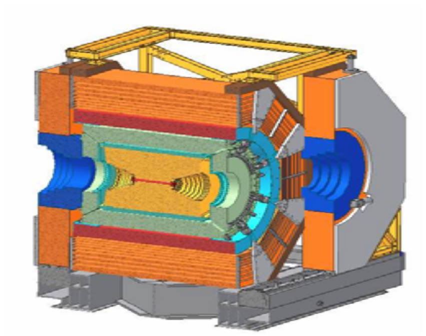
Experimental Results on $Z_c(3900)$ (BESIII & Belle)



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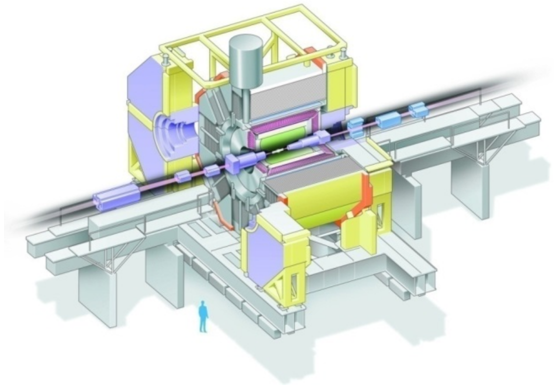
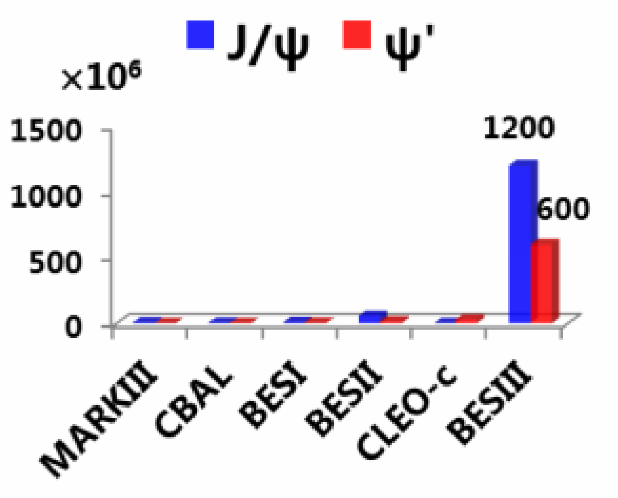


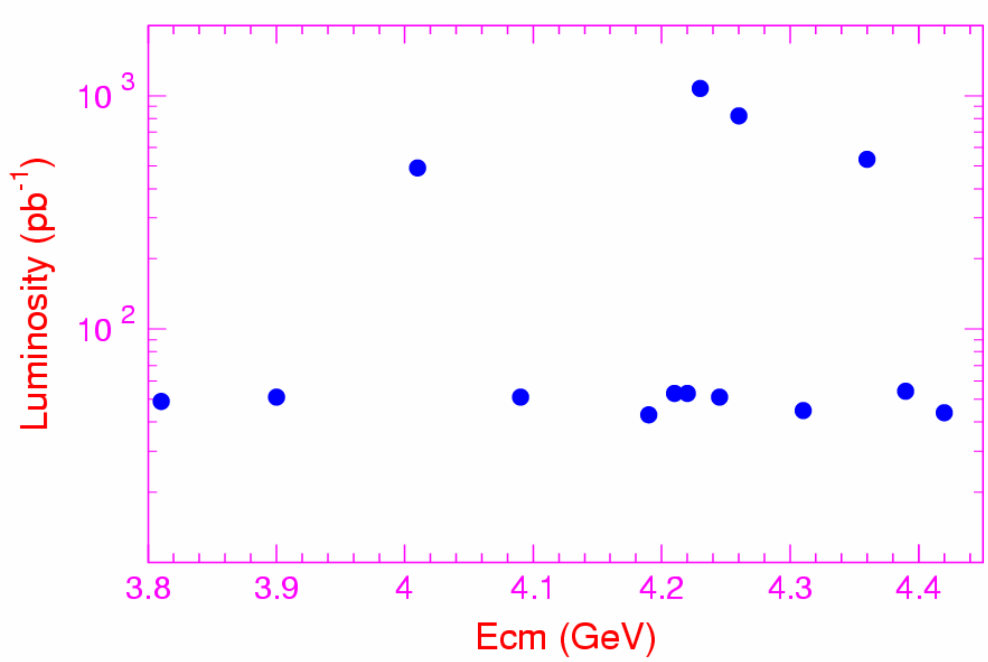
Outline

1. Discovery of $Z_c(3900)$ at BESIII.
2. Discovery of $Z(3900)^{\pm}$ at Belle.
3. Comparison between different experiments.
4. Future Working Plan for $Z_c(3900)$.
5. More Zc states from BESIII

BESIII's data

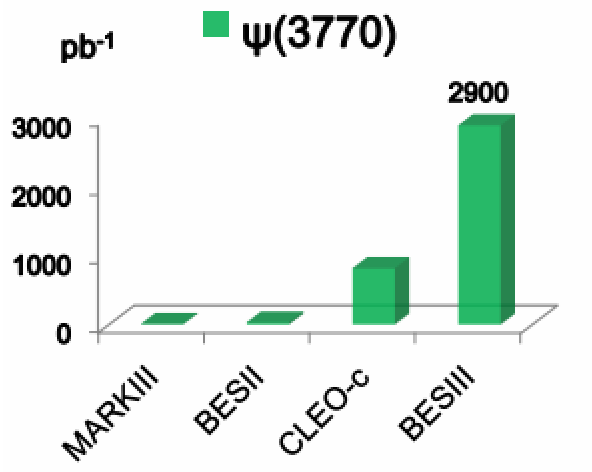


1. BEPCII is a symmetric Collider.
2. BESIII take data at e+e- c.m energy from 2 to 4.6 GeV.
3. Design luminosity $1*10^{33}/cm^2/s$, reach 70%.



Not enough…

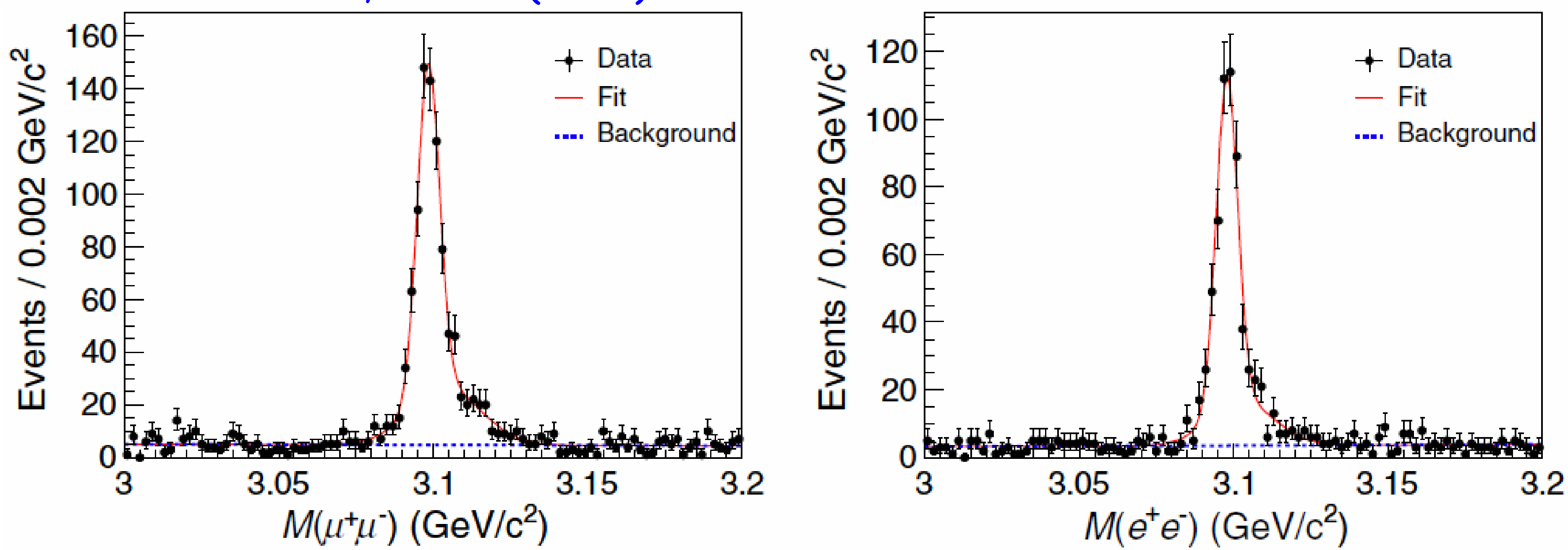
+



BESIII can study XYZ particle above 4 GeV with world's largest scan data sets.

