Momentum-space calculation of ^{2}H(d,p)^{3}H and ^{2}H(d,n)^{3}He reactions

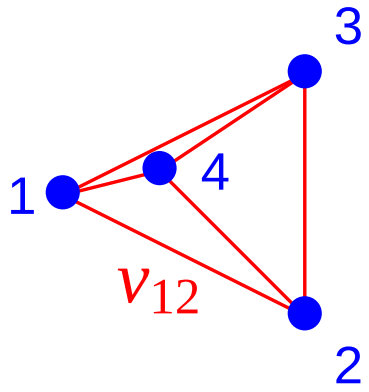
A. Deltuva

Centro de Física Nuclear da Universidade de Lisboa

Outline

- 4N scattering equations
- $^{2}H(d,p)^{3}H$ and $^{2}H(d,n)^{3}He$
- other 4N reactions

4N scattering



Hamiltonian $H_0 + \sum_{i>j} v_{ij}$

- Wave function:
  Schrödinger equation (HH + Kohn VP)
  [M. Viviani, A. Kievsky, L. E. Marcucci, S. Rosati, L. Girlanda]
- Wave function components:
  Faddeev-Yakubovsky equations
  [R. Lazauskas, J. Carbonell]
- Transition operators:
  Alt-Grassberger-Sandhas equations
  [AD, A. C. Fonseca]

Symmetrized AGS equations

$$t = v + vG_0 t$$

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

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

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

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

$$U_{11} = (G_0 t G_0)^{-1} \zeta P_{34} + \zeta P_{34} u_1 G_0 t G_0 U_{11} + u_2 G_0 t G_0 U_{21}$$

$$U_{21} = (G_0 t G_0)^{-1} (1 + \zeta P_{34}) + (1 + \zeta P_{34}) u_1 G_0 t G_0 U_{11}$$

$$U_{12} = (G_0 t G_0)^{-1} + \zeta P_{34} u_1 G_0 t G_0 U_{12} + u_2 G_0 t G_0 U_{22}$$

$$U_{22} = (1 + \zeta P_{34}) u_1 G_0 t G_0 U_{12}$$

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

basis states partially symmetrized

Scattering amplitudes

2-cluster reactions:

$$T_{fi} = s_{fi}\langle\phi_f|U_{fi}|\phi_i\rangle$$
$$|\phi_j\rangle = G_0 t P_j |\phi_j\rangle$$
$$|\Phi_j\rangle = (1+P_j)|\phi_j\rangle$$

3-cluster breakup/recombination:

$$T_{3i} = s_{3i}\langle\phi_3|[(1+\zeta P_{34})u_1 G_0 t G_0 U_{1i} + u_2 G_0 t G_0 U_{2i}]|\phi_i\rangle$$

4-cluster breakup/recombination:

$$T_{4i} = s_{4i}\{\langle\phi_4|[1+(1+P_1)\zeta P_{34}](1+P_1)tG_0\, u_1 G_0 t G_0 U_{1i}|\phi_i\rangle$$
$$+\langle\phi_4|(1+P_1)(1+P_2)tG_0\, u_2 G_0 t G_0 U_{2i}|\phi_i\rangle\}$$

Wave function

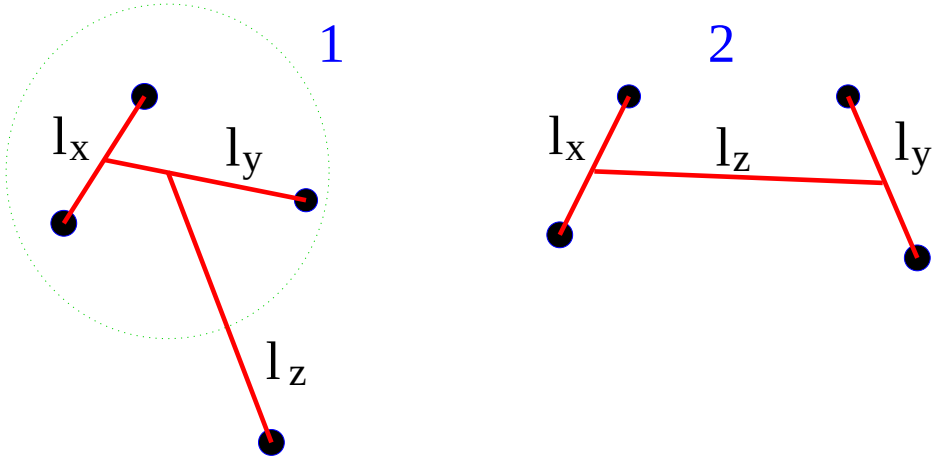
$$|\Psi_i\rangle = s_i\{[1+(1+P_1)\zeta P_{34}](1+P_1)|\psi_{1,i}\rangle + (1+P_1)(1+P_2)|\psi_{2,i}\rangle\}$$

with Faddeev-Yakubovsky components

$$|\psi_{j,i}\rangle = \delta_{ji}|\phi_i\rangle + G_0 t G_0 u_j G_0 t G_0 U_{ji}|\phi_i\rangle$$

