# INELASTIC ELECTRON SCATTERING FROM HYDROGEN 

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#### Abstract

Inelastic electron scattering cross sections have been mea－ sured for four－momentum transfers between $4.1 \mathrm{GeV}^{2}$ and $30.5 \mathrm{GeV}^{2}$ 。 At the large scattering angles of this experiment， the dominant contribution to the cross section comes from the $W_{1}$ structure function．In the conventional scaling variables， $x$ and $x^{\prime}$ ，this structure function does not exhibit scaling be－ havior，and at fixed $x$ or $x^{7}$ it is found to decrease with in－ creasing four－momentum transfer．


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[^0]We have measured inclusive cross sections for inelastic electron scatter－ ing from hydrogen at angles of $50^{\circ}$ and $60^{\circ}$ ，and incident energies ranging from 6.5 to 19.5 GeV ．For these kinematics the cross section is most sensitive to the nucleon structure function，$W_{1}$ ，which is proportional to the photoabsorption cross section $\sigma_{\mathrm{t}}{ }^{\circ}$

The differential cross section for the inelastic scattering of an electron with initial and final energies of $\mathrm{E}_{0}$ and $\mathrm{E}^{8}$ at an angle $\theta$ can be written

$$
\begin{equation*}
\frac{\mathrm{d} \sigma}{\mathrm{~d} \Omega \mathrm{~d} E^{\mathrm{q}}}=\Gamma_{\mathrm{t}}\left\{\sigma_{\mathrm{t}}\left(\nu, \mathrm{Q}^{2}\right)+\epsilon \sigma_{\mathrm{S}}\left(\nu, \mathrm{Q}^{2}\right)\right\} \tag{1}
\end{equation*}
$$

where $\Gamma_{\mathrm{t}}$ is the flux of virtual photons，$\sigma_{\mathrm{t}}$ and $\sigma_{\mathrm{s}}$ are the absorption cross sec－ tions for transverse and longitudinal photons，respectively，and $\epsilon$ is the po－ larization parameter

$$
\epsilon=\frac{1}{1+2\left(1+\nu^{2} / \mathrm{Q}^{2}\right) \tan ^{2} \theta / 2}
$$

with $\nu=\mathrm{E}_{0}-\mathrm{E}^{\prime}$ and $\mathrm{Q}^{2}=4 \mathrm{E}_{0} \mathrm{E}^{\prime} \sin ^{2} \theta / 2$ 。
The quantities $\sigma_{t}$ and $\sigma_{S}$ can be separated by measurements of the cross section at different values of $\theta$（different $\epsilon$ ）with $\nu$ and $Q^{2}$ fixed。Values of $R=\sigma_{S} / \sigma_{t}$ have been determined［1］in this way for a range of values of $\nu$ and $Q^{2}$ ，and $R$ is found to be small，averaging less than 0.2 。

This experiment［2］was performed at large angles（and large $\nu$ and $\mathrm{Q}^{2}$ ） where $\epsilon$ is small so that the longitudinal contribution to the cross section is suppressed。We can write

$$
\begin{equation*}
\sigma_{\mathrm{t}}{ }^{\mathrm{i}}=\frac{\mathrm{d} \sigma}{\mathrm{~d} \Omega \mathrm{dE}^{\mathrm{r}}} \frac{1}{\Gamma_{\mathrm{t}}} \frac{1}{(1+\epsilon \mathrm{R})} \tag{2}
\end{equation*}
$$

and note that with $\in$ small，the uncertainty in $\sigma_{t}$ is small if $R$ is small and known approximately．If $R$ varies between 0 and .4 the maximum changes in $\sigma_{t}$ for this experiment are considerably smaller than other systematic
uncertainties. $R$ has not been measured for some of the kinematics of our experiment, and we have used the average value found in ref. [1] $(R=0,14)$ for all values of $Q^{2}$ and $\nu$ 。

A major aim of the experiment was a study of the scaling behavior of the structure function, $\mathrm{W}_{1}$, which is directly related to $\sigma_{\mathrm{t}}$ :

$$
\begin{equation*}
2 \mathrm{MW}_{1}=\frac{\sigma_{\mathrm{t}}}{\sigma_{0}} \frac{\mathrm{~W}^{2}-\mathrm{M}^{2}}{\mathrm{M}^{2}} ; \sigma_{0}=\frac{4 \pi^{2} \alpha}{\mathrm{M}^{2}} \cong 127 \mu \mathrm{~b} \tag{3}
\end{equation*}
$$

where $W$ is the mass of the unobserved final hadron state,

$$
\mathrm{W}^{2}=\mathrm{M}^{2}+2 \mathrm{M} \nu-\mathrm{Q}^{2}
$$

and M is the mass of the nucleon.
Scaling of the structure functions $\nu \mathrm{W}_{2}$ and $2 \mathrm{MW}_{1}$ was first suggested by Bjorken [3], who postulated that, as $\mathrm{Q}^{2}$ and $\nu \rightarrow \infty$, both quantities should be functions of only a single variable $\omega=1 / \mathrm{x}=\frac{2 \mathrm{M} \nu}{\mathrm{Q}^{2}}$. Early experiments by the SLAC-MIT collaboration showed that this was true within experimental errors for $\nu \mathrm{W}_{2}$ when $\mathrm{Q}^{2} \sim 1 \mathrm{GeV}^{2}, \mathrm{~W}^{2} \check{>} \mathrm{GeV}^{2}$. More refined measurements [4] of $\nu \mathrm{W}_{2}$ established deviations from scaling in the variable $\omega$, but the scaling behavior for $\nu \mathrm{W}_{2}$ was reestablished by introducing another scaling variable

$$
\begin{equation*}
\omega^{\bar{\prime}}=1 / x^{\prime}=\omega+M^{2} / Q^{2}=1+W^{2} / Q^{2} \tag{4}
\end{equation*}
$$

which approaches $\omega$ as $Q^{2}$ goes to $\infty$. Recently both electron [1] and muon [5] experiments have shown that $\nu \mathrm{W}_{2}$ does not scale in $\mathrm{x}^{\gamma}$, and the electron experiment [1] reports that $2 \mathrm{MW}_{1}$ is barely consistent with scaling in $\mathrm{x}^{8}$ 。

