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1) Recent results on the elastic scattering of electrons show that the proton has an hard core in which part of its charge is concentrated. It seems reasonable to expect that this feature of the structure of the nucleons will manifest itself also in their weak interactions with high momentum transfer, in reactions of the kind:

$$\bar{\nu} + p \rightarrow n + e^{+} \qquad \text{1)}$$
$$\nu + n \rightarrow p + e^{-}$$

These processes have been investigated in a precedent letter.(1-2) Under the assumptions specified in I the differential cross sections for these processes were found (I, 7, 8) to depend essentially on three form factors F_1, F_2, H_1, functions of the momentum transfer k^2. These were supposed to be connected to the electromagnetic form factors of the nucleon through the relations:

$$F_1(k^2) = F_1^{V}(k^2) \qquad \text{2)}$$

$$F_2(k^2) = F_2^{V}(k^2) \qquad \text{3)}$$

$$H_1(k^2) = \frac{G_A}{G} F_1^{V}(k^2) \qquad \text{4)}$$

F_1^V and F_2^V are the form factors for the isotopic vector part of the charge and anomalous magnetic moment of the nucleon. While 2) and 3) are consequences of the hypothesys of conservation of the vector current in β interaction, 4) is a reasonable guess.

Experimental evidence at that time favored an exponential distribution for the density of both charge and magnetic moment of the nucleon, giving:

5) $$F_1^V(k^2) \approx F_2^V(k^2) \approx \left(1 + \frac{k^2}{a^2}\right)^{-2}$$

The total cross section for processes (1) thus evaluated (see I) increases at low energy with the square of the center of mass energy, but levels off, at $\mathcal{E} \approx a$, to a limiting value σ_∞ ($\approx 0.75\ 10^{-38}\mathrm{cm}^2$, if $a^2 \approx 37.5\ \mu_\Pi^2$).

The new data on the proton form factors(3) show that while the magnetic form factor falls to zero more rapidly than expected from eq. (5), the charge form factor levels off to a plateau value of ≈ 0.42. On the basis of eq. 2-4 we expect a similar behaviour to be exhibited also by the form factors F_1, F_2, H_1.

This will produce a substantial modification of the quantitative results of I. In fact in the processes we are considering the decrease of the differential cross section with increasing momentum transfer is only due to the decrease of the form factors of the nucleon. In the case of the scattering of electrons, on the contrary, high momentum transfers are already depressed by the propagator of a virtual photon, which introduces a factor $(k^2)^{-2}$ in the cross section.

2) The differential cross section in the laboratory system for production of $e^\pm$ through processes (1) is given by (I,7,8).

If one uses (2-4), it can be written:

$$\frac{d\sigma^{\pm}}{d\cos\theta} = \frac{G^2 \mathcal{E}^2}{\pi}\left(1+\frac{2\mathcal{E}}{M}\sin^2\frac{\theta}{2}\right)^{-3}\left\{\cos^2\frac{\theta}{2}\left(F_1^V(k^2)\right)^2 + \right.$$

$$+\frac{k^2}{4M^2}\left[2\left(F_1^V(k^2)+\mu F_2^V(k^2)\right)^2 \operatorname{tg}^2\frac{\theta}{2}+\mu^2\left(F_2^V(k^2)\right)^2\right]\Big\} + \qquad 6)$$

$$+\left(\frac{G_A}{G}F_1^V(k^2)\right)^2\left[1+\sin^2\frac{\theta}{2}+2\,\frac{\mathcal{E}^2}{M^2}\,\frac{\sin^4\frac{\theta}{2}}{1+2\frac{\mathcal{E}}{M}\sin^2\frac{\theta}{2}}\right]+$$

$$\mp\frac{G_A}{G}F_1^V(k^2)\left(F_1^V(k^2)+\mu F_2^V(k^2)\right)\frac{4\sin^2\frac{\theta}{2}}{1+2\frac{\mathcal{E}}{M}\sin^2\frac{\theta}{2}}\left(\frac{\mathcal{E}}{M}+\frac{\mathcal{E}^2}{M^2}\sin^2\frac{\theta}{2}\right)\Big\}$$

Where $\mathcal{E}$ is the neutrino energy, θ the angle of emission of the electron, M the nucleon mass. We have tabulated this expression for different neutrino energies as a function of cos θ, making use of two different sets of values for the form factors F^V:(4)

Set α equation 5) was used with $a^2 = 37.5\ \mu_\pi^2$

Set β the F^V were assumed to coincide with the form factors of the proton as given in(3); for high momentum transfer F_1^V was assumed to reamain at a constant value.

In fig. 1) we show the differential cross section at $\mathcal{E} = 1.84$ M. Set β has a substantial tail at large angles. Table 1) gives the total cross section at various energies; set β gives higher cross section, which increase linearly with the energy $\mathcal{E}$.

We must remark that set β implies an extrapolation of the present knowledge of the nucleon structure to regions of higher momentum transfers, which is perhaps unrealistic, being equivalent to the assumption of a pointlike nucleon core. These results, however, stress the fact tha the behaviour of the cross section for processes (1) are strongly dependent on the nucleon form factors for high momentum transfer, and that conversely from these processes we can gain information on features of the nucleon, such as the radius of its core, which are as yet unknown.

We thank dr. Maria Petilli, who helped in the numerical calculations.

References

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(2) B. Pontecorvo, JEPT 37, 1751 (1959); T.D. Lee and C.N. Yang, Phys. Rev. Lett. 4, 307, 1960; Y. Yamaguchi, Progr. Theor. Phys. 23, 1117, (1960). See also G. Bernardini, Proceedings of the 1960 Annual International Conference on High Energy Physics at Rochester, 581.

