The scientific legacy of Nicola Cabibbo

AST
Ateneo della Scienza e della Tecnologia

DIPARTIMENTO DI FISICA

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UNIVERSITÀ DEGLI STUDI DI ROMA LA SAPIENZA

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UTfit

INFN
Istituto Nazionale di Fisica Nucleare

Nicola Cabibbo

1) Let me thanks the organizers for the great honour - and responsability - of commemorating our dear colleague and friend Nicola Cabibbo at CKM 2010
2) I apologize in advance for possible mistakes, typos and inaccuracy due to the lack of time (this is indeed a very busy period for me and I was travelling all the time during the preparation of this talk)

Nicola Cabibbo

He was the "father of flavor physics" and will be missed. Of course like all great physicists he will live on through the important contributions he has made to our understanding of nature

M. Wise on behalf of the Caltech High Energy Physics

Fermi Constant

Dirac Equation

Goldstone boson

Cabibbo Angle

Cabibbo-Kobayashi-Maskawa mixing matrix

CKM 2006 Nagoya

Nicola Cabibbo, Makoto Kobayashi and (but for one) young italian physicists

Cecilia Tarantino, Nicola Cabibbo, G. M., Vittorio Lubicz

A few biographical notes on the beginning of an extraordinary mind (many info taken from Nicola facebook)

The son of a sicilian lawyer, Nicola Cabibbo, born in Roma, Italy, on April 10 1935, lived his childwood during the second world war. During these difficult years, Nicola discovered astronomy and developed a strong interest in the construction of radio devices. This was the starting point of a life-long interest and an extraordinary skillness in the realization of hardware, including the mirror of a telescope and a home made personal computer - the first of a series - at the beginning of the `80.

These passions and a book entitled ``Che cos’e` la matematica” pushed him to follow scientific studies. After the war, he also developed a passion for american literature, passion shared by his wife who is presently professor of american literature at the University La Sapienza.

Another great passion was the sea and sailing: at the end of the `70 (beginning of the `80 !?) he constructed a sailing boat by himself (indeed he bought the boat ``shell” and made the rest).

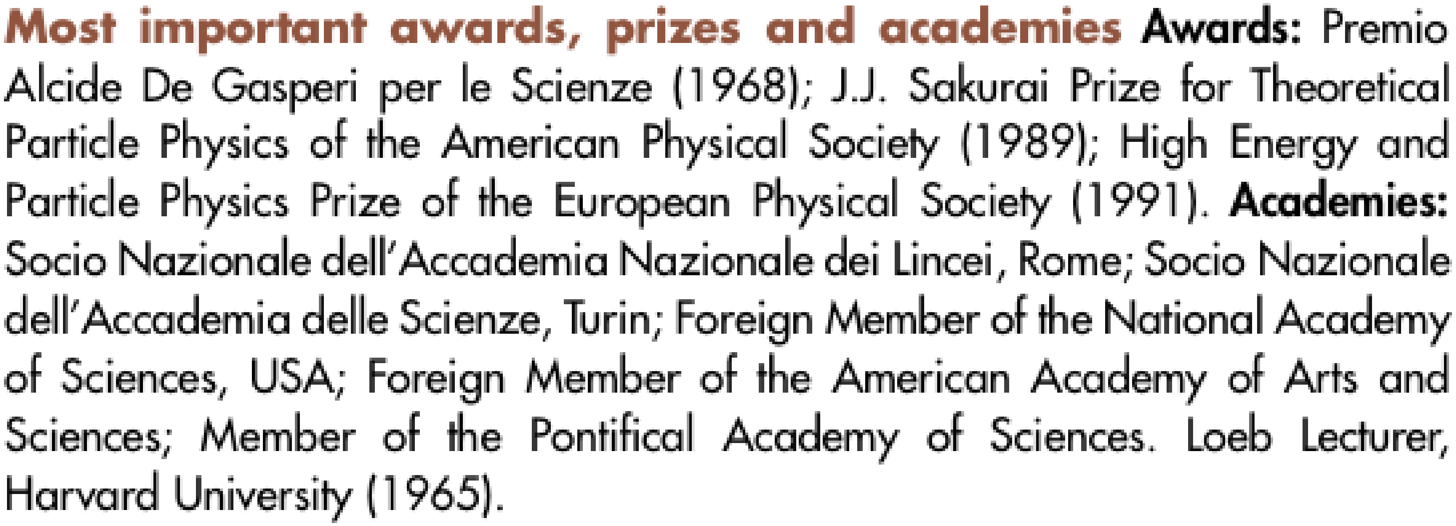
A few biographical notes on the beginning of an extraordinary mind (many info taken from Nicola facebook)

He graduated in theoretical physics at Universita’ di Roma “La Sapienza” , with a thesis on weak interactions and muon decays, under the supervision of Bruno Touschek, whom he always considered his mentor. He was immediately tenured and in 1960 moved to Frascati, where at the beginning of the sixties, Touschek and collaborators were building the first electron-positron collider.

With Raoul Gatto, the young Cabibbo wrote an exploratory paper on the physics that could be studied with e+ e- interactions, a paper that soon became a standard reference in the field. His collegues were used to call this paper ``the Bible” since it contained the calculation of all the cross sections for processes then envisageable.

A few relevant steps of Nicola Biography and Scientific Career

1. 1960-1962 LNF of INFN Frascati
2. 1962-1965 CERN, Lawrence Radiation Laboratory Berkeley and Harvard
3. 1965 Full Professor at L'Aquila, 1966 in Rome La Sapienza (from 84 for about 10 ys at Tor Vergata)
4. In the \`70s & \`80s Institute for Advanced Study Princeton, Paris, New York, Syracuse, CERN
5. 1985-1993 INFN President
6. 1993-1998 ENEA President
7. Member of the Accademia Nazionale dei Lincei, National Academy of Science of United States of America
8. President of the Pontifical Academy of Sciences



Most important awards, prizes and academies **Awards:** Premio Alcide De Gasperi per le Scienze (1968); J.J. Sakurai Prize for Theoretical Particle Physics of the American Physical Society (1989); High Energy and Particle Physics Prize of the European Physical Society (1991). **Academies:** Socio Nazionale dell'Accademia Nazionale dei Lincei, Rome; Socio Nazionale dell'Accademia delle Scienze, Turin; Foreign Member of the National Academy of Sciences, USA; Foreign Member of the American Academy of Arts and Sciences; Member of the Pontifical Academy of Sciences. Loeb Lecturer, Harvard University (1965).

Dirac Medal of the ICTP, 2010

Aggiungerei un piccolo dettaglio personale: quando decisi di fare fisica, mio padre me lo sconsigli□, mi disse: Ņma se fai fisica cosa potrai fare nella vita? forse potresti insegnare a scuola, ma ti piace l'idea?Ó,ed effettivamente quando cominciai le prospettive non erano brillanti, ma poi si aprirono, negli anni Sessanta ci fu unÕenorme apertura verso la scienza, e in particolare verso la fisica, che poi si ¸ spenta col Õ68; il Õ68 ¸ stato un poÕun tornante negativo, che andrebbe analizzato meglio.

N. Cabibbo, public debate with Odifreddi
Science Festival 2009

Ouverture

Venti Anni (*2) Dopo

Nicola Cabibbo

Ouverture

Twenty Years (* 2) After

Nicola Cabibbo

Original trasparencies by Cabibbo (2003)
translated by G.M.

Universality of Weak Interactions

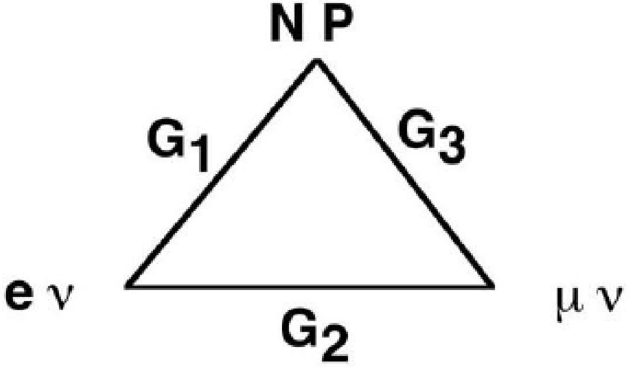
1 - $N \to P + e + \bar{\nu}$ $\quad G_1$

2 - $\mu \to e + \nu + \bar{\nu}$ $\quad G_2$

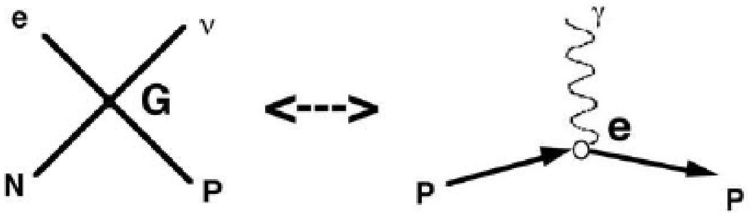
3 - $\mu^- + P \to N + \nu$ $\quad G_3$

In ~ 1950 $\quad G_1 \approx G_2 \approx G_3$

The Puppi Triangle



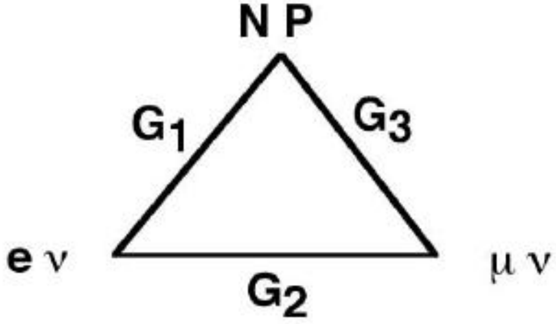
Suggestive in view of Fermi's idea:



Universality of Weak Interactions 1962-63

$G_1 \approx G_2 \approx G_3$

Suggestive, but true?



$G_{\text{beta decay}} \approx 0.96\ G_{\mu\ \text{decay}}$

(Significative Difference)

$4 - \Lambda \to P + e + \overline{\nu}$ G_4

And for strange particle decays....

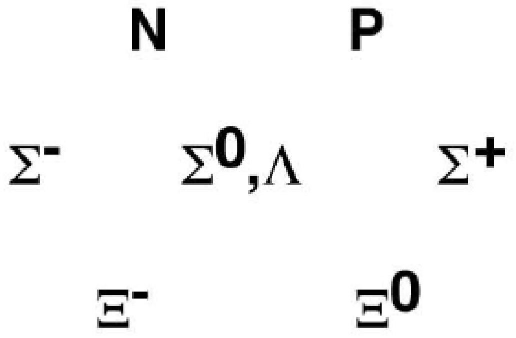
$G_4 \approx 0.2\ G_{m\ \text{decay}}$

Universality of Weak Interactions 1962-63

Towards a solution:

1) Gell-Mann's SU(3) symmetry and its application to weak transitions.
(N.C. + R. Gatto 1962)

2) High statistics (for that time) bubble chamber experiments.
(V. Soergel, Filthut, P. Franzini, G. Snow, etc.)



$N \quad P$

$\Sigma^- \quad \Sigma^0, \Lambda \quad \Sigma^+$

$\Xi^- \quad \Xi^0$

Universality and weak mixing

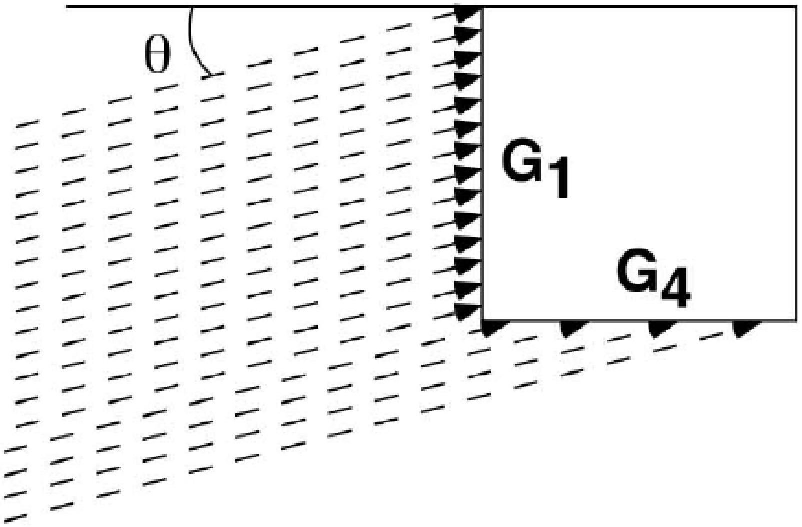
$N \rightarrow P + e^- + \nu$ $G_1 \approx 0.96\ G_{\mu\text{-decay}}$

$\Lambda \rightarrow P + e^- + \nu$ $G_4 \approx 0.2\ G_{\mu\text{-decay}}$

Broken Universality?
no, shared intensity

$G_1 = \cos\theta\ G_{\mu\text{-decay}}$

$G_4 = \sin\theta\ G_{\mu\text{-decay}}$



$\theta \approx$ **0.2 (today 0.221)**

The Weak Current

According to the proposal of the 1963 (by Cabibbo) the weak current belongs to an octect of currents, J^i_α

$$J_\alpha = cos\theta_c(J^1_\alpha + iJ^2_\alpha) = sin\theta_c(J^4_\alpha + iJ^5_\alpha)$$

which in terms of the quarks, proposed in 1964 by Gell-Mann and Zweig, are written as

$$J_\alpha = cos\theta_c(\bar{u}\gamma_\alpha(1-\gamma_5)d) = sin\theta_c(\bar{u}\gamma_\alpha(1-\gamma_5)s)$$

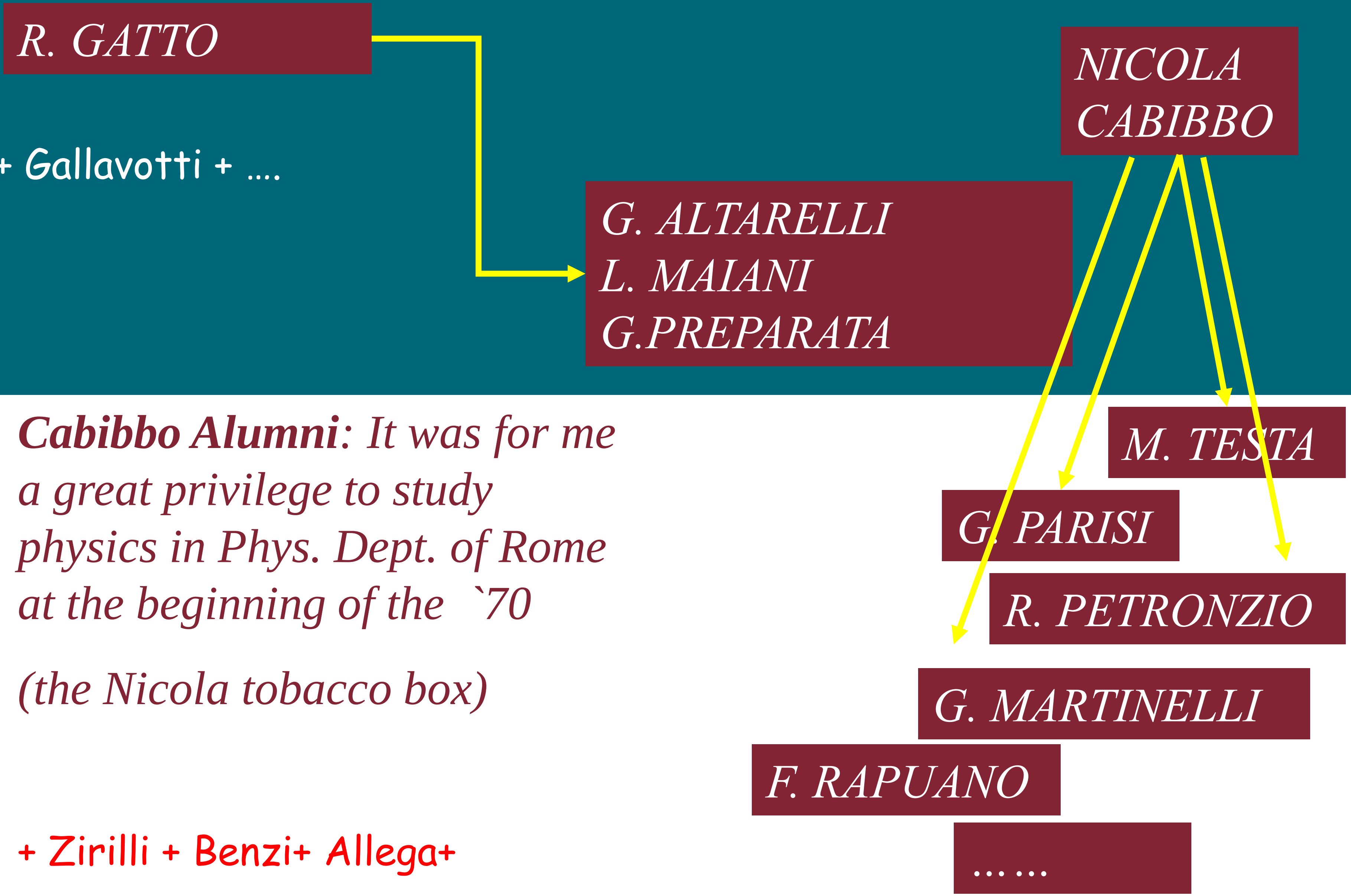
It is then possible to obtain relations between strangeness conserving and strangeness violating processes.

