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The study of the double charge exchange on nuclei (DBCX) can give informations on pion interaction with nuclei and nucleons in complex nuclei (1). Up to now, only few experimental data on DBCX have been obtained, especially on light nuclei (2-6).

When investigating DBCX of $\pi^{\pm}$ on ^3He and ^4He, it is of great interest the study of nucleons system of three or four neutrons or protons and the search for bound states of these nucleons in the following reactions:

$$\pi^- + {}^3He \longrightarrow \pi^+ + 3n \qquad (I)$$

$$\pi^- + {}^4He \longrightarrow \pi^+ + 4n \qquad (II)$$

$$\pi^+ + {}^4He \longrightarrow \pi^- + 4p \qquad (III)$$

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Earlier we have measured the total cross section of DBCX of positive pions on ^4He at about 100 MeV (7). In this paper we present the values obtained at 98, 135, 145 and 156 MeV. The study of the reaction (III) is of special interest because this reaction results as a star of five charged particles in the visual detectors and considerably increases the reliability of identifying this type of events, respect to reactions (I) and (II).

The experiment was carried out with a high pressure helium filled streamer chamber (8, 9) simultaneously used as target and as detector. The experiment has been mainly performed to measure the elastic scattering differential cross section of π^+ mesons on ^3He and ^4He (10, 11). The chamber, filled with ^4He, was exposed to the positive pion beam at 98, 135, 145 and 156 MeV of the SC of JINR. At the same energies (except at 135 MeV) the chamber was filled with ^3He in order to measure background processes (no DBCX of positive pions is allowed on ^3He nuclei). The chamber, with ^3He and ^4He, had equal amounts of hydrocarbons admixtures, added to improuve the chamber operation (0.2% of α-pinene). The background is evaluated with an accuracy of about 30 μb, similarly for ^3He and ^4He (see also ref. 7). The chamber was triggered when the secondary pion is detected by the scintillation hodoscope counters surrounding the chamber itself; the walls were sufficiently thick to stop the protons from reaction (III). The obtained pictures were scanned for five-prongs stars. The pion tracks have been discriminated from the proton ones using ionization criteria. The peak energy of the positive pion beam at each energy value, was measured with an accuracy of 2 MeV; the energy spread of the beam was 5%. The energy value has been determined by the measurements of the momenta of the incident pions in a deflecting magnet with a helium streamer chamber at atmospheric pressure, and also by measurements of angles and ranges in the elastic scattering events (12).

The total number of incoming pions was 1.9×10^8; 270000 pictures were taken. The rate for elastic scattering events and for double charge exchange events was 1/100 pictures and 1/10000 pictures respectively.

To select events of DBCX, kinematic criteria were used, taking also into account the results of background measurements on ^3He (7). The values, obtained according to kinematic criteria, at all energies agree with those obtained by subtracting, from the total number of five-prongs stars in ^4He, the background measured using ^3He. This is important, since, without the magnetic field, the kinematic criteria do not discriminate unambiguously the events of DBCX.

Table I presents the results of measurements, at different energies, of the five-prongs stars identified as events of DBCX using kinematic criteria. The Table presents the measured angles of the pion and the four protons of the reaction (III) (θ_π and θ_p , respectively).

Table II presents the calculated values of the cross sections, the total number of five-prongs stars n_1, the number of DBCX events n selected with kinematic criteria (this number was used to calculate the cross section), the number n_2 of events obtained after the subtraction of the measured background. The quoted errors are statistical only. The geometrical efficiency of the counter hodoscope was calculated supposing that the solid angle of the hodoscope is the same for any scattering angle of the pion in the range $30^o \div 150^o$. Table II also presents the cross section values from refs. (2, 13).

