Di-neutron correlations and Coulomb breakup reactions of ^{6}He

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General interests on Borrormean systems and their three-body decay

- Borromean systems and these exotic structures
  - Two-neutron halos and di-neutrons in ^{6}He and ^{11}Li
  - acondensed states in ^{12}C
- Three-body decay and its momentum distribution
  - It can be helpful tool to find some information on the correlation.
    - Coulomb breakup reaction of two-neutron halo nucleus and di-neutron
    - Two proton decay and di-proton

What's problem?

- How can we get the scattering states?
  - Faddeev method
    $\Rightarrow$ It is difficult to calculate.
  - Lippmann-Schwinger method
    $\Rightarrow$ The treatment of boundary conditions are not accurate.

Is there any way to include the boundary condition of each open channels o LS method?

Using Complex Scaled Hamiltonian.

Description of scattering states

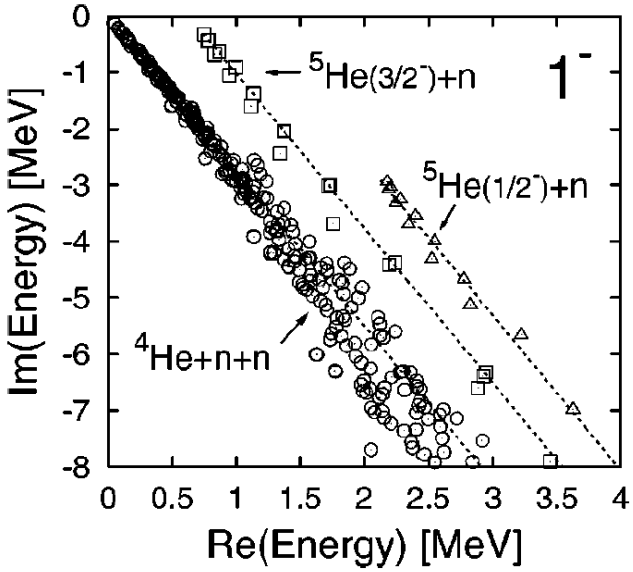
- We use the solutions of Lippmann-Schwinger-like eq. as the scattering state

$$|\Psi\rangle = |\boldsymbol{k}\rangle + \frac{1}{E^0 - \mathcal{H}}\mathcal{V}|\boldsymbol{k}\rangle$$

$$(\mathcal{H}^0 - E^0)|\boldsymbol{k}\rangle = 0$$

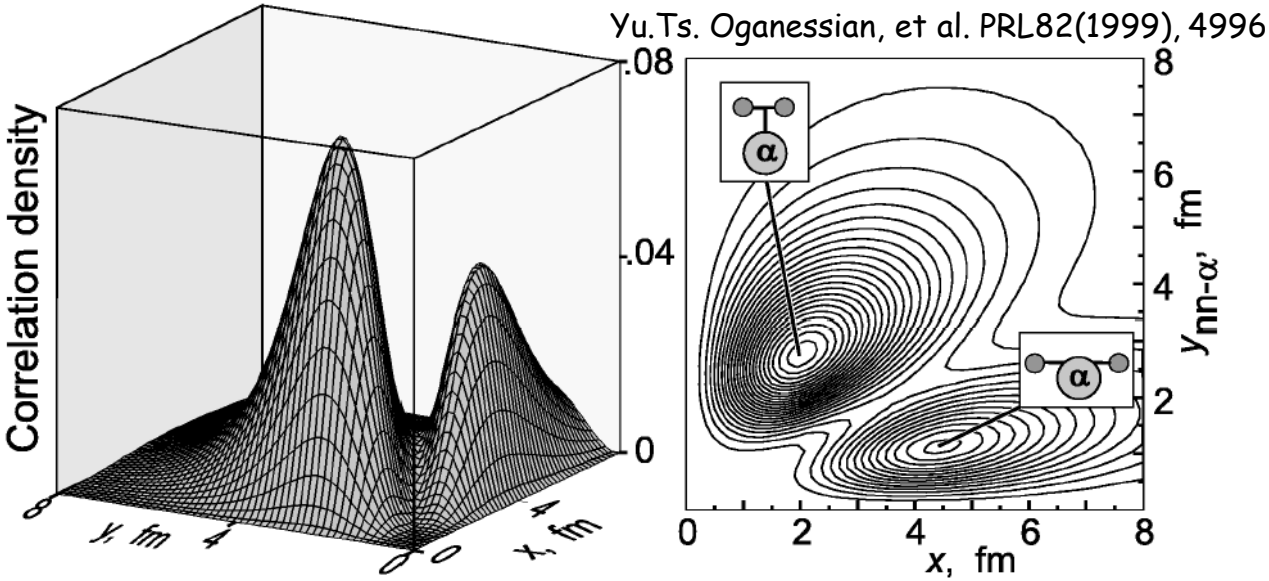
$$(\mathcal{H} - E)|\Psi\rangle = 0$$

We include each boundary conditions with Complex Scaled total Hamiltonian



^{6}He, the typical Borromean system
Halo structure and di-neutron correlation

- Two-neutron halo structure in ^{6}He
  - Exotic structure in ^{6}He[1]
- Di-neutron correlation in the ground state
  - It is suggested theoretically[2]

