Double differential cross sections for $d + p \to {}^3\mathrm{He} + \pi^+ + \pi^-$*

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Two pion production in nuclear scattering processes has been the subject of intensive research for many years, in particular due to the appearance of the so-called ABC effect [1]. Though distinct progress in its understanding has been made, there are still important questions to be solved. Especially the role of the Roper resonance in double pionic fusion is so far only poorly examined. In the $dp \to {}^3\mathrm{He}\,\pi^+\pi^-$ reaction its influence manifests itself through a difference between the $M_{^3\mathrm{He}\pi^+}$ and $M_{^3\mathrm{He}\pi^-}$ distributions, as already seen in [2]. The reason for this can be found in the difference between the Clebsch-Gordan coefficients for the decay channels $N^* \to \Delta\pi^- \to N\pi^+\pi^-$ and $N^* \to \Delta\pi^+ \to N\pi^-\pi^+$. With the benefit of the good momentum resolution of the ANKE detector, the resulting differences in the $M_{^3\mathrm{He}\pi}$ invariant mass spectra could be quantified.

The experiment was carried out at an excess energy of 265 MeV with respect to the reaction threshold. Events with coincident hits of ^{3}He nuclei in the forward detection system and at least one of the pions in the negative or positive detection system were used for the analysis. After the identification of the reaction with $\Delta E/p$, time-of-flight, and missing-mass selections, the residual background does not exceed 0.5%. For the resulting clean data sample the undetected pions were reconstructed through the missing momentum. A restriction to ^{3}He angles in centre-of-mass system (CMS) from 143° to 173° was imposed, because in this kinematical region there is practically a full coverage of the $dp \to {}^3\mathrm{He}\,\pi^+\pi^-$ Dalitz plot.

The limited ANKE acceptance at high excess energies, and the fact that the ABC effect causes a strong deviation from a phase-space behaviour, made it necessary to perform an accurate acceptance correction. This could be achieved by using Monte Carlo simulations with the following ansatz:

$$\sigma \propto \left| [(m_\pi)^2 + \alpha\, \vec{k_1} \cdot \vec{k_2}](3\Delta^{++} + \Delta^0) \right|^2 , \qquad (1)$$

where $\alpha = 0.2 + i0.3$ is a fitted value, $\vec{k_i}$ are the pion momenta in CMS, and Δ^{++} and Δ^0 are Breit Wigner functions of the respective nucleon excitation. The factors 3 and 1 reflect different isospin couplings coming from the Roper decay. The systematic uncertainties of this method were estimated through comparison to correction factors obtained with variants of Eq. (1). The model-dependence of the acceptance correction was also studied by using a multidimensional matrix method.

Figure 1 shows the measured double-differential cross sections for the three possible two-particle invariant mass combinations, compared with phase space distributions and Monte Carlo simulations according to Eq. (1). All the uncertainties shown are of a purely statistical nature. An evaluation of the systematics is currently in progress.

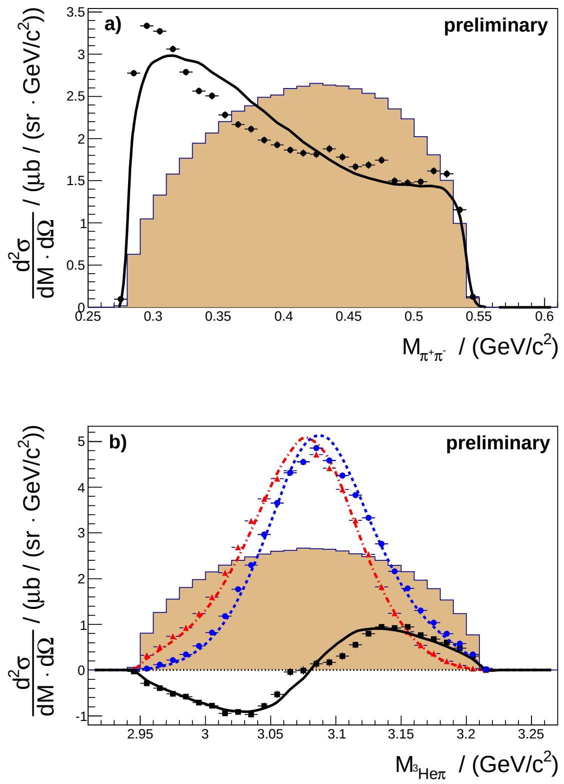

Figure 1: Centre-of-mass double-differential cross sections for the $dp \to {}^3\mathrm{He}\,\pi^+\pi^-$ reaction averaged over $143° < \vartheta^{CMS}_{^3\mathrm{He}} < 173°$ in terms of (a) $M_{\pi^+\pi^-}$ and (b) $M_{^3\mathrm{He}\,\pi^+}$ (blue circles) and $M_{^3\mathrm{He}\,\pi^-}$ (red triangles). The differences between the two $M_{^3\mathrm{He}\,\pi}$ distributions are plotted as black squares. The lines represent Monte Carlo simulations corresponding to Eq. (1). For comparison, the shaded areas show the phase space distributions.

The $M_{\pi^+\pi^-}$ spectrum shows a strong enhancement at low masses, which is characteristic for the ABC effect. Clear signs of Δ excitation are visible in the $M_{^3\mathrm{He}\pi^+}$ and $M_{^3\mathrm{He}\pi^-}$ distributions. Also shown is the difference between the $M_{^3\mathrm{He}\pi}$ combinations. This feature, and the gross structure of the $M_{\pi^+\pi^-}$ distribution, can be described with the presented ansatz that includes the assumed imbalance of Δ^{++} and Δ^0 resonances. Based on this the $\pi\pi$ isospin-one contribution to the $dp \to {}^3\mathrm{He}\,\pi^+\pi^-$ reaction associated with the Roper excitation is currently studied in more detail.

References

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[2] M. Bashkanov et al., Phys. Lett. B **637**, 223 (2006).

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