Recent results of charmonium decays at BESIII

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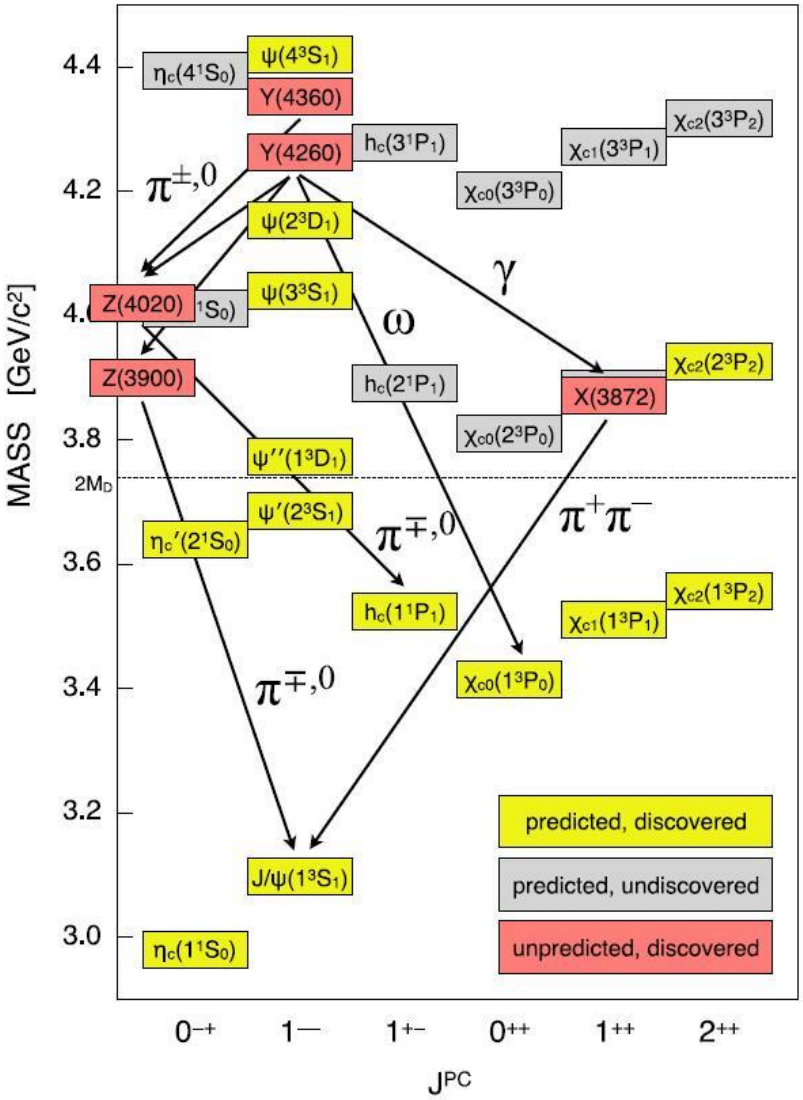
Hadron2021, 26th to 31st of July 2021,Mexico City