The vectorial part of the weak current belongs to the same octect of the electromagnetic current. Its matrix elements between mesons and baryons are uniquely determined. This, obviously, if we neglect the mass difference between the strange and down quark, in the limit of exact $SU(3)$.

Nicola found the solution to the puzzle of strange particle weak decays while in CERN, Geneva. He formulated what came to be known as “Cabibbo universality”, in terms of the partially conserved currents associated to the Unitary Symmetry, SU3, recently discovered by Gell-Mann and by Yuval Ne’eman, and of the axial currents associated with the chiral extension, SU3xSU3. He assumed that strangeness changing and non-changing beta decays had to be described by a single hadron weak current, the orthogonal combination of the corresponding SU3xSU3 currents, determined by a single unknown parameter, the Cabibbo angle. With a value of $\sin\theta \approx 0.22$ and the use of unitary symmetry, Cabibbo could describe the beta decays of strange mesons and baryons as well as explain the small discrepancy of the neutron and muon Fermi constants, the former being about 2.5% smaller than the latter. The discrepancy had been noticed already by Feynman and was being just confirmed by an accurate experiment performed by Valentino Telegdi in Chicago. Cabibbo’s universality consists in the fact that the weak hadron current he assumed obeys the same commutation relations as the electron or muon weak currents, which is the appropriate way to say that they have “equal strength”. Later, Cabibbo reformulated the same concept in the quark model, as the fact that the weak interaction couples the “up” quark to an orthogonal combination of the “down” and “strange” quarks determined by the angle θ previously introduced

L. Maiani Nature 2010

The Particle Theory Group in the `70s



R. GATTO

+ Gallavotti + ….

G. ALTARELLI
L. MAIANI
G.PREPARATA

NICOLA CABIBBO

M. TESTA
G. PARISI
R. PETRONZIO
G. MARTINELLI
F. RAPUANO
… …

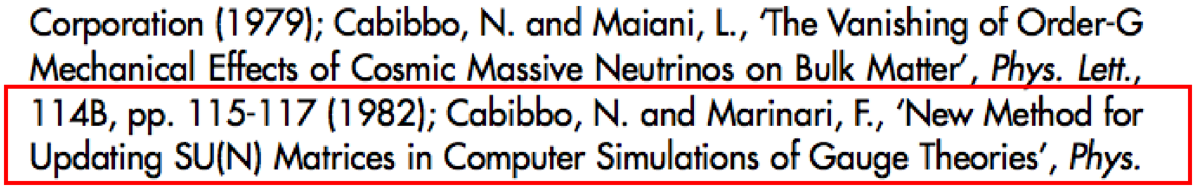
***Cabibbo Alumni**: It was for me a great privilege to study physics in Phys. Dept. of Rome at the beginning of the `70*

(the Nicola tobacco box)

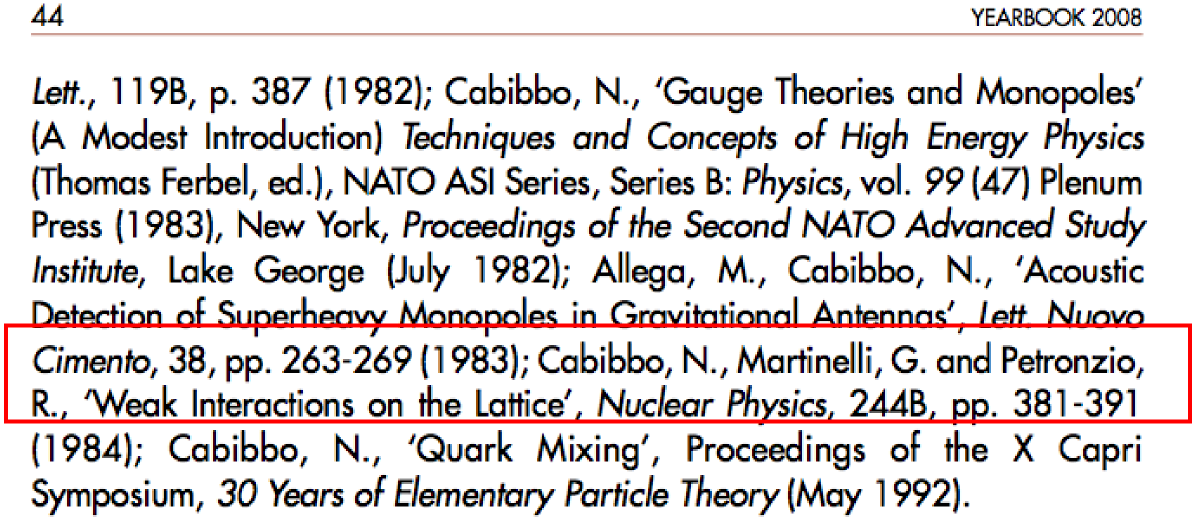
+ Zirilli + Benzi+ Allega+ ….

Nicola Cabibbo

Main publications Cabibbo, N., Gatto, R., 'Electron-Positron Colliding Beam Experiments', *Physical Review*, 124, p. 1577 (1961); Cabibbo, N., 'Measurement of the Linear Polarization of g Rays by the Elastic Photoproduction of p 0 on He 4', *Physical Review*, 124, p. 1577 (1961); Cabibbo, N. and Gatto, R., 'Proton-Antiproton Annihilation into Electrons, Muons and Vector Bosons', *Il Nuovo Cimento*, 24, pp. 170-180 (1962); Cabibbo, N., 'Unitary Symmetry and Leptonic Decays', *Phys. Rev. Lett.*, 10, pp. 531-533 (1963); Cabibbo, N. and Maksymowicz, A., 'Determination of the Form Factors in $K\mu_3$ Decays', *Phys. Lett.*, 9, pp. 352-353 (1964); Cabibbo, N., 'Unitary Symmetry and Nonleptonic Decays', *Phys. Rev. Lett.*, 12, pp. 62-63 (1964); Cabibbo, N. and Radicati, L.A., 'Sum Rule for the Isovector Magnetic Moment of the Nucleon', *Phys. Lett.*, 19, pp. 697-699 (1966); Cabibbo, N., Parisi, G. and Testa, M., 'Hadron Production in $e^+ e^-$ Collisions', *Lettere al Nuovo Cimento*, 4, pp. 35-39 (1970); Altarelli, G., Cabibbo, N. and Maiani, L., 'The Drell-Hearn Sum Rule and the lepton Magnetic Moment in the Weinberg Model of Weak and Electromagnetic Interactions', *Phys. Lett.*, 40B, pp. 415-419 (1972); Bahcall, J.N., Cabibbo, N. and Yahil, A., 'Are Neutrinos Stable Particles?', *Phys. Rev. Lett.*, 28, pp. 316-318 (1972); Cabibbo, N. and Parisi, G., 'Exponential Hadronic Spectrum and Quark Liberation', *Phys. Lett.*, 59B, pp. 67-69 (1975); Cabibbo, N., 'Bag Models', *Proceedings of the International Neutrino Conference*, Aachen (1976); Cabibbo, N., 'Time Reversal Violation in Neutrino Oscillation', *Phys. Lett.*, 72B, pp. 333-335 (1978); Cabibbo, N., 'The Impact of Gauge Theory on Elementary Particle Physics', *Proceedings of the Thirteenth 'Gauge Theories Leptons' Rencontre de Moriond*, Vol. II, (J. Tran Thanh Van, ed.)(1978); Cabibbo, N., 'Parton Distributions and their Q2 Dependence', *The Whys of Subnuclear Physics*, Plenum Publishing



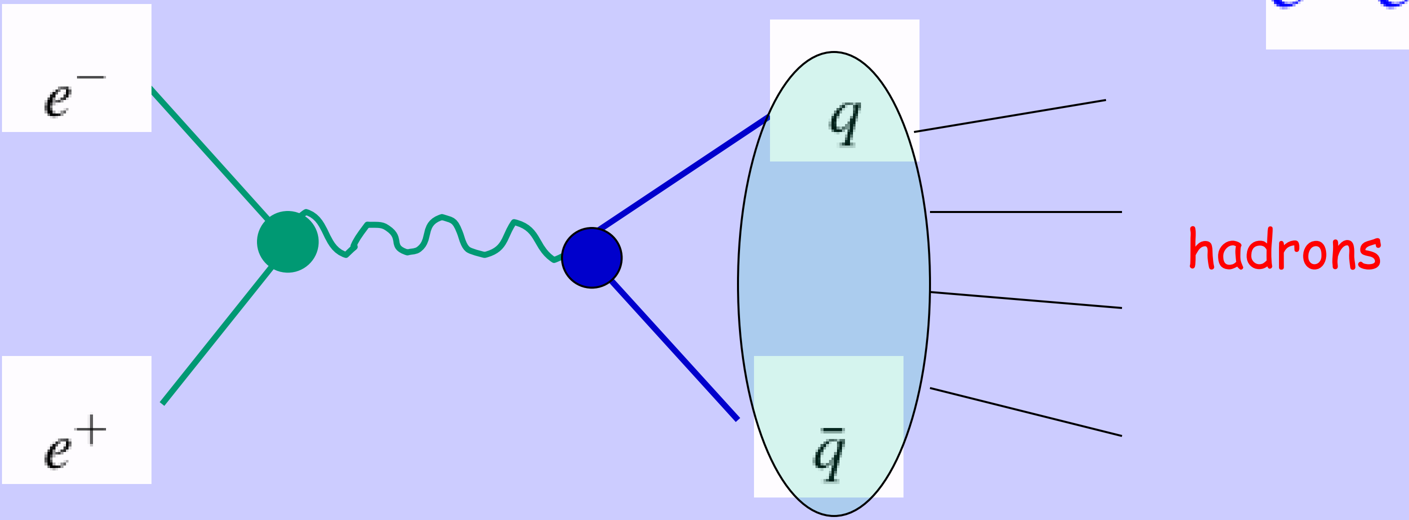
Corporation (1979); Cabibbo, N. and Maiani, L., 'The Vanishing of Order-G Mechanical Effects of Cosmic Massive Neutrinos on Bulk Matter', *Phys. Lett.*, 114B, pp. 115-117 (1982); Cabibbo, N. and Marinari, F., 'New Method for Updating SU(N) Matrices in Computer Simulations of Gauge Theories', *Phys.*



Lett., 119B, p. 387 (1982); Cabibbo, N., 'Gauge Theories and Monopoles' (A Modest Introduction) *Techniques and Concepts of High Energy Physics* (Thomas Ferbel, ed.), NATO ASI Series, Series B: *Physics*, vol. *99* (47) Plenum Press (1983), New York, *Proceedings of the Second NATO Advanced Study Institute*, Lake George (July 1982); Allega, M., Cabibbo, N., 'Acoustic Detection of Superheavy Monopoles in Gravitational Antennas', *Lett. Nuovo Cimento*, 38, pp. 263-269 (1983); Cabibbo, N., Martinelli, G. and Petronzio, R., 'Weak Interactions on the Lattice', *Nuclear Physics*, 244B, pp. 381-391 (1984); Cabibbo, N., 'Quark Mixing', Proceedings of the X Capri Symposium, *30 Years of Elementary Particle Theory* (May 1992).

$R_{e+e-}(S)$

$$e^+ e^- \rightarrow \bar{q} q$$

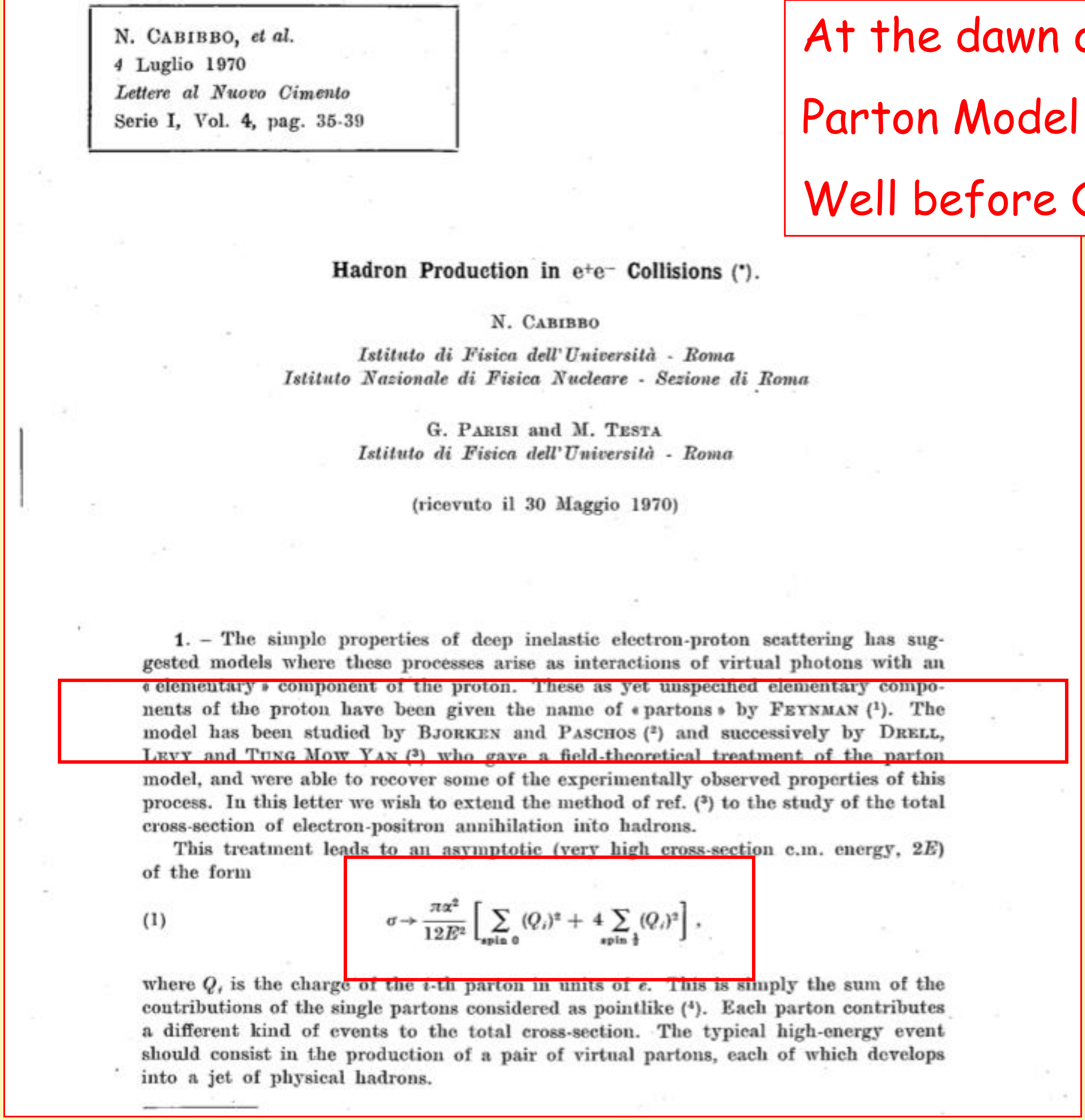


$$R_{e^+e^-}(S) = \frac{\sigma(e^+e^- \rightarrow hadrons)}{\sigma(e^+e^- \rightarrow \mu^+\mu^-)}$$

At the dawn of the

Parton Model

Well before QCD



N. Cabibbo, *et al.*
4 Luglio 1970
Lettere al Nuovo Cimento
Serie I, Vol. 4, pag. 35-39

Hadron Production in e⁺e⁻ Collisions (*).

