Recent Results from BESIII

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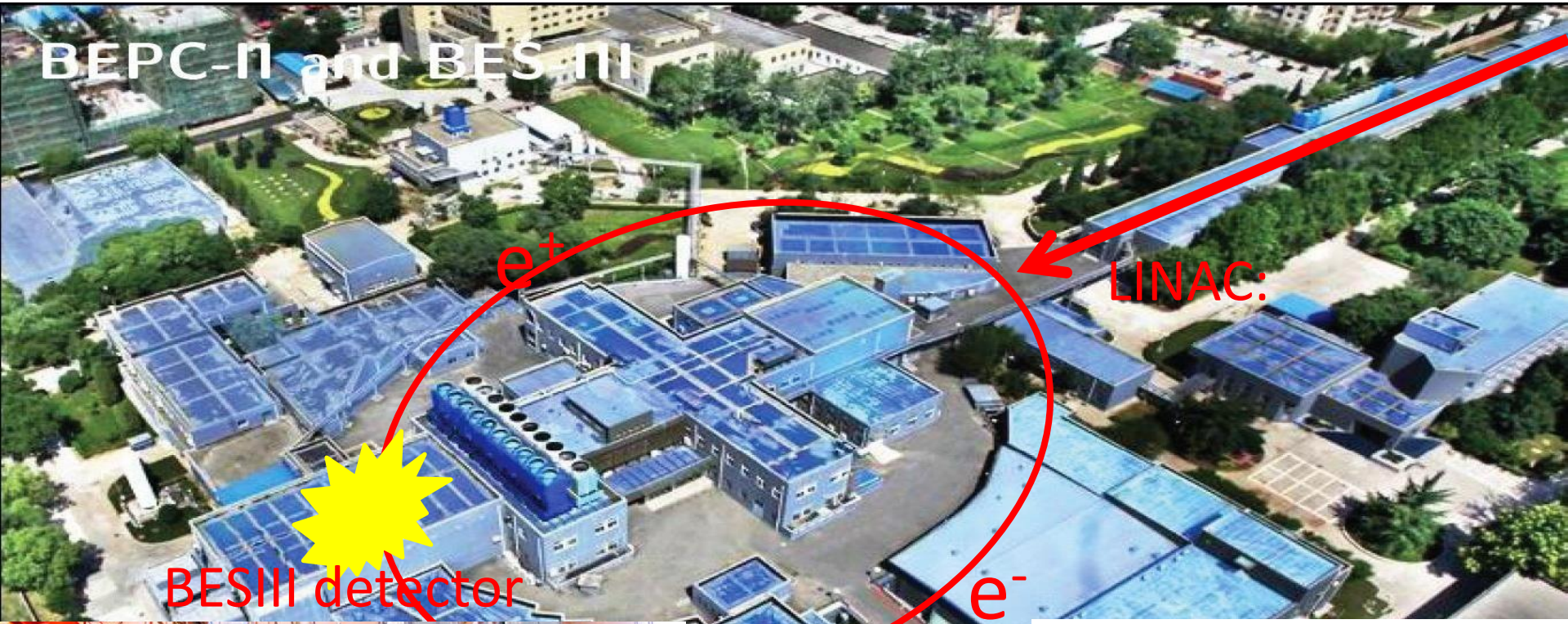
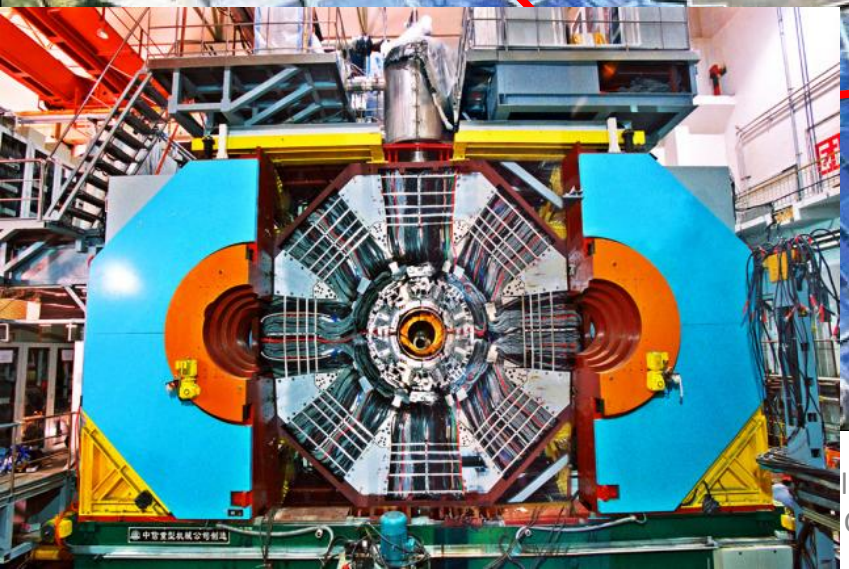
Outline

- Introduction to BEPCII&BESIII
- The recent results from BESIII
  - Charmonium & XYZ
  - Light hadron
  - Baryon
  - Charm
- Summary & outlook

Beijing Electron Positron Collider-II





2004: started BEPCII upgrade, BESIII construction

2008: test run

2009 - now: BESIII physics run

- 1989-2004 (BEPC): $L_{peak}=1.0\times10^{31}$ /cm^{2}s
- 2009-now (BEPCII): $L_{peak}=0.85\times10^{33}$/cm^{2}s

BESIII

RPC Muon Detector

8 layers (end caps), 9 layers (barrel)

$\delta R_\phi = 1.4 - 1.7\,\mathrm{mm}$

Superconducting Solenoid (1 T)

Electromagnetic CsI(Tl) Calorimeter

$\sigma_E/E < 2.5\%/\sqrt{E}$

$\sigma_{z,\phi} = 0.5 - 0.7\,\mathrm{cm}/\sqrt{\mathrm{E}}$

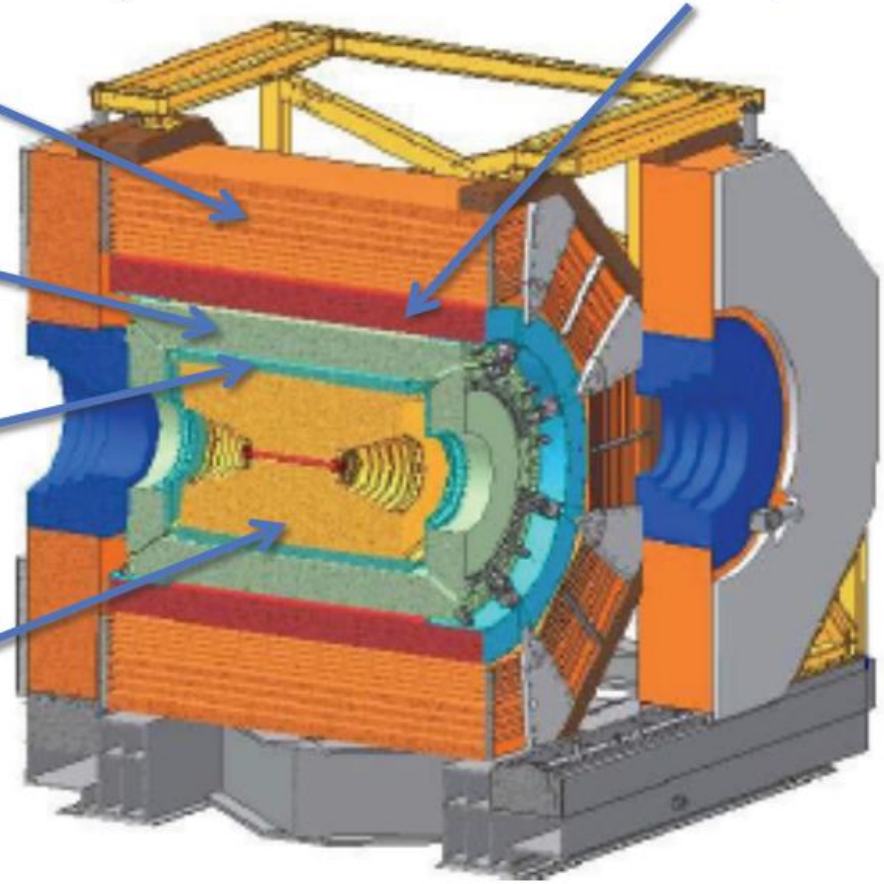
Time of Flight System

$\sigma_t = 80\,\mathrm{ps}$ (barrel)

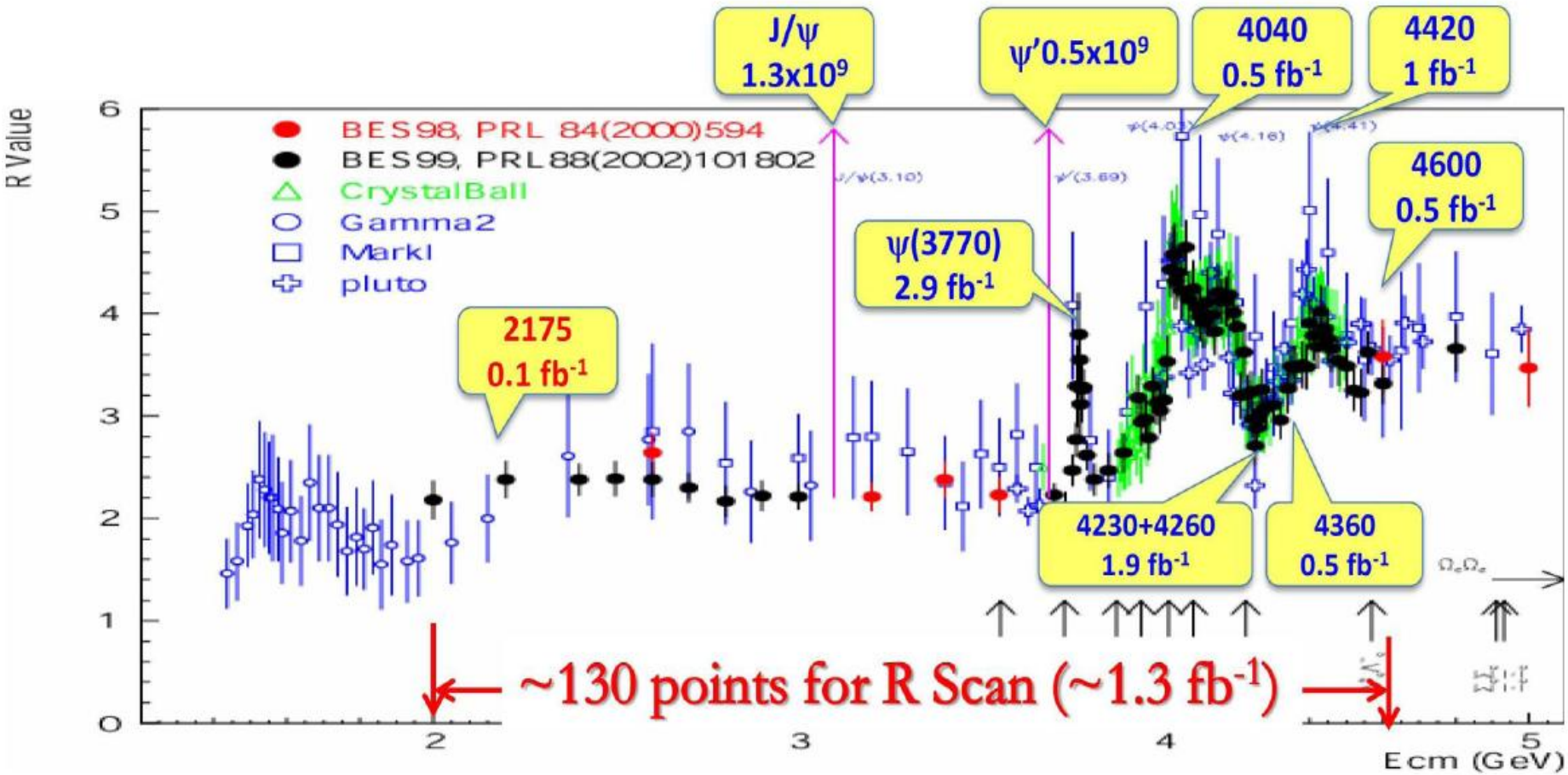
$\sigma_t = 110\,\mathrm{ps}$ (end caps)

Drift Chamber

$\sigma_{(dE/dx)} = 6\%$



BESIII Data Samples



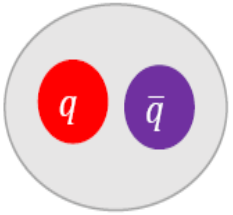
World largest data samples J/ψ, $\psi(2S)$, $\psi(3770)$, $Y(4260)$, etc., produced directly from e^+e^- collision.

Charmonium &XYZ

- Introduction to charmonium & XYZ
- Recent results of XYZ
  - X(3872), X(3823)
  - Y→ Hadron + lower charmonia
  - $Z_c(3900)/Z_c(3885)$
  - $Z_c(4020)/Z_c(4025)$
- Recent results of charmounium
  - $\psi(3770)\rightarrow\gamma\chi_{c2}$
  - isospin-violating transitions $\chi_{c0,2}\rightarrow\pi^0\eta_c$

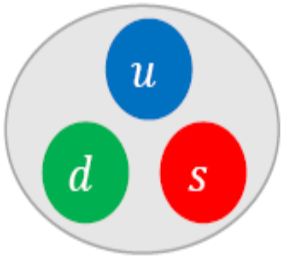
Hadrons: normal & exotic

- Quark Model:



Mesons

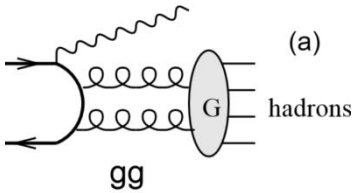
Color-anticolor pairs

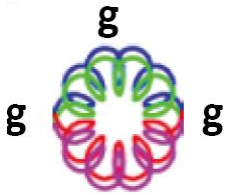


Baryons

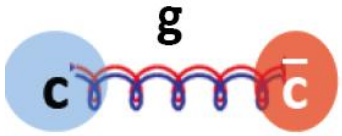
Red-blue-green triplets

- Exotic states are also predicted by QCD:
  - Glueball: (gg, ggg, …)

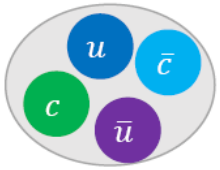




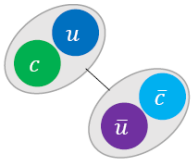
  - Hybrid: (qqg, …)



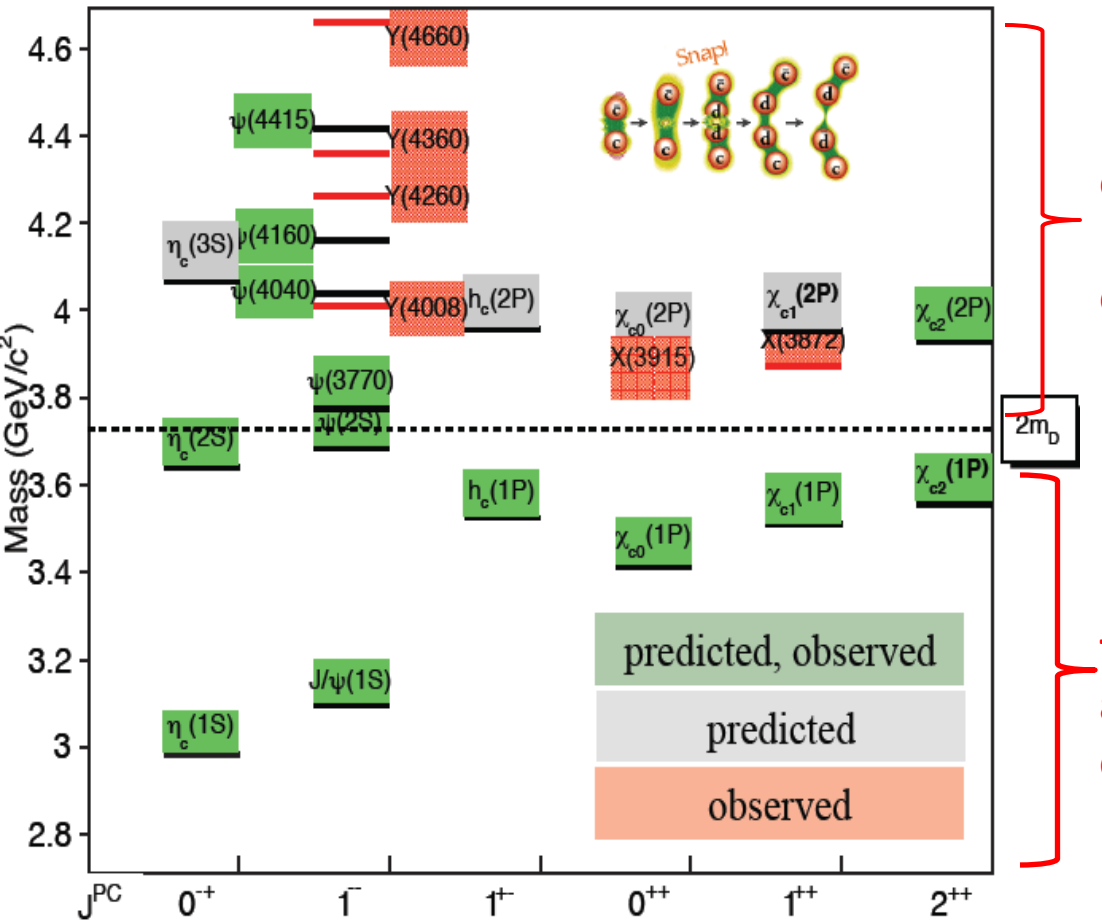
  - Multi-quark state: (qqqq, qqqqq, …)



  - Molecule: bound state of two hadrons



Charmonium spectroscopy

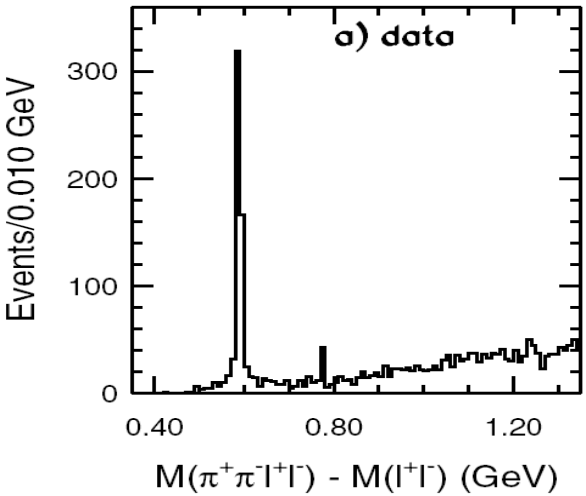


Many expected states are not observed;
Many unexpected states are observed: XY states.

Below the open charm threshold, good agreement between experiments and theory.

About X(3872)

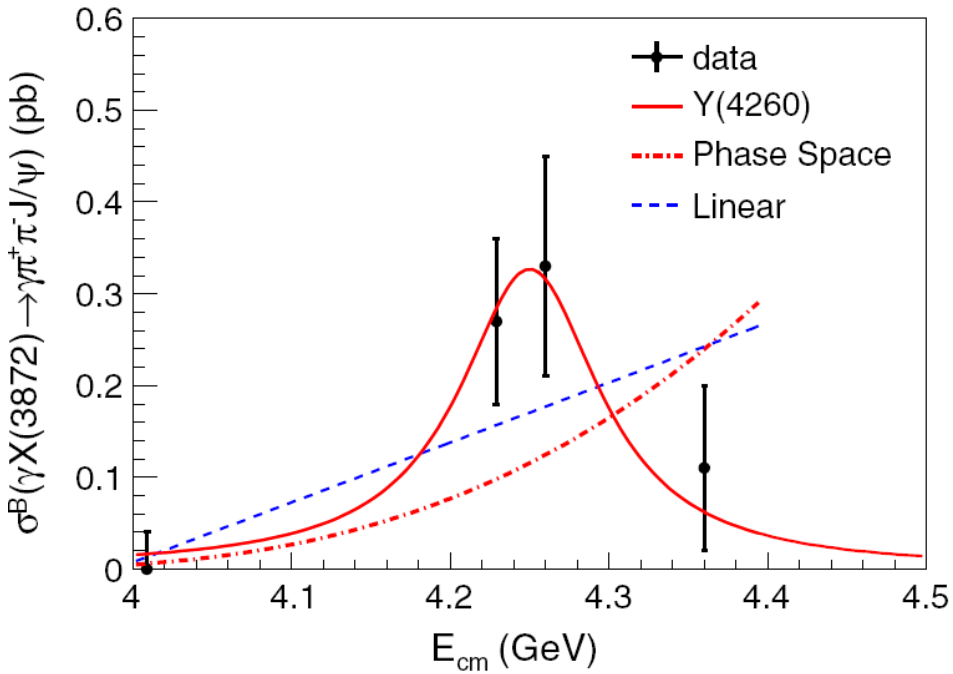
- Very close to $\bar{D}^0D^{*0}$ threshold, very narrow, < 1.2 MeV
- $J^{PC}=1^{++}$
- Production
  - in $p\bar{p}$/pp collison – rate similar to charmonia
  - In B decays – KX similar to cc, K*X smaller than $c\,\bar{c}$
  - Y(4260)→γX(3872)
- Decay BR:
  - open charm ~ 50%
  - charmonium~O(%)
- Nature (very likely exotic)
  - $\bar{D}^0D^{*0}$ bound state (like deuteron)?
  - Mixture of excited χ_{c1} and $\bar{D}^0D^{*0}$ bound state?
  - χ_{c1} (2P)? Hybrid? Tetraquark?

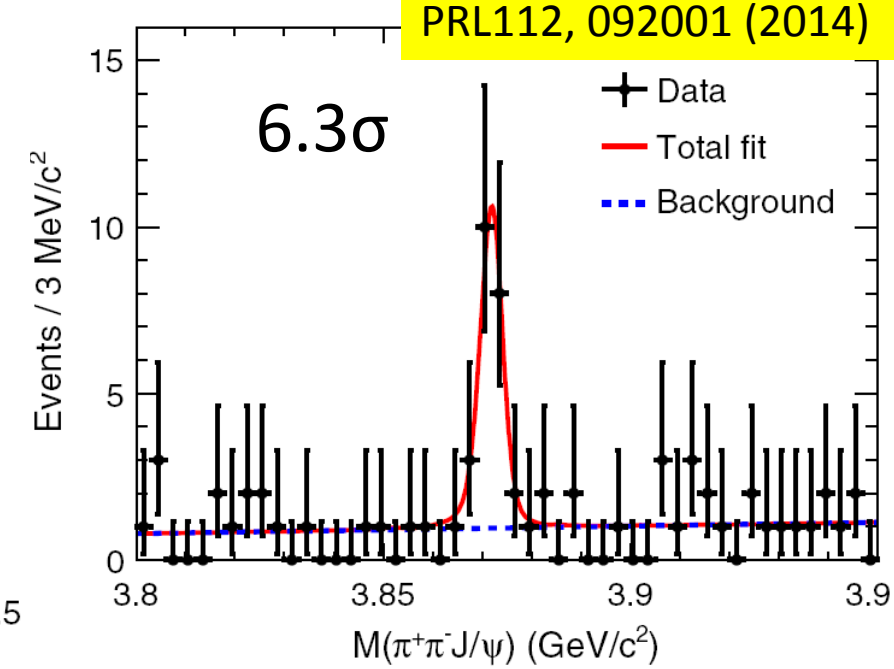


Firstly observed in Belle (2003): $B^{\pm} \rightarrow K^{\pm}\pi^+\pi^-J/\psi$. Also observed in Belle and tevatron.

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

PRL112, 092001 (2014)





- Via $X(3872) \rightarrow \pi^+\pi^- J/\psi$, $J/\psi \rightarrow l^+l^-$, $l=e,\mu$
- Observed $Y(4260) \rightarrow \gamma X(3872)$ for the first time;
- $M = 3871.9 \pm 0.7 \pm 0.2$ MeV/c^2 (PDG: 3871.68 ± 0.17 MeV/c^2)
- Taken $B(X(3872) \rightarrow \pi^+\pi^- J/\psi) \sim 5\%$,

$$\frac{\sigma(e^+e^- \rightarrow \gamma X(3872))}{\sigma(e^+e^- \rightarrow \pi^+\pi^- J/\psi)} \sim 10\%$$

About X(3823)

- QCD predicted $\psi_2(1D)$, 2^{--}
- Firstly observed @ Belle: $B \rightarrow \chi_{c1}\gamma K$;

$$M_{X(3823)} = M^{\text{meas}}_{X(3823)} - M^{\text{meas}}_{\psi'} + M^{\text{PDG}}_{\psi'}$$
$$= 3823.1 \pm 1.8 \pm 0.7 \text{ MeV}.$$

- The measured mass and width are consistent with the missing $\psi_2(1D)$ state.

