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ELECTROMAGNETIC AND SEMILEPTONIC FORMFACTORS OF HYPERONS IN BOOSTED BAG MODEL

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A Lorentz invariant formulation of the MIT bag model is presented. Electromagnetic formfactors (EMFs) and formfactors in semileptonic decays (FSDs), calculated using that formalism, are independent of reference frame. The second class EMFs and β-decay formfactors appear to be identically equal to zero. Second class FSDs have been found to be very small. The model can be applied for spacelike and timelike momentum transfers. FSDs are continuous when passing from one to the other region.

1. Introduction

Strong evidence is known that hyperons are composite particles. They are usually (approximately) described by quark models. These models are *static*, i. e. the *model's* hadronic wave function does not contain the information on the hyperon's motion as a whole. In order to include the q^2 dependence of formfactors (see Eq. (1)) wave functions of the initial and the final hyperon state have to describe objects with different velocities, i. e. the *model* wave functions of hyperons should contain information on the *movement* of hyperon as a whole. The bag boosting has been studied in many papers. In Ref. 1 spinor rotation part of the boost was studied. Guichon[2)] showed that one must include also a simultaneous coordinate transformation. In the same paper he claimed that the N representation MIT-bag wave functions, describing hadrons, cannot be boosted by arbitrary velocity because the hyperon wave functions cannot be expanded in terms of creation and destruction operators of the static bag. So, he claimed that Lorentz invariance is lost quantizing the bag states. The problem is resolved here introducing overlap combinations in the current operators. The same problem was recently treated[3,4] where semileptonic decays are disscused in several bag models. Lie-Svendsen and Hogasen[3] included the overlap combinations, however, but they are not Lorentz invariant and were not treated as operators acting on hyperon states. Also the usual Lorentz noninvariant integration measure was used in the calculations of formfactors.

In the second section a general formalism of boosting of wave functions and construction of Lorentz invariant matrix elements are presented. That includes discussion of the overlaps, the Lorentz invariant measure and normalization factors. Also, Guichon's claim on Lorentz invariance is discussed. Lorentz invariance is generally shown here. In the third section Lorentz invariance is shown explicitely and expressions for formfactors are derived. In the last section some numerical results are given and discussed.

2. *Basic formalism*

Electromagnetic formfactors (EMFs) and formfactors in semileptonic decays (FSDs) are defined through matrix elements, M_μ, of hadronic current[5]:

$$M_\mu = \langle B_b| \int \mathrm{d}^4 x\, J_\mu(x) \exp(-\mathrm{i}qx) |B_a\rangle =$$

$$= (2\pi)^4\, \delta^4 (P_b - P_a - q)\, \langle B_b| J_\mu(0) |B_a\rangle. \tag{1}$$

Here:

$$\langle B_b| V_\mu(0) |B_a\rangle = N_{ab}\, \overline{U}(\vec{P}_b\, S_b)\, [f_1 \gamma_\mu + \mathrm{i}\sigma_{\mu\nu} q^\nu f_2 +$$

$$+ q_\mu f_3]\, \overline{U}(\vec{P}_a\, S_a), \tag{2a}$$

$$\langle B_b| A_\mu(0) |B_a\rangle = N_{ab}\, \overline{U}(\vec{P}_b\, S_b)\, [g_1 \gamma_\mu \gamma_5 +$$

$$+ \mathrm{i}\sigma_{\mu\nu} \gamma_5 q^\nu g_2 + q_\mu \gamma_5 g_3]\, U(\vec{P}_a\, S_a), \tag{2b}$$

$$N_{ab} = (M_a\, M_b/E_a\, E_b)^{1/2}/(2\pi)^{3/2}. \tag{2c}$$

The $U(\vec{P}_a, S_a)$ and $U(\vec{P}_b, S_b)$ are free particle Dirac wave functions having momenta P_a and P_b, spin S_a and S_b and having masses M_a and M_b, respectively, $q = P_b - P_a$ is momentum transfer, A_μ and V_μ are the vector and axial-vector hadronic currents, respectively, N_{ab} is a normalization factor.

The boosted wave functions were constructed using the *bola-model* formalism[6]. For example, in models in which a hyperon has three quarks its wave functions in an arbitrary reference frame read[6]

$$\Psi^S_{HIP}(y^S; z^S_1, z^S_2, z^S_3) = N \exp(-iP^S y^S)\, \psi_1(z^S_1)\, \psi_2(z^S_2)\, \psi_3(z^S_3), \tag{3a}$$

$$N = (M/E^S)^{1/2}/(2\pi)^{3/2}. \tag{3b}$$

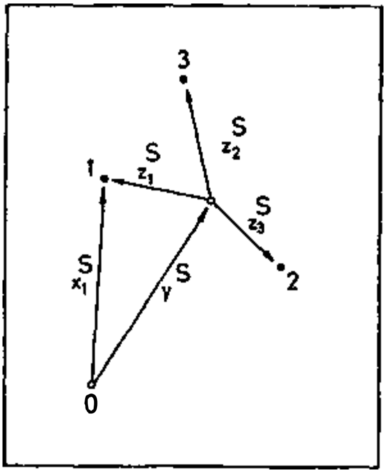

Fig. 1. Relation between z^S_i, x^S_i and y^S coordinates.

The superscript S indicates that the coordinates, momenta and wave functions are observed in the reference frame S. P^S is the total 4-momentum of the hyperon; y^S are the coordinates of the spurion scalar centre and $z^S_i = x^S_i - y^S$ are the relative coordinates of quarks with respect to the spurion scalar centre. Absolute coordinates of quarks are x^S_i (see Fig. 1). The $\psi_i(z^S_i)$'s are boosted quark wave functions of the relativistic problem scalar particle — constituent. In the bola model formalism they have the following form

$$\psi^S(z^S) = S(\vec{P})\, \eta\,(r\,(x^S) \exp(-z^S_{\shortparallel}\, \varepsilon_a). \tag{4}$$

Here ε_a is the static bag model energy,

$$z^{\shortparallel} = u_\mu z^\mu, \qquad u_\mu = P_\mu/M \tag{5a}$$

is a parallel coordinate of the quark, relatively to the momentum of the hyperon, and it corresponds to the time coordinate in the rest frame of the hyperon; the $\eta(r)$ and r are wave function and space coordinates of the quark in the rest frame of the hyperon (e. g. static MIT bag model wave function), and

$$S(P^S) = (2M(E^S + M))\,(\gamma^0 P^S + M) \tag{6}$$

is the boost operator. Notice that $\vec{r}$ can be viewed as a space part of 4-vector

$$z_{\perp}^{\mu} = z^{\mu} - u^{\mu}(uz) \tag{5b}$$

in the rest frame of the hyperon. In the bola model formalism every constituent wave function is a product of an exponential wave function, depending only on $z^{\parallel}$ and of a wave function depending only on $z_{\perp}$. We demand that formfactors obtained in the bola MIT bag model in the static limit coincide with the formfactors calculated in the static MIT bag model. In the static MIT bag model formfactors f_1 and g_2 are not equal to zero. They are obtained from expressions

$$\int \bar{\eta}(\vec{r})\, O\, \eta(\vec{r})\, \mathrm{d}^3 r \cdot 1 \cdot 1, \qquad O = \gamma_{\mu}, \gamma_{\mu}\gamma_5. \tag{7}$$

