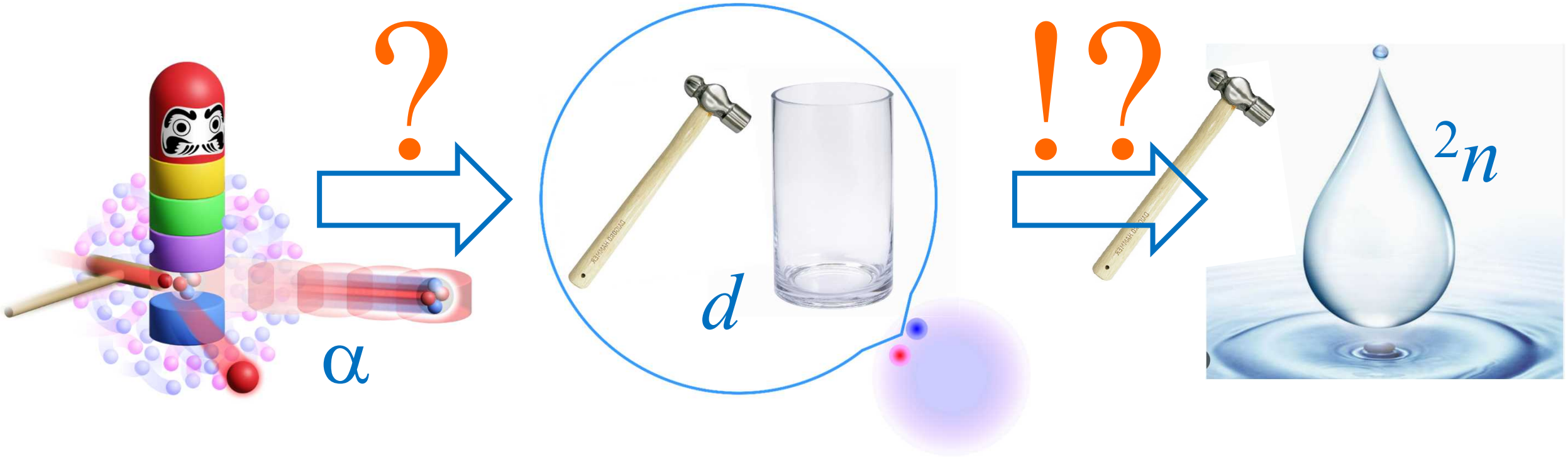
非束縛クラスターの観測について

Towards the observation of unbound clusters



Kazuyuki Ogata

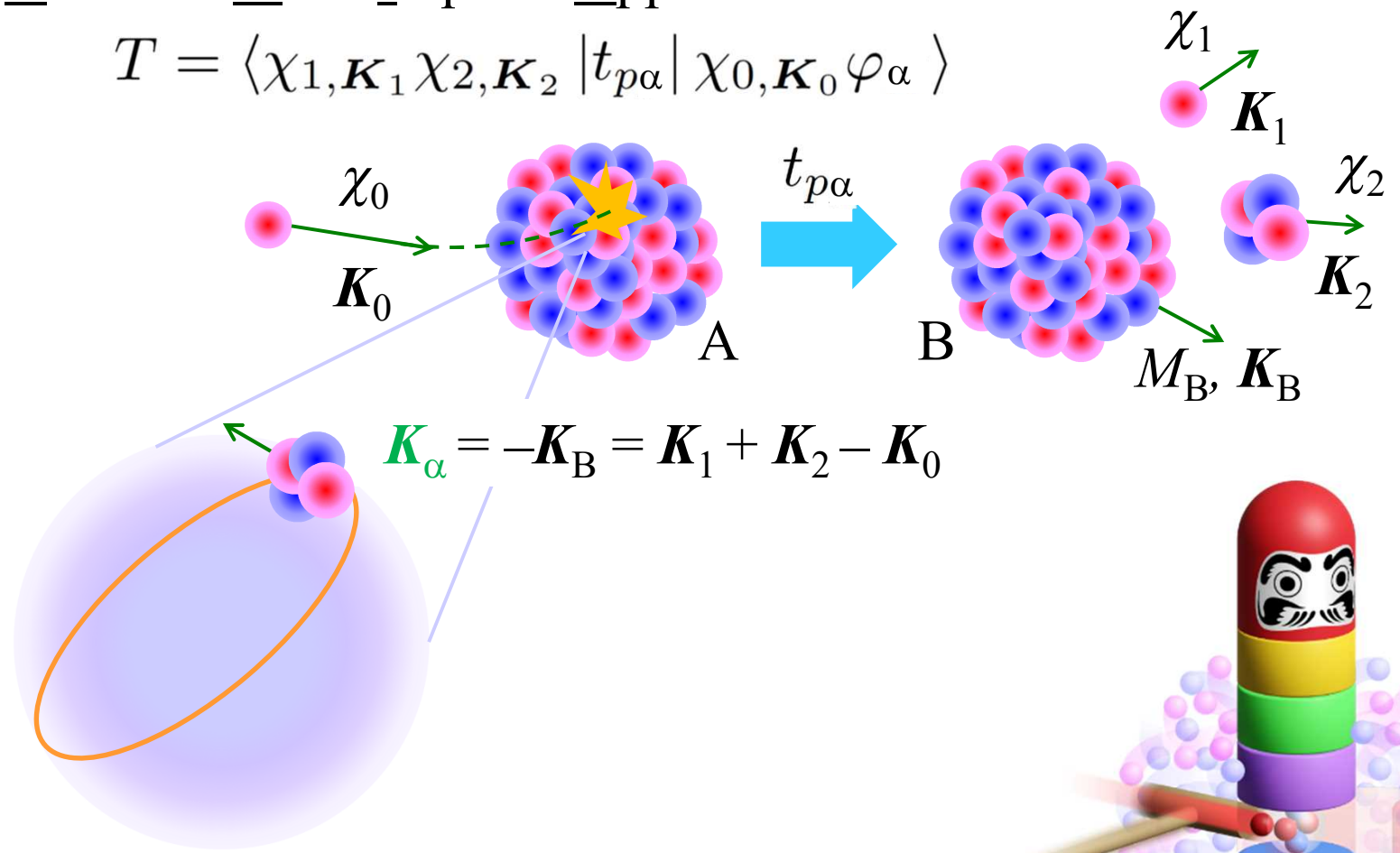
Kyushu University

Contents

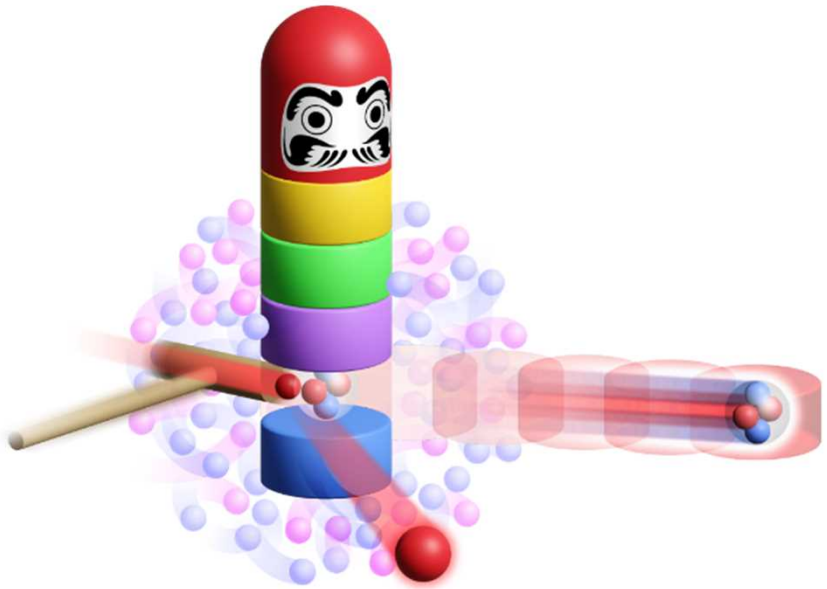
α knockout reaction as a probe for α cluster structure

Distorted Wave Impulse Approx^{n}

