Charmonium on the lattice

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Lattice QCD has been able to provide a wealth of results for the hadron spectrum, both in the quenched approximation and with dynamical quarks [1]. Even in the quenched approximation, most of the low-lying hadron masses are reproduced, deviations typically amounting to 10 per cent. An exception is the charmonium hyperfine splitting. The mass difference between J/ψ and η_c comes out about 30–40% smaller than the experimental value $\Delta M = 117$ MeV. Finding a solution to this discrepancy poses a real challenge to the lattice. On top of this, there are new results on the charmonium spectrum coming from Belle, BaBar and CLEO which make the study of charmonium a very atractive arena for lattice computations.

Despite this interest, attempts to extract the charmonium spectrum from the lattice face many difficulties. With current computational resources, the charm quark mass is not well below the accessible lattice cutoffs. Relativistic formulations require hence the use of $O(a)$ improved lattice quark actions which reduce the $O(am_q)$ errors. This is the approach we have taken in Ref. [2]. We have used the nonperturbatively $O(a)$-improved Wilson quark action on quenched isotropic lattices, with lattice cutoffs ranging from 2 to 5 GeV. A careful continuum extrapolation gives the result $\Delta M = 77(2)(6)$ MeV still far below the experimental value.

One of the candidates to explain this discrepancy is the contribution of OZI-suppressed diagrams. These diagrams contribute to singlet mesons as the J/Ψ or the η_c, and have not been incorporated in any of the lattice computations of ΔM performed up to now. According to the perturbative picture, their contribution is expected to be small in heavy quarkonium. Nevertheless, it might be non-negligible compared to the, also small, hyperfine splitting. The QCD-TARO collaboration has been analysing this contribution. First results have been presented in [3]. For charmonium the effect of the disconnected diagrams is very small. No contribution is seen in the vector meson channel. In the pseudo-scalar channel a small decrease of the pseudoscalar mass of up to about 20 MeV cannot be ruled out. If this result prevails it would go in the correct direction, bringing the hyperfine splitting closer to its experimental value.

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References

[1] For a recent review, see e.g. C. McNeile, arXiv:hep-lat/0307027.
[2] S. Choe et al. [QCD-TARO Collaboration], JHEP08(2003) 022 [arXiv:hep-lat/0307004].
[3] Ph. de Forcrand *et al.* [QCD-TARO Collaboration], 'Contribution of disconnected diagrams to the hyperfine splitting of charmonium', arXiv:hep-lat/0404016.