Recent highlights at BESIII

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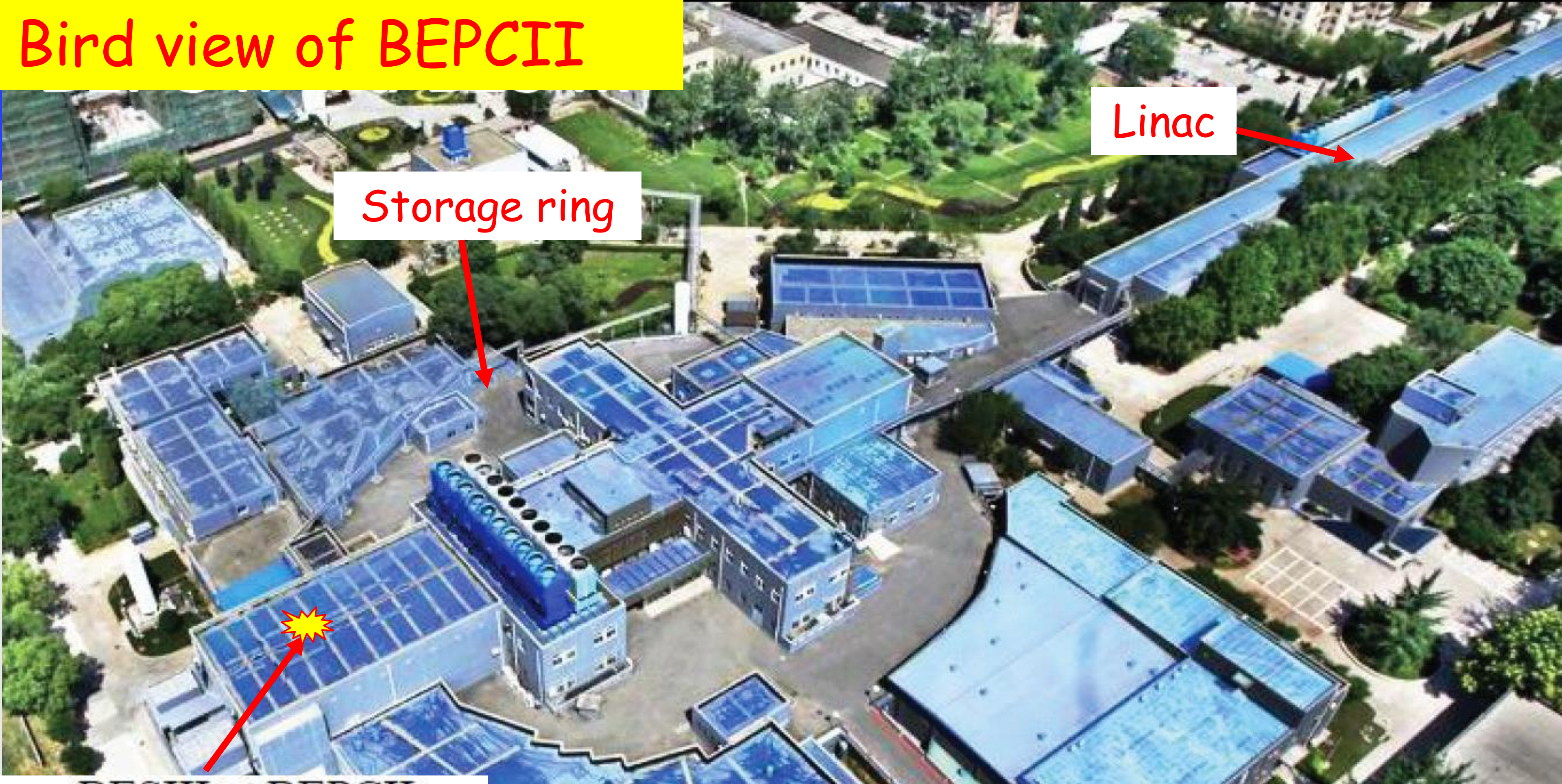
(for the BESIII Collaboration)

YongPyong-High1 2016

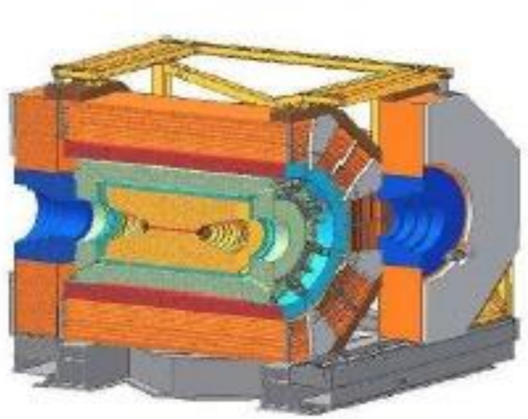
Joint Winter Conference on Particle Physics, String and Cosmology

Jan., 30−Feb.,4, 2016, High1 resort, Korea

Bird view of BEPCII



BESIII at BEPCII



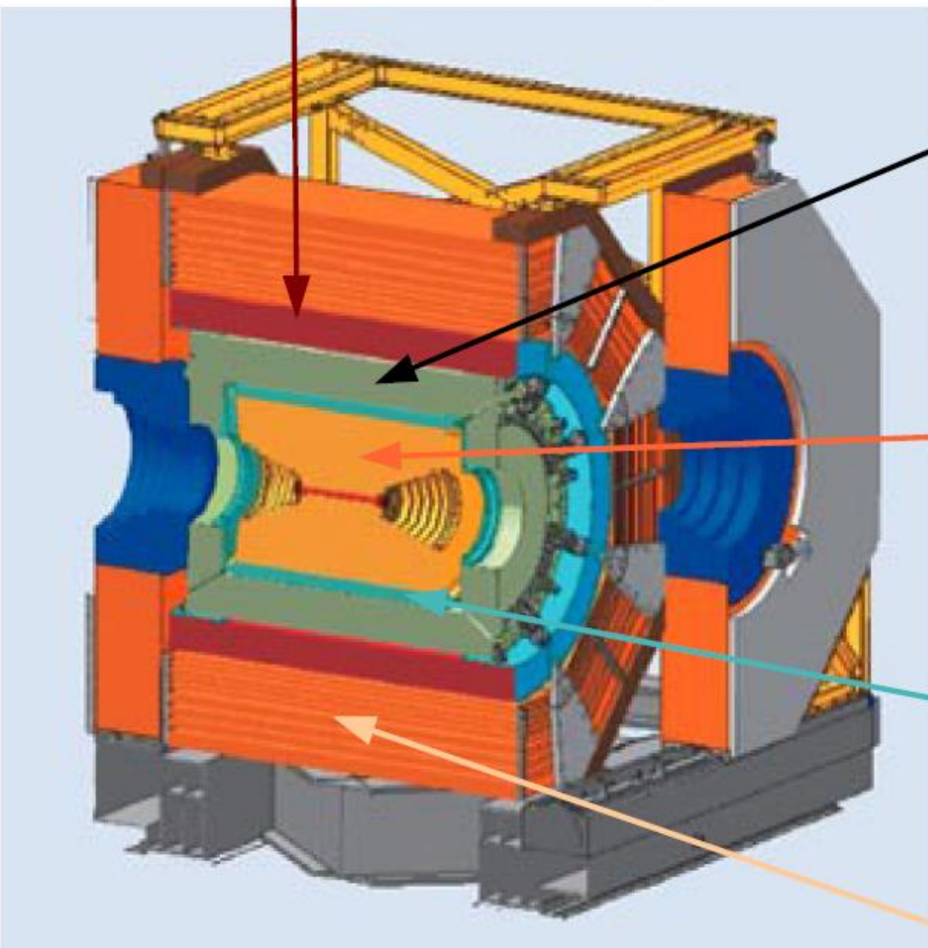
τ −charm physics

- Charmonium(-like) physics
- Light hadron spectroscopy
- Charm physics
- τ−QCD physics

The BES-III detector

NIM A614, 345(2010)

Super conducting magnet: 1 T



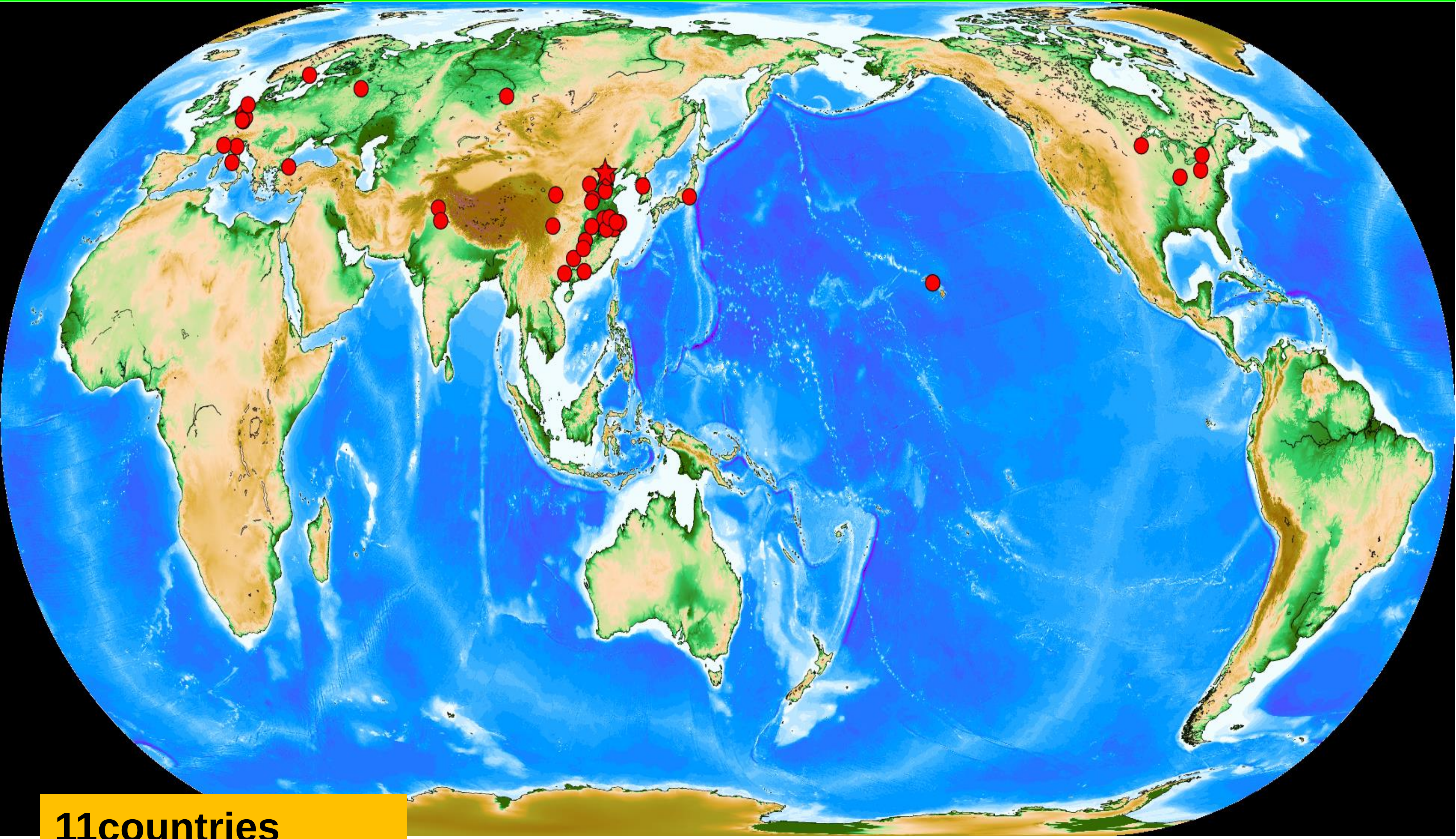
EMC: CsI cristal
- Energy resolution: **2.5% @1GeV**
- Spatial resolution: **6mm**

MDC:
- Spatial resolution: σ_{xy} **= 120μm**
- Momentum resolution:**0.5% @ 1GeV**
- **dE/dx** resolution: 6%

TOF:
Time resolution: **100ps** (barrel)
110ps (endcaps)

Muon ID:
9 layers RPC, 8 for endcaps

The BESIII Collaboration



11countries
58 institutes
~450 members

Outline

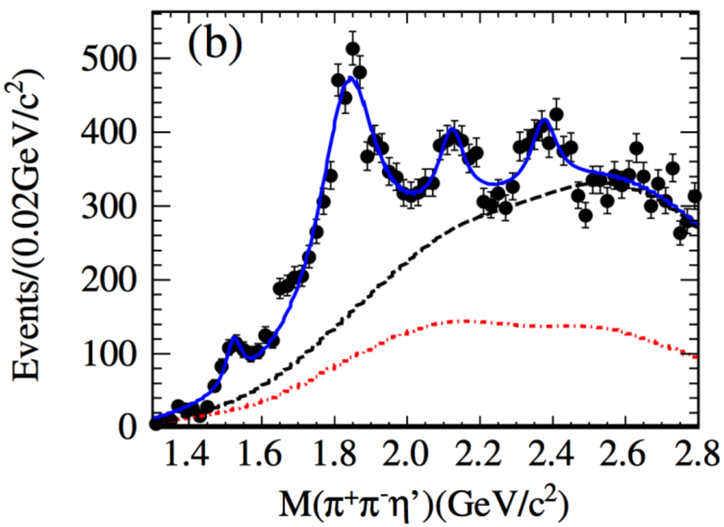
- Hadron spectroscopy
- Charmonium (charmonium-like) physics
- Charm physics
- R-QCD
- Summary

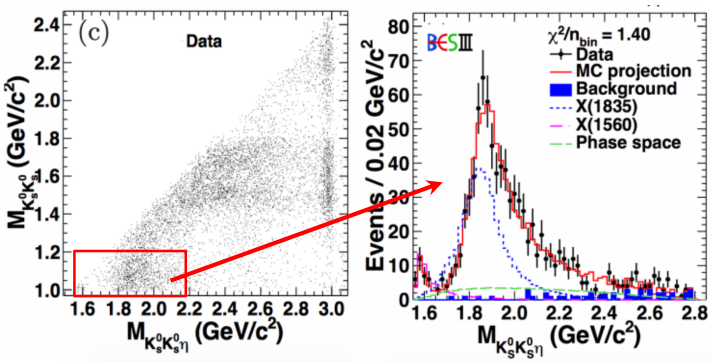
Hadron spectroscopy

- **X(1835) observation**
- **$J/\psi \rightarrow \eta\phi\pi^+\pi^-$**
- **Dalitz decay of $\eta' \rightarrow \gamma e^+e^-$**
- **$\psi' \rightarrow K^-\Lambda\Xi^+$ +c.c. && $\psi' \rightarrow \gamma K^-\Lambda\Xi^+$ +c.c.**

Overview of X(1835) observation

- First observation in $J/\psi \to \gamma\pi\pi\eta'$ at BESII, later confirmed at BESIII
- Second observation in $J/\psi \to \gamma K_S^0 K_S^0 \eta$





$X(1835) \to f_0(980)\eta$ (>12.9σ)

$m = 1844 \pm 19^{+16}_{-25}\ \mathrm{MeV}/c^2$

$\Gamma = 192^{+20+62}_{-17-43}\ \mathrm{MeV}$

$X(1560) \to f_0(980)\eta$ (>8.9σ)

$m = 1565 \pm 8^{+0}_{-63}\ \mathrm{MeV}/c^2$

$\Gamma = 45^{+14+21}_{-13-28}\ \mathrm{MeV}$

- Interpretations include glueball, pp bound state, excited η meson
- Two additional structures above 2 GeV/c^2 are observed

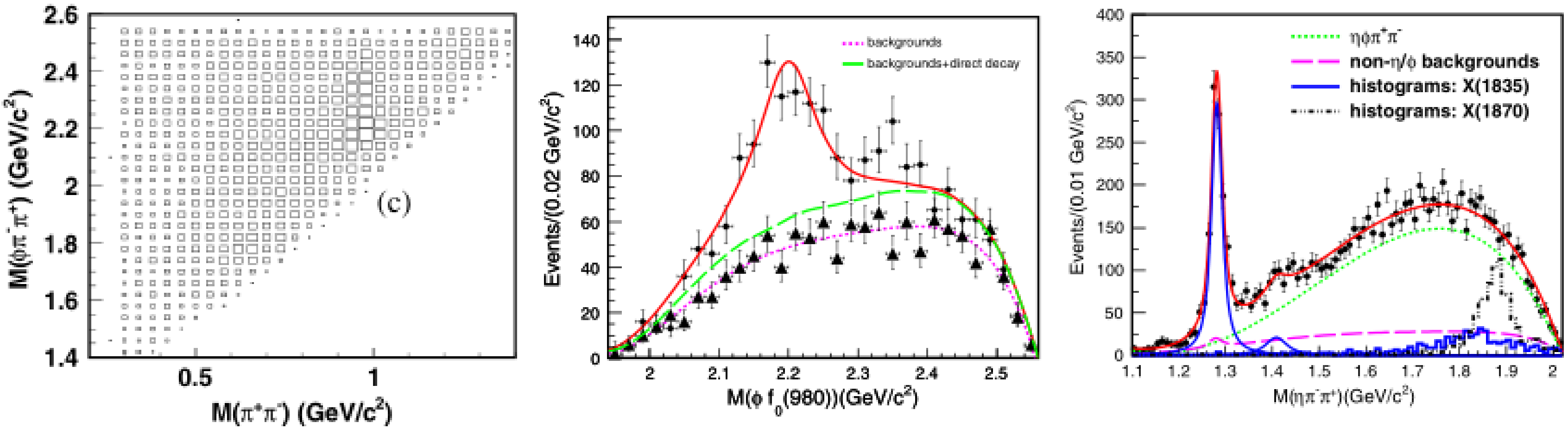
- Structure at ~1.85 GeV
- Strong correlation with enhancement at KsKs mass threshold (interpretated as $f_0(980)$)
- Two resonance pseudoscalar components (BW parameterization) required in best fit hypothesis

Phys. Rev. Lett. 106,072002 (2011)

Phys. Rev. Lett. 115,091803 (2015)

$J/\psi \to \eta\phi\pi^+\pi^-$

- Confirm the observed Y(2175) and clarify its nature
- Investigate the properties of f(1285), η(1295), and η(1405)/η(1475) resonances
- Search for the observed X(1835) and X(1870) in different decay modes.



