Colour Reconnection in $W^+W^- \to q\bar{q}'q\bar{q}'$ Events at OPAL

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The mass of the W boson in hadronic events $W^+W^- \to q\bar{q}'q\bar{q}'$ is determined at LEP2 by measuring the invariant mass of the two pairs of hadron jets arising from the four quarks in the final state. It has been suggested that in the hadronic case the two W bosons do not fragment independently but decay products from different Ws may interact. These final-state interactions could introduce a significant bias to the W-mass measurement [1].

Colour reconnection [2] is the general name applied to the case where such final-state interactions lead to colour flow between the decay products of the two W bosons. Such an interconnection can occur because the two W bosons which are produced in e^+e^- collisions decay at short distances of order $1/\Gamma_W \sim 0.1$ fm. The hadronization of their decay products occurs with a large space-time overlap at the typical hadronic scale of ~ 1 fm. Colour reconnection effects can be shown to be small in the perturbative phase [3], but may have large effects in the non-perturbative phase of the hadronization. With the current knowledge of non-perturbative QCD, such interference can be estimated only in the context of specific models [3,6].

Observables, such as the charged multiplicity, are expected to be sensitive to the effects of colour reconnection and have already been studied experimentally (see e.g. [4]). It has been suggested that the production rate of heavy hadrons, namely kaons and protons, at low momenta should be reduced due to colour reconnection and may lead to a larger experimental signature [5]. Fig. 1 shows the distribution of the scaled momentum, $x_p = p/E_{\text{beam}}$, for all charged hadrons (a) and for kaons and protons (b) in $W^+W^- \to q\bar{q}'q\bar{q}'$ events in the reconnection scenario using the model SK Type I [3] and two models implemented in the ARIADNE [6] Monte Carlo generator, AR 2 and AR 3, normalised to the expectation without colour reconnection.

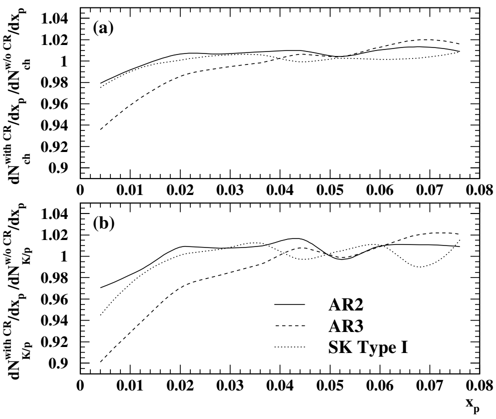

Fig. 1: Ratio of reconnection to no-reconnection x_p-spectra for all charged (a) and heavy hadrons (b) in $W^+W^- \to q\bar{q}'q\bar{q}'$ events at $\sqrt{s} = 189$ GeV using the colour reconnection models AR 2, AR 3 and SK Type I.

In order to test the suppression of low-momentum kaons and protons experimentally, we measured the production rate of heavy hadrons in the x_p-range $0.002 \le x_p \le 0.012$. Heavy particles are identified using the measurement of the specific energy loss dE/dx in the central jet chamber of OPAL. For each track, a χ^2 probability is formed for each stable particle hypothesis. From these particle weights a probability P_{heavy} to be a heavy particle is formed by adding the particle weights for the kaon and proton hypothesis and normalising it by the sum of particle weights for all particle hypothesis. By applying a cut on P_{heavy} one identifies heavy particles with a mean purity in the momentum region of interest of about 88 % and a mean efficiency of about 58 % with large variations depending on the momentum of the track.

As colour reconnection affects only the hadronic decay channel, the ratio of the number of kaons and protons in $W^+W^- \to q\bar{q}'q\bar{q}'$ events, $N^{4q}_{K,p}$, and twice the number in the hadronic part of $W^+W^- \to q\bar{q}'\ell\bar{\nu}_\ell$ events, $N^{qq l\nu}_{K,p}$, should be less then 1 if colour reconnection effect are present, and equal to 1 in their absence.
With the data recorded at centre-of-mass energies of $\sqrt{s} \simeq 183$ GeV and $\sqrt{s} \simeq 189$ GeV with the OPAL detector, the ratio of the production rates in $0.002 \le x_p \le 0.012$, $R = N^{4q}_{K,p}/(2 \times N^{qql\nu}_{K,p})$ was found to be [7]

$$R = 0.91 \pm 0.13_{\text{stat.}} \pm 0.08_{\text{syst.}} \text{ at } \sqrt{s} \simeq 183 \text{ GeV and}$$
$$R = 1.11 \pm 0.08_{\text{stat.}} \pm 0.06_{\text{syst.}} \text{ at } \sqrt{s} \simeq 189 \text{ GeV.}$$

At the current level of experimental precision, these results are consistent with the expectation of standard QCD models and two colour reconnection models implemented in the ARIADNE Monte Carlo generator (see Fig. 2).

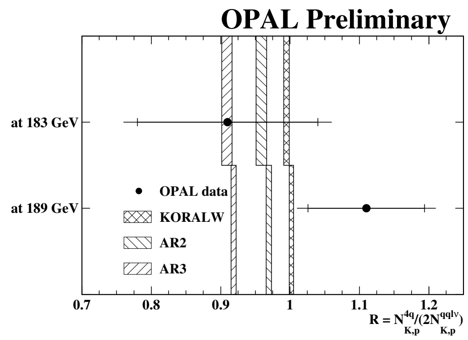

Fig. 2: Ratio $R = N^{4q}_{K,p}/(2 \times N^{qql\nu}_{K,p})$ at $\sqrt{s} = 183$ GeV and $\sqrt{s} = 189$ GeV. The points show the data with statistical and systematic uncertainties added in quadrature, and the shaded areas indicate the predictions of KORALW and two colour reconnection models, AR 2 and AR 3, with the statistical errors.

References

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