4. Non-W/Z^0 Electron Sample

Electrons from W and Z^0 decay account for only a fraction of the high-P_T inclusive electrons observed in our detector. In this section we investigate the sources of high-P_T electrons from *QCD* processes that create electrons embedded in hadron jets. This discussion will be of particular use in Section 5, in which we discuss the backgrounds to the W candidates. As mentioned in Section 3, we anticipate that electrons in hadron jets fall into three categories: 1) electrons which come in e^+e^- pairs, either from photon conversions or Dalitz decays; 2) electrons from heavy quark decay; and 3) hadrons that fake electrons. Hereafter, electron pairs from photon conversions and from Dalitz decays will be referred to collectively as "conversions."

In this section we use the 17805 electrons in the non-W/Z^0 electron sample to estimate the fraction, f_{conv}, of electrons in hadron jets that originate from photon conversions. We also estimate the fraction, f_b, of non-W/Z^0 electrons from heavy quark decay, and the fraction, f_{fake}, of non-W/Z^0 electrons that are not electrons but clusters of hadrons. Finally, we estimate how many electrons in the inclusive electron sample (see Section 3.1) come from these three *QCD* processes.

4.1 Estimate of the Conversion Electron Fraction

Electrons from photon conversions are identified by searching for a second, oppositely-signed charged track near the electron track which extrapolates to a common tangent point. We flag as conversions the electrons which have a second track nearby in the CTC passing the following cuts: $|\delta(r\text{-}\phi)| < 0.2$ *cm*; $|\delta(\cot\theta)| < 0.06$. The first cut is on the separation in the r-ϕ view[19] between the two tracks at their tangent point. This variable is given a positive sign if the two circles of the tracks in the r-ϕ view do not overlap, and a negative sign otherwise. The second cut is on the difference in $\cot\theta$ between the two tracks.[19] Figure 4.1 shows these variables for track pair candidates in the non-W/Z^0 electron sample.

Some hadron tracks are falsely flagged as conversion partners by the $\delta(r\text{-}\phi)$ and $\delta(\cot\theta)$ cuts. In Figure 4.2 we show the pulse height left in the CES by the partner track to the electron track for those pairs in Figure 4.1 which pass the $\delta(\cot\theta)$ and $\delta(r\text{-}\phi)$ cuts. Also shown is the expected shape for electrons, which is derived from a pure sample of conversion pairs which was selected based on having a conversion radius consistent with the outer wall of the VTX, at $r \sim 27$ cm. We estimate that 89 ± 2 % of the track pairs selected with the $\delta(\cot\theta)$ and $\delta(r\text{-}\phi)$ cuts are truly conversion pairs. Correcting for the backgrounds and the conversion finding efficiency, we find that $f_{conv} = 41.5 \pm 2.2$ % is the fraction of the non-W/Z^0 electron sample that are conversion pairs or Dalitz decays. The conversion-finding efficiency has two-components: the efficiency to find the partner track, and the efficiency for the track pair, if found, to pass the $\delta(\cot\theta)$ and $\delta(r\text{-}\phi)$ cuts. Both of these efficiencies are estimated with a sample of conversions that occur at $R \sim 27$ cm from the beamline.[16]

4.2 Estimate of the *b* Electron Fraction

One signature characteristic of a b quark is its long lifetime. Using the impact parameter significance, D/σ, of electrons in the Silicon Vertex Detector (SVX), an estimate is made of the number of electrons in the non-W/Z^0 sample from b decay. The impact parameter significance distribution of all electrons in the non-W/Z^0 sample is fit to a sum of shapes from b's, conversions, and fake electrons. In this fit, the conversion fraction is set to $f_{conv} = 41.5\%$ from Section 4.1, so that the b and fake fractions are determined. The impact parameter shape for fake electrons is assumed to be the same as that of Z^0 electrons, since they are presumably from light quark jets and have zero lifetime. The impact parameter distribution for the conversions is derived from the conversion sample of Section 4.1, with the additional requirement that the partner track leave at least 2000 Counts / (GeV/c) in the CES (see Figure 4.2). The additional requirement on the pulseheight is used to obtain a more pure conversion sample.

In order to obtain the D/σ shape for b electrons, we exploit the fact that b's in $p\overline{p}$ collisions are produced in $b\overline{b}$ pairs, so that we select a data sample of semileptonically-decaying b ($\overline{b}$) quarks by tagging the $\overline{b}$ (b) jet in the event with a b-tagging algorithm.[25] Selecting b events using only the away jet to identify the b electron applies negligible bias to the signed impact parameter distribution for b electrons.

In the b-tagging algorithm, a probability is formed per jet that the jet comes from the primary vertex of the event. Jets with low probability are likely to come from heavy quarks. This probability utilizes the signed impact parameters of the tracks in the jet, and is the probability that the impact parameters of the tracks are consistent with zero within the SVX resolution. The probability distribution for all jets (besides the electron jet) in the non-W/Z^0 electron sample is shown in Figure 4.3. Heavy quark jets are identified as those jets with Jet Probability < 0.02. From the flat component under the probability peak in Figure 4.3 backgrounds in this sample from false tags of the away jet are expected to be $\sim$ 10 %. The b electron D/σ shape is estimated from these tagged events.

Figure 4.4 shows the D/σ distribution for the electrons in the non-W/Z^0 sample that go through the SVX. We fit the tails of the D/σ distribution to the sum of b, fake, and conversion shapes, with the conversion fraction fixed. We find:

$$\begin{aligned} f_{conv} &= 41.5 \pm 2.2\ \% \\ f_b &= 31.5 \pm 3.7\ \% \\ f_{fake} &= 27.0 \pm 4.4\ \% \end{aligned}$$

The dominant uncertainty on these fractions comes from the small statistics available to estimate the b electron shape.

4.3 Estimate of Fake Electron Fraction

This section provides a second, independent estimate of the fraction of the non-W/Z^0 electrons that are fake electrons. The fraction f_{fake} of Section 4.2 is the fraction of the electrons consistent with coming from the primary vertex, which we interpreted as misidentified hadrons from light quark jets. Hadrons may also be identfied using the Central Pre-Radiator, since in general they do not begin to shower in the solenoidal coil, while electrons do. Plotted in Figure 4.5 is the CPR charge for all electrons in the non-W/Z^0 sample. Also shown is the CPR shape for electrons (obtained from electrons in $Z^0 \to e^+e^-$ decay) and hadrons (obtained from jets in W/Z^0 + jet events). With the conversion electron fraction fixed (see Section 4.1) we fit the distribtution to the sum of the two shapes to find:

$$f_{conv} = 41.5 \pm 2.2 \ \%$$
$$f_b = 31.9 \pm 4.0 \ \%$$
$$f_{fake} = 26.6 \pm 4.1 \ \%$$

The agreement with Section 4.3 is good, since the two estimates are independent: in one method the zero lifetime of hadrons is used to differentiate them from heavy quark electrons, and in the other method the longitudinal shower development of electrons and hadrons is used.

