Study of $\psi(2S) \to \gamma\pi^0\pi^0$ and $\gamma\eta\eta$

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Abstract

A sample of 3.7 $\times$ 10^6 produced $\psi(2S)$ events collected by BES detector at BEPC is used to investigate the $\gamma\pi^0\pi^0$ and $\gamma\eta\eta$ decays in five photon final states. In the $\gamma\pi^0\pi^0$ decay channel, significant production of f_2 has been observed which follows the expectation of the $''15\%\ rule''$. The branching fractions of $\chi_{cJ}(J = 0, 2)$ decays to $\pi^0\pi^0$ and $\eta\eta$ are obtained.

1 INTRODUCTION

Most of the branching ratios for exclusive hadronic channels allowed in both J/ψ and $\psi(2S)$ decays indeed scale with their lepton pair branching ratios, as would be expected from decay amplitudes controlled by the quarkonium wave function near the origin, namely, a universal ratio [1]

$$Q_h = \frac{B(\psi(2S) \to hadrons)}{B(J/\psi \to hadrons)} = \frac{B(\psi(2S) \to e^+e^-)}{B(J/\psi \to e^+e^-)} = 0.147 \pm 0.023, \tag{1}$$

appears to exist for most hadronic final states except vector-pseudoscala combinations, $\rho\pi$ and K^*K [2] observed at first by Mark II collaboration. Recently BES collaboration has observed that the hadronic decay of $\psi(2S)$ into vector-tensor combinations, ωf_2, ρa_2, $K^{*0}K_2^{*0}$, $\phi f_2'$, are suppressed at a level more than 3 [3]. The lowest order expression of the partial width of J/ψ or $\psi(2S)$ decay to a photon and two gluons also depends on the square of the wavefunction at the origin [4]. Thus one expects the $''15\%\ rule''$ stands also for radiative decays of $\psi(2S)$ and J/ψ to any non-charmonium hadrons. We measure the branching fraction of $\psi(2S) \to \gamma f_2$ in $\psi(2S) \to \gamma\pi^0\pi^0$ decay mode.

This memo contributes the first analysis of $\psi(2S)$ decays into five-photon states by using $\psi(2S)$ data sample at BES. The $Br(\psi(2S) \to \gamma f_2)$ will be measured in $\psi(2S) \to \gamma\pi^0\pi^0$ decay mode. The decay $\psi(2S) \to \gamma\chi_{cJ}$, $\chi_{cJ} \to \pi^0\pi^0$(J=0, 2) will be observed which are sufficiently free of backgrounds that we are able to give good results. The analagous decays to charged π's have been measured at BES [5], these can be compared with the results of the current analysis, so we can check the reliability of isospin invariance. For the $\psi(2S) \to \gamma\eta\eta$ decay channel, only rough results are obtained for $\chi_{c0,2} \to \eta\eta$.

The BES experiment has accumulated 3.7(1 $\pm$ 0.10) million $\psi(2S)$ sample. The position resolution of BES shower counter, which were outlined in [6], is $\delta_\phi = 7.9$mrad and $\delta_z = 36$mm, while the energy resolution is $\Delta E/E = 22\%/\sqrt{E}(E$ in GeV). It is expected that the better angular and position resolutions of BES in detecting photons may compensate its relatively poor energy resolution. Therefore, the information of the positions and directions of neutral tracks in shower counter is used as much as possible in selecting events.

2 General Event Selction

Events of no charged tracks which at least five neutral clusters have been selected. A neutral cluster is regarded as a good photon candidate when it satisfies the following conditions:

1. Only BSC informations are used;
2. For a neutral cluster, the first hit layer in BSC should not be the 6th layer;
3. The angle between cluster development direction and its emit direction must be greater than 60^0;
4. To remove two splitted showers from one γ, It is required:
   If $E_{\gamma_i} < E_{\gamma_j}$,
   (a) If $\theta_{\gamma_i\gamma_j} < 15^o$ and $M_{\gamma_i\gamma_j} < 60$MeV,
   γ_i will be rejected;
   (b) If $\theta_{\gamma_i\gamma_j} < 5^o$,
   γ_i will be rejected;

After the above good photon selection, at least five and at most eight photon candidates are allowed and a full $\psi(2S)$ kinematic fit is performed for each event. For this task the BES standard routine NEWSQUID is used. To check the reliability of all events, firstly, a 4-constrains kinematic fit(4C fit) is performed to get 5 photons with the smallest χ^2_{4C}. There are 15 combinations for these five photons to reconstruct $2\pi^0$'s in $\psi(2S) \rightarrow \gamma\pi^0\pi^0$ channel and δ is introduced as:

$$\delta = \sqrt{(m_{\gamma_1\gamma_2} - m_{\pi^0})^2 + (m_{\gamma_3\gamma_4} - m_{\pi^0})^2}, \tag{2}$$

where m_{π^0} is the mass of π^0. The minimum value of δ for all γ permutations is considered to be corresponding with the optimum π^0 pair. Two pairs of photons after the above selection are shown in fig. 1 from which, one can see clear π^0 structures. The similar selection has been done for $\psi(2S) \rightarrow \gamma\eta\eta$ decay mode and $\gamma\gamma$ mass spectra are shown in fig. 2.

