SLAC-PUB-677
November 1969
(TH) and (EXP)

INELASTIC ELECTRON-PROTON SCATTERING IN THE DEEP CONTINUUM REGION*

by

R. E. Taylor
Stanford Linear Accelerator Center
Stanford University, Stanford, California 94305

Presented at the 1969 International Conference on Electron and Photon Interactions at High Energies, Daresbury, England.

*Work supported by the U. S. Atomic Energy Commission

Last year at Vienna, the SLAC-MIT collaboration presented some preliminary results on e-p inelastic scattering at 6°. A striking feature of the data was the large cross section for excitation of the proton in the continuum region, above the region of resonance excitation. During the past year, we have completed the analysis of data for 6° and 10°[1] and have some preliminary results for some larger angle data. The scattering groups at DESY also have some new results which extend beyond the resonance region.[2] In principle, μ-p scattering will give similar information, and data in the region of interest should be available soon.

The experimental procedures for obtaining the scattering cross sections are by now quite familiar, and I will review them only briefly. Typically, an electron beam of well defined energy passes through a liquid hydrogen target, and scattered electrons are momentum analyzed by a magnetic spectrometer. The measured scattering angle is varied by rotating the spectrometer about the target. A momentum spectrum for scattered particles at a fixed angle is obtained by varying the fields in the spectrometer magnets. One of the DESY experiments was performed by varying both the initial electron energy and scattered momentum in such a way as to obtain a cross section at constant four-momentum transfer. Monitoring of the initial beam differs somewhat at the various laboratories, especially for internal beam measurements at DESY, but most of the external beam monitor calibrations can be traced to comparisons with Faraday cups.

Pions produced in the target contribute background in two ways:

1) π^- mesons pass through the spectrometer and may be misidentified as electrons. Various detectors are used to discriminate between π's and electrons, e.g., threshold Cerenkov counters, shower counters, and at SLAC, a set of three counters to measure dE/dx after the particles have passed through a radiation length of lead.

2) π^0 mesons give rise to $e^+ - e^-$ pairs, either by Dalitz decay or the conversion of decay γ's, and the electron member of the pair is detected in the spectrometer. This effect is eliminated by reversing the spectrometer polarity and subtracting positron yields from the electron measurements. These effects become larger as the initial energy and angle increase but are serious only for low scattered energies.

An example of the kind of spectrum obtained for constant initial energy is shown in Fig. 1 for scattering at 6^o. Elastic scattering is still a prominent feature of the data, but one observes the excitation of resonances and also a broad continuum of scattering as the energy of the scattered electron is decreased. Shown along the top of the figure is the "missing mass" of the unobserved final hadronic state. This is a convenient scale for observing the excitation of resonances, and data is usually plotted as $d^2\sigma/d\Omega dE'$ against increasing missing mass rather than against secondary electron energy.

Corrections to the data are required for radiative effects, including radiative straggling in the target, windows, etc., and the corrections to the scattering process itself. Using the known elastic form factors, the effects of elastic processes can be calculated without recourse to the peaking approximation.[3] Contributions from inelastic scattering can be taken into account using the peaking approximation but require knowledge of the scattering cross sections at a given angle for all primary and secondary energies less than the maximum primary energy and greater than the lowest secondary energy in the measurements. These are approximated in different ways by the various groups. At SLAC, the data are taken for several energies at each angle, and a two dimensional unfolding procedure using interpolation and extrapolation is used to obtain the corrections which then do not depend on a model for the behavior of the cross sections.[4]

A typical result of these procedures is shown in Fig. 2. Figure 2a is a spectrum taken at 6^{o} and 10 GeV incident energy. (This is a different spectrum taken with the same parameters as that shown in Fig. 1.) Figure 2b shows the corrected cross section and Fig. 2c is the ratio of corrected to uncorrected cross sections. While the procedures are complex and contain some approximations, the theoretical basis of the corrections seems fairly solid, and I doubt if the radiative corrections are a source of serious error in our measurements. The reader may remember that two years ago at the last Electron-Photon Conference there was a good deal of pessimism about making the corrections which were predicted to be very large for inelastic scatttering. These predictions were based on the assumption that the inelastic scattering would exhibit a four-momentum dependence similar to the elastic cross sections. In such a case, the radiative tail of the elastic peak dominates the measured cross sections. Since inelastic scattering has turned out to be much larger than assumed at that time, the percentage radiative corrections are correspondingly smaller.

