Happy birthday Guido !

Vittorio

The famous Guido's Christmas cards

The famous Guido's Christmas cards

1989: the beginning of the story (for me)

- When I was an undergraduate student in Rome, Guido was at CERN.

- I asked a thesis to Luciano Maiani and (as he was used to), before accepting me as a student, he gave me an "exercise":

"Compute the one-loop beta function of the $\lambda\phi^4$ theory in the continuum and on the lattice"

- As far as I remember, at that time I didn't know what the beta function is, and I never heard about the lattice…

- So, I went to the library at La Sapienza and started to study...

CALCOLO DELLA BETA-FUNCTION NELLA TEORIA $\lambda\phi^4$.

I) FORMULAZIONE DI FEYNMAN DELLA MECCANICA QUANTISTICA MEDIANTE IL PATH-INTEGRAL

- MECCANICA QUANTISTICA NON RELATIVISTICA:

Consideriamo un sistema ad un grado di libertà, con una variabile dinamica Q, un momento coniu-

---

$$= \frac{2a}{b}\ln\left(\frac{1+2b}{1-2b}\right) = \frac{2a}{\sqrt{1/4-a^2}}\ln\left(\frac{1+\sqrt{1-4a^2}}{1-\sqrt{1-4a^2}}\right) =$$

$$= \frac{4m/\mu}{\sqrt{1-4(m/\mu)^2}}\ln\left(\frac{1+\sqrt{1-4(m/\mu)^2}}{1-\sqrt{1-4(m/\mu)^2}}\right) \qquad (24)$$

Sostituendo infatti questa espressione nella (20) si trova

$$\beta\left(\lambda,\frac{m}{\mu}\right) = \frac{3\lambda^2}{16\pi^2}\left[1+\frac{(m/\mu)^2}{\sqrt{1-4(m/\mu)^2}}\ln\left(\frac{1+\sqrt{1-4(m/\mu)^2}}{1-\sqrt{1-4(m/\mu)^2}}\right)\right] \qquad (25)$$

Osserviamo che vale la relazione

$$\lim_{m\to 0}\beta(\lambda,m/\mu) = \lim_{\mu\to\infty}\beta(\lambda,m/\mu) = \frac{3\lambda^2}{16\pi^2}$$

III) TEORIA DEL CAMPO SCALARE SUL RETICOLO:

- IL CAMPO SCALARE LIBERO:

La teoria del campo scalare libero diviene sul reticolo il modello gaussiano della meccanica statistica. Come nel caso convenzionale del

---

Effettuiamo il calcolo su di un reticolo ipercubico 4-dimensionale. Restringiamo pertanto le coordinate alla forma

$$x_\mu = a\, n_\mu \qquad (4)$$

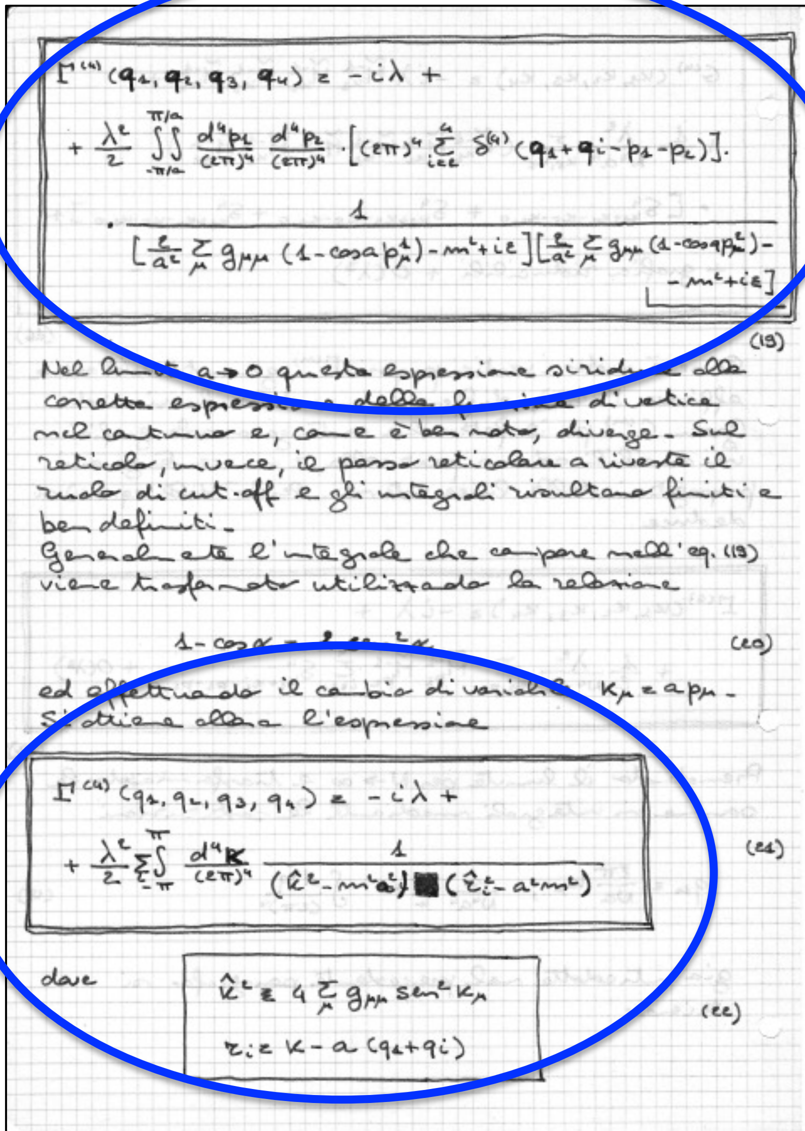
dove a è il passo reticolare ed n_μ un vettore con 4 componenti intere. Come cut off infrarosso imponiamo alle singole componenti di n di assumere solo un numero finito di N valori indipendenti:

$$N/2 < n_\mu \leq N/2 \qquad (5)$$

Al di fuori di questo range considereremo il reticolo periodico, cioè identificheremo n con N+n. Sostituiamo ora le derivate di ϕ con le differenze dei campi nei siti reticolari più vicini

$$\partial_\mu \phi(x) = [\phi(x+\hat{\mu}) - \phi(x)]/a \qquad (6)$$

dove $\hat{\mu}$ indica il vettore unitario nella direzione



$$\Gamma^{(4)}(q_1,q_2,q_3,q_4) = -i\lambda + \frac{\lambda^2}{2}\iint_{-\pi/a}^{\pi/a}\frac{d^4p_1}{(2\pi)^4}\frac{d^4p_2}{(2\pi)^4}\cdot\left[(2\pi)^4\sum_{i=2}^{4}\delta^{(4)}(q_1+q_i-p_1-p_2)\right]\cdot\frac{1}{\left[\frac{2}{a^2}\sum_\mu g_{\mu\mu}(1-\cos a p_\mu^1)-m^2+i\epsilon\right]\left[\frac{2}{a^2}\sum_\mu g_{\mu\mu}(1-\cos a p_\mu^2)-m^2+i\epsilon\right]} \qquad (19)$$

Nel limite $a\to 0$ questa espressione si riduce alla corretta espressione della funzione di vertice nel continuo e, come è ben noto, diverge. Sul reticolo, invece, il passo reticolare a riveste il ruolo di cut-off e gli integrali risultano finiti e ben definiti.

Generalmente l'integrale che compare nell'eq. (19) viene trasformato utilizzando la relazione

$$1-\cos\alpha = 2\,\mathrm{sen}^2\frac{\alpha}{2} \qquad (20)$$

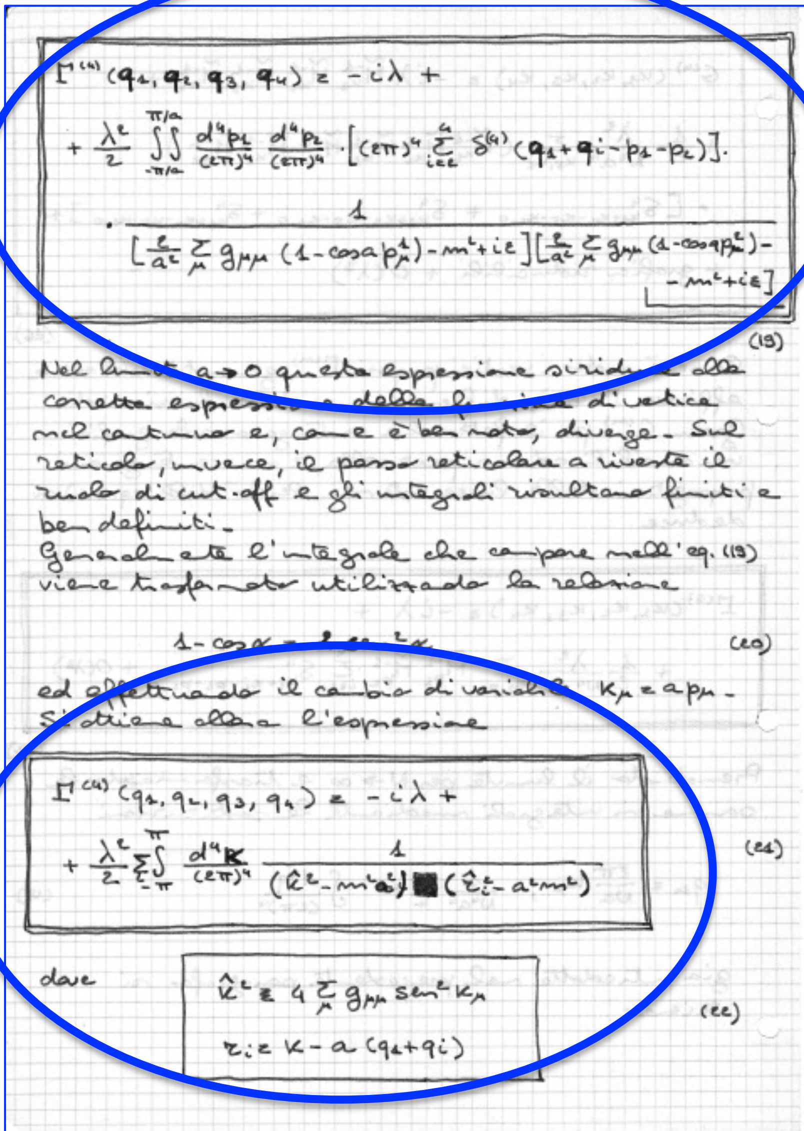
ed effettuando il cambio di variabile $k_\mu = a p_\mu$. Si ottiene allora l'espressione

$$\Gamma^{(4)}(q_1,q_2,q_3,q_4) = -i\lambda + \frac{\lambda^2}{2}\sum_i\int_{-\pi}^{\pi}\frac{d^4k}{(2\pi)^4}\frac{1}{(\hat{k}^2-m^2a^2)\,[\text{redacted}]\,(\hat{r}_i^2-a^2m^2)} \qquad (21)$$

dove

$$\hat{k}^2 = 4\sum_\mu g_{\mu\mu}\,\mathrm{sen}^2 k_\mu \qquad r_i = k - a(q_1+q_i) \qquad (22)$$

