Homage to Giannis Bakas: The Formative Years

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National Technical University
Athens
28th March 2018

Xmas Theoretical Physics Workshop @ University of Athens 20-21/12/2016

https://sites.google.com/site/xmasathens2016/programv2

Crete String meeting 9-16/07/2017 (Kolymbari)

http://hep.physics.uoc.gr/mideast9/Bakas-memories-Vladikas.pdf

John (later Giannis…) Bakas: the formative years

- Arrived at Imperial College Theory Group in 1982-83 as a postgrad
- The group was basking in the sun of fame:
    - Abdus Salam (Nobel in 1979) then in Trieste, visited the group about twice a year
    - Tom Kibble was head; Iain Halliday, Chris Isham, Hugh Jones, David Olive, Ray Rivers, are senior staff; Michael Duff was the new arrival, and Kelly Stelle was about to arrive….
- Students in the period 1981-1985 who stayed in Physics (apologies to many I forget):
    - Frank Gomez (Brazil), Mark Hindmarsh (Sussex), Desmond Johnson (Herriot Watt), Tony Kakas (Cyprus), Martin Lavelle (Plymouth), David McMullan (Plymouth), Kostas Panagiotakopoulos (Salonica), Regina Ricotta (Brazil), Neil Turok (Perimeter)…
- Postdocs: Ian Jack, Peter Orland, Chris Pope, Graham Shore…
- The group had many activities:
    - perturbative QCD; lattice field theory (scalar fields and triviality)
    - group theoretic aspects of field theory
    - unification (SUSY, SUGRA, later strings, cosmology…) and QUANTUM GRAVITY

      (NB: strings arrived in 1984-85 through a M.Green seminar at King's)

John (later Giannis…) Bakas: the formative years

- John knew from the start he wanted to work with Chris Isham on quantum gravity
- Isham accepted him as his PhD student after a very successful personal interview
- His first paper was with an older Isham student, Tony Kakas (1985):
  - I. Bakas and A.C.Kakas, "Quantization and Deformations: I. General Construction"
- … followed by other papers with Isham's students McMullan, Kakas and working on his own.
- He built a reputation of being a young, very serious and reliable mathematical physicist, always well focused on his objectives
- The group had a lot of illustrious guests who interacted with students. John had always been singled out by them for his focused dedication (Iliopoulos, Kuchar, Jackiw,…)

John (later Giannis…) Bakas: the formative years

Frankie Gomez & Regina Ricotta

The co-authors of the Bakas-Kakas paper

John (later Giannis…) Bakas: the formative years

Life in 3 Old Oak Rd.,
Acton (West London)

relaxing…

calling Greece…

John (later Giannis…) Bakas: the formative years

getting to grips with QED, QFT, symmetries, anomalies, and most importantly gravity beyond the classical level

it was clear from the start that the two flatmates, though living in complete harmony, had very different approaches to life and Physics, as shown in the next photo…

John (later Giannis…) Bakas: the formative years

John (later Giannis…) Bakas: the formative years

… a show of Greek temperament in a London back garden

but John's life had also many happy breaks, partying with the other students (not only of Imperial College)

John (later Giannis…) Bakas: the formative years

theory group party at the theoretical physics library

Chris Pope   Mirjam McMullan   Annie Andrikopoulou   Des Johnson &   Frankie Gomez

John Bakas   Nigel Gent   Susan Mokhtari

John (later Giannis…) Bakas: the formative years

life in Putney (southwest London) :dinning with food that just passed its sell-by date from the delicatessen-shop owned by Tony Kakas' family!

Bakas gourmet proposal: Scottish salmon on toast, topped with feta cheese !!!!!

John (later Giannis…) Bakas: the formative years

78 RELATIVISTIC QUANTUM FIELDS

The Overlapping Divergence

This completes our discussion of the analytic continuation. We now wish to use the technique to examine another basic diagram in $\lambda\phi^4/4!$ theory. The diagram in Fig. 6 is the lowest order, non-trivial diagram

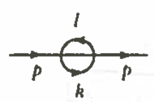


FIG. 6

contributing to the propagator. The symmetry factor for this diagram is $\frac{1}{6}$ and the integral to be examined is

$$I = \frac{i}{6}\frac{\lambda^2}{(2\pi)^8}\int \frac{dk\, dl}{[k^2-m^2][l^2-m^2][(p+l-k)^2-m^2]} \qquad (2.52)$$

Inspection of I shows that it is divergent. There are various regions of l and k in which the integral diverges, e.g. l small, k large, k small and l large, these give rise to logarithmic divergences. But if we take both k and l large the integral diverges quadratically. Furthermore this is what is called an overlapping divergence because one cannot ascribe the divergence to any subdiagram of Fig. 6. Also there does not exist a change of variables from l, k to l', k' for which the divergence only appears when one does only one of the loop integrations l' and k'. Overlapping divergences are much more difficult to deal with than the simpler kind (i.e. just associated with one loop of a diagram). They have the property that if one uses the Feynman parameters of eq. 2.5 and the formula of eq. 2.10 to evaluate the integral the divergence moves in part from the loop-momenta integrations to the integrations over the Feynman parameters. This usually makes the dimensional method very difficult to use and caution must be exercised in the face of multiloop calculations. Now as implied above not only does the overall diagram of Fig. 6 diverge but so do the various subdiagrams of which it is made up. We shall need therefore counter terms to eliminate the divergences in the subdiagrams as well as a counter term to eliminate the divergence due to the whole diagram. The subdiagrams are shown in Fig. 7(a)–(c). The subdiagrams of Fig. 7 can easily be checked to have logarithmic divergences. This reasoning leads one to believe that four counter terms are needed to eliminate these four

DIMENSIONAL REGULARIZATION AND $\lambda\phi^4/4!$ THEORY 79

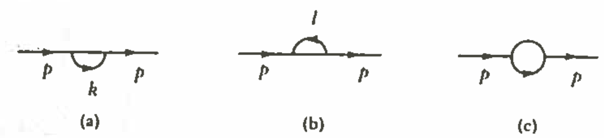


FIG. 7

sources of divergence. This is indeed the case, and is the proper way to tackle the overlapping divergence. The origins of the four subtractions that must be made from I can be isolated very simply in the dimensional method. They are as follows

(a) a subtraction due to a divergence exposed by integrating by parts with respect to k;

(b) a subtraction due to a divergence exposed by integrating by parts with respect to l;

(c) a subtraction due to a divergence exposed by changing variables from l to $k-l$ and integrating by parts with respect to k;

(d) a subtraction due to a divergence exposed by using the identity

$$1 = \frac{1}{2D}\sum_{i=1}^{D}\left(\frac{\partial k_i}{\partial k_i}+\frac{\partial l_i}{\partial l_i}\right) \qquad (2.53)$$

in the integrand.

