Recent results at BESIII

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(for the BESIII Collaboration)

17th High-energy Physics Internationanl Conference in Quantum Chromodynamics(QCD)

30 june-4 july 2014, Montpellier, France

Bird view of BEPCII

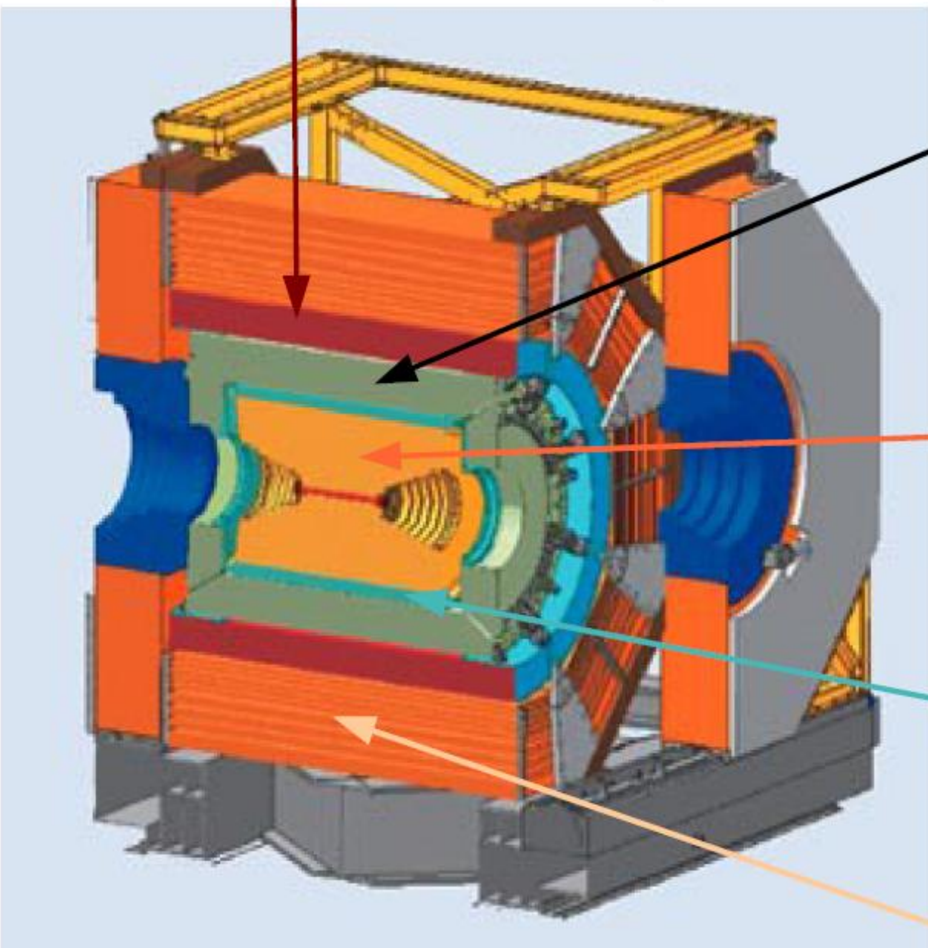
physics goal

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

The BES-III detector

NIM A614, 345(2010)

Super conducting magnet: 1 T



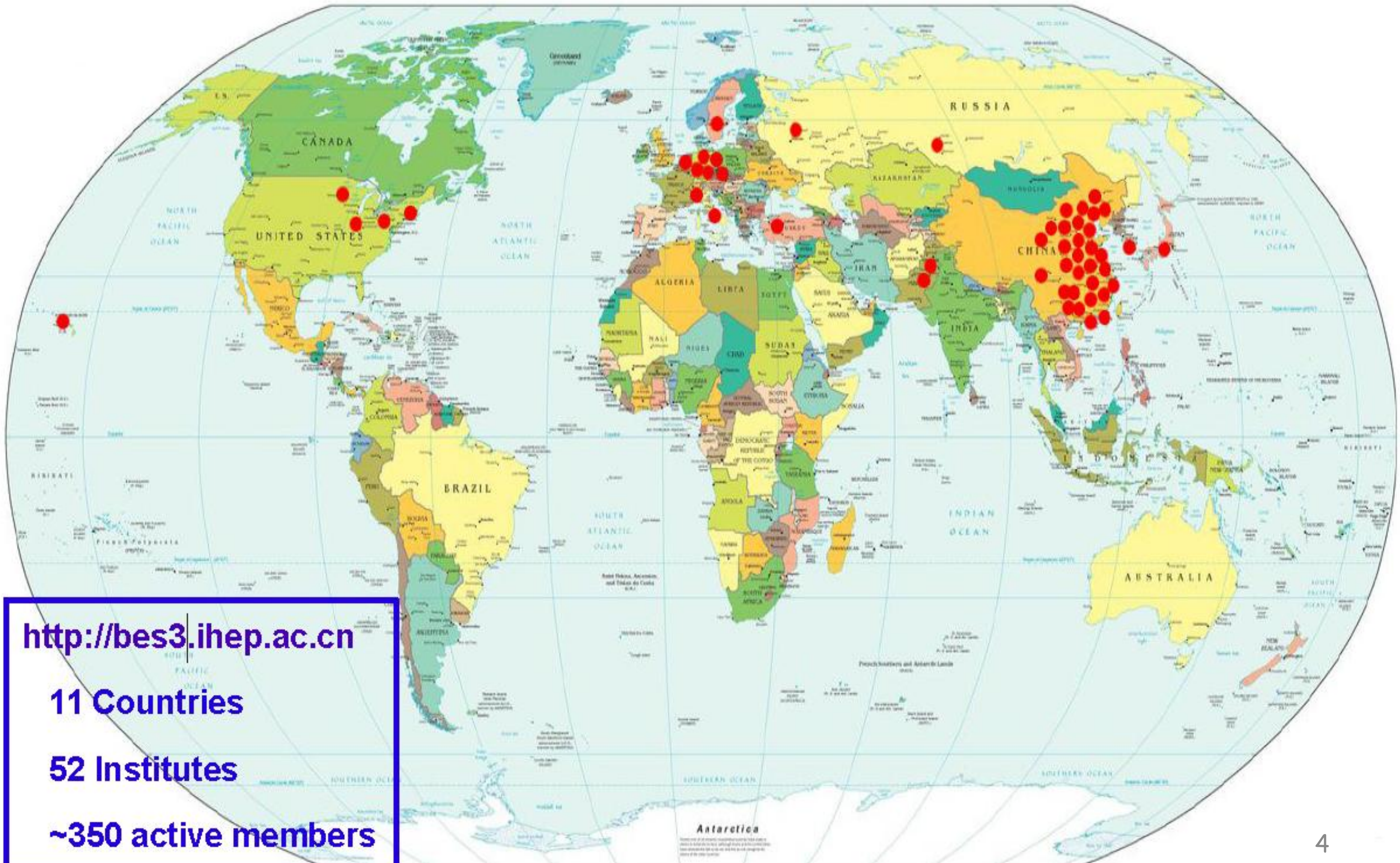
EMC: CsI cristal
- Energy resolution: **2.5% @1GeV**
- Spatial resolution: **6mm**

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 BES-III Collaboration



http://bes3.ihep.ac.cn

11 Countries

52 Institutes

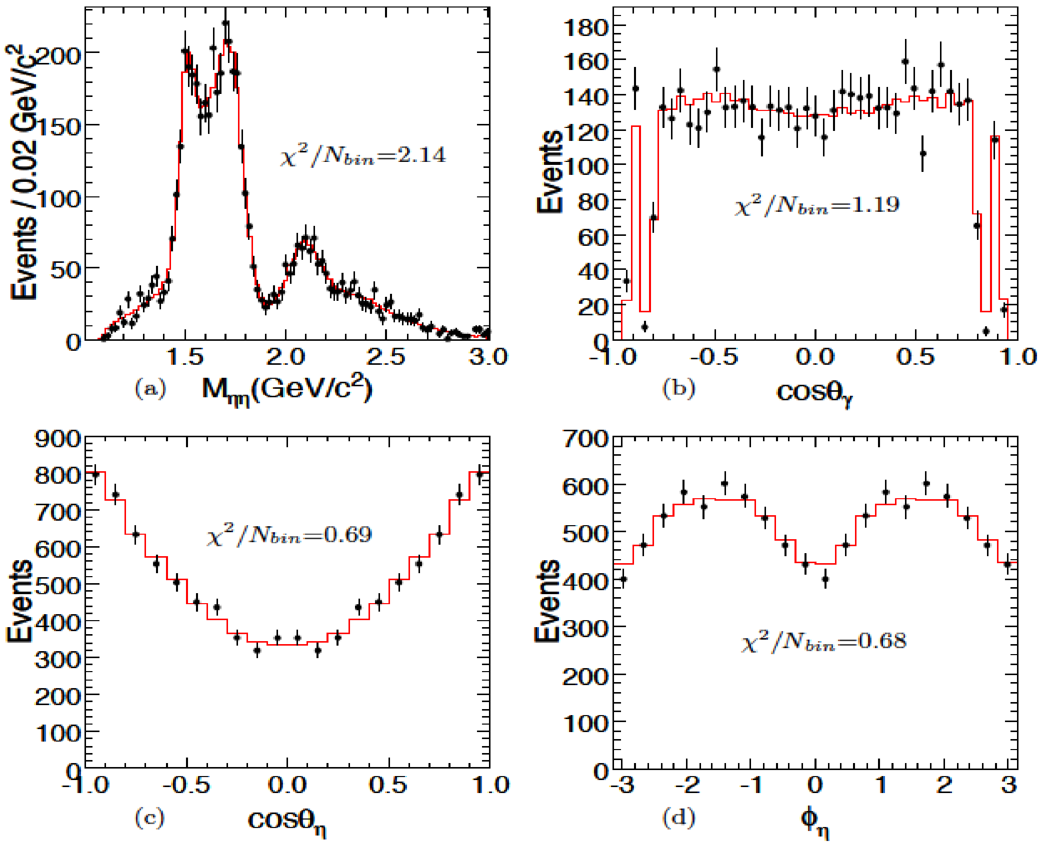
~350 active members

Outline

- Hadron spectroscopy
- Charmonium (charmonium-like) physics
- Charm physics
- τ mass measurement
- Summary