??



$$\Gamma^{(4)}(q_1,q_2,q_3,q_4) = -i\lambda + \frac{\lambda^2}{2}\int\!\!\int_{-\pi/a}^{\pi/a}\frac{d^4p_1}{(2\pi)^4}\frac{d^4p_2}{(2\pi)^4}\cdot\left[(2\pi)^4\sum_{i=2}^{4}\delta^{(4)}(q_1+q_i-p_1-p_2)\right]\cdot\frac{1}{\left[\frac{2}{a^2}\sum_\mu g_{\mu\mu}(1-\cos a p^1_\mu)-m^2+i\varepsilon\right]\left[\frac{2}{a^2}\sum_\mu g_{\mu\mu}(1-\cos a p^2_\mu)-m^2+i\varepsilon\right]} \quad (19)$$

Nel limite $a \to 0$ questa espressione si riduce alla corretta espressione della funzione di vertice nel continuo e, come è ben noto, diverge. Sul reticolo, invece, il passo reticolare a riveste il ruolo di cut-off e gli integrali risultano finiti e ben definiti.

Generalmente l'integrale che compare nell'eq. (19) viene trasformato utilizzando la relazione

$$1-\cos\alpha = 2\,\mathrm{sen}^2\frac{\alpha}{2} \quad (20)$$

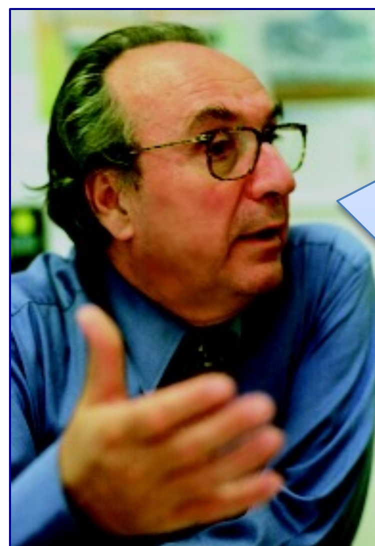
ed effettuando il cambio di variabile $k_\mu = a p_\mu$. Si ottiene allora l'espressione

$$\Gamma^{(4)}(q_1,q_2,q_3,q_4) = -i\lambda + \frac{\lambda^2}{2}\sum_i\int_{-\pi}^{\pi}\frac{d^4k}{(2\pi)^4}\frac{1}{(\hat{k}^2-m^2a^2)(\hat{r}_i^2-a^2m^2)} \quad (21)$$

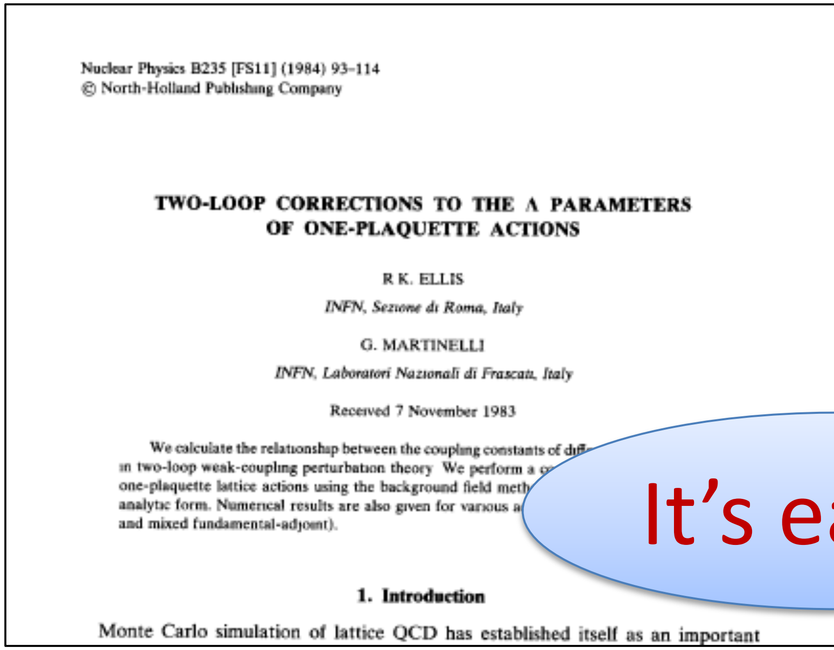
dove

$$\hat{k}^2 = 4\sum_\mu g_{\mu\mu}\,\mathrm{sen}^2\frac{k_\mu}{2} \qquad r_i = k - a(q_1+q_i) \quad (22)$$

??



There is a guy at CERN…his name is **Guido Martinelli**


Nuclear Physics B235 [FS11] (1984) 93-114
© North-Holland Publishing Company

TWO-LOOP CORRECTIONS TO THE Λ PARAMETERS OF ONE-PLAQUETTE ACTIONS

R.K. ELLIS
INFN, Sezione di Roma, Italy

G. MARTINELLI
INFN, Laboratori Nazionali di Frascati, Italy

Received 7 November 1983

We calculate the relationship between the coupling constants of diff
in two-loop weak-coupling perturbation theory We perform a c
one-plaquette lattice actions using the background field meth
analytic form. Numerical results are also given for various a
and mixed fundamental-adjoint).

1. Introduction

Monte Carlo simulation of lattice QCD has established itself as an important

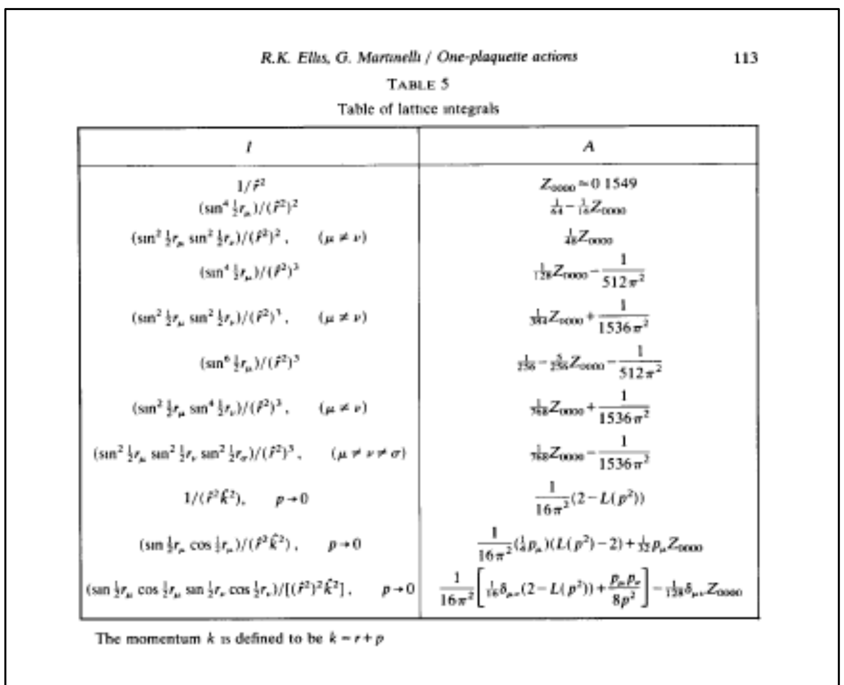
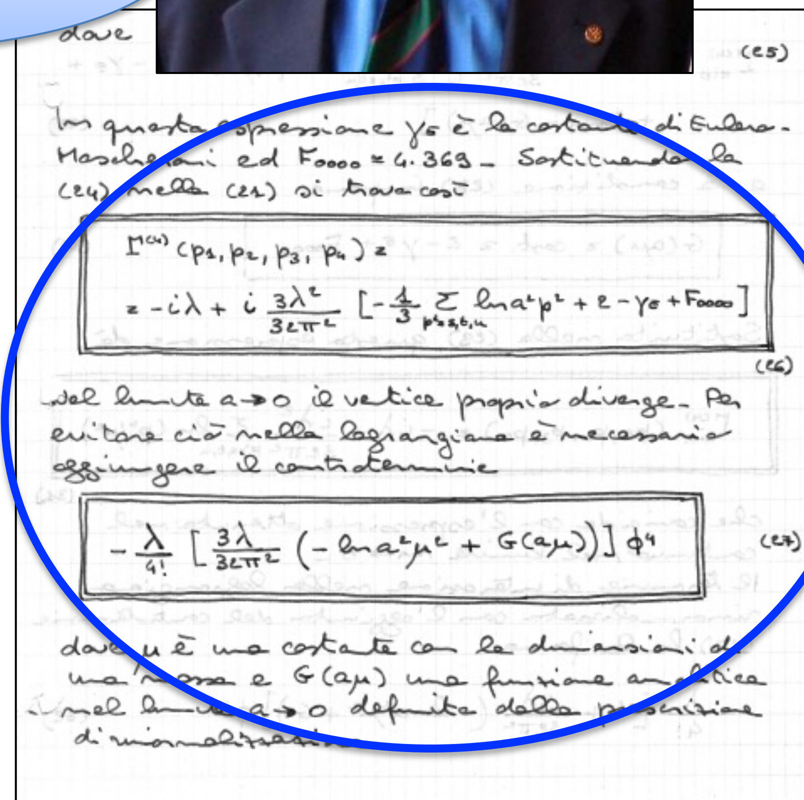


