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Study of the Average Track Multiplicity in WW $\rightarrow qqqq$ and WW $\rightarrow qq\ell\nu$ Events at $\sqrt{s} = 172$ GeV

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Abstract

We report on a study of the average track multiplicity in WW $\rightarrow qqqq$ and WW $\rightarrow qq\ell\nu$ events recorded with the L3 detector at LEP at $\sqrt{s} = 172$ GeV. Various Bose-Einstein correlation and colour reconnection models predict significant differences between the average track multiplicity in $qqqq$ and twice the average track multiplicity in $qq\ell\nu$ events; no such differences are observed in the data.

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1 Introduction

One of the most important physics aims of LEP2 is the study of the W boson and a measurement of its mass, through the process $e^+e^- \to W^+W^-$ [1]. The most sensitive measurement of the W boson mass makes use of the invariant masses of pairs of W decay products. It has been suggested that in events where both W's decay hadronically (denoted here as $qqqq$ events), both W's do not fragment independently. In particular, two sources of cross talk between W decay products have been suggested: Bose-Einstein correlations [1–4] between identical bosons, such as pions and kaons, originating from the decay of different W's, and possible reconnection of the colour flow [1,5–7] between partons from the decay of different W's, such that the partons from a single W no longer form a colour singlet state. If such effects indeed exist, the invariant masses of jet pairs originating from W decay are in general affected, and may no longer correspond to the mass of the W boson. In that case, the use of $qqqq$ events may pose problems to the W mass measurement, problems that do not exist in events where only one W boson decays hadronically and the other in a charged lepton and a neutrino ($qq\ell\nu$ events).

The existence of Bose-Einstein correlations between identical bosons has been verified by various experiments at e^+e^- colliders [8], including the ones at LEP1 [9,10]. How Bose-Einstein correlations affect WW production at LEP2, and in particular whether correlations between identical bosons resulting from the decay of different W's exist, is not well known [1]. The DELPHI Collaboration has recently reported results at LEP2 using charged pions from different W's [11]; within the limits of present statistics of available data, no enhancement of the correlation function above that expected from a pair of uncorrelated W's is observed. In a similar way, the predictions of the influence of colour reconnection on the W mass measurement vary from model to model [1]. Although such colour reconnection effects are suppressed in the hard perturbative phase [5], the typical distance scale of the hadronization is larger than the typical distance between W decay vertices, and partons resulting from the decay of different W's may well feel each other's colour forces.

It is important that these effects are not only studied theoretically, but also experimentally. If these effects have a sizable influence on the measured W mass, they are likely to also have an influence on other observables. One such observable is the average charged particle multiplicity in WW events. It is in particular interesting to study the possible difference between the average charged particle multiplicity in $qqqq$ events, and twice the average charged particle multiplicity in $qq\ell\nu$ events, of course with the lepton track subtracted. It has been suggested that differences may occur through Bose-Einstein correlations [4] (generally, but not necessarily, increasing the multiplicity in $qqqq$ events), or through colour reconnection effects [6] (generally decreasing it).

In this note we report on an experimental study of the average charged particle multiplicity in WW events selected from 10.25 pb^{-1} of data taken by L3 at $\sqrt{s} = 172$ GeV. The selection of the WW event sample is decribed in Ref [12]. The resulting sample consists of 61 $qqqq$ events, with 12.6 background events expected, and 40 $qq\ell\nu$ events, of which 28 are $qqe\nu$ and $qq\mu\nu$ events, with 3.1 (1.0) background events expected. The Monte Carlo program used to describe the WW signal is KORALW [13]. In this program, colour reconnection effects are not included, i.e. the colour flow remains within single W's. Bose-Einstein effects are modeled through the fragmentation with JETSET [14], in the LUBOEI routine [2]. This implementation of Bose-Einstein effects does not lead to a change in overall charged particle multiplicity, but does reshuffle particle momenta. The background is dominated by $q\bar{q}(\gamma)$ events, and has a small contribution from ZZ events; both of these processes are modeled with PYTHIA [14]. All Monte Carlo events are processed through a realistic L3 detector simulation.

