Study of the reaction $\pi^- A \to K^+ K^- \pi^- A$ at 37 GeV/c.

VES Collaboration

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Abstract.
The reaction $\pi^- A \to K^+ K^- \pi^- A$ was studied at the momentum 37 GeV/c on the berillium target at the wide aperture VES spectrometer. The partial-wave analysis of the $K^+ K^- \pi^-$ system produced at low $|t'| < 0.08$ GeV^2 was performed. It is shown that in the wave with $J^P = 0^-$ there exists an object with mass 1.79 ± 0.014 GeV/c^2 and width 0.21 ± 0.07 GeV/c^2 decaying into κK^- and $f_0(975)\pi^-$.

1 Introduction

The reaction $\pi^- A \to K^+ K^- \pi^- A$ was studied at the momentum 37 GeV/c on the berillium target. This reaction has earlier been studied [7, 8, 4] at lower energy and with lower statistics. The berillium target and higher energy allows one to select clearly diffraction process. High statistic data obtained in this experiment and good acceptance allowed us to perform the partial-wave analysis of the diffractively produced $K^+ K^- \pi^-$ system at low $|t'| < 0.08$ GeV^2.

2 Description of the setup

The experiment was performed at the VErtex Spectrometer (VES) of IHEP. VES is a large aperture magnet spectrometer with 29 planes of proportional and drift chambers , 1600 channel lead glass electromagnetic calorimeter, R200 channel scintillation hodoscope , multichannel threshold cherenkov counter for secondary particle identification . The magnet aperture is $2m \times 1m$. A detailed description of the spectrometer may be found in [1, 2] . Cherenkov counter had 28 mirrors with sizes varying from 14 $\times$ 25 cm in the centre up to 25 $\times$ 50 cm in the periphery. The radiator had the threshold 4.4 GeV for π-mesons. The amplitudes of the cherenkov's signals were used for π and K identification what allowed us to resolve π and K up to 24 GeV/c. To calculate a probability of particle to be π-meson a total amount of light deposited by each track in each mirror was used. At least two charged particles in forward direction and no charged particles outside spectrometer acceptance were used for the trigger.

3 Event's selection

For the selection of the events of the $K^+ K^- \pi^-$ system the following criteria were used :

- The event has one positive and two negative particles in the final state and no gammas;
- The total energy of the three charged particles lies in the region of the "elastic peak": $35.0 < E_{tot} < 38.5$ GeV;

