Updates on the X(3872) at BESIII

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BESIII

Outline

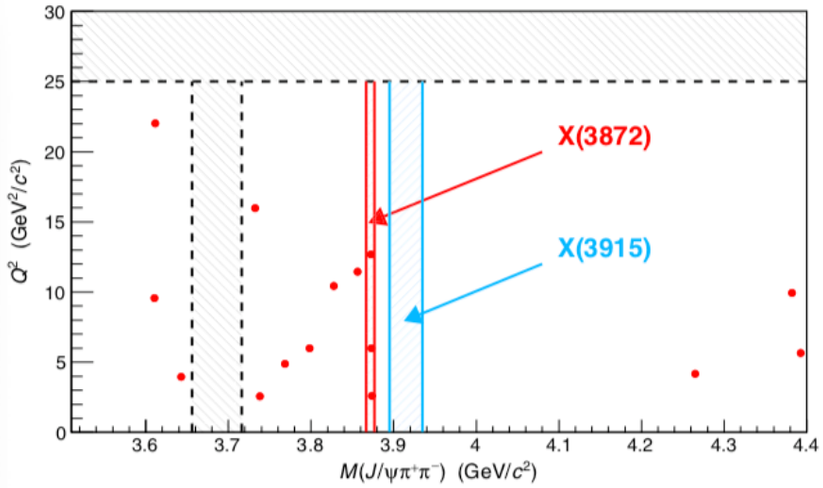
- Introduction
- Recent results on the X(3872) at BESIII
  - Preliminary results on the study of $e^+e^- \to \omega X(3872)$
  - Search for $X(3872) \to \pi^0\chi_{c0}$ and $\pi\pi\chi_{c0}$
- Summary

Productions of the X(3872)

Productions

- e+e-→γX(3872) (BESIII)
- B,B_s→KX(3872) (Belle, Babar, LHCb, CMS)
- γγ*→X(3872) (Belle)
- Λ_b decays (LHCb)
- pp/$p\bar{p}$ collision (LHCb, CDF, D0, ATLAS, CMS)
- PbPb collision (CMS)

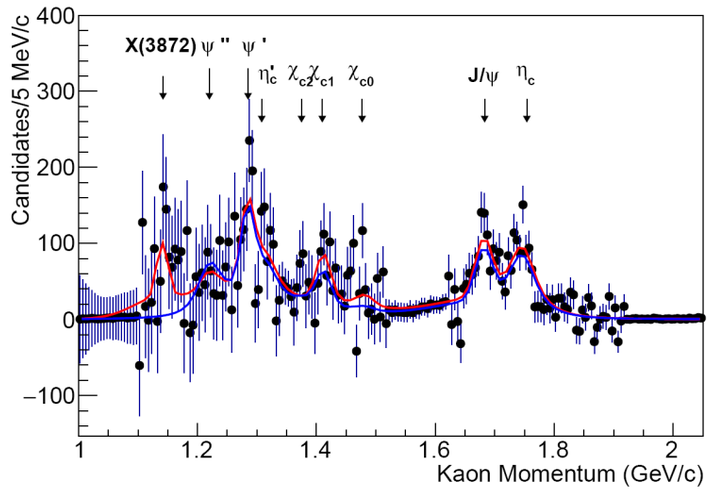
γγ*→X(3872)



$3^{+2.2}_{-2.0}\pm0.1$ signals, 3.2σ

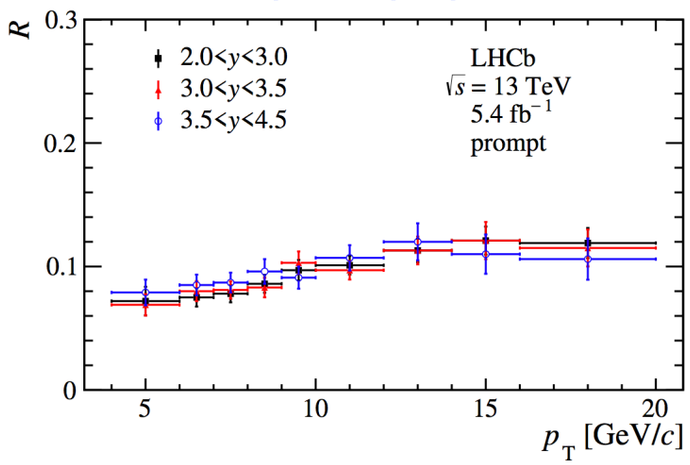
Belle: PRL126,122001 (2021)

B→KX(3872)

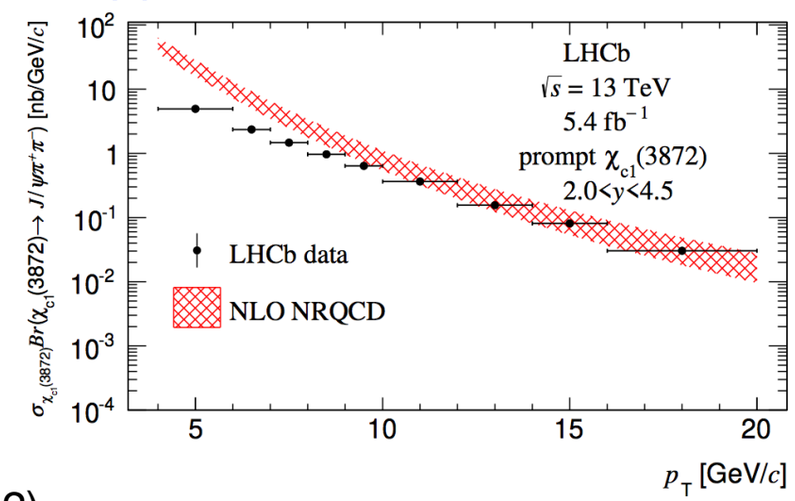


Babar: PRL124,152001 (2020)

prompt production from pp collision

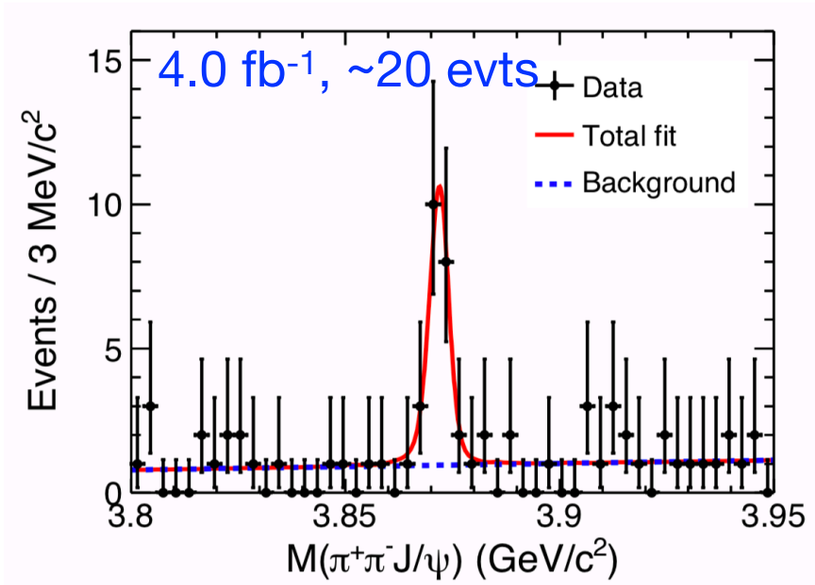


LHCb: JHEP 01,131 (2022)

