Recent results about X(3872) at BESIII

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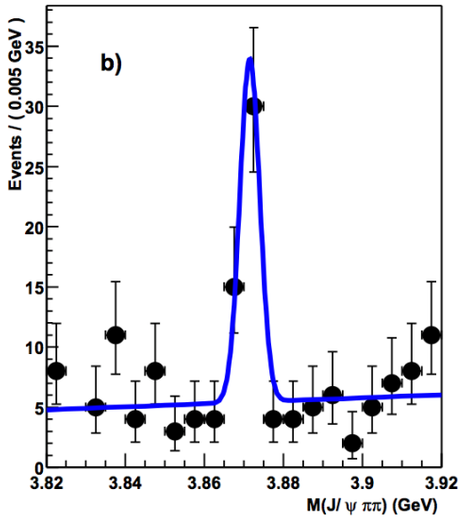
Outline

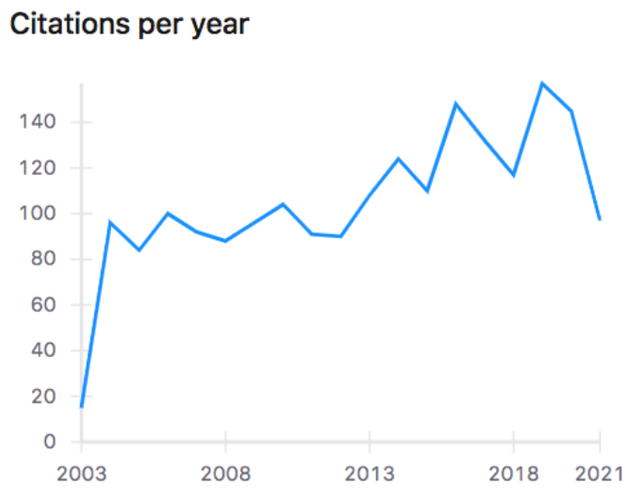
- Introduction of BESIII and BEPC
- Production of X(3872) at BESIII
- Decays of X(3872) at BESIII
- Summary

X(3872)

- First observation at Belle in 2003 (PRL 91 (2003) 262001)
- 1994 citations at Inspire-hep

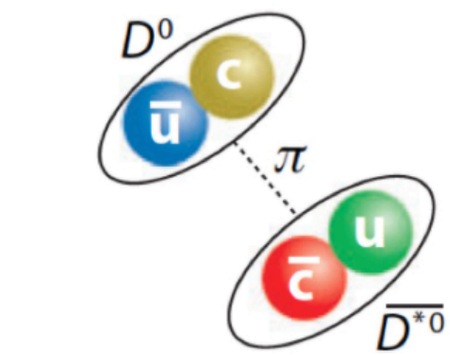
- $J^{PC} = 1^{++}$
- Mass and Width at PDG, dominated by LHCb measurements
  - M = 3871.65±0.06 MeV
  - Γ = 1.19±0.21 MeV



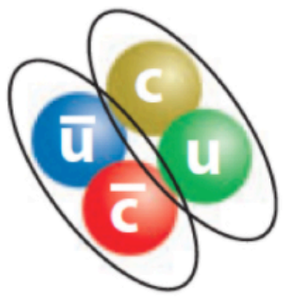


Explanations of the nature

- Bound molecule of D^0 and anti-D^{0*}
- Tetra-quark binding a di-quark and a di-antiquark
- Hybrid of charmonium and molecule
- ….

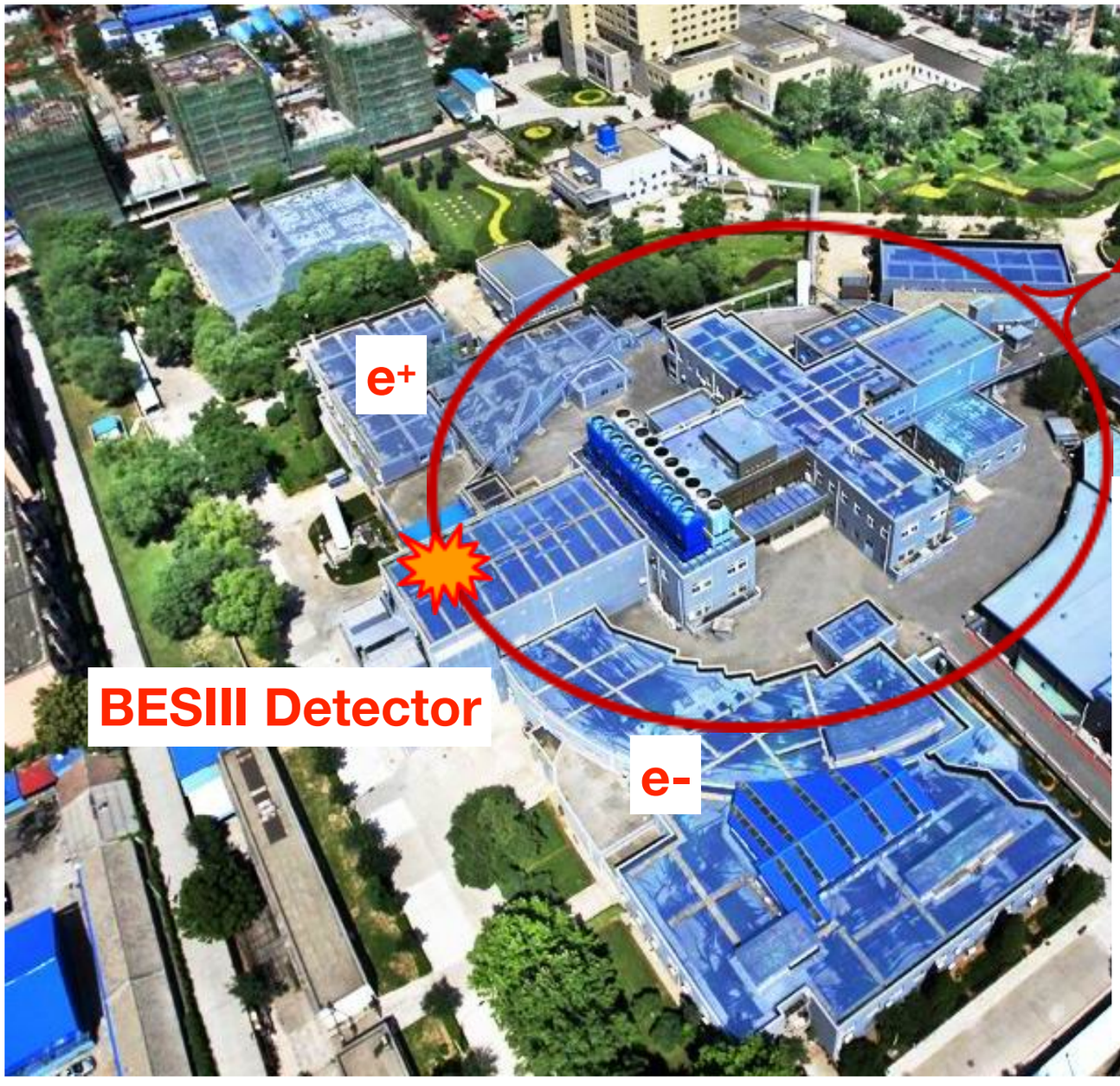


D^0–$\overline{D^{*0}}$ "molecule"



