Progress on $e^+e^- \to \pi^0\pi^0 J/\psi$ analysis

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Overview | Motivation

- Measure the cross section of $e^+e^- \to \pi^0\pi^0 J/\psi$ with all the data taking at 3.810 GeV ~ 4.600 GeV, fit to the line shape, and compare with charged process $e^+e^- \to \pi^+\pi^- J/\psi$
- Measure the J^P of neutral $Z_c(3900)^0$, as well as the mass and width, to confirm the results from charged process
- Extract the proportion of $e^+e^- \to \pi^0 Z_c(3900) \to \pi^0\pi^0 J/\psi$ from partial wave analysis

- Previous talk: https://indico.ihep.ac.cn/event/7447/session/17/contribution/35/material/slides/0.pdf

Overview | update

- Update all the data analysis to BOSS version 703
- Optimize the requirement on $\chi^2_{6C} < 75$
- Remove the contribution of $f_2(1270)J/\psi$ in nominal PWA fit
- Fit to of $e^+e^- \to \pi^0\pi^0 J/\psi$ cross section line shape
- Study the systematic uncertainties
    - Systematic uncertainty of $e^+e^- \to \pi^0\pi^0 J/\psi$ cross section
    - Systematic uncertainty of resonance parameters
    - Systematic uncertainty of Z_c^0 parameters and fraction
- Summary

Event selection

Charged tracks

- |Vr|<1.0 cm, |Vz|<10.0 cm, |cosθ|<0.93 && nGood==2
- e: E/p>0.7
- μ: E/p<0.3 && at least one hits more than 6 MUC layers

Good photons

- Barrel(Endcap): Eγ>25 (50) MeV, |cosθ|<0.8 ([0.86, 0.92])
- 0<TDC<=14, $\theta_{\gamma chg}<5^\circ$ && N(γ)>=4

Kinematic fit

- Constraint γγ invariant mass at nominal mass of π^0
- 0.110<M(γγ)<0.150 GeV/c^2 && N($\pi^0\pi^0$)<=2
- 4C+1C (two π^0s) fit to select the combination with minimal X^2
- Particles momentum after 6C fit (χ^2_{6C}<75) are used in further study

Cross section calculation $e^+e^- \to \pi^0\pi^0 J/\psi$

- Signal extraction: Fit to $M(l^+l^-)$ with MC shape ⊗ Gaussian + 1st poly
- Efficiency:
  - obtain from MC generated according to PWA results (4.1780~4.4156 GeV)
  - PHSP MC samples (other points with low statistics)
- Cross section calculation: $$\sigma^B(\sqrt{s}) = \frac{N_{obs}}{\mathcal{L}_{int}(1+\delta^{ISR})(1+\delta^V)\epsilon Br}$$

- $\mathcal{L}_{int}$ is the integrated luminosity
- N_{obs} is observed number of events from data
- ε is selection efficiency calculated from the MC samples
- Br stands for the branching ratio of $J/\psi \to e^+e^-(\mu^+\mu^-)$
- $(1+\delta^V)$ is vacuum polarization factor taken from QED
- $(1+\delta^{ISR})$ is the radiative correction factor

Cross section of $e^+e^-\to\pi^0\pi^0 J/\psi$

$\sqrt{s}$(GeV)	$\mathcal{L}$	$\varepsilon_{\pi^0\pi^0 J/\psi}(\%)$	$N^{obs}_{\pi^0\pi^0 J/\psi}$	$1+\delta^{ISR}$	$1+\delta^{V}$	σ^{Born} (pb)	$\mathcal{R}(\frac{\pi^0\pi^0 J/\psi}{\pi^+\pi^- J/\psi})$
3.8077	50.5±0.5	19.11	10±4	0.865	1.056	9.74±3.90±0.51	0.60± 0.25±0.13
3.8962	52.6±0.5	18.80	9±3	0.869	1.049	8.57±2.86±0.45	0.52± 0.18±0.11
4.0076	482.0±4.8	20.60	84±11	0.919	1.044	7.57±0.99±0.39	0.48± 0.06±0.05
4.0855	52.8±0.4	18.29	10±3	0.943	1.052	8.96±2.69±0.47	0.62± 0.19±0.14
4.1886	43.33±0.3	18.51	10±3	0.881	1.056	11.50±3.45±0.60	0.77± 0.24±0.20
4.2077	54.9±0.4	20.60	28±5	0.760	1.057	26.45±4.73±1.38	0.51± 0.09±0.07
4.2171	54.6±0.4	21.83	28±5	0.733	1.057	26.02±4.65±1.35	0.45± 0.08±0.06
4.2263	1100.9±7.0	21.90	823±29	0.730	1.056	38.01±1.38±1.98	0.47± 0.02±0.04
4.2417	55.88±0.4	22.28	47±7	0.792	1.056	38.74±5.78±2.01	0.48± 0.07±0.05
4.2580	828.4±5.5	21.21	548±24	0.847	1.054	29.99±1.34±1.56	0.53± 0.02±0.04
4.3079	45.1±0.3	21.46	24±5	0.896	1.052	22.58±4.71±1.17	0.45± 0.10±0.06
4.3583	543.9±3.6	18.36	188±15	1.097	1.051	12.97±1.04±0.67	0.57± 0.04±0.05
4.3874	55.6±0.4	17.52	5±3	1.215	1.051	3.45±2.07±0.18	0.18± 0.11±0.03
4.4156	1090.7±6.9	15.28	160±14	1.271	1.053	6.05±0.53±0.31	0.53± 0.05±0.05
4.4671	111.1±0.7	15.74	11±4	1.285	1.055	3.98±1.45±0.21	0.31± 0.11±0.05
4.5271	112.1±0.7	16.06	12±4	1.274	1.055	4.26±1.42±0.22	0.42± 0.14±0.08
4.5745	48.9±0.04	16.48	7±3	1.258	1.055	5.62±2.41±0.29	0.43± 0.19±0.11
4.5995	586.9±3.9	16.66	36±7	1.238	1.055	2.42±0.47±0.13	0.39± 0.08±0.05
4.1780	3194.5±31.9	19.90	345±20	0.919	1.055	4.85±0.28 ± 0.25	
4.1888	522.5±3.4	22.01	82±10	0.877	1.056	6.61±0.81 ± 0.34	0.45±0.06±0.11
4.1989	524.6±2.5	20.85	114±11	0.805	1.057	10.52±1.02 ± 0.55	
4.2092	518.1±1.8	20.40	222±15	0.752	1.057	22.68±1.54 ± 1.18	0.45±0.03±0.05
4.2187	514.3±1.9	21.02	312±18	0.729	1.057	32.15±1.87 ± 1.67	0.56±0.03±0.06
4.2357	530.6±2.4	21.23	409±21	0.763	1.056	38.67±2.00 ± 2.01	
4.2438	537.4±2.6	21.73	402±20	0.794	1.055	35.27±1.77 ± 1.83	
4.2668	529.7±2.8	22.80	334±19	0.859	1.053	26.25±1.51 ± 1.37	
4.2777	175.5±0.9	21.72	94±10	0.870	1.053	23.11±2.46 ± 1.20	

