Measurement of M_W and Γ_W at OPAL

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One of the main goals of the Large Electron Positron collider (LEP) at CERN was the precise determination of the properties of the W-boson [1], the charged gauge boson of the electroweak theory. After the shutdown of LEP in the year 2000 the collaborations of the four experiments (ALEPH, DELPHI, L3, and OPAL) are working on finishing their analyses. The W-bosons, which were produced in pairs in e^+e^- collisions at LEP above a threshold center-of-mass energy of $\sqrt{s} = 161$ GeV, can decay through several decay channels. We analyse the semileptonic W pair decays, where one W-boson decays into a quark-antiquark pair and the other into a lepton-antineutrino pair. In this report we will present the results of the W-boson width measurements in these type of decays.

Although the mass of the W-boson is very well measured, dedicated measurements of its width are rare. We concentrate therefore on the extension of a method developed to determine the mass of the W-boson to a simultaneous measurement of M_W and width Γ_W of the W-boson.

The convolution method is based on a unbinned maximum likelihood fit of a theoretical distribution to the data sample, with the individual errors of each event included in the calculation of the likelihood function.

Each event is reconstructed by identifying the primary lepton and forcing the remaining hadronic part into two jets. A χ^2-function of the resulting jet and lepton momenta is minimized in dependence of given invariant masses, taking into account energy and momentum conservation. Additionally an equal-mass constraint ($m_{W^+} = m_{W^-}$) is applied. The $\chi^2(m)$-relation is converted to the asymmetric error density of the single event mass value — the value of m at the minimum of $\chi^2(m)$.

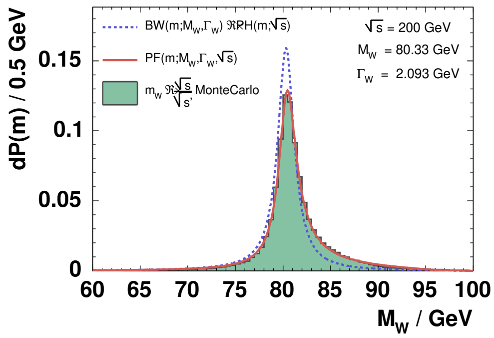

Fig. 1: Comparison of the physics function (solid red line) used by the convolution fit with a relativistic Breit-Wigner function which includes a phase space factor (dashed line). The filled histogram is the ISR-corrected true-mass-distribution of a Monte-Carlo sample.

An event-likelihood which depends on the W-boson mass M_W and width Γ_W is constructed by the convolution of a physics function, describing the production mechanism of the W-boson along with detector effects [2], and the event error density. The physics function is constructed from relativistic Breit-Wigner functions including corrections for initial-state radiation [2] (including a phase space factor). The event mass is shifted by the difference between the nominal and the real beam energy $(\sqrt{s} - \sqrt{s'})/2$ and is weighted by the probability that an event occurred at a center-of-mass energy of $\sqrt{s'}$; this takes the effects of initial-state radiation (the emission of a photon just before the e^+e^- collision, reducing the available center-of-mass energy) on the kinematic fit into account (see fig. 1).

Minimizing the combined likelihood from all data events eventually yields M_W and Γ_W (see fig. 2).

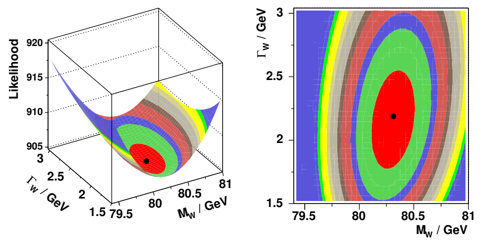

Fig. 2: Example of the resulting likelihood-function, dependent of the parameters M_W and Γ_W. The mimimum marked with the dot is the result of the combined measurement of the mass and the width, the red area marks the 1-σ error-interval.

The calculation of χ^2-functions can be very time consuming. Therefore we investigated the use of parallelization methods to speed up the computations. Object oriented LAM/MPI libraries [3] were implemented to set up a virtual parallel computer consisting of several Linux desktop computers.

For the data collected with the OPAL detector at center-of-mass energies of $\sqrt{s} = 183$ GeV to $\sqrt{s} = 208$ GeV we obtain results for M_W and Γ_W for every year of data-taking between 1997 and 2000. The combination of all data with an integrated luminosity of 683.84 pb^{-1} taking systematic errors into account yields the values [4]:

$$
\begin{aligned}
M_W &= 80.424 \pm 0.077 \text{ GeV} \\
\Gamma_W &= 2.126 \pm 0.130 \text{ GeV.}
\end{aligned}
$$

This analysis represents the first results on the width of the W-boson for the last four years of data-taking at OPAL.

References

[1] Physics at LEP2, G. Altarelli, T. Sjöstrand, and F. Zwirner (eds.), CERN 96-01 Vol. 1, February 1996

[2] J. Dubbert, Measurement of the W Boson Mass in the $W^+W^- \to q\bar{q}'\ell\bar{\nu}$ channel with the OPAL Detector at LEP, Ph.D. thesis, LMU München, 2000

[3] http://www.lam-mpi.org

[4] C.F. Vollmer, Bestimmung der Masse und Breite des W-Bosons im semileptonischen Zerfallskanal mit dem OPAL Detektor bei LEP, Ph.D. thesis, LMU München, 2004