To improve the mass resolution, we do a 6-constrains kinematic fit for each events, 6-constrains kinematic fit is a 4C fit plus (1)C per reconstructed π^0/η in the final state. For these kinematic fits, all possible permutations of the γs are tried to get optimum π^0/η pair with the smallest χ^2_{6C}. Further cuts, such as $Prob_{\chi^2}(6C) > 0.01$ and the number of good photons being 5 are applied to obtain clear $\gamma\pi^0\pi^0(\gamma\eta\eta)$ sample.

θ^*_{boost}, the angle between a γ from a π^0/η and the π^0/η's boost direction in that π^0/η's rest frame, here $|cos\theta^*_{boost}| < 0.98$ is required. Table. 1 shows the event number after each generic cut.

In addition to these generic cuts, a few specific cuts are imposed to the data set to improve signal to noise and are detailed with each mode analyzed in the following. The choise of these specific cuts is dictated by efficiency in removing background and in the simulation studies below.

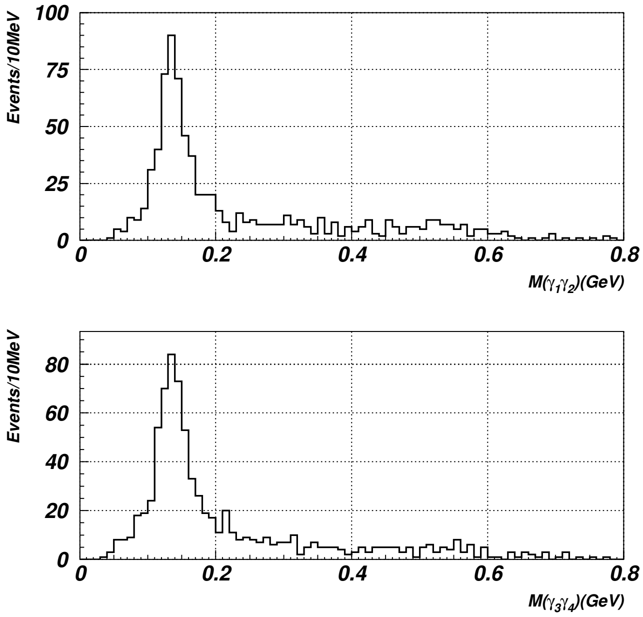


Figure 1: Invariant mass of $\gamma_1\gamma 2$ and $\gamma_3\gamma 4$ after 4C fit in $\psi(2S) \to \gamma\pi^0\pi^0$channel

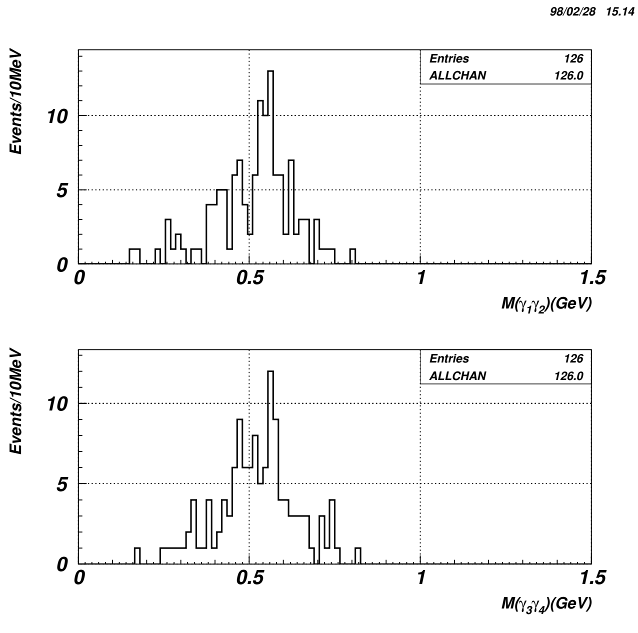


Figure 2: Invariant mass of $\gamma_1\gamma 2$ and $\gamma_3\gamma 4$ after 4C fit in $\psi(2S) \to \gamma\eta\eta$ channel

Table 1: Event number after each generic cut

Cut	$\gamma\pi^0\pi^0$(Data)	$\gamma\eta\eta$(Data)	$\gamma\pi^0\pi^0$(MC)	$\gamma\eta\eta$(MC)
Total Events	8253735	8253735	30000	30000
KJI.GT.0	7874638	7874638	30000	30000
NCHRG=0	5191264	5191264	24125	24211
NNEU$>$ 5	221091	221091	12245	16778
$N_\gamma = 5$	963	963	4311	6694
Prob6C$>$ 0.01	382	704	3915	6041
$\|cos\theta^*_{boost}\| < 0.98$	364	366	3894	5386

3 Analysis

3.1 $\psi(2S) \to \gamma\pi^0\pi^0$ Analysis

3.1.1 $\psi(2S)$ Non-Charmonium Decays via $\gamma\pi^0\pi^0$

In addition to the general cuts, the following two cuts are used:

1. The angle between two photons from π^0 decay should be less than 90^o, this condition will remove the backgrounds from more than two π^0s final states;

2. The radiative photon id defined as γ_1, and the photons from π^0s decay as γ_i, at least two $\theta_{\gamma_1\gamma_i}$ are greater than 90^0. This cut will remove the contamination from $\psi(2S) \to \gamma\chi_{cJ}(J = 0, 2), \chi_{cJ} \to \pi^0\pi^0$. Using the Monte Carlo data sample of $\psi(2S) \to \gamma\chi_{cJ}(J = 0, 2), \chi_{cJ} \to \pi^0\pi^0, \pi^0 \to 2\gamma$, after selection and 6C fit, the invariant mass $m_{\pi^0\pi^0}$ is shown in Fig. 3, Fig. 3(a) is the plot before this cut, Fig. 3(b) is the plot before this cut.

