Cross section measurements of the pion single-charge-exchange reaction $^{12}C(\pi^+,\pi^0)^{12}N(g.s.)$

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Total cross sections for the pion single-charge-exchange reaction $^{12}C(\pi^+,\pi^0)^{12}N$ (ground state) were measured at 116, 160, 180, 200, 230, and 291 MeV with a fast activation technique. The excitation function for this nonanalog, spin-flip transition was found to be flat over this energy region that includes the (3,3) resonance. Good agreement is noted between these measurements and the estimated cross sections obtained from pion inelastic scattering measurements for the analog reaction $^{12}C(\pi^+,\pi^{+\prime})^{12}C^*$ $(1^+,T=1,E_x=15.1$ MeV) for all energies except 230 MeV. Distorted-wave impulse-approximation calculations in the Δ-hole formalism do not reproduce the trend of the data.

I. INTRODUCTION

A large variety of pion single-charge-exchange (SCE) reactions have been in investigated, and the basic features of the isospin dependence of the Δ-nucleus interaction have been revealed for isobaric-analog transitions.[1] However, even for the earliest measured single-charge-exchange reaction, $^{13}C(\pi^+,\pi^0)^{13}N(g.s.)$, involving an isobaric-analog transition, serious discrepancies still remain between the observed excitation function and theoretical models.[2] Also, the integral cross section of pion single-charge-exchange reactions involving nonanalog transitions have been relatively unexplored. Presently, only the cross section measurements of Shamai *et al.*[3] for the reaction $^{10}B(\pi^+,\pi^0)^{10}C$ to the ground and first excited states, both of which are nonanalog transitions, have been published. Comparison of these data with the cross section calculations of Gibbs[4] has shown the theory to be too low by a factor of 2.

In the present study, the cross section for the $^{12}C(\pi^+,\pi^0)^{12}N(g.s.)$ reaction has been measured by means of an activation technique over the energy range 116–291 MeV. This particular reaction was selected for several reasons. First, because the ground state is the only particle-bound state of ^{12}N, activation techniques can be used to determine the cross section to a unique final state. Second, extensive studies of elastic and inelastic pion scattering on ^{12}C have been performed.[5,6] Third, detailed descriptions of both initial and final states in terms of shell-model configurations are available.[7] In fact, if we assume conservation of isospin, the measured cross section for the $^{12}C(\pi^+,\pi^{+\prime})^{12}C^*$ reaction leading to the 15.1 MeV, $T=1$ excited state of ^{12}C, which is the isobaric analog of the ^{12}N ground state, is related by isospin Clebsch-Gordon coefficients to the cross section for the $^{12}C(\pi^+,\pi^0)^{12}N(g.s.)$ reaction. Thus, a measurement of the SCE reaction constitutes a test of isospin symmetry. And fourth, DWIA optical-model calculations[8] are readily tractable for this reaction.

II. EXPERIMENTAL PROCEDURES

A. Pion channels

The study was carried out with the positive pion beam at the P^3 (Particle and Pion Physics) channel of the Clinton P. Anderson Meson Physics Facility (LAMPF).[9] The energies selected ranged from 116–291 MeV. The channel was tuned so as to produce a waist at the target position as observed with a position-sensitive, multiwire-proportional counter. The beam spot was checked with high-speed Polaroid film and typically measured 2.6 cm by 2.0 cm in the horizontal and vertical directions, respectively. The channel was set for a momentum transmission of $\Delta p/p=\pm4\%$.

Protons were removed from the π^+ beam by means of a differential energy-loss technique employing graphite degraders in the middle of the channel. Based on our previous study,[2] proton contamination of the pion beam was $<0.1\%$ at 291 MeV and less at lower energies. Thus, we conclude, from the measured cross sections for the $^{12}C(p,n)^{12}N$ reaction,[10] that these protons contributed $<3\%$ to our observed ^{12}N cross section.