Charmonium spectrum

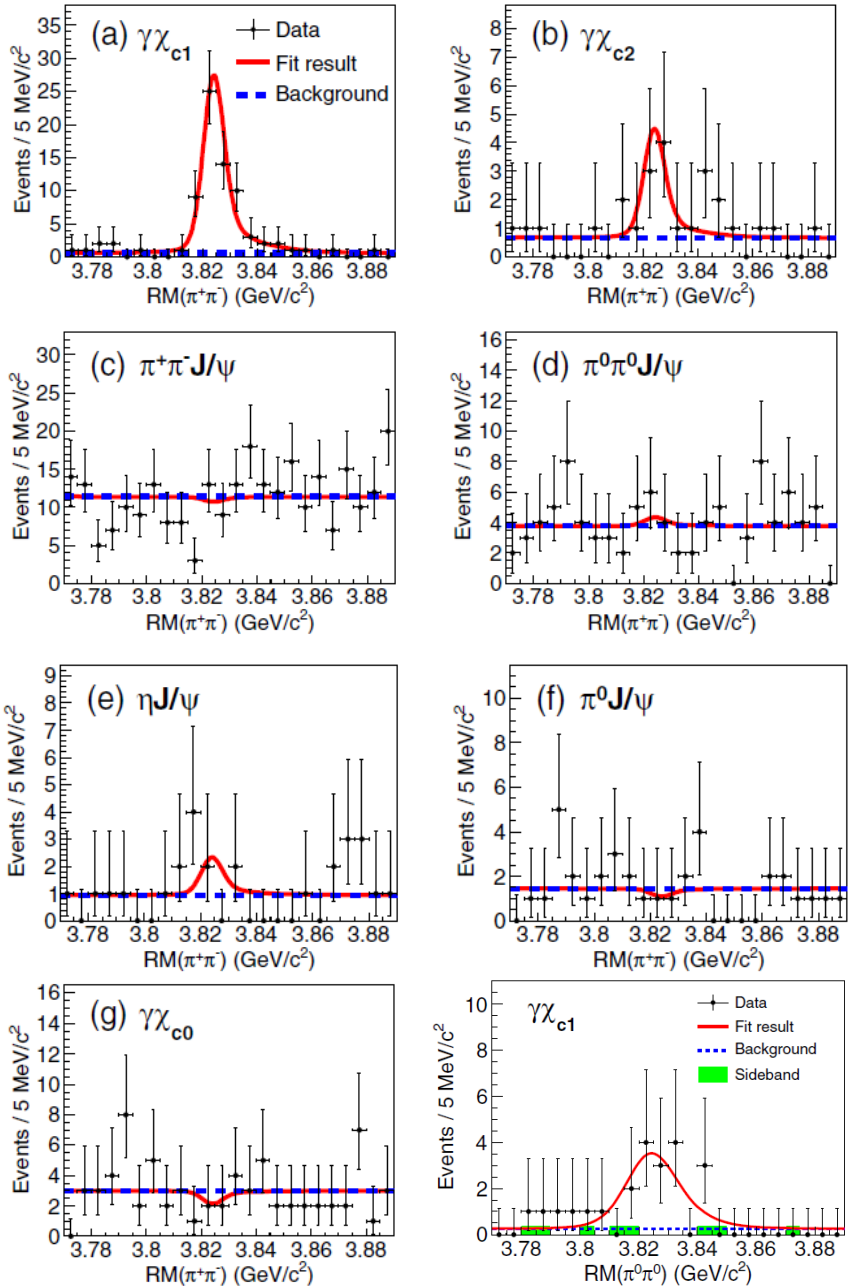


- Charmonium states located in the transition region between perturbative QCD and non-perturbative QCD.
- Various theoretical models make predictions for charmonium decays.
- New observed charmonium decays can provide more new information for theory.

Recent results of charmonium decays at BESIII

- ✓ $\psi_2(3823)$
  - $\gamma\chi_{c0,1,2}$
  - $\pi^+\pi^- J/\psi$
  - $\pi^0\pi^0 J/$
  - $\pi^0 J/\psi$
  - $\eta J/\psi$
- ✓ $\psi(3686)$
  - $\bar{\Sigma}^0\Lambda + c.c.$
  - K_S^0+anything
  - $\Sigma^+\bar{\Sigma}-$
- ✓ $\chi_{cJ(J=0,1,2)}$
  - $\Lambda\bar{\Lambda}$
  - $nK_S^0\bar{\Lambda} + c.c.$
- ✓ J/ψ
  - $\Sigma^+\bar{\Sigma}-$
- ✓ η_c
  - $\eta\eta\eta'$

New decay modes of $\psi_2(3823)$



PRD103, L091102 (2021)

