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SEARCH FOR RESONANCES IN Λ_p SYSTEM IN COLLISIONS OF NEUTRONS WITH CARBON NUCLEI AT AN AVERAGE MOMENTUM OF 7-8 GEV/C

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Enhancements revealed in effective mass spectra of the Λp system at 2062 MeV, 2220 MeV, 2573 MeV were reported in previous papers /1,2/. The results of analysis of the nature of the peak situated in the (2053 - 2093) MeV mass interval ($Q = (0 \div 40)$ MeV) are given below (Fig. 1).

This work is carried out using a part of photographs of 55 cm long propane bubble chamber irradiated with neutrons of an average momentum of 7÷8 GeV/c. The upper limit of the neutron spectrum was 11.0 Gev/c.

Events imitating interactions of neutrons with protons (q=1), neutrons with neutrons (q=0) and neutrons with carbon nuclei with apparent disintegration ($B > 2$, $q > 1$) were selected after a threefold scanning. The minimal measurable track length was 0.23 cm which corresponds to 140 MeV/c momentum for protons.

Events containing Λ -hyperons were processed according to the following scheme.

In a sample of one-, three- and five-prong events of the first group (q=1) using the χ^2 -method of hypotheses testing the following reaction channels were fitted

$$n p \to \Lambda K^0 p$$

$$\to \Lambda K^0 p \pi^+ \pi^-$$

$\to \Lambda K^0 p\, 2\pi^+ 2\pi^-$

$\to \Lambda K^+ p\, \pi^-$

$\to \Lambda K^+ p\, \pi^+ 2\pi^-$

The number of constraints in our case is equal to three due to the indefiniteness of the primary neutron momentum [3,11]. The events with χ^2 exceeding the confidence limit were further analysed by means of the so called limiting kinematics method [4] in order to select the events of interactions of neutrons with protons at rest followed by neutrals.

All events which did not satisfy to abovementioned hypotheses and to the limiting kinematics were compared with the following enough but not necessary criterion.

It is evident that a Λp system formed in a three particle reaction

$$n p \to \Lambda K^0 p$$

with a fixed effective mass value $M^{0}_{\Lambda p}$ at a fixed primary neutron momentum value P_n^0 and moving in c.m.s. at an angle of $\theta^*_{\Lambda p} = \pi$ posesses the minimal of all possible under these conditions momentum in the laboratory system $P^{min}_{\Lambda p}(M^0_{\Lambda p}, P^0_n, \theta^*_{\Lambda p} = \pi)$.

The curves of $P^{min}_{\Lambda p}(M_{\Lambda p}, P_n, \theta^*_{\Lambda p} = \pi)$ as a function of $M_{\Lambda p}$ and P_n at $\theta^*_{\Lambda p} = \pi$ are given in Fig. 2. The upper pair of curves refers to interactions of neutrons with protons at rest. Curve 1 corresponds to the minimal possible value of the neutron momentum P_n for each considered value of the effective mass $M_{\Lambda p}$. Curve 2 corresponds to P_n = 11.0 Gev/c. Curves 3 and 4 refer to interactions of neutrons with protons of a 216 MeV/c momentum at an angle π with respect to direction of motion of neutrons of 2.5 GeV/c and 11.0 GeV/c momenta respectively. (Note that s- and p -shell proton c.m.s. momenta values in carbon nuclei are equal to 90 MeV/c and 160 MeV/c respectively [5]). Finally curve 5 refers to interactions of neutrons with deuterons of a 500 MeV/c momentum moving at an angle π with respect to direction of motion of neutrons of a 2.5 GeV/c momentum. It is evident that all events brought into the region below curves 1 and 2 in Fig. 2 cannot be formed on free and quasifree protons at rest. Whereas the region over these curves does not exclude interactions with free and slow quasifree protons. The open circles correspond to interactions of neutron with neutrons (two-prong events).

