mass distribution is indicative of the existence of another $T=0$ vector meson, called $\varphi$. If this proves to be correct, the observed states $\omega$ (780 MeV) and $\varphi$ (1020 MeV) may well be mixtures of a $T=0$ vector meson belonging to a unitary octet with another $T=0$ vector meson which represents a unitary singlet. In this case, our estimates for the decay rates and the relations between the different partial widths connected with the $\rho\omega\pi$ vertex, will be affected. A quantitative analysis of this effect at the present stage of experimental knowledge seems to be premature.

Finally, we add a remark on the other strong decay of $\rho$, namely, $\rho\rightarrow 4\pi$. It could well be that this transition proceeds mainly through the $\omega\rho\pi$ vertex, i.e., $\rho^{+,-,0}\rightarrow(\omega)+\pi^{+,-,0}\rightarrow(\pi^{+}+\pi^{0}+\pi^{-})+\pi^{+,-,0}$. This would imply that the $\pi^{+}+\pi^{-}+2\pi^{0}$ configuration is prevalent in the $\rho^{0}\rightarrow 4\pi$ decay. The knowledge of $f_{\rho\omega\pi}$ would allow us to estimate the partial width of the decay. A reported experimental limit is[29]

$$(\rho^{+}\rightarrow\pi^{+}+\pi^{0}+\pi^{-}+\pi^{+})/(\rho^{+}\rightarrow\pi^{+}+\pi^{0})<5\%.$$

## ACKNOWLEDGMENTS

The author would like to thank Professor L. M. Brown and Professor W. W. Wada for helpful discussions and to thank also Professor W. W. Wada for his careful reading of the manuscript.

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PHYSICAL REVIEW VOLUME 130, NUMBER 6 15 JUNE 1963

# Energy Dependence of Proton Electromagnetic Form Factors

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(Received 13 February 1963)

A $\chi^2$ analysis of electron-proton scattering is made to test for the energy dependence of the form factors, in the Regge pole form, using the slope of the pole as a parameter. It is found that the form factors can tolerate considerable energy dependence. However, decisive conclusion regarding such an energy dependence has to await the data at higher energies.

In the light of the discussion of the photon as a Regge pole by Blankenbecler, Cook, and Goldberger[1] a reanalysis of the proton-electron scattering data is made here.

The cross section for the $p$-$e$ scattering via a single photon exchange is given in terms of the charge form factor $F_1(q^2)$ and momentum form factor $F_2(q^2)$ by the Rosenbluth formula:

$$\frac{d\sigma}{d\Omega}=\frac{e^2}{4(4\pi)^2E_0{}^2}\frac{\cos^2(\theta/2)}{\sin^4(\theta/2)}\frac{1}{1+(2E_0/M)\sin^2(\theta/2)}\times\left\{F_1{}^2-\frac{q^2}{4M^2}[2(F_1+2MF_2)^2\tan^2(\theta/2)+(2MF_2)^2]\right\},$$

where

$$q^2=-\{[2E_0\sin(\theta/2)]^2/[1+(2E_0/M)\sin^2(\theta/2)]\},$$

$E_0$= incident energy and $\theta$= scattering angle of the electron in the laboratory system.

Fifty-three pieces of data for the cross section and probable errors are taken from Bumiller, Croissiaux, Dally, and Hofstadter,[2] out of a total of fifty-eight pieces, five being discarded on the basis that they do not lie on a smooth curve. The discarded pieces are

| | Energy (MeV) | Angle (degree) |
|---|---|---|
| 1. | 700 | 135 |
| 2. | 700 | 145 |
| 3. | 850 | 135 |
| 4. | 850 | 145 |
| 5. | 900 | 75 |

The two-pole formula for the two form factors which has been found adequate for $p$-$e$ and $n$-$e$ scattering data by Hofstadter, de Vries, and Herman[3] was tried first and $\chi^2$ was calculated.

$$F_1=e[1+A_1q^2/(q^2+A_5)+A_2q^2/(q^2+A_6)],$$
$$F_2=1.79(e/2M)[1+A_3q^2/(q^2+A_5)+A_4q^2/(q^2+A_6)],$$

where $M$= nucleon mass.

$$\chi^2=\sum[(d\sigma/d\Omega|_{\exp}-(d\sigma/d\Omega|_{\mathrm{calc}})/\Delta(d\sigma/d\Omega)]^2,$$

where $\Delta(d\sigma/d\Omega)$= standard deviation.

The fit is considered to be good if $\chi^2\leq N-n$, where $N$= total number of pieces of data = 53 in the present case, $n$= number of parameters used.

