Discussion on g-2: future prospects

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IAS @ TU Munich

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HLbL

- Dispersive methods - state of the art (see Peter's talk) **[Colangelo, Hoferichter, Procura, Stoffer arXiv:1402.7081v2, arXiv:1506.01386v2]**
- Lattice - state of the art (see Taku's talk)

* Dispersive methods - control of systematics

- RBC/UKQCD method(s) **[Blum et al. '15, arXiv:1509.08372v1, Jin et al. '15 arXiv:1510.07100v1]**
  * Prospects for reducing FV effects?

* Dispersive + lattice:
  - ➡ Mainz Method - see Jeremy's slides **[Green et al. '15 arXiv:1507.01577v1, arXiv:1510.08384v1]**
  - ➡ Alternative approaches
* Both RBC&Mainz methods: relevance and timeline for the disconnected contributions?

HVP

- Introduction (see Christoph's talk)
- * Light Contribution **[ETMC '14, HPQCD '16, Bali&Endrodi '15, …]**
- * Finite volume effects **[Mainz '11, Mainz '13, BMW:lattice '14, Aubin et al., '16]**
- * Isospin breaking effects
- * Disconnected contribution **[Mainz: lattice '14, ETMC '14, HPQCD/TCD '15, RBC-UKQCD '15, BMW: lattice '15…]**
- Fit and moment based methods - systematics
- Strange and charm contribution **[ETMC '14, HPQCD '14, RBC-UKQCD '16]**

Disclaimer: List of references is here for illustration of recent activity in the community (in the past 1-2y) and probably incomplete. Apologies to all of those who are (unintentionally) omitted.

Goals for the next years

- HVP: how to achieve <1% precision, and should we stop there?
- HLbL: how to achieve <10% precision, and should we stop there?
- Future prospects from dispersive methods
- Are we ready for a FLAG(-like) report on hadronic contributions to g-2?
- Combining lattice and experimental data

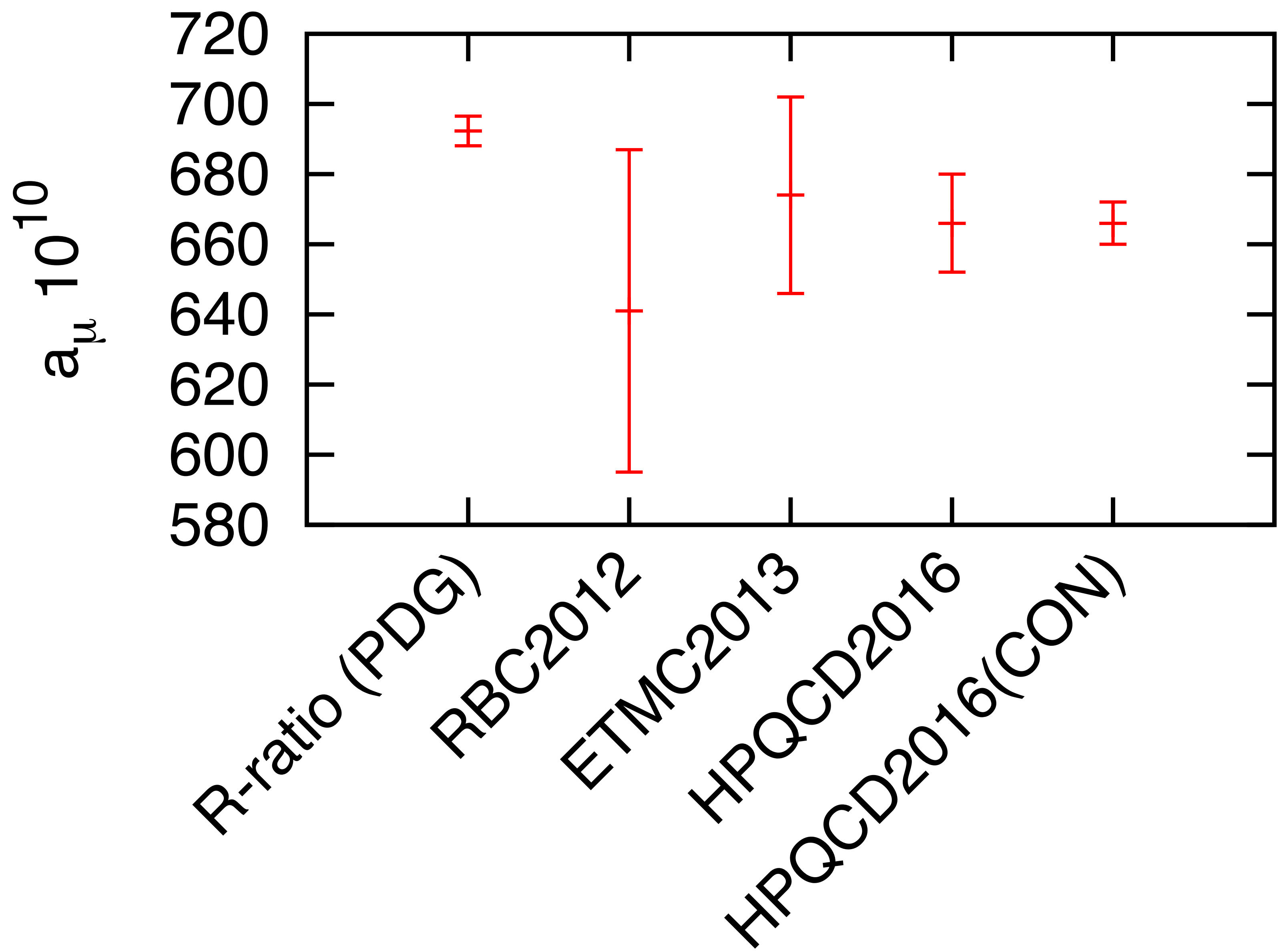
Muon g-2 Hadronic Vacuum Polarization

Christoph Lehner (BNL)

