Overview on BESIII results

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For BESIII Collaboration

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Lanzhou, China

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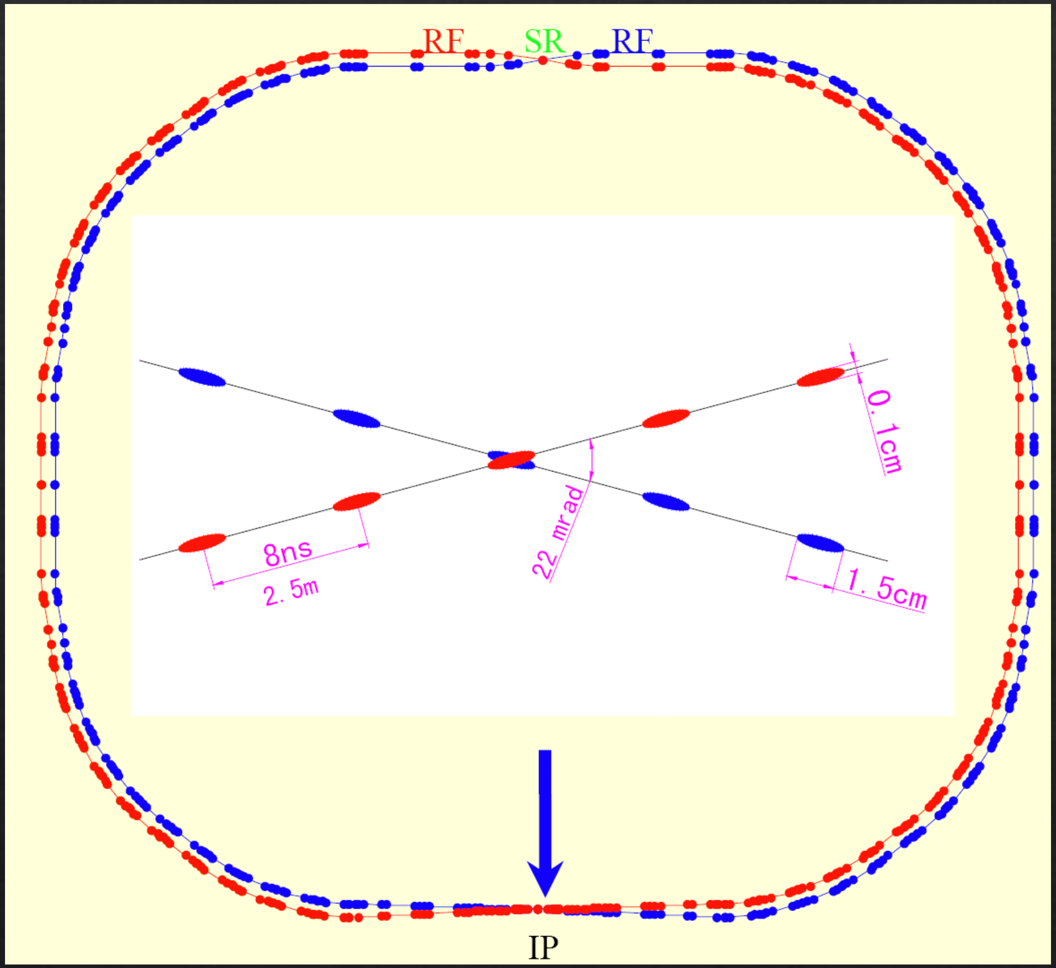
Outline

- BEPCII and BESIII
- Data samples
- Physics results
  - Light hadron spectrum
  - Charmonium(-like) physics
  - Charm physics
  - QCD & τ physics
- Summary

Beijing Electron Positron Collider (II)

BEPCII



Beam energy:
1.0 - 2.3 GeV

Design Luminosity:
1×10^{33} cm^{-2} s^{-1}
(0.7×10^{33} cm^{-2} s^{-1})

Optimum energy:
1.89 GeV

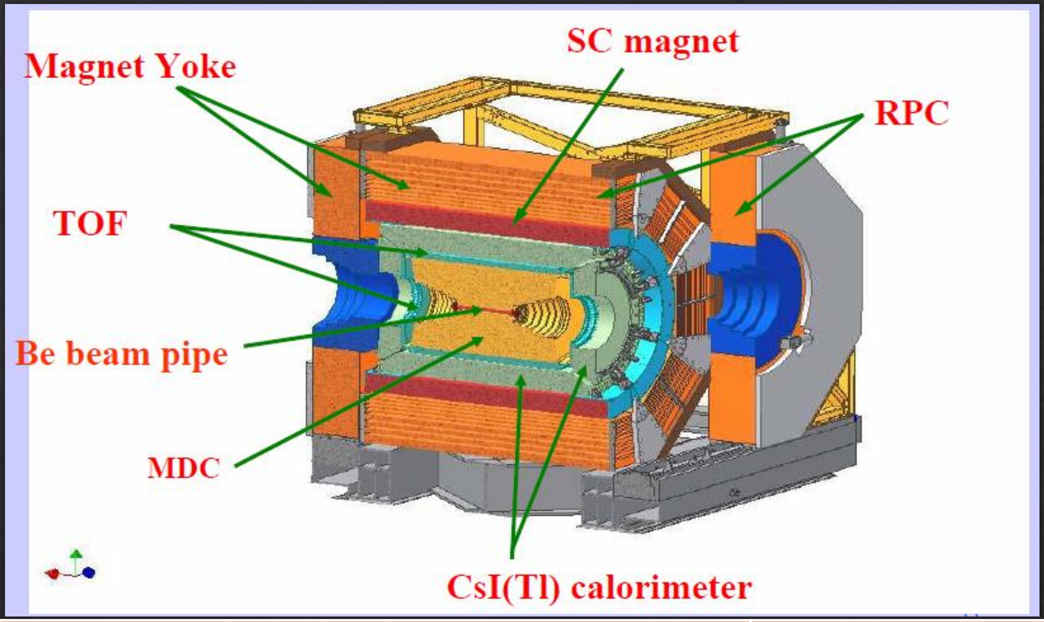
No. of bunches:
93

Bunch length:
1.5 cm

Total current:
0.91 A

SR mode:
0.25A @ 2.5 GeV

BESIII



Sub-detectors			Performance
MDC	Momentum resolution		0.5%@1GeV
	dE/dx resolution		6%
EMC	Energy resolution		2.5%@1GeV
	Spatial resolution		6 mm
TOF	Time resolution	Barrel	80 ps (Bhabha)
		Endcap	110 ps (Di-muon)
MUC	9 layers RPC, 8 layers for endcap		

BESIII Collaboration

Political Map of the World, June 1999

US (5)

Univ. of Hawaii
Carnegie Mellon Univ.
Univ. of Minnesota
Univ. of Rochester
Univ. of Indiana

Europe (13)

Germany: Univ. of Bochum, Univ. of Giessen, GSI
Univ. of Johannes Gutenberg Helmholtz Ins. In Mainz
Russia: JINR Dubna; BINP Novosibirsk
Italy: Univ. of Torino， Frascati Lab, Ferrara Univ.
Netherland：KVI/Univ. of Groningen
Sweden: Uppsala Univ.
Turkey: Turkey Accelerator Center

China(31)

IHEP, CCAST, UCAS, Shandong Univ.,
Univ. of Sci. and Tech. of China
Zhejiang Univ., Huangshan Coll.
Huazhong Normal Univ., Wuhan Univ.
Zhengzhou Univ., Henan Normal Univ.
Peking Univ., Tsinghua Univ. , Nankai Univ.
Zhongshan Univ., Shanghai Jiaotong Univ.
Shanxi Univ., Sichuan Univ., Univ. of South China
Hunan Univ., Liaoning Univ. , Beihang Univ.
Nanjing Univ., Nanjing Normal Univ.
Guangxi Normal Univ., Guangxi Univ.
Suzhou Univ., Hangzhou Normal Univ.
Lanzhou Univ., Henan Sci. and Tech. Univ.
Hong Kong Univ., Hong Kong Chinese Univ.

~350 members
53 institutions from 11 countries

Korea (1)

Seoul Nat. Univ.

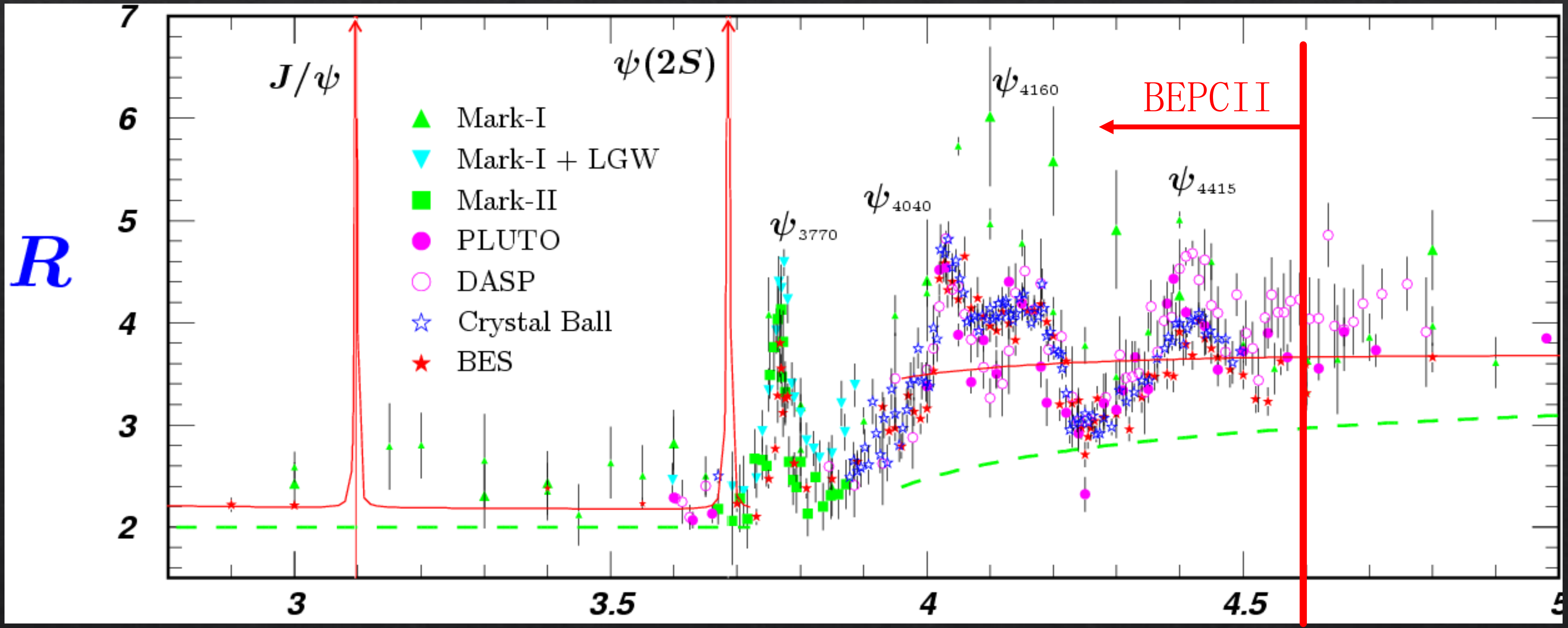
Japan (1)

Tokyo Univ.

Pakistan (2)

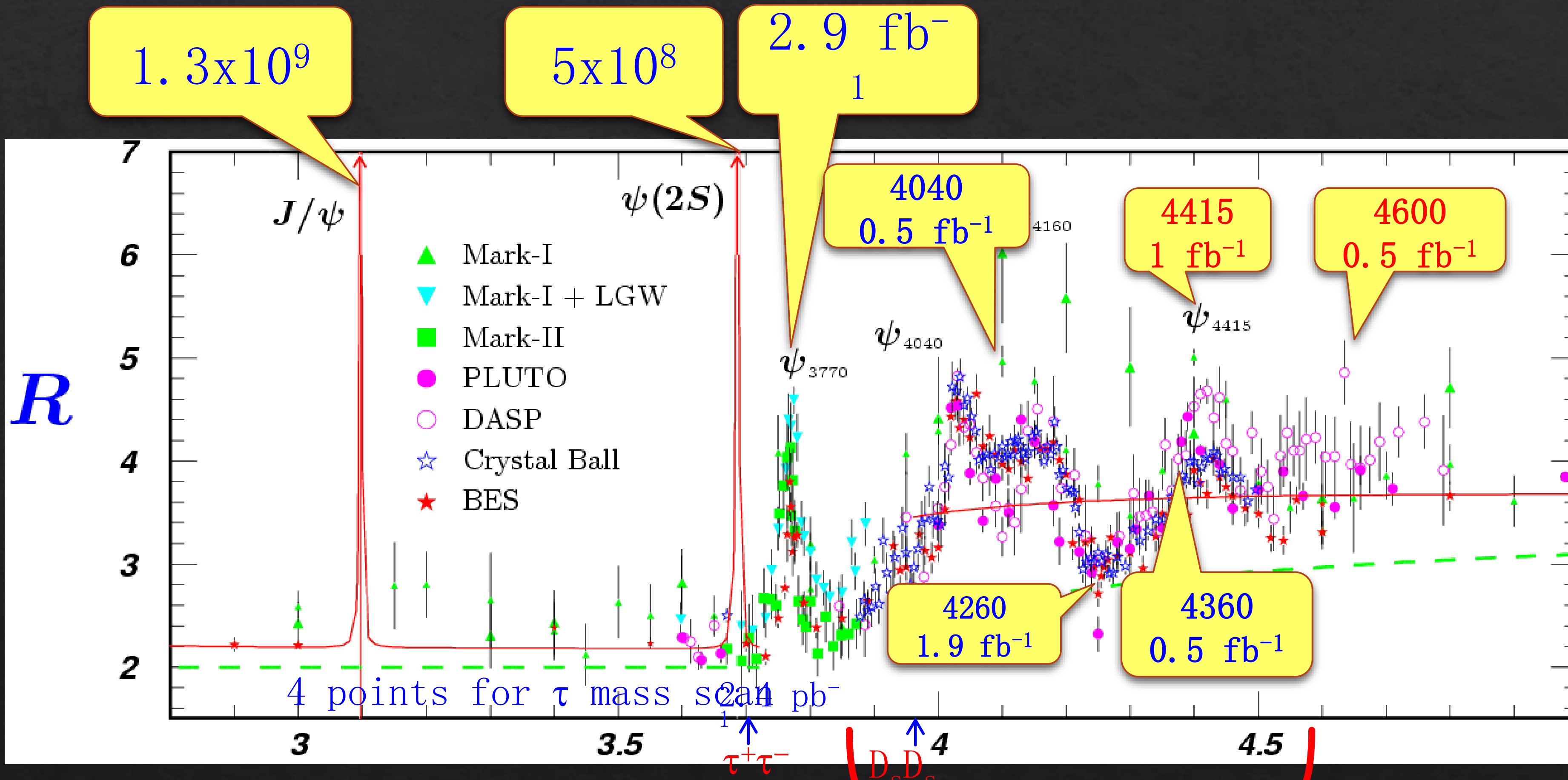
Univ. of Punjab
COMSAT CIIT

Production of charmonium(like) states



Vector ψ/Y states can be produced directly
C-even states can be produced from radiative transitions

