cathode that the phase of $i_f(r)$ does not vary with depth, so that the cathode can be considered two dimensional. Thus if the cathode is so small that the phase of $i_f(r)$ is practically constant everywhere on its surface, the amplitude of the beat frequency component of the total current I_f from the cathode is proportional to the area of the cathode, and the power activating the resonant cavity (Fig. 1, reference 2) is proportional to the square of the area. If the cathode is large, its surface can be subdivided into small regions of area $\sim\lambda^2/\Omega$ (defined below), in each of which the phase of i_f is constant, while the resultant currents I_f from separate regions are random in phase. In this case the total power activating the cavity is proportional to the number of subdivisions, i.e., to the area of the cathode.

These qualitative results are borne out by a more rigorous evaluation, using the exact phases at various points on the cathode. It should be emphasized that the received signal at the cavity increases with increasing cathode area. The limitation on the experiment is provided not by phase variations over the cathode, but by a phenomenon inherent in the emission process, namely, shot effect. The exact formula for the signal-to-noise ratio P is

$$P=2.11\cdot 10^{-3}\frac{Rg^2W^2\lambda^2S\Omega/\delta}{(RegWS\Omega/4\pi)+kT}, \qquad (1)$$

where W is the power radiated per unit area of the source into both lines, whose mean wave-length is λ. δ is the width of each line in cycles/sec., g the photoelectric efficiency, S the area of the cathode, Ω the solid angle included in the incident bundle of waves falling on the cathode, and R the shunt resistance of the resonant cavity. The first term in the denominator is the energy in the resonant cavity caused by shot noise in the photo-current, and the second term is the thermal noise in the cavity. Except for very small cathodes, the kT term is negligible. For larger cathodes the signal-to-noise ratio is independent of cathode area or of Ω.

A scheme developed by Dicke,[3] who measured signals only 0.0015 of noise, is applicable to this problem; in making estimates we assumed a signal-to-noise ratio of 0.01 could be detected. Using $g=0.04$ ampere/watt at $\lambda=4000$A (commercial S-4 photo-surface) makes the required value of W one watt/cm^2. This is a larger value than is ordinarily obtainable, but may be feasible because the source need be operated only for intervals longer than the response time of the detecting equipment ($\sim$1 second). Where the average heat dissipation is the factor limiting the power output of the source, continuous operation for an interval no longer than one second should permit using a peak power considerably larger than is possible with steady operation. An experimental program is now under way here to determine the spectral intensity obtainable in a source so operated.

It is expected that the details of the derivation of Eq. (1) will be presented in a paper to be submitted to this journal.

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On the Presence of Neutrons in the Extensive Cosmic-Ray Showers*

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An experiment has been performed in order to find out whether or not neutrons are present in the extensive showers of the cosmic radiation.

For studying neutrons associated with showers one has to record the coincidences between some Geiger counters struck by the electrons of the showers and a neutron detector: a BF$_3$ proportional counter surrounded by paraffin seems to be the simplest and most reliable one. However, a serious difficulty arises from the fact that, when an extensive shower falls on the recording system, the neutron counter is struck by such a large number of electrons that a pulse may occur as large as the pulse due to the α-particles produced in the BF$_3$ by the neutrons; also stars and slow protons associated with the showers may give rise to confusing records. By experimenting with and without cadmium screens on the BF$_3$ counter, one is able to select only the neutrons, but one has to deal with a small effect superimposed on a large background.

We attempted to face the problem by taking advantage of the fact that neutrons have a quite long mean lifetime in paraffin ($\sim$200 μsec.). If one records the coincidences between the pulses of the neutron counter and the pulses of the electron counters delayed by several microseconds, all particles but neutrons are cut off; the number of neutrons lost, however, is very small (<5 percent for delays smaller than 10 μsec.).

The experimental arrangement used is drawn in Fig. 1. The extensive showers were detected by the counter trays, a, b, and c, each consisting of four G-M counters in parallel (area of each tray 2000 cm^2). They were placed in a horizontal plane at the vertices of an equilateral triangle of 4-m sides.

Two identical neutron detectors N_1 and N_2 were used, each consisting of a paraffin box (45×45×50 cm^3) in which four BF$_3$ proportional counters connected in parallel were embedded. Boxes N_1 and N_2 were placed 1.3 meters apart. The experiment was performed under a deck of few g/cm^2 of light material, practically at sea level.

All neutron counters (surface 2.5×45 cm^2) were provided with Kovar guard ring seals and were filled to 100 cm Hg with enriched BF$_3$ (96 percent B^{10}), plus argon to 20 cm Hg. For all of them the operating voltage was about 5000 volts. Their calculated efficiency[1] was about 30 percent.

Figure 2 is the schematic diagram of the recording circuit. Pulses from N_1 and N_2, through cathode followers placed inside the paraffin boxes, were fed into Mod. 100 amplifiers, pulse discriminators, and blocking oscillator outputs (pulse width, 1.5 μsec.). Both N_1 and N_2 were put in coincidence with the coincidences $(a+b+c)$ delayed by 7 μsec. and shaped in a square pulse of 150-μsec. duration. Delayed coincidences $abc+N_1$, $abc+N_2$, and $abc+N_1+N_2$ were recorded.