TABLE 5
Table of lattice integrals

I	A
$1/\hat{r}^2$	$Z_{0000} \approx 0.1549$
$(\sin^4 \frac{1}{2}r_\mu)/(\hat{r}^2)^2$	$\frac{1}{64} - \frac{1}{16}Z_{0000}$
$(\sin^2 \frac{1}{2}r_\mu \sin^2 \frac{1}{2}r_\nu)/(\hat{r}^2)^2, \quad (\mu \neq \nu)$	$\frac{1}{48}Z_{0000}$
$(\sin^4 \frac{1}{2}r_\mu)/(\hat{r}^2)^3$	$\frac{1}{128}Z_{0000} - \frac{1}{512\pi^2}$
$(\sin^2 \frac{1}{2}r_\mu \sin^2 \frac{1}{2}r_\nu)/(\hat{r}^2)^3, \quad (\mu \neq \nu)$	$\frac{1}{384}Z_{0000} + \frac{1}{1536\pi^2}$
$(\sin^6 \frac{1}{2}r_\mu)/(\hat{r}^2)^3$	$\frac{1}{256} - \frac{3}{256}Z_{0000} - \frac{1}{512\pi^2}$
$(\sin^2 \frac{1}{2}r_\mu \sin^4 \frac{1}{2}r_\nu)/(\hat{r}^2)^3, \quad (\mu \neq \nu)$	$\frac{1}{768}Z_{0000} + \frac{1}{1536\pi^2}$
$(\sin^2 \frac{1}{2}r_\mu \sin^2 \frac{1}{2}r_\nu \sin^2 \frac{1}{2}r_\sigma)/(\hat{r}^2)^3, \quad (\mu \neq \nu \neq \sigma)$	$\frac{1}{768}Z_{0000} - \frac{1}{1536\pi^2}$
$1/(\hat{r}^2\hat{k}^2), \quad p \to 0$	$\frac{1}{16\pi^2}(2 - L(p^2))$
$(\sin \frac{1}{2}r_\mu \cos \frac{1}{2}r_\mu)/(\hat{r}^2\hat{k}^2), \quad p \to 0$	$\frac{1}{16\pi^2}(\frac{1}{4}p_\mu)(L(p^2) - 2) + \frac{1}{32}p_\mu Z_{0000}$
$(\sin \frac{1}{2}r_\mu \cos \frac{1}{2}r_\mu \sin \frac{1}{2}r_\nu \cos \frac{1}{2}r_\nu)/[(\hat{r}^2)^2\hat{k}^2], \quad p \to 0$	$\frac{1}{16\pi^2}\left[\frac{1}{16}\delta_{\mu\nu}(2 - L(p^2)) + \frac{p_\mu p_\nu}{8p^2}\right] - \frac{1}{128}\delta_{\mu\nu}Z_{0000}$

The momentum k is defined to be $k = r + p$


dove (25)

In questa espressione γ_E è la costante di Eulero-Mascheroni ed $F_{0000} = 4.369$ – Sostituendo la (24) nella (21) si trova così

$$\Gamma^{(4)}(p_1, p_2, p_3, p_4) = -i\lambda + i\,\frac{3\lambda^2}{32\pi^2}\left[-\frac{1}{3}\sum_{p^2=s,t,u} \ln a^2p^2 + 2 - \gamma_E + F_{0000}\right] \quad (26)$$

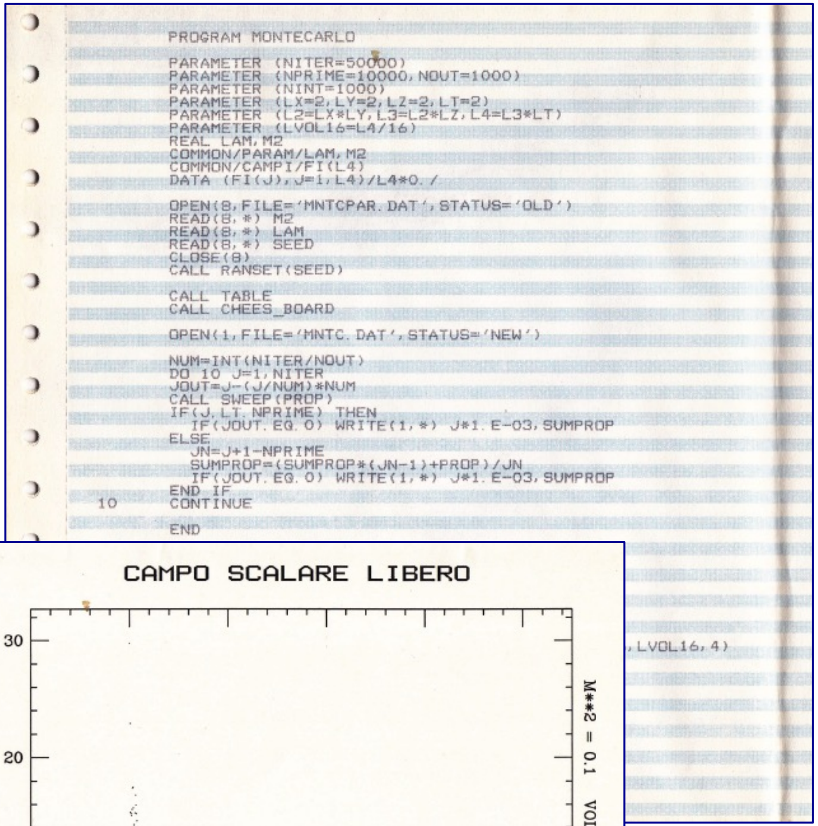
Nel limite $a \to 0$ il vertice proprio diverge – Per evitare ciò nella lagrangiana è necessario aggiungere il controtermine

$$-\frac{\lambda}{4!}\left[\frac{3\lambda}{32\pi^2}\left(-\ln a^2\mu^2 + G(a\mu)\right)\right]\phi^4 \quad (27)$$

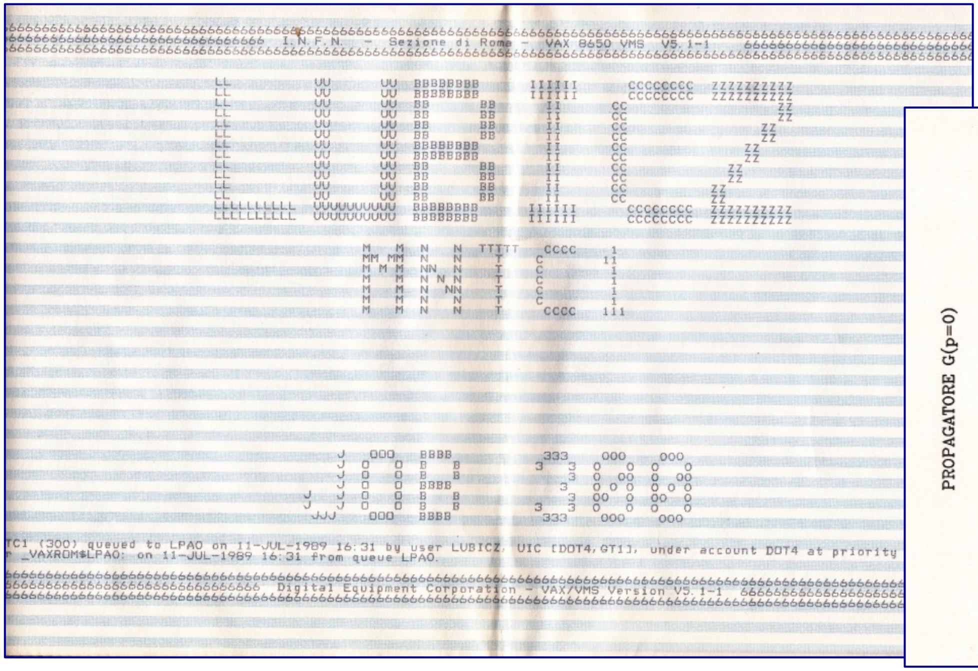
dove μ è una costante con le dimensioni di una massa e $G(a\mu)$ una funzione analitica nel limite $a \to 0$ definita dalla prescrizione di rinormalizzazione

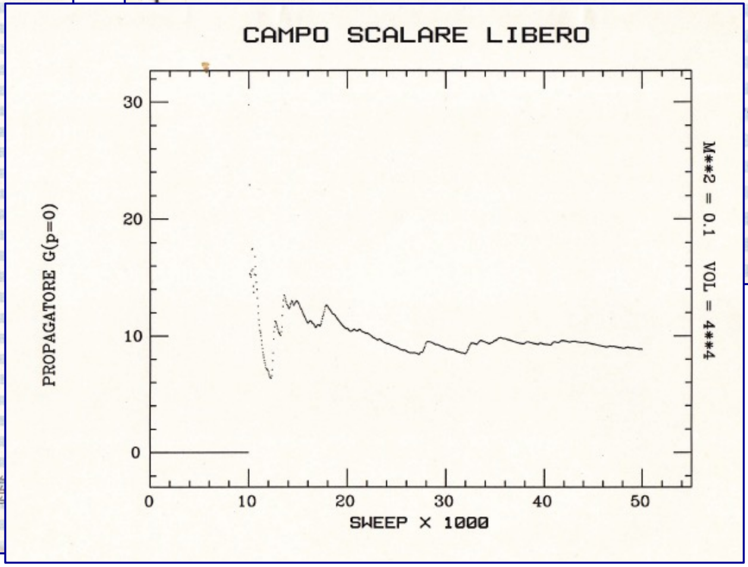
- So I got the thesis, and, under the supervision of Luciano, I started to work on the non-perturbative lattice determination of the upper bound on the Higgs boson mass.

