Properties and ensembles of Stabilised Wilson Fermions

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In collaboration with
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The 38th International Symposium on Lattice Field Theory

MIT, Virtual conference, 28.07.2021

Wilson-Clover fermions - an attractive setup with its drawbacks

- Wilson-Clover fermions are popular in the community
  $\rightsquigarrow$ @Lattice'21: $\mathcal{O}(120)$ WCF, $\mathcal{O}(70)$ STG, $\mathcal{O}(40)$ DWF, $\mathcal{O}(20)$ TMW - [dynamical]

- They are conceptually clear, with many advanced methods available, relatively cheap, and pose little restrictions on what observables can be computed.
- Together with a rigorous improvement program they can also be made $O(a^2)$.

There are also some drawbacks:

- without automatic $O(a)$ improvement observables often require finer a
  - have to deal with larger autocorrelations in gauge generation
  - this includes topological freezing problems
- without chiral symmetry the lowest DEV is not protected
  - exceptionally low values possible
  - problem especially when a=coarse or m_π=light or L_V=small
- further, during gauge generation errors can accumulate
  - large fluctuations have the potential to increase autocorrelation times
  - precision losses possible through global volume sums and integration errors

stabilised Wilson fermions (SWF) - the eClover

Focussing on the DEV's, there are 2 parts to this problem:

$$D = \frac{1}{2}\Big[\gamma_\mu\Big(\nabla^*_\mu + \nabla_\mu - a\nabla^*_\mu\nabla_\mu\Big)\Big] + m_0 + c_{SW}\frac{i}{4}\sigma_{\mu\nu}\hat{F}_{\mu\nu}$$

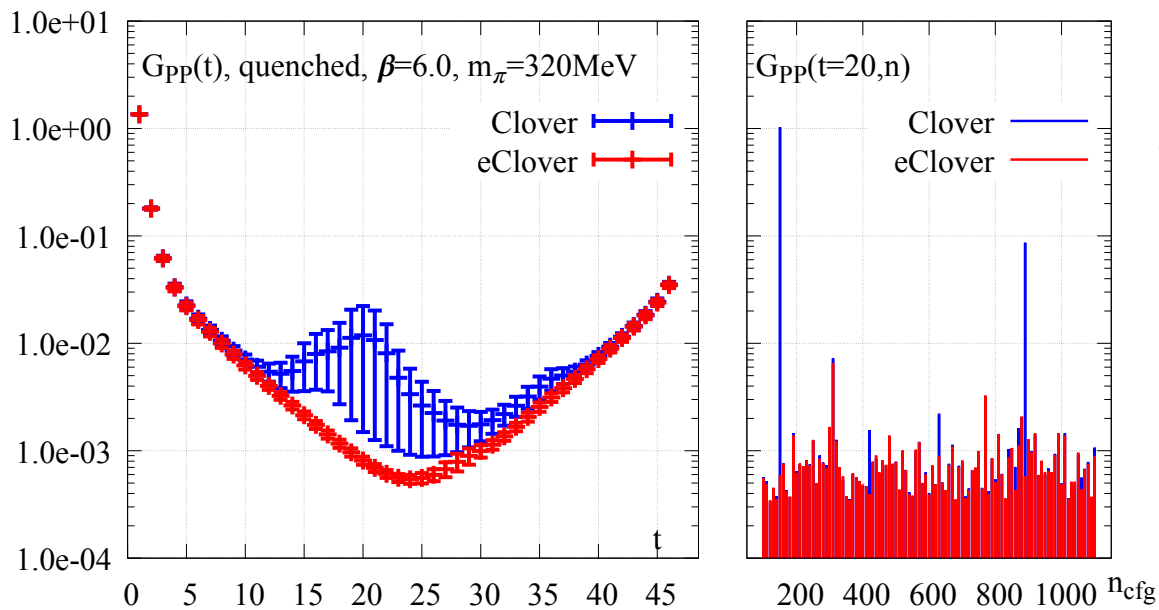
Wilson term $\rightsquigarrow$ unbounded below