Only one quark interacts with the carrier of force. Interaction is of vector ($O = \gamma_{\mu}$) or axial vector ($O = \gamma_{\mu}\gamma_5$) type. The other two quarks are spectators. The spectator contributions (the factor 1 in Eq. (7)) to the total interaction are known in literature as overlaps or overlap functions[7]. So, the total interaction in the static MIT bag model is

$$\int \mathrm{d}^3 r_1\, \mathrm{d}^3 r_2\, \mathrm{d}^3 r_3\, \bar{\eta}_1(\vec{r}_1)\, \bar{\eta}_2(\vec{r}_2)\, \bar{\eta}_3(\vec{r}_3)\, (O_1 \times \gamma_2^0 \times \gamma_3^0)\, \eta_1(\vec{r}_1)\, \eta_2(\vec{r}_2)\, \eta_3(\vec{r}_3) \tag{8}$$

(overlaps in Eq. (7) give factors equal to one). In the bola model based on the MIT bag the static MIT bag model function $\eta_1\eta_2\eta_3$ of a hyperon must be replaced by expression (3). The overlaps $\int \bar{\eta}\gamma^0 \eta\, \mathrm{d}^3 r$, have to be replaced with Lorentz invariant expressions which become the static MIT bag overlaps in the limit $\vec{P}_a, \vec{P}_b \to \to 0$. For example, one can substitute

$$\gamma^0 \to \hat{L}_{\mu}\gamma^{\mu}. \tag{9}$$

Here $\hat{L}_{\mu}$ is a unit 4-vector constructed of the initial and the final state 4-momenta. In the $\vec{P}_a, \vec{P}_b \to 0$ limit the $\hat{L}_{\mu}$ must become the $(1, 0)$ 4-vector. The static MIT quark interaction vertices, $O = \gamma_{\mu}, \gamma_{\mu}\gamma_5$ already carry the expected Lorentz structure. The operator O is multiplied by the exponential factor, $\exp(\mathrm{i}qx)$, due to the wave function of the carrier of force: $\varepsilon_{\mu}(q)\exp(\mathrm{i}qx)$. So, the interaction vertex for a composite hyperon is

$$\mathrm{VERTEX} = O \exp(\mathrm{i}qx) \times \hat{\mathcal{L}} \times \hat{\mathcal{L}}, \quad O = \gamma_{\mu}, \gamma_{\mu}\gamma_5. \tag{10}$$

The wave function (3) must behave under Lorentz transformations as if the hyperons were elementary particles. In the quantum field theory their wave functions can be expanded in terms of free particle wave functions. In the Bjorken-Drell notation[8] a hyperon wave function reads

$$\psi_{HIP}(x) = \int d^3p\, n\, [b(\vec{p}, s)\, u(\vec{p}, s) \exp(-ipx) +$$
$$+ d^{\dagger}(\vec{p}, s)\, v(\vec{p}, s) \exp(ipx)], \quad (11a)$$
$$n = (M/E)^{1/2}/(2\pi)^{3/2}, \quad (11b)$$

where $b(p, s)$ and $d^{\dagger}(p, s)$ are the annihilation operators of the hyperon and the creation operators of the antihyperon. E. g.

$$|B_a\rangle = b_a^{+}|0\rangle. \quad (12)$$

The information on the internal quark structure is contained in the spinors $u(\vec{p}, s)$ and $v(\vec{p}, s)$. The action of $|B_a\rangle$ and $|B_b\rangle$ on currents A_μ and V_μ yields factors $(M_a/E_a(2\pi)^3)^{1/2}$ and $(M_b/E_b(2\pi)^3)^{1/2}$. Therefore the model hyperon functions (3) must have a factor with $(1/E)^{1/2}$ Lorentz structure. The exact normalization factor of the hyperon wave function in Eq. (3) is obtained from the normalization condition

$$\int \overline{\Psi}_{HIP}(P_b; y; z_1, z_2, z_3)\, \gamma^0 \times \hat{L} \times \hat{L}\, \Psi_{HIP}(P_a; y; z_1, z_2, z_3)\, dl\, d^4y =$$
$$= 2\pi\, \delta^4(P_b - P_a) \quad (13)$$

which corresponds to the normalization condition satisfied by the hyperon wave function (11), when hyperon is treated as elementary particle

$$\int d^4x\, \overline{\psi}_{HIP}(P_b, x)\, \gamma^0\, \psi_{HIP}(P_a, x) = 2\pi\, \delta^4(P_b - P_a)$$
$$\psi_{HIP}(P, x) = n\, U(P, x) \exp(-ipx). \quad (14)$$

dl in Eq. (13) is integration measure and n is normalization factor (11b). In the formula (8) integration over the space and not over the whole space time appears. That space time integration can be written as integration over the whole space time by introducing $\delta(t)$ in the integration measure:

$$d^3x = \int d^4x\, \delta(t). \quad (15)$$

The $\delta(t)$ function shows that in the static MIT bag model a hyperon and a carrier of force interact just in one hypersurface, the so called *interaction hypersurface*, which is determined by $t = 0$. A natural Lorentz invariant measure that corresponds to the measure in Eq. (8), and in $\vec{P}_a, \vec{P}_b \to 0$ limit becomes equal to it, is

$$d^4x\, \delta(\hat{L}x). \quad (16)$$

Here $\hat{L} = \alpha P_a + \beta P_b$ is a unit 4-vector constructed of P_a and P_b momenta (α and β are constants). The interaction hypersurface is now determined by $\hat{L}x = 0$. It is natural to assume that $\hat{L}$'s in formulae (10) and (16) are equal. For the conserved electromagnetic current[9] from Eq. (2a) one obtains

$$f_3 = 0. \tag{17}$$

In that claim T invariance of foton—hyperon interaction is built. Any calculation with the model wave functions must also lead to the result (17). The condition $f_3 = 0$ assures T invariance of the model.

The following discussion of the relation (17), is valid not only for the static MIT bag model, but for any bola-potential model in which wave functions of quarks have, in the static limit, the form

$$\psi^{a_l}(r) = \begin{pmatrix} \mathrm{i} & U_{a_l}(r)\,\chi \\ \vec{\sigma}\,\vec{n} & V_{a_l}(r)\,\chi \end{pmatrix}. \tag{18}$$

Here χ is Pauli spinor, r is magnitude of radius vector, $\vec{n}$ is its direction, U and V are up and down components of quark wave functions, respectively, and a_l indices indicate flavour of quark and that it belongs to hyperon a. As shown in the next section f_3 can be written in the form of an integral over the expression

$$U_{a_l}(r_{a_l})\, V_{b_l}(r_{b_l}) - U_{b_l}(r_{b_l})\, V_{a_l}(r_{a_l}). \tag{19}$$

Arguments r_{a_l} etc. are determined by the space components of the position 4-vectors z_{a_l} etc. In the rest frame of the hyperon to which a particular quark belongs:

$$r_{a_l, b_l} = \left| \vec{z}^{\;S_a,\,S_b}_{\;a_l,\,b_l} \right| = (-z^2_{a_l,\,b_l})^{1/2} \tag{20}$$