As is seen from Fig. 2, the overwhelming part of events from the peak can be created on quasifree deutrons.

The events from the second group (q=0) were processed in the same way. The only exception consisted in the following reaction channels fitting:

$$
\begin{aligned}
n\,n &\rightarrow \Lambda K^0 p \pi^- \\
&\rightarrow \Lambda K^0 p \pi^+ 2\pi^- \\
&\rightarrow \Lambda K^+ p\, 2\pi^-
\end{aligned}
$$

All positively charged particles either of stars or V^0-particles were identified visually and when it was possible using the δ-electron track length. The visual identification was possible in this experiment up to 1.0 GeV/c momentum.

The efficiency of detection of events containing V^0-particles was computed for each event using a computing programme based on a method of modelizing developed for this purpose /6,7,8/.

One-, two-, three- and five-prong events are included in this work.

A strong peak is seen in Fig. 1 near the sum of masses of the Λ -hyperon and proton (Q = 0).

The curves in the same Figure represent the phase space volume distributions for reactions

$$
\begin{aligned}
n\,N_{s,p} &\rightarrow \Lambda K p\, (m\ \pi) \\
&\rightarrow \Lambda K \Delta_{33} (m\ \pi) \\
&\rightarrow Y_{1385} K\, p\, (m\ \pi)
\end{aligned}
$$

$$m = 0, 1, 2, 3, 4$$

and

$$nd \to \Lambda K\, pn\,(m\pi)$$
$$\Lambda K\, \Delta_{33} n\,(m\pi)$$
$$Y_{1385} K\, pn\,(m\pi)$$

initiated on s- and p -shell nucleons of carbon nucleus and on deuterons of 500 MeV/c momentum respectively averaged over multiplicities and charge states. Besides, all these curves were integrated over the experimental primary neutron spectrum. In calculation it was taken into account the restriction imposed on a proton momentum at visual identification.

The momentum distribution of the target-nucleon from s- and p -shell nuclei was obtained as a Fourier-image of the Schrödinger equation solution for the oscillatory potential which agrees well with the experiment /5/. In the second case the momentum distribution of the Fermi-gas consisting in deuterons was taken.

All these computations were performed using a computing programme "Force" /9/.

As is seen in Fig. 1, neither of these curves fit the experimental hystogram.

In the upper part of Fig. 1 the distribution of events from the peak over Q in 10 MeV bins is given.

As far as the majority of protons of events from the peak are stopping in the chamber and the errors of momenta and angles of emission of Λ -hyperons after the fitting are rather small the effective mass resolution is better than 3.0 MeV which circumstance permitted us to choose 10 MeV bins.

The peak observed can be due to one of three following phenomena:

1. Λ -hyperdeuteron formation
2. Resonance in Λp -system
3. Strong interaction of Λ -hyperons with protons in final state or what is the same a resonance on a virtual level of the Λp -system.

The first hypothesis is rejected by the obtained value of the position of the maximum of the distribution

$$Q_0 = (4.8 \pm 1.1) \text{ MeV}$$

and by the failure of attempts of revealing the Λ -hyperdeuteron.

A resonance on a true quasidiscrete level would fit the Breit-Wigner curve. The best fit Breit-Wigner curve ($\chi^2_{min} = 2.2$ at the expected value equal to 3.0) is possible only for the resonance true width equal to

$$T_0 = 24 {+10.0 \atop -5.2}$$

what makes this hypothesis physically meaningless.

By contrast the peak is well fitted ($\chi^2_{min} = 2.62$ at the expected value equal to 3.0) by a curve corresponding to strong interactions of Λ -hyperons with protons in final state.

Another confirmation of this hypothesis is found in the characteristic narrow distribution of opening angles of Λ -hyperons and protons in events from the peak (Fig. 3).

The dashed line hystogram in Fig. 1 represents the distribution normalised to the total number of events over $Q_{\Lambda p}$ of events with apparent disintegration of carbon nuclei. The enhancement though strongly smeared out because of the fake combinations is observed even in this case. (The number of protons exceeds unity $N_p > 1$).

