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SEARCH FOR DECAYS OF THE $W^\pm$ AND Z

BOSONS INTO QUARK-ANTIQUARK PAIRS

The UA2 Collaboration

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ABSTRACT

The invariant mass distribution of jet-pairs observed in the UA2 central calorimeter is examined in the search for an excess of events in the region of the $W^\pm$ and Z bosons, which would reveal their decays into quark-antiquark pairs. We give a detailed account of the methods of analysis used to optimize the mass resolution achieving $\approx \pm 10\%$. A structure is observed at the level of ≈ 3 standard deviations in the mass region of $W^\pm$ and Z with shape and position consistent with expectation from their $q\bar{q}$ decays. It contains 632 ± 190 events, 1.4 standard deviations above the standard model prediction of 340 ± 80 events.

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1. INTRODUCTION

In previous publications [1-4] we reported experimental results on the processes

$$\begin{aligned} p + \bar{p} &\rightarrow W^\pm + \text{anything} \\ &\rightarrow e^\pm + \nu(\bar{\nu}) + \text{anything} \\ p + \bar{p} &\rightarrow Z + \text{anything} \\ &\rightarrow e^+ + e^- + \text{anything} \end{aligned}$$

where $W^\pm$ and Z are the intermediate vector bosons (IVB) of the unified electroweak theory [5]. We observed, together with the UA1 Collaboration [6], that IVB's are produced at SPS Collider energies with a cross-section in agreement with the predictions of the Standard Model of the unified electroweak theory. This provides some evidence for the validity of the Standard Model expressions of the couplings between quarks and IVB's. As a direct consequence we expect the IVB's to decay into quark-antiquark pairs with well defined branching fractions. Namely, excluding decay modes with a top quark in the final state (if at all present they would have a very different configuration as a result of the large top mass), we expect [7] :

$$\Gamma(W \rightarrow q\bar{q}) / \Gamma(W \rightarrow e\nu) \simeq 6, \text{ and}$$

$$\Gamma(Z \rightarrow q\bar{q}) / \Gamma(Z \rightarrow ee) \simeq (15-28s^2 + 88s^4/3)/(1-4s^2 + 8s^4) \simeq 20,$$

where $s = \sin \theta_w$ is the sine of the mixing angle of the electroweak theory [5].

The observation of such decays is an important qualitative check of the Standard Model predictions. The experimental difficulties arise from the need to detect a signal which appears as an excess of only a few percent over the copious background of two-jet events produced by the strong interaction between colliding partons [8,9]. This requires both a very good two-jet mass resolution and a large integrated luminosity. An additional motivation for such a search is to provide one of the first test-cases of the ability of future Collider experiments [10] to analyse multiparticle final states in terms of hadron jets identified with their parent partons (a subject commonly referred to as "jet spectroscopy").

We report here the results of a search for a signal from IVB decays into quark-antiquark pairs in the mass distribution of jet-pairs observed in the UA2 detector. The data were collected in Autumn 1984 and Autumn 1985 at a total centre-of-mass energy $\sqrt{s} = 630$ GeV. The total integrated luminosity associated with these measurements is $\mathcal{L} = 0.73 \text{ pb}^{-1}$.

2. APPARATUS AND DATA TAKING

The UA2 detector has been described in detail elsewhere [11,12]. It consists of a vertex detector surrounded in the central region by a segmented hadron calorimeter covering polar angles $40^\circ < \theta < 140^\circ$. The forward regions ($20^\circ < \theta < 37.5^\circ$ and $142.5^\circ < \theta < 160^\circ$) are each instrumented with spectrometers and electromagnetic calorimeters.

