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A One-Paramenter Fit to the Electromagnetic Form Factors of the Nucleon (*).

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Summary. — A new fit to the world data on (ep) and (en) elastic scattering, and on ($\bar{\text{p}}$p) annihilation into lepton pairs, has been obtained by using a model for the isovector and isoscalar nucleon form factors, which is suggested by the use of unitary symmetry and of its breaking. The fit allows for a nonpointlike behaviour of one out of the two couplings which enter in the expression for nucleon electromagnetic form factors. The fit is a one-parameter fit and the corresponding values of χ^2 for the proton and neutron data are discussed. The contributions coming from the possible existence of « core-terms » and of « q^2-dependent background » in the expression of the nucleon electromagnetic form factors are found to be lower than a few per cent. The q^2 dependence of the vector-meson-nucleon couplings is also discussed.

1. – Introduction.

In trying to fit the experimental data on proton and neutron electromagnetic form factors using polelike formulae (1), the general trend followed so far has basically been to use the masses of the vector-meson resonances known from experiments, and to determine from the best fit the coefficients a_i, b_i, c_i, d_i

(*) A preliminary version of this work has been presented at the *International Conference on Elementary Particles*, Oxford, October 1965 (see ref. (12)).

(1) E. Clementel and C. Villi: *Nuovo Cimento*, **4**, 1207 (1958); M. Gell-Mann and F. Zachariasen: *Phys. Rev.*, **124**, 953 (1961).

(see eq. (1)), with which the pole terms pertaining to these resonances appear in the expression of the form factors (*), *i.e.*

$$(1)\qquad \begin{cases} F_1^p(q^2) = \sum_i \dfrac{a_i}{1 + q^2/m_i^2}\,, \\ F_2^p(q^2) = \sum_i \dfrac{b_i}{1 + q^2/m_i^2}\,, \\ F_1^n(q^2) = \sum_i \dfrac{c_i}{1 + q^2/m_i^2}\,, \\ F_2^n(q^2) = \sum \dfrac{d_i}{1 + q^2/m_i^2}\,, \end{cases}$$

where the index i should run from 1 to 3 because there are at present only three vector mesons (ρ, ω, φ) with the correct quantum numbers to contribute to the electromagnetic structure of the nucleon (**).

The physical meaning of the coefficients a_i, b_i, c_i, d_i is that of a product of pairs of coupling constants: i) a vector-meson–photon coupling constant and ii) a vector-meson–nucleon coupling constant as indicated in Fig. 1.

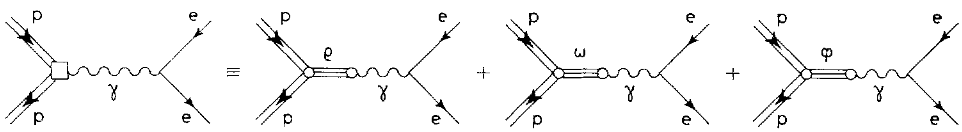

Fig. 1. – Feynman diagram relative to the electromagnetic form factors of the proton. The proton-photon coupling is the result of six couplings for the Dirac form-factor $F_1^p(q^2)$, $a_1 \equiv$ (ρ-meson proton coupling) $\times$ (ρ-meson photon coupling), $a_2 \equiv$ (ω-meson proton coupling) $\times$ (ω-meson photon coupling), $a_3 \equiv$ (φ-meson proton coupling) $\times$ (φ-meson photon coupling), and of another six couplings for the Pauli form-factor $F_2^p(q^2)$. Analogously for the neutron. Therefore, a typical coefficient a_i, b_i, c_i or d_i appearing in formulae (1) must be understood as the product of a pair of coupling constants, as indicated above.

If symmetries higher than the isospin exist, then these coefficients should be correlated. As is well known, even complete freedom in the choice of these coefficients is not enough to obtain a fit if only the three existing vector-meson masses are used. In order to get a fit for the isovector form factors, some

(*) Polelike formulae have been written for the F and also for the G form factors. The considerations which we will make for the F's may be applied in an analogous way to the G's.

(**) The widths of these vector mesons in the expressions of the nucleon form factors (1) are neglected because their contribution to the imaginary part of the F's is negligible in the physical timelike region. Our F's will therefore always be real functions.

authors (²) introduce another, so far unobserved, vector meson which they call ρ', while others (³) prefer to keep a unique ρ but use a mass value lower than the observed one. Furthermore, all the above-mentioned fits (*) neglect the consequences of the $(\omega\varphi)$ mixing in the isoscalar from factors.

