Investigation of dineutron correlation via ^{6}He(p,pn) reaction

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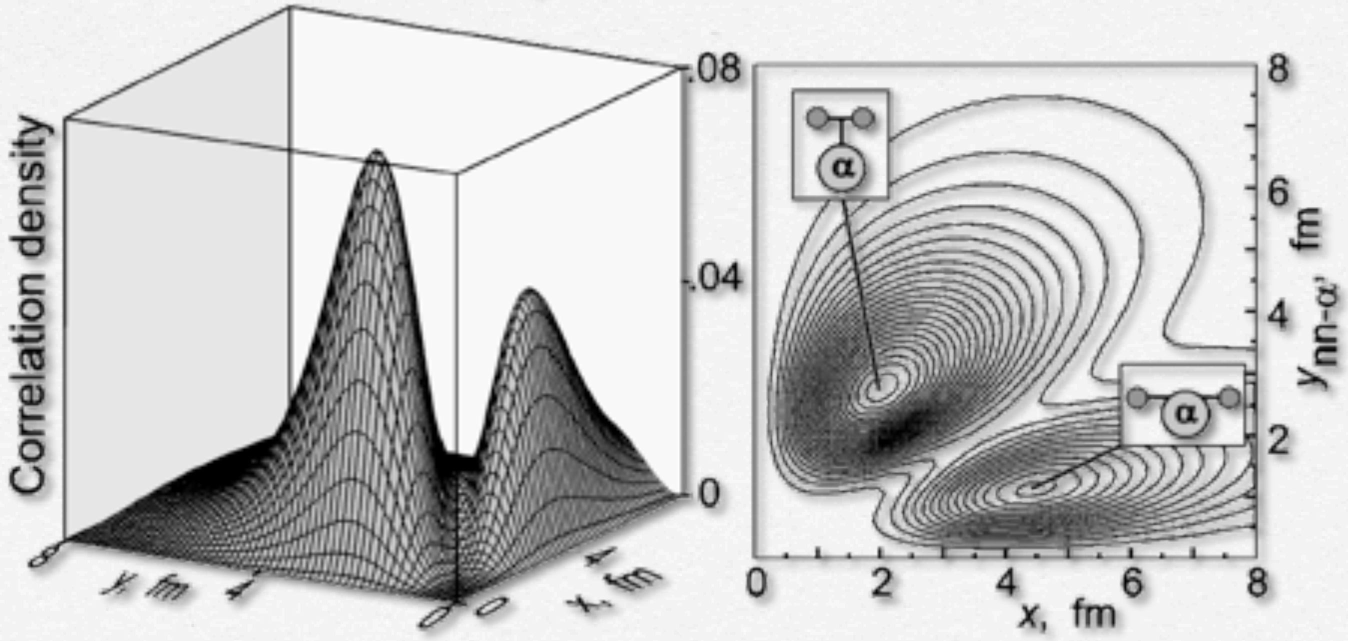
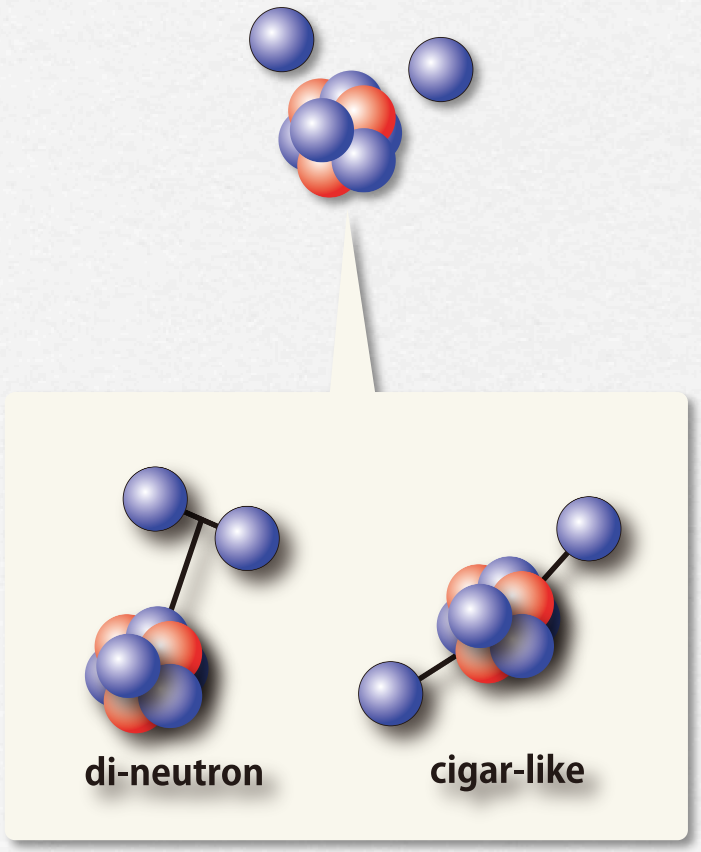
Dineutron correlation in two-neutron halo nuclei

- Two-neutron halo nuclei have been studied based on core+n+n three-body model.
  - The results of three-body models show that:
    - A correlation between halo neutrons has an important role in their binding mechanisms.
    - This correlation is characterized as a spatially-correlated n-n pair, the so-called “dineutron.”

