Search for $h_c \to \pi^0 J/\psi$ using XYZ data

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1、Motivation
2、Data sets
3、Study of $h_c \to \pi^0 J/\psi$, $J/\psi \to e^+e^-/\mu^+\mu^-$
4、Study of $h_c \to \gamma\eta_c$, $\eta_c \to p\bar{p}$
5、Results
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Motivation

- In 1992, E760 Collaboration reported the observation of h_c in the $\pi^0 J/\psi$ decay mode. However, such an observation was not confirmed by the successor E835 Collaboration with higher statistics in 2005. It needs more experiments to clarify it.
- Almost all theoretical calculations show the branching fraction $\mathcal{B}(h_c \to \pi^0 J/\psi)$ should be larger than 10^{-3}. While no experimental results to confirm it.
- The process $\psi' \to \pi^0 h_c$ is observed with branching fraction $\mathcal{B}(h_c \to \pi^0 J/\psi) = (8.6 \pm 1.3) \times 10^{-4}$, the process $h_c \to \pi^0 J/\psi$ should also exist.
- It is very hard to search for $h_c \to \pi^0 J/\psi$ using ψ' data, because there is large background $\psi' \to \pi^0 \pi^0 J/\psi$. However, it is very suitable to search for $h_c \to \pi^0 J/\psi$ using XYZ data through the process $e^+ e^- \to \pi^+ \pi^- h_c$.

Data sets

Boss Version : 7.0.3

Data sets :
Data from $\sqrt{s} = 4.178$ to 4.416 GeV (4.178, 4.189, 4.199, 4.209, 4.219, 4.226, 4.236, 4.244, 4.258, 4.267, 4.278, 4.358, 4.416)

Signal MC :
$e^+e^- \to \pi^+\pi^- h_c,\ h_c \to \pi^0 J/\psi,\ J/\psi \to e^+e^-/\mu^+\mu^-$

Normalized signal MC :
$e^+e^- \to \pi^+\pi^- h_c,\ h_c \to \gamma\eta_c,\ \eta_c \to p\bar{p}$

The input line-shape for signal MC is from the measured results of $e^+e^- \to \pi^+\pi^- h_c$

$$e^+e^- \to \pi^+\pi^- h_c,\ h_c \to \pi^0 J/\psi,\ J/\psi \to e^+e^-/\mu^+\mu^-$$

Event selections

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

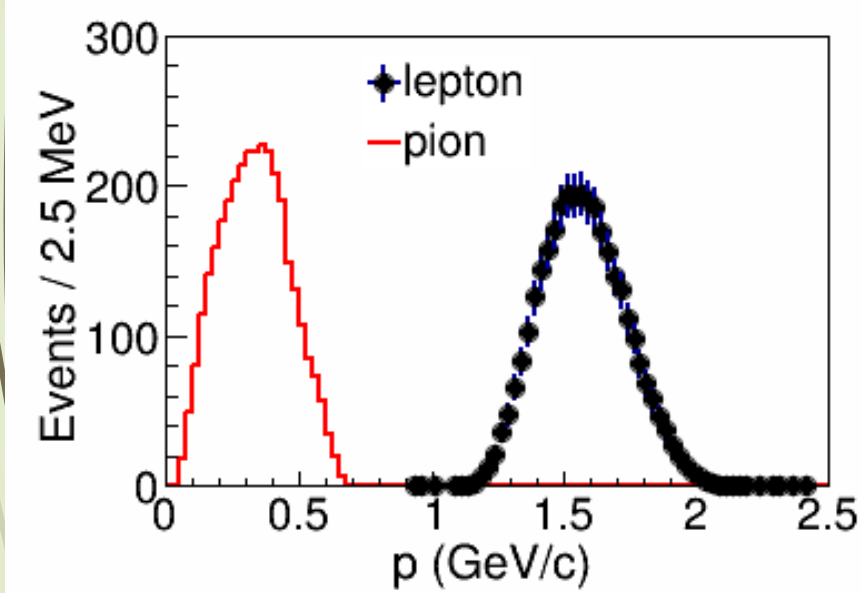
Particle identification
- π : $P_{mdc} < 0.8$ GeV
- e : $P_{mdc} > 0.8$ GeV&&$E_{emc} > 1$ GeV
- μ : $P_{mdc} > 0.8$ GeV&&$E_{emc} < 0.4$ GeV