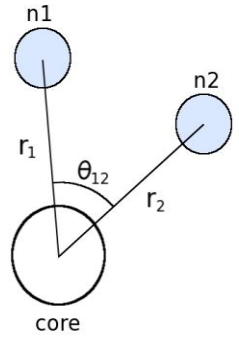


[1] I. Tanihata, et al., PRL55(1985), 2676

[2] B.V. Danilin, et al., Sov. J. Nucl. Phys. 48(1988), 766; 49(1989), 217, 233

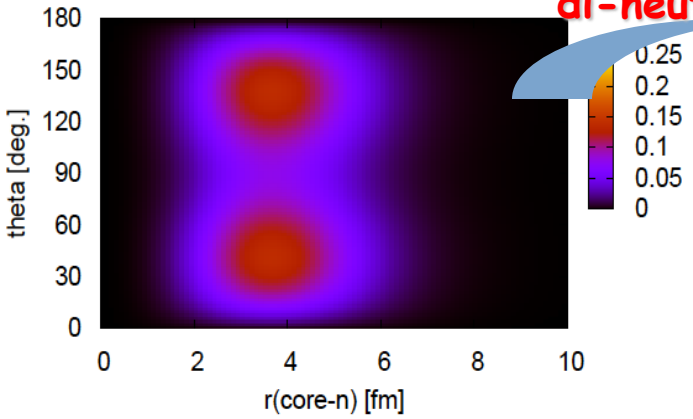
Di-neutron correlation in the ground state

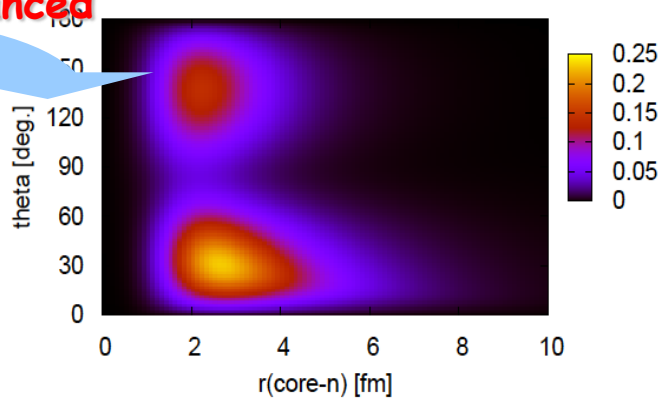
- The origin is $(0p)^2$ configuration
- Partial wave mixing enhances di-neutron



As partial wave mixing increases,

di-neutron is enhanced





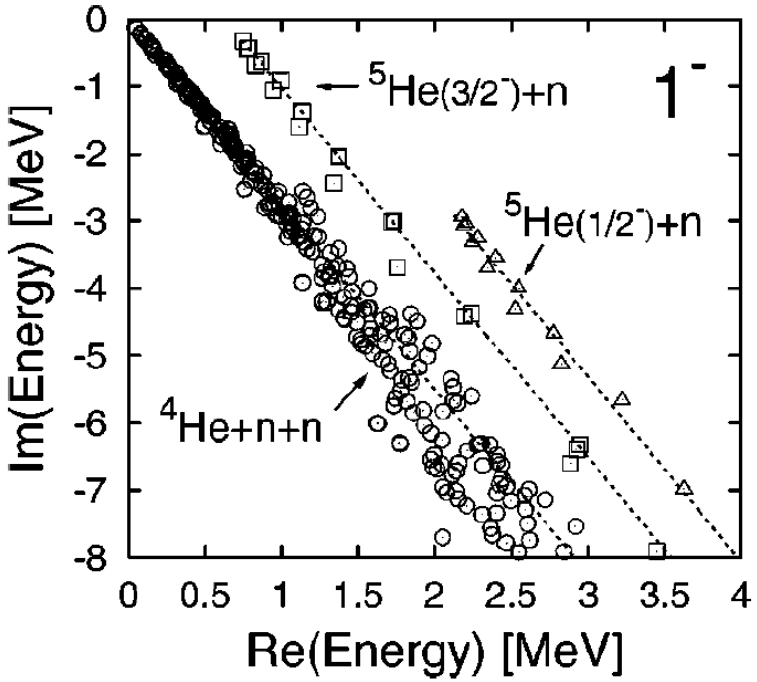
Mean field-like state $(0p)^2$

Clustering state + Mean field

Competition between mean field and clustering state is important in the ground state

