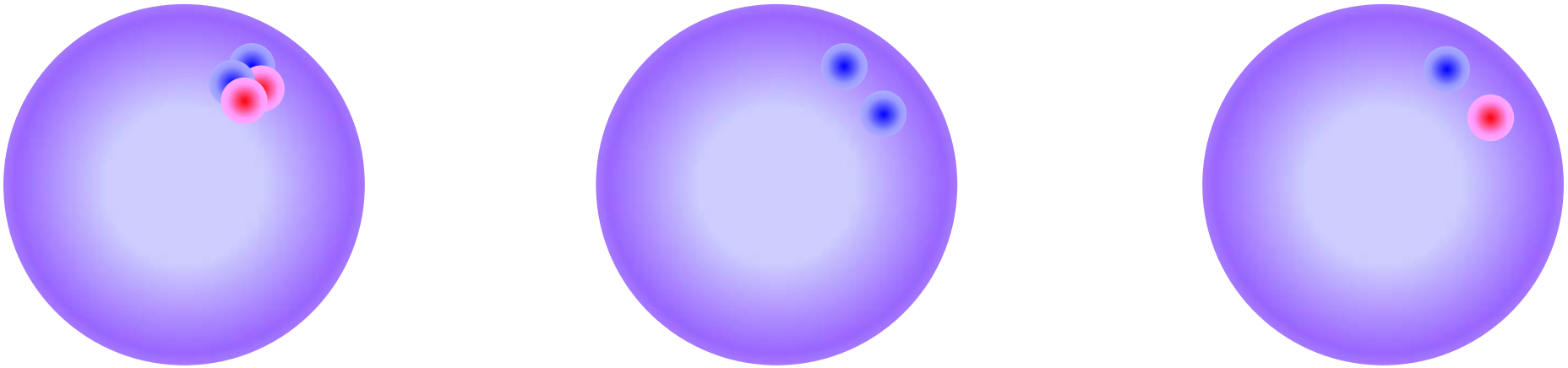
原子核のクラスター構造の実証に向けた取り組み

新学術領域研究

「量子クラスターで読み解く物質の階層構造」

キックオフシンポジウム



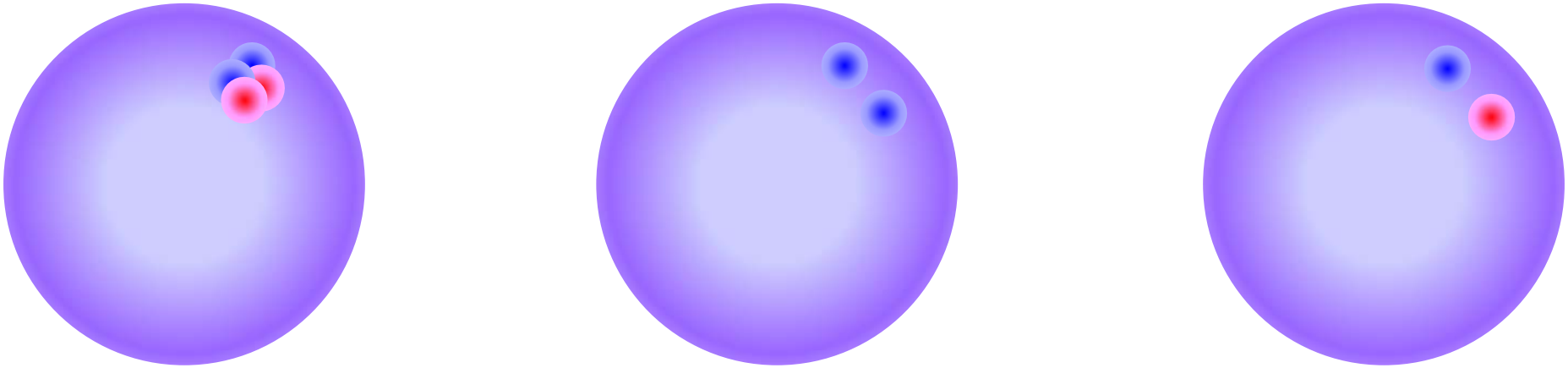
Kazuyuki Ogata

RCNP, Osaka University / Osaka City University

Clustering (spatial correlation) in nuclei

proton

neutron



α clustering

di-neutron pair

deuteron-like pair

Our purpose

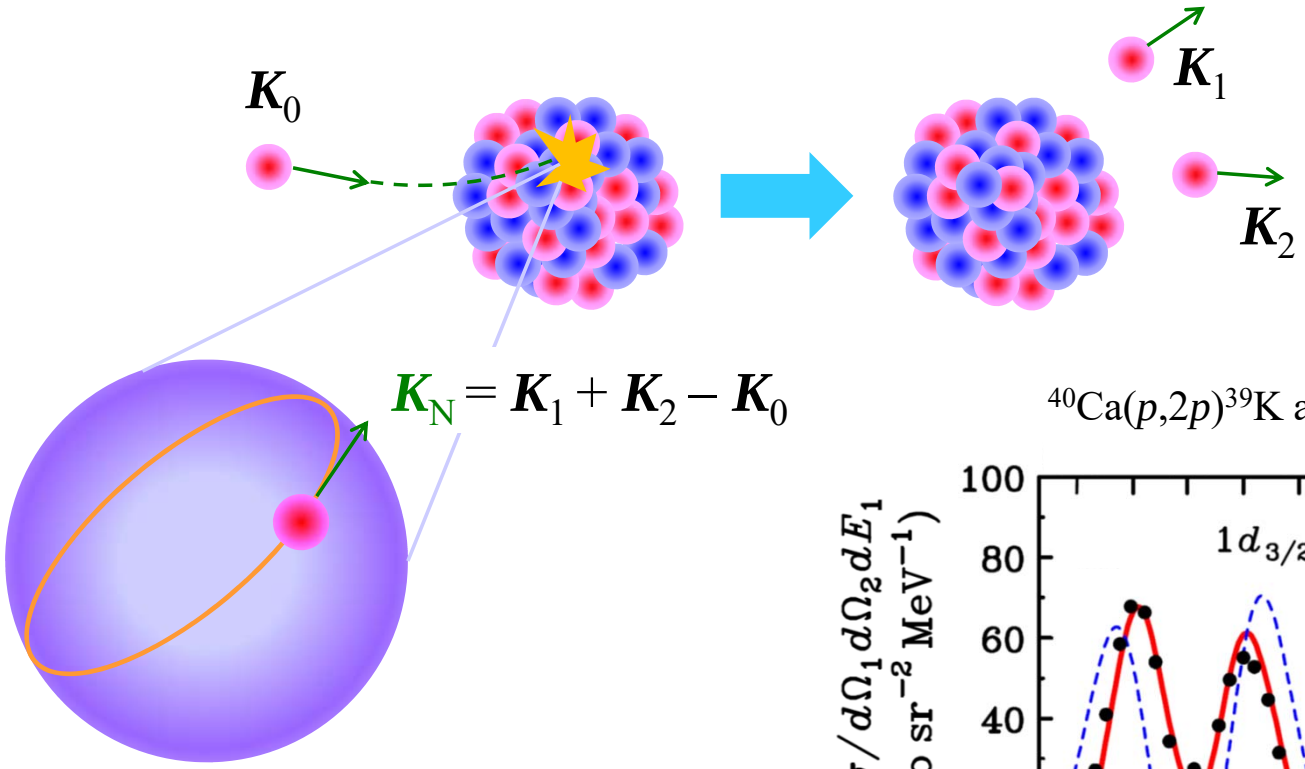
To “directly” probe these clustering structures via knockout reactions.

“Direct” means the relation between the observables and the clustering structure is transparent.