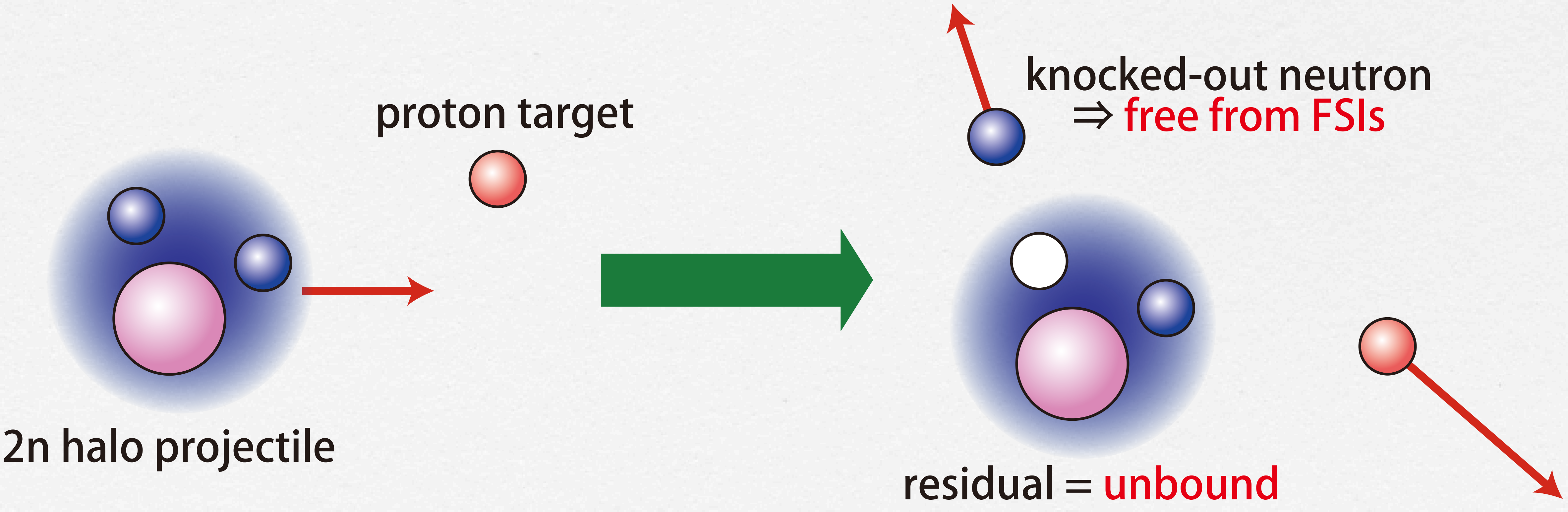
Yu.Ts. Oganessian, *et al.* PRL82(1999), 4996





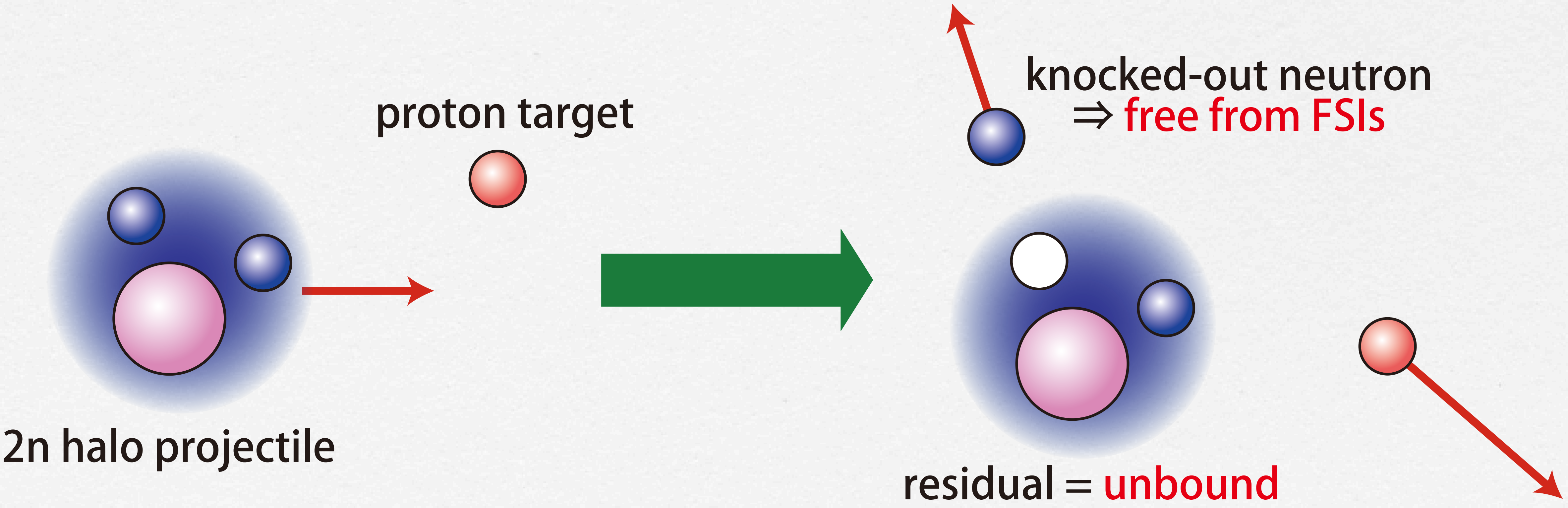
Quasi-free neutron knockout reactions

- The quasi-free neutron knockout reactions might be useful to investigate the ground-state structure such as a dineutron.
  - The knocked-out neutron is almost free from FSIs.



