BESIII

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Recent charmonium results at BESIII

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On behalf of the BESIII Collaboration

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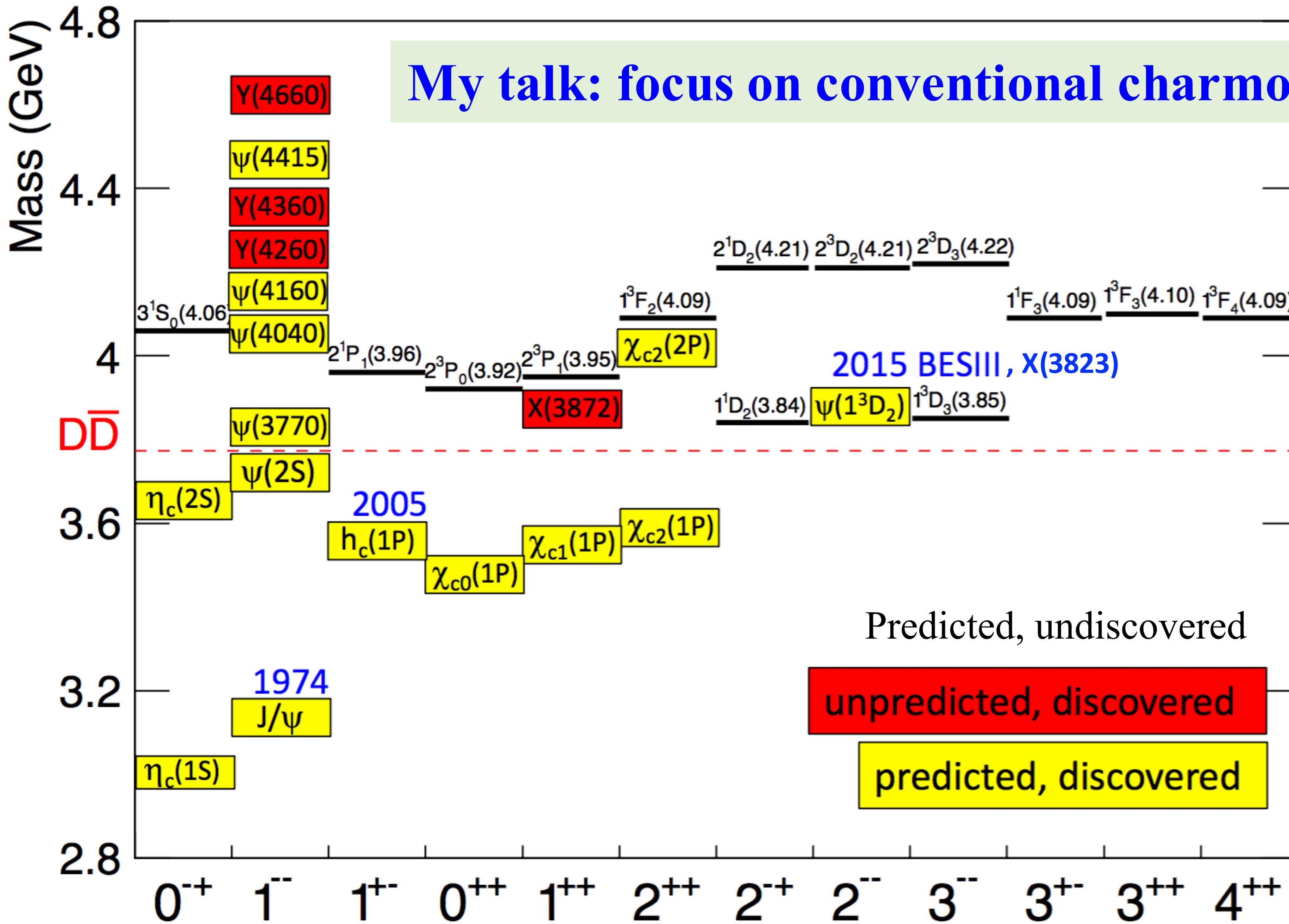
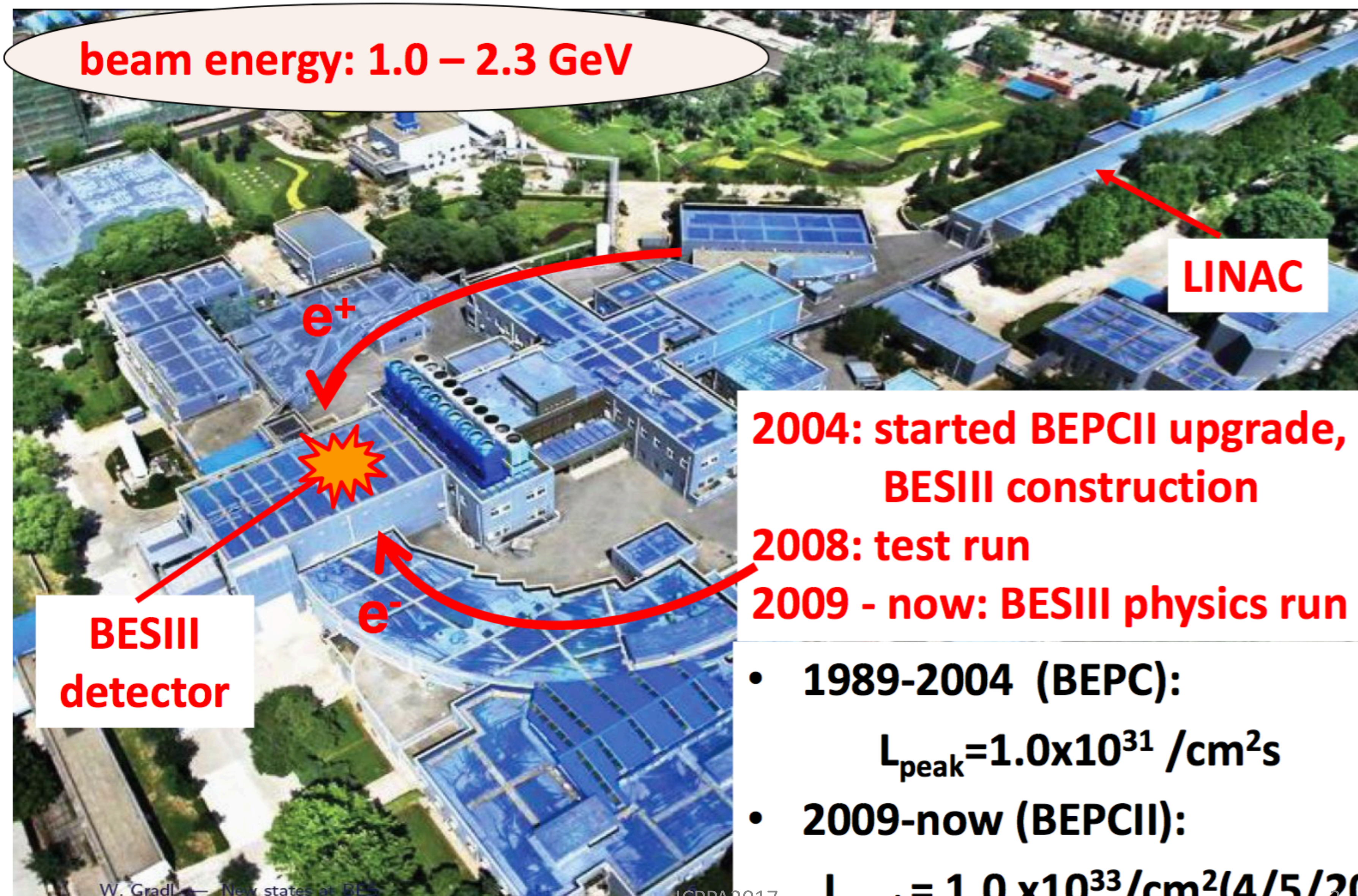
Charmonium spectroscopy

