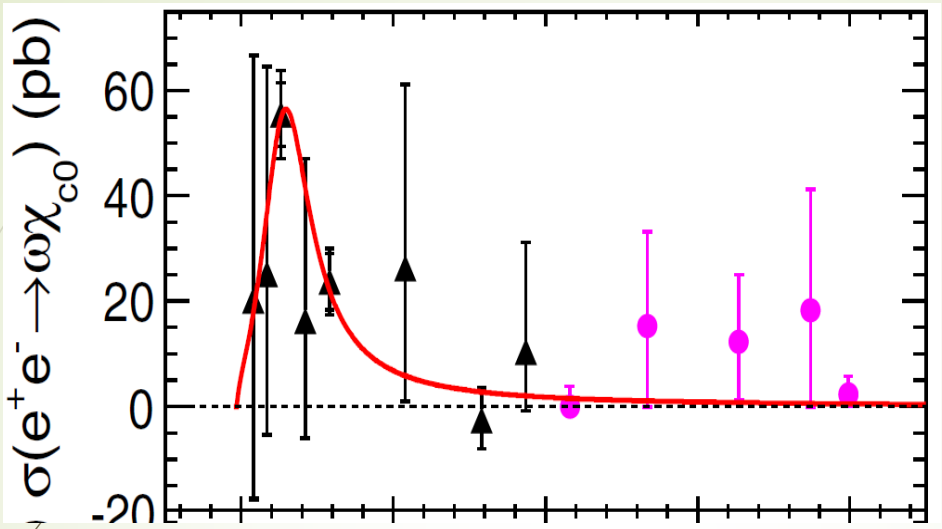
Study of $e^+e^- \to \omega\chi_{c0}$ around $\sqrt{s} = 4.2$ GeV

Jielei Zhang Jingzhi Zhang
Institute of High Energy Physics

Outline

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

Motivation



PRL 114,092003
PRD 93,011102(R)

- BESIII has observed the process $e^+e^- \to \omega\chi_{c0}$ around 4.23 GeV. There is a structure in the line-shape of $e^+e^- \to \omega\chi_{c0}$, if using a Breit-Winger function to fit, the structure' s parameters are $M = (4226 \pm 8 \pm 6)\ \mathrm{MeV}/c^2$, $\Gamma = (39 \pm 12 \pm 2)\ \mathrm{MeV}$.

- Now BESIII has collected about 5000 pb^{-1} data around $\sqrt{s}$ =4.2 GeV, it can be used to check whether there is a true structure Y(4220) in $\omega\chi_{c0}$ line-shape, and it also can be used to study the structure in more detail.

- The ω-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) GeV

Signal MC :

$e^+e^- \to \omega\chi_{c0}$, $\chi_{c0} \to \pi^+\pi^-/K^+K^-$, $\omega \to \pi^+\pi^-\pi^0$, $\pi^0 \to \gamma\gamma$

Event selections

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

Particle separation
- π (ω): $P_{mdc} < 1$ GeV
- $\pi/K(\chi_{c0})$: $P_{mdc} > 1$ GeV

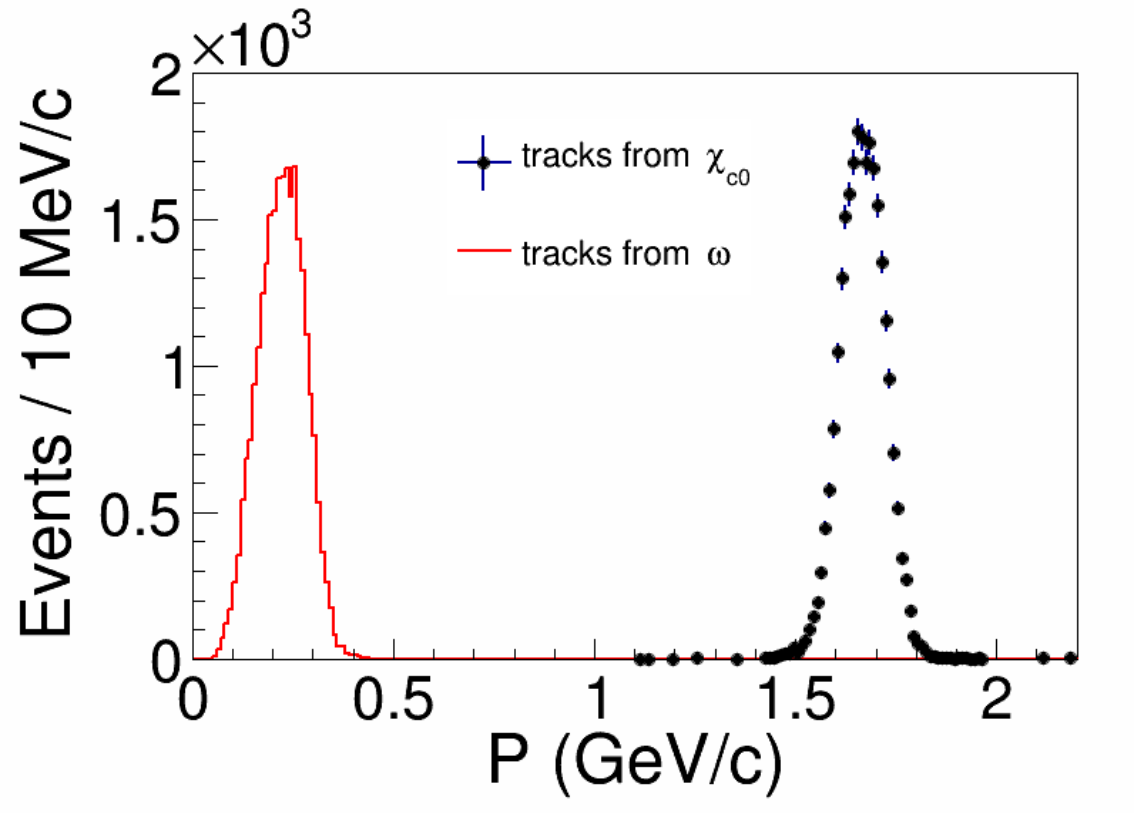
Good photon
- $0 \leq TDC \leq 14$
- Barrel :
  $E > 0.025$ GeV, $|cos\theta| < 0.8$
- Endcap :
  $E > 0.050$ GeV, $0.86 < |cos\theta| < 0.92$
- $\Delta\theta > 10^0$
- $N_\gamma \geq 2$

5C kinematic fit
- M($\gamma\gamma$) is constrained to M(π^0)
- Choose the photons with least χ^2
- $\chi^2_{5C} < 100$
- $\pi(\chi_{c0})$: $\chi^2_{5C}(\pi\pi) < \chi^2_{5C}(KK)$
- $K(\chi_{c0})$: $\chi^2_{5C}(KK) < \chi^2_{5C}(\pi\pi)$

Other selection
- ω mass window : (0.75, 0.81) GeV

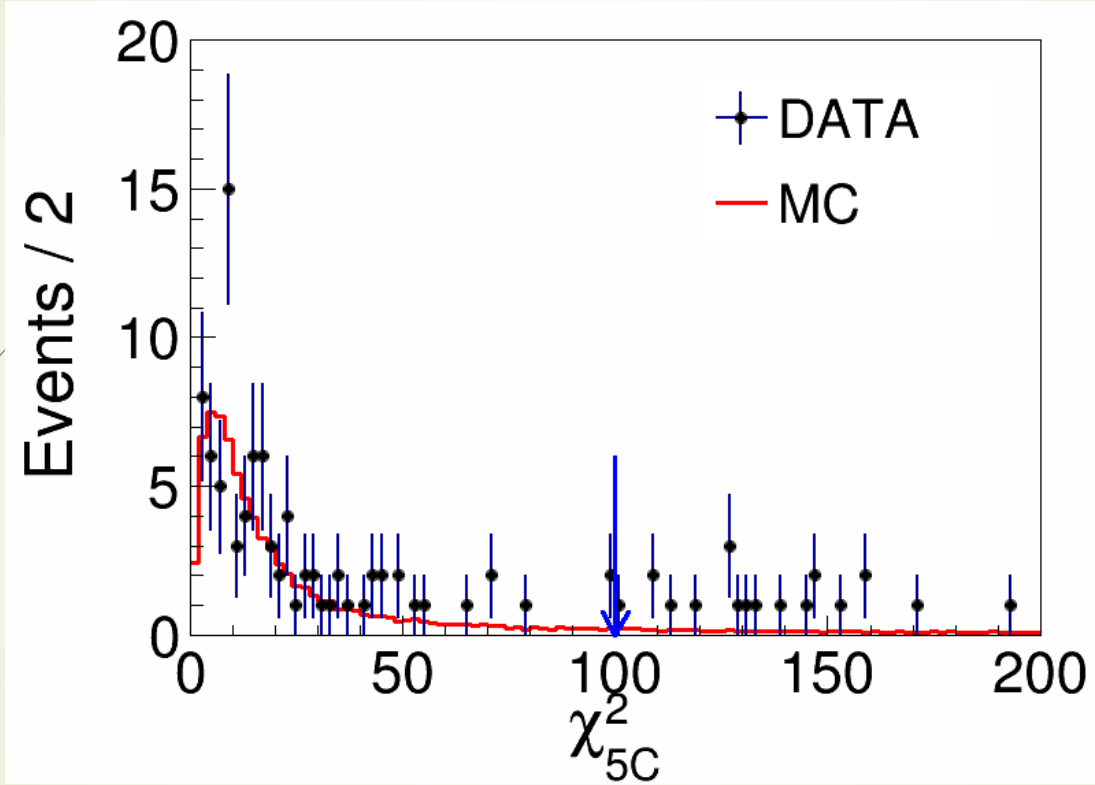
Data at $\sqrt{s} = 4.20$ GeV

Momentum distributions



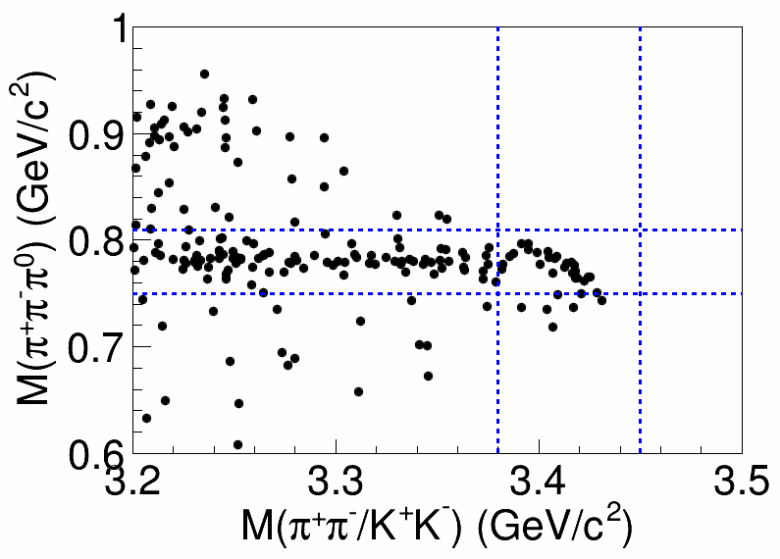
Momentum distributions of charged tracks for signal MC

