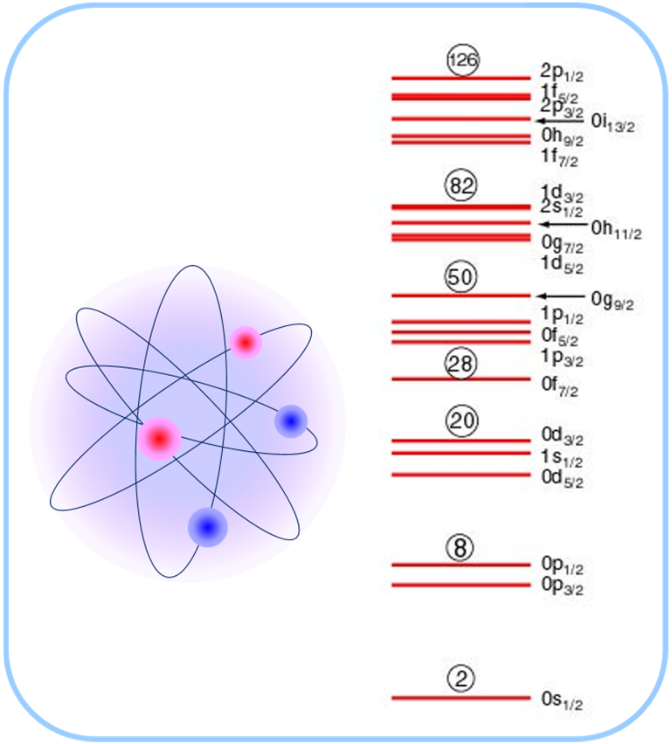
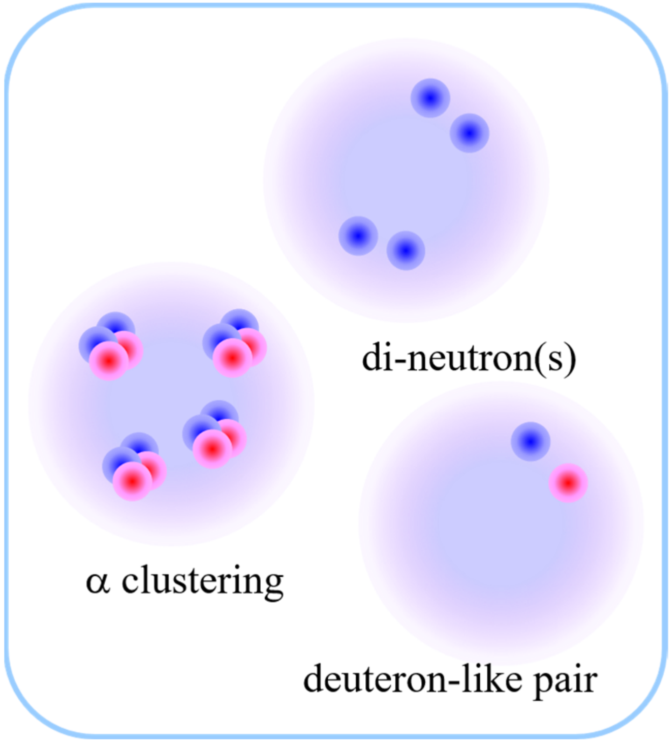
Some note on the correspondence between nuclear clustering and scattering observables

第5回クラスター階層領域研究会





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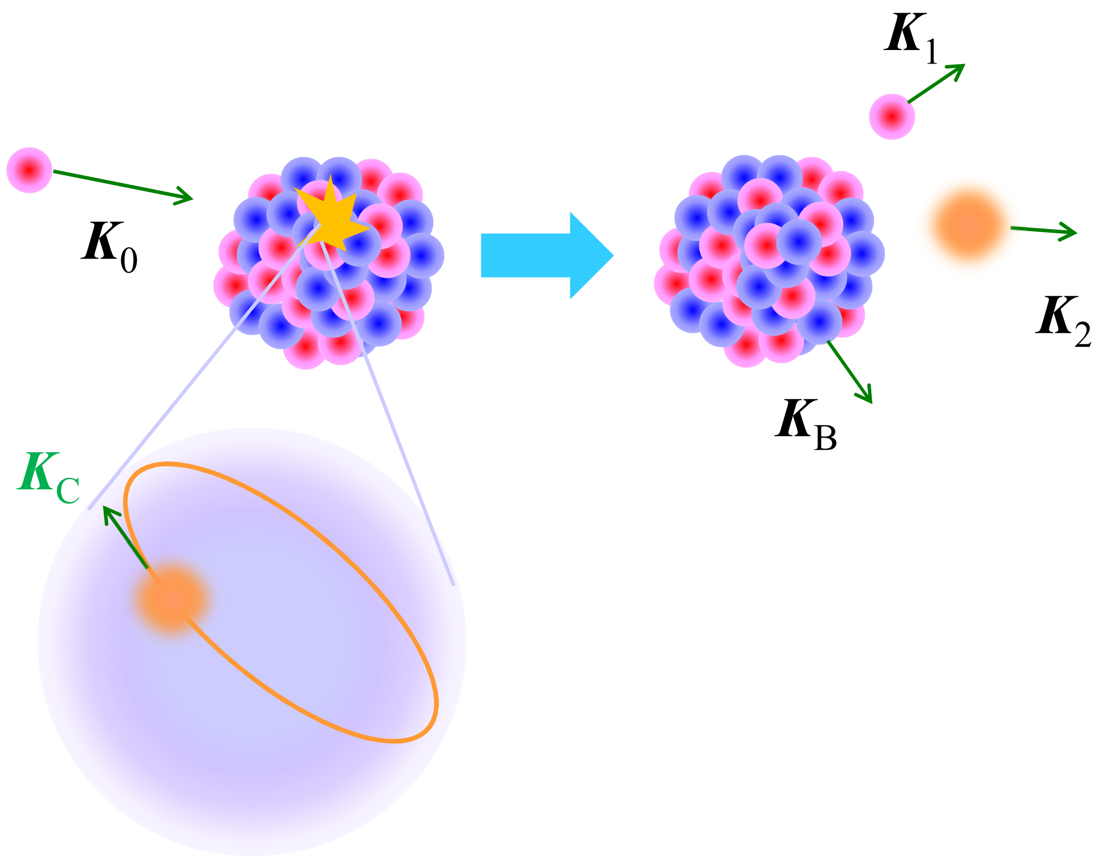
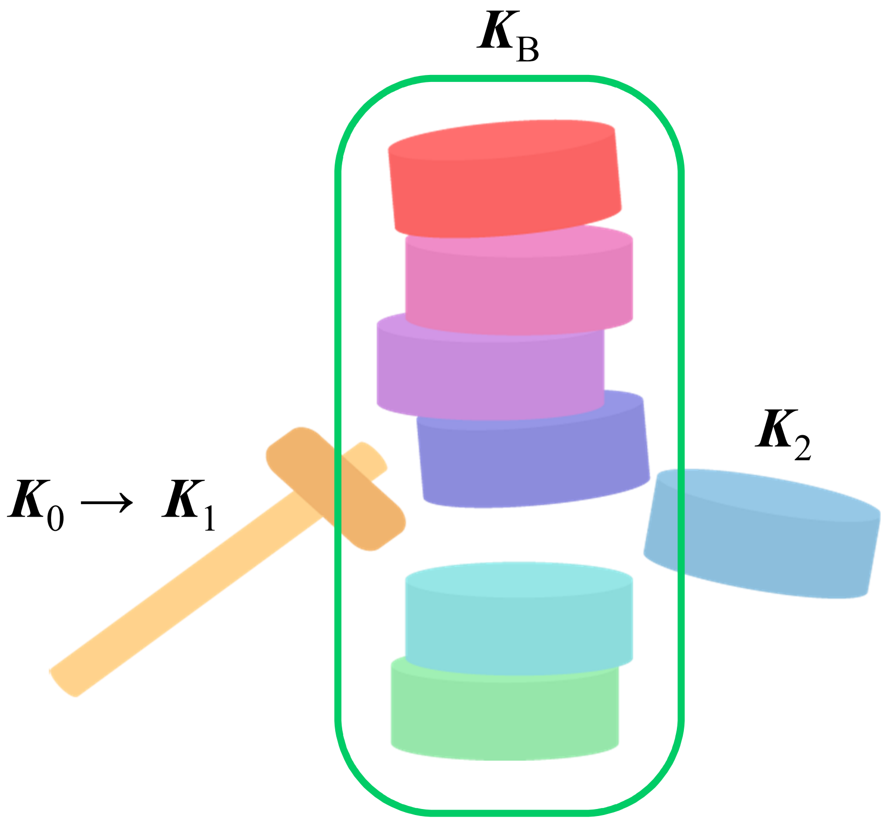
Knock it out!