4.4 Number of Inclusive Electrons from *QCD* Jets

The non-W/Z^0 electron sample is postulated to originate from *QCD* processes producing hadron jets. One can ask the simple question what fraction of events in the overall inclusive electron sample (see Section 3.1) come from such *QCD* processes? This question is not crucial to this analysis, but is interesting.

Noting that electrons with $Iso > 0.3$ are predominantly from *QCD* processes, we may use Figure 3.5(a) to estimate a 58% efficiency of the $\not{E}_T < 10$ *GeV* cut used to make the non-W/Z^0 sample for hadron jets. We then scale the 21637 hadron jet events of Section 3.4 up by this efficiency to obtain that approximately 37000 ± 4000, or (73 ± 7) %, of the 50861 inclusive electrons are from hadron jets. The number 21637, it was noted, has a ~ 1% background from W/Z^0 decay, but this can be neglected for our present purposes.

Figure 4.6 shows the E_T spectrum of electrons in the inclusive electron sample, along with the spectrum from the non-W/Z^0 electron sample (scaled up to 37000 events), and the Monte Carlo expectation for electrons from W/Z^0 decays (normalized using the number of W and Z^0 candidates). The events at the very highest E_T are mostly dijets, with one Z^0 event. The apparent excess of events above 80 *GeV* is due to the truncation of the sample used to obtain the hadron dijet spectrum: the very highest E_T dijets will have some $\not{E}_T$ due to mismeasurement, and the dijet shape comes from the $\not{E}_T < 10$ *GeV* sample. The conclusion from this study is that the inclusive electron data sample is adequately described by three sources: *QCD* hadron jets, W decays, and Z^0 decays.

5. *W* Candidate Sample

W candidates are selected with a signature of an isolated electron and $\not{E}_T$. This signature, however, can also be mimicked by other physics processes. The physics processes described in Section 4 can lead to backgrounds to the *W* signal if the hadron jet containing the electron fluctuates so that the electron is isolated in the calorimeters and if the other jet is mismeasured or falls into an uninstrumented region of the detector, creating $\not{E}_T$. Similarly, $Z^0 \to e^+e^-$ or $Z^0 \to \tau^+\tau^- \to e^{\pm}\nu\nu X$ decays can be misidentified as *W*'s if one electron is detected and the other lepton falls in an uninstrumented region or the neutrinos from τ decays are sufficiently energetic. This section discusses the backgrounds to the *W* signal from these processes.

5.1 *W* Candidate Selection

The *W* candidate selection is described in Section 3.3, but is briefly summarized here. To select *W*'s we (a) require a tight, isolated central electron in the event; (b) require $\not{E}_T > 20$ GeV; (c) reject events with second, isolated, electromagnetic clusters which forms a mass with the first electron in the 66 - 116 GeV/c^2 range. A total of 13796 events have $\not{E}_T > 20$ GeV and fail our Z^0 cuts. As shown in Figure 3.5, the missing transverse energy of the isolated electrons shows the characteristic peak, while the non-isolated electrons pile up at threshold. The problem now is to calculate the background under the peak in Figure 3.5(b) with missing $E_T > 20$ GeV.

5.2 Background from Hadron Jets

The background from hadron jets is estimated by extrapolating the Isolation variable for the electron from a region away from the *W* signal into the *W* signal region. We identify four regions within the plot of *Iso vs.* missing E_T in Figure 3.4:

1) Isolation < 0.1 and $\not{E}_T < 10$ GeV, at least one other jet
2) Isolation > 0.3 and $\not{E}_T < 10$ GeV, at least one other jet
3) Isolation > 0.3 and $\not{E}_T > 20$ GeV
4) Isolation < 0.1 and $\not{E}_T > 20$ GeV

(Region 4 is the W signal region). The requirement of one other jet in Regions 1) and 2) is that one jet besides the jet containing the electron exists in the event. We find the W background from the equation:

$$\frac{W \text{ Background}}{\#\text{ Events in Region 3}} = \frac{\#\text{ Events in Region 1}}{\#\text{ Events in Region 2}}$$

The motivation of the method is that electrons from hadron jets are generally produced embedded in a jet of other particles while electrons from W and Z^0 decay are isolated. The equation above amounts to using the electrons with $\not{E}_T < 10\ GeV$ in Figure 5.1(a) to determine the *Iso* shape of electrons in hadron jets and then normalizing to the $Iso > 0.3$ tail at $\not{E}_T > 20\ GeV$ (Figure 5.1(b)).

The requirement of at least one jet besides the electron jet in Regions 1) and 2) is intended to account for the fact that the Isolation of the electron on the one side of the *QCD* jet events is correlated with the magnitude of the jet E_T on the other side of the event, as is shown in Figure 5.2. In the case of the dijet events which fake a W, the mismeasured jet E_T must be large in order to create a large $\not{E}_T$. Because the actual value of the mismeasured jet's E_T is unknown, we average the the value of $r \equiv (Iso < 0.1)/(Iso > 0.3)$ from two different subsets of the QCD ($\not{E}_T < 10\ GeV$) sample which have different opposing jet E_T's:

Control Sample 1: Events with a Jet $> 10\ GeV$ and EM fraction < 0.8
Control Sample 2: Events with a Jet $> 20\ GeV$ and EM fraction < 0.8
(both have $\not{E}_T < 10\ GeV$)

Control Sample 2 is a subset of Control Sample 1. The control samples give $r = 1.5$ (Control Sample 1) and $r = 2.0$ (Control Sample 2). We average the results, obtaining $\langle r \rangle = 1.8 \pm 0.3$, to account for any systematic difference between the samples.

The hadron jet background is calculated as follows. There are 499 events in Region 3, so multiplying by $\langle r \rangle$ gives: W Background $= \langle r \rangle \cdot 499 = 898 \pm 155$ events. Given the 13796 W candidates, this is a 6.5% background contribution from electrons from hadron jets. Note in Figure 3.5 the $\not{E}_T$ shape of the events in Region 3. Most of the W background piles up at the threshold of our missing E_T cut.

5.3 Cross-Check of Hadron Jet Background

We check the method described in Section 5.2 by estimating the background from individual jet contributions separately - photon conversions, b decays, and fake electrons from hadron showers - and then adding them up to find the total jet background to the W's. This decomposition was applied to the non-W/Z^0 electron sample in Section 4. The non-W/Z^0 electron sample was selected from the total by requiring each event to have a jet with $E_T > 10$ GeV and $\not{E}_T < 10$ GeV. No isolation cut was applied to these data, because it would have greatly reduced the sample size, leaving too few events for further study. In order to compare the W's to the background, the Iso cut is removed from the W sample, which adds 1433 events to the 13796 events with $\not{E}_T > 20$ GeV and $Iso < 0.1$, resulting in 15229 events with $\not{E}_T > 20$ GeV alone. About 2/3 of these extra events are background, and 1/3 is signal: Table 8.1 gives the efficiency of the Iso cut of 97%, hence one expects that of the addition 1433 events added to the W sample, $0.03 \times 14000 = 420$ are really W's.