(3) R. Hofstadter, F. Bumiller, M. Croissiaux, Phys. Rev. Lett. 5, 263 (1960)

(4) For both sets, $G_A/G = 1.21$; $\mu = 3.7$.

$\mathcal{E}/M$	set α		set β	
	$\sigma_\nu \times 10^{38}$	$\sigma_{\bar{\nu}} \times 10^{38}$	$\sigma_\nu \times 10^{38}$	$\sigma_{\bar{\nu}} \times 10^{38}$
0.43	0.60	0.15	0.60	0.15
0.62	0.75	0.22	0.75	0.22
0.89	0.925	0.29	0.865	0.31
1.28	0.845	0.38	1.024	0.44
1.84	0.832	0.46	1.31	0.60
2.66	0.81	0.53	1.68	0.81
3.83	0.79	0.56	2.48	0.97
5.52	0.76	0.59	3.69	1.72

Table 1 - Total cross section for processes (1) at different neutrino energies, in cm^2.

Caption to figure 1):
Differential cross section in the laboratory system for the process $\nu + n \rightarrow p + e^-$ at a neutrino energy $\mathcal{E} = 1.84$ M.

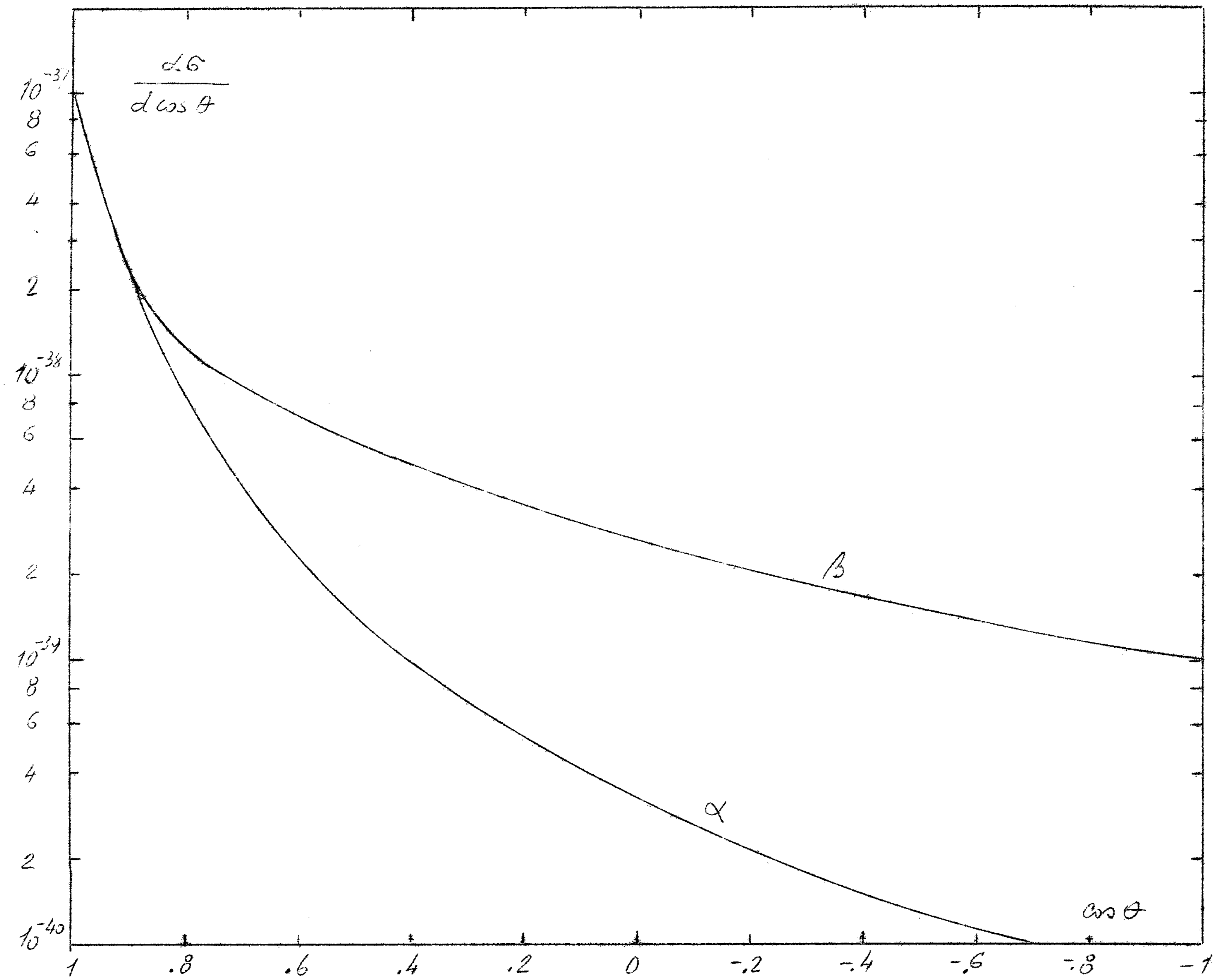
$\frac{d\sigma}{d\cos\theta}$
10^{-37}
8
6
4
2
10^{-38}
8
6
4
2
10^{-39}
8
6
4
2
10^{-40}
β
α
cos θ
1
.8
.6
.4
.2
0
-.2
-.4
-.6
-.8
-1

FIG. 1