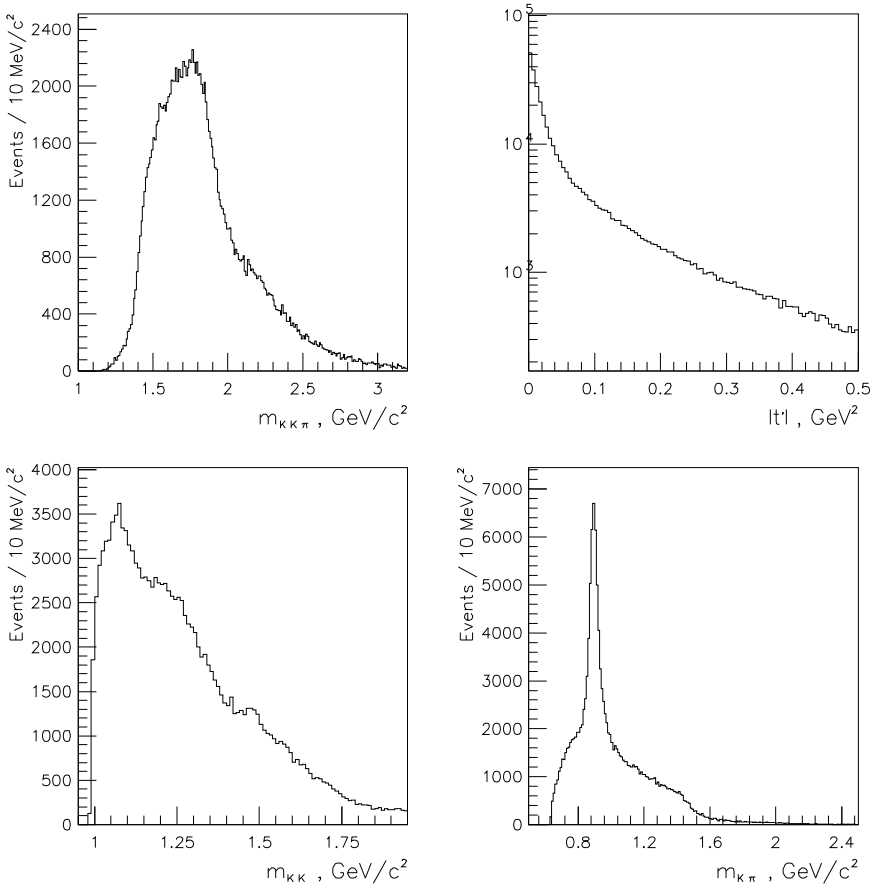

Figure 1: System $K^+K^-\pi^-$.

- The momentum transfer squared $|t'| < 0.08$ GeV^2.
- The energy deposition in the electromagnetic calorimeter unassociated with charged tracks is less than 0.8 GeV.
- The positive and at least one of the negative particles have momentum $5.0 < P_{ch} < 24.0$ GeV.
- Probabilities for these two tracks to be π-meson are less than 0.8.
- The product of these two probabilities is less than 0.1.
- The events were rejected if charged particle with momentum $P_{ch} > 18.0$ GeV had very low signal in the corresponding mirror. That was done for decreasing of the admixture of the background reaction $\pi^- A \to P\ \bar{P}\ \pi^- A$ in the final sample.

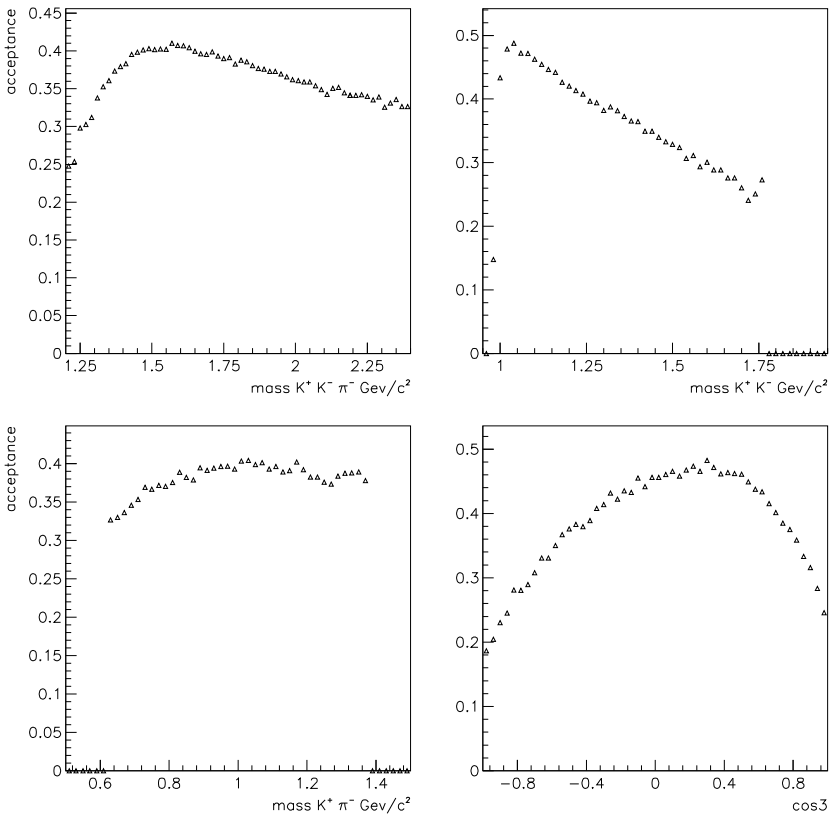

Figure 2: Acceptance of the setup

For further analysis $\sim 1.45 \times 10^5$ events in $0 < -t' < 0.08\ GeV^2$ region were selected. Fig.1 shows the effective mass spectrum for the systems $K^+K^-\pi^-$, $K^+\pi^-, K^+K^-$ and the t'-distribution as well. Because of the some inefficiency of the Cherenkov counter in the selected sample of the $K^+K^-\pi^-$ system there was an admixture of $\pi^+\pi^-\pi^-$ events whose production cross section is about 20 times higher in diffraction. This admixture was estimated by assigning the mass of π-meson to each particle identified as K-meson. In this effective "$\pi^+\pi^-$" mass spectrum a small bump around 0.8 GeV/c^2 was seen. It was attributed to the remnant of ρ-meson plus the reflection of the decay $f_2(1270) \rightarrow K^+K^-$. The fit of the "$\pi^+\pi^-$" mass spectrum showed that the fraction of $\pi^+\pi^-\pi^-$ events in selected sample did not exceed 15%.

