Study of the charmonium state χ_{c0} in $\psi(2S)$ decays — check the results from two-prong analysis

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Abstract

$\gamma\pi^+\pi^-\pi^+\pi^-$ and $\gamma\pi^+\pi^- K^+K^-$ final states are studied with the $\psi(2S)$ data collected by BES/BEPC to check the resonance parameters of the p-wave charmonium state χ_{c0} got from $\gamma\pi^+\pi^-$ and γK^+K^- analysis. The total width of χ_{c0} fitted from $\gamma\pi^+\pi^-\pi^+\pi^-$ mode is (14.0 ± 2.4)MeV and from $\gamma\pi^+\pi^- K^+K^-$ mode is (16.8 ± 3.7)MeV, the error is from fitting procedure only. From $\gamma\pi^+\pi^-\pi^+\pi^-$ final state, we calculate the branching fractions of χ_{cJ} to $K^0_sK^0_s$, the results are $B(\chi_{c0} \to K^0_sK^0_s) = (2.50 \pm 0.70) \times 10^{-3}$ and $B(\chi_{c2} \to K^0_sK^0_s) = (0.57 \pm 0.17) \times 10^{-3}$, where the error is statistical only. They agree with $B(\chi_{cJ} \to K\bar{K})$ estimated from $\psi(2S) \to \gamma K^+K^-$.

I. INTRODUCTION

The analysis described here is based on $3.6(1 \pm 0.10)$ million produced $\psi(2S)$ taken by BES (BEijing Spectrometer) at BEPC (Beijing Electron Positron Collider) in 1993/94 and 1995 running.

II. FOUR-PRONG SAMPLE SELECTION

The following criteria are used for the four-prong events sample selection, all the analysis in this paper is based on the sample selected with these conditions.

1. The number of charged tracks is required to be four with net charge zero and each track with high quality in track fitting(MFIT=2,-19 or -9);
2. Transverse momentum of each track $P_{xy} > 0.07GeV/c$ to remove the possible circling track in Main Drift Chamber(MDC).
3. $|\cos\theta| < 0.8$
   where θ is the polar angle relatives to the beam axis, $|\cos\theta_\pi| = 0.8$ corresponds to the coverage of the seventh MDC layer;
4. At most eight neutral tracks reconstructed and after photon selection at most five neutral clusters are allowed in the event.

5. A neutral cluster is regarded as an photon candidate when the angle to the nearest charged track in xy-plane greater than 15 degrees; the first hit of the cluster in the first five layers of BSC and the cosine of the angle between photon emit direction and cluster development direction greater than 0.80. After identification, at least one and at most three photon candidates are allowed in one events. The candidate has the largest SC energy is considered to be the photon radiated from $\psi(2S)$.

III. EVENT SELECTION CRITERIA

The following criteria are used for event selection:

1. Total MUID of the high momentum positive track and the negative track is required less than 4, and at least one of them has an energy deposited in shower counter less than $0.6GeV$ to remove the $\psi(2S) \to \pi^+\pi^- J/\psi \to \pi^+\pi^- l^+ l^-$ events.

2. TOF and dE/dx information is used for particle identification. The probabilities of the particle to be a pion, kaon and proton were assigned to each track. Event with one or more tracks which the probability of proton is the largest is regarded as proton event and removed from the sample.

3. $\gamma\pi^+\pi^-\pi^+\pi^-$ and different combinations of $\gamma\pi^+\pi^- K^+ K^-$ assumption is separated by comparing the product of the probabilities of particle ID to the four tracks and the kinematic fit. The one combination with the largest probability is considered to be the most probable assumption.

4. The probability of π candidate to be identified as π and kaon candidate as kaon is required to be greater than 1%, and the probability of 4C-fit to $\psi(2S) \to \gamma\pi^+\pi^- K^+ K^-$ or $\psi(2S) \to \gamma\pi^+\pi^- K^+ K^-$ is required to be $P_{\chi^2} > 1\%$.

After posing all above selections to the data, the invariant mass distributions of all the charged tracks are show in figure 1, fitting the mass plots of $\pi^+\pi^-\pi^+\pi^-$ and $\pi^+\pi^- K^+ K^-$ with three Breit-Wigners folding a gaussian like mass resolution (mass resolution fixed to Monte carlo simulated value, approximately 14MeV), results can be found in figure 1.