(see Eq. (5a)). The expression (19) vanishes for any P_a, P_b only if

$$r_a = r_b \tag{21a}$$

or

$$z^2_{a\perp} = z^2_{b\perp}. \tag{21b}$$

Relation (21b) defines the interaction hypersurfaces:

$$z^2_{a\perp} - z^2_{b\perp} = [(u_a + u_b)\, z]\, [-(u_a - u_b)\, z] = 0. \tag{22}$$

Only the hypersurface defined by

$$(u_a + u_b)\, z = 0 \tag{23}$$

$$u^{\mu}_{a,b} = P^{\mu}_{a,b}/M_{a,b},$$

becomes $t = 0$ hypersurface in the $\vec{P}_a, \vec{P}_b \to 0$ limit. Relation (21b) is correct for space time points of the *edge* (see Fig. 2 and Fig. 3) of the initial and the final bag which geometrically means that the boundary hypersurface of the bag surface is continuous (see Fig. 2). If the relation (21b) was satisfied the boundary hypersurface wold not be continuous (see Fig. 3). The continuity of boundary hypersurface of the bag insures that there are no surface contributions to the formfactors f_i. That is the reason why the same interaction hypersurface will be also taken in the calculation of FSDs, where the flavour of interaction quark changes. Through Eq. (20) time of the interaction can be expressed as a function of space coordinates

$$t_{HI} = (u_a^S + u_b^S)/(u_a^{0S} + u_b^{0S})\, z. \tag{24a}$$

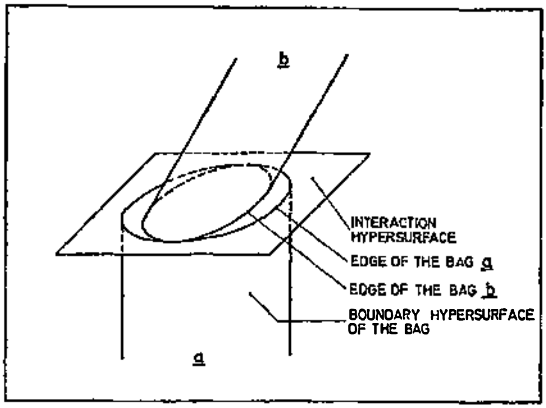

Fig. 2. The Breit's interaction hypersurface: the boundary hypersurface of the bag is continuous. Reference frame is S_a, the rest frame of the hyperon a.

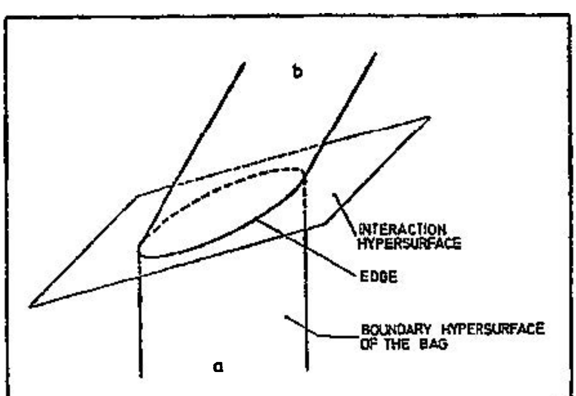

Fig. 3. The interaction hypersurface is defined with $\delta(P_a z)$. The boundary hypersurface of the bag is not continuous. Reference frame is the rest frame of the hyperon a, S_a.

One can define the general Breit's frame (GBF) by

$$\vec{u}^{S_{GBF}} = - \vec{u}^{S_{GBF}}, \tag{24b}$$

where

$$t_{HI}^{S_{GBF}} = 0. \tag{24c}$$

For equal hyperon (barion) masses this corresponds to the usual Breit's frame (BF)

$$M_a = M_b, \qquad \vec{P}_a^{S_{BF}} = -\vec{P}^{S_{BF}},$$

$$t_{HI}^{S_{BF}} = 0. \tag{24d}$$

The bola MIT bag model expression for the matrix elements of the vector (axial vector) hadronic current, which in $\vec{P}_a, \vec{P}_b \to 0$ limit agrees with the corresponding MIT bag model expressions and gives $f_3^{EM} = 0$, is

$$M_\mu^{\mathrm{BAG}} = \int \mathrm{d}^4 y \, \langle B_b | \, J_\mu (y) | B_a \rangle = \int \mathrm{d}^4 y \, \mathrm{d}^4 z_1 \, \hat{\delta} (L z_1) \, \mathrm{d}^4 z_2 \, \hat{\delta} (L z_2) \, \mathrm{d}^4 z_3 \, \hat{\delta} (L z_3)$$

$$\overline{\Psi}_b (y; z_1, z_2, z_3) \, \mathbf{O} \, \Psi_a (y; z_1, z_2, z_3) =$$

$$= 2\pi \, \delta^4 (P_b - P_a - q) \, N_{ab} \, I_{Os_1' s_1}^{b_1 a_1} \, Z^{a_2} \, Z^{a_3}. \tag{25a}$$

Here

$$J_\mu = A_\mu \text{ or } V_\mu,$$

$$\mathbf{O} = O \exp (-\mathrm{i} q x) \times \hat{L} \times \hat{L},$$

$$O = \gamma_\mu \text{ or } \gamma_\mu \gamma_5,$$

$$\hat{L} = (u_a + u_b) / ((u_a + u_b)^2)^{1/2}, \tag{25b}$$

$\Psi_{a,b}$ are functions (3) and $N_{a,b}$ is the norm (2c). The expression (25a) is valid for some arbitrary reference frame S. $I_{Os_1' s_1}^{a_1 b_1}$ is defined by

$$I_{Os_1' s_1}^{b_1 a_2} = \int \mathrm{d}^4 z_1 \, \delta (\hat{L} z_1) \, \eta_{s_1 b_1} (r_{b_1}) \, S^{-1} (\vec{P}_b) \, O \, S (\vec{P}_a) \, \eta_{s_1 a_1} (\vec{r}_{a_1}) \, \cdot$$

$$\cdot \exp [\mathrm{i} \, (\varepsilon_{b_1} z_{b_1}^{\parallel} - \varepsilon_{a_1} z_{a_1}^{\parallel} - q z_1)] = \int \mathrm{d} l_1 \, \mathrm{i}_{Os_1' s_1}^{b_1 a_1} \exp (\mathrm{i} \mathrm{Arg} \, [\mathrm{I}]), \tag{26}$$

$$\mathrm{d} l_1 = \mathrm{d} z_1 \, \delta (\hat{L} z), \quad \mathrm{Arg} \, [\mathrm{I}] = \varepsilon_{b_1} z_{b_1}^{\parallel} - \varepsilon_{a_1} z_{a_1}^{\parallel} - q z_1,$$

and Z, which has no spin dependence can be obtained from $I^{b_1 a_1}_{Os_1 s_1}$ by the following substitutions: $a_1, b_1 \to a_2$ or a_3, $0 \to \hat{\mathcal{L}}$ and Arg [I] $\to$ Arg [Z]. The last substitution is obtained by putting $q^\mu = 0$ in Arg [I].