Excited states and structure in it

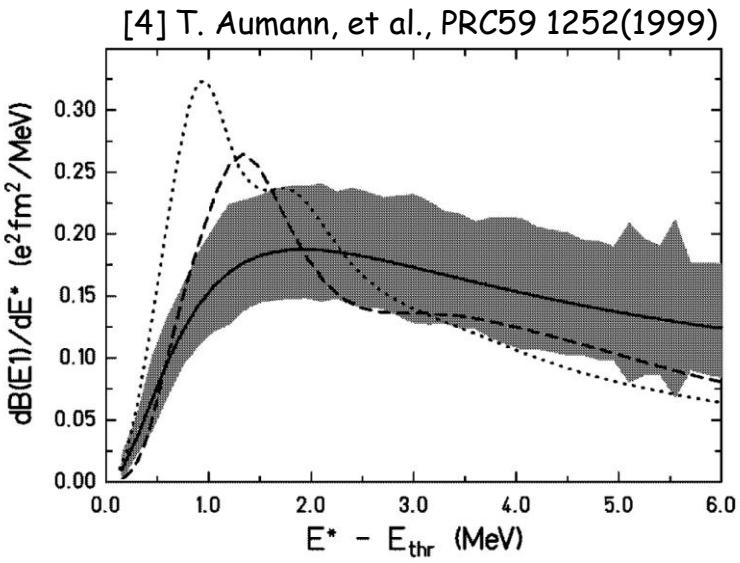
- No resonant or bound state in 1^- states[3]
- Only ^{5}He+n two-body and **α**+n+n three-body continuum states exist.



[3] T. Myo, et al., PRC63 054313(2001)

Low-lying peak in E1 transition

- Observed E1 distribution shows the low-lying peak around 1 MeV.[4]



Which correlation is important?

Ground state? or Intermediate states?
How about di-neutron correlation?