Channel	$N^{\psi_2(3823)}$	$\frac{\mathcal{B}(\psi_2(3823)\to\cdots)}{\mathcal{B}(\psi_2(3823)\to\gamma\chi_{c1})}$
$\gamma\chi_{c1}$	63.1 ± 8.5	...
$\gamma\chi_{c2}$	$8.8^{+4.3}_{-3.4}$	$0.28^{+0.14}_{-0.11} \pm 0.02$
$\pi^+\pi^- J/\psi$	<21.0	<0.06
$\pi^0\pi^0 J/\psi$	<10.0	<0.11
$\eta J/\psi$	<9.8	<0.14
$\pi^0 J/\psi$	<5.6	<0.03
$\gamma\chi_{c0}$	<6.3	<0.24

- ✓ $\psi_2(3823)\to\gamma\chi_{c1}$:confirms the previous observation[1,2] with 11.8σ.
- ✓ $\psi_2(3823)\to\gamma\chi_{c2}$: found for the first time with 3.2σ
- ✓ $e^+e^-\to\pi^0\pi^0\psi_2(3823)$ is found with 4.3σ.
- ✓ No significant $e^+e^-\to\pi^+\pi^-\psi_3(3842)$ signals in all channels.

Consistent with the theoretical predictions[3,4].

[1] Phys. Rev. Lett.111, 032001 (2013).
[2] Phys. Rev. Lett.115, 011803 (2015)
[3]Phys. Rev. D 55, 4001 (1997).
[4] Phys. Rev. Lett. 89, 162002 (2002).

Measurements of the branching fractions of $\psi(3686) \to \bar{\Sigma}^0\Lambda + c.c.$ and $\chi_{cJ(J=0,1,2)} \to \Lambda\bar{\Lambda}$

PRD 103, 112004 (2021)

✓ **The BF of $\psi(3686) \to \bar{\Sigma}^0\Lambda + c.c.$**

- CLEO[5]:

  $(12.3\pm2.4)\times10^{-6}$

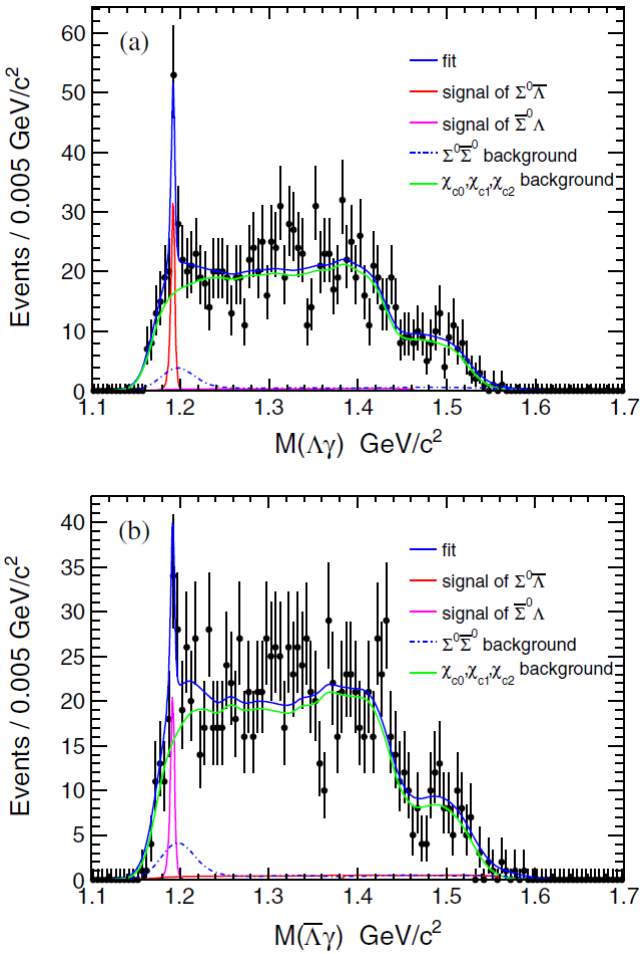
- Theoretical prediction[6]:

  $(4.0\pm2.3)\times10^{-6}$

- This work:

  $(1.60\pm0.31\pm0.13\pm0.58)\times10^{-6}$

Due to the uncertainty of interference with continuum process.

