Comment on “E2 contribution to the 8B→p+7Be Coulomb dissociation cross section”

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The E2 cross section calculated by Langanke and Shoppa for the RIKEN experiment on the Coulomb dissociation of 8B uses E2 nuclear matrix element from one specific model. Other nuclear models predict a considerably smaller E2 cross section (by approximately a factor of 3 to 4), and Langanke and Shoppa appear to assume the most optimistic scenario, predicting a large E2 cross section. We also note that Barker has already criticized the nuclear model used by Langanke and Shoppa. A model independent chi-square analysis of the RIKEN data suggest the best fit for the current RIKEN data is obtained with E1 amplitudes only. The upper limit (90% confidence) on the E2 component derived from our chi-square analysis is considerably smaller than that used by Langanke and Shoppa. The model dependent analysis of Langanke and Shoppa should not be considered as a correction to the RIKEN result, as claimed, and their quoted S_{12}(0) is not substantiated.

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In a recent publication Langanke and Shoppa (LS) [1,2] calculated the E2 cross section for the RIKEN experiment on the Coulomb dissociation of 8B [3]. The measured cross section of the 7Be(p,γ)8B reaction includes contributions from s and d waves (S_{S1}), p waves (S_{M1} and S_{S2}), and f waves (S_{E2}), where the p-wave cross section is dominated by a resonance at E_{c.m.} = 632 keV. All these amplitudes contribute to the measured Coulomb dissociation of 8B, with the E1 component being dominant, and the (small) E2 component being enhanced due to the large virtual photon flux (especially at large angles, θ ≈ 4°). In this Comment on the work of LS we concentrate on the E2 cross section of the Coulomb dissociation of 8B and ignore the M1 cross section, even though the M1 appears to contribute to the 600 keV angular distribution data of Motobayashi et al. [3] at a level comparable to that of the E2 (<10%), which is however smaller than the quoted accuracy of the RIKEN experiment (15–20 %).

Recently one of us (M.G.) notified LS of a number of mistakes in their original paper [1] which led to the publication of an Erratum [2] with a correction of Fig. 2 of LS [1]. We first note that LS state [1]: “We find that the ratio [of the E2/E1 Coulomb dissociation cross section] is robust against this [energy and angular] averaging,” but in their Erratum [2] they correct for the fact that they neglected to average over the energy resolution of the RIKEN experiment. A more severe problem in the LS paper is the fact that they ignored the angular resolution of the RIKEN experiment. Since the angular distribution of the E2 Coulomb dissociation cross section is different than that of the E1 cross section, the predicted E2/E1, after averaging over the angular resolution of the RIKEN experiment, is different than that predicted by LS. In fact, the acceptance of the RIKEN detector is such that the so-called efficiency (i.e., relative number of particle detected convoluted with angular resolution) is not the same for E1 and E2 cross sections. This invalidates the basic assumption of LS that “assumes the detector efficiency is the same for E1 and E2 contributions.” As it turns out the angular averaging tends to push the predicted E1 cross section to large angles, where the E2 dominates, and the large E2 predicted by LS appears to be a compensation for their neglect of the angular resolution of the RIKEN experiment. In that sense the entire analysis of LS as well as Fig. 1 of [1] are misleading and incorrect, and that figure does not reflect the E2 contribution predicted for the RIKEN experiment.

We also emphasize that while the LS “correction factors” are deduced with large uncertainties (with 30–75 % error), 1 – α = 0.30±0.09, 0.20±0.15, and 0.24±0.17, at 0.6, 0.8, and 1.0 MeV, respectively, the so called corrected S_{12}(0) is quoted with an error ±3 eV b [1], which is even smaller than the experimental error of ±3.2 eV b [3], indicating that LS did not carry out a correct error propagation analysis. Furthermore, LS quote a value for S_{12}(E) creating the impression that they had carried out precision correction
FIG. 1. The reduced $\chi^2$ obtained from fitting the 600 keV angular distribution of the RIKEN data [3] with $\sigma_{CD}(E1) + \sigma_{CD}(E2)$, as discussed in the text.

to the RIKEN result. Their quoted value of $S_{17}(0)$ is discussed by several authors, and referred to as the corrected RIKEN value, for example quoted by Bahcall et al. [4], which supports the notion that a substantial correction was applied to the RIKEN data. Bahcall et al. state [4]: "When the $E2$ contribution to this reaction is taken into account [1], the preliminary Coulomb-dissociation value differs from the six direct measurements of the $^7\text{Be}(p,\gamma)^8\text{B}$ reaction by a factor of two...", contrary to data shown by Motobayashi et al. [3].

In this Comment on LS we demonstrate that LS appear to have considered the most optimistic scenario for a large E2 contribution, which makes their model dependent analysis questionable. Furthermore, we demonstrate that they based their analysis on only one nuclear structure model, and the theoretical foundation of their paper is challenged. In addition as we have shown above, their analysis was based on a misunderstanding of the RIKEN experimental setup, and thus we also invalidate their analysis. We present here a preliminary model independent analysis that does not support LS conclusion and their quoted value of $S_{17}(0)$.

