Measurement of $\mathrm{M_W}$ and Γ_W in the $\mathrm{W^+W^-} \to \mathrm{q\bar{q}'}\ell\bar{\nu}$ Channel at OPAL

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After the shutdown of the Large Electron Positron collider (LEP) at CERN the collaborations of the four experiments (ALEPH, DELPHI, L3, and OPAL) are working on finishing their analyses. One of the main goals of LEP was the precise determination of the properties of the W-boson [1], the charged gauge boson of the electroweak theory.

One of the possible decay channels of the W-bosons, which were produced in pairs in $\mathrm{e^+e^-}$ collisions at LEP above a threshold center-of-mass energy of $\sqrt{s} = 161$ GeV, consists of one W-boson decaying into a quark-antiquark pair and the other into a lepton-antineutrino pair — this is the semileptonic decay channel, $\mathrm{W^+W^-} \to \mathrm{q\bar{q}'}\ell\bar{\nu}$.

In the detector this results in two jets, one isolated charged lepton track and an unobservable neurino. Fig. 1 shows a $\mathrm{W^+W^-} \to \mathrm{q\bar{q}'e}\bar{\nu}$ event in the OPAL event display.

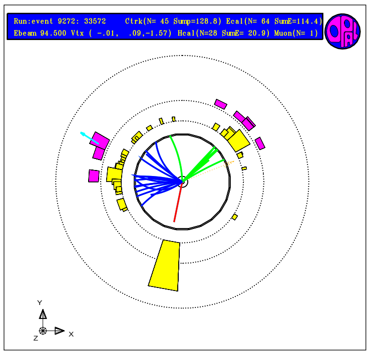

Fig. 1: An event selected as $\mathrm{W^+W^-} \to \mathrm{q\bar{q}'e}\bar{\nu}$ in the OPAL Event Display, a schematic view of the detector (along the beam pipe) and its response. One can see the two jets and the isolated track of the electron pointing to a cluster in the electromagnetic calorimeter.

The semileptonic decay of a W-boson pair has several advantages compared to the other decay channels:

- High statistics (approx. 44 % of all decays)
- Complete kinematic event reconstruction possible
- Low background
- No QCD final state interaction effects between the produced W-bosons
- No combinatorial background (wrong jet-pairing)

We are using a convolution method to measure the W-boson mass $\mathrm{M_W}$ or simultaneously $\mathrm{M_W}$ and the width Γ_W 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 of the event into two jets; this results in a set of measured jet and lepton momenta and directions. A χ^2-function of these kinematic variables is minimized in dependence of given invariant masses, taking into account energy and momentum conservation. The difference between applying an equal-mass constraint ($m_{\mathrm{W^+}} = m_{\mathrm{W^-}}$)—so called 1D fit—or leaving the two boson masses unrestricted—so called 2D fit—is investigated. The $\chi^2(\mathbf{m})$-relation is converted to the asymmetric error density (see fig. 2) of the single event mass value—the value of m or m_1, m_2 at the minimum of $\chi^2(\mathbf{m})$.

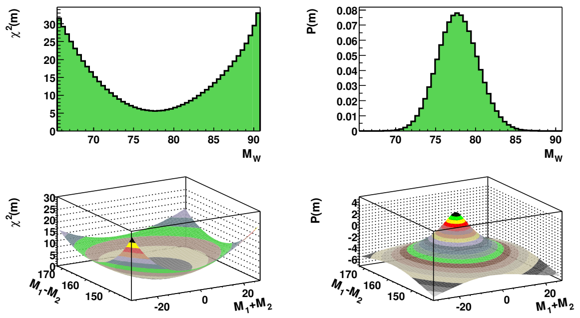

Fig. 2: Examples of $\chi^2(\mathbf{m})$-relations (left) and the corresponding asymmetric error densities (right) in an 1D (upper) and 2D (lower) kinematic fit of an OPAL WW-Monte-Carlo event at $\sqrt{s} = 189$ GeV.

An event-likelihood which depends on the W-boson mass $\mathrm{M_W}$ or additionally on the W-boson width Γ_W is constructed by the convolution of a theoretical distribution, the physics function, and the event error density. The physics function is constructed from relativistic Breit-Wigner functions including corrections for ISR [3]. The event-likelihoods are combined to a total likelihood function which is minimized to obtain $\mathrm{M_W}$ and optionally Γ_W. The calculation of 2-dimensional $P(m_1, m_2)$ curves and physics-functions is very time and memory consuming. Systematic studies with high statistics would take therefore too much time. To make a complete analysis with the 2D-method we use parallelization methods to speed up the computations. Object oriented LAM/MPI libraries [4] were implemented to set up a communication environment between severals Linux computers. The speed performance then scales roughly with the number of used CPUs.

First results of $\sqrt{s} = 189$ GeV OPAL-Monte-Carlo Data show that the $\mathrm{M_W}$ result in 2D is consistent with [2]. Statistical errors show a slight improvement over the 1D method. The convolution method is now extended to a simultanous measurement of $\mathrm{M_W}$ and Γ_W. The previous OPAL results on the width of the W-boson [5] were made with a reweighting fit. The convolution fit should give a second method for the width determination.

References

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[3] J.Dubbert, Ph.D. thesis, LMU München, 2000

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