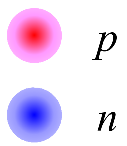


$K_C = K_1 + K_2 - K_0 = -K_B$
(Fermi motion)

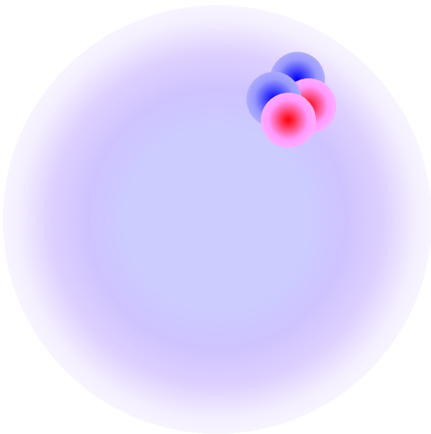


$K_C = 0$ in this toy.

Nuclear clustering

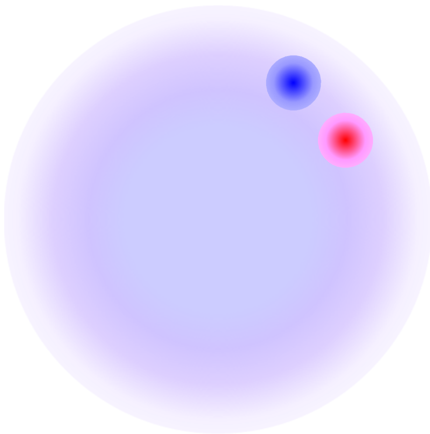


α, *d*, and ^{2}n in nuclei are of interest, not in free space.



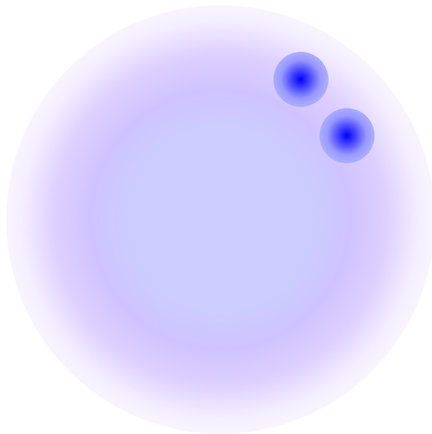
α clustering

- antisymmetrization effect on the α clustering picture



deuteron(-like) pair

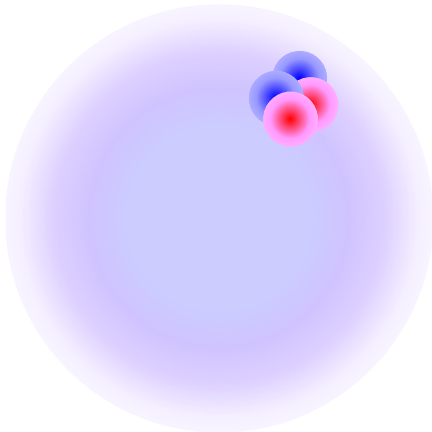
- fragileness of *d*
- breakup/reformation after emission



di-neutron pair

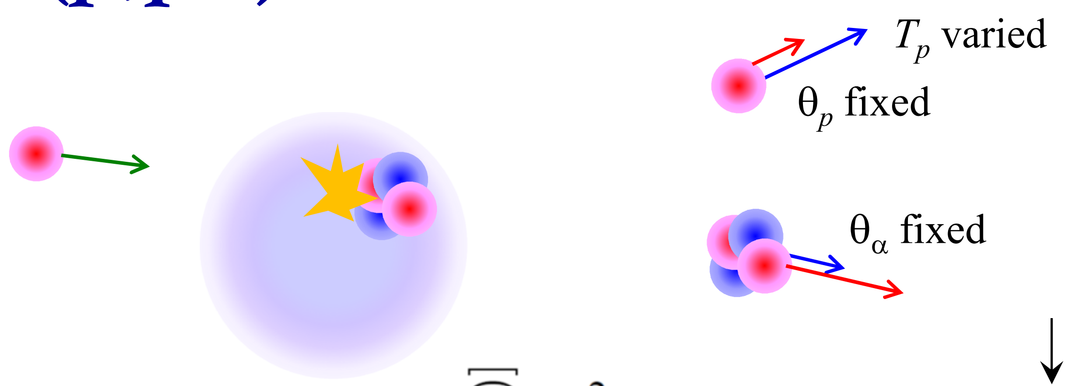
- not bound
- Final State Interaction (FSI)

