Compatibility of nuclear structure information extracted from heavy-ion and light-ion reactions

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With their often pronounced selectivity direct nuclear reactions are useful tools to obtain information about specific aspects of nuclear structure.

However, the structure quantities are not observables and we are therefore dependent on nuclear reaction models to infer them from the measured quantities (most often angular distributions of the differential cross section, $d\sigma/d\Omega$).

Naturally, the structure quantities should not depend on either the reaction used to obtain them or the energy at which the reaction is performed; if they do the reaction model is at fault.

A frequently quoted structure quantity is the so-called ANC or asymptotic normalisation coefficient. It is much less sensitive to aspects of the calculations not linked to the reaction mechanism than the more familiar spectroscopic factor.

However, any sensitivity to the completeness of the reaction model or choice of inputs directly associated with it remains. Validity of the ANC also depends on the reaction being truly peripheral, i.e. it takes place well outside the nuclear interior.

Thus, we would ideally like a reaction that is both wholly peripheral and at the same time has a simple mechanism (proceeds in a single step).

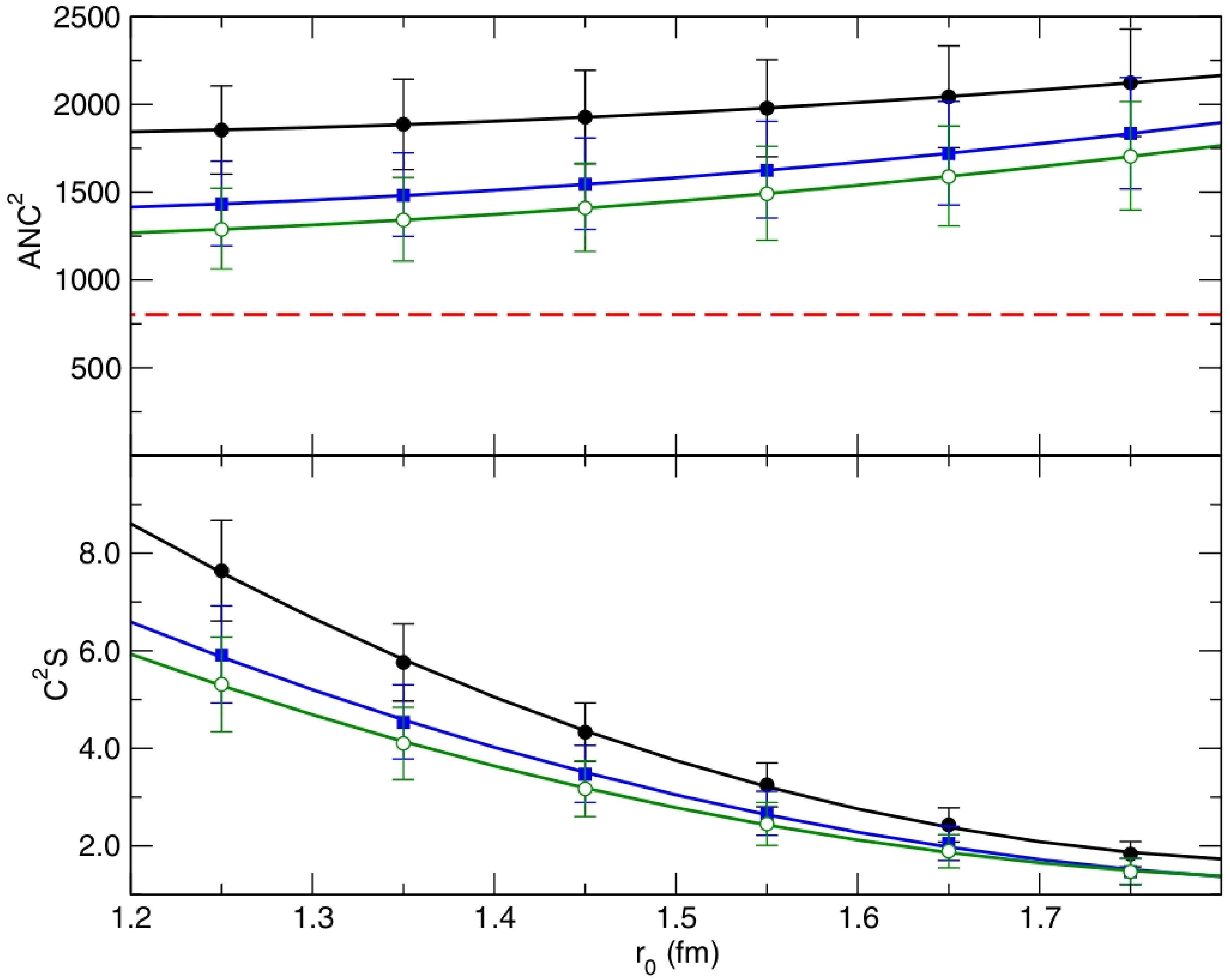
Light ion (p, d, t, ^{3}He, ^{4}He) reactions have been most frequently used to obtain structure information, usually using the DWBA to model the reaction: assumes single step transfer weak enough to be described by perturbation theory.

