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Comment on comparison of theory and experiment for pair-production cross sections near threshold

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We have compared theoretical predictions for pair-production cross sections near threshold with recent experiments of Coquette and of En'yo, Numao, and Yamazaki, using results from numerical calculations in partial waves for the Hartree-Fock-Slater potential with the exchange term omitted. A majority of these experimental results for germanium are consistent with these calculations, but a residual discrepancy does persist in the middle portion of the lowest-energy range studied by Coquette.

We wish to clarify recent assertions concerning the agreement of theory and experiment for pair-production total cross sections near threshold. For this purpose we have made further calculations with our numerical partial-wave code.[1] En'yo, Numao, and Yamazaki[2] have recently reported a measurement for germanium ($Z=32$) at 1064 keV. Combining their result with earlier data of Rao, Lakshminaraiyana, and Inanananda,[3] En'yo *et al.* conclude that their result (30% above theory with a 26% error) and that of Rao *et al.* (30% below theory) when taken together, indicate that present theory is unsatisfactory. In fact, the results of Rao *et al.* are also 30% *above* theory and so these experiments do not offer any clear evidence of a discrepancy between theory and experiment. Meanwhile, however, Coquette[4] has reported an extensive set of measurements (in steps of 2.85 keV) of cross sections for germanium in the three photon-energy ranges 1.057–1.110 MeV, 1.180–1.207 MeV, and 1.240–1.263 MeV. With the theoretical results then available, it appeared that there was good agreement for the higher-energy ranges but (depending on interpolation) a significant disagreement in the middle portion of the lowest range. Our explicit calculations in this range reduce but do not entirely remove this discrepancy. Even more recently Avignone[5] has remeasured the case of En'yo *et al.*, obtaining excellent agreement with our theoretical calculation.

Earlier experimental measurements of the pair-production total cross section, and comparisons with theory, have been discussed by Motz, Olsen, and Koch,[6] by Overbo,[7] and by Tseng and Pratt.[1] More recently we examined[8] the previous experimental measurements of near-threshold pair-production cross sections, again using our results calculated numerically in partial waves. The level of agreement with experiment has been variable and does not suggest any systematic trends.

We show in Fig. 1 the new experimental results of Coquette and his interpolation of available theory. We present in Table I our new calculations for this region and we have also superimposed these results on Fig. 1. In Fig. 2 we show the same experimental and theoretical data for the cross section itself, rather than its ratio to Born approximation. Half of the 20 experimental values in the lowest-energy range agree with our calculations within the assigned errors of the measurements, but half do not. There are still

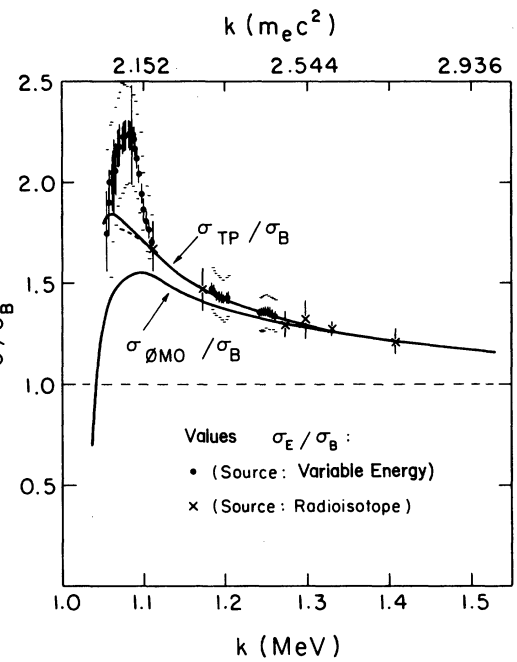

FIG. 1. Comparisons between theory (solid line) and the experiments of Coquette for the ratio σ/σ_B, where the symbol B refers to the point-Coulomb Born approximation, TP to our work, and ØMO to the work of Øverbø, Mork, and Olsen. This figure is superimposed on Fig. 1 of Ref. 4. The broken lines for σ_{TP}/σ_B, given by Coquette, are the extrapolated values from our results for $k \geq 2.10\ m_ec^2$, $Z=32$.

