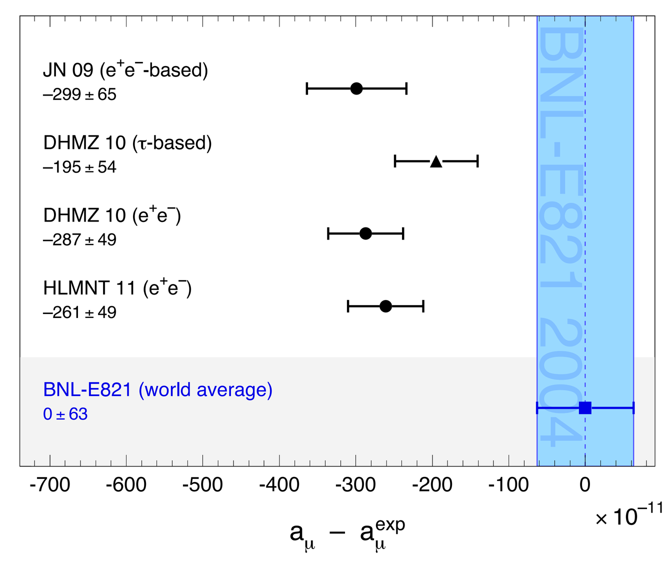
The leading-order hadronic contribution to $(g-2)_\mu$ from $N_f = 2+1+1$ twisted mass lattice QCD

GRADUIERTENKOLLEG Masse-Spektrum-Symmetrie

Motivation

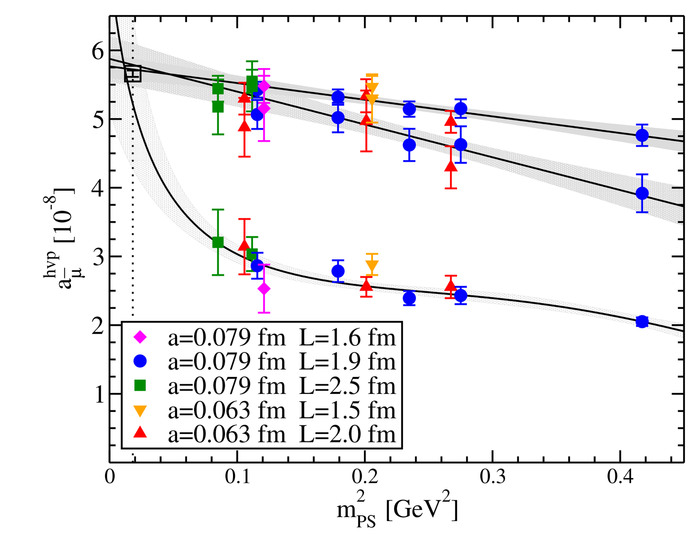
- anomalous magnetic moment of the muon, a_μ, serves as benchmark test of standard model of elementary particle physics (SM)
- key ingredient: leading-order hadronic vacuum-polarisation contribution a_μ^{hvp}
  - intrinsically nonperturbative $\rightarrow$ lattice QCD computation highly desirable
  - must be responsible for discrepancy since QED and weak contributions reliably computed in perturbation theoy
  - largest source of uncertainty in SM computation



[Hoecker, arXiv:1201.5093 [hep-ph], 2011]

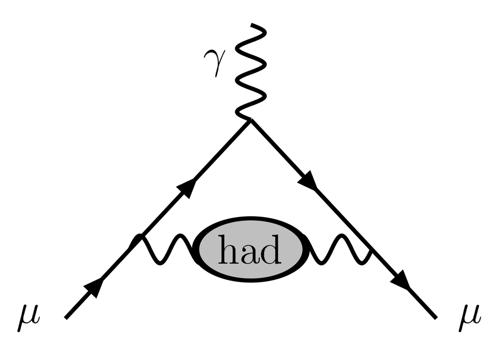
Method

- twisted mass lattice regularisation of QCD: alleviates discretisation effects by improving the continuum limit behaviour of *all* physical observables
- calculations based on configurations with four dynamical quark flavours generated by European Twisted Mass Collaboration (ETMC)
- computation of a_μ^{hvp} follows closely strategy of refs. [1,2] using an improved lattice definition of this quantity