Taking the operation described in (d) first and using the method that we have just developed we find

$$I = \frac{1}{2D-6}I_c,$$

$$I_c = +\frac{i\lambda^2}{6(2\pi)^8}\int dk\, dl\left[\frac{2m^2}{[k^2-m^2]^2[l^2-m^2][(p+l-k)^2-m^2]} + \frac{2m^2}{[k^2-m^2][l^2-m^2]^2[(p+l-k)^2-m^2]} + \frac{-2p^2+2m^2+2p\cdot(k-l)}{[k^2-m^2][l^2-m^2][(p+l-k)^2-m^2]^2}\right]. \qquad (2.54)$$

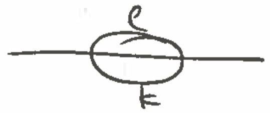
When $D=4$, $2D-6=2$ verifying the presence of the quadratic divergence already mentioned. For the other three diagrams we introduce the notation of putting a cross in the subdiagram to denote the counter term. The counter terms of (a), (b) and (c) can then be

Annotated pages from John's xeroxed copy of Nash's book on QED

John (later Giannis…) Bakas: the formative years

(N.B)

The idea for the overlapping divergences is the following one:

In diagrams like: 

in order to deal with U.V. divergences we must put <u>at least</u> one of ℓ or k tending to infinity.

∴

$k \backslash \ell$	small	large
small	▨	logarithmic
large	logarithmic	quadratic

we drop this region as $\left(\begin{matrix} k \text{ small} \\ \ell \text{ small} \end{matrix}\right)$

∴ No U.V. behaviour.

∴ <u>Result</u>: In diagrams like this we can have both logarithmic or quadratic divergences. These are the so called <u>overlapping divergences</u>.

Annotated pages from John's xeroxed copy of Nash's book on QED

John (later Giannis…) Bakas: the formative years

JOHN BAKAS (DIC)

ESSAY IN ALGEBRAIC TOPOLOGY

TITLE:

"TOPOLOGICAL SOLITONS IN FIELD THEORIES"

Coffee stained pages from his notes on a student seminar and/or DIC thesis

1. INTRODUCTION

It has been observed that non-linear field theories adm
the existence of stable finite energy solutions, which are of
topological origin, called topological solitons. In this essay we
study their nature and classification by using methods of al
braic topology, which seem to be a very powerful tool.

For topological solitons to exist, there must be an
internal degree of freedom for the fields, which gives rise
to an internal field space.

A most striking stability feature of these solution
is an associated topological charge, a consequence solely
of the continuity of the fields. This charge or kink
number takes on a discrete set of values, which remain in
variant under any continuous deformations, particularly in
the course of time evolution. Thus obeying homotopic con
servation laws, these kinks arise not from any symmetry
of the Lagrangian, but rather from the global topology
of the field manifold, a structure specified by appropri
of the boundary conditions. So topological charge is absolutely co
served; the field topology acts like an infinite potential
barrier.

Soliton solutions can not be reached by standard per
turbation theory, because they are associated with the glob
properties of the field manifold; these properties are unex
zed by perturbation methods, as whenever we use perturba
theory and expand about one point of the field manifold, w
thereby effectively replace it by the tangent space to the

John (later Giannis…) Bakas: the formative years

- Once in the States, he quickly matured to the scientist we knew and appreciated
- Utah
- Texas
- Maryland
- CERN
- Greece (Patras, Athens)

John (later Giannis…) Bakas: the formative years

- ~1992: I met him in Crete (a soldier on leave with girl friend!)
- ~1996: Returning to Greece (first Patras, then NTU Athens) was what his heart desired
- By 2016 he had reached full scientific maturity, as an esteemed researcher and senior Greek academic in a top Institute of his homeland, enjoying international prestige
- He was also rewarded by his wife's and daughter's love, affection, and admiration
- He had a lot to give to family and Physics. It is truly sad that the Gods decided otherwise. He will always be remembered fondly by all who knew him.

B_K in the SM and Beyond

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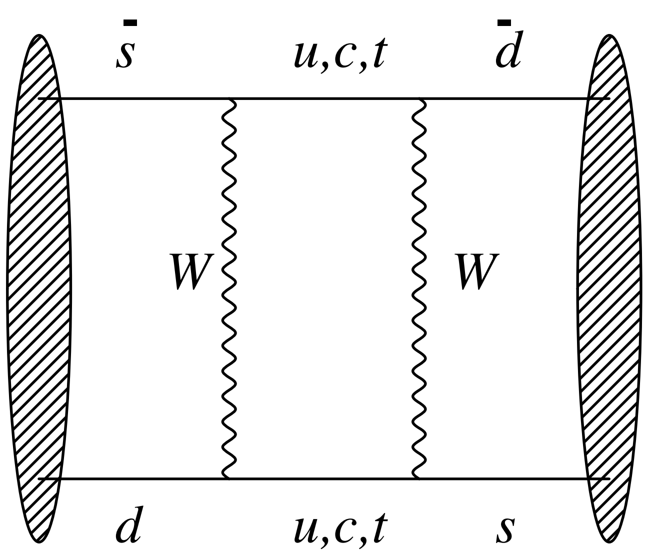
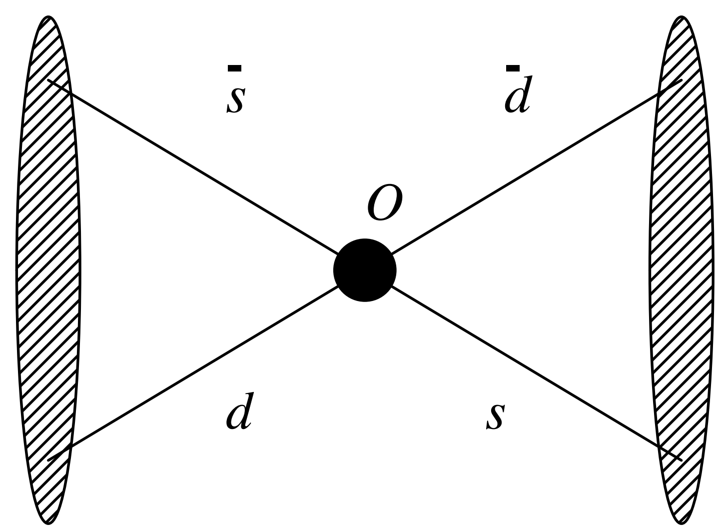
28th March 2018

B_K in the SM

- indirect CP-violation $\qquad \epsilon_K = \dfrac{\mathcal{A}[K_L \to (\pi\pi)_{I=0}]}{\mathcal{A}[K_S \to (\pi\pi)_{I=0}]} = [2.282(17) \times 10^{-3}]\, \exp(i\pi/4)$

can also be expressed in terms of neutral K-oscillations: dominant EW process is FCNC (2-W exchange)





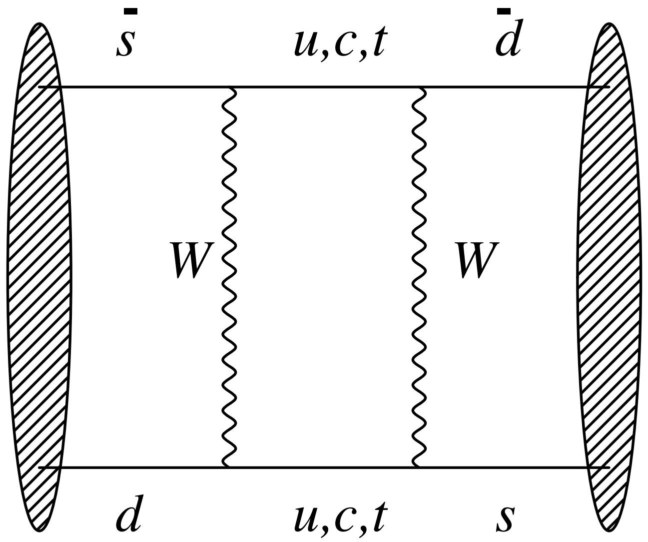
QCD effects consist in gluon and internal quark-loop exchanges (not shown here)

