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Rapid Communication

New insights to old problems*

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From the history of the θ–τ puzzle and the discovery of parity non-conservation in 1956, we review the current status of discrete symmetry violations in the weak interaction. Possible origin of these symmetry violations are discussed.

Keywords: history of discovery of parity violation, mixing angles, origin of symmetry violation, scalar field and properties of vacuum
PACC: 1130E, 1130Q, 1200

1. Symmetry violations: the discovery

Almost exactly 50 years ago, I had an important conversation with my dear friend and colleague C. S. Wu. This conversation was critical for setting in motion the events that led to the experimental discovery of parity nonconservation in β-decay by Wu *et al.*[1] In the words of Wu:[2]

'... One day in the early Spring of 1956, Professor T. D. Lee came up to my little office on the thirteenth floor of Pupin Physical Laboratories. He explained to me, first, the τ–θ puzzle. If the answer to the τ–θ puzzle is violation of parity—he went on—then the violation should also be observed in the space distribution of the beta-decay of polarized nuclei: one must measure the pseudo-scalar quantity $< \sigma \cdot \boldsymbol{p} >$ where $\boldsymbol{p}$ is the electron momentum and σ the spin of the nucleus.

... Following Professor Lee's visit, I began to think things through. This was a golden opportunity for a beta-decay physicist to perform a crucial test, and how could I let it pass? ⋯ That Spring, my husband, Chia-Liu Yuan, and I had planned to attend a conference in Geneva and then proceed to the Far East. Both of us had left China in 1936, exactly twenty years earlier. Our passages were booked on the Queen Elizabeth before I suddenly realized that I had to do the experiment immediately, before the rest of the Physics Community recognized the importance of this experiment and did it first. So I asked Chia-Liu to let me stay and go without me.

... As soon as the Spring semester ended in the last part of May, I started work in earnest in preparing for the experiment. ... In the middle of September, I finally went to Washington, DC for my first meeting with Dr Ambler. ... Between experimental runs in Washington, I had to dash back to Columbia for teaching and other research activities. On Christmas eve, I returned to New York on the last train; the airport was closed because of heavy snow. There I told Professor Lee that the observed asymmetry was reproducible and huge. The asymmetry parameter was nearly -1. Professor Lee said that this was very good. This result is just what one should expect for a two-component theory of the neutrino.'

A few days later in January 1957, my other Columbia University colleagues Leon Lederman and Richard Garwin followed with their experiment on parity nonconservation in $\pi - \mu - e$ decay[3] (as will be discussed in the second presentation of today's session by Leon Lederman himself). An explosion of hundreds of other experiments on parity (P) and charge conjugation (C) followed quickly in many physics labora-

*Based on an invited talk given at the 2006 APS Meeting as the first presentation in the Session on 50 Years Since the Discovery of Parity Nonconservation in the Weak Interaction I, April 22, 2006 (Appendix A).

tories all over the world. Their results answered the question that I raised with Yang in our 1956 paper[4] on 'Question of Parity Conservation in Weak Interactions'.

Columbia University was established in 1754 when America was still a British colony. In 1954 on the occasion of the 200th anniversary of Columbia University, the great theoretical physicist Pauli was invited to give a special Bicentennial Lecture at Columbia. His topic was CPT Theorem.[5] As a member of the Columbia physics department, I was in the audience. After his speech, Pauli, I. I. Rabi, C. S. Wu and I had dinner together. Both Rabi and Wu were Pauli's good friends. Pauli's lecture impressed me. By pure deduction, Pauli proved that for a Lorenz invariant local field theory, the combined invariance of CPT naturally follows. Of course, at that time everyone assumes that C, P and T are separately conserved. That one can derive CPT invariance based on locality and Lorenz invariance is interesting, but more as an intellectual curiosity. Two years later in 1956, when the θ–τ puzzle led to the question of parity violation, Pauli's CPT Theorem took on a new significance. If P were violated, at least one other discrete symmetry must also be violated: C or T, or both?

In general, it is difficult to observe T violation (because of the CPT Theorem, the same difficulty applies also to CP violation). In the same year, 1956, Leon Lederman and his group discovered[6] the long lived neutral kaon $K^0_{\rm L}$ (called θ^0_2 then). This discovery was heralded at that time as the proof of C invariance, based on the theoretical analysis of Gell-Mann and Pais.[7] If that were the case, with C conservation and only P and T violations, neither $\pi-\mu-e$ decay nor β-decay could show any sizable observable parity violation effects.

