Influence of Hard Gluon Radiation on the Determination of the Mass of the W Boson in the $W^+W^- \to q\bar{q}q\bar{q}$ Hadronic Channel with the OPAL Detector at LEP

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An introduction into the determination of the mass of the W-Boson is given in an other article in the report [1]. In the case of a hadronic decay of both W bosons, one expects four jets from the hadronization of the four quarks. The jets are constructed from the observed particles in an iterative procedure. A new particle is formed by adding the 4-momenta of the two particles with the smallest value of the jet resolution parameter

$$y_{ij} = 2\left(min\left[E_i^2, E_j^2\right] \frac{1-cos(\theta_{ij})}{s}\right)$$

where the subscripts i and j denote two particles and s is the square of the centre-of-mass energy. $E_{i,j}$ are the energies of the i^{th} and j^{th} particle while θ_{ij} denotes the angle between them. The algorithm finishes when a given number of particles, which are then called jets, is reached. The W mass M_W in an event can be determined by a kinematic fit which minimizes the difference between the observed and the fitted jets, taking into account energy and momentum conservation and the constrain that both W bosons have the same mass. There are three ways to combine four jets to two W bosons. The most likely one is chosen by a discriminator based on the probability of the fit and other kinematic properties of the event. The W-boson mass is then determined by varying M_W in the Monte Carlo simulation and by choosing the value for which the Monte Carlo best describes the observed mass distribution.

If events with hard gluon radiation are reconstructed as 4-jet events, the gluon jet is not necessarily combined with the jet from the quark which emitted the gluon. For these events, the mass information is lost or at least diluted. This information can be recovered by reconstructing the event as five jets. Since there are ten possibilities to associate five jets to two W bosons, the treatment of all events as 5-jet events would increase the probability of choosing the wrong jet combination for the determination of the mass. The parameter y_{45} is used in order to decide which events are treated as four and which as five jets. y_{45} is the jet resolution parameter y_{ij} of those two particles which are combined when the number of particles is reduced from five to four. Based on the integrated luminosity of 183 pb^{-1} at a centre-of-mass energy of 189 GeV, fig. 1 shows (as dots) the expected statistic uncertainty of the determination of M_W as a function of y_{45}^{cut} where events with $y_{45} > y_{45}^{cut}$ are treated as five jet events and events with $y_{45} < y_{45}^{cut}$ as four jet events. The plot also shows (as stars) the improvement one gets if the comparison between the observed mass distribution and the Monte Carlo is done in bins of the discriminator which decides which jet combinations should be used. In this case, events, for which the probability of using the correct jet combination is higher, contribute with a larger weight to the final result. The third curve (triangles) indicates the additional improvement from the additional consideration of the second most likely jet combination in a separate class.

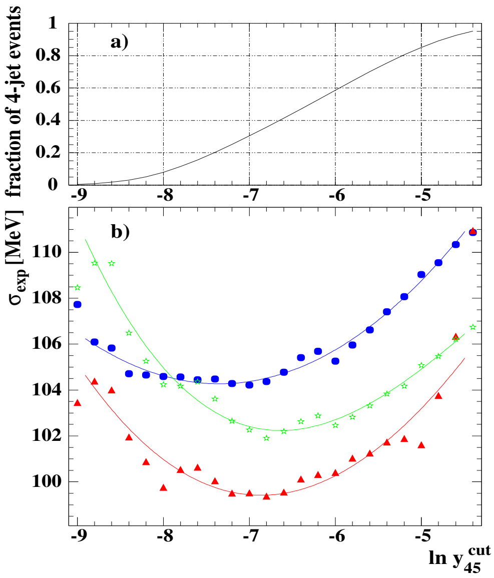

Fig. 1: a) Fraction of 4-jet events and b) the dependence of the expected statistical error on y_{45}^{cut} for the analyses described in the text

A different approach to include the hard gluon radiation is followed in a two dimensional convolution fit: In a preselection, on average three out of ten possible assignments of five jets to two W bosons are chosen. For these assignments, the two masses of the two W bosons of the event and their error matrix are estimated in a kinematic fit which only assumes energy and momentum conservation. Assuming Gaussian errors, this is converted into a probability that this specific event represents two W bosons with masses M_W^1 and M_W^2. In order to get an event Likelihood, this probability is convoluted with the probability to produce events with masses M_W^1 and M_W^2 which is basically given by the sum of a 2-dimensional Breit-Wigner distribution and a flat background. The value of the mass of the W boson is then extracted by a maximum Likelihood of the event Likelihoods.

The reason why this fit can tolerate the large number of wrong jet assignments (if one chooses three assignments for an event, two must be wrong) is the following: Events with wrong jet assignments have in most cases large differences between the values of M_W^1 and M_W^2 in this case the contribution from the 2-dimensional Breit-Wigner distribution to the event likelihood is small and thous the influence of this combination on the determination of the W-Boson mass is small.

The statistical and systematic uncertainties of the two methods are of the same order. The statistic error of the determination of the mass of the W boson from hadronic decays of W boson pairs has clearly been improved by the explicit consideration of 5-jet topologies from hard gluon radiation.

References

[1] B. Bußmann *et al.*, this report, p.30