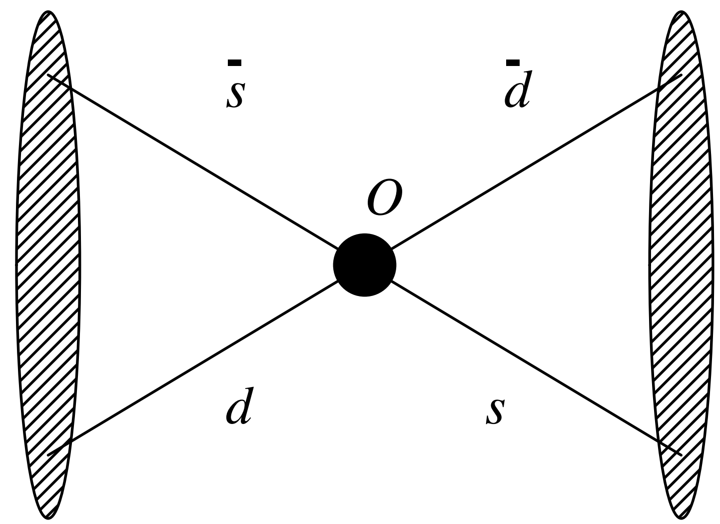
- $\Delta S = 2$ oscillations are governed by the transition amplitude of an effective Hamiltonian, obtained by successively integrating out W's and t- (b-) and c-quarks

- We are left with an OPE with a single, dim-6, 4-fermion, $L \otimes L$ operator, in a 3-quark approximation of QCD ($N_f = 3$)

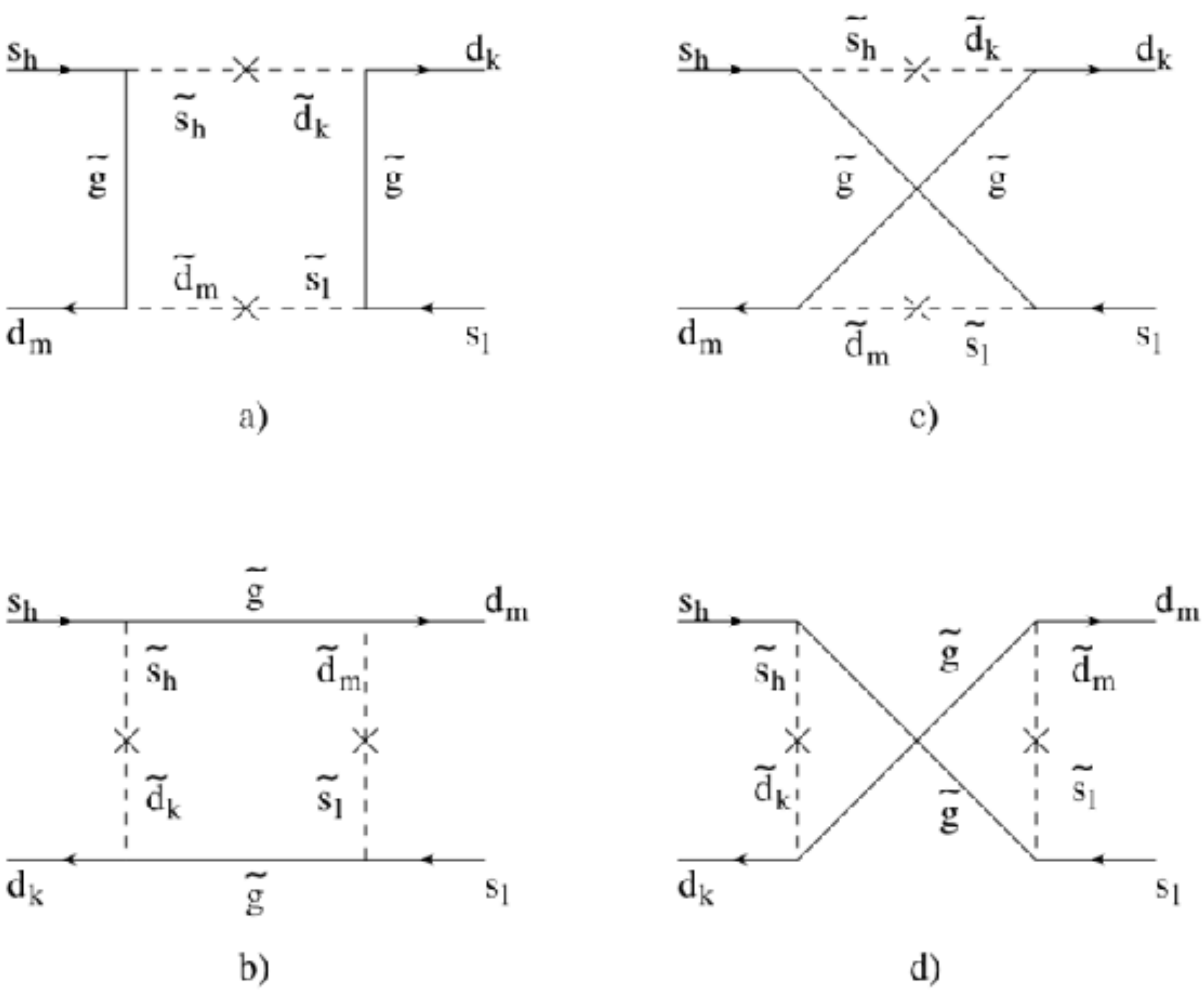
$$Q^{\Delta S=2} = [\bar{s}\gamma_\mu(1-\gamma_5)d]\,[\bar{s}\gamma_\mu(1-\gamma_5)d] \equiv O_{\mathrm{VV+AA}} - O_{\mathrm{VA+AV}}$$

B_K BSM





- More particles on the box diagrams
- More operators in the OPE



$$
\begin{aligned}
O_1 &= [\bar{s}^\alpha \gamma_\mu (1-\gamma_5) d^\alpha][\bar{s}^\beta \gamma_\mu (1-\gamma_5) d^\beta] \\
O_2 &= [\bar{s}^\alpha (1-\gamma_5) d^\alpha][\bar{s}^\beta (1-\gamma_5) d^\beta] \\
O_3 &= [\bar{s}^\alpha (1-\gamma_5) d^\beta][\bar{s}^\beta (1-\gamma_5) d^\alpha] \\
O_4 &= [\bar{s}^\alpha (1-\gamma_5) d^\alpha][\bar{s}^\beta (1+\gamma_5) d^\beta] \\
O_5 &= [\bar{s}^\alpha (1-\gamma_5) d^\beta][\bar{s}^\beta (1+\gamma_5) d^\alpha]
\end{aligned}
$$

NB: MIXING of (O_2 , O_3) & (O_4 , O_5)