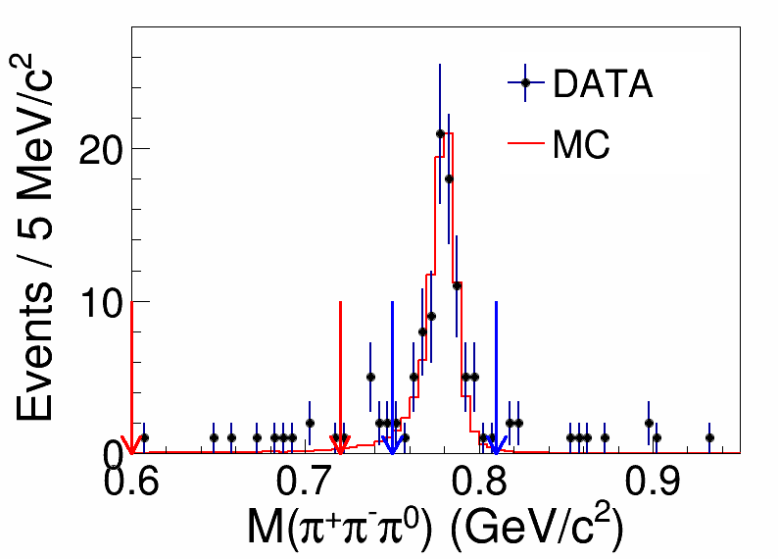
The χ^2_{5C} of kinematic fit

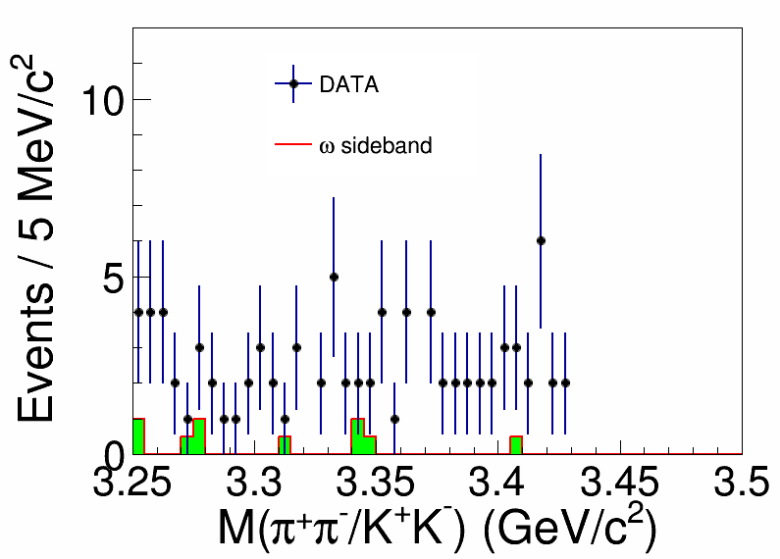


χ^2 distribution from 5C : $\chi^2_{5C} < 100$

Some plots from data

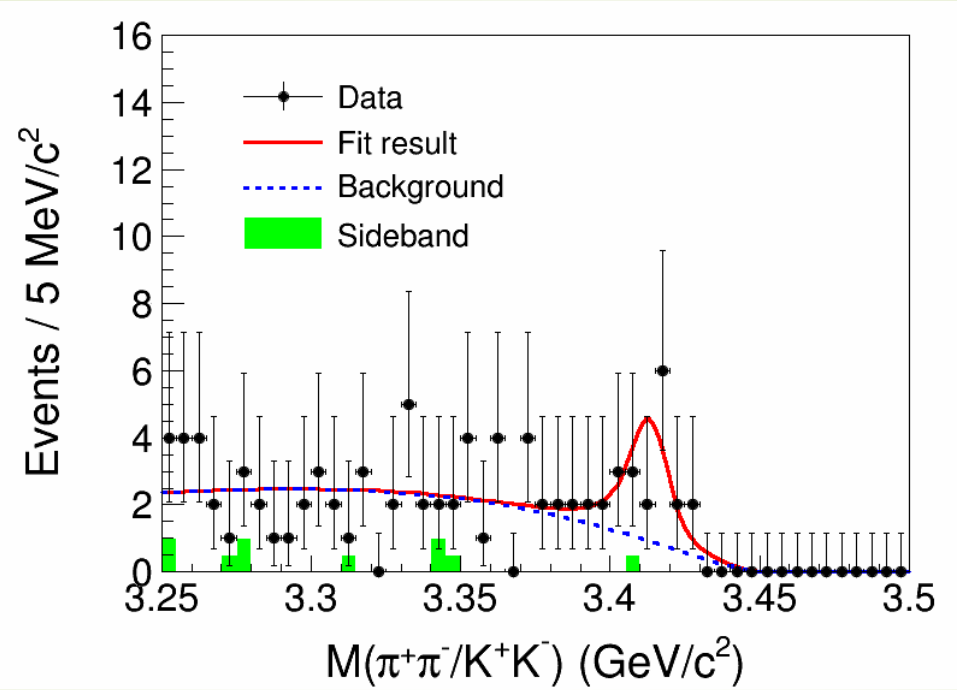






- ω mass window : (0.75, 0.81) GeV/c^2
- Sideband regions :
  $0.60 \leq M(\pi^+\pi^-\pi^0) \leq 0.72\ \mathrm{GeV}/c^2$

Signal extraction from data



$S = 2.9\sigma$

Signal :

MC-determined signal MC shape

Background :

ARGUS function $m(1-\left(\frac{m}{m_0}\right)^2)^p \cdot \exp(k(1-\left(\frac{m}{m_0}\right)^2)) \cdot \theta(m < m_0)$

m_0 is fixed to $(\sqrt{s} - 0.75) = 3.45$ GeV, the p and k are float

$$N^{sig} = 15.1 \pm 6.3$$

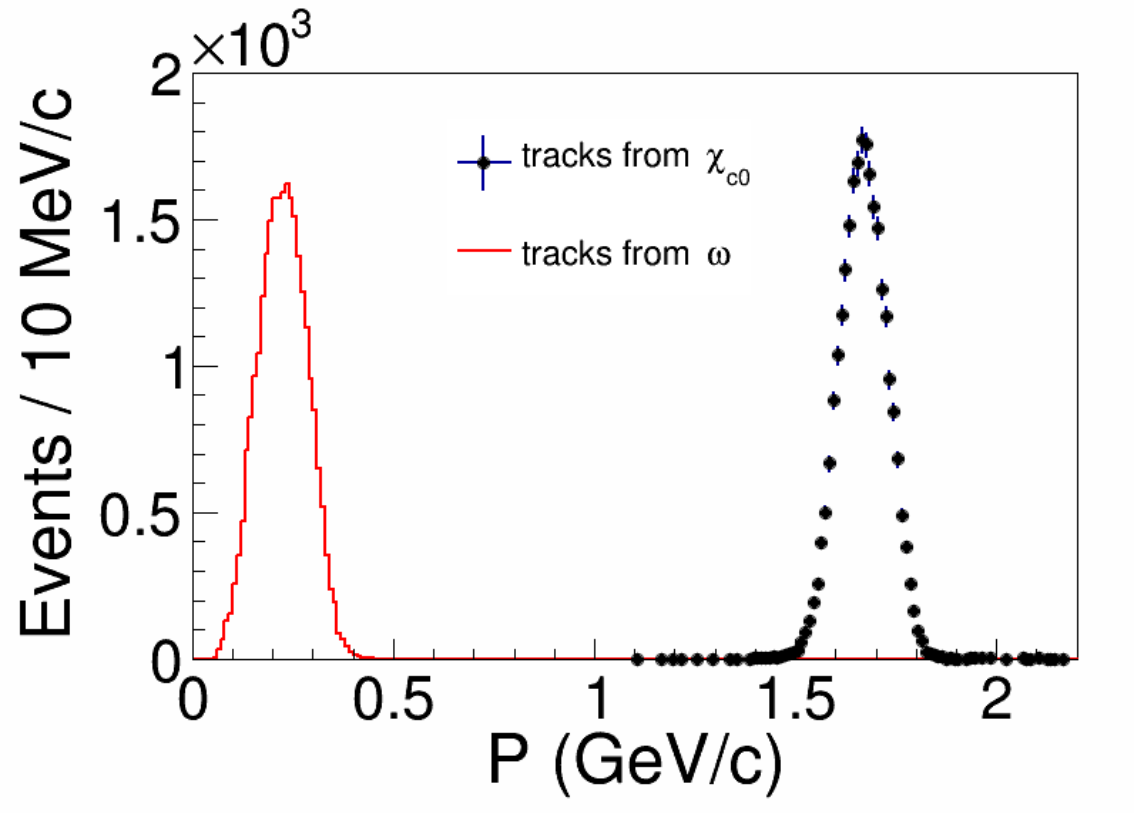
Cross section measurement

$$\sigma^B(e^+e^- \to \omega\chi_{c0}) = \frac{N^{sig}}{\mathcal{L}_{int}(1+\delta(s))\frac{1}{|1-\Pi|^2}\mathcal{B}(\chi_{c0} \to \pi^+\pi^-/K^+K^-)\mathcal{B}(\omega \to \pi^+\pi^-\pi^0)\mathcal{B}(\pi^0 \to \gamma\gamma)\epsilon}$$

$\sqrt{s}$(GeV)	$\mathcal{L}_{int}$(pb^{-1})	N^{sig}	$1+\delta$(s)	$\frac{1}{\lvert 1-\Pi\rvert^2}$	$\epsilon(\%)$	σ^B(pb)
4.20	519.4	15.1±6.3	0.59	1.057	25.92	17.8 ± 7.5

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

Momentum distributions



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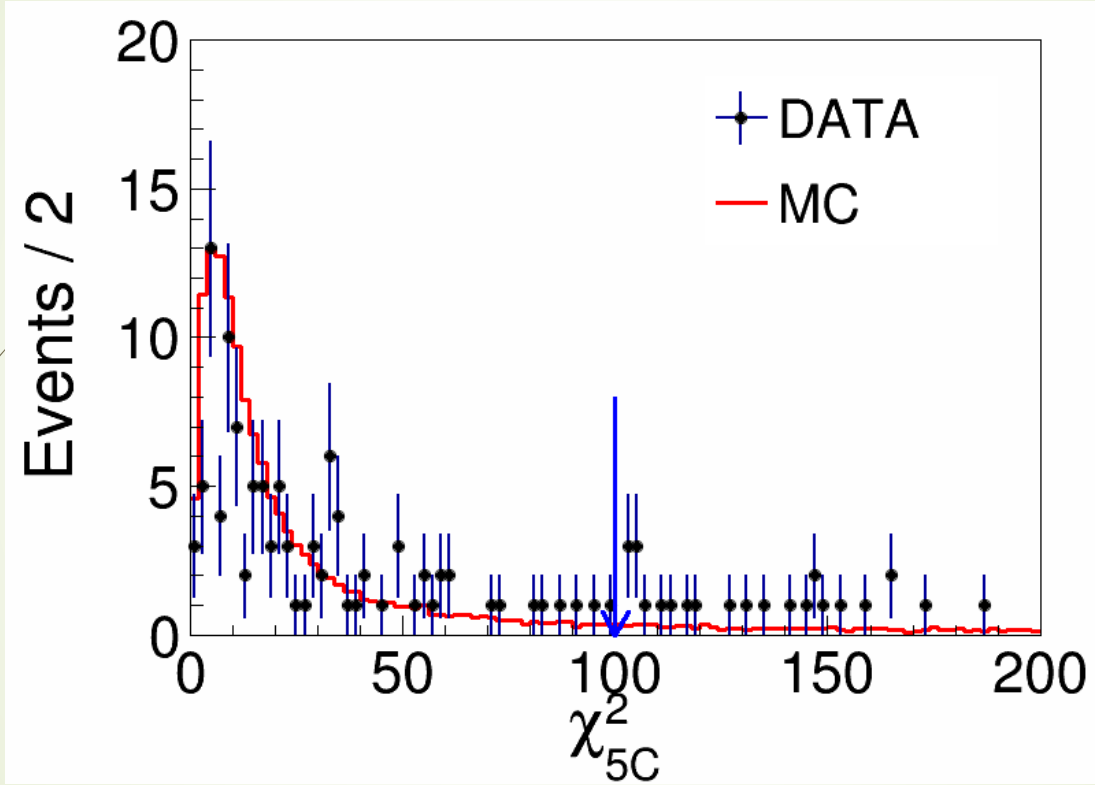