The experiment reported here was performed at angles of $50^{\circ}$ and $60^{\circ}$, using the $1,6-\mathrm{GeV}$ spectrometer in the SLAC spectrometer facility [6] for momentum analysis. Measurements were made for several values of incident electron energy varying from 6.5 to 19.5 GeV , using hydrogen and deuterium
targets which were both 17.7 cm long. The deuterium measurements will be reported separately. A significant experimental problem was the separation of a weak electron signal from a large pion background. The $1.6-\mathrm{GeV}$ spectrometer was equipped with a threshold Cerenkov counter using isobutane at atmospheric pressure and a total absorption counter consisting of several blocks of lead glass viewed separately. With these counters we were able to detect electrons with greater than $98 \%$ efficiency together with an efficiency for $\pi^{\text {s }} \mathrm{S}$ of less than $2 \times 10^{-5}$. This resulted in a correction of less than $2 \%$ for $\pi^{\imath} \mathrm{s}$ remaining in our electron sample, even for the worst case where there were about $1000 \pi^{\imath}$ s per electron. Several measurements of electrons scattered elastically at $50^{\circ}$ with incident energies of 1.5 GeV to 4.5 GeV were made in order to test and calibrate the response of the counters to electrons.

In addition to the correction for electron efficiency quoted above, there were various other smaller corrections such as trigger electronics dead time, accidentals, and a correction introduced by the inability of the electronics to record more than one event per accelerator pulse. These corrections usually changed the electron yields by less than $4 \%$. In the extraction of the differential cross section from the data several measured corrections were made. The measured yields of electrons include electrons which scattered from the . 005 cm stainless steel target walls and also electrons which were produced in the target ( $\mathrm{e}_{\circ} \mathrm{g}_{\circ}$, from $\pi^{\circ}$ Dalitz decay or from pair production by photons) 。 Empty target yields were measured for each spectrometer setting and subtracted from the full target yields. A correction for electrons produced in the target was made by subtracting the yield of positrons measured at the same momentum. This corrected for charge symmetric processes. A rough check that charge nonsymmetric sources of electrons were a small contribution was made by
measuring the yield of electrons produced by an incident positron beam［7］．
After these corrections were made，the effects of radiative processes were next calculated and corrections applied．The correction procedure was similar to that used on small angle data［8］and is given in detail in ref．［2］． $W_{1}$ can then be extracted provided that a value of $R$ is assumed［9］。 The values of the cross section were computed using $\Delta E^{\prime}$ bins corresponding to $\Delta W=0.1 \mathrm{GeV}$ 。

We estimate that the systematic errors are about $6 \%$ for $\mathrm{W} \widetilde{<} 3.5 \mathrm{GeV}$ and rise to about $10 \%$ for the largest W values where the measured and calculated corrections are largest．The principal contributions below $W \approx 3.5 \mathrm{GeV}$ are the inelastic radiative correction and the positron subtraction；the principal ad－ ditional contributions above $W \approx 3.5 \mathrm{GeV}$ are the pion correction and the elastic radiative correction．Ref．［2］contains detailed discussions of the systematic errors．For most of the data the statistical and systematic errors were com－ parable．For W larger than about 3.5 GeV ，the systematic errors became larger than the statistical errors by a factor of approximately 2 to 3 。

Figs．1a and 1 b display $2 \mathrm{MW}_{1}$ calculated from the measured cross section values（using $R=0.14$ ）as a function of $W$ 。 We present only data for which $\mathrm{W} \geq 2 \mathrm{GeV}$ ．The large scattering angles place these data in the $Q^{2}$ range from 4.1 to $30.5 \mathrm{GeV}^{2}$ and in the range of $x^{\prime}$ greater than about 0.4 ．Fig．1c shows all of the points in Figs．1a and 1b plotted against $x$＇。 Although the clustering of the points suggests a function of $x^{\prime}$ ，the spread in the points at a particular value of $x^{8}$ is often greater than the errors．These deviations are correlated with $Q^{2}$ so that $2 \mathrm{MW}_{1}$ at fixed $\mathrm{x}^{\prime}$ tends to decrease as $Q^{2}$ increases．This was suggested by the results in ref．［1］and constitutes a breakdown of scaling in the variable $x^{\circ}$ ．

In order to investigate this scale breaking，we want to compare values of $2 \mathrm{MW}_{1}$ at the same value of $\mathrm{x}^{9}$（or x ）but at different values of $Q^{2}$ ．Figure 2 il－ lustrates the $Q^{2}$ variation of $2 \mathrm{MW}_{1}$ in the scaling variable range 0.6 to 0.7 。 Within this range，a series of nonoverlapping $Q^{2}$ bins each $3 \mathrm{GeV}^{2}$ wide were chosen．In each bin the variation of $2 \mathrm{MW}_{1}$ with the scaling variable was re－ moved by making a linear fit in $\mathrm{x}^{8}$（or x ）to all the points，and evaluating the fit（with its error）at 0.65 ．These values were plotted at the average value of $Q^{2}$ for the points in each bin．Figs． $2 a$ and $2 b$ show the results of this pro－ cedure for the scaling variables $x$ and $x^{\prime}$ ．The residual $Q^{2}$ dependence is ob－ vious，demonstrating scale breaking in these two variables．Fig。2c shows the result of the same procedure using a new ad hoc scaling variable， $\mathrm{x}_{\mathrm{s}}$ ，defined as

$$
\begin{equation*}
\omega_{\mathrm{s}}=1 / \mathrm{x}_{\mathrm{s}}=\omega+\mathrm{M}_{\mathrm{s}}^{2} / \mathrm{Q}^{2}=\omega^{t}+\left(\mathrm{M}_{\mathrm{s}}^{2}-\mathrm{M}^{2}\right) / \mathrm{Q}^{2} \tag{5}
\end{equation*}
$$