After imposing all selections to the data, the invariant mass distribution are shown in Fig. 4(Fig. 5 is the Monte Carlo result), and Table. 2 shows the events number after the specific cuts for this channel. A fit to the mass plots of $\pi^0\pi^0$ with Breit-Wigners folding a gaussian mass resolution function shows that the mass of $f_2(m_{f_2} = (1.235 \pm 0.030)$GeV) is lower than the world average.

Table 2: Event number of $\psi(2S)$ Non-Charmonium Decays via $\gamma\pi^0\pi^0$ after Specific cuts

Cut	$\gamma\pi^0\pi^0$(real data) $(m_{\pi^0\pi^0} < 3.0)$	$\gamma\pi^0\pi^0$ M.C
After generic cuts	187	1683
After specific cuts	104	1565

3.1.2 $\psi(2S)$ Charmonium Decays via $\gamma\pi^0\pi^0$

In addition to the general cuts, the angle between two photons from π^0 decay should be less than 90^0.

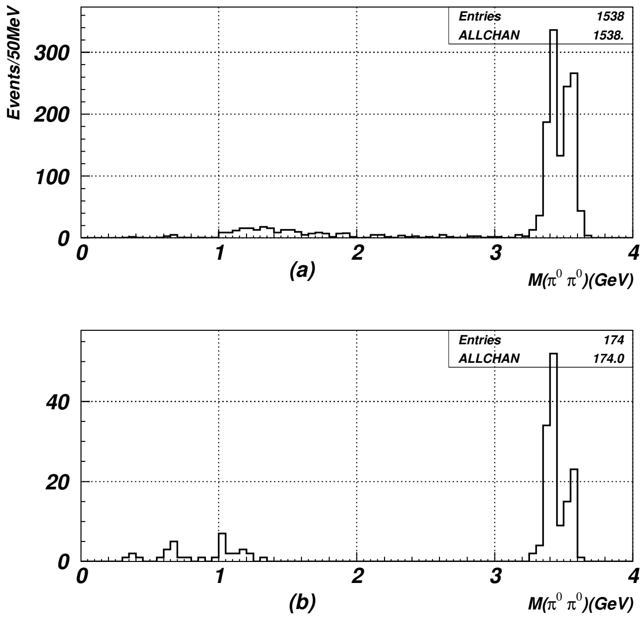


Figure 3: The contamination from $\psi(2S) \rightarrow \gamma\chi_{cJ}(J = 0, 2), \chi_{cJ} \rightarrow \pi^0\pi^0$ into $\psi(2S)$ Non-Charmonium decays. (a): Before Cut; (b): After Cut.(M.C. Data)

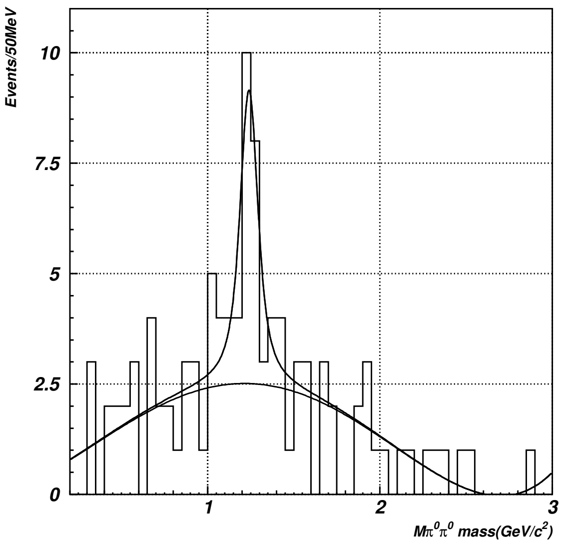


Figure 4: Invariant mass of $m_{\pi^0\pi^0}$ in $\psi(2S)$ Non-Charmonium decays(Real Data).

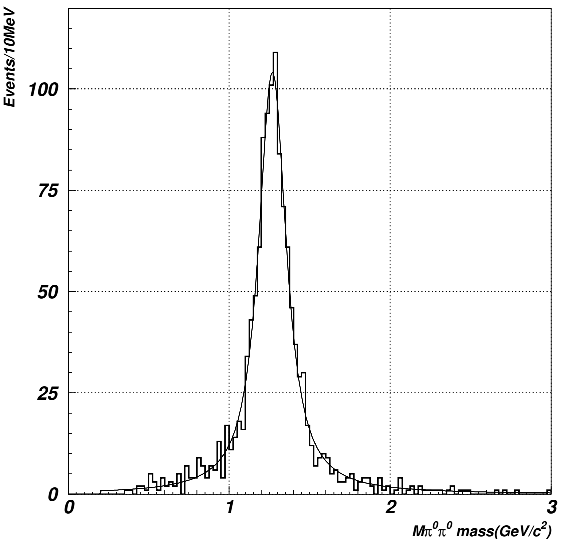


Figure 5: Invariant mass of $m_{\pi^0\pi^0}$ in $\psi(2S)$ Non-Charmonium decays(Monta Carlo).

