half-life of the 10^+ state in ^{190}Hg to be shorter than 2 ns, supporting our suggestion that the 10^+ state is not the isomer in ^{190}Hg. Furthermore, in nearby isotopes of platinum and lead the $(\nu i_{13/2})^2$ isomerism is well established with the 12^+-to-10^+ spacings ranging between 3.1 and 60 keV. It is likely that the same type of isomer exists in the mercury isotopes.

In conclusion, our measurement of the g factor of the 21-ns isomer in ^{190}Hg clearly demonstrates that the isomerism is due to the $\nu i_{13/2}$ orbital. The result is contrary to the commonly accepted assignment of the isomer as $(\pi h_{11/2})^{-2}$. Further, it suggests the existence of a hitherto unobserved 12^+ level close to the 10^+ state. Similar situations are likely to exist in $^{192-196}$Hg and in ^{194}Pt.

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Inelastic Proton Scattering at 800 MeV to the ^{12}C 15.11-MeV State: A Search for Nuclear Critical Opalescence

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The differential cross section for the reaction $^{12}C(p,p')^{12}C^*$ (15.11 MeV, 1^+, $T=1$) has been measured at 800 MeV; the range of the angular distribution corresponds to momentum transfers of 0.7–2.4 fm^{-1} $[(1-3.3)m_\pi]$. The cross section decreases almost exponentially at large angles; no maximum is observed in the region where nuclear critical opalescence might be expected.

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While it appears that a pion-condensed phase does not occur in nuclei at ordinary densities ρ_0, the probability that nuclei are close to the critical density ρ_c for pion condensation remains of strong interest.[1-3] Nuclei would then be expected to manifest various precursor phenomena, of which nuclear critical opalescence[4] has recently received the widest attention. The name arises by analogy with a standard term in condensed matter physics, a term applied, for example, to enhanced light scattering from a gas near its critical point.[5] The signature of nuclear critical opalescence is a strong maximum in the cross section at large momentum transfer q $[(2-3)m_\pi]$; this is predicted to occur in electron[3] or proton[1,2] scattering to nuclear states with pionlike quantum numbers if ρ_c/ρ_0 is not too far from 1.0. The effect would arise from correlated fluctuations in the pion field in nuclei, or, equivalently, from an enhancement of the nucleon-nucleon tensor force in the nuclear medium.

The large second maximum in the transverse form factor for electron scattering to the ^{12}C 15.11-MeV, 1^+, $T=1$ state[6] has recently been interpreted as possible evidence for nuclear critical opalescence,[3] although more conventional descriptions have also been proposed.[7,8] Comfort and Love have suggested that the evidence from 122-MeV proton scattering data on ^{12}C is generally negative[9]; uncertainties in the reaction mechanism at this energy, however, preclude a definitive statement. We present here differential cross sections for 800-MeV proton excitation of the ^{12}C 15.11-MeV state at momentum transfers of 0.7–2.4 fm^{-1}. The measured cross sections decrease almost exponentially in this region where a possible strong maximum indicative of precritical behavior has been predicted.[10]

Cross sections were measured at the high-resolution spectrometer (HRS) at the Clinton P. Anderson Meson Physics Facility. Scattered particles were detected in a focal plane array of drift chambers and scintillation counters that have been described previously.[11] Since the data-acquisition rate was computer limited, the energy range of the HRS was confined to excitation energies from about 7 to 17 MeV by adding an extra scintillator to the event trigger, Included in this range are the 7.65- and 9.64-MeV states of ^{12}C which, by comparison to previous data of Blanpied *et al.*,[11] provided an absolute normalization of the 15.11-MeV cross section at each angle. The target was a strip of natural graphite, 50 mg/cm^2 thick, and narrow enough to improve the energy resolution by intercepting only about 25% of the incident beam. The overall energy resolution varied between 110 and 160 keV as the kinematic contribution increased to about 100 keV at the largest angle.

An energy spectrum at a laboratory angle of 13.95° is shown in Fig. 1; this corresponds to a momentum transfer of 1.8 fm^{-1} where the maximum cross section has been predicted if critical opalescence occurs. The inset shows the region around 15 MeV of excitation on an expanded scale. The 15.11-MeV state is weakly excited, with a cross section somewhat smaller than the cross section for the 12.71-MeV, 1^+, $T=0$ state. [This statement remains true over essentially the entire angular range from about 10° (c.m.).] These two states lie on a background of broad natural-parity states which are strongly excited at 800 MeV.