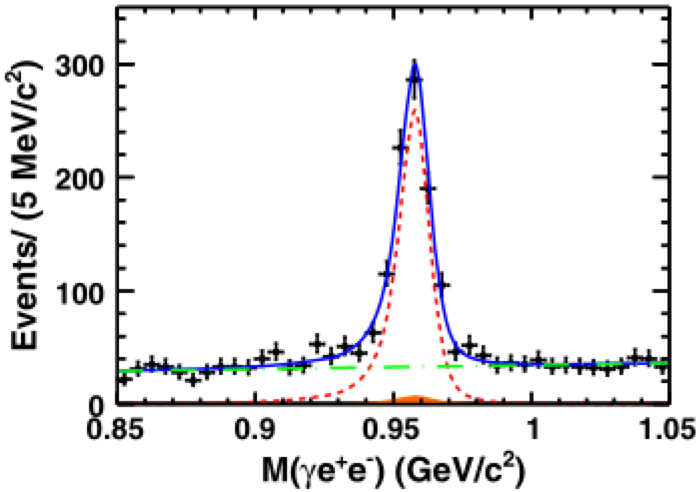
- ➢ **Y(2175) is clearly observed with a significance of >10σ**
- ➢ **f1(1285) is observed significantly**
- ➢ **No evidence of X(1835) and X(1870) is found.**

Phys. Rev. D91,052017 (2015)

Dalitz decay of $\eta' \to \gamma e^+ e^-$

- **Reveal the inner structure of the meson**
- **Study the transition form factor → providing information for the muon anomalous magnetic moment.**

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



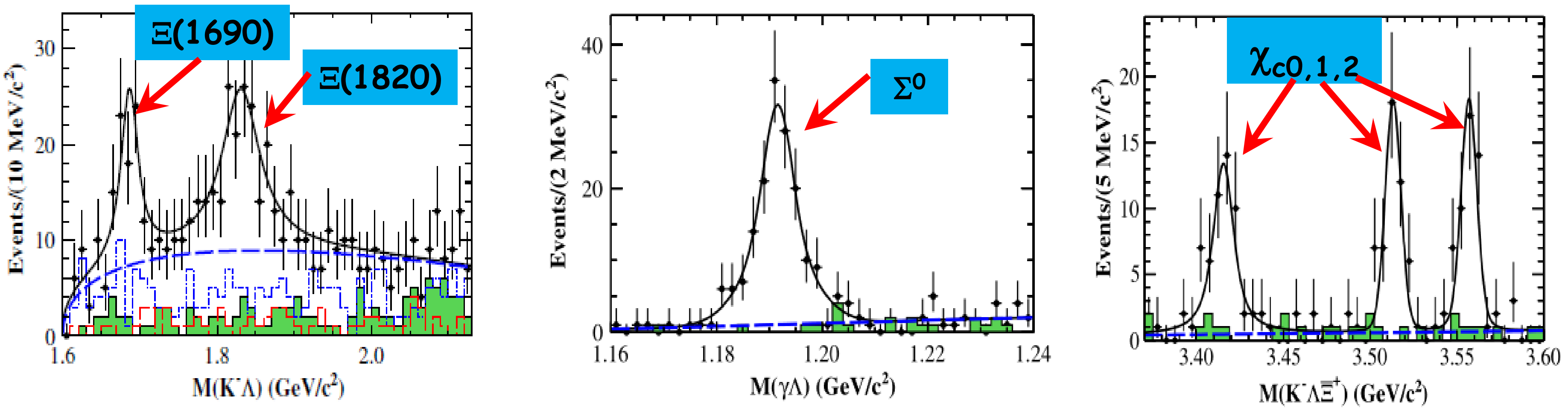
$|\mathrm{QED}(q^2)|$ represents the calculable QED part for a point-like meson

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

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

Phys. Rev. D92,012001 (2015)

$\psi' \to K^- \Lambda \bar{\Xi}^+$ +c.c. && $\psi' \to \gamma K^- \Lambda \bar{\Xi}^+$ +c.c.



- For $\psi' \to K^- \Lambda \bar{\Xi}^+$ +c.c., two structures around 1690 and 1820 MeV/c^2 are observed in M(KΛ) mass spectrum.
- For $\psi' \to \gamma K^- \Lambda \bar{\Xi}^+$ +c.c. , $\psi' \to \Sigma^0 K^- \bar{\Xi}^+$ + c.c. and $\chi_{cJ} \to \bar{K}^- \Lambda \Xi^+$ + c.c. are observed for the first time.

TABLE IV. Summary of the branching fractions measurements, where the first uncertainty is statistical and the second systematic.

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

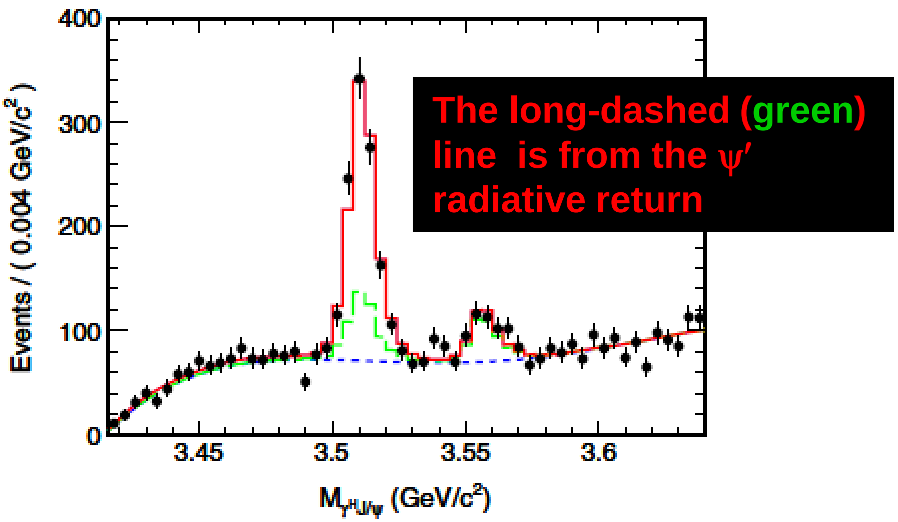
Phys. Rev. D92,012001 (2015)

Charmonium (like) physics

- $\psi(3770) \to \gamma\chi_{cJ}$
- DOZI decay: $J/\psi \to \phi\pi^0$
- XYZ study

$\psi(3770)\rightarrow\gamma\chi_{cJ}$ ($\chi_{cJ}\rightarrow\gamma J/\psi$)

- Search for the evidence of $\psi(3770)$ non-DD decay mode if it contains additional light quarks or gluons except $c\bar{c}$
- Test the S-D mixing model: $\psi=1^3D_1$ (dominant) + 2^3S_1 (small)



Phys. Rev. D91,092009 (2015)

TABLE II. Comparison of measured partial widths with theoretical predictions, where ϕ is the mixing angle of the S-D mixing model.

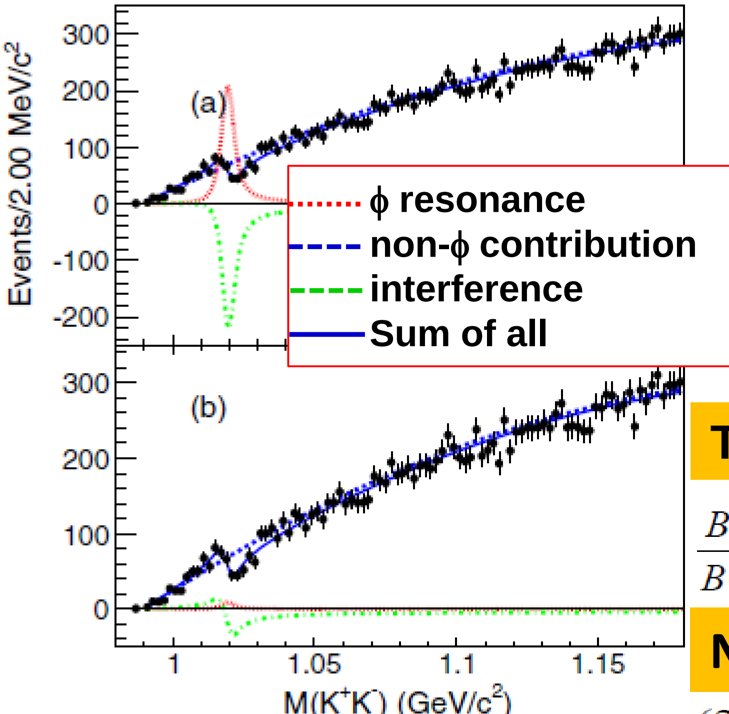
Experiment/theory	$\Gamma(\psi(3770)\rightarrow\gamma\chi_{cJ})$ (keV)	
	$J=1$	$J=2$
This work	$67.5\pm4.1\pm6.7$	<17.4
Ding-Qin-Chao [12]		
Nonrelativistic	95	3.6
Relativistic	72	3.0
Rosner S-D mixing [13]		
$\phi=12^\circ$ [13]	73 ± 9	24 ± 4
$\phi=(10.6\pm1.3)^\circ$ [32]	79 ± 6	21 ± 3
$\phi=0^\circ$ (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

$$\mathcal{B}(\psi(3770)\rightarrow\gamma\chi_{c1})=(2.8\pm0.5\pm0.4)\times10^{-3}$$

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

$J/\psi \to \phi\pi^0$

- **This decay mode is highly suppressed due to the DOZI rule.**
- **Such a search is helpful to understand the ω–ϕ mixing and SU(3) flavor symmetry breaking.**



Solution		N^{sig}	δ	$2\Delta \log \mathcal{L}/N_f$	Z
I	(a)	838.5 ± 45.8	$-95.9^\circ \pm 1.5^\circ$	$45.8/2$	6.4σ
II	(b)	35.3 ± 9.3	$-152.1^\circ \pm 7.7^\circ$	$45.8/2$	6.4σ

Branching fraction:

I: $[2.94 \pm 0.16(\text{stat.}) \pm 0.16(\text{syst.})] \times 10^{-6}$

II: $[1.24 \pm 0.33(\text{stat.}) \pm 0.30(\text{syst.})] \times 10^{-7}$

Theory prediction (Phys. Rev. 32, 2961 (1985)

$$\frac{B(\phi\pi^0)}{B(\omega\pi^0)} = \left(\frac{p_\phi}{p_\omega}\right)^3 \frac{(r_E \tan\theta_V - 1/\sqrt{2})^2}{(r_E + \tan\theta_V/\sqrt{2})^2} \Rightarrow$$

$r_E = 1$ (nonet symmetry)

$\theta_V = \arctan(1/\sqrt{2})$ (ideal $\omega-\phi$ mixing)

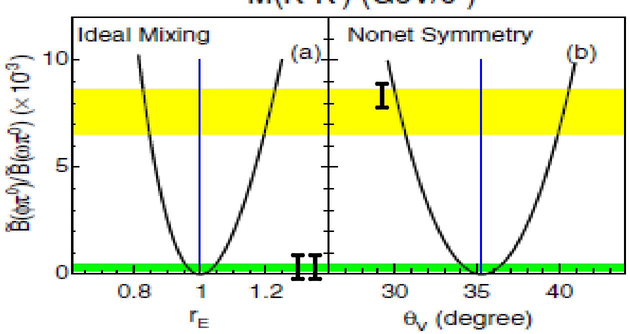
Nonet symmetry breaking strength $\delta = r_E - 1$ (a)

$(21.0 \pm 1.6)\%$ or $(-16.4 \pm 1.0)\%$ (solution I)

$(3.9 \pm 0.8)\%$ or $(-3.7 \pm 0.7)\%$ (solution II)

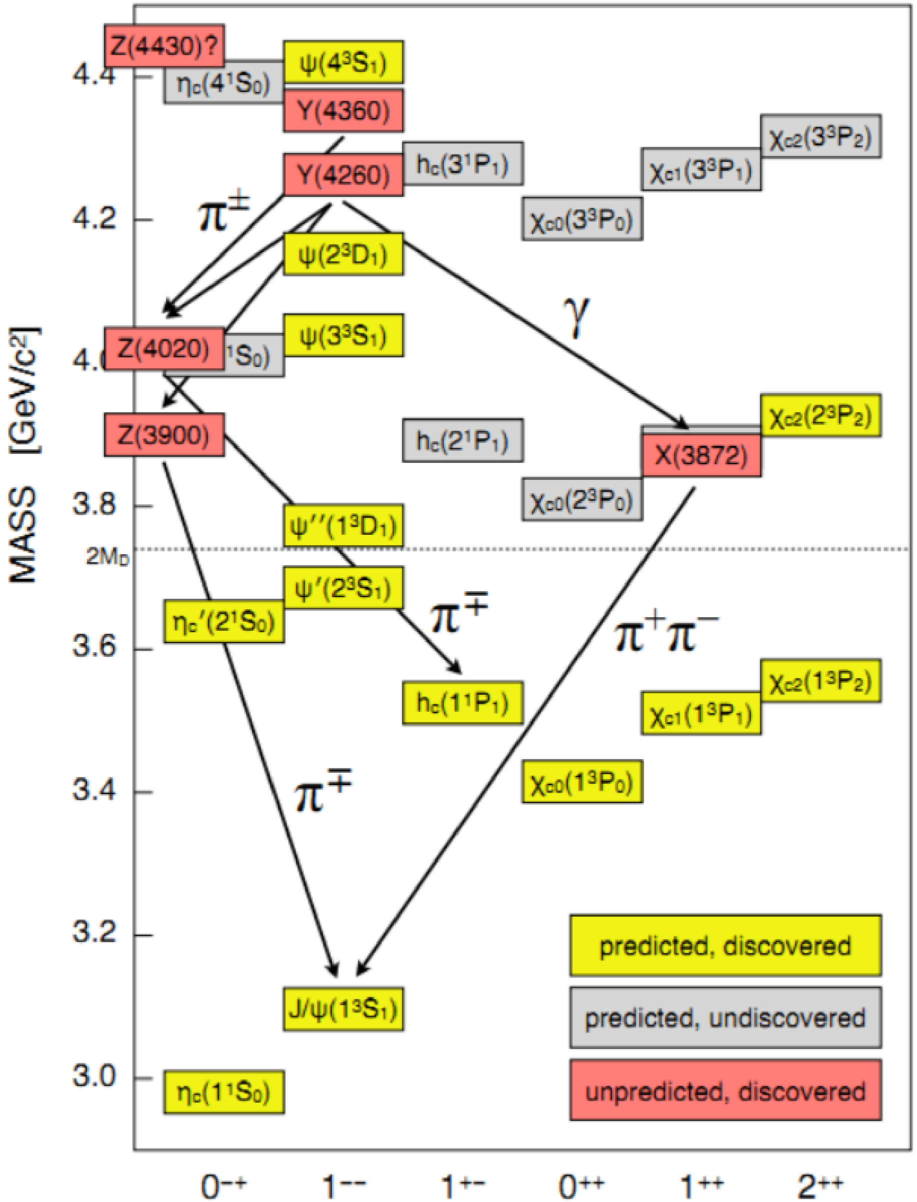
Nonet symmetry: $\phi_V = |\theta_V - \theta_V^{ideal}| = 4.97^\circ \pm 0.33^\circ$ (solution I)