Clover term $\rightsquigarrow$ unbounded below

Understand the Clover term as first part of an expansion:

$$D_{ee} + D_{oo} = 4 + m_0 + c_{SW}\frac{i}{4}\sigma_{\mu\nu}\hat{F}_{\mu\nu}\,(+\ldots) \quad \text{[in E/O form]}$$

$$\rightsquigarrow D_{ee}+D_{oo} = (4+m_0)\exp\left[\frac{c_{SW}}{4+m_0}\frac{i}{4}\sigma_{\mu\nu}\hat{F}_{\mu\nu}\right] \qquad \text{(invertible + bounded from below)}$$



Quenched demo:

- npt c_{SW} via tuning in SF
- cfg's: $\beta = 6.0$, $L = 48^4$
- $G_{PP}(t)$ tuned to $m_\pi = 320$MeV

Measurement on identical cfg's using the same solver.

stabilised Wilson fermions (SWF) - the full package

A toolkit for more stable running

SWF = a number of interconnecting stabilising measures. $\rightsquigarrow$ (not just eClover)

- eClover:
  - bound from below and guaranteed invertibility for Clover term
  - possible (observable dependent) scaling benefits
- precision loss:
  - increase precision of internal numbers to quad
  - use supremum-norm to ensure minimum solve quality
- autocorrelations:
  - SMD algorithm shows net gain in reduced autocorrelations at same cost

These go on top of the measures already deployed:

- twisted mass reweighting for light quarks
- mass preconditioning through Hasenbusch chains
- using improved solvers (for us: deflated SAP solver)
- high accuracy approximations for the strange quark RHMC

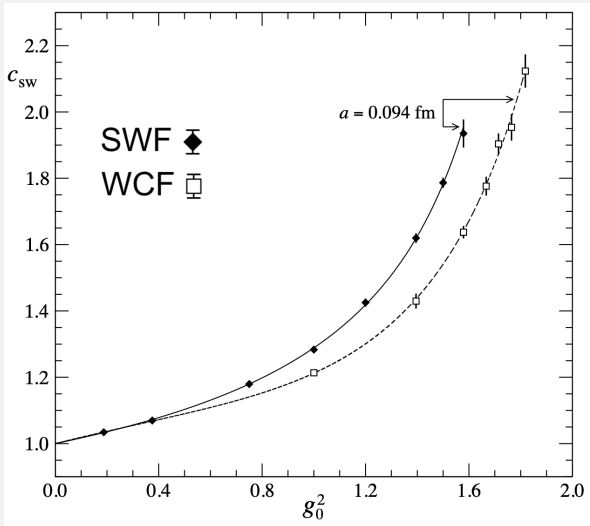
$\rightsquigarrow$ Combine all for the best, i.e. most stable in our experience, results.

Remark: Note that SWF preserve the pt-expansion, particularly important for renormalisation, and the change to the action is local only.

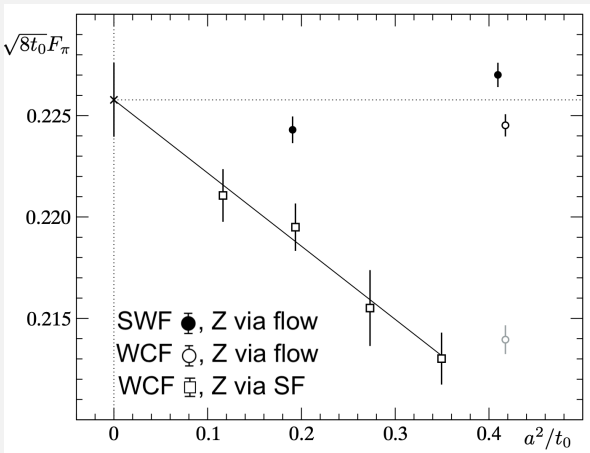
$\rightsquigarrow$ SWF could be combined with smearing, but we choose not to at this stage.

