## A Measurement of the Electron-Neutron Interaction

M. Hamermesh, G. R. Ringo, and A. Wattenberg*
*Argonne National Laboratory, Chicago, Illinois*
(Received December 10, 1951)

We have remeasured the electron-neutron interaction, using the method developed by Fermi and Marshall.[1] In this method the ratio of intensities of scattered thermal neutrons at 45° and 135° is measured. This ratio is given by,

$$\frac{d\sigma(45°)}{d\sigma(135°)}=1+\frac{2ba}{(\sigma_s/4\pi)}\left[\left(\int nFd\lambda\right)_{45°}-\left(\int nFd\lambda\right)_{135°}\right], \quad (1)$$

Table I. Observed and calculated data.

| Gas | Run | Average 45°/135° | Center-of-gravity motion factor[a] | Width of beam at center of chamber, inches | Angular spread of incident beam | $e-n$ scattering amplitude, cm | $e-n$ well depth, ev | |
|---|---|---|---|---|---|---|---|---|
| Argon | 1 | 1.0781 ±0.0038 | 1.0705 | 3.32 | ±2.04° | | | |
| | 2 | 1.0610 ±0.0019 | | 3.32 | ±2.04° | | | |
| Krypton | 1 | 1.0218 ±0.0005 | 1.0335 | 3.32 | ±2.04° | | | |
| | 2 | 1.0294 ±0.0008 | | 2.35 | ±1.28° | $-1.87\times10^{-16}$ | 5020 (±13%) | |
| | 3 | 1.0293 ±0.0012 | | 1.40 | ±0.60° | | | |
| Xenon | 1 | 1.0095 ±0.0003 | 1.0213 | 3.32 | ±2.04° | | | 4100 (±10%) |
| | 2[b] | 1.0103 ±0.0012 | | 3.32 | ±2.04° | | | |
| | 3 | 1.0185 ±0.0012 | | 2.10 | ±0.91° | $-1.06\times10^{-16}$ | 2860 (±16%) | |
| | 4 | 1.0124 ±0.0021 | | 1.40 | ±0.60° | | | |

[a] Gas temperature = 27°C, neutron temperature = 36°C.
[b] Gas pressure ½ atmosphere.

where $b$ is the electron-neutron scattering amplitude, $a$ is the coherent nuclear scattering amplitude, $\sigma_s$ is the total nuclear scattering cross section, $F$ is the atomic form factor of the monatomic scattering gas, and $n$ is the wavelength distribution of the neutrons. If one describes the interaction in terms of a rectangular potential well whose radius is the classical electron radius, the measured $b$ determines the depth $V$ of this well. Fermi and Marshall obtained $V=300\pm5000$ ev.

Our experiment differed from the original experiment in the following ways:

1. Instead of one counter at 45° and one at 135° to the beam, two were used at each angle, placed symmetrically with respect to the beam. This has the effect of canceling small errors in the alignment of the apparatus.
2. The scattering was measured in krypton as well as xenon in order to check on systematic errors, and in argon to check on the correction for center-of-gravity motion.
3. The statistical accuracy was improved by using longer counts and higher neutron fluxes. Counting rates were between 500 and 5000 per minute.
4. The effect of angular spread of the beam on the measured 45°/135° ratio was eliminated by reducing the angular beam spread until the ratio approached a constant value. This can be seen in the data on Kr given in Table I. In the case of Xe, where the statistics are not so good, the second change is in the opposite direction to the first, indicating that we are not dealing with a geometrical effect since the geometrical correction is a monotonic function of the beam divergence.

In order to calculate $b$, it is necessary to know the value of the coherent amplitude $a$. Since $a$ has never been measured for Kr and Xe, we assumed $a=0.90(\sigma_s/4\pi)^{\frac{1}{2}}$. For 90 percent of the elements with several important isotopes for which $a$ has been measured,[2] this estimate is within 12 percent of the measured value. In addition, in the case of Kr, where nearly 75 percent of the material is in the form of even-even isotopes of small thermal neutron capture cross section, it is almost certain that the assumption is within 12 percent of correct, since all such isotopes show small incoherence.

The errors given in Table I are those obtained from the fluctuations in the ratios in the series of five to ten measurements in each run. They are not much larger than the statistical errors to be expected from the total number of counts. Our value for the potential well depth is $V=4100\pm1000$ ev, where about 500 ev of the uncertainty is the result of statistics and the remainder is our estimate of systematic errors caused mainly by our uncertainty about the coherent amplitude. This value is in reasonable agreement with the value $V=5300\pm1000$ ev obtained by Havens, Rainwater, and Rabi.[3] An attempt will be made to improve our statistical accuracy and to measure the coherent amplitudes involved.

We are indebted to T. R. Robillard and D. Meneghetti for help in constructing the equipment and taking the data.

* Now at Laboratory of Nuclear Science and Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts.

[1] E. Fermi and L. Marshall, Phys. Rev. **72**, 1139 (1947).
[2] C. G. Shull and E. O. Wollan, Phys. Rev. **81**, 527 (1951).
[3] Havens, Rainwater, and Rabi, Phys. Rev. **82**, 345 (1951).

## Self-Energies of Nucleons and the Mass Spectra of Heavy Particles

H. Enatsu
*Department of Physics, Kyoto University, Kyoto, Japan*
(Received December 12, 1951)

In recent articles[1] we have arrived at the conclusion that, in order to remove the divergences of self-energies of nucleons caused by $\pi$-mesons for which a symmetrical pseudoscalar field with pseudovector couplings was assumed, it would seem natural to introduce heavy mesons ($C'$ mesons, briefly) which would be of the symmetrical scalar type with vector coupling. It was shown further that the mass of the latter might be about 1470 times larger than that of the electron. At that time this conclusion was drawn mainly on the basis of the descriptions of the observations by Powell *et al.*[2] and others.[3] The recent developments in cosmic-ray experiments, however, seem to show the presence of heavy particles of masses different from that of the $C'$ meson mentioned above.

In this note we would like to show that it is possible to modify our models in a favorable direction by the simple assumption that the observed $V_1$-particles[4] are elementary particles obeying Dirac's equation and that they interact with the nucleons and $C'$ mesons. The interaction Lagrangian density is of the form

$$L=i(f_2/\mu_0)\bar{\psi}_N\gamma_\mu\bar{\psi}_{V_1}\partial\phi_{C'}/\partial x_\mu+\text{c.c.}, \quad (1)$$

where the notation of $I$ (see note 1) is retained. We have confined ourselves in dealing with the lowest order approximation to