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S.Dubnicka, E. Etim:

A NEW VDM PREDICTION FOR TIME-LIKE FORM FACTORS

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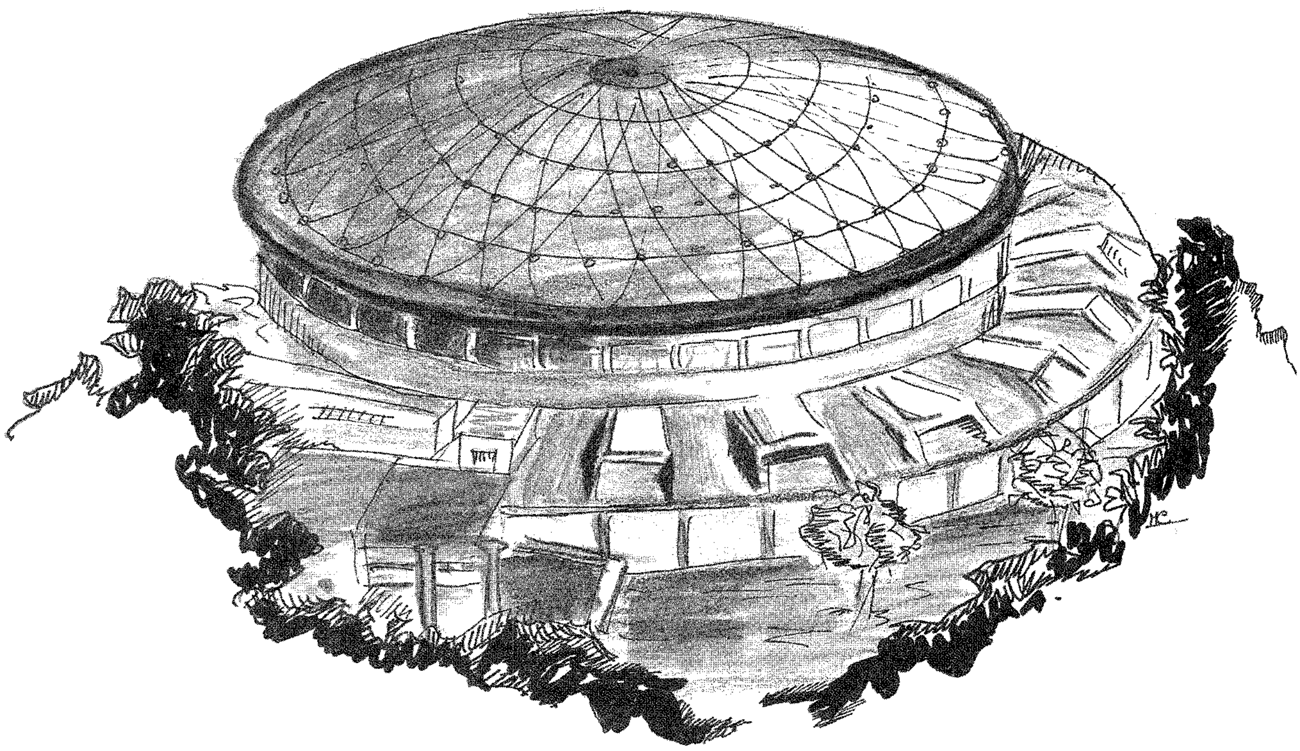

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A NEW VDM PREDICTION FOR TIME-LIKE FORM FACTORS

S.Dubnicka* and E. Etim
INFN - Laboratori Nazionali di Frascati, P.O. Box 13
00044 Frascati (Italy)

ABSTRACT

A VMD model which incorporates improved analyticity properties of electromagnetic form factors of hadrons and unitarity corrections is presented. It is applied to the description of the electromagnetic structure of pions, kaons and nucleons. In the case of pions and kaons, contributing higher vector meson resonances are determined from the analysis of the processes $e^+e^- \to \pi^+\pi^-$ and $e^+e^- \to K\bar{K}$, respectively. In the case of nucleons we predict the behaviour of the electric and magnetic form factors of the neutron in the time-like region.

1. - INTRODUCTION

The cross section for the two-body exclusive process

$$e^+e^- \to h\bar{h},$$

where h is a hadron and $\bar{h}$ the corresponding anti-particle, is determined wholely by the behaviour of the electromagnetic form factors of h in the time-like region. The vector meson dominance model (VMD)(1) gives a simple approximation for these form factors, for small values of the momentum transfer, in terms of vector meson intermediate states (cf. Fig. 1) viz