In the bola MIT bag model, described above, we have used wave functions of hyperons in the configuration space. Guichon[2] claims that N representation MIT bag model wave functions cannot be used for calculation of the formfactors because the Hilbert space of the static MIT bag model quark states is too small to describe moving bag quark states at high velocities. To find formfactors at low momentum transfers Guichon calculates matrix elements of hadronic currents

$$\int d^4 y \langle B_b | J_\mu (y) | B_a \rangle \tag{27}$$

in the rest frame of the hyperon a. $|B_a\rangle$ is the usual static MIT bag model wave function in the N representation and J_μ is the vector or axial vector current built of the N representation quark wave functions: $J_u = \psi_{b_1} O \psi_{a_1}$, where

$$\psi^\alpha_{a_1} = \sum_{nm} N(\omega_n) [b^{\alpha a_1}_{nm} \eta^{a_1}_{nm}(r) \exp(-i\varepsilon_{a_1} t) + \\ + d^{\dagger \alpha a_1}_{nm} \tilde{\eta}^{a_1}_{nm}(r) \exp(i\varepsilon_{a_1} t)] \tag{28}$$

is N representation of a, quark wave function, ψ_{b_1} has exactly the same form: $\eta^{a_1}_{nm} (\eta^{b_1}_{nm})$ and $\tilde{\eta}^{a_1}_{nm} (\tilde{\eta}^{b_1}_{nm})$ are usual wave functions of quark and antiquark in the *static* MIT bag model: indices a_1 and b_1 here denote just flavour and not to which hyperon quark belongs: $b^{a_1}_{nm} (b^{b_1}_{nm})$ and $d^{\dagger a_1}_{nm} (d^{\dagger b_1}_{nm})$ are the operators of annihilation of quraks and creation of antiquarks in the *static* MIT bag: α is the colour quantum number: m is projection of quark spin in z direction and n is the principal quantum number. It is important to notice that $|B_a\rangle$, ψ_{a_1} and ψ_{b_1} are all expanded in terms of operators of annihilation of quarks and creation of antiquarks in the *static* MIT bag. $|B_b\rangle$ is the usual hyperon wave function in the N representation but expressed in terms of quark creation operators of the *moving* MIT bag. To be able to calculate the matrix element (27) Guichon had to develop these operators in terms of the static MIT bag model operators. That is possible only for low momentum transfers.

In our approach in addition to interaction quark current $\bar{\psi}_{b_1} \mathbf{O} \psi_{a_1}$ we have two overlap combinations $\bar{\psi}_{a_i} \mathcal{L} \psi_{b_i}$, $i = 2, 3$. The ψ_{b_i}'s $i = 1, 2, 3$ are now operator quark wave functions of the quarks in the *final* bag **b** and contain quark annihilation operators of the *final* bag **b**. ψ_{a_i}'s are, as before, operator quark wave functions of the quarks in the *initial* bag **a** and contain annihilation operators and antiquark creation operators of the *initial* quark **a**;

$$\psi^\alpha_{a_1} = \sum_{nm} N(\omega_n) [b^{\alpha a_i}_{nm} S(\vec{P}_{al}) \eta^{a_i}_{nm}(\vec{r}_i) \exp(-i\, \varepsilon_{a_i} z^{||}_{ai}) + \\ + d^{\dagger \alpha a_1}_{nm} S(\vec{P}_{a_i}) \tilde{\eta}_{nm}(\vec{r}_i) \exp(i\, \varepsilon_{a_i} z^{||}_{ai})]. \tag{29}$$

Analogous formula can be written for ψ_{b_l}. The indices a_l and b_l now denote flavour of quark and also information to which hyperon the quark belongs, i. e. information on hyperon momenta. The states $|B_a\rangle$ and $|B_b\rangle$ are built of the operators $b_{nm}^{\dagger\alpha a_l}$ and $b_{nm}^{\dagger\alpha b_l}$, respectively. By action of the $|B_a\rangle$'s and $|B_b\rangle$'s operators on ψ_a and ψ_b, respectively the expressions in configuration space (25a) are obtained, eventually multiplied by simple numerical factors. Here ψ's are hyperon operator wave functions having the form (3) but built of operator wave functions (29) instead of configuration quark wave functions.

3. Formfactors in the bola MIT bag model

To show explicitely that the matrix elements of hadronic currents in the general formalism (2) and in the MIT bag model formalism (24a) have the same Lorentz transformation properties one has to calculate the formfactors comparing expressions (2) and (25a) in several reference frames including the most general one. The derived formfactors have to be the same in every reference frame. It is usefull to express formulae (2) and (25a) in such a form that the formfactors can be easily recognized. We will parametrize them using three boost parameters and express them in terms of Pauli spinors and matrices. First of the parameters, ω_{01}, connects the rest frames of a and b hyperons (S_a and S_b, respectively) with the Breit's frame (here called ①), the second, ω_{12}, boosts frame ① to the frame ② which moves parallely to $\hat{u}_1$, the direction of the relative velocity of a and b hyperons, and third ω_{23}, which connects frames ② and ③, ③ moving, relatively to ②, with velocity perpendicular to the $\hat{u}_1$ direction. The magnitudes of the relative velocities of S_a and ①, ① and S_b, ① and ②, and ② and ③ are tanh ω_{01}, tanh ω_{01}, tanh ω_{12}, and

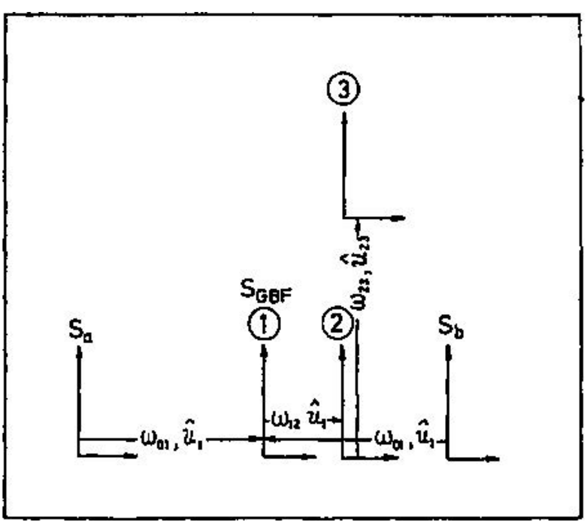

Fig. 4. Parametrization of the general reference frame ③ using three boost parameters ω_{01}, ω_{12} and ω_{23} in directions $\hat{u}_1$, $\hat{u}_1$ and $\hat{u}_{23}$, respectively; $\hat{u}_{23}\,\hat{u}_1 = 0$.

