Vacuum structure, spectrum of excitations and low-energy phenomenology in chiral preon-subpreon model of elementary particles.

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Abstract

Inner and empirically consistent model of elementary particles, including two matter structural levels beyond the quark one is built. Excitations spectra, masses and interactions are analysed using the phenomenological notion of non-pertubative vacuum condensate. Essential low-energy predictions of developed concepts are classified.

Effective gauge $U(1) \times U(1) \times SU(2)$-theory of quark-lepton excitations behavior based on the performed analysis of preon-subpreon phenomenology is consistently built. The ability of its expansion with fermions and scalar leptoquark coupling is also considered. Shown that the coupling constants generation hierarchy is the same as generation hierarchy of quark masses.

Using the built theory cross-sections of $e^+d \to e^+d$ and $e^+d \to u\bar{\nu}_e$ processes are calculated. The obtained resonance peak is proposed to be a possible explanation of deviating from Standard Model predictions discovered in DESY in the beginning of 1997 year.
Introduction

Standard Model (SM) which nowadays is thought to be a proper tool for elementary particles researches contains two clearly distinguishable concepts of physical vacuum. We mean Higgs vacuum of scalar particles, linear by field and having classical origin, and QCD vacuum provided with non-pertubative quantum fluctuations of quark-gluon fields. These different notions straightforwardly produce the ideas of spontaneously broken and hidden (confined) symmetry. Such a state of affair within the theory makes to think about evolution of vacuum concept in future physics. Two usual answers on the question are given by the two main expansions of SM.

Grand Unification Theories (GUTs) suppose Higgs mechanism and massive vector bosons are both fundamental. For gauge structure of the theory it means that we need to build a solid simple gauge group, including all known interactions. When the symmetry, corresponding to it, is broken we come to the observable manifold of physical phenomena.

Preon models take strongly into account, that only QCD vacuum, but not the Higgs one is certainly experimentally observable. Consequently, it is hidden symmetry concept which is of a big value within them, and the spirit of spontaneous breaking is completely banished out of the fundamental theory. This way leads us to building fundamental gauge group as a product of a few simple groups, gradually (with energy decreasing) transiting into confinement state.

In recent years a few quark inner structure evidences were obtained ([1]-[3]). That brings us to the necessity of extremely sharp determination of low-energy preon structure predictions. Among them is existence of leptoquark resonance, possible discovery of which in DESY in the beginning of 1997 year caused a new wave of preon models researches.

Existence of low-energy limit of SM bounds the number of different preons within the model, which then helps to build a minimal SM extention providing a possibility of phenomenological preon structure effects calculation. In that way, tiny ratio of weak interaction intensities for right- and left-chiral fermions allows us to draw a proper conclusion on a great difference of confinement scales for left- and right-chiral quarks and leptons. This makes reasonable for us to consider right-chiral quarks and leptons structureless.

We follow the standard for preon models concept of weak interactions interpreted as an exchange with universal spinor preons, which are contained in all left-chiral fermions (we’d like to note a great similarity to meson couplings in effective low-energy barion-meson theories). This approach unavoidably introduces an extra massive vector boson (so called Z'-boson). Its current mass constraint is \( m_{Z'} > 340 \text{GeV} \).

Within a built in such a way model quarks and leptons are composed of scalar and spinor preons. The later are universal preons, described in the previous paragraph and providing weak interaction. Existence of fundamental scalar particles, however, introduces triple and quadruple vertices, corresponding to new fundamental interactions (the vertices are not forbidden by either renormalizability or gauge symmetry). These strange interactions can be reduced to the gauge ones by declaring supersymmetry or prohibited after adding one more matter structural level – subpreon. In this paper we use the second of described possibilities: each scalar preon is composed of two spinor subpreons. This way leads us

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1 Nevertheless the idea of spontaneously broken symmetry is widely used when constructing low-energy phenomenological models. We break in them, however, not the symmetries of fundamental interactions, but effective gauge symmetries, which are classificational at the level of fundamental theory.

2 Within the built scheme technicolor concept are thought to be intermediate relatively to GUTs and preon models: massive gauge bosons in it are considered as fundamental, but Higgs mechanism isn’t accepted, and confined technicolor interaction provides techniquarks coupling into particles which spontaneously break the gauge symmetries.
Figure 1: a) a draft image of quark excitation within the examined model; b) vacuum condensates distributions within a quark excitation.

to a chiral model: in fundamental theory we have only massless chiral spinor fields (and the gauge ones) – other spin particles production and mass-gaining become possible due to non-pertubative, QCD-like vacuum condensates.

Analogously to hadron physics we suppose preons are confined in quarks, and subpreons – in preons. The confinement is provided by metacolor (gauge group SU_{mc}(N_{mc})) and submetacolor (group SU_{smc}(N_{smc})) interactions respectively. The suggestion is perhaps too strong, but it’s quite reasonable to believe that low-energy predictions aren’t sensitive to the exact mechanism of keeping preons inside quarks and (still more evident) subpreons in preons. The resulting image of left-chiral quark (or lepton) is shown at Fig.1.

In these paper our main hypothesis while building the model is the forms of vacuum averages of fundamental fields. When they are fixed our phenomenological notions and analogies to hadron physics completely determine excitations spectrum.

In accordance with hadron level, there are two main types of vacuum excitations in preon models:

1) so-called “bags” – proton-like regions of molten preon-metagluon condensate, made stable by valent preons.

2) collective excitations – pion-like waves, generated with breaking of fundamental fields correlations, which are inherent in vacuum state.

There is an important inner consistency criterion in a theory established in the aforesaid way. In it all vector particles are build of chiral preons and, consequently, initially massless. The only way for them to gain a non-zero mass is non-pertubative vacuum interactions. Massless particles (contrarily to massive ones) have only two independent polarization components. That is why, condensate interactions must also provide a transformation of each vector excitation appeared within the theory into a scalar one, which has the same quantum numbers. It is perceived as the third necessary polarization component. Thus, within the build spectrum, for each vector excitation we need to find a scalar one with the same quantum numbers and build diagrams of transformation processes through vacuum interactions. We can use some sort of condensate forms only if within the spectrum corresponding to them the established condition is satisfied (we also must require simplicity and lack of contradictions with present experimental data).

After the spectrum of excitations is analyzed, we can extract the minimal set of fields which are to be included into the low-energy model. As it has been shown, the set can be “put” into the frameworks of an extended SM with the group $U(1) \times U(1) \times SU(2)$. The symmetry breaking in it is provided with effective Higgs mechanism, which is not consid-
ered in our model as fundamental. It is carried out of preon model, that the build gauge theory must be extended with some specific interactions of quarks and leptons with scalar leptoquark, which are the most easily observable low-energy predictions of preon structure existence. (When interpreted as a leptoquark effect DESY data give it’s mass of about 200GeV). We can, after that, calculate the influence of leptoquark resonance on the cross-section of proton-positron scattering within the extended model.

In this paper we try to build a consistent model which contains all the above-introduced concepts. In section 1 we construct condensate forms and excitations spectra of subpreon and preon levels and use phenomenological method of preon diagrams to prove inner consistency of the build scheme. Section 2 is dedicated to building effective low-energy gauge theory with non-renormalizable leptoquark articles. In section 3 we calculate cross-section of elementary $e^+d$-scattering for processes with neutral and charged current and analyze some empirical features of the obtained results.

1 Preon phenomenology

1.1 Preon types and gauge structure of the theory

When constructing the set of elementary objects of the theory we aim to satisfy two usual preon ideology postulates:

1) All fundamental interactions correspond to exact gauge symmetries.
2) Elementary fields are representations of the gauge groups.

