PROCEEDINGS OF SCIENCE

Observation of the X(3872) state at CMS

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A measurement of the ratio of the production cross sections for $X(3872)$ and $\psi(2S)$ states in pp collisions at 7 TeV, using data recorded at the CMS experiment in 2010 corresponding to an integrated luminosity of 40 pb^{-1} is presented. The states are reconstructed in their decays into $J/\psi\,\pi^+\pi^-$ and the subsequent decay of the J/ψ candidates into two muons. Also the evolution of this analysis with 2011 data is discussed, and the first results corresponding to an integrated luminosity 896 pb^{-1} are showed.

The 2011 Europhysics Conference on High Energy Physics-HEP 2011,
July 21-27, 2011
Grenoble, Rhône-Alpes France

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PoS(EPS-HEP2011)177

1. Introduction

The X(3872) is the first unexpected state in the charmonium spectroscopy to be discovered and is still the most intriguing. The consistency of its the mass with the exact location of the $D^0\overline{D^{*0}}$ threshold at 3871.81 ± 0.36 MeV gives plausibility to the assumption of a molecular state of two D mesons [1].

Now LHC allows us to perform studies with large event samples in a new energy regime. The CMS experiment is particularly suited for the study of the decay in $J/\psi\,\pi^+\pi^-$ thanks to a high resolution central silicon tracking system and a highly efficient and redundant muon system.

2. Analysis of 2010 Data

2.1 Candidates Selection

In 2010 CMS recorded an integrated luminosity of 40 pb^{-1} of proton-proton collisions at 7 TeV.

The J/ψ selection follows the techniques developed in the previous CMS measurement of the J/ψ production cross section [2]. Events are triggered by requiring two muons in the event without an explicit requirement on the muon momentum. J/ψ candidates are selected with two good quality muon candidates of opposite charge consistent with the reconstructed invariant mass of the J/ψ mesons. About one million reconstructed J/ψ candidates are found with these selection criteria.

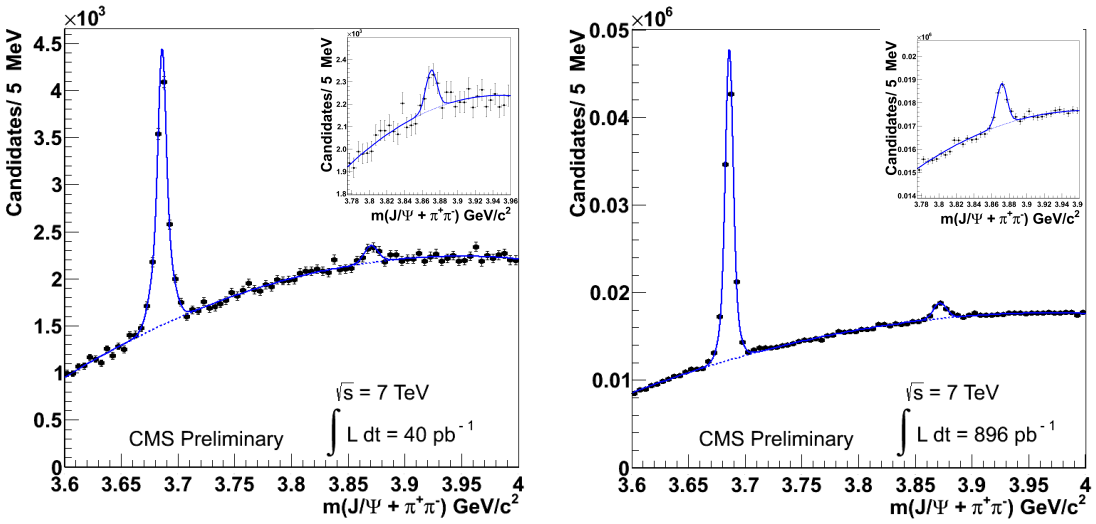
For the reconstruction of the $J/\psi\,\pi^+\pi^-$ system, the J/ψ meson candidates are combined with pairs of oppositely charged pion track candidates with transverse momentum larger than 400 MeV. The dimuon mass is constrained to the J/ψ one and candidates are kept in the kinematic region $p_{\mathrm{T}} > 8$ GeV and $|y| < 2.2$. In order to reduce the significant non-resonant background formed by random combinations of tracks, the opening angle $\Delta R = \sqrt{(\Delta\eta)^2 + (\Delta\phi)^2}$ between the pion pair and the J/ψ candidate is required to be less than 0.7 and the combined transverse momentum of the pion pair to be larger than 1.5 GeV.

The invariant mass distribution of selected $J/\psi\,\pi^+\pi^-$ candidates is shown in Fig. 1(a). Clear signals of the $\psi(2S)$ and $X(3872)$ are observed. The signal yield is extracted from an unbinned log likelihood fit to the invariant mass spectrum of the $J/\psi\,\pi^+\pi^-$ system. We obtain $N_{\psi(2S)} = 7346 \pm 55$ and $N_{X(3872)} = 548 \pm 104$.

