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EXACT SOLUTIONS OF EINSTEIN'S EQUATIONS FOR ENERGY DENSITIES OF SPECIAL TYPE

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KEYWORDS

Einstein's equations; solutions; gravitation.

ABSTRACT

It was obtained exact solutions of Einstein's equations for energy densities of special type in this paper. It is considered cylindrically symmetrical interval. It is used cylindrical coordinates ρ , z , φ when calculating. Obtained solutions contain points of singularity, that form axis x^3 and plane x^1ox^2 . Surface of equal times is hyperboloid of two sheets, that does not cross coordinate axes and plane x^1ox^2 .

I. INTRODUCTION

It was obtained exact solutions of Einstein's equations for energy densities of special type in this paper. It is considered cylindrically symmetrical interval. It is used cylindrical coordinates ρ, z, φ when calculating. Obtained solutions contain points of singularity, that form axis x^3 and plane x^1ox^2 . Surface of equal times is hyperboloid of two sheets, that does not cross coordinate axes and plane x^1ox^2 .

Results of this paper have physical interest by the next reasons:

1. It was shown in this paper, that at limit $\Lambda \rightarrow 0$ gravitational field may exist even in absolute vacuum ($w(\rho, z) = 0$).
2. In this paper it was shown, that gravitational field in absolute vacuum may have surface of equal times and equal lengths of hyperboloid type.

II. RICHI'S TENSOR

Einstein's equations are [1]

$$R_{\mu\nu} - \frac{R}{2}g_{\mu\nu} + \Lambda g_{\mu\nu} = \kappa T_{\mu\nu}, \quad (1)$$

$$\kappa = \frac{8\pi G}{c^4}.$$

$T_{\mu\nu}$ is momentum-energy tensor: $T_{oo} = w(\rho, z)$, other components are equal to zero. For physical calculations they use solutions in the limit $\Lambda \rightarrow 0$ [22, 23]. In case of axial symmetry we look for solutions of equations (1) of such a type:

$$ds^2 = A_0(\rho, z)dx^{o2} + A_1(\rho, z)d\rho^2 + A_2(\rho, z)\rho^2d\varphi^2 + A_3(\rho, z)dz^2.$$

So, we look only for solutions, which correspond to diagonal form of ds^2 . Functions A_i do not depend on cylindrical coordinate φ . Distortion of length for direction $\rho d\varphi$ is absent: $A_2(\rho, z) = -1$.

Metric tensor components are equal to

$$g_{00} = A_0(\rho, z);$$

$$g_{11} = A_2(\rho, z) + B(\rho, z) \cos^2 \varphi;$$

$$g_{12} = g_{21} = B(\rho, z) \sin \varphi \cdot \cos \varphi;$$

$$g_{22} = A_2(\rho, z) + B(\rho, z) \sin^2 \varphi;$$

$$g_{33} = A_3(\rho, z);$$

$$B(\rho, z) = A_1(\rho, z) - A_2(\rho, z).$$

Metric tensor with upper indexes components are equal to

$$g^{00} = A_0^{-1}(\rho, z);$$

$$g^{11} = \frac{A_2(\rho, z) + B(\rho, z) \sin^2 \varphi}{A_1(\rho, z) \cdot A_2(\rho, z)};$$

$$g^{12} = g^{21} = -\frac{B(\rho, z) \sin \varphi \cos \varphi}{A_1(\rho, z) \cdot A_2(\rho, z)};$$

$$g^{22} = \frac{A_2(\rho, z) + B(\rho, z) \cos^2 \varphi}{A_1(\rho, z) \cdot A_2(\rho, z)},$$

$$g^{33} = A_3^{-1}(\rho, z).$$

All other components of tensors $g_{\mu\nu}$ and $g^{\mu\nu}$ are equal to zero.

After calculation of Kristoffel's symbols $\Gamma_{\nu\rho\sigma}$ and $\Gamma^\nu_{\rho\sigma}$ and definition of tensor of crookedness $R_{\mu\nu\rho\sigma}$, [2-5], we determine components of Richi's tensor $R_{\mu\nu}$:

$$R_{00} = -\frac{1}{2A_1} \left\{ (\partial_\rho^2 A_0) - \frac{1}{2} (\partial_\rho A_0) \left[\left(\partial_\rho \ln \left| \frac{A_0 A_1}{A_3} \right| \right) - \frac{2}{\rho} \right] \right\} -$$

$$-\frac{1}{2A_3} \cdot \left\{ (\partial_z^2 A_0) - \frac{1}{2} (\partial_z A_0) \left(\partial_z \ln \left| \frac{A_0 A_3}{A_1} \right| \right) \right\};$$

$$R_{11} = D_1 \cos^2 \varphi + D_2 \sin^2 \varphi;$$

$$R_{12} = R_{21} = (D_1 - D_2) \sin \varphi \cos \varphi;$$

$$R_{13} = R_{31} = D_3 \cdot \cos \varphi;$$

$$R_{23} = R_{32} = D_3 \cdot \sin \varphi;$$

$$R_{22} = D_1 \sin^2 \varphi + D_2 \cos^2 \varphi;$$

$$\begin{aligned} R_{33} = & -\frac{1}{2A_0} (\partial_z^2 A_0) - \frac{1}{2A_1} (\partial_z^2 A_1) - \frac{1}{2A_1} (\partial_\rho^2 A_3) + \frac{1}{4} (\partial_z \ln |A_0|) \times \\ & \times (\partial_z \ln |A_0 A_3|) + \frac{1}{4} (\partial_z \ln |A_1|) \cdot (\partial_z \ln |A_1 A_3|) + \frac{1}{4A_1} (\partial_\rho A_3) \times \\ & \times \left[\left(\partial_\rho \ln \left| \frac{A_1 A_3}{A_0} \right| \right) - \frac{1}{\rho} \right]. \end{aligned}$$

Other components of tensor $R_{\mu\nu}$ are equal to zero. Functions D_i (ρ, z) are equal to

$$\begin{aligned} D_1(\rho, z) = & -\frac{1}{2A_0} (\partial_\rho^2 A_0) - \frac{1}{2A_3} (\partial_z^2 A_1) - \frac{1}{2A_3} (\partial_\rho^2 A_3) + \frac{1}{4} (\partial_\rho \ln |A_0|) \times \\ & \times (\partial_\rho \ln |A_0 A_1|) + \frac{1}{4} (\partial_\rho \ln |A_3|) \cdot (\partial_\rho \ln |A_1 A_3|) + \frac{1}{4A_3} (\partial_z A_1) (\partial_z \ln \left| \frac{A_1 A_3}{A_0} \right|) + \\ & + \frac{1}{2} (\partial_\rho \ln |A_1|) \cdot \frac{1}{\rho}; \end{aligned}$$

$$D_2(\rho, z) = \frac{1}{2A_1} \left(\partial_\rho \ln \left| \frac{A_0 A_3}{A_1} \right| \right) \cdot \frac{1}{\rho};$$

$$\begin{aligned} D_3(\rho, z) = & -\frac{1}{2A_0} (\partial_{\rho z}^2 A_0) + \frac{1}{4} (\partial_\rho \ln |A_0|) \cdot (\partial_z \ln |A_0 A_1|) + \frac{1}{4} (\partial_z \ln |A_0|) \times \\ & \times (\partial_\rho \ln |A_3|) + \frac{1}{2} (\partial_z \ln |A_1|) \cdot \frac{1}{\rho}. \end{aligned}$$

We determine scalar crookedness from equations (1) ($\Lambda = 0$):

$$R = -A_0^{-1} \kappa w.$$

Now equations (1) take the form

$$R_{00} - \frac{1}{2} \kappa w = 0; \quad (2)$$

$$D_1 + \frac{1}{2} \kappa w \cdot \frac{A_1}{A_0} = 0; \quad (3)$$

$$D_2 - \frac{1}{2} \kappa w \cdot \frac{1}{A_0} = 0; \quad (4)$$

$$D_3 = 0; \quad (5)$$

$$R_{33} + \frac{1}{2} \kappa w \cdot \frac{A_3}{A_0} = 0. \quad (6)$$

Other equations from system (1) turn into identities.

We shall use new functions:

$$Q_1(\rho, z) = -\frac{1}{2A_0}(\partial_\rho^2 A_0) + \frac{1}{4A_0}(\partial_\rho A_0) \cdot \left[\left(\partial_\rho \ln \left| \frac{A_0 A_1}{A_3} \right| \right) - \frac{2}{\rho} \right];$$

$$Q_2(\rho, z) = -\frac{1}{2A_0}(\partial_z^2 A_0) + \frac{1}{4A_0}(\partial_z A_0) \cdot \left(\partial_z \ln \left| \frac{A_0 A_3}{A_1} \right| \right);$$

$$Q_3(\rho, z) = -\frac{1}{2A_0}(\partial_\rho^2 A_0) - \frac{1}{2A_3}(\partial_\rho^2 A_3) + \frac{1}{4}(\partial_\rho \ln |A_0|) \cdot (\partial_\rho \ln |A_0 A_1|) +$$

$$+ \frac{1}{4}(\partial_\rho \ln |A_3|) \cdot (\partial_\rho \ln |A_1 A_3|) + \frac{1}{2}(\partial_\rho \ln |A_1|) \cdot \frac{1}{\rho};$$

$$Q_4(\rho, z) = -\frac{1}{2A_1}(\partial_z^2 A_1) + \frac{1}{4}(\partial_z \ln |A_1|) \cdot \left(\partial_z \ln \left| \frac{A_1 A_3}{A_0} \right| \right);$$

$$Q_5(\rho, z) = \frac{1}{2} \left(\partial_\rho \ln \left| \frac{A_0 A_3}{A_1} \right| \right) \cdot \frac{1}{\rho};$$

$$Q_6(\rho, z) = -\frac{1}{2A_0}(\partial_z^2 A_0) - \frac{1}{2A_1}(\partial_z^2 A_1) + \frac{1}{4}(\partial_z \ln |A_0|) \times \\ \times (\partial_z \ln |A_0 A_3|) + \frac{1}{4}(\partial_z \ln |A_1|) \cdot (\partial_z \ln |A_1 A_3|);$$

$$Q_7(\rho, z) = -\frac{1}{2A_3} (\partial_\rho^2 A_3) + \frac{1}{4} (\partial_\rho \ln |A_3|) \cdot \left[\left(\partial_\rho \ln \left| \frac{A_1 A_3}{A_0} \right| \right) - \frac{1}{\rho} \right].$$

Then we have

$$R_{00} = \frac{A_0}{A_1} Q_1 + \frac{A_0}{A_3} Q_2;$$

$$D_1 = Q_3 + \frac{A_1}{A_3} Q_4;$$

$$D_2 = \frac{1}{A_1} Q_5;$$

$$R_{33} = Q_6 + \frac{A_3}{A_1} Q_7.$$

Now after a number of transformations we write down equations (2) – (6) in the form

$$Q_2(Q_3 + Q_5) + Q_4(Q_5 - Q_1) = 0; \quad (7)$$

$$\frac{A_1}{A_3} Q_2 = (Q_5 - Q_1); \quad (8)$$

$$2 \frac{A_0}{A_1} Q_5 = \nu w; \quad (9)$$

$$D_3 = 0; \quad (10)$$

$$Q_6(Q_5 - Q_1) + Q_2(Q_7 + Q_5) = 0. \quad (11)$$

Then we cross to new functions $f_o(\rho, z)$, $f_1(\rho, z)$ and $f_3(\rho, z)$:

$$A_0 = e^{f_o}; \quad A_1 = -e^{f_1}; \quad A_3 = -e^{f_3}.$$

Then all functions Q_i and D_3 in equations (7) – (11) will depend only on functions f_o, f_1, f_3 derivatives and on coordinate ρ :

$$Q_1 = -\frac{1}{2} f_{o\rho\rho} - \frac{1}{4} f_{o\rho} \left[(f_{o\rho} - f_{1\rho} + f_{3\rho}) + \frac{2}{\rho} \right];$$

$$Q_2 = -\frac{1}{2} f_{ozz} - \frac{1}{4} f_{oz} (f_{oz} + f_{1z} - f_{3z});$$

$$Q_3 = -\frac{1}{2} f_{o\rho\rho} - \frac{1}{2} f_{3\rho\rho} - \frac{1}{4} f_{o\rho}^2 - \frac{1}{4} f_{3\rho}^2 + \frac{1}{4} f_{1\rho} (f_{o\rho} + f_{3\rho} + \frac{2}{\rho});$$

$$Q_4 = -\frac{1}{2} f_{1zz} + \frac{1}{4} f_{1z} (f_{3z} - f_{oz} - f_{1z});$$

$$Q_5 = \frac{1}{2} (f_{o\rho} + f_{3\rho} - f_{1\rho}) \cdot \frac{1}{\rho};$$

$$Q_6 = -\frac{1}{2} f_{ozz} - \frac{1}{2} f_{1zz} - \frac{1}{4} f_{oz}^2 - \frac{1}{4} f_{1z}^2 + \frac{1}{4} (f_{oz} + f_{1z}) \cdot f_{3z};$$

$$Q_7 = -\frac{1}{2} f_{3\rho\rho} - \frac{1}{4} f_{3\rho} (f_{o\rho} - f_{1\rho} + f_{3\rho} + \frac{1}{\rho});$$

$$D_3 = -\frac{1}{2} f_{o\rho z} - \frac{1}{4} f_{oz} (f_{o\rho} - f_{3\rho}) + \frac{1}{4} f_{1z} (f_{o\rho} + \frac{2}{\rho}).$$

We use marks: $f_{o\rho} = \partial_\rho f_o$, $f_{1z} = \partial_z f_1$, $f_{o\rho z} = \partial_{\rho z} f_o$ and so on.

Now we have to solve equations (7) – (11) relatively functions f_k . We look for solutions of such a form:

$$f_o = f_o(X); \quad f_1 = f_1(X); \quad f_3 = f_3(X);$$

$$X = \alpha \rho z; \quad X \geq 0.$$

α is dimensional constant: $[\alpha] = \frac{1}{m^2}$.

III. SOLUTIONS OF EINSTEIN'S EQUATIONS

We shall use new functions:

$$\begin{aligned} Q_1 &= Q_1^{(0)} \cdot \frac{1}{\rho^2}; & Q_2 &= Q_2^{(0)} \cdot \rho^2; & Q_3 &= Q_3^{(0)} \cdot \frac{1}{\rho^2}; \\ Q_4 &= Q_4^{(0)} \cdot \rho^2; & Q_5 &= Q_5^{(0)} \cdot \frac{1}{\rho^2}; & Q_6 &= Q_6^{(0)} \cdot \rho^2; \\ Q_7 &= Q_7^{(0)} \cdot \frac{1}{\rho^2}; & D_3 &= D_3^{(0)}. \end{aligned} \quad (12)$$

All functions $Q_i^{(0)}$, $D_3^{(0)}$ depend only on one new variable $X = \alpha\rho z$. Now we rewrite equations (7) – (11) in such a form:

$$Q_2^{(0)} (Q_3^{(0)} + Q_5^{(0)}) + Q_4^{(0)} (Q_5^{(0)} - Q_1^{(0)}) = 0; \quad (13)$$

$$\frac{A_1}{A_3} Q_2^{(0)} \cdot \rho^2 = (Q_5^{(0)} - Q_1^{(0)}) \cdot \frac{1}{\rho^2}; \quad (14)$$

$$2 \frac{A_0}{A_1} \cdot Q_5^{(0)} \cdot \frac{1}{\rho^2} = \kappa w; \quad (15)$$

$$D_3^{(0)} = 0; \quad (16)$$

$$Q_6^{(0)} (Q_5^{(0)} - Q_1^{(0)}) + Q_2^{(0)} (Q_7^{(0)} + Q_5^{(0)}) = 0. \quad (17)$$

Left parts of equations (13), (16), (17) contain quantities, that depend only on X . Equation (15) determines energy density $w(\rho, z)$.