My talk: focus on conventional charmonium.



Godfrey & Isgur, *PRD32, 189 (1985)*

Beijing Electron Positron Collider (BEPC)



2004: started BEPCII upgrade, BESIII construction

2008: test run

2009 - now: BESIII physics run

- 1989-2004 (BEPC):

  L_{peak}=1.0x10^{31} /cm^{2}s

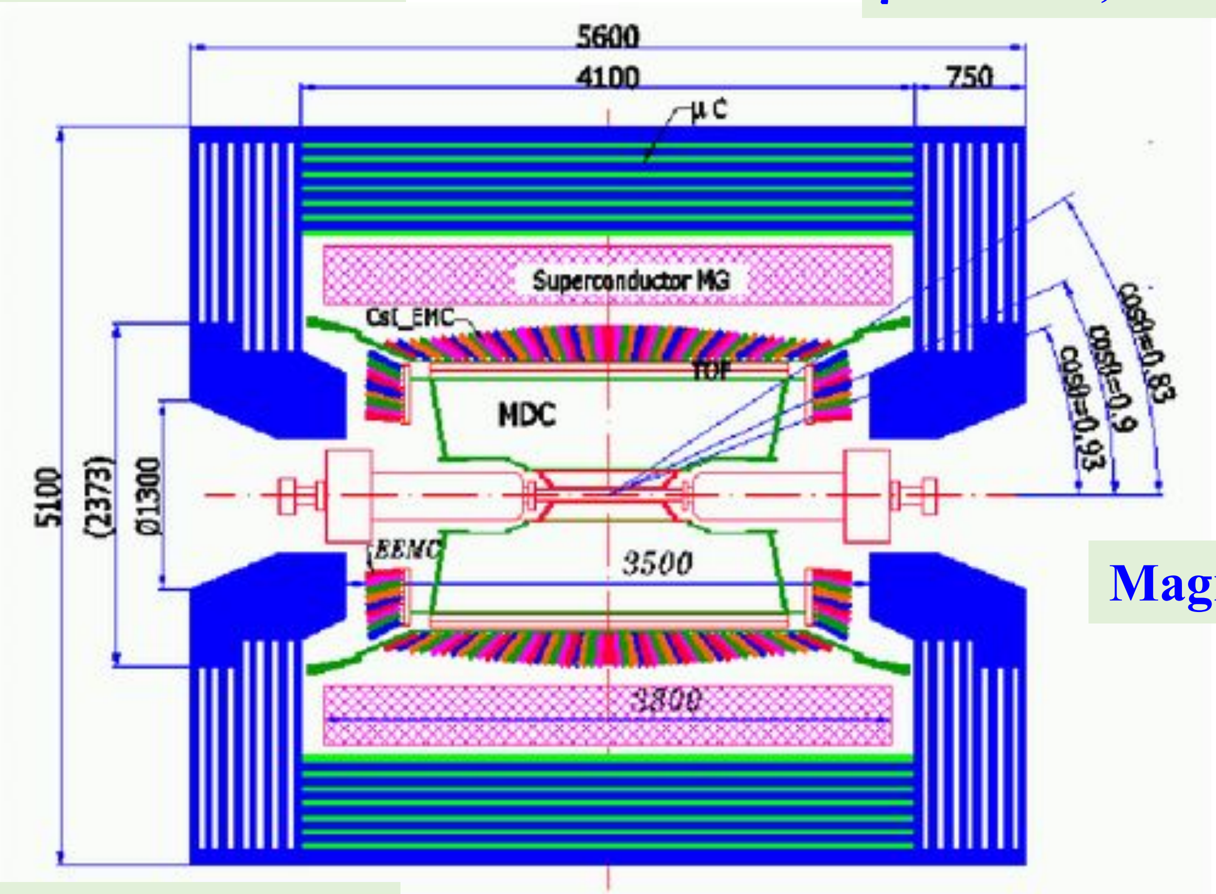
- 2009-now (BEPCII):

  L_{peak}= 1.0 x10^{33}/cm^2(4/5/2016)

BESIII detector

Main drift chamber (MDC)
Momentum: 0.5%@1GeV/c
dE/dx: 6%

Resistive plate chamber (RPC)
μ counter, <2 cm



Magnetic field: 1 T

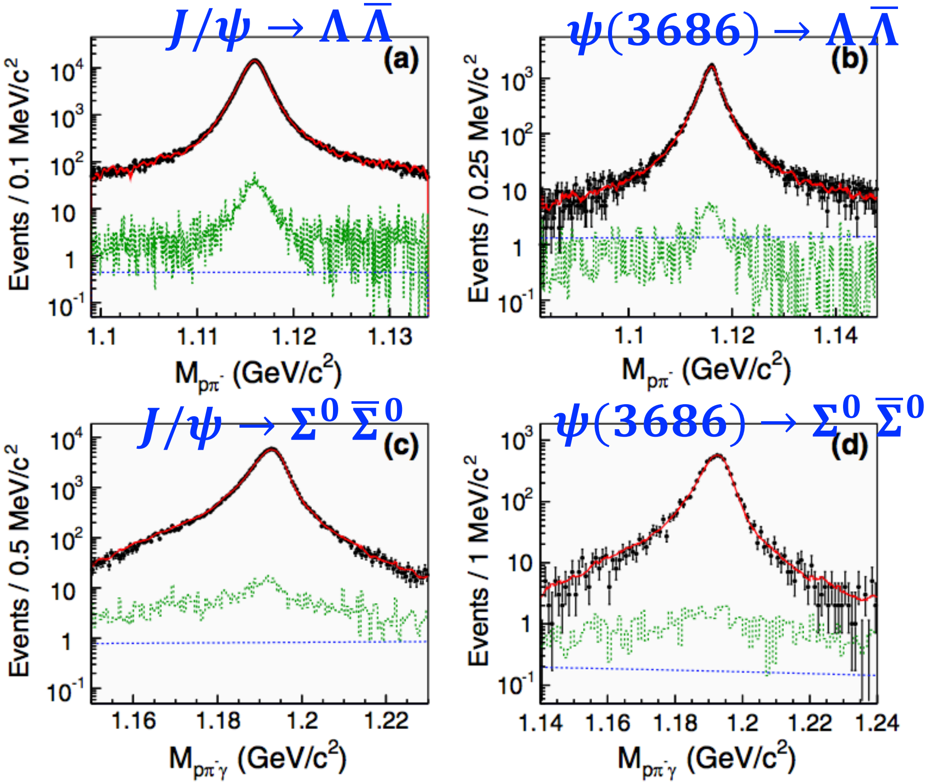
Time of flight (TOF)
Barrel: plastic scintillator
End-caps: MRPC
80 (70) ps for barrel (end-caps)