B_K in the SM

- $\Delta S = 2$ transitions are governed by the transition amplitude of the effective Hamiltonian:

$$\langle \bar{K}^0 | \mathcal{H}_{\rm eff}^{\Delta S=2} | K^0 \rangle = \frac{G_F^2 M_{\rm W}^2}{16\pi^2} \Big[\lambda_c^2 S_0(x_c)\eta_1 + \lambda_t^2 S_0(x_t)\eta_2 + 2\lambda_c\lambda_t S_0(x_c,x_t)\eta_3 \Big]$$

$$\times \left(\frac{\bar{g}(\mu)^2}{4\pi} \right)^{-\gamma_0/(2\beta_0)} \left\{ 1 + \frac{\bar{g}(\mu)^2}{(4\pi)^2} \left[\frac{\beta_1\gamma_0 - \beta_0\gamma_1}{2\beta_0^2} \right] \right\} \langle \bar{K}^0 | Q_{\rm R}^{\Delta S=2}(\mu) | K^0 \rangle + {\rm h.c.}$$

$$x_{c,t} \equiv m_{c,t}^2 / M_W^2 \qquad\qquad \lambda_f = V_{fs}^* V_{fd} \qquad f = c, t$$

Inami-Lim functions: $\quad S_0(x_{c,t}) \qquad S_0(x_c, x_t)$

B_K in the SM

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$$\times \left(\frac{\bar{g}(\mu)^2}{4\pi} \right)^{-\gamma_0/(2\beta_0)} \left\{ 1 + \frac{\bar{g}(\mu)^2}{(4\pi)^2} \left[\frac{\beta_1\gamma_0 - \beta_0\gamma_1}{2\beta_0^2} \right] \right\} \langle \bar{K}^0 | Q_{\rm R}^{\Delta S=2}(\mu) | K^0 \rangle \;+\; {\rm h.c.}$$

- Wilson coefficient

- Known to NLO in PT; afflicted by PT errors

- The higher the renormalisation scale μ, the more reliable PT (typically chose 2-4 GeV)

B_K in the SM

- $\Delta S = 2$ transitions are governed by the transition amplitude of the effective Hamiltonian:

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$$\times \left(\frac{\bar{g}(\mu)^2}{4\pi} \right)^{-\gamma_0/(2\beta_0)} \left\{ 1 + \frac{\bar{g}(\mu)^2}{(4\pi)^2} \left[\frac{\beta_1\gamma_0 - \beta_0\gamma_1}{2\beta_0^2} \right] \right\} \langle \bar{K}^0 | Q_{\rm R}^{\Delta S=2}(\mu) | K^0 \rangle + \text{h.c.}$$

- Matrix element is computed on the lattice through its B_K-parameter; afflicted by usual errors
- Habitually this is renormalised either:
  - in 1-loop PT (lattice regularisation ➔ MS renormalisation)
  - NPly (lattice regularisation ➔ MOM-subtraction renormalisation at 2-4 GeV ➔ MS renormalisation with finite matching)
- Often normalised by a constant →→→ "B-parameter"

$$B_{\rm K}(\mu) = \frac{\langle \bar{K}^0 \left| Q_{\rm R}^{\Delta S=2}(\mu) \right| K^0 \rangle}{\frac{8}{3} f_K^2 m_K^2}$$

B_K in the SM

- $\Delta S = 2$ transitions are governed by the transition amplitude of the effective Hamiltonian:

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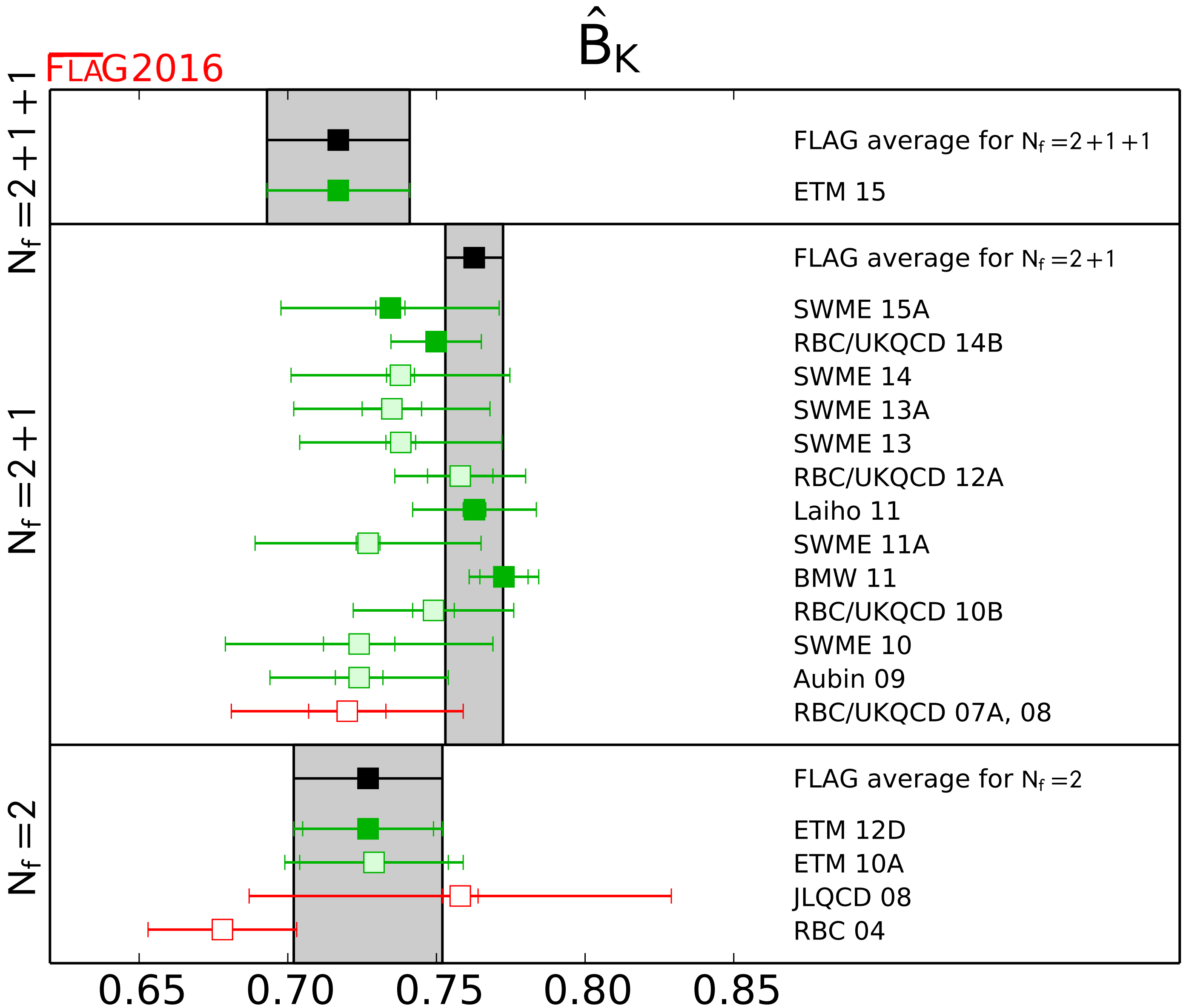
$$\times \left(\frac{\bar{g}(\mu)^2}{4\pi} \right)^{-\gamma_0/(2\beta_0)} \left\{ 1 + \frac{\bar{g}(\mu)^2}{(4\pi)^2} \left[\frac{\beta_1\gamma_0 - \beta_0\gamma_1}{2\beta_0^2} \right] \right\} \langle \bar{K}^0 | Q_{\rm R}^{\Delta S=2}(\mu) | K^0 \rangle + \text{ h.c.}$$

- The product is only nominally μ-independent; there is residual μ-dependence.