RBC and UKQCD Collaborations

May 18, 2016 – TUM

Overview of first-principles lattice QCD results

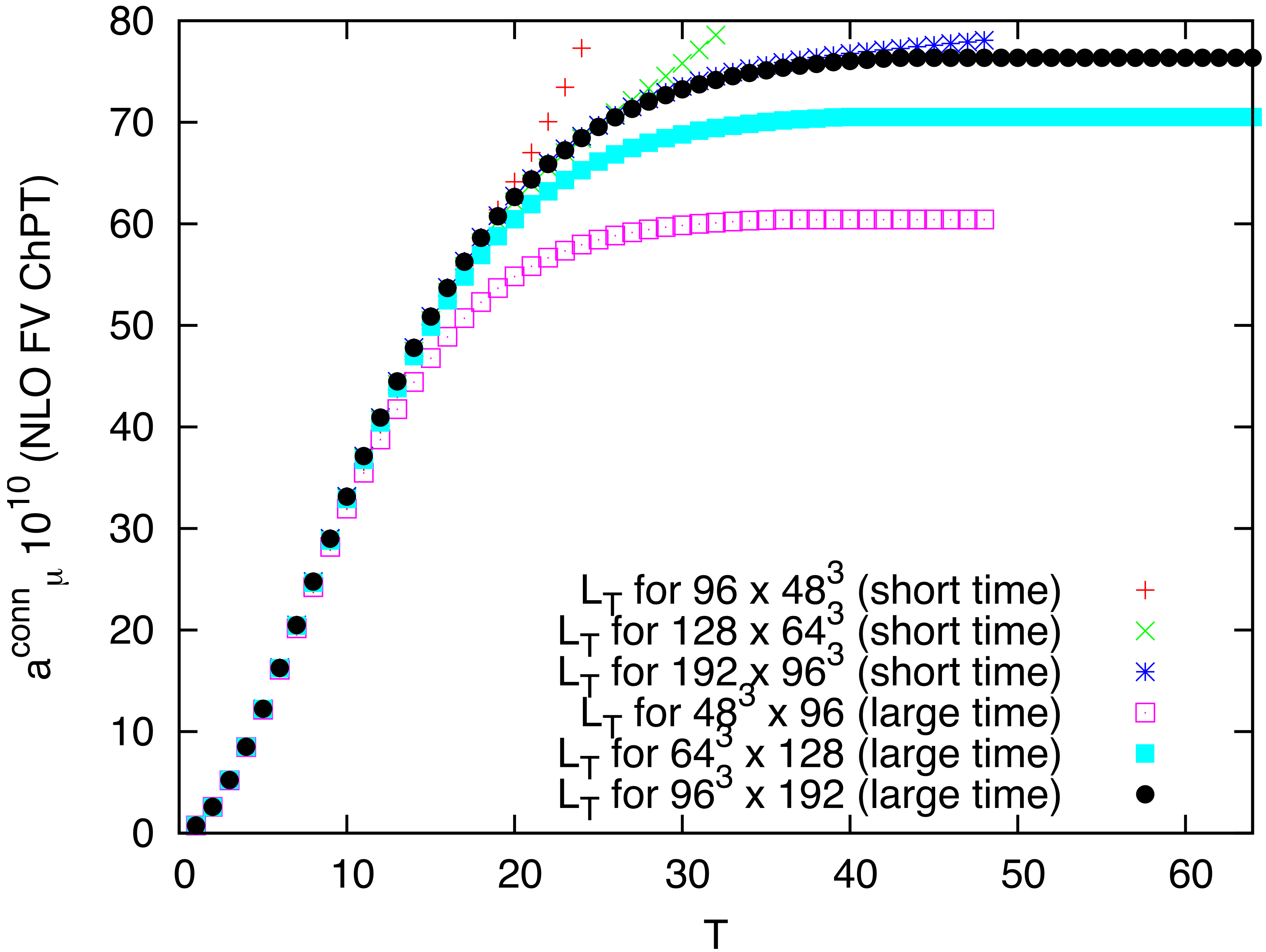


On-going efforts by ETMC, HPQCD+MILC, Mainz, RBC+UKQCD, . . .

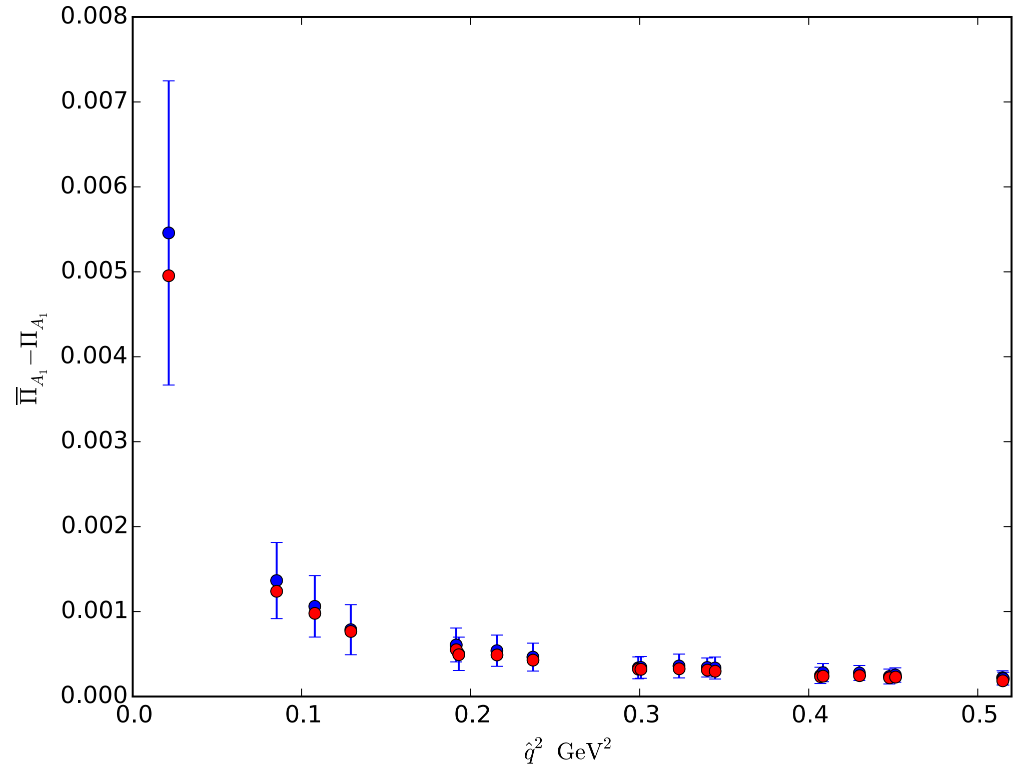
HPQCD2016(CON) neglects the systematic error estimates for the HVP disconnected and QED/isospin-breaking corrections.