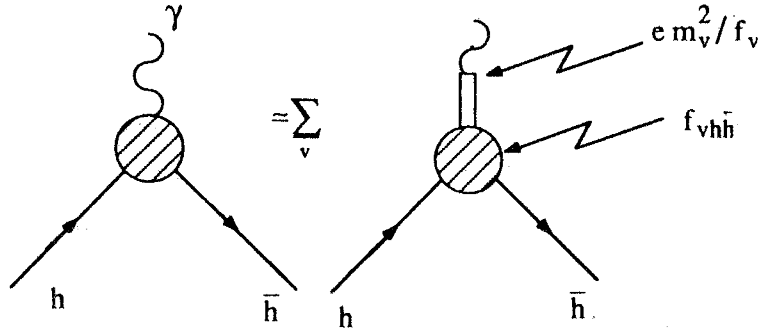

FIG. 1

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* On leave of absence from Institute of Physics EPRC, Slovak Academy of Sciences, 84228 Bratislava, Czechoslovakiv.

$$F_h(t) = \sum_v \frac{m_v^2}{f_v} \cdot \frac{f_{vh\bar{h}}}{m_v^2 - t} \tag{1}$$

For a finite number of vector mesons contributing in eq. (1), the leading asymptotic behaviour of F_h (t) is

$$F_h(t) \xrightarrow[|t|\to\infty]{} \frac{1}{t} \tag{2}$$

This behaviour is not consistent with quark parton model (or counting rule) predictions, where the fall-off

$$F_h(t) \xrightarrow[|t|\to\infty]{} t^{-(N_q - 1)} \tag{3}$$

is determined(2,3) by the number N_q of its valence quarks, except for pions kaons and other two valence quark systems. Secondly, the meromorphy of $F_h(t)$ in eq.(1) is not consistent with general analyticity properties of hadronic form factors. Our purpose in this paper is to introduce improvements in the naive VMD formula (1) in respect of its analyticity properties and asymptotic behaviour. These two aspects are obviously related. We will not achieve this exactly. We consider correct asymptotic behaviour to be more important and will, consequently, sacrifice the rigorous implementation of analyticity.

Here is a brief description of the approach. Let to be the threshold in the $h\bar{h}$-production channel and t_{inel} the threshold for inelastic contributions. The transformation

$$t = t_0 - \frac{4\,(t_{inel} - t_0)}{(u - \frac{1}{u})^2} \tag{4}$$

allows to factorise the asymptotic and analyticity properties of F_h (t). In fact, substituting (4) in (1) yields

$$F_h(u(t)) = \left(\frac{1 - u^2}{1 - u_o^2}\right)^2 \sum_v \frac{f_{vh\bar{h}}}{f_v} \frac{(u_o - u_v)(u_o + u_v)(u_o - \frac{1}{u_v})(u_o + \frac{1}{u_v})}{(u - u_v)(u + u_v)(u - \frac{1}{u_v})(u + \frac{1}{u_v})} \tag{5}$$

u_o is the value of u for t = 0 and u_v the value of u for $t = m_v{}^2$.

There are two symmetries involved in eq. (4) and which determine the way F_h (u(t)) is expressed in eq. (5). They are the inversion R: $u \to 1/u$ and reflection or parity P: $u \to -u$.

They leave $t = t(u)$ invariant and hence also the singularities of $F_h(u(t))$ in the t - plane. In the u - plane these singularities appear in quartets. Secondly, eq. (5) is in a factorised form: the limit $u \to \pm 1$ corresponds to $t \to \infty$, from eq. (4). This limit is governed by the first factor in eq.(5). The rest determines the analyticity structure of $F_h(u(t))$ in the finite t - plane. It is this part which we shall sacrifice in generalising (5) to incorporate eq. (3), that is

$$F_h(t) = \left(\frac{1-u^2}{1-u_o^2}\right)^{2(N_q-1)} \sum_v \frac{f_{vh\bar{h}}}{f_v} \frac{(u_o-u_v)(u_o+u_v)(u_o-\frac{1}{u_v})(u_o+\frac{1}{u_v})}{(u-u_v)(u+u_v)(u-\frac{1}{u_v})(u+\frac{1}{u_v})} \qquad (6)$$

The symmetries R and P in the u-plane allow to write eq. (6) as two sums: the first consists of contributions from vector mesons with $(\text{mass})^2\ m^2_{v_1} < t_{inel}$. For them the corresponding u_v satisfy $u_{v_1} = -u^*_{v_1}$. The second sum consists of contributions from vector mesons with $(\text{mass})^2\ m^2_{v_2} > t_{inel}$. For them $u_{v_2} = 1/u^*_{v_2}$. This observation allows to write (6) in the form of an explicit real analytic function of u; viz.

$$F_h(t) = \left(\frac{1-u^2}{1-u_o^2}\right)^{2(N_q-1)} \left[\sum_j \frac{f_{jh\bar{h}}}{f_j} \frac{(u_o-u_j)(u_o-u_j^*)(u_o-\frac{1}{u_j})(u_o-\frac{1}{u_j^*})}{(u-u_j)(u-u_j^*)(u-\frac{1}{u_j})(u-\frac{1}{u_j^*})} + \right.$$

$$\left. + \sum_k \frac{f_{kh\bar{h}}}{f_k} \frac{(u_o-u_k)(u_o-u_k^*)(u_o+u_k)(u_o+u_k^*)}{(u-u_k)(u-u_k^*)(u+u_k)(u+u_k^*)} \right] \qquad (7)$$