The mass resolutions used above are got from Monte carlo simulation. In the Monte carlo generator, the χ_{cJ}s are assumed to be generated via pure E1 transition of $\psi(2S)$, χ_{cJ} decaying to four charged tracks according to phase space distribution.

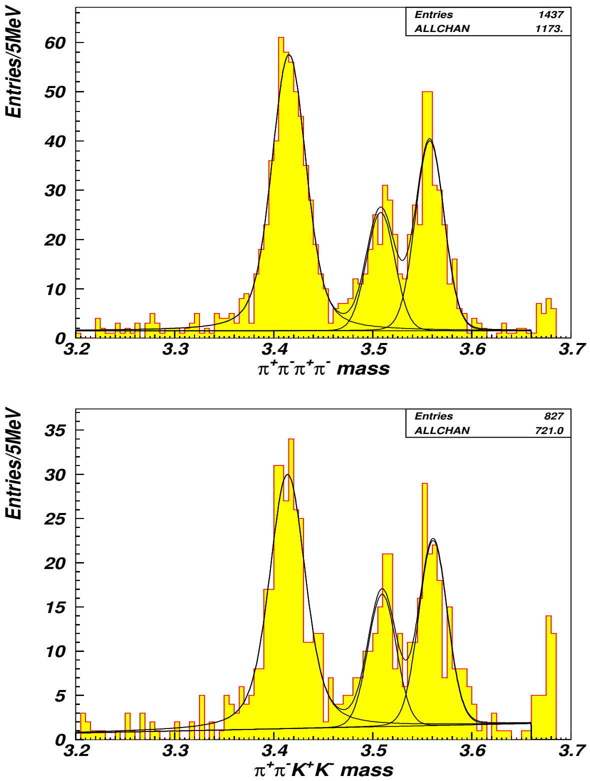
After requiring the mass of the two pairs of $\pi^+\pi^-$ of $\pi^+\pi^-\pi^+\pi^-$ events lies in the mass region of K^0_s (24MeV around nominal K^0 mass), the mass of $\pi^+\pi^-\pi^+\pi^-$ is show in figure 2. Clear χ_{c0} and χ_{c2} can be seen and the numbers of events are 51 ± 7 and 10.7 ± 3.4, Monte Carlo simulation gives the detection efficiencies of χ_{c0} and χ_{c2} to $K^0\bar{K^0}$ are 6.29% and 6.87%. So we get an estimation of the branching fractions of $\chi_{cJ} \to K\bar{K}$,

$$B(\chi_{c0} \to K^0_s K^0_s) = (2.50 \pm 0.70) \times 10^{-3},$$

$$B(\chi_{c2} \to K^0_s K^0_s) = (0.57 \pm 0.17) \times 10^{-3}.$$

These results are in agreement with what we got from two prongs events analysis.