Equation (14) contains “unnecessary” multipliers ρ^2 and $\frac{1}{\rho^2}$. That is why equation (14) may be satisfied only by conditions

$$Q_2^{(0)} = 0; \quad Q_5^{(0)} - Q_1^{(0)} = 0.$$

By that conditions equations (13) and (17) will be also satisfied automatically.

So, we rewrite equations (13) – (17) in such a form:

$$Q_2^{(0)} = 0; \quad (18)$$

$$Q_5^{(0)} - Q_1^{(0)} = 0; \quad (19)$$

$$2 \frac{A_0}{A_1} Q_5^{(0)} \cdot \frac{1}{\rho^2} = \kappa \cdot w; \quad (20)$$

$$D_3^{(0)} = 0. \quad (21)$$

Using formulas (12), we calculate functions $Q_i^{(0)}$ and $D_3^{(0)}$, that are contained in equations (18) – (21):

$$Q_2^{(0)} = \left[-\frac{1}{2}f_o'' - \frac{1}{4}f_o'(f_o' + f_1' - f_3') \right] \cdot \alpha^2;$$

$$Q_1^{(0)} = \left[-\frac{1}{2}f_o'' - \frac{1}{4}f_o'(f_o' - f_1' + f_3') \right] \cdot X^2 - \frac{1}{2}f_o' \cdot X;$$

$$Q_5^{(0)} = \frac{1}{2}(f_o' + f_3' - f_1') \cdot X;$$

$$D_3^{(0)} = \left[-\frac{1}{2}f_o'' - \frac{1}{4}f_o'(f_o' - f_3') + \frac{1}{4}f_o' \cdot f_1' \right] \cdot \alpha X - \frac{1}{2}(f_o' - f_1') \cdot \alpha.$$

Touch means variable X differentiation.

From equation (18) we find:

$$f_1' - f_3' = -2 \frac{f_o''}{f_o'} - f_o' \quad (22)$$

and substitute this result to equation (19). We have:

$$f_o''(1 + f_o'X) + \frac{3}{2} (f_o')^2 + \frac{1}{2} (f_o')^3 \cdot X = 0. \quad (23)$$

Two solutions of equation (23) have the form

$$f_o = a_0 \ln \frac{X}{|c_0|}; \quad a_{01} = 1; \quad a_{02} = -2. \quad (24)$$

We shall transform equation (23) to the system of first order equations:

$$f_o'(X) = y(X); \quad (23a)$$

$$y'(X) \cdot (1 + y(X) \cdot X) + \frac{3}{2} (y(X))^2 + \frac{1}{2} (y(X))^3 \cdot X = 0. \quad (23b)$$

Solution

$$\varphi_i(X) = \begin{pmatrix} a_0 \ln \frac{X}{|c_0|} \\ \frac{a_0}{X} \end{pmatrix}_i$$

of system (23a) – (23b) is unstable solution. In order to prove that we shall consider series of system (23a) – (23b) solutions

$$v_i(X) = \begin{pmatrix} c' \\ 0 \end{pmatrix}_i.$$

We see, that

$$|v_1(X) - \varphi_1(X)| = \left| c' - a_0 \ln \frac{X}{|c_0|} \right| < \varepsilon$$

for all $X \in [X_0, \infty)$. So, solution $\varphi_i(X)$ is unstable one.

Solution $\varphi_i(X)$ unstability is explained by such a fact: system (23a) – (23b) has different serieses of solutions, which correspond to gravitational fields of different configurations.

Now from equations (21) and (22) we find:

$$f_1 = a_1 \ln \frac{X}{|c_1|}; \quad f_3 = a_3 \ln \frac{X}{|c_3|}; \quad (25)$$

$$a_1 = \frac{a_0}{(a_0 + 1)} = \begin{cases} \frac{1}{2}, \\ 2; \end{cases} \quad a_3 = \frac{a_0^2 - 2}{(a_0 + 1)} = \begin{cases} -\frac{1}{2}, \\ -2. \end{cases}$$

So, solutions of Einstein's equations (1) have the form

$$A_0 = \left(\frac{X}{|c_0|}\right)^{a_0}; \quad A_1 = -\left(\frac{X}{|c_0|}\right)^{a_1}; \quad A_2 = -1; \quad A_3 = -\left(\frac{X}{|c_0|}\right)^{a_3}; \quad (26)$$

$$X = \alpha \rho z; \quad X \geq 0.$$

If "traveller" is at the same hyperboloid $X = |c_0|$, where "observer" is, then there will not be distortion of lengths for "observer". That is why we put $|c_0| = |c_1| = |c_3|$ in (26). Both solutions ($a_{01} = 1$ and $a_{02} = -2$) have singularities [20-21] when $X = 0$, that is at axis x^3 and at plane x^1ox^2 .

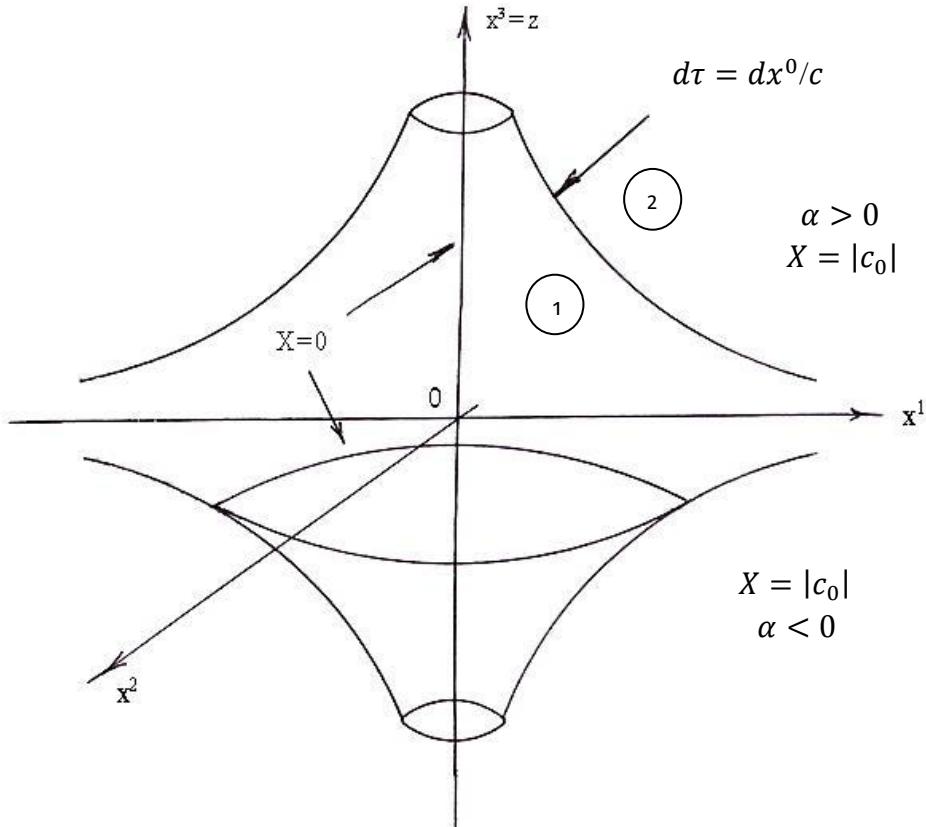
Energy density is determined by equation (20):

$$\kappa w = \begin{cases} 0 & \text{if } a_0 = 1; \\ 6 \frac{|c_0|^4}{X^4} \cdot \frac{1}{\rho^2} & \text{if } a_0 = -2. \end{cases}$$

First solution. Phenomenon of gravitational field existence in absolute vacuum was formerly examined in works [17-19]. Vacuum solutions of Einstein's equations are Miln's model and De Sitter's models [17]. In work [18] it was indicated that such a gravitational field, perhaps, is formed by superheavy virtual particles, that arise in vacuum in boundaries of quantum indefinability [6-16]. In this paper it was shown, that gravitational field in absolute vacuum may have surface of equal times and equal lengths of hyperboloid type.

For first solution time interval is $d\tau = \sqrt{\frac{X}{|c_0|}} \cdot dx^0/c$; "traveller" time is accelerated out of hyperboloid $X = |c_0|$, if "traveller" moves in direction of X

increase and time slows down, if it moves in direction of X decrease. When $X=0$, then “traveller” time stops. At hyperboloid $X = |c_0|$ $d\tau = dx^0/c$.



1 – domain of “traveller” time slowing-down; 2 – domain of “traveller” time acceleration.

Picture 1. Hyperboloid of equal times ($d\tau = dx^0/c$) for first solution.

Second solution. Time interval is $d\tau = \frac{|c_0|}{X} dx^0/c$; “traveller” time slows down if “traveller” moves out of hyperboloid $X = |c_0|$ in direction of X increase and time is accelerated if it moves in direction of X decrease. At hyperboloid $d\tau = dx^0/c$. $X = 0$ are points of singularity – axis x^3 and plane x^1ox^2 . When X

$\rightarrow 0$, then $\frac{d\tau}{dx^0} c \rightarrow \infty$. For second solution domains 1 and 2 at picture 1 exchange their places.

For second solution we obtain formula for “observer” ($X = |c_0|$) distance to singularity axis x^3 :

$$\rho_o = \left(\frac{6}{\kappa w} \right)^{1/2}.$$

If quantity of energy density w is too small, then singularity axis is at very large distance from “observer”.

IV. SUMMARY

So, in this paper it was shown, that at limit $\Lambda \rightarrow 0$ gravitational field may exist even in absolute vacuum ($w(\rho, z) = 0$). It was shown in this paper, that gravitational field in absolute vacuum may have surface of equal times and equal lengths of hyperboloid type. We have also determined points of singularity disposition for energy densities of special type in this paper.

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ТЕОРІЯ ЕЛЕКТРОСЛАБКОЇ ВЗАЄМОДІЇ З НЕЛІНІЙНОЮ РЕАЛІЗАЦІЄЮ ГРУПИ СИМЕТРІЇ НА ГОЛДСТОНІВСЬКОМУ СЕКТОРІ

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АНОТАЦІЯ

У статті показано, що в разі нелінійної реалізації $SU(2)_L \times U(1)_Y$ – симетрії на голдстонівському секторі вакуум скалярних полів відповідає нульовим значенням функцій поля і не є нестабільним. Голдстонівські поля задовольняють нелінійним рівнянням. Механізм спонтанного порушення симетрії не використовується. Для генерації мас калібровочних бозонів достатньо тільки зафіксувати калібровку. Наявність в природі хіггсовського бозону показує, що з двох альтернатив природа «вибирає» все ж таки лінійну реалізацію групи симетрії на голдстонівському секторі.

КЛЮЧОВІ СЛОВА

Електрослабка взаємодія, локальна симетрія, нелінійна реалізація, голдстонівський сектор.

I. ВСТУП

В цій статті сформульована теорія електрослабкої взаємодії з нелінійною реалізацією групи симетрії на голдстонівському секторі. В першому розділі статті калібрівка вибрана таким чином, що з теорії ідуть всі три голдстонівських поля, калібровочні бозони набувають «правильних» мас без зсуву поля, тому хіггсовського бозона в теорії не виникає. Сформульована теорія виявляється неперенормуємой.

У другому розділі статті інший вибір калібрівки також усуває з теорії весь голдстонівський сектор, зсув поля не здійснюється, хіггсовського бозону не виникає, а векторні бозони набувають нефізичних мас. Така теорія представляє тільки математичний інтерес.

У третьому розділі статті показано, що калібрівку можна вибрати таким чином, щоб з теорії йшли не всі три голдстонівських поля. Одне поле δ'_2 залишається. Це поле проявляє себе, як аналог хіггсовського бозону. Зсув поля не здійснюється, але векторні бозони набувають «правильних» мас при фіксації калібрівки. Питання про перенормуємість сформульованих теорій вимагає додаткового дослідження.

У цій статті для формулування нелінійних теорій електрослабкої взаємодії використовуються результати, що одержані і викладені у роботах [1-8].

ІІ. ПЕРШИЙ ВАРІАНТ КАЛІБРОВКИ

Розглянемо нелінійну реалізацію групи $SU(2)$ на голдстонівському секторі. Три дійсних поля $\gamma(x)$, $\delta_1(x)$, $\delta_2(x)$ утворюють стовпчик ξ :

$$\xi = \frac{1}{\sqrt{2}} \cdot \begin{pmatrix} \sin\gamma \cdot e^{ir\delta_1} \\ \cos\gamma \cdot e^{ir\delta_2} \end{pmatrix}, \quad (1)$$

де r – дійсна розмірна константа. При перетвореннях S з $SU(2)$ стовпчик ξ перетворюється відповідно до формули

$$\xi' = S\xi, \quad S \in SU(2).$$

Таким чином, голдстонівські поля перетворюються нелінійно.

Повний лагранжіан запишемо так [9-13]:

$$\mathcal{L} = -\frac{1}{2} Tr G_{\mu\nu} G^{\mu\nu} - \frac{1}{4} F_{\mu\nu} F^{\mu\nu} + i\bar{L}\hat{D}L + i\bar{e}_R\hat{D}e_R + i\bar{\nu}_R\hat{D}\nu_R + \mathcal{L}_G. \quad (2)$$

\mathcal{L}_G – частина повного лагранжіану, що містить стовпчик ξ :

$$\begin{aligned} \mathcal{L}_G = & |D_\mu \xi|^2 - \frac{1}{2} \lambda^2 \left(|\xi|^2 - \frac{1}{2} \eta^2 \right)^2 - f_e (\bar{L}e_R \xi + \bar{e}_R L \xi^+) - \\ & - f_{\nu_e} (\bar{L}\nu_R \xi_c + \bar{\nu}_R L \xi_c^+). \end{aligned} \quad (3)$$

В формулах (2), (3)

$$\begin{aligned} L &= \begin{pmatrix} v_L \\ e_L \end{pmatrix}, \quad D_\mu = \partial_\mu - igT^k A_\mu^k - ig' \frac{Y}{2} B_\mu, \\ G_{\mu\nu} &= \partial_\mu A_\nu - \partial_\nu A_\mu - ig[A_\mu A_\nu - A_\nu A_\mu], \quad A_\mu = T^k \cdot A_\mu^k, \\ F_{\mu\nu} &= \partial_\mu B_\nu - \partial_\nu B_\mu, \end{aligned}$$

інші означення є стандартними [1, 13].

В калібровці

$$S_1 = \begin{pmatrix} \cos\gamma \cdot e^{ir\delta_2} & -\sin\gamma \cdot e^{ir\delta_1} \\ \sin\gamma \cdot e^{-ir\delta_1} & \cos\gamma \cdot e^{-ir\delta_2} \end{pmatrix} \quad (4)$$

перетворений стовпчик приймає вигляд

$$\xi' = S_1 \xi = \frac{\eta}{\sqrt{2}} \begin{pmatrix} 0 \\ 1 \end{pmatrix}, \quad |\xi'|^2 = \frac{\eta^2}{2}.$$

При цьому голдстонівські поля перетворюються за формулами

$$\gamma \rightarrow \gamma' = \pi n; \quad r\delta_2 \rightarrow r\delta'_2 = \pi m; \quad n, m = 0, \pm 1, \pm 2, \pm 3, \dots$$

(парність n і m однакова).