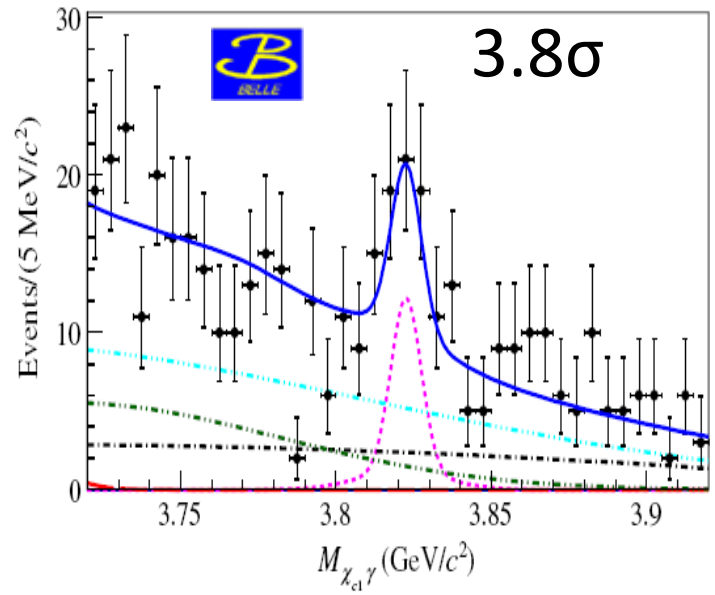
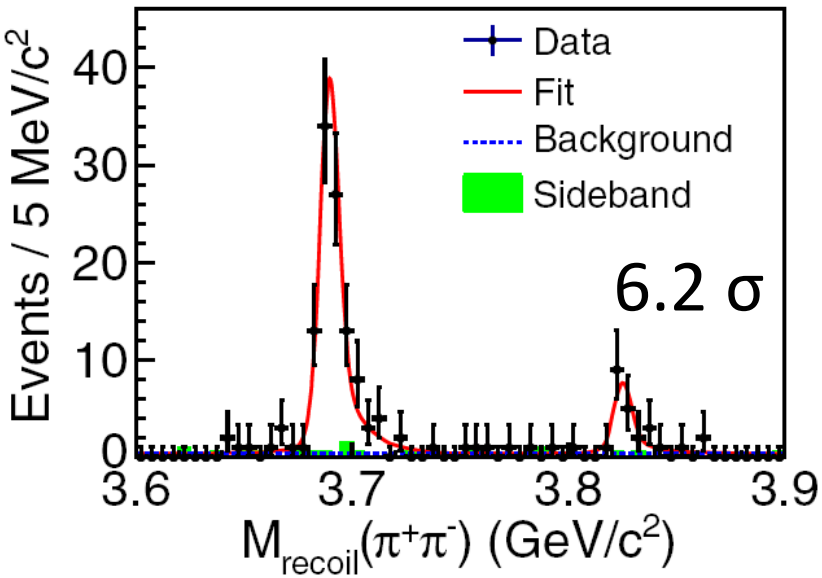


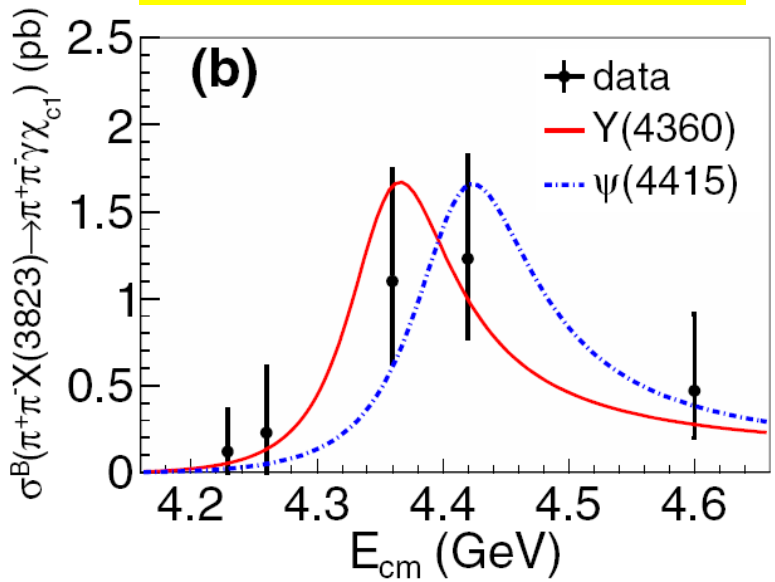
FIG. 4 (color online). 2D UML fit projection of the $M_{\chi_{c1}\gamma}$ distribution for the simultaneous fit of $B^{\pm} \rightarrow (\chi_{c1}\gamma)K^{\pm}$ and $B^0 \rightarrow (\chi_{c1}\gamma)K^0_S$ decays for $M_{bc} > 5.27$ GeV/c^2. The curves

PRL111, 032001 (2013) , Belle

$e^+e^- \to \pi^+\pi^- X(3823) \to \pi^+\pi^- \gamma\chi_{c1}$

Phys. Rev. Lett. 115, 011803



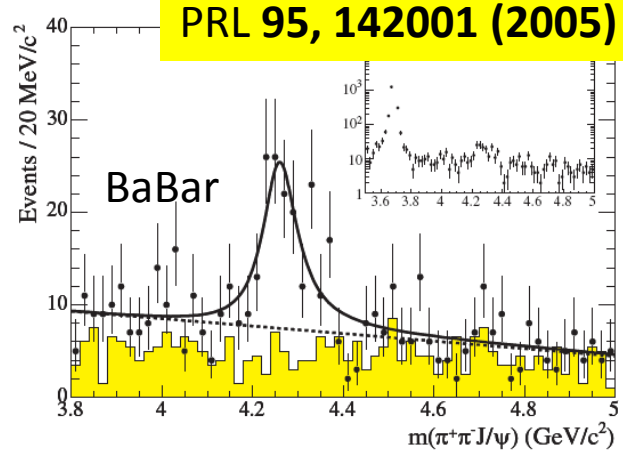


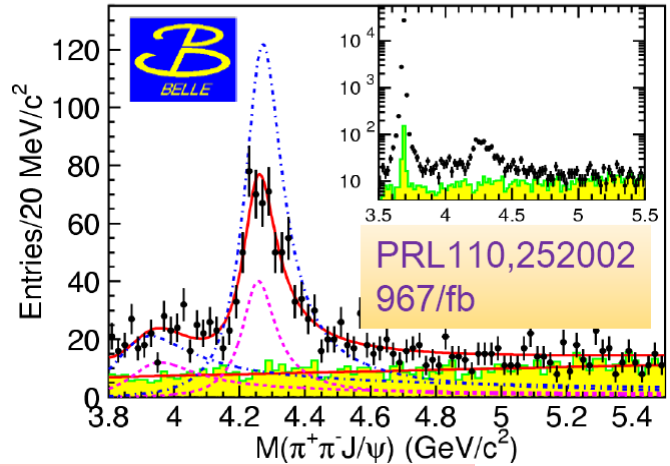
- M = 3821 ± 1.3 ± 0.7 MeV, Γ < 16 MeV, Significance: 6.2σ
- R = $B[X(3823) \to \gamma\chi_{c2}]/B[X(3823) \to \gamma\chi_{c1}] < 0.43$ @ 90% C.L.
- Both Y(4360) and ψ(4415) line shape give reasonable description
- Agree with BELLE's measurement
- Agree with $\psi(1^3D_2)$ candidate

About Y(4260)

- Charmonium-like, first observed in its decay to $\pi^+\pi^-J/\psi$ @BaBar via e^+e^- ISR process;
- Small coupling to open charm decay modes;
- Y(4260) decays to charged charmonium-like states:
  - $\pi Z_c(3900)$ ($\rightarrow \pi J/\psi$)
  - $\pi Z_c(3885)$ ($\rightarrow D\bar{D}^*$)
  - $\pi Z_c(4020)$ ($\rightarrow \pi h_c$)
  - $\pi Z_c(4025)$ ($\rightarrow D^*\bar{D}^*$)
- Nature: a quark-gluon charmonium hybrid, a tetraquark state, a hadrocharmonium, or a hadronic molecule?

PRL **95, 142001 (2005)**



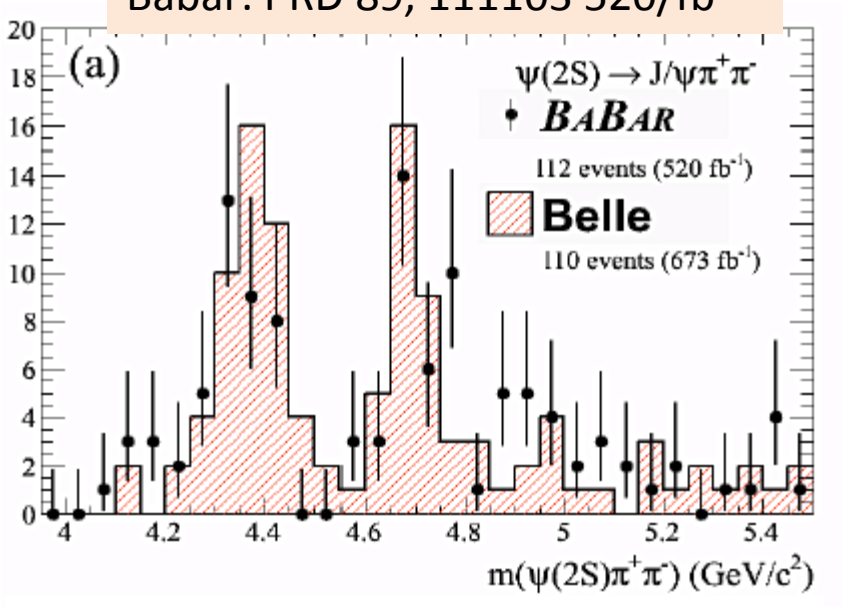


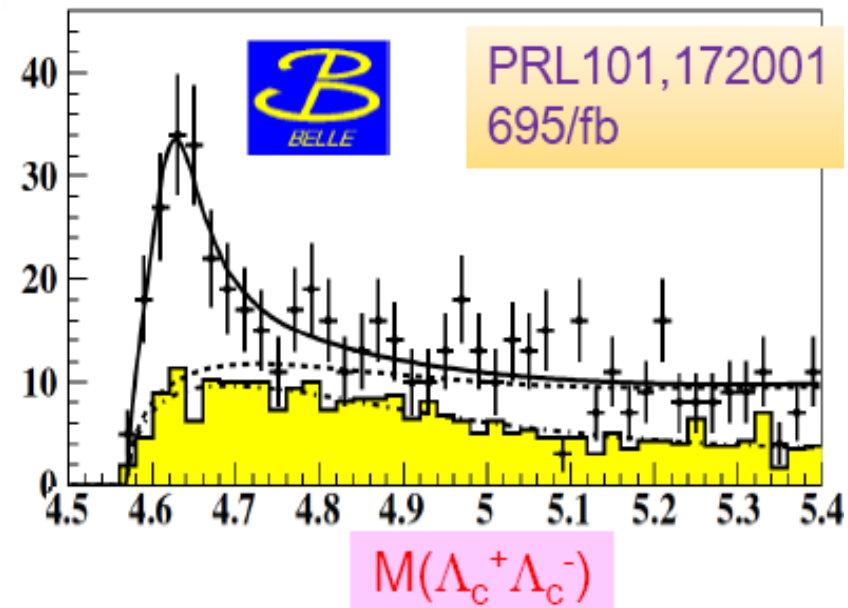
BESIII: $\sigma(e^+e^- \rightarrow \pi^+\pi^-J/\psi)$
$= (62.9 \pm 1.9 \pm 3.7)$ pb
Agree with BaBar & Belle!

BESIII is measuring cross sections at more energy points, and more data being taken!

Other Y states

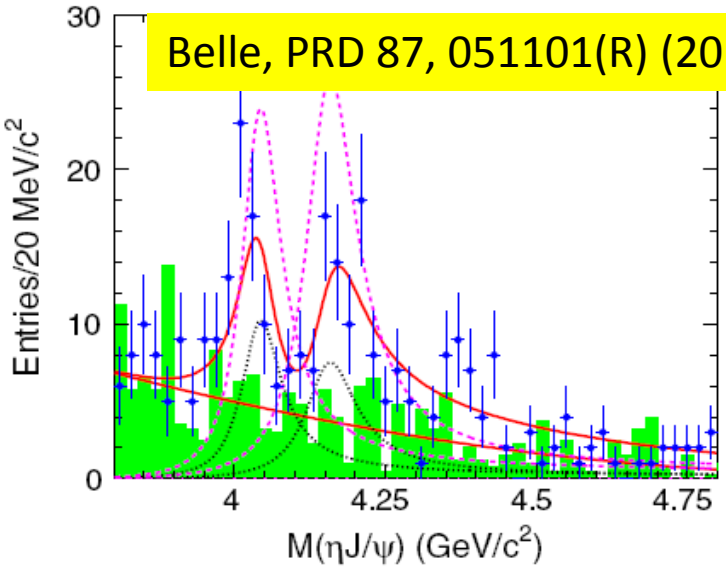
Belle: PRL99,142002, 670/fb
Babar: PRD 89, 111103 520/fb





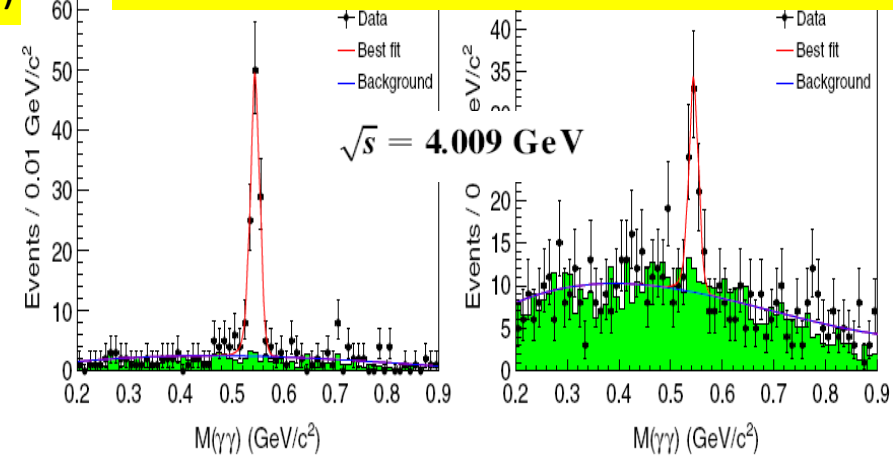
Y→ Hadron + lower charmonia

Belle, PRD 87, 051101(R) (2013)

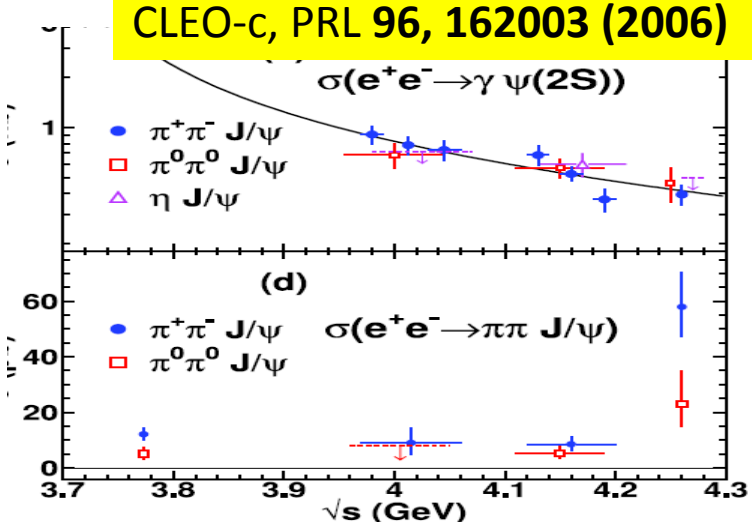


BESIII, PRD 86, 071101(R)

Searching for ηJ/ψ, J/ψ, J/ψ→ l^+l^-,l=e,μ



CLEO-c, PRL **96, 162003 (2006)**

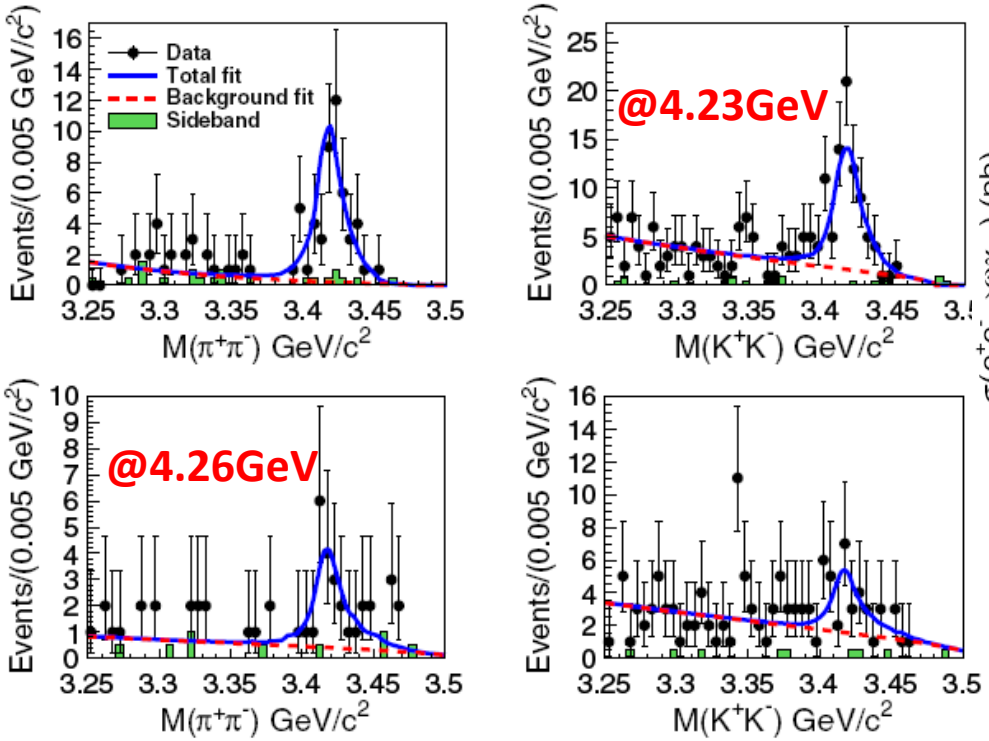


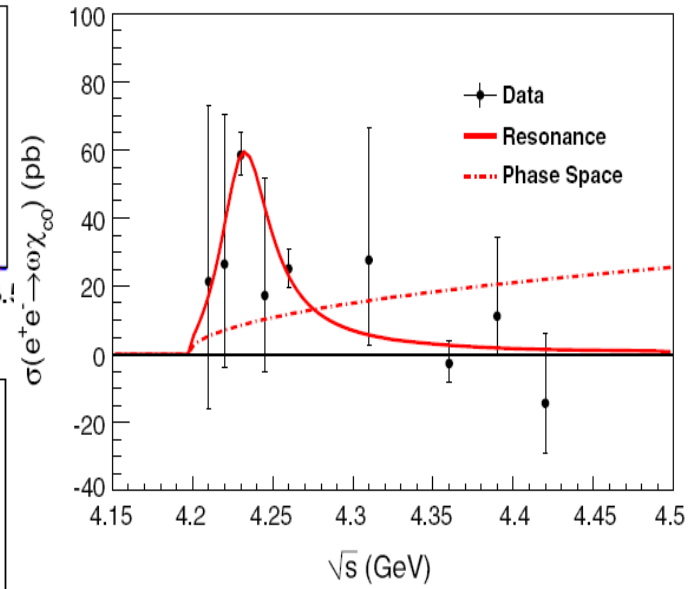
Hadronic transitions (by η, π^0 or a pion pair) to lower charmonia (J/ψ…): sensitive probes to study the properties of these Y states.

no evidence for the Y(4260), Y(4360), Y(4415), or Y(4660) in the ηJ/ψ final state.

Open-charm effects: PRD 84 014007

Observation of $e^+e^- \rightarrow \omega\chi_{c0}$ ($\chi_{c0} \rightarrow \pi^+\pi^-/K^+K^-$)



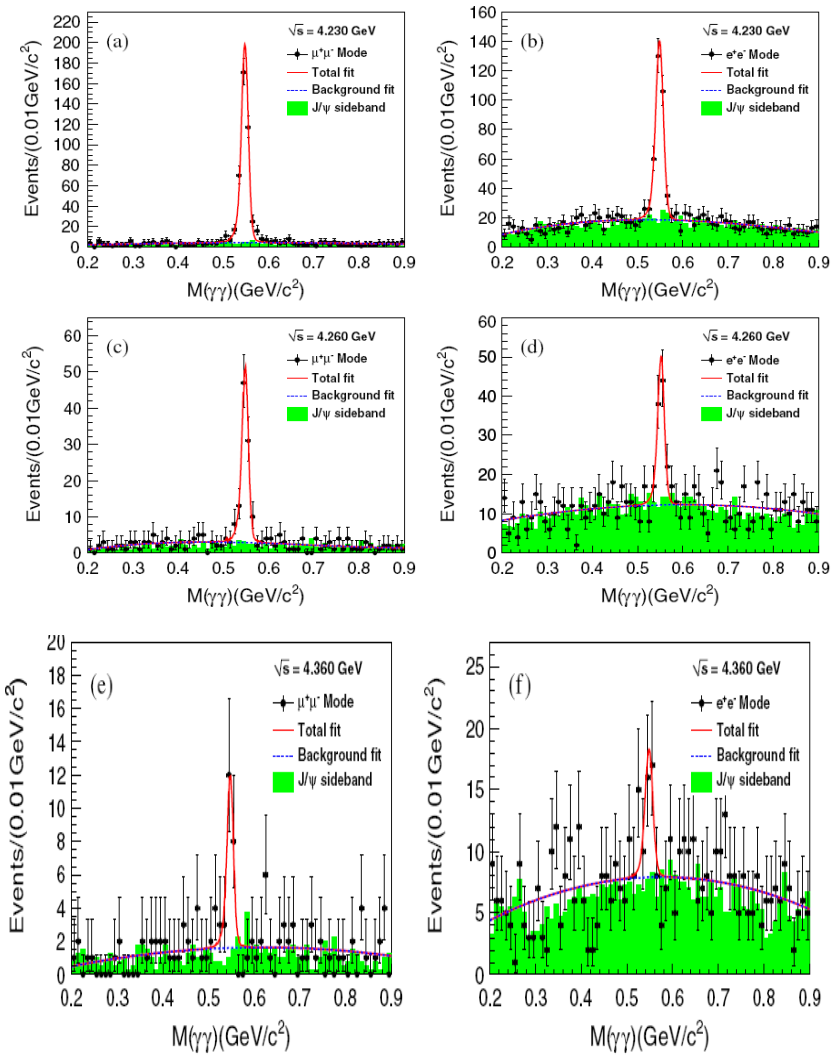


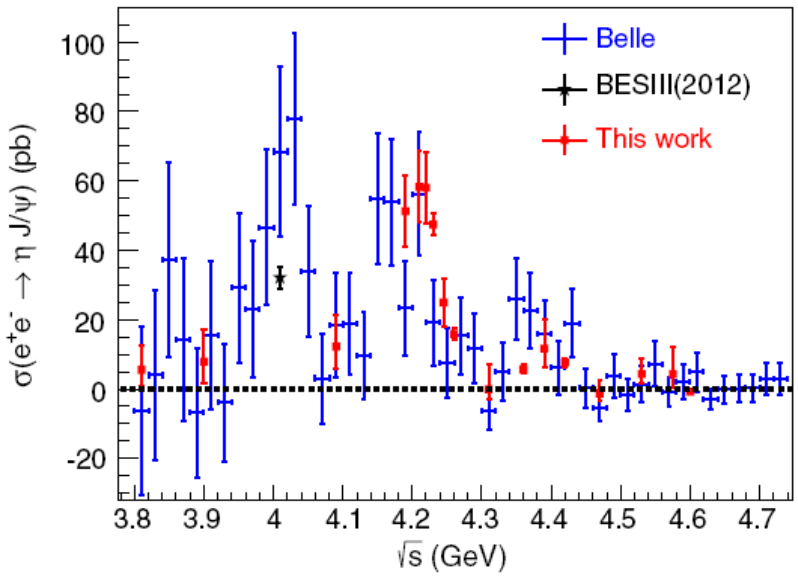
PRL 114, 092003 (2015)

By assuming the $\omega\chi_{c0}$ come from a single resonance, and Fit with a single BW :
Mass = 4230±8±6 MeV
Width = 38±12±2 MeV
Significance > 9σ

Nature is not clear to us:
A tetraquark? (PRD 91,117501 (2015)**)**
ψ(4S)? (EPJC 74:3208 (2014)**)**
Or Threshold effect?