Cross section of $e^+e^- \to \pi^0\pi^0 J/\psi$

$\sqrt{s}$(GeV)	$\mathcal{L}$	$\varepsilon_{\pi^0\pi^0 J/\psi}(\%)$	$N^{obs}_{\pi^0\pi^0 J/\psi}$	$1+\delta^{ISR}$	$1+\delta^{V}$	σ^{Born} (pb)	$\mathcal{R}(\frac{\pi^0\pi^0 J/\psi}{\pi^+\pi^- J/\psi})$
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4.1886	43.33±0.3	18.51	10±3	0.881	1.056	11.50±3.45±0.60	0.77± 0.24±0.20
4.2077	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.51± 0.09±0.07
4.2171							0.45± 0.08±0.06
4.2263							0.47± 0.02±0.04
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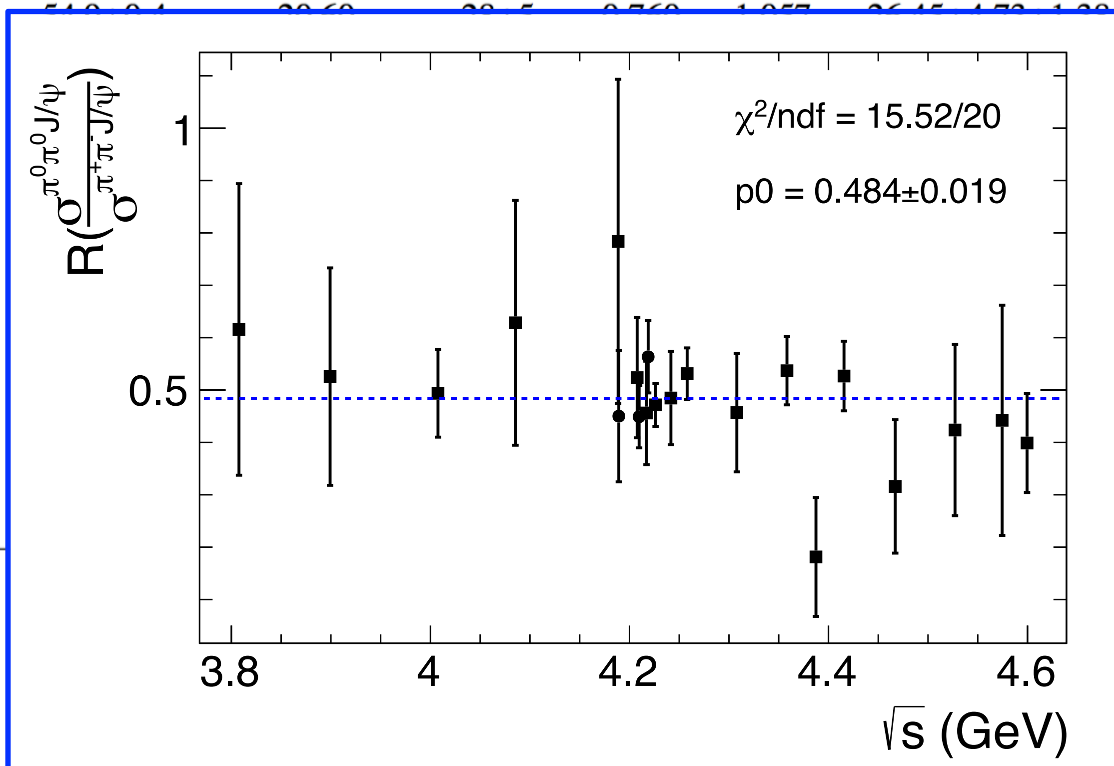


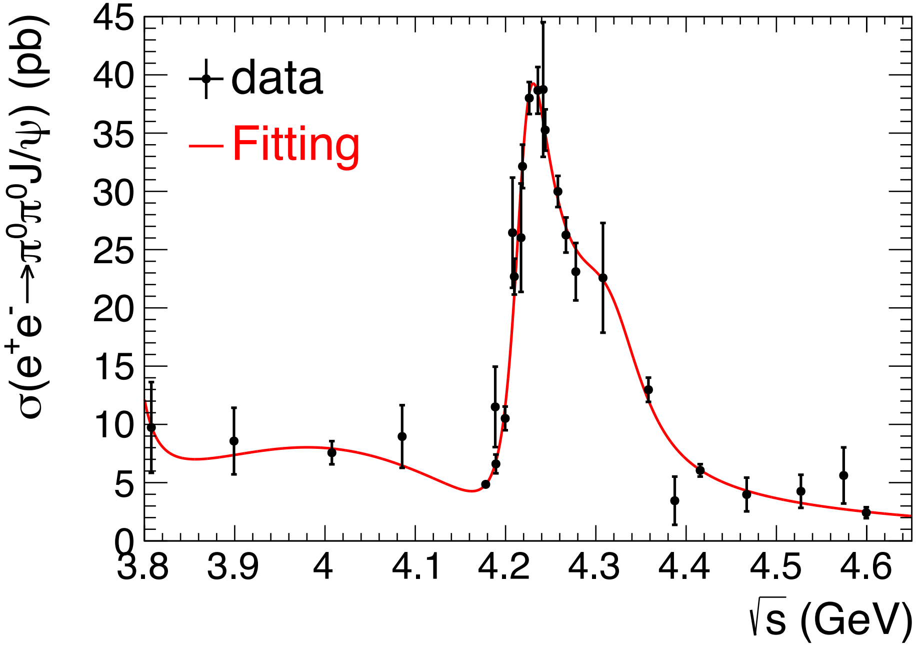
Fit to cross section

- **Line shape - Fit I:**

$$\sigma_{\rm fit}(s) = |{\rm BW}_{\psi(3770)}({\rm s})|^2 + |{\rm BW}_1({\rm s}) + {\rm BW}_2({\rm s})e^{i\phi_1} + {\rm BW}_3({\rm s})e^{i\phi_2}|^2$$

- Relativistic Breit-Wigner amplitude for resonances:

$$\mathrm{BW}(\sqrt{s}) = \frac{M}{\sqrt{s}} \frac{\sqrt{12\pi\Gamma_{ee}\Gamma_{tot}\mathcal{B}(R \to \pi^0\pi^0 J/\psi)}}{s - M^2 + iM\Gamma_{tot}} \sqrt{\frac{PS(\sqrt{s})}{PS(M)}}$$