PWA in $J/\psi\to\gamma\eta\eta$

Phys. Rev. D. 87, 092009 (2013)

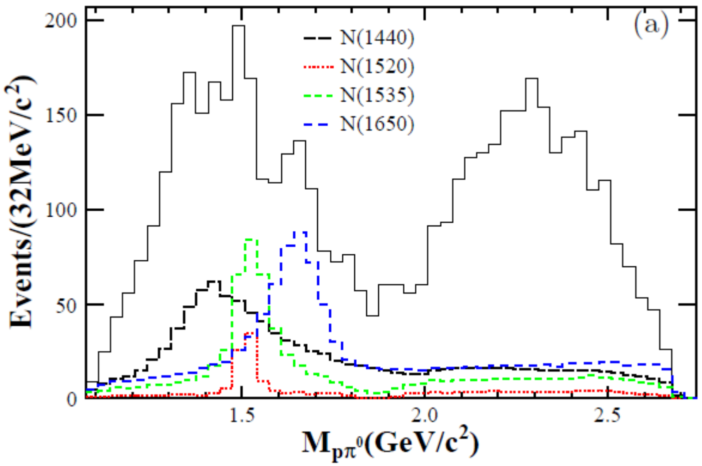


- $f_0(1710)$ and $f_0(2100)$ are dominant scalars
- $f_0(1500)$ exists (8.2σ)
- $f_2'(1525)$ is the dominant tensor
- $f_2(1810)$ and $f_2(2340)$ exist (6.4 and 7.6σ)
- No evidence for $f_J(2220)$

Resonance	Mass (MeV/c^2)	Width (MeV/c^2)	$\mathcal{B}(J/\psi\to\gamma X\to\gamma\eta\eta)$	Significance
$f_0(1500)$	1468^{+14+23}_{-15-74}	$136^{+41+28}_{-26-100}$	$(1.65^{+0.26+0.51}_{-0.31-1.40})\times10^{-5}$	8.2σ
$f_0(1710)$	$1759\pm6^{+14}_{-25}$	$172\pm10^{+32}_{-16}$	$(2.35^{+0.13+1.24}_{-0.11-0.74})\times10^{-4}$	25.0σ
$f_0(2100)$	$2081\pm13^{+24}_{-36}$	273^{+27+70}_{-24-23}	$(1.13^{+0.09+0.64}_{-0.10-0.28})\times10^{-4}$	13.9σ
$f_2'(1525)$	$1513\pm5^{+4}_{-10}$	75^{+12+16}_{-10-8}	$(3.42^{+0.43+1.37}_{-0.51-1.30})\times10^{-5}$	11.0σ
$f_2(1810)$	1822^{+29+66}_{-24-57}	$229^{+52+88}_{-42-155}$	$(5.40^{+0.60+3.42}_{-0.67-2.35})\times10^{-5}$	6.4σ
$f_2(2340)$	$2362^{+31+140}_{-30-63}$	$334^{+62+165}_{-54-100}$	$(5.60^{+0.62+2.37}_{-0.65-2.07})\times10^{-5}$	7.6σ

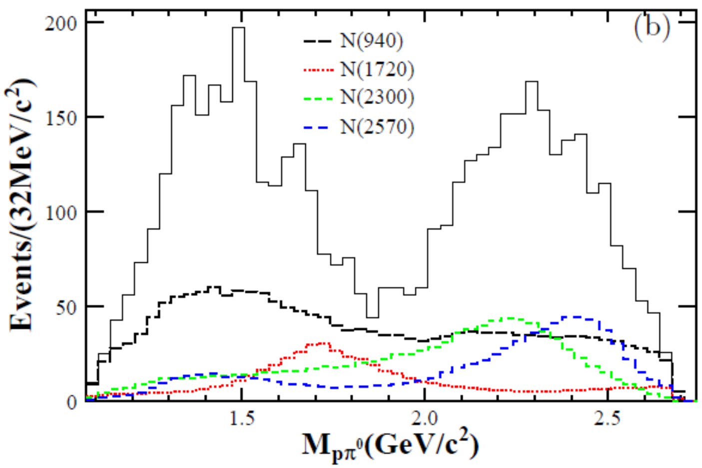
PWA results on N* baryons in $\psi'\to\pi^0 p\bar{p}$

Phys.Rev.Lett. 110 (2013) 022001



- 2-body decay:
  $\psi(2S) \to X\pi^0, X \to p\bar{p}$
  $\psi(2S) \to p\bar{N}^*, \bar{N}^* \to \bar{p}\pi^0$ + c.c.
- isospin conservation:
  Δ suppressed

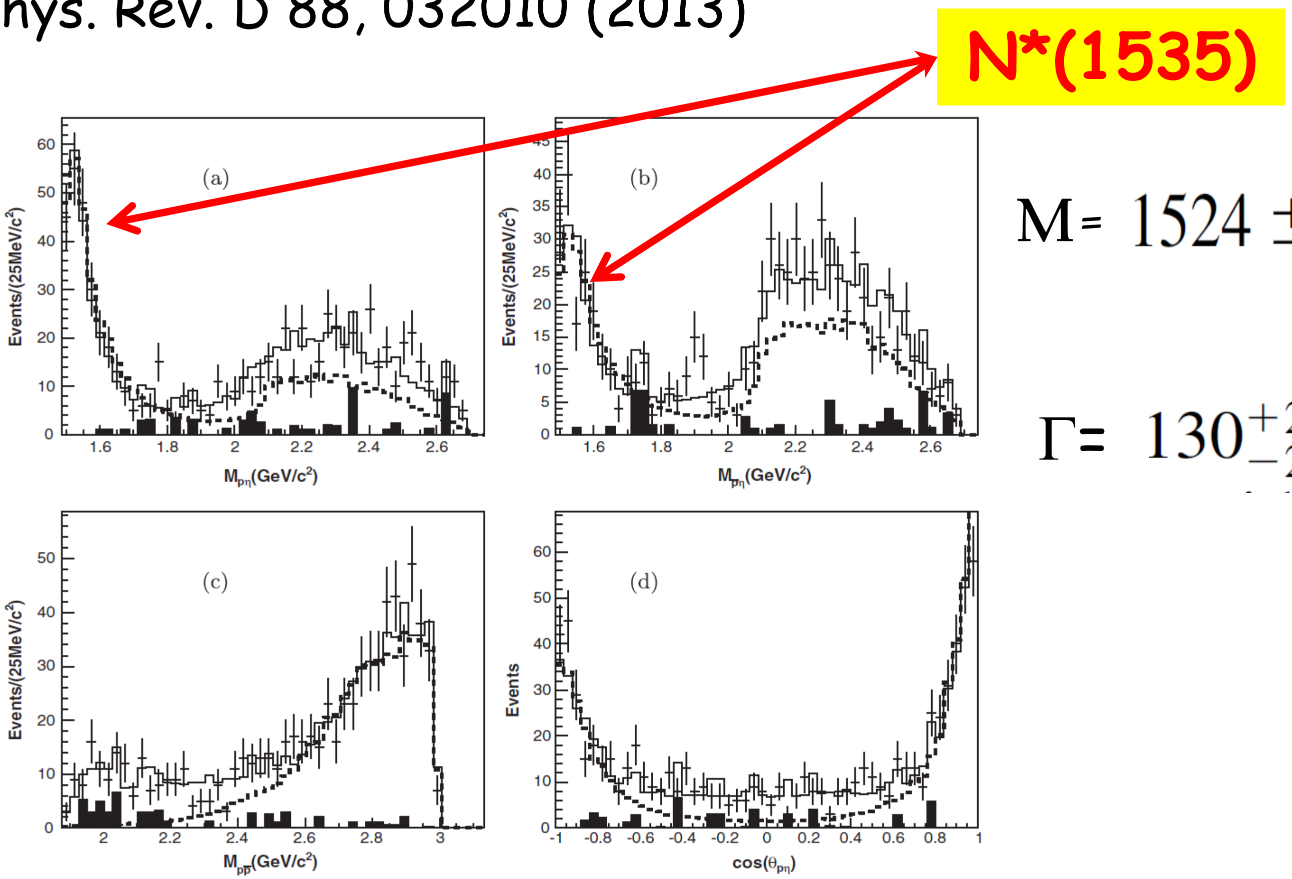
Two new baryonic excited states are observed !



Resonance	M(MeV/c^2)	Γ(MeV/c^2)	ΔS	ΔN_{dof}	C.L.
$N(1440)$	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
$N(2300)$	$2300^{+40+109}_{-30-0}$	$340^{+30+110}_{-30-58}$	120.7	4	15.0σ
$N(2570)$	2570^{+19+34}_{-10-10}	250^{+14+69}_{-24-21}	78.9	6	11.7σ

PWA results on N* baryons in $\psi' \to \eta p\bar{p}$

Phys. Rev. D 88, 032010 (2013)