α clustering

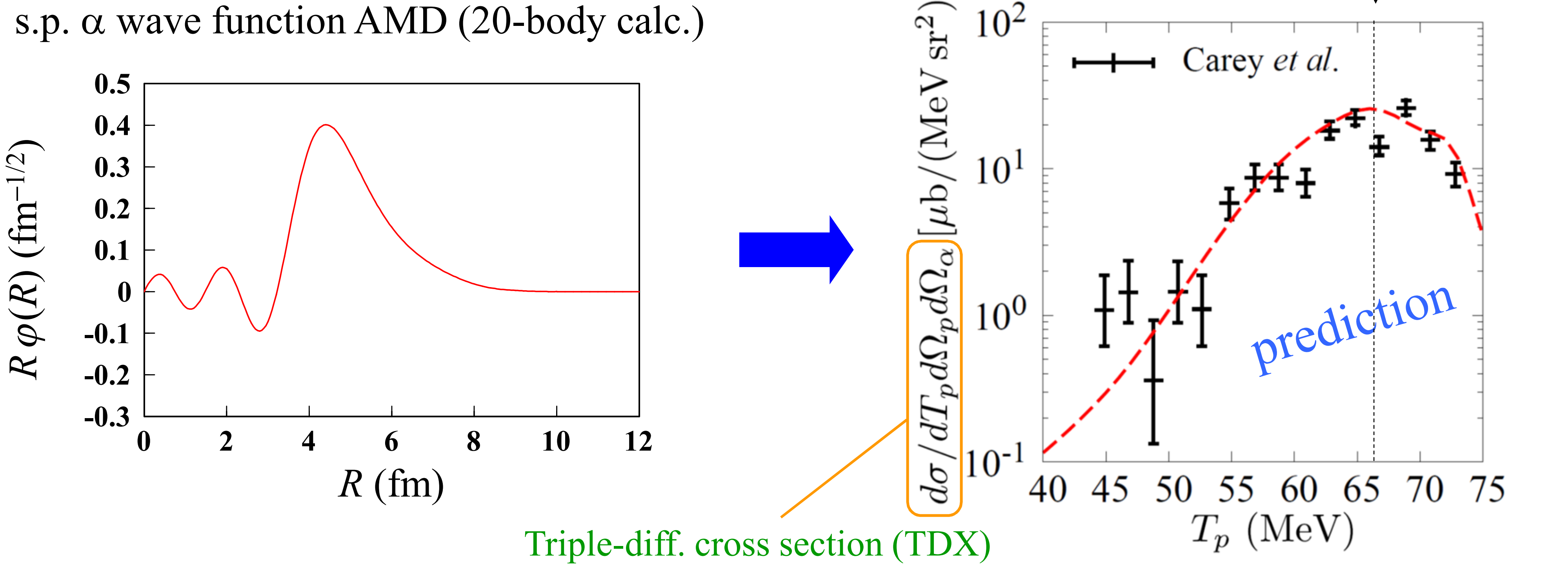


^{20}Ne(p,pα) at 101.5 MeV

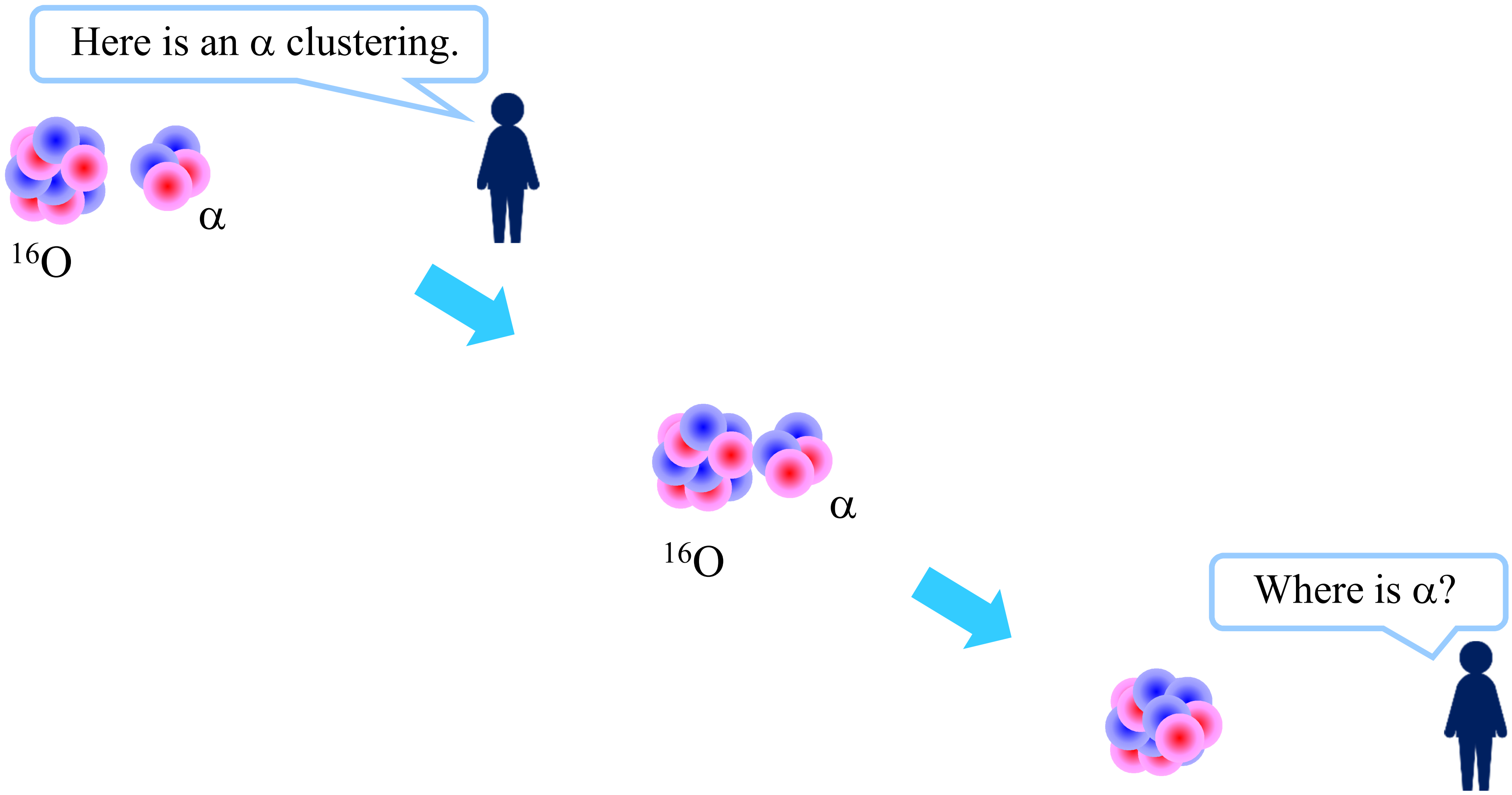
K. Yoshida+, PRC 100, 044601 (2019).



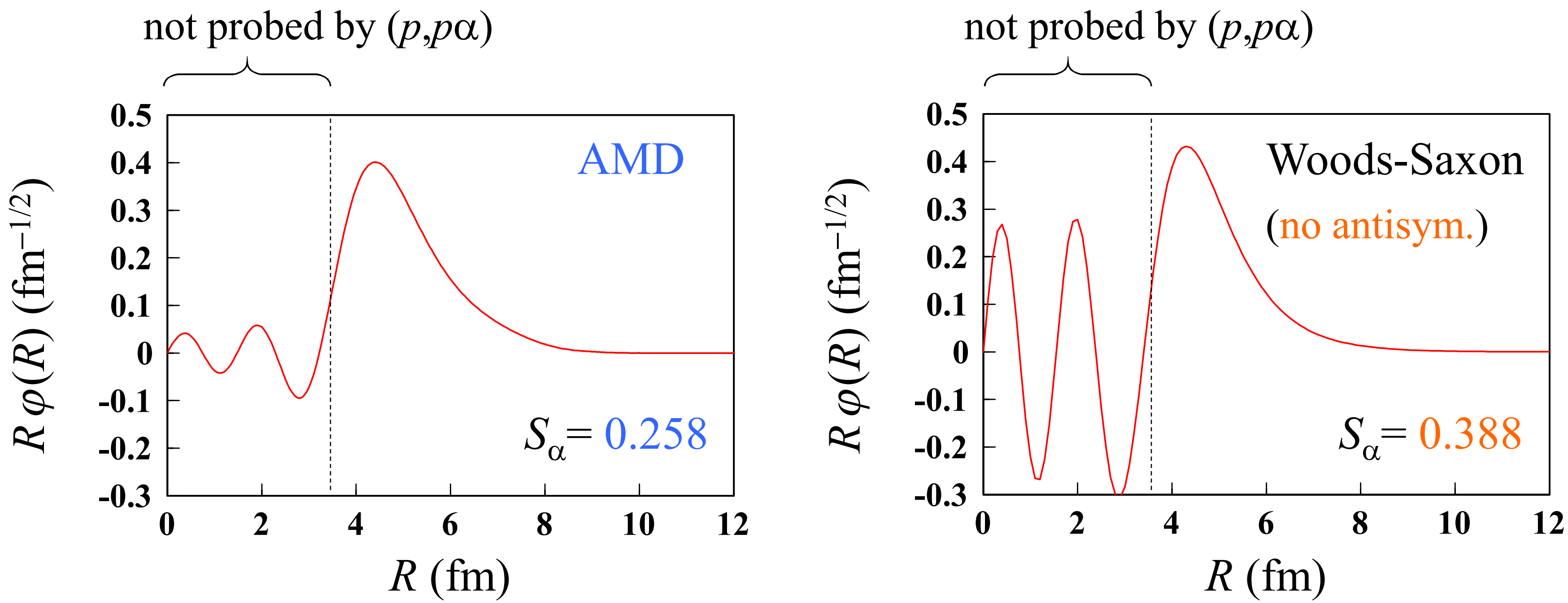
s.p. α wave function AMD (20-body calc.)