Data Samples

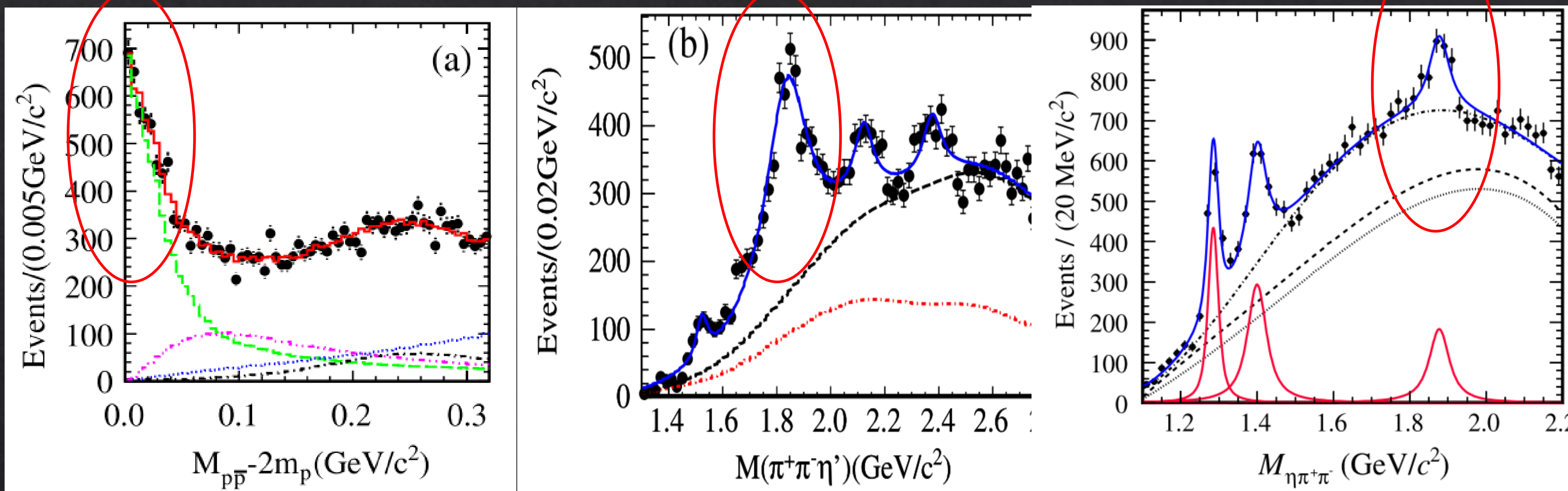


104 points for R scan, 0.8 fb^-1

Light hadron spectrum

- X(18??) found at BES
- PWA of $J/\psi \to \gamma\eta\eta$
- Baryon excited states (N*)

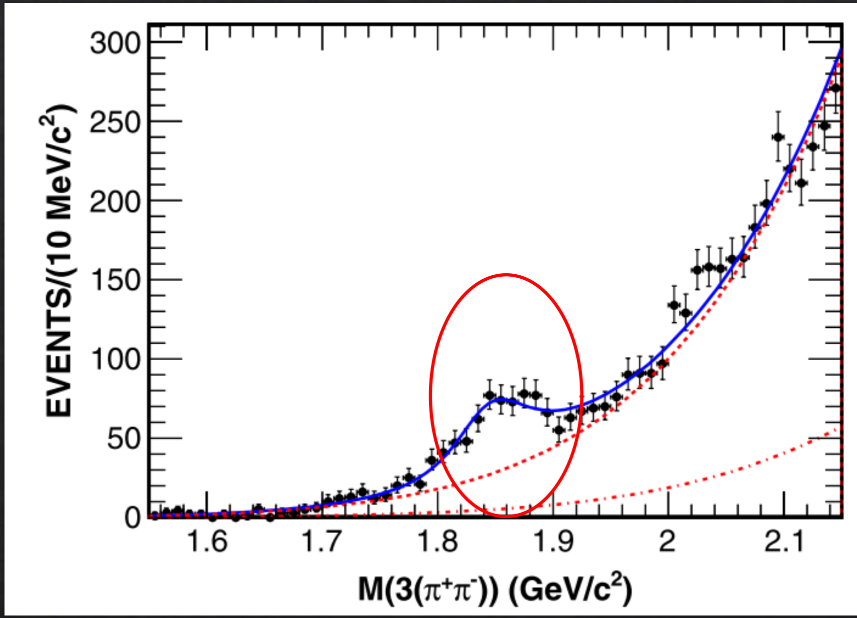
BES Observation



- $X(p\bar{p})$, $p\bar{p}$ threshold enhancement in $J/\psi\to\gamma p\bar{p}$ PRL 108, 112003
- $X(1835)$ in $J/\psi\to\gamma\pi^+\pi^-\eta'$ PRL 106, 072002
- $X(1870)$ in $J/\psi\to\omega\eta\pi\pi$ PRL 107, 182001

Observation of X(1840) in $J/\psi \to \gamma 3(\pi^+\pi^-)$

- Mass is consistent with that of X(1835), but the width is much smaller
- $M = 1842.2 \pm 4.2^{+7.1}_{-2.6}$ MeV/c2
  $\Gamma = 82 \pm 14 \pm 11$(model) MeV
- $B(J/\psi \to \gamma X(1840)) \times B(X(1840 \to 3(\pi^+\pi^-))$
  $= (2.44 \pm 0.36^{+0.60}_{-0.74}) \times 10^{-5}$
- A new decay modes of X(1835)?

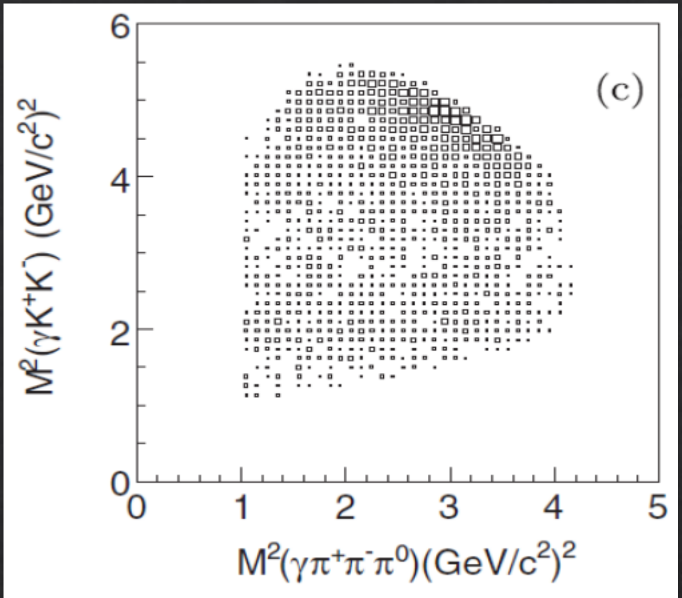


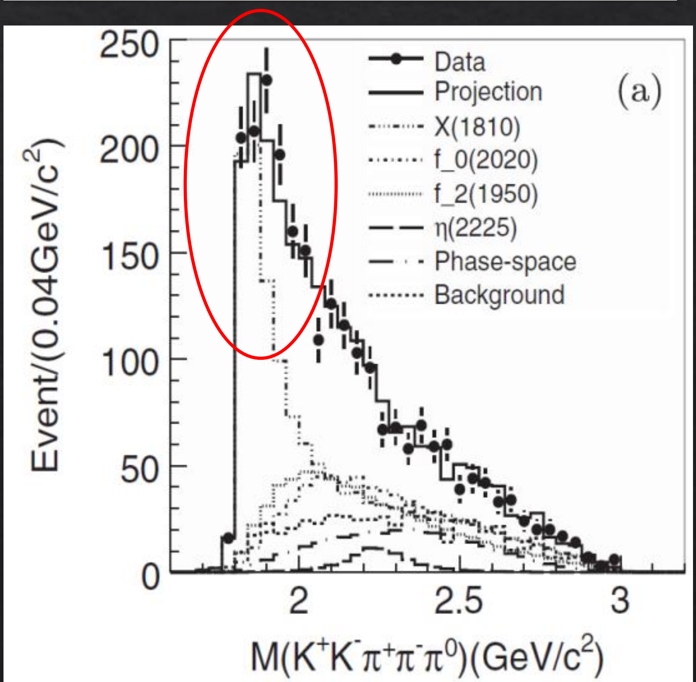
PRD 88, 091502

PWA of $J/\psi \to \gamma\omega\phi$

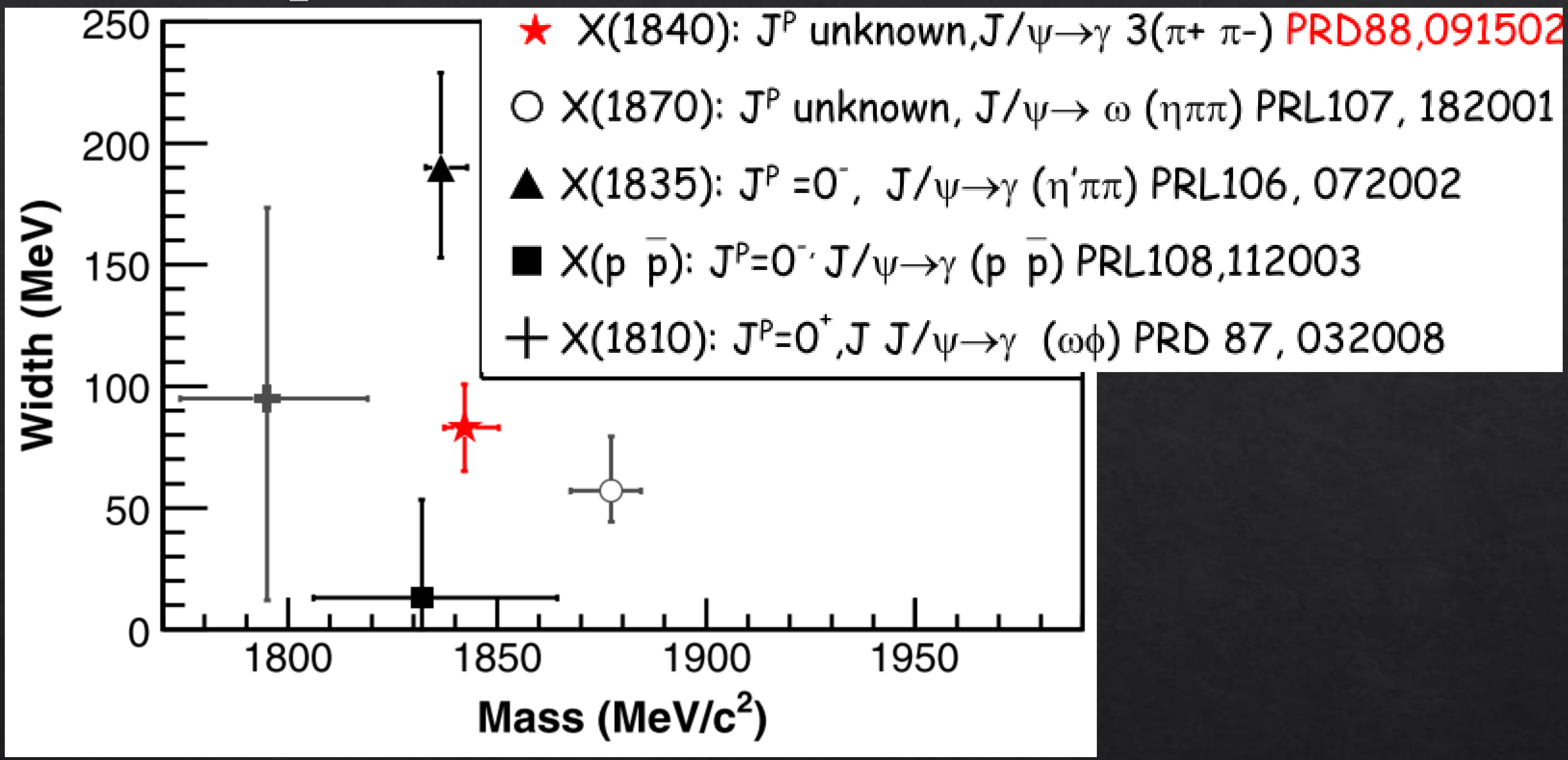
- DOZI process
- Confirmed the enhancement observed at BESII
- $M = 1795 \pm 7^{+13}_{-5} \pm 19(\text{model})$ MeV/c2
  $\Gamma = 95 \pm 10^{+21}_{-34} \pm 75(\text{model})$ MeV
- $B(J/\psi \to \gamma X(1810)) \times B(X(1810 \to \omega\phi) = (2.00 \pm 0.08^{+0.45}_{-1.00} \pm 1.30) \times 10^{-4}$
- Spin-parity is determined to be 0^{++}
- The same as $f_0(1710)/f_0(1790)$, or a new state?

