Proceedings of the DIS'2004, Štrbské Pleso, Slovakia

SINGLE BOSON PRODUCTION AT LEP

G. LEIBENGUTH
on the behalf of the LEP experiments
Institut de physique nucléaire
Université catholique de Louvain
Chemin du cyclotron 2,
B-1348 Louvain-la-Neuve, Belgium
E-mail: guillaume.leibenguth@cern.ch

The four LEP experiments have measured the cross section of both single-W and single-Z processes. The obtained cross sections are in agreement with the Standard Model expectations.

1 Introduction

The single-W and single-Z productions have been studied by the four LEP experiments. The production cross section of these processes is about 1 pb at LEP2, to compare to the W boson pair and the Z/γ productions (18 pb and 100 pb, respectively, for a centre-of-mass energy of 200 GeV) and to the integrated luminosity of about 700 pb^{-1} that has been gathered per experiment. As a result, these processes are background of many searches at LEP (see Ref. [1] and [2]) and a stringent test of the Standard Model. Moreover, the single-W also probes the WWγ coupling [3].

2 Charged Weak Boson

Single-W production at LEP2 is defined as the complete t-channel subset of Feynman diagrams (see Figure 1) contributing to the e$\nu_e f\bar{f}'$ final states, with extra phase space requirements: $m_{qq} > 45$ GeV/c^2 for the e$\nu q\bar{q}$ final states, $E_l > 20$ GeV for eν_elν_l where m_{qq} is the invariant mass of the quarks, E_l the energy of a lepton which is either a muon or a tau, and $|\cos\theta_{e^-}| > 0.95$, $|\cos\theta_{e^+}| < 0.95$ and $E_{e^+} >$ 20 GeV (or the charge conjugate cuts) for the eν_eeν_e final states.

For the leptonic decay of the W boson, a single track is expected for the electron, the muon and the one prong tau. For the hadronic decay, single-W events have only two jets inside the detector, some transverse missing momentum and no isolated lepton. Topological cuts which can be found in Ref [4], [5], [6] and [7] for the four LEP experiments are used to select the signal-like events. Typical selection efficiencies are between 30% and 50%.

To extract the cross section, the Standard Model branching ratios of the W boson are assumed. The individual results of each experiment are combined per centre-of-mass energy. Although the measurement uncertainties are dominated by statistics for each centre-of-mass energy, the correlation of systematic uncertainties between the LEP experiments is taken into account. The predicted cross section by the GRACE [9] or WPHACT [10] generators is in good agreement with the

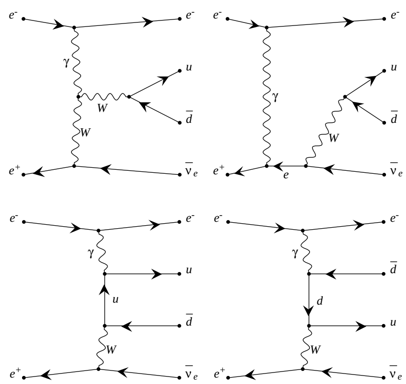

Figure 1. Feynman diagrams of the ee $\rightarrow W e\nu$ process.

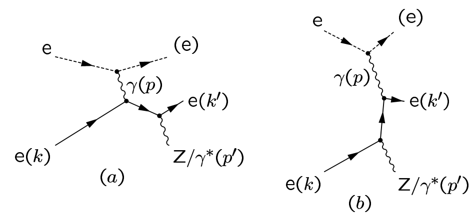

Figure 2. Feynman diagrams of the ee $\rightarrow Zee$ process.

measurement, as shown in Figure 3. The ratio between the observed and predicted cross sections by the GRACE generator, shown per center of mass energy in Figure 4, is, in average:

$$< \frac{\sigma_{We\nu}^{LEP}}{\sigma_{We\nu}^{GRACE}} >= 0.958 \pm 0.079.$$

3 Neutral Weak Bosons

The main diagram contributing to this process is shown in Figure 2. A quasi-real photon is emitted by one of the beam electrons. The other electron is scattered at very low angle and usually lost in the beam pipe. The "single-Z" signal is composed of the following four fermions events, $\mathrm{e^+e^-} \rightarrow e^+e^- f\bar{f}$, with $f\bar{f}$ being $q\bar{q}$ or $\mu^+\mu^-$. To enrich the sample, extra phase space requirements are applied:

$$m_{f\bar{f}} > 60 \text{ GeV/c}^2 \text{ and}$$

$$\theta_{e^+} > 168, 60 < \theta_{e^-} < 168 \text{ and } E_{e^-} > 3 \text{ GeV for a visible electron, or}$$

$$\theta_{e^-} < 12, 12 < \theta_{e^-} < 120 \text{ and } E_{e^+} > 3 \text{ GeV for a visible positron,}$$

the positron direction being +z. The selection of di-muon events is rather straightforward. Events are required to have one electron and two muons, the total charge of the events being +/- 1. Constraints on the allowed angular range were also set, to take into account the missing momentum of the electron lost in the beam pipe. To increase the statistical power of the di-muon channel, all data are merged by the

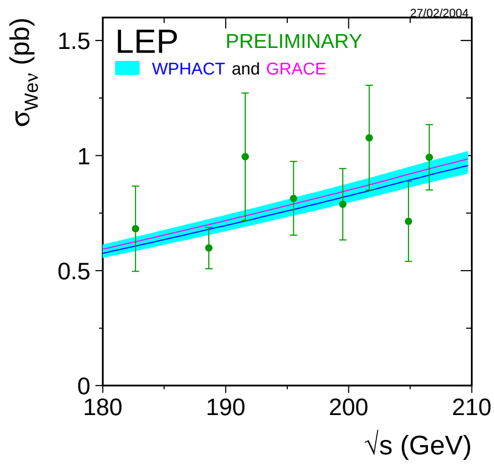

Figure 3. Measured single-W cross sections as function of the centre-of-mass energy. The shaded band represents the 5% theoritical uncertainty of the Monte Carlo generators GRACE and WPHACT

