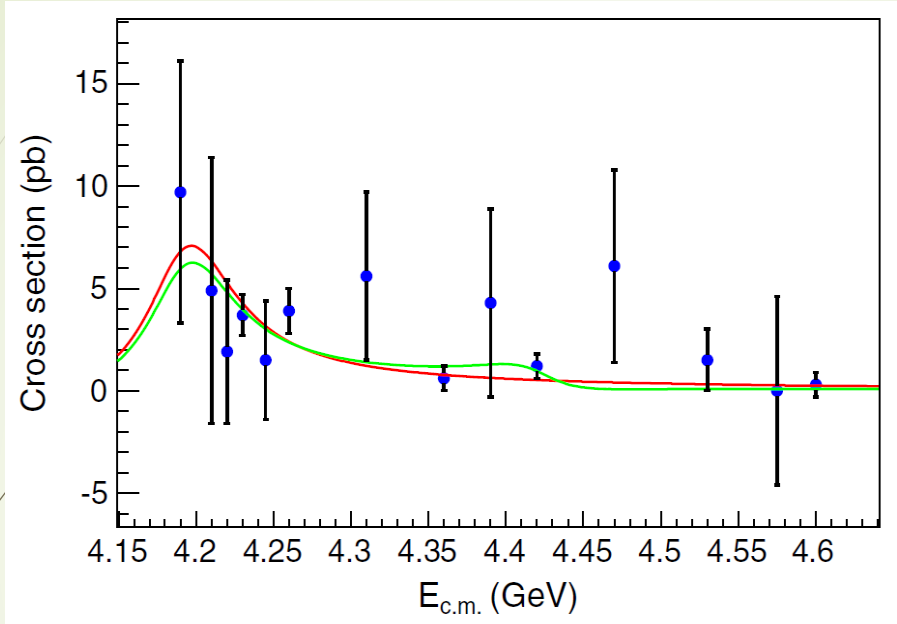
Study of $e^+e^- \to \eta' J/\psi$ around $\sqrt{s} = 4.2$ GeV

Jielei Zhang Jingzhi Zhang

Outline

1、Motivation
2、Data sets
3、Event selection
4、MC and data analysis
5、Cross section measurement
6、Summary

Motivation



PRD 94.032009

- BESIII has observed the process $e^+e^- \to \eta' J/\psi$ above 4 GeV. From the line-shape of $e^+e^- \to \eta' J/\psi$, it shows $\eta' J/\psi$ mainly comes from $\psi(4160)$.
- Now BESIII has collected many data samples around $\sqrt{s}$ =4.2 GeV, it can be used to check whether $\eta' J/\psi$ mainly comes from $\psi(4160)$.
- The η'-transition process between charmonium may provide information that is useful in understanding the nature of charmonium.

Data sets

Boss Version : 7.0.2p01

Data sets :
Data around $\sqrt{s} = 4.2$ (4.18, 4.19, 4.20, 4.21, 4.22, 4.237, 4.247, 4.27, 4.28) GeV

Signal MC :

1、 $e^+e^- \to \eta' J/\psi,\ \eta' \to \pi^+\pi^-\eta,\ \eta \to \gamma\gamma$
2、 $e^+e^- \to \eta' J/\psi,\ \eta' \to \gamma\pi^+\pi^-$

Background MC :

1、 $e^+e^- \to \pi^+\pi^-\psi',\ \psi' \to \eta J/\psi$
2、 $e^+e^- \to \gamma_{ISR}\psi',\ \psi' \to \pi^+\pi^- J/\psi$

Data at $\sqrt{s} = 4.18$ GeV

$$e^+e^- \to \eta' J/\psi,\ \eta' \to \pi^+\pi^-\eta,\ \eta \to \gamma\gamma$$

Event selections

Charged tracks
- $|R_{xy}| < 1cm, |R_z| < 10cm$
- $|cos\theta| < 0.93$
- $N = 4, \sum Q = 0$

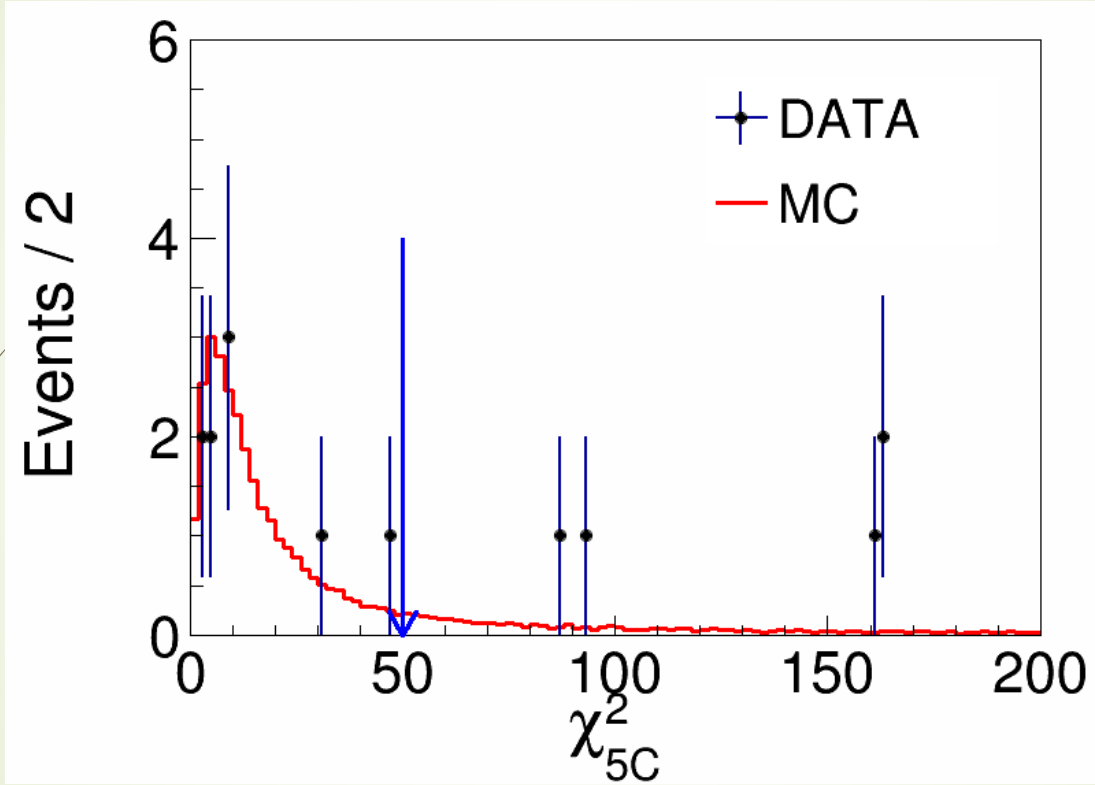
Particle separation
- π : $P_{mdc} < 1$ GeV
- e : $P_{mdc} > 1$ GeV&&$E_{emc} > 1$ GeV
- μ : $P_{mdc} > 1$ GeV&&$E_{emc} < 0.4$ GeV

Good photon
- $0 \leq TDC \leq 14$
- Barrel :
  $E > 0.025$ GeV, $|cos\theta| < 0.8$
- Endcap :
  $E > 0.050$ GeV, $0.86 < |cos\theta| < 0.92$
- $\Delta\theta > 20^0$
- $N_\gamma \geq 2$

5C kinematic fit
- $\mathrm{M}(\gamma\gamma)$ is constrained to $\mathrm{M}(\eta)$
- Choose the photons with least χ^2
- $\chi^2_{5C} < 50$

Other selections
- J/ψ mass window : (3.08, 3.12) GeV
- $M(\eta J/\psi) < 3.675 || M(\eta J/\psi) > 3.695$ GeV