4 Partial wave analysis

The PWA of the system $K^+K^-\pi^-$ was performed in the 1.2–2.4 GeV mass region divided into 30 mass bins, 40 MeV each. Acceptance of our setup for $K^+K^-\pi^-$ events distributed uniformly in the phase space is shown in fig.2. The main part of the acceptance loss was due to the momentum cut used for the event selection and was well under control. An upgraded version of the Illinois PWA program was used [5].

Table 1:

name	spin	mass	width
κ	0	$K^+\pi^-$ S-wave [8]	
K^*	1	0.896	0.058
K_2	2	1.432	0.109
f_0	0	K^+K^- S-wave [6]	
f_2	2	1.275	0.185

Table 2:

$0^-S0+\ \kappa K^-$	$1^+S0+\ K^*K^-$	$2^-S0+\ K_2K^-$	$3^+D0+\ K^*K^-$	$1^-P0-\ K^*K^-$
$0^-S0+\ f_0\pi^-$	$1^+P0+\ \kappa K^-$	$2^-S0+\ f_2\pi^-$		
$0^-P0+\ K^*K^-$	$1^+P0+\ f_0\pi^-$	$2^-P0+\ K^*K^-$		
	$1^+D0+\ K^*K^-$	$2^-D0+\ \kappa K^-$		

Table 1 summarizes the isobares used in the analysis. Resonances with spin 1,2 were parametrized by P,D-wave Breit-Wigner functions. For spin 0 resonances in the K^+K^- and $K^+\pi^-$ systems we used the S-wave amplutude and phase parametrizations from K^+K^- and $K^+\pi^-$ scattering [6, 8]. In the low t region ϕ-meson was not seen in the K^+K^- spectrum and it was not inserted into the fit. The orbital momentum was restricted by the value $L \leq 2$. The 12 waves with the negative spin-parity and zero spin projection on the Gottfried-Jackson axis plus one wave with the positive spin-parity and zero projection were included into the fit. We concluded that the set of 13 waves mentioned in the Table 2 was sufficient to describe the $K^+K^-\pi^-$ spectrum. For checking

