Interplay of core excitation and nonlocality in few-cluster reactions

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Direct Reactions with Exotic Beams - DREB 2024, Wiesbaden

Outline

- core excitation in three-cluster reactions:
  nonlocal optical potentials
  SF factorization in (d,p) reactions
  (p,pN) beyond DWIA
- extensions

Faddeev/AGS equations with core excitation

$$U_{\beta\alpha}^{ba} = \bar{\delta}_{\beta\alpha}\delta_{ba}G_0^{-1} + \sum_{\sigma}\sum_{j}\bar{\delta}_{\beta\sigma}T_{\sigma}^{bj}G_0U_{\sigma\alpha}^{ja}$$

$$U_{0\alpha}^{ba} = \delta_{ba}G_0^{-1} + \sum_{\sigma}\sum_{j}T_{\sigma}^{bj}G_0U_{\sigma\alpha}^{ja}$$

$$T_{\sigma}^{ba} = V_{\sigma}^{ba} + \sum_{j}V_{\sigma}^{bj}G_0T_{\sigma}^{ja}$$

$$G_0 = (E + i0 - H_0)^{-1}$$

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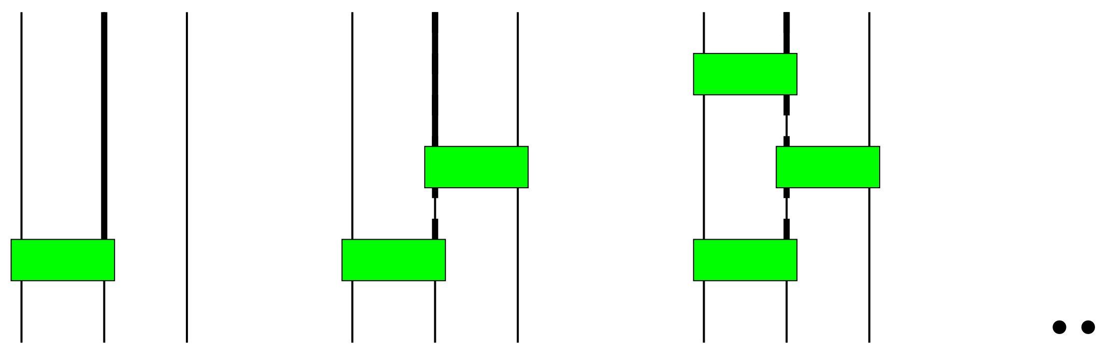

Nonlocal OP + core excitation + Faddeev equations

- 2009: Nonlocal OP in (d,p) reactions
  [AD, PRC 79, 021602]
- 2013: ADWA with nonlocal OP
  [Timofeyuk, Nunes, ...]
- 2018: ADWA with nonlocal OP is inaccurate,
  proven by Faddeev [AD, PRC 98, 021603]
  and CDCC [Gomez-Ramos et al, PRC 98, 011601]

Nonlocal OP with core excitation

$$V(r) = -V_V\, f_V(r) - iW_V\, f_W(r) - \ldots$$

$$f_j(r) = \frac{1}{1+e^{(r-R_j)/a_j}}$$

$$H(x) = \pi^{-3/2}\rho^{-3}e^{-(x/\rho)^2}$$

$$\langle \mathbf{r}'|V_N|\mathbf{r}\rangle = \frac{1}{2}\left[V(r')H(|\mathbf{r}'-\mathbf{r}|)+H(|\mathbf{r}'-\mathbf{r}|)V(r)\right]$$

[PLB 840, 137867]

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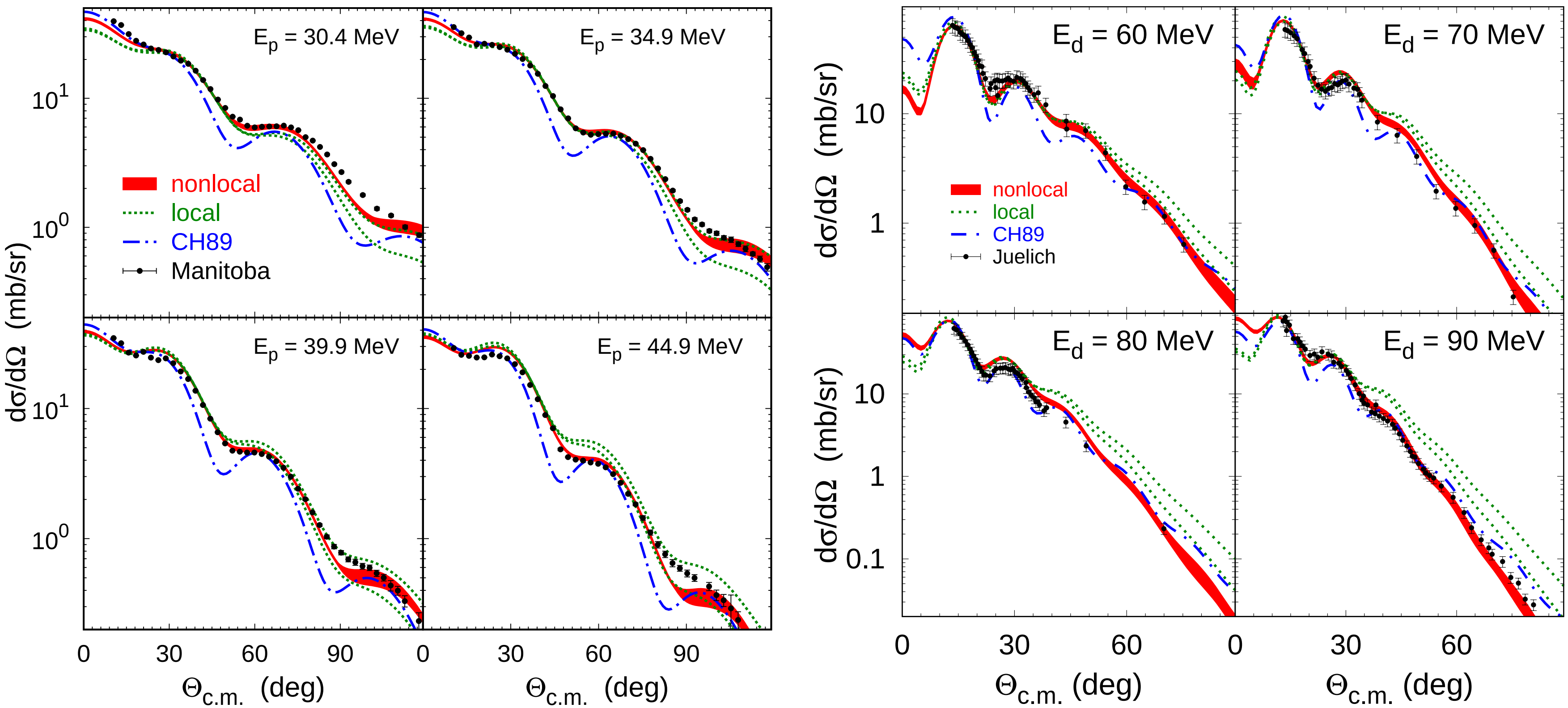
- Rotational core excitation: $R_j \rightarrow R_{j0}[1+\beta_2 Y_{20}(\hat{\xi})]$