The present results are based on jet identification and energy measurement in the high granularity central calorimeter [12] which detects electromagnetic and hadronic showers over the full azimuth (ϕ) range and in the pseudo-rapidity region $|\eta| \leq 1$. Because the angular distribution of jets coming from IVB decays is more central than that of jets coming from strong parton interactions, this rapidity interval provides an almost optimal signal-to-background ratio. The calorimeter is segmented into 240 cells, each covering 15° in ϕ and 10° in θ , and built in a tower structure pointing to the centre of

the interaction region. Each cell is segmented longitudinally into a 17 radiation lengths thick electromagnetic compartment (lead-scintillator) followed by two hadronic compartments (iron-scintillator) of two absorption lengths each.

The response of the calorimeter to electromagnetic and hadronic showers has been studied at the CERN PS and SPS machines using electron, muon and hadron beams from 1 to 70 GeV. Electromagnetic showers are measured with an energy resolution of $\sigma_E/E = 0.14/\sqrt{E}$ (E in GeV), whereas the energy resolution for single pions varies from 32% at 1 GeV to 11% at 70 GeV, approximately proportional to $E^{-1/4}$. An estimate of the energy resolution attainable for hadron jets was obtained from multihadron test-beam data [12] and found to be $\approx 12\%$ at 40 GeV. Two independent evaluations of this quantity are presented in the next section, in agreement with this estimate. The systematic uncertainty on the energy calibration for the data discussed here is estimated to be less than $\pm 1.5\%$ for the electromagnetic calorimeter and less than $\pm 6\%$ for the hadronic one. They combine in a global systematic error of less than $\pm 4\%$ on the jet energy scale. Details of the construction, calibration and performance of the calorimeter are reported in Ref. 12.

The data presented in this letter were recorded using a trigger selecting events with large transverse energies, E_T^1 and E_T^2 , deposited in any two opposite azimuthal calorimeter wedges (ϕ_1 and $\phi_2 = \phi_1 + \pi$, $\Delta\phi_1 = \pm 30^\circ$, $\Delta\phi_2 = \pm 60^\circ$, $|\eta| \leq 1$). The trigger required that both E_T^1 and E_T^2 exceeded a given threshold. The threshold was set at approximately 20 GeV during the 1984 data-taking period (0.31 pb^{-1}). In 1985, in order to accommodate lower thresholds without introducing excessive data-acquisition dead-time, data from the vertex detector and from the forward spectrometers were not recorded whenever the above trigger was exclusively satisfied. In this way, we could accept trigger rates of up to 6 Hz without significant deterioration of the experiment live-time. The threshold was set at $\approx 15 \text{ GeV}$ for part of the 1985 data-taking period ($\approx 0.27 \text{ pb}^{-1}$) and at $\approx 12.5 \text{ GeV}$ for the rest of the time ($\approx 0.15 \text{ pb}^{-1}$).

Background from sources other than $\bar{p}p$ collisions was suppressed at the trigger level by requiring a coincidence with two signals ("minimum bias" trigger) obtained from scintillator arrays covering the angular range $0.44^\circ < \theta < 2.84^\circ$ on each side of the interaction region [9,13]. As in previous studies [8,9] a small background contamination, resulting from the interaction of beam halo particles in the UA2 calorimeter, is reduced off-line to a negligible level ($< 2\%$) after applying stringent timing cuts and rejection of events having characteristic background configurations in their pattern of energy deposition.

3. DATA REDUCTION AND MASS RESOLUTION

Our primary concern in the subsequent analysis is to arrive at the best possible mass resolution [10] while still retaining the largest possible data sample. The emphasis placed on this goal is greater than in previous studies [9] and we have therefore developed a different jet definition algorithm. Furthermore, we shall use selection criteria which reject events departing substantially from average behaviour, and consequently populating the tails of the mass resolution curve. High mass tails are particularly dangerous in the present case, since the expected signal is superimposed on a steeply falling background.