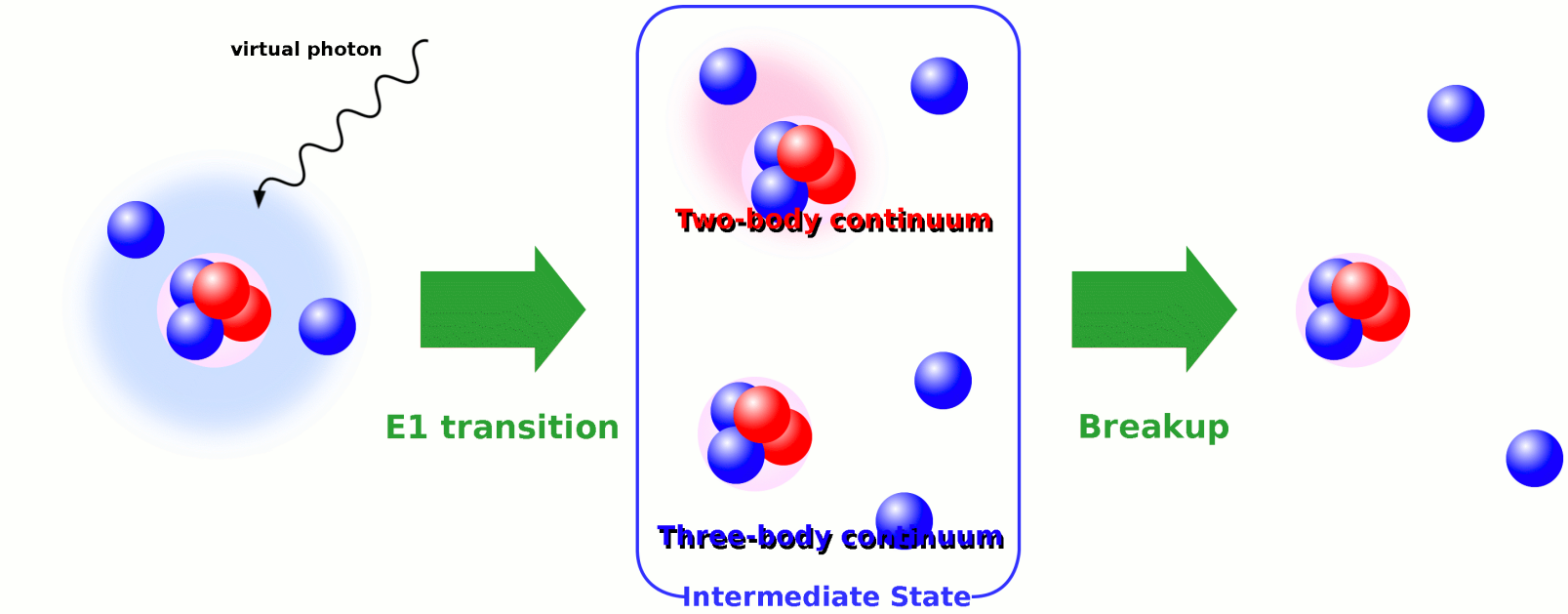
Our interest in this work

- How strong is the di-neutron correlation in the ground state and excited states?
- Through the Coulomb breakup, can we find some evidences for di-neutron correlation?

We investigate the momentum distribution of the E1 transition, and survey the evidence for di-neutron correlation via Dalitz plot of E1 transition.

Assumed breakup mechanism

- Breakup process and intermediate states



Dalitz plot for E1 transition #1

- We investigate following two types of correlations

$$\langle \Psi | \mathcal{O}(E1) | \Phi_{\mathrm{g.s}} \rangle = \underline{\langle \boldsymbol{k} | \mathcal{O}(E1) | \Phi_{\mathrm{g.s}} \rangle} + \underline{\langle \boldsymbol{k} | V \frac{1}{E^0 - H} \mathcal{O}(E1) | \Phi_{\mathrm{g.s}} \rangle}$$

direct breakup　　final state interaction(FSI)

