Critical assessment of the claim of a significant difference between the results of measurements of the Coulomb dissociation of ^{8}B and the ^{7}Be(p, γ)^{8}B direct capture reaction*

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The Coulomb dissociation (CD) of ^{8}B has emerged as a landmark testing ground of the very method of CD for measuring the cross section of the low-energy ^{7}Be(p, γ)^{8}B direct capture (DC) reaction. Recent claims of evidence of slope difference between CD and DC results are critically examined. We include all relevant RIKEN2 data and all previously published DC data, and we examine the extracted so-called average scale-independent slope (b). The parametrization used by the Seattle group to extract the so-called b-slope parameter is also examined at energies above 300 keV. Considering the physical slope ($S' = dS/dE$) above 300 keV, we observe a (1.7σ) agreement between slopes (S') measured in CD and DC above 300 keV. The claim that $S_{17}(0)$ values extracted from CD data are inconsistent and lower than DC results arises from a neglect of substantial systematic uncertainty of low-energy CD data. A consideration of the published CD $S_{17}(0)$ results yields very consistent $S_{17}(0)$ values that agree with most recent DC measurements. The recent correction of the b-slope parameter suggested by Esbensen, Bertsch, and Snover (EBS) was applied to the wrong b slope calculated using part of the RIKEN2 data. When the correct slope of the RIKEN2 data is used, the EBS correction in fact leads to a substantial disagreement between the slopes of the RIKEN2 data and DC data. In spite of an agreement between CD and DC data neither allow for extracting the slope above 300 keV with high accuracy. Uncertainty of the slope (S') leads to an additional uncertainty of the extrapolated $S_{17}(0)$. The slope of the astrophysical cross-section factor S_{17} must be measured with high precision to enable extraction of the d/s ratio and a high-precision extrapolation of $S_{17}(0)$.

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I. INTRODUCTION

The method of Coulomb dissociation (CD) was developed in the pioneering work of Baur, Bertulani, and Rebel [1] and has been applied to the case of the CD of ^{8}B [2–5], from which the cross section of the ^{7}Be(p, γ)^{8}B reaction and the astrophysical cross-section factors (S_{17}) were extracted. Indeed, the extraction of the low-energy cross section of the ^{7}Be(p, γ)^{8}B reaction from the CD of ^{8}B emerged as a landmark testing ground of the very method of CD. These data on the CD of ^{8}B were analyzed with a remarkable success, mostly using only the first-order Coulomb interaction that includes only the $E1$ contribution. Early attempts to refute this analysis by introducing a non-negligible $E2$ contribution were shown [6] to arise from a neglect of the acceptance of the RIKEN1 detector. Later claims by the MSU group for evidence [7] of a non-negligible $E2$ contribution in *inclusive measurement* of an asymmetry were disputed in a recent *exclusive measurement* of a similar asymmetry by the GSI2 collaboration [5].

In contrast, Esbensen, Bertsch, and Snover (EBS) [8] recently claimed that higher order terms and an $E2$ contribution are an important correction to the RIKEN2 data [3]. It is claimed that "S_{17} values extracted from CD data have a significant steeper slope as a function of $E_{\rm rel}$, the relative energy of the proton and the ^{7}Be fragment, than the direct result." However, they find a substantial correction only to the RIKEN2 CD data and claim that these corrections yield a slope of the RIKEN2 data in better agreement with direct capture (DC) data.

The statements in the EBS paper [8] are quotes from the Seattle paper [9]; hence in this paper we examine this and other statements on CD of the Seattle paper. We demonstrate that agreement exists between CD and DC data, in contrast to the claimed discrepancies [9] and the so-called need to reconcile CD and DC results [8].

It is well known that the "old" DC data of the ^{7}Be(p, γ)^{8}B reaction [10–13] exhibit major systematic disagreements. But the situation is not improved with "modern" data on DC [9,14–16]. The data of the Orsay group [14] and Bochum group [15] do not agree with those of the Seattle group [9] and Weizmann group [16]. The disagreement of individual S_{17} data points are by as much as five sigma and there is not a single measured data point of the Bochum group that agrees with data points measured by the Seattle group. The disagreement among measured absolute cross section is of great concern, but so is the disagreement of the relative normalization of data points. The latter leads to a disagreement among measured slopes, which as we show in the following is of major concern.