first SWF calculations - the dynamical case

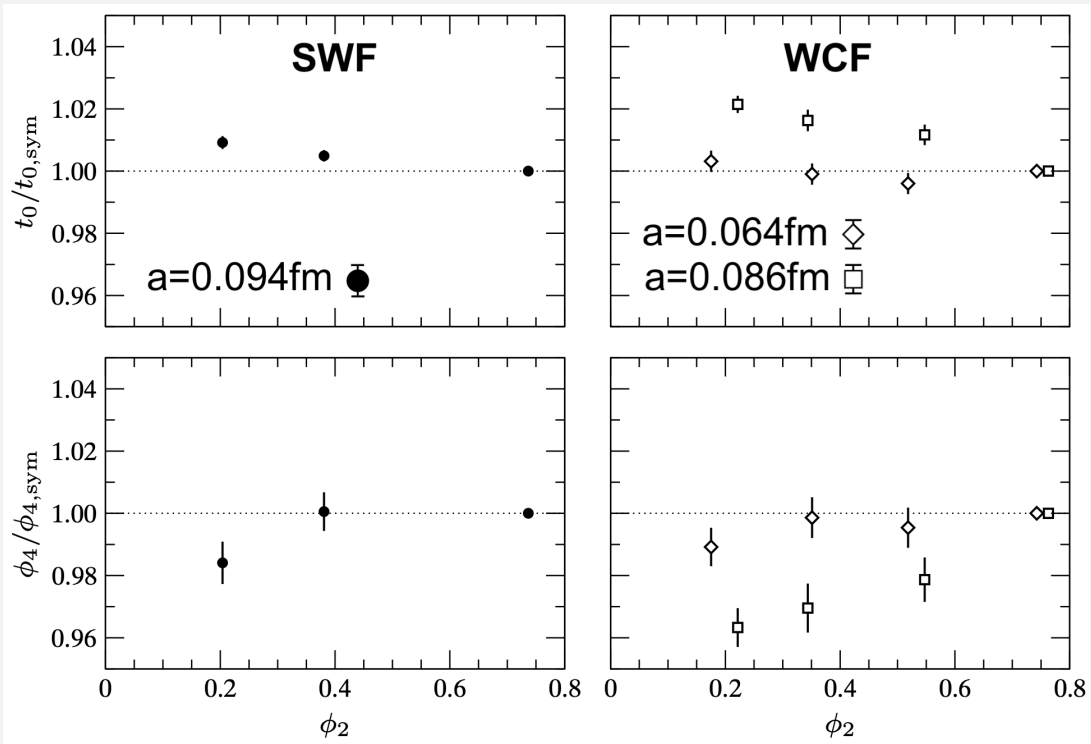
NP tuned c_{SW} (in SF)



f_π scaling in a



Chiral scaling at fixed a - update in G. Pederiva's talk



In `arxiv/1911.04533` (AF, P. Fritzsch, M. Lüscher, A. Rago):

- NP tuning of c_{SW} via SF, **extended to a=0.12fm**
- SWF: a=0.094fm ($m_\pi = 412, 293, 215$MeV),
  a=0.064fm ($m_\pi = 412$MeV)
  WCF: a=0.092fm ($m_\pi = 412$MeV)
- Z_A via Wilson flow
- overall, SWF show signs of some benefits ...

... to us this is the motivation to do something more:

OPEN LATtice initiative

Bringing together researchers from eight institutes. Our aim is to generate state-of-the-art QCD gauge ensembles for physics applications and to share them with the community to strengthen open science.

