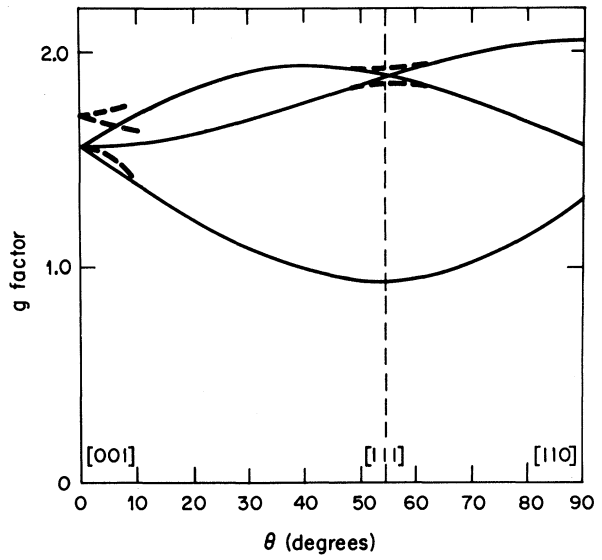

FIG. 2. Anisotropy of the g factor of bound electrons in the triplet state in germanium with $\vec{H}$ in the (110) plane. The solid lines are the first-order theory [Eq. (6)] and the splitting of the degeneracies are indicated by the dashed lines.

promising where the spin-orbit effect is large.

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INELASTIC ELECTRON SCATTERING FROM CARBON*

W. C. Barber and F. E. Gudden†
High-Energy Physics Laboratory, Stanford University, Stanford, California
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We have measured the energy spectrum of electrons inelastically scattered from nuclei, with the aim of studying the giant-resonance region of nuclear excitation. Scattered electrons corresponding to excitation of the giant resonance have been observed at large angles for targets of Si and C. The scattering distribution from C has been investigated in some detail, and a scattering peak corresponding to a nuclear excitation of 15 Mev is also observed. The results indicate that the investigation of nuclear properties by inelastic electron scattering, which has already been successful in the study of many low-lying states,[1] can be extended to other types of nuclear excitation and can be carried out with lower-energy electron beams.

The Mark II linear accelerator[2] and an 18-in. double-focusing spectrometer[3] were used for the experiment. The double magnetic deflecting system of Mark II was set to $E_0 = 42.6$ Mev, with an energy spread of 1%.

For the measurement of the energy distribution of electrons scattered through 160°, we used a graphite target 0.327 g/cm^2 thick. The scattered and magnetically analyzed electrons were detected by means of two plastic scintillators, one mounted directly on the photocathode of an RCA-6810 photomultiplier, the other supported on an aluminum reflector, $1\frac{3}{4}$ in. in front of the second photomultiplier. The output pulses of the photomultipliers were fed directly into a coincidence circuit with a 6-mμsec resolution time. Use of coincidences significantly reduced the background, which was mainly due to neutrons. Beam monitoring initially was done with a secondary-emission monitor and later with a Faraday cup.

Figure 1 shows the results. The target-out background has been subtracted from each meas-

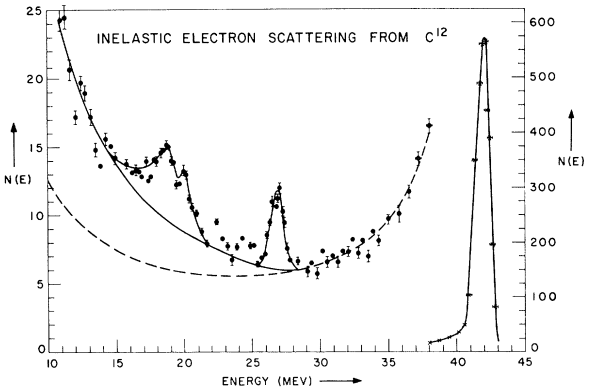

FIG. 1. Energy distribution of electrons scattered at 160° from carbon. The elastic peak is shown at the right with the ordinate scale indicated on the right margin. The dashed curve is the calculated tail of the elastic peak due to bremsstrahlung. The solid curves were drawn arbitrarily. The points without statistical errors indicated have errors comparable with those of neighboring points.

ured point, and the elastic peak has been corrected for counting losses. All points are corrected for the dispersion of the spectrometer to give the number of electrons at a certain energy per energy interval. Also shown is the calculated tail of the elastic peak due to bremsstrahlung accompanying the scattering event or produced in separate collisions preceding or following the scattering. While the agreement between the theoretical radiation tail and the measured spectrum is excellent for high energies, there is an increasing discrepancy toward lower final electron energies. Whether this is due to excitation of additional levels in the carbon nucleus, to contamination of the primary electron beam by low-energy electrons, or to some other cause, is not known. The sharp peak at 27 Mev undoubtedly belongs to the excitation of the well-known 15.1-Mev level with $J=1^+$, which is the first $T=1$ level in carbon. The giant resonance should be in the region of 19 Mev in Fig. 1. The data suggest two peaks, one at 20 Mev and the other at 19 Mev, corresponding to excitation energies of 22 and 23 Mev, respectively.

The expression

$$\frac{d\sigma_e}{d\Omega}(E_0,k_f,l)=\frac{dN_e}{d\Omega}(E_0,\theta,k_f,l)\frac{\sigma_\gamma(k_f)}{k_f} \qquad (1)$$

relates the inelastic-scattering cross section to the photon-absorption cross section $\sigma_\gamma(k_f)$, through the concept of virtual photons. In Eq. (1), $dN_e/d\Omega$ represents the virtual-photon intensity associated with a transition energy k_f and multipole order specified by l due to electrons scattering at an angle θ.