При перетвореннях групи $U(1)_Y$

$$S' = e^{i \frac{Y}{2} \alpha(x)}$$

поля $\gamma, \delta_1, \delta_2$ перетворюються відповідно до рівностей

$$\gamma' = \gamma; \quad r\delta'_1 = r\delta_1 + \frac{1}{2}\alpha; \quad r\delta'_2 = r\delta_2 + \frac{1}{2}\alpha.$$

В калібровці S_1 (4) перший доданок в лагранжіані \mathcal{L}_G (3) призводить до «правильних» значень мас векторних бозонів:

$$m_w = \frac{g\eta}{2}, \quad m_z = \frac{\bar{g}\eta}{2}, \quad m_A = 0. \quad (5)$$

Третій і четвертий доданки генерують ферміонні маси:

$$m_e = \frac{f_e \eta}{\sqrt{2}}, \quad m_{\nu_e} = \frac{f_{\nu_e} \eta}{\sqrt{2}}. \quad (6)$$

Таким чином, для генерації мас векторних бозонів і ферміонів зсув голдстонівського поля не застосовувався, була здійснена тільки фіксація калібровки (4). Хіггсовського бозону в такій теорії не виникає, оскільки калібровка (4) усуває з теорії всі три голдстонівські поля γ, δ_1 і δ_2 .

При відсутності векторних і ферміонних полів нелінійні дійсні поля $\gamma, \delta_1, \delta_2$ задовольняють рівнянням

$$\begin{aligned} \partial_\mu \partial^\mu \gamma - \frac{r^2}{2} \sin 2\gamma \cdot [(\partial_\mu \delta_1)(\partial^\mu \delta_1) - (\partial_\mu \delta_2)(\partial^\mu \delta_2)] &= 0, \\ \sin^2 \gamma (\partial_\mu \partial^\mu \delta_1) + \sin 2\gamma (\partial_\mu \gamma)(\partial^\mu \delta_1) &= 0, \\ \cos^2 \gamma (\partial_\mu \partial^\mu \delta_2) - \sin 2\gamma (\partial_\mu \gamma)(\partial^\mu \delta_2) &= 0. \end{aligned}$$

У довільній калібровці густина енергії вільних скалярних полів дорівнює

$$T^{00} = \frac{\eta^2}{2} \left[\left(\frac{\partial \gamma}{\partial x^0} \right)^2 + \left(\frac{\partial \gamma}{\partial \vec{x}} \right)^2 \right] + \frac{\eta^2 r^2}{2} \cdot \sin^2 \gamma \left[\left(\frac{\partial \delta_1}{\partial x^0} \right)^2 + \left(\frac{\partial \delta_1}{\partial \vec{x}} \right)^2 \right] +$$

$$+ \frac{n^2 r^2}{2} \cdot \cos^2 \gamma \left[\left(\frac{\partial \delta_2}{\partial x^0} \right)^2 + \left(\frac{\partial \delta_2}{\partial \vec{x}} \right)^2 \right].$$

Стан вакууму досягається при $\gamma(x) = const, \delta_1(x) = const, \delta_2(x) = const$ або при $\gamma(x) = \pi n, \delta_2(x) = const$, а також при $\gamma(x) = \frac{\pi}{2} + \pi n, \delta_1(x) = const$. Вакуум полів $\gamma, \delta_1, \delta_2$ не є нестабільним.

Після фіксації калібровки (4) лагранжіан \mathcal{L}_G (3) повністю співпадає з доданком в лагранжіані Стандартної Моделі \mathcal{L}_G , в якому покладено $\chi = 0$. Така теорія є неперенормуєма. Тому використана в цьому розділі статті калібровка S_1 (4) призводить до неперенормуємої теорії. Результати цього розділу мають тільки математичний інтерес.

ІІІ. ДРУГИЙ ВАРІАНТ КАЛІБРОВКИ

Зафіксуємо калібровку

$$S_2 = \begin{pmatrix} \sin \gamma \cdot e^{-ir\delta_1} & \cos \gamma \cdot e^{-ir\delta_2} \\ -\cos \gamma \cdot e^{ir\delta_2} & \sin \gamma \cdot e^{ir\delta_1} \end{pmatrix}. \quad (7)$$

Стовбчик ξ (1) після перетворення приймає вигляд

$$\xi' = S_2 \xi = \frac{n}{\sqrt{2}} \begin{pmatrix} 1 \\ 0 \end{pmatrix}.$$

При цьому голдстонівські поля перетворюються за формулами

$$\gamma \rightarrow \gamma' = \frac{\pi}{2} + \pi n; \quad r\delta_1 \rightarrow r\delta'_1 = \pi m; \quad n, m = 0, \pm 1, \pm 2, \pm 3, \dots$$

(парність n і m однакова).

В цій калібровці лагранжіан \mathcal{L}_G (3) призводить до нефізичних мас векторних бозонів і лептонів:

$$m_w = \frac{g \cdot n}{2}, \quad m_z = \frac{g n}{2} \cdot \frac{\cos 2\theta}{\cos \theta}, \quad m_A = n \cdot e,$$

$$m_e = 0, \quad m_{\nu_e} = 0.$$

Фотон придає масу, що відрізняється від нуля. Ця калібровка завбачає нефізичні переходи і пряме перетворення $A \rightarrow Z^0$.

Для генерації мас зсув поля не застосовувався, була здійснена тільки фіксація калібровки (7). Хіггсовського бозону в такій теорії не виникає, оскільки всі три голдстонівських поля $\gamma, \delta_1, \delta_2$ усуваються калібровкою (7).

Вакуум голдстонівських полів не є інваріантним відносно групи $SU(2)_L \times U(1)_Y$. Мінімальне значення густини енергії вільних голдстонівських полів $T^{00} = 0$ досягається при калібровках $S = S_1$ і $S = S_2$. До значень мас, що ми спостерігаємо, призводить калібровка $S = S_1$.

Питання про перенормувемість такої теорії вимагає додаткового дослідження. В усякому разі результати цього розділу мають тільки математичний інтерес.

IV. ТРЕТИЙ ВАРИАНТ КАЛІБРОВКИ

Зафіксуємо калібровку

$$S_3 = \begin{pmatrix} \cos\gamma & -\sin\gamma e^{ir(\delta_1-\delta_2)} \\ \sin\gamma e^{-ir(\delta_1-\delta_2)} & \cos\gamma \end{pmatrix}. \quad (8)$$

Стовпчик ξ (1) перетворюється за формулой

$$\xi' = S_3 \xi = \frac{\eta}{\sqrt{2}} \begin{pmatrix} 0 \\ e^{ir\delta_2} \end{pmatrix}. \quad (9)$$

При перетворенні S_3 голдстонівські поля перетворюються за формулами

$$\gamma \rightarrow \gamma' = 2\pi n; \quad r\delta_2 \rightarrow r\delta'_2 = r\delta_2 + 2\pi m; \quad n, m = 0, \pm 1, \pm 2, \pm 3, \dots$$

Особливістю калібровки S_3 (8) є те, що вона не усуває з теорії всі три голдстонівські поля, одне поле δ'_2 залишається. Це поле проявляє себе, як альтернатива хіггсовському бозону. В стовпчику ξ' (9) введемо позначення комбінації полів:

$$e^{ir\delta'_2} = 1 + \sum_{k=1}^{\infty} \frac{(ir\delta'_2)^k}{k!} = 1 + rH,$$

$$H = \frac{1}{r} \sum_{k=1}^{\infty} \frac{(ir\delta'_2)^k}{k!} = \frac{1}{r} (\cos(r\delta'_2) - 1 + i \sin(r\delta'_2)).$$

Лагранжіан \mathcal{L}_G (3) приймає вигляд

$$\begin{aligned} \mathcal{L}_G = & \eta^2 \left[\frac{r^2}{2} (\partial_\mu \delta'_2) (\partial^\mu \delta'_2) + \frac{r\bar{g}}{2} (\partial_\mu \delta'_2) Z^\mu + \frac{g^2}{4} W_\mu^+ W^{-\mu} + \frac{\bar{g}^2}{8} Z_\mu^2 \right] - \\ & - \frac{\eta}{\sqrt{2}} f_e \cdot \bar{e} e - \frac{r\eta}{\sqrt{2}} f_e (\bar{e}_L e_R H + \bar{e}_R e_L H^+) - \frac{\eta}{\sqrt{2}} f_{\nu_e} \cdot \bar{\nu} \nu - \\ & - \frac{r\eta}{\sqrt{2}} f_{\nu_e} (\bar{\nu}_L \nu_R H^+ + \bar{\nu}_R \nu_L H). \end{aligned} \quad (10)$$

Таким чином, в калібривці (8) векторні бозони і лептони набувають фізичних мас (5), (6). Для генерації мас зсув поля не застосовувався, була здійснена тільки фіксація калібривки (8). Хіггсовського бозону в теорії не виникає. Сформульована в цьому розділі теорія передбачає нові ефекти в електрослабкій взаємодії, наприклад, наявність складних вершин типу

$$r^n \bar{e} e (\delta'_2)^n, \quad r^n \bar{\nu} \nu (\delta'_2)^n; \quad n \geq 2$$

і інші.

Питання про перенормуємість теорії з нелінійною комбінацією полів вимагає додаткового дослідження. Якщо така теорія є перенормуємой і діаграми зі складними вершинами у кожному порядку вносять конечний внесок до матричних елементів, то при $r \rightarrow 0$ лагранжіан \mathcal{L}_G (10) можна записати так:

$$\begin{aligned} \mathcal{L}_G = & \eta^2 \left[\frac{r^2}{2} (\partial_\mu \delta'_2) (\partial^\mu \delta'_2) + \frac{r\bar{g}}{2} (\partial_\mu \delta'_2) Z^\mu + \frac{g^2}{4} W_\mu^+ W^{-\mu} + \frac{\bar{g}^2}{8} Z_\mu^2 \right] - \\ & - \frac{\eta}{\sqrt{2}} f_e \cdot \bar{e} e - \frac{r\eta}{\sqrt{2}} f_e \left[\bar{e}_L e_R \left(i\delta'_2 - \frac{1}{2} r \delta'^2_2 \right) + \bar{e}_R e_L \left(-i\delta'_2 - \frac{1}{2} r \delta'^2_2 \right) \right] - \\ & - \frac{\eta}{\sqrt{2}} f_{\nu_e} \cdot \bar{\nu} \nu - \frac{r\eta}{\sqrt{2}} f_{\nu_e} \left[\bar{\nu}_L \nu_R \left(-i\delta'_2 - \frac{1}{2} r \delta'^2_2 \right) + \bar{\nu}_R \nu_L \left(i\delta'_2 - \frac{1}{2} r \delta'^2_2 \right) \right]. \end{aligned} \quad (11)$$

В цьому випадку бозон δ'_2 виступає аналогом хіггсовського бозону, але його взаємодії з лептонами і калібривочними полями відрізняються від взаємодій хіггсовського бозону. Затравочна маса поля δ'_2 дорівнює нулеві; бозон δ'_2 може набувати масу при взаємодії з іншими полями.

Наявність в природі хіггсовського бозону показує, що з двох альтернатив природа «вибирає» все ж таки лінійну реалізацію групи симетрії на голдстонівському секторі.

Відмітимо також, що поле δ'_2 може існувати в природі разом з хіггсовським бозоном χ . Але в цьому випадку в теорію доводиться вводити нові калібровочні бозони Z_1, W_1, W_1^+, A_1 і нові ферміони v_{e1}, e_1 , які є суперпартнерами відомих бозонів і ферміонів Z^0, W^\pm, A, v_e, e по супермультиплету групи $SU(2)_{\xi_L} \times SU(2)_L \times U(1)_Y$. При цьому група $SU(2)$ лінійно перетворює чотири голдстонівські поля зі стовпчика $\varphi = \begin{pmatrix} \varphi_1 \\ \varphi_2 \end{pmatrix}$, а група $SU(2)_\xi$ нелінійно перетворює три голдстонівські поля зі стовпчика ξ (1). Звісно, теорія з двома скалярними бозонами χ і δ'_2 має бути досліджена на можливість перенормування.

V. ВИСНОВКИ

В цій статті розглянута теорія електрослабкої взаємодії з нелінійною реалізацією групи симетрії на голдстонівському секторі. Показано, що калібровку можна вибрати таким чином (S_3), що калібровочні і лептонні поля набувають «правильних» мас без зсуву поля. Достатньо тільки зафіксувати калібровку. Хіггсовського бозону в такій теорії не виникає, але виникає аналог хіггсовського бозону – дійсне скалярне поле δ'_2 , що є перетвореним голдстонівським полем. Подобно хіггсовському бозону поле δ'_2 взаємодіє з калібровочними і лептонними полями, але воно призводить до появи складних вершин, які відсутні в Стандартній Моделі. Затравочна маса поля δ'_2 дорівнює нулеві; бозон δ'_2 може набувати масу в процесі взаємодії з іншими полями. Така теорія вимагає додаткового дослідження з метою встановлення можливості перенормування.

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MINIMUM EXPANSION OF QUANTUM CHROMODYNAMICS

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ABSTRACT

This article proposes a theory of minimal expansion of quantum chromodynamics (MEQCD). In an extended QCD, there is only one hypothetical particle, that is a scalar ε – boson, which is an analogue of the Higgs boson. The article substantiates the renormalizability of the MEQCD theory and studies the reaction of ε – boson formation in the collision of two u – quarks. The intensity of ε – boson formation was estimated at the Large Hadron Collider.

KEYWORDS

Minimal expansion of quantum chromodynamics; ε – boson; renormalizability.

I. INTRODUCTION

The creation of gauge field theories and the study of their properties is an important direction in the physics of elementary particles [1-10, 15-43, 49-70, 77-78, 81-89]. The Yang-Mills model [11], the Glashow - Weinberg – Salam theory [12-14], quantum chromodynamics [1-2, 44-48, 71-76] allowed us to expand our understanding of the micro-world.

At the same time, well-known gauge theories have several disadvantages. For example, the Standard Model does not explain the origin of neutrino masses, neutrino oscillations, the asymmetry of matter and antimatter, the origin of dark matter and dark energy. The Standard Model does not agree with the general theory of relativity, it does not contain a solution to the strong CP problem, etc.

Extensions to the Standard Model are the Minimal Supersymmetric Standard Model (MSSM), Next-to-Minimal Supersymmetric Standard Model (NMSSM); completely new theories are being created, such as string theory [80-81], M-theory, and extra dimensions.

However, in these developments there are unresolved problems. For example, in the MSSM there is a large number of hypothetical particles that are not currently detected experimentally.

This article proposes a theory of minimal expansion of quantum chromodynamics, containing only one hypothetical scalar particle ε – boson. This boson interacts directly with gluon fields only; it is assumed that under certain conditions it can be detected at elementary particle accelerators.

II. EXPANSION OF QUANTUM CHROMODYNAMICS

The minimal expansion of quantum chromodynamics (MEQCD) is that in the QCD theory the space of a

$$\varphi = \begin{pmatrix} \varphi_1 \\ \varphi_2 \\ \varphi_3 \end{pmatrix} \quad (1)$$

is added to the representation space of the $SU(3)_c$ gauge group, which implements the irreducible representation of this group. Lagrangian of the MEQCD theory is written as follows:

$$\mathcal{L} = \bar{q}(i\gamma^\mu \partial_\mu + ig\gamma^\mu A_\mu - m)q + \mathcal{L}_B; \quad (2)$$

$$\mathcal{L}_B = -\frac{1}{2}TrG^{\mu\nu}G_{\mu\nu} + |D_\mu\varphi|^2 - \frac{1}{2}\lambda_1^2\left(|\varphi|^2 - \frac{1}{2}\eta_1^2\right)^2; \quad (3)$$

$$G_{\mu\nu} = \partial_\mu A_\nu - \partial_\nu A_\mu - ig[A_\mu, A_\nu],$$

$$D_\mu\varphi = (\partial_\mu - igA_\mu)\varphi, \quad A_\mu = \frac{\lambda_a}{2}A_\mu^a.$$

In the right side of formula (2), summation over quark flavors is assumed.

