paring the neutron and γ-ray yields. The calculated[10] energy of the first $T=\frac{3}{2}$ state in N^{15} (corresponding to the ground state of C^{15}) is 10.9 Mev. For the 1.50-Mev resonance at an excitation energy of 11.54 Mev the ratio of Γ_n to the single-particle width is exceptionally small, and it may be that this state has $T=\frac{3}{2}$ and is therefore the analog of a low-energy state in C^{15}.

The interference between the 1.31- and 1.50-Mev resonances is unusual in that it appears in the total cross section. This can only occur between states of the same spin and parity. Between two such interfering states of $J=0$ or $\frac{1}{2}$, terms higher than P_0 do not occur. A more detailed report of this work is being submitted to the *Canadian Journal of Physics*.

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Direct Interaction in $Fe^{56}(p,p')Fe^{56*}$†

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INVESTIGATIONS on the energy spectra of inelastically scattered nucleons[1–3] and measurements on the yield of nuclear reactions[4] have recently case some doubt on the applicability of the statistical theory of nuclear reactions. Austern, Butler, and McManus,[5] in order to explain the large observed (n,p) and (n,α) cross sections, proposed a new mechanism which describes the reaction as a consequence of an interaction between the incoming particle and one of the nucleons at the surface of the nucleus in place of an interaction between the bombarding particle and the whole nucleus. This theory, which is analogous to Butler's deuteron stripping calculations, predicts the differential cross section for a reaction in which the residual nucleus is left in an excited state. The angular distribution of the emitted particles is a function of the angular momentum and parity change between the initial and final states.

To test this hypothesis we investigated the angular distribution of protons inelastically scattered from iron. The experimental apparatus was the same as described by Dayton and Schrank.[6] Figure 1 presents the observed absolute differential cross sections for the inelastic scattering of 17-Mev protons (c.m. energy) to the 0.822-Mev level[7] of Fe^{56}. Some care had to be taken at small scattering angles in the separation of the inelastic and elastic scattering. The errors include the uncertainty in the correction which was necessary to account for the spilling over of elastically scattered protons into the inelastic channels. For this reason the point at 25° is to be regarded as an upper limit to the actual value there. The elastic scattering cross section at this angle is 767 mb/sterad.

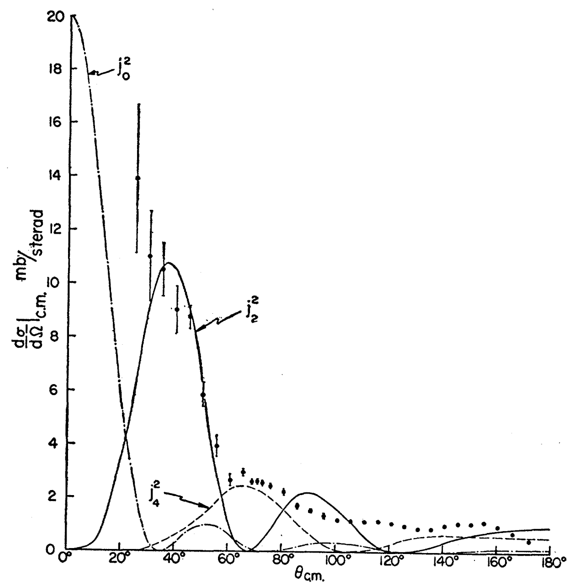

Fig. 1. Scattering of 17-Mev protons to the 822-kev level of Fe^{56}. The curves shown are the squares of the spherical Bessel functions of zeroth, second, and fourth order obtained from the work of Austern, Butler, and McManus.

In this case, where the initial state has zero spin and the final state is presumably a 2^+ level, the differential cross section will be proportional to $[j_2(QR)]^2$ according to the direct interaction picture, where $Q=|\mathbf{k}_{in}-\mathbf{k}_{out}|$, k is the wave number of the incoming or outgoing particle respectively, and R is the nuclear radius ($1.5\times10^{-13}A^{\frac{1}{3}}$ cm). Curves are shown for $[j_0(QR)]^2$, $[j_2(QR)]^2$, and $[j_4(QR)]^2$. The normalization is arbitrary for each curve. The figure shows that the main forward peak of the experimental cross section may be approximated by the spherical Bessel function of second order as predicted by the theory of Austern *et al.* Also, as predicted, the first-order and the third-order functions do not agree with the observed angular distribution since these functions of odd order prescribe a parity change between initial and final states.