Let's now compare our data with the results on pion DBCX in carbon (14). At pion energies of 138 MeV total DBCX cross section is: $\sigma(^{12}C) = 1.24 \pm 0.38$ mb. The cross section of the channel $\pi^+ + {}^{12}C \rightarrow 2\alpha + 4p + \pi^-$ has been shown to be 62% of the total cross section of DBCX, i.e. about 0.8 mb. This DBCX channel in carbon is then the most important channel; this fact shows that

E_π = 98 MeV

N	θ_π	θ_p	N	θ_π	θ_p	N	θ_π	θ_p
1	29±2	102±2	4	106±2	131±2	7	143±2	102±2
		22±2			52±3			27±4
		92±2			22±3			32±2
		95±2			76±2			60±4
2	68±2	76±2	5	113±4	114±2	8	148±2	85±5
		32±2			106±2			29±3
		100±5			24±2			78±4
		161±2			33±2			107±2
3	85±2	69±2	6	141±2	32±2	9	164±3	95±3
		52±5			41±2			10±2
		60±3			66±3			89±3
		87±2			145±3			95±4

E_π = 145 MeV

N	θ_π	θ_p	N	θ_π	θ_p	N	θ_π	θ_p
1	31±2	154±5	2	60±2	41±2	3	87±3	61±5
		6±3			50±2			33±4
		33±3			100±5			80±2
		44±3			136±4			113±4
4	127±5	62±2						
		47±2						
		57±5						
		99±4						

E_π = 135 MeV

N	θ_π	θ_p	N	θ_π	θ_p	N	θ_π	θ_p
1	39±2	84±3	4	110±2	111±3	7	163±2	142±3
		13±3			74±4			100±4
		90±5			35±5			20±5
		110±2			92±3			72±5
2	43±2	101±3	5	131±2	133±4			
		48±3			27±2			
		81±3			42±2			
		110±5			74±2			
3	103±3	70±4	6	144±2	144±2			
		56±4			45±3			
		55±4			18±4			
		141±2			89±4			

E_π = 156 MeV

N	θ_π	θ_p	N	θ_π	θ_p	N	θ_π	θ_p
1	36±2	67±2	2	118±2	66±3	3	128±2	61±2
		27±2			70±5			50±5
		102±2			47±2			54±2
		132±2			112±4			105±2

TABLE I - Results of the measurements of DBCX events. E_π is the kinetic energy of incident pion (MeV) N is the number of the event; θ_π and θ_p are the angles of emission of the outgoing pion and of the four protons respectively, relative to the incident pion direction.

TABLE II - Number of events and DBCX cross sections at different energies. E_π is the kinetic energy of the incident pions (MeV); n_1 is the number of the five-prong stars; n_2 is the number of five-prong stars after subtracting the background according to the results of experiment on ^{3}He; n is the number of DBCX events (according to the results of the kinematic analysis); σ is the cross section (mb).

E_π (MeV)	n_1	n_2	n	σ (mb)	ref.
40				< 0.002	13
98	17	10	9	0.30±0.10	
135	12		7	0.29±0.11	
145	6	5	4	0.34±0.17	
156	9	7	3	0.13±0.07	
485				1.20±0.21	2

DBCX seems to occur mainly on alpha-clusters of the carbon nucleus. These evaluations well agree with the DBCX cross section value measured by us on helium at 135 MeV (0.29 ± 0.11 mb).

Fig. 1 shows the experimental values of the cross section of DBCX of positive pions on ^{4}He at the different energies, including all