Diquark–diantiquark

Beijing Electron Positron Collider (BEPC II)

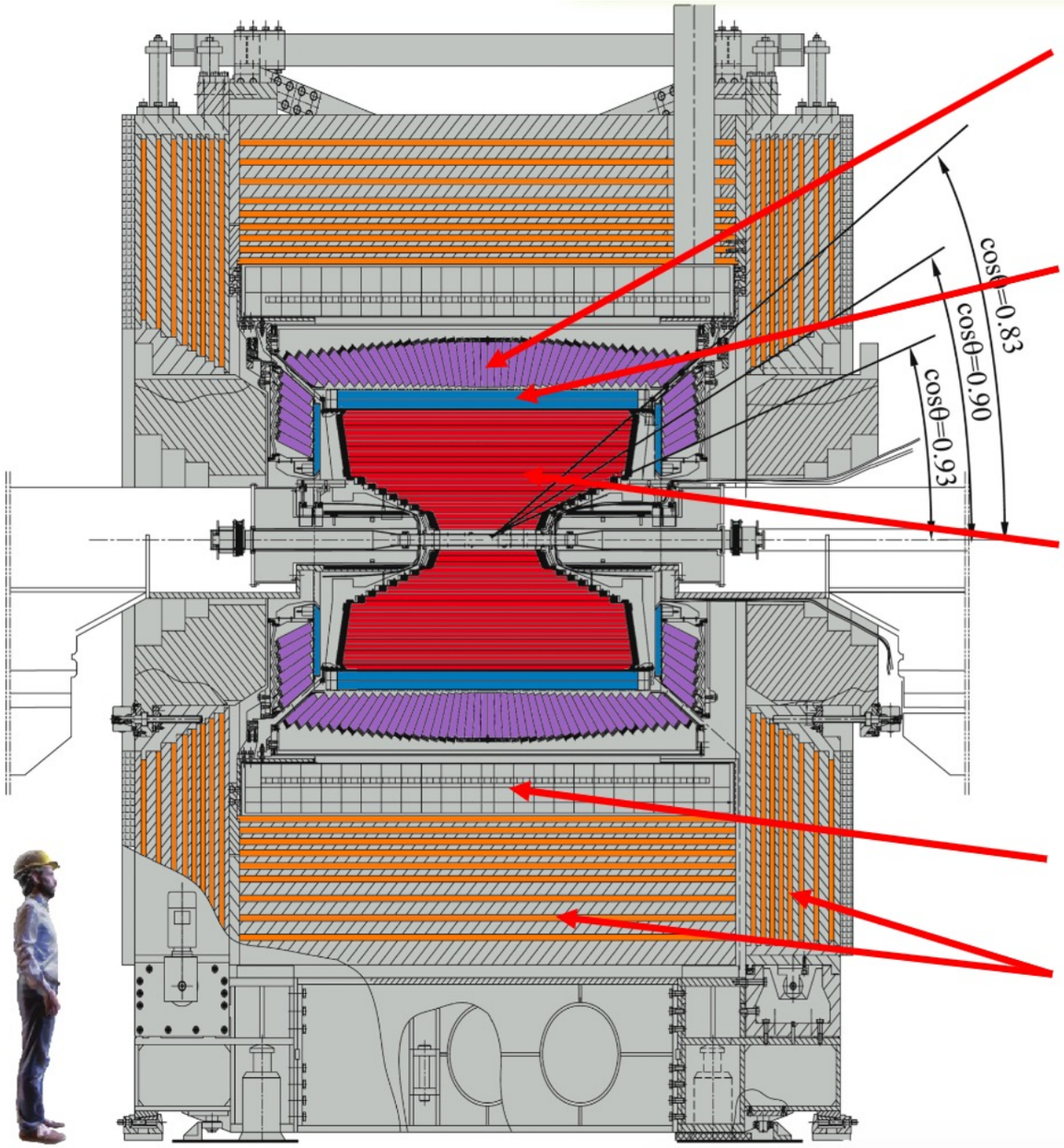


- 2020: beam energy upgrade to 2.45 GeV
- 2004: started BEPCII upgrade, BESIII construction
- 1989-2005 (BEPC):

  $L_{peak}=1.0x10^{31}$ /cm^{2}s
- 2008-now (BEPCII):

  $L_{peak}=1.0x10^{33}$/cm^{2}s (Apr. 5, 2016)

BESIII Detector



EMC: CsI crystals
$\Delta E/E$ = 2.5% @ 1 GeV - Barrel
$\Delta E/E$ = 5.0% @ 1 GeV - Endcaps