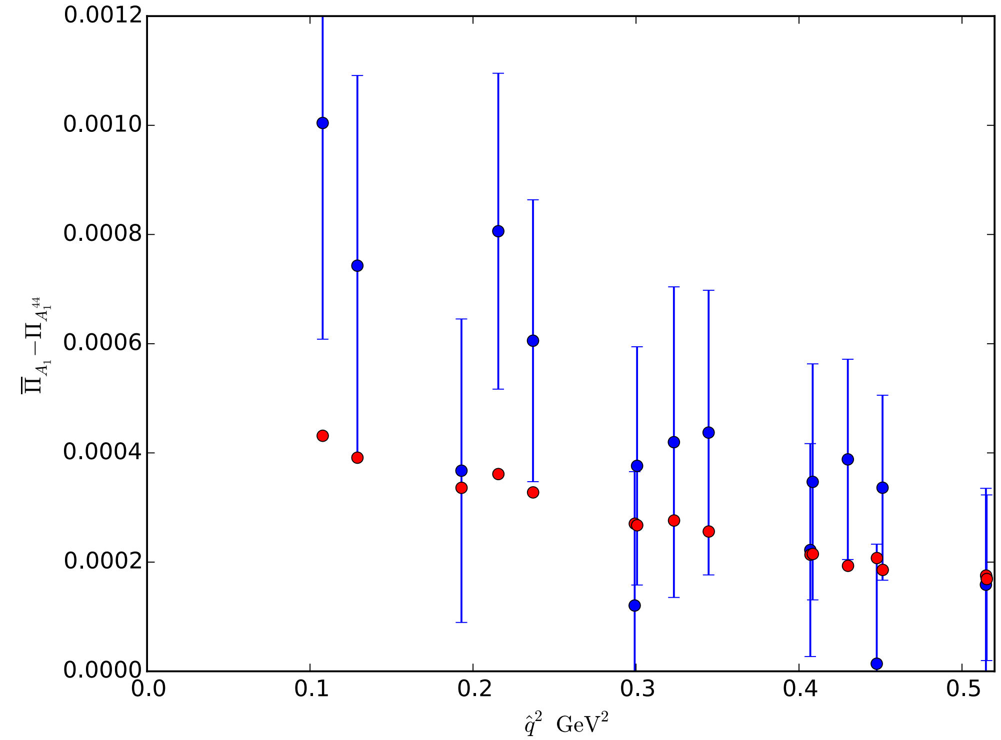
A closer look at the NLO FV ChPT prediction (1-loop sQED):

We show the partial sum $\sum_{t=0}^{T} w_t C(t)$ for different geometries and volumes:



From Aubin et al. 2015 (arXiv:1512.07555v2)



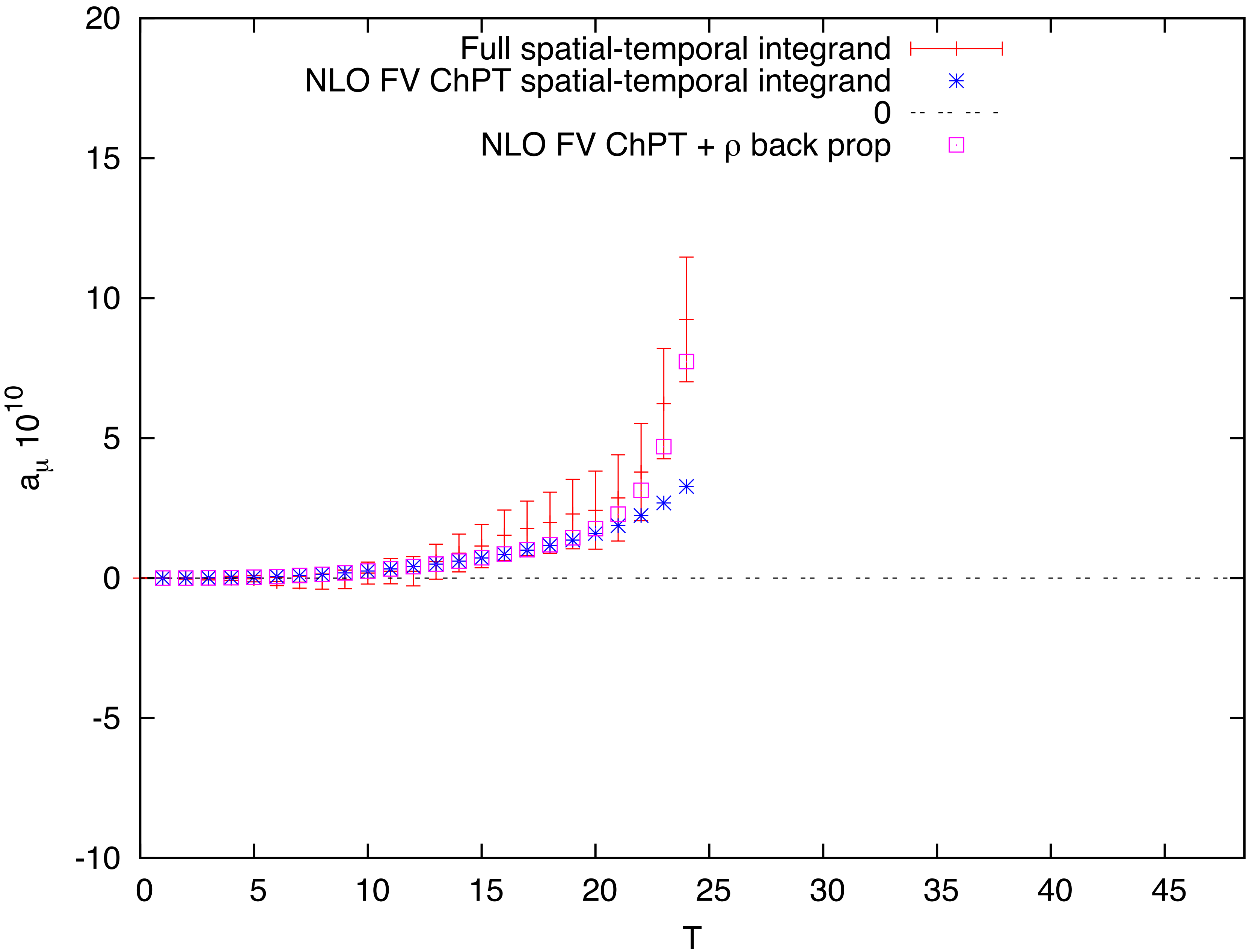


MILC lattice data with $m_\pi L = 4.2$, $m_\pi \approx 220$ MeV; Plot difference of $\Pi(q^2)$ from different irreps of 90-degree rotation symmetry of spatial components versus NLO FV ChPT prediction (red dots)

While the absolute value of a_μ is poorly described by the two-pion contribution, the volume dependence may be described sufficiently well to use ChPT to control FV errors at the 1% level; this needs further scrutiny