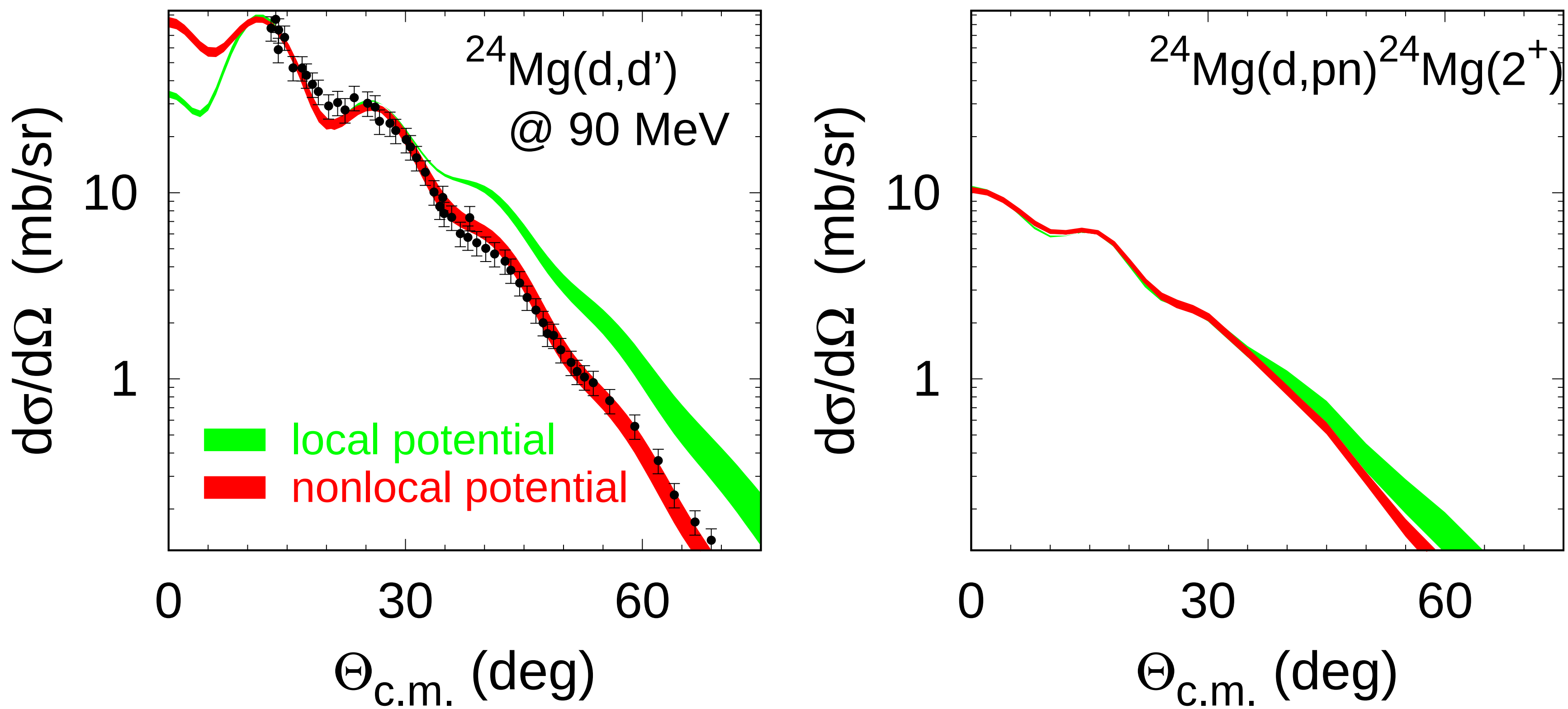
[PLB 840, 137867]

