COHERENT PRODUCTION OF PIONS IN NUCLEI WITH (^{3}He, t) CHARGE EXCHANGE REACTION AT 2 GeV *

L. Farhi[a], M. Roy-Stephan[a], W. Augustiniak[d], J.L. Boyard[a], R. Dahl[c], C. Ellegaard[c], C. Gaarde[c], T. Hennino[b], J.C. Jourdain[a], M. Kagarlis[b], J.S. Larsen[c], P. Radvanyi[b], B. Ramstein[a], M. Skousen[c], P. Zupranski[d]

[a] IPN, IN2P3(CNRS), 91406 Orsay Cedex, France
[b] LNS, IN2P3(CNRS), DSM(CEA) CE-Saclay, 91191 Gif-sur-Yvette Cedex, France
[c] Niels Bohr Institute, DK-2100 Copenhagen, Denmark
[d] Soltan Institute for Nuclear Studies, 00-681 Warsaw, Poland

(Received October 9, 1996)

The (^{3}He, t) charge exchange reaction at 2. GeV incident energy with the new setup SPES IV-π has been realized in December 1995 and March 1996, in order to study the coherent production process of pions. This setup allows to isolate the ground state of the target nucleus, and to sign this process without ambiguity. We give some preliminary results in target excitation energy and tranfered energy.

PACS numbers: 25.40. Kv, 25.40. Ve

1. Introduction

Several experiments have been realized with charge exchange reactions, at energies from 0.6 to 1 GeV/N at Dubna, Gatchina, Lampf and Saturne. A shift of about 70 MeV towards low energy transfers has been observed for the position of the resonance, with respect to the free Δ resonance position. One half of the shift has been accounted for by kinematics, Fermi motion and mean field considerations [1, 2]. An exclusive (^{3}He, t) experiment has then been realized at Saturne with the DIOGENE detector in order to study the Δ resonance in nuclei and its decay modes [3, 4]. From its results, it came that the $\Delta N \rightarrow NN$ absorption process can also explain one part of Δ resonance shift. Moreover, a first evidence of the coherent production

* Presented at the Meson-96 Workshop, Cracow, Poland, May 10–14, 1996.

of pions was pointed out, though the missing mass resolution was not adequate to sign it clearly [5]. In order to characterize this process without ambiguity, an additional experiment has been realized with the SPES IV-π setup at Laboratoire National Saturne.

2. The pion coherent production process

This process A(^{3}He,tπ^+)A is defined by two main features :

— the target nuclei remains in its ground state,

— one pion is emitted in the output stream.

Its origine is connected to the π-exchange interaction between Δ-hole states in the nuclear medium [6, 7]. It is a selective probe of the longitudinal component of the Δ-hole interaction. The spin-longitudinal $(\vec{S}^\dagger \cdot \vec{q})$ excitation should give a forward peaked angular distribution of the angle $\theta_{q,\pi}$ between the emitted pion and the transfered quantum. On the other hand, the spin-transverse $(\vec{S}^\dagger \times \vec{q})$ excitation will give an angular distribution peaked at higher angles. This contribution is cut off by the form factor of the target nuclei.

This features have already been observed with the DIOGENE experiment. Though the resolution on missing mass didn't allow to distinguish the ground state of the target from its excited states, one could note that the one pion events were mostly distributed at low target excitation energy. The angular distribution was also clearly peaked at 0° [5]. Still, the DIOGENE setup did not allow to study the coherent process at triton angles below 2.5°, where the cross section of the reaction is the highest. Due to the (^{3}He, t) form-factor, this cross-section decreases critically with the transfered momentum, and then the triton angle.

3. The SPES IV-π set-up

The aim of this extra experiment was to characterize the specific coherent process. This first needed to select the coherent pions, and requested a good resolution in missing mass. Then the setup had also to reach several $(\omega, \vec{q})$ four momentum transfers which means to scan the triton angle down to 0°.

Both triton and pion were detected in coincidence. The triton was detected in the SPES IV spectrometer with a resolution of about $7 \cdot 10^{-4}$ in $\Delta P/P$ and 1 mrad in horizontal angle. The acceptance of SPES IV ($\pm 3\%$ in momentum and ± 8 mrad) imposed that several settings of central momentum should be used to cover the whole Δ region in momentum.

The pions were deviated in a magnetic field of about 1 Tesla including the target. The vertical aperture of the magnet is $\pm 10°$. The detection of the pion was ensured by two wire-chambers, each of them composed by 3 planes of about 500 wires. The first chamber is 0.5 m high and 1 m large. The second one is twice larger. Both chambers cover a solid angle of about 0.5 srd in the relevant region of coherent pions and detects about 25% of those pions in coincidence with a triton in the spectrometer. The acquisition system used is the PCOS IV system.

The resolution expected in momentum for the pion is about 1%, and the angle should be determined with an accuracy of 1°. The identification of pions is realized by an hodoscope of 16 scintillators behind the second chamber. An helium bag was used just after the target in order to minimize the nuclear reaction in the air and multi-scattering effects. In the end, the resolution in missing mass should be less than 5 MeV/c^2, so that one can isolate the ground state of the target nuclei, and reject the incoherent pions. The accuracy expected on the angle between the pion and the transfered momentum is about 2.8°.

