NEW BOSE-EINSTEIN RESULTS FROM L3

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In hadronic Z decays, we compare Bose-Einstein correlations in π^0 pairs with those in identical charged pion pairs. We also measure Bose-Einstein correlations in triplets of identical charged pions. From the first study, the source radius is found to be smaller for π^0-π^0 than for $\pi^\pm$-$\pi^\pm$, as would be expected, *e.g.*, in a string model. However, the second study shows that the data are consistent with the pion production being completely incoherent. Both studies use data collected by the L3 collaboration at LEP.

1 Introduction

Two studies of Bose-Einstein correlations (BEC) are reported using hadronic Z decays detected by L3 at LEP. The first uses two-particle BEC to compare the size of the emission region of π^0 to that of $\pi^\pm$. The second uses three-particle BEC to investigate the incoherence of pion emission. Neither of these topics has previously been investigated in e^+e^- interactions.

2 Comparison of BEC in π^0-π^0 and $\pi^\pm$-$\pi^\pm$

Since this work is completed and the paper accepted for publication,[1] I only summarize it briefly here. The analysis uses a data sample of about 2 million hadronic Z decays corresponding to about 78 pb^{-1}. Making use of the correlation function,

$$R_2(Q) = \frac{\rho_2(Q)}{\rho_0(Q)} \tag{1}$$

where ρ_2 is the number density of pion pairs for the data and ρ_0 is the number density expected in the absence of BEC, both as a function of the four-momentum difference, Q, between the two pions making up the pair. Under the simplified assumptions of a static, spherical source with a Gaussian density, R_2 can be parametrized as

$$R_2(Q) = \mathcal{N}(1 + \alpha Q)(1 + \lambda e^{-Q^2R^2}) \tag{2}$$

where $\mathcal{N}(1 + \alpha Q)$ serves as normalization, taking into account some long-range correlation in Q. The factor λ is equal to unity if pion production is

incoherent and all pions come from the hypothesized source. The latter is certainly not the case because of long-lived resonances, and usually λ is found to be less than unity. With event and particle selection kept as identical as possible for π^0-π^0 and $\pi^\pm$-$\pi^\pm$, and using JETSET[2] without any BEC simulation to determine ρ_0, fits of (2) result in a smaller radius for π^0-π^0 than for $\pi^\pm$-$\pi^\pm$:

$$R_{\pm\pm} - R_{00} = 0.15 \pm 0.08 \pm 0.07 \text{ fm}$$
$$R_{00} \ / \ R_{\pm\pm} = 0.67 \pm 0.16 \pm 0.15$$

3 Three-particle BEC

This analysis is preliminary and at present makes use of a sample of about 1 million hadronic Z decays. Similarly to the two-particle case, we use the correlation function,

$$R_3(Q) = \frac{\rho(Q_3)}{\rho_0(Q_3)} \tag{3}$$

where $Q_3^2 = M_{123}^2 - 9m_\pi^2 = Q_{12}^2 + Q_{23}^2 + Q_{13}^2$ with Q_{ij} the four-momentum difference between the two pions i and j of the triplet. There are contributions to R_3 from two-particle BEC and from genuine three-particle BEC. With G the Fourier transform of the source density,

$$R_2(Q_{ij}) = 1 + \lambda|G(Q_{ij})|^2 \tag{4}$$
$$R_3^{\text{non-gen}}(Q_3) = 1 + \lambda\left(|G(Q_{12})|^2 + |G(Q_{23})|^2 + |G(Q_{13})|^2\right) \tag{5}$$
$$R_3^{\text{gen}}(Q_3) = 1 + 2\lambda^{1.5}\,\text{Re}\{G(Q_{12})G(Q_{23})G(Q_{13})\} \tag{6}$$
$$R_3(Q_3) = R_3^{\text{non-gen}}(Q_3) + R_3^{\text{gen}}(Q_3) - 1 \tag{7}$$

Note that R_3^{gen} depends on the phase of G, whereas R_2 and $R_3^{\text{non-gen}}$ do not. With $G(Q_{ij}) = |G|\exp(\imath\phi_{ij})$ and $\phi = \phi_{12} + \phi_{23} + \phi_{13}$, we see from (4) and (6) that

$$\cos\phi(Q_3) = \frac{R_3^{\text{gen}}(Q_3) - 1}{2\sqrt{(R_2(Q_{12}) - 1)(R_2(Q_{23}) - 1)(R_2(Q_{13}) - 1)}} \tag{8}$$

Departure of $\cos\phi$ from unity occurs if the pion source is asymmetric of if the pion emission is (partially) coherent. Genuine three-particle BEC have previously been observed in hadronic Z decay.[3] Our interest here is therefore mainly to investigate whether $\cos\phi = 1$. To measure $\cos\phi$, we must first measure R_2 using (1), $R_3 = \frac{\rho_3}{\rho_0}$ and $R_3^{\text{non-gen}} = \frac{\rho_1\rho_2}{\rho_0}$ from which R_3^{gen} is found using (7). Here ρ_n refers to the n-particle density and ρ_0 the corresponding density of the 'reference sample', *i.e.*, a sample without BEC. Then $\cos\phi$ is found from (8).