In spite of an over all agreement between CD and DC data, the slope of the astrophysical cross-section factor measured between 300 and 1400 keV cannot be extracted with high accuracy. This slope is needed to test model-dependent

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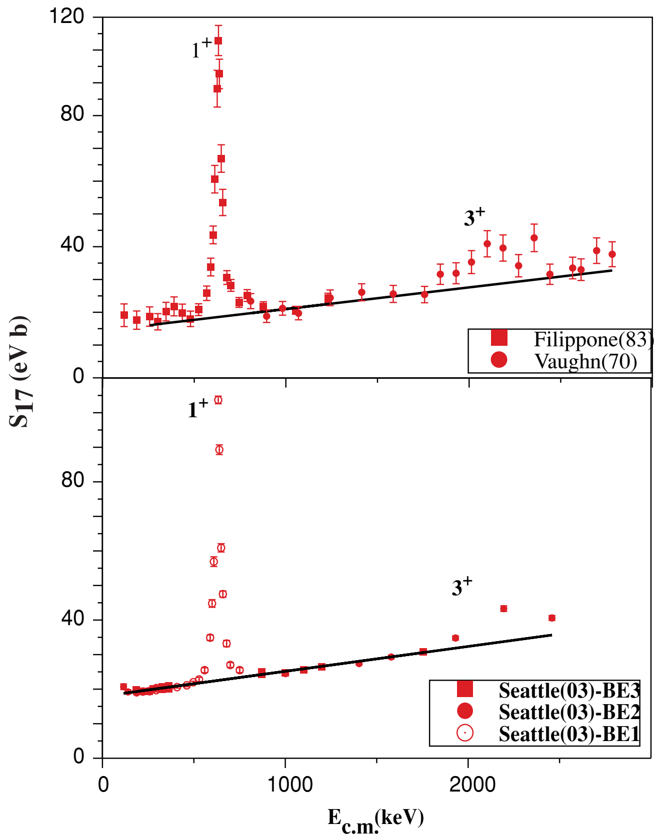

FIG. 1. (Color online) The measured S_{17} exhibiting at all measured energies above 300 keV and up to 2.5 MeV the predicted linearity (with positive slope) of a d-wave component as, for example, shown in Fig. 3.

predictions of the d/s ratio. The d-wave contribution is predicted to be large at all measured energies but very small at zero energy (approximately 6%). Hence the d-wave contribution must be subtracted from measured data to allow for an accurate extrapolation to zero energy. Lack of accurate knowledge of the large d-wave contribution at measured energies precludes accurate extrapolation to zero energies and it leads to additional uncertainty, owing to the extrapolation, that may yield a lower value $S_{17}(0)$.

II. THE SLOPE OF S_{17} ABOVE 300 keV

Early on it was recognized [17–19] that s-wave ^{7}Be$(p,\gamma)^8$B capture alone yields an astrophysical cross-section factor (S_{17}) with a negative slope. The observation of a linear dependence of the s factor with a positive slope at energies above 300 keV (shown in Fig. 1) was recognized as due to the d-wave contribution [17–20]. We emphasize that the data shown in Fig. 1 exhibit two resonances on top of a straight-line background, as predicted for d-wave dominance [17–20]. It was also recognized that since the d-wave contribution is very large at measured energies and in fact it dominates around 1.0 MeV, an accurate determination of the d-wave component must rely on data measured at higher energies. The value of the slope ($S' = dS/dE$) at energies above 300 keV was recognized as perhaps the best if not the only way to extract the d/s ratio.

The large variation of the measured absolute value of the cross section naturally leads to consideration of the parametrization: $S = a(1 + bE)$; see Fig. 19 of [9]. In this case the so-called b-slope parameter is a derived quantity ($b = S'/a$) that directly depends on the value of both S' and a. As we discuss in the following the parametrization $S = a(1 + bE)$ has physical significance only when the logarithmic derivative $S'/S(0)$ is an invariant, and this assumption is correct at very low energies, but it cannot be justified above 300 keV. Hence one must be careful when observing a disagreement of the b slope that, however, is not significant when comparing the physical slope $S' = dS/dE$ (see the following).

In Fig. 2 we show the b-slope parameter extracted from both DC [9–16] and CD data [2–5,7] in the energy range of 300–1400 keV. For the DC data we exclude the energy region of the 632-keV resonance and we subtract its $M1$ contributions at higher energies. At energies above 1,800 keV we observe in DC data a contribution of the 2.32-MeV state in ^{8}B; hence no DC data are included above 1700 keV. However, because of the small data sample measured by Parker [12] and the BE2 sample [9] above 875 keV, we extend these two samples and add one data point above 1400 keV. This extension does not affect the central value of the slopes but it does lower the error bars. At energies above 1.7 MeV a non-negligible $E2$ contribution was found in CD data [3]. Hence in this analysis we do not consider CD data above 1.5 MeV. But to extract the d-wave contribution and the slope, we must extend the fit region to energies as high as possible where the d-wave contribution dominates. At low energies, in contrast, a turnover (i.e., zero slope) is predicted owing to a large s-wave contribution; hence we exclude data points below 300 keV. Our choice of the low- and high-energy boundaries of the fit region is dictated by the physics of the astrophysical cross-section factor. This energy region exhibits a large sensitivity to the d-wave contribution and should allow for an accurate extraction of the d-wave contribution, should the data be sufficiently accurate and consistent. All linear fits so obtained have an acceptable reduced chi-squared (χ^2/ν). The data used in this analysis and linear fits are tabulated in numerical form in the Appendix.