$= 1.03^\circ \pm 0.19^\circ$ (solution II)



In fact, ϕ_V=3.84° (PDG), or 3.34°±0.09°, disagree with either → **Nonet symmetry is first indication**

Charmnonium spectrum



- Below the open charm threshold the spectrums well understood
  - very good agreement between predicted and discovered states
- Above the threshold the situation in more complex
  - only few of the predicted states have been found
  - in the last decades many new states have been observed with properties that are not consistent with expectations for charmonium: X, Y, Z

X states:

- charmonium-like states with $J^{PC} \neq 1^{--}$
- Observed in B decays, pp and pp collisions

Y states:

- charmonium-like states with $J^{PC} = 1^{--}$
- Observed in direct e + e - annihilation or in ISR

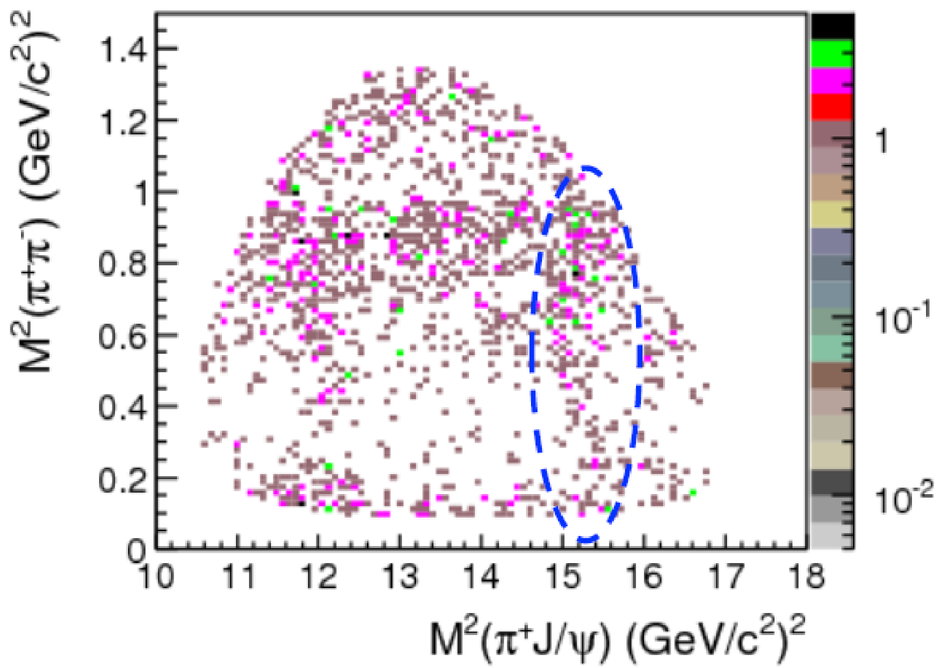
Z states:

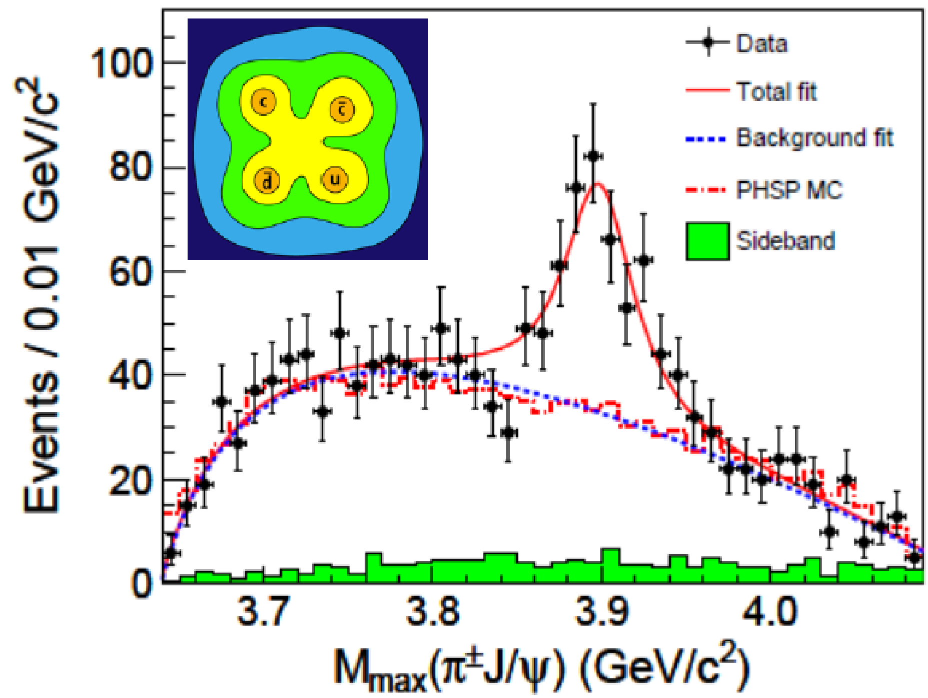
- Must contain at least a cc and a light qq pair

Z sates search at BESIII

$e^+e^- \to \pi^\pm Z_c(3900)^\mp \to \pi^+\pi^- J/\psi$

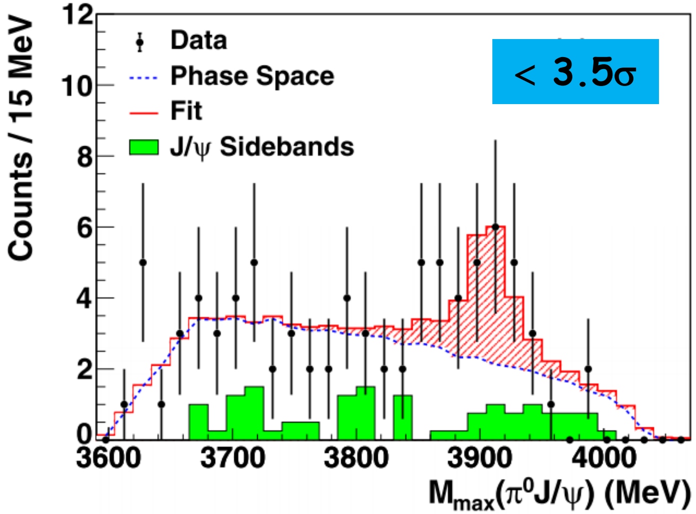
- Requiring J/ψ mass window: [3.08,3.12] GeV, we have 1595 signal events, with purity ~90%.



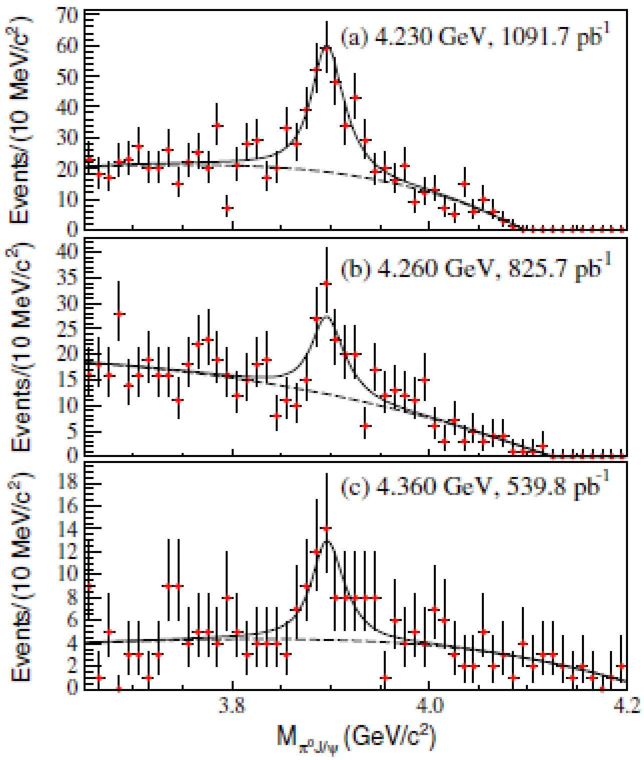


1. New charged resonance, exotic 4 quark hadron?!
2. Fit $M_{max}(\pi^\pm J/\psi)$ mass distribution; avoid cross counting
3. S-Wave Breit Wigner; phase space factor; efficiency corrected.
4. $M=(3899.0\pm3.6\pm4.9)$MeV; $\Gamma=(46\pm10\pm20)$MeV.
5. Statistical significance: $>8\sigma$, discovery!

$e^+e^- \rightarrow \pi^0 Z_c(3900)^0 \rightarrow \pi^0\pi^0 J/\psi$



CLEO-c data at 4.17GeV (PLB,727, 366)



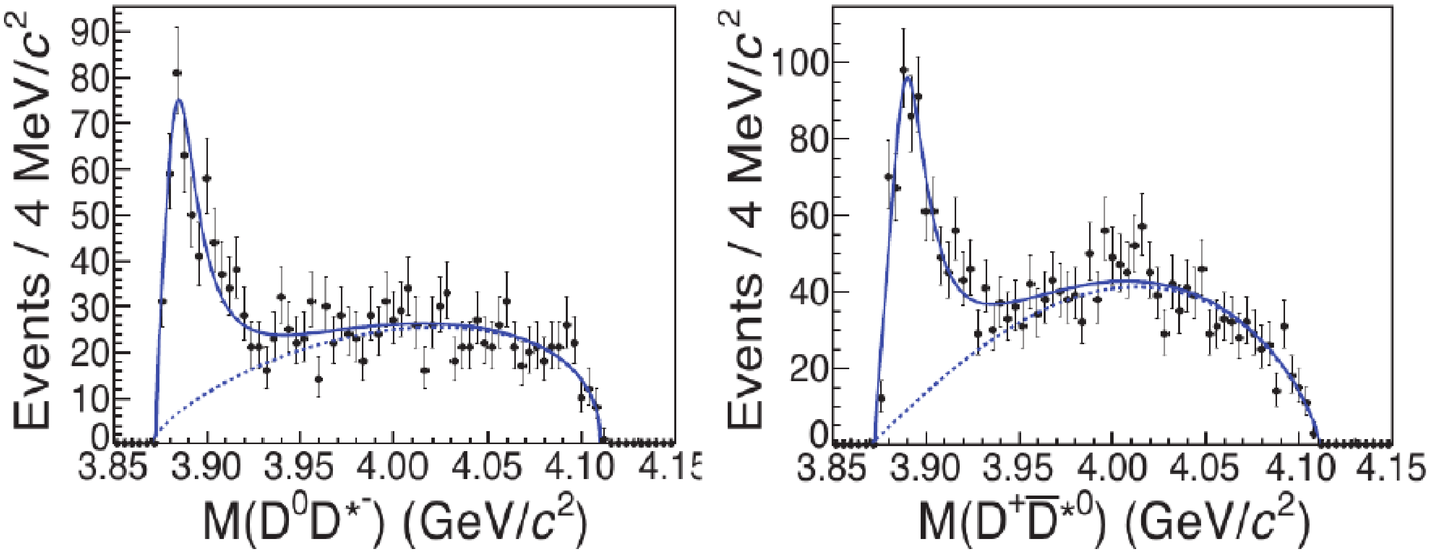
- $M = 3894.7 \pm 2.3(sta.) \pm 3.2(sys.)\ MeV/c^2$
- $\Gamma = 29.6 \pm 8.2(stat.) \pm 8.0(syst.)\ MeV$
- **statistical significance: 10.4 σ**

The mass and width for $Z_c(3900)^0$ are consistent with its charged partner. Therefore, an isospin triplet for $Z_c(3900)$ has been established.

PRL 115 112003 (2015)

$e^+e^- \rightarrow \pi^{\pm}Zc(3885)^{\mp} \rightarrow \pi^{\pm}(D\bar{D}^*)^{\mp}$

PRL 112, 022001 (2014)



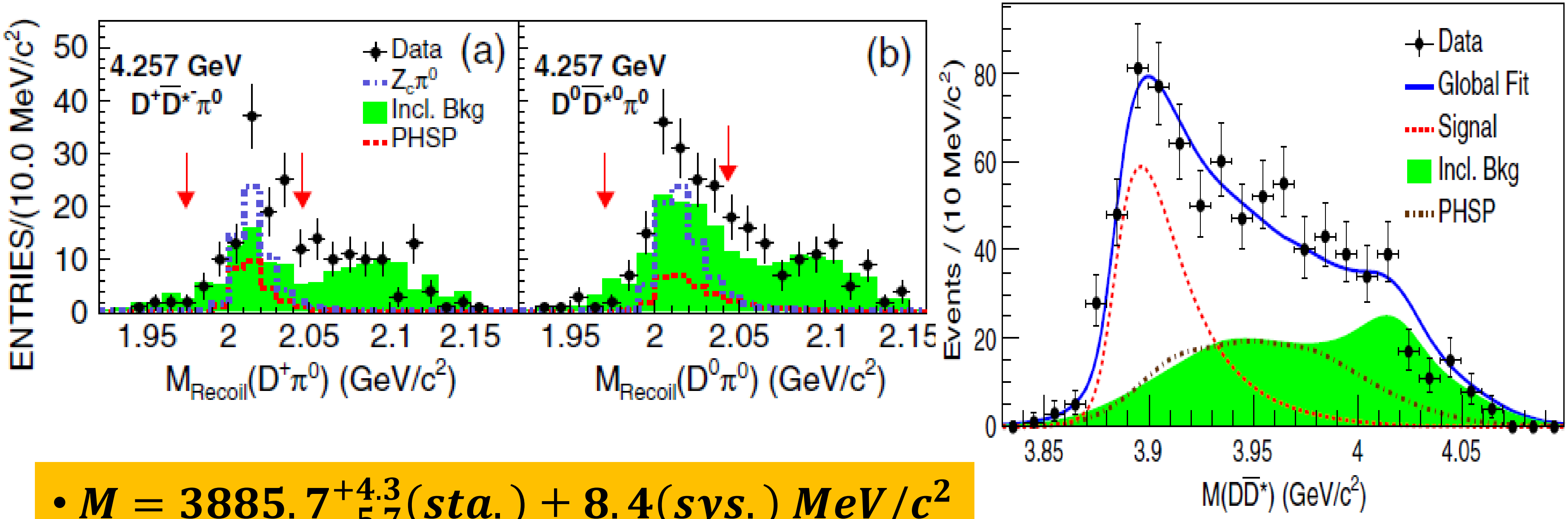
M = 3882.2±1.5 MeV
Γ = 24.6±3.3 MeV
N(Zc)=502 ± 41

M = 3885.5±1.5 MeV
Γ = 24.9±3.2 MeV
N(Zc)=710 ± 54

M = 3883.9±1.5±4.2 MeV
Γ = 24.8±3.3±11.0 MeV

$e^+e^- \to \pi^0 Z_c(3885)^0 \to \pi^0 D\bar{D}^*$

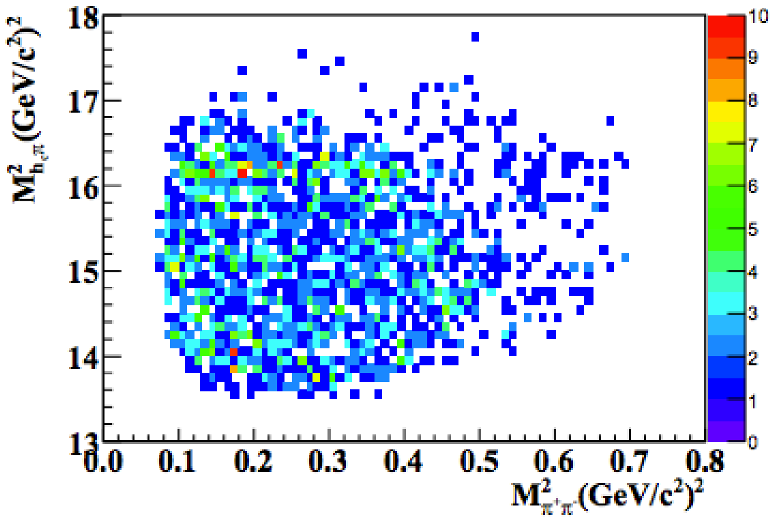
- Two decay modes, $\pi^0 D^+ \bar{D}^{*-}$+c.c., $\pi^0 D^0 \bar{D}^{*0}$ +c.c.
- Tagged D*by $M_{recoil}(D\pi)$
- Two energies are included, 4.226 &4.257 GeV

