Observation of $Z_c(3900)$ and X(3872) at BESIII

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Outline

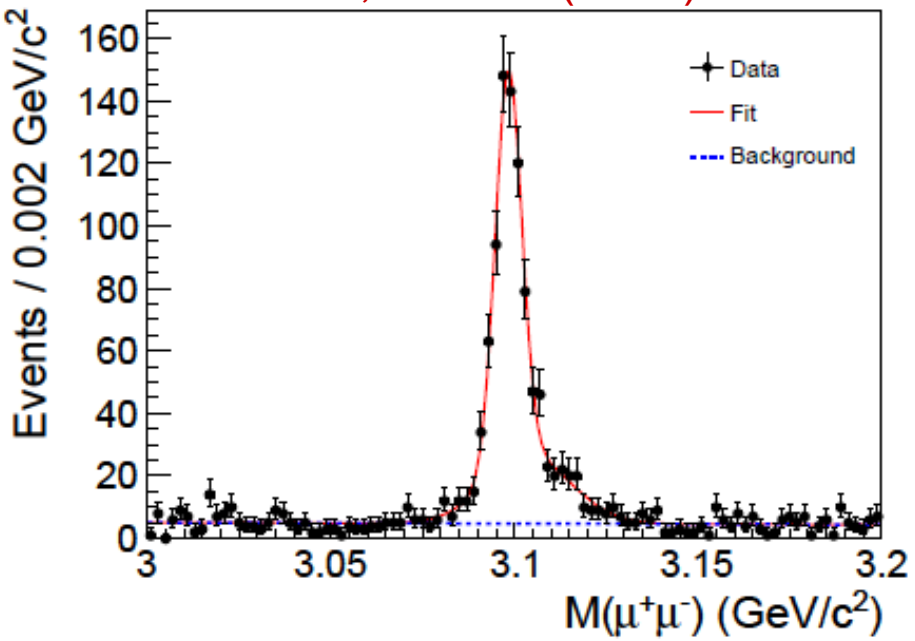
1. Observation of e+e-→$\pi^{\pm}Z_c(3900)$ at 4.26 GeV
2. Observation of e+e-→$\gamma X(3872)$ at 4.26 GeV
3. Summary

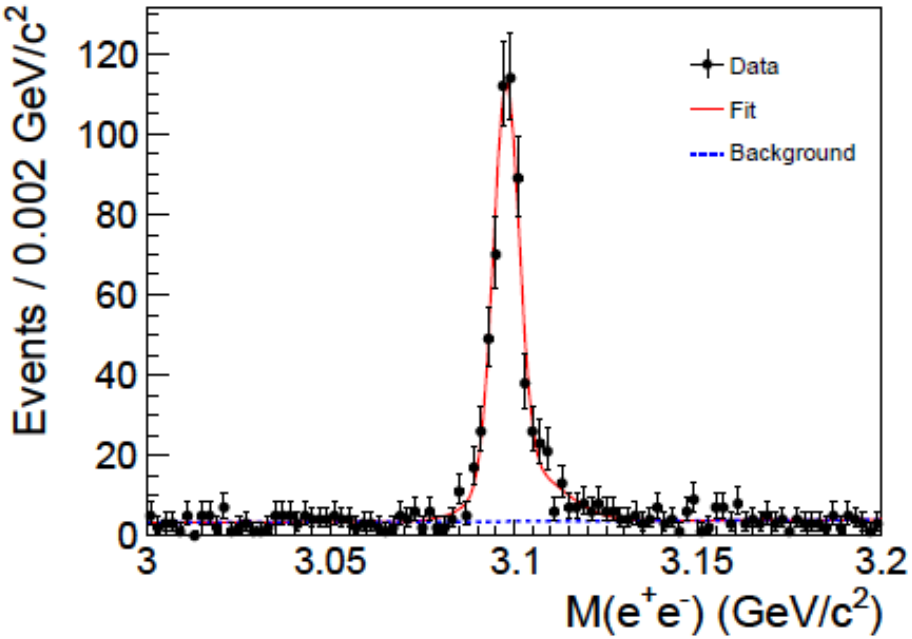
I. $e^+e^- \rightarrow \pi^{\pm} Z_c(3900)$

Study Y(4260) at BESIII

- Dec, 2012 to Jan, 2013, BESIII accumulate 525 pb^{-1} data @ 4.26 GeV, world's largest data set!
- Study e+e- →$\pi^+\pi^- J/\psi$ exclusive process.

PRL110, 252001 (2013)



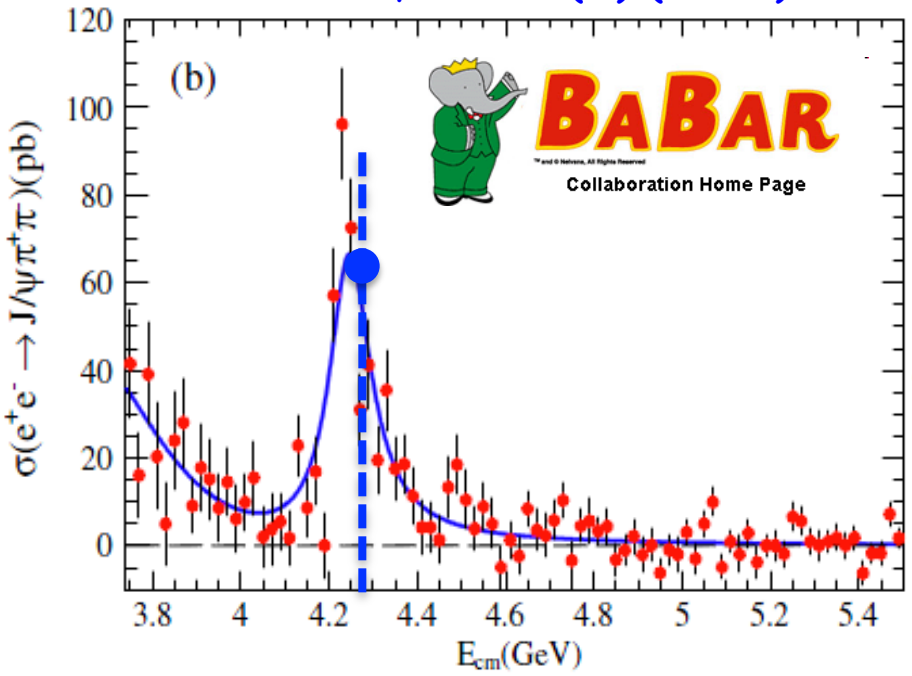


1. The obtained lepton pairs invariant mass distribution.

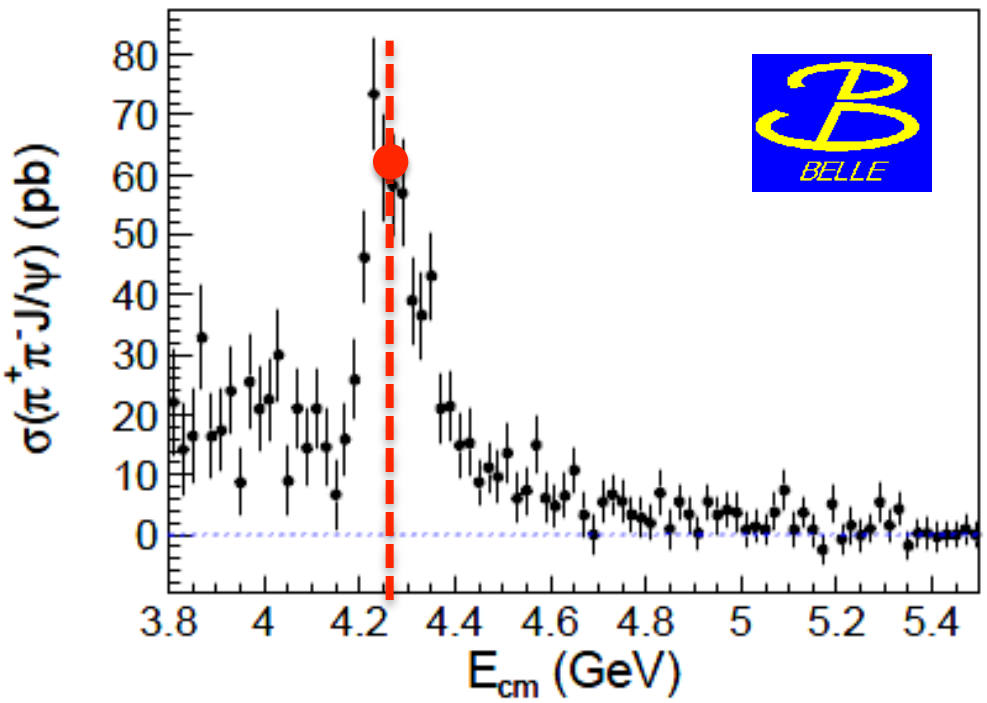
2. $N(\mu^+\mu^-)=882\pm33$; $N(e^+e^-)=595\pm28$.

Cross Section at BESIII

PRD **86**,051102(R) (2012).



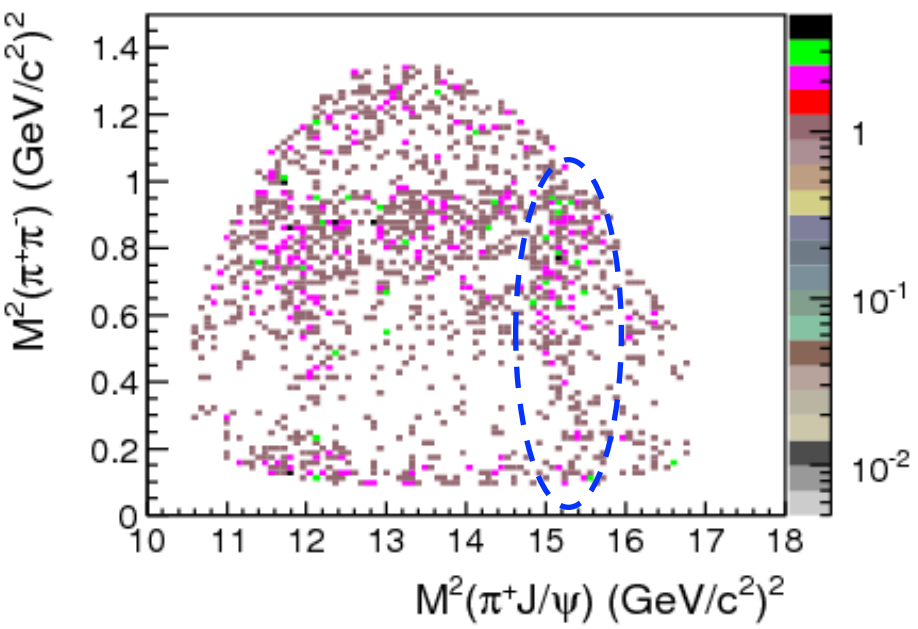
PRL **110**,252002 (2013).

