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EXPERIMENTAL SEARCH FOR A COHERENT NUCLEAR STRUCTURE

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Introduction

The remeasurement of the total neutron cross section for lead in the region of 30 to 150 Mev by two groups of workers,[1] using finer energy-resolution equipment than had been previously used, led to results that were quite unexpected. In the region of 50 to 70 Mev, or at a neutron wave length of about $\tau \approx 0.6 \times 10^{-13}$, the cross section exhibited a trough, rising rather rapidly with increasing energy to a peak at approximately 80 Mev, after which the cross section decreased monotonically.

Several hypotheses were advanced to explain this phenomenon. The most apparent explanation was an optical-type effect, where in the nucleus was treated as an absorbing refractive medium.[2] Upon closer examination this did not appear to explain the detailed behavior of the cross section, although the model did predict a maximum and minimum cross section at roughly the right energies using reasonable parameters.

A rather intriguing explanation, made rather jestfully by Dr. Robert Jastrow,[3] was that this could possibly be an effect due to some coherent structural phenomenon within the nucleus, giving rise to a coherent scattering similar to a Bragg scattering. Naive considerations concerning the spacing of nucleons in a nucleus show that the wave length of the neutron at these energies could possibly be appropriate to such an effect. In the first order the first possible scattering would be at 180° from the incident-neutron direction, similar to the scattering of thermal neutrons from crystalline carbon. Because of the simple nature of the experiment necessary to test this hypothesis and the important implications involved, the experiment described was undertaken.

Method

The technique used in the search for backward-scattered neutrons was almost identical with that used by Hildebrand et al.[4] In the first run carbon detectors were used; a recoil-counter telescope was substituted as the detector in a later run.

The source of neutrons is the "stripped" 180-Mev deuteron beam of the 184-inch cyclotron, which yields a spectrum of neutrons sharply peaked at 90 Mev. The neutrons were collimated by two stages comprising approximately twenty feet of lead and concrete.

A monitor (disc of carbon, or recoil-counter telescope) was placed in the path of the beam, after which the neutrons impinged on a cylindrical lead target. The detector (cylindrical segments of carbon, or a recoil-counter telescope) could then be moved to various angles with respect to the incident beam, and the detector counts per monitor counts could be tabulated with target in and out.

The carbon detector segments, after activation, were arranged in cylinders surrounding four Victoreen type 1B85 geiger tubes. The activity resulting from the 20-Mev-threshold $C^{12}(n, 2n)C^{11}$ reaction was then counted simultaneously with the activity induced in a carbon monitor disc viewed by an end-window geiger tube. Necessary corrections for background counting rates were subtracted.

For the counter telescopes used the recoil energy bias was set at 50 Mev by a copper absorber, and the counts of detectors and monitor telescopes were recorded simultaneously.

The cross sections were then calculated from the following relation:

$$\sigma(\theta) = \frac{D - B}{C} \frac{Ar^2}{N_o \rho v}$$

$$\Delta\sigma(\theta) = \frac{1}{C} \frac{Ar^2}{N_o \rho v} \sqrt{(AD)^2 + (AB)^2 + \left(\frac{D - B}{C}\right)^2 (\Delta C)^2}$$

where

D = ratio of activity of detector to activity of monitor with lead absorber in place.

B = ratio of activity of detector to activity of monitor with no absorber in place.

C = ratio of activity of detector to activity of monitor with detector in the beam.

$\frac{N_o \rho v}{A}$ = Number of scattering nuclei

For a fuller account of the method the reader is referred to UCRL-1159.[4]

Results and Discussions

Considerable difficulty was encountered in attempting to measure neutrons scattered at angles greater than 170^o, owing to the large "spray" effect from the mouth of the concrete collimator. In an attempt to obviate this difficulty a run was attempted using the 270-Mev neutron beam of the 184-inch cyclotron. In this case any first-order coherent scattering should have occurred in the forward direction.

In all a series of twelve angles was measured for the 90-Mev beam, varying from 178^o to 90^o from the incident-beam direction; for the 270-Mev beam, six angles varying from 90^o to 40^o in the forward direction. In all cases the cross sections measured were less than ten millibarns per steradian, some being less than one millibarn per steradian, and at all angles the results were statistically zero. The statistical errors were in general about the same magnitude as the cross section measured, i.e., of the order of or less than a few millibarns per steradian.

Dr. Owen Chamberlain, of the staff of UCRL, has attempted a subsidiary experiment using the 340-Mev proton beam of the 184-inch cyclotron. In this case the scattering of protons due to a coherent scattering from lead would appear as a slight bump in the elastic-scattering cross-section curves superposed on the Rutherford scattering for the forward direction. His results were also negative.

It would seem, therefore, that some other explanation than a coherent structural effect is needed for the variation in the total neutron cross section for lead.

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