

Search for $e^+e^- \rightarrow \eta\eta J/\psi$

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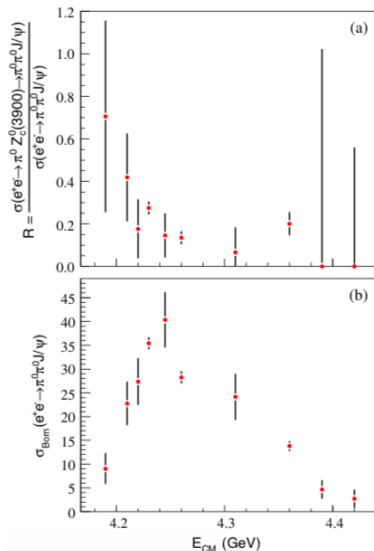
Introduction

- Great achievements in $e^+e^- \rightarrow \pi^0\pi^0 J/\psi$
PRL 115, 112003(2015)
 - $Z_c(3900)^0$ with 10.4σ
 - Born cross section of $e^+e^- \rightarrow \pi^0\pi^0 J/\psi$
- Search for the isospin violating decay $Y(4260) \rightarrow \pi^0\eta J/\psi$ PRD 92, 012008(2015)
 - Upper limits of Born cross section at 90%
 - No found $Z_c(3900) \rightarrow \eta J/\psi$
- Search for $e^+e^- \rightarrow J/\psi\eta\eta$

$$e^+e^- \rightarrow J/\psi \eta \eta$$

$\swarrow$
 $\swarrow$
 $\swarrow$

$\searrow \gamma\gamma$
 $\searrow$ anything
 $\searrow \mu^+\mu^-/e^+e^-$



Data samples at BESIII

Sample	Ecms	Luminosity
4230	$4226.26 \pm 0.04 \pm 0.65$	$1056.4 \pm 0.1 \pm 7.0$
4237	4235.7	$530.6 \pm 0.1 \pm 2.4$
4246	4243.8	$537.4 \pm 0.1 \pm 2.6$
4260	$4257.97 \pm 0.04 \pm 0.66$	$828.4 \pm 0.1 \pm 5.5$
4270	4266.8	$529.7 \pm 0.1 \pm 2.8$
4280	4277.7	$175.5 \pm 0.1 \pm 0.9$
4290	4287.88	500
4315	4312.05	500
4340	4337.39	500
4360	$4358.26 \pm 0.05 \pm 0.62$	$543.9 \pm 0.1 \pm 3.6$
4380	4377.37	500
4400	4396.45	500
4420	$4415.58 \pm 0.04 \pm 0.72$	$1043.9 \pm 0.1 \pm 6.9$
4440	570	570
4470	$4467.06 \pm 0.11 \pm 0.73$	$111.09 \pm 0.04 \pm 0.73$
4530	$4527.14 \pm 0.11 \pm 0.72$	$112.12 \pm 0.04 \pm 0.74$
4600	$4599.53 \pm 0.07 \pm 0.74$	$586.9 \pm 0.1 \pm 3.9$

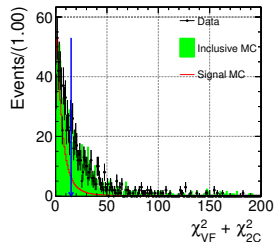
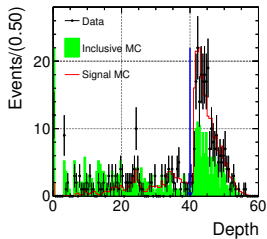
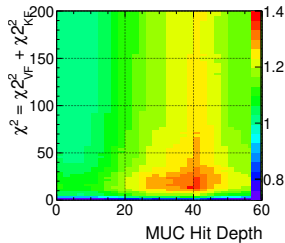
- Real data samples

- Inclusive MC
 - 5.0 times Hadrons luminosity
 - 0.1 times Bhabha; 1.0 times Dimumu and Digamma; 5 times Ditau luminosity
- Signal MC (100,000 events with PHSP generation mechanism)
- BOSS-7.0.4