A. Coulomb dissociation

In Fig. 2, we plot the b-slope parameter of all CD data. For the RIKEN2 data we include all available five data points and extract a smaller value [21] than shown in Fig. 19 of [9]. This in of itself might be of no consequence, except for its relevance for the newly published EBS paper [8], as we discuss in the following. Very recently it was also suggested [22] that a reanalysis of the GSI2 data (henceforth referred to as GSI2$'$) may yield a smaller corrected slope, as shown in Fig. 2. The published RIKEN2 [3], GSI1 [4], GSI2 [5], GSI2$'$ [22], and MSU data [7] yield a $1/\sigma$ weighted average for the "b-slope parameter" of $b = 0.51 \pm 0.06$ MeV^{-1} with $\chi^2/\nu\ = 1.1$.

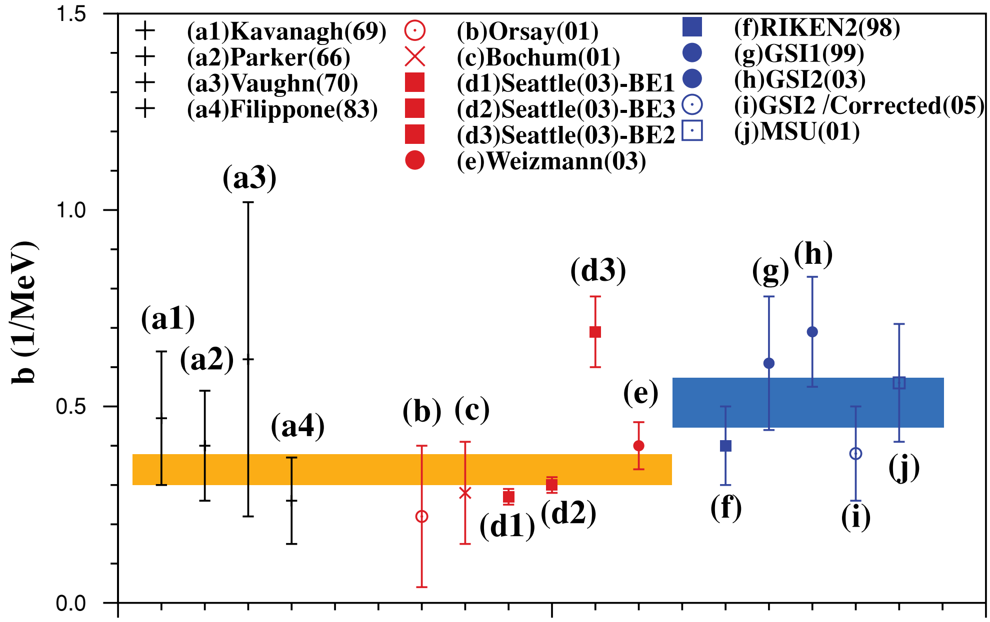

FIG. 2. (Color online) The extracted so-called scale-independent slopes (b) of world data. We correctly plot the RIKEN2 data and include all available data as discussed in the text. The range of "average values" is indicated and discussed in the text.

B. Direct capture

In Fig. 2 we plot the b-slope parameter of all measured DC data including the data of Vaughn *et al.* [11], Parker [12], and Kavangh *et al.* [13], as well as the BE2 data set of the Seattle group [9]. These four data sets were ignored in Fig. 19 of [9]. The three data sets of Vaughn, Parker, and Kavangh [11–13] were deemed [23] not useful at low energies for extrapolating $S_{17}(0)$, but they are certainly useful for studying the slope of the data measured at energies between 300 and 1400 keV, as are the BE2 data of the Seattle group. Hence the data sets of Vaughn, Parker, and Kavanagh and the BE2 set of Seattle are included in Fig. 2.

