CONCLUDING REMARKS

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Important new results have been presented at this conference. The direct violation of $CP$ in $K^0 \to \pi^+\pi^-$ has been firmly established in two independent experiments, NA48 at CERN and KTeV at Fermilab. Both Babar at SLAC and Belle at KeK have determined the $CP$ violation in $B^0_d - \bar{B}^0_d$ oscillations through the study of the golden $K_S + \Psi$ decay mode. The observed $CP$ violation agrees with the expectations of the Standard model, based on the quark-mixing phenomenon. The first results of the Sudbury Neutrino Observatory, SNO, suggest that the long-lasting solar neutrino puzzle has been finally solved in terms of neutrino oscillations. Results appeared after the conference which modify the theoretical prediction of the muon anomaly. This new result, if confirmed, would drastically reduce the significance of the discrepancy between the theoretically expected value for the muon anomaly and the recent results of the Brookhaven experiment.

1 Introduction

One of the pleasures of this conference has been the chance to meet Alberto Sirlin after many years. He reminded me of a recipe for the perfect closing lecture I offered him many (30+) years ago: “You have to mention everybody who gave a talk!”

I am glad to have the recipe back after such a long time, but I will not be able to follow it. This meeting is rich with important results, among which two new examples of $CP$ violation, the possible solution of the solar neutrino puzzle in terms of neutrino oscillations and a possible discrepancy between the recent measurement of the muon anomaly and theoretical predictions. I will concentrate my attention on these subjects.

The discussion of these very hot arguments should not however make us forget many other excellent results presented at the conference; the field is indeed progressing on a very wide front.

Among the many experimental results presented at the conference I was particularly impressed by those obtained at Hera by the ZEUS and H1 collaborations, which graphically demonstrate the unification of weak and electromagnetic interactions: at low $Q^2$ the cross section for charged current events, $e \to \nu$, is many orders of magnitude smaller than that for neutral current events, $e \to e$, dominated by e.m. interactions; at high $Q^2$ the two cross sections inch closer and become proportional, as predicted by the standard model.

The Hera groups have presented a detailed determination of the scaling violation in deep inelastic scattering, allowing an extensive check on the predictions obtained from perturbative QCD, and an accurate determination of $\alpha_s(M_Z)$. With the advent of more accurate (NNLO) calculations the new experimental results will allow a 1% precision in this important parameter.

2 $CP$ Violation

2.1 Quark mixing and $CP$ Violation

The charged-current weak interactions of hadrons are described by the unitary matrix $V$ ($V^\dagger V = 1$). With only two families, e.g. in a world without beauty (or $t$ quarks), $V$ can always be reduced to a real form, so that $CP$ is necessarily conserved.

With three families the matrix $V$ can be expressed in terms of four parameters:
The form of the unitarity triangle can be determined by measurements of $CP$ conserving quantities. The oscillation of $B_d^0$ mesons are dominated by graphs with virtual top quarks, so that the mass difference $\Delta m_d$ is proportional to $|1 - \rho - i\eta|^2$, the length squared of one of the upper sides of the triangle. The length of the other side, $|\rho + i\eta|$, can be extracted from a determination of $V_{ub}$, e.g. from a determination of the rates of the forbidden $b \to u$ leptonic transitions. These determinations point to a non-flat triangle, i.e. to the presence of a certain amount of $CP$ violation. As a first check the values of $\rho, \eta$ so obtained agree well with the observed value of the $CP$ violating $\epsilon$ parameter in $K^0 - \bar{K}^0$ mixing. These different constraints on $\rho$ and $\eta$ are displayed in figure 1, and lead to the following estimates for $\rho$ and $\eta$:

$$\rho = 0.224 \pm 0.038, \quad \eta = 0.317 \pm 0.040 \quad (5)$$

What is perhaps more relevant is the fitted value for $\sin(2\beta)$,

$$\sin(2\beta) = 0.698 \pm 0.066, \quad (6)$$

since this parameter is directly accessible through a study of $CP$ violation in the "golden decay mode" of $B_d^0$ mesons,