M = $1524 \pm 5^{+10}_{-4}$ MeV/c^2

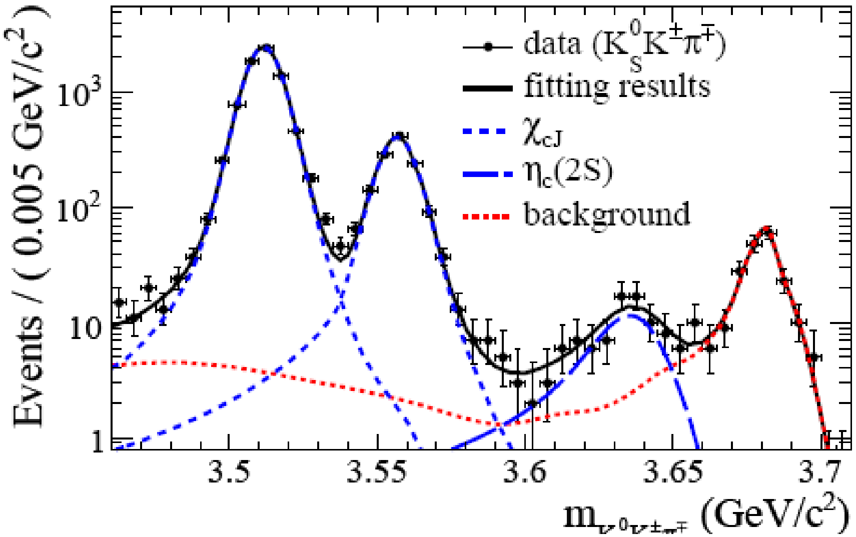
Γ = 130^{+27+57}_{-24-10} MeV/c^2

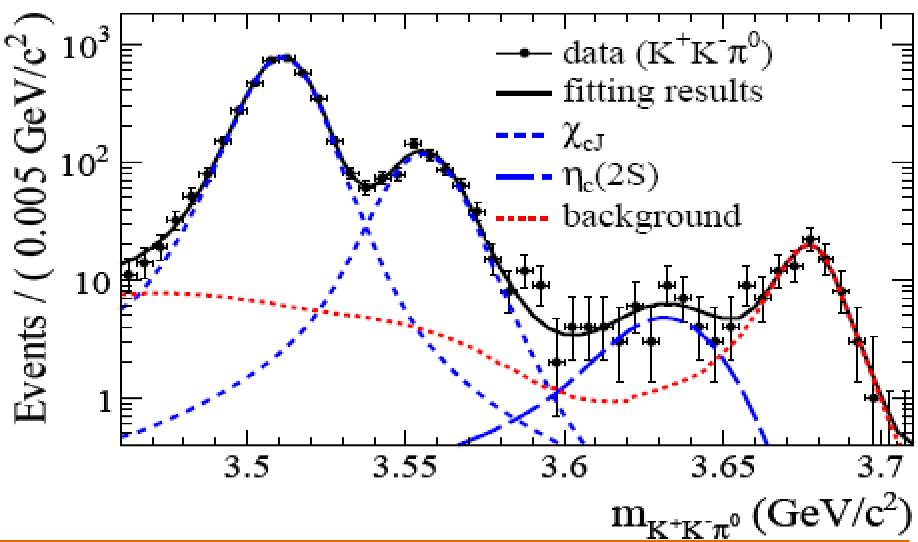
$$B(\psi(2S) \to N(1535)\bar{p}) \times B(N(1535) \to p\eta) + \text{c.c.} = (5.2 \pm 0.3^{+3.2}_{-1.2}) \times 10^{-5}$$

Charmonium (like) physics

Observation of $\eta_c(2S)$ in $\psi' \to \gamma\eta_c(2S)$, $\eta_c(2S) \to K_s K\pi$, $K^+K^-\pi^0$

With 106M ψ' events:





Phys. Rev. Lett. 109, 042003 (2012)

simultaneous fit results:

$M(\eta_c(2S))$ = (3637.6 ± 2.9 ± 1.6) MeV/c^2
$\Gamma(\eta_c(2S))$ = 16.9 ± 6.4 ± 4.8 MeV
Statistical significance larger than 10.2σ!

$Br(\psi' \to \gamma\eta_c(2S) \to \gamma K\underline{K}\pi)$
$=(1.30 \pm 0.20_{stat} \pm 0.30_{sys}) \times 10^{-5}$

+

$Br(\eta_c(2S) \to KK\pi) = (1.9 \pm 0.4 \pm 1.1)\%$
From BABAR(PRD78,012006)

$Br(\psi' \to \gamma\eta_c(2S))$
$=(6.8 \pm 1.1_{stat} \pm 4.5_{sys}) \times 10^{-4}$

CLEO-c: $<7.6\times10^{-4}$
PRD81,052002(2010)

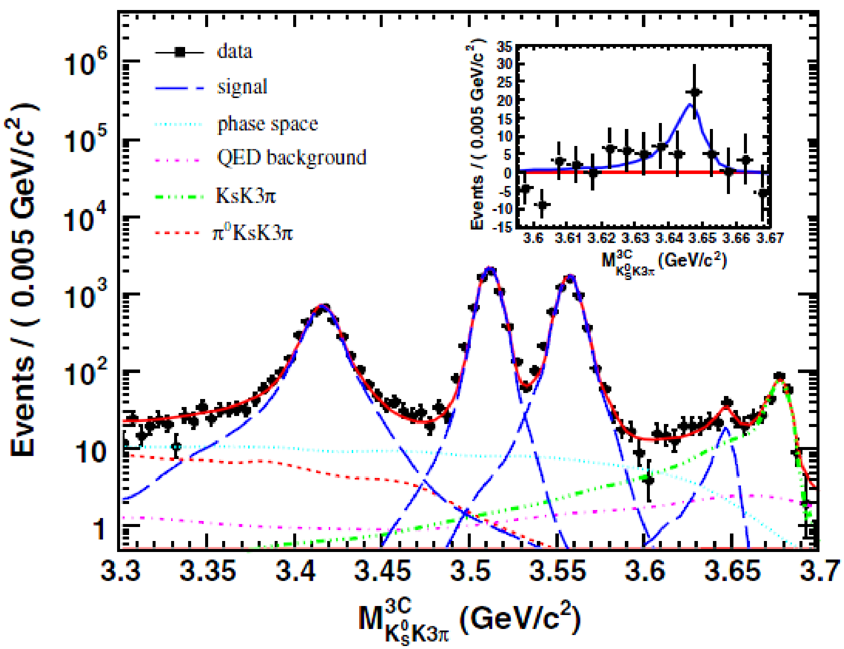
Potential model: $(0.1-6.2)\times10^{-4}$
PRL89,162002(2002)

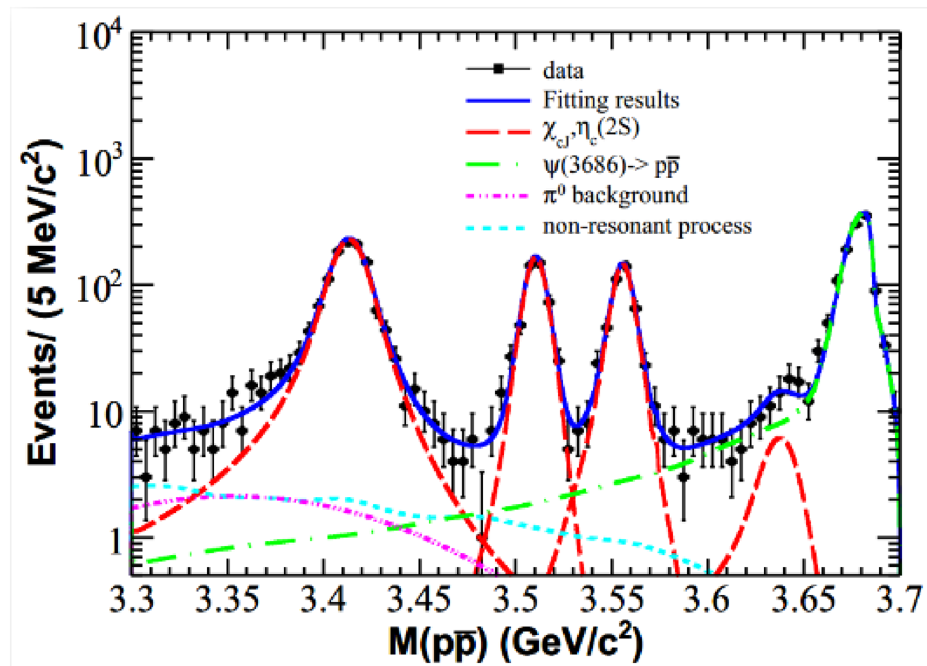
Evidence of $\eta_c(2S) \to K_s K 3\pi$

Search for $\eta_c(2S) \to p\bar{p}$

PRD87, 052005 (2013)

PRD88, 112001 (2013)





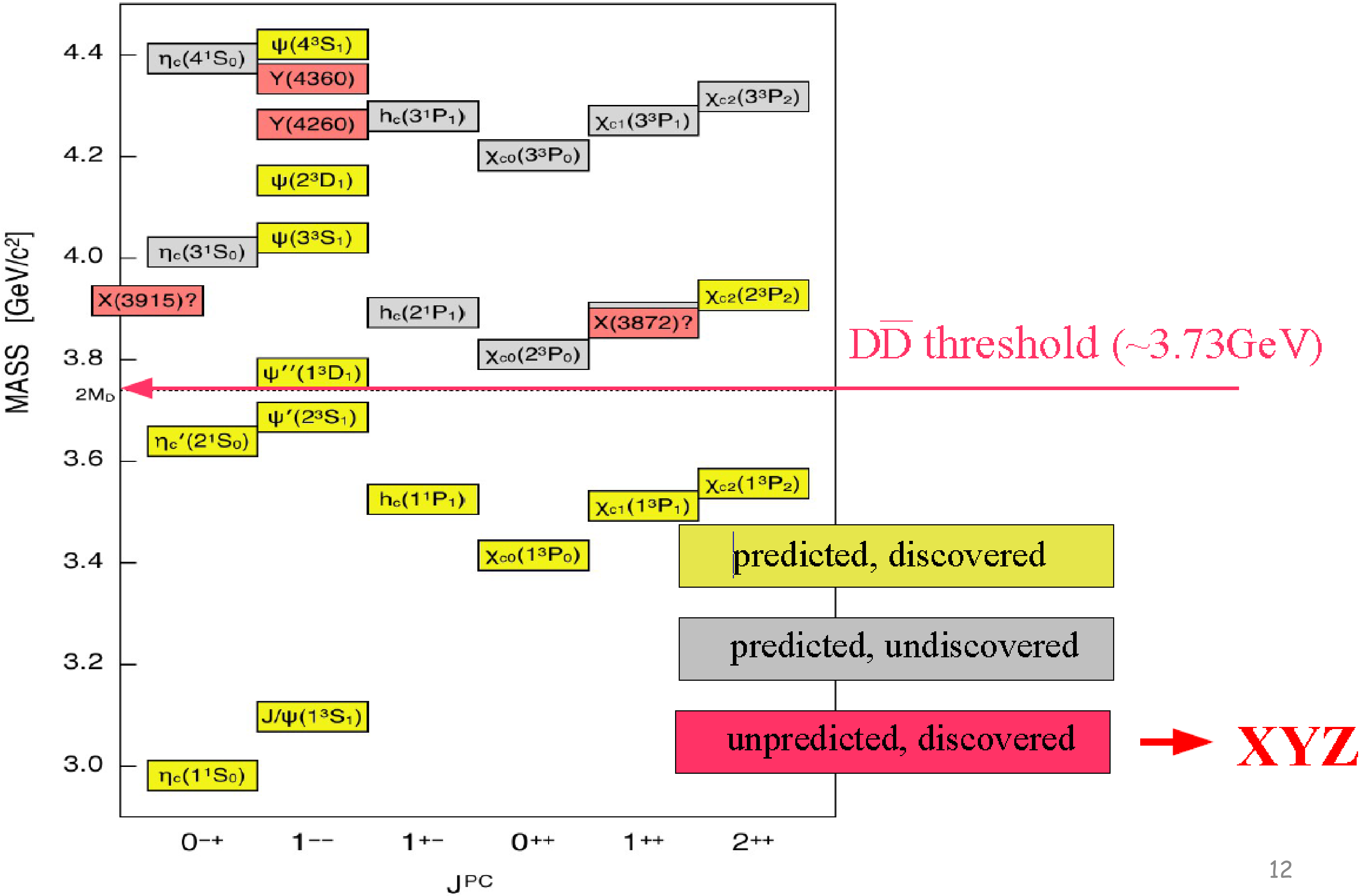
$M(\eta_c(2S)) = (3646.9 \pm 1.6 \pm 3.6)$ MeV/c^2
$\Gamma(\eta_c(2S)) = 9.2 \pm 4.8 \pm 2.9$ MeV
Statistical significance : 4.2σ