Electro-magnetic calorimeter (EMC): CsI (Tl)
2.5%(5.0%) for barrel (end-caps) @ 1 GeV

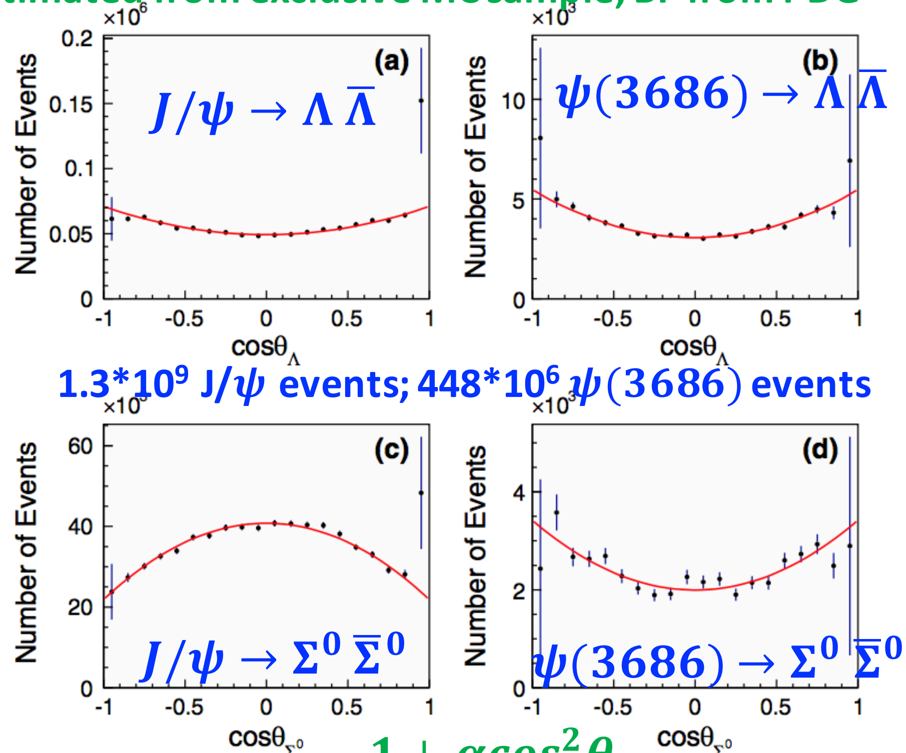
- J/ψ and $\psi(3686) \to \Lambda\,\bar{\Lambda}$ and $\Sigma^0\,\bar{\Sigma}^0$
- $\psi(3686) \to \gamma\chi_{cJ}$
- $h_c \to \gamma\eta'$ and $\gamma\eta$
- $\psi' \to e^+e^-\chi_{cJ}$ and $\chi_{cJ} \to e^+e^-J/\psi$

J/ψ and $\psi(3686) \to \Lambda\,\bar{\Lambda}$ and $\Sigma^0\,\bar{\Sigma}^0$

Double tag method



Estimated from exclusive MC sample; BF from PDG



$1.3*10^9$ J/ψ events; $448*10^6$ $\psi(3686)$ events

$1+\alpha cos^2\theta$

	Dominant peaking bkg.	Dominant smooth bkg.
$J/\psi \to \Lambda\,\bar{\Lambda}$	$J/\psi \to \Lambda\,\bar{\Sigma}^0 + \text{c.c.}$	$J/\psi \to \gamma K_s K_s, K_s \to \pi^+\pi^-$
$J/\psi \to \Sigma^0\,\bar{\Sigma}^0$	$J/\psi \to \Lambda\,\bar{\Sigma}^0 + \text{c.c.}$	$J/\psi \to \gamma\eta_c, \eta_c \to \Lambda\,\bar{\Lambda}$
$\psi(3686) \to \Lambda\,\bar{\Lambda}$	$\psi(3686) \to \Lambda\,\bar{\Sigma}^0 + \text{c.c.}$	$\psi(3686) \to \pi^+\pi^- J/\psi, J/\psi \to p\ \bar{p}$
$\psi(3686) \to \Sigma^0\,\bar{\Sigma}^0$	$\psi(3686) \to \gamma\chi_{cJ}, \chi_{cJ} \to \Sigma^0\,\bar{\Sigma}^0$	$\psi(3686) \to \gamma\chi_{cJ}, \chi_{cJ} \to \Lambda\,\bar{\Lambda}$