TOF:
σ_T = 80 ps Barrel
σ_T = 110 (60) ps Endcap

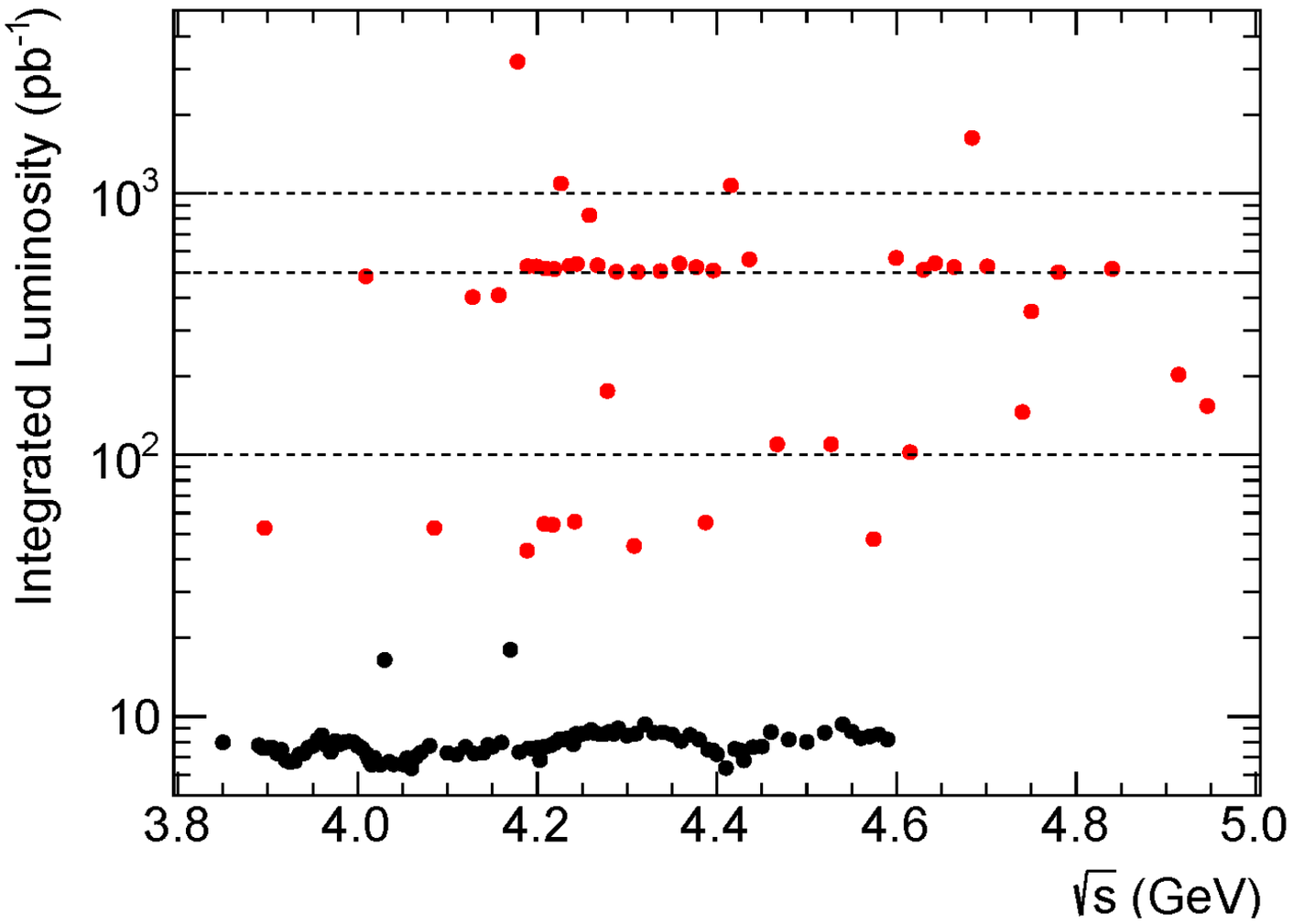
MDC: small cell & He gas
σ_{xy}= 130 μm
σ_p/p = 0.5% @1GeV
dE/dx = 6%

Magnet: 1T Super conducting

Muon ID: 9 layer RPC

Trigger: Tracks & Showers

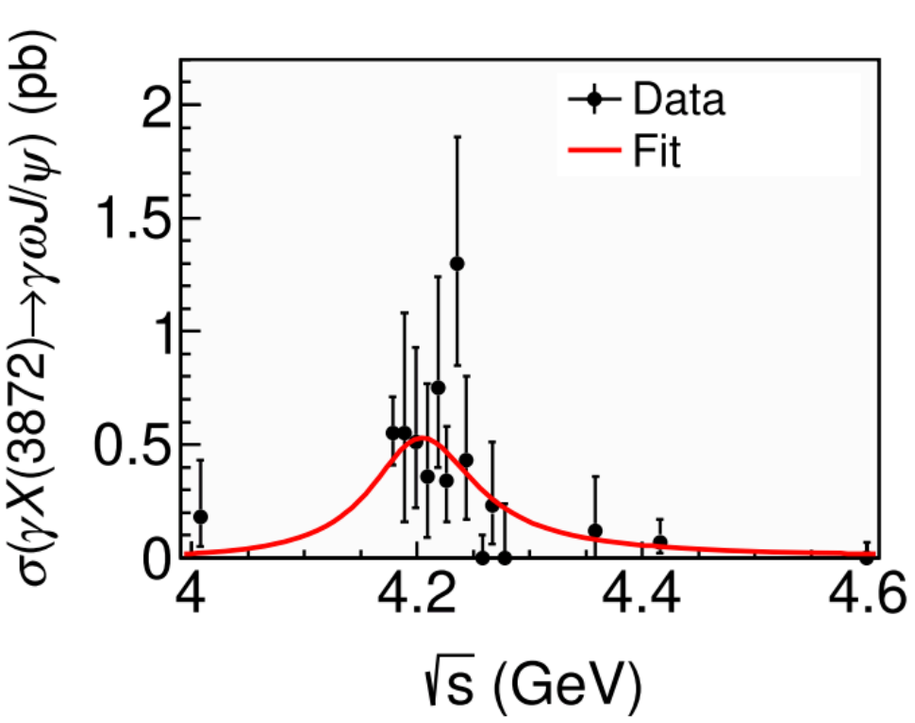
Data sets for XYZ Study at BESIII

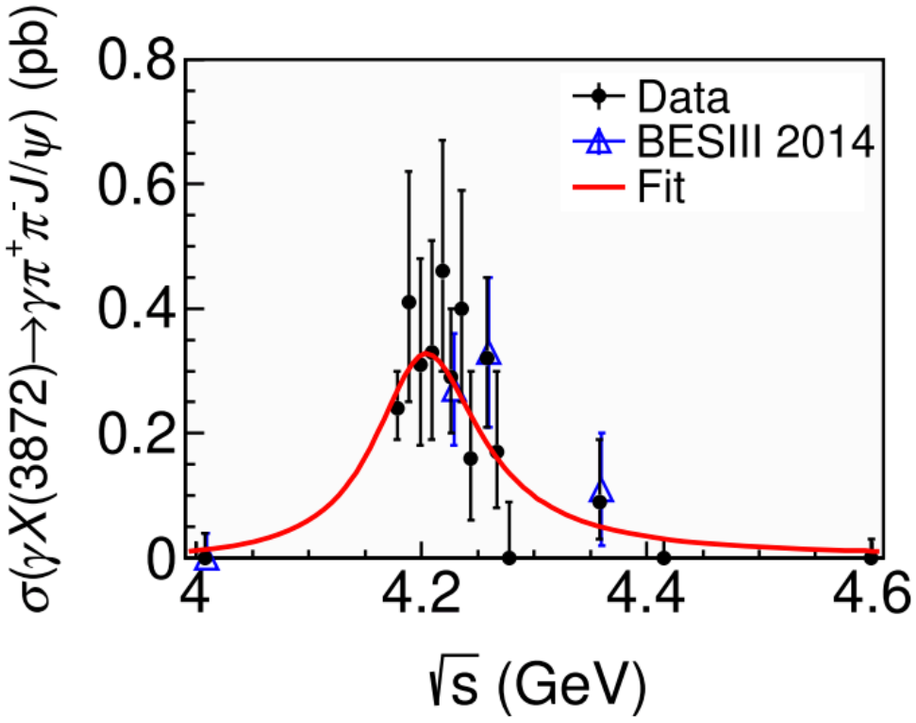


- Over 20 fb^{-1} data between 3.8 - 5.0 GeV is taken
- Excellent site for the studies of XYZ states