Fix the mass and width of 3rd BW Y(4320) to $e^+e^- \to \pi^+\pi^- J/\psi$

χ^2/ndf=18.029/17~1.06

M(Y(4220))=4220.2±2.5 MeV/c^2

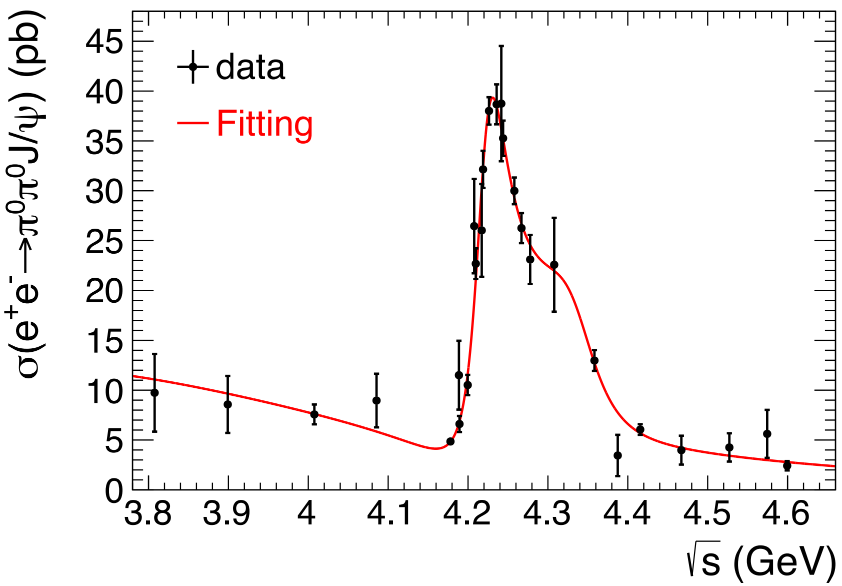
Γ(Y(4220))=48.6±3.9 MeV/c^2

Fit to cross section

- Line shape – Fit II (nominal):

$$\sigma_{\text{fit}}(\sqrt{s}) = |\sqrt{\sigma_{NY}(\sqrt{s})} + BW_1(s)e^{i\phi_1} + BW_2(s)e^{i\phi_2}|^2$$

$$\sigma_{NY}(\sqrt{s}) = PS(\sqrt{s})e^{-p_0(\sqrt{s}-M_{\text{threshold}})}p_1$$



χ^2/ndf=17.4313/16~1.09

Values(MeV/c^2)	Fit results	Ref($\pi^+\pi^- J/\psi$)
$M(R_1)$	4220.4± 3.1	4220.9± 2.9
$\Gamma(R_1)$	49.0± 4.3	44.1±3.8
$M(R_2)$	4336.2±13.3	4326.8±10.0
$\Gamma(R_2)$	99.7±74.2	$98.2^{+25.4}_{-19.6}$

- The observed resonances Y(4220) and Y(4320) are consistent with $\pi^+\pi^- J/\psi$
- The significance of Y(4320) is about 4.2σ

Systematic uncertainty | $e^+e^- \to \pi^0\pi^0 J/\psi$ cross section

Sources	Uncertainties (%)
Tracking for $e^\pm/\mu^\pm$	2.0
MUC layer	0.4
Photon efficiency	4.0
π^0 reconstruction	0.3
Peaking background	2.0
Kinematic fit	2.6
Fit to $M_{\ell^+\ell^-}$	1.4
MC model	2.1
Radiative correction	0.3
Luminosities	1.0
$\mathcal{B}_{\text{inter}}$	0.6
Total	6.3

Systematic uncertainty | $e^+e^-\to\pi^0\pi^0 J/\psi$ cross section

- **Tracking efficiency:** 1% is assigned to each e/μ, 2% in total
- **MUC layers:** change layer>=6 to layers>=5, (N_{obs}/ε_i) difference ~0.4%
- **Photon efficiency:** 1% is assigned to each photon, 4% in total
- **π^0 reconstruction:** enlarge π^0 mass window from (0.11, 0.15) GeV to (0.10, 0.16) GeV, (N_{obs}/ε_i) difference ~ 0.3%
- **Branching fraction of $\pi^0/J/\psi$:** 0.03% for $\pi^0\to\gamma\gamma$, 0.55% for $J/\psi\to l^+l^-$
- **Luminosity:** 1.0% from integrated luminosity measurement
- **Radiative correction**
  - Use the line shape from our measurement to replace the input line shape of $e^+e^-\to\pi^+\pi^-J/\psi$, difference of $(1+\delta^{ISR})\varepsilon$

Systematic uncertainty | $e^+e^-\to\pi^0\pi^0 J/\psi$ cross section

❑ Kinematic fit

- select control sample $e^+e^-\to\gamma\psi'\to\gamma\pi^0\pi^0 J/\psi$ at $\sqrt{s}$=4.1780GeV

•Almost same events selections, except:

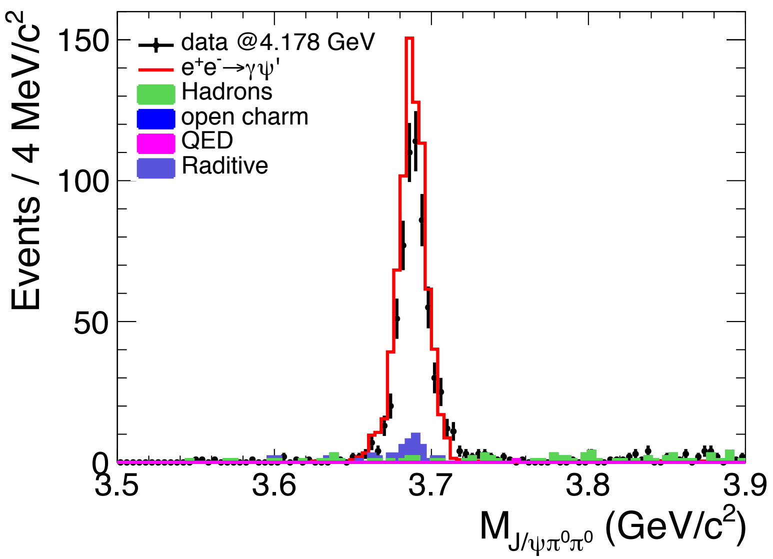
•$N\gamma$>=5

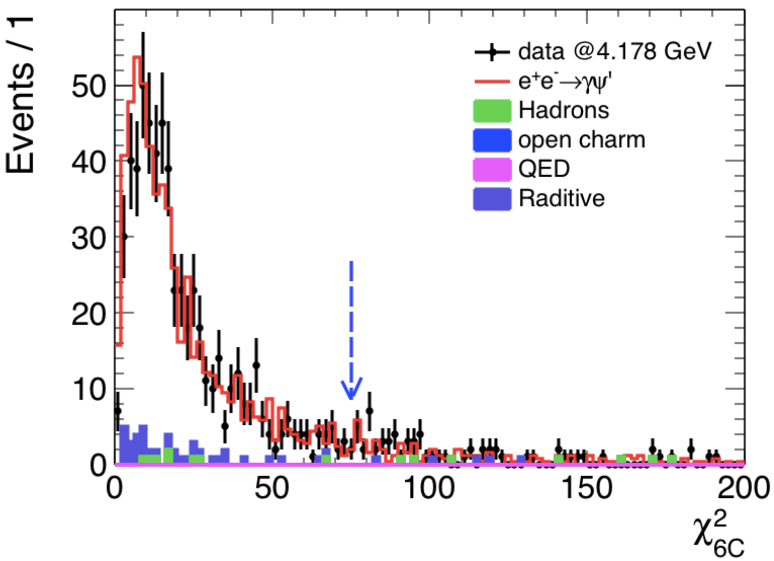
•Kinematic fit with one more photon track

