(p,t) transfer reactions studied within the CRC framework

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Two-nucleon transfers are significantly more complicated than their single-nucleon brethren

The mechanism can be more complicated: two-step sequential transfer in addition to the direct path

The two-nucleon form factors for the direct transfer step may require a more sophisticated approach than the usual well-depth prescription

This makes it even more difficult to derive empirical “spectroscopic factors” from the angular distribution data …

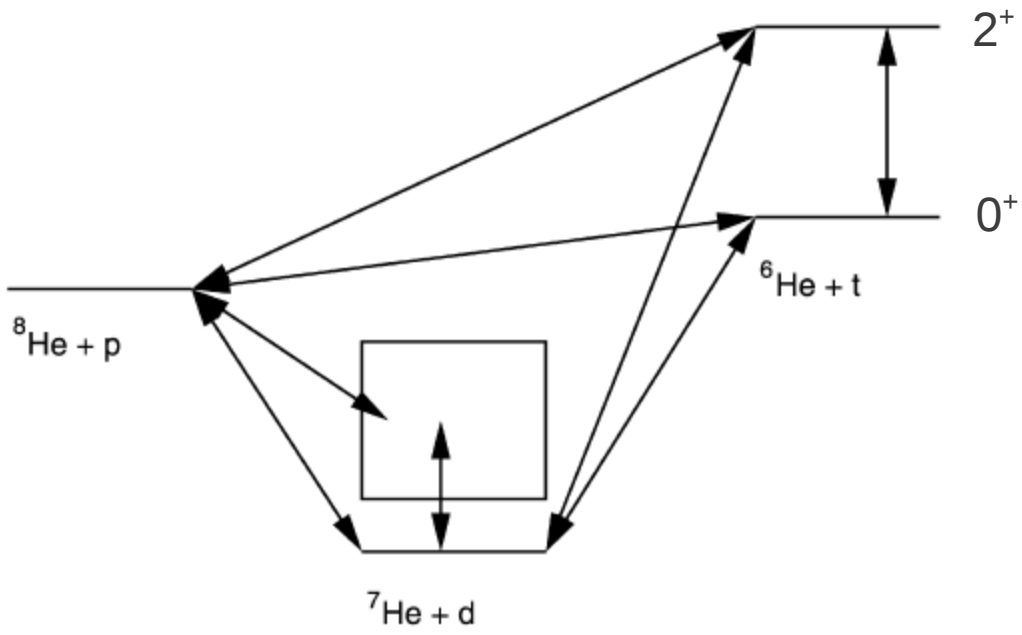
For (p,t) reactions, we also have the added complication that the intermediate (p,d) step involves deuteron breakup effects

Thus, to perform the best analysis we can, we more than ever need as complete a data set as possible – ideally elastic scattering, (p,d) and (p,t). Depending on the system, we may also require inelastic scattering.

For our test case, we take the ^{8}He(p,t)^{6}He reaction at 15.7 MeV/nucleon. Calculations with FRESCO, Comput. Phys. Rep. **7**, 167 (1988).

The calculations were briefly described in Phys. Lett. **B 646**, 222 (2007)

We make the simplifying assumption that we can use the standard well-depth prescription for the ^{2}n form factors but we treat deuteron breakup explicitly via CDCC



We can fix the $<^{8}He|^{7}He+n>$ spectroscopic amplitude by fitting the (p,d) data