The setup allows to take data at 0° triton angle, where counting rates are higher.

Several targets have been used : ^{12}C, CH_2, ^{40}Ca and ^{208}Pb.

4. Target excitation energy

The results of DIOGENE experiments at triton angle above 2.5° have pointed out that the branching ratio of coherent production process is about 5% on ^{12}C and that its cross-section is higher for light targets.

We present here some results on ^{12}C target obtained with the SPES IV-π setup.

The target excitation energy is the missing mass of (^{3}He, t) minus the mass of the target. It is expected to be 0 for the coherent process. After subtraction of empty target runs, the missing mass spectrum obtained is shown on Fig. 1. The FWHM is about 5 MeV/c^2, and is still not enough to isolate the ground state of the ^{12}C from its first excited state at 4.4 MeV/c^2. However, a better reconstruction of the pion from the wire-chamber positions, and of the triton in SPES IV should improve it to the expected resolution. Anyway, the coherent process obviously dominates the spectrum.

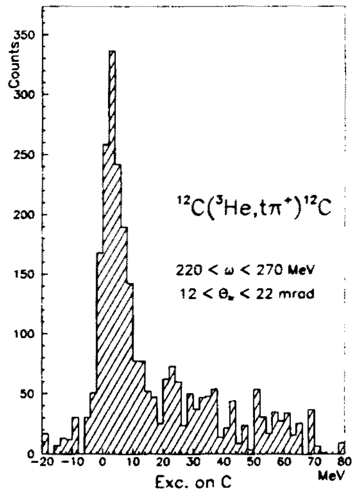

Fig. 1

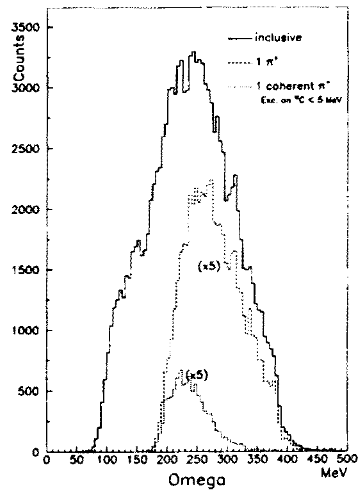

Fig. 2

Fig. 1. ^{12}C target excitation energy spectrum for (^3He, t) reaction at 2 GeV incident beam, 1° scattering angle, 3.61 GeV/c central momentum of triton.

Fig. 2. Energy transfer spectrum for (^3He, t) reaction at 2 GeV incident beam, 1° scattering angle, 3.61 GeV/c central momentum of triton.

5. Energy transfer

Another signature of the coherent production process is the distribution in transfered energy ω shown on Fig. 2. The coherent pions are selected by a cut on the excitation energy of the target nuclei. One can clearly see that the spectrum of the coherent pions is shifted towards small energy tranfers with respect to the inclusive spectrum or the whole pion spectrum. This shift is a direct evidence of the attractive nature of the longitudinal part of the Δ-hole interaction [6].

6. Conclusion

The new setup SPES IV-π has reached its aims in order of resolution and gives a striking evidence of the coherent production process in nuclei. This promising results still need to be refined. The shift in transfered energy ω observed also confirms the first results of DIOGENE.

The analysis that is to come should yield the angular distribution $\theta_{q,\pi}$ of the pion with respect to the exchanged quantum in the (^3He, t) reaction as a function of the $(\omega, \vec{q})$ four momentum transfer. We should also be able to estimate the total cross section of the process and its branching ratio for several targets and small triton angles.

REFERENCES

[1] J. Delorme, P.A.M. Guichon, *Phys. Lett.* **B263**, 157 (1991).

[2] T. Udagawa, S.W. Hong, F. Osterfeld, *Phys. Lett.* **B245**, 1 (1990).

[3] T. Hennino, B. Ramstein, D. Bachelier, H.G. Bohlen, J.L. Boyard, C. Ellegaard, C. Gaarde, J. Gosset, J.C. Jourdain, J.S. Larsen, M.C. Lemaire, D. L'Hôte, H.P. Morsch, M. Österlund, J. Poitou, P. Radvanyi, M. Roy-Stephan, T. Sams, K. Sneppen, O. Valette, P. Zupranski, *Phys. Lett.* **B283**, 42 (1992).

[4] B. Ramstein, Proceedings of this conference.

[5] T. Hennino, B. Ramstein, D. Bachelier, J.L. Boyard, C. Ellegaard, C. Gaarde, J. Gosset, J. C. Jourdain, J. S. Larsen, M. C. Lemaire, D. L'Hôte, H. P. Morsch, M. Österlund, J. Poitou, P. Radvanyi, M. Roy-Stephan, T. Sams, P. Zupranski, *Phys. Lett.* **B303**, 236 (1993).

[6] P. Oltmanns, F. Osterfeld, T. Udagawa, *Phys. Lett.* **B299**, 194 (1993).

[7] P.F. de Cordoba, J. Nieves, E. Oset, M. Vicente-Vacas, *Phys. Lett.* **B319**, 416 (1993).