- Alpha-collaboration has a long-term programme of NP renormalisation at scales $\sim\Lambda_{\rm QCD}$ and NP-running (continuum) up to scales $\sim M_{\rm W}$; so far applied at $N_f=0$

B_K in the SM



- Different lattice regularisations and renormalisation schemes give compatible, even N_f -weakly - dependent, results

- Lattice error subdominant in ε_K (1.6%); dominant error arises from V_{cb} (40%)

$$\hat{B}_K = 0.717(18)(16) \qquad N_f = 2+1+1$$

$$\hat{B}_K = 0.7625(97) \qquad N_f = 2+1$$

$$\hat{B}_K = 0.727(22)(12) \qquad N_f = 2$$

B_K beyond the SM

- Analyse New Physics (NP) effects in a model-independent way: assume a generalisation of the effective $\Delta S = 2$ Hamiltonian which contains operators beyond the SM one; the amplitude is:

$$< \bar{K}^0|\mathcal{H}_{\rm eff}^{\Delta S=2}|K^0 > \,=\, C_1 < \bar{K}^0|O_1|K^0 > \,+\, \sum_{i=2}^{5} C_i < \bar{K}^0|O_i|K^0 >$$

$$\begin{aligned}
O_1 &= [\bar{s}^\alpha\gamma_\mu(1-\gamma_5)d^\alpha][\bar{s}^\beta\gamma_\mu(1-\gamma_5)d^\beta] \\
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O_5 &= [\bar{s}^\alpha(1-\gamma_5)d^\beta][\bar{s}^\beta(1+\gamma_5)d^\alpha]
\end{aligned}$$

SM contributions

NP coupling

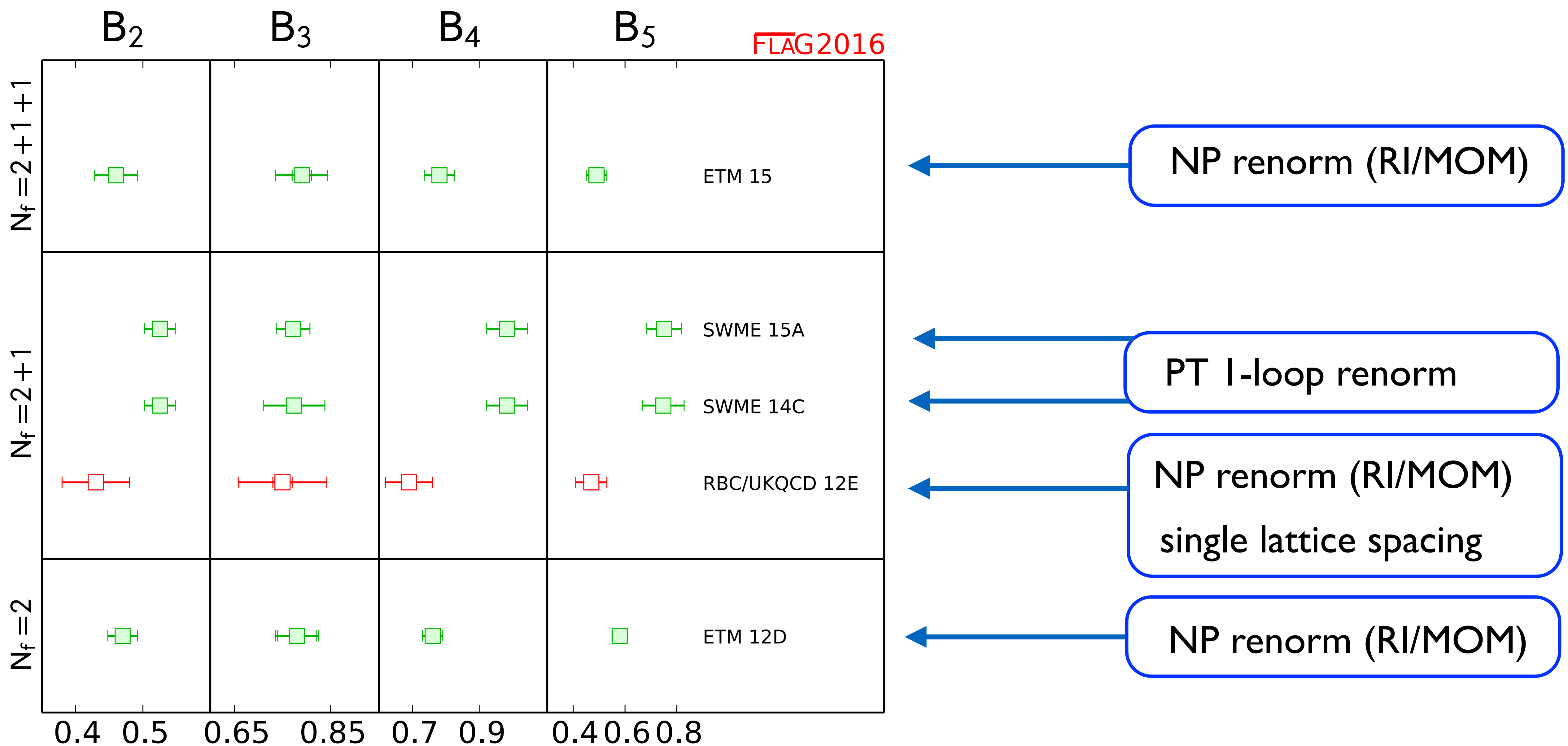
Loop factor coupling dependent

$$C_i(\Lambda) = \frac{F_i L_i}{\Lambda^2} \qquad i = 2, \cdots, 5$$

NewPhysics scale

- B-parameters defined analogously for all operators
- Assuming $F_i \sim L_i \sim 1$, generalised UT-fit analysis produces lower bounds for Λ; these depend very strongly (several orders of magnitude) on this assumption.