PRD 87, 032008





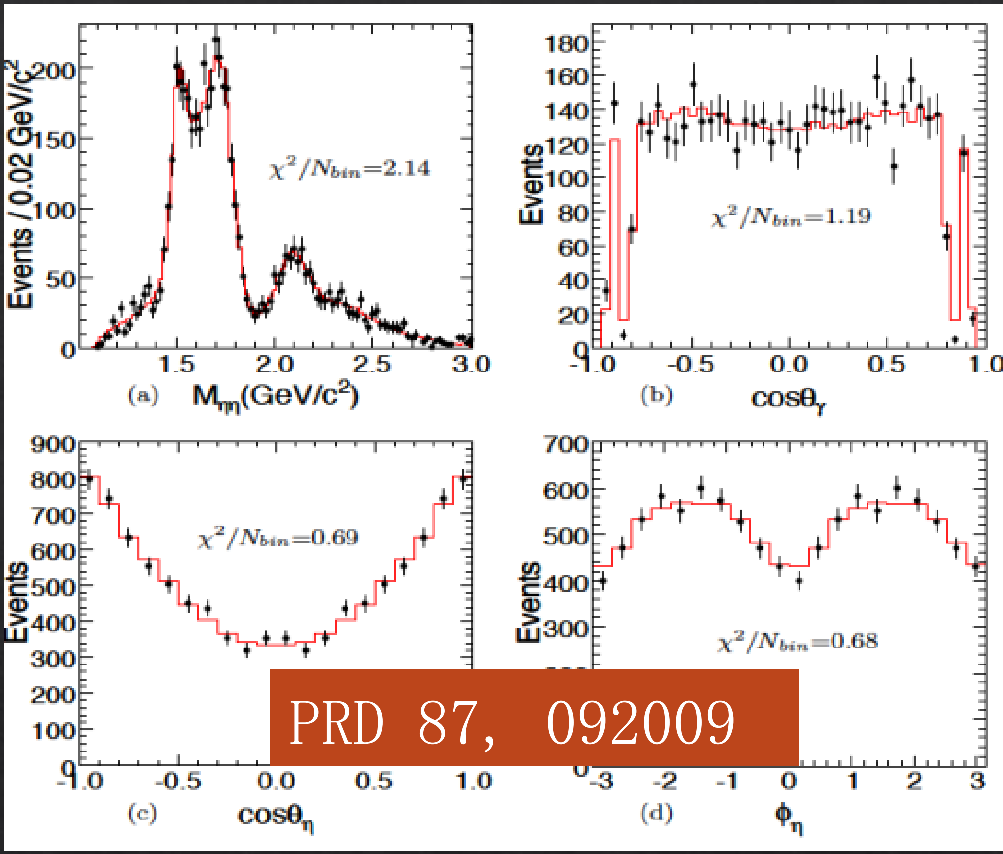
Comparison of BES observation



- X(18??) near the threshold position of proton-antiproton
- Are they the same particles? It is crucial to identify these observations.

PWA of J/ψ→γηη

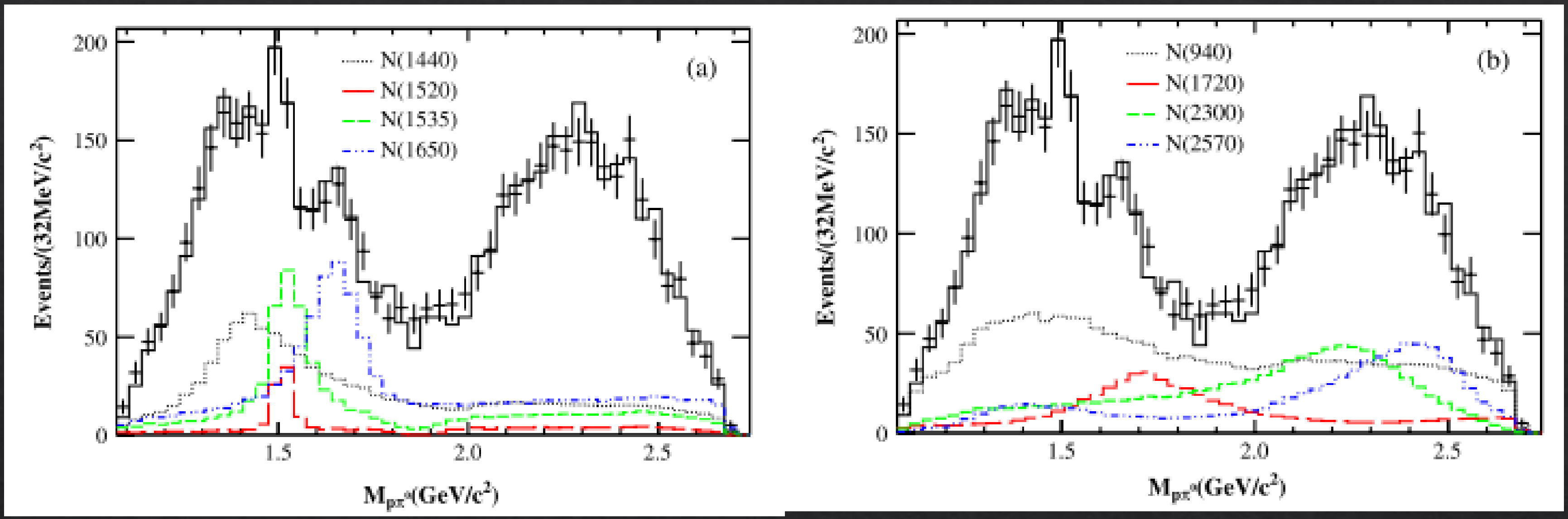
- $f_0(1710)$ and $f_0(2100)$ are dominant scalars
- $f_0(1500)$ exists (8.2σ)
- The significant tensor contribution comes from $f_2'(1525)$
- $f_2(1810)$ and $f_2(2340)$ exist
- No evidence for $f_J(2200)$



PRD 87, 092009

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}	$136^{+41+28}_{-26-100}$	$(1.65^{+0.26+0.51}_{-0.31-1.40}) \times 10^{-5}$	8.2σ
$f_0(1710)$	$1759 \pm 6^{+14}_{-25}$	$172 \pm 10^{+32}_{-16}$	$(2.35^{+0.13+1.24}_{-0.11-0.74}) \times 10^{-4}$	25.0σ
$f_0(2100)$	$2081 \pm 13^{+24}_{-36}$	273^{+27+70}_{-24-23}	$(1.13^{+0.09+0.64}_{-0.10-0.28}) \times 10^{-4}$	13.9σ
$f_2'(1525)$	$1513 \pm 5^{+4}_{-10}$	75^{+12+16}_{-10-8}	$(3.42^{+0.43+1.37}_{-0.51-1.30}) \times 10^{-5}$	11.0σ
$f_2(1810)$	1822^{+29+66}_{-24-57}	$229^{+52+88}_{-42-155}$	$(5.40^{+0.60+3.42}_{-0.67-2.35}) \times 10^{-5}$	6.4σ
$f_2(2340)$	$2362^{+31+140}_{-30-63}$	$334^{+62+165}_{-54-100}$	$(5.60^{+0.62+2.37}_{-0.65-2.07}) \times 10^{-5}$	7.6σ

N* in $\psi(3686) \to \bar{p}p\pi^0$



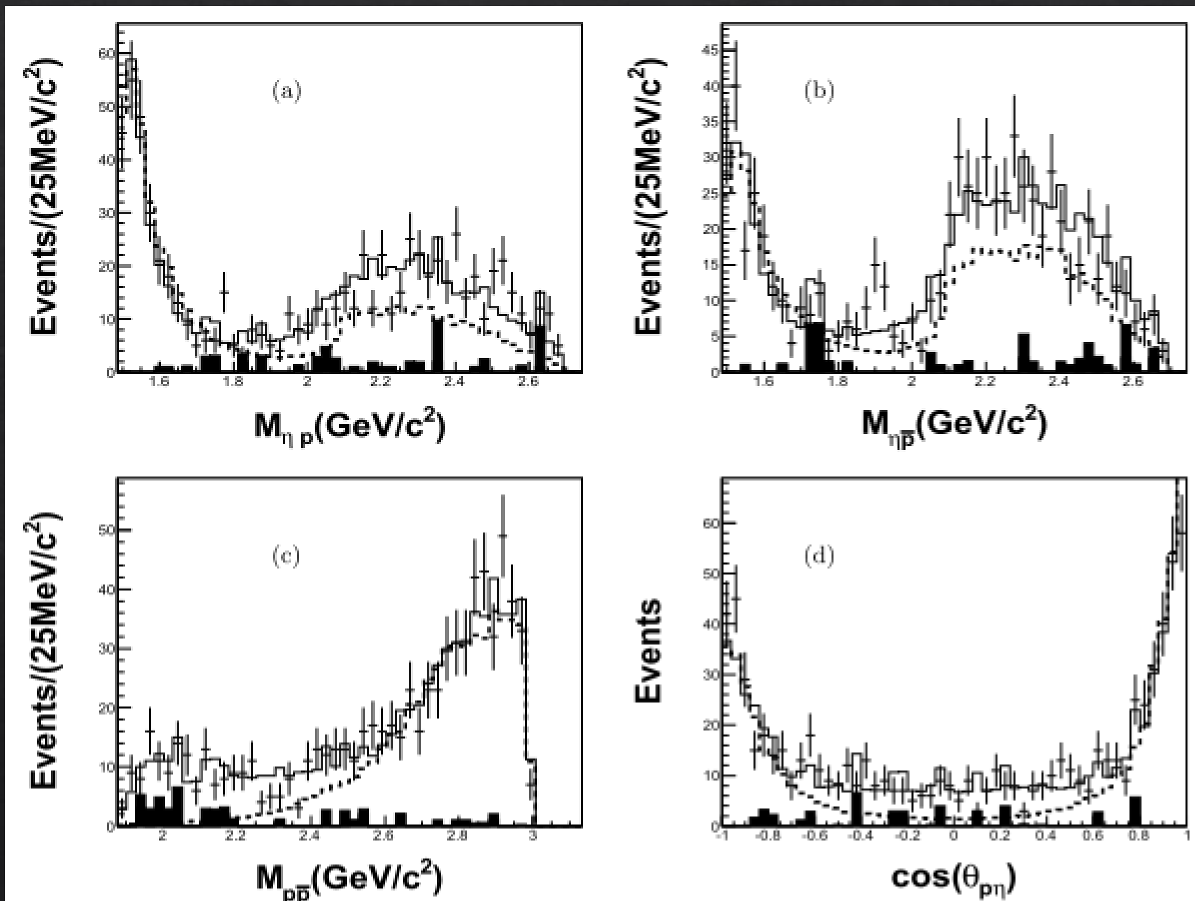
- Using 106 M $\psi(3686)$ data, detailed PWA of $\psi(3686)\to p\bar{p}\pi^0$ are performed.
- Two new N* are observed, N(2300) (1/2+) and N(2570) (5/2-) mass and width :

N(2300)	$2300^{+40+109}_{-30-0}$	$340^{+30+110}_{-30-58}$
N(2570)	2570^{+19+34}_{-10-10}	250^{+14+69}_{-24-21}

- Mass and width of 5 well-known N* are measured, agree with PDG
- No obvious $\bar{p}p$ enhancement

PRL 110, 022001

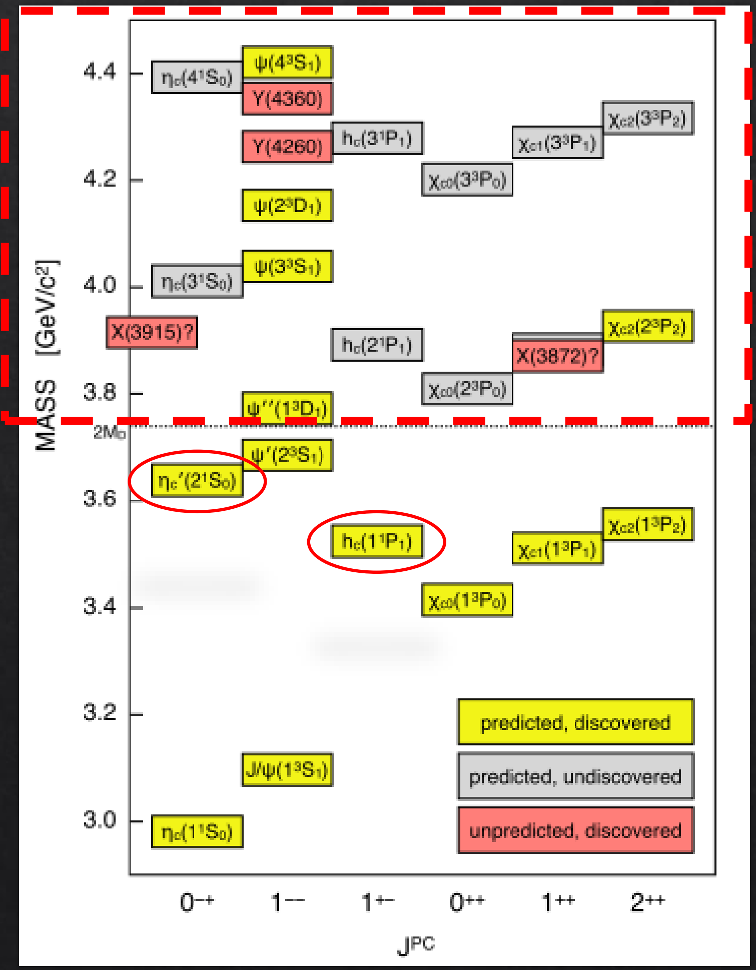
N* in $\psi(3686) \to \bar{p}p\eta$



- Low background
- Dominant contribution: N(1535) and PHSP
- No obvious $\bar{p}p$ enhancement
- $\frac{B(\psi(3686)\to\bar{p}p\eta)}{B(J/\psi\to\bar{p}p\eta)} = (3.2 \pm 0.4)\%$ Suppressed.