The pion beam intensities were determined by standard activation techniques involving the use of the established cross sections[11] for the monitor reaction $^{27}Al(\pi^+,xN)^{18}F$. A 5-cm diameter aluminum disk, 70.6-mg/cm^2 thick, sandwiched between two 5.4-mg/cm^2 aluminum guard foils that served to compensate for recoils of ^{18}F nuclei (recoils into monitor disk equaled recoils out), was irradiated 0.5 cm downstream of the primary target during each run. The ^{18}F activity induced in the monitor disk was measured by counting the 511-keV annihilation radiation with a calibrated pair of NaI(Tl) detectors operated in coincidence in a low background environment. The pion intensity thus determined ranged from 1.3×10^8 π^+/s to 7.9×10^8 π^+/s, increasing with increasing pion energy.

B. Target and detector system

A rotating-wheel, high-energy β-ray telescope system was used for the measurement of the short-lived activities produced in the $\pi^+ + {}^{12}C$ reactions. The system is described in detail elsewhere[12] and so is only briefly outlined here. Figure 1 is a schematic of the rotating wheel system that was composed of a target wheel and seven β-ray telescopes located every 45° around the periphery of the target wheel. A polystyrene $(CH)_n$ wheel of 35.6 cm in diameter, serving as a carbon target, was rotated at three different rates, 0.3, 4.0 or 37.5 revolutions per second (rps). Two target wheels, of 160 and 335 mg/cm^2 in areal thickness, were used to check for contributions from secondary reactions.

The β-ray telescopes were composed of two thin plastic scintillators (5.1×10.2 cm^2 of Pilot F)[13] with a graphite absorber (5.7×10.8 cm^2 and 4.52g/cm^2) located between them. The thickness of the front and rear scintillators were selected[12] to be 0.16 and 0.32 cm, respectively. The overall detection efficiency of the telescopes averaged along the path of the moving source was 2.2, 2.0, and 1.0% for β rays emitted from ^{12}N ($E_{\beta\,\max}=16.3$ MeV), ^{9}C (15.5 MeV), and [^{8}Li (13.0 MeV)+^{8}B(13.9 MeV)] nuclei, respectively. The determination of these efficiencies is described in detail in Ref. 12. To this calculated efficiency for the detection of the high-energy β rays (β rays with energies greater than 8 MeV as established by the carbon absorber), and efficiency correction was made to account for the detection of those β rays that were stopped in the absorber but produced a bremsstrahlung-related coincidence event. This latter correction is calculated[12] to increase the overall detection efficiency by 10%. The uncertainty in its value is about 20% as estimated from different assumed shapes of the bremsstrahlung distributions.[14]

C. Reduction of background

We observed that when the pion beam was turned on, the background gradually increased and then leveled off approximately 30 min after opening the beam plug, probably because of ^{11}C buildup. This background did not depend on the pion energy nor on the thickness of the target wheel, but depended linearly on the pion intensity. The β-ray telescopes closest to the pion beam showed the largest increase in background. The reason for this increase is that pions in the wings of the beam intensity distribution and pions scattered by the vacuum window of the pion channel and the target wheel activated these counter telescopes, increasing their background. To reduce this problem, a beam collimator composed of iron and borated paraffin was mounted along the beam line just upstream of the target wheel. The iron collimator was 40.6×30.5 cm$^2\times30.5$-cm long with an aperture of 10.2×10.2 cm^2. This aperture size was chosen to provide maximum shielding of the nearby telescope without intercepting the primary pion beam. The collimator was long enough to stop unwanted pions with energies up to 300 MeV. The borated paraffin that was located downstream of the iron served to absorb neutrons produced in the iron. Measurements of the background appropriate for each pion energy data run were made after the pion beam had been on for more than one hour to reach steady-state values and with the target wheel not rotating. The background level for the telescopes lying closest