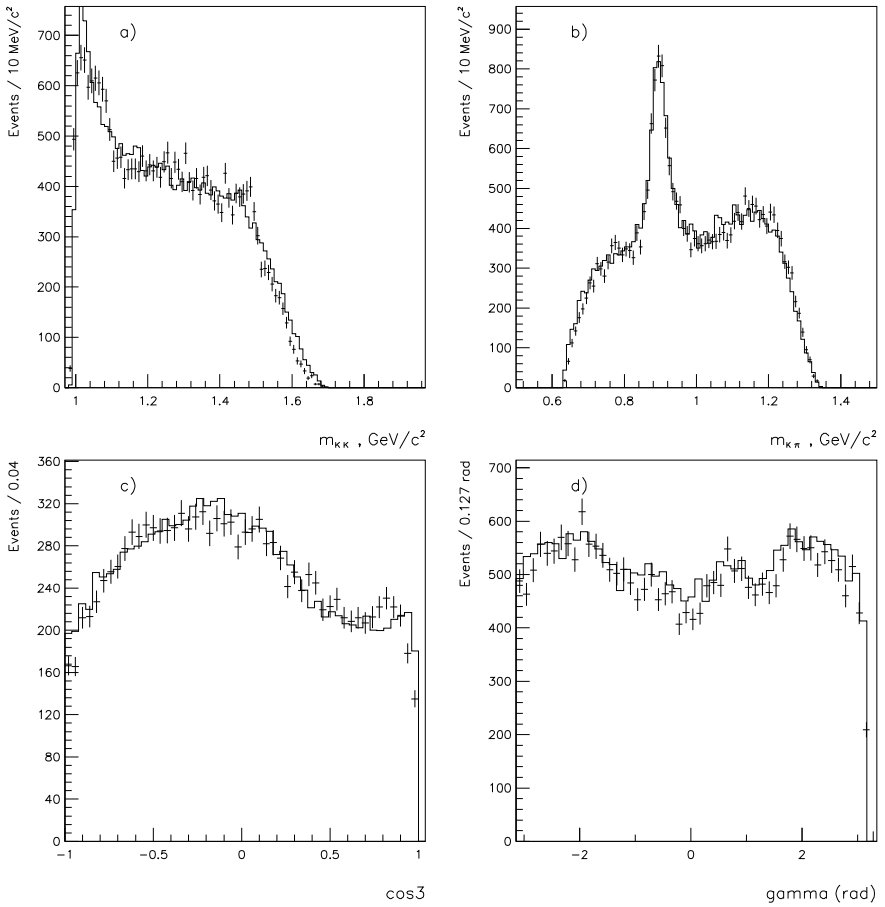

Figure 3: Comparison of MC(solid line) with experimental distributions

the quality of the fit the experimental distributions were compared with those predicted by PWA and showed only small deviations up to 2 GeV/c^2. The example of comparison of experimental and generated by PWA distributions is shown in fig.3 for $1.72 \div 1.84$ GeV/c^2 mass region. The results of our partial wave analysis are shown in fig.4 together with the Deck-effect calculations for some waves shown by dashed lines.

5 Discussion of results

Two waves $0^- S\ \kappa K^-$ and $0^- S\ f_0\pi^-$ dominate in the 0^- state. Both waves have a similar behaviour — they have a sharp maximum at ≈ 1.8 GeV/c^2 and their destructive interference also reaches maximum in the same region (fig 5). The sum of the two waves shows a structure with Breit-Wigner parameters:

$$M = 1.79 \pm 0.014 \text{ GeV}/c^2, \quad \Gamma = 0.21 \pm 0.07 \text{ GeV}/c^2.$$

