A STUDY OF ONE-PION EXCHANGE IN (p,n) REACTIONS USING PCAC AND THE ELEMENTARY PARTICLE MODEL

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It is interesting common feature of the reaction

$$p + {}^{6}Li \rightarrow n + {}^{6}Be \qquad (1)$$

$$p + {}^{12}C \rightarrow n + {}^{12}C \qquad (2)$$

$$p + {}^{14}N \rightarrow n + {}^{14}O \qquad (3)$$

that the isospin (T), angular momentum (J), and parity (P) change of the target nuclei are $\Delta J = \Delta T = 1$, $\Delta P = 0$. These quantum number changes are like those in Gamow-Teller beta decay, and they could be caused by one-pion exchange. We therefore conjectured that the reactions (1)-(3) are dominated by one-pion exchange for 144 MeV protons and small scattering angles. Then, accepting the suggestion of Kim and Primakoff that the nuclei be treated as elementary particles,[1] the interactions were described in terms of a pion-nucleus coupling constant in the framework of the Absorption Model.[2,3] The advantage of this procedure is that PCAC, beta decay, and inelastic electron scattering can be used to predict both the magnitude of the coupling constant and its dependence on momentum transfer.[4]

Angular distributions for reactions (1)-(3) were measured with the ad hoc Neutron Time-of-flight Facility[5] at 144 MeV. The detector consisted of a charged particle identifier followed by two plastic scintillator timing rods (in parallel) and a liquid scintillator vat, which was used to set the energy threshold. A valid neutron event consisted of a coincidence between one of the rods and the vat, with no signal in the charged particle identifier. Phototubes were placed on each end of the rods, and the time difference between each phototube pulse and the subsequent cyclotron RF peak pulse was stored. The neutron time of flight spectrum for each rod was then obtained by adding the time differences from each of its ends. Pulse selection of 1:4 was usually employed.

The efficiency of the detector was determined by comparing its yield to that of a 5" diameter by 5" deep liquid scintillator detector (5x5). This 5x5 was then calibrated for 130 MeV neutrons in a spearate experiment using a tagged-neutron beam. The experiment was done with the 64" scattering chamber using the reaction

$$p + {}^{7}Li \rightarrow n + {}^{7}Be. \qquad (4)$$

Since ${}^{7}Be$ has no excited states, this resulted in a monoenergetic neutron beam. A ΔE-E-veto telescope was placed inside of the chamber at 56° in order to detect the recoiling ${}^{7}Be$. The solid angle of the telescope was defined by two sets of horizontal and vertical slits. The 5x5 was placed outside of the chamber at 60° and was positioned such that if a ${}^{7}Be$ entered the telescope, then the corresponding neutron would pass through a 3 mil thick kapton window and into the 5x5. In order to insure that the 5x5 was positioned properly, the protons corresponding to the reaction

$$p + {}^{7}Li \rightarrow p + {}^{7}Li \qquad (5)$$

were detected in coincidence with the recoiling ${}^{7}Li$, and the center of their cone was found. The center of the neutron cone could then be found from kinematics (they were very close.) The data was recorded in event mode, so that the efficiency could be determined for many threshold settings. The normalized cross section for reactions (1)-(3) and for

$$p + {}^{14}N \rightarrow n + {}^{14}O\ (7.78\ MeV) \qquad (6)$$

are shown in Figure 1.

The theoretical calculations were done with the Absorption Model.[2,3] This takes the Born helicity amplitudes for one-meson exchange (given in momentum space) and inserts distortions through the elastic scattering S matrix. The model was originally used in Elementary Particle Physics, but it has been modified to apply to the nucleus. The nucleus was treated as an elementary particle, and the relationship between the weak axial vector current and the pion field given by PCAC was exploited to give the magnitude of the pion-nucleus coupling constant.[1] This relationship was also used in conjunction with inelastic electron scattering to obtain the momentum dependence of the coupling constant.[4] Consequently, the calculations contained no free parameters. The results are shown in Figure 1 (a)-(c).