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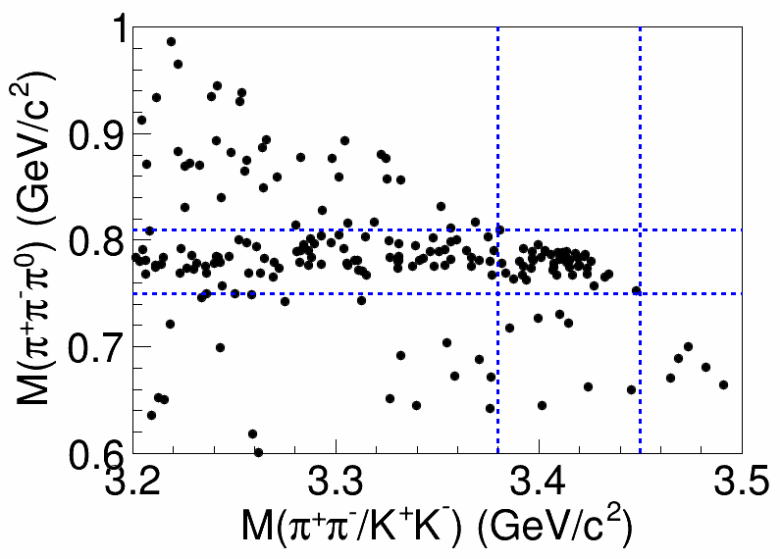

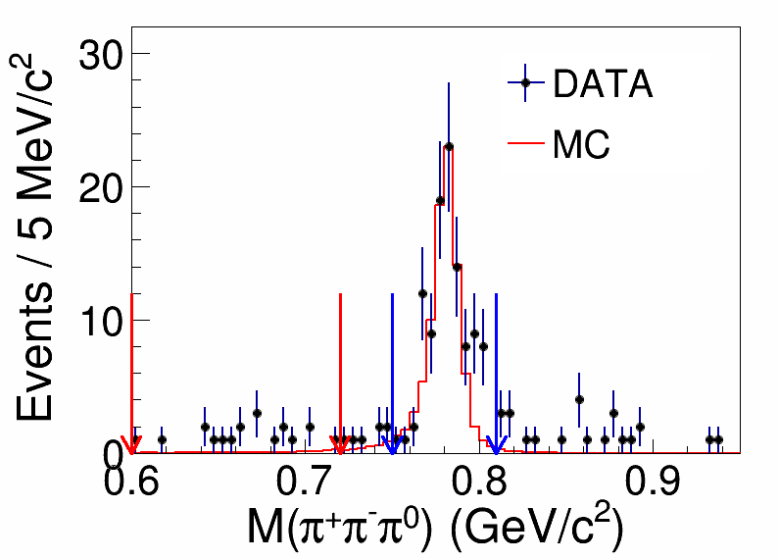

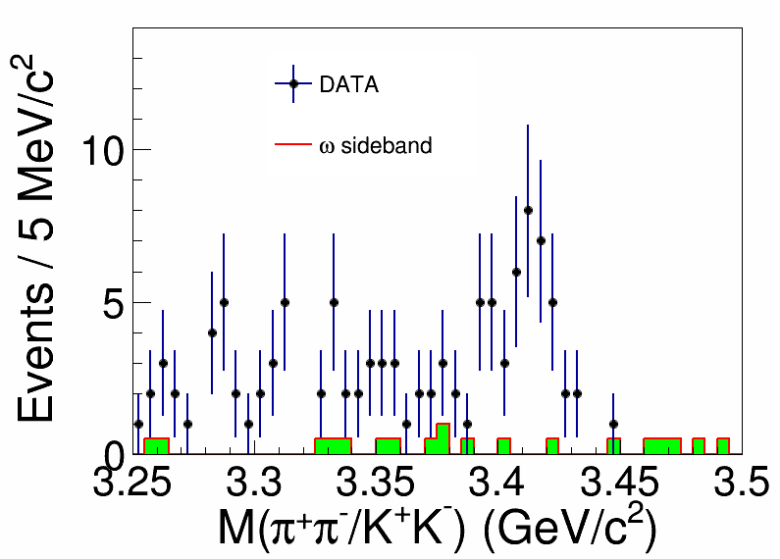

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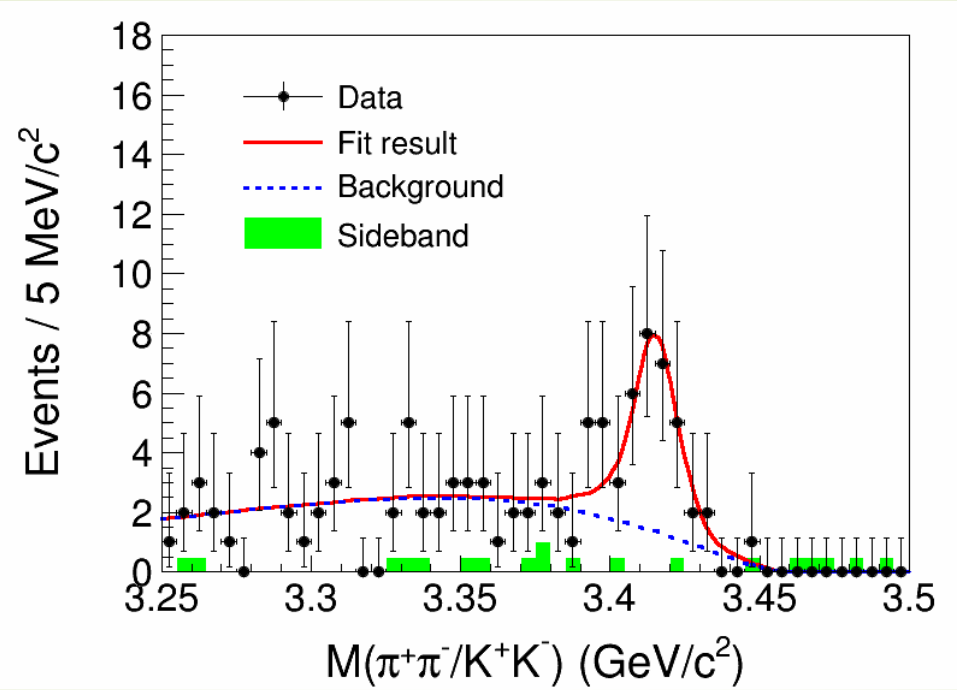
Signal extraction from data



$S = 4.3\sigma$

Signal :

MC-determined signal MC shape

Background :

ARGUS function $m(1-\left(\frac{m}{m_0}\right)^2)^p \cdot \exp(k(1-\left(\frac{m}{m_0}\right)^2)) \cdot \theta(m < m_0)$

m_0 is fixed to $(\sqrt{s} - 0.75) = 3.46$ GeV, the p and k are float

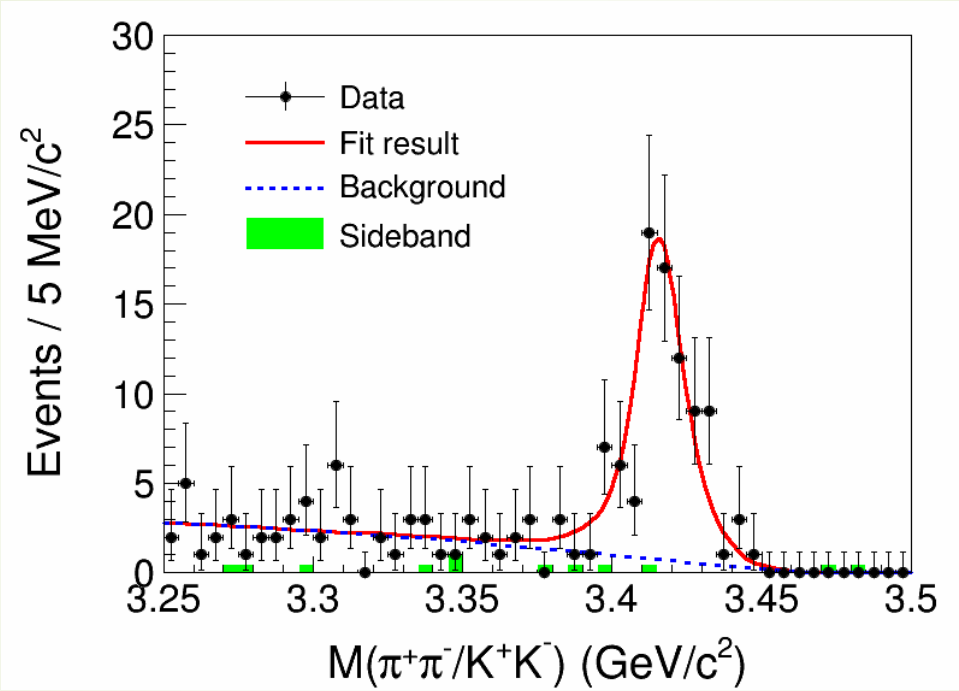
$$N^{sig} = 28.9 \pm 7.8$$

Cross section measurement

$$\sigma^B(e^+e^- \to \omega\chi_{c0}) = \frac{N^{sig}}{\mathcal{L}_{int}(1+\delta(s))\frac{1}{|1-\Pi|^2}\mathcal{B}(\chi_{c0} \to \pi^+\pi^-/K^+K^-)\mathcal{B}(\omega \to \pi^+\pi^-\pi^0)\mathcal{B}(\pi^0 \to \gamma\gamma)\epsilon}$$

$\sqrt{s}$(GeV)	$\mathcal{L}_{int}$(pb^{-1})	N^{sig}	$1+\delta$(s)	$\frac{1}{\lvert 1-\Pi\rvert^2}$	ϵ(%)	σ^B(pb)
4.21	509.0	28.9$\pm$7.8	0.66	1.057	26.11	30.9 ± 8.3

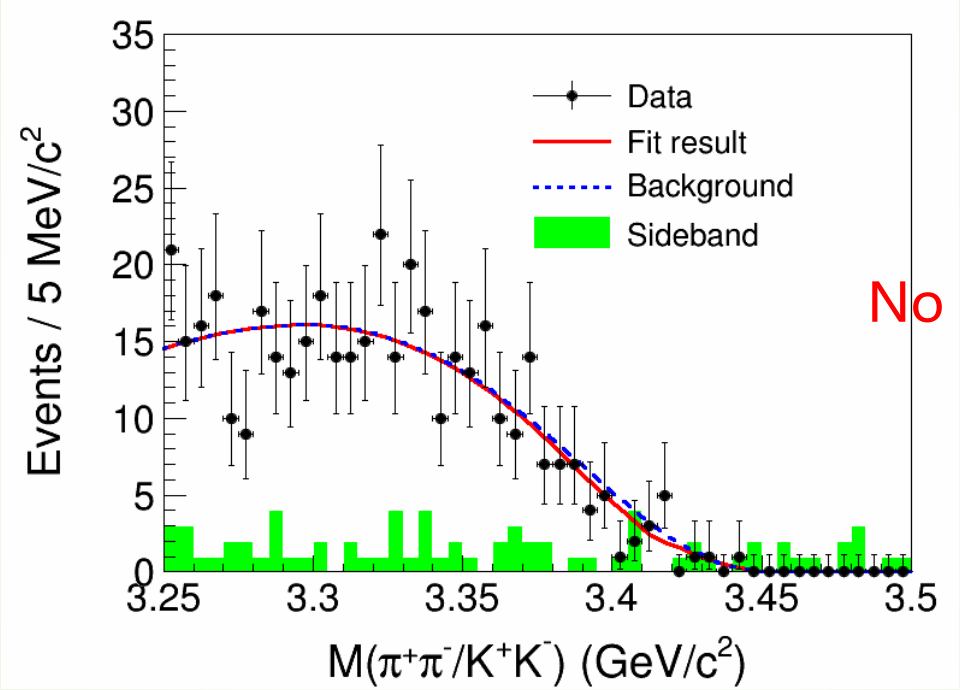
Data at $\sqrt{s} = 4.22$ GeV



$S = 9.4\sigma$

$\sqrt{s}$(GeV)	$\mathcal{L}_{int}$(pb^{-1})	N^{sig}	$1+\delta$(s)	$\frac{1}{\lvert 1-\Pi\rvert^2}$	$\epsilon(\%)$	σ^B(pb)
4.22	500	84.7±11.2	0.70	1.057	26.30	86.2 ± 11.4