Thus, it became necessary for me to examine the theoretical analysis of Gell-Mann and Pais. With only CPT invariance, the paper of Lee, Oehme and Yang[8] proved that the existence of a long-lived neutral kaon is the consequence of only CPT invariance. It does not imply C invariance. Assuming CPT invariance, the same Lee–Oehme–Yang paper questioned the validity of T and, therefore, also CP invariance. The analysis of interplay between $K^0_{\rm S}$, $K^0_{\rm L}$ (called K_1 and K_2 then) and the strangeness eigenstates was given in the same paper. This provided the theoretical basis for the 1964 experimental discovery of CP and T violations by Cronin, Fitch and their co-workers.[9]

2. Present status: the complexity

The hadronic weak current converts the three charge $2e/3$ quark mass eigenstates u, c, t into three charge $-e/3$ states d', s', b', which are in turn linear superpositions of the mass eigenstates d, s, b through the $SU(3)$ CKM matrix U_h:[10]

$$\left\{\begin{array}{c} d' \\ s' \\ b' \end{array}\right\} = U_h \left\{\begin{array}{c} d \\ s \\ b \end{array}\right\}. \tag{1}$$

Any $SU(3)$ matrix depends on 8 real parameters. Between the initial $(u,\ c,\ t)$ states there are 2 arbitrary relative phases; likewise, there are 2 additional arbitrary relative phases between the three final states $(d,\ s,\ b)$. It is customary[11] to choose the remaining $8-2^2=4$ parameters by four angles, θ_{12}, θ_{23}, θ_{13} and a phase angle δ:

$$\left\{\begin{array}{ccc} c_{12}c_{13} & s_{12}c_{13} & s_{13}{\rm e}^{-{\rm i}\delta} \\ -s_{12}c_{23}-c_{12}s_{23}s_{13}{\rm e}^{{\rm i}\delta} & c_{12}c_{23}-s_{12}s_{23}s_{13}{\rm e}^{{\rm i}\delta} & s_{23}c_{13} \\ s_{12}s_{23}-c_{12}c_{23}s_{13}{\rm e}^{{\rm i}\delta} & -c_{12}s_{23}-s_{12}c_{23}s_{13}{\rm e}^{{\rm i}\delta} & c_{23}c_{13} \end{array}\right\}, \tag{2}$$

with $c_{ij}=\cos\theta_{ij}$ and $s_{ij}=\sin\theta_{ij}$ for the generation labels $i,j=1,\ 2,\ 3$. The approximate experimental determination of the CKM matrix U_h can then be written as

$$U_h \simeq \left\{\begin{array}{ccc} 0.974 & 0.227 & (2-3{\rm i})10^{-3} \\ -0.227 & 0.973 & 0.04 \\ (7-3i)10^{-3} & -0.04 & 0.999 \end{array}\right\}. \tag{3}$$

Likewise, the leptonic weak current connects the three charge leptons $\rm e^-$, μ^- and τ^- into three neutral

states ν_e, ν_μ and ν_τ; which are in turn coherent superpositions of the three mass eigenstates ν_1, ν_2 and ν_3:

$$\left\{ \begin{array}{c} \nu_e \\ \nu_\mu \\ \nu_\tau \end{array} \right\} = U_l \left\{ \begin{array}{c} \nu_1 \\ \nu_2 \\ \nu_3 \end{array} \right\}, \tag{4}$$

where U_l can be cast into the same form (2) and given approximately by[11]

$$U_l \simeq \left\{ \begin{array}{ccc} 0.84 & 0.56 & s_{13}\mathrm{e}^{-\mathrm{i}\delta} \\ -0.4-0.6s_{13}\mathrm{e}^{\mathrm{i}\delta} & 0.6-0.4s_{13}\mathrm{e}^{\mathrm{i}\delta} & 0.7 \\ 0.4-0.6s_{13}\mathrm{e}^{\mathrm{i}\delta} & -0.6-0.4s_{13}\mathrm{e}^{\mathrm{i}\delta} & 0.7 \end{array} \right\} \tag{5}$$

with

$$s_{13}^2 = \sin^2\theta_{13} = 0.9 \begin{array}{c} +2.3 \\ -0.9 \end{array} \times 10^{-2} \tag{6}$$

and δ unknown. The three neutrino mass states form a doublet ν_1, ν_2, with

$$|m_2^2 - m_1^2| = 7.92(1 \pm 0.09) \cdot 10^{-5}\mathrm{eV}^2 \tag{7}$$

and a third singlet ν_3 with mass m_3 given by

$$\left| \, m_3^2 - \frac{m_1^2+m_2^2}{2} \, \right| = 2.4 \times (1 \begin{array}{c} +0.21 \\ -0.26 \end{array}) \times 10^{-3}\mathrm{eV}^2. \tag{8}$$

