RESULTS ON $W^{\pm}$ AND Z^{0} PHYSICS FROM THE UA1 COLLABORATION

S.J. Wimpenny
EP Division, CERN, Geneva

ABSTRACT

We present new results on the muonic decays of the $W^{\pm}$ and Z^{0} intermediate vector bosons. These are compared with the corresponding measurements of the electronic decays and to give tests of μ-e universality. The Standard Model parameters ρ and $\sin^2\theta_W$ are derived from the data and compared with theory and other experiments. Lastly a preliminary overview is given of the new data from the 1985 data taking run.

Introduction

Between 1982 and 1985 the UA1 experiment (1) has accumulated data corresponding to a total integrated luminosity of $729nb^{-1}$. Two different centre of mass energies of 546 and 630 GeV have been used with corresponding luminosities of 136 and $593nb^{-1}$ respectively. The analysis of these data have given large, essentially background free, samples of the decays of both the charged ($W^{\pm}$) and neutral (Z^{o}) intermediate vector bosons. Results from a subset of the 262 $W^{\pm}\rightarrow e^{\pm}\nu$ and 32 $Z^{o}\rightarrow e^{+}e^{-}$ decays have already been published (2,3) and these will not be discussed at length here. In the following sections we discuss new results from the corresponding subsamples of the 82 $W^{\pm}\rightarrow\mu^{\pm}\rightarrow\nu$ and 20 $Z^{o}\rightarrow\mu^{+}\mu^{-}$ decays observed in the data taken up to the end of 1984.

The Cross Section for the $W^{\pm}\rightarrow\mu^{\pm}\nu$ Decay

By using the selection criteria used for the published 1983 muon analysis (4) we have obtained a preliminary event sample of 82 $W^{\pm}\rightarrow\mu^{\pm}\nu$ events. These are in excellent agreement with Monte Carlo expectations for a conventional massive W decaying into a muon and a neutrino (see Figs. 1). In order to determine the production cross-sections at $\sqrt{s}$=546 and 630 GeV we now restrict ourselves to the data from the 1983 and 1984 runs.

To perform precise measurements of these we have applied further tight quality cuts on the muon tracks in order to remove the residual $\pi/K\rightarrow\mu$ decay

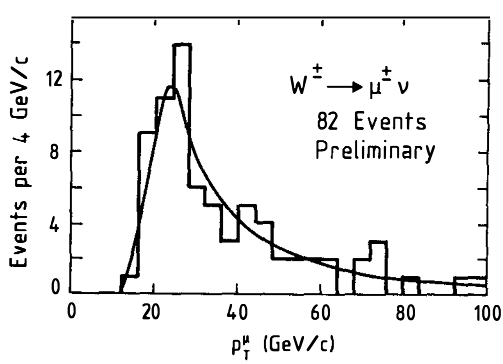

Fig. 1a

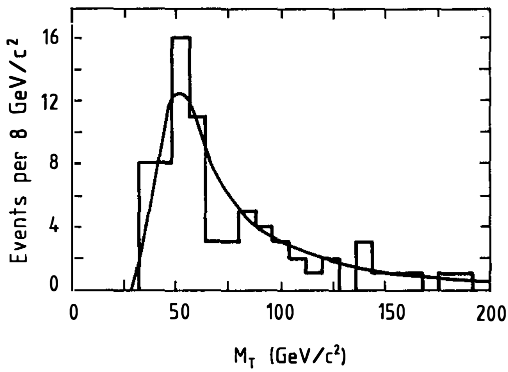

Fig. 1b

P_T^{μ} and $M_T(\mu-\nu)$ for the preliminary 82 event sample

background contamination. With these we obtain samples of 10 and 24 events at $\sqrt{s}$=546 and 630 GeV respectively, which have residual background contaminations of 0.6 ± 0.1 and 1.4 ± 0.1 events from $W\rightarrow\tau\nu$ decays in which the tau subsequently decays into a muon and a neutrino.