2 Analysis

We study the charged particle multiplicity on detector level by studying the multiplicity of tracks reconstructed in the tracking chamber TEC. Tracks are accepted if they have a fitted momentum of more than 100 MeV, a distance of closest approach to the interaction point (dca) of less than 8 mm, and at least 6 hits. The obtained average track multiplicity is corrected in $qqqq$ events as well as $qq\ell\nu$ events for the background, using the track multiplicities in background Monte Carlo events. In $qq\ell\nu$ events, the lepton track is subtracted from the track list; due to ambiguities in this subtraction for $qq\tau\nu$ events, $qq\tau\nu$ events are not used in this study.

The difference in average track multiplicity in data and Monte Carlo is shown as a function of track momentum in Figure 1. The momentum of tracks in this figure ranges between 100 MeV and 50 GeV, and is binned in 10 (unequal) bins. The Monte Carlo describes the average track multiplicity well within statistics.

With the above track selection cuts, the overall average track multiplicity is 37.9 ± 0.9 for $qqqq$ events, whereas for $qq\ell\nu$ events, twice the average track multiplicity equals 38.8 ± 1.2. The average track multiplicity (c.q. twice the average track multiplicity) is shown for $qqqq$ and $qq\ell\nu$ data events as a function of track momentum in figure 2(a). Figure 2(b) shows the difference between the $qqqq$ and $qq\ell\nu$ data. In this figure, data is compared to data, thus detector effects and possible deficiencies in the detector description in Monte Carlo cancel. Within the present data statistics, no significant difference is observed.

The minimum momentum cut and the maximum dca cut in the track selection have been varied between 80 and 500 MeV, and 1 and 10 mm respectively; the actual average track multiplicity varies as a function of these cuts, but there remain no significant differences between the two samples.

Various models [6, 15] predict that colour reconnection effects are largest when the angle between a quark from one W decay and an antiquark from the decay of the other W is small. Experimentally, it is very hard to distinguish a quark from an antiquark. Nevertheless, one can define an angle α as the smallest opening angle between any pair of jets originating from different W's; these jet pairs will then either be quark-quark pairs, or quark-antiquark pairs, and one can expect the colour reconnection effects to be still present, although diluted. The jet reconstruction procedure is described in Ref [12]. The average charged track multiplicity in $qqqq$ events has been studied in data and Monte Carlo as a function of the maximum allowed value of α (α_{max}), the results are shown in figure 3(a). The selection efficiency for this channel decreases with decreasing α, as events look less and less 4-jet like, but remains sufficiently high to study such effects. In figure 3(b) $qqqq$ data events are compared to KORALW Monte Carlo $qqqq$ events (without colour reconnection effects), again no significant deviations are observed.

3 Conclusion

With the present statistics of the 1996 data sample, no evidence is seen for a significant difference in charged particle multiplicity between $qqqq$ and two $qq\ell\nu$ events. However, as the size of the data sample will increase in the near future, it remains interesting to keep watching these observables. In addition, with more data, track multiplicity distributions can be studied in more detail, including the p_T and rapidity distributions of tracks, which can be sensitive to colour reconnection effects [6, 15, 16].