Eq. (7) is valid quite generally if $\text{Re}(m_j^2) < t_{inel}$ and $\text{Re}(m_k^2) > t_{inel}$. In other words, the masses can be complexified, $m_v^2 \to (m_v - i\,\Gamma_{v/2})^2$, to include non-zero widths Γ_v and thereby generate Breit-Wigner forms. Note that the complexified masses are on unphysical sheets.

2. - THE PION FORM FACTOR

The e.m. structure of the pion is completely described by one scalar function $F_\pi(t)$, which is directly measured in $e^+ e^- \to \pi^+ \pi^-$ through the cross section

$$\sigma(e^+e^- \to \pi^+\pi^-) = \frac{\pi\alpha^2\beta^3}{3t}\left| F_\pi(t) + Re^{i\varphi}\frac{m_\omega^2}{m_\omega^2 - t - i\, m_\omega\Gamma_\omega}\right| \tag{8}$$

where the $\rho - \omega$ interference amplitude R takes the form

$$R = \frac{6}{\alpha m_\omega}\left(\frac{m_\omega^2}{m_\omega^2 - 4\, m_\pi^2}\right)^{3/2}\left[\Gamma(\omega \to e^+e^-)\,\Gamma(\omega \to \pi^+\pi^-)\right]^{1/2} \tag{9}$$

α is the fine structure constant, $\beta = [1 - 4\, m_\pi^2/t]^{1/2}$ is the velocity of the outgoing pion and the $\rho - \omega$ interference phase φ can be expressed[(4)] through the $\rho(770)$ and $\omega(783)$ meson parameters as

$$\varphi = \text{arctg}\frac{m_\rho\Gamma_\rho}{m_\rho^2 - m_\omega^2} \tag{10}$$

There are other processes, like

$\pi^- p \to e^+ e^- n$, $\quad J/\psi \to \pi^+\pi^-$ $\quad$ for $t > 0$

and

$e^- N \to e^- \pi N$, $\quad \pi^- e^- \to \pi^- e^-$ $\quad$ for $t < 0$ (11)

in which the pion form factor is measured. As a result there are at present 288 reliable experimental points on $F_\pi(t)$ for $-9.770\ \text{GeV}^2 \leq t \leq 9.579\ \text{GeV}^2$. They have been analysed[(5)] in terms of the model in eq. (7). The contributing vector mesons are ρ, ρ', ρ''; $t_o = 4\, m_\pi^2$. The results are the following:

$\chi^2/NDF = 382/276$ $\qquad t_{inel}\ 1.3 \pm 0.1\ \text{GeV}^2$

$$\begin{aligned} m_\rho &= 762 \pm 3\ \text{MeV}; & \Gamma_\rho &= 143 \pm 5\ \text{MeV}; & f_{\rho\pi\pi}/f_\rho &= 1.02 \pm 0.02 \\ m_{\rho'} &= 1422 \pm 90\ \text{MeV}; & \Gamma_{\rho'} &= 685 \pm 170\ \text{MeV}; & f_{\rho'\pi\pi}/f_{\rho'} &= 0.18 \pm 0.02 \\ m_{\rho''} &= 1682 \pm 58\ \text{MeV}; & \Gamma_{\rho''} &= 402 \pm 81\ \text{MeV}; & f_{\rho''\pi\pi}/f_{\rho''} &= 0.16 \pm 0.01 \end{aligned} \tag{12}$$

One sees from eq. (12) that the first radial excitation of ρ(770) is the same as identified by Donnachie and Mirzaie[(6)] from $e^+ e^- \to \pi^+ \pi^-$ and by Govorkov[(7)] from $e^+ e^- \to \pi^o \omega$. A comparison of eq. (7) with data on $F_\pi(t)$ is made in Fig. 2.

