PION PRODUCTION IN THE ^{3}He–PROTON INTERACTIONS *

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The data collected by Dubna–Warsaw–Kosice–Moscow–Strasburg Collaboration at the Dubna proton accelerator on double pion production are presented.

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The momentum of ^{3}He beam was 13.5 GeV/c. In the standard kinematics with target nucleus and incoming protons such momentum corresponds to the incident proton momentum 4.5 GeV/c (kinetic energy 3.66 GeV).

The hydrogen bubble chamber was placed in the magnetic field (1.86 T). Charged particle momenta were measured over the full solid angle with a resolution $\Delta p/p$ varying from a 2.5% at maximum momentum to around 1.5% for the particles stopping in the chamber. Ionization information was used to distinguish protons from positive pions up to 1.2 GeV/c. For unidentified tracks the kinematic-Al fits were performed with different possible mass assumed. The final sample consists of about 37 000 fully reconstructed ^{3}Hep events. In the following all the variables are in the center of mass system of the incoming nucleus, in order to simplify the comparison with the experiments with the proton beam and nuclear target.

1. Two pion production

A possibility of the $\pi\pi$ system to form resonant state below ρ region has been frequently discussed and many controversial signals were reported.

For the present analysis, the sample of about 2600 events of the ^{3}He$p \to pppp\pi^+\pi^-n$ reaction was used. The total cross section for this reaction has been found to be (5.32±0.12) mb [2].

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For comparison, the cross section for $pp - pp\pi^+\pi^-$ at similar incident momentum (5.0 GeV/c) was found to be about 3mb [3]. The other ^{3}He p reaction channels with $\pi^+\pi^-$ pair in the final state are $dp\pi^+\pi^-$ and ^{3}He $\pi^+\pi^-$ with the cross sections (2.23±0.08) and (0.61±0.05) mb respectively [2]. The complete break-up reaction could be the one involving rearrangement of the three helium nucleons , so I will concentrate on this reaction.

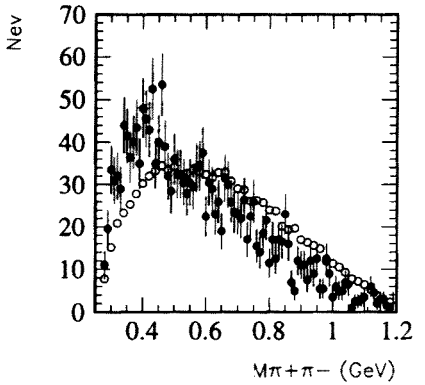

Fig. 1. Experimental distribution of the $\pi^+\pi^-$ invariant mass (open points) compared to the distribution generated in the double Δ production model (full points).

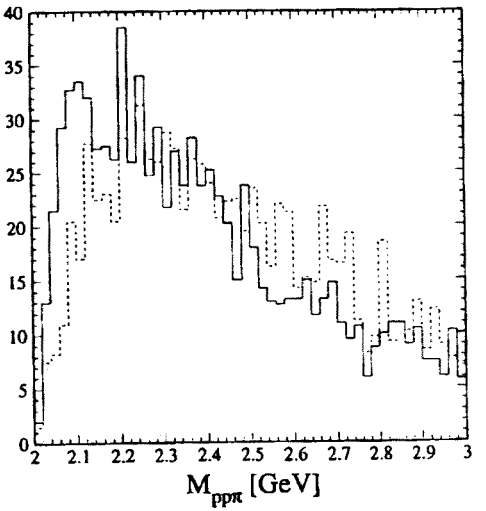

Fig. 2. Invariant mass distribution of the $pp\pi^-$ system — full line and $pp\pi^+$ system (dashed line).

The two pion invariant mass is shown in Fig. 1 and compared with the double Δ resonance production. An excess of events in the region of 450 MeV is observed. A structure in this region was observed in pd reaction (see *e.g.* the compilation by Codino and Plouin [6]). The negative pion energy spectrum appears to be significantly softer than the π^+ one. Such effect was observed *e.g.* in the old Los Alamos data at 730 MeV in an inclusive production on hydrogen and nuclei [4] and in Gatchina at 1 GeV in pd interactions [5]. Several explanations were put forward. The resonance in the $pp\pi^-$ system is one of them. The $pp\pi$ invariant mass distribution from our data is plotted in Fig. 2. The full line corresponds to negative pions. The dashed one to the positive ones.The two distributions differ in the small invariant mass region. The subtraction of the two spectra leads to rather wide enhancement in $pp\pi^-$ system at about 2.09 GeV. It is a few tenth MeV higher than the 2.065 exotic d' position.

2. $\Delta(1232)$ production and absorption

The problem of modification of the resonance width and position in nuclear matter has been widely discussed recently. In the same experiment the $\Delta(1232)$ production was studied in three main reaction channels with a positive pion production (see Fig. 3). The invariant mass distributions of the $p\pi^+$ system have been plotted for the events with four momentum transfer from the primary proton to the $p\pi^+$ pair smaller than 0.4 GeV/c^2. The selection of such events was based on the fact, that the Δ production is a peripheral process, due to the one pion exchange mechanism.