- After few months, Guido came back to Rome and started to follow my work. We wrote a Monte Carlo in the $\lambda\phi^4$ theory



```
      PROGRAM MONTECARLO

      PARAMETER (NITER=50000)
      PARAMETER (NPRIME=10000, NOUT=1000)
      PARAMETER (NINT=1000)
      PARAMETER (LX=2, LY=2, LZ=2, LT=2)
      PARAMETER (L2=LX*LY, L3=L2*LZ, L4=L3*LT)
      PARAMETER (LVOL16=L4/16)
      REAL LAM, M2
      COMMON/PARAM/LAM, M2
      COMMON/CAMPI/FI(L4)
      DATA (FI(J), J=1, L4)/L4*0. /

      OPEN(8, FILE='MNTCPAR.DAT', STATUS='OLD')
      READ(8, *) M2
      READ(8, *) LAM
      READ(8, *) SEED
      CLOSE(8)
      CALL RANSET(SEED)

      CALL TABLE
      CALL CHEES_BOARD

      OPEN(1, FILE='MNTC.DAT', STATUS='NEW')

      NUM=INT(NITER/NOUT)
      DO 10 J=1, NITER
      JOUT=J-(J/NUM)*NUM
      CALL SWEEP(PROP)
      IF(J.LT.NPRIME) THEN
        IF(JOUT.EQ.0) WRITE(1, *) J*1.E-03, SUMPROP
      ELSE
        JN=J+1-NPRIME
        SUMPROP=(SUMPROP*(JN-1)+PROP)/JN
        IF(JOUT.EQ.0) WRITE(1, *) J*1.E-03, SUMPROP
      END IF
   10 CONTINUE

      END
```

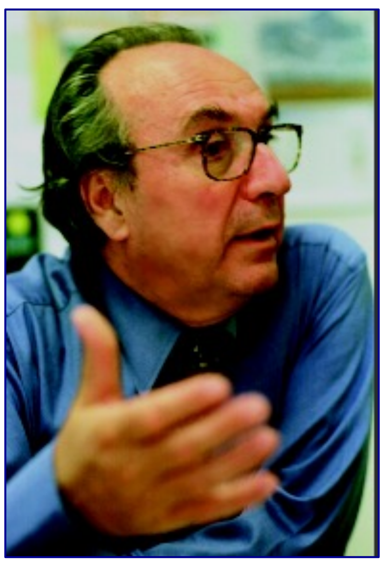


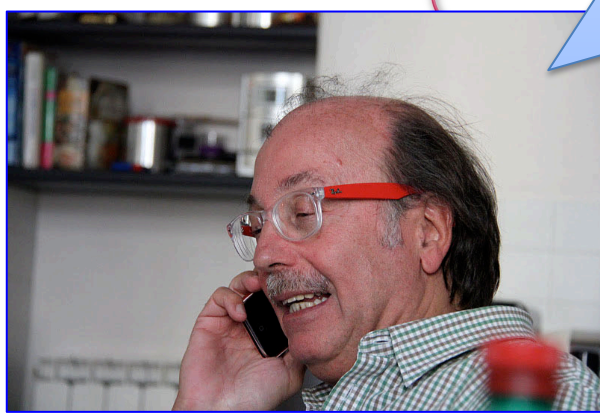


- I had already spent several months (almost 1 year!) working on the scalar theory on the lattice, when I received

a phone call by Guido at home:

I'm here together with Luciano.
We decided to change the subject of your thesis.
The new subject will be [lattice QCD]

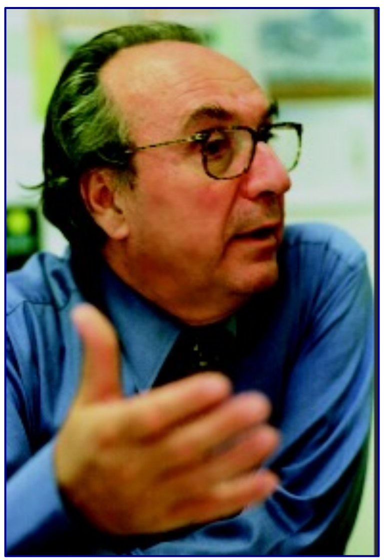


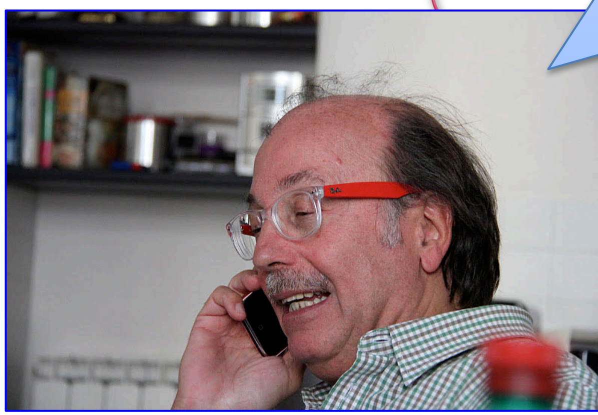


• I had already spent several months (almost 1 year!) working on the scalar theory on the lattice, when I received

a phone call by Guido at home:

I'm here together with Luciano.
We decided to change the subject of your thesis.
The new subject will be lattice QCD





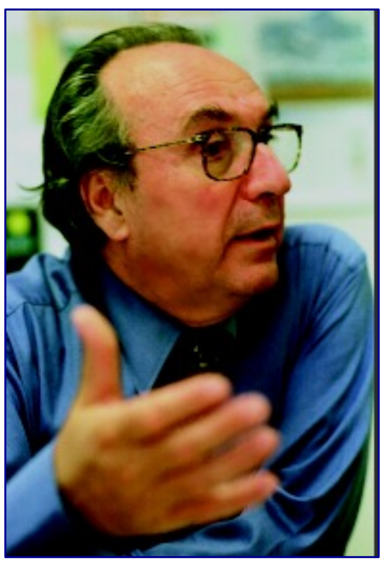
I never really knew the reason…

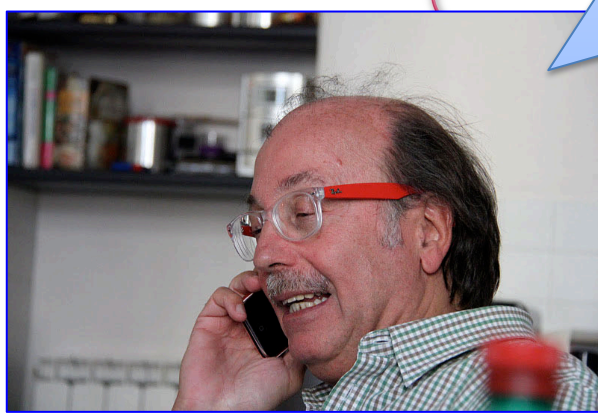
… but I almost collapsed!

• I had already spent several months (almost 1 year!) working on the scalar theory on the lattice, when I received

a phone call by Guido at home:

I'm here together with Luciano.
We decided to change the subject of your thesis.
The new subject will be lattice QCD





I never really knew the reason...

... but I almost collapsed!

Today, I suspect that the decision of changing the argument of my thesis was mainly due to Guido...

UNIVERSITÀ DEGLI STUDI DI ROMA
LA SAPIENZA

FACOLTÀ DI SCIENZE MATEMATICHE, FISICHE E NATURALI

TESI DI LAUREA IN FISICA

Decadimenti deboli semileptonici dei mesoni D e costante di decadimento del mesone B nella QCD sul reticolo

Relatore:
Prof. *Guido Martinelli*

Laureando:
Vittorio Lubicz
(matr. [illegible])

Anno Accademico 1989–1990

- The (new) thesis concerned two independent lattice QCD studies:

1) The semileptonic weak decays of D mesons

2) The B-meson decay constant fB

- Eventually my thesis supervisor was Guido. He followed this work more closely than Luciano

The B-meson leptonic decay constant fB

Talk at Cortona in 1990

Nuclear Physics B349 (1991) 598–616
North-Holland

A LATTICE COMPUTATION OF THE DECAY CONSTANT OF THE B-MESON

C.R. ALLTON and C.T. SACHRAJDA

Department of Physics, The University, Southampton SO9 5NH, UK

V. LUBICZ, L. MAIANI and G. MARTINELLI

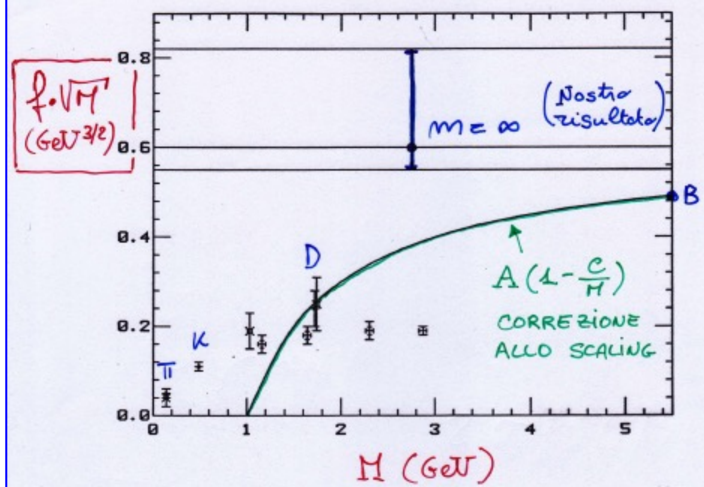
Dipartimento di Fisica, Universita di Roma, La Sapienza, I-00185 Rome, Italy,
INFN Sezione di Roma, Rome, Italy

Received 18 June 1990

We compute the decay constant of the B-meson, f_B, on a $10^2 \times 20 \times 40$ lattice at $\beta = 6.0$, with Wilson fermions, using 30 gauge field configurations, generated in the quenched approximation. For the propagator of the b-quark we keep only the leading term in the $1/m_b$ expansion. To improve our results we use, as the interpolating fields for the B-meson, lattice operators which are "smeared" over several lattice sites. We observe a clear signal for the lightest B-meson state, and obtain the value $f_B = 310 \pm 25 \pm 50$ MeV, where the first error is statistical and the second represents our uncertainty in the value of the lattice spacing. This result, combined with earlier lattice measurements of f_D ($f_D \simeq 180$ MeV), demonstrates that the asymptotic scaling law for the decay constants of heavy pseudoscalar mesons P, (i.e. $f_P\sqrt{M_P} \sim$ constant), has large corrections for charmed mesons. We estimate that the non-scaling corrections will reduce the above value of f_B by about 25%.