- Good charged candidates:
 - $|V_r| < 1.0$ cm and $|V_z| < 10.0$ cm
 - $|\cos \theta| < 0.93$
 - Number of good charged tracks is larger than 1
- Good photon candidates:
 - $E_{emc}^{endcap} > 50$ MeV ($0.86 < |\cos \theta| < 0.92$)
 - $E_{emc}^{barrel} > 25$ MeV ($0.80 < |\cos \theta|$)
 - $0 < T < 14$ (units 50 ns)
 - $\theta_{charged-\gamma} > 10^\circ$
 - Number of good photons is larger than 1
- Particle identification:
 - Electron: $E_{emc}/p > 0.8$ and $p > 1.0$ GeV/c
 - Muon: $E_{emc}/p \leq 0.8$ and $p > 1.0$ GeV/c
 - Only one electron and one muon
- 2C Kinematic fit after vertex fit (vertex fit with l^+l^-):
 - 1C: Constrain miss track mass on $M(\eta)$
 - 1C: Constrain lepton pair invariant mass on $M(J/\psi)$

Further requirements

- Signal region: $0.51 < RM(\eta J/\psi) < 0.57 \text{ GeV}/c^2$
- To suppress muon/pion misidentification, MUC depth is adopted for mu-mu mode
- To improve resolution and suppress background, χ^2 is given a further requirement
- $$\text{FOM} = \frac{S(\chi^2, \text{Depth}_{\text{muc}})}{\sqrt{S(\chi^2, \text{Depth}_{\text{muc}}) + B(\chi^2, \text{Depth}_{\text{muc}})}}$$



Background study

$$e^+e^- \rightarrow \psi(2S)\gamma, \psi(2S) \rightarrow J/\psi\pi^0\pi^0, J/\psi \rightarrow e^+e^-, \pi^0 \rightarrow \gamma\gamma, \pi^0 \rightarrow \gamma\gamma$$

$$e^+e^- \rightarrow \psi(2S)\pi^0\pi^0, \psi(2S) \rightarrow J/\psi\pi^0\pi^0, J/\psi \rightarrow e^+e^-, \pi^0 \rightarrow \gamma\gamma, \pi^0 \rightarrow \gamma\gamma, \pi^0 \rightarrow \gamma\gamma, \pi^0 \rightarrow \gamma\gamma, \pi^0 \rightarrow \gamma\gamma, \pi^0 \rightarrow \gamma\gamma$$

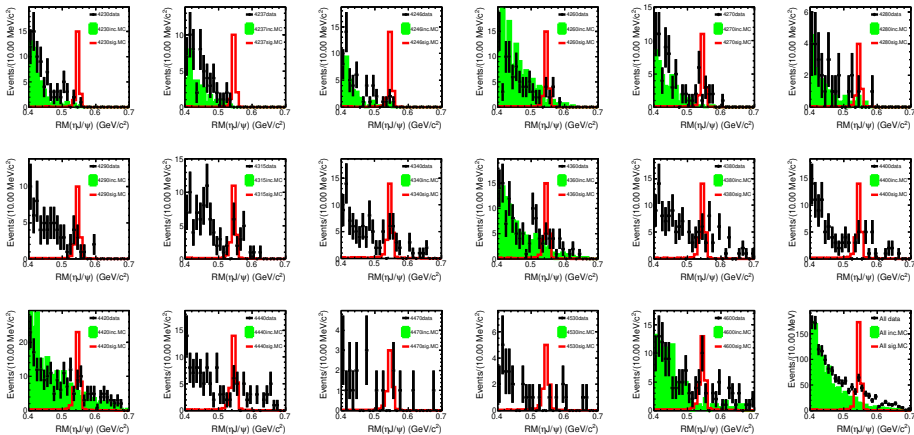
$$e^+e^- \rightarrow \psi(2S)\pi^0\pi^0, \psi(2S) \rightarrow J/\psi\pi^0\pi^0, J/\psi \rightarrow \mu^+\mu^-, \pi^0 \rightarrow \gamma\gamma, \pi^0 \rightarrow \gamma\gamma, \pi^0 \rightarrow \gamma\gamma, \pi^0 \rightarrow \gamma\gamma$$

$$e^+e^- \rightarrow \psi(2S)\pi^0\pi^0, \psi(2S) \rightarrow \gamma\chi_{c1}, \chi_{c1} \rightarrow \gamma J/\psi, J/\psi \rightarrow \mu^+\mu^-, \pi^0 \rightarrow \gamma\gamma, \pi^0 \rightarrow \gamma\gamma$$

$$e^+e^- \rightarrow \psi(2S)\pi^0\pi^0, \psi(2S) \rightarrow \gamma\chi_{c1}, \chi_{c1} \rightarrow \gamma J/\psi, J/\psi \rightarrow \mu^+\mu^-, \pi^0 \rightarrow \gamma\gamma, \pi^0 \rightarrow \gamma\gamma$$

$$e^+e^- \rightarrow \psi(2S)\pi^0\pi^0, \psi(2S) \rightarrow \gamma\chi_{c2}, \chi_{c2} \rightarrow \gamma J/\psi, J/\psi \rightarrow e^+e^-, \pi^0 \rightarrow \gamma\gamma, \pi^0 \rightarrow \gamma\gamma$$

$$e^+e^- \rightarrow \psi(2S)\pi^0\pi^0, \psi(2S) \rightarrow J/\psi\eta, J/\psi \rightarrow \mu^+\mu^-, \eta \rightarrow \gamma\gamma, \pi^0 \rightarrow \gamma\gamma, \pi^0 \rightarrow \gamma\gamma$$