One purpose of this paper is to point out that the theoretical predictions of the unitary-symmetry approach to particle physics and of its breaking allow the prediction of the structure of the isovector and isoscalar form factors without any freedom left for the choice of these coefficients, either in relative magnitude or phase (**). Obviously, no vector meson other than the three known ones (ρ, ω, φ) with the correct masses, may be included in this picture.

Under these conditions, it is impossible to obtain an acceptable fit.

Notice that eqs. (1), and consequently all fits which have been tried so far (²⁻⁴), imply that both the « vector-meson–photon » and the « vector-meson–nucleon » interactions are pointlike, *i.e.* the coefficients a_i, b_i, c_i, d_i have no q^2 dependence. While it seems that the first assumption is probably not far from the truth (⁵), we do not have any reason to believe that the second assumption is at all followed by nature.

In our fit we will permit the possibility of a nonpointlike interaction and let the fit show the deviations from pointlike interaction of these two couplings. Obviously, we cannot discriminate which is which, as in the form factors these couplings appear in a product form, but it is now possible to get a fit to the nucleon form factors using only the three known vector-meson resonances and all restrictions dictated by the unitary symmetry and its breaking.

2. – Explicit formulation of the form factors.

In the limit of validity of SU_3 symmetry, all form factors would be degenerate. However, we know that SU_3 is broken in nature. The most simple assumption is that this breaking will show up in the nucleon form factors in the same way

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(²) J. R. DUNNING jr., K. W. CHEN, A. A. CONE, G. HARTING, N. F. RAMSEY, J. K. WALKER and R. WILSON: *Phys. Rev. Lett.*, **13**, 631 (1964); B. DUDELZEK: Orsay Thesis, L.A.L. 1127 (11 May, 1965).

(³) E. B. HUGHES, T. A. GRIFFY, M. R. YEARIAN and R. HOFSTADTER: *Phys. Rev.*, **139**, B 458 (1965); T. JANSSENS, R. HOFSTADTER, E. B. HUGHES and R. YEARIAN: *Phys. Rev.*, **142**, B 922 (1966). These authors also add « core » terms.

(*) For the most recent set of fits with and without cores, with and without extra poles see L. H. CHAN *et al.* (⁴).

(⁴) L. H. CHAN, K. W. CHEN, J. R. DUNNING jr., N. F. RAMSEY, J. K. WALKER and R. WILSON: *Phys. Rev.*, **141**, B 1298 (1966).

(**) Obviously, the validity of « polelike formulae » of type (1) is assumed.

(⁵) J. K. DE PAGTER, J. I. FREEMAN, G. GLASS, R. C. CHASE, M. GETHNER, E. VON GOELER, R. WEINSTEIN and A. M. BOYARSKI: *Phys. Rev. Lett.*, **16**, 35 (1966).

as it has shown up in the other branches of particle physics, namely through a splitting of the three vector-meson masses and through the ($\omega\varphi$) mixing. As is well known, the physical ω and φ are believed to be mixtures [6] of a pure SU_3 singlet ω_1 and a pure eighth component of an SU_3 octet ω_8, according to

$$\omega = \sin\theta\cdot\omega_8 + \cos\theta\cdot\omega_1 \qquad (m_\omega = 782\ \text{MeV}),$$
$$\varphi = -\cos\theta\cdot\omega_8 + \sin\theta\cdot\omega_1 \qquad (m_\varphi = 1019\ \text{MeV}),$$

where θ is the ($\omega\varphi$) mixing angle.

If, as is generally believed, the electromagnetic current is contained in an SU_3 octet, then the electromagnetic field couples only to ω_8 and not to ω_1. Moreover, there is a definite relation between the coupling of the electromagnetic field to the isovector ρ and to the isoscalar ω_8 mesons, *i.e.*

$$C_{\omega_8\gamma} = \frac{1}{\sqrt{3}}\, C_{\rho\gamma}\,.$$

The electromagnetic couplings of the three vector mesons ρ, ω, φ are therefore related as follows:

$$C_{\omega\gamma} = \frac{1}{\sqrt{3}}\, C_{\rho\gamma}\cdot\sin\theta\,,$$
$$C_{\omega\gamma} = -\frac{1}{\sqrt{3}}\, C_{\rho\gamma}\cdot\cos\theta\,,$$

and it is possible to express the electromagnetic couplings of the three vector mesons as a function of only one $C_{\rho\gamma}$.