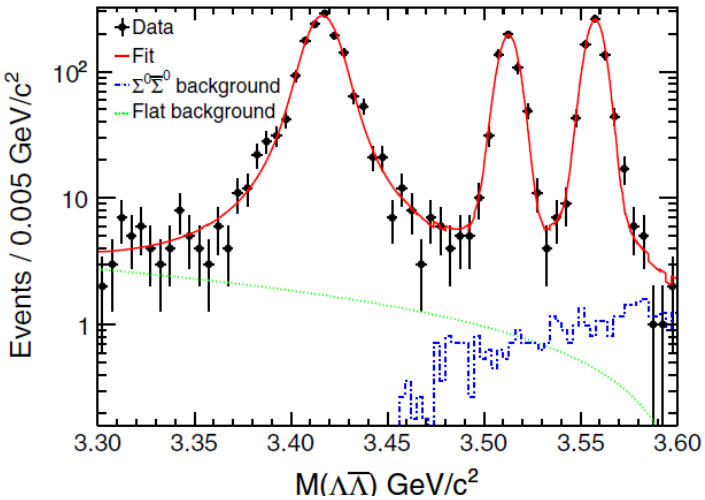


[5]Phys. Rev. D 96, 092004 (2017).
[6]Int. J. Mod.Phys. A 30, 1550148 (2015)

Measurements of the branching fractions of $\psi(3686) \to \bar{\Sigma}^0 \Lambda + c.c.$ and $\chi_{cJ(J=0,1,2)} \to \Lambda\bar{\Lambda}$

PRD 103, 112004 (2021)

- ✓ The BFs of $\chi_{cJ} \to \Lambda\bar{\Lambda}$ are measured with improved precision, and they are consistent with previous results[7].
- ✓ These results are not consistent with the theoretical predictions[8-10], e.g., $(1.19\sim1.51)\times10^{-4}$ for χ_{c0}



Mode	$N_{\chi_{cJ}}$	ϵ	$\mathcal{B}(\psi(3686) \to \gamma\chi_{cJ}) \times \mathcal{B}(\chi_{cJ} \to \Lambda\bar{\Lambda})(10^{-5})$	$\mathcal{B}(\chi_{cJ} \to \Lambda\bar{\Lambda})(\times10^{-4})$ This work	PDG
χ_{c0}	1486 ± 42	22.80%	$3.56 \pm 0.10 \pm 0.10$	$3.64 \pm 0.10 \pm 0.10 \pm 0.07$	3.27 ± 0.24
χ_{c1}	528 ± 24	22.61%	$1.28 \pm 0.06 \pm 0.06$	$1.31 \pm 0.06 \pm 0.06 \pm 0.03$	1.14 ± 0.11
χ_{c2}	670 ± 27	20.16%	$1.82 \pm 0.08 \pm 0.17$	$1.91 \pm 0.08 \pm 0.17 \pm 0.04$	1.84 ± 0.15

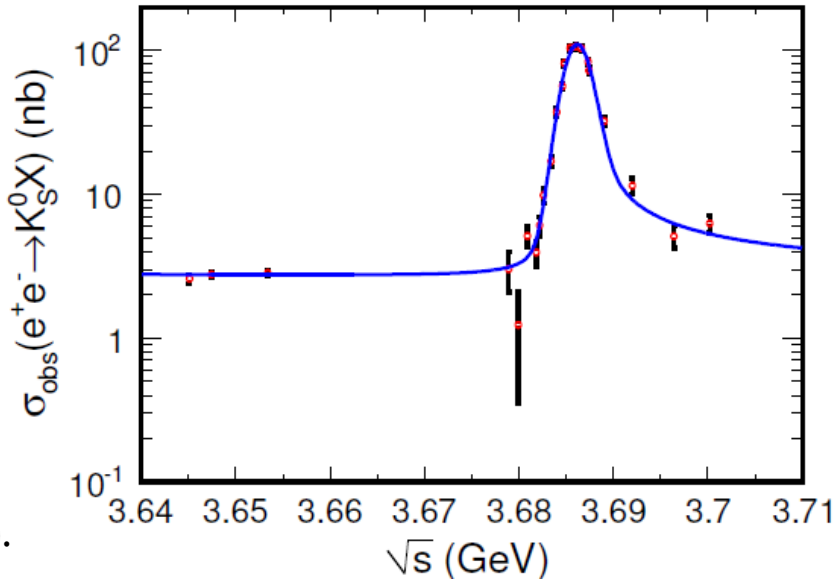
Due to the uncertainty of BF($\psi(3686) \to \gamma\chi_{cJ}$).

