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I. NUMERICAL RESULTS OF $\sigma[e^+e^- \to \pi^+\pi^-\psi_2(3823)] \cdot \mathcal{B}[\psi_2(3823) \to \gamma\chi_{c1}]$

TABLE I. The measured cross section $\sigma[e^+e^- \to \pi^+\pi^-\psi_2(3823)]$ times the branching ratio $\mathcal{B}[\psi_2(3823) \to \gamma\chi_{c1}]$ at different c.m. energies. Here the uncertainties are statistical only.

$\sqrt{s}$ (GeV)	$\mathcal{L}_{\rm int}(\rm pb^{-1})$	$N^{\rm sig}$	ϵ	$1+\delta$	$\sigma\cdot\mathcal{B}$ (pb)
4.2263	1056.4	$1.7^{+2.5}_{-1.7}$	0.311	0.737	$0.17^{+0.28}_{-0.18}$
4.2580	828.4	$1.2^{+2.1}_{-1.3}$	0.336	0.741	$0.15^{+0.25}_{-0.16}$
4.2879	502.4	$0.7^{+1.8}_{-1.0}$	0.334	0.743	$0.13^{+0.35}_{-0.19}$
4.3121	501.2	$0.6^{+1.9}_{-1.0}$	0.343	0.743	$0.11^{+0.36}_{-0.20}$
4.3374	505.0	$3.4^{+2.5}_{-1.8}$	0.356	0.742	$0.63^{+0.47}_{-0.34}$
4.3583	543.9	$6.7^{+3.2}_{-2.5}$	0.357	0.744	$1.13^{+0.54}_{-0.42}$
4.3774	522.7	$8.3^{+3.7}_{-3.0}$	0.338	0.750	$1.54^{+0.68}_{-0.55}$
4.3965	507.8	$12.3^{+4.2}_{-3.5}$	0.318	0.767	$2.42^{+0.83}_{-0.69}$
4.4156	1043.9	$14.2^{+5.2}_{-4.5}$	0.310	0.798	$1.35^{+0.49}_{-0.42}$
4.4362	569.9	$12.5^{+4.3}_{-3.6}$	0.323	0.841	$1.98^{+0.67}_{-0.56}$
4.4671	111.1	$5.3^{+2.9}_{-2.2}$	0.332	0.910	$3.85^{+2.09}_{-1.60}$
4.5271	112.1	$0.0^{+1.6}_{-0.0}$	0.320	1.017	$0.00^{+1.07}_{-0.00}$
4.5745	48.9	$2.0^{+1.8}_{-1.1}$	0.307	1.053	$3.02^{+2.82}_{-1.77}$
4.5995	586.9	$2.1^{+2.5}_{-1.7}$	0.318	1.014	$0.27^{+0.32}_{-0.22}$
4.6120	102.5	$1.5^{+1.9}_{-1.2}$	0.328	0.960	$1.12^{+1.45}_{-0.93}$
4.6278	511.1	$7.0^{+3.8}_{-3.0}$	0.348	0.860	$1.12^{+0.60}_{-0.48}$
4.6408	541.4	$10.0^{+3.9}_{-3.2}$	0.371	0.783	$1.56^{+0.60}_{-0.50}$
4.6613	523.6	$14.3^{+4.5}_{-3.8}$	0.384	0.796	$2.18^{+0.69}_{-0.58}$
4.6811	1631.7	$22.2^{+6.0}_{-5.2}$	0.364	0.943	$0.97^{+0.26}_{-0.23}$
4.6984	526.2	$6.2^{+3.5}_{-2.8}$	0.340	1.042	$0.81^{+0.46}_{-0.37}$

II. SYSTEMATIC ERROR OF RESONANCE PARAMETERS

TABLE II. The systematic uncertainties for the resonance parameters. $M[R_i]$ and $\Gamma_{\rm tot}[R_i]$ represent the mass (in MeV/c^2) and total width (in MeV) of resonance R_i, respectively; $\Gamma_{\rm e^+e^-}\mathcal{B}_1^{R_i}\mathcal{B}_2$ is the product of the e^+e^- partial width (in eV/c^2) and branching fraction of $R_i \to \pi^+\pi^-\psi_2(3823) \to \pi^+\pi^-\gamma\chi_{c1}$ (i = 1, 2). The parameter ϕ (in degrees) is the relative phase between the two resonances, and the values in the brackets are the corresponding systematic uncertainties for the second solution of the two-BW fit.