N. Cabibbo

Istituto di Fisica dell'Università - Roma
Istituto Nazionale di Fisica Nucleare - Sezione di Roma

G. Parisi and M. Testa
Istituto di Fisica dell'Università - Roma

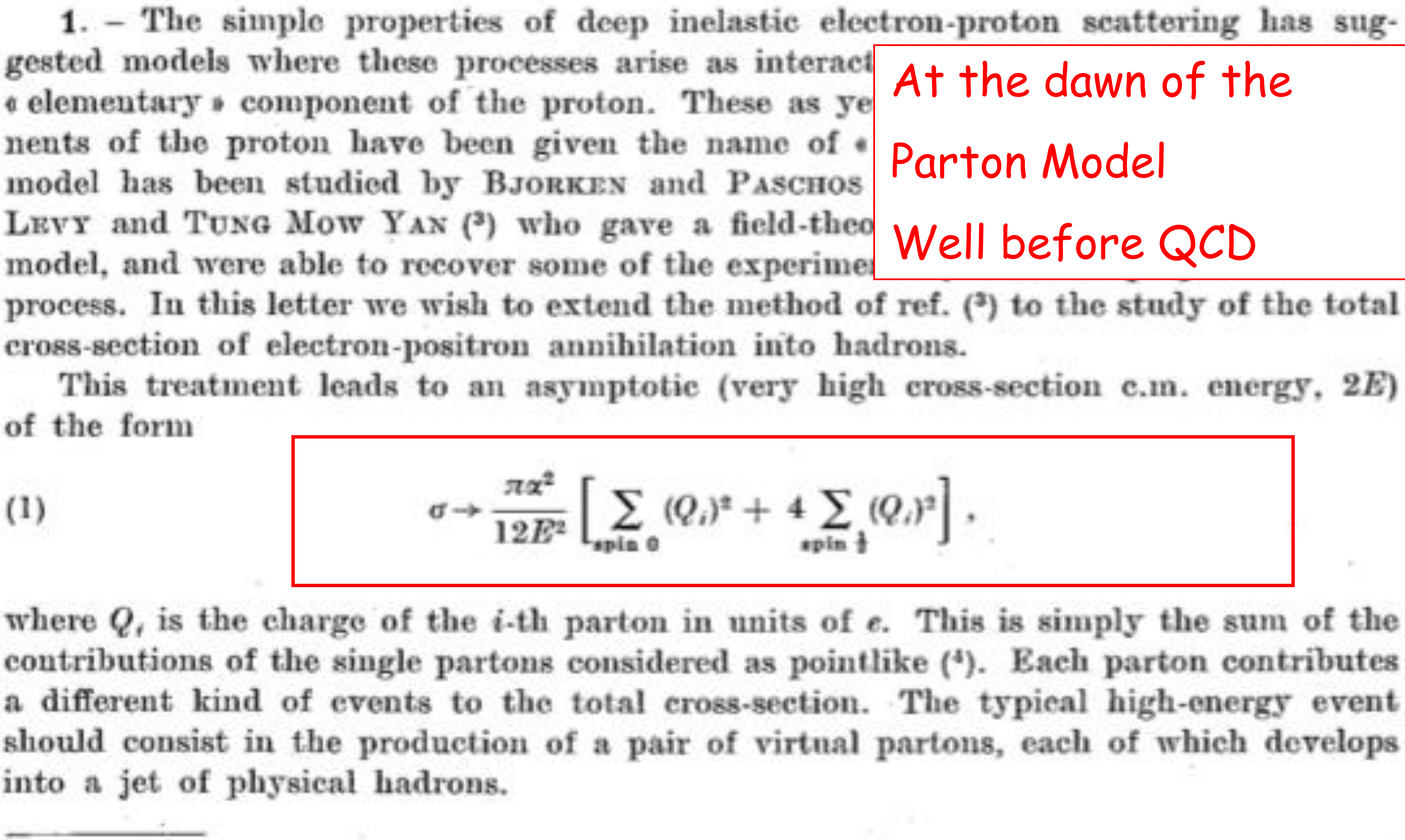
(ricevuto il 30 Maggio 1970)

1. – The simple properties of deep inelastic electron-proton scattering has suggested models where these processes arise as interactions of virtual photons with an « elementary » component of the proton. These as yet unspecified elementary components of the proton have been given the name of « partons » by Feynman (1). The model has been studied by Bjorken and Paschos (2) and successively by Drell, Levy and Tung Mow Yan (3) who gave a field-theoretical treatment of the parton model, and were able to recover some of the experimentally observed properties of this process. In this letter we wish to extend the method of ref. (3) to the study of the total cross-section of electron-positron annihilation into hadrons.

This treatment leads to an asymptotic (very high cross-section c.m. energy, $2E$) of the form

$$\sigma \to \frac{\pi\alpha^2}{12E^2}\left[\sum_{\text{spin }0}(Q_i)^2 + 4\sum_{\text{spin }\frac{1}{2}}(Q_i)^2\right]. \tag{1}$$

where Q_i is the charge of the i-th parton in units of e. This is simply the sum of the contributions of the single partons considered as pointlike (4). Each parton contributes a different kind of events to the total cross-section. The typical high-energy event should consist in the production of a pair of virtual partons, each of which develops into a jet of physical hadrons.



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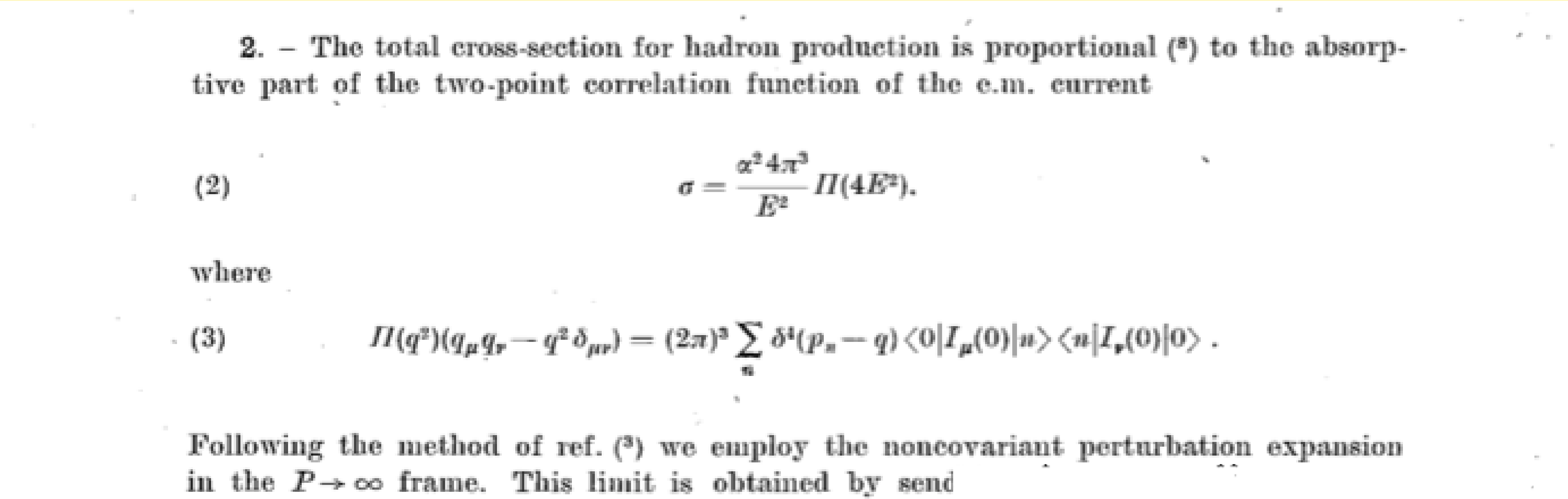
At the dawn of the

Parton Model

Well before QCD



2\. – The total cross-section for hadron production is proportional (8) to the absorptive part of the two-point correlation function of the e.m. current

$$\sigma = \frac{\alpha^2 4\pi^3}{E^2}\Pi(4E^2). \tag{2}$$

where

$$\Pi(q^2)(q_\mu q_\nu - q^2\delta_{\mu\nu}) = (2\pi)^3 \sum_n \delta^4(p_n - q)\langle 0|I_\mu(0)|n\rangle\langle n|I_\nu(0)|0\rangle . \tag{3}$$

Following the method of ref. (3) we employ the noncovariant perturbation expansion in the $P\to\infty$ frame. This limit is obtained by send
features of this limit, originated by FUBINI and FURLA
by WEINBERG (9).)

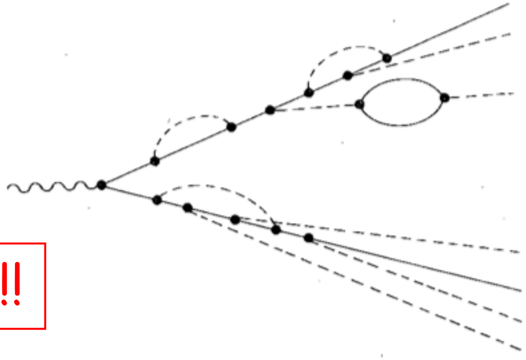
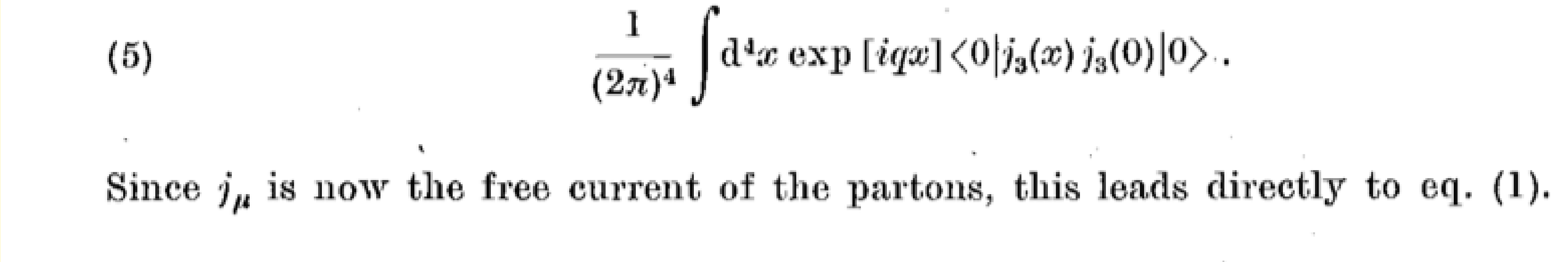


Fig. 1.

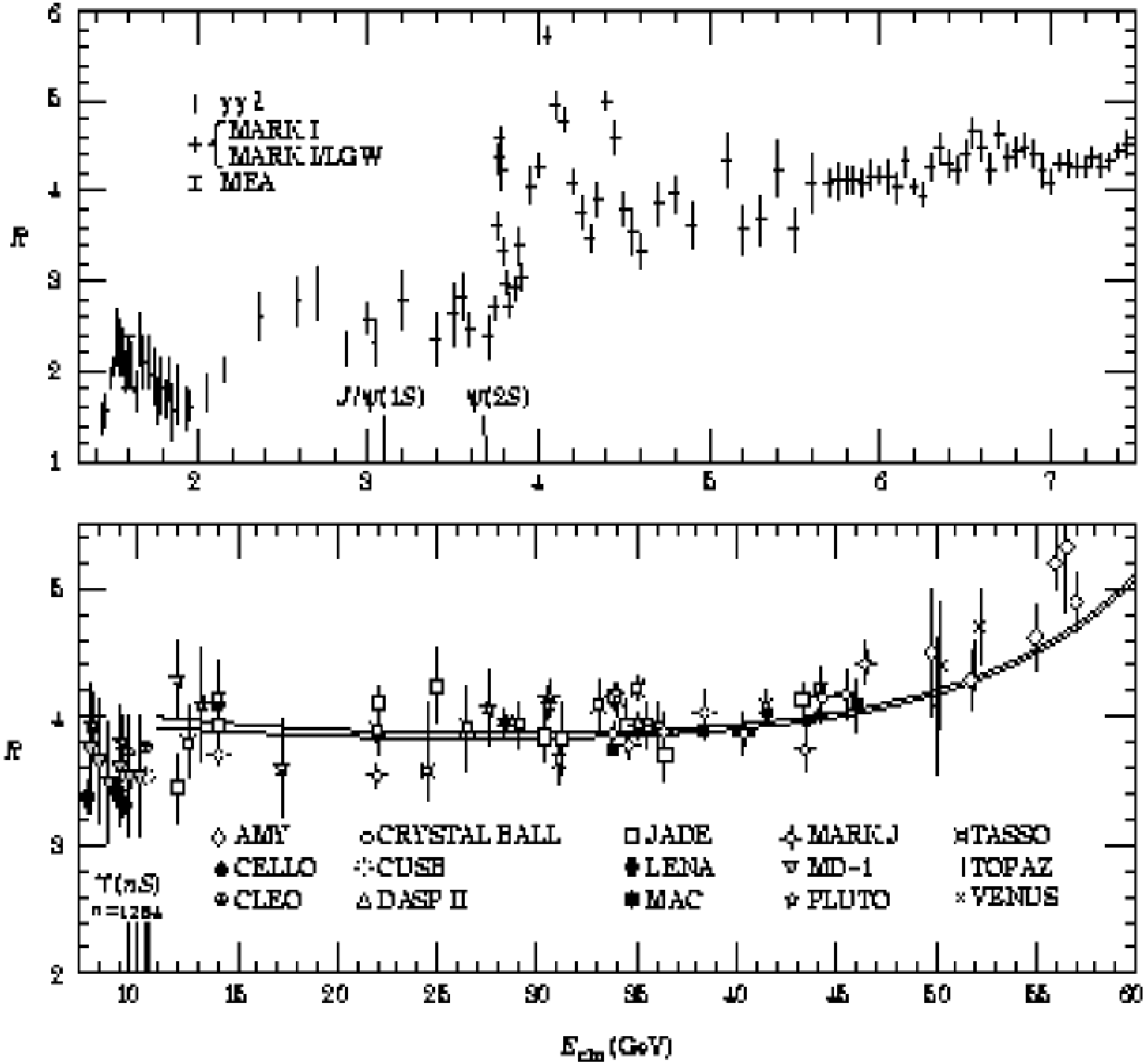
JET PHYSICS !!



$$\frac{1}{(2\pi)^4}\int d^4x \exp[iqx]\langle 0|j_3(x)\,j_3(0)|0\rangle . \tag{5}$$

Since j_μ is now the free current of the partons, this leads directly to eq. (1).

