Calculation of the Leading Order Hadronic Vacuum Polarization on HISQ Ensembles with 4 flavors

Muon g-2 theory initiative workshop,

KEK - June 28-July 2, 2021

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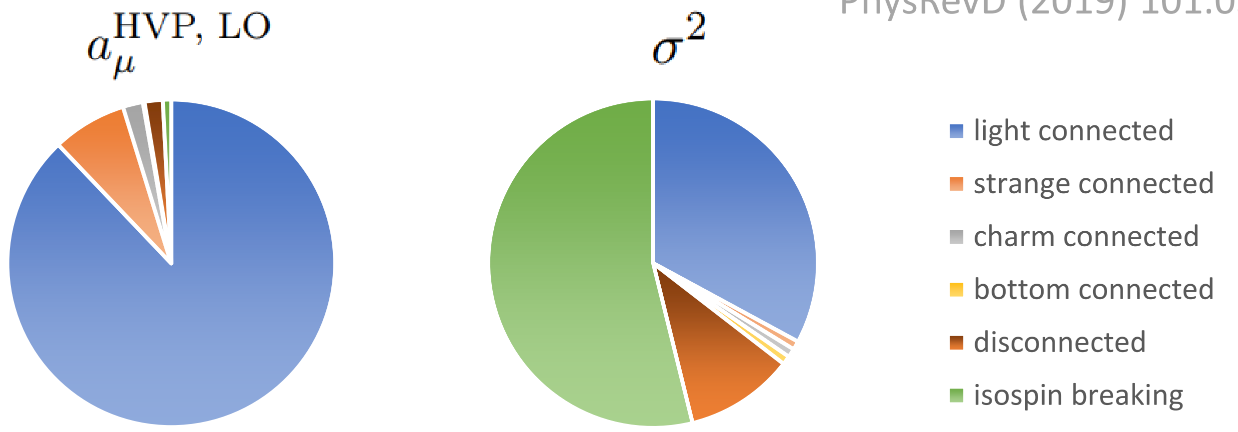
on behalf of the Fermilab Lattice, HPQCD, and MILC collaborations.

