Sagawa, PRC72('05)044321

✧ Role of pairing correlation

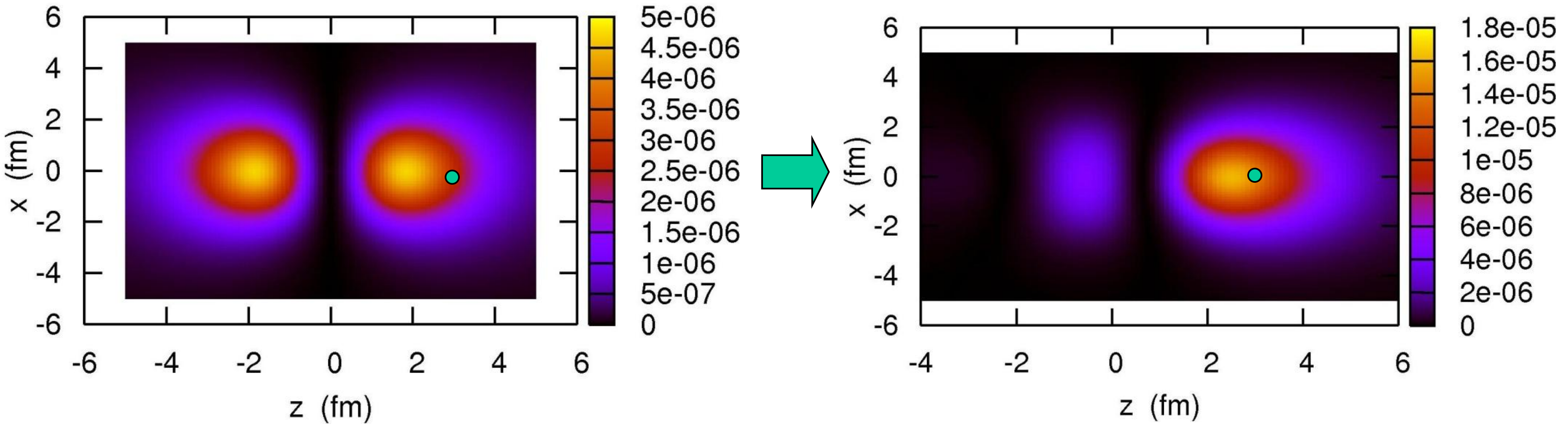
→ configuration mixing of different parity states

^{11}Li

without pairing $[1p_{1/2}]^2$ with pairing

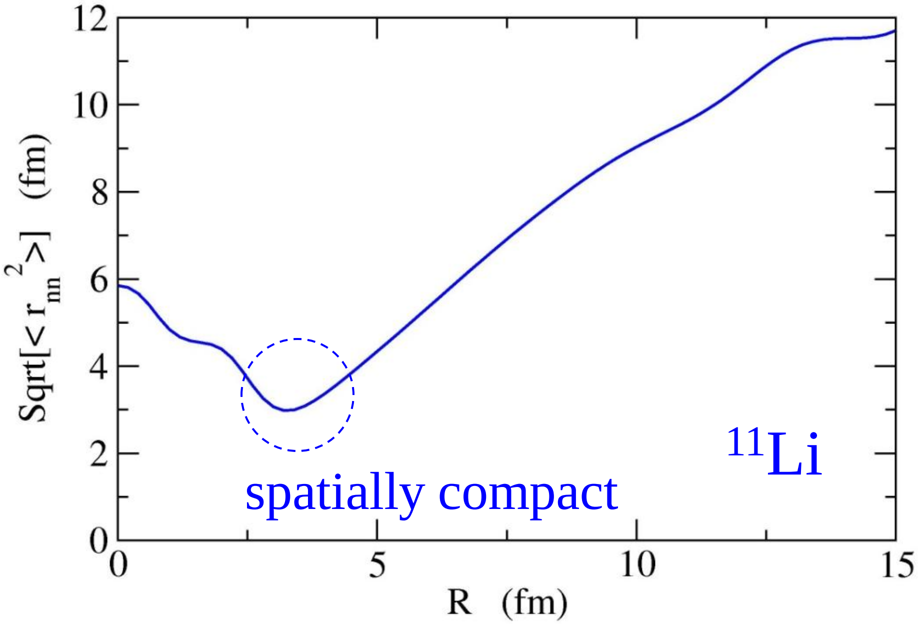


$(z_1,x_1)=(3.4\text{ fm}, 0)$



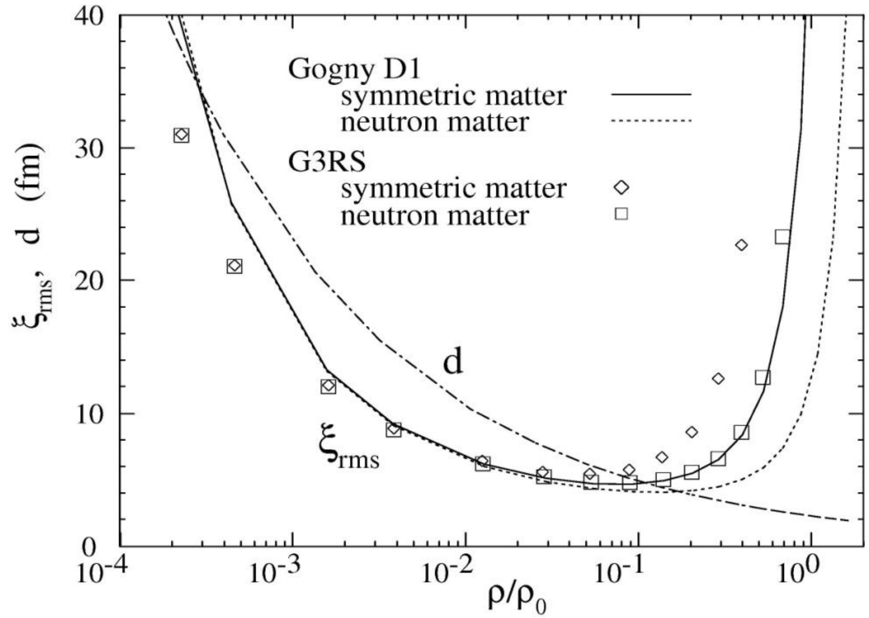
2n-rms distance

$$\sqrt{\langle r_{nn}^2 \rangle}(R) = \sqrt{\frac{\int r^4 dr\, |f_{L=0}(r,R)|^2}{\int r^2 dr\, |f_{L=0}(r,R)|^2}}$$

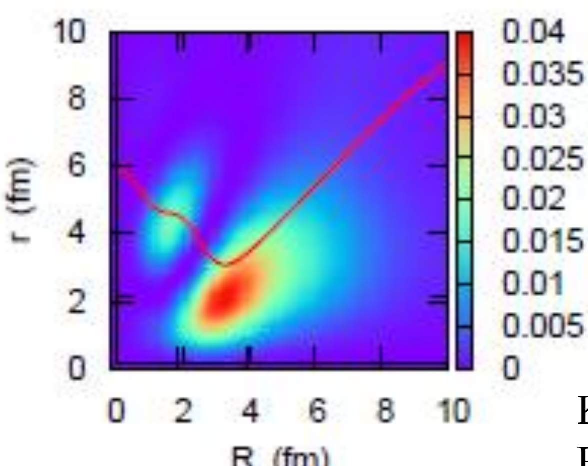


K.Hagino, H. Sagawa, J. Carbonell, and P. Schuck, PRL99('07)022506

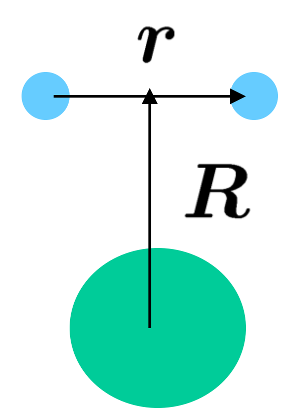
Matter Calc.



M. Matsuo, PRC73('06)044309

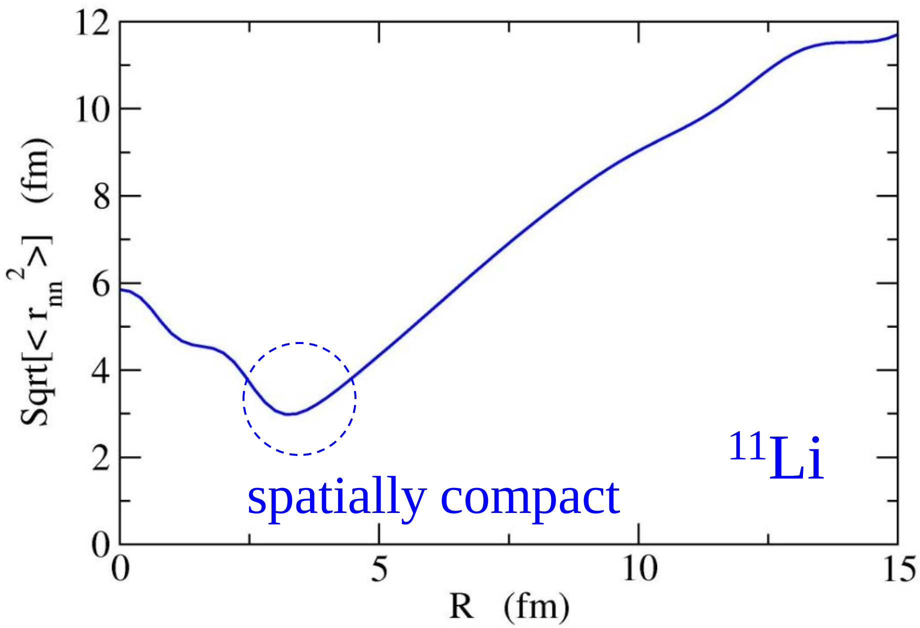


K.H., H. Sagawa, and
P. Schuck, J. of Phys. G37('10)064040

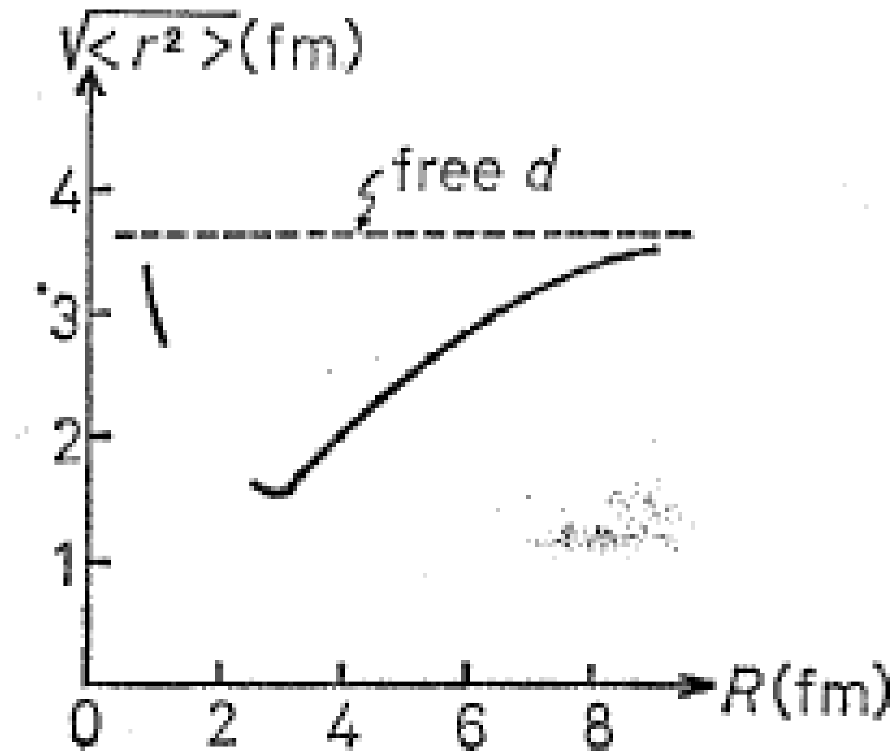


2n-rms distance

Size of deuteron in ^{6}Li



K.H., H. Sagawa, J. Carbonell, and P. Schuck, PRL99('07)022506



K. Itonaga and H. Bando, PTP44('70)1232

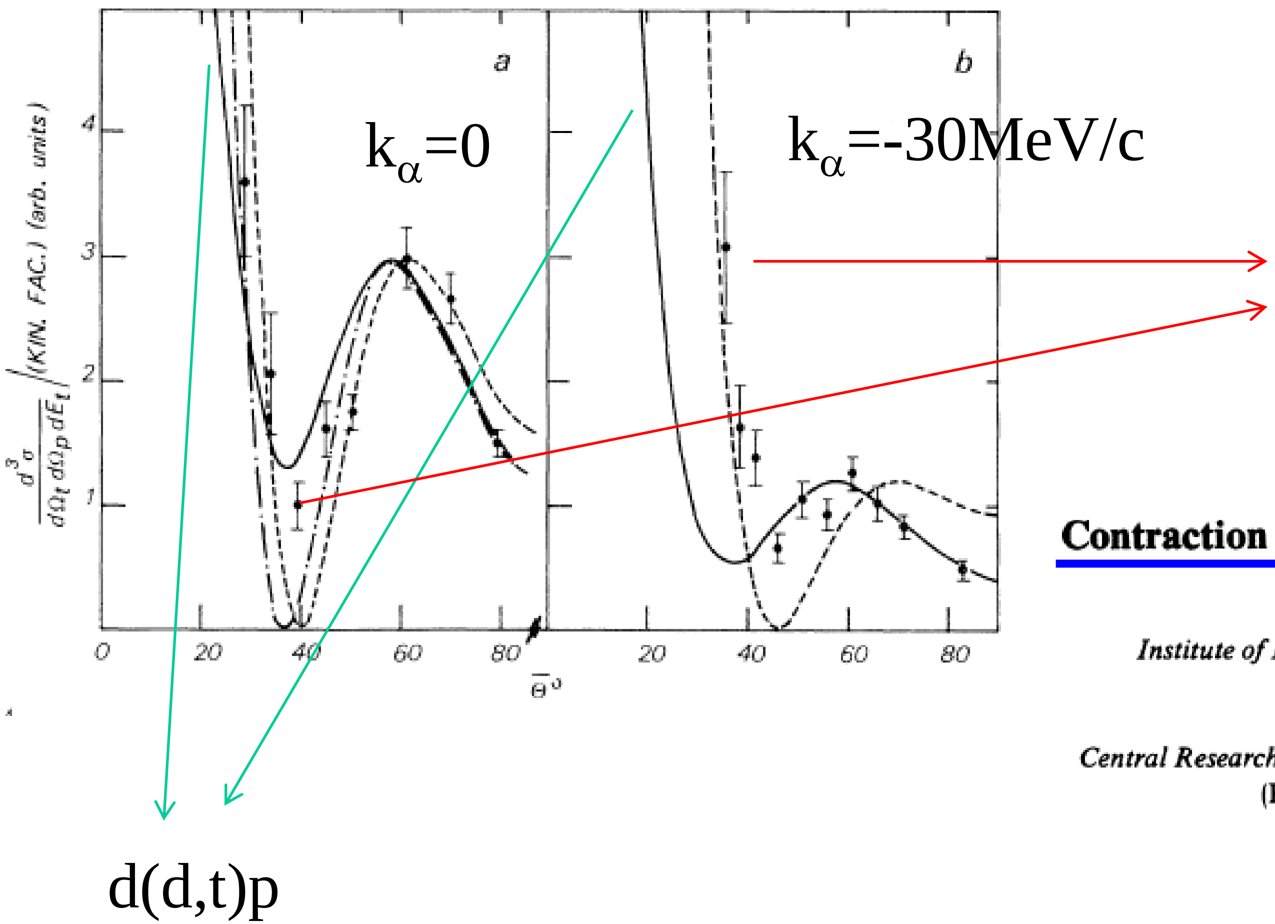
Study of Deuteron-Cluster Deformation Using the Reaction ^{6}Li(d, tp)^{4}He

J. Y. Grossiord, C. Coste, A. Guichard, M. Gusakow, A. K. Jain,* and J. R. Pizzi
Institut de Physique Nucléaire, Université Claude Bernard Lyon-I,
and Institut National de Physique Nucléaire et de Physique des Particules, 69621 Villeurbanne, France

and

G. Bagieu and R. de Swiniarski
Institut des Sciences Nucléaires de Grenoble
and Institut National de Physique Nucléaire et de Physique des Particules, 38044 Grenoble, France
(Received 20 November 1973)

PRL32('74)173



Contraction of the deuteron cluster in ^{6}Li

L. Végh
Institute of Nuclear Physics, Debrecen, Hungary

J. Erö
Central Research Institute for Physics, Budapest, Hungary
(Received 15 August 1980)

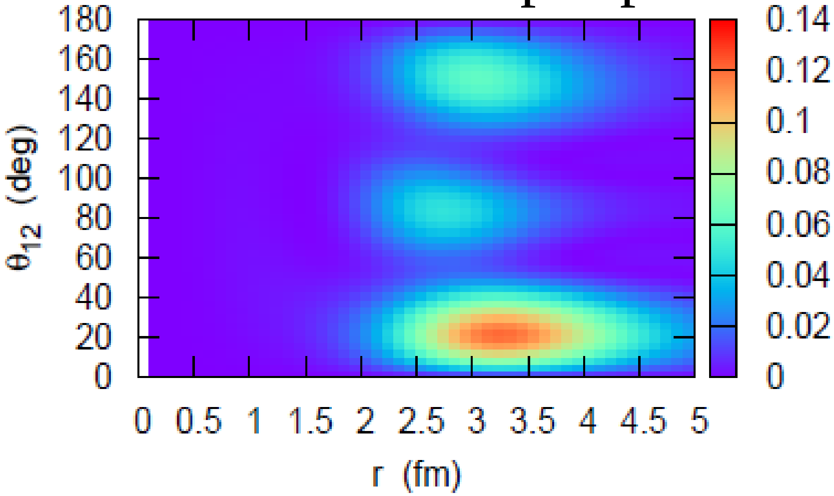
PRC23('81)2371

cf. “di-proton” correlation

^{17}Ne = ^{15}O + p + p   (S_{2p} = 0.944 MeV)