The integrated luminosities of the two samples are $108nb^{-1}$ at $\sqrt{s}$=546 GeV and $254nb^{-1}$ at $\sqrt{s}$=630 GeV where these are known to a precision of ± 15%. By using a combination of the $W\rightarrow e\nu$ data (2), event mixing (2,3) and ISAJET (5) Monte Carlo calculations we calculate corresponding trigger acceptances of 15.2 ± 2.1% and 14.7 ± 2.1%. The cross sections are then:

$$(\sigma.B)_W = 0.56 \pm 0.18 \pm 0.12 \text{ nb} \quad \text{at} \quad \sqrt{s} = 546 \text{ GeV}$$

and

$$(\sigma.B)_W = 0.66 \pm 0.12 \pm 0.14 \text{ nb} \quad \text{at} \quad \sqrt{s} = 630 \text{ GeV}$$

where the first error is statistical and the second is systematic. These results are in reasonable agreement with the theoretical predictions of $0.38^{+0.12}_{-0.05}$nb and $0.47^{+0.14}_{-0.08}$nb of Altarelli et al. (6). We also note that the ratio of the two cross sections in which most of the experimental and theoretical uncertainties cancel is:

$$\sigma_W(\sqrt{s} = 630 \text{ GeV})/\sigma_W(\sqrt{s} = 546 \text{ GeV}) = 1.18 \pm 0.44$$

which is in agreement with the theoretical expectation of 1.24.

Comparison of $W^\pm \to \mu^\pm \nu$ and $W^\pm \to e^\pm \nu$ - Tests of μ-e Universality

At present no other measurements of the muonic decay cross section exist. We may however, compare these to the measurements of the electronic decay and in doing so obtain a test of muon-electron Universality. If we do this we obtain:

(a) $\sqrt{s}$ = 546 GeV

$$R = \frac{\sigma.B(W^\pm \to \mu^\pm \nu)}{\sigma.B(W^\pm \to e^\pm \nu)} = \frac{0.56 \pm 0.18 \pm 0.12}{0.55 \pm 0.08 \pm 0.09}$$

$$= 1.02 \pm 0.35 \pm 0.15$$

(b) $\sqrt{s}$ = 630 GeV

$$R = \frac{0.66 \pm 0.12 \pm 0.14}{0.63 \pm 0.05 \pm 0.09} = 1.05 \pm 0.21 \pm 0.15$$

which shows that there is excellent agreement between the muon and electron decay cross sections at both values of $\sqrt{s}$.

The Cross Section for the $Z^o \to \mu^+ \mu^-$ Decay

As previously shown (7) the UA1 experiment also has the capability of detecting the muonic decay of the Z^o boson by selecting high mass dimuon events in the region Mass $(\mu^+\mu^-)$>50 GeV/c^2. The backgrounds for such a signal from conventional processes are negligible and so it is not necessary to require such stringent track quality cuts as were used in looking for the $W^\pm \to \mu^\pm \nu$ decay events. From the 1983 run 5 such events were found, giving a, production cross section $(\sigma.B)_Z$ of 100 ± 50 ± 15pb at $\sqrt{s}$=546 GeV (7). During the 1984 run a further 6 events were found for which we have an acceptance of 33.6±3.6% giving a cross section of:

$$(\sigma.B)_Z = 70 \pm 29 \pm 13 \text{ pb} \quad \text{at} \quad \sqrt{s} = 630 \text{ GeV}$$

where the errors are statistical and systematic. This is also consistent with the theoretical expectation for this energy of 51^{+16}_{-8}pb (6).

As with the W cross section, we can in principle make a test of μ-e universality by comparing the muonic and electronic decay cross sections. In the electron case the measured cross section is 85 ± 23 ± 13 pb (3), giving a ratio R of 0.82 ± 0.41 ± 0.09. The measurements are clearly in good agreement but for the present the size of the errors prevent any useful measurement of μ-e universality.