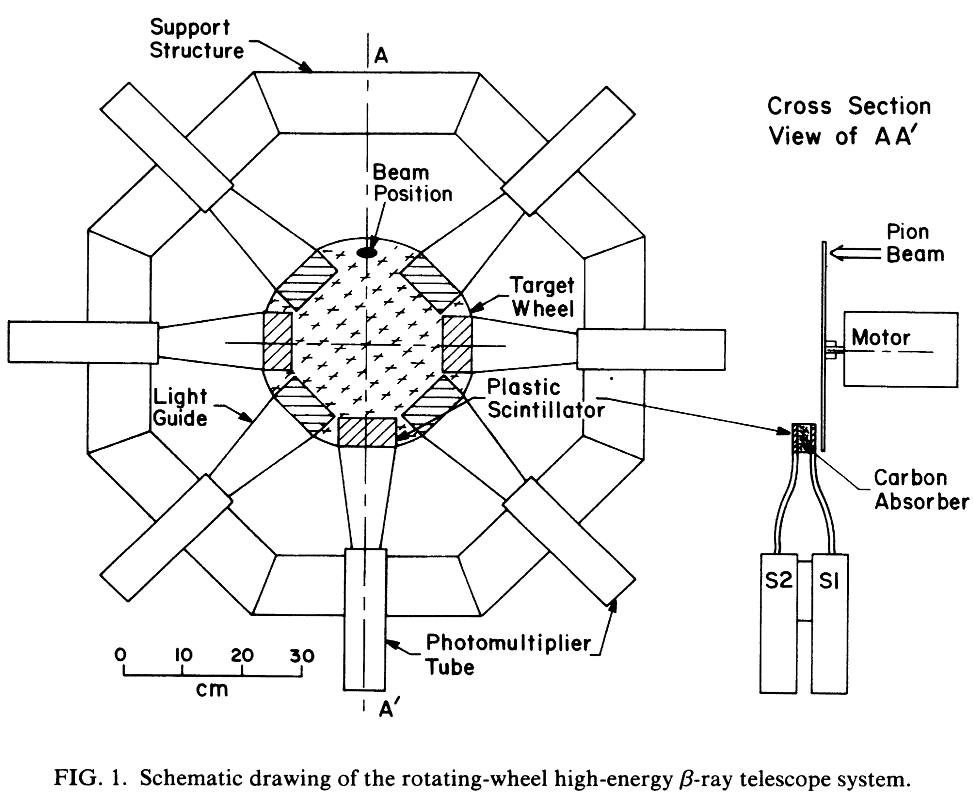

FIG. 1. Schematic drawing of the rotating-wheel high-energy β-ray telescope system.

to the pion beam contributed approximately 20% to the individual telescope coincidence rates, while the background level measured for the other five telescopes was typically at the level of 5% of the counting rate.

We recognized that ^{12}N produced by pion reactions with nitrogen and oxygen in the air could recoil onto the wheel and contribute to the observed yield of ^{12}N. To determine the magnitude of this contribution, measurements were made with a 0.32-cm-thick target wheel of Nylon-66 $(C_{12}N_{22}O_2H_2)_n$ (Ref. 15) that served as a combined nitrogen and oxygen target. Because the N:O ratio of nylon and air are similar, this target represented a good simulation of air. The total ^{12}N production cross section for 180-MeV π^+-induced reactions on the nitrogen and oxygen present in the nylon wheel was determined to be 1.3 mb. To minimize the ^{12}N contribution from the air surrounding the wheel 0.01-cm-thick polyethylene guard foils were mounted immediately upstream and downstream of the target wheel at a distance of 0.3 cm, which limited the effective nitrogen and oxygen thickness to 1 mg/cm^2. Using this combined nitrogen and oxygen areal thickness and the combined cross section measured above, and assuming that the ^{12}N is produced entirely from these elements and that all recoils are implanted in the target wheel, we estimated that ^{12}N produced in the dead layer of air located in front and in back of the target wheel contributes no more than 2 μb to our measured cross section.

D. Data acquisition

A 355-mg/cm^2-thick polystrene target wheel was irradiated at pion incident energies of 116, 160, 180, 200, 230, and 291 MeV. For each energy, data was taken for one hour at wheel rotation rates of 0.30, 4.0, and 37.5 revolutions per second (rps). These revolution rates were selected because it was expected, based on our 8-MeV β-energy threshold, that the main components of the activities from the $\pi^+ + {}^{12}C$ reaction would be $^8Li(T_{1/2}=838$ ms), ^8B (770 ms), ^9C(127 ms), and ^{12}N (11 ms). Data acquistion commenced one hour after the pion beam had been turned on in order to achieve steady-state background conditions. To check the symmetry of the telescope system, data runs at most energies were made with clockwise and counterclockwise rotation of the target wheel. Data for each run were acquired with scalers and also stored event by event to magnetic tape. Furthermore, at energies of 116, 180, and 291 MeV, the 160-mg/cm^2-thick polystyrene target wheel was irradiated in order to measure secondary reaction contributions to the production of ^{12}N.

