

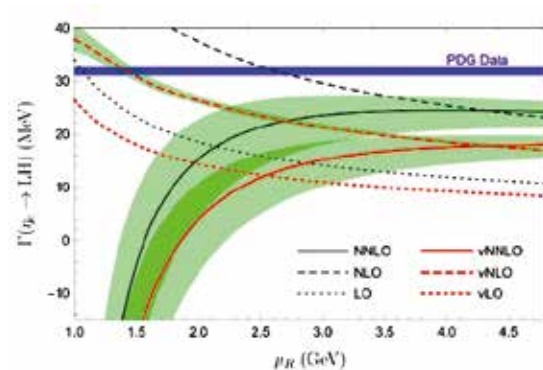
Understanding Heavy Quarkonium and QCD

Scientists have for the first time calculated the next-to-next-to-leading order (NNLO) radiative correction to the hadronic width of pseudoscalar quarkonium, and conducted a detailed phenomenological study using the latest experimental data. The work, which marks an important progress in heavy quarkonium physics and Quantum Chromodynamics (QCD), was published in the journal *Physical Review Letters* on December 20, 2017.

Understanding heavy quarkonium annihilation decay has historically played a key role in establishing the asymptotic freedom of QCD. Around 1980, the next-to-leading order (NLO) perturbative correction for the hadronic width of pseudoscalar quarkonium, at the lowest order in velocity expansion, was independently computed by one group from Italy, and another from Japan. The NLO correction was found to be significant, which naturally raised curiosity about the impact of the hitherto unknown NNLO correction.

Due to insurmountable technical difficulties, essentially no progress was made toward this goal in the following four decades. A breakthrough finally occurred in the summer of 2017. Benefiting from rapid technical advances in multi-loop computation in recent years, Prof. JIA Yu and his team finally accomplished the challenging calculation of the complete NNLO correction for the inclusive decay rate of η_c with the help of the National Tianhe Supercomputing Center in Guangzhou.

In their paper, the team has clearly verified, for the first time, that the effective-field-theory approach based on the first principles of QCD, the non-relativistic QCD (NRQCD) factorization, still remains valid at NNLO for this inclusive decay process. Nevertheless, when combining this new NNLO piece with existing relativistic corrections, they found that, the state-of-the-art NRQCD predictions are in severe tension with the measured η_c hadronic width, and in particular, with the



The predicted η_c total width as a function of renormalization scale μ_R . The blue band denotes the measured η_c hadronic width. The curves labeled by LO, NLO, NNLO represent the various perturbative accuracies in NRQCD predictions. The green band characterizes the theoretical uncertainty brought by varying the NRQCD factorization scale μ_Λ .

measured branching fraction of η_c decay to two photons.

These discrepancies indicate that, though the influential NRQCD approach has solid theoretical ground, the charm quark mass may not be viewed as truly large, therefore the utility of NRQCD, when applied to charmonium, appears to face serious challenges. On the other hand, NRQCD approach appears to be capable of reliably accounting for the measured η_b hadronic width.

The team's conclusion is compatible with an earlier paper they published in *Physical Review Letters* in 2015, which pointed out that the NRQCD approach faces some crisis when applied to charmonium exclusive production process.

The research was jointly conducted by JIA Yu from the Institute of High Energy Physics, Chinese Academy of Sciences (IHEP), FENG Feng from the China University of Mining and Technology, and SANG Wenlong from Southwest University. It was supported in part by the National Natural Science Foundation of China.