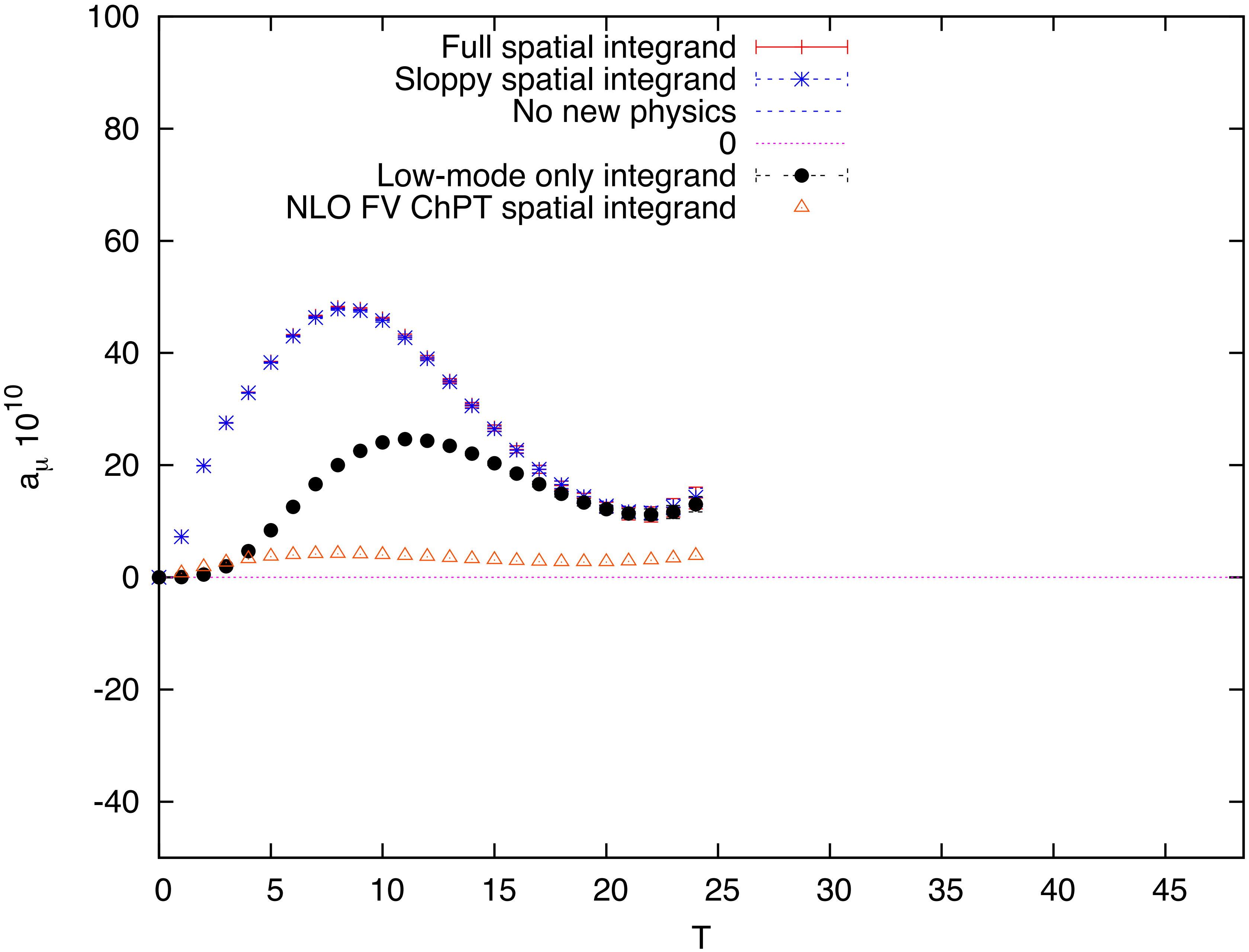
Aubin et al. find an $O(10\%)$ finite-volume error for $m_\pi L = 4.2$ based on the $A_1 - A_1^{44}$ difference (right-hand plot)

Compare difference of integrand of $48 \times 48 \times 96 \times 48$ (spatial) and $48 \times 48 \times 48 \times 96$ (temporal) geometries with NLO FV ChPT ($A_1 - A_1^{44}$):



$m_\pi = 140$ MeV, $a = 0.11$ fm (RBC/UKQCD 48^3 ensemble)

It may be worth verifying that the $O(10\%)$ finite-volume error estimate from Aubin et al. was not spoiled by a backwards-propagating ρ:

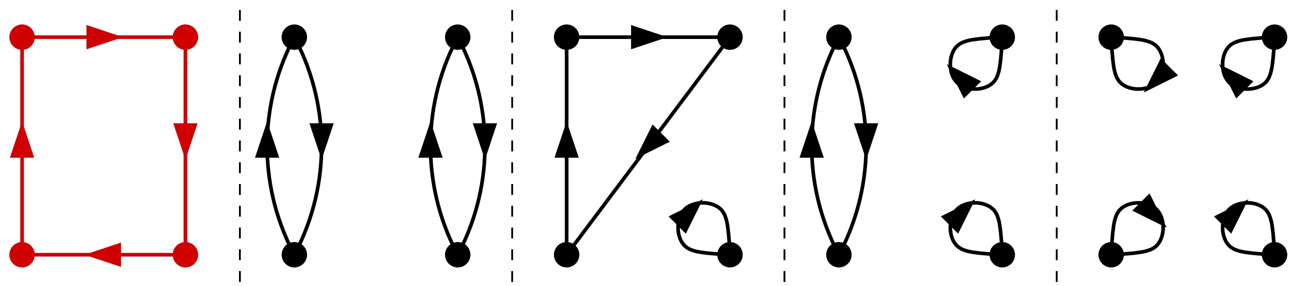


Forward hadronic light-by-light scattering

(Phys. Rev. Lett. **115**, 222003 (2015) [1507.01577]; proceedings of Lattice 2015 [1510.08384])

