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ANALYSIS OF NUCLEON FORM FACTOR DATA REVEALS THE $e^+e^- \to n\bar{n}$ CROSS SECTION TO BE REMARKABLY LARGER THAN THE $e^+e^- \to p\bar{p}$ ONE

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ABSTRACT

A modified six-resonance VMD model for a description of the nucleon electromagnetic structure is constructed. It possesses correct analytic properties and the asymptotic behaviour in accordance with a quark model prediction for baryons. Only parameters with clear physical meaning are contained in the model. They are evaluated numerically in a simultaneous fit of all existing data on electric and magnetic nucleon form factors. As a result, the behaviour in the time-like region of electric and magnetic neutron form factors, for which there are no data up to now, has been predicted. In comparison with the corresponding behaviour of proton form factors above the nucleon-antinucleon threshold one finds them to exceed by a factor of five. Consequently the cross section of $e^+e^- \to n\bar{n}$ is expected to be roughly twenty-five-times as large as the cross section of $e^+e^- \to p\bar{p}$.

PACS. 12.40 - Models of strong interactions
PACS. 12.40.V - Vector-meson dominance
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1. - Introduction.

Reactions $e^+e^- \to n\bar{n}$ and $e^+e^- \to p\bar{p}$ are t-channels of elastic electron scattering processes, $e^-n \to e^-n$ and $e^-p \to e^-p$ respectively, which historically have been the first source (1,2) of experimental information on the electromagnetic (elm.) structure of strongly interacting particles at all. Since the e^+e^- interaction is pointlike and predominantly electromagnetic, the amplitudes of these reactions are natural to be calculated in the one-photon approximation by using standard methods of quantum electrodynamics (QED). The difference between such results of theoretical calculations for corresponding cross sections and experimental observations is currently explained by a nonpointlike nature of the nucleons, which at present is believed to be generated by quark-gluon constituents. Phenomenologycally this so-called elm. structure of nucleons is taken into account by means of four scalar functions depending on the four-momentum transfer squared $t = -Q^2$, called Dirac $F_1^p(t)$, $F_1^n(t)$ and Pauli $F_2^p(t)$, $F_2^n(t)$ elm. form factors (ff's) , which appear in the most general decomposition (compatible with Lorentz invariance and charge conservation) of the proton and neutron elm. currents, respectively, into a maximal number of linearly independent covariants, constructed from momenta and spin parameters of nucleons. We note that the precise functional form of nucleon ff's is expected to be predicted by an accomplished dynamical theory of strong interactions.

Since the proton and neutron are components of ordinary matter, knowledge of their structure is permanently of basic general interest in high-energy physics, and has been focus of much work in both experiment and theory.

The systematic experimental study of elm. structure of nucleons in the space-like region ($t < 0$) by means of the electron-proton and electron-deuteron scattering was opened at the middle of fifties by Hofstadter experiments (2,3) in Stanford. The explanation of obtained results has been an exceptional problem in the theory of strong interactions, which has led to many new and fruitful ideas. We have in mind first of all postulation of the existence of isoscalar (4) and isovector (5) vector mesons (later confirmed experimentally) leading to the so-called vector-meson-dominance (VMD) model (6,7).

The time-like-region ($t > 0$) study of the nucleon elm. structure was initiated (8) and first practically realized (9) by Zichichi et. al., using the CERN antiproton beam and looking for the process $p\bar{p} \rightarrow e^+e^-$.

At present there are more than 400 experimental data points on nucleon elm. ff's in the space-like and time-like region. Nevertheless, there is no experimental information about the neutron elm. structure in the time-like region up to now.

Many papers have been devoted to the theoretical investigation of the nucleon elm. structure and have dealt with it from various points of view. An almost complete set of references up to 1975 can be found in the paper by Höhler (10). However, there is omitted the paper by Massam and Zichichi (11) with relevant results obtained in the description of the nucleon elm. structure by drawing attention to the knowledge of the unitary symmetry and its breaking which have allowed to reduce a number of free parameters of the model. Another is the paper by Wataghin (12) in which the author is for the first time trying to incorporate into the VMD model nonzero widths of vector meson resonances in accordance with correct analytic properties of nucleon ff's. Taking into account the fact that from the point of view of a global analysis of all nucleon ff's the VMD model is the most powerful one (11,13-15), the relevance of Wataghin results (12) even increases. Also an improvement of the latter approach was achieved recently (16). However, in neither of these papers the modification of the VMD model was attained in accordance with the quark model prediction for the asymptotic behaviour of nucleon ff's.

In this paper, the analysis of all existing experimental data on nucleon ff's by another modification of the VMD model (17) is carried out, where nonzero vector meson widths are incorporated into the VMD model compatibly with the two-cut analytic structure of ff's and, as a result, the asymptotic behaviour predicted by a quark model for nucleons is realized in a very natural way. Moreover, the normalization condition of the zero-width VMD model is conserved.

In section 2. we briefly summarize necessary formulae and definitions. Section 3. is devoted to the construction of the modified VMD model for the description of the elm. structure of nucleons. In section 4. we analyze the nucleon-ff's data and compare determined parameters with world averaged values. Conclusions and summary are given in section 5.

2. - Cross sections and form factors.

The one-photon approximation with the techniques of QED allows us to write $e^-N \rightarrow e^-N$ or $e^+e^- \rightarrow N\bar{N}$ cross sections in a very simple form.

Since the elm. structure of nucleons in the space-like region is investigated by scattering of electrons on nucleons at rest, the corresponding cross section is useful to write down in the laboratory system as follows

$$\frac{d\sigma^{lab}(e^-N \rightarrow e^-N)}{d\Omega} = \frac{\alpha^2}{4E^2}\,\frac{\cos^2\theta/2}{\sin^2\theta/2}\,\frac{1}{1+\frac{2E}{M}\sin^2\theta/2}\, \times$$

$$\times\left[F_1^2 - \frac{t}{4M^2}F_2^2 - 2\frac{t}{4M^2}(F_1+F_2)^2\, tg^2\theta/2\right] \tag{1}$$

where E is the incident electron energy, M the target nucleon mass, θ the scattering angle, and α the fine structure constant.

On the other hand, electron and positron (or proton and antiproton) beams are colliding at the center of mass system. Therefore the corresponding cross section takes the following form

$$\frac{d\sigma^{c.m.}(e^+e^- \rightarrow N\bar{N})}{d\Omega} = \frac{\alpha^2}{4t}\beta\left[\frac{4M^2}{t}\left|F_1 + \frac{t}{4M^2}F_2\right|^2\sin^2\theta + \left|F_1+F_2\right|^2(1+\cos^2\theta)\right] \tag{2}$$

where β and M are the velocity and mass of a produced nucleon (or antinucleon) respectively, and θ the angle of produced nucleon (or antinucleon) relative to the electron (or positron) beam.

The Dirac $F_1(t)$ and Pauli $F_2(t)$ ff's in (1) and (2) are real-valued functions in the space-like region ($t<0$), complex for $t>4m_\pi^2$ (m_π is a mass of the pion) and generally different for proton and neutron. They are normalized at $t = 0$ in the following way

$$F_1(0) = e \tag{3}$$

and

$$F_2(0) = \mu \tag{4}$$

where e and μ are the charge and anomalous magnetic moment of the nucleon, respectively.