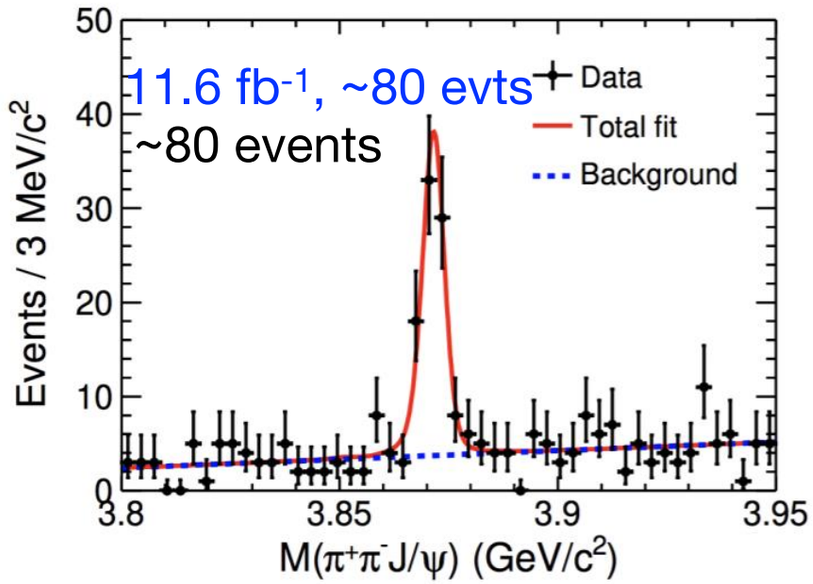


NLO NRQCD: Mixture of χ_{c1}(2P) and DD* molecule state [PRD 96, 074014 (2017)]

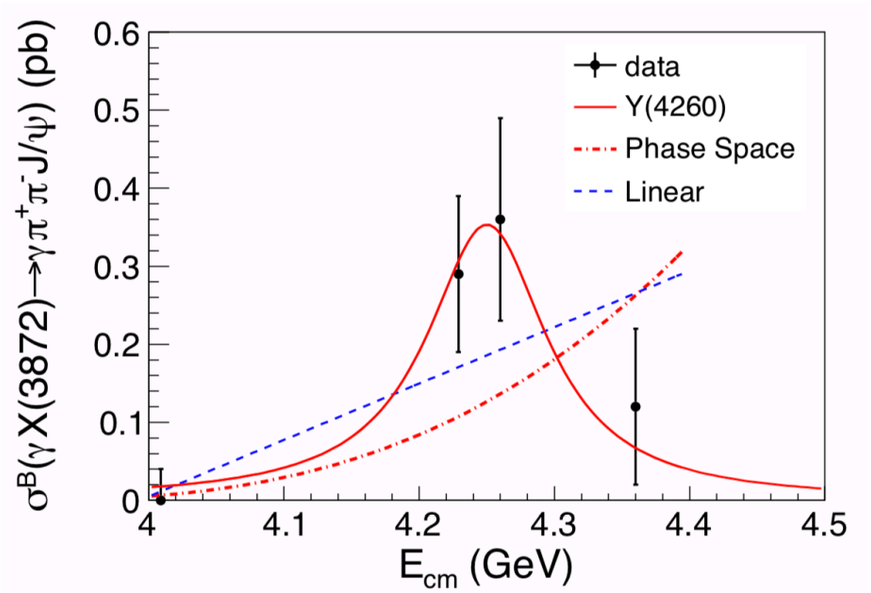
$e^+e^- \to \gamma X(3872)$ at BESIII



BESIII: PRL 112, 092001 (2014)



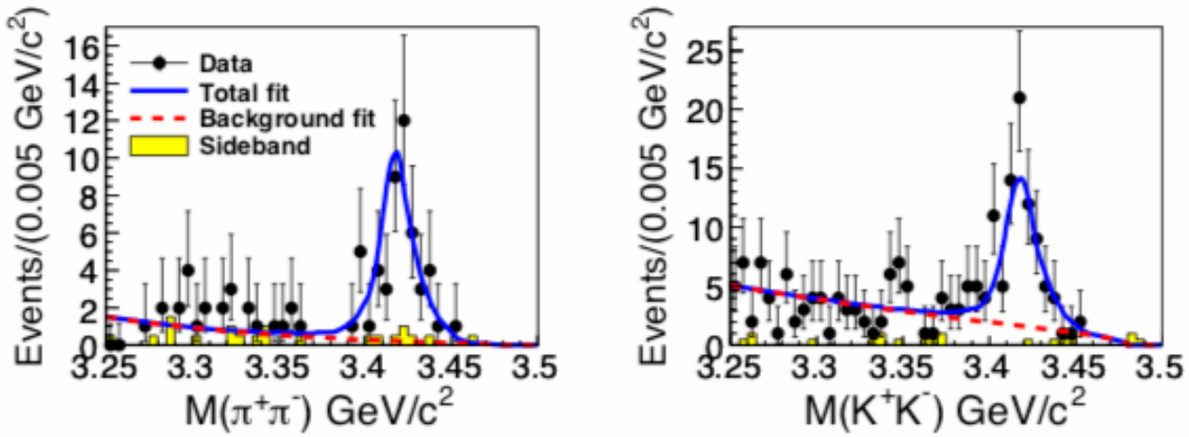
BESIII: PRL122,232002 (2019)



Favour Y(4230)→γX(3872)

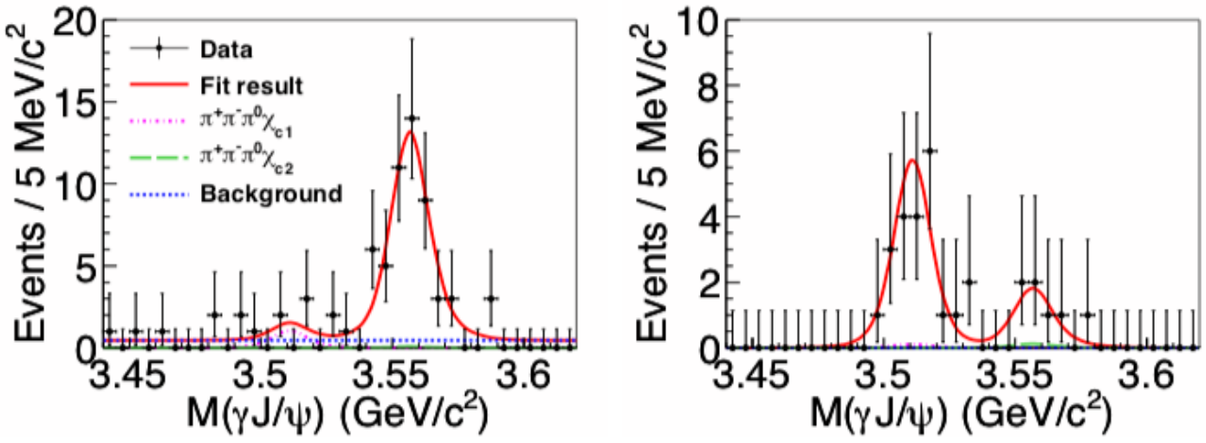
Study of $e^+e^- \to \omega\chi_{cJ}(1P)$ at BESIII