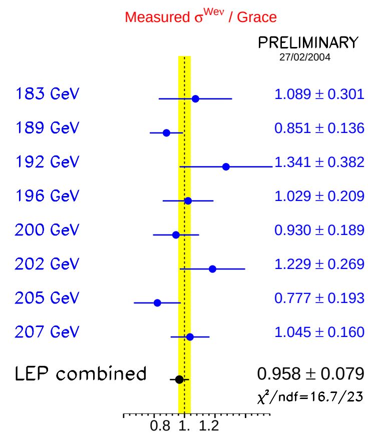

Figure 4. Ratio of LEP combined single-W cross section measurements to the GRACE predictions, the yellow band being the 5 % uncertainty on the theoretical cross section.

experiment themselves and then combined. The $ee\mu\mu$ cross section thus obtained is:

$$\sigma_{Zee\rightarrow\mu\mu ee} = 0.063 \pm 0.011 \text{ pb}.$$

Hadronic events are selected upon the following criteria: a loose preselection requiring sufficient hadronic activity, the presence of an electron candidate fulfilling the signal definition. Additional criteria are applied to the hadronic system. All the details of the selection can be found in Ref. [11] for ALEPH, Ref. [5] for DELPHI, Ref [12] for L3. Figure 5 shows the agreement between the measured single-Z cross section and the prediction of the GRACE and WPHACT simulation. A further test of this agreement is obtained by comparing the ratio of observed and predicted cross sections. The result is shown on Figure 6.

As can be seen in Figure 5, the single vector boson production will be the dominant source of weak bosons in upcoming linear colliders [13].

Acknowledgements

The author would like to thank the 4 fermions working group, for providing most of the material presented here. The work of the author is partially supported by the Federal Office for Scientific, Technical and Cultural Affairs (Belgium) through the Interuniversity Attraction Pole P5/27.

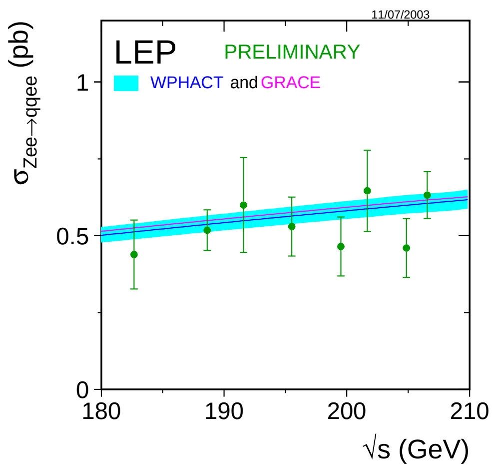

Figure 5. Measured hadronic single-Z cross sections as function of the centre-of-mass energy. The shaded band represents the 5% theoritical uncertainty of the Monte Carlo generators GRACE and WPHACT.

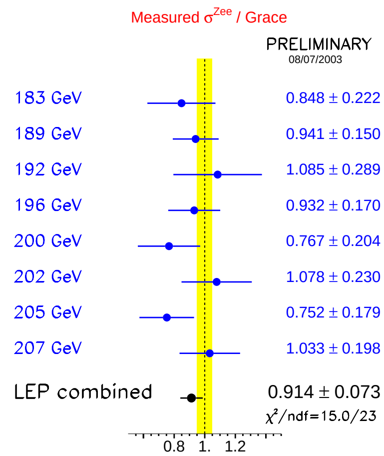

Figure 6. Ratio of LEP combined hadronic cross section measurements to the GRACE predictions, the yellow band being the 5 % uncertainty on the theoretical cross section.

References

1. P. Bechtle, "Searches at LEP", these proceedings.
2. A. Sopcak, "Higgs searches at LEP", these proceedings.
3. U. Parzefall, "Triple Gauge Couplings at LEP", these proceedings.
4. ALEPH Collaboration, "Measurement of the Single W Production Cross Section at Energies up to $sqrts$ = 209 GeV, ALEPH 2001-017 CONF 2001-014.
5. DELPHI Collaboration, "Single Intermediate Vector Boson Production in e^+e^- collision at $\sqrt{s}$ = 183-209 GeV, DELPHI 2003-055 CONF 675.
6. L3 Collaboration, "Production of Single W Bosons at LEP and Measurement of WWγ Gauge Couplings Parameters, Phys. Lett. **B547** (2002) 151.
7. OPAL Collaboration, OPAL Physics Note PN427, March 2000.
8. The LEP electroweak working group, "W and 4f production at LEP2", in hep-ex/0312023.
9. J. Fujimoto *et al.*, Comput. Phys. Commun. **100** (1997) 128.
10. E. Accomando and A. Ballestreto, Comput. Phys. Commun **99** (1997) 270.
11. ALEPH Collaboration, "Single Intermediate Neutral Vector Boson Production at LEP2", ALEPH 2003-012 CONF 2003-018.
12. L3 Collaboration, "Study of the $e^+e^- \to Zee$ process at LEP", Phys. Lett. **B561** (2003) 73.
13. E. Gabrielli, "Single Weak Boson Production at CLIC", CERN Yellow Report 87-07, Vol II (1987) 1.