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B hadron decays and spectroscopy results from the CMS Collaboration

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Recent results on the B hadrons decays from the CMS experiment at the LHC are reported. The observation of the $B^0 \to \psi(2S)K^0_S\pi^+\pi^-$ and $B^0_s \to \psi(2S)K^0_S$ decays is presented together with the observation of a new beauty strange baryon decaying to $\Xi^-_b\pi^+\pi^-$ and the first observation of the $\Lambda^0_b \to J/\psi\Xi^-K^+$ decay. The results are based on data sample collected in pp collisions at 13 TeV.

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1. Observation of $B^0 \to \psi(2S)K^0_S\pi^+\pi^-$ and $B^0_s \to \psi(2S)K^0_S$ decays

Decays of neutral B mesons into charmonium resonances (J/ψ, $\psi(2S)$, etc.) are well suited to study the flavour sector of the standard model (SM) and to search for indications of new physics beyond the SM.

As shown in Fig. 1, the measured $\psi(2S)K^0_S\pi^+\pi^-$ mass distribution presents a clear $B^0 \to \psi(2S)K^0_S\pi^+\pi^-$ signal peak on top of a relatively small background. The signal yield $N(B^0 \to \psi(2S)K^0_S\pi^+\pi^-)$ is found to be 3498 ± 87, where the uncertainty is statistical only. The significance of the $B^0 \to \psi(2S)K^0_S\pi^+\pi^-$ signal exceeds 30 standard deviations.

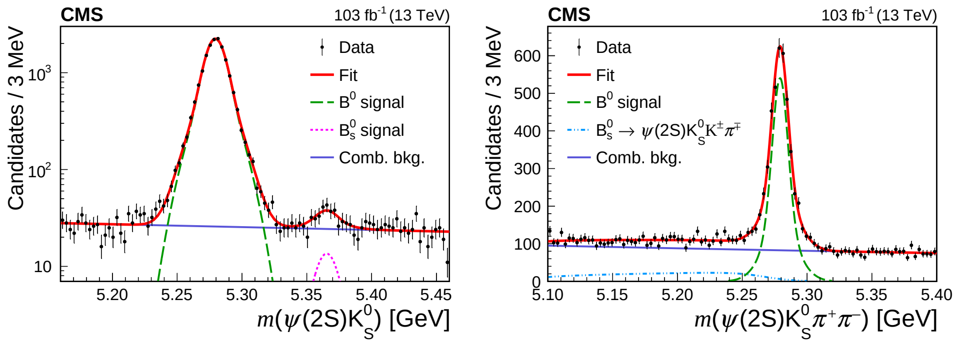

Figure 1: Measured invariant mass distributions of $\psi(2S)K^0_S$ (left) and $\psi(2S)K^0_S\pi^+\pi^-$ (right) candidates in CMS data [1]. The overlaid results from the fit are described in the text.

The 2- and 3-body intermediate invariant mass distributions of $\psi(2S)$ and one or two light mesons ($\psi(2S)K^0_S$, $\psi(2S)\pi^\pm$, $\psi(2S)K^0_S\pi^\pm$, $\psi(2S)\pi^+\pi^-$) do not present any significant narrow peak that could indicate a contribution from an exotic charmonium state. The small excess at about 4.3 GeV in the $m(\psi(2S)\pi^+)$ distribution is not significant, and there is no similar excess in the $m(\psi(2S)\pi^-)$ distribution.

Their branching fractions are measured with respect to the $B^0 \to \psi(2S)K^0_S$ decay to be $\mathcal{B}(B^0_s \to \psi(2S)K^0_S)/\mathcal{B}(B^0 \to \psi(2S)K^0_S) = (3.33 \pm 0.69\,(\text{stat}) \pm 0.11\,(\text{syst}) \pm 0.34\,(f_s/f_d)) \times 10^{-2}$, and $\mathcal{B}(B^0 \to \psi(2S)K^0_S\pi^+\pi^-)/\mathcal{B}(B^0 \to \psi(2S)K^0_S) = 0.480 \pm 0.013\,(\text{stat}) \pm 0.032\,(\text{syst})$, where the last uncertainty in the first ratio corresponds to the uncertainty in the ratio of production cross sections of B^0_s and B^0 mesons.