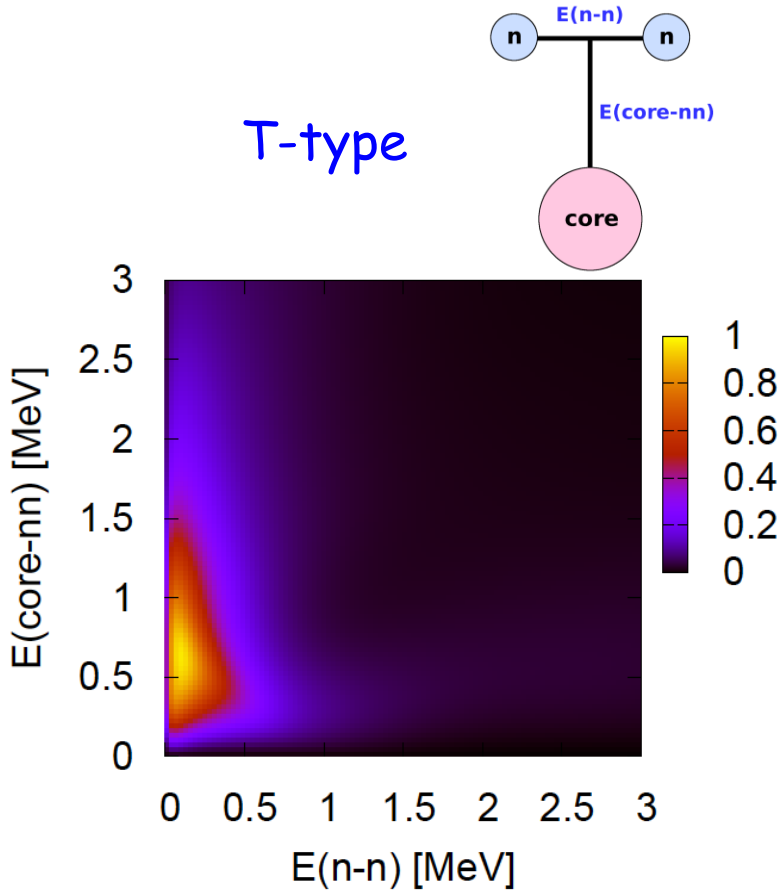
and

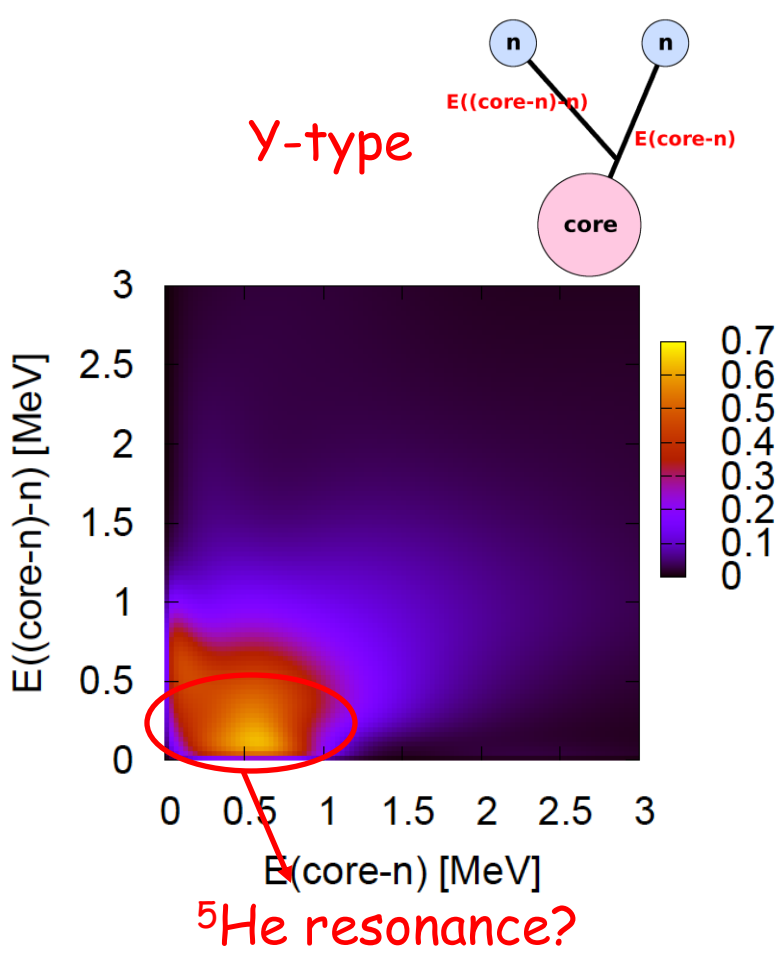
$$\langle \boldsymbol{k} | V \frac{1}{E^0 - H} \mathcal{O}(E1) | \Phi_{\mathrm{g.s}} \rangle = \sum_i \sum_j \langle \boldsymbol{k} | \phi_i^0 \rangle \langle \phi_i^0 | V \boxed{| \phi_j^\alpha \rangle \frac{1}{E_i^0 - E_j^\alpha} \langle \phi_j^\alpha |} \mathcal{O}(E1) | \Phi_{\mathrm{g.s}} \rangle$$

Insert the complete set and propagator of intermediate states

Dalitz plot for E1 transition #2

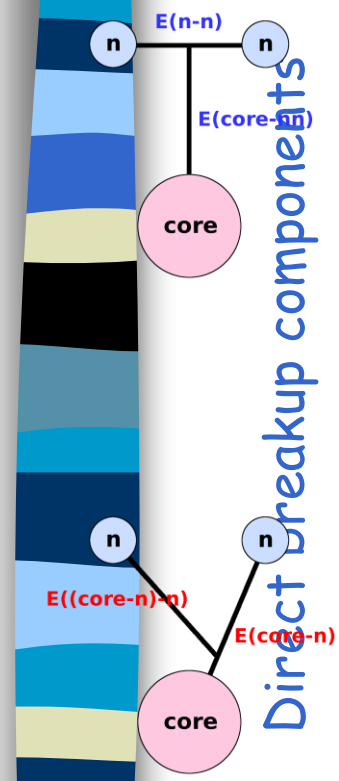
- Obtained Dalitz plot for E1 transition