No evident signal was observed

$B(\psi' \to \gamma\eta_c(2S) \to \gamma Ks\underline{K3}\pi)$
$=(7.03 \pm 2.10 \pm 0.70) \times 10^{-6}$

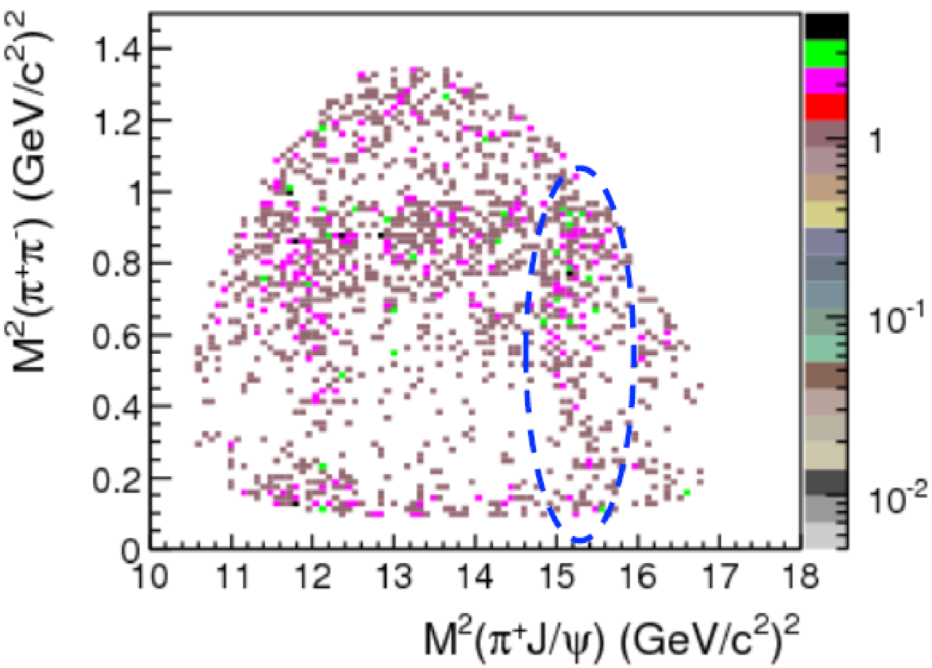
$B(\psi' \to \gamma\eta_c(2S) \to \gamma p\ \bar{p})$
$<1.4 \times 10^{-6}$ @90%C.L.

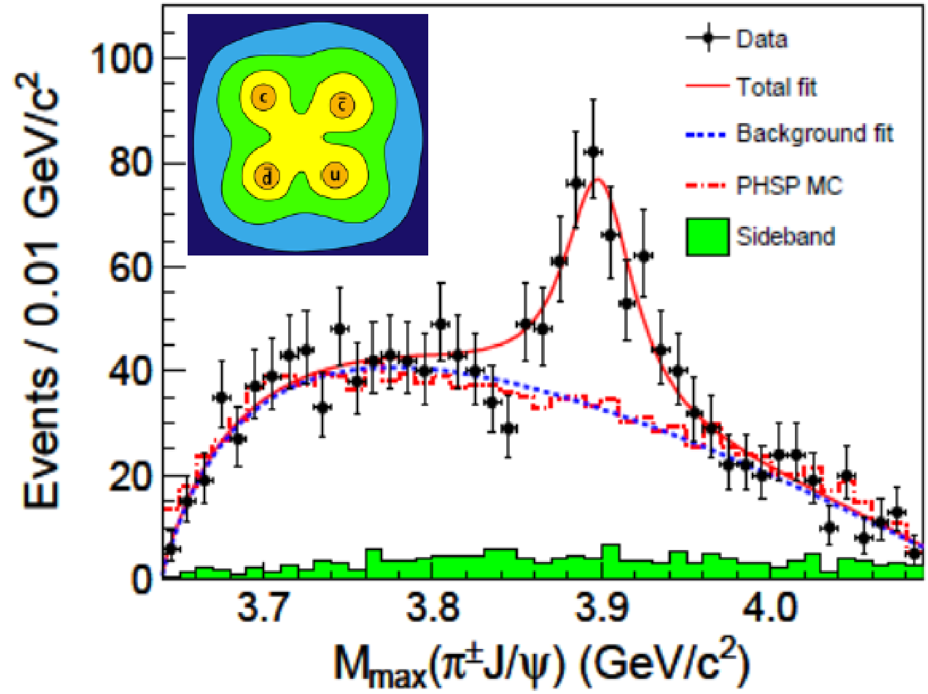
Charmonium and XYZ – states



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

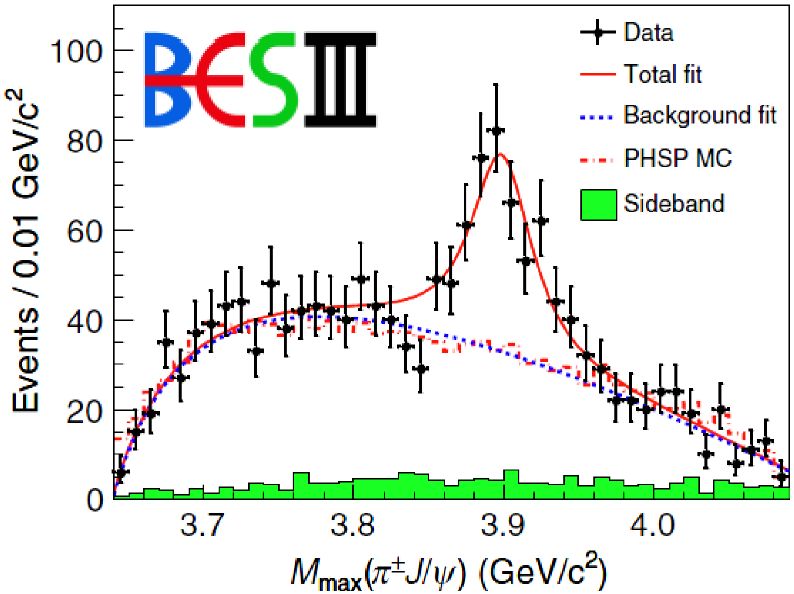
- Requiring J/ψ mass window: [3.08,3.12] GeV, we have 1595 signal events, with purity ~90%.

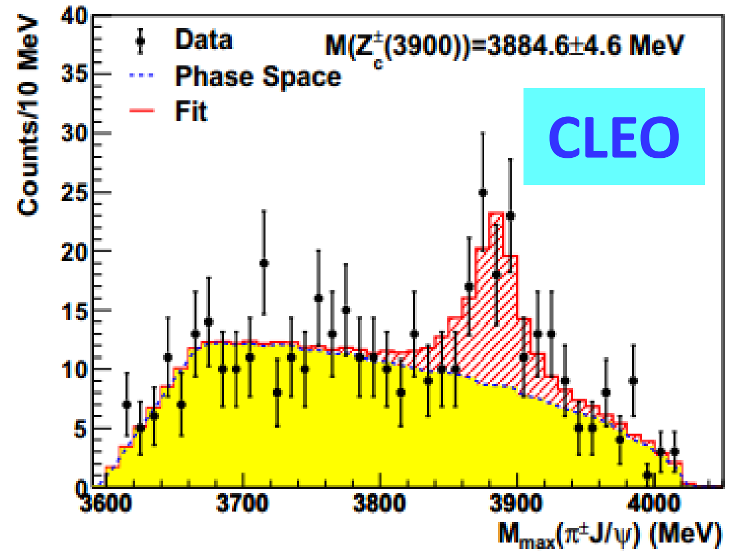


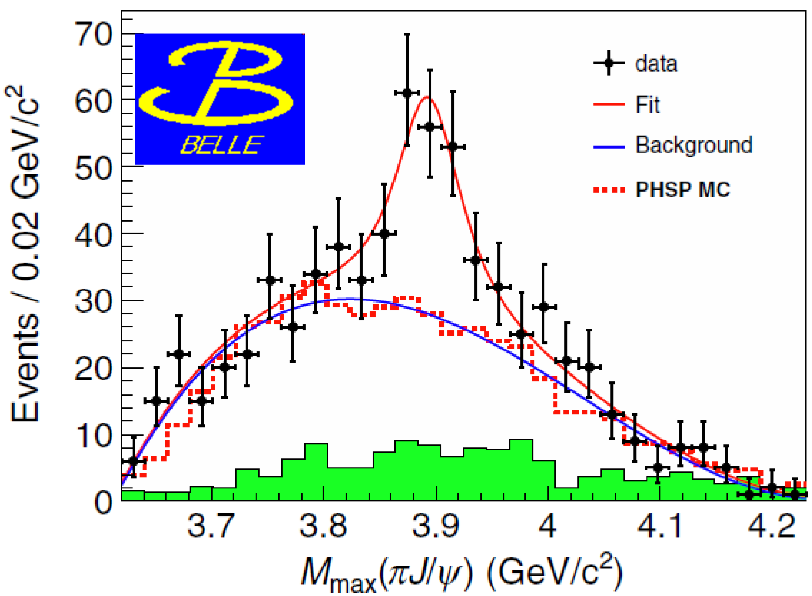


1. New charged resonance, exotic 4 quark hadron?!
2. Fit $M_{max}(\pi^\pm J/\psi)$ mass distribution; avoid cross counting
3. S-Wave Breit Wigner; phase space factor; efficiency corrected.
4. M=(3899.0±3.6±4.9)MeV; Γ=(46±10±20)MeV.
5. Statistical significance: >8σ, discovery!