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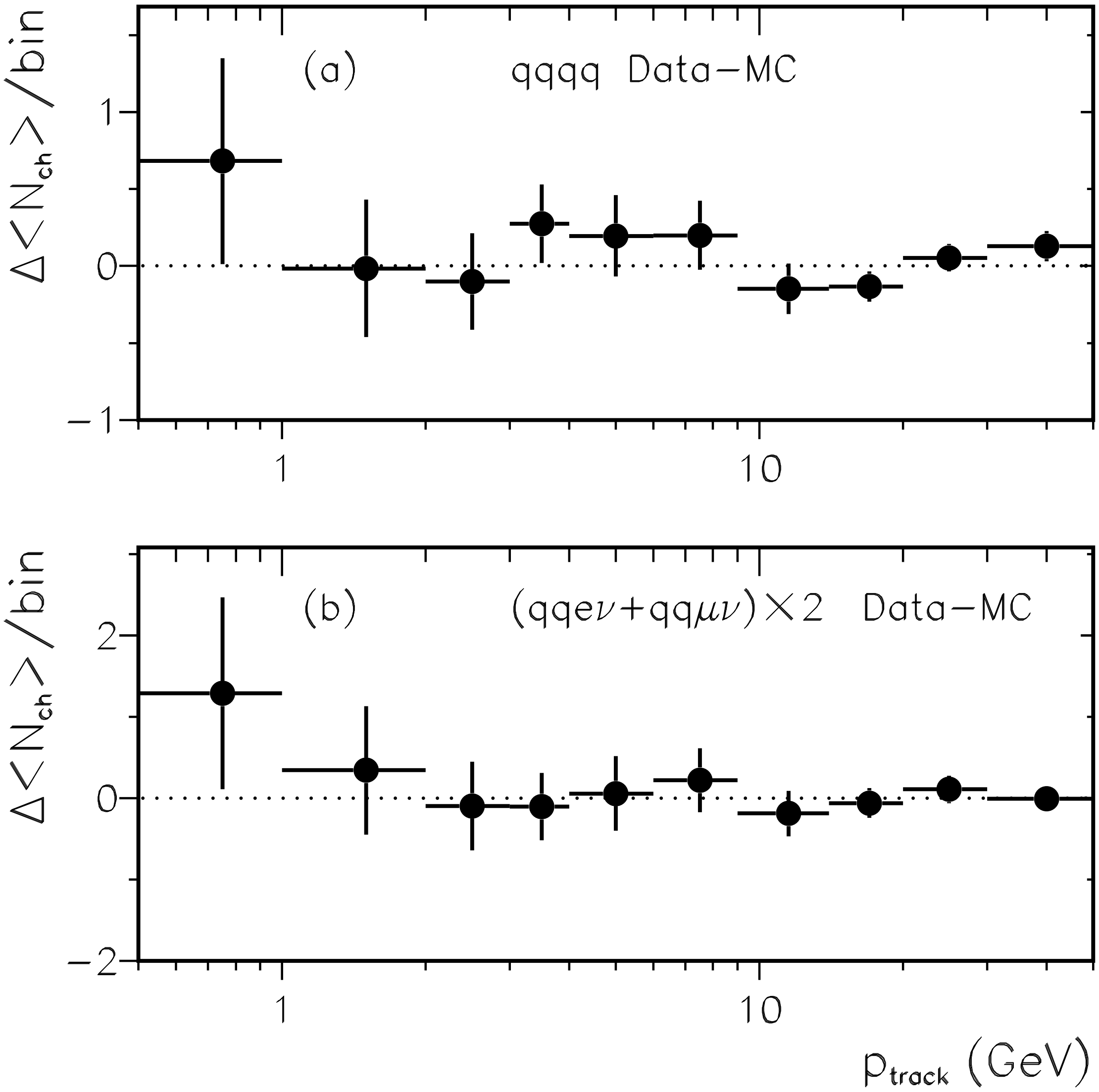

Figure 1: Difference in average track multiplicity as a function of track momentum between data and Monte Carlo for (a) $qqqq$ events, and (b) $qq\ell\nu$ events. The actual lower limit of the first bin is 100 MeV.

