The preliminary result from spectra of $K^0_s \pi^-$ in reaction p+propane at 10 GeV/c.

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Abstract

The experimental data from 2m propane bubble chamber have been analyzed to search for scalar meson $\kappa(800)$ in a $K^0_s \pi^-$ decay mode for the reaction p$+C_3H_8$ at 10 GeV/c. The $K^0_s \pi^-$ invariant mass spectrum has shown resonant structures with $M_{K^0_s \pi^-}=730, 900$ and $\Gamma=143, 48 \text{ MeV}/c^2$, respectively. The statistical significance are estimated to be of 14.2$\sigma$ and 4.2$\sigma$, respectively. The peak in M(900) is identified as reflection from the well known resonance with mass of 892 MeV/c$^2$.

1 Introduction

Already back in 1977 Jaffe [1] using the bag model [2] in which confined colored quarks and gluons interact as in perturbative QCD, suggested the existence of a light nonet composed of four quarks mesons [4]. There are theoretical arguments in favour of a light and broad $\kappa(800)$ [4] pole near the $K\pi$ threshold. However, the experimental evidence is not conclusive. The scalar mesons have vacuum quantum numbers and are crucial for a full understanding of the symmetry breaking mechanisms in QCD, and presumably also for confinement. In a recent topical review [5], it was suggested that the lightest scalars are at the central core composed of a four quarks. Following Jaffe’s QCD arguments this central core would consist predominantly of a four-quark $(q, q)^3(q, q)_3$ state. At larger distances from the core the four quarks would then recombine to a pair of colour singlet $q\bar{q}$s, building two pseudoscalar mesons as a meson cloud at the periphery. Suggestions that the $\sigma(600)$ and $\kappa(800)$ could be glueballs have been made. There are theoretical arguments for why a light and broad $\kappa(800)(q\bar{q}$ or 4-quark state) pole can exist near the $\kappa$ threshold and many phenomenological papers (Naive quark model [4]) support its existence. The $\sigma(600)$ and $\kappa(800)$ indeed belong to the same family as the $f_0(980)$ and $a_0(980)$ mesons (say if the $\sigma(600)$ were composed of 2 or 4 u and d type quarks) then no such mechanism would suppress the decay $\sigma(600) \rightarrow \pi^+\pi^-$ or $\kappa(800) \rightarrow K\pi$.

The PDG [3] numerous determinations of the pole mass in the neighbourhood of 600 MeV. There is believe that experimental groups should look for pole positions in their data analysis, which also include the aforementioned nonlinear effects from S-wave thresholds. The E791 [6] Collaboration reported a light ? with mass 797 MeV and width 410 MeV, but uses a Breit-Wigner amplitude. This claim was, however, not confirmed by the CLEO Collaboration. A lighter and very broad $\kappa$ pole is nonetheless possible and should be looked for in future data analyzes [4].

The effective mass distribution of $\pi^+\pi^-$ combinations from total statistics of the reaction np$\rightarrow \pi^+\pi^-X$ at $P_n=5.2$ GeV/c. The distribution is approximated by a polynomial background curve and by 3 resonance curves taken in the Breit-Wigner form Fig. 1. At least 3 states with quantum numbers of $\sigma_0$ meson $0^+(0^{++})$ have been found at masses of 418, 511 and 757 MeV/c$^2$. The fact low -mass $\sigma_0$-mesons are glueballs is one of the possible interpretations.
2 Experiment

The experimental information of more than 700000 stereo photographs from the LHE JINR 2m bubble chamber [7]-[9] were used to select the events with $V^0$ strange particles.

The effective mass distribution of 8657-events of $\Lambda$-hyperons, 4122-events of $K^0_s$-mesons were consistent with their mass values from PDG [3] (Figure 2). The average geometrical weights were $1.34\pm0.03$ for $\Lambda$ and $1.22\pm0.04$ for $K^0_s$.

As one of backgrounds for experimental data analysis was used FRITIOF model [11] in collision $p+C\rightarrow K^0_s X$. The experimental dates are described by the FRITIOF model satisfactorily [9].

3 $K^0_s\pi^-$ - spectra

The total experimental background has been obtained by three methods. In the first method, the experimental distribution on effective mass with removed areas of the resonance was approximated by the polynomial function while this procedure has provided the fit with $\chi^2=1$ and polynomial coefficient with errors less than 30%. The second of the angle between $K^0_s$ and $\pi$ for experimental events randomly mixing method was described in [10]. The third type of background has been obtained by FRITIOF model [11].

The statistical significance of resonance peaks were calculated as $NP/\sqrt{NB}$, where $NB$ is the number of counts in the background under the peak and $NP$ is the number of counts in the peak above background. The analysis of background done by three methods has shown that there are not observable structure in range of peaks. The statistical significance of resonance peaks were calculated as $NP/\sqrt{NB}$, where $NB$ is the number of counts in the background under the peak and $NP$ is the number of counts in the peak above background. The values for the mean position of the peak and the width obtained by using Breit-Wigner fits.

