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Recent BES Results on Scalar Meson

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Abstract. Partial wave analyses have been performed on BES data to study scalar mesons. The σ peak is seen in $\omega\pi^+\pi^-$ and an accurate pole position, $(541 \pm 39) - i(252 \pm 42)MeV$ is determined. There is evidence for the κ near the $k\pi$ threshold and the pole position is $(760 \sim 840) - i(310 \sim 420)MeV$. The $f_0(980)$ is seen in both $\phi\pi^+\pi^-$ and ϕk^+k^- data, the parameters of the Flatté formula for $f_0(980)$ are determined accurately. The $f_0(1370)$, $f_0(1500)$ and $f_0(1710)$ are studied in some radiative and hadronic decay channels.

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1. Introduction

The knowledge on the light scalars is very important in understanding QCD in nonperturbative region. There have been hot debates on the existence of σ and κ. $f_0(980)$ has been studied for many years, but weather it is a $s\bar{s}$ state, $k\bar{k}$ molecular or four quark state, it need precise parameters such as mass, width etc. of $f_0(980)$. Lattice QCD predicts the lightest scalar glueball is in the mas region from 1.5GeV to 1.7GeV. $f_0(1500)$ and $f_0(1710)$ are good candidates. $f_0(1370)$, $f_0(1500)$ and $f_0(1710)$ were found in the fixed target $p\bar{p}$, e^+e^- experiments. The confirmation of them is very important.

Recently, based on 58 million J/ψ events collected with the Beijing Spectrometer(BES II) detector[1], the scalar mesons have been studied by performing partial wave analysis (PWA) in many channels. In this paper, we present some of the results of scalar mesons from BES.

2. The σ and κ

The σ particle has been studied in the decay of $J/\psi \to \omega\pi^+\pi^-$, with the ω decaying to $\pi^+\pi^-\pi^0$[2]. Fig.1 shows the $\pi^+\pi^-$ invariant mass spectrum recoiling against the ω for the selected $J/\psi \to \omega\pi^+\pi^-$ events. The Dalitz plot of this channel is shown in Fig.2. At low $\pi\pi$ masses, a broad enhancement which is due to the σ pole is clearly seen. This peak is evident as a strong band along the upper right-hand edge of the Dalitz plot.

Two independent PWA methods have been performed on this channel. Different analysis methods and four parameterizations of the σ amplitude give consistent results for the σ pole. The upper full histogram in Fig.3 shows the maximum likelihood fit. The dashed histogram shows the σ contribution. The average σ pole position is determined to be $(541\pm39)-i(252\pm42)$ MeV.

The κ is studied from $J/\psi \to \bar{K}^*(892)K^+\pi^-$ and $K^+K^-\pi^+\pi^-$ decays through partial wave analysis. Fig.4 shows the $K^+\pi^-$ invariant mass distribution with the accompanying $K^-\pi^+$ being in the mass range of 892 ± 100 MeV. Three independent analyses have been performed and different parameterizations of κ pole are used. The preliminary results show the evidence of κ near the $K\pi$ threshold. Its pole position is around $(760 \sim 840) - i(310 \sim 420)$ MeV.

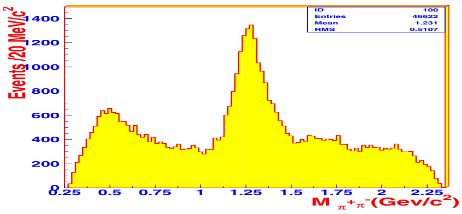

Figure 1. Distribution of $\pi^+\pi^-\pi^0$ mass.

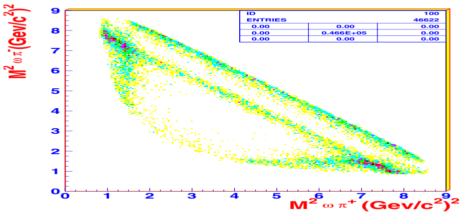

Figure 2. Dalitz plot.

