Branching Ratio Measurements of the Decays $\psi' \longrightarrow J/\psi$ Plus Neutrals

LU Feng GU YiFan MA JiMao
Institute of High Energy Physics,Academia Sinica

Abstract

The data sample corresponding to 3.788×10^6 ψ' events has been analysied.The experimental results are as follows:
1.Br($\psi' \to \pi^0\pi^0 J/\psi$)=($18.5\pm0.6^{+1.6}_{-1.7}$)% =($18.5^{+1.7}_{-1.8}$)%.
2.Br($\psi' \to \eta J/\psi$)=($2.9\pm0.1\pm0.3$)% =($2.92^{+0.35}_{-0.33}$)%.
3.Br($\psi' \to \pi^0 J/\psi$)=$(13.3\pm3.5\pm2.2) \times 10^{-4}$=$(13.3\pm4.1) \times 10^{-4}$.
4.Br($\psi' \to \gamma\chi_{c1}$)=($8.7\pm0.3\pm1.1$)% =($8.7\pm1.2$)%.
5.Br($\psi' \to \gamma\chi_{c2}$)=($7.8\pm0.5\pm1.2$)% =($7.8\pm1.3$)%.
Where the first error is statistic,and the second one is systematic.

1 Introduction

ψ' is a radial excitation of the J/ψ.It decays into J/ψ plus neutrals with large branching ratios,which were mostly measured more than ten years ago,see table 1,we don't use the listings of PDG98' since they are not reliable[1].BES has acquired the largest ψ' data sample in the world,which contains 3.788×10^6 ψ' events.This provides a good chance for BES to make its contributions in study of the ψ' decays.

Table 1

Decay model	PDG 96'	Group1	Group2
$\psi' \to \pi^0\pi^0 J/\psi$	(18.4 ± 2.7)%	(18 ± 6)%[2] DASP75'	
$\psi' \to \eta J/\psi$	(2.7 ± 0.4)%	(2.18 ± 0.38)%[3] CBAL80'	(3.6 ± 0.5)% CNTR78'
$\psi' \to \pi^0 J/\psi$	$(9.7\pm2.1) \times 10^{-4}$	$(9.0\pm2.2) \times 10^{-4}$[3] CBAL80'	$(15\pm6) \times 10^{-4}$ MRK2,80'
$\psi' \to \gamma\chi_{c1}$	(8.7 ± 0.8)%	(9.0 ± 0.9)%[4] CBAL86'	(7.1 ± 1.9)% CNTR77'
$\psi' \to \gamma\chi_{c2}$	(7.8 ± 0.8)%	(8.0 ± 0.9)%[4] CBAL86'	(7 ± 2)% CNTR77'

2 Analysis of $\psi' \to \pi^0\pi^0 J/\psi \to \gamma\gamma\gamma\gamma\mu^+\mu^-$

Event preselection:a good reconstructed(MFIT=2) event has two opposite charged tracks and more than three good gammas.A good gamma must satisfy:hitting barrel shower counter (BSC); First hitting layer number less than six;The angle(THNN) between the hitting and developing directions in the BSC less than 36.9°;The minimum angle between a good gamma hitting direction in BSC and any charged track's momentum direction(THNC) larger than 11.5°.The event has a good primary vertex,and for each charged track, $Rxy < 0.015m$, $|z| < 0.15m$.The event's two charged tracks satisfy: $|cos\theta|$ <0.8;1.2GeV< P_{high} <2.0GeV,P_{low} <1.9 GeV;hitting BSC,and ratio of deposit energy in BSC to the track's momentum $E/P <$ 0.6.Passing 4c kinetic fit under the model $\gamma\gamma\gamma\gamma\mu^+\mu^-$. After above preselection,the data sample is further required : 1. 1.48GeV< P_{high} <1.78GeV and 1.35GeV< P_{low} <1.69GeV.

2.χ^2_{4c-fit} <16.5. 3.After 4c fit,$M_{J/\psi}$ is between 2.9 to 3.3 GeV. 4.Good gammas number:NTRK=4,and a good gamma is further required:the nearest distance between the good gamma and other ones(XLNN) larger than 0.8 meter,or the minimum mass of the good gamma and other ones(MGG) larger than 0.05 GeV. 5.Two π^0 satisfy:
$\chi_{\pi^0} = \sqrt{(M_{\pi^0 1} - 0.135)^2 + (M_{\pi^0 2} - 0.135)^2}/0.027 < 4.0$.