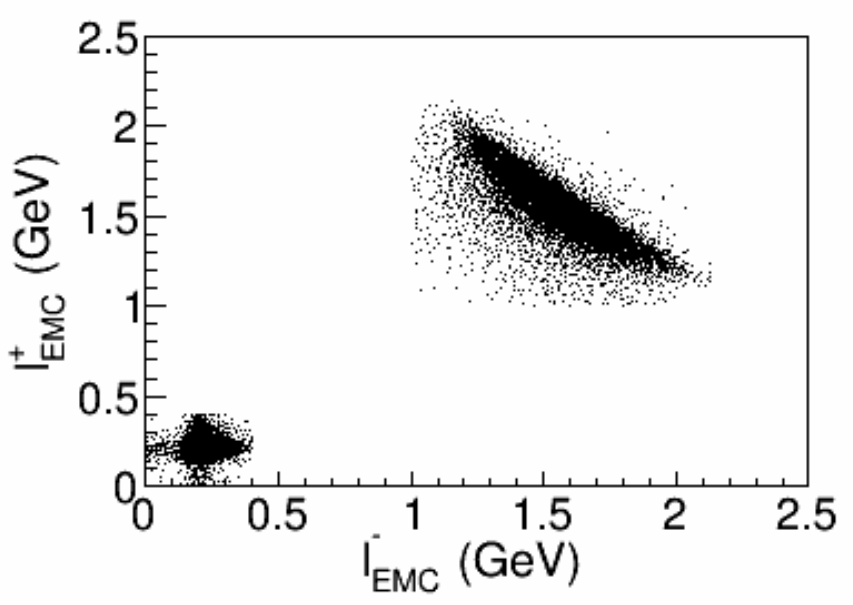
Good photon
- $0 \leq TDC \leq 14$
- Barrel :
  $E > 0.025$ GeV, $|cos\theta| < 0.8$
- Endcap :
  $E > 0.050$ GeV, $0.86 < |cos\theta| < 0.92$
- $\Delta\theta > 20^0$
- $N_\gamma \geq 2$

5C kinematic fit
- M($\gamma\gamma$) is constrained to M(π^0)
- Choose the photons with least χ^2
- $\chi^2 < 40$

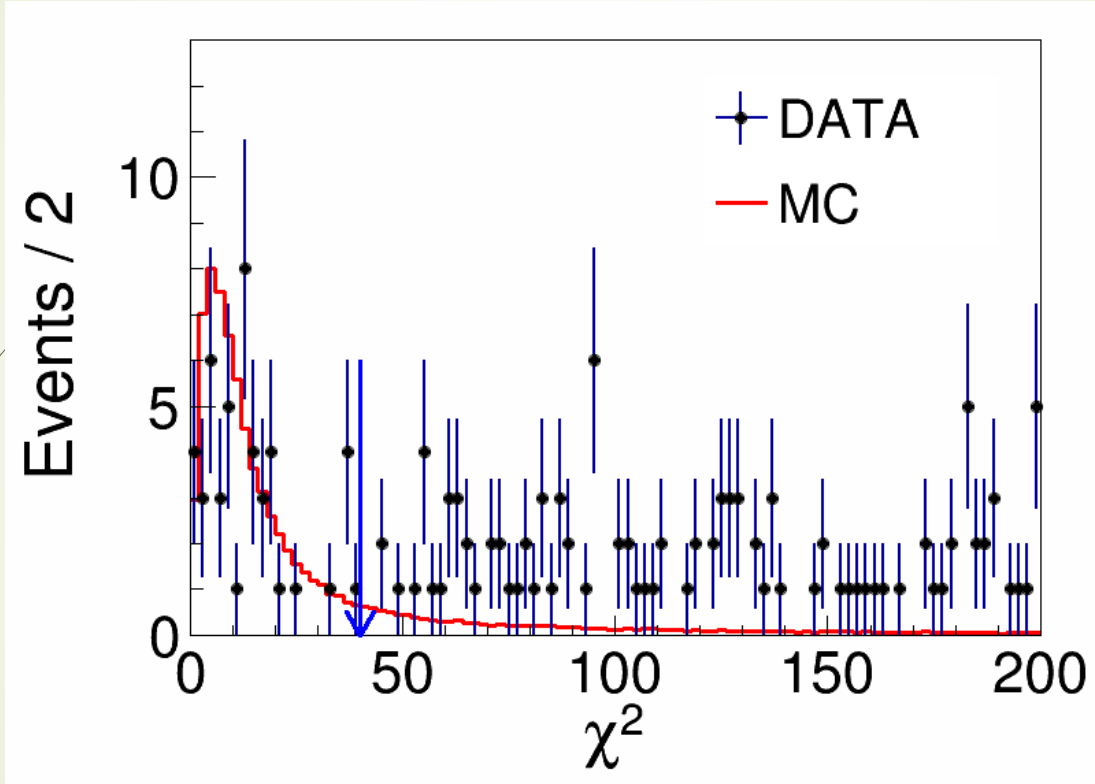
Other selections
- J/ψ mass window:(3.085, 3.115) GeV
- $M(\pi^+\pi^-\pi^0) < 0.52 || M(\pi^+\pi^-\pi^0) > 0.58$ GeV

