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NEUTRON PAIR EMISSION FOLLOWING THE CAPTURE OF π^- IN ^{14}N *)

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ABSTRACT

A first study of the reaction $^{14}N(\pi^-,2n)^{12}C$ at rest is reported. The nucleon pair quantum numbers favoured in the absorption process are deduced. The excitation spectrum of the residual ^{12}C nucleus differs from the one obtained through the $(\pi^+,2p)$ reaction.

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It has been shown experimentally that there is a strong angular correlation between two emitted nucleons following π absorption in nuclei[1]. This demonstrates a quasifree mechanism, and hence the study of the (π,2N) reaction is expected to give information on two-hole states[2], besides the general information on the absorption mechanism. However, very little is known so far about the quantum numbers of those nucleons on which the absorption process is favoured. Several groups reported the results of the measurements for the $(\pi^+,2p)$ [3,4] and $(\pi^-,2n)$ [5,6] reactions, mainly on 1p-shell nuclei. In general the excitation energy spectrum of the residual nucleus exhibited one strong peak in the vicinity of the ground state. An additional peak in the excitation spectrum was reported on only a few nuclei. However, according to the calculations[7,8], more levels with large fractional parentage coefficients for two-nucleon removal exist than were observed experimentally. The poor agreement between the fractional parentage calculations and the data was reported[4] in the particular case of the reaction $^{14}N(\pi^+,2p)^{12}C$, which was studied by two groups[3,4]. While, for example, the fractional parentage coefficient for the transition to the 4.4 MeV level is rather large, its contribution was not experimentally identified. No quantum numbers were assigned to the observed structure. In order to provide an additional insight into this problem, a first experiment on the reaction $^{14}N(\pi^-,2n)$ was performed.

Negative pions from the CERN Synchro-cyclotron were stopped in a 5 g/cm^2 liquid-nitrogen target. Coincident neutron events were measured by large-area, position-sensitive, neutron time-of-flight (TOF) counters used for the first time in this type of experiment. The centres of the two TOF counters were at a distance of 4.5 m from the target, with an opening angle of 164.5°. Each neutron counter is assembled from 48 rods, 2 m long, of plastic scintillator NE 110. The rods are viewed at both ends by photomultipliers. The time difference between the light signals at two ends determines the position of the neutron impact in the direction along the neutron counter to a precision of ±3 cm. The neutron impact position in a vertical direction and along the flight path is determined from the information on which rod has triggered. The TOF resolution was 800 psec for pulses of 20 MeV electron equivalents. With the 4.5 m TOF distances of the present set-up, the resulting resolution in the excitation energy of the residual nucleus was 5 MeV, which is about a factor of 3 better than in previous $(\pi^-,2n)$ experiments. The energy calibration was checked using the TOF peak accumulated simultaneously for the γ-rays produced in the target. A more detailed description of our set-up will be given elsewhere.

In Fig. 1 the excitation spectrum for the residual ^{12}C nucleus is shown together with levels for which the coefficients of fractional parentage[7,8] for two-nucleon transfer are large. The 4.4 MeV level, which was not observed in the

(π^+,2p) reaction, can be clearly identified. The second peak arising around 13 MeV is close to the one observed with positive pions, whereas the peak in the region of 22 MeV was not reported in the (π^+,2p) experiment. No other distinct peak is visible at higher energies, while in the experiment with positive pions a peak in the region of 30 MeV was observed. In Fig. 1 also a theoretical spectrum is shown for the deuteron knock-out reaction ^{14}N(p,pd)^{12}C for zero momentum transfer, with and without spin flip. Despite the difference in the reaction mechanism, there is a striking similarity between our measured spectrum and the calculation without spin flip. This suggest that in the (π^-,2n) process the contribution of np pairs in the spin triplet state is large compared to that of the singlet pairs.

In the spectator picture the recoil momentum distribution reflects the motion of the nucleon pair with respect to the residual nucleus before the absorption. In Fig. 2 these distributions are presented for the three windows in excitation energy which correspond to the observed peaks. All distributions are peaked towards zero momentum. This is conclusive for L = 0 predominance, where L is the orbital angular momentum for the nucleon pair centre-of-mass motion with respect to the core before the absorption. Comparing in Fig. 1 the ^{12}C excitation spectrum and the levels which are predicted to be populated, we observe a correspondence for the transitions with L = 0. There is no evidence for L $\neq$ 0 transitions in our results. For example, the (L=2) ^{12}C ground state is clearly not observed although the coefficient for this state is large.

In conclusion, from the first kinemtaically complete study of the reaction ^{14}N(π^-,2n)^{12}C we obtained the excitation spectrum of ^{12}C and the momentum distributions for the different peaks in the spectrum. The shape of the momentum distributions points towards L = 0 for all three peaks. Comparison with calculations for two nucleon transfer reactions indicates that the absorption process is favoured for triplet spin states of the np pair.