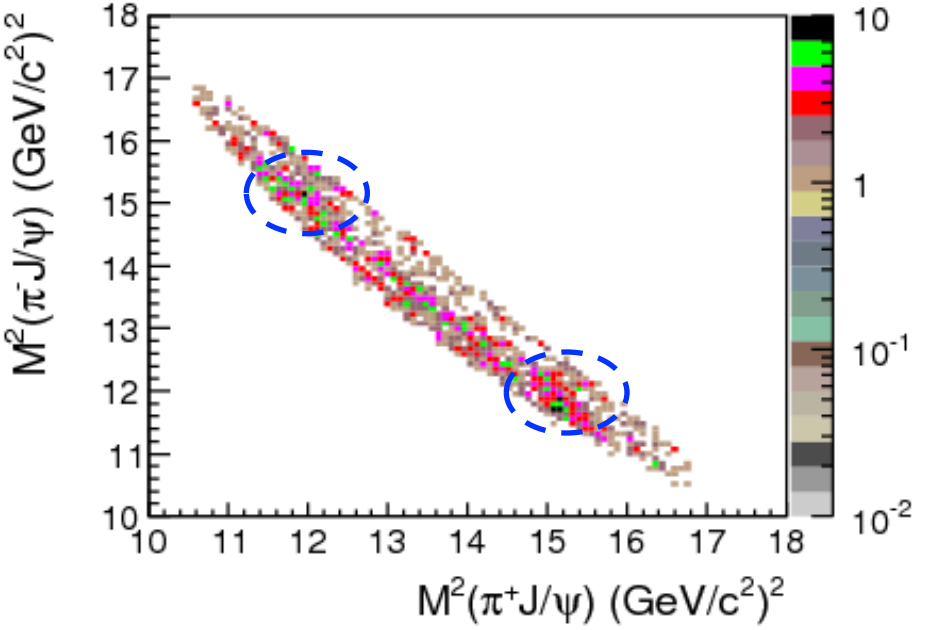


1. Lum=525 pb^{-1} @ BESIII
2. $N(\mu^+\mu^-)$=882±33; $N(e^+e^-)$=595±28.
3. Born cross section: σ^B=(62.9±1.9±3.7) pb @ BESIII.
4. Good agreement with Belle and BaBar.
5. Analysis is valid and unbiased.

Intermediate state——$Z_c(3900)$

- Requiring J/ψ mass window: [3.08,3.12] GeV, we have 1595 signal events, with purity ~90%.





1. Intermediate states both in $M(\pi^+\pi^-)$ mass distribution and $M(\pi^\pm J/\psi)$ mass distribution.
2. A clear band in the $M(\pi^\pm J/\psi)$ invariant mass projection.
3. Phase space reflection between $M(\pi^+J/\psi)$ and $M(\pi^-J/\psi)$.

Intermediate state——$Z_c(3900)$

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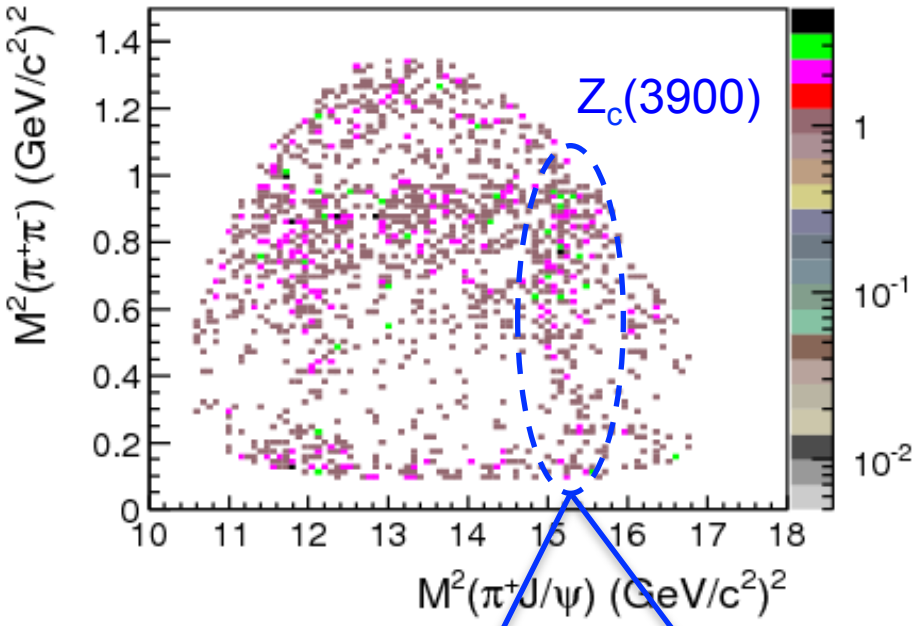
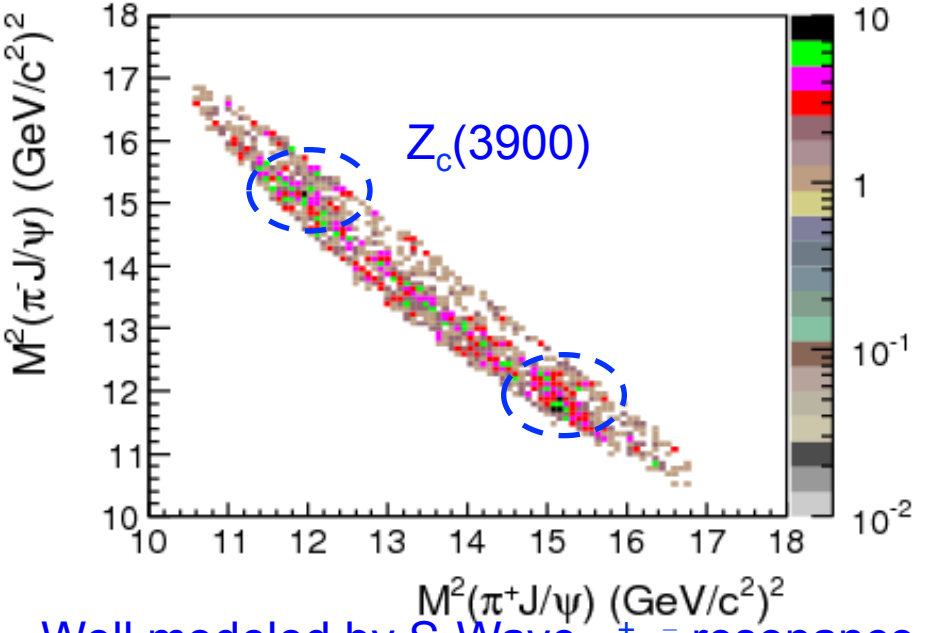
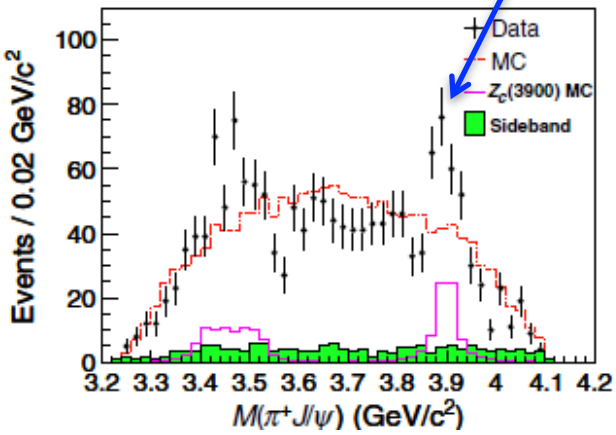
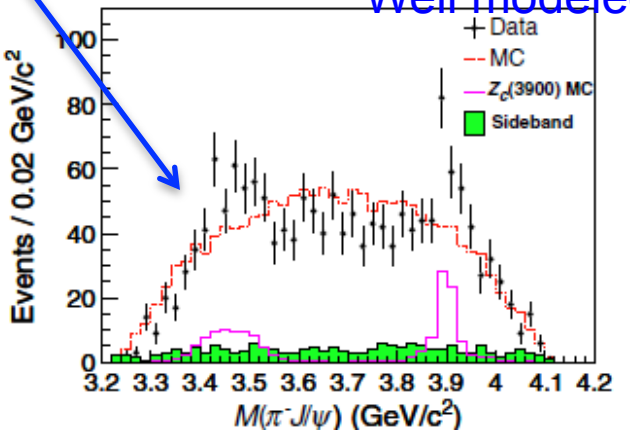
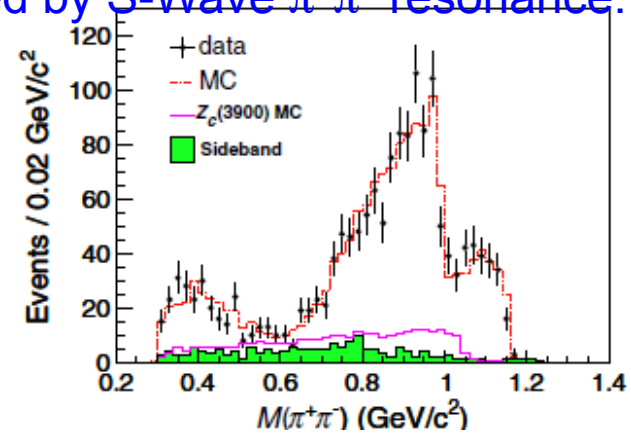




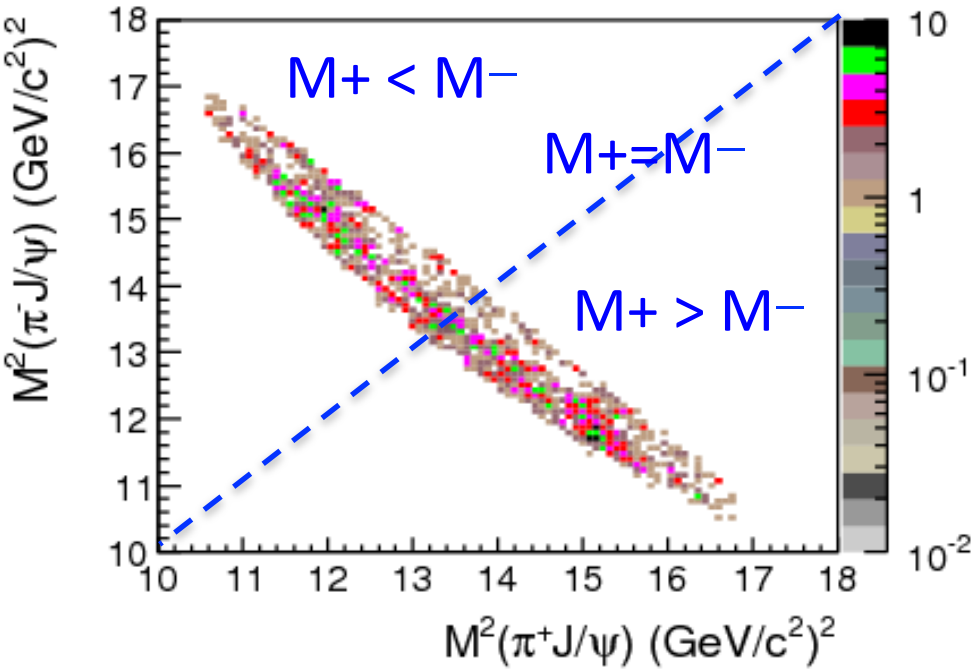
Well modeled by S-Wave $\pi^+\pi^-$ resonance.

