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Formation of Δ^0-izobar in nC-collisions at 4.2 GeV/c

R. N. Bekmirzaev✉[1], X. U. Bekmirzaeva[1], G. U. Khudoyberdiev[1], M. I. Mustafayeva[1], B. I. Nabiev[1]

[1] Jizzax State Pedagogical Institute, 4 Sh. Rashidov Str., Jizzax 100130, Uzbekistan

Authors
Rahmatillo N. Bekmirzaev, e-mail: bekmirzaev@mail.ru
Xursand U. Bekmirzaeva
Gulmurod U. Khudoyberdiev
Marjona I. Mustafayeva
Bahodir E. Nabiev

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Abstract. The study is dedicated to the multiplicity of momentum and angular characteristics of protons formed in nC-collisions at a pulse of 4.2 GeV/c. The experimental results on the formation of Δ^0 isobars in nC-collisions at 4.2 GeV/c are presented for the first time. Experimental and normalised background distribution of the effective mass for protons and π^--mesons was obtained. This study is a follow-up to prior research. It explores various kinematic characteristics of π^--mesons formed in nC-collisions at 4.2 GeV/c. The data obtained are compared with the experimental data obtained for pA interactions at the same energy. The experimental material used in this work was obtained using a 2-meter propane bubble chamber of the JINR LHE irradiated with beams of proton, deuteron and helium-4 nuclei at a pulse of 4.2 GeV/c per nucleon at the Dubna Synchrophasotron and consists of 6736 pC, 7071 dC and 11974 ^{4}HeC events. Negative π mesons are identified visually by the charge sign only.

Keywords: hadron and nucleus-nucleus collisions, Δ^0-isobar, π^--mesons, effective proton masses, accelerator, propane chamber, carbon.

Introduction

It is well known that so far there is no theory of strong interactions available. Here, an important role is played by the study of multiple processes where many secondary-charged and neutral particles are formed in inelastic hadron-nucleus and nucleus-nucleus interactions in a wide energy range. To obtain useful information, it is necessary to analyse processes where many nucleons are involved in the interaction. To date, quite a lot of material has been accumulated on the interactions of protons with nucleons and nuclei in a wide range of primary energies. Monochromatic neutron beams are difficult to obtain; therefore, experimental information on neutron collisions with nuclei (nA) obtained under conditions of the 4π geometry is scarce (Iqbal et al. 2014) and supported with little statistical data. In this regard, obtaining experimental data on nA collisions and comparing them with experimental data obtained at the same energy for the same target nucleus is of significant interest. One of the fundamental tasks in modern nuclear physics is the study of non-nucleon degrees of freedom. In the beginning, the proton-neutron composition of the nucleus was discovered followed by quasi-nucleons, pions, baryon resonances, partons, quarks and gluons.

As for baryon resonances, the relevance of Δ resonance formation remains an important research topic, both experimentally and theoretically. This is due to the fact that Δ resonances can be formed in various strong and electromagnetic interactions under the influence of various particles—pions, baryons, nuclei, γ-quanta and electrons. Moreover, not all existing theoretical models allow a unique description of the total experimental data on the generation of Δ resonance. The results obtained in this work showed that characteristics (width and mass) of the Δ resonance generated in nuclear collisions differ from those of the Δ resonance generated in free nuclear collisions.

Experiment

This study is a follow-up to prior research (Iqbal et al. 2014). It explores various kinematic characteristics of π^--mesons formed in nC-collisions at a pulse of 4.2 GeV/c. The data obtained are compared with the experimental data obtained for pA interactions at the same energy. The experimental material used in this study was obtained using a 2-meter propane bubble chamber of the JINR LHE irradiated with beams of proton, deuteron and helium-4 nuclei at a pulse of 4.2 GeV/c per nucleon at the Dubna Synchrophasotron and consists of 6736 pC, 7071 dC and 11974 ^{4}HeC events. Negative π mesons are identified visually by the sign of the charge only. The admixture of unidentifiable electrons among them does not exceed 5%, while negative strange particles do not exceed 1%. The lower boundary of the pulse which allows certain identification of the charged pions is 70 MeV/c.

Methodological features of the experiment regarding corrections for the loss of secondary charged particles are given in (Nakamura et al. 2010). In contrast to (Olimov et al. 2011; Olimov et al. 2007), this work takes into account the contributions to the impulse characteristics of the secondary π^--mesons with less than 4 cm projection length of the tracks. Only emission angles and, naturally, their impulses for a short projection length of tracks in the working volume of the camera were measured for such π mesons. The momenta restoration of such π^--mesons was carried out as follows. Pulse spectra of π^--mesons with a projection length of tracks greater than 4 cm were constructed. Each spectrum was divided into 18 histograms according to their emission angle θ $(0 \le \theta \le 180°)$ in a laboratory system with an angular interval width $\Delta\theta$=10°.