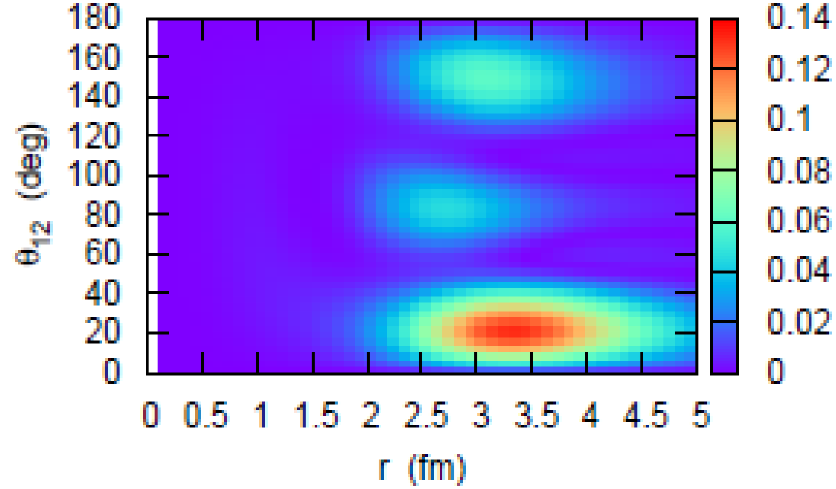
v_{pp} = density-dep. contact interaction + Coulomb

^{17}Ne = ^{15}O + p + p



similar

^{16}C = ^{14}C + n + n



$$\langle v_{pp}^{(\mathrm{nucl})} \rangle = -3.26 \quad \mathrm{MeV}$$

$$\langle v_{pp}^{(\mathrm{Coul})} \rangle = 0.448 \quad \mathrm{MeV}$$

about 14% contribution

T. Oishi, K. Hagino, and H. Sagawa, PRC82(‘10)024315

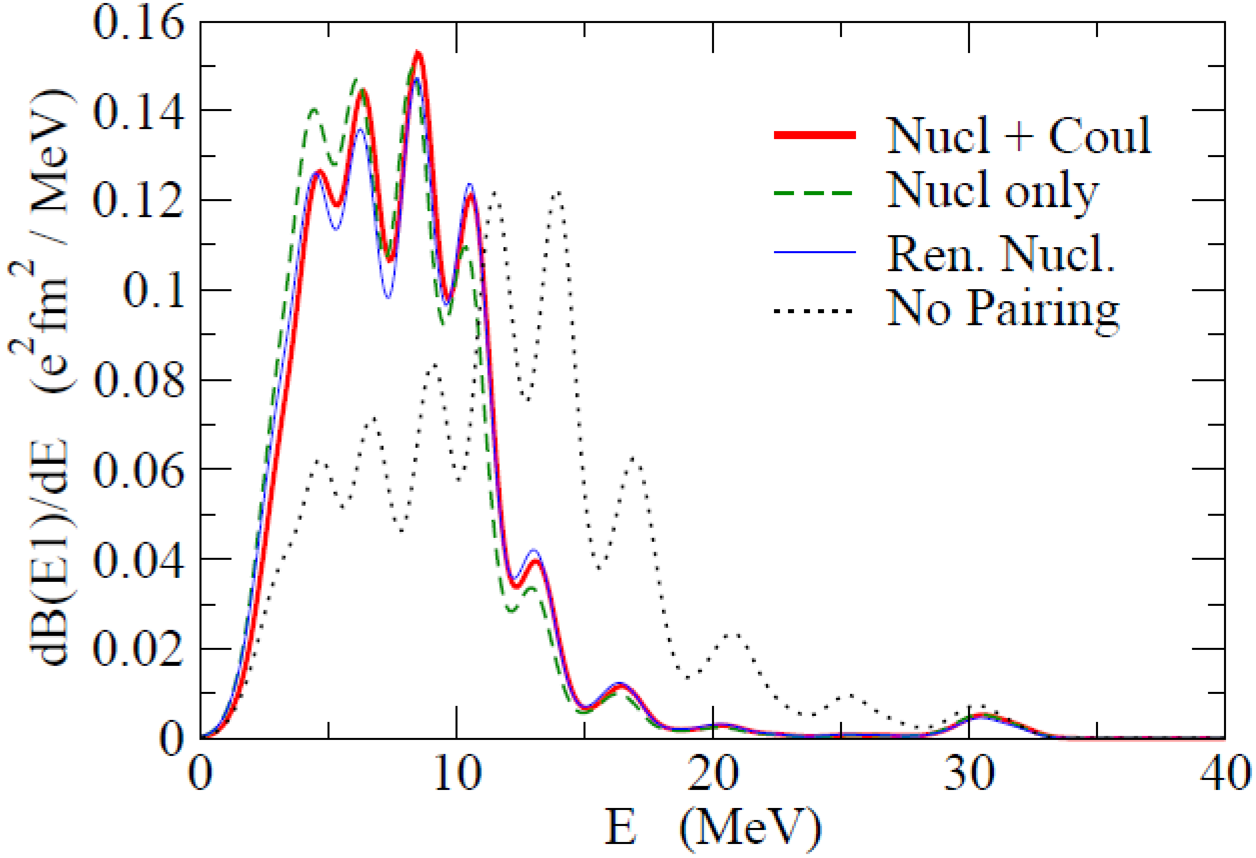
cf. "di-proton" correlation

	^{17}Ne	^{17}Ne (No Coulomb)	^{16}C
$\langle V_{\rm pp}^{(N)} \rangle$ (MeV)	−3.26	−2.76	−3.88
$\langle V_{\rm pp}^{(C)} \rangle$ (MeV)	0.448	0	0
$P([s_{1/2}]^2)$ (%)	15.16	15.91	20.69
$P([d_{5/2}]^2)$ (%)	75.19	75.68	64.97
$P([d_{3/2}]^2)$ (%)	3.83	3.26	6.63
$\langle r_{\rm NN}^2 \rangle^{1/2}$ (fm)	4.688	4.749	4.579
$\langle r_{\rm C-2N}^2 \rangle^{1/2}$ (fm)	3.037	3.037	3.099
$\delta \langle r^2 \rangle^{1/2}$ (fm)	1.267	1.273	1.306
$\langle \theta_{12} \rangle$ (deg)	76.64	76.03	74.35

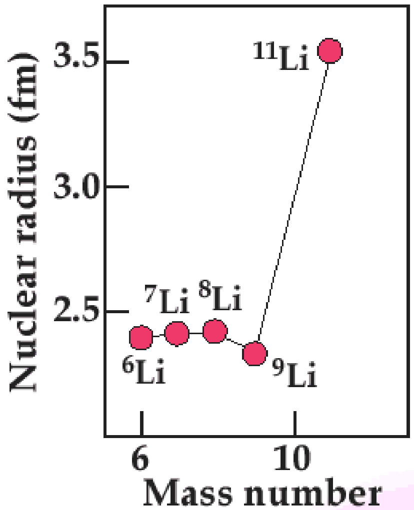
exact treatment
for Coulomb

switch off the Coulomb,
but renormalize the nuclear
force

T. Oishi, K. Hagino, and H. Sagawa, PRC82('10)024315



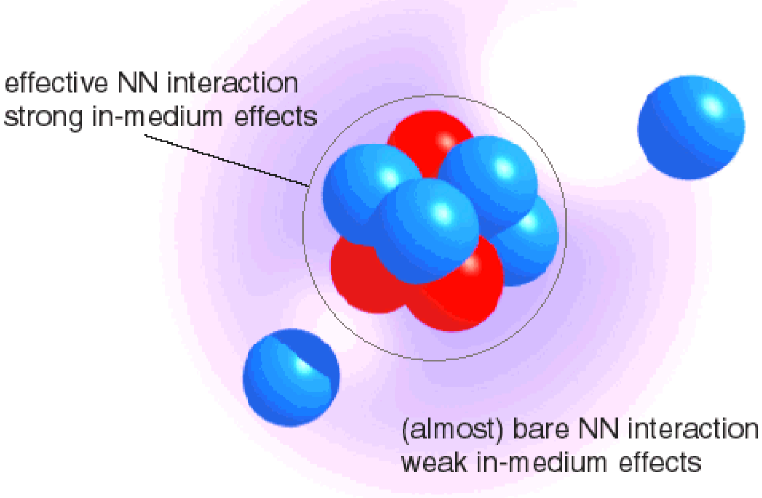
T. Oishi, K. Hagino, and H. Sagawa,
arXiv:1109.2994 [nucl-th]
Phys. Rev. C, in press.

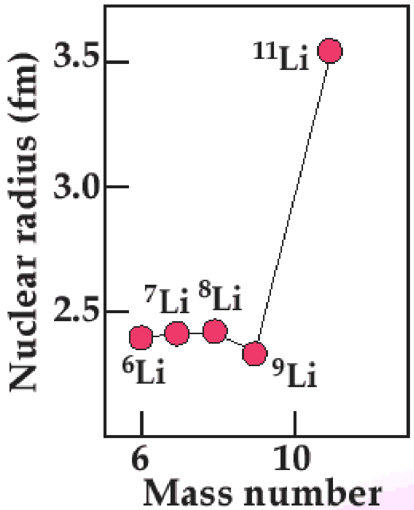


I. Tanihata et al.
Phys. Rev. Lett. 55, 2676 (1985)

Interaction cross section
measurements at Bevalac
(790 MeV/u)

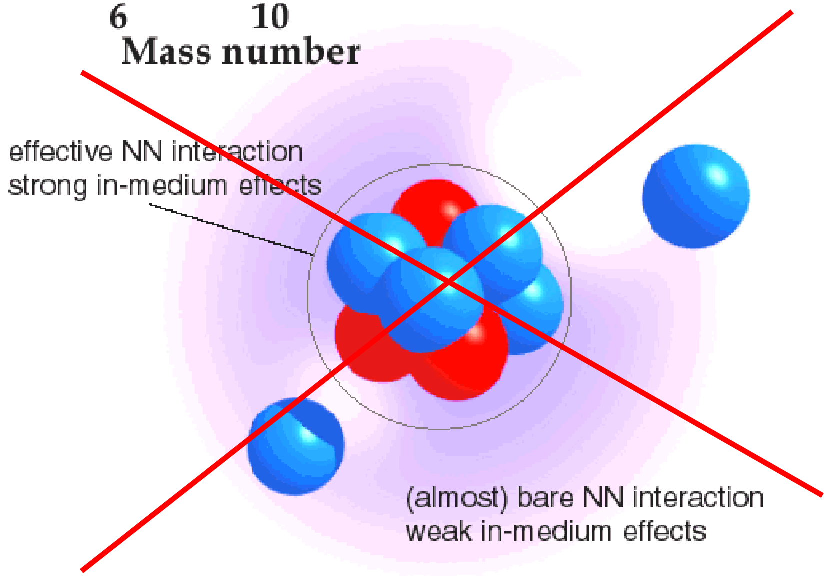
^{11}Li

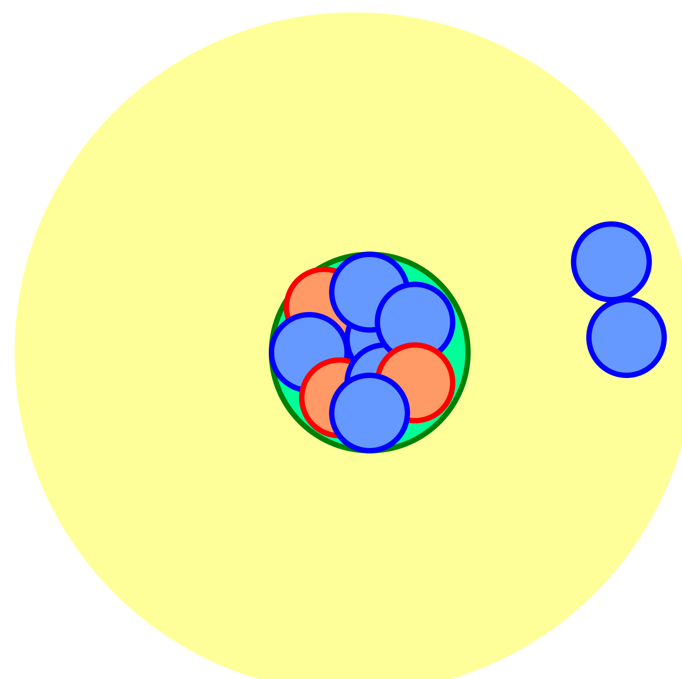




I. Tanihata et al.
Phys. Rev. Lett. 55, 2676 (1985)

Interaction cross section
measurements at Bevalac
(790 MeV/u)





Dipole excitations

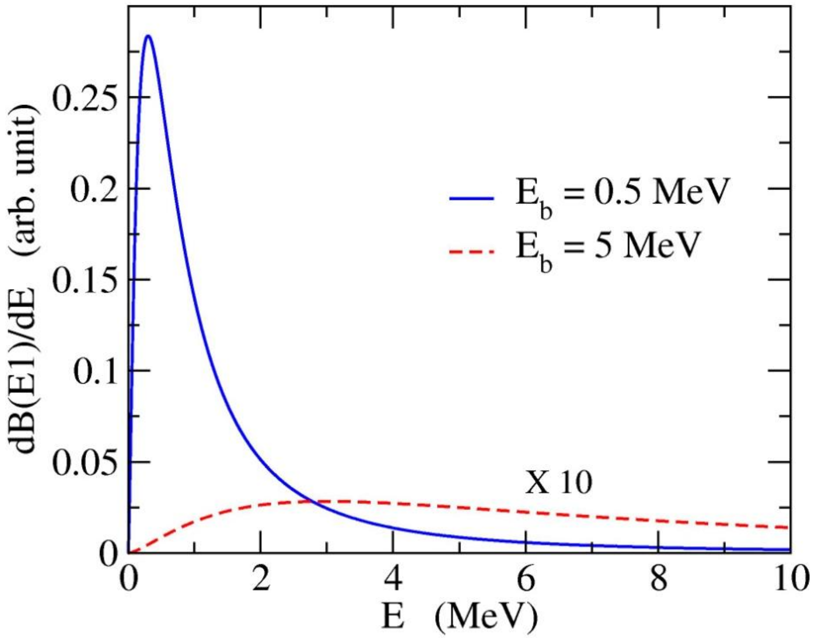
Response to the dipole field:

$$\boxed{B_k(E1) = 3\,|\langle \Psi^k_{1^-} | \hat{D}_0 | \Psi_{gs} \rangle|^2} \qquad \hat{\boldsymbol{D}} = -\frac{Ze}{A}(\boldsymbol{r}_1 + \boldsymbol{r}_2)$$

excited states   ground state

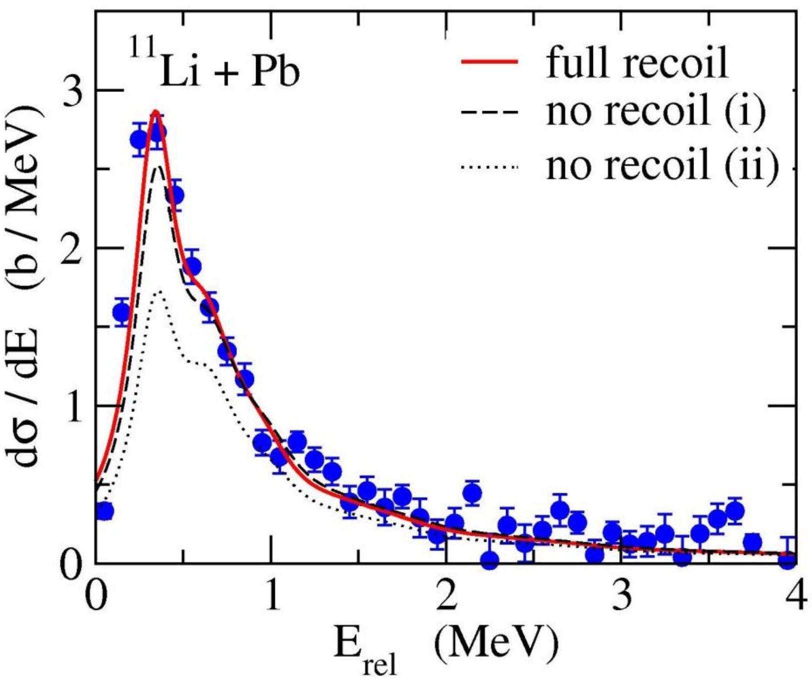
(note) analytic expression for a single-particle potential model