$R_{e+e-}(S)$



<u>The data clearly support the existence of colour</u>

Volume 59B, number 1 PHYSICS LETTERS 13 October 1975

EXPONENTIAL HADRONIC SPECTRUM AND QUARK LIBERATION

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Received 9 June 1975

The exponentially increasing spectrum proposed by Hagedorn is not necessarily connected with a limiting temperature, but it is present in any system which undergoes a second order phase transition. We suggest that the "observed" exponential spectrum is connected to the existence of a different phase of the vacuum in which quarks are not confined.

Following Hagedorn [1] we will impose the bootstrap condition:

$$\lim_{E\to\infty} \frac{\ln w(E)}{\ln \rho(E)} = 1. \qquad (8)$$

This relation can be satisfied if, for large E, $w(E) \to E^{\alpha-3} \exp(E\beta_c)$ with $\alpha < 2$ [1,8]. Under these hypothesis $F(\beta)$ will behave, for $\beta \approx \beta_c$, like [‡3]

$$F(\beta) = A(\beta - \beta_c)^{2-\alpha} + \text{less singular terms}. \qquad (9)$$

Only if $\alpha \geqslant 1$ the internal energy density

$$U(\beta) = \frac{d}{d\beta} F(\beta)$$

becomes divergent at $\beta = \beta_c$ and $T_c = 1/k\beta_c$ is a limiting temperature.

For $\alpha < 1$ $U(\beta)$ reaches a finite limit at $\beta = \beta_c$. At greater temperature all thermodynamical quantities remain finite, but the integral representations, eqs. (2) and (5) are not any more valid.

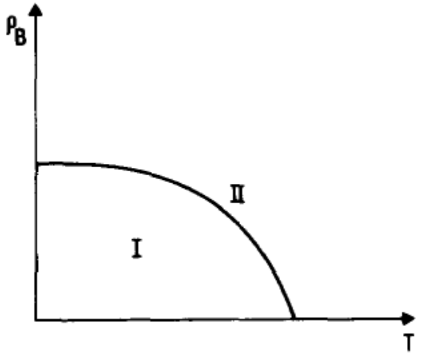

Fig. 1. Schematic phase diagram of hadronic matter. ρ_B is the density of baryonic number. Quarks are confined in phase I and unconfined in phase II.

Upper limits

Ref.TH.26

BOUNDS ON THE FERMIONS AND HIGGS BOSON MASSES IN GRAND UNIFIED THEORIES

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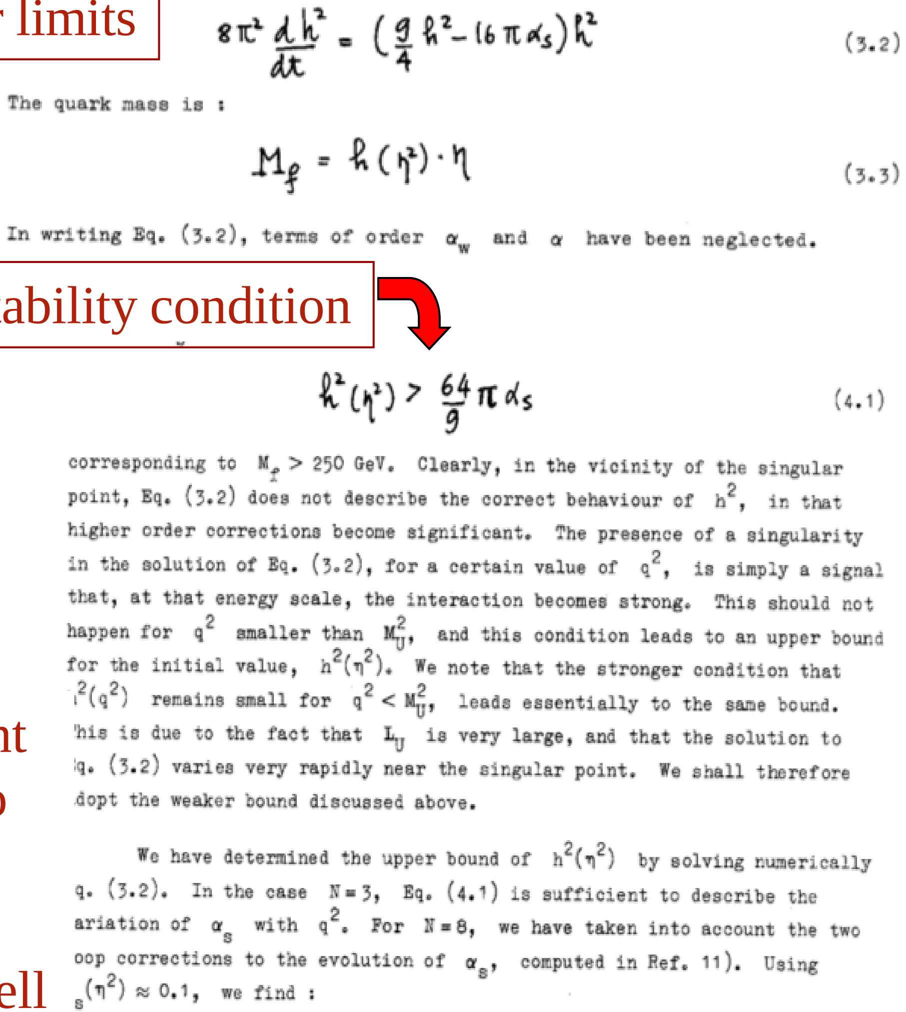
L. Maiani
CERN - Geneva

G. Parisi
INFN - Laboratori Nazionali di Frascati

and

R. Petronzio
CERN - Geneva



$$8\pi^2 \frac{dh^2}{dt} = \left(\frac{9}{4}h^2 - 16\pi\alpha_s\right)h^2 \tag{3.2}$$

The quark mass is :

$$M_f = h(\eta^2)\cdot\eta \tag{3.3}$$

In writing Eq. (3.2), terms of order α_w and α have been neglected.

stability condition

$$h^2(\eta^2) > \frac{64}{9}\pi\alpha_s \tag{4.1}$$

corresponding to $M_f > 250$ GeV. Clearly, in the vicinity of the singular point, Eq. (3.2) does not describe the correct behaviour of h^2, in that higher order corrections become significant. The presence of a singularity in the solution of Eq. (3.2), for a certain value of q^2, is simply a signal that, at that energy scale, the interaction becomes strong. This should not happen for q^2 smaller than M_U^2, and this condition leads to an upper bound for the initial value, $h^2(\eta^2)$. We note that the stronger condition that $^2(q^2)$ remains small for $q^2 < M_U^2$, leads essentially to the same bound. his is due to the fact that L_U is very large, and that the solution to q. (3.2) varies very rapidly near the singular point. We shall therefore dopt the weaker bound discussed above.

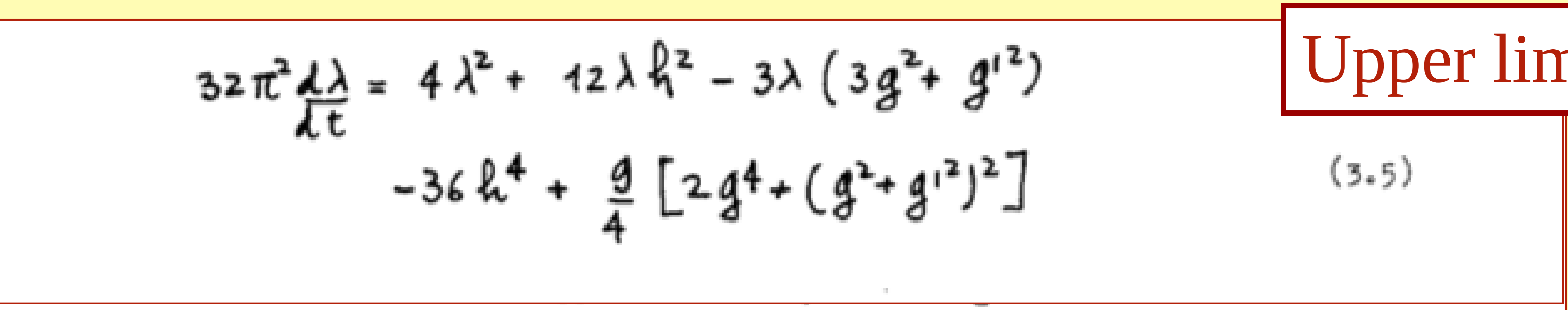
We have determined the upper bound of $h^2(\eta^2)$ by solving numerically q. (3.2). In the case $N=3$, Eq. (4.1) is sufficient to describe the ariation of α_s with q^2. For $N=8$, we have taken into account the two oop corrections to the evolution of α_s, computed in Ref. 11). Using $_s(\eta^2) \approx 0.1$, we find :

$$\boxed{M_f < 200 \text{ GeV} \quad (N=3)}$$

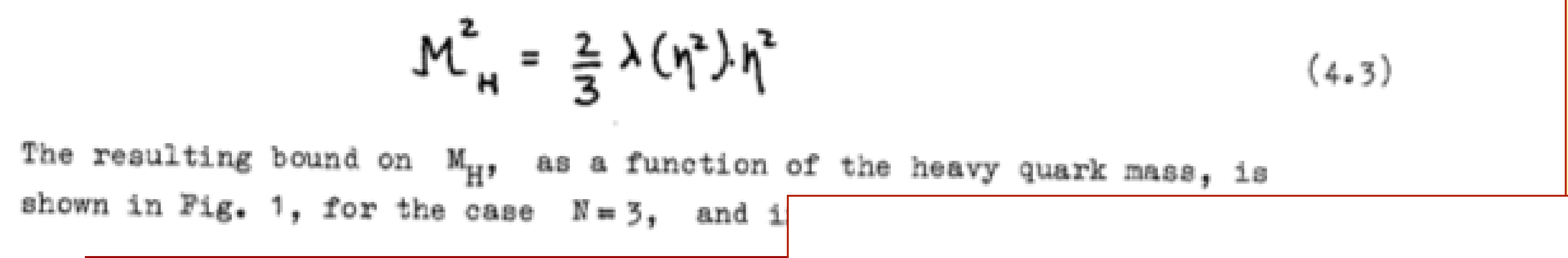
In the framework of GUT, the requirement that no interaction becomes strong and no vacuum instability develops up to the unification energy, is shown to imply upper bounds to the fermion masses as well as upper and lower bounds to the Higgs boson mass. These bounds tare studied in detail for the case of the unifying groups SU(5) or O(10)

12 June 1979

Upper limits



$$32\pi^2\frac{d\lambda}{dt} = 4\lambda^2 + 12\lambda h^2 - 3\lambda\left(3g^2 + g'^2\right) - 36h^4 + \frac{9}{4}\left[2g^4 + \left(g^2 + g'^2\right)^2\right] \qquad (3.5)$$



$$M_H^2 = \frac{2}{3}\lambda(\eta^2)\,\eta^2 \qquad (4.3)$$

The resulting bound on M_H, as a function of the heavy quark mass, is shown in Fig. 1, for the case $N = 3$, and i

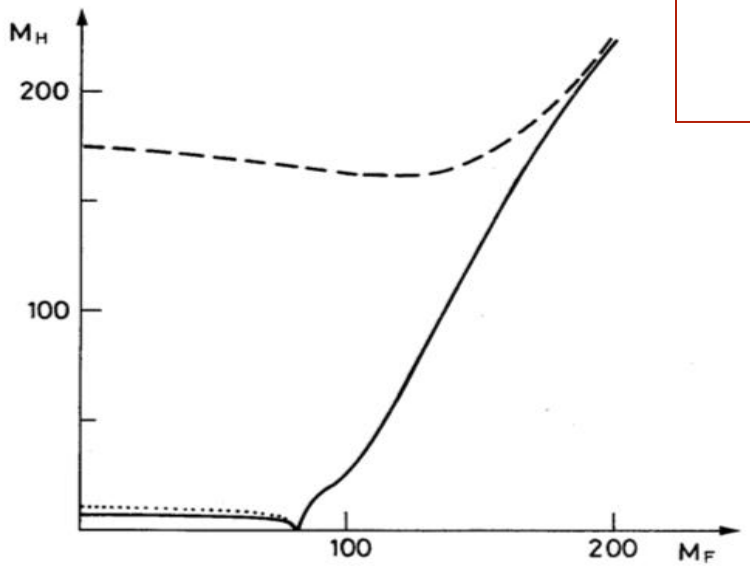
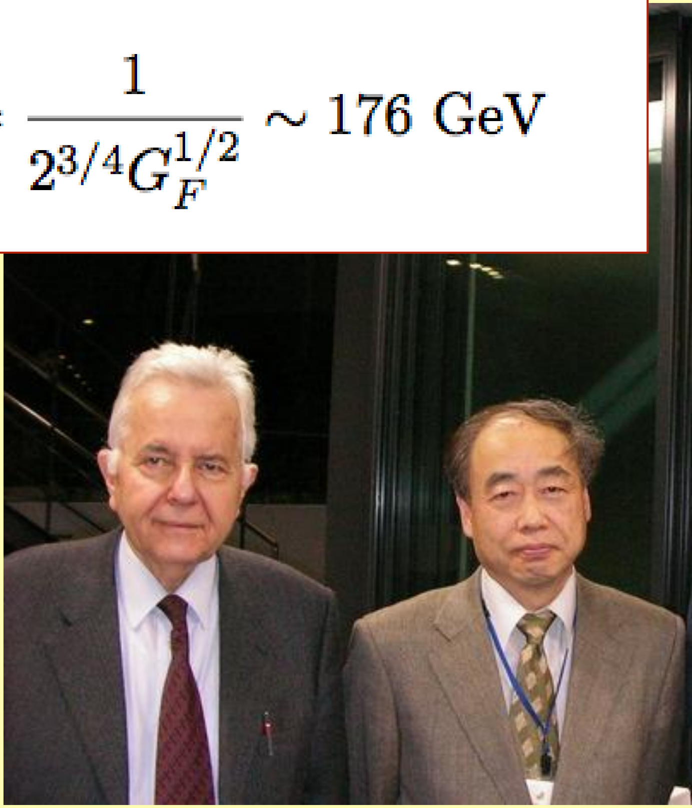


FIG. 1

$$\langle\phi\rangle \equiv \eta = \frac{1}{2^{3/4}G_F^{1/2}} \sim 176\ \text{GeV}$$



Lower limits given by the stability of the potential

Looking back at Eq. (3.5), we see that $\lambda(q^2)$ can be driven to negative values if the Yukawa coupling dominates the r.h.s. The situation is easy to analyze if we neglect the q^2 dependence of h, g and g^2. If :

$$\boxed{\begin{gathered} 36h^4 - \frac{9}{4}\left[2g^4 + (g^2 + g'^2)^2\right] \propto \\ \propto 12M_f^4 - 3(2M_W^4 + M_Z^4) > 0 \end{gathered}} \qquad (5.2)$$

the r.h.s. of Eq. (3.5) has one negative and one positive root : $\lambda_- < 0 < \lambda_+$. The negative root λ_- is an ultra-violet stable fixed point. Under these conditions, for any initial value in the region :

$$\boxed{0 \leq \lambda(\eta^2) \leq \lambda_+} \qquad (5.3)$$

λ becomes negative at some finite value of q^2. A lower bound for $\lambda(\eta^2)$ can thus be obtained, by requiring that this does not happen for q^2 less than M_U^2. In the more complicated case where h, g and g' evolve with q^2 according to Eqs. (2.1) and (3.2), the lower bound can be obtained numerically. The corresponding lower bound on M_H is displayed in Figs. 1 and 2, for $N = 3$ and 8 respectively *), as a function of the fermion mass, i.e., $h(\eta^2)$.