After spontaneous symmetry breaking, five Goldstone bosons leave the theory, five A_μ^a fields acquire masses, and in theory there remains one massive scalar ε – boson that is analogue of the Higgs boson:

$$\varphi = \frac{1}{\sqrt{2}} \begin{pmatrix} 0 \\ 0 \\ \eta_{1+\varepsilon(x)} \end{pmatrix}.$$

The bosonic part of Lagrangian (3) takes the form

$$\begin{aligned} \mathcal{L}_B = & -\frac{1}{2}TrG^{\mu\nu}G_{\mu\nu} + \frac{1}{2}(\partial^\mu\varepsilon)(\partial_\mu\varepsilon) + \frac{g^2}{8} \left(\sum_{a=4}^7 A^{a\mu}A_\mu^a + \frac{4}{3}A^{8\mu}A_\mu^8 \right) \times \\ & \times (\eta_1^2 + 2\eta_1\varepsilon + \varepsilon^2) - \frac{1}{2}\lambda_1^2\eta_1^2\varepsilon^2 - \frac{1}{2}\lambda_1^2\eta_1\varepsilon^3 - \frac{1}{8}\lambda_1^2\varepsilon^4. \end{aligned} \quad (4)$$

The masses of bosons are determined by the formulas

$$m(A_\mu^a) = 0, \quad (a = 1, 2, 3); \quad m(A_\mu^a) = \frac{g\eta_1}{2}, \quad (a = 4, 5, 6, 7);$$

$$m(A_\mu^8) = \frac{g\eta_1}{\sqrt{3}}; \quad m(\varepsilon) = \lambda_1\eta_1.$$

III. RENORMALIZABILITY

Consider the Lagrangian (2) – (3). The index of the i -th vertex in the diagram G is determined by the formula [1, 2]:

$$\omega_i = \frac{1}{2} \sum_{l=1}^L (r_l + 2) - 4,$$

where r_l is the highest degree of impulse in the numerator of the propagator corresponding to the l -th internal line entering the vertex. L is the number of internal lines entering the vertex. The vertex index takes the maximum value Ω_i when all the lines entering the i -th vertex are internal. Table 1 shows all the vertices of the Lagrangian (2) – (3) and the maximum values of their indices Ω_i .

Table 1. The maximum values of the indexes of the vertices of the Lagrangian (2) – (3).

№ in order.	Vertex type.	The maximum index value of the vertex Ω_i.
1	$ig\bar{q}\gamma^\mu A_\mu q$	$\Omega_1 = 0$
2	$-m\bar{q}q$	$\Omega_2 = -1$
3	$-g f_{abc} (\partial^\mu A^{av}) A_\mu^b A_v^c$	$\Omega_3 = 0$
4	$-\frac{g^2}{4} f_{abk} f_{cdk} A^{a\mu} A^{b\nu} A_\mu^c A_\nu^d$	$\Omega_4 = 0$
5	$\frac{ig}{2} (\partial^\mu \varphi^+) A_\mu^a \lambda_a \varphi$	$\Omega_5 = 0$
6	$-\frac{g^2}{4} A^{a\mu} A_\mu^b (\lambda_a \varphi)^+ (\lambda_b \varphi)$	$\Omega_6 = 0$
7	$-\frac{1}{2} \lambda_1^2 \varphi ^4$	$\Omega_7 = 0$
8	$\frac{1}{2} \lambda_1^2 \eta_1^2 \varphi ^2$	$\Omega_8 = -2$

For all vertices $\Omega_i \leq 0$. Therefore, a sufficient condition for the renormalizability of the theory based on the Lagrangian (2) – (3) is satisfied [1,2]. So, the formulated theory of extended chromodynamics is renormalizable.

The final Lagrangian (2), (4), obtained as a result of spontaneous symmetry breaking, is physically equivalent to the original Lagrangian (2) – (3); it differs from the original only in the choice of variables. This substantiates the renormalizability of the MEQCD theory based on the Lagrangian (2), (4).

The dimensions of the interaction constant in the Lagrangian (2), (4) are determined by the formulas

$$[g] = [m]^0; \quad [\eta_1] = [m]^1; \quad [\lambda_1] = [m]^0.$$

All constants have the dimension of mass in a nonnegative degree. This is another justification for the extended QCD renormalizability.

IV. THE FORMATION OF ε –BOSONS IN COLLISIONS OF QUARKS

Let us consider the reaction of formation of ε –bosons in collisions of u -quarks: $u_i(p_1) + u_k(p_2) \rightarrow u_l(p'_1) + u_m(p'_2) + \varepsilon(p)$. i, k, l, m are color indices. A diagram of this process is shown in Figure 1.

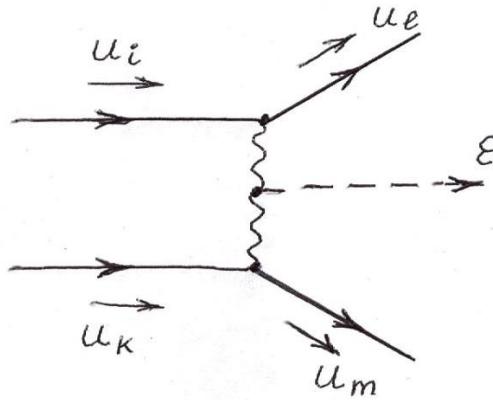


Figure 1. $u_i u_k \rightarrow u_l u_m \varepsilon$ process diagram.

Higher orders of perturbation theory are insignificant if the renormalized parameters g, η_1 are small quantities.

The matrix element corresponding to the diagram in Figure 1 is defined by the formula

$$\begin{aligned}
& < f | S | i > = \delta^{(4)}(p_1 + p_2 - p'_1 - p'_2 - p) \cdot F(p_q, p'_q, p); \\
& | i > = a_{i\lambda_1}^{*+}(\vec{p}_1) a_{k\lambda_2}^{*+}(\vec{p}_2) \Phi_o; \quad < f | = \Phi_o^* a_{l\lambda_3}^-(\vec{p}'_1) a_{m\lambda_4}^-(\vec{p}'_2) \varphi^-(\vec{p}); \\
& F(p_q, p'_q, p) = i \frac{g^4}{8} \eta_1 \frac{(2\pi)^{-7/2}}{(2p^o)^{1/2}} \cdot \left\{ -\bar{v}^{\lambda_3,+}(\vec{p}'_1) \gamma^\mu v^{\lambda_1,-}(\vec{p}_1) \times \right. \\
& \times \bar{v}^{\lambda_4,+}(\vec{p}'_2) \gamma^\nu v^{\lambda_2,-}(\vec{p}_2) [\Delta_\mu^\tau(p_1 - p'_1) \Delta_{\tau\nu}(p_2 - p'_2) \cdot r(l; m) \\
& + \Delta_{8\mu}^\tau(p_1 - p'_1) \Delta_{8\tau\nu}(p_2 - p'_2) h(l; m)] + \\
& + \bar{v}^{\lambda_3,+}(\vec{p}'_1) \gamma^\mu v^{\lambda_2,-}(\vec{p}_2) \bar{v}^{\lambda_4,+}(\vec{p}'_2) \gamma^\nu v^{\lambda_1,-}(\vec{p}_1) \times \\
& \times [\Delta_\mu^\tau(p_2 - p'_1) \Delta_{\tau\nu}(p_1 - p'_2) \cdot r(l; m) + \Delta_{8\mu}^\tau(p_2 - p'_1) \times \\
& \times \Delta_{8\tau\nu}(p_1 - p'_2) \cdot h(l; m)] \left. \right\}; \\
& r(l; m) = \sum_{a=4}^7 \lambda_a^{li} \cdot \lambda_a^{mk}; \quad h(l; m) = \frac{4}{3} \lambda_8^{li} \lambda_8^{mk};
\end{aligned}$$

λ_a are Gell-Mann matrices, $\Delta(k)$ and $\Delta_8(k)$ are gluon propagators.

We will work in the system of inertial center of incident u -quarks: $\vec{p}_1 = -\vec{p}_2$; $p_1^o = p_2^o = E/2$. Differential cross section is

$$d\sigma = \frac{(2\pi)^2 E}{4|\vec{p}_1| \cdot |\varphi'(p_1^o)|} \cdot |F(p_q, p'_q, p)|^2 \cdot |\vec{p}'_1| \cdot p_1'^o \cdot d\Omega'_1 \cdot d\Omega \cdot |\vec{p}|^2 d|\vec{p}|, \quad (5)$$

here $\varphi(p_1^o) = E - p_1'^o - p_2'^o - p^o$, E is the total energy of the colliding quarks.

When calculating the cross section of processes at high energies take $m_u = m_d = 0$ [85]. In addition, under the assumption that the interaction constants are small, the masses of gluons and the ε -boson are also small. Further we assume $m_A, m_8, m_\varepsilon \rightarrow 0$.

We consider only the cases of the formation of ε -bosons with relatively small impulses ($|\vec{p}| \leq \varepsilon \ll E$). Then we assume $\vec{p}'_1 + \vec{p}'_2 = 0$, $p_1'^o = p_2'^o \approx \frac{E}{2}$. The formula for $d\sigma$ (5) is simplified and after integrating the cross section (5) over the ε -boson impulse and over the angles we get

$$d\sigma(|\vec{p}| \leq \varepsilon) = \frac{g^8}{2^6} \cdot \eta_1^2 \cdot \frac{(2\pi)^{-3} \cdot \varepsilon^2}{E^6} \cdot \left\{ \frac{\left[1 + \frac{1}{4}(1 + \cos\theta)^2 \right] \cdot f^2(l; m)}{(1 - \cos\theta)^4} + \right.$$

$$+ \frac{\left[1 + \frac{1}{4}(1 - \cos\theta)^2\right] \cdot f^2(lk; mi)}{(1 + \cos\theta)^4} + \frac{2 \cdot f(li; mk) \cdot f(lk; mi)}{\sin^4\theta}\Bigg\} \cdot \sin\theta d\theta. \quad (6)$$

Here $\theta = \widehat{\vec{p}_1 \vec{p}'_1}$ is the scattering angle, $f(li; mk) = r(li; mk) + h(li; mk)$. The quark impulse vectors are depicted in Figure 2.

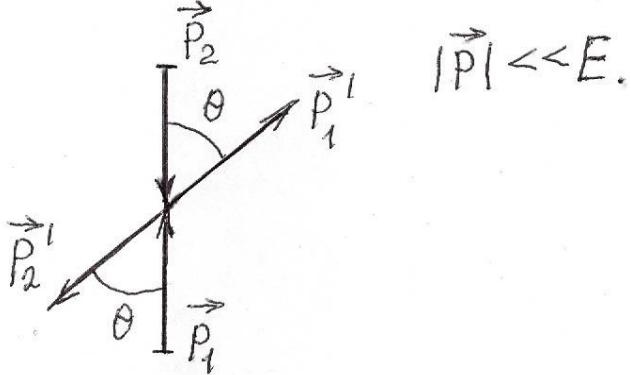


Figure 2. Quark impulse vectors for $|\vec{p}| \ll E$.

The expression (6) is the differential cross section for scattering of quark u_i with impulse p_1 into the element of angle $d\theta$ with the simultaneous formation of an ε -boson with impulse $|\vec{p}| \leq \varepsilon$.

In deriving the formula (6) we neglected the masses of gluons in the denominators of gluon propagators. This can be done if

$$(1 - \cos\theta) \geq \lambda_o \gg \frac{2m_8^2}{E^2}, \quad (1 + \cos\theta) \geq \lambda_o \gg \frac{2m_8^2}{E^2}.$$

Thus, the scope of the formula (6) is

$$(\lambda_o - 1) \leq \cos\theta \leq (1 - \lambda_o).$$

The total cross section of the process $u_i u_k \rightarrow u_l u_m \varepsilon$ is

$$\begin{aligned} \sigma_{tot}(|\vec{p}| \leq \varepsilon) = & \frac{g^8}{2^6} \cdot \eta_1^2 \cdot \frac{(2\pi)^{-3} \cdot \varepsilon^2}{E^6} \cdot \left\{ \frac{1}{6(2 - \lambda_o)^3 \lambda_o^3} \times \right. \\ & \times [3\lambda_o^4(5 - \lambda_o) - 44\lambda_o^3 + 72\lambda_o(\lambda_o - 1) + 32] \cdot (f^2(li; mk) + \\ & + f^2(lk; mi)) + \left[\frac{1}{\lambda_o} - \frac{1}{(2 - \lambda_o)} + \ln \left| \frac{2 - \lambda_o}{\lambda_o} \right| \right] \cdot f(li; mk) \cdot f(lk; mi) \Big\}. \quad (7) \end{aligned}$$

Cross section $\sigma_{tot}(|\vec{p}| \leq \varepsilon)$ contains two arbitrary parameters. The parameter $\varepsilon \ll E$ sets the impulse interval of the resulting ε -bosons; parameter

$\lambda_o \gg \frac{2m_8^2}{E^2}$ defines the range of applicability of the formula for the differential cross section (6). At high energies E , the value of λ_o may be small.

Perform an estimate of the intensity of the formation of ε – bosons at the LHC. Intensity is equal to

$$I_{ik}(|\vec{p}| \leq \varepsilon) = \sigma_{tot}(|\vec{p}| \leq \varepsilon) \cdot J(i; k), \quad (8)$$

were $J(i; k)$ is the number of collisions of quarks u_i and u_k for a unit of time per unit area of the particle beam. We take the approximate values of luminosities

$$J(i; k) \sim \left(\frac{2}{3}\right)^2 \cdot \frac{1}{9} J_p = 0,988 \cdot 10^{37} \frac{1}{m^2 s}. \quad \left(J_p = 2 \cdot 10^{38} \frac{1}{m^2 s} \right) \quad (9)$$

The total relative momentum carried by all u -quarks in the proton, $U \approx 0,28$ [85]. We will consider only the valence quarks. Then

$$E = U E_p = 0,28 \cdot 7 TeV = 1,96 TeV. \quad (10)$$

We will choose

$$\lambda_o = 10^2 \cdot \frac{2m_8^2}{E} \ll 1; \quad \varepsilon = 10^{-2} E = 19,6 GeV. \quad (11)$$

The formula for $\sigma_{tot}(|\vec{p}| \leq \varepsilon)$ (7) takes the form

$$\begin{aligned} \sigma_{tot}(|\vec{p}| \leq \varepsilon) &= \frac{g^6 (2\pi)^{-3}}{2^8 \cdot 10^6} \cdot \frac{\varepsilon^2}{m_8^4} \cdot [f^2(l_i; m_k) + f^2(l_k; m_i)]; \\ m_8 &= \frac{g\eta_1}{\sqrt{3}}. \end{aligned} \quad (12)$$

The estimated intensity value is determined by the formula (8) taking into account the formulas (9) – (12). The estimated value of $I_{ik}(|\vec{p}| \leq \varepsilon)$ (8) depends on the color indices of quarks and the parameters of the Lagrangian. The values of the renormalized parameters of the Lagrangian are not yet known, but if we assume

$$g^2 \lesssim \frac{\eta_1^4 \cdot \sigma_h}{9 \varepsilon^2},$$

then $\sigma_{tot}(|\vec{p}| \leq \varepsilon) \lesssim 1,26 \cdot 10^{-10} \cdot \sigma_H$, where σ_H is the total cross section for the formation of Higgs bosons in collisions of protons at the LHC. We see that when the parameter η_1 is small, the value of g^2 is also small.

V. SUMMARY

The article proposes a theory of minimal expansion of quantum chromodynamics (MEQCD). In this theory, there is only one hypothetical particle – the scalar ε – boson, which is an analogue of the Higgs boson. The article substantiates the renormalizability of the MEQCD theory and calculates the cross section for the formation of the ε – boson in collisions of two u -quarks. The estimation of the intensity of the formation of ε – bosons at the LHC was performed.