The experimental data on $e^-N \to e^-N$ cross section are more easily analysed if use is made of the so-called Sachs ff's (18), defined through Dirac and Pauli ff's by means of the following expressions

$$G_E(t) = F_1(t) + \frac{t}{4M^2} F_2(t) \tag{5}$$

$$G_M(t) = F_1(t) + F_2(t). \tag{6}$$

There is a coordinate system, in which $G_E(t)$ and $G_M(t)$ describe the distribution of the charge and magnetic moment of the nucleon. Hence they are called the electric $G_E(t)$ and magnetic $G_M(t)$ ff's. Sachs ff's enter into expression (1) only quadratically, without any interference term. Really, taking into account (5) and (6), the cross sections (1) and (2) can be written as

$$\frac{d\sigma^{lab}(e^-N \to e^-N)}{d\Omega} = \frac{\alpha^2}{4E^2} \frac{\cos^2\vartheta/2}{\sin^2\vartheta/2} \frac{1}{1 + \frac{2E}{M}\sin^2\vartheta/2} \times$$

$$\times \left[\frac{G_E^2 - \frac{t}{4M^2} G_M^2}{1 - \frac{t}{4M^2}} - 2\frac{t}{4M^2} G_M^2 \, tg^2\vartheta/2 \right] \tag{7}$$

and

$$\frac{d\sigma^{c.m.}(e^+e^- \to N\bar{N})}{d\Omega} = \frac{\alpha^2}{4t}\beta \left[\frac{4M^2}{t} |G_E|^2 \sin^2\vartheta + |G_M|^2 (1 + \cos^2\vartheta) \right] \tag{8}$$

respectively. Then the experimental information on $G_E(t)$ and $G_M(t)$ in the space-like region ($t<0$), using data on $e^-N \to e^-N$ cross section, can be easily determined from the parameters of the straight line plot of

$$\frac{d\sigma^{lab}(e^-N\rightarrow e^-N)}{d\Omega}\Bigg/\left[\frac{\alpha^2\cos^2\vartheta/2}{4E^2\sin^2\vartheta/2\,(1+\frac{2E}{M}\sin^2\vartheta/2)}\right] \qquad (9)$$

versus $tg^2\vartheta/2$ at fixed t (Rosenbluth plot).

Generally, there is no similar procedure to extract $|G_E|$ and $|G_M|$ from data on $e^+e^-\rightarrow N\bar{N}$ or $N\bar{N}\rightarrow e^+e^-$ cross sections separatelly, and all present data on proton ff's in the time-like region ($t>0$) were obtained only under the assumption that $|G_E| = |G_M|$. The latter is not far from the truth in the vicinity of the nucleon-antinucleon threshold, where at present just the measurements on $e^+e^-\rightarrow p\bar{p}$ and $p\bar{p}\rightarrow e^+e^-$ cross sections were carried out, because at the threshold $t = 4M^2$ this equality must be fulfilled exactly, in order to eliminate kinematic poles of $F_1(t)$ and $F_2(t)$ generated by relations inverse to (5) and (6).

3. - Modified VMD model for the electromagnetic structure of nucleons.

In the previous section we have pointed out that by means of the elastic electron scattering on nucleons or electron-positron annihilation into a nucleon-antinucleon pair, practically, we measure proton and neutron electric and magnetic ff's. They are related to the Dirac and Pauli ff's, defined by the most general decomposition of the matrix element of the nucleon elm. current, through relations (5) and (6). However, as a consequence of particular transformation properties of the nucleon elm. current according to rotations in the isotopic spin space, there is a splitting of the matrix element of the proton elm. current $j^p_\nu(x)$ and the matrix element of neutron elm. current $j^n_\nu(x)$ into isoscalar and isovector parts as follows

$$j_\nu^p(x) = j_\nu^s(x) + j_\nu^v(x)$$
$$j_\nu^n(x) = j_\nu^s(x) - j_\nu^v(x) \qquad (10)$$

which results in a similar splitting of Dirac and Pauli ff´s. Thus we have the following decompositions of nucleon electric and magnetic ff´s into isoscalar and isovector parts of the Dirac and Pauli ff´s

$$G_E^p(t) = \left[F_1^s(t) + F_1^v(t)\right] + \frac{t}{4m_p^2}\left[F_2^s(t) + F_2^v(t)\right]$$

$$G_M^p(t) = \left[F_1^s(t) + F_1^v(t)\right] + \left[F_2^s(t) + F_2^v(t)\right]$$

$$G_E^n(t) = \left[F_1^s(t) - F_1^v(t)\right] + \frac{t}{4m_n^2}\left[F_2^s(t) - F_2^v(t)\right] \qquad (11)$$

$$G_M^n(t) = \left[F_1^s(t) - F_1^v(t)\right] + \left[F_2^s(t) - F_2^v(t)\right]$$

which are very suitable to be a starting point for the construction of the modified VMD model [17] for a description of the nucleon elm. structure.

From normalizations (3) and (4), particularly taken for the proton

$$F_1^p(0) = 1, \qquad F_2^p(0) = \mu_p \qquad (12)$$

and the neutron

$$F_1^n(0) = 0, \qquad F_2^n(0) = \mu_n \qquad (13)$$

one obtaines the normalization conditions for the isoscalar and isovector parts of the Dirac and Pauli nucleon ff´s

$$F_1^s(0) = 1/2, \qquad F_1^v(0) = 1/2$$
$$F_2^s(0) = 1/2\,[\mu_p + \mu_n], \qquad F_2^v(0) = 1/2\,[\mu_p - \mu_n] \tag{14}$$

and from here and (11) the normalization of electric and magnetic proton and neutron ff's as follows

$$G_E^p(0) = 1, \qquad G_E^n(0) = 0$$
$$G_M^p(0) = 1 + \mu_p, \qquad G_M^n(0) = \mu_n. \tag{15}$$

According to the idea of the zero width VMD model [19] each of $F_{1,2}^{s,v}$ in (11) is expressed in the form (the subindex zero in the ff's $F_{1,2}^{s,v}(t)_0$ means the zero width of considered vector meson resonances)

$$F_1^s(t)_0 = \sum_{s=\omega,\varphi,\varphi'} \frac{m_s^2\,(f_{sNN}^{(1)}/f_s)}{m_s^2 - t}$$
$$F_1^v(t)_0 = \sum_{v=\rho,\rho',\rho''} \frac{m_v^2\,(f_{vNN}^{(1)}/f_v)}{m_v^2 - t}$$
$$F_2^s(t)_0 = \sum_{s=\omega,\varphi,\varphi'} \frac{m_s^2\,(f_{sNN}^{(2)}/f_s)}{m_s^2 - t} \tag{16}$$
$$F_2^v(t)_0 = \sum_{v=\rho,\rho',\rho''} \frac{m_v^2\,(f_{vNN}^{(2)}/f_v)}{m_v^2 - t}$$

where the corresponding ratios of coupling constants are constrained by the equations

$$\sum_{s=\omega,\varphi,\varphi'} (f_{sNN}^{(1)}/f_s) = 1/2, \qquad \sum_{s=\omega,\varphi,\varphi'} (f_{sNN}^{(2)}/f_s) = 1/2\,[\mu_p + \mu_n]$$
$$\sum_{v=\rho,\rho',\rho''} (f_{vNN}^{(1)}/f_v) = 1/2, \qquad \sum_{v=\rho,\rho',\rho''} (f_{vNN}^{(2)}/f_v) = 1/2\,[\mu_p - \mu_n] \tag{17}$$

following from the normalization conditions (14). The summations in (16) and (17) are carried out in the isoscalar and isovector case through the well-established vector mesons $\omega(783)$, $\varphi(1020)$, $\varphi'(1680)$ and $\rho(770)$, $\rho'(1250)$, $\rho''(1600)$ respectively. The ψ -particles have not been included because they are too far away from the region where data exist. On the other hand, nevertheless, the obscure $\rho'(1250)$ resonance [20,21] is taken into account, for the existence of which there are serious indications [22-29] nowadays.