The jet definition algorithm starts by reducing the measured cell energy pattern to a set of clusters, following the method described in earlier work [8,9]. Jet axes are then defined as straight lines joining the cluster centroids to the centre of the detector (around which interaction vertices are known to be distributed with rms deviations of $\approx 11 \text{ cm}$ along the beam and $< 1 \text{ mm}$ transversally). Finally, jet energies are measured as the sum of the energies of all calorimeter cells having their centre within a cone of angle ω around the jet axis. We adjust the value of ω in order to minimize energy measurement errors. This procedure requires a variable which is sensitive to the jet energy resolution. One such

variable is the difference between the average values of P_T^ξ and P_T^η , the components of the transverse momentum of the jet-pair projected on the bisectors of the jet transverse momenta (Figure 1). The observed widths of these distributions are a convolution of the transverse momentum of the jet system, arising mostly from soft initial state bremsstrahlung, and several instrumental effects. The P_T^ξ variable is mostly affected by energy measurement errors, while the latter is mostly affected by angular measurement errors which have a comparatively much smaller effect. Therefore the difference is mainly affected by the energy resolution. If the cone is chosen too large, more energy from the spectators is incorrectly assigned to the jet. If the cone is chosen too small, the energy of the parent parton is not sufficiently contained. We find that energy measurement errors are minimal over a broad range of $\cos \omega$, approximately between 0.2 and 0.6. We retain the value $\cos \omega = 0.6$ to be used in the jet definition algorithm, as that corresponding to the narrowest cone compatible with an optimum energy resolution.

In order to ensure sufficient containment, we require each jet to have its axis within a fiducial volume defined as $|\cos \theta| < 0.6$. Corrections to the energy and polar angle of each jet, accounting for the lack of calorimeter coverage outside the interval $40^\circ < \theta < 140^\circ$, are applied. They were evaluated from a study performed on a sample of well contained jets and amount to

$$\begin{aligned}\Delta\theta &= -0.05 \cos \theta \quad (\text{radians}), \\ \Delta E &= 0.06 E (\cos^2 \theta + |\cos \theta|).\end{aligned}$$

The selection criteria reject events in which the jet-pair mass measurement is unreliable or insufficiently accurate. Each individual cut (listed below) is adjusted to reject a fixed fraction (typically 5% to 10%) of the event sample, uniformly across the range of jet-pair masses under study (45 to 200 GeV).

- a. A good longitudinal energy containment of the jet hadronic shower in the calorimeter is obtained by rejecting events in which the energy fraction f_{em} deposited in the front electromagnetic compartment is too small or events in which the energy fraction f_{H2} deposited in the rear hadronic compartment is too large. In the IVB region we require $f_{em} > 23.5\%$ and $f_{H2} < 41\%$.
- b. Events displaying a large transverse momentum imbalance, which may indicate an inaccurate measurement of one of the two jet energies, are rejected by a cut on the jet-pair transverse momentum (< 24 GeV in the IVB region).
- c. We also reject events for which the energy measurement of either jet is too sensitive to the choice of the jet definition algorithm. A cut on the energy ΔE measured between the two cones having $\cos \omega = 0.5$ and $\cos \omega = 0.7$, $\Delta E < 4$ GeV, limits the sensitivity to the choice of cone aperture. Another cut, having a similar and correlated effect, requires that the jet-pair mass calculated with the present algorithm ($\cos \omega = 0.6$) does not differ by more than 17 GeV from that calculated with the cluster algorithm used in previous studies [8,9].

These cuts globally reduce the event sample to a fraction $\epsilon_{cut} = 0.66$ of its original population. Their efficiency to retain IVB decays may be slightly different to the extent that quark jets may be expected to be slightly harder than the gluon jets which dominate the event sample from which ϵ_{cut} has been evaluated. Using the Monte Carlo simulation described below we estimate that the cuts improve the jet-pair mass resolution by a factor $\simeq 1.5$.