In ordinary QCD, the interaction constant of quarks and gluons in the region $r < r_N$ is determined by the formula [60, 73]

$$\alpha_s(q^2) = g_s^2 \approx \left[\ln \frac{q^2}{\Lambda^2} \right]^{-1} \ll 1.$$

The smallness of the magnitude of g_s^2 is a consequence of the large transmitted momentum q^2 inside the nucleons. Reactions in MEQCD can also come with a large impulse transmitted. For example, with the formation of ε – bosons at the LHC $q^2 \approx \frac{E^2}{2} = 1,92 \text{ TeV}^2$, if $(1 - \cos\theta) \approx 1$. This justifies the assumption of the possible smallness of the magnitude of g^2 also in MEQCD.

The non – manifestation of ε – bosons at the LHC is explained by the supposedly small cross section for the formation of ε – bosons.

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ESTIMATION OF MICRO BLACK HOLES FORMATION AT LARGE HADRON COLLIDER CROSS-SECTION

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ABSTRACT

We have valued the cross-section of the reaction of micro black holes (MBH) formation at Large Hadron Collider in this paper. We used models of multiple production processes on high energies for estimation: evristic model of MBH formation, simplest parton model and parton model for superhigh energies. On the basis of this models we have made the conclusion, that threshold of MBH formation by proton collisions is larger by 35-36 decimal orders than energy, that was reached today at Large Hadron Collider (LHC) (14 TeV). That explains the absence of MBH observations on proton collisions at LHC.

We have also valued MBH formation cross-section on proton with Pb nucleus collisions in this paper. On the basis of hN-interaction hydrodynamic model it was shown, that threshold energy of protons at the system of equal speeds (S - system) is the value of 10^{35} TeV order. That corresponds to energy of 10^{74} TeV order at laboratory system ($\vec{p}_{Pb} = 0$). Sush an energy of protons can not be reached at elementary particles accelerators.

Possibly, calculation of quantum effects will lead to decrease of MBH formation threshold energy.

KEYWORDS

Black holes; formation; Collider.

INTRODUCTION

The successes of quantum field theory [6-8, 12-13, 15-17, 19, 22-31] and the classical theory of gravity [1-2, 9-11, 14, 18] make it possible to carry out a comprehensive theoretical study of the properties of singularities in solutions of Einstein's equations [1], which, in particular, are black holes [2, 20-21]. We have valued the cross-section of the reaction of micro black holes (MBH) formation at Large Hadron Collider in this paper. We used models of multiple production processes on high energies for estimation: evristic model of MBH formation, simplest parton model and parton model for superhigh energies. On the basis of this models we have made the conclusion, that threshold of MBH formation by proton collisions is larger by 35-36 decimal orders than energy, that was reached today at Large Hadron Collider (LHC) (14 TeV). That explains the absence of MBH observations on proton collisions at LHC.

We have also valued MBH formation cross-section on proton with Pb nucleus collisions in this paper. On the basis of hN-interaction hydrodynamic model it was shown, that threshold energy of protons at the system of equal speeds (S-system) is the value of 10^{35} TeV order. That corresponds to energy of 10^{74} TeV order at laboratory system ($\vec{p}_{Pb} = 0$). Such an energy of protons can not be reached at elementary particles accelerators.

I. EVRISTIC MBH FORMATION MODEL

The processes of black holes formation at the LHC were investigated in [3-5] and other papers. In work [3], potentially dangerous events in collisions of heavy ions at the LHC were studied. The article [4] reviews the safety of particle collisions at the LHC. In work [5], the astrophysical consequences of hypothetical stable black holes of the TeV – scale were considered. The authors come to the

conclusion about the safety of possible processes of black hole formation at the LHC.

We shall consider reaction $p+p \rightarrow \text{MBH}$. Radius of the sphere, where deconfinement realizes and virtual and real particles are formed by proton collisions at centre of inertia system, may be estimated by formula

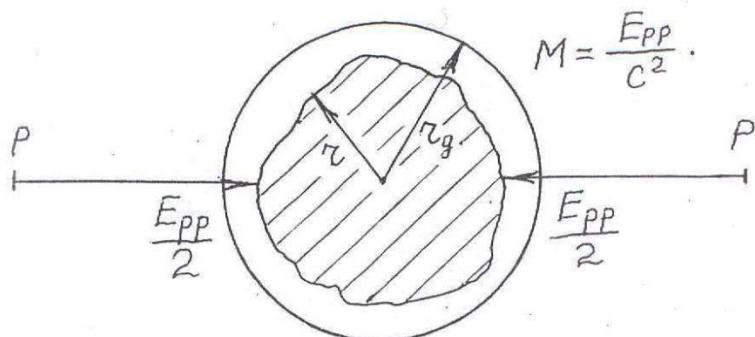
$$r = \sqrt{\frac{\sigma_{tot}(pp)}{\pi}}, \quad (1)$$

here $\sigma_{tot}(pp)$ is total cross-section of pp-interaction. Contemporary experimental data testify, that value of $\sigma_{tot}(pp)$ is constant at great interval of energies. When energy is very great, $\sigma_{tot}(pp)$ increases slowly with energy E_{pp} growth (E_{pp} is full protons energy at centre of inertia system).

If

$$r \leq r_g = \frac{2GM}{c^2} \quad \left(M = \frac{E_{pp}}{c^2} \right), \quad (2)$$

then second particles don't form on the outside of gravitational sphere [1-2], which is expected, and protons under collision come to gravitational sphere, which is expected, without energy loss for radiation. In that case protons pass full their energy E_{pp} to the volume inside of sphere r_g . In that case MBH with gravitational sphere r_g and with imaginary second particles inside of gravitational sphere is formed. This process is represented at picture 1.



Picture 1. MBH formation by proton collisions, when $r \leq r_g$.

From formulas (1) and (2) we have:

$$E_{pp}^2 \geq \frac{c^8 \sigma_{tot}(pp)}{4\pi G^2}. \quad (3)$$

Values of $\sigma_{tot}(pp)$ are represented at table 1.

Table 1. Values of $\sigma_{tot}(pp)$.

E_{pp}, TeV	$\sigma_{tot}(pp), mb$
1,0	67
7,0	95,35
10,0	107
60,0	144 (extrapolation)

We approximate $\sigma_{tot}(pp)$ by formula

$$\begin{aligned} \sigma_{tot}(pp) &= a_0 + a_1 \lg x + a_2 (\lg x)^2, \\ x &= \frac{E_{pp}}{2m_N c^2}, \end{aligned} \quad (4)$$

here

$$\begin{aligned} a_0 &= 77,3515 \text{ mb}, \\ a_1 &= -32,2941 \text{ mb}, \\ a_2 &= 10,4550 \text{ mb}. \end{aligned}$$

On such an approximation inequality (3) admits a solution

$$E_{pp} \geq E_{ppth} = 8,32 \cdot 10^{36} \text{ TeV}.$$

It is estimation of protons energy at centre of inertia system, when MBH begin to form. But protons energy at centre of inertia system, which was reached at LHC, is only 14 TeV. That explains the absence of MBH observations on proton collisions at LHC.

If $r > r_g = \frac{2GM}{c^2}$ ($M = \frac{E_{pp}}{c^2}$), then MBH don't form. It is illustrated by picture 2. Shaded domain with radius r is domain of virtual and real particles intensive formation. Real particles take away energy from shaded domain. So far as $r > r_g$, then radiation of energy by share of shaded domain, which is disposed

on the outside of expected gravitational sphere r_g , decreases initial energy of protons E_{pp} and only energy $E_{pp1} < E_{pp}$ comes to sphere r_g . Energy E_{pp1} is not enough for MBH formation with gravitational sphere r_g . Because of that we decrease radius of expected gravitational sphere to $r_1 = \frac{2GM_1}{c^2}$ ($M_1 = \frac{E_{pp1}}{c^2}$). But share of shaded domain between spheres r_{g1} and r_g also radiates energy. Because of that only energy $E_{pp2} < E_{pp1}$ comes to sphere r_{g1} . Energy E_{pp2} is not enough for MBH formation with gravitational sphere r_{g1} , because of that we decrease radius of gravitational sphere of expected MBH to $r_{g2} = \frac{2GM_2}{c^2}$ ($M_2 = \frac{E_{pp2}}{c^2}$). But share of shaded domain between spheres r_{g2} and r_{g1} also radiates energy. Because of that only energy $E_{pp3} < E_{pp2}$ comes to sphere r_{g2} . Energy E_{pp3} is not enough for MBH formation with gravitational sphere r_{g2} , because of that we decrease radius of gravitational sphere of expected MBH to $r_{g3} = \frac{2GM_3}{c^2}$ ($M_3 = \frac{E_{pp3}}{c^2}$) and so on. It will last like that until radius of gravitational sphere of probable MBH will turn into zero.

So, gravitational sphere of expected MBH decreases continuously, when shaded domain radiates the energy; particles, which find oneself inside of given sphere, have not enough energy for formation of MBH, which has given sphere as its gravitational sphere.

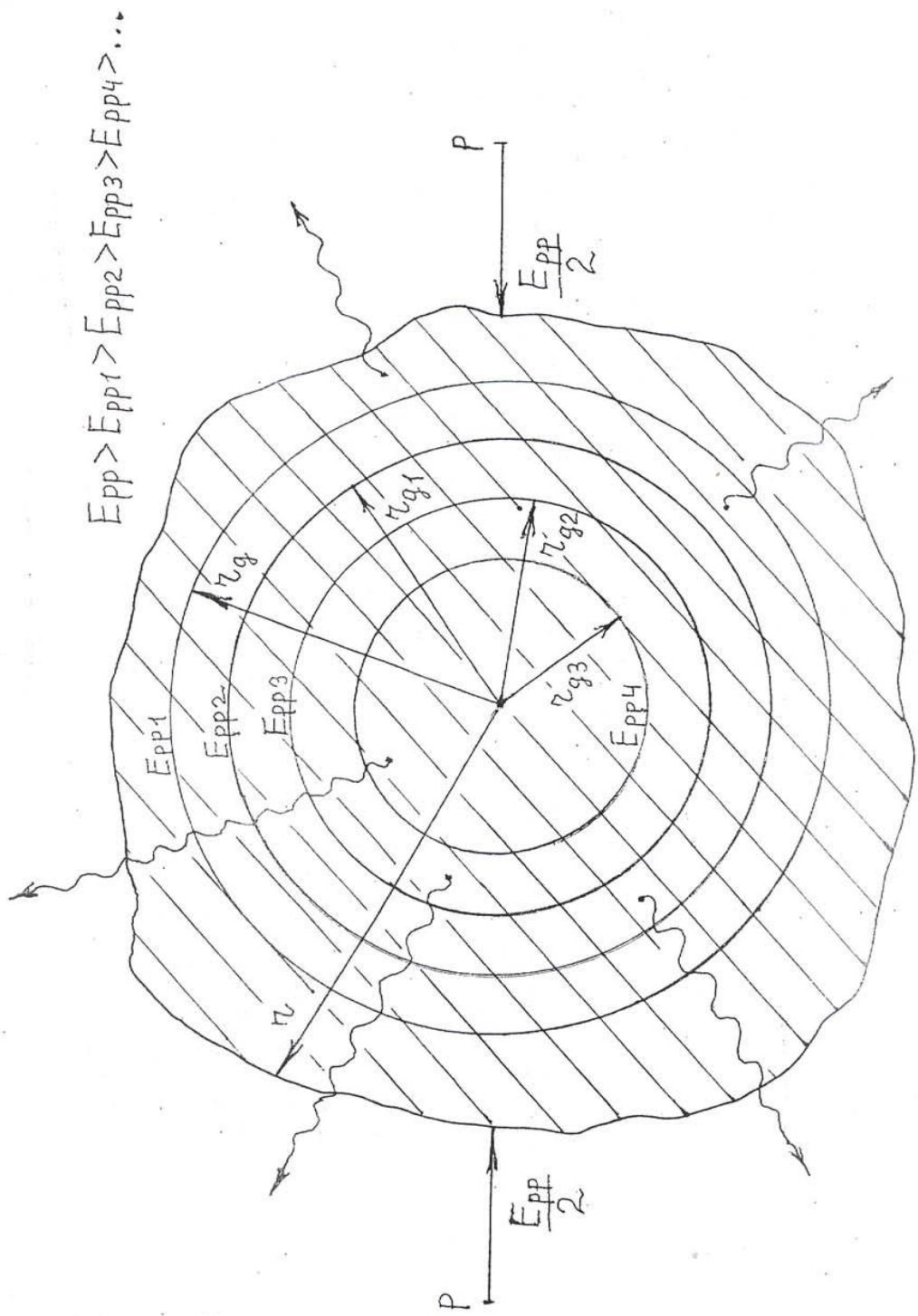
So, if $r > r_g$, then MBH don't form, if one assume, that radiation of energy realizes continuously from the whole domaine of virtual and real particles formation.

Cross-section of MBH formation on two protons collisions at centre of inertia system may be estimated in such a way:

$$\sigma \approx \pi(2r_g)^2 = \frac{16 \cdot \pi \cdot G^2}{c^8} \cdot E_{pp}^2. \quad (5)$$

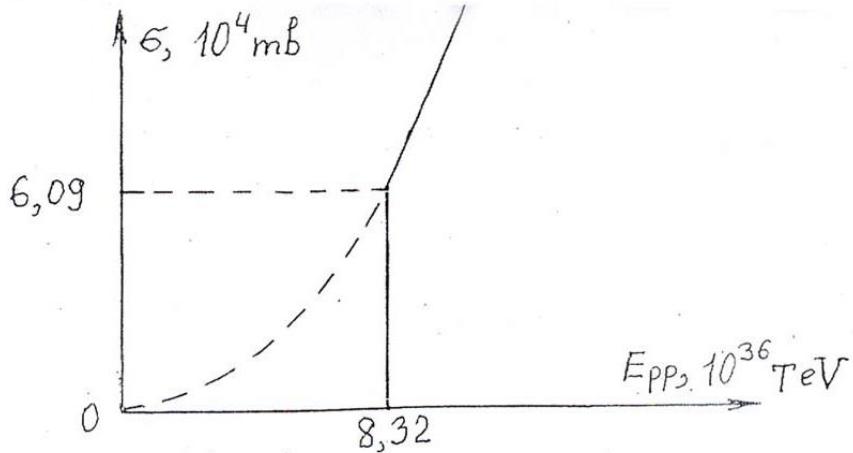
Cross-section of MBH formation on threshold energy is equal to

$$\sigma_{th} = \sigma(E_{ppth}) = 6,09 \cdot 10^4 \text{ mb.}$$



Picture 2. Process of decrease of expected MBH gravitational sphere on second particles formation, when $r > r_g$.

The dependence $\sigma(E_{pp})$ is adduced at picture 3.



Picture 3. The graph of dependence of MBH formation cross-section σ on full energy of protons, which are colliding, E_{pp} .