Production of X(3872) at BESIII

PRL 122, 232002 (2019)





- e+e-→γX(3872) is the only observed way to produce X(3872) at BESIII so far
- Line shape of e+e-→γX(3872) cross sections
- X(3872) at BESIII: low background, low production
- Single Breit-Wigner resonance could describe the line shape

Mass = $4200.6^{+7.9}_{-13.3} \pm 3.0\ \mathrm{MeV}/c^2$

Width = $115^{+38}_{-26} \pm 12\ \mathrm{MeV}$

Decays of X(3872) at BESIII

$\pi^+\pi^- J/\psi$

$\omega J/\psi$

$\gamma J/\psi$

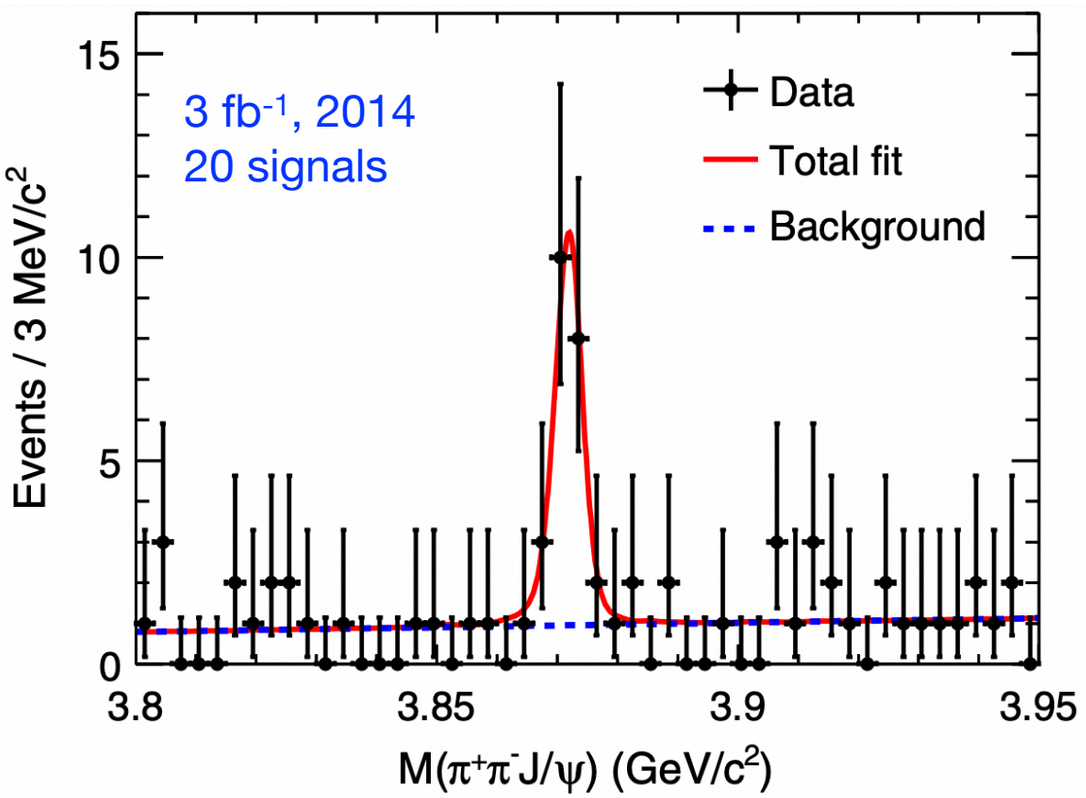