The coupling of ω_8 and ρ to the baryon is of two types, f and d [7]. It may be shown that the following coefficients specify the relative importance of the sovector-nucleon and isoscalar-nucleon couplings:

$(f+d)$ $\equiv$ strength of the coupling of the ρ meson with baryons,

$\left(\sqrt{3}f - \dfrac{1}{\sqrt{3}}d\right)$ $\equiv$ strength of the coupling of the ω_8 meson with baryons.

If d_S is the strength of the coupling of the SU_3 singlet ω_1 to the baryons, then

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([6]) J. J. SAKURAI: *Phys. Rev. Lett.*, **9**, 472 (1962); S. L. GLASHOW: *Phys. Rev. Lett.*, **11**, 48 (1963). Some consequences of an ω-μ mixing on the electromagnetic form factors have been considered in a pure Clementel-Villi model by W. ALLES and S. BERGIA: *Nuovo Cimento*, **31**, 262 (1964); and F. COLEMAN and H. J. SCHNITZER: *Phys. Rev.*, **134**, B 863 (1964). We thank Dr. S. BERGIA for calling our attention to these papers.

([7]) M. GELL-MANN: C.T.S.L. 20 (1961) (unpublished); Y. NE'EMAN: *Nucl. Phys.*, **26**, 222 (1961).

the physical mesons ρ, ω, φ have the following couplings to the baryons:

$$g_{\omega\mathcal{N}} = \sin\theta\cdot\sqrt{3}[f-\tfrac{1}{3}d]+\cos\theta\cdot d_S\,,$$
$$g_{\varphi\mathcal{N}} = -\cos\theta\cdot\sqrt{3}[f-\tfrac{1}{3}d]+\sin\theta\cdot d_S\,.$$

In the nonet model of OKUBO [8] (*) the mixing angle θ is predicted to be 35° and also the coupling of the SU_3 singlet to the baryons is given in terms of d to be

$$d_S = 2\sqrt{\tfrac{2}{3}}\,d\,.$$

Having made these premises, we may now write the isovector form factors F_1^S, F_2^S and the isoscalar form factors F_1^V, F_2^V:

$$F_1^S(q^2)=\left\{\left(f_1-\frac{1}{3}\,d_1\right)\left(\frac{\sin^2\theta}{1+q^2/m_\omega^2}+\frac{\cos^2\theta}{1+q^2/m_\varphi^2}\right)+\left(\frac{2}{3}\sqrt{2}\cdot d_1\cdot\cos\theta\cdot\sin\theta\right)\cdot\right.$$
$$\left.\cdot\left(\frac{1}{1+q^2/m_\omega^2}-\frac{1}{1+q^2/m_\varphi^2}\right)\right\}C_{\rho\gamma}\,,$$

$$F_2^S(q^2)=\left\{\left(f_2-\frac{1}{3}\,d_2\right)\left(\frac{\sin^2\theta}{1+q^2/m_\omega^2}+\frac{\cos^2\theta}{1+q^2/m_\varphi^2}\right)+\left(\frac{2}{3}\sqrt{2}\cdot d_2\cdot\cos\theta\cdot\sin\theta\right)\cdot\right.$$
$$\left.\cdot\left(\frac{1}{1+q^2/m_\omega^2}-\frac{1}{1+q^2/m_\varphi^2}\right)\right\}C_{\rho\gamma}\,,$$

$$F_1^V(q^2)=(f_1+d_1)\left(\frac{1}{1+q^2/m_\rho^2}\right)C_{\rho\gamma}\,,$$

$$F_2^V(q^2)=(f_2+d_2)\left(\frac{1}{1+q^2/m_\rho^2}\right)C_{\rho\gamma}\,.$$

The crucial point to notice now is that a deviation from pointlike coupling in the electromagnetic and strong interactions of the vector mesons implies that

$$C_{\rho\gamma}\,,\quad f_1\,,\quad d_1\,,\quad f_2\,,\quad d_2\,,$$

must all be q^2-dependent functions. If for each of these strong couplings we were to assume a different q^2 dependence, we would have a large number of free parameters to adjust, so we will take the most simple choice, namely that

$$f_1\,,\quad d_1\,,\quad f_2\,,\quad d_2\,,$$

([8]) S. OKUBO: *Phys. Lett.*, **5**, 165 (1963).