13

RISULTATO



- NEL LIMITE ASINTOTICO $m = \infty$:

$$f_B \sqrt{M_B} = (0.60 \pm 0.05 + 0.22)\ \mathrm{GeV}^{3/2}$$

$$\hookrightarrow \boxed{f_B = (0.26 \pm 0.02 + 0.10)\ \mathrm{GeV}}$$

- CORREZIONE AL COMPORTAMENTO DI SCALING:

da f_D: $C \simeq 1.1$ GeV

$$f \cdot \sqrt{M} = A\left(1 - \frac{C}{M}\right) \rightarrow \boxed{f_B \simeq 200\ \mathrm{MeV}}$$

↑ nostro calcolo

N.B. fB≃110 MeV using the exact scaling from fD. We know today that fB ≃190 MeV

Talk at Lattice 1990, Tallahassee

The D-meson semileptonic decays

①

D-MESON SEMILEPTONIC DECAYS ON THE LATTICE

(M. Crisafulli, V.J. Hill, V. Lubicz, G. Martinelli, M. McCarthy, C.T. Sachrajda)

1) PSEUDOSCALAR CHANNEL:

- $D \to K \ell \nu_e$
- $D \to \pi \ell \nu_e$

2) VECTOR CHANNEL:

First lattice calculation of

- $D \to K^* \ell \nu_e$
- $D \to \rho \ell \nu_e$

Good lab for $B \to \pi, \rho\, \ell \nu$ and measurement of $|V_{ub}|$

Nuclear Physics B356 (1991) 301–317
North-Holland

FIRST CALCULATION OF $D^+ \to \bar{K}^{*0} e^+ \nu_e$ IN LATTICE QCD

V. LUBICZ and G. MARTINELLI

Dipartimento di Fisica, Università di Roma, La Sapienza, I-00185 Rome, Italy, and INFN, Sezione di Roma, Rome, Italy

C.T. SACHRAJDA

Department of Physics, University of Southampton, Southampton SO9 5NH, UK

Received 30 July 1990
(Revised 13 November 1990)

When the paper was already written we became aware of a new experimental analysis of $D \to K^*$ decays made by the E691 collaboration [22]. The new experimental results give

$$A_1(0) = 0.46 \pm 0.05 \pm 0.05,$$

$$A_2(0) = 0.0 \pm 0.2 \pm 0.1,$$

$$V(0) = 0.9 \pm 0.3 \pm 0.1, \qquad (34)$$

to be confronted with the results of table 5. The agreement is extraordinary given the experimental and theoretical uncertainties. It is particularly interesting that the experimental result strongly suggests a very small value for $A_2(0)$, as also indicated by the lattice calculation and in contrast with the predictions of all the other phenomenological models.

Lattice setup:
15 gauge configurations
("the Bologna set"),
$1/a \simeq 2$ GeV, Vol= $10^3 \times 20$
duplicated in the
x- and t- directions

Talk at Lattice 1990, Tallahassee

The D-meson semileptonic decays

①

D-MESON SEMILEPTONIC DECAYS ON THE LATTICE

(M. Crisafulli, V.J. Hill, V. Lubicz, G. Martinelli, M. Mc Carthy, C.T. Sachrajda)

1) PSEUDOSCALAR CHANNEL:

- $D \to K \ell \nu_e$
- $D \to \pi \ell \nu_e$

2) VECTOR CHANNEL:

First lattice calculation of

- $D \to K^* \ell \nu_e$
- $D \to \rho \ell \nu_e$

Good lab for $B \to \pi, \rho\, \ell \nu$ and measurement of $|V_{ub}|$

Physics Letters B 274 (1992) 415–420
North-Holland

PHYSICS LETTERS B

Semi-leptonic decays of D-mesons in lattice QCD

V. Lubicz, G. Martinelli
Dipartimento di Fisica, Università di Roma, "La Sapienza", I-00185 Rome, Italy and INFN, Sezione di Roma, Rome, Italy

M.S. McCarthy and C.T. Sachrajda
Department of Physics, University of Southampton, Southampton SO9 5NH, UK

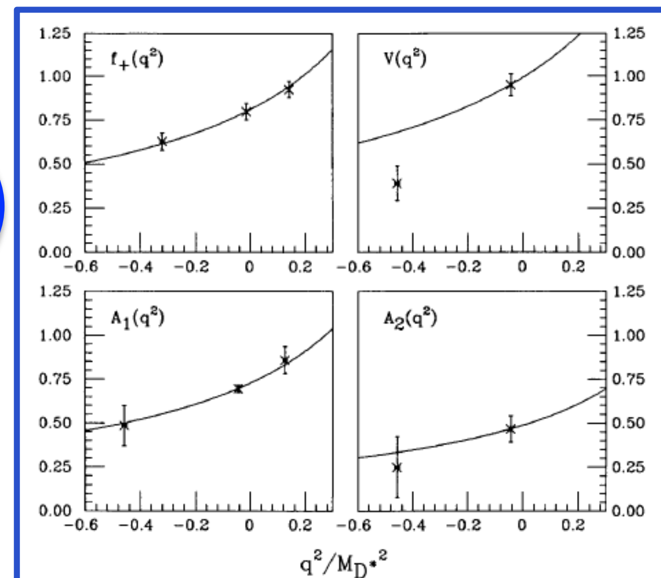
Received 21 October 1991

The results of a lattice calculation of D-meson semi-leptonic decays into pseudoscalar and vector particles are presented. With respect to our previous studies of D→K, K*, π and ρ decays we have doubled the statistics and have studied the SU(3) breaking

Lattice setup:
30 gauge configurations (Bologna + RAL),
1/a≃2 GeV,
Vol= 10^3 x 20 duplicated in the x- and t- directions

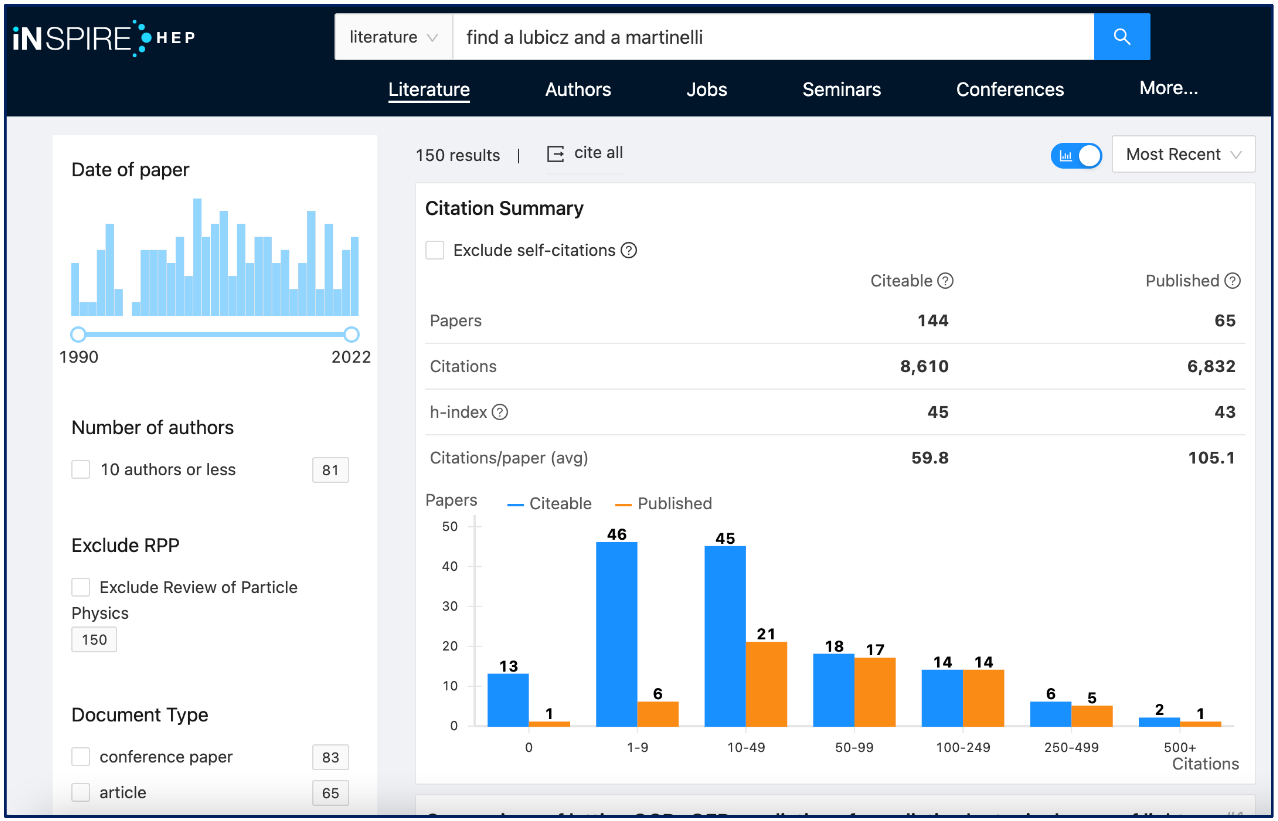
Double statistics !!

Thanks to the collaboration with Chris



Since then, a longstanding, fruitful and much enjoyable collaboration has started!

find a lubicz and a martinelli: 65 papers



- Out of my 120
- More than 100 citations/paper
- 6 papers with more than 250 citations
- 32 years of collaboration

1993: first attempt to extrapolate the semileptonic form factors from charm to b

Nuclear Physics B416 (1994) 675–695
North-Holland

NUCLEAR
PHYSICS B

Semi-leptonic decays of heavy flavours on a fine grained lattice

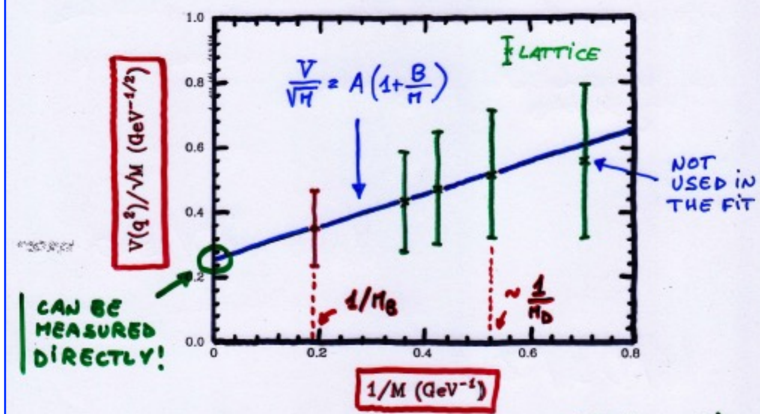
As. Abada[a], C.R. Allton[b], Ph. Boucaud[a], D.B. Carpenter[c], M. Crisafulli[b], S. Güsken[d], P. Hernandez[e], V. Lubicz[b], G. Martinelli[b,f], O. Pène[a], C.T. Sachrajda[g], K. Schilling[d], G. Siegert[d] and R. Sommer[h]

[a] *LPTHE, Orsay, France*[1]
[b] *Dipartimento di Fisica, Università di Roma, "La Sapienza", I-00185 Rome, and INFN, Sezione di Roma, Italy*
[c] *Department of Electronics and Computer Science, The University, Southampton SO9 5NH, UK*
[d] *Physics Department, University of Wuppertal, D-42097 Wuppertal, Germany*
[e] *Departamento de Física Teórica C-XI, Univ. Autónoma de Madrid, E-28049, Madrid, Spain*
[f] *Laboratoire de Physique Théorique de l'École Normale Supérieure, 24 rue Lhomond, 75231 Paris Cedex 05, France*[2]
[g] *Department of Physics, The University, Southampton SO9 5NH, UK*
[h] *Deutsches Elektronen-Synchrotron, DESY, Notkestrasse 85, D-22603 Hamburg, Germany*