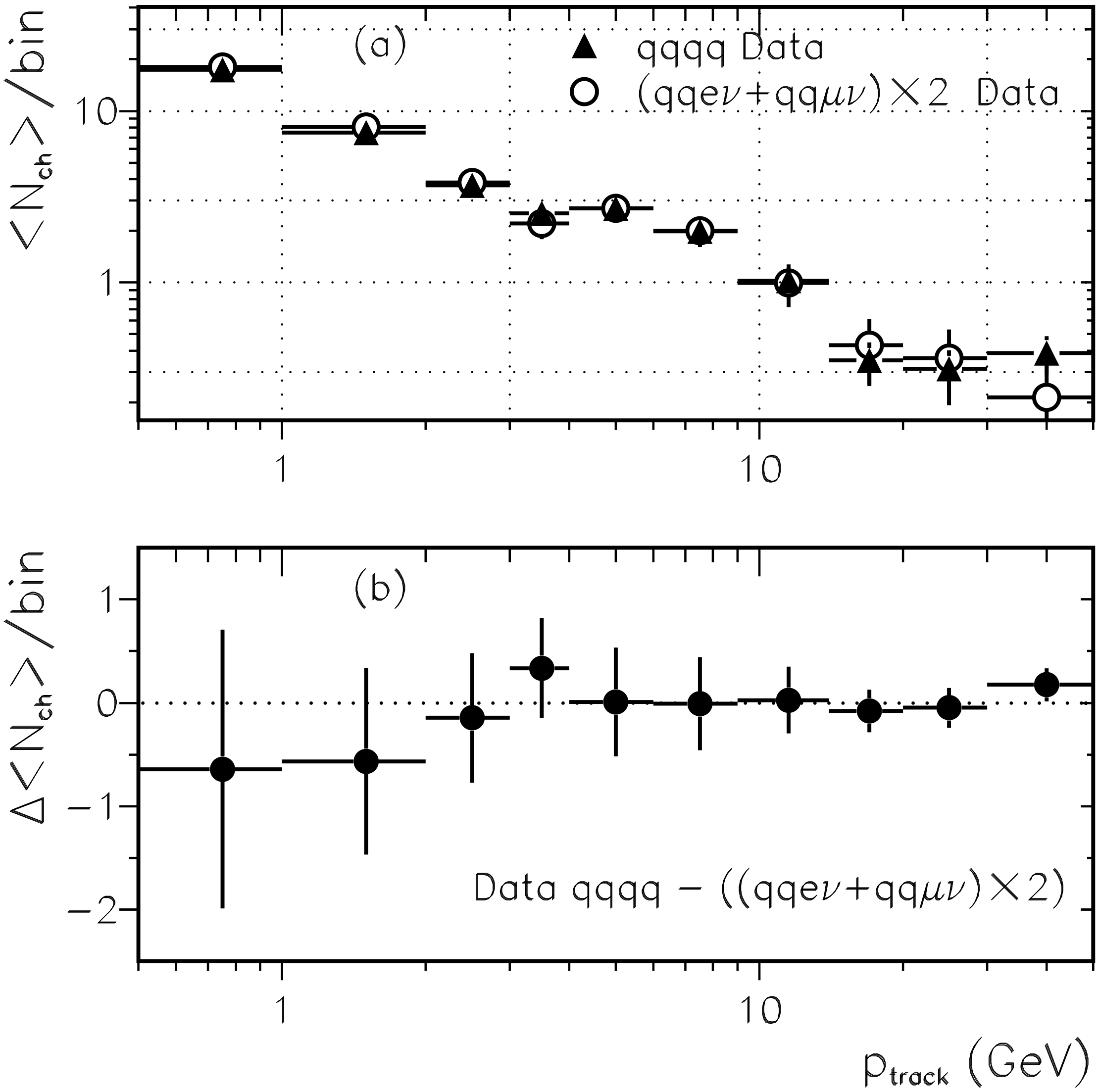

Figure 2: (a) Average track multiplicity for $qqqq$ data (triangles) and $qq\ell\nu$ data (open circles) as a function of track momentum. (b) Difference in average track multiplicity between $qqqq$ data and $qq\ell\nu$ data as a function of track momentum.