$e^+e^- \to \omega\,\chi_{c0}(1P)$

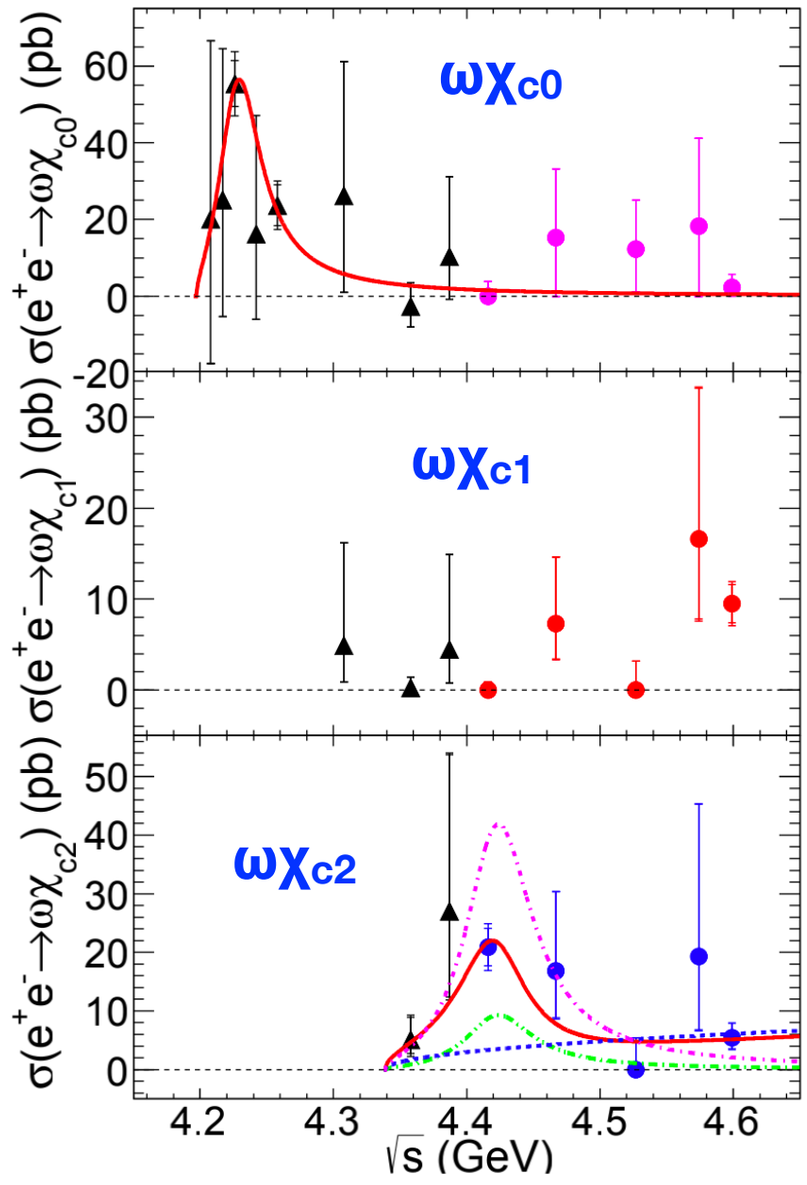


PRL114,092003 (2015)

$e^+e^- \to \omega\,\chi_{c1,2}(1P)$

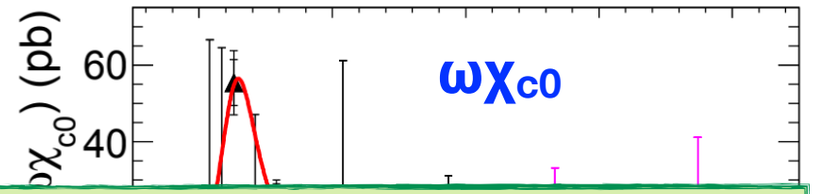


PRD93,011102 (2016)



Study of $e^+e^- \to \omega\chi_{cJ}(1P)$ at BESIII

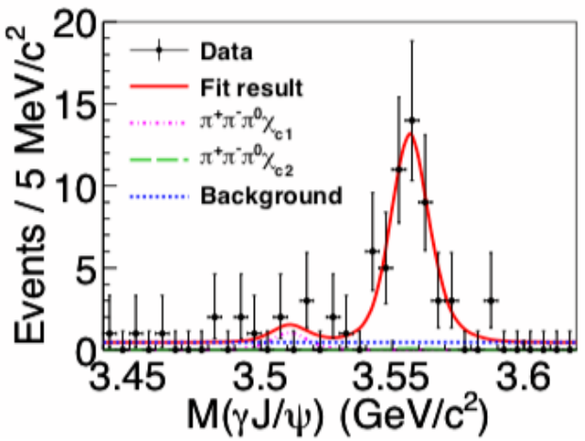
$e^+e^- \to \omega\,\chi_{c0}(1P)$

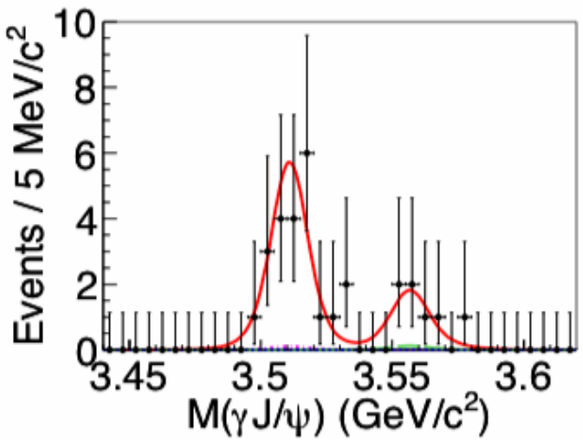


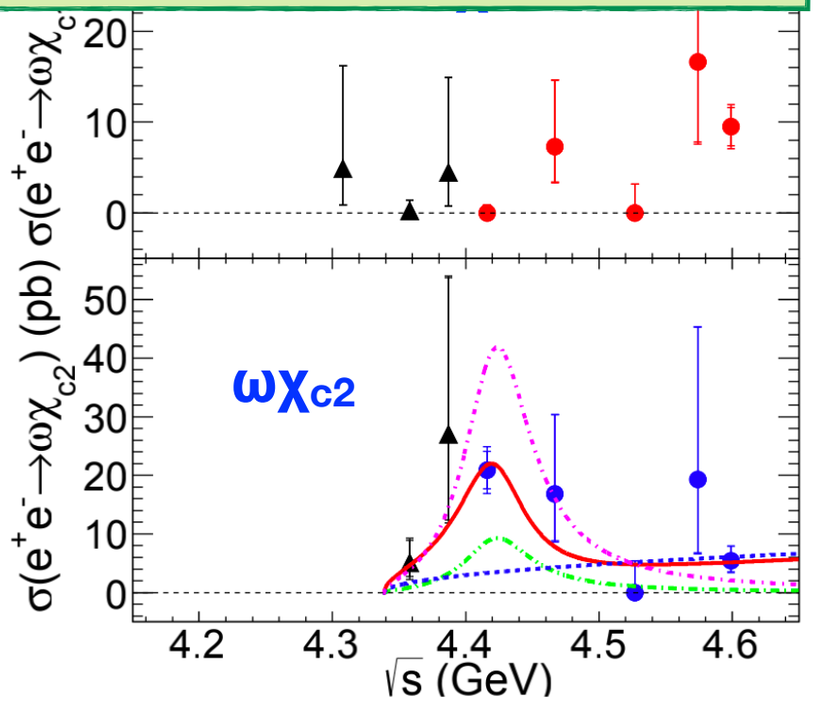
If X(3872) contains a component of the excited spin-triplet charmonium state $\chi_{c1}(2P)$, the process $e^+e^- \to \omega X(3872)$ may exist.

PRL114,092003 (2015)