A fit to all the data in fig。 1 （using statistical errors only）of the form

$$
\begin{equation*}
2 \mathrm{MW}_{1}=\sum_{i=3}^{7} \mathrm{a}_{\mathrm{i}}\left(1-\mathrm{x}_{\mathrm{s}}\right)^{\mathrm{i}} \tag{6}
\end{equation*}
$$

gave the value $M_{S}^{2}=1.48 \pm 0.04 \mathrm{GeV}^{2}$ 。 In this variable $W_{1}$ no longer depends on $Q^{2}$ ；therefore，for the data reported here，$W_{1}$ scales in $x_{S}$ ．

A study of the data for ranges other than 0.6 to 0.7 in the scaling variables results in similar conclusions．Although these three scaling variables are iden－ tical in the Bjorken scaling limit，they may give rise to different apparent scaling behavior at finite energy．The variables $x$ and $x^{8}$ are attractive because they are simple ratios of kinematic invariants；however，there appears to be no theoretical way to rule out variables like $\mathrm{x}_{\mathrm{S}}$ ．This analysis illustrates the close connection between scale breaking and the choice of scaling variable．In fact，
the use of $x_{S}$ may be viewed as the introduction of an implicit $Q^{2}$ dependence into a fit using the variable $\mathrm{x}^{8}$ (see eq. (5))。
$\overrightarrow{\text { An }}$ alternative parametrization of the data can be made by choosing a given variable and introducing an explicit scale breaking term; for example, using $\mathrm{x}^{\prime}$ we can fit

$$
\begin{equation*}
2 \mathrm{MW}_{1}\left(\mathrm{x}^{8}, Q^{2}\right)=\left(1+b Q^{2}\right) \sum_{i=3}^{7} \mathrm{a}_{\mathrm{i}}\left(1-x^{1}\right)^{i} \tag{7}
\end{equation*}
$$

An acceptable fit including systematic errors is found with the parameter

$$
\mathrm{b}\left(2 \mathrm{MW}_{1}\right)=(-.012 \pm .002) \mathrm{GeV}^{-2}
$$

A similar fitting procedure was carried out for $\nu \mathrm{W}_{2}$ in ref. [1], and the corresponding value of the scale breaking parameter is [10]

$$
\mathrm{b}\left(\nu \mathrm{~W}_{2}\right)=(-.011 \pm .002) \mathrm{GcV}^{-2}
$$

It appears that both $\nu \mathrm{W}_{2}$ and $2 \mathrm{MW}_{1}$ for the proton show similar deviations from scaling behavior within the experimental statistical errors. In the scaling variable $x^{\prime}$ the decrease of $2 M W_{1}$ as $Q^{2}$ increases is about one percent per $\mathrm{GeV}^{2}$. Even if one does not accept the variable $\mathrm{x}_{\mathrm{s}}$ as a reasonable scaling variable, the magnitude of the scale breaking observed in the inelastic electron scattering experiments at SLAC energies is such that many explanations are possible without giving up the general idea of the scaling hypothesis. A simple explanation could be that the present experiments have not reached values of $\nu$ and $Q^{2}$ where Bjorken scaling holds. The observed breaking could equally well correspond to the logarithmic scale breaking expected in asymptotically free theories or theories with anomalous dimensions.

## References

［1］E．M．Riordan et al。，SLAC－PUB－1634（1975）．
［2］W．B．Atwood，SLAC Report No．SLAC－185（1975），Stanford Ph．D．thesis， 1975 （unpublished）．
［3］J．D．Bjorken，Phys．Rev． 179 （1969）1547；J．D．Bjorken and E．A． Paschos，Phys．Rev． 185 （1969）1975．
［4］Go Miller et alo，Phys．Rev．D $\underline{5}$（1972）528。
［5］C．Chang et al。，Phys．Rev．Lett． 35 （1975） 901 and Y．Watanabe et al．， Phys．Rev．Lett． 35 （1975）898．
［6］R．Anderson et al．，Nucl．Instrum．Methods 66 （1968） 328.
［7］L．S．Rochester et al．，Phys．Rev．Lett． 36 （1976） 1284.
［8］S．Stein et alo，Phys．Rev．D 12 （1975）1884。
［9］In SLAC－PUB－1758（a preprint version of this paper），tables of $d^{2} \sigma / d \Omega d E$ ！ are given，and $W_{1}$ is shown calculated using the most recent value of $R=0.14$ from ref．［1］．In Atwood＇s thesis［2］the values of $W_{1}$ were cal－ culated using the then current value of $R=0.18$ ．The difference is well within quoted errors．
［10］At this stage it is difficult to compare our $\mathrm{W}_{1}$ data with the $\nu \mathrm{W}_{2}$ data from the muon experiment［5］，since there is an insignificant overlap in the scaling variable ranges of the two experiments as well as uncertainties in－ troduced by the values of R used．

## Figure Captions

1. Values of the proton structure function $2 \mathrm{MW}_{1}$ for $\mathrm{W} \geq 2 \mathrm{GeV}$ calculated assuming $R=0.14$ are plotted against $W$ for the $50^{\circ}$ data in fig。1a and for the $60^{\circ}$ data in fig. 1 b . The different incident energies for the various bands of data are indicated. Fig. 1c shows the points in figs. 1a and 1b plotted against the scaling variable $x^{\gamma}$ 。 The spread of the points at constant $x^{8}$ arises from a breakdown in scaling in this variable (see fig. 2). The errors shown are statistical only and do not include estimated systematic errors of $6 \%$ to $10 \%$ (see text).
2. This figure illustrates the scaling (or nonscaling) behavior of $2 \mathrm{MW}_{1}$ for various scaling variables. From the data in fig. 1 the average value of $2 \mathrm{MW}_{1}$ in the x or $\mathrm{x}^{8}$ or $\mathrm{x}_{\mathrm{S}}$ range from 0.6 to 0.7 is evaluated at a value of the scaling variables of 0.65 and is plotted as a function of $Q^{2}$. For $x$ and $\mathrm{x}^{\prime}, 2 \mathrm{MW}_{1}$ decreases as $\mathrm{Q}^{2}$ increases, indicating a breakdown of scaling in these variables. For $\mathrm{x}_{\mathrm{s}}$ the data are consistent with scaling. Other ranges of the scaling variables give similar results. The reason that fig. 2 c has one less point than figs. $2 a$ and $2 b$ is that for $x_{s}$ the lowest $Q^{2}$ bin has no experimental points in it.