Observation of $e^+e^- \to \eta\, J/\psi(\to l^+l^-, l=e,\mu)$





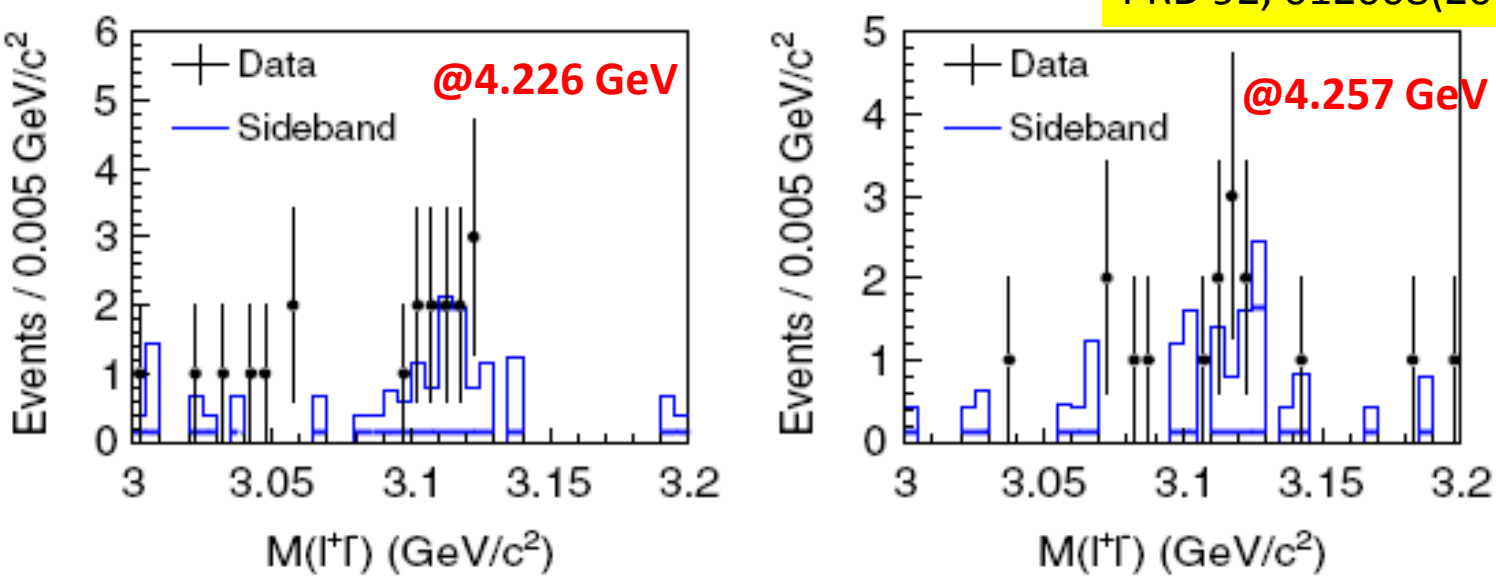
PRD 91, 112005 (2015)

- **Structure near 4.23 GeV is observed**
- **No π^0 J/ψ evidence**
- **Agree with previous results, more precision**
- **More data @4.10~4.20 GeV is needed!**

Searching for iso-spin violating decays in $\Upsilon(4260) \rightarrow \eta\pi^0 J/\psi(\rightarrow l^+l^-, l=e,\mu)$

- Theory prediction:
  - Hadron-quarkonium/tetraquark of Z_b and Z_c in $\Upsilon(5s) \rightarrow \eta\pi^0$ + bottomonium
    - M.Voloshin, PRD 86 034013
    - A. Ali et al., PRL 104 162001, PRL 106 092002
  - Tetraquark model: $Z_c \rightarrow \eta\, J/\psi$ or $\pi^0\, J/\psi$
    - L. Maiani et al., PRD 87 111102
  - $\Upsilon(4260)$ as a $D_1\bar{D}$ molecule:
    - X. Wu et al., PRD 89 054038
- No statistically significant signal is observed.

PRD 92, 012008(2015)



Charged charmonium-like states, Z_c

- Decay into a charmonium, thus contains $c\bar{c}$
- Have electric charge, thus has two light quarks→≥4 quarks
- Could exist in $\pi^{\pm}J/\psi$, $\pi^{\pm}\psi(2S)$, $\pi^{\pm}h_c$, $\pi^{\pm}\chi_{cJ}$,…
- Experimental search:
  - BESIII/CLEO-c: $e^+e^- \rightarrow \pi^{\pm}$ exotics,…
  - Belle/BaBar: $e^+e^- \rightarrow (\gamma_{ISR})\pi^{\pm}$ exotics,…
  - Belle/BaBar/LHCb: B→K exotics,…

About $Z_c(3900)^{\pm}$

$Z_c(3900)^+$:

$m = (3899.0 \pm 3.6 \pm 4.9)\ \mathrm{MeV}/c^2$

$\Gamma = (46 \pm 10 \pm 20)\ \mathrm{MeV}$

Mass close to $D\bar{D}^*$ threshold

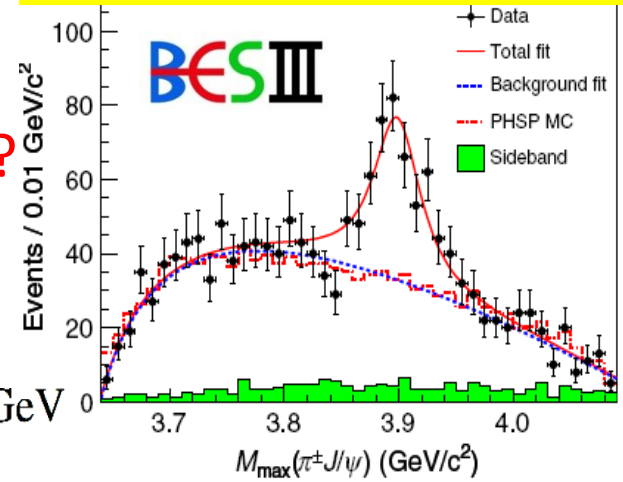
Decays to J/ψ → contains $c\bar{c}$
Electric charge → contains $u\bar{d}$

Tetraquark?
Molecule?

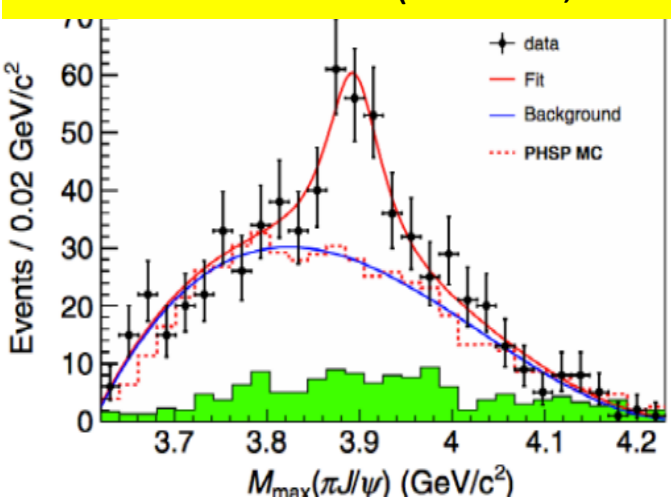
$\sigma[e^+e^- \to \pi^+\pi^- J/\psi] = 62.9 \pm 1.9 \pm 3.7$ pb at 4.26 GeV

$\frac{\sigma[e^+e^- \to \pi^\pm Z_c(3900)^\mp \to \pi^+\pi^- J/\psi]}{\sigma[e^+e^- \to \pi^+\pi^- J/\psi]} = (21.5 \pm 3.3 \pm 7.5)\%$ at 4.26 GeV

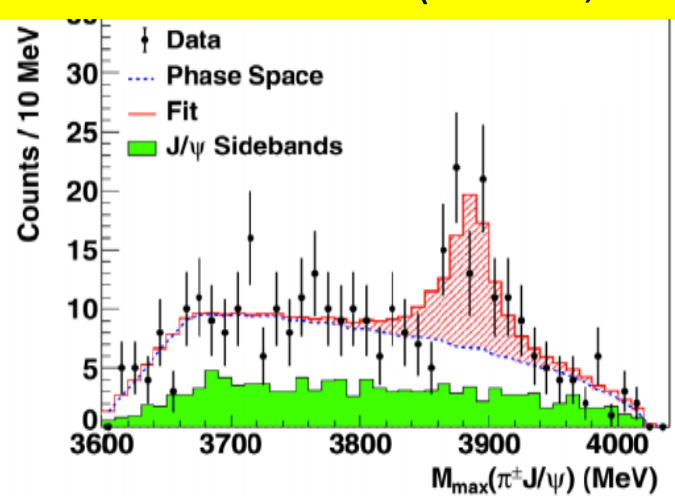
BESIII: PRL 110, 252001 (2013)



Belle with ISR data (PRL 110, 252002)



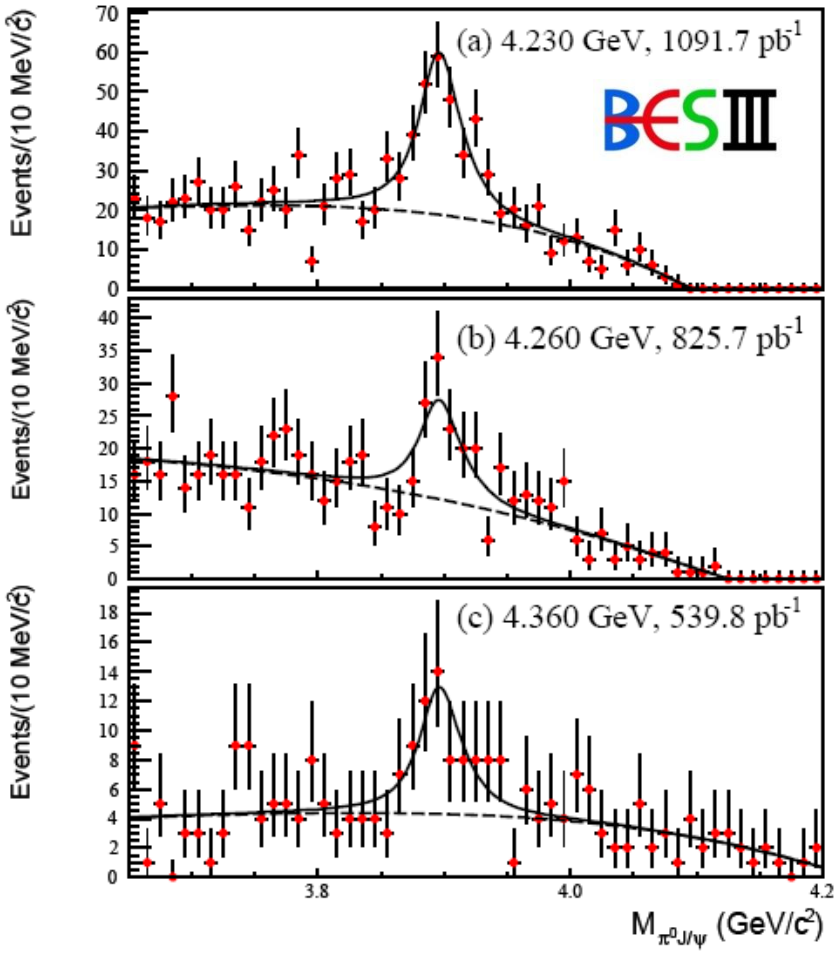
CLE0c data at 4.17 GeV (PLB 727, 366)



About $Z_c(3900)^0$

arXiv:1506.06018, Submitted to PRL

- Observation of $Z_c(3900)^0$ in e^+e^- to $\pi^0\pi^0 J/\psi$

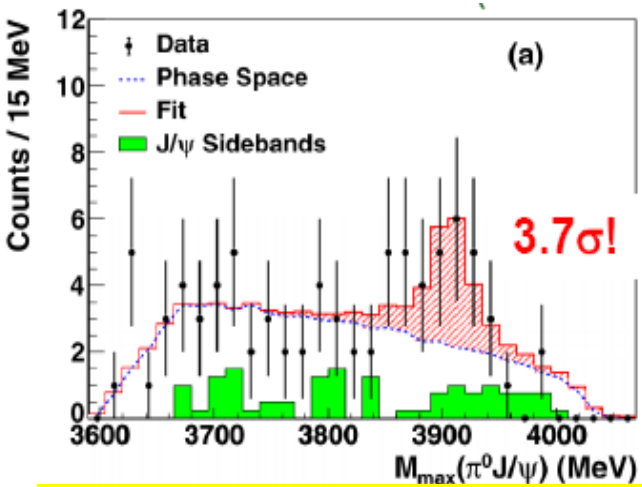


A structure on $\pi^0 J/\psi$ invariant mass spectrum can be observed:

Mass = 3894.8±2.3±2.7 MeV

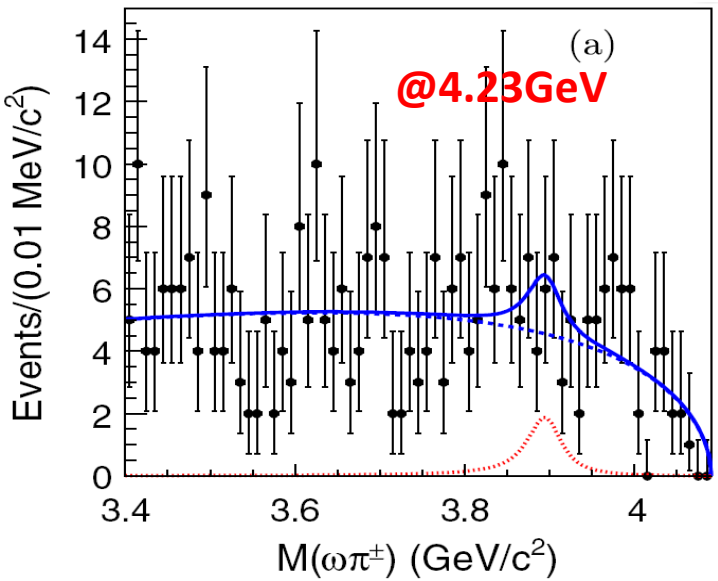
Width = 29.6±8.2±8.2 MeV

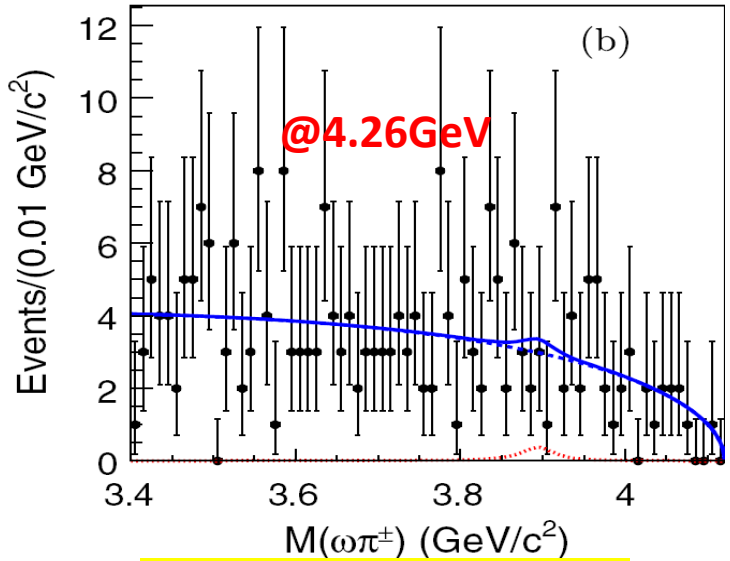
Significance = 10.4σ



CLE0c data at 4.17 GeV (PLB 727, 366)

Search for $Z_c(3900)^{\pm} \rightarrow \omega\pi^{\pm}$





PRD 92, 032009 (2015)

- No significant $Z_c(3900)^{\pm}$:

$\sigma(e^+e^- \rightarrow Z_c\pi^- + c.c., Z_c \rightarrow \omega\pi) < 0.27$ pb @ 4.23 GeV

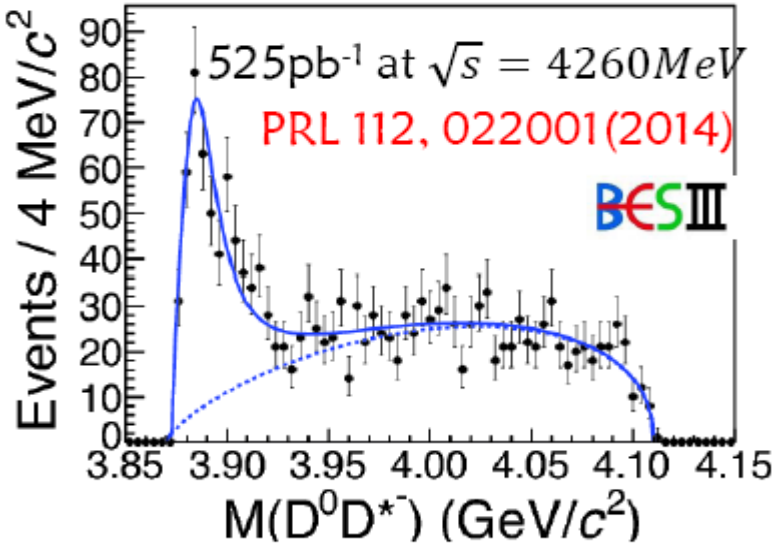
$\sigma(e^+e^- \rightarrow Z_c\pi^- + c.c., Z_c \rightarrow \omega\pi) < 0.18$ pb @ 4.26 GeV

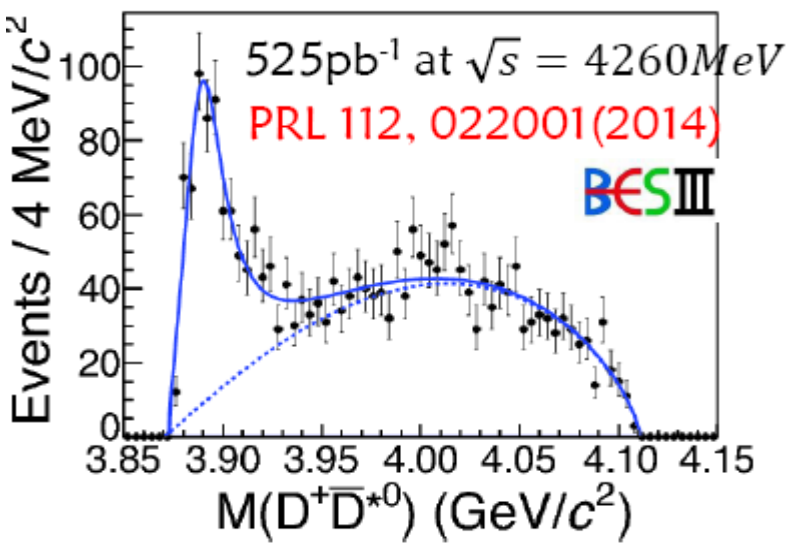
$B(Z_c \rightarrow \omega\pi) < 0.2\%$ [or $\Gamma_{\omega\pi} < 70$ keV] @ 90% C.L.

- since $\omega\pi$ is a typical light hadron decay mode for $I^G(J^P) = 1^+(1^+)$

$\rightarrow$ imply the annihilation of $c\bar{c}$ is suppressed.

Observation of $Z_c(3885)^{\pm}$ in $e^+e^- \to \pi^{\pm}(D\bar{D}^*)^{\mp}$ @4.26GeV using single D tag method



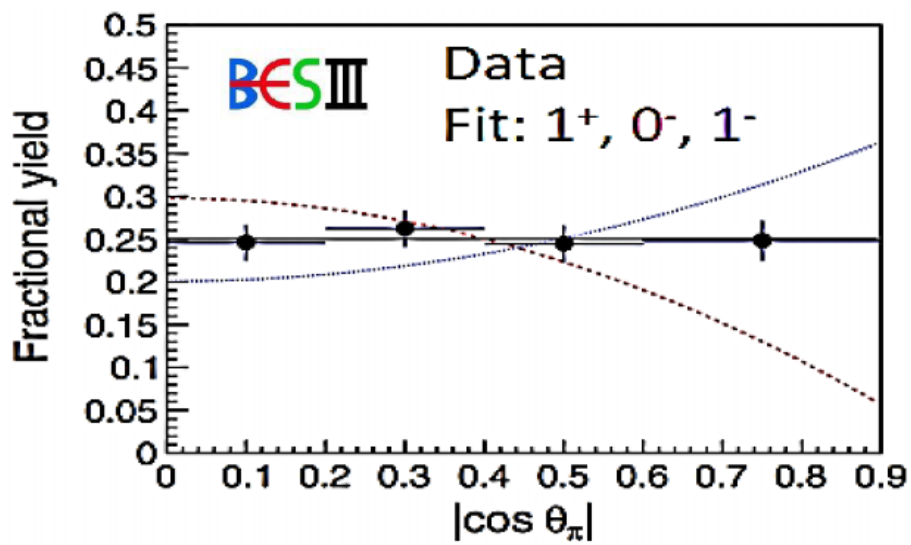


An enhancement near the $D\bar{D}^*$,

Mass = 3883.9±1.5±4.2 MeV, (fit with BW function)

Width = 24.8±3.3 ±11.0 MeV

Reconstruct the π^+ and $D^0 \to K^-\pi^+$ and infer the D^{*-}.
(Also analyze $\pi^+D^-D^{*0}$ with the same method.)



Fit to angular distribution favors $J^P = 1^+$ over 0^- and 1^-

Is $Z_c(3885)^{\pm}$ is $Z_c(3900)^{\pm}$?