Quasi-free neutron knockout reactions

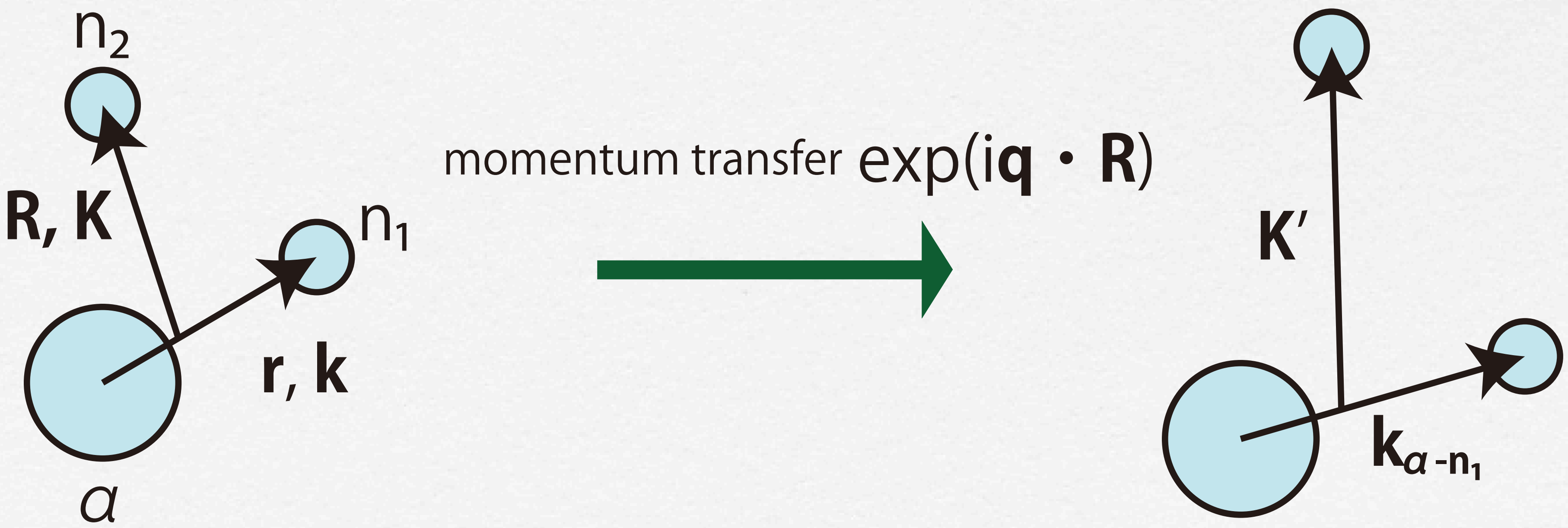
- ☐ The quasi-free neutron knockout reactions might be useful to investigate the ground-state structure such as a dineutron.
  - ☐ The knocked-out neutron is almost free from FSIs.
  - ☐ However, in the ^{6}He(p,pn) reaction, the residual nucleus ^{5}He is unbound due to the Borromean nature of ^{6}He.
  - ☐ How the process via ^{5}He resonances impact on the observables?



Quasi-free knockout reactions using sudden approx.

- As first step, we use the simple model in calculating the knockout reaction.
    - We here use the sudden approximation in the present calculation.
        - The (p,pn) part is treated by the simple momentum-transfer operator.
        - The scattering wave of the knocked-out neutron is described by a plane wave.
    - To estimate the effect of the process via ^{5}He resonance on the reaction, the exact scattering states of α+n system for the residual part.
    - The T-matrix for the knockout reaction is given as

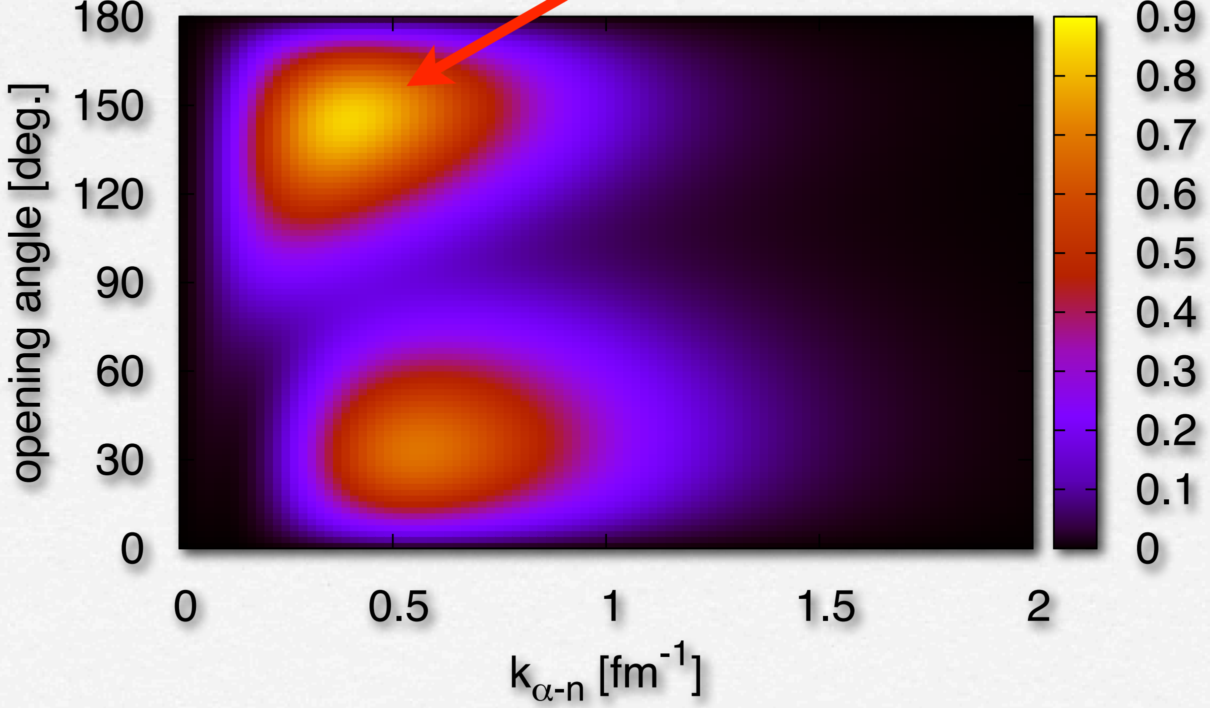
$$\mathcal{T} = \left\langle \Psi_{^5\mathrm{He}}(\mathbf{k}_{\alpha\text{-}n_1}) \otimes e^{i\mathbf{K}'\cdot\mathbf{R}} \left| e^{i\mathbf{q}\cdot\mathbf{R}} \right| \Phi_{^6\mathrm{He}} \right\rangle$$