In accordance with the first thesis, described in Introduction preon structure and the necessity of QED and QCD groups presence we build the fundamental gauge group in the form:

$$ G = U(1) \times SU_c(3) \times SU_{me}(N_{me}) \times SU_{mc}(N_{mc}) $$

When symmetries $S_{mc}(N_{mc})$ and, then, $SU_{mc}(N_{mc})$ successively transit into hidden state we are drawn into a usual quark-lepton level. Fields, corresponding to the four factors of the gauge group $G$ are hereafter designated as $S_{\mu}, G_{\mu}^m, B_{\omega}^\mu, C_{\Omega}^\mu$; their strength tensors are $S_{\mu\nu}, G_{\mu\nu}^m, B_{\omega\nu}^\mu, C_{\Omega\nu}^\mu$.

There are three subpreon fields within the theory: universal right-chiral subpreon $x_{R}^{\rho\alpha}$, which is included into all scalar preons, and left-chiral subpreons $Q_{La}^\rho$ and $L_{Ll}^\rho$, necessary for building quark and lepton preons respectively. (Here index $\rho$ is associated with submetacolor interaction, $\alpha$ – with metacolor, $i$ – with chromodinamic, $a$ and $l$ – flavour indices of quarks and leptons; all the listed fields are transformed after fundamental (when having two indices – after bifundamental) representations of corresponding groups). If we move through the build hierarchy backwards from quark-lepton level and require anomalies cancellation at each step, electric charges of the fields $x$, $Q$ and $L$ are absolutely determined and equal to 0, 1/6 and -1/2.

Using the introduced notation we can write fundamental Lagrangian as follows:

$$ L = -\frac{1}{4} \sum_G G_{\mu\nu} G^{\mu\nu} + \sum_f i \bar{f} \slashed{D} f $$

where $\sum_G$ means summation over gauge groups, and $\sum_f$ – over all right- and left-chiral fermion fields.

Note, that unless postulates 1) and 2) are violated Lagrangian is automatically invariant under transformation of an enormously rich global flavour group, including independent
flavour mixing of right- and left-chiral leptons, left-chiral quarks and up and down right-chiral quarks separately. We probably can reduce the flavour group, by introducing some correlations of right- and left-chiral quarks and leptons at preon level. Nevertheless, even when it’s done the group is surely still monstrously large.

For the reason that all fundamental fields are massless and all fundamental interactions are gauge ones with exact symmetries the above-written Lagrangian doesn’t contain any dimensional parameters. They, however, must appear in quantum theory because of non-pertubative vacuum condensates occurrence (which is necessary in a non-abelian theory). That is exactly the way, in which the fundamental scale hierarchy

\[ \Lambda_1 \gg \Lambda_{smc} \gg \Lambda_{mc} \gg \Lambda_c \]

appears. Here \( \Lambda_c = 100\text{MeV} \) – usual QCD dimensional parameter. The written scale takes a determining part in the formation of excitations spectrum and properties. Quantities \( \Lambda_c \), \( \Lambda_{mc} \) and \( \Lambda_{smc} \) characterize deconfinement energies of corresponding interactions. For QED dimensional parameter, \( \Lambda_1 \sim 10^{19}\text{GeV} \), it only can be said that it’s, probably, the boundary of our most general notions of matter structure applicability.

Quark and lepton scalar preons,

\[ \phi^{\alpha i}_a = \bar{x}_R Q_a^\rho \quad \text{and} \quad \phi^{\alpha}_l = \bar{x}_R L_l^\rho, \]

are constituted of spinor subpreons and have charges of 1/6 and -1/2. We also need some universal left-chiral preons at the level of submetacolor confinement: it is exchange with them which provides usual weak interaction. It’s not enough to introduce a single universal preon, for in the case we’d only be able to build one vector boson. The minimal number of weak interaction providing fields in physically consistent theory is two: preons \( U_L^\alpha \) and \( D_L^\alpha \), holding the charges of 1/2 and -1/2. “Chemical formulas” of quark and lepton fields are:

\[ u_{La}^i = U_L^\alpha \phi_{a}^{\alpha i} \quad d_{La}^i = D_L^\alpha \phi_{a}^{\alpha i} \]
\[ \nu_{Ll} = U_L^\alpha \phi_{l}^{\alpha} \quad e_{Ll} = D_L^\alpha \phi_{l}^{\alpha} \]

The four vector bosons contained in the theory are composed of universal preons.

\[ W^+_{\mu} = \bar{D}_L^\alpha \gamma_\mu U_L^\alpha \]
\[ W^-_{\mu} = \bar{U}_L^\alpha \gamma_\mu D_L^\alpha \]
\[ W^3_{\mu} = \frac{1}{\sqrt{2}}(\bar{U}_L^\alpha \gamma_\mu U_L^\alpha - \bar{D}_L^\alpha \gamma_\mu D_L^\alpha) \]
\[ W^0_{\mu} = \frac{1}{\sqrt{2}}(\bar{U}_L^\alpha \gamma_\mu U_L^\alpha + \bar{D}_L^\alpha \gamma_\mu D_L^\alpha) \]

Existence of an extra effective-gauge boson seems to be an important prediction of the developed theory. Its empirical consequences can be examined within the formalism which is to be build in section 2.

3 When energies are far above the confinement scales and pertubative theory is applicable, dimensional parameters appear after renormalization due to dimensional transmutation effect. As it is shown by QCD exploring experience, these parameters are equal to the characteristic scales of non-pertubative vacuum by the order of magnitude.
1.2 Submetacolor confinement level

As it has been already said, submetacolor confinement is provided by $SU_{smc}(N_{smc})$ gauge interaction. Condensate forms must be assumed as a hypothesis (criteria of its verification were described in Introduction). When making the choice we are guided by the following heuristic recipe: first we build all sorts of Lorenz-invariant forms, then construct of them non-abelian gauge groups singlets; the singlets are used for condensate expressions formation, which are invariant under $U(1)$-transformations. The performed sequence is produced by our general notion of fundamental symmetries hierarchy. More than that, requirement of throwing off all Lorenz non-invariant forms at the first stage of vacuum condensate construction follows from our wish not to have any low-energy excitations with high spin. After the assumption of the described principle we come to unique set of vacuum forms:

\[
\begin{align*}
\langle 0 | C_{\mu\nu}^{\Omega} C_{\Omega}^{\mu\nu} | 0 \rangle &= C_0 \\
\langle 0 | (\bar{x}^R_{\alpha} Q_{La}^i) (\bar{Q}_{Lb}^j x^R_{\alpha}) | 0 \rangle &= C_{ab}^{(Q)} \\
\langle 0 | (\bar{x}^R_{\alpha} L_{\sigma}^i) (\bar{L}_{Lm}^l x^R_{\alpha}) | 0 \rangle &= C_{lm}^{(L)}
\end{align*}
\]

where $C$ matrices can be chosen diagonal.

Analogously to QCD, where the characteristic scale of quark condensates is about one and a half times less than gluon ones, the ratios

\[
\Upsilon^{(Q)} = \sqrt{\frac{\|C_{ab}^{(Q)}\|}{\sqrt{C_0}}} \quad \text{and} \quad \Upsilon^{(L)} = \sqrt{\frac{\|C_{lm}^{(L)}\|}{\sqrt{C_0}}}
\]

in our theory must be less then one. The reason is that quark (and, as well, preon) condensates are induced: quantum tunneling between topologically different states of the field system produces gluon fields fluctuations, which at their turn excite right- and left-chiral fields. Forasmuch as QCD is a chiral theory, induced quark fluctuations distributions are the same. A finite width of the distributions, however, makes characteristic scale of quark condensate (which appears after averaging of right- and left-chiral fluctuations product) is less than gluon condensate scale factor.

Applying of the same approach to condensate forms (1.2.1) leads to even greater vacuum energies split. Subpreon condensates are of fourth degree by fields and the averaging must get a less result than in QCD case. Thus, built in the previous paragraph dimensionless ratios with a high probability can come close to one order of magnitude.