Knockout reaction

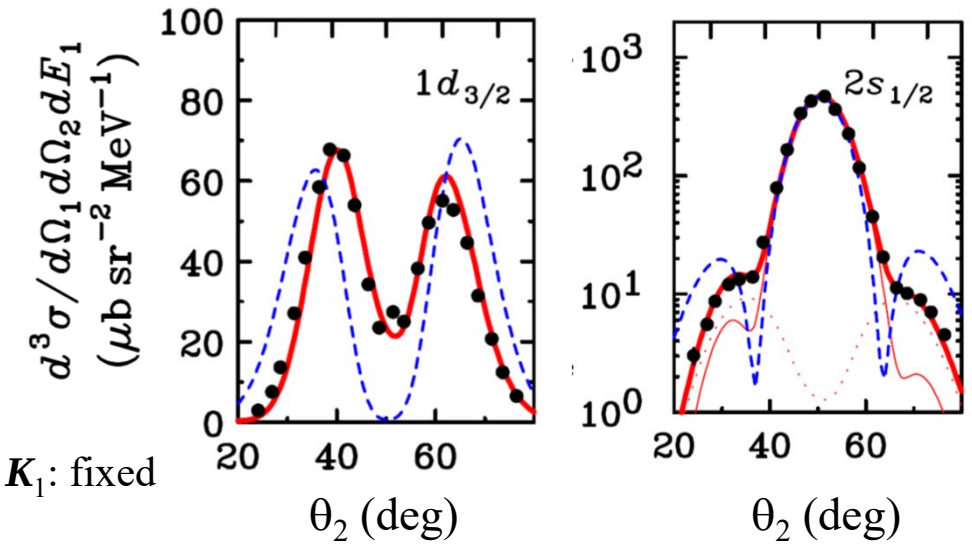
The (p,2p) reaction: a probe for s.p. structure

*T. Wakasa, KO, and T. Noro, PPNP**96**, 32 (2017).*



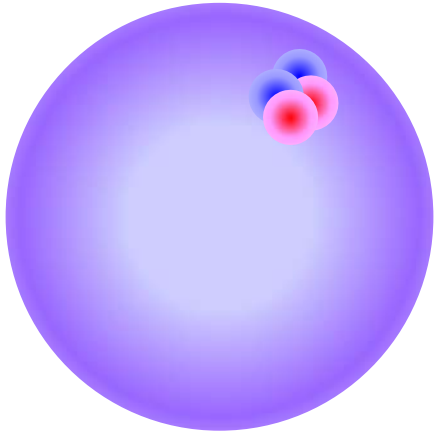
A "snapshot" of proton in a s.p. orbit in momentum space

^{40}Ca(p,2p)^{39}K at 392 MeV (RCNP data)

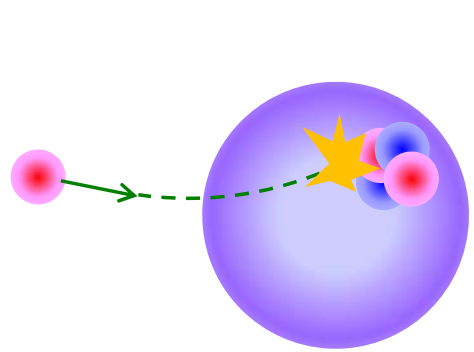


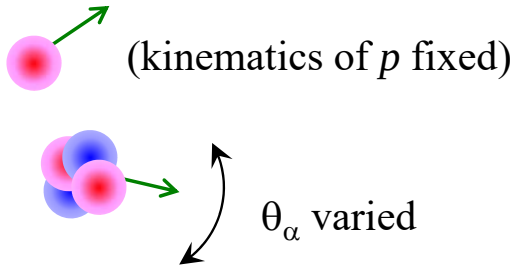
K_1: fixed

α clustering

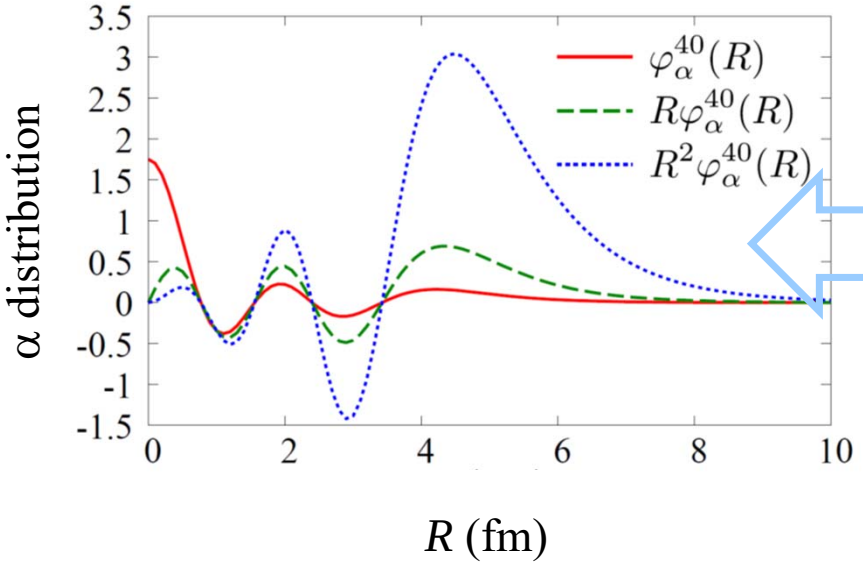


^{20}Ne(p,pα) at 392 MeV

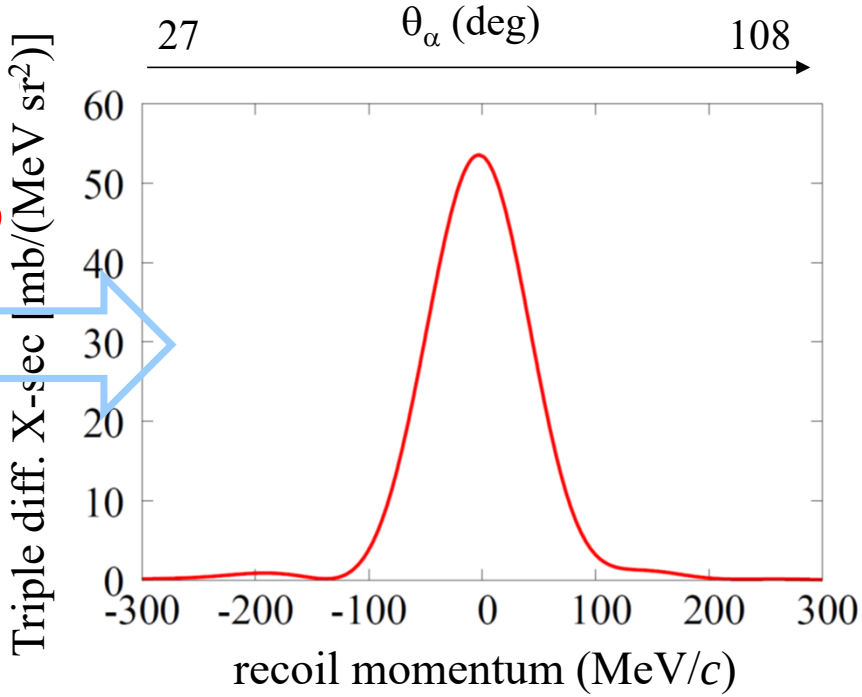




$$T = \langle \chi_{p,\boldsymbol{K}_1} \chi_{\alpha,\boldsymbol{K}_\alpha} \left| t_{p\alpha} \right| \chi_{p,\boldsymbol{K}_0} \varphi_\alpha \rangle$$