•$3.06 < M(l^+l^-) < 3.13$ GeV/c^2

•$3.65 < M(\pi^0\pi^0 J/\psi) < 3.72$ GeV/c^2

Uncertainty=$1-\varepsilon_{MC}/\varepsilon_{data}$=2.6%





Systematic uncertainty | $e^+e^-\to\pi^0\pi^0 J/\psi$ cross section

- Fit to $M(l^+l^-)$
  - **Fit range:** change (2.90, 3.30) GeV/c^2 to (2.85, 3.35) and (2.95, 3.25) GeV/c^2 (difference of N_i/ε_i as uncertainty)
  - **Signal shape:** change MC shape⊗Gaussian to double Gaussian
  - **Background shape:** change 1st poly to 2nd poly

Sources	Uncertainties (%)
Fitting range	0.6
Signal shape	1.2
Background shape	0.1
Fit to $M_{\ell^+\ell^-}$	1.4

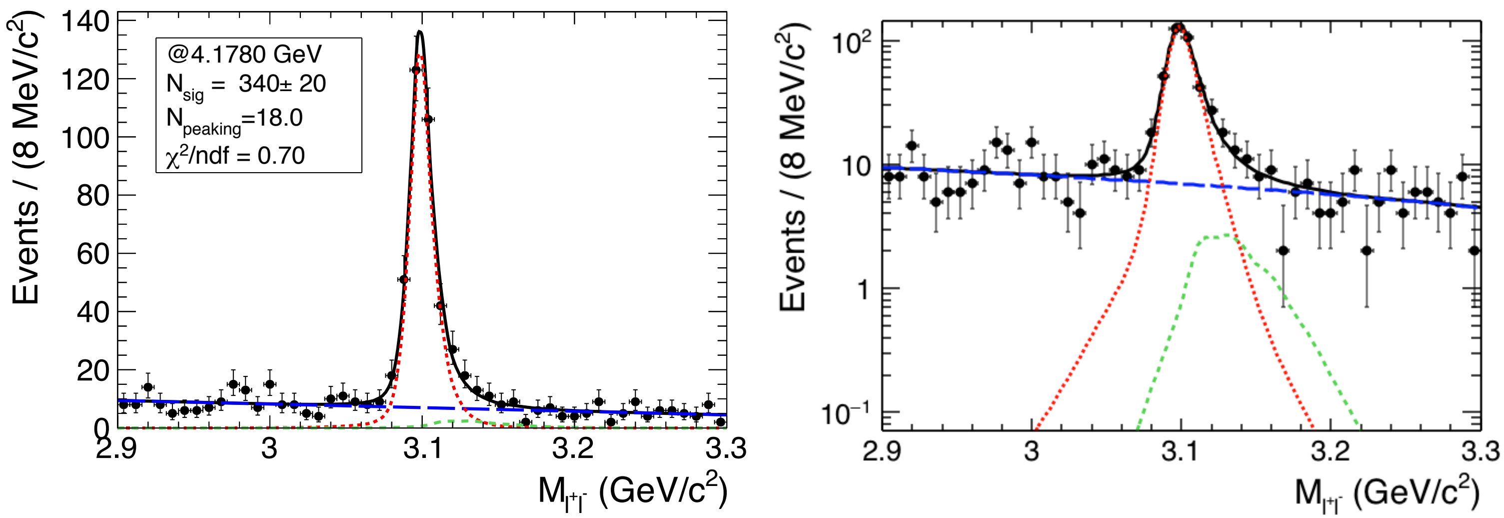
Systematic uncertainty | $e^+e^-\to\pi^0\pi^0 J/\psi$ cross section

- Peaking background
  - Signal shape => (Signal + peaking bkg) MC shape
  - Fix the expected number of event of peaking background in the fit

at $\sqrt{s}$=4.1780GeV

Decay channel	$\sqrt{s}$ = 4.1780 GeV	$\sqrt{s}$ = 4.2262 GeV
$e^+e^- \to \eta J/\psi, \eta \to \pi^0\pi^0\pi^0$	1.9	1.4
$e^+e^- \to \gamma\psi', \psi' \to \pi^0\pi^0 J/\psi$	16.1	5.3
total	18	6.7

Uncertainty=(347-340)/347=2.0%



Systematic uncertainty | $e^+e^- \to \pi^0\pi^0 J/\psi$ cross section

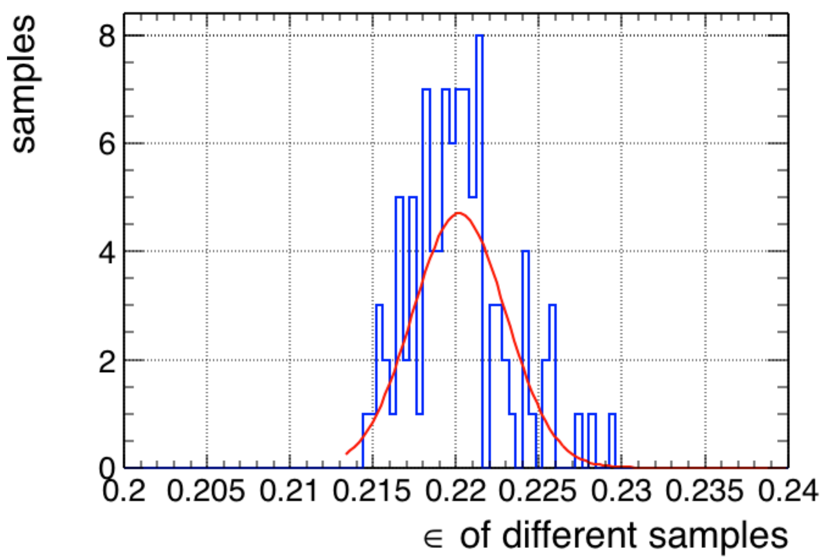
MC model

- For large statistic data points, we use PWA results to generate MC samples and obtain the efficiency by counting
- change the parameters of PWA amplitudes within errors randomly by a multi-variable Gaussian function 100 times
- regenerate MC sample to get new efficiencies
- fit the efficiency distribution by a Gaussian function

μ=0.22019±0.0004

σ=0.00281±0.0007

=> uncertainty as 1.4%



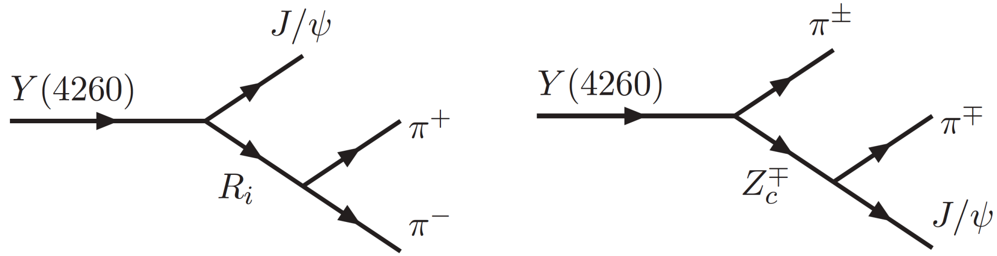
Systematic uncertainty | $e^+e^-\to\pi^0\pi^0 J/\psi$ line shape