A set of spectra, as in Fig. 2b, for various primary energies and angles constitutes the data from the experiments. Table 1 gives values of $d^2\sigma/d\Omega dE'$, after radiative corrections, for the data taken at 6^{o} and 10^{o} for missing masses above 2 GeV.

How the cross section behaves as the laboratory parameters of energy and angle are varied is sketched in Figs. 3 and 4.[5] These figures show that the excitation of discrete states is dominant for lower energies and angles, but that these discrete states become completely dominated by continuum channels at the higher energies and angles. The Mott cross section (without recoil terms) is given for each energy and angle to serve as a "scale" for the scattering cross sections. The behavior exhibited in the figures is at least reminiscent of inelastic electron scattering from nuclei.

The effects of proton structure in the scattering process can be seen more clearly by separating out the pure QED dependence of the scattering. The diagram for single photon exchange is shown in Fig. 5. The two kinematic invariants usually chosen to describe the process are:

$$q^2 = -(p - p')^2 = 4EE' \sin^2 \theta/2$$

and

$$\nu = \frac{P \cdot q}{M} = E - E'$$

The invariant missing mass can be expressed as:

$$W^2 = M^2 - q^2 + 2M\nu$$

and the energy of a photon required to produce a state of mass W

$$K = \nu - q^2/2M$$

The cross section in the single photon approximation can be written in terms of two functions of the kinematic invariants. These two functions can be chosen in an infinite number of ways, and perhaps we should be grateful that only two are in current use. They are:

$$\frac{d^2\sigma}{d\Omega dE'} = \sigma_M \left[W_2(q^2, \nu) + 2 \tan^2 \theta/2 \; W_1(q^2, \nu) \right]$$

$$\sigma_M = \frac{4\alpha^2 E'^2 \cos^2 \theta/2}{q^4} \tag{1}$$

$$\frac{d^2\sigma}{d\Omega dE'} = \Gamma_t \left[\sigma_T(q^2, W) + \epsilon \sigma_S(q^2, W) \right]$$

$$\Gamma_t = \frac{\alpha}{2\pi^2} \; \frac{K}{q^2} \; \frac{E'}{E} \; \frac{1}{1-\epsilon}$$

$$\epsilon = \frac{1}{1 + 2(1 + \nu^2/q^2) \tan^2 \theta/2} \tag{2}$$

The descriptions are equivalent, and evidently

$$W_1 = \frac{K}{4\pi^2 \alpha} \sigma_T$$

$$W_2 = \frac{K}{4\pi^2 \alpha} \frac{q^2}{q^2 + \nu^2} (\sigma_T + \sigma_S)$$

Equation (1) is an analogue of the usual Rosenbluth equation for elastic scattering (and includes elastic scattering when $\nu = q^2/2M$). Equation (2) shows the relationship of scattering to total absorption cross sections for virtual photons (and includes ordinary photoabsorption of γ's in the limit as $q^2 \longrightarrow 0$). In this description, Γ_t gives the virtual photon spectrum, and ϵ is a polarization parameter. Values of W_1 and W_2 (or σ_T and σ_S) can be determined by measurements at different angles for the same values of q^2 and ν.

It is instructive to look at a (q^2, ν) plot for the kinematics of a spectrum. Figure 6 shows where our measurements at 13.5 GeV, 6^o are located in this plane. The elastic limit is marked by the line passing through the origin and marked W = 0.938 GeV. Other lines of constant W are parallel to this line, and lines for W = 2, 3, 4 GeV are shown. Figure 7 shows a similar plot with lines drawn in for each initial energy and each angle where SLAC has taken data. At $q^2 = 4(\text{GeV/c})^2$, one can see where the data taking has been programmed so that separations can be made at W = 2, 3, 4 GeV without interpolation of the measured data.

At 6^o and 10^o, where our analysis is complete, it is difficult to make a convincing separation of W_1 and W_2 because of the small difference in angle. Figure 8 shows the quantity $(W_2 + 2W_1 \tan^2 \theta/2)$ plotted against q^2. At a W = 3.5 GeV, this quantity changes by less than a factor of 2 over the q^2 range, while the analogous quantity for elastic scattering changes by some 3 orders of magnitude. The observation of this weak q^2 behavior is a fundamental result of the experiment. The excitation of the resonances has been treated in other sessions of the Conference. Qualitatively, the resonances exhibit a q^2 behavior similar to that of the elastic cross sections above $q^2 = 1(\mathrm{GeV/c})^2$.