Figure 3 shows the invariant mass distribution from 3353 ($K^0_s\pi^-$ )combinations with bin sizes 33 MeV/$c^2$. The $2*10^6$ events for $p+$propane $\rightarrow \pi^- K^0_s X$ interaction by FRITIOF has simulated. This background was obtained by using our experimental condition. In Figure 3 the simulated background distribution has been normalized to the experimental distribution. The solid curve is the background by the FRITIOF taken in the form of a superposition of Legendre polynomials up to the 7-th degree. The values for the mean position of the peak and the width obtained by using Breit-Wigner fits.

The effective mass distribution of ($K^0_s\pi$ ) with bin size 20 MeV/$c^2$ is shown in Figures 3-4. This bin size don’t consistent with the experimental resolution. There are statistical enhancements in mass regions of 670-750, 750-850, 850 -950, 950-1030 and 1100-1200 MeV/$c^2$

The background by the mixing methods for $p+$propane $\rightarrow \pi^- K^0_s X$ interaction has
Table 1: The effective mass, the width(Γ) and the statistical significance of resonances produced in collisions of protons with propane at 10 GeV/c

| Resonance Decay Mode | \( M_{\Lambda K^0} \) MeV/c\(^2\) | Experimental width \( \Gamma_e \) MeV/c\(^2\) | \( \Gamma \) | The statistical significance \( S.D.\text{ max} - S.D.\text{ min} \) |
|---------------------|----------------------------------|----------------------------------|--------|--------------------------|
| \( K^0\pi^- \)      | 730                              | 165                              | 143    | 4.6-14.2                 |
| \( K^0_s\pi^- \)    | 900                              | 75                               | 48     | 4.0-6.0                  |

shown in Figure 4. In Figure 4, the background distribution has been normalized to the experimental distribution. Then, the effective mass distribution (\( K^0_s\pi^- \)) was fitted by the 8-th order polynomial function (Fig.4). There are significant enhancements in mass regions of 730 and 900 MeV/c\(^2\). The excess above background are equal to 4.6\( \sigma \) and 4.2 \( \sigma \), respectively.

4 Conclusion

A number of peculiarities were found in the effective mass spectrum of system \( K^0_s\pi^- \): 650-850, 850-1050 and 1100-1200 MeV/c\(^2\) in collisions of protons of a 10 GeV/c momentum with propane. The detailed research of structure of mass spectrum has shown, that the maximal significant statistical enhancements has been obtained in 730(14.2 \( \sigma \)) and 900(4.2\( \sigma \)) effective mass ranges with \( \Gamma \approx 143, 48 \) MeV/c\(^2\) submitted in Table 1.

The preliminary total cross section for M(730) production in p+propane interactions is estimated to be \( \approx 30 - 250 \)\( \mu \)b. The peak M(730) could be interpreted as a possible candidates for a scalar meson state of \( \kappa(800) \). The M(900) peak is interpreted as reflection from well known resonance in PDG with mass 892 MeV/c\(^2\).
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Figure 1: The effective mass distribution of \((\pi^+, \pi^-)\)-combinations from the total statistics of the reaction np→π−π+ np at \(P_n = 5.2\) GeV/c. The dotted curve is the background taken in the form of a superposition of Legendre polynomials up to the 10-th degree, inclusive.
Figure 2: (a) and (b) distributions of $\alpha$ (Armenteros parameter) and $\cos\Theta^*$ are used for correctly identification of the undivided V0s. $\alpha = (P_+ - P_-)/(P_+ + P_-)$. Where $P_+$ and $P_-$ are the parallel components of momenta positive and negative charged tracks. $\cos\Theta^*$ is the angular distribution of $\pi^-$ from $K_s^0$ decay in rest frame $K_s^0$. Distributions of $\alpha$ and $\cos\theta^-$ were isotropic in the rest frame of $K_s^0$ when undivided $\Lambda K_s^0$ were assumed to be events as $\Lambda$. c) and (d) distributions of experimental $V^0$ events produced from interactions of beam protons with propane: c) for the effective mass of $M_\Lambda$; d) for the effective mass of $M_{K_s^0}$. 
Figure 3: Invariant mass distribution ($K^0_s\pi^-$) in the inclusive reaction $p+C_3H_8$. The solid curve is the background by the FRITIOF taken in the form of a superposition of Legendre polynomials up to the 7-th degree. The red histogram is the background by FRITIOF [11].
Figure 4: Invariant mass distribution ($K_0^0\pi^-$) in the inclusive reaction p+$C_3H_8$. The curve is the experimental background by the second method taken in the form of a superposition of Legendre polynomials up to the 8-th degree. The red histogram is the background by the mixing method [18].