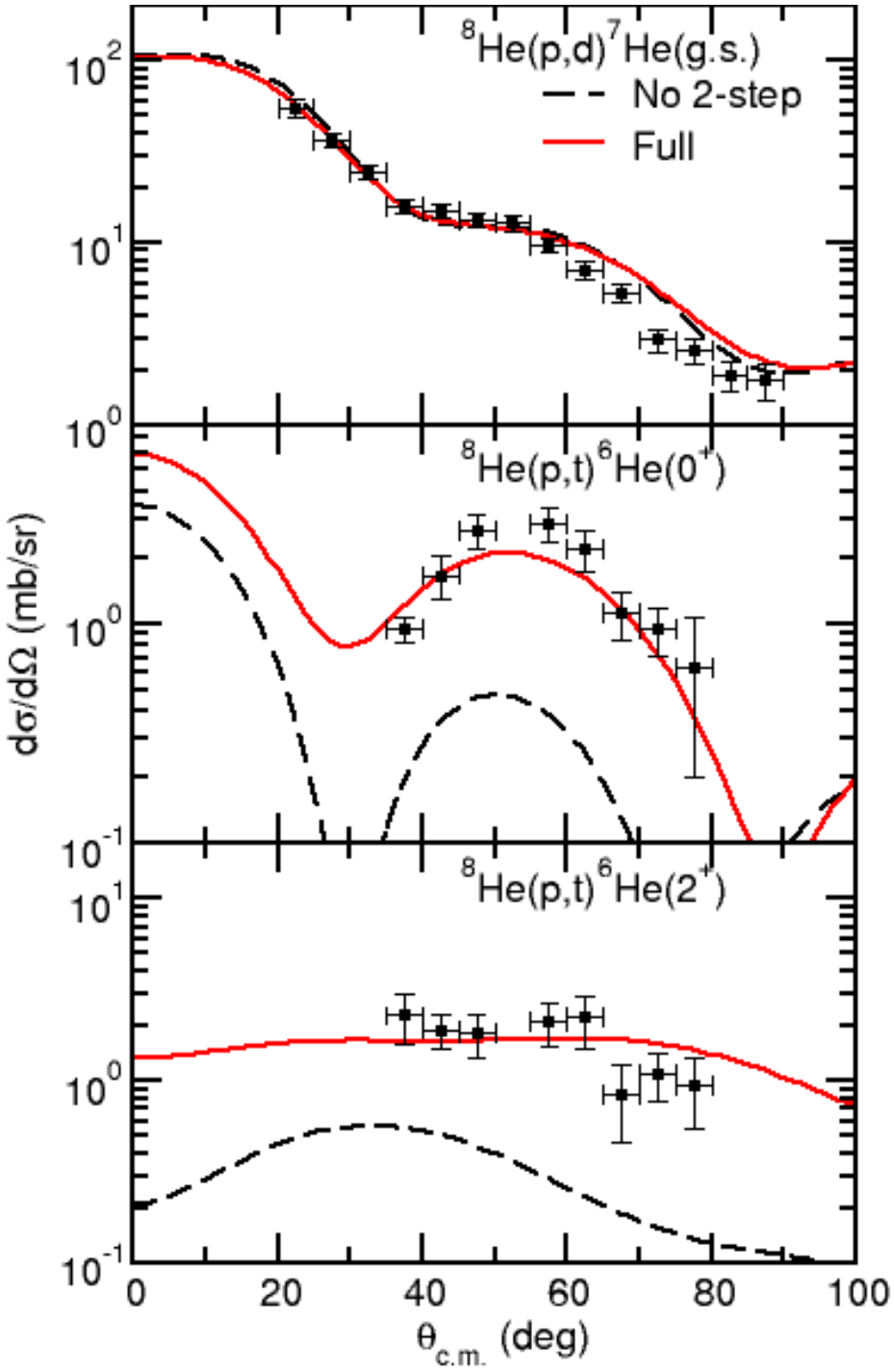
Other amplitudes have to be fixed by theory: <d|n+p>, <t|d+n>, <t|p+2n>, $<^{7}He|^{6}He(0^{+})+n>$ and $<^{7}He|^{6}He(2^{+})+n>$

All so that we can fix the $<^{8}He|^{6}He(0^{+})+2n>$ and $<^{8}He|^{6}He(2^{+})+2n>$ amplitudes by fitting the (p,t) data!

After all that, how do the calculations compare with the data?

Fit is good: loss of flux from (p,d) via 2-step transfer path is negligible but 2-step sequential transfer very important for (p,t) …

Nucleus	Configuration	nlj	SA
^{8}He	^{2}n+^{6}He$_{0+}$	2S$_{0}$	1.0
^{8}He	^{2}n +^{6}He$_{2+}$	1D$_{2}$	0.12
^{8}He	n+^{7}He$_{3/2-}$	1p$_{3/2}$	1.7
^{7}He	n+^{6}He$_{0+}$	1p$_{3/2}$	-0.728
^{7}He	n+^{6}He$_{2+}$	1p$_{3/2}$	-1.327



