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STABLE PARTICLES AS BUILDING BLOCKS OF MATTER *

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ABSTRACT

Only absolutely stable particles can be truly elementary. A simple theory of matter based on the three constituents, proton, electron and neutrino (and their antiparticles), bound together by the ordinary magnetic forces is presented, which allows us to give an intuitive picture of all processes of high-energy physics, including strong and weak interactions, and make quantitative predictions.

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I. INTRODUCTION

"Can high-energy physics be too easy?" asked a recent editorial in "Nature"[1]. At present, the picture mostly used in high-energy phenomenology is becoming admittedly very complicated. Besides leptons (which we see), one introduces families of "quarks", each with different colours, then the so-called "gluons", which are the gauge vector mesons binding the quarks, then there are the so-called "Higgs particles", which give masses to some of the vector mesons (all of which are not seen in the laboratory). One is already beginning to talk about a second generation of more fundamental and simpler objects for these quarks and gluons etc., even though these first generations of "basic" objects have not been seen. This type of framework seems to create more problems than it solves[2].

Against this background of recent developments, we wish to expand here a very intuitive and simple physical theory, along the traditions of atomic and nuclear structure theories, from which a unified picture of high-energy phenomena can be deduced. High-energy physics is very expensive. One must have alternative views, if only to test better the inevitability of the orthodox picture. Furthermore, physical phenomena must be explainable in a simple intuitive form in terms of already verified definite primary concepts, and continuous with the existing physics.

II. THE PHYSICAL PRINCIPLES

Atoms and molecules are best described as built from electrons and nuclei bound by Coulomb forces because they disintegrate into electrons and nuclei, which we detect, and because these constituents are stable as far as atomic processes are concerned. In turn, nuclei and all the hadrons eventually decay into the absolutely stable particles: protons, electrons, neutrinos and photons (electromagnetic field). We present here a theory in which all matter is made up of these stable constituents, bound again by electromagnetic forces. One can of course ask questions about the nature of the absolutely stable particles themselves. This is another level of enquiry. In this paper we shall take these as given and elementary.

At first such an idea might seem impossible or outrageous, because electromagnetic forces between p, e and ν (and their antiparticles) cannot possibly, one would think, give the necessary strong binding and strong interactions between hadrons. On the other hand, the idea that stable particles are the constituents of hadrons is probably very old as a general idea, if not carried out in specific details. For example, with the hypothesis of neutrino in β decay, Pauli's model of the neutron was a bound state proton, electron and antineutrino [3]. This model was soon abandoned (to be revived much later [4]) for one did not know how to suppress the large magnetic moment of the electron (on nuclear scale) inside the nucleus, and one did not know any deep enough well to contain or confine the electron in the nucleus.

What is new, however, is the recognition that magnetic forces between the stable particles, when treated non-perturbatively, become very strong at short distances (short ranged), provide a deep enough well to give rise to high mass narrow resonances, have saturation property and give rise by magnetic pairing to the compensation of the large magnetic moment of the electron. In the construction of atoms and molecules we make use only of the electric (Coulomb) part of the electromagnetic forces and treat magnetic forces as small perturbations. There is, however, another regime of energies and distances in which magnetic forces play the dominant role and the electric forces are small perturbations. We shall show this duality with explicit calculations. It would have been strange if Nature provided magnetic forces just to be tiny corrections to the building principle of atoms and molecules (which could exist without them) and not to play an equally important role in the structure of matter. Clearly, a model of this type also automatically provides a dynamical theory of nuclear forces.

There are two main immediate questions or objections to our propositions. Why do we not see in the laboratory strong forces between proton and electron, electron and positron, or electron and neutrino etc., whereas we see strong forces between pions and protons, or protons and neutrons etc.? How can we obtain the rich world of hadrons just starting from the three stable particles p, e, ν (and their antiparticles), the multitude of internal quantum numbers like isospin, strangeness, charm etc., the multiplet structures and symmetries?

Correspondingly, this work has two parts. A kinematical part showing the composition of all hadrons and their multiplet structures, hence the meaning of internal quantum numbers in terms of the stable particles, p, e, ν. This by itself is a remarkable mapping of hadron states onto the combinations of stable particles, the eventual final products of all unstable matter, and of hadron quantum numbers into those of three stable particles, p, e, ν.

The second part is dynamical showing that ordinary magnetic spin-spin and spin-orbit forces, when treated non-perturbatively, have the correct size (strength) and shape to give hadronic and nuclear states.

We begin with the second part in order to answer immediately the problems raised above.