Clustering picture of identical particals



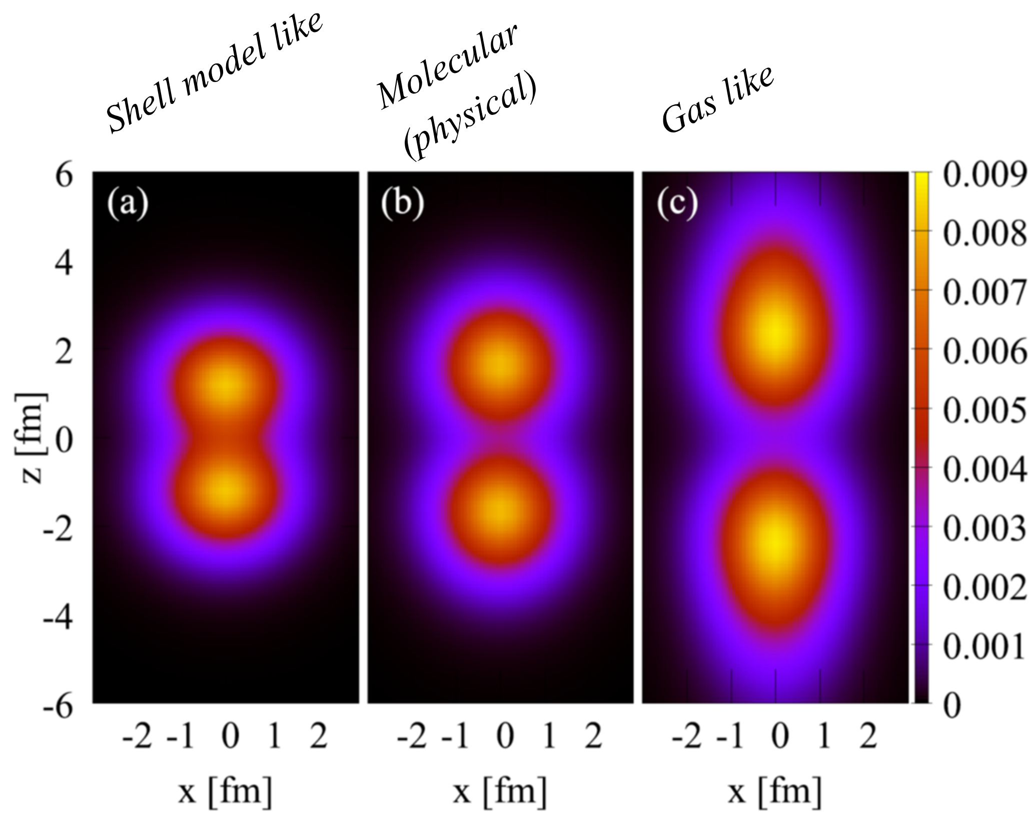
Antisymmetrization effect

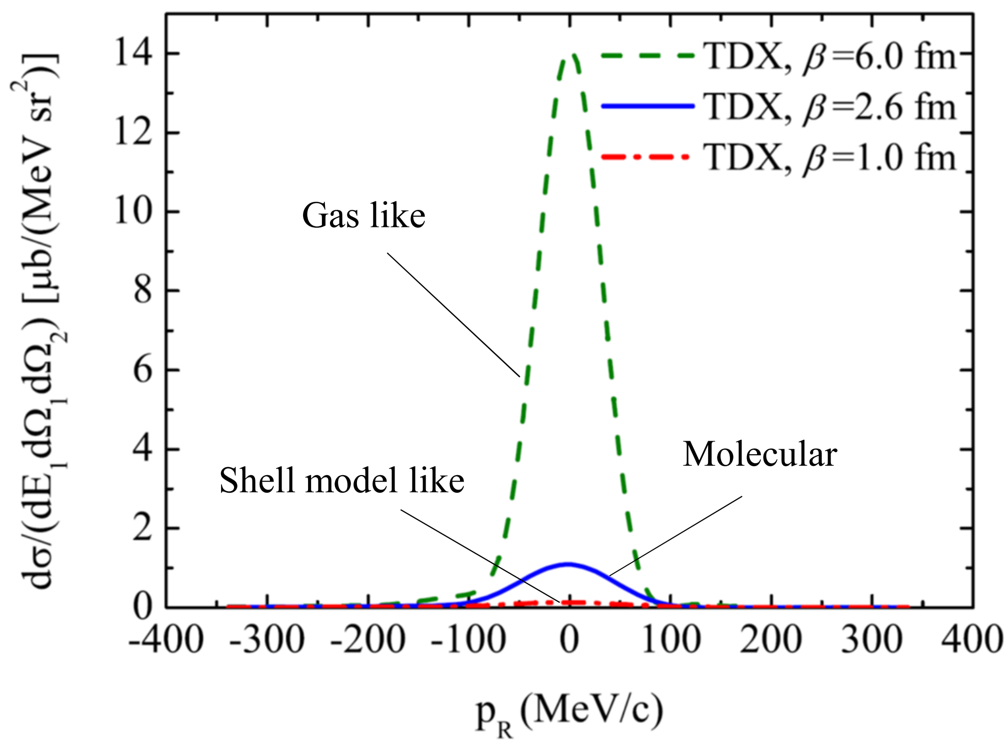


- Because of the absorption, only the surface region (R > 3.5 fm) is found to be probed.
- Using a WS model is ok when we just talk about the surface region (for α knockout).
- S_α (square norm of φ) is significantly (~50%) affected by the antisymmetrization.

$^{10}Be(p,p\alpha)^{6}He$ at 250 MeV

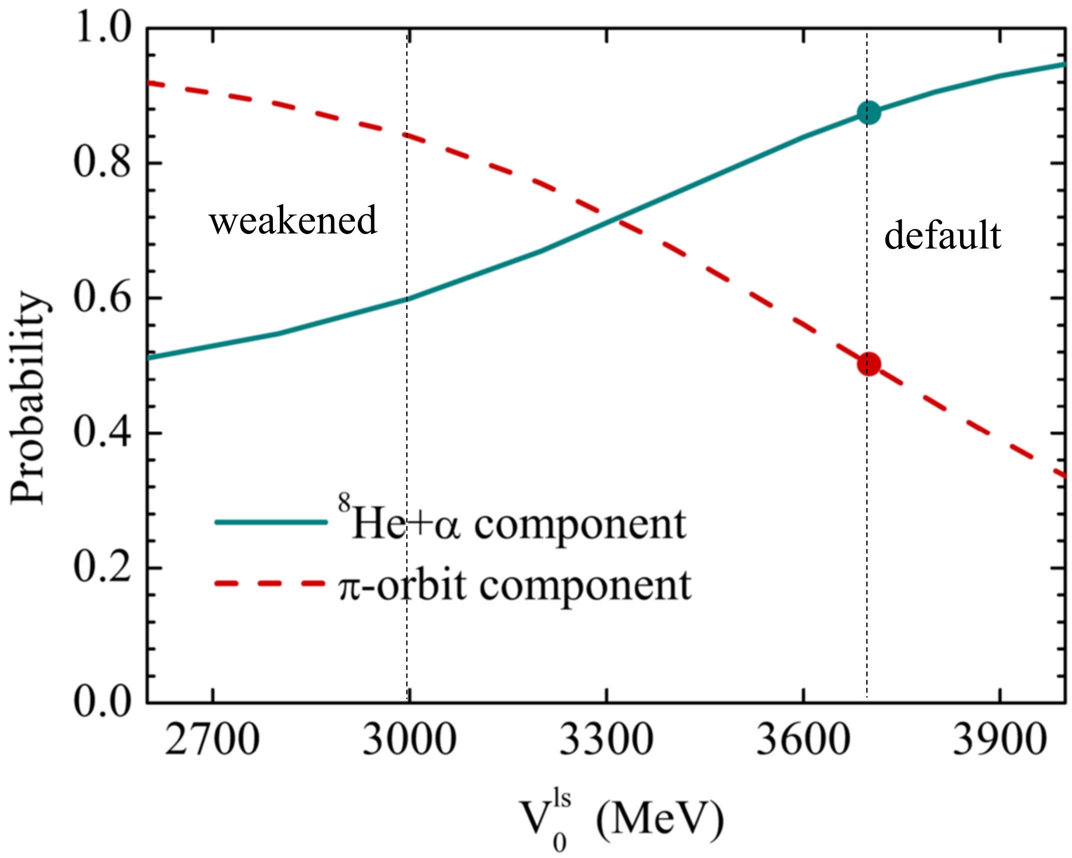
M. Lyu, K. Yoshida, Y. Kanada-En'yo, and KO, PRC 97, 044612 (2018).