The angular distribution for the 15.11-MeV

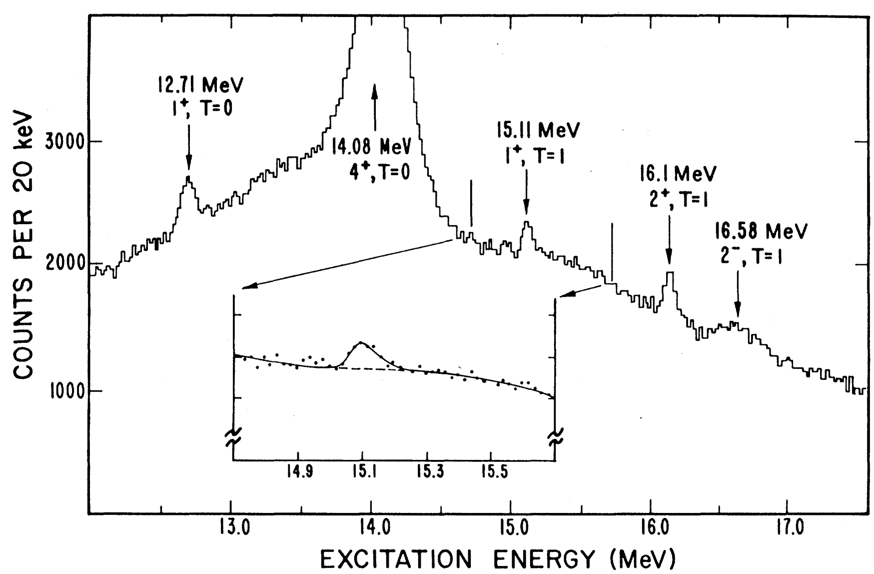

FIG. 1. Energy spectrum of the reaction ^{12}C$(p,p')^{12}$C at 800 MeV taken at a laboratory angle of 13.95°. The inset shows the excitation energy region around 15 MeV on an expanded scale. The solid line is a computer fit to these data.

state over the region from 3° to 22° (c.m.) is plotted in Fig. 2. Forward-angle data are taken from a previous experiment.[12] Data reduction was carefully performed in several ways, and the error bars shown include a reasonable estimate of background uncertainties. Horizontal error bars at large q represent the angular acceptance. Although there is a hint of a shoulder around 1.6 fm^{-1}, there is certainly no pronounced maximum in this region. Thus, independent of theoretical calculations, the absence of a secondary maximum at large q shows that no large precursor effects are present for this state with 800-MeV protons.

The possibility remains that there is some manifestation of precritical behavior in these data for which the name critical opalescence seems, however, inappropriate. But a detailed interpretation, such as a determination of ρ_c/ρ_0, depends on calculations. The incident energy is high enough here to minimize many of the complications possible at lower energies. However, such calculations are very sensitive to the spin-dependent terms in the free nucleon-nucleon interaction which are not known precisely. In order to obtain an estimate of precritical effects expected at 800 MeV, Toki and Weise[10] carried out a Glauber-theory calculation based on an amplitude of the following form:

$$F_{\sigma\tau} = -(M/2\pi)\{[f^2(q^2)/m_\pi^{\,2}]V_\pi(q)\vec{\sigma}_1\cdot\hat{q}\,\vec{\sigma}_2\cdot\hat{q} + t_s\vec{\sigma}_1\cdot\vec{\sigma}_2 + t_T S_{12}(\hat{q})\}\vec{\tau}_1\cdot\vec{\tau}_2.$$

The first term is the Born term with a one-pion-exchange range; this is the term expected to be enhanced near ρ_c. The terms t_s and t_T represent additional short-range interactions; they were adjusted to fit the small-angle data of Ref. 12, but, as Toki and Weise point out, they are by no means uniquely determined in this manner. Two of their predictions are shown in Fig. 2. The dashed curve is based on the wave functions of Cohen and Kurath (CK) without core polarization.[13] The solid curve includes the effects of core polarization to all orders by virtual excitation of nucleon- and Δ-hole states. The large enhancement in this curve at high q depends sensitively on the Landau parameter g'; this parameter determines the effect of short-range correlations which have a large influence on predicted values of ρ_c/ρ_0. For observables sensitive to small q, many theorists believe a value of about 0.7 for g' is correct; g' may, however, depend on q. The