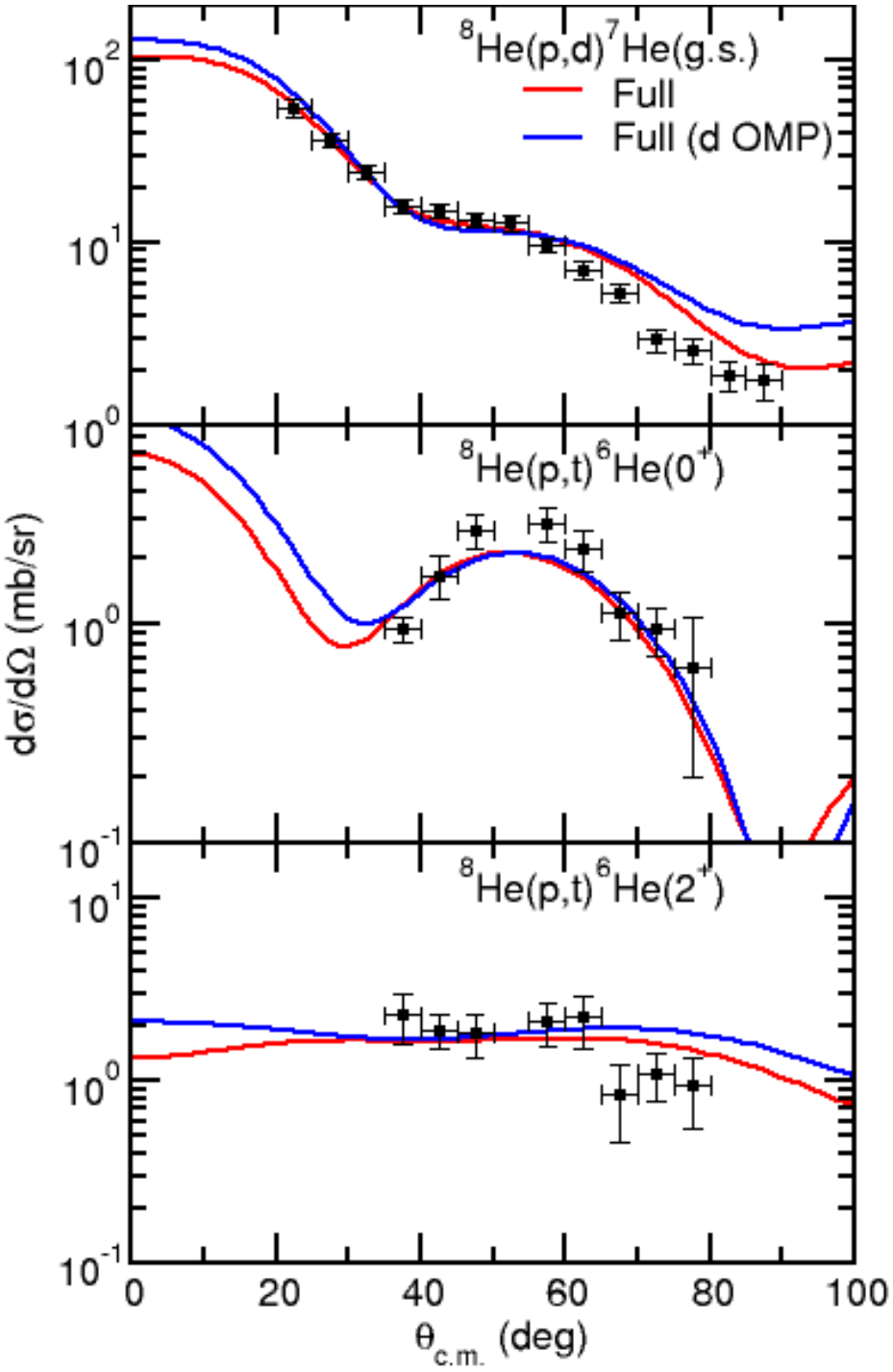
Results show importance of multi-step paths

But: we have assumed transfer of a structureless "di-neutron"-like particle. Seems to be adequate for light targets, as here, but fails completely for heavy targets like ^{208}Pb

Also, is CDCC treatment of breakup really necessary in context of (p,t) analysis? Would a simple deuteron optical model or adiabatic model potential suffice? If there are more than 1-2 states in the (p,d) partition this could be a major problem …

In this case, it appears not: (p,t) to ^{6}He(0^{+}) possible exception

Replaced CDCC treatment with global deuteron OMP: Daehnick *et al*., Phys. Rev. C **21**, 2253 (1980) and re-tuned entrance channel p+^{8}He OMP. All other inputs unchanged



Returning to the 2n form factors: can we improve on the simple well-depth prescription and the assumption of a structureless “di-neutron” cluster?

