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ON A POSSIBILITY OF PARTIAL WAVE ANALYSIS OF THE $K^- \pi^- \pi^+$ SYSTEM WITHOUT EXPERIMENTAL IDENTIFICATION OF SECONDARY MESONS

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The paper discusses a possible way of performing the partial-wave analysis of a $K^- \pi^- \pi^+$ system based on the data with $(K^- - \pi^-)$-ambiguity due to there experimentally unidentified secondary mesons (M_i) produced in the reaction $K^- A \to M_1^- M_2^- M_3^+ A$.

The investigation has been performed at the Laboratory of Nuclear Problems, JINR.

О возможном способе парциально-волнового анализа $K^- \pi^- \pi^+$-системы при отсутствии экспериментальной идентификации сорта вторичных мезонов

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Обсуждается способ парциально-волнового анализа $K^- \pi^- \pi^+$ системы, когда в эксперименте отсутствует система идентификации сорта вторичных мезонов, что приводит к $(K^- - \pi^-)$-неоднозначности в экспериментальных данных. Поэтому каждое событие исследуемого процесса представлено двумя гипотезами, одна из которых заведомо верная. С целью корректного проведения волнового анализа предлагается процедура вычитания "фона" ложных гипотез в функции максимального правдоподобия при использовании результатов ранее проведенных исследований данного процесса.

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This paper is to discuss the method of the partial-wave analysis of a $K^- \pi^- \pi^+$ system diffractively produced in the process on the nucleus

$$K^- A \to K^- \pi^- \pi^+ A \qquad (1)$$

when there is no secondaty particle identification system in the experiment.

The search for a method of analysing the reaction (1) was stimulated by the absence of experimental data on this process and by the fact, established in the 3π-diffraction processes[1], that the resonance properties of a finite three-meson system produced on nuclear targets are more distinct in comparision with processes on the proton. The experimental data were obtained at the MIS-1 facility, the K^--mesons beam energy being 40 GeV.

The electric charge sign of the secondary particles was determined by the direction of their deviation in the magnetic field of the spectrometer.

If there is an incident K^--meson in the final state of reaction (1), a three-body strange boson system with the total charge of -1 (e.g., $K^- \pi^- \pi^+$ and $K^- K^- K^+$) can be produced. Since the contribution of the total cross section for $K^- K^- K^+$ production is small (~ 5%) at high energies, in our further considerations we assume that only the $K^- \pi^- \pi^+$ system is produced.

Since the mesons in the final state of the reaction were not identified in the experiment, a two-fold ambiguity appears, and any of the two masses M_{K^-} and M_{π^-} can be assigned to negatively charged particles during the kinematic fit of the reaction. Therefore each event on the Data Summary Tape is represented by two hypotheses, one of them is known to be true, the other is known to be false. Note that one does not know a priori, which of the hypotheses is true for a given event.

In the bubble chamber experiments, when the recoil proton is also measured, the true hypothesis was selected by a relatively higher probability of the kinematic 4C-fit for both hypotheses[2,3]. Yet, this selection criterion is ineffective for ~ 22% of events with close values of momenta of secondary K^- and π^- mesons.

In process (1) the recoil nucleus is not registered, and the value of the given probability of the 1C-fit is not sensitive to the selection of the true hypothesis practically in the whole kinematic region of the reaction.

In the earlier experiment[3] on the study of process (1) in the K^+-meson beam the true hypothesis selection criterion was the smallest value of the quantity $|M_{K^-\pi^+} - M_{K^*(890)}|$ for two hypotheses.

This criterion is based on the known domination of the $K\pi\pi$ system decay into $K^*(890)\pi$. The hypotheses selected in this way include some incorrect hypotheses, since at the substitution $\pi^+ \leftrightarrow K^+$ the distributions of ρ and K^* resonances in the $\pi\pi$ and $K\pi$ systems, respectively, turn into their false images in the $K\pi$ and $\pi\pi$ systems largely overlapping the true distributions of the ρ and K^* resonances.

The contribution of the incorrectly selected hypotheses caused by the ineffectivenes of the given selection criterion did not allow a correct partial wave analysis and reliable information of the wave structure of $K^+\pi^+\pi^-$ events.

It should be mentioned that any criterion based on the selection by a kinematic quantity of process (1) leads to a certan admixture of false hypotheses. So the main task is to find not only a criterion that selects chiefly a true hypothesis but also a way of estimating distributions of the given set of false hypotheses and a method of their elimination from the further partial wave analysis.

In this paper the selection of the hypothesis for an event of reaction (1) is supposed to be based on the experimental fact /6/ that indicates the predominant leading of the secondary K^--meson over the π^--meson in the reaction of $K^- \pi^- \pi^+$ production on the proton. It means that of two hypotheses for each event the one with the K^--meson momentum larger than the π^--meson momentum ($P_{K^-} > P_{\pi^-}$) is selected. The effectiveness of this selection criterion was checked with generated events. The results of the partial wave analysis of process (1) on the proton target /4/ were used for generation. (These results allowed determination of the matrix element of the process).