It seems to be an extremely important question, that of flavour symmetry breaking with condensate forms (1.2.1). Heuristic analysis of the problem shows that the symmetry can only be reduced to $SU(2)$. The described picture of condensate inducing is flavour invariant. The suggestion of spontaneous breaking, however, brings to the necessity of instability development in the inducing processes. It is this instability which leads to vacuum averages matrix flavour symmetry breaking. Analogously to condensed matter physics state of affair, in low-symmetry phase we have a domain with explicit dynamic equality of flavours (which took place before symmetry breaking), the domain in which all the elements of vacuum averages matrices $C$ are equal. When diagonalize the matrices we obtain $C \sim \text{diag}(3,0,0)$, which corresponds to the domain in which symmetry breaking character is explicit.

\footnote{This, to tell the truth, a bit unclear statement can be confirmed by the following example taken from ferromagnetism physics. In ferromagnetic low-energy phase there is a domain with explicit equality of $x$, $y$ and $z$-directions ($M \sim (1,1,1)$), and the domain in which symmetry breaking down to $O(2)$ is evident ($M \sim (1,0,0)$).}
can also add some isotropic (i.e. proportional to the identity matrix) part to the built vacuum averages. It’s not too difficult to see, that the obtained vacuum shift matrices are $SU(2)$-invariant.

The above stated group theory arguments and a certain fact that first generation is almost massless, brings us to the following conclusion on diagonal elements of $C$-matrices values:

$$C_{11}^{(Q)} \ll C_{22}^{(Q)} = C_{33}^{(Q)} \quad \text{and} \quad C_{11}^{(L)} \ll C_{22}^{(L)} = C_{33}^{(L)}.$$  

This is quite a provocative result because small values of $C_{11}^{(Q)}$ and $C_{11}^{(L)}$ can, in principle, lead to the appearance of small mass excitations, different from scalar preons. It will be shown, that this an unpleasant possibility isn’t realized within the theory due to submetagluon condensate presence.

We use the following phenomenological notions when obtaining the excitations spectrum: a bag can be composed of any few (for low-energy excitations) particles forming a colorless by submetacolor object with some definite Lorenz-transformation properties. Such a system of particles stabilizes condensate cavity. Besides that, we can destroy some fields correlation by submetacolor object with some definite Lorenz-transformation properties. Such a system can also add some isotropic (i.e. proportional to the identity matrix) part to the built vacuum averages. It’s not too difficult to see, that the obtained vacuum shift matrices are $SU(2)$-invariant.

The last three particles are scalar subpreon leptoquark, submetagluonball and pseudosubmetagluon (submetaaxion). All the built excitations can be expanded into representations of the reminder flavour group $SU_{fam}^{(Q)}(2) \times SU_{fam}^{(L)}(2)$. When it’s done, fields with $ab$ and $lm$ indices are split into two singlets, two fundamental and a adjoined representation of a corresponding $SU_{fam}(2)$ group. As for leptoquark fields, their flavour group irreducible parts are a both flavour group singlet, $SU_{fam}^{(Q)}(2)$ fundamental representation, $SU_{fam}^{(L)}(2)$ fundamental and a bifundamental representation of the whole reminder flavour group.

It’s of a considerable importance to know $[1.2.2]$ and $[1.2.3]$ abilities for mutual transformations and interactions with $[1.2.1]$ condensate. Only by carrying out the answer, we can examine which combinations of $[1.2.3]$ fields are perceived as third independent polarization components. It’s impossible to achieve a quantitative answer to the question within...
modern field theory. We, however, can reveal some important processes features through phenomenological technique of preon diagrams, which are graphic images of processes with (1.2.2) and (1.2.3) particles. The later are visualized as composed of preons interacting in accordance with fundamental $U(1) \times SU_c(3) \times SU_{mc}(N_{mc}) \times SU_{smc}(N_{smc})$-Lagrangian. Within such an approach excitation-condensate interactions are described by special vertices, drawn at Fig. 2. In hadron physics a similar technique were established in a classical paper [4].

We examine only confinement-irreducible diagrams, i.e. those which can’t be decomposed into parts, external lines of which form colorless (by submetacolor) groups. (That sort of diagrams corresponds to elementary low-energy processes). More than that, it’s quite evident that external lines of each considered diagram must themselves form colorless groups (due to confinement). Size of the necessarily examined diagrams set is strongly reduced by the two stated requirements, and so we can do a complete enumeration. We don’t draw all the essential diagrams here because of quite a big number of them. It’s only possible to perform some important diagram examples and the results obtained for mass-gaining, mixing and third polarization components production processes.

Due to both fundamental and low-energy Lagrangians are gauge-invariant, only fields transforming after the same representation are able for mutual conversion. This divides (1.2.2) and (1.2.3) into subsets of particles, which mix and form polarization components only within the group:

I. $(X_\mu^Q, V_{\mu}^{(Q)}, V_{\mu}^{(L)})$;
II. $V_{\mu}^{(Q)}$
III. $V_{\mu}^{(L)}$
IV. $V_{\mu}^{\omega}$
V. $V_{\mu}^{n}$
VI. $\chi_{\mu}^{i}$

Below there are main results of preon diagrams analysis for each of the groups (the most essential mass-gaining and third components production diagrams are performed at Fig. 3).

I. Preon diagrams provide all third components production. All vector bosons are massive (for first flavour the main contribution into masses is given by diagram of interaction with submetagluon condensate at Fig. 3b). As it has been mentioned, lack of massless colorless object within the theory is of a great importance for not having contradiction with present experimental data.

II. Mass-gaining mechanism works. There are some less massive particles, but their masses aren’t catastrophically small (of order $\sqrt{C_{11}/C_{22}}$ relatively to submetacolor confinement scale).

III. Everything is analogous to II.
IV. Third components producing is provided. All vector particles are massive.

V. Vacuum interactions provide third components gaining. There are some almost massless particles among vector fields of the group (which together form massive gluons octet). Considerable mass split of heavy gluons must carry to chromodynamic interactions flavour symmetry breaking at high energies.

VI. Likely to the previous case, some of yet unobservable colored objects are almost massless. Third polarization components are bounded to vector particles with condensate interactions.

Thus, Introduction consistency criterion is satisfied, and the choice of (1.2.1) confirmed in the sense of theory inner consistency. There are also no rough and evident experimental data contradictions (e.g. extra massless observable objects presence, unnatural spin qualities fields etc.).

It’s quite reasonable to include all the constructed compound fields into an effective low-energy theory of submetacolor confinement level. The task is not too difficult, because all (1.2.2) and (1.2.3) fields decay into scalar preons and the latter have small masses. The last statement isn’t of a big evidence: there are two main arguments for it – the first is due to hypothesis of chiral character of the model, the last – due to molten condensate regions localization character.

Our first argument arises from a strong notion of the fact that the resulting compound field $q_{La}$ must be massless. Because of contained in it scalar preons have themselves a non-zero mass, we need some subtle dynamic adjustment, which provides vanishing of total rest energy of quark excitation. This happens due to summary scalar preon energy and condensate melting energy compensation with negative energy of preons’ interaction. Such an adjustment seems to be extremely improbable when scalar preon mass is big.

There are also some more plain arguments for small scalar preon mass: there is a picture of vacuum condensates state in quark (lepton) excitation at Fig. 1b (thick dashing corresponds to metacolor confinement condensates, thin – to submetacolor confinement ones). We represent quark as a bag excitation, but within the present notions any excitation is associated with a localized in some way region of molten condensate. Consequently, our arguments are applicable independently upon quark structure details. Dashing lack in inner part of Fig. 1b marks exactly the region of molten condensate.
It’s easy to see, that no one of (1.2.1) condensates provide scalar preon mass-gaining (contrarily to the other built subpreon scalar excitations). Fig. 4b shows that metacolor confinement condensates, the only ones which are able to give a non-zero mass to scalar preon, are molten in it’s vicinity and so can’t fully execute their functions. This makes us think that scalar preon masses are probably far less than metacolor confinement scale (and undoubtedly not similar to submetacolor confinement scale, which can be deduced from naive reasoning).