$$T = \langle \chi_{1,\boldsymbol{K}_1} \chi_{2,\boldsymbol{K}_2} \, | t_{p\alpha} | \, \chi_{0,\boldsymbol{K}_0} \varphi_\alpha \rangle$$

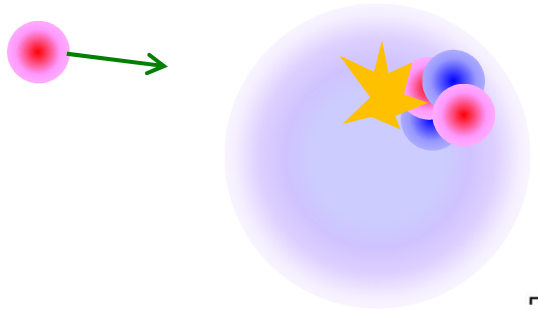


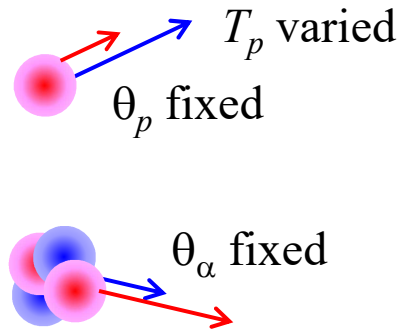
"Snapshot" of α inside a nucleus in momentum space



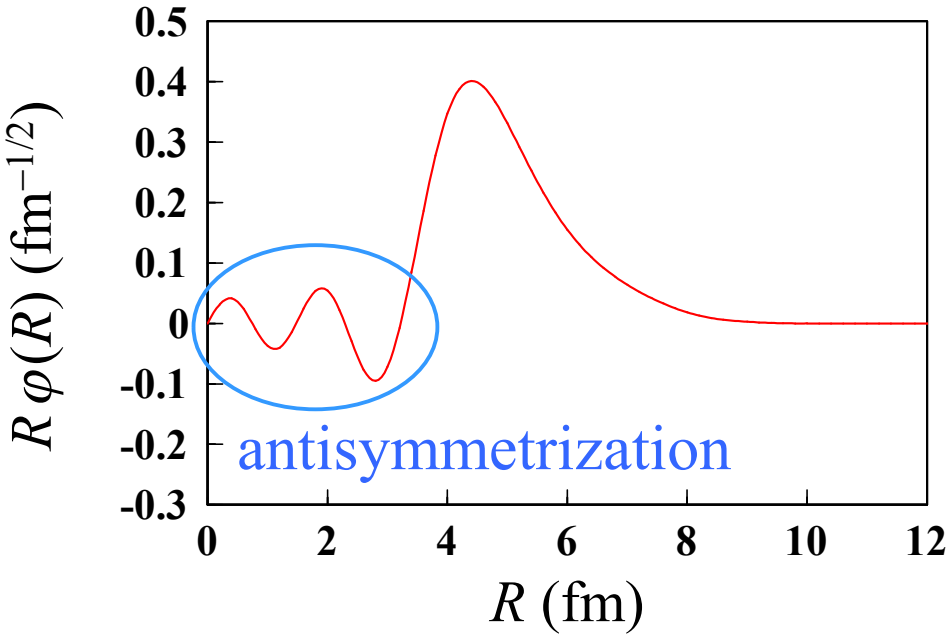
^{20}Ne(p,pα) at 101.5 MeV

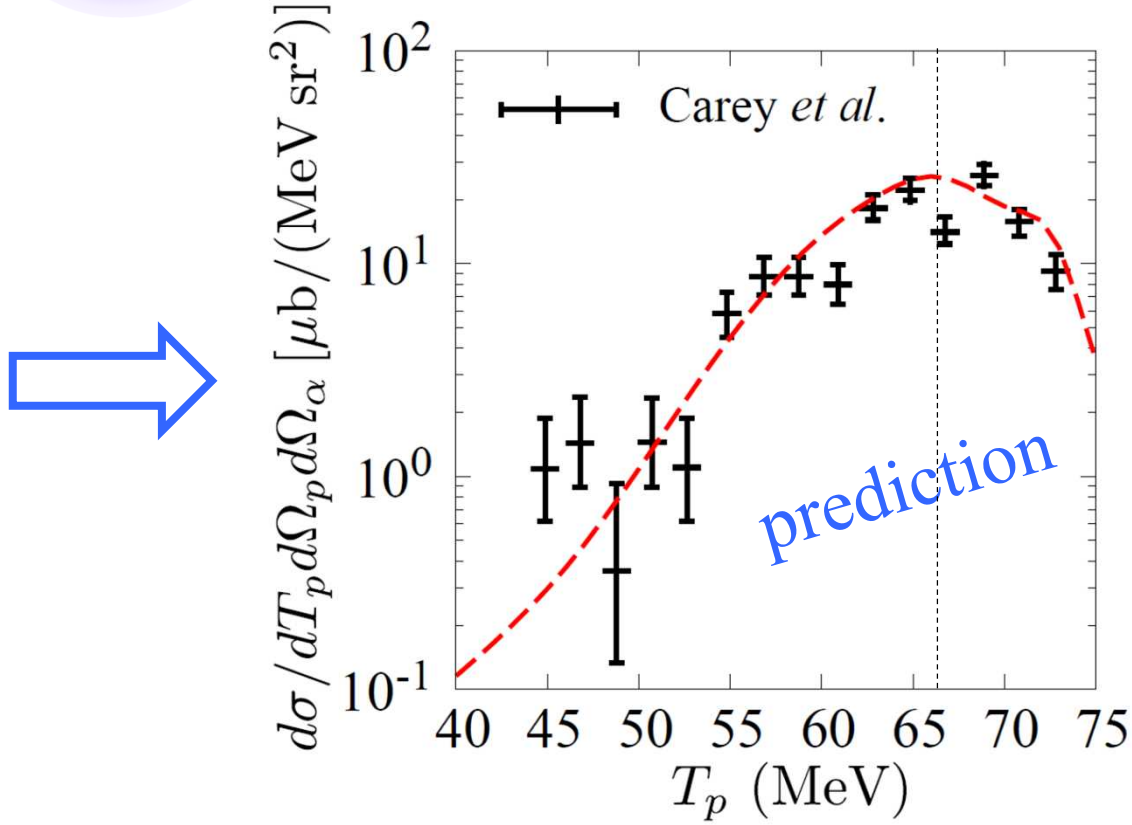
*K. Yoshida+, PRC **100**, 044601 (2019).*