- Their mass and width are consistent within 2 σ

	$Z_c(3885) \to D\bar{D}^*$	$Z_c(3900) \to \pi J/\psi$
Mass (MeV/c^2)	$3883.9 \pm 1.5 \pm 4.2$	$3899.0 \pm 3.6 \pm 4.9$
Γ (MeV)	$24.8 \pm 3.3 \pm 11.0$	$46 \pm 10 \pm 20$
$\sigma \times \mathcal{B}$ (pb)	$83.5 \pm 6.6 \pm 22.0$	$13.5 \pm 2.1 \pm 4.8$

- If so, open charm decays are suppressed, since

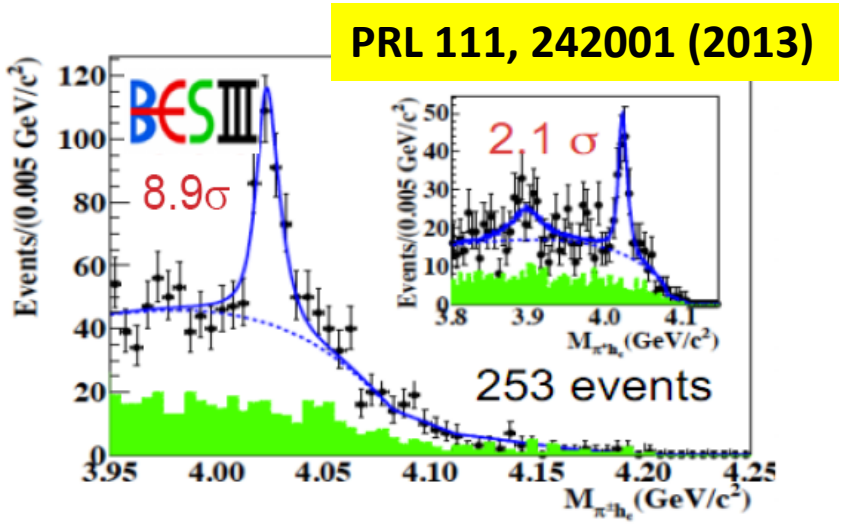
$$\frac{\Gamma(Z_c(3885) \to D\bar{D}^*)}{\Gamma(Z_c(3900) \to \pi J/\psi)} = 6.2 \pm 1.1 \pm 2.7$$

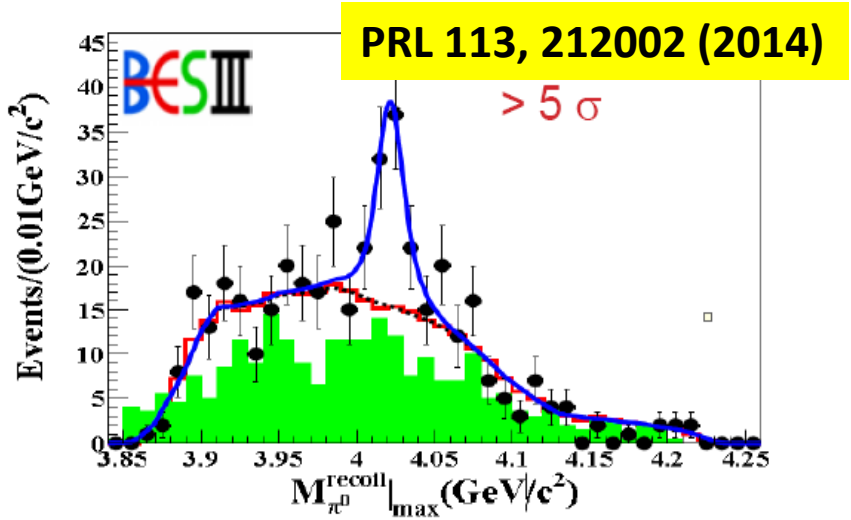
Compared with ,e.g.

$$\frac{\mathcal{B}(\psi(4040) \to D^{(*)}\bar{D}^{(*)})}{\mathcal{B}(\psi(4040) \to J/\psi\eta)} = 192 \pm 27$$

Different dynamics in Y(4260)-Z_c(3900) system!

$Z_c(4020)^{\pm/0}$ via $\pi^{\pm/0}$ h_c





- $h_c \rightarrow \gamma\eta_c$, $\eta_c \rightarrow$ 16 hadron decay modes;

- $Z_c(4020)^{\pm/0}$ is observed; another isospin triplet $Z_c(4020)^0$ is established.

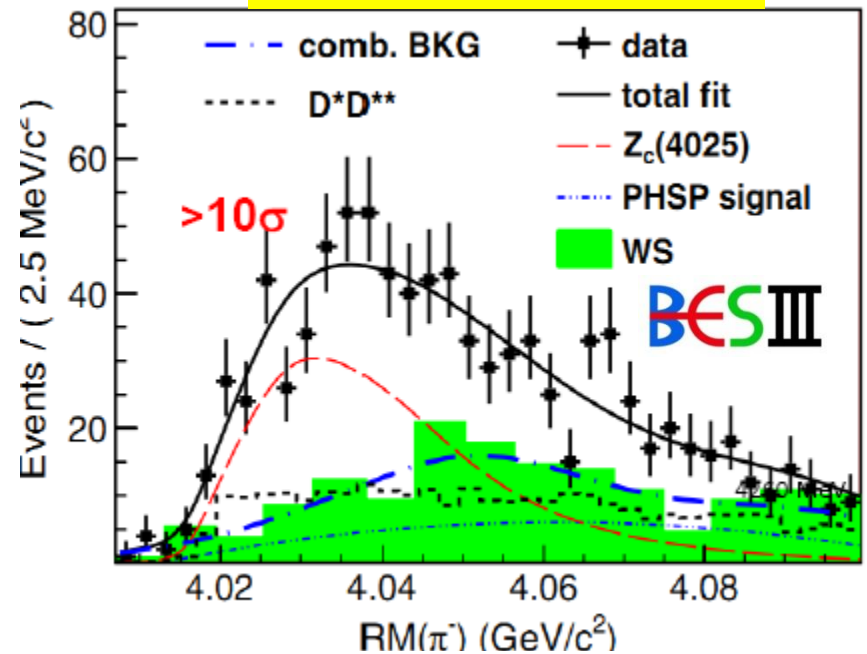
- A weak evidence for $Z_c(3900)^{\pm} \rightarrow \pi^{\pm} h_c$;

$Z_c(4020)$	Mass / MeV/c²	Width / MeV
$Z_c(4020)^{\pm}$	4022.9±0.8±2.7	7.9±2.7±2.6
$Z_c(4020)^0$	4023.8±2.2±3.8	Fixed(=7.9)

Observation of $Z_c(4025)^{\pm}$ in $e^+e^- \to \pi^{\pm}(D^*\bar{D}^*)^{\mp}$ @4.26GeV

PRL 112, 132001 (2014)

Tag a D^+ and a bachelor π^-, reconstruct one π^0 to suppress the background. A structure, named as Z_c (4025), can be observed in the recoil mass of the bachelor π^-.



$M(Z_c(4025)) = 4026.3 \pm 2.6 \pm 3.7$ MeV;
$\Gamma(Z_c(4025)) = 24.8 \pm 5.6 \pm 7.7$ MeV

$$\frac{\sigma[e^+e^- \to \pi^{\pm} Z_c(4025)^{\mp} \to (D^*\bar{D}^*)^{\pm}\pi^{\mp}]}{\sigma[e^+e^- \to (D^*\bar{D}^*)^{\pm}\pi^{\mp}]} = 0.65 \pm 0.09 \pm 0.06 \text{ at } 4.26 \text{ GeV}$$

Coupling to $\bar{D}^*D^*$ is much larger than to πh_c if $Z_c(4025)$ and $Z_c(4020)$ are the same state.

Summary on Z_c states

The BESIII experiment discovered several Z_c states.

State	Mass(MeV)	Width(MeV)	Decay mode	Process
$Z_c(3900)^{\pm}$	$3899.0 \pm 3.6 \pm 4.9$	$46 \pm 10 \pm 20$	$\pi^{\pm} J/\psi$	$e^+e^- \to \pi^+\pi^- J/\psi$
$Z_c(3900)^0$	$3894.8 \pm 2.3 \pm 2.7$	$29.6 \pm 8.2 \pm 8.2$	$\pi^0 J/\psi$	$e^+e^- \to \pi^0\pi^0 J/\psi$
$Z_c(3885)^{\pm}$	$3883.9 \pm 1.5 \pm 4.2$ [single D tag] $3884.3 \pm 1.2 \pm 1.5$ [double D tag]	$24.8 \pm 3.3 \pm 11.0$ [single D tag] $23.8 \pm 2.1 \pm 2.6$ [double D tag]	$D^0 D^{*-}$ $D^- D^{*0}$	$e^+e^- \to \pi^+ D^0 D^{*-}$ $e^+e^- \to \pi^+ D^- D^{*0}$
$Z_c(4020)^{\pm}$	$4022.9 \pm 0.8 \pm 2.7$	$7.9 \pm 2.7 \pm 2.6$	$\pi^{\pm} h_c$	$e^+e^- \to \pi^+\pi^- h_c$
$Z_c(4020)^0$	$4023.9 \pm 2.2 \pm 3.8$	fixed	$\pi^0 h_c$	$e^+e^- \to \pi^0\pi^0 h_c$
$Z_c(4025)^{\pm}$	$4026.3 \pm 2.6 \pm 3.7$	$24.8 \pm 5.6 \pm 7.7$	$D^{*0} D^{*-}$	$e^+e^- \to \pi^+ (D^* \bar{D}^*)^-$

charmonium

- Measurement of B($\psi(3770)\rightarrow\gamma\chi_{c1}$) and search for $\psi(3770)\rightarrow\gamma\chi_{c2}$
- Searches for isospin-violating transitions $\chi_{c0,2}\rightarrow\pi^0\eta_c$

Measurement of B(ψ(3770)→$\gamma\chi_{c1}$) and search for ψ(3770)→$\gamma\chi_{c2}$ (via $\chi_{c1,2}\to\gamma J/\psi, J/\psi\to l^+l^-$)

Ψ(3770)→non-D$\bar{D}$ decays is used to test and probe:
its constituent , S-D mixing model, decay mechanics…

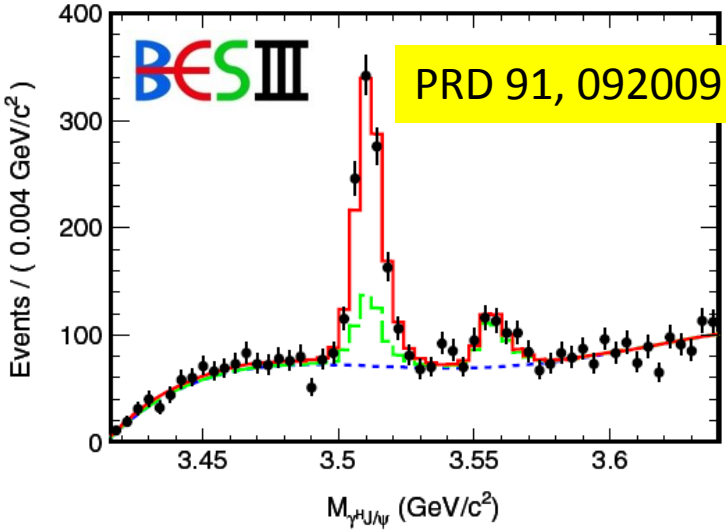


FIG. 2 (color online). Invariant mass spectrum of the $\gamma^{\rm H}J/\psi$ combinations selected from data. The dots with error bars represent the data. The solid (red) line shows the fit. The dashed (blue) line shows the smooth background. The long-dashed (green) line is the sum of the smooth background and the contribution from $e^+e^-\to(\gamma_{\rm ISR})\psi(3686)$ production.

Experiment/theory	$\Gamma(\psi(3770)\to\gamma\chi_{cJ})$ (keV)	
	$J=1$	$J=2$
This work	$67.5\pm4.1\pm6.7$	<17.4
Ding-Qin-Chao [12]		
Nonrelativistic	95	3.6
Relativistic	72	3.0
Rosner S-D mixing [13]		
$\phi=12^\circ$ [13]	73 ± 9	24 ± 4
$\phi=(10.6\pm1.3)^\circ$ [32]	79 ± 6	21 ± 3
$\phi=0^\circ$ (pure 1^3D_1 state) [32]	133	4.8
Eichten-Lane-Quigg [14]		
Nonrelativistic	183	3.2
With coupled-channel corr.	59	3.9
Barnes-Godfrey-Swanson [15]		
Nonrelativistic	125	4.9
Relativistic	77	3.3

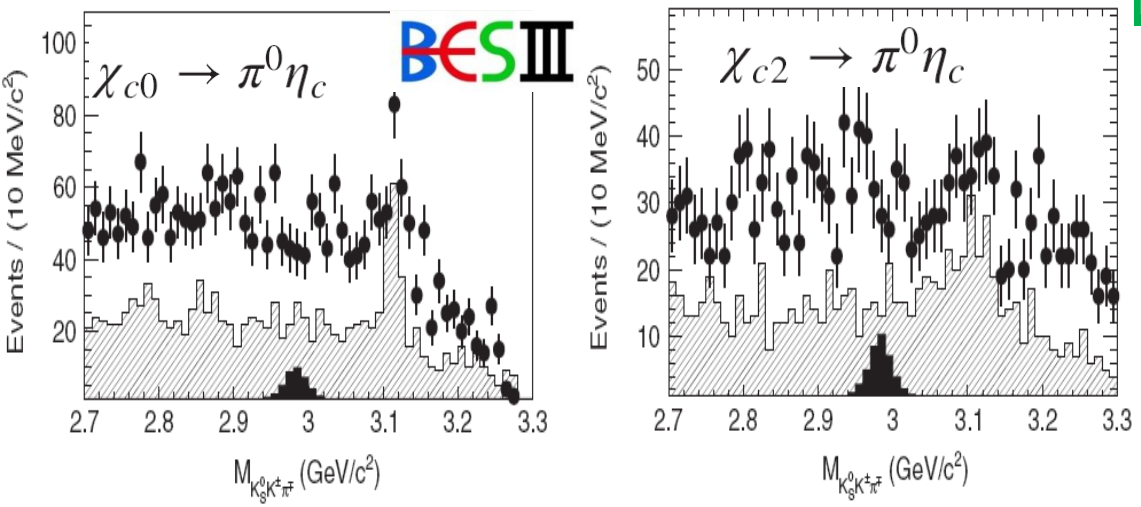
$$\mathcal{B}(\psi(3770)\to\gamma\chi_{c1})=(2.48\pm0.15\pm0.23)\times10^{-3},$$

$$\mathcal{B}(\psi(3770)\to\gamma\chi_{c2})<0.64\times10^{-3}$$

Searches for isospin-violating transitions $\chi_{c0,2} \to \pi^0 \eta_c$ (via $\eta_c \to K^0_S K^\pm \pi^\mp$)

PRD 91, 112018 (2015)

Based on 106 × 10^6 ψ(3686) data



	$\chi_{c0} \to \pi^0 \eta_c$	$\chi_{c2} \to \pi^0 \eta_c$
N_J^{UL}	14.1	35.9
ε_J	5.8%	8.6%
δ_J	13.8%	20.2%
$B(\chi_{cJ} \to \pi^0 \eta_c)(10^{-3})$	<1.6	<3.2

- No significant η_c signals are observed, and upper limits are set.
- The comparison indicates that the QCD multipole expansion (PRD 75, 054019) predicts that the branching fraction is 20 times of magnitude larger than our measurement.

Light Hadron Spectroscopy

- Introduction
- Recent results
  - PWA
    - Observation and Spin-Parity Determination of the X(1835) in $J/\psi \to \gamma K^0_s K^0_s \eta$
    - An amplitude analysis of the $\pi^0\pi^0$ system produced in radiative J/ψ decays
  - Y(2175)
    - The study of $J/\to \eta\phi\pi\pi$
  - Abnormal decays $P \to V l^+ l^-$
    - Observation of the Dalitz decay $\eta' \to \gamma e^+ e^-$
    - Observation of $\eta' \to \omega e^+ e^-$

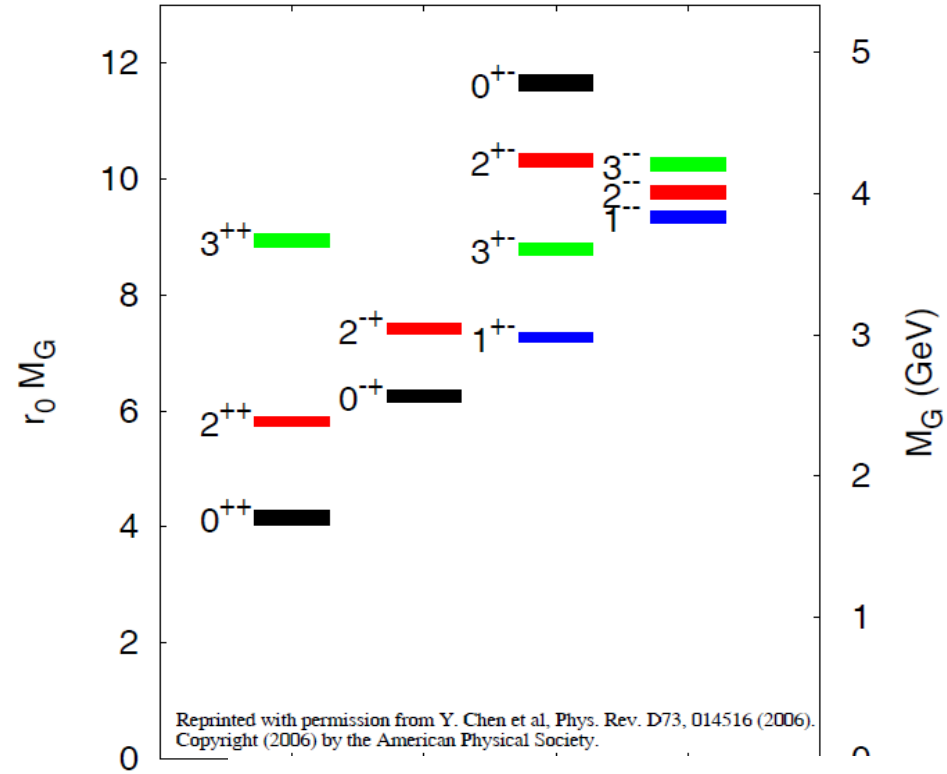
Scalar glueball candidates

- **LQCD:**
- 0^{++} , low mass glueball, 1.5~1.7 GeV
- $J/\psi \rightarrow \gamma PP$, even^{++}

- **$f_0(1710)$, $f_0(1500)$: glueball candidates.**

- **Experiments: $f_0(1710)$, $f_0(1790)$,X(1810);**

the same resonance?



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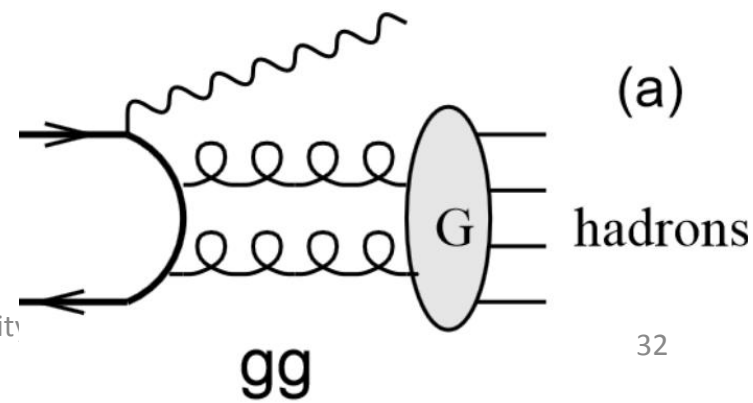
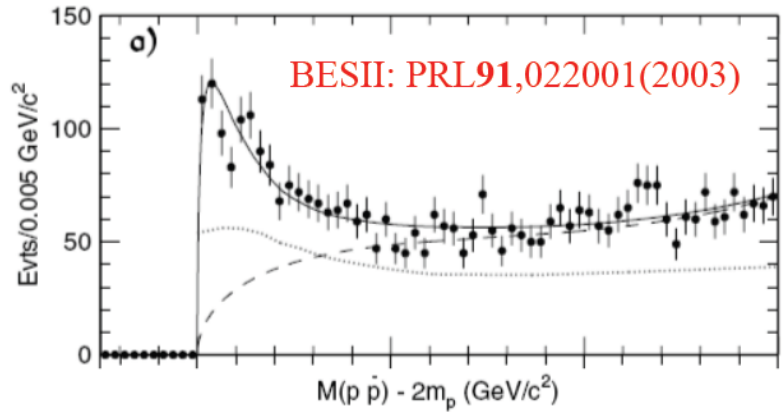


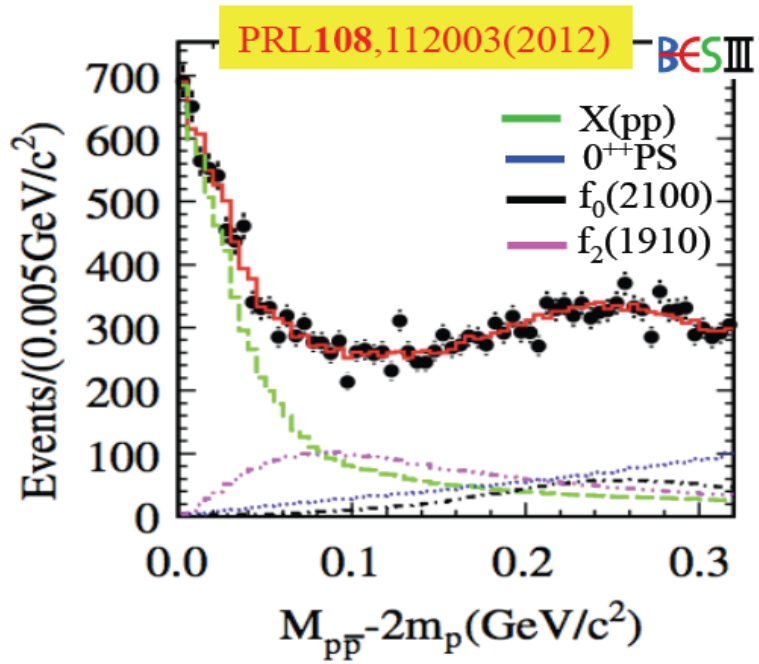
About X(18XX)

- $J/\psi \to \gamma P\bar{P}$:
  - Mass close to the $p\bar{p}$ threshold
  - What is the spin and parity?



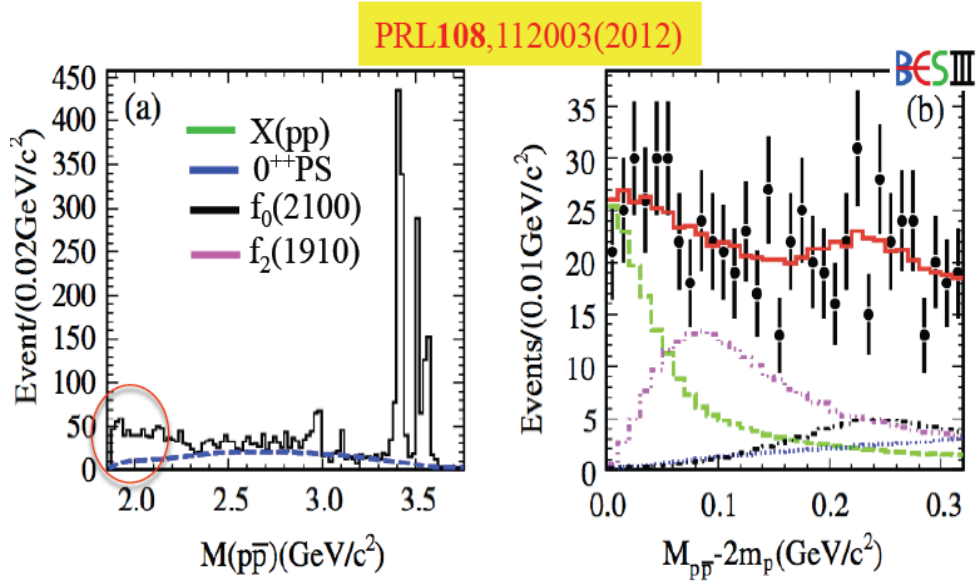
PWA analysis for the region below 2.2 GeV

- Four components included in the PWA fit: $X(p\bar{p})$, $f_2(1910)$, $f_0(2100)$ and 0^{++} phase space
- Parameters for $f_2(1910)$ and $f_0(2100)$ fixed at the PDG values
- **Statistical significance of the $X(p\bar{p})$ component > 30σ**, 5σ for the other components
- **The 0^{-+} assignment is better that other J^{PC}**



J/ψ, ψ(3686)→pp̄

- is consistent with the X(1835), but Γ is narrower.
- Need further measurement to clarify whether or not the X(pp̄)and the X(1835) are the same states.