PRD 88, 032010

Charmonium states

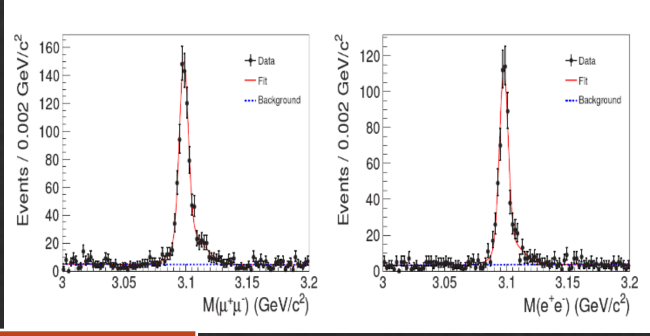


- XYZ
- η_C, BESIII results:
  PRL 108, 222002 (2012)
  $M = 2984.3 \pm 0.6 \pm 0.6$ MeV/c^2,
  $\Gamma = 32.0 \pm 1.2 \pm 1.0$ MeV
- $\eta_C(2S)$,
  $KK\pi$, PRL 109, 042003,
  $K_S K 3\pi$, PRD 87, 052005
- h_c,
  $\psi(2S) \to \pi^0 h_c$,
  PRL 104, 132002,
  PRD 86, 092009,
  $e^+e^- \to \pi^+\pi^- h_c$,
  PRL 111, 242001

XYZ

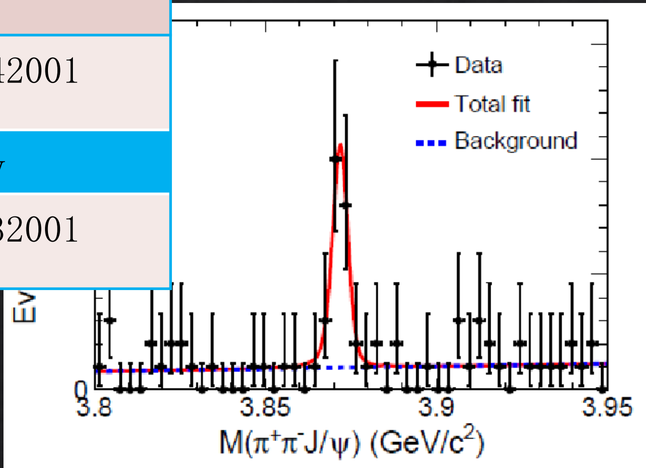
Please see Ronggang's talk **"XYZ states at BESIII"** on July 22 for detail.

- Y states can be produced directly



- Z states

Channel	Mass （MeV/c^2)	Width (MeV)	
$\pi^{\pm}J/\psi$	3899.0±3.6±4.9	46±10±20	PRL 110, 252001
$\pi^{0}J/\psi$	3894.8±2.3	29.6±8.2	preliminary
$(D\bar{D}^*)^+$	3883.9±1.5±4.2	24.8±3.3±11.0	PRL 112, 022001
$h_c\pi^{\pm}$	4022.9±0.8±2.7	7.9±2.7±2.6	PRL 111, 242001
$h_c\pi^{0}$	4023.6±2.2±3.9	Fixed	preliminary
$(D^*\bar{D}^*)^+$	4026.3±2.6±3.7	24.0±5.6±7.7	PRL 112, 132001



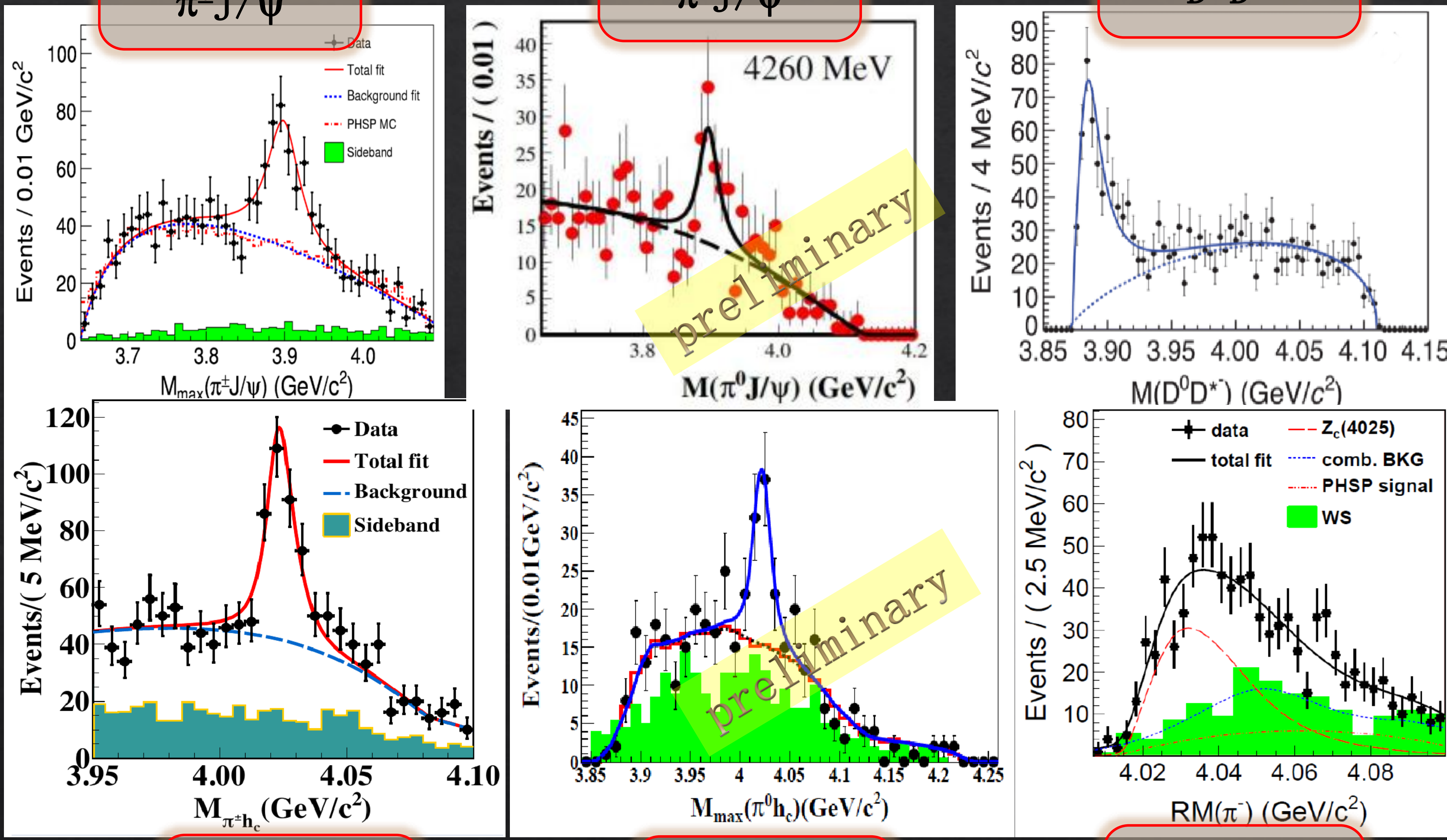
- X states

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

Zc (3900) $\pi^{\pm}J/\psi$

Zc (3900) $\pi^{0}J/\psi$

Zc (3885) $D\bar{D}^{*}$

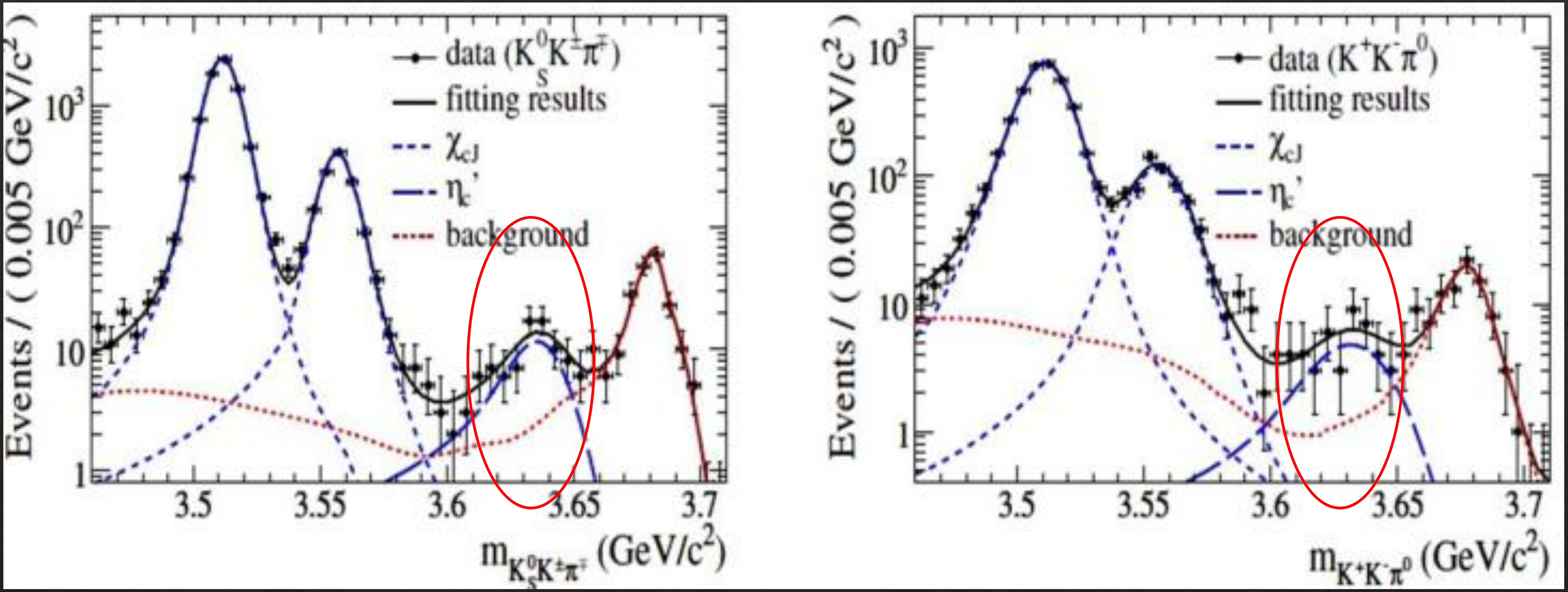


Zc (4020) $\pi^{\pm}h_c$

Zc (4020) $\pi^{0}h_c$

Zc (4025) $D^{*}\bar{D}^{*}$

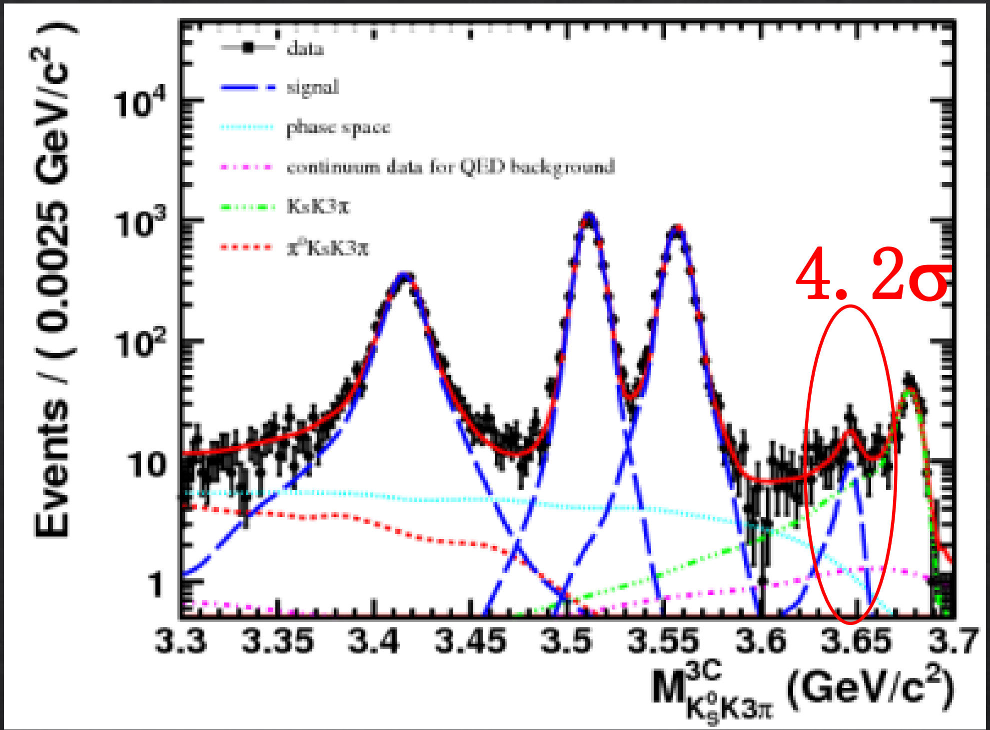
$\psi(3686) \to \gamma\eta_c(2S)$, $\eta_c(2S) \to KK\pi$