The result obtained in this work is in agreement with the hyperfragment data as well as with the data on direct Λp scattering which indicates that the sign of Λp scattering lengths should be negative.

The strong interaction of Λ -hyperons with protons in final states at such low energies leads to elastic scattering only. Λ -hyperons may have in the laboratory system any momentum permitted by conservation laws starting from a lower limit imposed by conditions of reliable identification of lambdas. But the values of relative kinetic energies $Q_{\Lambda p}$ can be arbitrary low at any permitted transferrent velocities of the Λp -system.

It follows then that the strong interaction in the final state gives a new method of investigation of Λ -hyperon-proton scattering in an energy region which is inaccessible to direct scattering experiments. This method is free of inevitable in direct scattering experiments losses and difficulties with identification of very slow Λ-hyperons. Besides, in this method it is possible to measure in one experiment both angular distributions and polarizations of scattered Λ -hyperons.

As an example the value of the average anisitropy coefficient of angular distributions of Λ -hyperons in the Λp rest system for the first interval $P_\Lambda = (0 \div 148)$ MeV/c is given below:

$$\frac{F - B}{F + B} = 0.055 \pm 0.020$$

The angular distribution is nearly isotopic.

This method can be extended to all systems possessing virtual levels. If such levels are available to (Λ, Λ), (Σ, Σ), (Σ, Λ) etc. systems then studying effective mass distributions of these pairs obtained on light nuclei such as D, He , C or on protons at corresponding threshhold it would be possible to study the scattering at exceedingly low energies.

The pairs of Λ -hyperons and protons of small relative velocities and small opening angles in laboratory system can be formed, in our opinion, by two following mechanisms. Firstly, Λ -hyperons can pick up protons of near velocity. Secondly, the incident neutron can exchange with a deuteron-like cluster situated near the nucleus surface by a K^0 -meson which in this case has to be fast. There are the following facts in favour of this mechanism.

1. The great majority of events from the peak is over the upper limiting curve for collisions of neutrons with moving deuterons (Fig. 5, curve 5).

2. The Λp -system transversal momenta from the peak are rather small.

3. The number of K^0 pairs in the peak events is lower than the expected number.

Note that a result analogous to ours on the nature of the observed peak obtained by counter method in p p collisions at 2.40 GeV and 2.85 GeV energy in a recent work /10/.

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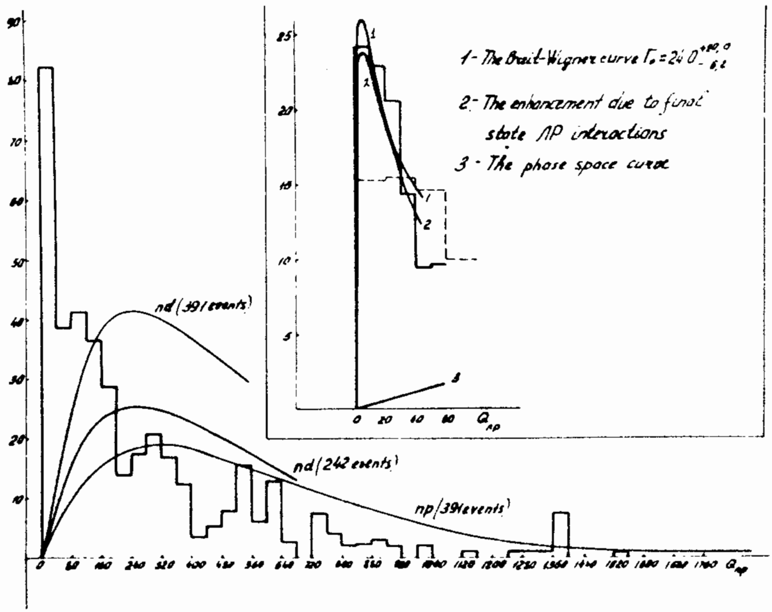

Fig. 1. Distribution of relative kinetic energy $Q_{\Lambda p}$ for 1-, 2-, 3-, 5-prong events.