$$(B_d^0 \text{ or } \bar{B}_d^0) \to K_S + \Psi \quad (7)$$

In his presentation to this conference, C. Sachrajda has emphasized the central role of Lattice QCD simulations in the determinations of the CKM parameters. Lattice QCD was used for evaluating the $B$ parameter for $K$ mesons, needed in the prediction of $\epsilon$ in terms of $\rho$ and $\eta$, and again for determining the decay and mixing parameters $f_B$ and $B_B$ for both the $B_d$ and $B_s$ mesons, parameters which are needed for the determination of the two mass differences $\Delta m_d$ and $\Delta m_s$. The present simulations are executed within the quenched approximation, due to the limited computer power available today, while more
Figure 1. Constraints on $\rho$, $\eta$ arising from $V_{ub}$, $\epsilon$ — the CP violating parameter in $K^0 - \bar{K}^0$ mixing, and the $B_d^0 - \bar{B}_d^0$ mixing parameter $\Delta m_d$.  

Accurate simulations will be possible with the advent of teraflop class computers.

2.2 New results on CP violation in $B^0$ decays

Results on CP violation in the “golden mode” of Eq. (7) have been presented at this conference both by the Babar experiment at SLAC and the Belle experiment at KeK. The results are in reasonable agreement among themselves and lead to a value of $\sin(2\beta)$ which is in good agreement with the prediction of Eq. (6), a remarkable confirmation of the hypothesis that CP violation phenomena arise from complex elements of the $V$ matrix. The “golden” character of $B_d^0 \to K_S + \psi$ derives from the fact that the final state is a CP eigenstate, and that this decay mode is dominated by a CP conserving tree diagram. Any CP violation observed in this mode must, to an excellent approximation, be attributed to $B_d^0 - \bar{B}_d^0$ mixing.

The interpretation of CP violation in $B_d^0 - \bar{B}_d^0$ mixing is uniquely simple, since this mixing is dominated by a single diagram whose phase is easily seen to be $\exp(2i\beta)$. The measurement of CP violation effects in the decays of Eq. (7) can be directly interpreted as a measurement of the $\beta$ angle in the unitarity triangle of figure 2.

The situation in $B_d^0 - \bar{B}_d^0$ mixing is very different from that in $K^0 - \bar{K}^0$ mixing, which is dominated by a CP conserving diagram, CP violation arising from a second smaller diagram. Contrary to $B_d^0$ case, obtaining information on the mixing matrix from the measurement of CP violation in $K^0$ mixing (the $\epsilon$ parameter) requires a complex theoretical analysis and one must, as noted above, recur to lattice QCD simulations to obtain an estimate of one of the required parameters.

The values of $\sin(2\beta)$ presented here by the two experimental groups are:

$$\sin(2\beta) = 0.59 \pm 0.14_{\text{stat}} \pm 0.05_{\text{syst}} \text{ (Babar)}$$

$$\sin(2\beta) = 0.99 \pm 0.14_{\text{stat}} \pm 0.06_{\text{syst}} \text{ (Belle)}$$

(8)

These are impressive results: each of them by itself establishes the existence of CP violation in $B^0$ decays to many $\sigma$'s. It is remarkable that two rather different experiments at different accelerators and in different laboratories were able to obtain results of comparable accuracy within a few days of each
other.

Three previous measurements of $\sin(2\beta)$, obtained by CDF at Fermilab\textsuperscript{8}, and by Aleph and Opal at CERN\textsuperscript{9}, have larger errors but are generally compatible with the new results, which however supersede earlier preliminary results by the same groups. Combining the five extant results Ahmed Ali\textsuperscript{a} obtains the “world average”

$$\sin(2\beta) = 0.79 \pm 0.12, \quad (9)$$

in excellent agreement with the theoretical prediction in Eq. (6).