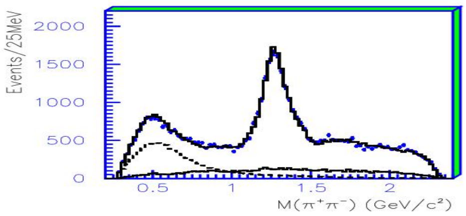

Figure 3. The $\pi^+\pi^-$ mass distribution. The upper full histogram shows the maximum likelihood fit, the dashed histogram shos the σ contribution.

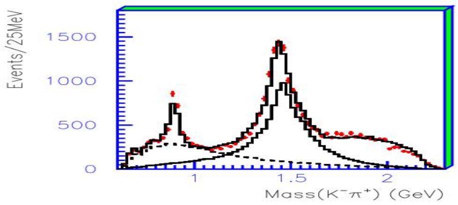

Figure 4. The $K^+\pi^-$ invariant mass spectrum with the accompanying $K^-\pi^+$ being in the mass range of 892 ± 100 MeV.

3. The $f_0(980)$

Fig.5 and Fig.6 show the $\pi^+\pi^-$ and K^+K^- invariant mass distributions from $J/\psi \to \phi\pi^+\pi^-$ and ϕK^+K^-, respectively. The shaded histograms correspond to the backgrounds estimated from ϕ sidebands. The $\phi\pi^+\pi^-$ and ϕK^+K^- data are fitted simultaneously by using partial

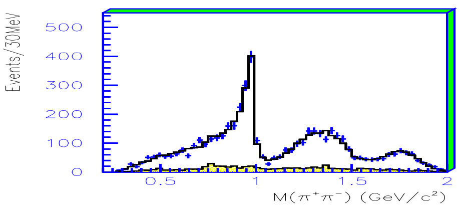

Figure 5. The mass spectrum of $\pi^+\pi^-$ in $J/\psi \to \phi\pi^+\pi^-$. Crosses are data and histograms are PWA fit projections.

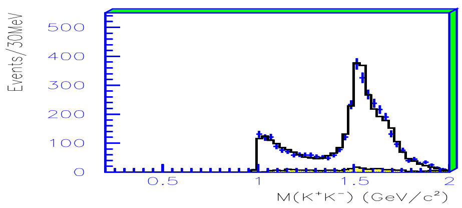

Figure 6. The mass spectrum of K^+K^- in $J/\psi \to \phi K^+K^-$. Crosses are data and histograms are PWA fit projections.

wave analysis, constraining resonance masses and widths to be the same in both sets of data. The full histograms in Fig.5 and Fig.6 show the maximum likelihood fit.

The $f_0(980)$ is observed clearly in both sets of data. The Flatté form:

$$f = \frac{1}{M^2 - s - i(g_1\rho_{\pi\pi} + g_2\rho_{K\bar{K}})}.$$

has been used to fit the $f_0(980)$ amplitude. Here ρ is Lorentz invariant phase space, $2k/\sqrt{s}$, k refers to π or K momentum in the rest frame of the resonance. The present data offer the opportunity to determine the parameters of $f_0(980)$ accurately: $M = 965 \pm 8(sta) \pm 6(sys)$ MeV, $g_1 = 165 \pm 10(sta) \pm 15(sys)$ MeV, $g_2/g_1 = 4.21 \pm 0.25(sta) \pm 0.21(sys)$.

4. The $f_0(1370)$, $f_0(1500)$, $f_0(1710)$ and $f_0(1790)$

The $\phi\pi\pi$(Fig.5) data also exhibit a strong peak centered at $M = 1335$ MeV. It may be fitted with $f_2(1270)$ and a dominant 0^+ signal made from $f_0(1370)$ interfering with a smaller $f_0(1500)$ component. The Mass and width of $f_0(1370)$ are determined to be: $M = 1350 \pm 50$ MeV and $\Gamma = 265 \pm 40$ MeV. But in the $\omega\pi\pi$ data, there are not clear evidence for $f_0(1370)$ in the $\pi\pi$ mass spectrum(Fig.1).

