A Novel Hadronization Model Explaining Charm-Quark Hadronization in Different Collision Systems Through Yet-Unobserved Excited States and Cluster Volume Dependence

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The study of hadronization, the process of quarks combined into hadrons, is pivotal for understanding the universe's formation, yet current theories inadequately explain this process. This study investigated the recently observed anomaly in charm-quark hadronization–an elevated baryon-to-meson ratio in pp collisions challenging the assumption of hadronization universality. // Starting from the hypothesis that possible production of yet-unobserved excited states causing the anomaly, 294 yet-unobserved excited states were incorporated into Statistical Hadronization Model calculation. Aiming to explain the full experimental picture of hadronization, the model underwent two significant refinements: the introduction of a cluster volume scheme and a rapidity dependence scheme. // The model accurately predicted the increase in charm baryon production, approaching the observed baryon-to-meson ratios with no more than 4% errors. The cluster volume dependence scheme extended the model's relevance, making it applicable to pp, ep, and e+e- collisions across all energy levels; the rapidity dependence scheme precisely described the charm hadron production in both mid-rapidity ($|y|<0.5$) and forward rapidity ($2<y<4.5$) ranges. // This study showed that the measured increase in baryon-to-meson ratio can be attributed to the existence of yet-unobserved excited states. The study of non-universal hadronization also sheds light on the question of whether the quark-gluon plasma (QGP) produced in colliders is the same as the QGP at the start of the universe.

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