Measurement of the spin correlation parameters in the $pd \to {}^3\mathrm{He}\,\pi^0$ reaction*

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Two-body pion production in the interaction of protons with few-nucleon systems is of interest, both from the point of view of studying the reaction mechanism, and from that of determining the structure of light nuclei. The success of microscopic models with explicit Δ-excitation for two-nucleon systems suggests that these models should be tested in the three-nucleon case, where production of Δ is intimately linked to 3N forces. The phenomenological approach, using impulse approximation with $pp \to d\pi^+$ cross section, as input was successful near the reaction threshold but only partial progress has been achieved at higher energies [1].
In general six invariant amplitudes are required to describe the $pd \to {}^3\mathrm{He}\,\pi^0$ reaction and these amplitudes will be functions of the angle between the incident proton and outgoing pion in the c.m. frame. The number of independent functions reduce to two at threshold or in the forward/backward directions. These may be written as [2]

$$F(dp \to {}^3\mathrm{He}\pi^0) = \bar{\mathrm{u}}_\tau \vec{\mathrm{p}}\cdot(\mathrm{A}\vec{\varepsilon} + \mathrm{iB}\vec{\varepsilon}\times\vec{\sigma})\mathrm{u}_\mathrm{p}. \qquad (1)$$

Here $\vec{\varepsilon}$ is the deuteron polarisation vector, $\vec{p}$ and $\vec{k}$ the proton and pion centre-of-mass momenta and u_p and u_τ the initial and final fermion spinors. The amplitude should be multiplied by a $\sqrt{2}$ factor if the $pd \to {}^3\mathrm{H}\,\pi^+$ reaction is being considered.
If only the two amplitudes A and B are retained, the unpolarised c.m. differential cross section, deuteron tensor analysing power, and vector transverse spin correlation become

$$\frac{d\sigma}{d\Omega} = \frac{kp}{3}(|A|^2 + 2|B|^2), \qquad (2)$$

$$T_{20} = \sqrt{2}\frac{|B|^2 - |A|^2}{|A|^2 + 2|B|^2}, \qquad (3)$$

$$C_{y,y} = -\frac{2Re(A^*B)}{|A|^2 + 2|B|^2}, \qquad (4)$$

whereas iT_{11} and T_{22} , as well as the proton analysing power A_y, must all vanish.
The $pd \to {}^3\mathrm{He}\,\pi^0$ and $pd \to {}^3\mathrm{H}\,\pi^+$ reactions have been studied experimentally over many decades and a wealth of data on the differential cross sections and analysing powers has been collected for these processes. However, the double polarisation observables have been explored far less and information on the spin correlations is still very scarce. The ANKE spectrometer equipped with an internal polarised target together with the polarised deuteron beam of COSY offer a unique opportunity to conduct measurements of the transverse spin correlation coefficients in these reactions.
Two double-polarisation experiments have been performed at ANKE with a polarised deuteron beam and a polarised hydrogen target, at the beam energies of 363 and 600 & 1115 MeV per nucleon (COSY proposals #172 and #205).
The data at the two lower energies were analysed to obtain the spin correlations in the $pd \to {}^3\mathrm{He}\,\pi^0$ reaction. These results can be used together with the existing data on the differential cross section and the tensor analysing power T_{20} [3] to extract information on the forward amplitudes A and B from eq. 2-4.