Inelastic proton and deuteron scattering off +^{24}Mg

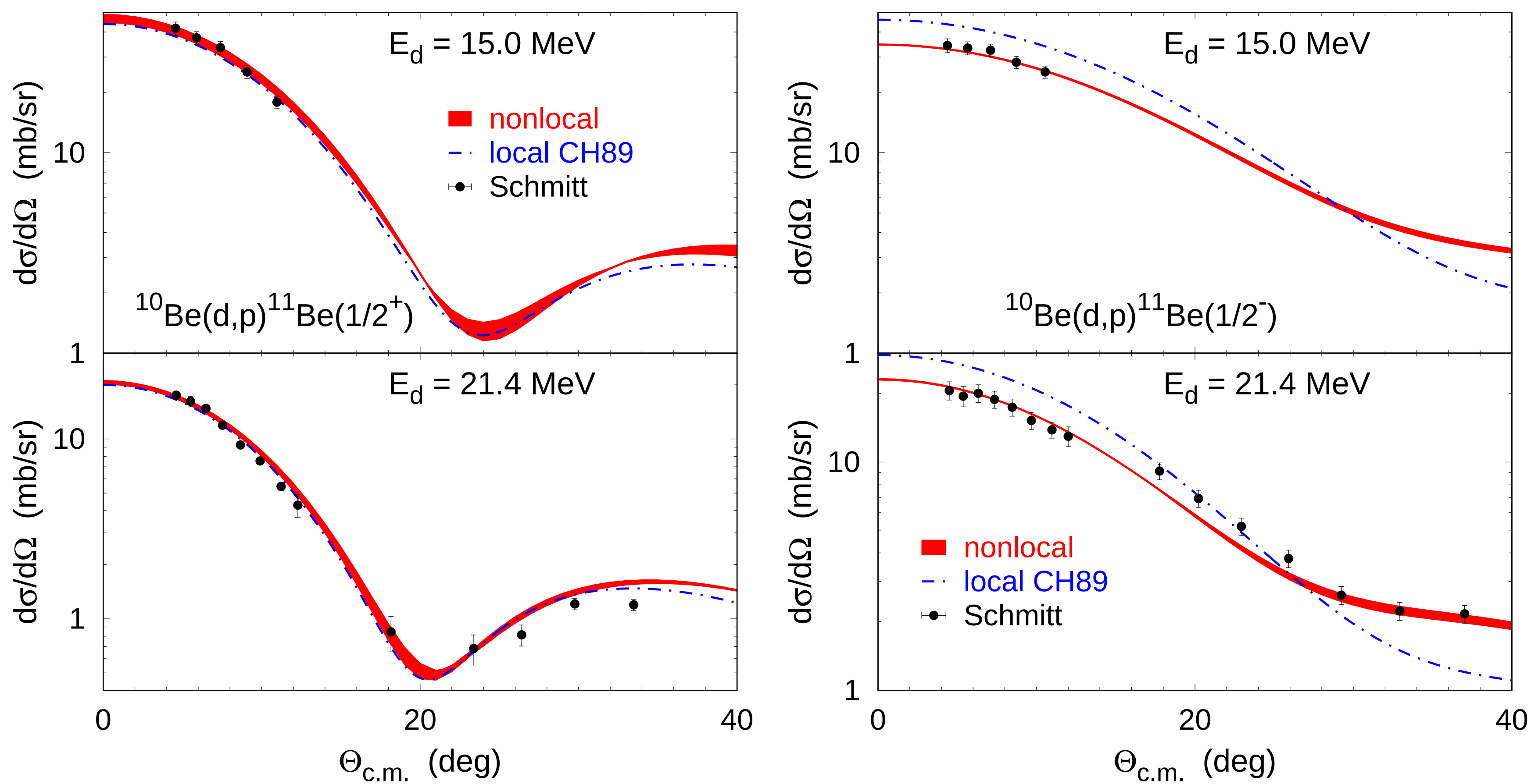


[PRC 107, 064602]