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





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1. **α knockout: (*p*,*pα*)**

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

   - Established as a quantitative probe for α cluster structure

2. **Deuteron knockout: (*p*,*pd*)**

   *Y. Chazono, K. Yoshida, KO, PRC **106**, 064613 (2022).*

   - Fragileness of *d* and various reaction paths
   - CDCCIA

3. **Dineutron knockout: (*p*,*pnn*)**

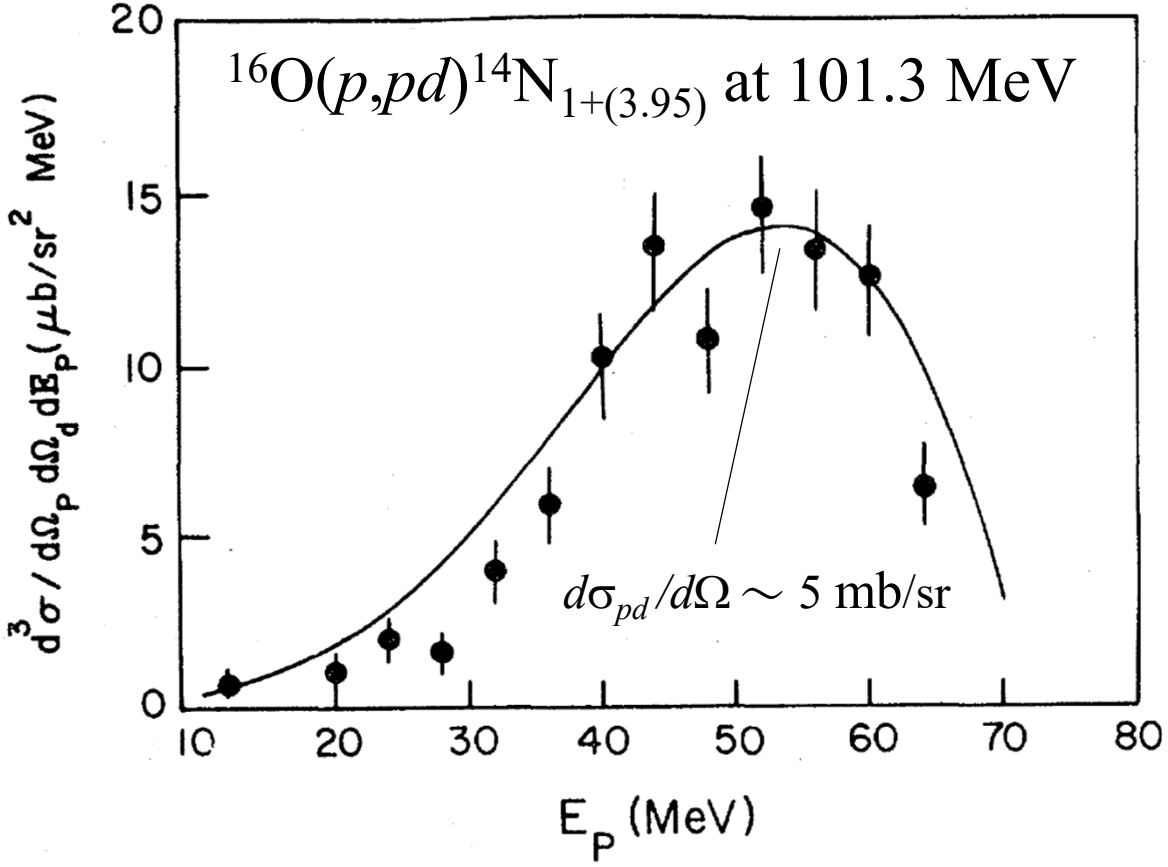
   S. Ogawa, Y. Chazono, K. Yoshida, KO, in preparation.

