Colour Reconnection Studies in $W^+W^- \to q\bar{q}'q\bar{q}'$ Events Using Inter-jet Multiplicity at OPAL

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Final state interactions in $W^+W^- \to q\bar{q}'q\bar{q}'$ events could introduce a significant bias to the W-mass measurement in this decay channel [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. 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 [3,4].

The method to study possible effects of colour reconnection described here [5] is a generalisation of the so-called "string effect" in three jet $e^+e^- \to Z^0/\gamma \to q\bar{q}g$ events to the four jet topology of $e^+e^- \to W^+W^- \to q\bar{q}'q\bar{q}'$. All tracks and calorimeter clusters in an event are combined into four jets. The analysis is carried out in four distinct planes, each of which is defined by a pair of jet axis. Two pairs of jets which are associated with the two W bosons using the likelihood method which was introduced in [6] define the two intra-W regions. With four jets, there exist two ways in which planes may be defined between jets which originate from different Ws (inter-W regions). The configuration which results in the smaller sum of inter-W angles are chosen.

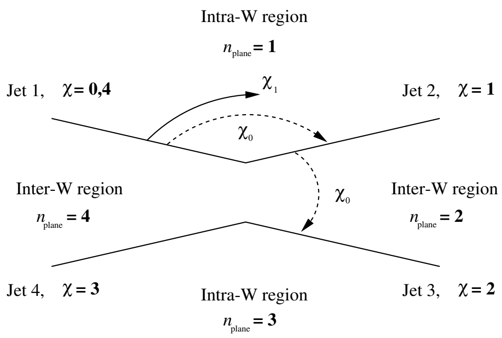

Fig. 1: Illustration of inter-W and intra-W regions, and numbering convention adopted.

All charged particles in the event are projected onto the intra-W and inter-W planes, as illustrated in Figure 1. 'Jet 1' is the most energetic jet. The angle χ_1 between the first jet in each plane and the projected track is measured. To account for the variation in the angle between pairs of jets, the distribution of particles as a function of χ_1 for each plane is scaled event-by-event to the angle between the jets which define the plane, χ_0, giving a normalised angle, $\chi_R = \chi_1/\chi_0$. The four normalised inter-jet regions are combined in a single distribution in the range $0 < \chi < 4$, as shown in figure 2. The predicted background from non-WW Standard Model processes has been subtracted from the data. The variable χ is defined as $\chi = \chi_R + (n_{\rm plane} - 1)$, where $n_{\rm plane}$ is an integer between 1 and 4, corresponding to the four planes in the order shown in figure 1.

It is expected, that a rearrangement of the colour flow in the event due to colour reconnection leads to a migration of particle flow away from the intra-W regions to the inter-W regions. A way to study this effect is to compare the particle flow in these regions. To quantify the level of consistency between the data and predictions of models, the ratio of the integral of the particle flow in the inter-W regions to that in the intra-W regions,

$$R_s = \frac{\int_{0.2}^{0.8} \frac{dn}{d\chi_R}(\text{inter} - \text{W}) d\chi_R}{\int_{0.2}^{0.8} \frac{dn}{d\chi_R}(\text{intra} - \text{W}) d\chi_R},$$

is measured, where n is the number of particle tracks projected into a given inter-jet region. The limits of integration are chosen to optimise the predicted sensitivity in one of the theoretically favoured models [3], referred to as SK I.

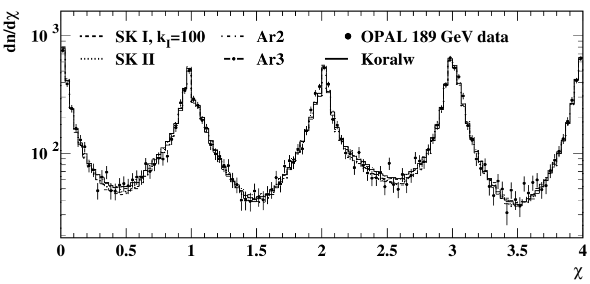

Fig. 2: The particle flow distribution in the four inter-jet planes, normalised event-by-event to the inter-jet angles. A partial data set of the OPAL experiment is compared with different models of colour reconnection.

Choosing the value for the free parameter in the SK I model $k_I = 0.9$ fm^{-4}, a value of $R_s = 0.795$ is expected, while for the corresponding 'no reconnection' model, KORALW, $R_s = 0.762$ is found. Such a difference corresponds to the statistical precision one obtains for R_s with the data collected in 1998. The measured value in this data set is $R_s = 0.83 \pm 0.03_{\rm stat} \pm 0.01_{\rm syst}$.

Using all the existing data from the four LEP experiments, it will be possible with this method to test the relevant models for colour reconnection with a sensitivity of approximately 4 standard deviations.

References

[1] Proceedings of CERN LEP2 Workshop, CERN 96-01, Vol. 1, p. 141, eds. G. Altarelli, T. Sjöstrand and F. Zwirner, February 1996.

[2] G. Gustafson, U. Pettersson and P.M. Zerwas, Phys. Lett. **B209** (1988) 90

[3] T. Sjöstrand and V.A. Khoze, Z. Phys. **C62** (1994) 281; Phys. Rev. Lett. **72** (1994) 28

[4] L. Lönnblad, Comp. Phys. Comm. **71** (1992) 15

[5] O.Sahr, Ph.D. thesis, LMU München, 2001; OPAL Collaboration, *Colour reconnection studies in* $W^+W^- \to q\bar{q}'q\bar{q}'$ *events at* $\sqrt{s} = 189$ *GeV using inter-jet multiplicity*, OPAL PN448, July 2000.

[6] OPAL Collaboration, G. Abbiendi *et al.*, *Measurement of the W boson mass in* e^+e^- *Collisions at 189 GeV*, CERN-EP/2000-99, June 2000, accepted by Phys. Lett. **B**.