To us this means:

define and uphold quality
Standards for control observables, continue to research and improve best practices, consensus based decision making, frequent internal communication

share and maintain repository
Manage downloads, maintain data integrity, make control measurements available

community boosting
Use resource injections from members and interested/early access parties to expand set of gauges.

grant and enable access
Configurations will be made open access with accompanying first publication;
Early access through sharing agreement - get in touch with us!
No embargo time, no access vetting after publication

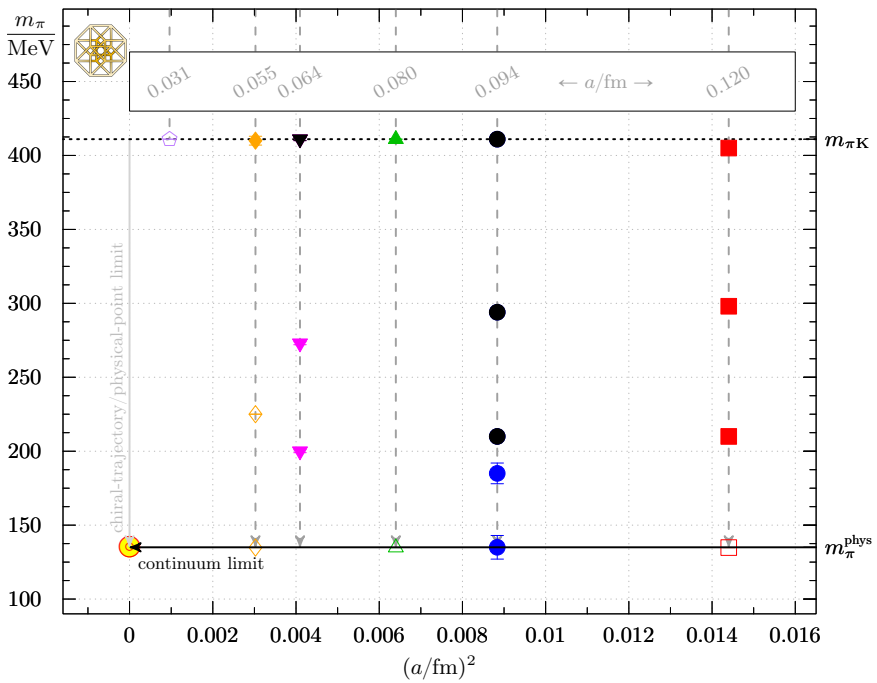
openLAT - gauges planned and running

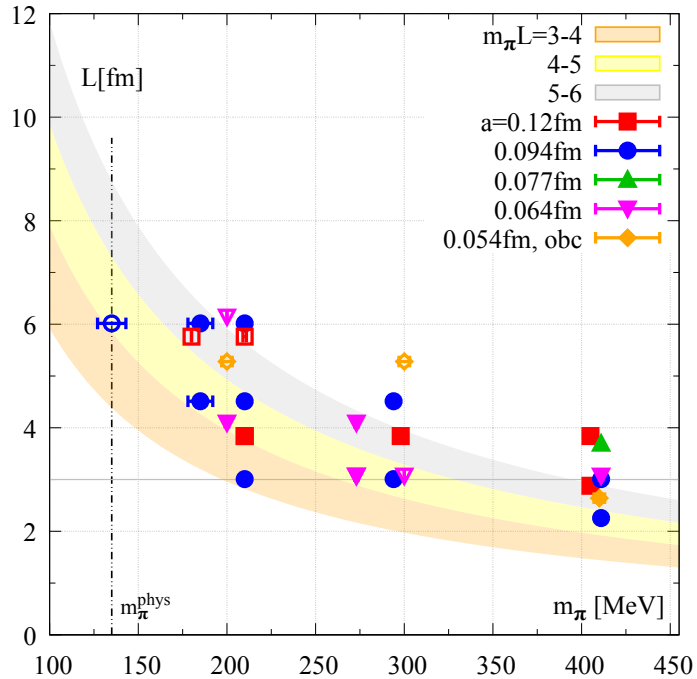
Our goal is to generate ensembles that

... exploit the benefits in the coarse regime (going lighter in particular)

... enable a extrapolation from a broad as possible window in a and m_π

... cater for a controlled estimation of finite volume effects





$\rightsquigarrow$ open symbols = planned, early stage; closed symbols = running

openLAT - interests and tuning aspects

⇝ skipable

Stability controls

- Plaquettes, $\langle E \rangle$, Q
- ΔH distribution
- Spectral gap via $\sqrt{D^\dagger D}$
- RWF, fluctuations below 5% (in future: sign)
- $G_{PP}(t)$, $G_{PA}(t)$, m_{pcac}, m_π, m_{Nucl}
- f_π with Z_A via flow

