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Observation of Electric Monopole Strength in the Electrodisintegration of ^{3}He

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A broad electric monopole excitation peaking at 6.4 MeV has been observed in the breakup of ^{3}He induced by inelastic electron scattering. The monopole cross section was obtained from the observed cross section by subtracting the electric-dipole contributions converted from photodisintegration cross sections by using the virtual photon theory, and also subtracting the magnetic multipole contributions obtained from a 180° electron-scattering experiment. The extracted monopole matrix element is 2.4 ± 0.5 fm^2.

We have observed a previously undetected electric monopole component near threshold in the breakup spectrum of ^{3}He. Although there have been many experiments in which ^{3}He has undergone two-[1] or three-body[2] photodisintegration, monopole transitions cannot be observed in photoreactions or their inverses.[3] Previous electron-scattering experiments[4] were not of sufficient resolution to single out a monopole excitation unambiguously from other continuum multipole components near threshold. Hence it is understandable that this effect has not been observed before.

The experiment was performed at the 140-MeV linear-accelerator facility of the National Bureau of Standards. Electron beams of 60, 75, 90, 110, and 120 MeV, defined in energy to 0.25%, with average currents of about 10 μA, were directed onto a 350-cm^3 sealed rectangular gas cell[5] pressurized to 10 atm. Backgrounds were held to relatively small values by ensuring that the magnetic spectrometer viewed only the thin side foils of the gas cell. Spectra were measured at a scattering angle of 92.6°, except for the 120-MeV spectrum which was taken at 127.7°. The usual corrections were made for spectrometer dispersion, detector efficiencies, and dead-time losses. Background was determined by measuring the scattering from an identical empty cell. A typical spectrum is shown in Fig. 1.

After applying bremsstrahlung, ionization-straggling, and the Schwinger corrections,[6] the elastic peak was used as a reference cross section for the continuum region. The elastic cross section for scattering from the charge and the magnetic dipole moment was calculated for a Gaussian form factor and was corrected for Coulomb distortion of the electron plane waves.

In order to extract the inelastic cross sections, a bin-by-bin radiative unfolding[7] was performed ᴈr the large radiation tail associated with elastic scattering[8] was subtracted from the spec-

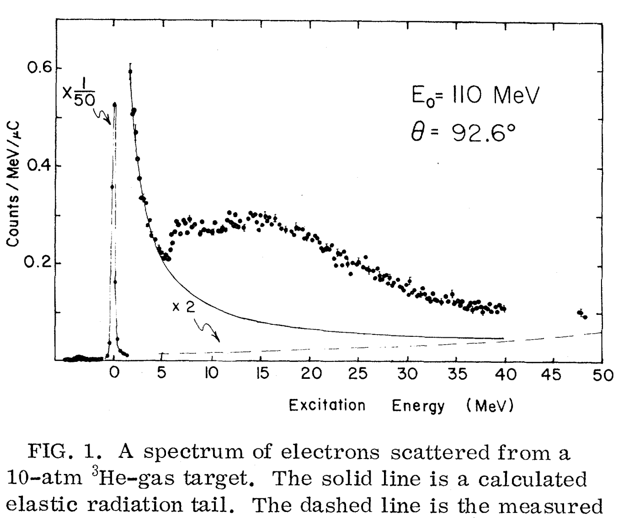

FIG. 1. A spectrum of electrons scattered from a 10-atm ^{3}He-gas target. The solid line is a calculated elastic radiation tail. The dashed line is the measured background multiplied by 2.

trum (see the solid line in Fig. 1). Additional data obtained on ^{4}He over the 19-MeV range from the elastic peak to the breakup threshold provided a check of the elastic-radiation-tail calculation. Some of the unfolded ^{3}He data near threshold are shown in Fig. 2.

Each spectrum was compared with the two-body photodisintegration measurements,[1,3] and the three-body photodisintegration calculation of Gibson and Lehman,[9] by using the virtual-photon spectrum[10] for electric dipole transitions to convert the photon cross sections to inelastic electron-scattering cross sections. The calculation in Ref. 8 has been chosen for comparison because the three-body photodisintegration measurements[2] are not in agreement with each other, whereas the calculation agrees qualitatively with any one of the three measurements for different energy regions. The accuracy of the virtual-photon calculations has been checked experimentally by Phenneger and Winter[11] who measured ratios of photodisintegration to electrodisintegration yields for ^{2}H$(e,e'n)$ between 4 and 11 MeV. The momentum-transfer (q) dependence of the virtual-photon calculation was taken into account by using a low-q expansion[12] of the reduced transition probability $B(CL,q)$, and by assuming the $E1$ transition radius to be the same as the ground-state radius. The magnetic dipole component was determined by translating the results of a 180° electron-scattering experiment[13] to our kinematic conditions. The contributions of these partial cross sections are shown in Fig. 2.

