COMMENTS

Comments are short papers which criticize or correct papers of other authors previously published in the **Physical Review.** *Each Comment should state clearly to which paper it refers and must be accompanied by a brief abstract. The same publication schedule as for regular articles is followed, and page proofs are sent to authors.*

Comment on "$E2$ contribution to the $^8B \rightarrow p + {}^7Be$ 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 $S_{17}(0)$ 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 $^7Be(p,\gamma)^8B$ reaction includes contributions from s and d waves (S_{E1}), p waves (S_{M1} and S_{E2}), and f waves (S_{E2}), where the p-wave cross section is dominated by a resonance at $E_{\rm c.m.}=632$ 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, $\theta \geqslant 4°$). 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), $1-\alpha = 0.30\pm0.09$, 0.20 ± 0.15, and 0.24 ± 0.17, at 0.6, 0.8, and 1.0 MeV, respectively, the so called corrected $S_{17}(0)$ 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 $S_{17}(E)$ creating the impression that they had carried out precision correction

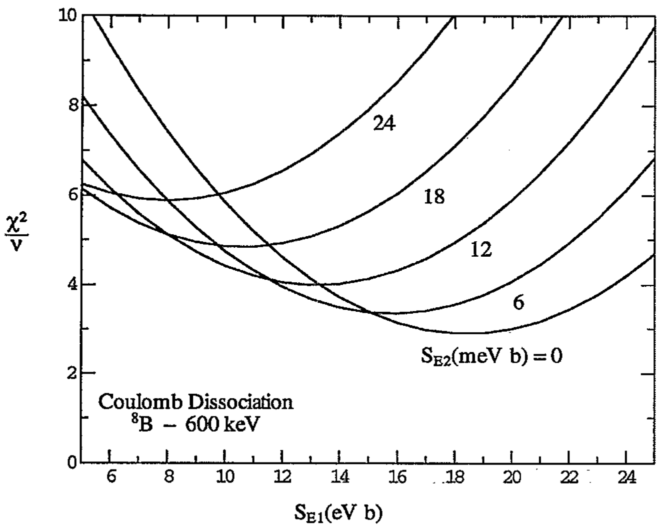

FIG. 1. The reduced χ^2 obtained from fitting the 600 keV angular distribution of the RIKEN data [3] with $\sigma_{CD}(E1) + \sigma_{CD}(E2)$, as discussed in the text.

to the RIKEN result. Their quoted value of $S_{17}(0)$ is discussed by several authors, and referred to as the corrected RIKEN value, as 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}Be$(p,\gamma)^8$B reaction by a factor of two...," contrary to data shown by Motobayashi *et al.* [3].

In this Comment on LS work 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}Be$(p,\gamma)^8$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}B. Current nuclear structure models are in agreement (approximately 10–20 %) with the calculated $E1$ (and resonant $M1$) cross section of the ^{7}Be$(p,\gamma)^8$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 $S_{E2}/S_{E1}=1.8\times10^{-3}$, Typel and Baur [10] predict a value of 5×10^{-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 $B(E2\text{: } 1^+\rightarrow2^+)=13$ 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}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 $S_{E2}/S_{E1} = 1.8\times10^{-3}$, 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}B. This conclusion raises serious doubts on the analysis carried out by Langanke and Shoppa 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}B are sufficiently different [12]. For the RIKEN data measured at 46.5 MeV/nucleon the $E1$ cross section is dominant at approximately $1-2°$, and the $E2$ at $4-5°$. 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 1 000 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 the (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 χ^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°, 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°. This analysis in fact yields a better fit with $E1$

amplitude only (with the minimum of reduced-χ^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 $S_{E1}=18\pm3$ eV b and $S_{E2}=0\pm6$ meV b, corresponding to a 90% confidence upper limit of $S_{E2}<12$ meV b, and $S_{E2}/S_{E1}<7\times10^{-4}$. 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 ${}^{7}\mathrm{Be}(p,\gamma){}^{8}\mathrm{B}$ do not allow for a meaningful model dependent estimate of the $E2$ cross section of the RIKEN data on the Coulomb dissociation of ${}^{8}\mathrm{B}$, 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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