The signs of these mass differences are not known. As a convention, ν_1 refers to the lighter member of the doublet.

Yes, parity is violated. CP is violated and so are C and T. The questions raised fifty years ago are all answered. Neutrinos are not two-component and leptons have three generations, like the quarks. These two matrices CKM and neutrino mapping represent the fruition of the tremendous 50 year-effort of nuclear and particle physics. The question is: can we read this Rosetta stone[1)] ?

3. Through the looking glass[12]

3.1. Can $U_h \to U_l$ at high energy?

Assume that the only differences between quarks and leptons are QCD and their masses. Since QCD is an asymptotically free theory, at high energy, QCD forces should be asymptotically free. Thus, except for the quark–lepton mass differences, the CKM matrix U_h would become the same as the neutrino mapping matrix U_l at high energy. This hypothesis can be tested either by high energy experiments, or by doing a lattice QCD calculation and examining the change of CKM matrix elements from their low energy values given by (3) to their high energy values given by (5). In the following, we shall assume that this is indeed the case: the CKM matrix U_h does approach the neutrino mapping matrix U_l at very high energy. Thus, the task of understanding the mystery of two matrices CKM and ν-mapping is reduced to that of one matrix, the ν-mapping matrix U_l.

3.2. An approximate geometric representation of U_l

We assume that the ν-mapping matrix elements are all determined by vacuum expectation values of a set of spin 0 fields. In that case, these vacuum expectation values can acquire a geometric shape.[13] As an approximation, we may set $s_{13}\mathrm{e}^{\mathrm{i}\delta} \simeq 0$, in accordance with (6); this reduces U_l to a standard rigid body rotation matrix in three dimensions.

1) Rosetta stone is an ancient stone found at a small village named Rosetta in Egypt in 1799. The text carved on the stone in 196 B.C. is in Egyptian and Greek, using three different scripts. Many people worked for over several hundred years to decipher the text written in hieroglyph.

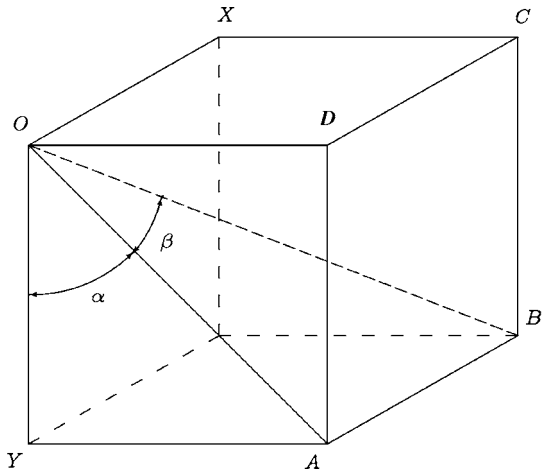


Fig.1. A Geometric representation of the neutrino-mapping matrix (see Eq.(12)).

Consider the cube in Fig.1, in which we designate the seven visible corners in the figure as O, X, Y and A, B, C, D. Regard $\overline{OX}$, $\overline{OY}$ and $\overline{OZ} = -\overline{OD}$ as the Cartesian coordinates along the state vectors representing ν_e, ν_μ and ν_τ. Let the angles α and β be

$$\alpha = \angle YOA = 45^\circ$$

and

$$\beta = \angle AOB = \sin^{-1}\sqrt{\frac{1}{3}}. \tag{9}$$

A left-hand rotation of $\alpha = 45^\circ$ along $\overline{OX}$ is represented by the matrix

$$R_1 = \begin{Vmatrix} 1 & 0 & 0 \\ 0 & \sqrt{\frac{1}{2}} & -\sqrt{\frac{1}{2}} \\ 0 & \sqrt{\frac{1}{2}} & \sqrt{\frac{1}{2}} \end{Vmatrix}, \tag{10}$$