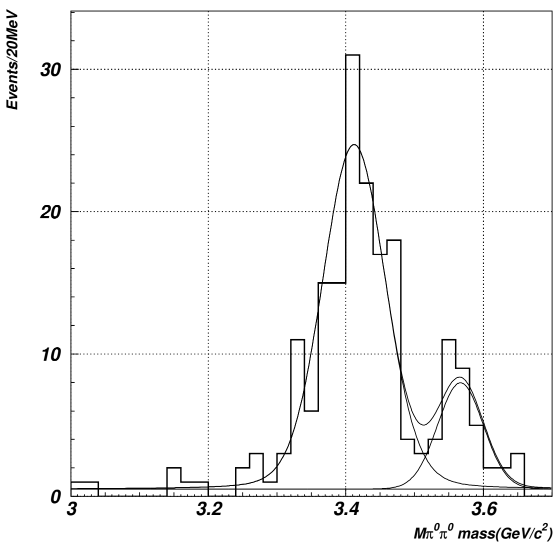


Figure 6: Invariant mass of $m_{\pi^0\pi^0}$ in $\psi(2S)$ Charmonium decays(Real Data).

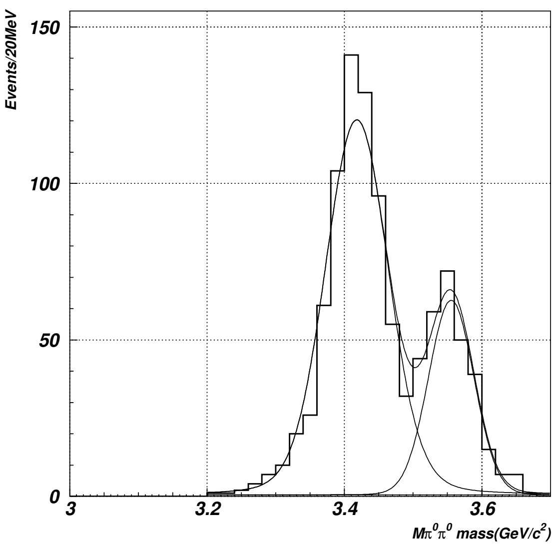


Figure 7: Invariant mass of $m_{\pi^0\pi^0}$ in $\psi(2S)$ Charmonium decays(Monta Carlo).

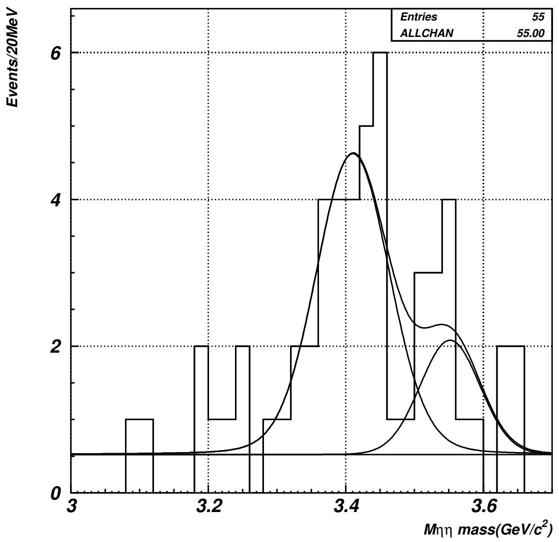


Figure 8: Invariant mass of $m_{\eta\eta}$ in $\psi(2S)$ Charmonium decays(Real Data).

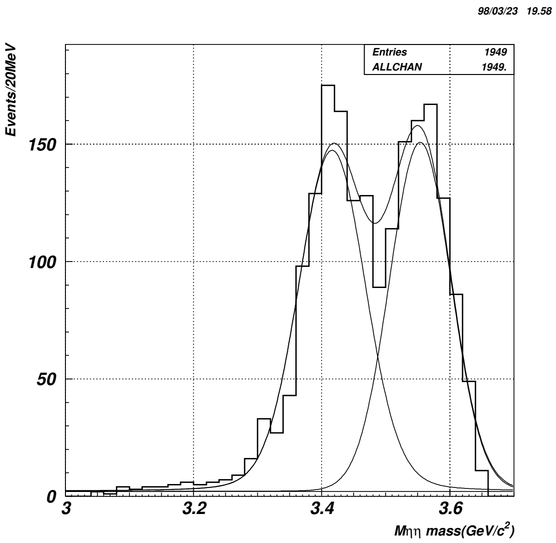


Figure 9: Invariant mass of $m_{\eta\eta}$ in $\psi(2S)$ Charmonium decays(Monte Carlo).

After all selections and 6C fitting, the invariant mass distributions are shown in Fig. 6(Fig. 7 is the Monte Carlo result), and Table. 3 shows the events number after the specific cuts for this channel. The results of fitting the mass plots of $\pi^0\pi^0$ with two Breit-Wigners folding a gaussion mass resolution function shows that the mass of χ_{c0}(3412.1 $\pm$ 4.6MeV) and χ_{c2}(3566.8 $\pm$ 7.8GeV) is agree with the world average.