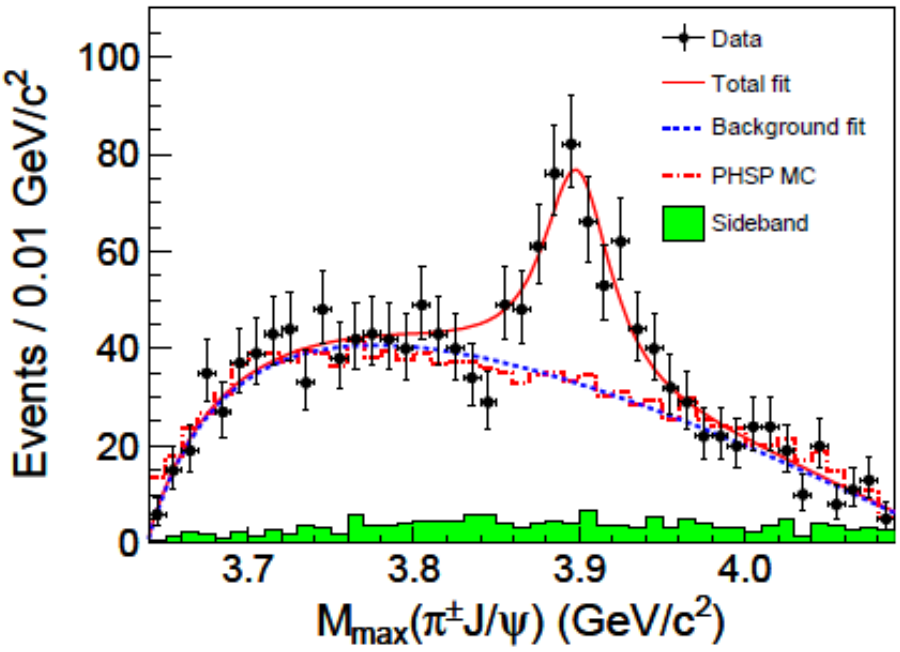






Intermediate state——$Z_c(3900)$



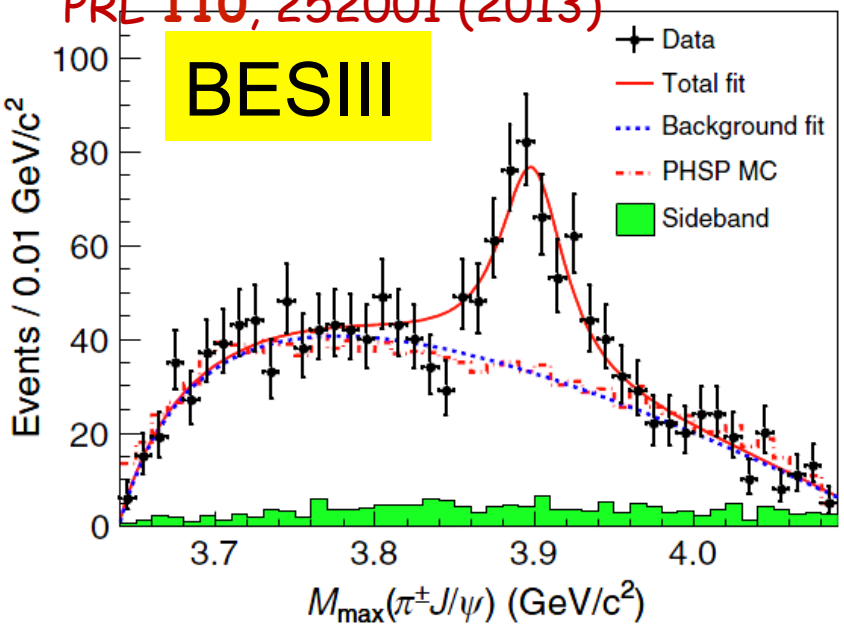


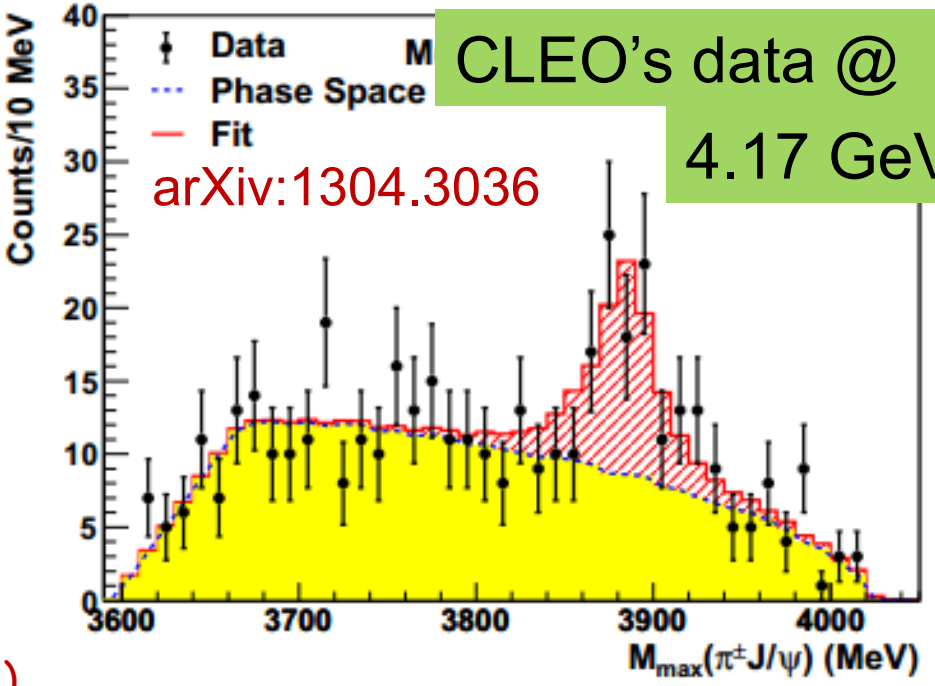
1. First stage, 1D fit to extract resonant parameters.
2. Divided by diagonal line of the dalitz plot and fit $M_{max}(\pi^\pm J/\psi)$ mass distribution; best way to avoid cross counting.
3. S-Wave Breit Wigner; p*q phase space factor; efficiency corrected.
4. M=(3899.0±3.6±4.9)MeV; Γ=(46±10±20)MeV.
5. Statistical significance: >8σ, discovery!

Good News

PRL 110, 252001 (2013)

BESIII

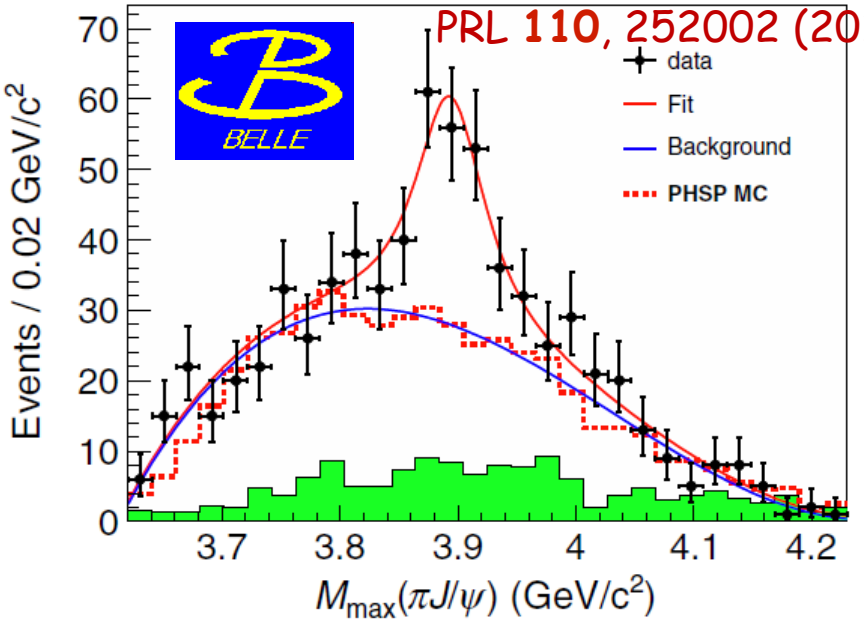




CLEO's data @ 4.17 GeV

arXiv:1304.3036

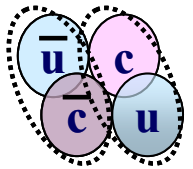
PRL 110, 252002 (2013)



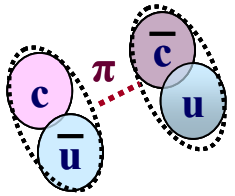
1. CLEO's data: M=3885±5 MeV, Γ=34±13 MeV.
2. Belle: M=(3894.5±6.6±4.5) MeV; Γ=(63±24±26) MeV.
3. BESIII: M=(3899.0±3.6±4.9) MeV; Γ=(46±10±20)MeV
4. $Z_c(3900)=Z(3900)^{\pm}$.

The nature of $Z_c(3900)$?

