PART II

ELECTRON-BREMSSTRAHLUNG CROSS SECTION MEASUREMENTS AT INCIDENT ELECTRON ENERGIES OF 0.2, 1.0, 1.7, AND 2.5 MeV

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INTRODUCTION

In the intermediate energy range, i.e., below 4.0 MeV down to the non-relativistic energies, no exact theory for predicting the electron-bremsstrahlung cross sections exists. This is not due to a lack of understanding of the interaction process itself, but rather due to the computational difficulties encountered in obtaining the exact values. Present theoretical values of the bremsstrahlung cross sections available for comparison to experiment have been obtained by use of the Born Approximation.

Several earlier experiments of importance have been published which report measured cross sections values in the intermediate energy region. At 0.5 and 1.0 MeV J. W. Motz[1] reports experimental values which are several times greater than the Born-Approximation values at most angles. On the other hand, N. Starfelt and H. W. Koch[2] report experimental values at 2.72 MeV which are slightly below the Born-Approximation values. The results of the experiments imply that the region of energy between 1.0 and 2.72 MeV is a transition region in which the cross sections vary from well above the theory at 1.0 MeV to below it at 2.72 MeV.

The present experiment was intended to explore this apparent transition region systematically by including measurements near 1.0 and 2.72 MeV and at one intermediate energy for a number of elements. Measurements were made at 1.0, 1.7, and 2.5 MeV and at the additional energy of 0.2 MeV. Cross section values at these incident electron energies are reported for thin targets of Al, Cu, Sn, and Au (Z = 13, 29, 50, and 79). The data are plotted along with the corresponding Born-Approximation values. The comparison to the theory allows the trends with energy for a given element, and with element at a given energy to be readily discerned. A comparison of the experimental values from the present work to those of Motz at 1.0 MeV and those of Starfelt and Koch at 2.72 MeV is also given.

The bremsstrahlung cross sections differential in energy only were derived from the values at the various angles by integration over solid angle. Although much information is lost in the integration process, the values after integration are important for two reasons. The limiting value of the integrated cross section at the high energy end point has been estimated and is available for comparison to the experiment. It allows cross sections used in thick target bremsstrahlung yield computations to be adjusted in a relatively simple manner to conform with the measured cross section values.

EXPERIMENTAL RESULTS

The experimental procedure followed in making the present measurements and the data reduction scheme have been previously outlined[3]. Also the present measurements at 1.0, 1.7, and 2.5 MeV have been reported in the literature[4]. The measurements at 1.0 MeV and at 1.7 and 2.5 MeV for Al were included in the Final Report of the Electron Interactions Contract No. NASw-1385. The present report includes all the measurements of electron-bremsstrahlung cross sections which have been made during the NASA-sponsored study of electron interaction processes, even though some of these have been reported earlier to NASA. This is considered desirable since of primary importance is the trend of the data with incident energy and with atomic number.

To interpret the experimental results discussed below a consideration of the probable errors is necessary. These have been discussed elsewhere in detail[3,4]. Where comparisons to other experimental data are made, error bars are included at typical points. At 1.0, 1.7 and 2.5 MeV the estimated uncertainties are the following:

(1) In the photon region between 10% and 90% of the incident energy, an average experimental error of 15% is assigned.

(2) At 0, 4 and 10 deg, where the angular distribution is relatively flat, the uncertainty in the same photon region is estimated to be 7%.

(3) In the photon energy region greater than 90% of the end point additional uncertainty arises due to poor statistics and detector response removal, and the total uncertainty is estimated to be 30-50%.

A 15% uncertainty is estimated in the cross sections integrated over solid angle in the photon energy region of the spectra below 90% of the high energy end point. An uncertainty of 30-50% in the high energy region is assigned. At an incident energy of 0.2 MeV an average uncertainty in the measured cross sections of 20% is estimated at angles less than 90 deg. At angles greater than 90 deg the estimate of uncertainty is increased to 30%. The characteristic x ray of Au has been removed from the Au data, which has introduced an additional uncertainty of 10% below 100 keV in the spectra at angles greater than 60 deg. An average uncertainty of 20% is estimated in the cross sections integrated over solid angle at 0.2 MeV.

Measured cross sections differential in energy and solid angle at an incident energy of 0.2 MeV are shown in Figs. 1-5. Figures 1-4 show the cross sections for each of the four elements. Figure 5 shows the values at 10 and 20 deg for the four elements. These have been plotted separately on one figure, since the values at these angles overlap the values at neighboring angles. The trend of the experimental values relative to the Born-Approximation theory is apparent in Fig. 5. Increased yields near the high energy end point is observed with increasing atomic number.

The experimental cross sections, compared to the Born-Approximation theory, at an incident energy of 1.0 MeV are shown in Figs. 6-10. A separate plot of the cross sections at 4 deg for the four elements is given in Fig. 10. As at 0.2 MeV this graph allows an easy comparison of the experiment to the theory to be made as a function of atomic number. At 1.0 MeV the measured values for Al are close to the Born Approximation, except near the high energy end point where the Born Approximation is not valid. There is some variation with angle observed, however, especially in the low photon energy region. Here at the small angles the measured values are below the theory slightly, while at larger angles they are above the theory. The reduction in yield is ascribed to the effect of atomic electron screening of the nuclear charge. An increasing departure from the theory at 1.0 MeV is seen with increasing atomic number.

A comparison to the experiment of Motz for Al at 1.0 MeV and Θ = 10 and 30 deg is given in Fig. 11. Both sets of cross sections have been normalized to the Born-Approximation values. The disagreement between the two experiments below a photon energy of 0.8 MeV at Θ = 10 deg is well outside the limits of errors of the two experiments. The error bars on Motz's data are based on a limit of error of 22% given in his article. An estimate of error of 7% at 10 deg and 15% at 30 deg has been assigned to the present data. If the lower limit of the value allowed by Motz is compared to the upper limit allowed from the present experiment, the value from the present experiment at 0.2 MeV and 10 deg is still 25% below that of Motz. At 30 deg the experimental values are closer but are still outside the limits of errors below a photon energy of 300 keV. A comparison to the experiment of Motz at 1.0 MeV for Au and Θ = 0, 20, 30, and 90 deg is given in Fig. 12. The two experiments disagree significantly at 0 deg. At a photon energy of 0.2 MeV the measurements are outside their respective error limits by about 20% of the lower limit stated by Motz. However, the measurements indicate decreasing discrepancy with photon energy and are within the limit of errors at 0.55 MeV. The two experiments are generally closer at Θ = 20 deg. At this angle the measurements are within the estimated uncertainties from a photon energy of about 0.35 MeV. With an increased uncertainty in the present experiment at 30 deg, the two results overlap except in the region below 0.2 MeV. The two measurements are in agreement at 90 deg.

Figures 13-16 give the experimental results for an incident electron energy of 1.7 MeV. The Born-Approximation values at an atomic number 13 are quite good, if allowance for the expected departure in the region above 80% of the end point energy is made. In addition at $\Theta = 0$ and 4 deg the effect of screening is significant below 0.4 MeV. For the higher atomic numbers the theory and the experiment are generally much closer than they were at the lower energies. For Au the screening effect is large with the 0-deg experimental values falling below the 4-deg theoretical values. At larger angles, however, the experimental values become increasingly larger relative to the theory.

The cross sections at 2.5 MeV are given in Figs. 17-20. Fewer angles are given at this energy. This is because the emitted bremsstrahlung becomes more and more peaked in the direction of the incident electron beam as the incident energy is increased. Generally, the results at 2.5 MeV are closer to the theory than at the lower energies. However, at 0 and 4 deg the measured values tend to drop below the theory over a significant fraction of the photon spectrum.

The comparison of the present measurements at 2.5 MeV to those of Starfelt and Koch at 2.72 MeV is shown in Fig. 21. Comparable measurements at 0 deg for Al and Au normalized to the Born-Approximation theory are plotted versus the fraction of the incident energy. The agreement between the two experiments is within the experimental error.

The experimental cross sections and the theory integrated over solid angle are shown in Figs. 22-25. At 0.2 MeV a correction to the Born-Approximation values has been made by use of the Elwert factors. The Born-Elwert values are shown as dashed lines. For the case of Al, the experiment is in agreement with the Born-Elwert values. However, at higher atomic numbers the Born-Elwert values are below the experiment, indicating that they inadequately account for the

Coulomb effect for large atomic number.

The estimated value of the cross section at the end point of the spectra (at the photon energy equal to the incident electron energy) is also shown in Figs. 22-25 as the corrected Sauter-Fano limit. In most cases the measured values agree with the estimated values. The uncertainty in the experimental value at the end-point, however, is quite large (as much as 50%).

A partial tabulation of the measured cross sections differential in solid angle and photon energy shown in the figures is given in Table I. A complete table of the 1.0-MeV cross sections and the 1.7 and 2.5 MeV cross sections for Al were reported earlier[3]. Table II gives a complete tabulation of the experimental cross sections differential in energy only. The comparison to the Born-Approximation values (which can be computed easily) given in the figures and the experimental values given in tabular form should allow an accurate determination of any of the experimental values.

CONCLUSIONS

The present measurements together with the results of Starfelt and Koch provide a consistent set of experimental cross sections from 0.2 to 10 MeV for comparison to theory or for application in thick target bremsstrahlung calculations. The disagreement between the present experiment and the work of Motz, however, is significant. It is felt that the agreement of the present measurements with that of Starfelt and Koch and the comparisons with the Born-Approximation theory provide important evidence in favor of the present work. The presence of background in the measurements of Motz is the most likely difference between the two experiments (see ref. 4).

The most significant problem that remains in the intermediate energy range is the determination of the magnitude of bremsstrahlung produced by the interaction between the bound atomic electrons and the incoming bombarding electrons. To investigate this bremsstrahlung component, measurements similar to those reported for Al, Cu, Sn, and Au should be carried out on Be targets.

REFERENCES

1. J. W. Motz, Phys. Rev. 100, 1560 (1955).

2. N. Starfelt and H. W. Koch, Phys. Rev. 102, 1598 (1956).

3. NASA Contractor Report CR-759, "Electron Scattering and Bremsstrahlung Cross Section Measurements", 23 (1967).

4. D. H. Rester and W. E. Dance, Phys. Rev. 161, 85 (1966).

TABLE I

EXPERIMENTAL ELECTRON-BREMSSTRAHLUNG CROSS SECTIONS

A. T_o = 0.2 MeV

k(MeV)	dσ/dkdΩ (barns/MeV Sr)			
	θ = 10	θ = 30	θ = 60	θ = 105
1. Z = 13				
0.046	1.47 (1)	9.60 (0)	4.30 (0)	1.78 (0)
0.076	9.15 (0)	6.18 (0)	2.85 (0)	9.51(-1)
0.106	4.58 (0)	4.00 (0)	1.78 (0)	5.00(-1)
0.136	2.45 (0)	2.65 (0)	1.10 (0)	3.31(-1)
0.166	1.15 (0)	1.75 (0)	6.70(-1)	1.43(-1)
0.196	3.80(-1)	8.90(-1)	2.70(-1)	6.00(-2)
2. Z = 29				
0.046	7.75 (1)	5.68 (1)	2.44 (1)	1.02 (1)
0.076	4.60 (1)	3.92 (1)	1.75 (1)	5.73 (0)
0.106	2.50 (1)	2.30 (1)	1.03 (1)	2.93 (0)
0.136	1.45 (1)	1.52 (1)	6.80 (0)	2.02 (0)
0.166	7.90 (0)	1.15 (1)	5.10 (0)	1.11 (0)
0.196	2.45 (0)	5.10 (0)	2.50 (0)	6.00(-1)
3. Z = 50				
0.046	2.55 (2)	1.74 (2)	7.10 (1)	2.50 (1)
0.076	1.44 (2)	1.12 (2)	4.91 (1)	1.46 (1)
0.106	8.30 (1)	7.60 (1)	3.30 (1)	7.50 (0)
0.136	5.25 (1)	5.45 (1)	2.27 (1)	5.90 (0)
0.166	2.79 (1)	4.30 (1)	1.60 (1)	3.10 (0)
0.196	1.15 (1)	2.35 (1)	1.24 (1)	1.50 (0)
4. Z = 79				
0.046	4.65 (2)	3.48 (2)	1.73 (2)	7.15 (1)
0.076	3.15 (2)	2.60 (2)	1.34 (2)	4.47 (1)
0.106	1.90 (2)	1.82 (2)	8.88 (1)	2.52 (1)
0.136	1.14 (2)	1.38 (2)	6.70 (1)	2.00 (1)
0.166	7.50 (1)	1.02 (2)	5.30 (1)	1.15 (1)
0.196	3.90 (1)	5.60 (1)	2.79 (1)	6.80 (0)

TABLE I (Continued)

B. T_o = 1.7 MeV

k(MeV)	dσ/dkdΩ (barns/MeV Sr) θ = 0	θ = 10	θ = 20	θ = 40
1. Z = 29				
0.156	3.78 (2)	1.32 (2)	3.65 (1)	5.80 (0)
0.305	1.68 (2)	5.95 (1)	1.55 (1)	2.26 (0)
0.454	9.40 (1)	3.41 (1)	8.98 (0)	1.18 (0)
0.603	6.05 (1)	2.23 (1)	5.60 (0)	6.70(-1)
0.752	3.76 (1)	1.46 (1)	3.55 (0)	4.60(-1)
0.901	2.57 (1)	1.07 (1)	2.70 (0)	2.93(-1)
1.050	1.84 (1)	8.00 (0)	1.82 (0)	2.08(-1)
1.198	1.29 (1)	5.85 (0)	1.41 (0)	1.41(-1)
1.347	8.30 (0)	4.55 (0)	1.01 (0)	1.01(-1)
1.496	6.22 (0)	3.05 (0)	7.30(-1)	8.00(-2)
1.645	2.38 (0)	2.00 (0)	5.20(-1)	5.60(-2)
2. Z = 50				
0.156	9.04 (2)	3.40 (2)	9.60 (1)	1.62 (1)
0.305	3.90 (2)	1.56 (2)	4.25 (1)	6.50 (0)
0.454	2.31 (2)	9.20 (1)	2.49 (1)	3.45 (0)
0.603	1.43 (2)	6.05 (1)	1.57 (1)	2.16 (0)
0.752	9.40 (1)	4.15 (1)	1.06 (1)	1.42 (0)
0.901	6.50 (1)	3.00 (1)	7.70 (0)	8.45(-1)
1.050	4.57 (1)	2.22 (1)	5.62 (0)	6.30(-1)
1.198	3.21 (1)	1.65 (1)	4.10 (0)	4.60(-1)
1.347	2.35 (1)	1.29 (1)	3.15 (0)	3.38(-1)
1.496	1.48 (1)	9.60 (0)	2.28 (0)	2.65(-1)
1.645	7.60 (0)	6.00 (0)	1.75 (0)	2.05(-1)
3. Z = 79				
0.156	2.15 (3)	8.50 (2)	2.55 (2)	4.45 (1)
0.305	9.30 (2)	3.82 (2)	1.16 (2)	1.86 (1)
0.454	5.48 (2)	2.35 (2)	6.80 (1)	1.05 (1)
0.603	3.45 (2)	1.52 (2)	4.56 (1)	6.68 (0)
0.752	2.22 (2)	1.05 (2)	3.00 (1)	4.20 (0)
0.901	1.58 (2)	8.25 (1)	2.26 (1)	2.85 (0)
1.050	1.12 (2)	5.90 (1)	1.66 (1)	2.18 (0)
1.198	8.22 (1)	4.45 (1)	1.28 (1)	1.68 (0)
1.347	6.00 (1)	3.80 (1)	1.06 (1)	1.19 (0)
1.496	4.50 (1)	2.95 (1)	8.00 (0)	9.60(-1)
1.645	3.00 (1)	2.30 (1)	6.10 (0)	7.90(-1)