III. DATA ANALYSIS

The decay data obtained at three different revolution rates were analyzed in the order of longer-to-shorter-lived components, as described in the following subsections.

A. 0.3-rps data

The pion-intensity and position-dependent backgrounds, obtained with the wheel stationary, were subtracted from the raw scintillator-telescope data, and then the net counts were corrected for veto-period losses caused by the beam-gate veto pulse (since data was not recorded during beam-on macropulses). Because of excessive activation, data from the first and last telescopes, which were closest to the pion beam, were not used. Finally, the data were treated with a least-squares decay

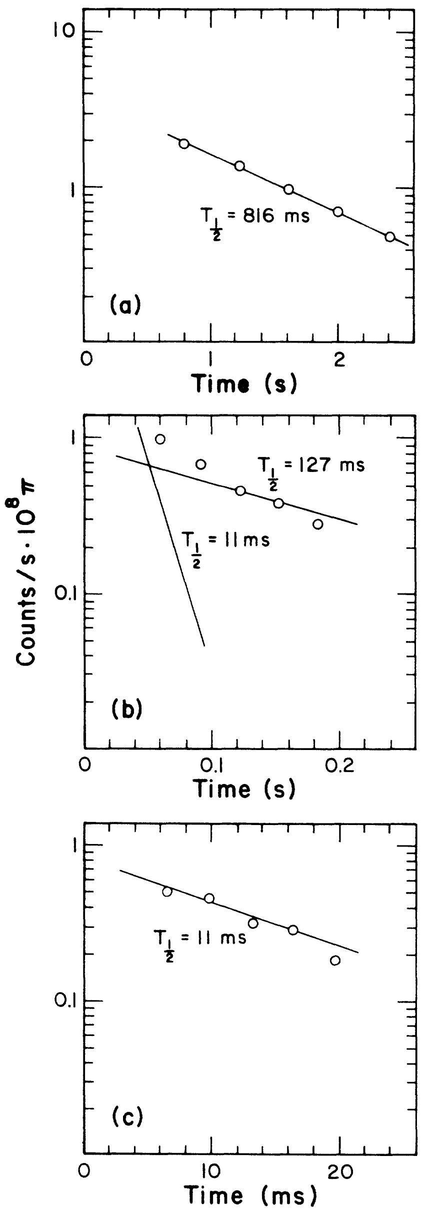

FIG. 2. (a) Decay of ^8Li and ^8B components. Data were taken at a pion energy of 160 MeV and at a wheel rotation rate of 0.3 Hz. Circles are experimental points with a constant background component subtracted. The line is a result of a least-squares fit giving a half-life of 816 ms. (b) Decay of ^9C and ^{12}N components. Data taken at 160 MeV and 4 Hz. Experimental points have the background and the 816-ms component subtracted. (c) Decay of ^{12}N component. Data taken at 160 MeV and 37.5 Hz. Background and the 127- and 816-ms components subtracted; data fit with an 11-ms half-life.

analysis computer program CLSQ.[16] This resulted in an 816-ms component [shown in Fig. 2(a)] plus a long-lived constant background component, not shown. The 816-ms component corresponds well with the average half-life one might expect if 838-ms ^{8}Li and 770-ms ^{8}B were produced in comparable yields.