Another way of looking at the same data, but in the total absorption description, is shown in Fig. 9. Here $(\sigma_T + \epsilon\sigma_S)$ is shown as a function of missing mass W for $q^2 = 1, 2, 4\ (\mathrm{GeV/c})^2$. Also shown is σ_T for $q^2 = 0$ (where σ_S must be zero by gauge invariance) obtained by extrapolation from other scattering data at 1.5°. These curves can be looked on as upper limits for the absorption of transversely polarized virtual photons. (Of course, if σ_S is small compared with σ_T, then the graphs show simply the behavior of σ_T.) The diffractive models[6] and vector dominance models[7] concern themselves with the σ quantities rather than the W's.

A different kind of behavior, much discussed since our early data, was suggested by Bjorken[8] on the basis of the existence of an equal time commutator of the electromagnetic current, well before any data were available. He suggested that

$$W_2 = \frac{1}{\nu} F(\nu/q^2)$$

The existence of a "universal" function conjectured to be valid for large ν and q^2 and depending only on a particular combination of ν and q^2, has come to be known as "scaling." Scaling is a rather powerful constraint on the behavior of the structure functions and arises very naturally in the so called parton models[9,10] and also in field theory models.[11] (Notice, that for scattering from free particles of a given mass, ν/q^2 has a particular value proportional to the reciprocal of the mass for elastic scattering. Quasi-elastic scattering from subparticles lighter than the proton could show up as peaks in the data at a particular value of ω.)

In the diffraction models, scaling can be obtained by a simple assumption about the q^2 dependence of the Pomeron exchange, but scaling is not required by the theory. The detailed model of Sakurai[7] predicts scaling for large q^2, and, in addition, predicts that $\sigma_S/\sigma_T \gg 1$ as $q^2 \longrightarrow \infty$.

As a convenience we adopt the notation:

$$\omega = \frac{2M\nu}{q^2} = \frac{1}{x} \quad \text{where } M = \text{proton mass}$$

We urge others to adopt this notation, or at least not to define ω and x differently.

W_1 and W_2 cannot be easily separated using only 6^o and 10^o data, as already remarked. However, let us write

$$W_2 = \frac{\frac{d^2\sigma}{d\Omega dE'}}{\sigma_M} \left[1 + \frac{2W_1}{W_2} \tan^2 \theta/2\right]^{-1}$$

and

$$\frac{W_1}{W_2} = \left(1 + \frac{\nu^2}{q^2}\right) \frac{\sigma_T}{\sigma_T + \sigma_S}$$

Taking $R = \sigma_S/\sigma_T$ we can write

$$\nu W_2 = \nu \frac{\frac{d^2\sigma}{d\Omega dE'}}{\sigma_M} \left[1 + 2\left(\frac{1}{1+R}\right)\left(1 + \frac{\nu^2}{q^2}\right)\tan^2 \theta/2\right]^{-1}$$

The sensitivity of νW_2 to the value of R is not great if $2\left(1 + \frac{\nu^2}{q^2}\right) \tan^2 \theta/2 \ll 1$. We can obtain limits for the values of νW_2 by making the extreme assumptions $R = 0$ and $R = \infty$. Figure 10 shows values of νW_2 for all 6^o and 10^o data plotted against $\omega = 2M\nu/q^2$. Figures 10a and 10b show the values obtained, assuming $R = 0$ for all points $q^2 > 0.5\ (\text{GeV}/c)^2$. Figure 10c and 10d show the same data with $R = \infty$. Finally, 10e shows the results taken at 7 GeV, 6^o (where $q^2 < 0.5\ (\text{GeV}/c)^2$) for both assumptions about R. The results shown indicate the following:

1) If $\sigma_T \gg \sigma_S$ the results "scale," i.e., are consistent with a universal curve for $\omega \gtrsim 4$ and $q^2 \gtrsim 0.5\ (\text{GeV}/c)^2$. Above these values of ω and q^2, the measurements at 6^o and 10^o give the same results within errors. The 7 GeV, 6^o results are somewhat smaller than those from other spectra in the continuum region. The values of νW_2 for $\omega > 5$ show a slight but definite decrease as ω increases.

