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Exotic structures in B meson decays at CMS

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Summary. — The studies of the production of the $X(3872)$, either prompt or from B hadron decays and of the $J/\psi\phi$ mass spectrum in B hadron decays have been carried out by using pp collisions at $\sqrt{s} = 7\,\text{TeV}$ collected with the CMS detector at the LHC. Selected features of these studies are reviewed.

1. – Introduction

In the last ten years many new states (X, Y, Z), decaying to conventional charmonium, have been observed in spite of being above the open-charm threshold(s). They do not fit into the charmonium spectrum predicted by potential models in the contest of conventional quark model of hadrons. This renewed the interest in exotic quarkonia spectroscopy. Experimental and theoretical pictures are far from being clear [1] and there are opportunities at LHC to confirm these states and study their properties. The nature of $X(3872)$, despite a series of detailed studies performed at B-factories (where was discovered), Tevatron and recently at the LHC, still remains unknown; some interpretations describe the $X(3872)$ as a molecular state (loosely bound state of $D^{0*}\bar{D}^0$) or as a tetraquark state (bound state of diquark-antidiquark) [1].

The observation of $Y(3940)$ near the $J/\psi\omega$ [1] threshold motivated the search close to the $J/\psi\phi$ threshold of other states with similar characteristics (threshold enhancement? rescattering effect?) or eventually partner states with a new quarks' aggregate (tetraquark?) or a molecule ($D_s^*\bar{D}_s^*$ partner of a $D^*\bar{D}^*$ loosely bound molecule?).

2. – Measurements of the $X(3872)$ production

All the details of the study of the production mechanisms of the $X(3872)$ are reported in [2]. Four main quantities are measured with the data recorded by CMS in 2011 (corresponding to an integrated luminosity of $4.8\,\text{fb}^{-1}$): 1) the *invariant mass distribution of the $\pi\pi$ system* favours the presence of an intermediate ρ^0 state in the $X(3872)$ decay; 2) the *production cross section (times the unknowm branching fraction of the decay to*

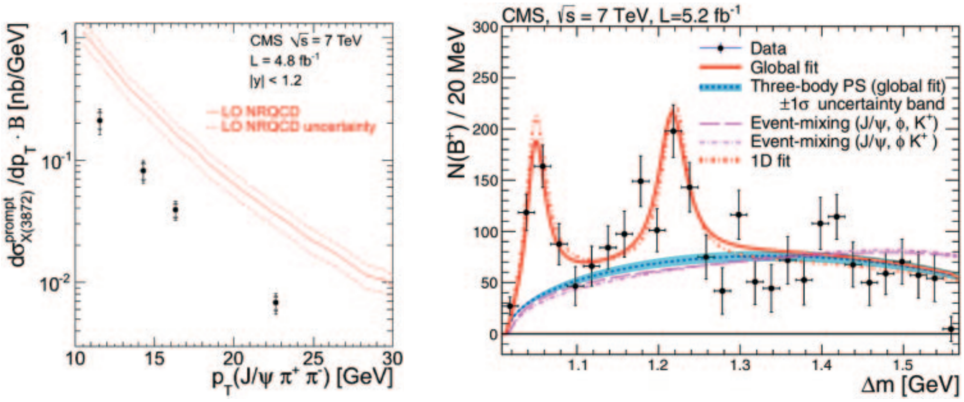

Fig. 1. – Left: measured differential cross section for prompt $X(3872)$ production times branching fraction of $X(3872) \to J/\psi\pi^+\pi^-$ as a function of p_T. The inner error bars indicate the statistical uncertainty while the outer error bars represent the total uncertainty. Prediction from [3] are shown by the lines and data points are placed where the theoretical value is equal to its mean value over each bin. Right: number of $B^+ \to J/\psi\phi K^+$ candidates as a function of $\Delta m = m(\mu^+\mu^-K^+K^-) - m(\mu^+\mu^-)$. The solid curve is the global UML fit of the data, and the dotted curve is the background contribution assuming three-body PS. The band is the $\pm 1\sigma$ uncertainty range for the background obtained from the global fit. The dashed and dash-dotted curves are background curves obtained from two different event-mixing procedures and normalized to the number of three-body PS background events. The short-dashed curve is the 1D fit to the data.

$J/\psi\pi\pi$) with respect to $\psi(2S)$; 3) the *non prompt fraction* associated to $X(3872)$ candidates produced by B hadrons decays (selected by requiring a decay length $> 100\,\mu$m) shows no significant dependence on the p_T of the $J/\psi\pi\pi$ system; 4) the *prompt* $X(3872)$ *production cross section (times the unknown branching fraction)* as a function of the p_T of the $J/\psi\pi\pi$ system is shown in fig. 1 (left) where is compared with a theoretical prediction [3] obtained by calculations normalized using Tevatron results and modified by the authors to match the CMS phase space. The shape is reasonably well described by the theory while the predicted cross section is overestimated by over 3σ. The simulations used to determine acceptances ed efficiencies assume the $X(3872)$ to be an unpolarized state and its J^{PC} is fixed to 1^{++} as strongly favoured by LHCb study [4].

3. – A peaking structure in the $J/\psi\phi$ system for $B^\pm \to J/\psi\phi K^\pm$ decays

All the details of this study, exploiting the data recorded by CMS in 2011 (corresponding to an integrated luminosity of $5.2\,\text{fb}^{-1}$), are reported in [5]. The selection criteria, designed to maximize the B signal yield, were determined before examining the mass difference $\Delta m \equiv m(\mu^+\mu^-K^+K^-) - m(\mu^+\mu^-)$, that is the observable used to search for possibile structures in the $J/\psi\phi$ mass.

After performing a background subtraction and correcting for relative efficiency the resulting Δm distribution and its 1D-fit is shown in fig. 1 (right): two peaking structures are observed above the phase-space (PS) continuum distribution. On the plot is also shown the result of a 2D simultaneous fit of both B^+ invariant mass and Δm distributions with implicit background subtraction and efficiency correction.

Interpreting the two structures as $J/\psi\phi$ resonances with S-wave relativistic Breit-Wigner lineshapes laying over a residual three-body phase-space non-resonant component, the fitted mass of the structure close to the kinematical threshold is $m = (4148.2 \pm 2.0(stat.) \pm 4.6(sys.))\,\mathrm{MeV}$; this structure is observed with a significance exceeding 5σ and is consistent with a previous evidence by the CDF Collaboration [6].

The $J/\psi\phi$ system should be properly studied with more data by performing an amplitude analysis of this five-body decay able to properly account for eventual ϕK^+ resonances.

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