The construction of a reliable nuclear structure model for the $^7\text{Be}(p,\gamma)^8\text{B}$ reaction has received a great deal of theoretical attention [5–11]. Once such a model is constructed the predicted cross sections could be used in conjunction with the formalism developed by Baur, Bertulani, and Rebel [12] to calculate (differential) cross sections for the Coulomb dissociation of $^8\text{B}$. Current nuclear structure models are in agreement (approximately 10–20%) with the calculated $E1$ (and resonant $M1$) cross section of the $^7\text{Be}(p,\gamma)^8\text{B}$ reaction, but in disagreement with the predicted small E2 cross section. For example, while Kim et al. [5] predict for the 632 keV resonance $S_{E2}/S_{E1} = 1.8 \times 10^{-3}$, Typel and Baur [10] predict a value of $5 \times 10^{-4}$, almost a factor of 4 smaller. While Krauss et al. [9] are in agreement with Kim et al., Descouvemont and Baye [8] predict for the 632 keV resonance a $B(E2; 1^+ \rightarrow 2^+) = 13$ W.u. which is a factor of 2.4 smaller than that predicted by Kim et al. Nakada and Otsuka [11] also predict a $B(E2)$ substantially smaller than that predicted by Kim et al.

We note that Barker has constructed a model that includes the 632 keV resonance, which allows for predicting all required cross sections including the $E2$ [6]. Such calculations yield $E2$ (and $M1$) cross sections which are considerably smaller [6] than predicted by Kim et al. In fact, Barker has already criticized [7] the theoretical foundation of the model of Kim et al. [5], and in the absence of a reply from the original authors (Kim et al.) or a refutation of Barker’s criticism by LS, the very theoretical foundation of LS are in doubt, as LS heavily rely on Kim et al. as an input model for the nuclear structure of $^8\text{B}$.

Clearly LS used in their estimate of the $E2$ cross section a nuclear structure model that appears to be at the high end of the calculated $E2$ cross section. While LS do not list the value they used for $S_{E2}/S_{E1}$, we assume (based on a private communication) that for the 600 keV angular distribution they originally used the value of $S_{E2}/S_{E1} = 1.8 \times 10^{-3}$, for example, a factor of 4 larger than predicted by Typel and Baur [10] after averaging their results over the energy resolution of the RIKEN experiment. Indeed, Typel and Baur calculate $E2$ cross sections which are approximately a factor of 4 smaller than predicted by LS [2].

We conclude that the uncertainty in nuclear models for the predicted nuclear $E2$ cross section does not allow for a meaningful model dependent estimate of the $E2$ cross section in the Coulomb dissociation of $^8\text{B}$. This conclusion raises serious doubts on the analysis carried out by Langanke and Shopps of the RIKEN data. We also conclude that these cross sections ($E1$ and $E2$) are best extracted from a fit to the data, even if the current data [3] are of low precision (15–20%). Such a fit is expected to be less uncertain than current model dependent theoretical estimates.

The predicted angular distribution of the $E1$ and $E2$ cross section of the Coulomb dissociation of $^8\text{B}$ are sufficiently different [12]. For the RIKEN data measured at 46.5 MeV/nucleon the $E1$ cross section is dominant at approximately $1^\circ - 2^\circ$, and the $E2$ at $4^\circ - 5^\circ$. This should allow in principle for an extraction of the $E1$ and $E2$ cross section in the RIKEN data.

We chose to demonstrate this point for the 600 keV angular distribution measured at RIKEN, where LS predict the largest $E2$ cross section (see Fig. 1 of LS [1]). Similar conclusions are found for the other (800 and 1000 keV) angular distributions analyzed by LS, but we emphasize that even LS do not claim any significant $E2$ contributions to either 800 or 1000 keV angular distributions.

We have fitted (600 keV) measured Coulomb dissociation angular distribution with $\sigma_{CD}(E1) + \sigma_{CD}(E2)$, which are linearly proportional to $S_{E1}$ and $S_{E2}$, respectively, and the $S$ factors are treated as free fit parameters. We have included in our analysis all experimental resolutions of the RIKEN experiment and in Fig. 1 we show the resulting reduced $\chi^2$ of this fit to the 600 keV angular distribution of the RIKEN data [3]. Note that since the grazing angle for the RIKEN kinematics is approximately $9^\circ$, one expects some contribution from nuclear breakup at the large angles. Hence we also analyzed the RIKEN data without including the data point at $5.5^\circ$. This analysis in fact yields a better fit with $E1$
amplitude only (with the minimum of reduced-$\chi^2$ close to unity) and a similar exclusion of the $E2$ component as shown in Fig. 1.

As shown in Fig. 1 the best fit is obtained for $S_{E1} = 18 \pm 3$ eV b and $S_{E2} = 0 \pm 6$ meV b, corresponding to a 90% confidence upper limit of $S_{E2} < 12$ meV b, and $S_{E2}/S_{E1} < 7 \times 10^{-4}$. The extracted upper limit is considerably smaller than that used by LS, but is still consistent with the lower values predicted by the other models. Our quoted upper limit contradicts LS and do not substantiate their analysis, but in fact it confirms the original assumption of the RIKEN experiment [3], that the data could be analyzed assuming $E1$ contribution only.

In conclusion we have demonstrated that theoretical uncertainties in the estimated $E2$ cross section of the $^7$Be($p, \gamma$)$^8$B do not allow for a meaningful model dependent estimate of the $E2$ cross section of the RIKEN data on the Coulomb dissociation of $^8$B, as performed by LS. A model independent chi-square analysis yields $E2$ cross sections that are considerably smaller than assumed by Langanke and Shoppa. This invalidates the so-called extracted (or corrected) value of $S_{17}(0)$ as quoted by Langanke and Shoppa for the RIKEN experiment.

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