which rotates $\overline{OY}$ and $\overline{OZ}$ to $\overline{OY}'$ and $\overline{OZ}'$. A subsequent left-hand rotation of $\beta = \sin^{-1}\sqrt{\frac{1}{3}}$ along $\overline{OZ}'$ is represented by

$$R_2 = \begin{Vmatrix} \sqrt{\frac{2}{3}} & -\sqrt{\frac{1}{3}} & 0 \\ \sqrt{\frac{1}{3}} & \sqrt{\frac{2}{3}} & 0 \\ 0 & 0 & 1 \end{Vmatrix}. \tag{11}$$

Consider the transformation

$$\begin{Vmatrix} \nu_1 \\ \nu_2 \\ \nu_3 \end{Vmatrix} = R_2 R_1 \begin{Vmatrix} \nu_e \\ \nu_\mu \\ \nu_\tau \end{Vmatrix}$$

i.e.,

$$\begin{Vmatrix} \nu_e \\ \nu_\mu \\ \nu_\tau \end{Vmatrix} = \tilde{R}_1 \tilde{R}_2 \begin{Vmatrix} \nu_1 \\ \nu_2 \\ \nu_3 \end{Vmatrix}$$

with $\sim$ denoting the transpose. From (10) and (11), we have

$$\tilde{R}_1\tilde{R}_2 = \begin{Vmatrix} \sqrt{\frac{2}{3}} & \sqrt{\frac{1}{3}} & 0 \\ -\sqrt{\frac{1}{6}} & \sqrt{\frac{1}{3}} & \sqrt{\frac{1}{2}} \\ \sqrt{\frac{1}{6}} & -\sqrt{\frac{1}{3}} & \sqrt{\frac{1}{2}} \end{Vmatrix} \cong \begin{Vmatrix} .8165 & .5773 & 0 \\ -.4082 & .5773 & .7071 \\ .4082 & -.5773 & .7071 \end{Vmatrix}, \tag{12}$$

consistent with (5), our present knowledge of U_l within the experimental uncertainties of its matrix elements.[11]

3.3. Origin of symmetry violation

We shall explore the attractive possibility that all symmetry violations occur spontaneously; i.e., via the Higgs mechanism.[14] It follows then that the electroweak gauge fields (i.e., $W_\mu^\pm$, Z_μ^0 and A_μ^0) are right-left symmetric, as well as time reversal and CP symmetric. The simplest theory would be the $SU(2)_{\rm L} \times SU(2)_{\rm R} \times U(1)$ model;[15] such a model predicts the existence of additional heavier righthanded $W_\mu^\pm(R)$ and $Z_\mu^0(R)$, which are as yet not observed.[11] In this approach, all spin$\neq 0$ fields are symmetry conserving and, by themselves, are all of zero mass; these include graviton in general relativity, $SU(3)$ colour gauge field in quantum chromodynamics, the electro-weak gauge field, as well as the spin $\frac{1}{2}$ quark and lepton fields. Thus the gauge fields are simple to comprehend, but the complexity

of our universe is rested in the spin 0 fields.

There are good reasons to believe that the Higgs mass $m_{\rm H}$ is not too high, with $m_{\rm H} < 195{\rm GeV}$.[11,16] One reason for the experimental difficulty of detecting Higgs could be that the radial size $r_{\rm H}$ of the Higgs is much larger than its Compton wavelength $m_{\rm H}^{-1}$:

$$r_{\rm H} > m_{\rm H}^{-1}. \tag{13}$$

Such an object would be hard to detect by searching for its complex poles. A good example is the Cooper pair in superconductivity.[17] Another example is the σ-model,[18] which is extremely valuable in describing the low energy pion–nucleon physics; yet, the σ-pole itself is still not discovered.

The search for Higgs is a deep and important subject; it has relevance to several other major fields of physics, as we shall discuss.

4. Importance of the spin 0 field

Recently there exists strong evidence[19] that the cosmological constant Λ is not only nonzero, but very large and most likely not a constant. Its energy density (also called dark energy) is

$$\rho_\Lambda \sim 3 \ - \ 7 \times 10^{-6} \ {\rm GeV/cm}^3 \tag{14}$$

comparable to the critical energy density of our entire universe

$$\rho_c \sim 1 \times 10^{-5} \ {\rm GeV/cm}^3. \tag{15}$$

Furthermore, Λ corresponds to a negative pressure. What is the origin of this negative pressure? Why should ρ_Λ and ρ_c be of the same order of magnitude?