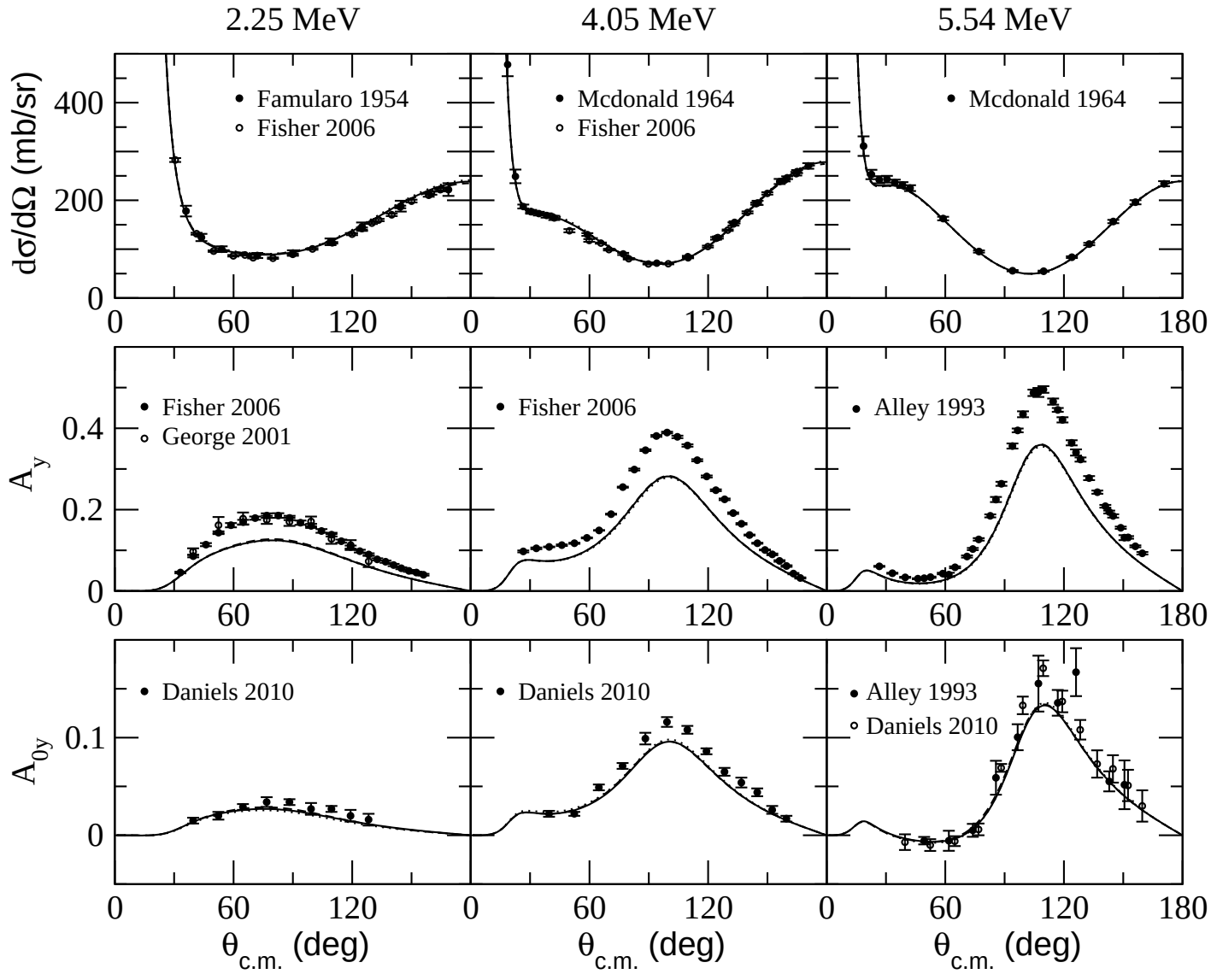
Solution of 4N AGS equations

$$U_{12}|\phi_2\rangle = G_0^{-1}P_2|\phi_2\rangle - P_{34}u_1 G_0 t G_0 U_{12}|\phi_2\rangle + u_2 G_0 t G_0 U_{22}|\phi_2\rangle$$



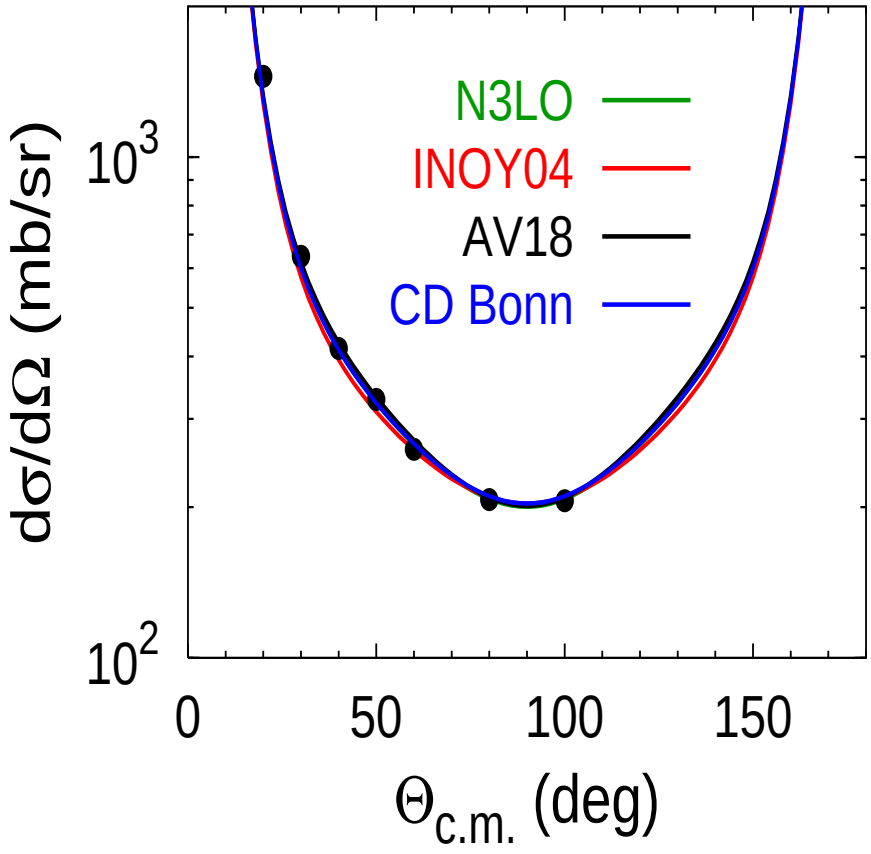
- momentum-space partial-wave basis
  $|k_x k_y k_z [l_z(\{l_y[(l_x S_x) j_x s_y] S_y\} J_y s_z) S_z] JM, [(T_x t_y) T_y t_z] T M_T\rangle_1$
  $|k_x k_y k_z [l_z\{(l_x S_x) j_x [l_y(s_y s_z) S_y] j_y\} S_z] JM, [T_x(t_y t_z) T_y] T M_T\rangle_2$
- large system (up to 30000) of coupled 3-variable integral equations with integrable singularities
- Coulomb interaction: screening and renormalization
  [PRC 75, 014005; PRL 98, 162502]