In what follows we incorporate into (16) the correct analytic properties of $F^{s,v}_{1,2}$ ff's with the aim of a more realistic description of all existing data on electric and magnetic nucleon ff's simultaneously. In fact they consist of an infinite sequence of branch points on the positive real axis of t-plane, the positions of which are determined by allowed intermediate states in the unitarity condition.

No one at all is able to realize such complicated analytic structure, consisting of an infinite number of cuts, practically. Therefore, further we restrict ourselves to the two-square-root branch-point approximation of analytic properties of $F^{s,v}_{1,2}$ ff's.

As is well-known, the lowest branch-point of isoscalar $F^s_1(t)$, $F^s_2(t)$ and isovector $F^v_1(t)$, $F^v_2(t)$ ff's are $t^s_o = 9m^2_\pi$ and $t^v_o = 4m^2_\pi$ respectively. They will be identified with the first fixed-square-root branch-point t_o of the general approach proposed in [17]. In the role of the second one will be taken t^s_{inl} and t^v_{inl}. Both of them are also of a square-root type and free in a position (they will be fixed in a fitting procedure of data) , in order to simulate contributions of other branch points of $F^{s,v}_{1,2}$ ff's effectively.

Though essentially different inelastic thresholds t^{s1}_{inl}, t^{s2}_{inl}

and t_{inl}^{v1}, t_{inl}^{v2} can exist for $F_1^s(t)$, $F_2^s(t)$ and $F_1^v(t)$, $F_2^v(t)$ respectively, owing to a reduction of the total number of free parameters of the constructed model, only one free threshold t_{inl}^s is taken for isoscalar ff's and the other t_{inl}^v for isovector ff's.

As a result of the two-square-root-cut structure every $F_{1,2}^{s,v}$ is defined on the four-sheeted Riemann surface in t-variable.

In order to get an explicit form of nucleon ff's with such analytic properties, we use transformations

$$r = \left[\frac{t - 9m_\pi^2}{9m_\pi^2}\right]^{1/2}, \qquad q = \left[\frac{t - 4m_\pi^2}{4m_\pi^2}\right]^{1/2} \tag{18}$$

which map four-sheeted Riemann surfaces of t-variable into two-sheeted Riemann r- and q-surfaces. The effective branch points t_{inl}^s and t_{inl}^v are then each transformed into two points

$$r_{inl} = \pm\left[\frac{t_{inl}^s - 9m_\pi^2}{9m_\pi^2}\right]^{1/2} \text{ and } q_{inl} = \pm\left[\frac{t_{inl}^v - 4m_\pi^2}{4m_\pi^2}\right]^{1/2} \tag{19}$$

respectively. Finally, by using the inverse Zhukovsky transformations

$$V = i\,\frac{[r_{inl} + r]^{1/2} - [r_{inl} - r]^{1/2}}{[r_{inl} + r]^{1/2} + [r_{inl} - r]^{1/2}} \tag{20a}$$

and

$$W = i\,\frac{[q_{inl} + q]^{1/2} - [q_{inl} - q]^{1/2}}{[q_{inl} + q]^{1/2} + [q_{inl} - q]^{1/2}} \tag{20b}$$

the two-sheeted Riemann r- and q-surfaces are transformed into V- and W-planes. The physical sheets of t-variable are then brought on the left-half of the unit disc with $t = \pm\infty$ transformed into $V = -1$ and $W = -1$. The second sheets are mapped on the right-half of the unit disc with $t = \pm\infty$ transformed into $V = +1$ and $W = +1$, and the third and fourth sheets on the left and right half-planes outside the unit disc respectively.

Now the relations (18) give (further for simplicity $m_\pi = 1$ is considered)

$$t = 9\,(r^2 + 1) \tag{21a}$$

$$t = 4\,(q^2 + 1) \tag{21b}$$

and if we denote the positions of zero-width VMD poles in the r- and q-planes by r_{so} and q_{vo}, respectively, one can write the following relations for the mass of isoscalar and isovector vector mesons in (16)

$$m_s^2 = 9\,(r_{so}^2 + 1) \tag{22a}$$

$$m_v^2 = 4\,(q_{vo}^2 + 1). \tag{22b}$$

Substituting (21a,b) and (22a,b) into relations (16) we obtain

$$\begin{aligned}
F_1^s(t)_o &= \sum_{s=\omega,\varphi,\varphi'} \frac{r_{so}^2 - r_N^2}{r_{so}^2 - r^2}\,(f^{(1)}_{sN\bar{N}}/f_s) \\
F_1^v(t)_o &= \sum_{v=\rho,\rho',\rho''} \frac{q_{vo}^2 - q_N^2}{q_{vo}^2 - q^2}\,(f^{(1)}_{vN\bar{N}}/f_v) \\
F_2^s(t)_o &= \sum_{s=\omega,\varphi,\varphi'} \frac{r_{so}^2 - r_N^2}{r_{so}^2 - r^2}\,(f^{(2)}_{sN\bar{N}}/f_s) \\
F_2^v(t)_o &= \sum_{v=\rho,\rho',\rho''} \frac{q_{vo}^2 - q_N^2}{q_{vo}^2 - q^2}\,(f^{(2)}_{vN\bar{N}}/f_v)
\end{aligned} \tag{23}$$

where the normalization points $t = 0$ in the r- and q-planes have been denoted by r_N and q_N respectively.

If we denote in addition to that the same normalization points in the V- and W-plane by

$$V_N = i\,\frac{[r_{inl}+r_N]^{1/2} - [r_{inl}-r_N]^{1/2}}{[r_{inl}+r_N]^{1/2} + [r_{inl}-r_N]^{1/2}} \tag{24a}$$

$$W_N = i\,\frac{[q_{inl}+q_N]^{1/2} - [q_{inl}-q_N]^{1/2}}{[q_{inl}+q_N]^{1/2} + [q_{inl}-q_N]^{1/2}} \tag{24b}$$

and the positions of zero-width VMD poles by

$$V_{so} = i\,\frac{[r_{inl}+r_{so}]^{1/2} - [r_{inl}-r_{so}]^{1/2}}{[r_{inl}+r_{so}]^{1/2} + [r_{inl}-r_{so}]^{1/2}} \tag{25a}$$

$$W_{vo} = i\,\frac{[q_{inl}+q_{vo}]^{1/2} - [q_{inl}-q_{vo}]^{1/2}}{[q_{inl}+q_{vo}]^{1/2} + [q_{inl}-q_{vo}]^{1/2}} \tag{25b}$$

we obtain for r^2, r_N^2, r_{so}^2 and q^2, q_N^2, q_{vo}^2

$$r^2 = r_{inl}^2\left[1-\left(\frac{1+V^2}{1-V^2}\right)\right]^2$$

$$r_N^2 = r_{inl}^2\left[1-\left(\frac{1+V_N^2}{1-V_N^2}\right)\right]^2 \tag{26a}$$

$$r_{so}^2 = r_{inl}^2\left[1-\left(\frac{1+V_{so}^2}{1-V_{so}^2}\right)\right]^2$$

and

$$q^2 = q_{inl}^2\left[1-\left(\frac{1+W^2}{1-W^2}\right)\right]^2$$

$$q_N^2 = q_{inl}^2\left[1-\left(\frac{1+W_N^2}{1-W_N^2}\right)\right]^2 \tag{26b}$$

$$q_{vo}^2 = q_{inl}^2\left[1-\left(\frac{1+W_{vo}^2}{1-W_{vo}^2}\right)\right]^2$$