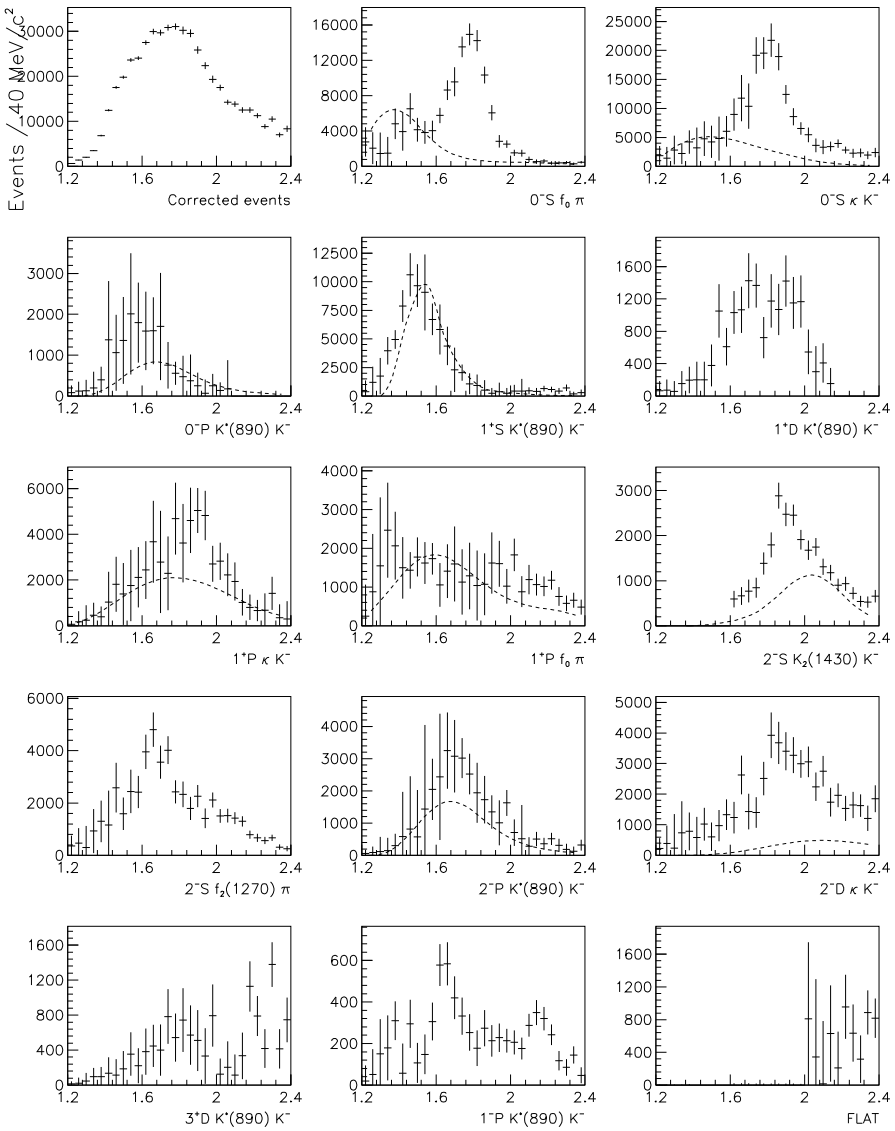

Figure 4: Results of $K^+K^-\pi^-$ system partial wave analysis.

Phases also show a resonance-like behaviour at $\approx$ 1.8 GeV/c^2 (see fig.5g,h). This structure can easily be seen without any PWA in fig.5b where events with $m_{KK} < 1.1\ GeV/c^2$ are plotted . The cut $m_{KK} < 1.1\ GeV/c^2$ selects the events with $f_0(974)$ in the final states (see fig.5a). The first peak at 1.5 GeV/c^2 in fig.5b is due to the intersection of band of $K^*(890)$ with the band of the cut in the Dalitz plot . Different parametrisations of the $K^+\pi^-$ and K^+K^- S-waves were tested but the PWA results remained stable. Presumably the same resonance was seen earlier in [2] in diffractively produced 3π system. A similar behavior of 0^--wave was seen in [7] with lower statistics but summary wave there didn't have a distinctive peak at 1.8 GeV/c^2.