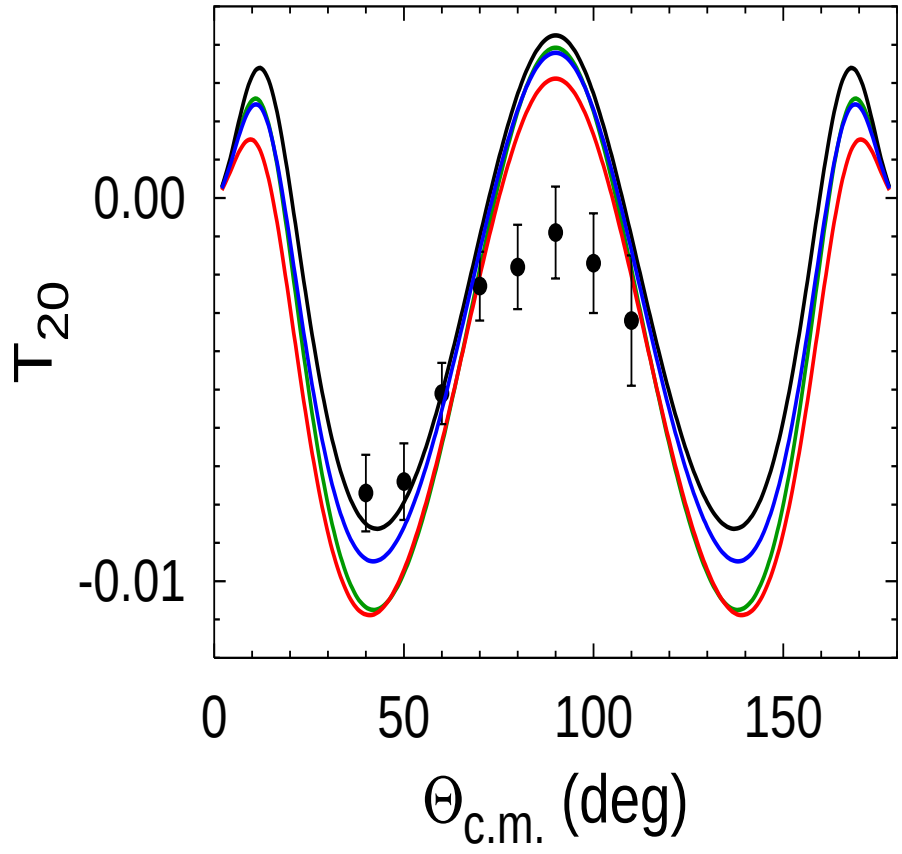
AGS/HH/FY: p+^{3}He elastic scattering



[PRC 84, 054010]