A number of models, with increasing complexity, have been studied in recent years, and we have a good understanding of the spin-spin and spin-orbit potentials at short distances [4)-7)]. Consider, for example, a relativistic charged spinless particle m in the field of a fixed (quantum) magnetic momentum $\mu\vec{\sigma}$ [8], or alternatively, a charged spin-$\frac{1}{2}$ particle of mass m and magnetic moment $\vec{\mu}$, in the field of a fixed charge [9]. In both cases, the effective radial equation can be written, in appropriate co-ordinates, as

$$\left(-\frac{d^2}{dy^2} + V(j,\ell,r)\right) u = \lambda u , \qquad (1)$$

where the effective potential is given, apart from the Coulomb potential $\frac{a}{y}$, by

$$V(j,\ell,r) = \frac{\ell(\ell+1) - \alpha^2}{y^2} + \varepsilon\,\frac{2c(j,\ell)}{y^3} + \frac{1}{y^4} \; . \qquad (2)$$

with $\varepsilon = \pm 1$ (relative sign of the charge and magnetic moment); $c(j,\ell)$ is equal to $-(\ell+1)$ for $\ell = j + \frac{1}{2}$ and equal to ℓ for $\ell = j - \frac{1}{2}$. Furthermore (in units $c = \hbar = 1$), $r = \mu e y = \mu_0 \frac{\alpha}{2M} y$ (M is the mass of fixed magnetic moment - in the second case put $M = m$), and the eigenvalue λ is

$$\lambda = (E^2 - m^2)\,\mu^2\alpha^2 = (E^2 - m^2)\,\frac{\mu_0^2\alpha^2}{4M^2} \; . \qquad (3)$$

If we solve the same problem with a Dirac equation and give also an anomalous magnetic moment a to the particle, then additional terms are added to Eq.(2).[5] Further models also treat the magnetic moments of both of the particles.

The potential (2) is treated in atomic phenomena (lately also in the quark model) as a perturbation. This is justified if the energies are of the order of Coulomb energies and for Coulombic bound state wave functions. New phenomena occur, however, if the magnetic potential is treated non-perturbatively. Fig.1 shows the schematic form of the potential at two different energies and angular momenta in the case when the anomalous magnetic moment terms are included. We see three distinct regions of potential wells: The Coulomb region at distances $r \cong \frac{1}{\alpha m}$ (Bohr radius), hence momenta of the order of αm or non-relativistic energies of the order of $\alpha^2 m$ the nuclear region at $r \cong \frac{\alpha}{m}$, (relativistic) energies $\frac{m}{\alpha}$ (~100 MeV) and the supernuclear region of $r \cong \frac{\alpha^2}{m}$ and energies $\frac{m}{\alpha^2}$ (10 GeV).

The form of the potential at very short distances is still quite uncertain in these models. Furthermore, the potentials are modified by form factors. Form factors must also be calculated non-perturbatively, and self-consistently from the wave functions which are localized around each well, respectively, in Fig.1. 6),7) Form factors can easily be incorporated into the model (1)-(2) by taking $\mu = \mu(r)$. At intermediate distances the form of the potential is essentially correct. Unfortunately, quantum electrodynamics cannot tell us anything about the non-perturbative short distance behaviour of the potential between two particles.

Zero-mass limit

It is important for our model later to remark that Eqs.(1) and (2) also hold for a massless particle in the field of a magnetic moment, or for a massless particle with an anomalous magnetic moment (or with only an anomalous form factor) in the field of a charge 10). Note that mass m appears only in Eq.(3).

We can now answer the question as to why we apparently do not see strong interactions in the laboratory between the stable particles p, e, ν.

Scattering against a barrier

The effect of large repulsive potential barriers as in Fig.1 on the scattering of two fermions (say e^+, e^-) can be evaluated numerically (and sometimes analytically). The cross-section of penetration to the attractive region is very small except at the sharp energy and angular momentum of the resonance, when "resonance penetration" 11) takes place. The partial phase shift, shown in Fig.2, shows a sharp jump of about π near the resonance energy (anomalous scattering). The sharper the resonance, the steeper is the jump of the phase shift. The effect of this behaviour on the total cross-section is, however, only a small bump, its width being proportional to the width of the resonance (Fig.2). Indeed most hadron resonances are experimentally seen as such small bumps in cross-sections on a large background. Some predictions based on this phenomenon will be made after we present the model of hadrons.

On the other hand, a pion, being itself a spin-zero resonance state of stable particles (see following sections), can penetrate much more easily into the region of strong magnetic forces of other hadron constituents, because of the absence of the spin-spin barrier.

An important property of magnetic potentials (Fig.1) is that the scattering amplitude is analytic in the whole of the angular momentum plane, hence is a sum of Regge pole contributions only. This has many applications in the analysis of scattering processes.