$\tanh \omega_{23}$, respectively (see Fig. 4). Using that parametrization one gets wave functions momenta and wave functions (4) in the general frame

$$\psi_{a_i}^{③} = S(\vec{\omega}_{23})\, S(\vec{\omega}_{12})\, S(\vec{\omega}_{01})\, \psi_{a_i}^{S_a},$$

$$\psi_{b_i}^{③} = S(\vec{\omega}_{23})\, S(\vec{\omega}_{12})\, S(-\vec{\omega}_{01})\, \psi_{b_i}^{S_b}, \tag{30a}$$

$$P_a^{③\mu} = \Lambda_\nu^\mu(\vec{\omega}_{23})\, \Lambda_\varrho^\nu(\vec{\omega}_{12})\, \Lambda_\sigma^\varrho(\vec{\omega}_{12})\, P_a^{S_a\sigma},$$

$$P_b^{③\mu} = \Lambda_\nu^\mu(\vec{\omega}_{23})\, \Lambda_\varrho^\nu(\vec{\omega}_{12})\, \Lambda_\sigma^\varrho(-\vec{\omega}_{12})\, P_b^{S_b\sigma}, \tag{30b}$$

$$z_{a_i}^{S_a\mu} = \Lambda_\nu^\mu(-\vec{\omega}_{01})\, \Lambda_\varrho^\nu(-\vec{\omega}_{12})\, \Lambda_\sigma^\varrho(-\vec{\omega}_{23})\, z^{③\sigma},$$

$$z_{b_i}^{S_b\mu} = \Lambda_\nu^\mu(-\vec{\omega}_{01})\, \Lambda_\varrho^\nu(-\vec{\omega}_{12})\, \Lambda_\sigma^\varrho(\vec{\omega}_{23})\, z^{③\sigma}. \tag{30c}$$

A boost operator $S(\vec{\omega})$ and Lorentz transformation $\Lambda_\nu^\mu(\vec{\omega})$ are given by

$$S(\vec{\omega}) = \begin{pmatrix} \cosh(\omega/2) & -\vec{\sigma}\hat{u}\sinh(\omega/2) \\ \vec{\sigma}\hat{u}\sinh(\omega/2) & \cosh(\omega/2) \end{pmatrix}, \tag{31a}$$

$$\Lambda_\nu^\mu(\vec{\omega})\, p^\nu = \begin{pmatrix} p^0\cosh\omega & -\hat{u}\vec{p}\sinh\omega \\ \hat{u}p^0\sinh\omega & \vec{p} + \hat{u}(\hat{u}\vec{p})(\cosh\omega - 1) \end{pmatrix}. \tag{31b}$$

Here $\hat{u}$ is a boost direction and p_μ is arbitrary 4-vector. Notice that space parts of $z_a^{S_a}$ and $z_b^{S_b}$ 4-vectors are equal, what is a consequence of using the Breit's hypersurface as an interaction hypersurface. Using formulae (30) one gets expressions for i_0's, Arg [I], Arg [Z], $(M/E_{a,b})$ and Lorentz invariant measure $d^4z\, \delta(Lz)$ appearing in Eq. (26)

$$i_O^{③} = \Lambda_\nu^\mu(\vec{\omega}_{23})\, \Lambda_\varrho^\nu(\vec{\omega}_{12})\, i_O^{①\varrho}, \qquad O = \gamma^\mu, \gamma^\mu\gamma_5, \tag{32a}$$

$$\mathrm{Arg}\,[\mathrm{I}] = (1/u_{12}^0)\,(\hat{u}_1\, \hat{z}^{③})\,(M_a + M_b - \varepsilon_a - \varepsilon_b)\, u_1\, z^{③}, \tag{32b}$$

$$\mathrm{Arg}\,[Z] = (1/u_{12}^0)\,(\hat{u}_1\, \hat{z}^{③})\,(-\varepsilon_a - \varepsilon_b)\, u_1\, z^{③}, \tag{32c}$$

$$(M/E_\alpha^{③}) = (1/u_\alpha^{③}) \qquad \alpha = a, b: \tag{32d}$$

$$\int d^4z_i\, \delta(\hat{L}z_i) \rightarrow$$

$$\rightarrow \int_{\mathrm{BAG}} d^3z_i \frac{\sqrt{L^2}}{L^0} = \int_0^R dr_i\, r_i^2\, 2\pi \int_{-1}^{1} d\cos\Theta_i^S \frac{1}{f^S(\Theta_i^S)} \frac{\sqrt{L^2}}{L^{0S}}. \tag{32e}$$

Here u_1, u_1^0 and $z^{③}$ are $\cosh \omega_{01}$, $\sinh \omega_{01}$ and magnitude of $\vec{z}^{③}$, respectively: $\hat{u}_1$ and $z^{③}$ are $\hat{\omega}_{01}$ and direction of $\vec{z}^{③}$, respectively. Quantities (32b, c, e) are Lorentz invariant. Transformation of i_0's is a consequence of the Lorentz transformation of the γ_μ matrices (see Ref. 4). In relation (32e) Lorentz invariant measure is expressed in terms of Lorentz invariant »radial« coordinates $r_l = (-z_{a_l\perp}^2)^{1/2} = (-z_{b_l\perp})^{1/2}$ and angles in the corresponding frame. Relations (32) for ②, ①, S_a and S_b frames are obtained putting $\omega_{23} = 0$, $\omega_{23} = \omega_{12} = 0$; $\omega_{23} = 0$, $\omega_{12} = -\omega_{01}$ and $\omega_{23} = 0$, $\omega_{12} = \omega_{01}$, respectively. From relations (32, 25a and 24a) one obtains

$$M_\mu^{\mathrm{BAG}} = 2\pi\, \delta^4 (P_b - P_a - q)\, (u_b^0\, u_a^0)^{1/2}\, \vec{\Lambda}_\nu^\mu (\omega_{23})\, \vec{\Lambda}_\varrho^\nu (\omega_{12}) \cdot$$

$$\cdot\, I_{Os_1s_1}^{b_1a_1①}\, z^{a_2①}\, z^{a_3①}, \tag{33a}$$

$$O = \gamma^\varrho,\ \gamma^\varrho \gamma_5. \tag{33b}$$

Here $I_{Os_1s_1}^{b_1a_1①}$ are expressions (26) in the frame ①. They are given by

$$I_{\gamma^0}^{b_1a_1①} = \chi^\dagger\, \mathbf{1}\, I_{\gamma^0}^{b_1a_1①}\, \chi, \tag{34a}$$

$$I_{\vec{\gamma}}^{b_1a_1①} = \chi^\dagger\, [\hat{u}_1\, I_{\vec{\gamma}}^{b_1a_1①} (\hat{u}_1) + \mathrm{i}\vec{\sigma} \times \hat{u}_1\, I_{\vec{\gamma}}^{b_1a_1①} (\mathrm{i}\vec{\sigma} \times \hat{u}_1)]\, \chi, \tag{34b}$$

$$I_{\gamma^0\gamma_5}^{b_1a_1①} = \chi^\dagger\, \vec{\sigma}\, \hat{u}_1\, I_{\gamma^0\gamma_5}^{b_1a_1①}\, \chi, \tag{34c}$$

$$I_{\vec{\gamma}\gamma_5}^{b_1a_1①} = \chi^\dagger\, [\vec{\sigma} \cdot I_{\vec{\gamma}\gamma_5}^{b_1a_1①} (\vec{\sigma}) + \hat{u}_1\, (\hat{u}_1\, \vec{\sigma})\, I_{\vec{\gamma}\gamma_5}^{b_1a_1①} (\hat{u}_1\, (\hat{u}_1\, \vec{\sigma}))]\, \chi, \tag{34d}$$