The large discrepancies between measured individual DC data points demonstrate large systematic differences among "modern" DC data. Most disturbing are the disagreements between the b-slopes of the Seattle data and the Weizmann data, shown in Fig. 2, as well as the larger disagreement of the slope of the BE1 and BE2 data sets measured by the same group. These large systematic differences must be resolved before these data are used to extract the "world average b slope" of DC data. The systematically disagreeing DC data cannot be handled algebraically using statistical methods to, for example, extract a meaningful average slope. Nonetheless, it has been customary to artificially enlarge the error bars by multiplying them by the square root of χ^2/ν, so as to make data with systematic differences appear as if they are statistically distributed. Using such a procedure for all published DC data [10–12,14–16] for the BE1, BE3, and BE2 data sets of the Seattle group [9] we extract a $1/\sigma$ weighted average b-slope parameter of $b = 0.34 \pm 0.02$ MeV $^{-1}$ with $\chi^2/\nu = 3.7$. The bad χ^2/ν reflects the large fluctuations among "b-slope parameters" of DC data including a substantial disagreement between the b slopes of the BE2 and BE1 data [9]. Taking into account the bad χ^2/ν as discussed here, we obtain $b = 0.34 \pm\ 0.04$ MeV^{-1}.

We conclude that the b-slope parameter cannot be extracted from DC data with the accuracy of 6% [9], unless one excludes some of the DC measurements discussed previously. An error that is approximately a factor of 2 larger seems like a more reasonable choice. Also, the large difference of the extracted b-slope parameter for DC and CD data with a central value of approximately 0.25 MeV^{-1} [9] is not confirmed.

III. THEORETICAL CONSIDERATION OF THE SLOPE ABOVE 300 keV

It is well known that for an external capture reaction (and only when the conditions for an external capture reaction are satisfied, i.e., below 100 keV), the linear term in the Taylor expansion of the astrophysical cross factor dominates; hence

$$S(E) = S(0)[1 + s_1 \times E], \tag{1}$$

$$S(0) = S_d(0) + S_s(0), \tag{2}$$

and

$$s_1 = \frac{S_s(0)}{S(0)}\left[s_{1s} + s_{1d} \times \frac{S_d(0)}{S_s(0)}\right]. \tag{3}$$

Equations (1)–(3) were derived for external capture and are correct only when the conditions for external capture are met. Specifically, the value of s_1 is explicitly negative, as predicted for energies below 100 keV. In such a case the logarithmic derivative $S'/S(0)$ is shown to be an invariant [24].

At energies above 300 keV the observed slope is manifestly positive as shown in Fig. 1. For higher energies one must add

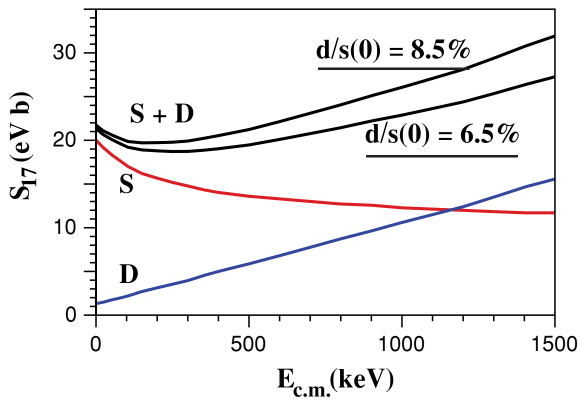

FIG. 3. (Color online) The s- and d-wave contributions calculated by Jennings *et al.* [20] and with an increased $d/s(0) = 8.5\%$ value. We note that the logarithmic derivative $S'/S(0)$ is not an invariant above 300 keV, as discussed in the text.

higher order terms beyond the linear term used in Eq. (1) to turn the sign of the slope from negative to positive. For example, the Taylor expansion of the theoretical curve predicted by Descouvemont and Baye [25] cannot be truncated below third order to yield a reasonable representation of the predicted curve at all energies up to 1.4 MeV. Clearly, at energies above 300 keV, the truncation of the Taylor expansion to a linear term [9] leads to unphysical expansion.

In the following we examine in detail the nonphysical nature of the parametrization $S = a(1 + bE)$ above 300 keV. This is important in view of the fact that the comparison of the b slope leads to a disagreement between DC and CD data that is larger than when comparing the physical slope $S' = dS/dE$. Variation of the a parameter accentuates slight differences of the slopes (S') of DC and CD data to produce a larger disagreement.

