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Decoding charmonia polarization in pp collisions at LHC energies: PYTHIA8 analysis and future trajectories

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In this study, we investigate the polarization parameters of J/ψ and ψ(2S) in proton-proton (pp) collisions at LHC energies, utilizing PYTHIA8 to analyze dimuon angular distributions. Our findings reveal intriguing insights: at low transverse momentum (p_T), both particles exhibit longitudinal polarization, transitioning to transverse polarization at higher p_T in both helicity and Collins-Soper reference frames. Moreover, longitudinal polarization is evident across all energies, while transverse polarization is prominent in the Collins-Soper frame. Notably, the degree of longitudinal polarization of ψ(2S) increases with charged particle multiplicity, contrasting the relatively constant polarization observed for J/ψ. Although we find no clear dependence of polarization parameters on rapidity, future studies with wider kinematics acceptance, such as the ALICE 3 setup, could shed light on this aspect. Our results, based on pQCD-based PYTHIA8 simulation, suggest the necessity for comprehensive studies utilizing theoretical models in conjunction with experimental data to fully understand charmonia polarization in ultra-relativistic pp collisions.

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