   - Strong continuum-continuum coupling

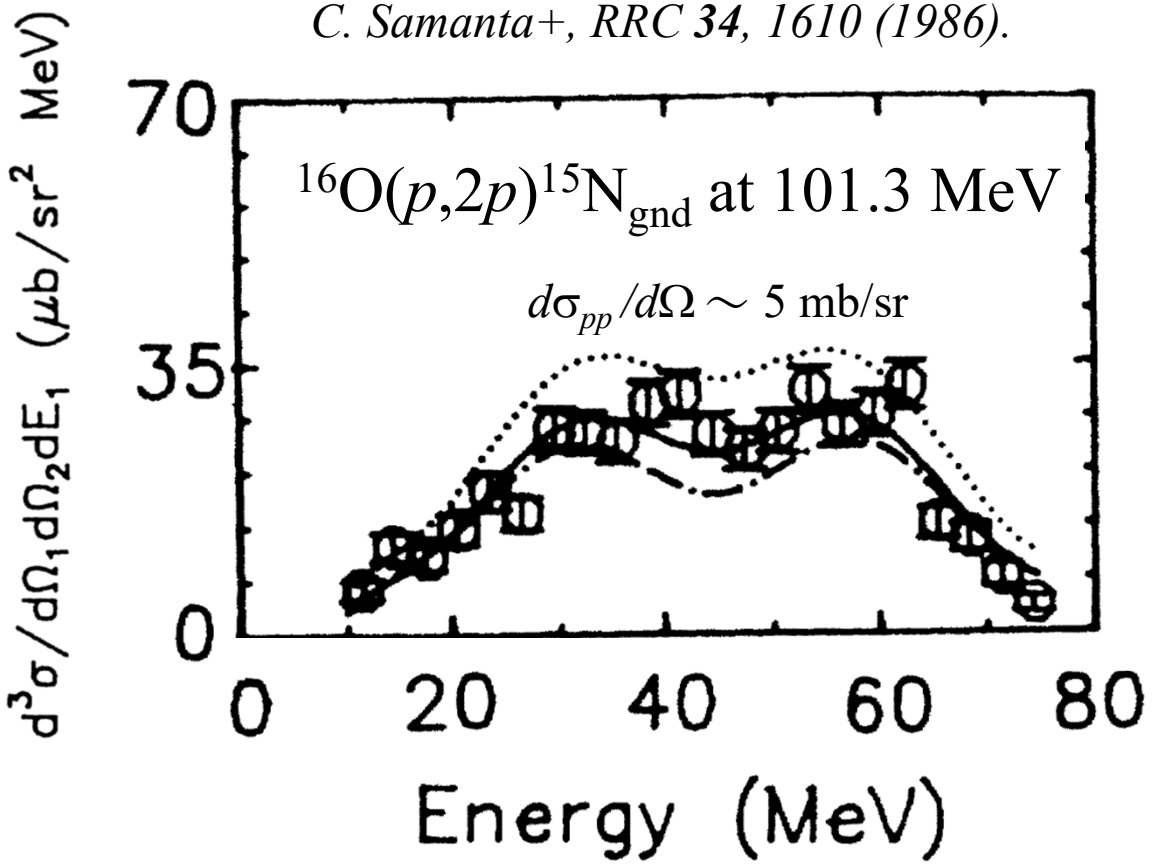
4. **Summary**

Our starting point (experimental fact)

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



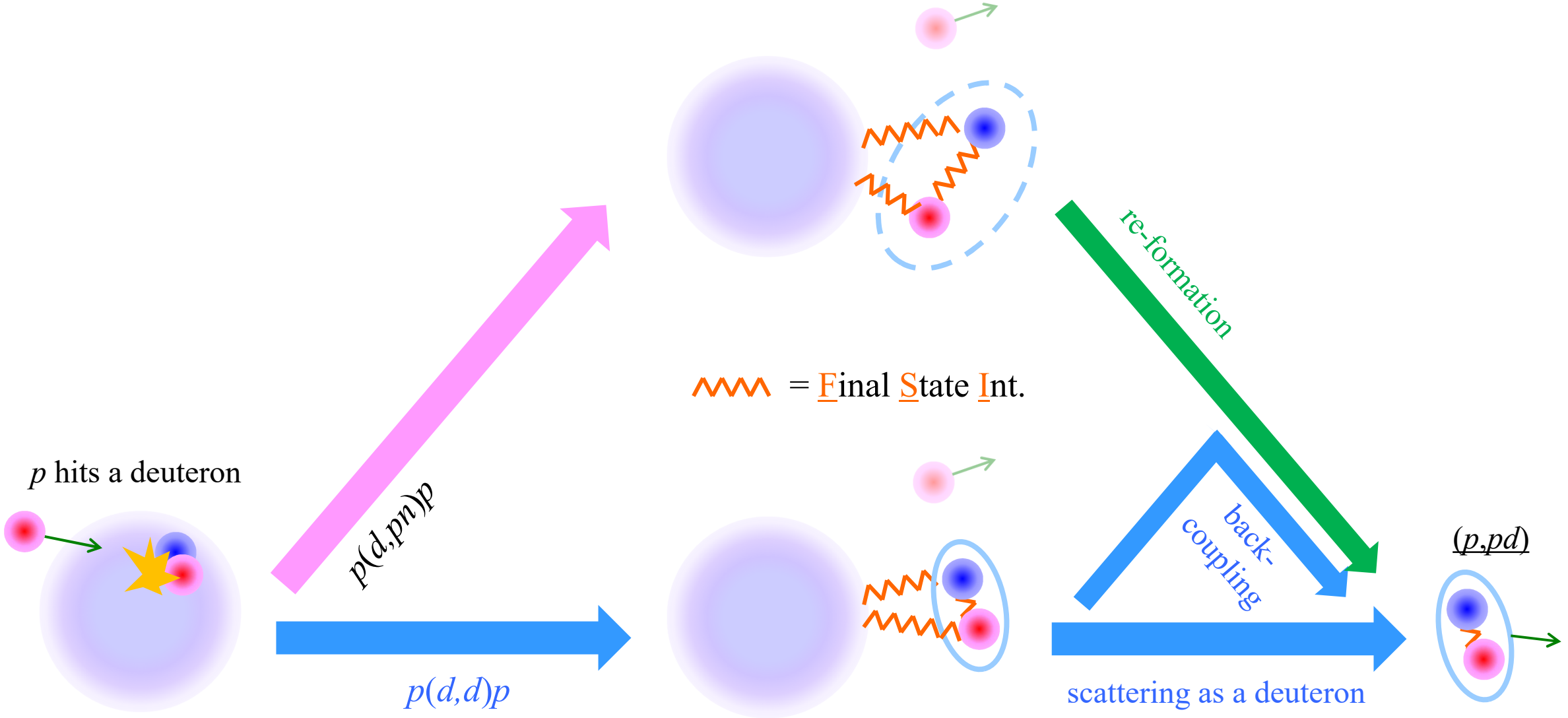
*C. Samanta+, RRC **34**, 1610 (1986).*



The (p,pd) cross section is "abnormally" large.