30-Jun-21

Introduction

$$10^{10} a_\mu^{\mathrm{HVP,LO}} = 699(15)_{u,d}(1)_{s,c,b}$$

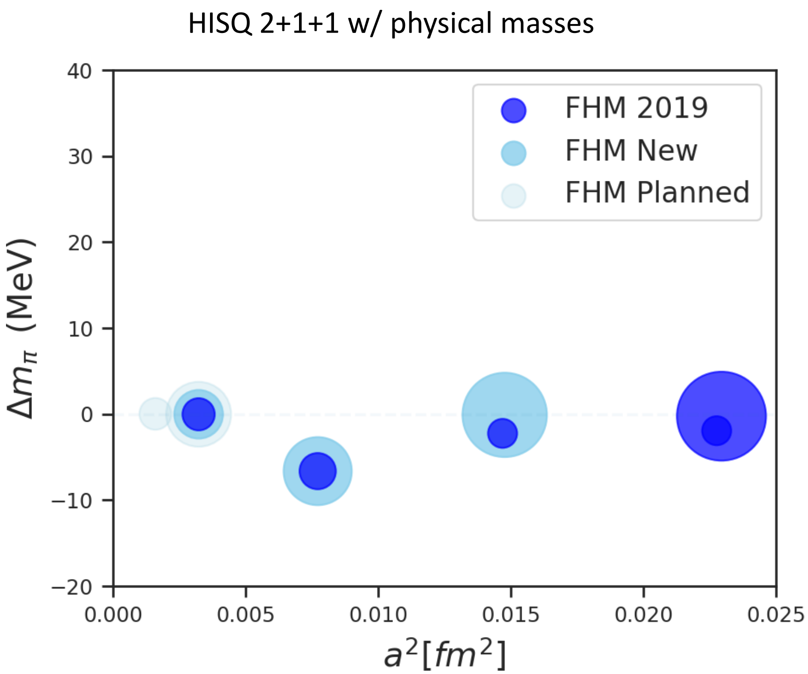
PhysRevD (2019) 101.034512

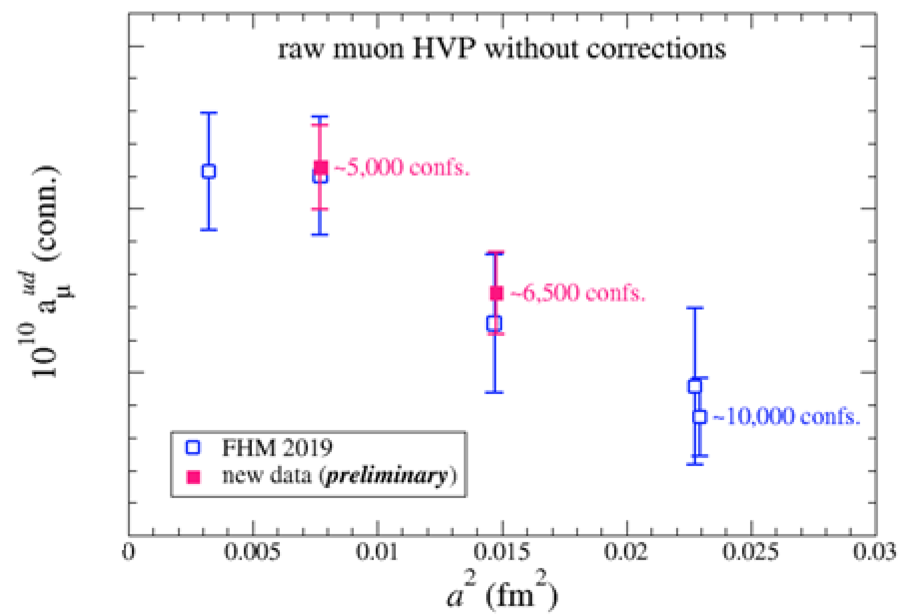


- Error on light-quark, connected contribution dominated by scale-setting uncertainty, statistics, continuum extrapolation & finite volume effect estimates.
- Isospin breaking & disconnected errors due to large uncertainties from phenomenological model estimates. Dedicated lattice calculations to address these contributions.

Plan for reducing **statistical** & **continuum extrapolation** uncertainty.

- Increase statistics on current ensembles, focusing on 0.06 fm.
- Move to 0.042 fm





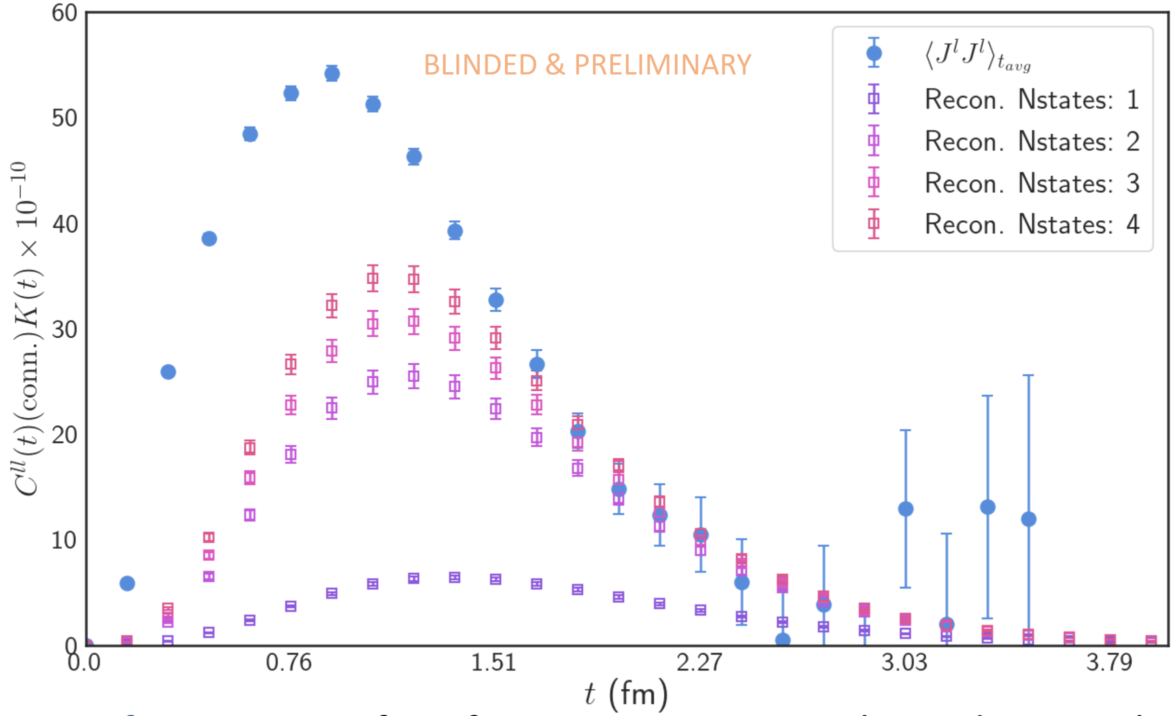
Ongoing analysis on SIB at 0.15fm (1710.11212) & 0.12fm.