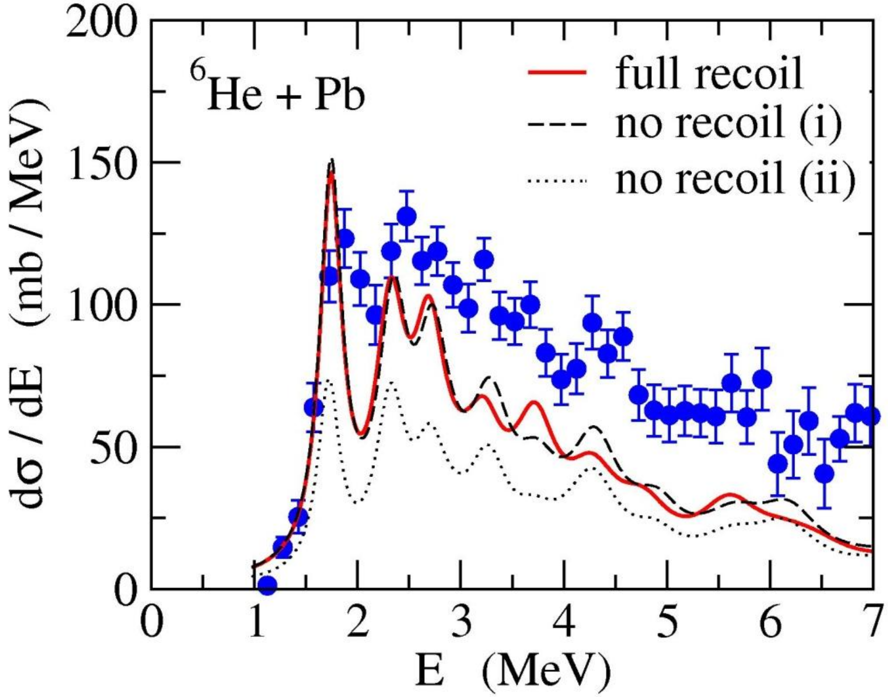
$$\psi_b(r) \sim h_l(ik_b r), \quad \psi_c(r) \sim j_l(k_c r)$$



$$\frac{dB(E1)}{dE} \propto \frac{\sqrt{E_b}E_c^{3/2}}{(E_c + E_b)^4}$$

Dipole excitations

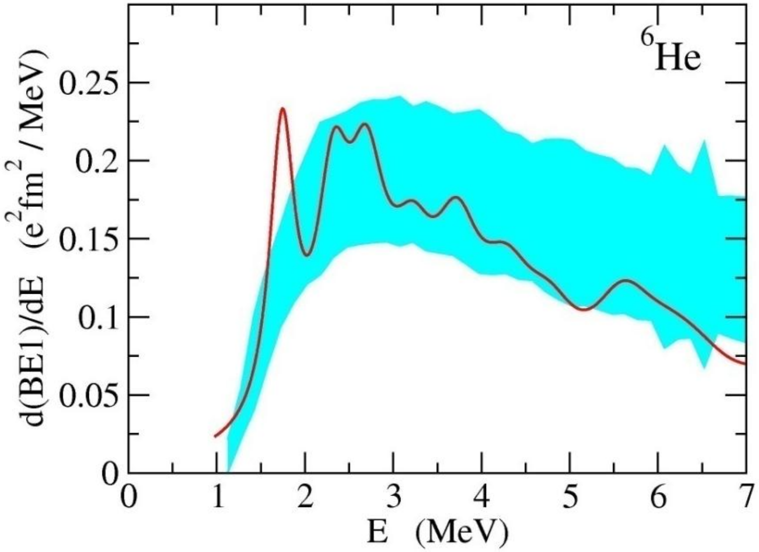




Response to the dipole field:

$$\boxed{B_k(E1) = 3\,|\langle\Psi^k_{1^-}|\hat{D}_0|\Psi_{gs}\rangle|^2}$$

$$\hat{\boldsymbol{D}} = -\frac{Ze}{A}(\boldsymbol{r}_1 + \boldsymbol{r}_2)$$

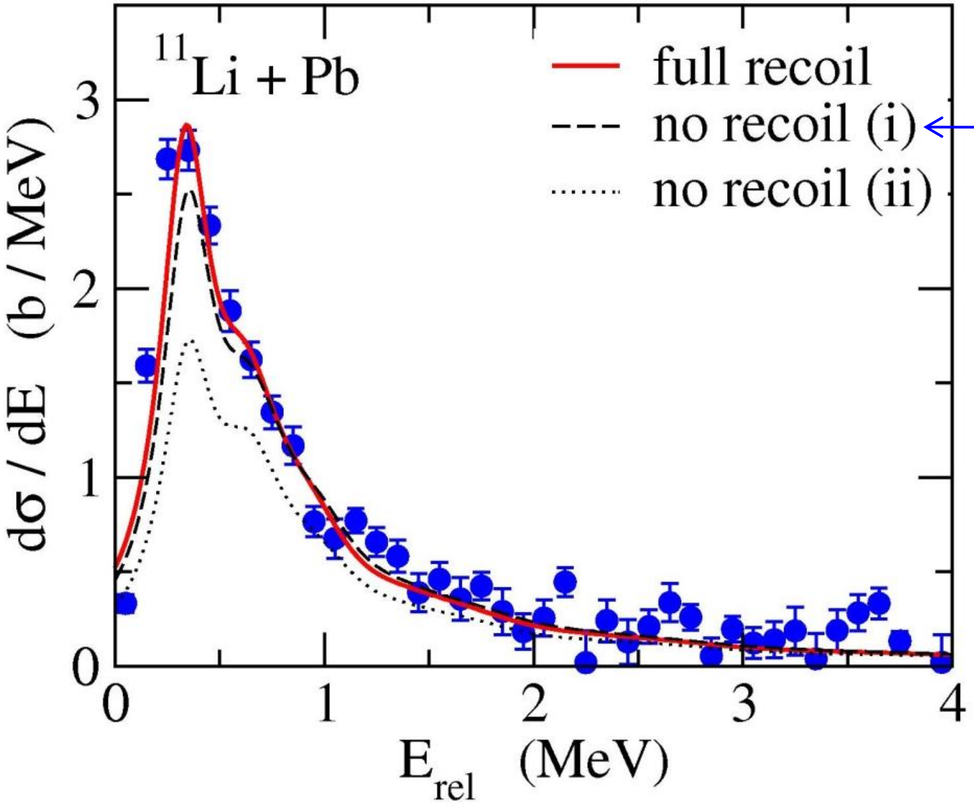


K.H. and H. Sagawa,PRC76('07)047302

recoil term

$$H = \frac{\boldsymbol{p}_1^2}{2m} + \frac{\boldsymbol{p}_2^2}{2m} + V_{nC}(r_1) + V_{nC}(r_2) + V_{nn}(\boldsymbol{r}_1, \boldsymbol{r}_2) + \frac{(\boldsymbol{p}_1 + \boldsymbol{p}_2)^2}{2A_c m}$$

$$= \frac{\boldsymbol{p}_1^2}{2\mu} + \frac{\boldsymbol{p}_2^2}{2\mu} + V_{nC}(r_1) + V_{nC}(r_2) + V_{nn}(\boldsymbol{r}_1, \boldsymbol{r}_2) + \frac{\boldsymbol{p}_1 \cdot \boldsymbol{p}_2}{A_c m}$$



with recoil for the g.s.
but without for 1$^-$

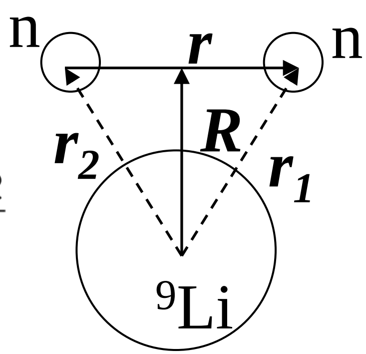
continuum calculations

K.Hagino and H. Sagawa,PRC76('07)047302

More direct information on the correlation?

$$|\Psi_{1^-}\rangle = \hat{D}|\Psi_{gs}\rangle$$

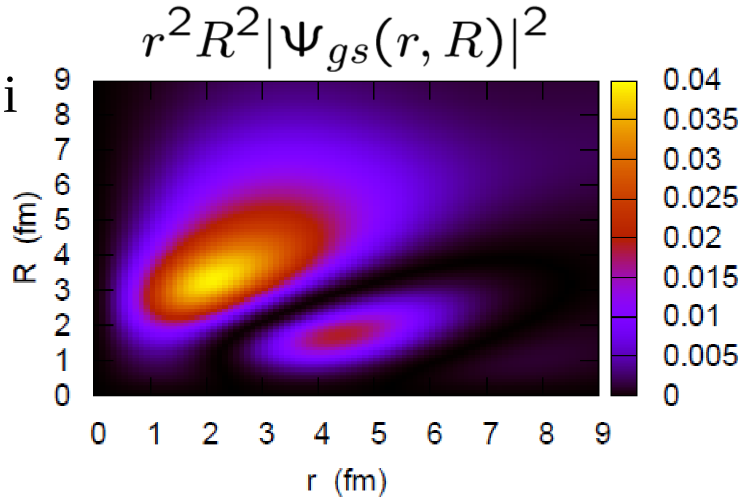
$$\boldsymbol{R} = \frac{\boldsymbol{r}_1 + \boldsymbol{r}_2}{2}$$



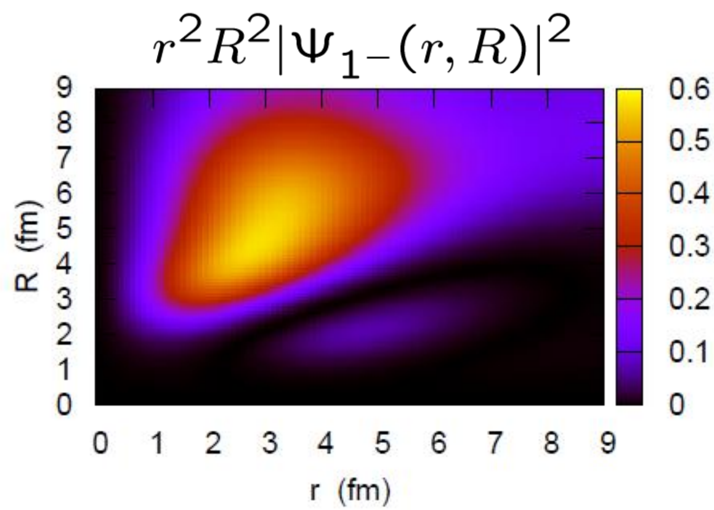
dipole operator

$$\boxed{\hat{D} = -\frac{Ze}{A}(\boldsymbol{r}_1 + \boldsymbol{r}_2) = -\frac{2Ze}{A}\boldsymbol{R}}$$

^{11}Li



dipole

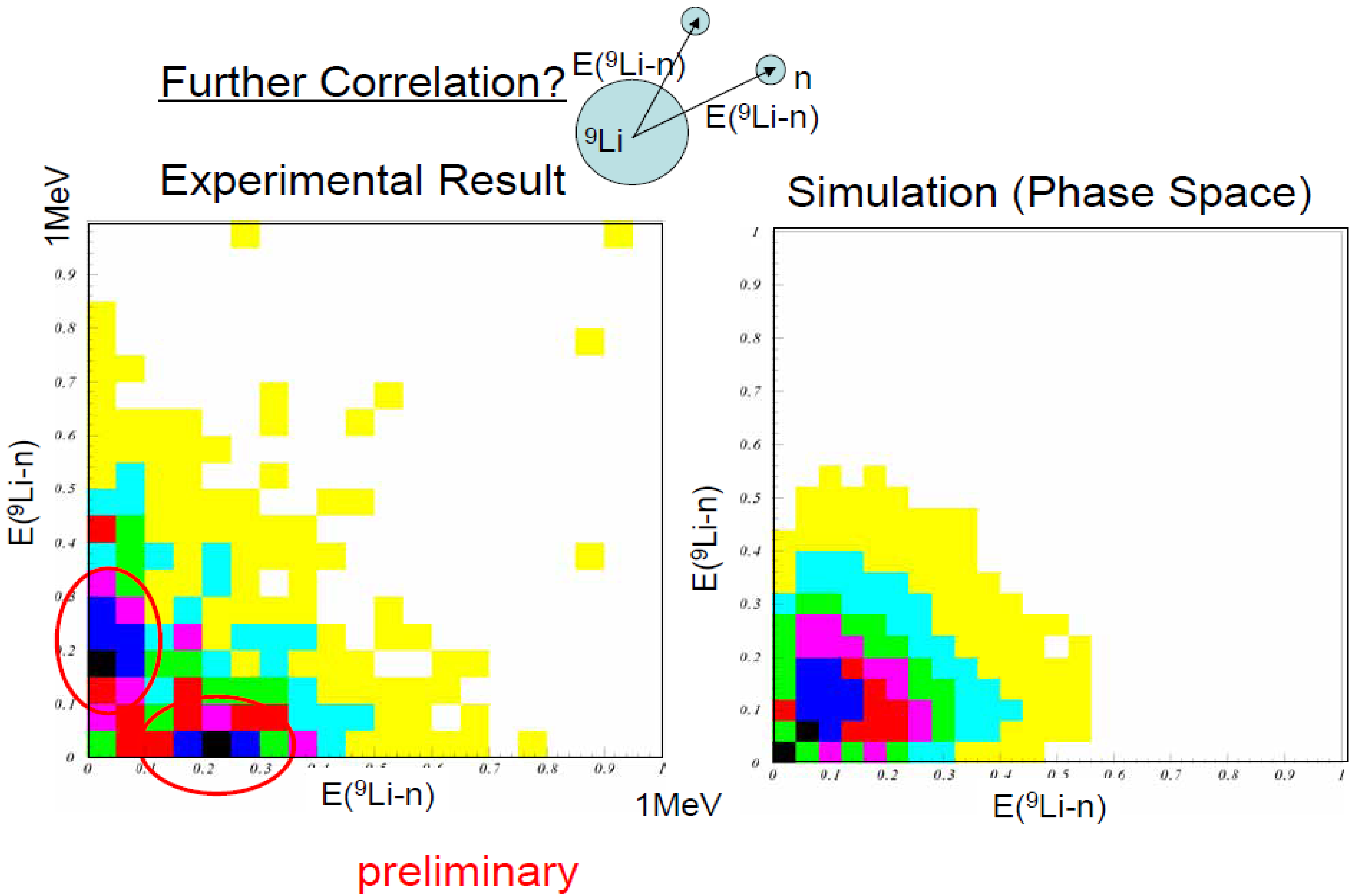


The relative motion $r = r_1 - r_2$ is not affected by the dipole operator.

Probing dineutron correlation with E1 excitation?

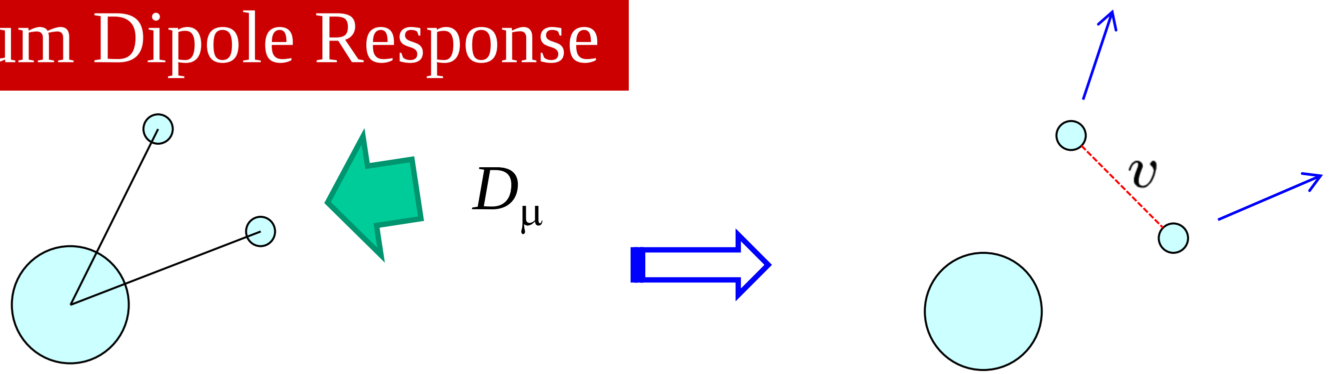
especially with energy (and angular) distribution(s)?

New 2n correlation experiment (Nakamura et al.)