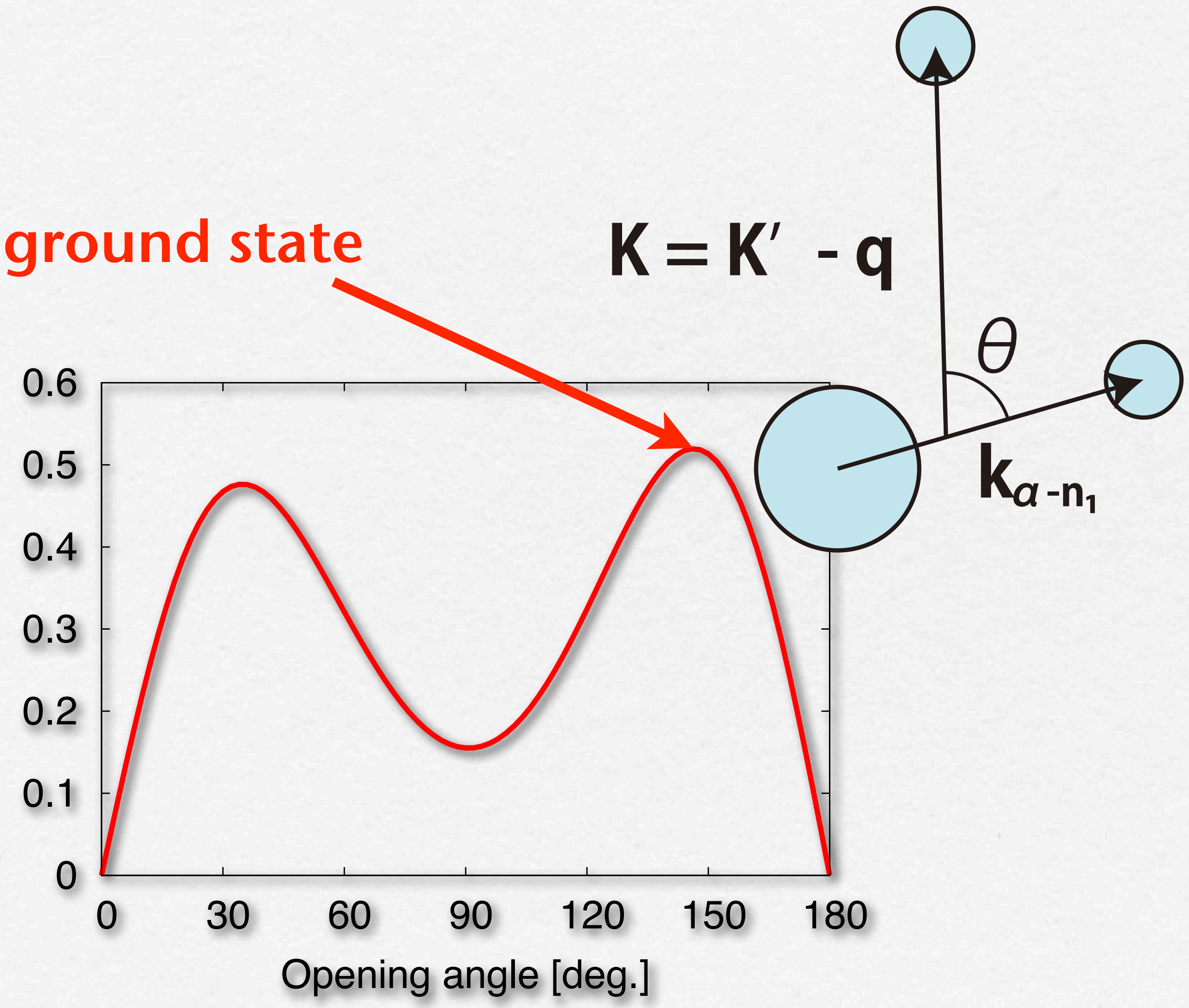


Momentum distributions in the ground state of ^{6}He

- ☐ Momentum distribution and angular correlation in the ground state of ^{6}He
  - = Fourier transform of the ground-state wave function
  - ☐ In both distributions, the peaks are seen at the region of large angle.
    - ☐ These indicate the dineutron in the ground state.