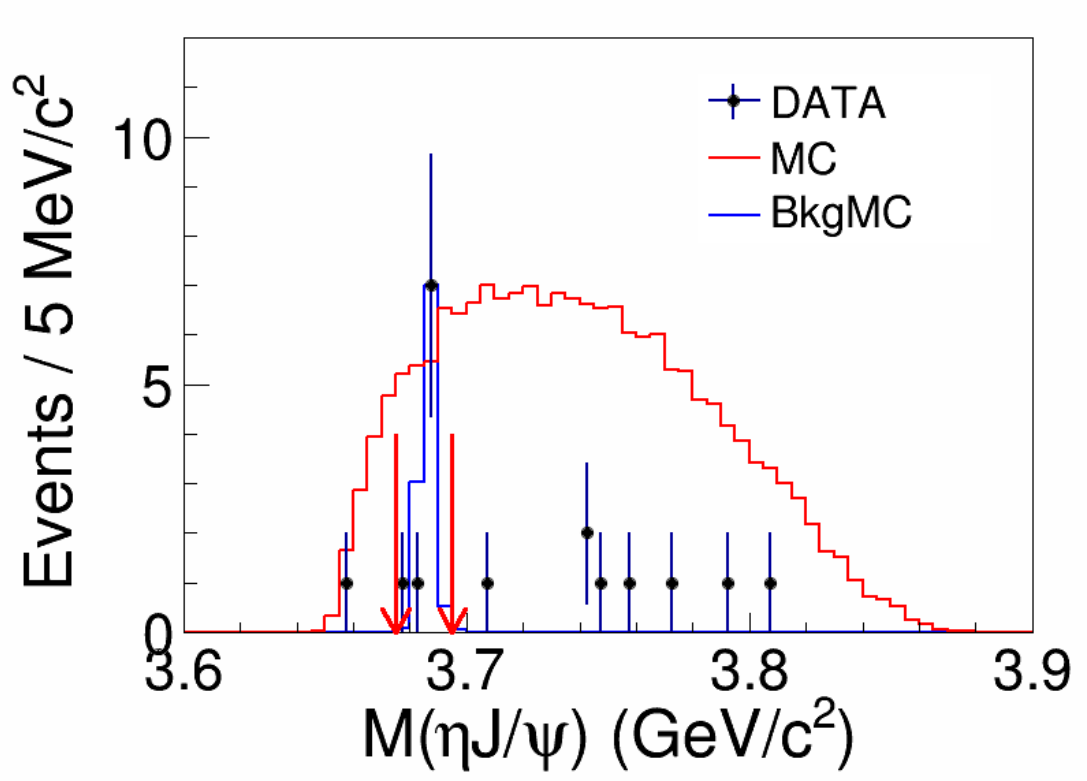
The χ^2_{5C} of kinematic fit



χ^2 distribution from 5C : $\chi^2_{5C} < 50$

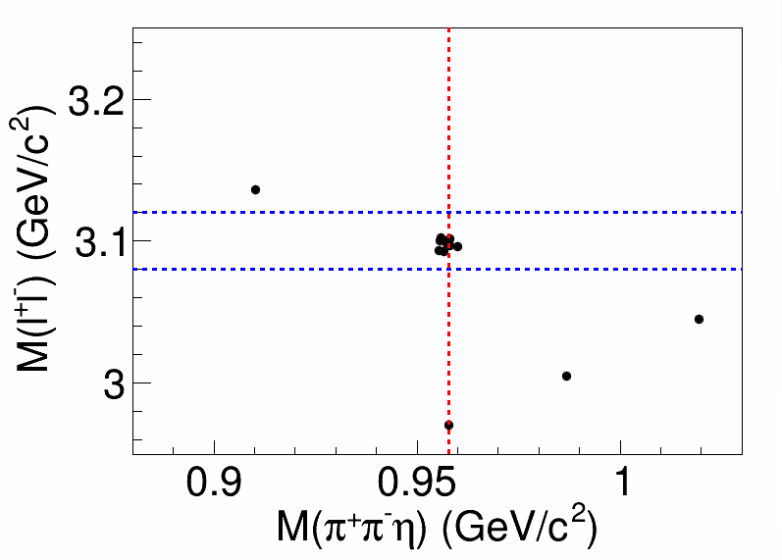
Background study

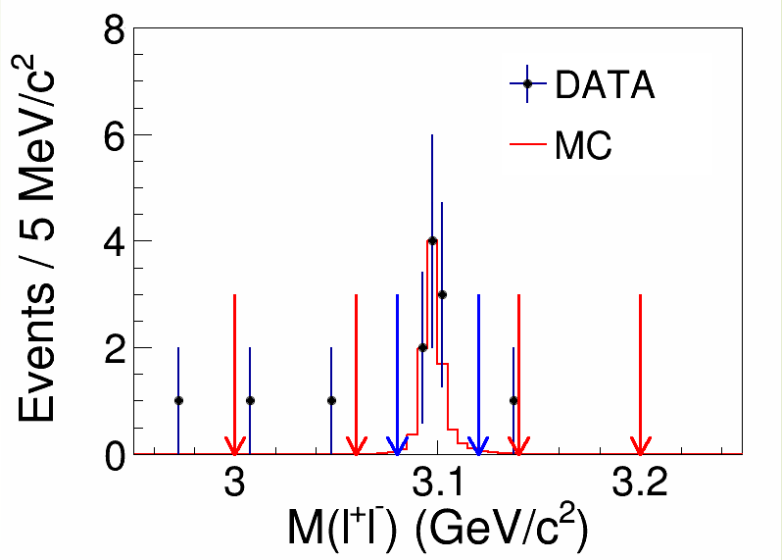
BkgMC: $e^+e^- \to \pi^+\pi^-\psi', \psi' \to \eta J/\psi$

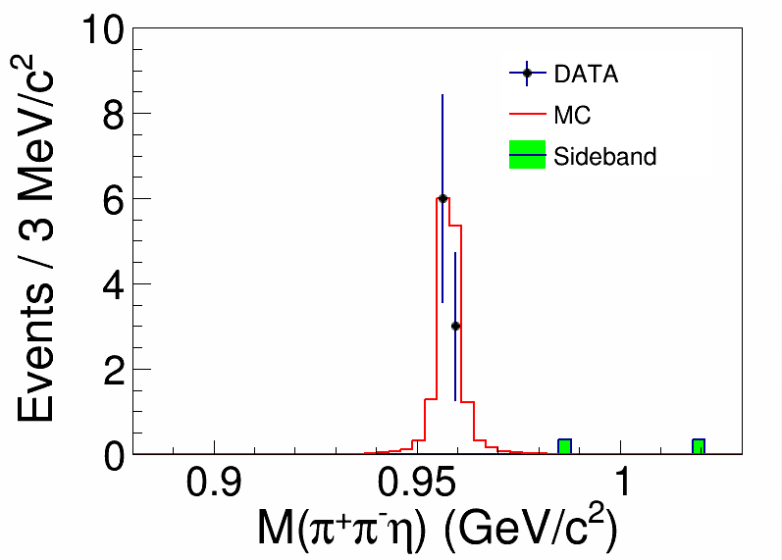


$M(\eta J/\psi) < 3.675 || M(\eta J/\psi) > 3.695$ GeV

Some plots from data

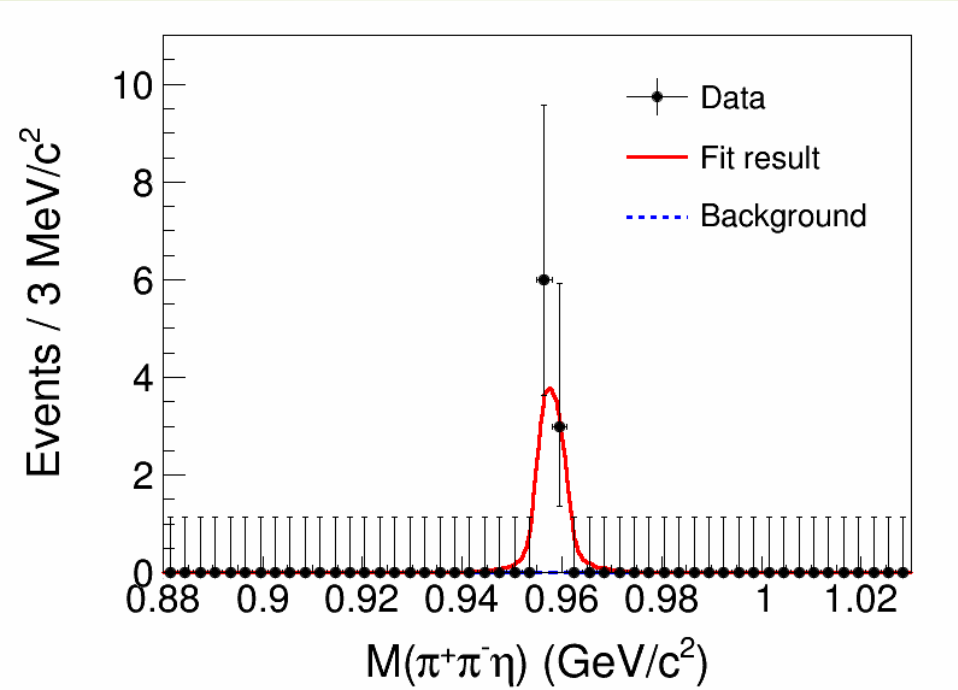






- J/ψ mass window : (3.08, 3.12) GeV
- Sideband regions :
  $3.00 \leq M(l^+l^-) \leq 3.06\ \mathrm{GeV}/c^2$ and
  $3.14 \leq M(l^+l^-) \leq 3.20\ \mathrm{GeV}/c^2$

Signal extraction from data



Signal :

MC-determined signal MC shape to describe

Background :

1st-order Polynomial function

$$N^{sig} = 9.0 \pm 3.0 \qquad S > 5\sigma$$

$$e^+e^- \to \eta' J/\psi, \eta' \to \gamma\pi^+\pi^-$$

Event selections

Charged tracks
- $|R_{xy}| < 1cm, |R_z| < 10cm$
- $|cos\theta| < 0.93$
- $N = 4, \sum Q = 0$