As we show in Fig. 3 the slope of the d-wave component is essentially constant as a function of energy [20] (approximately +10 eV b/MeV), but the slope of the s-wave component varies with energy between approximately −20 eV b/MeV at zero energy to approximately −3 eV b/MeV at higher energies. The overall slope ($S' = dS/dE$) is the sum of the two components and hence it is energy dependent. At very low energies the s-wave negative slope dominates, being almost constant, and hence we have the linear truncation as in Eq. (1). At energies above 500 keV the d-wave slope dominates and the variation of the s-wave slope is small, leading to almost constant positive slope. At high energies the linear dependence of the S factor with a positive slope is an artifact of the d/s ratio. But the overall slope depends on the low-energy cut of the data. In particular, the fit parameter a used in $S = a(1 + bE)$ is most sensitive to the choice of the low-energy cutoff of the data. Including data at approximately 200 keV leads to a substantial change of the a fit parameter, and in this case the so-called scale-independent b-slope parameter varies owing to the selected range of data or the value of a and not owing to the physical slope (S') measured above 300 keV. Such a fit region (including very low energy data) does not allow for an accurate determination of the d-wave component and is not justified by the physics of S_{17}, as discussed before.

In Eq. (1) the overall normalization factor $S(0)$ is directly related to the astrophysical cross-section factor at zero energy, as well as the Asymptotic Normalization Coefficient (ANC) of the physical wave function [24]. But the fit parameter a has no physical meaning when the energy range is restricted to above 300 keV.

Furthermore, the observed positive slope ($S' = dS/dE$) of the cross-section factor at energies above 500 keV is directly related to the (model-dependent) d-wave contribution designated by the d/s ratio [10,17–20,24]. It is self-evident that the d/s ratio is independent of $S(0)$, since both d and s components are proportional to the same ANC [24]. Hence it is clear that at energies above 300 keV the slope (S') is *not* directly related to the overall normalization $S(0)$ and the logarithmic derivative $S'/S(0)$ is not an invariant above 300 keV. In that sense the parametrization $S = a(1 + bE)$ can be justified at very low energies (below 100 keV) [24] but above 300 keV the extracted a and b fit parameters have no physical meaning.

To illustrate this point we show in Fig. 3 the s- and d-wave contributions calculated by Jennings *et al.* [20]. In the same figure we show the predicted S factor with $S_d(0)$ increased from 1.3 [20] to 1.7 eV b, which is certainly within the limit of accuracy of theoretical predictions. This yields a very insignificant (1.8%) change of $S(0)$ but a very significant change (≈25%) of the observed slope (S') above 300 keV. This schematic model most vividly demonstrates the fact that the logarithmic derivative $S'/S(0)$ is not an invariant above 300 keV and that the parametrization $S = a(1 + bE)$ lacks physical justification above 300 keV.

As we discussed, a knowledge of the d-wave component at measured energies (e.g., above 300 keV) is essential for extrapolating $S_{17}(0)$. For example, at 500 keV the d-wave contribution amounts to 30% of the measured S_{17} and above 1150 keV it is dominant. At zero energy, in contrast, the d-wave contribution is predicted to be small [$S_d(0)/S_s(0) \approx 6\%$]. Thus to accurately extrapolate S_{17} from data measured at lab energies to zero energies one must remove the d-wave contribution from the measured S_{17}, as has been emphasized long ago by Robertson [17]. This so far has been done by means of theoretical estimate of the d-wave component and a chi-square fit of data by the predicted s- plus d-wave components.

However, currently there is no direct way to test the validity of the model-dependent prediction of the d-wave component. In fact the slope (S') measured above 300 keV seems thus far the best (if not the only) way to determine the d-wave contribution. As we show in the following, the slope thus far has not been measured with high accuracy and large discrepancies still exist among measured slopes. Indeed, the ill-defined theoretical d/s ratio leads to an uncertainty of the extrapolation. Other theoretical issues were also discussed by Descouvemnot, where it is shown that an overall uncertainty of at least 6% [26] exists if one includes all data to approximately 1.0 MeV. As already explained one must include higher energy data when extrapolating $S_{17}(0)$ to constrain the d-wave contribution. Hence such a theoretical uncertainty of 6% seems

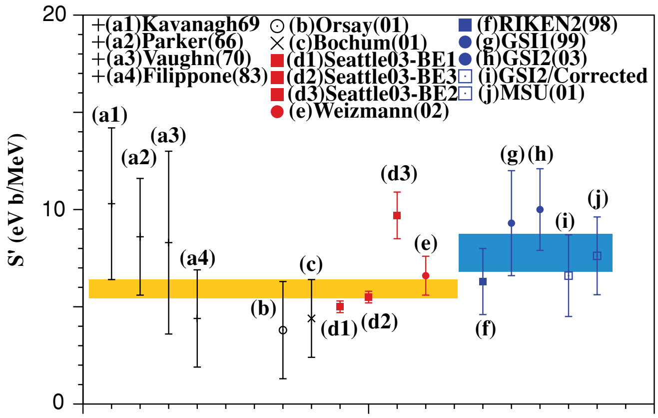

FIG. 4. (Color online) The measured slopes ($S' = dS/dE$) of world data measured between 300 and 1400 keV, as discussed in the text (see also Fig. 1). The range of "average values" is indicated and discussed in the text.

like a reasonable conservative estimate. Error resulting from poor knowledge of the d/s ratio increases the theoretical uncertainty because of extrapolation.