[7] Phys. Rev. D 87,032007 (2013).
[8] Eur. Phys. J. C 14, 643 (2000).
[9] Eur. Phys. J. A 23, 129 (2005).
[10] J. Phys. G 38, 035007 (2011).

Measurements of $\psi(3686) \rightarrow K_S^0$+anything

arXiv:2106.08766

- ✓ Measurements of the BFs of inclusive $\psi(3686)$ decays can guide the search for new exclusive decay modes.
- ✓ The BF of $\psi(3686) \rightarrow K_S^0$ +anything is measured to be (16.04±0.29±0.90)% for the first time. The sum of all the BFs of $\psi(3686)$ decays to exclusive K_S^0 final states is ~ 5.95% as reported in PDG[11].
- ✓ Some undiscovered exclusive channels for $\psi(3686)$ decay to final states associated with K_S^0 .

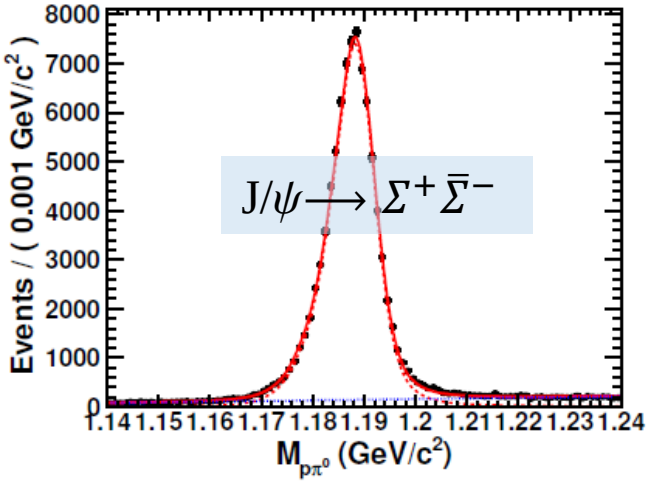


[11]Phys. Rev. D 98, 030001 (2018).

Measurement of branching fractions of J/ψ and ψ(3686) decays to Σ^+ and $\bar{\Sigma}^-$

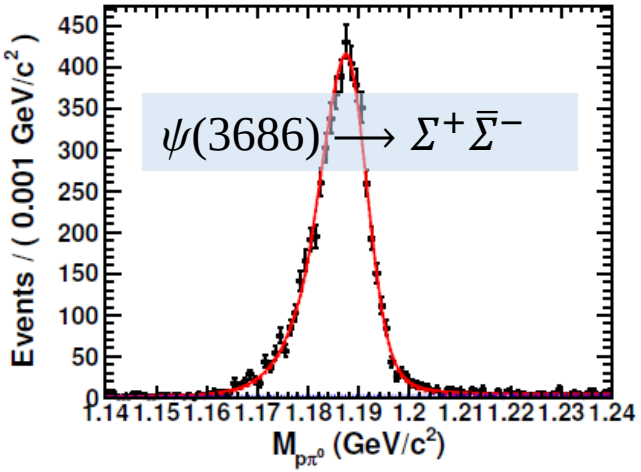
arXiv:2107.02977

- ✓ The precision of the BF of $J/\psi \longrightarrow \Sigma^+\bar{\Sigma}^-$ is poor[12], $(1.50\pm0.10\pm0.22)\times10^{-3}$.
- ✓ The BFs of them are in agreement with the previous measurement [12, 13].
- ✓ The precision of J/ψ is improved by a factor of 7.