Thus, eliminating all massive unstable objects, we have only quark and lepton scalar preons and gauge fields to be included into a consistent low-energy theory. When adding universal spinor preons which arise at the next level of confinement hierarchy and fix the $U(1) \times SU_c(3) \times SU_{mc}(N_{mc})$ gauge group we come to well-known boson-fermion preon model ([5], [6]). We’d like to note that in this paper four-particle interactions are not considered to be fundamental: it’s easy to build preon diagrams expressing this exotic processes inner structure in terms of $U(1) \times SU_c(3) \times SU_{mc}(N_{mc}) \times SU_{smc}(N_{smc})$ theory, which doesn’t contain any unnatural vertices.

1.3 Metacolor confinement level

Acting similarly to the previous section, we introduce the following condensates of the gauge field and scalar and spinor preon fields to provide confinement

$$\langle 0 | B^\mu_\omega B^\mu_\omega | 0 \rangle = C_B$$

$$\langle 0 | \tilde{\varphi}^\alpha_{r_a \omega \alpha} | 0 \rangle = C_{\tilde{\varphi}(Q)}$$

$$\langle 0 | \tilde{\varphi}^\alpha_{l \alpha} l_{m \alpha} | 0 \rangle = C_{\tilde{\varphi}(L)}$$

$$\langle 0 | (\bar{\varphi}^\alpha_{L \rho \alpha} U^\rho_{\beta \alpha} L^\beta_{\alpha} \bar{U}^\beta_{\alpha \beta} R) | 0 \rangle = C_U^{(1)}$$

$$\langle 0 | (\bar{\varphi}^\alpha_{L \rho \alpha} U^\rho_{\beta \alpha} L^\beta_{\alpha} \bar{U}^\beta_{\alpha \beta} R) | 0 \rangle = C_U^{(2)}$$

$$\langle 0 | (\bar{\varphi}^\alpha_{L \rho \alpha} D^\rho_{\alpha \beta} L^\beta_{\alpha} \bar{D}^\beta_{\beta \alpha} R) | 0 \rangle = C_D^{(1)}$$

$$\langle 0 | (\bar{\varphi}^\alpha_{L \rho \alpha} D^\rho_{\alpha \beta} L^\beta_{\alpha} \bar{D}^\beta_{\beta \alpha} R) | 0 \rangle = C_D^{(2)}$$

The fact, that we successively excluded all the submetacolor confinement level excitation with only exception for boson-fermion model fields, can make subpreon level to seem unnecessary and unnatural. Such arguments, however, doesn’t hurt the built hierarchy scheme, for $C_U$ and $C_D$ cannot be composed from boson-fermion model fields only. That is one more (perhaps, even more strong) theoretical approval of subpreon level necessity – excitations spectrum, which both passes through our consistency criterion and doesn’t contradict to known experimental facts, can’t be built without its assuming.

As for (1.3.1) condensates characteristic scales ratio, everything said in the previous section is applicable. More than that, $U$- and $D$-condensates non-zero values are caused by correlations of induced fluctuations of different scales, and, consequently, their energy split has to be even greater than in case of subpreon level. In low-energy theory $U$- and $D$-condensates correspond to vacuum averages of Higgs fields and so they are about the scale of effective gauge $SU(2)$-symmetry breaking, which is experimentally known ($\Lambda_{SM} \approx 100 GeV$). When the arguments are revealed, small value of this quantity relatively to the presupposed metacolor deconfinement scale seems to be a natural theory’s consequence, but not a destroying its orderliness paradox.

We construct excitations spectrum using principles established in previous section:

1. Vector bags:

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5 We don’t take into account condensates of any fields but those of boson-fermion model and those which considered as fundamental within the paper. Condensates of other excitations built in previous section are negligibly small because of their huge masses.
$W^\mu_\mu = (\bar{D}^\alpha L_\mu \gamma^\mu U^\alpha L)$

$W^{(U)}_\mu = (\bar{U}^\alpha L_\mu \gamma^\mu U^\alpha U)$

$W^{(D)}_\mu = (\bar{D}^\alpha L_\mu \gamma^\mu D^\alpha L)$  (1.3.2)

2. Spinor bags – quark and leptons.

3. Scalar collective excitations:
   a) excitations of scalar preon condensates:

   $\Psi^{ik}_{ab} = (\tilde{\varphi}_a^{\alpha_i} \varphi_b^{\beta_k}) = (\Psi_{ab}, \Psi^n_{ab})$

   $\Phi^{lm}_{\mu} = (\tilde{\varphi}_l^{\alpha} \varphi_m^{\alpha})$

   $\chi^i_{al} = (\tilde{\varphi}_a^{\alpha_i} \varphi_l^{\alpha})$  (1.3.3)

   the later excitation is scalar preon leptoquark, observed as a resonance in proton-positron scattering.

   b) excitations of spinor preon condensate

   $W^+ = (\bar{D}^\alpha L \tilde{x}_R^\beta U^\alpha L)$

   $H^+ = (\bar{D}^\alpha L \tilde{x}_R^\beta U^\alpha U)$

   $W^{(U)} = (\bar{U}^\alpha L \tilde{x}_R^\beta U^\alpha L)$

   $H^{(U)} = (\bar{U}^\alpha L \tilde{x}_R^\beta U^\alpha U)$  (1.3.4)

   $W^{(D)} = (\bar{D}^\alpha L \tilde{x}_R^\beta D^\alpha L)$

   $H^{(D)} = (\bar{D}^\alpha L \tilde{x}_R^\beta D^\alpha U)$

   $W$ and $H$ particles form eight degrees of freedom, which play the roles of four Goldstone and four Higgs bosons in effective low-energy theory.

   c) metaglueballs

   $B = B^\omega_{\alpha \nu} B^{\alpha \nu}_{\omega} a_B = e^{\mu \nu \rho \sigma} B_{\mu \nu}^\omega B^\omega_{\rho \sigma}$  (1.3.5)

   add two more Higgs-Goldstone degrees of freedom, which allows to build a theory with two doublets and a complex singlet.

   Within the standard method, we divide excitations into groups capable for mutual transformation:

   I. $W^\mu_\mu$  

   II. $(W^{(U)}_\mu, W^{(D)}_\mu)$  $(W^{(U)}_\mu, W^{(D)}_\mu, B, a_B)$ where we also need to take into account the ability of mixing II group particles with I group bosons from the previous section. Diagram analysis assures that third polarization components producing mechanism works properly at this level too.

   As it can be seen, the main degrees of freedom of metacolor confinement level theory, i.e. quark-lepton model, can be caught into a gauge theory with $U(1) \times U(1) \times SU_L(2)$-group, two Higgs-doublets and a singlet transforming after $U_W(1)$ only. Preon model predicts singlet vacuum shift to be far greater than doublet ones. At preon level singlet corresponds to a mixture of excitations, the main component of which is metaglueball; but vacuum average of the later is nothing else but $C_B$, which, as it has been said above, strongly exceeds all the other condensates. Such a state of affair causes a small ratio of $Z$- and $Z'$-bosons masses, which, thus, unavoidably follows from preon level existence.