MBH life time at vacuum is equal to

$$\Delta t = \frac{5120 \cdot \pi \cdot G^2 \cdot M^3}{\hbar \cdot c^4}, \quad M = \frac{E_{pp}}{c^2}. \quad (6)$$

The indeterminacy of MBH formation energy is equal to

$$\Delta E_{pp} \approx \frac{\hbar}{\Delta t} = \frac{\hbar^2 \cdot c^{10}}{5120 \cdot \pi \cdot G^2 \cdot E_{pp}^3}. \quad (7)$$

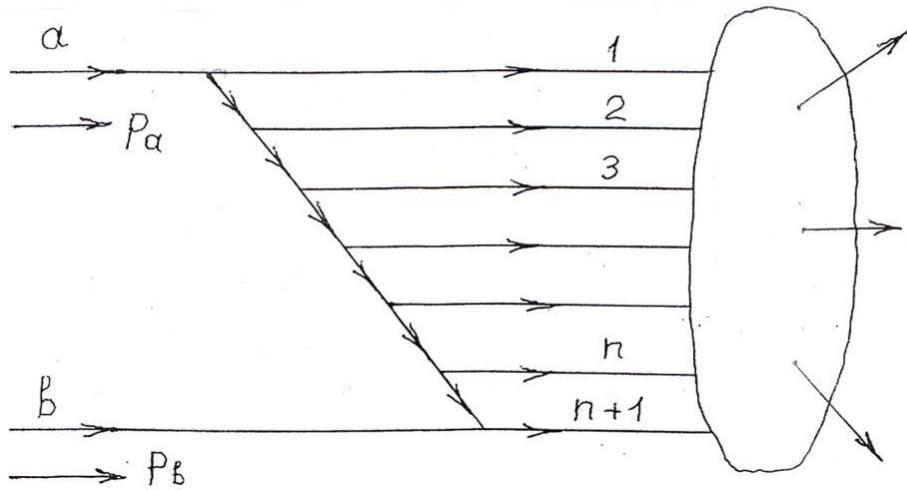
The indeterminacy of MBH formation energy decreases, when protons energy E_{pp} increases. On threshold energy

$$\Delta E_{ppth} = 2,40 \cdot 10^{-51} \text{ TeV}.$$

The adduced estimations are approximate ones because we combined mechanically quantum theory formulas with formulas from general relativity. For carefully investigation of MBH formation one have to use quantum theory of gravitation; but such a theory is not worked out enough today. Besides that, we don't know whether approximation (4) is correct on very high energies.

II. PARTON MODEL

We shall consider reaction $p+p \rightarrow MBH+X$ at centre of inertia system of protons, which collide. Scheme of pp-interaction process in parton model is adduced at picture 4.



Picture 4. Scheme of pp-interaction process in parton model.

In accordance with parton model free proton a dissociates virtually to system of partons until slow parton with impulse

$$p_q = \frac{p_a}{2^n} \approx \langle m_{q\perp} \rangle \quad (8)$$

will form; such a parton may to interact with slow parton from other proton b. We use mark $m_{q\perp} = (k_{q\perp}^2 + m_q^2)^{1/2}$. At simplest parton model they suppose $\langle m_{q\perp} \rangle \approx m_N$. From formula (8) we have

$$n = \frac{\ln(p_a/\langle m_{q\perp} \rangle)}{\ln 2}.$$

The dimension of parton fluctuation in diametrical direction is

$$|\vec{b}| \approx \langle m_{q\perp} \rangle^{-1} \cdot \sqrt{n} = \langle m_{q\perp} \rangle^{-1} \cdot \left(\frac{\ln(p_a/\langle m_{q\perp} \rangle)}{\ln 2} \right)^{1/2}.$$

It is hadron disk radius. Slow parton is disposed at the border of the disk.

One may estimate radius of domain, where real and virtual particles form on pp – interaction, in such a way: $r \approx 2|\vec{b}|$. The condition of MBH formation is

$$r \leq r_g ;$$

$$\frac{2}{\langle m_{q_\perp} \rangle} \cdot \left(\frac{\ln(p_a/\langle m_{q_\perp} \rangle)}{\ln 2} \right)^{1/2} \leq 2G E_{pp}.$$

For usual units we have inequality

$$\frac{2\hbar}{m_N \cdot c} \left(\frac{\ln(E_{pp}/2m_N c^2)}{\ln 2} \right)^{1/2} \leq \frac{2G E_{pp}}{c^4}.$$

This inequality admits the solution

$$E_{pp} \geq E_{ppth} = 1,81 \cdot 10^{36} \text{ TeV}.$$

So, reaction p+p→MBH+X threshold is larger by 35 decimal orders than energy, that was reached today at LHC (14 TeV).

Cross-section of MBH formation reaction, when threshold of reaction is reached, determines by formula (5). At threshold of reaction cross-section is equal to

$$\sigma_{th} = \sigma(E_{ppth}) = 2,88 \cdot 10^3 \text{ mb.}$$

Indeterminacy of MBH formation energy determines by formula (7). At threshold of reaction indeterminacy of energy is equal to

$$\Delta E_{ppth} = 2,34 \cdot 10^{-49} \text{ TeV}.$$

If energy is very high, then in a multitude of fluctuations the particular fluctuation may realizes. For particular fluctuation development of parton picture until slow parton formations will be carried out, in the main, in one direction at plane of sighting parameters. In that case effective diametrical dimension of parton fluctuation is equal to

$$|\vec{b}|_{eff} \approx \langle m_{q\perp} \rangle^{-1} \cdot n = \langle m_{q\perp} \rangle^{-1} \frac{\ln(p_a/\langle m_{q\perp} \rangle)}{\ln 2}.$$

The condition of MBH formation is

$$r \approx 2|\vec{b}|_{eff} \leq r_g$$

or for usual units

$$\frac{2\hbar}{m_N \cdot c} \frac{\ln(E_{pp}/2m_Nc^2)}{\ln 2} \leq \frac{2G E_{pp}}{c^4}. \quad (9)$$

The inequality (9) solution is

$$E_{pp} \geq E_{ppth} = 2,11 \cdot 10^{37} \text{ TeV}.$$

So, reaction threshold E_{ppth} on superhigh energies is larger by 36 decimal orders than energy, that was reached today at LHC.

From formulas (5) and (7) we obtain reaction cross-section at threshold of reaction and MBH formation energy indeterminacy at threshold of reaction:

$$\sigma_{th} = \sigma(E_{ppth}) = 3,93 \cdot 10^5 \text{ mb};$$

$$\Delta E_{ppth} = 1,46 \cdot 10^{-52} \text{ TeV}.$$

For three considered models values of threshold energy E_{ppth} , cross-section at threshold σ_{th} and MBH formation energy indeterminacy at threshold of reaction p+p→MBH+X ΔE_{ppth} are adduced at table 2.

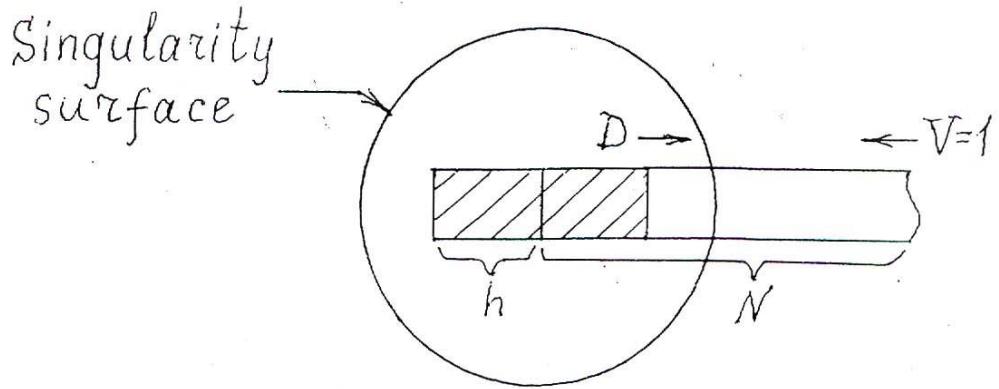
Table 2. Values of E_{ppth} , σ_{th} and ΔE_{ppth} for different models at centre of inertia system of protons, which collide.

Model	E_{ppth}, TeV	σ_{th}, mb	$\Delta E_{ppth}, TeV$
1.Evristic MBH formation model.	$8,32 \cdot 10^{36}$	$6,09 \cdot 10^4$	$2,40 \cdot 10^{-51}$
2.Simplest parton model.	$1,81 \cdot 10^{36}$	$2,88 \cdot 10^3$	$2,34 \cdot 10^{-49}$
3.Parton model for superhigh energies.	$2,11 \cdot 10^{37}$	$3,93 \cdot 10^5$	$1,46 \cdot 10^{-52}$

So, different phenomenological models lead to essentially different values of E_{ppth} , σ_{th} and ΔE_{ppth} , but all models testify, that E_{ppth} is essentially larger, than energy, which was reached today at LHC. That explains the absence of MBH observations on proton collisions at LHC.

III. MBH FORMATION ON PROTONS WITH PB NUCLEUSES COLLISIONS

We shall consider reaction $p+Pb \rightarrow MBH+X$ at the system of equal speeds (S - system). In accordance with hN – interaction hydrodynamic model the collision of hadron with nucleus leads to the tube with radius $r_o = m_\pi^{-1}$ formation. The length of this tube is equal to longitudinal dimension of nucleus. At first stage of multiple production process two disks come into contact, after that to both sides from plane of contact blow waves begin to spread through hadron liquid with speed D. When blow wave comes to hadron “border”, hadron substance between fronts of waves is resting and has mass $M \approx 2E$. Here E is hadron energy at S – system. Just at that moment one have to expect for singularity surface formation around of hadron substance between fronts of waves, if such a surface had not formed still earlier.



Picture 5. Moment of hadron with nucleus interaction, when blow wave have came to hadron “border”.

If singularity surface have formed, then it means MBH formation on hadron with nucleus collision. The condition $r_o \leq r_g$ have to be executed for MBH formation; for usual units this condition is wrote as

$$\frac{\hbar}{m_\pi c} \leq \frac{4GE}{c^4};$$

$$E \geq E_{th} = \frac{\hbar c^3}{4Gm_\pi} = 2,67 \cdot 10^{35} \text{ TeV}.$$

One may estimate reaction $p + Pb \rightarrow MBH + X$ cross-section in such a way:

$$\sigma = \pi \cdot r_{Pb}^2 = 1,70 \cdot 10^3 \text{ mb.}$$

Cross-section doesn't depend on energy, when threshold energy is reached.

The energy indeterminacy is defined by formula (7). At reaction threshold for S-system

$$\Delta E_{th} = \frac{Gm_\pi^3 \cdot c}{640 \cdot \pi \cdot \hbar} = 9,07 \cdot 10^{-48} \text{ TeV.}$$

Transition to laboratory system (L-system), where nucleus is at state of rest, is realized by formula

$$E' = \frac{2A \cdot E^2}{m_{Pb} \cdot c^2},$$

here A is quantity of nucleons in nucleus (for Pb $A=207$), m_{Pb} is nucleus mass ($m_{Pb} = 3,44 \times 10^{-25}$ kg), E' is hadron energy at laboratory system. The calculations give:

$$E'_{th} = 1,53 \cdot 10^{74} \text{ TeV}.$$

Of course, such an energy of protons can not be reached at elementary particles accelerators.

The estimations, which were realized in this paper, are founded on famous fenomenological models of multiple production. Possibly, calculation of quantum effects will lead to decrease of MBH formation threshold energy.

In papers [25, 30], field theories in space–time with additional dimensions were considered. If additional dimensions do exist, then there is the theoretical possibility of creating micro black holes on particle accelerators. Therefore, if the MBH is still found on particle accelerators, this will become a serious argument in favor of the space–time theories with $N > 4$.

IV. MODELING THE PROCESS OF BLACK HOLE FORMATION IN COLLISIONS OF QUARKS AND ANTIQUARKS

The literature suggests that all particles with a Compton wavelength less than the gravitational radius are black holes:

$$\lambda_c \lesssim r_g; \quad \frac{hc}{2G} \lesssim M^2.$$

An example of such a micro black hole is the Planck black hole (maximon) with Planck mass

$$M_p = \sqrt{\frac{\hbar c}{G}}.$$

It is suggested that the Planck mass is the lower limit of the masses of black holes and the upper limit for the masses of elementary particles [32, 33]. However, the stability of the maximon and the absence of Hawking radiation contradict the predictions of the quantum theory of gravity.

In this section of the article, modeling of the process of black hole formation during collisions of quarks and antiquarks is carried out. The simulation consists in identifying a black hole with a real scalar field $H(x)$, which is introduced into the Lagrangian of chromodynamics:

$$\begin{aligned} \mathcal{L} &= -\frac{1}{2} \operatorname{Tr} G^{\mu\nu} G_{\mu\nu} + \bar{q}(i\gamma^\mu \partial_\mu + g\gamma^\mu A_\mu - m)q + \mathcal{L}_H; \\ \mathcal{L}_H &= \frac{1}{2}(\partial^\mu H)(\partial_\mu H) - \frac{M^2}{2}H^2 + \lambda\bar{q}qH. \end{aligned}$$

The new vertex has a maximum index $\Omega = 0$, the dimension of the constant λ : $[\lambda] = [m]^0$. This justifies the conservation of the renormalizability of the theory.

Consider the reaction $u(p_1) + \bar{u}(p_2) \rightarrow H(p)$. The matrix element is equal to

$$\Phi_{\vec{p}}^+ S \Phi_{\vec{p}_1, \vec{p}_2} = \frac{i\lambda}{2p^o} \cdot \frac{1}{(2\pi)^{1/2}} \cdot \delta^{(4)}(p_1 + p_2 - p) \bar{v}^{\mu,-}(\vec{p}_2) v^{\nu,-}(\vec{p}_1).$$

The effective cross-section invariant under Lorentz transformations is determined by the formula

$$\begin{aligned} \sigma(p_1^o, p_2^o, \cos\theta) &= \frac{2\pi \cdot \lambda^2 p_1^o p_2^o}{8 p^{o3}} \left(\frac{(p_1 p_2) - m^2}{(p_1 p_2) + m^2} \right)^{1/2} \cdot \delta(p_1^o + p_2^o - p^o); \\ p^o &= \left(p_1^o + p_2^o + 2\sqrt{p_1^{o2} - m^2} \cdot \sqrt{p_2^{o2} - m^2} \cdot \cos\theta + M^2 - 2m^2 \right)^{1/2}. \end{aligned} \quad (10)$$

In the experiment, the δ -function “broadens” due to the uncertainty of its argument p_*^o :

$$p_*^o = p_1^o + p_2^o - p^o. \quad (11)$$

We have

$$\sigma(p_1^o, p_2^o, \cos\theta) = \frac{2\pi \cdot \lambda^2 p_1^o p_2^o}{8 p^{o3}} \left(\frac{(p_1 p_2) - m^2}{(p_1 p_2) + m^2} \right)^{1/2} \cdot A e^{-\alpha p_*^{o2}}. \quad (12)$$

Uncertainty p_*^o is given by the formula

$$\Delta p_*^o = \frac{\partial p_*^o}{\partial p_1^o} \Delta p_1^o + \frac{\partial p_*^o}{\partial p_2^o} \Delta p_2^o + \frac{\partial p_*^o}{\partial (\cos\theta)} \Delta(\cos\theta) + \frac{\partial p_*^o}{\partial M} \Delta M; \quad (13)$$

$$\frac{\partial p_*^o}{\partial p_1^o} = 1 - \frac{p_1^o}{p^o} \left(1 + \sqrt{\frac{p_2^{o2} - m^2}{p_1^{o2} - m^2}} \cdot \cos\theta \right); \quad (14)$$

$$\frac{\partial p_*^o}{\partial p_2^o} = 1 - \frac{p_2^o}{p^o} \left(1 + \sqrt{\frac{p_1^{o2} - m^2}{p_2^{o2} - m^2}} \cdot \cos\theta \right); \quad (15)$$

$$\frac{\partial p_*^o}{\partial (\cos\theta)} = -\frac{1}{p^o} (p_1^{o2} - m^2)^{1/2} \cdot (p_2^{o2} - m^2)^{1/2}; \quad (16)$$

$$\frac{\partial p_*^o}{\partial M} = -\frac{M}{p^o}. \quad (17)$$

The values of Δp_1^o , Δp_2^o and $\Delta(\cos\theta)$ are determined by the technical characteristics of the accelerator. The uncertainty of the boson mass is

$$\Delta M \approx \frac{\hbar}{2\Delta t} = \frac{\hbar^2 c^4}{10240 \cdot \pi \cdot G^2 \cdot M^3}, \quad (18)$$

Δt – time life of a black hole in its rest system. In addition, in the usual way we obtain the relations:

$$\alpha = \frac{\ln 2}{(\Delta p_*^o)^2}; \quad A = \frac{1}{|\Delta p_*^o|} \cdot \sqrt{\frac{\ln 2}{\pi}}. \quad (19)$$

Thus, the total invariant cross-section of the reaction of the formation of a black hole in a collision of a quark and an antiquark is determined by formula (12) taking into account formulas (10), (11), (19), (13-18). The lack of experimental data makes it impossible to estimate the constant

λ . We assume that it is very small. Therefore, in collisions of quarks and marine antiquarks on the LHC, the reaction $u\bar{u} \rightarrow H$ was not observed.