$Z_c(3900)$ from BESIII

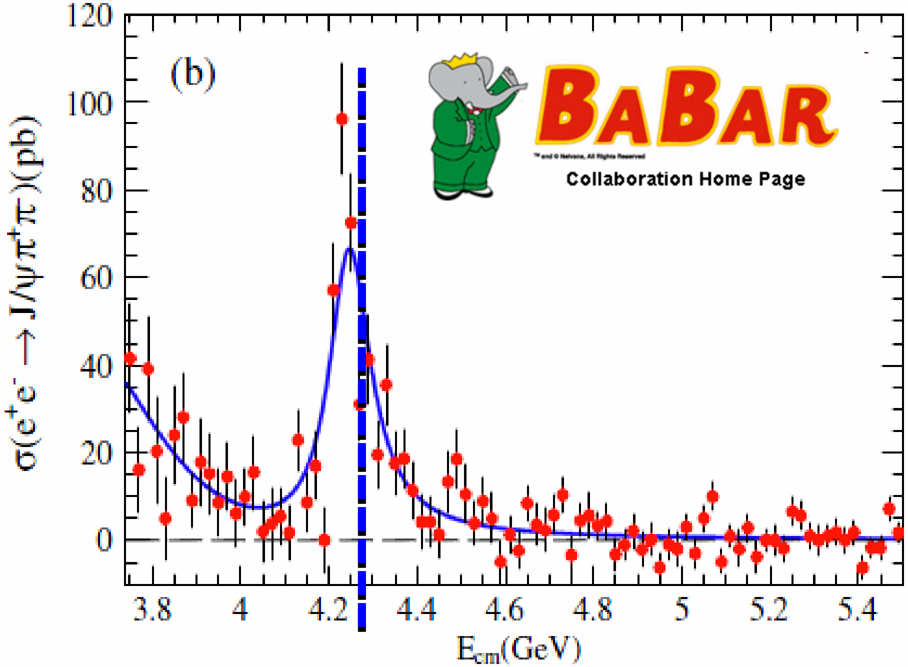
PRL **110**,252001 (2013).



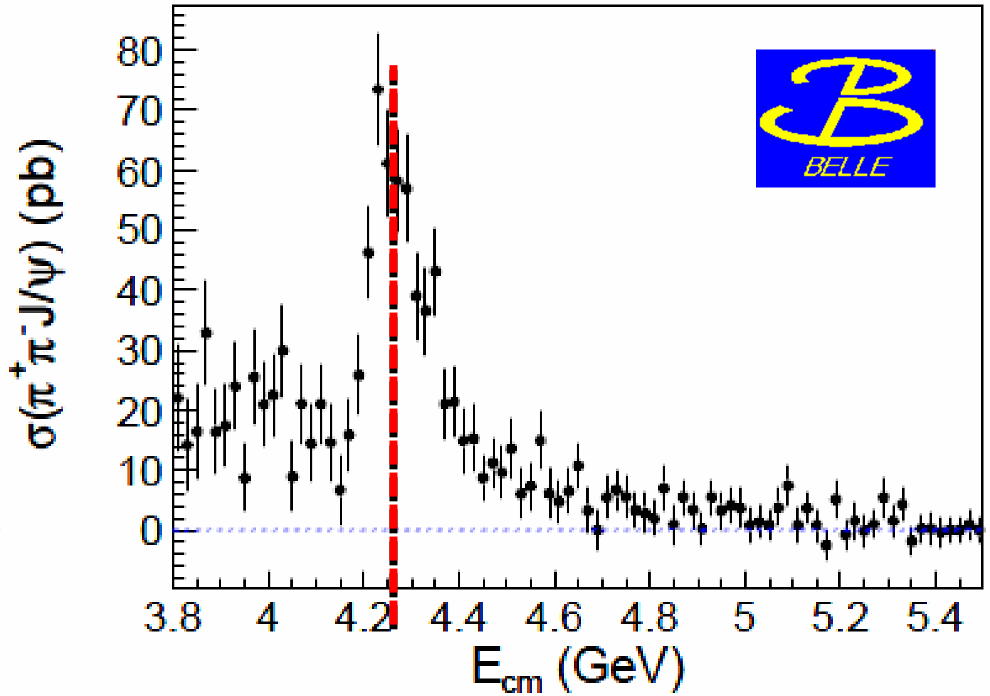
1. Dec, 2012 to Jan, 2013, BESIII accumulate 525 pb^{-1} data @ 4.26 GeV.
2. Peak position of $Y(4260) \rightarrow \pi^+\pi^- J/\psi$ cross section.
3. $N(\mu+\mu-)=882\pm33$; $N(e+e-)=595\pm28$; purity ~90%.

$Z_c(3900)$ from BESIII

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



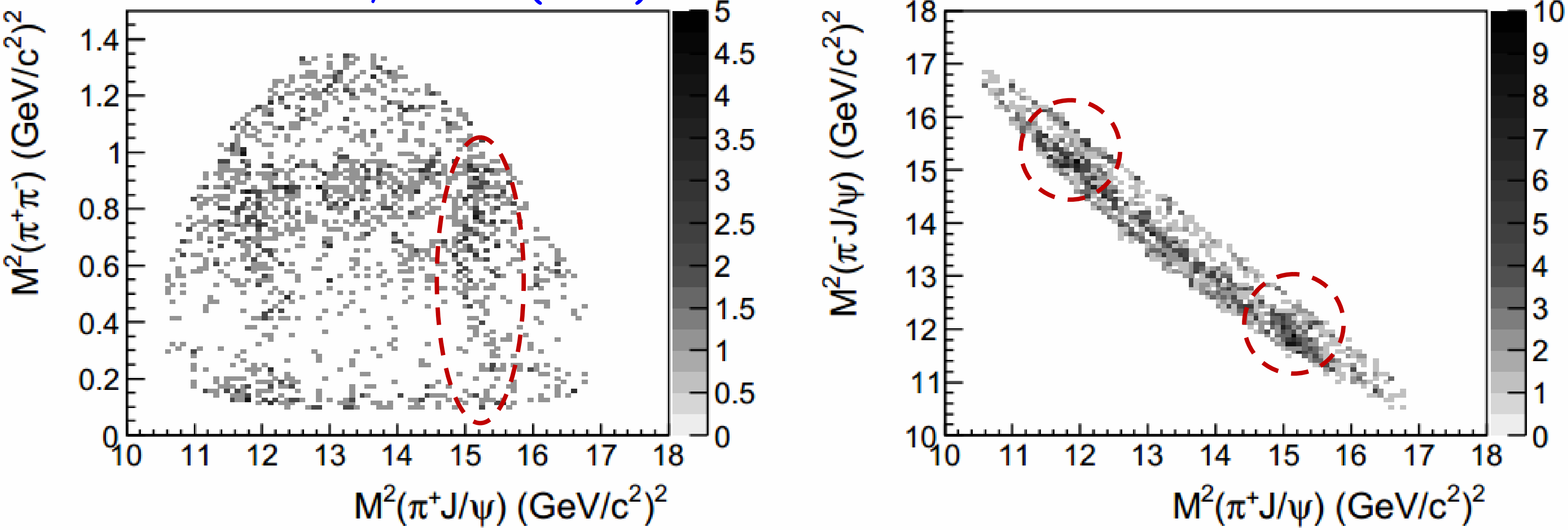
PRL **110**,252002 (2013).



1. Dec, 2012 to Jan, 2013, BESIII accumulate 525 pb^{-1} data @ 4.26 GeV.
2. Peak position of $Y(4260)\to\pi^+\pi^- J/\psi$ cross section.
3. $N(\mu+\mu-)=882\pm33$; $N(e+e-)=595\pm28$; purity ~90%.
4. Born cross section: $\sigma^B=(62.9\pm1.9\pm3.7)$ pb at BESIII.
5. Good agreement with Belle and BaBar.