Particle identification





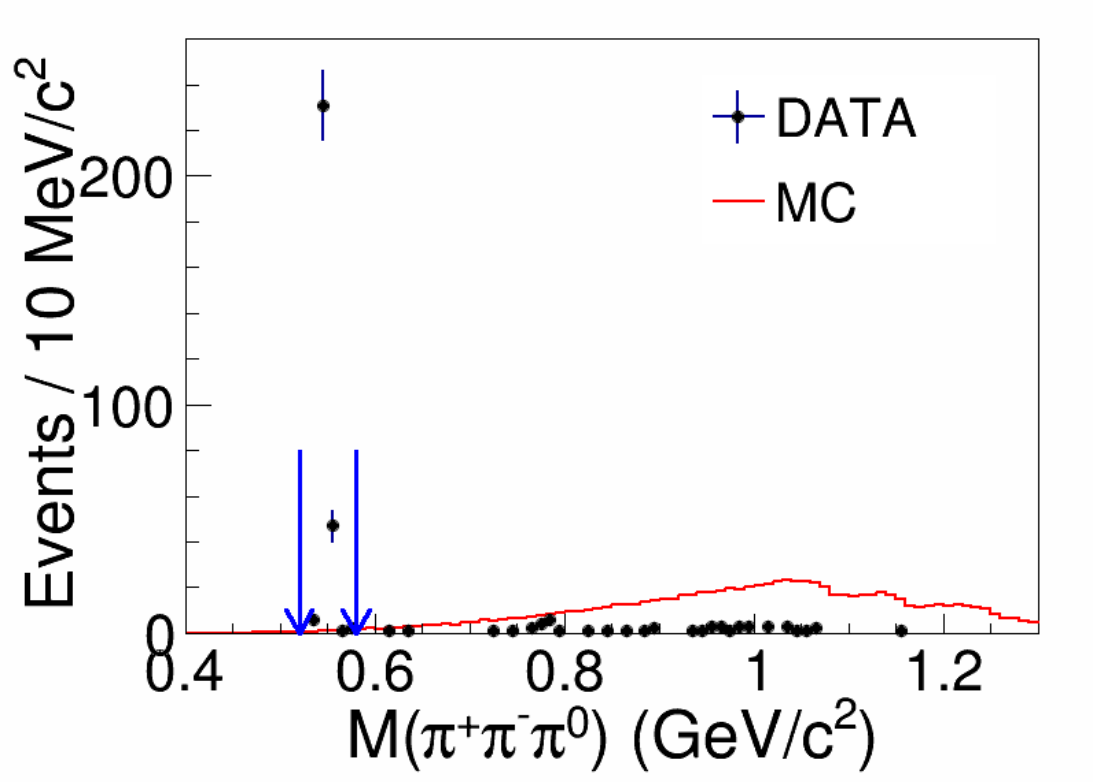
The χ^2 of kinematic fit



χ^2 distribution : $\chi^2 < 40$

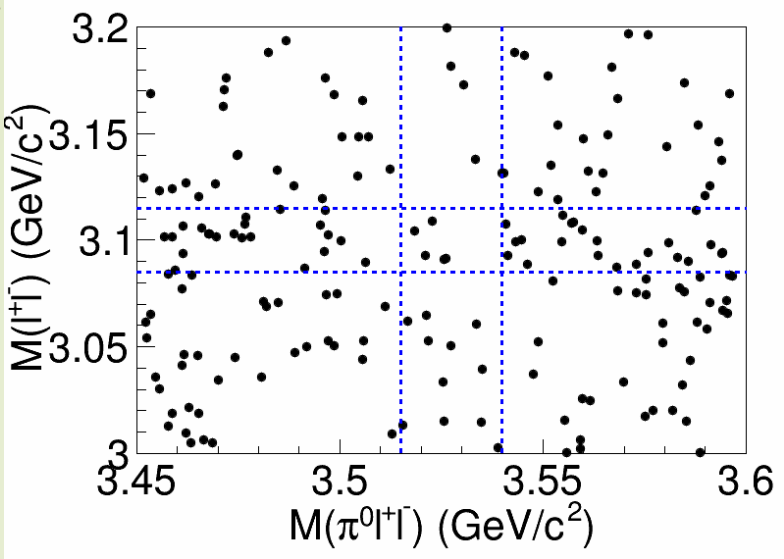
Background study

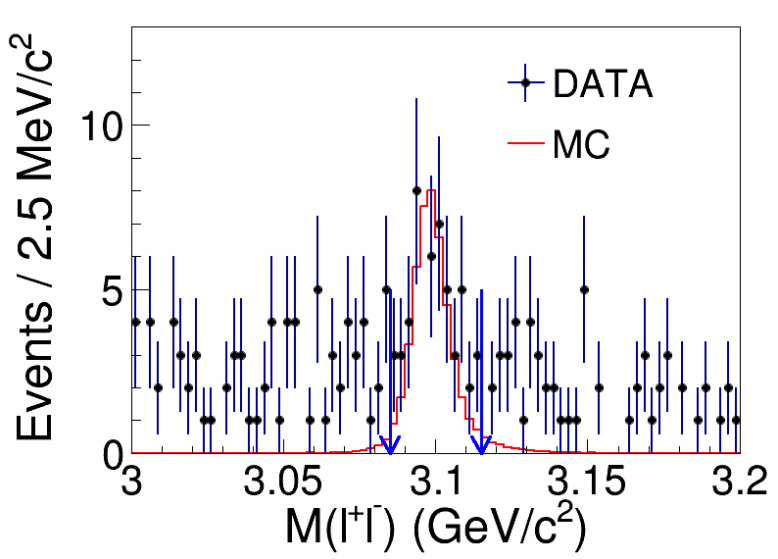
Background: $e^+e^- \to \eta J/\psi, \eta \to \pi^+\pi^-\pi^0$