   Without any violation of gauge symmetry we can also add into the built low-energy theory a non-renormalizable vertex, coupling first flavour scalar leptoquark to fermions and Higgs particles. Extended in this way theory can be used for resonance $e^+d$- and $u\bar{\nu}_e$-scattering calculations.
2 Effective low-energy gauge model of quark-lepton level

2.1 $U(1) \times U(1) \times SU(2)$ gauge theory

It’s quite reasonable to try building a gauge low-energy theory. First, we know that it must at least include a gauge theory with $U(1) \times SU(2)$ group (SM namely). Second, requirement of renormalizability of some model sector (formed by the lightest particles) and presence of massive vector bosons among the particles which are to be included brings us to the necessity of gauge structure.

Four massive vector bosons extracted from the metacolor level excitation spectrum can be driven out of a $U(1) \times U_W(1) \times SU_L(2)$-theory after spontaneous symmetry breaking to $U(1)$. Fields $S_\mu, W_\mu^0$ and $W_\mu^i$ correspond to three simple gauge groups. Higgs sector contains two $SU_L(2)$-doublets with equal $U_W(1)$-charges and $U(1)$-charges which ratio is equal to -1 (the doublets are designated as $h_1$ and $h_2$). Complex singlet $\sigma$ is transformed after $U_W(1)$ only; its charge can be chosen in some different ways. When usual discrete symmetries of two-doublet standard model (7) are accepted the Higgs potential structure, necessary for lack of massless Goldstone bosons within the theory, puts the singlet $U_W(1)$-charge twice greater than doublets’ ones.

We chose vacuum shifts in the form:

$$h_1 = \begin{pmatrix} 0 \\ \rho_1 \end{pmatrix}, \quad h_2 = \begin{pmatrix} \rho_2 \\ \delta \end{pmatrix}, \quad \sigma = \frac{\sigma_0}{2}$$  (2.1.1)

where $\delta = 0$ in massless photon phase (which only will be analyzed below). Singlet vacuum shift can be made real by redefining the $\sigma$ field, which hereafter is supposed to be done. When these two restrictions are satisfied any vacuum shifts set can be reduced to the form (2.1.1) by gauge transformations.

Applying unitary gauge conditions we obtain the following expressions for the Higgs fields:

$$h_1 = \begin{pmatrix} H^+ \sin \varphi \\ \rho \sin \xi \cos \varphi + H_1^0 + i \frac{\cos \xi \sin \varphi}{\sqrt{1 - \sin^2 \xi \cos^2 2\varphi}} A^0 \end{pmatrix}$$

$$h_1 = \begin{pmatrix} \rho \sin \xi \sin \varphi + H_2^0 + i \frac{\cos \xi \cos \varphi}{\sqrt{1 - \sin^2 \xi \cos^2 2\varphi}} A^0 \\ H^- \cos \varphi \end{pmatrix}$$  (2.1.2)

$$\sigma = \frac{\rho \cos \xi}{2} + H_3^0 + i \frac{\sin \xi \sin 2\varphi}{\sqrt{1 - \sin^2 \xi \cos^2 2\varphi}} A^0$$

where $H^+, H_1^0, H_2^0, H_3^0$ and $A^0$ are charged and neutral Higgs fields.

$$\rho = \sqrt{\rho_1^2 + \rho_2^2 + \sigma_0^2}, \quad \xi = \arccos(\sigma_0/\rho), \quad \varphi = \arctan(\rho_2/\rho_1)$$

Supposing coupling constants equal to $g_1/2$ for $U(1)$, $g_W/2$ for $U_W(1)$ and $g_2$ for $SU_L(2)$ and substituting (2.1.2) expressions into articles with covariant derivatives of Higgs fields, we obtain $W_\mu^+$ mass and $A_\mu$, $Z_\mu$ and $Z'_\mu$ mass matrix in the form:
First article in

\[ m_{W^+} = g_2 \sqrt{ \frac{\rho_1^2 + \rho_2^2}{2} } \]

\[
(M^2)_{S,W^0,W^0} = \frac{\rho_2^2}{2} \begin{pmatrix}
  g_1^2 \sin^2 \xi & - g_1 g_2 \sin^2 \xi & - g_1 g_w \sin^2 \xi \cos 2 \varphi \\
  - g_1 g_2 \sin^2 \xi & g_2^2 \sin^2 \xi & g_2 g_w \sin^2 \xi \cos 2 \varphi \\
  - g_1 g_w \sin^2 \xi \cos 2 \varphi & g_2 g_w \sin^2 \xi \cos 2 \varphi & g_w^2
\end{pmatrix}
\]

When diagonalized, (2.1.3) gives massless electromagnetic field and two massive vector boson fields:

\[
m_Z^2 = \frac{\rho_2^2}{4} \left( (g_1^2 + g_2^2) \sin^2 \xi + g_w^2 - \sqrt{[(g_1^2 + g_2^2) \sin^2 \xi - g_w^2]^2 - 4(g_1^2 + g_2^2)g_w^2 \sin^2 \xi \cos^2 2 \varphi} \right)
\]

\[
m_{Z'}^2 = \frac{\rho_2^2}{4} \left( (g_1^2 + g_2^2) \sin^2 \xi + g_w^2 + \sqrt{[(g_1^2 + g_2^2) \sin^2 \xi - g_w^2]^2 - 4(g_1^2 + g_2^2)g_w^2 \sin^2 \xi \cos^2 2 \varphi} \right)
\]

Because the quantity \( m_Z/m_{Z'} \) is small we can expand this expressions into series by \( \sin^2 \xi \):

\[
m_Z^2 = \frac{m_{W^+}}{\cos^2 \theta_W} \left( 1 - \sin^2 \xi \cos^2 2 \varphi - \frac{g_1^2 + g_2^2}{g_w^2} \sin^4 \xi \cos^2 2 \varphi + \cdots \right)
\]

\[
m_{Z'}^2 = \frac{g_w^2 \sigma_0^2}{2 \cos^2 \xi} \left( 1 + \frac{g_1^2 + g_2^2}{g_w^2} \sin^4 \xi \cos^2 2 \varphi + \left( \frac{g_1^2 + g_2^2}{g_w^2} \right)^2 \sin^6 \xi \cos^2 2 \varphi + \cdots \right)
\]

First article in \( m_Z^2 \) expansion gives a usual ratio of \( W^+ \)- and \( Z \)-bosons masses in SM. Due to equality of doublets \( U_W(1) \)-charges (which follows from preon model) when doublets shifts are equal (\( \cos 2 \varphi = 0 \)) \( W^0 \) field doesn’t mix with other fields and SM mass ratio is sharply reproduced. Note, that \( W^+ \)- and \( Z \)-bosons masses, determined mainly by doublets shifts lie at Salam-Weinberg scale, and \( Z' \)-boson mass, formed by singlet vacuum shift, must be of about metacolor deconfinement energy scale.

We analyzed Higgs potential in the most general form allowed by discrete and gauge symmetries:

\[
U(h_1, h_2, \sigma) = -\mu_1 (h_1^+ h_1) - \mu_2 (h_2^+ h_2) - \mu_3 (\sigma^+ \sigma) + \lambda_{11} (h_1^+ h_1)^2 + \lambda_{22} (h_2^+ h_2)^2 + \lambda_{33} (\sigma^+ \sigma)^2 + \lambda_{12} (h_1^+ h_1)(h_2^+ h_2) + \bar{\lambda}_{12} (h_1^+ h_2)(h_2^+ h_1) + \lambda_{13} (h_1^+ h_1)(\sigma^+ \sigma) + \lambda_{23} (h_2^+ h_2)(\sigma^+ \sigma) + \nu [(h_1^+ h_2)\sigma + (h_2^+ h_1)\sigma^+] \tag{2.1.6}
\]

where \( \tilde{h} = i \tau_2 h^+ \).