B. 4.0-rps data

The flux-dependent background and then a corrected 816-ms component were subtracted from the raw data. The correct 816-ms component for the 4.0-rps data was calculated by multiplying the 0.3-rps data by the following multiple-turn counting factor:

$$\frac{\Delta T_2[1-\exp(-\lambda T_{R_1})]}{\Delta T_1[1-\exp(-\lambda T_{R_2})]}\ , \tag{1}$$

where ΔT is the time required for the source to move past the telescope; the factor $[1-\exp(-\lambda T_R)]$ accounts for the accumulation of residual activities after the first, second, etc. rotation of the target wheel; T_R is the period for one revolution; and λ is the decay constant for the 816-ms component. Subscripts 1 and 2 correspond to 0.3- and 4.0-rps data points, respectively. The efficiency and veto-period corrections were applied as described in the previous section. Finally, the corrected counting data were analyzed with the CLSQ program, and an expected 127-ms ^{9}C component was extracted [shown in Fig. 2(b)]. A short component of approximately 11-ms half-life also resulted from this analysis.

C. 37.5-rps data

The backgrounds and the 127- and 816-ms components were subtracted from these data in a manner similar to that described above for the 4.0-rps case. Then the multiple-turn counting factor and veto-period corrections were made. Because of the high rotation rate of the wheel, comparable to the beam macropulse rate of 120 Hz, the source moved about $\frac{1}{4}$ of its path across the telescope during a beam-gate veto pulse. This required a precise calculation of the veto-period correction for each telescope. By combining the known repetition rate of the beam bursts with the target wheel rotation rate and the counting efficiency versus position for an activated spot moving past the telescope, we calculated the veto-period correction for each telescope. These calculations were verified in off-line tests using a ^{106}Ru-^{106}Rh β source mounted on a rotating target wheel. Analysis of the final net decay data resulted in a single 11-ms component as shown in Fig. 2(c).

IV. RESULTS

A. Cross sections

Cross sections have been computed for the π^+ reactions leading to the production of 11-ms ^{12}N(g.s.), 127-ms ^{9}C, and 816-ms (^{8}Li+^{8}B) after corrections for background, veto period, and multiturn counting factor, mentioned above, and for the β-counting efficiencies and the branching ratios. The known half-lives were fixed in these analyses. The averaged cross sections from several runs at each energy are shown in Table I, where the data for ^{12}N are those before applying the corrections discussed in the following.

B. Contributions of secondary reactions

There are two secondary reactions of concern for this study: (a) ^{12}C$(p,n)^{12}$N and (b) ^{12}C$(n,p)^{12}$B. ^{12}B, with its 20.2-ms half-life and 13.4-MeV β end-point energy, could contribute counts to the 11-ms portion of the ^{12}N decay curve. Although the early portion of the decay data showed no evidence for a contribution from a 20.2-ms component, a calculated estimate of this contribution was made as follows.

The intensity and energy distributions of secondary protons and neutrons from π^+ reactions in ^{12}C were estimated from results calculated for Al at 220 MeV with the intranuclear cascade/evaporation codes

TABLE I. Production cross section for ^{12}C+π^+ reactions before corrections for contributions from other reactions.

Pion energy (MeV)	Monitor reaction cross section[a] (mb)	Target thickness (mg/cm^2)	^{8}Li+^{8}B[b]	Cross section (μb) ^{9}C[c]	^{12}N[d] (uncorrected)
116±7.2	13.3±0.6	160	510 ±10		76±3
		335	560±10	180±10	80±2
160±9.4	13.9±0.5	335	700±10	190±20	98±3
180±10.3	13.6±0.5	160	570±10		75±5
		335	670±10	200±20	76±2
200±11.3	12.7±0.4	335	710±10	170±20	82±3
230±12.7	11.3±0.4	335	680±10	190±20	86±7
291±15.4	9.6±0.4	160	600±10		77±5
		335	600±15	230±10	72±5

[a] ^{27}Al$(\pi^+,xN)^{18}$F reaction, Ref. 11.
[b] Beta-decay branching ratio, $\eta=0.965$.
[c] $\eta=0.65$.
[d] $\eta=0.943$.

TABLE II. Estimated cross section of the $^{13}C(\pi^+,\pi^0 n)^{12}N$ reaction.

Pion energy (MeV)	Calculated cross section (mb)[a] $^{12}C(\pi^-,\pi^- n)^{11}C$(g.s.)	$^{13}C(\pi^+,\pi^0 n)^{12}N$
100	0.22	0.055
140	0.55	0.14
190	0.75	0.19
240	0.73	0.18
280	0.70	0.18

[a]Reference 20.