Fit results including the final state interaction effects:

$$M = 1832^{+19}_{-5}(\text{stat})\ ^{+18}_{-17}(\text{syst}) \pm 19(\text{model})\ \text{MeV/c}^2$$

$$\Gamma = 13 \pm 39(\text{stat})\ ^{+10}_{-13}(\text{syst}) \pm 4(\text{model})\ \text{MeV/c}^2 \text{ or } \Gamma<76\ \text{MeV/c}^2\ (90\%\ \text{C.L.})$$

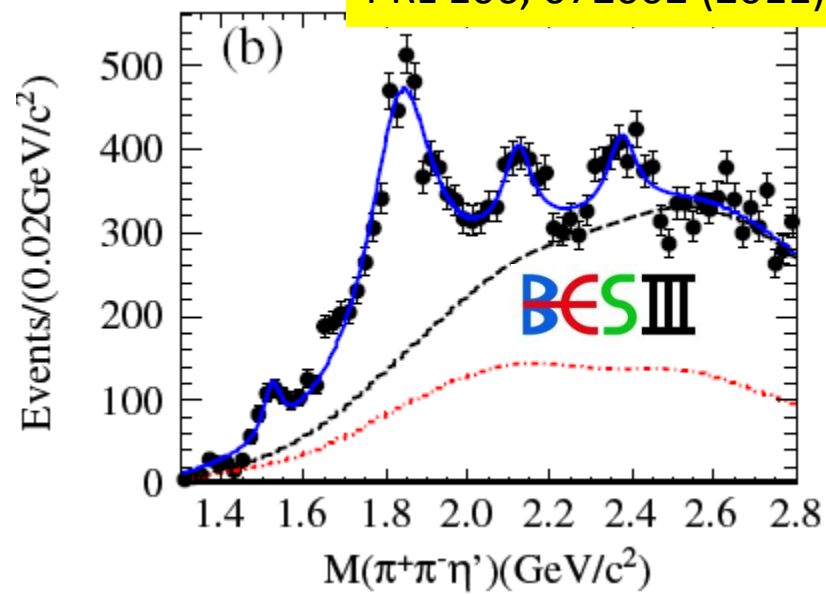
$$BR[J/\psi(3686)\rightarrow\gamma X]\times BR[X\rightarrow pp]=[9.0^{+0.4}_{-1.1}(\text{stat})^{+1.5}_{-5.0}(\text{syst})\pm 2.3(\text{model})]\times 10^{-5}$$

X(1835) in $J/\psi \to \gamma\eta'\pi^+\pi^-$

PRL 106, 072002 (2011)

- X(1835) previously observed at BES and BESII, now confirm @BESIII with two additional structures above 2 GeV/c^2.

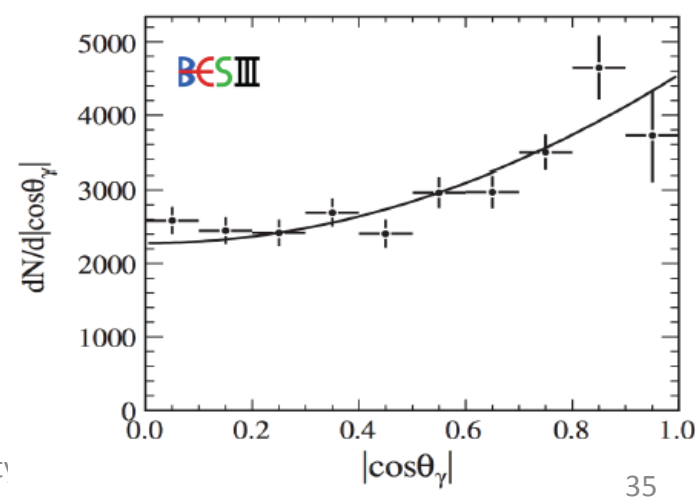
Resonance	M(MeV/c^2)	Γ(MeV/c^2)	
$f_1(1510)$	1522.7 ± 5.0	48 ± 11	>5.7σ
$X(1835)$	1836.5 ± 3.0	190.1 ± 9.0	>20σ
$X(2120)$	2122.4 ± 6.7	83 ± 16	>7.2σ
$X(2370)$	2376.3 ± 8.7	83 ± 17	>6.4σ



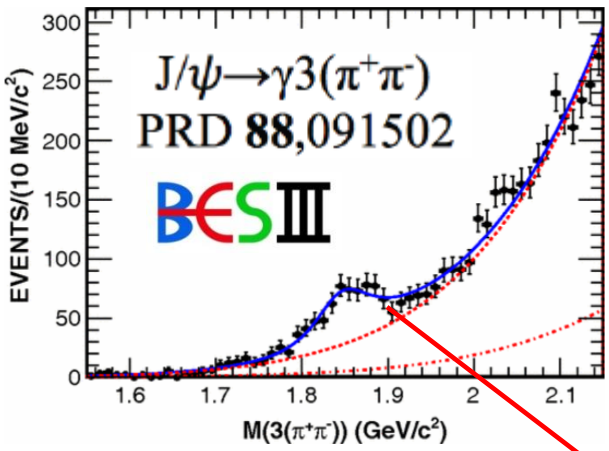
- Nature interpretations: glueball, pp bound state, excited η meson…
- angular distribution

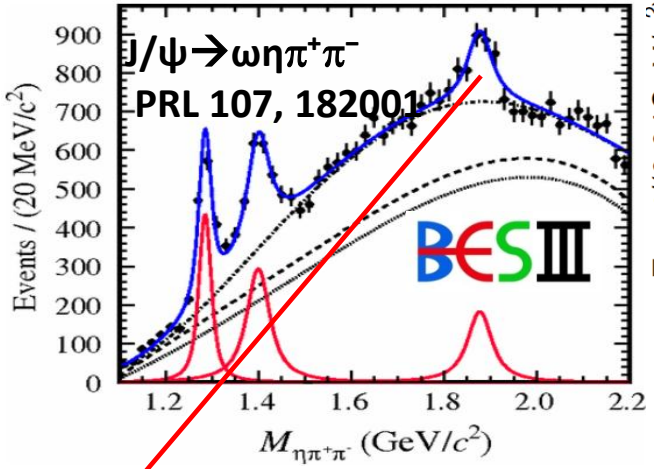
  consistent with pseudoscalar, but

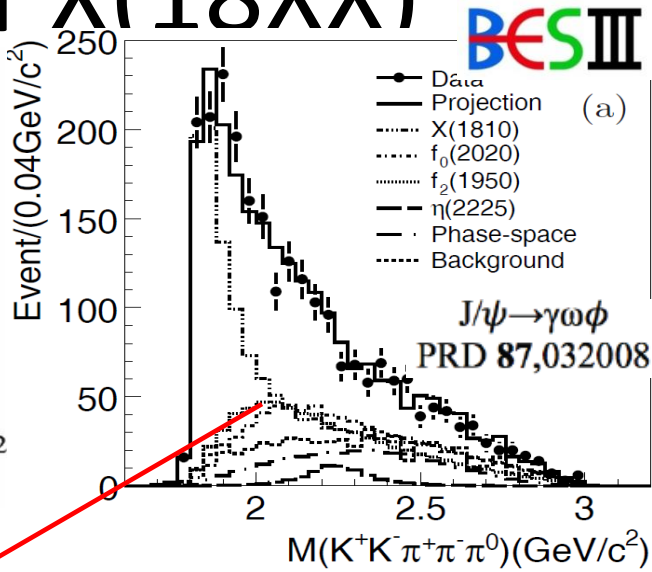
  other spin-parity assignments not excluded

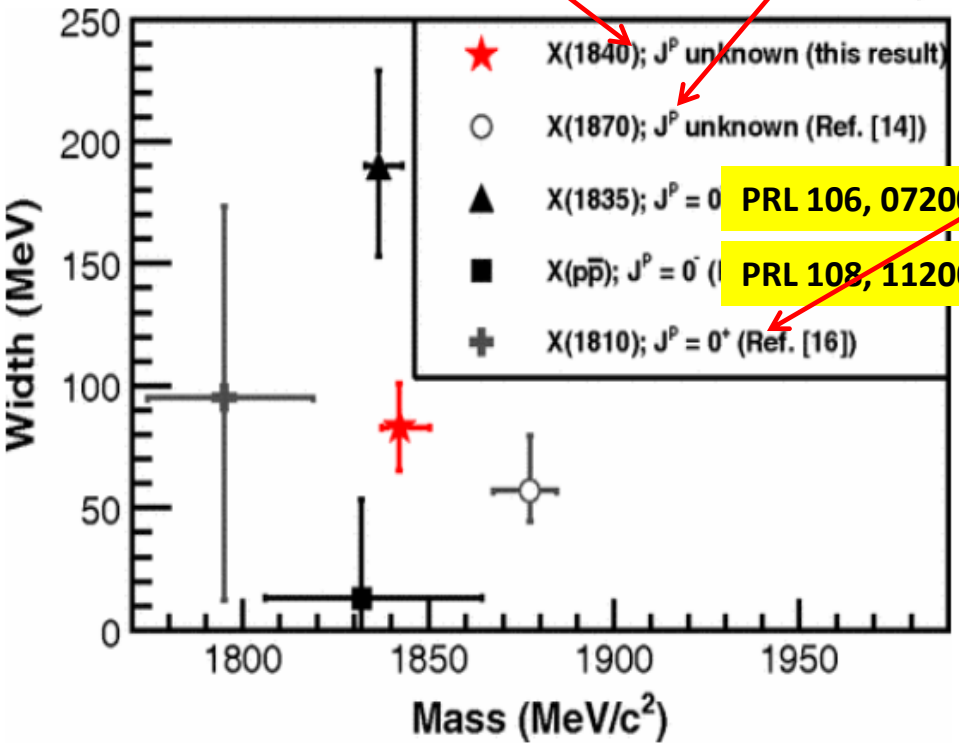


Other observations of X(18XX)









PRL 106, 072002 (2011)

PRL 108, 112003 (2012)

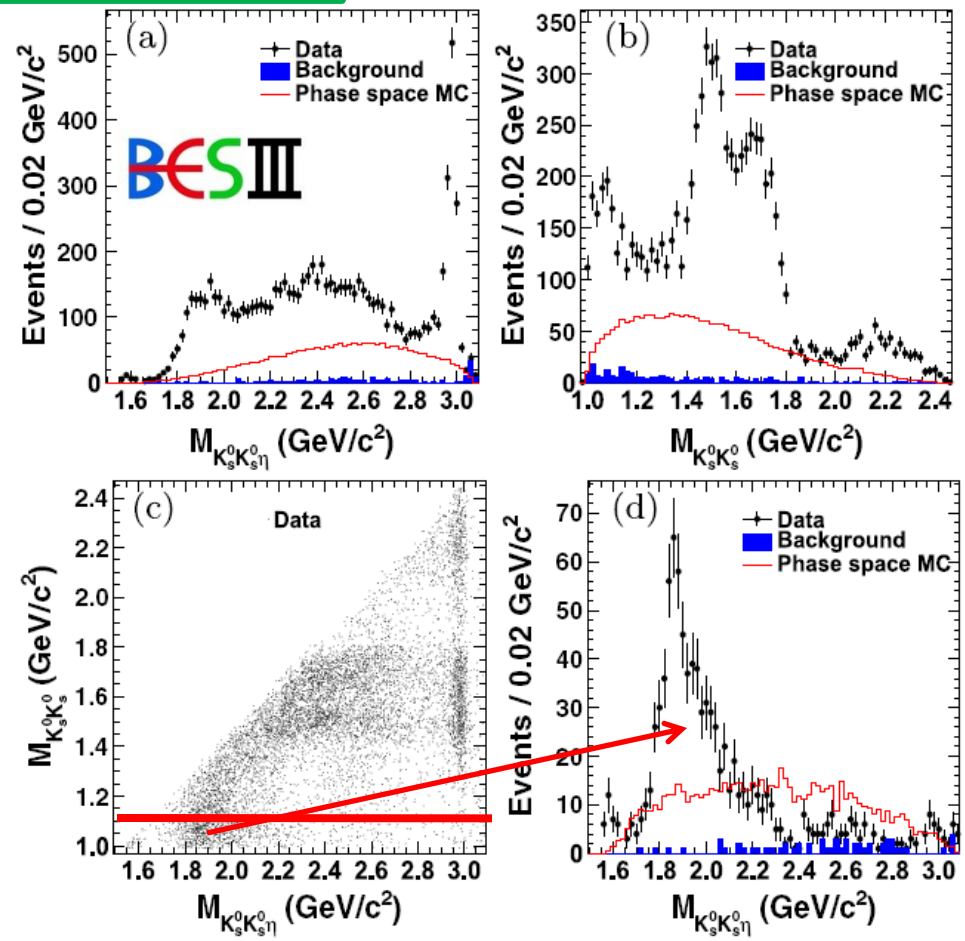
We need more measurement, more decay modes, More statistic.

Observation and Spin-Parity Determination of the X(1835) in $J/\psi \to \gamma K^0_S K^0_S \eta$

1.3 billion J/ψ data taken in 2009 and 2012

PRL 115, 091803 (2015)

- Structure in invariant $K_S K_S \eta$ mass at ~1.85 GeV/c^2
- Strong correlation with enhancement at $K_S K_S$ mass threshold (interpretated as $f_0(980)$)
- Structure in $K_S K_S \eta$ is enhanced for $m(K_S K_S)$<1.1 GeV/c^2



Observation and Spin-Parity Determination of the X(1835) in $J/\psi \to \gamma K^0_S K^0_S \eta$

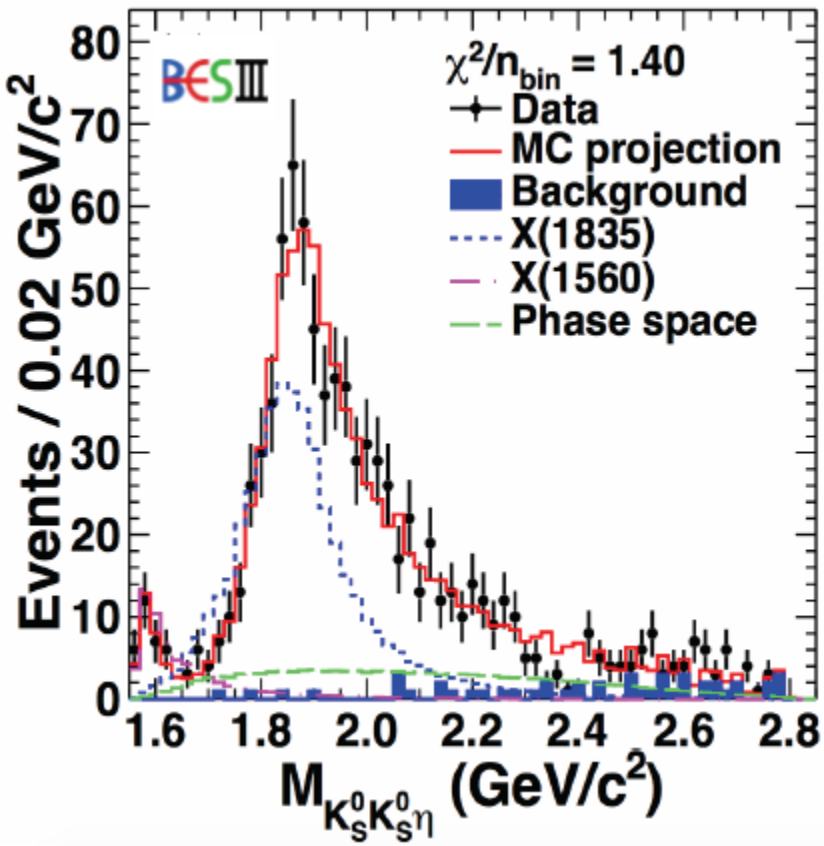
PRL 115, 091803 (2015)

- Partial Wave analysis is performed with $M(K^0_S K^0_S) < 1.1$ GeV/c^2 , $< M(K^0_S K^0_S \eta) < 2.8$ GeV/c^2 ;
- Dominant by $f_o(980) \to K^0_S K^0_S$;
- 0^{-+} , mass and width in agreement with the X(1835) in $J/\psi \to \gamma \eta' \pi^+ \pi^-$

$$X(1835) \to f_0(980)\eta \quad (>12.9\sigma)$$
$$m = 1844 \pm 19^{+16}_{-25}\ \mathrm{MeV}/c^2$$
$$\Gamma = 192^{+20+62}_{-17-43}\ \mathrm{MeV}$$

$$X(1560) \to f_0(980)\eta \quad (>8.9\sigma)$$
$$m = 1565 \pm 8^{+0}_{-63}\ \mathrm{MeV}/c^2$$
$$\Gamma = 45^{+14+21}_{-13-28}\ \mathrm{MeV}$$

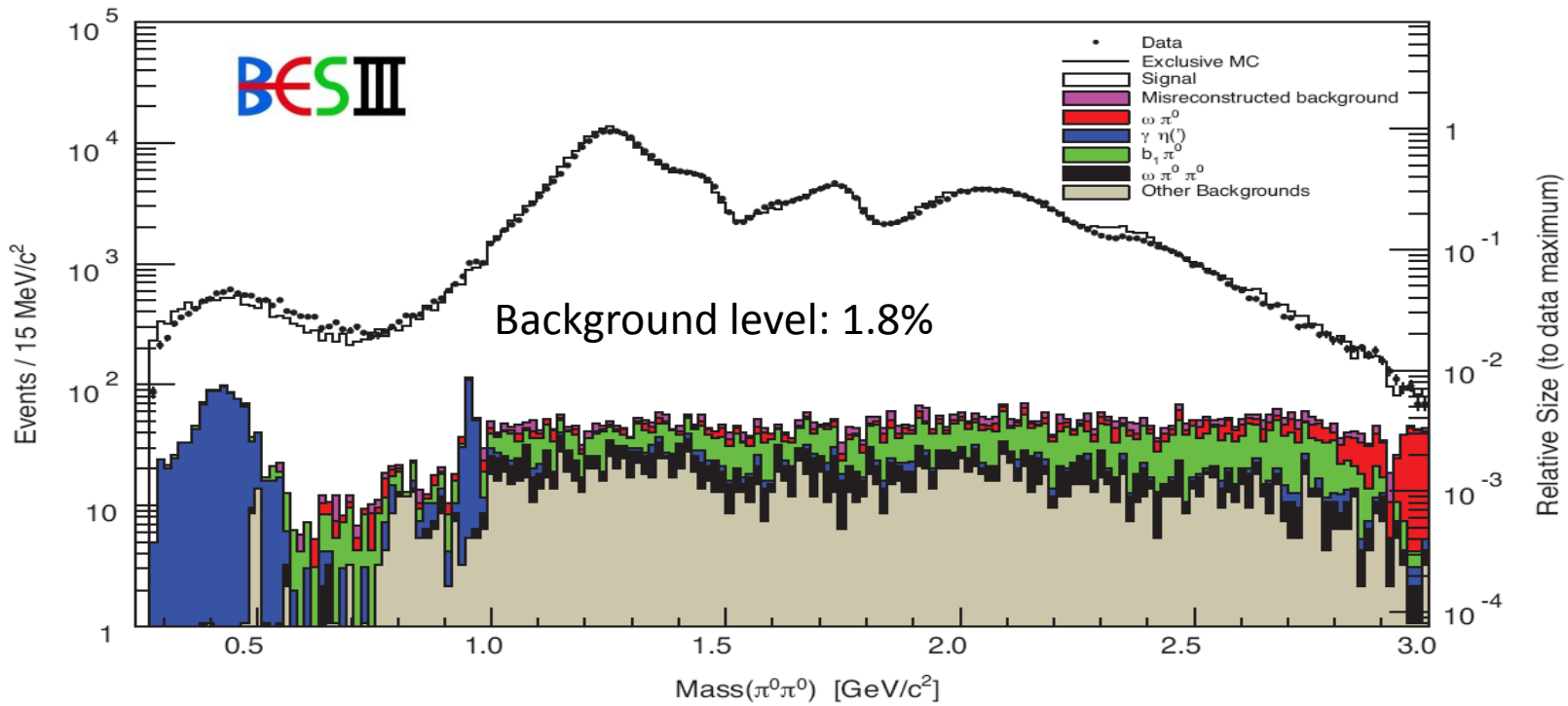
- These results are all first-time measurements and provide important information to further understand the nature of the X(1835).



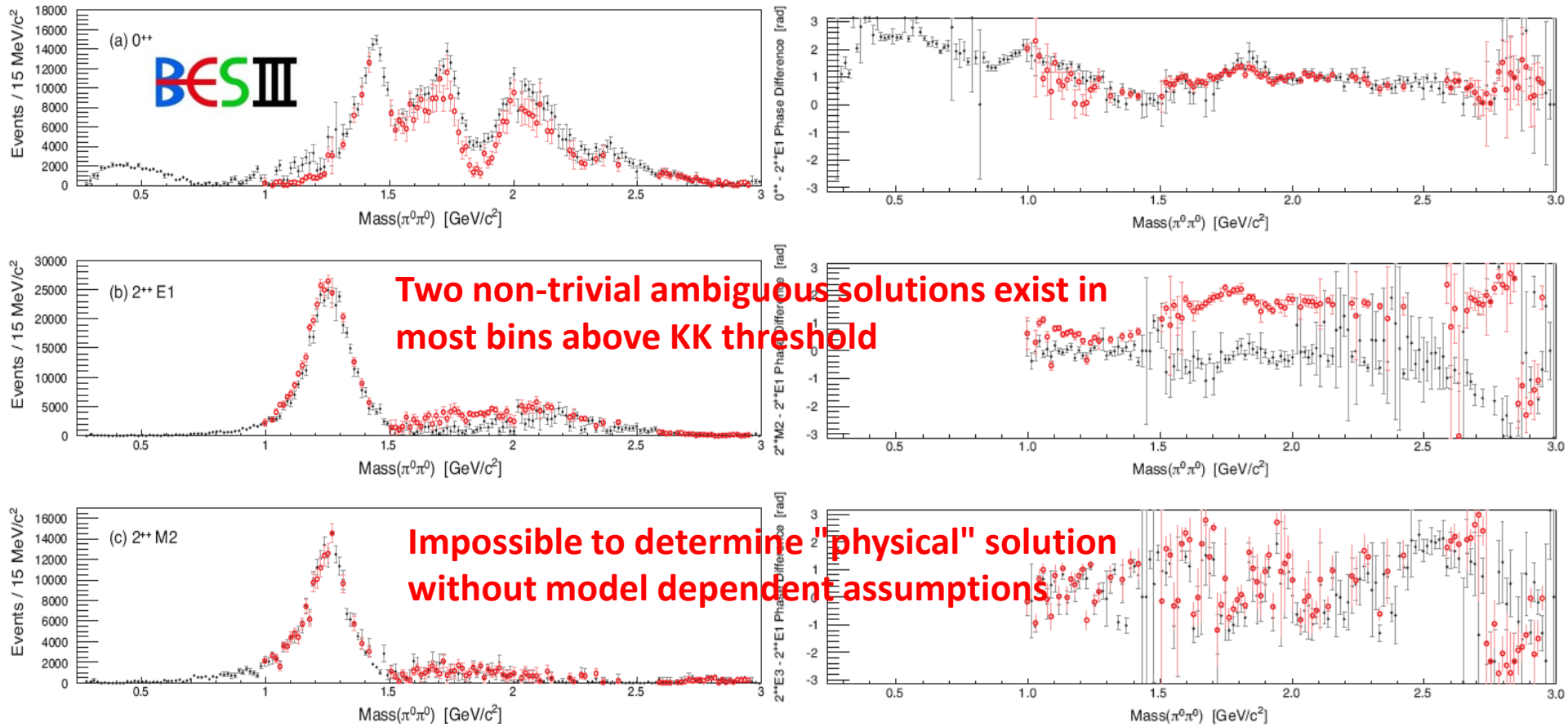
PWA of $J/\psi \rightarrow \gamma\pi^0\pi^0$

1.3 billion J/ψ data taken in 2009 and 2012

arXiv: 1506.00546
Accepted by PRD



- Only significant 0++ and 2++ contributions
- Model Independent Partial Wave Analysis



- From 0++, significant structures around 1.5, 1.7 and 2.0 GeV are observed.
- $Br(J/\psi \rightarrow \gamma\pi^0\pi^0) = (1.15 \pm 0.05(sys.)) \times 10^{-3}$
- Results may be combined with other related results for development of phenomenological models…

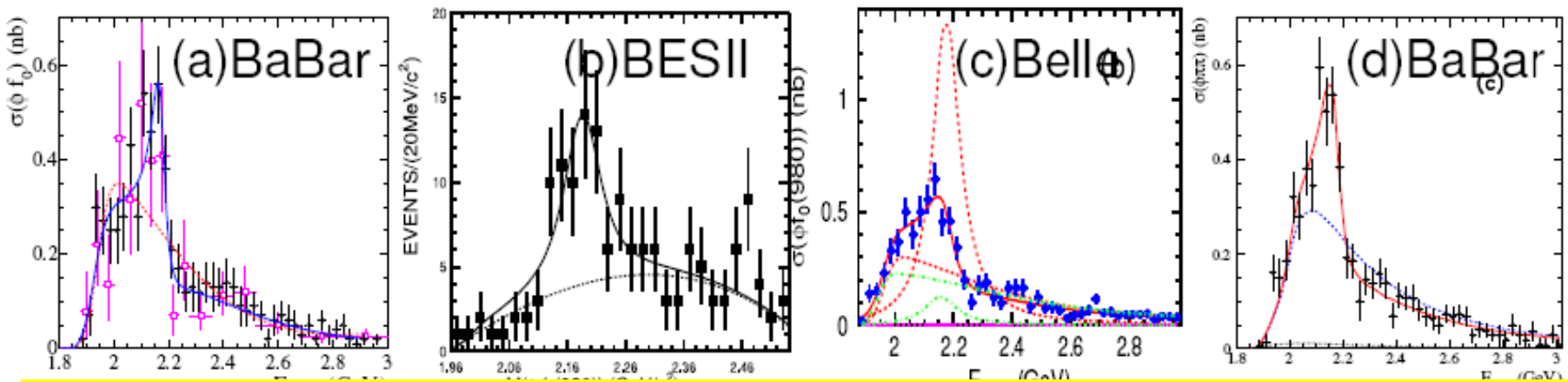
arXiv: 1506.00546
Accepted by PRD

About Y(2175)

- Y(2175): $s\bar{s}$-gluon Hybrid as a counterpart of Y(4260), or 2^3D_1 quarkonium ?

