GENERAL FORMULATION OF STANDARD MODEL
THE STANDARD MODEL IS IN NEED OF NEW CONCEPTS

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ABSTRACT

The phenomenological basis for formulation of the Standard Model has been reviewed. The Standard Model based on the fundamental postulates has been formulated. The concept of the fundamental symmetries has been introduced: To look for not fundamental particles but fundamental symmetries. By searching of more general theory it is natural to search first of all global symmetries and than to learn consequence connected with the localisation of this global symmetries like wise of the standard Model.

INTRODUCTION

Gauge field theory which underlie modern high energy physics as well as the theory of gravity and hence all of physics as we know it today, is itself based on a few fundamental concepts such as all fundamental forces of nature such as strong, electroweak (and gravitation) are gauge forces, exact symmetry in nature are always local, gauge symmetry may be broken only spontaneously, gauge field theory is renomalizable. Consequences of these concepts are often as beautiful as they are deep.

We may summarize the main features of a Yang-Mills theory by listing the full Lagranjian L (ψ, A) and the trasformatun properties of the fields below

$$L(\psi, A) = \overline{\psi}\left(i\gamma_\lambda D^\lambda - m\right)\psi - \frac{1}{4}F^a_{\mu\nu}F^{a\mu\nu}$$

$$D_\lambda \equiv \partial_\lambda - igI_a A^a_\lambda$$

$$\psi \to \psi' \equiv \exp\left[igI_a\Lambda^a(x)\right]\psi(x)$$

$$A^a_\mu \to A^{a'}_\mu = A^a_\mu + \partial_\mu\Lambda^a - gf^{abc}\Lambda^b A^c_\mu$$

$$F^a_{\mu\nu} \equiv \partial_\mu A^a_\nu - \partial_\nu A^a_\mu + gf^{abc}A^b_\mu A^c_\nu$$

Gauge field theories possess of power and sufficiently effective explanatory and also foretell forces. On the new solid sturdy foundation of the gauge quantum field theory is constructed the Standard Model of Modern Particle Physics.

A very novel feature of the Standard Model involving Quantum Chromodynamics QCP and Electroweak Theory of Weinberg and Salam EWT on gauge theories is that it is of **Yang-Mills** type, i. e. is based on non-Abelian gauge group

$$SU(3)_{Colour} \times SU(2)_{Left} \times U(1)_{Hypercharge}$$

In the following sections we shall see how this properties of strong and Electroweak interacting fit into the Standard Model of Modern Particle Physics.

A. THE PHENOMENOLOGICAL BASIS FOR THE FORMULATION OF THE STANDARD MODEL

(*i*) Concept of fundamental particles

The concept of fundamental particles means: of what does matter consist and what are the geometrical or dynamical configurations of small particles in the nature?

The Particle Postulates

What we do understand under word of fundamental particles? For us it is enough to answer to this question with the postulate I as follows:

(a) Fundamentality

Postulate I - The Particle Fundamentality:

The particale may be consider as fundamental if it is impossible to describe it as composite system which consist from other particles of more fundamental objects.

The fundamental particles are taken to mean indecompozable structure constituents of matter.

Consequence 1 - Quark-Lepton Fundamentality:

The quarks and lepton have no internal Structure, no size, no form factors, no exited states and no composite but point like structureless fundamental particles of matter from which all other particles could be made. The quarks colour triplets, so experience the strong interaction, where as the leptons colour singlet, do not.

Consequence 2 - The Quarks and Lepton are fundamental degrees of freedom of constituents of matter.

Fermion sector **(spin 1/2)**

(*ii*) **The fundamental quark-lepton generations.**

It is well established experimentally that there are three generations of spin 1/2 fundamental fermions of nature, quarks and leptons - fundamental matter particles:

$$(u, d, e^-, \nu_e),\ (c, s, \mu^-, \nu_\mu),\ (t, b, \tau^-, \nu_\tau)$$

$$\left(M_{u,d,c,...} \neq 0, M_{e,\mu,\tau} \neq 0, M_{\nu_0,\nu_\mu,\nu_\tau} = 0\right)$$

each of which consist of a charge +2/3 colour-triplet quark, a charge - 1/3 colour-triplet quark, a colour singlet lepton, a colour-singlet mussless neutrino and their anti-particles.

(*iii*) **Global symmetry**

The basic internal **global symmetry** of the Standard Model is defined by non-Abelian group.

$$G_{SM}^{global} SU(3)_{colour} \times SU(2)_{left} \times U(1)_{hypercharge}$$

$$g_s \qquad\qquad g \qquad\qquad g'$$

where $SU(3)_c$ is a non-Abelian colour group, SU(2) is a non-Abelian weak isospin group, U(1) is an Abelian weak hypercharge group; g_S, g, g′ are coupling constants of the SU(3), SU (2), U(1) groups respectively.