Finally, we introduce two quantities related to the amount of transverse energy measured in the UA2 calorimeters outside the jet definition cones: $\tilde{E}_T^C$ is that measured in the central calorimeter and $\tilde{E}_T^F$ that measured in the electromagnetic compartments of the forward calorimeters. These quantities are convenient to monitor a possible contamination from soft collisions. Such a contamination was studied using the cluster algorithm to define jets [14] and is expected to be negligible, even though jets

from the present algorithm are wider. The $\tilde{E}_T^{F,C}$ distributions of events passing the selection criteria and having a jet-pair mass in the IVB region ($70 < m < 100$ GeV) are shown in Figure 2. A cut $\tilde{E}_T^C < 10$ GeV, $\tilde{E}_T^F < 6$ GeV retains $\approx 60\%$ of the jet-pairs in the IVB region and will be occasionally applied (we refer to it as the "standard" $\tilde{E}_T$ cut). Using $W \rightarrow e\nu$ events to evaluate the amount of transverse energy associated with W production, we estimate that this cut retains $62 \pm 4\%$ of the $W \rightarrow q\bar{q}$ events passing the selection criteria.

Two independent evaluations of the mass resolution Δm have been made. One is obtained from a direct comparison of the experimental P_T^ξ and P_T^η distributions discussed above, thereby including all factors entering the jet energy resolution. The other is obtained from a Monte Carlo simulation of the experiment and allows for independent evaluations of each of the relevant contributions.

The P_T^ξ and P_T^η distributions (Figure 1) of events passing the cuts (including the standard $\tilde{E}_T$ cut) and having a jet-pair mass in the IVB region, $70 < m < 100$ GeV, have average values $\langle P_T^\xi \rangle = 6.25$ GeV and $\langle P_T^\eta \rangle = 4.33$ GeV. Accounting for the effect of angular measurement errors brings this latter value down to 4.25 GeV. The quantity $Q = \{ \langle P_T^\xi \rangle^2 - \langle P_T^\eta \rangle^2 \}^{1/2} \approx 4.6$ GeV is related to the mass resolution Δm . To evaluate Δm from Q we generate a set of events obtained from observed two-jet events by changing the jet energies according to a gaussian distribution of zero mean and of a specified variance. The events obtained in this way are filtered through the selection criteria defined above. We find that an energy resolution of $\approx 12.6 \pm 0.7\%$ is necessary to increase Q by 4.6 GeV. This corresponds to a mass resolution $\Delta m/m \approx 8.9 \pm 0.5\%$. The effect of angular errors and the fact that the interaction vertex is assumed to be located at the centre of the detector are not accounted for by the method. The error on m resulting from these approximations is small, $\approx 4\%$ on the average. Combining the two contributions we find $\Delta m = 7.9 \pm 0.5$ GeV in the W region.

An independent evaluation of Δm is obtained from a Monte Carlo simulation of the experiment accounting for the factors which are of relevance to the measurement of jet-pair masses. Another purpose of this simulation is to evaluate the average mass values at which the W and Z signals are expected and to predict the expected number of events. The Monte Carlo simulation programme describing the IVB production mechanism and the UA2 detector [12] correctly reproduces our measurements in the $W \rightarrow e\nu$ and $Z \rightarrow e^+e^-$ decay modes [1-4]. However a number of parameters have been adjusted with particular care in view of their relevance to the present study:

- i. the fraction of jet energy outside the cone ($\cos \omega = 0.6$) has been measured for quark jets at electron colliders up to $\sqrt{s} \approx 46$ GeV and can easily be extrapolated to higher energies [15]. We use in the Monte Carlo simulation a fragmentation algorithm [16] which reproduces these data, with the result that the energy leakage of the IVB decay jets outside of their definition cones contribute -3.4 ± 1.5 GeV to the measured jet-pair mass, with an rms fluctuation of 3.8 GeV around the mean.
- ii. particles produced in the collective interaction of the spectator partons not directly involved in the IVB production and initial state bremsstrahlung gluons uniformly populate the central rapidity region. Some of these happen to fall inside the jet-definition cones, thus causing a spurious increase of the measured jet energies. This effect is independent of the IVB decay mode and can be studied from a sample of identified $W \rightarrow e\nu$ events observed in the UA2 detector. In this way, we measure an average spectator contribution of 4.2 ± 0.7 GeV to the jet-pair mass, with an rms fluctuation of 3.1 GeV around the mean.
- iii. the calorimeter response to low energy particles, ≤ 2 GeV, (jet fragments include such particles) was not extensively studied in our test beam measurements [12] and must be extrapolated from higher energy data. As a check on this procedure we have studied the density of transverse energy per unit of rapidity in the central region of "minimum bias" events. The measurement is compared to a calculation using Collider data on the low