Received 11 August 1993
Accepted for publication 13 September 1993

We present the results of a numerical calculation of semi-leptonic form factors relevant for heavy flavour meson decays into light mesons. The results have been obtained by studying two- and three-point correlation functions at $\beta = 6.4$ on a $24^3 \times 60$ lattice, using the Wilson action in the quenched approximation.
From the study of the matrix element $\langle K^- | J_\mu | D^0 \rangle$ we obtain $f_K^+(0) = 0.60 \pm 0.15 \pm 0.07$, where the first error is the statistical error and the second a systematic error. The latter

WE HAVE EXPLORED THE SECOND POSSIBILITY:



$(A_2/A_1 \sim M)$

	$f_+(0)$	$V(0)$	$A_1(0)$	$A_2(0)$
ELC	0.42±0.15	0.35±0.11	0.21±0.05	0.46±0.27
WSB	0.33	0.33	0.28	0.28
ISGUR ET AL.	0.09	0.27	0.05	0.02
SUM RULES (BALL)	0.26±0.02	0.6±0.2	0.5±0.1	0.4±0.2

$$\Gamma(B \to \pi e \nu) = |V_{ub}|^2 (12 \pm 8) \cdot 10^{12}\ \text{sec}^{-1}$$
$$\Gamma(B \to \rho e \nu) = |V_{ub}|^2 (13 \pm 12) \cdot 10^{12}\ \text{sec}^{-1}$$

↑ WE FIND

Talk at the 3rd Workshop on the tau-charm factory, Marbella, 1993

1994: first lattice calculation of quark masses at NLO in QCD. After that, many other lattice calculations have followed

ELSEVIER

Nuclear Physics B 431 (1994) 667–685

NUCLEAR PHYSICS B

Quark masses from lattice QCD at the next-to-leading order

C.R. Allton [a], M. Ciuchini [a,b], M. Crisafulli [a], E. Franco [a], V. Lubicz [a], G. Martinelli [a,c]

[a] *Dip. di Fisica, Università degli Studi di Roma "La Sapienza" and INFN, Sezione di Roma, P.le A. Moro 2, 00185 Rome, Italy*

[b] *INFN, Sezione Sanità, V.le Regina Elena 299, 00161 Rome, Italy*

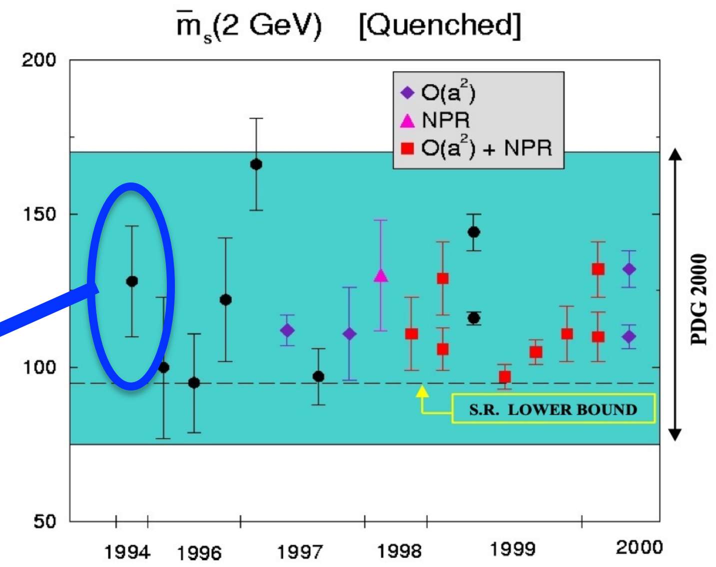
[c] *TH Division, CERN, CH-1211 Geneva 23, Switzerland*

Received 15 June 1994; accepted 21 September 1994

Abstract

Using the results of several quenched lattice simulations, we predict the value of the strange and charm quark masses in the continuum at the next-to-leading order, $m_s^{\overline{MS}}(\mu = 2\,\text{GeV}) = (128 \pm 18)$, and $m_{ch}^{\overline{MS}}(\mu = 2\,\text{GeV}) = (1.48 \pm 0.28)\,\text{GeV}$. The errors quoted above have been estimated by taking into account the original statistical error of the lattice results and the uncertainties coming from the matching of the lattice to the continuum theory. A detailed presentation of the relevant

THE STRANGE QUARK MASS



LATTICE QCD REFERENCES:

- **1994:** Allton et al. **1996:** LANL, FNAL, APE
- **1997:** SESAM, QCDSF, JLQCD, APETOV
- **1998:** APE, APE
- **1999:** JLQCD, CP-PACS, ALPHA+UKQCD, QCDSF, APE
- **2000:** RBC, CP-PACS

SUM RULES LOWER BOUND:

- Lellouch, de Rafael, Taron: m_s(2 GeV) 100 MeV (N^2LO)
- Becirevic: m_s(2 GeV) 95 MeV (N^3LO)

Plenary talk at Lattice 2000, Bangalore

1997: Next-to-leading order QCD corrections to the most general ΔF = 2 effective Hamiltonian

N·H
ELSEVIER

Nuclear Physics B 523 (1998) 501–525

Next-to-leading order QCD corrections to $\Delta F = 2$ effective hamiltonians

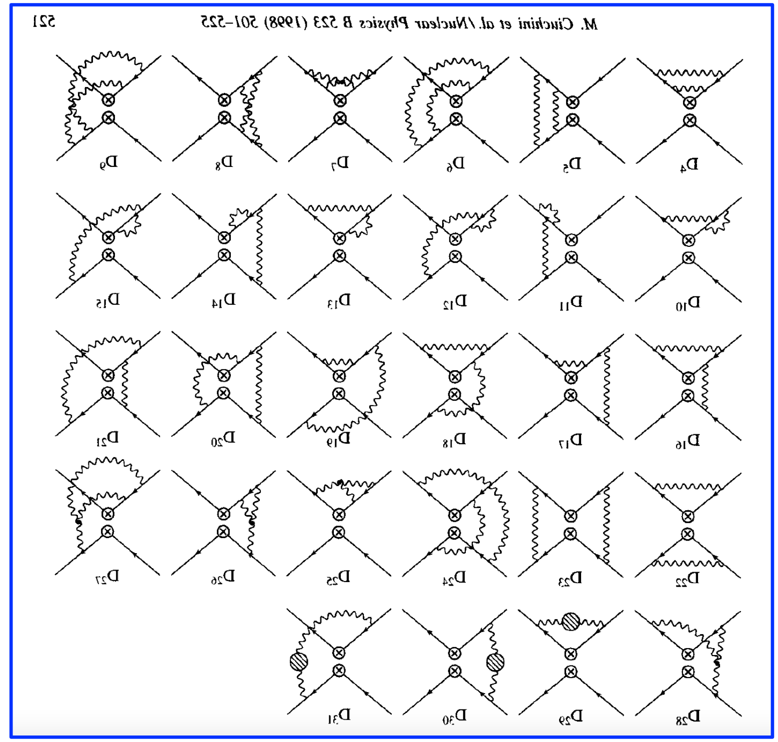
M. Ciuchini [a], E. Franco [b], V. Lubicz [c], G. Martinelli [b], I. Scimemi [b], L. Silvestrini [d]

[a] INFN, Sezione Sanità, V.le Regina Elena 299, I-00161 Rome, Italy
[b] Dip. di Fisica, Università degli Studi di Roma "La Sapienza" and INFN, Sezione di Roma, P.le A. Moro 2, I-00185 Rome, Italy
[c] Dip. di Fisica, Univ. di Roma Tre and INFN, Sezione di Roma, Via della Vasca Navale 84, I-00146 Rome, Italy
[d] Physik Department, Technische Universität München, D-85748 Garching, Germany

Received 26 November 1997; accepted 5 February 1998

Abstract

The most general QCD next-to-leading anomalous-dimension matrix of all four-fermion dimension-six $\Delta F = 2$ operators is computed. The results of this calculation can be used in many phenomenological applications, among which the most important are those related to theoretical predictions of K^0–$\bar{K}^0$ and B^0–$\bar{B}^0$ mixing in several extensions of the Standard Model (supersymmetry, left–right symmetric models, multi-Higgs models, etc.), to estimates the B_s^0–$\bar{B}_s^0$ width difference, and to the calculation of the $O(1/m_b^3)$ corrections for inclusive b-hadron decay rates.



We then applied it to SUSY

JHEP HYPER VERSION

Received: *August 14, 1998*, Accepted: *October 8, 1998*

ΔM_K and ε_K in SUSY at the Next-to-Leading order

Marco Ciuchini[1], Livio Conti[2], Andrea Donini[3], Enrico Franco[4], Vicent Gimenez[5], Leonardo Giusti[6], Vittorio Lubicz[1], Guido Martinelli[4], Antonio Masiero[7], Ignazio Scimemi[4], Luca Silvestrini[8], Mauro Talevi[9], Anastassios Vladikas[2]

2000: The starting of the UTfit Collaboration

JHEP HYPER VERSION
RECEIVED: *April 11, 2001*, ACCEPTED: *July 13, 2001*

2000 CKM-triangle analysis. A critical review with updated experimental inputs and theoretical parameters

Marco Ciuchini and Vittorio Lubicz
Università di Roma Tre and INFN, Sezione di Roma III
Via della Vasca Navale 84, I-00146 Roma, Italy
E-mail: marco.ciuchini@cern.ch, lubicz@fis.uniroma3.it

Giulio D'Agostini, Enrico Franco, Guido Martinelli
Università "La Sapienza" and Sezione INFN di Roma
Piazzale A. Moro 2, 00185 Roma, Italy
E-mail: dagostini@roma1.infn.it, enrico.franco@cern.ch, guido.martinelli@cern.ch

Fabrizio Parodi
Dipartimento di Fisica, Università di Genova and INFN
Via Dodecaneso 33, 16146 Genova, Italy
E-mail: fabrizio.parodi@cern.ch