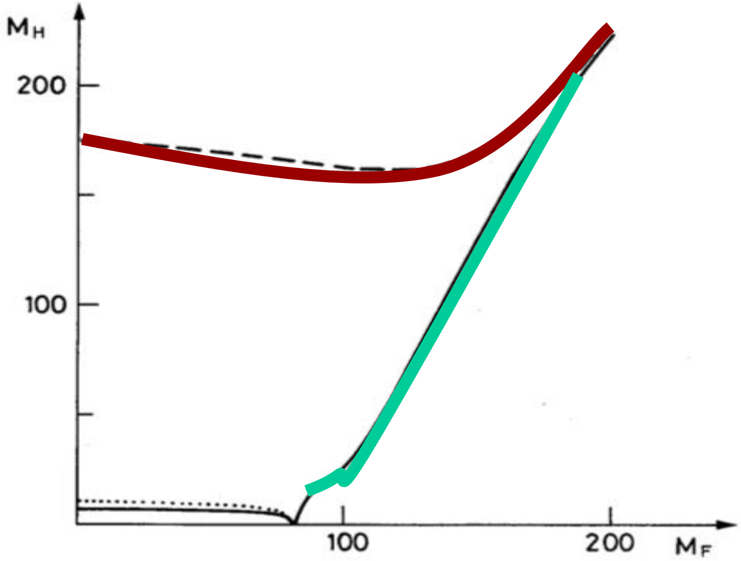


FIG. 1

G. Altarelli & G. Isidori
Coleman-Weimberg Effective Potential approach

LOWER LIMIT ON THE HIGGS MASS IN THE STANDARD MODEL: AN UPDATE

$$\begin{aligned} V_0^{1-loop}[\phi] &= -\frac{1}{2}m_0^2\phi^2 + \frac{1}{24}\lambda_0\phi^4 + \\ &\frac{1}{16\pi^2}\left[\frac{1}{4}H^2\left(\ln\frac{H}{\mu_0^2}-\frac{3}{2}\right)+\frac{3}{4}G^2\left(\ln\frac{G}{\mu_0^2}-\frac{3}{2}\right)+\frac{3}{2}W^2\left(\ln\frac{W}{\mu_0^2}-\frac{5}{6}\right)\right. \\ &\left.+\frac{3}{4}Z^2\left(\ln\frac{Z}{\mu_0^2}-\frac{5}{6}\right)-3T^2\left(\ln\frac{T}{\mu_0^2}-\frac{3}{2}\right)\right], \qquad (1) \end{aligned}$$

where

$$\begin{aligned} H &= -m_0^2+\lambda_0\phi^2/2, \qquad G = -m_0^2+\lambda_0\phi^2/6, \\ W &= g_{10}^2\phi^2/4, \qquad Z = (g_{10}^2+g_{20}^2)\phi^2/4, \qquad T = g_{t0}^2\phi^2/2, \qquad (2) \end{aligned}$$

requirement that the running coupling $\lambda(\Lambda)$ never becomes negative. Indeed for ϕ much larger than all mass scales in the theory the one-loop potential of eq.(1) can be written as:

$$V_0^{1-loop}[\phi] \simeq +\frac{1}{24}\phi^4\left\{\lambda_0+\left[\beta_\lambda(\lambda_0,g_{i0})-4\lambda_0\gamma(\lambda_0,g_{i0})\right]\ln\left(\frac{\phi}{\mu_0}\right)+O(\lambda_0^2,g_{i0}^2)\right\}. \qquad (3)$$

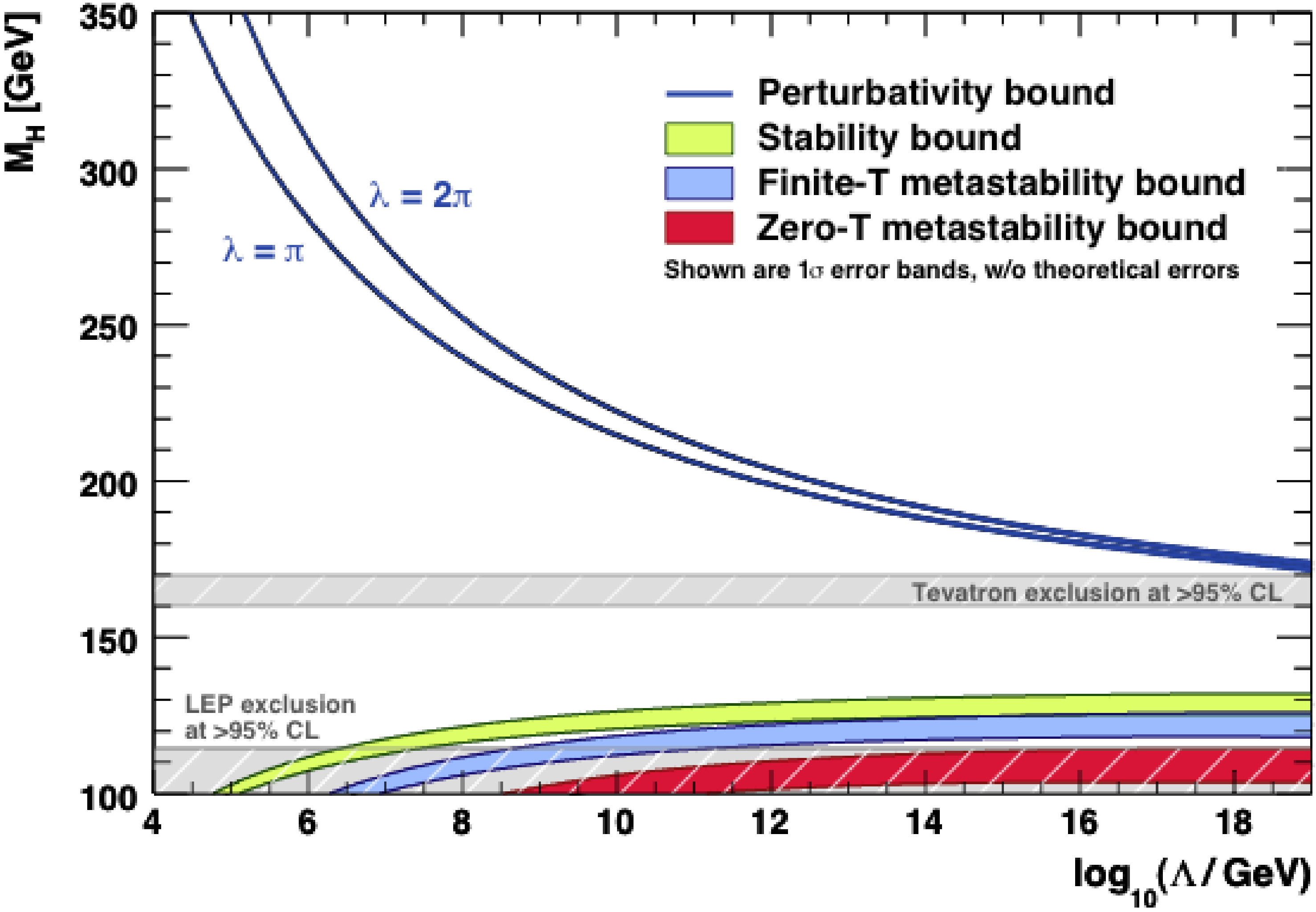
This is just the expansion of the quartic term in the RG improved potential:

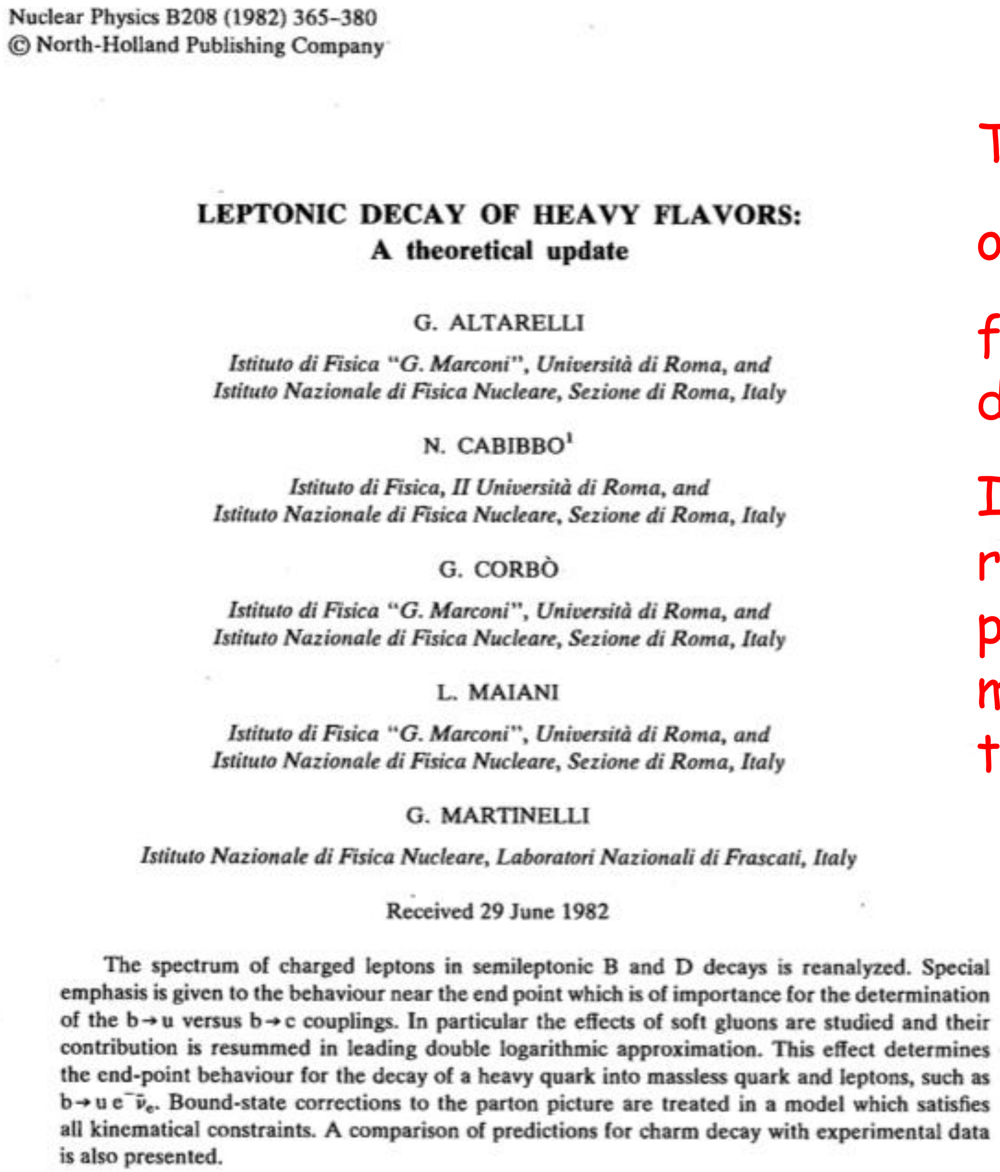
$$V_{RG}^{1-loop}(\phi) \simeq +\frac{1}{24}\lambda(t)[\xi(t)\phi]^4+O(\lambda(t)^2,g_i(t)^2), \qquad (4)$$

where

$$\begin{aligned} \xi(t) &= \exp\left(-\int_0^t\gamma(\lambda(t'),g_i(t'))dt'\right), \qquad & t &= \log(\Lambda/\mu_0), \qquad (5) \\ \frac{d\lambda(t)}{dt} &= \beta_\lambda(\lambda,g_i), & \frac{dg_i(t)}{dt} &= \beta_i(\lambda,g_i), \qquad (6) \\ \lambda(0) &= \lambda_0 & g_i(0) &= g_{i0}. \qquad (7) \end{aligned}$$

By J. Ellis and Collaborators (via A. Djouadi)





Nuclear Physics B208 (1982) 365–380
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LEPTONIC DECAY OF HEAVY FLAVORS:
A theoretical update

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Received 29 June 1982

The spectrum of charged leptons in semileptonic B and D decays is reanalyzed. Special emphasis is given to the behaviour near the end point which is of importance for the determination of the $b\to u$ versus $b\to c$ couplings. In particular the effects of soft gluons are studied and their contribution is resummed in leading double logarithmic approximation. This effect determines the end-point behaviour for the decay of a heavy quark into massless quark and leptons, such as $b\to u\, e^-\bar{\nu}_e$. Bound-state corrections to the parton picture are treated in a model which satisfies all kinematical constraints. A comparison of predictions for charm decay with experimental data is also presented.

The ``naïve" ancestor of

of the HQET shape function

for semileptonic and radiative decays

It contains, however, up to a redefinition of the non perturbative parameters, the main features of the modern theory

Fit of the parameters from The lepton spectrum of D decays

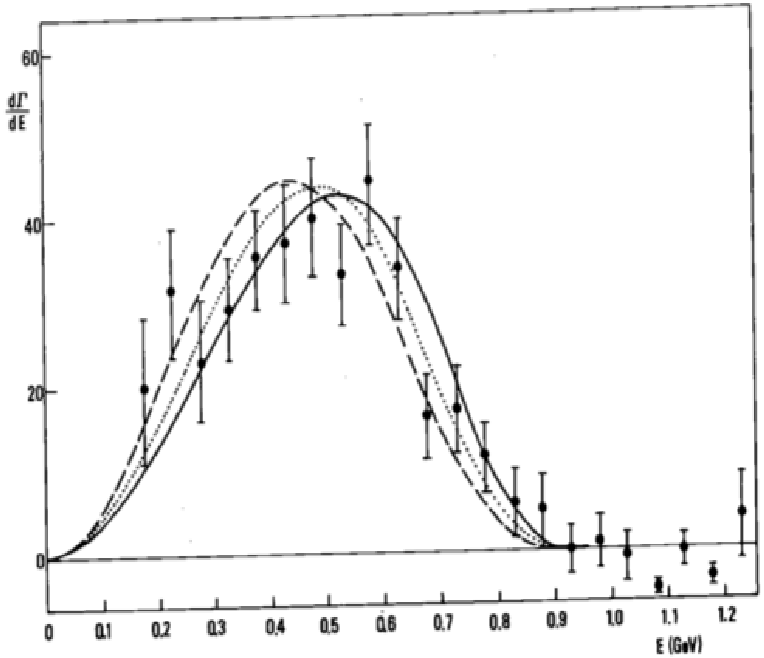
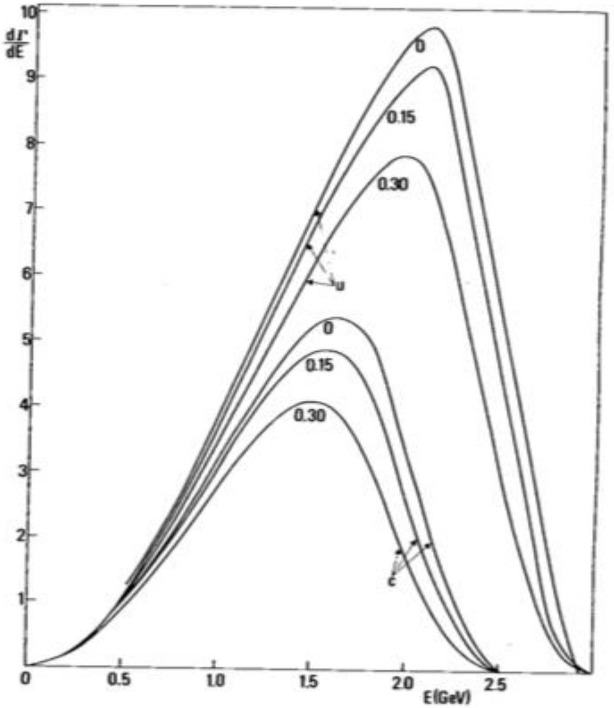


Fig. 3. Charged lepton spectrum in D decay for $M_D = 1.866$ GeV, $m = 0.3$ GeV, $m_{sp} = 0.15$ GeV, $\alpha_s = 0.38$, $P_B = 0.26$ GeV and $P_F = 0$ (solid), $P_F = 0.15$ GeV (dotted), $P_F = 0.3$ GeV (dashed). The normalization is fixed to the number of events.