transverse momentum particle spectrum and on its composition [17]. The measured and calculated densities are in good agreement, respectively 3.1 and 2.8 GeV per unit of rapidity, from which we infer an uncertainty $\Delta m < 3$ GeV on the mass scale.

- iv. the jet-pair mass, m , is calculated under the assumption that jets are massless. Namely the jet energy, E , is calculated as the sum of the cell energies inside the definition cone and the jet momentum is a vector of length E directed towards the centroid of these cells. The effect of this approximation is negligible ($< 1\%$) and is implicitly included in the Monte Carlo calculation.

A summary of various factors affecting the mass scale and the mass resolution is presented in Table 1. The two independent evaluations of Δm are in excellent agreement, ≈ 8 GeV in the W region, and the measured jet-pair mass does not significantly differ from the real one, a result of the use of relatively wide cones in the jet definition algorithm.

4. RESULTS

From the results of the previous section we expect the reconstructed IVB signals to be shifted downwards by 2.3 ± 4.8 GeV and, as a consequence of the experimental mass resolution, we expect their rms spreads to be ≈ 8 and 9 GeV for W and Z respectively. The Z-W mass difference is unfortunately too small to allow for a separation between the signals. We expect therefore to observe an excess of events in a wide mass region, typically $65 < m < 105$ GeV, which we define as the signal region.

Figure 3 shows the mass distribution of the events which pass the standard $\tilde{E}_T$ cut. Each event has been given a weight $(m/100)^5$ in order to attenuate the steep decrease of the mass spectrum while collecting data in relatively wide mass bins. A structure is clearly visible in qualitative agreement with that expected from W and Z decays.

In the signal region the level of the strong interaction background above which the signal should be measured must be interpolated from the yield of jet-pairs in the two control regions on either side of the signal region. The low mass control region ($m < 65$ GeV) is very densely populated. Once a specific form is chosen to describe the mass dependence of the background in this region, its extrapolation into the signal region is constrained to take a restricted range of values. This constraint becomes stronger for larger low mass control regions. The high mass control region ($m > 105$ GeV) contains instead very few events. Its role is merely to further constrain the form chosen for the background as it bridges across the signal region towards higher masses. It is therefore essential that the low mass control region be free of biases which might distort the extrapolation into the signal region, such as threshold biases or contaminations by soft collisions [14]. From a study of the mass dependence of the ratio between the 1985 high threshold and low threshold data on one hand, and between the 1984 and 1985 data on the other hand, we define lower limits of the mass range above which threshold biases are negligible. These are 45 GeV for the 1985 low threshold data, 49 GeV for the 1985 high threshold data and 57 GeV for the 1984 data. We use the region $m > 57$ GeV to evaluate the relative normalization between the three sets of data and subsequently combine them accordingly. The availability of low threshold data is essential to the success of the measurement. In particular the significance of the signal observed in the study described below would be halved if the lowest mass threshold were 51 GeV instead of 45 GeV and no significant signal would have been found if the lowest mass threshold had been as high as 57 GeV.

The control regions are used to study the ability of various parametrizations to describe the shape of the strong interaction background. In particular, parametrizations of the forms $m^{-\alpha} \exp(-\beta m)$, $m^{-\alpha} \ln(\beta/m)$, and $m^{\alpha+\beta} \ln m$ are found to be satisfactory. A fit to the control regions of the form

$\propto m^{-\alpha} \exp(-\beta m)$ gives a good χ^2 , 4.7 for 7 degrees of freedom, while a fit of the same form to the whole mass range (including the signal region) gives a χ^2 of 21.1 for 12 degrees of freedom.