At the end of last year, the American Institute of Physics announced[20] that the top physics story of 2005 is the RHIC discovery (at the Relativistic Heavy Ion Collider, Brookhaven National Laboratory) of a strongly interacting quark–gluon plasma (called sQGP), which behaves almost like a perfect fluid, with very low viscosity. The search for such a new state of nuclear matter has been a holy grail of high energy nuclear physicists since early 1974,[21] through intensive experimental efforts at BEVALAC at Berkeley, AGS at Brookhaven and SPS at CERN. Now, finally it is discovered at RHIC. However, the theoretical basis and understanding of sQGP is still at the very beginning. Undoubtedly, the start of LHC programs at CERN next year will be critical to our future understanding. What is the nature of this nearly perfect nuclear sQGP fluid? Does it depend only on quantum chromodynamics? Does it also depend on other interactions?

In the following, I wish to present a unifying view: the negative pressure of dark energy, the nearly perfect fluidity of sQGP and the symmetry violations in the electroweak (as well as that in all physics) are all due to a family of spin 0 fields. The basic mechanism is the same as that used in the MIT bag model[22] and the Dirac model of muon.[23]

Consider a scalar field ϕ, which can be either a fundamental field or a composite one, made of other fields, such as the σ-model and Higgs field. Since by using the products of any field, one can always construct a scalar component, the physical basis for the existence of such a scalar component ϕ is quite general. The vacuum is a scalar, hence ϕ is coupled to the vacuum and therefore, to the inertia of any physical particle. In the physical vacuum state, the field ϕ has an expectation value designated by $\phi_{\rm vac}$. Take the state of any single ith particle. Define its coupling g_i to ϕ by

$$m_i = g_i \ \phi_{\rm vac}, \tag{16}$$

where m_i is its physical mass. Next, consider the transformation

$$\phi \to \phi + c, \tag{17}$$

where c is a constant; correspondingly the vacuum state is changed to an excited state, in which the expectation value of ϕ changes accordingly

$$\phi_{\rm vac} \to \phi_{\rm vac} + c. \tag{18}$$

Hence the mass m_i of any ith particle will also be altered, with

$$m_i \to m_i + g_i \ c \tag{19}$$

(except ϕ, its mass changes in a different way). Choose the constant c to be given by

$$c = -\phi_{\rm vac}. \tag{20}$$

Then, (18) and (19) become

$$\phi_{\rm vac} \to 0 \tag{21}$$

and

$$m_i \to 0. \tag{22}$$

Since in any field theory, one can always construct a scalar component ϕ, this means for any single physical ith particle, there exists an excited single particle state in which its mass is zero. The generality of this argument is the origin of negative pressure, as we shall see.

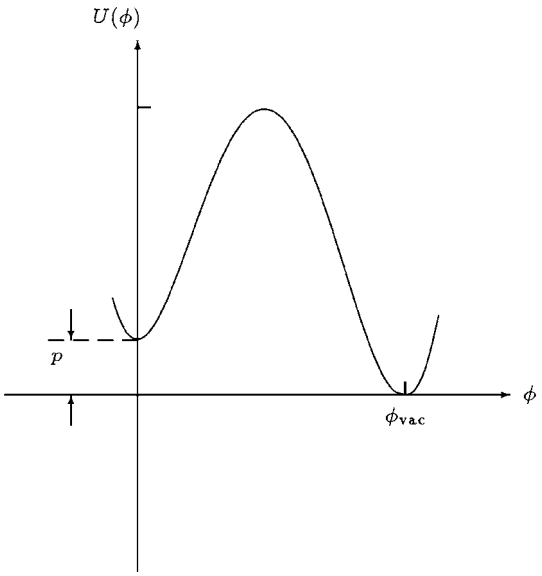


Fig.2. A phenomenological potential function $U(\phi)$.

The transformation (17) transforms the vacuum state to an excited state with a different expectation value from $\phi_{\rm vac}$. Its excited energy is proportional to the energy density function $U(\phi)$ and the volume Ω of the excitation. An example of $U(\phi)$ is given in Fig.2, with the abscissa ϕ denoting the value $\phi_{\rm vac}+c$ in (18).