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Figure captions

Fig. 1 : Data points represent the excitation energy spectrum of ^{12}C from the reaction $^{14}N(\pi^-,2n)^{12}C$, with statistical errors. Positions of levels predicted by fractional parentage calculations for T = 0 and T = 1 nucleon pairs from Ref. 7 (CK) and Ref. 8 (BBR) are indicated. Levels marked with solid and dotted lines correspond to L = 0 and L = 2 values of orbital angular momentum for the nucleon pair, respectively. The theoretically calculated excitation spectra for the reaction $^{14}N(p,pd)^{12}C$ of Ref. 8 are indicated as a solid and a dashed curve without and with spin-flip, respectively.

Fig. 2 : Recoil momentum distributions for three windows in excitation energy, corresponding to the three peaks in Fig. 1, with statistical errors (ω is the angle spanned by the two neutron momenta). The distributions are corrected for geometrical effects as well as for neutron counter efficiencies, and are divided by the phase space factors. Also the reduction in phase space for the high q-values (> 185 MeV/c) due to the restricted ω-range has been taken into account. Assuming no θ-dependence of the matrix element (θ is the angle spanned by the sum and the difference of the neutron momenta) the distributions shown for high q-values (> 185 MeV/c) also represent the true q-dependence of the matrix element.

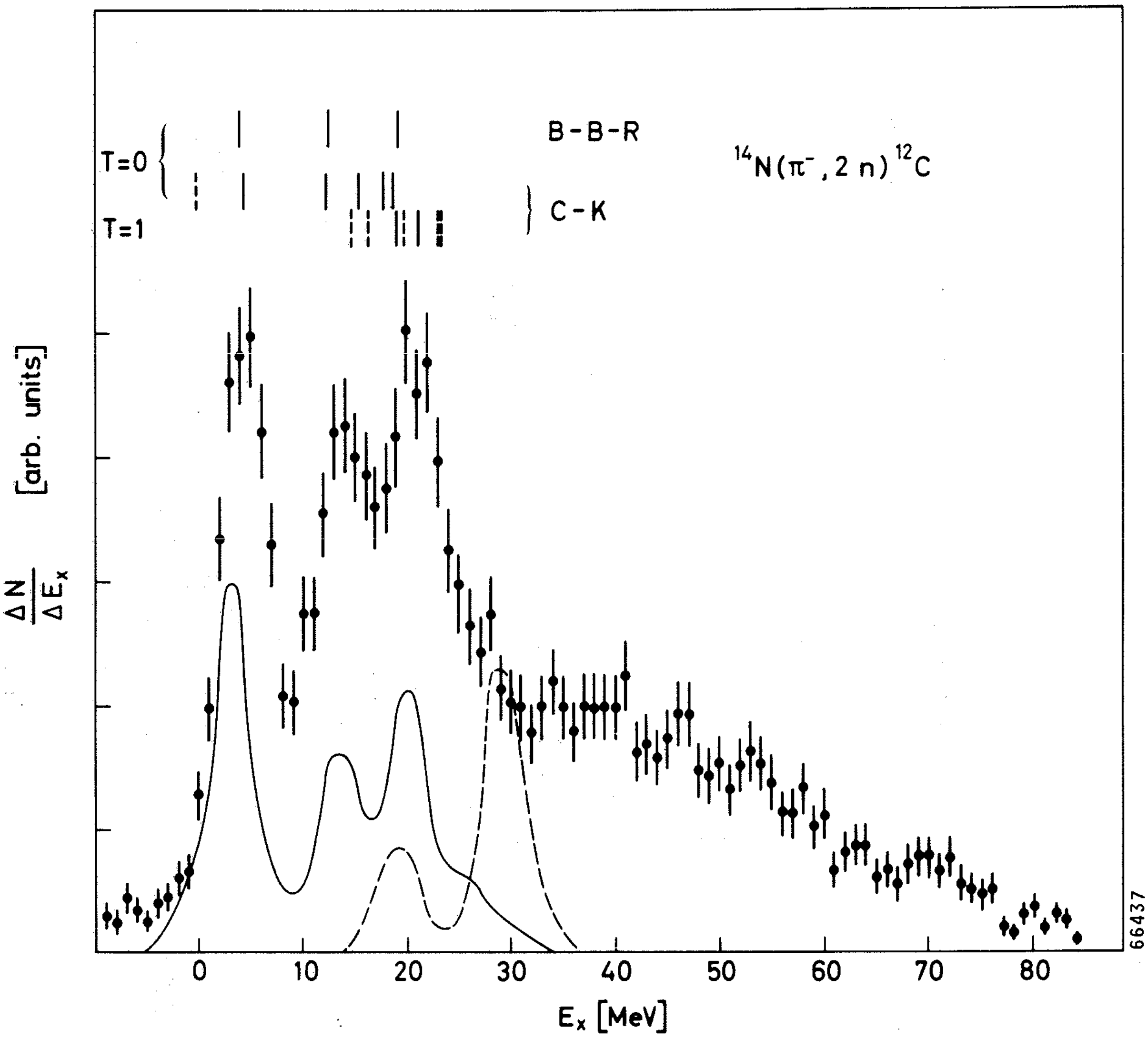
T=0
T=1
B-B-R
C-K
$^{14}N(\pi^-, 2n)^{12}C$
$\frac{\Delta N}{\Delta E_x}$ [arb. units]
0
10
20
30
40
50
60
70
80
E_x [MeV]
66437