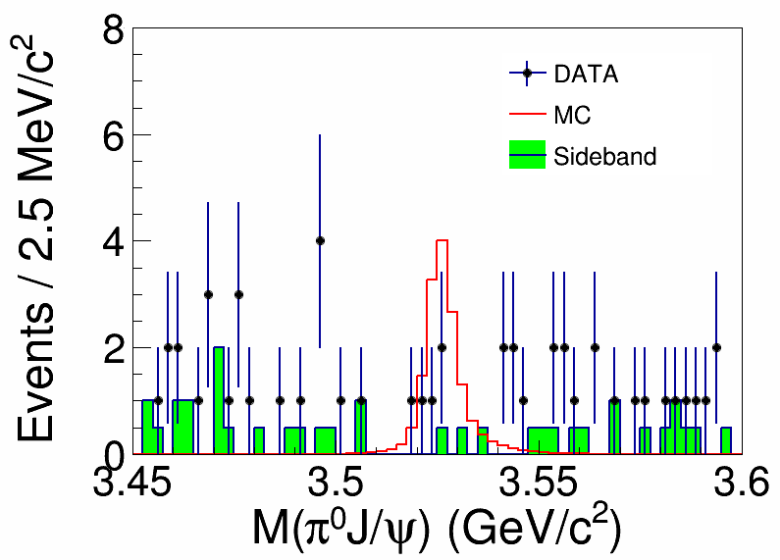


$M(\pi^+\pi^-\pi^0) < 0.52 || M(\pi^+\pi^-\pi^0) > 0.58$ GeV

Some plots from data

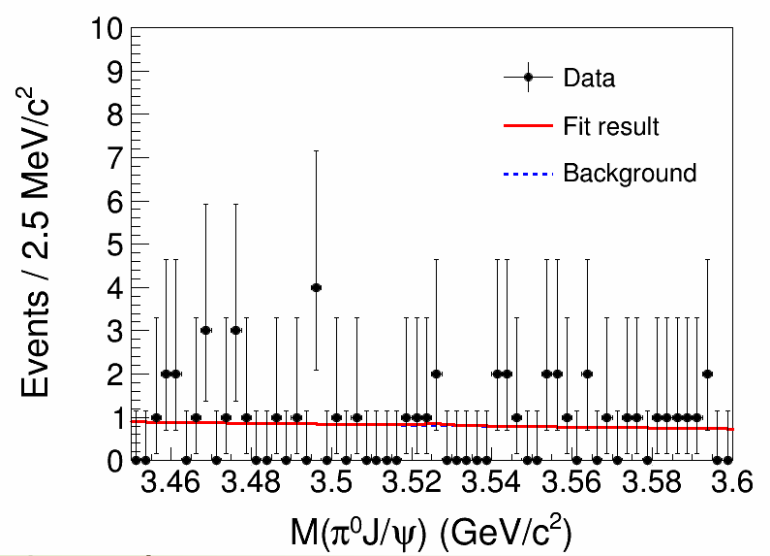


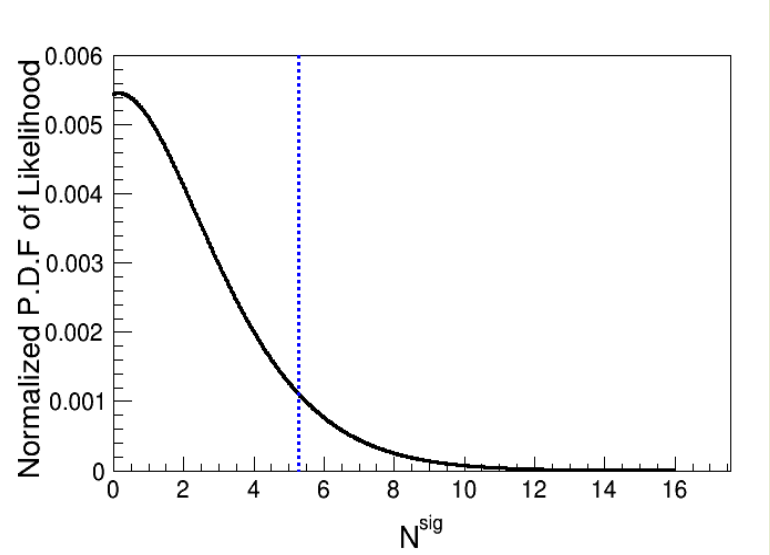




- J/ψ mass window : (3.085, 3.115) GeV
- Sideband regions :
  $3.02 \leq M(l^+l^-) \leq 3.05\ \mathrm{GeV}/c^2$ and
  $3.15 \leq M(l^+l^-) \leq 3.18\ \mathrm{GeV}/c^2$

Signal extraction from data





Signal :

MC-determined signal MC shape to describe

Background :

1st-order Polynomial function

$$N_{sig}^{\pi^0 J/\psi} = 0.2 \pm 2.2$$