$\gamma\psi(2S)$

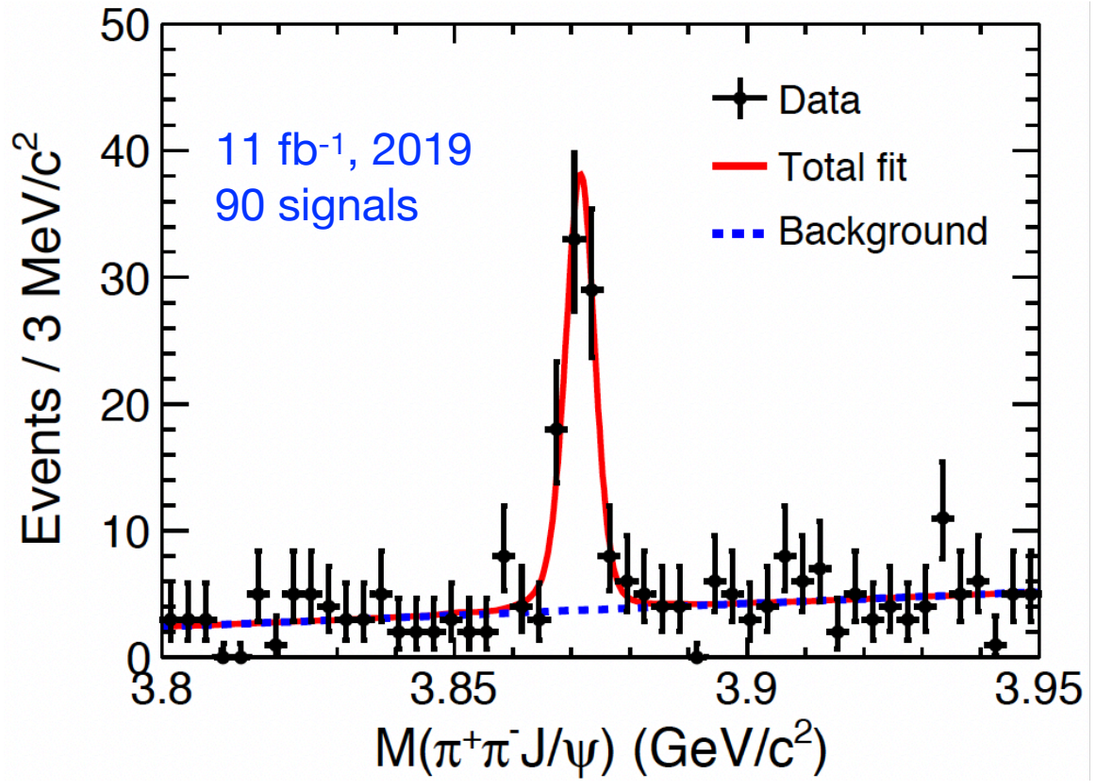
$\pi^0 X_{c1}$

$D^0 D^{*0}$

X(3872)→$\pi^+\pi^-J/\psi$

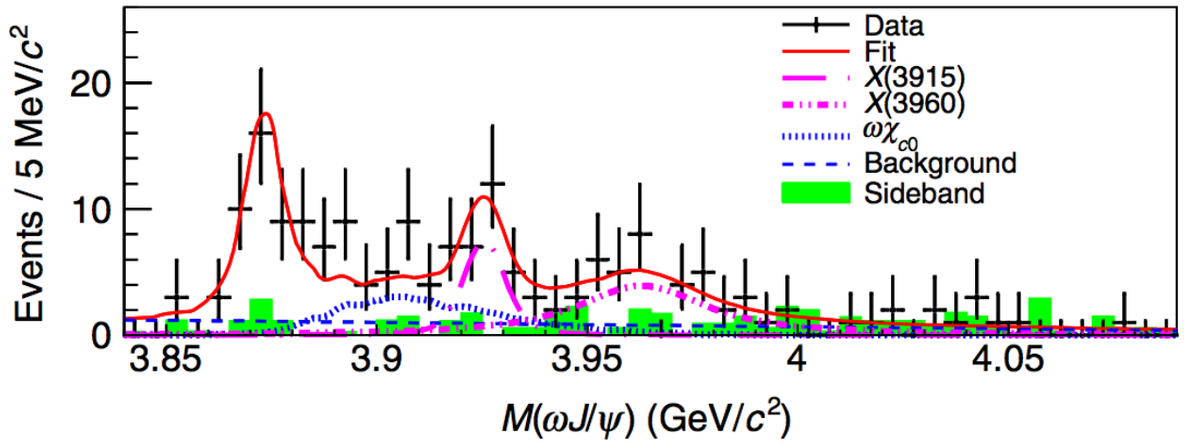
PRL 112, 092001 (2014)
PRL 122, 232002 (2019)

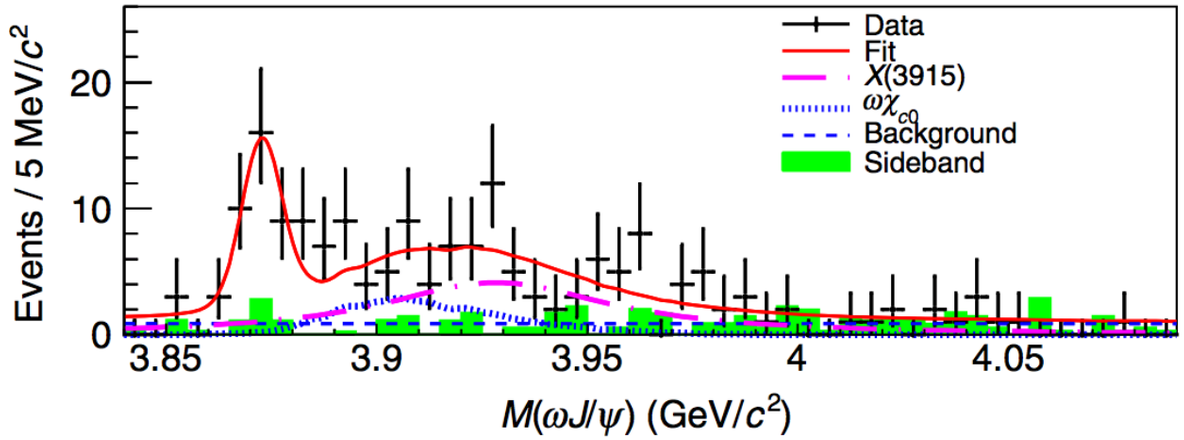




X(3872)→ωJ/ψ

PRL 122, 232002 (2019)

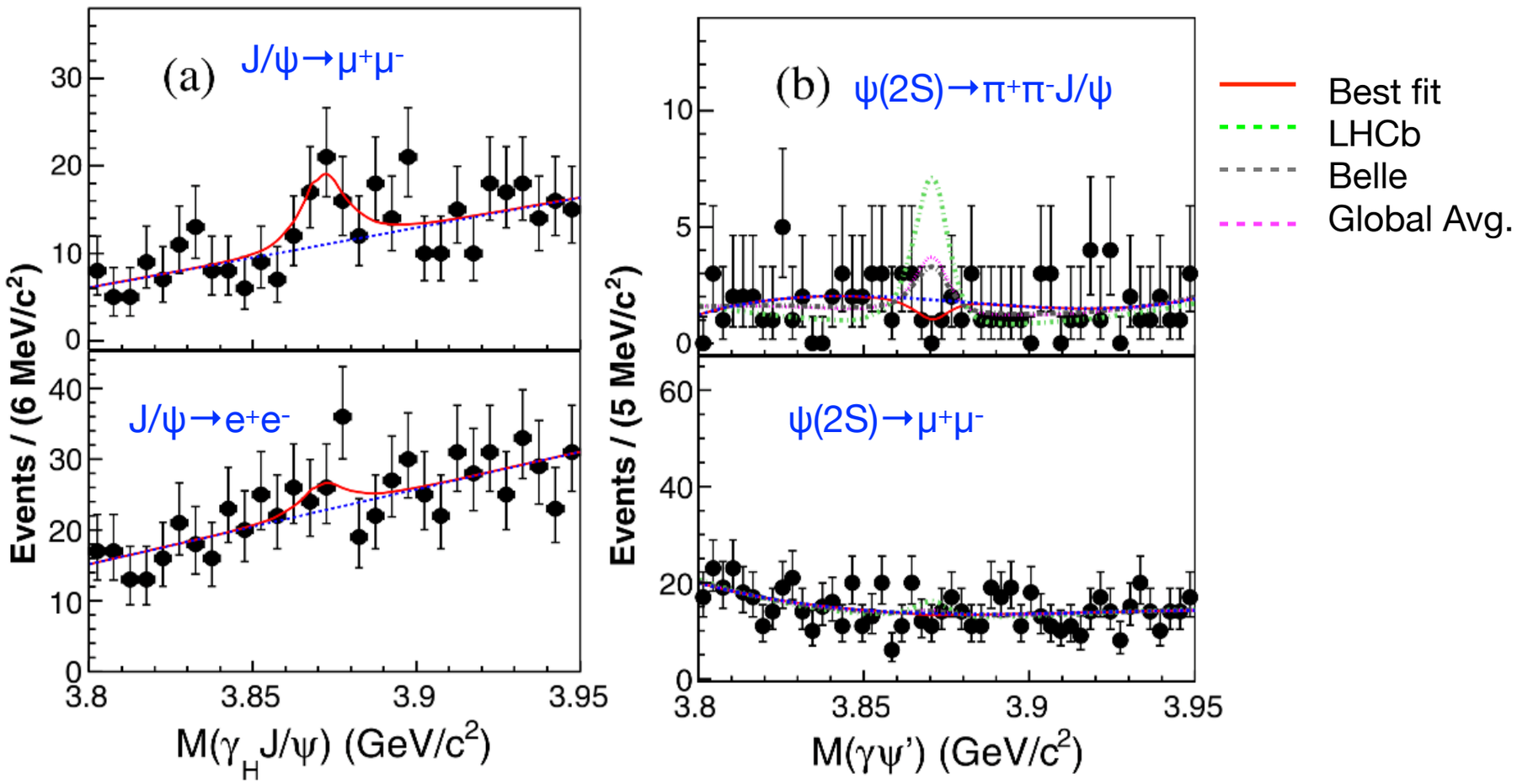




- Breit-Wigner function to describe X(3872)
- Observed significant X(3872)→ωJ/ψ (>5σ)
- $Br(X(3872)\to\omega J/\psi)/Br(X(3872)\to\pi^+\pi^- J/\psi)=1.6^{+0.4}_{-0.3}\pm0.2$