6. $d\tilde{\Gamma}_{c,u}/dE$ for B meson decay for $M_B = 5.218$ GeV, $m_u = 0.15$ GeV, $m_c = 1.7$ GeV, $m_{sp} =$ GeV, $= 0.24$, various values of P_F as indicated (in GeV) and $P_B = 0.76$ GeV. The absolute scale is arbitrary, but the relative normalizations are correct.

comparing our predictions with the spectra obtained in $e^+e^- \to \Upsilon''' \to B\bar{B}$, the est uncertainty, at present, seems to arise from the poor determination of the B mass, i.e. of the B momentum at a given value of the beam energy. The present bounds on the B-meson mass are [14]

$$5.162 \text{ GeV} \leq M_B \leq 5.275 \text{ GeV}, \qquad (42)$$

5279.17 ± 0.29 PDG FIT

Prediction of the spectrum in B decays for b -> c and b -> u

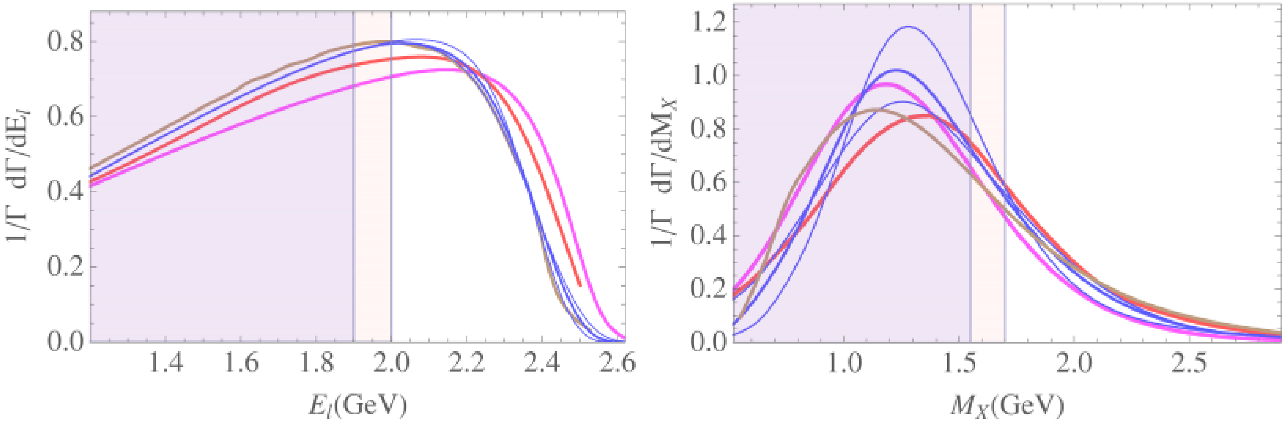


Fig. 38. Comparison of different theoretical treatments of inclusive $b \to u$ transitions: (a) E_l spectrum; (b) M_X spectrum. Red, magenta, brown and blue lines refer, respectively, to DGE, ADFR, BLNP, GGOU with a sample of three different functional forms. The actual experimental cuts at $E_l = 1.9, 2.0\,\text{GeV}$ and $M_X = 1.55, 1.7\,\text{GeV}$ are also indicated.

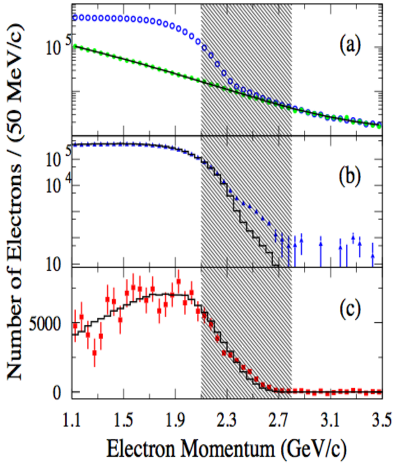


Fig. 40. The inclusive electron energy spectrum [594] from BaBar is shown for (a) on-peak data and q^2 continuum (histogram); (b) data subtracted for non-$B\overline{B}$ contributions (points) and the simulated contribution from B decays other than $b \to u\ell\nu$ (histogram); and (c) background-subtracted data (points) with a model of the $b \to u\ell\nu$ spectrum (histogram).

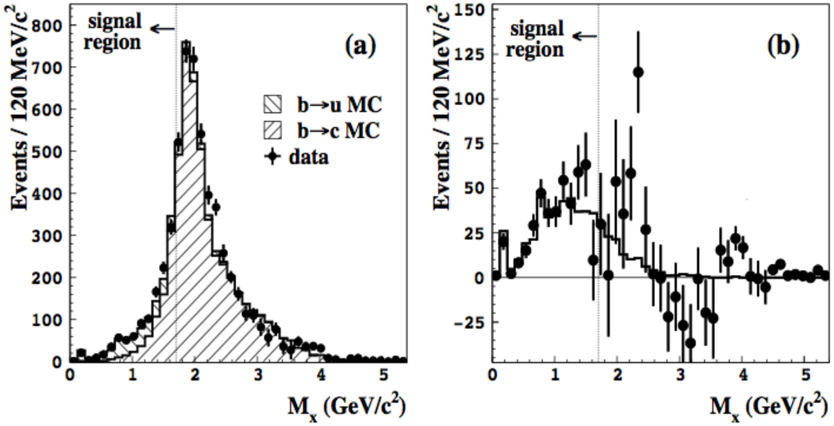
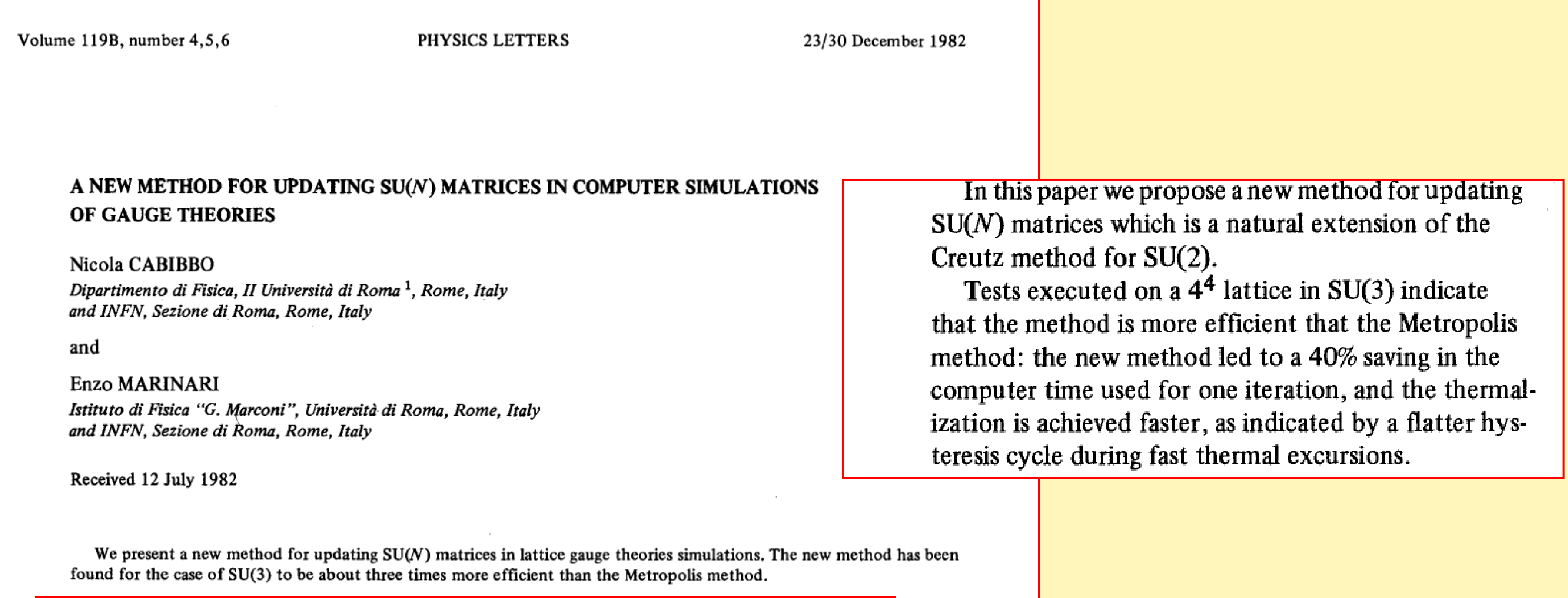


Fig. 41. The hadronic invariant mass spectrum [595] in Belle data (points) is shown in (a) with histograms corresponding to the fitted contributions from $b \to c\ell\nu$ and $b \to u\ell\nu$. After subtracting the expected contribution from $b \to c\ell\nu$, the data (points) are compared to a model $b \to u\ell\nu$ spectrum (histogram) in (b).



Volume 119B, number 4,5,6 PHYSICS LETTERS 23/30 December 1982

A NEW METHOD FOR UPDATING SU(N) MATRICES IN COMPUTER SIMULATIONS OF GAUGE THEORIES

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Received 12 July 1982

We present a new method for updating SU(N) matrices in lattice gauge theories simulations. The new method has been found for the case of SU(3) to be about three times more efficient than the Metropolis method.

In this paper we propose a new method for updating SU(N) matrices which is a natural extension of the Creutz method for SU(2).

Tests executed on a 4^4 lattice in SU(3) indicate that the method is more efficient that the Metropolis method: the new method led to a 40% saving in the computer time used for one iteration, and the thermalization is achieved faster, as indicated by a flatter hysteresis cycle during fast thermal excursions.

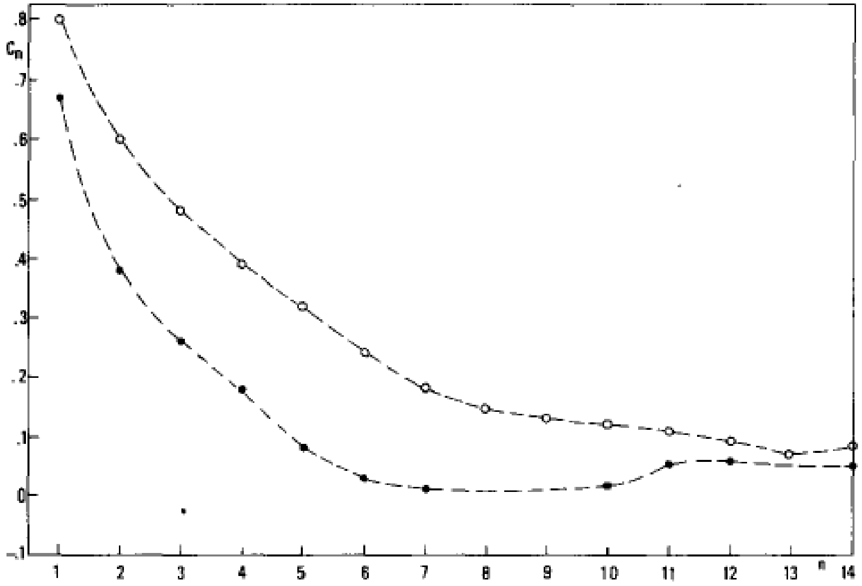
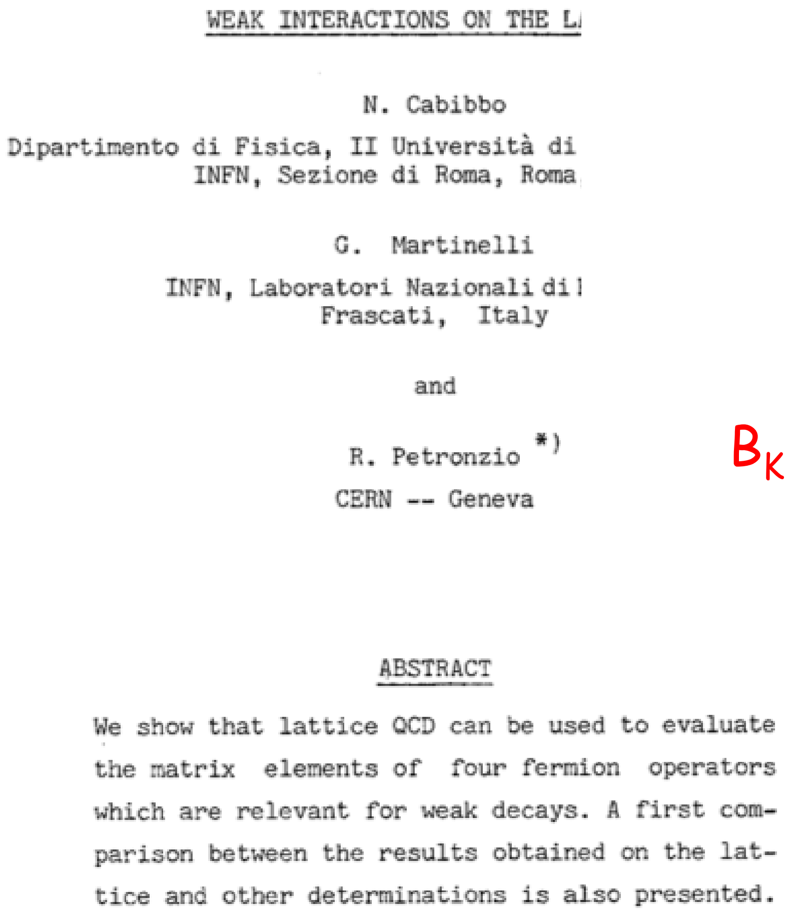


Fig. 3. Correlation function C_n [see eq. (17)]. Black dots: new method. Open circles: Metropolis.

Published in Nucl.Phys.B244:381-391,1984.

mid-August holiday paper !!



WEAK INTERACTIONS ON THE L

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and

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CERN -- Geneva

ABSTRACT

We show that lattice QCD can be used to evaluate the matrix elements of four fermion operators which are relevant for weak decays. A first comparison between the results obtained on the lattice and other determinations is also presented.

Calculation Of Weak Transitions In Lattice Qcd.
Richard C. Brower, Guillermo Maturana, (UC, Santa Cruz) , M. Belen Gavela, (Brandeis U.) , Rajan Gupta, (Harvard U.)
Phys.Rev.Lett.53:1318,1984.

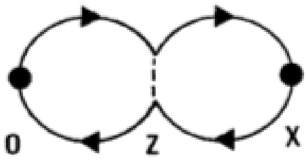


fig.1a

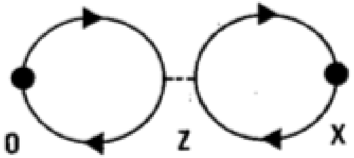
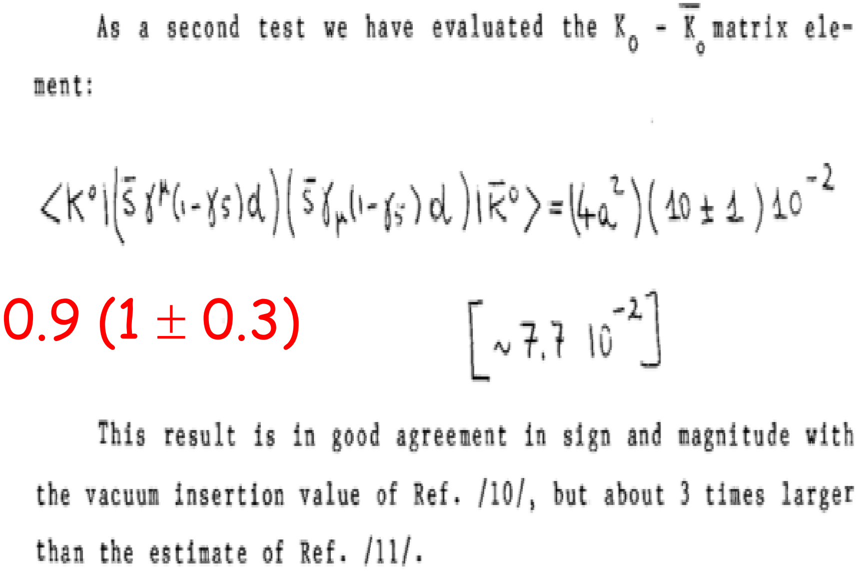


fig.1b



As a second test we have evaluated the $K_0 - \bar{K}_0$ matrix element:

$$\langle K^0 | (\bar{s}\gamma^\mu(1-\gamma_5)d)(\bar{s}\gamma_\mu(1-\gamma_5)d) | \bar{K}^0 \rangle = (4a^2)(10 \pm 1)10^{-2}$$

$$[\sim 7.7\ 10^{-2}]$$

$B_K \sim 0.9\ (1 \pm 0.3)$

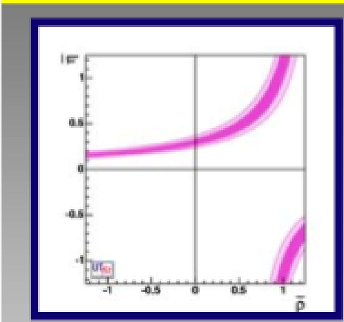
This result is in good agreement in sign and magnitude with the vacuum insertion value of Ref. /10/, but about 3 times larger than the estimate of Ref. /11/.