Yes, in two ways:

1) Generate 2n form factor from combinations of 1n form factors: Bayman and Kallio, Phys. Rev. **156**, 1121 (1967)

2) Read in theoretical 2n form factors (possible in FRESCO if format is right)

Both methods allow a more realistic treatment of the form factors, particularly for the <t|p+2n> overlap

Bayman-Kallio has been more widely used to date – although shapes are well described absolute values of cross sections often badly off: “enhancement” factors can be up to x 20 in DWBA calculations …

Depending on target, this could be due to neglect of multi-step transfer paths: not just sequential neutron transfer but also transfers via inelastic excitations in entrance and exit partitions

As an example of this, we shall investigate the $^{14}C(p,t)^{12}C$ reaction at an incident proton energy of 40 MeV

Good data set available, although unfortunately not for the intermediate $^{14}C(p,d)^{13}C$ reaction

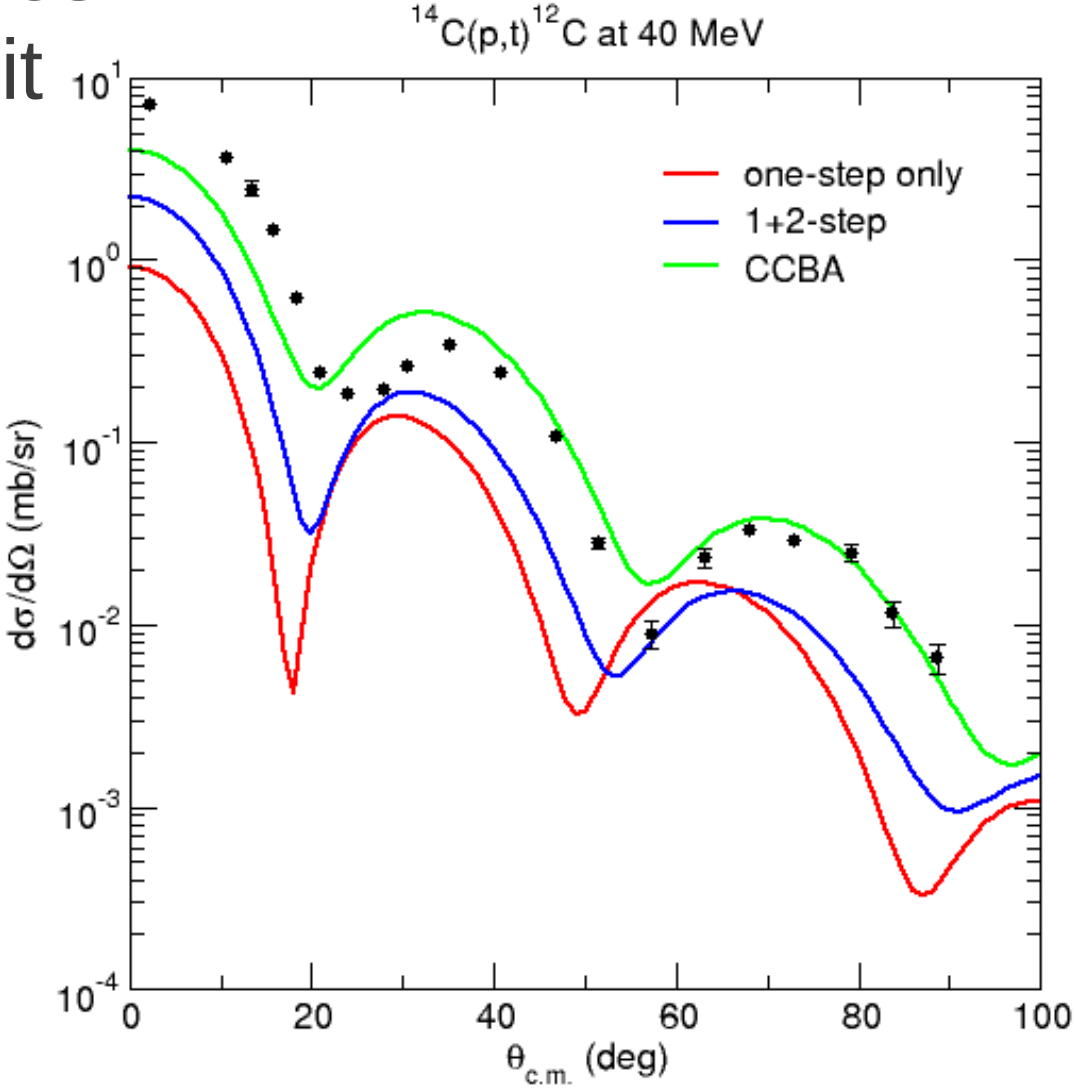
Necessary spectroscopic amplitudes are also available – an important point!

