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. In semileptonic W pair decays one W-boson decays into a quark-antiquark pair and the other into a lepton-antineutrino pair. In fully hadronic W pair decays both W-bosons decay into quark-antiquark pairs. In this report we will discuss the measurements of the W-boson width in semileptonic W pair decays and the systematic uncertainty of the mass measurement in fully hadronic W pair decays due to color reconnection effects.

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 the convolution method to a simultaneous measurement of mass and width of the W-boson.

We are using a convolution method to measure the mass M_W and width Γ_W of the W-boson by including the individual errors of each event in an unbinned maximum likelihood fit of a theoretical distribution to the data sample.

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. The difference between applying an equal-mass constraint ($m_{W^+} = m_{W^-}$)—so called 1D fit—or leaving the two boson masses unrestricted—so called 2D fit—is additionally investigated. The $\chi^2(\mathbf{m})$-relation is converted to the asymmetric error density (see fig. 1) of the single event mass value—the value of m or m_1, m_2 at the minimum of $\chi^2(\mathbf{m})$.

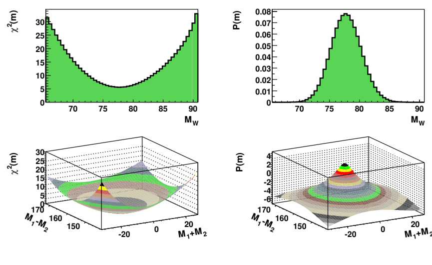

Fig. 1: Examples of $\chi^2(\mathbf{m})$-relations (left) and the corresponding asymmetric error densities (right) in an 1D (upper) and 2D (lower) kinematic fit of an OPAL WW-Monte-Carlo event at $\sqrt{s} = 189$ GeV.

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 event error density and the W-boson along with detector effects [2]. Minimizing the combined event-likelihoods eventually yields M_W and Γ_W.

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.

First results of $\sqrt{s} = 189$ GeV OPAL-Monte-Carlo Data look promising. The expected statistical errors are comparable with previous OPAL results on the width of the W-boson [4] which were made with a reweighting fit. The convolution fit should give a second method for the width determination. The effect of using a 2D fit is further investigated.

The W-boson lifetime is shorter than the typical time scale of the hadronization of the W-boson decay products into color neutral hadrons. It is therefore possible that the decay products of two hadronically decaying W exchange colored objects during their hadronization. This effect is referred to as color reconnection. In the model of Sjöstrand and Khoze (SKI) [5] strings which originally connect partons from the same W are rearranged to connect partons from different W, if the original strings have a sufficient phase-space overlap. This model predicts an increased particle production in the region between jets from different W-bosons and a reduced particle production in the region between the jets from the same W boson. This change in particle production leads on average to an increased angle between the jets from the same W bosons and therefore to an overestimation of the W mass. The color reconnection mainly affects particles with low momenta. The mass shift can therefore be reduced as indicated in fig. 2 if only particles above a threshold are used in the calculation of the jet directions or if particles with larger momentum get a larger weight in the calculation of the jet direction. Our study [6] shows that the mass shift in the SKI model can be reduced by a factor of 4 while the statistical error on the mass determination increases by 33%.

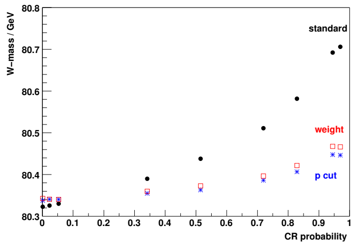

Fig. 2: Mass shift as function of the reconnection probability.

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, PhD Thesis, LMU Munich, November 2000

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

[4] OPAL Collaboration, Phys. Lett. **B507** (2001) 29-46

[5] T. Sjöstrand and V.A. Khoze,Z. Phys. **C62** (1994) 281; Phys. Rev. Lett. **72** (1994) 28

[6] Jana Traupel, Untersuchung der Sensitivität der W-Masse auf Colour Reconnection für verschiedene Methodenen der Ereignisrekonstruktion, Diplomarbeit September 2002