$Z_c(3900)$ from BESIII

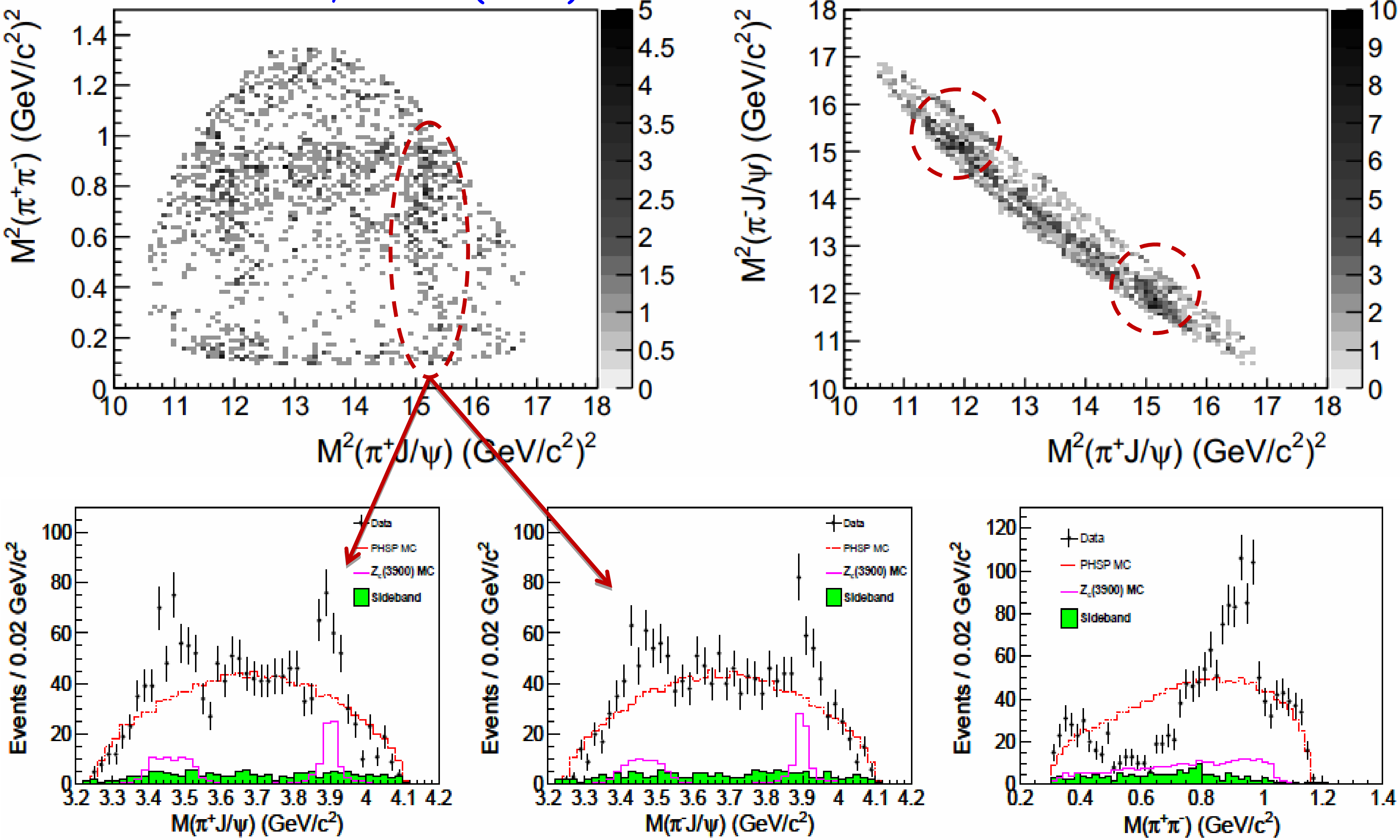
PRL **110**,252001 (2013).

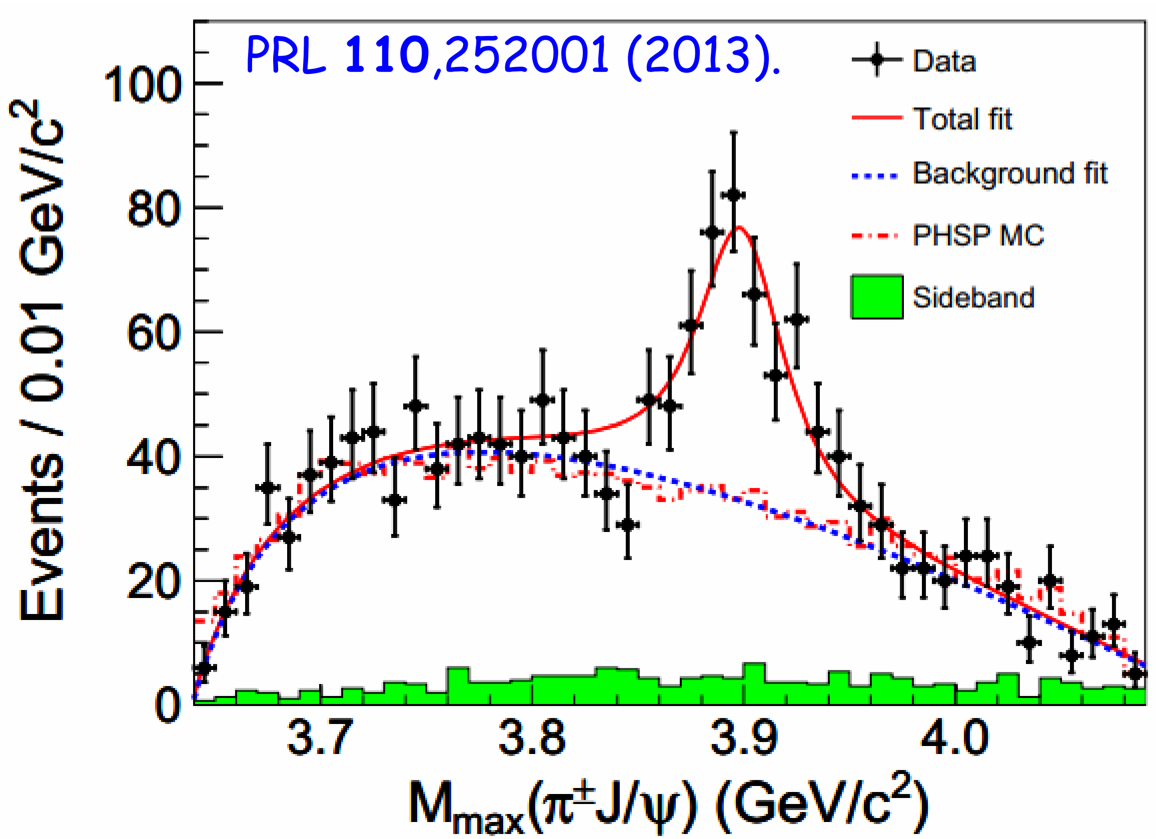


1. Structure in $M(\pi^{\pm}J/\psi)$ mass distribution.
2. Phase space reflection of $Z_c(3900)$.

$Z_c(3900)$ from BESIII

PRL **110**,252001 (2013).

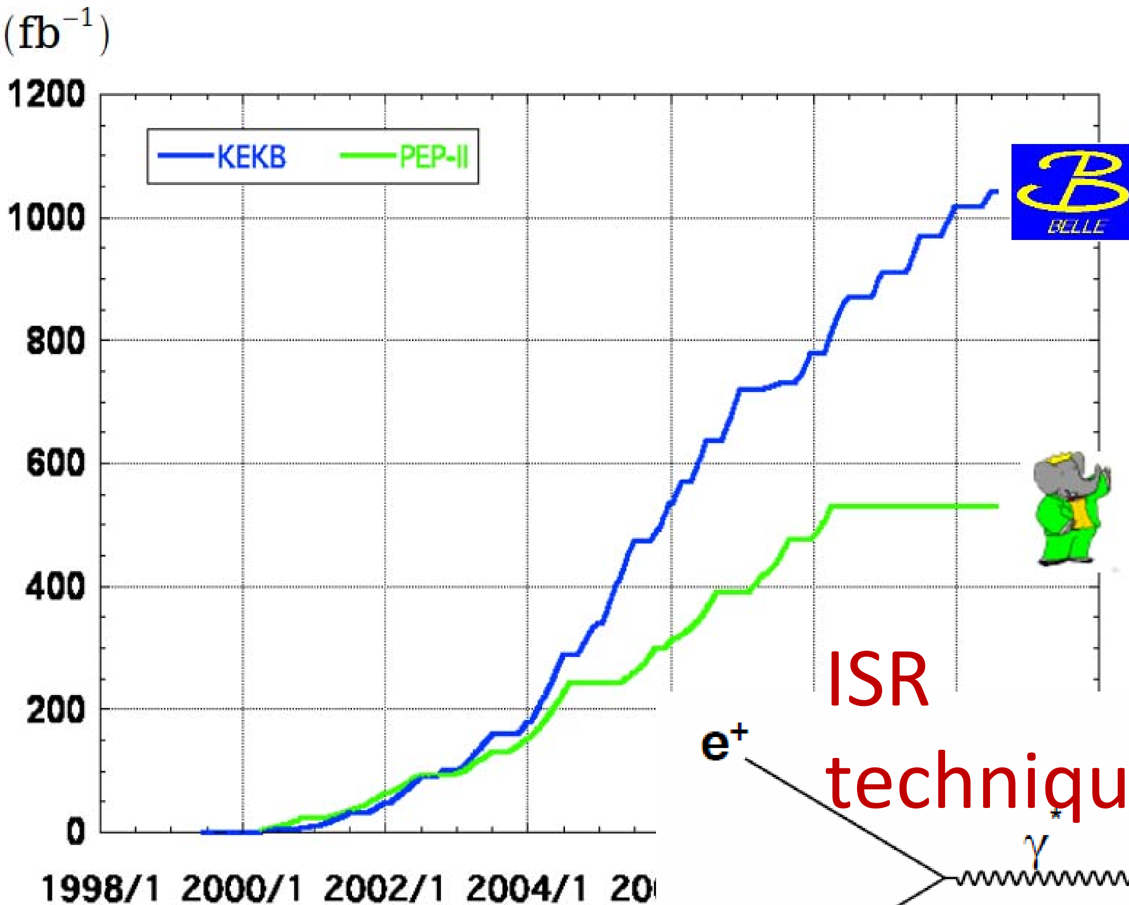




1. 1D fit to extract resonant parameters.
2. Divided Dalitz plot by diagonal line; Fit $M_{max}(\pi^{\pm}J/\psi)$ mass distribution.
3. S-Wave Breit Wigner; p*q phase space factor; efficiency applied.
4. $M=(3899.0\pm3.6\pm4.9)$MeV; $\Gamma=(46\pm10\pm20)$MeV.
5. Statistical significance: $>8\sigma$, discovery!