2. Observation of a new excited beauty strange baryon decaying to $\Xi^-_b\pi^+\pi^-$

The Ξ^-_b baryon family consists of isodoublet states composed of bsq quarks, where q represents an up or a down quark for the Ξ^0_b and Ξ^-_b states, respectively. According to the quark model for baryons containing one heavy quark, three such isodoublets that are neither orbitally nor radially excited should exist, including one with the light diquark angular momentum $j_{qs} = 0$ and spin-parity $J^P = 1/2^+$ (the Ξ_b ground states), one with $j_{qs} = 1$ and $J^P = 1/2^+$ (the Ξ'_b), and one with $j_{qs} = 1$ and $J^P = 3/2^+$ (the Ξ^*_b).

The signal yields from the fits described above are 859 ± 36 and 815 ± 74 for the $\Xi^-_b \to J/\psi\Xi^-$ and fully reconstructed $\Xi^-_b \to J/\psi\Lambda K^-$ decay modes and 820 ± 158 the partially reconstructed $\Xi^-_b \to J/\psi\Sigma^0K^-$ contribution (the dotted-dashed curve in Fig. 2). The fitted Ξ^-_b masses of 5797.0 ± 0.7

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and 5800.1 ± 1.2 MeV, respectively for the $J/\psi\Xi^-$ and $J/\psi\Lambda K^-$ channels, are consistent with each other and with the world-average value, 5797.0 ± 0.6 MeV.

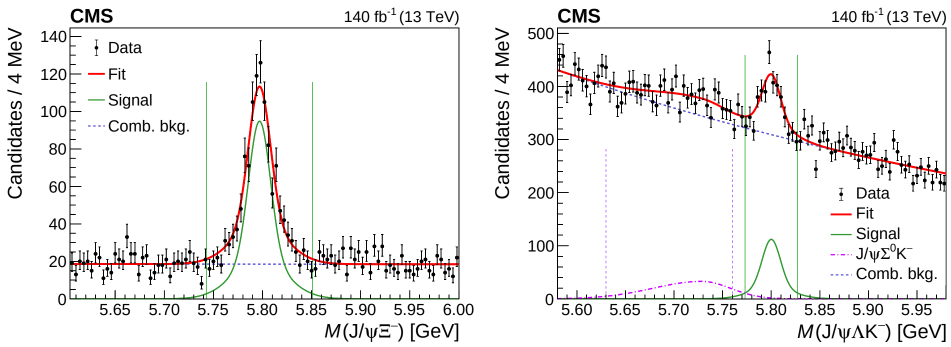

Figure 2: Invariant mass distributions of the selected Ξ_b^- candidates in the $J/\psi\ \Xi^-$ (left) and $J/\psi\ \Lambda\ K^-$ (right) decay channels with the fit results superimposed in CMS data [2]. The vertical solid (dashed) lines show the mass windows discussed in the text and used in the reconstruction of the $\Xi_b^-\pi^+\pi^-$ candidates in $J/\psi\ \Xi^-$ and $J/\psi\ \Lambda\ K^-$ ($J/\psi\Sigma^0 K^-$) channels.

The fitted mass difference of the new $\Xi_b(6100)^-$ state is $\Delta M_{\Xi_b(6100)^-} = 24.14 \pm 0.22$ MeV and signal yields are 26 ± 7 and 34 ± 9 for the fully reconstructed and the $\Xi_b^- \to J/\psi\Sigma^0 K^-$ channels, respectively. An upper limit on $\Gamma(\Xi_b(6100)^-)$ has been obtained through a scan of the profiled likelihood, assuming an asymptotic distribution. The measured upper limit, at 95% confidence level, is $\Gamma(\Xi_b(6100)^-) < 1.9$ MeV, where the systematic uncertainties are taken into account.

3. Observation of the $\Lambda_b^0 \to J/\psi\ \Xi^-\ K^+$ decay

The mass distribution of the $\psi(2S)\Lambda$ candidates obtained in data is shown in Fig 3 (left). The fitted mass of Λ_b^0 is in agreement with its known value, and the mass resolution of 8.90 ± 0.40 MeV is slightly larger than, yet in agreement with, its value of 8.52 MeV found in simulation. The measured yield is $N(\Lambda_b^0 \to \psi(2S)\Lambda) = 1744 \pm 63$.