- M = 3637.6±2.9 ±1.6 MeV/c^2, Γ=16.9 ±6.4 ±4.8 MeV
- $B(\psi(3686) \to \gamma\eta_c(2S) \to KK\pi)$ = (1.30 ±0.20 ±0.30)x10^{-5}
- $B(\psi(3686) \to \gamma\eta_c(2S))$ = (6.8 ±1.1 ±4.5)x10^{-4} First observation

PRL 109, 042003

$\psi(3686)\to\gamma\eta_c(2S)$, $\eta_c(2S)\to K_S K 3\pi$

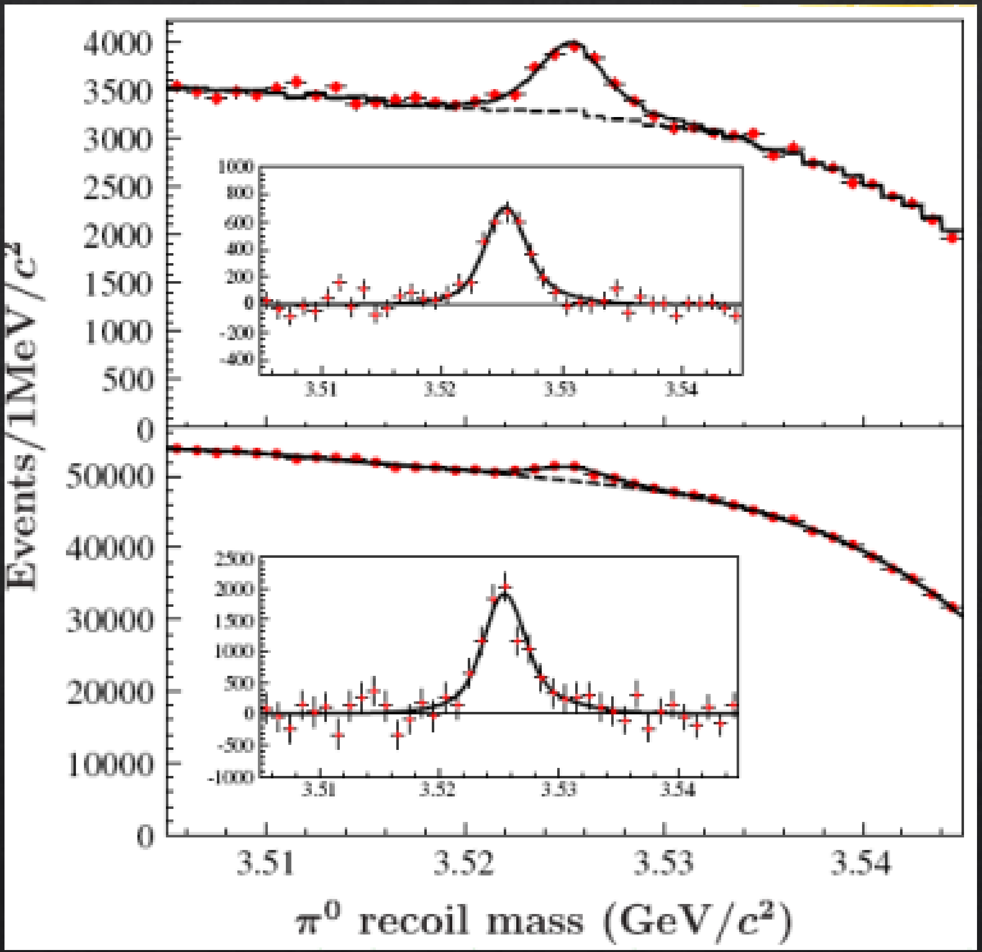


- $M = 3646.9 \pm 1.6 \pm 3.6$ MeV/c^2, $\Gamma = 9.2 \pm 4.8 \pm 2.9$ MeV
- $B(\psi(3686)\to\gamma\eta_c(2S)\to K_S K 3\pi) = (7.03 \pm 2.10 \pm 0.70)\times10^{-6}$

PRD 87, 052005

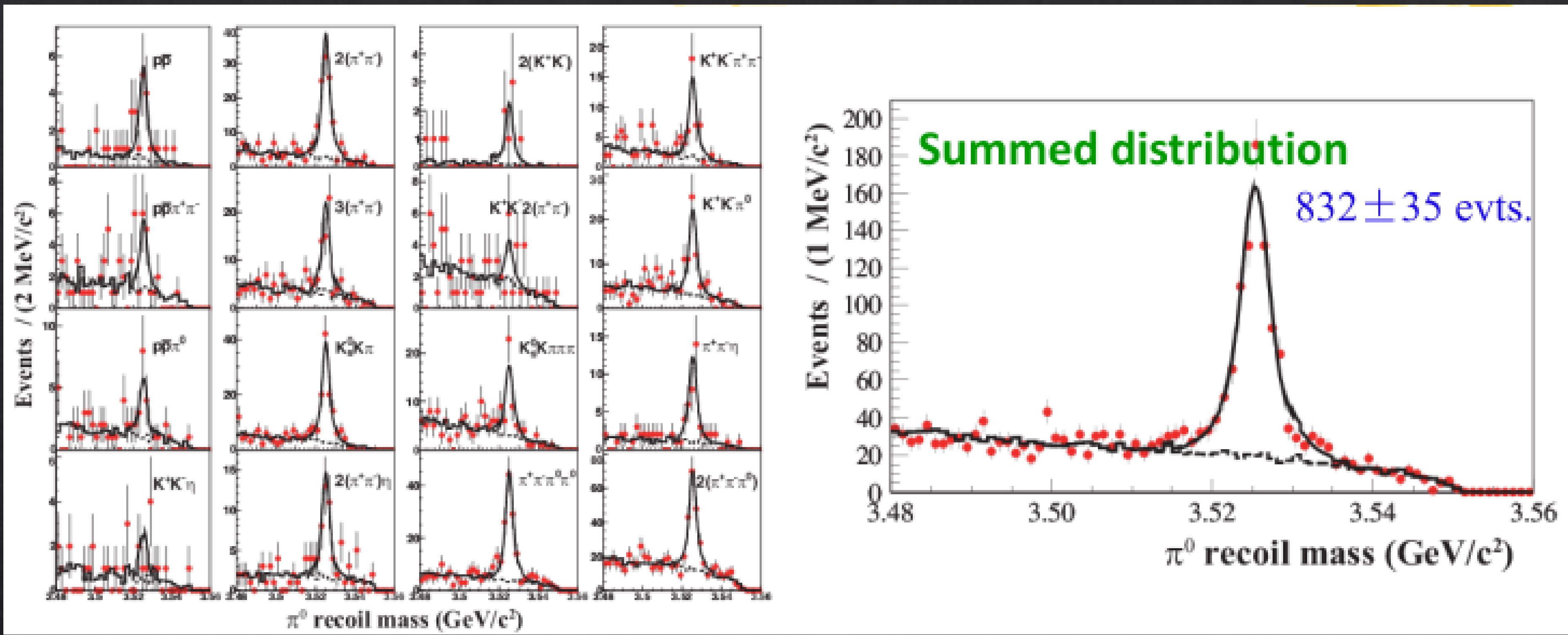
$\psi \to \pi^0 h_c(1P)$, $h_c \to \gamma\eta_C$

- Methods to find h_c
  - Inclusive:
    only detect the π^0
  - E1 tagged:
    detect π^0 and γ
  - Exclusive:
    detect all final particles



PRL 104, 132002

$\psi \to \pi^0 h_c(1P)$, $h_c \to \gamma \eta_C$



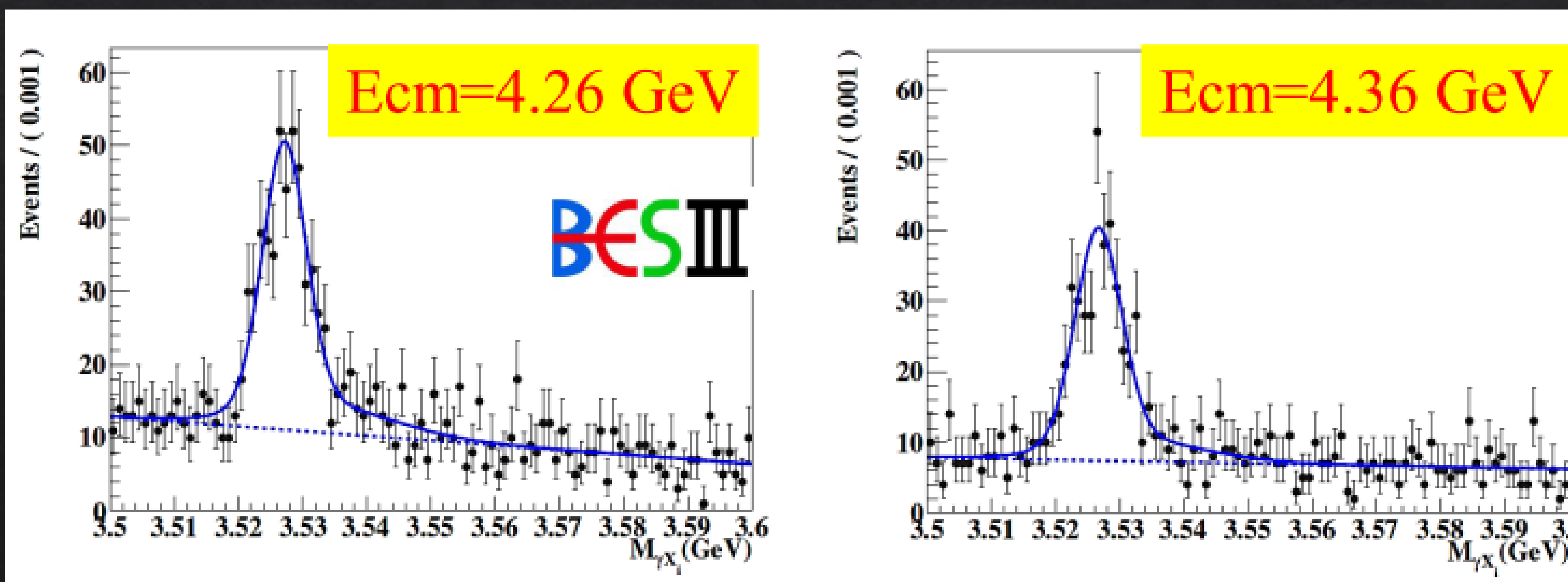
(MeV/c^2)	BESIII Exclusive	BESIII Inclusive	CLEO
M	3525.31±0.11±0.14	3525.40±0.13±0.18	3525.21±0.27±0.14
Γ	0.70±0.28±0.22	0.73±0.45±0.28	--
$\Delta M_{hf}(1P)$	-0.01±0.11±0.15	0.10±0.13±0.18	0.08±0.18±0.12

PRD 86, 092009

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

$h_c \to \gamma\eta_c$, $\eta_c \to$ hadrons [16 exclusive decay modes]

- $p\bar{p}$, $\pi^+\pi^-K^+K^-$, $\pi^+\pi^-p\bar{p}$, $2(K^+K^-)$, $2(\pi^+\pi^-)$, $3(\pi^+\pi^-)$
- $2(\pi^+\pi^-)K^+K^-$, $K_S^0K^+\pi^-$+c.c., $K_S^0K^+\pi^-\pi^+\pi^-$+c.c., $K^+K^-\pi^0$
- $p\bar{p}\pi^0$, $K^+K^-\eta$, $\pi^+\pi^-\eta$, $\pi^+\pi^-\pi^0\pi^0$, $2(\pi^+\pi^-)\eta$, $2(\pi^+\pi^-\pi^0)$