The values of parameters $A_i$ $(i=1,6)$ given by Hof-

[1] R. Blankenbecler, L. F. Cook, and M. L. Goldberger, Phys. Rev. Letters **8**, 463 (1962).

[2] F. Bumiller, M. Croissaux, E. Dally, and R. Hofstadter, Phys. Rev. **124**, 1623 (1961).

[3] C. de Vries, R. Hofstadter, and Robert Herman, Phys. Rev. Letters **8**, 381 (1962).

stadter *et al.*[3] gave a $\chi^2$ of 134.7, which does not satisfy the criterion of a good fit to the *p-e* data alone. On minimizing the $\chi^2$ with respect to the parameters, the minimum $\chi^2$ was found to be 24.57 with parameters $A_1=-0.494$, $A_2=-0.482$, $A_3=-0.0157$, $A_4=-1.141$, $A_5=-17.05$, and $A_6=-15.66$.

It is to be noted that this may not be the best fit yet, since $\chi^2$ is a very complicated function of the parameters and, hence, there are a large number of extremum values.

An attempt was then made to improve the fit by introducing an energy dependence of the Regge form in the form factors.

$$\bar{F}_1=F_1(q^2)\times(z_t)^{\alpha' t},$$
$$\bar{F}_2=F_2(q^2)\times(z_t)^{\alpha' t},$$

where the "Regge slope" $\alpha'$ is an unknown parameter, and

$$z_t=2[ME_0+q^2/2]/[(4M^2-q^2)(4m_e^2-q^2)]^{1/2}.$$

The minimum $\chi^2$ for the same 53 pieces of data was 22.71 with the parameter values $A_1=-0.375$, $A_2=-0.455$, $A_3=0.056$, $A_4=-1.284$, $A_5=-20.26$, $A_6=-14.81$, and $\alpha'=0.0141$.

It is seen that the fit is not much improved by introducing the energy dependence in the form factors but that the form factors can withstand a considerable energy dependence corresponding to the value of $\alpha'$ given above.

The above analysis would be more meaningful in terms of the photon as a Regge pole for higher energy data which may soon be available. It is, however, understood that there is an energy dependence not only due to the possible Regge-pole character of the photon but also due to higher order exchanges as discussed by Frautschi[4] and Lévy.[5] In any case the slope $\alpha'$ is used here only as a phenomenological parameter. It gives a convenient measure of the energy dependence of form factors for high-energy scattering.


## ACKNOWLEDGMENT

It is a pleasure to thank Professor David Wong for his constant guidance through the work.


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PHYSICAL REVIEW VOLUME 130, NUMBER 6 15 JUNE 1963

# *K*-Leptonic Decay and Partially Conserved Currents†

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(Received 7 February 1963)

An operational definition for the partial conservation of the strangeness-changing vector current is given and applied to leptonic $K^+$ and $K_2^0$ decay. The $K^*$ resonance is explicitly included in the calculation and quantitative agreement with experiment is obtained. A detailed comparison with the $K^+$ data of Brown *et al.* and Dobbs *et al.* is given. Because of rapid variations of a form factor, it is found that the data of these two groups are not in contradiction. From the $K_2^0$ experiment of Luers *et al.*, $I=\frac{1}{2}$ and $\frac{3}{2}$ currents are seen to exist. $\Lambda\beta$ decay is briefly considered. It is found that an explanation for the slowness of $K$ leptonic decay and the vector part of $\Lambda\beta$ decay may be connected with the partial conservation of the strangeness-changing vector current.

## I. DETERMINATION OF A THEORY FOR LEPTONIC *K* DECAY

ONE of the outstanding problems in the theory of weak interactions consists of finding a unifying principle for the strangeness changing and nonstrangeness changing decays. Attempts to use a universal Fermi interaction or to generalize the idea of a conserved nonstrangeness changing vector current have not been fruitful in the sense that an understanding of the experimental data has not been obtained.[1] Furthermore, the ideas developed in attempting to explain the striking success of the Goldberger-Treiman formula in $\pi-\mu\nu$ decay[2] have not been carried over successfully into the theory of $K$ decays.[3] Many of the present difficulties may well stem from our inability to give operational definitions to such concepts as a "partially conserved current" and "universal interaction." In an attempt to sharpen our understanding of these terms, we have considered the leptonic decays of the $K^+$.

The assumption is made that the $K^+\rightarrow l^++\nu+\pi^0$ interaction is of the vector form, in which case we may

† This work was supported in part by the U. S. Atomic Energy Commission, and an IBM Fellowship.
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