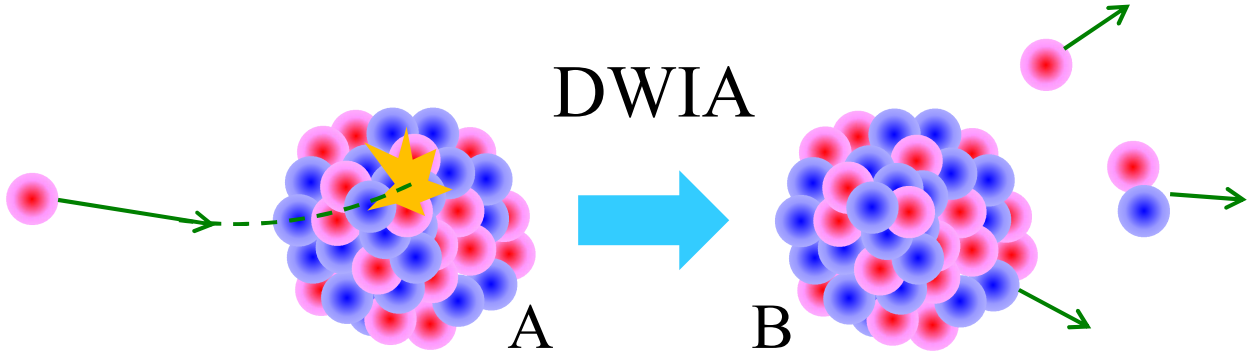
cf. preliminary result of ^{11}Li(p,pd)

Various reaction paths for the pn knockout



CDCCIA

*Y. Chazono, K. Yoshida, and KO, PRC **106**, 064613 (2022).*



+

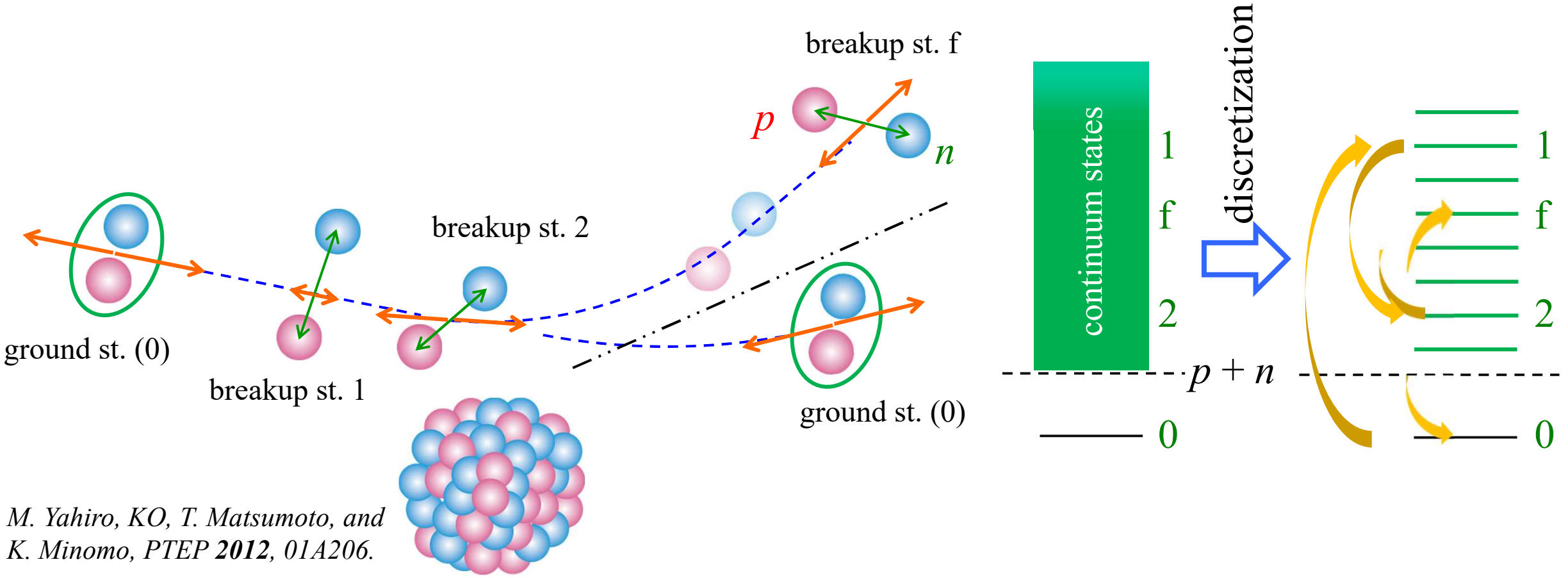
Development 1

Description of the elementary process w/ a $p + (pn)$ 3B model employing an effective NN interaction

Development 2

$p + n +$ B 3B scattering W.Fn. in the final state obtained with the Continuum- Discretized Coupled-Channels method

The Continuum-Discretized Coupled-Channels method

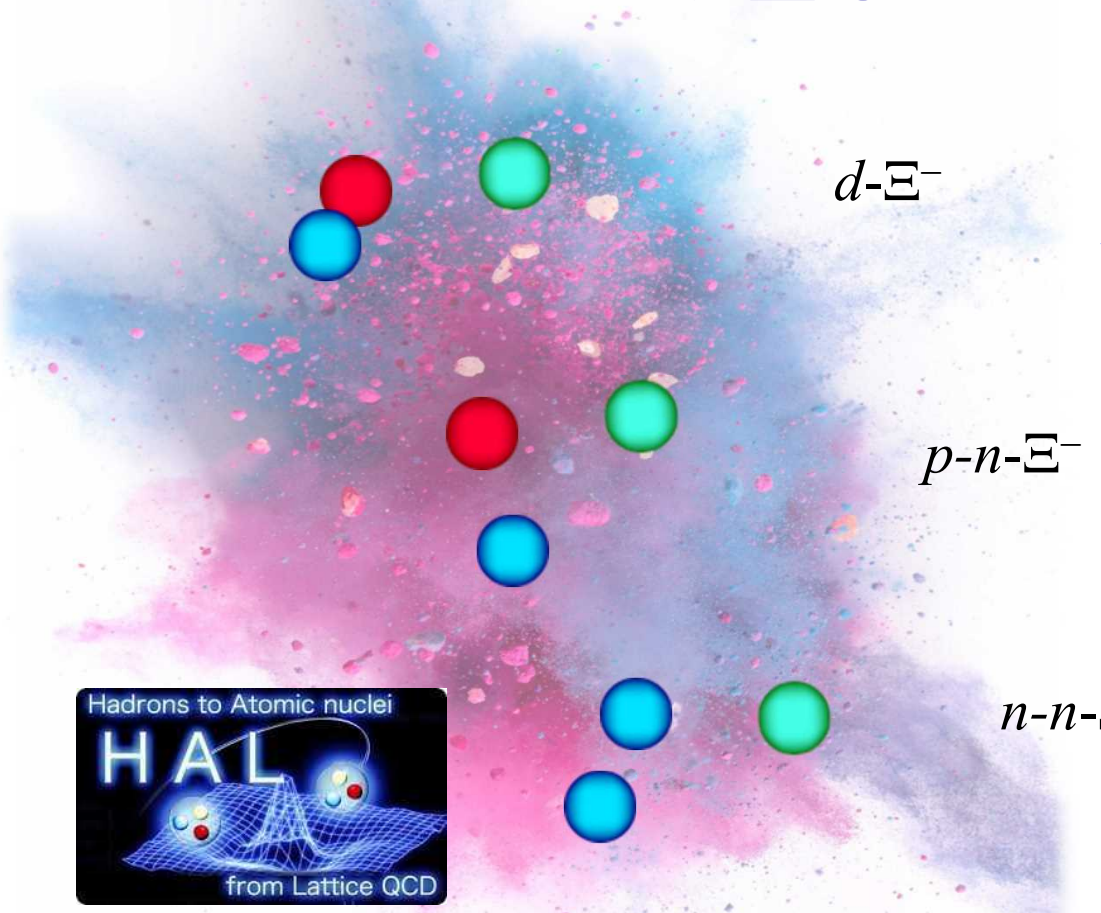


M. Yahiro, KO, T. Matsumoto, and K. Minomo, PTEP ***2012****, 01A206.*

A time-reversal calculation can describe how the deuteron and its breakup states in the interaction region are ultimately measured as a deuteron.