TABLE I (Continued)

C. T_o = 2.50 MeV

k(MeV)	dσ/dkdΩ (barns/MeV Sr)			
	θ = 0	θ = 10	θ = 20	θ = 30
1. Z = 29				
0.227	4.55 (2)	9.90 (1)	2.15 (1)	7.00 (0)
0.451	2.10 (2)	4.60 (1)	9.00 (0)	2.82 (0)
0.676	1.14 (2)	2.55 (1)	4.80 (0)	1.46 (0)
0.900	7.20 (1)	1.58 (1)	2.88 (0)	8.30(-1)
1.124	4.65 (1)	1.13 (1)	1.83 (0)	5.42(-1)
1.348	3.22 (1)	8.11 (0)	1.36 (0)	3.75(-1)
1.573	2.24 (1)	5.63 (0)	9.50(-1)	2.33(-1)
1.797	1.53 (1)	4.15 (0)	6.70(-1)	1.59(-1)
2.021	1.10 (1)	3.30 (0)	4.49(-1)	1.23(-1)
2.245	6.50 (0)	2.29 (0)	3.28(-1)	9.30(-2)
2.470	2.73 (0)	1.66 (0)	2.80(-1)	7.80(-2)
2. Z = 50				
0.227	1.08 (3)	2.39 (2)	5.30 (1)	1.74 (1)
0.451	5.02 (2)	1.13 (2)	2.30 (1)	6.90 (0)
0.676	2.78 (2)	6.30 (1)	1.25 (1)	3.55 (0)
0.900	1.72 (2)	4.05 (1)	7.40 (0)	2.00 (0)
1.124	1.16 (2)	2.78 (1)	5.32 (0)	1.36 (0)
1.348	8.20 (1)	2.18 (1)	3.43 (0)	9.70(-1)
1.573	5.55 (1)	1.50 (1)	2.62 (0)	6.30(-1)
1.797	3.85 (1)	1.11 (1)	1.71 (0)	4.65(-1)
2.021	2.82 (1)	9.00 (0)	1.35 (0)	3.50(-1)
2.245	1.96 (1)	6.70 (0)	1.01 (0)	2.72(-1)
2.470	1.15 (1)	5.45 (0)	8.80(-1)	2.51(-1)
3. Z = 79				
0.227	2.48 (3)	6.20 (2)	1.32 (2)	5.00 (1)
0.451	1.13 (3)	2.92 (2)	5.90 (1)	2.02 (1)
0.676	6.50 (2)	1.61 (2)	3.22 (1)	1.08 (1)
0.900	3.95 (2)	1.07 (2)	2.05 (1)	6.62 (0)
1.124	2.64 (2)	7.50 (1)	1.38 (1)	4.18 (0)
1.348	1.96 (2)	5.80 (1)	9.90 (0)	2.95 (0)
1.573	1.38 (2)	4.05 (1)	7.75 (0)	2.17 (0)
1.797	9.90 (1)	3.05 (1)	6.20 (0)	1.50 (0)
2.021	7.28 (1)	2.68 (1)	4.76 (0)	1.10 (0)
2.245	5.38 (1)	2.00 (1)	3.35 (0)	8.75(-1)
2.470	4.04 (1)	1.76 (1)	3.00 (0)	8.00(-1)

TABLE II

EXPERIMENTAL BREMSSTRAHLUNG CROSS SECTIONS
INTEGRATED OVER SOLID ANGLE

A. T_o = 0.20 MeV

k(MeV)	dσ/dk (barns/MeV)			
	Z = 79	Z = 50	Z = 29	Z = 13
0.046	1.60 (3)	6.91 (2)	2.40 (2)	4.12 (1)
0.056	1.40 (3)	6.07 (2)	2.06 (2)	3.59 (1)
0.066	1.22 (3)	5.05 (2)	1.64 (2)	3.09 (1)
0.076	1.12 (3)	4.44 (2)	1.59 (2)	2.60 (1)
0.086	9.57 (2)	3.89 (2)	1.26 (2)	2.21 (1)
0.096	8.55 (2)	3.24 (2)	1.02 (2)	1.72 (1)
0.106	7.39 (2)	2.88 (2)	8.88 (1)	1.54 (1)
0.116	6.62 (2)	2.55 (2)	7.44 (1)	1.31 (1)
0.126	5.90 (2)	2.17 (2)	6.48 (1)	1.13 (1)
0.136	5.51 (2)	2.00 (2)	5.85 (1)	9.71 (0)
0.146	4.98 (2)	1.69 (2)	5.08 (1)	8.32 (0)
0.156	4.48 (2)	1.47 (2)	4.28 (1)	7.08 (0)
0.166	4.02 (2)	1.42 (2)	4.08 (1)	5.81 (0)
0.176	3.78 (2)	1.26 (2)	3.38 (1)	5.19 (0)
0.186	3.30 (2)	1.13 (2)	2.58 (1)	4.14 (0)
0.196	2.22 (2)	9.00 (1)	2.01 (1)	2.63 (0)

B. T_o = 1.0 MeV

k(MeV)	Z = 79	Z = 50	Z = 29	Z = 13
0.079	8.70 (2)	3.12 (2)	1.15 (2)	2.21 (1)
0.113	5.32 (2)	2.07 (2)	7.91 (1)	1.45 (1)
0.147	3.69 (2)	1.40 (2)	5.41 (1)	9.80 (0)
0.181	2.78 (2)	1.06 (2)	3.99 (1)	7.16 (0)
0.215	2.24 (2)	8.38 (1)	3.11 (1)	5.63 (0)
0.250	1.84 (2)	6.86 (1)	2.56 (1)	4.55 (0)
0.284	1.60 (2)	6.00 (1)	2.19 (1)	3.88 (0)
0.318	1.40 (2)	5.11 (1)	1.82 (1)	3.27 (0)
0.352	1.21 (2)	4.52 (1)	1.59 (1)	2.80 (0)
0.386	1.11 (2)	3.85 (1)	1.37 (1)	2.39 (0)
0.420	9.41 (1)	3.43 (1)	1.19 (1)	2.09 (0)
0.454	8.33 (1)	2.93 (1)	1.04 (1)	1.80 (0)
0.488	7.33 (1)	2.58 (1)	9.09 (0)	1.60 (0)
0.522	6.74 (1)	2.30 (1)	8.19 (0)	1.34 (0)
0.556	5.63 (1)	2.00 (1)	7.25 (0)	1.14 (0)
0.590	5.28 (1)	1.81 (1)	5.97 (0)	1.00 (0)
0.624	4.62 (1)	1.63 (1)	5.25 (0)	8.90(-1)
0.659	4.43 (1)	1.40 (1)	4.68 (0)	7.61(-1)
0.693	3.86 (1)	1.24 (1)	4.36 (0)	6.88(-1)

TABLE II (Continued)

k(MeV)	dσ/dk (barns/MeV)			
	Z = 79	Z = 50	Z = 29	Z = 13
0.727	3.44 (1)	1.15 (1)	3.66 (0)	6.06(-1)
0.761	3.04 (1)	9.70 (0)	3.17 (0)	5.18(-1)
0.795	2.72 (1)	8.79 (0)	2.91 (0)	4.22(-1)
0.829	2.60 (1)	7.44 (0)	2.54 (0)	3.74(-1)
0.863	2.41 (1)	6.69 (0)	2.08 (0)	3.21(-1)
0.897	2.15 (1)	5.97 (0)	1.91 (0)	2.74(-1)
0.931	1.96 (1)	5.03 (0)	1.60 (0)	2.21(-1)
0.965	1.83 (1)	4.87 (0)	1.40 (0)	1.74(-1)
0.999	1.70 (1)	3.41 (0)	1.18 (0)	1.20(-1)

C. T_o = 1.7 MeV

k(MeV)	Z = 79	Z = 50	Z = 29	Z = 13
0.186	3.08 (2)	1.19 (2)	4.54 (1)	8.74 (0)
0.245	2.30 (2)	8.80 (1)	3.36 (1)	6.36 (0)
0.305	1.81 (2)	6.94 (1)	2.59 (1)	4.87 (0)
0.364	1.43 (2)	5.51 (1)	2.06 (1)	3.83 (0)
0.424	1.16 (2)	4.45 (1)	1.64 (1)	3.09 (0)
0.484	9.69 (1)	3.65 (1)	1.42 (1)	2.47 (0)
0.543	8.24 (1)	2.99 (1)	1.10 (1)	2.03 (0)
0.603	6.91 (1)	2.55 (1)	9.27 (0)	1.70 (0)
0.662	5.85 (1)	2.18 (1)	7.83 (0)	1.43 (0)
0.722	5.01 (1)	1.88 (1)	6.59 (0)	1.21 (0)
0.781	4.25 (1)	1.66 (1)	5.57 (0)	1.04 (0)
0.841	3.80 (1)	1.37 (1)	4.87 (0)	8.81(-1)
0.901	3.38 (1)	1.20 (1)	4.28 (0)	7.64(-1)
0.960	2.92 (1)	1.04 (1)	3.71 (0)	6.58(-1)
1.020	2.57 (1)	9.27 (0)	3.22 (0)	5.81(-1)
1.079	2.33 (1)	8.16 (0)	2.85 (0)	4.97(-1)
1.139	2.11 (1)	7.18 (0)	2.50 (0)	4.35(-1)
1.198	1.87 (1)	6.41 (0)	2.22 (0)	3.74(-1)
1.258	1.72 (1)	5.89 (0)	1.98 (0)	3.36(-1)
1.318	1.52 (1)	5.20 (0)	1.80 (0)	2.79(-1)
1.377	1.42 (1)	4.52 (0)	1.53 (0)	2.52(-1)
1.437	1.31 (1)	4.02 (0)	1.31 (0)	2.07(-1)
1.496	1.16 (1)	3.54 (0)	1.14 (0)	1.78(-1)
1.556	1.01 (1)	3.10 (0)	9.70(-1)	1.52(-1)
1.615	9.35 (0)	2.69 (0)	8.10(-1)	1.26(-1)
1.675	8.24 (0)	2.30 (0)	6.60(-1)	8.52(-2)

TABLE II (Continued)

D. $T_o = 2.5$ MeV

k(MeV)	dσ/dk (barns/MeV)			
	Z = 79	Z = 50	Z = 29	Z = 13
0.227	2.36 (2)	9.42 (1)	3.98 (1)	7.63 (0)
0.317	1.67 (2)	6.66 (1)	2.78 (1)	5.27 (0)
0.407	1.32 (2)	5.16 (1)	2.19 (0)	4.11 (0)
0.496	9.63 (1)	3.81 (1)	1.59 (1)	2.97 (0)
0.586	7.65 (1)	2.97 (1)	1.23 (1)	2.31 (0)
0.676	6.08 (1)	2.40 (1)	9.83 (0)	1.82 (0)
0.765	5.00 (1)	1.95 (1)	8.01 (0)	1.50 (0)
0.855	4.25 (1)	1.60 (1)	6.73 (0)	1.28 (0)
0.945	3.61 (1)	1.35 (1)	5.66 (0)	1.06 (0)
1.035	3.13 (1)	1.18 (1)	4.93 (0)	9.11(-1)
1.124	2.70 (1)	1.02 (1)	4.30 (0)	7.50(-1)
1.214	2.40 (1)	8.95 (0)	3.74 (0)	6.61(-1)
1.304	2.01 (1)	7.69 (0)	3.23 (0)	5.75(-1)
1.393	1.76 (1)	6.55 (0)	2.61 (0)	4.90(-1)
1.483	1.57 (1)	5.84 (0)	2.24 (0)	4.29(-1)
1.573	1.42 (1)	5.04 (0)	2.03 (0)	3.71(-1)
1.662	1.26 (1)	4.55 (0)	1.74 (0)	3.33(-1)
1.752	1.13 (1)	4.06 (0)	1.57 (0)	2.94(-1)
1.842	1.01 (1)	3.52 (0)	1.39 (0)	2.53(-1)
1.932	9.25 (0)	3.26 (0)	1.22 (0)	2.25(-1)
2.021	8.36 (0)	2.92 (0)	1.09 (0)	1.96(-1)
2.111	7.48 (0)	2.51 (0)	9.46(-1)	1.63(-1)
2.201	6.55 (0)	2.15 (0)	8.24(-1)	1.39(-1)
2.290	5.89 (0)	1.92 (0)	6.92(-1)	1.20(-1)
2.380	5.33 (0)	1.69 (0)	5.89(-1)	9.87(-2)
2.470	4.94 (0)	1.48 (0)	5.03(-1)	8.95(-2)

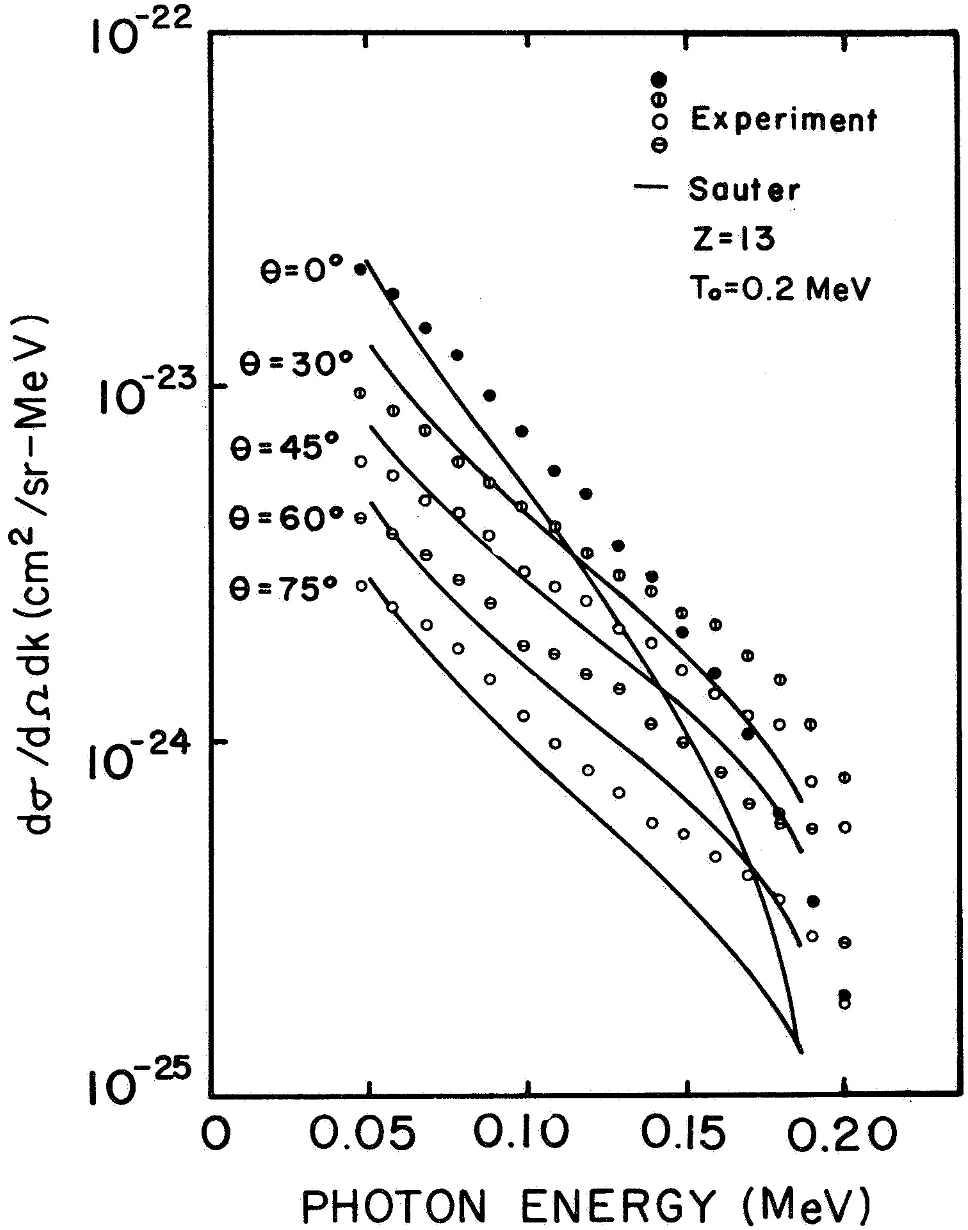

FIGURE 1 BREMSSTRAHLUNG DIFFERENTIAL CROSS SECTIONS FOR 0.2 - MeV ELECTRONS ON AL.