III. ORDINARY AND STRANGE MATTER

Ordinary matter can be built up from p, e and ν (and their antiparticles) according to the rules that we shall state explicitly. These are pions, neutron and Δ resonances, hence also nuclear matter, atoms and molecules. In order to describe the building-up principle in a more general way to include "strange" particles, we must first talk about the μ meson. The μ meson can be thought of as a magnetic excitation of the electron due to the interaction of its anomalous magnetic moment with its own field. These arguments are at present semiclassical 12),13). Another (perhaps equivalent) way, from our point of view, is to consider μ as a magnetic resonance state of $(e\nu\bar{\nu})$ into which it decays. We shall see that the pairs of the type $(e\bar{\nu})$ are identified with pions. Thus, in order to obtain a spin-$\frac{1}{2}$ state we need three stable particles, and $(e\nu\bar{\nu})$ is then dynamically a little more stable than the $(e\bar{\nu})$ states.

The magnetic three-body problem $(e\nu\bar{\nu})$ can be approximated by an equivalent two-body problem $(e\bar{\nu})\nu$ and considerations similar to Eqs.(1)-(3) may be applied. The charge-magnetic moment system gives in the Bohr-Sommerfeld quantization a quantized energy spectrum of the form $\Delta E = \lambda n^4$, $n = 1,2,3,\ldots$ Adding this to the rest mass, one obtains a leptonic mass spectrum

$$M_N = m_e + \frac{3}{2}\frac{1}{\alpha}\, m_e \sum_{n=0}^{N} n^4 \qquad (4)$$

for electron ($N = 0$), muon ($N = 1$), τ($N = 2$),... The predictions for muon (105.55 MeV) and τ(1786.08 MeV) work very well and the next lepton predicted is δ(10.293 GeV). The coefficient $\lambda = \frac{3}{2}\frac{1}{\alpha} m_e$ can also be derived by semiclassical arguments 12). These results should only be considered as a beginning of a dynamical theory of heavy leptons. Nevertheless, they are interesting, because we have no other hints or ideas concerning the repetitions of leptons in the series e, μ, τ,..., which is one of the most fundamental open problems of particle physics 14).

The ν resonances are inferred from the $m = 0$ limit of the Dirac equation in models similar to Eqs.(1)-(3). Hence an interacting ν is necessarily a four-component neutrino. Only in the asymptotic region can the free Dirac equation split into two two-component equations. We shall make the hypothesis that the neutrino has an anomalous magnetic moment, or at least a magnetic form factor, even if its magnetic moment is zero (on the mass shell). We also do not make, at this stage, a difference between ν_e and ν_μ.

The μ meson, behaving very much like the electron, can in turn form magnetic pairings and resonances with the stable particles, forming the so-called "strange" hadrons. In fact, it will turn out that the number of $\mu^{\pm}$ mesons in hadrons is exactly equal to the "strangeness" quantum number of hadrons. This apparently new type of hadrons is more unstable and decays into ordinary hadrons if the μ inside the hadron decays. During strong interactions, μ is stable, hence strangeness is conserved (see also next section). The μ meson, rather than being a "redundant" particle ("the world would be the same if μ did not exist"(!)) now plays an essential role in building up the hadrons.

IV. CONSTRUCTION OF HADRON STATES AND BUILT-IN CONSERVATION LAWS

There is a very simple relationship between lepton quantum numbers and quark quantum numbers. If we compare the triplet $\ell = (\nu, e^-, \mu^-)$ with the quark triplet $q = (u, d, s)$, we have

$$Q_q = Q_\ell + \frac{2}{3} B_\ell , \quad B_q = B_\ell - \frac{2}{3} B_\ell \quad , \tag{5}$$

where B_ℓ stands for the lepton number and B_q for the baryon number. This we have called the "shifting principle": shifting two-thirds of the lepton number into the electric charge. Hence

$$Q_\ell + B_\ell = Q_q + B_q \quad .$$

It is then straightforward to construct the meson quantum numbers as $(\ell\bar{\ell})$ states, both pseudoscalar and vector mesons.

In the case of baryons, the proton is always a final constituent of all baryons. The baryons cannot be constructed as $(\ell\ell\ell)$ states because then L would be equal to 3 and B = 0 but as $p\ell\bar{\ell}$ states giving total baryon number B = 1 and lepton number L zero.

The conservation of lepton and baryon numbers and charge are automatically built-in in this model, because p, e and ν are absolutely stable. The only dynamical process is the pair production of constituents which conserves Q, B and L.

A physical interpretation of the mysterious internal quantum numbers, like isospin and strangeness, emerges from the model. As we have noted, the μ number is equal to the strangeness number S. Hence the number of all quantum numbers is reduced by 1: $S = N_{\mu^+} - N_{\mu^-}$.