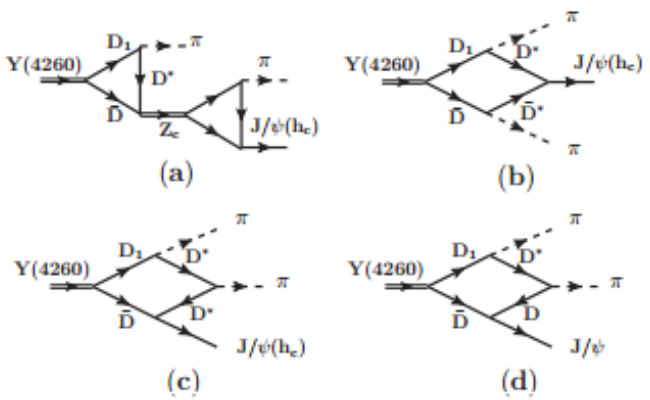
1. Tetraquarks
   - arXiv:1110.1333, 1303.6857
   - arXiv:1304.0345, 1304.1301…
2. Hadronic molecules
   - arXiv:1303.6608, 1304.2882, 1304.1850…
3. Four quark state (1 or 2)
   - arXiv:1304.0380…
4. Meson loop
   - arXiv:1303.6355
   - arXiv:1304.4458…
5. ISPE model
   - arXiv:1303.6842…
6. …



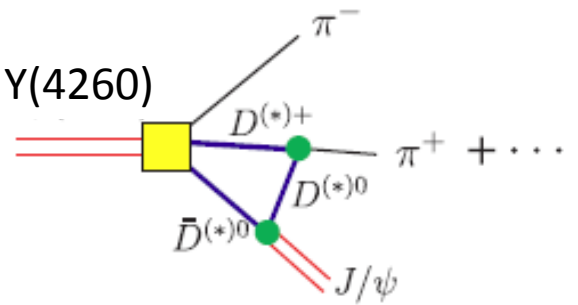
4 quarks



Exotic!