Particle separation
- π : $P_{mdc} < 1$ GeV
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Good photon
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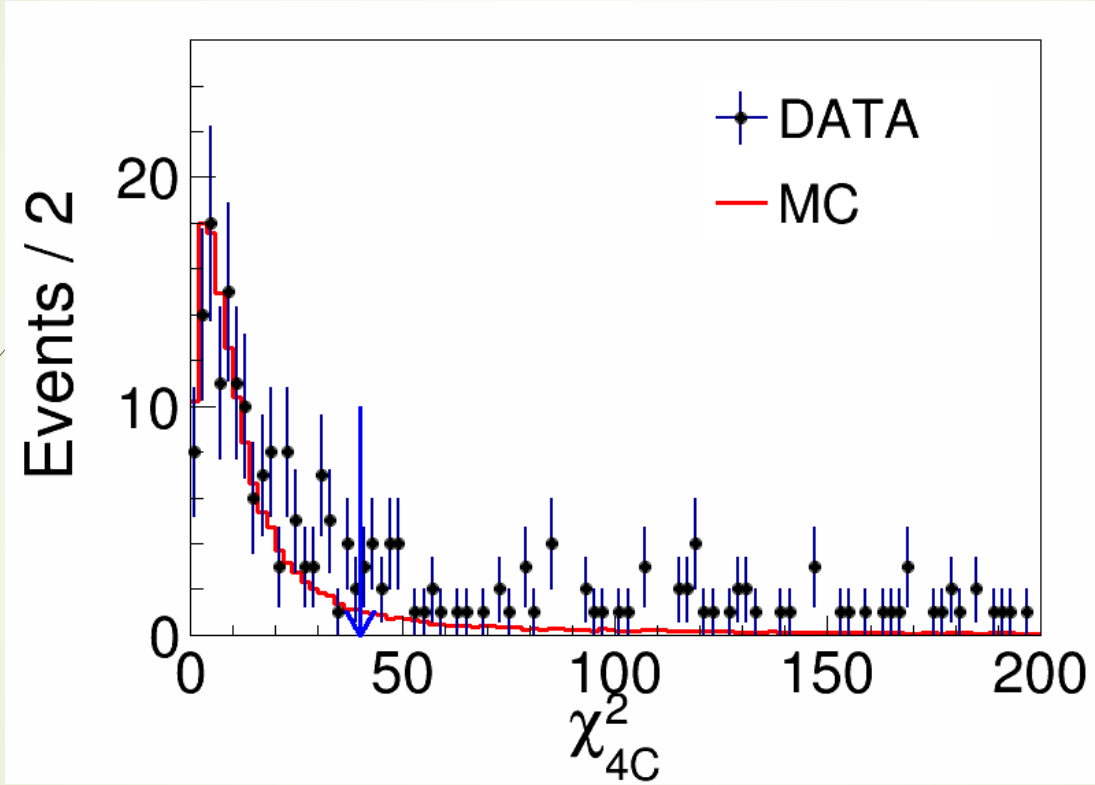
- Endcap :
  $E > 0.050$ GeV, $0.86 < |cos\theta| < 0.92$
- $\Delta\theta > 20^0$
- $N_\gamma \geq 1$

4C kinematic fit
- Choose the photons with least χ^2
- $\chi^2_{4C} < 40$

Other selections
- J/ψ mass window : (3.08, 3.12) GeV
- $M(\pi^+\pi^- J/\psi) < 3.67 || M(\pi^+\pi^- J/\psi) > 3.70$ GeV
- $M(\pi^+\pi^- J/\psi) < 3.855 || M(\pi^+\pi^- J/\psi) > 3.885$ GeV

The χ^2_{4C} of kinematic fit

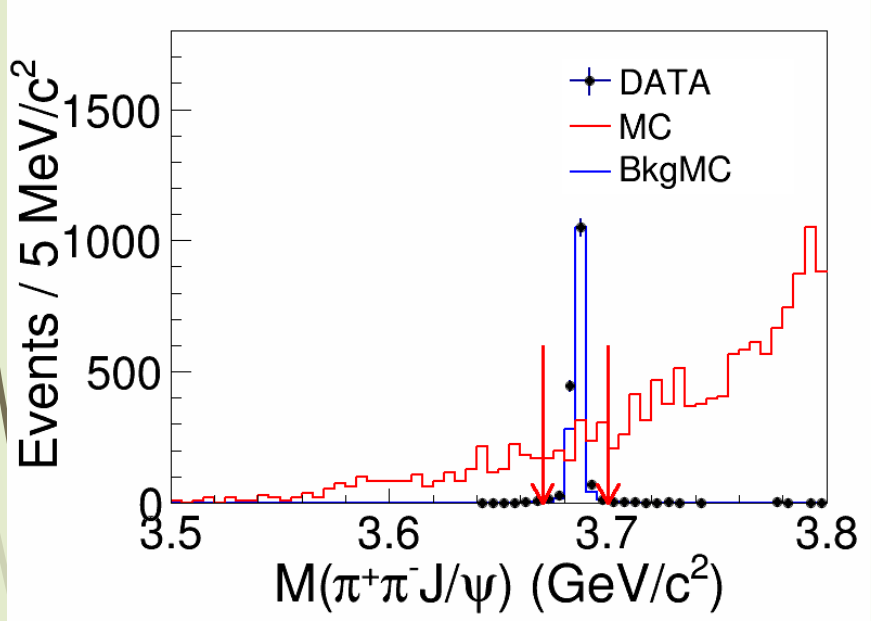


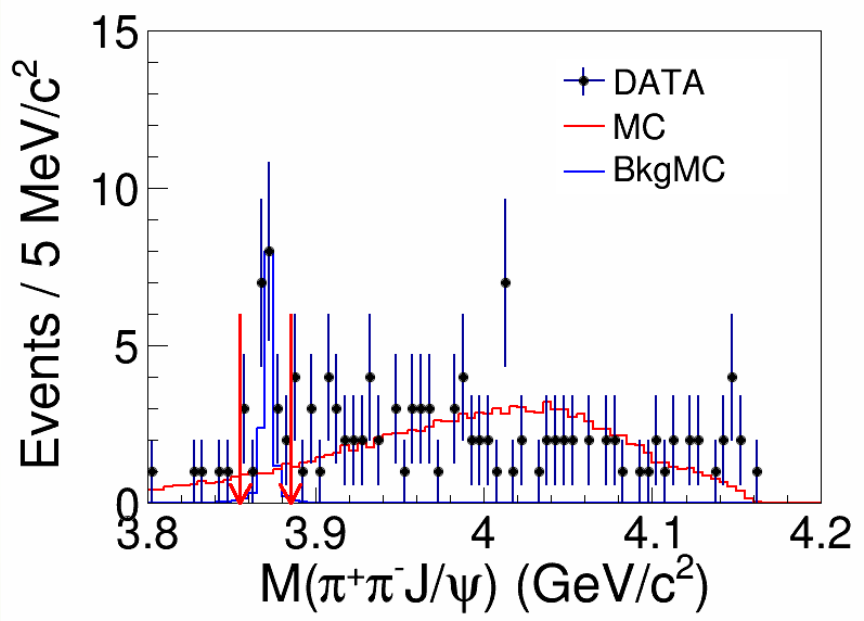
χ^2 distribution from 4C : $\chi^2_{4C} < 40$

