MITP Scientific Programme "Fundamental Parameters From Lattice QCD" – Summary –

G.M. von Hippel

JOHANNES GUTENBERG UNIVERSITÄT MAINZ

Mainz Institute of Theoretical Physics
Johannes Gutenberg-Universität Mainz

Mainz, August 31 – September 11, 2015

Too many excellent talks to review

FLAG: Lattice QCD tests of the SM and foretaste for beyond

A. Vladikas
INFN - TOR VERGATA

Mainz Institute for Theoretical Physics
31st August 2015

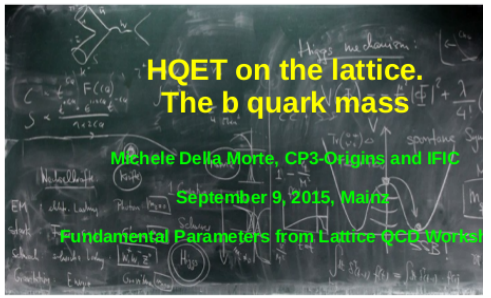
Data Analysis with Theoretical Errors

Jérôme Charles

Centre de Physique Théorique (Marseille)

Fundamental Parameters from Lattice QCD, 2 September 2015

in collaboration with S. Descotes-Genon, V. Niess, L. Vale and CKMfitter group



CP-violation in the kaon sector on the lattice

Christopher Kelly
(RBC & UKQCD Collaboration)

Talk, MITP "Fundamental parameters from Lattice QCD" workshop, Mainz, Germany
September 7th 2015

Hunting Renormalons

Gunnar Bali
University of Regensburg

Determination of α_s from the QCD static energy

Xavier Garcia i Tormo
Universität Bern

Based on:

A. Bazavov, N. Brambilla, XGT, P. Petreczky, J. Soto and A. Vairo, Phys. Rev. D **86**, 114031 (2012) [arXiv:1205.6155 [hep-ph]];
Phys. Rev. D **90**, 074038 (2014) [arXiv:1407.8437 [hep-ph]]