$Z_c(3900)$ from Belle

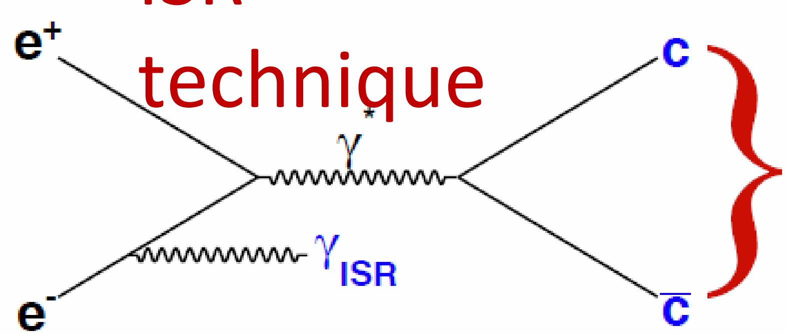
Integrated luminosity of B factories



> 1 ab^{-1}
On resonance:
$\Upsilon(5S)$: 121 fb^{-1}
$\Upsilon(4S)$: 711 fb^{-1}
$\Upsilon(3S)$: 3 fb^{-1}
$\Upsilon(2S)$: 25 fb^{-1}
$\Upsilon(1S)$: 6 fb^{-1}
Off reson./scan:
~100 fb^{-1}

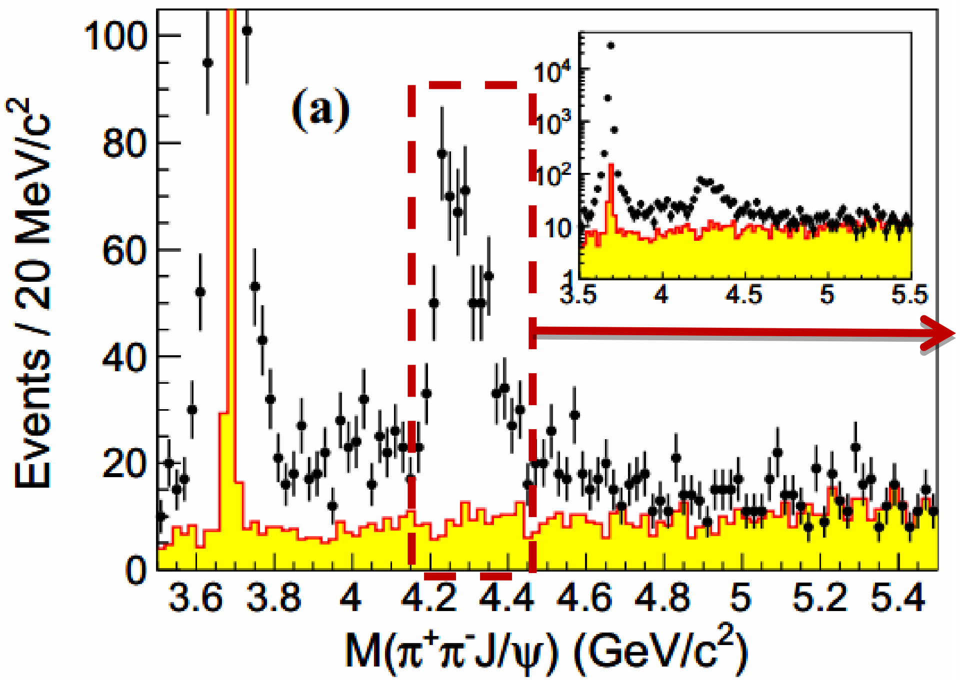
~ 550 fb^{-1}
On resonance:
$\Upsilon(4S)$: 433 fb^{-1}
$\Upsilon(3S)$: 30 fb^{-1}