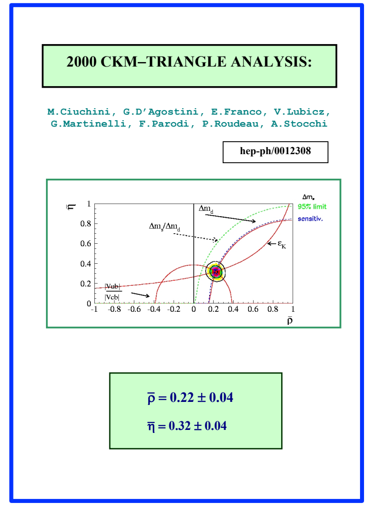
Patrick Roudeau and Achille Stocchi
Laboratoire de l'Accélérateur Linéaire IN2P3-CNRS et Université de Paris-Sud

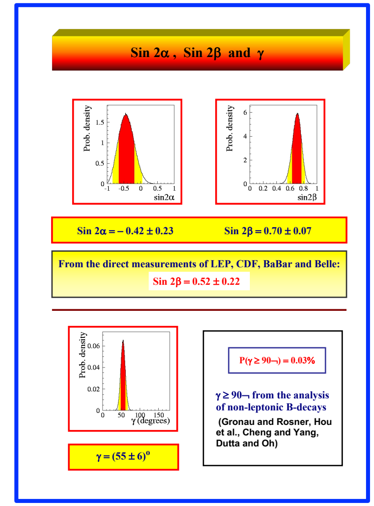
JHEP07(2001)0

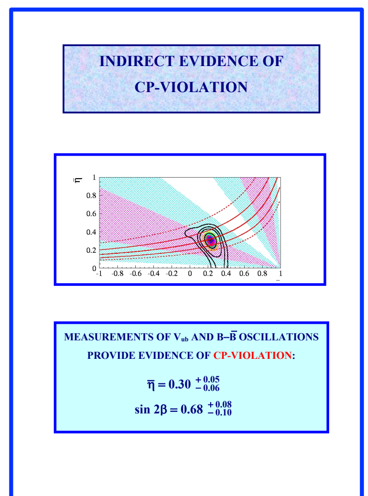
JHEP
PUBLISHED BY INSTITUTE OF PHYSICS PUBLISHING FOR SISSA
RECEIVED: *February 2, 2005*
REVISED: *May 23, 2005*
ACCEPTED: *May 24, 2005*
PUBLISHED: *July 12, 2005*

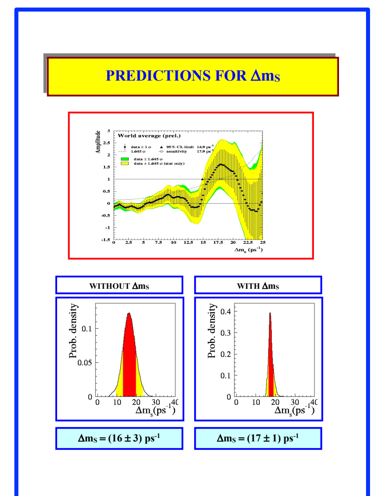
The 2004 UTfit collaboration report on the status of the unitarity triangle in the standard model

Marcella Bona[a], Marco Ciuchini[b], Enrico Franco[c], Vittorio Lubicz[b], Guido Martinelli[c], Fabrizio Parodi[d], Maurizio Pierini[e], Patrick Roudeau[e], Carlo Schiavi[d], Luca Silvestrini[c] and Achille Stocchi[e]



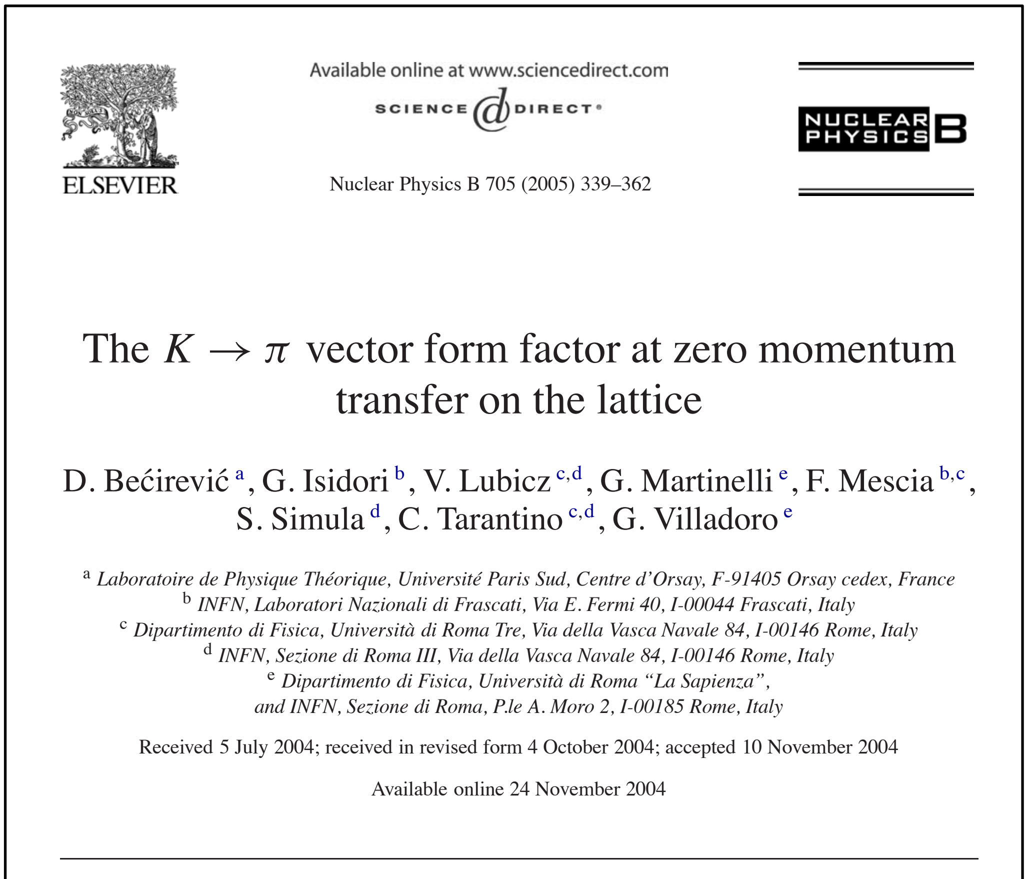






Talk at Tor Vergata, 08/01/2001

2004: first lattice calculation of the K→π vector form factor with the required O(1%) accuracy



Available online at www.sciencedirect.com

SCIENCE DIRECT®

ELSEVIER

NUCLEAR PHYSICS B

Nuclear Physics B 705 (2005) 339–362

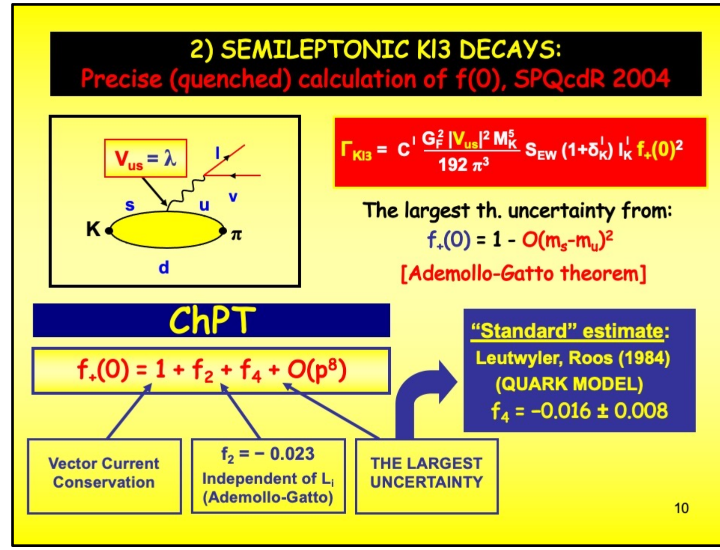
The $K \to \pi$ vector form factor at zero momentum transfer on the lattice

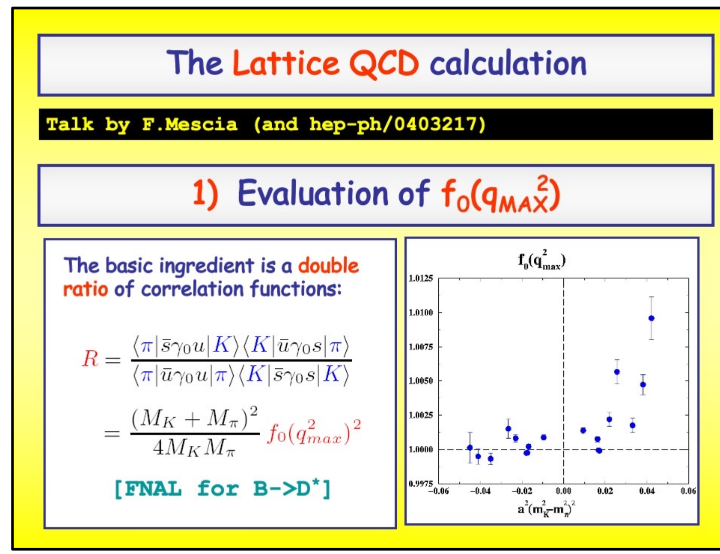
D. Bećirević [a], G. Isidori [b], V. Lubicz [c,d], G. Martinelli [e], F. Mescia [b,c], S. Simula [d], C. Tarantino [c,d], G. Villadoro [e]

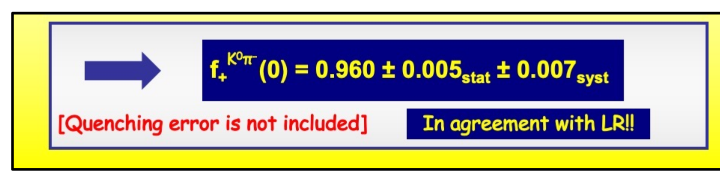
[a] *Laboratoire de Physique Théorique, Université Paris Sud, Centre d'Orsay, F-91405 Orsay cedex, France*
[b] *INFN, Laboratori Nazionali di Frascati, Via E. Fermi 40, I-00044 Frascati, Italy*
[c] *Dipartimento di Fisica, Università di Roma Tre, Via della Vasca Navale 84, I-00146 Rome, Italy*
[d] *INFN, Sezione di Roma III, Via della Vasca Navale 84, I-00146 Rome, Italy*
[e] *Dipartimento di Fisica, Università di Roma "La Sapienza", and INFN, Sezione di Roma, P.le A. Moro 2, I-00185 Rome, Italy*

Received 5 July 2004; received in revised form 4 October 2004; accepted 10 November 2004