The agreement between the theory and experiment for ^{6}Li and ^{12}C is remarkable. This is strong evidence that these reactions are being dominated by one-pion exchange. On the other hand, why is the ^{14}N case so different? Part of the discrepancy is probably due to the neglect of higher order terms in the determination of the coupling constant. If the coupling constant is determined from the Impulse Approximation, then the theoretical calculations are low by only a factor of three, which could be due to the uncertainty of the coupling constant. Also, it is quite probable that the formfactor used was incorrect because of terms neglected in its derivation. Consequently, it is unclear as to whether the ^{14}N case could be explained by

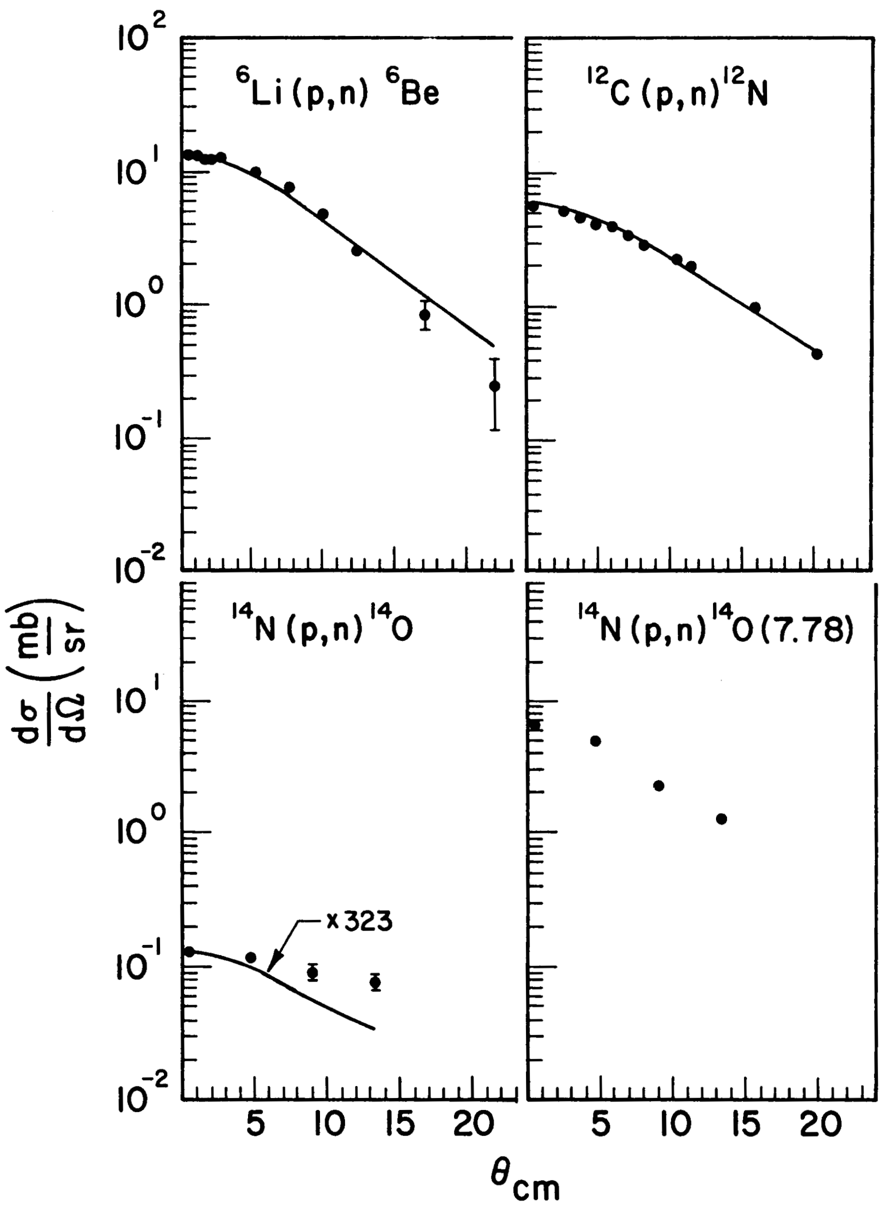

Figure 1. The measured center of mass cross sections (dots) and the theoretical predictions (curves) calculated assuming one-pion exchange dominance.

one-pion exchange dominance, or whether other interactions are involved.

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