T. Nakamura et al., unpublished

Continuum Dipole Response



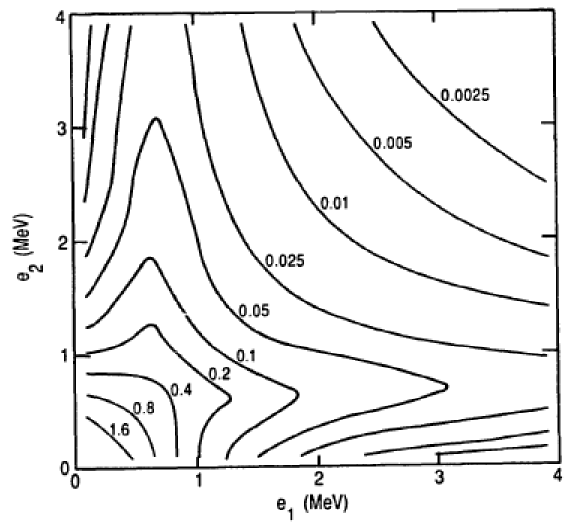
$$M(E1) = \langle (j_1 j_2)^1_\mu | (1 - vG_0 + vG_0 vG_0 - \cdots) D_\mu | \Psi_{gs} \rangle$$
$$= \langle (j_1 j_2)^1_\mu | \underbrace{(1 + vG_0)^{-1}}_{\text{FSI}} D_\mu | \Psi_{gs} \rangle$$

unperturbed continuum wf

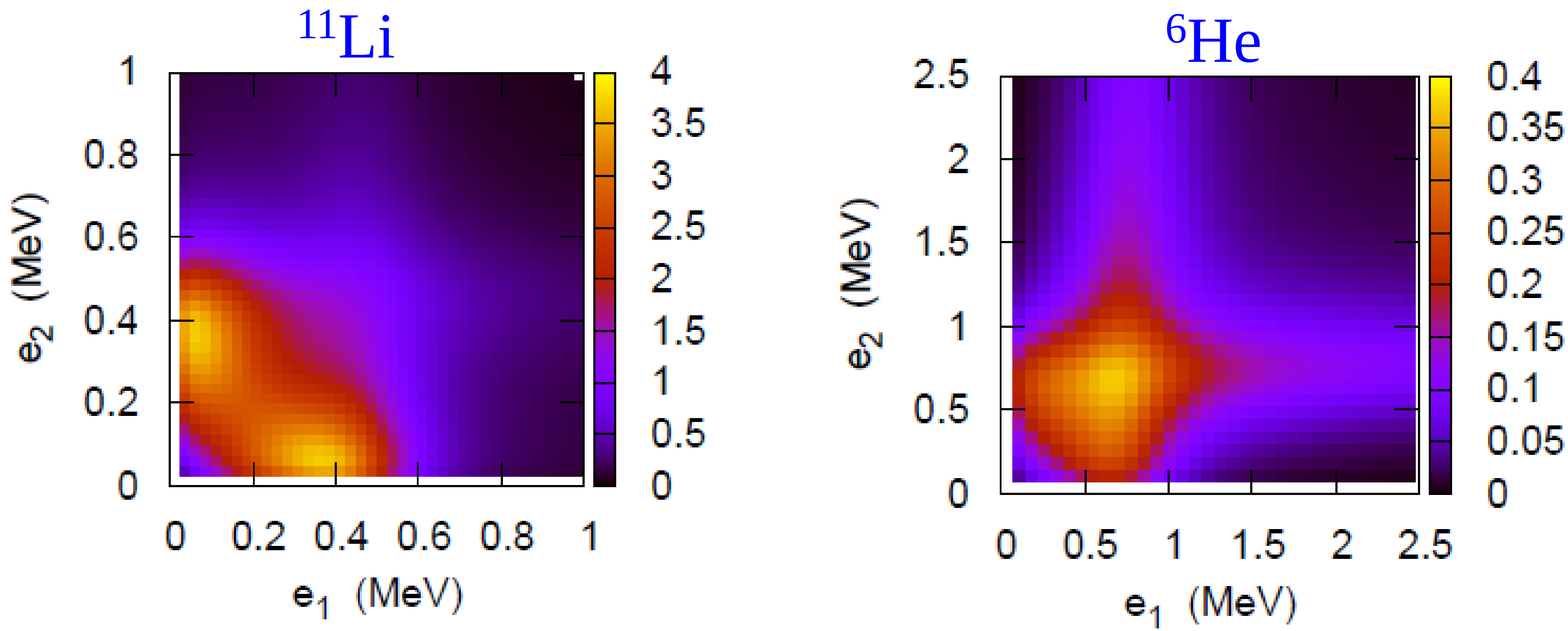
dipole operator

$$G_0(E) = \sum_{\mu, f.st.} \frac{\left| (j_1 j_2)^1_\mu \right\rangle \left\langle (j_1 j_2)^1_\mu \right|}{e_1 + e_2 - E - i\eta}$$

$$\boxed{\frac{d^2 B(E1)}{de_1 de_2} = 3 \sum_{l_1 j_2 l_2 j_2} |M(E1)|^2 \frac{dk_1}{de_1} \frac{dk_2}{de_2}}$$

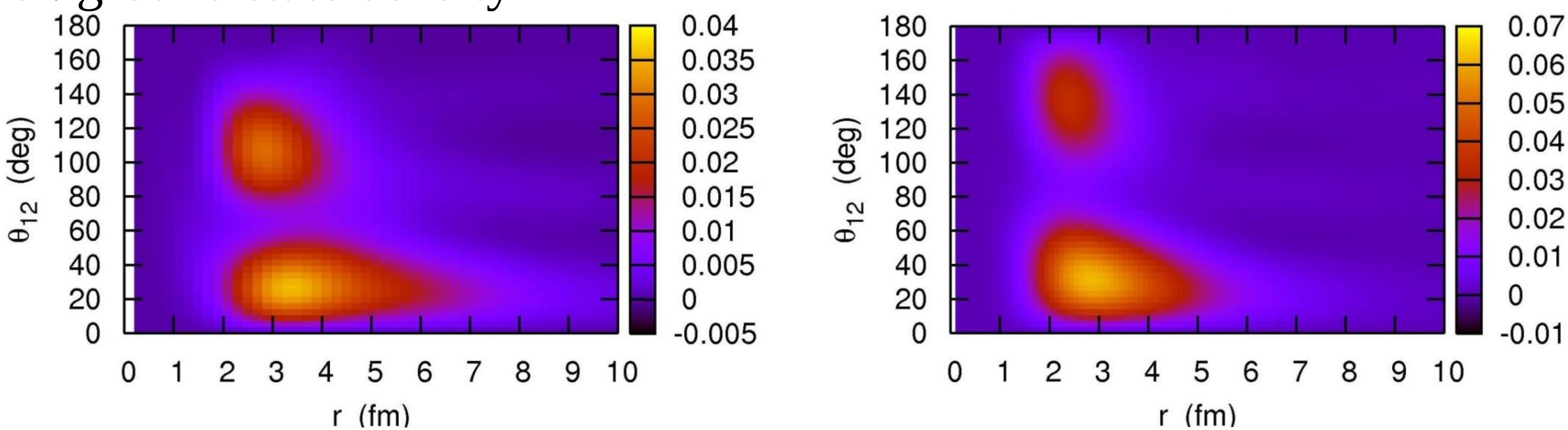


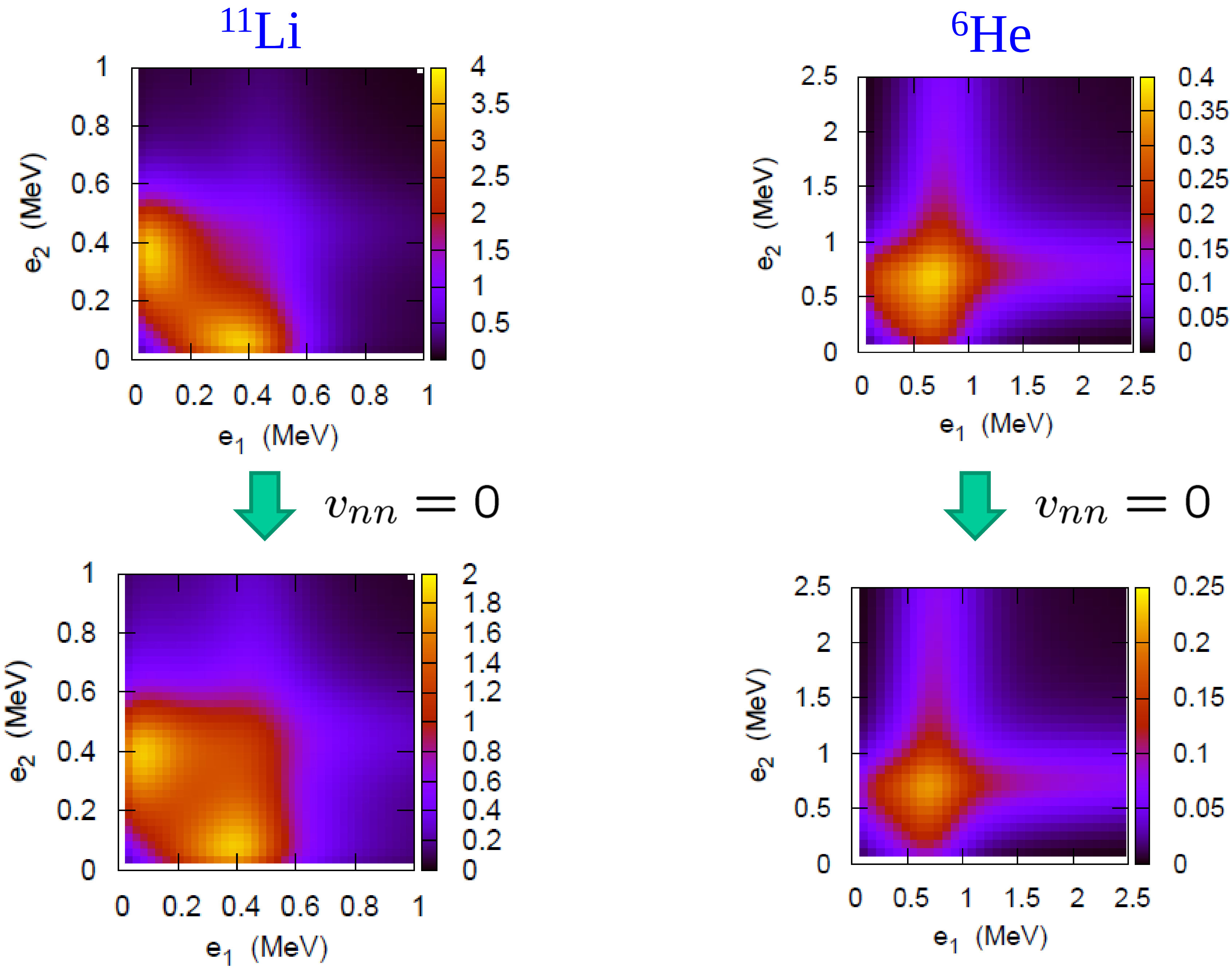
H. Esbensen and G.F. Bertsch, NPA542('92)310



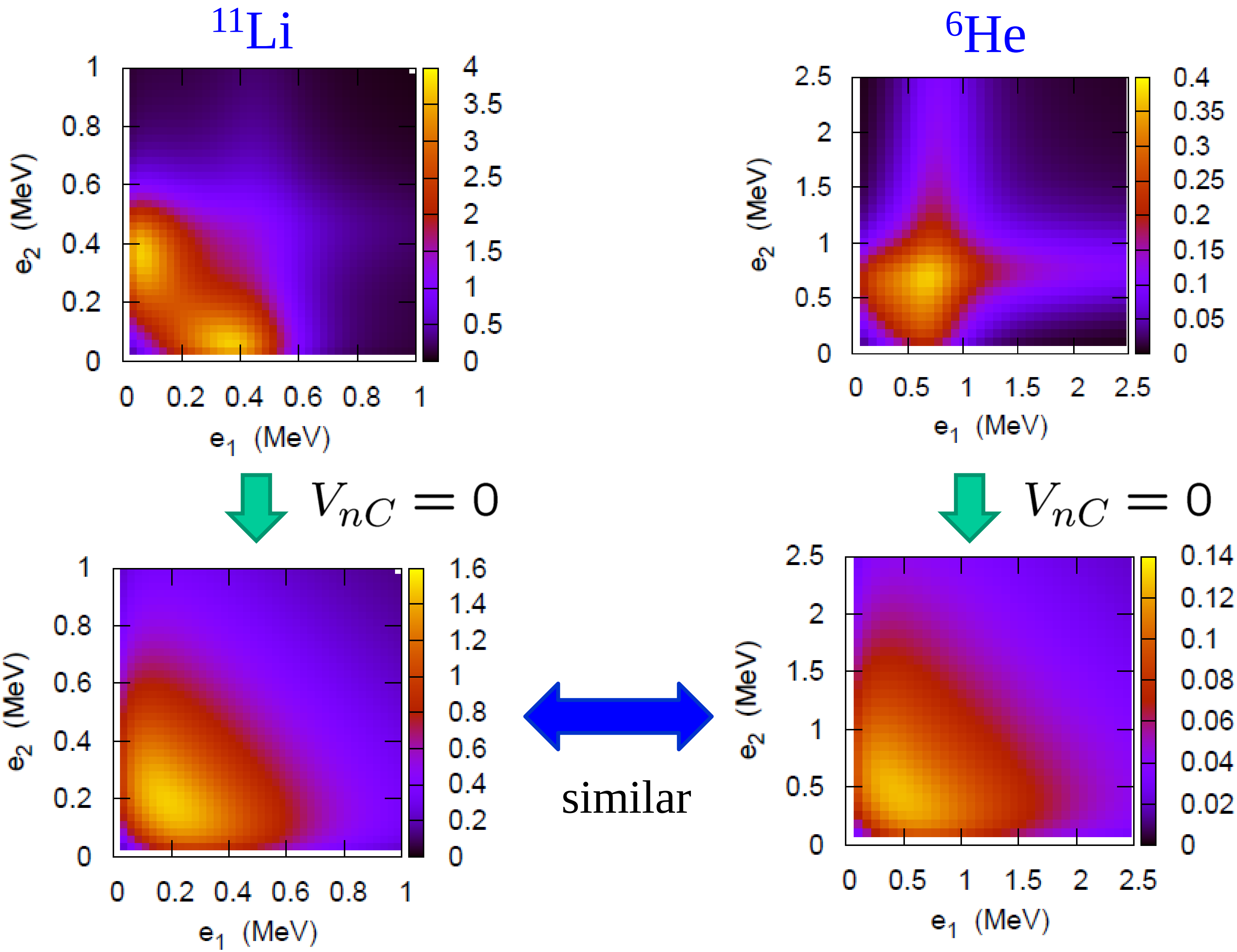
K.H., H. Sagawa, T. Nakamura, S. Shimoura, PRC80('09)031301(R)

cf. ground state density



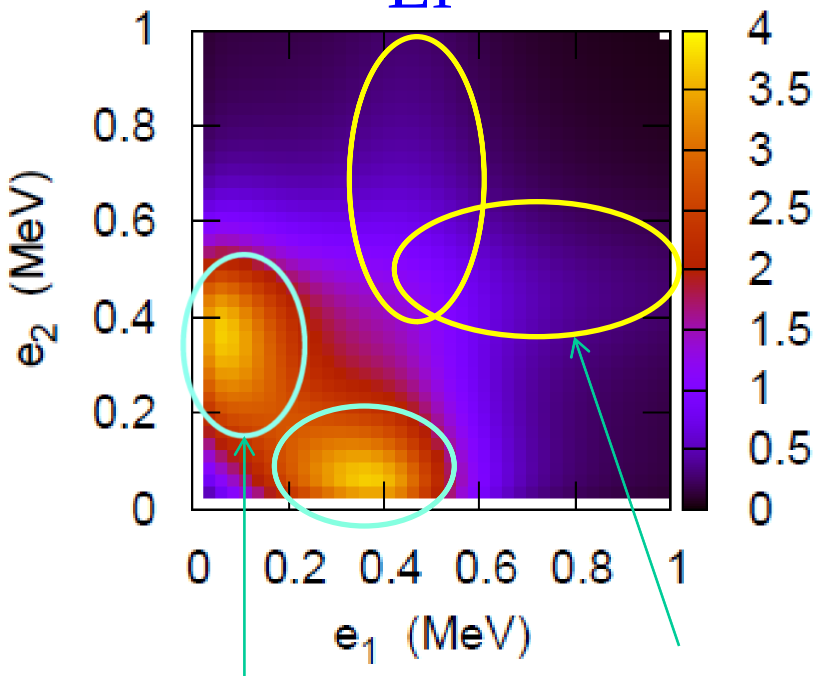


K.H., H. Sagawa, T. Nakamura, S. Shimoura, PRC80('09)031301(R)

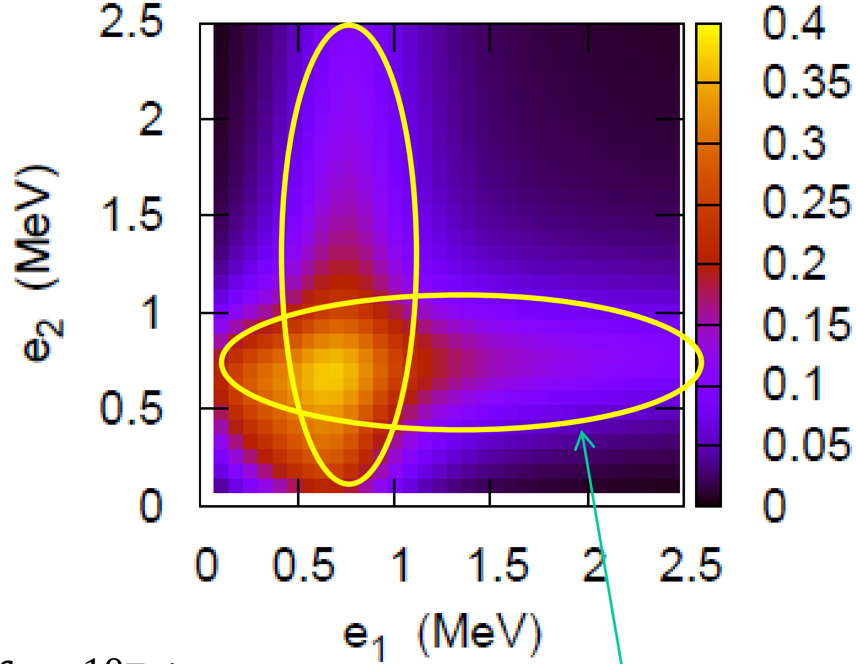


K.H., H. Sagawa, T. Nakamura, S. Shimoura, PRC80('09)031301(R)

^{11}Li



^{6}He



s-wave virtual state in ^{10}Li

(scattering length: a =-30 $^{+12}_{-31}$ fm)

$p_{1/2}$ resonance for ^{10}Li at 0.54 MeV

$p_{3/2}$ resonance for ^{5}He at 0.91 MeV

(cf. s-wave scattering length: a = +4.97 +/- 0.12 fm)

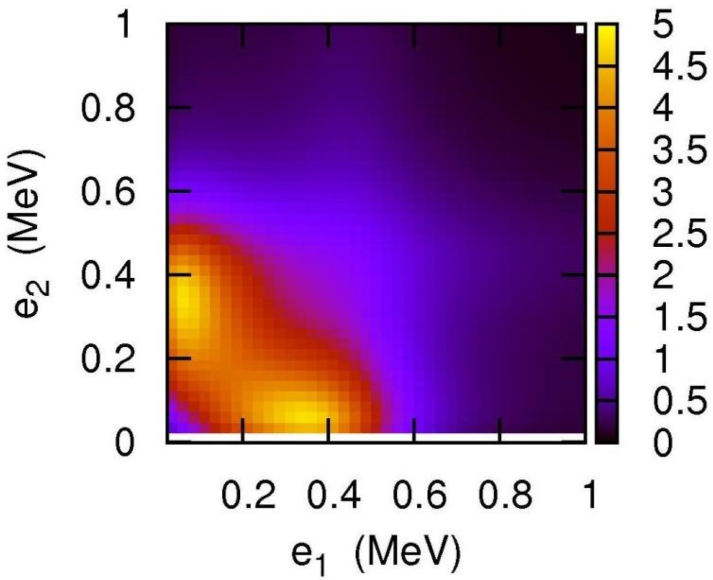
◆distribution for ^{11}Li: consistent with preliminary expt. data (T. Nakamura et al.)