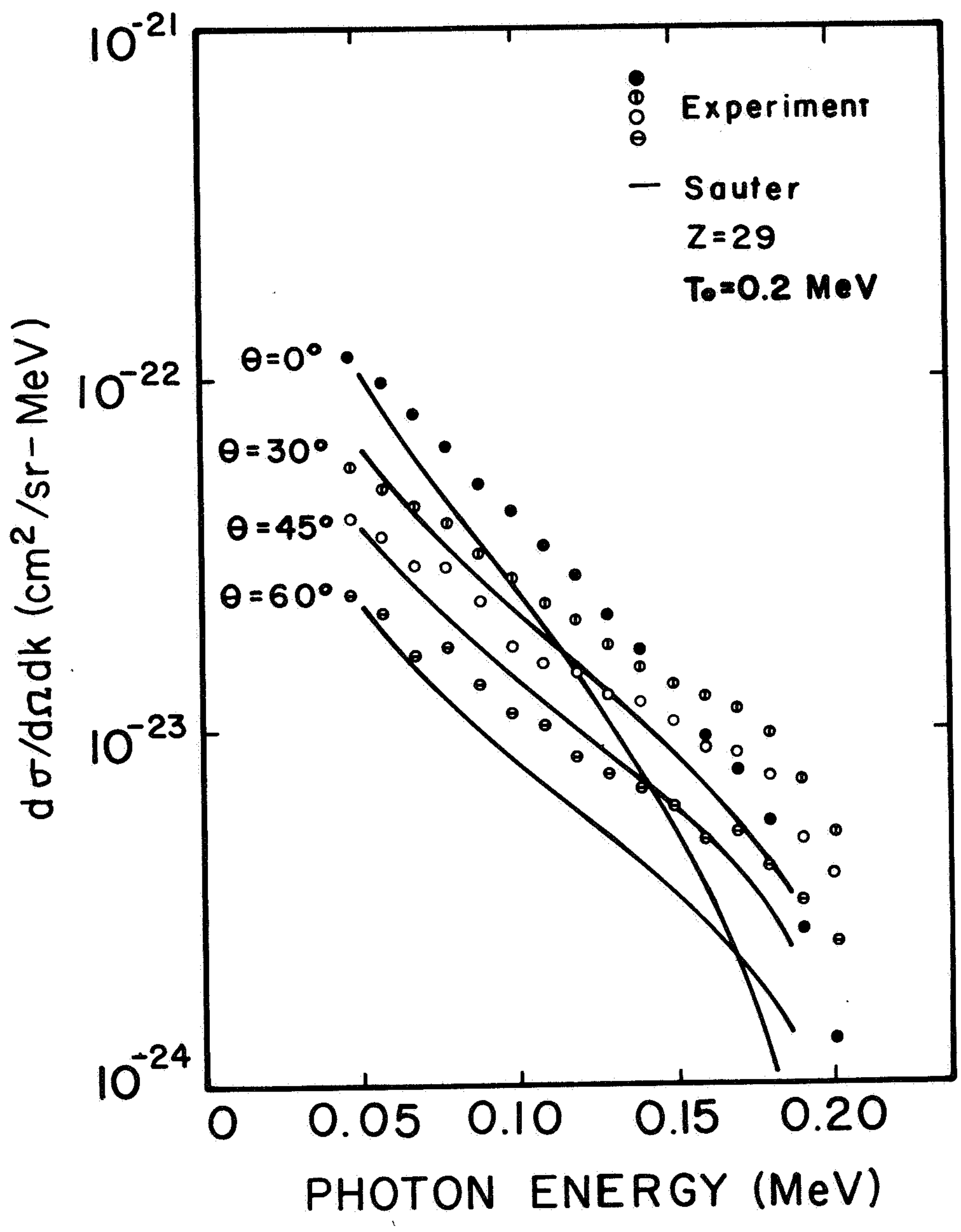

FIGURE 2. BREMSSTRAHLUNG DIFFERENTIAL CROSS SECTIONS FOR 0.2 - MeV ELECTRONS ON CU.

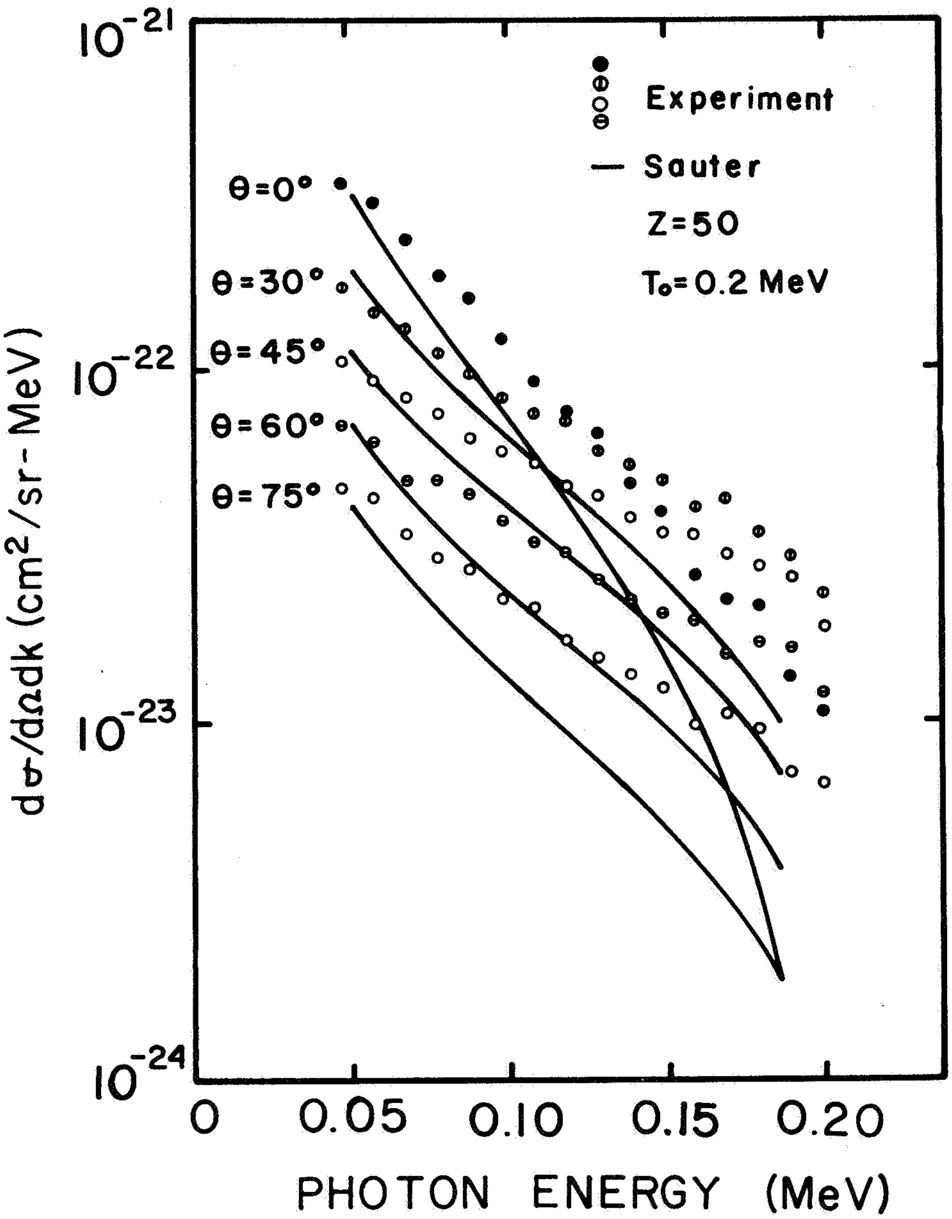

FIGURE 3. BREMSSTRAHLUNG DIFFERENTIAL CROSS SECTIONS FOR 0.2 - MeV ELECTRONS ON SN.

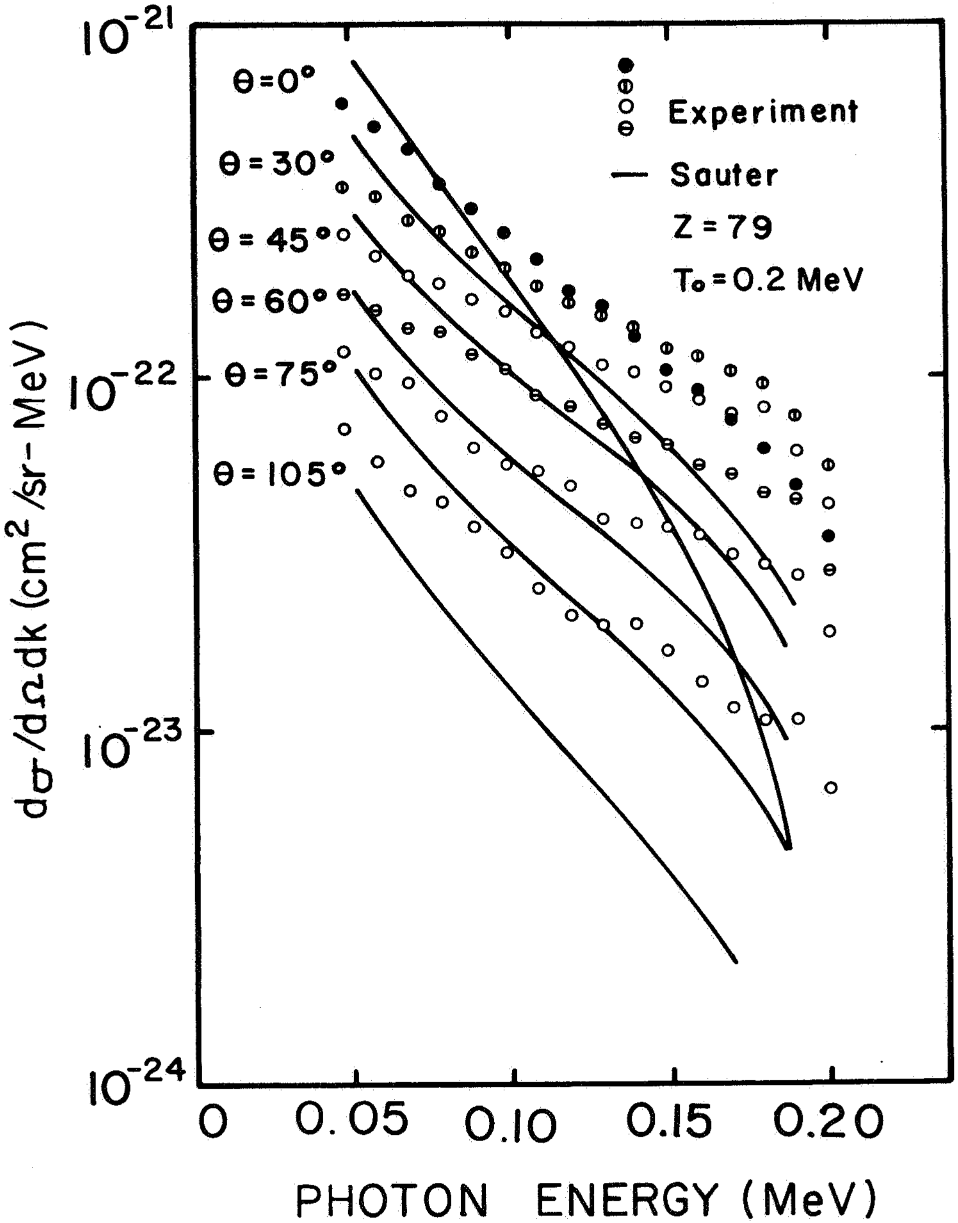

FIGURE 4. BREMSSTRAHLUNG DIFFERENTIAL CROSS SECTIONS FOR 0.2 - MeV ELECTRONS ON AU.

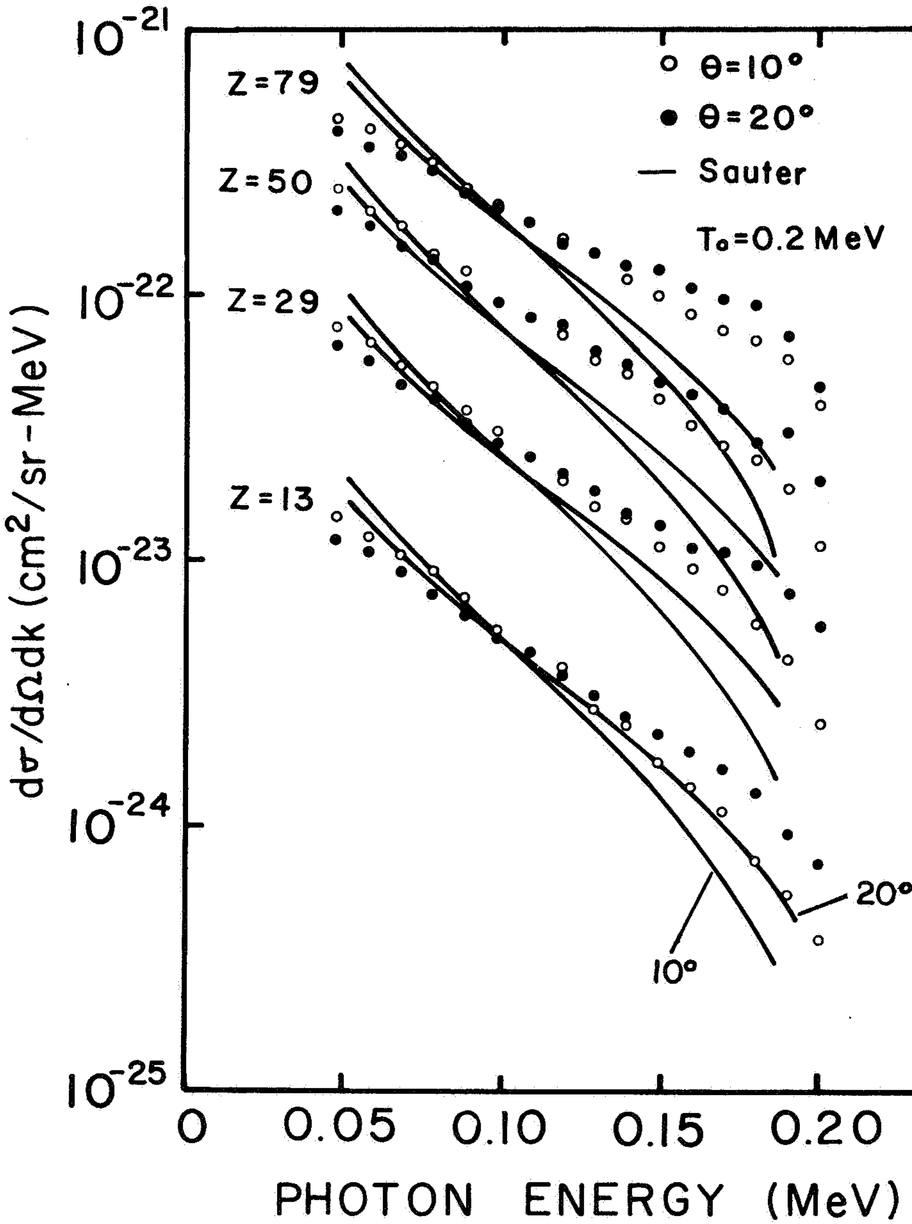

FIGURE 5. BREMSSTRAHLUNG DIFFERENTIAL CROSS SECTIONS, Θ = 10 AND 20 DEG, FOR 0.2 - MeV ELECTRONS ON AL, CU, SN, AND AU.

