INVESTIGATION OF BOSE-EINSTEIN CORRELATIONS IN 3 JET EVENTS WITH THE DELPHI DETECTOR

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A preliminary investigation of Bose-Einstein correlations in 3 jet events has been made by analysing the collected data at the Z^0 peak from '94 and '95 and the calibration runs during the LEP2 period from '97 to 2000. Three methods were used to extract two-particle correlation functions. No significant difference was found between quark and gluon jets for all three methods.

1 Introduction

Bose-Einstein Correlations (BEC) have been extensively investigated in e^+e^- annihilations at LEP [?]. In the classical approach [?,?] they are viewed as interference of identical bosons produced incoherently from their source. The source extensions can be deduced from the momentum-difference spectra. Both ingredients: incoherence and symmetrization of the wave function are needed in their derivation. In a more recent development, the Lund string picture [?] offers an alternative approach for e^+e^- reactions. It has been shown in [?] that in this coherent scenario, by making a minimum of assumptions and without introducing extra hadronisation parameters, the predicted source sizes of particle production are typically of the order of 1 fm, in agreement with most experimental observations. Both scenarios differ in predicting whether BEC between particles coming from different W bosons in $e^+e^- \rightarrow W^+W^-$ events is possible. While in the classical approach they are unavoidably expected, in the Lund string picture they are predicted to be absent if there is no color (re)connection between the strings. Much effort has been spent to test and distinguish between these two predictions experimentally [?]. However, since the measurements are statistically very limited, probably no strong statement can be made.

According to the Lund string picture there exists another reaction where two strings (color flux tubes) are produced together, namely in 3-jet events

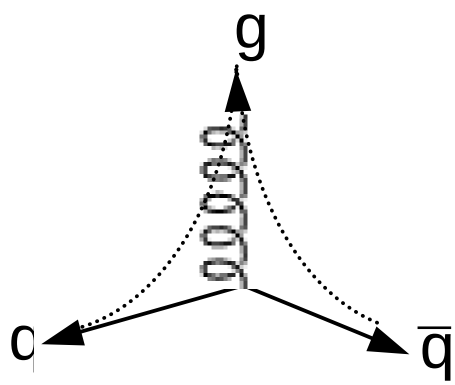

Figure 1. Lund string picture of a 3 jet Z^0 decay.

$e^+e^- \to Z^0 \to q\bar{q}g$ (see sketch in Fig. 1). If the two strings (dotted lines in Fig. 1) hadronise independently without color connection, BEC are expected to be weakened because there will be no correlations between particles stemming from different strings - in analogy to the situation with W-pair production [?]. This is again at variance with the classical picture. In both approaches not only the radii but also the strengths measured in gluon and quark jets could be different.

In this study we will investigate whether BEC manifests itself differently in gluon jets and quark jets. In case of an incoherent manifestation of inter-string BEC, an extra component with bigger radius should be observed in gluon jets. About a possible manifestation of a coherent type of inter-string BEC, no statements can be made. For this study the 1994 and 1995 LEP1 data set taken by the DELPHI detector was analysed, together with the calibration runs taken in the years 1997 till 2000, corresponding to a 3 jet event sample of respectively 236489 and 38166 selected events. Our Monte Carlo reference samples without BEC were statistically limited and corresponded to respectively 130244 and 69189 events for the LEP1 and LEP2 period.

2 Correlation Functions

In most cases, the Bose-Einstein effect is investigated by means of two-particle correlation functions, although there are other methods which prove to be more accurate [?]. In this note we define the two-particle correlation function as the ratio of the two particle density of the data (or signal MC) with the

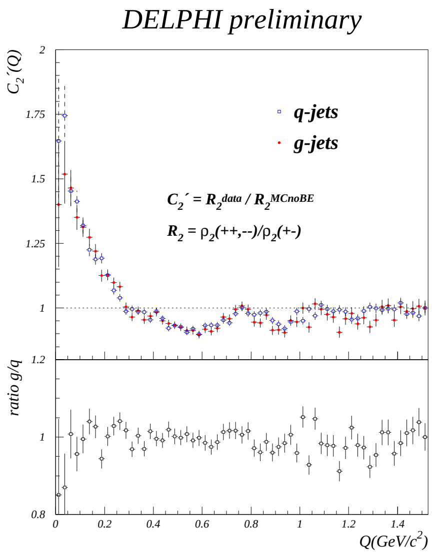

Figure 2. Comparison of the $C\,'_2(Q)$ for the LEP1 datasample between gluon jets and light quark jets. The ratio between gluon and quark jets is shown below.