(*) This model finds a very natural explanation in symmetries higher than SU_3 as, for example, SU_6: see T. K. KUO and TSU YAO ([9]).

([9]) T. K. KUO and TSU YAO: *Phys. Rev. Lett.*, **13**, 415 (1964).

must all have the same q^2 dependence to be determined by the best fit, and that the vector-meson–photon interaction has a similar q^2 dependence.

The function which is the simplest and the most popularly used to describe deviation from pointlike interactions is of the form

$$\frac{1}{1+q^2/\Lambda^2}\,,$$

where Λ^2 is the parameter which characterizes the deviation from a pointlike interaction ($\Lambda=\infty$ means pointlike interaction). In our formulae we will use

a parameter Λ_S for the strong couplings,

and

a parameter Λ_γ for the electromagnetic couplings.

If we re-define

$$C_{\rho\gamma}\,,\quad f_1\,,\quad f_2\,,\quad d_1\,,\quad d_2\,,$$

to be the values of the coupling constants at $q^2=0$, the isoscalar and the isovector form factors of the nucleon will take the form

$$(2)\quad\left\{\begin{aligned}
F_1^S(q^2) &= \left\{\frac{(f_1-\frac{1}{3}d_1)}{(1+q^2/\Lambda_S^2)}\left(\frac{\sin^2\theta}{1+q^2/m_\omega^2}+\frac{\cos^2\theta}{1+q^2/m_\varphi^2}\right)+\right.\\
&\quad\left.+\frac{2}{3}\sqrt{2}\,\frac{d_1}{(1+q^2/\Lambda_S^2)}\cos\theta\cdot\sin\theta\left(\frac{1}{1+q^2/m_\omega^2}-\frac{1}{1+q^2/m_\varphi^2}\right)\right\}\frac{C_{\rho\gamma}}{1+q^2/\Lambda_\gamma^2}\,,\\
F_2^S(q^2) &= \left\{\frac{(f_2-\frac{1}{3}d_2)}{(1+q^2/\Lambda_S^2)}\left(\frac{\sin^2\theta}{1+q^2/m_\omega^2}+\frac{\cos^2\theta}{1+q^2/m_\varphi^2}\right)+\right.\\
&\quad\left.+\frac{2}{3}\sqrt{2}\,\frac{d_2}{(1+q^2/\Lambda_S^2)}\cos\theta\cdot\sin\theta\left(\frac{1}{1+q^2/m_\omega^2}-\frac{1}{1+q^2/m_\varphi^2}\right)\right\}\frac{C_{\rho\gamma}}{(1+q^2/\Lambda_\gamma^2)}\,,\\
F_1^V(q^2) &= \frac{(f_1+d_1)}{(1+q^2/\Lambda_\rho^2)}\left(\frac{1}{1+q^2/m_\rho^2}\right)\left(\frac{C_{\rho\gamma}}{1+q^2/\Lambda_\gamma^2}\right),\\
F_2^V(q^2) &= \frac{(f_2+d_2)}{(1+q^2/\Lambda_S^2)}\left(\frac{1}{1+q^2/m_\rho^2}\right)\left(\frac{C_{\rho\gamma}}{1+q^2/\Lambda_\gamma^2}\right).
\end{aligned}\right.$$

So far, we have used the old-fashioned Dirac and Pauli form factors $F_1^{S,V}$ and $F_2^{S,V}$, and have postulated a polelike form for these functions. The experimental data are more easily analysed if use is made of the so-called Sachs form factors [10]

$$G_E^S(q^2)\,,\quad G_E^V(q^2)\,,\quad G_M^S(q^2)\,,\quad G_M^V(q^2)\,,$$

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[10] D. R. YENNIE, M. M. LEVY and D. G. RAVENHALL: *Rev. Mod. Phys.*, **29**, 144 (1957); F. J. ERNST, R. G. SACHS and K. C. WALI: *Phys. Rev.*, **119**, 1105 (1960); R. G. SACHS: *Phys. Rev.*, **126**, 2256 (1962).

which can be written in terms of $F_1^{S,V}$ and $F_2^{S,V}$, *i.e.*

$$G_E^{S,V} = F_1^{S,V}(q^2) - \frac{q^2}{4M^2} F_2^{S,V}(q^2) ,$$

$$G_M^{S,V} = F_1^{S,V}(q^2) + F_2^{S,V}(q^2) ,$$

where M is the nucleon mass and S and V stand for « isoscalar » and « isovector », respectively, while q^2 is the invariant four-momentum transfer which in our notation is negative in the timelike region.