$e^+e^- \to \omega\,\chi_{c1,2}(1P)$

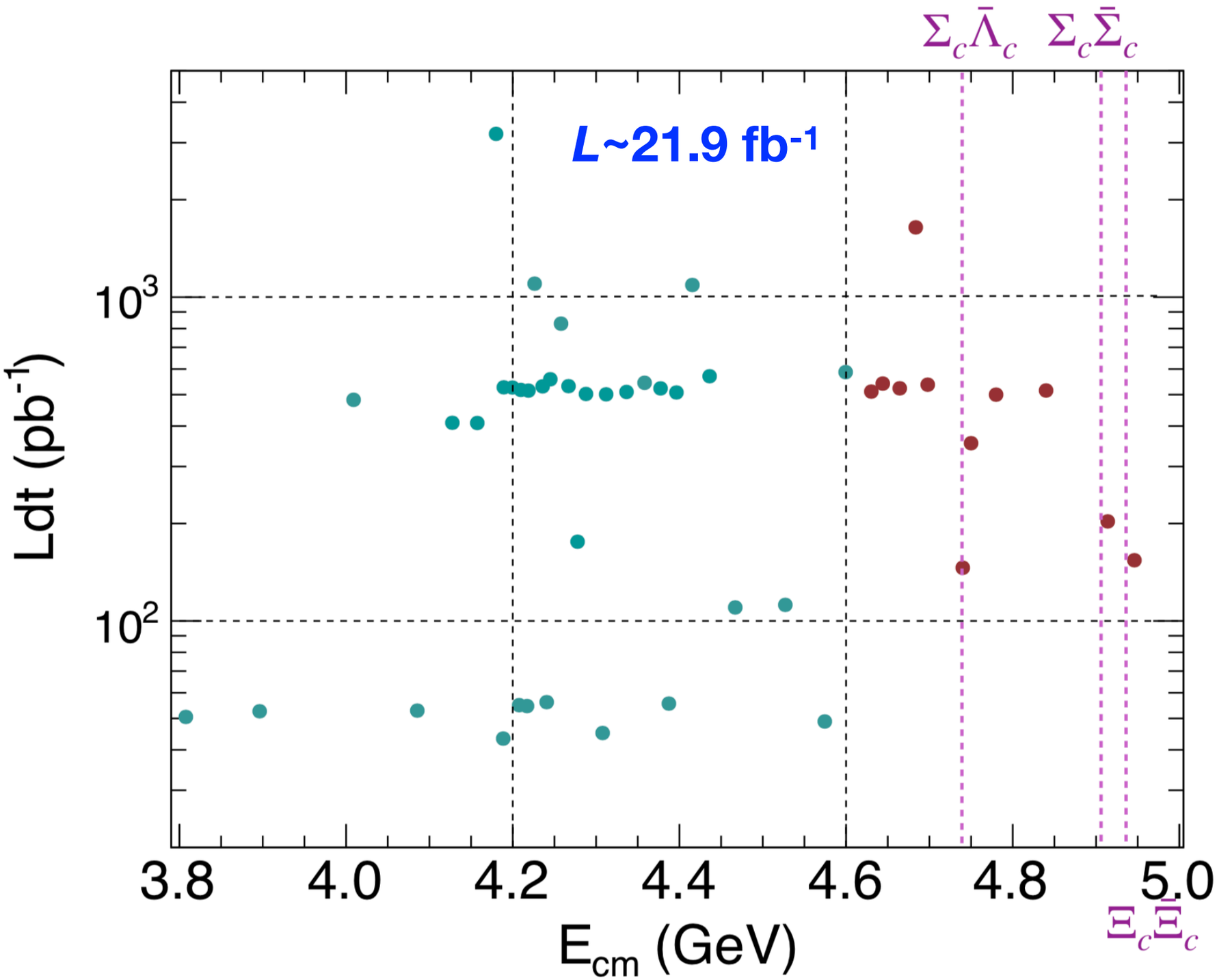




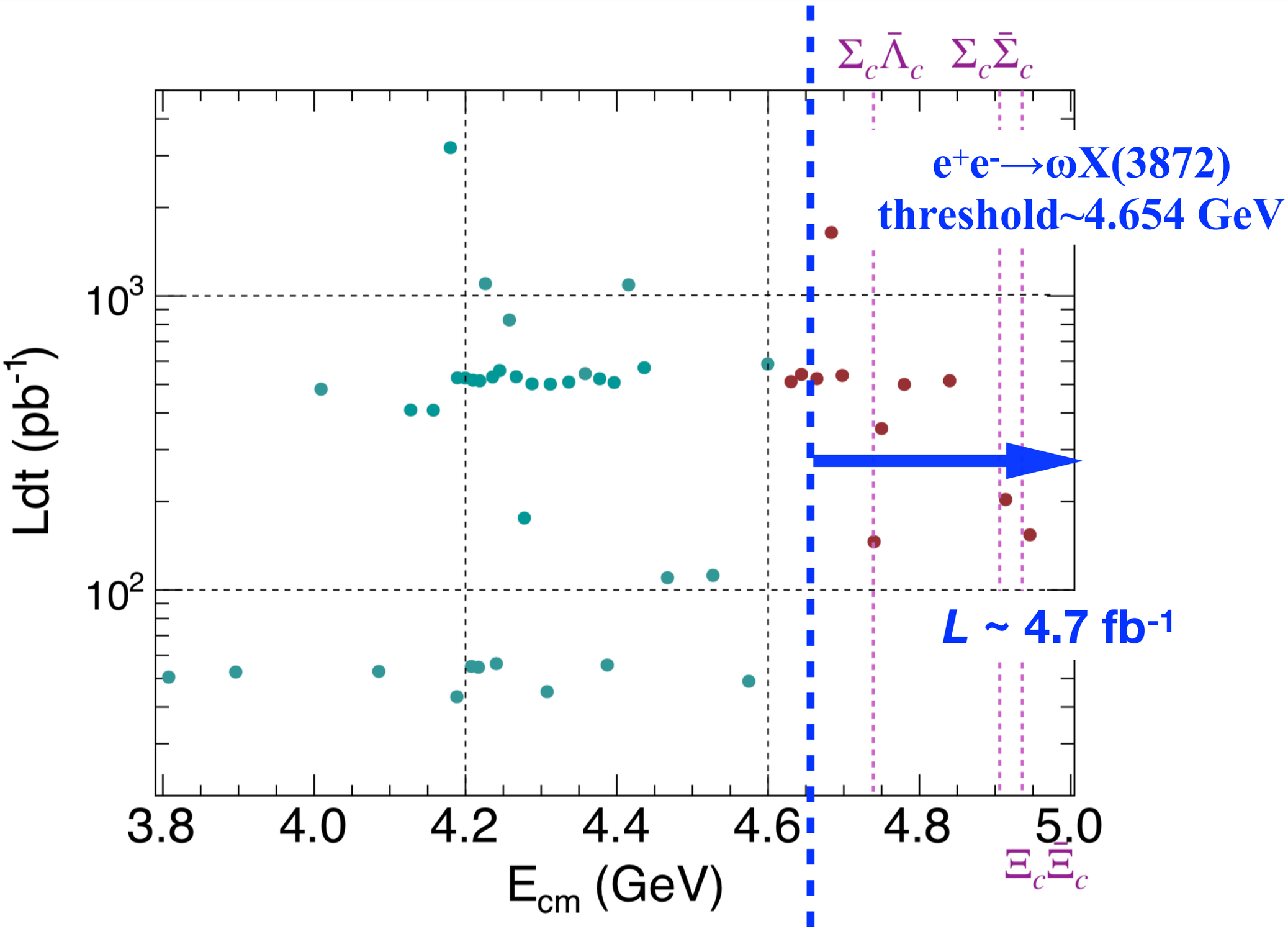


PRD93,011102 (2016)