- **The $SU(3)_c \times SU(2)_l \times U(1)_y$ generation structure of the fundamental fermions - quarks and leptons.**

The fermions appear as generation with left-handed doublets and right-handed singleft:

Quarks	**Quantum numbers Under** $(SU(3)_c \times SU(2)_L \times U(1)_y)$
$\begin{pmatrix} u_c \\ d_c \end{pmatrix}_L, \begin{pmatrix} c_c \\ s_c \end{pmatrix}_L, \begin{pmatrix} t_c \\ b_c \end{pmatrix}_L \begin{matrix} \leftarrow Q = +2/3 \\ \leftarrow Q = -1/3 \end{matrix}$	$\left(3, \quad 2, \quad +1/3\right)$
$(u_c, c_c, t_c)_R \leftarrow Q = +2/3$	$\left(3, \quad 1, \quad +4/3\right)$
$(d_c, s_c, b_c)_R \leftarrow Q = -1/3$	$\left(3, \quad 1, \quad -2/3\right)$

leptons

$$\begin{pmatrix} \nu_e \\ e^- \end{pmatrix}_L, \begin{pmatrix} \nu_\mu \\ \mu^- \end{pmatrix}_L, \begin{pmatrix} \nu_\tau \\ \tau^- \end{pmatrix}_L \begin{matrix} \leftarrow Q = 0 \\ \leftarrow Q = -1 \end{matrix} \qquad \left(1, \quad 2, \quad -1 \right)$$

$$\left(e^-, \mu^-, \tau_-\right)_R \leftarrow Q = -1 \qquad \left(1, \quad 1, \quad -2 \right)$$

where c = R, G, B - colour indices.

The parentheses show the representations of $SU(3)_C$ and $SU(2)_L$ (both indicated by their dimentiality), and the value of the weak hypercharge Y, for each set of fields.

The generalised Gell Mann-Nishijima relation

Between the quantum numbers classifying quark-lepton generations and their electric charge Q the relation

$$Q = I_3 + \frac{1}{2}Y + \frac{2}{3}C$$

is valid, where

$$Y = S + Bq - \frac{1}{2}C$$

in hypercharge, Bq is a baryon number, C is a charm, S is a strangeness and I_3 is the third component of the isospin I. $Bq = +\frac{1}{3}$ is a baryon number for quarks (q) and $B\overline{q} = -\frac{1}{3}$ is a baryon number for anti-quark $(\overline{q})$.

Quarks and leptons constitute the basic building blocks of matter in the Standard Model. There are three generations of quarks and leptons in the Model with identical quantum numbers but different masses. Within each generations quarks and leptons appear in pairs. The left-handed quarks form weak isospin doublets, with the electric charge Q=+2/3 and Q=-1/3 quarks having weak isospin I_3=+1/2 and - 1/2 respectively.

The existence of vector bosons

There are 12 spin 1 vector bosons as carriers of the strong and electroweak gauge forces

$$g_{i=1,..,8}, w^+, w^-, z^0, \gamma,$$

where the gluons and photon are massless $M_g=0$, $M_{\gamma=0}$ and the w^+, w^-, z^0 have musses $M_W \neq 0$, $M_Z \neq 0$.

The vector bosons are carrying strong forces between colour quarks ($C \neq 0$) mediated by octet gluons g, weak forces between leptons ($C=0$) mediated by triplet weak bosons w^+, w^-, z^0 and electromagnetic forces between electrically charged particles mediated by the singlet photon γ.

Higgs sector **(spin 0)**

The existence of one massive scalar particles

There is spin 0 one massive scalar particle of Higgs H^0, $M_H \neq 0$.

This empirical structure can be embedded in a gauge invariant field theory of the unified strong and electroweak interaction by interpreting $SU(3)_C \times SU(2)_I \times U(1)_4$ as the group of local gauge transformations under which the Lagrangian of the Standard Model is invariant. This full symmetry has to be broken by the Higgs mechanism down to the electromagnetic symmetry; otherwise the $w^{\pm}$ and z bosons would also be massless The minimal formulation, the Standard Model, requires a single scalar field (Higgs field) which is a doublet under SU(2).

B. The fundamental postulates of Standard Model and immediate consequences

What we have learned so for about the phenomenological basis for the formulation of the Standard Model, were deduced from observation facts by non-rigorous arguments. Beginning with a formal statement of these as basic postulates, we shall now study their consequences in some detail. In the course of this study, the mathematical structure and their physical content will be made more explicit.

Now we are ready to formulate the basic principle of the Standard Model. We shall do it by establishing the definite postulates which similar axioms of geometry, are not provide. From this postulates will be followed all the theory, and, at last, we shall come to the conclusion which can be checked experimentally. In dependence on the results of this experimental check, the theory must be excepted or rejected.