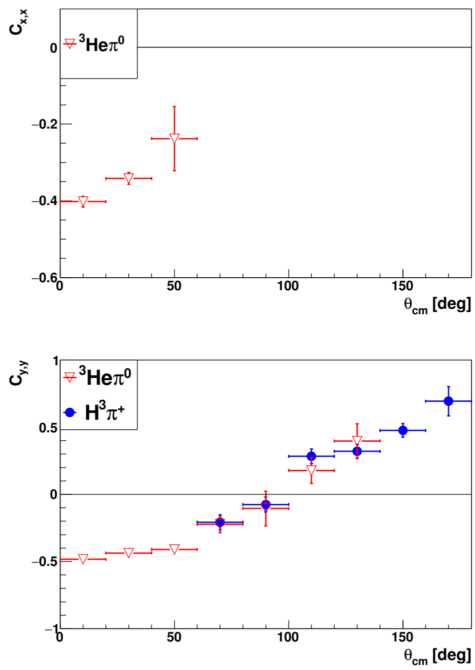

Fig. 1: Transverse spin correlation coefficients $C_{x,x}$ and $C_{y,y}$ in the $\vec{d}\vec{p} \to {}^3\mathrm{He}\,\pi^0$ and $\vec{d}\vec{p} \to {}^3\mathrm{H}\,\pi^+$ reactions at 363 MeV per nucleon.

Preliminary results at 363 MeV are presented in Fig. 1. Both ^{3}He and ^{3}H production processes could be investigated at this energy and the results in the angular range of $60 - 140^o$ covered by the both reactions are completely compatible. The ANKE detector acceptance is limited by the size of the gap in the analysing magnet D2 and is concentrated around $\phi = 0^\circ$ and 180° regions. This leads to a better definition of the $C_{y,y}$ coefficient as compared to $C_{x,x}$.
Since a clean selection of tritium by the energy loss in the scintillation hodoscope is no longer feasible at 600 MeV per nucleon, only data on the $pd \to {}^3\mathrm{He}\,\pi^0$ reaction are shown at this higher energy. The $C_{x,x}$ and $C_{y,y}$ coefficients measured at small angles are presented in Fig. 2. In addition to these spin correlation parameters, the proton and deuteron vector analysing powers can also be extracted from these data. At 363 MeV, A_y^p can be compared to the data of Ref. [4] and to the high statistics ANKE measurement with a polarised proton beam and a deuterium cluster-jet target [5], as it is

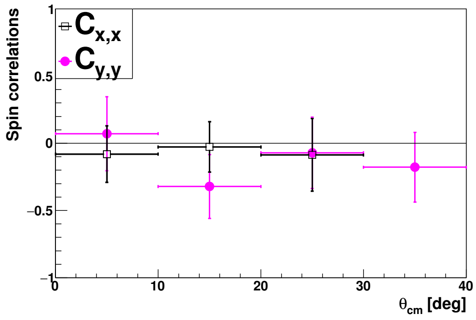

Fig. 2: Transverse spin correlation coefficients $C_{x,x}$ and $C_{y,y}$ in the $\vec{d}\vec{p} \to {}^3\mathrm{He}\,\pi^0$ reaction at 600 MeV per nucleon.

shown in Fig. 3. The new results from the double-polarisation experiment are completely compatible with the existing data.

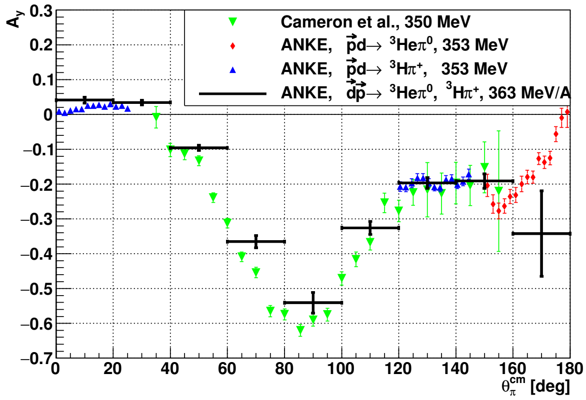

Fig. 3: Proton vector analysing power in the $pd \to {}^3\mathrm{He}\,\pi^0$ and $pd \to {}^3\mathrm{H}\,\pi^+$ reactions at $T_p = 353$ (363) MeV per nucleon. ANKE data with a polarised proton beam and a deuterium cluster-jet target (blue triangles up and red diamonds), and the ANKE double-polarisation data (black line), are compared to the data from Ref. [4] shown with green triangles down.

References:

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