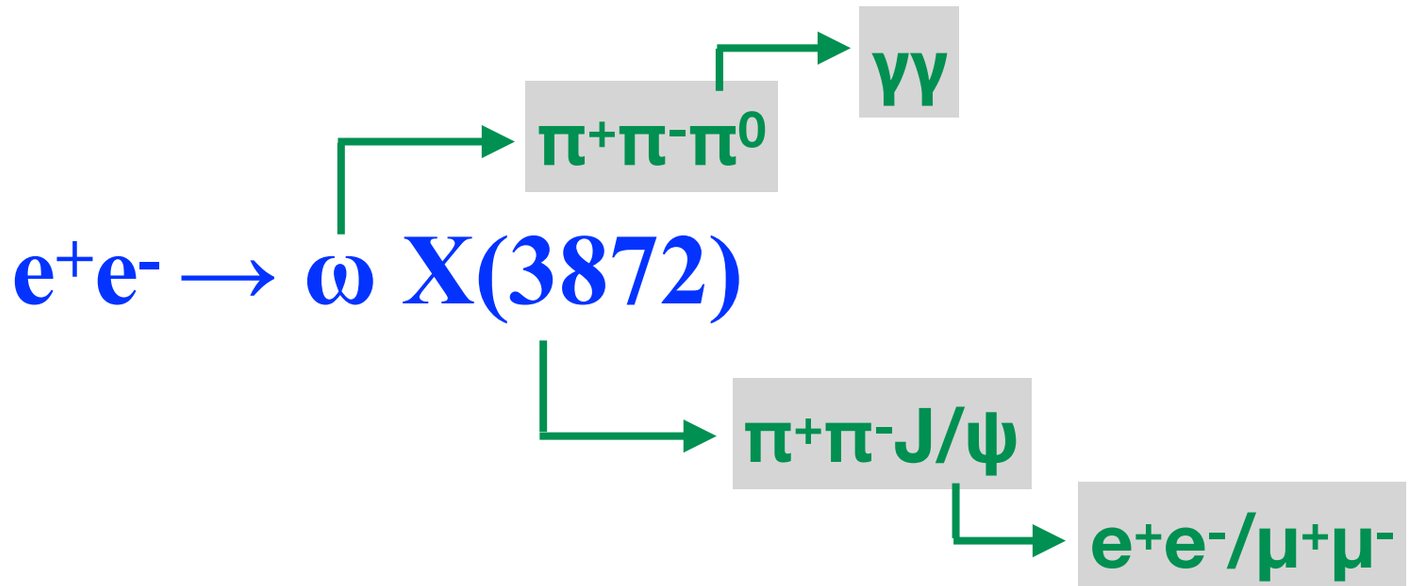
XYZ Datasets at BESIII



XYZ Datasets at BESIII



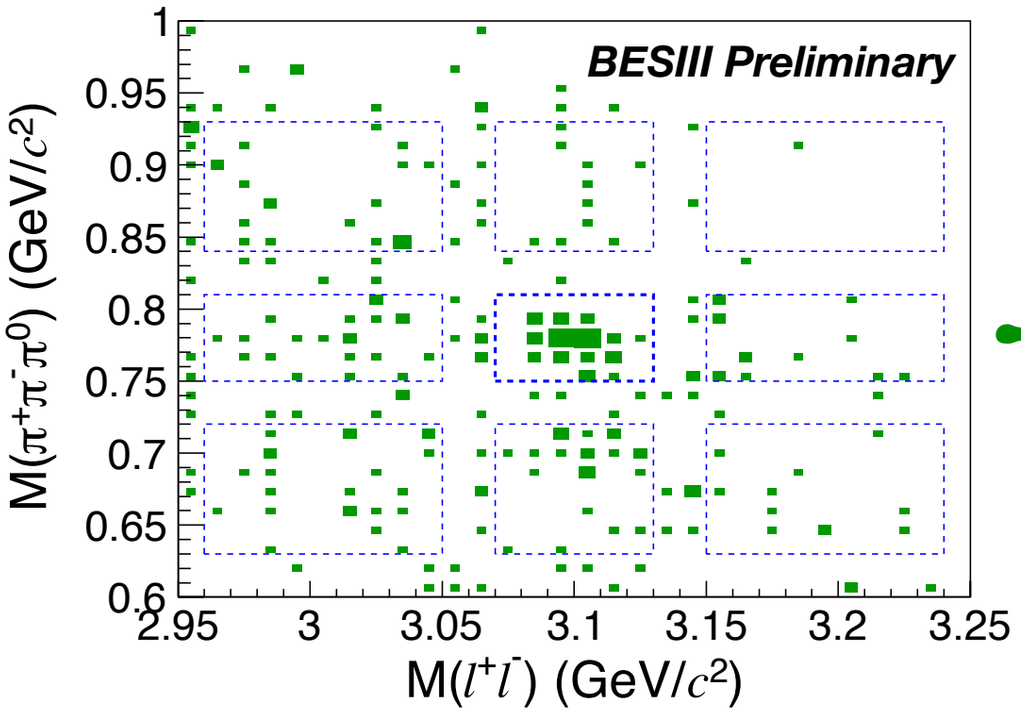
Search for $e^+e^- \to \omega X(3872)$



- Signal reconstruction
  - Final state includes six charged particles and two photons
  - Partial reconstruction by missing one pion in kinematic fit is applied to improve the signal efficiency
  - Retain all four $\pi^-\pi^+$ combinations per event

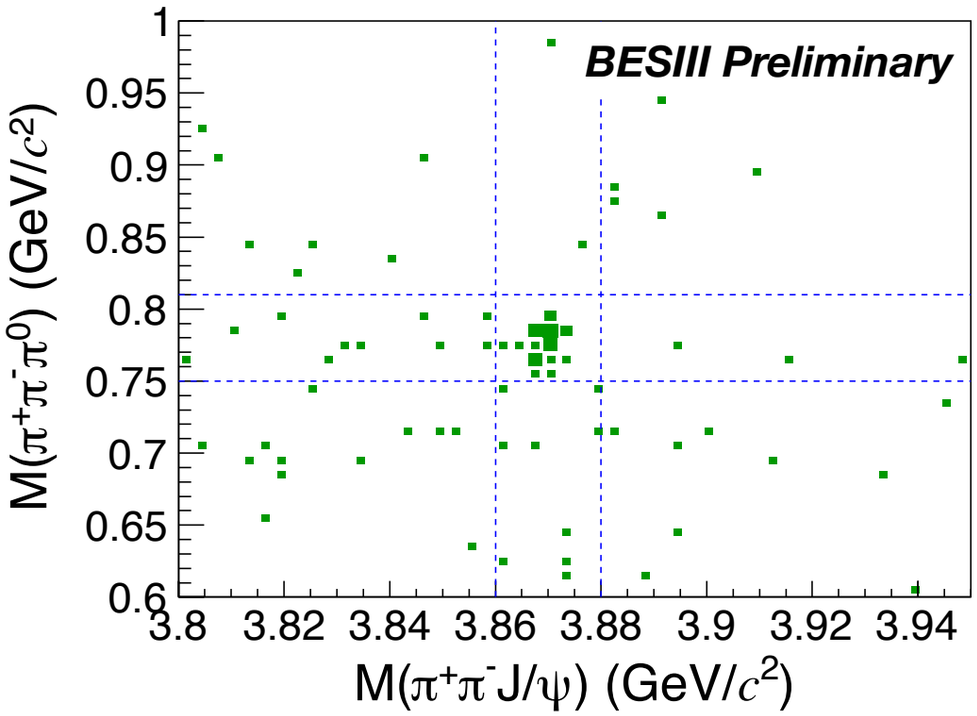
Search for $e^+e^-\to\omega X(3872)$

$M(\pi^+\pi^-\pi^0)$ vs. $M(l^+l^-)$



$M(l^+l^-)$: [3.07,3.13] GeV/c^2

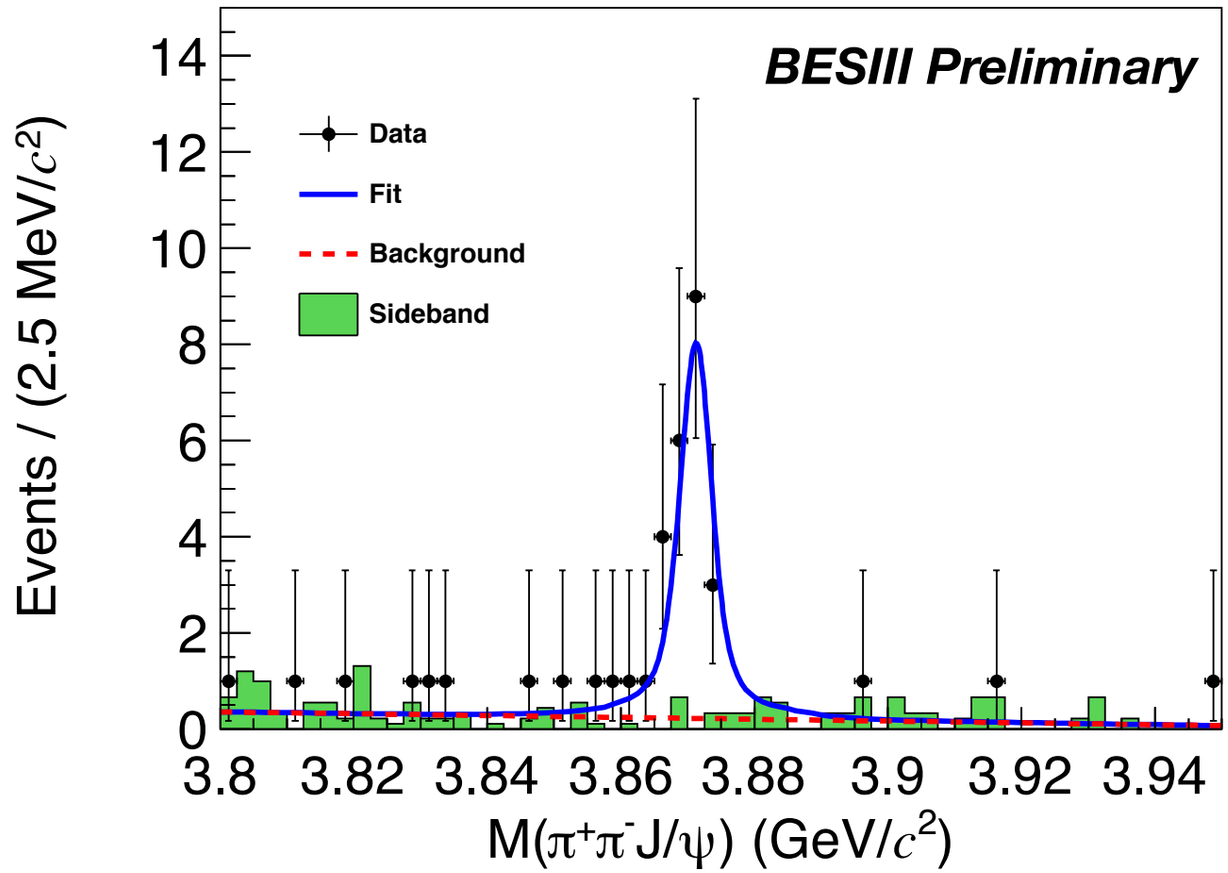
$M(\pi^+\pi^-\pi^0)$ vs. $M(\pi^+\pi^-J/\psi)$