- c.m. energy measurement
  - All data sets are measured by di-muon events with uncertainty of 1 MeV
- Cross section measurement
  - The systematic error are common for all c.m. energy, thus it will not affect the mass and width of resonance
- Fit model
  - Consider the PDF of three BW as systematic uncertainty
- Y(4320)
  - Float Y(4320) mass and width

Sources	Uncertainties (MeV/c^2)	
	$M(Y(4220))$	$\Gamma(Y(4220))$
c.m. energies	1.0	1.0
Fit model	0.2	0.4
Y(4320)	0.0	1.1
Total	1.0	1.8

Systematic uncertainty | PWA

☞ Amplitude construction (Helicity amplitude)



(a) (b)

$$(a)A^i_R(\lambda_Y,\lambda_R,\lambda_{l^+},\lambda_{l^-}) = F^{J_Y}_{\lambda_R,\lambda_{J/\psi}} D^{J_Y}_{\lambda_Y,\lambda_R-\lambda_{J/\psi}}(\theta_R,\phi_R) BW_i(R) F^{J_R}_{0,0} D^{J_R}_{\lambda_R,0}(\theta_{\pi^0},\phi_{\pi^0}) \cdot F^{J_{J/\psi}}_{\lambda_{l^+},\lambda_{l^-}} D^{J_{J/\psi}}_{\lambda_{J/\psi},\lambda_{l^+}-\lambda_{l^-}}(\theta_{l^+},\phi_{l^+})$$

$$(b)A_{Z_c}(\lambda_Y,\lambda_{Z_c},\lambda_{l^+},\lambda_{l^-}) = F^{J_Y}_{\lambda_{Z_c},0} D^{J_Y}_{\lambda_Y,\lambda_{Z_c}}(\theta_{Z_c},\phi_{Z_c}) BW(Z_c) F^{J_{Z_c}}_{\lambda_{J/\psi},0} D^{J_{Z_c}}_{\lambda_{Z_c},\lambda_{J/\psi}}(\theta_{J/\psi},\phi_{J/\psi}) \cdot F^{J_{J/\psi}}_{\lambda_{l^+},\lambda_{l^-}} D^{J_{J/\psi}}_{\lambda_{J/\psi},\lambda_{l^+}-\lambda_{l^-}}(\theta_{l^+},\phi_{l^+})$$

- Amplitudes include Z_c^0, σ_0, $f_0(980)$ and $f_0(1370)$ which have significances larger than 5σ.

Systematic uncertainty | Z_c^0 mass and fraction

❑ Z_c^0 Parameterization

- Nominal: parameterized with Flatte-like formula:

$$f = \frac{1}{M^2 - s - i(g_1\rho_{DD^*} + g_2\rho_{\pi J\psi})}$$

- Alternative: $BW_{Z_c}(s) = \dfrac{1}{s - M^2 + iM\Gamma}$
  - The likelihood only increases 2, no big difference

❑ $f_0(980)$ Parameterization

- Nominal: parameterized with Flatte formula: $f = \dfrac{1}{M^2 - s - i(g_1\rho_{\pi\pi}(s) + g_2\rho_{K\bar{K}(s)})}$

  Fix g_1=0.138, g_2/g_1=4.45 according to BESII~[Phys. Lett., B 598, 149 (2004)]

- Alternative: change g_2/g_1 within error to 4.2 or 4.7

Systematic uncertainty | Z_c^0 mass and fraction

❑ σ Parameterization

- Breit-Wigner with different widths: $BW(s) = \frac{1}{s - M^2 + iM\Gamma}$
- E791 type (nominal) $\Gamma(s) = \sqrt{1 - \frac{4m_{\pi^0}^2}{s}}\Gamma$
- PKU ansatz $\Gamma(s) = \sqrt{1 - \frac{4m_{\pi^0}^2}{s}}\frac{s}{M_0^2}\Gamma$
- Zou & Bugg's method

$$\Gamma(s) = g_1 \frac{\rho_{\pi\pi}(s)}{\rho_{\pi\pi}(M_\sigma^2)} + g_2 \frac{\rho_{4\pi}(s)}{\rho_{4\pi}(M_\sigma^2)}, \text{ with } g_1 = f(s)\frac{s - m_\pi^2/2}{M_\sigma^2 - m_\pi^2/2} e^{-\frac{s - M_\sigma^2}{a}}$$

Systematic uncertainty | Z_c^0 mass and fraction

❑ $f_0(1370)$ Parameterization

- Constant BW: M = 1.35 GeV, Γ = 0.35 GeV
- Alternative: mass-dependent BW

$$BW(s) = \frac{1}{s - M^2 + i\sqrt{s}\Gamma(s)}$$

$$\Gamma(s) = \Gamma_0(\frac{p}{p_0})^{(2L+1)}\frac{M}{\sqrt{s}}B_L(p, p_0, d)^2$$

❑ $f_2(1270)$ Parameterization

- Add the contribution of $f_2(1270)$ as systematic uncertainty, since the significance of $f_2(1270)$ is about 3σ
- Constant BW: M = 1.2751 GeV, Γ = 0.185 GeV

❑ Barrier radius

- Change the nominal radius r_0=0.6 fm to 1.0 fm

Systematic uncertainty | Z_c^0 mass and fraction

Event selection

- Change the signal region from (3.06, 3.13) GeV to (3.05, 3.14) GeV, and the bkg region from (2.93, 3.00)&(3.20, 3.27) GeV to (2.95, 3.00)&(3.20, 3.24) GeV

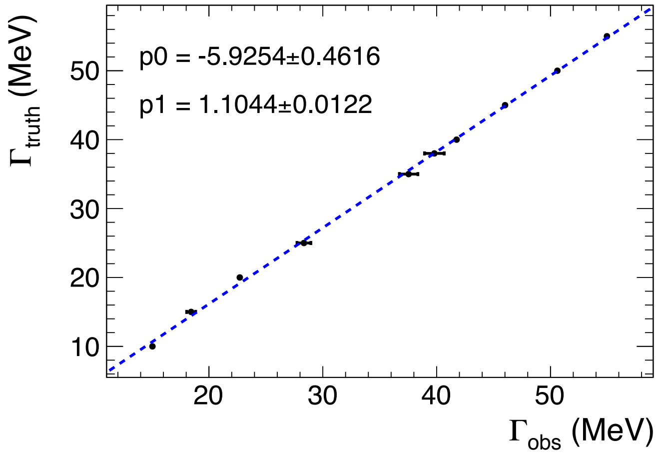
Mass resolution

- Mass resolution affect the determined Z_c^0 width or coupling constant
- MC simulation, generate Z_c^0 with a BW function with a given mass and width