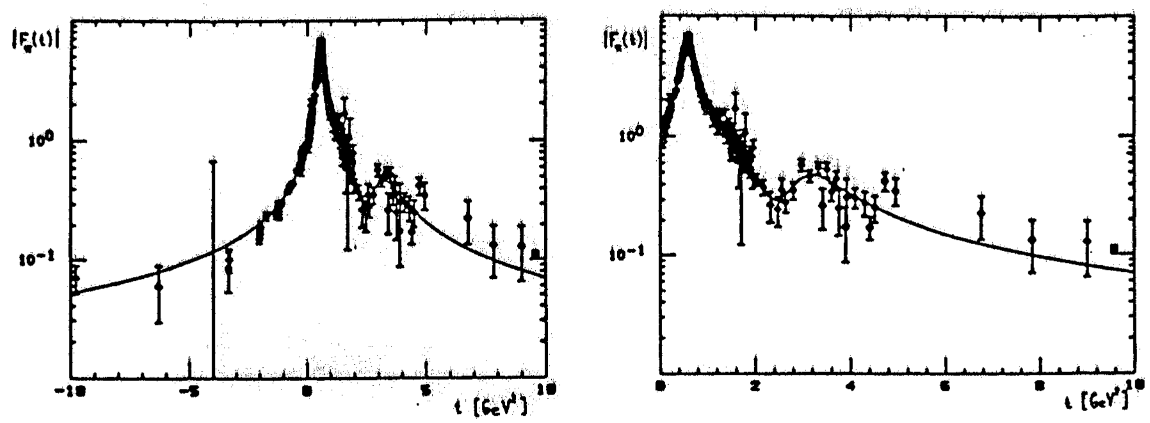

FIG. 2 - Comparison of the model (15 with the data on the pion form factor in the whole experimentally measurable region.

The Kaon Form Factor: K^+ and K^o form an isodoublet. Their scalar form factors $F_{K^+}(t)$ and $F_{K^o}(t)$ can be decomposed into isoscalar and isovector contributions

$$\begin{aligned} F_{K^+}(t) &= F_K^s(t) + F_K^v(t) \\ F_{K^o}(t) &= F_K^s(t) - F_K^v(t). \end{aligned} \tag{13}$$

The normalization of $F_K^{s,v}(t)$ is

$$F_K^s(0) = 1/2 \quad ; \quad F_K^v(0) = 0 \tag{14}$$

from $F_{K^+}(0) = 1$ and $F_{K^o}(0) = 0$. Eq. (7) is applied to $F_K^s(t)$ and $F_K^v(t)$:

$$F_K^s[V(t)] = \left(\frac{1-V^2}{1-V_o^2}\right)^2 \left[\sum_{s=\omega,\varphi} \frac{(V_o - V_s)(V_o - V_s^*)(V_o - 1/V_s)(V_o - 1/V_s^*)}{(V - V_s)(V - 1/V^*_s)(V - 1/V_s)(V - 1/V^*_s)} (f_{sK\bar{K}}/f_s) + \right.$$

$$\left. + \frac{(V_o - V_{\varphi'})(V_o - V_{\varphi'}^*)(V_o + V_{\varphi'})(V_o + V_{\varphi'}^*)}{(V - V_{\varphi'})(V - V_{\varphi'}^*)(V_N + V_{\varphi'})(V + V_{\varphi'}^*)} (f_{\varphi' K\bar{K}}/f_{\varphi'})\right]$$

$$F_K^V[W(t)] = \left(\frac{1-W^2}{1-W_o^2}\right)^2 \left[\frac{(W_o - W_\rho)(W_o - W^*_\rho)(W_o - 1/W_\rho)(W_o - 1/W^*_\rho)}{(W - W_\rho)(W - W^*_\rho)(W - 1/W_\rho)(W - 1/W^*_\rho)} (f_{\rho K\bar{K}}/f_\rho) + \right.$$

$$\left. \sum_{v=\rho',\rho''} \frac{(W_o - W_v)(W_o - W^*_v)(W_o + W_v)(W_o + W^*_v)}{(W - W_v)(W - W^*_v)(W + W_v)(W + W^*_v)} (f_{vK\bar{K}}/f_v) \right] \qquad (15)$$

with the asymptotic behaviours

$$F_K^S[V(t)] \sim t^{-1}|_{t \to \pm\infty}; \qquad F_K^S[W(t)] \sim t^{-1}|_{t \to \pm\infty}.$$

Eq. (15) contains 20 parameters: t^s_{inel}, t^v_{inel}, m_s, Γ_s, $f_{VK\bar{K}}/f_s$ (s= ω, φ, φ'), m_v, Γ_v, $f_{SK\bar{K}}/f_{sv}$ (v= ρ, ρ', ρ''). This number reduces to 18 on account of eq. (14) that is

$$\sum_s (f_{SK\bar{K}}/f_S) = \frac{1}{2}; \qquad \sum_v (f_{VK\bar{K}}/f_V) = \frac{1}{2} \qquad (16)$$

There are no data on these form factors in the region of ρ(770) and ω(783). However, since these resonances are well determined, we fix their masses and widths at the world averaged values. Our interest is then in the determination of the parameters of the higher vector mesons from data on $F_{K^+}(t)$, $F_{K^o}(t)$. Note that the φ(1020) meson is situated just on the border of the existing data. Consequently, the determination of its parameters, is a test for our model.