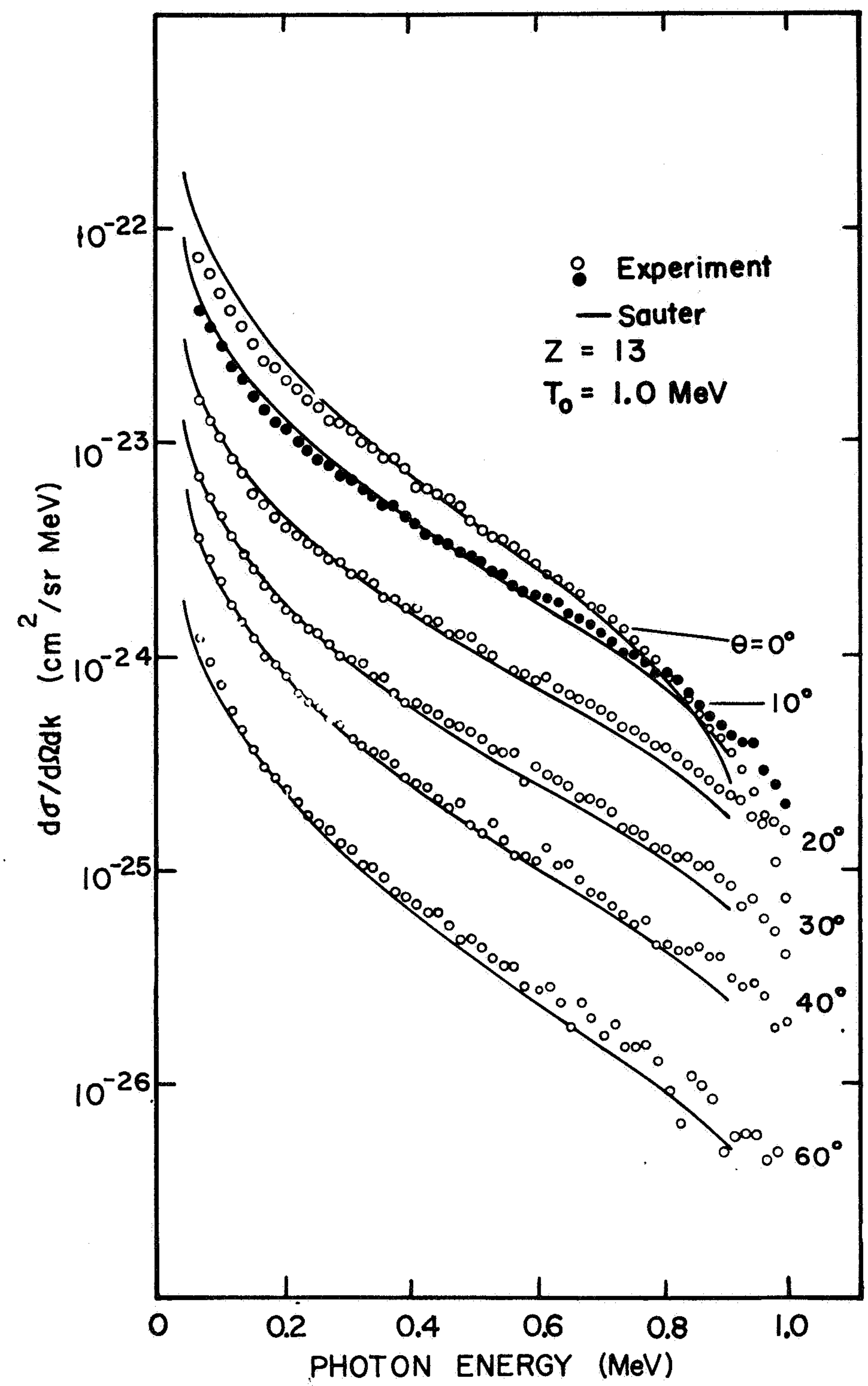

FIGURE 6. BREMSSTRAHLUNG DIFFERENTIAL CROSS SECTIONS FOR 1.0-MeV ELECTRON ON AL.

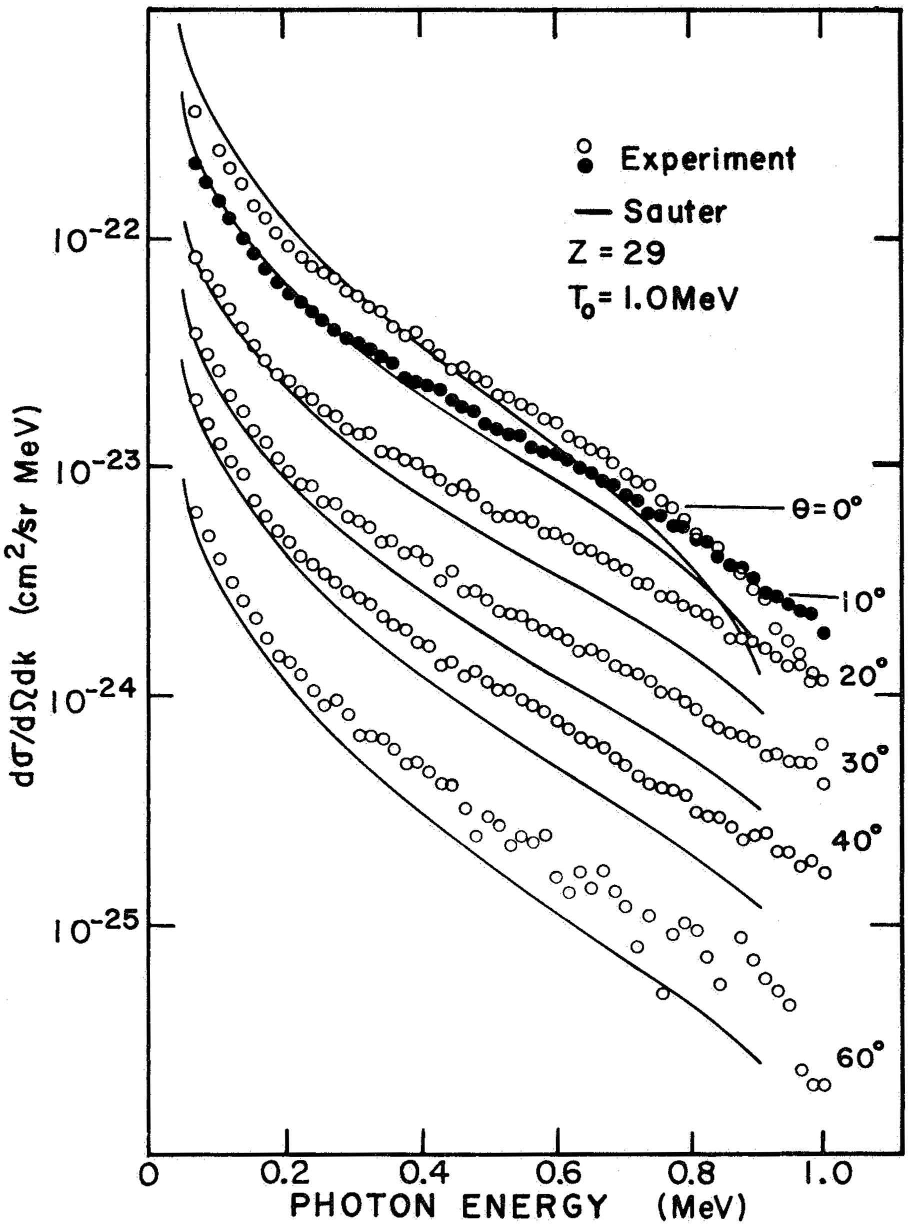

FIGURE 7. BREMSSTRAHLUNG DIFFERENTIAL CROSS SECTIONS FOR 1.0-MeV ELECTRON ON CU.

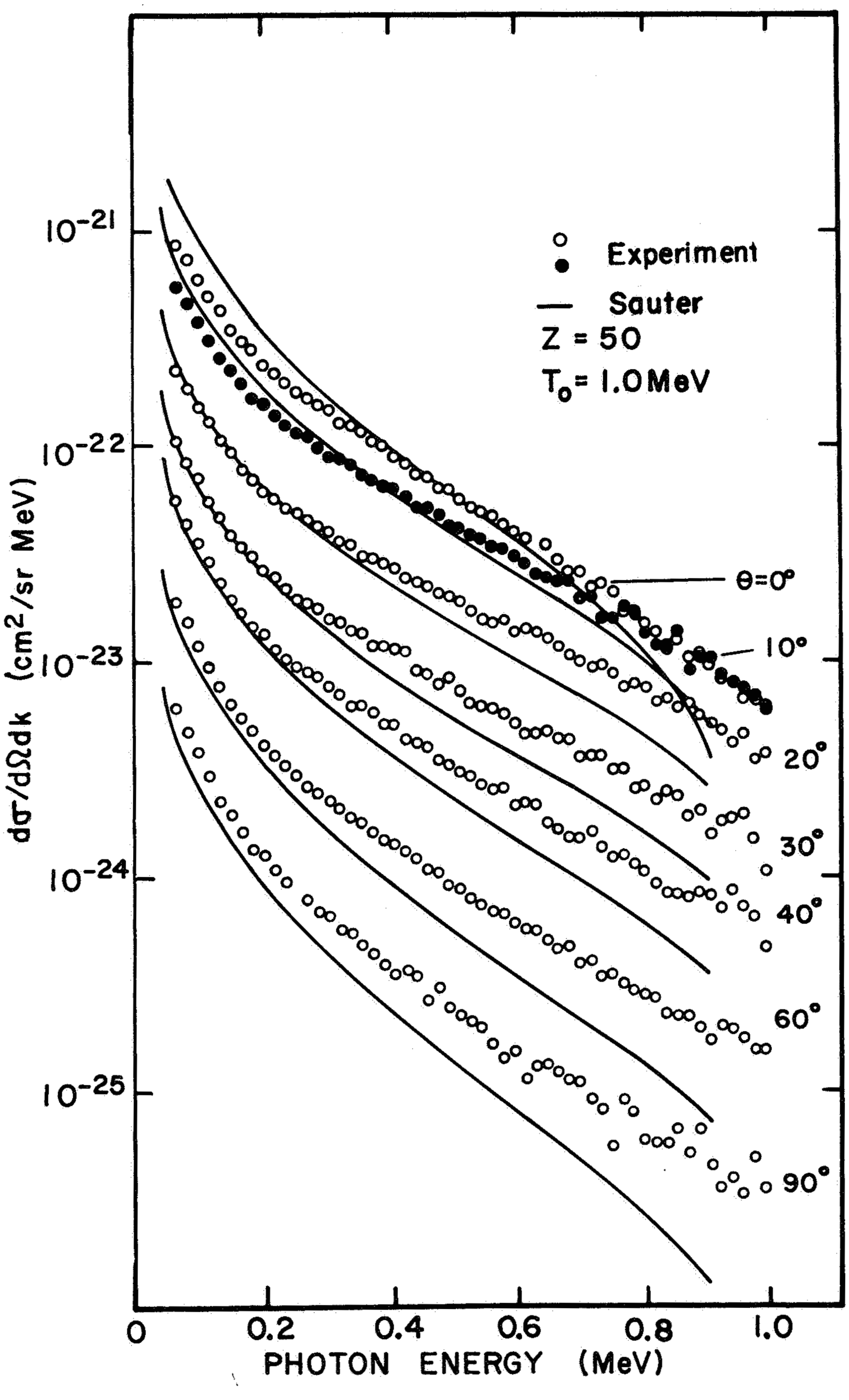

FIGURE 8. BREMSSTRAHLUNG DIFFERENTIAL CROSS SECTIONS FOR 1.0-MeV ELECTRON ON SN.

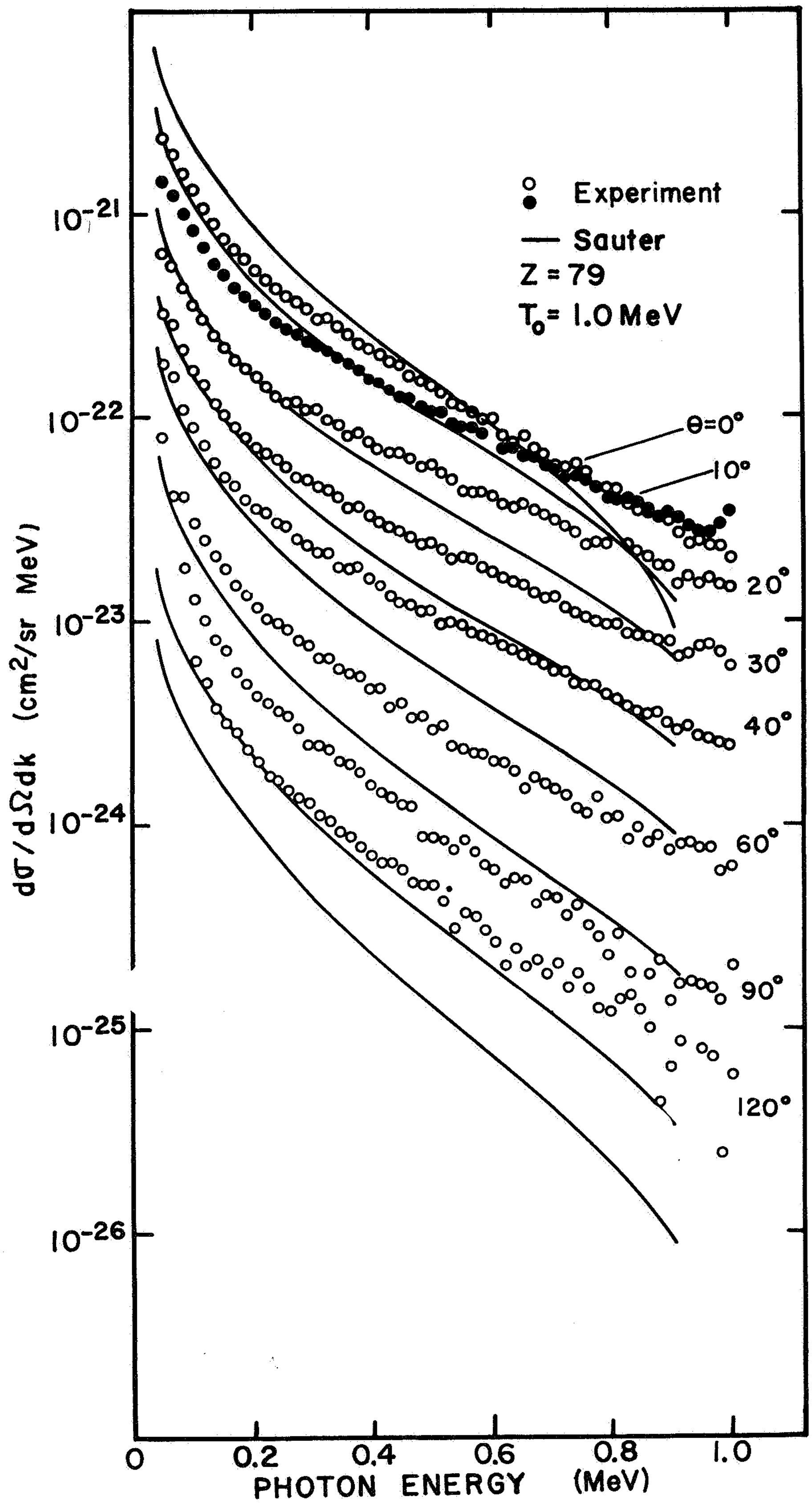

FIGURE 9. BREMSSTRAHLUNG DIFFERENTIAL CROSS SECTIONS FOR 1.0 MeV ELECTRON ON AU.