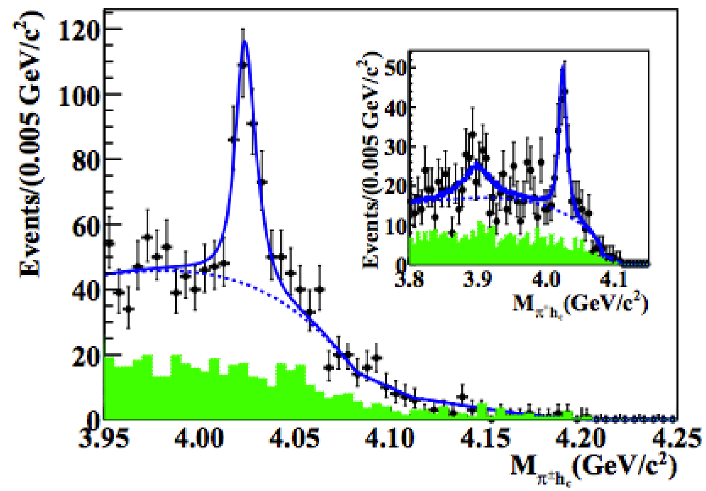


- $M = 3885.7^{+4.3}_{-5.7}(sta.) \pm 8.4(sys.)\ MeV/c^2$
- $\Gamma = 35^{+11}_{-12}\ (stat.) \pm 15(syst.)\ MeV$
- statistical significance >12 σ
- No isospin violation is found between charged and neutral mode

PRL 115 222002 (2015)

$e^+e^- \to \pi^{\pm} Z_c(4020)^{\mp} \to \pi^+\pi^- h_c$





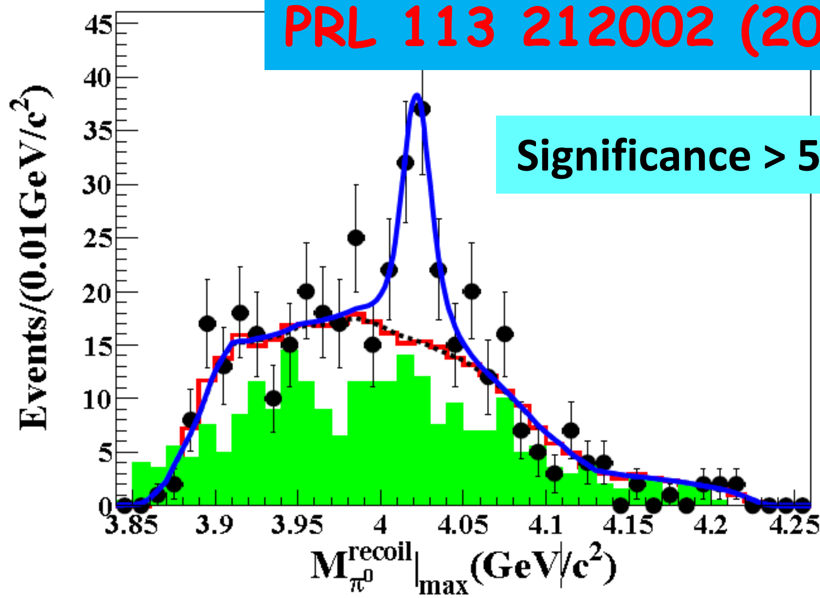
- 1D projection of $M(\pi^{\pm}h_c)$ invariant mass distribution.
- M[Zc(4020)]=(4022.9$\pm$0.8$\pm$2.7)MeV;
  Γ[Zc(4020)]=(7.9$\pm$2.7$\pm$2.6)MeV.
  Significance:>8.9σ
- No significant signal for $Z_c(3900)^{\pm} \to \pi^{\pm} h_c$ (<2.1σ)

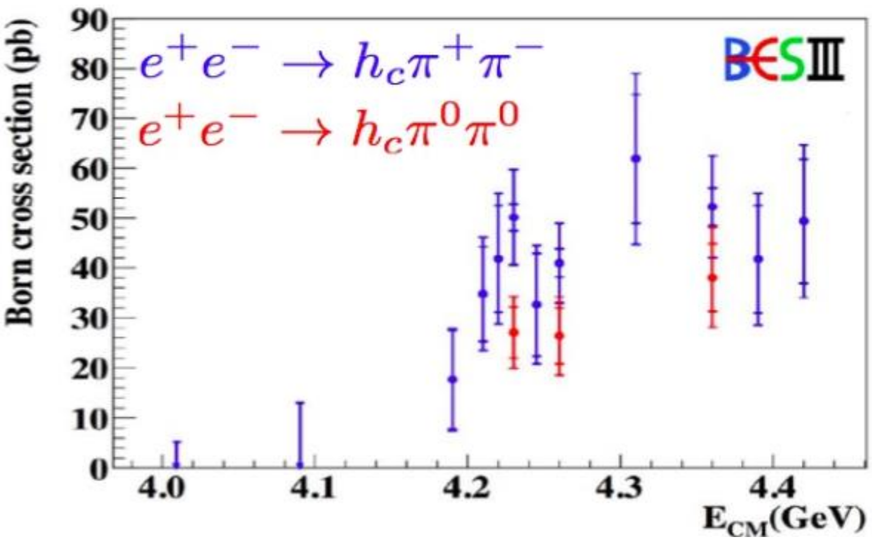
PRL111 242001 (2014)

$e^+e^- \to \pi^0 Z_c(4020)^0 \to \pi^0\pi^0 h_c$

- Observe $Z_c(4020)^0$ structure in $\pi^0 h_c$ mass distribution.
- $M[Z_c(4020)^0] = 4023.6 \pm 4.5$ MeV with a fixed width
- It is the neutral isospin partner of the $Z_c(4020)^\pm$.

PRL 113 212002 (2014)

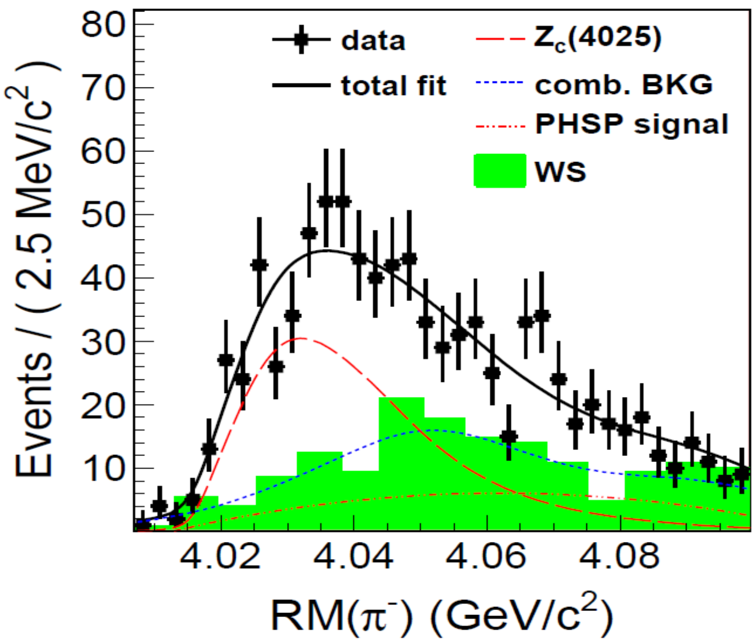




Cross sections for $e^+e^- \to \pi^+\pi^- h_c$ and $e^+e^- \to \pi^0\pi^0 h_c$ are in agreement with isospin conservation within 2σ: $R_{\pi\pi hc} = 0.63 \pm 0.09$

An isospin triplet for $Z_c(4020)$ has also been established.

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



M=4026.3±2.6±3.7 MeV
Γ=24.8±5.6±7.7 MeV
N=401±47
Significance>10σ

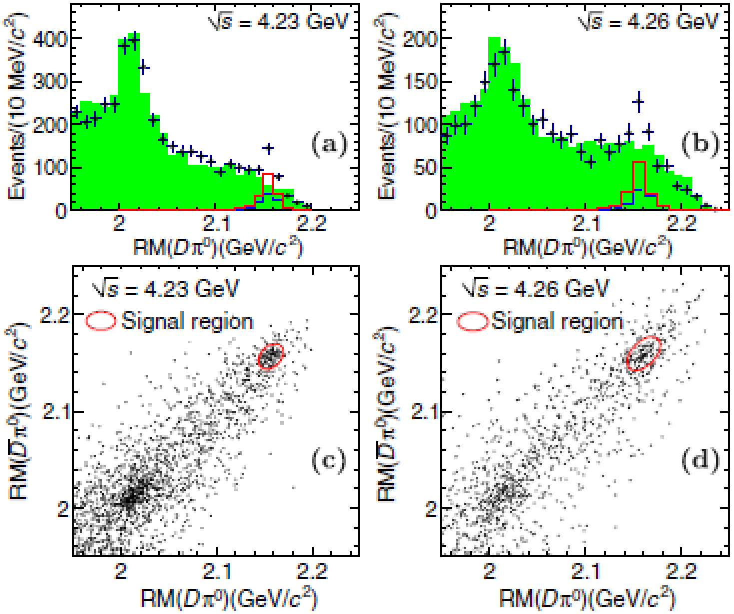
PRL 112 132001 (2014)

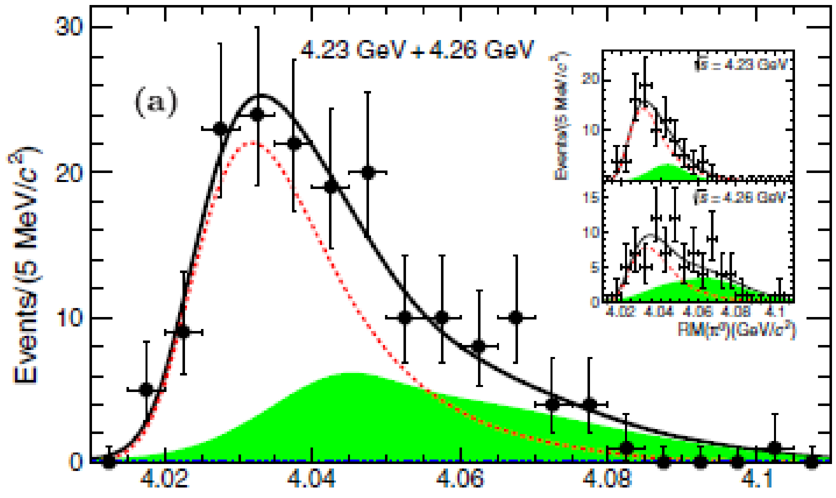
- if $Z_c(4025)^\pm$ is the $Z_c(4020)^\pm$ observed in the $\pi^\pm h_c$ spectrum:

$$\frac{\Gamma(Z_c(4020) \to D^* \bar{D}^*)}{\Gamma(Z_c(4020) \to \pi h_c)} = 12 \pm 5$$

$e^+e^- \rightarrow \pi^0 Z_c(4020)^0 \rightarrow \pi^0 D^* \bar{D}^*$

- Two decay modes, $\pi^0 D^{*+}\bar{D}^{*-}$+c.c., $\pi^0 D^{*0}\bar{D}^{*0}$ +c.c.
- Two energies are included, 4.23 &4.26 GeV

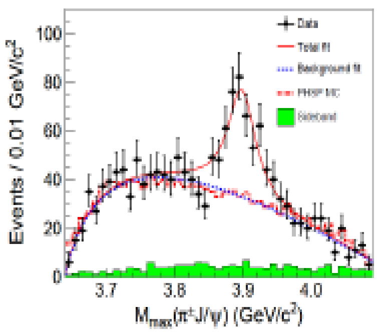


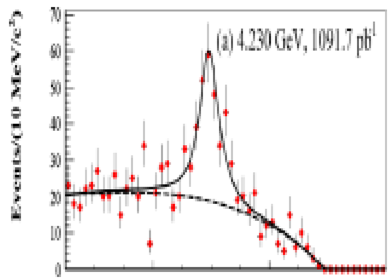


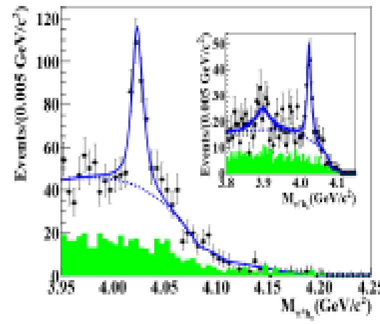
- $M = 4025.5^{+2.0}_{-4.7}(sta.) \pm 3.1(sys.)\ MeV/c^2$
- $\Gamma = 23.0 \pm 6.0(stat.) \pm 1.0(syst.)\ MeV$
- **statistical significance: ~6.0σ**

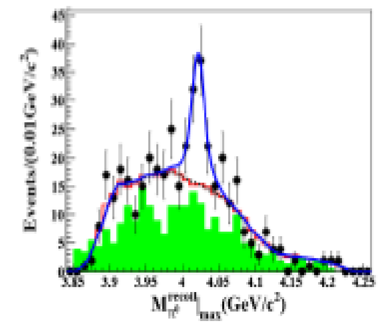
PRL 115 222002 (2015)

Summary Z_c states at BESIII







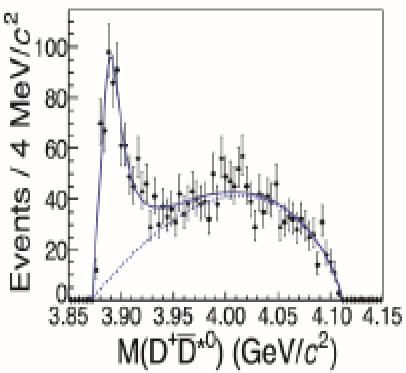


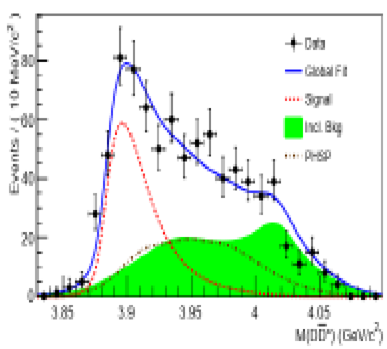
$e^+e^- \rightarrow \pi^+ \pi^- J/\Psi$

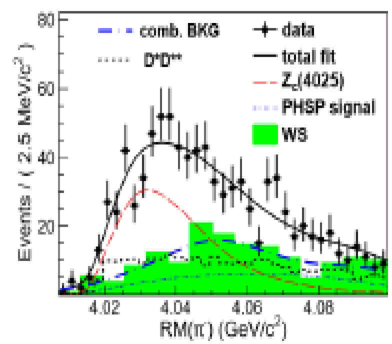
$e^+e^- \rightarrow \pi^0 \pi^0 J/\Psi$

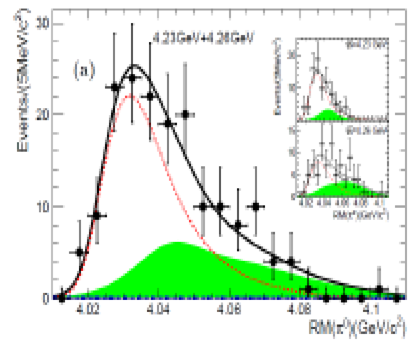
$e^+e^- \rightarrow \pi^+ \pi^- h_c$

$e^+e^- \rightarrow \pi^0 \pi^0 h_c$









$e^+e^- \rightarrow \pi^+ (D\bar{D}^*)^-$

$e^+e^- \rightarrow \pi^0 (D\bar{D}^*)^0$

$e^+e^- \rightarrow \pi^+ (D^*\bar{D}^*)^-$

$e^+e^- \rightarrow \pi^0 (D^*\bar{D}^*)^0$

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

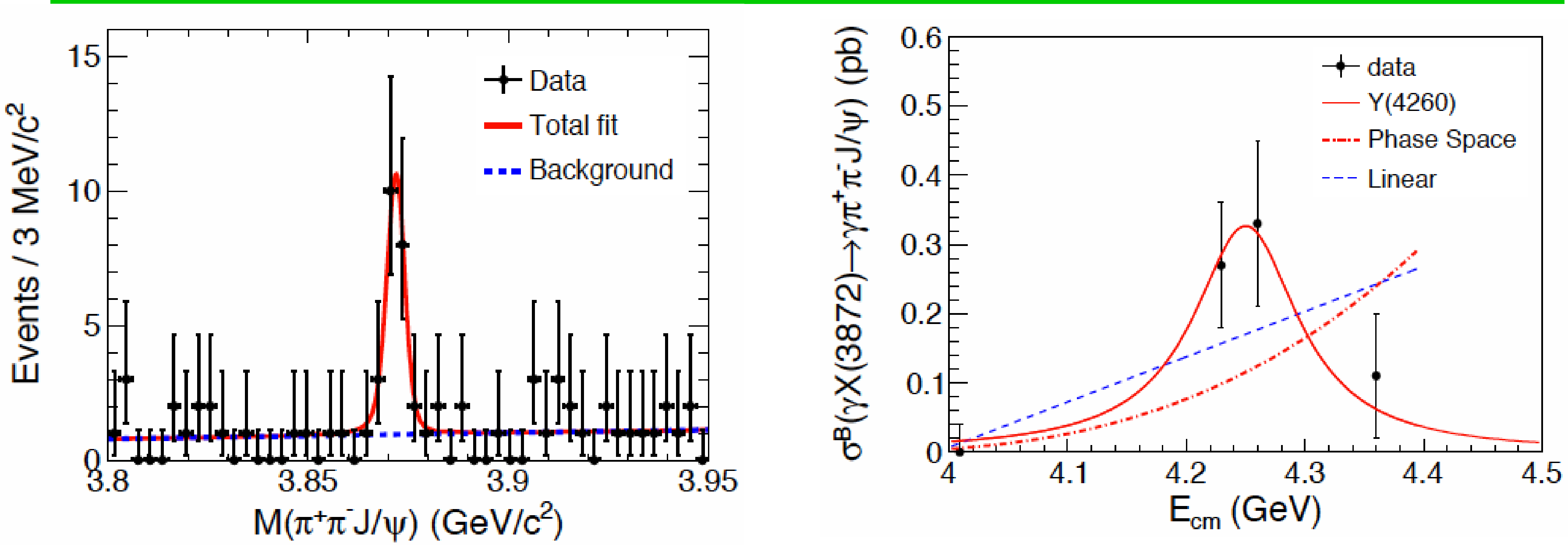
$Z_c(3900)^0$?