We have compiled 117 experimental points on $F_{K^+}(t)$, $F_{K^o}(t)$: 25 points in the region $t < 0$ from $K^- e^- \to K^- e^-$; 75 and 17 points respectively for $t > 0$, from $e^+ e^- \to K^+ K^-$ and $e^+ e^- \to K^o \bar{K}^o$. Their simultaneous fit, using (13), and (15), gives[8], for the remaining 14 free parameters, the values $\chi^2/NDF= 146/103$

t^s_{inel}	$= 1.68\ GeV^2$	t^v_{inel}	$= 1.72\ GeV^2$
$f_{\omega K\bar{K}}/f_\omega$	$= 0.200 \pm 0.005$	$f_{\rho K\bar{K}}/f_\rho$	$= 0.569 \pm 0.012$
m_φ	$= 1019.4 \pm 0.7$ MeV	$m_{\rho'}$	$= 1314.9 \pm 182.8$ MeV
Γ_ρ	$= 4.3 \pm 0.8$ MeV	$\Gamma_{\rho'}$	$= 245 \pm 167$ MeV
$f_{\rho K\bar{K}}/f_\varphi$	$= 0.333 \pm 0.005$	$f_{\rho' K\bar{K}}/f_{\rho'}$	$= 0.032$ – calculated by using the second relation of (16)
$m_{\varphi'}$	$= 1659.7 \pm 21.2$ MeV	$m_{\rho''}$	$= 2114.4 \pm 39.8$ MeV
$\Gamma_{\varphi'}$	$= 158.3 \pm 37.5$ MeV	$\Gamma_{\rho''}$	$= 150.1 \pm 103.9$ MeV
$f_{\rho'' K\bar{K}}/f_\rho$	$= -0.033$ – calculated by using the first relation of (16)	$f_{\rho'' K\bar{K}}/f_{\rho''}$	$= -0.037 \pm 0.011$.

(17)

We note that the data prefer the contribution of ρ''(2150) in $e^+ e^- \to K\bar{K}$ to ρ'(1600). The results of the analysis are shown in Fig. 3.

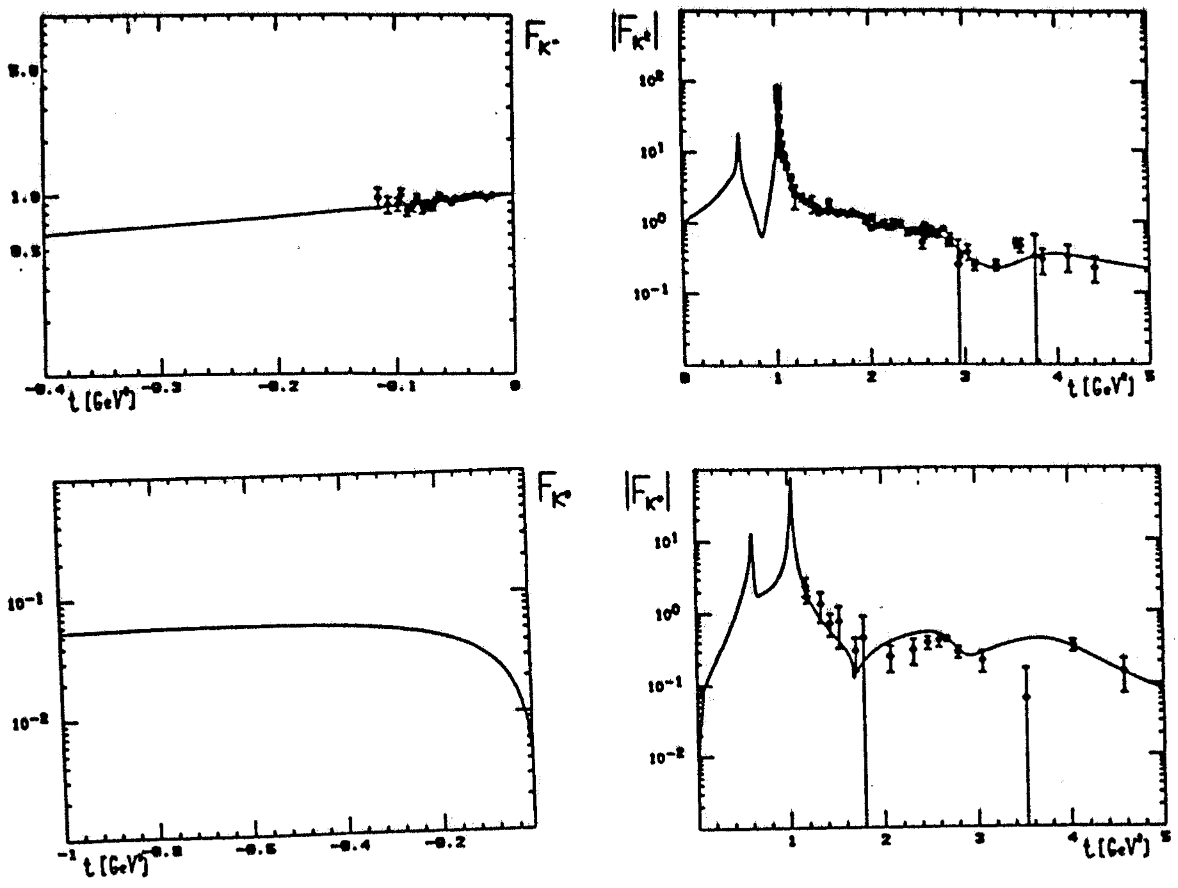

FIG. 3 - The K-meson ff data description by VMD model.

