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Towards a parameter-free determination of critical exponents and chiral phase transition temperature in QCD

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The chiral phase transition in QCD is frequently studied by either locating the inflection point of a suitably renormalized order parameter or the extrema of chiral susceptibilities as function of the light quark masses. In the limit of vanishing light quark masses their scaling behaviour is dominated by scaling functions and critical exponents that are unique for a given universality class.
Generally properties of the relevant universality class, $i.e.$ the 3-d, $O(2)$ or $O(4)$ universality classes are used to extract the chiral phase transition temperature at vanishing values of the chemical potentials. No serious attempt exists so far, to extract the relevant universal critical exponents directly from lattice QCD calculations.

In this talk, we will use properties of a renormalized chiral order parameter M, obtained as a suitable difference of the 2-flavor light quark chiral condensate M_b and its susceptibility χ_b and given by $M = M_b - H\,\chi_b$ [1,2].
Similar to the related observable $H\,\chi_b/M_b$, the improved order parameter M also is directly proportional to a scaling function. In addition the latter has the advantage of eliminating additive UV divergences as well as $calO(H)$ regular contributions.
In the scaling region the logarithm of the ratio of this order parameter, evaluated for two different light quark masses, has a unique crossing point as function of temperature. This crossing-point arises at the chiral phase transition temperature T_c and directly gives the value of the critical exponent δ without any prior information regarding the associated universality class of the phase transition.
We present first results from our numerical study of this order parameter ratio on lattices with fixed temporal extent $N_\tau = 8$. We discuss the prospects for a parameter free determination of T_c and δ in the chiral limit of (2+1)-flavor QCD.

References:

[1] L. Dini et al, Phys.Rev.D 105 (2022) 034510, arXiv:2111.12599
[2] H.-T. Ding et al, arXiv:2403.09390

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