Such reactions are not always truly peripheral at the most convenient energies. On the other hand, reactions induced by heavy ions almost always are, but frequently involve multi-step paths and/or strong couplings so that use of the DWBA to model the reaction can lead to erroneous results.

Can we reconcile the two and obtain a consistent ANC from both?

Recently, we extracted the ANC for the <^{14}C|^{13}B+p> overlap from an analysis of ^{14}C(^{11}B,^{12}C)^{13}B data [S.Yu. Mezhevych *et al.*, Phys. Rev. C **105**, 024615 (2022)]. A relatively complete data set (elastic, inelastic, transfer) enabled realistic modelling of multi-step paths.

The most complete reaction model (green) yielded an ANC^2 about 25% smaller than the DWBA (black).



Source	ANC^2 (fm^{-1})
DWBA	2044 ± 168
CRC (no ^{13}B reor)	1716 ± 170
CRC (^{13}B reor)	1532 ± 138
Theoretical (STA) [14]	803

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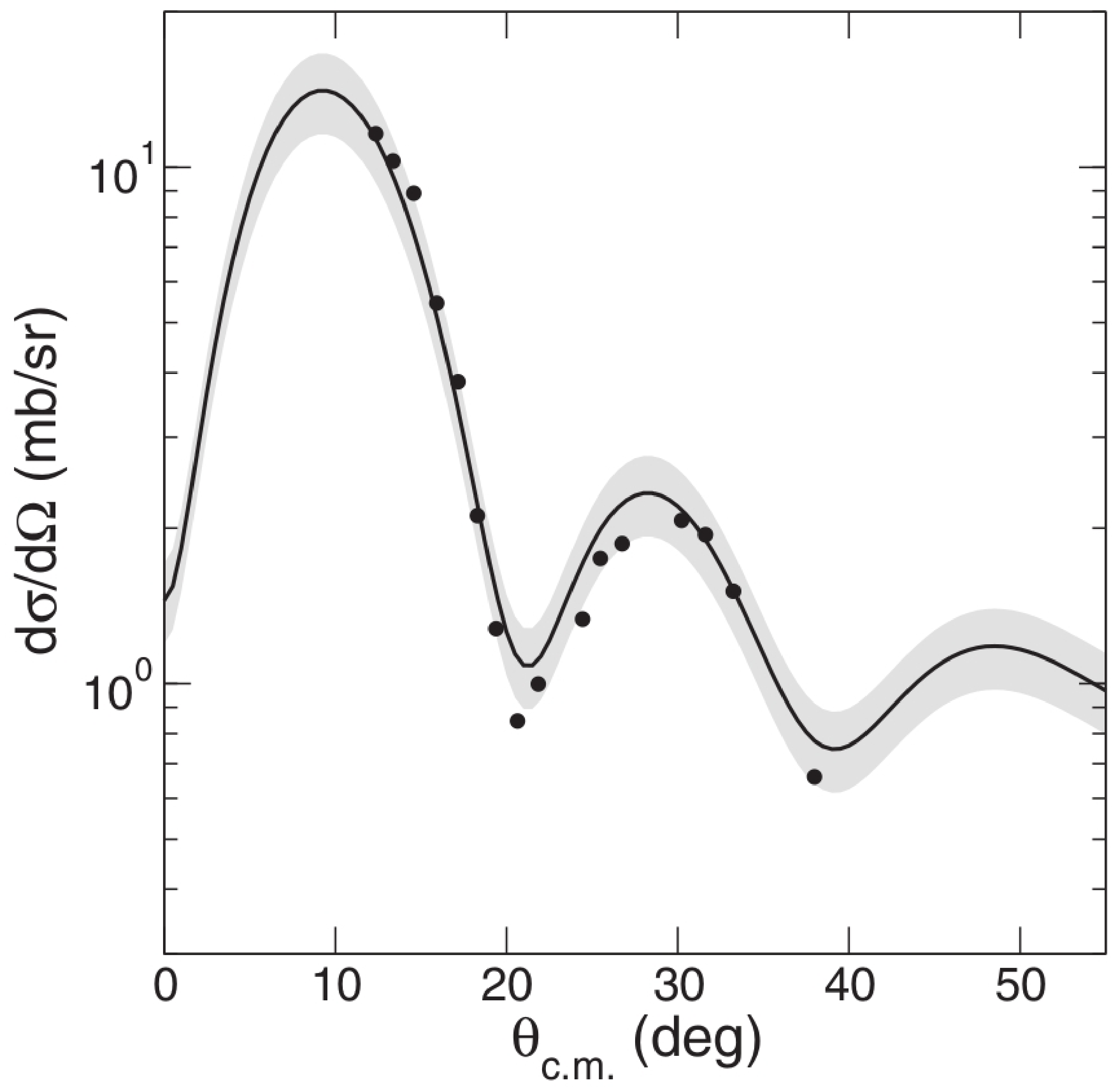
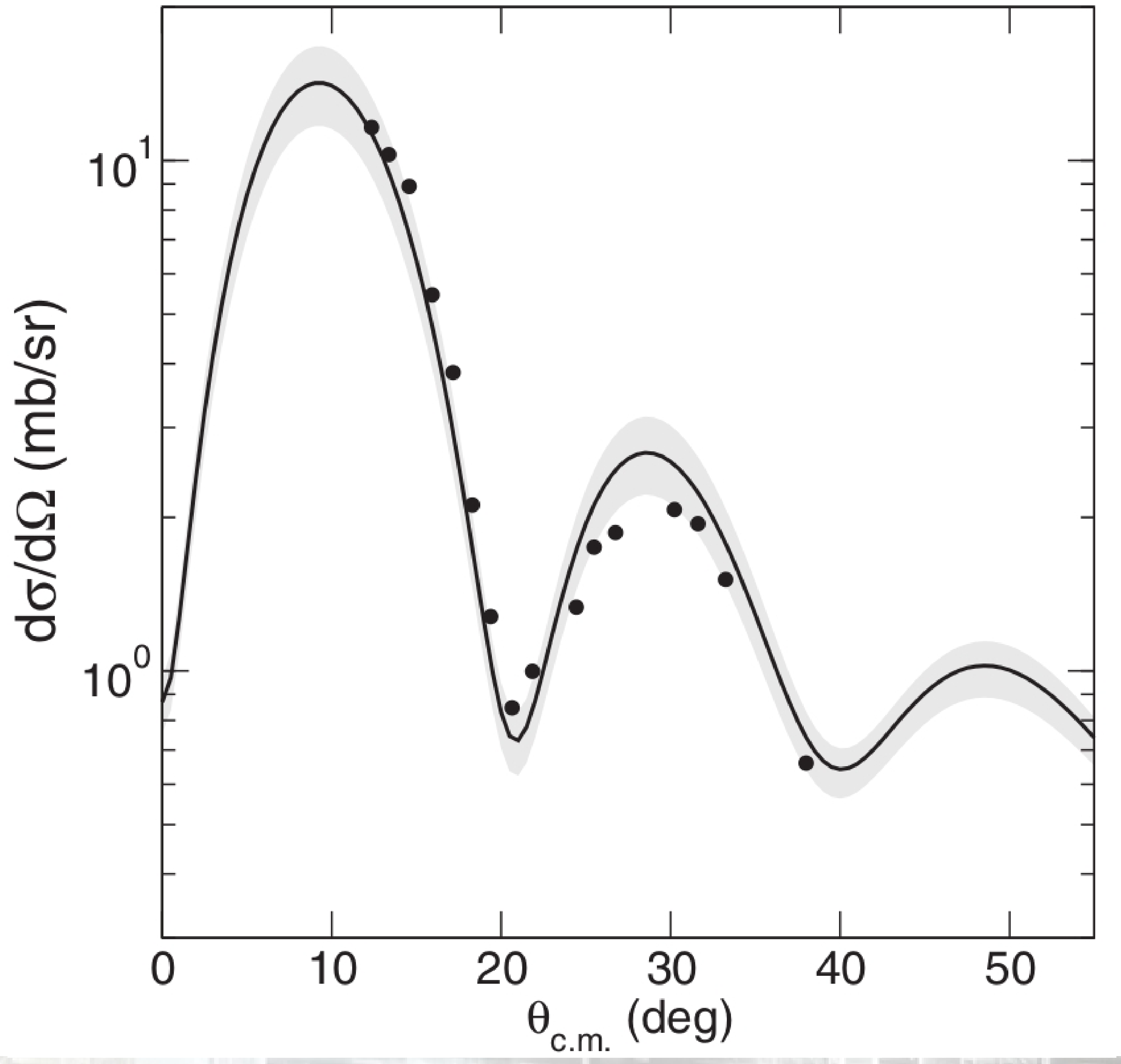
The ANC for the <^{14}C|^{13}B+p> overlap may also be extracted from ^{14}C(d,^{3}He)^{13}B data. If we have modelled the heavy-ion reaction correctly the ANC we obtained should be compatible with the light-ion data.

Data exist at E_d = 52 MeV [G. Mairle & G.J. Wagner, Nucl. Phys. A **253**, 253 (1975)]. Well described using the “heavy-ion” ANC in DWBA and more sophisticated calculations [N. Keeley, K.W. Kemper & K. Rusek, Phys. Rev. C **106**, 014623 (2022)]:



← DWBA

CRC →



Consistent results for ANC from heavy-ion and light-ion data provided most complete modelling of heavy-ion data is applied. DWBA analysis of heavy-ion data inadequate – ANC incompatible with light-ion data.

DWBA and more complete reaction models give similar results for (d,^{3}He) data; confirms (for this case) usual expectation that DWBA is adequate for light-ion reactions (essentially one-step mechanism).

More complete result is less sensitive to details of input (distorting potentials etc.) than DWBA.

If heavy-ion data are used to obtain ANCs reaction model is important – need complete data sets.

Thank you for your attention

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