To estimate the conversion contamination of the $\not{E}_T > 20$ GeV region, we identify conversions by searching for the partner track to the electron using the $\delta(r\text{-}\phi)$ and $\delta(\cot\theta)$ cuts from Section 4.1. Using the efficiency and correcting for the overefficiency of the conversion-finding cuts, we estimate that there are 910 ± 90 events with $\not{E}_T > 20$ GeV that are conversion pairs. The $\not{E}_T$ of the flagged conversions is shown in Figure 5.3.

To estimate the contamination to the $\not{E}_T > 20$ GeV region from b electrons we employ the impact parameter method described in Section 4.2. In Figure 5.4(a) is plotted the signed impact parameter significance for the electrons with $\not{E}_T > 20$ GeV. In Figure 5.4(b), we show the $\not{E}_T$ distribution of the electrons with $|D/\sigma| > 2$. There is a bump at 40 GeV, which indicates that some W electrons have a large impact parameter significance, simply due to resolution effects. Using electrons from $Z^0 \rightarrow e^+e^-$ decays to estimate number of W's in the D/σ tails due to resolution effects, we superimpose the expected $\not{E}_T$ curve for W electrons. We find that 850 ± 360 events with $\not{E}_T > 20$ GeV are from heavy quarks.

To estimate the contamination to the $\not{E}_T > 20$ GeV region from misidentified hadrons, we use the charge deposited in the CPR, shown in Figure 5.5. Also shown is the expected shape for good electrons and for hadrons. We estimate that there are 580 ± 370 of the 15229 events with $\not{E}_T > 20\ GeV$ which are really hadron fakes.

Adding these numbers, there are 910 ± 90 conversions, 850 ± 360 b electrons, and 580 ± 370 hadron fakes for a grand total of 2340 ± 530 hadron jet background events obtained by application of the analyses described in Section 4 applied to the W sample itself. Within the quoted uncertainties, this number is consistent with the $Iso < 0.1$ number of 898 ± 155 background events quoted in Section 5.2, plus an extra 1433 - 420 ≈ 1000 events background from relaxing the Iso cut.

An independent method of estimating the total jet background in the $\not{E}_T > 20\ GeV$ sample with the Iso cut relaxed, that is to check that the extra 1000 added background events are reasonable, is to use the Iso *vs.* $\not{E}_T$ extrapolation technique of Section 5.2 again. First, we define $R \equiv$ (all Iso electrons)/($Iso > 0.3$) for hadron jet electrons in the $\not{E}_T < 10\ GeV$ sample. This ratio, averaging over the two Control Samples 1 and 2, is $\langle R \rangle = 4.2 \pm 0.7$. Multiplying this ratio by the number of events in Region 3 obtained in Section 5.2 gives 2100 ± 350 events. Within the uncertainties, this direct extrapolation result and the 2340 ± 530 events obtained by adding up the three components are consistent. This analysis supports the 898 ± 155 background number with $Iso < 0.1$, which will be subtracted from the W sample to calculate the W/Z^0 cross section ratio.

5.4 Background from $Z^0 \rightarrow e^+e^-$

5.4.1 $Z^0 \rightarrow e^+e^-$ Background Estimate

We use the ISAJET Monte Carlo program and a detailed detector simulation to determine the background to the W's from $Z^0 \rightarrow e^+e^-$ decays that mimic the W signature. We find that 18 ± 2 % of all $Z^0 \rightarrow e^+e^-$ decays where the first leg is reconstructed in the Central region will mimic W's. We normalize this rate to the observed number of Z^0 candidates, which avoids the systematic uncertainties of normalizing to the measured[26] cross section times branching ratio $\sigma \cdot B(p\overline{p} \rightarrow Z^0 \rightarrow e^+e^-)$ at $\sqrt{s} = 1800\ GeV$. The background to the W's from $Z^0 \rightarrow e^+e^-$ decays is 281 ± 32 events.

5.4.2 $Z^0 \rightarrow e^+e^-$ Background Cross-Check

The ISAJET Monte Carlo program is used to determine several of the W backgrounds, so its performance is checked using $Z^0 \rightarrow e^+e^-$ decays. We can recover some of the 18% of $Z^0 \rightarrow e^+e^-$ decays by looking for the charged track of the second electron in the Central Tracking Chamber. In the central region, the second electron is typically not observed in the calorimeter because it goes through a ϕ crack or the $\theta = 90°$ crack or the chimney module. Its charged track is nonetheless detected with 99.7% efficiency in the CTC if it passes through all 8 superlayers. ISAJET studies indicate that 81 ± 12 events of the 281 Z^0's that fake W's should be detectable as having a track with $P_T > 10$ GeV/c, even though the calorimeter cluster is not observed.

In our W sample, we search for second, isolated tracks in the CTC which come from the same primary vertex as the "W" electron" and which have $P_T > 10$ GeV/c. If the track extrapolates to a region in the calorimeter where energy is deposited, the electromagnetic fraction is required to be > 0.8. Approximately 3800 events in the W sample are observed to have a high-P_T track, and 904 of these come from the same primary vertex, are isolated, and point to possible electromagnetic energy. Figure 5.6 shows the electron + track invariant mass of the 3800 and 904 events. Also shown is the expected shape from ISAJET. In 213 events, there is $\not{E}_T > 20$ GeV, and in 83 of the 213 events no second electron cluster (as defined in Section 2.2) is observed. This compares well to the 81 ± 12 events predicted by ISAJET. Figure 5.7 shows that when $\not{E}_T > 20$ GeV, the second track tends to point to a calorimeter ϕ crack.

5.5 Background from $Z^0 \rightarrow \tau^+\tau^-$

The process $Z^0 \rightarrow \tau^+\tau^-$ can mimic the W signature if one τ decays to an electron. Using ISAJET and a detector simulation and normalizing to the observed $Z^0 \rightarrow e^+e^-$ yield, we find the background from this process to be 48 ± 7 events.

5.6 Background from $W \rightarrow \tau\nu$

The process of W bosons decaying to $\tau\nu$, where the τ then decays leptonically to an electron, can also produce a high P_T electron in the central region with large $\not{E}_T$.

We similarly use ISAJET to estimate the acceptance for this process but normalize instead to the ISAJET $W \to e\nu$ acceptance and the observed number of $W \to e\nu$ events. We find the background from $W \to \tau\nu$ to be 473 $\pm$ 29 events. This normalization avoids the uncertainties introduced by using the luminosity and the previously measured W cross section.[26]

5.7 Background from Heavy Top Quark

The background of real W's produced from a heavy top quark is considered. Direct searches[1] for the top quark have to date have given evidence for its existence, but we take this background to be 0, with an error given by the number of events expected for a 130 GeV/c^2 top, which is the 95% confidence level limit[1,2] on its mass. This prescription for the top quark background leads to the most conservative limit on new decay modes obtained with the W leptonic branching ratio extracted from the W/Z^0 cross section ratio. Using the ISAJET Monte Carlo, we find the expected background from a heavy top quark is $0 ^{+40}_{-0}$ events. While a 130 GeV/c^2 top would contribute 40 events background, a 150 GeV/c^2 top quark would lead to an expected background of 19 events and a 175 GeV/c^2 top quark[2] would lead to 9 events background.