2.3 Direct CP Violation in $K^0 \to \pi\pi$; $\epsilon'/\epsilon$

Two experimental groups, NA48\textsuperscript{10} at CERN and KTeV\textsuperscript{11} at Fermilab, have presented new determinations of the direct violation of CP in the decays $K^0 \to \pi^+\pi^-$, $K^0 \to \pi^0\pi^0$, through a measurement of $Re(\epsilon'/\epsilon)$:

$$Re(\epsilon'/\epsilon) = (15.3 \pm 2.6) \times 10^{-4} \quad NA48$$
$$Re(\epsilon'/\epsilon) = (20.7 \pm 2.8) \times 10^{-4} \quad KTeV \quad (10)$$

The two new results are in good agreement, and each of them is many $\sigma$’s away from $Re(\epsilon'/\epsilon) = 0$, so that the presence of direct CP violations in $K^0$ decays is firmly established. The new results are in rough agreement with the previous result by NA31 at CERN and with that obtained by the E731 experiment at Fermilab (which was however compatible with $\epsilon' = 0$).

The new world average is

$$Re(\epsilon'/\epsilon) = (17.2 \pm 1.8) \times 10^{-4} \quad (11)$$

This is in general agreement with the theoretical evaluations, which are however not excessively precise. They are normally quoted as “from a few $10^{-4}$ to $\approx 2 \times 10^{-3}$”. The problem is that the direct violation of CP in $K^0 \to \pi\pi$ decays involves “penguin diagrams” which are at present very hard to evaluate in Lattice QCD. Progress is expected in this direction with the advent on the one side of new high-performance parallel computers and on the other of new algorithms for the simulation of low-mass quarks.

3 Neutrino oscillation: the Solar neutrino puzzle solved?

The solar neutrino puzzle has been with us for over thirty years, since the Davis chlorine experiment\textsuperscript{12} detected only about a third of the neutrinos expected on the basis of the current solar model\textsuperscript{13}.

The deficit of solar neutrinos has over the years been confirmed by the Kamiokande and Super-Kamiokande water detectors, and by the gallium experiments, GALLEX, SAGE and GNO. At the same time the solar model has been refined, and tightened with the help of data on heliosismography, so that we can exclude that the neutrino deficit can find its explanation in some modification of the solar model itself. We can refer the reader to the recent review\textsuperscript{15} by Bahcall, Pinsonneault and Basu.

Already in 1968 Bruno Pontecorvo\textsuperscript{14} proposed that a deficit in solar neutrinos could signal the presence of neutrino oscillations. An important theoretical development was the realization that the coherent interaction with the solar matter can modify the neutrino oscillations\textsuperscript{16} and that this can give rise to resonant transformation between neutrino species even for small mixing angles\textsuperscript{17}.

The coherent interaction of solar neutrinos with the bulk matter of earth could give rise to day-night effects which could be explored by real-time detectors such as Kamland or Borexino.

Many questions remained open: are oscillations real? are the oscillations confined to the known neutrino flavours, or do they in-
volve also new flavours (called sterile neutrinos) which do not partake of neutral current interactions, and do not therefore contribute to the $Z^0$ width.

Results obtained at the Sudbury Neutrino Observatory (SNO)\(^\text{[14]}\), presented at this conference, seem to give a positive answer to this two questions: The solar neutrinos which arrive at the Earth behave as a mixture of $\nu_e$ and other active neutrinos, i.e. $\nu_\mu$ and $\nu_\tau$.

The principle of the SNO experiment is to compare the rate of charged current inverse beta decay events, which can only arise from $\nu_e$’s, and of neutrino-electron scattering events, to which also $\nu_\mu$’s and $\nu_\tau$’s can contribute. The ratio of the two type of events,

$$\frac{CC}{ES} \propto \frac{\nu_e}{\nu_e + 0.14(\nu_\mu + \nu_\tau)}$$

(12)

can be used to deduce the total number of neutrinos, which can than be compared with the solar model prediction. The SNO collaboration has obtained an accurate determination of the CC rate, while their determination of the ES rate is not accurate enough to establish the existence, in the solar flux at the Earth, of a fraction of $\nu_\mu$ and $\nu_\tau$. They can however use the determination of the ES rate obtained\(^\text{[14]}\) at Super-Kamiokande which has the required precision. The two measurements are mainly sensitive to neutrinos in the same energy band, the $B^8$ neutrinos, so that their combination is meaningful. The neutrino fluxes determined through CC and ES events differ by more than three standard deviations, thus giving a strong support for the existence of neutrino oscillations:

$$\Phi^{ES}_{S-K} - \Phi^{CC}_{SNO} = (0.57 \pm 0.17) \times 10^6 \text{cm}^{-2}\text{s}^{-1}$$