B_K beyond the SM



- RBC/UKQCD 2017: new results with 2 RI/SMOM schemes (at 2 lattice spacings) agree with SWME; authors suggest that RI/MOM may be the culprit for these operators
- ALPHA results (with SF renormalisation scheme) and NP-running are badly needed

B_K in the SM

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$$\langle \bar{K}^0 | \mathcal{H}_{\rm eff}^{\Delta S=2} | K^0 \rangle = \frac{G_F^2 M_{\rm W}^2}{16\pi^2} \left[\lambda_c^2 S_0(x_c)\eta_1 + \lambda_t^2 S_0(x_t)\eta_2 + 2\lambda_c\lambda_t S_0(x_c,x_t)\eta_3 \right]$$
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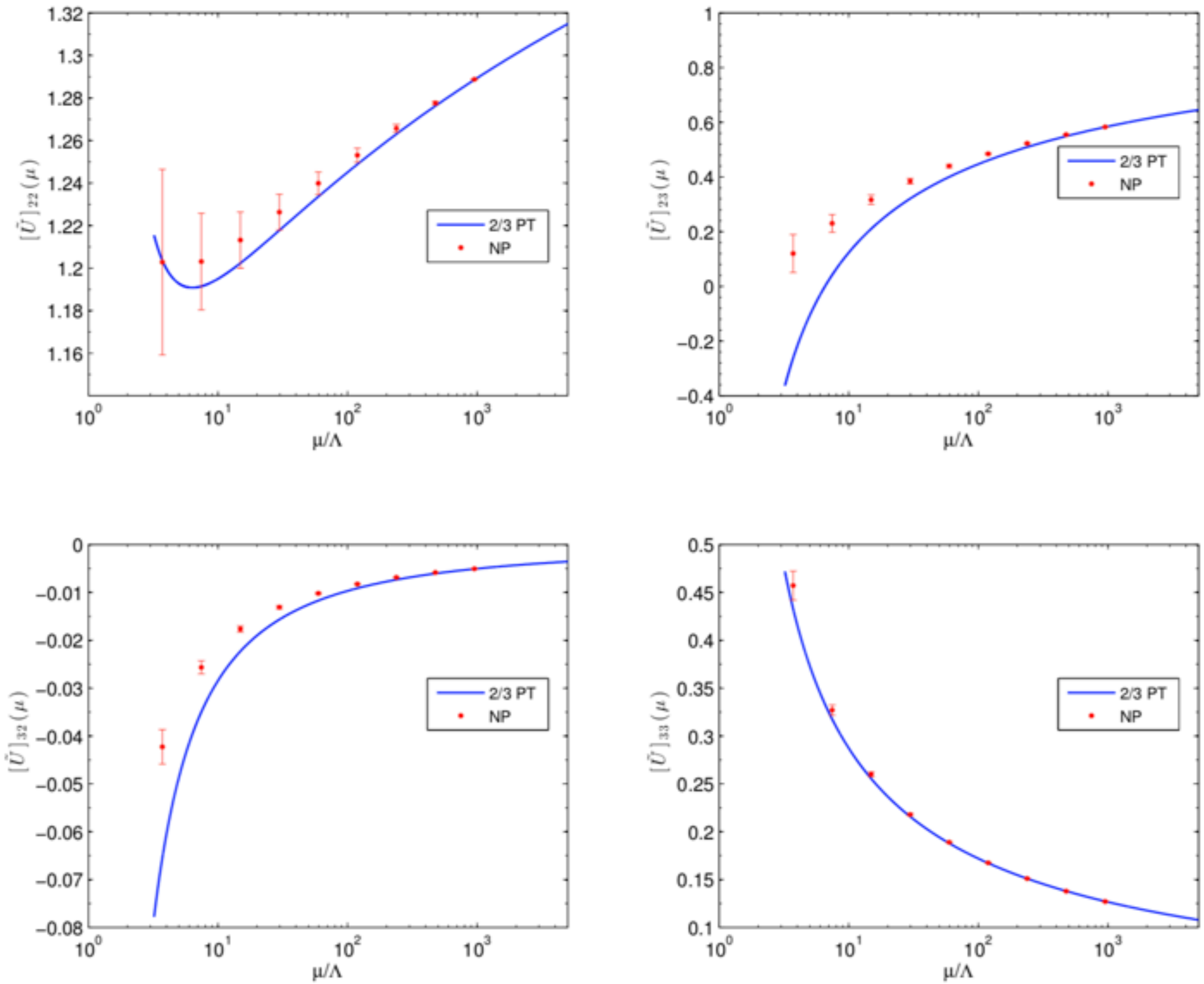
- The product is only nominally μ-independent; there is residual μ-dependence.
- Alpha-collaboration has a long-term programme of NP renormalisation at scales $\sim\Lambda_{\rm QCD}$ and NP-running (continuum) up to scales $\sim M_W$; so far applied at $N_f=0$
- In the late ‘90s the Schroedinger Functional scheme was introduced and results were obtained for the QCD coupling and quark masses (albeit in the quenched approximation)
- Generalised to BK (quenched) in the early 00’s
- Generalised to QCD coupling and quark masses (Nf=2) in the early 00’s
- Generalised to BK - SM and beyond (Nf=2,3) nowadays

B_K beyond the SM

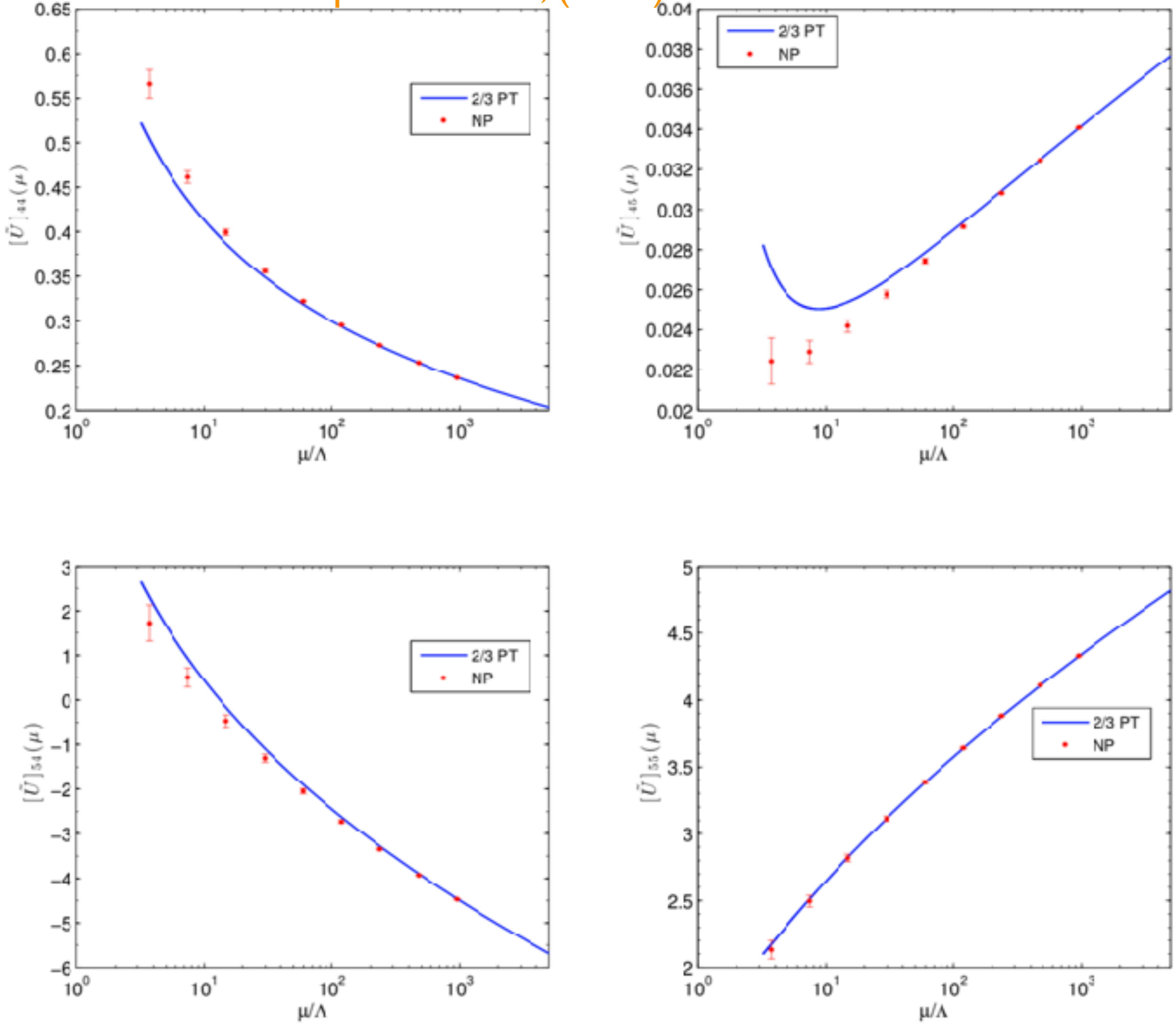
P. Dimopoulos et al., (2018) arXiv:1801. 09455