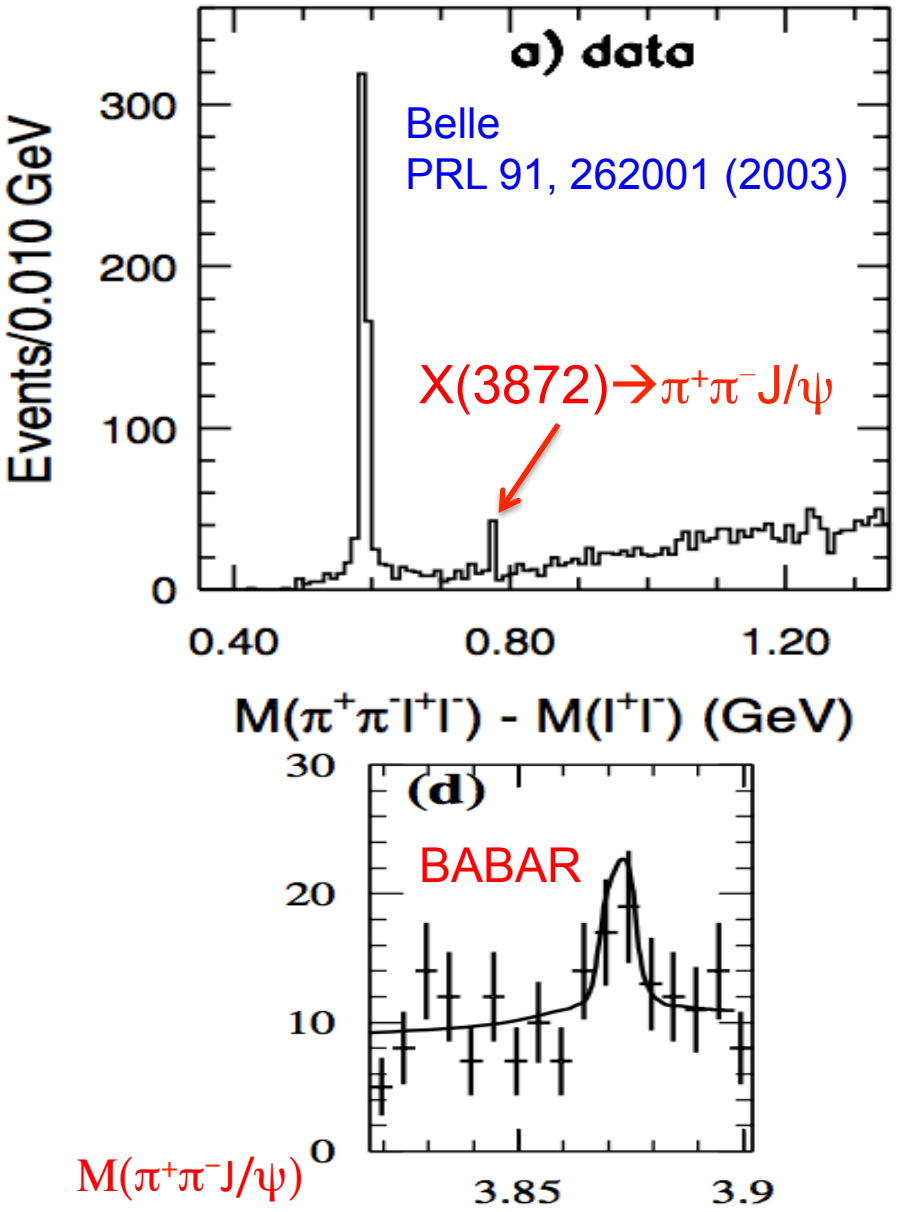
Meson loop

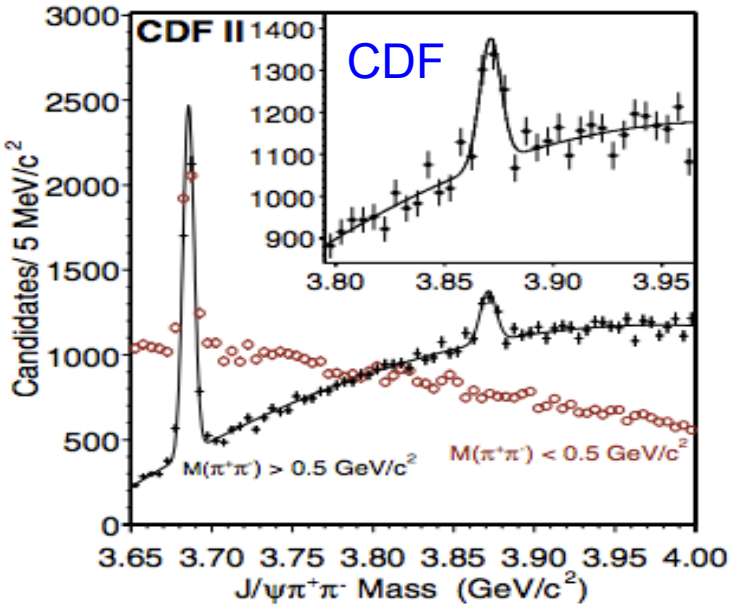


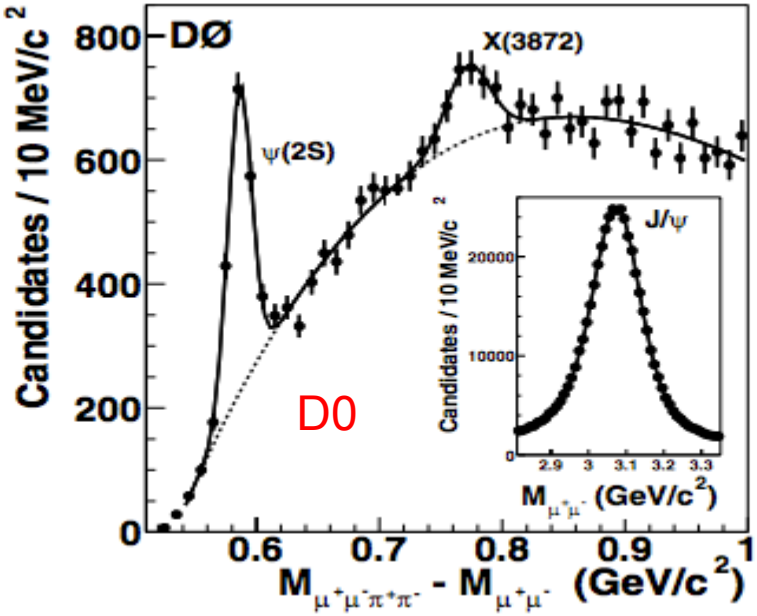
ISPE model

II. e+e-→γX(3872)

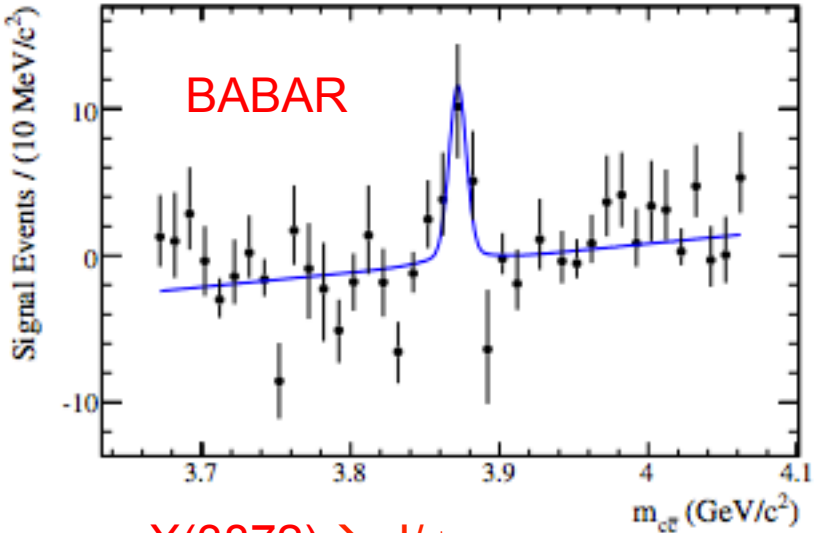
X(3872)——first exotic particle





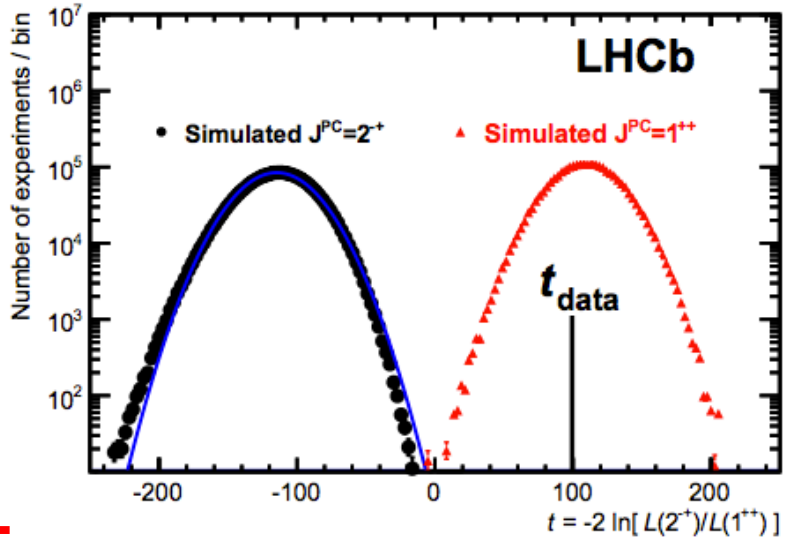


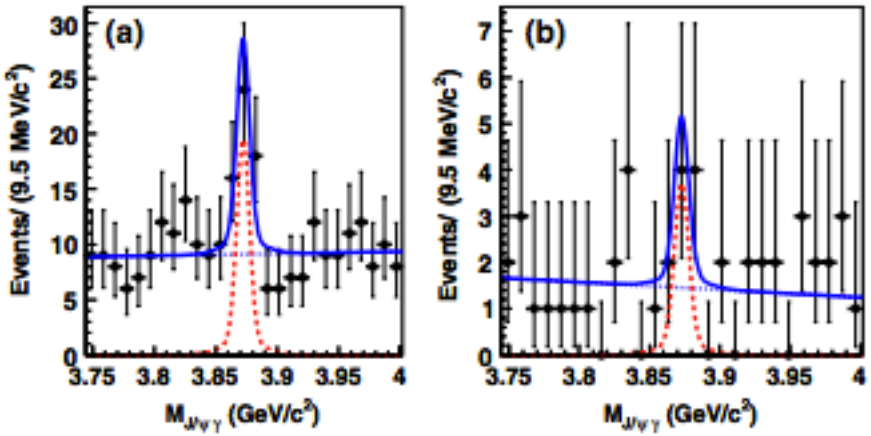
X(3872) spin-parity



X(3872)→γJ/ψ

C=+

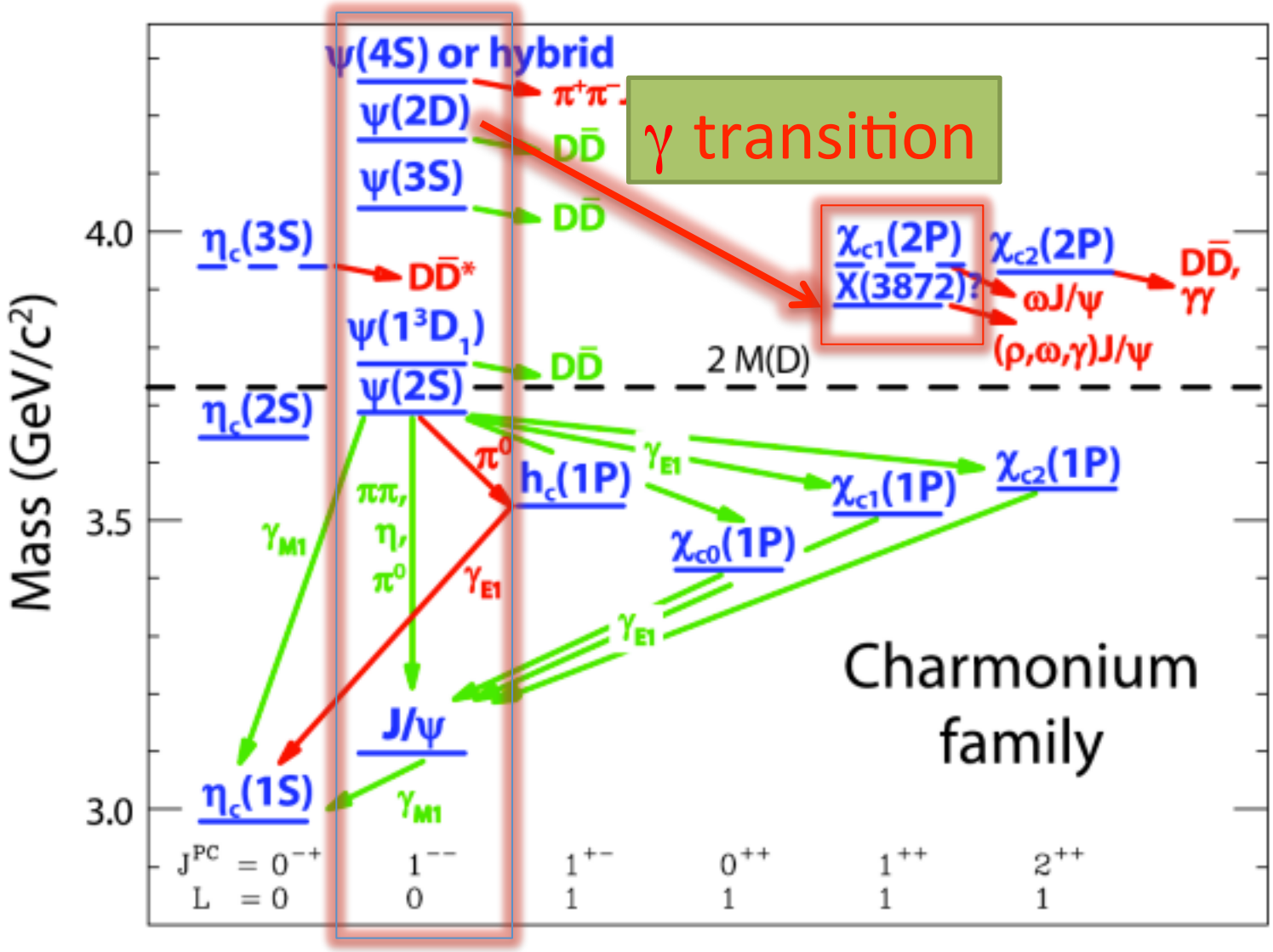




Belle

$J^{PC}=1^{++}$

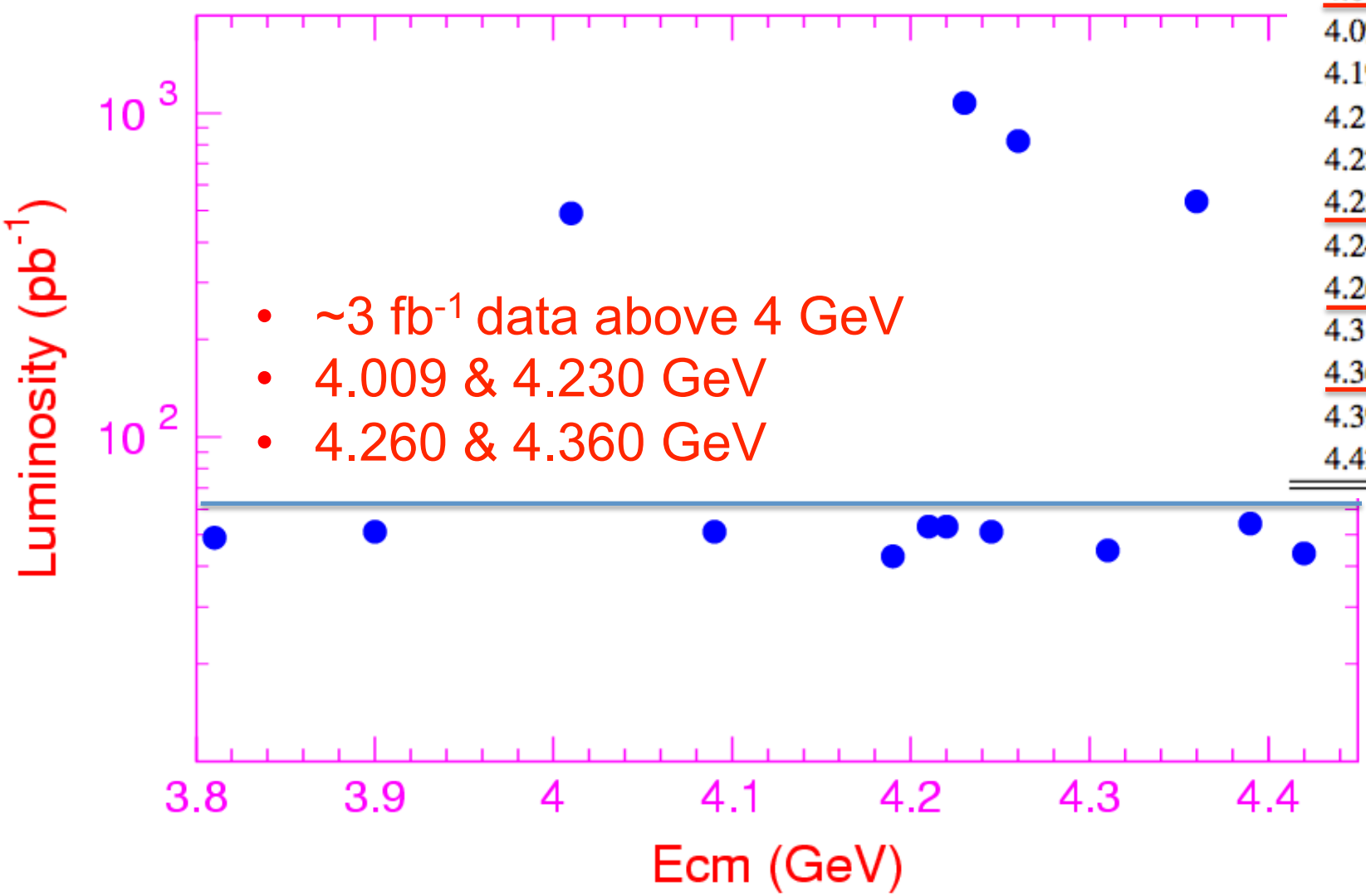
X(3872) at BESIII



BESIII can produce lots of vector charmonium and charmoniumlike state.

