Influence of Color Reconnection on the Determination of the W Boson Mass

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At LEP W bosons are produced in pairs. If both W decay hadronically it might be possible that their fragmentation is not independent from each other. Since the time scale of the fragmentation of the quarks into hadrons is larger than the lifetime of the W boson one can imagine that the two systems exchanged gluons. Since colored gluons are exchanged the decay products of the two W no longer form independent color singlet states and therefore particles produced during the fragmentation are not longer unambiguously associated to one of the W bosons. The dominant soft component of this effect can only be described with phenomenological models.

The SK models [1] are based on the PYTHIA Monte Carlo generator. PYTHIA describes the fragmentation in two steps. The first step is a perturbatively calculated parton shower where quarks and gluons radiate further gluons and where gluons split into quark pairs. The showering stops when the mass of the partons reaches a cutoff value which is typically between 1 and 2 GeV. The partons which form a color singlet are connected by a string which starts at a quark, has kinks at the gluons and ends at the antiquark. Hadrons are formed from quark-antiquark pairs which are created along the string. The color reconnection in the SK models is based on the string fragmentation and basically two crossing strings are reconnected. In the SKI model the strings are assumed to have a finite width. Their phase space overlap is calculated and if it is large enough the strings are reconnected at the point of the largest phase space overlap. The width is a parameter of the model which can be used to produce an arbitrary overall reconnection probability. In the SKII models the strings are assumed to be infinitly narrow and color reconnection happens if two strings cross. The string configuration is only changed if this reduces the length of the strings. Particles produced in the middle of the string have low energy and are far from the jets. Since they are influenced most strongly by the color reconnection we tried to minimize their influence on the mass determination.

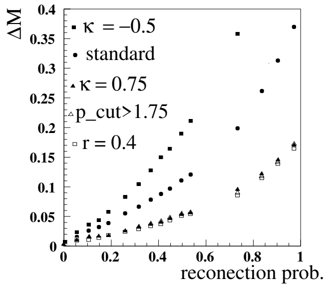

Fig. 1: Mass bias as function of color reconnection probability.

We tried three different strategies: We either only used particles with a momentum larger than p_{cut} to calculate the jet directions, or only particles which where inside a cone ρ around the Jet axis (this was done iteratively). In the third approach the jet direction was determined from the sum $\sum p|p|^\kappa$ over all particles in a jet. This way each particle is weighted with an extra factor $|p|^\kappa$. For positive κ high energetic particles are emphasied and vice versa. In fig. 1 the three approaches are compared with the standard analysis. The values for p_{cut}, ρ and κ are chosen such that the statistical loss due to the additional uncertainty in the determination of the jet direction compared to the standard analysis is similar. The plot shows the mass difference for a Monte Carlo without color reconnection to the SKI model as function of the color reconnection probability. One sees that all three approaches are able to drastically reduce the mass bias of color reconnection and the bias is increased as expected for negative values of κ.

However the SK models are not the only way to implement the color reconnection. In the ARIADNE [2] model the perturbative shower is described by the radiation of gluons from color dipoles. Higher order effects are implemented by the requirement that the gluon can only be radiated with an angle smaller than the opening angle of the two partons forming the dipole. When the option of color reconnection is switched on the dipole radiating the gluon can also be formed by partons from different W bosons. This means that the angle under which gluons are radiated is influenced by the presence of patrons from the other W. In the AR2 model only gluons with virtually less then 2 GeV are allowed to influence the opposite W (other gluons do not exist long enough.) If color reconnection is switched on, the strings between all quarks and gluons are formed in a way to minimize the overall string length; otherwise this is done seperately for both W bosons.

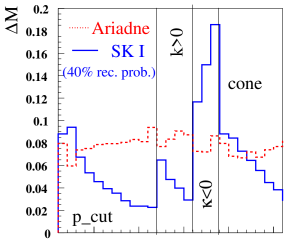

Fig. 2: Comparison of mass bias for the Ariadne (Ar2) and Phytia (SKI) model.

Fig. 2 shows the mass bias for the SKI and AR2 model for different values of p_{cut}, ρ and κ. The effect on the SKI model can be clearly seen while the effect for the AR2 model is small or not existing. This difference in behaviour might be due to the fact that in the AR2 model the presence of the other W already affects the radiation of gluons in the parton shower. Because of the 2 GeV requirement for the gluons one had naively expected that only low energetic particles were significantly influenced by the color reconnection, but that is obviously not the case.

References

[1] T. Sjöstrand and V.A. Khoze, Z. Phys. **C62** (1994) 281; Phys. Rev. Lett. **72** (1994) 28
[2] L. Lönnblad, Z. Phys. **C70** (1996) 107