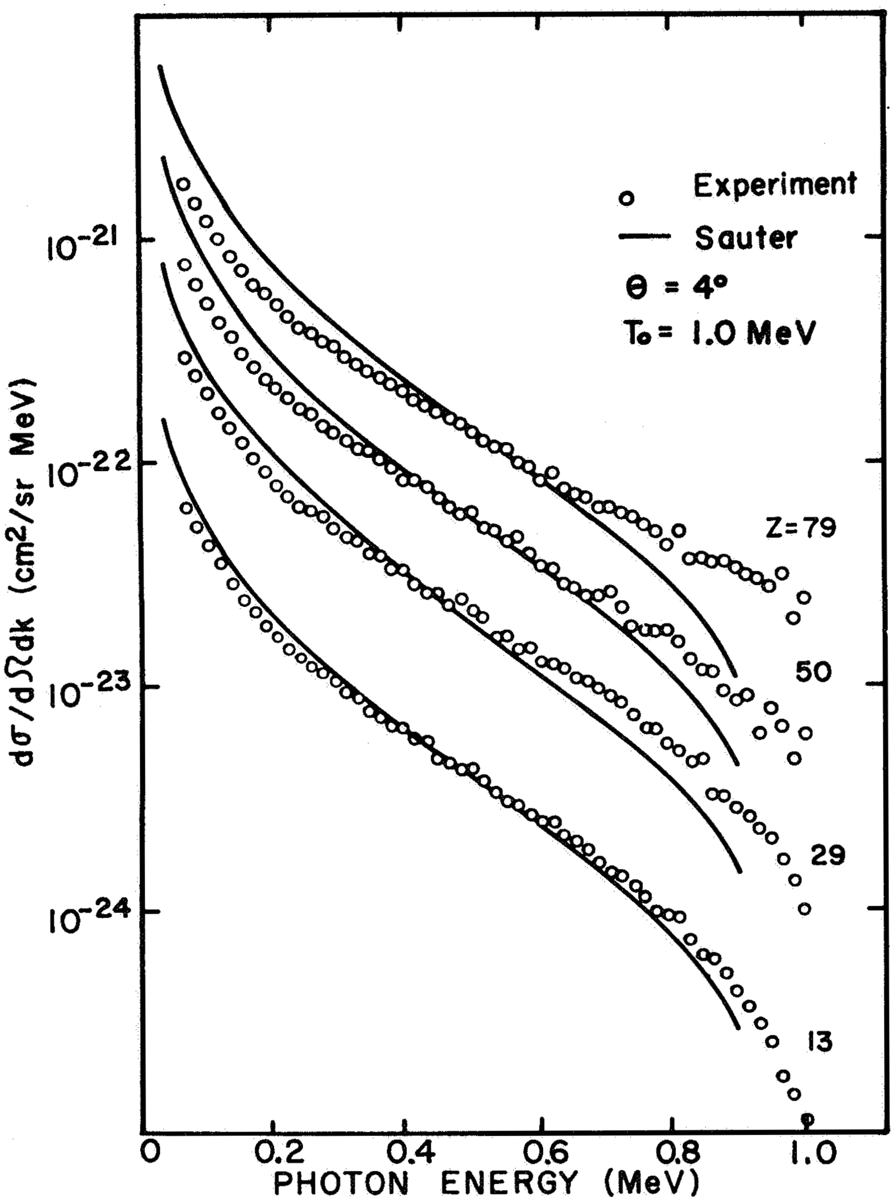

FIGURE 10. BREMSSTRAHLUNG DIFFERENTIAL CROSS SECTIONS, Θ = 4 DEG, FOR 1.0 - MeV ELECTRONS ON AL, CU, SN, AND AU.

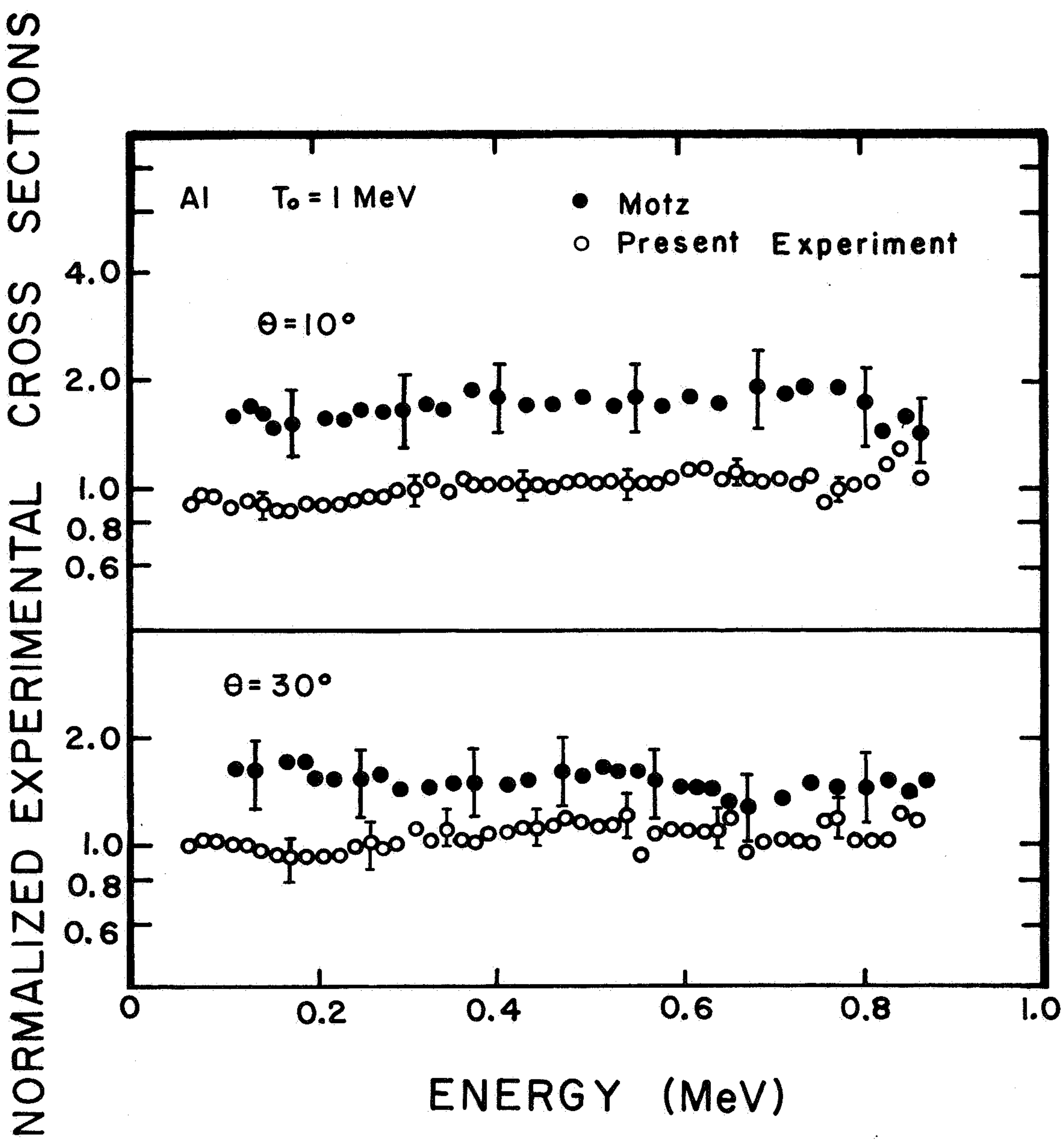

FIGURE 11. COMPARISON OF PRESENT MEASUREMENTS ON AL AT 1.0 MeV TO THE MEASUREMENTS OF MOTZ (REF. 1).

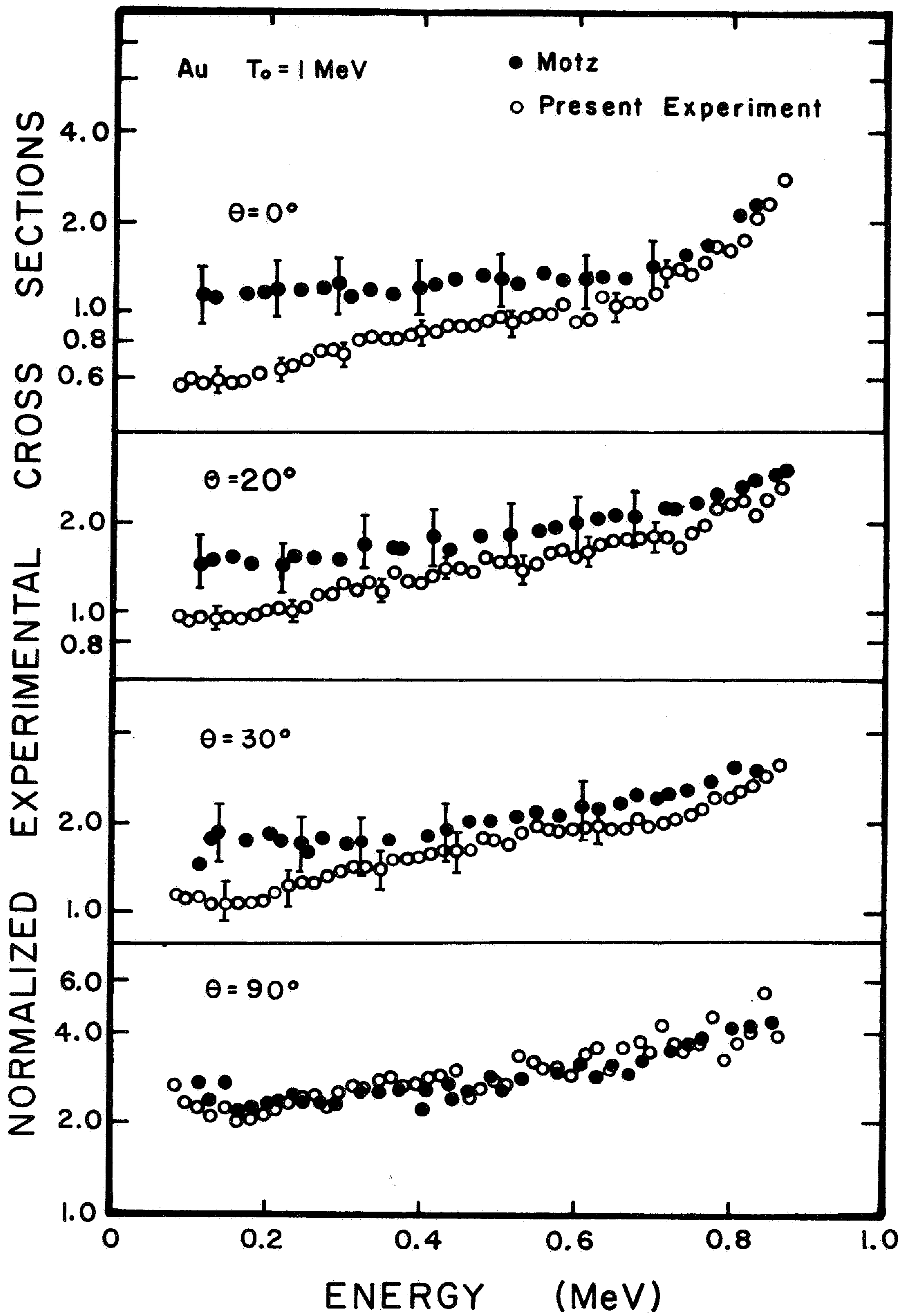

FIGURE 12. COMPARISON OF PRESENT MEASUREMENTS ON AU AT 1.0 MeV TO THE MEASUREMENTS OF MOTZ (REF. 1).

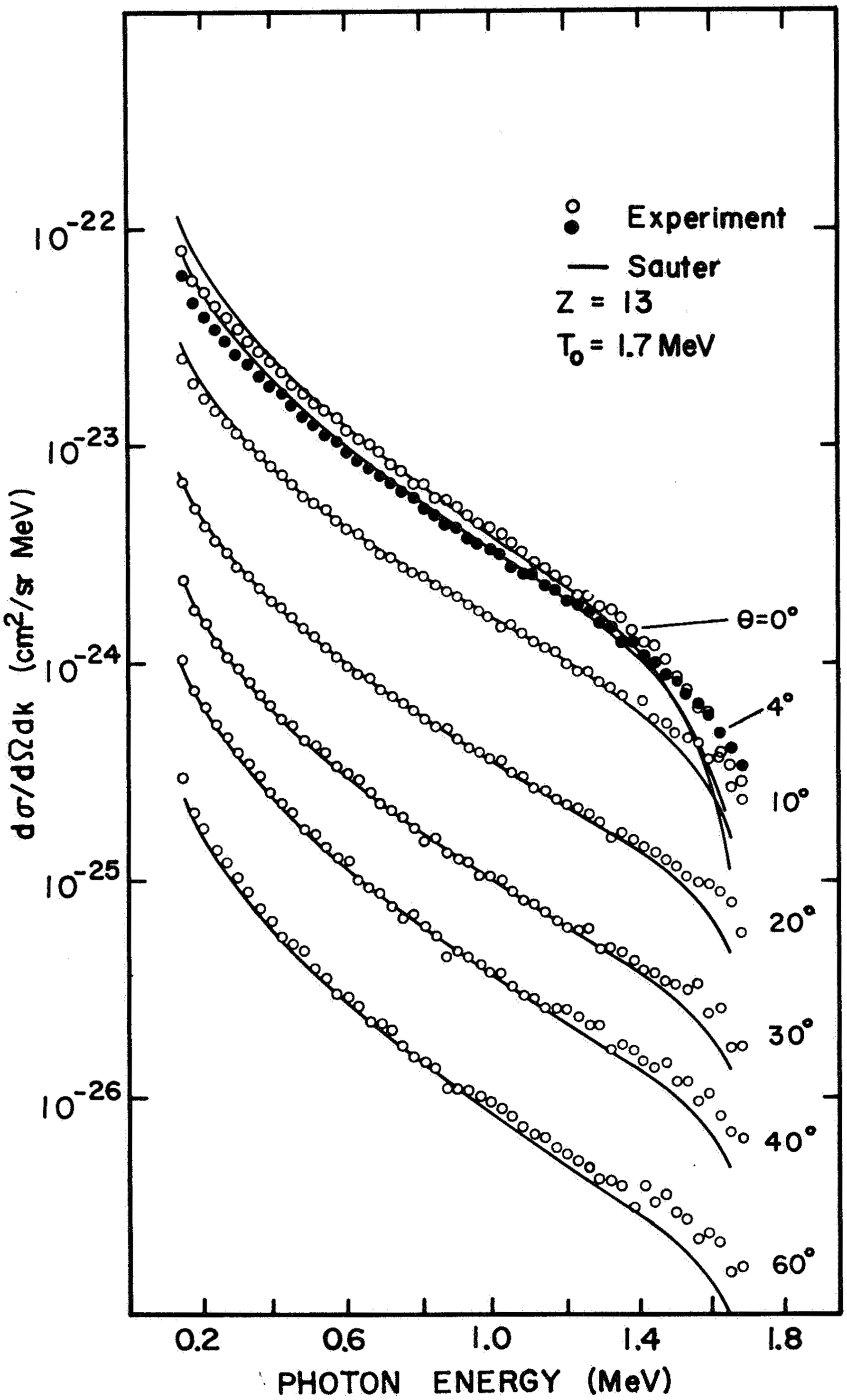

FIGURE 13. BREMSSTRAHLUNG DIFFERENTIAL CROSS SECTIONS FOR 1.7 - MeV ELECTRONS ON AL.