... being extended

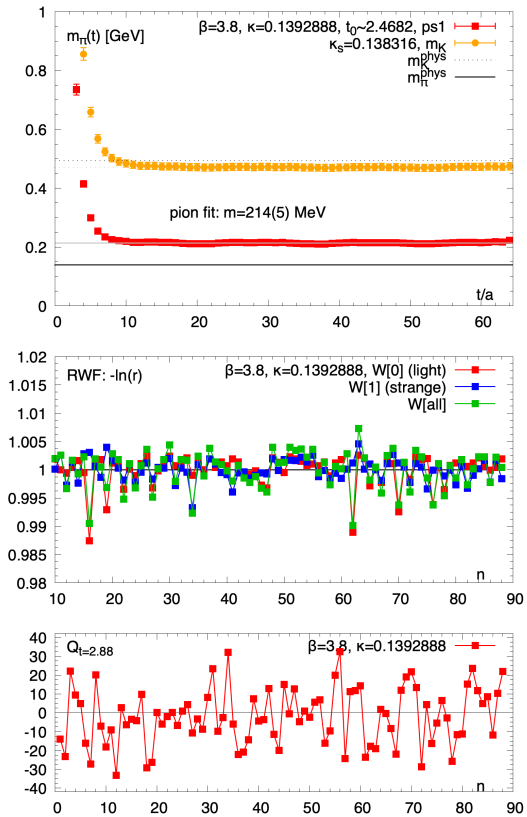
Member physics interests

- Symanzik improvement
- flavor physics
- nucleons (PDF)
- multi-hadrons/nucleons
- nonzero isospin
- fundamental symmetries
- ...

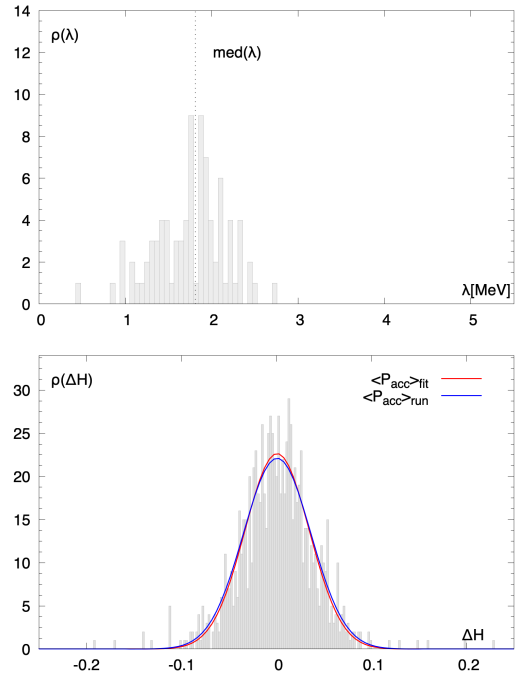
Want to contribute or join?
Get in touch!

Mass tuning and chiral trajectory

- $\mathrm{Tr}\,\mathrm{M} = \mathrm{m_u} + \mathrm{m_d} + \mathrm{m_s} = \mathrm{N_f m_\ell} = \text{const}$
- $\phi^4 = 8t_0(m_K^2 + m_\pi^2/2) = \phi^4_{\text{phys}} = 1.115 \simeq 412\,\text{MeV}$
- Tuning goal: 0.5% error and max. 1σ deviation