For a single particle state in an infinite volume, transformations (21) and (22) lead to excited states with an infinite excitation energy. But for a system of particles within finite volume, such changes may occur spontaneously.

Figure 3 gives the energy balance of the MIT bag model of a single nucleon, consisting of three quarks. One assumes the expectation value of ϕ to be $\phi_{\rm vac}$ outside the bag, but zero inside. Thus the quark mass is zero inside the bag, yielding a quark matter energy $E_{\rm Q}$ proportional to $1/R$, where R is the bag radius. Since the magnitude $E_{\rm p}$ of the energy due to the negative pressure $-p$ is proportional to R^3, from equipartition of energy it follows that

$$E_{\rm Q}=3E_{\rm p}. \tag{23}$$

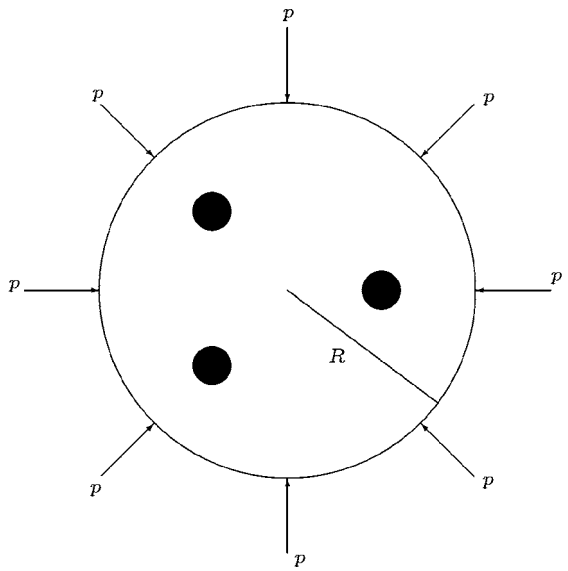
The total energy E of the system is determined by

$$E-E_{\rm p}=E_{\rm Q}. \tag{24}$$

From (23) it follows then

$$E=4E_{\rm p}. \tag{25}$$

For more complex bag models, the ratio of the total energy E to the energy $E_{\rm p}$ due to the negative pressure can vary, but $E_{\rm p}$ is always a sizable fraction of E, like the virial coefficient in the kinetic theory of gases.



$$E-\frac{4\pi}{3}R^3p=N_{\rm Q}\frac{2.04}{R},$$
$$4\pi R^2p=N_{\rm Q}\frac{2.04}{R^2},$$
$$\rho_E\equiv\frac{E}{4\pi R^3/3}=4p,$$
$$\rho_{\rm Q}\equiv N_{\rm Q}\frac{2.04}{4\pi R^4/3}=3p.$$

Fig.3. MIT bag model.

The Higgs field in the electroweak theory is a member of a larger family of spin 0 fields which may all be called the inertia field. Because the inertia field can convert inertia to energy and vice versa, it connects the microscopic world (like $W^{\pm}$ and Z^0) to the macroscopic world (like the cosmological constant). In this view, the origin of all symmetry breaking is due to the inertia field, and the action of all spin $\neq 0$ fields are symmetry conserving.

Thus, $W^{\pm}$ and Z^0 are tiny bags, the nucleons are small bags, the sQGP are manifestations of bigger bags and our whole universe is a very, very large bag. Through the inertia field, our microscopic world of particles becomes closely connected to the macroscopic world of our universe.

After 50 years since the discovery of parity nonconservation in the weak interaction, we may poise at the beginning of search for the origin of all symmetry violations in fundamental physics.

Appendix A

2006 APS April Meeting
Saturday-Tuesday, April 22-25, 2006, Dallas, TX

Session E5a: 50 Years Since the Discovery of Parity Nonconservation in the Weak Interaction I

Sponsoring Units: FHP DPF
Chair: Natalie Roe, Lawrence Berkeley National Laboratory
Hyatt Regency Dallas—Pegasus B

Saturday, April 22, 2006	E5a.00001: New Insights to Old Problems
3:30pm - 3:57pm	Invited Speaker: Tsung Dao Lee, Columbia University

Abstract

From the history of the $\theta - \tau$ puzzle and the discovery of parity non-conservation in 1956, we review the current status of discrete symmetry violations in the weak interaction. Possible origins of these symmetry violations are discussed.