which in combination with (23) give

$$F_1^s[V(t)]_o=\left(\frac{1-V^2}{1-V_N^2}\right)^2\sum_{s=\omega,\varphi,\varphi'}\frac{(V_N-V_{so})(V_N+V_{so})(V_N-1/V_{so})(V_N+1/V_{so})}{(V-V_{so})(V+V_{so})(V-1/V_{so})(V+1/V_{so})}(f^{(1)}_{sN\bar{N}}/f_s)$$

$$F_1^v[W(t)]_o=\left(\frac{1-W^2}{1-W_N^2}\right)^2\sum_{v=\rho,\rho',\rho''}\frac{(W_N-W_{vo})(W_N+W_{vo})(W_N-1/W_{vo})(W_N+1/W_{vo})}{(W-W_{vo})(W+W_{vo})(W-1/W_{vo})(W+1/W_{vo})}(f^{(1)}_{vN\bar{N}}/f_v)$$

$$F_2^s[V(t)]_o=\left(\frac{1-V^2}{1-V_N^2}\right)^2\sum_{s=\omega,\varphi,\varphi'}\frac{(V_N-V_{so})(V_N+V_{so})(V_N-1/V_{so})(V_N+1/V_{so})}{(V-V_{so})(V+V_{so})(V-1/V_{so})(V+1/V_{so})}(f^{(2)}_{sN\bar{N}}/f_s) \tag{27}$$

$$F_2^v[W(t)]_o=\left(\frac{1-W^2}{1-W_N^2}\right)^2\sum_{v=\rho,\rho',\rho''}\frac{(W_N-W_{vo})(W_N+W_{vo})(W_N-1/W_{vo})(W_N+1/W_{vo})}{(W-W_{vo})(W+W_{vo})(W-1/W_{vo})(W+1/W_{vo})}(f^{(2)}_{vN\bar{N}}/f_v)$$

A further arrangement of (27) depends on the relation of the corresponding vector meson mass values to t^s_{inl} and t^v_{inl}. By a successive experience in analysing nucleon ff data we knew that

$$m^2_\omega,\ m^2_\varphi < t^s_{inl},\qquad m^2_{\varphi'} \gtrsim t^s_{inl} \tag{28a}$$

and

$$m^2_\rho < t^v_{inl},\qquad m^2_{\rho'},\ m^2_{\rho''} > t^v_{inl}\ . \tag{28b}$$

Then

$$V_{\omega o} = -\bar{V}^*_{\omega o},\ V_{\varphi o} = -\bar{V}^*_{\varphi o},\ V_{\varphi' o} = 1/V^*_{\varphi' o} \tag{29a}$$

$$W_{\rho o} = -\bar{W}^*_{\rho o},\ W_{\rho' o} = 1/\bar{W}^*_{\rho' o},\ W_{\rho'' o} = 1/W^*_{\rho'' o} \tag{29b}$$

and the relations (27) can be rewritten as follows

$$F_1^s[V(t)]_o=\left(\frac{1-V^2}{1-V_N^2}\right)^2\left[\sum_{s=\omega,\varphi}\frac{(V_N-V_{so})(V_N-V^*_{so})(V_N-1/V_{so})(V_N-1/V^*_{so})}{(V-V_{so})(V-V^*_{so})(V-1/V_{so})(V-1/V^*_{so})}(f^{(1)}_{sN\bar{N}}/f_s)+\right.$$

$$\left.+\frac{(V_N-V_{\varphi' o})(V_N-V^*_{\varphi' o})(V_N+V_{\varphi' o})(V_N+V^*_{\varphi' o})}{(V-V_{\varphi' o})(V-V^*_{\varphi' o})(V+V_{\varphi' o})(V+V^*_{\varphi' o})}(f^{(1)}_{\varphi' N\bar{N}}/f_{\varphi'})\right] \tag{30a}$$

$$F_1^V[W(t)]_0=\left(\frac{1-W^2}{1-W_N^2}\right)^2\left[\frac{(W_N-W_{\rho o})(W_N-W^*_{\rho o})(W_N-1/W_{\rho o})(W_N-1/W^*_{\rho o})}{(W-W_{\rho o})(W-W^*_{\rho o})(W-1/W_{\rho o})(W-1/W^*_{\rho o})}\left(f^{(1)}_{\rho N\bar{N}}/f_\rho\right)+\right.$$

$$\left.+\sum_{v=\rho',\rho''}\frac{(W_N-W_{vo})(W_N-W^*_{vo})(W_N+W_{vo})(W_N+W^*_{vo})}{(W-W_{vo})(W-W^*_{vo})(W+W_{vo})(W+W^*_{vo})}\left(f^{(1)}_{vN\bar{N}}/f_v\right)\right] \tag{30b}$$

$$F_2^S[V(t)]_0=\left(\frac{1-V^2}{1-V_N^2}\right)^2\left[\sum_{s=\omega,\varphi}\frac{(V_N-V_{so})(V_N-V^*_{so})(V_N-1/V_{so})(V_N-1/V^*_{so})}{(V-V_{so})(V-V^*_{so})(V-1/V_{so})(V-1/V^*_{so})}\left(f^{(2)}_{sN\bar{N}}/f_s\right)+\right.$$

$$\left.+\frac{(V_N-V_{\varphi'o})(V_N-V^*_{\varphi'o})(V_N+V_{\varphi'o})(V_N+V^*_{\varphi'o})}{(V-V_{\varphi'o})(V-V^*_{\varphi'o})(V+V_{\varphi'o})(V+V^*_{\varphi'o})}\left(f^{(2)}_{\varphi' NN}/f_{\varphi'}\right)\right] \tag{30c}$$

$$F_2^V[W(t)]_0=\left(\frac{1-W^2}{1-W_N^2}\right)^2\left[\frac{(W_N-W_{\rho o})(W_N-W^*_{\rho o})(W_N-1/W_{\rho o})(W_N-1/W^*_{\rho o})}{(W-W_{\rho o})(W-W^*_{\rho o})(W-1/W_{\rho o})(W-1/W^*_{\rho o})}\left(f^{(2)}_{\rho N\bar{N}}/f_\rho\right)+\right.$$

$$\left.+\sum_{v=\rho',\rho''}\frac{(W_N-W_{vo})(W_N-W^*_{vo})(W_N+W_{vo})(W_N+W^*_{vo})}{(W-W_{vo})(W-W^*_{vo})(W+W_{vo})(W+W^*_{vo})}\left(f^{(2)}_{vN\bar{N}}/f_v\right)\right] \tag{30d}$$

From here one can immediately see that the asymptotic behaviour of the initial zero-width VMD model (16) is hidden only in the normalized factors $[(1-V^2)/(1-V_N^2)]^2$ and $[(1-W^2)/(1-W_N^2)]^2$, because if $t\to\pm\infty$, then $V\to -1$, $W\to -1$ and all terms in the square brackets turn out to be constants. Its particular form $\sim t^{-1}|_{t\to\pm\infty}$ is specified by the power "2". The change of this power to an arbitrary positive even number leads to a natural generalization of the power asymptotic behaviour of isoscalar and isovector Dirac and Pauli ff's, which, however, was possible to realize only due to the proposed method of incorporation of correct analytic properties by means of the transformations (18) and (20a,b).

In conformity with the quark model predictions for nucleons (30,31) the power "2" in (30a,b) will be changed to the power

"4" and in (30c,d) to the power "6".