The isotopic spin quantum number essentially counts the number of stable constituents (p, e and ν). In order to see this more precisely, we first define the third component of isospin and the isospin creation and annihilation operators

$$I_3 = \frac{1}{2} (N_p - N_{\bar{p}} + N_{e^+} - N_{e^-} + N_\nu - N_{\bar{\nu}}) \quad ,$$

$$I_+ = \frac{1}{\sqrt{2}} (a_\nu^+ a_{e^-} + a_{e^-}^+ a_{\bar{\nu}}), \; I_- = (I_+)^\dagger \quad . \tag{6}$$

The empirical Gell-Mann-Nishijima formula is now derived and automatically also built in the model:

$$Q = N_p - N_{\bar{p}} + N_{e^+} - N_{e^-} + N_{\mu^+} - N_{\mu^-} = I_3 + \frac{1}{2} (N_p - N_{\bar{p}} + S) , \tag{7}$$

because $\sum_\ell N_\ell = \sum_{\bar{\ell}} N_{\bar{\ell}}$ for all states (i.e. $N_{e^+} + N_{\mu^+} + N_{\bar{\nu}} = N_{e^-} + N_{\mu^-} + N_\nu$).

Figs. 3, 4 and 5 show the hadron multiplets in minimal realization.15) We can of course add to each hadron a lepton pair $(\ell\bar{\ell})$ of the same species without changing the quantum numbers. For example, the physical proton can be thought of as having a π^0 cloud:

$$p_{\text{physical}} = p \left(\frac{1}{\sqrt{2}} (e^- e^+ - \nu\bar{\nu}) \right) , \tag{8}$$

as can be seen by applying I_- to it or I_+ to the neutron state.

A full physical interpretation can be given to the concept of isospin as the quantum-mechanical exchange process of the lepton pair $(e^-\bar{\nu})$ between two systems, exactly like the exchange effects in H_2^+ molecule. To see this we go to the two-nucleon problem, where the notion of isospin has historically originated. The states of definite isospin are

$$pp, \; \frac{1}{\sqrt{2}} (pn + np), \; nn \; (I = 1), \text{ and } \; \frac{1}{\sqrt{2}} (pn - np) \quad (I = 0) \quad .$$

In the $I_3 = 0$ state, $(e\bar{\nu})$ is exchanged between the two protons and we have the symmetric (I = 1) and antisymmetric (I = 0) states with respect to the exchange, which are eigenstates of the total Hamiltonian. We could make a similar isospin triplet and singlet in atomic physics with

$$pp, \; \frac{1}{\sqrt{2}} (Hp + pH) \equiv H_2^-{}_{\text{sym.}} , \; H_2 \; ; \quad \frac{1}{\sqrt{2}} (Hp - pH) \equiv H_2^-{}_{\text{antisym.}} \quad .$$

Here (p,H) is an isospin-doublet ($I_3 = +\frac{1}{2}$ and $-\frac{1}{2}$) and $Q = I_3 + \frac{1}{2}$. Also $I_+ = a_p a_H^+$. Similarly, if we look at two-pion states of definite isospin

$$|\pi^\pm\pi^\pm\rangle \;,\; \frac{1}{\sqrt{2}}\{|\pi^\pm,\pi^0\rangle + |\pi^0,\pi^\pm\rangle\},\; \frac{1}{\sqrt{6}}\{2|\pi^0\pi^0\rangle + |\pi^+\pi^-\rangle + |\pi^-\pi^+\rangle\}$$

$$\frac{1}{\sqrt{2}}\{|\pi^\pm,\pi^0\rangle - |\pi^0,\pi^\pm\rangle\},\; \frac{1}{\sqrt{2}}\{|\pi^+\pi^-\rangle - |\pi^-\pi^+\rangle\}$$

$$\frac{1}{\sqrt{3}}\{|\pi^+,\pi^-\rangle + |\pi^-\pi^+\rangle - |\pi^0\pi^0\rangle\} \quad ,$$

or, pion-nucleon states of definite isospin

$$p\pi^+ \;,\; \frac{1}{\sqrt{3}}\{2|p\pi^0\rangle + |n\pi^+\rangle\},\; \frac{1}{\sqrt{3}}\{2|n\pi^0\rangle + |p\pi^-\rangle\},\; n\pi^-$$

$$\frac{1}{\sqrt{3}}\{|p\pi^0\rangle - 2|n\pi^+\rangle\},\; \frac{1}{\sqrt{3}}\{-|n\pi^0\rangle + 2|p\pi^-\rangle\} \quad ,$$

we see that the isospin is identical to the symmetric and antisymmetric exchange or rearrangement of constituents. Isospin conservation is always used or tested in the reactions of two or more hadrons when stable constituents can be exchanged between the two hadrons, as between two atoms. It is not necessary to assign an isospin to individual hadrons, let alone to the constituents of hadrons, although the third component of isospin can be assigned to the constituents via the Gell-Mann-Nishijima formula. The conservation of the third component of isospin is equivalent to the conservation of the number of stable constituents, because the only processes occurring in nature, according to the present model, are the rearrangement of constituents when two hadrons interact and pair production and annihilation of stable particles. The conservation of $\vec{I}$ or I^2, in strong interactions, on the other hand, is the conservation of symmetry properties of stable leptons ($e\bar{\nu}$) under exchange between the hadrons.