In Fig. 4 we plot the extracted physical slope $S' = dS/dE$ for data measured between 300 and 1400 keV, with the same conditions and stipulations as discussed in Sec. II. From these data we extract for CD data the $1/\sigma$ weighted average $S' = 7.8\pm\ 0.9$ eV b/MeV with $\chi^2/\nu = 0.6$ and for DC data $S' = 5.9 \pm 0.3$ eV b/MeV with $\chi^2/\nu = 2.8$. The poor χ^2/ν for DC data reflects the large fluctuations among DC data, including a substantial disagreement between the slopes of the BE2 and BE1 data [9] and it leads to an increased error (see above) of ±0.5 eV b/MeV. The average slope extracted in CD data agrees (within 1.7σ) with that extracted from DC data. This agreement is considerably better than observed between individual DC measurements, as we have already discussed.

Considering the observed agreement we also conclude that the corrections suggested by Esbensen, Bertsch, and Snover [8] in fact lead to a disagreement between the slopes of the RIKEN2 data and DC data, and not to reconciling the slopes as stressed in [27]. In this paper [8] we find a substantial (50%) correction of the b-slope parameter extracted for the RIKEN2 data that is implied to be 0.25 MeV^{-1}, leading to the predicted $b = 0.4 - 0.25 = 0.15 \pm 0.1$ MeV^{-1}, which is considerably smaller (by approximately a factor of 2) than the observed central value of the average of DC data.

IV. $S_{17}(0)$ EXTRACTED FROM CD DATA

In Fig. 20 of the Seattle paper [9] the authors show extracted $S_{17}(0)$ from CD using the extrapolation procedure of Descouvemont and Baye [25], and based on this analysis it is stated [8] that "the zero-energy extrapolated $S_{17}(0)$ values inferred from CD measurements are, on the average 10% lower than the mean of modern direct measurements." The extracted $S_{17}(0)$ shown in Fig. 20 [9] are only from data measured at energies below 425 keV and the majority of CD data points that were measured above 425 keV were excluded in Fig. 20 [9].

This arbitrary exclusion of (CD) data above 425 keV has no physical justification (especially in view of the fact that the contribution of the 632-keV resonance is negligible in CD). For example, as shown by Descouvemont [26], the theoretical error increases to approximately 5% at 500 keV and in fact it is slightly decreased up to approximately 1.0 MeV, and there is no theoretical justification for including data up to 450 keV but excluding (either CD or DC) data between 500 keV and 1.0 MeV. In DC measurements the well-known contribution of the 632-keV resonance needs to be subtracted, but that is not the case for example in the RIKEN2 CD data. Furthermore, as we have already discussed, the slope of the data between 300 and 1,400 keV is essential for determining the d/s ratio and the extrapolation to zero energy. Excluding data above 425 keV reduces our sensitivity for testing the various model prediction of the d/s ratio.

When including CD data measured only at energies below 425 one runs into a more serious systematic problem. Namely, the relative energy measured in CD ($E_{\rm rel}$) is determined mostly from the proton-^{7}Be relative angle (θ_{17}). At small relative energies (as well as at small scattering angles, θ_8) plural scattering in the target (and in the helium gas [3]) are of major concern. These are estimated theoretically and are known to be inaccurate. The effect of plural scattering in the target is indeed known for practitioners in the field of CD and has been discussed on several occasions and emphasized in Ref. [3]. It leads to a systematical uncertainty of the measured S_{17} of the order of 2 eV b (approximately 10%).

Furthermore, the yield of the CD of ^{8}B arises from a convolution of the nuclear cross section, which is rapidly dropping toward low energies, and the virtual photon flux, which is rapidly increasing toward low energies. This generates a yield that is almost constant ($\pm20\%$) at $E_{\rm rel}$ = 300–800 keV. Note that over the same energy range the DC yield changes by almost a factor of 10.