Saturday, April 22, 2006	E5a.00002: Cracks in the Mirror: Saga of a 36 Hour Experiment
3:57pm - 4:24pm	Invited Speaker: Leon Lederman, Fermi National Accelerator Laboratory

Abstract

The history of the fall of parity, mirror symmetry, emerges from a puzzle in the behaviour of particles ($\tau - \theta$ puzzle). This stimulated the Lee-Yang paper of mid-1956 questioning the validity of parity in the weak interactions. They specifically raised the issue of the weak decays $\pi^{\pm} \to \mu^{\pm} + \nu$ and $\mu^{\pm} \to e^{\pm} + 2\nu$. In subsequent detailed discussions between C.S. Wu and T.D. Lee, Wu designed a collaborative experiment with physicists from the Bureau of Standards in Washington, DC, which examined the decay of Co^{60}, an easily polarizable nucleus. Early positive results of the Wu experiment were discussed at a Friday lunch traditionally 'chaired' by T. D. Lee. The precise date was the Friday of the first working week after the New Year, 1957. Here, for what was probably the first time, the possibility was raised that the failure of parity conservation could be a large effect. The conversation at the very traditional Chinese lunch was exciting. This new concept stirred me in my drive from Columbia to home in Irvington, actually a short walk to the Nevis laboratory where Columbia's 400 MeV synchrocyclotron laboratory was housed. The events of the next few days are the substance of my paper. By Tuesday noon, the word had spread around the world that parity conservation was dead. By that time we had a 20 σ effect and many of the essential tests of validity of our experiment were done. Some of the consequences important to that time, and some still relevant in 2006, will be presented.

Saturday, April 22, 2006	E5a.00003: Do Left-handed Neutrino Have Rights Too?
4:24pm - 4:51pm	Invited Speaker: Janet Conrad, Columbia University

Abstract

As with any great discovery, the result of C. S. Wu's experiment on parity violation opened up many more questions. This talk explores these questions in light of recent discoveries about neutrino properties and the potential for new discoveries at the highest energy scales.

Session E5b: 50 Years Since the Discovery of Parity Nonconservation in the Weak Interaction II

Sponsoring Units: FHP DPF
Chair: Noemie Koller, Rutgers University
Hyatt Regency Dallas—Pegasus B

Saturday, April 22, 2006 E5b.00001: In Which Direction Is the Door?
5:00pm - 5:27pm Invited Speaker: C. N. Yang, SUNY-Stony Brook, Emeritus

Abstract

This abstract was not received electronically.

Session P10: 50 Years Since the Discovery of Parity Nonconservation in the Weak Interaction III

Sponsoring Units: FHP DNP
Chair: Susan Seestrom, Los Alamos National Laboratory
Hyatt Regency Dallas—Cumberland C

Monday, April 24, 2006 P10.00001: The Question Answered
10:45 - 11:21am Invited speaker: Ralph P. Hudson
National Institute of Standards and Technology (retired)

Abstract

Fifty years ago, theoreticians T. D. Lee and C. N. Yang reached the conclusion that no experimental evidence existed to show that parity is conserved in weak interactions. The speaker will explain how it happened that a team of physicists at the U.S. National Bureau of Standards in Washington, DC came to perform the revolutionary experiment that demonstrated the failure of parity conservation in nuclear beta-decay.

Monday, April 24, 2006 P10.00002: Chien-Shiung Wu as a Person and a Scientist
11:21am - 11:57am Invited Speaker: Vincent Yuan, Los Alamos National Laboratory

Abstract

Chien-Shiung Wu is well known for her outstanding contributions to Nuclear Physics in Parity Violation and Beta Decay. I will discuss my view of her as seen from my vantage point as her son.

Monday, April 224, 2006 P10.00003: Looking through the Mirror: Future Directions in Parity Violations
11:57am - 12:33am Invited Speaker: M. Ramsay-Musolf, California Institute of Technology

Abstract

Over the past fifty years, studies of parity violation (PV) involving atoms, nuclei, and elementary particles have taught us a great deal about the electroweak and strong interactions. The future of this field promises to be equally rich. In this talk, I discuss new initiatives using PV to study weak interactions among quarks, to probe the structure of the nucleon, and to search for physics beyond the Standard Model.

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