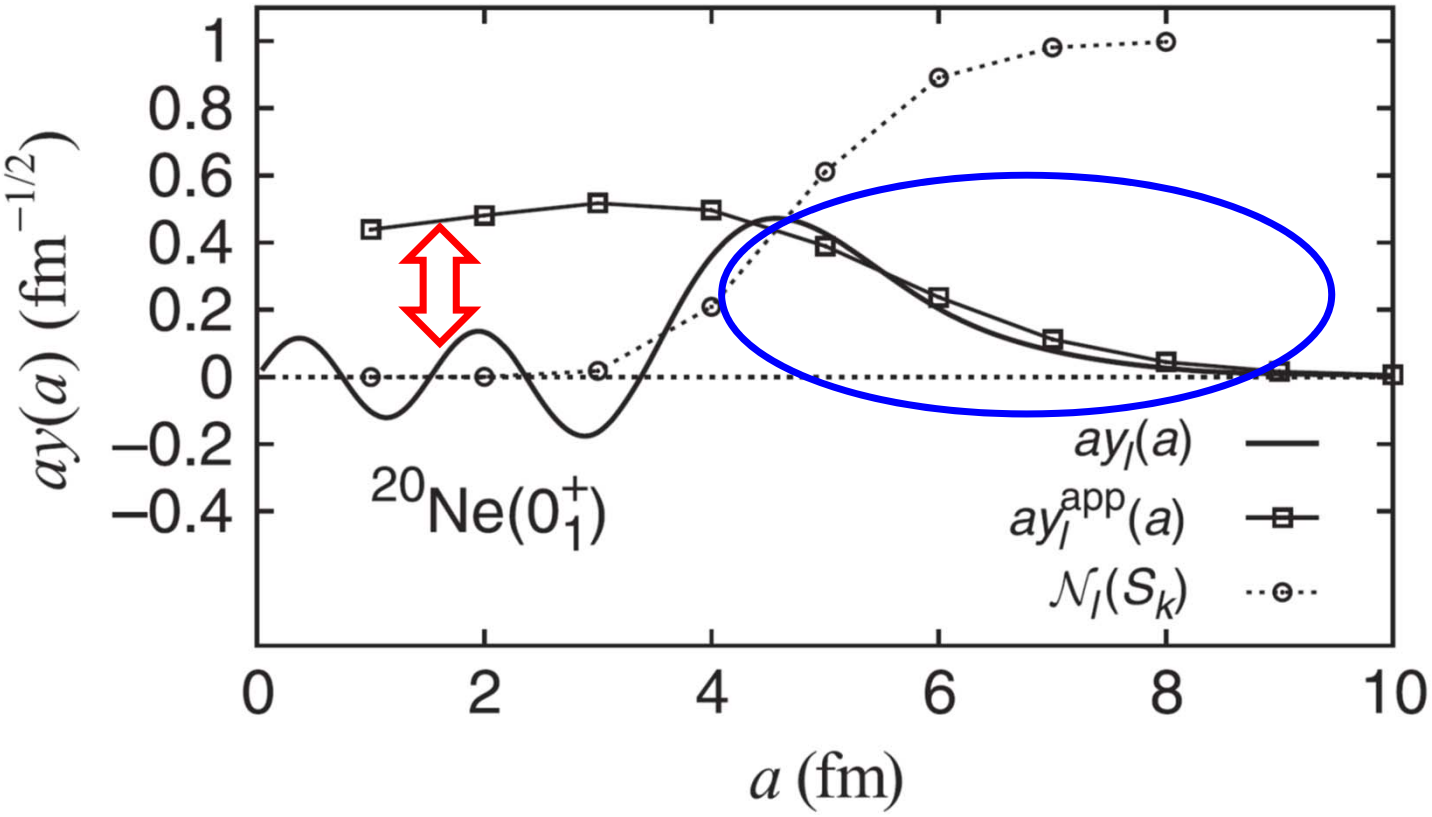


?



The surface α

*Y. Kanada-En'yo, T. Suhara, and Y. Taniguchi, PTEP **2014**, 073D02.*

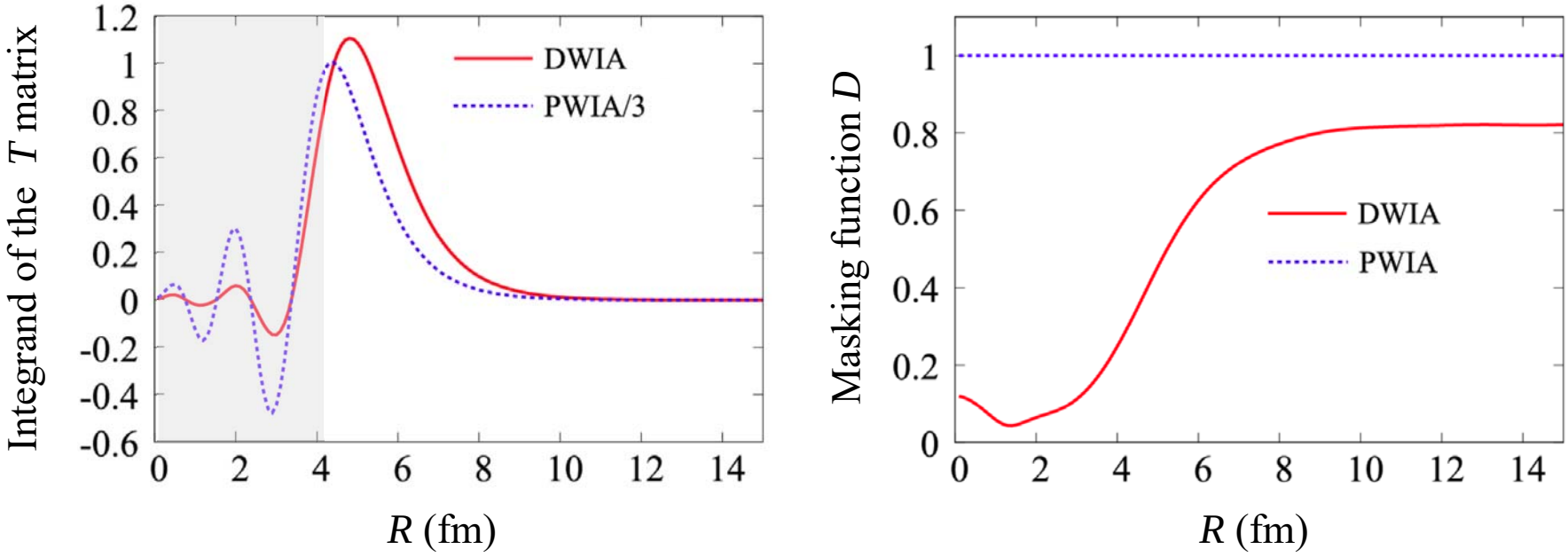


✓ The surface α amplitude, rather than S_α, will be the measure of the α clustering.

The masking function D(R) for ^{20}Ne(p,pα) at 392 MeV

$$T = \langle \chi_{p,\boldsymbol{K}_1} \chi_{\alpha,\boldsymbol{K}_\alpha} \left| t_{p\alpha} \right| \chi_{p,\boldsymbol{K}_0} \varphi_\alpha \rangle$$

$$D \equiv \chi^*_{p,\boldsymbol{K}_1} \chi^*_{\alpha,\boldsymbol{K}_\alpha} \chi_{p,\boldsymbol{K}_0}$$

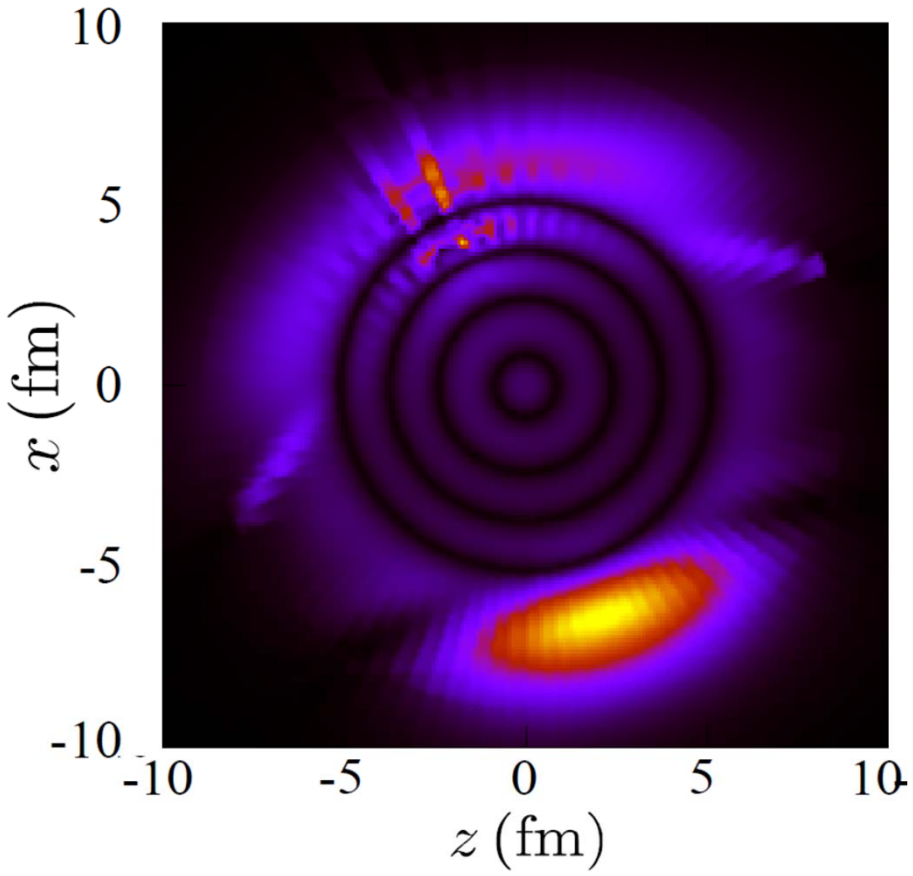


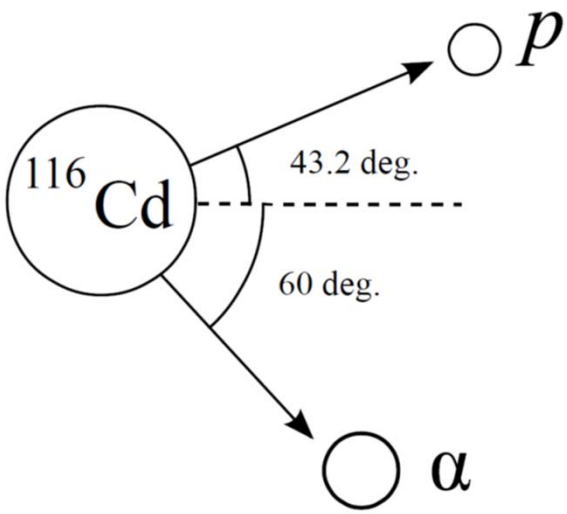
α-cluster WF multiplied by *D*, i.e., the surface a distribution, is probed.