3. - THE NUCLEON FORM FACTORS IN THE TIME-LIKE REGION

There are four independent form factors $G_E{}^p(t)$, $G_M{}^p(t)$, $G_E{}^n(t)$, $G_M{}^n(t)$ describing e.m. structure of the nucleon, i.e. the proton (p) and neutron (n). They have been measured in the space-like region mainly in the scattering process $e^- N \rightarrow e^- N$, and in the time-like region in the annihilation processes $e^+ e^- \rightarrow N \overline{N}$ and $N\overline{N} \rightarrow e^+ e^-$. They are connected with the Dirac $F^p{}_1(t)$, $F^n{}_1(t)$ and Pauli $F^p{}_2(t)$, $F^n{}_2(t)$ form factors by

$$G_E^p(t) = F_1^p(t) + \frac{t}{4M^2} F_2^p(t) \qquad G_M^p(t) = F_1^p(t) + F_2^p(t)$$

$$G_E^n(t) = F_1^n(t) + \frac{t}{4M^2} F_2^n(t) \qquad G_M^n(t) = F_1^n(t) + F_2^n(t) \tag{18}$$

They many also be expressed in terms of isoscalar and isovector parts:

$$
\begin{aligned}
G_E^p(t) &= \left[F_1^s(t) + F_1^v(t)\right] + t/4M^2\left[F_2^s(t) + F_2^v(t)\right] \\
G_M^p(t) &= \left[F_1^s(t) + F_1^v(t)\right] + \left[F_2^s(t) + F_2^v(t)\right] \\
G_E^n(t) &= \left[F_1^s(t) - F_1^v(t)\right] + \frac{t}{4M^2}\left[F_2^s(t) - F_2^v(t)\right] \\
G_M^n(t) &= \left[F_1^s(t) - F_2^v(t)\right] + \left[F_2^s(t) - F_2^v(t)\right].
\end{aligned}
\tag{19}
$$

Again we apply eq. (7) to $F_{1,2}^{S,V}(t)$:

$$
\begin{aligned}
F_1^s[V(t)] = \left(\frac{1-V^2}{1-V_o^2}\right)^4 \Bigg[\sum_{s=\omega,\varphi} \frac{(V_o - V_s)(V_o - V_s^*)(V_o - 1/V_s)(V_o - 1/V_s^*)}{(V - V_s)(V - V_s^*)(V - 1/V_s)(V - 1/V_s^*)} (f_{sN\bar{N}}^{(1)}/fs) \; + \\
+ \frac{(V_o - V_{\varphi'})(V_o - V_{\varphi'}^*)(V_o + V_{\varphi'})(V_o + V_{\varphi'}^*)}{(V - V_{\varphi'})(V - V_{\varphi'}^*)(V + V_{\varphi'})(V + V_{\varphi'}^*)} (f_{\varphi' N\bar{N}}^{(1)}/f\varphi') \Bigg]
\end{aligned}
\tag{20a}
$$

$$
\begin{aligned}
F_1^v[W(t)] = \left(\frac{1-W^2}{1-W_o^2}\right)^4 \Bigg[\frac{(W_o - V_\rho)(W_o - W_\rho^*)(W_o - 1/W_\rho)(W_o - 1/W_\rho^*)}{(W - W_\rho)(W - W_\rho^*)(W - 1/W_\rho)(W - 1/W_\rho^*)} (f_{\rho N\bar{N}}^{(1)}/f\rho) \; + \\
+ \sum_{v=\rho',\rho''} \frac{(W_o - W_v)(W_o - W_v^*)(W_o + W_v)(W_o + W_v^*)}{(W - W_v)(W - W_v^*)(W + W_v)(W + W_v^*)} (f_{VN\bar{N}}^{(1)}/fv) \Bigg]
\end{aligned}
\tag{20b}
$$

$$
\begin{aligned}
F_2^s[V(t)] = \left(\frac{1-V^2}{1-V_o^2}\right)^6 \Bigg[\sum_{s=\omega,\varphi} \frac{(V_o - V_s)(V_o - V_s^*)(V_o - 1/V_s)(V_o - 1/V_s^*)}{(V - V_s)(V - V_s^*)(V - 1/V_s)(V - 1/V_s^*)} (f_{SN\bar{N}}^{(2)}/f_s) \; + \\
+ \frac{(V_o - V_{\varphi'})(V_o - V_{\varphi'}^*)(V_o + V_{\varphi'})(V_o + V_{\varphi'}^*)}{(V - V_{\varphi'})(V - V_{\varphi'}^*)(V + V_{\varphi'})(V + V_{\varphi'}^*)} (f_{\varphi' N\bar{N}}^{(2)}/f_{\varphi'}) \Bigg]
\end{aligned}
\tag{20c}
$$