$$N_{sig}^{\pi^0 J/\psi} < 5.3 \text{ at } 90\% \text{ C.L.}$$

$$e^+e^- \to \pi^+\pi^- h_c,\ h_c \to \gamma\eta_c,\ \eta_c \to p\bar{p}$$

Event selections

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

Particle identification
- π : $P_{mdc} < 0.8$ GeV
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Good photon
- $0 \leq TDC \leq 14$
- Barrel :
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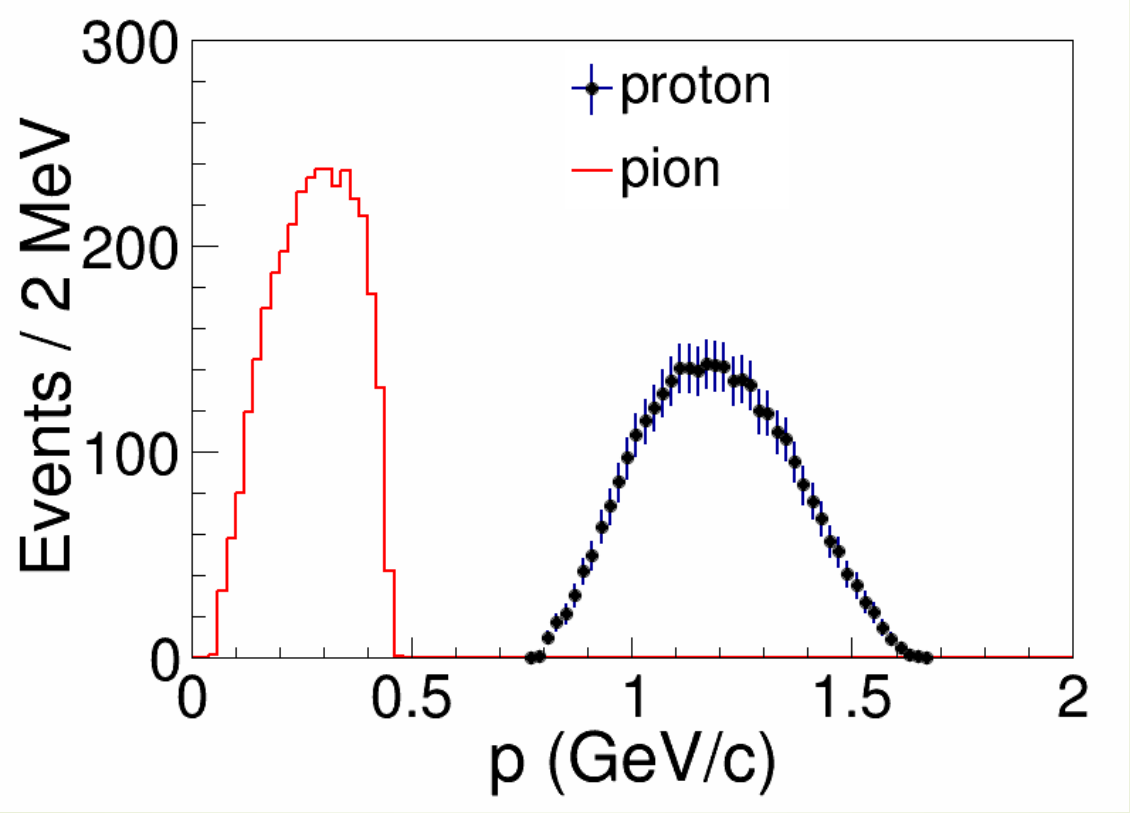
- Endcap :
  $E > 0.050$ GeV, $0.86 < |cos\theta| < 0.92$
- $\Delta\theta > 20^0$
- $N_\gamma \geq 1$