Taking into account these changes of the power in (30a)-(30d) and introducing nonzero vector meson widths Γ_s, $\Gamma_v \neq 0$ by means of the following replacements

$$r_{so} \longrightarrow r_s = \left[\frac{(m_s - i\Gamma_s/2)^2 - 9}{9}\right]^{1/2} \quad \text{for} \quad s=\omega, \varphi, \varphi' \qquad (31a)$$

and

$$q_{vo} \longrightarrow q_v = \left[\frac{(m_v - i\Gamma_v/2)^2 - 4}{4}\right]^{1/2} \quad \text{for} \quad v=\rho, \rho', \rho'' \qquad (31b)$$

one obtaines finally

$$F_1^s[V(t)] = \left(\frac{1-V^2}{1-V_N^2}\right)^4 \left[\sum_{s=\omega,\varphi} \frac{(V_N-V_s)(V_N-V_s^*)(V_N-1/V_s)(V_N-1/V_s^*)}{(V-V_s)(V-V_s^*)(V-1/V_s)(V-1/V_s^*)} \left(f^{(1)}_{sN\bar{N}}/f_s\right) + \right.$$

$$\left. + \frac{(V_N-V_{\varphi'})(V_N-V_{\varphi'}^*)(V_N+V_{\varphi'})(V_N+V_{\varphi'}^*)}{(V-V_{\varphi'})(V-V_{\varphi'}^*)(V+V_{\varphi'})(V+V_{\varphi'}^*)} \left(f^{(1)}_{\varphi' N\bar{N}}/f_{\varphi'}\right)\right]$$

$$F_1^v[W(t)] = \left(\frac{1-W^2}{1-W_N^2}\right)^4 \left[\frac{(W_N-W_\rho)(W_N-W_\rho^*)(W_N-1/W_\rho)(W_N-1/W_\rho^*)}{(W-W_\rho)(W-W_\rho^*)(W-1/W_\rho)(W-1/W_\rho^*)} \left(f^{(1)}_{\rho N\bar{N}}/f_\rho\right) + \right.$$

$$\left. + \sum_{v=\rho',\rho''} \frac{(W_N-W_v)(W_N-W_v^*)(W_N+W_v)(W_N+W_v^*)}{(W-W_v)(W-W_v^*)(W+W_v)(W+W_v^*)} \left(f^{1}_{vN\bar{N}}/f_v\right)\right]$$

$$(32)$$

$$F_2^s[V(t)] = \left(\frac{1-V^2}{1-V_N^2}\right)^6 \left[\sum_{s=\omega,\varphi} \frac{(V_N-V_s)(V_N-V_s^*)(V_N-1/V_s)(V_N-1/V_s^*)}{(V-V_s)(V-V_s^*)(V-1/V_s)(V-1/V_s^*)} \left(f^{(2)}_{sN\bar{N}}/f_s\right) + \right.$$

$$\left. + \frac{(V_N-V_{\varphi'})(V_N-V_{\varphi'}^*)(V_N+V_{\varphi'})(V_N+V_{\varphi'}^*)}{(V-V_{\varphi'})(V-V_{\varphi'}^*)(V+V_{\varphi'})(V+V_{\varphi'}^*)} \left(f^{(2)}_{\varphi' N\bar{N}}/f_{\varphi'}\right)\right]$$

$$F_2^v[W(t)] = \left(\frac{1-W^2}{1-W_N^2}\right)^6 \left[\frac{(W_N-W_\rho)(W_N-W_\rho^*)(W_N-1/W_\rho)(W_N-1/W_\rho^*)}{(W-W_\rho)(W-W_\rho^*)(W-1/W_\rho)(W-1/W_\rho^*)} \left(f^{(2)}_{\rho N\bar{N}}/f_\rho\right) + \right.$$

$$\left. + \sum_{v=\rho',\rho''} \frac{(W_N-W_v)(W_N-W_v^*)(W_N+W_v)(W_N+W_v^*)}{(W-W_v)(W-W_v^*)(W+W_v)(W+W_v^*)} \left(f^{(2)}_{vN\bar{N}}/f_v\right)\right]$$

which are real analytic functions defined on the four-sheeted Riemann surface, with the conserved normalization conditions (17) of the zero width VMD model and the following asymptotic behaviour

$$
\begin{aligned}
F_1^s[V(t)] &\sim t^{-2}|_{t\to\pm\infty} \\
F_1^v[W(t)] &\sim t^{-2}|_{t\to\pm\infty} \\
F_2^s[V(t)] &\sim t^{-3}|_{t\to\pm\infty} \\
F_2^v[W(t)] &\sim t^{-3}|_{t\to\pm\infty} \quad .
\end{aligned}
\tag{33}
$$

Inserting explicit formulae (32) into (11) we obtain the modified VMD model for the elm. structure of nucleons, which will be used for the analysis of all existing experimental data on electric and magnetic proton and neutron ff's in the space-like and time-like region simultaneously. However, the latter is a subject of the next section.

4. - Analysis of nucleon electric and magnetic form-factor data.

The modified VMD model, constructed in the previous section, depends on the following 26 parameters t_{inl}^s, t_{inl}^v, m_ω, Γ_ω, m_φ, Γ_φ, $m_{\varphi'}$, $\Gamma_{\varphi'}$, m_ρ, Γ_ρ, $m_{\rho'}$, $\Gamma_{\rho'}$, $m_{\rho''}$, $\Gamma_{\rho''}$, $f^{(1)}_{\omega N\bar{N}}/f_\omega$, $f^{(1)}_{\varphi N\bar{N}}/f_\varphi$, $f^{(1)}_{\varphi' N\bar{N}}/f_{\varphi'}$, $f^{(1)}_{\rho N\bar{N}}/f_\rho$, $f^{(1)}_{\rho' N\bar{N}}/f_{\rho'}$, $f^{(1)}_{\rho'' N\bar{N}}/f_{\rho''}$, $f^{(2)}_{\omega N\bar{N}}/f_\omega$, $f^{(2)}_{\varphi N\bar{N}}/f_\varphi$, $f^{(2)}_{\varphi' N\bar{N}}/f_{\varphi'}$, $f^{(2)}_{\rho N\bar{N}}/f_\rho$, $f^{(2)}_{\rho' N\bar{N}}/f_{\rho'}$, $f^{(2)}_{\rho'' N\bar{N}}/f_{\rho''}$ with clear physical meaning. Their number is reduced to 22 by four equations (17), which result from normalization conditions (14) applied to the zero-width VMD representation of $F^{s,v}_{1,2}$, however, conserved also in the modified VMD model (32).