ISOBAR/DFF.[17] These distributions were combined with the measured excitation functions for the $^{12}C(p,n)^{12}N$ ($Q_m=-18.12$ MeV, Ref. 10) and $^{12}C(n,p)^{12}B$ ($Q_m=-12.59$ MeV, Ref. 18) reactions to give effective cross sections of 11 μb/g/cm^2 and 24 μb/g/cm^2 for these secondary reactions, respectively. Therefore, for the 335-mg/cm^2 target, the effective cross sections for the secondary (p,n) and (n,p) reactions in ^{12}C are estimated to be ~ 4 μb and ~ 8 μb, respectively. Furthermore, the detection efficiency for β rays from ^{12}B is calculated to be half of that for ^{12}N. When this is taken into account the total contribution to the observed ^{12}N yield due to both secondary reactions amounts to less than 10% of the observed cross section.

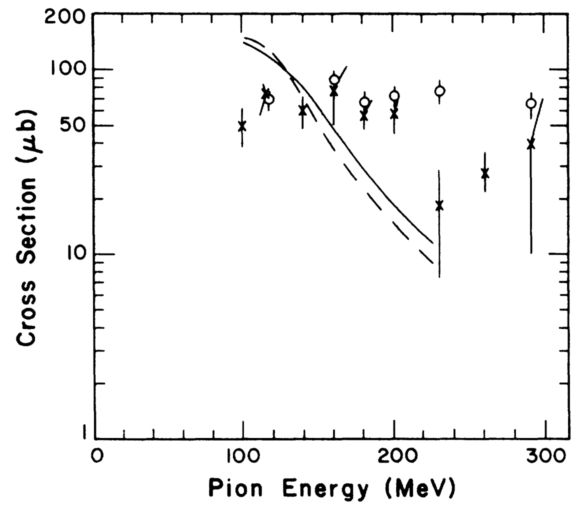

FIG. 3. Excitation functions for the SCE reaction $^{12}C(\pi^+,\pi^0)^{12}N$ (g.s.) reaction (circles, this work) and the inelastic scattering to its analog state in ^{12}C via the $^{12}C(\pi^+,\pi^{+'})^{12}C^*(1^+;1)$ reaction (crosses, taken from Ref. 5 assuming a simple $|J_1(kR\sin\theta)|^2$ angular dependence. The solid and dashed lines are the results of Δ-h DWIA calculations (Ref. 8) of the $^{12}C(\pi^+,\pi^{+'})^{12}C^*(1^+;1)$ reaction in which two different forms for the wave function of the $^{12}C^*(1^+;1)$ state have been used (see the text).

C. Contribution from other reactions

The reaction $^{13}C(\pi^+,\pi^0 n)^{12}N$ on the 1.1% ^{13}C in natural carbon contributed to the observed yield of ^{12}N. The cross sections for the $^{13}C(\pi^+,\pi^0 n)^{12}N$ reaction were estimated from the following considerations. It is important to note that the $^{13}C(\pi^+,\pi^0 n)^{12}N$ reaction does not proceed through a pure quasifree knockout process. In fact, the $(\pi,\pi N)$ reaction in ^{12}C was revealed to have important nonquasifree characteristics.[19] Ohkubo and Liu[20] investigated these nonquasifree characteristics using a model which takes into account quasifree, final-state nucleon charge exchange, and final-state pion charge exchange amplitudes. Their calculations reproduce, reasonably well, the energy dependence and the absolute magnitude of the cross sections of the $^{12}C(\pi^+,\pi N)^{11}C$ reaction. Their calculations emphasize that the nonquasifree component comes from the final-state nucleon charge exchange amplitude, and the contribution from the final-state pion charge exchange process is very small. Therefore, if the $^{13}C(\pi^+,\pi^0 n)^{12}N$ reaction is assumed to proceed through a sequential process $\pi^+ + {}^{13}C \rightarrow \pi^0 + (p + {}^{12}C) \rightarrow \pi^0 + n + {}^{12}N$, then its cross section can be estimated by scaling to the calculated cross section of the $^{12}C(\pi^-,\pi^- n)^{11}C$ reaction, which according to Ref. 20 goes via the $\pi^- + {}^{12}C \rightarrow \pi^- + (p + {}^{11}B) \rightarrow \pi^- + n + {}^{11}C$(g.s.) process.