For each generated event its false hypothesis was obtained by assigning the masses M_π and M_K to K^- and π^- mesons respectively followed by the kinematic fit of the false hypothesis. The knowledge of the true and false hypotheses for each generated event allowed the properties of the selection criterion used to be investigated. It was found that for ~ 75% of the generated events the secondary K^--meson is actually a faster particle than the π^--meson, and for the rest ~ 25% of the events the criterion selects a false hypothesis.

It is important that the results of the partial wave analysis for the proton data used for generation were obtained for the region of small momentum transfer to the nucleus $t' \leq 0.05\ (GeV/c)^2$ which covers the greate part of the cross section for the process on the nucleus and a set of waves equally describing both the proton and nuclear data (in particular, there are no spin-flip states). So, if one takes the kinematic properties of events equal for the proton and nuclear data, one may expect that selection of the hypothesis by the relative leading of the K^--meson, applied to the data of the process (1), will yield approximately the same ratio of contributions of the true and false hypotheses as for the generated proton data, i.e. ~ 75% and ~ 25% respectively. These ~ 25% of false hypotheses will lead to strong distortion of total contributions of $K^- \pi^- \pi^+$ wave states and distributions of their intensities and phases over the $M_{K\pi\pi}$ in the results of the partial wave analysis of the selected events.

This conclusion was checked by the generated proton data. In order to extract the true information on partial $K^- \pi^- \pi^+$ states, one must exclude from the analysis all these false hypotheses for the experimental data, which we shall call the "background" for our case. Since the "background" events are a priori unknown, one can estimate the given "background" by the set of false hypotheses for the generated proton data.

In the partial wave analysis the maximum likelihood method is used to describe the experimental distributions of events by the set of wave $K^- \pi^- \pi^+$-states. So the "background" can be eliminated from the analysis by the method described in ref.5.

The point of the method is as follows. Let there be two groups of events: $X = x_1, x_2, ..., x_N$ including both the physical signal and the background events, and $Y = y_1, y_2, ..., y_L$ including only the background events obtained in the special background experiment. The background events in X as well as the analytical form of their distribution density function are unknown. In this case, when describing the physical signal, one can statistically subtract the background from X using the likelihood function of the form

$$\mathcal{L} = \sum_{i=1}^{N} \log f(x_i, \{\alpha\}) - \eta \sum_{j=1}^{L} \log f(y_j, \{\alpha\}), \qquad (2)$$

where $f(x, \{\alpha\})$ is the physical signal distribution density function, $\{\alpha\}$ are the parameters to be determined, η is the normalization related to the X and Y data collection time.

Applying expression (2) to the partial wave analysis, when the generalized method of maximum likelihood is used, one can rewrite it as

$$\mathcal{L} = \sum_{i=1}^{N} \log f(\tau_i, \{\rho\}) - \eta \sum_{j=1}^{N'} \log f(\tau_j^*, \{\rho\}) - \int_{P.S.} f(\tau, \{\rho\}) A(\tau) d\tau, \qquad (3)$$

where $\tau = \{ M^2_{K^-\pi^-}, M^2_{\pi^-\pi^+}, \alpha, \cos\theta, \gamma \}$, $A(\tau)$ is the facility acceptance function. In the first term of (3) summation is made over all experimental events whose hypotheses were selected by the leading criterion, thus including both true hupotheses ($\sim$ 75%) and the "background" ($\sim$ 25%). In the second term summation is made over the "background" events of the generated proton data taking into account the form-factor of the nucleus. Integration in (3) is over whole kinematically allowed phase space of reaction (1).

This subtraction of the "background" results in the fact that instead of the whole physical signal only its part where $P_{K^-} > P_{\pi^-}$ is analysed. The checking showed that for any partial $K\pi\pi$-wave its relative contribution to the region $P_{K^-} > P_{\pi^-}$ is $\sim 50 \div 85\%$. The correction for the given momentum cut-off is taken into account in the same way as the geometrical acceptance of the facility[8], i.e. function $A(\tau)$ is the product of the acceptance function and the function of the $(P_{K^-} > P_{\pi^-})$ criterion effectiveness for each partial wave.

The procedure of the "background" subtraction in the partial wave analysis can be checked by the generated data.

The use of the above procedure of selection of hypotheses followed by subtraction of the "background" of false hypotheses, estimated by the proton data, allows at least to considerably reduce the contribution of the "background" events, if not eliminate it completely from the data. Thus one may hope that the analysis of the partial $K\pi\pi$-structure in the group of true events (~ 75%) of reaction (1) will allow one to find the $K\pi\pi$ system properties typical of the process of its production on nuclear targets.

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