(13)

The two measurements, together with Eq. (12), determine the total flux of $B^8$ neutrinos,

$$\Phi = (5.44 \pm 0.99) \times 10^6 \text{cm}^{-2}\text{s}^{-1},$$

(14)

which is in excellent agreement with the solar model predictions. The solar neutrino gap seems to have closed.

In the next few years we expect important results from both SuperKamiokande and SNO. Two new experiments will give important contributions to the unravelling of the solar neutrino problem:

- KamLand will study oscillations in reactor neutrinos with a sensitivity sufficient to confirm or exclude the — now favoured — LM solution for neutrino oscillations.

- Borexino will be able to observe in real time the flux of the low-energy $Be^7$ solar neutrinos. This will allow refined studies of day/night and seasonal effects.

The new SNO data favour\(^\text{[14]}\) large mixing angle oscillation solutions, which opens the way to the possibility of CP and T violation in neutrino oscillations:

$$\begin{align*}
CP : (\nu_1 \rightarrow \nu_2) & \leftrightarrow (\bar{\nu}_1 \rightarrow \bar{\nu}_2) \\
T : (\nu_1 \rightarrow \nu_2) & \leftrightarrow (\nu_2 \rightarrow \nu_1)
\end{align*}$$

Disappearance experiments ($\nu_1 \rightarrow \nu_1$) cannot display CP or T violations

Exploring CP or T violations requires superbeams, or better a dedicated neutrino factory, which is also the first step for a muon collider. Both possibilities have been discussed during this conference.

I cannot resist quoting from a paper I wrote in 1978\(^\text{[13]}\):

"maximal neutrino mixing requires CP violation"

By maximal I mean that all matrix elements of the lepton mixing matrix $V_L$ should have equal size.

Since $V_L$ is unitary, the requirement of maximal mixing has essentially a unique solution which is necessarily complex:

$$V_L = \begin{pmatrix}
1 & x & x^2 \\
x & x^2 & 1 \\
x^2 & 1 & x
\end{pmatrix} ; \ \ x = \exp\left(\frac{2\pi i}{3}\right)$$

We are probably far from this solution, but perhaps not very far.
4 The muon anomaly: signal for new physics?

James Miller presented here the recent results of the Brookhaven measurement \( \mu^0 \) of the muon magnetic anomaly. The new world average,

\[
a_{\mu}^{\text{exp}} = (1165920.3 \pm 1.5) \times 10^{-9}
\]

disagrees with the theoretical prediction \( \mu^0 \) by nearly three standard deviations.

\[
a_{\mu}^{\text{exp}} - a_{\mu}^{\text{th}} = (4.3 \pm 1.6) \times 10^{-9}
\]

The Brookhaven collaboration expects to be able to decrease the experimental error by nearly a factor three in the near future. Already in its present state the discrepancy seems serious and has stimulated a multitude of theoretical papers which examine different possible implications of this discrepancy, which would clearly be a signal for new physics.

The interesting aspect is that the discrepancy is relatively large; by comparison the contribution to the muon anomaly of electroweak effects — diagrams with virtual \( Z^0, W^\pm \) bosons contribute a correction

\[
\delta^{\text{EW}} a_{\mu} = (1.51 \pm 0.04) \times 10^{-9}
\]

In order to explain a discrepancy of \((4.3 \pm 1.6) \times 10^{-9}\) one would need new physics at relatively low energies, in other words this discrepancy looks as excellent news for the forthcoming LHC experiments. It is also clear that in view of the importance of a possible discrepancy both the experimental analysis and the theoretical computations must be submitted to the most careful scrutiny.