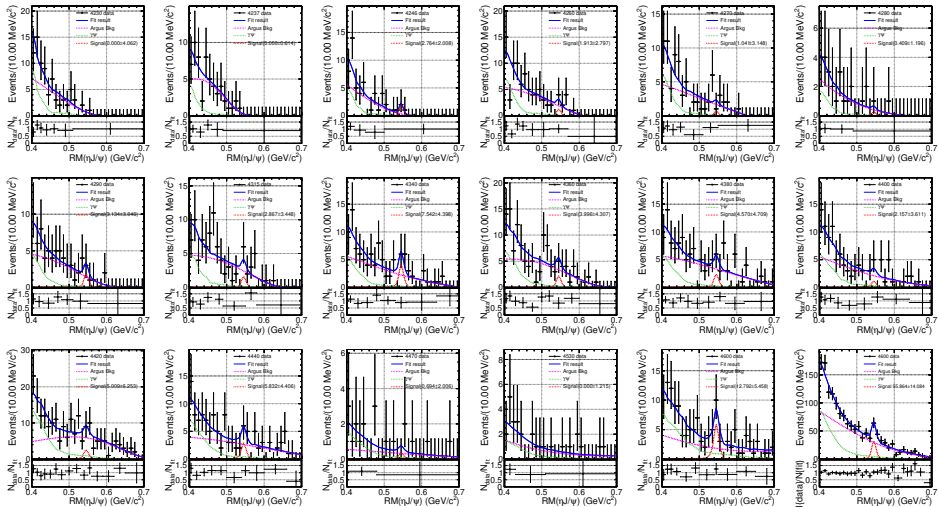


Data fit

- Signal: $RM(\eta J/\psi)$ line shape extracted from signal MC
- Dominate background: $RM(\eta J/\psi)$ line shape extracted from exclusive MC $e^+e^- \rightarrow \gamma_{ISR}\psi'$ ($\psi' \rightarrow \pi^0\pi^0 J/\psi$, $\pi^0 \rightarrow \gamma\gamma$, $J/\psi \rightarrow e^+e^-/\mu^+\mu^-$)
- Other background: $Argus(RM(\eta J/\psi), t, m, p)$ with $t = \sqrt{s} - m(\eta) - m(J/\psi)$
- The number of dominate background is fix

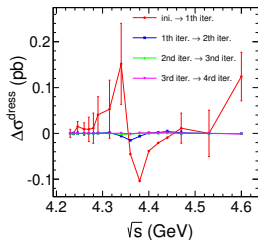
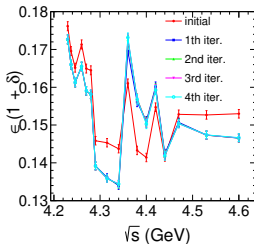
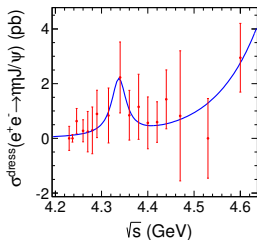
Sample	Cross Section(pb^{-1})	Efficiency(%)	$N_{\psi'}$
4230	404.13	0.23	23.07
4237	398.10	0.23	11.34
4246	390.58	0.29	14.16
4260	379.36	0.33	24.07
4270	371.68	0.35	16.13
4280	364.26	0.39	5.829
4290	357.09	0.40	16.46
4315	340.20	0.50	19.59
4340	324.63	0.61	22.65
4360	313.04	0.79	30.95
4380	302.14	0.77	26.78
4400	291.87	0.85	28.54
4420	282.18	1.02	69.13
4440	273.03	1.03	36.61
4470	260.22	1.30	8.585
4530	237.46	1.59	9.677
4600	214.89	1.93	55.72

