Photoabsorption reactions and the influence on closed shells

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The response of nuclei to dipole radiation has long been a valued tool in nuclear physics. The dipole response impacts on the production of elements in stellar environments, industrial applications, stockpile stewardship and medical physics. In heavier nuclei, once a high-energy photon has been absorbed, the nuclei typically deexcite by emission of neutrons: electromagnetic transitions (i.e. gamma rays) tend to be slow compared to particle emission and charged-particle decays are suppressed due to the Coulomb barrier. It is well known that there are lasting and serious problems with historic photoneutron data due to background and the problem of neutron multiplicity sorting: how many neutrons were produced with what average energy and what does this mean for the efficiency of the system?

A previous study [1] found a reduction in the strength of photoabsorption reactions near the neutron shell closures. This was suggested to be the result of shell effects at the N=50, 82 and 126 shell closures. However, two questions come to mind: first, why does this effect only seem to appear at the neutron shell closures and second, given the problems with neutron multiplicity sorting in the historical data, if the effect is only seen at the neutron shell closures, is this a sign that problems with historical data leads to artefacts in systematic analyses of those data. This is especially acute given the corrections made to photoneutron data in the careful nuclear-data work of the IAEA photonuclear data working group and other groups, notably Varlamov and collaborators [2].

To test these questions, we extracted photoneutron cross sections from the EXFOR database and recomputed the dipole polarisability using Markov-Chain Monte Carlo methods to estimate the uncertainties. In general, our reanalysis does not support the reduction in the photoabsorption strength at the neutron shell closures for various different reasons. First, for some nuclei, the dipole polarizability reported by Dietrich and Berman in their compilation of photoabsorption data3 is evaluated over only a sub-range of the total energy which the giant dipole response is expected to cover. For other nuclei, the updated cross sections result in an increase of the dipole polarizability which removes the reduction at the shell closures. Finally, one of the dipole polarizability values reported by Orce and Ngwetsheni with enhancements due to low-energy contributions are smaller than the data from literature which is contrary to expectations and may be due to some artefact of the analysis. Figure 1 summarises the results of the present analysis which largely does not support a reduction at the shell closures. Note that some of the data have problems: for example, the reported EXFOR cross section for 207Pb does not appear to correspond to the data in the figure in the paper4 in which it is reported and the zirconium and molybdenum isotopes have been observed to be deeply problematic in various past experimental studies5 and so extreme scepticism should be used when interpreting those results.

Despite this null result which seemingly contradicts the previous analysis of these data, there remain the possibility that there are continuing shell effects at high excitation energies. For example, the giant responses are known to split due to deformation and continued studies of these effects are a valuable exercise for the community. Certainly, better understanding of covariances between the various

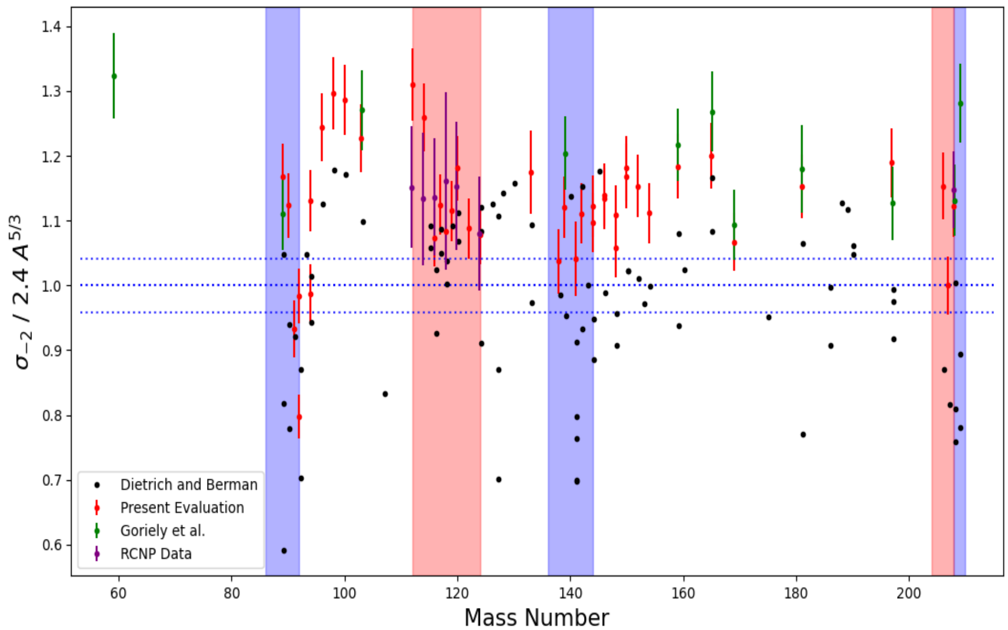

Fig. 1. The ratio of the dipole polarisability computed in the present analysis to the systematic trend expected. The black data are from the compilation in Ref. 3, the green and purple data are from alternative studieswith real and virtual photons, respectively, and the red data are those from the present evaluation.

data would be helpful in testing some of these theories and, overall, better experimental data taken with the same experimental apparatus to search for these effects would be a valuable research investment.

[1] Cebo Ngwetsheni and José Nicolás Orce, Phys. Lett. B **792**, 335 (2019).

[2] Kawano *et al*., Nuclear Data Sheets **163**, 109 (2020) and references therein.

[3] Samuel S. Dietrich and Barry L. Berman, Atomic Data and Nuclear Data Tables **38** 199 (1988).

[4] Varlamov, Davydov and Orlin, Eur. Phys. J. A **57**, 287 (2021),

[5] Banu *et al.*, Phys. Rev. C **99** 025802 (2019), Utsunomiya *et al.*, Phys. Rev. C **88** 015805 (2013), Varlamov, Davydov, Ishkanov, Orlin, Eur. Phys. J. A **54**, 74 (2018).