Table 1: The observation of $Y(2175)$ at BABAR, Belle and BESII

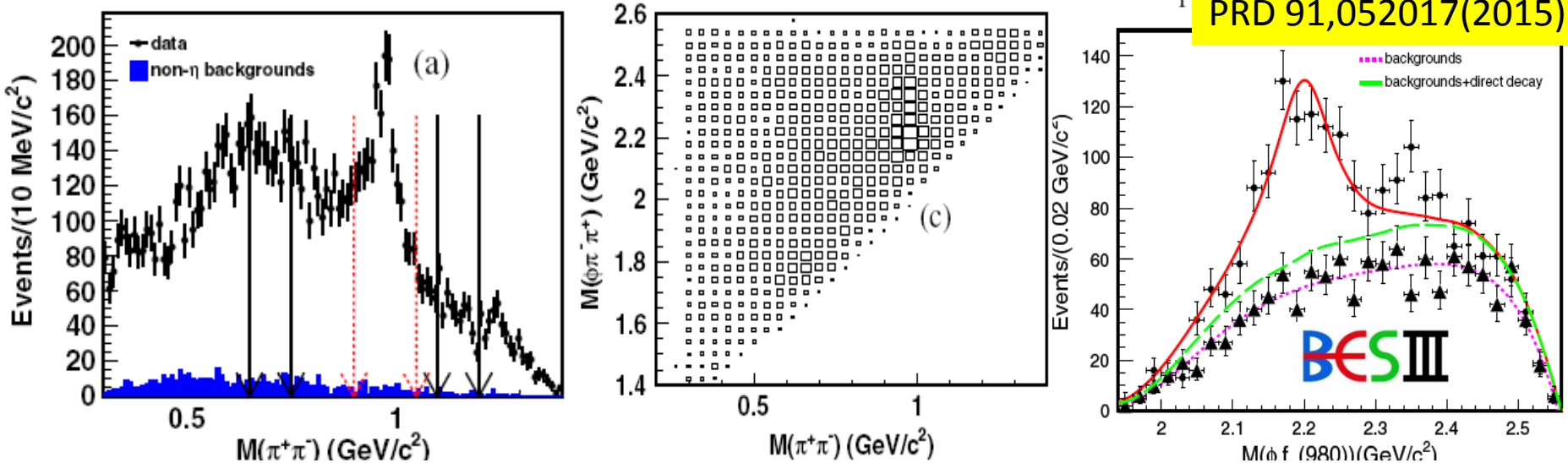
collaboration	process	mass (MeV/c^2)	Γ (MeV/c^2)
BABAR	ISR:$e^+e^- \to \phi f_0$	$2175 \pm 10 \pm 15$	$58 \pm 16 \pm 20$
BESII	$J/\psi \to \eta\phi f_0(980)$	$2186 \pm 10 \pm 6$	$65 \pm 23 \pm 17$
Belle	ISR:$e^+e^- \to \phi f_0$	$2079 \pm 13^{+79}_{-28}$	$192 \pm 23^{+25}_{-61}$
BABAR(updated)	ISR:$e^+e^- \to \phi f_0$	$2172 \pm 10 \pm 8$	$96 \pm 19 \pm 12$



PRD 74, 091103(R) **PRL 100, 102003** **PRD 80, 031101(R)** **PRD86, 012008**

Study of Y(2175) in $J/\psi \to \eta\phi\pi^+\pi^-$ at BESIII

PRD 91,052017(2015)



Collaboration	Process	M (MeV/c^2)	Γ (MeV)
BABAR [2]	$e^+e^- \to \phi f_0$ (ISR)	$2175 \pm 10 \pm 15$	$58 \pm 16 \pm 20$
BESII [3]	$J/\psi \to \eta\phi f_0(980)$	$2186 \pm 10 \pm 6$	$65 \pm 23 \pm 17$
BELLE [4]	$e^+e^- \to \phi f_0$ (ISR)	$2079 \pm 13^{+79}_{-28}$	$192 \pm 23^{+25}_{-61}$
BABAR (updated) [5]	$e^+e^- \to \phi f_0$ (ISR)	$2172 \pm 10 \pm 8$	$96 \pm 19 \pm 12$
BESIII	$J/\psi \to \eta\phi f_0(980)$	$2200 \pm 6 \pm 5$	$104 \pm 15 \pm 15$

Confirm the existence of Y(2175)(>10σ)

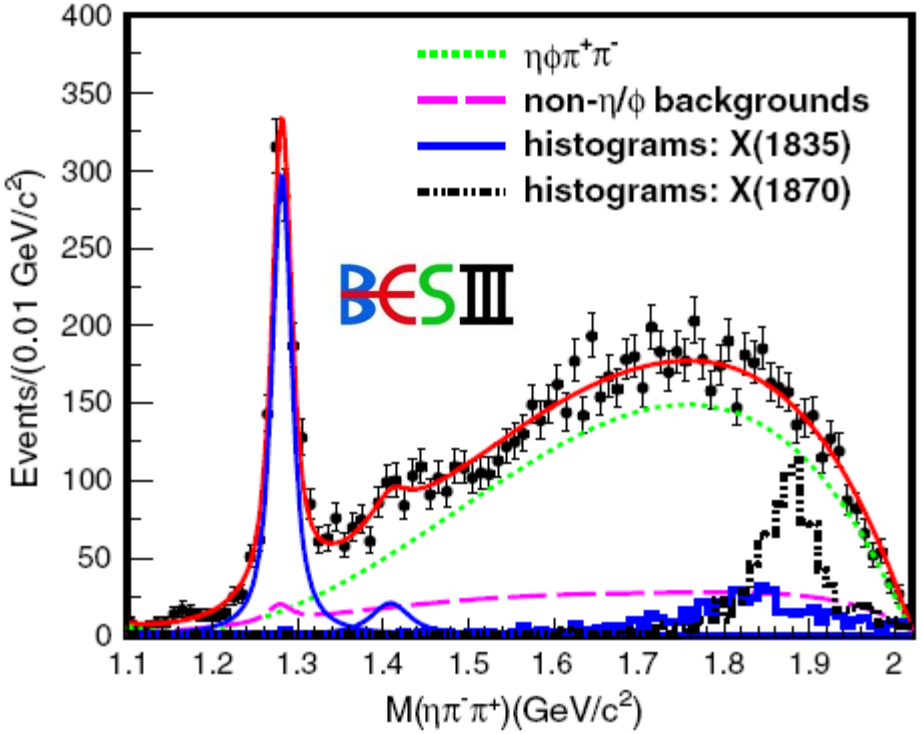
225M J/ψdata taken in 2009

- Unknown BG: two dimensional sidebands of ϕ, $f_0(980)$;
- Mass & width: Consistent with former results .

PRD 91,052017(2015)

$\eta\pi^+\pi^-$ mass spectrum recoiling against the ϕ

- Br($J/\psi \to \phi\, f_1(1285)$) ;
- $\eta(1405)/\eta(1440)$ quark content : u and d;
- searches for the X(1835) and X(1870);



Resonance	N_{obs}	Significance	Efficiency(%)
$Y(2175)$	471 ± 54	$> 10\sigma$	9.10 ± 0.01
$f_1(1285)$	1154 ± 56	$\cdots$	22.14 ± 0.09
$\eta(1405)$	172 ± 50 (< 345)	3.6σ	19.75 ± 0.12
$X(1835)$	394 ± 360 (< 1522)	1.1σ	13.85 ± 0.14
$X(1870)$	25 ± 73 (< 330)	0.8σ	13.73 ± 0.14

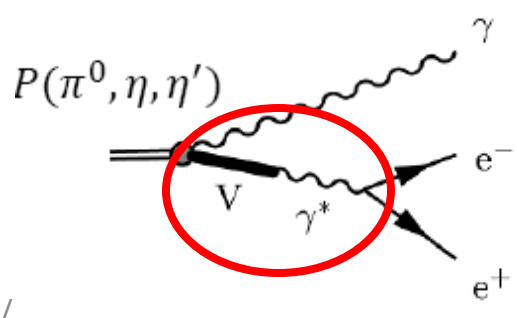
TABLE III. Measurements of the branching fractions for the decay modes. Upper limits are given at the 90% C.L.

Decay mode	Branching fraction $\mathcal{B}$
$J/\psi \to \eta Y(2175)$, $Y(2175) \to \phi f_0(980)$, $f_0(980) \to \pi^+\pi^-$	$(1.20 \pm 0.14 \pm 0.37) \times 10^{-4}$
$J/\psi \to \phi f_1(1285)$, $f_1(1285) \to \eta\pi^+\pi^-$	$(1.20 \pm 0.06 \pm 0.14) \times 10^{-4}$
$J/\psi \to \phi\eta(1405)$, $\eta(1405) \to \eta\pi^+\pi^-$	$(2.01 \pm 0.58 \pm 0.82)$ $(< 4.45) \times 10^{-5}$
$J/\psi \to \phi X(1835)$, $X(1835) \to \eta\pi^+\pi^-$	$< 2.80 \times 10^{-4}$
$J/\psi \to \phi X(1870)$, $X(1870) \to \eta\pi^+\pi^-$	$< 6.13 \times 10^{-5}$

P→Vl⁺l⁻, l=e,μ

- Study of the rare and forbidden decays of η/η′: probe to test fundamental symmetries of QCD and search for new physics beyond the SM.

- Vector meson dominance (VMD) models have reached good agreement in describing the experimental data of the triangle anomaly sector and are also valid in the box anomaly sector.



Decay mode	$B^{\rm theor}_{e^+e^-}$	$B^{\rm expt}_{e^+e^-}$	$B^{\rm theor}_{\mu^+\mu^-}$	$B^{\rm expt}_{\mu^+\mu^-}$
$\rho^0\to l^+l^-$	input	$(4.48\pm0.22)\times10^{-5}$	4.5×10^{-5}	$(4.60\pm0.28)\times10^{-5}$
$\rho\to\pi l^+l^-$	4.1×10^{-6}		4.6×10^{-7}	
$\rho^0\to\eta l^+l^-$	2.7×10^{-6}		7.0×10^{-11}	
$\rho^\pm\to\pi^\pm\pi^0 l^+l^-$	5.4×10^{-5}		1.8×10^{-7}	
$\rho^0\to\pi^+\pi^- l^+l^-$	1.7×10^{-4}		6.7×10^{-7}	
$\rho^0\to\pi^0\pi^0 l^+l^-$	7.5×10^{-8}		2.4×10^{-9}	
$\rho\to\pi\eta l^+l^-$	1.9×10^{-12}			
$\omega\to l^+l^-$	input	$(7.15\pm0.19)\times10^{-5}$	7.1×10^{-5}	$<1.8\times10^{-4}$
$\omega\to\pi^0 l^+l^-$	7.9×10^{-4}	$(5.9\pm1.9)\times10^{-4}$	9.2×10^{-5}	$(9.6\pm2.3)\times10^{-5}$
$\omega\to\eta l^+l^-$	6.0×10^{-6}		1.8×10^{-9}	
$\omega\to\pi^+\pi^- l^+l^-$	3.9×10^{-6}		2.9×10^{-8}	
$\omega\to\pi^0\pi^0 l^+l^-$	2.0×10^{-7}		7.4×10^{-9}	
$\omega\to\pi^0\eta l^+l^-$	8.7×10^{-10}			
$\phi\to l^+l^-$	input	$(3.00\pm0.06)\times10^{-4}$	3.0×10^{-4}	$(2.48\pm0.34)\times10^{-4}$
$\phi\to\pi^0 l^+l^-$	1.6×10^{-5}	$<1.2\times10^{-4}$	4.8×10^{-6}	
$\phi\to\eta l^+l^-$	1.1×10^{-4}	$(1.3^{+0.8}_{-0.6})\times10^{-4}$	6.8×10^{-6}	
$\eta\to\gamma l^+l^-$	6.5×10^{-3}	$(4.9\pm1.1)\times10^{-3}$	3.0×10^{-4}	$(3.1\pm0.4)\times10^{-4}$
$\eta\to\pi^+\pi^- l^+l^-$	3.6×10^{-4}	$(1.3^{+1.2}_{-0.8})\times10^{-3}$	1.2×10^{-8}	
$\eta'\to\gamma l^+l^-$	4.2×10^{-4}		8.1×10^{-5}	$(1.04\pm0.26)\times10^{-4}$
$\eta'\to\omega l^+l^-$	2.0×10^{-4}			
$\eta'\to\pi^+\pi^- l^+l^-$	1.8×10^{-3}		2.0×10^{-5}	
$f_0\to\gamma l^+l^-$	2.2×10^{-7}		2.8×10^{-8}	
$f_0\to\pi^+\pi^- l^+l^-$	1.4×10^{-4}		4.1×10^{-7}	
$a_0^0\to\gamma l^+l^-$	6.0×10^{-8}		7.4×10^{-9}	
$a_0\to\pi\eta l^+l^-$	4.0×10^{-5}		1.4×10^{-9}	
$\pi^0\to\gamma l^+l^-$	1.18×10^{-2}	$(1.198\pm0.032)\times10^{-2}$		

PRC **61 035206**

$P \rightarrow V l^+ l^-$, $l = e, \mu$

$$\frac{d\Gamma(\eta' \to \gamma l^+ l^-)}{dq^2 \Gamma(\eta' \to \gamma\gamma)} = \frac{2\alpha}{3\pi}\frac{1}{q^2}\sqrt{1-\frac{4m_l^2}{q^2}}\left(1+\frac{2m_l^2}{q^2}\right)\left(1-\frac{q^2}{m_{\eta'}^2}\right)^3 |F(q^2)|^2 = [\mathrm{QED}(q^2)] \times |F(q^2)|^2,$$

e.g. single pole approximation:

$$|F(q^2)| = \frac{1}{(1-q^2/\Lambda^2)} \approx 1 + \frac{q^2}{\Lambda^2}$$

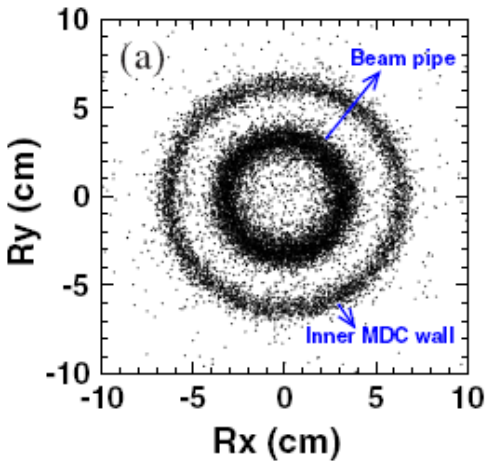
$$b = \left.\frac{dF}{dq^2}\right|_{q^2=0} = \Lambda^{-2}.$$

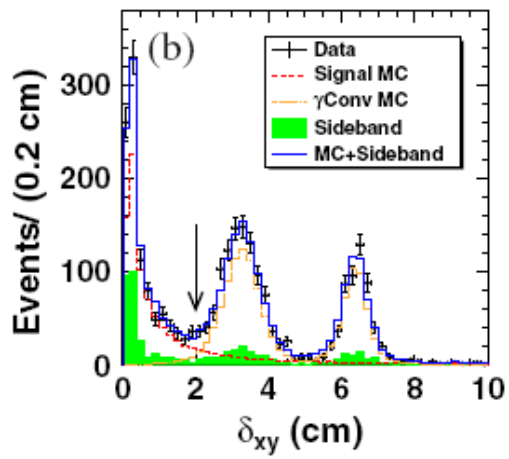
VMD model: $b_{\eta'}$=1.45 GeV^{-2}

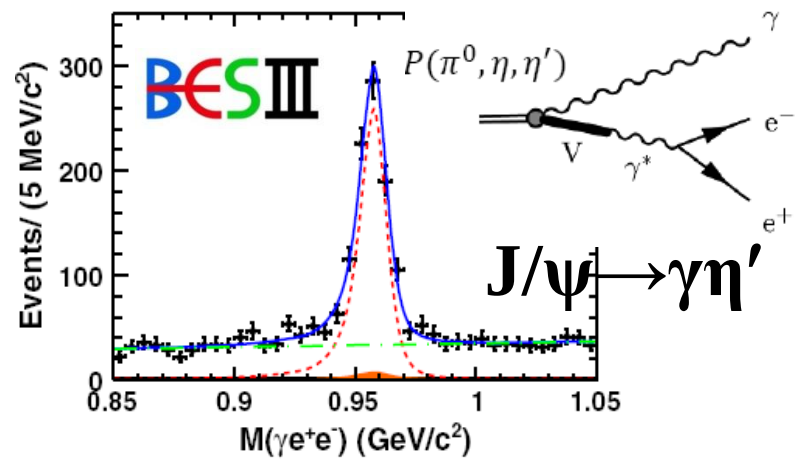
Chiral perturbation theory: $b_{\eta'}$=1.60 GeV^{-2}

Used to test the VMD model chiral perturbation theory.

Observation of the Dalitz decay η' → γe⁺e⁻





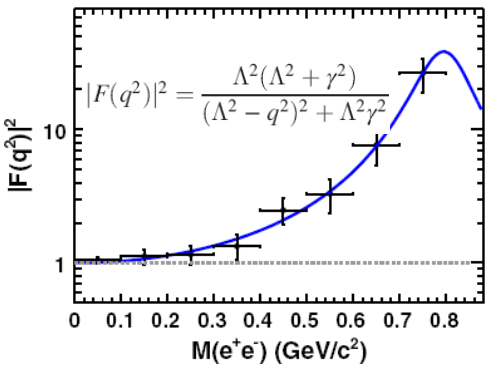


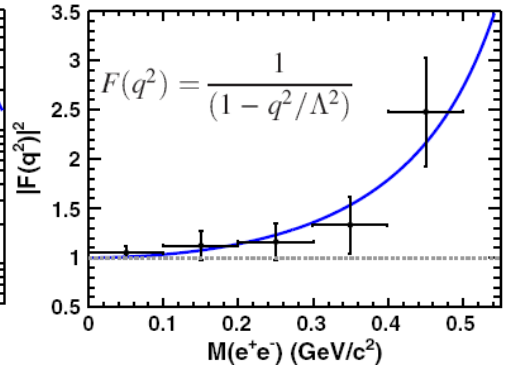
measured for the first time

$$\mathcal{B}(\eta' \to \gamma e^+e^-) = (4.69 \pm 0.20(\text{stat}) \pm 0.23(\text{sys})) \times 10^{-4}.$$

PRD 92, 012001 (2015)

$$\Gamma(\eta' \to \gamma e^+e^-)/\Gamma(\eta' \to \gamma\gamma) = (2.13 \pm 0.09(\text{stat}) \pm 0.07(\text{sys})) \times 10^{-2}$$

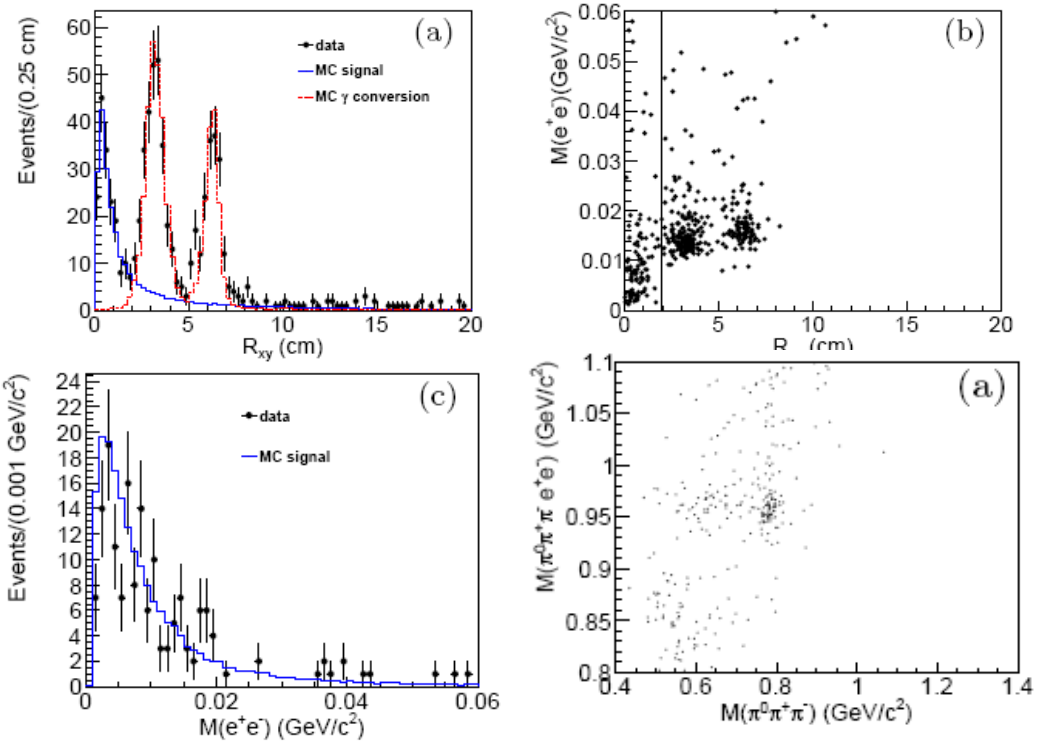




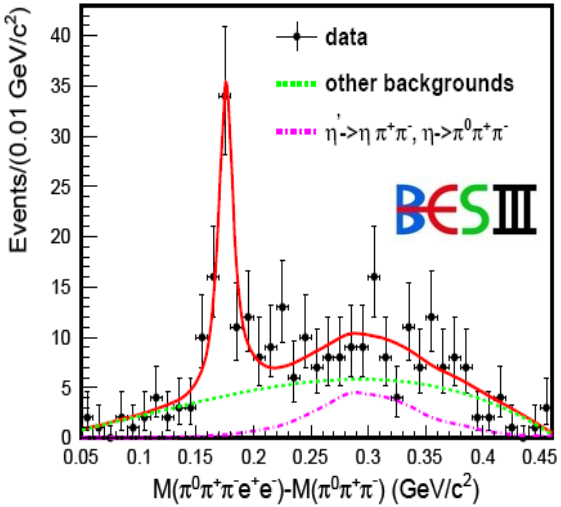
The results are consistent with the prediction of the VMD model:

$b_{\eta'}$=(1.60 ±0.17±0.08)GeV^{-2}

The observation of $\eta' \to \omega e^+ e^-$



$J/\psi \to \gamma\eta', \eta' \to \omega e^+ e^-$



arXiv: 1507.06734
accepted by PRD

- (different from other analysis!) Fit to $M(\pi^0\pi^+\pi^- e^+e^-)-M(\pi^0\pi^+\pi^-)$: improve the mass resolution and BG description;

$Br(\eta' \to \omega e^+ e^-)$
$=(1.97 \pm 0.34 \pm 0.17) \times 10^{-4}$
consistent well with theory prediction.