PRD 95, 052003 (2017)

J/ψ and $\psi(3686) \to \Lambda\bar{\Lambda}$ and $\Sigma^0\bar{\Sigma}^0$

Results $1+\alpha\cos^2\theta$

Channel	α	$\mathcal{B}$ $(\times 10^{-4})$
$J/\psi \to \Lambda\bar{\Lambda}$	$0.469 \pm 0.026 \pm 0.008$	$19.43 \pm 0.03 \pm 0.33$
$J/\psi \to \Sigma^0\bar{\Sigma}^0$	$-0.449 \pm 0.020 \pm 0.008$	$11.64 \pm 0.04 \pm 0.23$
$\psi(3686) \to \Lambda\bar{\Lambda}$	$0.82 \pm 0.08 \pm 0.02$	$3.97 \pm 0.02 \pm 0.12$
$\psi(3686) \to \Sigma^0\bar{\Sigma}^0$	$0.71 \pm 0.11 \pm 0.04$	$2.44 \pm 0.03 \pm 0.11$

α comparison with theories and experiments

	$\alpha_{J/\psi\to\Lambda\bar{\Lambda}}$	$\alpha_{J/\psi\to\Sigma^0\bar{\Sigma}^0}$
Theory	0.32	0.31 [16]
	0.51	0.43 [17]
Experiment	0.72 ± 0.36	0.70 ± 1.10 [5]
	0.62 ± 0.22	0.22 ± 0.31 [6]
	0.65 ± 0.14	-0.22 ± 0.19 [10]

Re-scattering effect of B and anti-B

BF comparison with others

	$J/\psi \to \Lambda\bar{\Lambda}$	$\psi(3686) \to \Lambda\bar{\Lambda}$	$J/\psi \to \Sigma^0\bar{\Sigma}^0$	$\psi(3686) \to \Sigma^0\bar{\Sigma}^0$
MARKII Collaboration [5]	$15.8 \pm 0.8 \pm 1.9$	...	$15.8 \pm 1.6 \pm 2.5$	...
DM2 Collaboration [6]	$13.8 \pm 0.5 \pm 2.0$	...	$10.6 \pm 0.4 \pm 2.3$	...
BES Collaboration [7,8]	$10.8 \pm 0.6 \pm 2.4$	$1.8 \pm 0.2 \pm 0.3$	...	$1.2 \pm 0.4 \pm 0.4$
CLEO Collaboration [9]	...	$3.3 \pm 0.3 \pm 0.3$	...	$2.6 \pm 0.4 \pm 0.4$
BESII Collaboration [10,11]	$20.3 \pm 0.3 \pm 1.5$	$3.4 \pm 0.2 \pm 0.4$	$13.3 \pm 0.4 \pm 1.1$	$2.4 \pm 0.4 \pm 0.4$
BABAR Collaboration [12]	$19.3 \pm 2.1 \pm 0.5$	$6.4 \pm 1.8 \pm 0.1$	$11.5 \pm 2.4 \pm 0.3$	...
Dobbs *et al.* [13]	...	$3.8 \pm 0.1 \pm 0.3$	...	$2.3 \pm 0.2 \pm 0.2$
PDG [15]	16.1 ± 1.5	3.6 ± 0.2	12.9 ± 0.9	2.3 ± 0.2

- **The BFs are determined with much improved precision.**
- **The polar angular distribution of $\psi(3686)$ decays are measured for the first time.** $R_\Lambda = 20.43 \pm 0.11 \pm 0.58\%$; $R_{\Sigma^0} = 20.96 \pm 0.27 \pm 0.92\%$
- **The "12% rule" is tested to be violated.**

PRD 95, 052003 (2017)

