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

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One of the current major aims of the four experiments (ALEPH, DELPHI, L3, and OPAL) at the Large Electron Positron collider (LEP) at CERN is the precise determination of the properties of the W-boson [1], the charged gauge boson of the electroweak theory.

The W-bosons, which are produced in pairs in $\mathrm{e^+e^-}$ collisions at LEP above a threshold center-of-mass energy of $\sqrt{s} = 161$ GeV, decay immediately after their creation; in the semileptonic decay channel, $\mathrm{W^+W^-} \to \mathrm{q\bar{q}'}\ell\bar{\nu}$, one W-boson decays into a quark-antiquark pair and the other into a lepton-antineutrino pair — resulting in two jets and one isolated charged lepton track in the detector; the neutrino is not observed. Fig. 1 shows a $\mathrm{W^+W^-} \to \mathrm{q\bar{q}'e}\bar{\nu}$ event in the OPAL Event Display.

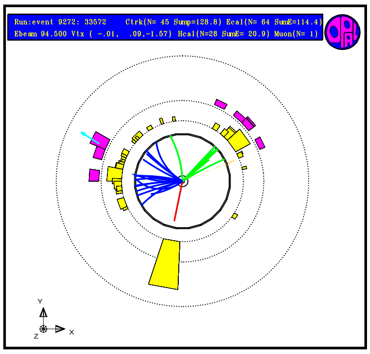

Fig. 1: An event selected as $\mathrm{W^+W^-} \to \mathrm{q\bar{q}'e}\bar{\nu}$ in the OPAL Event Display, a schematic view of the detector (along the beam pipe) and its response. One can see the two jets and the isolated track of the electron pointing to a cluster in the electromagnetic calorimeter.

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 effect on $\mathrm{M_W}$ from QCD final state interactions
- No combinatorial background (wrong jet-pairing)

We are working on a convolution method to measure the W-boson mass $\mathrm{M_W}$ 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 forcing the hadronic part into two jets, excluding tracks/calorimeter cluster which belong to the primary lepton; 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 a given mass, taking into account energy and momentum conservation and applying an equal-mass constraint ($m_{\mathrm{W^+}} = m_{\mathrm{W^-}}$). The $\chi^2(m)$-relation is converted to the asymmetric error density (see fig. 2) of the single event mass value—the value of m at the minimum of $\chi^2(m)$.

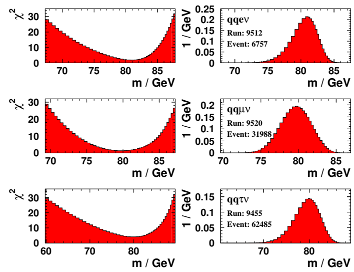

Fig. 2: Examples of $\chi^2(m)$-relations (left) and the corresponding asymmetric error densities (right) for some data events recorded with the OPAL detector at $\sqrt{s} = 189$ GeV.

An event-likelihood which depends on the W-boson mass $\mathrm{M_W}$ and 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 a superposition of relativistic Breit-Wigner functions (including a phase space factor) which are shifted by the difference between the nominal and the real beam energy $(\sqrt{s} - \sqrt{s'})/2$ and are weighted by the probability that an event occurred at a center-of-mass energy of $\sqrt{s'}$ (see fig. 3); 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. The event-likelihoods are combined to a total likelihood function which is minimized to obtain $\mathrm{M_W}$ and Γ_W.

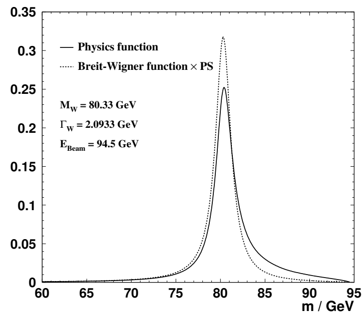

Fig. 3: Comparison of the physics function (solid line) used by the convolution fit with a relativistic Breit-Wigner function which includes a phase space factor (dashed line).

For the data collected with the OPAL detector at center-of-mass energies of $\sqrt{s} = 183$ GeV and $\sqrt{s} = 189$ GeV we obtain for the W-boson mass values consistent with [2,3]. As the method is complementary to [2,3] it represents an important cross-check of the W mass measurement.

References

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

[2] OPAL Collaboration, G. Abbiendi *et al.*, Phys. Lett. **B453** (1999) 138

[3] OPAL Collaboration, Measurement of the W boson mass in e+e- Collisions at 189 GeV, OPAL PN385, March 1999