d+^{24}Mg inelastic scattering and breakup

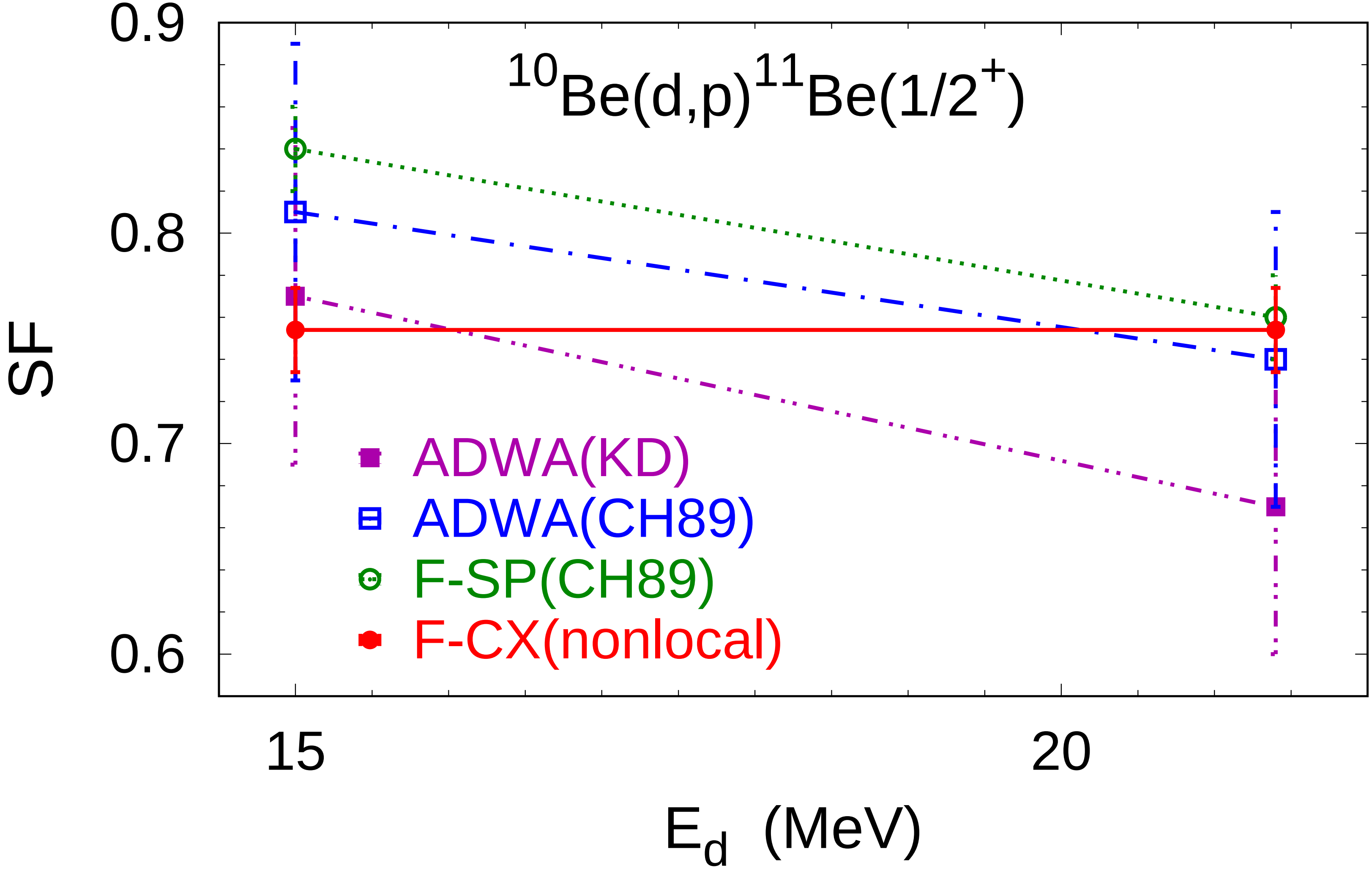


Neutron transfer: ^{10}Be(d,p)^{11}Be



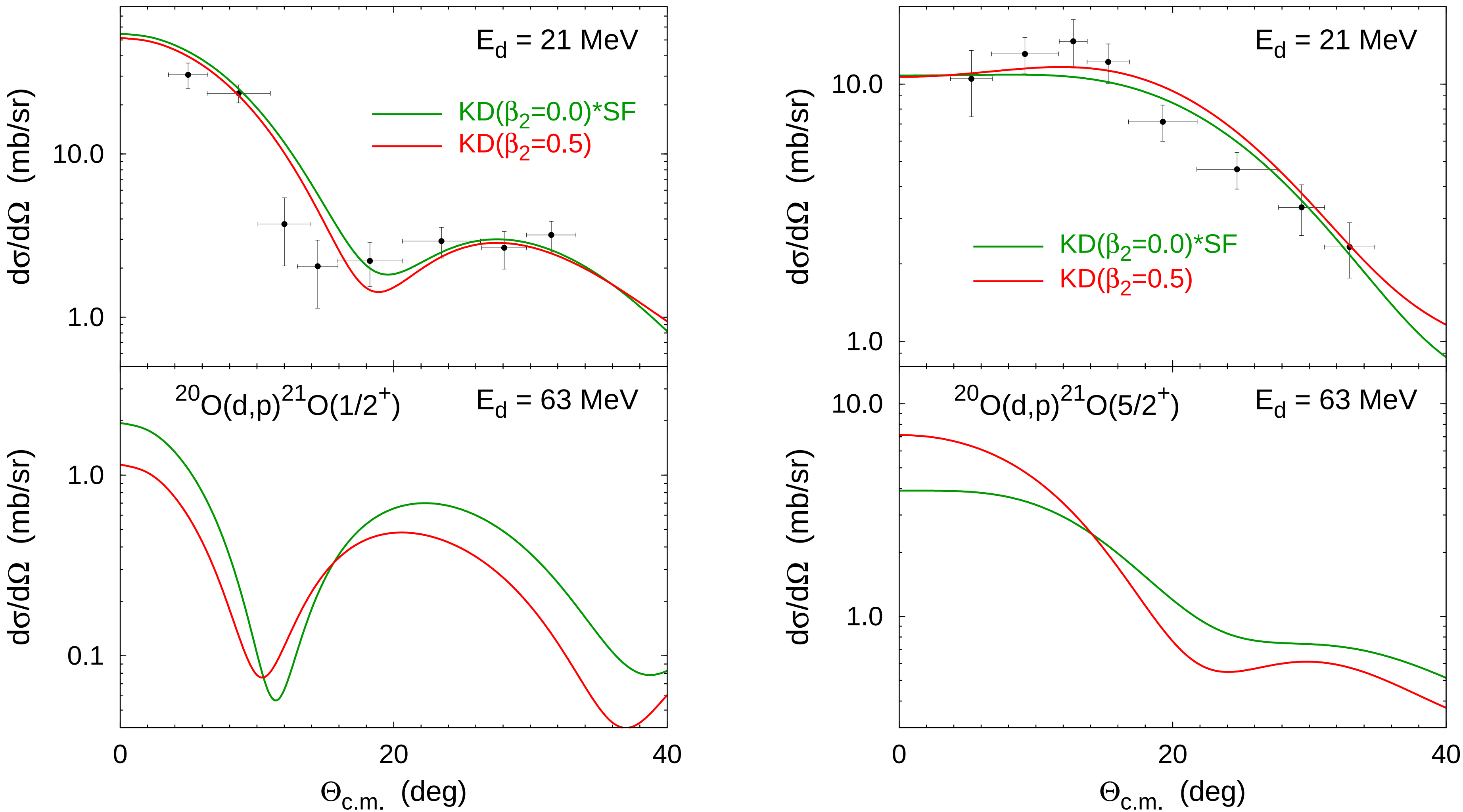
[PLB 840, 137867]

Spectroscopic factors: $^{10}Be(d,p)^{11}Be$



[ADWA: Schmitt et al., PRL 108, 192701]

$^{20}O(d,p)^{21}O$: SF factorization?



$SF \times \sigma_{SP} \neq \sigma_{CX}$ at higher energy!

[PRC 88, 011601; PLB 769, 202; data PRC 84, 01301]

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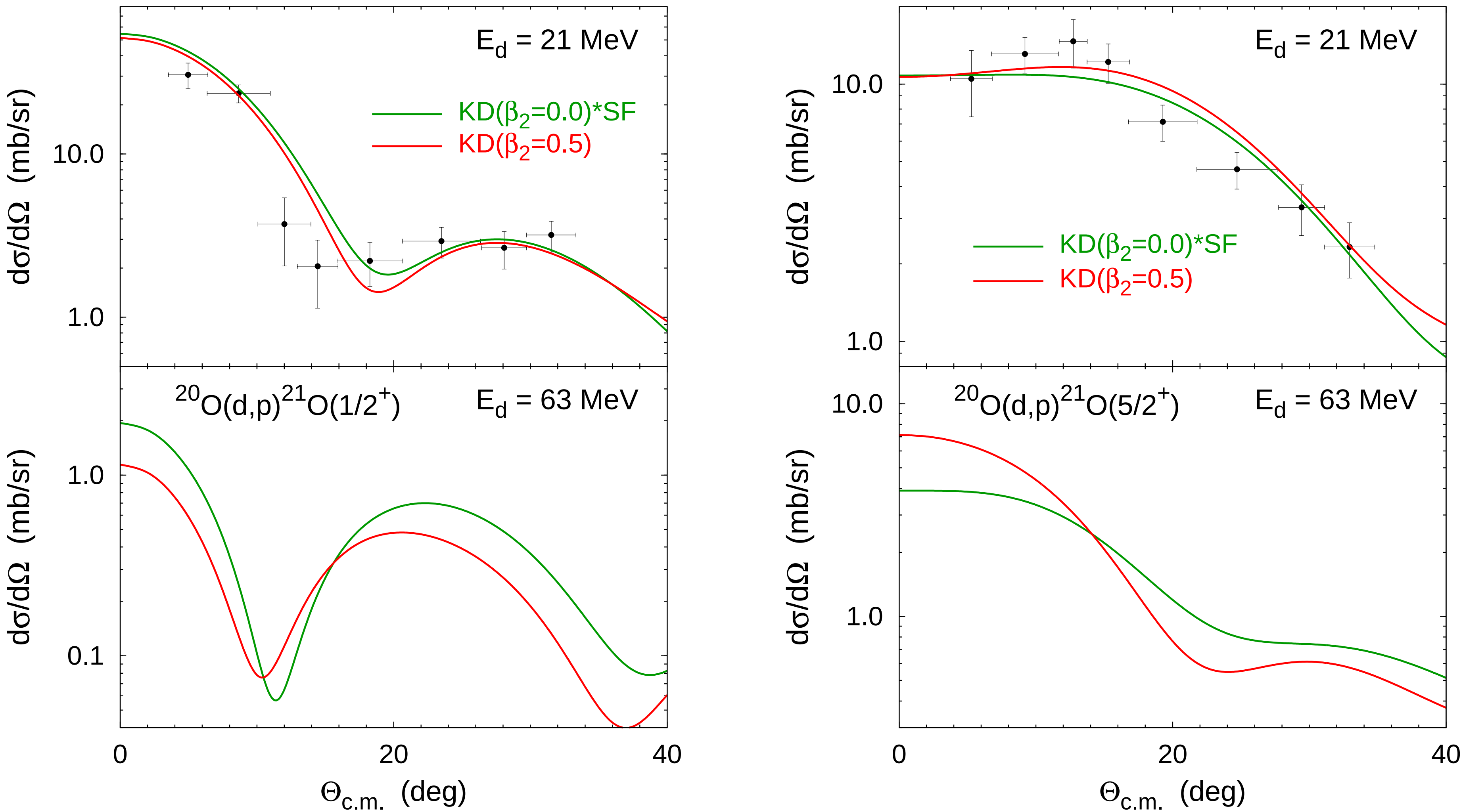

$SF \times \sigma_{SP} \neq \sigma_{CX}$ at higher energy! $SF \times \sigma_{SP} \neq \sigma_{exp}$?