- Alpha 2018 warm-up exercise: RG-running for operators O_2 and O_3 for $N_f = 2$

B_K beyond the SM

P. Dimopoulos et al., (2018) arXiv:1801. 09455



- Alpha 2018 warm-up exercise: RG-running for operators O_4 and O_5 for $N_f = 2$

Conclusions

- Lattice nowadays competes with the accuracy of experiments (in recent years we moved from 5% to 1%-2%).
- SM results are in many cases well under control; activity beyond SM.
- It is the responsibility of the lattice community to provide experimentalists and non-lattice theorists with a review of phenomenologically relevant lattice results with conservative error estimates (FLAG), not only for he SM but also beyond.

- 2011: G. Colangelo et al., "Review of Lattice Results Concerning Low-Energy Particle Physics", Eur. Phys. J. C 71 (2011) 1695
- 2014: S. Aoki et al., "Review of Lattice Results Concerning Low-Energy Particle Physics", Eur. Phys. J. C 74 (2014) 2890
- 2016: S. Aoki et al., "Review of Lattice Results Concerning Low-Energy Particle Physics",

Backup pages

B_K beyond the SM

- Analyse New Physics (NP) effects in a model-independent way: assume a generalisation of the effective $\Delta S = 2$ Hamiltonian which contains operators beyond the SM one; the amplitude is:

$$< \bar{K}^0 | \mathcal{H}_{\text{eff}}^{\Delta S=2} | K^0 > \; = \; C_1 < \bar{K}^0 | O_1 | K^0 > \; + \; \sum_{i=2}^{5} C_i < \bar{K}^0 | O_i | K^0 >$$

SM contributions

- Minimal Flavour Violation (MFV) models: $F_1 = F_{SM}$; $F_{2,3,4,5} = 0$
- Assuming $L_i \sim 1$, corresponds to strongly-interacting and/or tree-level coupled New Physics
- gluino exchange in the minimal super-symmetric SM $L_i \sim \alpha_s^2$
- all models with SM-like loop-mediated weak interactions $L_i \sim \alpha_W^2$

NP coupling

Loop factor coupling dependent

$$C_i(\Lambda) \; = \; \frac{F_i L_i}{\Lambda^2} \qquad i = 2, \cdots, 5$$

NewPhysics scale

B_K beyond the SM

$$< \bar{K}^0 | \mathcal{H}_{\rm eff}^{\Delta S=2} | K^0 > \; = \; C_1 < \bar{K}^0 | O_1 | K^0 > \; + \; \sum_{i=2}^{5} C_i < \bar{K}^0 | O_i | K^0 >$$

NP coupling

Loop factor coupling dependent

$$C_i(\Lambda) \; = \; \frac{F_i L_i}{\Lambda^2} \qquad i = 2, \cdots, 5$$

NewPhysics scale

In particular, in the Randall-Sundrum (RS) scenario one has

$$L_4 = (g_s^*)^2, \quad F_4 = \frac{2 m_d m_s}{Y_*^2 v^2}, \quad \Lambda = M_G\,, \tag{3.2}$$

where M_G and $g_s^* \sim 6$ are the mass and coupling of Kaluza-Klein excitations of the gluon, $Y_* \sim 3$ is the five-dimensional Yukawa coupling (whose flavour structure is assumed to be anarchic), $m_d \sim 3\,\mathrm{MeV}$ and $m_s \sim 50\,\mathrm{MeV}$ are $\overline{\rm MS}$ quark masses at the high scale and $v = 246\,\mathrm{GeV}$ is the Higgs vev. Running from a reference scale of $5\,\mathrm{TeV}$, we obtain at 95% probability $\mathrm{Im}\, C_4^K \in [-4.7, 10.6] \cdot 10^{-18}$, from which we get

$$M_G > 43\,\mathrm{TeV}. \tag{3.3}$$

B_K beyond the SM

$$< \bar{K}^0 | \mathcal{H}_{\rm eff}^{\Delta S=2} | K^0 > = C_1 < \bar{K}^0 | O_1 | K^0 > + \sum_{i=2}^{5} C_i < \bar{K}^0 | O_i | K^0 >$$