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

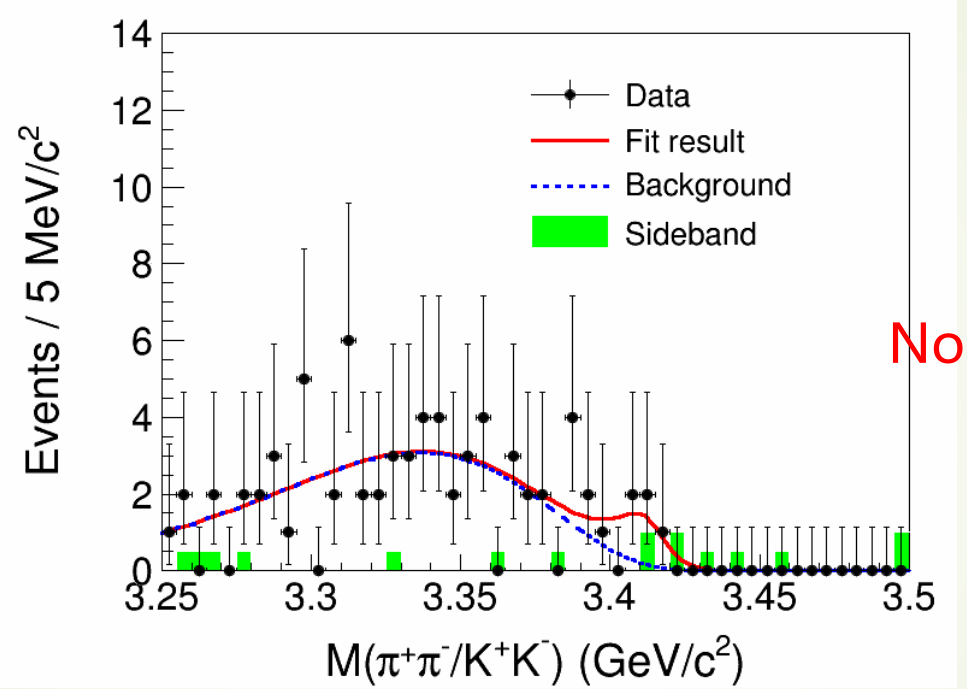


No significant signals

$\sqrt{s}$(GeV)	$\mathcal{L}_{int}$(pb^{-1})	N^{sig}	$1+\delta$(s)	$\frac{1}{\lvert 1-\Pi\rvert^2}$	ϵ(%)	σ^B(pb)
4.18	3161	-7.2±13.6	1.0	1.055	24.48	-0.9 ± 1.7

$M(\omega) + M(\chi_{c0}) = 4.1974$ GeV

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



$S = 1.5\sigma$

No significant signals

$\sqrt{s}$(GeV)	$\mathcal{L}_{int}$(pb^{-1})	N^{sig}	$1+\delta$(s)	$\frac{1}{\lvert 1-\Pi\rvert^2}$	ϵ(%)	σ^B(pb)
4.19	517.5	7.3±4.4	1.0	1.056	23.70	5.6 ± 3.4

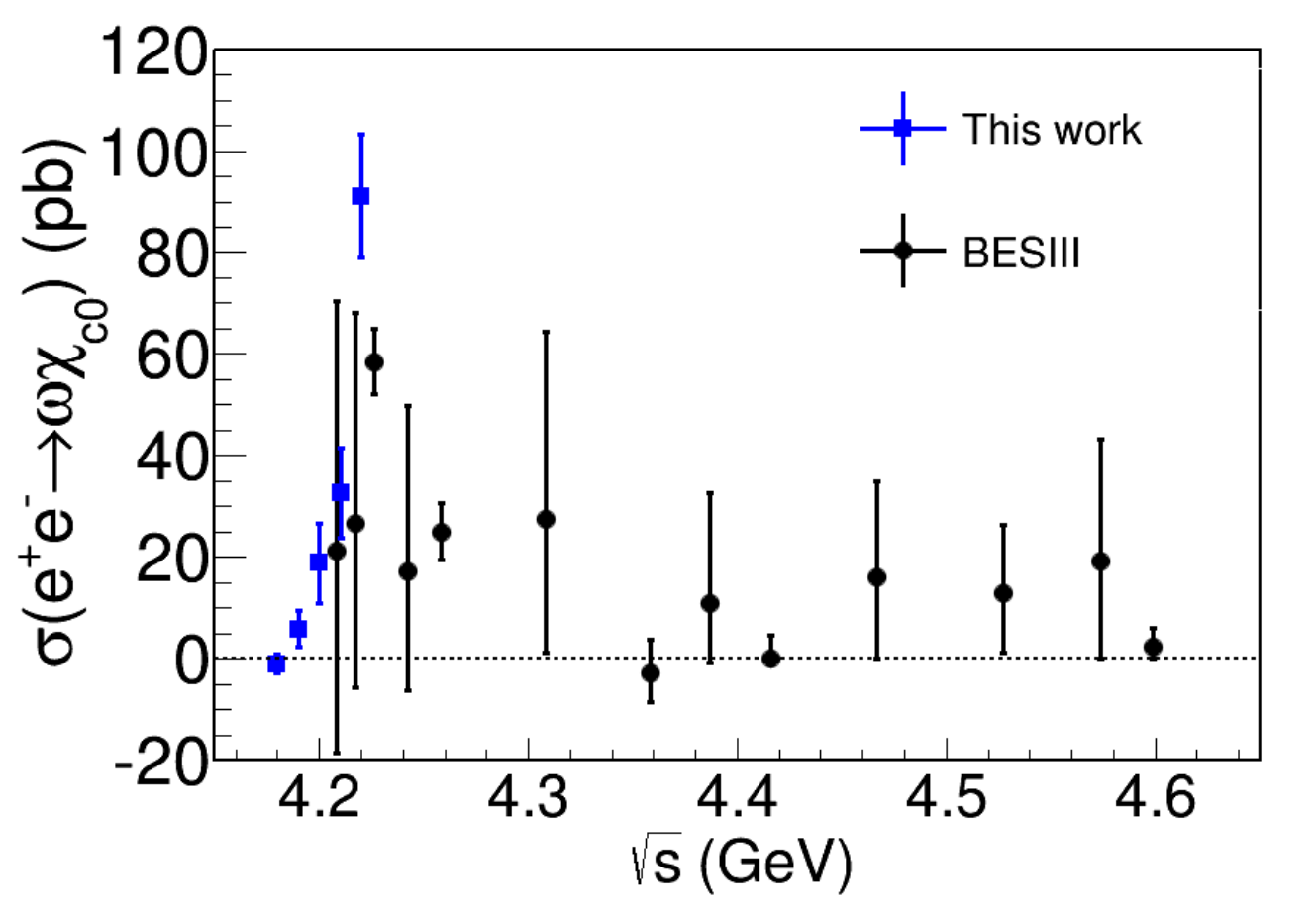
$M(\omega) + M(\chi_{c0}) = 4.1974$ GeV

Cross section measurement

$$e^+e^- \to \omega\chi_{c0}$$

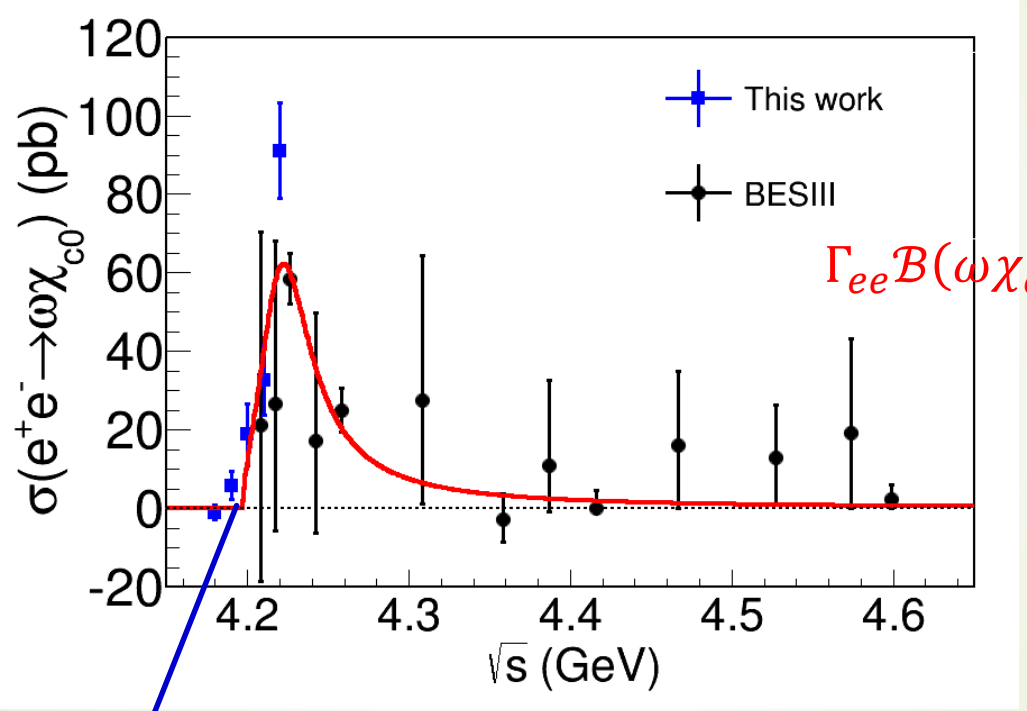
$\sqrt{s}$(GeV)	$\mathcal{L}_{int}$(pb^{-1})	N^{sig}	$1+\delta$(s)	$\frac{1}{\lvert 1-\Pi\rvert^2}$	$\epsilon(\%)$	σ^B(pb)
4.18	3161	-7.2±13.6	1.0	1.055	24.48	-0.9 ± 1.7
4.19	517.5	7.3±4.4	1.0	1.056	23.70	5.6 ± 3.4
4.20	519.4	15.1±6.3	0.59	1.057	25.92	17.8 ± 7.5
4.21	509.0	28.9±7.8	0.66	1.057	26.11	30.9 ± 8.3
4.22	500	84.7±11.2	0.70	1.057	26.30	86.2 ± 11.4

Line-shape


120
100
80
60
40
20
0
-20
4.2
4.3
4.4
4.5
4.6
$\sigma(e^+e^-\to\omega\chi_{c0})$ (pb)
$\sqrt{s}$ (GeV)
This work
BESIII

Line-shape

$$\mathrm{BW}(\sqrt{s}) = \frac{\Gamma_{ee}\mathcal{B}(\omega\chi_{c0})\Gamma_t}{(s-M^2)^2+(M\Gamma_t)^2} \times \frac{\Phi(\sqrt{s})}{\Phi(M)}$$



$\Gamma_{ee}\mathcal{B}(\omega\chi_{c0}) = (2.9 \pm 0.4)$ eV

Threshold: $M(\omega) + M(\chi_{c0}) = 4.1974$ GeV

$M = (4218.4 \pm 2.9)\ \mathrm{MeV}/c^2$, $\Gamma_t = (40.6 \pm 7.4)$ MeV

Y(4220)

$\omega\chi_{c0}$:

$M = (4218.4 \pm 2.9)\ \mathrm{MeV}/c^2$, $\Gamma_t = (40.6 \pm 7.4)\ \mathrm{MeV}$

$\pi^+\pi^- J/\psi$: PRL 118, 092001

$M = (4222.0 \pm 3.1 \pm 1.4)\ \mathrm{MeV}/c^2$, $\Gamma_t = (44.1 \pm 4.3 \pm 2.0)\ \mathrm{MeV}$

$\pi^+\pi^- h_c$: PRL 118, 092002

$M = \left(4218.4^{+5.5}_{-4.5} \pm 0.9\right)\ \mathrm{MeV}/c^2$, $\Gamma_t = (66.0^{+12.3}_{-8.3} \pm 0.4)\ \mathrm{MeV}$

Systematic uncertainty

1、Luminosity (1%)

2、Tracking (1% per track)

$e^+e^- \to K^+K^-\pi^+\pi^-$

http://indico.ihep.ac.cn/event/6113/session/19/contribution/62/material/slides/0.pdf

3、Photon (2% per photon)

$e^+e^- \to K^+K^-\pi^+\pi^-\pi^0$

http://indico.ihep.ac.cn/event/6113/session/5/contribution/16/material/slides/0.pdf

Systematic uncertainty

4、Kinematic fit

The difference in MC efficiency between before and after the helix parameters correction is taken as the systematic uncertainty.