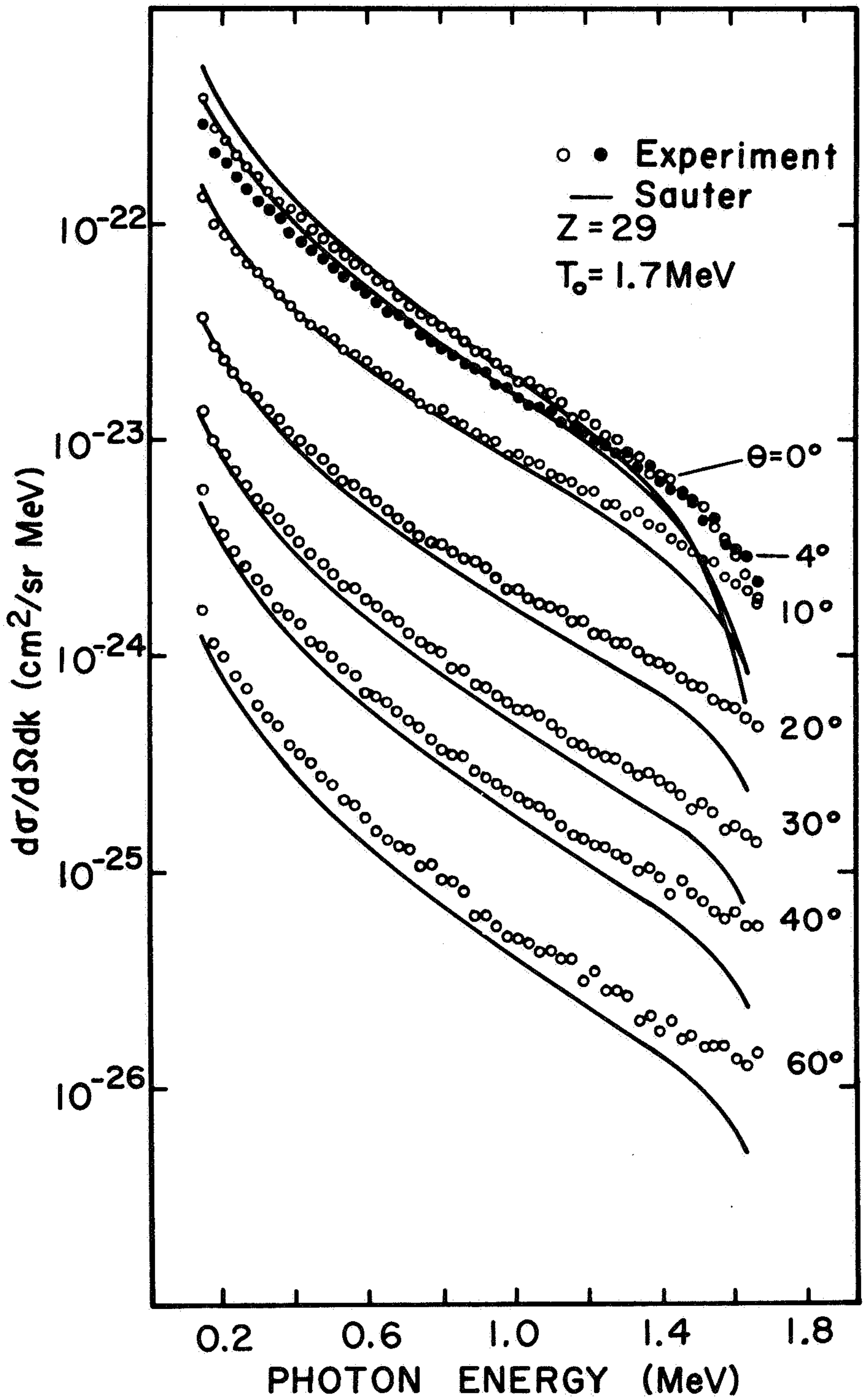

FIGURE 14. BREMSSTRAHLUNG DIFFERENTIAL CROSS SECTIONS FOR 1.7 - MeV ELECTRONS ON CU.

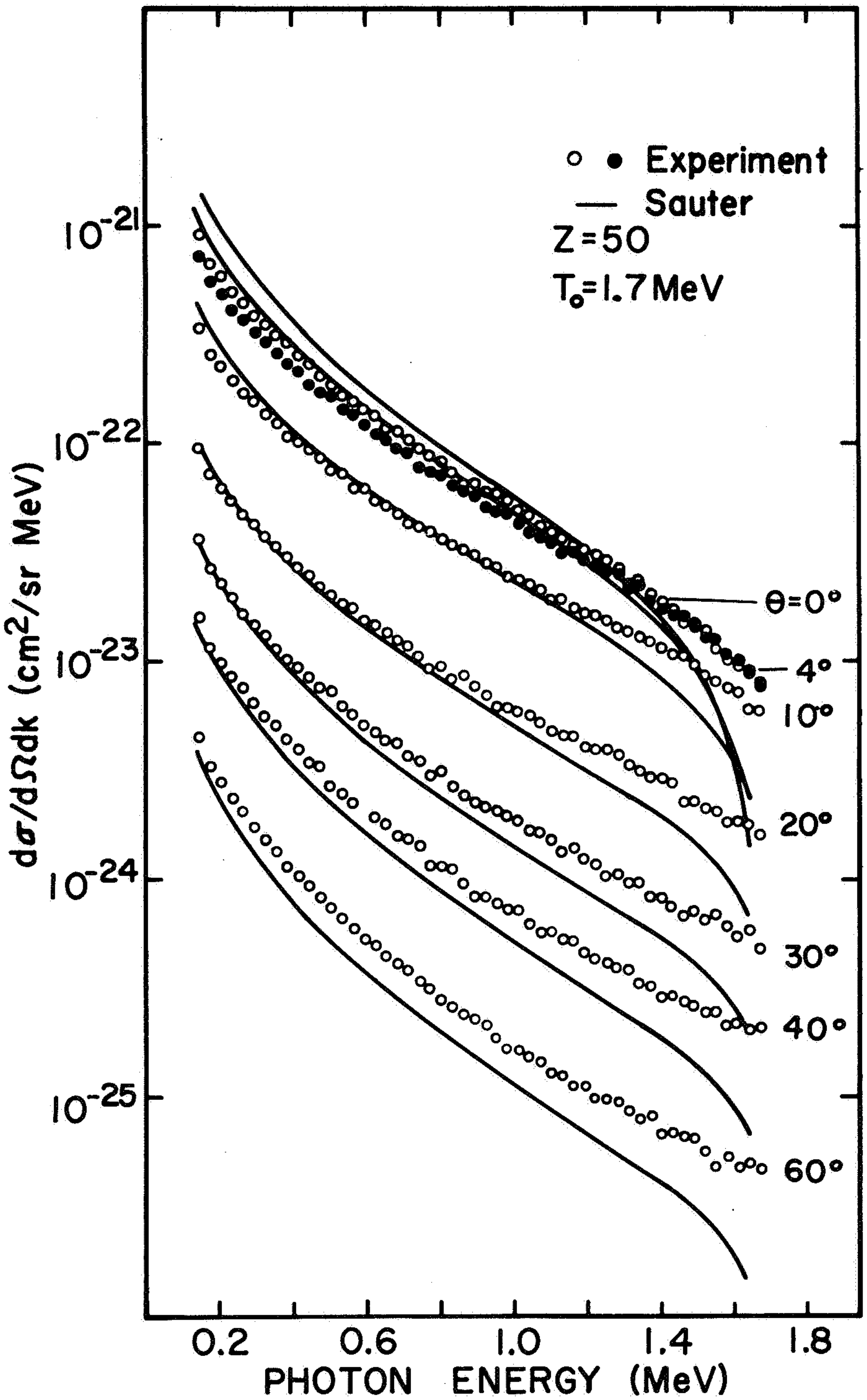

FIGURE 15. BREMSSTRAHLUNG DIFFERENTIAL CROSS SECTIONS FOR 1.7 - MeV ELECTRONS ON SN.

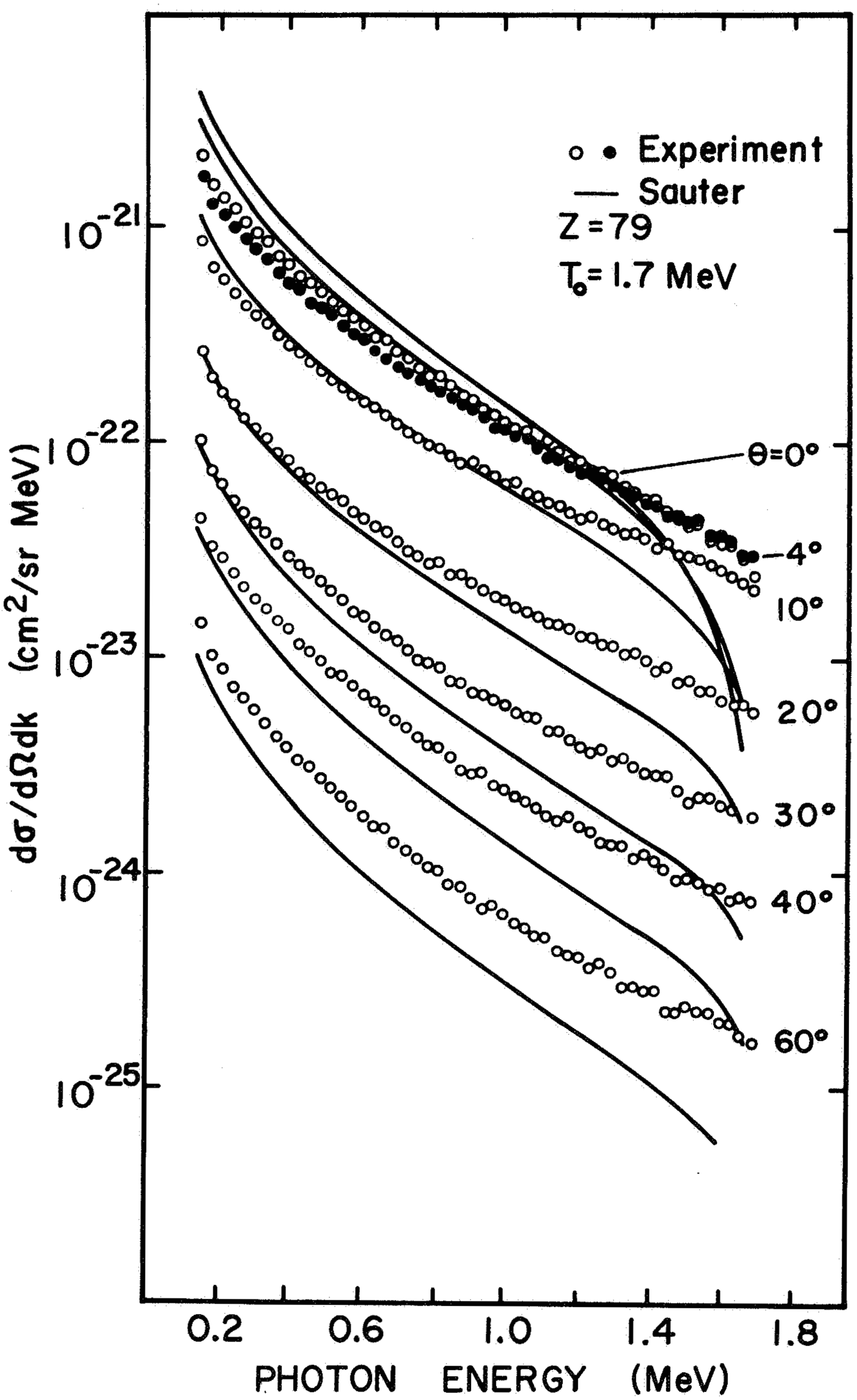

FIGURE 16. BREMSSTRAHLUNG DIFFERENTIAL CROSS SECTIONS FOR 1.7 - MeV ELECTRONS ON AU.

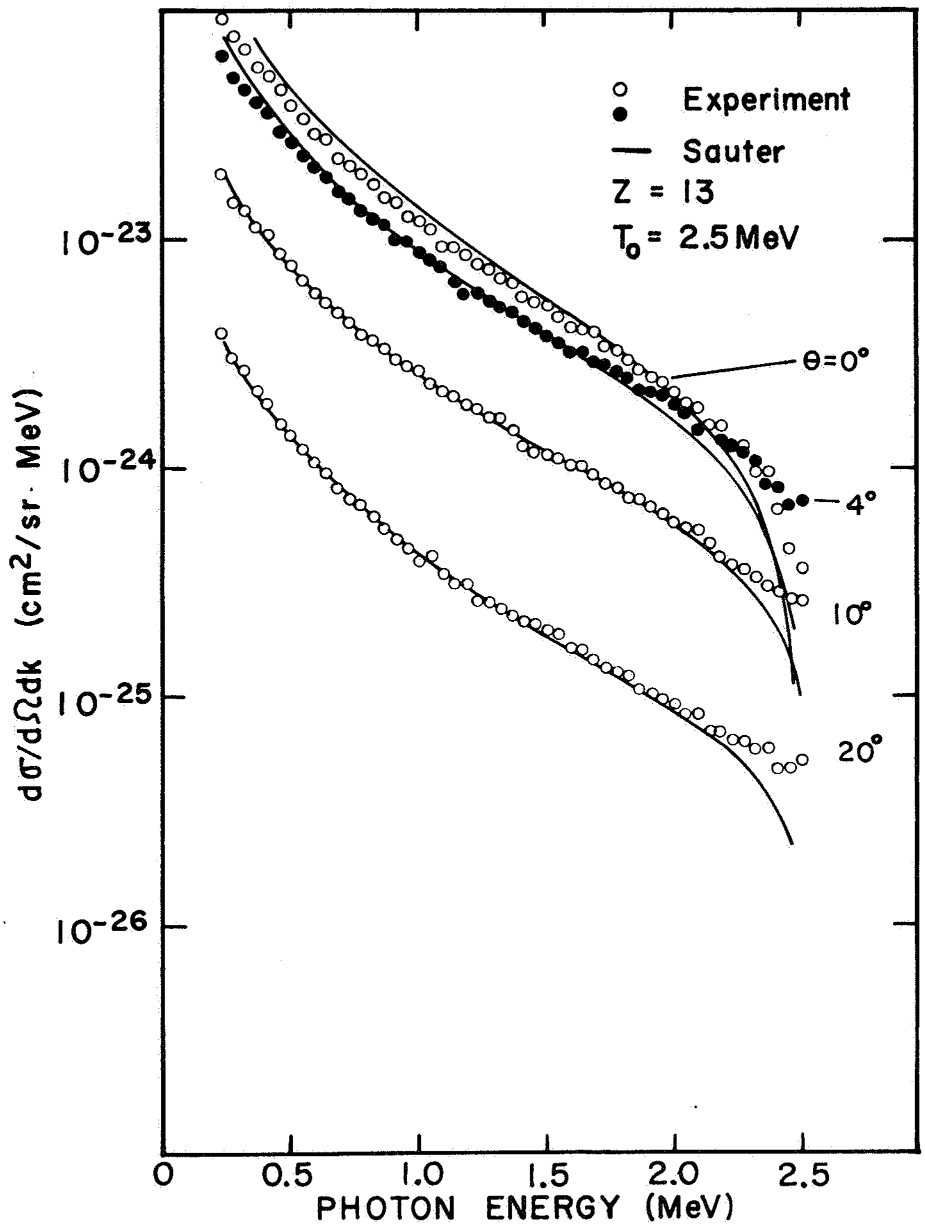

FIGURE 17. BREMSSTRAHLUNG DIFFERENTIAL CROSS SECTIONS FOR 2.5 - MeV ELECTRONS ON AL.