[PRC 88, 011601; PLB 769, 202; data PRC 84, 01301]

Faddeev/AGS equations with core excitation

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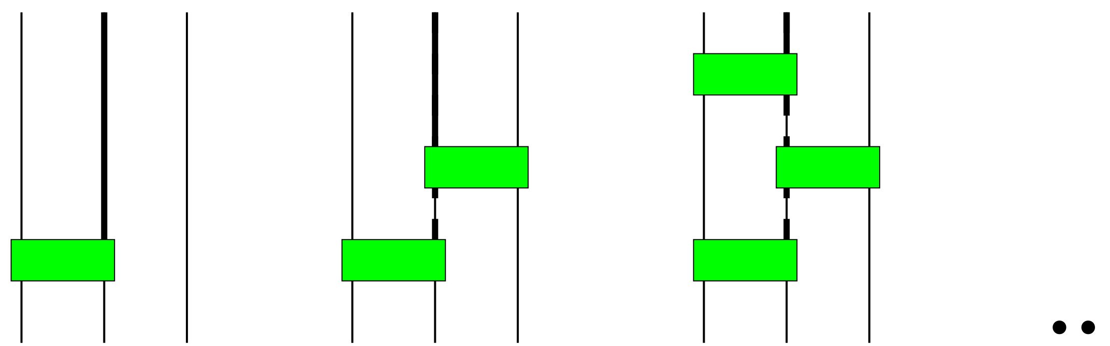

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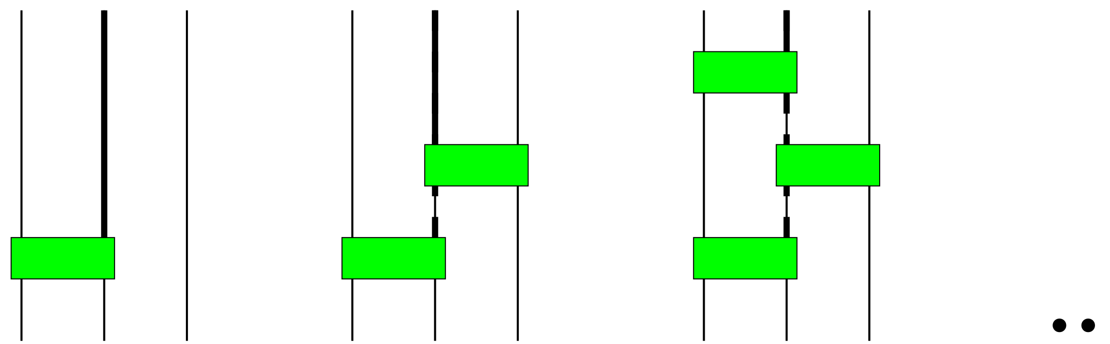
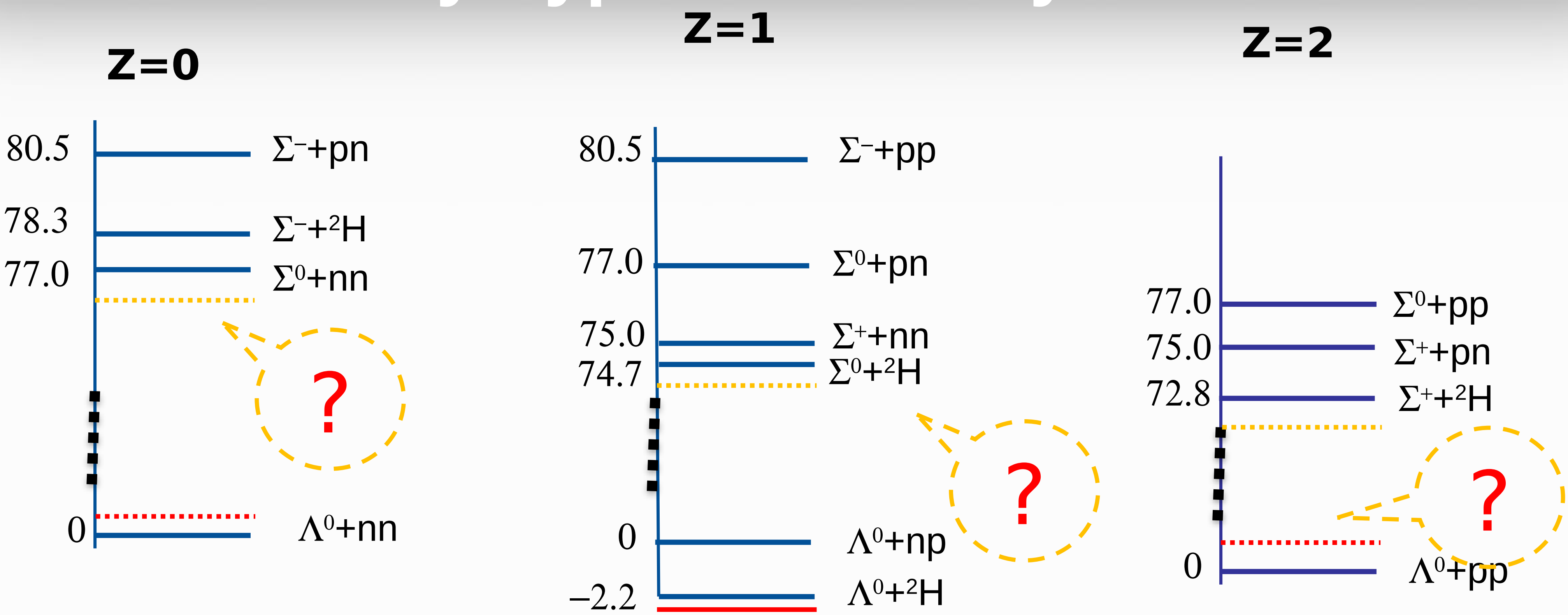