Fig. 1


Fig. 2

## APPENDIX A

Table of kinematics, cross sections and the structure function $2 \mathrm{MW}_{1}$ measured off hydrogen.

The kinematics in the Tables were calculated using the values of $E_{o}$ and $\theta$ given at the top of each data group. We used the value . 938279 GeV for the proton mass; for the fine structure constant, $\boldsymbol{\alpha}$, we have used $1 / 137.03604$, and for $R=\sigma_{s} / \sigma_{t}$ the value .14 was used.

We have listed two errors of each measurement of the cross section and the extracted structure function. The first number in parenthesis is the statistical (counting) error, and the second is the total systematic error. Included in the systematic error are both point to point errors as well as overall normalization errors. Typical sizes of various errors were as follows: incident beam associated errors (energy determination, flux, halo, etc.) were estimated at $1.6 \frac{\%}{\circ}$; target associated errors amounted to $1.5 \%$; spectrometer solid ang1e, $1 \%$; empty target and positron subtraction, $2.7 \%$; radiative corrections, $5 \%$; and extraction of $2 \mathrm{MN}_{1}$, $1 \%$. A more detailed account of the various sources of systematic errors is given in Ref. 2 . These errors were added in quadrature to produce the final error estimate.

$$
E_{o}=19.50 \mathrm{GeV}, \quad \theta=50.00^{\circ}
$$

| $\begin{gathered} \mathrm{W} \\ (\mathrm{GeV}) \end{gathered}$ | $\begin{gathered} Q^{2} \\ \left(\mathrm{Gev}^{2}\right) \end{gathered}$ | E | $x \quad x^{\prime}$ | $\frac{\mathrm{d}^{2} \mathrm{o}}{\mathrm{~d} \mathrm{dE}^{\prime}}\left(\frac{\mathrm{pb}}{\mathrm{GeV}-\mathrm{sr}}\right)$ | $2 \mathrm{MN}_{1}$ |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 3.100 | 24.555 | 0.1428 | 0.7380 .719 | $2.973 \pm(0.658,0.135)$ | $0.03071 \pm(0.00690,0.00130)$ |
| 3．290 | 24.000 | 0.1397 | 0.7190 .701 | 三．ç1e $\pm(0.435,0.173)$ | $0.03338 \pm(0.00451 \cdot 0.00179)$ |
| 3．$=00$ | 23.427 | 0.1365 | 0.7010 .693 | $3.752 \pm(0.351 .0 .220)$ | $0.03908 \pm(0.00366,0.00229)$ |
| 3.400 | 22.836 | 0.1332 | 0.5810 .654 | $4.515 \pm(0.330 .0 .279)$ | $0.04828 \pm(0.00346,0.00292)$ |
| 3． 5 cc | 22.229 | 0.1298 | 0.6520 .645 | $5.931 \pm(0.340 .0 .353)$ | $0.06230 \pm(0.00357 \cdot 0.00371)$ |
| 3.600 | 21.603 | 0.1263 | $0.6410 .6 \geq 5$ | $7.365 \pm(0.390 \cdot 0.443)$ | $0.07776 \pm(0.00412,0.00468)$ |
| 3.700 | 20.555 | 0.1227 | 0.6210 .605 | $7.652 \pm(0.424,0.557)$ | $0.08112 \pm(0.00449,0.00590)$ |
| 3.860 | 20.298 | 0.1189 | 0.6000 .584 | $10.059 \pm(0.508,0.707)$ | $0.10714 \pm(0.00542,0.00753)$ |
| 3.900 | 19.620 | $0.11 E_{1}$ | 0.5780 .553 | $12.063 \pm(0.581,0.899)$ | $0.12912 \pm(0.00822 \cdot 0.00962)$ |
| 4.000 | 18.924 | 0.11112 | 0.5560 .542 | $13.690 \pm(0.673 .1 .155)$ | $0.14716 \pm(0.00724,0.01242)$ |
| 4.100 | 18.210 | 0.1071 | $0.5330 . \pm 20$ | $15.485 \pm(0.849 .1 .511)$ | $0.16744 \pm(0.00988,0.01633)$ |
| 4.200 | 17.478 | 0.1029 | 0.5100 .458 | $19.058 \pm(1.157,2.001)$ | $0.20714 \pm(0.01258,0.02175)$ |
| 4.300 | 16．アニ9 | 0.0986 | 0.4270 .475 | $23.516 \pm(1.510 .2 .759)$ | $0.26135 \pm(0.01650,0.03015)$ |
| 4.400 | 15．963 | 0.0943 | 0.4630 .452 | $29.137 \pm$（1．895，3．978） | $0.32014 \pm(0.02082 \cdot 0.04371)$ |
| 4.500 | 15.178 | 0.0897 | 0.4390 .428 | $29.083 \pm$（2．622．5．990） | $0.32134 \pm(0.02897 \cdot 0.06610)$ |
| 4.600 | 14．37t | 0．ce51 | 0.4150 .405 | $39.494 \pm$（6．186． 9.499$)$ | $0.43887 \pm(0.06874 \cdot 0.10556)$ |