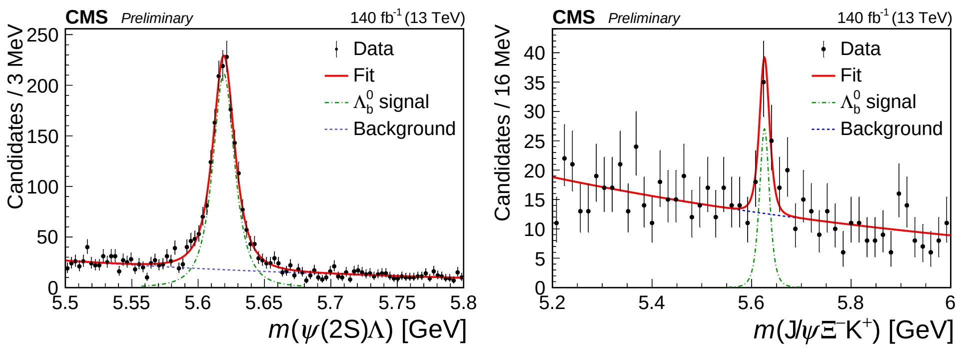

Figure 3: The measured $\psi(2S)\Lambda$ (left) and $J/\psi\Xi^- K^+$ (right) invariant mass distribution with the fit results overlaid in CMS data [3].

The measured invariant mass distribution of the selected $J/\psi\Xi^- K^+$ candidates is shown in Fig. 3 (right). The Λ_b^0 signal is modelled with a Student's t-distribution with mass and σ floating, but the n

parameter fixed to the value found by fitting the simulated distribution, because of the limited signal yield of $N(\Lambda_b^0 \to J/\psi\Xi^-K^+) = 46 \pm 11$. The significance obtained with the alternative models varies in the range from 5.27 to 5.85 standard deviations.

The sensitivity of this analysis to potential pentaquark signals in the intermediate invariant mass distributions of the $\Lambda_b^0 \to J/\psi\Xi^-K^+$ decay is limited by the low signal yield. The two-body invariant mass distributions obtained with the ${}_s\mathcal{P}$lot technique [4] have been examined and found to be consistent with the phase space simulation without any narrow peaks as shown on Fig. 4.

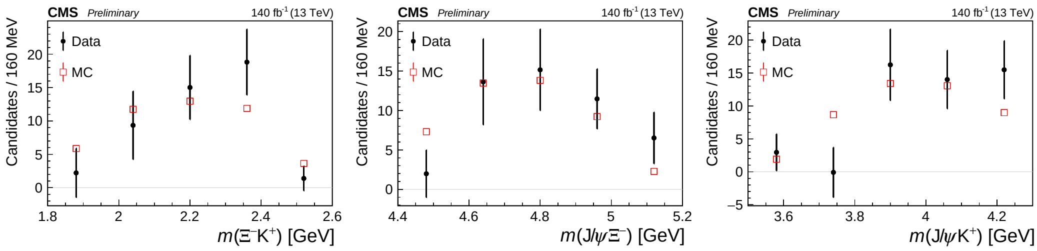

Figure 4: Intermediate invariant mass distributions of the $\Lambda_b^0 \to J/\psi\Xi^-K^+$ decay in CMS data [3]. Black points represent the background-subtracted data, while red ones show the predictions of phase space simulation.

The branching fraction is measured with respect to the $\Lambda_b^0 \to \psi(2S)\Lambda$ decay to be $\mathcal{B}(\Lambda_b^0 \to J/\psi\Xi^-K^+)/\mathcal{B}(\Lambda_b^0 \to \psi(2S)\Lambda) = [2.5 \pm 0.8\,(\text{stat}) \pm 0.9\,(\text{syst})]\%$. This is the first discovered multibody decay containing the $J/\psi\Xi^-$ system, which opens the possibility to search for doubly-strange hidden-charm pentaquarks once more data are collected.

4. Summary

Decays $\Lambda_b^0 \to J/\psi\Xi^-K^+$, $B^0 \to \psi(2S)K_S^0\pi^+\pi^-$ and $B_s^0 \to \psi(2S)K_S^0$ are observed for the first time and its branching fraction is found to be in agreement with the Standard Model predictions. The new $\Xi_b(6100)^-$ excited state in the $\Xi_b^-\pi^+\pi^-$ mass spectrum is also observed for the first time. The new state and its decay are consistent with the possible interpretation as Ξ_b^- baryon with $J^P = 3/2^-$. The results are obtained using 13 TeV pp collision data recorded by the CMS experiment [5] at the LHC.

Acknowledgments

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