Dynamic CX: (p,pN) reactions beyond DWIA

^{12}C(p,2p)^{11}B$(5/2^-)$ with $\mathrm{SF}(5/2^-) \to 0$

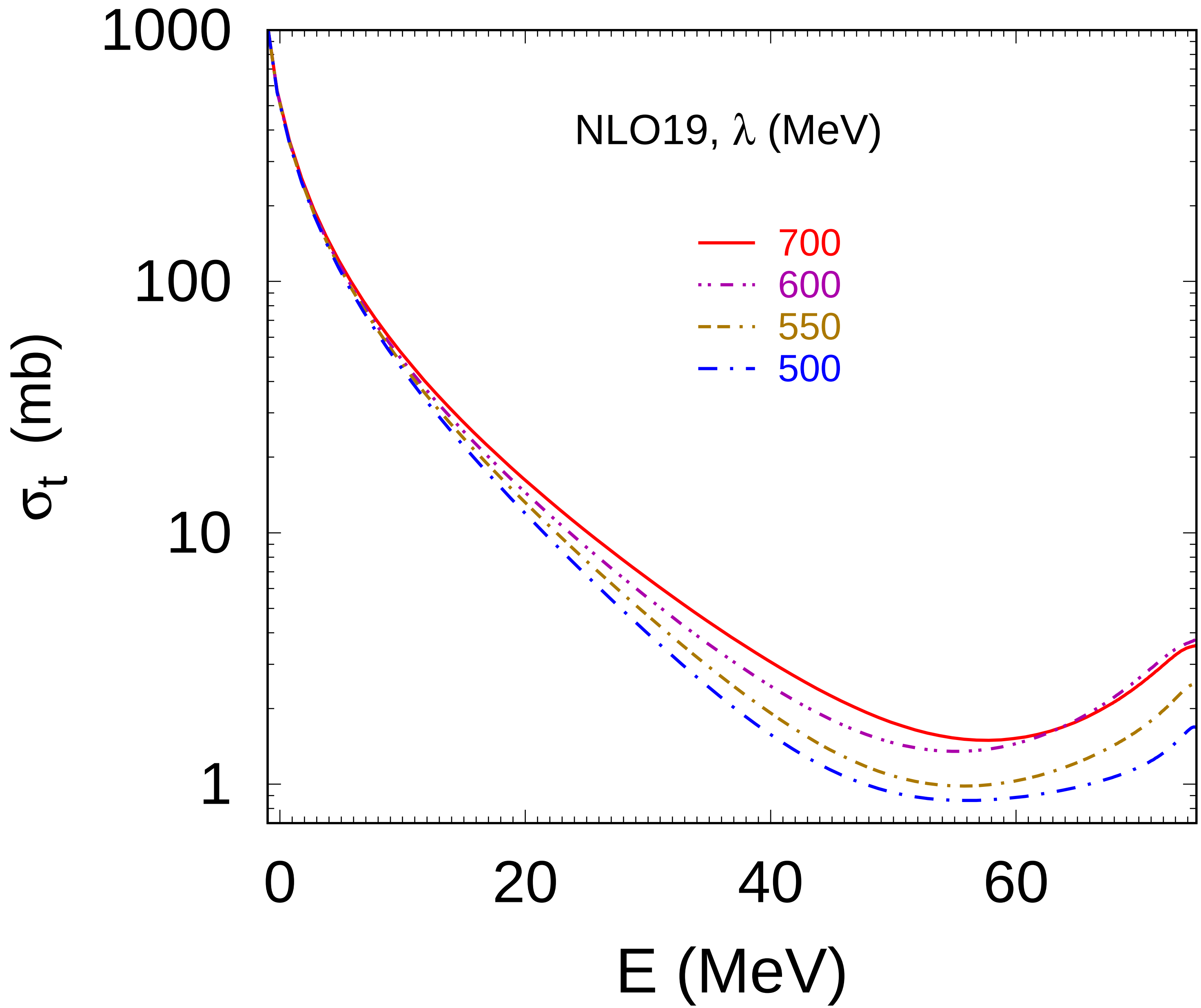
→ Talk by R. Crespo

3-body hypernuclear systems



- Extended Faddeev equations with channel coupling

$\Lambda + d$ total cross section in $\frac{1}{2}^+$ state



[collaboration with R. Lazauskas, D. Gazda, M. Schäfer]

4N scattering: symmetrized AGS equations

$$t = v + vG_0 t$$

$$G_0 = (E + i\varepsilon - H_0)^{-1}$$

$$U_j = P_j G_0^{-1} + P_j t G_0 U_j$$

$$3+1: \quad P_1 = P_{12} P_{23} + P_{13} P_{23}$$

$$2+2: \quad P_2 = P_{13} P_{24}$$

$$\mathcal{U}_{11} = (G_0 t G_0)^{-1} \zeta P_{34} + \zeta P_{34} U_1 G_0 t G_0 \, \mathcal{U}_{11} + U_2 G_0 t G_0 \, \mathcal{U}_{21}$$

$$\mathcal{U}_{21} = (G_0 t G_0)^{-1} (1 + \zeta P_{34}) + (1 + \zeta P_{34}) U_1 G_0 t G_0 \, \mathcal{U}_{11}$$

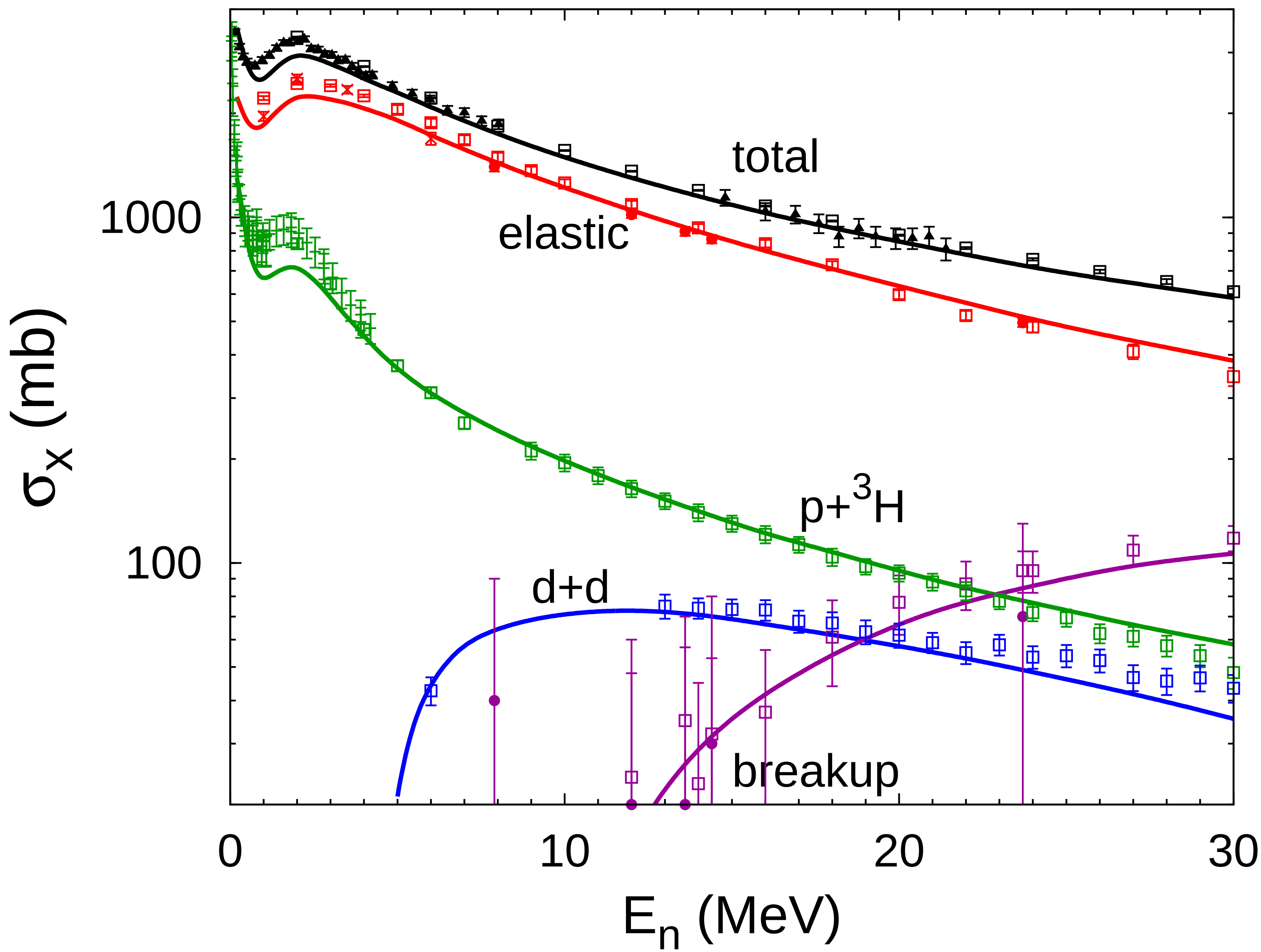
$$\mathcal{U}_{12} = (G_0 t G_0)^{-1} + \zeta P_{34} U_1 G_0 t G_0 \, \mathcal{U}_{12} + U_2 G_0 t G_0 \, \mathcal{U}_{22}$$

