Two pion production study at ANKE

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The ABC effect, which is a enhancement of the two-pion invariant mass spectrum near its threshold, has presented a puzzle for hadron physicists for almost fifty years. It was first observed in a $pd \to {}^3\mathrm{He}X$ missing-mass experiment [1] and further confirmed in other reactions.

The aim of the experiment carried out with the ANKE setup was the study of the $pp \to \{pp\}_s X$ reaction under the condition that the excitation energy in the final diproton system is low, $E_{pp} < 3$ MeV. The experiment has been set up to investigate the reaction at four proton beam energies $T_p = 0.8$, 1.1, 1.4, and 2 GeV.

The proton beam was directed onto a hydrogen cluster jet target with an areal density of $2 \cdot 10^{14}\, atoms/cm^2$. Positively charged particles were registered in the forward detectors of ANKE setup. Particle momenta were reconstructed by the back-tracing Runge-Kutta method through the analysing magnetic field. The momentum reconstruction uncertainty is equal to 1% on average [2]. Proton-pairs were identified by the time-of-flight difference Δt measured by the hodoscope and the same difference calculated using the reconstructed particle momenta assuming proton masses. The remaining background does not exceed 0.1%.

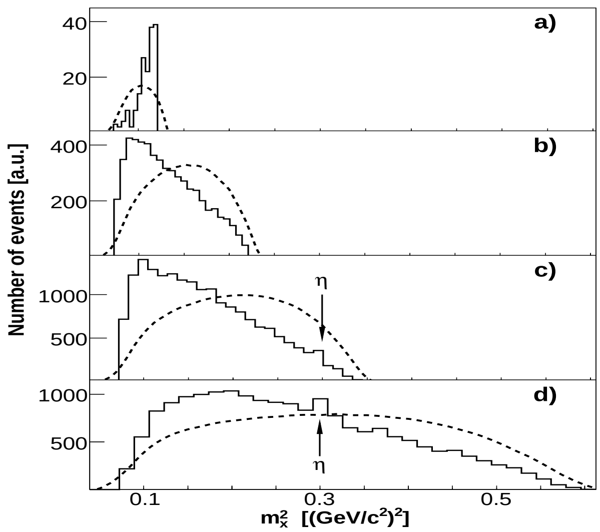

Fig. 1: Distribution in missing-mass squared for the $pp \to \{pp\}_s X$ reaction for $E_{pp} < 3$ MeV and $\cos\vartheta_{pp} > 0.95$ at a) 0.8, b) 1.1, c) 1.4, and d) 2.0 GeV. The η signal is seen at the expected position for the two higher energies. The lines represent normalized simulations within a phase-space model.

Fig.1 shows the pp-system missing-mass squared distribution for the multipion region at different beam energies. Two protons in the relative ${}^1S_o$ state were selected by applying the cut on the excitation energy $E_{pp} < 3\,MeV$. The selected proton pairs weighted by the detection efficiency are distributed isotropically in the pair rest system which reveals that they actually are in the ${}^1S_o$ state. Event distribution over the two proton excitation energy E_{pp} also clearly shows the *final state interaction* enhancement corresponding to the ${}^1S_o$ state. The events in the forward cone with $cos\vartheta_{pp} > 0.95$ were selected for the further analysis.

Only at the highest energy $2\,GeV$ there might be any significant contribution of three-pion production while at the lower energies it is negligible. Therefore, the model description should be based upon the assumption that two-pion production dominates.

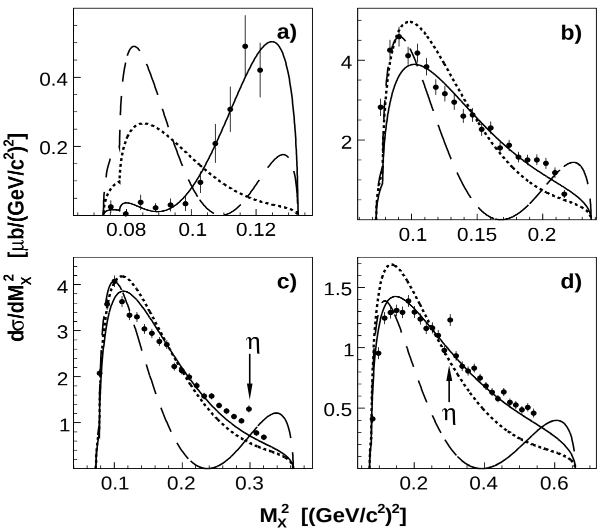

Fig. 2: The $pp \to ppX$ differential cross section with statistical errors as a function of the square of the missing mass at a) 0.8, b) 1.1, c) 1.4, and d) 2.0 GeV for $E_{pp} < 3$ MeV and $\cos\vartheta_{pp} > 0.95$. The η peaks are indicated. Events were simulated using Eq. (1) with $A_D = 0$ (long dashes), with $A_S = 0$ (short-dashed), and with the best fit of A_S/A_D ratio (solid line).

Fig.2 shows the measured differential cross sections and the results of implementing a simple double–Δ model. The matrix element squared (averaged over the pion angles) for this model can be written in the form

$$\langle|\mathcal{M}|^2\rangle = |A_S(\alpha^2k^2-\beta^2q^2)+\tfrac{1}{2}A_D\alpha^2(3k_z^2-k^2)|^2+\tfrac{1}{5}|A_D|^2\beta^4q^4\,. \quad (1)$$

where α and β are the kinematical factors, q is the ππ pair momentum in c.m.s, and k pion momenta in the ππ system. The S and D–wave amplitudes A_S and A_D are scalar functions that may depend upon T_p.

We have measured the differential cross section for the $pp \to \{pp\}_s(\pi\pi)^o$ reaction at four beam energies from 0.8 to 2.0 GeV under conditions mentioned above. Strong structure is observed in the missing-mass variable, with a peak in M_x whose position varies with beam energy. Gross structure of the distributions is well described within the ΔΔ model. Exclusive measurements of $pp \to \{pp\}_s(\pi\pi)^0$ over a wider range of angles would provide more stringent tests of the phenomenological description.

References:

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[2] S. Dymov *et al.*, Part. Nucl. Lett. **2** (119), 40 (2004).

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