The reference sample is constructed using a mixing technique and corrected by Monte Carlo for non-BEC correlations.[4] Corrections for detector acceptance and efficiency, also determined from Monte Carlo, are applied to the data. There are six different combinations of Monte Carlo programs used to determine these corrections. Differences in results using the different combinations are the dominant contribution to the systematic uncertainty. Further, the Q-distributions are corrected for Coulomb repulsion by weighting each pair of pions by the inverse Gamow factor.[5] At very small Q, statistics are small and the corrections are large; accordingly the regions $Q_3 < 0.16\,\mathrm{GeV}$ and $Q < 0.08\,\mathrm{GeV}$ are not used.

The resulting distributions of R_2 and R_3^{gen} are shown in Figs. 1 and 2, respectively. As found in previous studies,[4] the Gaussian parametrization (2) of R_2 is found to be inferior to a parametrization using the Edgeworth expansion about a Gaussian,

$$R_2(Q) = \mathcal{N}(1+\alpha Q)\left[1+\lambda e^{-Q^2R^2}(1+\kappa H_3(\sqrt{2}RQ)/6)\right] \qquad (9)$$

where H_3 is a 3$^{\mathrm{rd}}$ order Hermite polynomial and κ a free parameter. Also R_3^{gen} is found to be better fit by an Edgeworth expansion than by a Gaussian parametrization. The result of this Edgeworth fit is shown in Fig. 2. Also shown is the expectation calculated from the result of the fit to R_2 together with the assumption $\cos\phi = 1$. It is seen that R_3^{gen} is well described by this assumption. The values of λ and R found in the Edgeworth fits are shown in Table 1. The values found in these fits agree. Fig. 3 shows the distribution of $\cos\phi$ found bin-by-bin from the Edgeworth fit to R_2 and the distribution of R_3^{gen}. It is seen that $\cos\phi$ is consistent with unity over the entire range of Q_3.

Table 1. Results of the Edgeworth fits to R_2 and R_3^{gen}.

fit to	λ	R (fm)
R_2	$0.72 \pm 0.02 \pm 0.07$	$0.73 \pm 0.02 \pm 0.04$
R_3^{gen}	$0.72 \pm 0.04 \pm 0.07$	$0.72 \pm 0.04 \pm 0.05$

4 Conclusions

The radius of the pion source found in BEC studies of neutral pions is smaller than that of charged pions. Studies of three-particle BEC show agreement with completely incoherent pion production. Naively, the first result is expected in string models, but the second result is surprising.

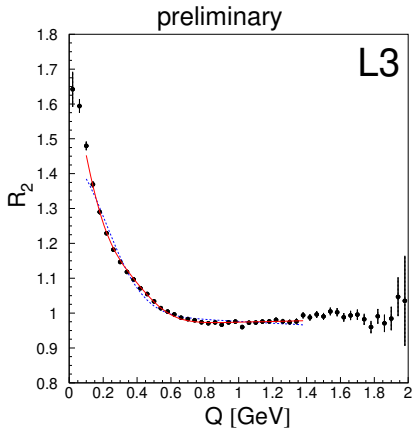

Figure 1. Distribution of R_2. The dashed (full) line is the result of a fit using the Gaussian (Edgeworth) parametrization.

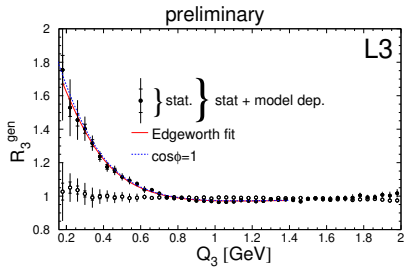

Figure 2. Distribution of $R_3^{\rm gen}$. The full line is the result of a fit using the Edgeworth parametrization, while the dashed line is the expectation from the Edgeworth fit to R_2 and the assumption $\cos\phi = 1$. The open circles are the result of analyzing a MC sample without BEC as though it were data.

Acknowledgments

The comparison of BEC in π^0-π^0 and $\pi^\pm$-$\pi^\pm$ was done by M.P. Sanders[1] and the study of three-particle BEC by J.A. van Dalen.[6]

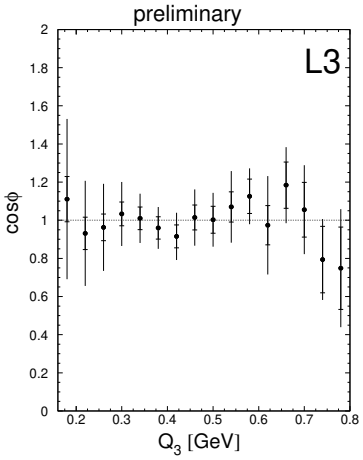

Figure 3. Distribution of $\cos\phi$.

References

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