range field (range κ^{-1}) besides the electromagnetic field. As the implicit equation for m: $W=mc^2$ would lead to $\kappa^{-1}\sim 10^{-68}$ cm, a quite unfamiliar value, while, moreover, it will turn out below that this relation would lead to inconsistencies with respect to further applications of the theory, we consider W as a perturbation compared with mc^2. The circumstance that the electron mass thus is essentially "mechanical" must be considered as a fundamental implication of the non-unitarity of the theory.

For all Kemmer types of fields (charged or neutral) one can introduce an interaction depending only on the meson field wave functions ("f-interaction") and one depending only on the first derivatives of these functions ("g-interaction"). By generalizing an argument due to Weisskopf[2] it can be shown that, in a development with respect to $(\text{charge})^2/hc$, f-interactions lead to logarithmic (log) divergences only, to any order of approximation. g-interactions yield in first approximation a quadratic (qu) and a log divergence.[3]

The introduction of a "subtractive" short range vector field with f-interaction, similar to Bopp's classical endeavor,[4] appears to yield a finite W (to any order of approximation) if the "convergence relation" $e^2=f^2$ is satisfied (e = electric charge, f = charge of the electron due to its coupling with the short range field). It can be shown that this convergence relation, like all other convergence relations mentioned in this note, is relativistically invariant. However, subtractive fields are incompatible with a stable vacuum distribution of electrons as required by hole theory. Thus they have to be discarded within the present interpretation of hole theory.

The further investigation of convergence relations has been confined to the first approximation, the question whether they also hold in higher approximations is still an open one. For a scalar f-coupling it has been found that

$$e^2=\tfrac{1}{2}f^2, \tag{1}$$

and that $W\ll mc^2$ if κ^{-1} is roughly $\approx r_0$, the classical electron radius.

b. NUCLEONS

In the wave equation of nucleons we put the mass term equal to βMc^2, i.e., we do not *a priori* distinguish between the proton mass M_P and the neutron mass M_N. The term $\Delta = M_P - M_N$ appears *a posteriori* in the theory as a self-energy term.

For an arbitrary set of meson fields responsible for nuclear interaction, the convergence relations are for the

$$\text{proton}\begin{cases} e^2+L=0 \\ Q=0 \end{cases} \qquad \text{neutron}\begin{cases} L=0 \\ Q=0 \end{cases}. \tag{2}$$

The L-(Q-)relations are necessary to eliminate the log (qu) divergences. Clearly the L-relations for proton and neutron are incompatible. Compatibility is obtained, however, if the proton, like the electron, also is assumed to create a scalar "f-field"—in accordance with the requirement of f-charge conservation applied to $N\rightarrow P+e^-+n$, etc. For then (2) becomes $e^2-\frac{1}{2}f^2+L=0$ or $L=0$, in virtue of (1).

Δ can now (at any rate in first approximation) be computed as the sum of electromagnetic and f-self-energy of the proton. One finds $\Delta=-1.25m$ if $\kappa^{-1}=r_0$, or $\Delta=-1.90m$ if $\kappa^{-1}=3r_0$: Δ has the right sign and order of magnitude if a reasonable value of κ is adopted. It should be stressed that the assumption $W=mc^2$ for the electron leads to grave inconsistencies with respect to Δ.

The discussion of $L=0$, $Q=0$ reveals that none of the most habitual meson theories of nuclear forces yields finite self-energies. As examples of theories which do lead to finite W (at any rate in first approximation) we mention: Hulthén's pseudoscalar-scalar theory[5] and the set of fields proposed by Møller and Rosenfeld, again combined with a scalar field. In both cases this scalar field (which from the point of view of convergence plays a similar role as the f-field but should not be confused with it) is neutral and its range considerably shorter than that of the other meson fields. It is tempting to identify this field with the neutral interaction of very short range that, according to Hulthén,[6] should be introduced to interpret the angular distribution of high speed neutrons by protons.