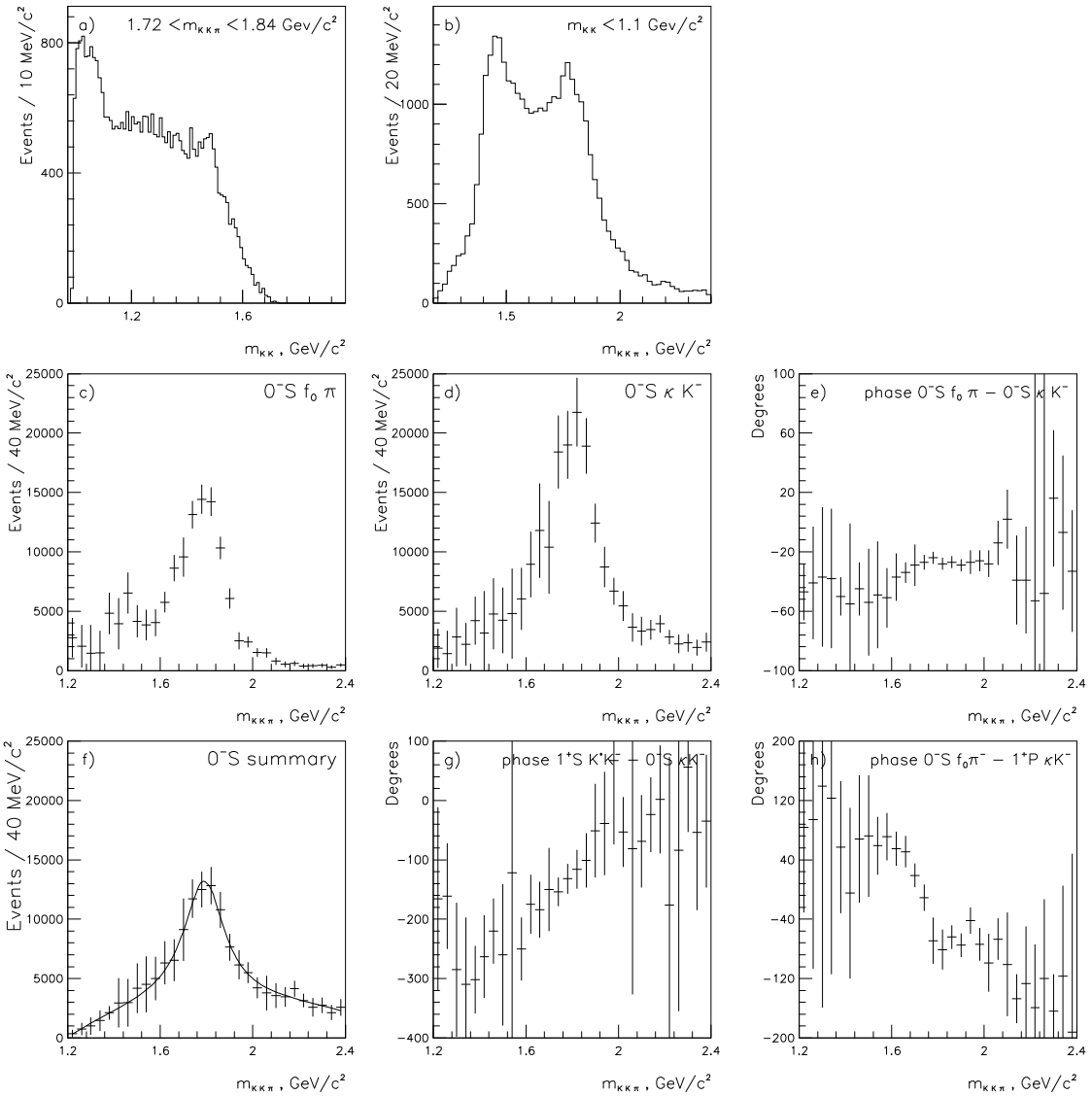

Figure 5: Waves $0^-S\kappa K^-$,$0^-Sf_0\pi^-$, with their interference

The wave $1^+S\ K^*(890)K^-$ dominates in the low-mass region $1.4\div1.6\ GeV/c^2$ in the 1^+ state. In the mass region above 1.6 GeV/c^2 wave $1^+P\ \kappa K^-$ is the single big wave in the 1^+ state. For both waves the Deck-effect have been calculated and shown in the picture by smooth curve. One can see that Deck-effect describes a large part of these waves.

The resonance $\pi_2(1670)$ is seen in $2^-S\ f_2\pi^-$ wave. The fitted mass 1.69 ± 0.014 and width $0.19\pm0.05\ GeV/c^2$ coincide with those from [9] within errors. The phases demonstrate a resonance behaviour (see fig.6). In wave $2^-P\ K^*K^-$ one can also see a maximum at 1.7 GeV/c^2 which was attributed in [7] as a decay of $\pi_2(1670)$ into K^*K^-. In our case this structure is broader than the