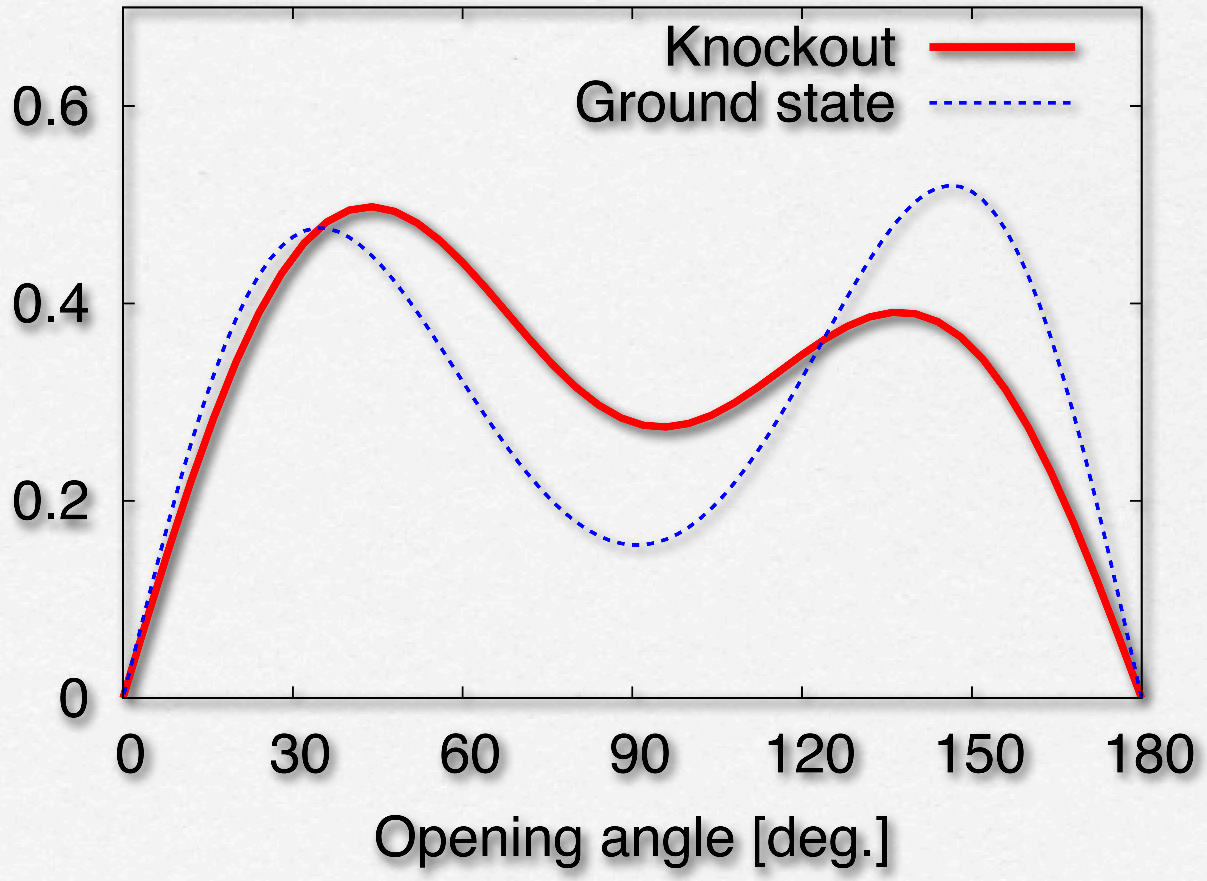
dineutron in the ground state





Angular correlations in the knockout reaction

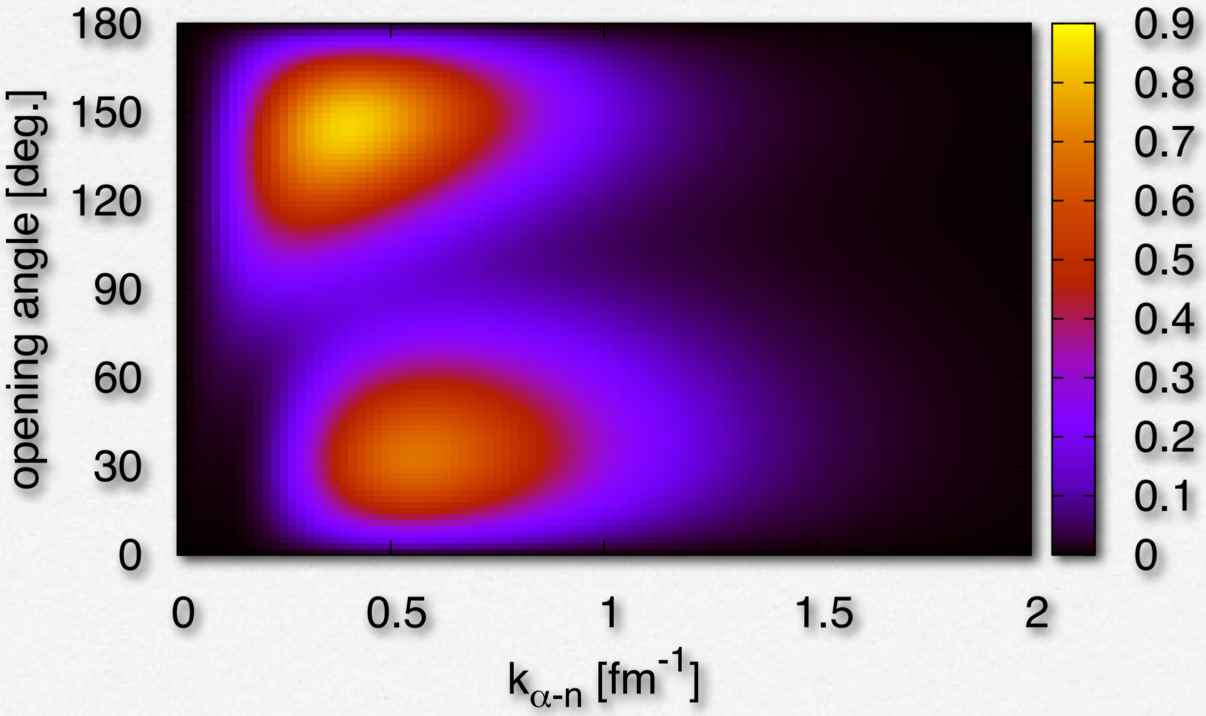
- We calculate the angular correlation in the knockout reaction.
  - The calculated distribution shows the two-peaked structure.
  - However, in the result for knockout, the 2nd peak, corresponding to the dineutron, is reduced compared to the ground-state distribution.
  - The process via ^{5}He changes the angular correlation, especially for the dineutron part.