Light quark, connected - two pion contribution

Pilot study to reduce uncertainty in the tail of the light-quark, connected correlator with spectral reconstruction of the (staggered) two-pion states.

$$a_\mu^{ll}(\text{conn.}) = 4\alpha^2 \int_0^\infty \mathrm{d}t\, C^{ll}(t)(\text{conn.})\, \tilde{K}(t)$$

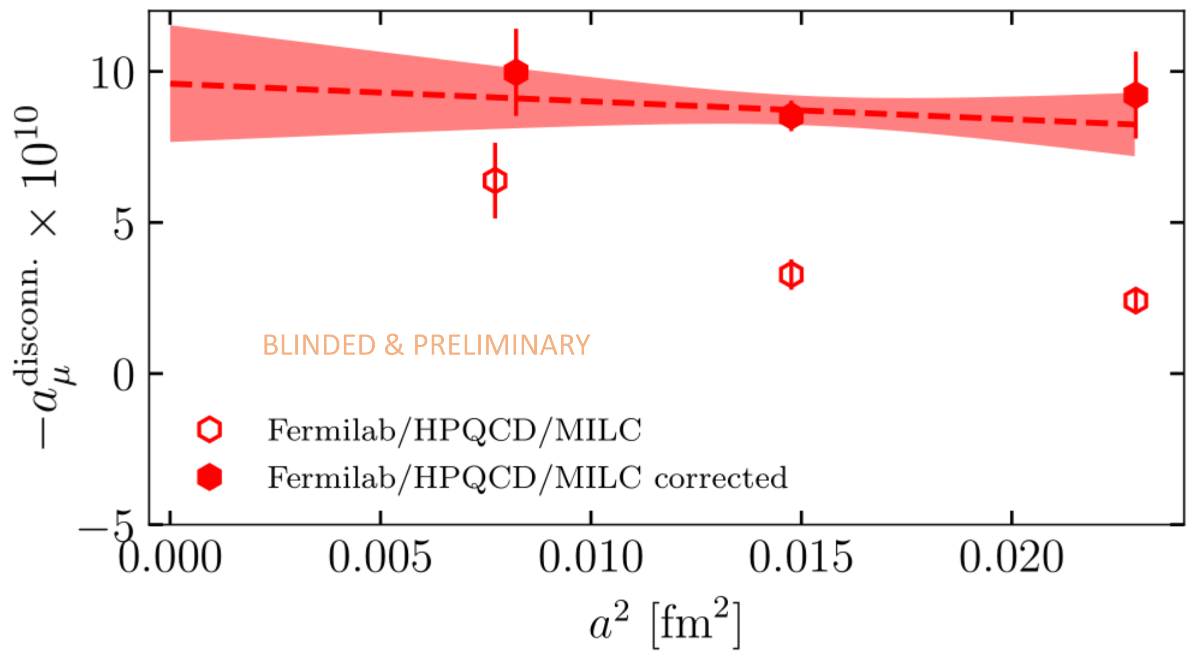
$$\mathbf{C}(t) = \begin{pmatrix} C(t)_{J,\tilde{J}\to J,\tilde{J}} & C(t)_{J,\tilde{J}\to\pi\pi} \\ C(t)_{\pi\pi\to J,\tilde{J}} & C(t)_{\pi\pi\to\pi\pi} \end{pmatrix} \qquad C^{ll}(t)(\text{conn.}) = \sum_n |\langle 0|J_l|\pi\pi_n\rangle|^2 e^{-E_n t}$$



a=0.15fm 3500 configs, factor ~ 3 gain over bounding method.

Generating data at 0.12 fm with plans to move to smaller lattice spacing.

Disconnected contribution



a=0.15fm Yamamoto et al., 1811.06058 Lattice 2018
a=0.12fm DeTar et al., 1912.04382 Lattice 2019
a=0.09fm Correlator generation ongoing