Thus when excluding the CD data above 425 keV, one excludes the data that were measured with the best accuracy and with smallest systematic uncertainty. If in fact one insists on such an analysis of CD data [9], one must estimate the systematic uncertainty caused by this selection of data (which is approximately 2 eV b, as already discussed).

Instead, in this paper we rely on the original analyses of the authors of CD experiments. In Fig. 5 we show the $S_{17}(0)$ factors extracted by the original authors who performed the CD experiments. These results include all measured data points and are consistently analyzed with the extrapolation procedure of Descouvemont and Baye [25]. The potential model of Typel [5] was also used in the GSI2 paper, but the so-quoted (smaller) $S_{17}(0)$ values are not shown in Fig. 4.

We note that the five experiments on the CD of ^{8}B [2–5,7] show a remarkably good agreement within the quoted error bars, in sharp contrast to the confusion that exists in "old" [10–13] and "modern" DC results [9,14–16]. The results of the RIKEN-GSI experiments must be considered as a continuation of the same experiment (essentially the same experiment repeated four times) with improved kinematical and experimental conditions. Thus the four results cannot all be

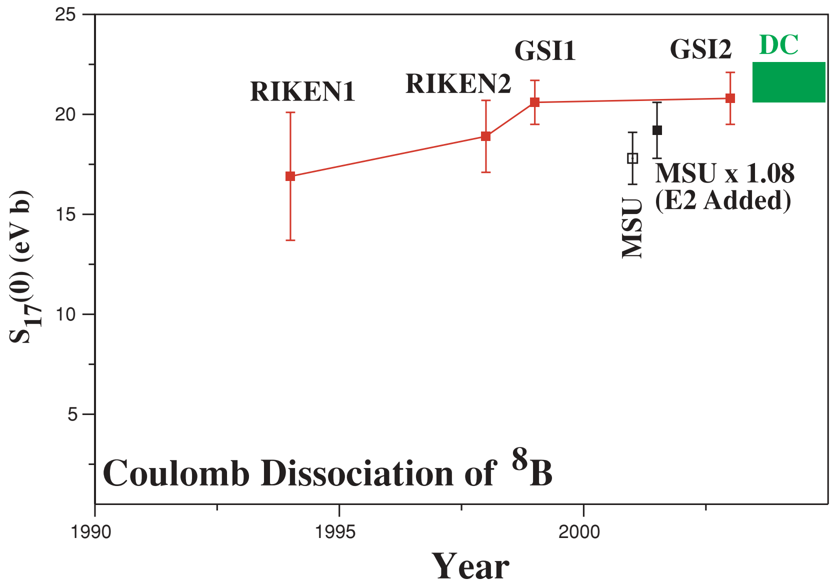

FIG. 5. (Color online) Measured $S_{17}(0)$ as originally published by the authors who performed the CD experiments. These analyses include all measured data points [2–5,7] using the extrapolation procedure of Descouvemont and Baye [25]. We also plot the MSU data as published as well as with the $E2$ correction ($\approx$8%) [7] added back to the quoted $S_{17}(0)$, as discussed in the text. The range of $S_{17}(0)$ results from the measurements of DC by the Seattle [9] and Weizmann groups [16] is indicated.

assigned the same weight (i.e., they have correlated systematic uncertainties).

We note that although these four results are consistent within the quoted error bars, they show a systematic trend of an increased $S_{17}(0)$ (to approximately 20.7 eV b), while the error bars are reduced. The MSU result, however, includes a model-dependent $E2$ correction ($\approx$8%) deduced from inclusive experiments [7], which was not confirmed in a recent exclusive measurement of a similar asymmetry [5]. When this $E2$ correction is added back to the quoted MSU result [7], as shown in Fig. 4, together with the published RIKEN2 [3], GSI1 [4], and GSI2 [5] results, we obtain a $1/\sigma$ weighted average of $S_{17}(0) = 20.0 \pm 0.7$ eV b, with $\chi^2/\nu = 0.5$. An average that gives larger weight to the latest results (i.e., since these CD results are not considered independent of each other) yields $S_{17}(0) = 20.5 \pm 0.8$ eV b. Both values are in excellent agreement with the measurement of the Weizmann group [16] and in agreement with the measurement of the Seattle group [9], which were also extrapolated using [25].

We do not substantiate the claimed disagreement between measured slopes of DC and CD data as well as extracted $S_{17}(0)$ [8,9]. Quite to the contrary, we find a good agreement among CD measurements as well as an agreement of the CD results with the two most recent high-precision results of DC experiments measured by the Weizmann and Seattle groups.

