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A Test of QCD Coherence and LPHD using Symmetric 3-Jet Events

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Abstract

Data collected at the Z resonance using the DELPHI detector at LEP are used to determine the charged hadron multiplicity in a cone perpendicular to the event plane of symmetric three jet events. The dependence of the multiplicity on the event opening angle between the jets is predicted by QCD. The measurement constitutes a test of the colour coherence property of QCD and of LPHD.

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1 Introduction

The experimental verification of coherence effects has been important to show the validity of the analytical perturbative approach to jet physics (for a report see [1]). Beyond the early, more qualitative tests in the recent years, quantitative tests in a direct comparison of data and theoretical predictions became feasible. The so called string effect has been quantitatively tested [1, 2] and the energy evolution of the maximum of the $\xi_p = \ln \frac{p_{max}}{p_{hadron}}$ distribution is found to precisely follow the perturbative prediction [3] (for a summary of other results see [1]). Further evidence comes from the universal behaviour of the hadron momentum distributions for very low momenta which is well described by a perturbative calculation in the energy range 3 GeV - 189 GeV [4, 3]

In this brief note we present evidence for colour coherence from the evolution of the hadron multiplicity perpendicular to the event plane in mirror symmetric three jet events (the so called Y events) as a function of the opening angle between the jets.

2 Theory and Analysis

Soft radiation is sensitive to the total colour flow in the underlying hard partonic events. Consider for example a $q\bar{q}g$ event. If the gluon is collinear to one of the quarks, the colour flow is identical to the $q\bar{q}$ (two jet) case whereas if the gluon exactly recoils w.r.t. the two quarks, the colour flow corresponds to that of a gg (two jet) event. Soft radiation at large angle in this case is expected to be increased by the colour factor ratio C_A/C_F compared to the $q\bar{q}$ case. In [4] the evolution between those extreme cases has been calculated as a function of the opening angles between the jets ($\theta_{gq}, \theta_{g\bar{q}}, \theta_{q\bar{q}}$) in three jet $q\bar{q}g$ events.

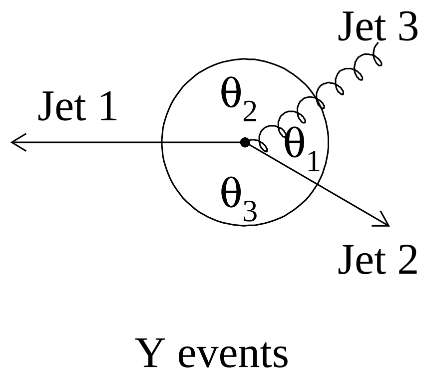

Figure 1: Mirror symmetric events

We apply this prediction to strictly mirror symmetric events (see Fig. 1) and measure the multiplicity in a cone of 30° opening angle perpendicular to the event plane (see Fig. 2). Symmetric events were selected by demanding that θ_2 should be equal to θ_3 within 2ϵ. Here ϵ is half the angular bin width of θ_1 taken to be 2.5°. The event selection, analysis techniques, and corrections are identical to those given in [5] with the exception of an additional cut $y_{cut} = 0.02$ applied using the DURHAM algorithm [6] in the selection of the

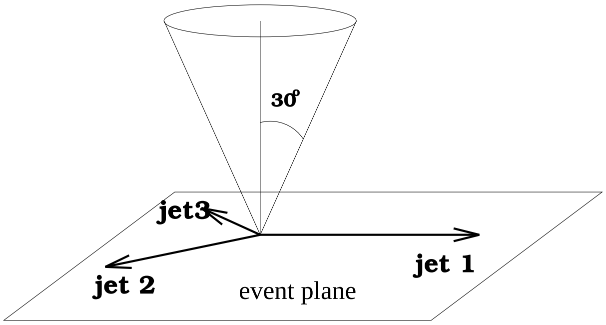

Figure 2: Definition of the cone perpendicular to the event plane

events. This cut has been applied since the prediction [4] refers to three jet events [7]. The result of this cut is equivalent to a lower angle cut of about 30°. Furthermore this cut deselects four and more jet events. As described in the second part of [5], no gluon jet identification is needed for mirror symmetric events.

Different from the proposal made in [4] we do not compare the radiation in two and symmetric three jet events but study instead the evolution of the multiplicity with opening angle θ_1 of the three jet event. This study avoids an additional dependence on a y_{cut} used for the definition of the two jet events (as discussed in [8]).