$$
E_{0}=16.00 \mathrm{GeV}, \quad \theta=50.00^{\circ}
$$

$Q^{2}$
$\left(\mathrm{Gev}^{2}\right)$

$$
2.700
$$

$$
2.80 \mathrm{C}
$$

$$
2.900
$$

$3.000 \quad 18.91 \in \quad 0.1 \in 14$
$3.100 \quad 18.292 \quad 0.1572$
$3.200 \quad 17.751 \quad 0.1527$
3．300 17．19 $0.14 \varepsilon 2$
$3.400 \quad 10.617 \quad 0.1435$
3.500
$3.600 \quad 15.414 \quad 0.2 .35$ $3.700 \quad 14.787 \quad 0.1283$
3.300
13.4820 .1174
$4.100 \quad 12.107 \quad 0.1059$
4． 200
$11.3 ¢ 4 \quad 0.0<58$
x

$$
0.760 \quad 0.736
$$



$$
0.740 \quad 0.716
$$

$$
0.720 \quad 0.697
$$

$$
0.6990 .676
$$

$$
0.5770 .656
$$

$$
0.6550 .6 \Xi 4
$$

$$
0.6320 .612
$$

$$
0.5090 .590
$$

$$
0.5850 .567
$$

$$
\begin{array}{lll}
0.585 & 0.567 & 19.369 \pm(1.402,1.218) \\
0.561 & 0.543 & 19.451 \pm(1.431,1.562)
\end{array}
$$

$$
0.5360 .519 \quad 26.463 \pm(1.727 .2 .025)
$$

$$
0.5110 .455
$$

$$
i 0.485 \quad 0.470
$$

$$
0.4590 .445
$$

$$
0.4 \equiv 20.415
$$

$$
0.405 \quad 6.392
$$

$0.02142 \pm(0.00697 .0 .00106)$ $0.01993 \pm(0.00395 .0 .00140)$ $0.03025 \pm(0.00364 .0 .00183)$ $0.04049 \pm(0.00369,0.00239)$ $0.05558 \pm(0.00422 \cdot 0.00310)$ $0.07352 \pm 10.00548,0.00390$ ） $0.07345 \pm(0.00611 .0 .00513)$ $0.10775 \pm(0.00795 .0 .00651)$ $0.13544 \pm(0.00981 \cdot 0.00852)$ $0.13691 \pm 10.01007,0.011007$ $0.18752 \pm(0.01224 \cdot 0.01435)$ $0.22026 \pm\{0.01465,0.01906\}$ $0.26426 \pm(0.01839 .0 .02616)$ $0.29394 \pm(0.02214,0.03753)$ $0.33731 \pm(0.02833 \cdot 0.05725)$ $0.37262 \pm(0.04185 .0 .09220)$

$$
E_{0}=13.50 \mathrm{GeV}, \quad \theta=50.00^{\circ}
$$

| $\begin{gathered} \mathrm{W} \\ (\mathrm{GeV}) \end{gathered}$ | $\begin{gathered} Q^{2} \\ \left(G e v^{2}\right) \end{gathered}$ | $\varepsilon$ | $x \quad x^{\prime}$ | $\frac{\mathrm{d}^{2} \sigma}{\mathrm{~d} \Omega \mathrm{dE}^{\prime}}\left(\frac{\mathrm{pb}}{\mathrm{GeV}-\mathrm{sr}}\right)$ | $2 \mathrm{MN}_{1}$ |
| :---: | :---: | :---: | :---: | :---: | :---: |
| * | $\rightarrow$ |  |  |  |  |
| 2.400 | 17.122 | 0.2030 | $0.778 \quad 0.748$ | $3.869 \pm 10.969 .0 .240)$ | $0.01767 \pm(0.00442,0.00110)$ |
| 2.500 | 16.712 | 0.1985 | 0.7570 .728 | 4.395 $\pm$ (1.105. 0.311$)$ | $0.02019 \pm(0.00509 .0 .00143)$ |
| 2.600 | 16.285 | 0.1938 | 0.7350 .707 | $7.810 \pm(1.184 .0 .406)$ | $0.03612 \pm(0.00547,0.00188)$ |
| 2.700 | 15.E41 | 0.1989 | $0.7120 .6 E 5$ | $10.028 \pm(1.119,0.501)$ | $0.04669 \pm(0.00521 .0 .00233)$ |
| 2. $\operatorname{ecc}$ | 15.381 | 0.1838 | 0.6880 .662 | $11.449 \pm(1.127,0.664)$ | $0.05362 \pm(0.00529,0.00311)$ |
| 2.900 | 14.904 | 0.1784 | 0.6640 .639 | $14.362 \pm(1.241,0.874)$ | $0.06783 \pm(0.00585 \cdot 0.00413)$ |
| 3.000 | 14.410 | 0.1729 | 0.6400 .616 | $18.431 \pm(1.462,1.090)$ | $0.08770 \pm(0.00696 \cdot 0.00518)$ |
| 3.100 | 13.899 | 0.1671 | 0.614 0.Est | =0.588 $\pm$ (1.814. 1.368$)$ | $0.09872 \pm(0.00870 \cdot 0.00656)$ |
| 3.200 | 13.372 | 0.1611 | 0.5880 .566 | $24.944 \pm(2.181,1.757)$ | $0.12057 \pm(0.01054,0.00849)$ |
| 3.300 | 12.828 | 0.1549 | 0.5620 .541 | $33.571 \pm(2.518 .2 .284)$ | $0.16360 \pm(0.01227,0.01113)$ |
| 3.400 | 12.267 | 0.1485 | 0.5350 .515 | $41.059 \pm(3.162 .3 .000)$ | $0.20180 \pm(0.01554,0.01474)$ |
| 3.500 | 11.689 | 0.1418 | 0.5070 .488 | $47.265 \pm(3.504 .3 .914)$ | $0.23433 \pm(0.01737 \cdot 0.01941)$ |
| 3.600 | 11.055 | 0.1349 | 0.4790 .461 | $53.889 \pm(3.570 .5 .329)$ | $0.26958 \pm(0.01786,0.02666)$ |
| 3.700 | 10.484 | 0.1278 | 0.4500 .434 | $67.394 \pm(4.565 .7 .605)$ | $0.34024 \pm(0.02305,0.03840)$ |
| 3.800 | 9.856 | 0.1204 | 0.4210 .406 | $73.099 \pm(6.374 .11 .205)$ | $0.37254 \pm(0.03248,0.05711)$ |