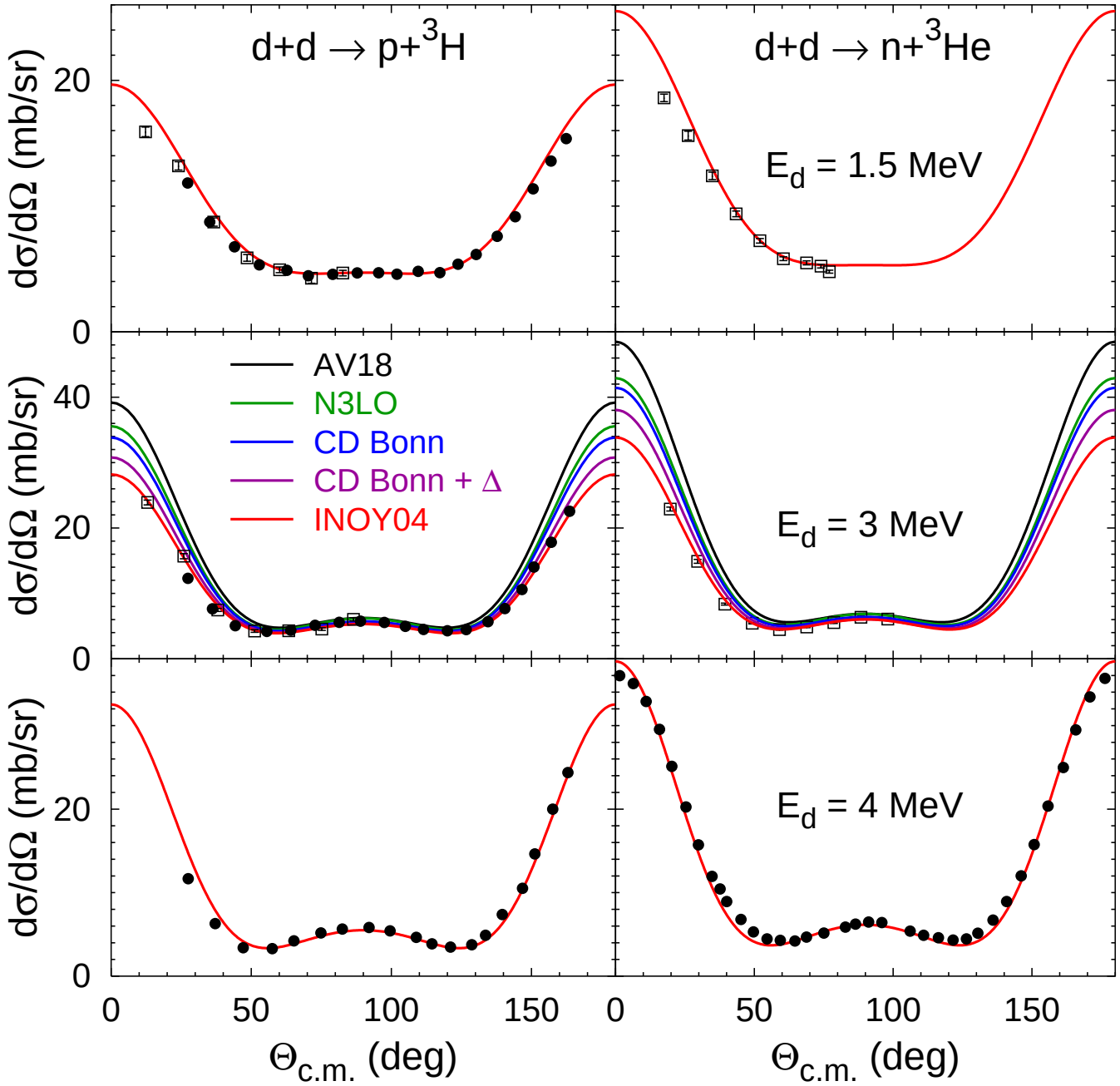
d+d elastic scattering at $E_d = 3$ MeV





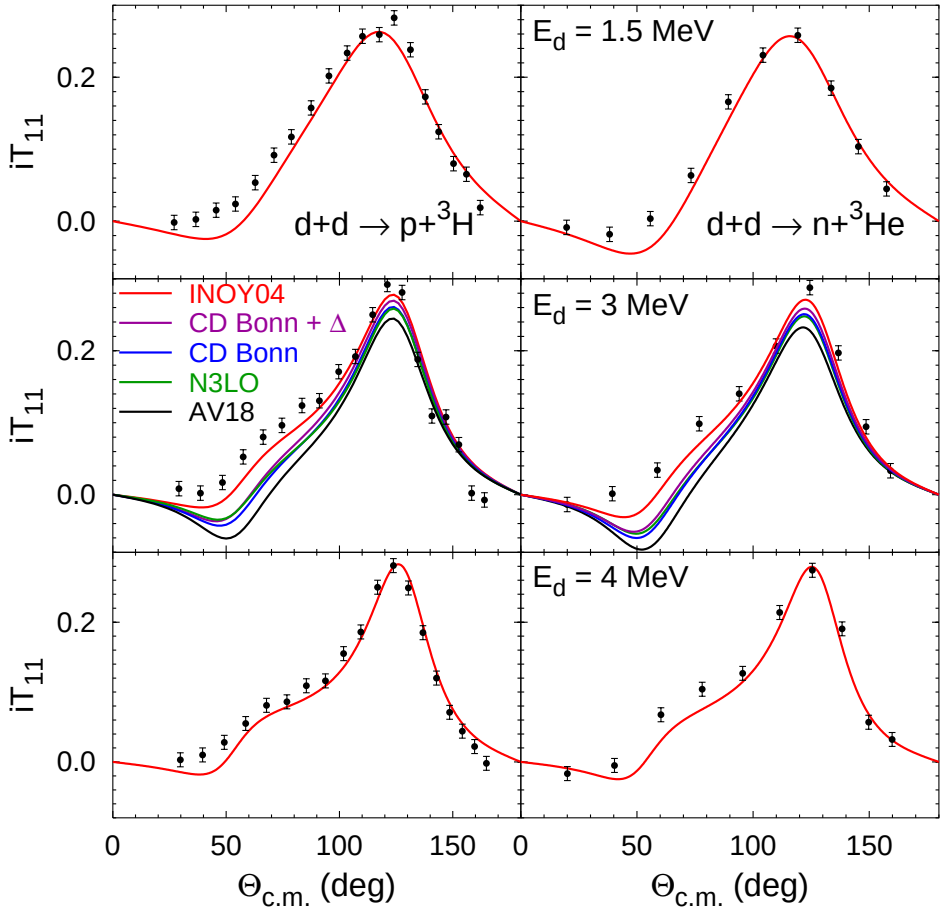
[PLB 660, 471]

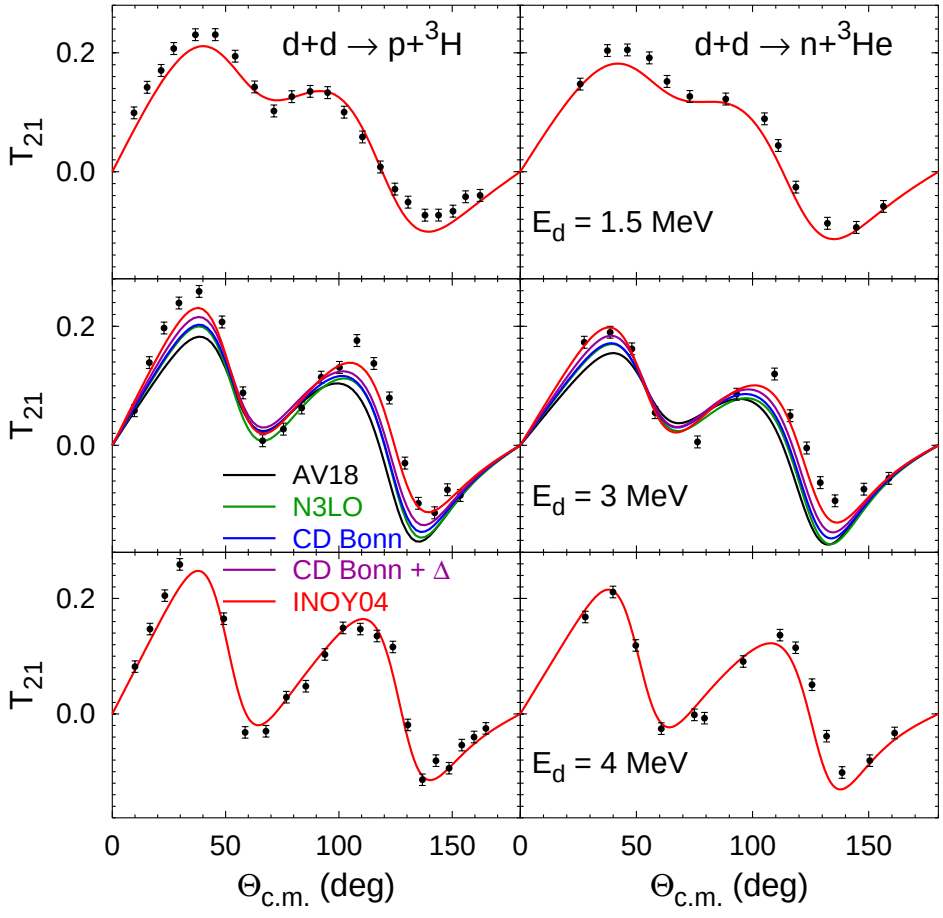
^{2}H(d,p)^{3}H and ^{2}H(d,n)^{3}He – cross section



