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# Measurement of the $X(3872)$ production cross section via decays to $J/\psi\pi^+\pi^-$

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**Summary.** — The production of the $X(3872)$ is studied in $pp$ collisions at $\sqrt{s} = 7\,\text{TeV}$ with the CMS detector at LHC, using decays to $J/\psi\pi^+\pi^-$ where the $J/\psi$ decays to two muons. For the first time, the prompt $X(3872)$ cross section times branching fraction is extracted differentially in $p_T$. The available NRQCD predictions significantly exceed the measured value, while the $p_T$ dependence is reasonably well described. The dipion invariant-mass spectrum of the $J/\psi\pi^+\pi^-$ system in the $X(3872)$ decay is measured and favours the presence of an intermediate $\rho_0$ state.

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The $X(3872)$ is one of the states with mass above the open-charm threshold that do not fit into the conventional quark model. It was discovered by the Belle experiment in 2003 and its nature still remains unknown. At Large Hadron Collider (LHC) there is the opportunity to study this state with high statistics and the measurement of the prompt $X(3872)$ production rate as a function of transverse momentum ($p_T$) can provide a test of the NRQCD factorization approach to $X(3872)$ production. This analysis is performed on the data recorded by the CMS experiment in 2011 in $pp$ collisions at a centre-of-mass energy ($\sqrt{s}$) of 7 TeV. The $X(3872)$ is observed using the decays into $J/\psi\pi^+\pi^-$, with the subsequent decay of the $J/\psi$ into a pair of muons. This decay channel has a clean experimental signature in CMS, whose features can be found in ref. [1]. The analysis is performed in the kinematic range of 10–50 GeV/c for the $p_T$ of the $J/\psi\pi^+\pi^-$ system and the rapidity within $|y| < 1.2$, collecting about 12000 $X(3872)$ candidates. The event selection and the event simulations, used to determine acceptances and efficiencies, are described in detail in ref. [2]. The $X(3872)$ is assumed to be an unpolarized state with $J^{PC} = 1^{++}$, as confirmed by latest LHCb study [3].

In order to determine the cross section for prompt $X(3872)$ production, the ratio ($R$) of the $X(3872)$ and $\psi(2S)$ cross sections times their branching fraction to $J/\psi\pi^+\pi^-$ and the fraction of $X(3872)$ produced from decays of B hadrons (nonprompt fraction) are measured as described in ref. [2]. No significant dependence on $p_T$ is observed for both quantities. These two measurements are combined with a previous result of the prompt $\psi(2S)$ cross section obtained in CMS using the $\psi(2S) \to \mu^+\mu^-$ decay mode [4]. By means

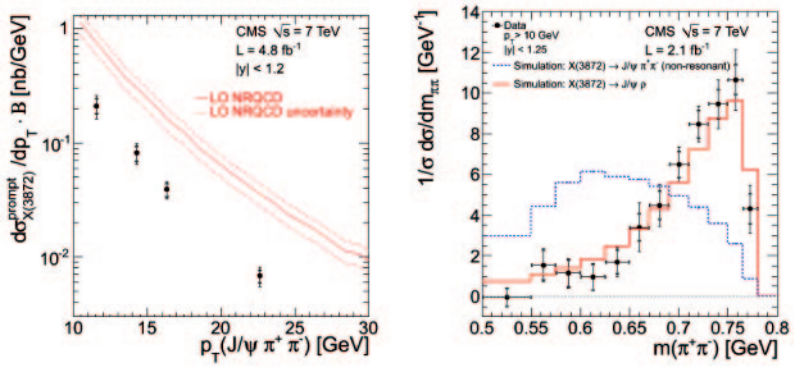


Fig. 1. – Measured differential cross section for prompt $X(3872)$ production times branching fraction of $X(3872) \to J/\psi\pi^+\pi^-$ ($B$) as a function of $p_T$ (left). Dipion invariant-mass spectrum for $X(3872) \to J/\psi\pi^+\pi^-$ decays corrected for acceptance and efficiency (right).

of this combination, the differential cross section for prompt $X(3872)$ production times the branching fraction is obtained as a function of $p_T$, in the rapidity region $|y| < 1.2$, as shown in fig. 1 (left). The $X(3872)$ and $\psi(2S)$ states are assumed to be unpolarized and no cancellation of systematic uncertainties is considered in the combination. The main sources of systematic uncertainty are related to the measurement of $R$ [2] and of the prompt $\psi(2S)$ cross section [4]. The differential cross section for prompt $X(3872)$ production in $pp$ collisions at $\sqrt{s} = 7\,\text{TeV}$ has also been predicted with a calculation made within the NRQCD factorization formalism [5]. The comparison of this prediction with the data is shown in fig. 1 (left) and demonstrates that, while the shape is reasonably well described, the predicted cross section is much larger than the measured one. The integrated prompt $X(3872)$ cross section times branching fraction is determined to be $1.06 \pm 0.11(stat.) \pm 0.15(syst.)\,\text{nb}$, for $10 < p_T < 30\,\text{GeV/c}$ and $|y| < 1.2$. This measured value is significantly below the NRQCD prediction in the same kinematic region, which is $4.01 \pm 0.88\,\text{nb}$ [5].

The dipion invariant-mass distribution from $X(3872)$ decays to $J/\psi\pi^+\pi^-$ is also measured in order to investigate the decay properties of this state. The event sample is divided into intervals of $m(\pi^+\pi^-)$ and a maximum-likelihood fit is performed in each interval extracting the signal yields. The dipion invariant-mass distribution is obtained from these yields, after correction for detector acceptance and efficiency estimated from the simulation, as described in ref. [2]. The main systematic uncertainties are related to the signal extraction ($\sim 15\%$). The resulting dipion invariant-mass spectrum, normalized to the total cross section in the interval $0.5 < m(\pi^+\pi^-) < 0.78\,\text{GeV/c}$, is presented in fig. 1 (right). The data are compared to $X(3872)$ signal simulations with and without an intermediate $\rho^0$ in the $X(3872)$ decay. The assumption of an intermediate $\rho^0$ decay gives better agreement with the data.

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