$Z_c(4020)^{\pm}$?

$Z_c(4020)^0$?

X states search at BESIII

$e^+e^- \rightarrow \gamma X(3872) \rightarrow \gamma\pi^+\pi^- J/\psi$

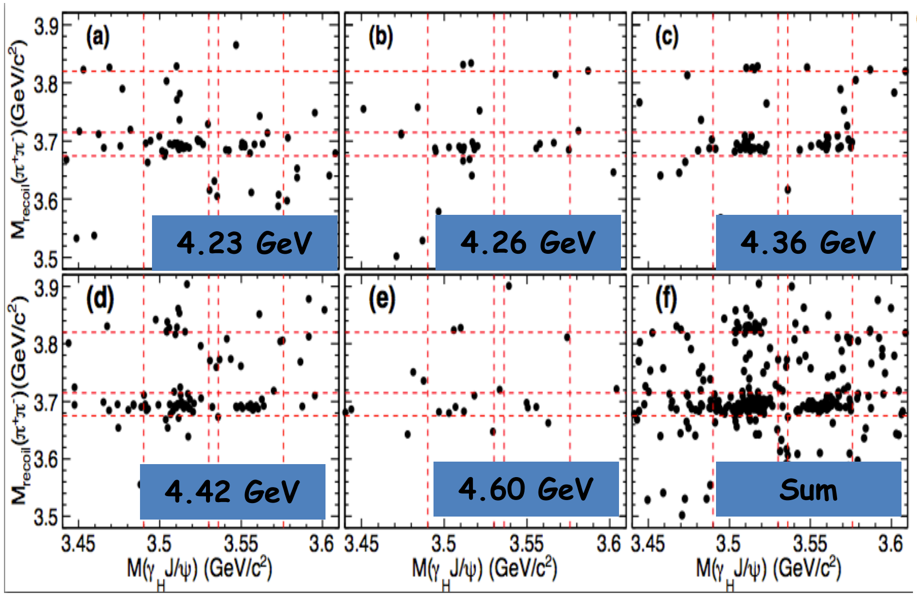


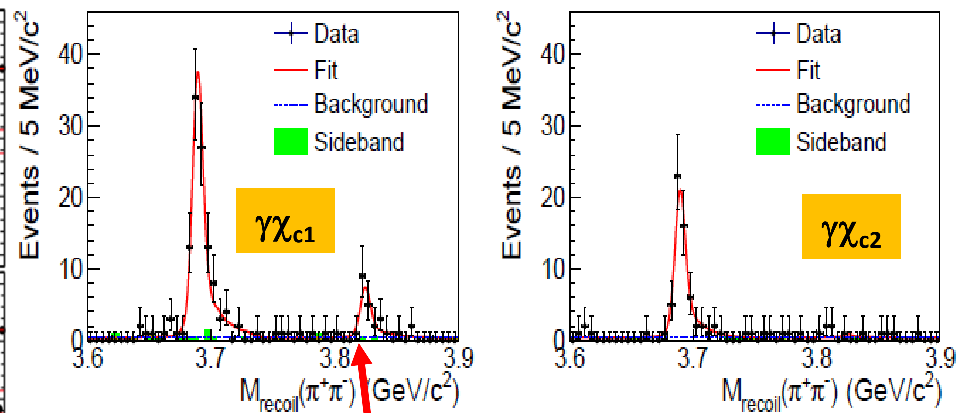
PRL 112 092001 (2014)

- **M = (3871.9±0.7±0.2) MeV, Γ<2.4 MeV, Significance:6.3σ**
- **production in *Y*(4260) decay suggestive, but not conclusive**

$$\frac{\mathcal{B}[Y(4260)\rightarrow\gamma X(3872)]}{\mathcal{B}(Y(4260)\rightarrow\pi^+\pi^- J/\psi)} = 0.1$$

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

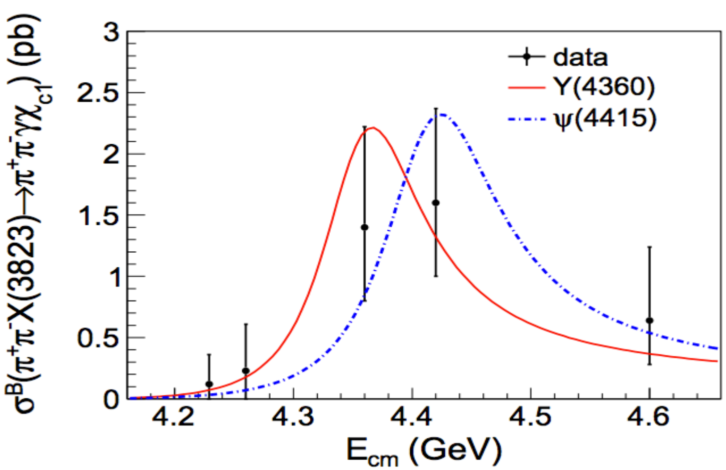




Fit: M=3821.7±1.3±0.7 MeV;

Significance: 6.7σ, observation

Phys. Rev. Lett. 91, 112015 (2015)

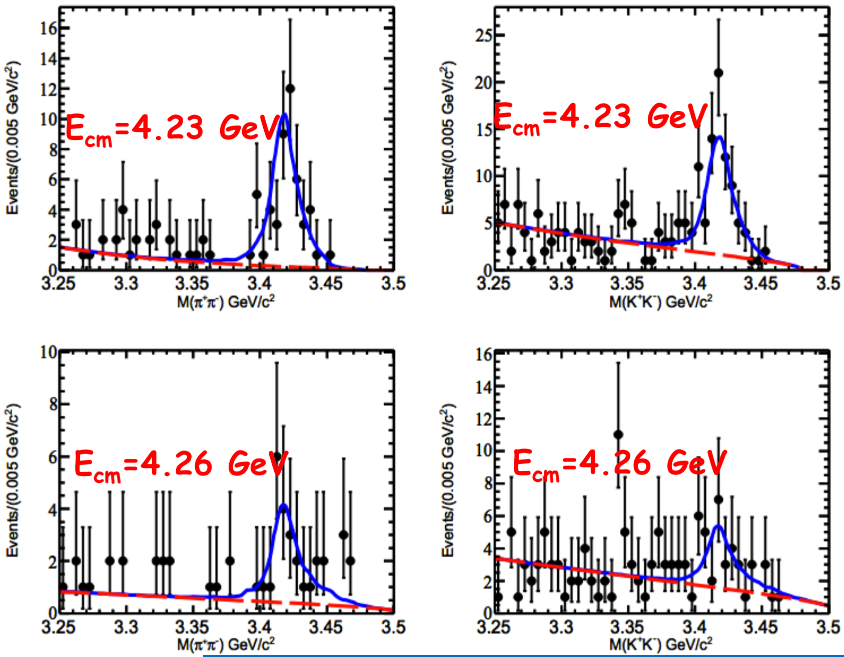


X(3823) as the $\psi(1^3D_2)$

- Mass argees with $\psi(1^3D_2)$
- Narrow width (<16 MeV @90% C.L.)
- R=B[X(3823)→gc_{c2}]/B[X(3823)→gc_{c1}]<0.43 @ 90% C.L. Agree with predicted ~0.2
- 1^1D_2→gc_{c1} forbidden; 1^3D_3→gc_{c1} amplitude=0.

Y states search at BESIII

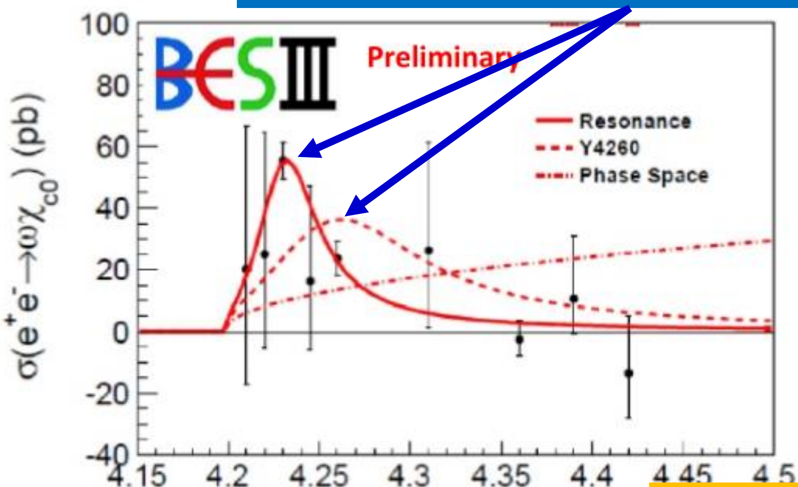
$e^+e^- \to \omega\chi_{c0}$ ($\sqrt{s}$=4.23, 4.26 GeV)



$\omega \to \pi^+\pi^-\pi^0$,
$\chi_{c0} \to \pi^+\pi^-, K^+K^-$

$\sqrt{s}$ (GeV)	σ^{Born} (pb^{-1})
4.23	55.4±6.0±5.9
4.26	23.7±5.3±3.5

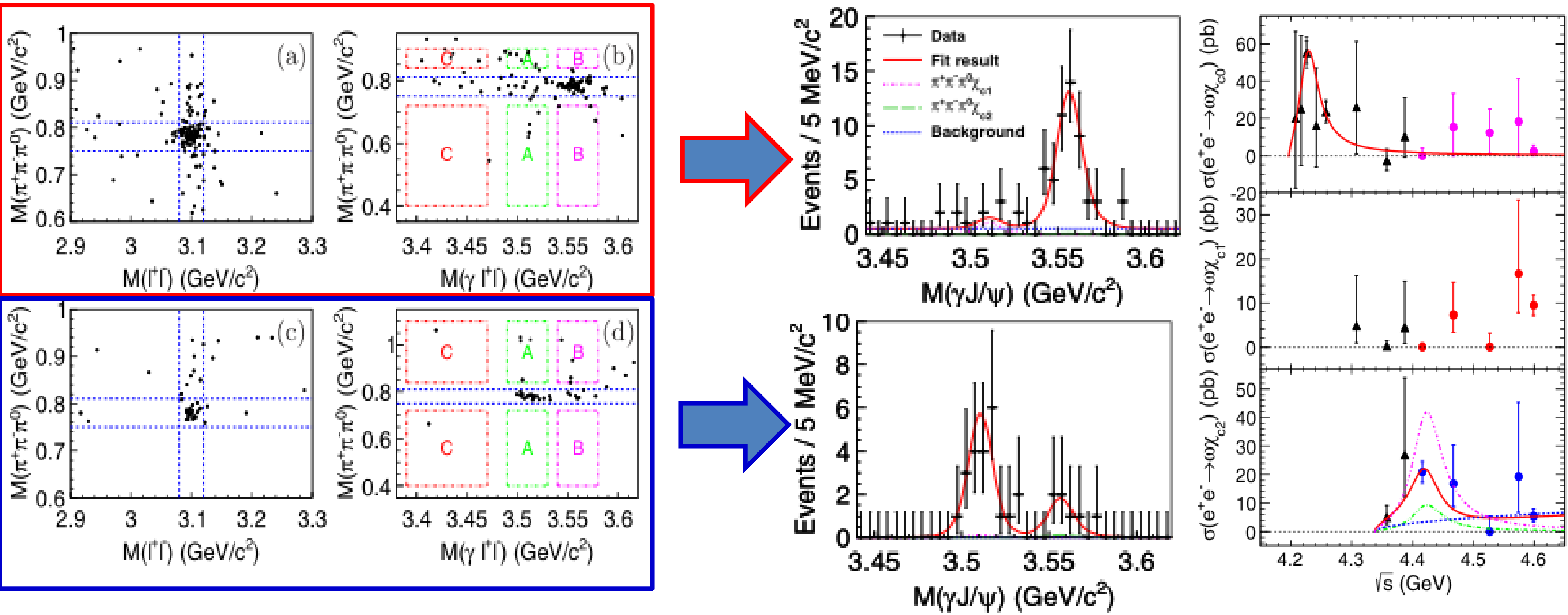
This is not consistent with the Y(4260) (!?)



Assuming the $\omega\chi_{c0}$ signals come from a resonance, we extract the $\Gamma_{ee} \cdot B(\omega\chi_{c0})$, mass, and width of the resonance to be (2.9±0.7±0.4) eV, M=(4230±8±6) MeV/c^2, and (38±12±2) MeV.