$\Gamma_{truth}=-5.925+1.104\Gamma_{obs}$

$\Gamma_{obs}=45.3$ MeV ~ $\Gamma_{truth}=44.1$ MeV

$\delta g_1'/g_1' \sim \delta\Gamma(Z_c^0)/\Gamma(Z_c^0) \sim 2.6\%$



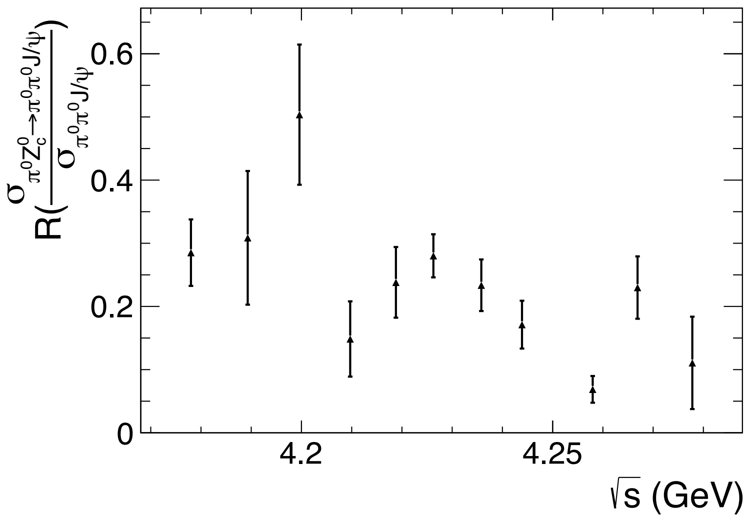
Systematic uncertainty | Z_c^0 mass and fraction

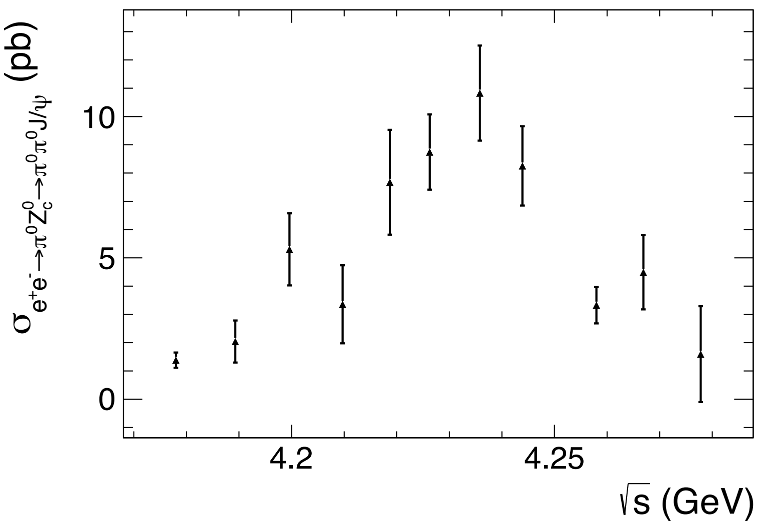
Sources	Mass	g_1'	fraction			
			4.2263	4.2357	4.2438	4.2580
Nominal fit	3913.7± 4.2	0.077±0.010	0.280±0.034	0.233±0.041	0.171±0.038	0.069±0.021
Event selection	3913.8±4.2	0.076±0.009	0.289±0.033	0.231±0.043	0.167±0.037	0.070±0.021
σ-ZB parametrization	3911.1±4.2	0.085±0.012	0.156±0.023	0.209±0.042	0.153±0.033	0.069±0.021
σ-PKU	3922.2±5.8	0.079±0.010	0.266±0.030	0.249±0.043	0.224±0.047	0.093±0.035
Z_c^0 parametrization	3892.4±2.6	49.2±5.3 (width)	0.159±0.024	0.201±0.041	0.148±0.033	0.079±0.025
$f_0(980)$ Coupling constant	3913.3±4.1	0.076±0.010	0.277±0.034	0.231±0.041	0.169±0.037	0.069±0.021
$f_0(1370)$ parametrization	3914.5±4.0	0.079±0.010	0.287±0.035	0.237±0.041	0.176±0.038	0.069±0.020
Barrier radius	3914.9±4.3	0.083±0.011	0.283±0.034	0.247±0.041	0.176±0.037	0.087±0.025
$f_2(1270)$ amplitude	3916.4±4.8	0.085±0.012	0.229±0.038	0.226±0.047	0.170±0.041	0.070±0.023

Summary of systematic uncertainties in percentage

Sources	Mass	g_1'	$\pi^0 Z_c^0$ fraction			
			4.2263	4.2357	4.2438	4.2580
Event selection	0.01	1.2	3.0	1.1	2.7	2.3
σ-ZB parametrization	0.06	11.0	44.3	10.7	10.6	0.9
σ-PKU parametrization	0.2	3.3	5.1	6.4	30.6	35.5
Z_c^0 parametrization	0.5	-	43.3	14.1	13.8	15.6
$f_0(980)$ Coupling constant	0.01	0.9	1.1	1.0	1.0	0.2
$f_0(1370)$ parametrization	0.02	2.9	1.2	1.5	2.6	0.9
Barrier radius	0.03	7.6	1.2	5.6	3.2	26.1
Mass resolution	0.01	2.6	0.1	0.2	0.1	0.4
$f_2(1270)$ amplitude	0.07	11.3	18.3	3.2	0.4	2.2
Total	0.55	18.3	64.9	20.0	35.6	46.9

$e^+e^- \to \pi^0 Z_c(3900)^0$ cross section

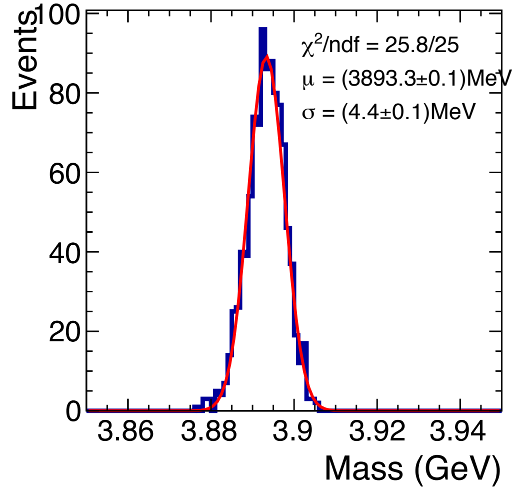


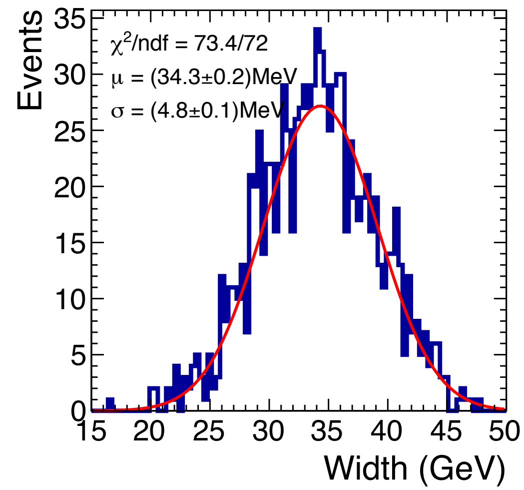


$\sqrt{s}$	$R_{Z_c^0}$	$\sigma_{e^+e^- \to \pi^0 Z_c^0}(pb)$
4180	0.285±0.053± 0.185	1.38±0.27± 0.90
4190	0.309±0.106± 0.201	2.04±0.74± 1.33
4200	0.504±0.111± 0.327	5.30±1.27± 3.45
4210	0.148±0.060± 0.096	3.36±1.38± 2.19
4220	0.238±0.056± 0.154	7.65±1.85± 4.98
4230	0.280±0.034± 0.182	10.83±1.68± 2.24
4237	0.234±0.041± 0.047	8.25±1.40± 2.97
4246	0.171±0.038± 0.061	4.49±1.31± 2.92
4260	0.069±0.021± 0.032	1.59±1.70± 1.04
4270	0.230±0.049± 0.149	8.74±1.33± 5.69
4280	0.111±0.073± 0.072	3.33±0.65± 1.57

