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# Charmonium-like states at BaBar

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In the past few years, several new charmonium-like states have been observed above the open-charm threshold, with properties that disfavor their interpretation as conventional charmonium states. It is not clear whether all these states are unique. Specifically, it has been suggested that the X(3915), observed in gamma gamma ->J/psi omega, and the Y(3940), observed in B−>J/psi omega K, may be one and the same as the chi_c2(2P), which was discovered in gamma gamma -> D Dbar. We use the full BABAR dataset to study the process gamma gamma −> J/psi omega. We measure the mass and width of the X(3915) and conduct the first assessment of its spin to determine whether it is the chi_c2(2P) or a new state. We also search for the X(3872), which should be produced in gamma gamma events if it has spin and parity 2+, while the alternative JˆP = 1+ assignment would preclude X(3872) production via this mechanism.

Di-pion transitions are well known for vector charmonium states. However, they have not been studied for non-vector states, where they may shed light on the nature of some of the new charmonium-like resonances, which are not well understood and whose properties often disfavor interpretation as conventional charmonium. In particular, it has been suggested that the decay X(3872)−>eta_c(1S) pi+ pi- will favor identification of the X(3872) as the eta_c2. In addition, measurement of di-pion transition rates for well-understood charmonium states serves to test charmonium-model predictions. Using two-photon-fusion events, we perform the first search for the decays of the chi_c2(1S), eta_c(2S), X(3872), X(3915), and chi_c2(2P) into the final state eta_c(1S) pi+ pi-, and report limits on the branching fractions for these decays or on the products of the branching fractions and 2-photon widths.

In recent years, several new Charmonium-like states have been discovered, which cannot be fully explained by a simple charmonium model. The Y(4260) was discovered by BABAR via its decay into J/psi pi pi. Its production in initial-state-radiation events determines its quantum numbers to be JPC=1−, so the fact that it has not been observed decaying into D*D*bar is in contradiction to the charmonium-model expectation. Other interpretations are also not in good agreement with the data. We use the full BABAR dataset to improve determination of the parameters of the Y(4260) and to study the pi+pi- system, which we find to be predominantly in an S-wave state, with a f0(980) component. We do not confirm the report from Belle of a broad structure around 4.01 GeV.

A number of new charmonium-like states have been discovered recently, with properties that disfavor their identification as charmonium states. An understanding of the nature of these states requires precision measurements of their properties. Several of the new states are produced in initial-state-radiation events, indicating the quantum numbers JPC=1−. Of these, the Y(4660) has been observed only in the Belle experiment, and still requires independent confirmation. We report a new study of the final state psi(2S) pi+ pi- in initial-state-radiation events using the entire BABAR dataset. We measure the masses and widths of the Y(4360) and Y(4660), and study the di-pion mass spectrum distributions.

Recent discoveries of new charmonium-like states have prompted development of various models to explain them. None of the models, including the standard charmonium interpretation, account well for all the properties of these states. A clear prediction of the 4-quark interpretation is the existence of charged charmonium-like states. Such states are the Z1(4050)+ and Z2(4250)+, which is been reported by Belle to be produced in B−>ZK and to decay into chi_c1 pi+. We search for these states in the decays B0−>chi_c1 pi- K+ and B−>chi_c1 pi- Ks. We show that adequate treatment of the background requires addressing the angular distribution of the Kpi system, which produces features in the chi_c1 pi+ invariant-mass distribution if not properly handled. Once this is done, we see no evidence for the Z1(4050)+ and Z2(4250)+ states, and set upper limits

on the branching fractions of the decays B−>ZK. We also report the total branching fractions of the decays B0−>chi_c1 pi- K+ and B- −>chi_c1 pi- Ks.

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