Background study

Bkg: $e^+e^- \to \gamma_{ISR}\psi'$, $\psi' \to \pi^+\pi^- J/\psi$

$e^+e^- \to \gamma X(3872)$, $X(3872) \to \pi^+\pi^- J/\psi$



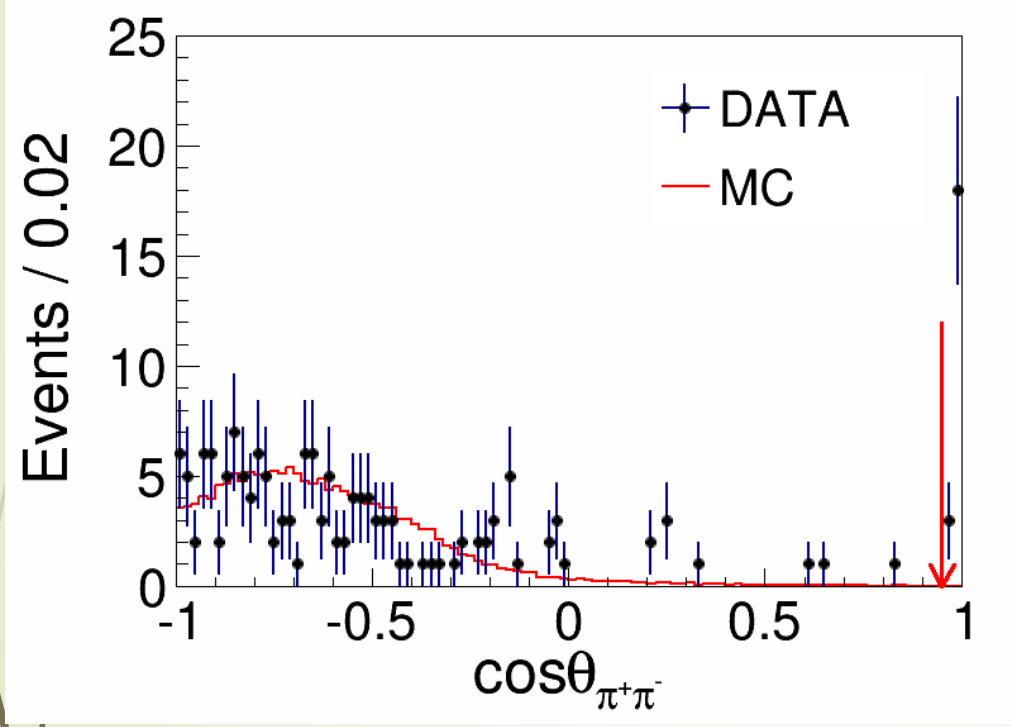


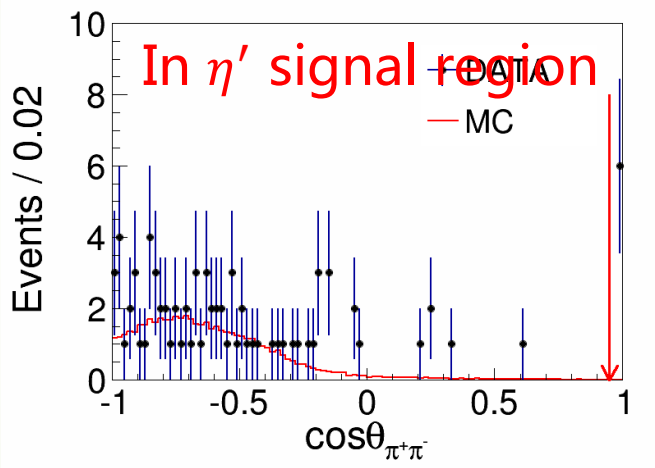
$M(\pi^+\pi^- J/\psi) < 3.67 || M(\pi^+\pi^- J/\psi) > 3.70$ GeV

$M(\pi^+\pi^- J/\psi) < 3.855 || M(\pi^+\pi^- J/\psi) > 3.885$ GeV

Background study

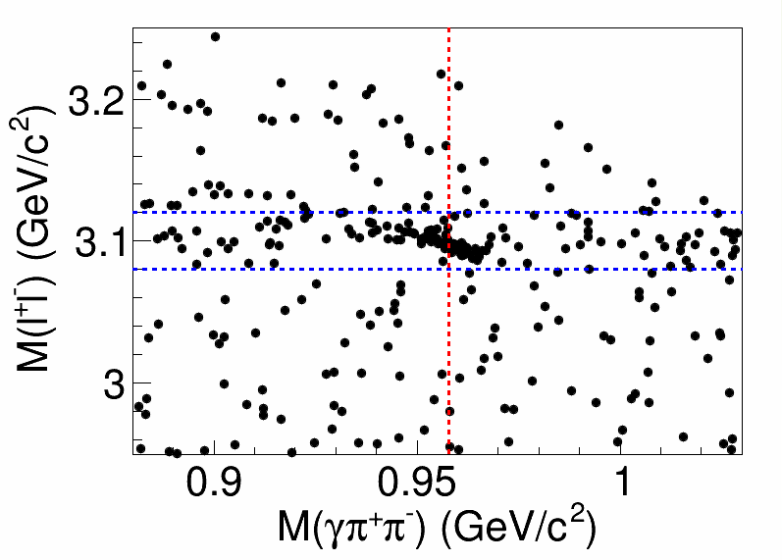
γ conversion background

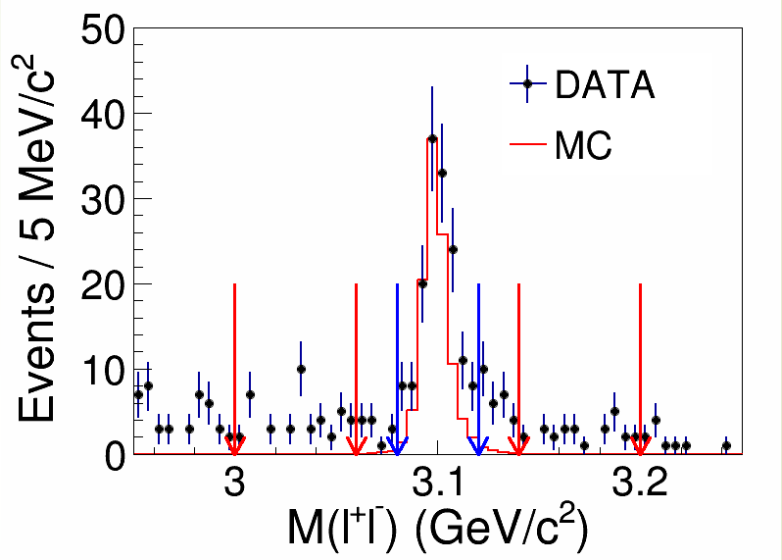


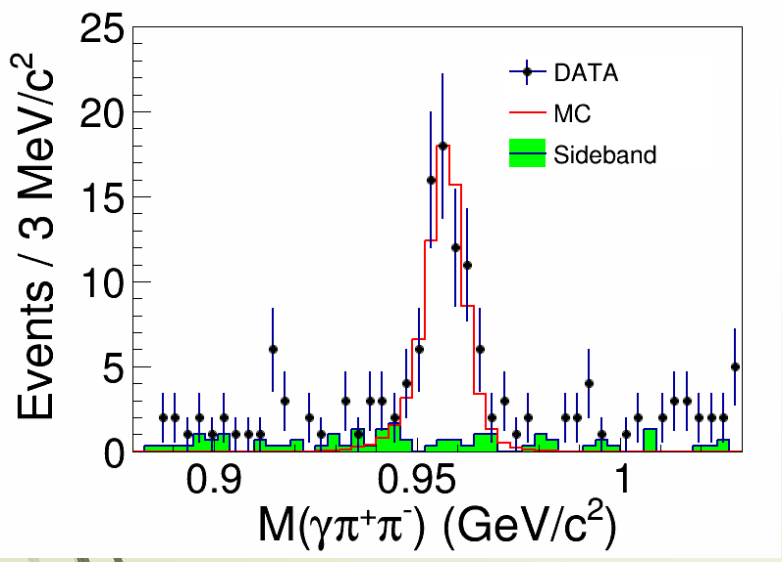


$$cos\theta_{\pi^+\pi^-} < 0.95$$

Some plots from data







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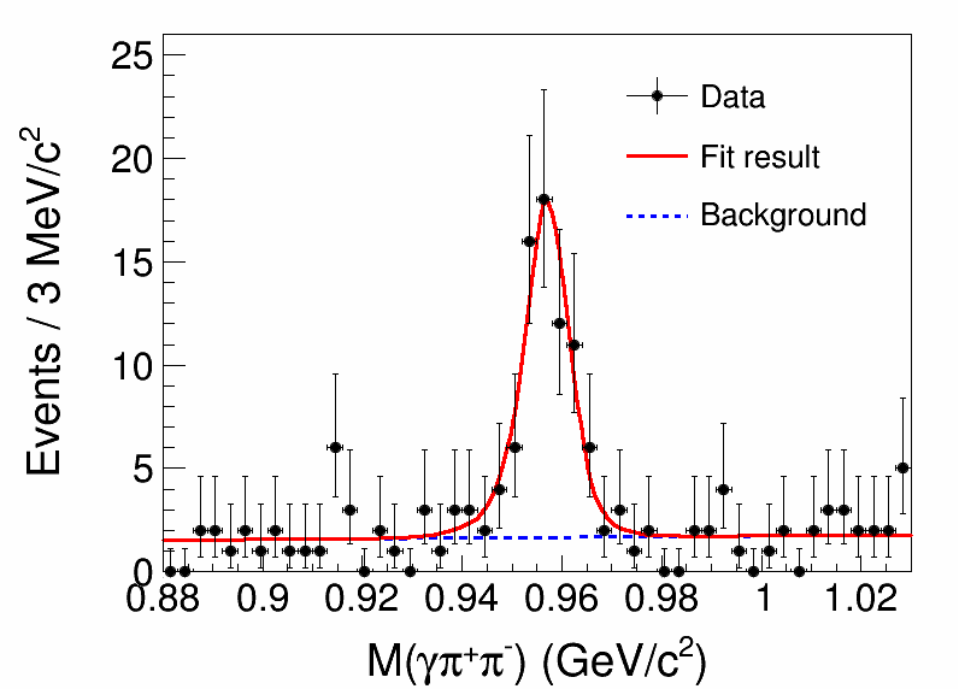
Signal extraction from data



Signal :

MC-determined signal MC shape to describe

Background :