⇝ T=128, L=48, a=0.094 fm

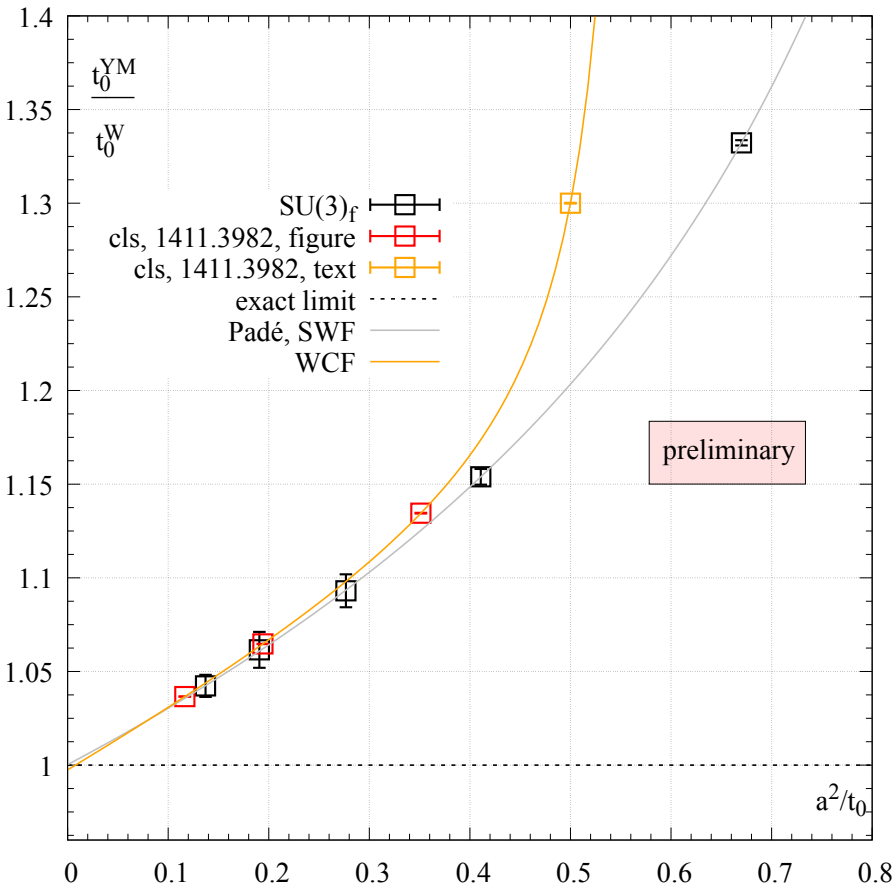


Early results - more in G. Pederiva's talk right after

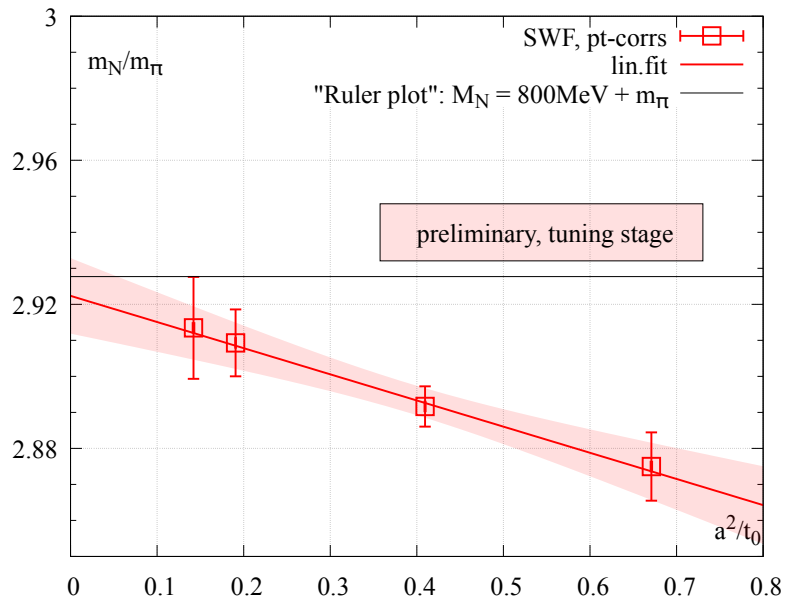
Our initative enables us to study the SWF further, here:

- First results at the $SU(3)_F$ point where $m_\pi = m_K = 412\text{MeV}$, or $\phi^4 = 1.115$, with TrM = fixed.

