A Study of Proton-Induced Pion Production on ^{12}C at Intermediate Energies via Recoil Detection

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for my parents

Abstract

This work describes a study of proton-induced pion production from ^{12}C, for proton energies in the range E_p = 166–350 MeV. The (p,π) reaction is particularly useful as a means by which the π-N interaction mechanism within a bound nuclear system can be sampled. Of further interest, double-pion production processes $(p,\pi\pi)$ near threshold in nuclei may be sensitive to any breaking of the underlying chiral symmetry. A full description of the pion-production process in nuclei is a key step toward understanding the long-range part of the nuclear strong force.

The experiment for this study was carried out at the Indiana University Cyclotron Facility Cooler ring, a high-resolution, electron-cooled, proton beam storage device. Recoil detection techniques, in which the heavy, highly-ionizing recoil nuclei are detected rather than the light, outgoing particles, were used for this experiment. The advantages of the recoil method include: the capability of simultaneous study of several processes such as (p,π) for different pion charge states; large center-of-mass acceptance fractions close to the reaction thresholds; and, the obviation of high-energy, neutral-particle detection.

A kinematically complete and unique reconstruction of the two-body reaction parameters was carried out through the use of raytracing code developed for both online analysis and offline calculations. Differential cross-sections for $^{12}C(p,\pi^+)^{13}C$ leading to strongly-bound final nuclear states are presented for proton energies of 166 MeV, 294 MeV, and 330 MeV, corresponding in particular to extreme forward and backward pion angles in the center-of-mass frame. Angular distributions for $^{12}C(p,\pi^0)^{13}N_{g.s.}$ have also been obtained at 166 MeV and 294 MeV. The total cross-section for this process at 166 MeV is found to be $\sigma(\pi^0) = 374\pm46$ nb, leading to a pion charge state ratio of $R \equiv \sigma(\pi^+)/\sigma(\pi^0) = 2.0\pm0.3$, in good agreement with the value $R = 2$ expected from isospin invariance arguments.

At E_p = 330 MeV, a search for events corresponding to $^{12}C(p,\pi^+\pi^0)^{13}C$ was performed, leading to an upper limit (at the 2σ confidence level) of $\sigma_{\pi\pi} < 17$ nb. This limit corresponds to less than 1% of the single positive-pion production strength.

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