1st-order Polynomial function

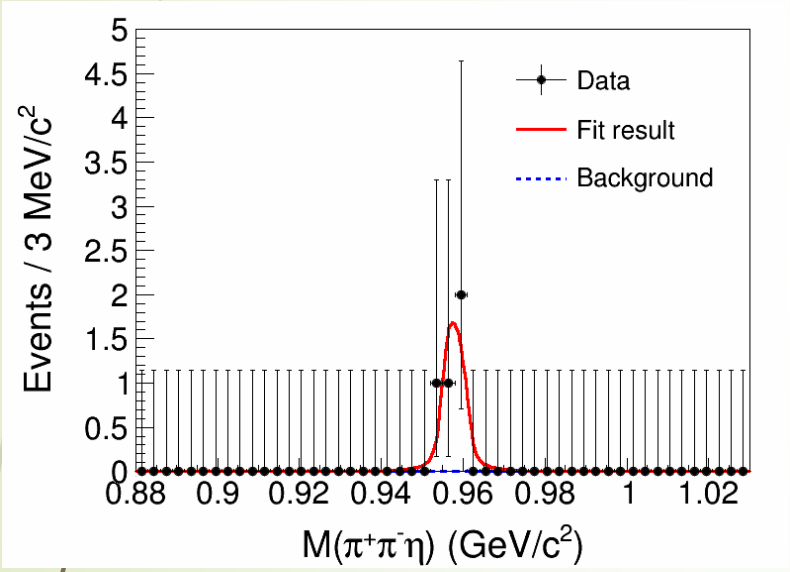
$$N^{sig} = 66.6 \pm 9.2 \qquad S > 5\sigma$$

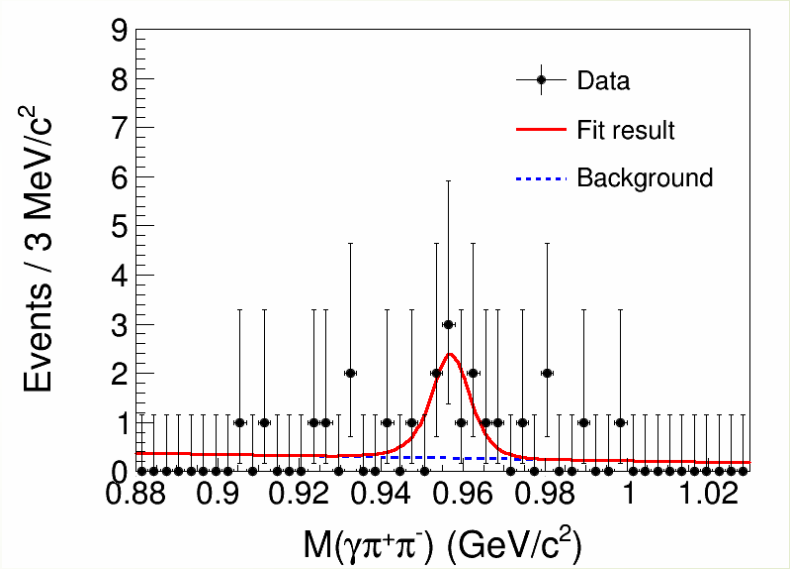
Combine two results

$$\sigma^B(e^+e^- \to \eta' J/\psi) = \frac{N^{sig1} + N^{sig2}}{\mathcal{L}_{int}(1+\delta(s))\frac{1}{|1-\Pi|^2}\mathcal{B}(J/\psi \to l^+l^-)(\mathcal{B}(\eta' \to \pi^+\pi^-\eta)\mathcal{B}(\eta \to \gamma\gamma)\epsilon_{\pi^+\pi^-\eta} + \mathcal{B}(\eta' \to \gamma\pi^+\pi^-)\epsilon_{\gamma\pi^+\pi^-})}$$

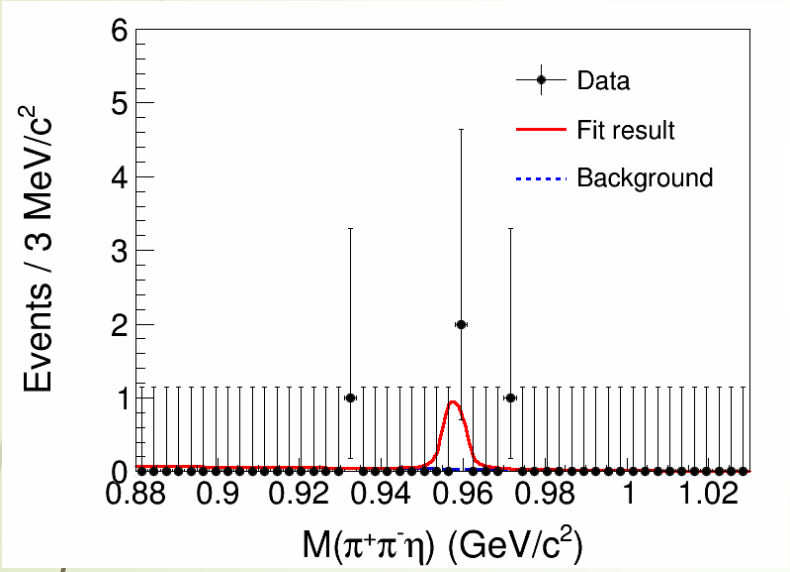
$\sqrt{s}$(GeV)	$\mathcal{L}_{int}$(pb^{-1})	N^{sig1}	N^{sig2}	$1+\delta$(s)	$\frac{1}{\lvert 1-\Pi\rvert^2}$	$\epsilon_{\pi^+\pi^-\eta}(\%)$	$\epsilon_{\gamma\pi^+\pi^-}(\%)$	σ^B(pb)
4.18	3189.0	9.0±3.0	66.6±9.2	0.723	1.055	14.30	29.26	2.4 ± 0.3