Up to a normalization constant, a, the dependence of the multiplicity on the angles is determined in [4] to be

$$\begin{aligned} N_{\perp}^{q\bar{q}g} &\propto [2 - \cos\theta_{1+} - \cos\theta_{1-} - \frac{1}{N_C^2}(1 - \cos\theta_{+-})] \qquad (1) \\ \text{with} \quad \theta_{1+} &= \theta_{qg} = \pi - \theta_1/2, \\ \theta_{1-} &= \theta_{\bar{q}g} \equiv \theta_1, \\ \theta_{+-} &= \theta_{q\bar{q}} = 2\pi - \theta_{1+} - \theta_{1-}, \end{aligned}$$

$N_C = 3$ is the number of colours. Assuming firstly that the gluon is always less energetic than the quarks, for mirror symmetric events this transforms to:

$$N_{\perp}^{q\bar{q}g} = a \cdot [2 + \cos\frac{\theta_1}{2} - \cos\theta_1 - \frac{1}{N_C^2}(1 + \cos\frac{\theta_1}{2})] \qquad (2)$$

A correction has been applied for the cases where the gluon is highly energetic analogously to [5]. Thus the comparison of Equ. 2 to the data directly tests the prediction [4] and thus the coherence of soft gluon emission from the hard underlying partons as well as the LPHD assumption for these large angle, mainly low energy tracks.

3 Result

Fig. 3 shows the measured multiplicity as a function of the angle θ_1. No data is available below $\theta_1 = 30°$ due to the presence of a y_{cut}.

Omitting this y_{cut} leads to a stronger decreasing multiplicity to smaller angles (i.e. close to the two jet region) as the y_{cut} implicitly imposed by the angle cut also reduces

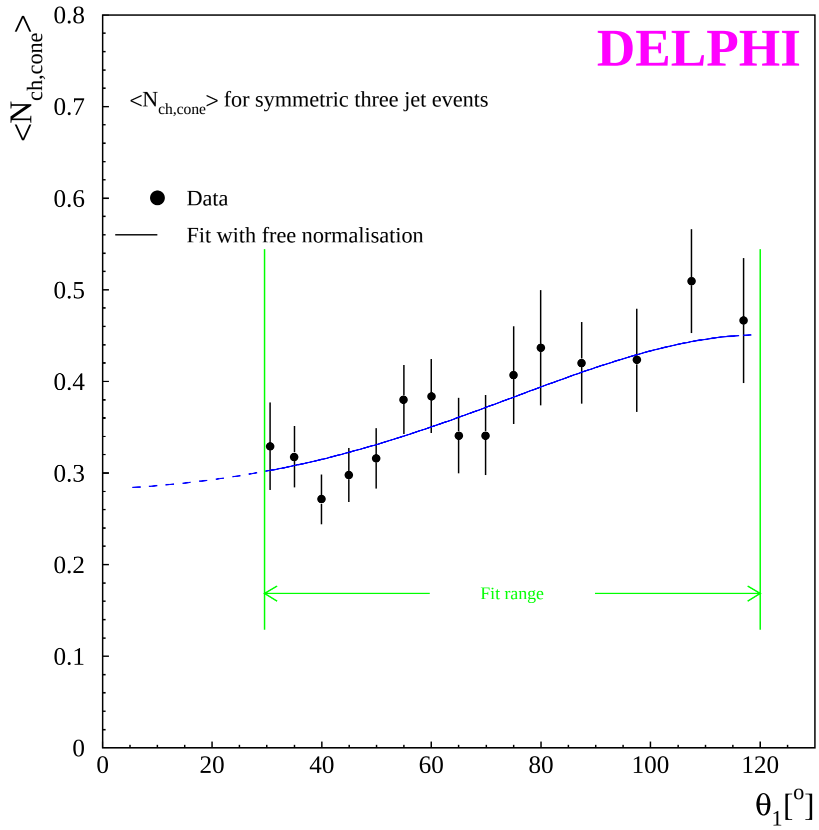

Figure 3: Cone multiplicity

the multiplicity in two jet like events [8]. The multiplicity at large angle decreases as (possibly aplanar) four and more jet events are removed from the sample.

The prediction Equ. 2 was fitted to the data. The normalization is determined to be $a = 0.28 \pm 0.01$ $\chi^2/n.d.f. = 0.6$. The theoretical expectation Equ. 2 is found to describe the behaviour of the data very well (see Fig. 3). This good agreement provides evidence for colour coherence from a direct comparison of a perturbative calculation [4] to data, i.e. independent of fragmentation models. Also the LPHD assumption is tested for the (low energetic) tracks emitted perpendicular to the event plane.

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