$$
\mathrm{E}_{\mathrm{O}}=7.00 \mathrm{GeV}, \quad \theta=50.00^{\circ}
$$

| $\begin{gathered} \mathrm{W} \\ (\mathrm{GeV}) \end{gathered}$ | $\begin{gathered} Q^{2} \\ \left(\mathrm{Gev}^{2}\right) \end{gathered}$ | $\varepsilon$ | $x \quad x^{\prime}$ | $\frac{\mathrm{d}^{2}{ }_{\mathrm{o}}}{\mathrm{~d} \Omega \mathrm{dE}}\left(\frac{\mathrm{pb}}{\mathrm{GeV}-\mathrm{sr}}\right)$ | $2 \mathrm{MW}_{1}$ |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 2.000 | 7.283 | 0.3058 | 0.7000 .645 | $69.54 \pm(6.57,4.32)$ | $0.07332 \pm(0.00693 \cdot 0.00455)$ |
| 2.100 | K. 585 | 0.2950 | 0.6640 .613 | $22.03 \pm$ ( 7.14. 5.74) | $0.08797 \pm(0.00766,0.00616\}$ |
| 2.200 | 6.67 ? | 0.2935 | 0.6280 .580 | $112.56 \pm$ ( 9.55, 7.55) | $0.12330 \pm(0.01042,0.00824)$ |
| 2.300 | 6.345 | 0.2713 | 0.5900 .545 | $155.33 \pm(11.11,10.10)$ | $0.17274 \pm(0.01236,0.01123)$ |
| 2.400 | 6.003 | 0.2583 | 0.5520 .510 | $185.54 \pm(12.03,13.33)$ | $0.21037 \pm(0.01364,0.01511)$ |
| 2.500 | 5.647 | 0.2446 | 0.5130 .475 | $237.86 \pm(13.94 .17 .26)$ | $0.27521 \pm(0.01613 \cdot 0.01997)$ |
| 2.800 | 5.276 | 0.2300 | 0.4730 .438 | ミ00.61 $\pm(14.80,22.73)$ | $0.35522 \pm(0.01749 \cdot 0.02685)$ |
| 2.700 | 4.891 | 0.2146 | 0.4330 .402 | $387.83 \pm(16.35,30.75)$ | $0.46842 \pm(0.01975 \cdot 0.03714)$ |
| 2.800 | 4.491 | 0.1984 | $0.392 \quad 0.564$ | $460.71 \pm(19.41 .40 .38)$ | $0.56918 \pm(0.02398 \cdot 0.04989)$ |
| 2.900 | 4.076 | 0.1213 | 0.3510 .326 | $536.56 \pm(28.07 .56 .81)$ | $0.67862 \pm(0.03551,0.07185)$ |


| $\begin{gathered} \mathrm{W} \\ (\mathrm{GeV}) \end{gathered}$ | $\begin{gathered} Q^{2} \\ \left(\mathrm{Gev}^{2}\right) \end{gathered}$ | $\varepsilon$ | $x \quad \mathrm{x}^{\prime}$ | $\frac{\mathrm{d}^{2} \mathrm{o}}{\mathrm{~d} \Omega \mathrm{dE}}\left(\frac{\mathrm{pb}}{\mathrm{GeV}-\mathrm{sr}}\right)$ | $2 \mathrm{MN}_{1}$ |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 2.000 | 30.544 | 0.1151 | $0.9070 . \varepsilon \in 4$ | $0.053 \pm(0.010 .0 .004)$ | $0.00080 \pm(0.00015,0.00006)$ |
| 2.100 | 30.170 | 0.1137 | 0.8950 .872 | $0.053 \pm(0.011,0.006)$ | $0.00080 \pm(0.00017 \cdot 0.00008)$ |
| 2.200 | 29.778 | 0.1123 | 0.9830 .660 | $0.131 \pm(0.015 .0 .008)$ | $0.00196 \pm(0.00023,0.00011)$ |
| 2. 300 | 29.367 | 0.11 CB | 0.8690 .847 | $0.140 \pm(0.016 .0 .010)$ | $0.00211 \pm(0.00024,0.00015)$ |
| 2.40 C | 23.938 | 0.1093 | 0.8560 .834 | $0.244 \pm(0.020,0.014)$ | $0.00368 \pm(0.00031,0.00021)$ |
| 2.500 | 28.491 | 0.1077 | $0.841 \mathrm{C.820}$ | c. $304 \pm(0.024 \cdot 0.029)$ | $0.00460 \pm(0.00037 .0 .00028)$ |
| 2.600 | 28.026 | 0.1050 | $0.8270 .8 c 6$ | $0.379 \pm(0.030 .0 .025)$ | $0.00575 \pm(0.00045,0.00038)$ |
| 2.700 | 27.543 | 0.1043 | 0.8110 .791 | $0.563 \pm(0.037 .0 .034)$ | $0.00955 \pm(0.00056,0.00051)$ |
| 2.800 | 27.041 | 0.1025 | 0.7950 .775 | $0.716 \pm(0.044,0.045)$ | $0.01091 \pm(0.00068,0.00069)$ |
| 2.900 | 2t. 521 | c. 1006 | 0.7790 .759 | $0.922 \pm(0.055 \cdot 0.060)$ | $0.01407 \pm(0.00084,0.00092)$ |
| 3.00C | 25.983 | 0.0985 | 0.7620 .743 | $1.039 \pm(0.067,0.079)$ | $0.01591 \pm(0.00103 .0 .00122)$ |
| 3.100 | 25.426 | 0.0966 | 0.7440 .726 | $1.383 \pm(0.090 .0 .105)$ | $0.02122 \pm(0.00139,0.00161)$ |
| 3.200 | 24.8E2 | 0.0945 | 0.7260 .708 | $1.825 \pm(0.119 .0 .138)$ | $0.02808 \pm(0.00183 \cdot 0.00212)$ |
| 3.300 | 24.259 | 0.0923 | 0.7080 .890 | $2.317 \pm(0.147 .0 .181)$ | $0.03575 \pm(0.00227 .0 .00280)$ |
| 3.400 | 23.548 | 0.0901 | 0.6890 .672 | $2.957 \pm(0.180 .0 .238)$ | $0.04637 \pm(0.00278,0.00369)$ |
| 3.500 | 23.018 | 0.6878 | 0.5690 .653 | $3.508 \pm(0.201 \cdot 0.315)$ | $0.05442 \pm(0.00312,0.00489)$ |
| 3.600 | 22.370 | 0.0854 | 0.6490 .633 | $4.730 \pm(0.234,0.418)$ | $0.07360 \pm(0.00363,0.00650)$ |
| 3.700 | 21.704 | 0.0229 | 0.6290 .613 | $5.679 \pm(0.266 .0 .560)$ | $0.08864 \pm(0.00416 .0 .00873)$ |
| 3.900 | 21.020 | $0.08 \mathrm{C4}$ | 0.6080 .553 | $6.348 \pm(0.346,0.760)$ | $0.09938 \pm(0.00542,0.01190)$ |
| 3.900 | 20.318 | 0.0778 | 0.5860 .572 | $7.509 \pm(0.346,1.051)$ | $0.11794 \pm(0.00544 \cdot 0.01651)$ |