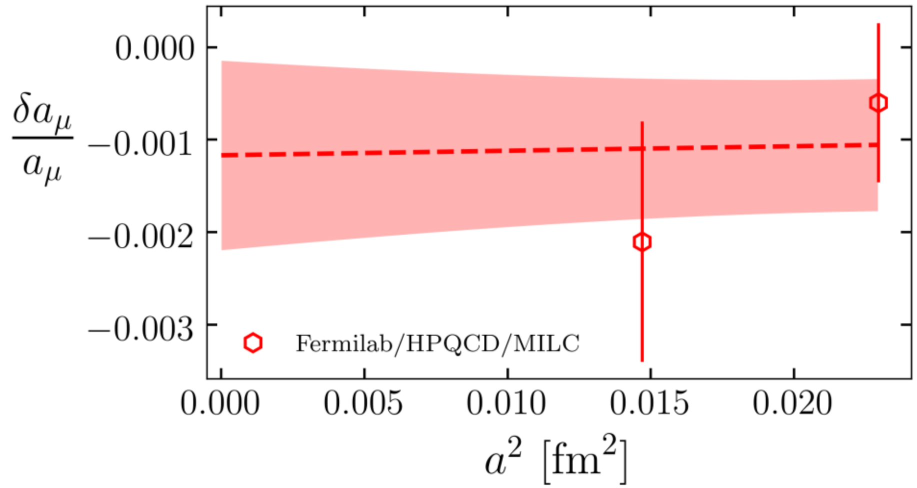
- Overall goal is <10% error.
- Plan to move to 0.06 fm.
- SIB disconnected correlators at 0.15, 0.12 & 0.09 fm, analysis ongoing.

Poster at Lattice 2021, Craig McNeile

QED effects

We are using two approaches:

1. Quenched QED with QCD (Sea quarks are neutral).



- Preliminary results at two lattice spacings, 0.15 & 0.12 fm. Correlator generation ongoing at current lattice spacings with plans for 0.09fm.
- Supplement with separate perturbative calculation of charged sea quark effects.

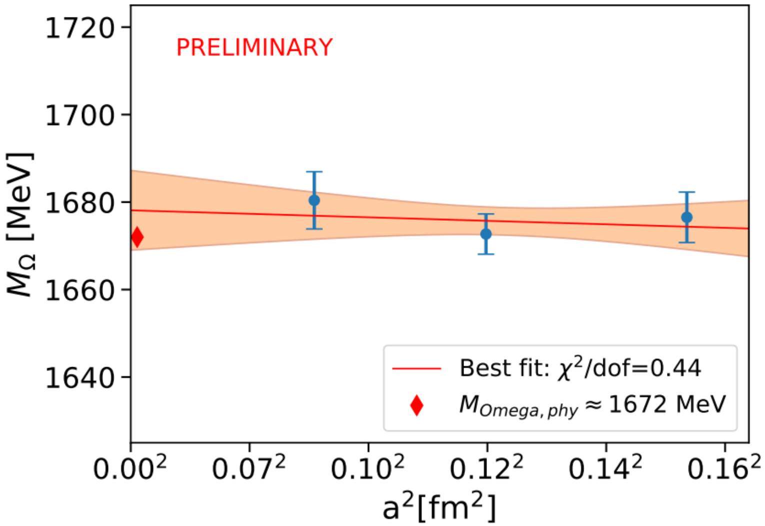
2. Fully dynamical QED+QCD

- 0.15fm ensemble & correlation function generation and ongoing.
- Serve as crosscheck on first approach

Scale-setting – M_Ω & w_0/a

Absolute scale parameter M_Ω

- Insensitive to isospin breaking effects compared with f_π.
- M_Ω at 0.15, 0.12 and 0.09 fm, C Hughes et al., 1912.00028.
- Increasing statistics & extending to 0.06 fm.