The Measurement of the Masses of the $W^{\pm}$ and Z^{o}

In order to determine the $W^{\pm}$ mass we have performed a maximum likelihood fit to all of the measured parameters of the events i.e. the muon momentum, its direction and the recoil transverse momentum of the W. For optimal precision we use a momentum measurement taken from a combined fit to the central detector and muon chamber tracks, similar to that used in reference 7. The data used are the background free sample of 24 events from the 1984 run. With these we obtain a result of:

$$M_W = 80.7^{+4.5}_{-4.1}(\text{stat.})^{+9.0}_{-8.1}(\text{syst.})\ \text{GeV}/c^2$$

This compares well with the corresponding electron measurements of this experiment and of the UA2 collaboration (8):

$$M_W = 83.5^{+1.1}_{-1.0}(\text{stat.}) \pm 2.7(\text{Syst.})\ \text{GeV}/c^2 \qquad \text{UA1}$$

and

$$M_W = 81.2 \pm 1.1(\text{stat.}) \pm 1.3(\text{Syst.})\ \text{GeV}/c^2 \qquad \text{UA2.}$$

For the Z^{o} mass determination we have performed a similar log liklihood fit to the momenta of the two decay muons. Again the combined fit momenta are used and we use 7 out of the 9 observed $Z^{o} \rightarrow \mu^{+}\mu^{-}$ events. Two events are excluded from the fit, one of which is the well known $Z^{o} \rightarrow \mu^{+}\mu^{-}\gamma$ event (9) and the second is a problematic dimuon with missing energy. We obtain a result of:

$$M_Z = 91.8^{+4.8}_{-4.5}(\text{stat.})^{+3.8}_{-3.6}(\text{syst.})\ \text{GeV}/c^2$$

which is in good agreement with the published UA1 (3) and UA2 (8) electron measurements of:

$$M_Z = 93.0 \pm 1.4\ (\text{stat.}) \pm 3.0\ (\text{syst.})\ \text{GeV}/c^2 \qquad \text{UA1}$$

and

$$M_Z = 92.5 \pm 1.3\ (\text{stat.}) \pm 1.5\ (\text{syst.})\ \text{GeV}/c^2 \qquad \text{UA2}$$

Standard Model Parameters

In the previous section we have reviewed the current UA1 and UA2 measurements of the $W^{\pm}$ and Z^{0} boson masses. Using these as a basis we can now go on to determine the parameters of the Standards SU(2) ⊗ U(1) Model. The muon data do not significantly improve the precision of the published electron data and so we will restruct the discussion to the use of the latter only.

Taking the definitions of Marciano and Sirlin (10), the Standard Model parameters can be written as:

$$\sin^2\theta_W = 1 - \frac{M_W^2}{M_Z^2} \;,\quad \sin^2\hat{\theta}_W = \frac{(38.5)^2}{M_W^2} \;,\quad \rho = \frac{M_W^2}{(M_Z\cos\hat{\theta}_W)^2} \;,$$

from which we obtain:

$$\sin^2\theta_W = \begin{cases} 0.194 \pm 0.031 & \text{UA1} \\ 0.229 \pm 0.030 & \text{UA2} \end{cases}$$

$$\sin^2\hat{\theta}_W = \begin{cases} 0.214 \begin{array}{l} + 0.005 \\ - 0.006 \end{array} \pm 0.015 & \text{UA1} \\ 0.226 \pm 0.005 \pm 0.008 & \text{UA2} \end{cases}$$

$$\rho = \begin{cases} 1.026 \pm 0.037 \pm 0.019 & \text{UA1} \\ 0.996 \pm 0.033 \pm 0.009 & \text{UA2} \end{cases}$$

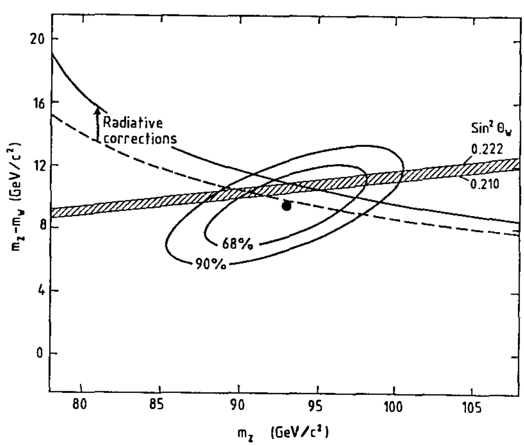

Fig. 2

Comparison of the UA1 results and the expectations of the Standard SU(2) ⊗ U(1) Model

Figure 2 shows the UA1 results plotted in the M_W verses M_Z plane. The contours show the energy scale uncertainties at 68 and 90% confidence levels and the curves show the Standard Model expectations for $\rho=1$ as a function of the boson masses. The width of the shaded band indicates the expectation from the low energy ν charged and neutral current data published prior to this conference (11,12).