$$
E_{0}=16.002 \mathrm{GeV}, \quad \theta=60.00^{\circ}
$$

| $\begin{gathered} W \\ (\mathrm{GeV}) \end{gathered}$ | $\begin{gathered} Q^{2} \\ \left(\operatorname{Gev}^{2}\right) \end{gathered}$ | E | $\mathrm{x} \quad \mathrm{x}^{\boldsymbol{1}}$ | $\frac{d^{2} \sigma}{d \Omega d E}\left(\frac{\mathrm{pb}}{\mathrm{GeV}-\mathrm{sr}}\right)$ | $2 \mathrm{MN}_{1}$ |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 2.000 | 24.085 | 0.1336 | 0.8850 .658 | $0.203 \pm(0.021 .0 .012)$ | $0.00200 \pm(0.00020,0.00011)$ |
| 2.100 | 23.71E | 0.1317 | 0.8700 .843 | $0.362 \pm(0.027 .0 .016)$ | $0.00357 \pm(0.00025,0.00016)$ |
| 2.200 | 23.333 | 0.1297 | 0.8550 .828 | $0.461 \pm(0.033,0.023)$ | $0.00457 \pm(0.00033 .0 .00023)$ |
| 2.300 | 22.930 | 0.1276 | 0.8390 .813 | $0.565 \pm(0.043 \cdot 0.032)$ | $0.00561 \pm(0.00043 \cdot 0.00032)$ |
| 2.400 | 22.565 | 0.1254 | 0.8220 .756 | $0.748 \pm(0.056 \cdot 0.045)$ | $0.00745 \pm(0.00056 \cdot 0.00045)$ |
| 2. 500 | 22.071 | 0.1231 | 0.8040 .779 | $1.138 \pm(0.075 \cdot 0.061)$ | $0.01137 \pm(0.00075,0.00061)$ |
| 2.600 | 21.614 | 0.1207 | 0.7860 .762 | $1.327 \pm(0.090,0 . C E 4)$ | $0.01330 \pm(0.00090,0.00084)$ |
| 2.700 | 21.140 | 0.1182 | 0.7670 .744 | $1.872 \pm(0.120,0.113)$ | $0.01882 \pm(0.00121,0.00114)$ |
| 2.800 | 20.648 | 0.1155 | 0.7480 .725 | $2.439 \pm(0.156 .0 .152)$ | $0.02460 \pm(0.00157,0.00153)$ |
| 2.900 | 20.137 | 0.1128 | 0.7280 .705 | $3.087 \pm(0.196,0.204)$ | $0.03125 \pm(0.00198 \cdot 0.00206)$ |
| 3.000 | 19.609 | 0.1100 | 0.7070 .695 | $3.353 \pm(0.221 .0 .271)$ | $0.03406 \pm(0.00225,0.00275)$ |
| 3.100 | 19.063 | 0.1071 | 0.686 0.tes | $4.673 \pm(0.262,0.359)$ | $0.04764 \pm(0.00267,0.00366)$ |
| 3.200 | 18.498 | 0.1041 | $0.6 \in 40.644$ | $5.516 \pm(0.323 .0 .477)$ | $0.05645 \pm(0.00331,0.00488)$ |
| 3.300 | 17.519 | 0.1009 | 0.6420 .622 | $7.578 \pm(0.480,0.634)$ | $0.07785 \pm(0.00493,0.00652)$ |
| 3.400 | 17.313 | 0.0977 | 0.6190 .600 | $9.528 \pm(0.776,0.256)$ | $0.09828 \pm$ (0.00800, 0.00879$\}$ |
| 3.500 | 15.7 CO | 0.0944 | $0.5950 . \leqslant 77$ | 11.1 C ( $\pm$ (0.776, 1.159) | $0.11506 \pm(0.00803,0.012 .00)$ |