The physical intuitive meanings given to the abstract internal quantum numbers of hadrons is an important feature of the present theory: The constituents no longer carry mysterious properties such as strangeness, isospin, charm etc. The only charge is the electric charge.

Relation to quark assignments

The relation of our constituents to quark constituents is very simple. For mesons: $\ell\bar{\ell} \to q\bar{q}$, and for baryons: if we think of p as (uud) then our assignments become the same as the $q_1q_2q_3$ assignment with additional definite ($q\bar{q}$) terms of the same species (so-called $q\bar{q}$ sea terms). Such terms are introduced into the quark model anyway.

If we continue this correspondence or shift between quarks and leptons, then the next "excited" neutrino with the quantum numbers of ν_μ would correspond precisely to the so-called "charmed" quark and the next leptons τ and ν_τ to the other two new quarks, b and t. It is not known at present if ν_μ or ν_τ are massless or absolutely stable. According to the experimental limit so far, ν_μ is heavier than the electron!

It is important to remark that from deep inelastic electron-nucleon scattering experiments one can infer two solutions for the charges of constituents (assumed to be point-like at high energies) [16]. One solution gives for proton constituents the charges +1, +1, -1 and for neutron constituents +1, -1, 0. This is in agreement in our model with the physical proton being pe^+e^- and neutron being $pe^-\bar{\nu}$. The second solution gives the fractional quark charges. The additivity assumption of the magnetic moments and equal additive quark masses then selects quark assignments. However, in a dynamical physical bound state model, magnetic moments also have orbital contributions and constituent masses are unequal.

V. STRONG AND WEAK INTERACTIONS

All strong interactions including nuclear forces are, according to the present theory, of magnetic type and are further determined by the composite structure of the hadrons. Specifically there are two fundamental processes at short distances when hadrons collide: i) Rearrangement of constituent stable particles, ii) pair production (or annihilation) of leptons (and subsequent rearrangement). It is possible to give diagrams for every strong process using i) and ii). The ideas of the old meson theory, the many models of meson exchanges or Regge-pole exchanges emerge as approximate schemes from this theory, as well as the ideas of the S-matrix theory and nuclear democracy: different rearrangements of constituents with real or virtual lepton pairs obviously imply that hadrons can be thought to be built of other hadrons. In particular, the meson cloud around the nucleon is an immediate approximation here, but not in the quark model.

We propose here a new model of the nucleus, which seems to combine two apparently contradictory features of the nucleus. On the one hand, the nucleus consists of closely packed large nucleons with an occupancy between 60 and 90%, or may even have a crystalline structure. On the other hand, the nucleons seem to be moving freely inside the nucleus, as the shell model or other Fermi gas models are implying. These two features are reconciled in the present theory as follows. The stable protons form the closed packing or even the crystalline skeleton of the nucleus. On top of it the stable lepton pairs $(e^-\bar{\nu})$ acting like a boson are hopping from one proton to another. When an $(e^-\bar{\nu})$ is attached to a proton, it then becomes a neutron. Thus moving $(e^-\bar{\nu})$'s will appear exactly as moving neutrons, or moving protons in the opposite direction. We can then study the motion of $(e^-\bar{\nu})$ pairs in the periodic potential of the lattice of protons.

The weak interactions of the β-decay type are due to barrier penetration, e.g. $n(pe^-\bar{\nu})$ decay or $\mu(e\nu\bar{\nu})$ decay. In fact, a theory of the neutron with an equation of type (1)-(2) correlates (in this approximation) the lifetime of the neutron, the n-p mass difference (which is positive and can be estimated as the excess magnetic energy of $(e^-\bar{\nu})$ bound to the proton) and the magnetic moment of the neutron 8). Hence, indirectly, the Fermi constant G is related to the fine-structure constant α. All other decay modes of hadrons can be understood as a barrier penetration between two wells of the potential (see Fig.1), μ decay inside the hadron (suppressed by the Cabibbo angle as compared with the free μ decay) and barrier penetration with or without μ decay. Different decay channels result in different rearrangements of the constituents. Finally, a weak scattering process such as $e\nu \to e\nu$ should be related to the anomalous magnetic moment of the neutrino. This remains to be seen when we shall have more experimental data on the angular and energy dependence of this process.

VI. SOME FURTHER APPLICATIONS: K^0 PHYSICS AND CP VIOLATION

As an example of the intuitive value of the model we consider its application to the remarkable physics of the K^0 mesons.