3. – Curve fitting and results.

An advantage in starting with polelike formulae for the F's and then deriving the G's lies in the fact that we automatically get the conditions

$$G_E^{S,V} = G_M^{S,V} \qquad \text{at} \qquad q^2 = -4M^2,$$

which must be fulfilled if we do not want to violate space isotropy.

The four conditions at $q^2 = 0$, which give the charge and magnetic moments of the proton and neutron, fix the values of the products

$$C_{\rho\gamma} f_1 , \quad C_{\rho\gamma} f_2 , \quad C_{\rho\gamma} d_1 , \quad C_{\rho\gamma} d_2 .$$

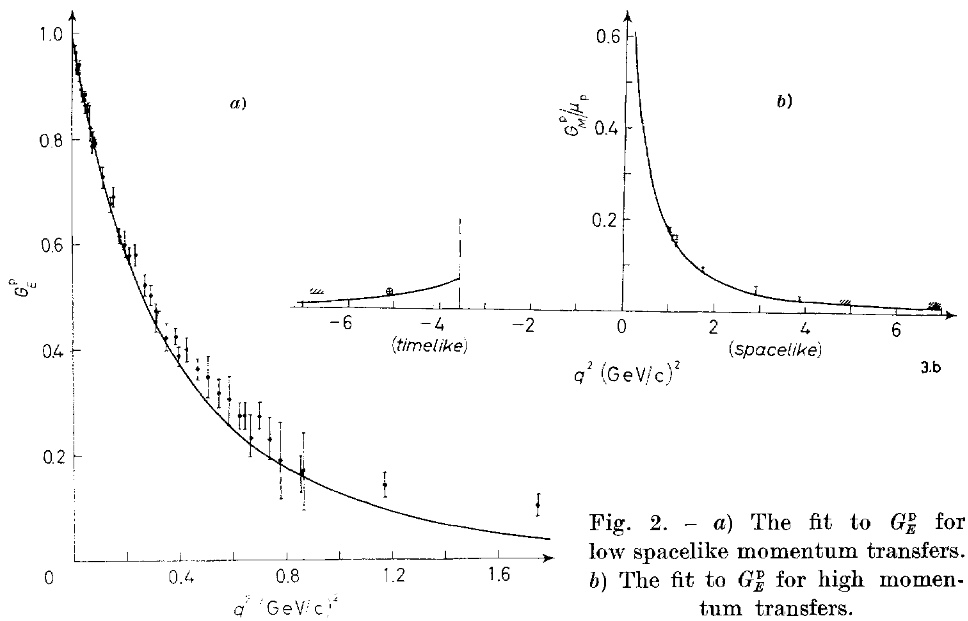

Fig. 2. – *a*) The fit to G_E^p for low spacelike momentum transfers. *b*) The fit to G_E^p for high momentum transfers.