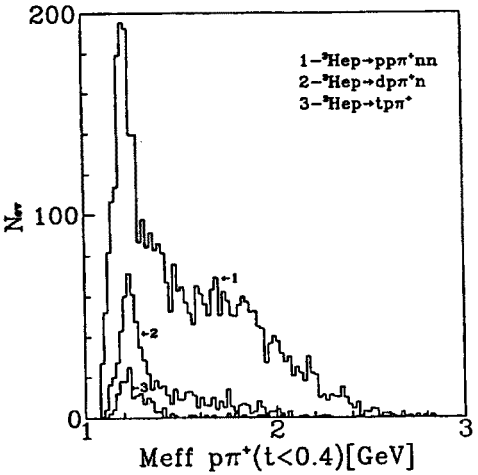

Fig. 3. Invariant mass distribution of $p\pi^+$ pairs in different reaction channels.

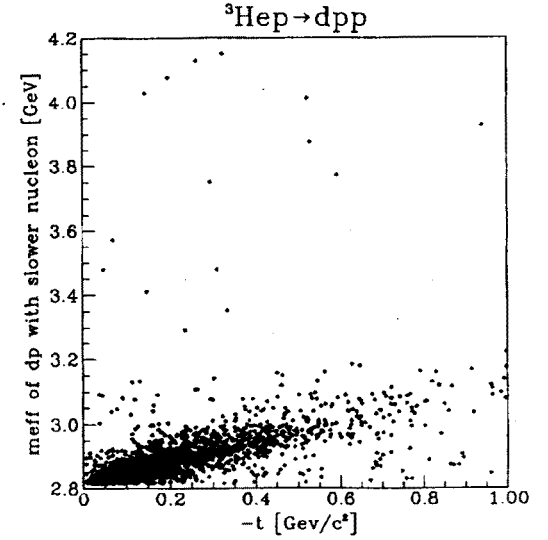

Fig.4a. Plot of the pd invariant mass from ^{3}He $p \rightarrow dpp$ reaction as a function of the four momentum transfer from the incident proton to the fastest nucleon in the He rest system.

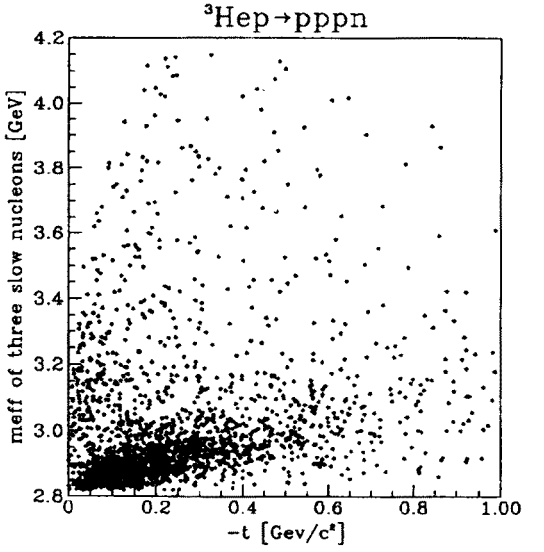

Fig. 4b. Plot of the three slow nucleon invariant mass, from ^{3}He $p \rightarrow nppp$ reaction, as a function of the four momentum transfer from the incident proton to the fastest nucleon (in the He rest system).

The position of the peak does not depend on the final state of the three helium remnant nucleons in the limit of error and no shift of the resonant mass is observed.

The Δ production and absorption signal is also observed in the channels without pion in the final state. Small four momentum transfer between initial and leading nucleon and large inelasticity observed in such events was an indication that one pion exchange occurs.

A convenient representation of the data is the Chew-Low plot shown in Fig. 4; for (a) $^3\mathrm{He}\,p - dpp$ and (b) $^3\mathrm{He}\,p - pppn$. The four momentum transfer t between the primary proton and the fastest nucleon(in the CM system of the initial nucleus) is plotted versus the invariant mass M_x of the product of helium nucleus fragmentation (pd or three nucleons).

The impulse-model band is spread around the line represented by the formula:

$$M_x^2 = 9m_N^2 - 2t\,. \tag{1}$$

Such relation between M_x and t can be derived if the incident protons scatters on one deuteron component (nucleon) and the Fermi motion is neglected.

In the Fig. 4b, in addition to the dominant quasi elastic band, an additional cluster of points is seen at low t along the Chew-Low plot boundary. In the dpp final state (Fig. 4a) very few events have been observed near the boundary of the Chew-Low plot. It is because the absorption of a pion almost always leads to the deuteron break-up. All the characteristics of the events in the high mass-low t region are consistent with intermediate Δ production via one-pion exchange. The effect of the intermediate Δ absorption has been seen also for proton interaction with ^4He nuclei [8]. Recently pd-npp charge-exchange reaction was measured the region of small t and large Mpp was measured at CELSIUS storage ring in Uppsala by WASA Collaboration in the large statistic experiment [7]. The initial energy of protons was 1.15 GeV. The total cross section for the events in the pion absorption region was estimated at about 250±50 μb and the mass of intermediate Δ was found to be shifted by about 20 MeV [7].

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