Phys. Rev. Lett 115, 012005 (2015)

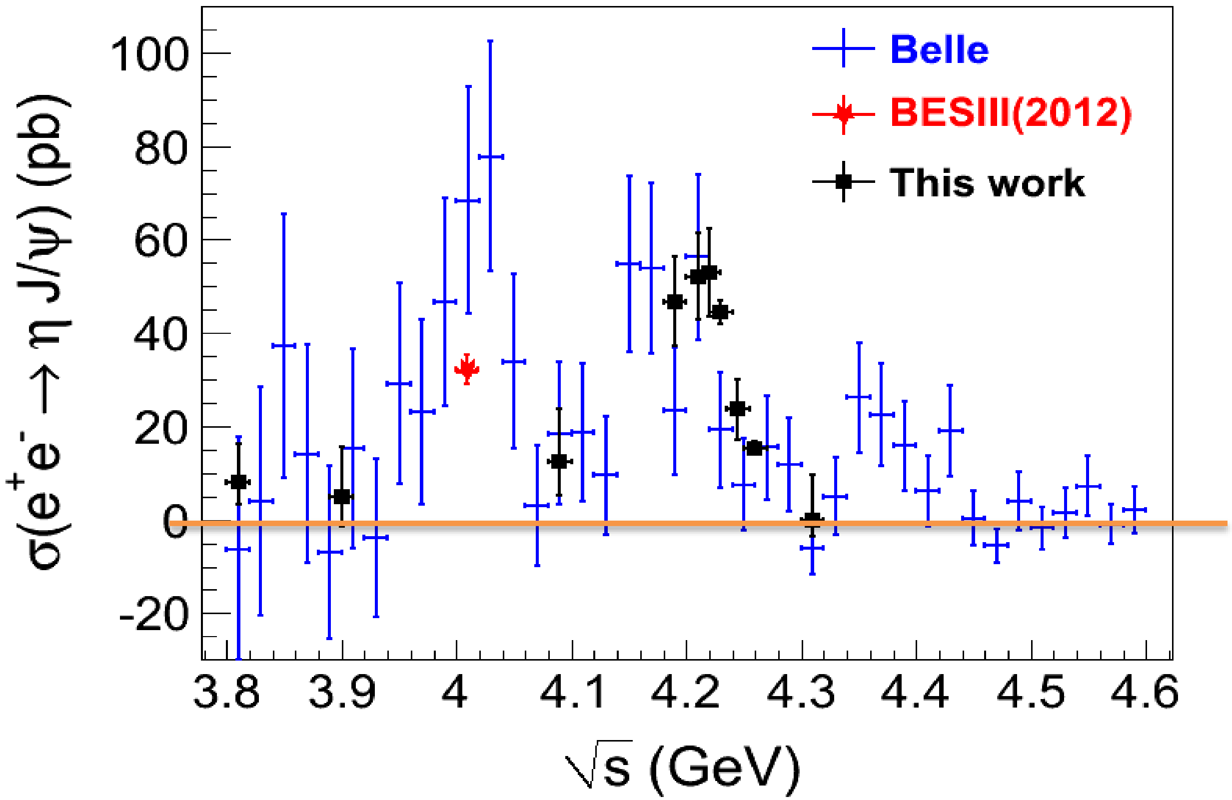
$e^+e^- \to \omega\chi_{c1,2}$ ($\sqrt{s}$=4.42, 4.6 GeV)



- Clear χ_{c2},χ_{c1} are observed at $\sqrt{s}$=4.42, 4.6 GeV, respectively
- The Born cross section have been measured for $e^+e^- \to \omega\chi_{c1,2}$
- $\sigma(e^+e^- \to \omega\chi_{c2})$ is fitted with the coherent sum of the ψ(4415) BW function and a phase-space term. Two solutions are obtained: ······ constructive, --- destructive

Phys. Rev. D 93, 011102 (2016)

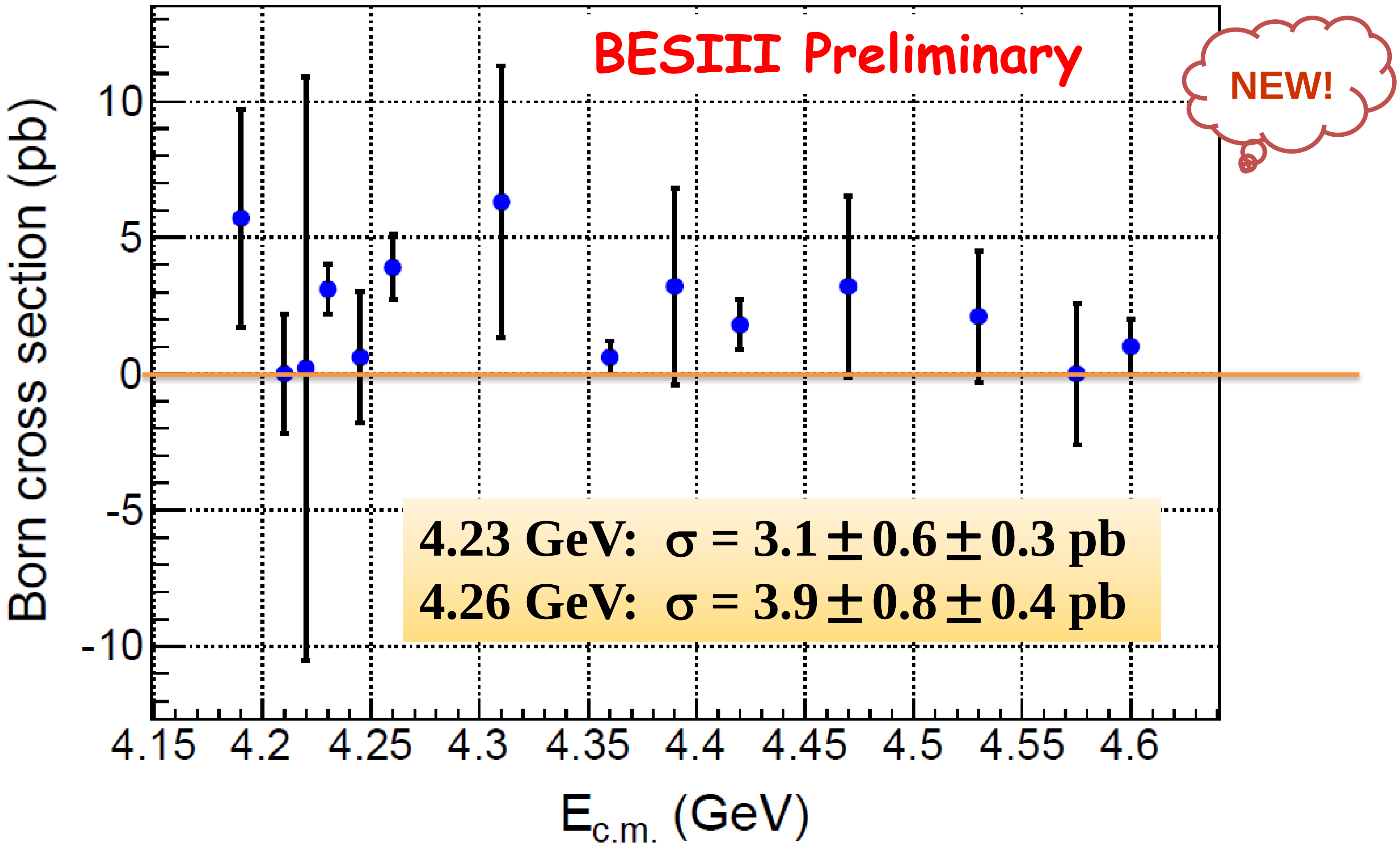
Observation of $e^+e^- \to \eta J/\psi$



- Agree with previous results with improved precision
- The cross section peaks around 4.2 GeV
- Analysis of high energy points underway

Phys. Rev. D 91, 112005 (2015)

Observation of $e^+e^- \to \eta' J/\psi$



4.23 GeV: $\sigma = 3.1 \pm 0.6 \pm 0.3$ pb

4.26 GeV: $\sigma = 3.9 \pm 0.8 \pm 0.4$ pb

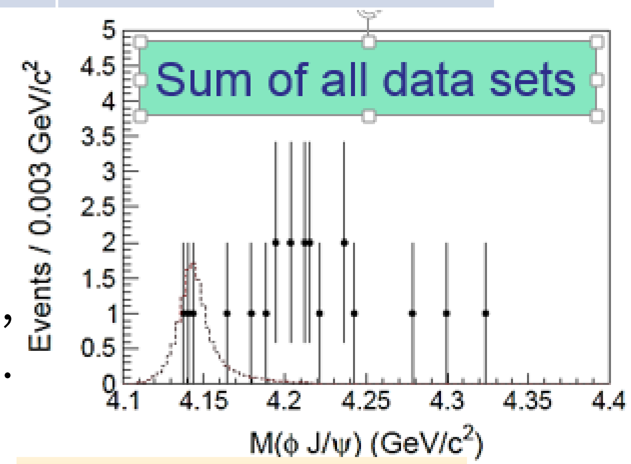
- First observation, cannot tell the line shape due to statistics

No significant $e^+e^- \rightarrow \gamma Y(4140)$

Upper limit at the 90% C.L. for $\sigma^B \cdot \mathcal{B} = \sigma^B\left(e^+e^- \rightarrow \gamma Y(4140)\right) \cdot \mathcal{B}(Y(4140) \rightarrow \phi J/\psi)$

(GeV/)	Luminosity (pb^{-1})	()	prod	(pb)
4.23	1094	0.840	<339	<0.35
4.26	827	0.847	<207	<0.28
4.36	545	0.944	<179	<0.33

Systematic uncertainty is considered.



Compared with $X(3872)$ production. PRL 112, 092001

$$\sigma^B\left(e^+e^- \rightarrow \gamma X(3872)\right) \cdot \mathcal{B}(X(3872) \rightarrow \pi^+\pi^- J/\psi)$$

$= 0.27 \pm 0.09(\text{stat}) \pm 0.02(\text{syst})$ pb at $\sqrt{s}=$ 4.23 GeV,

$= 0.33 \pm 0.12(\text{stat}) \pm 0.02(\text{syst})$ pb at $\sqrt{s}$ = 4.26 GeV.

Take $\mathcal{B}(X(3872) \rightarrow \pi^+\pi^- J/\psi)$ = 5%. arXiv: 0910.3138

And $\mathcal{B}(Y(4140) \rightarrow \phi J/\psi)$ = 30%, molecular calculation, PRD 80, 054019.

$$\frac{\sigma^B(e^+e^- \rightarrow \gamma Y(4140))}{\sigma(e^+e^- \rightarrow \gamma X(3872))} \leq 0.1 \text{ at } \sqrt{s}=4.23 \text{ and } 4.26 \text{ GeV}.$$

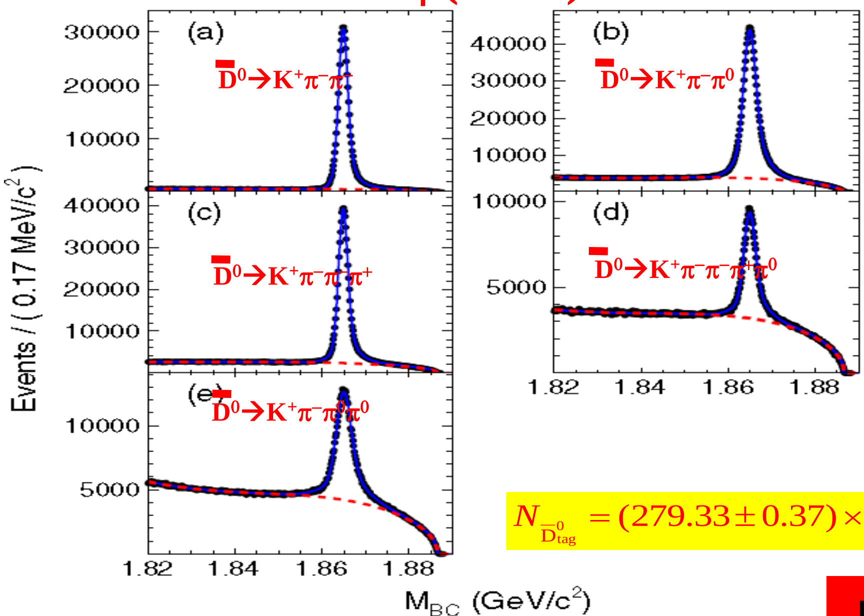
Phys. Rev. D91, 032002 (2015)

Charm physics

- **Measurement of $B[D^0 \rightarrow K(\pi)^- e^+ v]$ &&$f_+^{K(\pi)}(0)$**
- **$D^+ \rightarrow K_L e^+ v$, $\omega e^+ v$, $\phi e^+ v$**
- **DD mixing parameter y_{CP}**
- **Search for $D^0 \rightarrow \gamma\gamma$ and Measurement of $B[D^0 \rightarrow \pi^0 \pi^0]$**
- **Absolute BF for $\Lambda_c^+ \rightarrow \Lambda e^+ v_e$**
- **Absolute BFs for Λ_c^+ hadron decays**

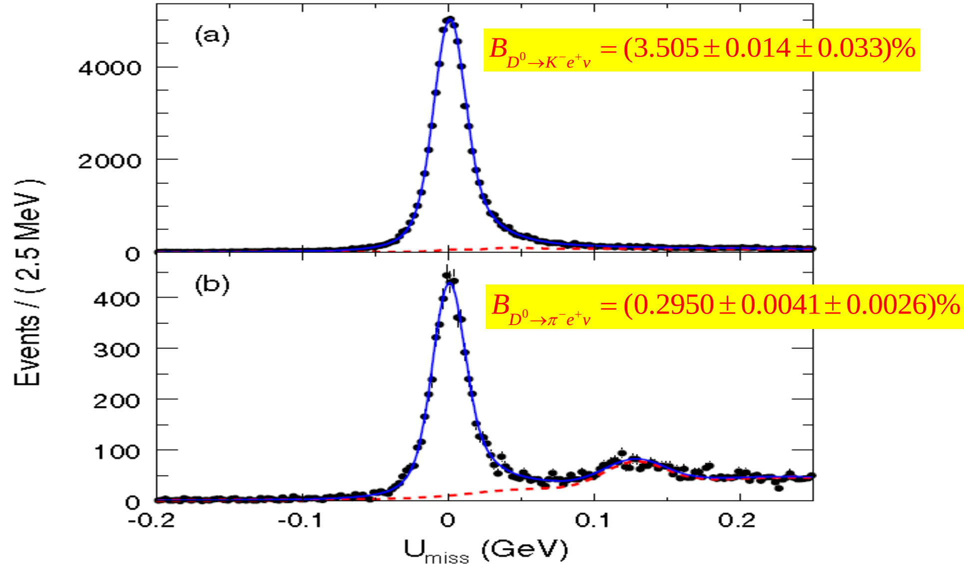
Measurement of B[$D^0 \rightarrow K(\pi)^- e^+ \nu$]

$e^+e^- \rightarrow \psi(3770) \rightarrow D^0\bar{D}^0$

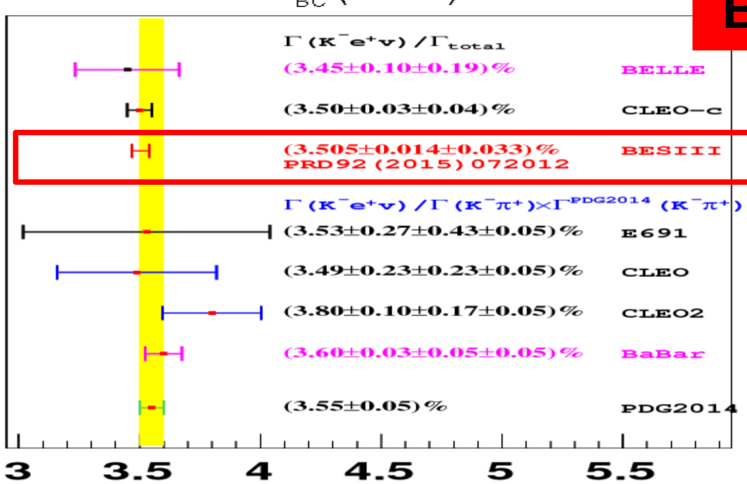


$N_{\bar{D}^0_{tag}} = (279.33 \pm 0.37) \times 10^4$

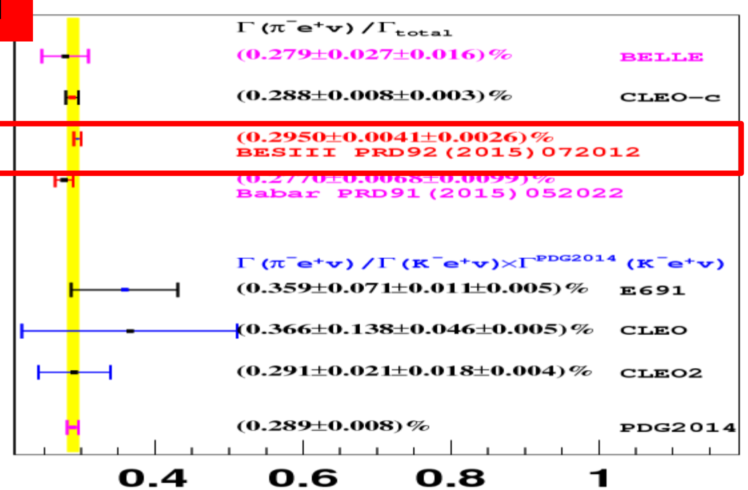
PRD92(2015)0720



BESIII



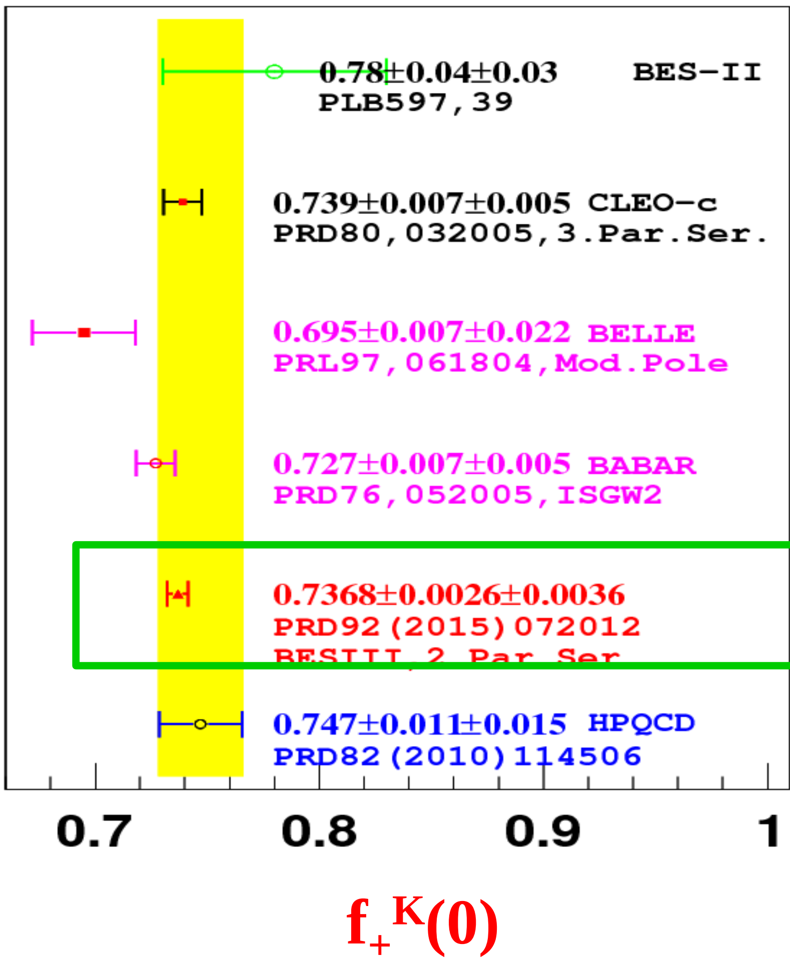
B[$D^0 \rightarrow K^- e^+ \nu$]