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STUDY OF THE HIGGS BOSONS FORMATION REACTION AT THE LARGE HADRON COLLIDER

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ABSTRACT

The possibility to identify new particle, that was discovered at Large Hadron Collider in CERN, with Higgs boson from Standard model has been showed in this paper. In this paper it has offered to realize identification of new particle with Higgs boson according to ratio of frequencies of different new-discovered particle decay canals. Probabilities of Higgs boson decay canals are already determined by theoretical way.

In this paper H^0 – boson formation under two quarks collision cross-section has also been calculated; exact formula for cross-section of reaction $u + d \rightarrow u + d + H^0$, that corresponds to diagrams of definite type, has also been obtained in this paper.

KEYWORDS

Higgs boson; Large Hadron Collider; Reaction.

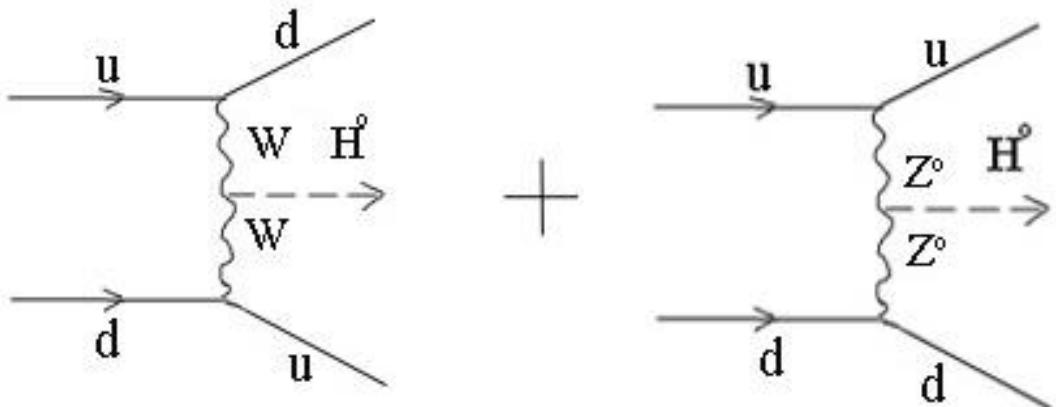
1. INTRODUCTION

At 04 July 2012 it had been declared, that new particle with mass about 125 GeV was discovered at Large Hadron Collider in CERN. The possibility to identify new-discovered particle with Higgs boson from Standard model [1-16] has been showed in this paper. In this paper it has offered to realize identification of new particle with Higgs boson according to ratio of frequencies of different new-discovered particle decay canals. Probabilities of Higgs boson decay canals are already determined by theoretical way.

In this paper H^0 – boson formation under two quarks collision cross-section has also been calculated; exact formula for cross-section of reaction $u + d \rightarrow u + d + H^0$, that corresponds to diagrams at picture 1, has also been obtained in this paper.

2. HIGGS BOSONS FORMATION UNDER U – AND D – QUARKS COLLISION.

We shall consider Higgs bosons formation under reaction $u(p_1) + d(p_2) \rightarrow u(p'_1) + d(p'_2) + H^0(p')$. We shall consider diagrams at picture 1.



Picture 1. Feinmans diagrams for reaction $u+d \rightarrow u+d+H^0$.

We shall choose interaction Lagrangian, which corresponds to diagrams at picture 1, from full Lagrangian of set of particles:

$$\begin{aligned}\mathcal{L}_{int}(x) = & i\bar{L}_1 \left(-ig\vec{T}\hat{\vec{A}} - ig' \frac{Y}{2} \hat{B} \right) L_1 + i\bar{L}_2 \left(-ig\vec{T}\hat{\vec{A}} - ig' \frac{Y}{2} \hat{B} \right) L_2 + \\ & + i\bar{u}_R (-ig' \frac{Y}{2} \hat{B}) u_R + i\bar{d}'_R \left(-ig' \frac{Y}{2} \hat{B} \right) d'_R + i\bar{s}'_R \left(-ig' \frac{Y}{2} \hat{B} \right) s'_R + \\ & + \left[\left(-ig\vec{T}\vec{A}_\mu - ig' \frac{Y}{2} B_\mu \right) \varphi \right]^* \cdot \left[\left(-ig\vec{T}\vec{A}^\mu - ig' \frac{Y}{2} B^\mu \right) \varphi \right].\end{aligned}$$

Here

$$L_1 = \begin{pmatrix} u \\ d' \end{pmatrix}_L; \quad L_2 = \begin{pmatrix} c \\ s' \end{pmatrix}_L,$$

other marks are standard ones. Then we have to realize spontaneous symmetry breaking and to remove c – and s – quarks. Then we remove addendum, which determine W – and Z⁰ – bosons masses. As a result, we obtain:

$$\begin{aligned}\mathcal{L}_{int}^{(1)}(x) = & \bar{u} N_\mu u \cdot Z^\mu + \bar{d} O_\mu d \cdot Z^\mu + \bar{u} R_\mu d \cdot W^{-\mu} + \bar{d} R_\mu u \cdot W^{+\mu} + \\ & + \frac{\bar{g}^2}{4} \left(\cos^2 \theta_w \cdot W_\mu^+ W^{-\mu} + \frac{1}{2} Z_\mu Z^\mu \right) (2\eta \chi + \chi^2).\end{aligned}$$

Here

$$\begin{aligned}N_\mu &= \bar{g} \gamma_\mu \left[\frac{1}{4} \left(\cos^2 \theta_w - \frac{1}{3} \sin^2 \theta_w \right) (1 + \gamma^5) - \frac{1}{3} \sin^2 \theta_w (1 - \gamma^5) \right]; \\ O_\mu &= \bar{g} \gamma_\mu \left[-\frac{1}{4} \left(\cos^2 \theta_w + \frac{1}{3} \sin^2 \theta_w \right) (1 + \gamma^5) + \frac{1}{6} \sin^2 \theta_w (1 - \gamma^5) \right]; \\ R_\mu &= \frac{\bar{g} \cos \theta_w}{2 \sqrt{2}} \cdot \cos \theta_c \cdot \gamma_\mu (1 + \gamma^5);\end{aligned}$$

$\theta_w \approx 30^\circ$ – Weinberg angle, $\theta_c \approx 13^\circ$ – Cabibo angle. Other marks are standard ones.

Scattering matrix is [17-28]

$$S_{fi} = (2\pi)^4 i \delta^{(4)}(P_f - P_i) \frac{M_{fi}}{(2p_1^0 \cdot 2p_2^0 \cdot 2p_1'^0 \cdot 2p_2'^0 \cdot 2p'^0)^{1/2}},$$

where

$$\begin{aligned} M_{fi} = & \frac{\bar{g}^2 \cdot \eta}{2} [\bar{u}_{1c}(p'_1) N^\mu u_{1A}(p_1) \cdot \bar{u}_{2D}(p'_2) O^\nu u_{2B}(p_2) \cdot D_{z\mu}^\lambda (p'_1 - p_1) \times \\ & \times D_{zv\lambda} (p'_2 - p_2) + \bar{u}_{1c}(p'_1) R_\mu^{(1)} u_{2B}(p_2) \cdot \bar{u}_{2D}(p'_2) R_\nu^{(1)} u_{1A}(p_1) \times \\ & \times D_w^\mu \lambda (p'_1 - p_2) \cdot D_w^\nu \lambda (p'_2 - p_1)]; \\ R_\mu^{(1)} = & \frac{\bar{g}}{2} \cdot \frac{\cos^3 \theta_w}{\sqrt{2}} \cdot \cos \theta_c \cdot \gamma_\mu (1 + \gamma^5). \end{aligned}$$

$|M_{fi}|^2$ is determined by formula:

$$\begin{aligned} |M_{fi}|^2 = & \frac{\bar{g}^8 \cdot \eta^2}{4} \left[\frac{G_1(p_1, p_2, k, p')}{(k^2 - m_z^2)^2 ((k - p')^2 - m_z^2)^2} + \right. \\ & + \frac{G_2(p_1, p_2, k, p')}{(k^2 - m_z^2)((k - p')^2 - m_z^2)((p'_1 - p_2)^2 - m_w^2)((p'_2 - p_1)^2 - m_w^2)} + \\ & \left. + \frac{G_3(p_1, p_2, k, p')}{((p_1 - p_2 - k)^2 - m_w^2)^2 ((p_2 - p_1 + k - p')^2 - m_w^2)^2} \right]. \quad (1) \end{aligned}$$

Exact formulas for functions G_1, G_2, G_3 are given in part “Supplement”.

Here $k = p_1 - p'_1$ is passed impulse,

$$p'_1 = p_1 - k; \quad p'_2 = p_2 + k - p'.$$

Probability of transition during one unit of time is [29-41]

$$\begin{aligned} dw_{fi} = & (2\pi)^4 \delta^{(4)}(P_f - P_i) \frac{|M_{fi}|^2}{4 p_1^0 p_2^0 V} \cdot \frac{d^3 \vec{p}'_2}{(2\pi)^3 \cdot 2p_2'^0} \times \\ & \times \frac{d^3 \vec{p}'_1}{(2\pi)^3 \cdot 2p_1'^0} \cdot \frac{d^3 \vec{p}'}{(2\pi)^3 \cdot 2p'^0}. \end{aligned}$$

H^0 – boson formation cross – section is determined by formula

$$d\sigma = (2\pi)^4 \cdot \delta^{(4)}(P_f - P_i) \frac{|M_{fi}|^2}{4 \cdot I} \cdot \frac{d^3 \vec{p}'_2}{(2\pi)^3 \cdot 2p'^0_2} \cdot \frac{d^3 \vec{p}'_1}{(2\pi)^3 \cdot 2p'^0_1} \times \\ \times \frac{d^3 \vec{p}'}{(2\pi)^3 \cdot 2p'^0}, \quad (2)$$

where in system $\vec{p}_1 = -\vec{p}_2$, $\vec{P}_i = 0$

$$I = |\vec{p}_1|(p_1^0 + p_2^0).$$

Then we integrate $d\sigma$ (2) over variables \vec{p}'_2, p'^0_1 . We obtain after that:

$$d\sigma = \frac{(p'^{02} - m_u^2) \cdot |M_{fi}|^2 \cdot d\Omega_1 \cdot d\Omega \cdot |\vec{p}'|^2 d|\vec{p}'|}{(4\pi)^5 |(p'^0 - p_1^0 - p_2^0)(p'^{02} - m_u^2)^{1/2} - p'^0_1 \cdot |\vec{p}'| \cos \gamma|} \times \\ \times \frac{1}{(p_1^{02} - m_u^2)^{1/2} \cdot p'^0_2 \cdot p'^0} . \quad (3)$$

Here p'^0_2 is determined by formula

$$p'^0_2 = \frac{(p_1^0 + p_2^0)^2 - m_u^2 + m_d^2 - m_H^2 + 2(\sqrt{p'^{02} - m_u^2} \cdot |\vec{p}'| \cos \gamma - p'^0_1 \cdot p'^0)}{2(p_1^0 + p_2^0)},$$

and p'^0_1 is solution of equation

$$(p_1^0 + p_2^0)(p_1^0 + p_2^0 - 2p'^0) + m_u^2 - m_d^2 + m_H^2 - 2p'^0_1(p_1^0 + p_2^0 - p'^0) = \\ = 2|\vec{p}'| \cdot \cos \gamma (p'^{02} - m_u^2)^{1/2};$$

$$|\vec{p}'| = \sqrt{p'^{02} - m_H^2}.$$

Axis x is directed along vector \vec{p}_1 . We use marks:

$$d\Omega_1 = \sin \theta_1 d\theta_1 d\varphi_1; \quad d\Omega = \sin \theta d\theta d\varphi,$$

$d\Omega_1$ and $d\Omega$ are elements of volume angles along vectors \vec{p}'_1 and \vec{p}' ,

$$\cos \gamma = \sin \theta_1 \sin \theta \cdot \cos (\varphi_1 - \varphi) + \cos \theta_1 \cdot \cos \theta,$$

γ is angle between vectors \vec{p}'_1 and \vec{p}' .

Differential cross – section (3) depends on five variables: $\theta_1, \varphi_1, \theta, \varphi, |\vec{p}'|$. One may obtain full cross – section by integrating $d\sigma$ (3) over variables $\theta_1, \varphi_1, \theta, \varphi, |\vec{p}'|$ inside of physical volume.

Formulas (1) and (3) are exact formulas for $|M_{fi}|^2$ and cross – section of reaction $u + d \rightarrow u + d + H^0$, which corresponds to diagrams at picture 1.

If one consider quarks as partons, then one may suppose $m_u = 0, m_d = 0$ [42]. On that case formula (3) is got simplify. We shall make estimate of full cross-section σ for this case.

Phase volume of the reaction, that we consider, is equal to

$$\Phi = \int d\Omega_1 d\Omega |\vec{p}'|^2 \cdot d|\vec{p}'| \sim \frac{2}{3}\pi^2 \frac{(E^2 - m_H^2)^3}{E^3},$$

where $E = P_i^0$.

Full cross-section is equal to

$$\begin{aligned} \sigma = \int d\sigma &\sim \frac{1}{(4\pi)^5} \cdot \frac{(p_1'^{02} - m_u^2) \cdot |M_{fi}|^2}{|(p'^0 - p_1^0 - p_2^0)(p_1'^{02} - m_u^2)^{1/2} - p_1'^0 \cdot |\vec{p}'| \cos \gamma|} \times \\ &\times \frac{1}{(p_1^{02} - m_u^2)^{1/2} \cdot p_2'^0 \cdot p'^0} \cdot \Phi. \end{aligned} \quad (4)$$

We shall estimate cross-section σ (4) by calculation of multiplier near phase volume Φ at the point

$$p_1^0 = p_2^0 = \frac{1}{2}E, \quad |\vec{p}_2'| = \varepsilon \rightarrow 0,$$

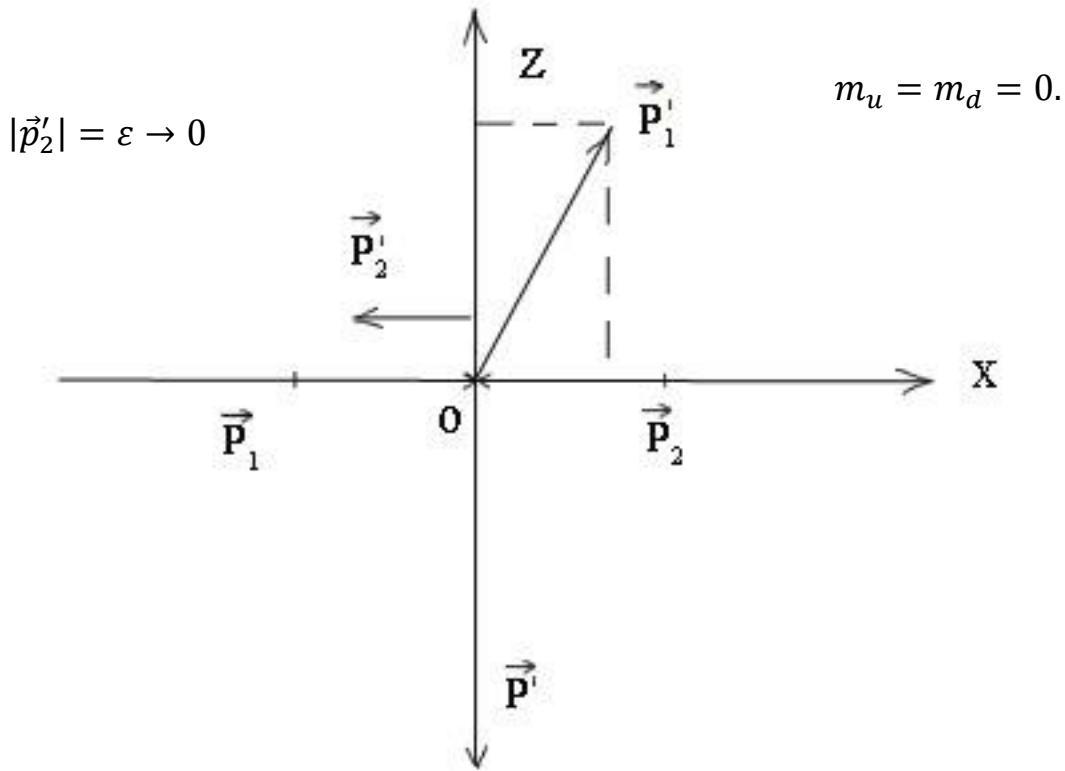
$$|\vec{p}_1'| = \frac{(E - \varepsilon)^2 + \varepsilon^2 - m_H^2}{2(E - \varepsilon)},$$

$$|\vec{p}'| = \frac{\sqrt{[(E - \varepsilon)^2 + \varepsilon^2 - m_H^2]^2 - 4(E - \varepsilon)^2 \cdot \varepsilon^2}}{2(E - \varepsilon)},$$

$$p_1'^0 = |\vec{p}_1'|, \quad p_2'^0 = |\vec{p}_2'| = \varepsilon \rightarrow 0,$$

$$p'^0 = \frac{(E - \varepsilon)^2 - \varepsilon^2 + m_H^2}{2(E - \varepsilon)},$$

$$\cos \gamma = -\frac{|\vec{p}'|}{|\vec{p}_1'|} \quad (\text{picture 2}).$$



Picture 2. The point for calculation of multiplier near phase volume Φ in (4).