These results show that this low-lying state is excited by a process different than that of the decay of a compound nucleus, since the angular distribution predicted by Hauser and Feshbach[8] on the basis of the statistical theory should be symmetric around 90°, and a rough calculation showed that the distribution is

expected to be almost isotropic. Besides, any reasonable level density function[9] will predict a cross section for this scattering process which is several orders of magnitude smaller than the observed value of about 40 mb. Further work will be carried out to improve the separation of the elastic and inelastic scattering at small angles in order to test the theory of Austern, Butler, and McManus.

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Conservation of the Number of Nucleons*

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It has often been surmised that there exists a conservation law of nucleons, i.e., that they neither decay spontaneously nor are destroyed or created singly in nuclear collisions.[1] In view of the fundamental nature of such an assumption, it seemed of interest to investigate the extent to which the stability of nucleons could be experimentally demonstrated.[2]

To investigate the possible decay of a free proton, the large scintillation detector developed for the neutrino search[3] was employed. The detector was partially shielded from cosmic rays by placing it in an underground room with about 100 feet of rock above. The counting rate and pulse spectrum as seen by the detector may be used in arriving at a lower limit for the proton lifetime for certain postulated modes of decay. For fast particles the output of the detector is proportional to the energy deposited in the scintillator and hence for minimum ionizing particles to the track length in the scintillator.

The spectrum expected from any hypothetical proton decay depends then on the geometrical disposition of the protons as well as on the decay scheme assumed. As to the decay, we are free to assume any scheme which is consistent with the laws of conservation of charge, energy, momentum, and angular momentum. In view of the proton rest energy of 0.9 Bev and the known lighter particles into which it might conceivably decay, it seems reasonable to expect that these charged products would have a kinetic energy of the order of 100 Mev. If this decay occurred within the scintillator, the spectrum would essentially reflect the detector geometry because the decay-particle ranges would probably exceed the maximum detector dimension ($\sim$100 cm, equivalent for minimum ionizing particles to $\approx$140 Mev). There are 1.5×10^{28} protons in the scintillator (approximate chemical formula C_7H_8). The scintillator was surrounded by paraffin walls 2 ft thick. This effectively doubled the source of protons, giving $\sim3\times10^{28}$ protons. The pulse-height distribution observed is shown in Fig. 1. The integrated counting rate

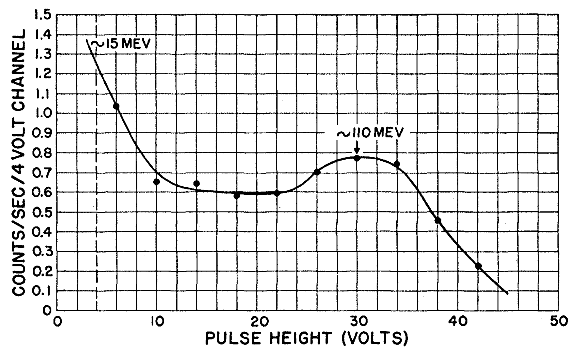

Fig. 1. Pulse-height spectrum in 300-liter liquid scintillator located underground. Time of run = 1000 sec per point. The integrated area for pulses larger than the cut-off bias, which corresponds to $\sim$15 Mev, is 6.6 counts/sec.

for pulses >15 Mev is 6.6 counts/sec. This corresponds to a lower limit of 1.5×10^{20} yr for the mean lifetime of an unbound proton. However, most of the counts in our experiment can be attributed to cosmic rays for two reasons: (1) The counting rate is in fair agreement with that expected from cosmic-ray μ mesons; (2) the spectral shape with its characteristic maximum at $\sim$110 Mev is consistent with what would be expected for cosmic-ray mesons underground traversing our scintillator. It seems, therefore, safe to conclude that at most $\sim\frac{1}{5}$ of the observed counts could be due to proton decay, and hence the lifetime of free protons is $>10^{21}$ yr. Lifetimes for some specific decay schemes which might be assumed can be shown to be even greater.

In our scintillator bound nucleons are an order of magnitude more numerous than hydrogen atoms. This yields a lifetime for bound nucleons $>10^{22}$ yr, a result which can also be interpreted as indicating the absence of "nucleon-destroying" collisions within nuclei.

It is clear that the technique here employed is capable of considerably higher sensitivity, but we believe that the values already obtained are of sufficient interest to be put on record. Higher sensitivity could be obtained both by using larger counters and by going deeper underground or in the ocean to eliminate cosmic rays.

We cannot conceive of an experiment which would prove the absolute stability of nucleons, but judging from the demonstrated "practical" stability of nucleons