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Investigation of Resonance Structure in the System of two KS Mesons in the Mass Regions around 2230 MeV

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This report is devoted to narrow resonance in the K_SK_S-system that is observed in experimental data coming from 6-m spectrometer (MIS ITEP). The experimental data on the production of K_S pair were obtained in $\pi^- p$ interaction at 40 GeV by using a neutral trigger. In the K_SK_S-system a maximum of width <8 MeV is observed at mass of about 2230 MeV. The statistical confidence of this state is better than 6 standard deviations. Spin-parity of the state X(2230) is preferably $J^{PC} = 2^{++}$. Seeing its very small width this resonance is likely to be cryptoexotics (see [1],[2] for details)

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1. Introduction

The experimental data we analyze had been accumulated by using 6-m spectrometer developed at the Institute for Theoretical and Experimental Physics (ITEP, Moscow) and installed at a 40 GeV π^--meson beam from the accelerator at the Institute for High Energy Physics (IHEP, Serpukhov). A detailed description of the 6-m spectrometer is presented in [3]. The system of two K_S-mesons that was recorded under the experimental conditions of the 6-m spectrometer is produced in the following two reactions:

$$\pi^- p \to K_S K_S n, \tag{1.1}$$

$$\pi^- p \to K_S K_S + (n + m\pi^0, p + \pi^-, \ldots). \tag{1.2}$$

Reaction 1.1 is separated with a trigger facility based on veto counters surrounding the liquid-hydrogen target. Due to imperfect trigger operation, some fraction of events of the reaction 1.2 is recorded by the setup. The spectrometer records with high efficiency K_S-mesons going to the forward direction and decaying into to charged π-mesons. The precision of the measurement of the effective mass of the $K_S K_S$-system is better than 8 MeV in mass region around 2200 MeV. The recording efficiency is about 40% for the $K_S K_S$-system in the mass region around 2200 MeV. It depends on the K_S-meson momenta.

In the analysis of the $K_S K_S$-system we used the following kinematical variables: the effective mass M_{KK} of the pair of K_S-mesons; the missing mass squared MM^2 defined as the squared mass of particles that are produced together with the $K_S K_S$-system and which are not recorded in the spectrometer; the 4-momentum transferred from the beam to the system being studied, t; the cosine of the Gottfried-Jackson angle, $cos\theta_{GJ}$; the Treiman-Yang angle, ϕ_{TY}.

The angles are calculated in the rest frame of the pair of K_S-mesons, the beam axis direction in this system being taken for the polar axis. The plane from which the Treiman-Yang angle is reckoned is spanned by the momenta of the beam and of the target proton in this reference frame.

2. Resonance X(2230)

The Figure 1 shows the mass spectrum of the $K_S K_S$-system from 2100 to 2450 MeV and from 2170 to 2280 MeV with the bin width being 20 and 5 MeV, respectively. The resonance feature manifests itself as a maximum in the vicinity of 2230 MeV.

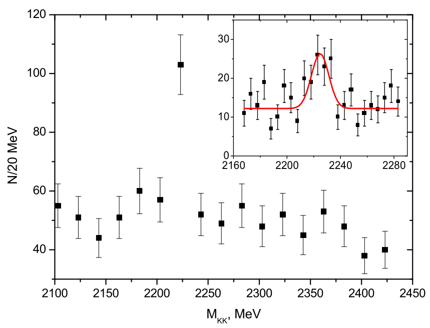

Figure 1: Effective-mass spectrum of two K_S-mesons.

The figure 2 represents the distribution of number of events with respect to the transferred momentum. Momentum-transfer distribution of events from the effective mass region of the $K_S K_S$-system that are adjacent to the resonance region from the left and from the right (2170$<$ M_{KK} $<$2210, 2236$<$ M_{KK} $<$2280 (MeV)) is represented by the curve and dots and of events from the resonance region (2213< M_{KK} <2233 (MeV)) only by the dots. It is seen that these distributions are quite different.

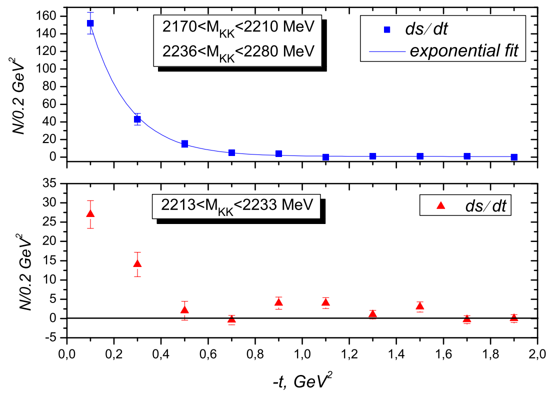

Figure 2: Momentum-transfer distribution for X(2230).