5.8 Summary of W Signal, Backgrounds.

In Figures 5.8, 5.9, and 5.10 we plot the electron E_T, the $\not{E}_T$, and the transverse mass of the W candidates, along with the background estimates and the expectations of the Monte Carlo described in Section 7. The agreement of the shapes of all of these distributions gives further confidence in the background estimates presented here. The measured W P_T distribution which is input to the Monte Carlo is not sufficiently accurate to provide a precise Monte Carlo prediction for the electron E_T distribution, as reflected in Figure 5.8. The $\not{E}_T$ is in principle sensitive to the boson P_T as well, but the neutrino resolution is poor enough so that the shape mismatch is less noticeable. The transverse mass distribution is insensitive to the boson P_T.

6. Z^0 Candidate Sample

The signature used to select $Z^0 \rightarrow e^+e^-$ candidates is an isolated, tight central electron plus a second, loosely-selected electromagnetic cluster. Very few processes mimic the signature of two high-P_T electron clusters. Thus, while the $W \rightarrow e\nu$ candidate sample had backgrounds from other processes totaling approximately 12% of the observed candidates, the backgrounds to the Z^0 candidates are observed total less than 2%.

6.1 Z^0 Candidate Selection

Z^0 candidates are selected from the inclusive electron sample by requiring an isolated tight central electron and a second isolated electron which passes loose selection criteria. The cuts on the tight electron are summarized in Table 3.1 and for the second electron in Table 3.2. Figure 3.2 shows the invariant mass spectrum of electron pairs passing these cuts. We observe 1312 events which fall in the 66 - 116 GeV/c^2 mass range.

6.2 Background from Hadron Jets

Hadron jet events can fake the signature of a Z^0 decay into electrons if two of the jets fluctuate in such a way as to fake electrons. As with the hadron jet background to W's, we attempt to measure the hadron jet background to Z^0's from the data by extrapolating the Isolation distribution of the electrons. Figure 6.1 shows the electron-positron invariant mass *vs.* the Isolation of the second electron, where the isolation cut of Table 3.2 has been removed. While there is an unambiguous cluster at the Z^0 mass and low Isolation, some background events in the Z^0 mass window extend as far as $Iso = 1.4$.

We posit that all events with $Iso > 0.3$ on either leg are background from hadron jets. This assumption is equivalent to assuming that an Isolation cut of 0.3 is 100% efficient for electrons from Z^0's. This is quite reasonable, since in Figure 2.4(g) none of the 9000 W electrons have $Iso > 0.14$. We divide the electron pairs into four regions:

1) Events with $Iso_1 < 0.1$ and $Iso_2 < 0.1$
2) Events with $Iso_1 < 0.1$ and $Iso_2 > 0.3$
3) Events with $Iso_1 > 0.3$ and $Iso_2 < 0.1$
4) Events with $Iso_1 > 0.3$ and $Iso_2 > 0.3$

None of samples 2) - 4) have a Z^0 peak. The Z^0 background calculated from the equation:

$$\frac{Z^0 \text{ Background}}{\#\text{ Events in Region 2}} = \frac{\#\text{ Events in Region 3}}{\#\text{ Events in Region 4}}$$

We find that there are 20 ± 9 events background to the Z^0 candidates due to hadron jets. We find that 0^{+1}_{-0} of these come from the central-central Z^0's, whereas the plug region contributes 14 ± 14 events background and the forward region contributes 6 ± 3 events background.

In the central region, the same-sign electrons serve as a cross check of background estimated by the *Iso* extrapolation method. Background would likely have equal numbers of same- and opposite-sign events. This hypothesis is supported by the fact that most non-isolated same-sign pairs have $|\delta x| > 2$, indicating a poor match between the track and the EM shower, as characteristic of overlaps of π^+ and π^0 showers, and not b electron pairs (b electron pairs would have $|\delta x| < 2$, and would be mostly oppositely signed, with only ≈ 30% same-sign). There are 3 central-central same-sign $e^{\pm}e^{\pm}$ pairs in the mass window passing all our cuts, to be compared with the *Iso* estimate of 0^{+1}_{-0} central-central background events.

6.3 Background from $Z^0 \rightarrow \tau^+\tau^-$

The production of $Z^0 \rightarrow \tau^+\tau^-$ can fake $Z^0 \rightarrow e^+e^-$ decay if both taus decay via $\tau \rightarrow e\nu\nu$ and if the electrons form an invariant mass in the 66 - 116 GeV/c^2 invariant mass range. We use the ISAJET Monte Carlo program and a detector simulation to estimate that the background due to $Z^0 \rightarrow \tau^+\tau^-$ as 1 ± 1 event.

6.4 Background from the Drell-Yan Process

We apply a correction to the number of Z^0 candidates to account for the fact that some e^+e^- pairs in the 66 - 116 GeV/c^2 mass range come from continuum $p\overline{p} \rightarrow \gamma^* \rightarrow e^+e^-$, and not resonant Z^0 production. The correction is applied so our result is consistent with theoretical calculations, which typically use only the Z^0 amplitude, and not the γ^* term or the Z^0-γ^* interference term. We include in our Monte Carlo described in Section 7 both the Z^0 and γ^* amplitudes to determine the number of the events in our mass window from continuum Drell-Yan production. This correction also takes into account the effect of the mass window cut, since this is not accounted for in the Monte Carlo results of Section 7. We compute the integrals $I_1 \equiv \int_{66}^{116} |Z^0 + \gamma|^2 dM$ and $I_2 \equiv \int_0^{\infty} |Z^0|^2 dM$. The number of Z^0 candidates must be divided by the number I_1/I_2, which we find to be 1.005 ± 0.002.

6.5 Comparison of Z^0 Signal, Backgrounds:

Finally, in Figure 6.2 we show the invariant mass distribution for the e^+e^- candidates, along with the shape for the Z^0+γ^*, and the expected hadron jet background shape. The Z^0+γ^* signal shape is derived from the Monte Carlo described in Section 7). The background shape is derived from 'dielectrons' in Region 2 described in Section 6.2 above, and is normalized to have 20 events in the 66 - 116 GeV/c^2. The signal Monte Carlo is normalized to 1291 events in the 66 - 116 GeV/c^2 mass range.

7. Acceptances

We use a Monte Carlo program to determine the ratio, A_W/A_Z, of the kinematic and geometric acceptances A_W and A_Z. The kinematic portion of the acceptance is the efficiency of W and Z^0 events to pass our P_T cuts on the leptons, and the geometric portion of the acceptances is the efficiency for the leptons to fall into the parts of the detector accepted as part of our fiducial volume. Note that, because of the requirement of at least one electron in the Central region common to both W and Z^0 decays, the problem of determining A_W/A_Z reduces to modeling the difference in the acceptance of the second lepton only, *viz.*, the electron or neutrino.