In the first step of these two processes, the probability for the $\pi^+ n \rightarrow \pi^0 p$ process is two times higher than that for the $\pi^- p \rightarrow \pi^- p$ process. The numbers of nucleons involved in the interaction with pions are five and four for the $^{13}C+\pi^+$ and $^{12}C+\pi^-$ reactions, respectively. Finally, the $p + {}^{11}B(g.s.) \rightarrow n + {}^{11}C(g.s.)$ nucleon charge exchange process proceeds through the isobaric analog transition, but the $p + {}^{12}C(g.s.) \rightarrow n + {}^{12}N(g.s.)$ proceeds through a nonanalog transition. This provides another reduction factor of about 1/10.[21] By combining these

TABLE III. Cross sections of the $^{12}C(\pi^+,\pi^0)^{12}N$ reaction.

Pion energy (MeV)	Measured cross section (μb)	Secondary reaction contribution (μb)	$^{13}C(\pi^+,\pi^0 n)^{12}N$ contribution (μb)	Corrected $^{12}C(\pi^+,\pi^0 n)^{12}N$ cross section (μb)
116±7.2	78±3	8±8	1±2	69±9
160±9.4	98±3	8±8	2±2	88±9
180±10.3	76±5	8±8	2±2	66±10
200±11.3	82±3	8±8	2±2	72±9
230±12.7	82±7	8±8	2±2	76±11
291±15.4	75±5	8±8	2±2	65±10

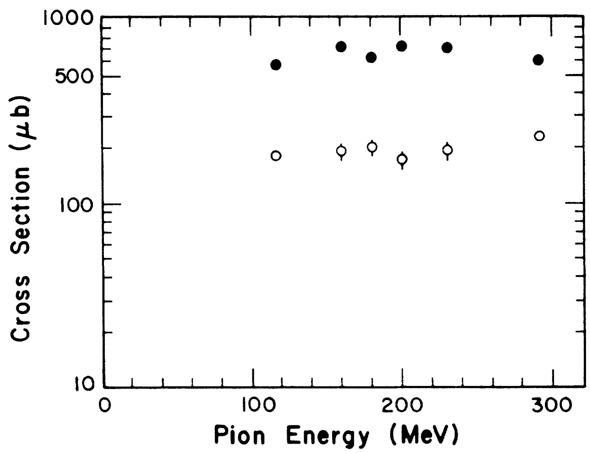

FIG. 4. Excitation functions for $^{12}C(\pi^+,X)^8Li+^8B$ and $^{12}C(\pi^+,Y)^9C$ reactions, denoted by solid and open circles, respectively.

factors, we get a scaling factor of 0.25, yielding the cross sections shown in Table II. Similar scaling is applied to the calculated cross section[22] of 0.18 mb for the $^{12}C(\pi^-,\pi^0p)$ ^{11}Be reaction that proceeds through the nonanalog transition and yields a value of 0.14 mb at 180 MeV for the $^{13}C(\pi^+,\pi^0n)^{12}N$ reaction. Therefore, the estimated cross sections given above should be reliable within a factor of 2.

D. Excitation functions

The results of correcting the cross section values for the contributions discussed above are presented in Table III along with the estimated magnitudes of the corrections. Figure 3 shows the excitation functions for the reactions $^{12}C(\pi^+,\pi^0)^{12}N$ and $^{12}C(\pi^+,\pi^{+'})^{12}C^*(1^+;1)$. The uncertainties shown for the ^{12}N cross sections reflect the uncertain contributions from secondary reactions. The excitation functions for the reactions $^{12}C(\pi^+,X)^8Li+^8B$ and $^{12}C(\pi^+,Y)^9C$ are shown in Fig. 4.