PRL 111, 242001

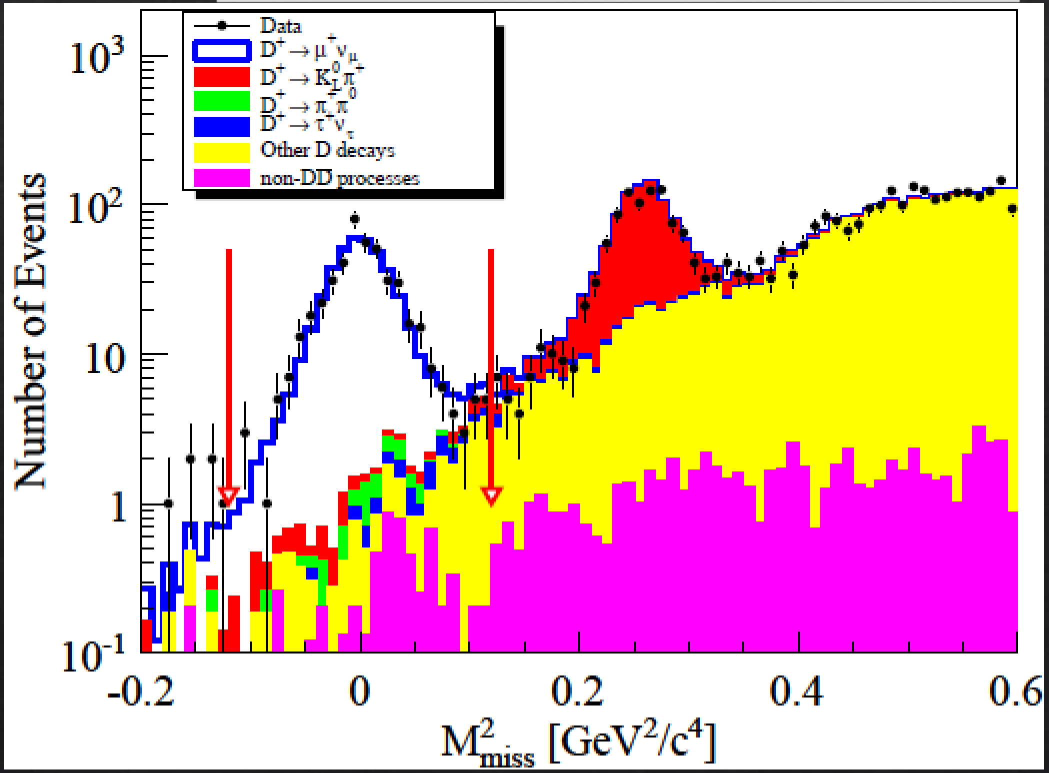
Charm physics

- $D^+ \to \mu^+ \nu$
- $D^0 \to K/\pi\ e^+ \nu$
- Dalitz plot analysis of $D^+ \to K_S{}^0 \pi^+ \pi^0$
  - Gold channel for $K\pi$ S wave studies

$D^+ \to \mu^+ \nu$

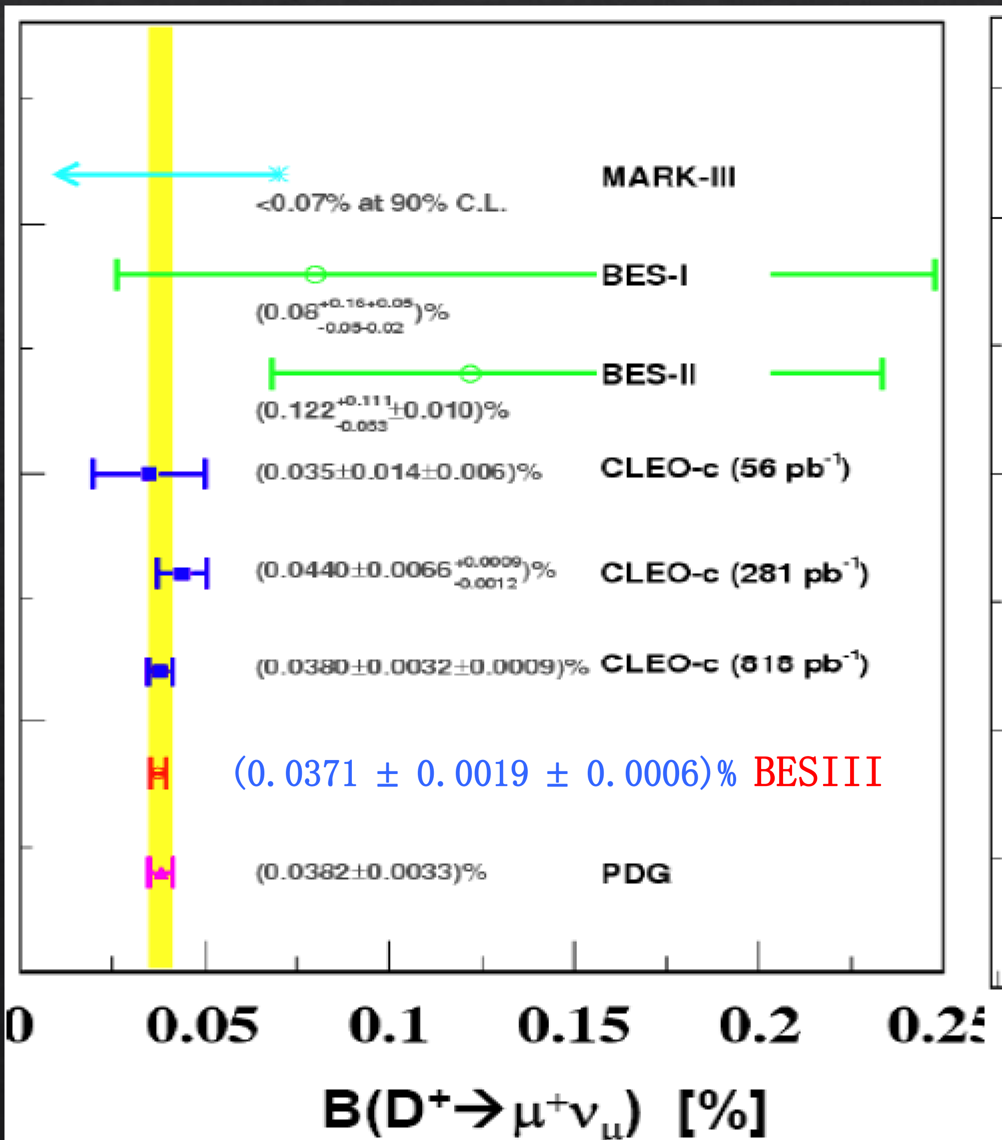
- Extract decay constant $f_{D(s)}$ incorporates the strong interaction effects
- To validate Lattice QCD calculation of fB(s) and provide constrain of CKM-unitarity
- Sensitive to New Physics
- 9 D^- tag modes
- $N(D^+ \to \mu^+\nu) = 409.0 \pm 21.2 \pm 2.3$

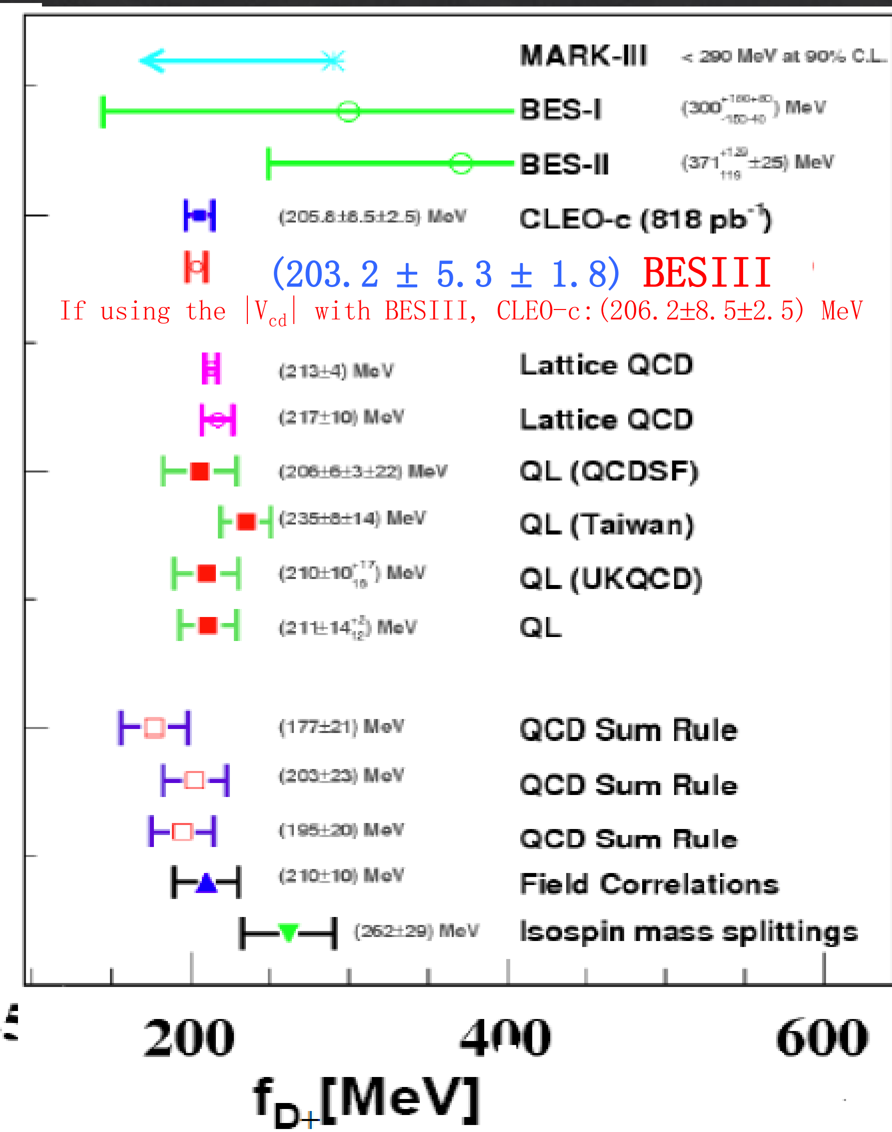
$$\Gamma\left(D^+ \to \ell^+ \nu_\ell\right) = f_D^2 \left|V_{cd}\right|^2 \frac{G_F^2}{8\pi} m_D m_\ell^2 \left(1 - \frac{m_\ell^2}{m_D^2}\right)^2$$