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

$$\left. + \sum_{v=\rho',\rho''} \frac{(W_o - W_v)(W_o - W_v^*)(W_o + W_v)(W_o + W_v^*)}{(W - W_v)(W - W_v^*)(W + W_v)(W + W_v^*)} (f^{(2)}_{vN\bar{N}}/f_v) \right] \qquad (20d)$$

The model then depends on the following 26 parameters $t^s{}_{inel}$, $t^v{}_{inel}$, m_s, Γ_s, $f^{(1)}_{SN\bar{N}}/f_s, f^{(2)}_{SN\bar{N}}/f_s$, $(s = \omega, \varphi, \varphi')$, m_v, Γ_v, $f^{(1)}_{VN\bar{N}}/f_v, f^{(2)}_{VN\bar{N}}/f_v$ $(v = \rho, \rho', \rho'')$. This number reduces to 22 on account of the conditions

$$\sum_{s=\omega,\varphi,\varphi'} (f^{(1)}_{SN\bar{N}}/f_s) = \frac{1}{2} \qquad \sum_{s=\omega,\varphi,\varphi'} (f^{(2)}_{SN\bar{N}}/f_s) = \frac{1}{2}[\mu_p + \mu_n]$$

$$\sum_{v=\rho,\rho''} (f^{(1)}_{VN\bar{N}}/f_v) = \frac{1}{2} \qquad \sum_{v=\rho,\rho''} (f^{(2)}_{VN\bar{N}}/f_v) = \frac{1}{2}[\mu_p - \mu_n] \qquad (21)$$

which follow from the normalizations

$$F_1^s(0) = \frac{1}{2} \qquad F_2^s(0) = \frac{1}{2}[\mu_p + \mu_n]$$

$$F_1^v(0) = \frac{1}{2} \qquad F_2^v(0) = \frac{1}{2}[\mu_p - \mu_n] . \qquad (22)$$

Eq. (22), in turn, follows from

$$F_1^p(0) = \frac{1}{2} \qquad F_2^p(0) = \mu_p$$

$$F_1^n(0) = 0 \qquad F_2^n(0) = \mu_n . \qquad (23)$$

The parameters of the model are fixed in a simultaneous fit of proton and neutron form factors in the region $t < 0$. Using these parameters one extrapolates the model easily to the time-like region. Since all contributing resonances are in the unphysical region $0 < t < 4\,M^2$, we fix their widths at the world averaged values. Then from the analysis [9] of 387 experimental points using eq. (20), the remaining parameters of the model are found to have the values

$\chi^2/NDF = 560/387$ $\quad t^s_{inel} = 1.078\ GeV^2$, $\quad t^v_{inel} = 1.036\ GeV^2$

$m_\varphi = 1037 \pm 2$ MeV $\qquad m_\rho = 720 \pm 39$ MeV

$m_{\varphi'} = 14.04 \pm 16$ MeV $\qquad m_{\rho'} = 1315 \pm 15$ MeV

$m_{\rho''} = 1410 \pm 48$ MeV

$f^{(1)}_{\omega N\bar{N}}/f_\omega = 0.91 \pm 0.04$ $\qquad f^{(1)}_{\rho N\bar{N}}/f_\rho = 0.22 \pm 0.03$

$f^{(1)}_{\varphi N\bar{N}}/f_\varphi = -0.59 \pm 0.06$ $\qquad f^{(1)}_{\rho'' N\bar{N}}/f_{\rho''} = -1.84 \pm 0.18$

$f^{(2)}_{\omega N\bar{N}}/f_\omega = -1.08 \pm 0.02$ $\qquad f^{(2)}_{\rho N\bar{N}}/f_\rho = -1.90 \pm 0.03$

$f^{(2)}_{\varphi N\bar{N}}/f_\varphi = 2.09 \pm 0.04$ $\qquad f^{(2)}_{\rho'' N\bar{N}}/f_{\rho''} = 0.63 \pm 0.22$

The ratios of coupling constants calculated using eq. (21) have the values

$f^{(1)}_{\varphi' N\bar{N}}/f_{\varphi'} = 0.18$ $\qquad f^{(1)}_{\rho' N\bar{N}}/f_{\rho'} = 2.12$

$f^{(2)}_{\varphi' N\bar{N}}/f_{\varphi'} = -1.07$ $\qquad f^{(2)}_{\rho' N\bar{N}}/f_{\rho'} = -0.68$

The comparison of our model with data is carried out in Fig. 4. The numerical comparison of $|G^p_E|$, $|G^p_M|$ with $|G^n_E|$, $|G^n_M|$, above the threshold $t \approx 4\ M^2$ is shown in Table I.