Parameters	$\sqrt{s}$	$\sigma\cdot\mathcal{B}$	Fit model	Sum
$M[R_1]$	3.9	–	2.2	4.5
$\Gamma_{\rm tot}[R_1]$	1.6	–	1.6	2.3
$\Gamma_{\rm e^+e^-}\mathcal{B}_1^{R_1}\mathcal{B}_2$	0.01 (0.01)	0.03 (0.03)	0.01 (0.01)	0.03 (0.03)
$M[R_2]$	0.7	–	0.4	0.8
$\Gamma_{\rm tot}[R_2]$	0.4	–	4.1	4.1
$\Gamma_{\rm e^+e^-}\mathcal{B}_1^{R_2}\mathcal{B}_2$	0.01 (0.01)	0.02 (0.01)	0.01 (0.01)	0.02 (0.01)
ϕ	0.3 (1.8)	–	3.2 (5.4)	3.2 (5.7)
$M[R]$	3.2	–	1.3	3.5
$\Gamma_{\rm tot}[R]$	1.7	–	12.2	12.3
$\Gamma_{\rm e^+e^-}\mathcal{B}_1^{R}\mathcal{B}_2$	0.01	0.05	0.02	0.05

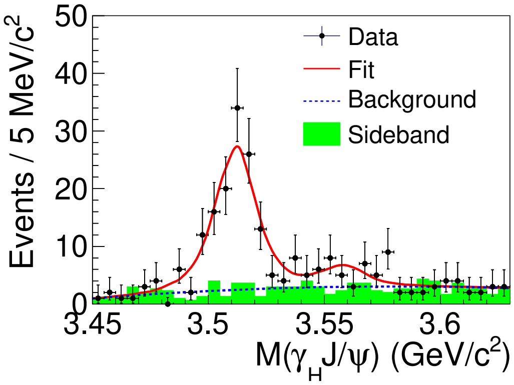

FIG. 1. Result of the fit to the $M(\gamma_H J/\psi)$ distribution for the events in the $\psi_2(3823)$ signal region ($3.815 < M^{\rm recoil}(\pi^+\pi^-) < 3.835$ GeV/c^2). Dots with error bars are data, the red solid curve is the total fit, the blue dashed curve is background, and the green shaded histogram is the background estimated from $\psi_2(3823)$ sideband events.

III. RESULTS OF $\mathcal{B}[\psi_2(3823) \to \gamma\chi_{c2}]$

For the $\psi_2(3823) \to \gamma\chi_{c2}$ decay, we study the $M(\gamma_H J/\psi)$ distribution by requiring $3.815 < M^{\rm recoil}(\pi^+\pi^-) < 3.835$ GeV/c^2 to select $\psi_2(3823)$ signal candidates. In order to estimate non-$\psi_2(3823)$ background, we also define a sideband region as $3.74 < M^{\rm recoil}(\pi^+\pi^-) < 3.78$ GeV/c^2. Figure 1 shows the $M(\gamma_H J/\psi)$ distribution, where no significant χ_{c2} signal is seen. A fit with χ_{c1} and χ_{c2} signal shapes determined from MC simulation as the signal PDF, and a second-order polynomial as the background is used to extract the relative decay rate of $R = \frac{\mathcal{B}[\psi_2(3823)\to\gamma\chi_{c2}]}{\mathcal{B}[\psi_2(3823)\to\gamma\chi_{c1}]} = 0.33\pm0.12$. Since the χ_{c2} signal is not significant (the statistical significance is only 2.0σ), an upper limit of $R < 0.51$ at the 90% C.L. is given, taking into account the systematic uncertainty.

IV. SCATTERING ANGLE DISTRIBUTION

The $\pi^+\pi^-$ system in the $e^+e^- \to \pi^+\pi^-\psi_2(3823)$ process is expected to be dominated by S-wave, such as $f_0(500)$. According to spin-parity conservation, the orbital angular momentum L between $\pi^+\pi^-$ and $\psi_2(3823)$ is therefore 2. With helicity amplitude calculations, the scattering angle distribution of $\psi_2(3823)$ is $(1 + \cos^2\theta)$, where θ is the polar angle of $\psi_2(3823)$ in the e^+e^- c.m. frame. Figure 2 shows the $\cos\theta$ distribution of the selected $e^+e^- \to \pi^+\pi^-\psi_2(3823)$ signal candidates after efficiency correction. We perform fits to the angular distribution with an $L = 0$ PDF (flat) and an $L = 2$ PDF ($1 + \alpha\cos^2\theta$, where $\alpha = 1.3 \pm 0.8$ is obtained from the fit). A χ^2-test for the $L = 2$ fit yields $\chi^2/ndf = 2.3/3 = 0.8$, which is better than that of the $L = 0$ fit ($\chi^2/ndf = 6.8/4 = 1.7$).

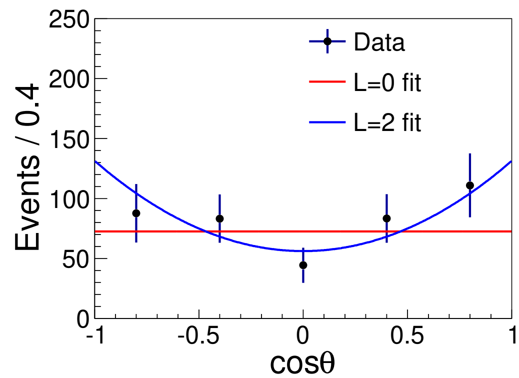

FIG. 2. Scattering angle distribution for $\psi_2(3823)$ events in e^+e^- CM frame (after efficiency correction). Dots with error bars are data, the red and blue curves are from the $L = 0$ and $L = 2$ fits, respectively.