Table 3: Event number of $\psi(2S)$ Charmonium Decays via $\gamma\pi^0\pi^0$ after Specific cuts

Cut	$\gamma\pi^0\pi^0$(real data) $(3.0 < m_{\pi^0\pi^0} < 3.7)$	$\gamma\pi^0\pi^0$ M.C
After Generic cuts	178	2211
After Specific Cuts	177	2211

Table 4: Event number of $\psi(2S)$ Charmonium Decays via $\gamma\eta\eta$ after Specific cuts

Cut	$\gamma\eta\eta$(real data) $3.0 < (m_{\eta\eta} < 3.7)$	$\gamma\eta\eta$ M.C
After Generic cuts	102	2696
After Specific Cuts	55	2100

3.2 $\psi(2S) \to \gamma\eta\eta$ Analysis

As this is the only χ_{cJ} hadronic decay mode in this analysis series which has been reported in PDG not to be updated, It is very important for BES to study this mode.

Apart from only general cuts, the additional cuts are used:

1. The energy of radiative γ: $E_\gamma < 0.4GeV$;
2. To remove the background from $\gamma\pi^0\pi^0$ final states:
   $Prob_{\chi^2}(\gamma\pi^0\pi^0) < 1.0\%$ and $Prob_{\chi^2}(\gamma\eta\eta) > Prob_{\chi^2}(\gamma\pi^0\pi^0)$.

The result of an $\eta\eta$ search is shown in Fig. 8(Fig. 9 is the Monte Carlo result), and Table. 4 shows the event number after the specific cuts for this channel. A fit to the mass plots of $\eta\eta$ shows that the mass of χ_{c0} (3410.4 $\pm$ 15.8MeV) and χ_{c2}(3551.7 $\pm$ 33.7) are lower than the world average.

4 Monte Carlo

In the Monte Carlo generator, the χ_{cJ}'s are assumed to be generated via pure E1 transition of $\psi(2S)$ [7], $\chi_{c0,2}$ decaying to 0^-0^- meson pairs has only one independent helicity amplitude and so the whole process is determined [8]. For $\psi(2S) \to \gamma f_2$, $f_2 \to \pi^0\pi^0$ decay channel, we only use phase space generator to determine this channel.

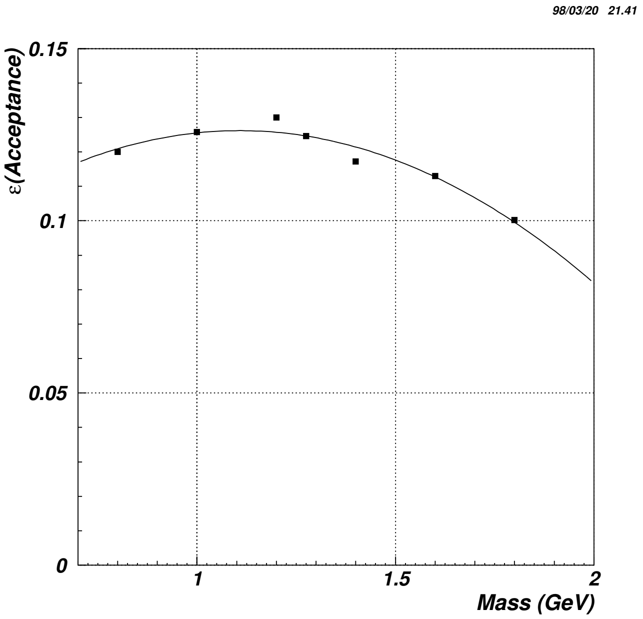


Figure 10: The efficiency at different mass points(M.C) for $\psi(2S) \rightarrow \gamma f_2$, $f_2 \rightarrow \pi^0\pi^0$

Table 5: The detection efficiencies and mass resolution for each $\psi(2S)$ decay channel from Monte Carlo study

Decay Mode	Efficiency(%)	Mass Resolution(MeV)
$\psi(2S) \rightarrow \gamma f_2$, $f_2 \rightarrow \pi^0\pi^0$	10.8(Average)	27.8
$\psi(2S) \rightarrow \gamma\chi_{c0}$, $\chi_{c0} \rightarrow \pi^0\pi^0$	13.3	42.6
$\psi(2S) \rightarrow \gamma\chi_{c2}$, $\chi_{c2} \rightarrow \pi^0\pi^0$	10.6	32.7
$\psi(2S) \rightarrow \gamma\chi_{c0}$, $\chi_{c0} \rightarrow \eta\eta$	10.2	50.0
$\psi(2S) \rightarrow \gamma\chi_{c2}$, $\chi_{c2} \rightarrow \eta\eta$	10.5	42.9

10000 simulated events per decay channel are used to study the detection efficiencies and mass resolution. Table 5 gives the final results for all modes. For f_2 resonance, the width of f_2 is about 185MeV, the efficiencies will be different in so large region, Fitting the efficiencies from 0.8 to 2.0GeV for $\pi^0\pi^0$ as a function of meson pair mass gives:

$$\epsilon(M) = -0.056M^2 + 0.123M + 0.058,, \tag{3}$$

correct the mass spectrum of simulated $\psi(2S) \rightarrow \gamma f_2$, $f_2 \rightarrow \pi^0\pi^0$ with the efficiency function, Fig. 10 shows the plots of the efficiency function, one can see that the efficiency decrease as the mass goes up.