Thus far have been recorded, in 482 hours, 25,901 extensive showers ($\sim$53 showers/hour) and 117 coinci-

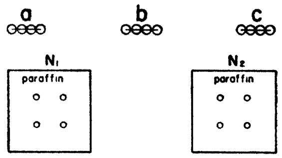

FIG. 1.

dences of the types $abc+N_1$ or $abc+N_2$ ($\sim$0.25 neutron associated with showers/hour). Taking into account the efficiency of the counters and the geometrical efficiency of the system (a rough calculation yields about 0.1 for the probability that a neutron slowed down in the paraffin box should strike the counters), the actual frequency of neutrons associated with extensive showers becomes greater than 8/hour. In 482 hours only one coincidence $abc+N_1+N_2$ was recorded.

In order to ascertain that the delayed coincidences were caused only by neutrons, tests have been made with cadmium foils (0.75 mm thick) surrounding all neutron counters: in 157 hours no coincidences $abc+N_1$ or $abc+N_2$ were recorded. These results demonstrate the existence of neutrons in the extensive air showers.

From the data, the ratio of neutrons to electrons may be evaluated. Assuming for the extensive showers the density spectrum determined in reference 2 and assuming that the ratio of neutrons to electrons is constant throughout the showers, we find that there are in the extensive showers at sea level about one neutron for every 30–40 electrons. Roughly the same figure has been found[3] for the penetrating ionizing particles (likely mesons) present in the extensive showers. The above-mentioned ratio refers, of course, only to those neutrons which our paraffin is able to slow down, i.e., neutrons of energies not bigger than 5–10 Mev. But it is reasonable to assume that faster neutrons, if they exist, are only a small fraction of the neutron component associated with the extensive showers.

During the performing of this experiment the total number of neutrons (associated or not with extensive showers) was also recorded with and without cadmium on the counters. The frequency of the Cd difference is in good agreement with the figures given by other authors[4] for the neutron component of cosmic radiation at sea level.

Experiments are in progress to investigate the mechanism of production of the neutrons associated with extensive air showers.

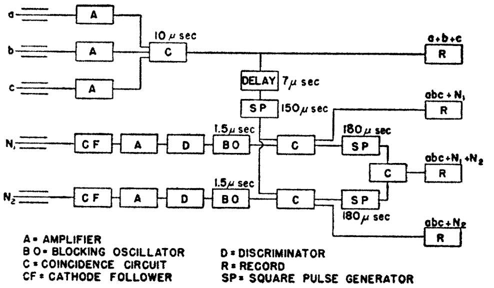

FIG. 2.

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On the Magnetic Moment of H^3 and He^3 in the Møller-Rosenfeld Theory of Nuclear Forces†

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A SYSTEMATIC investigation has been carried through to see whether the M-R model of nuclear forces is able to account for the magnetic moment M of the H^3 nucleus. M is composed of three parts:

1. The sum of the proper moments of all nucleons:
$$M_p=\Sigma_A\,\sigma^A\{\mu_p[(1+\tau_3{}^A)/2]+\mu_n[(1-\tau_3{}^A)/2]\}.$$
2. The orbital moment: $M_{\text{orb}}=\Sigma_A\,[(1+\tau_3{}^A)/2]\cdot l^A$.
3. The exchange moment, which is the sum of the contributions from the vector and the pseudoscalar field:

$$\begin{aligned}M_{ps}=-(e/2\hbar c)(f\mu)^2\sum_{A<B}(\tau^A\times\tau^B)_3&\\ \times\{(1/\mu)[(\sigma^A\times\sigma^B\cdot r_{AB})(r_{AB}/r_{AB}{}^2)((1/\mu r_{AB})+1)&\\ -(\sigma^A\times\sigma^B)]e^{-\mu r_{AB}}-(r_A\times r_B)\,V_{AB}{}^0\}&\end{aligned}$$

$$\begin{aligned}M_v=-(e/2\hbar c)\sum_{A<B}(\tau^A\times\tau^B)_3\{(f\mu)^2[(1/\mu)(\sigma^A\times\sigma^B)&\\ \times((1/\mu r_{AB})-1)e^{-\mu r_{AB}}-(r_A\times r_B)\,V_{AB}{}^1]&\\ -(g\mu)^2(r_A\times r_B)(e^{-\mu r_{AB}}/r_{AB})\}^*&\end{aligned}$$

where $V_{AB}{}^0$ and $V_{AB}{}^1$ are the interaction energies of the corresponding fields.

According to the absence of tensor forces in the M-R model, the total spin S and the total orbital angular momentum L are good quantum numbers, and also the total isotopic spin T and the charge number $T_3(|T_3|\leq T)$. The ground state of the three-body system belongs to $S=T=\frac{1}{2}$, $L=0$ and may be considered, in a first approximation, as symmetrical in the space coordinates. The orbital symmetry class, however, is not a good quantum number, and a closer investigation shows that the deviation from space symmetry, taken in connection with the exclusion principle, may change the expectation value of M to an amount which is of the same order of magnitude as the exchange effect.

To give a more precise description of the investigation, let us introduce the two ortho-normal spin states ξ_1 and ξ_2,