- η' anomalous decay: test chiral perturbation theory and VMD model;

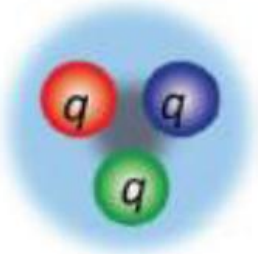
Decay mode	$B^{theor}_{e^+e^-}$	$B^{expt}_{e^+e^-}$	$B^{theor}_{\mu^+\mu^-}$	$B^{expt}_{\mu^+\mu^-}$
$\eta' \to \gamma l^+ l^-$	4.2×10^{-4}		8.1×10^{-5}	$(1.04 \pm 0.26) \times 10^{-4}$
$\eta' \to \omega l^+ l^-$	2.0×10^{-4}	No exp. measurements		
$\eta' \to \pi^+\pi^- l^+ l^-$	1.8×10^{-3}	PRC, 61, 035206	2.0×10^{-5}	

1.3 billion J/ψ data taken in 2009 and 2012

Baryon Spectroscopy

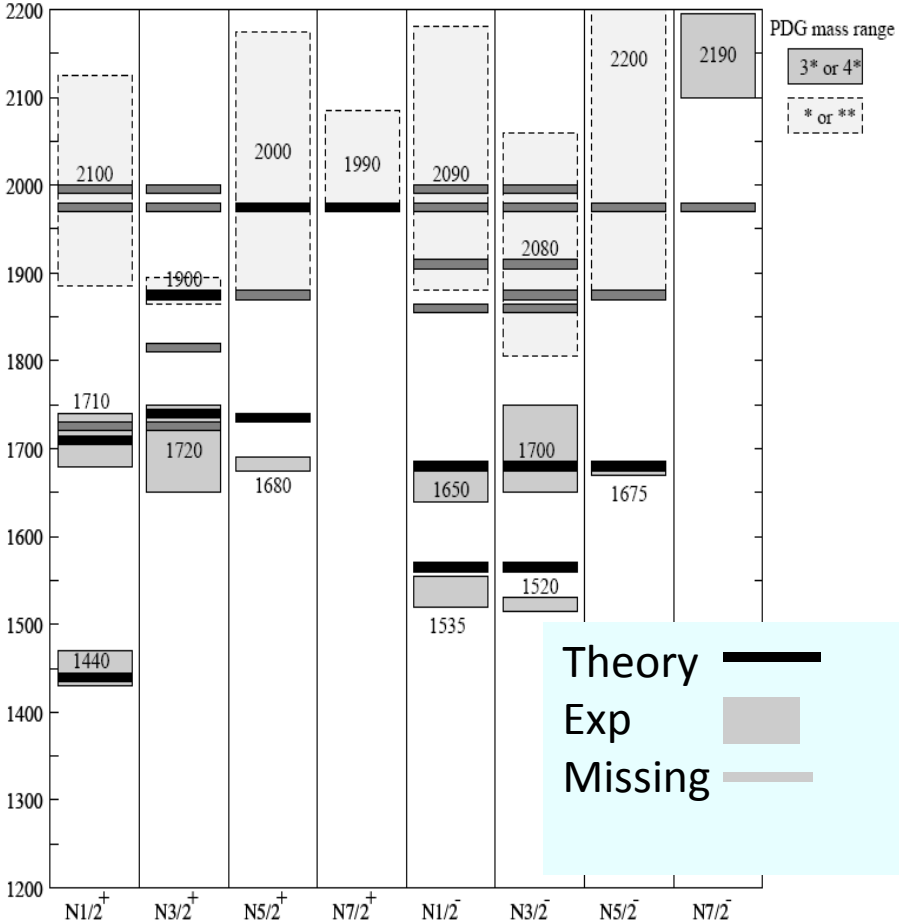
- Introduction
- Recent results
  - Observation of two hyperons $\Xi^-(1690)$ and $\Xi^-(1820)$
  - Observation of two new excited baryon states in $\psi(3686) \to p\bar{p}\,\pi^0$
  - N(1535) in $\psi(3686) \to p\bar{p}\,\eta$

introduction

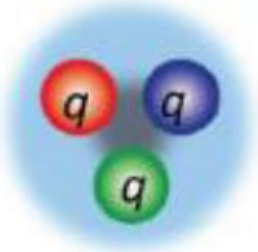


baryon

- **An important field for understanding the structure of hadron.**
- **Non-relativistic quark model(NRQCD):**
  - **successful in interpreting baryon resonances.**
  - **an explicit classification for light baryons in terms of group symmetry.**
  - **"miss resonance problem"**

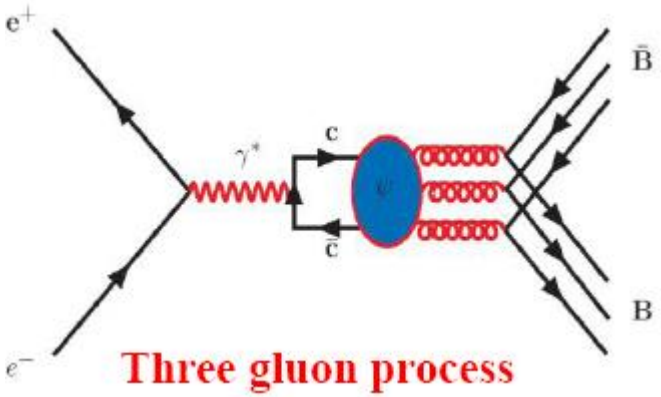


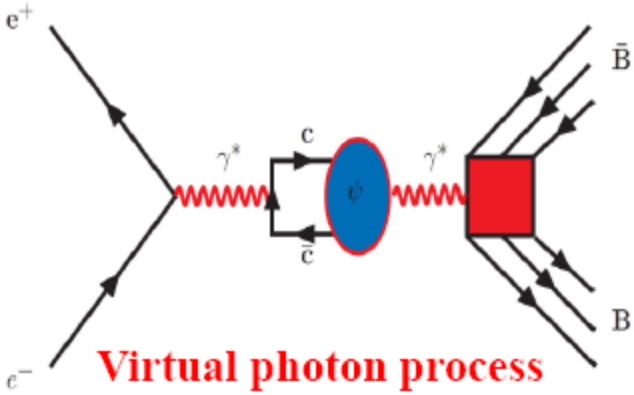
introduction



baryon

- BESIII, high charmonium statistics : a good measurement of baryon spectroscopy
  - Isospin 1/2 filter: $\psi \to NN\ \pi$, $\psi \to NN\ \pi\pi$
  - Missing N* with small couplings to πN & γN , but large coupling to gggN : $\psi \to NN\ \pi/\eta/\eta'/\omega/\phi$, $p\ \Sigma\ \pi$, $p\ \Lambda K$ …





About Ξ

Ξ, hyperons with strangeness S =−2

- **Quark model predicts over 30 Ξ* states,** only **11** Ξ* states have been observed to date. Few of them are well established with spin parity determined.

- most observations: bubble chamber experiments or diffractive K−p interactions.

- **Charmonium decays** offer a good opportunity to study Ξ: narrow width, low background, high statistics…

Particle	J^P	Overall status	Status as seen in				
			$\Xi\pi$	ΛK	ΣK	$\Xi(1530)\pi$	Other channels
$\Xi(1318)$	$1/2+$	****					Decays weakly
$\Xi(1530)$	$3/2+$	****	****				
$\Xi(1620)$		*	*				
$\Xi(1690)$		***		***	**		
$\Xi(1820)$	$3/2-$	***	**	***	**	**	
$\Xi(1950)$		***	**	**		*	
$\Xi(2030)$		***		**	***		
$\Xi(2120)$		*		*			
$\Xi(2250)$		**					3-body decays
$\Xi(2370)$		**					3-body decays
$\Xi(2500)$		*		*	*		3-body decays

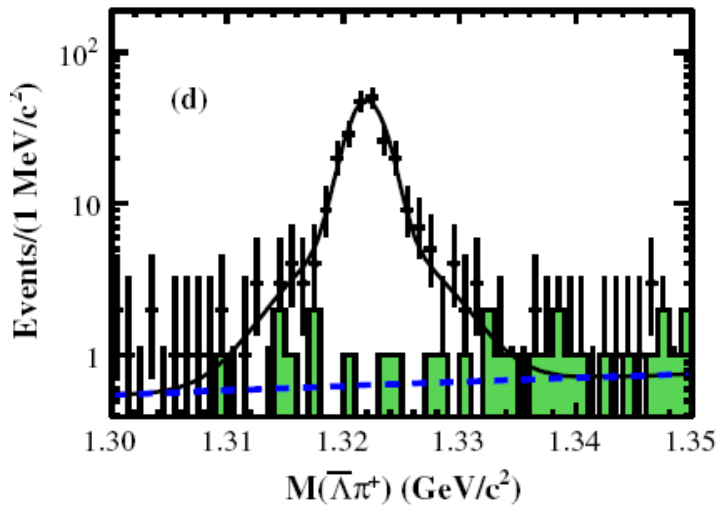
Observation of two hyperons $\Xi^-(1690)$ and $\Xi^-(1820)$ in $\psi(3686) \to K^+\Lambda\,\Xi^+$+c.c.

PRD 91, 092006 (2015)

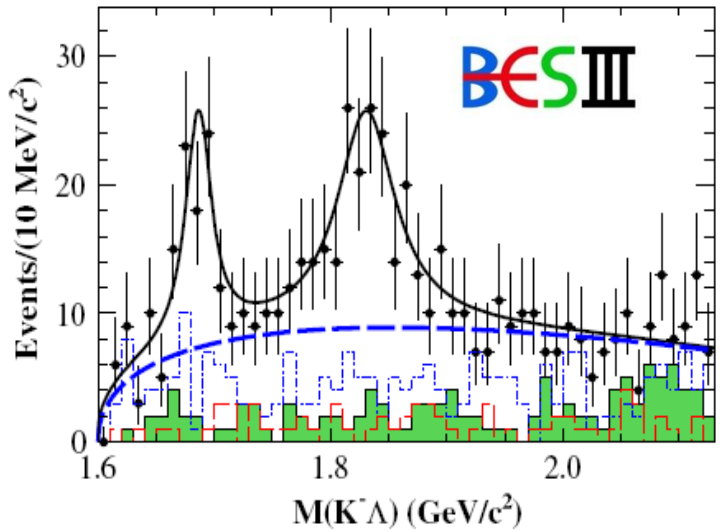
Based on 106 × 10^6 $\psi(3686)$ data

The decays is reconstructed from cascade decay:

$\psi(3686) \to K^-\Lambda\bar{\Xi}^+$, $\bar{\Xi}^+ \to \bar{\Lambda}\pi^+$, $\bar{\Lambda} \to \bar{p}\pi^+$, $\Lambda \to p\pi^-$



$B(\psi(3686) \to K^-\Lambda\,\Xi^+) = (3.86 \pm 0.27 \pm 0.32) \times 10^{-5}$

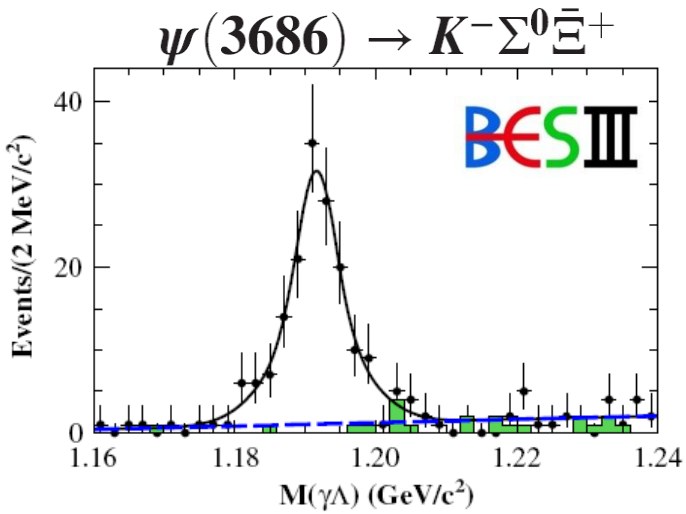


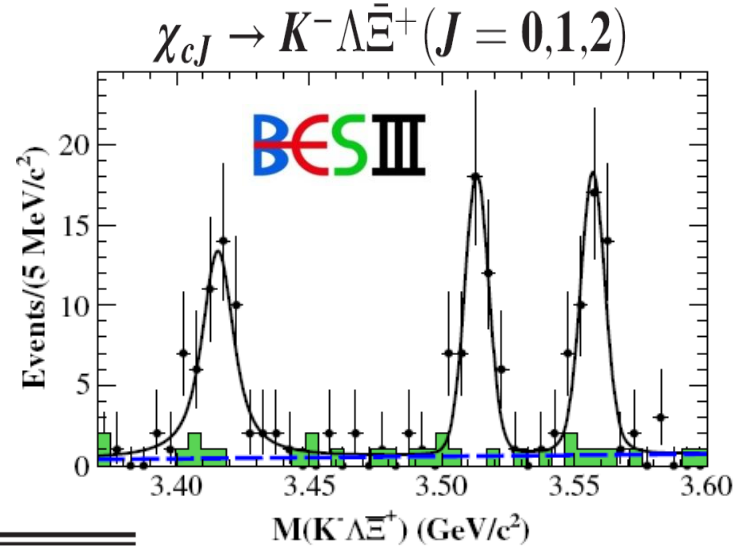
	$\Xi(1690)^-$	$\Xi(1820)^-$
$M(\mathrm{MeV}/c^2)$	$1687.7 \pm 3.8 \pm 1.0$	$1826.7 \pm 5.5 \pm 1.6$
$\Gamma(\mathrm{MeV})$	$27.1 \pm 10.0 \pm 2.7$	$54.4 \pm 15.7 \pm 4.2$
Event yields	74.4 ± 21.2	136.2 ± 33.4
Significance(σ)	4.9	6.2
Efficiency(%)	32.8	26.1
$\mathcal{B}(10^{-6})$	$5.21 \pm 1.48 \pm 0.57$	$12.03 \pm 2.94 \pm 1.22$
$M_{\mathrm{PDG}}(\mathrm{MeV}/c^2)$	1690 ± 10	1823 ± 5
$\Gamma_{\mathrm{PDG}}(\mathrm{MeV})$	< 30	24^{+15}_{-10}

- Two hyperons $\Xi^-(1690)$ and $\Xi^-(1820)$ are observed in $\psi(3686) \to K^-\Lambda\,\bar{\Xi}^+$+c.c
- Resonance parameters consist with PDG

$\psi(3686) \rightarrow \gamma K^+ \Lambda \Xi^+$

PRD 91, 092006 (2015)





Decay	Branching fraction
$\psi(3686) \rightarrow K^-\Lambda\bar{\Xi}^+$	$(3.86 \pm 0.27 \pm 0.32) \times 10^{-5}$
$\psi(3686) \rightarrow \Xi(1690)^-\bar{\Xi}^+$, $\Xi(1690)^- \rightarrow K^-\Lambda$	$(5.21 \pm 1.48 \pm 0.57) \times 10^{-6}$
$\psi(3686) \rightarrow \Xi(1820)^-\bar{\Xi}^+$, $\Xi(1820)^- \rightarrow K^-\Lambda$	$(12.03 \pm 2.94 \pm 1.22) \times 10^{-6}$
$\psi(3686) \rightarrow K^-\Sigma^0\bar{\Xi}^+$	$(3.67 \pm 0.33 \pm 0.28) \times 10^{-5}$
$\psi(3686) \rightarrow \gamma\chi_{c0}, \chi_{c0} \rightarrow K^-\Lambda\bar{\Xi}^+$	$(1.90 \pm 0.30 \pm 0.16) \times 10^{-5}$
$\psi(3686) \rightarrow \gamma\chi_{c1}, \chi_{c1} \rightarrow K^-\Lambda\bar{\Xi}^+$	$(1.32 \pm 0.20 \pm 0.12) \times 10^{-5}$
$\psi(3686) \rightarrow \gamma\chi_{c2}, \chi_{c2} \rightarrow K^-\Lambda\bar{\Xi}^+$	$(1.68 \pm 0.26 \pm 0.15) \times 10^{-5}$
$\chi_{c0} \rightarrow K^-\Lambda\bar{\Xi}^+$	$(1.96 \pm 0.31 \pm 0.16) \times 10^{-4}$
$\chi_{c1} \rightarrow K^-\Lambda\bar{\Xi}^+$	$(1.43 \pm 0.22 \pm 0.12) \times 10^{-4}$
$\chi_{c2} \rightarrow K^-\Lambda\bar{\Xi}^+$	$(1.93 \pm 0.30 \pm 0.15) \times 10^{-4}$

These BRs are measured at first time!

Observation of two new excited baryon states in $\psi(3686) \to p\bar{p}\,\pi^0$

PRL 110, 022001(2013)

- **Two body decay:**

PWA results

➢ $\psi(3686) \to p\,\bar{N}^*$, $\bar{N}^* \to \bar{p}\,\pi^0$ +c.c

$\to X\pi^0$, $X \to p\,\bar{p}$

➢ Isospin conservation: Δ suppressed;

- **The best solution:**

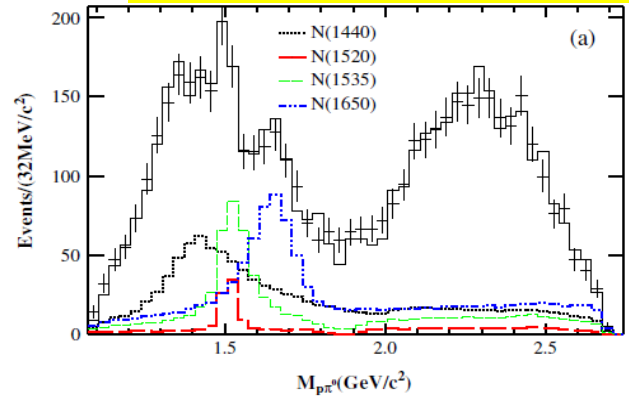
N(1440),N(1520),N(2090),N(1535),N(1650), N(1720),N(2300),N(2570)

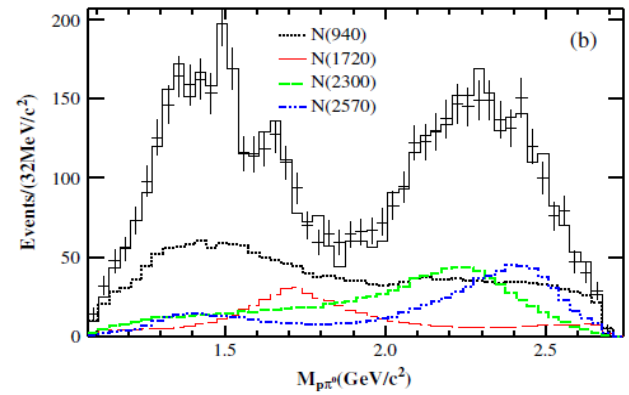
(J^{PC});

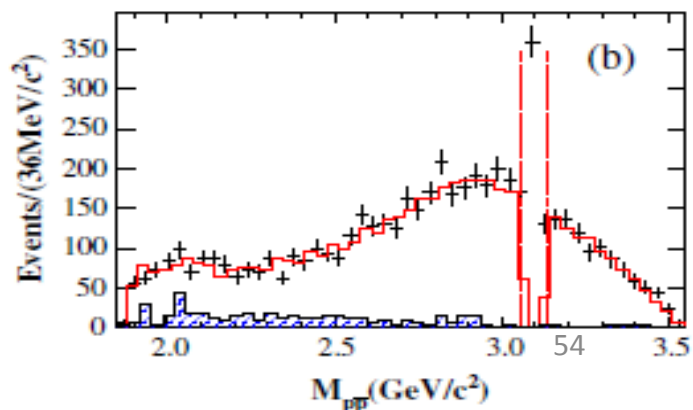
- **No significant evidence.**

➢ N(1885) and N(2065), $p\,\bar{p}$ enhancement;

➢ The uncertainties from additional possible resonances are considered.







Observation of two new excited baryon states in $\psi(3686) \to p\bar{p}\,\pi^0$

PRL 110, 022001(2013)

Resonance	$M(\mathrm{MeV}/c^2)$	$\Gamma(\mathrm{MeV}/c^2)$	ΔS	ΔN_{dof}	Sig.
$N(1440)$	1390^{+11+21}_{-21-30}	$340^{+46+70}_{-40-156}$	72.5	4	11.5σ
$N(1520)$	1510^{+3+11}_{-7-9}	115^{+20+0}_{-15-40}	19.8	6	5.0σ
$N(1535)$	1535^{+9+15}_{-8-22}	120^{+20+0}_{-20-42}	49.4	4	9.3σ
$N(1650)$	1650^{+5+11}_{-5-30}	150^{+21+14}_{-22-50}	82.1	4	12.2σ
$N(1720)$	1700^{+30+32}_{-28-35}	$450^{+109+149}_{-94-44}$	55.6	6	9.6σ
N(2300)$_{(1/2)^+}$	$\mathbf{2300^{+40+109}_{-30-0}}$	$\mathbf{340^{+30+110}_{-30-58}}$	**120.7**	**4**	$\mathbf{15.0\sigma}$
N(2570)$_{(5/2)^-}$	$\mathbf{2570^{+19+34}_{-10-10}}$	$\mathbf{250^{+14+69}_{-24-21}}$	**78.9**	**6**	$\mathbf{11.7\sigma}$

- ***B***$(\psi(3686) \to p\bar{p}\pi^0) = (1.65 \pm 0.03 \pm 0.15) \times 10^{-4}$
- 2 new resonances
- No significant N(1885) or N(2065)(<5σ)

N(1535) in ψ(3686)→p p̄ η

PRD 88,032010(2013)

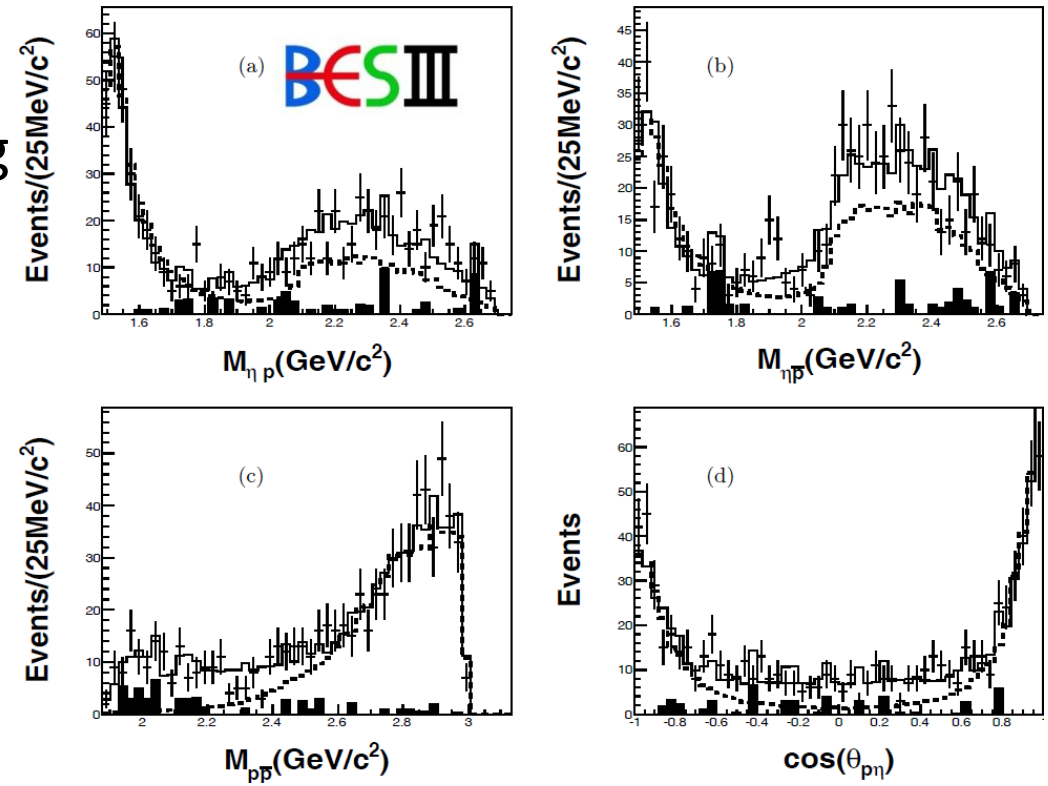
- **PWA results.**
- **Best solution**: N(1535) combined with an interfering phase space;
- N(1535):

➢ $M=1524\pm5^{+10}_{-4}$ MeV/c^2

➢ $\Gamma=130^{+27}_{-24}{}^{+56}_{-10}$ MeV/c^2

•$p\bar{p}$ enhancement <3σ;

•Supressed compare with "12% rule":