5 The results

After selection, the $\pi^0\pi^0$ mass plot of $\gamma\pi^0\pi^0$ and $\eta\eta$ mass plot of $\gamma\eta\eta$ events are gotten. The mass spectrum is fitted event by event using an unbined maximum likelyhood method:

For the $\pi^0\pi^0$ mass plot below 3.0GeV, we used one Breit-Weigner folding a Gaussian mass resolution function and a Legendre Polynomial background function, we fitted the mass plot and got:

$$m_{\pi^0\pi^0} = (1241 \pm 22)\text{MeV}, \Gamma = (90.7 \pm 99.0)\text{MeV}.$$

With Γ fixed to the PDG value of 185 MeV, we got:

$$m_{\pi^0\pi^0} = (1235 \pm 30)\text{MeV},$$

where the error is from fitting itself. Fitted mass plot and relevant properties can be seen in Fig. 11.

The events number of $\psi(2S) \to \gamma f_2(f_2 \to \pi^0\pi^0)$ are fitted out for determination of the branching fraction of this channel. We got $n^{obs}_{\psi(2S)\to\gamma f_2} = 23 \pm 13$($\Gamma$ unfixed), where the error is statistical one.

For the $\pi^0\pi^0$ mass plot above 3.0GeV, we fit with two Breit-Wigner and a linear background. With the widths of χ_{c0} and χ_{c2} fixed at the PDG value, we got:

$$m(\chi_{c0}) = (3412.1 \pm 4.6)\text{MeV}, m(\chi_{c2}) = (3556.8 \pm 7.8)\text{MeV}.$$

and the observed event number for both case are:

$$n^{obs}_{\chi_{c0}\to\pi^0\pi^0} = 144 \pm 8, n^{obs}_{\chi_{c2}\to\pi^0\pi^0} = 31 \pm 6.$$

where all errors are statistical. Fitted mass plot and relevant properties can be seen in Fig. 12.

For the $\eta\eta$ mass plot above 3.0GeV, The same operation as above is done, we got:

$$m(\chi_{c0}) = (3410.4 \pm 15.8)\text{MeV}, m(\chi_{c2}) = (3551.7 \pm 33.7)\text{MeV}.$$

and the observed event number for both case are:

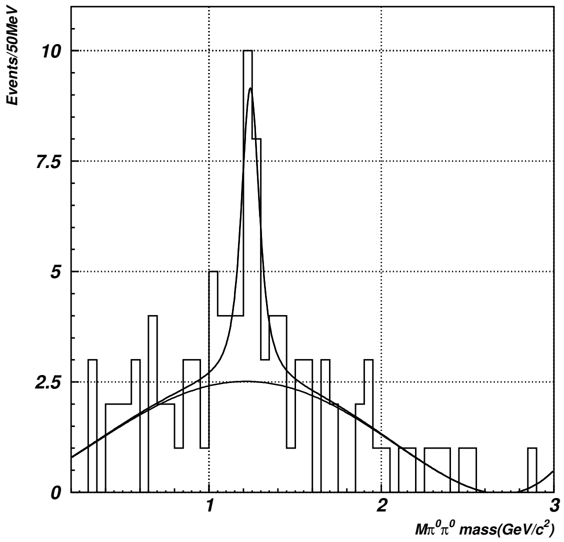
$$n^{obs}_{\chi_{c0}\to\eta\eta} = 28 \pm 6, n^{obs}_{\chi_{c2}\to\eta\eta} = 9 \pm 4.$$

where all errors are statistical. Fitted mass plot and relevant properties can be seen in Fig 13.

6 Systematic Error

The systematic errors of the branching fraction, which mainly arise from uncertainty of the mass resolution, the efficiency determination and selection criteria, are 12.4%, 11.8%, 20.8% and 22.6% respectively for $B(\chi_{c0} \to \pi^0\pi^0)$, $B(\chi_{c2} \to \pi^0\pi^0)$, $B(\chi_{c0} \to \eta\eta)$ and $B(\chi_{c2} \to \eta\eta)$; the uncertainty of $B(\psi(2S) \to \gamma\chi_{c0,2})$ contributes 8.6% error to χ_{c0} decay channels and 10.3% error to χ_{c2} decay channels; the error caused by the uncertainty of total events number of $\psi(2S)$ are 10% for all channels. Add all those errors in quadrature, the total percentage errors of $B(\chi_{c0} \to \pi^0\pi^0)$, $B(\chi_{c2} \to \pi^0\pi^0)$, $B(\chi_{c0} \to \eta\eta)$ and $B(\chi_{c2} \to \eta\eta)$ are 18.8%, 19.2%, 24.5% and 27.2% respectively.

The systematic errors of $B(\psi(2S) \to \gamma f_2)$, which mainly arise from the uncertainty of the mass resolution, the shape of the background, the efficiency determination and selection criteria, are about 62.0%; the uncertainty of $B(f_2 \to \pi^0\pi^0)$ contributes 3.4% error to $B(\psi(2S) \to \gamma f_2)$ decay; the error caused by the uncertainty of total events number of $\psi(2S)$ are also 10% for this channel. Finally, we can get that the the total percentage errors of $B(\psi(2S) \to \gamma f_2)$ are 63.1%.