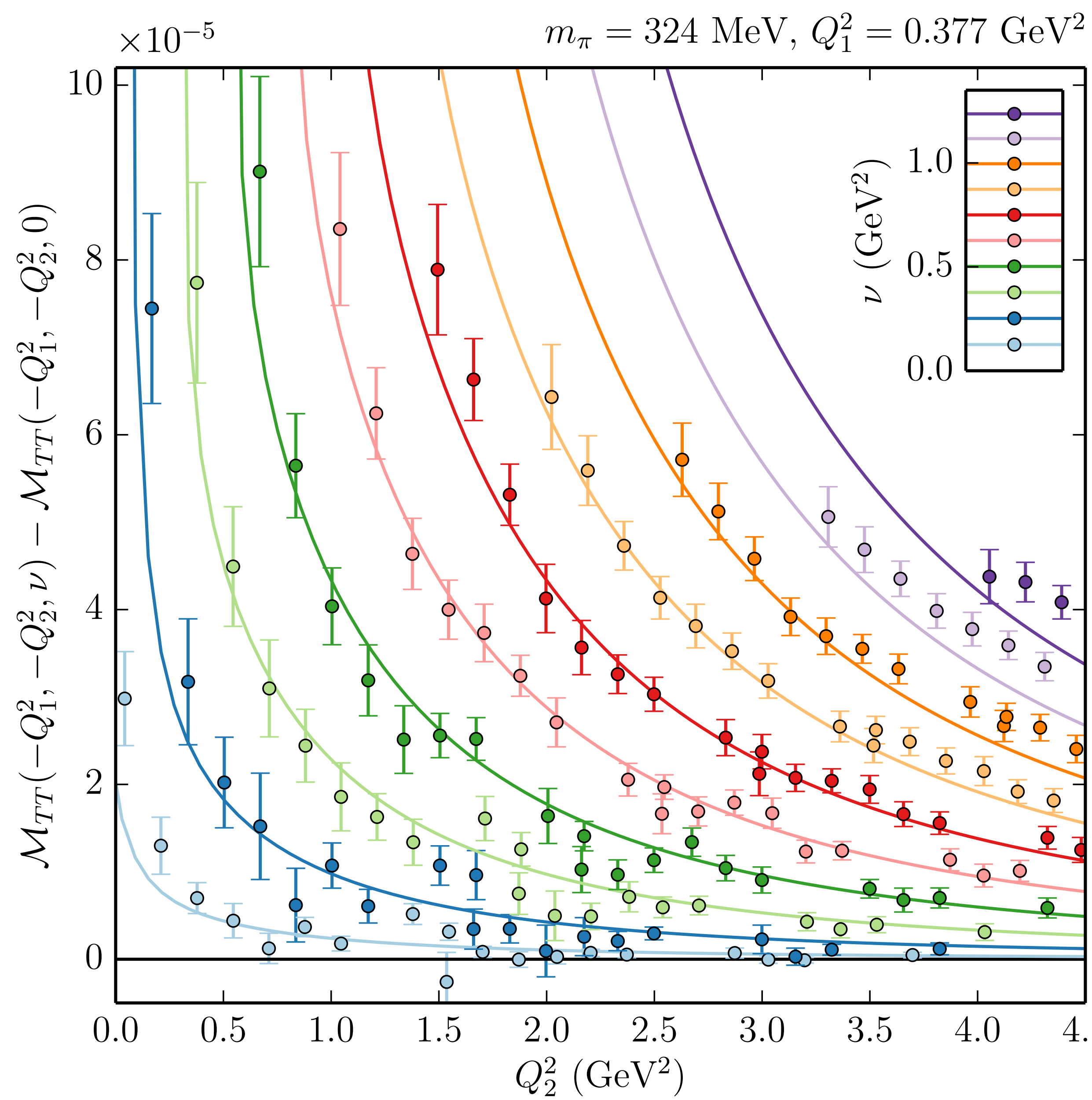
Dispersion relations exist between

$$\mathcal{M}_{\text{had}}\Big(\gamma^*(Q_1)\gamma^*(Q_2) \to \gamma^*(Q_1)\gamma^*(Q_2)\Big) \quad \text{and} \quad \sigma\Big(\gamma^*(Q_1)\gamma^*(Q_2) \to \text{hadrons}\Big)$$

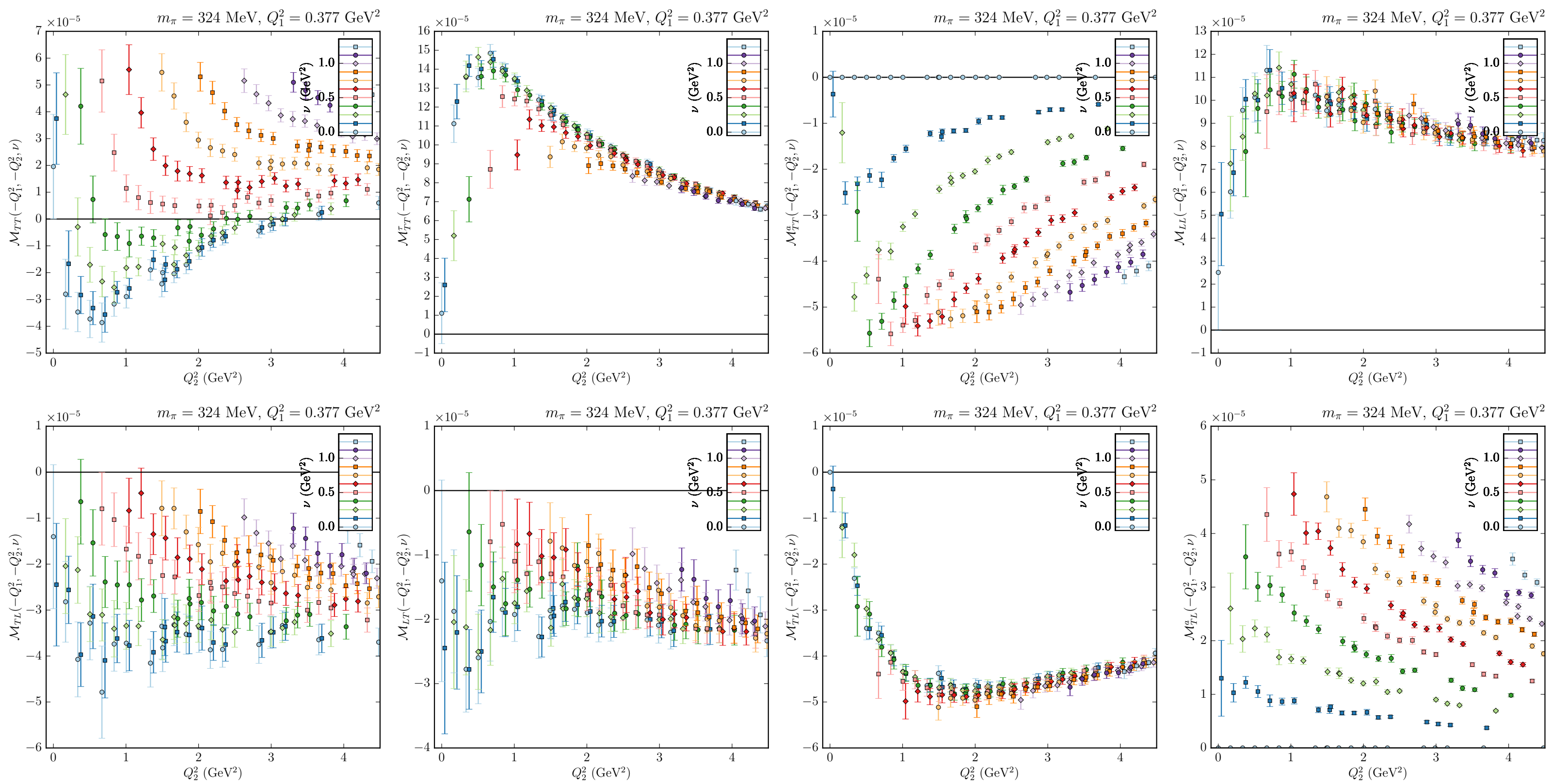


Evaluate fully-connected contribution to $\mathcal{M}$ on the lattice using sequential propagators, for fixed Q_1^2, with arbitrary Q_2^2 and $\nu \equiv -Q_1 \cdot Q_2$. (points)