Channel	Branching fraction(10^{-4})	BF(ψ(3686)) / BF(J/ψ)
$\psi(3686) \longrightarrow \Sigma^+\bar{\Sigma}^-$	$2.52\pm0.04\pm0.10$	$(23.8\pm1.3)\%$
$J/\psi \longrightarrow \Sigma^+\bar{\Sigma}^-$	$10.61\pm0.04\pm0.38$	

violates the "12% rule"

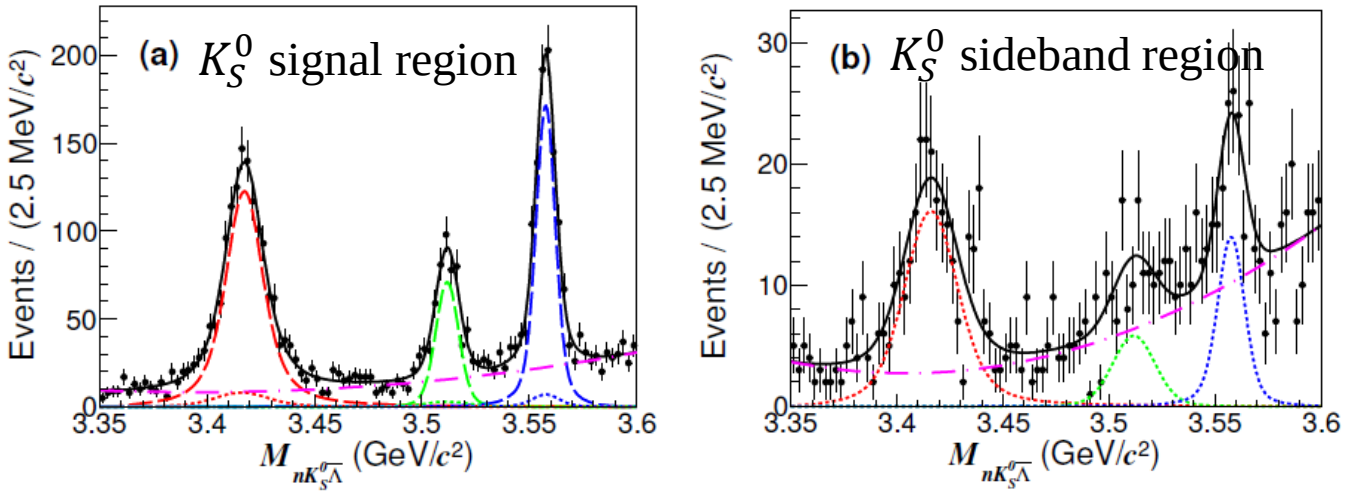


[12]Phys. Rev. D 78, 092005 (2008).
[13]Phys. Rev. D 96, 092004(2017).

Observation of the decays $\chi_{cJ} \to nK_S^0\bar{\Lambda} + c.c.$

arXiv:2106.13442

- ✓ $\chi_{cJ} \to nK_S^0\bar{\Lambda} + c.c.$ is observed for the first time.
- ✓ Check with $\chi_{cJ} \to pK^-\bar{\Lambda} + c.c$[14], and no obvious isospin violation is observed.



Mode	$N_{1,J}$	ϵ_J (%)	BF (10^{-4})	BF($pK^-\bar{\Lambda}$) / BF($nK_S^0\bar{\Lambda}$)
χ_{c0}	1288 ± 50	9.95	$6.67 \pm 0.26 \pm 0.41$	(1.98±0.09±0.14)
χ_{c1}	410 ± 30	12.44	$1.71 \pm 0.12 \pm 0.12$	(2.64±0.23±0.20)
χ_{c2}	900 ± 41	13.03	$3.66 \pm 0.17 \pm 0.23$	(2.29±0.13±0.16)

[14] Phys. Rev. D 87, 012007(2013)

Observation of $\eta_c \to \eta\eta\eta'$ in J/$\psi \longrightarrow \gamma\eta\eta\eta'$