We do not expect to be able to determine all 22 parameters in the fit of existing nucleon ff data owing to a simple reason that all considered resonances are situated in the unphysical region, where no experimental point exists up to now. So, certainly we are unable to determine at least correct values of vector meson widths in such circumstances. Therefore, they are all fixed at the values taken either from Review of particle properties [32] ($\Gamma_\omega = 9.8$ MeV, $\Gamma_\varphi = 4.22$ MeV, $\Gamma_{\varphi'} = 130$ MeV, $\Gamma_\rho = 153$ MeV) or from the previous analysis [24] ($\Gamma_{\rho'} = 323.8$ MeV, $\Gamma_{\rho''} = 454$ MeV) of all existing data on the pion ff by means of the three-resonance model respecting all well-established pion ff features. Moreover, since the ω-resonance is experimentally rather accurately determined, we have fixed also its mass at the tabulated value [32]. Thus, we are left finally only with the following 15 free parameters t^s_{inl}, t^v_{inl}, m_φ, $m_{\varphi'}$, m_ρ, $m_{\rho'}$, $m_{\rho''}$, $f^{(1)}_{\omega N\bar{N}}/f_\omega$, $f^{(1)}_{\varphi N\bar{N}}/f_\varphi$, $f^{(2)}_{\omega N\bar{N}}/f_\omega$, $f^{(2)}_{\varphi N\bar{N}}/f_\varphi$, $f^{(1)}_{\rho N\bar{N}}/f_\rho$, $f^{(1)}_{\rho'' N\bar{N}}/f_{\rho''}$, $f^{(2)}_{\rho N\bar{N}}/f_\rho$, $f^{(2)}_{\rho'' N\bar{N}}/f_{\rho''}$, if particularly $f^{(1)}_{\varphi' N\bar{N}}/f_{\varphi'}$, $f^{(2)}_{\varphi' N\bar{N}}/f_{\varphi'}$, $f^{(1)}_{\rho' N\bar{N}}/f_{\rho'}$ and $f^{(2)}_{\rho' N\bar{N}}/f_{\rho'}$ are chosen to be expressed via other ratios of coupling constants. For their determination we have collected 130 experimental points [33] on G^p_E in the space-like region, 13 experimental points [34-37] on $|G^p_E|$ in the time-like region, 143 experimental points [33,38] on G^p_M in the space-like region, 13 experimental points [34-37] on $|G^p_M|$ in the time-like region, 63 experimental points [39-49] on G^n_E and 44 experimental points [43,45,47-56] on G^n_M, both in the space-like region only. The data have been analysed by means of the relations (11) and (32) by using the CERN program MINUIT [57]. The best description of them was achieved with $\chi^2/ndf = 921/391$, which is not very satisfactory. Its partition into every G^p_E, G^p_M, G^n_E and G^n_M separately is presented in Table I. An average value of χ^2 for one experimental point reveals rather a good description of G^p_E, $|G^p_E|$ and $|G^p_M|$, but no adequate description of G^p_M, G^n_E and G^n_M. However, taking notice of individual partial chi-squared χ^2_p, we find only a few experimental points (altogether 19) with an extremely high value of χ_p^2. For instance, in the case of G_E^p there are four such points,

at	$t\ [\mathrm{GeV}^2]$:	-0.0990	-0.0840	-0.0660	-0.0460
with	χ_p^2 :	14.41	23.94	12.43	15.25 .

(34)

They all are from the experiment of Borkowski et.al. (for a reference, see [33]) at low momenta transfer squared.

In the case of G_M^p we find eight points with high values of χ_p^2. They are

$t\ [\mathrm{GeV}^2]$:	-27.0800	-23.3100	-19.5300	-15.7700
χ_p^2 :	13.23	10.27	28.37	21.31
$t\ [\mathrm{GeV}^2]$:	-2.9200	-0.5841	-0.3900	-0.2726
χ_p^2 :	27.28	17.32	11.83	11.58 .

(35)

The first four experimental data are from new measurements [38] on G_M^p at SLAC, about which the authors themselves are declaring that they are more precise and reliable than the previous ones at the same values of t. However, on the basis of our global analysis we came to the conclusion that they are (at least the four points from (35)) inconsistent with all other nucleon electric and magnetic ff data.

In the case of G_E^n we have revealed five peculiar points

$t\ [\mathrm{GeV}^2]$:	-0.7788	-0.1955	-0.1441	-0.0970	-0.0962
χ_p^2 :	30.86	18.17	13.19	16.29	10.03

(36)

and in G_M^n only two exceptional points with a high values of χ_p^2 as follows

$t\ [\mathrm{GeV}^2]$:	-1.1670	-0.7788
χ_p^2 :	54.71	10.91

(37)

If we eliminate all, compiled in (34)-(37), experimental data from the global analysis, rather good results in the description of electric and magnetic proton and neutron ff's (for a graphical presentation of the results see figs. 1a,b; 2a,b; 3a,b and 4a,b) are obtained with

$$\chi^2/ndf = 560/372 \tag{38}$$

and the parameters

$$\begin{aligned}
&t^s_{inl} = 1.078 \pm 0.001\ \mathrm{GeV}^2 && t^v_{inl} = 1.036 \pm 0.030\ \mathrm{GeV}^2 \\
&m_\varphi = 1037 \pm 2\ \mathrm{MeV} && m_\rho = 720 \pm 39\ \mathrm{MeV} \\
&m_{\varphi'} = 1404 \pm 16\ \mathrm{MeV} && m_{\rho'} = 1315 \pm 15\ \mathrm{MeV} \\
& && m_{\rho''} = 1410 \pm 48\ \mathrm{MeV} \\
&f^{(1)}_{\omega N\bar{N}}/f_\omega = 0.91 \pm 0.04 && f^{(1)}_{\rho N\bar{N}}/f_\rho = 0.22 \pm 0.03 \\
&f^{(1)}_{\varphi N\bar{N}}/f_\varphi = -0.59 \pm 0.06 && f^{(1)}_{\rho'' N\bar{N}}/f_{\rho''} = -1.84 \pm 0.18 \\
&f^{(2)}_{\omega N\bar{N}}/f_\omega = -1.08 \pm 0.02 && f^{(2)}_{\rho N\bar{N}}/f_\rho = 1.90 \pm 0.03 \\
&f^{(2)}_{\varphi N\bar{N}}/f_\varphi = 2.09 \pm 0.04 && f^{(2)}_{\rho'' N\bar{N}}/f_{\rho''} = 0.63 \pm 0.22
\end{aligned} \tag{39}$$

whereas the rest of four ratios of coupling constants, calculated by using (39) and (17), acquire the values as follows

$$\begin{aligned}
&f^{(1)}_{\varphi' N\bar{N}}/f_{\varphi'} = 0.18 \pm 0.07 && f^{(1)}_{\rho' N\bar{N}}/f_{\rho'} = 2.12 \pm 0.18 \\
&f^{(2)}_{\varphi' N\bar{N}}/f_{\varphi'} = -1.07 \pm 0.05 && f^{(2)}_{\rho' N\bar{N}}/f_{\rho'} = -0.68 \pm 0.23
\end{aligned} \tag{40}$$

Really, the value $\chi^2/ndf \approx 1.51$ in (38) is quite reasonable. The inelastic thresholds t^s_{inl} and t^v_{inl} indicate that roughly up to the $K\bar{K}$ threshold (i.e. ≈ 1 GeV) only 3π and 2π intermediate states are dominating in the unitarity condition of isoscalar and isovector Dirac and Pauli nucleon ff's respectively. The vector meson masses in (39) are acceptable, as soon as one recognizes their determination from the data without any typical jump (even no experimental point) at the place of vector mesons, which is