The Monte Carlo is also used to determine the relative acceptances of the central, plug, and forward detector regions for electrons from $Z^0 \to e^+e^-$ decays. For those Z^0's with at least one electron that falls in the central detector region, we calculate the fractions F_{cc}, F_{cp}, and F_{cf} of Z^0's where the second electron falls in the central, plug, and forward regions. These fractions will be used in Section 8.

7.1 Description of the Monte Carlo

The Monte Carlo program generates W's and Z^0's using the lowest order diagram, $q\overline{q} \to W(Z^0)$. No quark-gluon diagrams or initial-state radiation are considered. The bosons masses are generated according to a relativistic Breit-Wigner distribution. In order to mimic the effects of higher-order diagrams, the bosons are given a P_T according to the measured[27] W P_T distribution in $p\overline{p}$ collisions at $\sqrt{s} = 1.8$ TeV. The leptons are propagated to the calorimeter and their momenta are smeared according the nominal detector resolutions. The electrons in our Monte Carlo are required to propagate to a fiducial region of the detector.

The electron resolution in the simulation is $\left(\sigma/E\right)^2 = \frac{(13.5\%)^2}{E\ (GeV)} + \left(2\pm1\%\right)^2$, where the energy-independent term of $\left(2\pm1\right)\%$ represents tower-to-tower variations in the energy scale calibrations and is measured using the observed width of the $Z^0 \to e^+e^-$ resonance. A model is also made for the $\not{E}_T$ resolution. Since the neutrino transverse momentum is inferred from momentum conservation, the $\not{E}_T$

measurement is dominated by the electron, but is also sensitive to the calorimeter response to the hadrons which recoil against the W. In this model, we use a parameterization of the smearing on the component of the $\not{E}_T$ parallel and perpendicular to the P_T of the boson as a function of the boson P_T which is obtained from a detailed simulation of the detector. Using the parameters M_W= 80.21 GeV/c^2, M_Z = 91.18 GeV/c^2, and the MRS D-' parton distribution functions,[28] we find A_W = 0.3416 ± 0.0008 and A_Z = 0.4120 ± 0.0008, where the errors are statistical only. Note that, because central-central Z^0's have two chances of having one electron in the central detector region, the Z^0 acceptance is higher. The fractions F_{cc}, F_{cp}, and F_{cf} are found to be 0.372, 0.509, and 0.120, respectively.

7.2 Systematic Uncertainties in A_W/A_Z

In this section, we investigate the systematic uncertainties due the choice of parton distribution functions (PDF's), the underlying event model, the boson masses, the calorimeter energy scales, the P_T distribution input to the Monte Carlo, and higher order diagrams. For each possible source of systematic uncertainty, we repeat the Monte Carlo calculation with different values for these parameters and take the error to be one half of the spread in the results. As is discussed below, while the individual acceptances are sensitive to variations in these parameters, the ratio is more stable. In the tables which follow, all of the values for W and Z^0 acceptances have a statistical error of ± 0.0008.

In order to estimate the systematic uncertainty due to the parton distribution functions, we employ different sets of PDF's not excluded by current experimental data. We find a 0.9% uncertainty in A_W/A_Z due to PDF's, as shown in Table 7.1.

Table 7.1: Acceptances Calculated With Different Parton Distribution Functions

PDF	A_W	A_Z	A_W/A_Z
MRS D-'	0.3416	0.4102	0.833
MRS D0'	0.3458	0.4133	0.837
MRS S0'	0.3486	0.4118	0.847
CTEQ 1M	0.3522	0.4137	0.851
CTEQ 1MS	0.3517	0.4152	0.847
CTEQ 1L	0.3422	0.4096	0.835
CTEQ 1ML	0.3533	0.4159	0.849
Uncertainty:	0.0059	0.0029	0.009

The acceptances depend upon the W mass through the lepton P_T's. Using M_Z = 91.18 GeV/c^2, and MRS D-' PDF's we find a 0.1% uncertainty in A_W/A_Z when M_W = 80.2 ±0.2 GeV/c^2 is varied wihin its uncertainty, as shown in Table 7.2.

The measurement of the W boson P_T spectrum[27] has sufficiently large uncertainties that the variations in its shape allowed by the measurement lead to variations in the boson acceptances. To estimate the systematic uncertainty due to the input boson P_T distribution, we take the 'nominal' P_T distribution to be the measured spectrum, the 'soft' P_T distribution to be the distribution one gets when varying the nominal by one sigma in each bin so as to give a more steeply falling spectrum (deforming about the point P_T = 16 GeV/c), and the 'hard' distribution to be the shape that one gets by varying by one sigma so as to get a more slowly falling spectrum. Trying these three shapes for the P_T choice, we find a 0.2% variation in A_W/A_Z,, as shown in Table 7.2.

It has been assumed that the W and Z^0 have the same P_T spectra. Experimental measurements of these spectra are consistent with this assumption.[29] Theoretical calculations[30] indicate that the differences are expected to be less than 2%. If we assume that the spectra are different, and use calculations[31] of their individual P_T spectra, we introduce an extra uncertainty from this effect of ±0.0005, which is negligible compared to the ±0.0020 uncertainty from our knowledge of the W P_T spectrum.

The electron energy scale in the data is set for this analysis using $Z^0 \rightarrow e^+e^-$ decays to an accuracy of approximately 0.2%. We vary the energy scale of the central calorimeters in the simulation by 0.2% and summarize the variations in A_W/A_Z in Table 7.2. Variations in the plug detector energy scale cause similar variations in A_W/A_Z, while variations in the forward detector energy scale result in 0.2 times this variation in A_W/A_Z because the forward detector has 0.2 times the acceptance of the central and plug. The uncertainty in A_W/A_Z due to the energy scale is estimated to be 0.3%.

We also estimate the systematic uncertainty on A_W due to the model of the $\not{E}_T$ resolution. We have, in addition to the simulation-based model, estimated the acceptances with two other models of the resolution. One model[32] utilizes parameterizations of the calorimeter response to hadrons obtained from a sample of minimum bias triggers, where $\not{E}_T$ is dominated by calorimeter response, not neutrinos. The other model[33] uses $Z^0 \rightarrow e^+e^-$ data to measure the calorimeter response as a function of boson P_T. Again, in Z^0 events, observed $\not{E}_T$ is dominated by the response to hadrons which recoil against the Z^0. This new method would in principle be the best model to use, but we lack adequate statistics in the Z^0's at high P_T , where the $\not{E}_T$ smearing is the largest. We find a 0.5% uncertainty in A_W/A_Z due to the choice of the $\not{E}_T$ resolution model, as shown in Table 7.2.