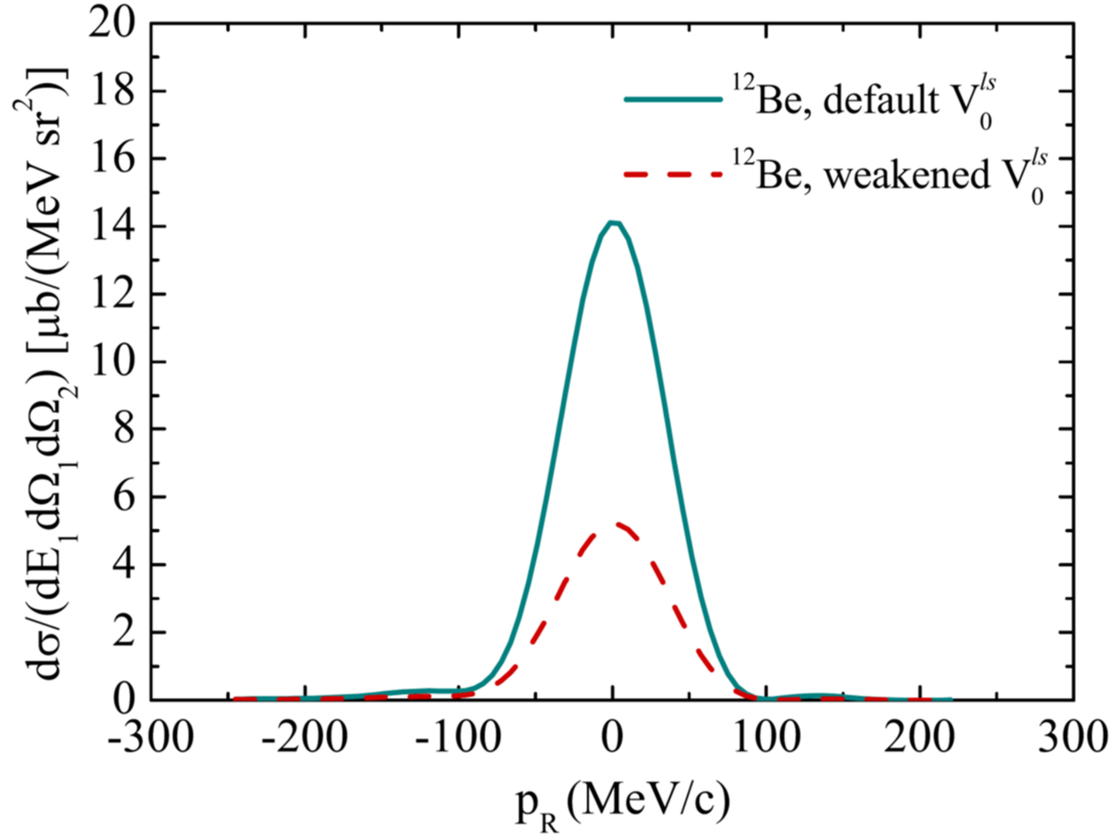




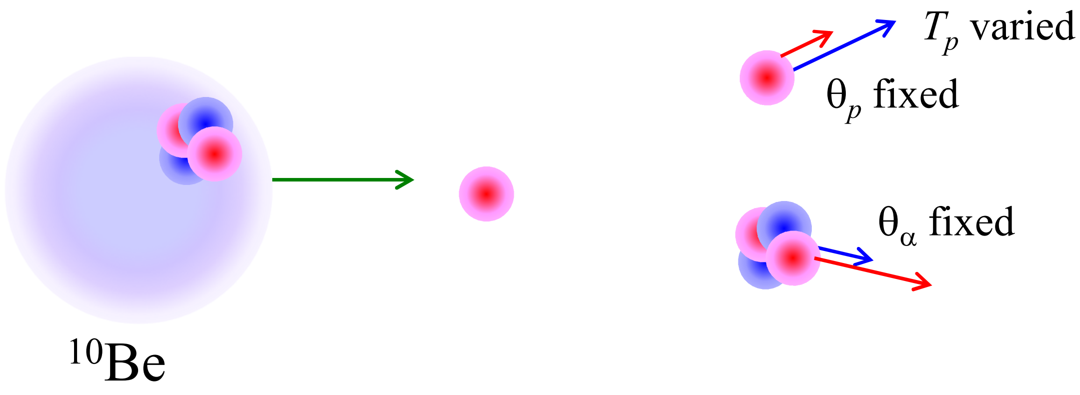
^{12}Be(p,pα)^{8}He at 250 MeV

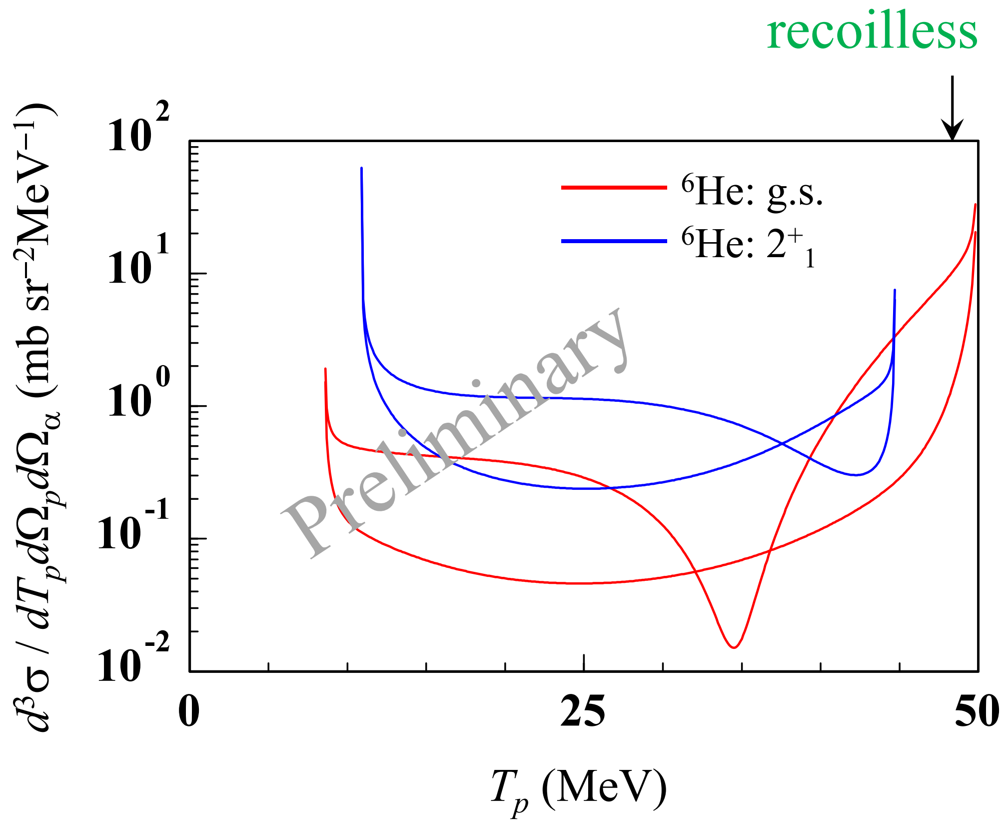
M. Lyu, K. Yoshida, Y. Kanada-En'yo, and KO, PRC 99, 064610 (2019).





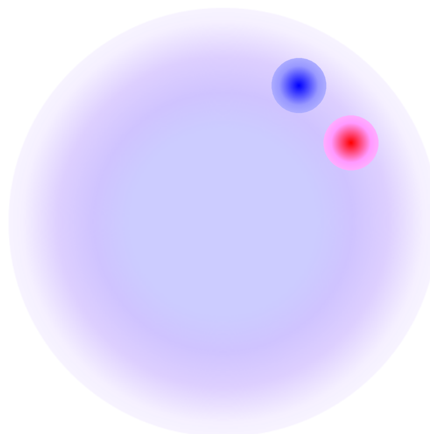
^{10}Be(p,pα)^{6}He in inverse kinematics





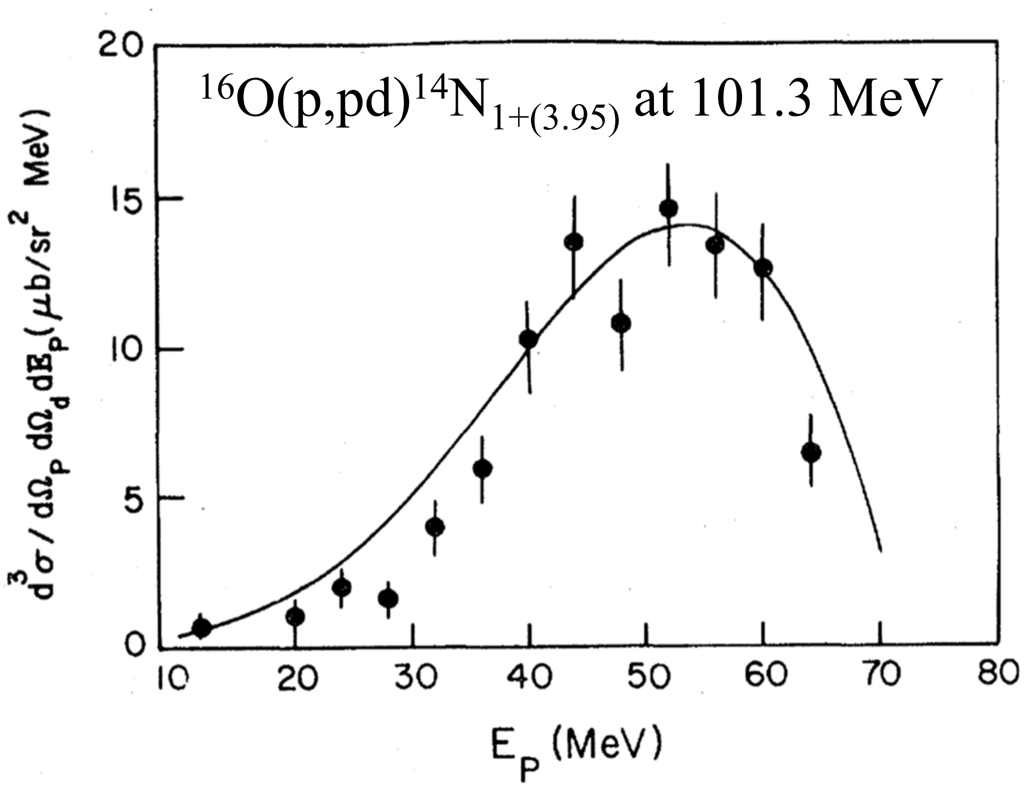
- Phase space determines the shape of the TDX.
- For each T_p, there are two solutions for the kinematics of the three particles.
- TDX in inverse kinematics will not be a good observable.