NP coupling

Loop factor coupling dependent

$$C_i(\Lambda) = \frac{F_i L_i}{\Lambda^2} \qquad i = 2, \cdots, 5$$

NewPhysics scale

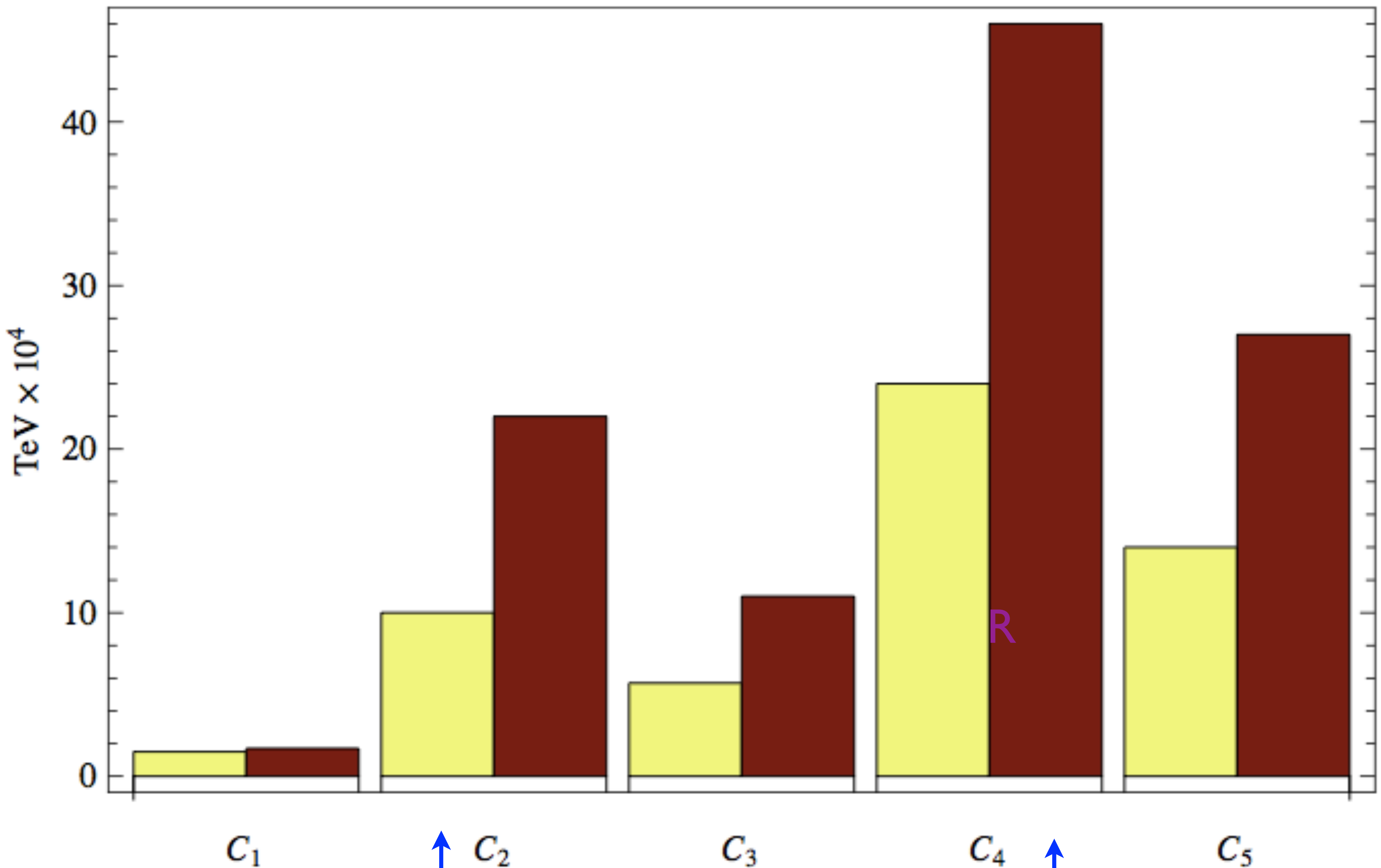
Considering instead gauge-Higgs unification (GHU) models, from ref. [26] we have

$$L_4 = (g_s^*)^2 \,, \quad F_4 \sim \frac{8 m_d m_s}{g_*^2 v^2} \,, \quad \Lambda = M_G \,, \tag{3.4}$$

where in this case $g_* \sim 4$ is the five-dimensional gauge coupling in units of the radius of the compact dimension. We obtain the bound

$$M_G > 65\,\text{TeV}. \tag{3.5}$$

B_K beyond the SM



$$R_i = \frac{<\bar{K}^0|O_i|K^0>}{<\bar{K}^0|O_1|K^0>} \qquad i = 2, \cdots, 5$$

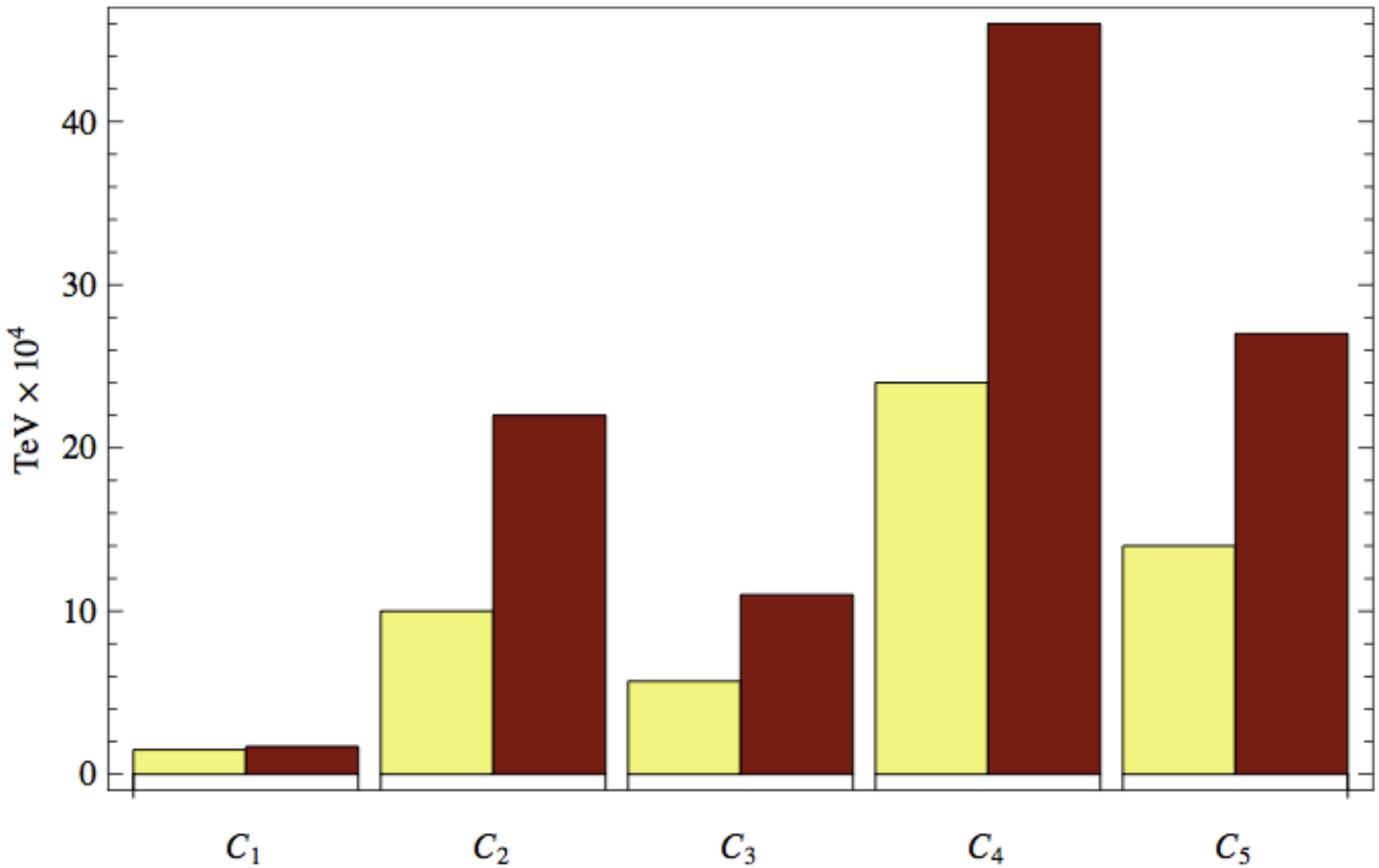
N_f=0 data; accuracy of ratios $R_i \sim$ 20%-23%

UTfit: M.Bona et al., JHEP03(2008)049

N_f=2 data; accuracy of ratios $R_i \sim$ 3%-6%

ETM: V.Bertone et al., JHEP03(2013)089

B_K beyond the SM



- NB: each contribution analysed separately (avoids accidental cancellations).
- NB: SM bound is several orders of magnitude weaker thank those arising form BSM operators.