d-Ξ 3B correlation function

*KO, T. Fukui, Y. Kamiya, and A. Ohnishi, PRC **103**, 065205 (2021).*

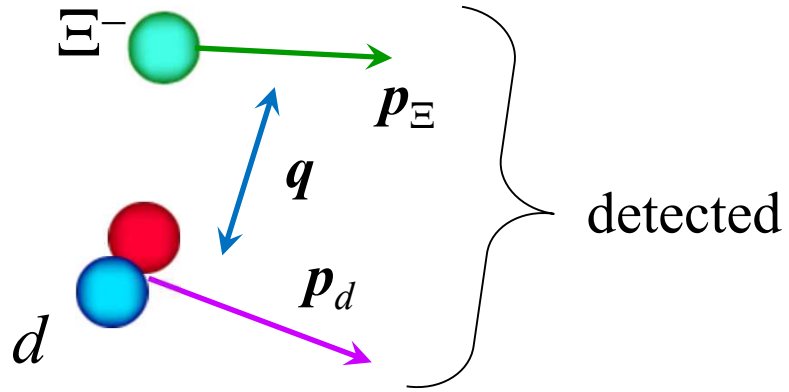


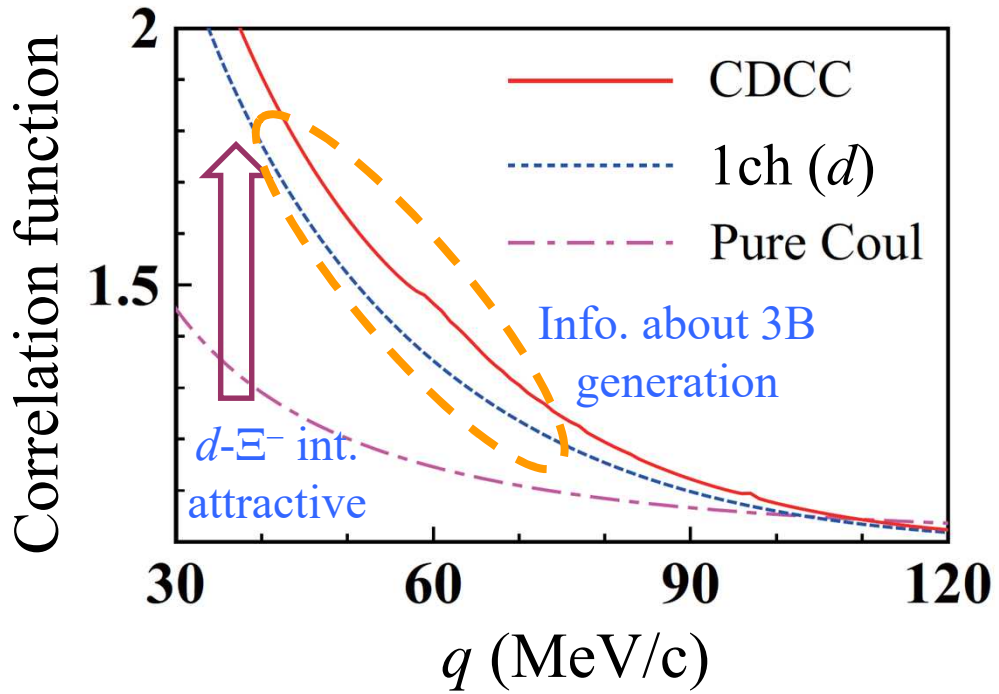
d-Ξ⁻

p-n-Ξ⁻

n-n-Ξ⁰

"Starts" from various channels



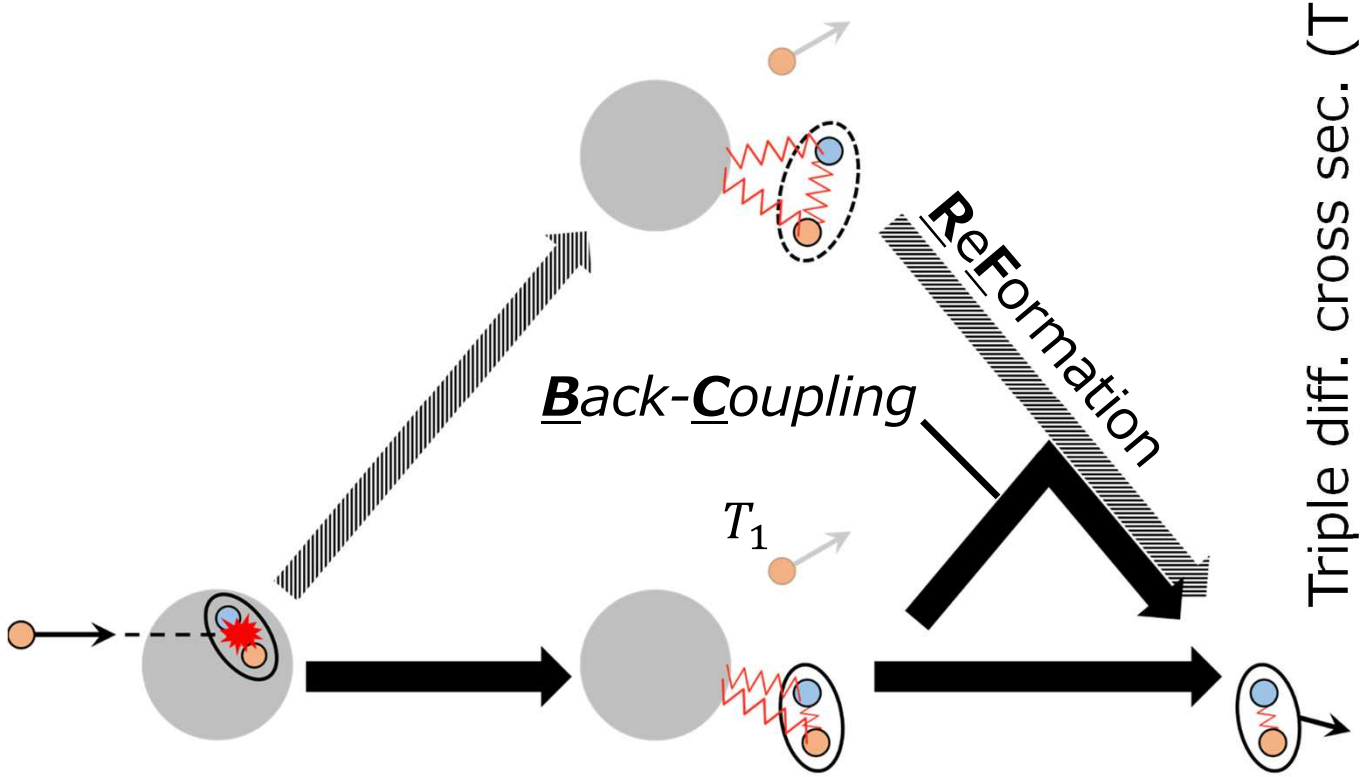


This idea also works in hadron physics.