PRD 89, 051104

Comparisons of $B[D^+ \to \mu^+ \nu_\mu]$ and f_{D+}

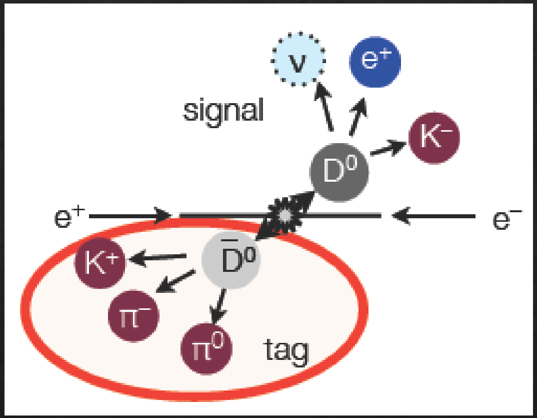


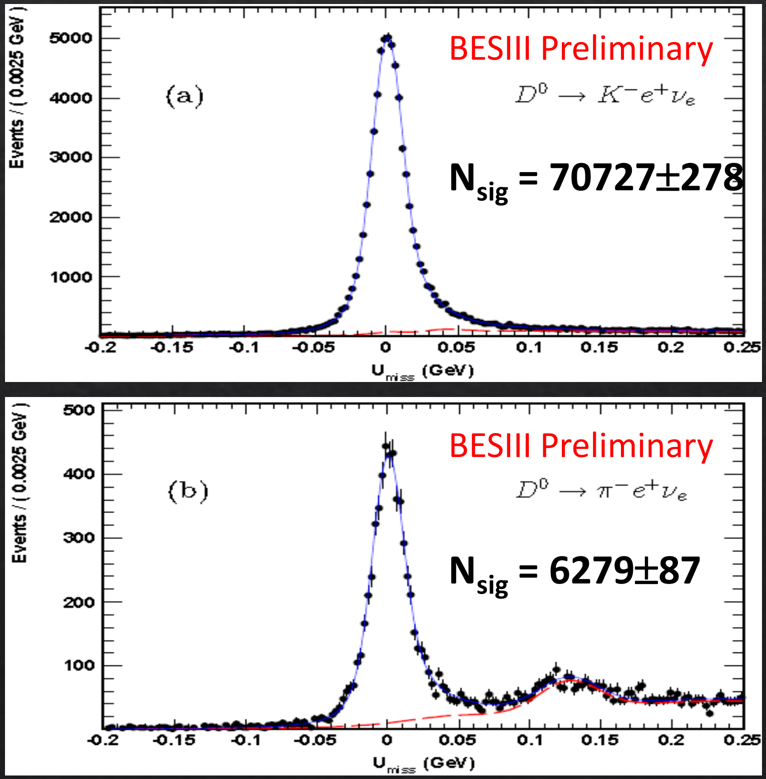


$D^0 \to K/\pi\ e^+\nu$

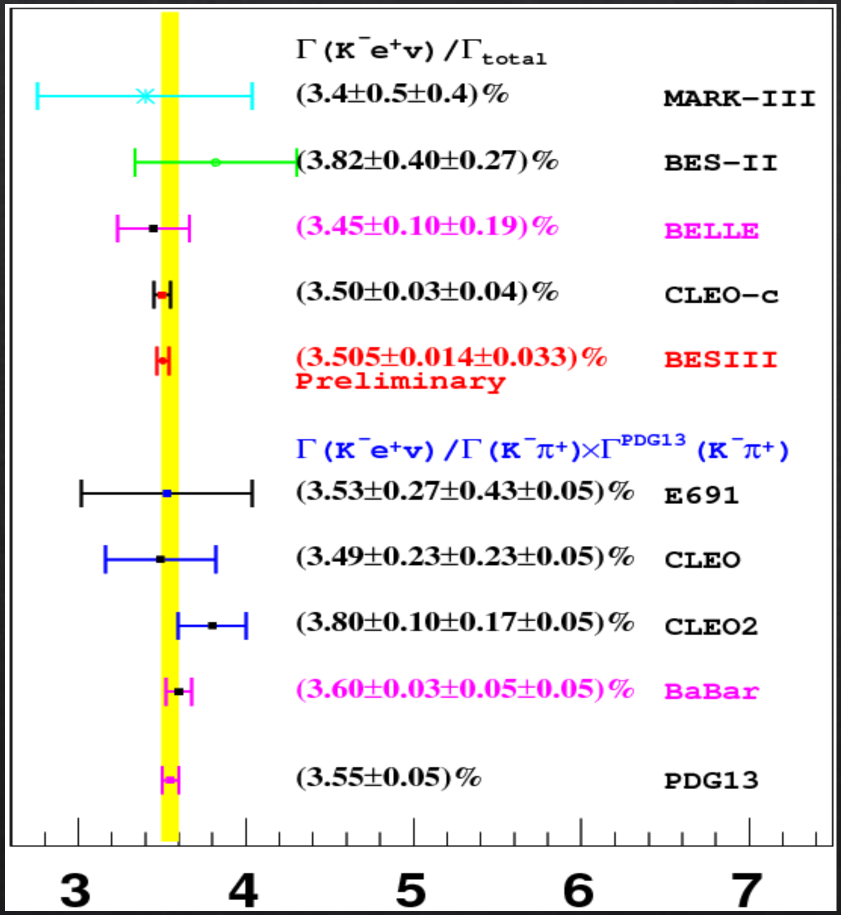
$$\frac{d\Gamma(D\to K(\pi)e\nu)}{dq^2} = \frac{G_F^2 |V_{cs(d)}|^2 P_{K(\pi)}^3}{24\pi^3} |f_+(q^2)|^2$$

- Theoretically clean
- Measurement $|V_{cx}|$ x FF
- Full dataset: 2.9 fb^{-1}

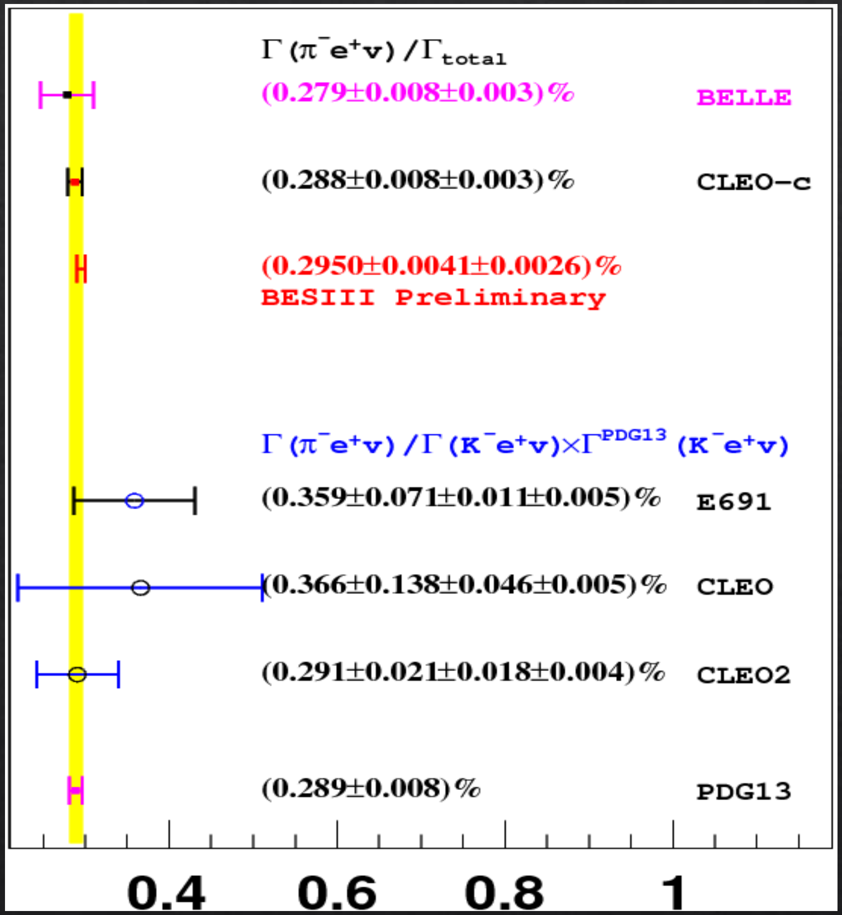




Comparisons of $B[D^0 \to K(\pi)^- e^+ \nu]$



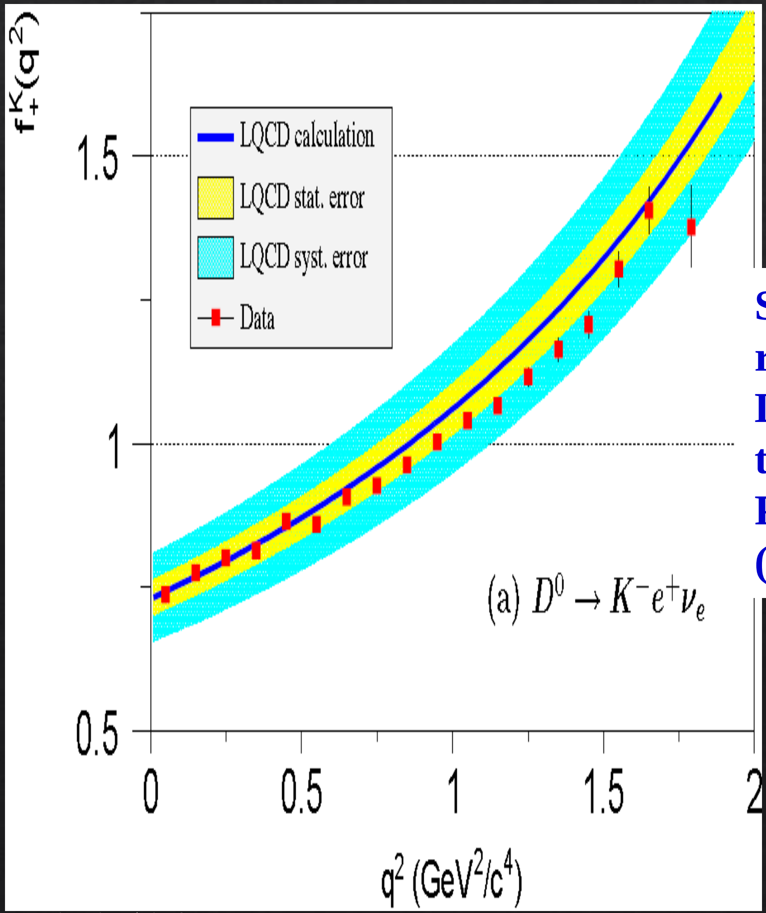
$B[D^0 \to K^- e^+ \nu]$



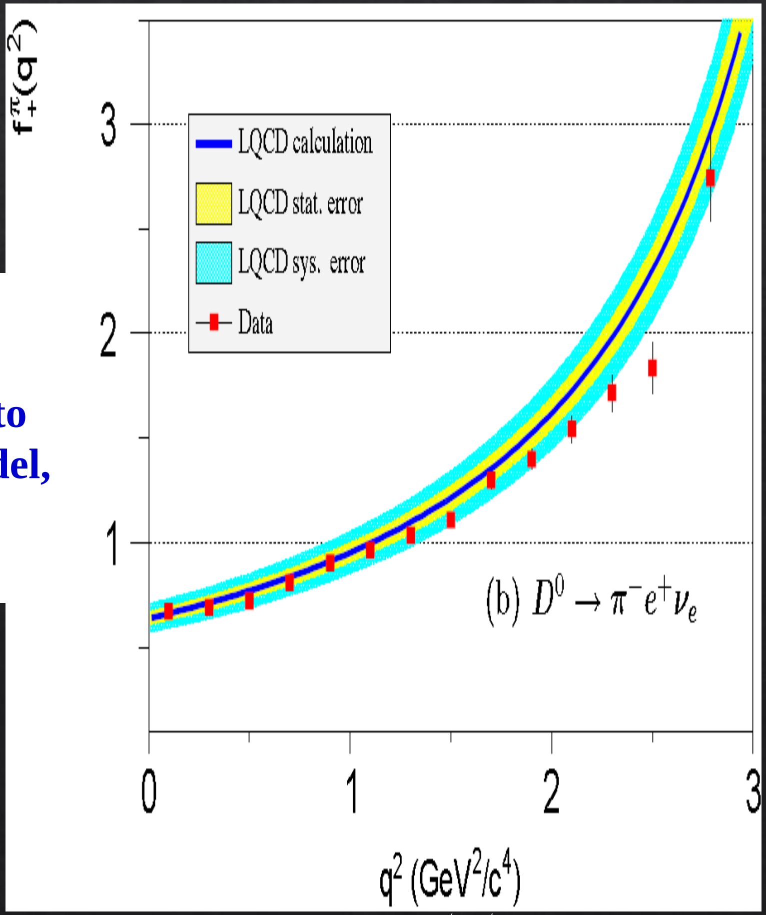
$B[D^0 \to \pi^- e^+ \nu]$

Comparisons of Form Factors

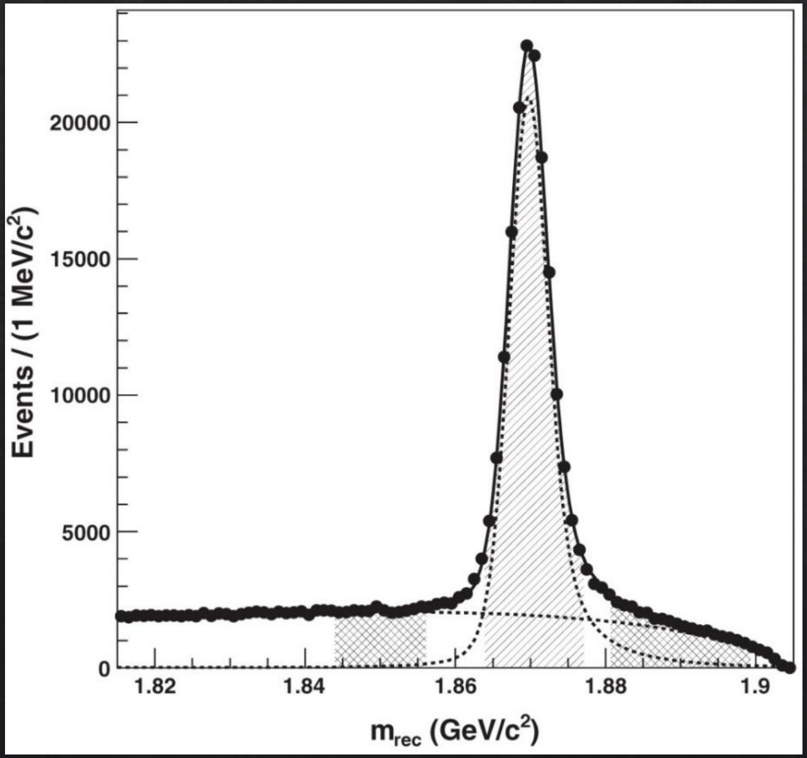
- Experimental data calibrate LQCD calculation
  - Points: BESIII preiminary data
  - Curves: from Fermilab-MILC-HPQCD , PRL94 (2005) 011601;
    Fermilib Lattice and MILC, PRD80 (2009) 034026



Solid lines represent LQCD fits to the BK model, PLB478 (2000)417



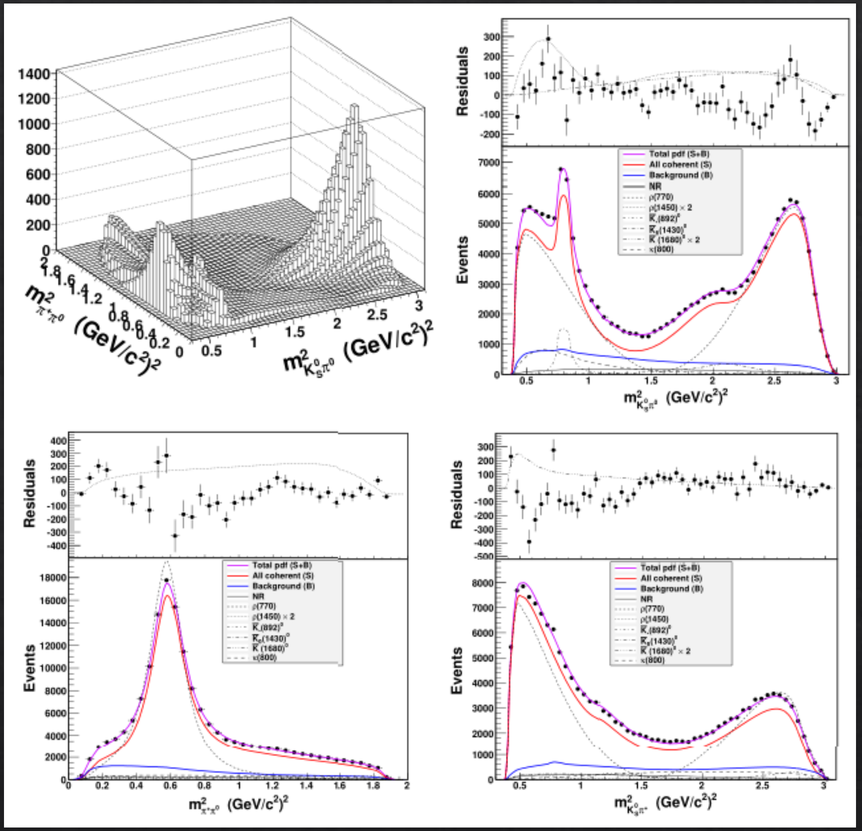
Dalitz plot analysis of $D^+ \to K_S{}^0 \pi^+ \pi^0$