deuteron-like correlation

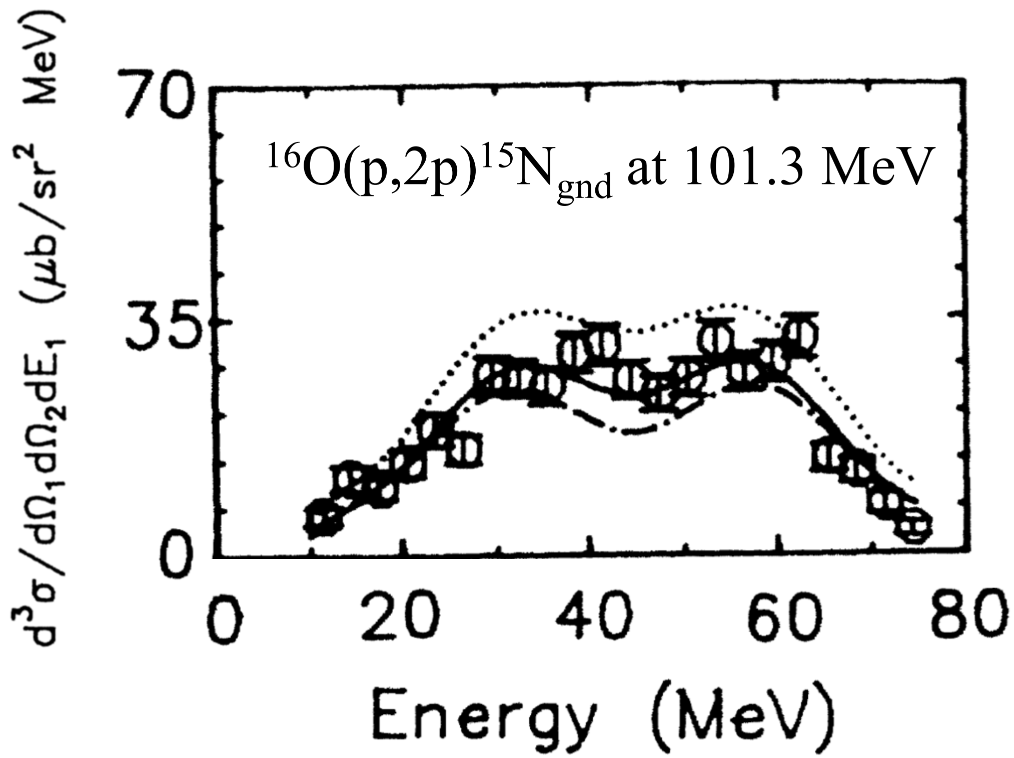


Experimental fact

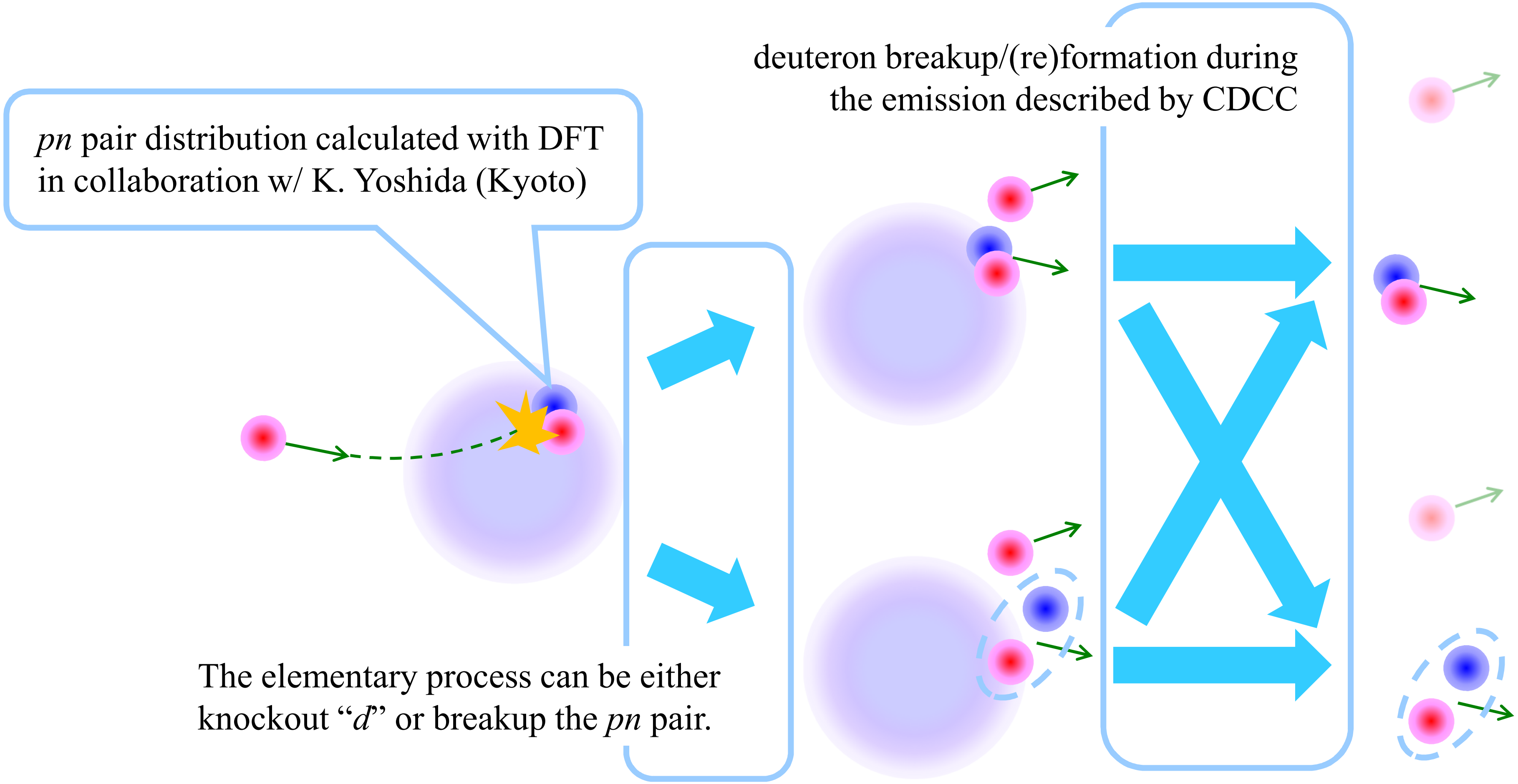
*C. Samanta+, RRC **26**, 1379 (1982).*



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

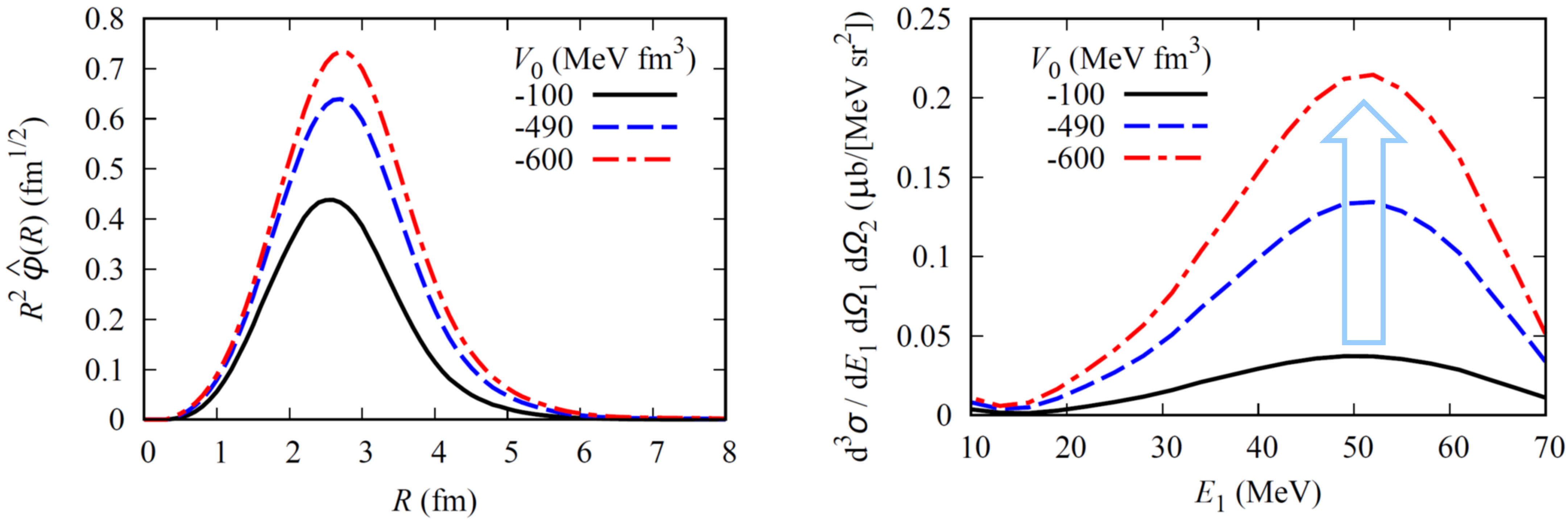


Remarks on the pn knockout



Pairing strength vs. TDX

Y. Chazono, K. Yoshida, K. Yoshida, and KO, arXiv:2007.06771

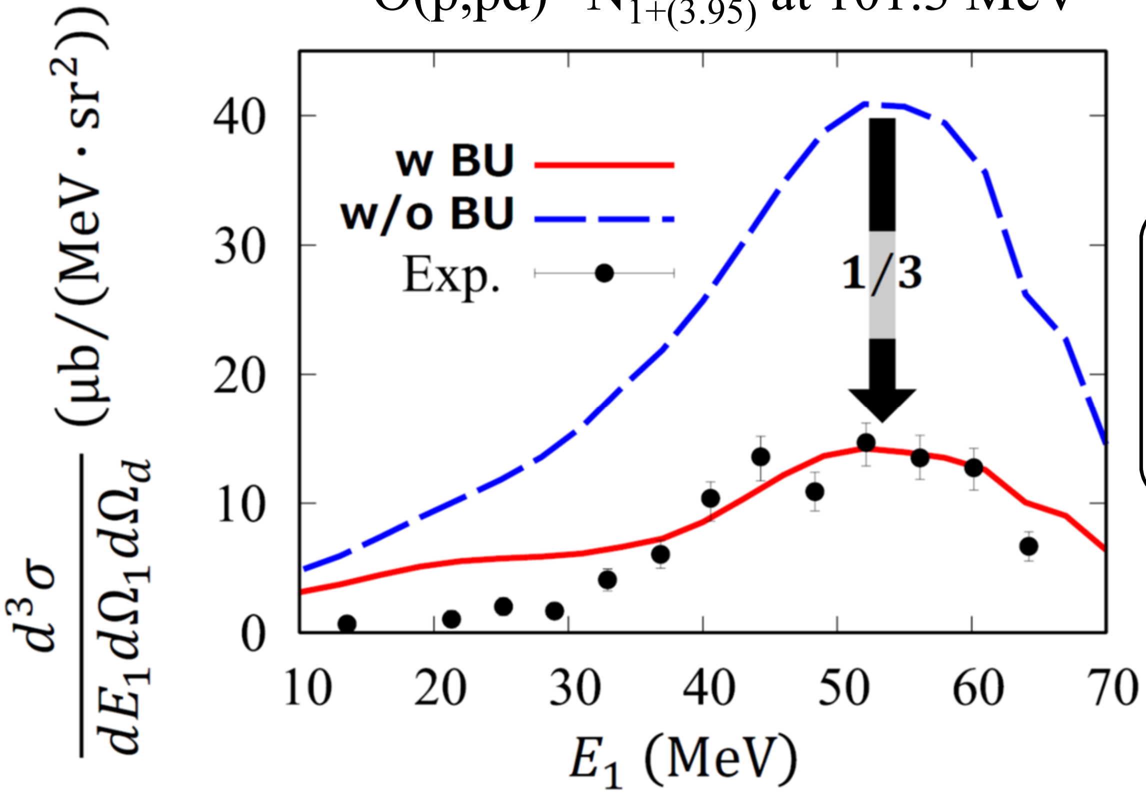


- The peak height of the TDX clearly reflects the *pn* pairing strength.