- ✓ The nuclear interior region is masked, as desired.
- ✓ If you use S_α, you implicitly mention something on the nuclear interior region.

^{120}Sn(p,pα)^{116}Cd

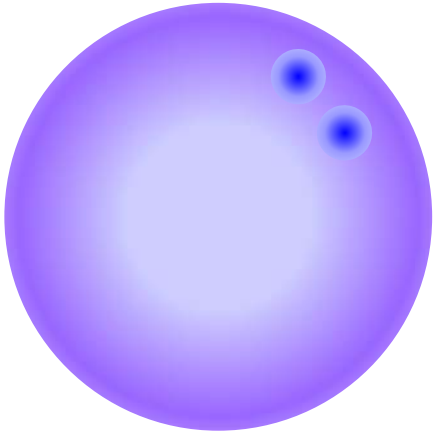
*K. Yoshida, K. Minomo, and KO, PRC **94**, 044604 (2016).*



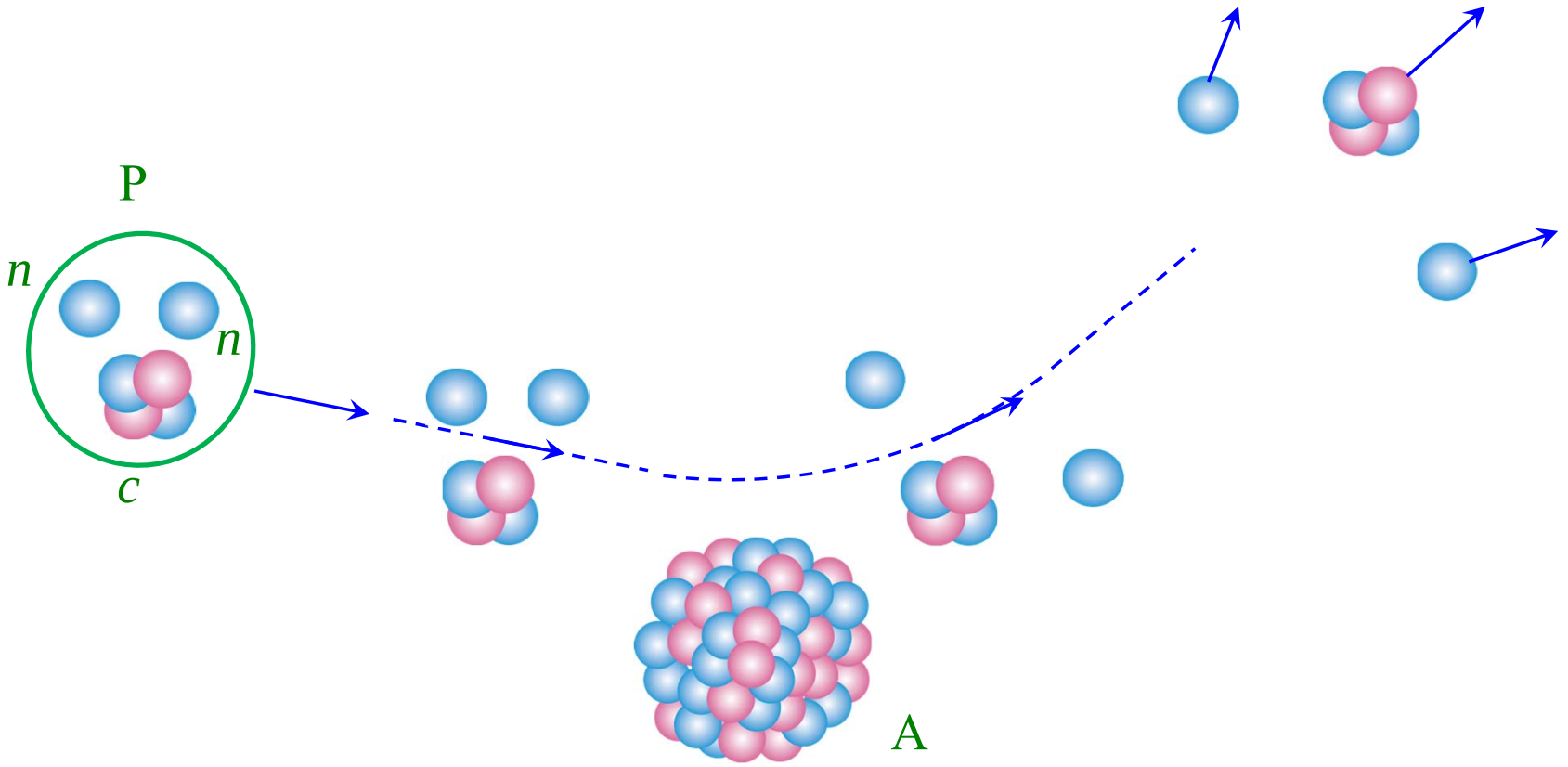


- (p,pα) has a strong selectivity for the position of α inside a nucleus.
- Experimental data measured at RCNP will appear soon.

di-neutron correlation



Breakup of a 2n halo nucleus

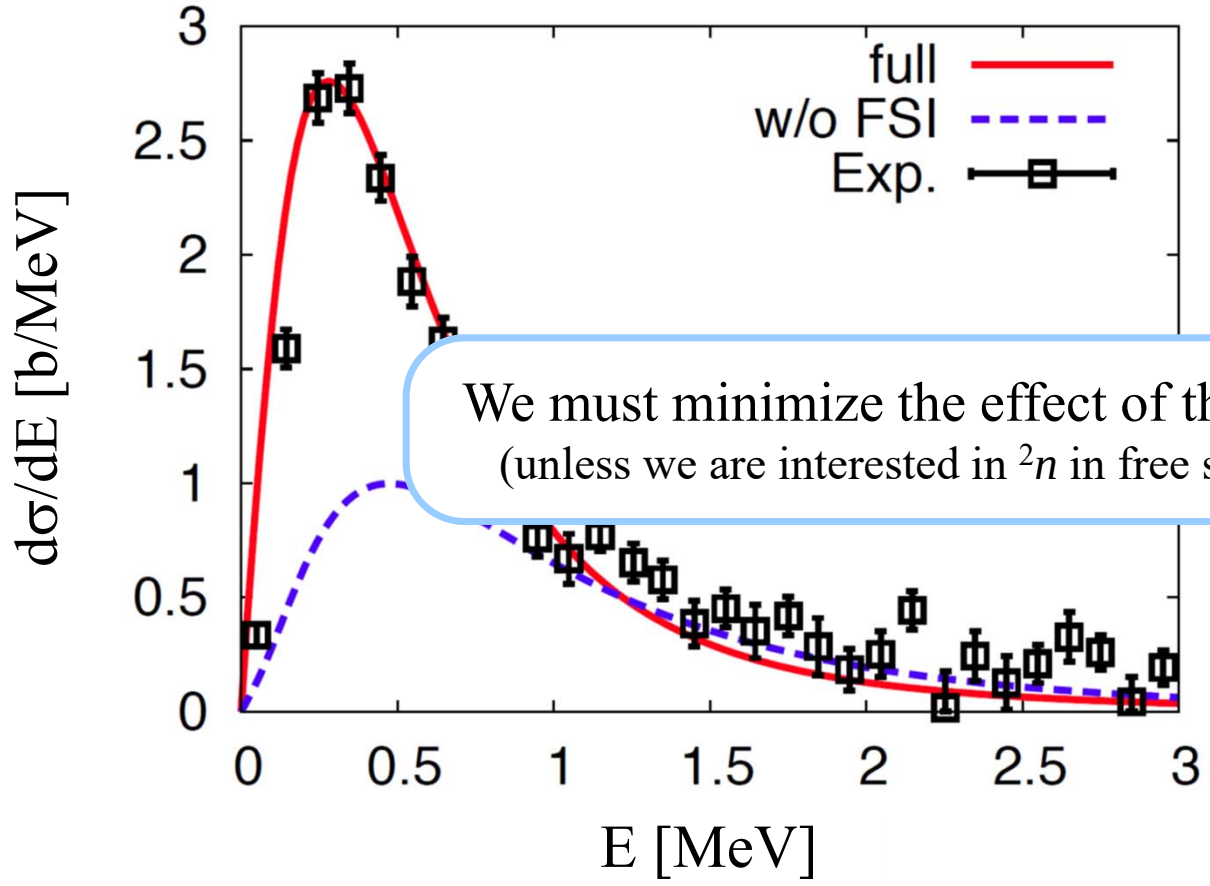


Can we probe the structure of P via breakup observables?