Finally, we investigate the assumption that A_W/A_Z is insensitive to higher-order diagrams. It is likely that the ratio of acceptances is insensitive to QCD corrections, since one chooses a common leg in the central region and then the only thing that can change the ratio is a difference in the η distribution of the second lepton for W's and Z^0's. With the LO Monte Carlo the η distribution of leptons seems well-modeled (see Figures 3.3 and 3.6). We have employed a Monte Carlo program which incorporates a next-to-leading order (NLO) calculation by Giele *et al.*[34]. The events from this generator are fed through the same detector simulation as with the LO Monte Carlo so as to minimize differences in the comparison. The results are shown in Table 7.2. The difference in results is taken as the systematic uncertainty.

Table 7.2: Systematic Uncertainties in the Boson Acceptances

Effect	δA_W	δA_Z	$\delta(A_W/A_Z)$
PDF's	0.0059	0.0029	0.009
M_W	0.0004	-	0.001
Boson P_T	0.0019	0.0013	0.002
Energy Scale	0.0004	0.0030	0.003
Neutrino Model	0.0020	-	0.005
NLO Diagrams	0.0010	0.0030	0.006
Total Uncertainty:	0.008	0.005	0.013

7.3 Effects of Radiative Corrections

The effects of radiative decay, $Z^0 \rightarrow e^+e^-\gamma$ or $W \rightarrow e\nu\gamma$, are largely accounted for in our calculations of the *E/p* and *Iso* efficiencies for electrons (See Section 8), since most radiated photons tend to be collinear with one of the electrons in W or Z^0 decay. In addition, the radiated photons tend to shift the lepton P_T's downward, but this shift is largely common to both W's and Z^0's, and hence cancel in the ratio of cross sections. A residual effect to the cross section ratio due to photons radiated at wide angles to the electrons is that the observed e^+e^- pair mass from Z^0 decays is shifted downward. We use a Monte Carlo program[35] with the full matrix elements for radiative decay, to find that 0.3 ± 0.2 % of Z^0's fall outside of the 66-116 GeV/c^2 mass window after the kinematic cuts are applied. Correcting for this loss of acceptance shifts the result for A_Z from 0.4102 to 0.4090 and A_W/A_Z from 0.833 to 0.835.

7.4 Summary of Acceptance Results

Incorporating all the systematic shifts and uncertainties quoted above, we find for the acceptances:

$$A_W = 0.342 \pm 0.001 \text{ (stat.)} \pm 0.008 \text{ (sys.)}$$
$$A_Z = 0.409 \pm 0.001 \text{ (stat.)} \pm 0.005 \text{ (sys.)}$$
$$A_W/A_Z = 0.835 \pm 0.001 \text{ (stat.)} \pm 0.013 \text{ (sys.)}$$

Using the Monte Carlo to calculate the fractions F_{cc}, F_{cp}, and F_{cf} of Z^0's with one leg in the central that have the second leg in the central, plug, or forward, respectively, we find:

$$F_{cc} = 0.372 \pm 0.001 \text{ (stat.)} \pm 0.007 \text{ (sys.)}$$
$$F_{cp} = 0.509 \pm 0.001 \text{ (stat.)} \pm 0.007 \text{ (sys.)}$$
$$F_{cf} = 0.120 \pm 0.001 \text{ (stat.)} \pm 0.004 \text{ (sys.)}$$

It is important to note that the uncertainty in the ratio of acceptances is smaller than the sum in quadrature of the uncertainties in the individual W and Z^0 acceptances. This smaller uncertainty is partially the result of the method of requiring a common central electron for W and Z^0 decays which decreases our sensitivity to many of the systematic effects discussed in this section.

8. Efficiencies

This section concerns the efficiencies of the leptons from W and Z^0 decays to pass the electron selection criteria described in Section 3 and to pass the electron trigger. To estimate these efficiencies, we select a sample of high P_T electrons unbiased by the cuts whose efficiencies we wish to estimate. The high P_T electrons we use come from W and Z^0 decay, but are selected with criteria different from those used in Section 3.

We identify 5 efficiencies which must be measured: (1) the efficiency, which we call "c_1," for a central electron in the fiducial region from W or Z^0 decay to pass the tight cuts; (2) the efficiency, "c_2," for the second leg of a Z^0 in the fiducial central region to pass the loose central cuts; (3) the efficiency, "p," for the second leg of a Z^0 in the plug region to pass the loose plug cuts; (4) the efficiency, "f," for the second leg of a Z^0 in the forward region to pass the loose forward cuts; and finally (5) the efficiency, "ε_T" of a central electron from W or Z^0 decay which passes the tight c_1 cuts to pass the electron trigger.

The electron identification efficiencies are measured using the second leg of Z^0 events. The Z^0 events are selected with tight cuts on the first central leg and then requiring for a second electromagnetic cluster that has an invariant mass with the first in a tight window around the Z^0 mass. No further identification cuts are used on the second leg. Efficiencies are then measured by observing what fraction of the Z^0 second electrons pass the identification cuts.

8.1 Tight Central Identification Efficiency, c_1

We select a sample of central-central Z^0's which satisfy the following requirements on the event:

One leg passes tight cuts
Second electromagnetic cluster in central with $E_T > 20\ GeV$
CTC (opposite sign) track pointing at 2nd cluster, $P_T > 5\ GeV$
$Iso < 0.05$ on first electron

Had/EM $<$ 0.05 on first electron
$81 < M_{e+e-} < 101\ GeV/c^2$

There are 514 central-central Z^0's satisfying these cuts. The efficiency of each of the tight central cuts c_1 obtained from this sample is summarized in Table 8.1. The net c_1 efficiency, which, because of correlations between the cuts is not simply the product of the cut efficiencies, is 85.1 ± 1.1 %.

Table 8.1: Efficiency of the Tight Central Cuts

Cut	Efficiency (%)
Had/EM	$100.0\ ^{+0.0}_{-0.5}$
Iso	97.3 ± 0.5
Lshr	98.0 ± 0.4
E/p	95.0 ± 0.7
δx	94.1 ± 0.8
δz	98.2 ± 0.4
χ^2_{strip}	95.0 ± 0.7
All Cuts	85.1 ± 1.1
Tracking, *E/p* Corrections	99.2 ± 0.4
c_1 Efficiency	84.5 ± 1.2

There are two corrections to apply to the result for c_1. There is first an efficiency for the offline track reconstruction algorithm to reconstruct a track. This efficiency has been estimated by examining *W*'s which pass $\not{E}_T$ triggers in Level 2 and Level 3. *W* candidates were selected by requiring $E_T > 25\ GeV$, $\not{E}_T > 25\ GeV$, $Lshr < 0.2$, $Iso < 0.1$, $\sqrt{(\chi^2_{strip})^2+(\chi^2_{wire})^2} < 20$. Events with no 3-dimensional track pointing at the cluster were counted as tracking failures. The tracking efficiency was found to be 99.7 ± 0.2 %

We also correct for a small *E/p* bias in our Z^0 efficiency sample. In our Z^0 efficiency sample, we require a track with $P_T > 5\ GeV$ to point at the second cluster. This cut throws away real Z^0's with $E/p > 4$ from our efficiency sample. To estimate the magnitude of this effect, we scanned the Z^0 events which failed the $P_T > 5\ GeV$ cut on the second electron. We factor in an additional efficiency of 99.5 ± 0.3 % as an estimate of this bias.