Here

$$I_{\gamma^0}^{b_1a_1①} = \int \mathrm{d}l^{①} \cos (\mathrm{Arg}\, [\mathrm{I}]\, (U_{b_1} (r)\, U_{a_1} (r) + V_{b_2} (r)\, V_{a_1} (r)), \tag{35a}$$

$$I_{\gamma_0\gamma_5}^{b_1a_1①} = \int \mathrm{d}l^{①} \sin (\mathrm{Arg}\, [\mathrm{I}])\, (U_{b_1} (r)\, V_{a_1} (r) - V_{b_1} (r)\, U_{a_1} (r)), \tag{35b}$$

$$I_{\vec{\gamma}}^{b_1a_1①} (\hat{u}_1) = \int \mathrm{d}l^{①} \sin (\mathrm{Arg}\, [\mathrm{I}])\, (U_{b_1} (r)\, V_{a_1} (r) - V_{b_1} (r)\, U_{a_1} (r)) \cos \Theta, \tag{35c}$$

$$I_{\vec{\gamma}}^{b_1a_1①} (\mathrm{i}\vec{\sigma} \times \hat{u}_1) = \int \mathrm{d}l^{①}\, [\cos (\mathrm{Arg}\, [\mathrm{I}])\, (U_{b_1} (r)\, U_{a_1} (r) -$$

$$- \cos^2 \Theta\, V_{b_1} (r)\, V_{a_1} (r))\, u_1 - \sin (\mathrm{Arg}\, [\mathrm{I}])\, (U_{b_1} (r)\, V_{a_1} (r) +$$

$$+ V_{b_1} (r)\, U_{a_1} (r))\, u_1^0 \cos \Theta], \tag{35d}$$

$$I^{b_1 a_1 ①}_{\vec{\gamma} \gamma_5} (\vec{\sigma}) = \int dl^{①} [\cos (\mathrm{Arg}\, [I]) (U_{b_1} (r)\, U_{a_1} (r) -$$

$$- \cos^2 \Theta\, V_{b_1} (r)\, V_{a_1} (r))\, u_1^0 - \sin (\mathrm{Arg}\, [I]) (U_{b_1} (r)\, V_{a_1} (r) +$$

$$+ V_{b_1} (r)\, U_{a_1} (r)) \cos \Theta\, u_1], \tag{35e}$$

$$I^{b_1 a_1 ①}_{\vec{\gamma} \gamma_5} (\hat{u}_1 (\hat{u}_1 \sigma)) = \int dl^{①} [\cos (\mathrm{Arg}\, [I]) (U_{b_1} (r)\, U_{a_1} (r) (1 - u_1^0) +$$

$$+ V_{b_1} (r)\, V_{a_1} (r) (2 \cos^2 \Theta - 1) + u_1^0 \cos^2 \Theta) +$$

$$+ \sin (\mathrm{Arg}\, [I]) (U_{b_1} (r)\, V_{a_1} (r) + V_{b_1} (r)\, U_{a_1} (r))\, u_1 \cos \Theta]. \tag{35f}$$

In the expressions (32) Θ is the angle in one of the rest frames e. g. S_a. In the following we will use

$$J^{b_1 a_1 ① a_2 a_3}_{O s_1 s_1} = Z^{a_2}\, Z^{a_3}\, I^{a_1 b_1 ①}_{O s_1 s_1}. \tag{36}$$

Using the $\omega_{01} - \omega_{12} - \omega_{23}$ parametrization of the matrix elements (2) one obtains relations of general matrix elements (2) in reference frames ③ and ①

$$\langle B_b |\, J^{\mu} (0)\, | B_a \rangle^{③} = (2\pi)^{-3}\, u_1^0 (u_b^{0③}\, u_a^{0③})^{-1/2} \cdot$$

$$\cdot\, \Lambda^{\mu}_{\nu} (\vec{\omega}_{23})\, \Lambda^{\nu}_{\varrho} (\vec{\omega}_{12}) \rangle B_b |\, J^{\varrho} (0)\, | B_a \rangle^{①}. \tag{37}$$

The matrix elements $\langle B_b |\, J_{\mu} (0)\, | B_a \rangle$ (Eq. (36)) written in terms of Pauli matrices and spinors are

$$\langle B_b |\, V^0 (0)\, | B_a \rangle^{①} = \chi^{\dagger} [f_2 (-M_b - M_a)\, u_1^0 + f_3 (M_b - M_a)\, u_1^0 +$$

$$+ (f_1 + (M_b + M_a) f_2)/u_1^0]\, \chi \tag{38a}$$

$$\langle B_b |\, \vec{V} (0)\, | B_a \rangle^{①} = \chi^{\dagger} [f_2 (-M_b + M_a)\, \vec{u}_1 + f_3 (M_b + M_a)\, \vec{u}_1 +$$

$$+ ((i\vec{\sigma} \times \vec{u}_1)/u_1^0) (f_1 + (M_b + M_a) f_2)]\, \chi, \tag{38b}$$

$$\langle B_b |\, A^0 (0)\, | B_a \rangle^{①} = \chi^{\dagger} [(-u_1/u_1^0) ((-M_b - M_a)\, u_1^0 g_2 +$$

$$+ (M_b - M_a)\, u_1^0 g_3)\, \vec{\sigma}\, \hat{u}_1)]\, \chi, \tag{38c}$$

$$\langle B_b |\, \vec{A} (0)\, | B_a \rangle^{①} = \chi^{\dagger} (\vec{\sigma}\, \hat{u}_1)\, \hat{u}_1\, \chi\, [(-u_1^2/u_1^0) ((-M_b + M_a) g_2 +$$

$$+ (M_b + M_a) g_3) - ((u_1^0 - 1)/u_1^0) (M_b - M_a) g_2 + g_1)] +$$

$$+ \chi^{\dagger} \vec{\sigma}\, \chi\, [g_1 + (M_b - M_a) g_2]. \tag{38d}$$

Here $u_1 = \sinh \omega_{01}$, $u_1^0 = \cosh \omega_{01}$ and $\hat{u}_1 = \hat{\omega}_{01}$. For brevity q^2 dependence of the formfactors is omitted in formulae (37). It is obvious that they have the same $\vec{\sigma} - \hat{u}_1$ structure as the expressions (34). By comparison one finds the following expressions

$$f_1 = u_1^{-1} J_{\vec{\gamma}} (\mathrm{i}\vec{\sigma} \times \hat{u}_1) - (M_b + M_a) f_2, \tag{39a}$$

$$f_2 = -(4M_b M_a u_1^{02})^{-1} [(M_b + M_a) K - (M_b - M_a) u_1^0/u_1 J_{\vec{\gamma}} (\hat{u}_1)], \tag{39b}$$

$$f_3 = -(4M_b M_a u_1^{02})^{-1} [(M_b - M_a) K - (M_b + M_a) u_1^0/u_1 J_{\vec{\gamma}} (\hat{u}_1)], \tag{39c}$$

$$g_1 = u_1^{0-1} J_{\vec{\gamma}\gamma_5} (\vec{\sigma}) + (M_a - M_b) g_2, \tag{39d}$$

$$g_2 = (4M_b M_a u_1 u_1^0)^{-1} [(M_b + M_a) J_{\gamma^0\gamma_5} + (M_a - M_b) N], \tag{39e}$$

$$g_3 = (4M_b M_a u_1 u_1^0)^{-1} [-(M_b - M_a) J_{\gamma^0\gamma_5} - (M_a + M_b) N], \tag{39f}$$

$$K = J_{\gamma 0} - u_1^{-1} J_{\vec{\gamma}} (\mathrm{i}\vec{\sigma} \times \hat{u}_1), \tag{39g}$$

$$N = u_1^0/u_1 [J_{\vec{\gamma}\gamma_5} (\hat{u}_1 (\hat{u}_1 \vec{\sigma})) + u_1^{0-1} (u_1^0 - 1) J_{\vec{\gamma}\gamma_5} (\vec{\sigma})]. \tag{39h}$$