Datasets at $\sqrt{S}$ =4.661-4.951 GeV

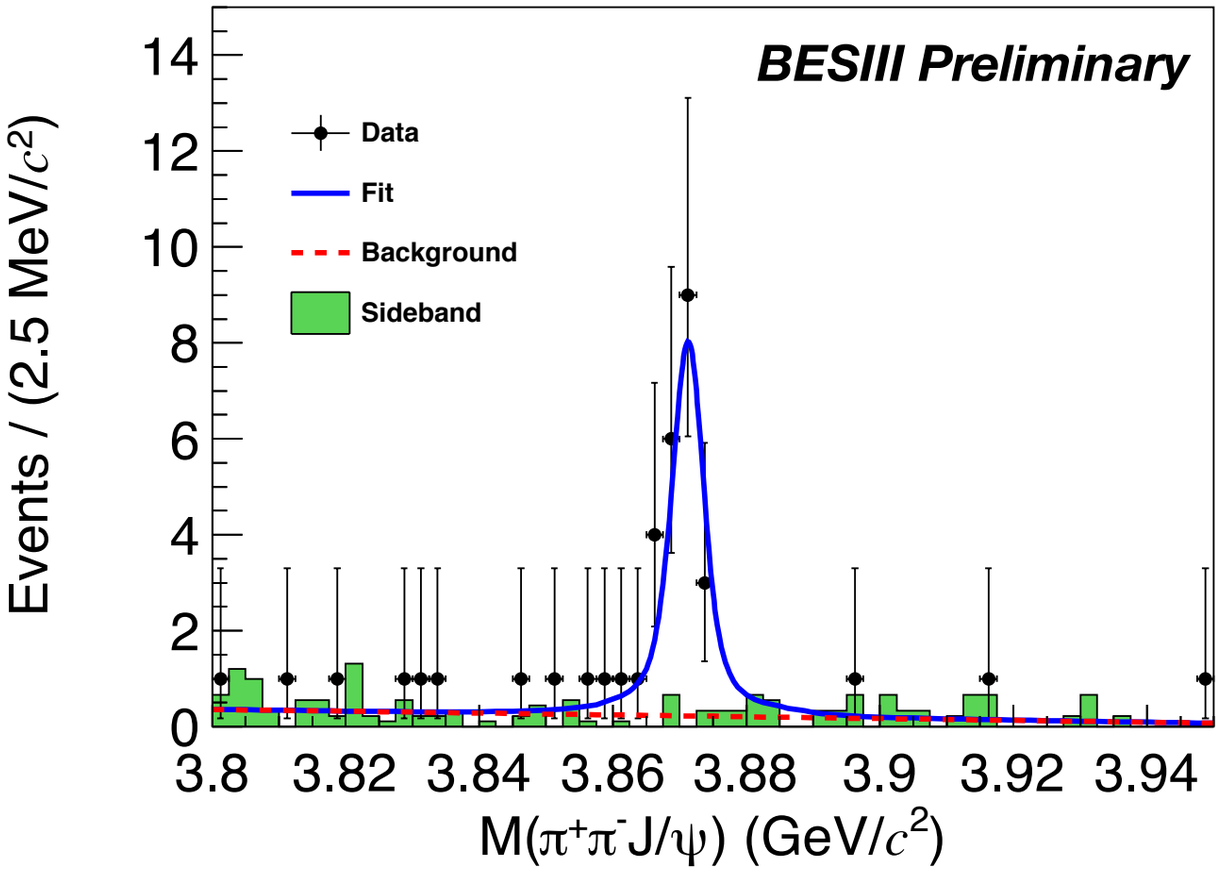
Signal yields

- The M($\pi^+\pi^-J/\psi$) distribution with the datasets $\sqrt{s}$=4.661-4.951 GeV/c^2 is shown below
  - Events accumulation in X(3872) signal regions
  - The two-dimensional ω-J/ψ sidebands show flat contribution in X(3872) signal region



Signal yields

- Fit
  - Signal line shape is determined by signal MC shape.
  - The resolution discrepancy and mass shift between data and simulation are calibrated with the control sample $e^+e^- \to \gamma_{ISR}\pi^+\pi^- J/\psi$
  - Background is described by 1st order polynomial
- The significance including statistical and systematic uncertainties is provided.