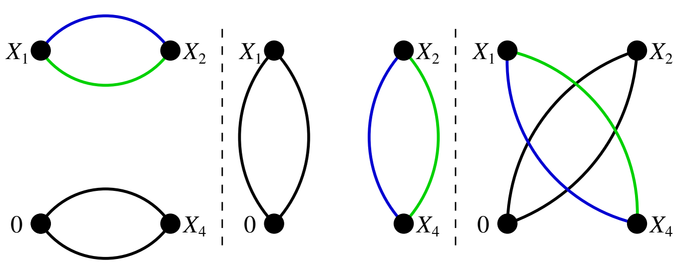
Use a phenomenological model for σ with meson resonances and $\pi^+\pi^-$ final states. (curves)



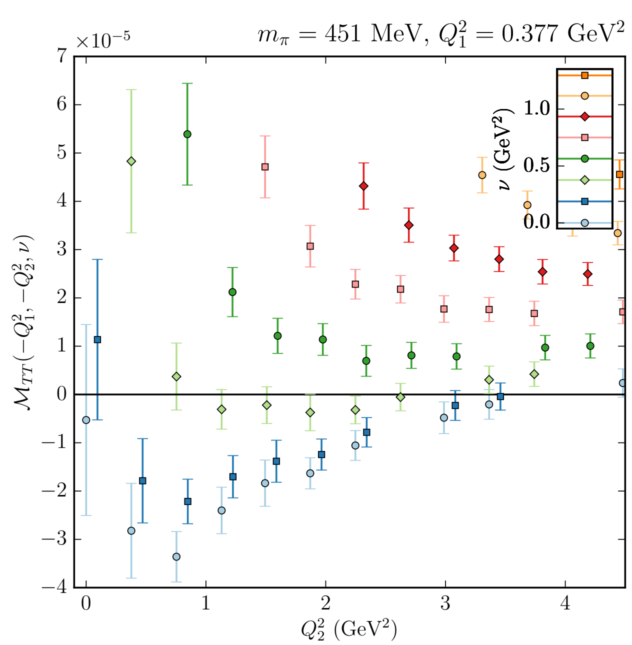
Eight forward amplitudes; (2,2)-disconnected diagrams



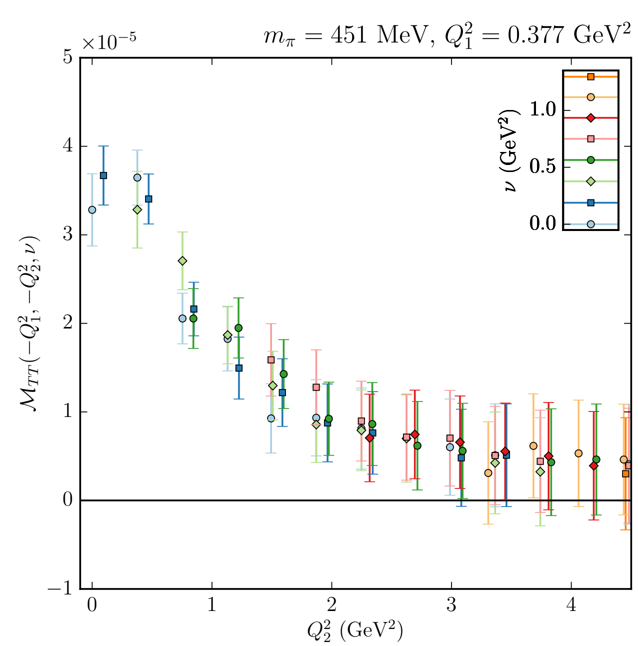
Using all eight forward-scattering amplitudes will better constrain the model for $\sigma(\gamma^*\gamma^* \to \text{hadrons})$.



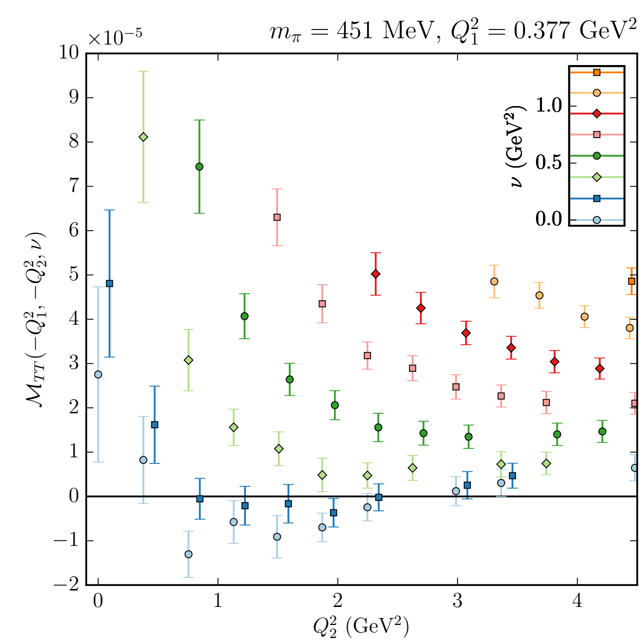
For (2,2)-disconnected diagrams, use one **point-source** propagator and two noise-source propagators.