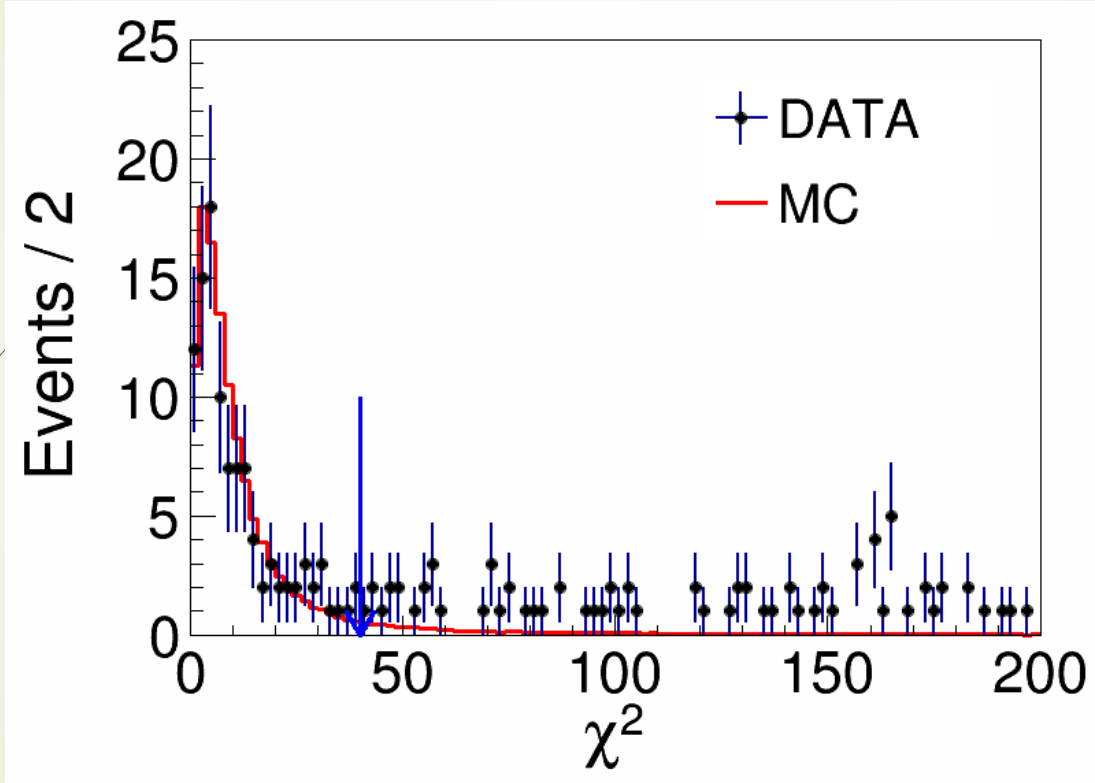
4C kinematic fit
- Choose the photons with least χ^2
- $\chi^2 < 40$