$^{16}\mathrm{O}(p,pd)^{14}\mathrm{N}$ at 250 MeV

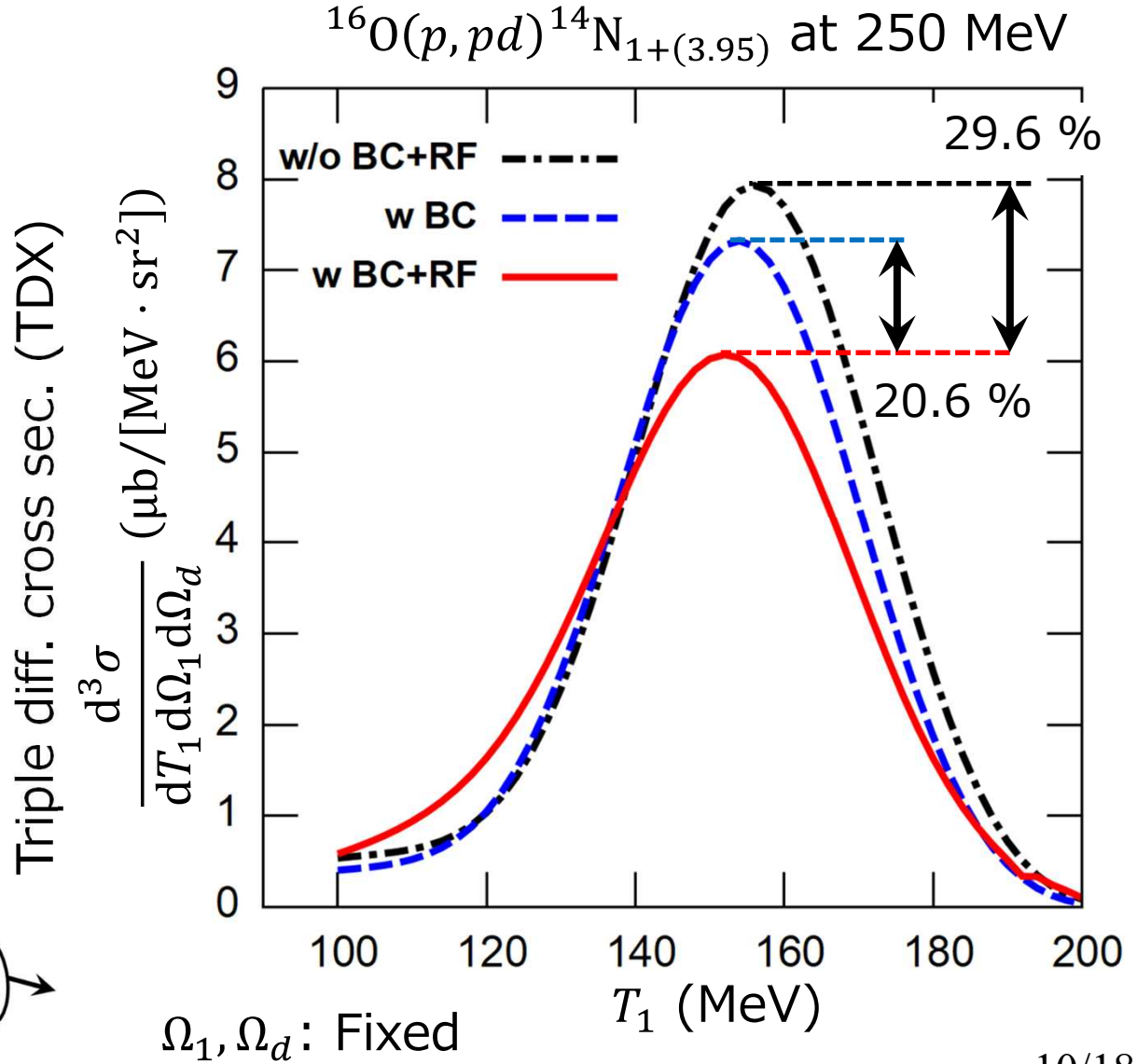
Transition matrix (***CDCCIA***)

$$T = \sum_i \left\langle \chi_1 \chi_{pn}^{(i)} \Phi_{pn}^{(i)} \middle| t_{pp} + t_{pn} \middle| \chi_0 \varphi_d \Phi_d \right\rangle$$



Courtesy of Y. Chazono

Note: **Only the S-waves** are included in BU states.