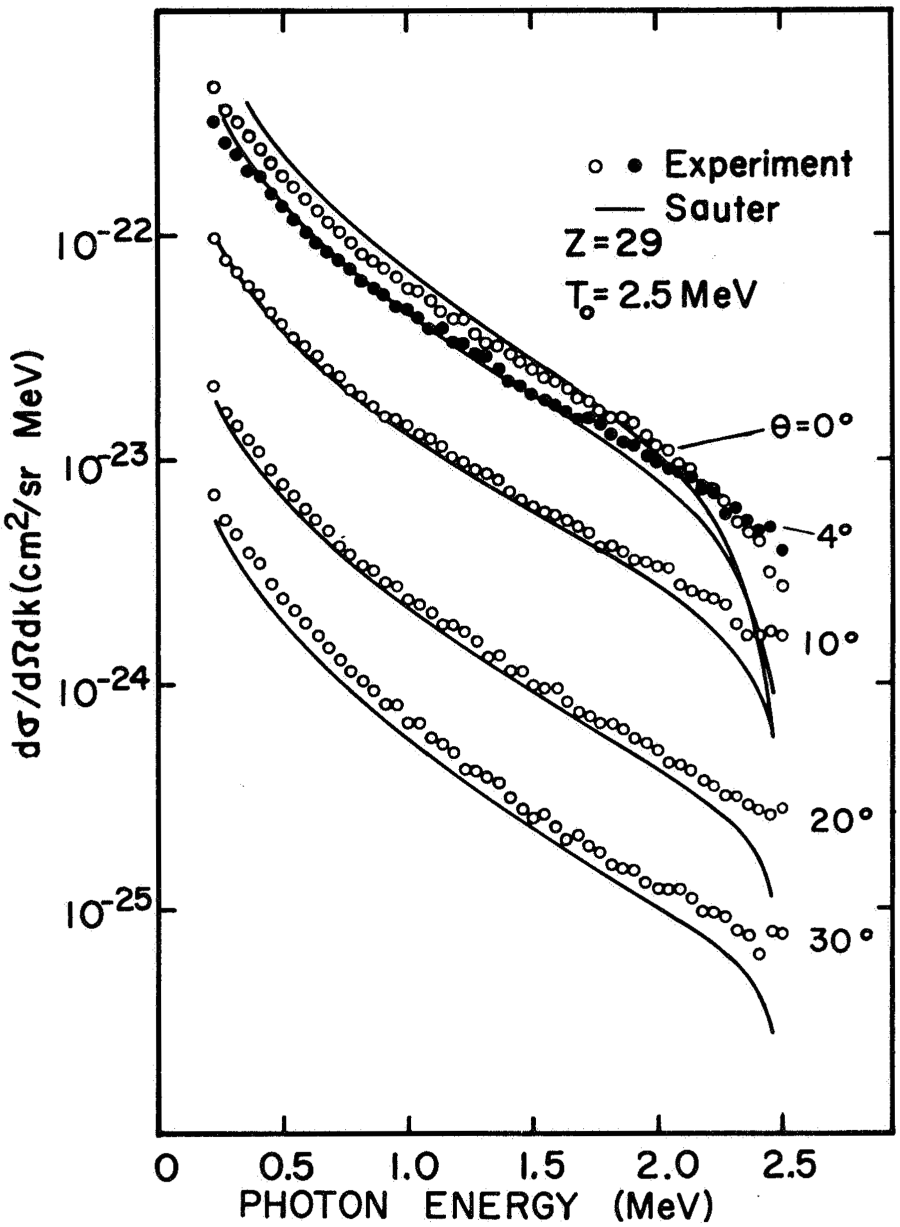

FIGURE 18. BREMSSTRAHLUNG DIFFERENTIAL CROSS SECTIONS FOR 2.5 - MeV ELECTRONS ON CU.

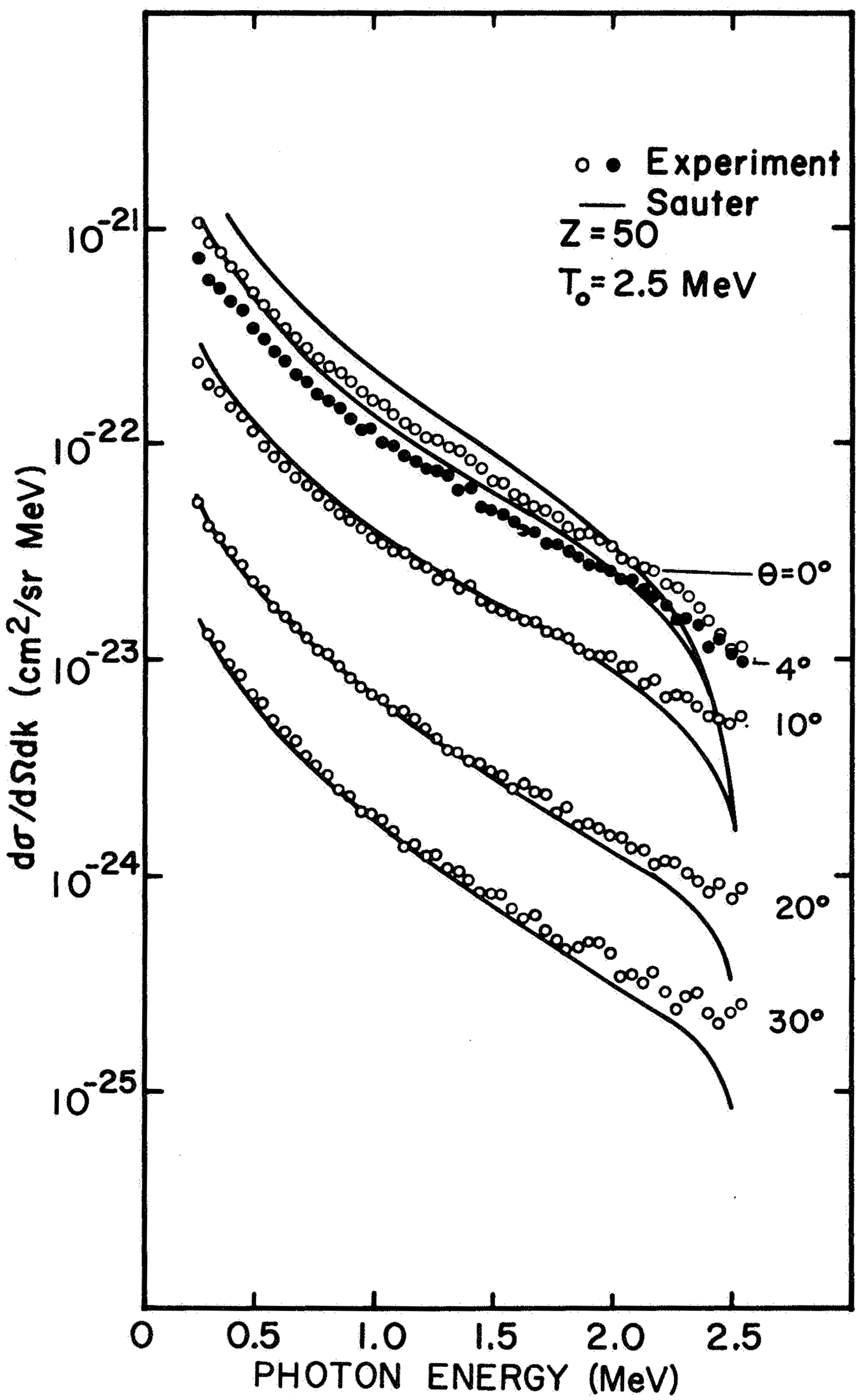

FIGURE 19. BREMSSTRAHLUNG DIFFERENTIAL CROSS SECTIONS FOR 2.5 - MeV ELECTRONS ON SN.

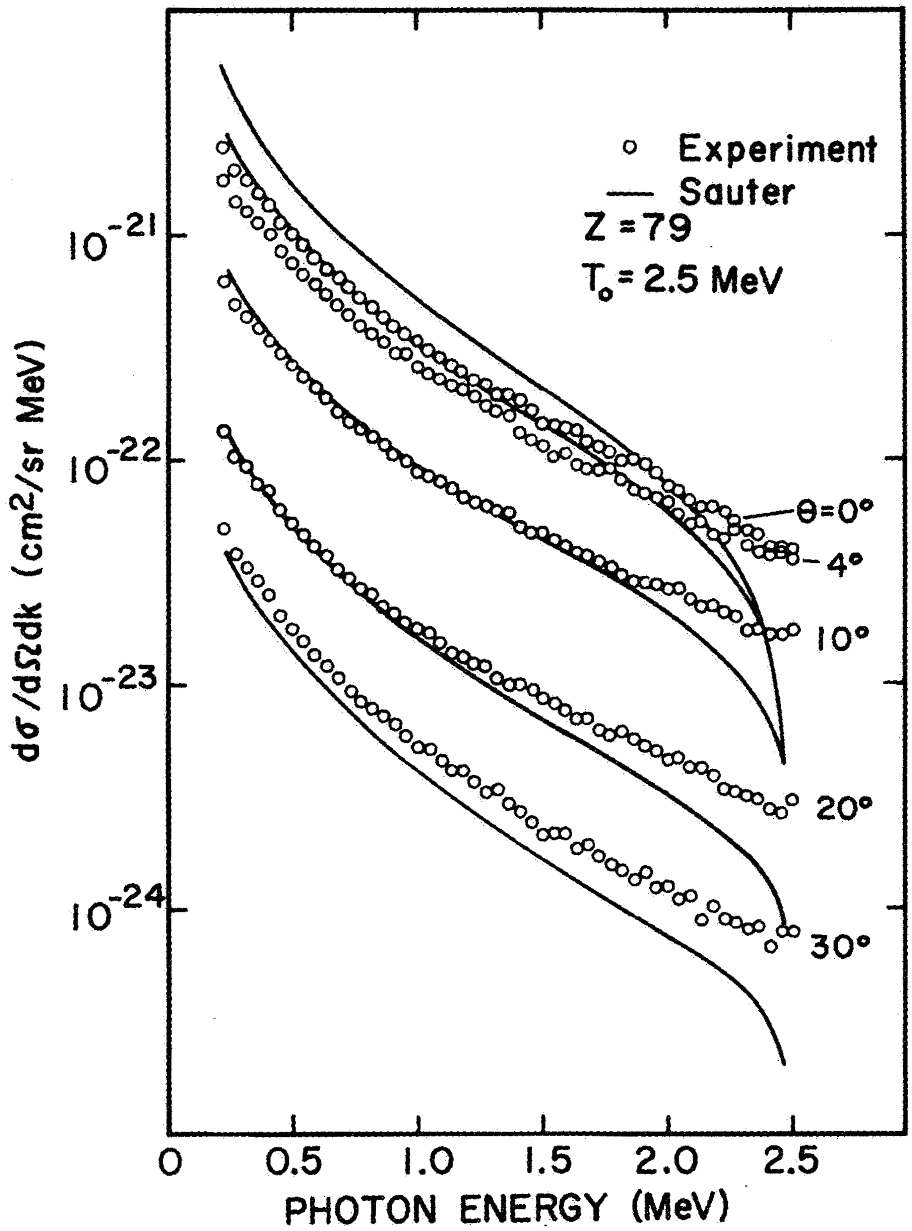

FIGURE 20. BREMSSTRAHLUNG DIFFERENTIAL CROSS SECTIONS FOR 2.5 - MeV ELECTRONS ON AU.

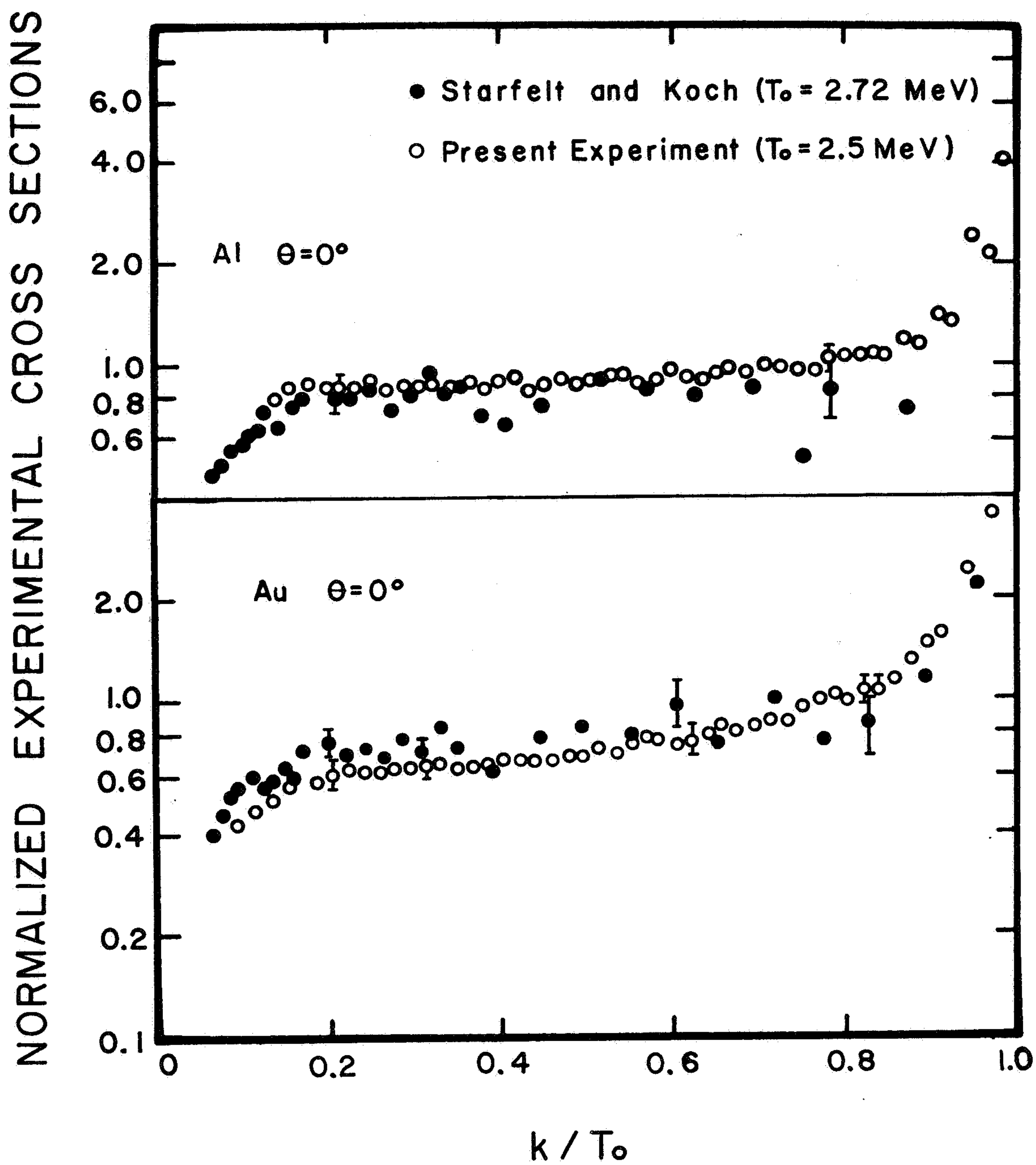

FIGURE 21. COMPARISON OF PRESENT MEASUREMENTS ON AL AND AU AT 2.5 MeV TO THE MEASUREMENTS OF STARFELT AND KOCH AT 2.72 MeV (REF. 2).