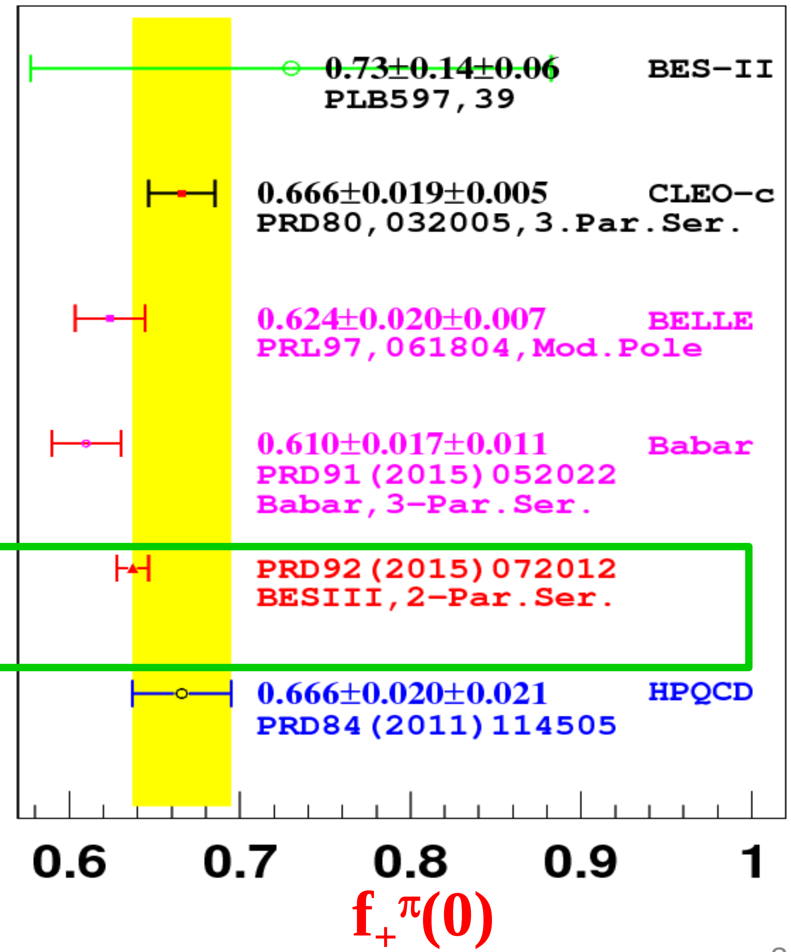


B[$D^0 \rightarrow \pi^- e^+ \nu$]

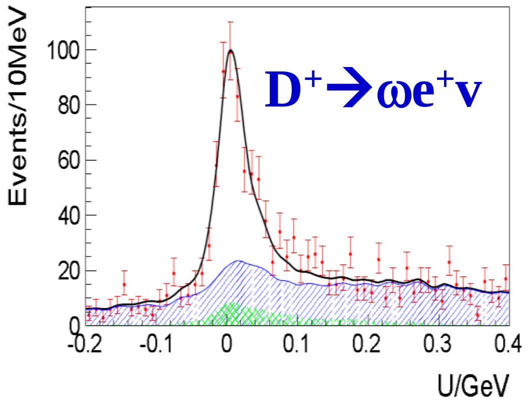
Measurement of $f_+^{K(\pi)}(0)$

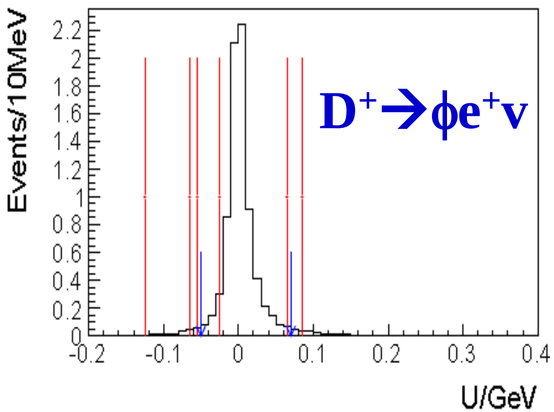
$f^{D\rightarrow K(\pi)}_+(0)|V_{cs(d)}|$ → Input $|V_{cs(d)}|$ of CKM-Fitter → $f^{D\rightarrow K(\pi)}_+(0)$





$D^+ \to K_L e^+\nu$, $\omega e^+\nu$, $\phi e^+\nu$





PRD92(2015) 112008

PRD92(2015) 071101R

Amplitude analysis of $D^+ \to \omega e^+\nu$ is performed for the first time

Comparisons with previous results

Mode	This work	Previous
$K_L e^+\nu$	$(4.482\pm0.027\pm0.103)\%$	---
$\omega e^+\nu$	$(1.63\pm0.11\pm0.08)\times10^{-3}$	$(1.82\pm0.18\pm0.07)\times10^{-3}$
$\phi e^+\nu$	$<1.3\times10^{-5}$	$<9.0\times10^{-5}$

$A_{CP}^{D^+\to K_L e^+\nu} = (-0.59\pm0.60 \pm 1.50)\%$

$f^K_+(0)|V_{cs}| = 0.728\pm0.006\pm0.011$

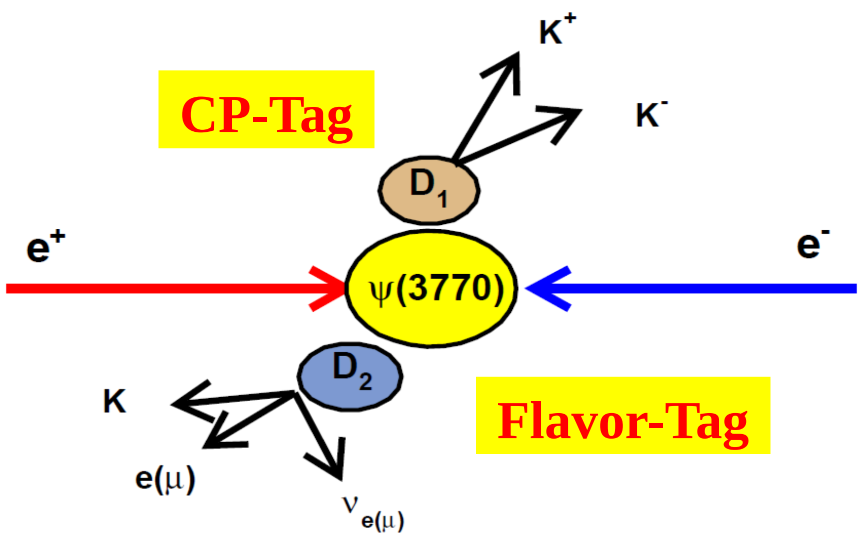
Results of form factor ratios:

$$r_V = V(0)/A_1(0) = 1.24 \pm 0.09 \pm 0.06$$
$$r_2 = A_2(0)/A_1(0) = 1.06 \pm 0.15 \pm 0.05$$

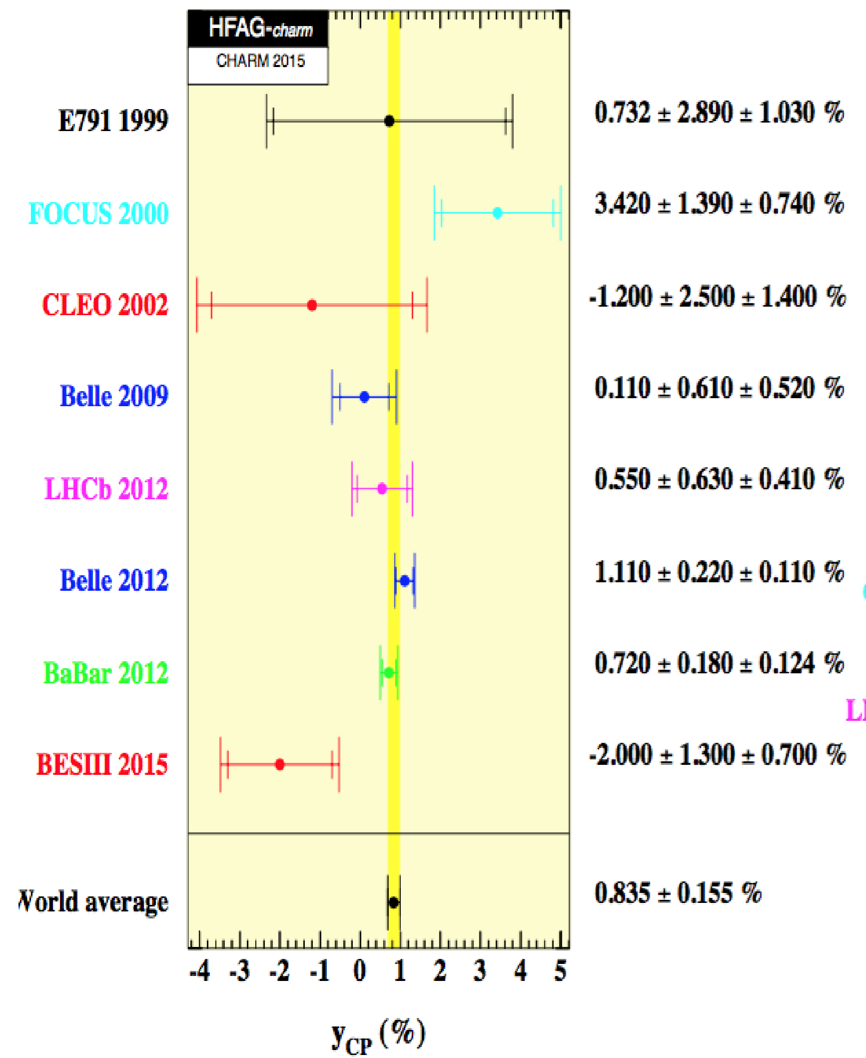
$D\bar{D}$ mixing parameter y_{CP}

PLB 744, 339 (2015)

We measure the y_{CP} using CP-tagged semi-leptonic D decays, which allows to access CP asymmetry in mixing and decays.



agree with the previous measurements



Reconstructed Modes:

Type	Mode
$CP+$	K^+K^-, $\pi^+\pi^-$, $K^0_S\pi^0\pi^0$
$CP-$	$K^0_S\pi^0$, $K^0_S\omega$, $K^0_S\eta$
Semileptonic	$K^\mp e^\pm\nu$, $K^\mp\mu^\pm\nu$

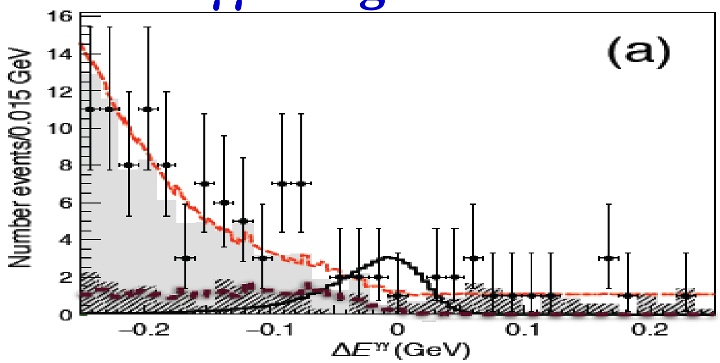
$$y_{CP}=(-2.1\pm1.3\pm0.7)\%$$

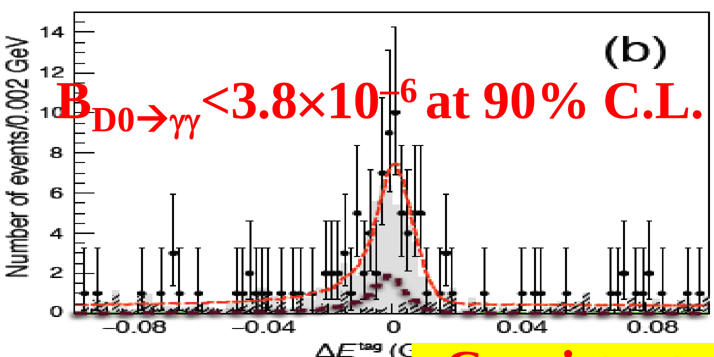
Search for $D^0 \to \gamma\gamma$ and Measurement of $B[D^0 \to \pi^0\pi^0]$

PRD91 112015(2015)

In SM, $D^0 \bar{D}^0$ mixing, CP violation and rare decay of charm are small. Searching for rare decays probes for New Physics beyond SM.

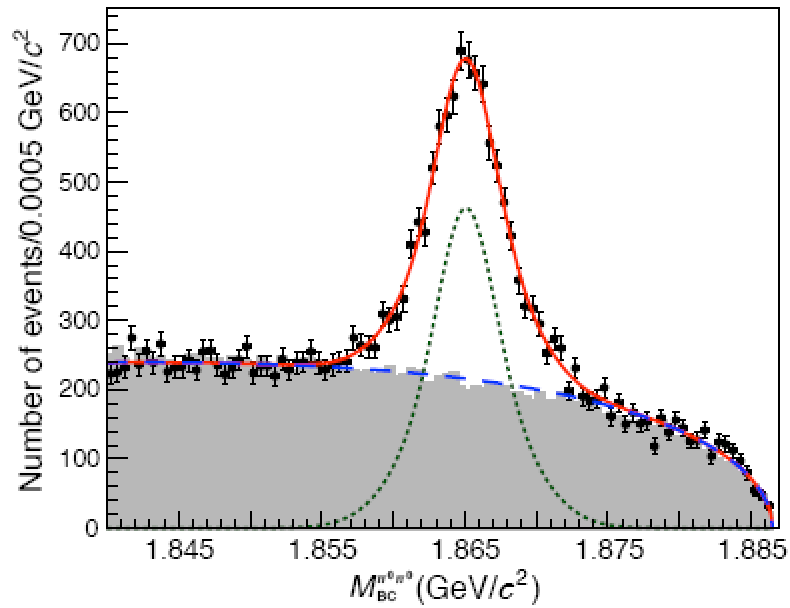
Search for flavor-changing neutral current (FCNC) decay $D^0 \to \gamma\gamma$ using DT method.





$B_{D0\to\gamma\gamma} < 3.8\times10^{-6}$ at 90% C.L.

Improved measurement of $B[D^0 \to \pi^0\pi^0]$ by using ST.



$$\mathcal{B}(D^0 \to \pi^0\pi^0) = \frac{N_{\pi^0\pi^0}}{\epsilon_{\pi^0\pi^0} \cdot 2N_{D^0\bar{D}^0}},$$

$B[D^0 \to \pi^0\pi^0] = (8.24 \pm 0.21 \pm 0.30) \times 10^{-4}$

Consistent with Babar measurements and SM predication.