X(3872)→γJ/ψ, γψ(2S)

PRL 124, 242001 (2020)



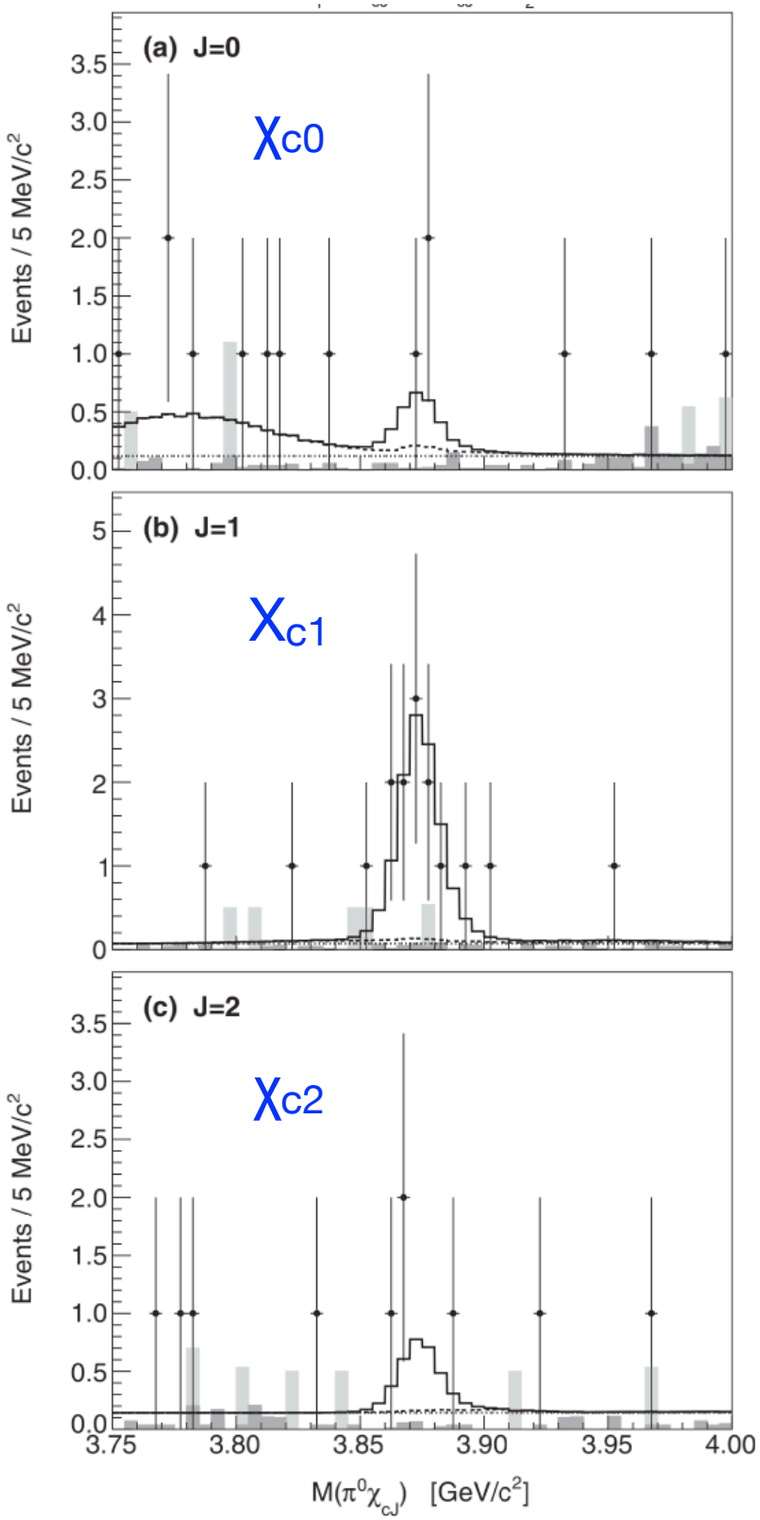
- Evidence of X(3872)→γJ/ψ with 3.5σ significance
  - N(J/ψ→μ⁺μ⁻)=38.8±11.9, N(J/ψ→e⁺e⁻)=18.4±5.6
- No significant X(3872)→γψ(2S) signal

$$\frac{B[X(3872)\to\gamma\psi(2S)]}{B[X(3872)\to\gamma J/\psi]} < 0.59$$

$X(3872)\to\pi^0\chi_{c1}$

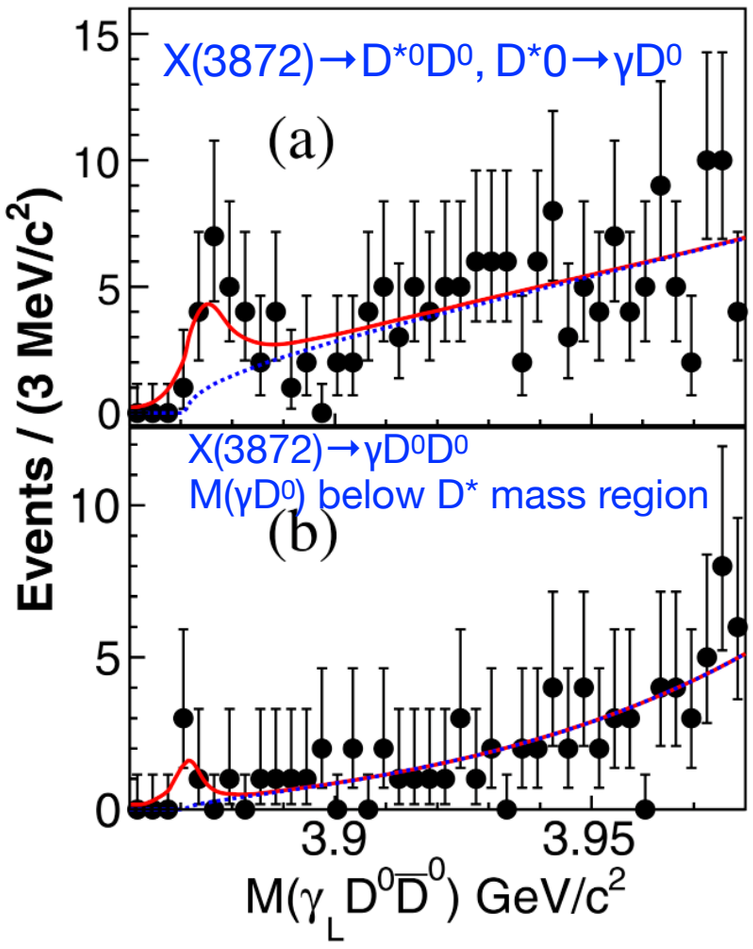
PRL 122, 202001 (2019)