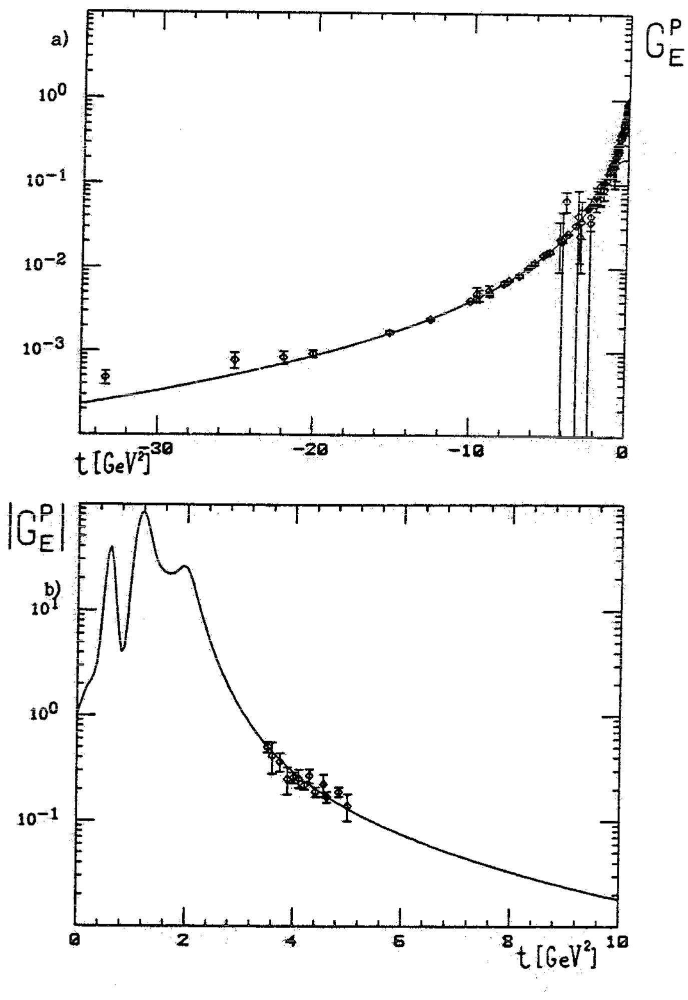

Fig.1. a/ Comparison of electric proton form factor with the data in the space-like region.

b/ The behaviour of electric proton form factor in the time-like region and its comparison with the data obtained from $e^+e^- \to p\,\bar{p}$ and $p\,\bar{p} \to e^+e^-$.

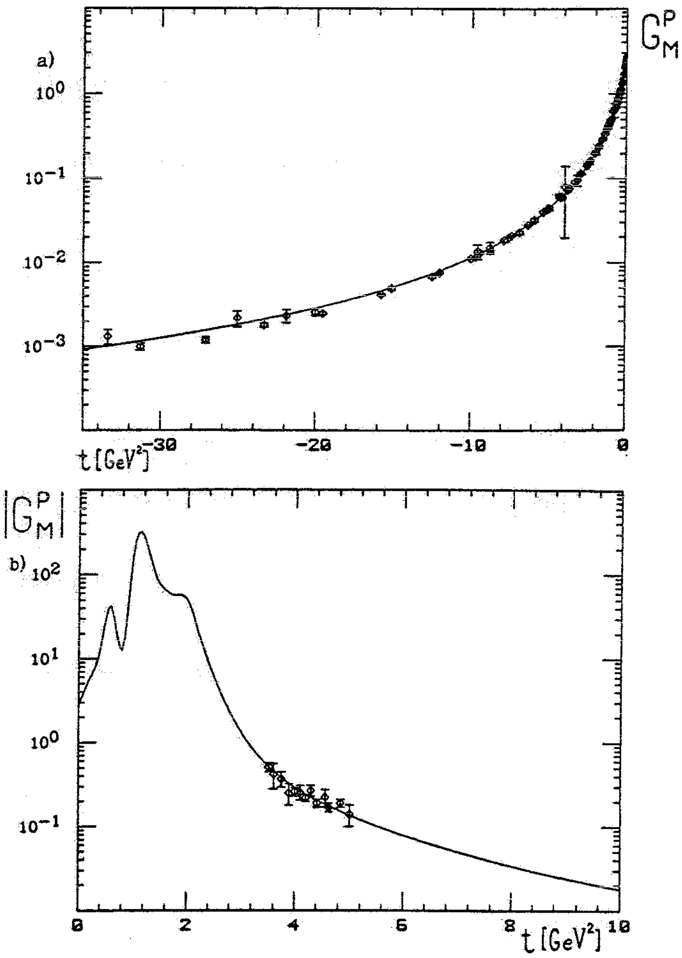

Fig.2. a/ Comparison of magnetic proton form factor with the data in the space-like region.

b/ The time-like behaviour of magnetic proton form factor and its comparison with existing data.

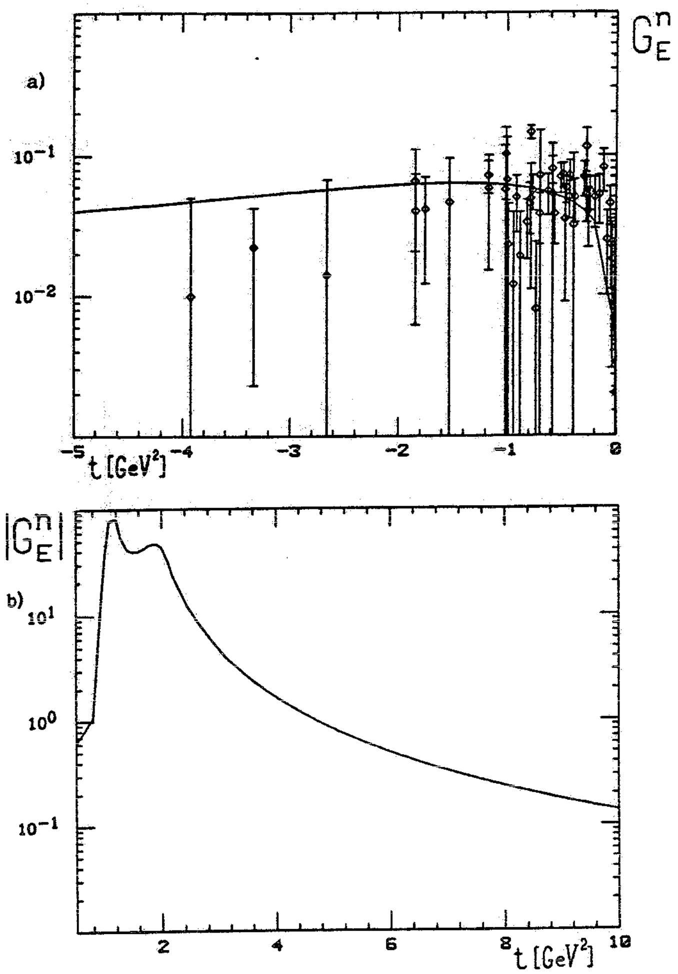

Fig.3. a/ Electric neutron form factor versus t in the space-like region.

b/ The prediction of time-like behaviour of neutron electric form factor by the modified VMD model.

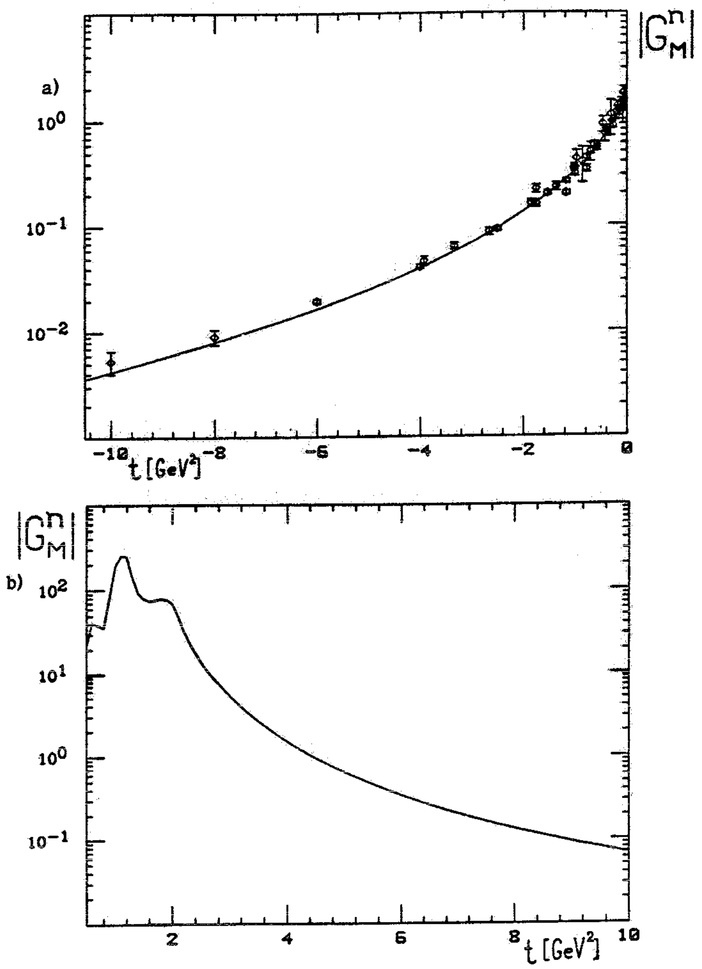

Fig.4. a/ Magnetic neutron form factor versus t in the space-like region and its comparison with existing data.