ψ(4040)
Y(4260)
Y(4360)
…

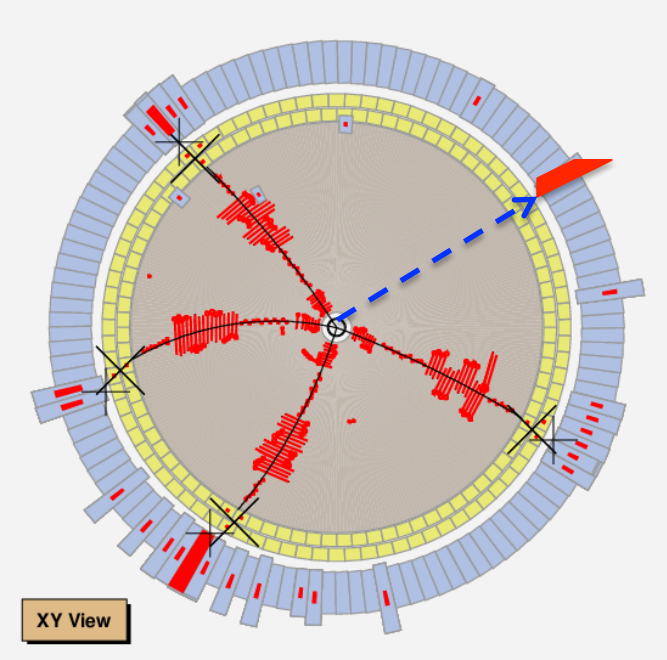
BESIII data sets

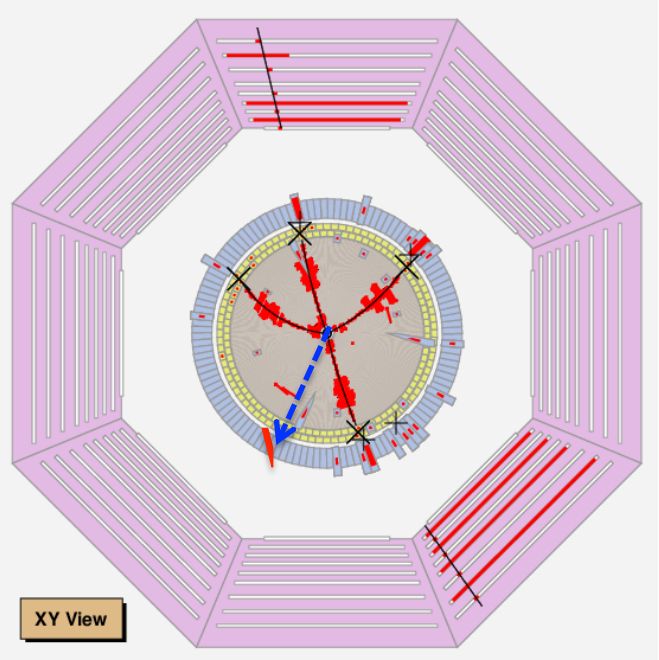


$\sqrt{s}$ (GeV)	$\mathcal{L}$ (pb^{-1})
3.900	52.8
4.009	482.0
4.090	51.0
4.190	43.0
4.210	54.7
4.220	54.6
4.230	1090.0
4.245	56.0
4.260	826.8
4.310	44.9
4.360	544.5
4.390	55.1
4.420	44.7

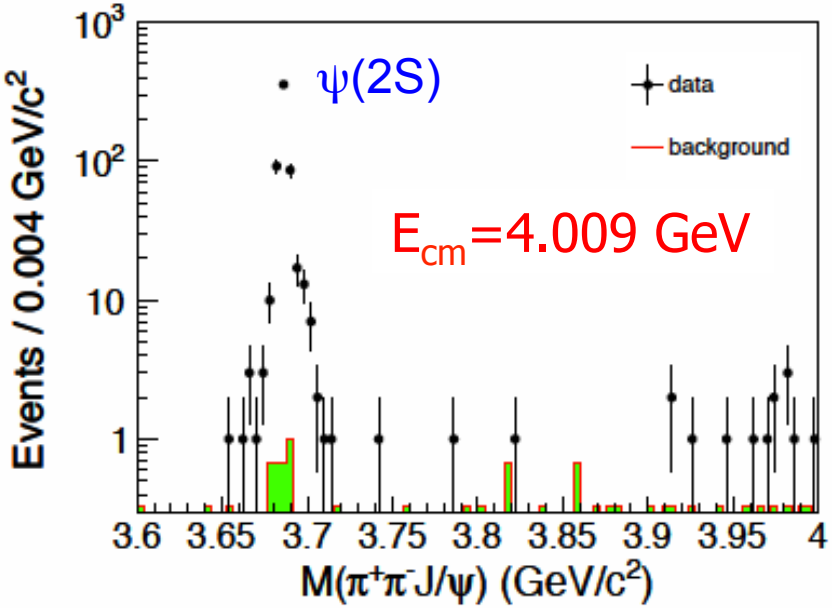
Golden Channel X(3872)→$\pi^+\pi^-J/\psi$

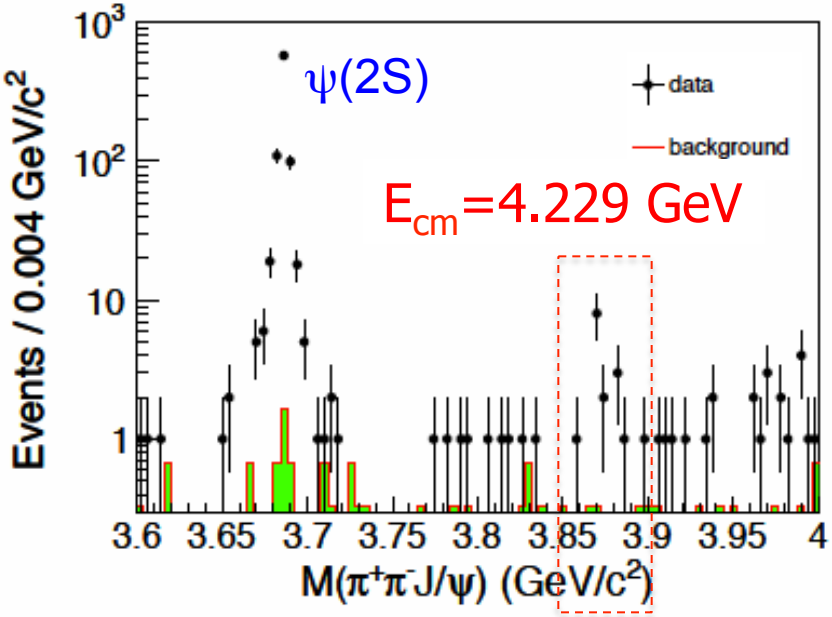
- No QED background compared with $\gamma J/\psi$
- Easy to reconstructed compared with $DD\pi^0$
- Relative large branching ratio: >2.6% @ PDG
- Clean and good control sample: ISR $\psi(2S)$