The experimental results at high and low energies are in excellent agreement and both agree well with the current expectations for the Standard Model (10). However, for the present the size of the errors are two large to be sensitive to the magnitude of expected radiative corrections (indicated by the difference between the two curves in Fig. 1, see also ref. 13).

Preliminary Results from the 1985 Run

Having completed the discussion of the 1983 and 1984 data we now turn to briefly review the data from the 1985 run. The results presented are preliminary and represent the current status of the analysis much of which still remains to be completed. The data selections have been performed by using essentially the same cuts as discussed in references 2, 3, and 4 and full calorimetric corrections have been applied.

In the two $W^{\pm}$ decay channels we have new events samples of 35 $W^{\pm}\rightarrow\mu^{\pm}\nu$ and 90 $W^{\pm}\rightarrow e^{\pm}\nu$ events from the $330nb^{-1}$ of data taken. The yields are in good agreement with expectations based on the 1984 run and in terms of kinematic variables the distributions are in excellent agreement with the older data and with theory.

The increase in statistics has enabled us to considerably extend our measurements of the W transverse momentum spectra. In 1984 these stopped at 37 GeV/$_c$ and 39 GeV/$_c$ for the muon and electron channels, respectively. The new distributions (Figs. 3(a),(b)) extend out to 66 GeV/$_c$ in the muon case and 85 GeV/$_c$ in the electron case. The shape of the overall distributions are well described by the QCD predictions of Altarelli et al., (6). In passing it is interesting to note that both of the highest p_T^W events are quite spectacular and contain two hard asymmetric jets recoiling against a very asymmetric $\mu(e)\nu$ system (Figs. 4(a),(b)).

In the Z^o decay channels we have 9 new $Z^o\rightarrow\mu^+\mu^-$ events and 17 new $Z^o\rightarrow e^+e^-$ events. As with the W's the yields agree well with expectations. The increase in statistics provided by these data have enabled us to perform much more systematic studies of the Z^o production properties. These will be discussed in the talk of Claudia Stubenrauch (14) later in this conference.

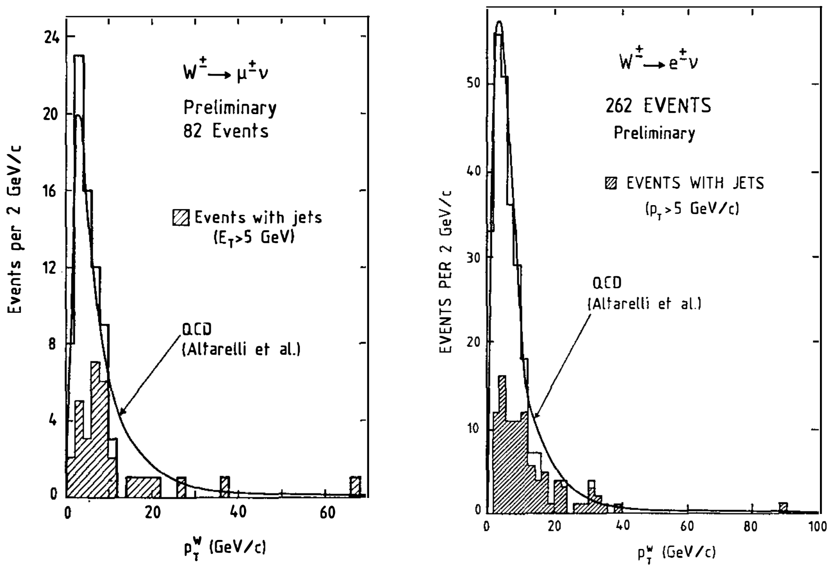

Fig. 3

The p_T^W spectra for the preliminary $W^{\pm} \to \mu^{\pm}\nu$ and $W^{\pm} \to e^{\pm}\nu$ data samples