The $\pi^+\pi^-$ and $\pi^0\pi^0$ invariant mass distributions from $J/\psi \to \gamma\pi^+\pi^-$ and $\gamma\pi^0\pi^0$ are shown in Fig.7 and Fig.8. The partial wave analyses are carried out in the 1.0-2.3 GeV $\pi\pi$ mass range. Two 0^{++} states exist in the mass lower than 1.8 GeV(Fig.11). The first one peaks at $1466\pm6\pm16$ MeV with a width of $108^{+14}_{-11} \pm 21$ MeV, which is approximately consistent with $f_0(1500)$. Due to the large interference between S-wave states, a possible contribution from $f_0(1370)$ can not be excluded.

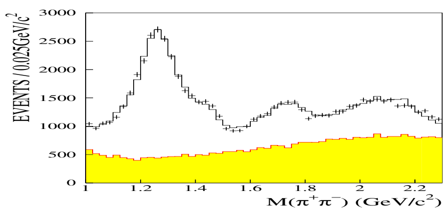

Figure 7. The mass spectrum of $\pi^+\pi^-$ in $J/\psi \to \gamma\pi^+\pi^-$. Crosses are data and histograms are PWA fit projections.

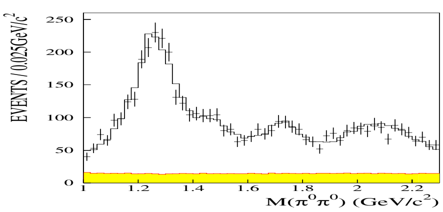

Figure 8. The mass spectrum of $\pi^0\pi^0$ in $J/\psi \to \gamma\pi^0\pi^0$. Crosses are data and histograms are PWA fit projections.

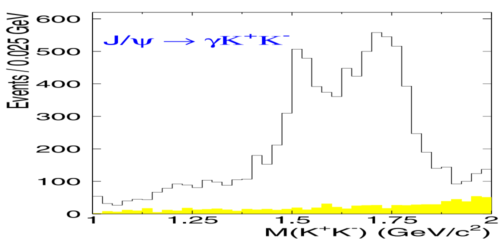

Figure 9. The mass spectrum of K^+K^- in $J/\psi \to \gamma K^+K^-$.

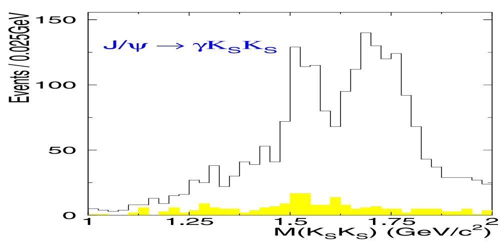

Figure 10. The mass spectrum of K_sK_s in $J/\psi \to \gamma K_sK_s$.

The $f_0(1710)$ is well observed in the $J/\psi \to \gamma K^+K^-$ and $J/\psi \to \gamma K_sK_s$ channels(Fig.9 and Fig.10) [3]. Both global fit and bin-by-bin fit of PWA have been performed. The mass and width of $f_0(1710)$ are determined to be: $M = 1740 \pm 4^{+10}_{-25}$ MeV and $\Gamma = 166^{+5+15}_{-8-10}$ MeV. The second 0^{++} peaks in $\pi^+\pi^-$ of the $J/\psi \to \gamma\pi^+\pi^-$ is around 1.75 GeV(Fig.11). If it is the same state with that observed in $J/\psi \to \gamma K\bar{K}$, we obtain the ratio of decaying to $\pi\pi$ and $K\bar{K}$ as $0.41^{+0.22}_{-0.18}$. Fig. 12 shows the K^+K^- invariant mass distribution from $J/\psi \to \omega K^+K^-$. The crosses are data and the shaded area indicates background events from the ω sideband estimation. A dominant feature of this channel is the structure around 1.74 GeV, denoted as $f_0(1710)$. A partial wave analysis (PWA) shows that the J^P of this structure favors 0^+ and the mass and width are optimized at $M = 1738 \pm 30$ MeV, $\Gamma = 125 \pm 20$ MeV. In $J/\psi \to \omega\pi^+\pi^-$ [2], there is no definite evidence for the presence of $f_0(1710)$. Therefore, we find at the 95% confidence level