In order to determine the parameters of the observed resonance feature and its statistical confidence, the experimental data were fitted by the Maximum-likelihood method (MLM). The main advantage of this method over the histogramming is that the mass and angles are not averaged over the bin width in the fitting procedure, so that the result does not depend on the choice of the reference point and the number of bins into which the mass range under study is divided. Describing the experimental data, we used the probability-density function $F(P;\Omega)$, where P is the set of the parameters (the amplitude, the mass M, the width σ appearing in the Gauss function and the coefficients of the squared amplitudes of the angular distributions). Elements of the phase space Ω are effective mass of two K_S-mesons, the cosine of the Gottfried-Jackson angle $cos\theta_{GJ}$, the Treiman-Yang angle ϕ_{TY}.

Fitting was performed for events falling within the range 2100-2350 MeV of K_SK_S masses. There were 711 events in this range. A first-degree polynomial proved to be sufficient for describing the mass dependence of the background. The resonance was approximated by a Gauss function. In order to obtain the most probable values of the parameters we minimized the functional:

$$\int_{\Omega} \varepsilon(\Omega)F(P;\Omega)d\Omega - \sum_{i=1}^{N} \ln F(P;\Omega_i). \qquad (2.1)$$

where $\varepsilon(\Omega)$ is the event-detection recording, N being the number of events. To compare the probabilities of experimental-data description with different parameter set, we calculated χ^2 by the formula:

$$\chi^2 = -2\ln L + const, \qquad (2.2)$$

where $L = \prod_{i=1}^{N} F(P;\Omega_i)$. The constant was chosen in such a way that χ^2 obtained via minimization without allowing for the Gauss function was equal to 100. The results of various version of fitting are given in the table, where the number of events in each of the waves of background and the resonance is displayed, along with the central values of the resonance's mass and width. The last column shows the χ^2 values, with the number of degrees of freedom $N_{d.f.}$ being subtracted.

The first line of the table 1 represents the result of fitting without allowing for the Gauss function and without discarding events falling within the resonance region. In the second line is given the result of fitting in terms of the D_0- and D_+-waves.

	Background N_{events}					Resonance N_{events}		Parameters M, σ, Γ, MeV			$\delta\chi^2$	$N_{st.dev.}$
	S	D_0	D_{++}	G_0	G_+	D_0	D_+	$M \pm \Delta M$	$\sigma \pm \Delta\sigma$	Γ		
1	864	313	161	389	369	–	–	–	–	–	100	
2	815	295	162	338	295	183	32	$2223.9\ ^{+2.0}_{-2.2}$	$8.6\ ^{+2.6}_{-1.0}$	≤ 8.0	-40	6.0

Table 1: Different sets of minimization for X(2230).

3. Comparison with other results

Here is presented comparison with other results

TECN	Reaction	Mass, MeV	Width, MeV
96 BES	$e^+e^- \to J/\psi \to \gamma\pi^+\pi^-$	2235 ± 4 ± 6	19 $^{+13}_{-11}$ ± 12
96 BES	$e^+e^- \to J/\psi \to \gamma K^+K^-$	2230 $^{+6}_{-7}$ ± 16	20 $^{+20}_{-15}$ ± 17
96 BES	$e^+e^- \to J/\psi \to \gamma K^0_S K^0_S$	2232 $^{+8}_{-7}$ ± 15	20 $^{+25}_{-16}$ ± 14
96 BES	$e^+e^- \to J/\psi \to \gamma p\bar{p}$	2235 ± 4 ± 5	15 $^{+12}_{-9}$ ± 9
88 LASS	11 $K^- p \to K^+K^-\Lambda$	2209 $^{+17}_{-15}$ ± 10	60 $^{+107}_{-57}$
88 SPEC	40 $\pi^- p \to K_S K_S n$	2230 ± 20	80 ± 30
86 MRK3	$e^+e^- \to \gamma K^+K^-$	2230 ± 6 ± 14	26 $^{+20}_{-16}$ ± 17
86 MRK3	$e^+e^- \to \gamma K^0_S K^0_S$	2232 ± 7 ± 7	18 $^{+23}_{-15}$ ± 170
05 SPEC	40 $\pi^- p \to K_S K_S n$	2223.9 $^{+2.0}_{-2.2}$ ± 5	≤ 8

4. Conclusions

Let us summarize results. At the confidence better than 6 standard deviation we have obtained an indication of the existence of the resonance feature having a mass 2223.9 $^{+2.0}_{-2.2} \pm 5.0$ MeV and a width less than 8 MeV. The spin-parity of this resonance is preferably $J^{PC} = 2^{++}$ The product of the cross section for X(2230) formation and the relevant branching ratio $\sigma \dot{B}R(K_S K_S)$ is estimated at about 9±5nbn

Main feature of this resonance is its very small width (<8 MeV) and extraordinary cross-section dependence on the transferred momentum.

References

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