fully-connected



(2,2)-disconnected

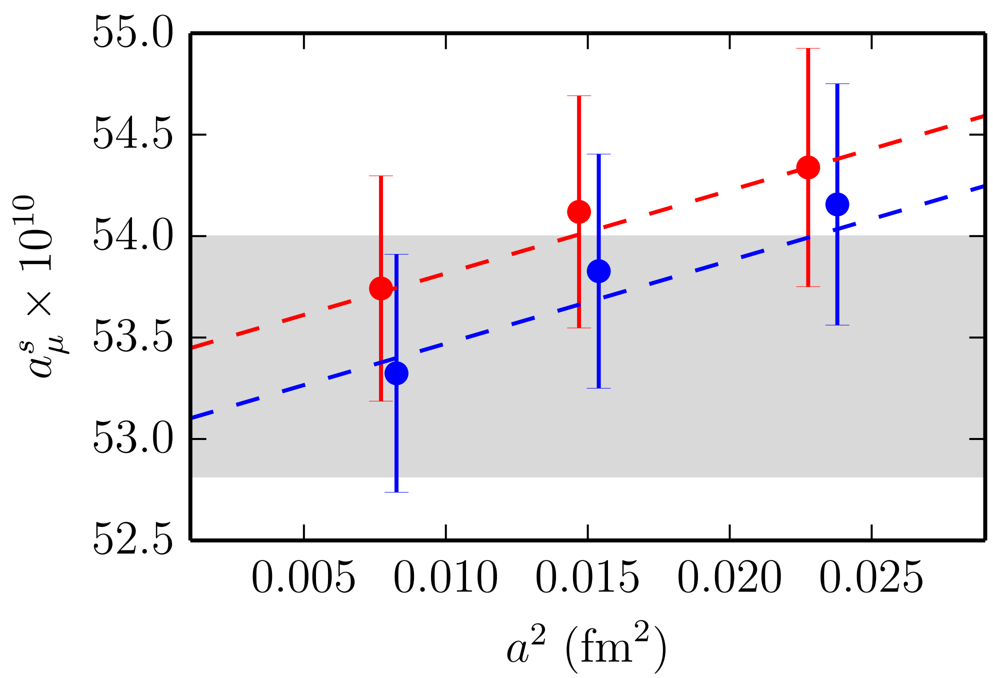


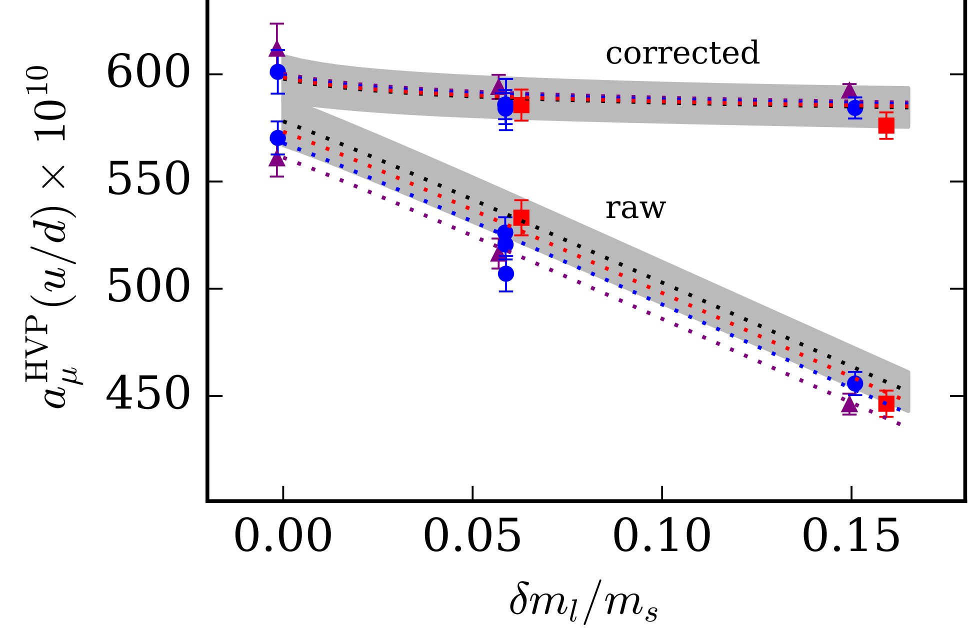
both

HPQCD results for HVP,LO

1403.1778, 1512.03270, 1601.03071

$$a_\mu^{\mathrm{HVP,LO}}\Big|_{\mathrm{conn.}} \times 10^{10} = \begin{cases} 598(11) & \text{from } u/d \text{ quarks} \\ 53.4(6) & \text{from } s \text{ quarks} \\ 14.4(4) & \text{from } c \text{ quarks} \\ 0.27(4) & \text{from } b \text{ quarks} \end{cases}$$





s quark connected contribution

u/d quark connected contribn

Future (with MILC/FNAL): improving physical u/d results: finer lattices, higher stats.

Hadronic LO corrections to electroweak observables from twisted mass lattice QCD

Marcus Petschlies
for
$g-2$ @ ETMC
F. Burger, G. Pientka, K. Jansen and M. P.

Helmholtz-Institut für Strahlen- und Kernphysik, Rheinische Friedrich-Willhelms-Universität Bonn

18 May, IAS, TUM

Hadronic LO running of electroweak couplings [JHEP 1511 (2015) 215]