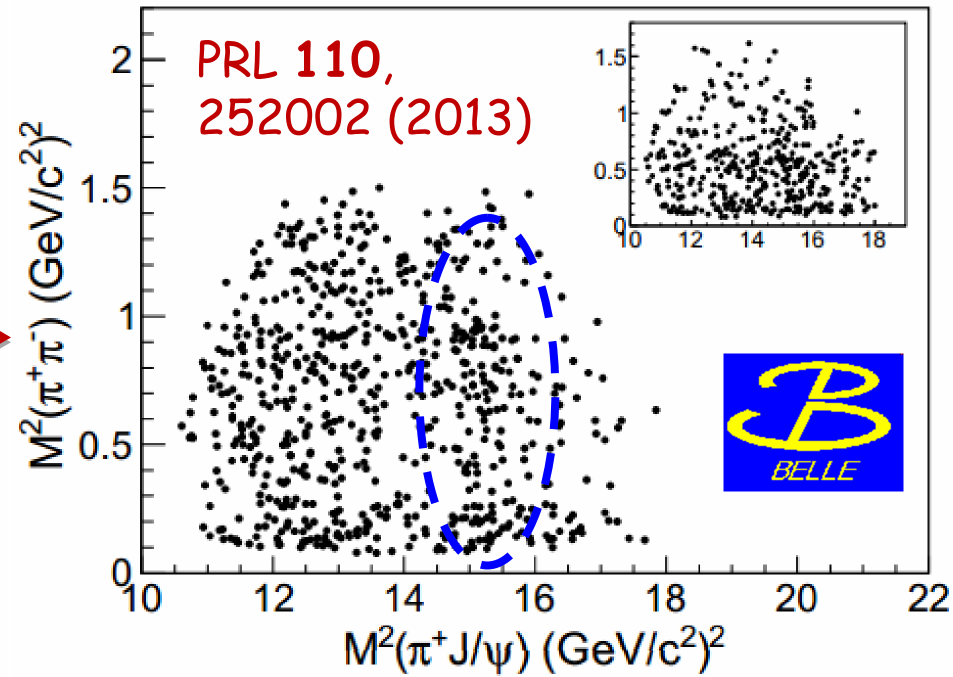
ISR technique



$J^{PC} = 1^{--}$
ψ', ψ'', Υ…

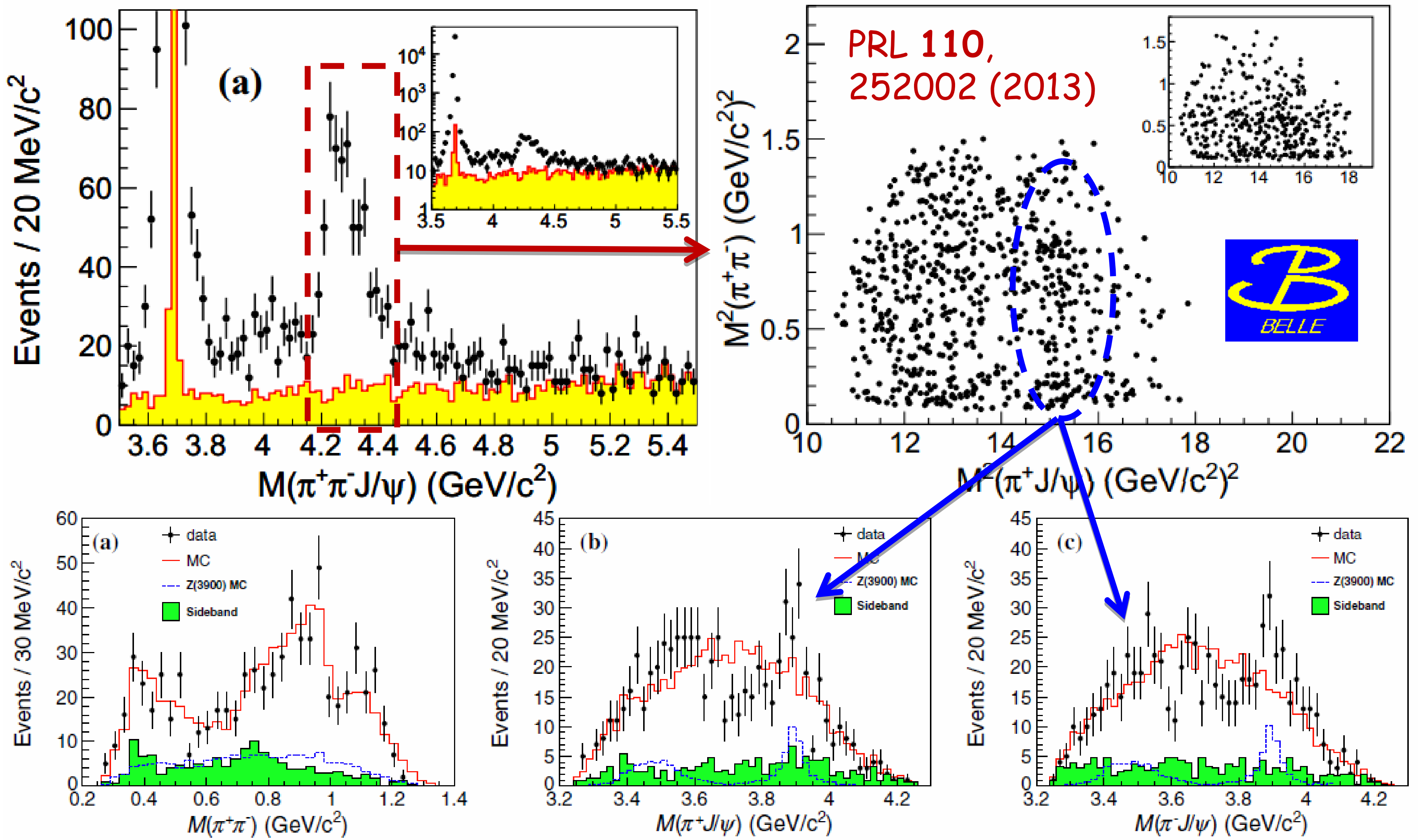
$Z(3900)^{\pm}$ from Belle



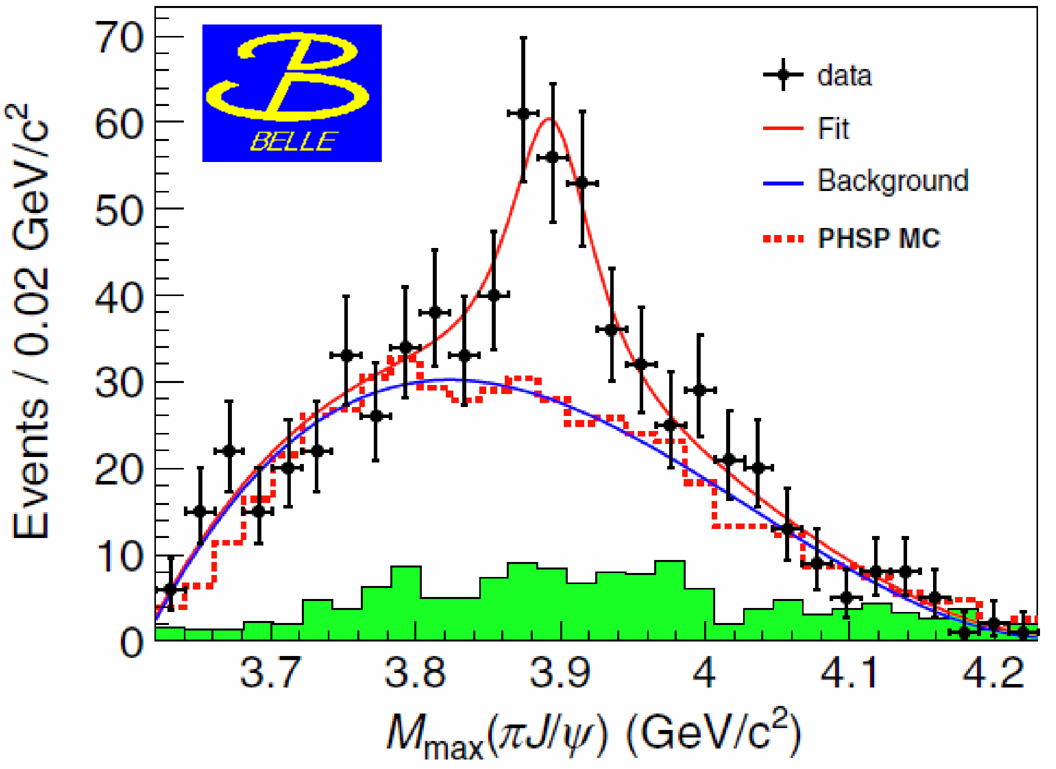


1. Belle collected data at/near Y(nS) (n=1,…,5) resonance.
2. Almost full Belle data sample used: Lum=967 fb^{-1} data.
3. Using ISR photon non-tagged method, Y(4260) was observed significantly.
4. $4.15 < M(\pi^+\pi^- J/\psi) < 4.45$ GeV to select Y(4260) resonance.
5. Dalitz plot also shows structures.

$Z(3900)^{\pm}$ from Belle

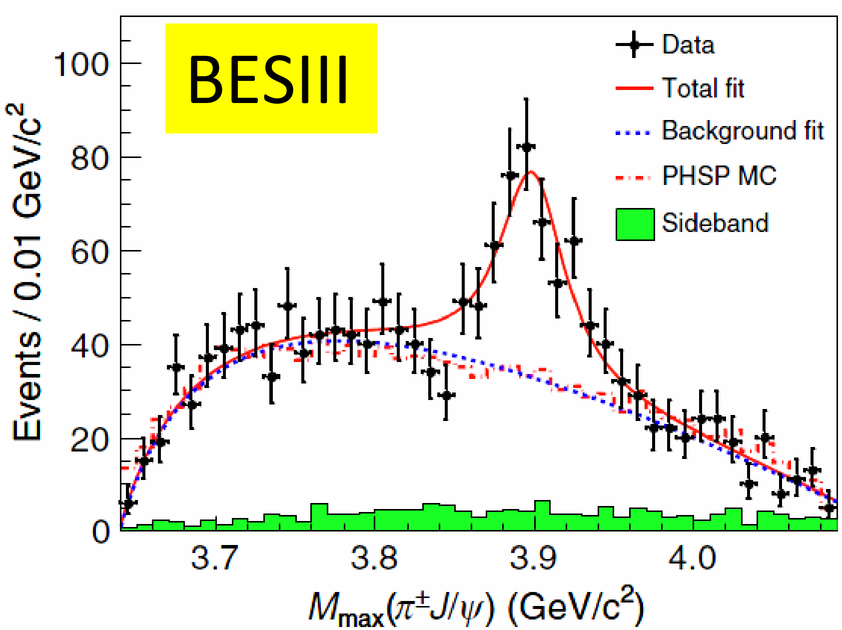


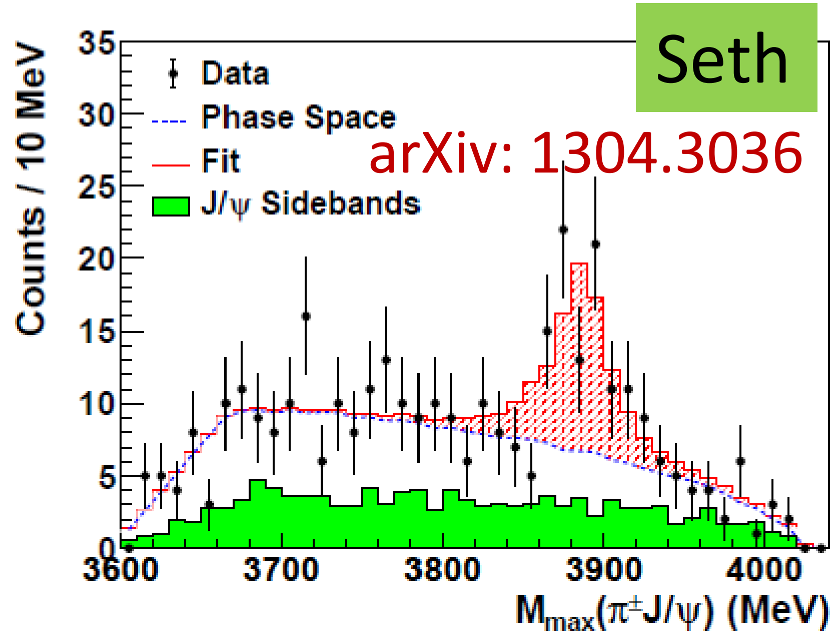
$Z(3900)^{\pm}$ from Belle

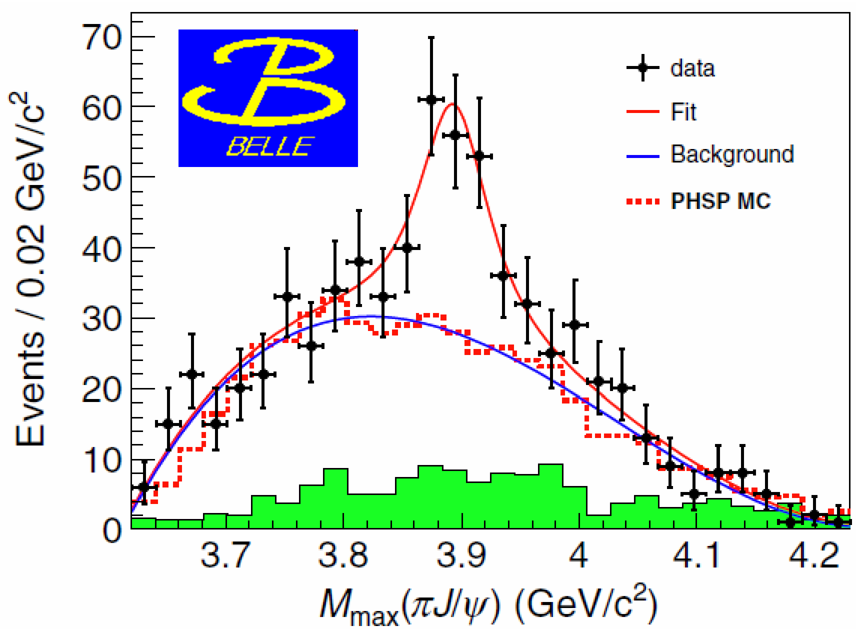


1. Belle use the same fit strategy to $M_{max}(\pi^{\pm}J/\psi)$ distribution.
2. S-Wave BW, p*q phase space factor, efficiency applied.
3. Belle observed 689 events, with 139 background.
4. $M=(3894.5\pm6.6\pm4.5)$ MeV; $\Gamma=(63\pm24\pm26)$ MeV.
5. Significance:5.2σ.