Substitution (2.1.1) into (2.1.6) and following minimization brings us to vacuum averages equations:
\[
\begin{align*}
-m_1 \rho_1 + 2\lambda_1 \rho_1^3 + (\lambda_1 + \lambda_2) \rho_1 \rho_2 + \frac{1}{4} \lambda_3 \rho_1 \sigma_0^2 - \frac{1}{2} \nu \rho_2 \sigma_0 &= 0 \\
-m_2 \rho_2 + 2\lambda_2 \rho_2^3 + (\lambda_1 + \lambda_2) \rho_1 \rho_2 + \frac{1}{4} \lambda_3 \rho_2 \sigma_0^2 - \frac{1}{2} \nu \rho_1 \sigma_0 &= 0 \\
-m_3 \sigma_0 + \frac{1}{2} \lambda_3 \sigma_0^2 + (\lambda_1 \rho_1 + \lambda_2 \rho_2) \sigma_0 + 2\nu \rho_1 \rho_2 &= 0
\end{align*}
\]

(2.1.7)

\[m_{H^+}^2 = (\lambda_1 - \lambda_1)(\rho_1^2 + \rho_2^2) + \frac{\nu \sigma_0 \cos^2 2\varphi}{\sin 2\varphi}
\]

\[m_{A^0}^2 = \nu \sigma_0 \cos^2 \xi \frac{\cos^2 2\varphi}{\sin 2\varphi}
\]

\[\begin{pmatrix}
4\lambda_1 \rho_1^2 + \frac{1}{2} \nu \sigma_0 \tan \varphi & 2(\lambda_1 + \lambda_1) \rho_1 \rho_2 - \frac{1}{2} \nu \sigma_0 & \lambda_1 \rho_1 \sigma_0 - \nu \rho_2 \\
2(\lambda_1 + \lambda_1) \rho_1 \rho_2 - \frac{1}{2} \nu \sigma_0 & 4\lambda_2 \rho_2^2 + \frac{1}{2} \nu \sigma_0 \cot \varphi & \lambda_2 \rho_2 \sigma_0 - \nu \rho_1 \\
\lambda_1 \rho_1 \sigma_0 - \nu \rho_2 & \lambda_2 \rho_2 \sigma_0 - \nu \rho_1 & \lambda_3 \sigma_0^2 + 2\nu \frac{\rho_1 \rho_2}{\sigma_0}
\end{pmatrix}
\]

(2.1.8)

\[
\begin{align*}
\frac{\nu}{4\pi^2 \sigma_0} &\ll 1 \\
\frac{\lambda}{4\pi^2} &\ll 1.
\end{align*}
\]

Using these relations and \(\sin \xi \ll 1\) inequality, we can approximately (in first order by \(\sin \xi\)) diagonalize Higgs fields mass matrix. Two of the obtained in this way masses, \(\sqrt{\lambda_3} \sigma_0\) and \(\sqrt{\nu \sigma_0 (\tan \varphi + \cot \varphi)}\), lie at the scale of metacolor confinement, and the third (vanishing within the considered approximation) – at Salam-Weinberg scale.

To draw any conclusions on \(H^+\) and \(A^0\)-bosons masses, we need to know the quantity \(\cos 2\varphi\). It’s quite obvious at preon level that it must be small: \(\cos 2\varphi \sim \rho_1^2 - \rho_2^2\) and doublet shifts are determined by condensate forms \(C_U\) and \(C_D\) from (1.3.1). Taking into view that \(C^{(1)}\) and \(C^{(2)}\) expressions, corresponding to \(h_1\) and \(h_2\) at low-energy level, have similar structure, we almost unavoidably arrive to the conclusion that induced by similar processes \(C^{(1)}\) and \(C^{(2)}\) condensates are equal to each other quite precisely.

We would like to stress, that sharp equality \(\rho_1 = \rho_2\) can’t take place within a consistent theory, because, in such a situation, \(A^0\) boson turns out to be massless. Thus, the quantity \(\cos 2\varphi\) which is determined by doublets vacuum shift ratio is of a small non-zero value, and axial neutral Higgs-boson mass is formed as a product of big singlet vacuum shift \(\sigma_0\) and small \(\cos 2\varphi\) and lie at a scale which cannot be determined with a heuristic investigation.

Some remarks can also be made on the built theory predictions for the value of \(W^+\)- and \(Z\)-bosons masses precision ratio, which experimental value is according to SM predictions up to 1% sharp. It can be seen from (2.1.7) formula that relative deviation of \(m_Z/m_W\) ratio from SM predictions in our theory is proportional to \(\sin^2 \xi \cos^2 2\varphi\). As it has been mentioned, \(\cos 2\varphi\) is a small quantity and \(\sin \xi \sim m_Z/m_{Z^*}\). Thus, (due to carried out of preon model doublets \(U_W\) (1-charges equality) within the examined theory high sharpness of SM predictions for precision ratio doesn’t put any restrictions on \(Z^*\)-boson mass. Even when it’s not too big, presence of small multiplier will make deviations from SM predictions negligible.
2.2 Low-energy theory expansion with non-renormalizable interactions

In previous section we included into effective low-energy model the maximum field set, which allows to build a renormalizable theory. However DESY collider experiments make considerably important to establish a calculation technique for scalar leptoquark engaging processes.

Preon diagrams analysis brings to a conclusion that all fermion-leptoquark interactions are non-renormalizable (it’s not a bit wondrous as low-energy interactions are \textit{a priori} non-local).

It’s easy to see that due to exactly interactions non-locality the number of different low-energy vertices engaging leptoquark is infinite. We’ll try to point out their main features and consider some simplest representatives.

Note, that within the excitations structure notions, developed in section 1, leptoquark interacts with left-chiral fermions only. It, however, can’t decay into left-chiral quark and left-chiral fermion due to momentum and angular momentum conservation laws. We know two ways to overcome this obstacle.

1) The born left-chiral quark “immediately” interacts with the condensate, providing quarks mass-gaining and transforms into a right-chiral one (Fig. 4). Non-renormalizability here is provided with presence of an unremovable non-pertubative process.

2) Left-chiral particles appear not in the same spatial point – then summary spin can be compensated by orbital momentum of their relative motion. Such interaction is described, in particular, by the following vertex:

$$L = \lambda_{\pbar q} \gamma^{\mu} l^\mu \partial_{\mu} \chi^i$$ \hspace{1cm} (2.2.1)

In this paper we examine first possibility only. Note, however, that (2.2.1) must produce an unusual resonance cross-section dependence upon the scattering angle, which, undoubtedly, of a considerable importance for experimental theory verification. More than that, presence of interactions, having non-local origin and similar to (2.2.1), seems to be a critical test for composite quark and lepton models. This is the property which distinguishes the examined leptoquark from those appearing in GUTs and other (preon-less) elementary particles theories. We hope that this important property will help to determine wether DESY discovery (if it is confirmed) can be considered as an argument for quark and leptons inner structure existence.

Let’s examine more properly the diagram shown at Fig. 4. \textit{VAC} vertex represents effective sum of all local processes of leptoquark decaying into left-chiral fermions pair (they are \([1.3.1]\) \textit{U-} and \textit{D}-condensates interactions, pertubative birth of \(U\bar{U}(D\bar{D})\)-pair from emitted by \(x\)-subpreon metagluon etc.). After this process is completed left-chiral quark transforms into right-chiral, which is necessary as it has been mentioned above.
In fact, we have a solid process, a leptoquark interaction with correlated condensates pair, as the first of described decay process components is itself impossible. Nevertheless, the two formally introduced subprocesses arise at a different energy hierarchy levels (preon and quark-lepton respectively), and, consequently, we can suppose them to be independent in a high degree. When this is accepted, the fact, that carrying flavour indices subpreons doesn’t take any part in VAC interaction, makes us to think that relations of different generation leptoquarks decays are determined only by the diagram part, containing quark vacuum interaction. Thus, flavour hierarchy of effective leptoquark coupling constants is similar to quark masses hierarchy. We establish low-energy description of Fig. 4 diagram analogously to quark masses generation low-energy description (i.e. substituting quark condensate interactions with interactions with Higgs one):

\[
L_{\text{leptoquark}} = \lambda_1 m_{ab} \chi_{ab} \bar{q}_b (h^+_1 l_L) + \lambda_2 m_{ab} \chi_{ab} \bar{q}_b (h^+_2 l_L) + \text{h.c.} \tag{2.2.2}
\]

Note, that alternatively to (2.2.2) we can in explicit form write renormalizable vertices, corresponding to leptoquark decay, without entering any Higgs fields into them. In this way we, however, would obtain initially broken gauge symmetry Lagrangian. Within the above-introduced (in our mind, more logical) approach, we arrive to a similar state after spontaneous breaking.

