## Derivation of the Formula for the Cross Section for Formation of High Energy Neutrons in Deuteron-Nuclei Collisions

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SOMEWHAT prior to the appearance of Serber's article,[1] we suggested that the formation of a narrow beam of neutrons upon interaction of high energy deuterons with matter, was due to the stripping of deuterons colliding with atomic nuclei. We derive here the formula for the effective cross section for the formation of neutrons by the stripping reaction; this was set forth in an unpublished report[2].

The formation of a neutron by stripping will of course take place every time that the proton in the deuteron interacts with the nuclear surface, while the neutron is outside the nuclear force radius. Let $R$ be the nuclear radius, and $d$ be average distance between the neutron and the proton of the deuteron. We shall call $r$ the distance between the neuteron and the point at which the $pn$ (proton-neutron) line intersects the nucleus. Let $\theta$ be the angle between the $x$-axis (the $x$-axis is drawn from the center of the nucleus through the point where the $pn$ line intersects the nuclear surface) and the $pn$ direction; the cross section for formation of neutrons for given values of $\theta$, $r$, and $R \gg r$ is then:

$$\sigma_{r\theta} = \pi(\rho^2 - R^2) \approx 2\pi Rr\cos\theta,$$

$$\rho^2 = R^2 + r^2 - 2Rr\cos(\pi - \theta) \approx R^2 + 2Rr\cos\theta.$$

The average cross section for neutron formation for a given $r$ and arbitrary $\theta$ is:

$$\sigma_r = \frac{1}{2\pi}\int\limits_0^{\Omega\max}\sigma_{r\theta}d\Omega \approx \frac{1}{2\pi}\int\limits_0^{\pi/2} 2\pi Rr\cos\theta\, 2\pi\sin\theta d\theta = \pi Rr,$$

$$\Omega_{\max} \approx \pi/2 - (d-r)/2\pi R,$$

where $d\Omega = 2\pi\sin\theta d\theta$ is the solid angle formed by a change in the deuteron direction from $\theta + d\theta$. The average cross section for neuteron formation for arbitrary $\theta$ and $r$ is found the formula:

$$\sigma = \frac{1}{d}\int\limits_0^d \sigma_r dr = \frac{\pi}{2}Rd;$$

this is the effective cross section which we were seeking.

[1] R. Serber, Phys. Rev **72**, 1008 (1947).
[2] V. S. Anastasevich, Otchet Akad. Nauk SSSR (Nov., 1947).

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## Possible Correlations in $\pi$-$\mu$-$e$ Decay

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LEE and Yang[1] have recently shown that if parity is violated in $\pi$-$\mu$-$e$ decay, there must be correlations between the orientations of the momenta of the $\mu$-mesons and the electrons. We present here the results of computations of such correlations when parity is violated in both the $\pi \to \mu + \nu$ decay and the $\mu \to e + 2\nu$ decay.

The interaction leading to $\pi$-meson decay has the form:

$$H_\pi = f\varphi_\pi\overline{\psi}_\nu(1 + \alpha\gamma_5)\psi_\mu. \tag{1}$$

The coefficient $\alpha$ characterizes here the degree of violation of parity conservation. The probability that during the decay of $\pi$-meson, a $\mu$-meson will be emitted with momentum **n** and spin **s** is given by

$$\frac{dW_\pi}{d\Omega} = \frac{f^2}{16\pi}\left\{(1 + |\alpha|^2)\left(1 + \frac{m^2 - \mu^2}{m^2 + \mu^2}\right) + (\alpha + \alpha^*)(\mathbf{ns})\right\}$$

$$\times\frac{(m^2 - \mu^2)^2(m^2 + \mu^2)}{m^5} = u_1 + u_2(\mathbf{ns}), \tag{2}$$

where $m$ is the mass of $\pi$-meson and $\mu$ the mass of the $\mu$-messon. Expression (2) indicates that the $\mu$-meson is longitudinally polarized. It may be shown that if $\alpha = 1$, the $\mu$-meson is completely polarized in the rest system of the $\mu$-meson.

Let us consider now the decay of a $\mu$-meson at rest. The interaction for this process has the form

$$H_\mu = \sum_1^5 g_i(\overline{\psi}_\mu(1 + \alpha_i\gamma_5)O_i\psi_e)(\psi_\nu O_i\psi_\nu). \tag{3}$$

If the two neutrinos which appear during the decay of the $\mu$-meson are identical, then it is well known that $g_2 = g_3 = 0$. Applying Lenard's method[2], one obtains the following expression for the angular dis-