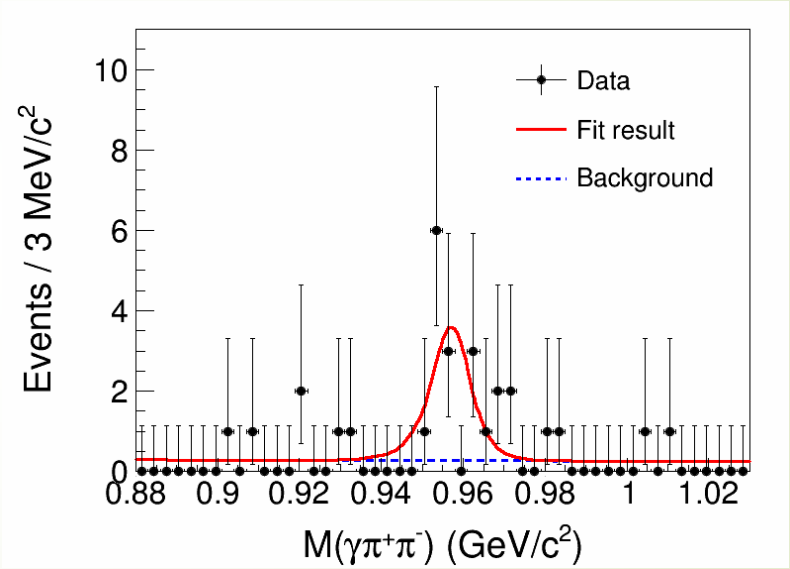
Data at $\sqrt{s} = 4.19$ GeV



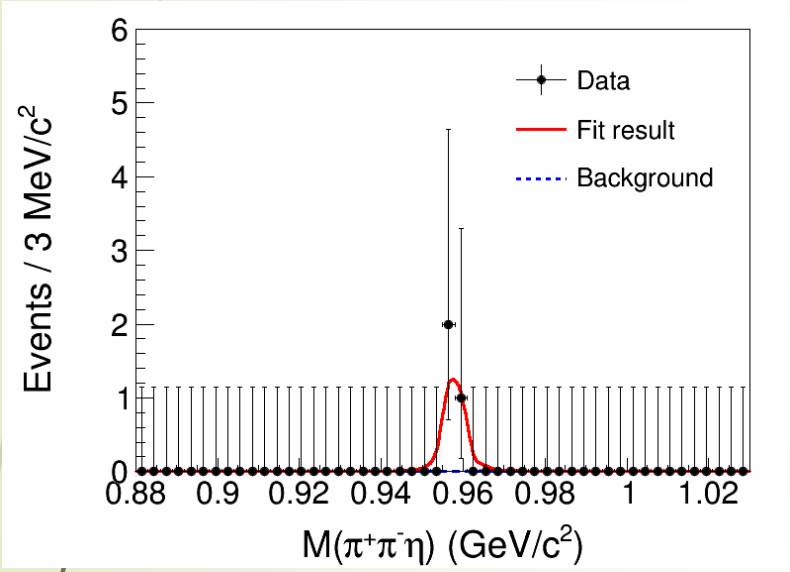


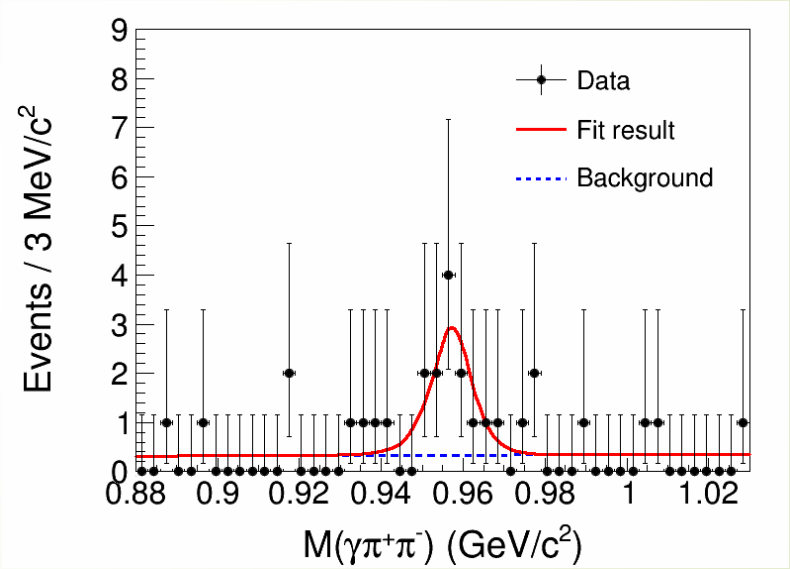
Data at $\sqrt{s} = 4.20$ GeV



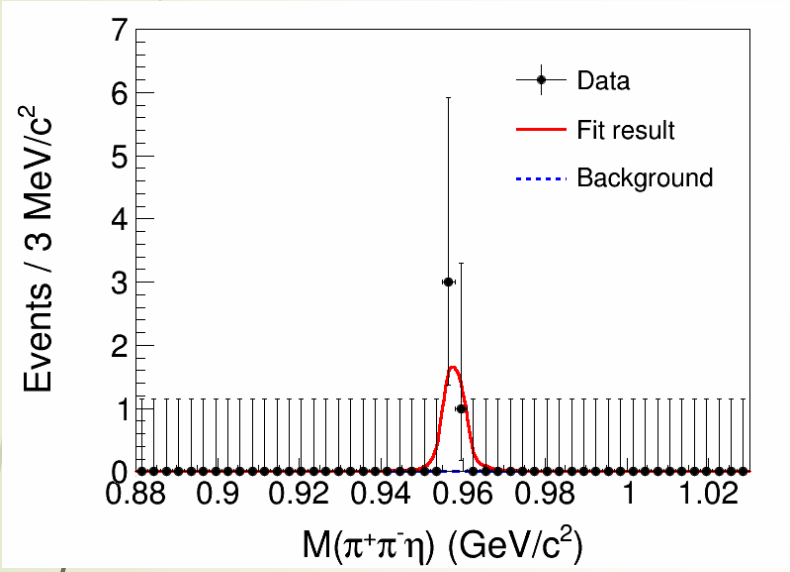


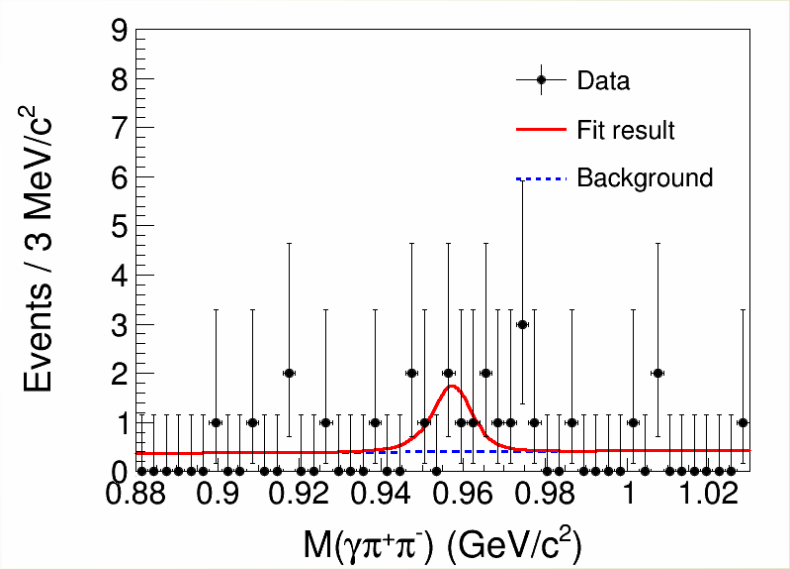
Data at $\sqrt{s} = 4.21$ GeV



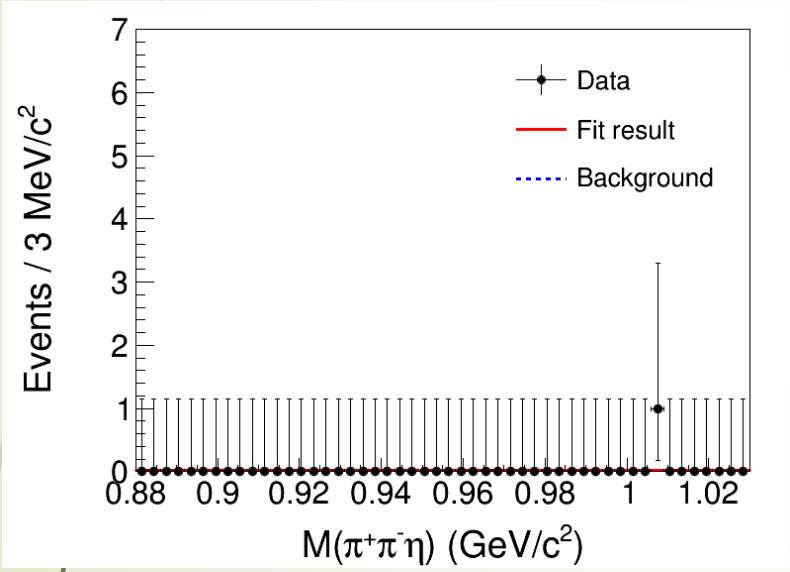


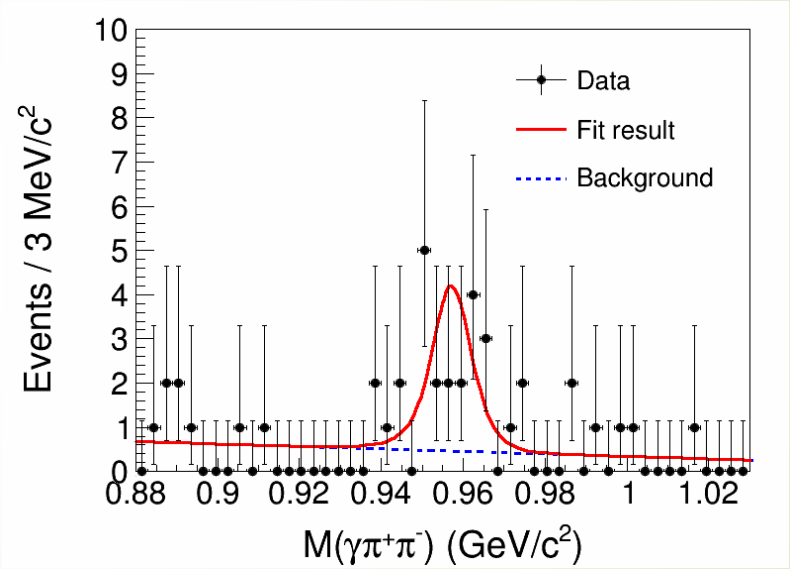
Data at $\sqrt{s} = 4.22$ GeV



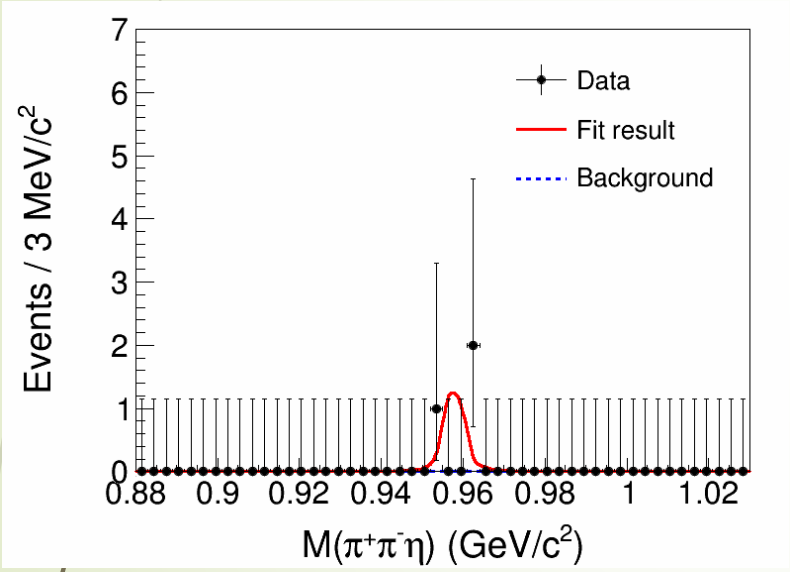


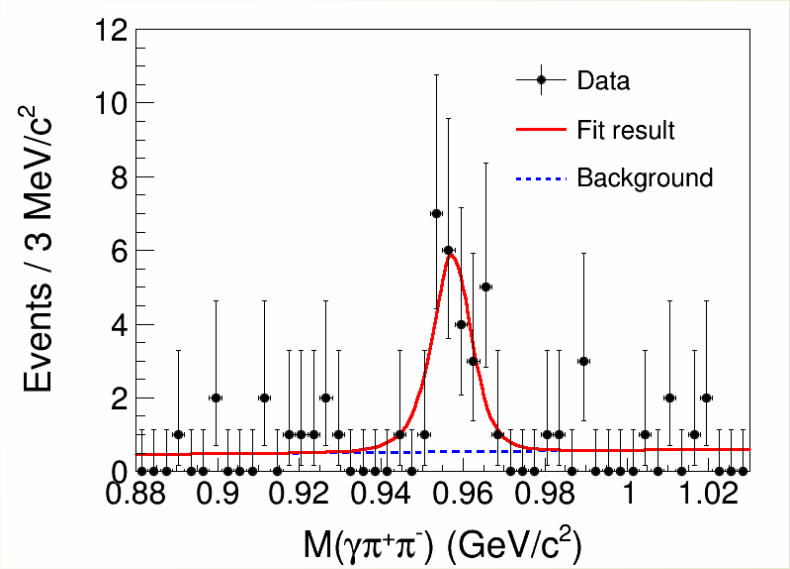
Data at $\sqrt{s} = 4.237$ GeV



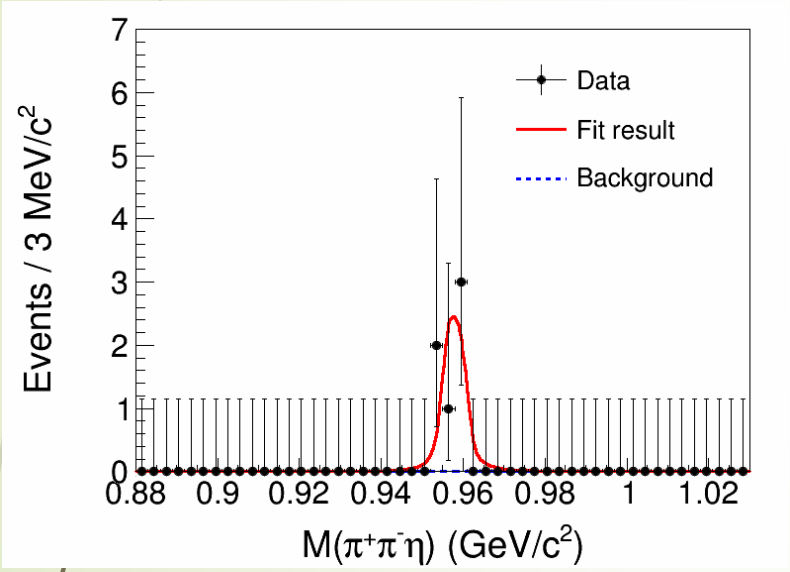


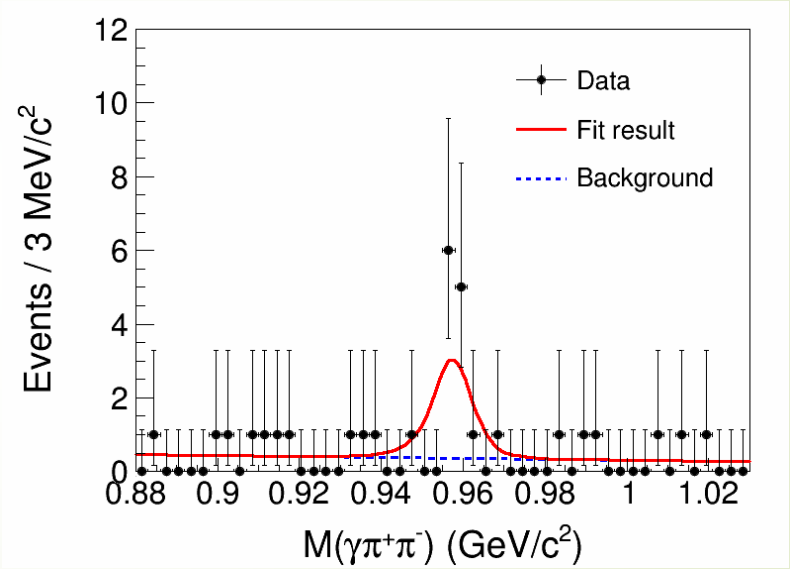
Data at $\sqrt{s} = 4.247$ GeV



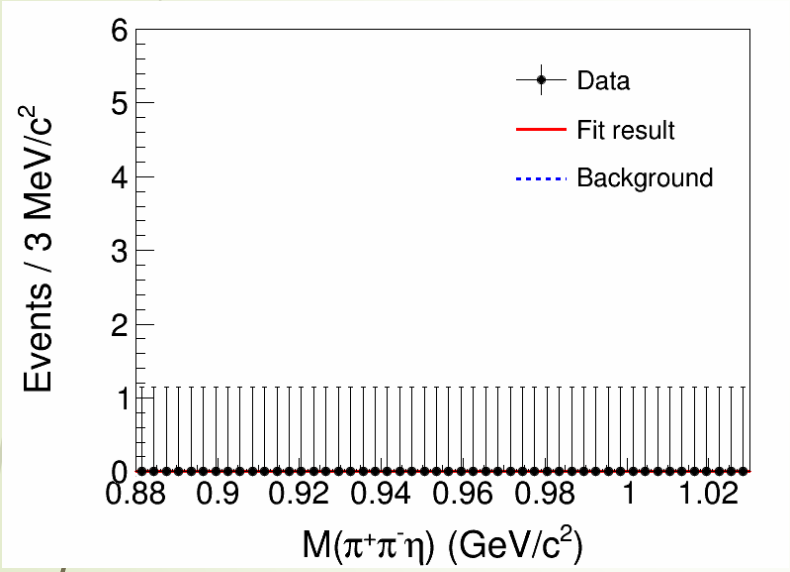


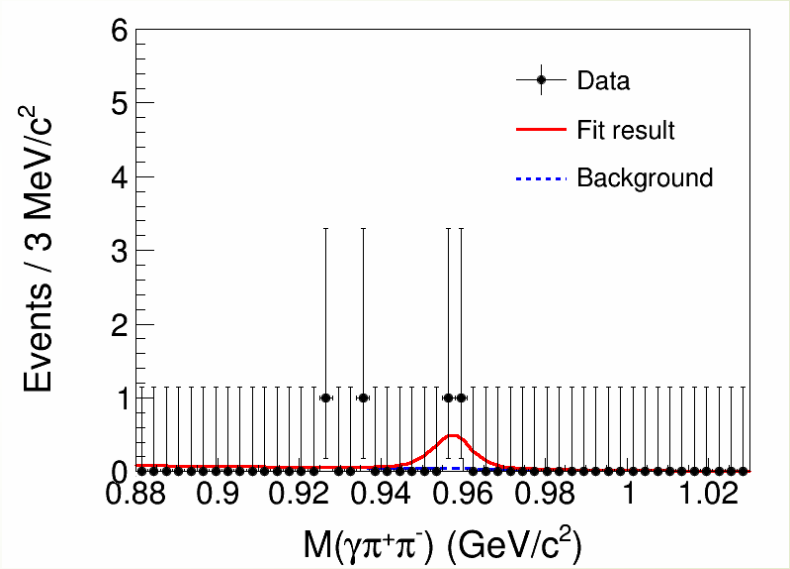
Data at $\sqrt{s} = 4.27$ GeV





Data at $\sqrt{s} = 4.28$ GeV





Cross section measurement

$$e^+e^- \to \eta' J/\psi$$

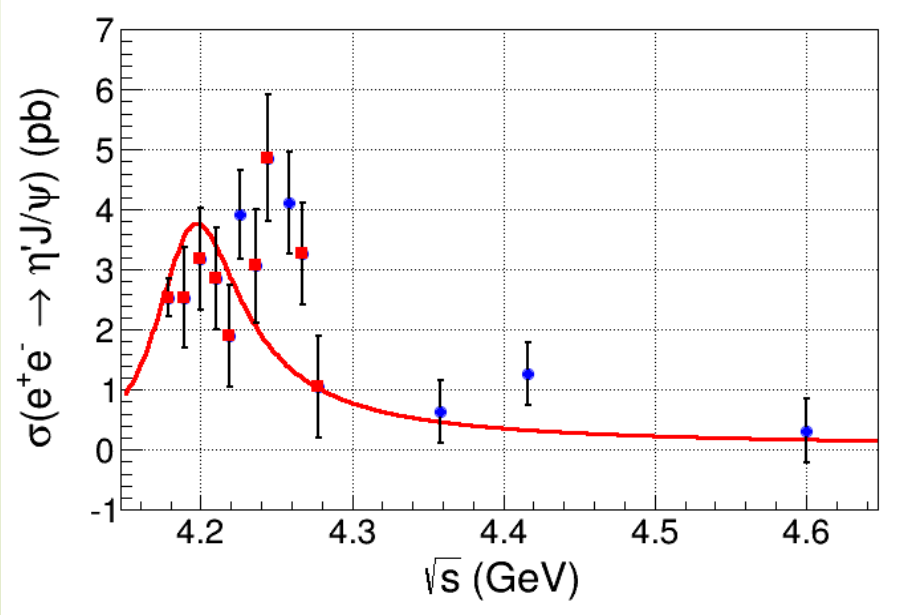
$\sqrt{s}$(GeV)	$\mathcal{L}_{int}$(pb^{-1})	N^{sig1}	N^{sig2}	$1+\delta(s)$	$\frac{1}{\lvert 1-\Pi\rvert^2}$	$\epsilon_{\pi^+\pi^-\eta}(\%)$	$\epsilon_{\gamma\pi^+\pi^-}(\%)$	σ^B(pb)
4.18	3189.0	9.0±3.0	66.6±9.2	0.723	1.055	14.30	29.26	2.4 ± 0.3
4.19	521.9	4.0±2.0	9.1±3.6	0.734	1.056	14.72	30.01	2.4 ± 0.8