To evaluate the number of events in the observed signal and to obtain a measure of its significance, we fit the data (distributed in 1 GeV wide mass bins) to a form

$$A \{ m^{-\alpha} \exp(-\beta m) + \xi S(m, m_0) \}$$

where $S(m, m_0)$ is the sum of two gaussian distributions describing W and Z decays respectively: the first one has mean m_0 , rms 8 GeV and unit area, the other one has mean $1.14 m_0$, rms 9 GeV and an area equal to the expected ratio (1/3) between the numbers of observed Z and W decays. The parameters α , β and ξ are adjusted to maximize the fit likelihood, the constant A being calculated each time to provide the appropriate normalization. The mass parameter m_0 is either set to the expected value, $m_0 = 78.5$ GeV, or treated as an additional free parameter, in which case we obtain $m_0 = 82 \pm 3$ GeV. The statistical significance of the signal is 3.3 standard deviations, and the integrated signal is 632 ± 190 events for m_0 free or 686 ± 210 events for m_0 fixed. We have studied the behaviour of the signal when we release the standard $\tilde{E}_T$ cut and, more generally, we have studied its dependence on the values of the $\tilde{E}_T^{F,C}$ cuts. The expected number of signal events in the absence of $\tilde{E}_T^{F,C}$ cuts is evaluated with an uncertainty of $\approx \pm 20\%$ using the Monte Carlo simulation described earlier under the assumption that the efficiency $\epsilon_{\text{cut}} = 0.66$, evaluated for the other cuts from the strong interaction background, applies to W and Z decays. Since our calculation of the expected signal includes measured W and Z production cross-sections [1-4] the effect of neglecting higher order QCD corrections should not exceed a few percent. The dependence on the $\tilde{E}_T^{F,C}$ cuts is estimated either from the background events observed in the signal region or from measured $W \rightarrow e\nu$ events modified to account for the presence of jet fragments outside the definition cones. It is in good agreement with the measured dependence of the observed signal on the $\tilde{E}_T^{F,C}$ cuts. The expected number of signal events obeying the standard $\tilde{E}_T$ cut is 340 ± 80 . The number of signal events obtained from the result of the fit is larger than expectation by approximately 1.4 standard deviations, independent of the value of the $\tilde{E}_T^{F,C}$ cut.

We have performed a number of other fits, using either different parametrizations of the strong interaction background or different data subsamples obtained by altering the selection criteria. A fit to a sample of data for which at least two selection criteria are not satisfied gives no evidence for a signal. In data subsamples passing the selection criteria we always observe a signal with a statistical significance consistent with the number of events in the data sample. We have been unable to find a systematic effect which could produce a signal in the region where we observe it. A summary of the fit results is given in Table 2.

5. CONCLUSIONS

We have discussed various factors of relevance to the measurement of jet-pair masses, with the aim of searching for IVB decays into a pair of quark jets. We were able to achieve a two-jet mass resolution of $\approx \pm 10\%$ in the IVB region by including in the jet definition all particles contained in a cone having $\cos \omega = 0.6$ and by rejecting events with very atypical configurations. This study is one of the first test-cases of the ability of future collider experiments to analyse multiparticle final states in terms of hadron jets identified with their parent partons.

We have presented evidence for a signal, at the level of ≈ 3 standard deviations above the copious and steeply falling strong interaction background, in agreement with Standard Model expectations for W and Z bosons decaying into two quark jets. It contains 632 ± 190 events, 1.4 standard deviations above the expectation of 340 ± 80 events. Stronger evidence for the signal and a significant quantitative measurement of the $W, Z \rightarrow q\bar{q}$ branching fractions will require the collection of a significantly larger data sample [18].