$\psi(3686) \rightarrow \gamma\chi_{cJ}$

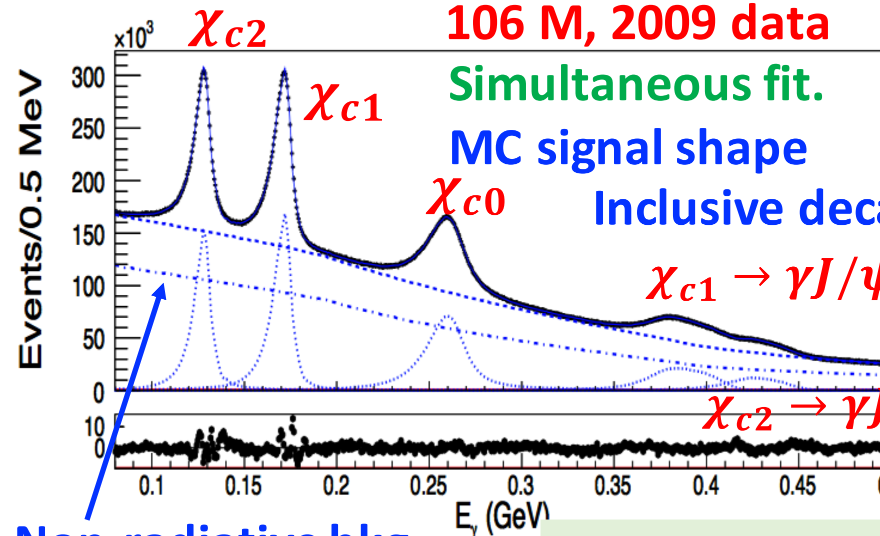
- **Electromagnetic decays are important decay modes for $\psi(3686)$; Sensitive to inner structure of hadrons.**
- **Improved precision on BF of $\psi(3686) \rightarrow \gamma\chi_{cJ}$ is necessary in determination of BF of χ_{cJ} decays.**
- **The most precise BFs of $\psi(3686) \rightarrow \gamma\chi_{cJ}$ are measured at BESIII.**

106 M, 2009 data

Simultaneous fit.

MC signal shape

Inclusive decays



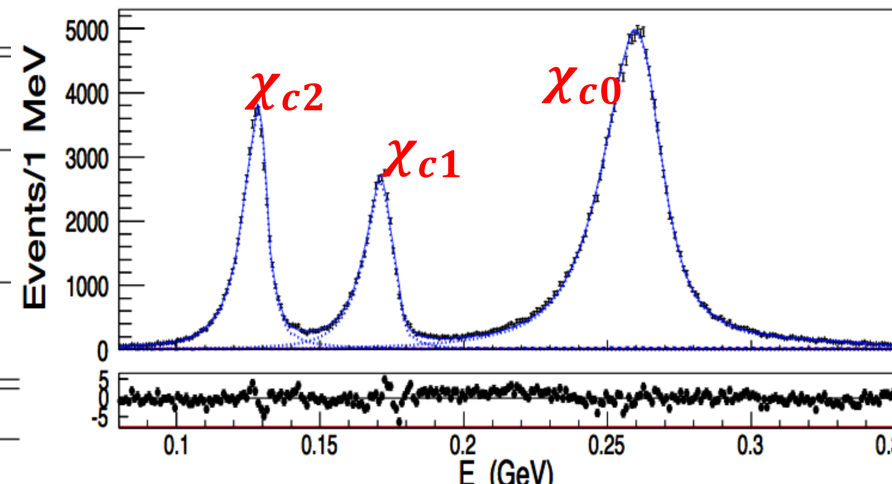
Non-radiative bkg.

PRD96, 032001(2017)

Branching Fraction	This analysis (%)
$\mathcal{B}(\psi(3686) \rightarrow \gamma\chi_{c0})$	$9.389 \pm 0.014 \pm 0.332$
$\mathcal{B}(\psi(3686) \rightarrow \gamma\chi_{c1})$	$9.905 \pm 0.011 \pm 0.353$
$\mathcal{B}(\psi(3686) \rightarrow \gamma\chi_{c2})$	$9.621 \pm 0.013 \pm 0.272$