Comparisons between different experiments on $Z_c(3900)$







1. **CLEO**: PLB 727 (2013) 366

M=3886±6±4 MeV,

Γ=33±6±7 MeV.

2. **Belle**: PRL 110, 252002 (2013)

M=(3894.5±6.6±4.5) MeV;

Γ=(63±24±26) MeV.

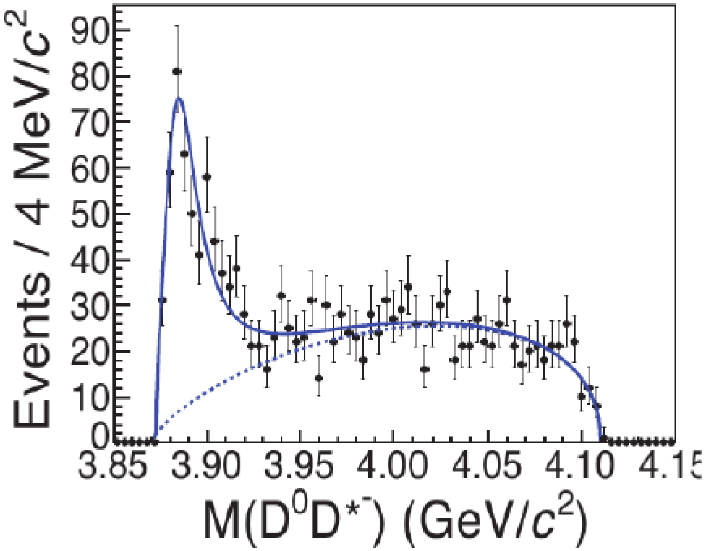
3. **BESIII**: PRL 110, 252001 (2013)

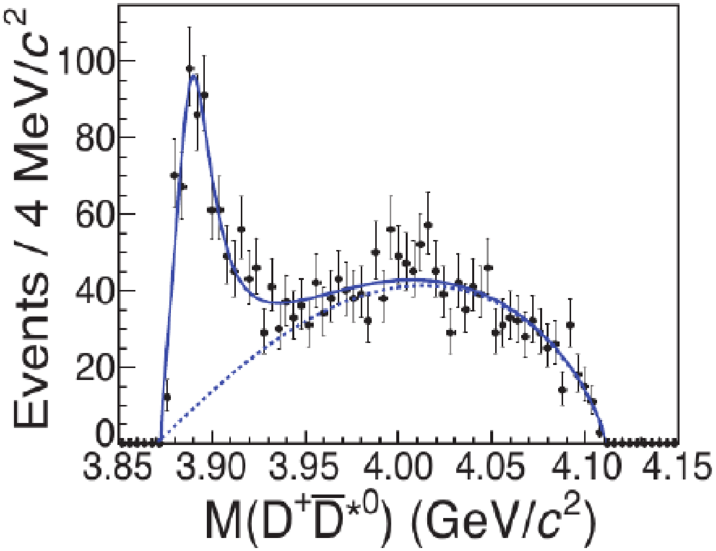
M=(3899.0±3.6±4.9) MeV;

Γ=(46±10±20)MeV

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

PRL 112, 022001 (2014)





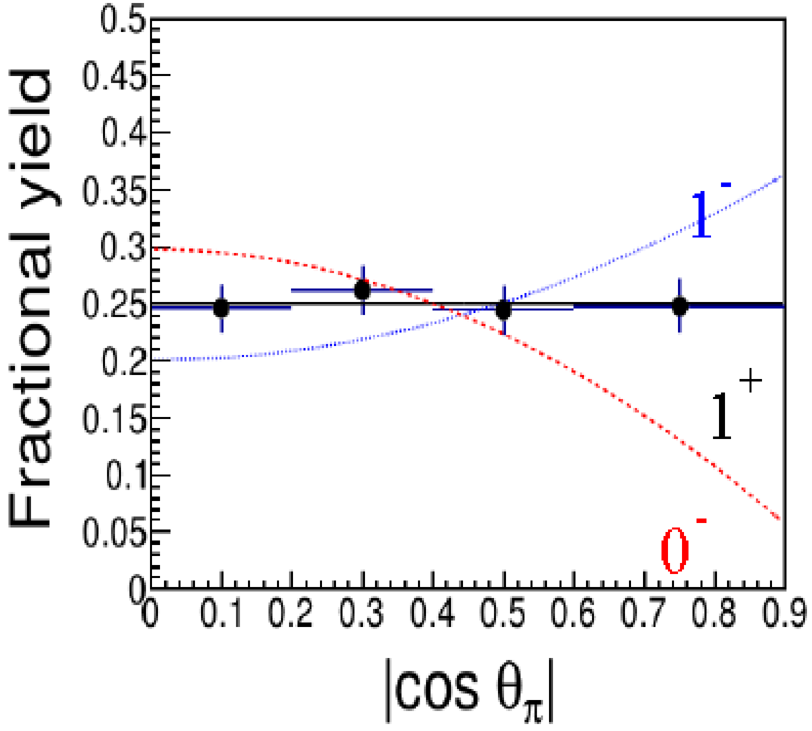
M = 3882.2±1.5 MeV
Γ = 24.6±3.3 MeV
N(Zc)=502 ± 41

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

Quantum numbers of Zc(3885)

PRL 112, 022001 (2014)



$\cos(\theta_\pi)$ – angle of bachelor π^+ in the CMS

$J^P=0^-$, $dN/d\cos(\theta_\pi) \sim 1-\cos^2(\theta_\pi)$

$J^P=1^-$, $dN/d\cos(\theta_\pi) \sim 1+\cos^2(\theta_\pi)$

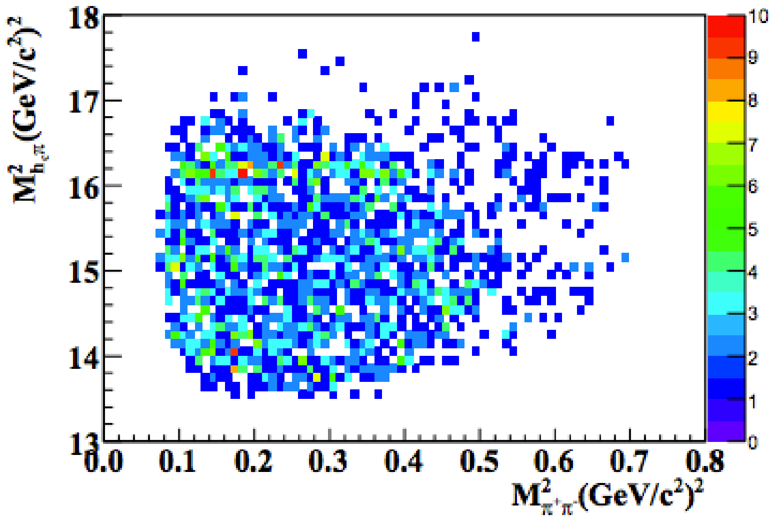
$J^P=1^+$, $dN/d\cos(\theta_\pi) \sim$ flat

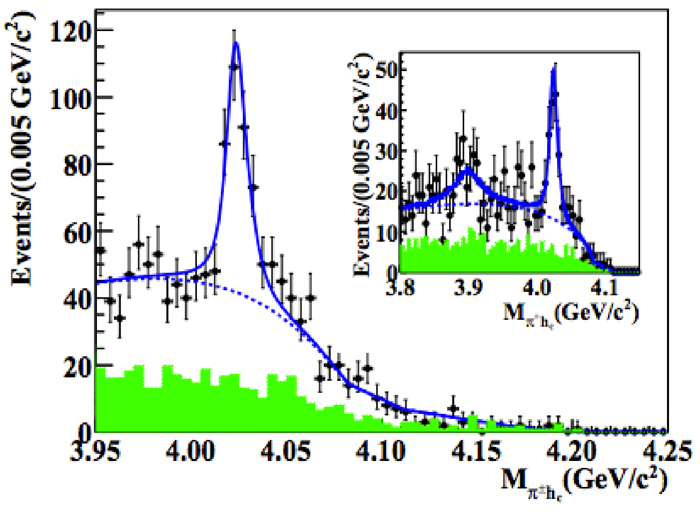
$J^P=0^+$, parity conservation

- If Zc(3885) is Zc(3900): $\dfrac{\Gamma(Z_c(3900) \to D\bar{D}^*)}{\Gamma(Z_c(3900) \to \pi J/\psi)} = 6.2 \pm 1.1 \pm 2.7$

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

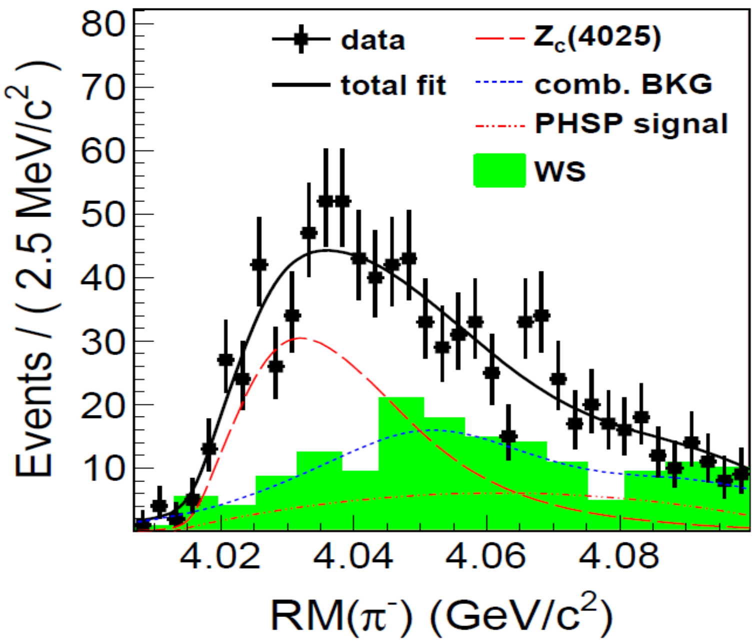
PRL 111 242001 (2014)





