Determination of the W Mass in the Leptonic Channel at OPAL

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The precise measurement of the W mass is one of the major goals of the LEPII program. Together with other precision electroweak measurements, it provides stringent tests of the Standard Model. When combined with the mass of the Z boson, measured precisely at LEPI, the W mass can be used to constrain the range of the Higgs boson mass.

We present an analysis performed with the data recorded from 1997 until 1999 at center-of-mass energies of 183, 189, 192, 196, 200 and 202 GeV with the OPAL detector at LEP to measure the mass of the W boson in the leptonic channel.

In purely leptonic events, each W boson decays to a lepton and a neutrino after its creation. In spite of the small rate of these events (10% of all W decays, 5% without considering tau decays, in comparison with 44% for semileptonic or 46% for hadronic events), the leptonic decay modes give the cleanest signal of the W-pair production process: two acoplanar charged leptons and a large missing energy due to at least two unobserved neutrinos in the final state [1].

The standard method for the W mass determination, the full kinematic reconstruction of the final state cannot be applied in this channel. Due to the presence of the neutrinos, there are not enough contraints for a kinematic fit. Therefore alternative methods must be used to determine the mass.

We have studied two sensitive variables, the pseudomass and the leptonic energy. The pseudomass is obtained from an approximative reconstruction of the events, assuming both unobserved neutrinos in the same plane as the charged leptons [2,3].

To maximize the sensitivity of the measurement, the different energy resolutions for electrons and muons must be taken into account. Electrons are best measured in the electromagnetic calorimeter with a resolution of 3%, while the resolution of the charged momentum measurement for muons ranges from 5-8%. Three (two) classes are defined for the pseudomass (leptonic energy) which contain the different leptonic flavours [2].

The analysis is based on a parametrization of the spectra of the sensitive variables by analytical functions at each center-of-mass energy and for each class independently. These functions depend on the values of the pseudomass and the leptonic energy for each event and on a group of parameters. The pseudomass is parametrized with a Fermi function (see Figure 1.) which depends on three parameters, the middle point, the width and a constant factor. The leptonic energy is parametrized as the product of two Fermi functions and a linear function, which are described by five parameters, the middle points of the Fermi functions, their widths and the slope of the linear function (see Figure 2.). The dependence of each parameter on the W mass is tested with Monte Carlo samples. These studies show that only the middle points of the Fermi functions in the case of the pseudomass and the leptonic energy have a significant dependence on the W mass, which is well approximated by a linear function.

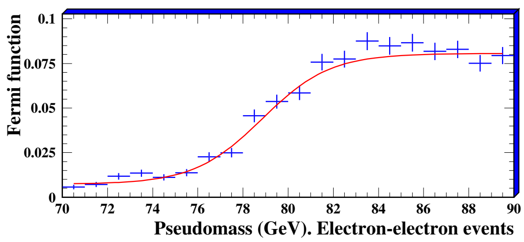

Fig. 1: Fit to the pseudomass distribution generated with a W mass of 80.33 GeV at a center-of-mass energy of 189 GeV. The crosses correspond to the Monte Carlo data and the curve to the Fermi function which fit the pseudomass. The distribution contains the information which comes from electron-electron events only.

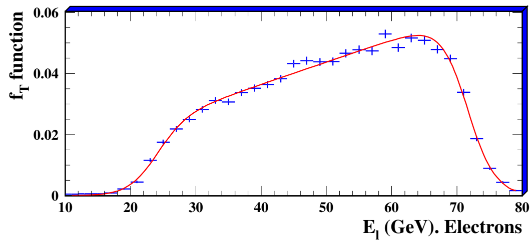

Fig. 2: Fit to the leptonic energy distribution generated with a W mass of 80.33 GeV at a center-of-mass energy of 189 GeV. The crosses correspond to the Monte Carlo data and the curve to the total function (Two Fermi functions and a linear) which fit the leptonic energy. The distribution contains electrons only.

In order to extract the W mass, a simultaneous unbinned likelihood fit for both sensitive variables is used. These likelihoods depend on the W mass and the values of the pseudomass and the leptonic energy. Systematic uncertainties have been studied in detail. Since almost all the sensitivity of the method comes from the electrons which are measured with the information of the electromagnetic calorimeter, the largest systematic errors are due to the resolution and the energy scale in this calorimeter. Nevertheless the systematic uncertainties are much smaller than the statistic error associated to the measurement. The result for the W mass is:

$$\mathrm{M_W} = 80.38 \ \pm 0.51 \pm 0.16 \text{ GeV},$$

where the first error is statistic and the second systematic. The result is consistent with the world average of $\mathrm{M_W}$ [4]:

$$\mathrm{M_W} = 80.436 \ \pm 0.037_{\mathrm{stat}} \text{ GeV}.$$

References

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