According to Fig.3, K^0 and $\bar{K}^0$ mesons are $(e^-\mu^+)$ and $(e^+\mu^-)$, respectively, i.e. the magnetic analogues of muonium and antimuonium. (Such states have also been called superpositronium (e^+e^-) or supermuonium $(e^-\mu^+)$.) They are obviously charge conjugates of each other. If one of the states is produced, say $e^-\mu^+$, and we view μ^+ as $(e^+\nu\bar{\nu})$, then $(\nu\bar{\nu})$ pair can oscillate between e^- and e^+ in a magnetic potential as shown in Fig.6. When $(\nu\bar{\nu})$ is attached to e^+ we have a $\bar{K}^0$, when it is attached to e^- we have a K^0. Under these circumstances, we know from general quantum mechanics that the observed eigenstates of the energy are the symmetric and antisymmetric combinations with respect to the $(\nu\bar{\nu})$ exchange, namely $K_S = K^0 \pm \bar{K}^0$, which are also eigenstates of CP. In fact the problem is

exactly the same quantum-mechanically as in the ammonium (NH_3) laser 17), where N oscillates between two positions in a potential as in Fig.6. We therefore have the unambiguous prediction that the antisymmetric state is heavier than the symmetric one. In our case $m(K_L) > m(K_S)$. This is, to my knowledge, the first theory of the sign of the K_L-K_S mass difference. Moreover, the Dennison-Uhlenbeck mass formula 18) gives for the mass difference $\frac{\Delta m}{m} = \frac{1}{\pi A^2}$, where A is the barrier penetration factor in the potential (Fig.6). We do not know A, but we can obtain it from the decay rate Γ_S of K_S into $\pi^- + \pi^+$ $(e^-\bar{\nu} + e^+\nu)$, which uses the same potential barrier. This gives $\Delta m = \frac{1}{2}\Gamma_S$. Experimentally we have for the K_L-K_S mass difference $\Delta m = 0.477\ \Gamma_S$.

The two decay modes of K_S are given by two ways of rearranging the constituents. K_L cannot decay in this way because of CP invariance. But an additional lepton pair production gives all the decay channels of K_L. The rate is down by $\pi\alpha$ due to this pair production, which agrees with experiment.

Finally we discuss a mechanism of CP violation which occurs only in the K^0 mesons. CP violation in our picture means a small violation of the symmetric and antisymmetric combination. There is, in fact, a feature in the model, which brings an asymmetry. In the above discussion we have not made a distinction between ν_e and ν_μ. If we do make a distinction, then we have $(e^-\bar{\nu}_e\nu_\mu e^+)$ combination for $\bar{K}^0$ and $(e^-\bar{\nu}_\mu\nu_e e^+)$ combination for K^0. Hence an extra interaction must convert $\bar{\nu}_e\nu_\mu$ into $\to \bar{\nu}_\mu\nu_e$, which provides a further asymmetry between K_1 and K_2 leading to K_L and K_S. We can further predict that CP violation should also occur in the neutral mesons built from $(e^-\tau^+$ and $e^+\tau^-)$ and $(\mu^-\tau^+$ and $\mu^+\tau^-)$.

VII. CONCLUSIONS

High-energy physics according to the present theory can be considered as an extension of atomic and molecular physics. The Coulomb forces being replaced by the short-ranged strong magnetic forces. The only additional particle not present in atomic physics is the neutrino, which is in fact a limiting case of the electron. There is then a welcome continuity and simplicity in the physics, which was perhaps lost by the abstract concepts and free inventiveness of particle physics. No new particles, or no new interactions or forces are introduced 19) except the stable ones and the electromagnetic field. In this sense it is a truly already-unified theory with one coupling constant e. The only parameter so far, in principle, is the neutrino magnetic moment. All other "particles" are transitory; they come as resonances and eventually decay into the absolutely stable particles. The division of forces in nature into strong,weak and elementary was a temporary one; there is no need for such a division.

Although much detailed quantitative work must be done, and is being done, we have shown that, conceptually and logically, it is possible to understand the world of fundamental particles and their interactions from the very simple framework of stable particles and stable electromagnetic forces. Our guiding principle has been the same as that of Lord Kelvin under similar circumstances: "I want to understand light as well as I can, without introducing things that we can understand even less of".

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19) "When one thinks back to these days, one finds that it is really remarkable how unwilling people were to postulate a new particle. This applies both to theoretical and experimental workers. It seems that they would look for any explanation rather than postulate a new

particle. It needed the most obvious and unassailable evidence to be presented before them before they were reluctantly forced to postulate a new theory. The climate has completely changed since these early days. New particles are now being postulated and proposed continually, in large numbers. There are a hundred or more in current use today. People are only too keen to publish evidence for a new particle, whether this evidence comes from experiment or from ill-established theoretical ideas." (P.A.M. Dirac, in The Development of Quantum Theory (Gordon and Breach, 1971), p.60.)