5、Radiative correction

We take BW function $M = 4218.4\ \mathrm{MeV}/c^2$, $\Gamma_t = 40.6\ \mathrm{MeV}$ as the line-shape to get the nominal results, and change the line-shape to BW function $M = 4226\ \mathrm{MeV}/c^2$, $\Gamma_t = 39\ \mathrm{MeV}$ to get uncertainty.

6、Fit range

Varying the limit of the fit range by $\pm 5\ \mathrm{MeV}/c^2$ to get the systematic uncertainty.

Systematic uncertainty

7、Signal shape

Using MC shape convoluted with a Gaussian function to fit the data to get the uncertainty, and the Gaussian function's mean and sigma are fixed in the results from data at $\sqrt{s} = 4.22$ GeV.

8、Background shape

The ARGUS function's m_0 is fixed to $(\sqrt{s} - 0.75)$ GeV, varying the m_0 by $\pm 0.01\ \mathrm{GeV}/c^2$ to get the systematic uncertainty.

9、Branching fraction

The systematic uncertainty of the branching fraction is quoted from PDG.

Systematic uncertainty

The summary of systematic uncertainty

Source / $\sqrt{s}$ (GeV)	4.18	4.19	4.20	4.21	4.22
Luminosity	1.0	1.0	1.0	1.0	1.0
Tracking efficiency	4.0	4.0	4.0	4.0	4.0
Photon detection	4.0	4.0	4.0	4.0	4.0
Kinematic fit	0.6	0.6	0.6	0.5	0.6
Radiative correction	–	–	0.1	0.8	4.2
Fit Range	7.0	1.4	4.6	0.7	7.9
Signal shape	1.4	0.2	0.7	0.4	0.2
Background shape	31.9	5.5	9.9	5.6	2.5
Branching fraction	6.9	6.9	6.9	6.9	6.9
sum	33.9	10.7	14.2	10.7	13.0

Summary

1、Using data samples at $\sqrt{s} = 4.18, 4.19, 4.20, 4.21, 4.22$ GeV, the process $e^+e^- \to \omega\chi_{c0}$ is measured. The cross section is measured to be $(-0.9 \pm 1.7 \pm 0.3)$, $(5.6 \pm 3.4 \pm 0.6)$, $(17.8 \pm 7.5 \pm 2.6)$, $(30.9 \pm 8.3 \pm 3.3)$, $(86.2 \pm 11.4 \pm 11.2)$ pb.

2、There is a structure Y(4220) in $\omega\chi_{c0}$ line-shape, and the structure Y(4220) parameters are measured with higher precision, $M = (4218.4 \pm 2.9)\ \mathrm{MeV}/c^2$, $\Gamma_t = (40.6 \pm 7.4)\ \mathrm{MeV}$.

3、More data samples at this energy region are producing and they are useful to understand the structure Y(4220).

4、Analysis memo has been finished, and we have sent it to conveners to review. The memo link is http://docbes3.ihep.ac.cn/DocDB/0006/000624/001/omegachic0_v1.1.pdf

Study of $e^+e^- \to \omega\chi_{c0}$ around $\sqrt{s} = 4.2$ GeV

Jielei Zhang[1], Jingzhi Zhang[1]
[1]Institute of High Energy Physics, Beijing, 100049, China

(Dated: March 21, 2017)

Abstract

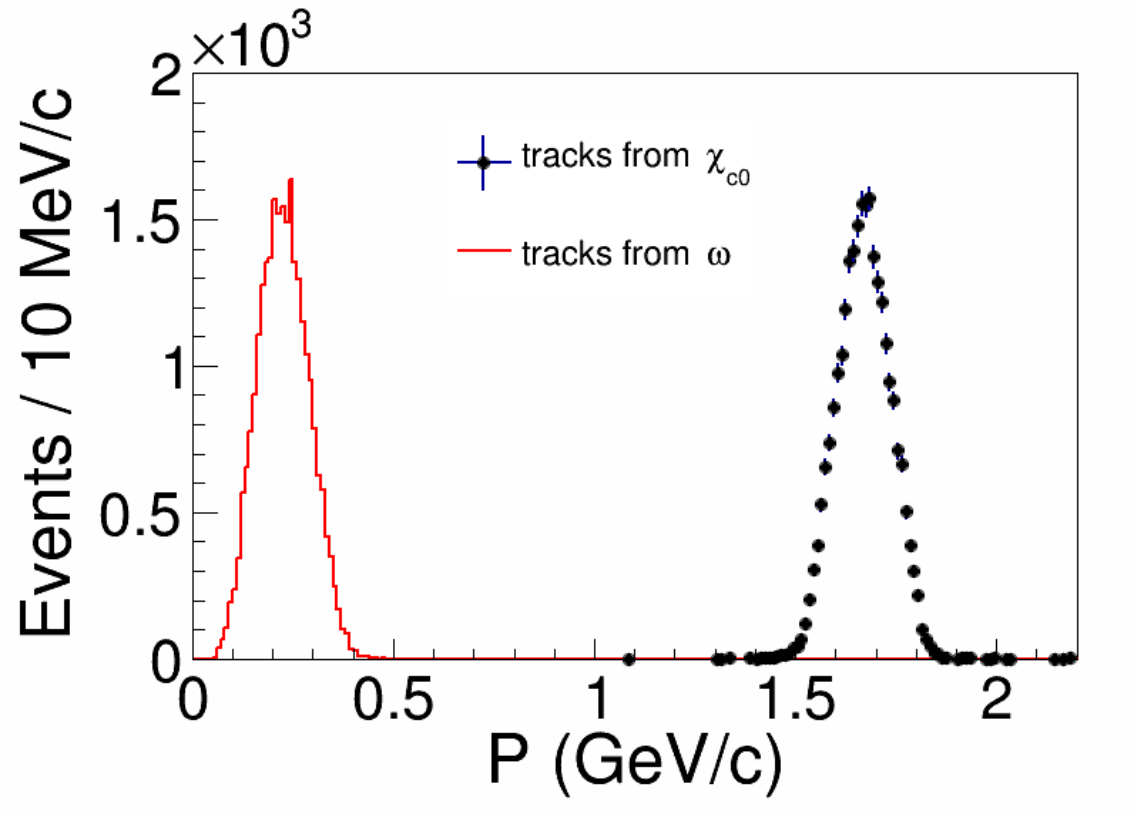
Using data samples collected with the BESIII detector operating at the BEPCII storage ring at center-of-mass energies from 4.18 to 4.22 GeV, the process $e^+e^- \to \omega\chi_{c0}$ is observed with a statistical significance of $> 5\sigma$. The cross sections for $e^+e^- \to \omega\chi_{c0}$ at each energy point are measured, the results are $(-0.9 \pm 1.7 \pm 0.3)$, $(5.6 \pm 3.4 \pm 0.6)$, $(17.8 \pm 7.5 \pm 2.6)$, $(30.9 \pm 8.3 \pm 3.3)$, $(86.2 \pm 11.4 \pm 11.2)$ pb for $\sqrt{s} = 4.18, 4.19, 4.20, 4.21, 4.22$ GeV, respectively. An obvious structure is observed in the $\omega\chi_{c0}$ line shape. If we use a phase-space modified Breit-Wigner function to fit, the mass and width for the structure are $M = (4218.4 \pm 2.9)\ \mathrm{MeV}/c^2$ and $\Gamma_t = (40.6 \pm 7.4)$ MeV.

Thanks for your attention!

BACK UP

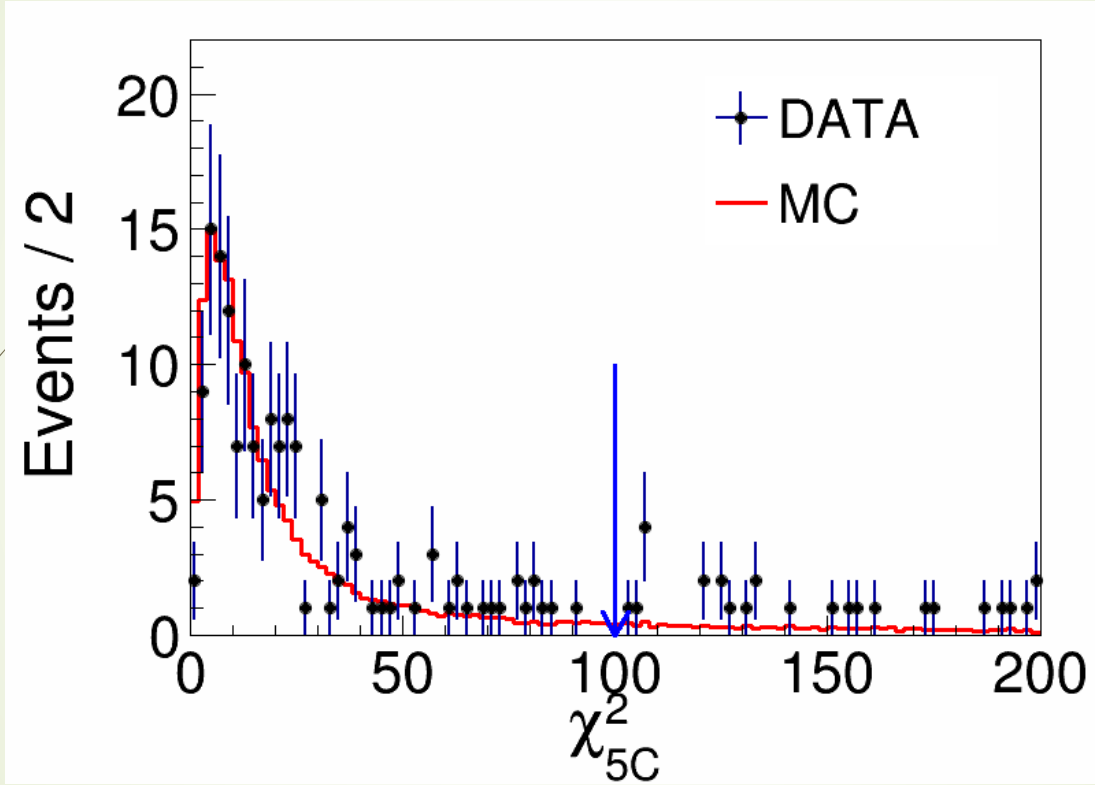
Data at $\sqrt{s} = 4.22$ GeV

Momentum distributions



Momentum distributions of charged tracks for signal MC

The χ^2_{5C} of kinematic fit



χ^2 distribution from 5C : $\chi^2_{5C} < 100$

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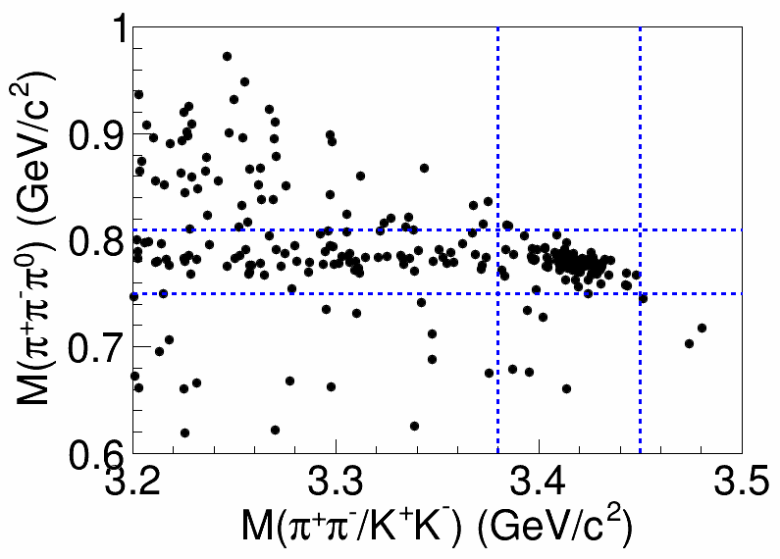

