Final Results on Bose-Einstein Correlations of π^0 Pairs from Hadronic Z^0 Decays

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Due to the experimental difficulties in photon and π^0 reconstruction, only one study [1] exists for Bose-Einstein correlations (BEC) in π^0 pairs, even though they are crucial and complementary to the available measurements in the charged pion system in order to provide direct tests of the fragmentation models. The string fragmentation model predicts a larger BEC strength or chaoticity and a smaller effective radius of the emitting source for π^0 pairs compared to $\pi^\pm$ pairs while the cluster fragmentation model predicts the same source strength and size. However, neither model of primary hadron production has a mechanism to allow BEC between π^0s produced in different strong decays. This analysis [2] presents a study of BEC in π^0 pairs using the full hadronic event sample, i.e. about four million events, collected at centre-of-mass energies at and near the Z^0 peak by the OPAL detector at LEP. A sample of π^0 mesons is reconstructed using photon pairs measured in the barrel part of the electromagnetic calorimeter, with an average purity of 80%. The correlation function is defined as the ratio, $C(Q) = \frac{\rho(Q)}{\rho_0(Q)}$, where Q is a Lorentz-invariant variable expressed in terms of the two π^0 four-momenta p_1 and p_2 via $Q^2 = -(p_1-p_2)^2$, $\rho(Q)$ is the measured Q distribution of the two π^0s and $\rho_0(Q)$ is a reference distribution which should, in principle, contain all the correlations included in $\rho(Q)$ except the BEC. The $\rho_0(Q)$ distribution is constructed using an event mixing method [2]. This method offers the advantage of being independent of Monte Carlo simulations, since $C(Q)$ can be obtained from data alone. According to the string fragmentation model implemented in JETSET, the selected sample consists of about 97.9% of mixed pion-pairs from different hadron decays, 2% of pairs belonging to the decay products of the same hadron and only 0.1% prompt pairs from the string break-ups. Similarly, using the cluster fragmentation model implemented in HERWIG, the selected sample consists of 97% of pairs from different hadron decays, 2.3% belonging to the decay products of the same hadron and only 0.7% originating directly from cluster decays. Thus, our analysis has no sensitivity to direct pion pairs originating from string break-up or cluster decay.

The measured correlation distribution $C(Q)$, corrected for background and resonance contributions, is parametrised using the Fourier transform of the expression for a static sphere of emitters with a Gaussian density: $C(Q) = N(1 + \lambda \exp(-R^2Q^2))(1 + \delta Q + \epsilon Q^2)$. Here λ is the chaoticity of the correlation which equals zero for a fully coherent (non-chaotic) source and one for a chaotic source, R is the radius of the source, and N a normalisation factor. The empirical term, $(1 + \delta Q + \epsilon Q^2)$, accounts for the behaviour of the correlation function at high Q due to any remaining long-range correlations. The $C(Q)$ distribution for data is shown in Figure 1 as the points with corresponding statistical errors, and the smooth curve is the fitted correlation function in the Q range between 0 and 2.5 GeV. A clear BEC enhancement is observed in the low Q region of the distribution. Potential sources of systematic error are investigated. In each case the effect on the parameters R and λ and their deviations with respect to the standard analysis are estimated. The total systematic errors are obtained from quadratically adding the deviations from the central value. The final results are: $\lambda = 0.55 \pm 0.10 \pm 0.10$ and $R = (0.59 \pm 0.08 \pm 0.05)$ fm., which give clear evidence for the presence of Bose-Einstein correlations of π^0 pairs produced in hadronic Z^0 decays.

In order to construct a reference sample with the event mixing method, this analysis is restricted to well defined back-to-back two-jet events. Furthermore, in order to remove π^0s not originating from the primary interaction vertex, the considered momentum phase space is restricted to $p_{\pi^0} > 1$ GeV. Pions from strong decays constitute the dominant part of our sample of reconstructed π^0 pairs and this analysis is not sensitive to prompt boson pairs produced directly from the string or cluster decays. As an important outcome, we establish for the first time, that Bose-Einstein correlations exist essentially between π^0 pairs in which each π^0 is a strong decay product of a different hadron. So far such correlations are only implemented as approximate "post-fix" corrections in the known fragmetaion model; a full quantum-level treatment of interference and coherence effects does not yet exist.

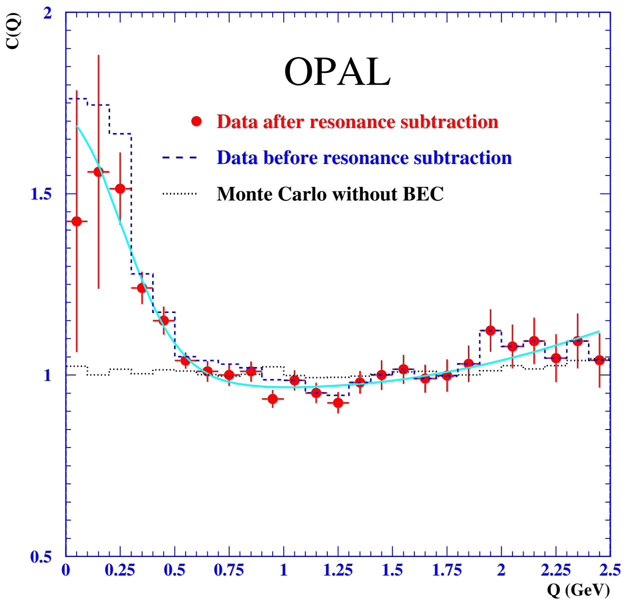

Fig. 1: The correlation distribution $C(Q)$ as measured for OPAL data. The smooth curve is the fitted correlation function. See [2] for a more detailed explanation.

References

[1] L3 Collaboration, P. Achard *et al.*, Phys. Lett. **B524** (2002) 55
[2] OPAL Collaboration, G. Abbiendi *et al.*, CERN-EP/2003-005, accepted by Phys. Lett. B. march 2003.