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

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



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

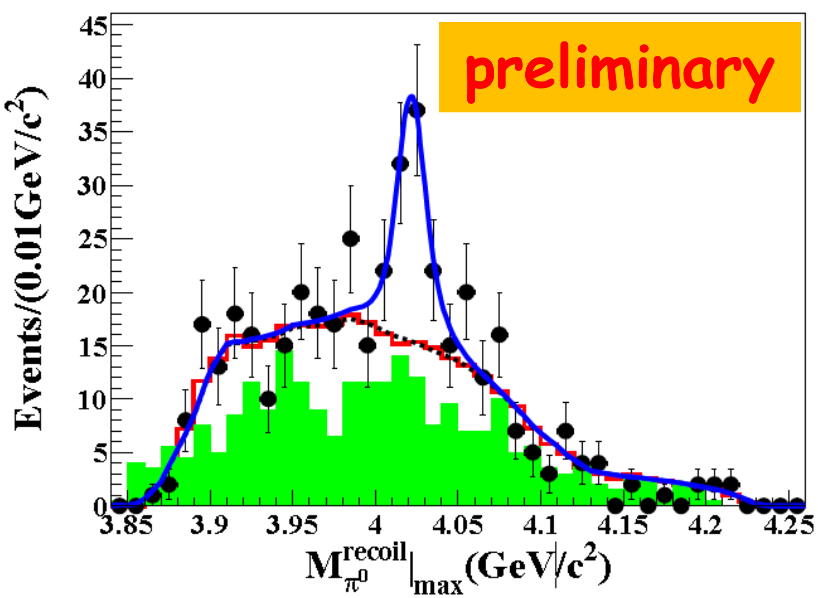
PRL 112 132001 (2014)

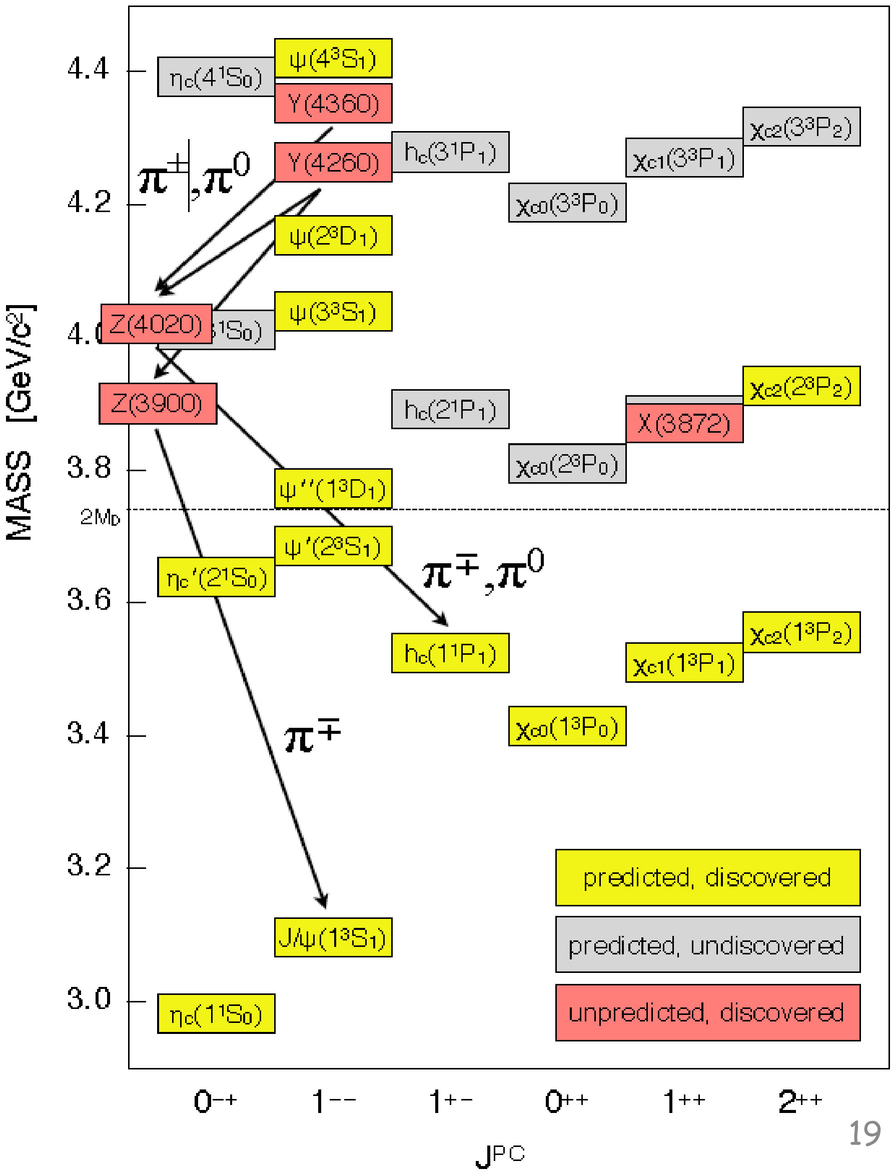
- **if $Z_c(4025)^\pm$ is the $Z_c(4020)^\pm$ observed in the $\pi^\pm h_c$ spectrum:**

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

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

- 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
- **Neutral isospin partner of the $Z_c(4020)^{\pm}$**





Summary of Z states

Channel	Mass [MeV/c2]	Width
$J/\psi\pi^{\pm}$	$3899.0\pm3.6\pm4.9$	$46\pm10\pm20$
$(DD^{*})^{+}$	$3883.9\pm1.5\pm4.2$	$24.8\pm3.3\pm11.0$
$h_c\pi^{\pm}$	$4022.9\pm0.8\pm2.7$	$7.9\pm2.7\pm2.6$
$h_c\pi^{0}$	$4023.6\pm2.2\pm3.9$	Fixed
$(D^{*}D^{*})^{+}$	$4026.3\pm2.6\pm3.7$	$24.0\pm5.6\pm7.7$

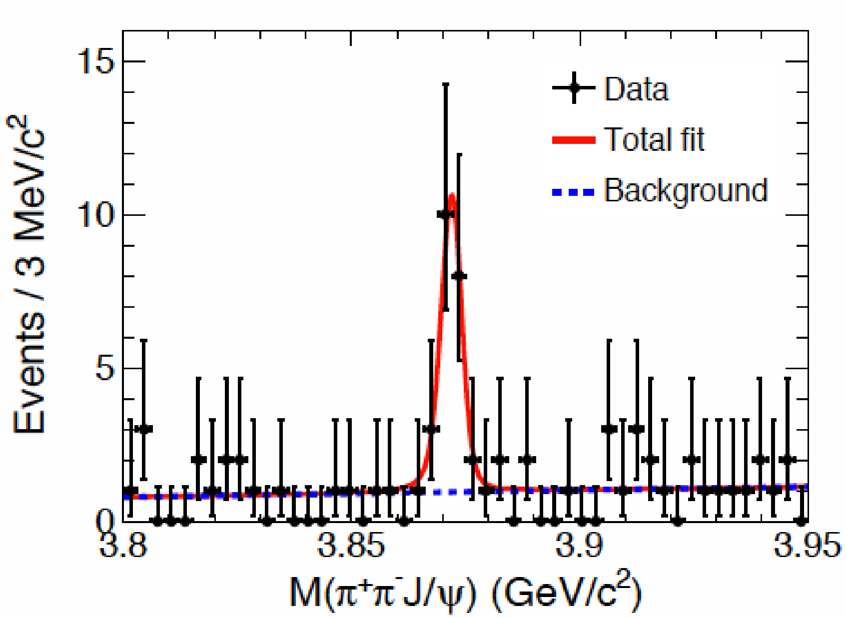
- **Nature of these states ?**
  - **Tetraquark L. Maiani, A. Ali et al**
  - **Hadronic molecule U.-G. Meissner, F.K. Guo et al.**
  - **Hadro-charmonium M. B. Boloshin**
  - **Meson loop Q. Zhao et al.**
  - **ISPE model X. Liu et al**
  - **...**

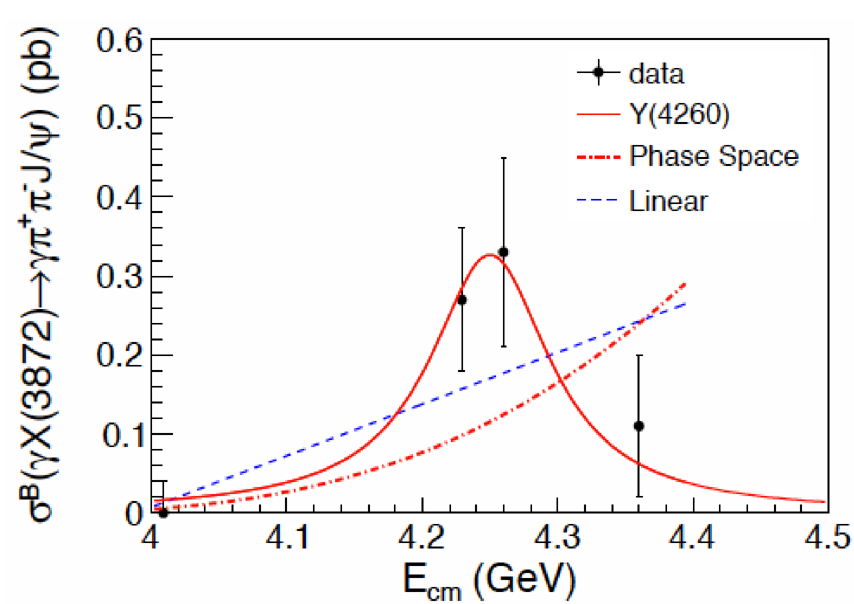
Z_c charmonium-like meson

- **Well defined signature of event:**
  - decay into known charmonium state
  - electric charge ==> Nquark ≥ 4
- **Possible directions of searches:**

$\pi J/\psi$, $\pi\, h_c(1P)$, $\pi\psi'$, $\pi\chi_{cJ}$, πDD...