The theoretical prediction of the muon anomaly is the sum of diagrams with virtual leptons, photons and intermediate vector bosons,

\[
\begin{align*}
\text{QED} & \quad 116584706(3) \times 10^{-11} \\
\text{EW} & \quad 151(4) \times 10^{-11}
\end{align*}
\]

and diagrams which include virtual hadrons, further divided in \( \alpha^2 \) and \( \alpha^3 \) diagrams which include hadron corrections to the photon propagator (PP), and diagrams with hadronic light by light (LL) subdiagrams. These diagrams are the main sources of the theoretical error,

\[
\begin{align*}
\text{PP; } \alpha^2 & \quad 6924(62) \times 10^{-11} \\
\text{PP; } \alpha^3 & \quad -100(6) \times 10^{-11} \\
\text{LL; } \alpha^3 & \quad -85(25) \times 10^{-11}
\end{align*}
\]

The numbers reported in eqs. \((18 - 23)\) are those used by the Brookhaven collaboration in their analysis.

The hadron corrections to the photon propagator can be related to the total cross section for hadron production in electron positron collisions \( \tau \) and slightly different evaluations of this contribution and of its error arises from the low energy \((\leq 1\text{GeV})\) region. As an alternative to low energy \( e^+ e^- \) data one can use, via the CVC relation, data on the \( \tau \) decay into hadrons, which are at present more accurate. \( \tau \) A number of evaluations of the hadronic photon propagator contribution to the muon anomaly have appeared in recent times, with slightly different results and slightly different evaluations of the error.

Since the hadron correction to the photon propagator is safely anchored to experimental data on \( e^+ e^- \) collisions and \( \tau \) decays, the error on this contribution to the muon anomaly will improve in the next few years. Particularly promising is the advent of the KLOE experiment at the DAΦNE \( \phi \) factory, which should provide a new standard of accuracy for \( e^+ e^- \) cross sections in the low energy region.

The situation of the light by light (LL) hadronic contribution is very different, as we have not found in this case a way to evade the complexities of hadron physics by relating...
this contribution to other measurable phenomena. Waiting for a frontal attack on this contribution using lattice QCD (not easy) we must be satisfied with models whose accuracy is difficult to estimate.

The current evaluations of the hadronic light by light contributions to the muon anomaly are based on models of the light pseudoscalar mesons and their interactions at low energy - chiral perturbation theory or the extended Nambu - Jona Lasinio model. The dominant hadronic LL contribution turns out to be the one mediated by a single intermediate neutral pion.

After the LP01 conference was concluded, a new calculation of the $\pi^0$ contribution to the muon anomaly reached a very surprising conclusion: while previous calculations had found a negative sign, the new result, recently confirmed by an independent computation, found a positive sign. The authors of the two complete evaluations of the LL contributions have been able to identify the origin of what they now see as a sign error in the previous computations and have presented new evaluations for the overall LL contributions, which are respectively $(89 \pm 16) \times 10^{-11}$ and $(83 \pm 32) \times 10^{-11}$. The effect of this sign change is a reduction of the discrepancy to less than 2 standard deviations.

Quite apart from the question of sign of the $\pi^0$ contribution, which only arose after the conference, we must note a detailed criticism by K. Melnikov, who argues that the contribution of quark-loop light by light diagrams has been underestimated in ref. In referring the interested reader to Melnikov’s paper for the details of his argument, I note that this would further reduce the discrepancy between theoretical evaluations and the experimental result. Although the authors of ref. do not agree with this argument, it is clear that, in order to calculate the muon anomaly with a precision comparable with that expected from the Brookhaven experiment, the hadronic light by light contributions must be carefully re-evaluated. The forthcoming measurements of hadron production in low energy electron-positron collisions should lead to an improved evaluation of the contribution of hadronic corrections to the photon propagator.

5 We are not alone!

While all this has been going on, cosmologists . . .

We heard in the talks by Halzen and Turner of the exciting progress our neighbours are making in Cosmology and Astrophysics. With the recent results on the cosmic background anisotropy cosmologists are confirming their own Standard Model.

The new results on the cosmic background arise from a serendipitous use of the antartic winds which circulate around the South Pole: a balloon released from an antartic station comes back close to the same spot in about a month. A balloon circling the South Pole can be very competitive with a satellite: the launch is by far less expensive, and the payload does not need to meet the high standards and associated cost in both money and time that a space launch requires.