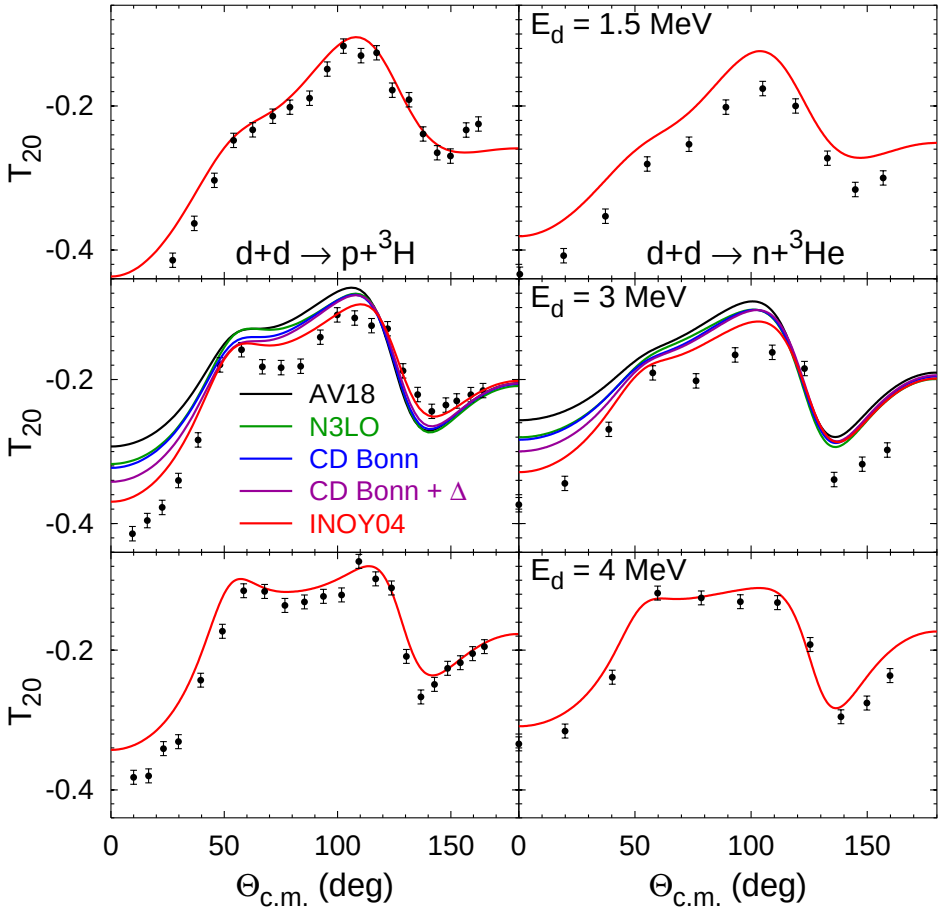
[PRC 81, 054002]

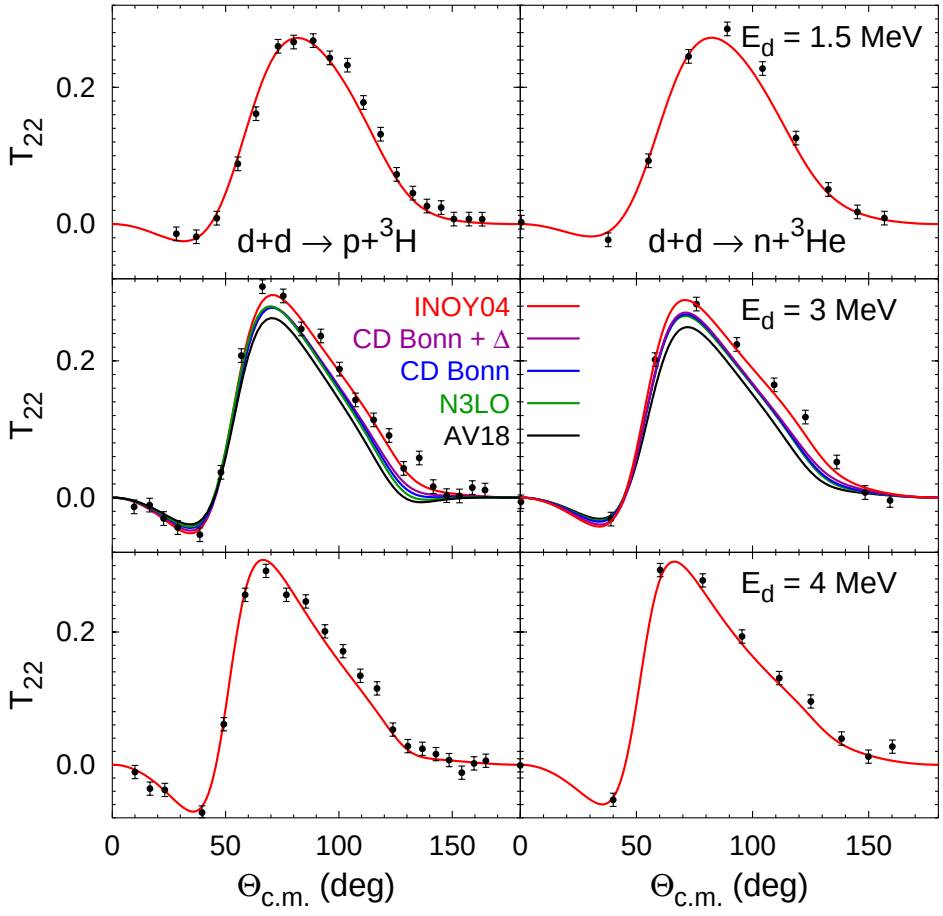
^{2}H(d,p)^{3}H and ^{2}H(d,n)^{3}He – analyzing powers