- ~167k events are selected in signal region.
- Shape of Argus background on Dalitz plot is estimated by combination of two sidebands (left & right).
- A peaking background is very small (~0.6% of signal) is estimated by MC shape

Dalitz plot analysis of $D^+ \to K_S^0 \pi^+ \pi^0$

- Fit to data using isobar model
- Six intermediate resonances (including κ) plus a non-resonant component
- Float parameters of $\bar{K}^{*0}(1430)$ and κ(800)



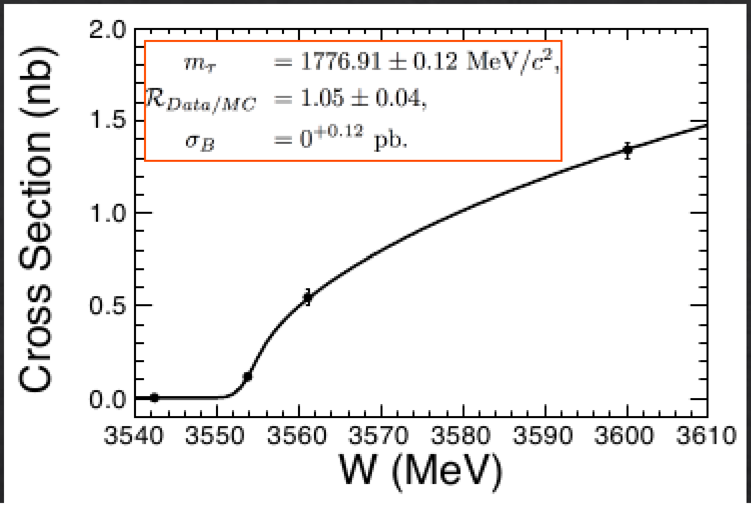
Mode	Partial branching fraction (%)
$D^+ \to K_S^0\pi^+\pi^0$ nonresonant	$0.32 \pm 0.05 \pm 0.25^{+0.28}_{-0.25}$
$D^+ \to \rho^+ K_S^0$, $\rho^+ \to \pi^+\pi^0$	$5.83 \pm 0.16 \pm 0.30^{+0.45}_{-0.15}$
$D^+ \to \rho(1450)^+ K_S^0$, $\rho(1450)^+ \to \pi^+\pi^0$	$0.15 \pm 0.02 \pm 0.09^{+0.07}_{-0.11}$
$D^+ \to \bar{K}^*(892)^0\pi^+$, $\bar{K}^*(892)^0 \to K_S^0\pi^0$	$0.250 \pm 0.012 \pm 0.015^{+0.025}_{-0.024}$
$D^+ \to \bar{K}_0^*(1430)^0\pi^+$, $\bar{K}_0^*(1430)^0 \to K_S^0\pi^0$	$0.26 \pm 0.04 \pm 0.05 \pm 0.06$
$D^+ \to \bar{K}^*(1680)^0\pi^+$, $\bar{K}^*(1680)^0 \to K_S^0\pi^0$	$0.09 \pm 0.01 \pm 0.05^{+0.04}_{-0.08}$
$D^+ \to \bar{\kappa}^0\pi^+$, $\bar{\kappa}^0 \to K_S^0\pi^0$	$0.54 \pm 0.09 \pm 0.28^{+0.36}_{-0.19}$
$NR + \bar{\kappa}^0\pi^+$	$1.30 \pm 0.12 \pm 0.12^{+0.12}_{-0.30}$
$K_S^0\pi^0$ S-wave	$1.21 \pm 0.10 \pm 0.16^{+0.19}_{-0.27}$

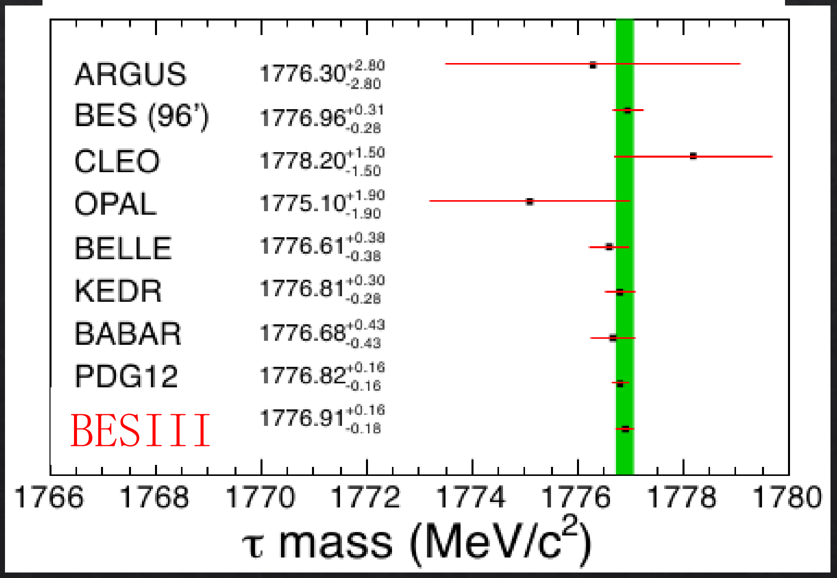
PRD 89, 052001

τ Mass measurement

- Threshold scan method
- Four scan points data near τ pair production threshold
- $M = 1776.91 \pm 0.12^{+0.10}_{-0.13}$ MeV/c^2
- Calculate g_τ with $B(\tau \to e\nu\bar{\nu})$ and τ_τ from PDG
  $g_\tau = (1.1650 \pm 0.0034) \times 10^{-5}$ GeV^{-2}
- The ratio of squared coupling constants:
  $(g_\tau/g_\mu)^2 = 1.0016 \pm 0.0042$
  Satisfied at the 0.4σ level!

PRD 90, 012001

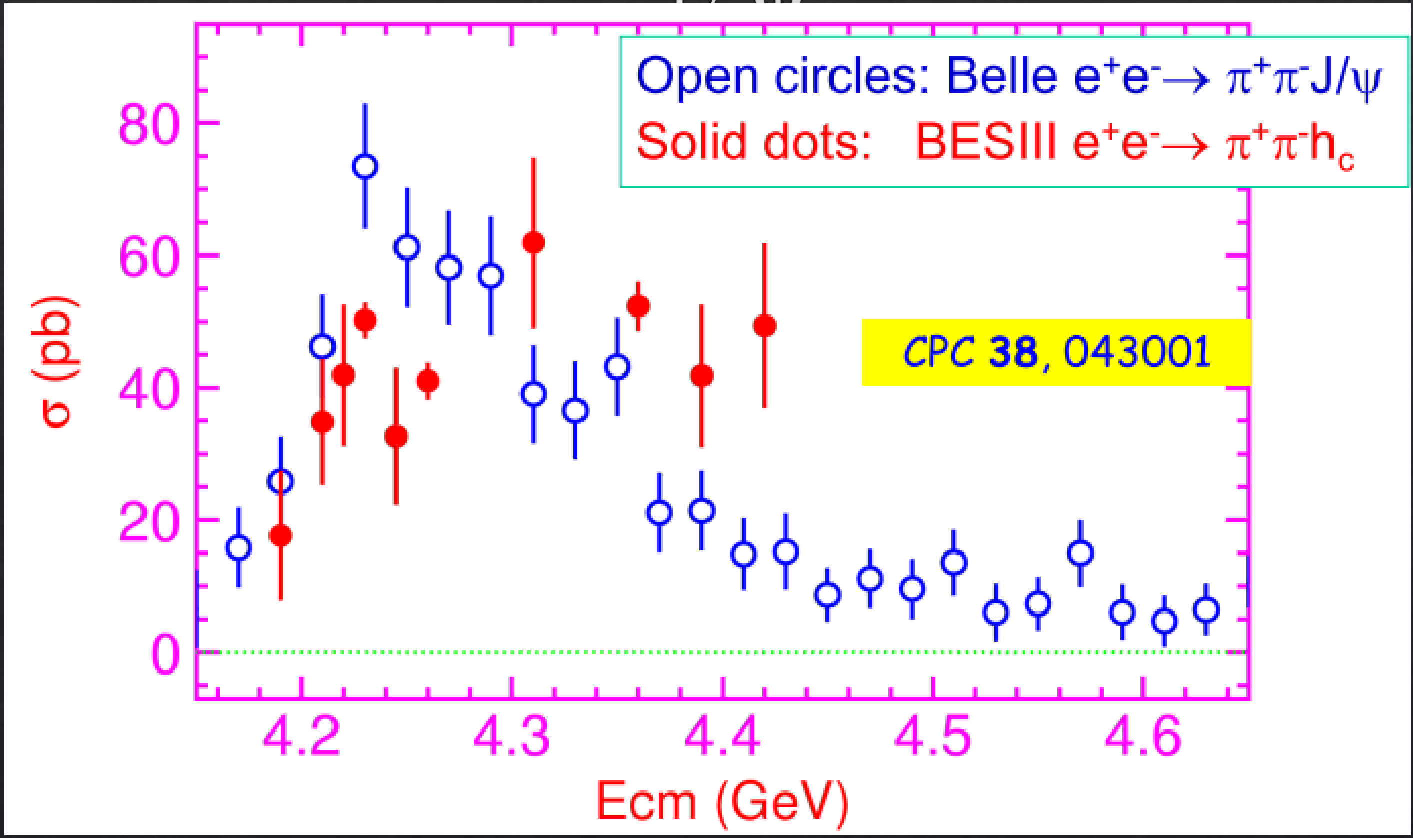




Summary

- BESIII has been successfully operating since 2008: world largest data samples at J/ψ, $\psi(3686)$, $\psi(3770)$, $Y(4260)$, and so on. More data samples in the future
- Excellent place for precision measurements and new discoveries
- More results from BESIII in the future

Comparison of $e^+e^-\to\pi^+\pi^-hc$ and $\pi^+\pi^-$ J/ψ



- Broad structure at ~ 4.4 GeV? Need more data at high energies to complete the line shape measurement.

Resonance	$M(\mathrm{MeV}/c^2)$	$\Gamma(\mathrm{MeV}/c^2)$	ΔS	ΔN_{dof}	Sig.	N	B.F.($\times 10^{-5}$)	
$N(1440)$	1390^{+11+21}_{-21-30}	$340^{+46+70}_{-40-156}$	72.5	4	11.5σ	$1870^{+90+487}_{-90-327}$	$6.42^{+0.20+1.78}_{-0.20-1.28}$	
$N(1520)$	1510^{+3+11}_{-7-9}	115^{+20+0}_{-15-40}	19.8	6	5.0σ	$1060^{+90+459}_{-90-227}$	$3.58^{+0.25+1.59}_{-0.25-0.84}$	
$N(1535)$	1535^{+9+15}_{-8-22}	120^{+20+0}_{-20-42}	49.4	4	9.3σ	190^{+14+64}_{-14-48}	$0.64^{+0.05+0.22}_{-0.05-0.17}$	
$N(1650)$	1650^{+5+11}_{-5-30}	150^{+21+14}_{-22-50}	82.1	4	12.2σ	$673^{+45+263}_{-45-256}$	$2.47^{+0.28+0.99}_{-0.28-0.97}$	
$N(1720)$	1700^{+30+32}_{-28-35}	$450^{+109+149}_{-94-44}$	55.6	6	9.6σ	$1080^{+77+382}_{-77-467}$	$3.76^{+0.28+1.37}_{-0.28-1.66}$	
						$510^{+27+50}_{-27-197}$	$1.79^{+0.10+0.24}_{-0.10-0.71}$	
N(2300)	$\mathbf{2300^{+40+109}_{-30-0}}$	$\mathbf{340^{+30+110}_{-30-58}}$	**120.7**	**4**	$\mathbf{15.0\sigma}$	$948^{+68+394}_{-68-213}$	$2.62^{+0.28+1.12}_{-0.28-0.64}$	J^P=1/2+
N(2570)	$\mathbf{2570^{+19+34}_{-10-10}}$	$\mathbf{250^{+14+69}_{-24-21}}$	**78.9**	**6**	$\mathbf{11.7\sigma}$	$795^{+45+127}_{-45-83}$	$2.13^{+0.08+0.40}_{-0.08-0.30}$	J^P=5/2−

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

$$\frac{d\Gamma\left(D \to K(\pi) e \nu\right)}{dq^2} = \frac{G_F^2 \left|V_{cs(d)}\right|^2 P_{K(\pi)}^3}{24\pi^3} \left|f_+\left(q^2\right)\right|^2$$