4.20	523.7	2.2±1.6	14.4±4.3	0.753	1.057	14.75	29.85	3.0 ± 0.8
4.21	511.2	3.0±1.8	11.3±4.0	0.773	1.057	13.82	29.13	2.7 ± 0.8
4.22	508.2	4.0±2.0	5.9±3.4	0.789	1.057	13.98	28.58	1.8 ± 0.8
4.237	528.9	0.0±1.2	16.5±4.9	0.807	1.056	13.94	27.92	2.9 ± 0.9
4.247	532.7	3.0±1.8	23.2±5.4	0.814	1.055	13.84	27.90	4.6 ± 1.0
4.27	529.3	6.0±2.5	11.7±3.9	0.842	1.053	13.59	27.55	3.1 ± 0.8
4.28	174.5	0.0±0.0	2.0±1.5	0.861	1.053	13.51	26.85	1.0 ± 0.8

Discussion

If we assume the $\eta' J/\psi$ signals all come from the $\psi(4160)$ decay, the cross section is fitted with the following formula:

$$\sigma(\sqrt{s}) = |\mathcal{A}_{\psi(4160)}(\sqrt{s})\sqrt{\frac{\Phi^3(\sqrt{s})}{\Phi^3(M)}}|^2$$

$$\mathcal{A}_{\psi(4160)}(\sqrt{s}) = \frac{\sqrt{12\pi\Gamma_{ee}\Gamma_{tot}\mathcal{B}(\psi(4160)\to\eta' J/\psi)}}{s-M^2+iM\Gamma_{tot}}$$



$\chi^2/ndf = 37.7/13$

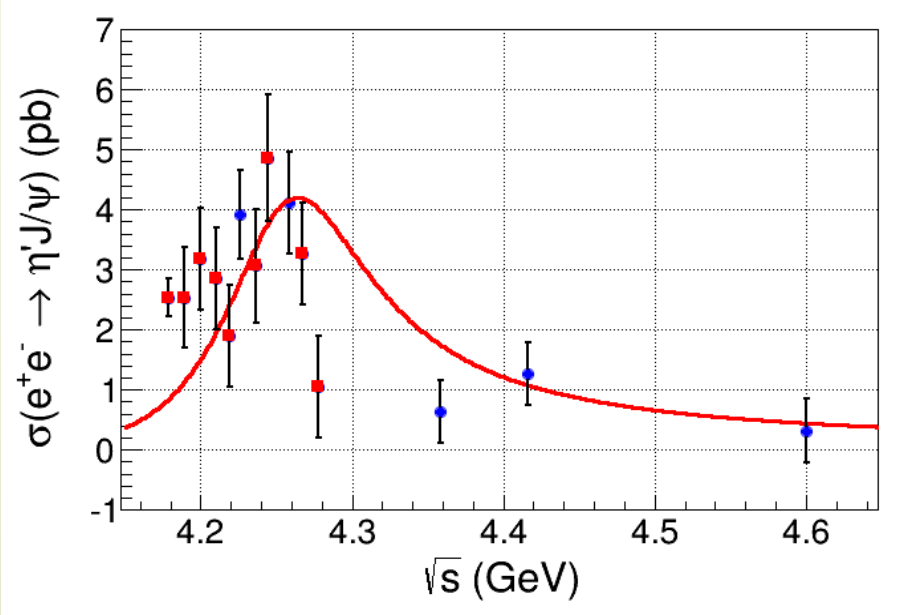
Only a $\psi(4160)$ resonance can' t describe the $e^+e^- \to \eta' J/\psi$ line-shape very well.

Discussion

If we assume the $\eta' J/\psi$ signals all come from the $Y(4260)$ decay, the cross section is fitted with the following formula:

$$\sigma(\sqrt{s}) = |\mathcal{A}_{Y(4260)}(\sqrt{s})\sqrt{\frac{\Phi^3(\sqrt{s})}{\Phi^3(M)}}|^2$$