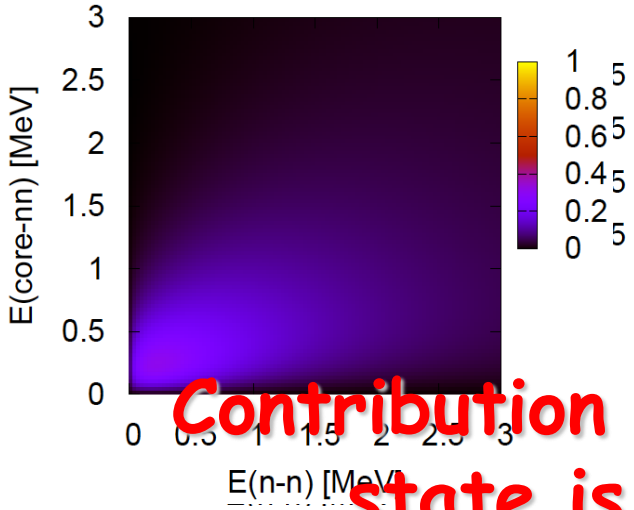


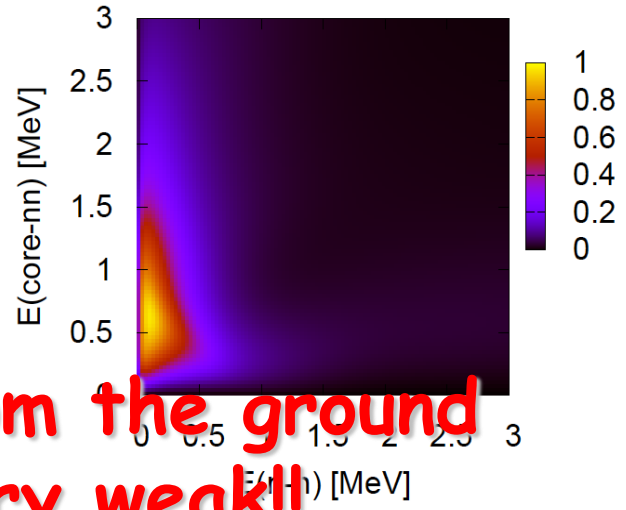
Possibility to observe the direct breakup

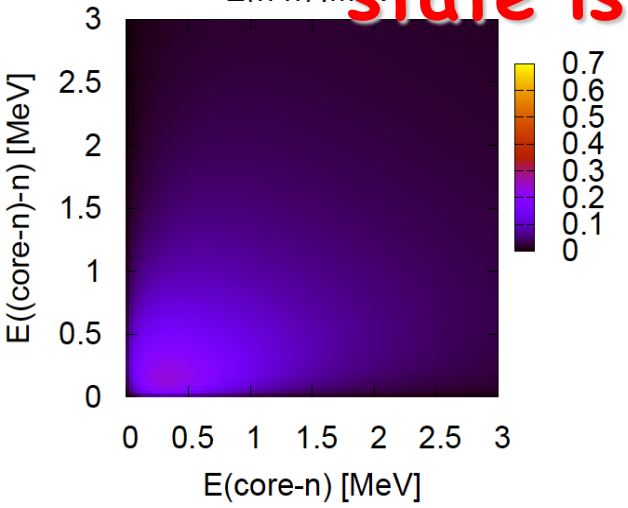
- Comparison - direct breakup vs. total strength -