Available online 24 November 2004







Plenary talk at Lattice 2004, Fermilab

2011-2013: lattice calculation of isospin breaking effects

PUBLISHED FOR SISSA BY SPRINGER
RECEIVED: *November 7, 2011*
REVISED: *March 16, 2012*
ACCEPTED: *April 2, 2012*
PUBLISHED: *April 26, 2012*

2011

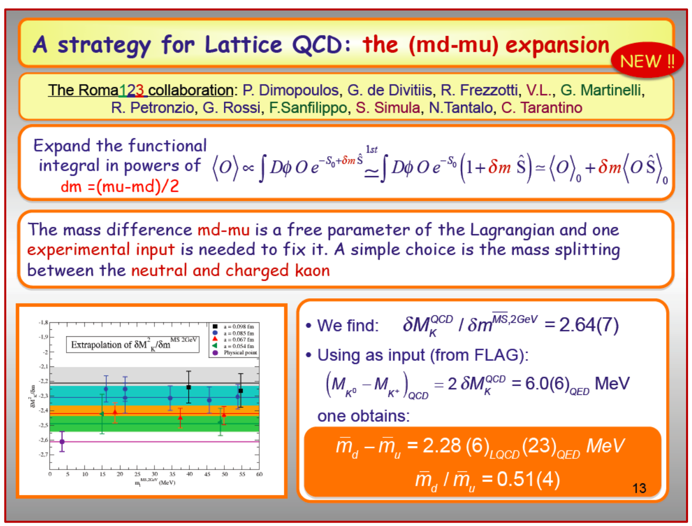
Isospin breaking effects due to the up-down mass difference in lattice QCD

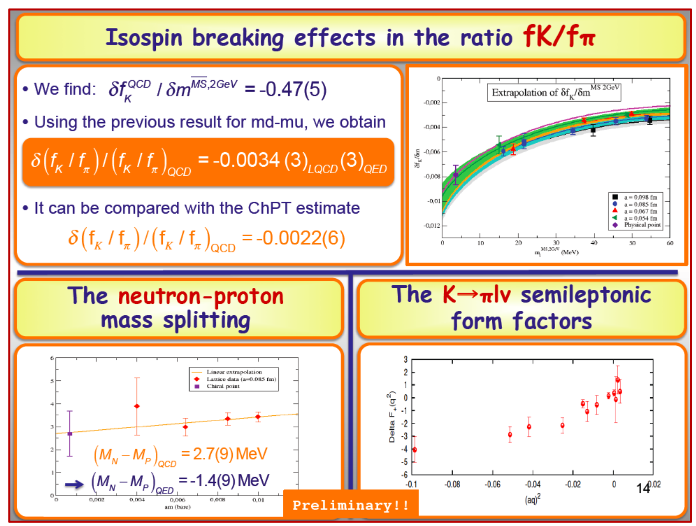
RM123 collaboration

G.M. de Divitiis,[a,b] P. Dimopoulos,[c,d] R. Frezzotti,[a,b] V. Lubicz,[e,f] G. Martinelli,[g,d] R. Petronzio,[a,b] G.C. Rossi,[a,b] F. Sanfilippo,[c,d] S. Simula,[f] N. Tantalo[a,b] and C. Tarantino[e,f]

JHEP

Strong (md-mu) isospin breaking effects





Plenary talk at Lepton Photon 2011, Mumbai

2011-2013: lattice calculation of isospin breaking effects

2013

PHYSICAL REVIEW D **87,** 114505 (2013)

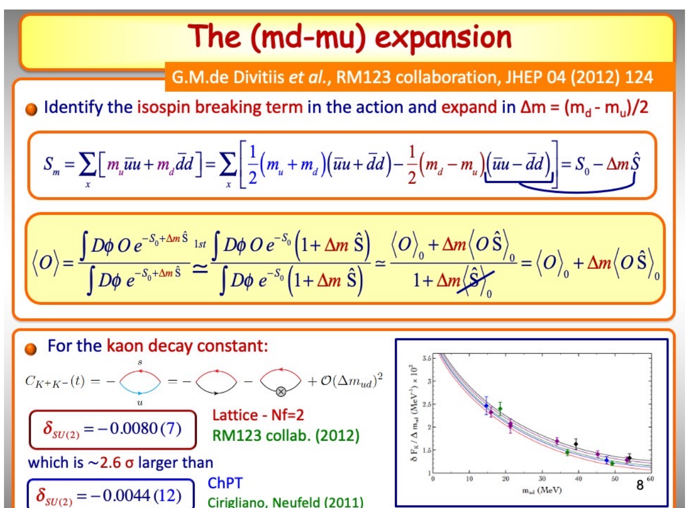
Leading isospin breaking effects on the lattice

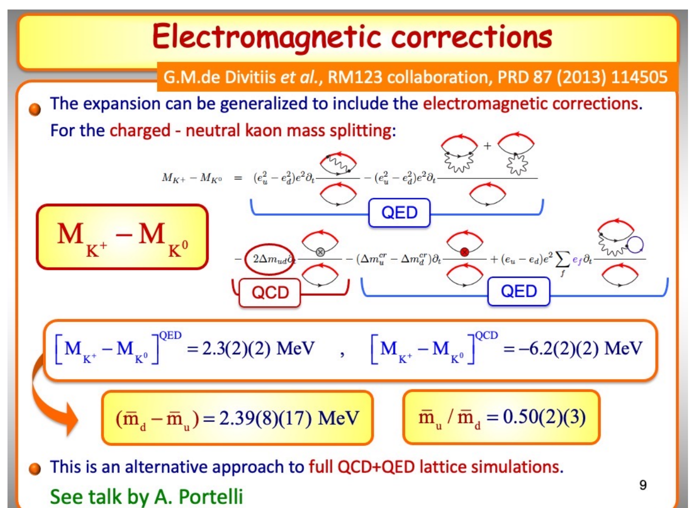
G. M. de Divitiis,[1,2] R. Frezzotti,[1,2] V. Lubicz,[3,4] G. Martinelli,[5,6] R. Petronzio,[1,2] G. C. Rossi,[1,2] F. Sanfilippo,[7] S. Simula,[4] and N. Tantalo[1,2]

(RM123 Collaboration)

[1]*Dipartimento di Fisica, Università di Roma "Tor Vergata", Via della Ricerca Scientifica 1, I-00133 Rome, Italy*
[2]*INFN, Sezione di Roma "Tor Vergata", Via della Ricerca Scientifica 1, I-00133 Rome, Italy*
[3]*Dipartimento di Matematica e Fisica, Università Roma Tre, Via della Vasca Navale 84, I-00146 Rome, Italy*
[4]*INFN, Sezione di Roma Tre, Via della Vasca Navale 84, I-00146 Rome, Italy*
[5]*SISSA, Via Bonomea 265, 34136 Trieste, Italy*
[6]*INFN, Sezione di Roma, Piazzale Aldo Moro 5, I-00185 Rome, Italy*
[7]*Laboratoire de Physique Théorique (Bâtiment 210), Université Paris Sud, F-91405 Orasay-Cedex, France*
(Received 3 April 2013; published 7 June 2013)

Strong (md-mu) + electromagnetic (α_{em}) isospin breaking effects





Plenary talk at Chiral Dynamics 2015, Pisa

2015: QED corrections to hadronic processes

PHYSICAL REVIEW D **91,** 074506 (2015)

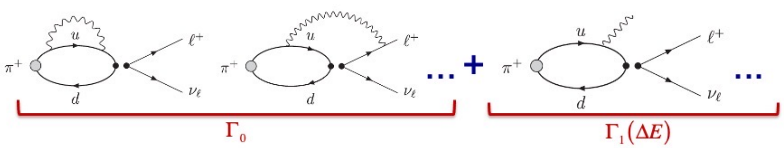
QED corrections to hadronic processes in lattice QCD

N. Carrasco,[1] V. Lubicz,[1] G. Martinelli,[2] C. T. Sachrajda,[3] N. Tantalo,[4,5] C. Tarantino,[1] and M. Testa[6]

[1]*Dipartimento di Fisica, Università Roma Tre and INFN, Sezione di Roma Tre, Via della Vasca Navale 84, I-00146 Rome, Italy*

The strategy

- At O(α), the rate Γ_0 contains infrared divergences. One has to consider:



$$\Gamma(\Delta E) = \Gamma(\pi^+ \to \ell^+ \nu_\ell) + \Gamma(\pi^+ \to \ell^+ \nu_\ell \gamma(\Delta E)) \equiv \Gamma_0 + \Gamma_1(\Delta E)$$

with $0 \le E_\gamma \le \Delta E$. The sum is infrared finite — F. Bloch and A. Nordsieck, PR 52 (1937) 54

- In principle, both Γ_0 and $\Gamma_1(\Delta E)$ can be evaluated in lattice simulations.

But $\Gamma_1(\Delta E)$ is very challenging, due to discretized photon momenta: the integral up to ΔE replaced by a finite sum, many correlation functions…

We thus propose a different strategy ➡

12

The strategy

$$\Gamma(\Delta E) = \lim_{V\to\infty}\left(\Gamma_0 - \Gamma_0^{pt}\right) + \lim_{V\to\infty}\left(\Gamma_0^{pt} + \Gamma_1^{pt}(\Delta E)\right)$$

- The second term is calculated in perturbation theory directly in infinite volume. The sum $\Gamma_0^{pt} + \Gamma_1^{pt}(\Delta E)$ is IR finite.
- $\Gamma_0 - \Gamma_0^{pt}$ in the first term is calculated, in the intermediate step, in the finite volume. The contributions from small virtual photon momenta to Γ_0 and Γ_0^{pt} are the same, and the first term is IR finite.
- ➡ IR divergences cancel separately in each of the two terms, and so we can calculate each of these terms separately. We also use different IR regulators: the finite volume for the first term and a photon mass for the second term.
- The two terms are also separately gauge invariant.

16

Plenary talk at Chiral Dynamics 2015, Pisa

But, you should also know,

my scientific life with Guido has not been all sunshine and roses

(in Italian: “non tutta rose e fiori”)

But, you should also know,

my scientific life with Guido has not been all sunshine and roses

Ahhhh, Vittorio !!!
The colors of your
slides are awful !!

Look at this composition, and, please,… LEARN !!

the “present” I got from Guido

I learned a lot from Guido, not only physics (and colors)

We know each other since more than 30 years and, for me, Guido is mainly a

friend

Happy birthday !!