After above selections,backgrounds of $\psi' \to \pi^0\pi^0 J/\psi \to \gamma\,\gamma\,\gamma\,\gamma\,\mu^+\,\mu^-$ are very small(about 5%) as known from MC study.Main backgrounds come from $\psi' \to \eta J/\psi, \eta \to 3\pi^0$ which loss two low-energy gammas;and $\psi' \to \pi^0\pi^0 J/\psi$, $J/\psi \to e^+e^-$ in which electrons are misidentifed as mouns.The numbers of events surviving each requirement for different type events are shown in Table 2.

Table 2

REQUIREMENT	In	Preselection	cut1	cut2	cut3	cut4	cut5	normalized
DATA	5575465	6062	4534	3671	3616	2117	2071	2063
MC1	50000	4520	4162	3530	3521	2455	2427	1965
MC2	30000	5470	5239	2902	2853	1504	1327	83
MC3	50000	40	35	29	29	18	18	15

MC1: $\psi' \to \pi^0\pi^0 J/\psi \to \gamma\gamma\gamma\gamma\mu^+\mu^-$. MC2: $\psi' \to \eta J/\psi \to 3\pi^0\mu^+\mu^- \to \gamma\gamma\gamma\gamma\gamma\gamma\mu^+\mu^-$.
MC3:$\psi' \to \pi^0\pi^0 J/\psi \to \gamma\gamma\gamma\gamma e^+e^-$.

We have:Br($\psi' \to \pi^0\pi^0 J/\psi$)=($18.5 \pm 0.6^{+1.6}_{-1.7}$)%. Systematic error comes from:neutral track selection;charged track's momentum P,E/P,vetex requirement,$|cos\theta|$;χ^2_{4c-fit};χ_{π^0};$M_{J/\psi}$;$N_{\psi'}$ and strengthen rib($|cos\theta|$ <0.12).Main contributions are:$N_{\psi'}(\pm 1.5)$; neutral track selection($^{+0.54}_{-0.73}$).

3 Analysis of $\psi' \to \gamma\gamma J/\psi \to \gamma\gamma\mu^+\mu^-$

Common event preselection requires:a good reconstructed(MFIT=2) event has two opposite charged tracks and more than one good gammas (hitting BSC;LAYF<6;THNN< 36.9°;THNC> 11.5°).The event has a good primary vertex,and for each charged track,$Rxy < 0.015m$, $|z| < 0.15m$. The two charged tracks satisfy:$|cos\theta|$ <0.8;1.2GeV< $P_{1,2}$ <2.0GeV;hitting BSC and E/P<0.6. The event can Pass 5c kinetic fit under the model $\psi' \to \gamma\gamma J/\psi$, $J/\psi \to \mu^+\mu^-$.

3.1 $\psi' \to \eta J/\psi \to \gamma\gamma\mu^+\mu^-$

The common preselected data sample is futher required : 1.χ^2_{5c-fit} <15. 2.Recoil mass from the

Table 3

REQUIREMENT	DATA	MC1	MC2	MC3	MC4	MC5
In	5575465	50000	50000	50000	50000	20000
Preselection	12902	16619	8490	16058	14904	1759
CUT1	7584	15122	3198	7584	13598	380
CUT2	3947	15080	2484	1739	110	355
CUT3	1924	13317	765	1527	83	30
CUT4	1013	13152	198	22	1	21
Normalized	799.4	635	160	2.4	0	2

MC1: $\psi' \to \eta J/\psi \to \gamma\gamma\mu^+\mu^-$. MC2: $\psi' \to \pi^0\pi^0 J/\psi \to \gamma\gamma\gamma\gamma\mu^+\mu^-$. MC3: $\psi' \to \gamma\chi_{c1} \to \gamma\gamma\mu^+\mu^-$.
MC4: $\psi' \to \gamma\chi_{c2} \to \gamma\gamma\mu^+\mu^-$. MC5: $\psi' \to \eta J/\psi \to \pi^0\pi^0\pi^0 J/\psi \to \gamma\gamma\gamma\gamma\gamma\gamma\mu^+\mu^-$.