Xavier Garcia i Tormo MITP - September 3 2015 – 1 / 18

hadronic corrections to electroweak observables

Gregorio Herdoíza

IFT, UAM/CSIC

ental Parameters from Lattice QCD, MITP, Mainz, Sept. 8, 2015

Quark masses, strong CP, and all that

Michael Creutz

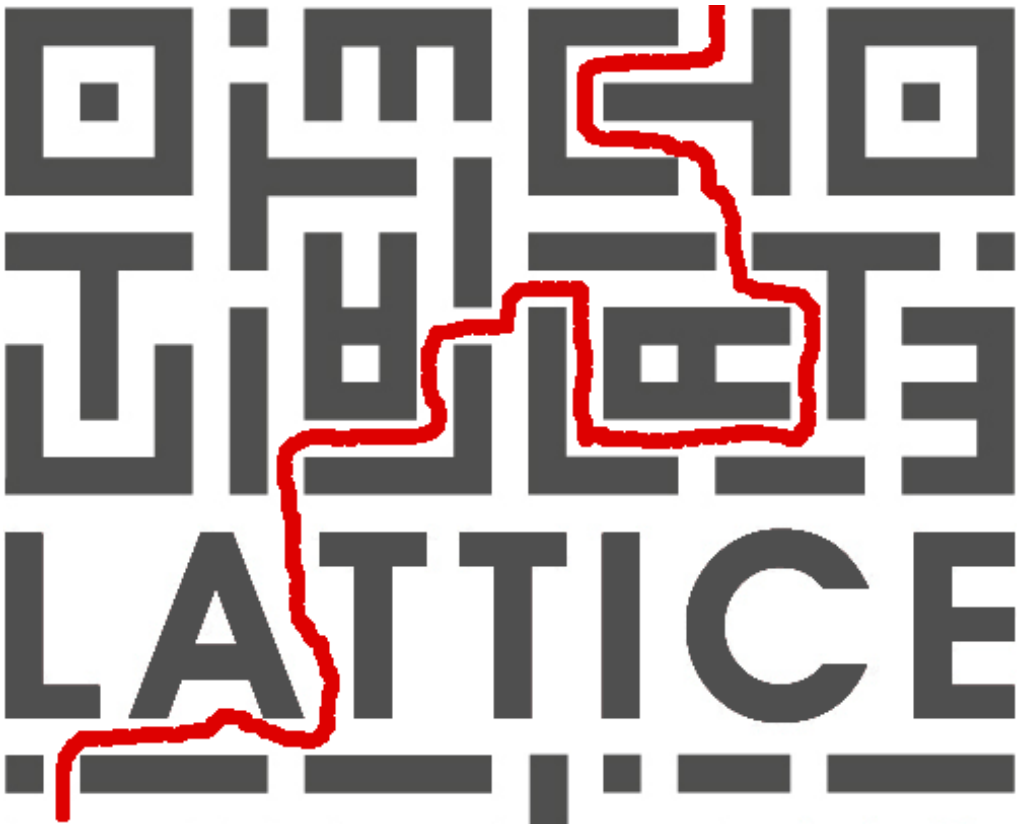
Too many excellent talks to review

Too many excellent talks to review

Ariadne's thread

Risk getting lost in detail

Ariadne's thread



To avoid getting lost, follow a red thread

Red thread #1: Systematic errors

- Big topic in many talks (explicitly or implicitly)
  - As statistics increase, precision is limited by systematics
- How to estimate?
  - Sources with controllable parameters (a, m_π, L)
    - Fits with or without priors
    - Variations of fit range or fit function
  - Sources without controllable parameters (N_f, HQ action, ...)
    - Often not assessed
    - Can at most be guesstimated
  - Combined systematics
    - Error budgets now standard
    - Extended Frequentist's Method
    - May not necessarily add to 100%
  - Remain somewhat subjective

Red thread #1: Systematic errors

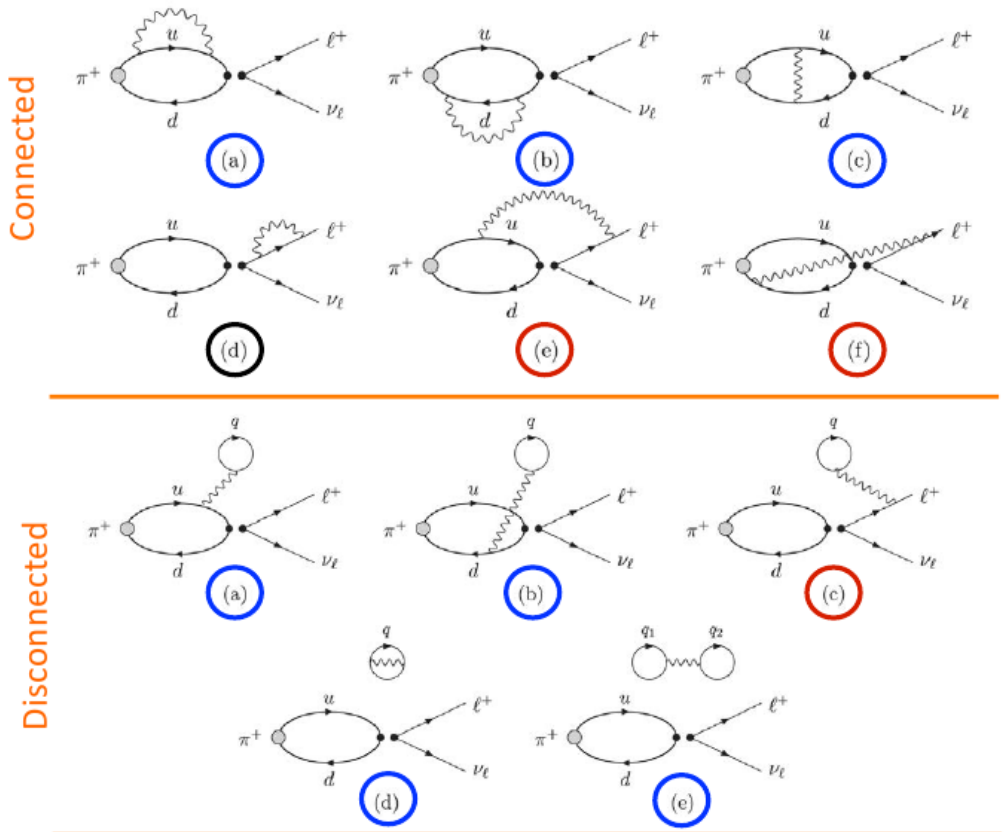
- Big topic in many talks (explicitly or implicitly)
  - As statistics increase, precision is limited by systematics
- How to combine?
  - Important issue especially for FLAG, CKMfitter, PDG ...
  - Even more subjective than estimation
    - Does one believe the quoted errors?
    - What kind of thing is a systematic error?
  - Wide range of methods
    - Linear vs. Quadratic addition
    - Range method used by PDG, except for lattice [S. Bethke's Talk]
    - Rfitter method used by CKMfitter [J. Charles' Talk]
    - Weighted average using Schmelling's method used by FLAG [R. Horsley's Talk]
  - No consensus ...
    - ... no problem?