N_{sig} = 24.0±5.3

Significance: 7.5σ

Born cross sections

- Born cross section at each energy point is provided

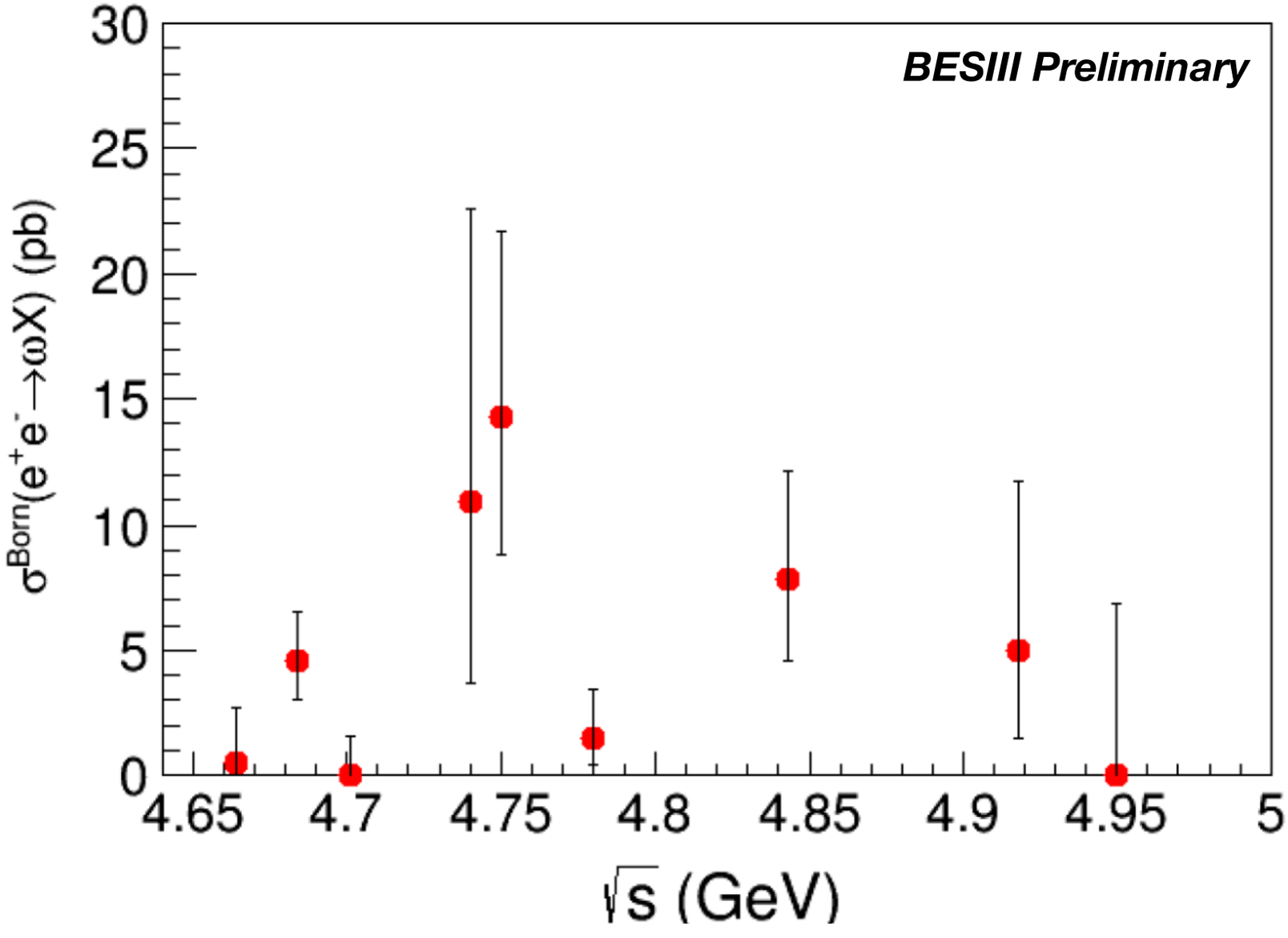
$$\sigma^{\mathrm{B}} = \frac{N_{\mathrm{sig}}}{\mathcal{L}_{\mathrm{int}}\mathcal{B}_1(\epsilon_{ee}\mathcal{B}_{ee} + \epsilon_{\mu\mu}\mathcal{B}_{\mu\mu})(1+\delta)\frac{1}{|1+\Pi|^2}}$$

BESIII Preliminary

$\sqrt{s}$ (GeV)	$\mathcal{L}_{\mathrm{int}}(\mathrm{pb}^{-1})$	N_{sig}	$\epsilon(1+\delta)$ (%)	σ^{B}(pb)	$\sigma^{\mathrm{B}}_{\mathrm{up}}$(pb)	Significance
4.6612	529.63	$0.33^{+1.36}_{-0.33}$	28.25	$0.53^{+2.14}_{-0.53} \pm 0.05 \pm 0.17$	5.66	-
4.6819	1669.31	$8.00^{+3.34}_{-2.68}$	24.62	$4.59^{+1.92}_{-1.54} \pm 0.40 \pm 1.45$	11.54	3.4σ
4.6988	536.45	$0.00^{+0.95}_{-0.00}$	26.96	$0.00^{+1.55}_{-0.00} \pm 0.00 \pm 0.00$	3.33	-
4.7397	164.27	$1.67^{+1.77}_{-1.10}$	21.83	$10.96^{+11.61}_{-7.25} \pm 1.03 \pm 3.46$	40.77	1.0σ
4.7501	367.21	$5.00^{+2.58}_{-1.92}$	22.43	$14.31^{+7.38}_{-5.48} \pm 1.43 \pm 4.52$	38.36	3.1σ
4.7805	512.78	$1.00^{+1.36}_{-0.70}$	31.60	$1.46^{+1.98}_{-1.02} \pm 0.22 \pm 0.46$	6.54	0.7σ
4.8431	527.29	$4.67^{+2.58}_{-1.92}$	26.73	$7.81^{+4.32}_{-3.20} \pm 0.67 \pm 2.47$	21.24	2.6σ
4.9180	208.11	$1.00^{+1.36}_{-0.70}$	22.64	$5.00^{+6.79}_{-3.49} \pm 0.44 \pm 1.58$	21.80	0.7σ
4.9509	160.37	$0.00^{+0.95}_{-0.00}$	20.42	$0.00^{+6.84}_{-0.00} \pm 0.00 \pm 0.00$	14.74	-

- The errors of Born cross sections (σ^{B}): the first error is statistical, the second systematic, and the third from Br(X(3872)→$\pi^+\pi^-$J/ψ)
- ε here is the average efficiency of electron and muon channels

Born cross sections



Systematic uncertainties

- Main sources of systematic uncertainties on Born cross section
  - Detection efficiency (σ_ε)
  - ISR correction factor (σ_{ISR})
  - Method of signal extraction(σ_{sig})
  - Luminosity (σ_L)
  - Br(X→π+π-J/ψ) which is listed standalone as the third error
- The estimated uncertainties are listed in the table below

BESIII Preliminary

$\sqrt{s}$ (GeV)	$\sigma_{\mathcal{L}}$	σ_ϵ	$\sigma_{\rm ISR}$	$\sigma_{\rm sig}$	$\sigma_{\rm sum}$
4.6612	1.0	8.1	5.0	1.6	9.7
4.6819	1.0	8.1	2.3	1.6	8.6
4.6988	1.0	8.1	12.0	1.6	14.6
4.7397	1.0	8.1	4.3	1.6	9.4
4.7501	1.0	8.2	5.4	1.6	10.0
4.7805	1.0	8.3	12.2	1.6	14.9
4.8431	1.0	8.3	1.4	1.6	8.6
4.9180	1.0	8.4	1.2	1.6	8.7
4.9509	1.0	8.5	0.5	1.6	8.7

Search for X(3872)→$\pi^0\chi_{c0}$ *PRD 105, 072009 (2022)*

Theoretical predictions [PRD 77, 014013 (2008)]

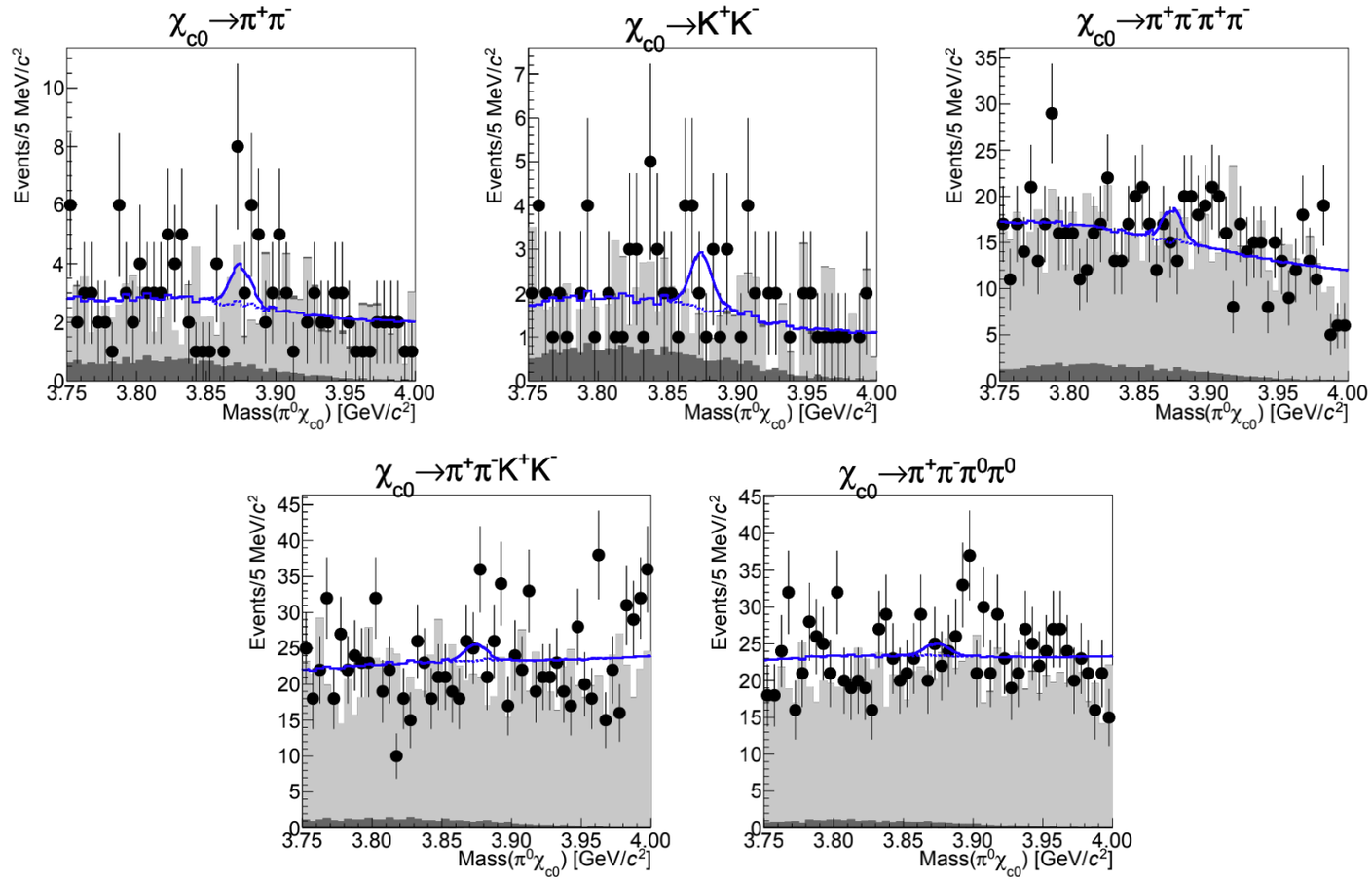
Interpretation	$\frac{\mathcal{B}(X(3872)\to\pi^0\chi_{c0})}{\mathcal{B}(X(3872)\to\pi^+\pi^- J/\psi)}$	$\frac{\mathcal{B}(X(3872)\to\pi^0\chi_{c0})}{\mathcal{B}(X(3872)\to\pi^0\chi_{c1})}$
Four-quark/molecule	NA	2.97
$\chi_{c1}(2P)$	0.0	0.0