lower-energy gamma:M_{recoil} <3.5GeV. 3.NTRK=2. 4.$M_{\gamma\gamma}$ is between 0.535 to 0.560 GeV.Main containing J/ψ background comes from $\psi' \to \pi^0\pi^0 J/\psi$.The numbers of events surviving each requirement for different type events are shown in Table 3. We have: Br($\psi' \to \eta J/\psi$)= ($2.9 \pm 0.1 \pm 0.3$)%. Systematic error comes from:Neutral track selection;charged track's mo-

mentum P,E/p, vetex requirement, $|cos\theta|$; χ^2_{5c}; M_{recoil}; $M_{\gamma\gamma}$; $N_{\psi'}$ and strengthen rib($|cos\theta|$ <0.12).Main contribution are: $N_{\psi'}(^+_-0.24)$;Neutral track selection
$(^{+0.14}_{-0.07})$, strengthen rib($^+_-0.14$), $|cos\theta|(^+_-0.13)$.

3.2 $\psi' \to \pi^0 J/\psi \to \gamma\gamma\mu^+\mu^-$

In common preselection,this channel has a loose good gamma identification(just hitting BSC).The common preselected data sample is further required : 1.χ^2_{5c-fit} <15,1.47GeV< P_{high} <1.95GeV, 1.22GeV< P_{low} <1.65GeV. 2.M_{recoil} <3.46GeV to suppress χ_{c1} backgrounds. 3.NTRK=2. 4.$M_{\gamma\gamma}$ is between 0.07 to 0.20 GeV.This channel's backgrounds have been carefully studied.The numbers of events surviving each requirement for different type events are shown in Table 4. We have: Br($\psi' \to \pi^0 J/\psi$)=(13.3$^+_-$3.5$^+_-$2.2) $\times 10^{-4}$.Systematic error comes from:Neutral track selection;charged track's momentum P,E/P,vetex requirement, $|cos\theta|$;χ^2_{5c};M_{recoil};$M_{\gamma\gamma}$; $N_{\psi'}$ and strengthen rib($cos|\theta|$ <0.11).Main contributions are: $N_{\psi'}(^+_-1.1)$;$P(^+_-1.1)$;strengthen rib($^+_-1.0$);neutral track selection($^+_-0.8$) and $M_{recoil}(^+_-0.7)$.

3.3 $\psi' \to \gamma\chi_{c1,2}, \chi_{c1,2} \to \gamma J/\psi, J/\psi \to \mu^+\mu^-$

The common preselected data sample is futher required: 1.J/ψ momentum $P_{J/\psi}$ >0.22GeV. 2.The decay angle of two gamma system $|cos\theta_{decay}|$ >0.3. ($|cos\theta_{decay}| = |P_{\gamma1} - P_{\gamma2}|/E_{\gamma1\gamma2}$). 3.NTRK=2. 4.

Table 4

REQUIREMENT	DATA	MC1	MC2	MC3	MC4	MC5	MC6	MC7
In	5575465	50000	50000	50000	50000	50000	50000	10000
Preselection	14377	12782	9335	17996	17453	16349	17514	130
CUT1	8354	11312	3495	16279	15741	14855	15778	61
CUT2	2925	2590	1962	11837	170	28	15464	17
CUT3	1152	2185	529	10009	138	19	13181	16
CUT4	29	2179	0	0	74	4	1326	16
Normalized	21.73	9.4	0	0	7.9	0.2	3.7	0.53

MC1: $\psi' \to \pi^0 J/\psi \to \gamma\gamma\mu^+\mu^-$. MC2: $\psi' \to \pi^0\pi^0 J/\psi \to \gamma\gamma\gamma\gamma\mu^+\mu^-$. MC3: $\psi' \to \eta J/\psi \to \gamma\gamma\mu^+\mu^-$. MC4: $\psi' \to \gamma\chi_{c1} \to \gamma\gamma\mu^+\mu^-$. MC5: $\psi' \to \gamma\chi_{c2} \to \gamma\gamma\mu^+\mu^-$. MC6: $\psi' \to \gamma\chi_{c0} \to \gamma\gamma\mu^+\mu^-$. MC7: $\psi' \to \pi^0\pi^+\pi^- \to \gamma\gamma\pi^+\pi^-$.