Other selections
- η_c mass window:(2.90, 3.05) GeV

Particle identification

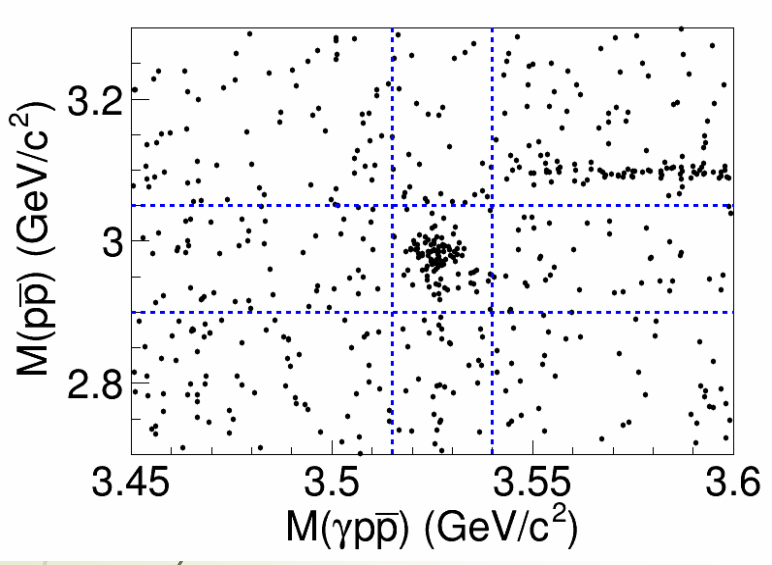


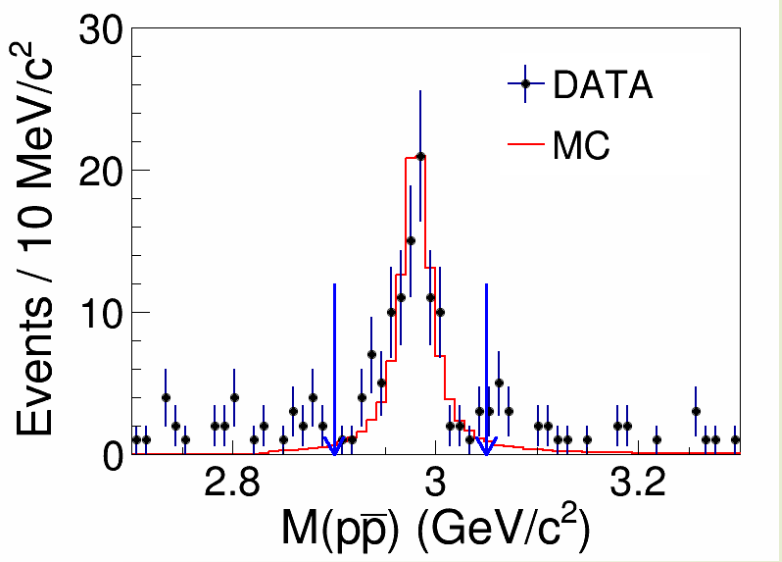
The χ^2 of kinematic fit

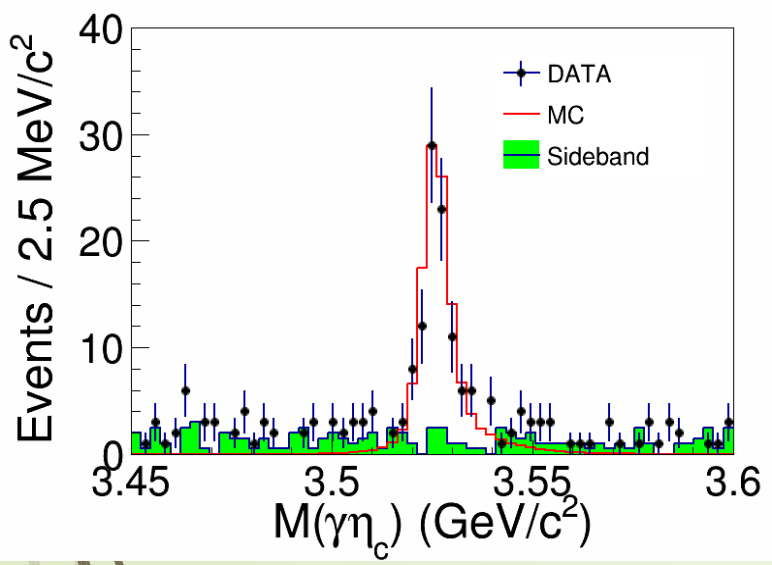


χ^2 distribution : $\chi^2 < 40$

Some plots from data

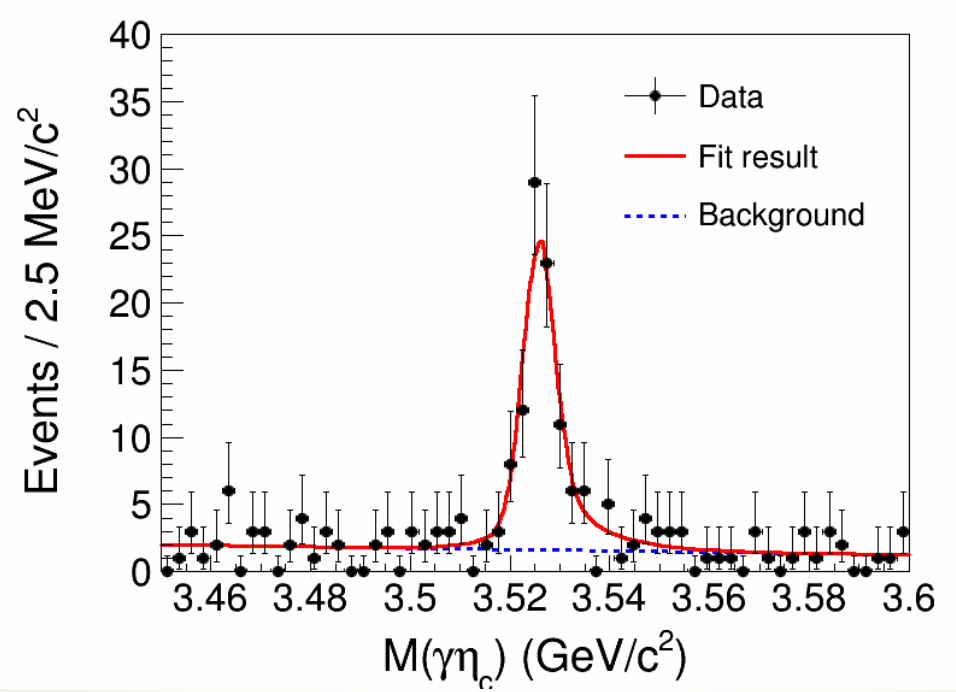






- η_c mass window : (2.90, 3.05) GeV
- Sideband regions :
  $2.65 \leq M(p\bar{p}) \leq 2.80\ \mathrm{GeV}/c^2$ and
  $3.20 \leq M(p\bar{p}) \leq 3.35\ \mathrm{GeV}/c^2$

Signal extraction from data



Signal :

MC-determined signal MC shape to describe

Background :

1st-order Polynomial function

$$N_{sig}^{\gamma\eta_c} = 94.1 \pm 10.5$$

Results

$$\sum_i \mathcal{L}_i \sigma_i (1+\delta)_i \varepsilon_i^{\pi^0 J/\psi} \mathcal{B}(h_c \to \pi^0 J/\psi)\mathcal{B}(\pi^0 \to \gamma\gamma)\mathcal{B}(J/\psi \to l^+ l^-) = N_{sig}^{\pi^0 J/\psi}$$

$$\sum_i \mathcal{L}_i \sigma_i (1+\delta)_i \varepsilon_i^{\gamma\eta_c} \mathcal{B}(h_c \to \gamma\eta_c)\mathcal{B}(\eta_c \to p\bar{p}) = N_{sig}^{\gamma\eta_c}$$

$$\frac{\mathcal{B}(h_c \to \pi^0 J/\psi)}{\mathcal{B}(h_c \to \gamma\eta_c)\mathcal{B}(\eta_c \to p\bar{p})} = \frac{N_{sig}^{\pi^0 J/\psi}}{N_{sig}^{\gamma\eta_c}} \frac{\sum_i \mathcal{L}_i \sigma_i (1+\delta)_i \varepsilon_i^{\gamma\eta_c}}{\sum_i \mathcal{L}_i \sigma_i (1+\delta)_i \varepsilon_i^{\pi^0 J/\psi}} \frac{1}{\mathcal{B}(\pi^0 \to \gamma\gamma)\mathcal{B}(J/\psi \to l^+ l^-)}$$