- Search for X(3872)→$\pi^0\chi_{c0}$ with 9.9fb^{-1} between 4.15-4.30 GeV

$$\frac{\mathcal{B}(X(3872)\to\pi^0\chi_{c0})}{\mathcal{B}(X(3872)\to\pi^0\chi_{c1})} < 4.5$$

$$\frac{\mathcal{B}(X(3872)\to\pi^0\chi_{c0})}{\mathcal{B}(X(3872)\to\pi^+\pi^- J/\psi)} < 3.6$$

@90 C.L.

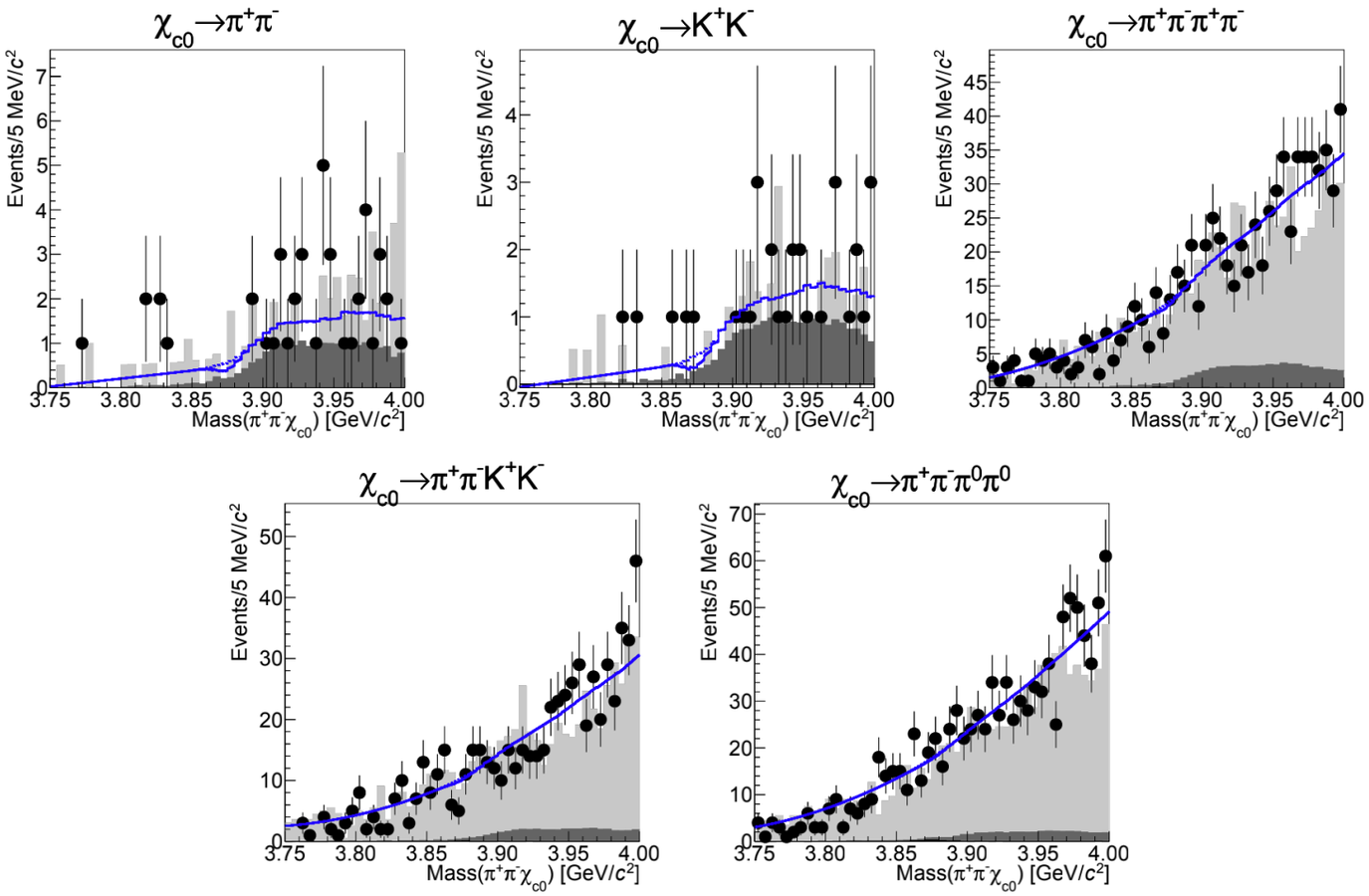


Search for X(3872)→ππχc0

PRD 105, 072009 (2022)

EFT predictions [PRD 79, 094013 (2009), PRD 78, 094019 (2008)]

$$\frac{\mathcal{B}(X(3872)\to\pi\pi\chi_{c0})}{\mathcal{B}(X(3872)\to\pi^0\chi_{c0})} \approx \mathcal{O}(10^{-3}) \text{ or } \mathcal{O}(10^{-5})$$



$$\frac{\mathcal{B}(X(3872)\to\pi^0\pi^0\chi_{c0})}{\mathcal{B}(X(3872)\to\pi^+\pi^- J/\psi)} < 1.7 \qquad \frac{\mathcal{B}(X(3872)\to\pi^+\pi^-\chi_{c0})}{\mathcal{B}(X(3872)\to\pi^+\pi^- J/\psi)} < 0.56 \qquad \text{@90 C.L.}$$

Summary

- The preliminary results on the study of $e^+e^- \to \omega X(3872)$ are reported.
  - $e^+e^- \to \omega X(3872)$ is observed for the first time using 4.7 fb^{-1} data from 4.661 to 4.951 GeV.
  - The significance is 7.5σ including both statistical and systematic uncertainty.
  - The Born cross section at each energy point is provided.
- The new decays of $X(3872) \to \pi^0\chi_{c0}$ and $\pi\pi\chi_{c0}$ are searched
  - No significant signals are observed, and the upper limits are provided.
- BESIII keeps outputting important measurements on the X(3872) and other exotic hadrons.