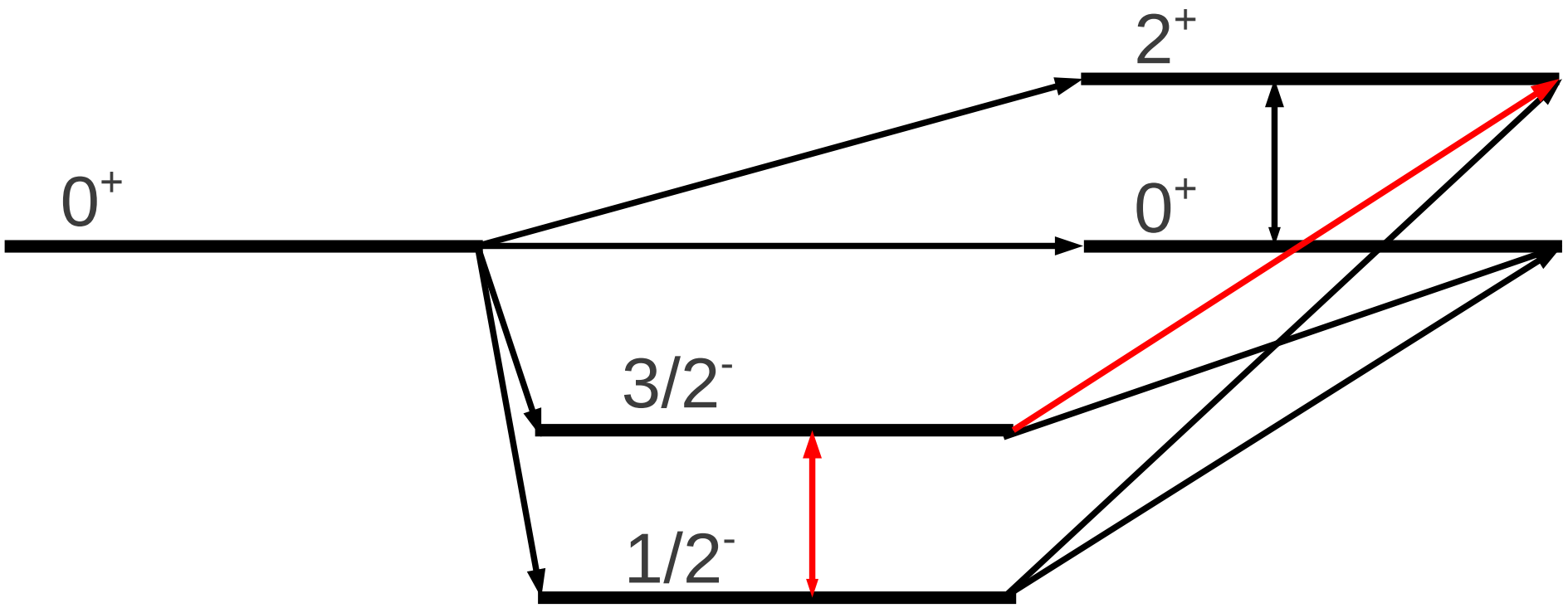
Compares 1 + 2-step DWBA with CCBA (includes $^{12}C\ 0^+ \rightarrow 2^+$ coupling in exit partition)

Data and spectroscopic amplitudes from Yasue *et al*., Nucl. Phys. **A510**, 285 (1990)