The J indices a_1, b_1, a_2, a_3 and ① are omitted to make the expressions more compact. When considering EMFs i. e. when the initial and final hyperon masses are equal and the initial and final quarks are the same, from Eqs. (39c) and (35c) one obtains directly $f_3 = 0$. In the case of neutron beta decay if all relevant masses are taken to be equal ($M_p = M_n$, $m_u = m_d$) one finds $f_3^\beta = 0$, and also

$$g_2^\beta = 0 \tag{40}$$

(see Eqs. (39e) and (35b)).

Relation $g_2^\beta = 0$ (and also $f_\beta^3 = 0$) is valid if the vector and the axial vector current are the first class currents. This assumption is reflected in the selection of the vertex operator (10). If there are second class currents, the operator O from (10) would obtain some additional terms.

4. *Numerical results*

We used the bola MIT bag model to calculate EMFs for proton, formfactors for $n \to p$ decay and FSDs for $\Lambda \to p$ decay.

In the calculation of proton EMFs we assumed that the energies of quarks, appearing in the arguments of the exponential functions Arg [I] and Arg [Z], are equal to one third of the proton mass. For the arguments of the U and V functions we put $p_i r$ where $0 < r < R$, $p_i = \omega/R$, $\omega = 2.045$ and $R = 5\ \mathrm{GeV}^{-1}$ (e. g. $U(r) = j(p_i r)$). A possible difference between p_i and ε_i might be caused by surface, gluon and other contributions to the ε_i energies. For mass M_a proton mass $M_p = 0.938$ GeV was used. It should be stressed that the momentum transfer q^2 has to be smaller than zero because M_a is equal to M_b. The EMFs of the proton are given in Table 1. Formfactors for $q^2 = 0$ agree with the values obtained in the static MIT bag model: Sach's combinations of the f_1 and f_2 formfactors*

$$G_E = f_1 + (q^2/2M) f_2, \tag{41a}$$

$$G_M = f_1 + 2M f_2, \tag{41b}$$

TABLE 1.

$-q^2$	f_1	f_2	f_3	G_E	G_M	Z
0.000	1.0000	0.4894	0.0000	1.0000	1.918	1.0000
0.035	0.9443	0.4622	0.0000	0.9356	1.811	0.9865
0.141	0.7995	0.3910	0.0000	0.7702	1.533	0.9483
0.317	0.6160	0.2999	0.0000	0.5653	1.179	0.8912
0.563	0.4408	0.2121	0.0000	0.3772	0.8388	0.8225
0.880	0.2997	0.1411	0.0000	0.2335	0.5645	0.7493
1.267	0.1976	0.0901	0.0000	0.1368	0.3666	0.6772
1.724	0.1285	0.0561	0.0000	0.0769	0.2337	0.6096
2.252	0.0834	0.0346	0.0000	0.0419	0.1483	0.5484
3.519	0.0362	0.0133	0.0000	0.0112	0.0611	0.4468
5.067	0.0167	0.0054	0.0000	0.0021	0.0269	0.3700
6.897	0.0083	0.0024	0.0000	−0.0004	0.0128	0.3123

f_1, f_2 and f_3 are proton EMFs, G_E and G_M are Sach's combinations of the f_1 and f_2 formfactors. Z is the overlap for u and d quarks. (q^2 in units GeV)^2.

have values $G_E = 1$ and $G_M = 1.918$ for $q^2 = 0$ (see Table 1). The formfactor f_3 is equal to zero for every q^2 value as expected (see Eq. (19)). The q^2 dependence of Sach's formfactors G_E and G_M is not in good agreement with the dipole fromula

$$D(q^2) = (1 + q^2/0.71\ \mathrm{GeV}^2) \tag{42}$$

which is in very good agreement with experimental results for $G_E(q^2)$ and $G_M(q^2)/G_M(0)$[10]. That is not surprising as the bola model is essentially a low energy potential model. The disagreement is shown in Table 2 and Fig. 5. From Table 2 one can see that G_E is bigger than D in the region $-q^2 < 1.724\ \mathrm{GeV}^2$. The largest relative $G_E - D$ disagreement in that region is 21%, for $-q^2 = 0.5630\ \mathrm{GeV}^2$.

* As seen from formula (3), f_2 used here has to be multiplied with $(2M)^{-1}$ to obtain f_2 that is usually used in literature[1,5,8,9,10].

TABLE 2.

$-q^2$	$D(q^2)$	$G_E(q^2)$	$G_M(q^2)$
0.000	1.0000	1.0000	1.0000
0.035	0.9078	0.9356	0.9444
0.141	0.6965	0.7702	0.7994
0.317	0.4782	0.5654	0.6146
0.563	0.3111	0.3773	0.4375
0.880	0.1995	0.2336	0.2945
1.267	0.1290	0.1368	0.1912
1.724	0.0850	0.0769	0.1220
2.252	0.0575	0.0419	0.0774
3.519	0.0282	0.0112	0.0319
5.067	0.0151	0.0021	0.0140
6.897	0.0081	−0.0004	0.0067

The comparison of the dipole formula $D(q^2) = (1 + q^2/0.71\ \text{GeV}^2)$ with G_E and G_M normalized to one at $q^2 = 0\ \text{GeV}^2$. (q^2 in units GeV^2).

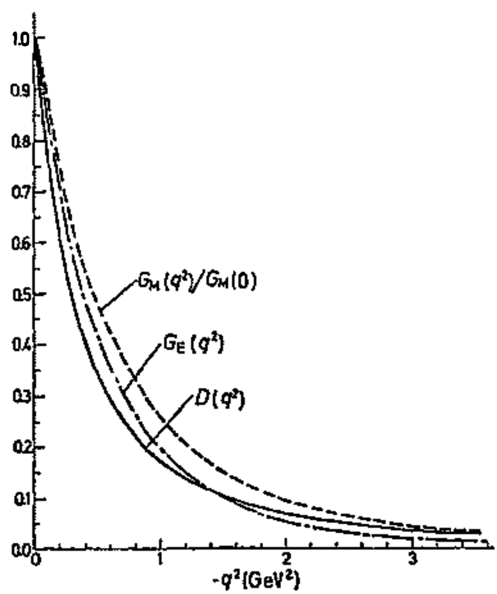

Fig. 5. Comparison of the dipole formula with the Sach's form| factors G_E and G_M. G_M is normalized to one at $q^2 = 0$.