We choose $\varepsilon = \alpha \cdot \frac{E^2}{m_H}$, α is estimate parameter. Such a choice is our estimate of cross-section σ .

So, full cross-section estimate is

$$\sigma \sim \frac{1}{3 \cdot 4^4 \pi^3} \cdot \frac{(E^2 - m_H^2)^4 \cdot |M_{fi}|^2}{E^4(E^2 + m_H^2) \cdot \varepsilon^2}.$$

Functions G_1, G_2, G_3 calculation gives:

$$G_1(p_1, p_2, k, p') \Big| \begin{array}{l} m_u = 0, \\ m_d = 0 \end{array} = 0,0251 \cdot \varepsilon E (E^2 - m_H^2);$$

$$G_2(p_1, p_2, k, p') \Big| \begin{array}{l} m_u = 0, \\ m_d = 0 \end{array} = 0,0555 \cdot \varepsilon E (E^2 - m_H^2);$$

$$G_3(p_1, p_2, k, p') \Big|_{\substack{m_u = 0 \\ m_d = 0}} = 0,0400 \cdot \varepsilon E (E^2 - m_H^2).$$

Let us suppose $E = P_i^0 = 437,5 \text{ GeV} = 3,5 m_H$ ($m_H = 125 \text{ GeV}$).

Then we have:

$$\begin{aligned} |M_{fi}|^2 &= 1,87 \cdot \alpha \cdot \frac{\bar{g}^8 \cdot \eta^2}{m_H^4}, \\ \sigma &\sim 2,40 \cdot 10^{-15} \cdot \frac{1}{\alpha} \text{ GeV}^{-2}. \end{aligned}$$

For usual system of units

$$\sigma \sim 9,35 \cdot 10^{-47} \cdot \frac{1}{\alpha} m^2 = 9,35 \cdot 10^{-7} \cdot \frac{1}{\alpha} \text{ pb.}$$

If we choose $\alpha = 10^{-5}$, then $\sigma \sim 9,35 \cdot 10^{-2} \text{ pb}$. We shall note, that, according to M.Spira et al [43], $\sigma(pp \rightarrow H^0 + X) = 4,9 \text{ pb}$, $\sqrt{s} = 14 \text{ TeV}$, as a result of reactions $qq \rightarrow H^0 qq$.

If one suppose, that lightening for u-d – collisions is

$$L_{u-d} \sim 1,7 \cdot 10^{38} \frac{1}{m^2 \cdot sec},$$

then intensity of H^0 – bosons formation is equal to

$$\mathcal{J} = \sigma \cdot L_{u-d} \sim 1,59 \cdot 10^{-3} \text{ sec}^{-1}.$$

So, about 0,954 Higgs bosons will be formed per 10 minutes as a result of considered reaction $u + d \rightarrow u + d + H^0$ (when all particles in initial and final states are free ones).

Results of estimate of cross – section for other values of energy are placed in table 1.

Table 1. Cross – section of reaction $u + d \rightarrow u + d + H^0 (\alpha = 10^{-5})$.

Energy E , GeV	Estimate value of cross - section $\sigma(E)$, GeV $^{-2}$
125	0
187,5	$0,365 \cdot 10^{-10}$
250	$1,36 \cdot 10^{-10}$
312,5	$2,03 \cdot 10^{-10}$
375	$2,33 \cdot 10^{-10}$
437,5	$2,40 \cdot 10^{-10}$
500	$2,37 \cdot 10^{-10}$
625	$2,17 \cdot 10^{-10}$
750	$1,94 \cdot 10^{-10}$

The precision of estimate depends on choice of the point for calculation of multiplier near phase volume Φ .

3. THE POSSIBILITY TO IDENTIFY NEW – DISCOVERED PARTICLE WITH HIGGS BOSON AT LARGE HADRON COLLIDER.

Theoretical calculations show, that H^0 – bosons time of life is not much. This bosons decay according to different canals and radiate second particles [42-44, 57-58]. Higgs boson, that was formed under p-p-collision [59-61], decays and forms stream of particles, and that leads to exceeding of average quantity of particles, which are formed under p-p-scattering. One may fix events of H^0 – bosons birth by study of exceedings of formed particles quantity over average level under p-p-collisions [45-56].

Canals of H^0 – boson decay with indication of time of life, decay width and percentage of width to full H^0 – boson decay width are cited in table 2.

Table 2. Canals of H^0 – boson decay.

Decay canal	Equation of decay	Time of life, sec.	Decay width, GeV	Per cent ratio, %	Literature
1	2	3	4	5	6
1	$H^0 \rightarrow \tau^+ \tau^-$	$2,52 \cdot 10^{-21}$	$26,11 \cdot 10^{-5}$	7,70	According to [42]; [43-44, 57]
		$2,03 \cdot 10^{-21}$	$32,42 \cdot 10^{-5}$		
2	$H^0 \rightarrow c\bar{c}$	$0,83 \cdot 10^{-21}$	$79,74 \cdot 10^{-5}$	3,28	According to [42]; [43-44, 57]
		$4,77 \cdot 10^{-21}$	$13,81 \cdot 10^{-5}$		
3	$H^0 \rightarrow 2g \rightarrow \text{hadrons}$	$7,66 \cdot 10^{-21}$	$8,59 \cdot 10^{-5}$	7,19	According to [42] ($\Lambda=200$ MeV); [43-44, 57]
		$2,17 \cdot 10^{-21}$	$30,27 \cdot 10^{-5}$		
4	$H^0 \rightarrow 2\gamma$	$73,96 \cdot 10^{-21}$	$0,89 \cdot 10^{-5}$	0,21	[43-44, 57]
5	$H^0 \rightarrow Z^0 Z^0$	$15,49 \cdot 10^{-21}$	$4,25 \cdot 10^{-5}$	1,01	[43-44, 57]
6	$H^0 \rightarrow W^+ W^-$	$1,79 \cdot 10^{-21}$	$36,75 \cdot 10^{-5}$	8,73	[43-44, 57]
7	$H^0 \rightarrow b\bar{b}$	$0,22 \cdot 10^{-21}$	$302,61 \cdot 10^{-5}$	71,88	[43-44, 57]

If one suppose, that canals, which are showed in table 2, are main canals, then full width of H^0 – boson decay in accordance with [43-44, 57] is about $421 \cdot 10^{-5}$ GeV.

Formation and following decay of H^0 – boson according to definite canal corresponds to exceeding of formed particles quantity over average level as result of birth of particles of definite kind.

Table 2 shows, that exceedings of particles quantity in result of leptons τ^+, τ^- formation (canal 1) compose 7,70 percent from all exceedings over average level, which are explained by H^0 – bosons birth and following decay. Exceedings of particles quantity in result of formation of charming quarks and antiquarks (canal 2) compose 3,28 percent from all exceedings over

average quantity of particles. Exceedings in result of formation of two gluons (canal 3) compose 7,19 percent from all exceedings and so on.

If analysis of experimental data about exceedings of particles quantity over average level will show, that percentage of exceedings, which are created by particles of definite kind (by definite canal of decay), corresponds to values from table 2, then one may affirm, that particle with mass m=125 GeV, which was discovered, is just Higgs boson from Standard model.

4. SUPPLEMENT.

Functions G_1, G_2, G_3 are given by formulas:

$$\begin{aligned}
 G_1(p_1, p_2, k, p') = & \frac{1}{4} Tr\{(\hat{p}'_1 + m_u) \cdot [A \cdot \gamma^\mu(1 + \gamma^5) - B \cdot \gamma^\mu(1 - \gamma^5)] \times \\
 & \times (\hat{p}_1 + m_u) \cdot [A \cdot (1 - \gamma^5)\gamma^\xi - B(1 + \gamma^5)\gamma^\xi]\} \cdot \left(g_\mu^\lambda - \frac{k_\mu k^\lambda}{m_z^2}\right) \cdot \left(g_\xi^\alpha - \frac{k_\xi k^\alpha}{m_z^2}\right) \times \\
 & \times Tr\left\{(\hat{p}'_2 + m_d) \left[-A' \cdot \gamma^\nu(1 + \gamma^5) + \frac{1}{2} B\gamma^\nu(1 - \gamma^5)\right] \times \right. \\
 & \times (\hat{p}_2 + m_d) \left[-A'(1 - \gamma^5)\gamma^\delta + \frac{1}{2} B(1 + \gamma^5)\gamma^\delta\right]\} \times \\
 & \times \left(g_{\nu\lambda} - \frac{(k - p')_\nu (k - p')_\lambda}{m_z^2}\right) \cdot \left(g_{\delta\alpha} - \frac{(k - p')_\delta (k - p')_\alpha}{m_z^2}\right);
 \end{aligned}$$

$$\begin{aligned}
 G_2(p_1, p_2, k, p') = & \frac{1}{2} C^2 [-2 \cdot AA' \cdot f_1(p_1, p_2, k, p') + AB \cdot m_d^2 \cdot f_2(p_1, p_2, k, p') + \\
 & + 2A' \cdot B \cdot m_u^2 \cdot f_3(p_1, p_2, k, p') - B^2 \cdot m_u^2 \cdot m_d^2 \cdot f_4(p_1, p_2, k, p')],
 \end{aligned}$$

$$f_1(p_1, p_2, k, p') = Tr\gamma^\xi \hat{p}'_1 \gamma^\mu \hat{p}_1 \gamma^\delta \hat{p}'_2 \gamma^\nu \hat{p}_2 \cdot W_{\mu\nu\xi\delta}(p_1, p_2, k, p'),$$

$$f_2(p_1, p_2, k, p') = Tr\gamma^\xi \hat{p}'_1 \gamma^\mu \hat{p}_1 \gamma^\delta \gamma^\nu \cdot W_{\mu\nu\xi\delta}(p_1, p_2, k, p'),$$

$$f_3(p_1, p_2, k, p') = Tr\gamma^\xi \gamma^\mu \gamma^\delta \hat{p}'_2 \gamma^\nu \hat{p}_2 \cdot W_{\mu\nu\xi\delta}(p_1, p_2, k, p'),$$

$$f_4(p_1, p_2, k, p') = Tr\gamma^\xi \gamma^\mu \gamma^\delta \gamma^\nu \cdot W_{\mu\nu\xi\delta}(p_1, p_2, k, p'),$$

$$W_{\mu\nu\xi\delta}(p_1, p_2, k, p') = \{U_{1\mu\nu} + b_1(p'_1 - p_1)_\mu (p'_2 - p_2)_\nu\} \times$$

$$\begin{aligned}
& \times \{U_{2\xi\delta} + b_2(p'_1 - p_2)_\xi (p'_2 - p_1)_\delta\}; \\
G_3(p_1, p_2, k, p') &= \frac{1}{16} C^4 \cdot Tr \hat{p}_2 (1 - \gamma^5) \gamma^\xi (\hat{p}'_1 + m_u) \gamma^\mu \times \\
& \times \left(g_{\xi\alpha} - \frac{(p'_1 - p_2)_\xi (p'_1 - p_2)_\alpha}{m_w^2} \right) \left(g_{\mu\lambda} - \frac{(p'_1 - p_2)_\mu (p'_1 - p_2)_\lambda}{m_w^2} \right) \cdot Tr (\hat{p}'_2 + m_d) \gamma^\nu \hat{p}_1 \times \\
& \times (1 - \gamma^5) \gamma^\delta \cdot \left(g_\nu^\lambda - \frac{(p'_2 - p_1)_\nu (p'_2 - p_1)^\lambda}{m_w^2} \right) \cdot \left(g_\delta^\alpha - \frac{(p'_2 - p_1)_\delta (p'_2 - p_1)^\alpha}{m_w^2} \right).
\end{aligned}$$

In this formulas

$$\begin{aligned}
A &= \frac{1}{4} \left(\cos^2 \theta_w - \frac{1}{3} \sin^2 \theta_w \right); \\
A' &= \frac{1}{4} \left(\cos^2 \theta_w + \frac{1}{3} \sin^2 \theta_w \right); \\
B &= \frac{1}{3} \sin^2 \theta_w; \quad C = \frac{\cos^3 \theta_w}{\sqrt{2}} \cdot \cos \theta_c; \\
b_1 &= \frac{(p'_1 - p_1)(p'_2 - p_2)}{m_z^4}; \quad b_2 = \frac{(p'_1 - p_2)(p'_2 - p_1)}{m_w^4}; \\
U_{1\mu\nu} &= g_{\mu\nu} - \frac{1}{m_z^2} ((p'_2 - p_2)_\nu (p'_2 - p_2)_\mu + (p'_1 - p_1)_\mu (p'_1 - p_1)_\nu); \\
U_{2\xi\delta} &= g_{\xi\delta} - \frac{1}{m_w^2} ((p'_2 - p_1)_\xi (p'_2 - p_1)_\delta + (p'_1 - p_2)_\xi (p'_1 - p_2)_\delta); \\
U_{1\mu\nu} &= U_{1\nu\mu}; \quad U_{2\xi\delta} = U_{2\delta\xi}.
\end{aligned}$$

Other marks are standard ones. In this formulas $k = p_1 - p'_1$ is passed impulse,

$$p'_1 = p_1 - k; \quad p'_2 = p_2 + k - p'.$$

Functions G_1, G_2, G_3 were calculated in paper [58]. Exact formulas for G_1, G_2, G_3 were adduced in [58].

CONCLUSION

So, in this paper it has been showed the possibility to identify particles, which form at Large Hadron Collider, with Higgs boson from Standard model. In this paper it has offered to realize identification of new particles with Higgs boson according to ratio of frequencies of new particles decay canals. Probabilities of Higgs boson decay canals are already determined by theoretical way.

In this paper it has obtained exact formula for cross-section of reaction $u + d \rightarrow u + d + H^0$, which corresponds to diagrams at picture 1.

In this paper it has calculated also H^0 – boson formation cross-section under $u -$ and $d -$ quarks collision.

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