It appears that the nucleon self-energies are always $\ll Mc^2$. Thus *all quantum field self-energies are perturbations compared to the corresponding mechanical masses.*

Finally two consequences of the f-field hypothesis may be mentioned: according to (1) the Coulomb potential of the hydrogen atom is modified to

$$-\frac{e^2}{r}(1-2e^{-\kappa r}),$$

yielding a hydrogen S-level shift of

$$\Delta\nu(nS)\approx\frac{8\alpha^6}{n^3}\cdot\frac{1}{\kappa^2 r_0^2}\cdot\frac{mc}{\hbar}\ \text{cm}^{-1},\quad \alpha=\frac{1}{137}.$$

The shift for $n=2$ reported by Williams-Pasternack[7] is obtained for $\kappa^{-1}=2.5\,r_0$. Further the f-quanta are unobservable as their life-time in the rest system is (cf. (1))

$$\frac{1}{2\alpha\kappa c}\sim 10^{-21}\ \text{sec}.$$

Full details will be given in a paper, "On the Theory of Elementary Particles," the publication of which has been delayed considerably by war circumstances and which will appear as soon as practicable.

1 Pryce, Proc. Roy. Soc. **A159**, 355 (1937).
2 V. F. Weisskopf, Phys. Rev. **56**, 72 (1939).
3 The calculations of W by Kemmer, Proc. Roy. Soc. **A166**, 127 (1938), have appeared to be incorrect.
4 Bopp, Ann. d. Physik **38**, 345 (1940); **42**, 575 (1943); cf. also A. Landé and L. H. Thomas, Phys. Rev. **60**, 121, 514 (1940).
5 Hulthén, Fysiogr. Sellsk. Lund **14**, 2 (1944).
6 Hulthén, Arkiv Mat. Astr. og Fys. **29a**, no. 33 (1943).
7 Williams, Phys. Rev. **54**, 558 (1938); Pasternack, ibid. **54**, 1113 (1938).

Width of Resonance Process in Boron (11)

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AN attempt was made to determine the true width of the resonance process of the long range alpha-particles from the first of the alternate reactions

$$B^{11}+H^1\rightarrow Be^8+He^4,$$
$$\rightarrow 3\ He^4.$$

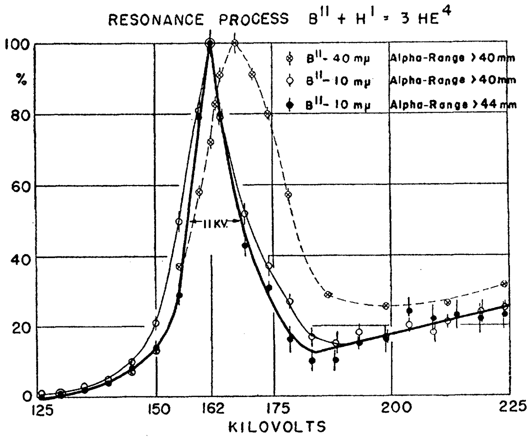

FIG. 1.

The present data are offered in corroboration of the data of Kanne, Taschek, and Ragan[1] on the position of the resonance peak, and of Jacobs and Whitson[2] on the shape of the yield curve. Data on the width of the resonance are offered, in which constancy of the voltage is not a factor. (Figure 1.)

The resistance controlled transformer-kenotron condenser set[3] was used to supply voltage up to 225 kilovolts. Ripple of approximately 4.5 kilovolts[4] was reduced to about 100 volts by loading the set with five condensers of capacity 0.5 mf each, tapped onto the potential divider. Voltage was monitored manually with a deviation of less than ± 1 kilovolt. Voltage was measured with a high resistance voltmeter, calibrated in sections with the aid of a potentiometer and standard cell to an accuracy of 0.5 percent.