Red thread #2: Isospin breaking

- Another recurring topic
- $\alpha_{rmQED} \approx 1/137 \rightsquigarrow$ need QED beyond 1% level
- Strong isospin breaking from $m_{\mathrm{d}} - m_{\mathrm{u}}$ of similar size
- Different proposals on the market:
  - QCD+QED simulations
  - reweighting methods
  - RM123 method [V. Lubicz's Talk]
- Significant effort required in any case
  - direct methods: implementation of Gauss law, new ensembles needed
  - Rome method: Bloch-Nordsieck treatment of IR divergences, four-point functions and higher needed [V. Lubicz's Talk]
- Cannot be avoided

Lattice calculation of $\Gamma_0(L)$ at $O(\alpha)$

- The Feynman diagrams at O(α) can be divided in 3 classes



1. The photon connects two quark lines
2. The photon connects one quark and one charged lepton line
3. Leptonic wave function renormalization. It cancels in $\Gamma_0(L) - \Gamma_0^{\mathrm{pt}}(L)$

34

[V. Lubicz's's Talk]

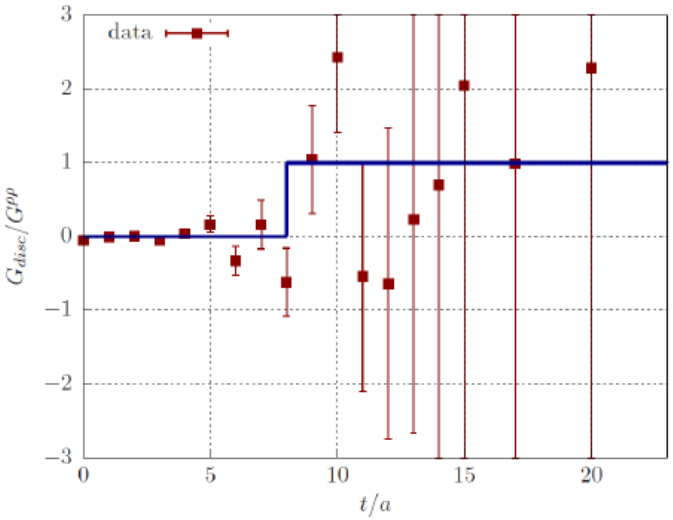
Red thread #3: Disconnected diagrams

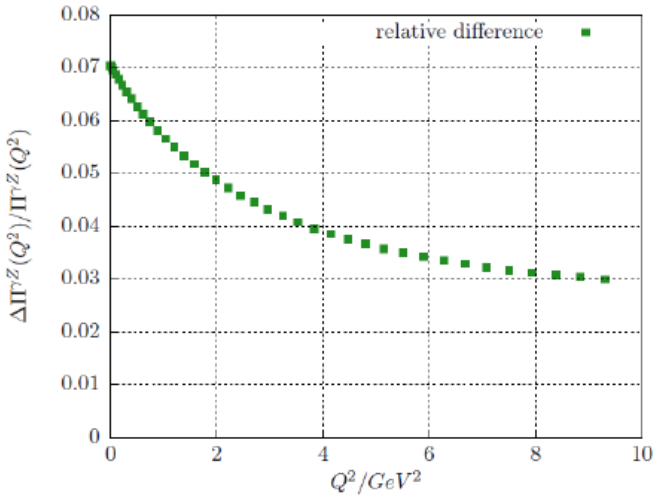
- Mentioned repeatedly, with different emphasis
- A leading source of systematic error in various contexts:
  - $(g-2)_\mu$ [T. Izubuchi's Talk]
  - running of electroweak couplings [G. Herdoíza's Talk]
  - direct CP violation [C. Kelly's Talk]
  - decays like $D_s^+ \to \eta' \ell^+ \nu_\ell$ [S. Collins' Talk]
- Some interesting quantities are purely disconnected:
  - strangeness form factors of nucleon [J. Green's Talk]
- Many clever methods used
  - dilution, hierarchical probing
  - (generalized) HPE, TSM
- Still massive statistics needed to get reasonable signal
  - ... but at least we know how to do that

mixed representation: disconnected contribution

- $x_0 \to \infty$

$$\frac{G_{\text{disc}}^{(\ell+As),(\ell-s)}(x_0)}{G^{\rho\rho}(x_0)} \longrightarrow 1$$