These results imply that σ_T varies approximately as $1/q^2$, and that σ_T falls slowly at constant q^2 as ν increases. Let me emphasize again that these conclusions assume $\sigma_T \gg \sigma_S$.

2) If $\sigma_S \gg \sigma_T$, the measurements of νW_2 do not follow a universal curve, and generally νW_2 increases with q^2 at constant ω.

3) For either assumption νW_2 shows a threshold behavior in the range $1 \leq \omega \leq 4$. W_2 is constrained to zero at inelastic threshold which corresponds to $\omega \approx 1$ for large q^2. In this threshold region, W_2 falls rapidly as q^2 increases at constant ν. This is qualitatively different from the weak q^2 behavior for $\omega > 4$. For $q^2 \approx 1\ (\text{GeV/c})^2$ the threshold region contains those resonances which we have electroproduced. As q^2 increases, and the resonances damp out, νW_2 does not appear to vary rapidly with q^2 at constant ω.

4) Since W_1 can be written as $W_1 = \frac{1}{1+R}\left(\frac{\omega}{2M} + \frac{1}{\nu}\right)(\nu W_2)$ it is clear that, for $R = 0$, W_1 will scale if W_2 scales for large values of ν, such that $\frac{\omega}{2M} \gg \frac{1}{\nu}$. Note that values of W_1 are more sensitive to the assumption $R = 0$ than are the values of W_2.

I will now turn to separations of W_1 and W_2 (or σ_T and σ_S). The DESY data at 48° can be combined with the small angle SLAC-MIT data to yield separations for $q^2 = 0.8$ and $2\ (\text{GeV/c})^2$. This has been done by the DESY group and submitted to the conference.[12] The SLAC-MIT group is just now completing an analysis of data taken at 18°, 26° and 34° with the 8 GeV spectrometer. The data we have are preliminary, and various checks and minor corrections remain to be made, but preliminary separations for higher q^2 can be obtained.

Figure 11 shows separation plots obtained by the DESY group.[12] Figure 12 shows similar separations for the cross-over points of Fig. 7 at $q^2 = 4\ (\text{GeV/c})^2$, $W = 2$, 3, and 4 GeV, and at $q^2 = 1.89\ (\text{GeV/c})^2$, $W = 3$ GeV using the preliminary

SLAC-MIT data at 10^o, 18^o, and 26^o. The values of $R = \sigma_T/\sigma_S$ obtained show that $\sigma_S \lesssim 0.5\ \sigma_T$. (For the SLAC-MIT separations the values obtained do not exclude R = 0.) The dotted lines in Fig. 12 show predictions from the model of Sakurai where the adjustable parameter ξ in that model has been taken to 1.5, a value which gives a good fit to the 6^o and 10^o data.

From these and similar plots, a rough idea of the q^2 dependence and ω dependence of R can be obtained. In the case of SLAC-MIT separations, this involves interpolations of cross sections in the q^2, ν plane. Figure 13 shows the results obtained in Ref. 12 for $q^2 = 2(\text{GeV/c})^2$ as a function of $\frac{\nu}{q^2}$. Figure 14 shows SLAC-MIT results for $q^2 = 1.5$, 3.0, and 4.5 (GeV/c). There is no obvious dependence on ω evident in any of the plots. Figure 15 shows the q^2 dependence of R for W = 3 GeV where, again, there is no obvious trend. For points near the high end of the q^2 scale, there is a discrepancy of about an order of magnitude with the model of Sakurai. In Figs. 14 and 15, a large fraction of the error shown for each point is a systematic error. The graphs have been included to illustrate the dependence of R on q^2 and ω, but the actual values of R should not be taken too seriously at the present time.

When the analysis of the higher angle data is completed, we will re-evaluate W_1 and W_2, but we do not expect that the result will be greatly different from the curves shown in Fig. 10 for R = 0.

Several sum rules have been proposed for inelastic scattering by the application of current algebra and the use of current commutators. From the present data, one can provide estimates of some of these with varying degrees of confidence.

A reasonable estimate can be made for the energy weighted sum rule,[13] which is related to the equal-time commutator of the current and its time derivative.