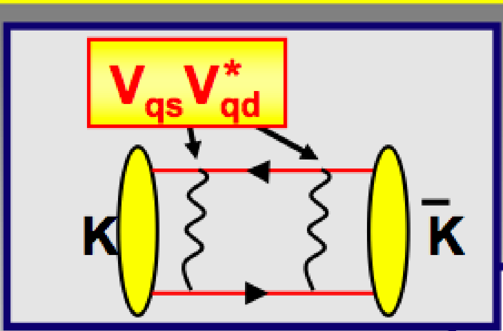
J Donoghue Phys. Lett. 119B (1982) 412

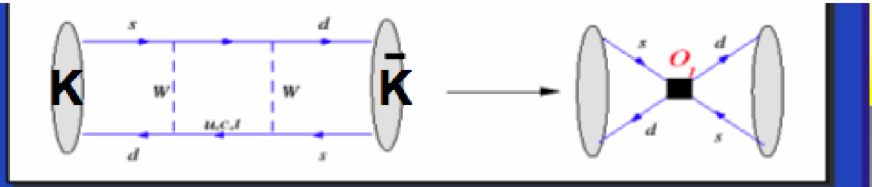
We were opening the Pandora box of Weak Interactions on the lattice (chiral symmetry, power diver. and renormalization, FSI etc.)

K^0-$\bar{K}^0$ mixing: B_K

V. Lubicz SuperB meeting nov. 2009







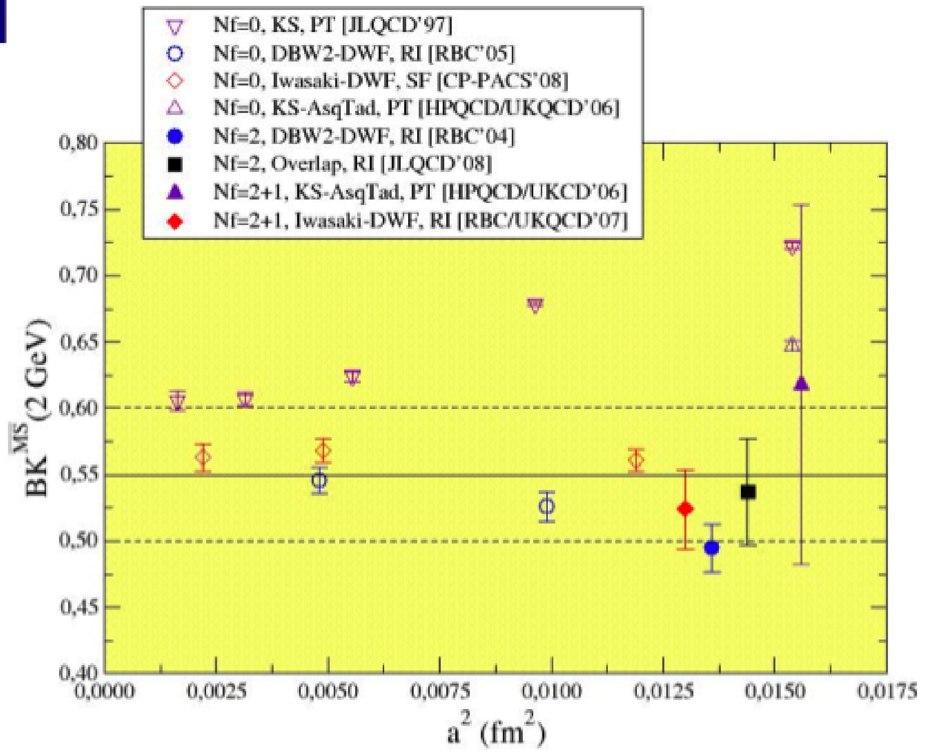
$$\langle \bar{K}^0 | Q(\mu) | K^0 \rangle = \frac{8}{3} f_K^2 m_K^2 B_K(\mu)$$

$\hat{B}_K = 0.90 \pm 0.03 \pm 0.15$
S.Sharpe@Latt'96
17%

$\hat{B}_K = 0.86 \pm 0.05 \pm 0.14$
L.Lellouch@Latt'00
17%

$\hat{B}_K = 0.79 \pm 0.04 \pm 0.08$
C.Dawson@Latt'05
11%

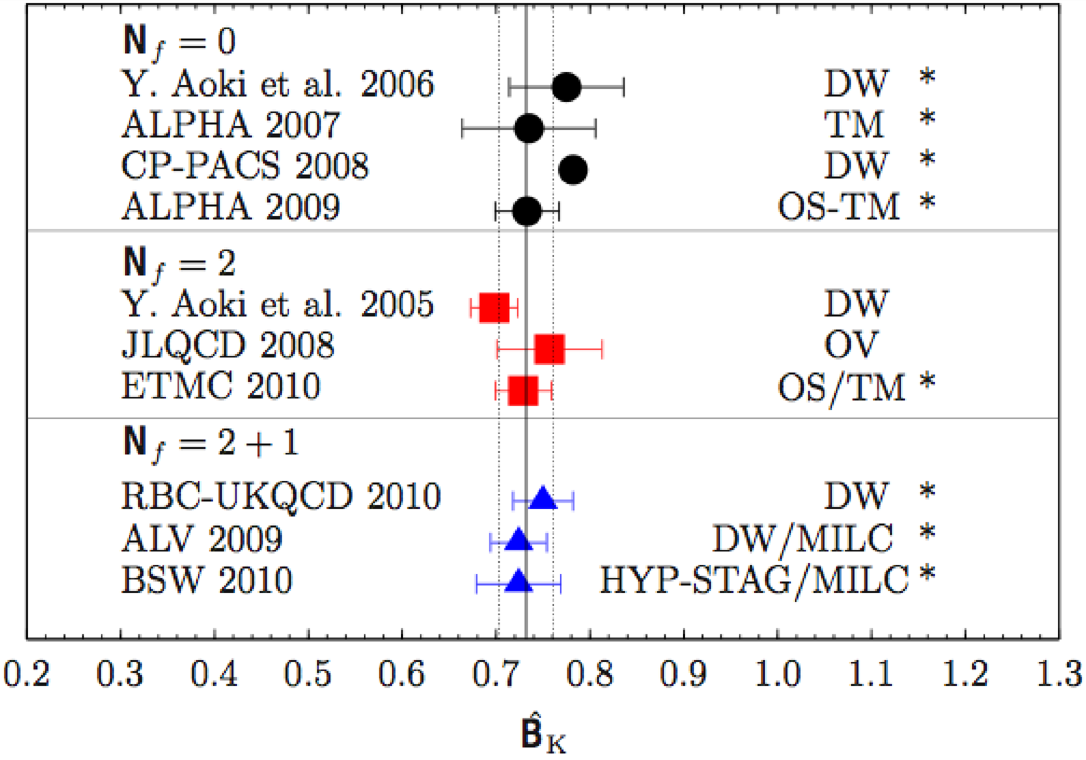
$\hat{B}_K = 0.723 \pm 0.037$
L.Lellouch@Latt'08
5%



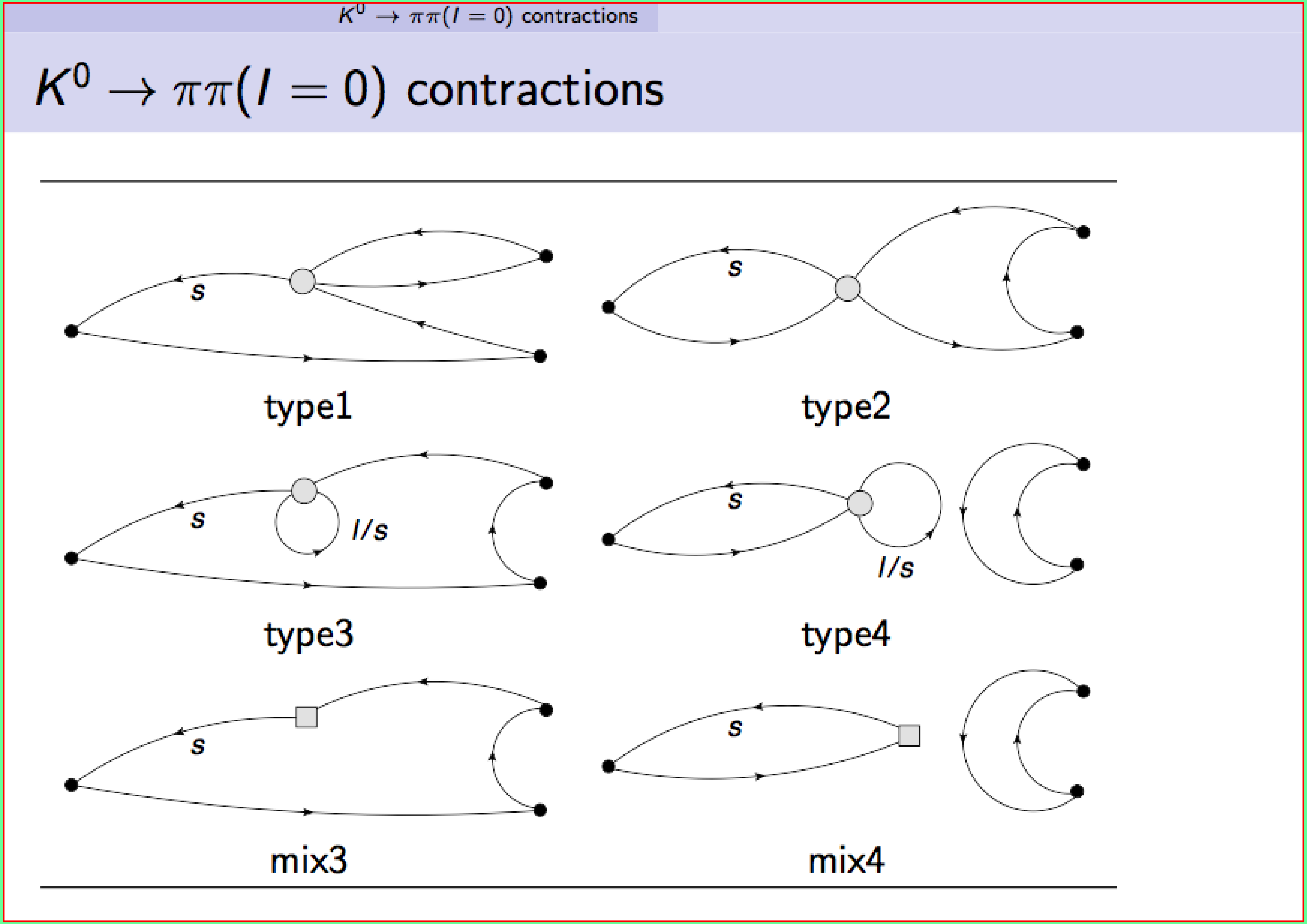
[VL, C.Tarantino 0807.4605]

All unquenched calculations until last year at fixed (and rather large) lattice spacing

$\hat{B}_K$



- $*$ ⟶ result already in the **CL**.
- Average: $\hat{B}_K^{(N_f=2)}(\text{ETMC}) = 0.729(30)$; $\hat{B}_K^{(N_f=2+1)} = 0.732(06)(28)$
- No dependence on the strange quark (with the present precision)!
- Difference of less than $\sim 2\,\sigma$ with the most precise quenched result.



$K^0 \to \pi\pi(I=0)$ contractions

type1

type2

type3

type4

mix3

mix4

Nicola attention for new projects

February 2006 Inauguration of the APENEXT LAB (INFN-La Sapienza)

Breve Storia del progetto APE

Nicola Cabibbo

Dipartimento di Fisica
Università di Roma "La Sapienza"

8 Febbraio 2006

This is not translated because it is rather simple to understand ...... ->

I Progetti APE — i primi 10 anni

I Progetti APE

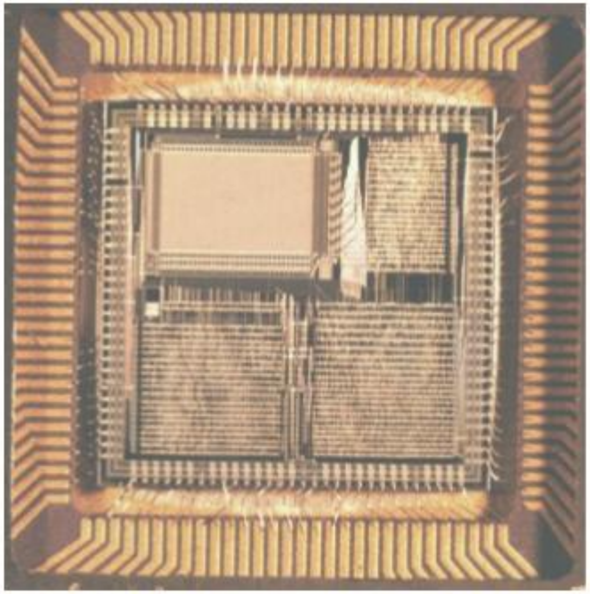
1984-1989: APE1

- 16 nodi di calcolo, 1 Gflops
- Software "primitivo"
- Prodotti alcuni prototipi

Gaetano sono finiti i registri !!