Comparison with others

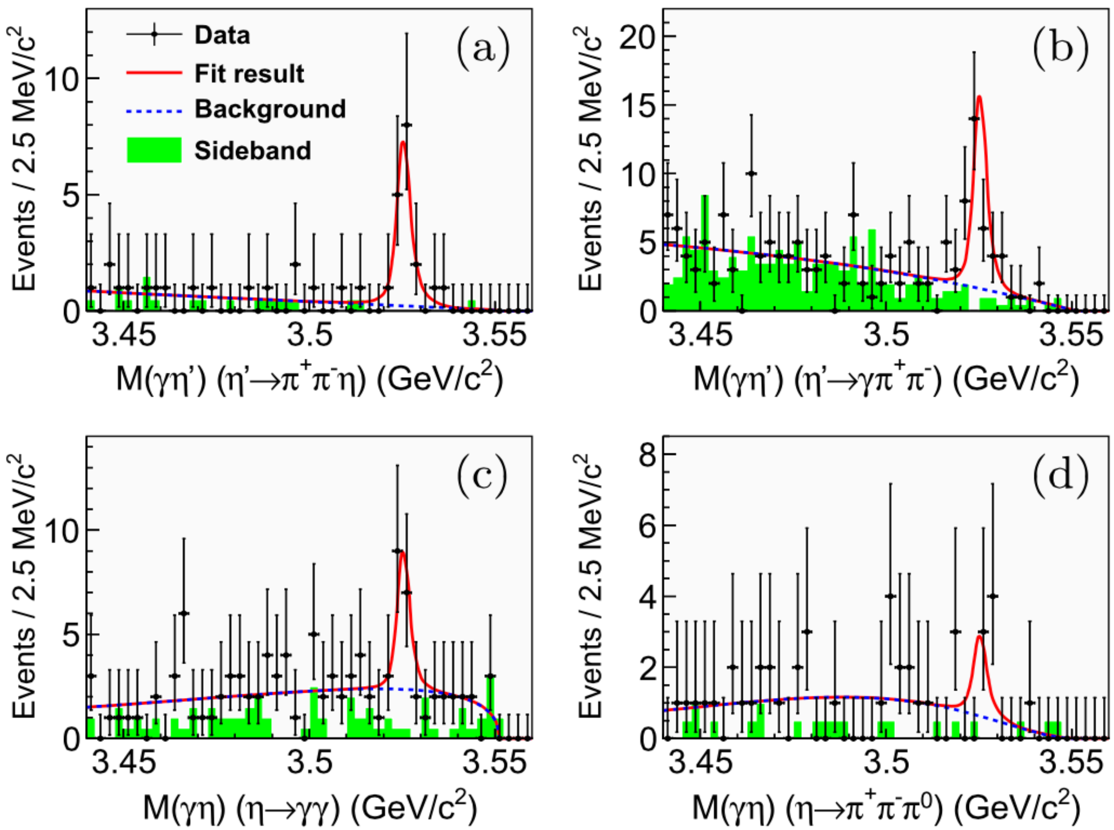
Decay	Crystal Ball (%)	CLEO (%)	PDG (%)
$\psi(3686) \rightarrow \gamma\chi_{c0}$	$9.9 \pm 0.5 \pm 0.8$	$9.22 \pm 0.11 \pm 0.46$	9.2 ± 0.4
$\psi(3686) \rightarrow \gamma\chi_{c1}$	$9.0 \pm 0.5 \pm 0.7$	$9.07 \pm 0.11 \pm 0.54$	8.9 ± 0.5
$\psi(3686) \rightarrow \gamma\chi_{c2}$	$8.0 \pm 0.5 \pm 0.7$	$9.33 \pm 0.14 \pm 0.61$	8.8 ± 0.5



To constrain the signal shape;

$\chi_{cJ} \rightarrow$ 2 or 4 charged tracks; negligible bkg.

Observation of $h_c \to \gamma\eta'$ and evidence of $\gamma\eta$



448*10^6 $\psi(3686)$ events
$\psi(3686) \to \pi^0 h_c$ ~10^-3.

- Knowledge on h_c (P-wave singlet) decay is sparse.
  - $B(h_c \to \gamma\, \eta_c)$~50%
  - $B(h_c \to 2(\pi^+\pi^-)\pi^0$~2%
- Searches for the new decay modes are desired to further understand its decay properties.
- The ratio branching fraction $\frac{B(h_c\to\gamma\,\eta')}{B(h_c\to\gamma\,\eta)}$ can be used to study the $\eta - \eta'$ mixing angle.

PRD 36, 2761(1987)

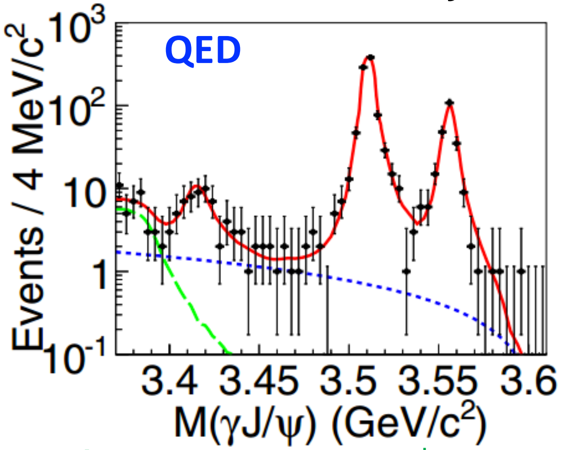
- The BFs of $h_c \to \gamma\, \eta'$ is observed with 8.4σ;
- $h_c \to \gamma\, \eta$ with 4.0 σ