2.2 Production cross section Ratio

The acceptance and efficiency for prompt and non-prompt $\psi(2S)$ and $X(3872)$ production and their decays to the final $J/\psi\pi^+\pi^-$ state are determined from Monte Carlo samples. The $X(3872)$ is simulated in PYTHIA as a $c\bar{c}$ meson with $m_{PDG} = 3871.56$ MeV and under the hypothesis $J^{PC} = 1^{++}$.

Due to the similar properties of the $X(3872)$ and the $\psi(2S)$, the ratio of acceptances and efficiencies is close to, but not identical to, unity. Remaining corrections arise from the fact that the analysis is performed at the acceptance and efficiency thresholds of the CMS detector for both the muons coming from the J/ψ decay and the final state pions. Assuming that 30% of the candidates in both the $X(3872)$ and the $\psi(2S)$ samples are from non-prompt production processes, a final



(a) 2010 Data (b) First 2011 Data

Figure 1: $J/\psi\pi^+\pi^-$ invariant mass spectrums. The insert shows the mass region around the $X(3872)$. The solid line shows the result of the unbinned fit to the mass spectrum, and the dashed curve shows the background component of the fit.

correction factor of 0.872 ± 0.015 (stat.) is obtained. The assumption on the non-prompt amount is confirmed by a measurement of the signal yields from a B-enriched sample of CMS data.

The systematic error on the cross section ratio is composed of those contributions to the uncertainty that are uncorrelated between the $X(3872)$ and the $\psi(2S)$. The list of these contributions is given in the following.

Background parameterization and signal extraction : the systematic error is assigned as the maximum difference found in the cross section ratio using different probability density functions still fitting the data. It amounts to 5.3%

Unknown production mechanism of the X(3872) : the prompt $X(3872)$ p_{T} production spectrum in the simulation was reweighed using various functions to evaluate the effect on the correction calculated for acceptances and efficiencies. Half of the maximum difference between the standard result and the results from the variations is assigned as systematic uncertainty. It amounts to 3.5%

X(3872) and $\psi(2S)$ *non-prompt fraction* : non-prompt components from 20% to 40% for both particles are considered, resulting in differences in the final result as large as 6% with respect to the nominal assumption of non-prompt fractions of 30%.

Uncertainty on the pion tracking efficiency : In a kinematic region similar to our analysis, the absolute uncertainty on the efficiency to reconstruct a single pion track has been determined to be 3.9% [3]. For the measurement of the cross section ratio, the uncertainty on the track finding efficiency is expected to partially cancel. Moreover the pion efficiency taken from

simulation is cross checked with the corrected data yields ratio for $\psi(2S) \to J/\psi\,\pi^+\pi^-$ and $\psi(2S) \to \mu^+\mu^-$, obtaining compatible results. The systematic on the ratio is conservatively estimated to be 4%.

Uncertainty due to finite Monte Carlo statistics : determined to be 1.8%.

In total, the relative systematic error on the cross section ratio is estimated to be 10%, about half the size of the statistical uncertainty.

2.3 Conclusion

The ratio of production cross sections [4]

$$R = \frac{\sigma(pp \to X(3872) + \text{anything}) \times BR(X(3872) \to J/\psi\,\pi^+\pi^-)}{\sigma(pp \to \psi(2S) + \text{anything}) \times BR(\psi(2S) \to J/\psi\,\pi^+\pi^-)} \tag{2.1}$$

for pp collisions at 7 TeV, in the kinematic region $p_{\mathrm{T}} > 8$ GeV and $|y| < 2.2$, is measured to be

$$R = 0.087 \pm 0.017(stat.) \pm 0.009(syst.), \tag{2.2}$$

where the first error refers to the statistical uncertainty of the data and the second error contains the sum of all systematic uncertainties, as described above, added in quadrature.

3. First look at 2011 data and future prospects

During 2011 LHC has gradually increased the delivered instantaneous luminosity. Due to the limited bandwidth available the di-muons are already required at trigger level in the first period of 2011 run to have p_{T}>7 GeV, $|y|$ < 1.25 and reconstructed mass between 2.95 and 3.25 GeV. In order to work in a fiducial region with a sufficient acceptance the analysis is restricted to the kinematical region $p_{\mathrm{T}} > 9$ GeV and $|y| < 2.2$. The requirement of the minimal p_{T} of the charged pion candidate is also increased to 600 MeV to improve the significance of the signal.

The invariant mass distribution of selected $J/\psi\,\pi^+\pi^-$ candidates corresponding to an integrated luminosity of 896 pb^{-1} is shown in Fig. 1(b). From the fit we obtain $N_{\psi(2S)}$ = 72594 $\pm$ 518 and $N_{X(3872)}$ = 5303 $\pm$ 341. In a stricter kinematic region an event sample of $X(3872)$ 10 times the one of 2010 is already collected and the statistical uncertainty on the X(3872) yield is reduced from 20% to 6%. With the foreseen delivered integrated luminosity for 2011 it will be possible to measure the ratio of the production cross sections for $X(3872)$ and $\psi(2S)$ differentially in p_{T}. Also a more detailed study of the non-prompt component for the $X(3872)$ will be performed.

References

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