This axiomatical approach is economical if the reader’s interest is limited to the use of the Standard Model as a readymade and trustworthy tool exploring the properties of specific system.

The Fundamental Postulates

Postulate I – Local Gauge Invariance

Gauge group:

$$G_{SM}^{Local} = SU(3)_{colour} \times SU(2)_{left} \times U(1)_{hypercharge}$$

Postulate II – Fundamental Quantized Fields

Fermions sector **(spin ½)**

The matter field describing three generations of spin ½ fundamental fermious – quarks and leptons – are given by the 15-plet of Left-handed (LH) and Right-handed (RH) 2 component quantized **Weil spinor** fields with zero masses (M_{spinor}=0):

$$\psi_{\alpha}^{(1)}(x) = \left(u_{CL}(x), d_{CL}(x), u_{CR}(x), d_{CR}(x), e_l(x), e_R(x), \nu_{e_L}(x)\right)$$

$$\psi_{\alpha}^{(2)}(x) = \left(c_{CL}(x), s_{CL}(x), c_{CR}(x), s_{CR}(x), \mu_l(x), \mu_R(x), \nu_{\mu_L}(x)\right)$$

$$\psi_{\alpha}^{(3)}(x) = \left(t_{CL}(x), b_{CL}(x), t_{CR}(x), b_{CR}(x), \tau_l(x), \tau_R(x), \nu_{\tau_L}(x)\right)$$

(3 + 3 + 3 + 3 + 1 + 1 + 1 = 15),

α = 1,…, 15, c = R, 6, B – colour index.

Note: We label Weil spinors of the quarks and leptons by their particles symbol.

Postulate III – Local Gauge Invariant Standard Model Lagrangian.

Postulate IV – Anomaly free and Charge Quantization.

Postulate V – Spontaneously Breaking the Local $(SU(3) \times SU(2) \times U(1))$ Gauge Invariance.

Postulate VI – After Spontaneous Breaking Symmetry the Standard Model Lagragian.

Postulate VII – Renomalizability of the Standard Model

The fundamental postulates provide set of rules enabling the information contained in the mathematical representations to be translated into physical terms. More exactly, definitly, fundamental representations of the Standard Model group G_{SM} to be translated into quark and lepton matter fields and adjoin representations of G_{SM} to be translated into Yang-Mills gauge field of strong and electroweak force.

The Standard Model provides a characterisation of the fundamental particles of the nature such as quarks, leptons and intermediate vector bosons in terms of essentially mathematical objects – quantized field, or at a deep level, operator-valued distributions, which are constructed by the fundamental postulates of quantization.

The Standard Model is a Yang-Mills gauge field theory basically decfated by **the generalised gauge principle**. According to this principle all the fundamental forces of nature such as strong, electroweak (and gravitation) are mediated by an exchange of the Yang-Mills gauge field corresponding gauge group.

The Standard Model is constructed by extension of the global non-Abenian $SU(3)\times SU(2)\times U(1)$ symmetry to the local $SU(3)\times SU(2)\times U(1)$ symmetry under which the Lagrangian of the Standard Model is invariant. This full symmetry has to be broken by Higgs Mechanism down to the electromagnetic gauge symmetry.

The Standard Model which contains fundamental particles of matter such as 6 quarks: u, d, s, c, b, t and 6 leptons: e^-, ν_e, μ^-, ν_μ, ι^-, ν_ι and 12 gauge bosons such as gluons $g_{I=1,\ \ldots,\ 8}$, photon γ, intermediate vector bosons, except one Higgs particle H^0 have been discovered, and their masses and spins have been defined. The Standard Model is stunning. Until now, no cracks have been found. There is no any experiments that contradicts the Standard Model. Moreover there is nothing observed beyond the Standard Model. The Standard Model works better and better.

At present it is generally believed that the strong and electroweak interactions are probably correctly described by the SM up to 10^{-15} – 10^{-16} sm inside the matter.

The Standard Model is Renomalizable and therefor potentially consistent at all energy scales

The Standard Model in principle can describe the properties of the Univers beginning at 10^{-43} sec. after Big Bang. A "Standard Model" of the Big Bang Particale Physics provides one of the few windows on the high energy world beyond Standard Model which is consistent with the Standard Model and Cosmology.

The Standard Model in its present form is not the ultimate theory and is in need of new concepts.

(*iv*) Inadequacy of concept of Fundamental Particles

The concept of the fundamental particles does not exist. It is an error

What has to replace the concept of the fundamental particles?

We think that we have to replace the concept fundamental particles by **the concept of the fundamental symmetries.**

The fundamental symmetry defines the underlying law which determines the spectrum of elementary particles.

To look for not Fundamental particles but Fundamental Symmetries

By searching of more general theory it is natural to use procedure which has been brought once to the success. Obvious program, therefore, is **to search first of all global symmetries and then learn consequences connected with the localization of these global symmetries.**

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