8.2 Loose Central Identification Efficiency, c_2

Using the same sample of Section 8.1, we find $c_2 = 91.7 \pm 0.8$ %, as summarized in Table 8.2.

Table 8.2: Efficiency of the Loose Central Cuts

Cut	Efficiency (%)
Had/EM	$100.0\ ^{+0.0}_{-0.5}$
Iso	97.3 ± 0.5
E/p	95.0 ± 0.7
All Cuts	92.4 ± 0.7
Tracking, *E/p* Corrections	99.2 ± 0.4
c_2 Efficiency	91.7 ± 0.8

8.3 Loose Plug Identification Efficiency, p

To measure the efficiency of the plug electron identification efficiencies, we select central-plug Z^0 events which pass the following cuts:

One central leg that passes tight cuts
Second electromagnetic cluster in plug with $E_T > 15\ GeV$
No other jets with $E_T > 10\ GeV$ in the event
$81 < M_{e+e-} < 101\ GeV/c^2$
Had/EM < 0.05, *Iso* < 0.05 on central electron
VTX Occupancy > 0.5 in octant pointing to plug cluster

There are 418 events passing these cuts. We find a $90.9 \pm 1.4\%$ efficiency (see Table 8.3).

Table 8.3: Efficiency of the Loose Plug Cuts

Cut	Efficiency (%)
Had/EM	$100.0\ ^{+0.0}_{-0.3}$
Iso	96.4 ± 0.9
$\chi^2_{3\times3}$	95.2 ± 1.1
p Efficiency	90.9 ± 1.4

8.4 Loose Forward Identification Efficiency, f

To measure the efficiency of the forward electron identification, we select a sample of central-forward Z^0 events identical to the plug sample above, but this time with a forward electron with $E_T > 10$ GeV and VTX Occupancy > 0.25. There are 64 events passing these cuts. We find an efficiency of 85.9 ± 4.4%.

Table 8.4: Efficiency of the Loose Forward Cuts

Cut	Efficiency (%)
Had/EM	$100.0\ ^{+0.0}_{-1.8}$
Iso	85.9 ± 4.4
f Efficiency	85.9 ± 4.4

8.5 Central Electron Trigger Efficiency, ε_T

The efficiency of the inclusive electron trigger in Level 2 and Level 3 is measured with W's that pass the independent backup trigger that selects events based on $\not{E}_T$ (see Section 2.7). A total of 10813 of our W candidates come in on the $\not{E}_T$ triggers. Table 8.5 shows the efficiency results for Level 2 and Level 3.

The Level 1 calorimeter trigger efficiency is estimated using a sample of muon + jet events that trigger the Level 1 and Level 2 muon triggers. The Level 1 calorimeter trigger efficiency is determined from the fraction of jet(s) in these events that satisfy the calorimeter trigger. The Level 1 Calorimeter Trigger is 99.18 ± 0.08% efficient for $E_T > 12$ GeV (see Figure 2.12).

Table 8.5: Efficiency of the Central Electron Trigger

Trigger	Efficiency (%)
Level 1 Trigger	99.2 ± 0.1
Level 2 Trigger	91.5 ± 0.3
Level 3 Trigger	98.2 ± 0.1
Total Trigger Eff., ε_T	89.2 ± 0.3

8.6 Combined Efficiencies ε_W and ε_Z:

Combining the results above, we compute the efficiencies ε_W and ε_Z for W and Z^0 events to pass our electron selection. The W selection efficiency for electrons in the fiducial region is

$$\varepsilon_W = \varepsilon_T \cdot c_1$$

The Z^0 efficiency is more complicated because the central-central Z^0's have two chances for passing the inclusive electron trigger and because the selection criteria have slightly different efficiencies in the three detector regions. Considering only the central region, each leg has three possible outcomes: (a) it can pass tight cuts (see Table 3.1) with probability $\varepsilon_1 = \varepsilon_T c_1$, (b) it can pass loose cuts (see Table 3.2) but not the tight cuts, with probability $\varepsilon_2 = c_2 - \varepsilon_1$, or (c) it can fail the loose cuts as well, with probability $1 - c_2$. Given that 'tight'-'tight' and 'tight'-'loose' combinations are accepted as candidates, the efficiency for central central Z^0's is $(\varepsilon_1)^2 + 2(\varepsilon_1\varepsilon_2)$, or $\varepsilon_T c_1(2c_2 - \varepsilon_T c_1)$. Thus, the Z^0 efficiency is:

$$\varepsilon_Z = \varepsilon_T \cdot c_1 \; [\; F_{cc}(2c_2 - \varepsilon_T \cdot c_1) + F_{cp}p + F_{cf}f]$$

where the fractions F_{cc}, F_{cp}, and F_{cf} are the fractions of the Z^0's in our acceptance which have one leg in the central region and the second in the central, plug, and forward, respectively. These fractions are determined with the Monte Carlo described in Section 7. We find for the W and Z^0 efficiencies:

$$\varepsilon_W = 75.4 \pm 1.0 \ \%$$
$$\varepsilon_Z = 72.9 \pm 1.6 \ \%$$
$$\varepsilon_W / \varepsilon_Z = 1.035 \pm 0.016$$

It is important to note that the factor $\varepsilon_T \cdot c_1$ nearly cancels in the ratio $\varepsilon_W / \varepsilon_Z$, and thus the systematic error in $\varepsilon_W / \varepsilon_Z$ is smaller than one gets adding the errors of ε_W and ε_Z in quadrature. This lower systematic uncertainty is one of the motivations for selecting a common tight central electron in measuring the ratio of the two cross sections.

9. Check of the Results

The analysis for R, the W/Z^0 cross section ratio, have been presented in Sections 2-8, and the results are presented in Section 10. In this analysis, it has been stressed that many systematic effects tend to cancel in the ratio. These effects include the requirement of a common Central electron, the kinematic criteria, and the lepton identification selection. It has also been stressed that the W's require a larger background subtraction than do the Z^0's. An important check of all these aspects of the result is provided by performing the entire analysis using an E_T cut on the first leg of $E_T > 25$ GeV (for both W's and Z^0's), and a cut of $\not{E}_T > 25$ GeV (for W's). With these cuts, the number of background events to the W's decreases, but Monte Carlo correction for the detector acceptances for W's and Z^0's increases. The comparison is shown below:

$$\frac{\sigma B(W \rightarrow e\nu)\ (20\ GeV\ \text{cuts})}{\sigma B(W \rightarrow e\nu)\ (25\ GeV\ \text{cuts})} = 0.992\ \pm 0.003\ (stat.)\ \pm\ 0.008\ (sys.)$$