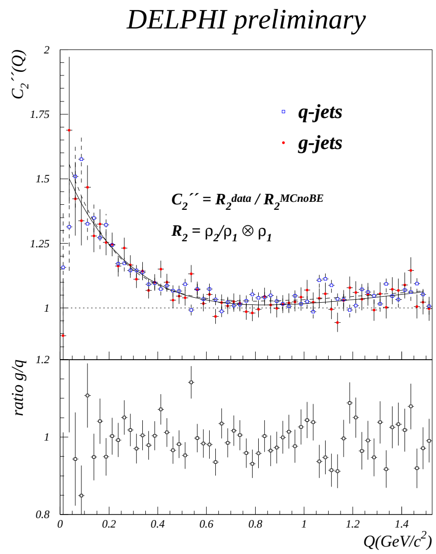

Figure 3. Comparison of the $C\,''_2(Q)$ for the LEP2 datasample between gluon jets and light quark jets. The ratio between gluon and quark jets is shown below.

two particle density of a reference sample which does not include the Bose-Einstein effect. The two-particle densities [?] are calculated as a function of the Lorentz-invariant four momentum difference $Q = \sqrt{-(p_1 - p_2)^2}$, where p_1 and p_2 are the four-momenta of the two particles:

$$\rho_2(Q) = \frac{1}{N_{ev}} \frac{dn_{\text{ pairs}}}{dQ}. \tag{1}$$

Here n_{pairs} stands for the number of like-sign (unlike-sign) particle combinations. Three approaches were chosen to construct the two-particle correlation function. First a MC sample without any BEC was chosen to construct C_2:

$$C_2(Q) = \frac{\rho_2(Q)_{\text{ signal}}}{\rho_2(Q)_{\text{ MC no BEC}}}. \tag{2}$$

This method is obviously the simplest, but one has to rely entirely on the fact that the Monte Carlo reference sample has to reproduce all single particle spectra and event shapes perfectly. Secondly, unlike sign particle pairs were

Table 1. Fit results of $C_2''(Q)$ for the LEP1 data

Parameter	udsc	gluon
λ	0.685 ± 0.046	0.681 ± 0.063
r	0.754 ± 0.064	0.697 ± 0.067
δ	0.126 ± 0.027	0.228 ± 0.039
N	0.833 ± 0.025	0.752 ± 0.030
χ^2	1.5 (55 ndf)	1.0 (55 ndf)

chosen as reference, but a double ratio with MC without BEC was chosen to correct for residual additional correlation effects.

$$C\,'_2(Q) = \frac{\rho_2(Q)_{\text{ like-sign}}/\rho_2(Q)_{\text{ unlike-sign}}}{\rho_2(Q)_{\text{ MC no BEC like-sign}}/\rho_2(Q)_{\text{ MC no BEC unlike-sign}}}. \quad (3)$$

This approach has the advantage that data is essentially compared with data, although reflections of resonances and detector effects, certainly for particles close in momentum-energy space, can be different for like-sign and unlike-sign pairs. The last approach made use of a mixing technique, mixing particles from several events. Again a double ratio with a MC sample without BEC was chosen to correct for possible biases due to the mixing procedure:

$$C\,''_2(Q) = \frac{\rho_2(Q)_{\text{ signal}}/\rho_1(Q) \otimes \rho_1(Q)}{\rho_2(Q)_{\text{ MC no BEC}}/\rho_1(Q) \otimes \rho_1(Q)_{\text{ MC no BEC}}}. \quad (4)$$

This method compares like-sign pairs from data with mixed like-sign pairs from data, including most detector effects. One has to correct with MC however to take into account detector resolution for close particle pairs and other dynamical correlations.

3 Analysis

Since the two-particle correlation functions of gluon jets were compared with those for jets coming from a light quark, an anti b-tag [?] was applied to the event, reducing the b quark contamination to 2%. The lowest energetic jet was chosen as being the gluon jet, while the highest energetic jet was chosen to be the quark jet The purities of these taggings were calculated using the first order QCD matrix element [?], and amounted to 78% by requiring that the energy of the lowest energetic jet did not exceed 15 GeV. The comparison of the two-particle correlation function for light quark and gluon jets was made. Two examples are shown in Figs. 2 and 3. Fig. 2 shows the

Table 2. Fit results of $C_2''(Q)$ for the LEP2 calibration runs

Parameter	udsc	gluon
λ	0.766 ± 0.072	0.82 ± 0.087
r	0.94 ± 0.10	0.72 ± 0.088
δ	0.085 ± 0.037	0.148 ± 0.061
N	0.945 ± 0.037	0.867 ± 0.057
χ^2	1.1 (55 ndf)	0.9 (55 ndf)

comparison of the correlation functions $C\,'_2(Q)$ for the LEP1 dataset, using unlike-sign combinations as a reference sample. Fig. 3 shows the comparison of the correlation functions $C\,''_2(Q)$ for the LEP2 dataset, using mixed tracks as a reference sample. All three methods as described in section 2 were used for both datasets. All comparisons between light quark and gluon jet correlation functions showed no excess at low Q values in gluon jets wrt. quark jets, which would indicate an extra component with bigger radius. Finally the $C_2''(Q)$ distributions were parametrised in the region 0.025 $GeV/c^2 <$ Q $<$ 1.5 GeV/c^2, with an exponential function and a long range correlation term:

$$C\,''_2(Q) = N(1 + \lambda e^{-rQ})(1 + \delta Q) \tag{5}$$

The results of the fit are summarized in Table 1 and Table 2. All errors are statistical only and are not corrected for bin-to-bin correlations. Again, the values of λ and r indicating the strength and the radius of the correlation source for both datasets are compatible with each other within their errors.

4 Conclusions

Differences in the two-particle correlation functions were investigated in large event samples, using the data collected in '94 and '95 and during the calibration runs of the LEP2 period. Using 3 different methods, no extra component was found in the two-particle correlation function for gluon jets wrt. light quark jets. All results are preliminary. We would like to thank E. De Wolf, G. Gustafsson, K. Hamacher and M. Siebel for useful hints and discussions.