Associated $\phi\Lambda^0$ Production in the EXCHARM Experiment


The EXCHARM Collaboration

Joint Institute for Nuclear Research, Dubna, Moscow oblast, 141980 Russia

Received October 3, 2003; in final form, February 6, 2004

Abstract—The features of the associated production of $\phi$ mesons with $\Lambda^0$ hyperons in neutron—carbon interactions were investigated. The experiment was performed with the aid of the EXCHARM spectrometer at the Serpukhov accelerator in a neutron beam of energy in the interval 20–70 GeV. The differential cross section for inclusive associated $\phi\Lambda^0$ production was measured. © 2004 MAIK “Nauka/Interperiodica”.

1. INTRODUCTION

Within the quark model of broken $SU(3)$ symmetry, the $\phi$ meson can be represented as a particle entering into the vector-meson nonet, consisting of $s\bar{s}$ valence quarks, and involving a small admixture of $q\bar{q}$ nonstrange quark pairs; it is the first member of the family of vector mesons featuring hidden flavors ($\phi$, $J/\psi$, $\Upsilon$).

The dynamics of the interaction of systems composed of quarks manifests itself in the Okubo–Zweig–Iizuka rule [1]. According to this rule, disconnected quark diagrams are forbidden in strong interactions; as a consequence, the production and annihilation of quark–antiquark pairs fully belonging to the same hadron are also forbidden. This means, among other things, that, if the $\phi$ meson were a pure $s\bar{s}$ state, it could not be produced in the interactions of hadrons not containing strange quarks in the initial state or without the emergence of additional strange particles in the final state.

Investigation of the features of $\phi$ production can be of use for obtaining deeper insight into the mechanisms of the production of heavier vector mesons featuring hidden flavors ($J/\psi$ and $\Upsilon$) and for determining those regularities in hadron processes that are associated with the flavors of the quarks entering into the hadron involved.

In this article, we present the results obtained by studying the associated production of $\phi$ mesons with $\Lambda^0$ hyperons in neutron—carbon interactions detected at neutron energies in the range 20–70 GeV by the EXCHARM spectrometer. Events of the associated production $\phi$ mesons with $\Lambda^0$ hyperons were selected among about $172 \times 10^6$ original neutron—carbon interactions recorded by the spectrometer in one of the exposures of the EXCHARM facility.

2. EXCHARM EXPERIMENT

The EXCHARM spectrometer is situated in the 5N neutron channel of the U–70 Serpukhov accelerator. A beam of neutrons is produced upon the interaction of 70-GeV protons circulating in the accelerator ring with the internal beryllium target and is formed by a system of collimators arranged along the axis...
that is nearly parallel to the momentum of incident protons. Figure 1 shows the energy spectrum of beam neutrons that was obtained in [2] by measuring neutron energies with the aid of the hadronic calorimeter entering into the composition of the spectrometer. The energy spectrum of the beam has a maximum in the vicinity of 58 GeV and a width of about 12 GeV.

In order to reduce the admixture of photons, a lead filter of variable thickness (from 0 to 20 cm, depending on the position along the beam) was installed in a beam. The admixture of charged particles was removed by the deflecting magnets of the accelerator and the SP-129 magnet, which was arranged in the nose part of the experimental zone.

The intensity of the beam during an accelerator spill was about $6 \times 10^6$ neutrons per $5 \times 10^{11}$ protons dumped onto the internal target.

The arrangement of basic units of the operating EXCHARM spectrometer is displayed in Fig. 2. The spectrometer includes the following elements:

(i) a carbon target T of thickness 1.3 g/cm$^2$ along the beam,

(ii) an analyzing magnet SP-40A having an aperture of $274 \times 49$ cm$^2$ and generating a magnetic field of maximum strength 0.79 T (the system of the magnet power supply provides the possibility of a fast reversal of its polarity);

(iii) a system of 11 multiwire proportional chambers PC [3, 4] (25 signal planes) positioned upstream (PC 1–8) and downstream (PC A–C) of the magnet (the maximum dimensions of the chambers were $100 \times 60$ cm$^2$ upstream and $200 \times 100$ cm$^2$ downstream of the magnet);

(iv) hodoscopes H1 and H2 of scintillation counters (these hodoscopes are used to develop a signal triggering the facility);

(v) neutron-beam monitor Mn;

(vi) a hadronic calorimeter HC, which is used to measure the energy spectrum of beam neutrons;

(vii) a 14-channel (MTGCC-14) and a 32-channel (MTGCC-32) threshold gas Cherenkov counter [5, 6], which are used to identify charged particles.

The MTGCC-14 and MTGCC-32 counters are filled with, respectively, Freon-12 and air at atmospheric pressure. The calculated thresholds for charged-particle detection are given in Table 1.

The facility is triggered by pulses formed by a majority scheme of coincidence from two hodoscopic planes of proportional chambers upstream of the magnet, one such plane downstream of the magnet, and two hodoscopes of scintillation counters. The system of triggering the spectrometer requires that not less than four charged particles traverse the main units of the facility.

The EXCHARM spectrometer is described in greater detail elsewhere [7].

Associated $\phi \Lambda^0$ production was investigated by two independent methods. In calculating the cross section for associated $\phi \Lambda^0$ production, different models of the production of this pair of particles were used within these two methods.

3. EVENT SELECTION

Events involving the associated production of $\phi$ mesons and $\Lambda^0$ hyperons were selected in the reaction

$$n + N \rightarrow \phi + \Lambda^0 + X.$$  \tag{1}

We identified $\Lambda^0$ hyperons by their decays to a proton and a pion:

$$\Lambda^0 \rightarrow p\pi^-.$$  \tag{2}

Neutral-vee ($V^0$) topology corresponds to the decay process in (2). For $V^0$, we took a pair of unlikely charged particles whose trajectories were spaced by a distance not less than 0.5 cm, this corresponding to

![Figure 1. Energy spectrum of beam neutrons. Here and in the figures that follow, $N$ is the number of combinations.](image-url)