Uses Bayman-Kallio for $<^{14}C|^{12}C+2n>$ and simplified <t|p+2n> of similar type

$^{12}C\ 0^+$



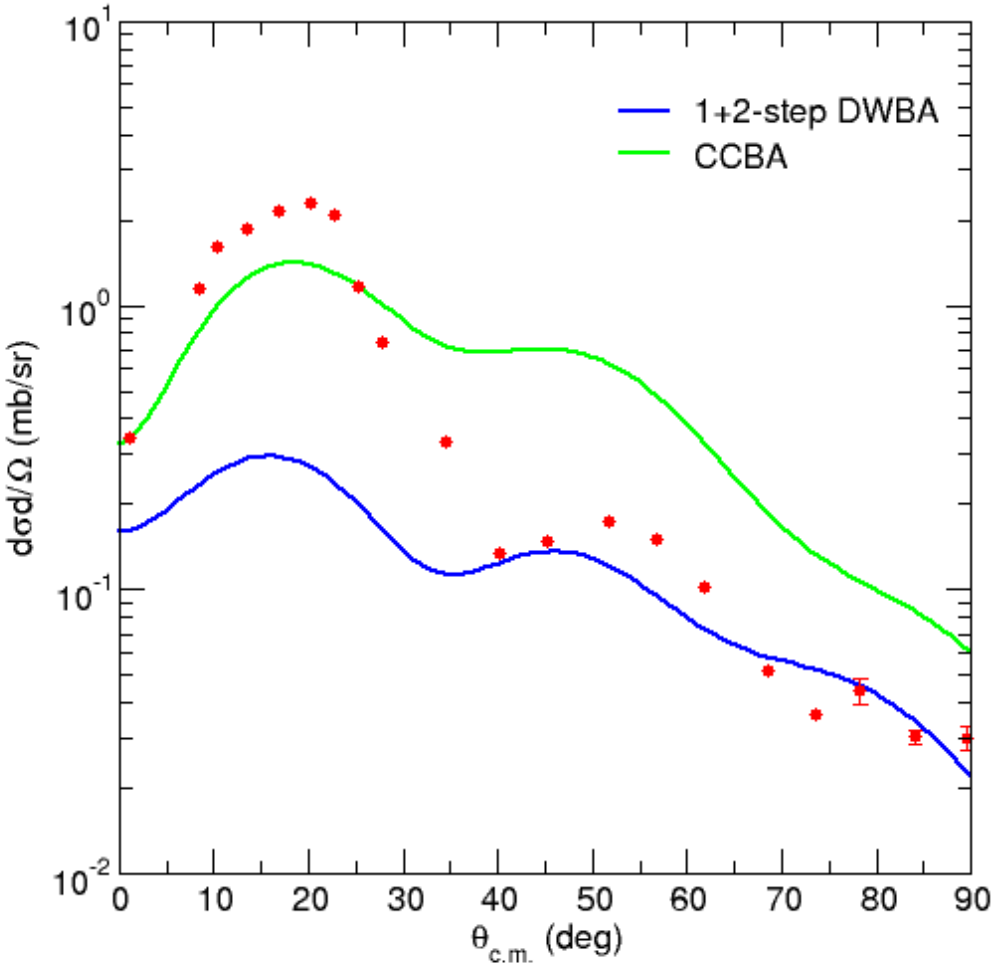


p + ^{14}C d + ^{13}C t + ^{12}C

CCBA coupling scheme still relatively simple …

Further couplings could easily be added, but the necessary spectroscopic amplitudes were not available (note that the *amplitudes*, with their correct signs, are needed)

CCBA much improved, even over 1+2-step DWBA, but still not perfect: ^{12}C 2^+ is rather poorly described too …



Note that all amplitudes in ^{14}C(p,t) calculations come from structure calculations, including the necessary amplitudes for constructing the Bayman-Kallio 2n form factors

There are simply too many to attempt to fix them by fitting data

Could also improve things by using a structure calculation for the <t|p+2n> overlap

Final conclusion is that rather than attempting to fit data and thus obtain empirical “spectroscopic factors” the way forward is to use theoretical form factors directly in the reaction calculations and test whether the data can be described with appropriate modelling of the reaction mechanism

Dziękuję za uwagę!