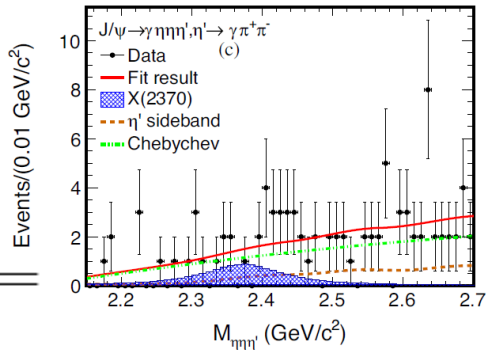
PRD103, 012009 (2021)

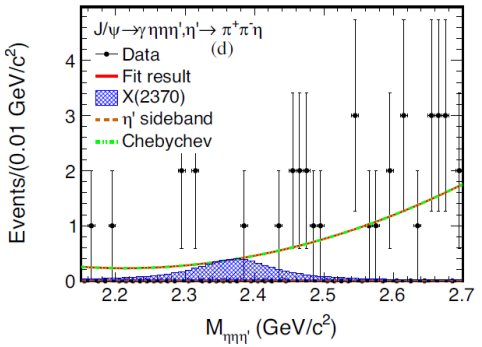
✓ A possible pseudoscalar glueball candidate, the X(2370), is observed in experiment[15,16].

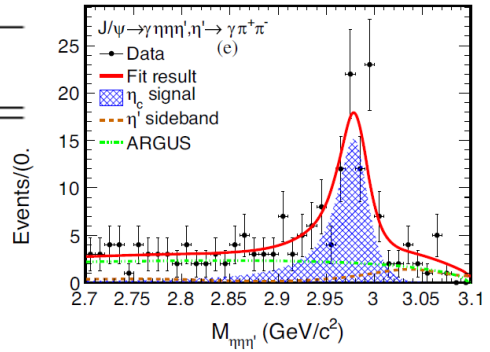
It is not in contradiction with the theoretical prediction[17],where X(2370) is assumed as a pseudoscalar glueball.

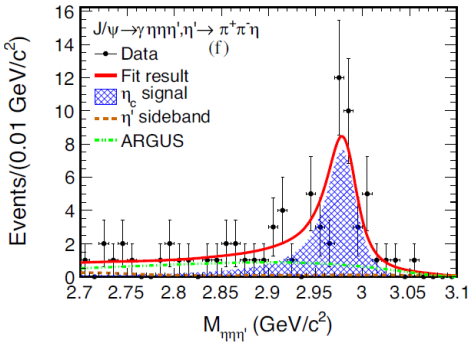
Channel	Branching fraction
$J/\psi \longrightarrow \gamma X(2370) \longrightarrow \gamma\eta\eta\eta'$	$< 9.2\times10^{-6}$
$J/\psi \longrightarrow \gamma\eta_c \longrightarrow \gamma\eta\eta\eta'$	$(4.86\pm0.62\pm0.45)\times10^{-5}$

Compatible with the theoretical prediction[18].









[15]Phys. Rev. Lett.106, 072002 (2011)
[16] Eur. Phys. J. C 80,746 (2020).
[17] Phys. Rev. D 87, 054036 (2013).
[18] Eur. Phys. J. A 54, 139 (2018).

Summary

- ✓The largest data samples of J/ψ and $\psi(3686)$ collected by BESIII provide a wonderful opportunity not only to search for rare decays, but also to study the unknown decays of charmonium.
- ✓6 analyses are presented:
  - New decay modes of $\psi_2(3823)$
  - $\psi(3686) \to \bar{\Sigma}^0\Lambda + c.c.$ and $\chi_{cJ(J=0,1,2)} \to \Lambda\bar{\Lambda}$
  - $\psi(3686) \to K_S^0$+anything
  - J/ψ and $\psi(3686) \longrightarrow \Sigma^+$ and $\bar{\Sigma}^-$
  - $\chi_{cJ} \to nK_S^0\bar{\Lambda} + c.c.$
  - $\eta_c \to \eta\eta\eta'$
- ✓BESIII will keep running !

Thanks for your attention!