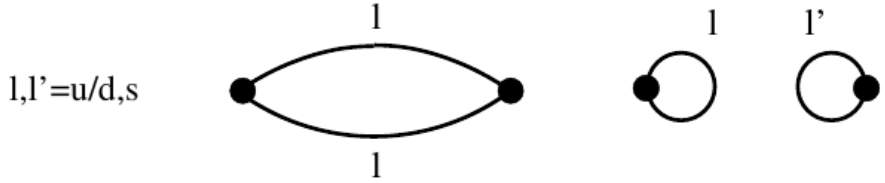
4% : conservative estimate for systematic error from neglecting disconnected contribution at $Q^2 \sim 4\,\text{GeV}^2$

[V. Gülpers et al., lattice 2015]

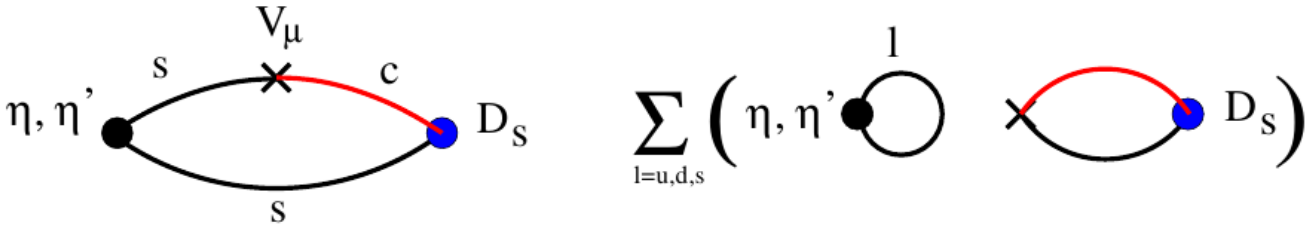
[G. Herdoíza's Talk]

Technically challenging

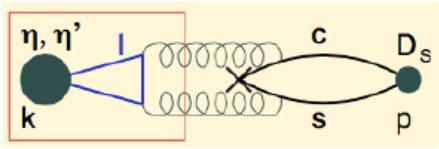
Quark line diagrams for studying η and η'.



For $D_s \to \eta(\eta')$



- Disconnected diagrams which may give a large contribution due to the anomaly also due to sum over $l = u, d, s$.



- Sensitivity to the topology of the gauge field configurations.

First step, determine the physical basis for η/η'.

[S. Collin's Talk]