$$\frac{\sigma B(Z^0 \rightarrow e^+e^-)\ (20\ GeV\ \text{cuts})}{\sigma B(Z^0 \rightarrow e^+e^-)\ (25\ GeV\ \text{cuts})} = 0.995\ \pm 0.007\ (stat.)\ \pm\ 0.008\ (sys.)$$

$$\frac{R\ (20\ GeV\ \text{cuts})}{R\ (25\ GeV\ \text{cuts})} = 0.995\ \pm 0.008\ (stat.)\ \pm\ 0.011\ (sys.)$$

where the statistical uncertainty in the ratios reflects only the statistically independent part of the two samples and the systematic uncertainty is only the additional uncertainty in the Monte Carlo that results from making higher kinematic cuts. The two measurements are complementary, since both the background and acceptance calculations are thus checked. The analysis with the 20 GeV cuts, however, has a smaller statistical uncertainty and an overall smaller systematic uncertainty, since the systematic uncertainty of determining the efficiency for the higher $\not{E}_T$ cut offsets the smaller background uncertainties.

10. Conclusions

Recall that the ratio of W and Z^0 cross sections is given by the formula

$$R \equiv \frac{\sigma \cdot B(p\overline{p} \to W \to e\nu)}{\sigma \cdot B(p\overline{p} \to Z^0 \to ee)} = \frac{\sigma(p\overline{p} \to W)}{\sigma(p\overline{p} \to Z^0)} \frac{\Gamma(W \to e\nu)}{\Gamma(Z^0 \to ee)} \frac{\Gamma(Z^0)}{\Gamma(W)}$$

The background, efficiency, and acceptance results from the previous sections are summarized in Table 10.1. We find for the ratio, R:

$$R = 10.90 \pm 0.32\,(stat.) \pm 0.29\,(sys.).$$

In order to extract a value for the leptonic branching ratio of the W from the measurement of R, we use a theoretical calculation[36] of the ratio of production cross sections $\sigma(p\overline{p} \to W)/\sigma(p\overline{p} \to Z^0) = 3.35 \pm 0.03$, together with the LEP[8] measurements of $\Gamma(Z^0) = 2.4969 \pm 0.0038$ GeV and $\Gamma(Z^0 \to e^+e^-) = 83.98 \pm 0.18$ MeV. We find for the branching ratio:

$$\Gamma(W \to e\nu)/\Gamma(W) = 0.1094 \pm 0.0033(stat.) \pm 0.0031(sys.).$$

The Standard Model Prediction,[5] assuming $m_{top} > M_W - m_b$, is 0.1084 ± 0.0002.

In order to set a model-independent limit on the top mass, we use the 'inverse' branching ratio since its uncertainty is more nearly gaussian: $\Gamma(W)/\Gamma(W \to e\nu) = 9.14 \pm 0.28(stat.) \pm 0.26(sys.)$. As the mass of the top quark increases toward the W mass, the partial width $\Gamma(W \to tb)$ goes to zero, and the ratio $\Gamma(W)/\Gamma(W \to e\nu)$ approaches the Standard Model value of 9.225. In Figure 9.1 we plot our value for $\Gamma(W)/\Gamma(W \to e\nu)$ along with the expected curve as a function of top mass. We establish the limit[37]

$$m_{top} > 62\ GeV/c^2 \text{ (95\% confidence level)}$$

We emphasize again that this limit is independent of models of the top quark's allowed decay modes, providing the W can decay with normal coupling to $t\overline{b}$. Previous direct searches for the top have either assumed that the top must decay only via Wb,[1,2] or assumed particular Higgs decay modes, which can depend upon the parameter $\tan\beta$.[3]

With the present measurement of the W leptonic branching ratio and the previous direct measurement[15] by CDF of the total width, $\Gamma(W) = 2.11 \pm 0.32$ GeV, we may extract a measurement of the W-fermion coupling, g, at $Q^2 = M_W^2$ (see Section 1). We combine the two to obtain $\Gamma(W \to e\nu) = 231 \pm 36$ MeV, and assuming $\Gamma(W \to \ell\nu) = \frac{g^2 M_W}{48\pi}$ and using the world average[38] for the W mass, $M_W = 80.23 \pm 0.18$ GeV^2, we find:

$$g = 0.659 \pm 0.052.$$

Note that the Standard Model expectation is $g^2 = \frac{8}{\sqrt{2}} G_F M_W^2 = 0.425 \pm 0.002$, or $g = 0.652 \pm 0.001$. The leptonic partial width $\Gamma(W \to e\nu)$ is preferable to quark widths for extracting a value of g, since it does not receive any QCD corrections and it is not sensitive to uncertainties in Cabbibo-Kobayashi-Miskawa matrix elements.

If we assume the Standard Model value of g, we can calculate the W leptonic partial width $\Gamma(W \to e\nu) = 225.9 \pm 0.9$ MeV and obtain a value for $\Gamma(W)$ from the branching ratio measurement:

$$\Gamma(W) = 2.064 \pm 0.060\ (stat.) \pm 0.059 (sys.)\ GeV.$$

It must be emphasized, however, that this value for $\Gamma(W)$ is not sensitive to g. The Standard Model prediction,[5] assuming $m_{top} > M_W - m_b$, is $\Gamma(W) = 2.067 \pm 0.021$ GeV. Figure 9.2 shows this measurement of $\Gamma(W)$ in comparison to previous measurements.

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Table 10.1: Summary of Results for R

	W's	Z^0's
Candidates:	13796	1312
Background:		
hadron jets	898 ± 155	20 ± 9
$W^{\pm} \rightarrow \tau^{\pm} \nu$	473 ± 29	-
$Z^0 \rightarrow \tau^+ \tau^-$	48 ± 7	1 ± 1
$Z^0 \rightarrow e^+ e^-$	281 ± 32	-
heavy top	0^{+40}_{-0}	-
Total Background:	1700^{+167}_{-163}	21 ± 9
Signal:	$12096 \pm 117 ^{+163}_{-167}$	1291 ± 36 ± 9
Acceptance:		
$A_{W,Z}$	0.342 ± 0.008	0.409 ± 0.005
A_W / A_Z	0.835 ± 0.013	
F_{cc}	-	0.372 ± 0.007
F_{cp}	-	0.509 ± 0.007
F_{cf}	-	0.120 ± 0.004
Efficiencies:		
$\varepsilon_T \cdot c_1$	0.754 ± 0.011	0.754 ± 0.011
c_2	-	0.917 ± 0.008
p	-	0.909 ± 0.014
f	-	0.859 ± 0.044
$\varepsilon_{W,Z}$	0.754 ± 0.011	0.729 ± 0.016
$\varepsilon_W / \varepsilon_Z$	1.035 ± 0.016	
Drell-Yan Correction	-	1.005 ± 0.002
$\sigma(W \rightarrow e\nu) / \sigma(Z \rightarrow ee)$	10.90 ± 0.32 (*stat.*) ± 0.29 (*sys.*)	