FIGURES

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=========================================’==============================
I                        Summary Of BWFIT Results’                          I
=========================================’==============================
Histogram ID=    31  AdapQuad Breit-Wigner Fit using   92 Points
Fit Parameters:Npoly=   2 Nbw=   3 Namp=   0 Range=    3.200  To  3.660
Hist. Chisq =      76.92 for   8 params &  84 DF.
Chisquare Probability =  69.51%. Mean and S.D. for pulls:      -.0096  .9094
Likelihood ratio and probability                   :     84.410    46.69%
Final Value of Log Likelihood                      :  -1581.58
Error Correspond to a Function Chage               :        .50
Phase Space limits for tails corrections           :        .280GEV  2.817GEV
Breit-Wigner efficiency correction factors         :        .980       .999   .996
Include Breit-Wigner tails outside fit region :        .000       .000   .000
Efficiency-corrected events in fit region          :   1146.[average eff. :1.000]
---THE FITTED VALUES AND ERRORS OF THE PARAMETERS:---
   LEG_1Value : -.57952E-02Error(Cov,-/+):    .192       .000E+00  .000E+00
   AREA0Value :  .48142    Error(Cov,-/+):    .191E-01  .000E+00  .000E+00
   RESL0Value :  .14000E-01Error(Cov,-/+):    .000E+00  .000E+00  .000E+00
   GAMA0Value :  .14047E-01Error(Cov,-/+):    .241E-02  .000E+00  .000E+00
   MASS0Value :  3.4153    Error(Cov,-/+):    .963E-03  .000E+00  .000E+00
   AREA1Value :  .15034    Error(Cov,-/+):    .119E-01  .000E+00  .000E+00
   RESL1Value :  .14000E-01Error(Cov,-/+):    .000E+00  .000E+00  .000E+00
   GAMA1Value :  .88000E-03Error(Cov,-/+):    .000E+00  .000E+00  .000E+00
   MASS1Value :  3.5080    Error(Cov,-/+):    .163E-02  .000E+00  .000E+00
   AREA2Value :  .24872    Error(Cov,-/+):    .148E-01  .000E+00  .000E+00
   RESL2Value :  .14000E-01Error(Cov,-/+):    .000E+00  .000E+00  .000E+00
   GAMA2Value :  .20000E-02Error(Cov,-/+):    .000E+00  .000E+00  .000E+00
   MASS2Value :  3.5575    Error(Cov,-/+):    .102E-02  .000E+00  .000E+00
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=========================================’==============================
I                        Summary Of BWFIT Results’                          I
=========================================’==============================
Histogram ID=    32  AdapQuad Breit-Wigner Fit using   92 Points
Fit Parameters:Npoly=   2 Nbw=   3 Namp=   0 Range=   3.200 To  3.660
Hist. Chisq =     104.65 for   8 params &  84 DF.
Chisquare Probability =   6.31%. Mean and S.D. for pulls:      .0075 1.0608
Likelihood ratio and probability                   :    123.256     .34%
Final Value of Log Likelihood                      :   -878.04
Error Correspond to a Function Chage               :        .50
Phase Space limits for tails corrections           :        .280GEV 2.817GEV
Breit-Wigner efficiency correction factors         :        .977     .999   .996
Include Breit-Wigner tails outside fit region :        .004     .000   .000
Efficiency-corrected events in fit region          :    680.[average eff. :1.000]
---THE FITTED VALUES AND ERRORS OF THE PARAMETERS:---
   LEG_1Value :  .42533    Error(Cov,-/+):    .181       .000E+00  .000E+00
   AREA0Value :  .44154    Error(Cov,-/+):    .274E-01  .000E+00  .000E+00
   RESL0Value :  .14000E-01Error(Cov,-/+):    .000E+00  .000E+00  .000E+00
   GAMA0Value :  .16835E-01Error(Cov,-/+):    .374E-02  .000E+00  .000E+00
   MASS0Value :  3.4139    Error(Cov,-/+):    .142E-02  .000E+00  .000E+00
   AREA1Value :  .15829    Error(Cov,-/+):    .173E-01  .000E+00  .000E+00
   RESL1Value :  .14000E-01Error(Cov,-/+):    .000E+00  .000E+00  .000E+00
   GAMA1Value :  .88000E-03Error(Cov,-/+):    .000E+00  .000E+00  .000E+00
   MASS1Value :  3.5094    Error(Cov,-/+):    .207E-02  .000E+00  .000E+00
   AREA2Value :  .22746    Error(Cov,-/+):    .198E-01  .000E+00  .000E+00
   RESL2Value :  .14000E-01Error(Cov,-/+):    .000E+00  .000E+00  .000E+00
   GAMA2Value :  .20000E-02Error(Cov,-/+):    .000E+00  .000E+00  .000E+00
   MASS2Value :  3.5609    Error(Cov,-/+):    .170E-02  .000E+00  .000E+00
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FIG. 1. Mass plots and fitted results

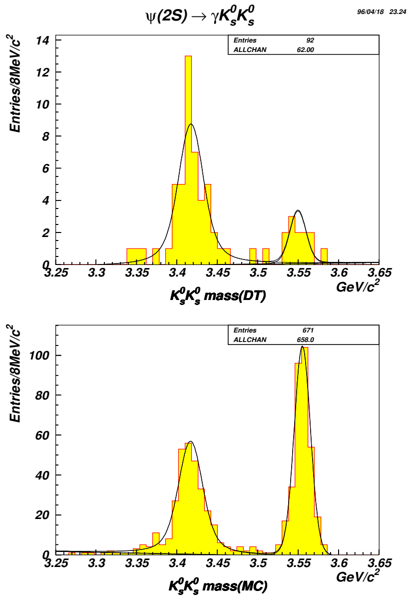

FIG. 2. $K^0_s K^0_s$ invariant mass