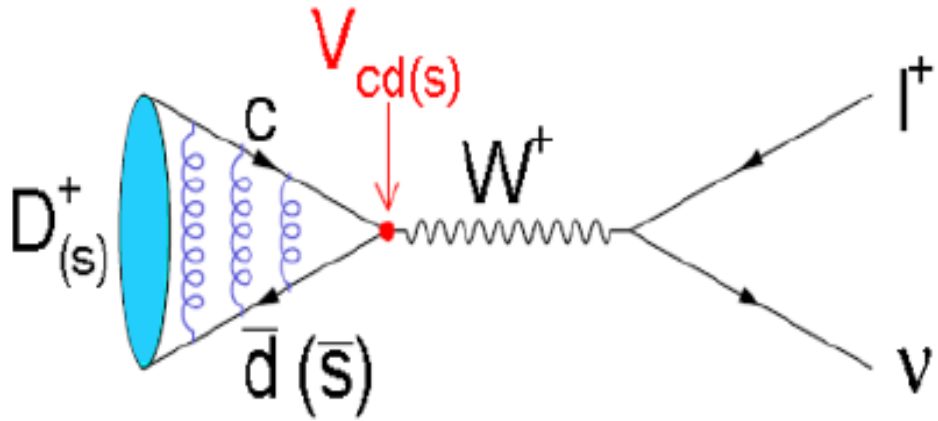


$$Q_{p\bar{p}\eta} = \frac{B(\psi(2S)\to\eta p\bar{p})}{B(J/\psi\to\eta p\bar{p})} = (3.2\pm0.4)\%$$

Charm

- Leptonic decays
  - $D^{+} \rightarrow \mu\nu$
- Semi-leptonic decays
  - Measurement of y_{CP} in $D^0\bar{D}^0$ oscillation

Leptonic decays



SM prediction:

$$\Gamma(D^+_{(s)} \to \ell^+ \nu_\ell) = \frac{G_F^2 f^2_{D^+_{(s)}}}{8\pi} |V_{cd(s)}|^2 m_\ell^2 m_{D^+_{(s)}} \left(1 - \frac{m_\ell^2}{m^2_{D^+_{(s)}}}\right)^2$$

Allows us to explore precision measurements of :

- Decay constants $f_{D^+_{(s)}}$ using input from $|V_{cd(s)}|^{\text{CKMfitter}}$
- CKM matrix elements $|V_{cd(s)}|$ using input from $f^{LQCD}{}_{D^+_{(s)}}$

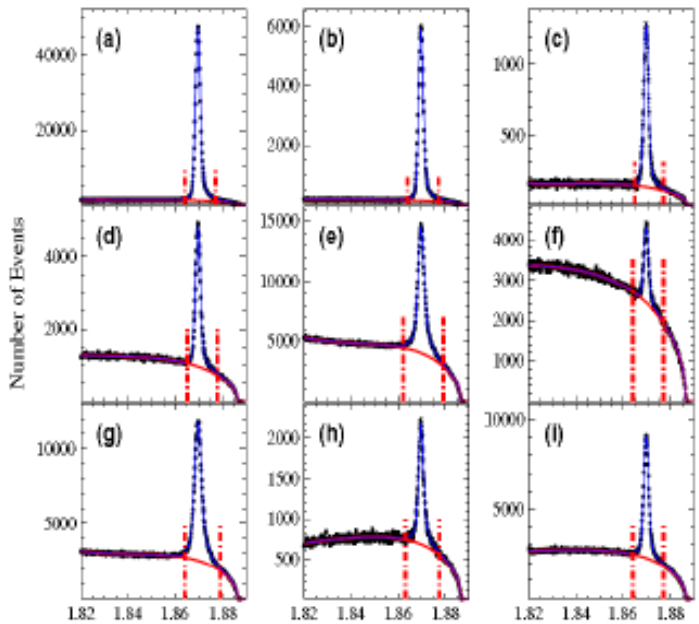
Measurement of $\mathcal{B}(D^+\to\mu^+\nu_\mu)$, f_{D^+} and V_{cd}

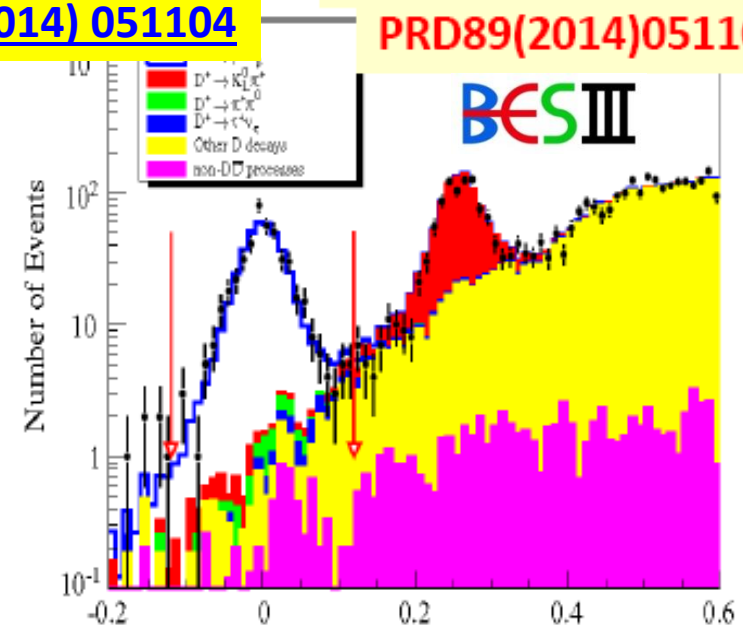
$e^+e^-\to\psi(3770)\to D^+D^-$

PRD89 (2014) 051104

2.92 fb^{-1} data@ 3.773 GeV

PRD89(2014)051104R





$$M_{BC}[\mathrm{GeV/c^2}] = \sqrt{E_{beam}^2 - |\vec{P}_{D\,Rec}|^2}$$

$$M_{miss}^2[\mathrm{GeV}^2/\mathrm{c}^4] = E_{miss}{}^2 - |\vec{p}_{miss}|^2$$

$N_{D^-_{tag}} = (170.31 \pm 0.34)\times 10^4$

$B[D^+\to\mu^+\nu] = (3.71\pm0.19\pm0.06)\times 10^{-4}$

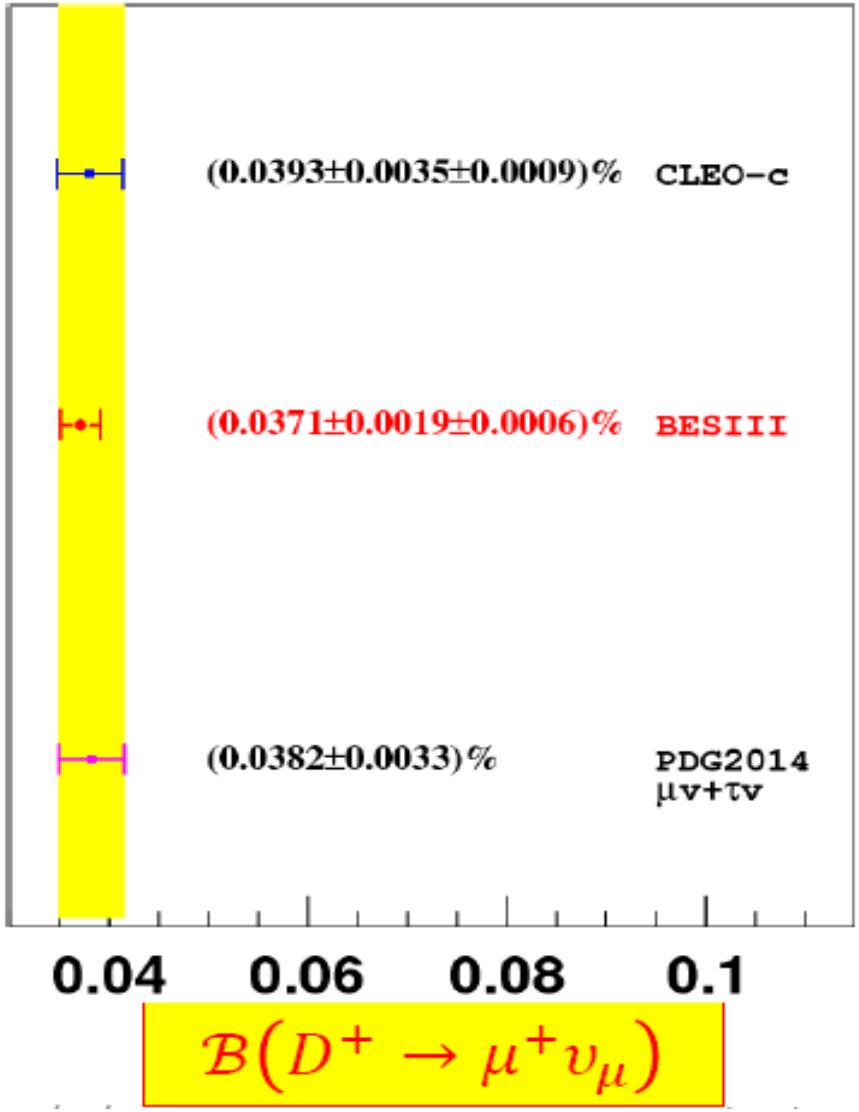
Input t_{D+}, m_{D+}, $m_{\mu+}$ on PDG and $|V_{cd}|$=0.22520 ±0.00065 from CKM-Fitter

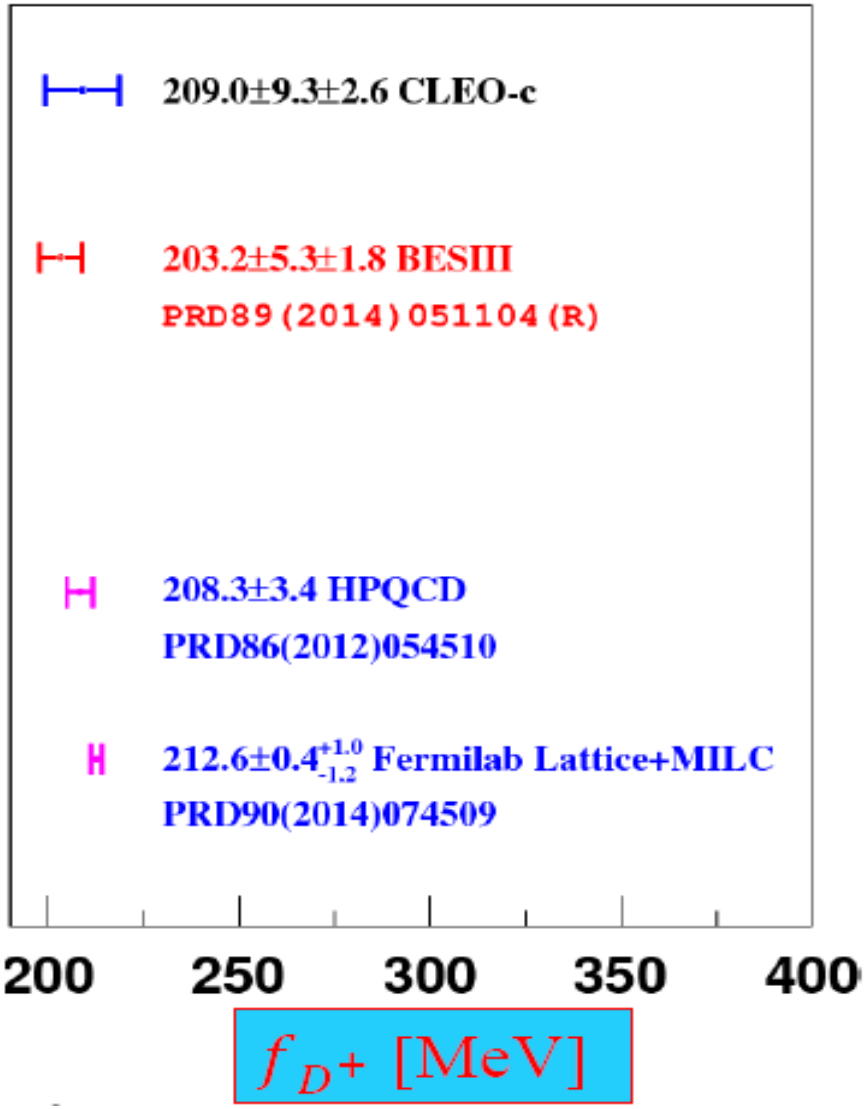
$f_{D^+} = (203.2 \pm 5.3 \pm 1.8)$ MeV

Input t_{D+}, m_{D+}, $m_{\mu+}$ on PDG and LQCD calculated f_{D+}=207±4 MeV[PRL100(2008)062002]

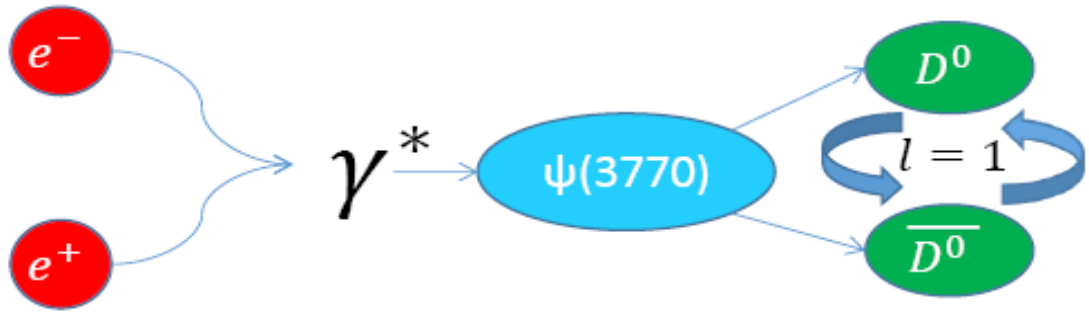
$|V_{cd}| = 0.2210 \pm 0.0058 \pm 0.0047$

Comparison of of $\mathcal{B}(D^+ \to \mu^+ \upsilon_\mu)$, f_{D^+}





Using Semi-leptonic decays to measure y_{CP}



If D^0 in CP eigenstate, $\overline{D^0}$ must be in opposite CP eigenstate

Total decay width of CP eigenstates:

$$\Gamma_{CP\pm} = \Gamma(1 \mp y_{CP})$$

Semi-leptonic $(D \to l)$ decay width is only sensitive to flavor content

Therefore, Semi-leptonic decay from a CP eigenstate

$$\mathcal{B}_{D_{CP\pm}\to l} \approx \mathcal{B}_{D\to l}(1 \mp y_{CP})$$

$$\therefore\ y_{CP} \approx \frac{1}{4}\left(\frac{\mathcal{B}_{D_{CP-}\to l}}{\mathcal{B}_{D_{CP+}\to l}} - \frac{\mathcal{B}_{D_{CP+}\to l}}{\mathcal{B}_{D_{CP-}\to l}}\right)$$

This can be obtained through Single and double tag yields and efficiencies

$$\mathcal{B}_{D_{CP\mp}\to l} = \frac{N_{CP\pm;l}}{N_{CP\pm}} \cdot \frac{\varepsilon_{CP\pm}}{\varepsilon_{CP\pm;l}}$$

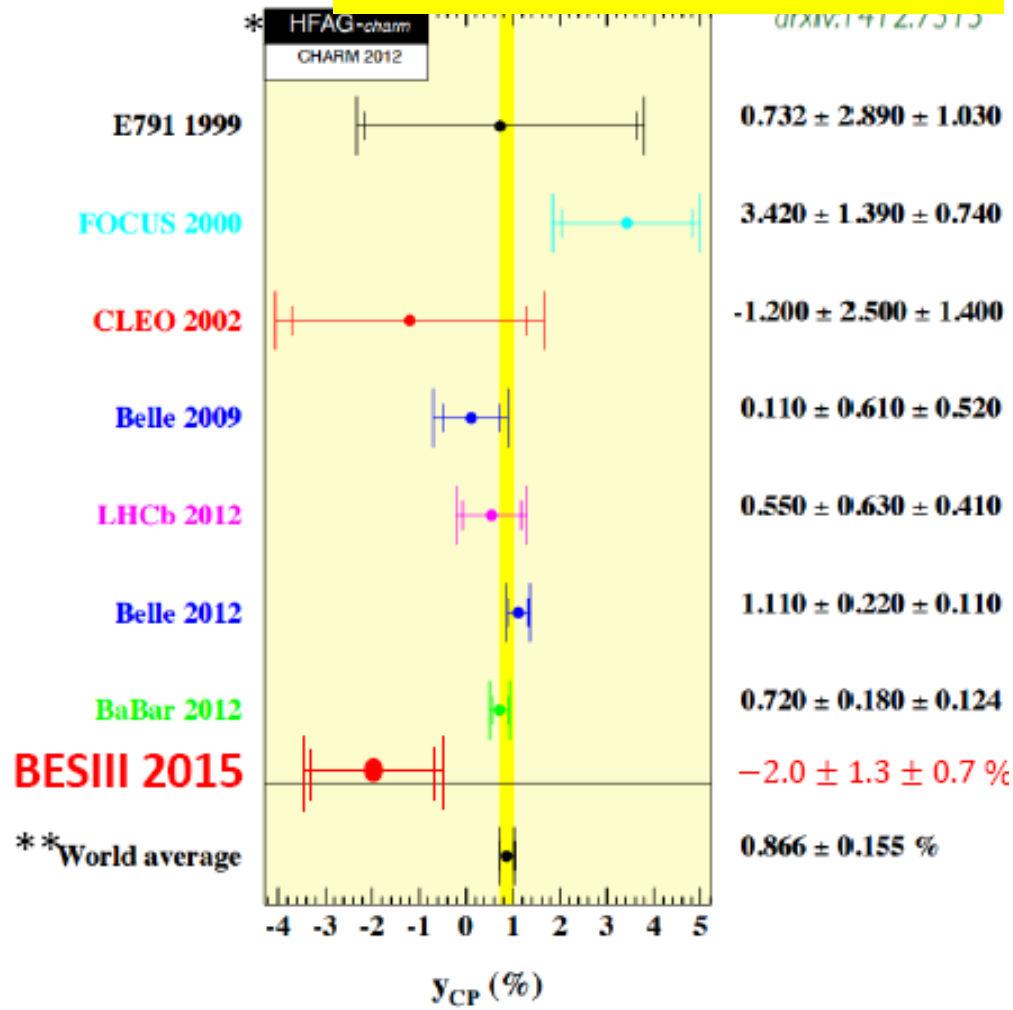
y_{cp} results

Phys.Lett. B744 (2015) 339-346

$$\mathcal{B}_{D_{CP\mp}\to l} = \frac{N_{CP\pm;l}}{N_{CP\pm}} \cdot \frac{\varepsilon_{CP\pm}}{\varepsilon_{CP\pm;l}}$$

Branching ratios of Kev and $K\mu v$ are combined to get $\mathcal{B}_{D_{CP\mp}\to l}$

Results are combined from different CP modes into a global fit using standard weighted least-square method.



Result:

$$y_{cp} = (-2.0 \pm 1.3_{(\mathrm{stat})} \pm 0.7_{(\mathrm{sys})})\%$$

Phys.Lett.B 744(2015) 339-346

*Edited to compare with BESIII result

**BESIII not included in world average

Summary &outlook

- Many progress @ BESIII recently;
  - ***XYZ decaymodes, espectially Zc process,***
  - ***new measurement about important parameters&constants,***
  - ***newly discovered resonance…***
- More results are on the way!
- BESIII may continue data taking until 2020-2022 .

Thanks very much for your attention!

Back Up

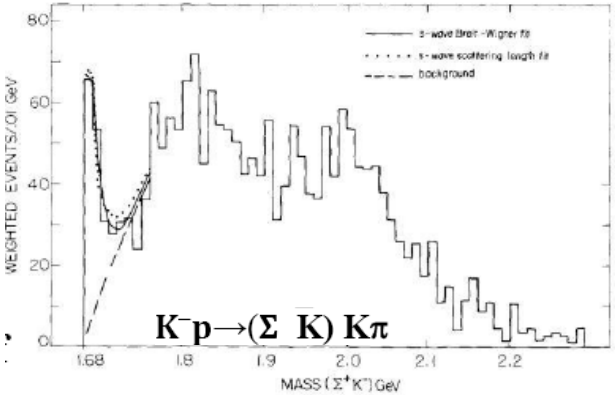
Light Hadron Spectroscopy

- Observation and Spin-Parity Determination of the X(1835) in J/ ψ→γKsKsη
- The study of J/→ηϕππ
- Observation of the electromagnetic doubly OZI-suppressed decay J/ψ → φπ0
- Observation of the isospin-violating decay J/ψ → φπ0f 0980
- Observation of the Dalitz decay η0 → γete−
- Observation of electromagnetic Dalitz decays J/*ψ* → *Pete−*
- *Observation of* J/*ψ* → *omegaete−*

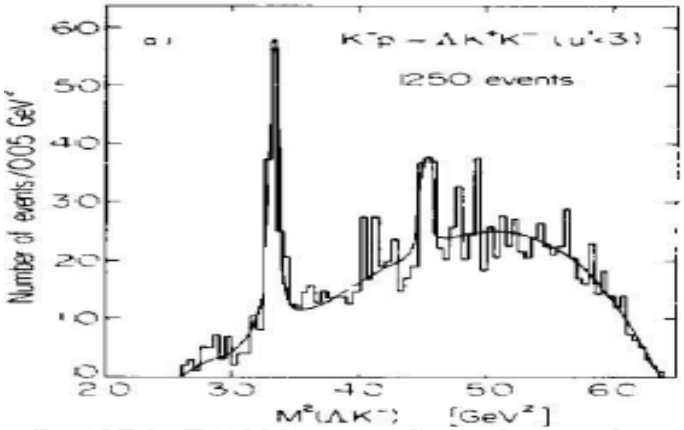
- Measurement of the proton form factor by studying ete− → p¯

Observation of two hyperons $\Xi^-(1690)$ and $\Xi^-(1820)$ in $\psi(3686) \rightarrow K^+\Lambda\ \Xi^+ + c.c.$

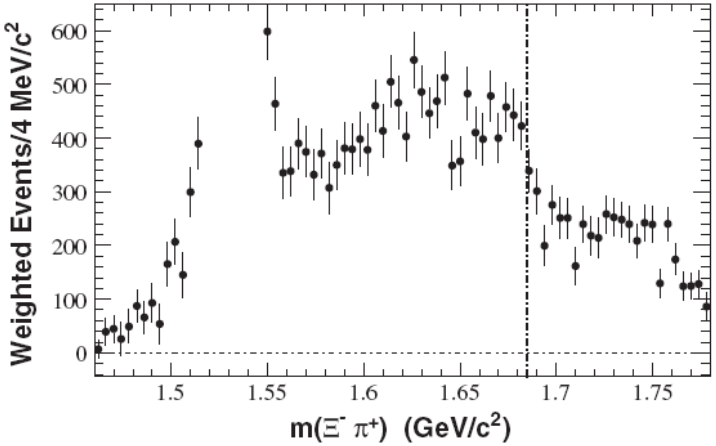
- $\Xi^-(1690)$ and $\Xi^-(1820)$ are firmly established.



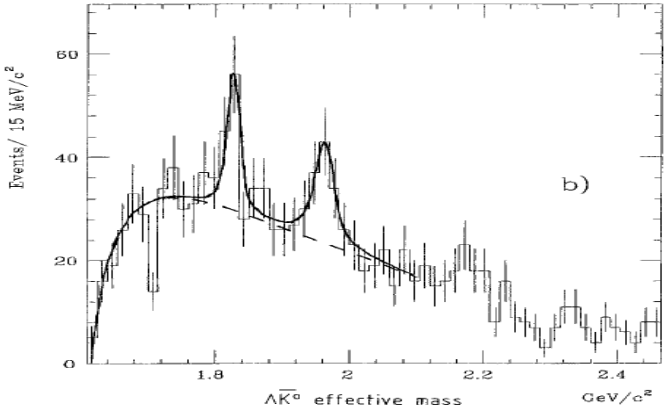
In 1978, the $\Xi(1690)$ was first observed in the $(\Sigma\ \bar{K})$ final state in the reaction $K^-p \rightarrow (\Sigma\ \bar{K})\ K\pi$ at CERN



In 1976, $\Xi(1820)$ was first observed in $K^-\Lambda$ mass spectrum in Kp scattering at CERN



In 2008, BABAR determined spin-parity of $\Xi(1690)$ to be $J^P = 1/2^-$ in $\Lambda_c^+ \rightarrow \Xi^-\pi^+K^+$



In 1987, CERN-SPS experiment determined spin-parity of $\Xi(1820)$ to be $J^P = 3/2^-$