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============================================='=================================
Histogram ID= *****  UnBinned Breit-Wigner Fit using  599 Points
Fit Parameters:Npoly=   1 Nbw=   1 Namp=   0 Range=       .750 To      3.000
Hist. Chisq =      112.52 for   3 params & 116 DF.
Chisquare Probability =  57.40%. Mean and S.D. for pulls:    -.0218     .9681
Likelihood ratio and probability             :    121.508        34.47%
Final Value of Log Likelihood                :      -143.69
Error Correspond to a Function Chage         :      .50
Phase Space limits for tails corrections     :       .280GEV     2.817GEV
Breit-Wigner efficiency correction factors   :      .930
Include Breit-Wigner tails outside fit region :        .953
Efficiency-corrected events in fit region    :      599.[average eff. :1.000]
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    sigmValue :  .35987E-01Error(Cov,-/+):    .110E-01  .000E+00  .000E+00
    widtValue :  .18500    Error(Cov,-/+):    .000E+00  .000E+00  .000E+00
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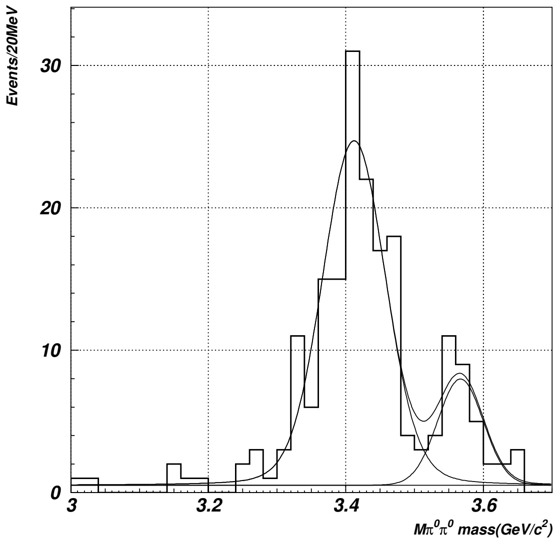
Figure 11: Invariant mass of $m_{\pi^0\pi^0}$ in $\psi(2S)$ Non-Charmonium decays

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I                       Summary Of BWFIT Results'                             I
============================================='=================================
Histogram ID= *****  UnBinned Breit-Wigner Fit using  984 Points
Fit Parameters:Npoly=   1 Nbw=   2 Namp=   0 Range=      3.000 To      3.700
Hist. Chisq =       40.34 for   4 params &  30 DF.
Chisquare Probability =   9.84%. Mean and S.D. for pulls:     .0843    1.0703
Likelihood ratio and probability             :     36.679        18.67%
Final Value of Log Likelihood                :    -1178.48
Error Correspond to a Function Chage         :      .50
Phase Space limits for tails corrections     :       .280GEV     2.817GEV
Breit-Wigner efficiency correction factors   :      .987         .997
Include Breit-Wigner tails outside fit region :        .003         .000
Efficiency-corrected events in fit region    :      984.[average eff. :1.000]
---THE FITTED VALUES AND ERRORS OF THE PARAMETERS:---
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GAMA2   Value :  .14000E-01Error(Cov,-/+):    .000E+00 -.162E-01  .165E-01
MASS2   Value :  3.4167    Error(Cov,-/+):    .187E-02 -.255E-02  .254E-02
Rat     Value :  .28196    Error(Cov,-/+):    .170E-01  .000E+00  .000E+00
RESL2   Value :  .32800E-01Error(Cov,-/+):    .000E+00  .000E+00  .000E+00
GAMA2   Value :  .20000E-02Error(Cov,-/+):    .000E+00  .000E+00  .000E+00
MASS2   Value :  3.5535    Error(Cov,-/+):    .255E-02  .000E+00  .000E+00
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Figure 12: Invariant mass of $m_{\pi^0\pi^0}$ in $\psi(2S)$ Charmonium decays