Results

$\sqrt{s}$	4.178	4.258	4.358	4.416
$\frac{\varepsilon_i^{\pi^0 J/\psi}}{\varepsilon_i^{\gamma\eta_c}}$	0.510	0.506	0.510	0.514

$N_{sig}^{\pi^0 J/\psi} < 5.3$ at 90% C.L. $\qquad N_{sig}^{\gamma\eta_c} = 94.1 \pm 10.5$

$$\frac{\mathcal{B}(h_c \to \pi^0 J/\psi)}{\mathcal{B}(h_c \to \gamma\eta_c)\mathcal{B}(\eta_c \to p\bar{p})} = \frac{N_{sig}^{\pi^0 J/\psi}}{N_{sig}^{\gamma\eta_c}} \frac{\sum_i \mathcal{L}_i \sigma_i (1+\delta)_i \varepsilon_i^{\gamma\eta_c}}{\sum_i \mathcal{L}_i \sigma_i (1+\delta)_i \varepsilon_i^{\pi^0 J/\psi}} \frac{1}{\mathcal{B}(\pi^0 \to \gamma\gamma)\mathcal{B}(J/\psi \to l^+ l^-)}$$

$$= \frac{N_{sig}^{\pi^0 J/\psi}}{N_{sig}^{\gamma\eta_c}} \frac{1}{0.51} \frac{1}{\mathcal{B}(\pi^0 \to \gamma\gamma)\mathcal{B}(J/\psi \to l^+ l^-)}$$

$$< 0.94$$

$$\mathcal{B}(h_c \to \pi^0 J/\psi) < 0.73 \times 10^{-3}$$

Summary

1、Using XYZ data samples from $\sqrt{s} = 4.178$ to 4.416 GeV, the process $h_c \to \pi^0 J/\psi$ is searched, no significant signals, the upper limits are $\frac{\mathcal{B}(h_c \to \pi^0 J/\psi)}{\mathcal{B}(h_c \to \gamma\eta_c)\mathcal{B}(\eta_c \to p\bar{p})} < 0.94$ and $\mathcal{B}(h_c \to \pi^0 J/\psi) < 0.73 \times 10^{-3}$.

2、The measured branching fraction for $h_c \to \pi^0 J/\psi$ is slightly inconsistent with the theoretical calculations.

Thanks for your attention!

BACK UP