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MULTIPION CORRELATIONS IN e^+e^- ANNIHILATION AT SPEAR

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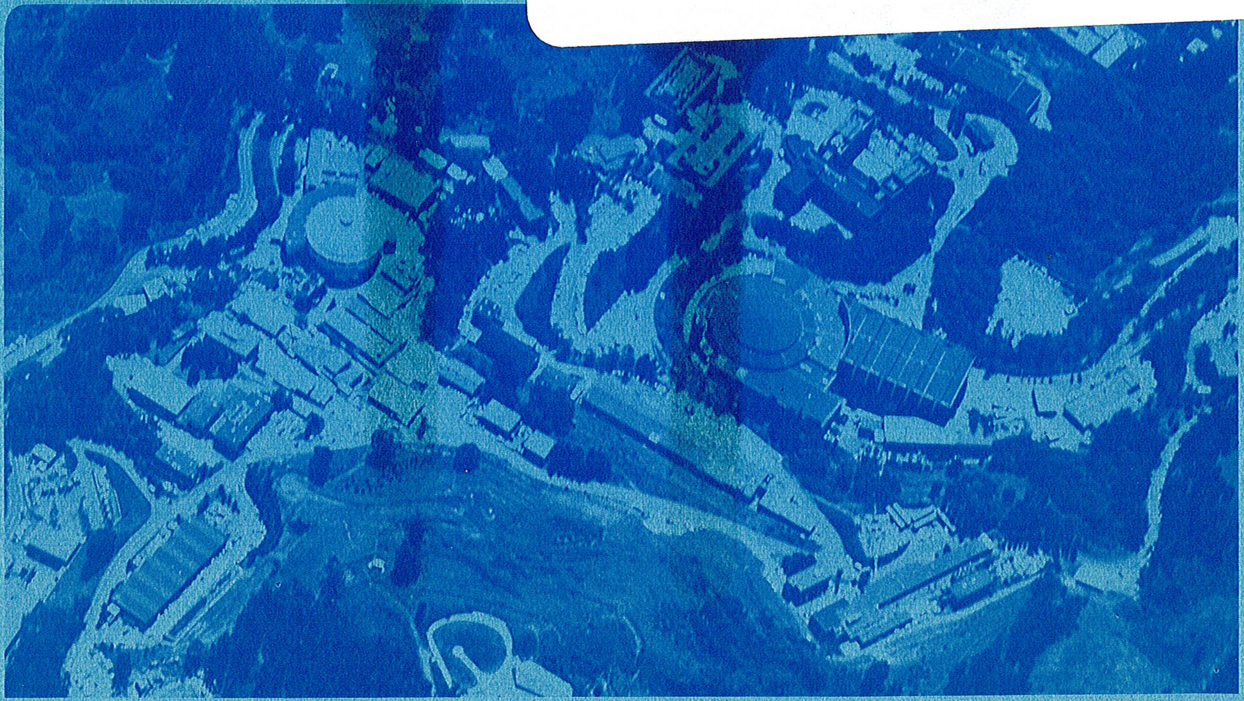

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MULTIPION CORRELATIONS IN e^+e^- ANNIHILATION AT SPEAR†

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A comparison between like charge and unlike charge particle distributions allow the study of both Bose-Einstein effects and of inclusive resonance production. In this paper I will present some results on the first of these topics.‡

- The data presented here is based on 1.3×10^6 events at the ψ/J and a much smaller number obtained in the $E_{cm} = 4-7$ GeV region in the Mark II detector operating at SPEAR.
- The Bose-Einstein effects are obtained in terms of ratios R^{--}_{+-} ($\equiv R^L_U$) of distributions of the Lorentz invariant quantities[1] $Q^2(12) = M^2(12) - (m_1+m_2)^2$ for two particles and the corresponding three-particle quantity: $Q^2(123) = M^2(123) - (\sum_{i=1}^{3} m_i)^2$; viz.,

$$R^{--}_{+-} = \left(\frac{1}{\sigma_{--}}\frac{d\sigma^{--}}{dQ^2(12)}\right)\Big/\left(\frac{1}{\sigma_{+-}}\frac{d\sigma^{+-}}{dQ^2(12)}\right)$$

  with an analogous definition for R^{---}_{+--} for three-particle correlations. Here M(12), M(123) are effective masses for two and three particles respectively, m_i are rest masses of the particles.
- The Bose-Einstein enhancement in R can be expressed[1] as $1+\alpha e^{-\beta Q^2}$. Here α measures the degree of chaoticity[2,3] of the production process. For two pions $\alpha \to 1$ corresponds to maximal chaoticity, while β corresponds to an effective radius (squared) of the interaction volume from which the pions originate. Alternately the three-dimensional radius r_o and the time development $c\tau_o$ are sometimes treated independently.[4]

Results at the $\psi/J(3.1)$ Resonance

- R^{--}_{+-} for identical and non-identical boson pairs.
  The high-statistics data sample available at the ψ/J allows a clear demonstration that the enhancement is present for identical particles (two pions) and not for non-identical particles ($K\pi$). Figure 1 shows R^{--}_{+-} for $Q^2(\pi\pi)$ and $Q^2(K\pi)$ distributions integrated over all other variables. These distributions are fitted with $(1+\alpha e^{-\beta Q^2})\gamma$ where γ is a normalizing constant for the local region considered. This fit is made in regions which avoid known resonances (K^o region, ρ^o region, etc.) and spurious effects (converted γ rays yield e^+e^- pairs which are partly misidentified as $\pi^+\pi^-$ pairs).* Thus only the Q^2 regions 0.02 - 0.15, 0.19 - 0.38 are used for the fits.