Using the 6^o data, we find

$$\int_1^\infty \frac{d\omega}{\omega^2}(\nu W_2) \approx \int_1^{20} \frac{d\omega}{\omega^2}(\nu W_2) = 0.16 \pm 0.001 \ (R=0)$$

The value of the integral is not very sensitive to the behavior of νW_2 above $\omega = 20$. This integral also arises in parton theories where its value is the mean square charge per parton.

Gottfried[14] has calculated a constant q^2 sum rule for a nonrelativistic quark model:

$$\int_1^\infty \frac{d\omega}{\omega}(\nu W_2) = 1 - \frac{G_{EP}^2 + q^2/4M^2 \cdot G_{MP}^2}{1 + q^2/4M^2}$$

An evaluation of this integral is more sensitive to the value of R and to the unmeasured values of νW_2 in the integral. (For example, if νW_2 does not approach zero as $\omega \to \infty$, the integral diverges.)

The data suggest that the sum rule is saturated in the region $\nu = 20 - 40$ GeV.

The constant q^2 sum rule inequality, proposed by Bjorken[15] on the basis of current algebra, requires data from both the neutron and the proton:

$$\int_1^\infty \frac{d\omega}{\omega}\left[\nu W_{2P} + \nu W_{2N}\right] \geq \frac{1}{2}$$

It appears that, with reasonable guesses for νW_{2N}, the sum rule will be satisfied around $\omega = 4$ to 5. The theoretical implications of these sum rules are discussed more fully in F. Gilman's contribution to the conference.

The SLAC-MIT group is planning experiments on deuterium (D_2), similar to those reported here for the proton. Runs are scheduled to begin early in 1970.

There are some other experiments which could shed more light on the results presented here. Coincidence experiments to identify the channels involved in the continuum scattering are obviously desirable. Such experiments are very difficult at SLAC because of the duty cycle, but might be possible at Cornell or DESY. Larger values of ν in the experiments would extend the range of ω at a given q^2. We can possibly gain about 3 GeV in ν at SLAC, with reliable operation now possible at 20 GeV, and will attempt to do so during the D_2 experiment (for both H_2 and D_2). Another factor of 2 over SLAC energies would be very welcome.

To summarize the results presented here:

1) The cross section in the continuum W > 2GeV shows a much weaker q^2 dependence than elastic scattering and resonance excitation.

2) In the continuum region, the absorption cross section for transversely polarized virtual photons is greater than that for longitudinally polarized virtual photons and varies roughly as $\frac{1}{q^2}$.

3) The structure function νW_2 appears to "scale" $\left(\text{i.e., is a function of only } \frac{\nu}{q^2}\right)$ to within the accuracy of the data, approximately ± 10%.

4) Both "diffraction" models and "parton" models can be constructed to fit the data, but the detailed models of ρ dominance proposed by Sakurai and others[7] fail at large angles for high q^2.

REFERENCES AND FOOTNOTES

1. The bulk of this report is based on two papers which will soon be published and are available as SLAC Publications 642 and 650. The authors are: E. D. Bloom, M. Breidenbach, D. H. Coward, H. DeStaebler, J. Drees, J. I. Friedman, G. C. Hartmann, H. W. Kendall, G. Miller, L. W. Mo, and R. E. Taylor. C. Jordan is also involved with the experiment at larger angles (18°, 26°, 34°) from which we quote preliminary data.
2. W. Bartel, B. Dudelzak, H. Krehbiel, J. McElroy, U. Meyer-Berkhout, W. Schmidt, V. Walther, and G. Weber, DESY Report 68/53 (1968); W. Albrecht, F. W. Brasse, H. Dorner, W. Flauger, K. Frank, E. Ganssauge, J. Gayler, H. Hultschig, and J. May, DESY Report 69/7 (1969).
3. R. Hofstadter and L. Schiff (Eds.), Proceedings of Nucleon Structure Conference at Stanford, (Stanford University Press, Stanford, California, 1963); p. 221.
4. L. W. Mo and Y. S. Tsai, Rev. Mod. Phys. 41, 205 (1969).
5. The data for the 4.89 GeV curve in Fig. 3 is taken from Ref. 2 and I have made very crude radiative corrections. The top curve in Fig. 4 is extrapolated from SLAC scattering data at $\theta_{lab} = 1.5^{\circ}$. These data were taken to obtain the total γp cross section and are reported separately to the conference.
6. H. Harari, Phys. Rev. Letters 22, 1078 (1969).
7. J. J. Sakurai, Phys. Rev. Letters 22, 981 (1969); Y. S. Tsai, "Old fashioned perturbation theory and vector meson dominance," Report No. SLAC-PUB-600, Stanford Linear Accelerator Center, Stanford University, Stanford, California (1969); H. Fraas and D. Schildknecht, DESY Report 69/18 (1969).
8. J. D. Bjorken, Phys. Rev. 179, 1547 (1969).