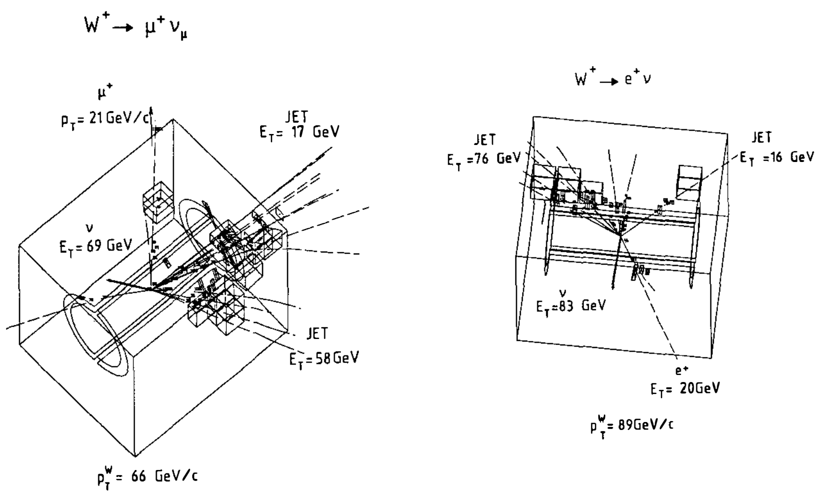

Fig. 4

The two highest p_T^W events from the 1985 run

(a) $W^{\pm} \to \mu^{\pm}\nu$ at p_T^W = 66 GeV/c

(b) $W^{\pm} \to e^{\pm}\nu$ at p_T^W = 89 GeV/c

One of the 9 $Z^o \to \mu^+\mu^-$ events is a candidate for a radiative Z^o decay into $\mu^+\mu^-\gamma$. This is shown in Figs. 5 and is the first such event observed by UA1 or UA2 since 1983. The event contains a μ^+ of P_T~45 GeV/$_c$ recoiling in the transverse plane against a μ^- of p_T=18 GeV/$_c$ and a γ of E_T=19 GeV where the angle between the μ^- and the γ is ~30°. In geometry it is very similar to the original $Z^o \to e^+e^-\gamma$ event seen by UA2 (15). The event is very clean and the $\mu^+\mu^-$ and $\mu^+\mu^-\gamma$ masses of 64 and 101 GeV/$_{c^2}$ favour the radiative hypothesis. However, the μ^+ momentum is poorly measured and the $\mu^+\mu^-$ mass is conistent with the Z^o mass within errors. Further work is in progress to understand this event and results will be available later this year.

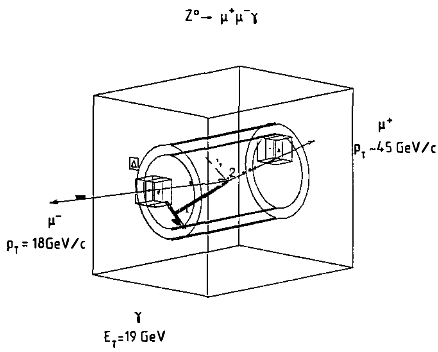

Fig. 5

The 1985 radiative Z° candidate

Conclusions

The UA1 experiment has accumulated 729nb^{-1} of data from the data taking runs up to the end of 1985 and has observed 344 $W^\pm$ decays into $\mu^\pm(e^\pm)\nu$ and 52 Z^o decays into $\mu^+\mu^-(e^+e^-)$.

- New results on the muonic cross sections are in excellent agreement with the published electron results and are consistent with theoretical predictions.

- The measured and calculated Standard Model parameters are good agreement with other experiments and with theory.

- The new data from the 1985 run have enabled the extension of W physics to very large p_T^W and more detailed studies of Z^o production properties.

- One new radiative Z^{o} event has been observed in the 1985 data. This event is still under study.

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12. At this conference new results have been presented by the CHARM and CDHSW Collaborators which significantly decrease this uncertainty.
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