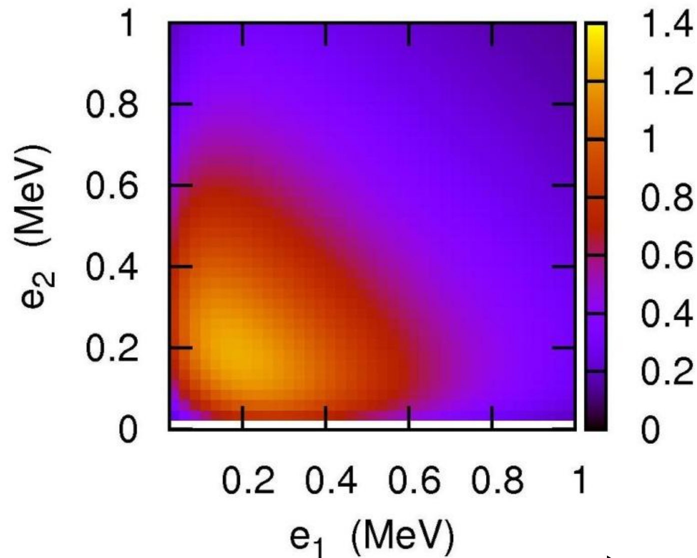
K.H., H. Sagawa, T. Nakamura, S. Shimoura, PRC80('09)031301(R)

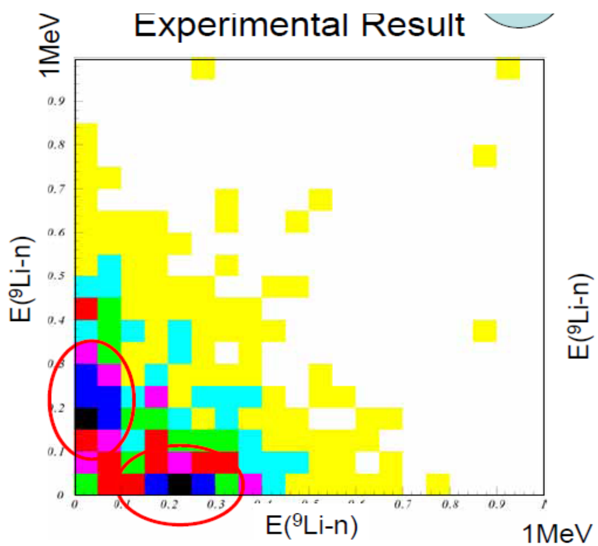
Analysis with three-body model

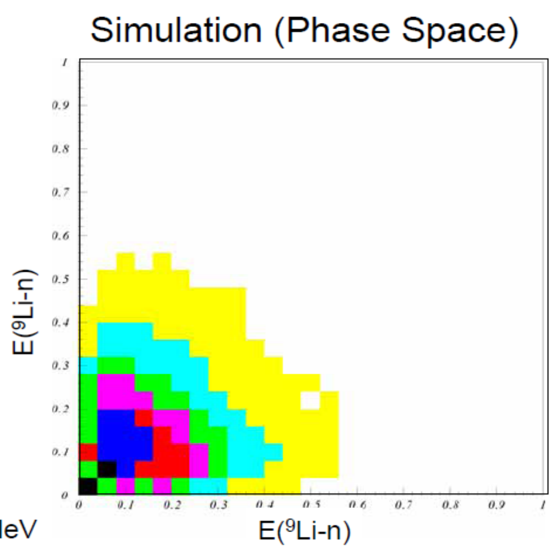
$$\frac{d^2B(E1)}{de_1\,de_2} = \sum_{l_1j_1l_2j_2} |\langle[(e_1j_1l_1)(e_2j_2l_2)]^{(J=1)}|\hat{O}_{E1}|\Psi_{gs}\rangle|^2$$

continuum response







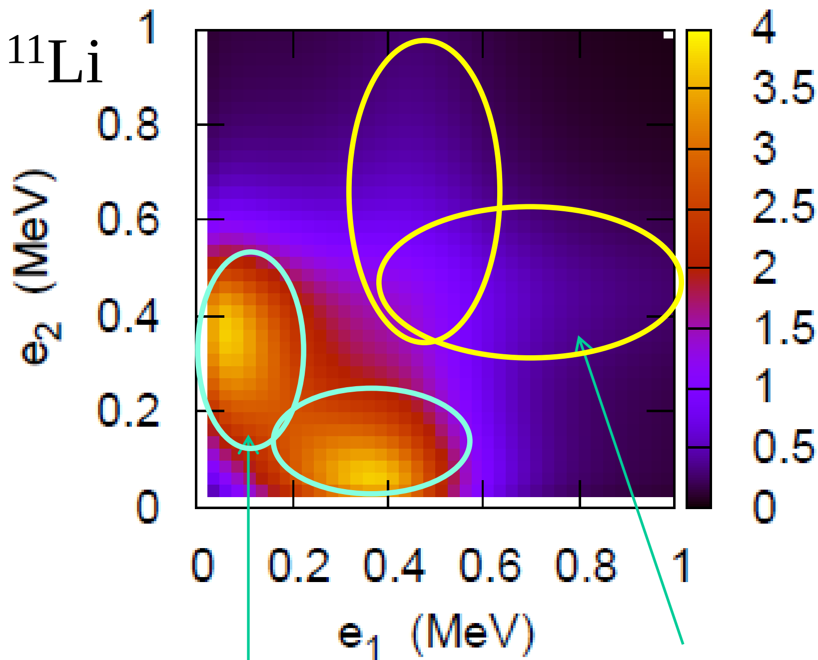


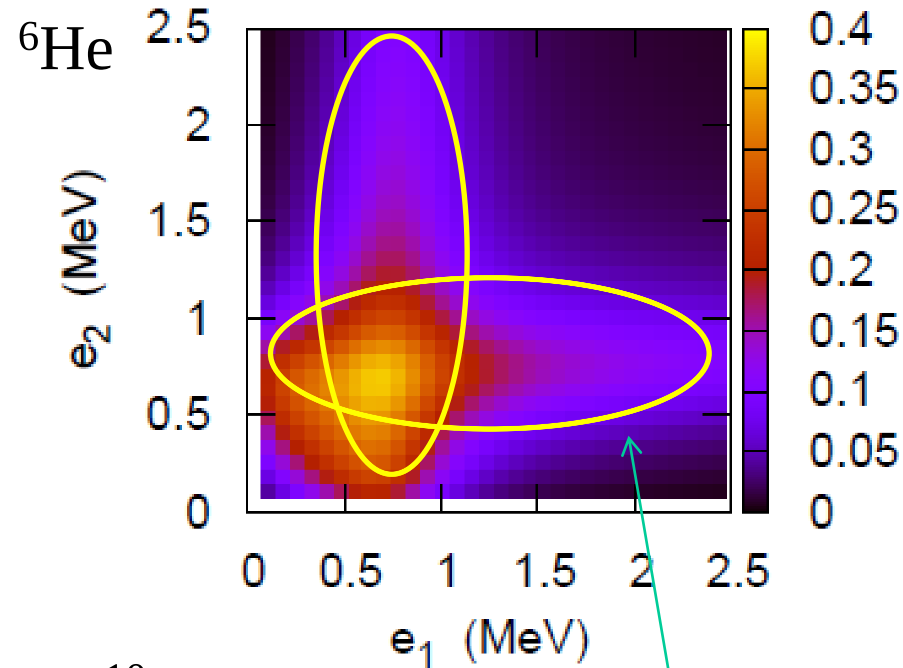
plane wave
final state wf
(No FSI):
(v_{nn} =0, V_{nc}=0)

Remaining problem:

How to probe the strong dineutron correlation?

•Coulomb excitations? ⟶ A problem: an external field is too weak





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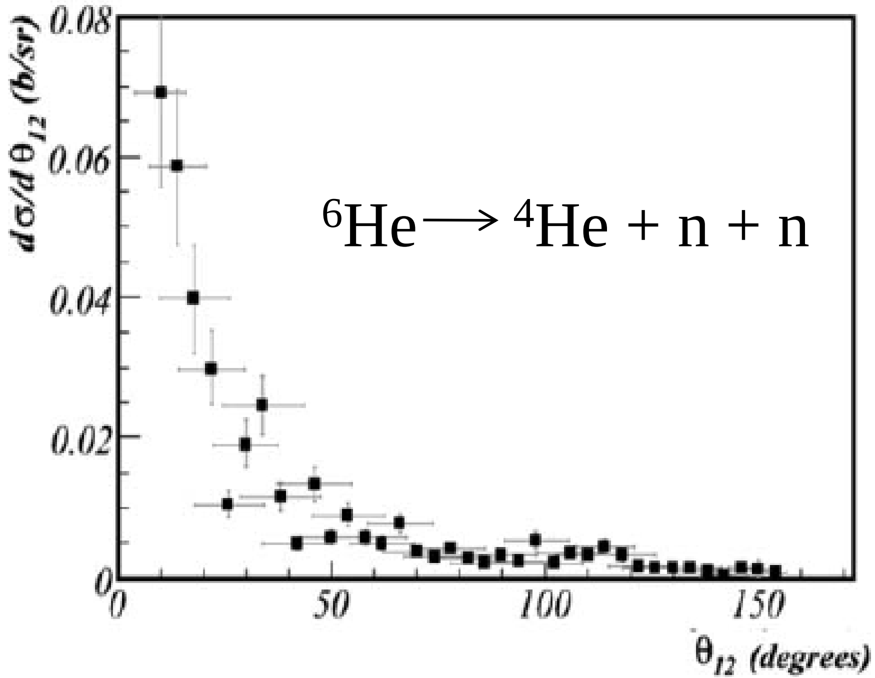
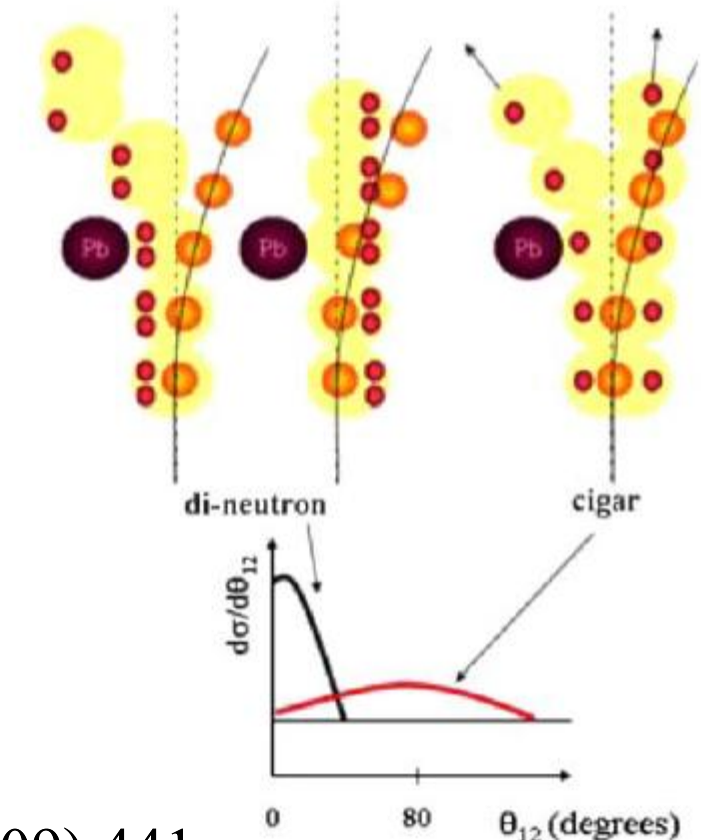
K.H., H. Sagawa, T. Nakamura, S. Shimoura, PRC80('09)031301(R)

Remaining problem:

How to probe the strong dineutron correlation?

- Coulomb excitations?
- Nuclear breakup?





M. Assie et al., Eur. Phys. J. A42 ('09) 441

cf. 4-body CDCC for exclusive cross sections?

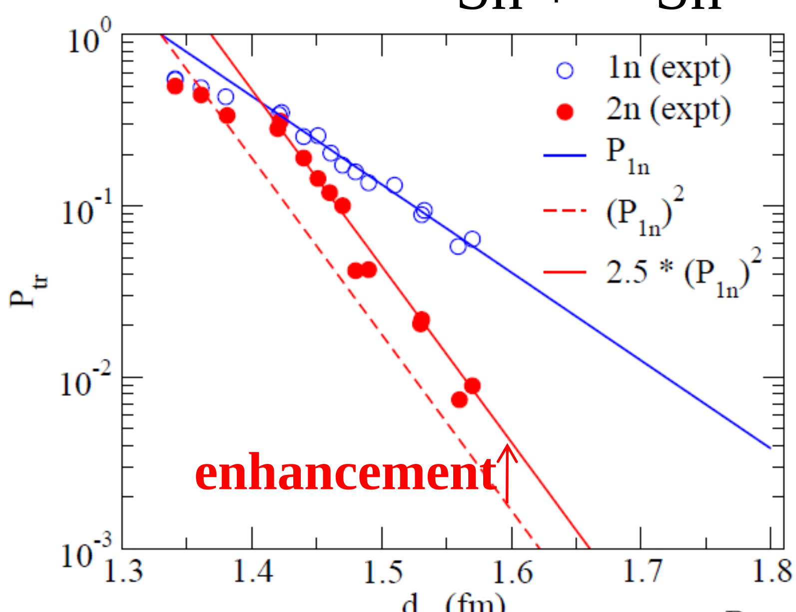
Remaining problem:

How to probe the strong dineutron correlation?

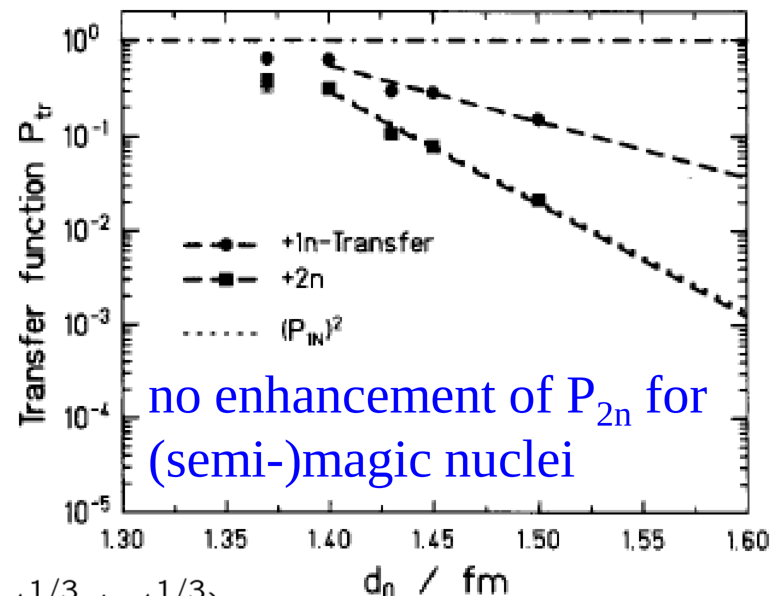
- Coulomb excitations?
- Nuclear breakup?

- <u>Pair transfer?</u>

^{112}Sn + ^{120}Sn



^{144}Sm + ^{208}Pb



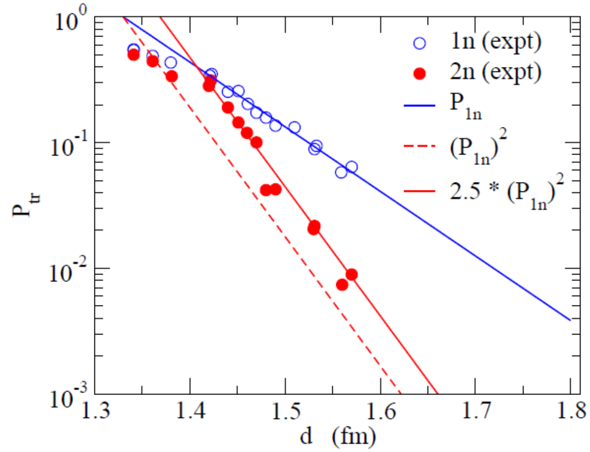
$$R_{\rm min} = d\,(A_P^{1/3} + A_T^{1/3})$$

W. von Oertzen et al., Z. Phys. A326('87)463

J. Speer et al., PLB259('91)422

Remaining problem:

How to probe the strong dineutron correlation?



- Coulomb excitations?
- Nuclear breakup?

- <u>Pair transfer?</u>

✓**Reaction mechanism?**

- sequential vs simultaneous
- Q-value, angular momentum matchings

✓Role of dineutron correlation (on the surface)?