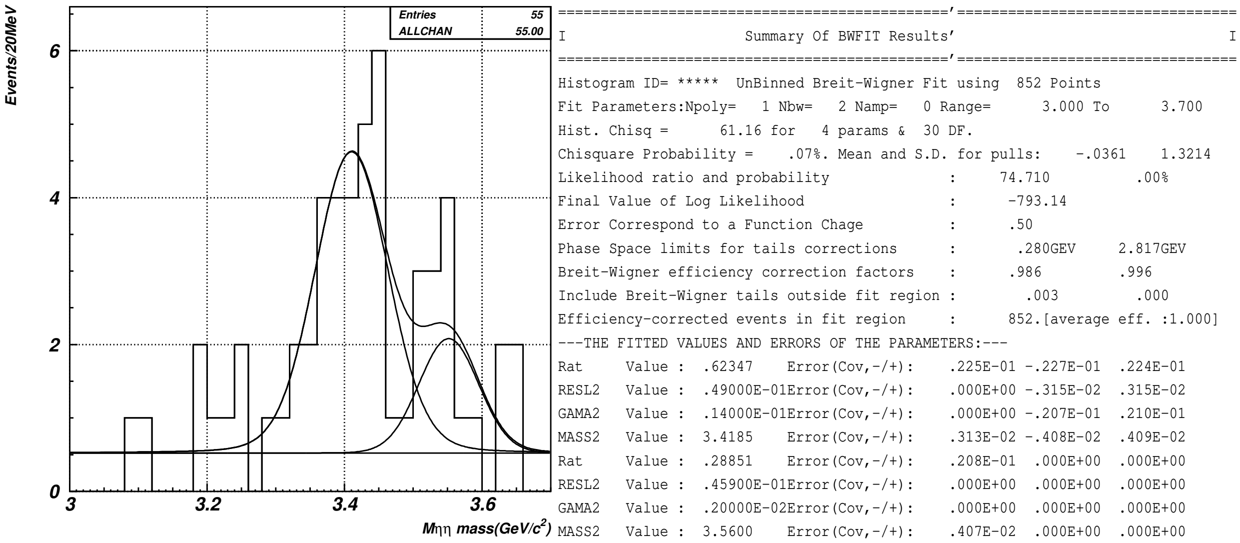

Figure 13: Invariant mass of $m_{\eta\eta}$ in $\psi(2S)$ Charmonium decays

7 Conclusion and Discussion

In this memo, we measured the $\psi(2S)$ Charmonium decay and non-Charmonium decay to 5γ final states.

For $\psi(2S)$ non-Charmonium radiative decay, we get:

$$Br(\psi(2S) \to \gamma f_2) = (2.01 \pm 1.12 \pm 0.79) \times 10^{-4},$$

where the To test the "15% rule" in $\psi(2S) \to \gamma f_2$(VT mode), BES got the result:

$$Q_{\gamma f_2} = \frac{B(\psi(2S) \to \gamma f_2)}{B(J/\psi \to \gamma f_2)} = (14.5 \pm 9.1)\%, \tag{4}$$

>From the $f_2 \to \pi^+\pi^-$ analysis of Xinhua [9], the ratio is $Q_{\gamma f_2} = (11.5 \pm 4.0)\%$, $Q_{\gamma f_2} = (9 \pm 3)\%$ was also gotten from CBAL experiment [10].

For $\psi(2S)$ Charmonium radiative decay, the results of the branching fractions of $\chi_{c0,2}$ decays are listed in Table 6, the values of $\pi^0\pi^0$ mode consistent with the world average in error but the values of $\eta\eta$ are almost 2 times of the world average.

Table 6: BES Preliminary results for $\psi(2S)$ 5γ decay channels

	BES		CBAL Results
Measurements	Event number	Results	
$Br(\chi_{c0} \to \pi^0\pi^0)$	144 ± 8	$(3.15 \pm 0.17 \pm 0.59) \times 10^{-3}$	$(3.1 \pm 0.6) \times 10^{-3}$
$Br(\chi_{c2} \to \pi^0\pi^0)$	31 ± 6	$(1.02 \pm 0.19 \pm 0.19) \times 10^{-3}$	$(1.10 \pm 0.28) \times 10^{-3}$
$Br(\chi_{c0} \to \eta\eta)$	28 ± 6	$(4.92 \pm 1.01 \pm 1.21) \times 10^{-3}$	$(2.5 \pm 1.1) \times 10^{-3}$
$Br(\chi_{c2} \to \eta\eta)$	9 ± 4	$(1.78 \pm 0.92 \pm 0.48) \times 10^{-3}$	$(0.8 \pm 0.5) \times 10^{-3}$

In according to the SU(3) flavor symmetry, the decay widths of $\chi_{c0,2} \to \pi^0\pi^0$ and $\chi_{c0,2} \to \eta\eta$ should be the same apart from the different phase space. We can obtain the ratios of the branching fractions:

$$\frac{BR(\chi_{c0} \to \eta\eta)}{BR(\chi_{c0} \to \pi^0\pi^0)} = 1.56 \pm 0.40$$

$$\frac{BR(\chi_{c2} \to \eta\eta)}{BR(\chi_{c2} \to \pi^0\pi^0)} = 1.74 \pm 0.81$$

Although an all-photon analysis restricts the decay channels we can observe, we could see that in some cases the channels which are accessible are exceptionally clean. In particular, the the decay $\psi(2S) \to \gamma\chi_{cJ}$, $\chi_{cJ} \to \pi^0\pi^0$(J=0, 2) are sufficiently free of backgrounds that we are able to give good results.

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References

[1] Applequist T, Politzer D., Phys. Rev. Lett.34(1975)43;

[2] Franklin M E B et al. Phys. Rev. Lett.51(1983)11;

[3] BES Colla., High Energy Phys. and Nucl. Phys.(in Chinese)20(1996)481;

[4] Kwong W. Phys. Rev. D37(1988)3210;
Applequist T et al. Phys. Rev. Lett.34(1975)363;

[5] C.Z Yuan, "Dtermination of the total width of χ_{c0}" BES Analysis Memo, 1998;

[6] BES Collab. Nucl. Inst. Meth. A344(1994)319;

[7] G.Karl, S. Meshkov and J.L.Rosner, Phys. Rev.D13(1976)1203;
W.Tanenbaum et al., Phys. Rev.D17(1978)731;
M.Oreglia et al., Phys. Rev.D25(1982)2259;

[8] P.K.kabir and A.J.G. Hey, Phys. Rev.D13(1976)3161;

[9] Li Xinhua, BES Analysis Note, 1998;

[10] R.A.Lee, SLAC-282, 1985;