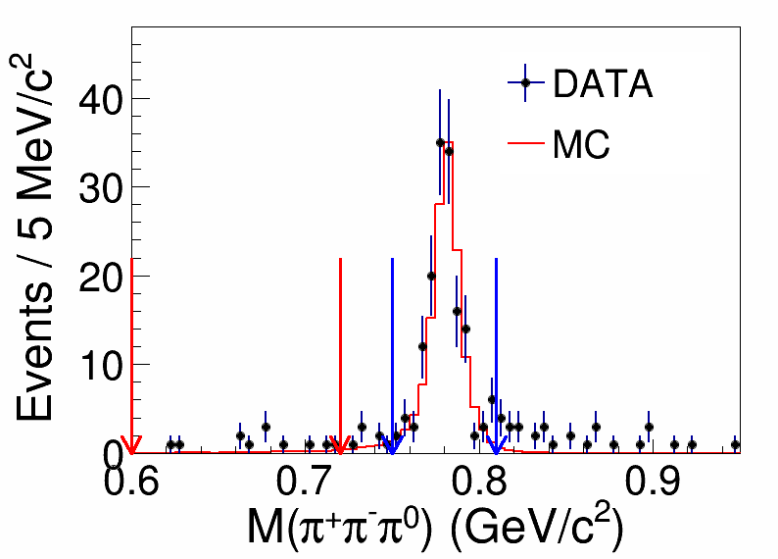

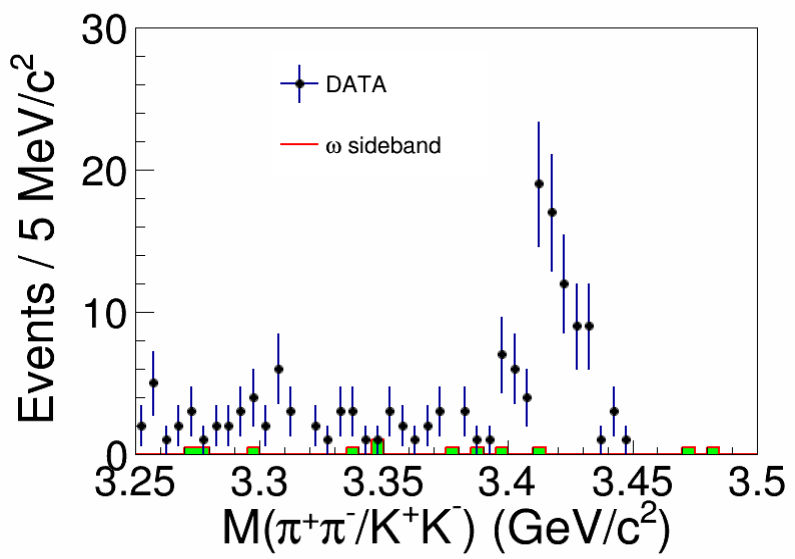

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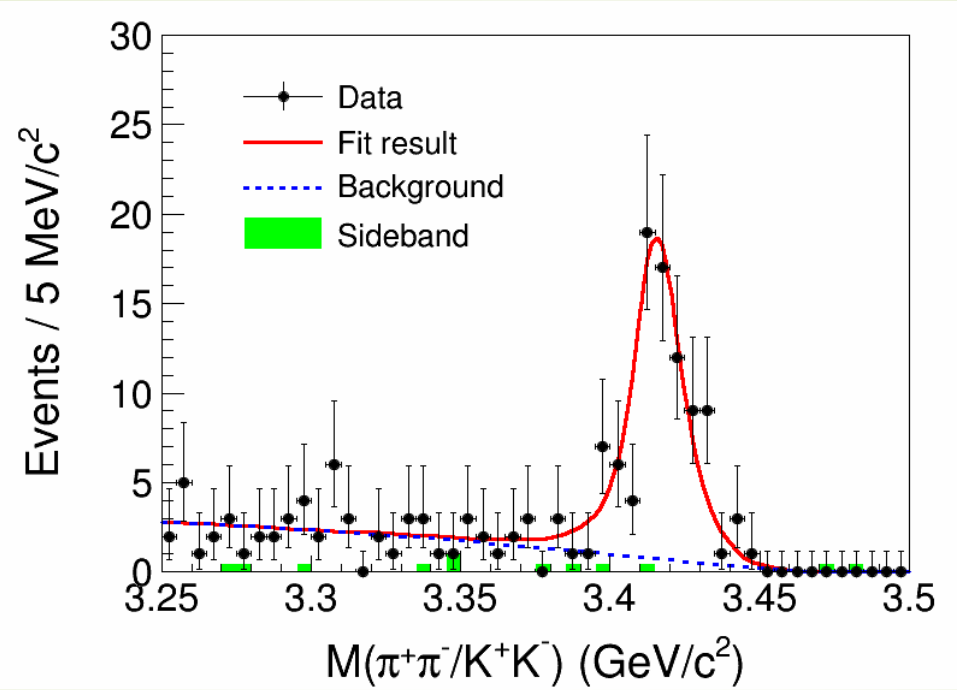
- Sideband regions :
  $0.60 \leq M(\pi^+\pi^-\pi^0) \leq 0.72\ \mathrm{GeV}/c^2$

Signal extraction from data



Signal :

MC-determined signal MC shape

Background :

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m_0 is fixed to $(\sqrt{s} - 0.75) = 3.47$ GeV, the p and k are float

$$N^{sig} = 84.7 \pm 11.2$$

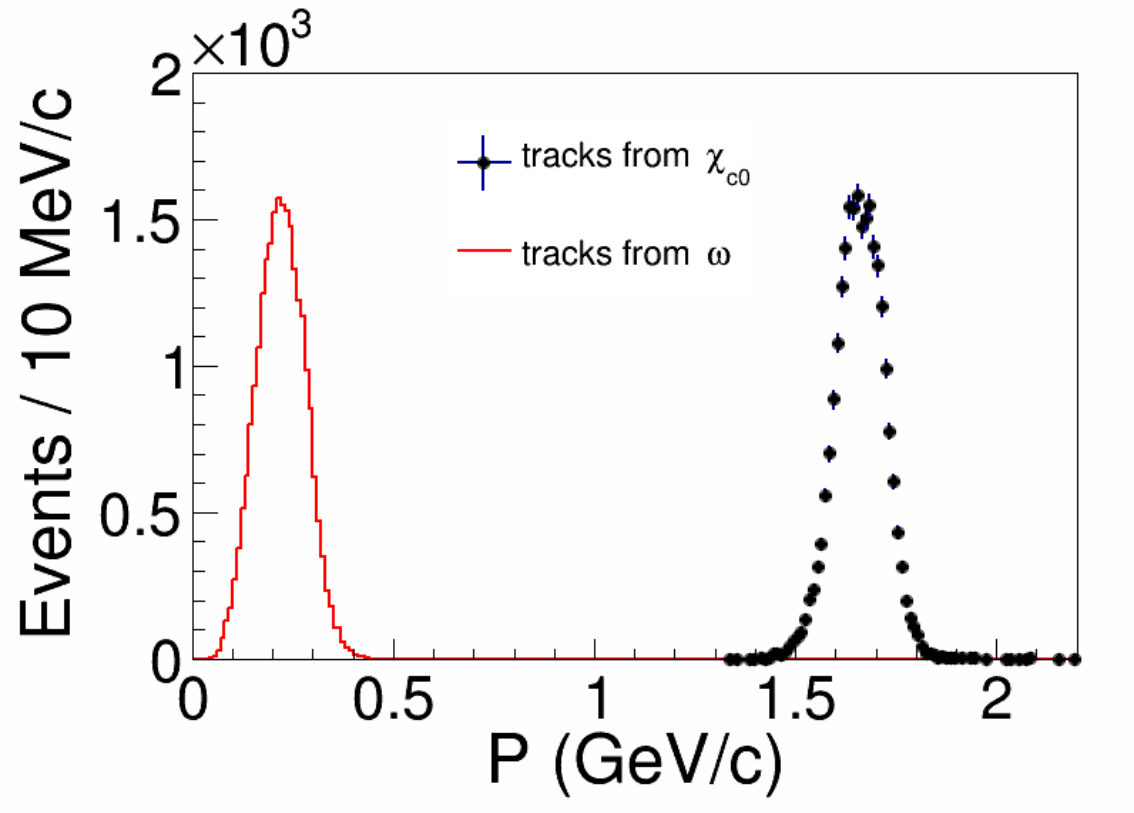
Cross section measurement

$$\sigma^B(e^+e^- \to \omega\chi_{c0}) = \frac{N^{sig}}{\mathcal{L}_{int}(1+\delta(s))\frac{1}{|1-\Pi|^2}\mathcal{B}(\chi_{c0} \to \pi^+\pi^-/K^+K^-)\mathcal{B}(\omega \to \pi^+\pi^-\pi^0)\mathcal{B}(\pi^0 \to \gamma\gamma)\epsilon}$$

$\sqrt{s}$(GeV)	$\mathcal{L}_{int}$(pb^{-1})	N^{sig}	$1+\delta$(s)	$\frac{1}{\lvert 1-\Pi\rvert^2}$	$\epsilon(\%)$	σ^B(pb)
4.22	500	84.7$\pm$11.2	0.70	1.057	26.30	86.2 ± 11.4