✓Influence to other reaction processes (e.g., subbarrier fusion)?

have not yet been fully clarified

$\longrightarrow$ to be discussed on the next Monday

example of 2n transfer calculation

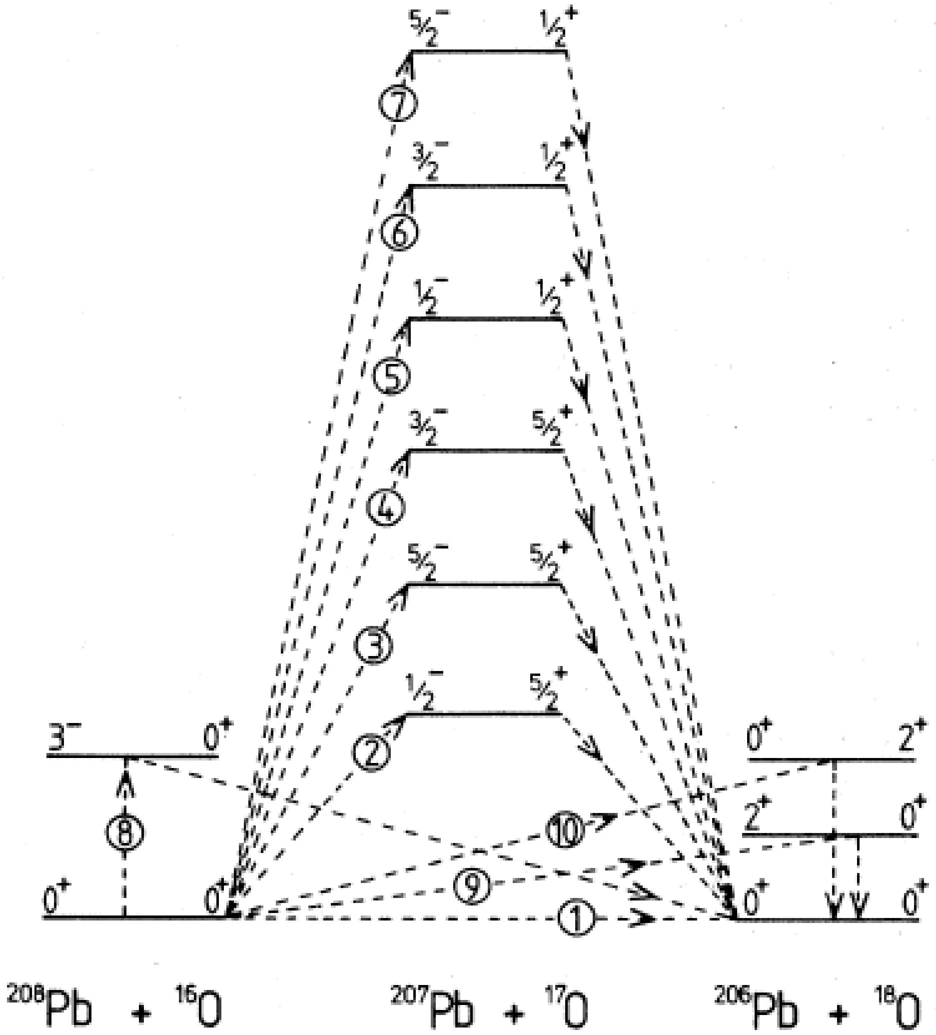
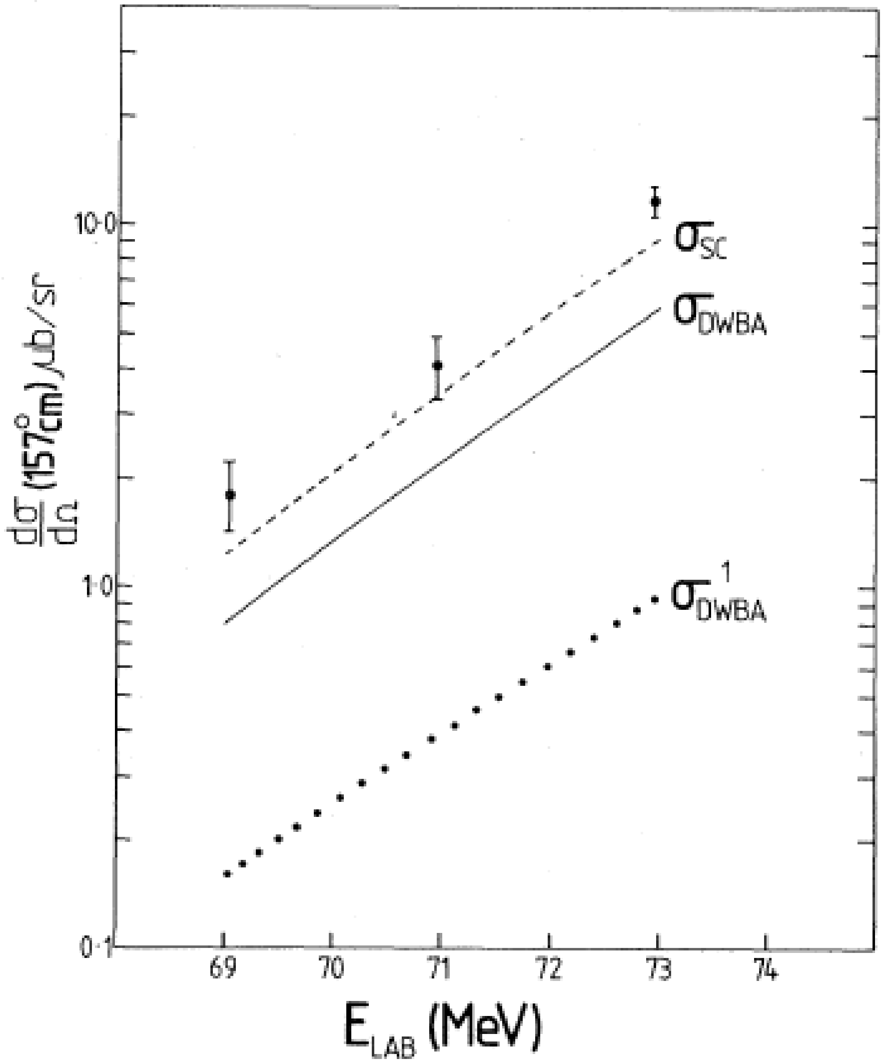


FIG. 2. The direct and two-step paths considered in the predictions of the cross section for the reaction $^{208}Pb(^{16}O, ^{18}O)^{206}Pb$. The levels in ^{207}Pb and ^{17}O concerned in the sequential transfer paths are the $p_{1/2}$, $f_{5/2}$, and $p_{3/2}$ single-hole states and the $d_{5/2}$ and $s_{1/2}$ single-particle states, respectively.

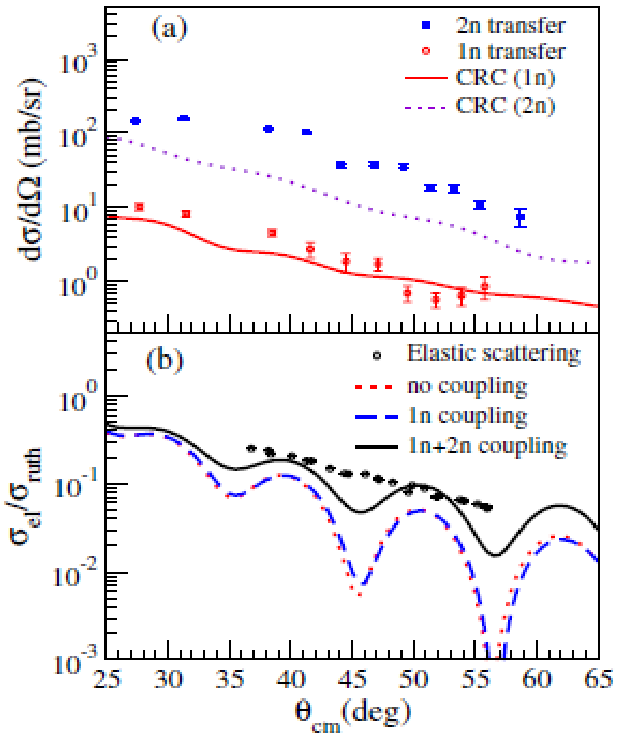


M.A. Franey et al., PRL41('78)837

effects of unbound intermediate states?

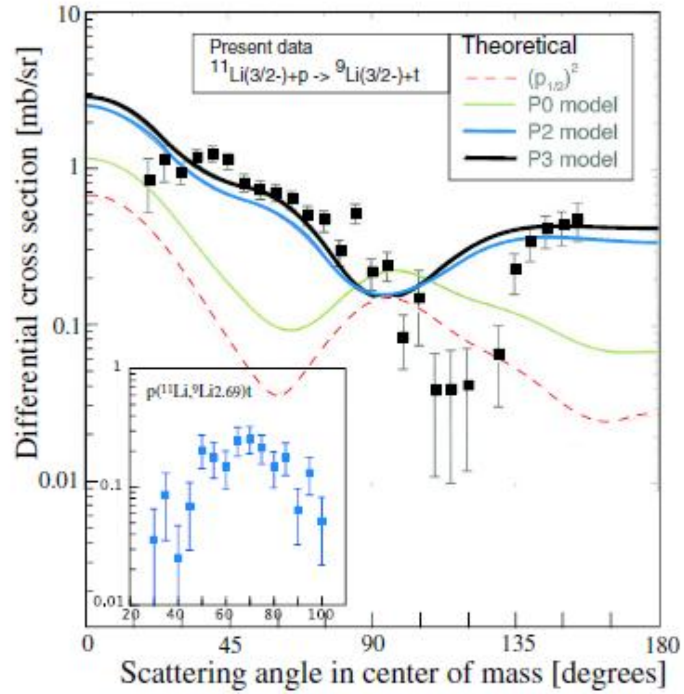
Recent experiments for transfer reaction of neutron-rich nuclei

^{6}He + ^{65}Cu



A. Chatterjee et al., PRL101('08)032701

^{1}H(^{11}Li,^{9}Li)^{3}H



I. Tanihata et al., PRL100('08)192502

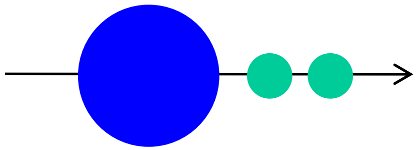
It is timely to construct:

a new theory of pair transfer with dineutron correlation.

⟶ need a deep understanding of reaction dynamics

➡ a simple and intuitive schematic model

One-dimensional three-body model

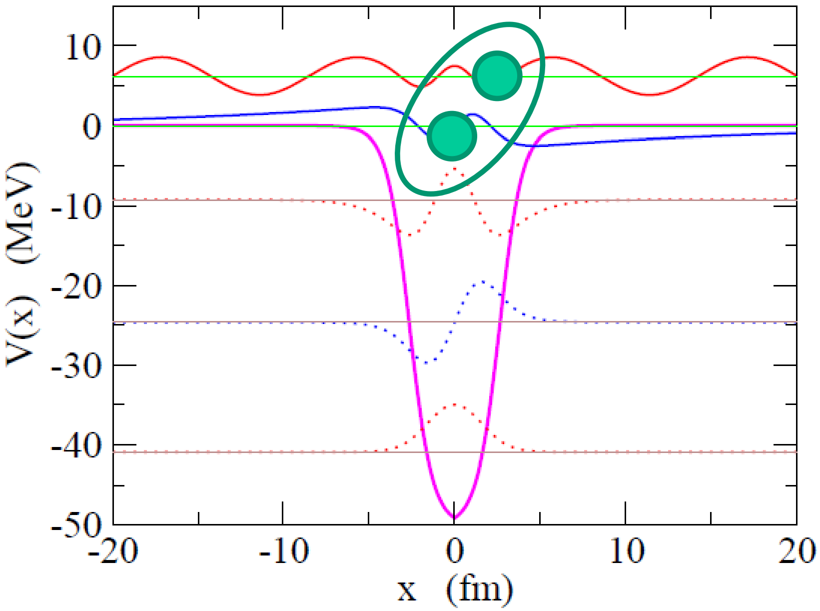


Two interacting neutrons in a one-dimensional potential well:

$$\boxed{H = -\frac{\hbar^2}{2m}\frac{d^2}{dx_1^2} + V(x_1) - \frac{\hbar^2}{2m}\frac{d^2}{dx_2^2} + V(x_2) + v_{nn}(x_1, x_2)}$$

density-dependent contact interaction:

$$v_{nn}(x, x') = -g\left(1 - \frac{1}{1 + e^{(|x|-R)/a}}\right)\delta(x - x')$$



$$\Psi_{\rm gs}(x_1, x_2) = \sum_{n \le n'} \alpha_{nn'}\Psi_{nn'}(x_1, x_2)$$

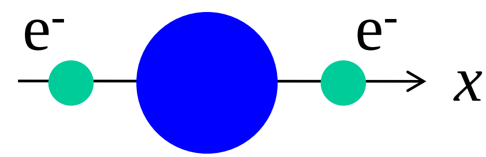
$$\Psi_{nn'}(x_1, x_2) \propto \mathcal{S}[\phi_n(x_1)\phi_{n'}(x_2)] \times |S = 0\rangle$$

- $S = 0$ state: symmetric for the spatial part of wf

- n, n': the same parity

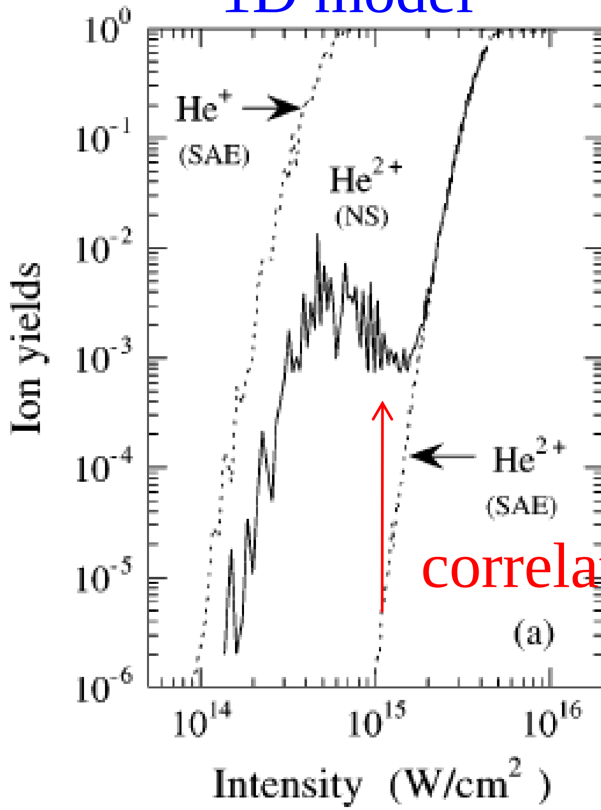
Similar one-dimensional model for two-electron systems

He atom (^{4}He + e$^-$ + e$^-$)
H$^-$ atom (p + e$^-$ + e$^-$)

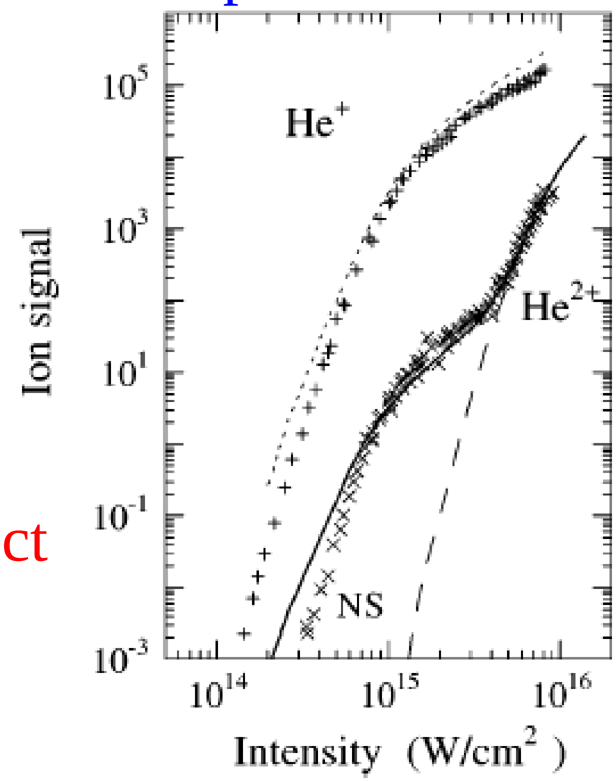


double ionization by intense laser fields

1D model



Experimental Data



SAE: single active electron approximation
NS: non-sequential

J.B. Watson et al., PRL78('97)1884

cf. TDH(F) for a one-dimensional system

B. Yoon and J.W. Negele, PRA16('77) 1451

PHYSICAL REVIEW A VOLUME 16, NUMBER 4 OCTOBER 1977

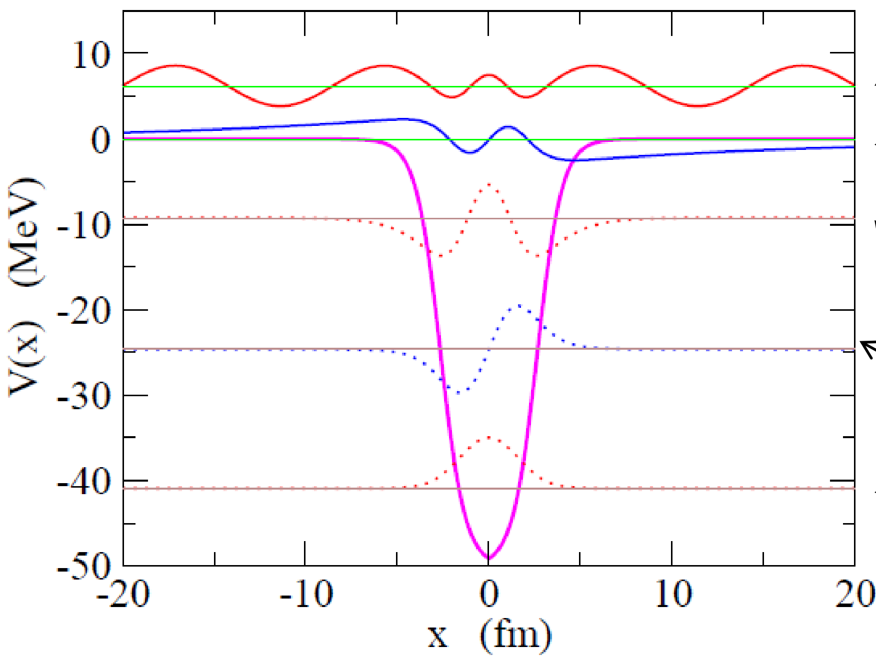
Time-dependent Hartree approximation for a one-dimensional system of bosons with attractive δ-function interactions*

B. Yoon and J. W. Negele†
Laboratory for Nuclear Science and Department of Physics, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139
(Received 29 November 1976)