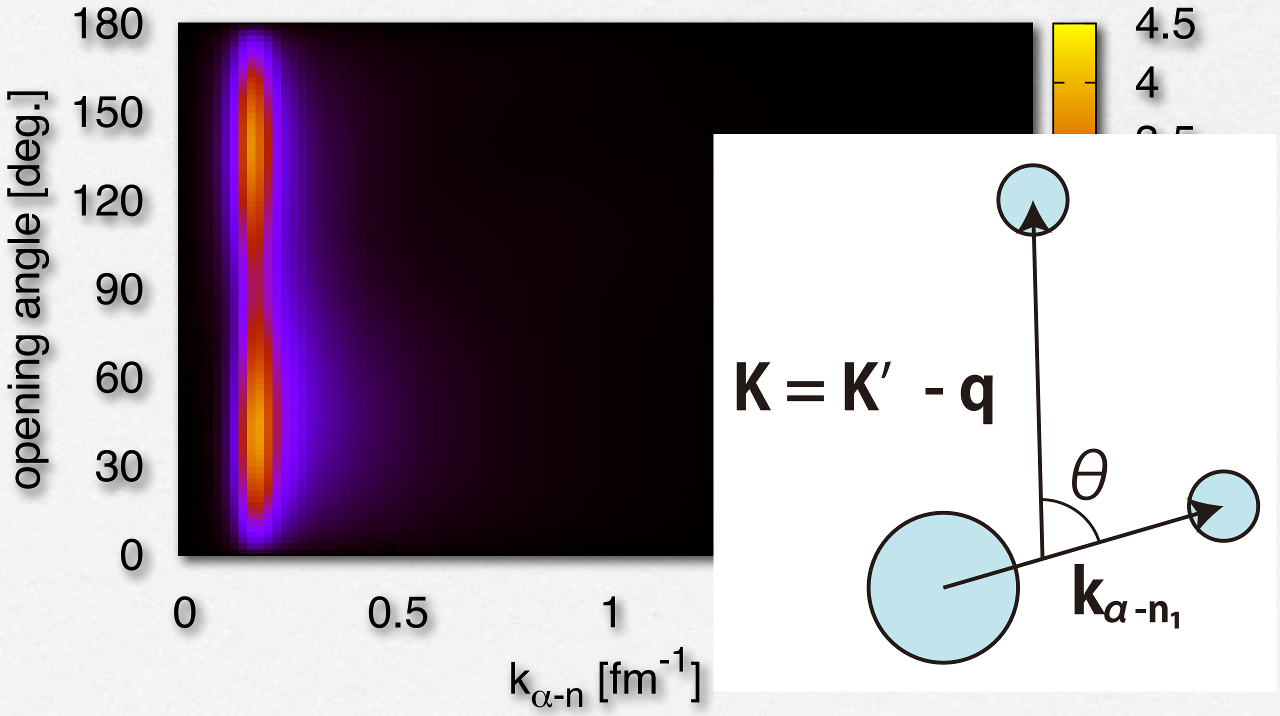
Angular correlations in the knockout reaction

- What happens by taking into account the process via ^{5}He resonance?
  - Inclusion of the process via ^{5}He resonance, the momentum distributions is concentrated on the momentum region corresponding to ^{5}He($3/2^-$).
  - The process via ^{5}He drastically changes the angular correlation.

2D distribution for g.s.



2D distribution for knockout



To find the evidence of dineutron

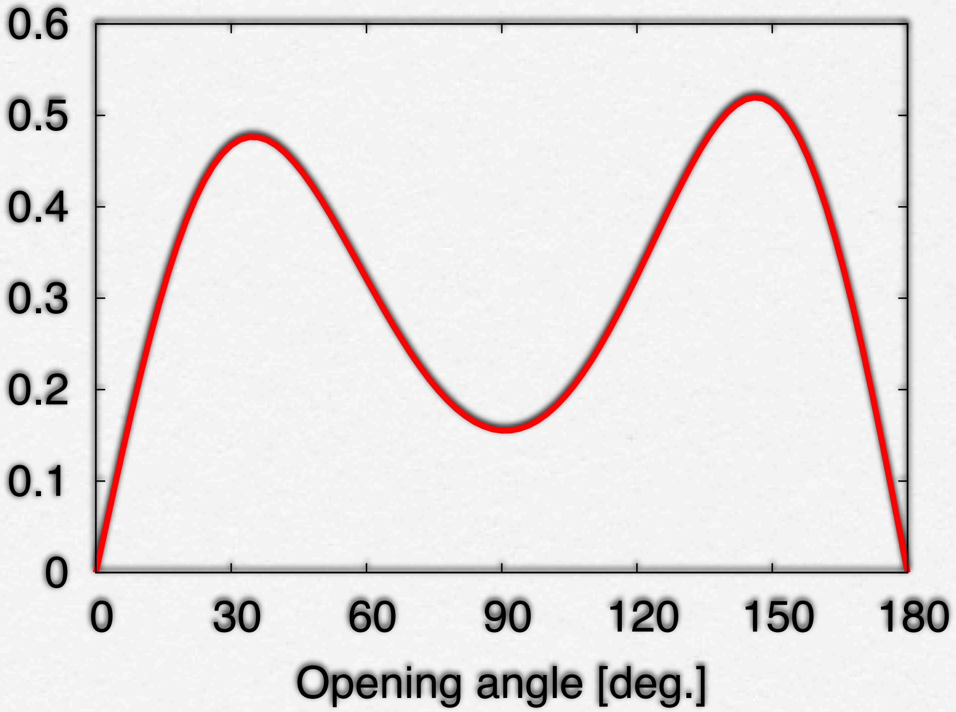
- ☐ Dineutron: Asymmetric shape in the angular correlation
  - ☐ The origin of the asymmetry is an interference between different parity states.

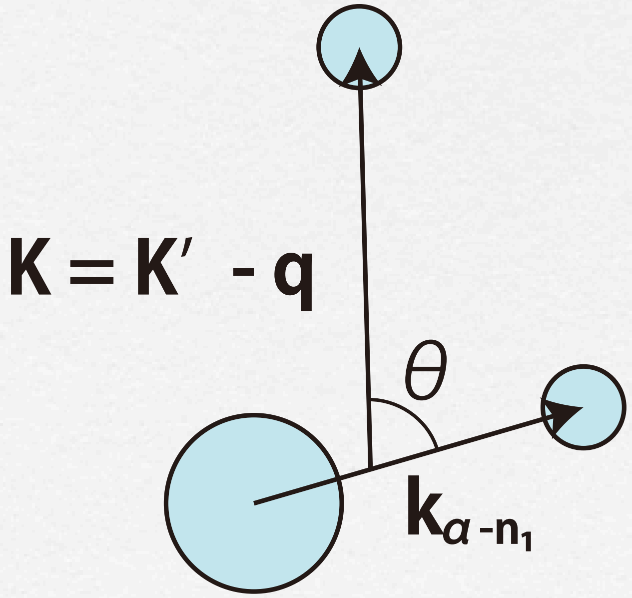
$$\left|\Phi(^6\mathrm{He})\right|^2 = \left|\alpha\phi(s^2)+\beta\phi(p^2)+\cdots\right|^2$$

$$=\alpha^2\left|\phi(s^2)\right|^2+\beta^2\left|\phi(p^2)\right|^2+\cdots \longleftarrow \text{Symmetric part in ang. corr.}$$

$$+\underline{2\alpha\beta\phi(s^2)\phi(p^2)}+\cdots \longleftarrow \text{Asymmetric}$$