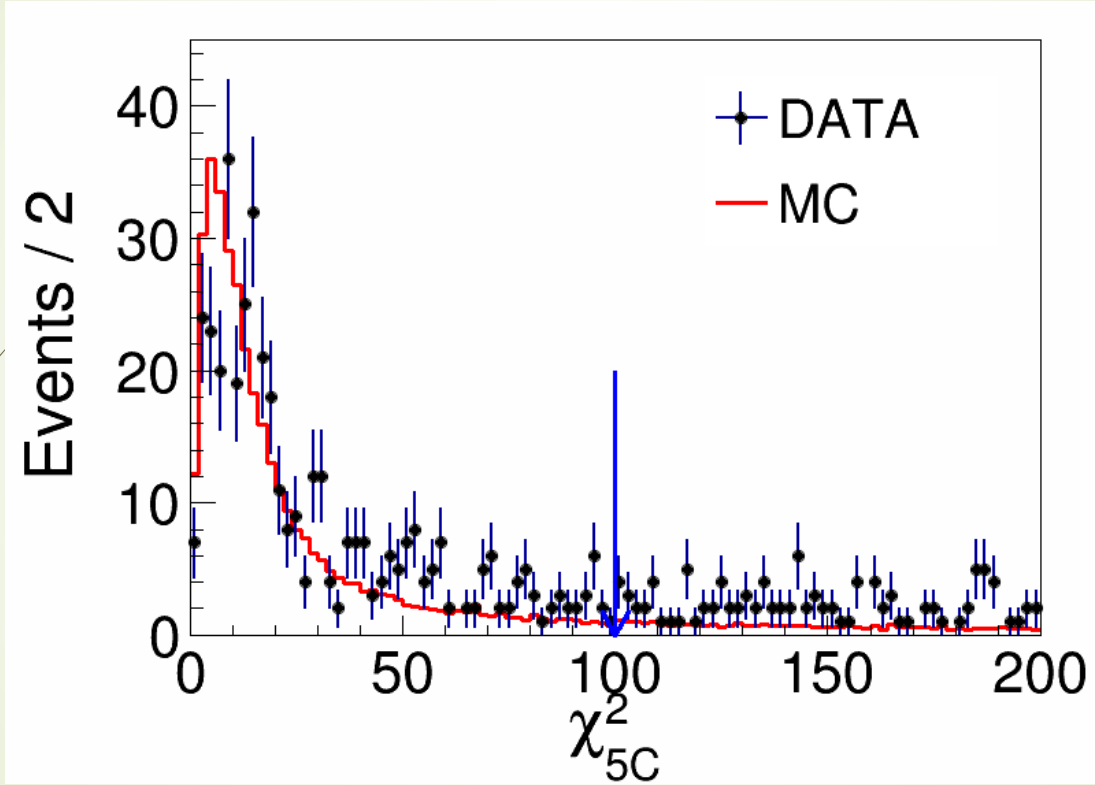
Data at $\sqrt{s} = 4.18$ GeV

Momentum distributions



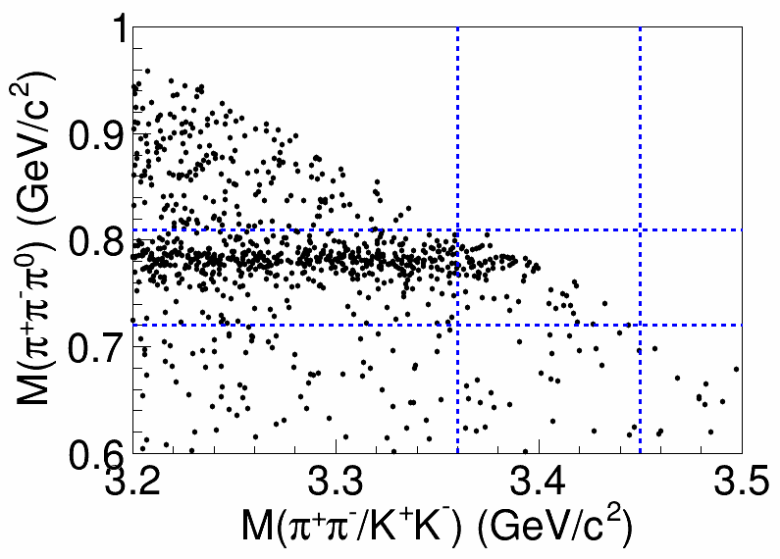
Momentum distributions of charged tracks for signal MC

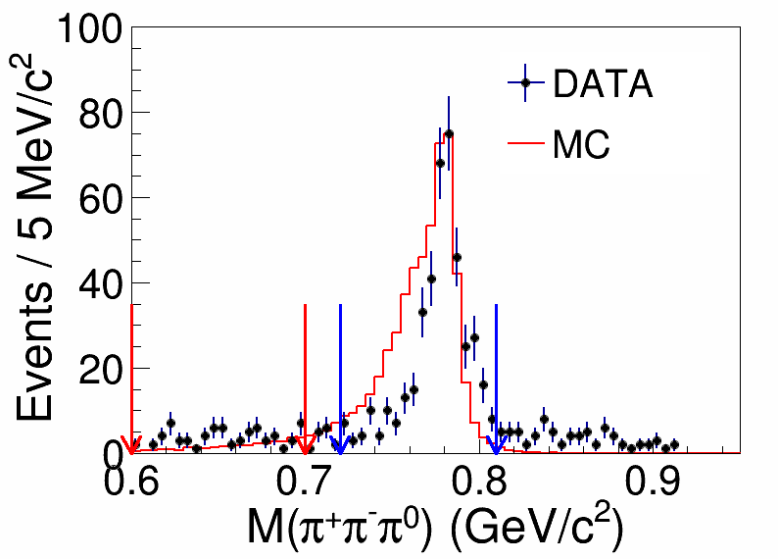
The χ^2_{5C} of kinematic fit

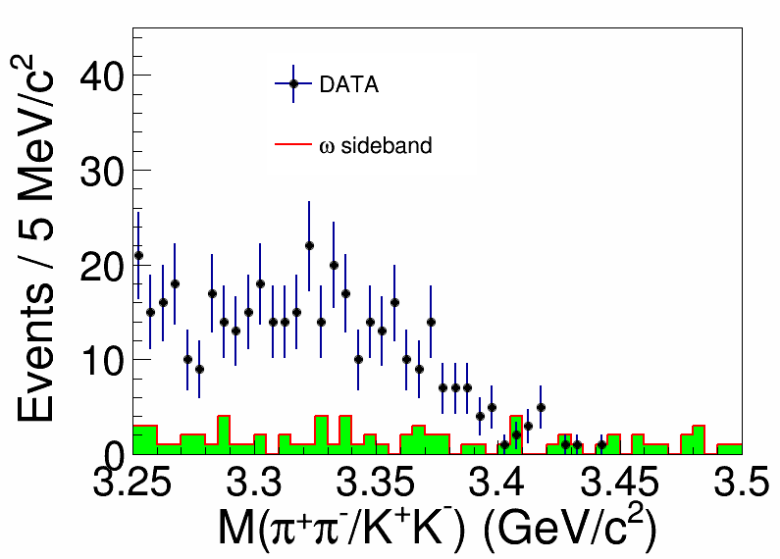


χ^2 distribution from 5C : $\chi^2_{5C} < 100$

Some plots from data

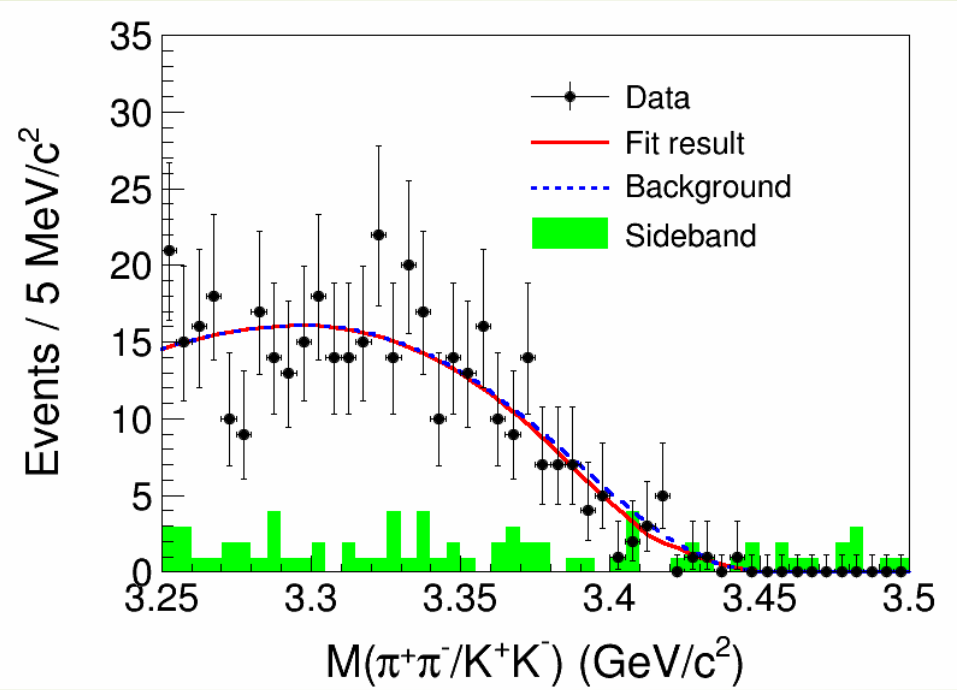






- ω mass window : (0.72, 0.81) GeV/c^2
- Sideband regions :
  $0.60 \leq M(\pi^+\pi^-\pi^0) \leq 0.70\ \mathrm{GeV}/c^2$

Signal extraction from data



Signal :

MC-determined signal MC shape

Background :

ARGUS function $m(1-\left(\frac{m}{m_0}\right)^2)^p \cdot \exp(k(1-\left(\frac{m}{m_0}\right)^2)) \cdot \theta(m < m_0)$

m_0 is fixed to $(\sqrt{s} - 0.72) = 3.46$ GeV, the p and k are float

$$N^{sig} = -7.2 \pm 13.6$$

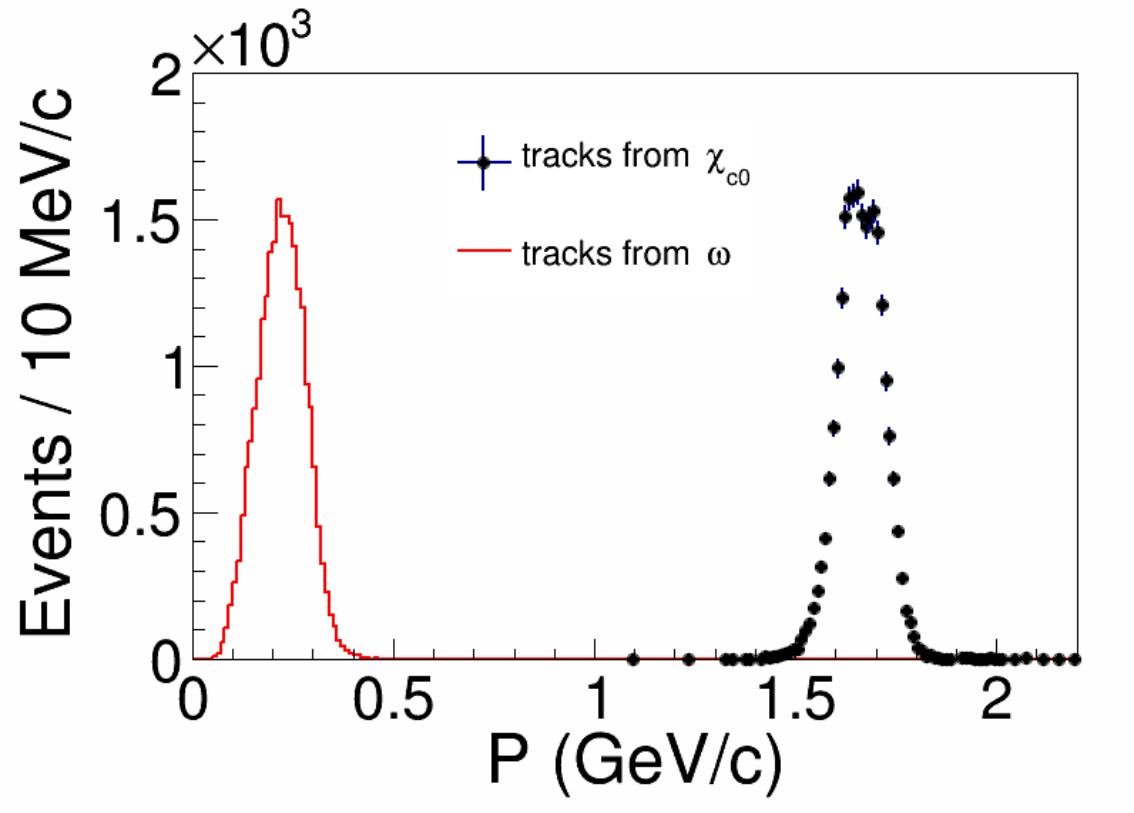
Cross section measurement

$$\sigma^B(e^+e^- \to \omega\chi_{c0}) = \frac{N^{sig}}{\mathcal{L}_{int}(1+\delta(s))\frac{1}{|1-\Pi|^2}\mathcal{B}(\chi_{c0} \to \pi^+\pi^-/K^+K^-)\mathcal{B}(\omega \to \pi^+\pi^-\pi^0)\mathcal{B}(\pi^0 \to \gamma\gamma)\epsilon}$$