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*Furthermore Coulomb repulsion effects which also occur in the very low Q^2 region have been ignored here.

‡Results on S^* resonance: G. Gidal et al., LBL-13239, submitted to Phys. Lett.

Results:	α	β $(\text{GeV}/c)^{-2}$	r (Fermi)
$\pi\pi$	0.71 ± 0.03	18.7 ± 0.8	0.85 ± 0.02
$K\pi$	0.16 ± 0.04	10.0 ± 4.1	0.62 ± 0.12

Conclusion: The observed enhancement occurs for identical particles only; it is not the result of some reflection of resonances.*

- Dependence on $\delta = ||\bar{p}_1| - |\bar{p}_2||$.
  If we define R in terms $(1/\sigma)(d^2\sigma/dQ^2(12)d\delta)$, we can study the maximal Bose-Einstein effect as $\delta \to 0$. Figure 2 shows R^{--}_{+-} for several δ intervals as shown.
  Conclusion: The corresponding fits to α and β are given in Table I and show that as $\delta \to 0$, $\alpha \to 1$ indicating maximal chaoticity at the ψ/J.
- Three-pion correlations.
  Figure 3 shows R^{---}_{+--} at the ψ/J. We obtain a very striking enhancement at low $Q^2(123)$ values. Here we must remember that ideally we would like to study R^{---}_{+-o} and that R^{---}_{+--} contains an enhancement in the denominator as well as in the numerator. The total enhancement factor expected for R^{---}_{+-o} can be approximated by the product of $(1+\alpha_2)(1+\alpha_3')$ where α_2 is the two-body value for $\psi \to 3\pi^+ + 3\pi^- + X$ and α_3' is the value from the fit to R^{---}_{+--} (see Table II). The total enhancement of ~ 6 at the ψ/J again indicates maximal chaoticity.

Results from the $E_{cm} = 4-7$ GeV Region

This is the region where jet formation begins and the e^+e^- annihilation is believed to proceed via $q\bar{q}$ rather than via ggg as at the ψ/J. Table II gives the fits to R^{--}_{+-} and R^{---}_{+--} for this region (figure not shown).

Conclusion: There is a dramatic decrease in the enhancement between ψ/J and the $4-7$ GeV region. Whether this represents a dynamic effect[3] or a decrease in chaoticity (more coherence) is not clear at present. It will be interesting to learn whether the Υ will behave like the ψ/J or not. We also note that r differs markedly for the two- and three-body system but is not very different on and off the ψ/J resonance.[5]

References

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2. G. N. Fowler and R. M. Weiner, Phys. Lett. 70B, 201 (1977).
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*The small enhancement ($\alpha = 0.16$) for the $K\pi$ system may be due to feedthrough because of K-π misidentification, although a small $I = 3/2$ effect cannot be ruled out.

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5. G. Cocconi, Phys. Lett. 49B, 459 (1974) and private communication.

Table I. Results from fits of $(1+\alpha e^{-\beta Q^2})\gamma$ to the $\pi\pi$ data at the $\psi/J(3.1)$ for various δ regions.

δ (GeV/c)	α	β $(GeV/c)^{-2}$	r (Fermi)
< 0.1	0.94 ± 0.01	22.2 ± 0.2	0.93 ± 0.01
0.1, 0.2	0.71 ± 0.03	16.0 ± 1.2	0.79 ± 0.03
0.2, 0.3	0.55 ± 0.04	12.6 ± 1.7	0.70 ± 0.05
> 0.3	0.44 ± 0.05	10.5 ± 2.5	0.64 ± 0.07

Table II. Parameters from Bose-Einstein correlation fits as a function of E_{cm} for $3\pi^+ + 3\pi^- + X$ final states.

