ANGULAR INTERMITTENCY AND ANALYTICAL QCD PREDICTIONS

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Abstract

We present a comparison of local multiplicity fluctuations in angular phase-space intervals with first-order QCD predictions. The data are based on 810k hadronic events at $\sqrt{s} \approx 91.2$ GeV collected with the L3 detector at LEP during 1994.

Recently, progress has been made to derive analytical QCD predictions for angular intermittency [1–3]. Attempts have been undertaken by the DELPHI Collaboration to compare the predictions of [1] with the data for hadronic $Z^0$ decay [4].

In this paper we extend this study and present a first quantitative comparison of the theoretical first-order QCD predictions [2,3] with the L3 data, emphasizing the behavior of normalized factorial moments of orders $q = 2, \ldots, 5$ in angular phase-space intervals.

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QCD predictions have been obtained \[2, 3\] for normalized factorial moments (NFMs) \( F_q(\Theta) = \frac{\langle n(n-1)\ldots(n-q+1) \rangle}{\langle n \rangle^q}, \) which show following scaling behavior \( F_q(\Theta) \propto (\Theta_0/\Theta)^{(D-D_q)(q-1)} \). For the one-dimensional case \((D = 1)\), \( \Theta_0 \) is the opening half angle of a cone around the jet-axis, \( \Theta \) is the angular half-width window of rings around the jet-axis centered at \( \Theta_0 \) and \( n \) is the number of particles in this window. QCD expectations for \( D_q \) are as follows \[2, 3\]:

1) In a fixed coupling regime of the Double Leading Log Approximation (DLLA), \( D_q = \gamma_0(Q)(q + 1)/q \), where \( \gamma_0(Q) = \sqrt{2C_A\alpha_s(Q)/\pi} \) is the anomalous QCD dimension calculated at \( Q \simeq E\Theta_0, \) \( E = \sqrt{s}/2, \) and \( C_A = 3 \) is the gluon color factor. \( \alpha_s(Q) \) is evaluated according to the first order QCD with \( n_f = 5 \) flavors.

2) In a running-coupling regime of DLLA, the \( D_q \) have the form

\[
 D_q \simeq \gamma_0(Q) \frac{q+1}{q} \left(1 + \frac{q^2 + 1}{4q^2}z\right) \quad (1), \quad D_q \simeq 2\gamma_0(Q) \frac{q+1}{q} \left(\frac{1 - \sqrt{1-z}}{z}\right) \quad (2),
\]

were \( z = \ln(\Theta_0/\Theta)/\ln(E\Theta_0/\Lambda) \). Expressions \( (1) \) and \( (2) \) were obtained in \[2\] and \[3\], respectively.

3) In the Modified Leading Log Approximation (MLLA), \( (1) \) remains valid, except that \( \gamma_0(Q) \) is replaced by an effective \( \gamma_0^{\text{eff}}(Q) \) depending on \( q \) \[3\].

For our comparison of the data with the theoretical predictions quoted above, we will use the following parameters: \( \Theta_0 = 25^0, \Lambda = 0.16 \text{ GeV} \). The first parameter is free. Its value is chosen to make our study comparable with the DELPHI analysis \[4\]. The value of \( \Lambda \) chosen is that found in our most recent determination of \( \alpha_s(m_Z) \) \[5\].

The comparison of the analytical QCD predictions to the data is shown in Fig. 1. The data are corrected for detector imperfections, initial-state photon radiation, Bose-Einstein correlations and Dalitz decays using Monte Carlo. The predictions lead to the saturation effects seen in the data, but significantly underestimate the observed signal for \( q = 2 \). The reason for the saturation effect seen on the QCD predictions is the dependence of \( \alpha_s(Q) \) on \( \Theta \). The fixed coupling regime (solid lines in Fig. 1) approximates the running
The analytical QCD predictions for $\Lambda = 0.16$ GeV: 1) $\alpha_s = \text{const}$; 2) DLLA (eq. (1)); 3) DLLA (eq. (2)); 4) MLLA.

coupling regime for small $z$, but does not exhibit the saturation effect seen in the data. The MLLA predictions do not differ significantly from the two DLLA result for running coupling regime.

We have varied $\Lambda$ in the range of $0.04 - 0.25$ GeV. We found that the disagreement observed is valid for relatively large values of $\Lambda$ as well as for small values (down to $\Lambda = 0.04$ GeV). In the latter case, a reasonable estimate for the second-order NFM can be reached, consistent with the DELPHI conclusion [4]. However, our analysis shows that, in this case, the theoretical higher-order NFMs overestimate the data.

Note that the disagreement for the second-order NFMs can be reduced by considering the second-order expression for $\alpha_s(Q)$ or by replacing $n_f = 3$, instead of $n_f = 5$. This leads to a decrease of the $\gamma_0(E\Theta_0)$. However, also in this case good agreement cannot be achieved for higher-order NFMs.

**Conclusion.** The analytical first-order perturbative QCD predictions are shown to be in disagreement with the local fluctuations observed for hadronic $Z^0$ decay.

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