In the Boomerang flights the cosmic background has been studied with unprecedented resolution. The angular resolution of the recent data corresponds to spherical harmonics of $\approx 1000$. In this range three peaks are evident in the power spectrum, which fit very well the expectation for a Big-Bang universe at $\Omega = 1$, i.e. a flat universe, whose energy density is much larger than the “observed” baryon density which would correspond to $\Omega \approx 0.05$. This offers further evidence for the conclusion that most of the matter in the universe is “dark matter”, most probably “cold dark matter”, i.e. matter constituted of relatively heavy particles, which have decoupled from “normal” matter early in the history of the universe.
While it is clearly the task of astronomers and cosmologist to ascertain the geometry and history of the universe, the task of attempting the detection of these slow particles coasting along in the present universe falls to the high energy community. Many experiments are now underway for the detection of the weak interacting cold matter, and might bear fruit in the coming years.

6 Conclusions and acknowledgements

This conference has been enlivened by many exciting results. Will the next one be even better? It is a tall order, but beautiful things are brewing.

After decades in which CP violation was established in a single process, the $K^0 - \bar{K}^0$ oscillations, we now have two more well established examples, the first in $B^0 - \bar{B}^0$ oscillations and the second a direct violation in $K^0 \to \pi \pi$. The first is important for the light it sheds on quark mixing and the Standard Model in general, while the measurement of $\epsilon'/\epsilon$ has a very special impact because, apart from it being in general agreement with the still imprecise expectations of the Standard Model, it definitely excludes the “Superweak” models of CP violation.

We can look forward to new results on CP violation: Babar and Belle should be able to establish new examples of direct violation in $B$ decays and the KLOE experiment at DAΦNE should offer a determination of $\epsilon'/\epsilon$ which is logically independent from those presented by the NA48 and KTeV experiments.

The other very exciting development comes from the SNO results which corroborate the conclusion that the solar neutrino puzzle will find its solution in neutrino oscillations. Here we expect important results in the near future from both SNO and Super-Kamiokande, but also from experiments which are now approaching the data-taking phase, in the first instance Kamland and Borexino.

The new results by SNO reinforce the proposal that neutrino oscillations are characterized by large mixing angles, and this opens up a very exciting possibility of detecting CP violation effects in neutrino oscillations. The detection of these effects will however require new neutrino beam facilities, which have been discussed during LP01. A first attempt could be carried out with superbeams while more detailed studies will require the availability of full—fleged neutrino factories.

The success of this conference is certainly the merit of the many research groups who have contributed important new results, and of the many physicists who have contributed well prepared and well documented presentations of the new data, but LP01 would not have succeeded without the efforts of the organizers and of the many young people who have devoted so much time and efforts to its success.

I am particularly grateful to Juliet Lee Franzini and Paolo Franzini, who invited me to give these concluding remarks to a very exciting conference which has turned out to be a real turning point in the kind of physics I have been working on for many years.

To everybody who participated in the conference I would like to present my best wishes that we may all be working very hard, and be ready to surprise each other when we meet in 2003 for the next Lepton Photon Conference.