[Feng, Jansen, Petschlies, Renner, Phys. Rev. Lett. **107**, 2011]

More Details



- a_μ^{hvp} can be computed in Euclidean spacetime

$$a_\mu^{\mathrm{hvp}} = \alpha^2 \int_0^\infty \frac{dQ^2}{Q^2} w\left(\frac{Q^2}{m_\mu^2}\right) \Pi_{\mathrm{R}}(Q^2)$$

- $\Pi_{\mathrm{R}}(Q^2) = \Pi(Q^2) - \Pi(0)$ is renormalised hadronic vacuum polarisation function

- can be obtained from transverse part of hadronic vacuum polarisation tensor

$$\Pi_{\mu\nu}(Q) = \int d^4x e^{iQ\cdot(x-y)} \langle J_\mu^{\mathrm{em}}(x) J_\nu^{\mathrm{em}}(y)\rangle = (Q_\mu Q_\nu - Q^2\delta_{\mu\nu})\Pi(Q^2)$$

- correlator of electromagnetic vector currents

$$J_\mu^{\mathrm{em}}(x) = \frac{2}{3}\overline{u}(x)\gamma_\mu u(x) - \frac{1}{3}\overline{d}(x)\gamma_\mu d(x) + \frac{2}{3}\overline{c}(x)\gamma_\mu c(x) - \frac{1}{3}\overline{s}(x)\gamma_\mu s(x)$$

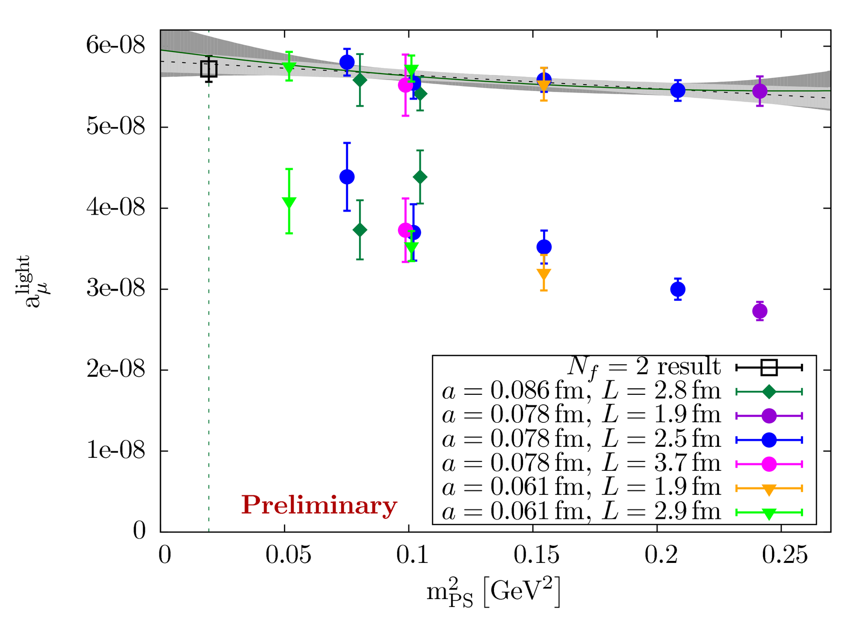
- on the lattice: point-split vector current $\rightarrow$ conserved, satisfies lattice Ward-Takahashi identity $\partial_\mu^* J_\mu^C(x) = 0$