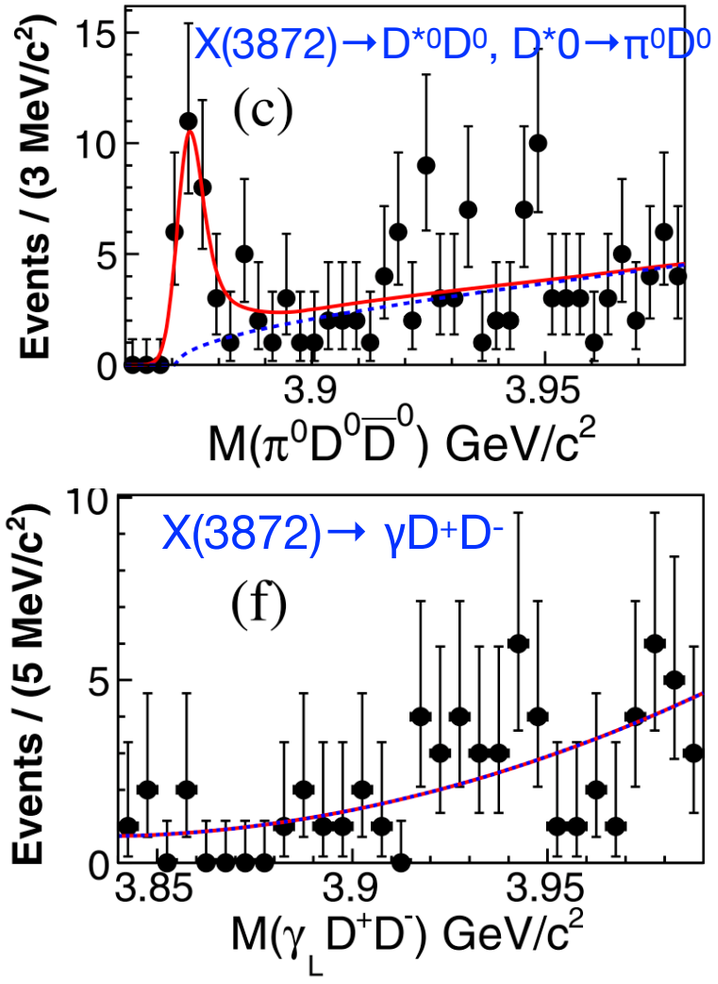
- 9.0 fb^{-1} data with collision energies of 4.15-4.3 GeV
- Observed significant $X(3872)\to\pi^0\chi_{c1}$ for the first time with >5σ significance
- $N(\pi^0\chi_{c1})=10.8^{+3.8}_{-3.1}$
- $Br(\pi^0\chi_{c1})/Br(\pi^+\pi^-J/\psi)=0.88^{+0.33}_{-0.27}\pm0.10$
- No significant $\pi^0\chi_{c0,2}$ signals



X(3872)→γ/π⁰D⁰$\bar{D}^0$ and γD⁺D⁻

PRL 124, 242001 (2020)