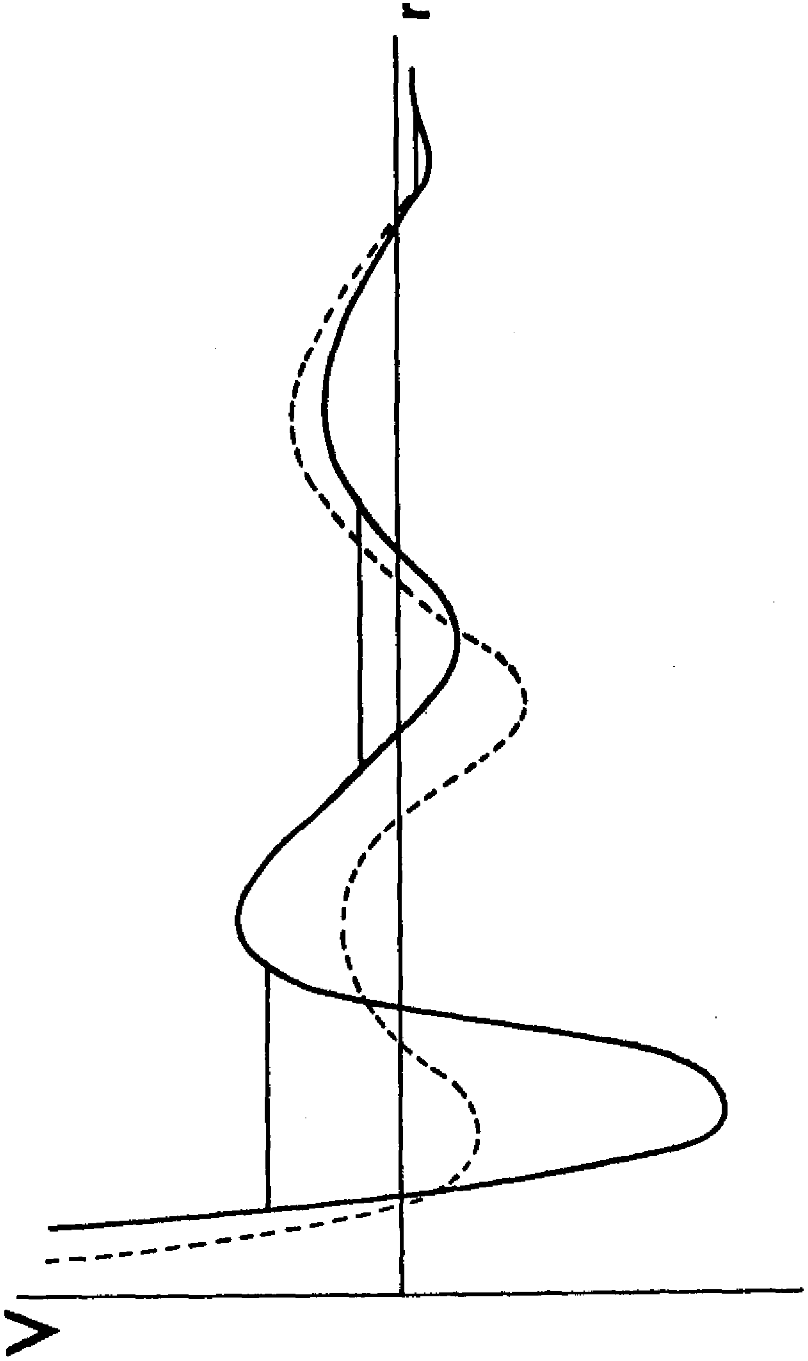


Fig.1 Schematic form of the effective radial magnetic potential V as a function of the radial distance r for two different fixed values of energy and angular momentum.

