Search for charmonium-like exotic states with the BESIII experiment

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The BESIII experiment [1] at the BEPCII e^+e^- collider in Beijing, China, started data taking in 2009. Large data samples at centre-of-mass energies corresponding to J/ψ, ψ' and $\psi(3770)$ resonances have been recorded. More recently, data were also taken between about 4 GeV and 4.4 GeV, allowing for the study of the so-called XYZ states. Recent discoveries of charged states in the charmonium mass region – ten years after the discovery of the $X(3872)$ by Belle – make this field a very active one that will continue to be very exciting until the nature of these new states will be understood. One highlight is the recent discovery of the $Z_c(3900)^\pm$ state [2] by BESIII, confirmed by Belle; it is manifestly an exotic state.

For understanding the nature, a precise measurement of the lineshapes is needed as it is only possible in a direct formation experiment. The physics analysis of BESIII data offers an excellent opportunity for hadron spectroscopy, in particular for the search for further charmonium-like (exotic) XYZ states. In contrast to the $p\bar{p}$ annihilation experiment PANDA/FAIR, only $J^{PC} = 1^{--}$ mesons can be directly produced in formation at BESIII, whereas other J^{PC} states can only be studied in production reactions with additional recoil particles being produced. Before PANDA will help solving the puzzle of the new XYZ states by precise measurements of the lineshapes, there is not only the great chance to complete the observation of entire multiplets and to explore further decay channels with BESIII, but also to bridge the period until PANDA will start data taking. Already analysing similar but complementary real data from BESIII to keep and gain important experience on this newly very active field of research, is a perfect preparation of physics analysis of PANDA data, including the developement of software analysis tools.

The first charged charmonium-like state was discovered by BESIII in the reaction $e^+e^- \to J/\psi\pi^+\pi^-$ at a centre-of-mass energy $\sqrt{s} = 4.26$ GeV, corresponding to the the $Y(4260)$ resonance. The signal was observed in the $J/\psi\pi^\pm$ invariant mass distributions [2], leading to the direct formation and subsequent decay chain $e^+e^- \to Y(4260)$, with $Y(4260) \to Z_c(3900)^\pm\pi^\mp$, and $Z_c(3900)^\pm \to J/\psi\pi^\mp$. Importantly, the $Z_c(3900)^\pm$ is a charged state while it couples to a $c\bar{c}$ state. It can thus not be a charmonium state; speculations comprise interpretations as a tetraquark state or a hadronic molecule.

Preliminary BESIII results show also a significant and similar structure in the $J/\psi\pi^0$ invariant mass measured in the isospin-partner channel $e^+e^- \to J/\psi\pi^0\pi^0$. Evidence for the neutral partner of the $Z_c(3900)^\pm$ in the CLEO-c data was published [3]. The determination of the spin-parity is needed for the interpretation, especially if the charged and neutral partners have the same, the corresponding isospin triplet would be established. Further decay channels are under investigation. Replacing the J/ψ by an h_c, a clean narrow structure has consistently been observed in the invariant mass of both, $h_c\pi^+$ (Fig. 1, top) and $h_c\pi^0$ (Fig. 1, bottom), whereas the masses obtained from the fits of about 4.02 GeV/c^2 are consistent within uncertainties [4]; this state is referred to the $Z_c(4020)$. Another decay channel of the $Z_c(3900)$ that we started to analyse at GSI is $\eta_c\pi$. Due to the low cross-section distributed over various decay modes, all 16 hadronic final states need to be included in our analysis – first results will come soon.

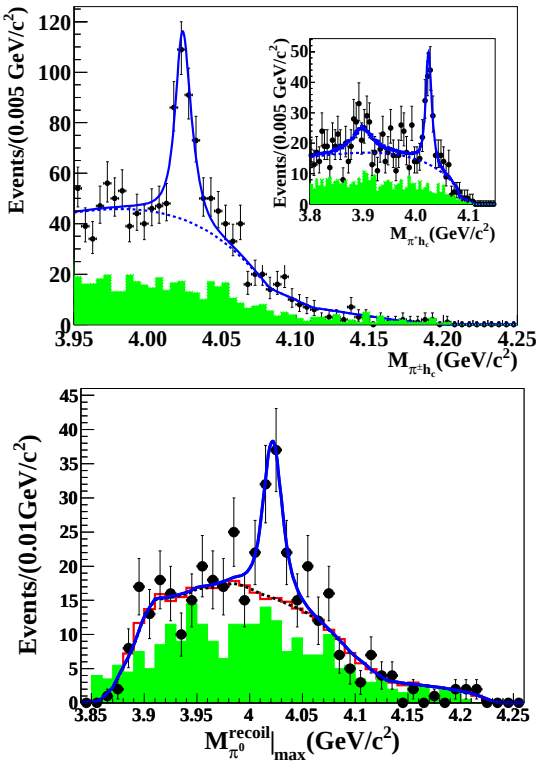

Figure 1: Recent observation of the new charged *(top)* and neutral *(bottom)* narrow state referred to the $Z_c(4020)$ [4].

References

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