- The deuteron breakup is neglected.
- The elementary process is assumed to be the *pd* elastic scattering.

Breakup effect of the emitted deuteron

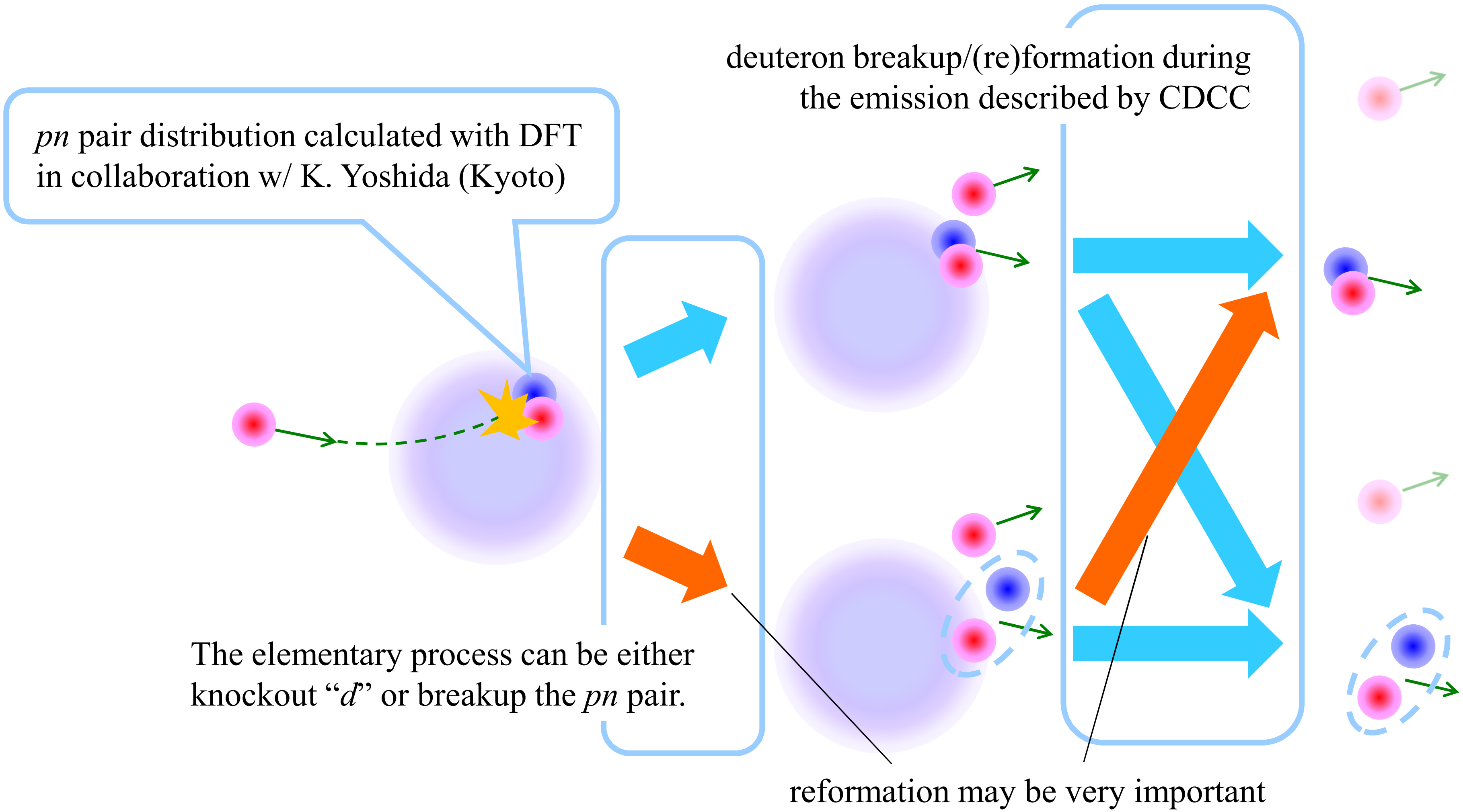
Y. Chazono, K. Yoshida, and KO, in preparation.

^{16}O(p,pd)^{14}N$_{1+(3.95)}$ at 101.3 MeV

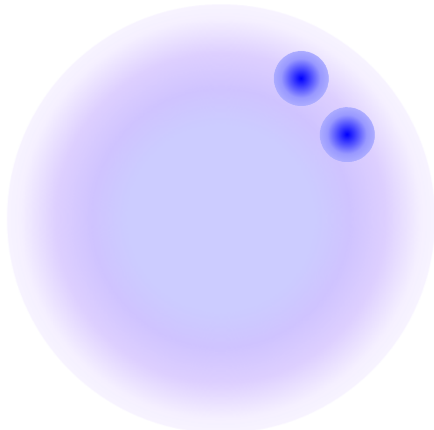


- The deuteron breakup effect is very large.
- A naïve *pn* single-particle wave function is adopted.
- The elementary process is assumed to be the *pd* elastic scattering.

