# SEARCH FOR CHARMONIUM AND EXOTICS WITH HIDDEN CHARM AND STRANGENESS IN ANTIPROTON-PROTON ANNIHILATION

Barabanov M., Vodopyanov A.
*Joint Institute for Nuclear Research, Dubna, Moscow region, Russia*
E-mail : barabanov@jinr.ru

The study of strong interactions and hadron matter in the process of antiproton-proton annihilation seems to be a challenge nowadays. One of the main goals of contemporary physics is to search for new exotic forms of matter, which must manifest in the existence of charmed hybrids $c\bar{c}g$ and multiquark states such as meson molecules and tetraquarks [1, 2]. The researches of spectrum of charmed hybrids and tetraquarks with hidden charm and strangeness ($cq\overline{cq}'$, $q$ and $q' = u, d, s$) together with the charmonioum spectrum are promising to understand the dynamics of quark interactions at small distances. It is a good testing tool for the theories of strong interactions: QCD in both perturbative and non-perturbative regimes, QCD inspired potential models, phenomenological models, non-relativistic QCD and LQCD.

Two generic types of multiquark states have been described in the literature [2 - 4]. The first, a molecular state, is comprised of two charmed mesons bound together to form a molecule. These states are by nature loosely bound. Molecular states bind through two mechanisms: quark/colour exchange interactions at short distances and pion exchange at large distance (although pion exchange is expected to dominate). Since the mesons inside the molecule are weakly bound, they tend to decay as if they are free. The second type is a tightly bound four-quark state, so called tetraquark that is predicted to have properties that are distinct from those of a molecular state. In the model of Maiani [2], for example, the tetraquark is described as a diquark-diantiquark structure in which the quarks group into colour-triplet scalar and vector clusters and the interactions are dominated by a simple spin-spin interaction. A prediction that distinguishes tetraquark states containing a $c\bar{c}$ pair from conventional charmonia is possible existence of multiplets which include members with non-zero charge $cu\overline{cd}$, strangeness $cd\overline{cs}$, or both $cu\overline{cs}$.

The detailed analysis of the spectrum of charmed hybrids with exotic ($J^{PC} = 0^{--}, 0^{+-}, 1^{-+}, 2^{+-}, 3^{-+}$) and non-exotic ($J^{PC} = 0^{-+}, 1^{+-}, 2^{-+}, 1^{++}, 1^{--}, 2^{--}, 2^{++}, 3^{+-}$) quantum numbers and tetraquarks with hidden charm and strangeness was carried out, and attempts to interpret a great quantity of experimental data above the $D\bar{D}$ threshold were considered. The analysis of charmonium spectrum was carried out earlier [5, 6]. New higher lying states of charmonium, charmed hybrids and tetraquarks are expected to exist in the mass region above the $D\bar{D}$ threshold. But much more data on different decay modes are needed for deeper analysis. These data can be derived directly from the experiments with high quality antiproton beam.

A special attention is given to the new *XYZ* states with hidden charm discovered recently [3, 4, 7, 8]. Their interpretation is far from being obvious nowadays [2 -4]. The experimental data from different collaborations like BES, Belle, BaBar, LHCb, CLEO were carefully studied. Some of these states can be interpreted as charmonium [5, 6] and tetraquarks [9, 10] in the framework of the combined approach proposed earlier [11, 12]. It has been shown that charge/neutral tetraquarks must have neutral/charge partners with mass values which differ by few tens of MeV. This treatment coincides with hypothesis proposed by Maiani and Polosa [13, 14]. It seems to be a promising approach and needs to be carefully verified in experiments using high quality antiproton beam with momentum ranging up to 15 GeV/c.


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