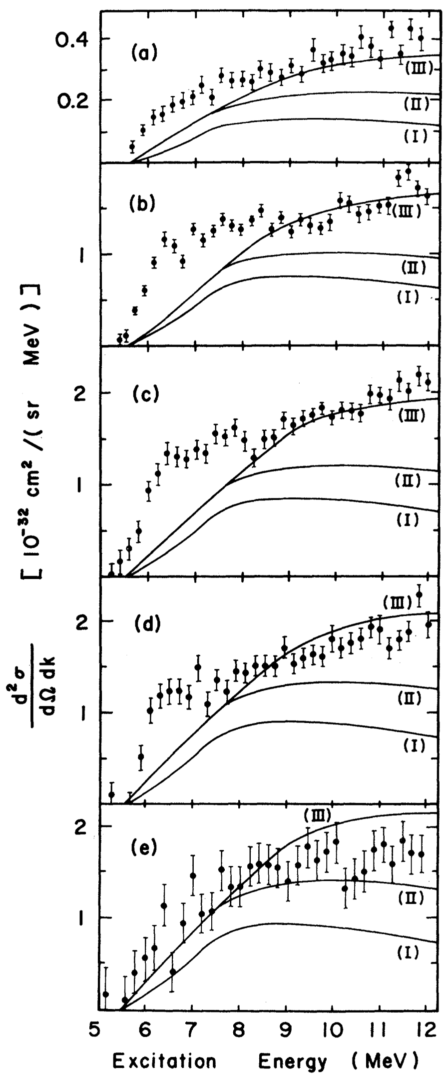

FIG. 2. Measured cross sections in the region of breakup thresholds. In (a), $E_0=120$ MeV and $\theta=127.7°$; in (b)–(d), $E_0=110$, 90, 75, and 60 MeV, respectively, for a fixed $\theta=92.6°$. Curve (I) is the $E1$ contribution converted from two-body photodisintegration cross sections by virtual-photon theory, curve (II) is the sum of (I) and the $M1$ contribution from a 180° electron-scattering experiment, and curve (III) is the sum of (II) and the $E1$ contribution from the three-body photodisintegration calculation of Gibson and Lehman, converted by virtual-photon theory.

The cross sections between the two- and the three-body breakup thresholds at 5.5 and 7.7 MeV, respectively, were larger than the sum of the $E1$ and $M1$ contributions, thus indicating an additional cross section peaked at 6.4 MeV. From photonuclear experiments[1-3] the $E2$ strength has been shown to be very small near the two-body threshold, and monotonically increasing with excitation energy, thus ruling out the possibility that the observed excess cross section in this experiment is due to $E2$ excitation. The only other possibility in the relatively low q range of this experiment is an electric monopole excitation. The reduced transition probability $B(\mathrm{C0},q)$ has been determined by integrating the additional cross section from 5.5 to 8.5 MeV. The monopole matrix element M_{mon} and the transition radius r_{tr} were obtained by a low-q expansion[14]

$$\frac{[4\pi B(\mathrm{C0},q)]^{1/2}}{q^2} = \frac{M_{\mathrm{mon}}}{6}\left[1-\frac{q^2 r_{\mathrm{tr}}^2}{20}+\frac{q^4 r_{\mathrm{tr}}^4}{840}-\dots\right].$$

A least-squares fit of this expression to the data (see Fig. 3) gave $r_{\mathrm{tr}}=3.6\pm0.8$ fm and $M_{\mathrm{mon}}=2.4\pm0.5$ fm^2. An electric monopole transition is also present[15] between the (γ,p) and (γ,n)

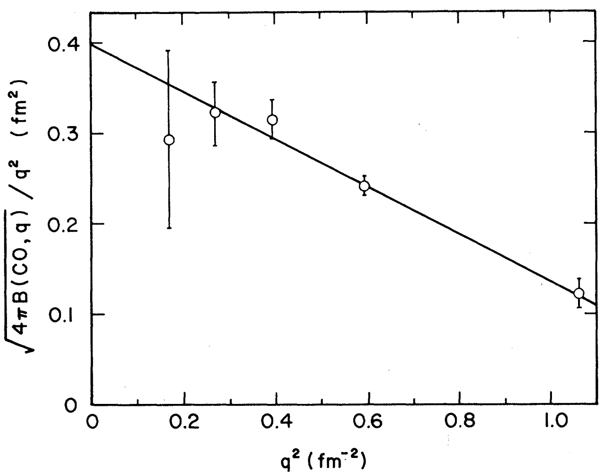

FIG. 3. The square root of the reduced transition probability as a function of momentum transfer for the monopole excitations above curve (III) in Fig. 2, integrated between 5.5 and 8.5 MeV. Errors indicated on the data points are statistical only. An additional 10% uncertainty should be included to account for systematic errors and uncertainties in the analysis. The solid line is a least-squares fit to the data.

thresholds of ^{4}He at 20.1 MeV which has a comparable transition radius and matrix element of 3.0 ± 1.0 fm and 1.10 ± 0.16 fm^2, respectively. A broad monopole excitation in ^{3}He, peaked at 6.4 MeV, has been predicted in a zero-range-approximation calculation by O'Connell,[16] who assumes a simple model of a proton bound to a deuteron.

*Work supported in part by the Office of Naval Research and by the National Science Foundation.

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Synchrotron Emission from an Oblique Rotator and Its Application to Pulsars

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A method is presented which permits rapid interpretation of the synchrotron patterns emitted by a charged particle moving in the uniform magnetic field of an oblique rotator. The analysis predicts a variety of intensity and polarization patterns that are compared with data from a number of pulsars. It also predicts the observed frequency dependence of the peak-to-peak separation of two double-peaked pulsars.

In a uniform magnetic field, single-particle synchrotron emission at the mth harmonic of the fundamental, ω_0, is given by[1]

$$P_m(\theta)=\frac{e^2m^2\omega_0^2}{8\pi^2c\epsilon_0(1-\beta_\parallel\cos\theta)^3}\left|\left(\frac{\cos\theta-\beta_\parallel}{\sin\theta}\right)^2 J_m^2(x)+\beta_\perp^2 J_m'^2(x)\right| \text{ erg/sec/sr}, \tag{1}$$