Remarks on the pn knockout

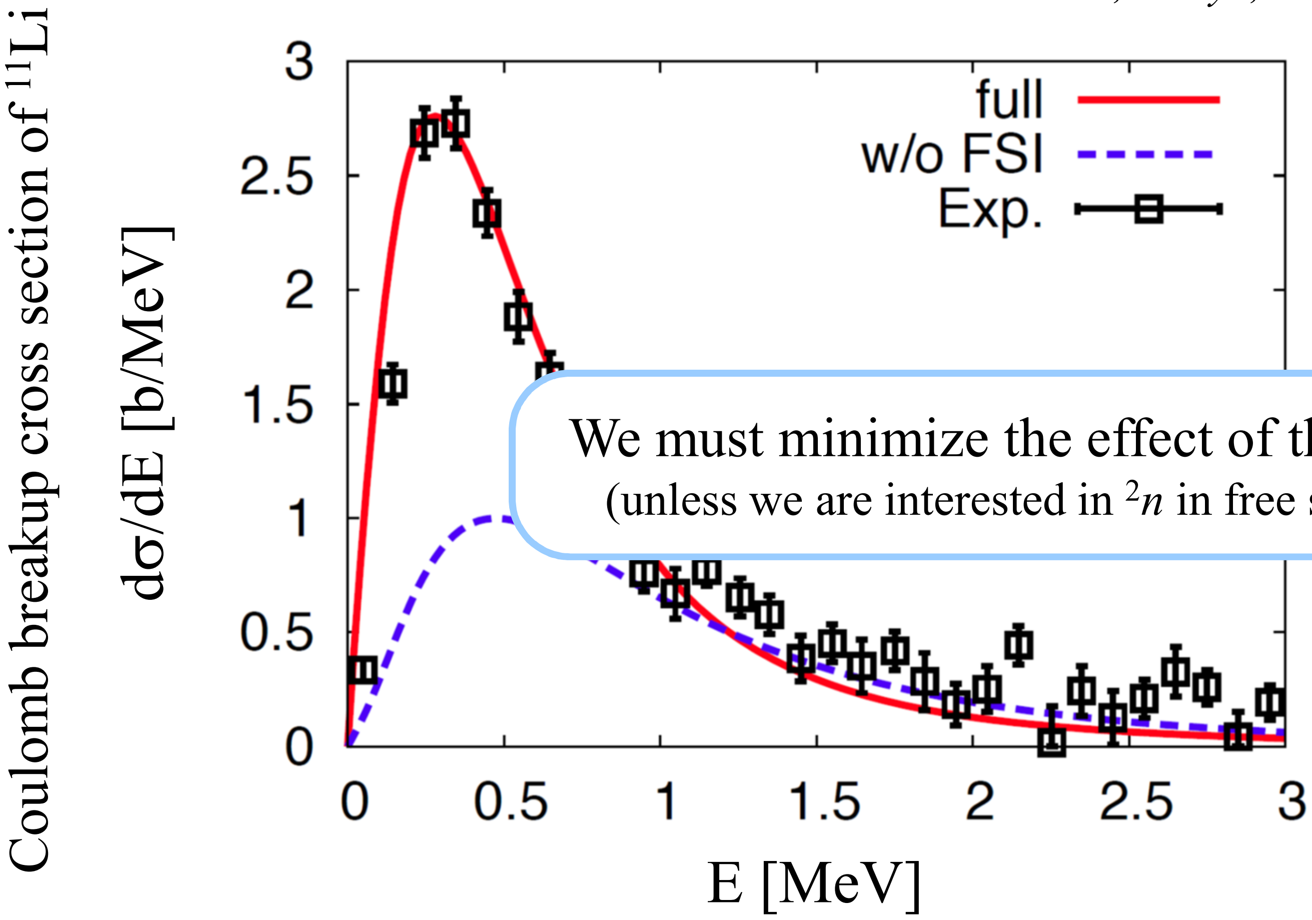


di-neutron correlation

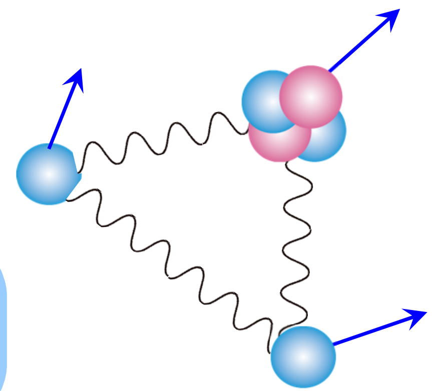


Our starting point

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



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



These fragments interact each other after breakup

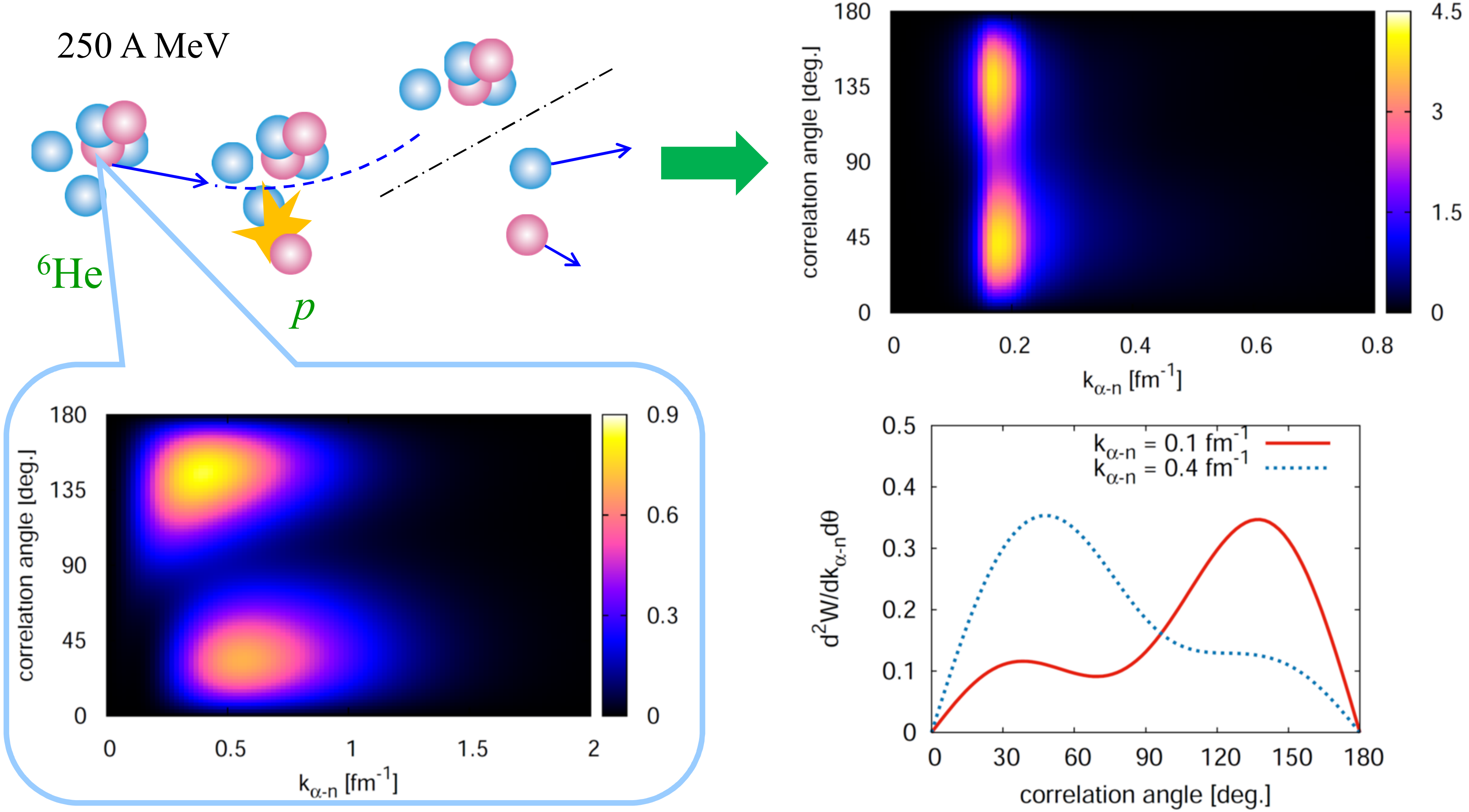
||

Final State Interaction (FSI)

Note: E1 sum rule is free from the FSI.

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).*

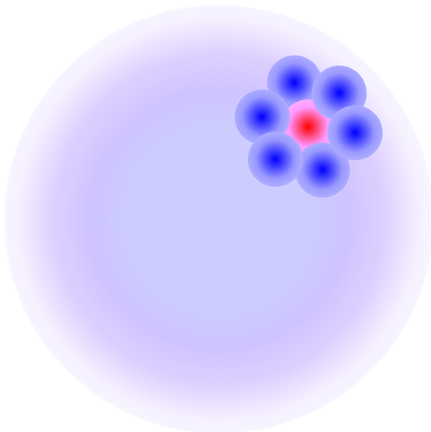


Nuclear “clustering” (future study)

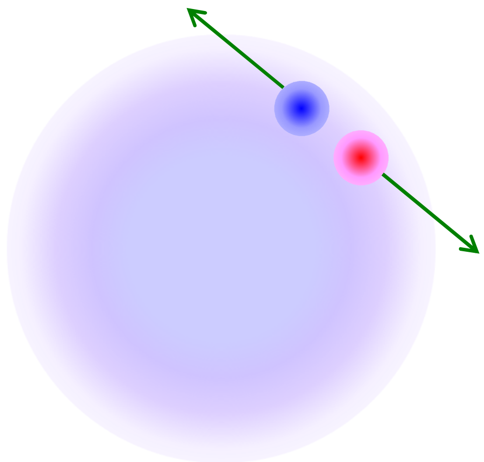
^4n and ^{7}H in free space is of interest.

short-range/tensor corr.

tetra neutron



^{7}H



spatial depletion

- FSI should be maximized.
- ^{8}He(p,$p\alpha$) has been measured at RIBF.
- DWIA+5-body CDCC

- FSI should be maximized.
- ^{8}He(p,2p) has been measured at RIBF.
- DWIA+6-body CDCC

- pickup (exchange) type (p,pd) can be used.
  cf. Terashima+, PRL121, 242501

Summary of the notes

I. α cluster structure via (p,pα)

- Antisymmetrization should be kept in mind. S_α will not be a useful measure of the α clustering.
- Triple-differential cross section has an "ill behavior" in inverse kinematics. Conversion of it to forward kinematics will be recommended.

II. deuteron-like correlation

- The final-state interaction (FSI) can not be avoided.
- Even the breakup/reformation process in the final channel will be needed.

III. di-neutron correlation

- (p,pn) for two-neutron halo nuclei is suitable to minimize the FSI.
- Detection of $2n$ is not a outcome of the di-neutron correlation.

IV. Other related activities

- ${}^4n$ and ^{7}H can be studied by KO reactions with kinematics in which the FSI is maximized.
- Tensor correlation can be studied by pickup-type (p,pd) reactions.

To integrate our knowledge on clustering, an appropriate interpretation of (nuclear) reaction data will be indispensable.