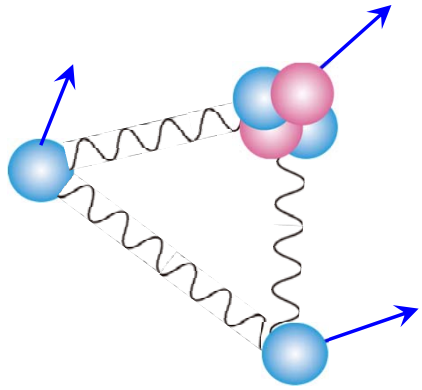
Our starting point

*Y. Kikuchi, T. Myo, K. Kato, and K. Ikeda, PRC **87**, 034606 (2013).*

Coulomb breakup cross section of ^{11}Li



We must minimize the effect of the FSI.
(unless we are interested in ^2n in free space)



These fragments interact each other after breakup

||

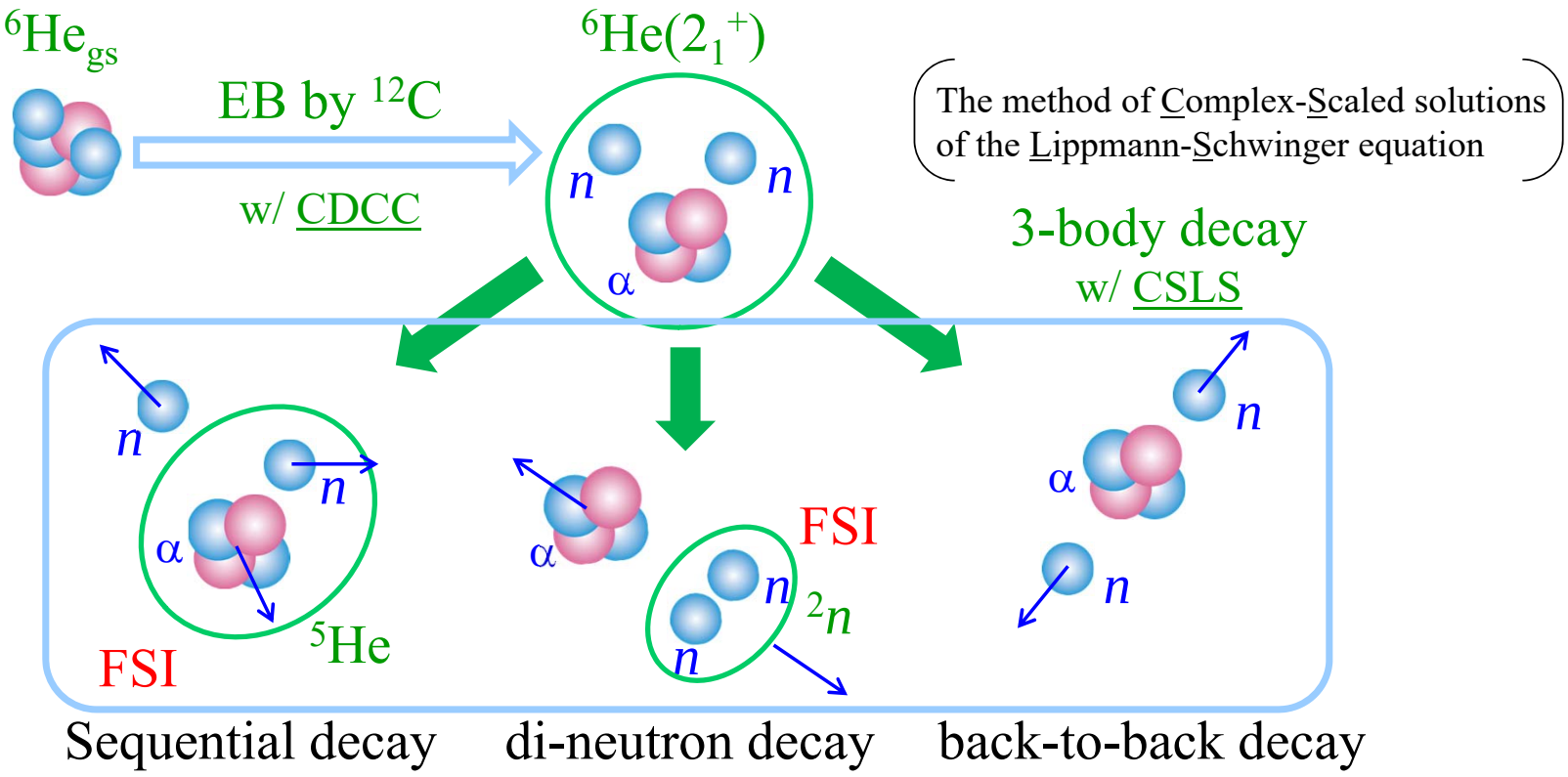
Final State Interaction (FSI)

Note: E1 sum rule is free from the FSI.

Decay mode of the 2_1^+ state of ^{6}He

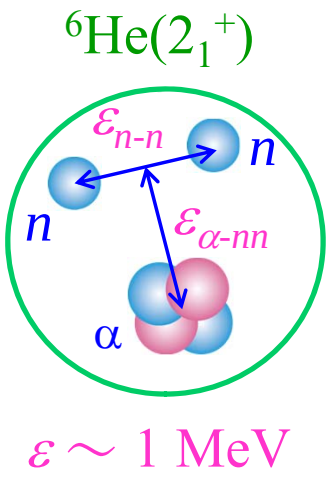
Dynamical description of both formation and decay of the 2_1^+ state of ^{6}He

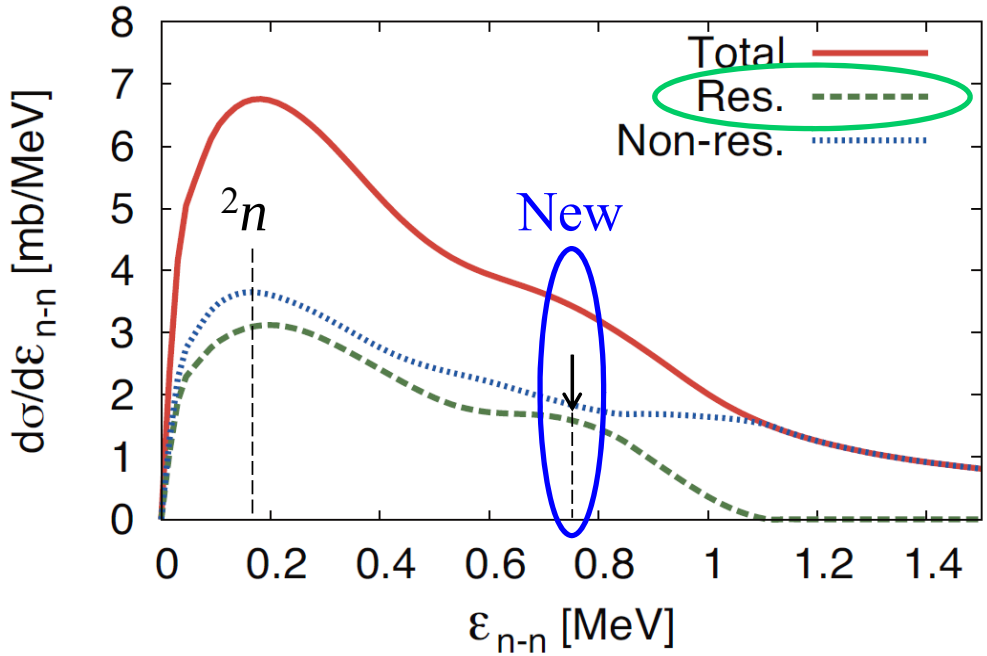
Y. Kikuchi, Matsumoto, Minomo, O, PRC **88**, 021602 (2013).