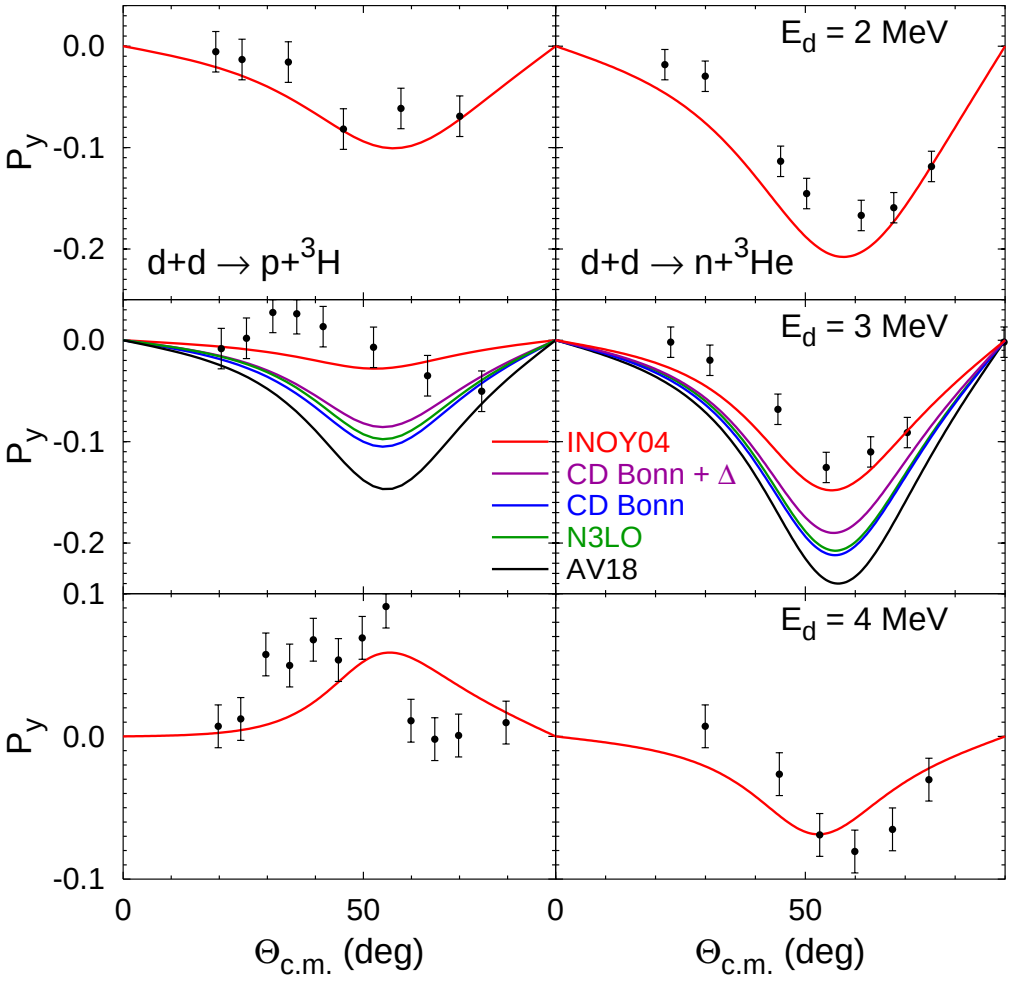


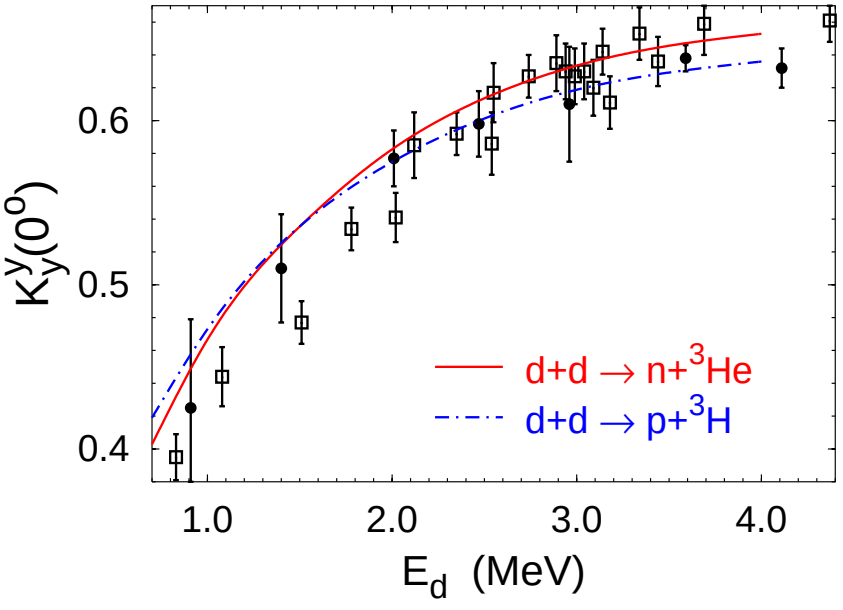
^{2}H(d,p)^{3}H and ^{2}H(d,n)^{3}He – analyzing powers