Dalitz and Yennie[4] have given expressions for virtual photon spectra which are in convenient form for determining $dN_e/d\Omega$. As an example we give the expression for $M1$ transitions:

$$\frac{dN_e^{M1}}{d\Omega}=\frac{\alpha}{4\pi^2}\left[\frac{p^2+p'^2+pp'(1-\cos\theta)}{p^2(1-\cos\theta)}\right]\frac{(1-\frac{1}{3}k^2\langle r^2\rangle)}{(1-\frac{1}{3}k_f^2\langle r^2\rangle)}, \qquad (2)$$

where p and p' are the magnitudes of the electron's momentum before and after scattering, respectively; k is the magnitude of the momentum transferred; and the units are such that $\hbar=c=1$. The terms containing $\langle r^2\rangle$ are an approximate small correction[5] for the finite nuclear radius r.

The relative areas of inelastic and elastic peaks can be expressed simply in terms of the integral of Eq. (1) and the Mott cross section for elastic scattering $d\sigma(E_0,Z)/d\Omega$. The result is

$$\frac{\text{Area}_{\text{inelastic}}}{\text{Area}_{\text{elastic}}}=\frac{\int(dN_e/d\Omega)\,k_f^{-1}\sigma_\gamma(k_f)\,dk_f}{[d\sigma(E_0,Z)/d\Omega]F^2(kr)}, \qquad (3)$$

where $F(kr)$ is the form factor for a momentum transfer $k=2E_0\sin(\theta/2)$.

If the resonance is narrow, k_f and $dN_e/d\Omega$ can be considered constant and can be taken out of the integral in Eq. (3). The equation can then be solved for the integrated cross section for γ absorption.

For the peak at 27 Mev the measured ratio of the areas is 0.82×10^{-2}. The transition is magnetic dipole; therefore we use Eqs. (2) and (3), together with $F^2(kr)=0.7$ and $\langle r^2\rangle=(2.4\times10^{-13})^2$ taken from reference 1, to find an integrated cross section of 1.47 Mev-mb. Because of the uncertainties in the form factors involved in the theory, the result could be in error by approximately 20%. Fuller and Hayward[6] found (1.9 $\pm$0.27) Mev-mb, and Garwin[7] found (2.3$\pm$0.19) Mev-mb for the integrated cross section by studying the elastic scattering of γ rays from this level.

A similar calculation for the giant resonance, assuming only $E1$ transitions and taking the area enclosed by the solid lines, which is 0.02 times the elastic peak, yields a value of 41 Mev-mb

for the integrated cross section. This is about three times smaller than the sum of the (γ, n) and (γ, p) integrated cross sections. Part of the discrepancy is because of the uncertainty in determining the background curve. The smooth curve we have drawn is certainly too high in that it does not allow for the long tail which is known to be present on the high-energy side of the (γ, n) cross section.[8] Until the difference between the calculated radiation tail and the measurements at low electron energies is understood, we have no unique way of determining the background curve. A quantitative interpretation of our results also requires a better understanding of the nuclear form factors in inelastic scattering for the process where the nucleus is excited as well as for the background process where bremsstrahlung occurs during the scattering.

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NUCLEAR RESONANCE ABSORPTION OF GAMMA RAYS IN Ir^{191}†

P. P. Craig, J. G. Dash, A. D. McGuire, D. Nagle, and R. R. Reiswig
Los Alamos Scientific Laboratory, University of California, Los Alamos, New Mexico
(Received August 3, 1959)

Conditions for resonant absorption of nuclear gamma rays are difficult to obtain, since the natural widths of nuclear excited states are typically small compared to the energy lost to nuclear recoil by the emitted gamma ray.[1] If E_0 is the energy of the nuclear excited state and the nucleus is free to recoil, the gamma-ray energy will be $E_0 - R$, where R is the recoil energy of the nucleus. Moreover, a gamma ray can be resonantly absorbed by a free nucleus at rest only if the gamma-ray energy equals $E_0 + R$, since the free absorbing nucleus must also recoil with energy R. Earlier systems for observation of resonance absorption all involved supplying the $2R$ energy deficit in one way or another; e.g., by Doppler-shifting the emitted gamma ray by ultracentrifuging the source.

Recently Mössbauer[2] has demonstrated a different technique for observing nuclear resonant absorption, based on the fact that in crystals at low temperature there can be an appreciable probability that gamma-ray absorption and/or emission take place with the recoil being absorbed by the crystal as a whole, i.e., with no phonon creation in the crystal and essentially no energy lost to recoil. If the recoil is shared by about 10^5 atoms in both the emission and absorption events, the energy deficit $2R$ is small compared to a typical nuclear energy level width, and the absorption cross section very large. Mössbauer demonstrated the existence of nuclear resonance absorption of the 129-kev gamma-ray of Ir^{191} in metallic Ir (38.5% Ir^{191}) with source and absorber at a temperature of 88°K. By mounting the source on a turntable, he measured the variation in transmission as a function of the Doppler shift of the emitted gamma rays, and thereby obtained the width of the first excited level of Ir^{191}.

This Letter reports our repetition of Mössbauer's measurements, the extension of the temperature range to 1.5°K, measurements on various foil thicknesses, and a demonstration of semiquantitative agreement of the results with theoretical calculations by Visscher[3] based upon a theory of Lamb.[4]

By neutron bombardment of metallic osmium we prepared 16-day Os^{191}, which decays to an excited state of Ir^{191}. The Os source and two absorber foils were mounted within a cryostat so that either foil could be moved into position between the source and a collimated detector beneath the cryostat. A triangular-wave drive could be applied to the source to provide linear mechanical motion relative to the absorber at