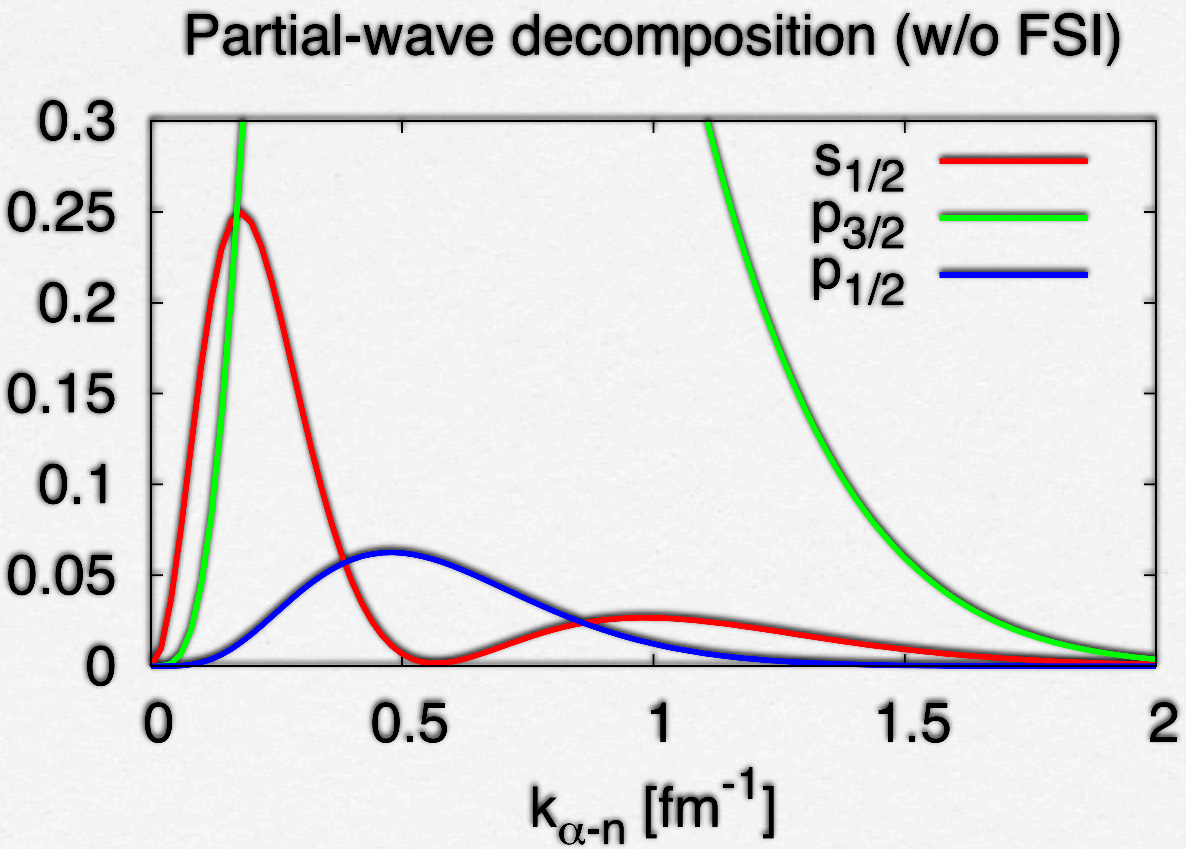
Relative phase is crucial to determine the asymmetry