$$\mathcal{A}_{Y(4260)}(\sqrt{s}) = \frac{\sqrt{12\pi\Gamma_{ee}\Gamma_{tot}\mathcal{B}(Y(4260)\to\eta' J/\psi)}}{s-M^2+iM\Gamma_{tot}}$$



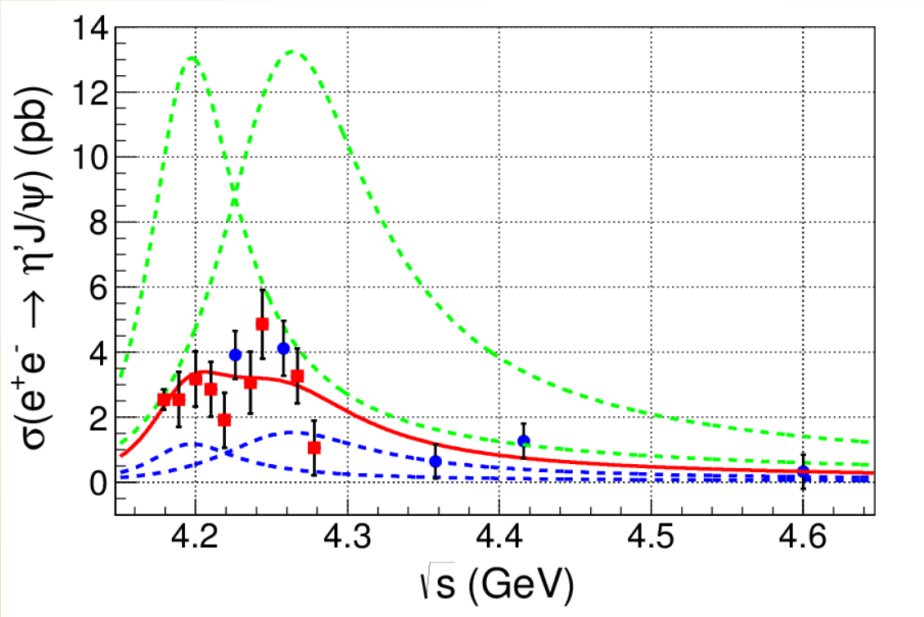
$\chi^2/ndf = 58.0/13$

Only a $Y(4260)$ resonance can' t describe the $e^+e^- \to \eta' J/\psi$ line-shape very well.

Iteration function

If we assume the $\eta' J/\psi$ signals come from the $\psi(4160)$ and $Y(4260)$ decay, the cross section is fitted with the following formula:

$$\sigma(\sqrt{s}) = |\mathcal{A}_{\psi(4160)}(\sqrt{s})\sqrt{\frac{\Phi_1^3(\sqrt{s})}{\Phi_1^3(M)}}e^{i\phi} + \mathcal{A}_{Y(4260)}(\sqrt{s})\sqrt{\frac{\Phi_2^3(\sqrt{s})}{\Phi_2^3(M)}}|^2$$



$\chi^2/ndf = 14.7/11$

A coherent sum of $\psi(4160)$ and $Y(4260)$ resonances can describe the $e^+e^- \to \eta' J/\psi$ line-shape.

Summary

1、Using data samples at $\sqrt{s} = 4.18, 4.19, 4.20, 4.21, 4.22, 4.237, 4.247, 4.27$ and 4.28 GeV, the cross section of the process $e^+e^- \to \eta' J/\psi$ is measured.

2、Only $\psi(4160)$ or $Y(4260)$ resonance can’t describe the line-shape very well, while a coherent sum of $\psi(4160)$ and $Y(4260)$ resonances can describe the $e^+e^- \to \eta' J/\psi$ line-shape.

Thanks for your attention!