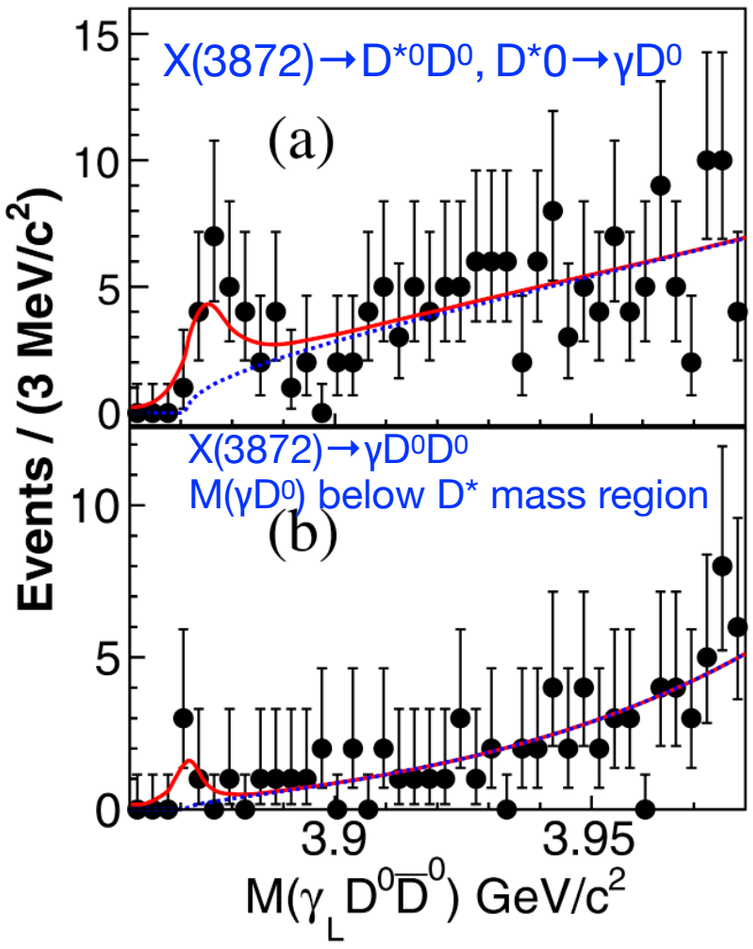


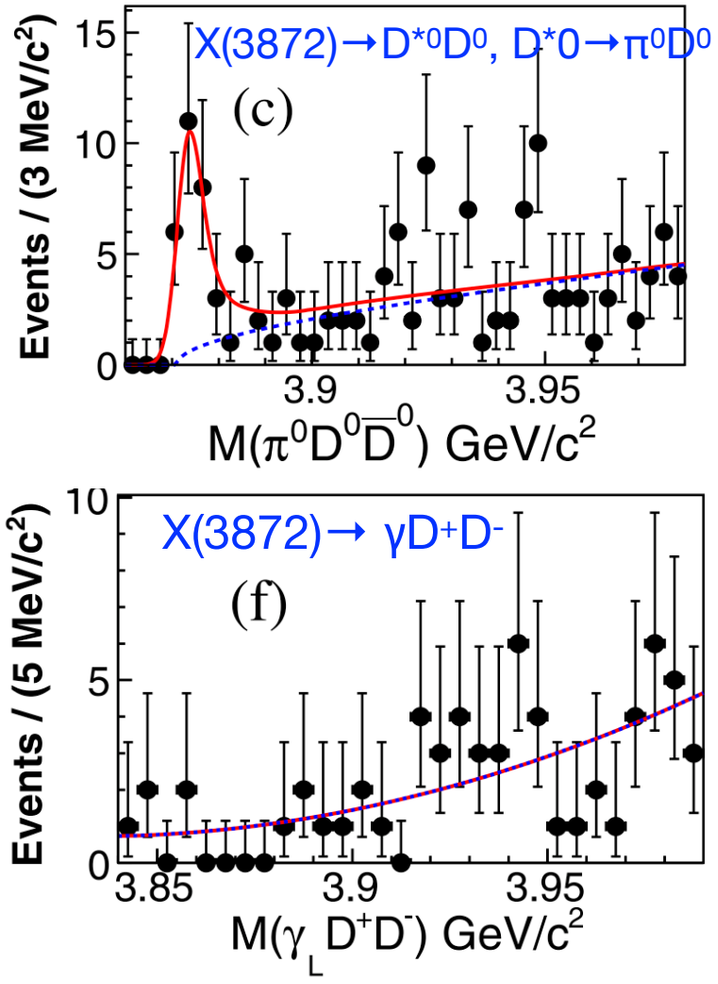


- X(3872)→γ/π⁰D⁰D⁰ and γD⁺D⁻ are studied
- Full reconstruction of signal
  - D⁰→K⁻π⁺, K⁻π⁺π⁰, K⁻π⁺π⁺π⁻
  - D⁺→K⁻π⁺π⁺, K⁻π⁺π⁺π⁰
  - Kinematic fit is applied with the constraints on
    - the masses of π⁰ and D⁺/⁰
    - the initial four momentum of the colliding beams

X(3872)→γ/π⁰D⁰D̄⁰ and γD⁺D⁻

PRL 124, 242001 (2020)

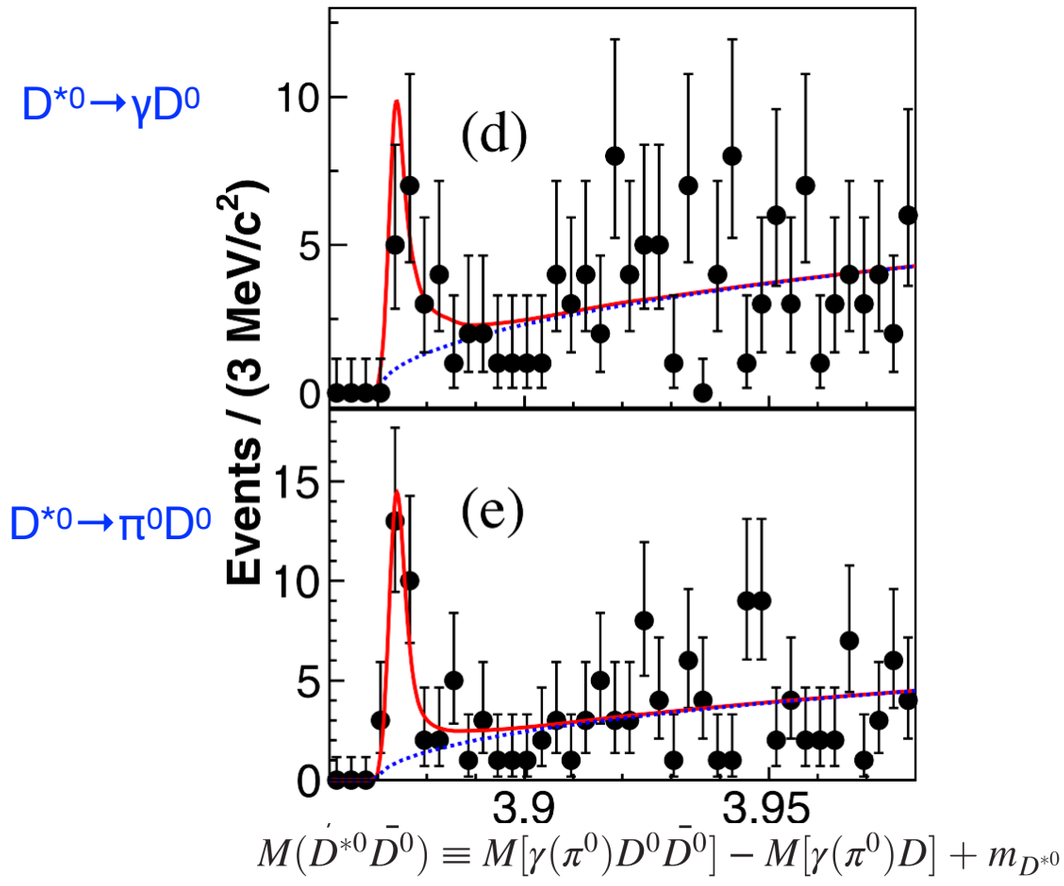




- X(3872)→γ/π⁰D⁰D⁰
  - X(3872)→D*⁰D⁰ is dominant with 7.4σ significance
  - No significant nonresonant three-body decay X(3872)→γ/π⁰D⁰D⁰ is found
- No significant X(3872)→γD⁺D- signal

X(3872)→D*⁰D̄⁰

PRL 124, 242001 (2020)



- X(3872)→D*⁰D⁰
  - Simultaneous fit to D*⁰→γD⁰ and π⁰D⁰ modes
  - N(γD⁰) =20.2±3.6, N(π⁰D⁰) =25.5±4.6

Branching ratios of X(3872)

PRL 124, 242001 (2020)

- Branching ratios compared with Br($\pi^+\pi^- J/\psi$)

Mode	Ratio	UL
$\gamma J/\psi$	0.79 ± 0.28	...
$\gamma\psi'$	-0.03 ± 0.22	< 0.42
$\gamma D^0 \bar{D}^0$	0.54 ± 0.48	< 1.58
$\pi^0 D^0 \bar{D}^0$	-0.13 ± 0.47	< 1.16
$D^{*0} D^0 + \text{c.c.}$	11.77 ± 3.09	...
$\gamma D^+ D^-$	$0.00^{+0.48}_{-0.00}$	< 0.99
$\omega J/\psi$	$1.6^{+0.4}_{-0.3} \pm 0.2$ [18]	...
$\pi^0 \chi_{c1}$	$0.88^{+0.33}_{-0.27} \pm 0.10$ [27]	...

Summary

- The radiative decay $e^+e^- \to \gamma X(3872)$ is the main production to study the particle at BESIII
- $X(3872) \to \pi^+\pi^- J/\psi$, $\omega J/\psi$, $\gamma J/\psi$, $\pi^0 X_{c1}$, $D^0 D^{*0}$ are observed at BESIII so far.
- Any further experimental measurement about X(3872) is essential for the understanding of the nature of the particle
- More data will be collected at BESIII