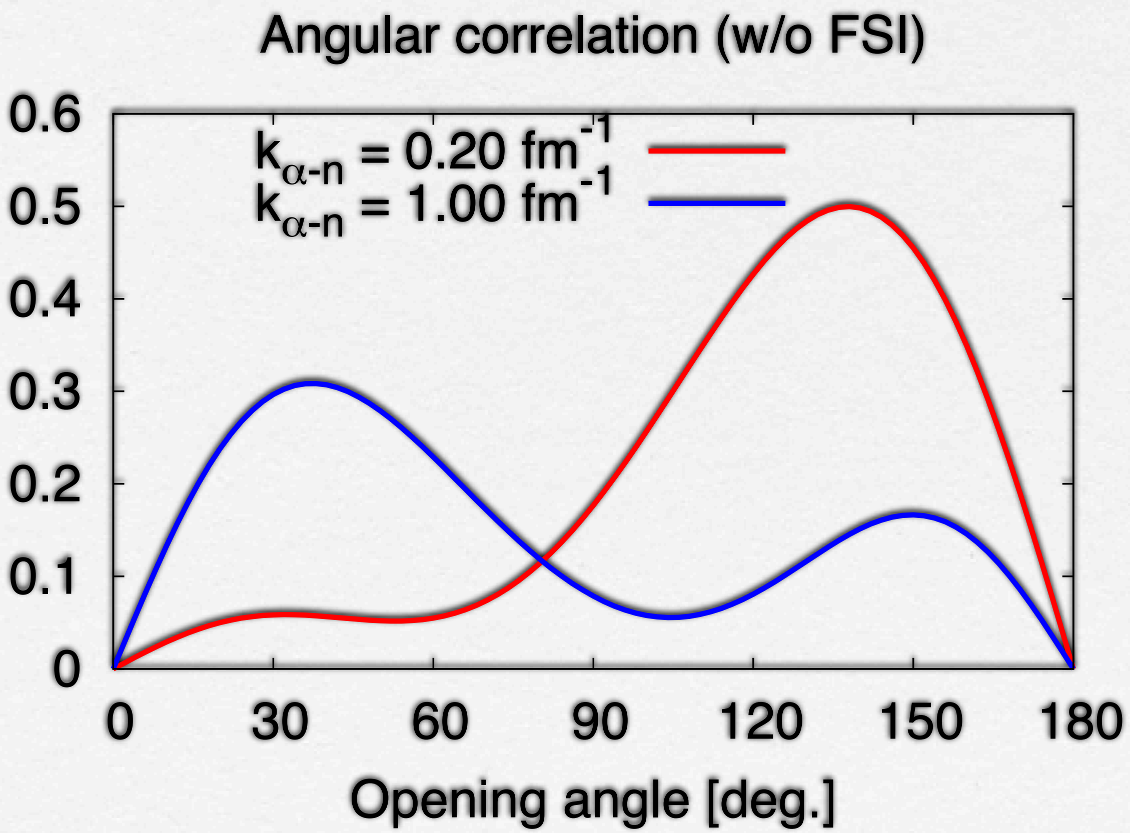




To find the evidence of dineutron

- Dineutron: Asymmetric shape in the angular correlation
  - The relative phase between different parity states is crucial to determine the dineutron in the ground state.
    - At $k_{\alpha\text{-}n}\sim 0.5\text{fm}^{-1}$, the relative phase between s- and p-waves changes because the s-wave has a node.
    - Asymmetries in the angular correlations of the ground state are opposite to each other in lower and higher region of $k_{\alpha\text{-}n}$.


Partial-wave decomposition (w/o FSI)

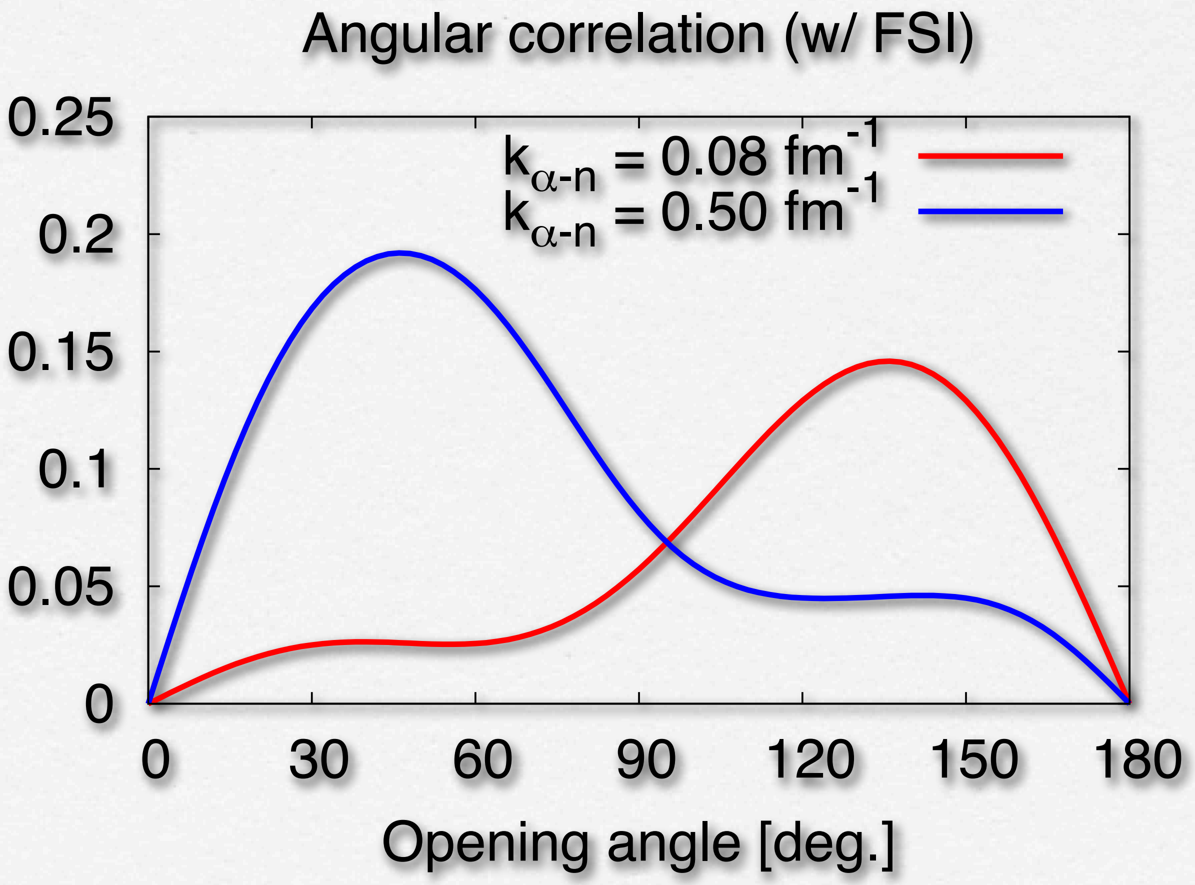

Angular correlation (w/o FSI)

To find the evidence of dineutron

- In the quasi-free knockout reaction, it is necessary to consider:
  - How to minimize the effect of the process via ^{5}He resonance
    - We minimize this effect by selecting the off-resonance region in the relative momentum between α and the decayed neutron, $k_{\alpha\text{-}n}$.
  - How to identify the relative phase between different parity states
    - We identify the relative phase from the asymmetries in the angular correlations at the lower and higher parts of $k_{\alpha\text{-}n}$.

Angular correlations in off-resonance region

- We calculate the angular correlations for lower and higher parts of off-resonance region.
  - We find the similar trend to that in the ground state even if the process via ^{5}He resonance dominates the knockout reaction.
  - The lower momentum region, we can clearly find an enhancement of dineutron in the angular correlation.



For Experimental setup

- To select the off-resonance region and to investigate the asymmetries in angular correlations in the knockout reaction, a good resolution for $k_{\alpha\text{-}n}$ is required.
  - For the most serious case, maybe ^{11}Li, the s-wave virtual and p-wave resonant states are located in separation of 200 keV (in theoretical prediction).
  - The resolution of ~ 50 keV, which is relevant to $k_{\alpha\text{-}n} \sim 0.05\ \mathrm{fm}^{-1}$, is required in such as case.
- It is also useful to measure momentum distributions for the relative motion between the core-n subsystem and neutron.
  - It tells us the direct information on the initial momentum in the nucleus.
  - Is it possible experimentally?