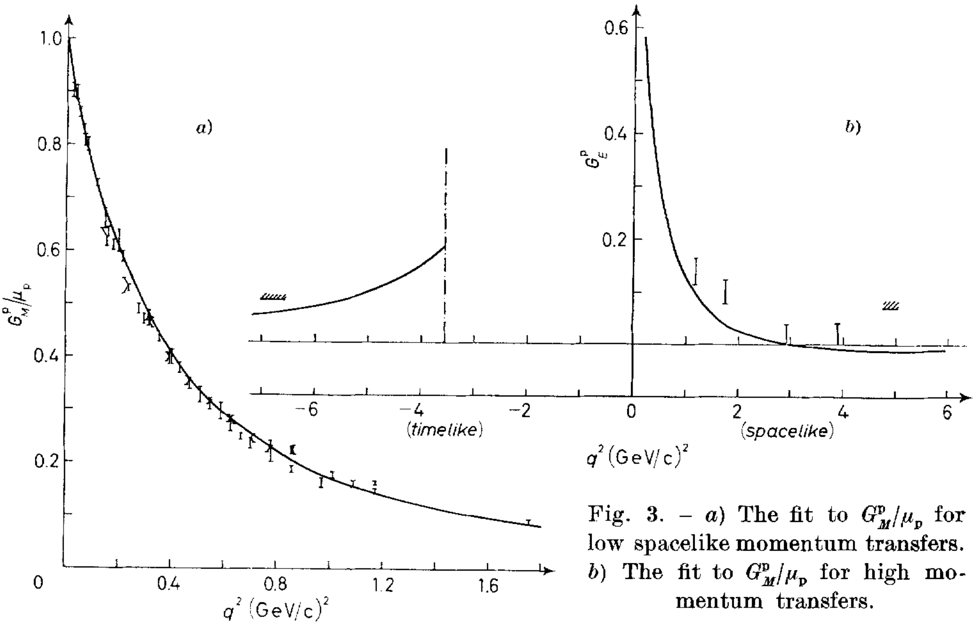

Fig. 3. – a) The fit to G^p_M/μ_p for low spacelike momentum transfers. b) The fit to G^p_M/μ_p for high momentum transfers.

As mentioned earlier, the vector-meson–photon interaction is probably not far from being pointlike ([5]); furthermore, the ($\omega\varphi$) mixing angle is theoretically predicted ([8]) to be $\theta = 35°$. If these two data are assumed, then there remains only one free parameter Λ_S, *i.e.* the parameter which characterizes the deviation of the vector-meson–nucleon interaction from a pointlike behaviour. The possibility of fitting the electron-nucleon scattering data and the data on the antiproton-proton annihilation into lepton pairs ([11]) with only one free parameter has already been pointed out ([12]).

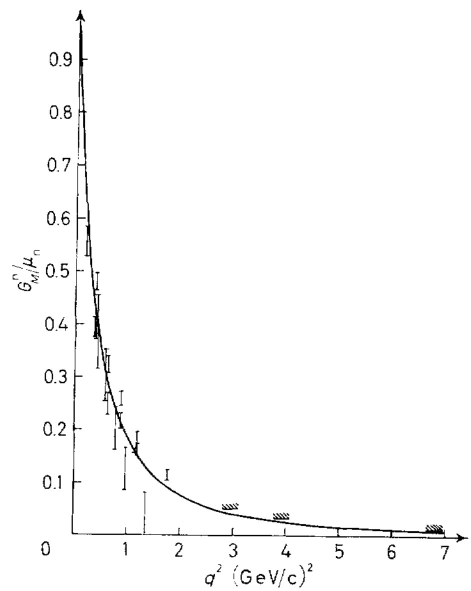

Fig. 4. – The fit to G^n_M/μ_n for spacelike momentum transfers.

([11]) M. CONVERSI, T. MASSAM, TH. MULLER and A. ZICHICHI: *Nuovo Cimento*, **40**, 690 (1965).

([12]) T. MASSAM and A. ZICHICHI: *A new fit to the form factors of the proton and the neutron*, in *Proc. Int. Conf. on Elementary Particles*, Oxford (1965), p. 80.

The fitting procedure adopted is to obtain a least-squares fit of the proton form factors to their experimental values in order to obtain Λ_S, and then to use this value for predicting the neutron form factors which are compared with the experimental values. This procedure is followed because the proton data appear to be more reliable than the neutron data, which must, of course, be deduced from the results of electron-deuteron scattering experiments.

The results of this curve fitting and the experimental points ([13]) are shown in Fig. 2 to 5, and the principal features of the fit are summarized below.

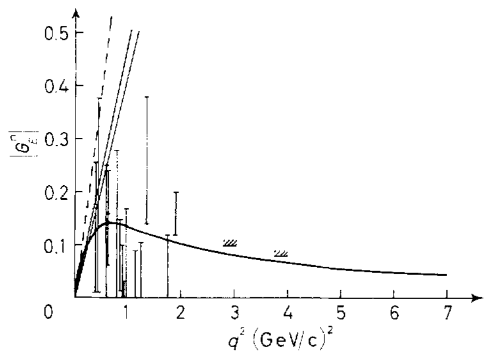

Fig. 5. – The fit to $|G_E^n|$ for spacelike momentum transfers. The solid straight lines represent the limits of error of the measurement of the initial slope by KROHN and RINGO ref. ([13,ii]), and the broken line is the value predicted by this fit. Both the measured and predicted slopes of G_E^n have the same (positive) sign.