BESIII + Belle + CLEO's data

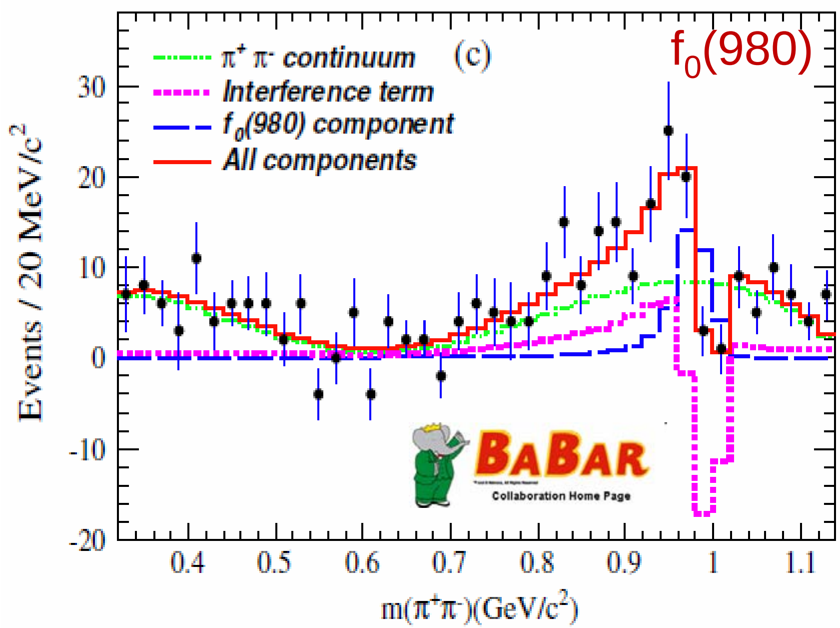


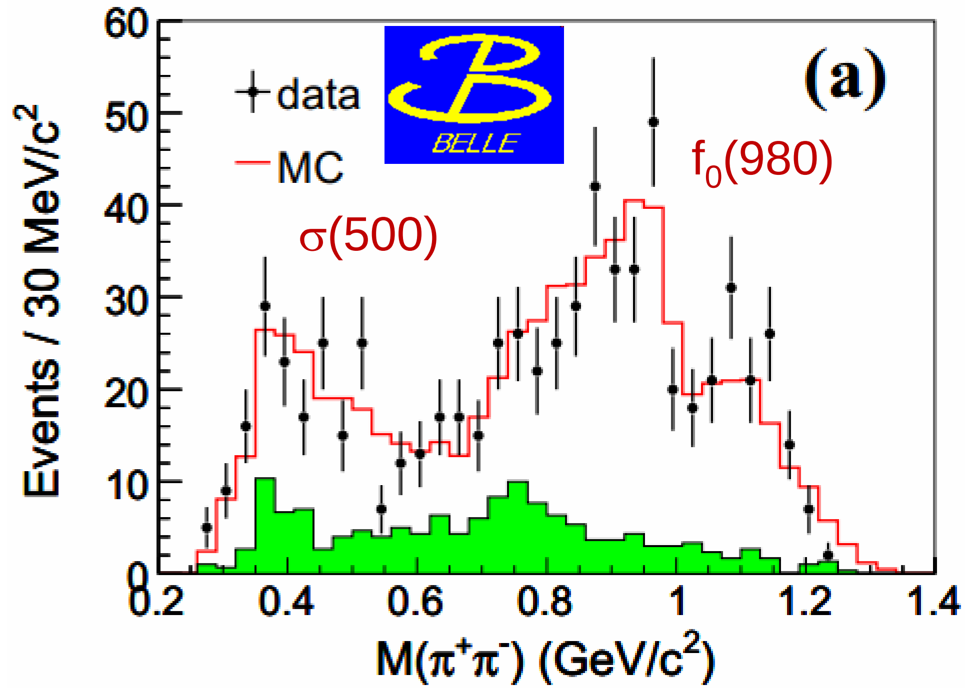


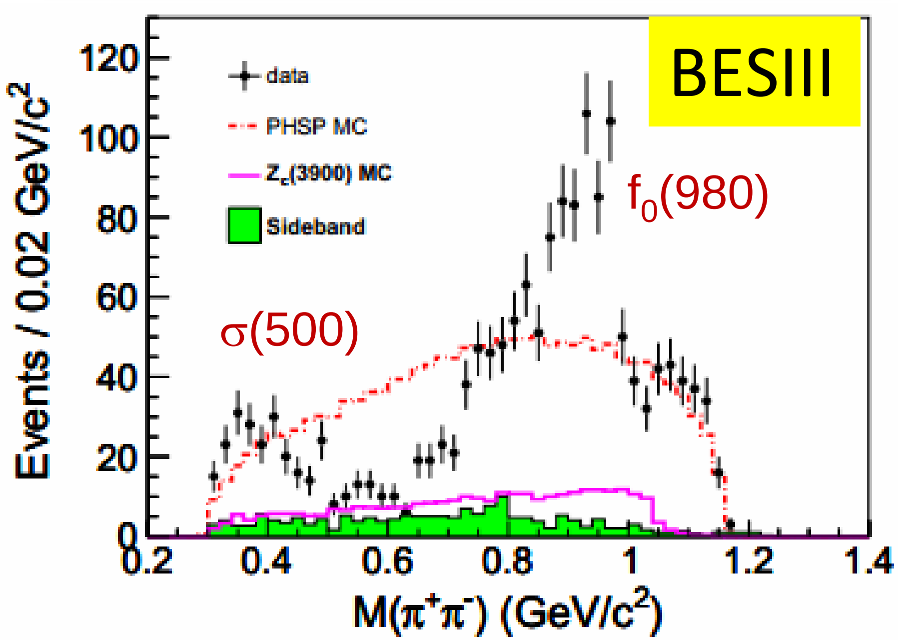


1. $Z_c(3900)=Z(3900)^{\pm}$.
2. CLEO's data at 4.17 GeV by K. Seth. ($586pb^{-1}$)
3. M=3886±4±2 MeV, Γ=37±4±8 MeV.
4. Significance > 5σ

$M(\pi^+\pi^-)$ amplitude in $Y(4260) \rightarrow \pi^+\pi^- J/\psi$







1. The $\pi^+\pi^-$ amplitude is similar in $Y(4260) \rightarrow \pi^+\pi^- J/\psi$ decay.
2. Help understand the Y(4260) and $Z_c(3900)$?

The nature of $Z_c(3900)$?

1. Tetraquarks
- arXiv:1110.1333, 1303.6857
- arXiv:1304.0345, 1304.1301…

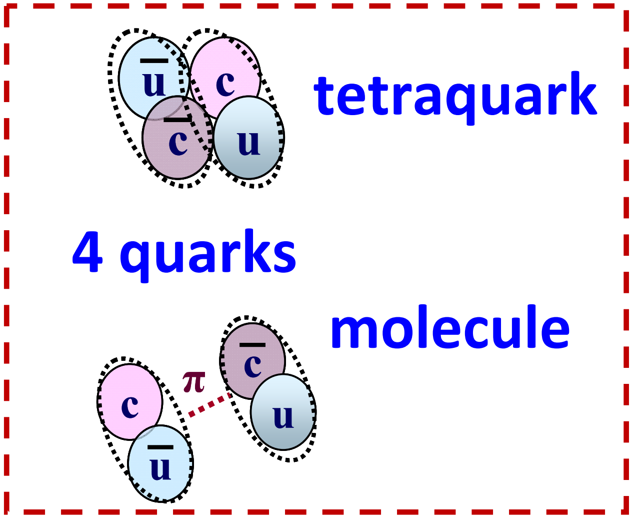
2. Hadronic molecules
- arXiv:1303.6608, 1304.2882, 1304.1850…

3. Four quark state (1 or 2)
- arXiv:1304.0380…

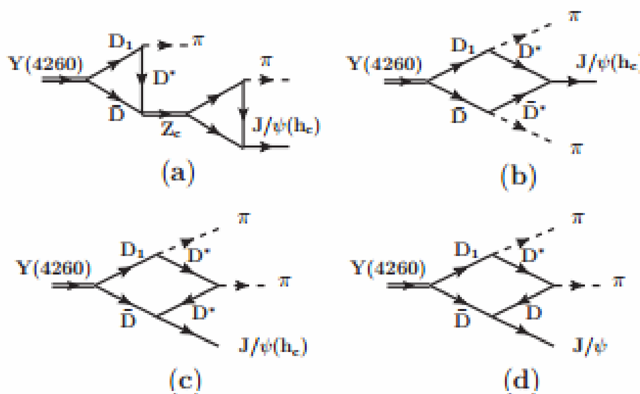
4. Meson loop
- arXiv:1303.6355
- arXiv:1304.4458…

5. ISPE model
- arXiv:1303.6842…

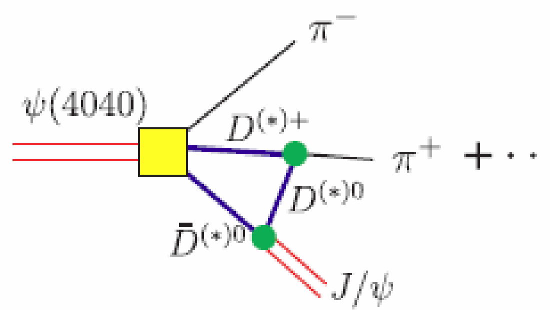
6. …



Exotic!