Relative effects in t_0 over a



Preliminary scaling of $M_{nucleon}/M_\pi$



- pt-pt corrs of the nucleon
- 2-state + 1-state fits to decide plateau
- "Ruler" pheno estimate, but here: $m_s \neq m_s^{\text{phys}}$

OPEN
LATtice
initiative

SWF package

is a number of measures, like the SMD and the eClover, for more stable running

eClover

local change in action; lower bound; some (scaling, chiral) benefits observed

open lattice initative

open science approach to further research SWF and use them in physics applications

get in touch!

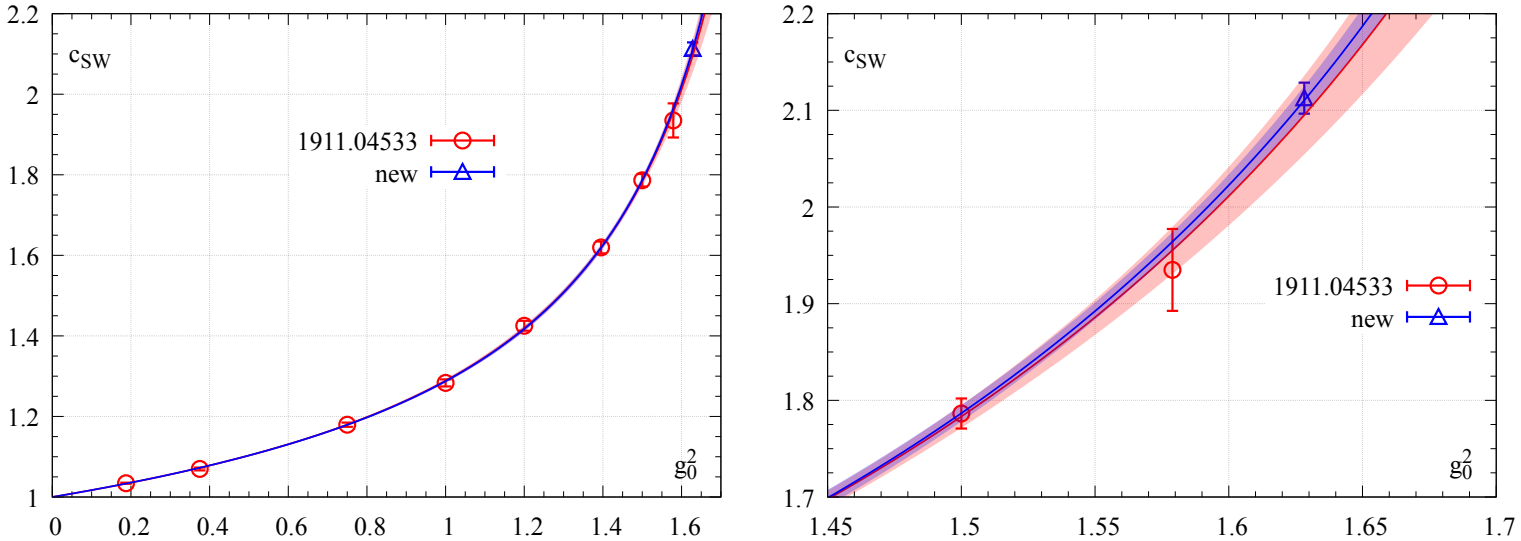
looking for members, contributors and users. ⇝ check us out at: openlat1.gitlab.io

Thank you for your attention.

Further material

stabilised Wilson fermions (SWF) - tuning c_{SW}

Extension of SF tuning of clover coefficient: a=0.12fm, lattice sizes: 16^4



Interpolation formula of 1911.04533 confirmed

$$c_{sw}(g_0^2) = \frac{1 - 0.325022 g_0^2 - 0.0167274 g_0^4}{1 - 0.489157 g_0^2}$$