	α_2	r_2 (Fermi)	α_3'	r_3 (Fermi)	$(1+\alpha_2)(1+\alpha_3')$
$\psi/J(3.1)$	0.89 ± 0.03	0.78 ± 0.02	2.33 ± 0.06	0.49 ± 0.003	6.2 ± 0.14
4 - 7 GeV	0.52 ± 0.06	0.77 ± 0.08	1.09 ± 0.11	0.39 ± 0.04	3.3 ± 0.3

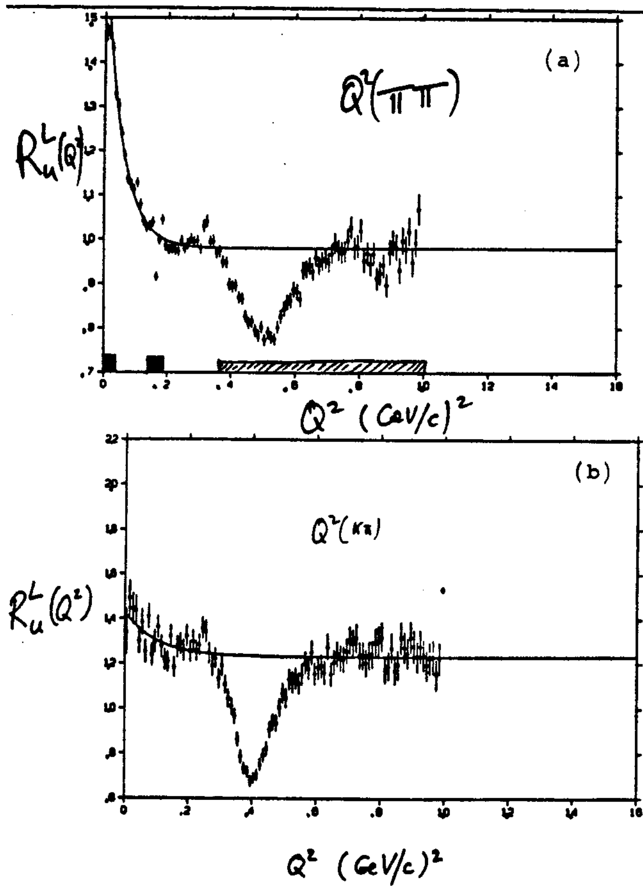

Fig. 1. The R_U^L distribution for $\pi\pi$ and $K\pi$ systems as function of Q^2 at the ψ/J. The shaded regions along the x-axis in (a) represent the regions left out in the fits both here and in Fig. 2. The curves are the result of fits to $(1 + \alpha e^{-\beta Q^2})\gamma$.

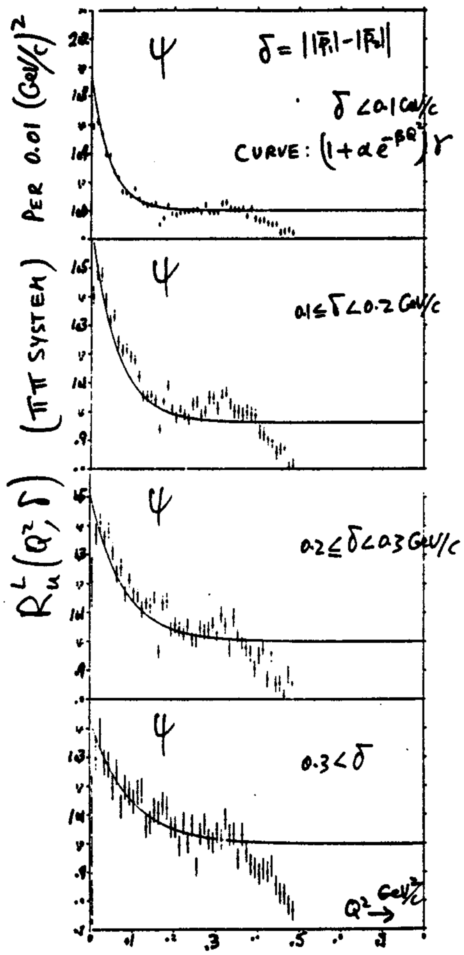

Fig. 2. The $R_U^L(Q^2,\delta)$ distribution for $\pi\pi$ at the ψ/J.

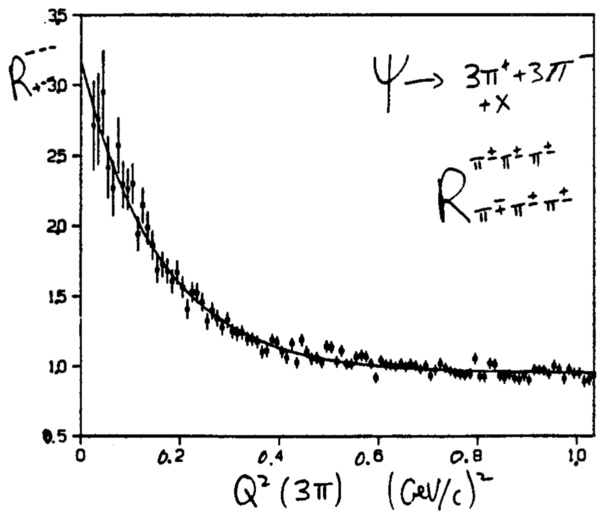

Fig. 3. The $R^{---}_{+--}(Q^2)$ distribution for $\pi\pi\pi$ at the ψ/J.