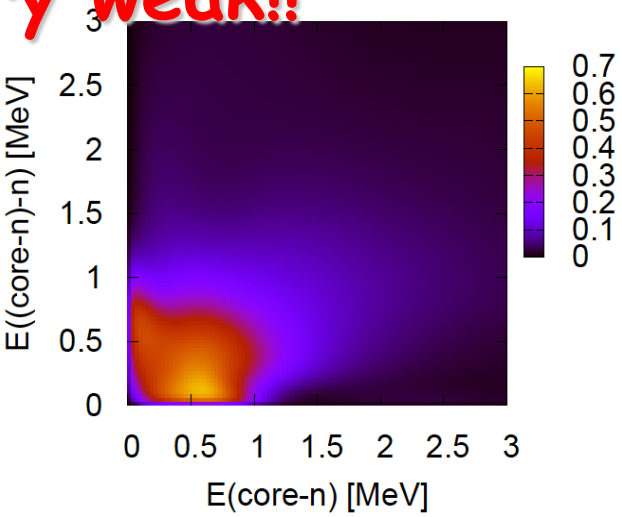


Direct breakup components







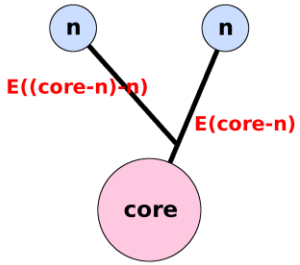


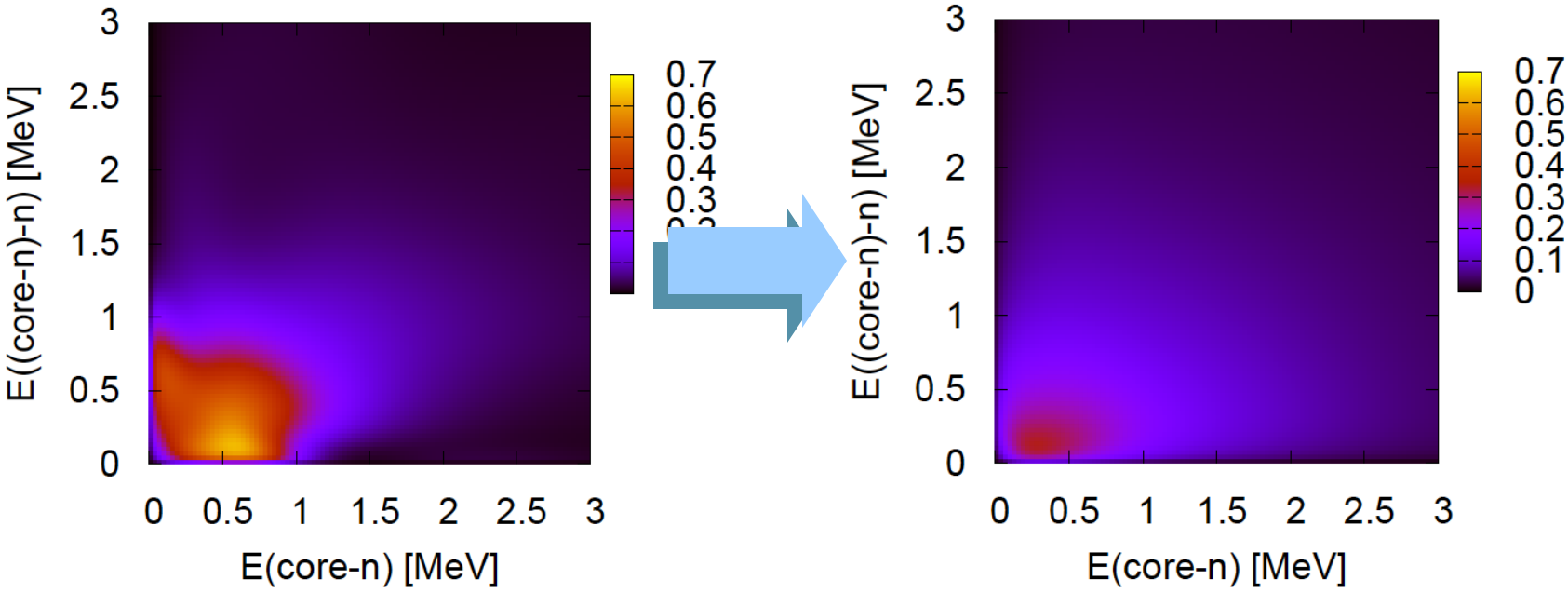
Total strength

Contribution from the ground state is very weak!!

α-n correlation in the 1^- state

- Effect of FSI - no **α**-n interaction-





No core-n int. case → The peak in Y-type weakened

It becomes almost like phase space decay

Intermediate state and its structure

- Above results shows :
  - We can't get clear information on the ground state via the E1 transition reaction.
  - The distributions show that ^{5}He resonance configuration is dominant and di-neutron contribution is weak compared to ^{5}He resonance effect

Through the E1 transition reaction, for the strong contribution from ^{5}He resonance,

It may be difficult to obtain the evidence for di-neutron.

Summary

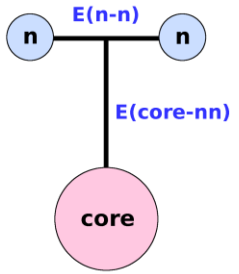
- We investigated the Dalitz plot of the E1 transition strength of the ^{6}He nucleus by using the solution of LS-like eq using CSM.
- We found some peaks in the Dalitz plot
  - The contribution from the ground state is very weak.
  - ^{5}He resonance peak exists and is dominant in the E1 transition reaction.
- From strong effects of the ^{5}He resonance , it is suggested that it is difficult to find some evidences for di-neutron via the Coulomb breakup reaction of ^{6}He.