Then, according to the measured departure angle of π^--mesons with less than 4 cm track projection length, the value of their momentum was played randomly by one of the pulsed histograms. Interactions of neutrons with carbon nuclei were distinguished from collisions of deuterons and ^{4}He nuclei with carbon nuclei by the presence of a stripping proton or a ^{3}He nucleus in these events, respectively. The average multiplicities of π^--mesons in nC events isolated from dC and ^{4}HeC collisions coincided within the statistical error, being 0.72 ± 0.02 and 0.70 ± 0.03, respectively. The average values of the total momenta of π^--mesons in nC events obtained from dC and ^{4}HeC collisions turned out to be 0.59 ± 0.01 GeV/c and 0.59 ± 0.02 GeV/c, respectively, coinciding with one another. We also note the coincidence within the statistical error of the average transverse momenta of the π^--mesons in nC events obtained from dC and ^{4}HeC collisions, which amounted to 0.25 ± 0.01 GeV/c and 0.24 ± 0.01 GeV/c, respectively. From the above facts, the average values of the escape angles of π^--mesons in nC events isolated from dC and ^{4}HeC collisions coincide. Further analysis of the momentum and angular distributions of π-mesons was carried out for the combined group of nC events in the laboratory system.

Figure 1 shows the experimental and background distribution of the effective mass for protons and π^--mesons in nC collisions. The experimental distribution over the invariant mass of the pairs $(p\pi^-)$ was obtained by combining protons and pions in each individual experimental event. The background distribution over the invariant mass of pairs $(p\pi^-)$ was obtained by combining protons and pions selected randomly from different events. Figure 1 shows that the experimental spectrum dn/dM for most pairs $(p\pi^-)$ contains a large contribution from uncorrelated pairs of protons and pions. Experimental distributions were obtained using a set of developed criteria by combining protons and π^--mesons in each individual event. Background distributions were constructed according to the same criteria as the experimental distributions, but protons and pions were selected randomly from different events.

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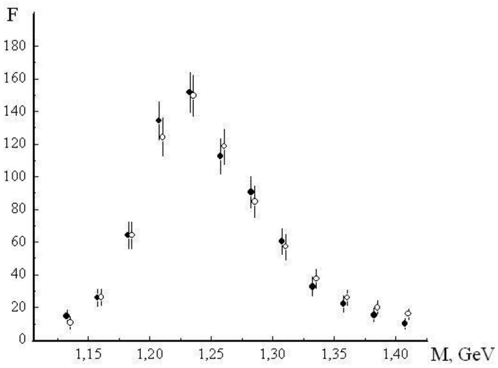

Fig. 1. The experimental and background distribution of the effective mass for protons and π^--mesons in nC-collisions

The isolation of Δ^0 isobars was performed in accordance with the procedure given in (Olimov et al. 2012). Figure 1 shows the experimental and normalised background distribution of the effective mass for protons and π^--mesons

$$F(M) = \frac{CM\Gamma M_\Delta}{(M^2 - M^2{}_\Delta)^2 + \Gamma^2 M^2{}_\Delta},$$

where M_Δ and Γ are the mass and the width of the resonance. A set of distributions $D(M)$ for various parameters ε and a values was fixed by the Breit-Wigner function and a value was found for each fit. The parameters M_Δ and Γ were determined by minimising the difference $|D(M) - b(M)|$. Figure 2 shows that the spectrum is well described by this formula with values M = 1226 ± 7 MeV/c^2 and Γ = 83 ± 14 MeV. In this case, the fraction of π^--mesons from the decay of Δ^0 isobars turned out to be 36 ± 4%. This result coincides within the statistical error with the data of (Olimov et al. 2012) and also indicates a 1.45-fold decrease in the width of Δ^0 isobars in the nucleus compared to the collisions of free nucleons.

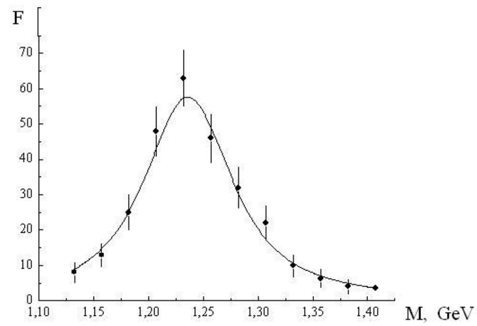

Fig. 2. The spectrum described by the formula with M = 1226 ± 7 MeV/c^2 and Γ= 83 ± 14 MeV

Conclusion

A comparative analysis of the pulsed and angular spectra of π^--mesons in pC and nC events was carried out. The analysis showed that there is no additional production of π^--mesons on the carbon nucleus in comparison to nucleon-nucleon interactions at a primary pulse of 4.2 GeV/c per nucleon. The pulsed and rapid spectra of π^--mesons for pC and nC collisions differ in the entire variation range of these quantities. At the same time, the transverse momentum distributions are almost identical for the types of interactions discussed, which may be due to the fact that the transverse momentum transferred is identical to the carbon core for pC and nC collisions.

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