V. DISCUSSION

All the excited levels in ^{12}N are particle-unbound states, and the decay width through the γ-ray transition is very small.[23] For example, it is estimated to be one part in 10^4 for the 0.96-MeV first excited state, and the magnitudes for the higher-lying states are presumably similar, as inferred from the measured data[23] on ^{12}B, which is the mirror nucleus of ^{12}N. Therefore, the contribution to the production of the ground state in ^{12}N coming from all excited states is considered negligible.

Inelastic scattering cross sections for ^{12}C were measured for the 12.7-MeV$(1^+;0)$, 15.1-MeV$(1^+;1)$, and 16.1 MeV$(2^+;1)$ levels for π^+ beam energies between 100 and 291 MeV.[5] Among these levels, the 15.1-MeV level is interesting because it is the isobaric analog of the ^{12}N ground state. For strongly absorbed particles, such as pions of energy greater than 100 MeV, a semiclassical theory[5] yields a differential cross section for a 1^+ state (at small angles) that is proportional to $|J_1(kR\sin\theta)|^2$, irrespective of the theoretical models for calculating pion distortions. Peterson *et al.*[5] succeeded in fitting their data using the function $J_1(kR\sin\theta)$ up to an energy of 291 MeV. Using their fit as a guide, we have summed up their differential cross sections to 180° and plotted the results as integral cross sections in Fig. 3.

A comparison of the absolute cross sections for the inelastic scattering reaction $^{12}C(\pi^+,\pi^{+'})^{12}C^*(1^+,1)$ with those of our measured single-charge-exchange reaction (Fig. 3) shows them to agree within the uncertainties of the measurements at all energies except 230 MeV where the inelastic scattering data point falls well below that observed in our work. The discrepancy at 230 MeV cannot be explained, but it may be the result of a departure from the simple angular distribution that was assumed.

Excitation functions for inelastic pion scattering to natural-parity and unnatural-parity states with $\Delta T=0$ are reasonably well understood in both the eikonal model and through DWIA calculations.[8,24] However, there remain uncertainties in the case of inelastic pion scattering leading to the low spin $\Delta T=1$ state, for example, from the ^{12}C ground state to the 1^+, $T=1$ state. In this case, delta-hole (Δ-h) components have been proposed to reproduce an enhancement observed near 180 MeV (Ref. 6) of the inelastic pion scattering cross section to the 1^+, $T=1$, 15.11- MeV state in ^{12}C. A more sophisticated Δ-h formalism is applied to the $\pi^\pm+{}^{12}C$ inelastic scattering by Lenz *et al.*[8] Their model is able to account for the angular distribution of the pion-nucleus inelastic scattering for the $\Delta T=0$ transition to the 12.7-MeV state, but is in serious disagreement, both with respect to the shape and absolute magnitude, with the experimental angular distributions for the $\Delta T=1$ reaction $^{12}C(\pi^+,\pi^{+'})^{12}C^*(1^+;1)$.

The results of the Δ-h DWIA calculations[8] for a spin-flip transition are further compared with the integral cross sections of the present $^{12}C(\pi^+,\pi^0)^{12}N$ data in Fig. 3. As pointed out above, the measured cross sections are almost independent of energy between 116 and 291 MeV, while the results of the calculations show a dramatic decrease with increasing pion energy as shown in Fig. 3. The discrepancy between the measured and calculated results cannot be reconciled even if one introduces admixtures of large convection currents in the Δ-h model.[8]

VI. CONCLUSION

In summary, total cross sections for the isovector SCE nonanalog $^{12}C(\pi^+,\pi^0)^{12}N$(g.s.) reaction have been measured by means of a fast activation technique between incident pion energies of 116 and 291 MeV. The excitation function obtained is flat over this energy region that includes the (3,3) resonance. The trend of the data cannot be reproduced by distorted-wave impulse-approximation calculations in the Δ-h formalism. However, a comparison of the angle-integrated cross sections deduced from inelastic scattering to the ^{12}N isobaric-analog state in ^{12}C, i.e., $^{12}C(\pi^+,\pi^{+'})^{12}C^*(1^+,1)$, and the measurements reported here agree at all energies except 230 MeV.

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