9. R. P. Feynman (private communication).

10. J. D. Bjorken and E. A. Paschos, "Inelastic electron-proton and γ-proton scattering, and the structure of the nucleon," Report No. SLAC-PUB-572, Stanford Linear Accelerator Center, Stanford University, Stanford, California (1969).

11. S. D. Drell, D. J. Levy and T. M. Yan, Phys. Rev. Letters 22, 744 (1969).

12. W. Albrecht, F. W. Brasse, H. Dorner, W. Flauger, K. H. Frank, E. Ganssauge, J. Gayler, H. Hultschig and J. May, report submitted to this conference.

13. C. Callan and D. Gross, Phys. Rev. Letters 22, 156 (1969).

14. K. Gottfried, Phys. Rev. Letters 18, 1174 (1967).

15. J. Bjorken, Phys. Rev. 16 408 (1966).

TABLE I

Measured cross sections for $W \geq 2.0$ GeV after all corrections. The errors are one standard deviation. The systematic error is not included in the table but is estimated at 5% for $E' > 5$ GeV increasing to 10% at $E' \approx 3$ GeV.

θ (deg)	E (GeV)	E' (GeV)	q^2 $(GeV/c)^2$	W (GeV)	$d^2\sigma/d\Omega dE'$ $(10^{-31} cm^2/sr\text{-}GeV)$
6.000	7.000	5.130	.393	2.000	21.5 ± .49
		4.586	.352	2.249	15.6 ± .40
		3.750	.287	2.587	9.33 ± .64
		3.250	.249	2.769	7.96 ± .73
	10.005	7.886	.864	1.998	10.7 ± .23
		7.349	.806	2.249	9.24 ± .20
		6.745	.739	2.502	7.01 ± .27
		5.361	.587	3.001	4.97 ± .24
		3.724	.408	3.501	3.54 ± .30
	13.529	11.00	1.630	1.999	4.26 ± .087
		10.48	1.553	2.249	4.10 ± .093
		9.936	1.473	2.480	3.85 ± .056
		8.512	1.262	3.004	2.79 ± .085
		6.906	1.023	3.505	2.09 ± .11
		5.054	.749	4.004	1.85 ± .11
		3.394	.503	4.404	1.59 ± .27
	16.049	13.16	2.314	1.998	2.19 ± .042
		12.64	2.222	2.250	2.21 ± .043
		12.03	2.116	2.510	2.16 ± .042
		10.69	1.880	3.008	1.84 ± .042
		9.109	1.602	3.507	1.59 ± .056
		7.282	1.280	4.006	1.24 ± .066
		5.644	.992	4.406	1.11 ± .074
		3.851	.677	4.805	1.13 ± .17
10.000	7.010	4.802	1.023	2.000	2.82 ± .090
		4.294	.915	2.250	2.34 ± .099
		3.717	.792	2.504	2.05 ± .12