$$\mathcal{U}_{22} = (1 + \zeta P_{34}) U_1 G_0 t G_0 \, \mathcal{U}_{12}$$

$\zeta = -1 \; (+1)$ for fermions (bosons)

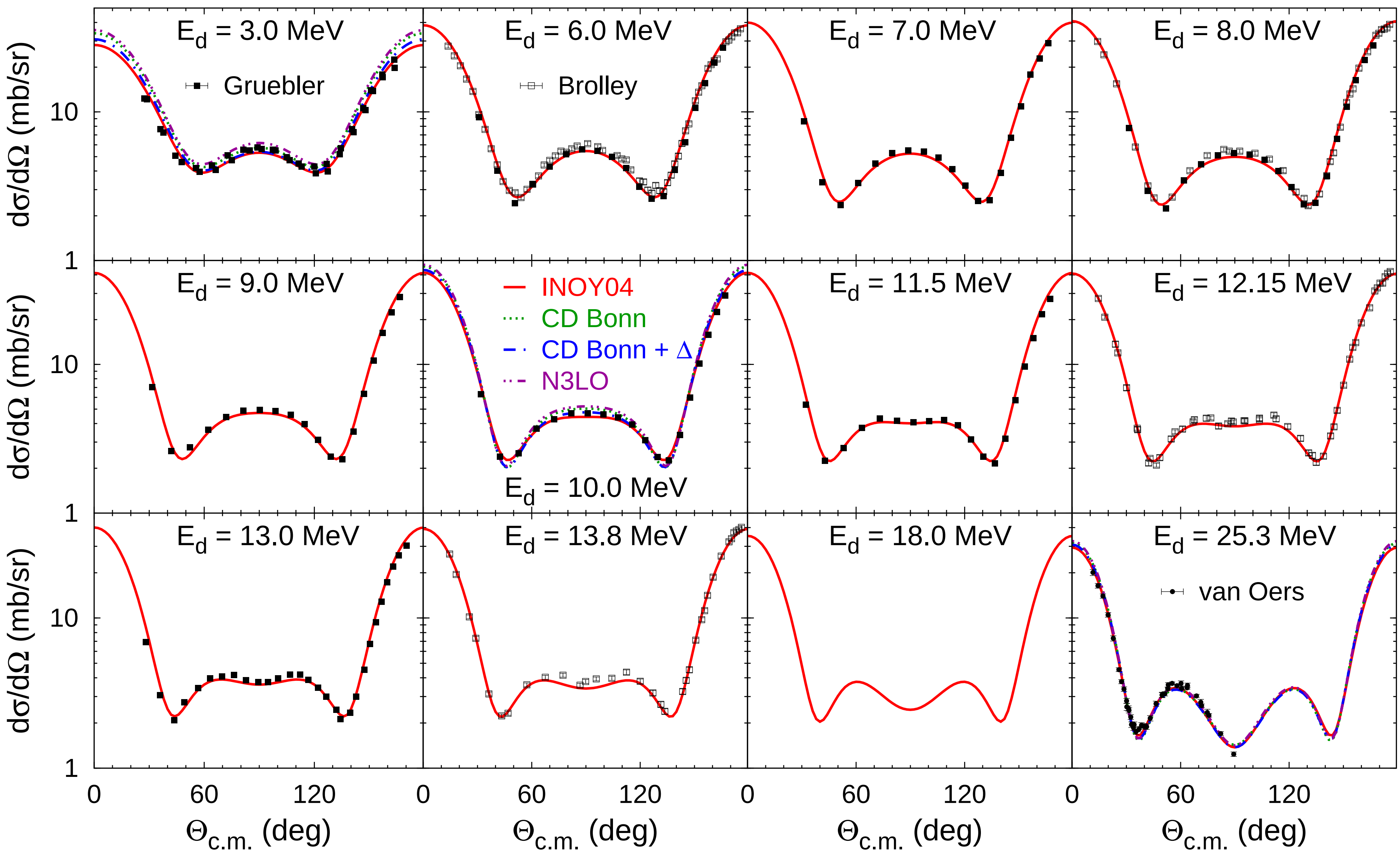
basis states partially symmetrized

n+^{3}He total and partial cross sections



[PRL 113, 102502; PRC 90, 044002]