3·1. *Fixed input data.*

$$G_E^p(q^2=0) = 1\,, \qquad m_\rho = 765\ \text{MeV}\,,$$

$$G_E^n(q^2=0) = 0\,, \qquad m_\omega = 783\ \text{MeV}\,,$$

$$G_M^p(q^2=0) = 2.79\,, \qquad m_\varphi = 1020\ \text{MeV}\,,$$

$$G_M^n(q^2=0) = -1.91\,,$$

$$(\omega\varphi)\ \text{mixing angle},\ \theta = 35^\circ\,,$$

$$\Lambda_\gamma = \infty\ \text{MeV}.$$

([13]) The data were taken from the following sources: i) *Electron-nucleon scattering*, *a*) C. AKERLOF, K. BERKELMAN, G. ROUSE and M. TIGNER: *Phys. Rev.*, **135**, B 810 (1964); *b*) D. BENAKSAS: *Thesis*, Orsay (1964); *c*) D. J. DRICKEY and L. N. HAND: *Phys. Rev. Lett.*, **9**, 521 (1962); *d*) B. DUDELZAK: *Thesis*, Orsay (1965); *e*) J. R. DUNNING jr., K. W. CHEN, A. A. CONE, G. HARTWIG, N. F. RAMSEY, J. K. WALKER and R. WILSON: *Phys. Rev. Lett.*, **13**, 631 (1964); *f*) D. FREREJACQUE: *Thesis*, Orsay (1964); *g*) T. JANSSENS, E. B. HUGHES, M. R. YEARIAN and R. HOFSTADTER: *Phys. Rev.*, **142**, 922 (1966); *h*) P. STEIN, R. W. MCALLISTER, B. D. MCDANIEL and W. M. WOODWARD, *Phys. Rev. Lett.*, **9**, 403 (1962); *i*) C. DE VRIES, R. HOFSTADTER, A. JOHANSSON and R. HERMAN: *Phys. Rev.*, **134**, B 848 (1964); *j*) D. YOUNG and J. PINE: *Phys. Rev.*, **128**, 1842 (1962). ii) *Initial slope of* $G_E^n(q^2)$, V. E. KROHN and G. R. RINGO: *Phys. Lett.*, **18**, 297 (1965). iii) *Proton-antiproton annihilation into lepton pairs,* The limit given at $-$ 6.8 (GeV/c)^2 momentum transfer is the combined limit of the CERN experiment

3·2. *Results.*

$\Lambda_S \qquad = (980 \pm 18)$ MeV.

χ^2 (proton data) $= 222$ with 96 degrees of freedom.

χ^2 (neutron data) $= 310$ with 38 degrees of freedom.

χ^2 (neutron data) $= 77.5$ with 37 degrees of freedom.

$\left(\text{excluding } \left.\frac{\partial G_E^n}{\partial q^2}\right|_{q^2=0}\right)$

4. – Discussion and conclusions.

The χ^2 values quoted above do not appear to be very satisfactory.

In order to investigate the origin of these high χ^2 values and hence the validity of our model, we have plotted in Fig. 6, 7, 8 and 9 the differences between the values predicted by our fit and the experimental ones. These differences show that a considerable contribution to the χ^2 values probably comes from inconsistencies in the experimental data. The first conclusion we can draw from this analysis (Fig. 6 to 9) is that the maximum contribution of

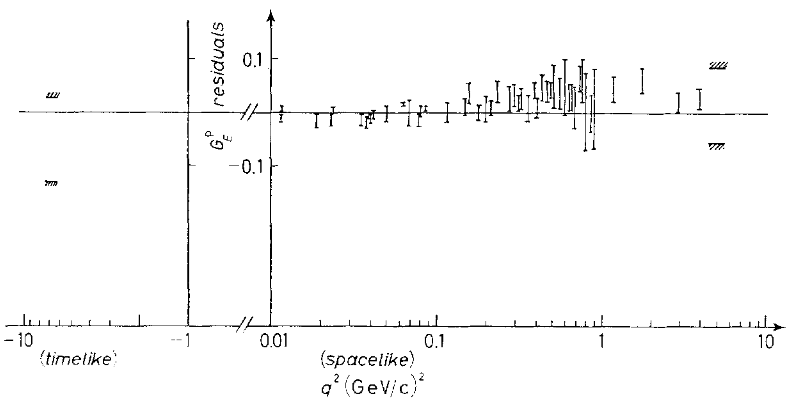

Fig. 6. – The residuals (observed values minus calculated values) for G_E^p.

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ref. ([11]) on ($\bar{p}p$) annihilation into electron or muon pairs with the Brookhaven (A. Tollestrup *et al.*, private communication) results on annihilation into electron pairs. In evaluating this point, G_E was assumed equal to G_M. The result at -5.7 (GeV/c)^2 is the result given by the one event found by Tollestrup *et al.* (private communication), and is based on the assumption that $G_E = 0$.