θ (deg)	E (GeV)	E' (GeV)	q^2 $(GeV/c)^2$	W (GeV)	$d^2\sigma/d\Omega dE'$ $(10^{-32} cm^2/sr\text{-}GeV)$
10.000	10.988	7.915	2.643	2.001	5.66 ± .38
		6.879	2.297	2.509	6.17 ± .27
		5.634	1.881	3.008	5.59 ± .30
		4.163	1.390	3.507	5.19 ± .43
		3.000	1.001	3.856	5.38 ± .77
	13.534	9.737	4.004	2.000	1.80 ± .072
		9.270	3.812	2.252	2.20 ± .083
		8.737	3.593	2.508	2.62 ± .10
		7.534	3.098	3.007	3.03 ± .15
		6.113	2.514	3.506	2.93 ± .15
		4.473	1.839	4.005	2.98 ± .25
		3.000	1.234	4.406	3.75 ± .54
	15.201	10.86	5.016	2.002	.876 ± .058
		9.868	4.558	2.516	1.57 ± .060
		8.691	4.014	3.014	1.94 ± .089
		7.300	3.372	3.512	2.08 ± .083
		5.696	2.631	4.011	1.98 ± .094
		4.258	1.967	4.410	2.26 ± .15
		3.700	1.709	4.555	2.17 ± .22
		3.000	1.386	4.732	2.46 ± .28
	17.696	12.46	6.699	2.002	.336 ± .020
		11.50	6.184	2.514	.617 ± .027
		10.36	5.571	3.012	.957 ± .042
		9.015	4.847	3.510	1.19 ± .057
		7.461	4.012	4.009	1.33 ± .073
		6.069	3.263	4.408	1.32 ± .091
		4.544	2.443	4.808	1.50 ± .15
		3.800	2.043	4.991	1.70 ± .21
		3.000	1.613	5.181	1.79 ± .37

FIGURE CAPTIONS

1. A spectrum of scattered electrons at 6° for 10 GeV electrons incident on hydrogen. $\frac{d^2\sigma}{d\Omega dE'}$ is shown as a function of scattered electron energy, E'. This curve is taken from preliminary data presented last year at Vienna.

2. Effects of the radiative corrections:

   a) uncorrected spectrum;

   b) corrected spectrum; and

   c) ratio of corrected to uncorrected spectrum.

   $\frac{d^2\sigma}{d\Omega dE'}$ is shown as a function of the missing mass of the final hadronic state.

3. Sketch of the behavior of radiatively corrected e-p cross sections for various energies.

4. Sketch of the behavior of radiatively corrected e-p cross sections for various angles. The 1.5 degree curve is taken from other SLAC-MIT data used to obtain total photo-absorption cross sections, and the 18° curve is based on preliminary data which is not yet published.

5. Single photon exchange diagram for inelastic e-p scattering.

6. Kinematics of scattering at 13.5 GeV, and 6° in $q^2 - \nu$ plane.

7. $q^2 - \nu$ plane showing lines on which SLAC-MIT have taken data.

8. Variation of the inelastic scattering $\frac{d^2\sigma}{d\Omega dE'} / \sigma_M$ with q^2 for W = 2, 3, 3.5 GeV. Also shown is the cross section for elastic e-p scattering divided by σ_M calculated for 10°, using the dipole form factor. (Note the difference in units for elastic and inelastic scattering.) The relatively slow variation of the inelastic cross section is evident.

9. Variation of the photo-absorption cross section $(\sigma_T + \epsilon\sigma_S)$ with W at constant q^2. The upper curve is the total real photo-absorption cross section σ_T at $q^2 = 0$ as determined by the SLAC-MIT data at 1.5^o. At q^2 equals zero, σ_S equals zero. The lower curves are obtained by interpolation from the 6^o and 10^o data.

10. Plots of νW_2 against ω under different assumptions for $R = \sigma_S/\sigma_T$:

a) 6^o data for E = 10, 13.5, 16 GeV, R = 0;

b) 10^o data for E = 7, 11, 13.5, 15.2, 17.7 GeV, R = 0;

c) as in (a) for $R = \infty$;

d) as in (b) for $R = \infty$; and

e) 6^o, 7 GeV spectrum for R = 0 and $R = \infty$.

11. Separation of σ_T and σ_S by Albrecht et al.,[12] using DESY large angle data in conjunction with 6^o and 10^o SLAC-MIT data.

12. Separation of σ_T and σ_S using preliminary 18^o and 26^o and the 6^o and 10^o SLAC-MIT data.

13. $\frac{\sigma_S}{\sigma_T}$ as obtained by Albrecht et al.,[12] against $\frac{\nu}{q^2}$ for $q^2 = 2\ (\mathrm{GeV/c})^2$.

14. R against ω for $q^2 = 1.5$, 3, and 4.5 $(\mathrm{GeV/c})^2$. The points shown have been obtained by interpolating between the spectra measured at 6^o, 10^o, 18^o, 26^o, and 34^o. The 34^o data are not included in Fig. 12.

15. R against q^2 for fixed W = 3 GeV. Most of the data points have been obtained by interpolating between the measured data.