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STUDY OF THE $p+d\to^3$He $+2\pi$ REACTION AT CELSIUS*

M. Andersson[a], Chr. Bargholtz[a], E. Fumero[a], K. Fransson[a]
L. Holmberg[a], K. Lindh[a], L. Mårtensson[a], I. Sitnikova[a]
P.-E. Tegnér[a], P. Thörngren Engblom[a], G. Weiss[a]
K. Wilhelmsen Rolander[a]

and Members of the WASA/PROMICE collaboration[b]

[a]Department of Physics, Stockholm University, Box 6730
S-113 85 Stockholm, Sweden
[b]Department of Radiation Sciences, Uppsala University
S-751 21 Uppsala, Sweden

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The exclusive $p+d\to^3$ He $+2\pi$ reaction has been studied at CELSIUS at a beam energy of 477 MeV. Preliminary results indicate that the two pions are created mainly in an isospin $T=1$ state.

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The investigation of the inclusive reaction $p+d\to^3$ He $+X$ has played a major role in the search for resonant two pion states. The ABC enhancement was first observed by Abashian, Booth and Crowe [1] in this reaction for incident proton energies between 624 and 743 MeV. Their results were consistent with an enhancement at a missing mass of 310 ± 10 MeV/c^2. In a later study of the reaction, in inverse kinematics, Banaigs *et al.* [2] placed the enhancement at a missing mass varying between 297 and 365 MeV/c^2, depending on the kinematical conditions, for deuteron beam energies between 1.5 and 2.4 GeV (corresponding to 760 to 1200 MeV protons). Banaigs *et al.* also found that the ABC-effect was seen only in reactions where the system X was produced in an isospin $T=0$ state.

The reaction $p+d\to^3$ He $+\pi^++\pi^-$ was studied by the MOMO-collaboration and they have reported interesting preliminary results [3]. For an incident proton energy of 546 MeV the collaboration could not confirm

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any enhancement for low invariant mass of the pion pair but rather reported a relative deficit of events for invariant masses below 320 MeV/c^2. Similar results have been reported from later experiments by the collaboration for a beam energy of 477 MeV [4].

One possible explanation of the MOMO results, suggested by Wilkin [5], is that the two pions are produced in a relative p-state, thus with isospin $T = 1$. This could be the tail of the ρ^0-meson ($p + d \rightarrow^3$ He $+ \rho^0$, $\rho^0 \rightarrow \pi^+ + \pi^-$).

By studying the exclusive reactions

$$p + d \rightarrow {}^3\mathrm{He} + 2\pi^0 , \qquad T = 0 , \tag{1}$$

$$p + d \rightarrow {}^3\mathrm{He} + \pi^+ + \pi^- , \quad T = 0, 1 , \tag{2}$$

it is possible to distinguish which of the isospin channels that dominates. The cross section for the two reactions can be written

$$\sigma_{\pi^0\pi^0} = k \int d\Phi({}^3\mathrm{He}, \pi^0, \pi^0) \tfrac{1}{3} \left|M_{T=0}\right|^2 , \tag{3}$$

$$\sigma_{\pi^+\pi^-} = k \int d\Phi({}^3\mathrm{He}, \pi^+, \pi^-) \left\{ \tfrac{2}{3} \left|M_{T=0}\right|^2 + \left|M_{T=1}\right|^2 \right\} , \tag{4}$$

where $d\Phi$ is the three-body phase space, M_T is the production matrix element and k a constant. For pure isospin $T = 0$ and a constant matrix element at a proton energy of 477 MeV the ratio of the two cross sections is calculated to be

$$\frac{\sigma_{\pi^0\pi^0}}{\sigma_{\pi^+\pi^-}} = 0.87 . \tag{5}$$

For pure isospin $T = 1$ the ratio is zero.

At CELSIUS [6] the $p + d$ reaction was studied using a cooled proton beam with a kinetic energy with a 477 MeV and a cluster-jet target of deuterium. The ^{3}He particles were detected in a zero-degree spectrometer [7] inclusively and in coincidence with any charge or neutral pions in the WASA/PROMICE detector set-up [8].

The charged particle telescope of the zero-degree spectrometer is placed 6 m behind the cluster-jet target, using the fourth quadrant as a spectrometer. The spectrometer telescope consisted of two high-purity germanium detectors, one position sensitive transmission detector and one stopping detector, and one silicon detector placed in between the two germanium detectors. With different radial positions of telescope the full range of momenta of ^{3}He particles from the $p + d \rightarrow^3$ He $+ 2\pi$ reaction was covered. ^{3}He particles from the $p + d \rightarrow^3$ He $+ \pi^0$ reaction were detected for calibration purposes.

Charged pions were detected in the WASA/PROMICE forward detector, composed of a set of plastic scintillator planes and straw chambers covering emission angles between 3° and 20°. Charged pions were also detected in the central detector, which consists of plastic scintillators followed by CsI scintillator arrays. To detect gamma rays from decaying neutral pions the CsI scintillator arrays are operated in anticoincidence with the plastic scintillators.

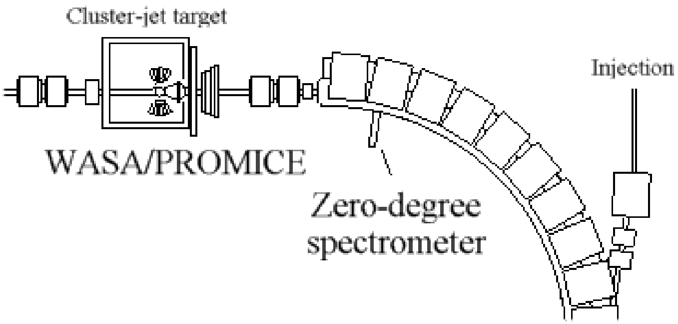

Fig. 1. Experimental set-up. The fourth quadrant of Celsius.

With ΔE-E-technique ^{3}He particles in the zero-degree spectrometer were selected in coincidences with at least one gamma ray or one charge particle in the WASA/PROMICE detector. A ratio of the number of events for the different reactions could be calculated. Taking into account the acceptance of the detectors, the ratio of the number of detected events for the two reactions, (1) and (2), is expected to be 0.78 if the isospin is pure $T = 0$. The ratio in the preliminary analysis of part of the total data is determined to be 0.18(16). The preliminary conclusion to be drawn is that the reaction is neither pure isospin $T = 0$ nor pure $T = 1$, but isospin $T = 1$ seems to dominate.

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