$\sqrt{s}$(GeV)	$\mathcal{L}_{int}$(pb^{-1})	N^{sig}	$1+\delta$(s)	$\frac{1}{\lvert 1-\Pi\rvert^2}$	ϵ(%)	σ^B(pb)
4.18	3161	-7.2±13.6	1.0	1.055	24.48	-0.9 ± 1.7

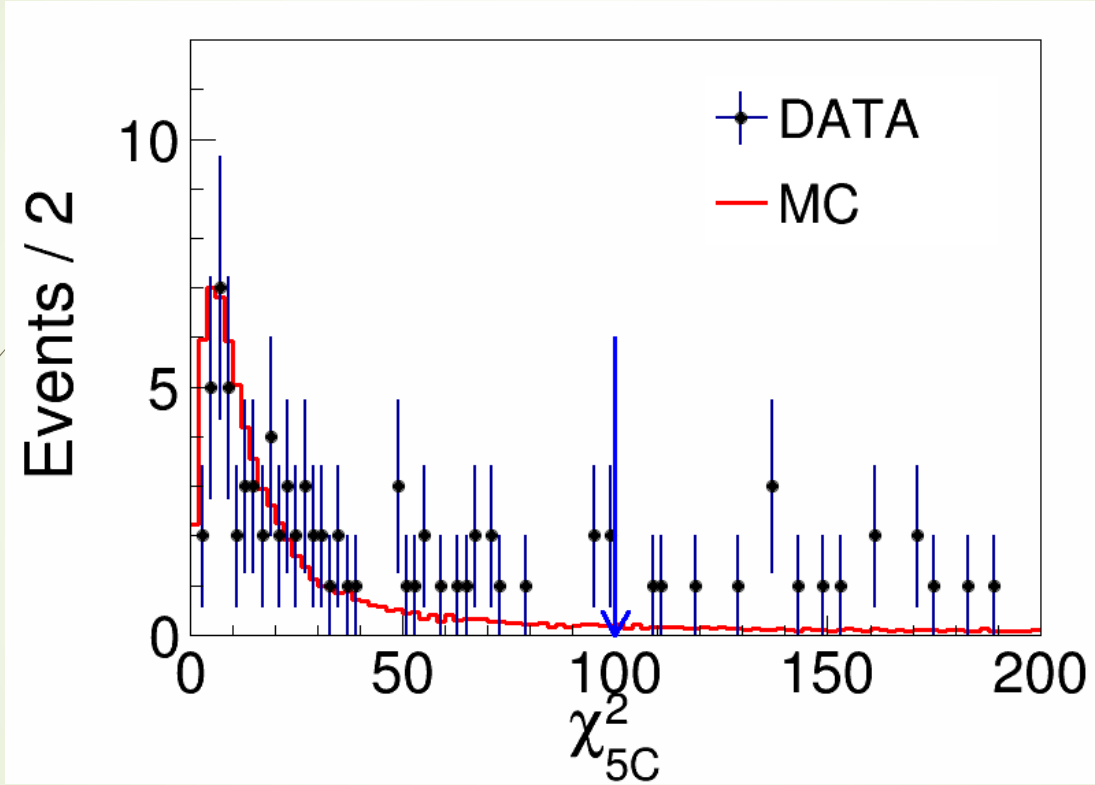
Data at $\sqrt{s} = 4.19$ GeV

Momentum distributions



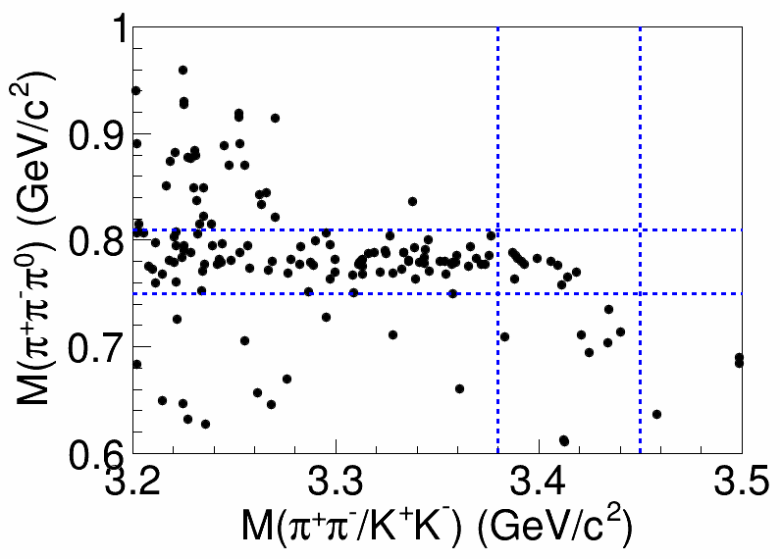
Momentum distributions of charged tracks for signal MC

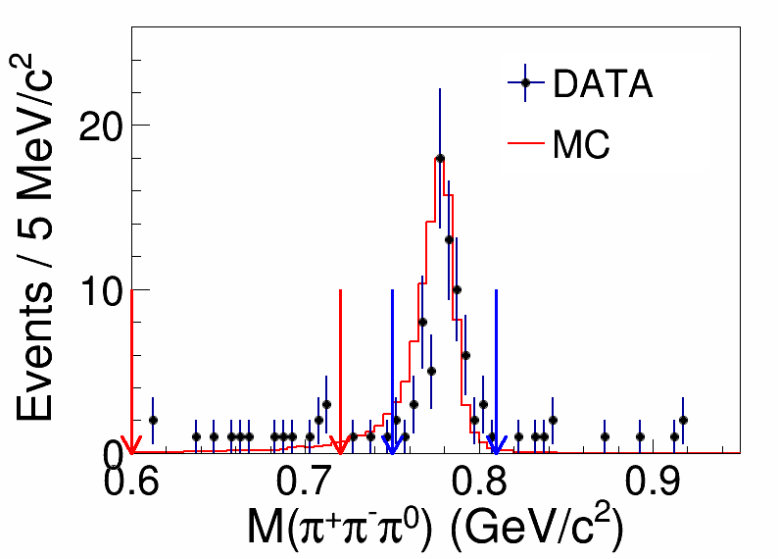
The χ^2_{5C} of kinematic fit

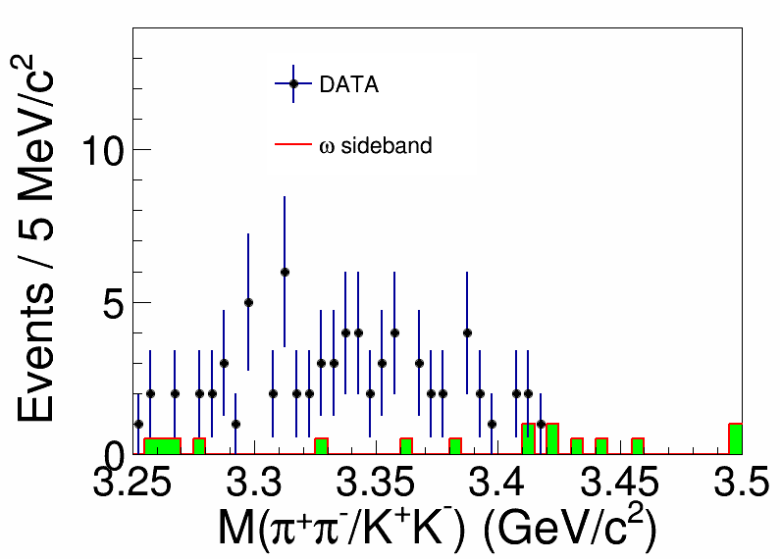


χ^2 distribution from 5C : $\chi^2_{5C} < 100$

Some plots from data

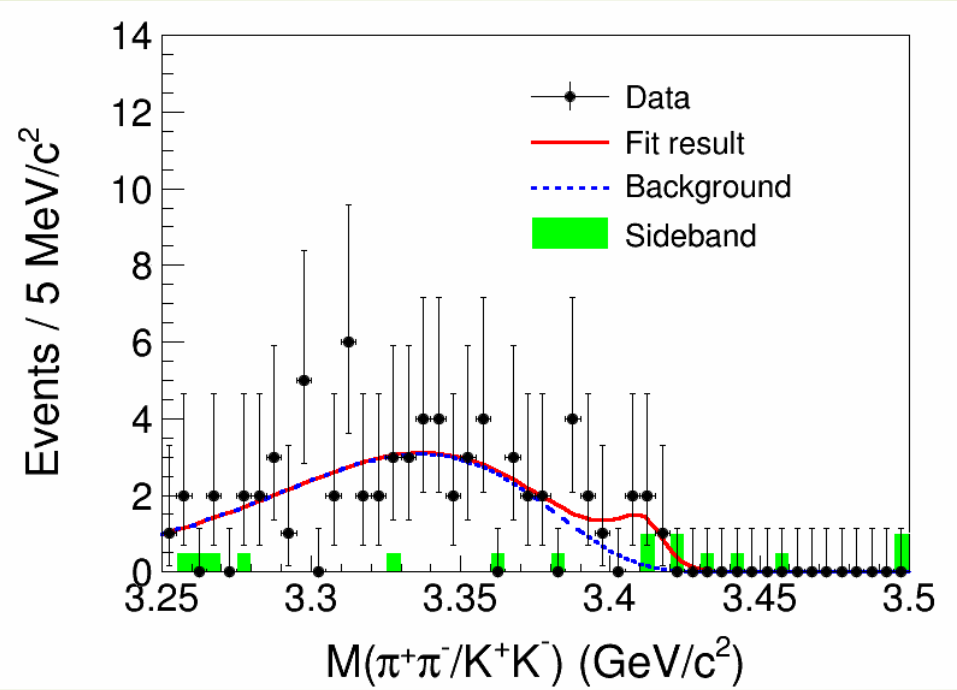






- ω mass window : (0.75, 0.81) GeV/c^2
- Sideband regions :
  $0.60 \leq M(\pi^+\pi^-\pi^0) \leq 0.72\ \mathrm{GeV}/c^2$

Signal extraction from data



Signal :

MC-determined signal MC shape

Background :

ARGUS function $m(1-\left(\frac{m}{m_0}\right)^2)^p \cdot \exp(k(1-\left(\frac{m}{m_0}\right)^2)) \cdot \theta(m < m_0)$

m_0 is fixed to $(\sqrt{s} - 0.75) = 3.44$ GeV, the p and k are float

$$N^{sig} = 7.3 \pm 4.4$$

Cross section measurement

$$\sigma^B(e^+e^- \to \omega\chi_{c0}) = \frac{N^{sig}}{\mathcal{L}_{int}(1+\delta(s))\frac{1}{|1-\Pi|^2}\mathcal{B}(\chi_{c0} \to \pi^+\pi^-/K^+K^-)\mathcal{B}(\omega \to \pi^+\pi^-\pi^0)\mathcal{B}(\pi^0 \to \gamma\gamma)\epsilon}$$

$\sqrt{s}$(GeV)	$\mathcal{L}_{int}$(pb^{-1})	N^{sig}	$1+\delta$(s)	$\frac{1}{\lvert 1-\Pi\rvert^2}$	ϵ(%)	σ^B(pb)
4.19	517.5	7.3±4.4	1.0	1.056	23.70	5.6 ± 3.4