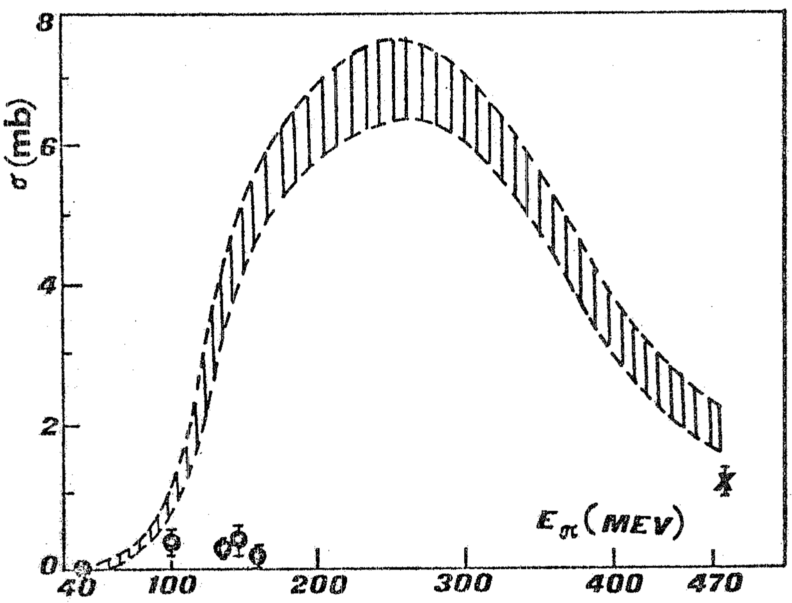

FIG. 1 - DBCX cross section prevision of the pair correlation model (1) with the indication of calculation uncertainties. Open circles - present experiment: full point - from ref. (13); cross ref. (2).

the existing experimental data. The same figure shows the calculated curve (1, 13) for $\pi^- + {}^4He \to \pi^+ + 4n$ reaction, with the indication of calculation uncertainties (dashed area). The cross section of this reaction can not be quite different from that of $\pi^+ + {}^4He \to \pi^- + 4p$ reaction. The calculations have been made using the pair correlation model. In the figure there is a great difference between the experimental and calculated cross section values. It should be noted that in the pair correlation model calculations, the effect of the absorption was not taken into account. The impulse approximation has been used and the curve shows a maximum at about 250 MeV, characteristic of the first barion resonance Δ_{33}. The experimental data seem to exclude a resonant behaviour of the cross section.

In fig. 2, is shown the theoretical behaviour of the DBCX cross section deduced on the basis of the exchange current theory (15).

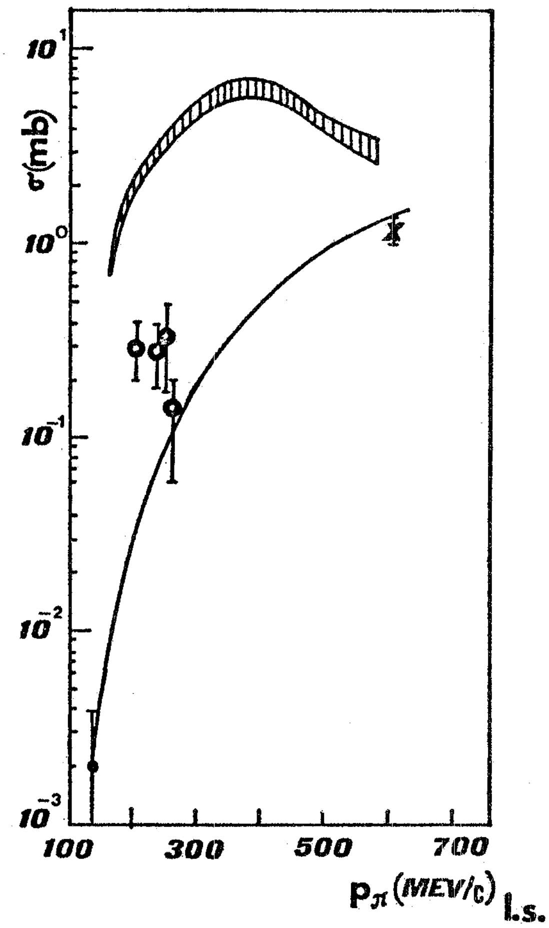

FIG. 2 - Cross section of $\pi^+ + {}^4He \to \pi^- + 4p$ reaction as a function of the pion momentum. Upper curve - pair correlation model prevision (1); lower curve - exchange current model prevision (15); open circles - present experiment; cross - ref. (2); full point - from ref. (15).

compared with the existing experimental data. The cross section monotonously increases in the range from 140 to 610 MeV/c, without any maximum, as in the case of the pair correlation model.

At present, it can then be noted that there is a rough qualitative agreement between exchange current theory and the experiments. Further experiments and more accurate theoretical models for DBCX are necessary. To establish whether the effect of the first barion resonance Δ_{33} appears (and how) in the DBCX of pions on helium, it is necessary to perform new experiments at different pion energies from 200 up to 400 MeV. It is worth mentioning that in this energy region no maximum has been observed (14) in the cross section behaviour of the DBCX of pions on carbon.

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