The time-dependent Hartree approximation is compared with an exact solution for the scattering between two N-particle bound states in the case of a 1-dimensional system of bosons with attractive δ-function interactions. It is shown that to leading order in N, the approximation is exact, and arguments are presented relating this asymptotic agreement to the nonsaturation of the bound states.

$$H = -\frac{1}{2}\sum_{i=1}^{N}\frac{\partial^2}{\partial x_i^2} - g\sum_{i<j=1}^{N}\delta(x_i - x_j)$$

Model Setup for core+2n



discretized continuum states

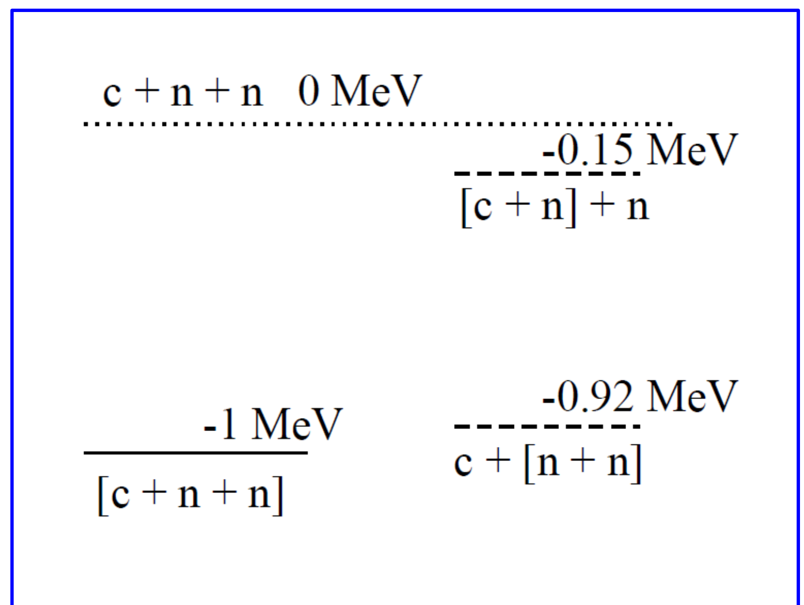
Weakly bound s.p. level at -0.15 MeV

occupied by the core nucleus

the strength of the pairing interaction *g*: adjusted so that E_{gs} = -1 MeV

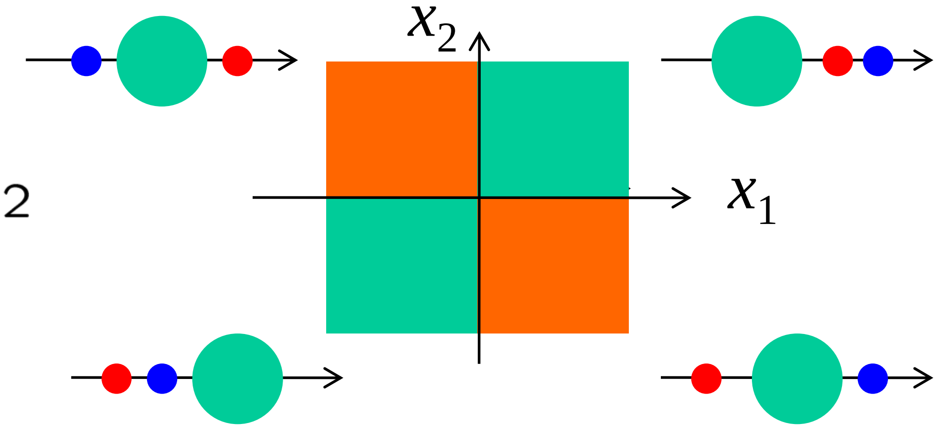
E_{cut} = 30 MeV, R_{box} = 90 fm

$$P_{\rm bb}^{(gs)} = 81.2\%$$



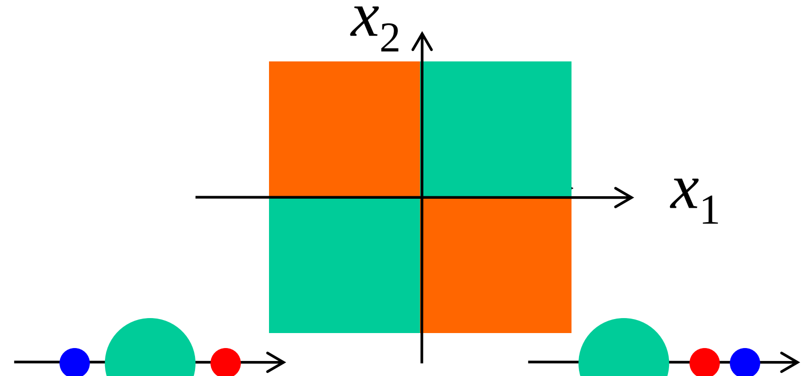
Ground state properties

two-particle density: $|\Psi_{\mathrm{gs}}(x_1, x_2)|^2$

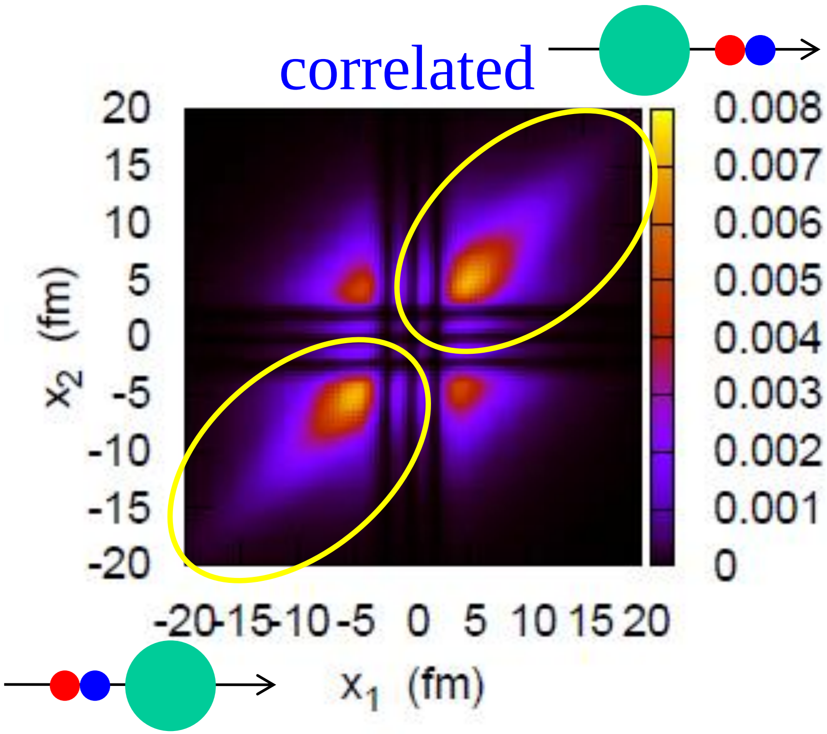


Ground state properties

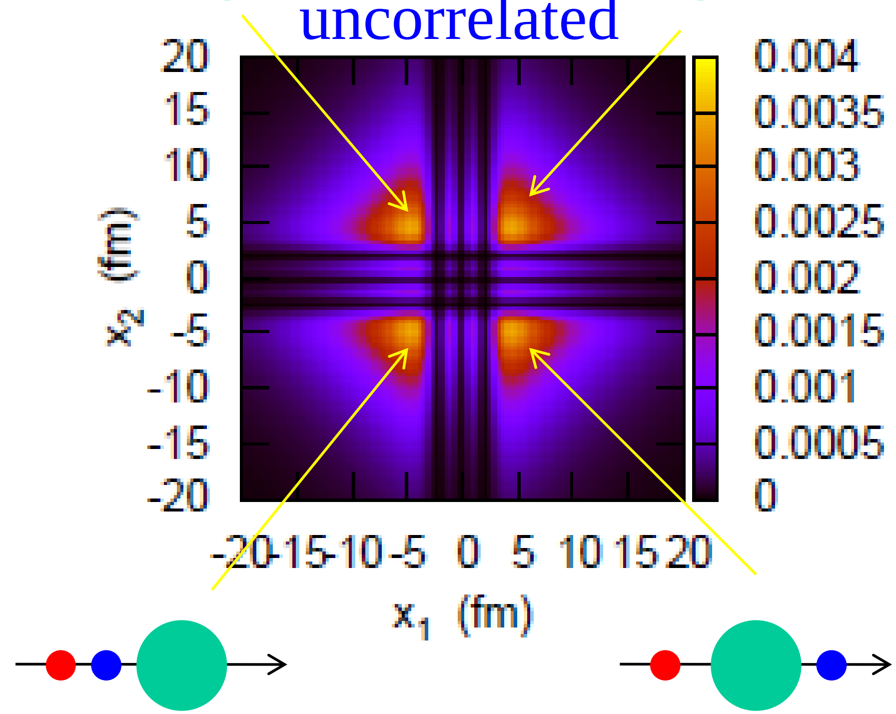
two-particle density: $|\Psi_{\rm gs}(x_1,x_2)|^2$



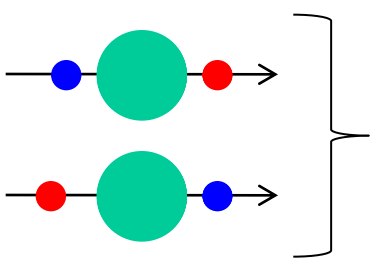
correlated



uncorrelated



dineutron correlation



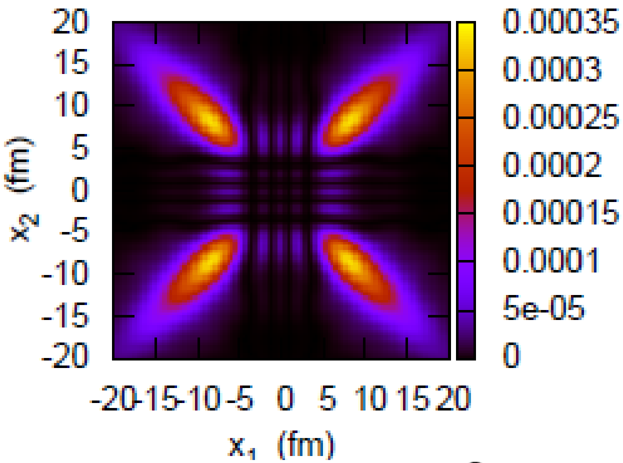
largely suppressed

four symmetric peaks

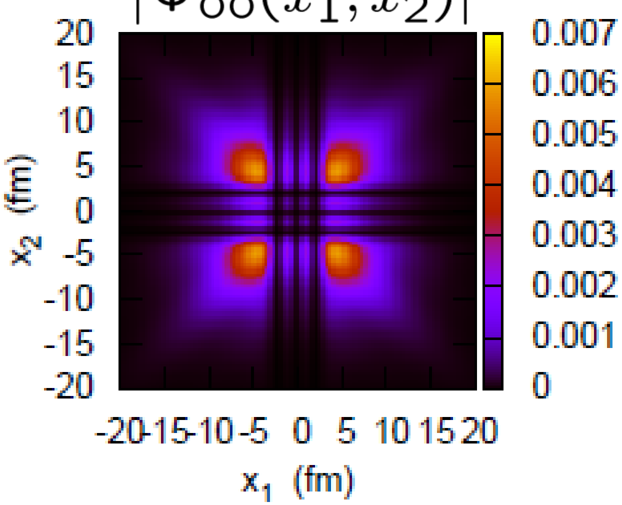
$$\Psi_{\rm gs}(x_1,x_2) = \Psi_{\rm ee}(x_1,x_2) + \Psi_{\rm oo}(x_1,x_2)$$

$$\longrightarrow \rho_2(x_1,x_2) = |\Psi_{\rm ee}(x_1,x_2)|^2 + |\Psi_{\rm oo}(x_1,x_2)|^2 + 2\Psi_{\rm ee}(x_1,x_2)\Psi_{\rm oo}(x_1,x_2)$$

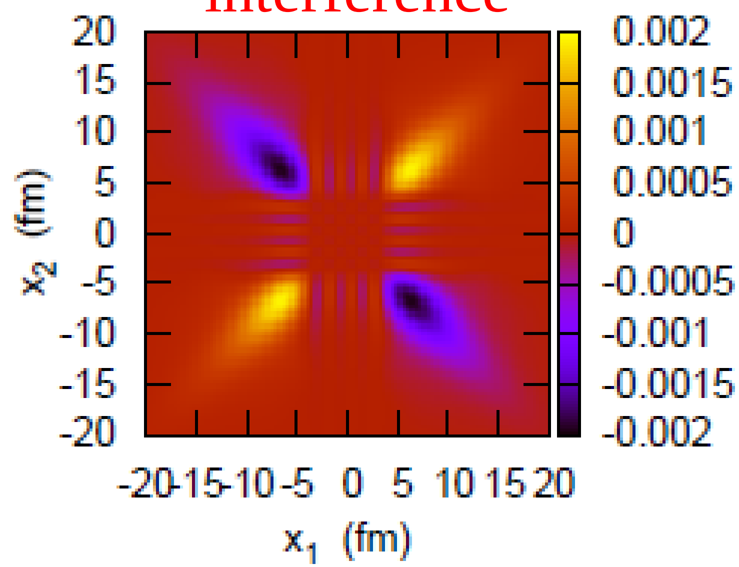
$|\Psi_{\rm ee}(x_1,x_2)|^2$



$|\Psi_{\rm oo}(x_1,x_2)|^2$



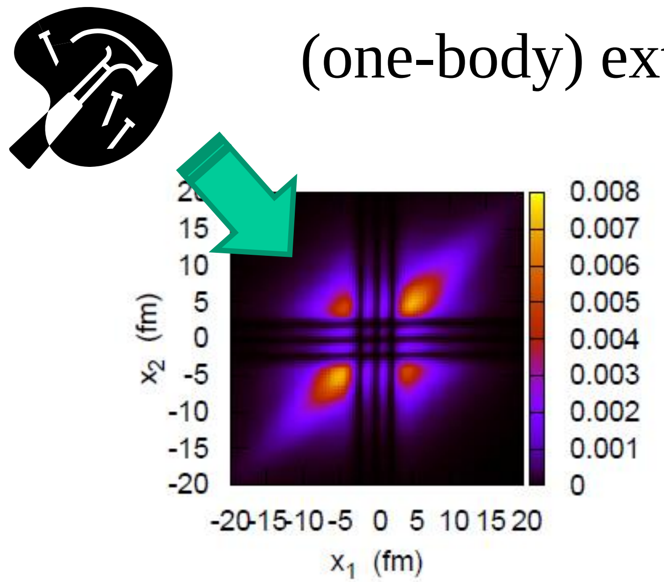
interference



$$\Psi_{\rm ee}(x_1,x_2)\Psi_{\rm oo}(x_1,x_2) = -\Psi_{\rm ee}(x_1,-x_2)\Psi_{\rm oo}(x_1,-x_2)$$

Nuclear Breakup Process

(one-body) external field



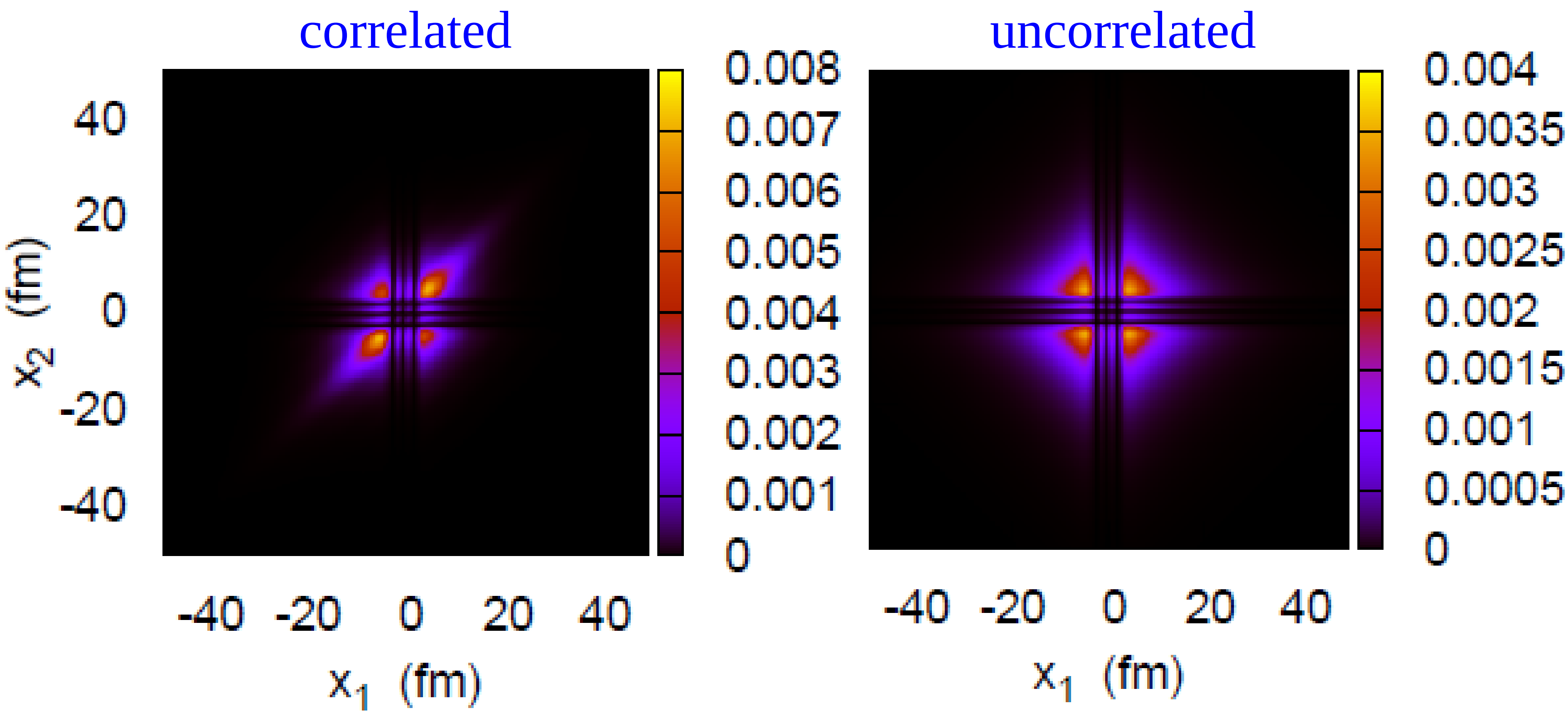
$$\Psi_{\mathrm{gs}}(x_1, x_2)$$

Time-dependent two-particle Schroedinger equation:

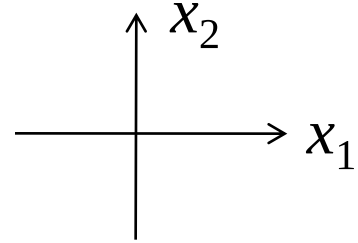
$$\boxed{i\hbar\frac{\partial}{\partial t}\Psi(x_1, x_2, t) = [H + V_{\mathrm{ext}}(x_1, x_2, t)]\Psi(x_1, x_2, t)}$$

$$V_{\mathrm{ext}}(x_1, x_2, t) = \sum_{i=1,2} V_c\, e^{-t^2/2\sigma_t^2} e^{-(x_i - x_0)^2/2\sigma_x^2}$$

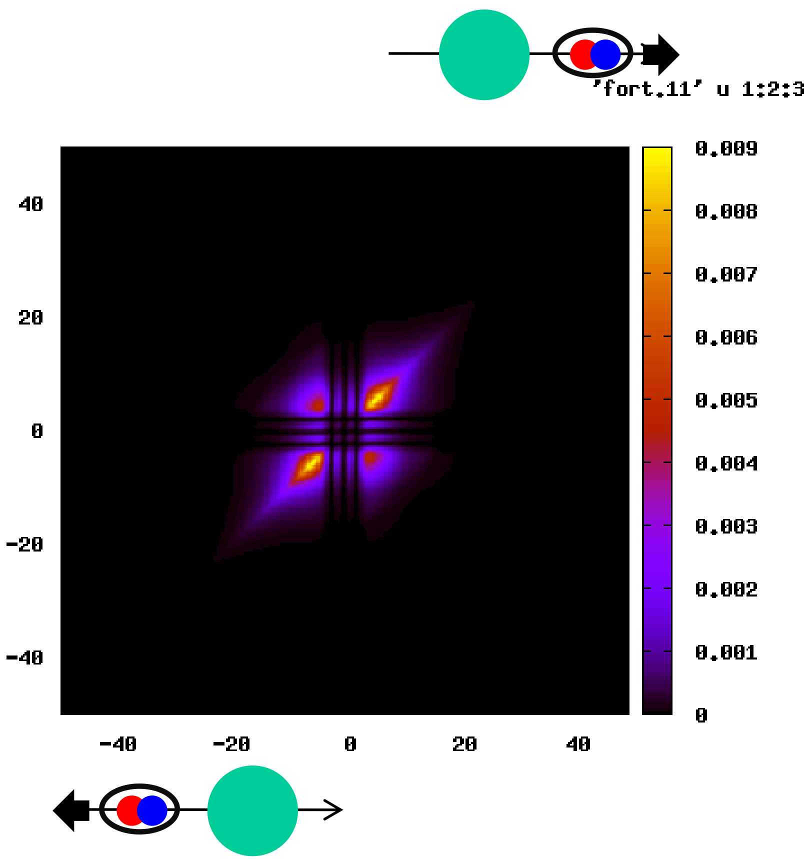
V_c = 3 MeV, σ_t = 2.1 hbar/MeV, x_0 = 0 two-particle density at $\boldsymbol{t} = \boldsymbol{t}_{\mathbf{ini}}$



time evolution

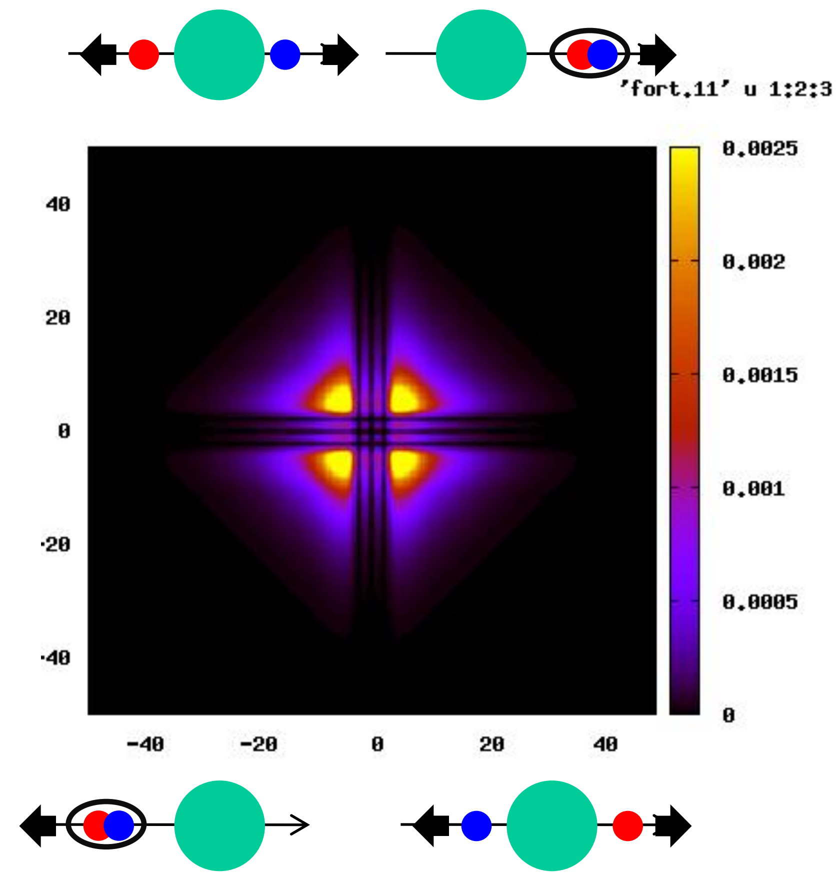


correlated

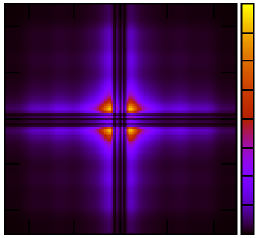


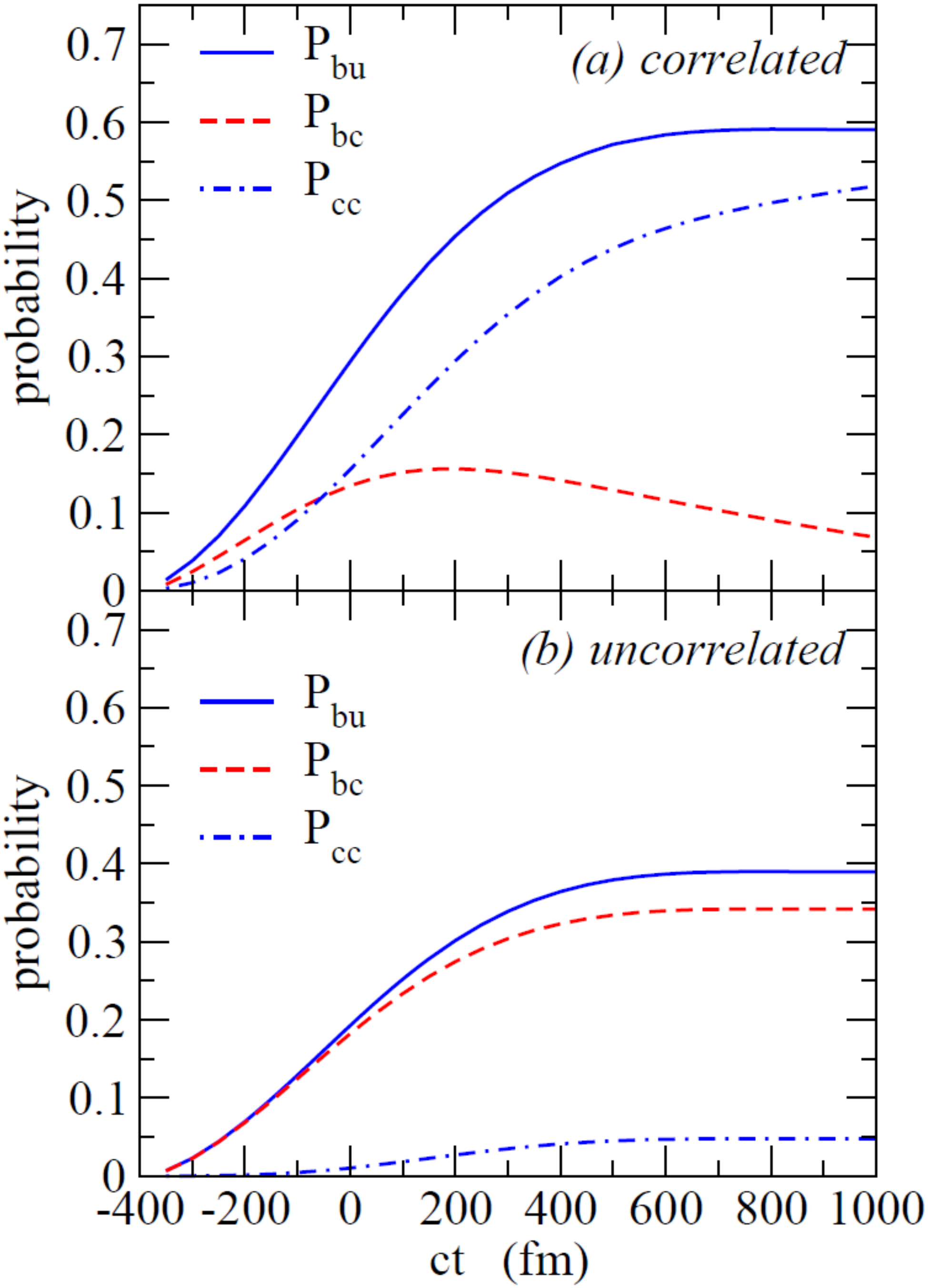
“dineutron emission”

uncorrelated



large (bc) component



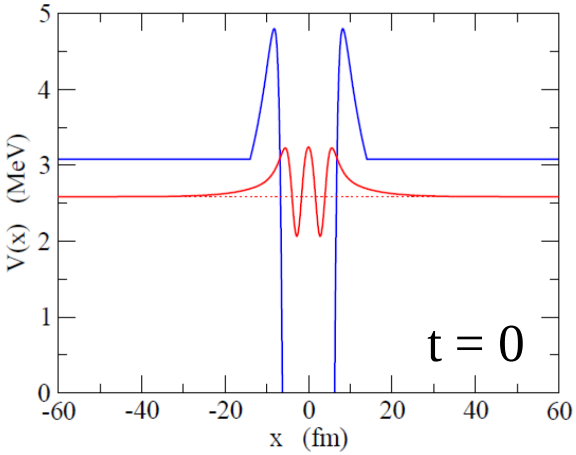


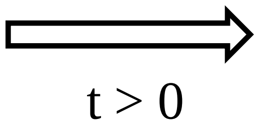
- Pairing: enhances the breakup
- Correlated: (cc) process
- Uncorrelated: (bc) process

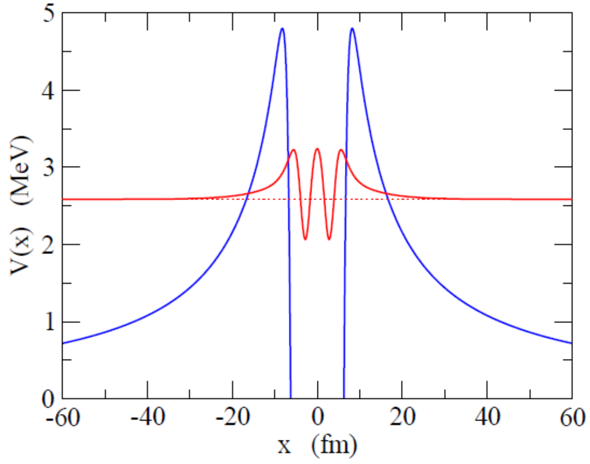
P_{cc}: 2 neutron breakup
P_{bc}: 1 neutron breakup

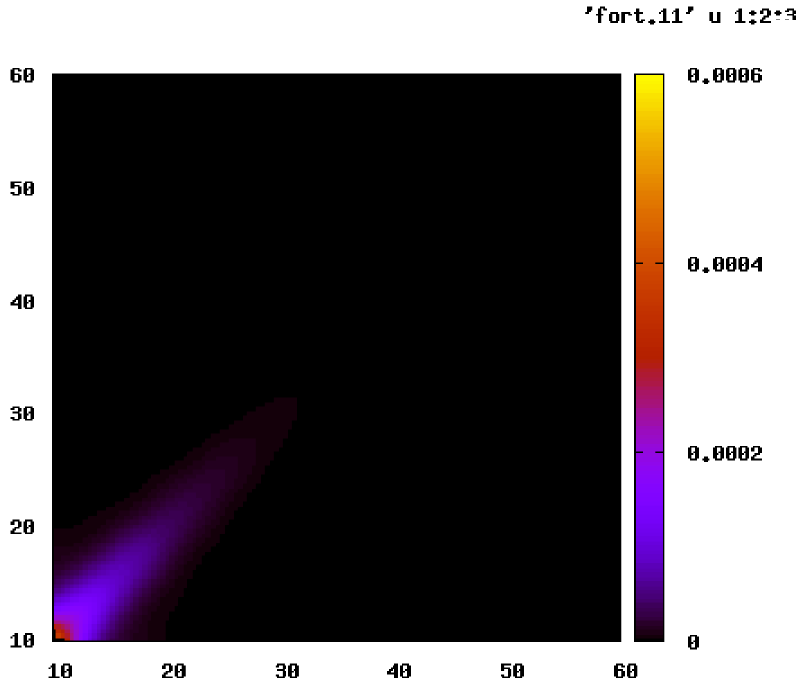
Application to 2p radioactivity

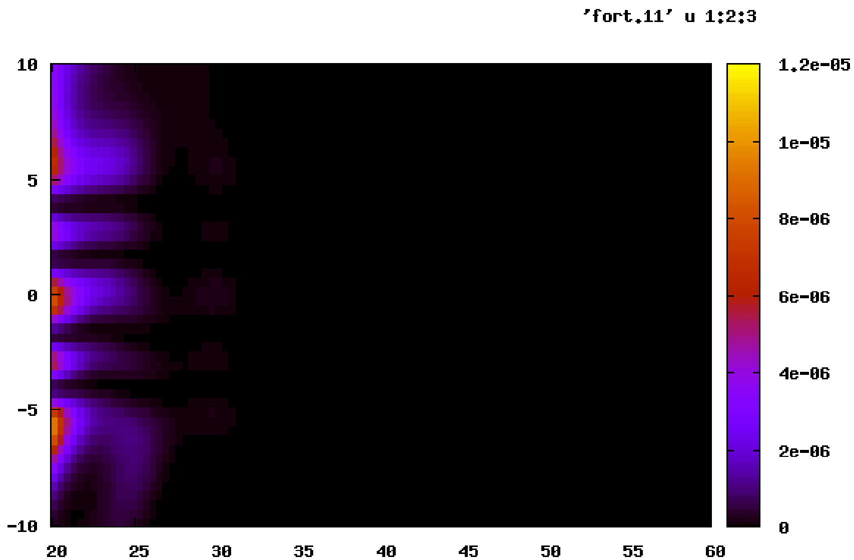
T. Maruyama, T. Oishi, K.H., preliminary









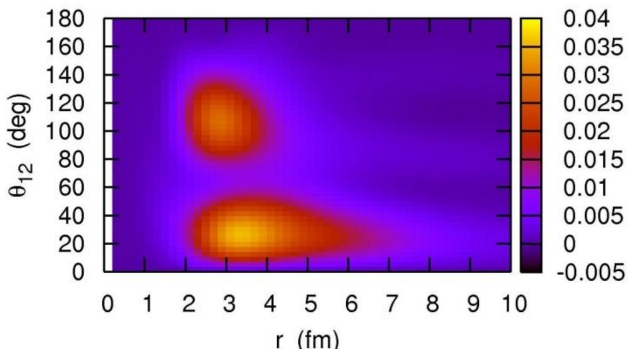


di-proton emission ($x_1 = x_2$)

sequential 2p emission ($x_2 \sim 0$)

Summary

Three-body model with density-dependent contact interaction

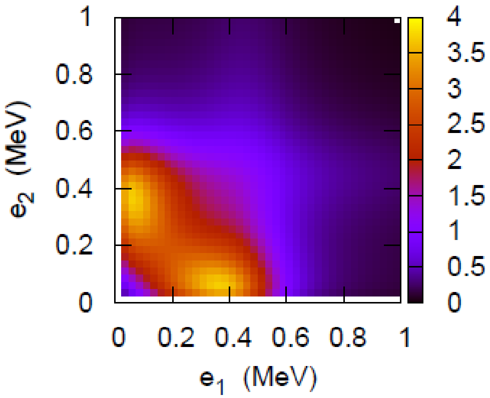


◆Ground state of ^{11}Li and ^{6}He

➢similar di-neutron correlation

◆Energy distribution

of neutrons from the E1 excitations in ^{11}Li and ^{6}He



➢continuum responses

➢the shape of distributions: primarily determined by n-core dynamics rather than n-n

➢energy distribution: very different between ^{11}Li and ^{6}He

⟶ s-wave virtual state in ^{11}Li

cf. similar dineutron correlations in the g.s.

◆One dimensional model for 2n halo nuclei

➢simple, and schematic model. detailed studies of dynamics