3 Leptoquark resonance influence on the cross-section of \(e^+d\)-scattering

In the beginning of 1997 year two independent research groups at Hamburg collider HERA announced that the number of \(e^+p \rightarrow e^+X\) and \(e^+p \rightarrow \bar{\nu}_e X\) events exceeds SM predictions (beams momenta were \(p_e = 27.5\text{GeV}\) and \(p_p = 820\text{GeV}\)). One of the suggested hypotheses explaining such an anomaly is that kinematic variables of the experiment turned out to be within the leptoquark resonance boundaries. Supposing that the suggested leptoquark has preonic origin we can easily calculate its influences on \(e^+d \rightarrow e^+d\) and \(e^+d \rightarrow u\bar{\nu}_e\) processes within the built in section 2 effective low-energy \(U(1) \times U(1) \times SU(2)\) theory.

After spontaneous symmetry breaking the part of interaction Lagrangian, corresponding to neutral current process is written in the form:

\[
L_{(e^+d \rightarrow e^+d)} = -\frac{e}{3} \bar{d} A d - e \bar{e} \hat{A} e - \frac{\beta_d}{6} \bar{d} \hat{Z} (1 + \delta_d \gamma^5) d - \frac{\beta_e}{2} \bar{e} \hat{Z} (1 + \delta_e \gamma^5) e -
\]

\[
- \frac{\beta_d'}{6} \bar{d} \hat{Z}' (1 + \delta_d' \gamma^5) d - \frac{\beta_e'}{2} \bar{e} \hat{Z}' (1 + \delta_e' \gamma^5) e + \]

\[
+ G_{ed} \left[ \chi_{11} \bar{d} (1 - \gamma^5) e + \chi_{11}^- \bar{e} (1 + \gamma^5) d \right] \tag{3.1}
\]

To examine the charged current process we also need the following vertices:

\[
L_{(e^+d \rightarrow u\bar{\nu}_e)} = \frac{g_2}{2\sqrt{2}} \left( \bar{u} i \hat{W}^+ d + \bar{d} i \hat{\bar{W}}^- u + \bar{\nu}_e i \hat{W}^+ e + \bar{e} i \hat{\bar{W}}^- \nu_e \right) +
\]

\[
+ G_{u\bar{\nu}_e} \left[ \chi_{11} \bar{u} (1 - \gamma^5) \nu_e + \chi_{11}^- \bar{\nu}_e (1 + \gamma^5) u \right] \tag{3.2}
\]

Effective broken symmetry Lagrangian parameters are expressed through gauge constants, vacuum shifts and leptoquark coupling constants. Thus \(G_{ed} = \lambda_1 \rho_1 m_{11}/2, G_{u\bar{\nu}_e} = \lambda_2 \rho_2 \bar{m}_{11}/2\).

When calculating the cross-sections we take into account a finite leptoquark width within Breit-Wigner approximation. All below-written results are obtained in chiral limit, which
is quite logical when reactions energies are about four orders of magnitude higher than the fermion masses. In this approach leptoquark width (due to $e^+d$ and $u\bar{u}_e$ decay processes) is equal to:

$$\Gamma = \frac{1}{4\pi} \left( G_{ed}^2 + G_{u\bar{u}_e}^2 \right) m_{\chi}$$  \hspace{1cm} (3.3)$$

The following four loopless diagrams contribute to elastic scattering: transformation into leptoquark, succeeded with its reverse decay into $e^+d$-pair (s-channel) and exchanges with photon, $Z$- and $Z'$-bosons in t-channel. The corresponding expression in chiral limit in centre of mass related frame of reference is:

$$d\sigma = \frac{\sin \chi d\chi}{64\pi} \left\{ \frac{32G_{ed}^4 p^2}{(m_{\chi} - s)^2 + m_{\chi}^2 \Gamma^2} + \frac{8}{3} G_{ed}^2 \frac{m_{\chi}^2 - s}{(m_{\chi} - s)^2 + m_{\chi}^2 \Gamma^2} \frac{1}{\sin^2(\chi/2)} + \right.$$  

$$+ \frac{8}{3} G_{ed}^2 \beta_e \beta_d \frac{m_{\chi}^2 - s}{(m_{\chi} - s)^2 + m_{\chi}^2 \Gamma^2} \frac{(1 - \delta_e)(1 + \delta_d)p^2}{m_{\chi}^2 + 4p^2 \sin^2(\chi/2)} + \right.$$  

$$+ \frac{8}{3} G_{ed}^2 \beta_e \beta_d \frac{m_{\chi}^2 - s}{(m_{\chi} - s)^2 + m_{\chi}^2 \Gamma^2} \frac{(1 - \delta_e')(1 + \delta_d')p^2}{m_{\chi}^2 + 4p^2 \sin^2(\chi/2)} + \right.$$  

$$+ \frac{1}{9} \frac{e^4}{p^2 \sin^4(\chi/2)} \left(1 + \cos^4(\chi/2)\right) + \right.$$  

$$+ \frac{2}{9} \frac{\beta_e \beta_d \beta_e' \beta_d'}{p^2} \left( m_{\chi}^2 + 4p^2 \sin^2(\chi/2) \right) \left( m_{\chi}^2 + 4p^2 \sin^2(\chi/2) \right) \times \left[ (1 + \delta_e \delta_e')(1 + \delta_d \delta_d')(1 + \cos^4(\chi/2)) + \right.$$  

$$+ (\delta_e + \delta_e')(\delta_d + \delta_d') \sin^2(\chi/2) \left( \sin^2(\chi/2) - 2 \right) \right] + \right.$$  

$$+ \frac{1}{9} \frac{\beta_e^2 \beta_d^2 p^2}{(m_{\chi}^2 + 4p^2 \sin^2(\chi/2))^2} \left[ (1 + \delta_e^2)(1 + \delta_d^2)' \left(1 + \cos^4(\chi/2)\right) + \right.$$  

$$+ 4\delta_e \delta_e \sin^2(\chi/2) \left( \sin^2(\chi/2) - 2 \right) \right] + \right.$$  

$$+ \frac{1}{9} \frac{\beta_e^2 \beta_d^2 p^2}{(m_{\chi}^2 + 4p^2 \sin^2(\chi/2))^2} \left[ (1 + \delta_e^2')(1 + \delta_d^2) \left(1 + \cos^4(\chi/2)\right) + \right.$$  

$$+ 4\delta_e' \delta_d \sin^2(\chi/2) \left( \sin^2(\chi/2) - 2 \right) \right] + \right.$$  

$$+ \frac{2}{9} \frac{e^2 \beta_e \beta_d}{\sin^2(\chi/2)} \left( m_{\chi}^2 + 4p^2 \sin^2(\chi/2) \right) \left[ 1 + \cos^4(\chi/2) + \delta_e \delta_d \sin^2 \frac{\chi}{2} \left( \sin^2 \frac{\chi}{2} - 2 \right) \right] + \right.$$  

$$+ \frac{2}{9} \frac{e^2 \beta_e' \beta_d'}{\sin^2(\chi/2)} \left( m_{\chi}^2 + 4p^2 \sin^2(\chi/2) \right) \left[ 1 + \cos^4(\chi/2) + \delta_e' \delta_d' \sin^2 \frac{\chi}{2} \left( \sin^2 \frac{\chi}{2} - 2 \right) \right] \right\} \right.$$  

where $s = 4p_e p_d$ is first Mandelstam invariant, $p = \sqrt{p_e p_d}$ - scattering momentum, and $\chi$ - scattering angle in center of mass related frame of reference. Scattering angle expression in laboratory frame of reference:

$$\theta = \arctan \left( \frac{2(p_e p_d)^{3/2} \sin \chi}{p_e p_d (1 + \cos \chi) - p_e p_d (1 - \cos \chi)} \right)$$  \hspace{1cm} (3.5)
allows to calculate observable cross-section.