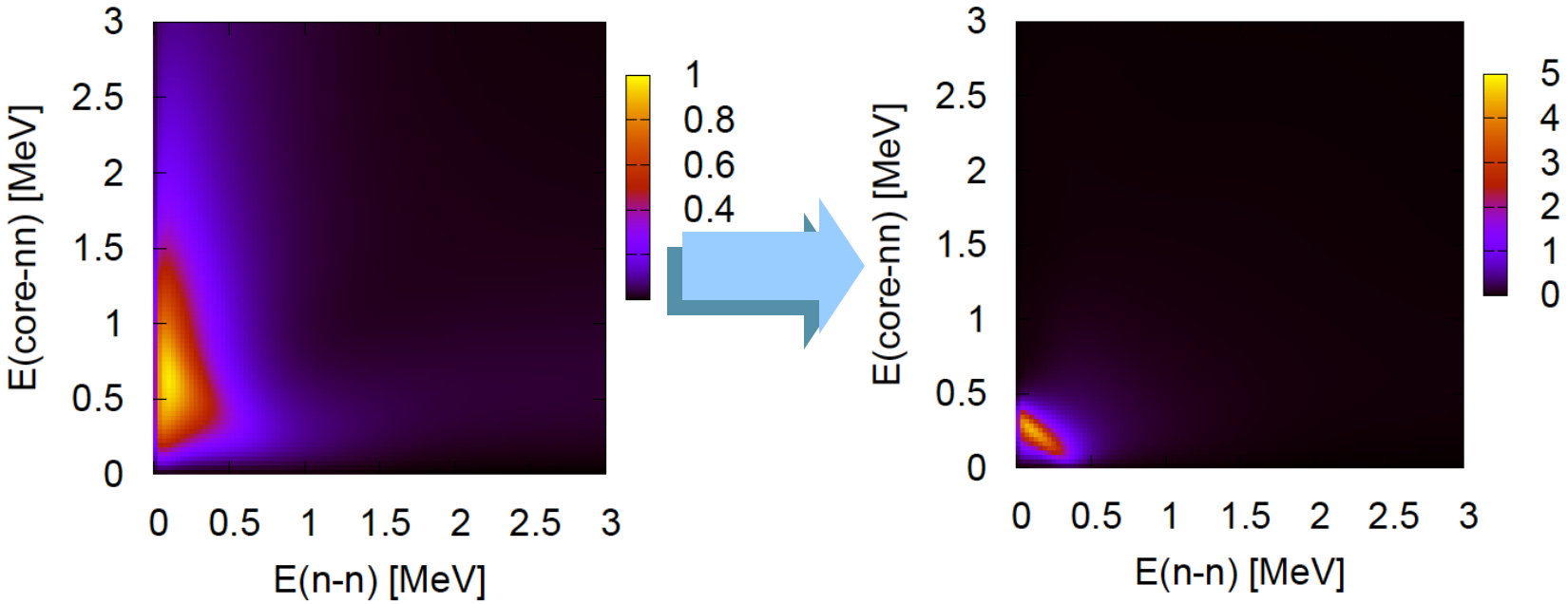
Future works

- Two proton decay in ^{6}Be
  - Can be di-proton decay found?
  - How about the difference from ^{6}He breakup?
- Three-body decay in ^{12}C through the acondensed states
  - Are the direct breakup components dominant in the three-body decay, if acondensed state exists and it is like the dilute gases?
  - How about the many body decay of the candidates of a condensed states?

n-n correlation in the 1^- state

- Effect of FSI - strong n-n interaction-

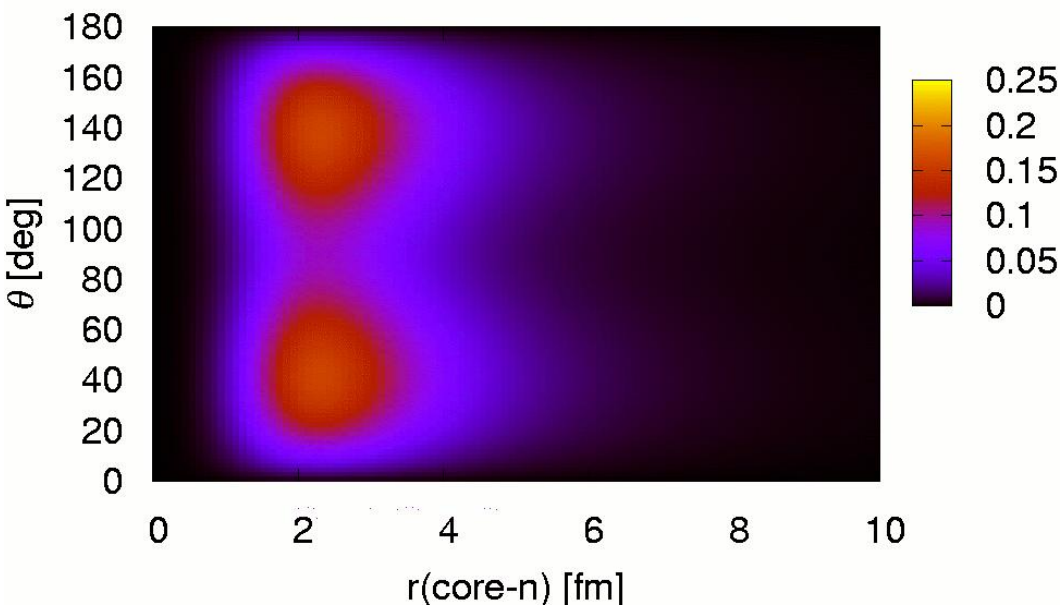




Strong n-n int. case → The peak moves on toward E(n-n) axis

The di-neutron correlation is weak in E1 strength?

Backups #1
Convergence of 2n density of ^{6}He



Backups #2
2n density of ^{11}Li

Backups #3
Probability of E1 transition