Meson loop



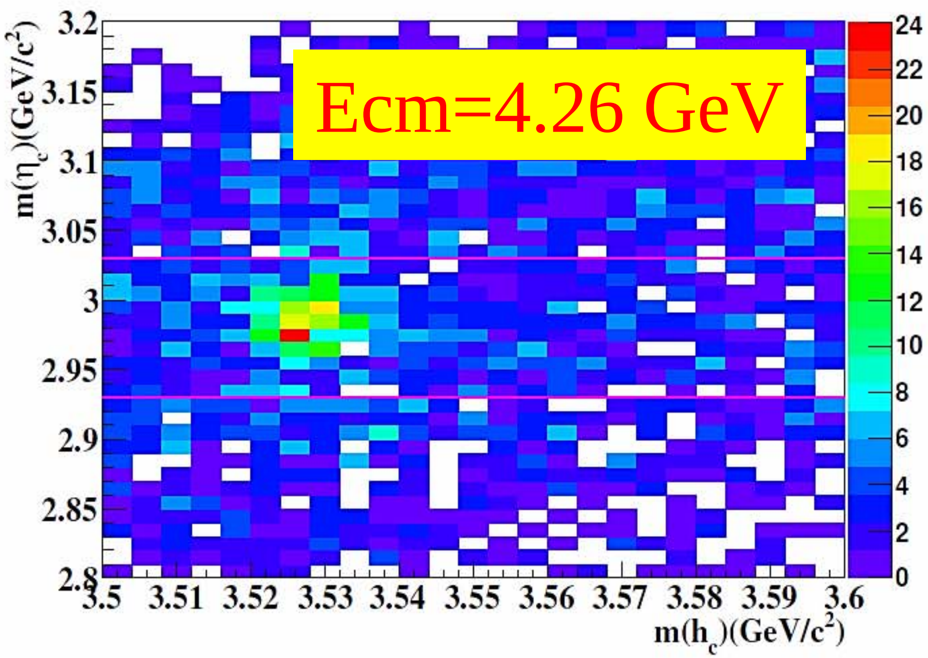
ISPE model

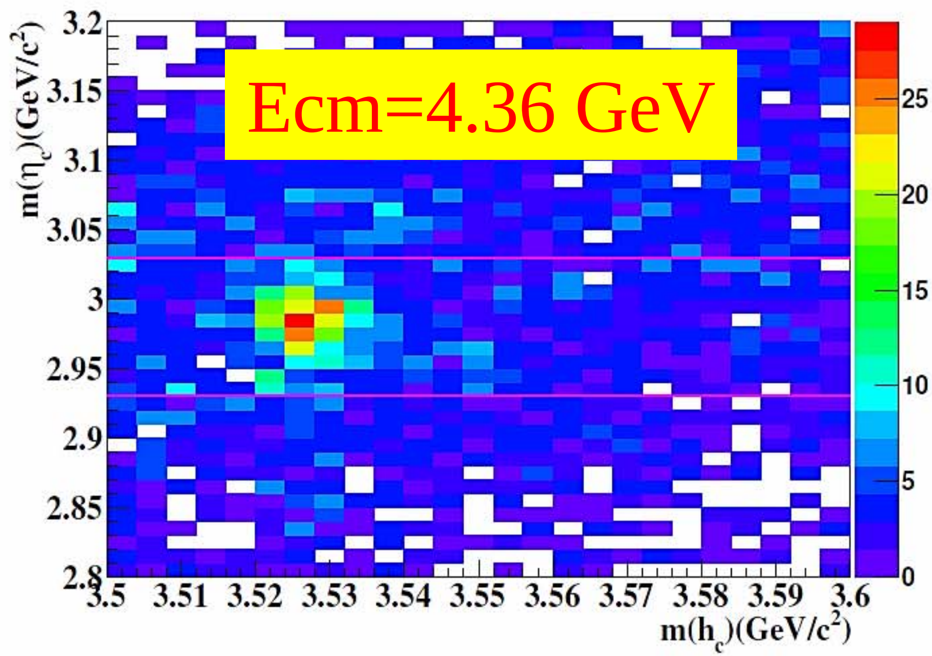
Future Working Plan

1. Precise mass and width measurement; and Spin-Parity determination with more data (4 $\times$ @4.26 GeV) at BESIII (PWA ongoing).
2. Give a line-shape measurement of both Y(4260) and $\pi^{\pm}Z_c(3900)$ with BESIII scan data.
3. More decay modes [$\pi\psi'$, $\rho\eta_c$, open charm,…]
4. Spin-parity of Zc and Zc'
5. Production mechanisms, production rates
6. Test various theoretical models
7. Neutral partners of Zc and Zc'
8. Excited Zc, Zc' states? $Z_{cs} \rightarrow KJ/\psi$ states?
9. Other XYZ states?

$e^+e^- \to \pi^+\pi^- h_c(1P)$ at BESIII

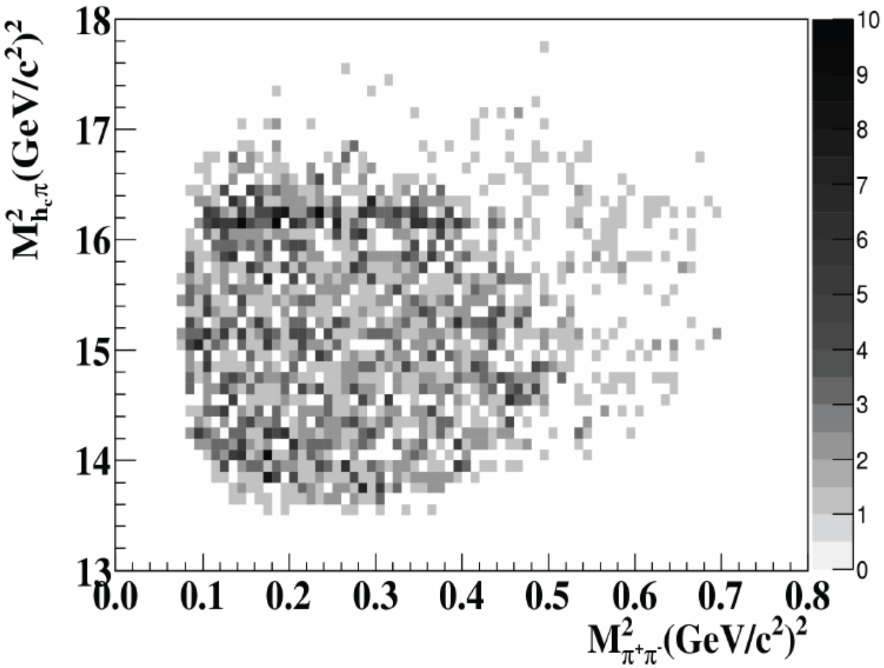
- $h_c \to \gamma\eta_c$, $\eta_c \to$ hadrons [16 exclusive decay modes]
  - $p\bar{p}$, $\pi^+\pi^-K^+K^-$, $\pi^+\pi^-p\bar{p}$, $2(K^+K^-)$, $2(\pi^+\pi^-)$, $3(\pi^+\pi^-)$
  - $2(\pi^+\pi^-)K^+K^-$, $K_S^0K^+\pi^-$+c.c., $K_S^0K^+\pi^-\pi^+\pi^-$+c.c., $K^+K^-\pi^0$
  - $p\bar{p}\pi^0$, $K^+K^-\eta$, $\pi^+\pi^-\eta$, $\pi^+\pi^-\pi^0\pi^0$, $2(\pi^+\pi^-)\eta$, $2(\pi^+\pi^-\pi^0)$