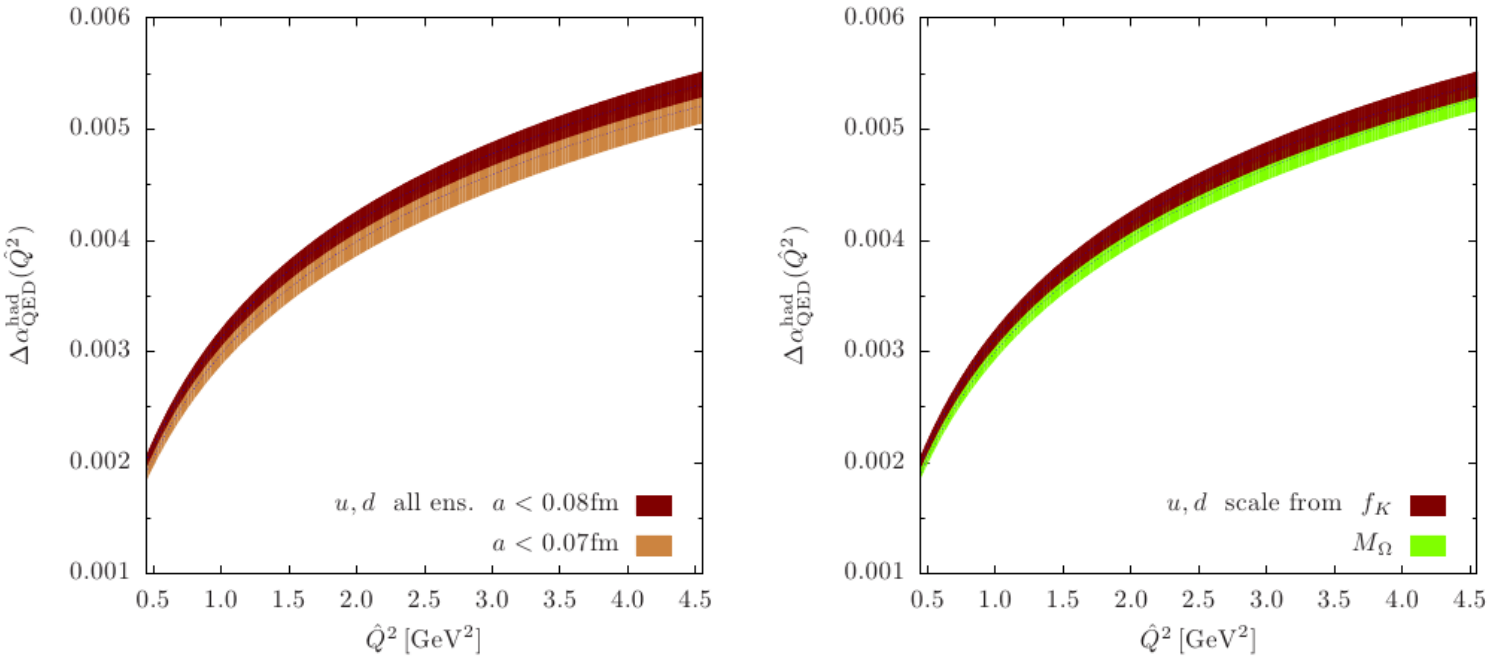
Red thread #4: Scale setting

- Not mentioned quite so often
- Still likely to be relevant at the 1% level
- Different quantities have different strengths and weaknesses
  - f_K – statistically precise, but Z factors needed, isospin/QED?
  - m_Ω – no Z factors needed, sss state, but noisy
  - $m_{\Upsilon(2S)} - m_{\Upsilon(1S)}$ – statistically precise, no Z factors needed, but with heavy-quark EFT uncertainties
  - r_0, r_1, t_0, w_0 – very precise, but not directly physical
- Impact on running of couplings
  - of same order as current statistical errors [G. Herdoíza's Talk]
- Will also need to be addressed

$\Delta\alpha^{\rm had}_{\rm QED}(Q^2)$: systematic effects

$$D(Q^2) = \frac{3\pi}{\alpha}\frac{d}{d\log(Q^2)}\Delta\alpha^{\rm had}_{\rm QED}(Q^2)$$

u, d; $a \to 0$; $M_\pi^{\rm phys}$



Padé [1, 2] with O(a) lattice artefacts and quadratic form in $M^2_{\rm PS}$

[G. Herdoíza's Talk]

Red thread #5: Ambiguities

- Quantities that are ambiguous have a built-in limit on precision
- Quark masses
  - pole mass has renormalon ambiguity of ~ 180 MeV
    [G. Bali's Talk]
  - masslessness of up quark scheme-dependent
    [M. Creutz's Talk]
- Are these therefore even precision quantities?

Red thread #6: Coordination of Efforts

- An aim of this Scientific Programme
- Good news:
  - Lattice and phenomenology communities talk to each other
  - PDG now uses FLAG average for lattice [S. Bethke's Talk]
- Other than good news:
  - CKMfitter cannot use FLAG average [Discussion 31/08]
  - UTfit could not participate in averaging discussion
- Future directions:
  - Some kind of "Les Houches Accord" for lattice data?
  - Possible? Desirable? Necessary?
  - To some extent, FLAG's ($\star$, $\bigcirc$, $\blacksquare$) system can be seen as a step in this direction

Summary (of the Summary)

- Systematics are becoming dominant source of uncertainty in lattice QCD, especially for flavour quantities
- Treatment remains somewhat subjective, especially when averaging results from different sources
- At the 1% level, isospin breaking and scale setting issues must be tackled
- There are promising approaches to isospin breaking
- Disconnected diagrams require massive statistics
- Scale setting may need further effort

Thank you ...

... for your participation!