$B(h_c \to \gamma\eta') = (1.52 \pm 0.27 \pm 0.29)\times 10^{-3}$;
$B(h_c \to \gamma\eta) = (4.7 \pm 1.5 \pm 1.4)\times 10^{-4}$;

PRL 116, 251802 (2016)

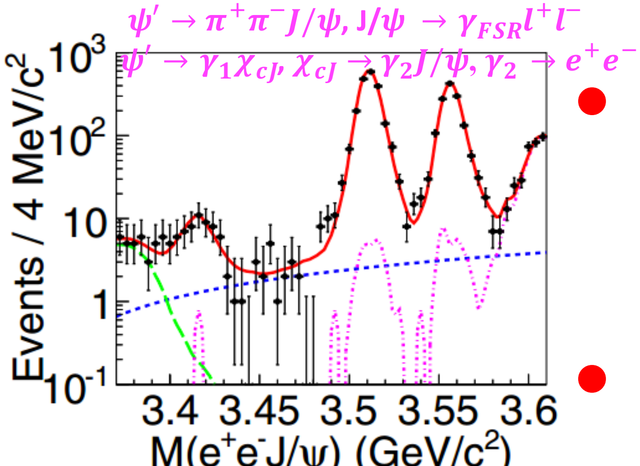
$\psi' \to e^+e^-\chi_{cJ}$ and $\chi_{cJ} \to e^+e^-J/\psi$

$\psi' \to e^+e^-\chi_{cJ}$



$\psi' \to \gamma\chi_{c0};\ \chi_{c0} \to e^+e^-J/\psi$

$\chi_{cJ} \to e^+e^-J/\psi$



$\psi' \to e^+e^-\chi_{c0},\ \chi_{c0} \to \gamma J/\psi$; MC shape

448*10^6 $\psi(3686)$ events

- The EM Dalitz decays are widely observed in light-quark meson sector
  - ➢ $\eta' \to \gamma e^+e^-, \eta' \to \omega e^+e^-,$ $\phi \to \eta e^+e^-$.
- The analogous decays in $c\bar{c}$ have not been observed yet.

Mode	Yields	Efficiency(%)	Branching fraction	$\mathcal{B}(\psi(3686) \to e^+e^-\chi_{cJ})/$ $\mathcal{B}(\psi(3686) \to \gamma\chi_{cJ})$	$\mathcal{B}(\chi_{cJ} \to e^+e^-J/\psi)/$ $\mathcal{B}(\chi_{cJ} \to \gamma J/\psi)$
$\psi(3686) \to e^+e^-\chi_{c0}$	48 ± 10	6.06	$(11.7 \pm 2.5 \pm 1.0) \times 10^{-4}$	$(9.4 \pm 1.9 \pm 0.6) \times 10^{-3}$	...
$\psi(3686) \to e^+e^-\chi_{c1}$	873 ± 30	5.61	$(8.6 \pm 0.3 \pm 0.6) \times 10^{-4}$	$(8.3 \pm 0.3 \pm 0.4) \times 10^{-3}$	...
$\psi(3686) \to e^+e^-\chi_{c2}$	227 ± 16	3.19	$(6.9 \pm 0.5 \pm 0.6) \times 10^{-4}$	$(6.6 \pm 0.5 \pm 0.4) \times 10^{-3}$	...
$\chi_{c0} \to e^+e^-J/\psi$	56 ± 11	6.95	$(1.51 \pm 0.30 \pm 0.13) \times 10^{-4}$	...	$(9.5 \pm 1.9 \pm 0.7) \times 10^{-3}$
$\chi_{c1} \to e^+e^-J/\psi$	1969 ± 46	10.35	$(3.73 \pm 0.09 \pm 0.25) \times 10^{-3}$	...	$(10.1 \pm 0.3 \pm 0.5) \times 10^{-3}$
$\chi_{c2} \to e^+e^-J/\psi$	1354 ± 39	11.23	$(2.48 \pm 0.08 \pm 0.16) \times 10^{-3}$	...	$(11.3 \pm 0.4 \pm 0.5) \times 10^{-3}$

- **The BFs of $\psi' \to e^+e^-\chi_{cJ}$ and $\chi_{cJ} \to e^+e^-J/\psi$ are observed for the first time.**

PRL 118, 221802 (2017)

Summary

- **BESIII has collected the world's largest J/ψ and $\psi(3686)$ data samples.**
- **Several recent charmonium analyses based on the samples are presented in this talk. More precise results/first observations are obtained with the high statistics.**
- **More interesting results are expected in the near future.**

Thanks for your attention!