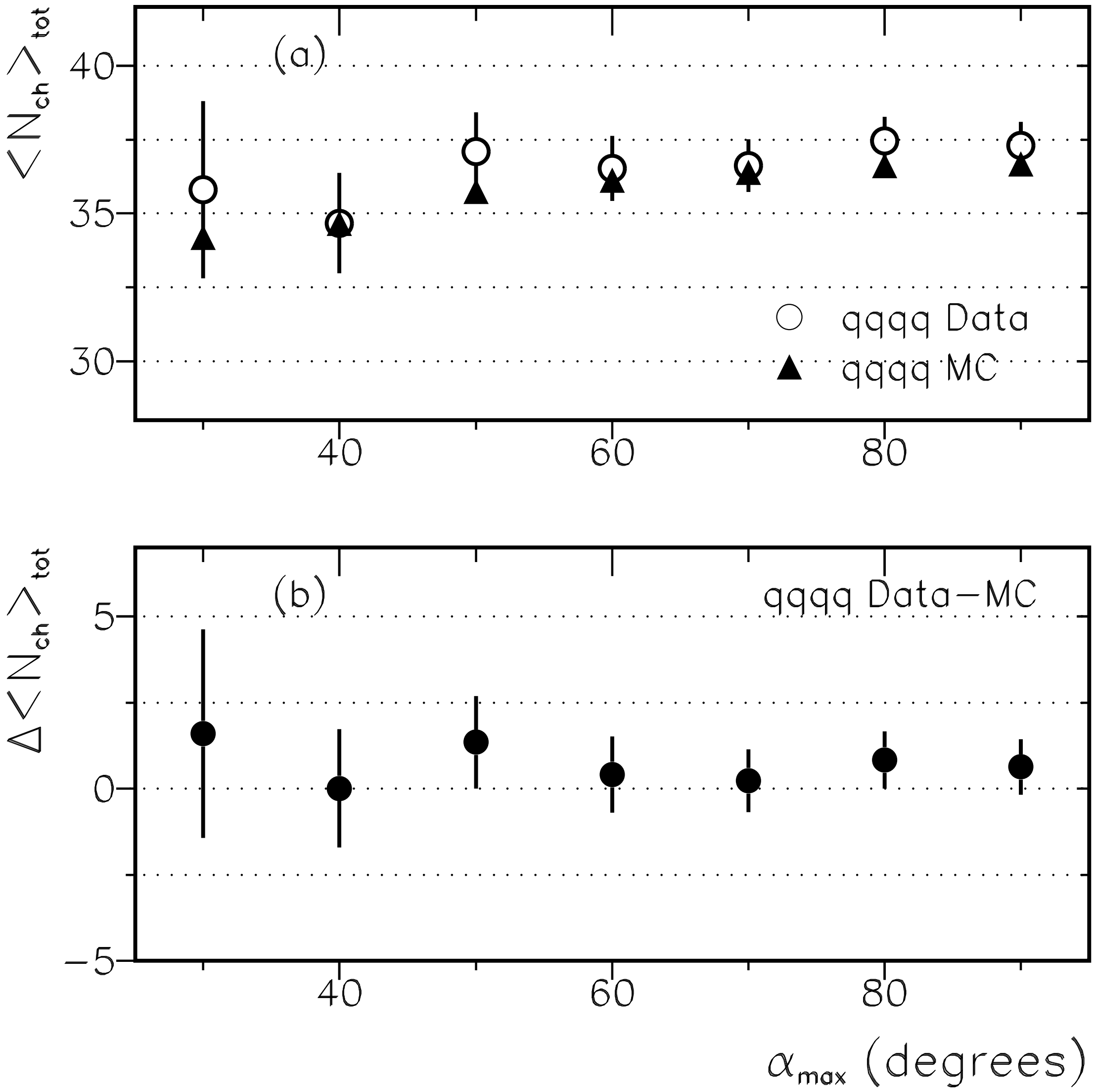

Figure 3: (a) Average total track multiplicity for $qqqq$ data and Monte Carlo as a function of the cut α_{max} on the smallest opening angle between two jets from different W's. (b) The difference between $qqqq$ data and Monte Carlo average track multiplicity as a function of α_{max}.