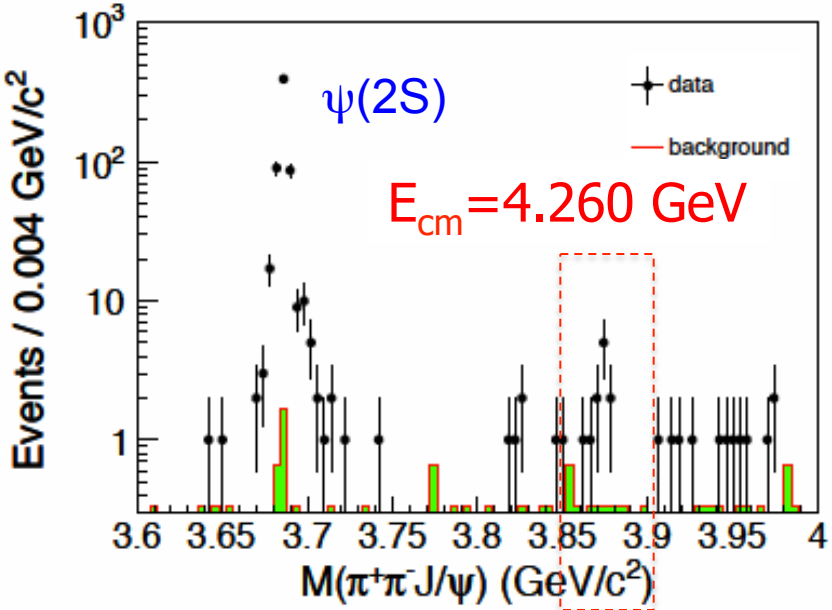


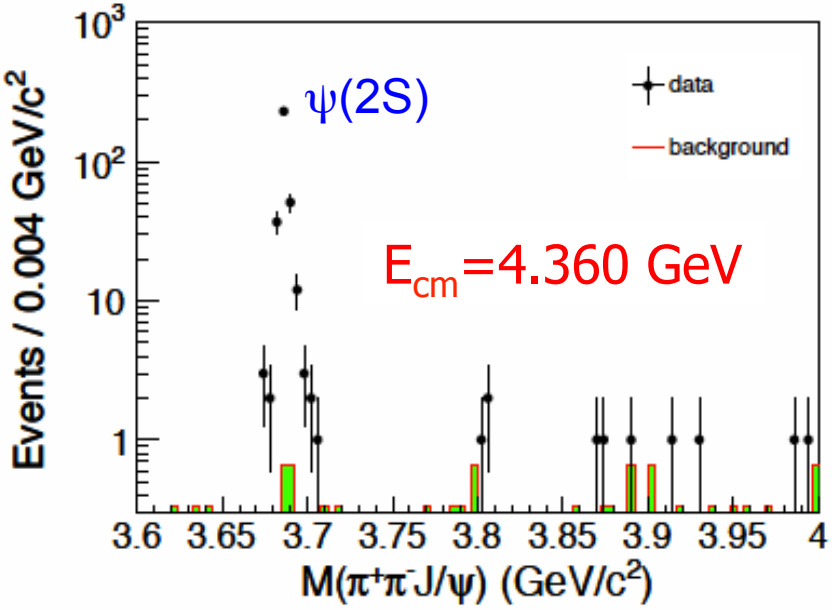


$e^+e^- \rightarrow \gamma(\pi^+\pi^- J/\psi)$ at BESIII

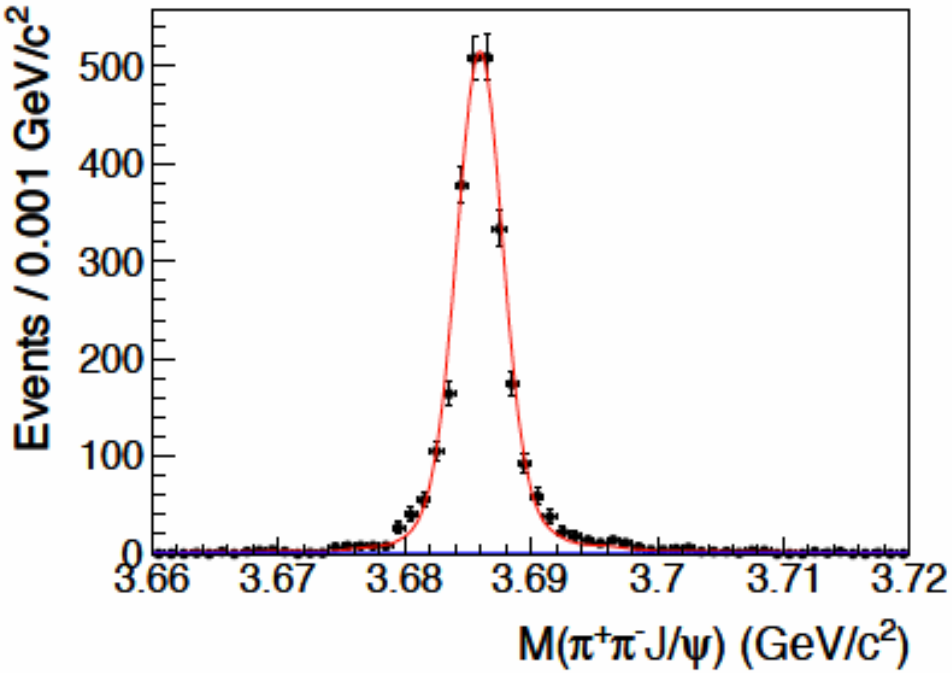


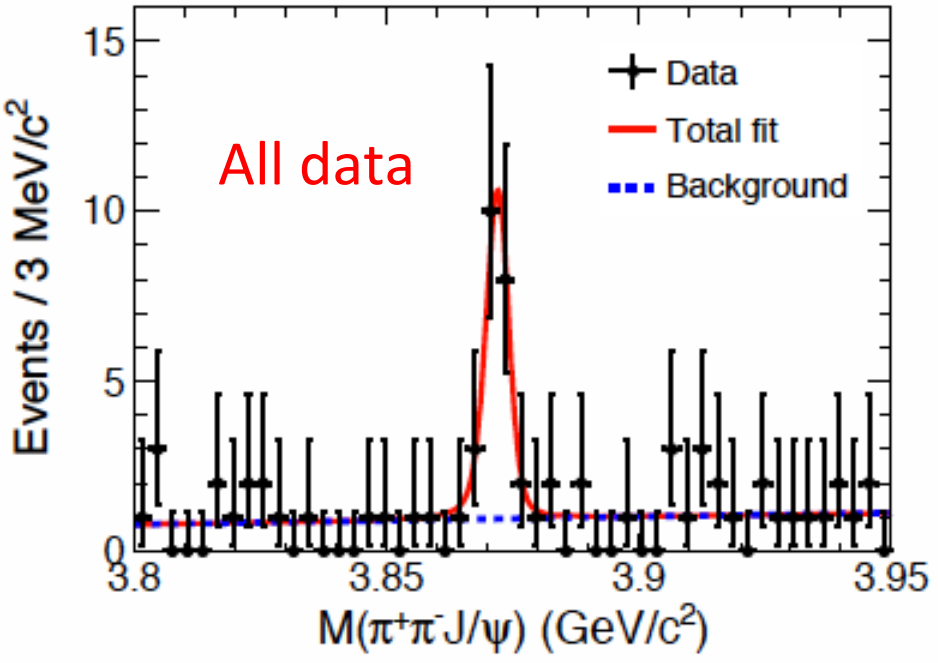






Observation of $e^+e^- \rightarrow \gamma X(3872)$





1. ISR ψ' signal is used for rate, mass, and mass resolution calibration.
2. N(ψ')=2632 ; Mass=3685.96±0.05 MeV; σ_M=1.84 ±0.06 MeV
3. Add all the data sets together blindly.
4. N(X(3872))=20.1±4.5 **6.3σ**
5. M(X(3872)) = 3871.9±0.7±0.2 MeV [PDG: 3871.68 ±0.17 MeV]

Cross section for $e^+e^- \rightarrow \gamma X(3872)$

$\sqrt{s}$ (GeV)	$N^{\rm obs}$	ϵ (%)	$1+\delta$	$\sigma^B \cdot \mathcal{B}$ (pb)	$\sigma^{\rm ISR}$ (pb)	QED (pb)
4.009	< 1.4	25.5	0.861	< 0.12	712 ± 29	735±13
4.229	9.6 ± 3.1	31.5	0.799	$0.29 \pm 0.10 \pm 0.02$	412 ± 14	408±7
4.260	8.7 ± 3.0	30.5	0.814	$0.36 \pm 0.13 \pm 0.03$	385 ± 16	382±7
4.360	< 5.1	21.1	1.023	< 0.39	309 ± 17	316±5

1. Energy dependent cross section measurement at BESIII.
2. The ISR $\psi(2S)$ production cross section is used to calibrate.
3. Give the value $\sigma^B \bullet Br[X(3872) \rightarrow \pi^+\pi^- J/\psi]$.
4. For 4.009 GeV and 4.360 GeV, upper limits at 90% C.L.

Cross section for $e^+e^- \to \gamma X(3872)$

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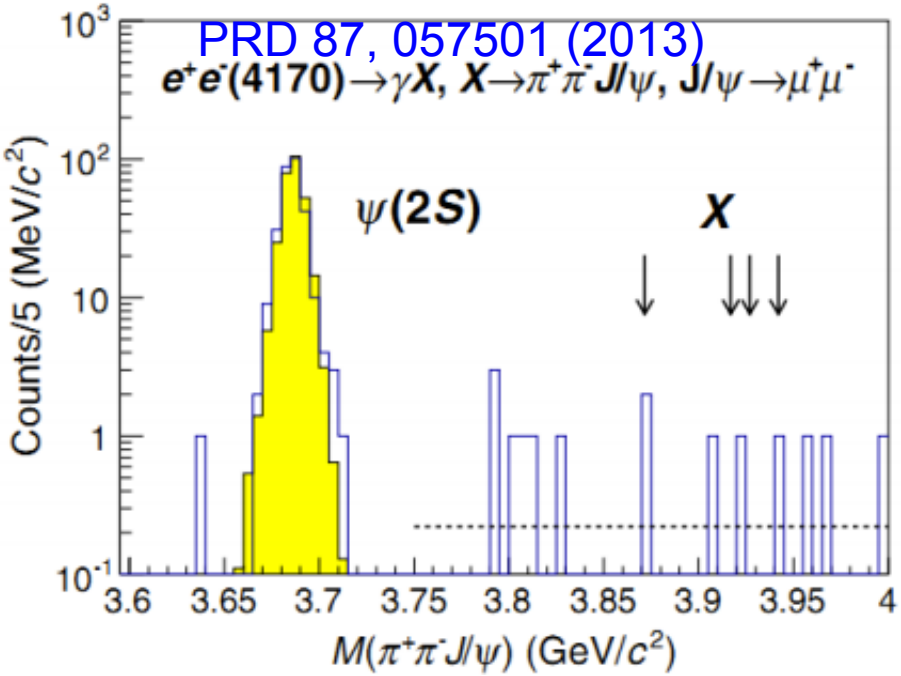
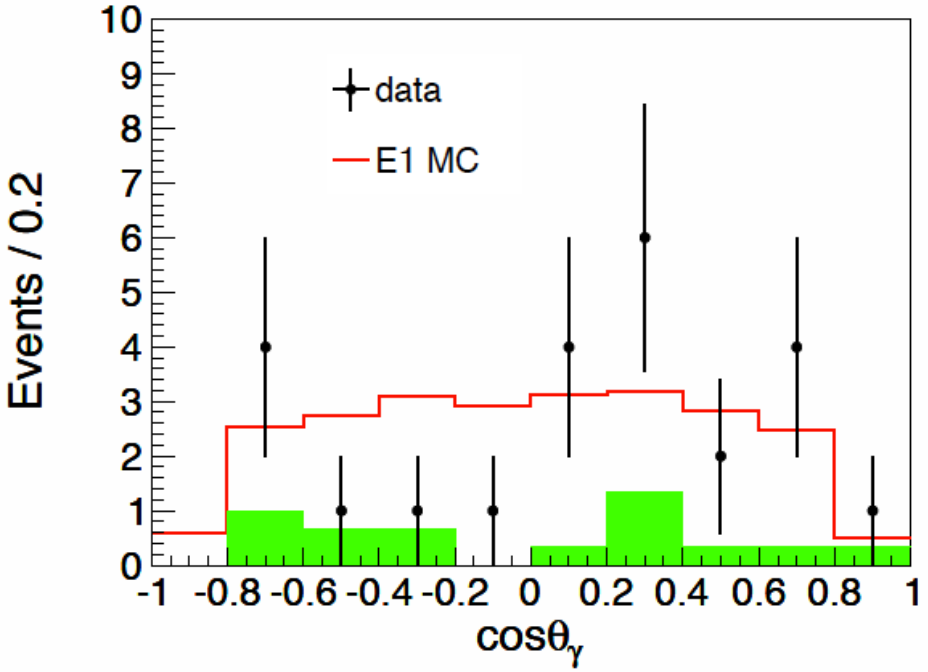
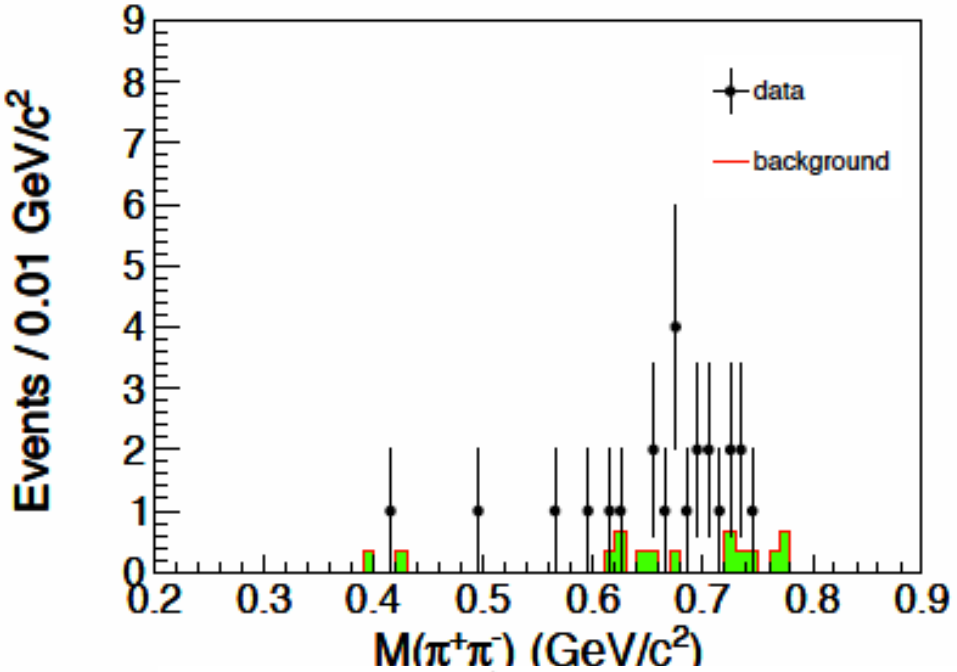