Systematic uncertainty | Z_c^0 pole mass

- **Statistic error:** Pole mass: (3893.3 ± 4.4±11.4)-i(34.3±4.8±13.7)
  - use multi-variable Gaussian function to sample by considering the error matrix
  - 1000 samples of mass and g_1' to calculate the pole mass
  - Fit to pole mass distribution with Gaussian function





- **Systematic error:**
  - consider all the sources discussed in systematic uncertainty study for $e^+e^- \to \pi^0 Z_c^0$ parameters and fraciton

Summary

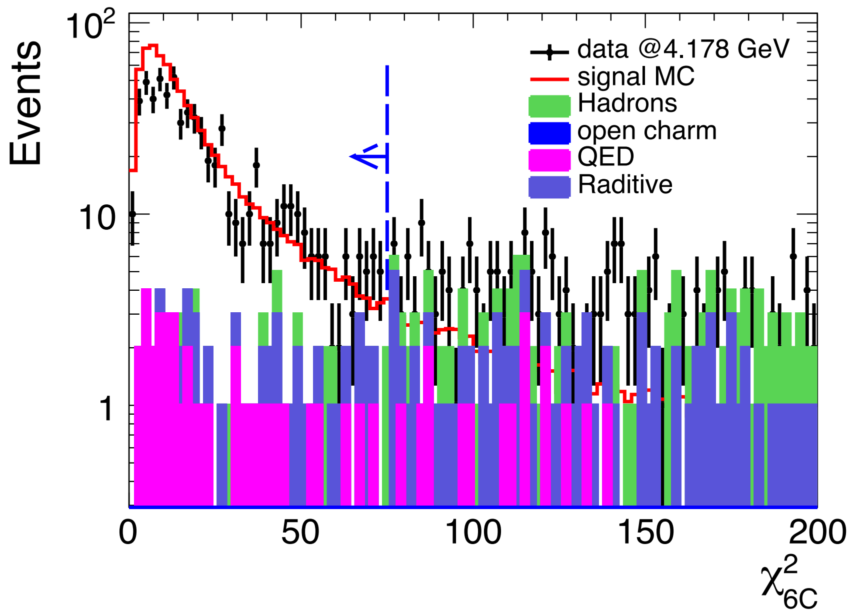
- Measure the cross section of $e^+e^- \to \pi^0\pi^0 J/\Psi$ from 3.81~4.60 GeV, which is consistent with half of those cross section of $e^+e^- \to \pi^+\pi^- J/\Psi$
- Fitting to the measured $e^+e^- \to \pi^0\pi^0 J/\Psi$ cross section line shape gives the mass and width of Y(4220) to be $(4220.4\pm3.1\pm1.0)\mathrm{MeV}/c^2$ and $(49.0\pm4.3\pm1.8)\mathrm{MeV}/c^2$, and shows the evidence of Y(4320) with 4.1σ
- Amplitudes analysis is applied to $\pi^0\pi^0 J/\Psi$ and the spin and parity of $Z_c(3900)^0$ is measured to be 1^+, and the pole mass of $Z_c(3900)^0$ is $(3893.3 \pm 4.4\pm11.4)-i(34.3\pm4.8\pm13.7)$ MeV/c^2
- $e^+e^- \to \pi^0 Z_c(3900)^0$ component is extracted from PWA, ratio to $\pi^0\pi^0 J/\Psi$ cross section is given.

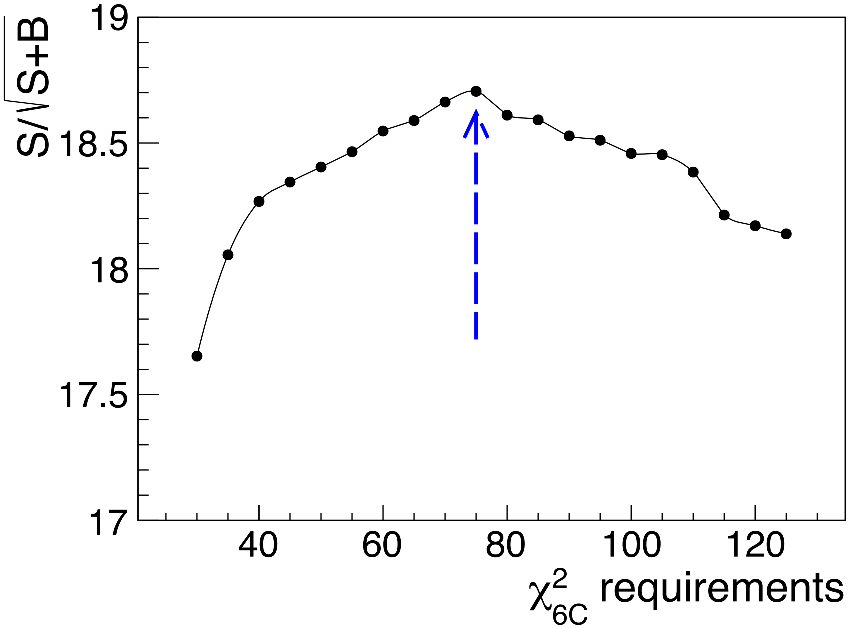
▶ Memo has been finished and will be released soon

Thanks!