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



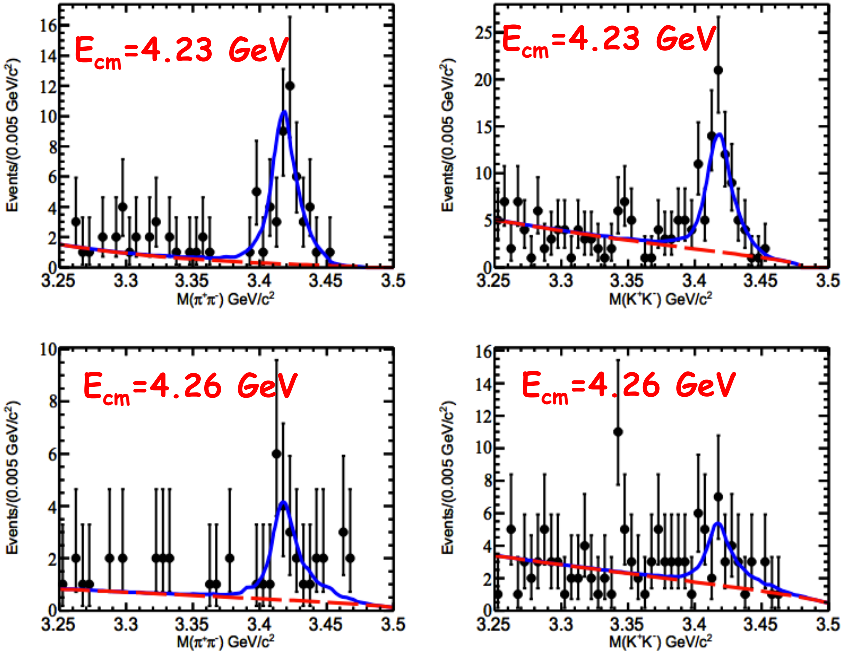


PRL 112 092001 (2014)

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

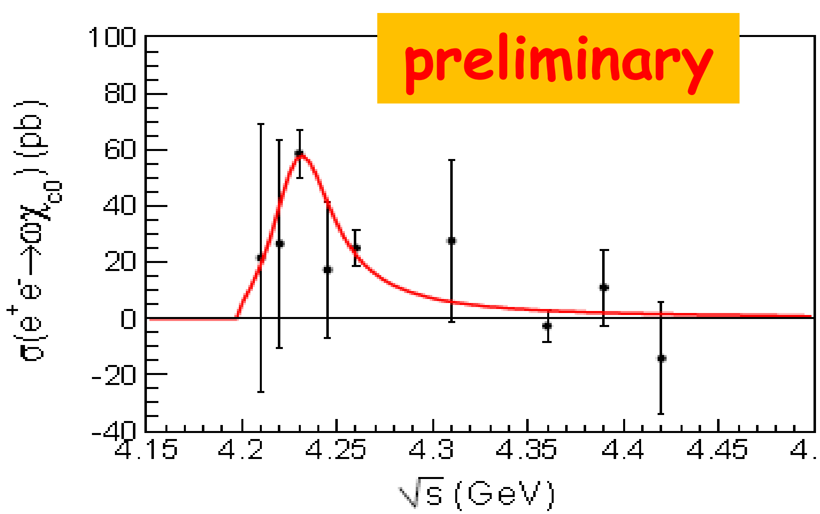
$$\frac{\mathcal{B}[Y(4260)\to\gamma X(3872)]}{\mathcal{B}(Y(4260)\to\pi^+\pi^- J/\psi)} = 0.1$$

$e^+e^- \to \omega\chi_{c0}$



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

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



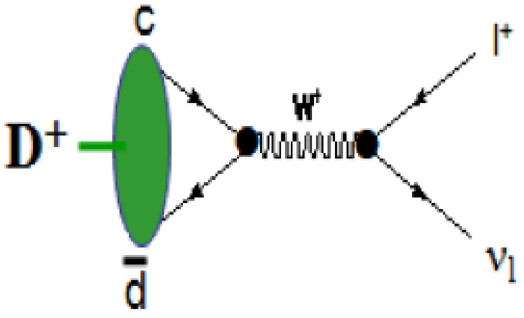
Assuming the $\omega\chi_{c0}$ signals come from a resonance, we extract the $\Gamma_{ee} \cdot B(\omega\chi_{c0})$, mass, and width of the resonance to be (2.9±0.7±0.4) eV, M=(4229±13±6) MeV/c^2, and (40±13±2) MeV.

Charm physics

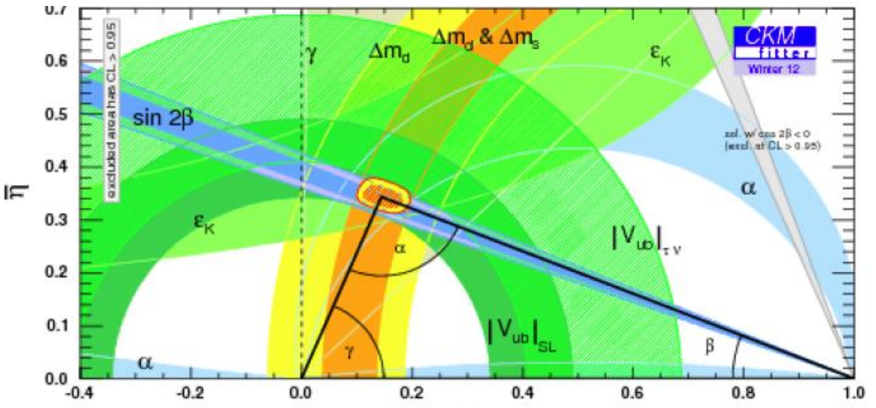
$D^+ \to \mu^+ \nu$ and Decay constant f_{D+}

- D^+ leptonic decays play an important role in understanding of the SM
- Test LQCD calculation of f_D

$$\Gamma_{SM}(D^+_{(s)} \to l^+ \nu) = \frac{G_F^2}{8\pi} m_l^2 m_{D_{(s)}} \left(1 - \frac{m_l^2}{m_{D_{(s)}}^2}\right)^2 |V_{cd(s)}|^2 f_{D^+_{(s)}}$$



- Precise measurement of $|V_{cd}|$
- Theoretical uncertainty will be reduced in determination of $|V_{ud}|$ If FF calculations can be validated with charm

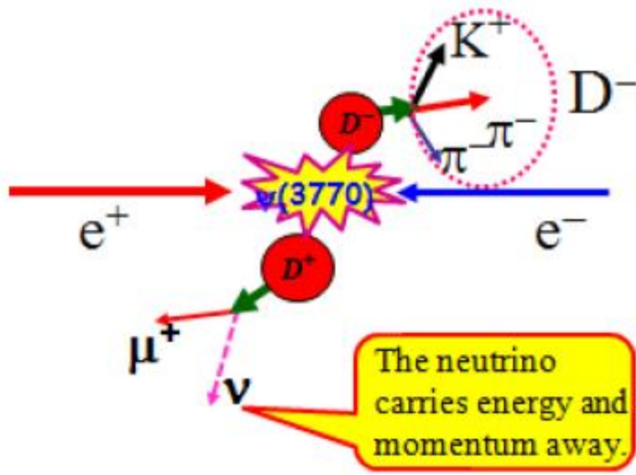


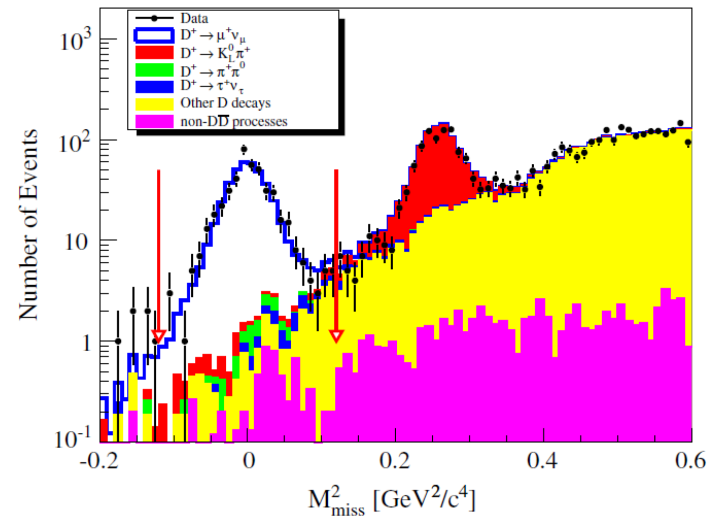
PRD 89, 051104 (2014)

- Reduced width of band in triangle would lead to precisely test the SM, and search for new physics beyond the SM

$D^+ \to \mu^+ \nu$ and Decay constant f_{D+}

In the system recoiling against the singly tagged D^-, BES-III selected the purely leptonic decay events for $D^0 \to \mu^+ \nu$