Di-neutron in the 2_1^+ of ^{6}He

Y. Kikuchi, Matsumoto, Minomo, O, PRC **88**, 021602 (2013).



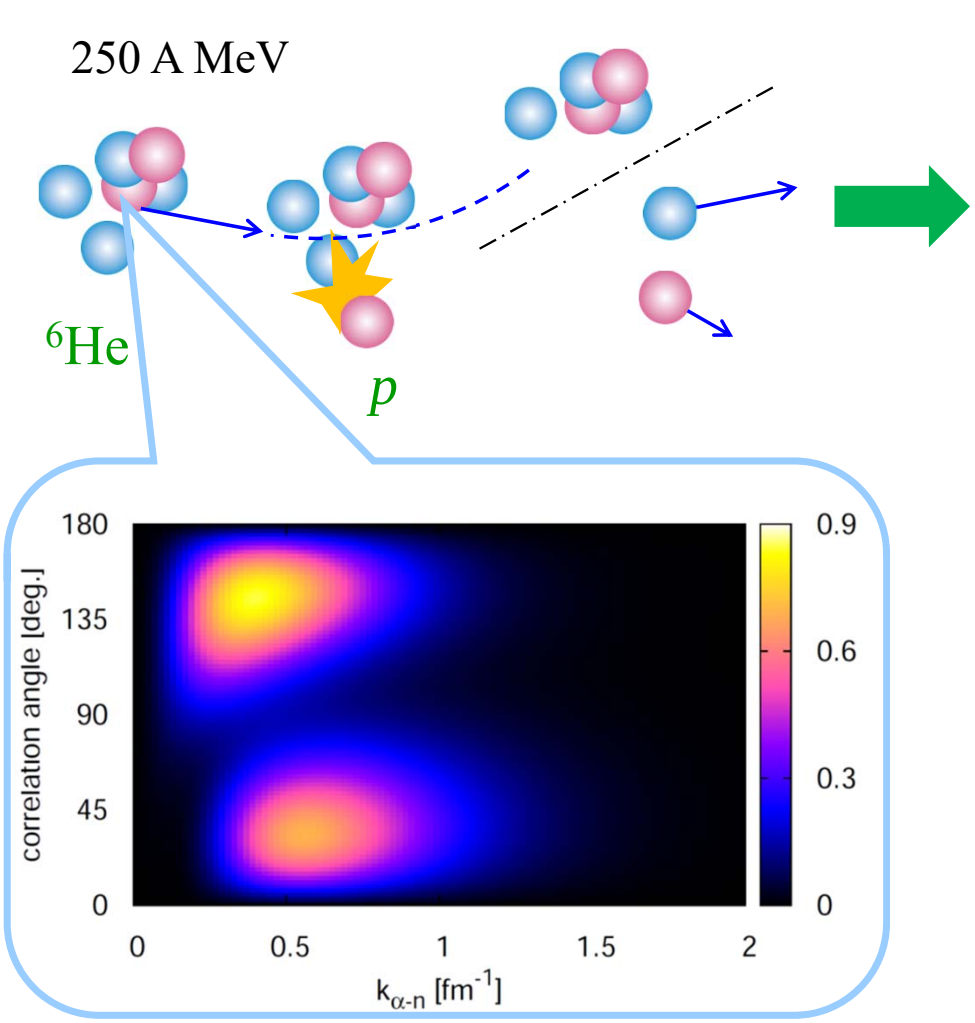


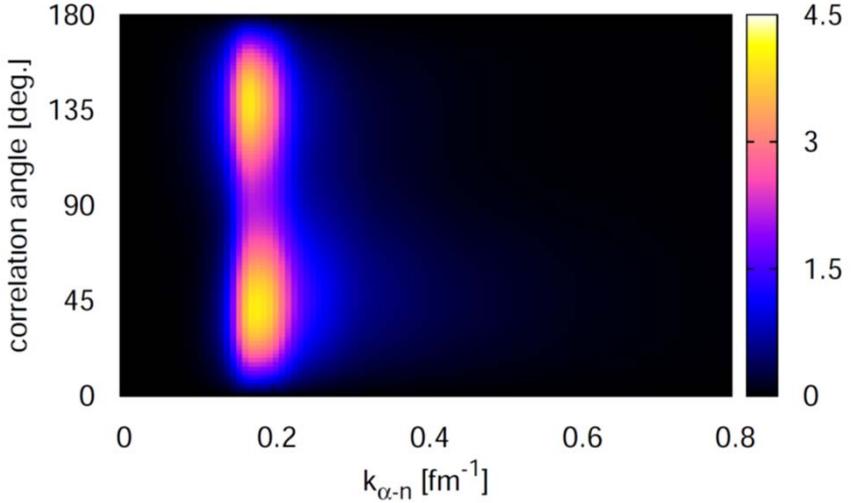
- ✓ The peak at lower $\varepsilon_{n\text{-}n}$ suggests the di-neutron decay due to the Fin. State Int. (FSI).
- ✓ The peak at higher $\varepsilon_{n\text{-}n}$ peak indicates the back-to-back decay.

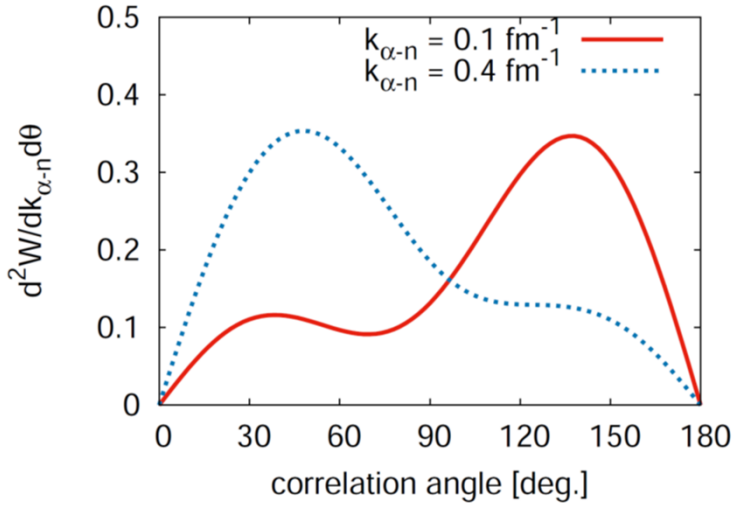
➡ Decay of a di-neutron in the 2_1^+ state not due to the FSI.

Proving ^{2}n correlation in ^{6}He via (p,pn) process

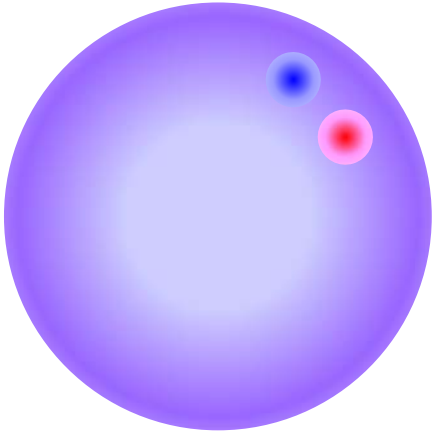
Y. Kikuchi, KO, Y. Kubota, M. Sasano, and T. Uesaka, PTEP ***2016****, 103D03 (2016).*