References

1. N. Cabibbo, Phys. Rev. Lett. 10, 531 (1963).
2. M. Kobayashi and T. Maskawa, Prog. Theor. Phys. 49, 652 (1973).
3. L. Wolfenstein, Phys. Rev. Lett. 51, 1945 (1983).
4. M. Ciuchini, G. D’Agostini, E. Franco, V. Lubicz, G. Martinelli, F. Parodi, P.
Roudeau and A. Stocchi \textit{JHEP} \textbf{0107}, 013 (2001).
5. I.Y. Bigi, A.I. Sanda \textit{Nucl.Phys.} B \textbf{281}, 41 (1987).
6. B. Aubert, \textit{et al} (The BABAR Collaboration), \textit{Phys. Rev. Lett.} \textbf{86}, 2515-2522 (2001).
7. A. Abashian \textit{et al} (Belle Collaboration) \textit{Phys. Rev. Lett.} \textbf{86}, 2509-2514 (2001).
8. T. Affolder \textit{et al}, \textit{Phys. Rev. D} \textbf{61}, 072005 (2000).
9. R. Barate \textit{et al} (ALEPH Collaboration), \textit{Phys. Lett.} B \textbf{492}, 259-274 (2000). K. Ackerstaff \textit{et al.} (OPAL Collaboration) \textit{Eur. Phys. C} \textbf{5}, 379 (1998).
10. L. Iconomidou-Fayard, presented at LP01.
11. R. Kessler, presented at LP01.
12. R. Davis, Jr., D. S. Harmer and K. C. Hoffman \textit{Phys. Rev. Lett.} \textbf{20}, 1205 (1968). R. Davis \textit{Progr. Part. Nucl. Phys.} \textbf{32}, 13 (1994).
13. J. N. Bahcall, N. A. Bahcall and G. Shawiv \textit{Phys. Rev. Lett.} \textbf{20}, 1209 (1968).
14. B. Pontecorvo, \textit{Sov. Phys. JETP}, \textbf{26}, 981 (1968)
15. J. N. Bahcall, S. Basu, and M. H. Pinsonneault, \textit{Astrophys.J.} \textbf{555}, 990-1012 (2001)
16. L. Wolfenstein, \textit{Phys. Rev. D} \textbf{17}, 2369 (1978)
17. S. P. Mikheyev, A. Yu. Smirnov \textit{Sov. J. Nucl. Phys.} \textbf{42}, 913 (1985)
18. Q.R. Ahmad \textit{et al} (The SNO Collaboration), \textit{Phys. Rev. Lett.} \textbf{87}, 071301 (2001).
19. S. Fukuda \textit{et al}, \textit{Phys. Rev. Lett.} \textbf{86}, 5651 (2001).
20. G.L. Fogli, E. Lisi, D. Montanino and A. Palazzo \textit{Phys. Rev. D} \textbf{64}, 093007 (2001).
21. John N. Bahcall, M. C. Gonzalez-Garcia, Carlos Pena-Garay \textit{JHEP} \textbf{0108}, 014 (2001).
22. N. Cabibbo \textit{Phys. Lett} B \textbf{72}, 333–335 (1978)
23. H. N. Brown \textit{et al} (Muon g-2 collaboration), \textit{Phys. Rev. Lett.} \textbf{86}, 2227 (2001).
24. A. Czarnecki and W. J. Marciano, \textit{Phys. Rev. D} \textbf{64}, 013014 (2001).
25. N. Cabibbo and R. Gatto, \textit{Phys. Rev.} \textbf{124}, 1577 (1961).
26. M. Davier and A. Hocker, \textit{Phys. Lett.} B \textbf{435}, 427 (1998).
27. J. F. de Trocóniz and F. J. Ynduráin, \textit{hep-ph/0106023}. F. Jegerlehner, \textit{hep-ph/0104304}. S. Narison, \textit{Phys. Lett.} B \textbf{513}, 53 (2001).
28. M. Hayakawa and T. Kinoshita, \textit{Phys. Rev. D} \textbf{57}, 465 (1998).
29. J. Bijnens, E. Pallante and J. Prades, \textit{Phys. Rev. Lett.} \textbf{75}, 1447 (1995); ibid., \textbf{75}, 3781 (1995), erratum.
30. M. Knecht and A. Nyffeler, Marseille preprint CPT-2001/P.4253, \textit{hep-ph/0111058}, submitted to \textit{Phys. Rev. D}.
31. M. Knecht, A. Nyffeler, M. Perrottet and E. de Rafael, Marseille preprint CPT-2001/P.4260, \textit{hep-ph/0111059}.
32. I. Blokland, A. Czarnecki and Kirill Melnikov SLAC-PUB-9084, \textit{hep-ph/0112117}.
33. M. Hayakawa and T. Kinoshita, \textit{hep-ph/0112102}.
34. J. Bijnens, E. Pallante and J. Prades, \textit{hep-ph/0112253}.
35. K. Melnikov, \textit{hep-ph/0105267}. 