b/ The prediction of the modified VMD model for magnetic neutron form factor in the time-like region.

always crucial in an accurate fixing of resonance parameters. Similarly to the previous pion ff data analyses [24,28,29], we confirm again the existence of both higher rho-resonances, $\rho'(1250)$ and $\rho''(1600)$, now from the global analysis of the data on electric and magnetic proton and neutron ff's simultaneously. Any neglect of one of these resonances in the used modified VMD model for the elm. structure of nucleons leads to a failure of the nice description of existing data with the value of χ^2/ndf given by (38).

In order to find vector and tensor couplings of vector mesons under consideration to nucleons from (39) and (40), first we have to calculate the universal vector meson coupling constants $f_V^2/4\pi$ from the relation

$$\frac{f_V^2}{4\pi} = \frac{\alpha^2}{3} \frac{m_V^2}{\Gamma(V \rightarrow e^+e^-)} \tag{41}$$

where the $\Gamma(V \rightarrow e^+e^-)$ for ρ, ω, φ and ρ'' are taken from Review of particle properties [32]. The results are as follows

$$f_\rho^2/4\pi = 1.98 \qquad f_\omega^2/4\pi = 21.06 \qquad f_\varphi^2/4\pi = 13.82 \qquad f_{\rho''}^2/4\pi = 3.77 \; . \tag{42}$$

The universal vector meson coupling constant for $\rho'(1250)$ is taken from [20] to be $f_{\rho'}^2/4\pi = 9.1$. Unfortunately, there is no experimental information on the leptonic width of $\varphi'(1680)$ up to now.

Taking all these values into account we find from (39) and (40) the following coupling constant values

$$\frac{f^{(1)2}_{\omega N\bar{N}}}{4\pi} = 17.44; \quad \frac{f^{(1)2}_{\varphi N\bar{N}}}{4\pi} = 4.81; \quad \frac{f^{(1)2}_{\rho N\bar{N}}}{4\pi} = 0.10; \quad \frac{f^{(1)2}_{\rho' N\bar{N}}}{4\pi} = 40.50; \quad \frac{f^{(1)2}_{\rho'' N\bar{N}}}{4\pi} = 12.75;$$
$$\frac{f^{(2)2}_{\omega N\bar{N}}}{4\pi} = 24.56; \quad \frac{f^{(2)2}_{\varphi N\bar{N}}}{4\pi} = 60.37; \quad \frac{f^{(2)2}_{\rho N\bar{N}}}{4\pi} = 7.15; \quad \frac{f^{(2)2}_{\rho' N\bar{N}}}{4\pi} = 4.21; \quad \frac{f^{(2)2}_{\rho'' N\bar{N}}}{4\pi} = 1.50; \tag{43}$$

We did not calculate the errors of corresponding coupling constants, because they are considerably influenced by the masses of vector mesons which are, however, mostly not very well known.

Now we would like to draw attention to the most interesting result of our analysis. Though there are no experimental data on neutron electric and magnetic ff's in the time-like (i.e. $t > 0$) region, we are predicting their behaviour (see figs. 3b and 4b) from our modified VMD model for the nucleon elm. structure in which all free parameters have been fixed by the demonstrated fitting procedure of proton ff data in the space-like and time-like regions and the neutron ff data only in the space-like region simultaneously. Close above the nucleon-antinucleon threshold they are (see Table III) approximately five times as large as the corresponding proton form factors. So, the cross section of $e^+e^- \rightarrow n\,\bar{n}$ in this region is expected to be roughly twenty-five times as large as the cross section of $e^+e^- \rightarrow p\,\bar{p}$.

Thus we have confirmed indications for a phenomenon of the previous analysis (15), obtained by the simple VMD model, which seems to be interesting in connection with a planned ADONE experiment (58) in Frascati, where measurements of the process $e^+e^- \rightarrow n\,\bar{n}$ will be carried out for the first time.

5. - Summary and conclusions.

In accordance with the general procedure proposed in (17), we have constructed a modified VMD model for a description of the nucleon elm. structure. It possesses correct analytic properties and the asymptotic behaviour corresponding to a prediction of the quark model for baryons. The model depends only on parameters with clear physical meaning, like isoscalar and isovector effective inelastic thresholds, masses and widths of correctly incorporated vector-me-

Table I. - The partition of total χ^2 into individual nucleon form factors. N means the number of experimental points.

	space-like				time-like		total
	G_E^p	G_M^p	G_E^n	G_M^n	$\|G_E^p\|$	$\|G_M^p\|$	
N	130	143	63	44	13	13	406
χ^2	254	364	163	119	11	10	921
χ^2/N	1.96	2.55	2.60	2.71	0.85	0.79	2.27

Table II. - The partition of total χ^2 into individual nucleon form factors after an elimination of 19 exp. points with extremely high value of partial χ_p^2.

	space-like				time-like		total
	G_E^p	G_M^p	G_E^n	G_M^n	$\|G_E^p\|$	$\|G_M^p\|$	
N	126	135	58	42	13	13	387
χ^2	188	223	75	53	11	10	560
χ^2/N	1.49	1.65	1.29	1.26	0.86	0.79	1.45

Table III. - The numerical comparison of electric and magnetic proton and neutron ff's in time-like region above the nucleon-antinucleon threshold.

t [GeV^2]	G_E^p	G_E^n	G_M^p	G_M^n
3.6	0.462	2.374	0.460	2.343
3.8	0.364	1.965	0.361	1.870
4.0	0.295	1.653	0.294	1.518
4.2	0.244	1.410	0.245	1.252
4.4	0.205	1.217	0.209	1.046
4.6	0.175	1.061	0.180	0.884
4.8	0.152	0.933	0.156	0.755
5.0	0.132	0.827	0.137	0.651

son resonances and the corresponding ratios of coupling constants. The number of free parameters was reduced considerably. The latter was achieved by application of four ff normalization conditions and fixing all resonance widths at the world averaged values. In addition, the mass of ω-meson was also taken from the Review of Particle Properties (32), since it is really measured very accurately. The rest of 15 free parameters have been determined in the analysis of the existing electric and magnetic nucleon ff data in the space-like and time-like regions simultaneously. Their values are rather reasonable. The existence of $\rho'(1250)$ and $\rho''(1600)$ is established from this analysis of nucleon ff data in a sense that a better χ^2 value with three isovector vector mesons incorporated into the model was achieved than with the incorporation of only two of them. The behaviour of neutron electric and magnetic ff's in the time-like region is predicted by the modified VMD model. Comparing the latter with the behaviour of proton ff's we came to the conclusion that the $e^+e^- \to n\bar{n}$ cross section above the nucleon-antinucleon threshold is remarkably larger than the $e^+e^- \to p\bar{p}$ one. This conclusion will be soon verified (58) by the new ADONE experiment in Frascati.

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