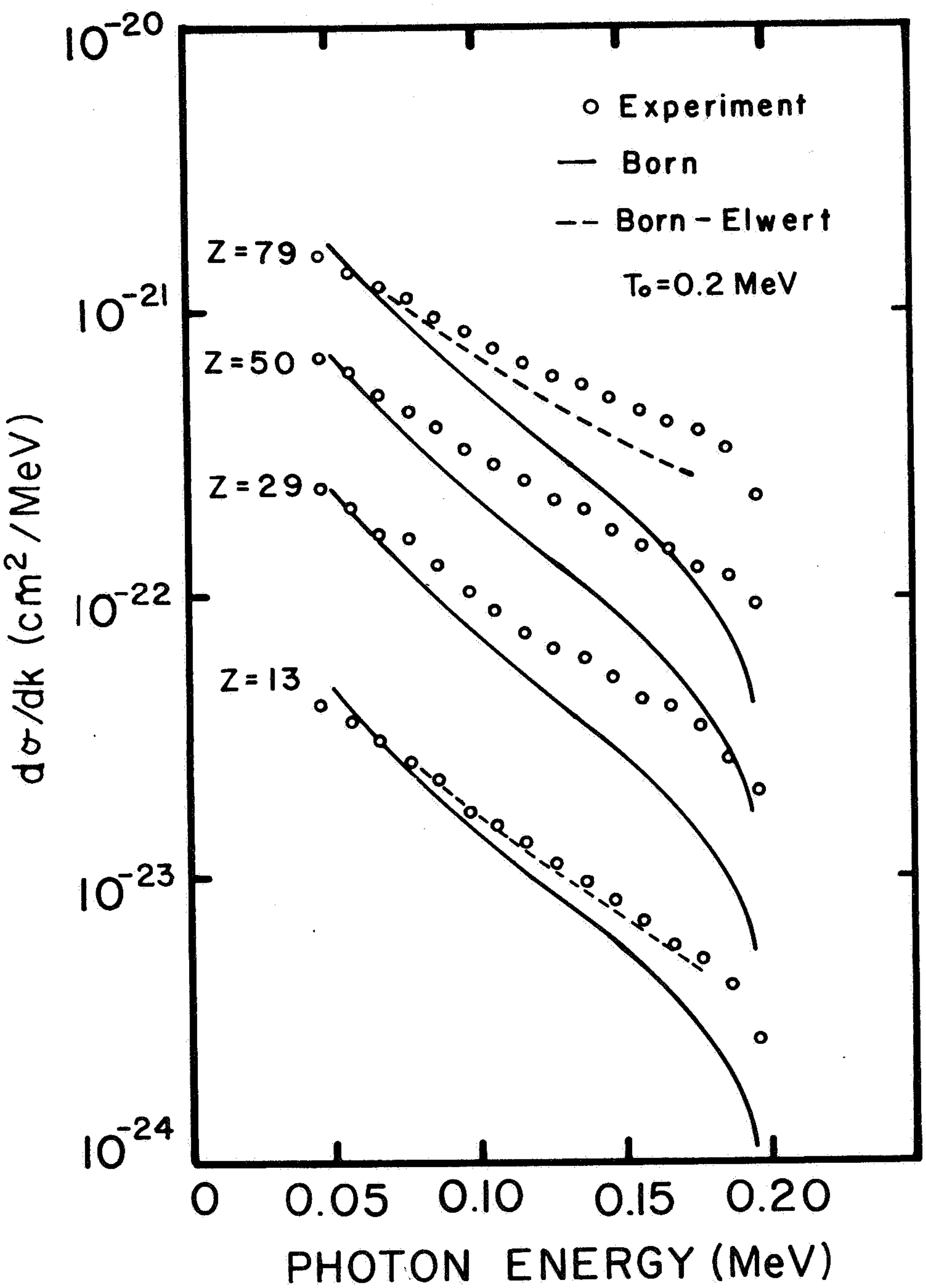

FIGURE 22. BREMSSTRAHLUNG CROSS SECTIONS DIFFERENTIAL IN ENERGY FOR 0.2 - MeV ELECTRONS ON AL, CU, SN, AND AU.

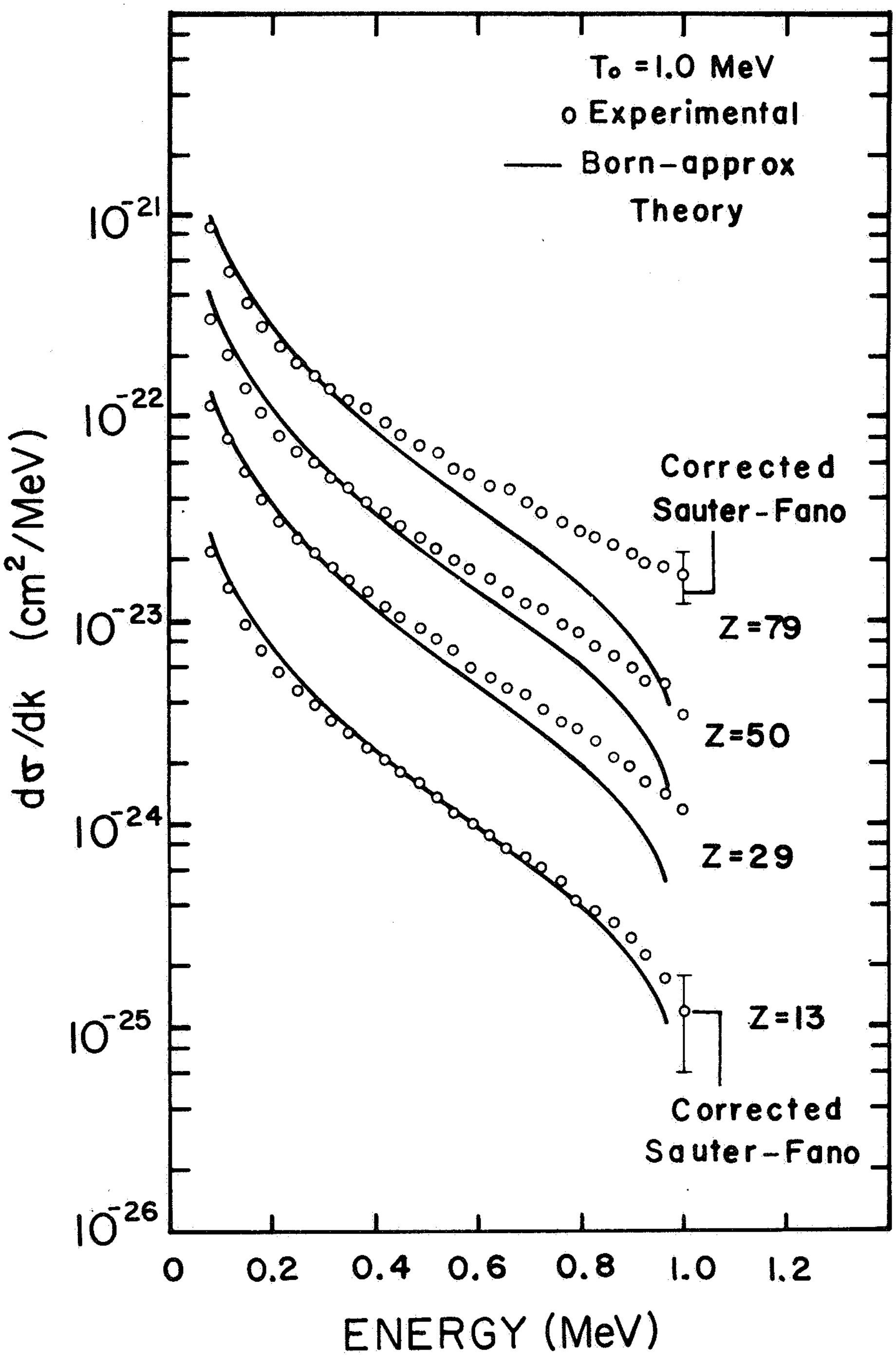

FIGURE 23 BREMSSTRAHLUNG CROSS SECTIONS DIFFERENTIAL IN ENERGY FOR 1.0 - MeV ELECTRONS ON AL, CU, SN, AND AU.

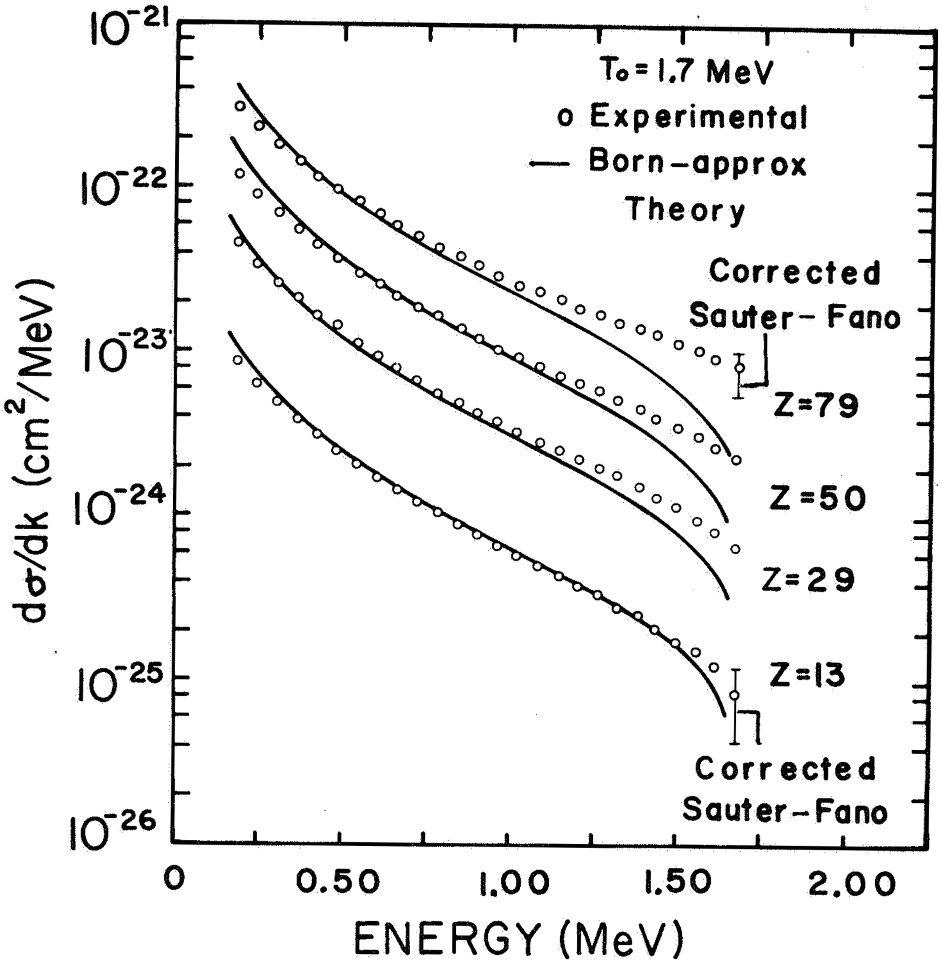

FIGURE 24 BREMSSTRAHLUNG CROSS SECTIONS DIFFERENTIAL IN ENERGY FOR 1.7 - MeV ELECTRONS ON AL, CU, SN, AND AU.

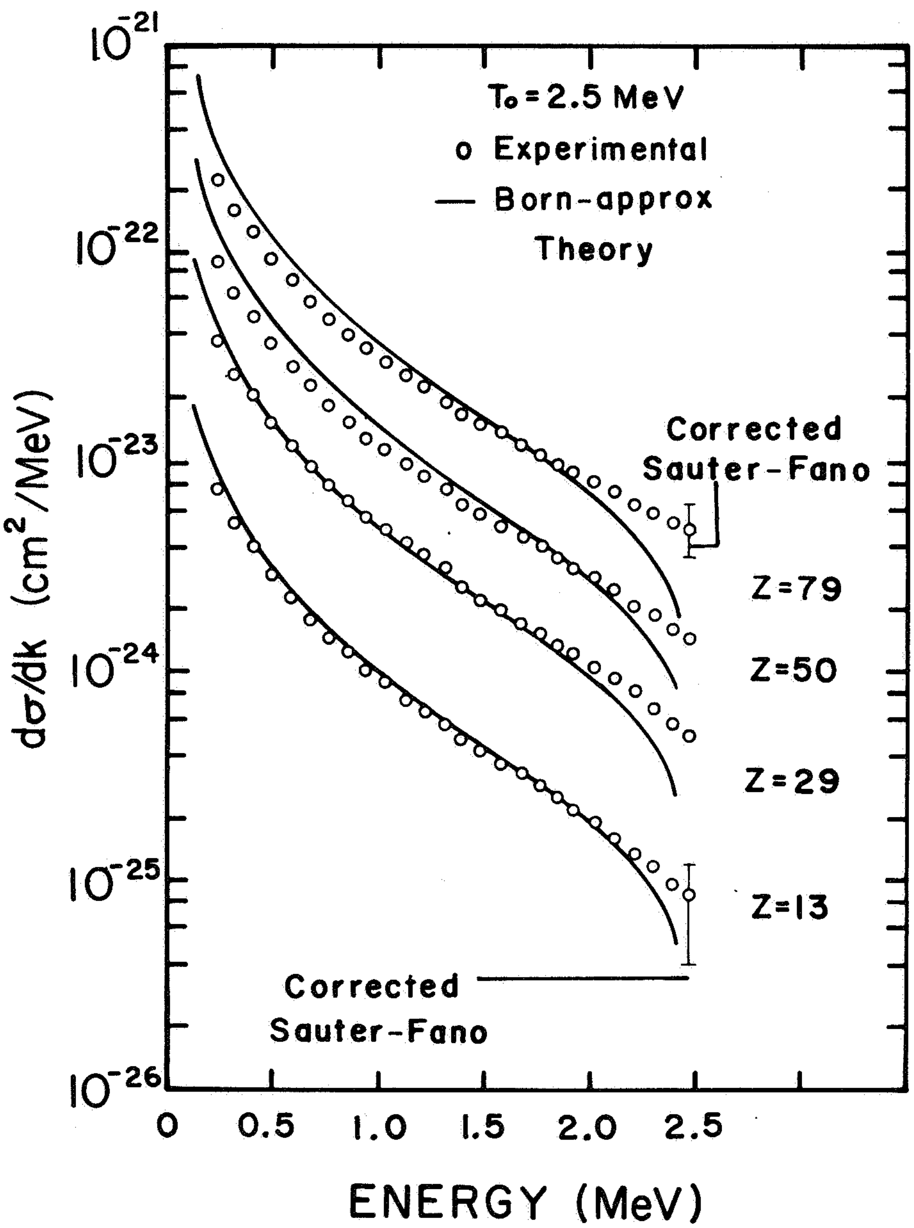

FIGURE 25. BREMSSTRAHLUNG CROSS SECTIONS DIFFERENTIAL IN ENERGY FOR 2.5 - MeV ELECTRONS ON AL, CU, SN, AND AU.