Data fit results



Estimation of efficiency and ISR corrected factor

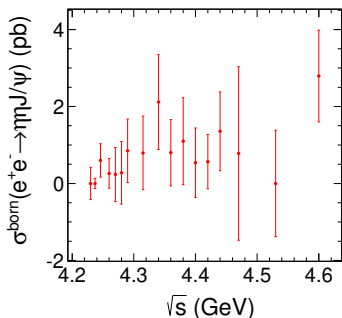
- ① Dressed cross section: $\sigma^{dress} = \frac{N_{sig}}{L \epsilon_{B_{J/\psi \rightarrow \parallel}} B_{\eta \rightarrow \gamma \gamma} (1 + \delta)}$
- ② Fit dressed cross section: $F(\sqrt{s}) = \frac{a}{b\sqrt{s}} + BW(\sqrt{s}, m, w)$
- ③ Weight: $W_i = \frac{\sigma_i^{dress}(\sqrt{s}=M(\eta\eta J/\psi))}{\sigma_i^{dress}(\sqrt{s}=E_{cms})}$
- ④ Efficiency: $\epsilon^{weighted} = \frac{\sum_{i=0}^{N_{left}} W_i}{\sum_{i=0}^{N_{gen}} W_i}$; ISR corrected factor: $(1 + \delta)^{weight} = (1 + \delta)^{ini} \frac{\sum_{i=0}^{N_{gen}} W_i}{N_{gen}}$
- ⑤ An event-by-event weight method is used to perform dressed cross section iterations.



Results

Sample	Luminosity(pb^{-1})	N_{sig}	$\epsilon(\%)$	$1 + \delta$	$\frac{1}{1-\Pi^2}$	S.S.	$\sigma^{born}(\text{pb})$
4230	$1056.4 \pm 0.1 \pm 7.0$	0.000 ± 4.062	17.8	0.968	1.056	0	0.0 ± 0.418
4237	$530.6 \pm 0.1 \pm 2.4$	0.000 ± 0.614	17.3	0.961	1.056	0	0.0 ± 0.131
4246	$537.4 \pm 0.1 \pm 2.6$	2.764 ± 2.008	16.9	0.952	1.056	1.84	0.598 ± 0.435
4260	$828.4 \pm 0.1 \pm 5.5$	1.913 ± 2.797	17.7	0.937	1.054	0.69	0.262 ± 0.383
4270	$529.7 \pm 0.1 \pm 2.8$	1.041 ± 3.148	17.2	0.925	1.053	0.34	0.232 ± 0.702
4280	$175.5 \pm 0.1 \pm 0.9$	0.409 ± 1.196	17.3	0.913	1.053	0.38	0.277 ± 0.811
4290	500	3.134 ± 3.046	15.5	0.899	1.052	1.18	0.848 ± 0.824
4315	500	2.867 ± 3.448	15.8	0.859	1.052	0.90	0.794 ± 0.956
4340	500	7.542 ± 4.398	15.7	0.856	1.051	1.91	2.115 ± 1.234
4360	$543.9 \pm 0.1 \pm 3.6$	3.996 ± 4.307	16.5	1.049	1.051	0.99	0.800 ± 0.862
4380	500	4.570 ± 4.709	13.6	1.154	1.052	1.06	1.097 ± 1.131
4400	500	2.157 ± 3.611	13.2	1.143	1.053	0.63	0.540 ± 0.904
4420	$1043.9 \pm 0.1 \pm 6.9$	5.009 ± 6.253	14.6	1.092	1.052	0.84	0.567 ± 0.708
4440	570	5.832 ± 4.406	13.7	1.036	1.054	1.48	1.356 ± 1.024
4470	$111.1 \pm 0.04 \pm 0.7$	0.694 ± 2.006	15.5	0.971	1.055	0.36	0.780 ± 2.255
4530	$112.1 \pm 0.04 \pm 0.7$	0.000 ± 1.215	16.3	0.902	1.054	0	0.0 ± 1.382
4600	$586.9 \pm 0.1 \pm 3.9$	12.792 ± 5.458	16.9	0.870	1.055	2.84	2.790 ± 1.190

Results and Next to do



- Estimation of uncertainties
 - Data luminosity: $< 1.0\%$
(studied by BESIII collaboration)
 - Subsequent decay branching fractions: 0.6%
(quoted from PDG)
 - Tracking and PID: 2.0%
(PID system without dE/dx and TOF)
 - Photon reconstruction: 2.0%
(at least two photons)
 - Fit procedure: $10\% - 50\%$
(fit range, signal and background shape)
 - Kinematic fit: $< 1.0\%$
- Memo is preparing

Thanks for your attention