$$\frac{BR(f_0(1710) \to \pi\pi)}{BR(f_0(1710) \to K\bar{K})} < 0.11.$$

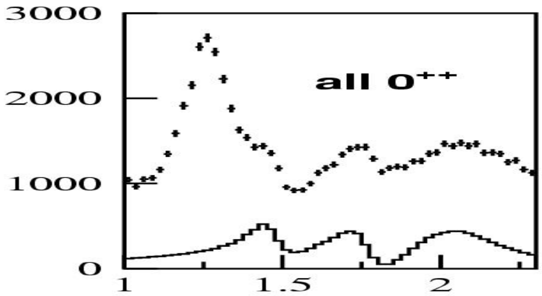

Figure 11. The $\pi^+\pi^-$ invariant mass distribution from $J/\psi \to \gamma\pi^+\pi^-$ (crosses). The histground shows the 0^{++} component contribution

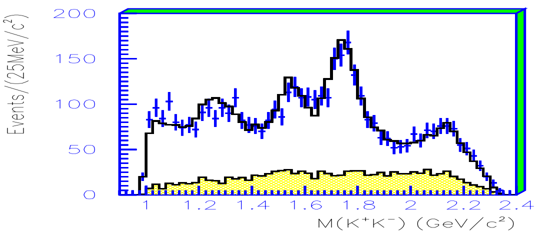

Figure 12. The K^+K^- invariant mass distribution from $J/\psi \to \omega K^+K^-$ (crosses). The full histogram shows the maximum likelihood fit and the shaded histogram the background estimated from ω sidebands.

There is also a signal at around 1.79 GeV in $J/\psi \to \phi\pi^+\pi^-$ with $M = 1790^{+40}_{-30}$ MeV and $\Gamma = 270^{+60}_{-30}$ MeV. The spin 0 is prefered over spin 2.

5. Summary

Partial wave analyses have been performed in BES data to study the scalar meson. Each particle observed in each channels can be showed in the table 1($\surd$ means the particles is clearly seen in the mass spectrum, $\perp$ means the particle is included in the fit). The σ is seen clearly in $\omega\pi^+\pi^-$ and its pole position is $(541 \pm 39) - i(252 \pm 42)$MeV. The κ near the $K\pi$ threshold is needed and the pole position is $(760 \sim 840) - i(310 \sim 420)$MeV. The $f_0(980)$ is clearly seen in both $\phi\pi^+\pi^-$, ϕK^+K^- data, the parameters are well determined. The $f_0(1370)$ is clearly seen in $J/\psi \to \phi\pi^+\pi^-$, but not evidence in $J/\psi \to \omega\pi^+\pi^-$. The $f_0(1500)$ is seen in $J/\psi \to \gamma\pi\pi$ with mass $1466 \pm 6 \pm 16$MeV. The mass and width of $f_0(1710)$ are well determined in $J/\psi \to \gamma KK$, it is also seen in the $J/\psi \to \gamma\pi\pi$ and $J/\psi \to \omega KK$, but not seen in $J/\psi \to \omega\pi\pi$. The$f_0(1790)$ is needed in the fit of $J/\psi \to \phi\pi\pi$, but need further study.

Table 1. Each particle in each channel. captions.

	$K^*K\pi$	$\omega\pi^+\pi^-$	ωK^+K^-	$\phi\pi^+\pi^-$	ϕK^+K^-	$\gamma\pi\pi$	γKK
σ		$\surd$		$\perp$		$\perp$	
κ	$\surd$						
$f_0(980)$		$\perp$	$\perp$	$\surd$	$\surd$		
$f_0(1370)$				$\surd$	$\perp$		
$f_0(1500)$				$\perp$	$\perp$	$\perp$	
$f_0(1710)$			$\surd$		$\surd$	$\perp$	$\surd$
$f_0(1790)$				$\surd$	$\perp$		

6. References

[1] BES Collaboration, Nucl. Instr. Meth., **A344** 319 (1994), **A458** 627 (2001).
[2] BES Collaboration, Phys. Lett. **B598**, (2004) 149
[3] BES Collaboration, Phys. Rev. **D68**, (2003) 052003