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Table I

Effect	Values evaluated at $m_W = 81$ GeV	
	Mass shift (GeV)	Mass resolution (GeV)
1 - Energy leakage outside definition cone	-3.4 ± 1.5	3.8
2 - Spectator contribution inside definition cone	$+4.2 \pm 0.7$	3.1
3 - Combination of 1 + 2 (ideal detector)	$+0.8 \pm 1.7$	4.9
4 - Calorimeter response	-3.0 ± 3.0	6.2
5 - Energy calibration	0 ± 3.4	1.1
6 - Combination of all above effects (1 + 2 + 4 + 5)	-2.3 ± 4.8	8.0
7 - Direct estimate of mass resolution from $p_T^{\xi, \eta}$	-	7.9 ± 0.5

Table 2. Summary of fit results.

Description	m_0 (GeV)	N_s (a)	σ (b)
Fits to the full sample, all standard cuts applied, using different background forms $B(m)$:			
1. $B(m) = m^{-\alpha} \exp(-\beta m)$	$82.3^{+2.9}_{-2.4}$	632^{+196}_{-186}	3.3
2. $B(m) = m^{-\alpha} \ln(\beta/m)$	$82.1^{+3.0}_{-2.4}$	596^{+201}_{-191}	2.9
3. $B(m) = m^{\alpha+\beta \ln(m)}$	$82.3^{+2.7}_{-2.2}$	713 ± 190	3.9
Fits to subsamples, all standard cuts applied ^(c) , using a background form $B(m) = m^{-\alpha} \exp(-\beta m)$:			
4. Strict f_{em} cut (47% instead of 23.5%)	$79.6^{+2.7}_{-2.2}$	437 ± 145	2.9
5. Complementary subsample	$88.5^{+7.9}_{-6.6}$	168^{+117}_{-102}	1.2
6. Strict P_T cut (8 instead of 24 GeV)	$79.5^{+4.5}_{-3.1}$	232 ± 150	1.1
7. Complementary subsample	$86.7^{+3.2}_{-3.0}$	357 ± 105	3.4
8. Strict Δm (cone - cluster) cut (8 instead of 17 GeV)	$87.5^{+8.5}_{-5.6}$	221^{+112}_{-100}	2.1
9. Complementary subsample	$82.1^{+3.4}_{-2.9}$	385 ± 140	2.6
10. Strict fiducial volume cut ($ \cos \theta < 0.4$ instead of 0.6)	$83.6^{+5.3}_{-4.2}$	175^{+106}_{-98}	1.4

(a) N_s is the total number of events in the W and Z gaussian signals obtained as a result of the fit. For fits 1 to 3 the expected value for N_s is 340 ± 80 (see text).

(b) Statistical significance of the presence of a signal measured in terms of standard deviations.

(c) A fit to the subsample of events which fail at least two standard cuts, using $B(m) = m^{-\alpha} \exp(-\beta m)$ and having $m_0 = 78.5$ GeV gives $N_s = -86 \pm 144$.

FIGURE CAPTIONS

1. The P_T^ξ (open circles) and P_T^η (full circles) distributions of events passing the selection criteria and the standard $\tilde{E}_T$ cut (see text) and having a jet-pair mass in the IVB region. The difference between the two distributions allows for an evaluation of the energy measurement errors. The definition of P_T^ξ and P_T^η is illustrated in the insert.
2. The $\tilde{E}_T^F$ and $\tilde{E}_T^C$ distributions of events passing the selection criteria. The cross-hatched area are excluded by the standard $\tilde{E}_T$ cut.
3. The jet-pair mass distribution of events passing the selection criteria and the standard $\tilde{E}_T$ cut. Each event is given a weight $(m/100)^5$. The smooth curves are the results of the best fits to the strong interaction background alone (curve a) or including two gaussians describing W,Z decays (curve b, see Table 2).

Fig. 1

Fig. 2

Fig. 3