TABLE I

$t(GeV^2)$	$\lvert G^p_E\rvert$	$\lvert G^n_E\rvert$	$\lvert G^p_M\rvert$	$\lvert G^n_M\rvert$
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

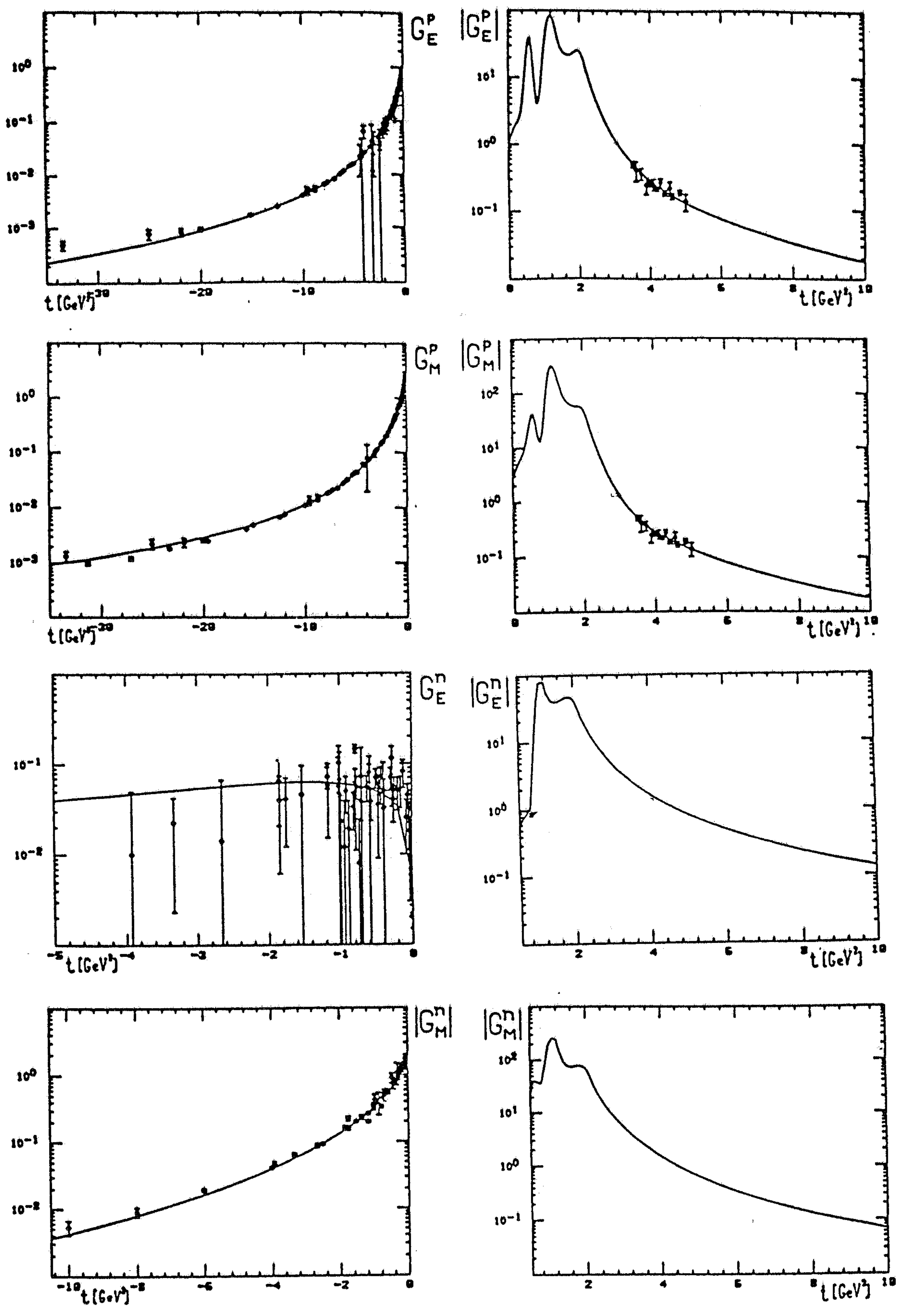

FIG. 4 - The description of the proton and neutron em. ff data by the VMD model.

From this table one finds that

$$|F^n(t)| \cong 5 \cdot |F^p(t)| \qquad (25)$$

and consequently

$$\sigma(e^+e^- \to n\bar{n}) \approx 25 \cdot \sigma(e^+e^- \to p\bar{p}). \qquad (26)$$

The FENICE experiment in Frascati will soon be able to test predictions such as eq. (26).

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