Br. & f_{D+} at BES-III

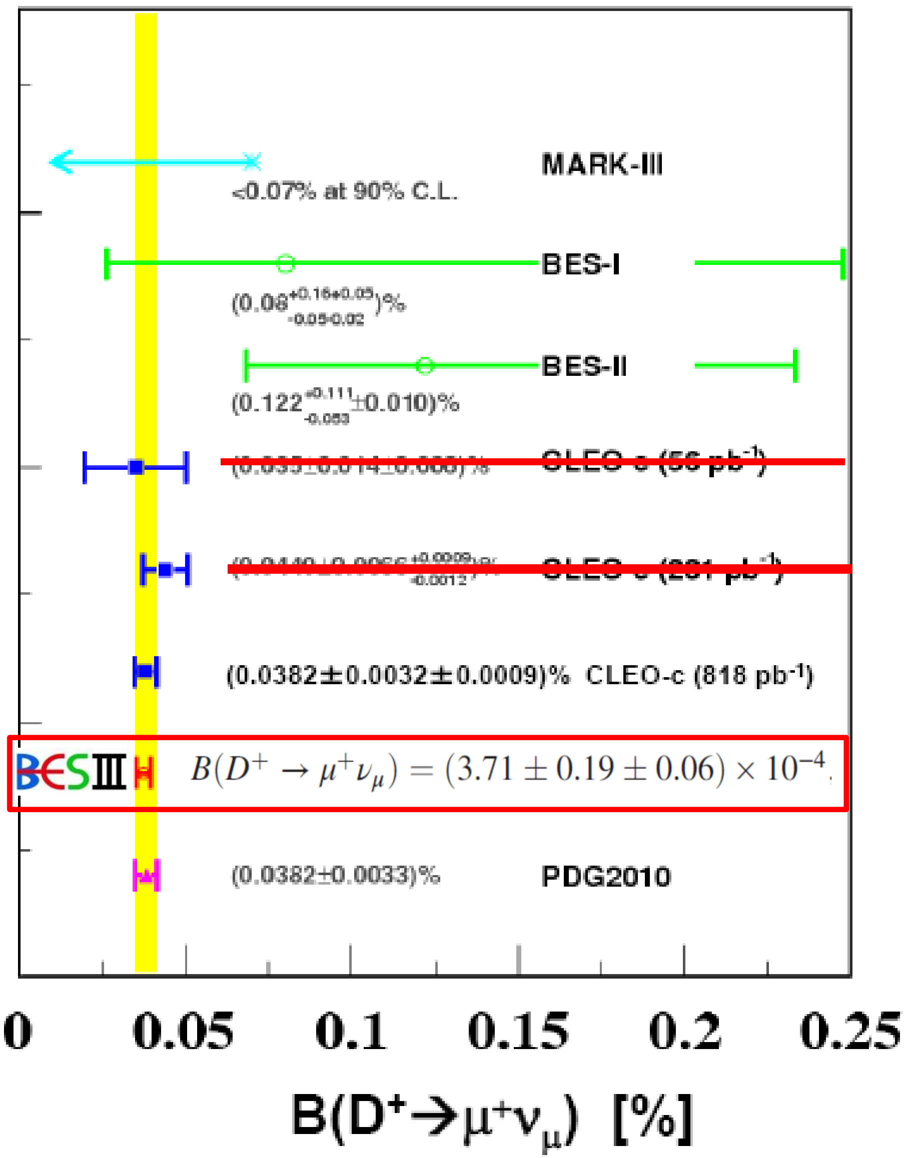
$$B(D^+ \to \mu^+ \nu_\mu) = (3.71 \pm 0.19 \pm 0.06) \times 10^{-4}.$$

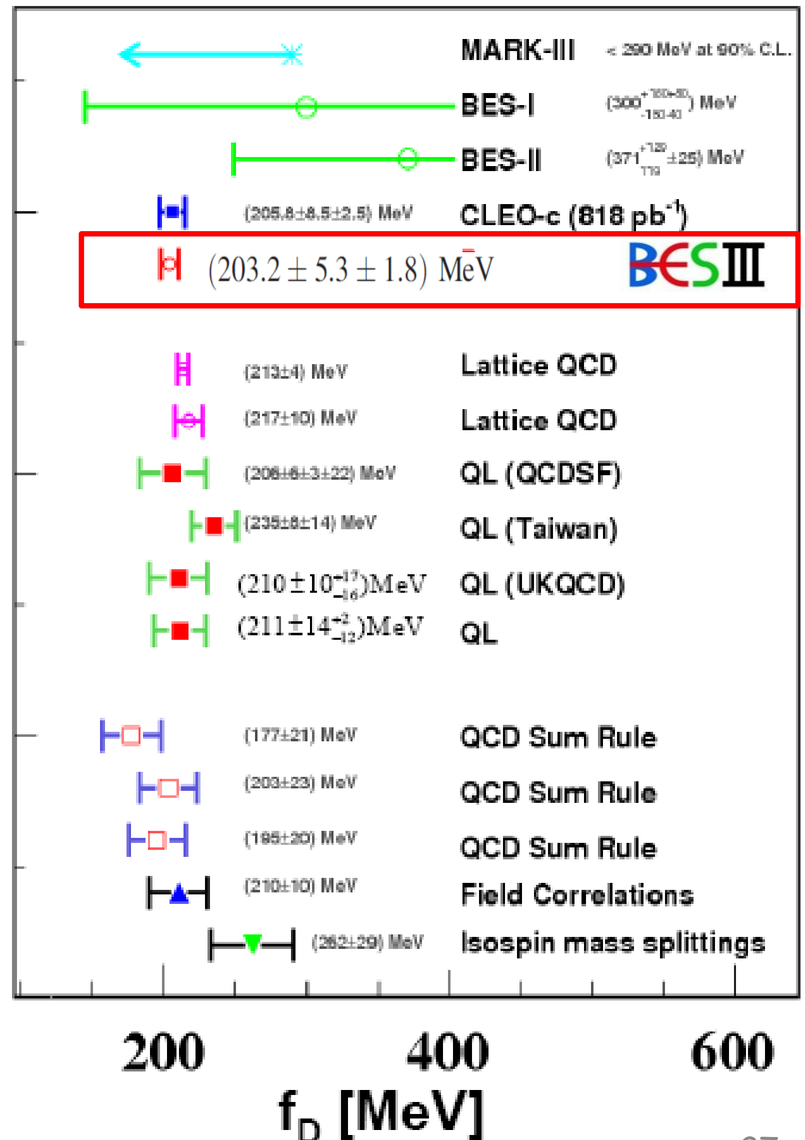
$$f_{D^+} = (203.2 \pm 5.3 \pm 1.8)\ \text{MeV}$$

PRD 89, 051104 (2014)

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

Comparison of $B(D^+ \to \mu^+ \nu)$ & f_D





τ mass measurement

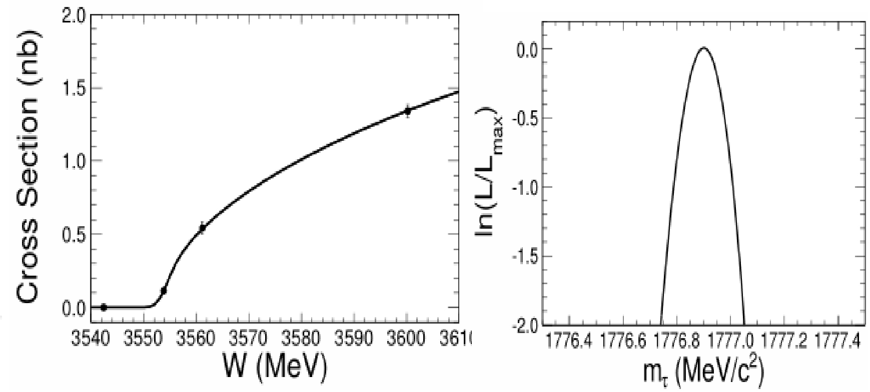
- The likelihood function for the maxir likelihood fitting:

$$L(m_\tau, R_{Data/MC}, \sigma_B) = \prod_{i=1}^{4} \frac{\mu_i^{N_i} e^{-\mu_i}}{N_i!},$$

$$\mu_i = [R_{Data/MC} \times \varepsilon_i \times \sigma(E^i_{CM}, m_\tau) + \sigma_B] \times l_i$$

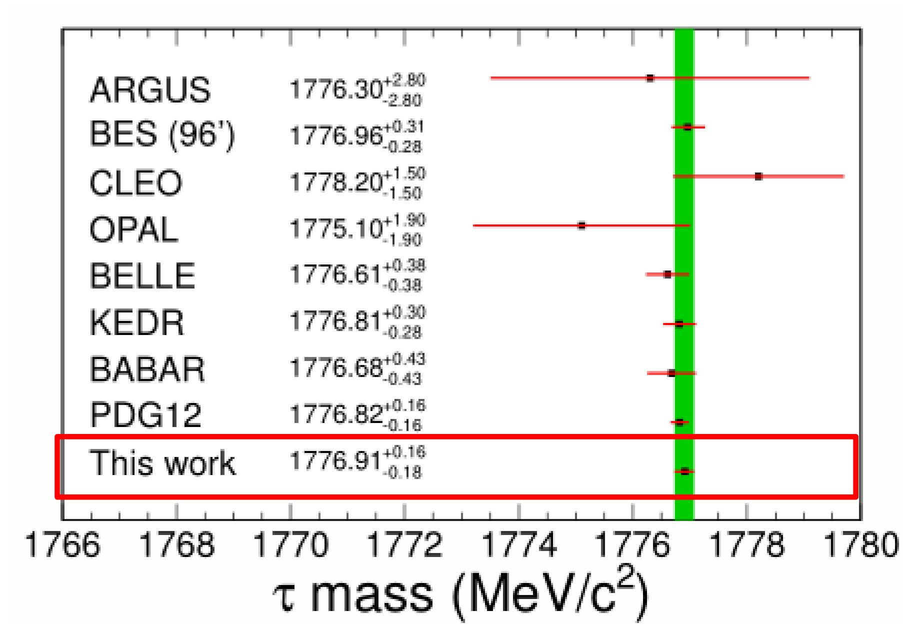
$$\varepsilon_i = Br_j \varepsilon_{ij},$$

i represents energy points, j represent channels



- In carrying out the ML fit, m_τ , $R_{data/MC}$, σB are floated

The CM energy dependence of the τ pair cross section resulting from the likelihood fit (curve), compared to the data (Poisson errors)



Summary

- It is good place to search for N* and new resonance in hadron spectroscopy study at BESIII.
- A lot of Z, X states are found or confirmed at BESIII, i.e. $Z_c(3900)$, $Z_c(4020)$, X(3872), much more are in progress.
- More precise measurement on $B(D^+ \to \mu^+ \nu)$ and f_{D+} are available with BESII's data.
- τ mass is measured with a higher precision at BESIII.

Thank you!