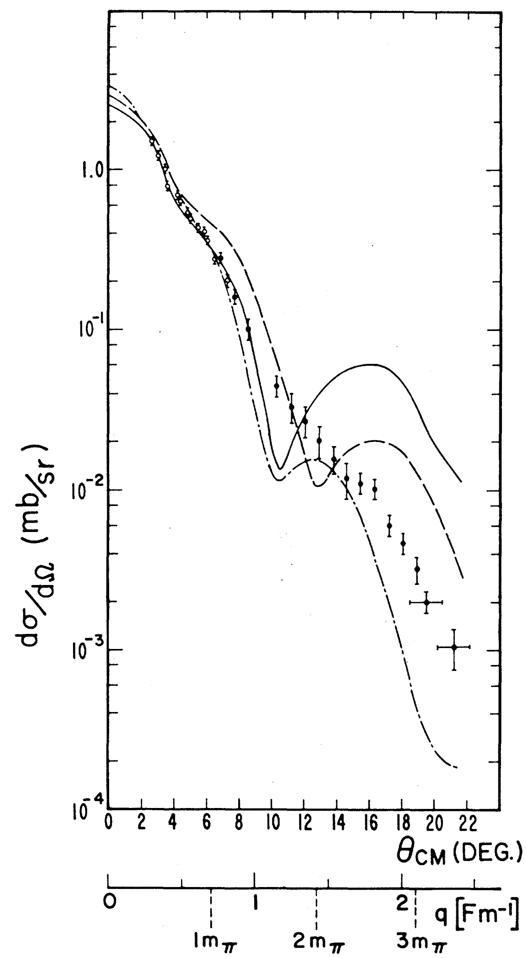

FIG. 2. Experimental angular distributions and theoretical calculations for the reaction ^{12}C$(p,p')^{12}$C to the 15.11-MeV state. The open circles represent data from Moss *et al.* (Ref. 12); the closed circles represent data from the present experiment. The solid and dashed curves show Glauber-model calculations by Toki and Weise (Ref. 2) with ($g' = 0.5$) and without nuclear critical opalescence effects, respectively. The dash-dot curve is a DWIA calculation without opalescence effects.

value chosen here, 0.5, yields a reasonable fit to the electron scattering data for the 15.11-MeV state in a parallel calculation[10]; it corresponds to a value of about 3 for the ratio ρ_c/ρ_0. It is evident from Fig. 2 that the measured cross sections are far below the estimates at large q. The fact that even the CK calculation overestimates the large-q cross section presumably reflects deficiencies in the two-body force chosen (see below). Toki and Weise comment, however, that the relative enhancement of the curve with $g' = 0.5$ is approximately independent of the values of t_s and t_T, provided that the fit to the small-angle data is maintained.[10] It is also noteworthy that our independent calculations show that the small modifications to the CK wave functions proposed by Dubach and Haxton hardly affect the CK predictions of proton scattering, while the electron scattering predictions at large q are very sensitive to them.[8]

The third curve in Fig. 2 is probably a bettter estimate of the scattering with pure CK wave functions. This is a distorted-wave impulse-approximation (DWIA) calculation using a two-body force determined by Franey and Love[14] on the basis of the Arndt phase shifts.[15] Although this N-N force is not unique and has not been tested in other similar applications, it provides fits to the reasonable amount of available data which constrain the $\Delta T = 1$, $\Delta S = 1$ interaction in the range of q of interest here. For the curve shown, which includes both direct and exchange (knockout) terms, the predicted cross section has been multiplied by 1.5 to reproduce the forward-angle data; a similar factor was also necessary at lower energies.[16] The discrepancy between this curve and the data for $q > 1.6\ \mathrm{fm}^{-1}$ is reminiscent of a larger discrepancy observed at lower energies.[16]

The present differential-cross-section data resemble in shape and magnitude the corresponding data at 122 (Ref. 16) and 200 MeV,[17] although the minimum or shoulder around $1.6\ \mathrm{fm}^{-1}$ appears more pronounced at the lower energies and the large-q cross section falls more quickly at 800 MeV. It does not appear likely, then, that clearly identifiable nuclear critical opalescence will be observed for proton scattering to this state at any energy. It will be important, however, to carry out such experiments at an energy around 400 to 500 MeV where the spin dependence of the nucleon-nucleon interaction is much better known, and accurate theoretical calculations can thus be performed. Then it will be useful to try to explain the discrepancies at the largest momentum transfers in detail, to determine whether they may be evidence for some precritical behavior. Such experiments may be viewed as a measurement of g' at large q, although different parametrizations may now be found more appropriate. It will also be very interesting to compare quantitatively the proton data with corresponding electron data which do have a strong maximum at large q.[6] A consistent explanation of data from both probes would be a good test of theory.

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