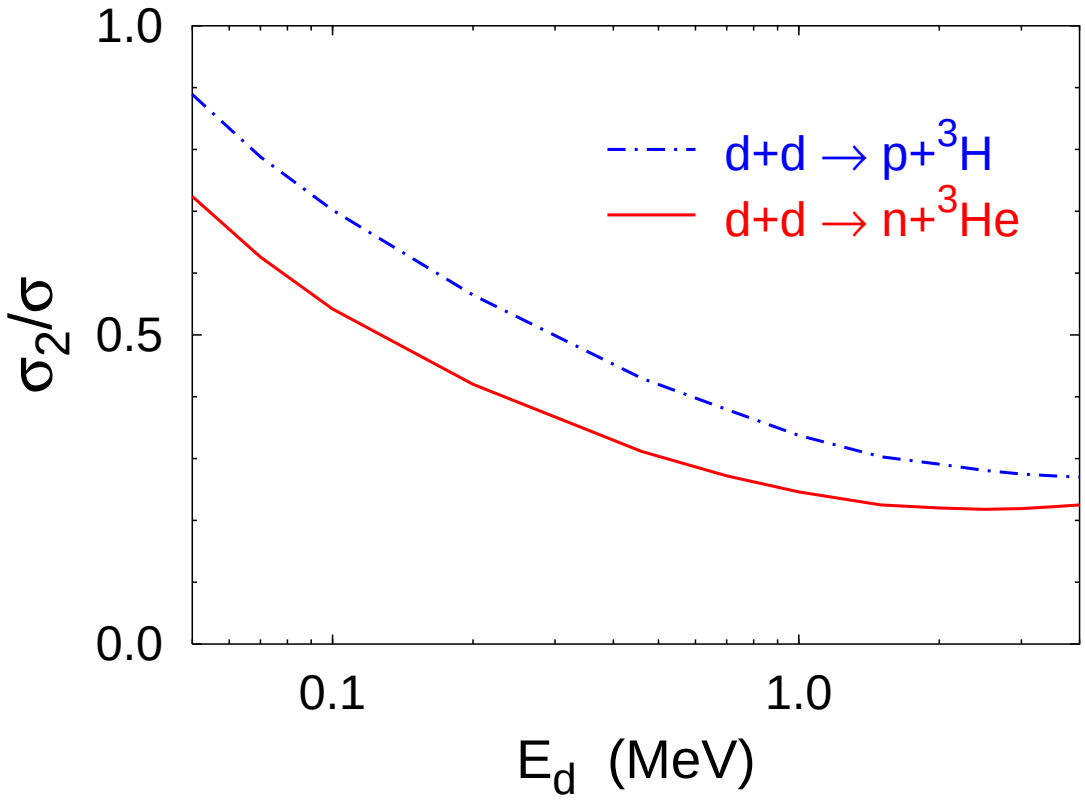


^{2}H(d,p)^{3}H and ^{2}H(d,n)^{3}He – final-state polarization



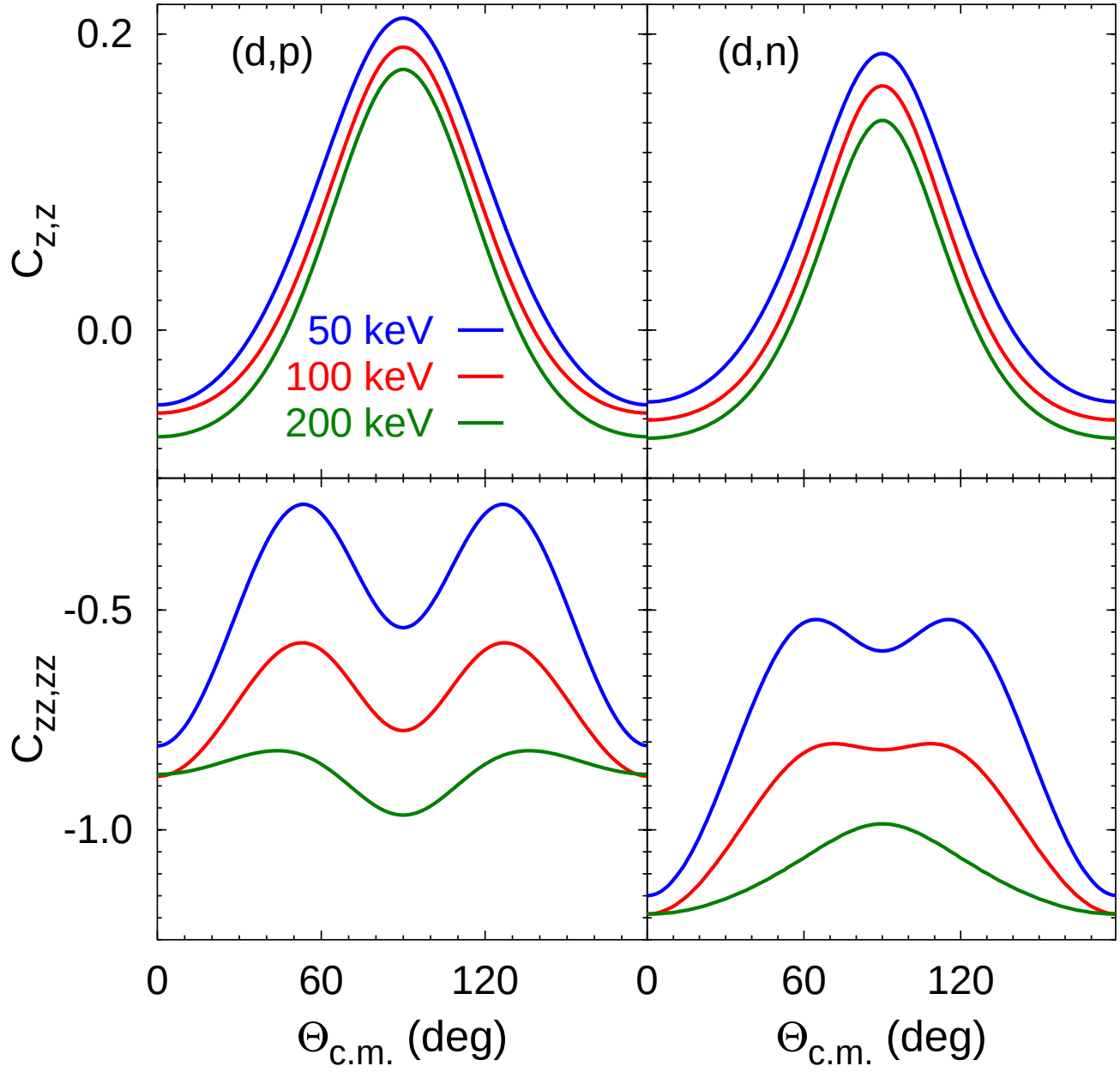


^{2}H(d,p)^{3}H and ^{2}H(d,n)^{3}He – QSF

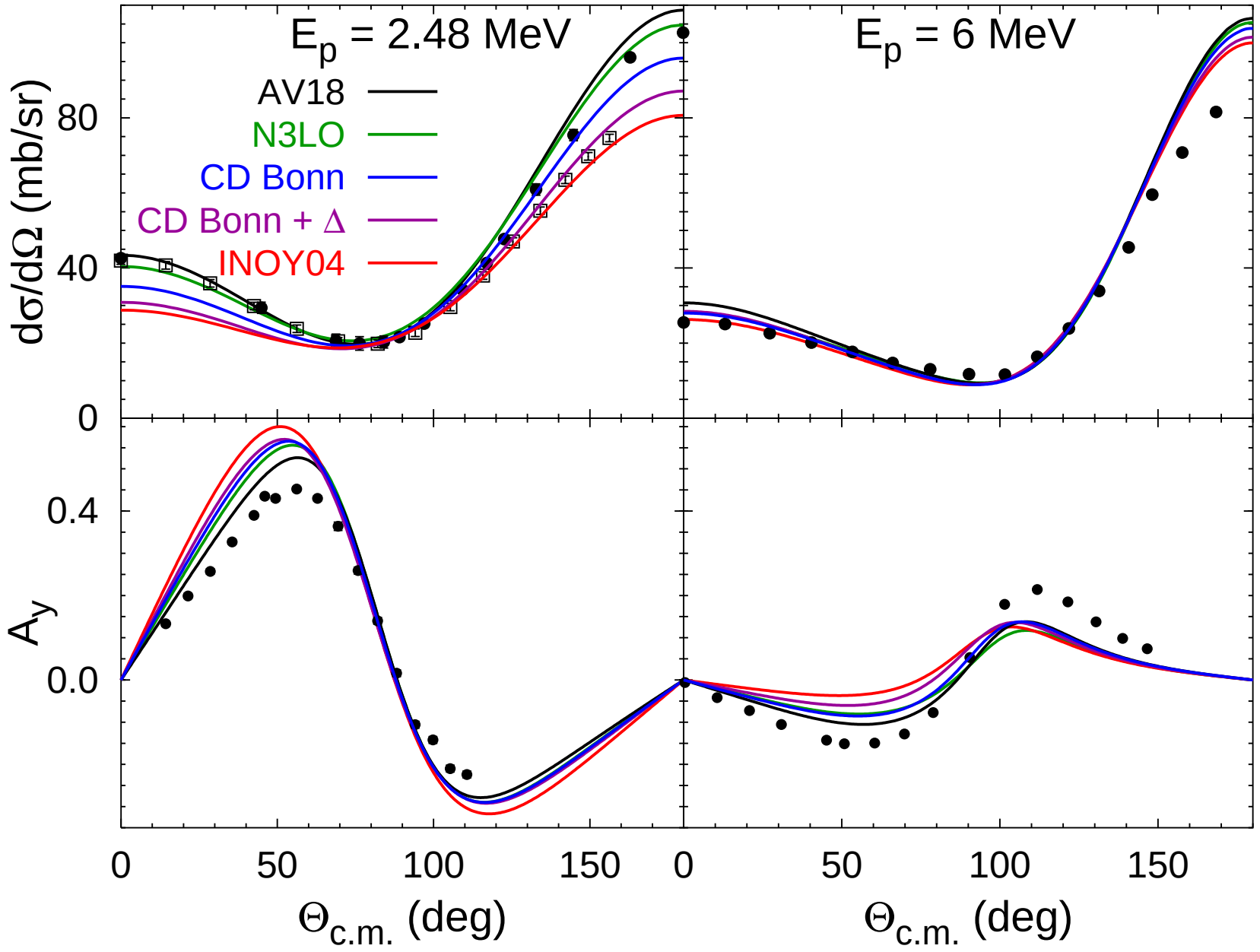


$$\sigma_{11}/\sigma - \sigma_2/\sigma < 0.025$$

$^{2}H(d,p)^{3}H$ and $^{2}H(d,n)^{3}He$ – spin correlation

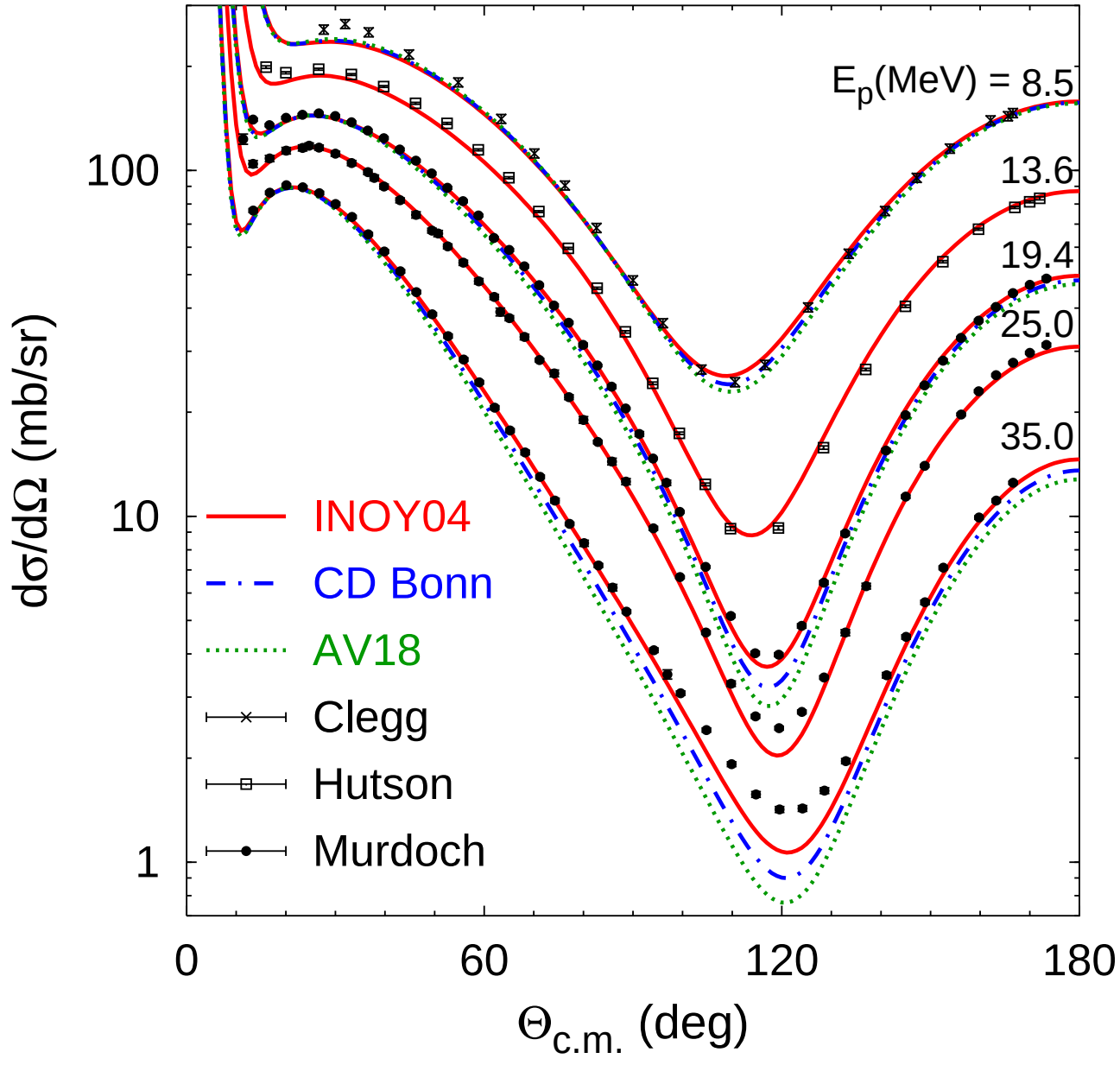


Charge exchange reaction $^3H(p,n)^3He$



[PRC 76, 021001]

p+^{3}He elastic scattering



[PRC 87, 054002]

Summary

- 4N scattering:
  AGS equations in momentum space

- so far quite successful description (INOY04)
  of ^{2}H(d,p)^{3}H and ^{2}H(d,n)^{3}He reactions
- spin correlation, very low energies?

- interesting physics in other 4N reactions