3.464GeV< M_{recoil} <3.6GeV.The numbers of events surviving each requirement for different type events are shown in Table 5. We have: BR($\psi' \to \gamma\chi_{c1}$)= (8.7$^+_-0.3^+_-$1.1)%; BR($\psi' \to \gamma\chi_{c2}$)= (7.8$^+_-0.5^+_-$1.2)%. Systematic error comes from:Neutral track selection;charged track's momentum P,E/P,vetex requirement,$|cos\theta|$;M_{recoil};$N_{\psi'}$;$P_{J/\psi}$;$MC\sigma_{Xc1,2}$;$|cos\theta_{decay}|$;$Br(\chi_{c1,2} \to$ γJ/ψ) and streng- then rib($|cos\theta|$ <0.06).Main contributions are: $N_{\psi'}$($^+_-$0.72 for χ_{c1},$^+_-$ 0.64 for χ_{c2}); Br($\chi_{c1,2} \to \gamma$J/ψ)
($^+_-$0.51 for χ_{c1},$^+_-$ 0.63 for χ_{c2});neutral track selection($^+_-$0.63 for χ_{c1},$^+_-$ 0.48 for χ_{c2}) and strengthen rib($^+_-$0.2 for χ_{c1},$^+_-$ 0.42 for χ_{c2}).

Table 5

REQUIREMENT	DATA	MC1	MC2	MC3	MC4
IN	5575465	50000	50000	50000	50000
PRESELECTION	12902	16058	14904	16619	8490
CUT1	9432	16029	14898	439	5907
CUT2	7643	15550	14816	401	4183
CUT3	4014	13793	13126	294	1150
CUT4	3663	13714	12864	206	835
Normalized	2764.6	1468.2	610.6	9.8	676

MC1: $\psi' \to \gamma\chi_{c1} \to \gamma\gamma\mu^+\mu^-$. MC2: $\psi' \to \gamma\chi_{c2} \to \gamma\gamma\mu^+\mu^-$. MC3: $\psi' \to \eta J/\psi \to \gamma\gamma\mu^+\mu^-$. MC4: $\psi' \to \pi^0\pi^0 J/\psi \to \gamma\gamma\gamma\gamma\mu^+\mu^-$.

4 Conclusion

The decays of ψ' to J/ψ plus neutrals have been carefully studied.All of the branching ratioes are consistent with PDG96' values.We have got the best accuracy of branching ratio measurements in decay channels $\psi' \to \pi^0\pi^0 J/\psi$ and $\eta J/\psi$,and better accuracy in $\psi' \to \pi^0 J/\psi$,$\gamma\chi_{c1}$ and $\gamma\chi_{c2}$.

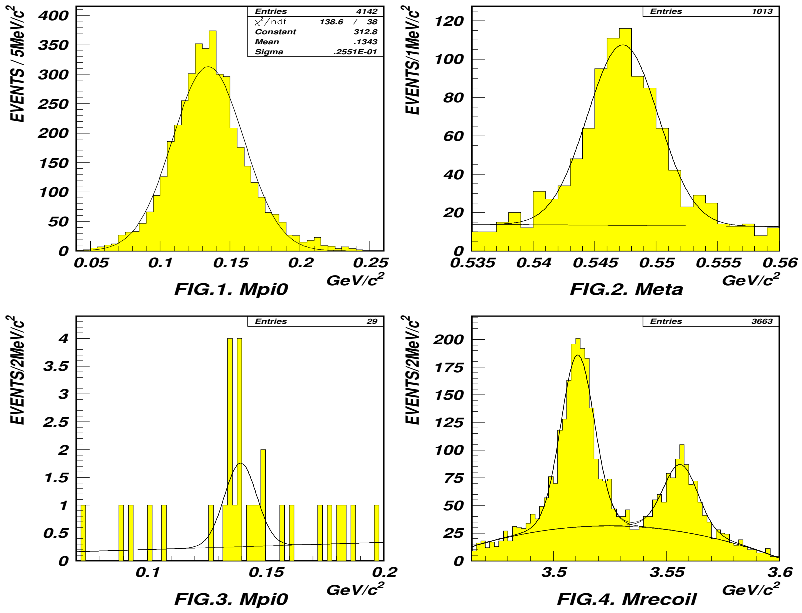

FIG.1.Gauss-FIT on π^0 mass distribution after $\psi' \to \pi^0\pi^0 J/\psi$ selection. FIG.2.BW-FIT on invariant mass distribution of the two gammas after all cuts to select $\psi' \to \eta J/\psi$. FIG.3.BW-FIT on invariant mass distribution of the two gammas after all cuts to select $\psi' \to \pi^0 J/\psi$. FIG.4.BW-FIT on recoil mass of the lower-energy gamma after all cuts to select $\psi' \to \gamma\chi_{c1,2} \to \gamma\gamma J/\psi$.

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6 References

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