In the region $q^2 > 1.724\ \text{GeV}^2$ G_E is smaller than D, and even becomes negative. G_M is bigger than D in the region $-q^2 < 5.067\ \text{GeV}^2$. The largest relative disagreement between G_M and D (48%) is found for $-q^2 = 1.267\ \text{GeV}^2$. For $-q^2 >$ $> 1.267\ \text{GeV}^2$ G_M is smaller than D.

In the calculation of nuclear β-decay formfactors we used the same values for ε_i, the same arguments $p_i R$ of U and V functions as in EMFs of proton and for masses of proton and neutron we used the same value: $M_p = M_n = 0.938$ GeV. The f_1, f_2 and f_3 formfactors are found to be the same to the corresponding EMFs. For $q^2 = 0$ g_2 is found to be equal 3/5 g_A^{MIT}, where $g_A^{MIT} = 1.095$ is the value of the axial vector coupling constant found in the static MIT bag model. Factor 5/3 appearing in the g_A^{MIT} comes from the spin flavour structure (in the N representation) of the wave functions of the proton and neutron. Formfactor g_2 is zero for every $-q^2$ value (see Table 3). Formfactors for nuclear β-decay are given in Table 3.

TABLE 3.

q^2	f_1	f_2	f_3	g_1	g_2	g_3	Z
0.000	1.0000	0.4893	0.0000	0.6530	0.0000	1.998	1.0000
0.035	0.9443	0.4622	0.0000	0.6286	0.0000	1.086	0.9865
0.141	0.7995	0.3910	0.0000	0.5611	0.0000	0.8974	0.9483
0.317	0.6159	0.2999	0.0000	0.4659	0.0000	0.6641	0.8912
0.563	0.4408	0.2121	0.0000	0.3624	0.0000	0.4494	0.8225
0.880	0.2997	0.1411	0.0000	0.2672	0.0000	0.2848	0.7493
1.267	0.1976	0.0901	0.0000	0.1892	0.0000	0.1729	0.6772
1.724	0.1285	0.0561	0.0000	0.1306	0.0000	0.1026	0.6096
2.252	0.0834	0.0346	0.0000	0.0889	0.0000	0.0604	0.5484
3.519	0.0362	0.0133	0.0000	0.0411	0.0000	0.0214	0.4468
5.067	0.0167	0.0054	0.0000	0.0197	0.0000	0.0081	0.3700
6.897	0.0083	0.0024	0.0000	0.0100	0.0000	0.0033	0.3123

Formfactor for nuclear β-decay. For masses we put $M_p = M_n = 0.938$ GeV and $m_u = m_d = 0$. (q^2 in units GeV^2).

TABLE 4.

q^2	f_1	f_2	$10 f_3$	g_1	$10 g_2$	g_3	Z
+0.317	0.9875	0.4055	0.1396	0.7044	−0.2788	0.8884	1.0000
+0.294	0.9846	0.4043	0.1391	0.7029	−0.2766	0.8839	0.9993
+0.227	0.9757	0.4005	0.1374	0.6983	−0.2744	0.8757	0.9971
+0.114	0.9613	0.3944	0.1347	0.6907	−0.2695	0.8607	0.9934
+0.000	0.9469	0.3882	0.1320	0.6831	−0.2645	0.8457	0.9898
−0.000	0.9469	0.3882	0.1320	0.6831	−0.2645	0.8457	0.9898
−0.035	0.9044	0.3701	0.1241	0.6602	−0.2496	0.8014	0.9787
−0.141	0.7906	0.3216	0.1036	0.5969	−0.2106	0.6842	0.9469
−0.317	0.6391	0.2569	0.0777	0.5067	−0.1606	0.5318	0.8985
−0.563	0.4847	0.1910	0.0533	0.4064	−0.1123	0.3822	0.8390
−0.880	0.3505	0.1343	0.0342	0.3114	−0.0734	0.2585	0.7739
−1.267	0.2456	0.0906	0.0209	0.2300	−0.0457	0.1674	0.7079
−1.724	0.1690	0.0595	0.0124	0.1658	−0.0275	0.1056	0.6443
−2.252	0.1155	0.0386	0.0073	0.1177	−0.0162	0.0657	0.5852
−3.519	0.0546	0.0161	0.0026	0.0587	−0.0055	0.0255	0.4838
−5.067	0.0269	0.0069	0.0010	0.0299	−0.0019	0.0103	0.4043
−6.897	0.0141	0.00316	0.0004	0.0159	−0.0007	0.0045	0.3430

Formafactors in $\Lambda \to p$ decay exist for every $q^2 < (M_\Lambda - M_p)^2$. In the bola MIT model formfactors are continuous when passing from the $q^2 < 0$ region to the $q^2 > 0$ region. (q^2 in units GeV^2).

In the calculation of FSDs for $\Lambda \to p$ decay we put $m_u = m_d = 0$ GeV and $m_s = 0.279$ GeV[11]. Arguments of the wave functions U and V are $p_u r$ and $p_s r$ where $p_u = \omega_u/R$, $p_s = \omega_s/R$ and ω_u and ω_s are solutions of the transcendental MIT bag model functions for the masses m_u and m_s. Because now $M_a \neq M_b$, the momentum transfer can have values both bigger $((M_\Lambda - M_p) < q^2 < 0)$, and smaller than zero. The bola MIT bag model can be applied in both q^2 regions. The formfactors are continuous when passing from the timelike to the spacelike region. The formfactors f_3 and g_2 do not vanish because expression (19) is not equal to zero, as flavours of the initial and final interacting quark are not the same. Formfactors for $\Lambda \to p$ decay are given in Table 4. The g_1 $(q^2 = 0)$ value with agrees experimentally determined value for $(2/3)^{1/2}\, g_A (\Lambda \to p) = 0.73$, where $g_A (\Lambda \to p)$ is the axial vector coupling constant for $\Lambda \to p$ semileptonic transition and $(3/2)^1/^2$ is a factor coming from N representation structure of the Λ and p wave functions.

5. *Conclusion*

This work shows that the Lorentz invariant formulation of the MIT bag model can be obtained. The results for the proton EMFs obtained here are in much better agreement with experimental data (i. e. dipole formula) than the result obtained in MIT models known in the literature[3,4,12]. Those models also do not give Lorentz invariant formfactors. Calculated formfactors show some theoretically expected properties: second class EMFs are equal to zero, second class FSDs are much smaller than first class FSDs and FSDs are continuous in the whole q^2 region. It is expected that the boosting procedure used here can be extended to all potential models, two phase bag models and soliton models of hadrons.

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ELEKTROMAGNETSKI I SEMILEPTONSKI FORMFAKTORI HIPERONA U MODELU POTISNUTE VREĆE

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Prikazana je Lorentz invarijantna formulacija MIT vreća modela. Elektromagnetski formfaktori (EMFi) i formfaktori u semileptonskim raspadima (FSDi) izračunati u tom formalizmu neovisni su o referentnom sustavu. Nađeno je da su EMFi i formfaktori u β raspadu identički jednaki nuli. Model je primjenjiv za prijenose impulsa vremenske i prostorne vrste. FSDi su kontinuirani pri prijelazu iz jednog intervala u drugi.