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## Quarkonium production and polarization

Studies of the production of heavy quarkonium states are very important to improve our understanding of QCD and hadron formation, given that the heavy quark masses allow the application of theoretical tools less sensitive to nonperturbative effects.  $J/\psi$  and Upsilon cross sections can be reproduced by nonrelativistic QCD calculations, dominated by “color octet” production, but the corresponding predictions of strong transverse polarizations are in strong disagreement with the negligible polarizations measured at the Tevatron for the  $J/\psi$ . However, this comparison is affected by the feed-down decays from  $\chi_c$  mesons, of unknown influence on the measurements. Given their heavier masses, measurements of the Upsilon production cross sections and polarizations are a more decisive test of NRQCD, especially at the high transverse momentum ranges reachable at the LHC.

This talk presents recent CMS measurements of the differential cross sections and polarizations of the Upsilon(1S), Upsilon(2S) and Upsilon(3S) mesons produced in proton-proton collisions at  $\sqrt{s} = 7$  TeV, using the dimuon data sample collected in 2011, corresponding to an integrated luminosity of  $4.9 \text{ fb}^{-1}$ . This is the most comprehensive measurement of Upsilon properties made at hadron colliders so far.

All the three frame-dependent polarization parameters ( $\lambda_\theta$ ,  $\lambda_\phi$  and  $\lambda_{\theta\phi}$ ), plus the frame-invariant parameter  $\tilde{\lambda}$ , are measured in three different polarization frames, in five transverse momentum bins and two rapidity ranges, significantly extending the  $p_T$  and rapidity ranges probed by previous experiments. The observations are in disagreement with the available theoretical expectations.

Preliminary results on  $J/\psi$  and  $\psi(2S)$  polarizations will also be shown.

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