\[ e^+ d \rightarrow u \bar{u} e \] process is described by two diagrams only: leptoquark one in s-channel and \( W^+ \)-exchange graph in t-channel. Cross-section expression structure in the case is quite similar to (3.4):

\[
d\sigma = \frac{\sin \chi d\chi}{8\pi} p^2 \left\{ \frac{4G_{\text{ed}}^2G_{\text{ue}}^2}{(m^2_s - s)^2 + m^2_x} + \frac{g_4^4}{4 \left( m_{W^+}^2 + 4p^2\sin^2(\chi/2) \right)^2} \frac{\cos^4 \chi}{2} \right\}
\]

(3.6)

\[ s = 4p_u p_{\bar{u}e} \quad p = \sqrt{p_u p_{\bar{u}e}} \]

Note some important features of (3.4) and (3.6) expressions:

1) The cross-section has a sharp maximum in the vicinity of \( p = m_x/2 \) point (so-called leptoquark resonance)

2) Interference effects brings to peak asymmetry in the neutral current process. With some proper (3.1) and (3.2) Lagrangians constants values notable holes in cross-section graph may appear. Their location relatively to the peak is determined by positiveness or negativeness of Lagrangian constants pair products.

3) In case of \( e^+ d \rightarrow u \bar{u} e \) scattering s- and t-channels interference is supressed due to the fact that \( W^+ \)-boson interacts with left-chiral quarks only. Cross-section peak then must be symmetric of a great degree.

4) For elementary processes (scattering of quarks, but not hadrons) the peak height doesn’t depend on leptoquark coupling constant – the later can influence it’s width only.

5) The resonance is most easily observable in the case of backward scattering.

We have examined (3.4) and (3.6) expressions behavior for constant values, which seem to be realistic ones. The built in section 2 effective low-energy model contains some parameters, which are not fixed by known experimental facts (\( Z' \)-boson mass, different Higgs fields vacuum shifts ratios). Recalling the preon model, however, helps to draw some conclusions on those undetermined quantities.

As it has been said in section 2.1, vacuum shifts of \( h_1 \) and \( h_2 \) doublets are close to each other, but can’t be equal precisely, for this will cause a zero axial neutral Higgs-boson mass. In \( e^+ d \)-scattering calculations, however, assuming sharp doublet shifts equality doesn’t carry to any anomalous consequences. All physical quantities show a smooth behavior when changing \( \cos^2 \varphi \) parameter, which vanishes when the doublets shifts are equal. Thus, within the approximate calculation we can put \( \rho_1 = \rho_2 \), i.e. \( \varphi = \pi/4 \). \( g_2 \) and \( g_W \) constants having similar origin at preon level will also be considered as equal. Within this approach effective Lagrangian parameters are expressed through experimentally known quantities: electron charge \( e \) and Weinberg angle \( \theta_W \):

\[
\begin{align*}
\beta_d &= \frac{e}{\sin 2\theta_W} (3 - 4 \sin^2 \theta_W) & \delta_d &= \frac{3}{4 \sin^2 \theta_W - 3} & \beta'_d &= -\frac{3}{2 \sin \theta_W} & \delta'_d &= -1 \\
\beta_e &= \frac{e}{\sin 2\theta_W} (1 - 4 \sin^2 \theta_W) & \delta_e &= \frac{1}{4 \sin^2 \theta_W - 1} & \beta'_e &= -\frac{e}{2 \sin \theta_W} & \delta'_e &= -1
\end{align*}
\]

(3.7)

For essential masses the following values were used: \( m_x = 200 GeV \), \( m_{W^+} = 82 GeV \), \( m_Z = 91 GeV \), \( m_{Z'} = 465 GeV \). We studied \( (d\sigma/d\theta) \) graphs with a fixed scattering angle and positron beam energy \( (p_e = 27.5 GeV) \) and varied energy of the colliding quarks; \( G_{\text{ed}} \) and \( G_{\text{ue}} \) constants were put equal to 0.05. The results (Fig. 3-8) straightforwardly confirm all the stated general properties of the resonance scattering process.
Figure 5: Dependence graph of $e^+d \to e^+d$ elastic scattering to $\pi/4$ angle differential cross-section on $d$-quark beam momentum in laboratory frame of reference. Dashed line is SM cross-section.

Figure 6: Dependence graph of $e^+d \to e^+d$ elastic scattering to $\pi/4$ angle differential cross-section on $d$-quark beam momentum in laboratory frame of reference (in logarithmic scale).

Figure 7: Dependence graph of $e^+d \to e^+d$ elastic scattering to $3\pi/4$ angle differential cross-section on $d$-quark beam momentum in laboratory frame of reference (in logarithmic scale).

Figure 8: Dependence graph of $e^+d \to u\bar{\nu}_e$ inelastic scattering to $\pi/4$ angle differential cross-section on $d$-quark beam momentum in laboratory frame of reference.
4 Low-energy empiric predictions status

The obtained in previous section expressions (3.4) and (3.6) don’t belong to the set of quantities which are directly experimentally observable. Starting from them, however, we can easily come to inclusive cross-sections of $e^+p \rightarrow e^+X$ and $e^+p \rightarrow \bar{\nu}_eX$ processes, which are examined in DESY. Even now we can draw some conclusions on their properties.

The first striking discordance between graphs at Fig. 5-8 and German researchers data is that peak cross-section value (independently upon leptoquark coupling constant) exceeds background one in a few orders of magnitude, but H1 and ZEUS groups announced just about observation of events, which number surpasses SM predictions about a time with half only. Under a scrutiny this argument falls, for we examine only an elementary process, but not an inclusive cross-section. In case of proton scattering partons spread over momentum brings to a dependence of inclusive cross-section peak value not only on elementary process peak cross-section value, but also on resonance width, which itself depends on leptoquark coupling constants values. Hence, leptoquark-fermion interactions weakness can cause an unboundedly strong resonance slackening. All the rest, said on quark-lepton cross-sections in the previous section can, probably, without notable changes be considered as statements about deep-inelastic scattering features.

We would like to stress, that even an absolute coincidence of the built cross-sections with those which are to be carried out of the future experiments, can’t be considered as a confirmation of the preon structure stated in the beginning of the paper. Leptoquark resonance existence is predicted by a vast class of preon models and by some theories with structureless fermions. Nevertheless, the obtained cross-sections possess some features which can be considered as a “signature” of some sort of leptoquarks: scalar particles with chiral coupling to fermions, i.e. exactly those leptoquarks which are predicted by preon models.

Thus, statistics volume increasing at HERA will allow to judge whether preon notions development is reasonable. Unless first empirical cross-sections behavior observations reject some most simple and general predictions of preon leptoquark models, the further studying with paying great attention to non-local interactions (similar to the one described in section 2.2) will allow to obtain a definitive answer about vital capacity of the developed concepts.

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