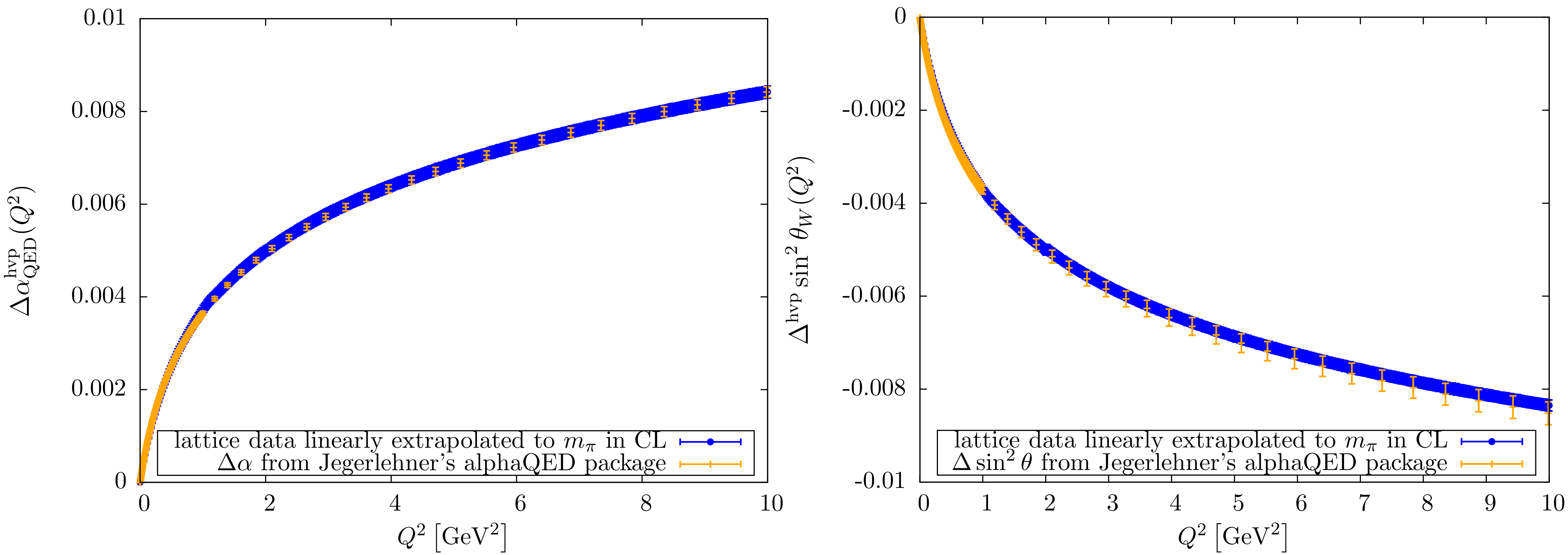


Figure: Q^2-dependence of $\Delta\alpha_{\rm QED}$ (left) and $\Delta\sin^2(\theta_W)$ (right)

$$\alpha_{\rm QED}(Q^2) = \frac{\alpha_0}{1-\Delta\alpha_{\rm QED}(Q^2)}\,, \quad \Delta\alpha^{\rm hvp}_{\rm QED}(Q^2) = -4\pi\alpha_0\Pi_{\rm R}\left(Q^2\right)$$

$$\sin^2\theta_W(Q^2) = \sin^2(\theta^0)\frac{1-\Delta\alpha_2(Q^2)}{1-\Delta\alpha_{\rm QED}(Q^2)} = \sin^2(\theta_0)(1+\Delta(Q^2))$$

$$\Delta^{\rm hvp}\sin^2\theta_W(Q^2) = \Delta\alpha^{\rm hvp}_{\rm QED}(Q^2) - \Delta\alpha^{\rm hvp}_2(Q^2)$$

Hadronic LO contribution to lepton anomalous magnetic moments from twisted mass lattice QCD at physical pion mass [arXiv:1507.05068]

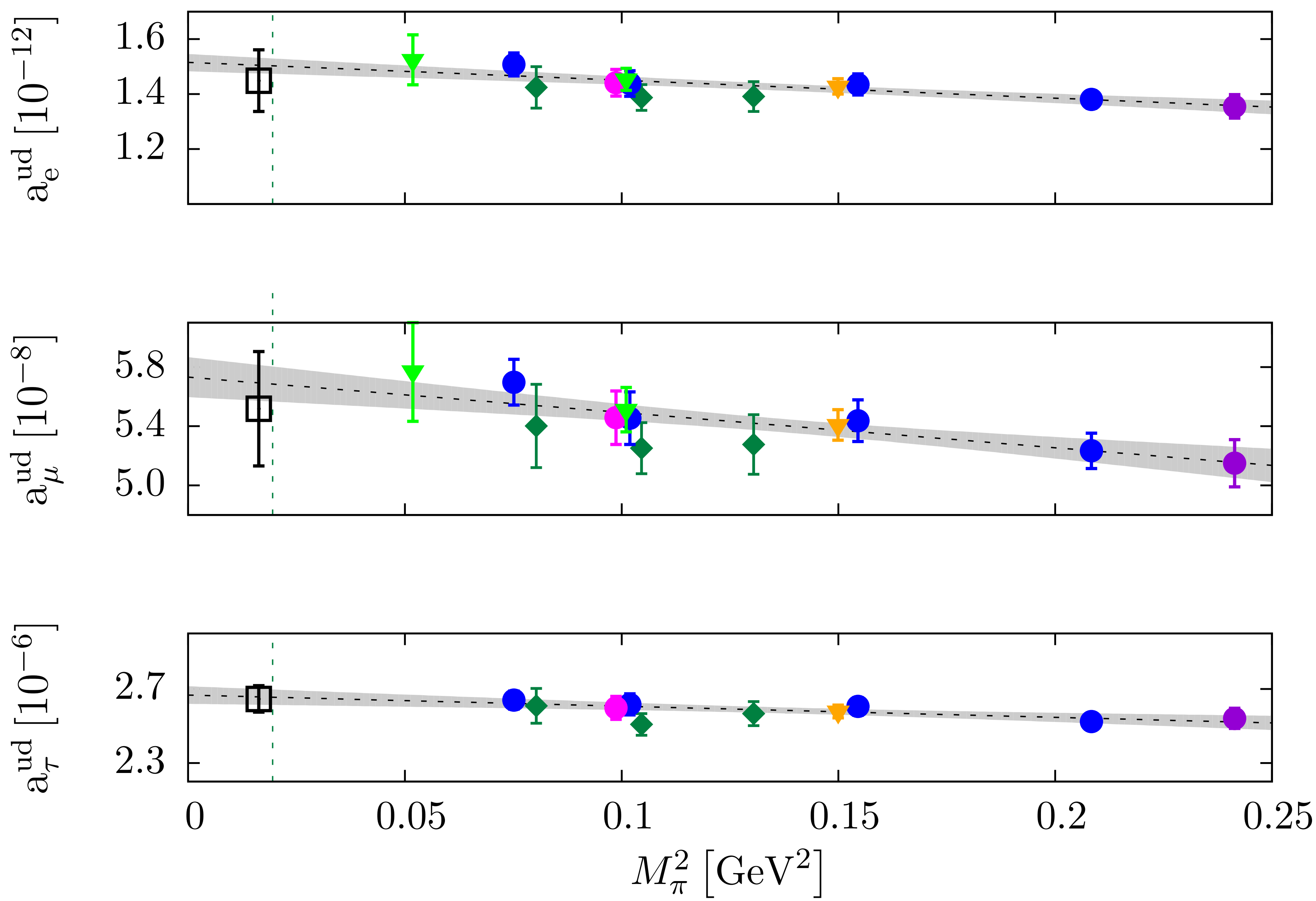


Figure: up and down contribution to a_l^{hlo} for electron (top), muon (center) and τ (bottom)

$g-2$ @ ETMC outlook and plans

- HVP analysis at physical pion mass with $N_f = 2$ tmLQCD and $L \approx 6\,\mathrm{fm}$, $m_{PS} \cdot L \approx 4$ (*under production*)
- HVP analysis at physical pion mass with $N_f = 2+1+1$ tmLQCD (*tuning stage*)
- transition form factors for dispersive approach with $N_f = 2+1+1$ tmLQCD (part of the Bonn lattice scattering analysis program, *running*)