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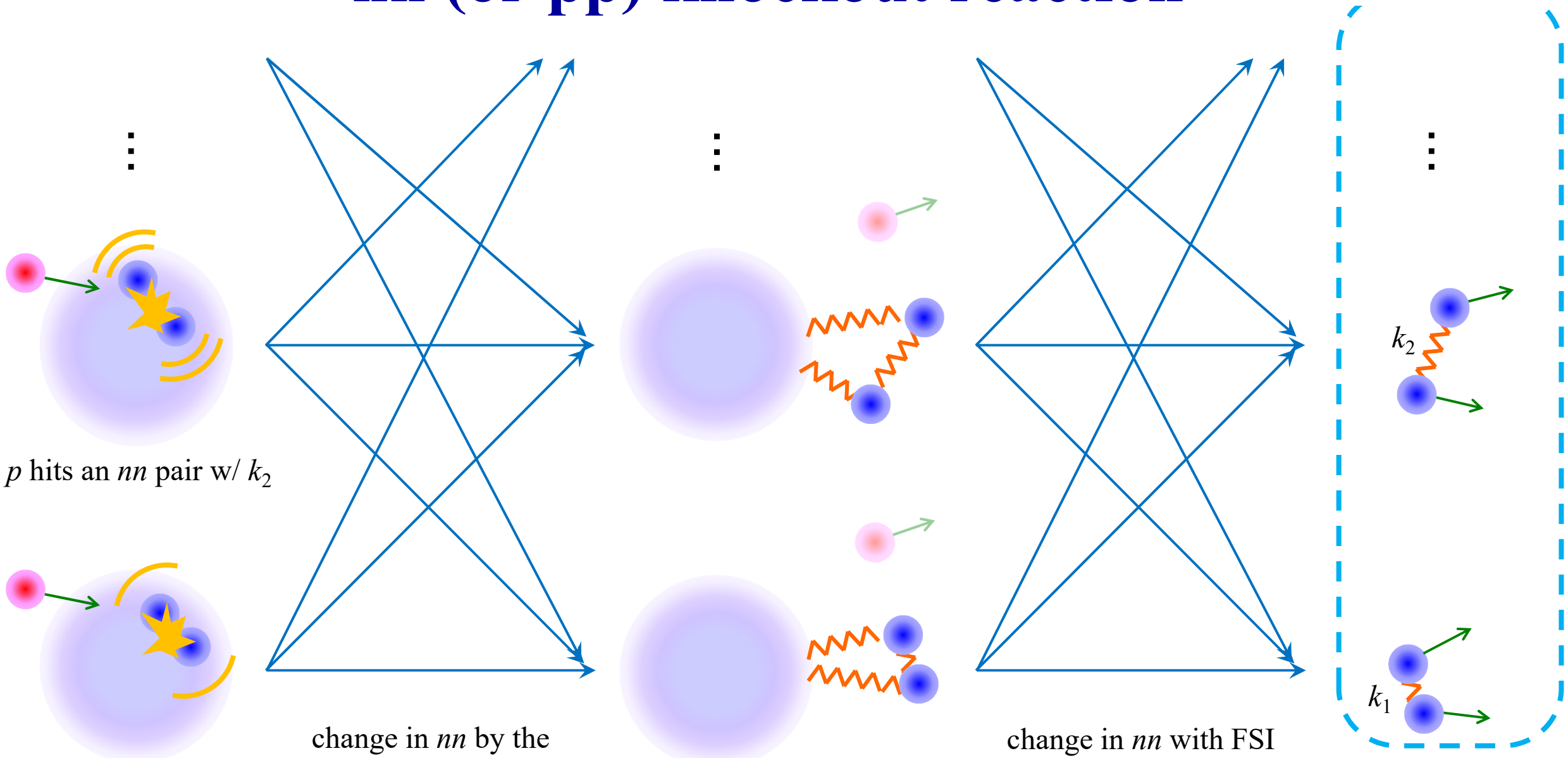
4. **Summary**

nn (or pp) knockout reaction

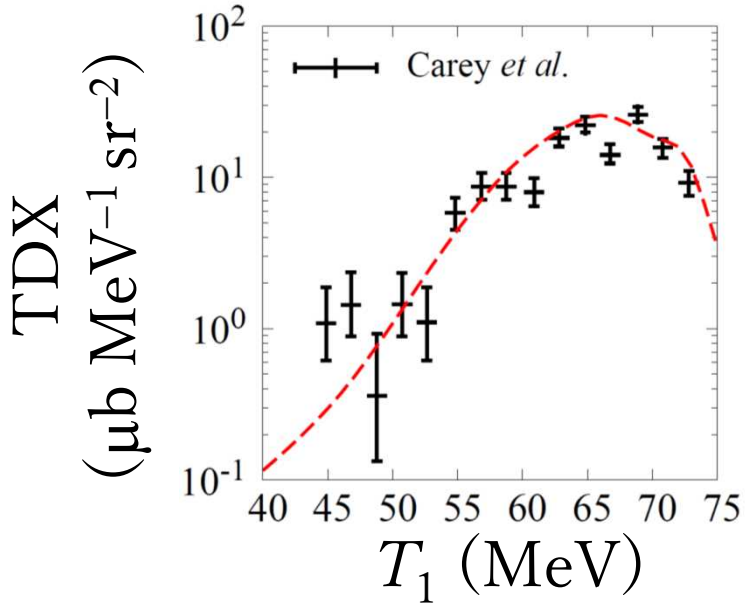


Quadruple differential cross section (QDX)

- Triple Diff. X-sec. (TDX)

$$\frac{d^3\sigma}{dT_1 d\Omega_1 d\Omega_d}$$

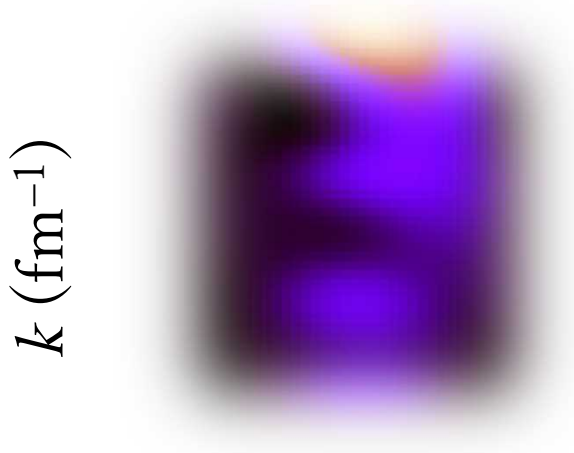
varied: T_1 fixed: Ω_1, Ω_d



- QDX: k dependence added

$$\frac{d^4\sigma}{dT_1 d\Omega_1 d\Omega_{nn} dk}$$

varied: T_1, k fixed: Ω_1, Ω_{nn}



Courtesy of S. Ogawa

Summary

1. **α knockout: (*p*,*p*α)**

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

   (*p*,*p*α) has been Established as a quantitative and clean probe for α cluster structure.

2. **Deuteron knockout: (*p*,*pd*)**

   *Y. Chazono, K. Yoshida, KO, PRC **106**, 064613 (2022).*

   A new reaction model *CDCCIA* implementing the fragileness of *d* and various reaction paths was proposed.

3. **Dineutron knockout: (*p*,*pnn*)**

   S. Ogawa, Y. Chazono, K. Yoshida, KO, in preparation.

   A preliminary result of the application of CDCCIA to the unbound cluster knockout was reported.