Transfer reaction $^2\mathrm{H}(d,p)^3\mathrm{H}$

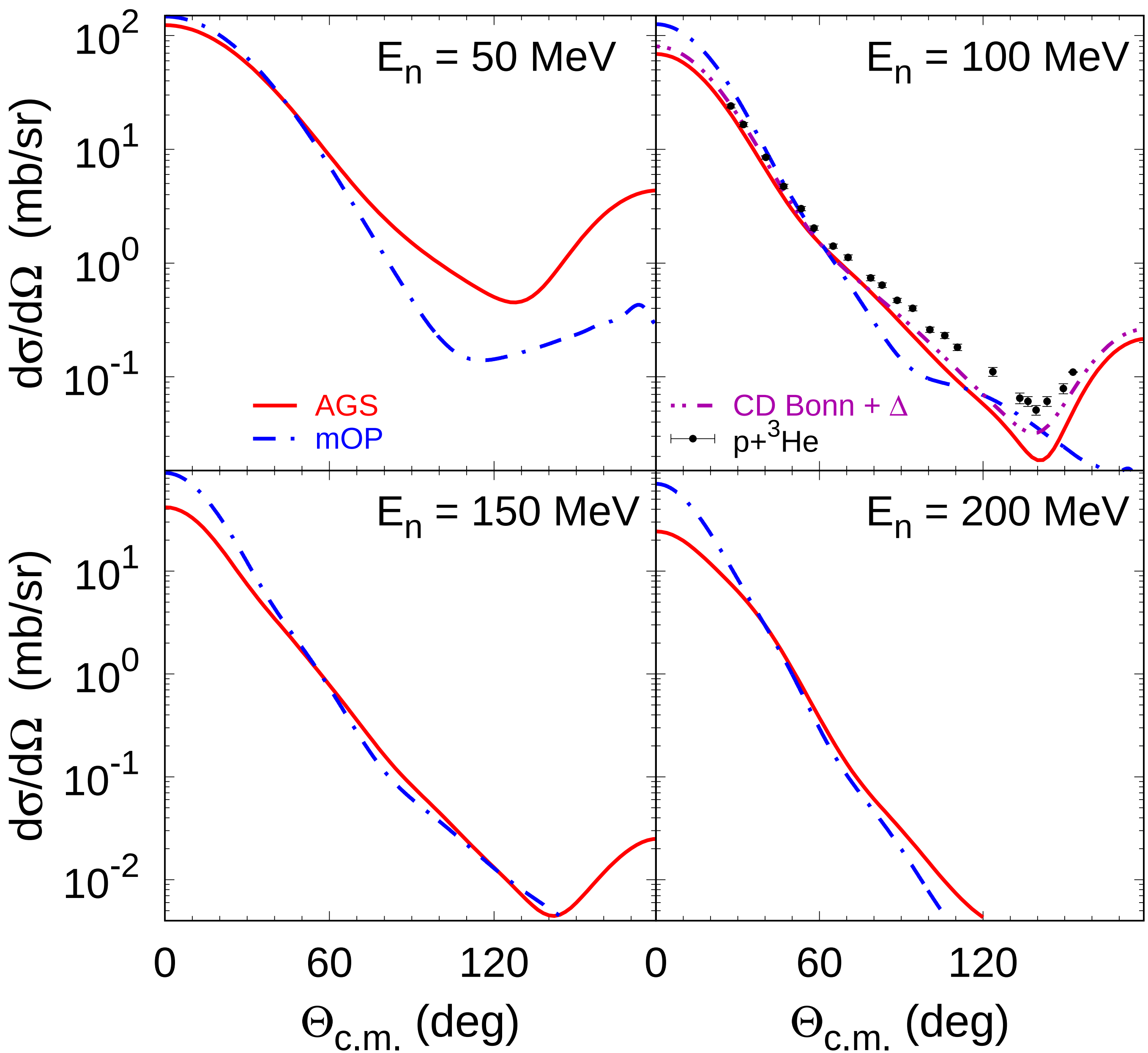


Microscopic OP

free nucleon-nucleon scattering matrix
folded with NCSM one-body density of target nucleus
[M. Vorabbi, P. Navratil et al., PRC 105, 014621]

test case:
$n + {}^3$H elastic scattering at intermediate energy,
NNLO$_{\mathrm{opt}}$ force

n+^{3}H: AGS vs microscopic OP



[preliminary!]

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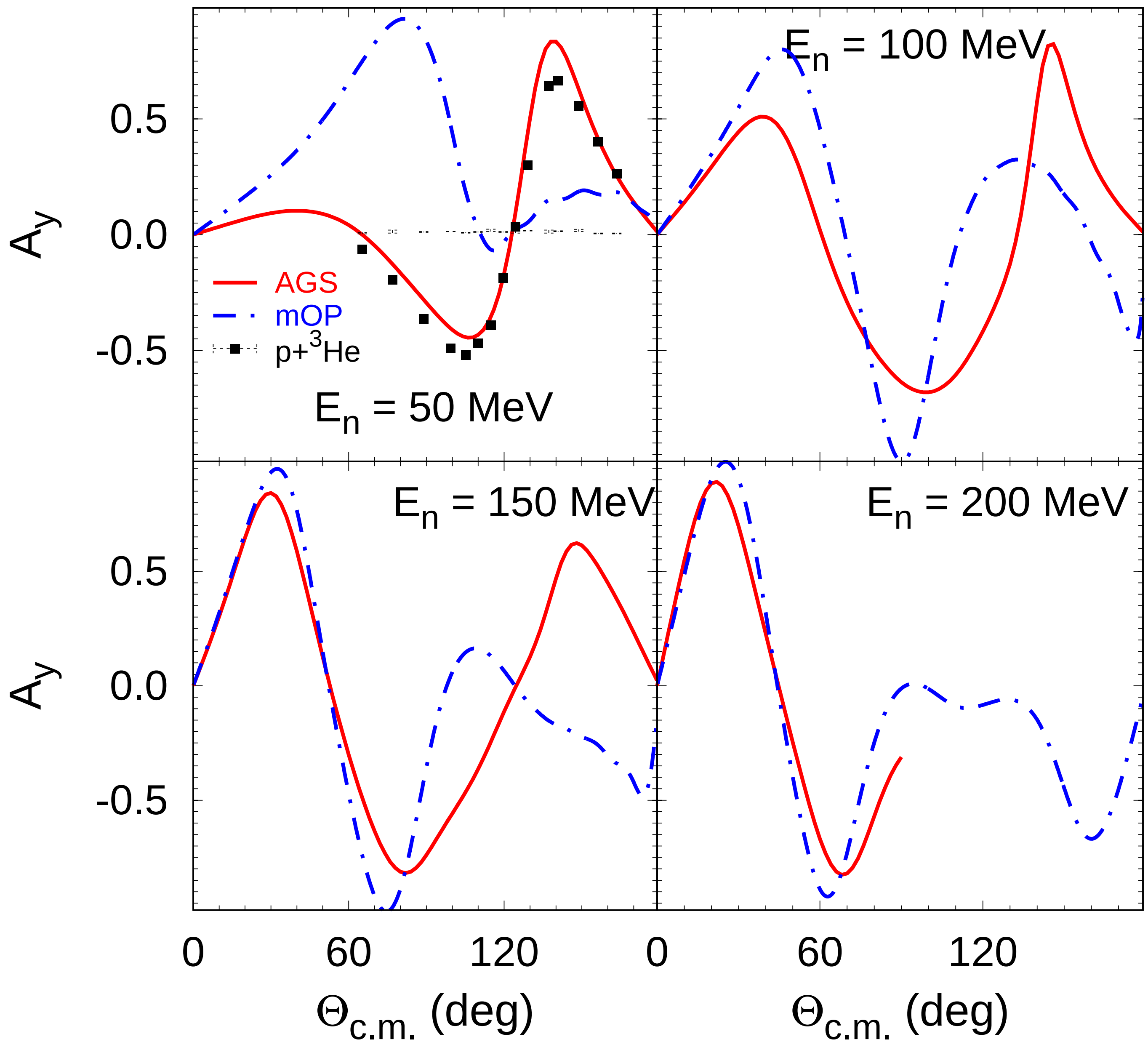

[preliminary!]

Summary

- nonlocal OP + core excitation + Faddeev theory: improved consistency in the description of 2- and 3-body reactions
- SF factorization energy-dependent
- (p, pN) beyond DWIA: $\rightarrow$ **talk by R. Crespo**
- scattering and resonant states in ΛNN-ΣNN hypernuclear systems
- testing microscopic OP by exact four-body calculation