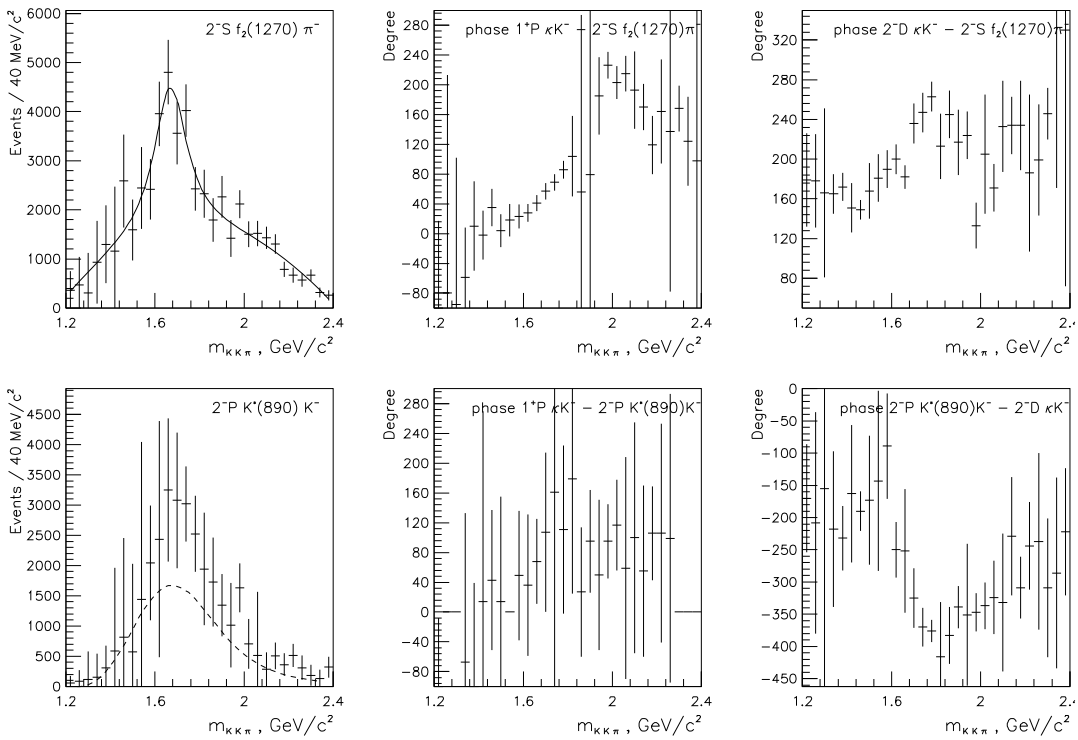

Figure 6: Waves $2^-Sf_2\pi^-$,$2^-PK^*K^-$, with their phases

$\pi_2(1670)$ seen in the $f_2\pi^-$ system and has a phase motion which is not so definite. Moreover the p-wave Deck-effect for K^*K^- shown by a smooth curve in fig.6 describes a main part of this wave. By these reasons we can not distinguish the decay of $\pi_2(1670)$ into K^*K^- from the Deck-effect background.

The wave 2^-S K_2K^- grows quickly above kinematical threshold and has it's maximum around $\sim$1.9 GeV/c^2. The wave 2^-D κK^- has an identical structure at 1.9 GeV/c^2. In both waves the Deck-effect can not describe their behavior. Large errors in phases prevents us from making definite conclusion about the nature of these waves. At $m_{KK\pi} > 2\,GeV/c^2$ the quality of the PWA fit becomes worse and an unphysical wave FLAT appears(see fig.4). The wave FLAT was included in our analysis for the absorption of a garbage in experimental data and events which can't be described with our set of the waves. The main reason for this is the absence of the reliable parametrisation of K^+K^- system above $\sim$ 1.4 GeV/c^2. Our data indicate a possible existence of the 2 structures of unknown nature in this mass region :

- M = 1.49$\pm$0.01 and Γ = 0.04$\pm$0.01 GeV/c^2 (fig.7a) (statistical errors only)

- $M \sim 1.6$ and $\Gamma \sim 0.2$ GeV/c^2 (fig.7b)

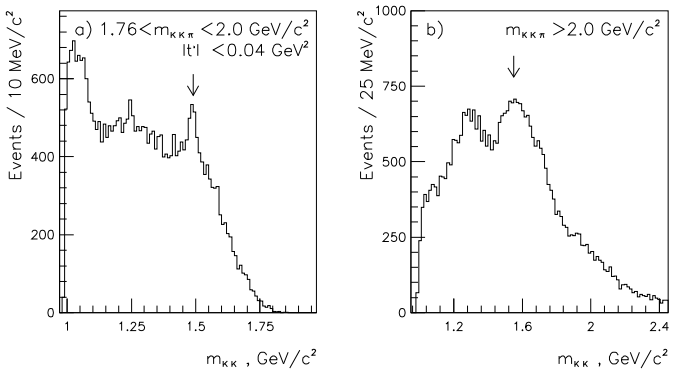

Figure 7: a) m_{KK} for $1.76 < m_{KK\pi} < 2.0$ Gev/c^2
b) m_{KK} for $m_{KK\pi} > 2.0$ Gev/c^2

6 Conclusion

The reaction $\pi^- A \to K^+K^-\pi^- A$ was studied at the momentum 37 GeV/c at VES IHEP spectrometer and the partial-wave analysis of the $K^+K^-\pi^-$ system produced at low $|t'| < 0.08$ GeV^2 was performed. The 13 waves listed in table 2 are found to be sufficient to describe data up to 2 GeV/c^2 , while at a higher mass the PWA results become less significant.

The resonance with mass 1.79$\pm$0.014 and width 0.21$\pm$0.07 GeV/c^2 is clearly seen in both the raw invariant mass spectrum and in the 0^- wave. This structure is decomposed into two waves 0^-S κK and 0^-S $f_0(974)\pi$ with large interference between them. A resonance with similar parameters was previously seen in diffractively produced 3π system in [2].

The resonance $\pi_2(1670)$ is clearly seen in 2^-S $f_2(1270)\pi$ wave with proper phase behaviour.

Acknowledgement

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