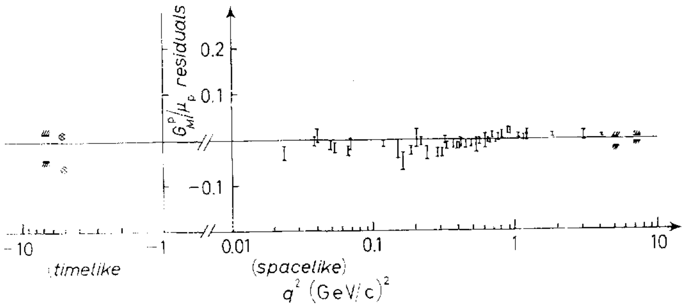

Fig. 7. – The residuals (observed values minus calculated values) for G_M^p in units of μ_p.

either a « core term » or a « q^2-dependent background » in the expressions of the nucleon form factors can never exceed a level of $\sim 5\%$ in the spacelike region.

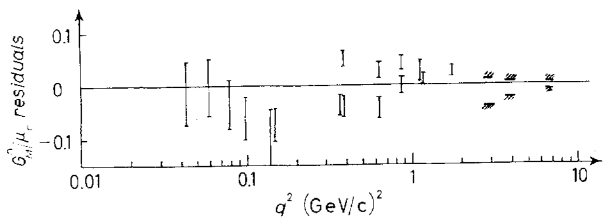

Fig. 8. – The residuals (observed values minus calculated values) for G_M^n in units of μ_p.

In conclusion we may say that it is possible to make a very simple model for the electromagnetic form factors of the nucleon, using only the three known

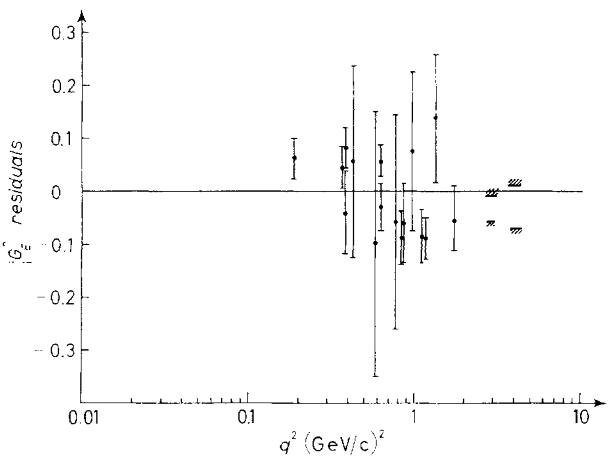

Fig. 9. – The residuals (observed values minus calculated values) for $|G_E^n|$.

vector mesons and what we may consider to be our present knowledge of the unitary symmetry and of its breaking. After the experimental values of the charges and magnetic moments of the nucleons have been used in this model, there remains only one unknown parameter, whose value is obtained as the best fit to all existing data on «electron-proton» and «electron-neutron» elastic scattering, and on «proton-antiproton annihilation into lepton pairs».

The physical significance of the model and of the result obtained for Λ_S is that the vector-meson–nucleon helicity flip and helicity nonflip isoscalar and isovector couplings have a unique q^2 dependence of the form

$$\frac{1}{1+q^2/\Lambda_S^2}\,,$$

where Λ_S is about equal to 1 GeV.

In the near future it will be possible to make an experimental verification of all these conclusions.

* * *

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RIASSUNTO

Si è ottenuta una nuova approssimazione ai dati universali sullo scattering elastico (ep) e (en) e sulla annichilazione ($\bar{p}p$) in coppie di leptoni, facendo uso di un modello per i fattori di forma isovettoriali ed isoscalari del nucleone, suggerito dall'uso della simmetria unitaria e della sua infrazione. L'approssimazione tiene conto del comportamento non puntiforme di uno dei due accoppiamenti che entrano nell'espressione dei fattori di forma elettromagnetici del nucleone. L'approssimazione è ad un solo parametro e si discutono i corrispondenti valori di χ^2 per i dati dei protoni e dei neutroni. Si trova che i contributi derivanti dalla possibile esistenza di «core terms» e di «un fondo dipendente da ϱ^2» nell'espressione dei fattori di forma elettromagnetici del nucleone sono inferiori ad alcuni percento. Si discute anche la dipendenza da q^2 dell'accoppiamento mesone vettoriale-nucleone.