$$
E_{0}=13.290 \mathrm{GeV}, \quad \theta=60.00^{\circ}
$$

| $\begin{gathered} \mathrm{W} \\ (\mathrm{GeV}) \end{gathered}$ | $\begin{gathered} Q^{2} \\ \left(\mathrm{Gev}^{2}\right) \end{gathered}$ | $\varepsilon$ | $x \quad x^{\prime}$ | $\frac{d^{2} \sigma}{d \Omega d E},\left(\frac{\mathrm{pb}}{\mathrm{GeV}-\mathrm{sr}}\right)$ | $2 \mathrm{MN}_{1}$ |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 2.000 | 19.120 | 0.1523 | 0.8600 .827 | $0.658 \pm(0.066 \cdot 0.043)$ | $0.00437 \pm(0.00044 \cdot 0.00029)$ |
| 2.100 | 19.761 | 0.1457 | 0.842 C.E10 | $0.940 \pm(0.069,0.064)$ | $0.00626 \pm(0.00046,0.00042)$ |
| 2.200 | 18.384 | 0.1469 | 0.8230 .792 | $1.342 \pm(0.093,0.128)$ | $0.00896 \pm(0.00052,0.00085)$ |
| 2.300 | 17.990 | 0.1440 | 0.8030 .773 | $1.689 \pm(0.114,0.164)$ | $0.01133 \pm(0.00077,0.00110)$ |
| 2.400 | 17.578 | 0.1409 | 0.7830 .753 | $2.455 \pm(0.149,0.173)$ | $0.01654 \pm(0.00100,0.00116)$ |
| 2.500 | 17.148 | 0.1377 | 0.7620 .733 | $3.099 \pm(0.183 .0 .237)$ | $0.02096 \pm(0.00124,0.00160)$ |
| 2.500 | 16.702 | 0.1343 | 0.7400 .712 | $3.792 \pm(0.227 .0 .385)$ | $0.02575 \pm(0.00154,0.00261)$ |
| 2.700 | 16.237 | 0.1308 | $0.717 \quad 0.690$ | $4.849 \pm(0.313,0.578)$ | $0.03309 \pm(0.00214,0.00395)$ |
| 2.800 | 15.755 | 0.1271 | $0.694 \quad 0.658$ | $6.611 \pm(0.469,0.801)$ | $0.04532 \pm(0.00321,0.00549)$ |
| 2.900 | 15.256 | 0.1233 | 0.6700 .645 | $8.823 \pm(0.64 E .0 .967)$ | $0.06077 \pm(0.00445,0.00666)$ |
| 3.000 | $14.7 \geq 9$ | 0.1194 | c.645 0.621 | $11.855 \pm(0.877 .1 .017)$ | $0.08208 \pm(0.00607,0.00704)$ |
| 3.100 | 14.204 | 0.1153 | 0.6190 .596 | $16.803 \pm(1.247 .1 .280)$ | $0.11694 \pm(0.00868,0.00891)$ |
| 3.200 | 13.652 | 0.11110 | 0.553 c .571 | $17.300 \pm(1.321 .1 .846)$ | $0.12105 \pm(0.00925 \cdot 0.01291)$ |
| 3.300 | 13.083 | 0.1066 | 0.5570 .546 | $24.100 \pm(1.264 .2 .444)$ | $0.15957 \pm(0.00889,0.01720)$ |
| 3.400 | 12.495 | 0.1020 | 0.5390 .619 | ES.057 $\pm$ (1.518, 3.161) | $0.20563 \pm 10.01074,0.022$ |

$$
E_{0}=10.400 \mathrm{GeV}, \quad \theta=60.00^{\circ}
$$

| $W$ <br> $(\mathrm{GeV})$ | $Q^{2}$ <br> $\left(\mathrm{Gev}^{2}\right)$ |  |
| :---: | :---: | :---: |
| 2.000 | 13.890 | 0. |
| 2.100 | $13.54 \equiv$ | 0. |
| $2.200-$ | 13.179 | 0. |
| 2.300 | 12.797 | 0. |
| 2.400 | 12.399 | 0. |
| 2.500 | 11.524 | 0. |
| 2.600 | 11.552 | 0. |
| 2.700 | 11.103 | 0. |
| 2.800 | 10.637 | 0. |
| 2.900 | 10.154 | 0. |
| 3.000 | 9.555 | 0. |
| 3.100 | 9.138 | 0. |

$$
E_{0}=6.5 \mathrm{GeV}, \quad \theta=60.00^{\circ}
$$

| $\begin{gathered} \mathrm{W} \\ (\mathrm{GeV}) \end{gathered}$ | $\begin{gathered} Q^{2} \\ \left(G e v^{2}\right) \end{gathered}$ | $\varepsilon$ |  | $\frac{\mathrm{d}^{2} \sigma}{\mathrm{~d} \Omega \mathrm{dE}},\left(\frac{\mathrm{pb}}{\mathrm{GeV}-\mathrm{sr}}\right)$ | $2 \mathrm{MW}_{1}$ |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 2. 100 | 7.044 | 0.2251 | 0.6930 .638 | $55.29 \pm$ ( 1.07. 3.32) | $0.07941 \pm(0.00153,0.00478)$ |
| 2.100 | 6.726 | 0.2161 | 0.6560 .604 | 75.04 $\pm$ ( 1.16. 4.63) | $0.10916 \pm(0.00168 \cdot 0.00674)$ |
| 2.200 | 6.392 | 0.2086 | 0.6180 .569 | $97.71 \pm$ (1.45. 6.58) | $0.14405 \pm(0.00214,0.00971)$ |
| 2.300 | 6.043 | 0.1965 | 0.5780 .533 | $128.22 \pm$ ( 2.77. 9.29) | $0.19171 \pm(0.00415 .0 .01389)$ |
| 2.400 | 5.679 | 0.1858 | 0.5380 .496 | 157.58 $\pm$ ( 7.15. 13.63) | $0.23970 \pm(0.01085,0.02068)$ |
| 2. 500 | 5.298 | 0.1744 | 0.4970 .459 | $202.57 \pm$ (11.40. 21.27$)$ | $0.31212 \pm(0.01757,0.03277)$ |
| 2. 6 c C | 4.903 | 0.1625 | 0.4550 .420 | 288.77 $\pm(16.48,25.33)$ | $0.45214 \pm(0.02580,0.03967)$ |


[^0]:    ＊Work supported by the Energy Research and Development Administration． Present address：
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