Absolute BF for $\Lambda_c^+ \rightarrow \Lambda e^+ \nu_e$

Theoretical calculations on the BF ranges from 1.4% to 9.2%

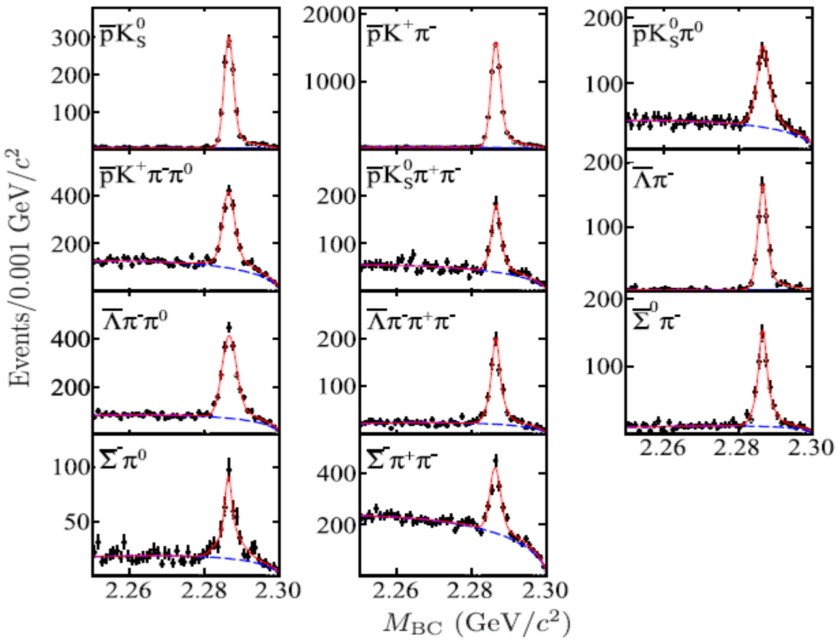
PDG2014: (2.1±0.6)%

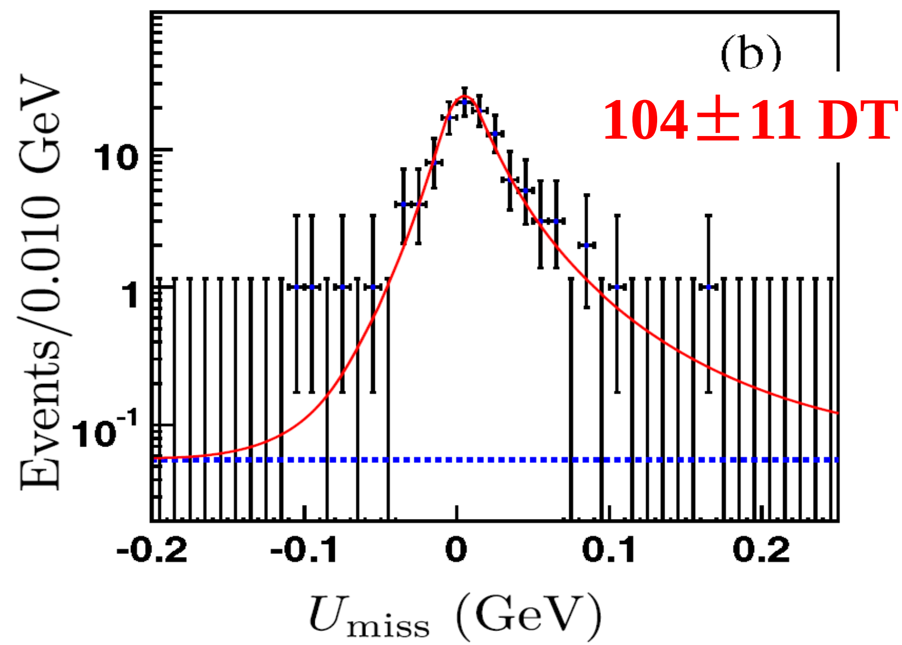
PDG2015: (2.9±0.5)%

Input $B[\Lambda_C^+ \rightarrow pK^-\pi^+] = (6.84^{+0.32}_{-0.40})\%$ by BELLE [PRL113,042002(2014)]

14415±159 events with 11 ST modes

PRL115(2015)221805





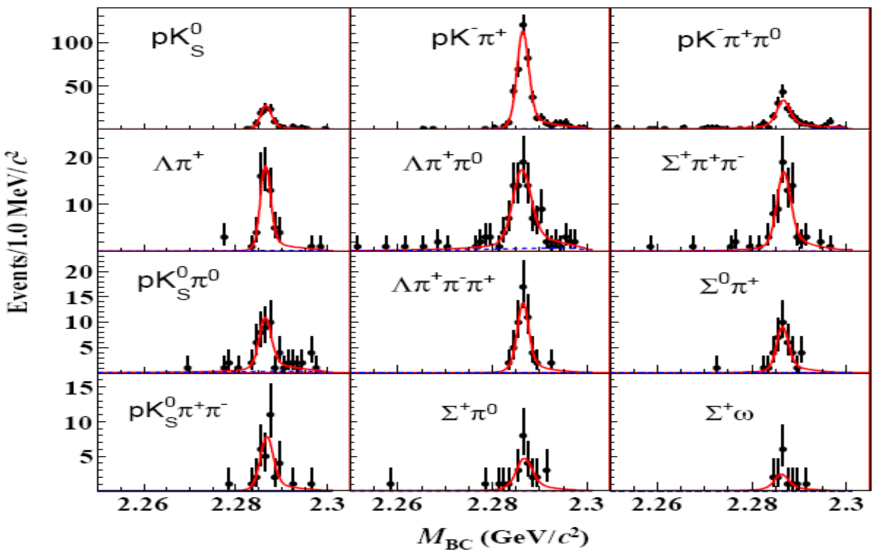
$B[\Lambda_c^+ \rightarrow \Lambda e^+ \nu] = (3.63 \pm 0.38 \pm 0.20)\%$ **First absolute measurement**

Important for test and calibrate the LQCD calculations.

Absolute BFs for Λ_c^+ hadron decays

Measurement using the threshold pair-productions via e^+e^- annihilation is unique: the most simple and straightforward

Phys. Rev. Lett (in press)



A global least-square global fitter is utilized to improve the measured precision for 12 Λ_c^+ hadronic decay channels.

$$N^{DT}_{-j} = \sum_{i^+\neq i} N^{DT}_{i^+j^-} + \sum_{i^-\neq i} N^{DT}_{i^-j^+} + N^{DT}_{jj}$$

Mode	This work (%)	PDG (%)	Belle $\mathcal{B}$
pK^0_S	$1.52 \pm 0.08 \pm 0.03$	1.15 ± 0.30	
$pK^-\pi^+$	$5.84 \pm 0.27 \pm 0.23$	5.0 ± 1.3	$6.84 \pm 0.24^{+0.21}_{-0.27}$
$pK^0_S\pi^0$	$1.87 \pm 0.13 \pm 0.05$	1.65 ± 0.50	
$pK^0_S\pi^+\pi^-$	$1.53 \pm 0.11 \pm 0.09$	1.30 ± 0.35	
$pK^-\pi^+\pi^0$	$4.53 \pm 0.23 \pm 0.30$	3.4 ± 1.0	
$\Lambda\pi^+$	$1.24 \pm 0.07 \pm 0.03$	1.07 ± 0.28	
$\Lambda\pi^+\pi^0$	$7.01 \pm 0.37 \pm 0.19$	3.6 ± 1.3	
$\Lambda\pi^+\pi^-\pi^+$	$3.81 \pm 0.24 \pm 0.18$	2.6 ± 0.7	
$\Sigma^0\pi^+$	$1.27 \pm 0.08 \pm 0.03$	1.05 ± 0.28	
$\Sigma^+\pi^0$	$1.18 \pm 0.10 \pm 0.03$	1.00 ± 0.34	
$\Sigma^+\pi^+\pi^-$	$4.25 \pm 0.24 \pm 0.20$	3.6 ± 1.0	
$\Sigma^+\omega$	$1.56 \pm 0.20 \pm 0.07$	2.7 ± 1.0	

- ✓ **Absolute BFs are improved significantly.**
- ✓ **BESIII BF for $\Lambda_c^+ \rightarrow pK^-\pi^+$ is smaller.**
- ✓ **Improved absolute BF of $pK^-\pi^+$ together with BELLE's result are key to calibrate other decays.**

R-QCD

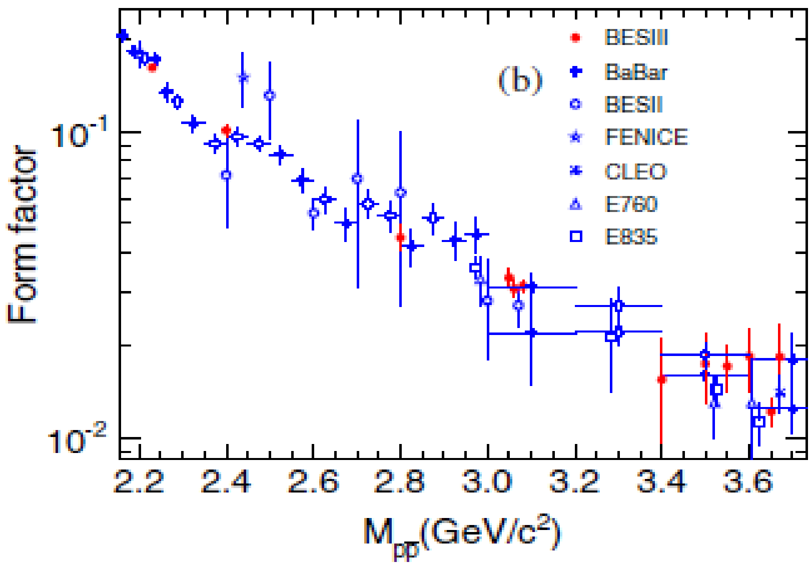
- **Proton form factor measurement**
- **$\sigma(e^+e^- \to \pi^+\pi^-)$ and form factor**
- **Collins Asymmetry**

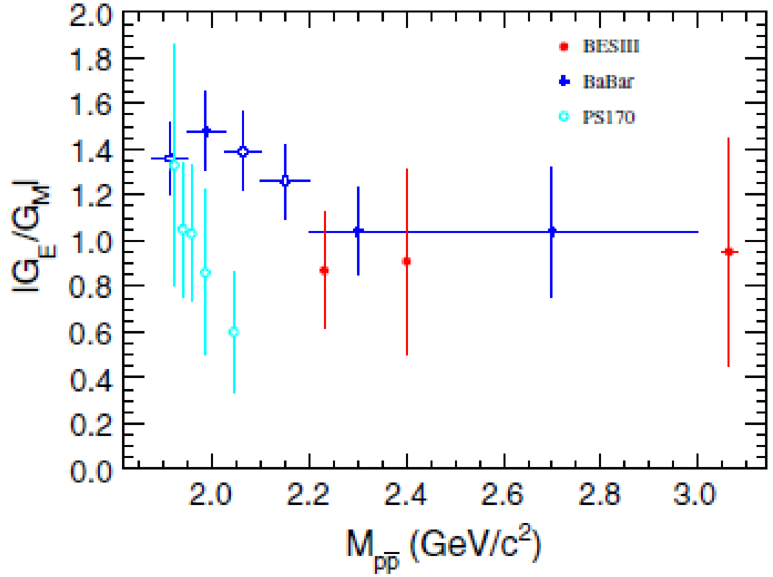
Proton form factor measurement

- Radiative corrections from Phokhara8.0 (scan)
- Normalization to $e^+e^- \to e^+e^-, e^+e^- \to \gamma\gamma$ (BABAYAGA 3.5)
- Efficiencies from 60% (2.23 GeV) to 3.0% (~4 GeV)
- $|G_E/G_M|$ ratio obtained from 3 c.m. energies

E_{cm}/GeV	L_{int} / pb^{-1}
2.23	2.6
2.40	3.4
2.80	3.8
3.05, 3.06, 3.08	60.7
3.40, 3.50, 3.54, 3.56	23.3
3.60, 3.65, 3.67	63.0

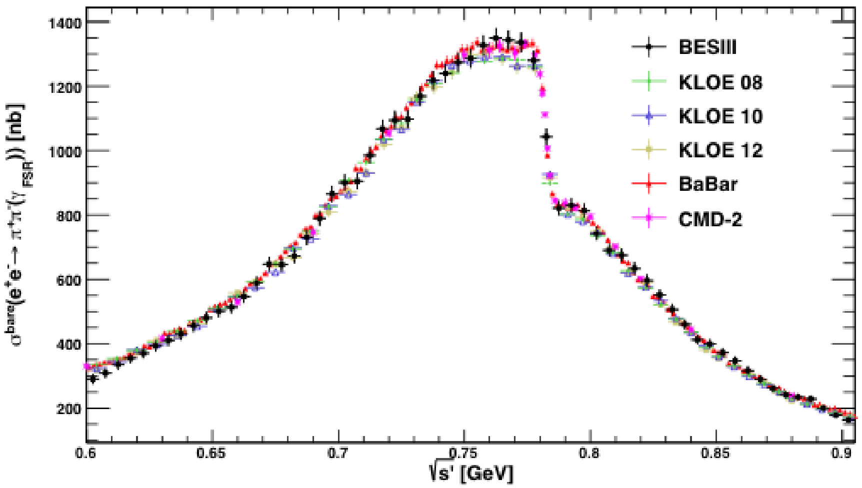
Phys. Rev. D91, 112004 (2015)

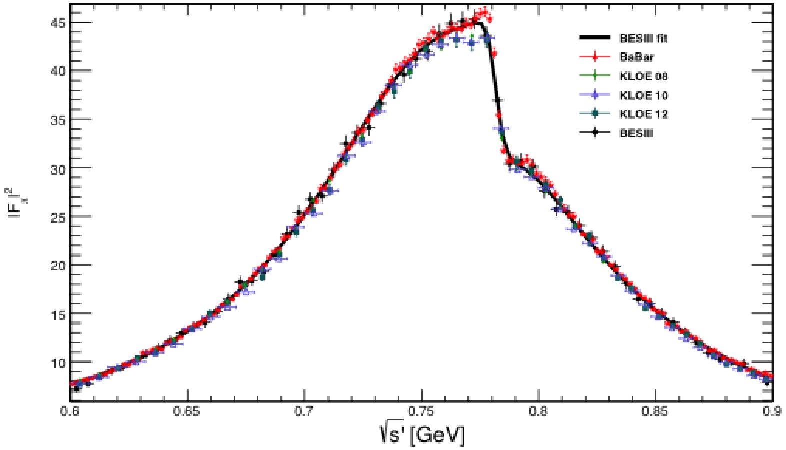


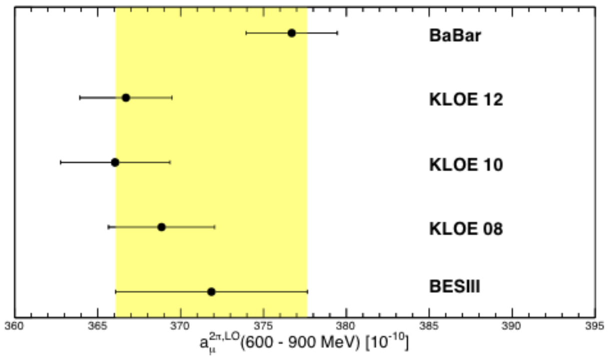


$\sigma(e^+e^- \to \pi^+\pi^-)$ and form factor

ISR analysis using 2.9 fb^{-1} data at $\psi(3770)$: $e^+e^- \to \pi^+\pi^-\gamma_{ISR}$







Exp.	$a_\mu^{2\pi,LO}$ (600 – 900 MeV) [10^{-10}]
BaBar	$376.7 \pm 2.0_{stat} \pm 1.9_{sys}$
KLOE08	$368.9 \pm 0.4_{stat} \pm 2.3_{sys,exp} \pm 2.2_{sys,theo}$
KLOE10	$366.1 \pm 0.9_{stat} \pm 2.3_{sys,exp} \pm 2.2_{sys,theo}$
KLOE12	$366.7 \pm 1.2_{stat} \pm 2.4_{sys,exp} \pm 0.8_{sys,theo}$
BESIII	$371.9 \pm 2.6_{stat} \pm 5.2_{sys}$

Phys. Lett. B, 753, 629-638 (2016)

Summary

- **X(1835), Y(2175) and other new N* are either observed or confirmed.**
- **Some semi-leptonic decay for charm mesons are observed for the first time. DD mixing is searched**
- **X,Y,Z states are searched. A lot of new neutral Z states are observed recently.**
- **The absolute BF for Λ_c semi-leptonic and hadronic decay are measured. Some of them are the first time.**
- **The form factor for $e^+e^-\to pp,\pi^+\pi^-$ are measured.**

Thank you!

Backup