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New approach to lattice QCD at finite density: reweighting without an overlap problem

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All methods currently used to study finite baryon density lattice QCD suffer from uncontrolled systematic uncertainties in addition to the well-known sign problem. We formulate and test a method - sign reweighting - that works directly at finite chemical potential and is yet free from any such uncontrolled systematics: with this approach the only problem is the sign problem itself. In practice the approach involves the generation of configurations with the positive fermionic weights $|\text{Redet}D(\mu)|$ where $D(\mu)$ is the Dirac matrix and the signs $\text{sign}(\text{Redet}D(\mu)) = \pm 1$ are handled by a discrete reweighting. Hence there are only two sectors, $+1$ and -1 and as long as the average $\langle \pm 1 \rangle \neq 0$ (with respect to the positive weight) this discrete reweighting has no overlap problem - unlike other reweighting methods - and the results are reliable. We will also present results based on this algorithm on the phase diagram of lattice QCD with two different actions: as a first test, we apply the method to calculate the position of the critical endpoint with unimproved staggered fermions at $N_\tau = 4$; as a second application, we study the phase diagram with 2stout improved staggered fermions at $N_\tau = 6$. This second one is already a reasonably fine lattice - relevant for phenomenology.

Primary authors: PASZTOR, Attila (Eötvös University); BORSANYI, Szabolcs (University of Wuppertal); FODOR, Zoltan (BUW); GIORDANO, Matteo (Eötvös Loránd University, Budapest); KAPAS, Kornel (Eotvos University); KATZ, Sandor (Eotvos University); NOGRADI, Daniel

Presenter: PASZTOR, Attila (Eötvös University)

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