Back up

χ^2_{6C} distribution

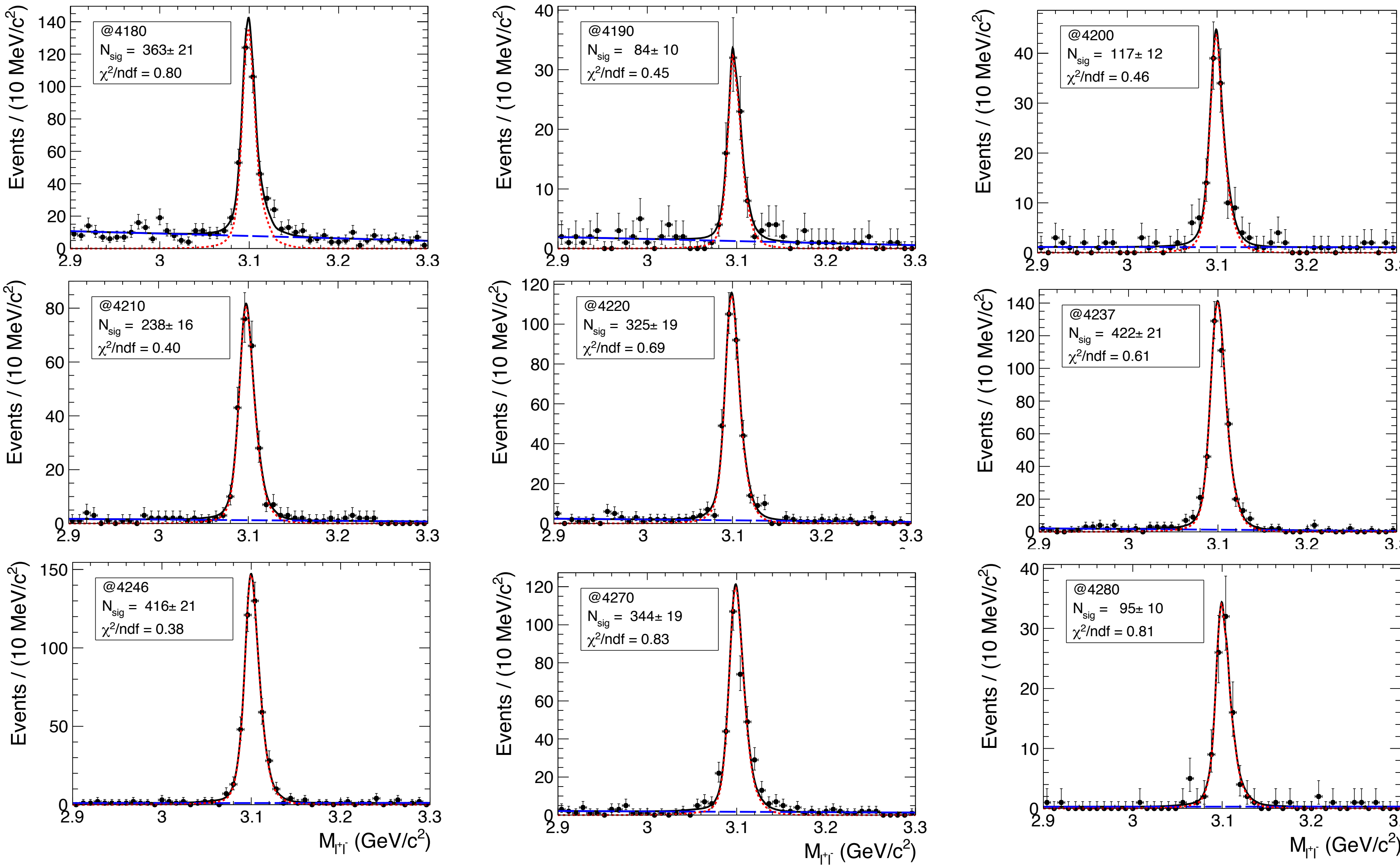




Signal extraction for $e^+e^- \to \pi^0\pi^0 J/\psi$

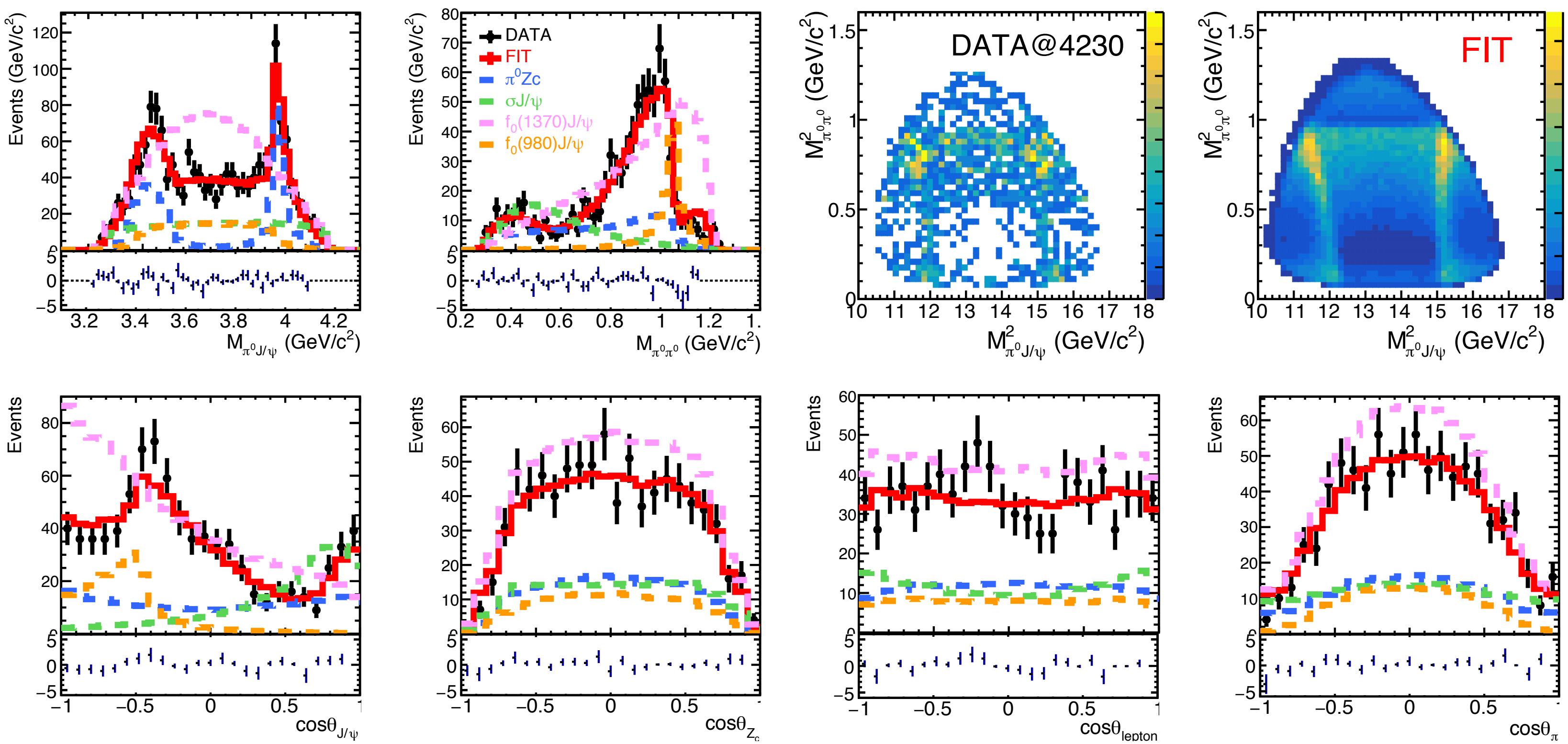
MC shape ⊗ Gaussian + 1st polynomial

For data taken in 2016/2017



PWA results

$Z_c(1^+)$	M (MeV/c^2)	g'_1	g'_2/g'_1	-ln$L$
$\pi^0\pi^0 J/\psi$	3913.7± 4.2	0.077 ±0.010	27.1(fixed)	-30471.0
$\pi^0\pi^0 J/\psi$	3915.2± 4.2	0.069±0.018	31.9±7.8	-30471.1
$\pi^+\pi^- J/\psi$	3901.5± 2.7	0.075±0.006	27.1± 2.0	...



PWA results

Significance to distinguish the quantum number $J^P = 1^+$ over other different J^P.

J^P	$\Delta(-2\ln L)$	N_{par}	significance
0^-	-163.6	$4\times4+5$	$10.1\,\sigma$
1^-	-172.9	$4\times4+5$	$10.5\,\sigma$
2^+	-160.0	$4\times4+5$	$10.0\,\sigma$
2^-	-122.1	$4\times4+5$	$8.2\,\sigma$