ferred to as the spherical model or mean spherical model.

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COMMENTS

Exotic Mesons with Hidden Charm*

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The color $\underline{6}^*$ model of charmed quarks is shown to have exotic $c\bar{c}q\bar{q}$ states of exactly the right properties to be interpreted as the structures seen in e^+e^- annihilation in the center-of-mass energy range 3.9 to 4.6 GeV.

Recently, there have been suggestions[1,2] that the structures observed[3,4] in e^+e^- annihilation in the center-of-mass energy range 3.9 to 4.6 GeV are exotic $c\bar{c}q\bar{q}$ states. In Ref. 1, it is assumed that these exotic states are in fact bound states of $c\bar{q}$ and $q\bar{c}$, and that quark rearrangements are necessary for their decay into $c\bar{c}$ and $q\bar{q}$ states. In Ref. 2, on the other hand, the assumption is that they are bound states of cq and $\overline{cq}$, i.e., charmed diquarks, and that they are kinematically forbidden to decay into baryon-antibaryon pairs, so that quark rearrangements are again necessary for them to decay—this time mostly into $c\bar{q}$ and $q\bar{c}$ states. In either case, there is no *fundamental* explanation as to why exotic $c\bar{c}q\bar{q}$ states should not be able to decay strongly into $c\bar{q}$ and $q\bar{c}$, kinematically or otherwise, while ordinary exotic $q\bar{q}q\bar{q}$ states of such narrow widths[5] are not observed. Furthermore, the production of charmed mesons is still *required* in both schemes, whereas compelling evidence for their existence is still lacking, even at 4.8 GeV.[6] However, both of these important points can be easily understood in terms of the color $\underline{6}^*$ model of charmed quarks.[7]

In this model, the charmed quark c is taken to be a $\underline{6}^*$ under color SU(3). As a result, $c\bar{q}$ cannot be a color singlet, and hence there are no such mesons. Charmed baryons, on the other hand, are possible, and they are cqq states. (For more details, the reader is urged to consult Ref. 7.) Now, on the basis of simple color dynamics,[8] a four-quark state is expected to be less massive than two three-quark states; an exotic $c\bar{c}q\bar{q}$ color singlet which is formed by $c\bar{c}$ and $q\bar{q}$ octets should therefore be relatively stable against decay. This is not so for ordinary exotic states. There are only two ways to form a $q_1\bar{q}_2q_3\bar{q}_4$ color singlet: (a) $q_1\bar{q}_2$ and $q_3\bar{q}_4$ are color singlets themselves in which case the decay is strong, and (b) $q_1\bar{q}_2$ and $q_3\bar{q}_4$ are color octets, but then this is equivalent to a linear combination of $q_1\bar{q}_4$ and $q_3\bar{q}_2$ which are either both singlets or both octets, so again the decay is strong. Therefore, exotic hadrons made up entirely of the usual color triplet quarks (u, d, and s) must have very large widths. In the case of the color singlet state made up of $c\bar{c}$ and $q\bar{q}$ octets, no rearrangement can result in two singlets, so it is relatively stable against decay. Here, no detailed dynamical assumption is made with regard to the spatial properties of the quark wave functions, and in fact no such assumption is necessary, in contrast to the schemes of Refs. 1 and 2.

The decay of $c\bar{c}q\bar{q}$ is therefore mainly into $q\bar{q}$'s. This involves the transition $c\bar{c}\rightarrow q\bar{q}$, and is therefore suppressed by the Okubo-Zweig-Iizuka (OZI) rule.[9] But this suppression is not nearly as strong as in the decays of the resonances at 3.1 and 3.7 GeV. The reason is as follows: A $c\bar{c}$ octet can become a $q\bar{q}$ octet via just a single gluon, whereas a $c\bar{c}$ singlet, because of charge conjugation invariance and color symmetry, takes three gluons to turn into a $q\bar{q}$ singlet; so in a color gauge model of quarks which is asymptotically free, the former rate is expected to be much larger than the latter.[10] Experimentally,[4] the total width of $\psi(4414)$ is 33 ± 10 MeV, while that of $\psi(3095)$ is only 69 ± 15 keV. A rough estimate then shows that an OZI-allowed exotic decay would have a width of about 700 MeV, which would be much too broad for it to be detected. In addition, the small partial width of $\psi(4414)$ into e^+e^- is naturally explained by the fact that the photon is a color singlet and does not couple directly to the $c\bar{c}$ and $q\bar{q}$ color octets, as opposed to the case of $\psi(3095)$ or $\psi(3684)$ which are $c\bar{c}$ color singlets. $\psi(4414) \to e^+e^-$ is in fact an OZI-suppressed electromagnetic decay.

The color $\underline{6}^*$ model of charmed quarks, therefore, has been shown to offer a natural explanation of the resonance at 4.4 GeV as well as the structures near 4.1 GeV as $c\bar{c}q\bar{q}$ states. The crucial difference between this and the models of Refs. 1 and 2 is that charmed mesons are not $c\bar{q}$ but rather $c\bar{q}q\bar{q}$ states, as explained in Ref. 7, and are expected to be heavier than charmed baryons.

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Differences in the Production of Noncharacteristic Radiation in Gaseous and Solid Targets*

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Testing the recent findings of Bell *et al.* on the Si-Si collision system, we find that the yield of noncharacteristic radiation differs markedly in gaseous and solid targets.

The recent results of Bell *et al.*[1] for 55-MeV S → Al and 48-MeV S → Ne indicate that the observed yield of noncharacteristic radiation (NCR) is of approximately equal magnitude for gaseous and solid targets under similar collision conditions. The authors used their data to support a model which indicated that NCR is predominantly produced in single collisions (about $\frac{2}{3}$ of the time) for 55-MeV S → Al. We test this conclusion in a similar collision system by comparing the NCR yield obtained with 40-MeV $Si^{+6} \to SiH_4$ (gaseous target) and 40-MeV $Si^{+6} \to Al$ (solid target). Our data suggest instead that double collisions dominate the NCR production, in consonance with other experimental evidence to date[2] which also indicates that two collisions contribute most to production of NCR. Our data support a single-collision production contribution of 15–20% as an *upper* limit for our projectile-target system.

Beams of silicon ions from the Oak Ridge National Laboratory tandem Van de Graaff were passed through a gaseous or solid target. The