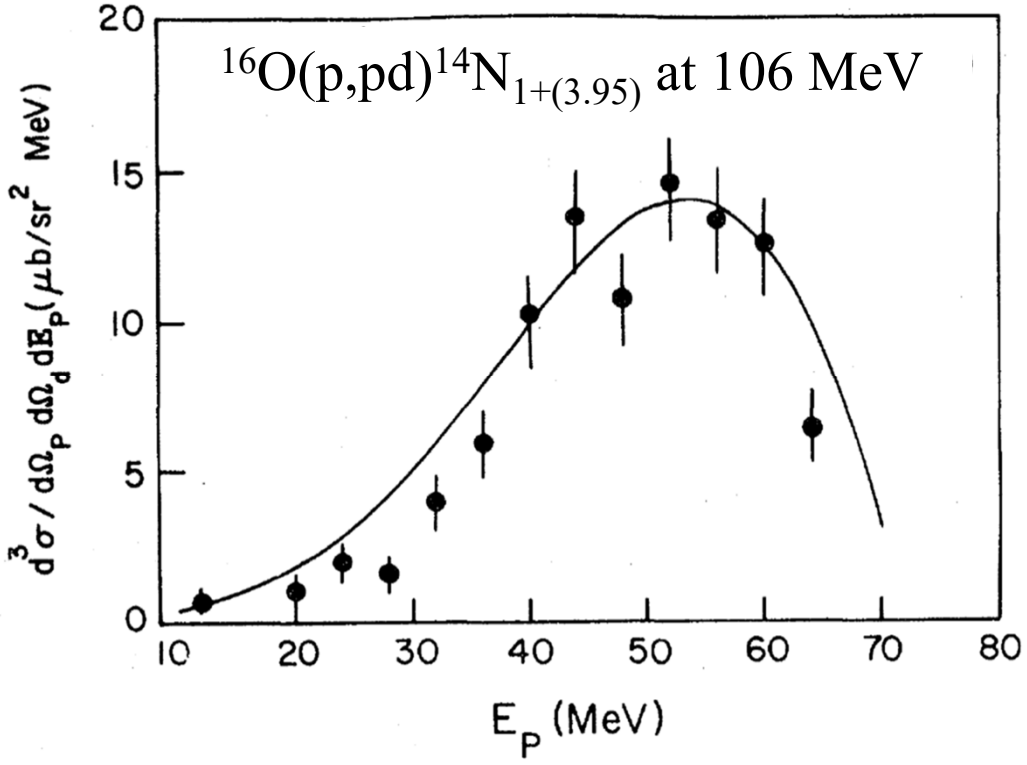


deuteron-like correlation

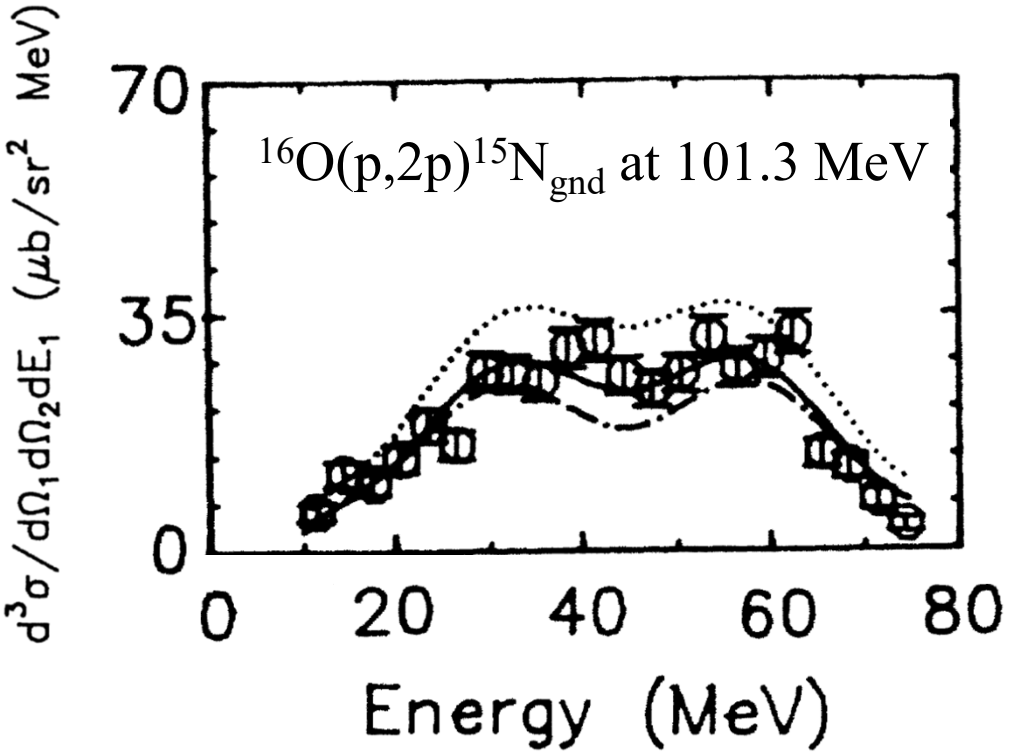


Experimental fact

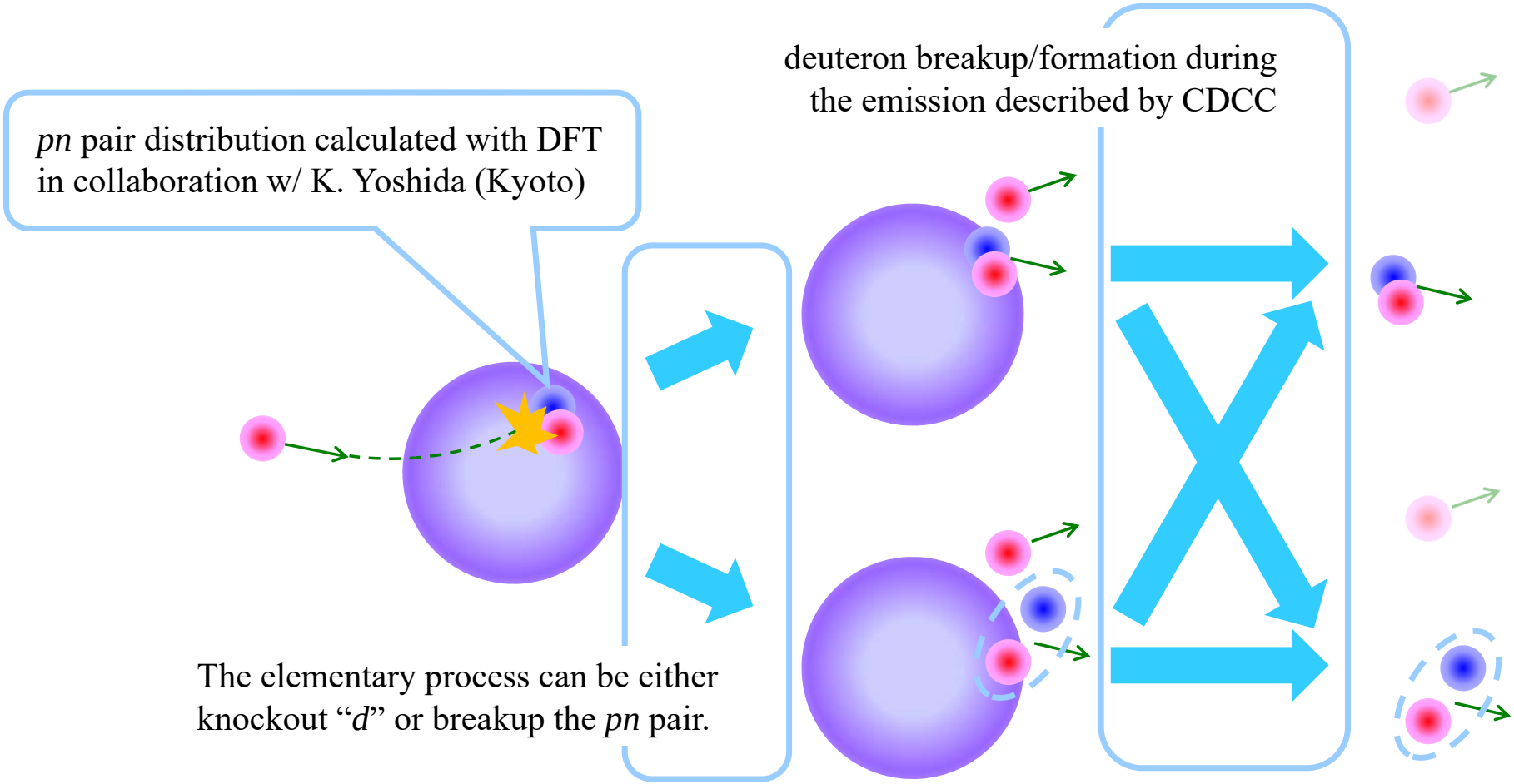
*C. Samanta+, RRC **26**, 1379 (1982).*



*C. Samanta+, RRC **34**, 1610 (1986).*

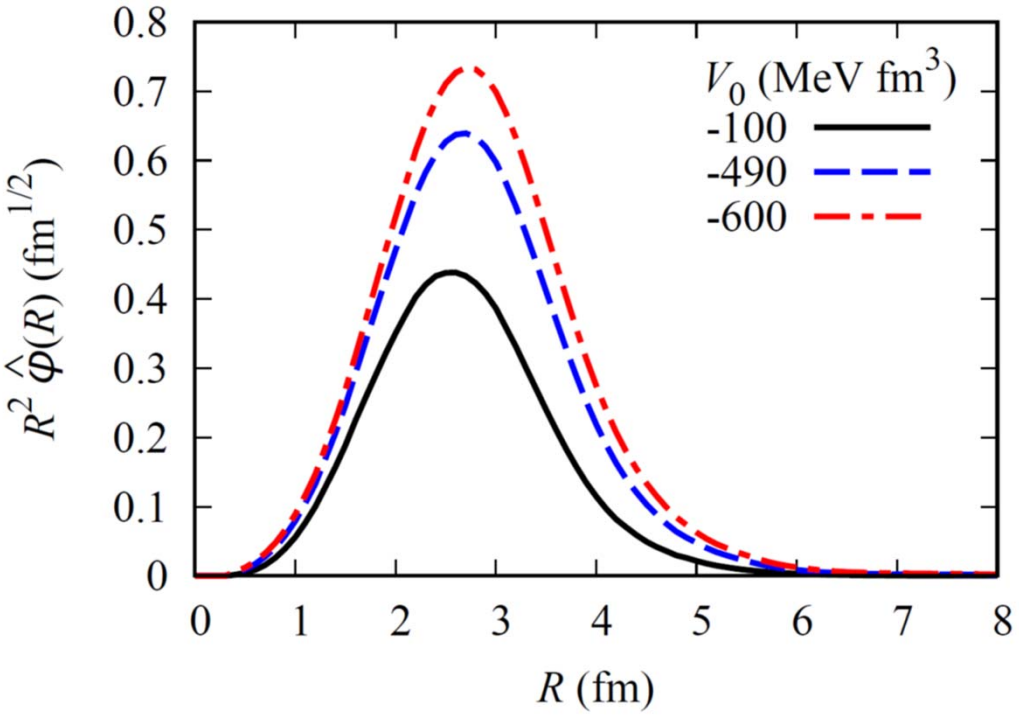


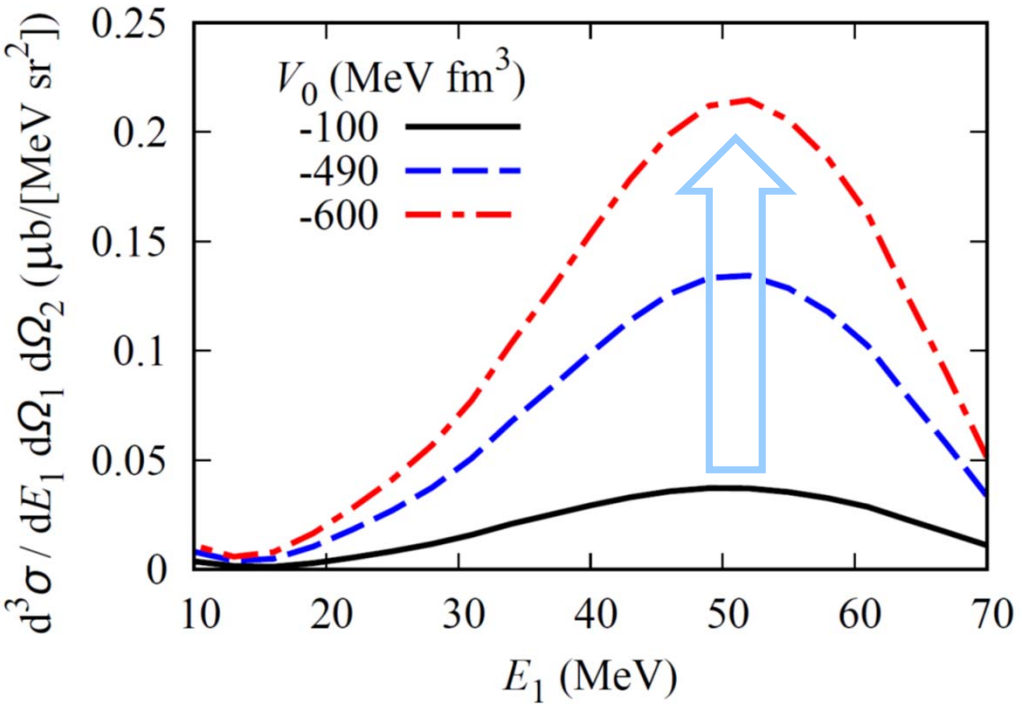
Possible next step: pn (d-like) correlation



Pairing strength vs. TDX

Y. Chazono, K. Yoshida, K. Yoshida, and KO, in preparation.

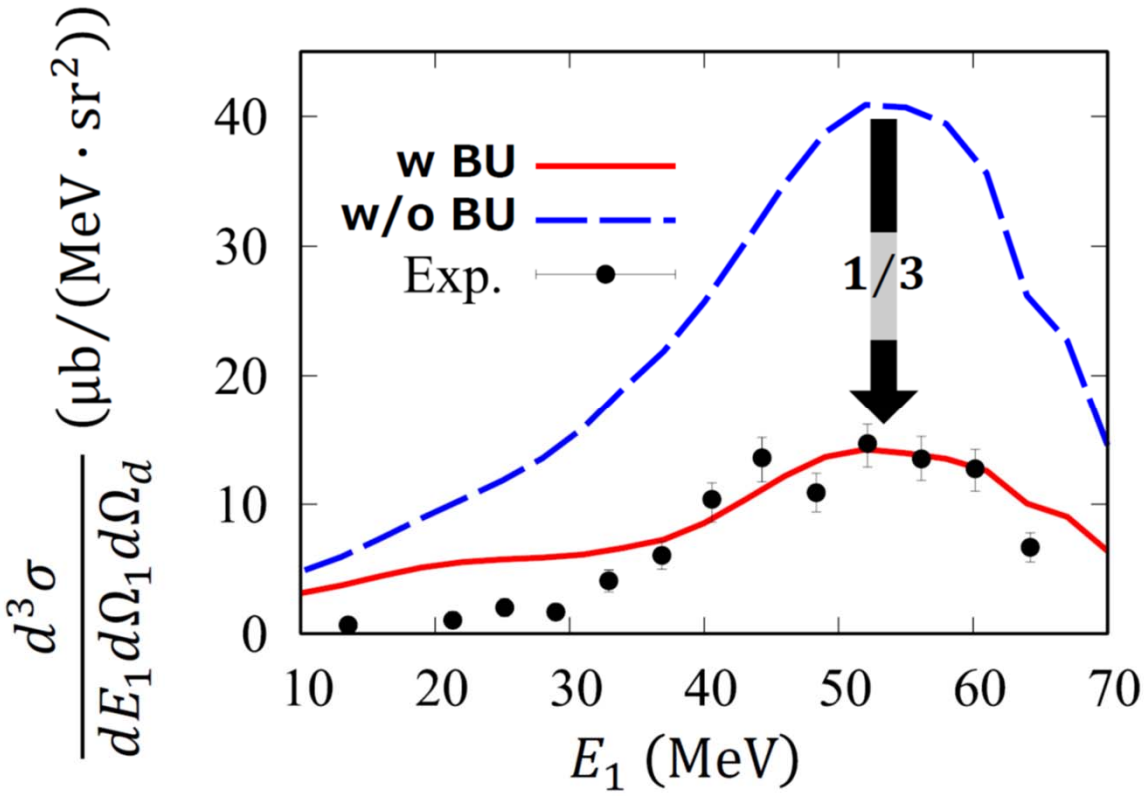




- The peak height of the TDX clearly reflects the *pn* pairing strength.
- The deuteron breakup is neglected.
- The elementary process is assumed to be the *pd* elastic scattering.

Breakup effect of the emitted deuteron

Y. Chazono, K. Yoshida, and KO, in preparation.



- The deuteron breakup effect is very large.
- A naïve *pn* single-particle wave function is adopted.
- The elementary process is assumed to be the *pd* elastic scattering.

Summary

I. α cluster structure via (p,pα) [Yoshida$_{数}$, Lyu, Kanada-En'yo, Taniguchi, Chiba, Kimura]

- Not S_α but the surface α amplitude should be respected.
- (p,pa) has a strong selectivity of the position of a insude a nucleus
- New experimental data will appear soon.

II. di-neutron correlation [Kikuchi, Matsumoto, Uesaka]

- The most important thing is to minimize the effect of the final-state interaction.
- Back-to-back decay mode will be the signature of the ^2n in the 2_1^+ state of ^{6}He.
- (*p*,*pn*) reaction with high momentum transfer is suitable to probe the ^2n in the ground state of ^{6}He

III. deuteron-like correlation [Chazono, Yoshida$_{賢}$, Yoshida$_{数}$, Uesaka]

- (*p*,*pd*) reaction may be used as a probe.
- (*p*,*ppn*) can also be used.
- One should be careful for discussing such a fragile *pn* pair inside a nucleus.

IV. Other activities for probing α clustering

- α inelastic scattering [Chiba, Kimura, Sakuragi]
- α transfer [Fukui, Kanada-En'yo, Suhara, Taniguchi]