Targets were of boron (11), on a polished copper button, prepared by Hoff Lu[5] with a high intensity mass spectrograph. One target had boron deposited to a thickness of 10 millimicron (mμ) and another a thickness of 40 mμ. Heating of the targets, as recommended by Bowersox,[6] prevented deposition of carbon on the 10 mμ target. The 40 mμ target had some abuse before the present experiment, but no further deposition occurred after it was heated. Thus, the yield curves remained constant during the course of the experiment.

Alpha-particles were observed at 90°, with the targets at a 45° angle. A shallow ionization chamber was used. Observations were made at ranges of 40 and 44 millimeters to make certain the long range alpha-particles appearing at energies of over 180 kilovolts could not be accounted for by the slight increase in range of the continuous group of alpha-particles from the second alternate reaction due to the greater kinetic energy of the bombarding protons. That the two curves for 40 and 44 millimeters range agree settles this point. Slight deviations are noted, however, in the region of 175 kilovolts.

The yield curves indicate, as shown by Jacobs and Whitson, a sharp resonance superimposed on an exponentially increasing background. The theoretical aspects of this phase of the problem have been discussed by Wheeler.[7]

The proton energy required at the resonance peak is 162 ± 1 kilovolts. This value agrees with that of Kanne, *et al.* (163 ± 6 kilovolts). Other values given have varied from 159 to 165 kilovolts. Higher values than these have been shown to be in error because of deposition of carbon on the targets.

The experimental half-width at half-maximum of the resonance for the 10-mμ target is 5.5 kilovolts. This width cannot be a broadening of the resonance due to variation in the voltage. Ripple was 100 volts, and variation in voltage for other reasons was held to ± 1 kilovolt. Half-width for the 40-mμ target is 10.5 kilovolts. This agrees with the value of 1.6 kilovolts for the stopping power of the 10-mμ target. The third factor in the experimental broadening of the resonance is the presence of scratches in the polished copper button. Heidenreich and Matheson[8] have utilized the electron microscope for the study of polished steel surfaces. They have demonstrated the presence of scratches of depth 13–50 mμ. The presence of such scratches would give an apparent thickness to the target which would readily account for the observed width of the resonance. It seems reasonable to conclude, therefore, that the width of the resonance is considerably less than the minimum measured width.

[1] W. R. Kanne, R. F. Taschek, and G. L. Ragan, Phys. Rev. **58**, 693 (1940).
[2] J. A. Jacobs and W. L. Whitson, Phys. Rev. **A59**, 108 (1941).
[3] J. H. Williams, W. H. Wells, J. T. Tate, and E. L. Hill, Phys. Rev. **51**, 434 (1937).
[4] J. S. Allen, R. O. Haxby, and J. H. Williams, Phys. Rev. **A53**, 325 (1938).
[5] Hoff Lu, unpublished.
[6] R. B. Bowersox, Phys. Rev. **55**, 323 (1939).
[7] J. A. Wheeler, Phys. Rev. **59**, 27 (1941).
[8] R. D. Heidenreich and L. A. Matheson, J. App. Phys. **15**, 423 (1944).

Electron Beams in Strong Magnetic Fields

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IN a recent paper,[1] Brillouin derives some types of electron flow in beams and states several conclusions. It should be emphasized that these conclusions do not apply to beams derived from a cathode of finite size located in the magnetic field unless the cathode is everywhere parallel to the magnetic field.

Consider, for instance, a circular disk cathode and axially symmetrical accelerating electrodes, the whole system immersed in a strong uniform magnetic field perpendicular to the cathode. Assuming no component of electric field in the θ direction we have from the angular momentum equation

$$\dot{\theta}=\frac{\omega_0}{2}(1-(r_0/r)^2). \qquad (1)$$

Here $\omega_0=(e/m)B$ and r_0 is the radius at which the electron leaves the cathode. We have also

$$\ddot{r}-r\dot{\theta}^2=-(e/m)E_r-\omega_0 r\dot{\theta}. \qquad (2)$$

Here E_r is the radial field, which may be due to space charge or to the accelerating voltages applied to the electrodes.