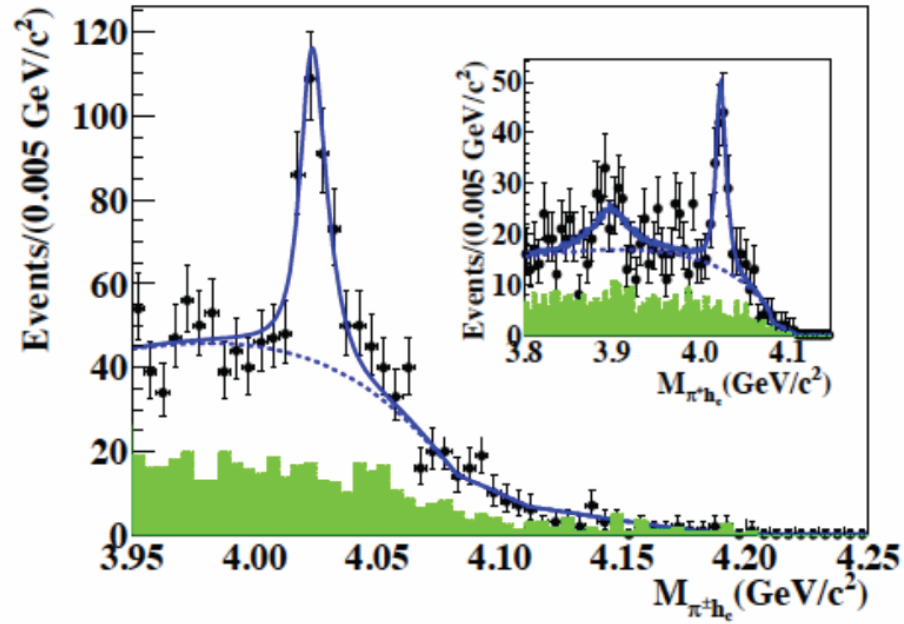




Observation of $Z_c(4020)$

arXiv:1309.1896
submitted to PRL





- Obvious structure around 4.2 GeV
- Simultaneously fit to 4.230/4.260/4.360 data (2.4 fb^{-1})
- $M = 4022.9 \pm 0.8 \pm 2.7$ MeV;
- $\Gamma = 7.9 \pm 2.7 \pm 2.6$ MeV

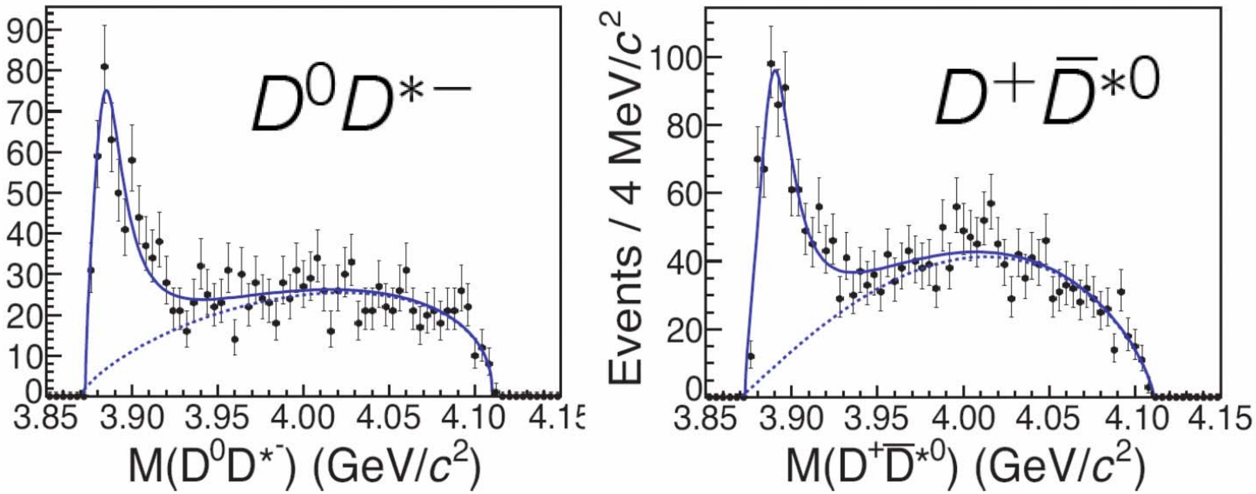
- $\sigma = 8.7 \pm 1.9 \pm 2.8 \pm 1.4$ pb @ 4.230
  $7.4 \pm 1.7 \pm 2.1 \pm 1.2$ pb @ 4.260
  $10.3 \pm 2.3 \pm 3.1 \pm 1.6$ pb @ 4.360

Significance: 8.9σ (Zc(4020))
No significant $Z_c(3900)$ (2.1σ)

$e^+e^- \to \pi^\pm(D\bar{D}^*)^\mp - Z_c(3885)$ with 525/pb @4.26 GeV

Partial reconstruct: reconstruct "bachelor" π
reconstruct $D^0 \to K\pi$ and $D^+ \to K\pi$
looking at the recoiling mass of π

BESIII: arXiv:1310.1163
Submitted to PRL



Fit with mass-dependent BW with phase space factor and efficiency correction.

	$Z_c(3885) \to D\bar{D}^*$	$Z_c(3900) \to \pi J/\psi$
Mass (MeV/c^2)	$3883.9 \pm 1.5 \pm 4.2$	$3899 \pm 3.6 \pm 4.9$
Γ (MeV)	$24.8 \pm 3.3 \pm 11.0$	$46 \pm 10 \pm 20$
$\sigma \times \mathcal{B}$ (pb)	$83.5 \pm 6.6 \pm 22.0$	$13.5 \pm 2.1 \pm 4.8$

The pole mass and width are reported for Zc(3885).

Assuming the Zc(3885) is due to Zc(3900):

$$\frac{\Gamma(Z_c(3885) \to D\bar{D}^*)}{\Gamma(Z_c(3900) \to \pi J/\psi)} = 6.2 \pm 1.1 \pm 2.7$$

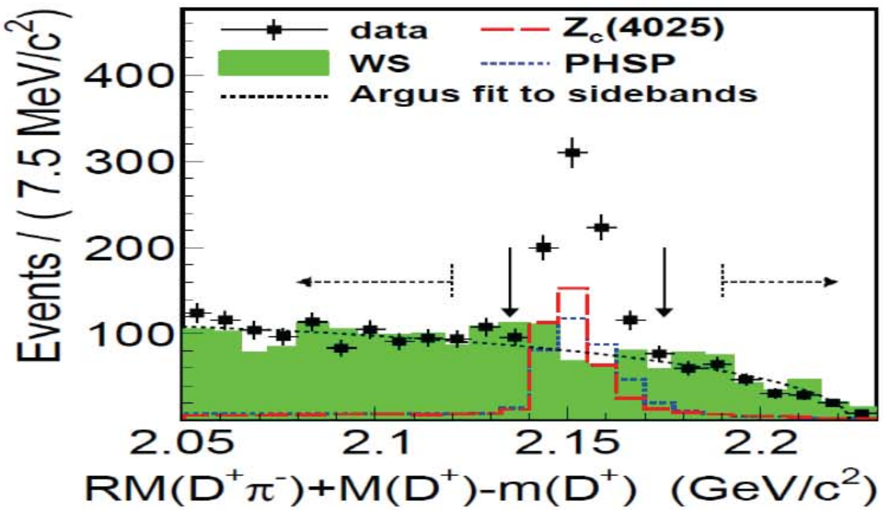
Strange behavior of Y(4260)–Zc(3900)! Large non-DD coupling!

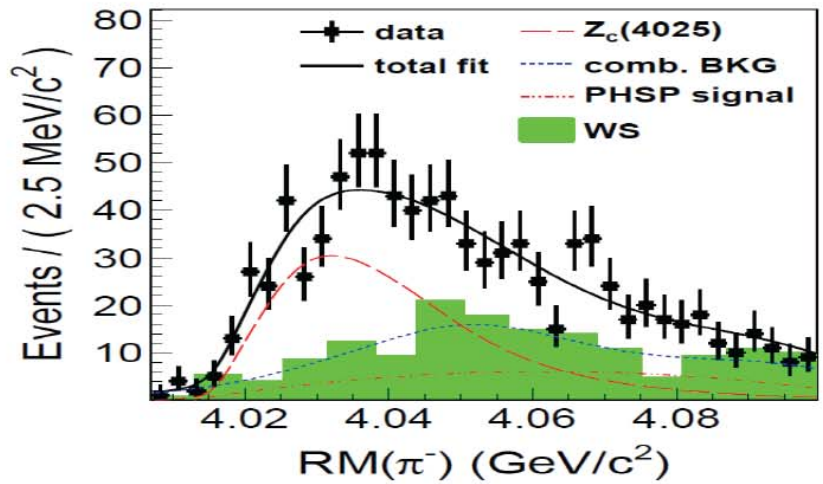
$e^+e^- \rightarrow \pi Z_c(4025) \rightarrow \pi^- (D^*\bar{D}^*)^+ + c.c.$

Strategy: reconstruct D^+ from D^{*+};
reconstruct "bachelor" π
at least on π^0 from D^* decays
looking at the recoil side of π

827 pb^{-1} data at 4.260 GeV

arXiv: 1308.2760
Submitted to PRL





Fit to $\pi^\pm$ recoil mass yields 401±47 $Z_c(4025)$ events
M= 4026.3±2.6±3.7 MeV ; Γ= 24.8±5.6±7.7 MeV

$$R = \frac{\sigma(e^+e^- \rightarrow Z_c^\pm(4025)\pi^\mp \rightarrow (D^*\bar{D}^*)^\pm \pi^\mp)}{\sigma(e^+e^- \rightarrow (D^*\bar{D}^*)^\pm \pi^\mp)} = (65 \pm 9 \pm 6)\%$$

Summary

- The charged charmoniumlike state $Z_c(3900)$ has been observed by BESIII + Belle + (CLEO's data?).
- Coupling to charmonium state and charged.
- Can not be an conventional Charmonium!
- Probably a four quark state (tetraquark or hadron molecule?).
- Further work is need experimentally to identify the nature.

Thanks !