However, owing to the ill-determined slope of S_{17} above 300 keV, the extrapolation of $S_{17}(0)$ is also ill-determined. Further attention must be given to an accurate measurement of the slope and to the d/s ratio to allow accurate extrapolation to zero energy. A larger d/s ratio leads to a smaller extracted $S_{17}(0)$. In this case it seems reasonable to include an additional downward error resulting from a possibly larger d/s ratio. Such an error can be eliminated only when the slope of S_{17} is determined with high precision at energies above 300 keV.

APPENDIX

World data on S_{17} and linear fits are tabulated here in numerical form.

TABLE I. Kavanagh data ($\sigma_{dp} = 157$ mb).

$E_{\text{c.m.}}$ (keV)	S_{17}	Error
331	23.5	2.3
386.2	25.1	2.5
431.3	26.4	2.6
497	27.8	2.8
516.3	29.5	2.9
516.3	26.1	2.6
525.7	28	2.8
738.4	31.1	3.1
763.8	31.8	3.2
795.6	30.8	3.1
824.9	29	2.9
856.4	30.1	3.0
937.2	29	2.9

$S = 0.0103E_{\text{c.m.}} + 21.7(\chi^2/\nu = 0.3)$

TABLE II. Parker data ($\sigma_{dp} = 157$ mb).

$E_{\text{c.m.}}$ (keV)	S_{17}	Error
422.1	25	2.5
835.6	32.4	3.2
1033.1	27.6	2.7
1283	30.2	3.0
1688.6	38.4	3.4

$S = 0.0086E_{\text{c.m.}} + 21.3(\chi^2/\nu = 1.2)$

TABLE III. Vaughn data ($\sigma_{dp} = 157$ mb).

$E_{c.m.}$(keV)	S_{17}	Error
808	23.4	2.3
895	18.8	1.9
982	21.2	2.1
1069	19.7	2.0
1242	24.4	2.4
1414	26.1	2.6
$S = 0.0083E_{c.m.} + 13.0(\chi^2/\nu\ = 1.2)$		

TABLE IV. Seattle data minus $M1$ contribution.

$E_{c.m.}$ (keV)	S_{17}	Error
328.2	20.3	0.4
363.8	20.4	0.4
408.1	20.6	0.3
461.3	21.1	0.4
820.7	21.9	0.5
876.3	22.3	0.2
876.3	22.0	0.4
1002.3	23.3	0.2
1102.8	24.2	0.3
1203.2	25.4	0.3
BE1:		
$S = 0.0051E_{c.m.} + 18.3(\chi^2/\nu\ = 3.1)$		
875.5	22.5	0.6
1001.6	23.5	0.6
1403.6	27.4	0.8
1579.4	29.3	0.8
BE2:		
$S = 0.0097E_{c.m.} + 13.9(\chi^2/\nu\ = 0.05)$		
326.4	19.9	0.3
326.4	20.7	0.4
361.9	20.9	0.4
361.9	20.1	0.3
871.4	23.0	0.4
871.2	22.3	0.3
999.5	24.0	0.3
1099.8	24.6	0.3
1200.1	26.4	0.6
BE3:		
$S = 0.0056E_{c.m.} + 18.3(\chi^2/\nu\ = 2.8)$		

TABLE V. Weizmann data minus $M1$ contribution.

$E_{c.m.}$ (keV)	S_{17}	Error
302	18.1	2.0
356	18.8	1.2
415	20.1	1.6
856	21.8	0.6
1078	24.0	0.9
$S = 0.0066E_{c.m.} + 16.4(\chi^2/\nu\ = 0.3)$		

TABLE VI. CD data.

$E_{c.m.}$ (keV)	S_{17}	Error
375	17.5	1.70
625	19.9	1.08
875	21.4	1.05
1125	22.5	2.30
1375	24.1	1.64
RIKEN2:		
$S = 0.0063E_{c.m.} + 15.7(\chi^2/\nu\ = 0.1)$		
415	19.18	0.81
639	21.20	4.8
979	24.46	2.3
1386	28.18	3.1
GSI1: $S = 0.0093E_{c.m.} + 15.3(\chi^2/\nu\ = 0.0)$		
316	17.47	1.07
507	19.42	1.21
695	21.67	1.48
942	24.34	1.69
1244	26.17	2.05
GSI2: $S = 0.0100E_{c.m.} + 14.4(\chi^2/\nu\ = 0.1)$		
316	19.3	1.2
507	20.6	1.3
695	22.9	1.7
942	23.6	1.6
1244	25.2	1.9
GSI2′:		
$S = 0.0066E_{c.m.} + 17.4(\chi^2/\nu\ = 0.1)$		

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