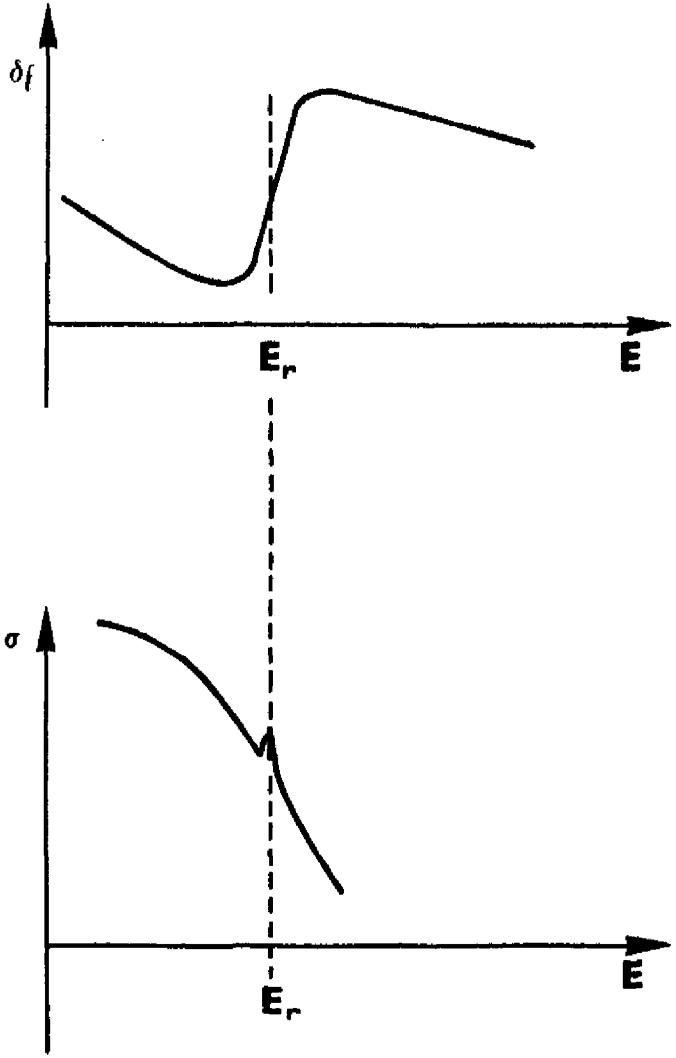
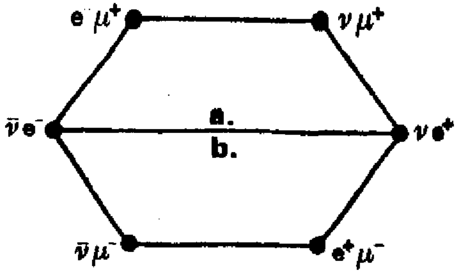
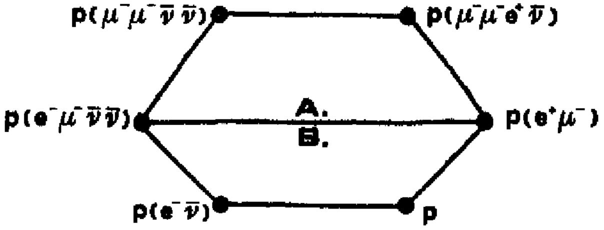


Fig.2 The effect of a repulsive barrier on the cross-section σ around the resonance energy E_r .



$$a = \frac{1}{\sqrt{2}}(\bar{\nu}\nu - e^+e^-),\ b = \frac{1}{\sqrt{6}}(\bar{\nu}\nu + e^+e^- - 2\mu^+\mu^-)$$

Fig.3 The meson octet.



$$A = p(\mu^-\bar{\nu})\ ,\ B = p(\mu^-\bar{\nu}\nu\bar{\nu})$$

Fig.4 The baryon octet.

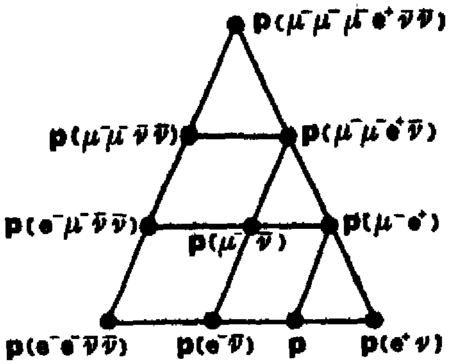


Fig.5 The baryon decouplet. The nearly linear mass formula of about the μ mass is a consequence of nearly zero-energy bound states in the magnetic potential well.

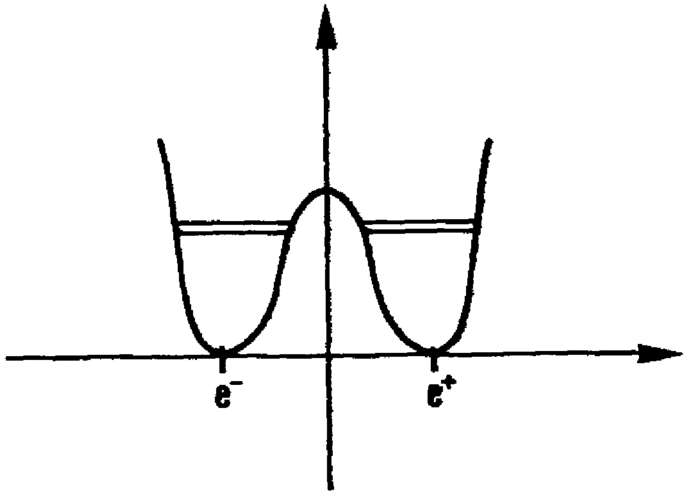


Fig.6 The effective magnetic potential barrier for ν and $\bar{\nu}$ exchange and oscillations between e^- and e^+ in the K^0-$\bar{K}^0$ system.