

RADIATIVE PROTON CAPTURE: RECENT RESULTS

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The first studies of (p,γ) reactions in the 40-100 MeV range were undertaken by our group less than two years ago. Although the initial motivations for these studies were centered on ground-state capture phenomena, the results of our early experiments have directed our efforts toward an unexpected aspect of these reactions: strong captures to high-lying ex-

cited states. The measurements which first demonstrated this effect have been published in Physical Review Letters.¹ More recently, the unfolding evidence has been presented at a number of conferences and workshops.²⁻⁴ At least three theoretical works⁵⁻⁷ have been prompted by our results.

In these studies, we have concentrated on the reactions $^{11}\text{B}(p,\gamma)^{12}\text{C}$ and $^{12}\text{C}(p,\gamma)^{13}\text{N}$. However, other reactions have also been studied, in a less detailed way, to gain some understanding of the systematics of the final states³ observed in the proton capture reaction at energies above those obtainable with tandem Van de Graaffs. The picture which emerges is a simple one: the final states are ones which have a structure which looks like the undisturbed target nucleus coupled to a single proton one major shell above the highest shell occupied by protons in the target nucleus. Thus, for example, in $^{11}\text{B}(p,\gamma)^{12}\text{C}$, the states most strongly populated are those with one $p_{3/2}$ hole and an s-d shell proton (see Fig. 1). In $^{12}\text{C}(p,\gamma)^{13}\text{N}$, single-particle s-d shell states predominate; and in $^{12}\text{C}(p,\gamma)^{13}\text{N}$, studied elsewhere,⁸ the primary final states are of $p_{3/2}^{-1}(s-d)^1$ nature.

The energy dependence of the strongest capture transitions in $^{11}\text{B}(p,\gamma)^{12}\text{C}$ shows a resonance-like behavior, peaking near $E_p=30$ MeV (see Fig. 2). Since the final states upon which this resonance is built are components of the ground-state giant resonances, and

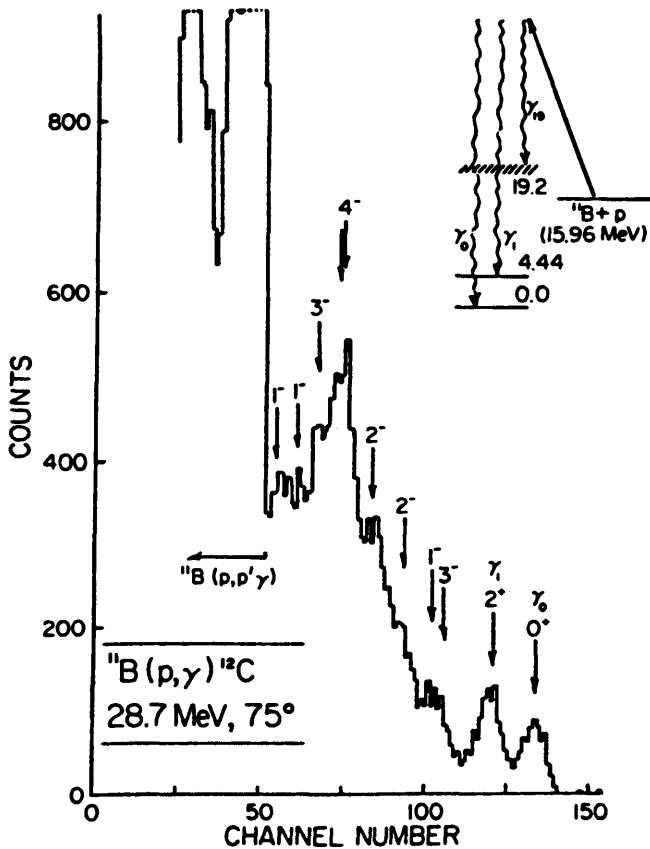


Figure 1. Gamma-ray spectrum from $^{11}\text{B}(p,\gamma)^{12}\text{C}$ at $E_p=28.7$ MeV, $\theta_{\text{LAB}}=75^\circ$. Structure in the γ_{19} complex corresponds to capture to known negative-parity states, which may be identified as $(p_{3/2}^{-1}, s-d^1)$ configurations.

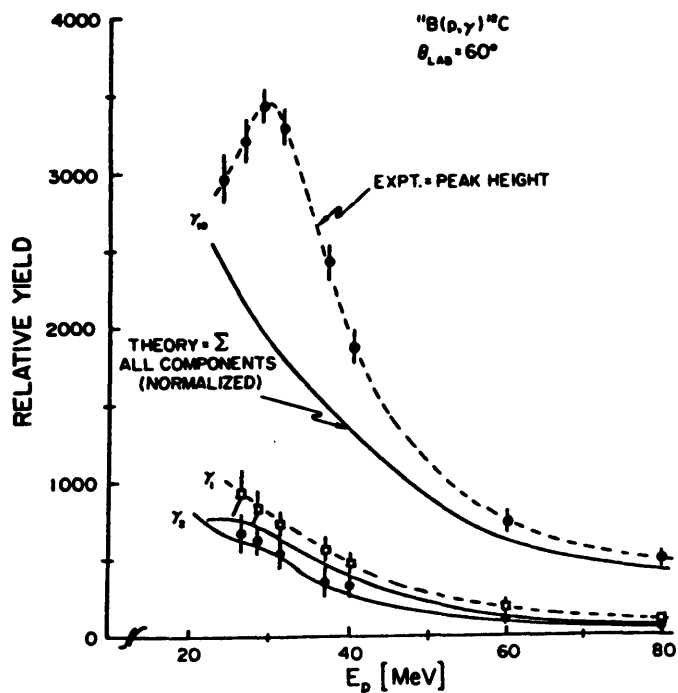


Figure 2. Excitation functions for proton capture into ^{12}C , at $\theta_{\text{LAB}}=60^\circ$. Calculations of Londergan and Tsai are shown as solid lines; the dashed lines merely join the data points.

since the integrated cross section exhausts over 15% of the dipole sum-rule value, the phenomenon can be described as a "second-harmonic giant resonance." The theory of Tsai and Londergan,⁶ which is essentially a direct-capture picture, does not reproduce the observed energy dependence.

Additional data are being collected to extend our understanding of these effects. Detailed spectra at energies ≥ 50 MeV show much strength at gamma-ray energies below the transitions to the ground-state giant resonance region; i.e., we may be seeing transitions

to even higher excitations in the final nuclei. A simple analysis suggests that transitions to the second harmonic resonance region, perhaps from a still-higher resonance, may explain the observations. A further extension of the experimental information is also being pursued through the measurement of analyzing powers with the polarized proton beam. Preliminary results from our first run, at 28.5 MeV, show substantial analyzing powers. Further, the $^{11}\text{B}(p,\gamma)^{12}\text{C}$ transition to the $(p_{3/2}^{-1}, d_{5/2}^1)$ states has an analyzing power strikingly similar to the transition to the single-particle $d_{5/2}$ state in $^{12}\text{C}(p,\gamma)^{13}\text{N}$.

Work is continuing in the effort to develop as complete an understanding as possible of the (p,γ) reaction, and of the nuclear structure effects it reveals.

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