TABLE I. Total pair-production cross section σ computed with out partial-wave methods for germanium ($Z=32$) and photon energies $k=2.06$–2.178 m_ec^2, using the Hartree-Fock-Slater potential with the exchange term omitted (HFN).

$k(m_ec^2)$	σ_{HFN}(mb/atom)
2.06	0.0552
2.08	0.130
2.10	0.244
2.127	0.472
2.15	0.735
2.178	1.15

10% discrepancies[9] for the energy range 1.074–1.10 MeV (2.102–2.152 m_ec^2). We are not prepared to offer any explanation for these remaining discrepancies. We do note that the contribution from pair production in the field of atomic electrons has not been included. At higher energies, one could anticipate an order $1/Z$ contribution (order 5%) from this source. Here the energy is below threshold ($4m_ec^2$) for production in the field of a free electron and so the contribution is reduced due to its dependence on the binding of the electron.

We also show in Fig. 2 the comparison between our calculations and the older experiment of Yamazaki and Hollander,[10] as well as the recent result of En'yo, Numao, and Yamazaki.[2] There is no clear evidence of any disagreement, contrary to the suggestion of En'yo *et al.*

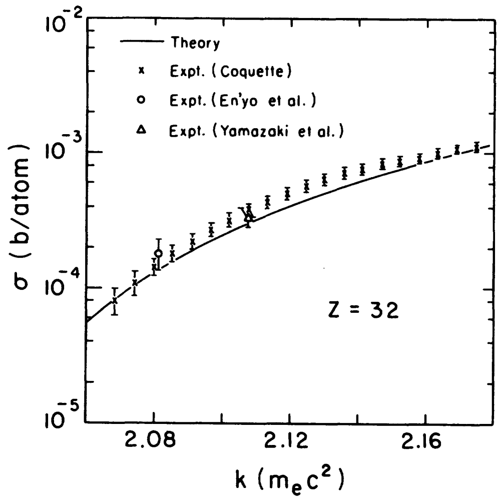

FIG. 2. Comparisons between theory (solid line) and experiments for the total pair production σ near threshold for $Z=32$, as a function of photon energy $k(m_ec^2)$.

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[1]H. K. Tseng and R. H. Pratt, Phys. Rev. A 6, 2049 (1972).

[2]H. En'yo, T. Numao, and T. Yamazaki, Phys. Rev. A 21, 1439 (1980).

[3]J. R. Rao, V. Lakshminaraiyana, and S. Inanananda, Proc. Phys. Soc. London 81, 949 (1963); Indian J. Pure Appl. Phys. 1, 199 (1963). The result of Rao *et al.* at $k=1.1192$ MeV for $Z=29$ is larger than our result, instead of smaller as supposed by En'yo *et al.* Thus, as can be seen from Fig. 2 of Ref. 2, the interpolated value obtained from Rao's data is somewhat above the smooth curve of the experimental results, showing that there is not significant Z dependence in the discrepancy between theory and experiment.

[4]A. Coquette, Nucl. Instrum. Methods 164, 337 (1979); and J. Phys. (Paris) 41, 97 (1980).

[5]F. Avignone (unpublished).

[6]J. W. Motz, H. A. Olsen, and H. W. Koch, Rev. Mod. Phys. 41, 581 (1969).

[7]I. Øverbø (unpublished); I. Øverbø, K. J. Mork, and H. A. Olsen, Phys. Rev. 175, 1978 (1968); Phys. Rev. A 8, 668 (1973).

[8]H. K. Tseng and R. H. Pratt, Phys. Rev. A 21, 454 (1980).

[9]The values of σ_{TP}/σ_B given by Coquette are the extrapolated values from our results for $k \geq 2.10$ m_ec^2 (or 1.073 MeV).

[10]T. Yamazaki and J. M. Hollander, Phys. Rev. 140, B630 (1965).