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Renormalization constants of fermionic operators in lattice QCD with $N_f = 4$ dynamical Wilson quarks

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We report on preliminary non-perturbative computations of the renormalization constants in the RI-MOM scheme relevant for the lattice action currently used by the European Twisted Mass Collaboration (ETMC) and for $N_f = 4$ flavours of active dynamical quarks. The knowledge of these constants is necessary in order to extract physical quantities from the rich program of lattice QCD simulations being performed by the ETMC. This step will enable the precise computation (at a few percent level) of quantities like quark masses, leptonic decay constants, form factors, bag-parameters, which play a major role in the determination of the CKM matrix elements. For the purpose of this investigation dedicated simulations with four degenerate sea quark flavours are being performed. We also comment on issue of code optimization for the Aurora machine.

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1. Motivations And Method

Lattice QCD calculations provide today some of the most precise and model-independent estimates of the parameters of the Standard Model (see the CKM matrix on the right). But—in order to compare with the experiments—most quantities computed on a lattice regularization need to be renormalized.

A convenient renormalization prescription, which is valid also non perturbatively, is the RI-MOM scheme [1]. The mass independence of this scheme is achieved via an extrapolation to the chiral limit of QCD with the appropriate number of active quark fields.

ETMC is one of the largest lattice QCD collaborations worldwide and it has an ambitious physics program of Lattice QCD simulations with $N_f = 2+1+1$ flavors of quarks in the twisted mass regularization [2]. The renormalization constants (RCs) must be computed in the chiral limit of the twisted mass lattice QCD action (tmLQCD) with $N_f = 4$ degenerate quarks.

It was realized [3] that, in this setup, tuning at maximal twist is rather expensive. Performing simulations out of maximal twists introduces $O(a)$ lattice artifacts. However, these are expected to be small in the RCs and can be subtracted through the average of results obtained at different twisting angles (θ). We are therefore simulating different sea and valence quark masses ($M_{\rm sea}$ and $M_{\rm val}$) and different θ. Averaging the results obtained with opposite θ reduces the $O(a)$ lattice artifacts to $O(a^2)$.

After extracting the chiral limit of the RCs in both in the sea and the valence quark masses ($M_{\rm sea}, M_{\rm val} \to 0$), we are using two alternative methods [3]: In the first method (M_1) we subtract the $O(q^2a^2)$ artifacts with the help of a perturbative computation [5], and the residual $O(a^2)$ lattice artifacts are reduced by extrapolating the (q^2a^2) dependence to zero. In the second method (M_2) we choose a sufficiently high momentum $q^2 = 12.2GeV^2$, which is eventually kept fixed in physical units.

2. Results

Preliminary results at $a = 0.078$fm ($\beta = 1.95$) are presented here. Simulations at $a = 0.09$fm ($\beta = 1.90$) $a = 0.06$fm ($\beta = 2.10$) are in progress. Table 1 shows the results obtained with methods M_1 and M_2 and, where available, the Ward Identity method (WI). Figure 1 shows an example of chiral extrapolation ($M_{\rm sea} \to 0$) for Z_P, Z_S, (left) and an example of the $(qa)^2$ dependence on the RCs (right).

The tmLQCD code has been optimized for the Aurora architecture within the AuroraScience project [6], with a gain of 50% over the previous most efficient version of the code. This result could be obtained thanks to the introduction of an algorithm (originally proposed in [7]), that, after each timeslice computation, exchanges the relative boundaries, and hence allow an overlap of computations and communications.

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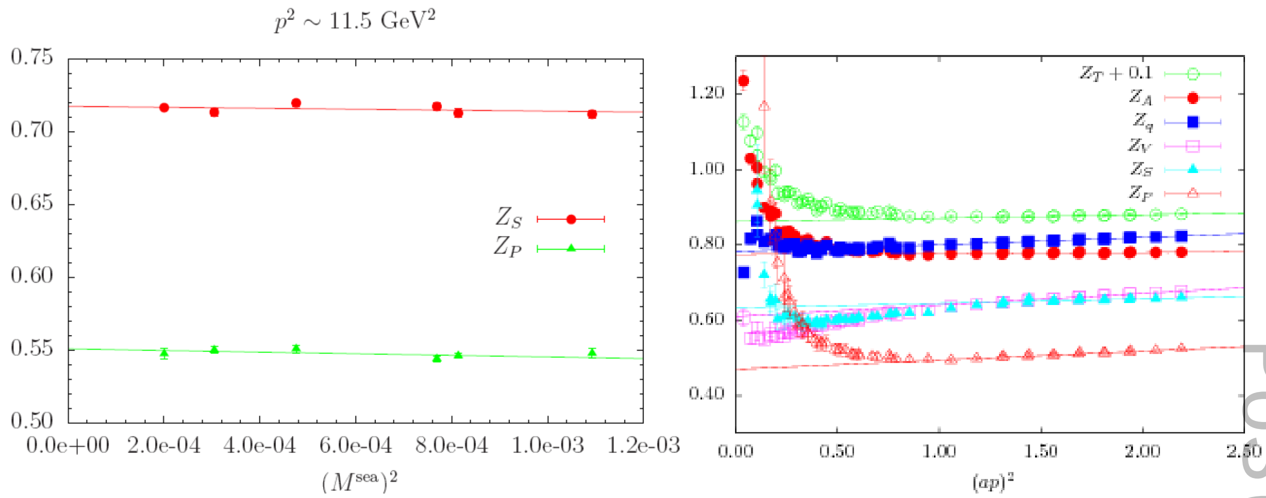

Figure 1: Left: chiral extrapolation on the sea quark mass for Z_P and Z_S. Right: example of the $(qa)^2$ dependence on the RCs.

	M_1	M_2	WI
Z_A	0.746(5)	0.738(1)	
Z_V	0.614(3)	0.639(2)	0.6120(5)
$Z_P(\mu = 1/a)$	0.426(6)	0.483(2)	
$Z_S(\mu = 1/a)$	0.609(8)	0.684(1)	

Table 1: Preliminary renormalization constants obtained at $\beta = 1.95$ with methods M_1 and M_2 and, where available, the Ward Identity method (WI).

with the BG/P systems at U. of Groningen, Cineca, IDRIS, Jülich Supercomputing Center and the Aurora system in Trento.

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