1990-1995: APE100

- Modulare, 2048 nodi "custom", 100 GFlops
- Sviluppo di un linguaggio dedicato (TAO)
- Ambiente software "user friendly"
- Affidabilita' alta, 300 GFlops installati



I Progetti APE — Il team del primo APE

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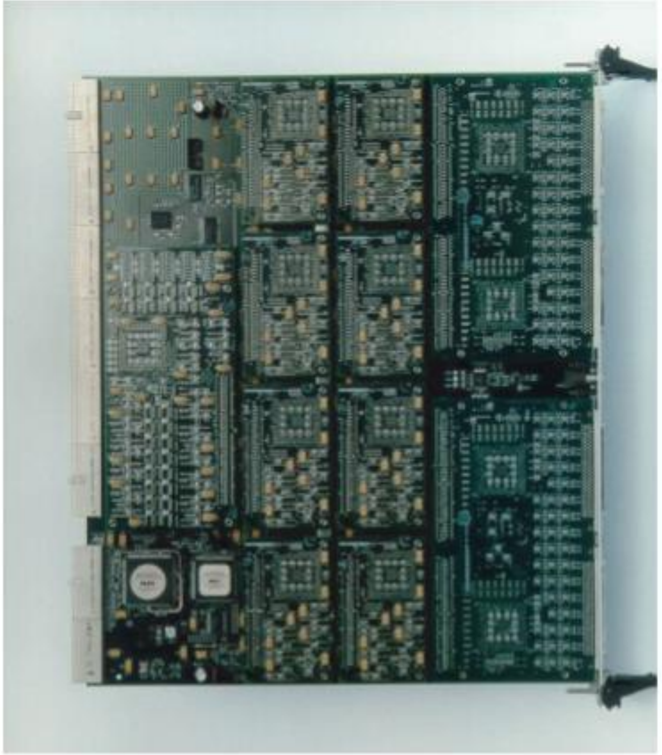
Dipartimento di Matematica - Universita' "La Sapienza" Roma, Italy

1984-1989

I Progetti APE — APEmille

1995-2000: APEMille

- Progetto internazionale INFN-DESY "up and running!!"
- "processor array" tridimensionale scalabile da 8 a 2048 nodi con perf. da 4 GF ad 1.1TFlops
- Architettura SIMD, comunicazioni sincrone a primo vicino
- 32 MByte di memoria locale per nodo
- Singola e doppia precisione
- Rete di 64 PCs realizza "Host computer" completamente integrato (bus cPCI)

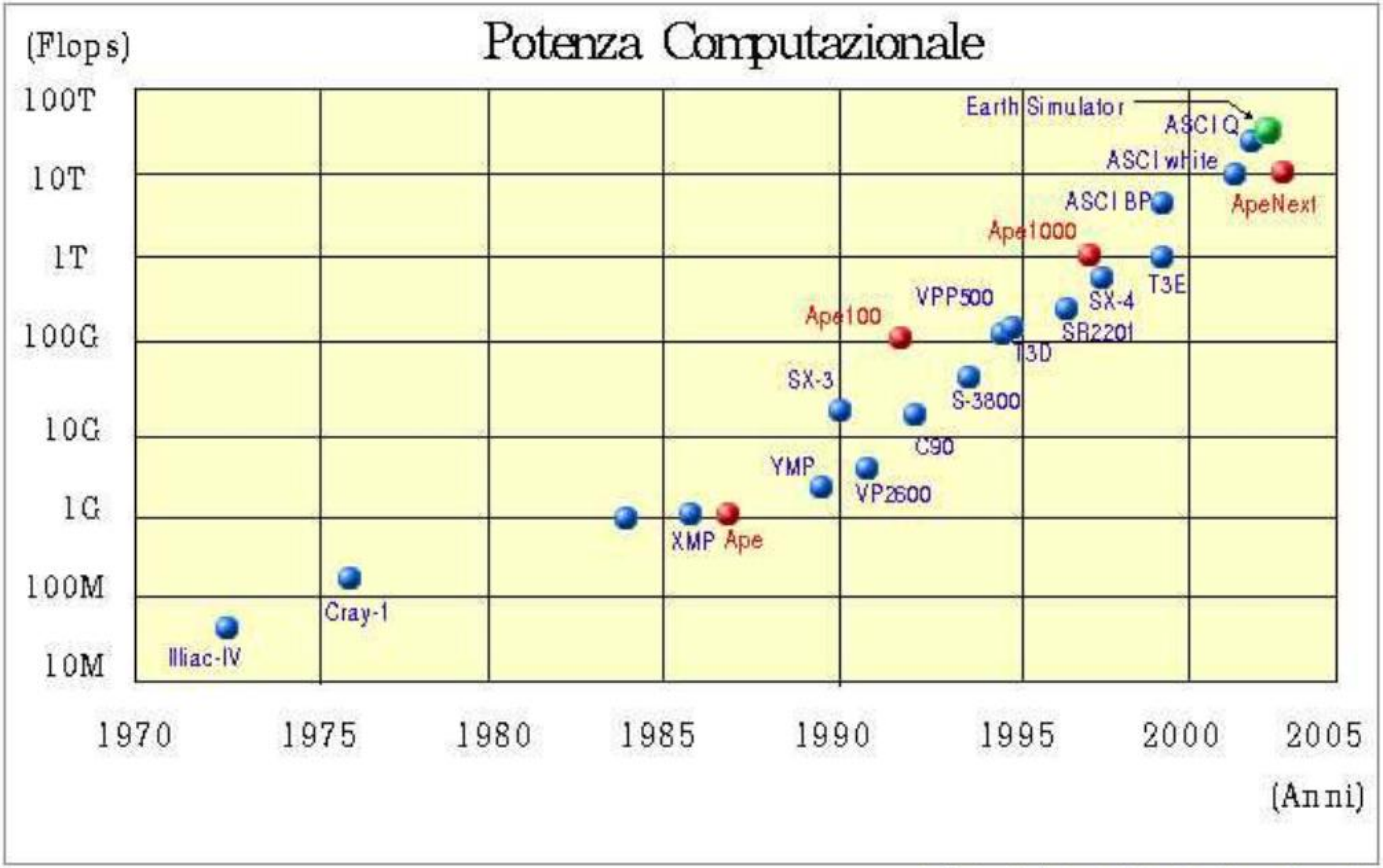


I Progetti APE — APEmille in Italia e in Europa

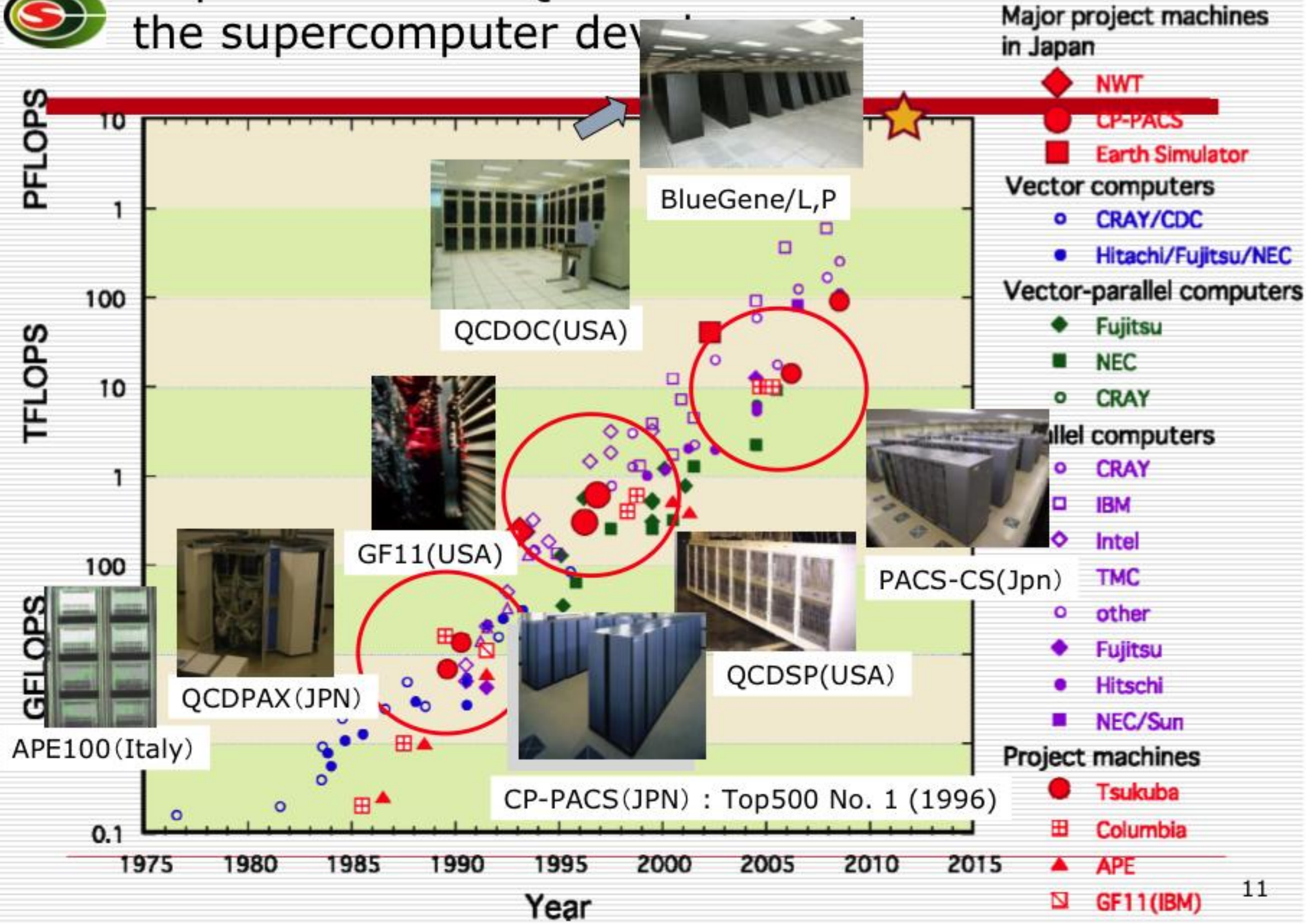
APEMille

Site	Peak Perf. GFlops
Roma 1	640
Desy	576
Pisa	256
Roma 2	256
Bielefeld	128
Milano	128
Bari	64
Swansea	64
Orsay	16
Totale	**2128 !**

I Progetti APE nel contesto mondiale



Impact of lattice QCD machines on the supercomputer dev



CP-PACS(JPN) : Top500 No. 1 (1996)

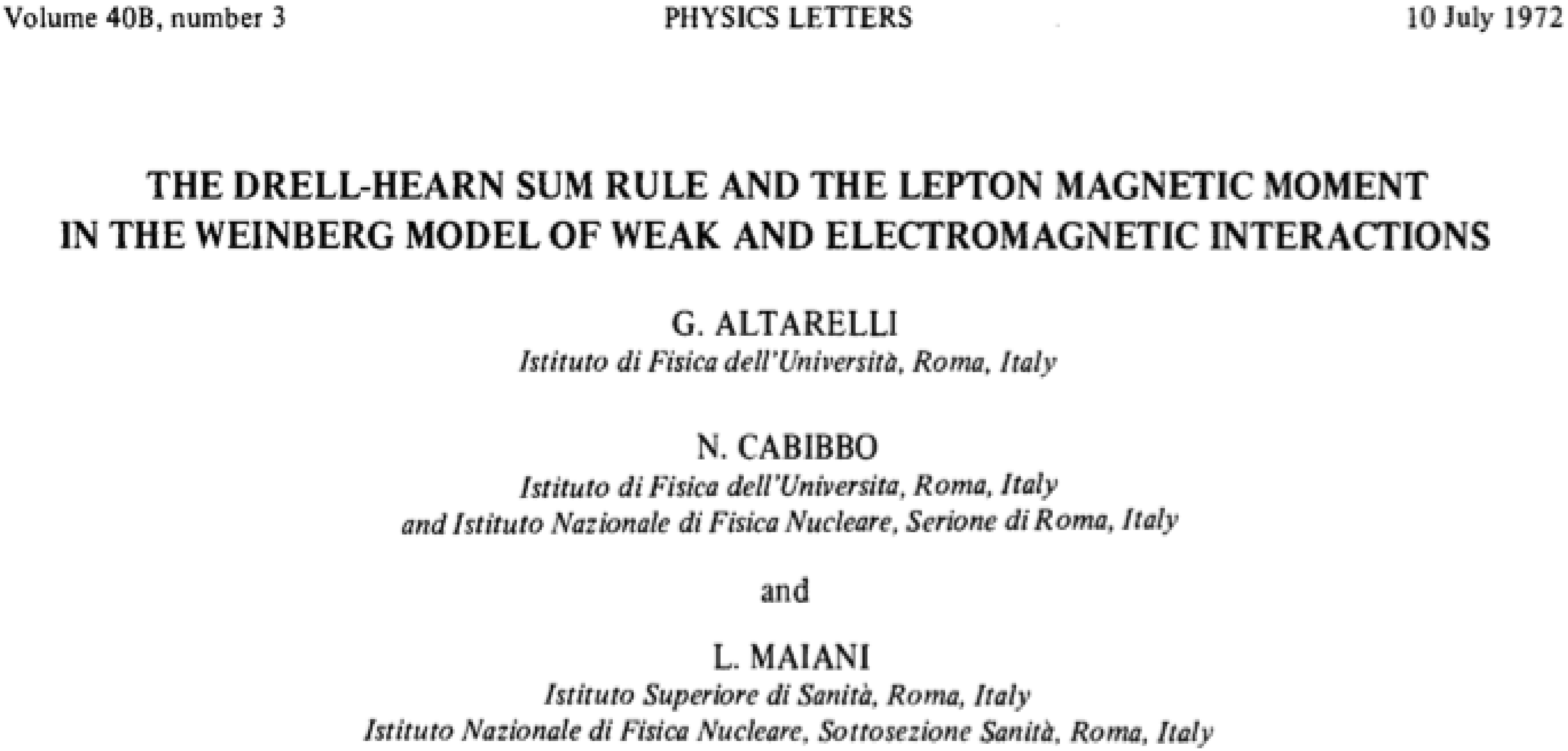
L'impatto di APE

- Scientific, technological and social impacts:
  - APE is standard "de facto" in European LQCD computing area
  - Huge number of scientific and technological (HW, SW, Architecture) papers
  - Establishment of an international computing facility fully dedicated to scientific numerical computing
    - Laboratorio di Calcolo apeNEXT: 12 TFs installed, opening on February, 8th
  - Strategic opportunities to increase national(European) industry capability
    - Eurotech
      - INFN collaboration -> HPC division, market expansion, international visibility
    - Finmeccanica/QSW
  - Training, dissemination and establishment of spin-off companies
    - Atmel/Ipitec
    - Nergal
    - Digital Video
    - Venere

SPIN OFF OF THE APE PROJECT

Cabibbo as smart manager
as INFN and ENEA President

Other papers that I do not have time to discuss



Volume 40B, number 3 PHYSICS LETTERS 10 July 1972

THE DRELL-HEARN SUM RULE AND THE LEPTON MAGNETIC MOMENT IN THE WEINBERG MODEL OF WEAK AND ELECTROMAGNETIC INTERACTIONS

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and

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Istituto Nazionale di Fisica Nucleare, Sottosezione Sanità, Roma, Italy

1) DETERMINATION OF THE A0 - A(2) PION SCATTERING LENGTH FROM
K+ ---> PI+ PI0 PI0 DECAY.
By Nicola Cabibbo (CERN),. CERN-PH-TH-2004-073, May 2004. 8pp.
e-Print Archive: hep-ph/0405001

Nicola was keen to teach and continued to do it until very recently.

He was able to find simple arguments, and arrive to classical results with original and intuitive demonstrations, to explain difficult concepts.

His students were fascinated by his simplicity, gentle modes and sense of humour. So we did, all of us we who had the privilege to be his collaborators and friends. (L. Maiani)


VIETATO FUMARE

Nicola was a superb physicist who made huge contributions
to our field, and at the same time he was a kind and gentle
man.
With our sympathy and best wishes,
Mike Chanowitz
Mary K. Gaillard
Bruno Zumino

Dear Luciano, Guido, Massimo,
It was with profound sorrow that I heard of Nicola's death.
On behalf of the Fermilab theory group I would like to express
our condolences at the passing of a great man.
I would also like to extend my deepest sympathy to you
at the loss of a good friend. Although I did not know him well
Nicola displayed great kindness and openness towards me
whilst I was in Rome as a student and took great care to advise
me about my future career. Iclearly remember him inviting me
to his home and opening my eyes to the big world of opportunities
which I could have as a post-doc. For that I will always be grateful.
I would be grateful if you would communicate my sympathy
and the condolences from our theory group also to Nicola's family.
Sincerely, Keith (Ellis)

Before the end….

In all circumstances, Nicola has shown an extreme courtesy and kindness to anybody, refusing, for example, any controversy for the missing/missed Nobel prize.

With the same precious style, he has accomplished his obligations as President of INFN, first, President of ENEA and President of the Pontificial Academy of Sciences.

Nicola was able to combine an extraordinary physics insight, vision with management skill and integrity.

He will remain a reference for those who had the privilege to interact with him, and for the future generations of young researchers who will share with him the passion for physics and in general the love for the investigation of the misteries of Nature.

We are all grateful to him and we shall sorely miss him.