- to weaken quark mass dependence use redefinition

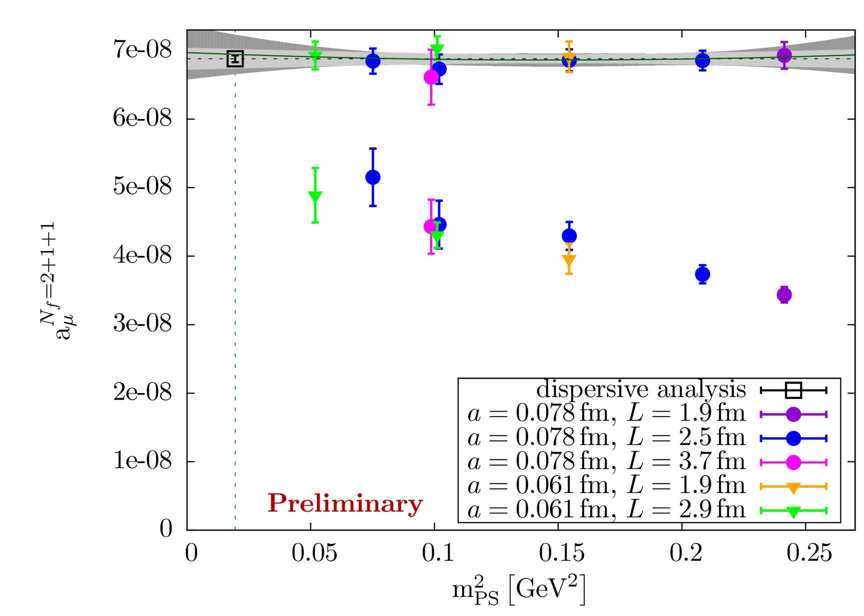
$$a_{\overline{\mu}}^{\mathrm{hvp}} = \alpha^2 \int_0^\infty \frac{dQ^2}{Q^2} w\left(\frac{Q^2}{H^2}\frac{H_{\mathrm{phys}}^2}{m_\mu^2}\right) \Pi_{\mathrm{R}}(Q^2)$$

- H is either $H=1$ (standard definition) or any hadronic scale which can be computed at unphysical values of pion mass m_{PS}
- for $m_{PS} \rightarrow m_\pi$, $H \rightarrow H_{\mathrm{phys}}$, i.e. by definition $a_{\overline{\mu}}^{\mathrm{hvp}} \rightarrow a_\mu^{\mathrm{hvp}}$
- $H = m_V$, mass of the ρ-meson, has proven to be especially beneficial

Preliminary Results



- only mass-degenerate up and down quarks in valence sector (left figure): value for light quark contribution to a_μ^{hvp} found for $N_f = 2$ in refs. [1,2] reproduced
- very first lattice results worldwide for four-flavour contribution to a_μ^{hvp} (right figure)
- promising prospect for future experiments
- full agreement with result of dispersive analysis by Benayoun, David, DelBuono, Jegerlehner (Eur.Phys.J. C72 (2012) 1848) found
- systematic uncertainties remain to be quantified



Publications

[1] X. Feng, K. Jansen, M. Petschlies and D. B. Renner, "Two-flavor QCD correction to lepton magnetic moments at leading-order in the electromagnetic coupling" Phys. Rev. Lett. **107** (2011) 081802 [arXiv:1103.4818 [hep-lat]].

[2] D. B. Renner, X. Feng, K. Jansen and M. Petschlies, "Nonperturbative QCD corrections to electroweak observables", arXiv:1206.3113 [hep-lat].

[3] X. Feng, G. Hotzel, K. Jansen, M. Petschlies and D. B. Renner, "Leading-order hadronic contributions to a_μ and α_{QED} from $N_f = 2+1+1$ twisted mass fermions", PoS **LATTICE2012** (2012) 174, [arXiV:1211.0828 [hep-lat]].

Selected Talks

- "The leading-order hadronic contribution to the anomalous magnetic moment of the muon from twisted mass lattice QCD", seminar given at INFN Laboratori Nazionali di Frascati, Italy, January 2012
- "Leading-order hadronic contributions to a_μ and α_{QED} from $N_f = 2+1+1$ twisted mass fermions", Lattice 2012, Cairns, Australia, July 2012

Collaborations

- Xu Feng (KEK, Tsukuba, Japan), Dru B. Renner (Jefferson Laboratory, Newport News, USA), Marcus Petschlies (The Cyprus Institute, Nicosia, Cyprus)
- European Twisted Mass Collaboration (ETMC)
- SFB TR9 - "Computational Particle Physics"

Profit from the GK

- Participation in Lattice 2012, the 30^{th} International Symposium on Lattice Field Theory
- Broader knowledge of the field due to discussions beyond the own group and informative lectures at the last block course

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