Fig. 1

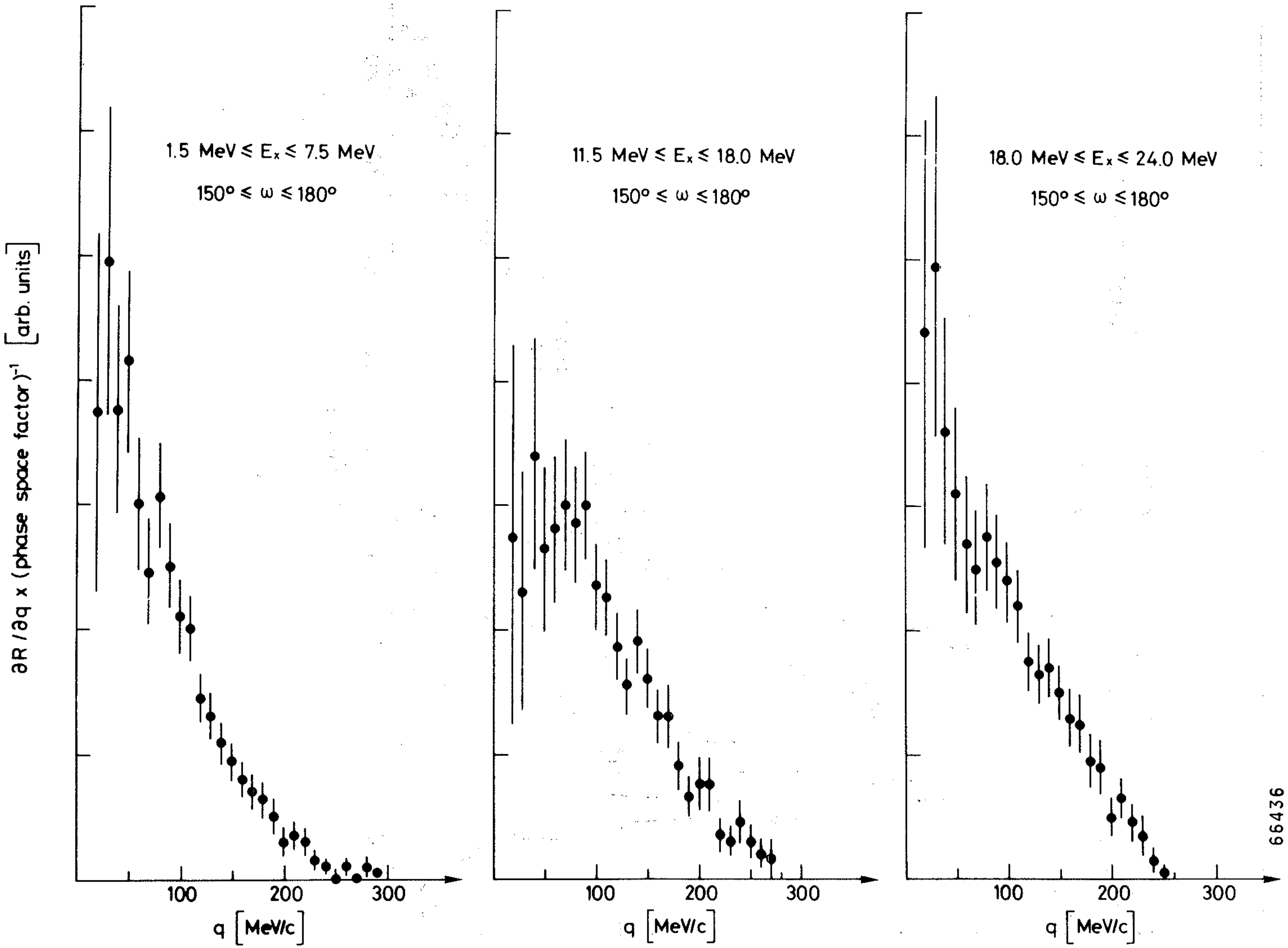
1.5 MeV ≤ Ex ≤ 7.5 MeV
150° ≤ ω ≤ 180°
11.5 MeV ≤ Ex ≤ 18.0 MeV
150° ≤ ω ≤ 180°
18.0 MeV ≤ Ex ≤ 24.0 MeV
150° ≤ ω ≤ 180°
∂R / ∂q x (phase space factor)⁻¹ [arb. units]
q [MeV/c]
100
200
300
66436

Fig. 2