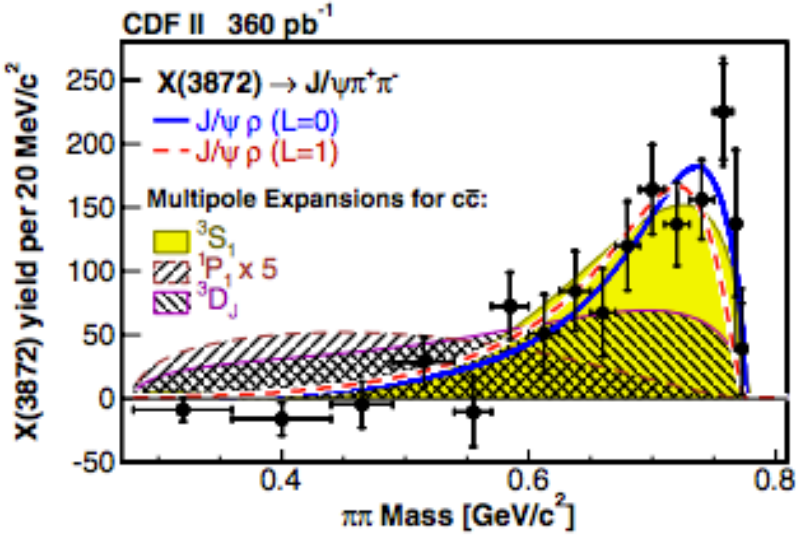
- CLEO's data 586 pb^{-1} @ 4.17 GeV: $B_1 * B_2 < 0.7 \times 10^{-4}$ @ 90 C.L.
- It seems X(3872) is from Y(4260) decays.
- $\sigma(e^+e^- \to \pi^+\pi^- J/\psi) = (62.9 \pm 1.9 \pm 3.7)$ pb @ 4.26 GeV by BESIII.
- If we take $Br[X(3872) \to \pi^+\pi^- J/\psi] = 5\%$, then $Br[Y(4260) \to \gamma X(3872)] \sim 11\%$

$\cos\theta_\gamma$ distribution and $M(\pi^+\pi^-)$ mass spectrum

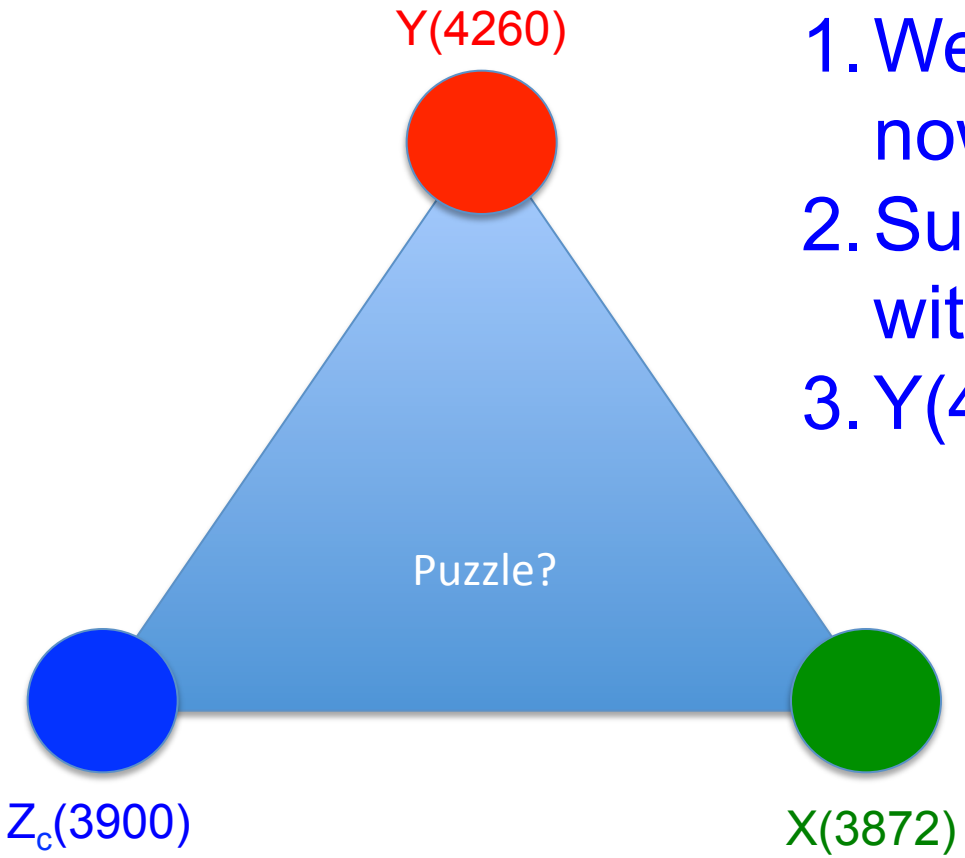




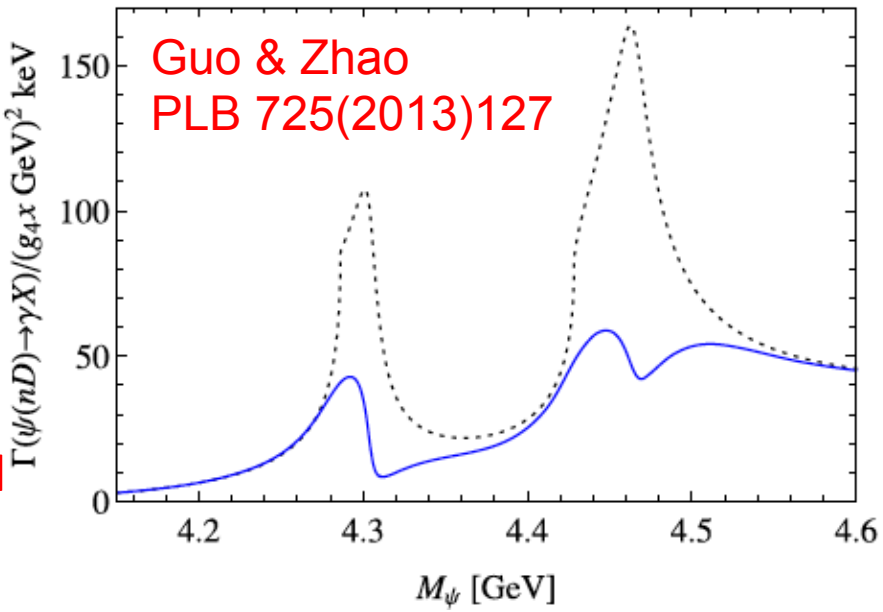
1. Polar angle distribution of the radiative photon, agree with MC simulation assuming a pure E1 transition
2. $M(\pi^+\pi^-)$ mass spectrum for $X(3872)\rightarrow\pi^+\pi^- J/\psi$ decay, agree with CDF observation.



Puzzle or Chance?



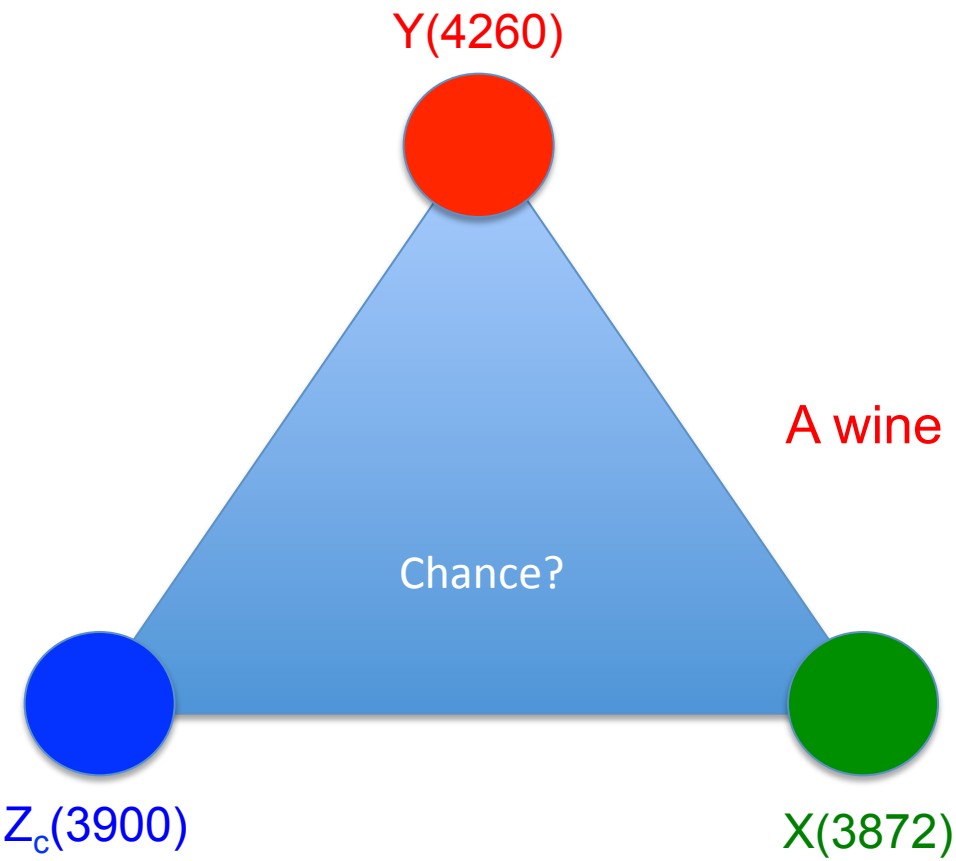
1. We have X, Y & Z at BESIII now.
2. Surprisingly, they connected with each other.
3. Y(4260) is DD_1 molecule?



K. T. Chao et al. arXiv:1310.8597

1. Continuum e+e-→$\gamma\chi_{c1}(2P)$~0.3-0.4 pb level
2. Should be from resonance decay.

Puzzle or Chance?



A wine cup with 3 legs!

K. T. Chao et al. arXiv:1310.8597

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2. Should be from resonance decay.

Summary

- BESIII observed a charged charmoniumlike state in $Y(4260) \rightarrow \pi^{\pm} Z_c(3900)$.
- $Y(4260) \rightarrow \gamma X(3872)$ radiative transition probably has been observed.
- Interesting to investigate the potential connection between these X, Y & Z particles.

Thanks !