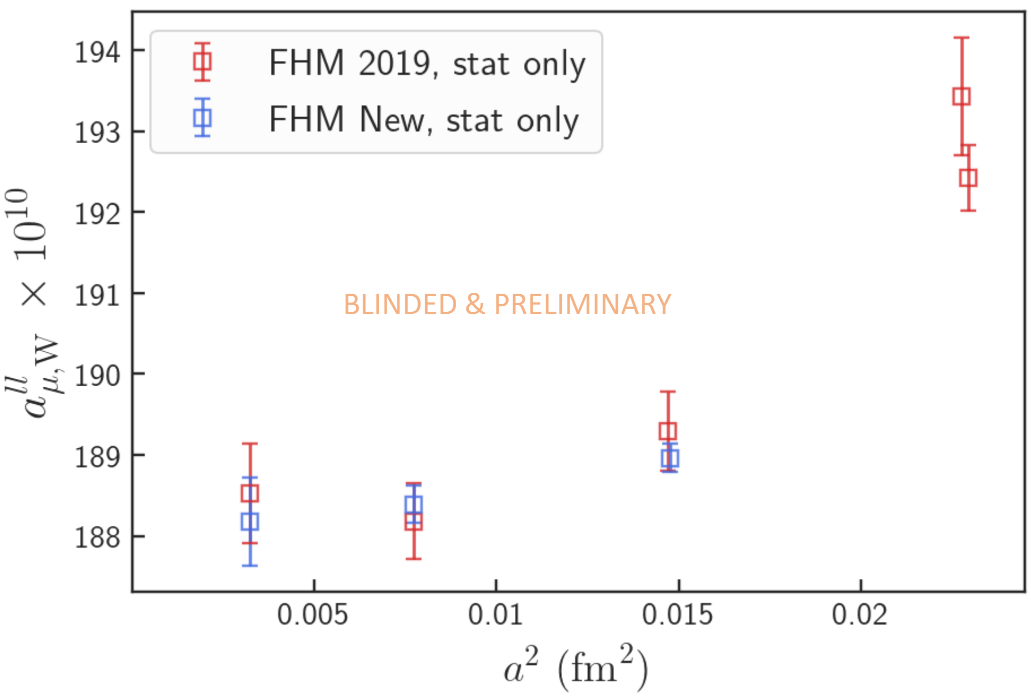


Relative scale parameter w_0/a

- Ongoing high statistics gradient flow study on all HISQ ensembles.
- 6 combinations of ensemble/flow/observable action discretization to study & quantify cut-off effects.

Window Quantities & Blinding

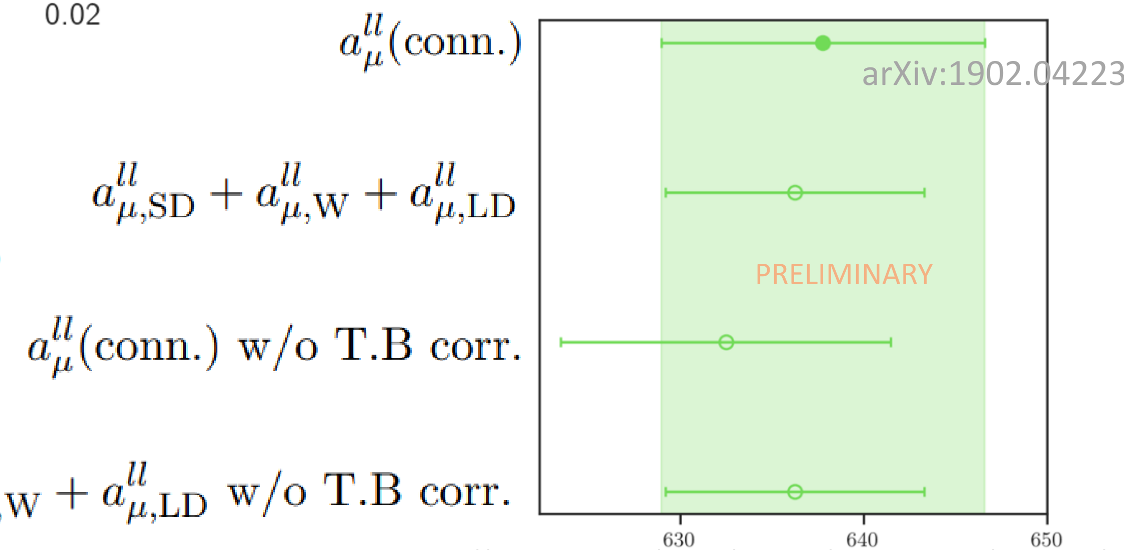
Intermediate window, 0.4-1 fm



- Blinding window quantities independently.

Self-consistency

$$a^{ll}_{\mu}(\mathrm{conn.}) = a^{ll}_{\mu,\mathrm{SD}} + a^{ll}_{\mu,\mathrm{W}} + a^{ll}_{\mu,\mathrm{LD}}$$



https://indico.cern.ch/event/956699/contributions/4117838/

Conclusions

Our goal is to compute the HVP contribution to g-2 using lattice QCD with an uncertainty of <0.5%. Our plans to achieve this are

- Reduce uncertainty on light-quark, connected contribution (90% of contrib.).
  - Increase statistics at finest lattice spacings.
  - Add a 5^{th} lattice spacing (0.042 fm) to analysis.
  - Compute two-pion tail exclusively.
- Disconnected contribution: goal <10% total.
  - Increase statistics at 0.09 fm.
- IB effects: goal is explicit calculation of all leading-order effects.
  - Extend study of SIB effects on connected contribution to more lattice spacings.
  - Incorporate SIB to disconnected calculation.
  - Calculate QED effects.
- Reducing scale setting uncertainty through absolute & relative scale calculations.

Thank you