Fig. 2. Scatter diagram $P^{min}_{\Lambda p}(M_{\Lambda p}, P_n, \theta_{\Lambda p} = \pi)$. Curves 1 and 2 refer to neutron-free proton interactions; curves 3,4 refer to neutron-moving proton interactions and curve 5 refers to the neutron-moving deuteron interaction.

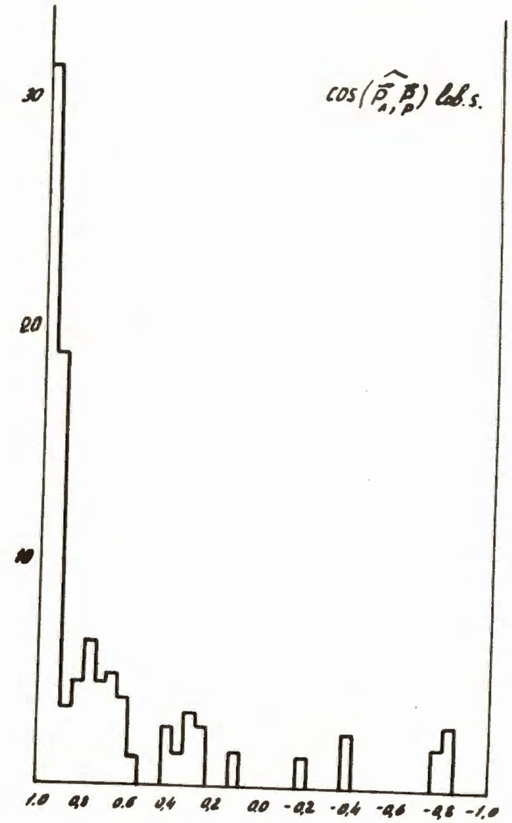

Fig. 3. The opening angle distribution of Λp -system in laborat
system for events from the peak.

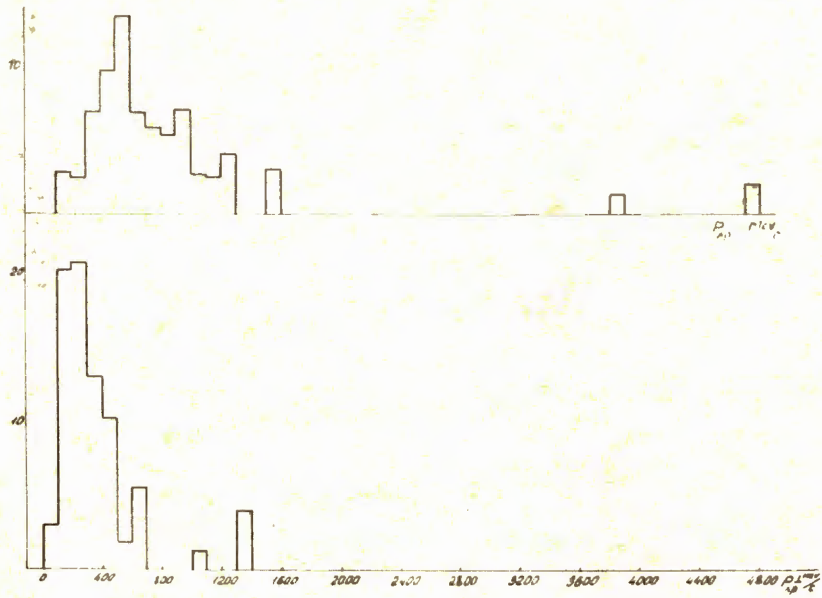

Fig. 4. Total and transversal momenta distributions of Λp -system for events from the peak.