中国科学院高能物理研究所
Institute of High Energy Physics Chinese Academy of Sciences

Overview of the $J^{PC} = 1^{--}$ charmonium (-like) states decaying in $B\bar{B}$ @ BESIII

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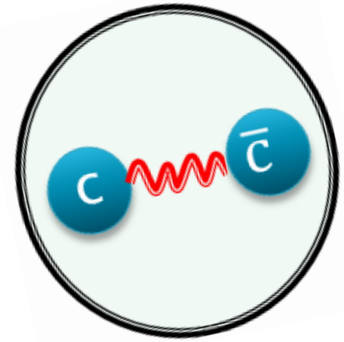
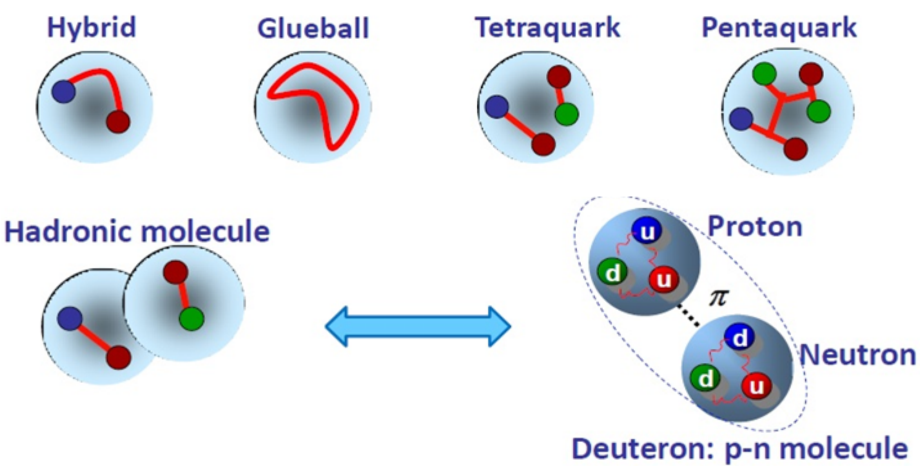
Outline

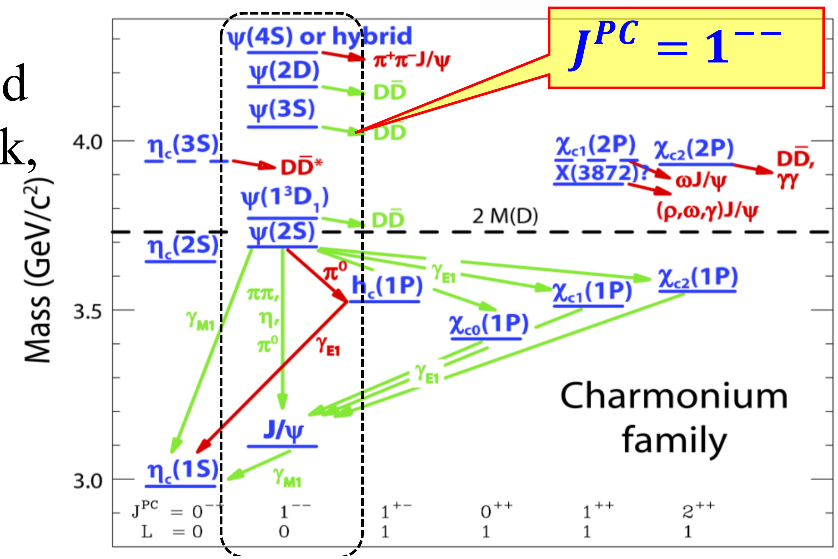
- Introduction
- Recent results
  - Study of $J/\psi, \psi(3686) \to B\bar{B}$ (B:baryon)
    1. $J/\psi, \psi(3686) \to \Xi^-\bar{\Xi}^+, \Sigma(1385)^{\mp}\bar{\Sigma}(1385)^{\pm}$
    2. $J/\psi, \psi(3686) \to \Xi^0\bar{\Xi}^0, \Sigma(1385)^0\bar{\Sigma}(1385)^0$
    3. $J/\psi, \psi(3686) \to \Lambda\bar{\Lambda}, \Sigma^0\bar{\Sigma}^0$
    4. $J/\psi, \psi(3686) \to N\bar{N}(p\bar{p}, n\bar{n})$
    5. $\psi(3686) \to \Xi(1690/1820)\bar{\Xi}$
  - Measurement of cross section of $e^+e^- \to B\bar{B}$
    1. $e^+e^- \to p\bar{p}$
    2. $e^+e^- \to \Lambda\bar{\Lambda}$
    3. $e^+e^- \to \Lambda_c\bar{\Lambda}_c$
- Summary

Charmonium(-like) states



- Nonrelativistic $c\bar{c}$ bound states, $J/\psi\ (1^3S_1)$ is the first member with $J^{PC}=1^{--}$, other *below charm threshold* like $\psi(2S), etc.$.
- Chamonium (-like) states *above charm threshold* like Y(4260), Y(4360),etc., proposed more exotic explanations as hybrids, tetraquark, hadronic molecule, glueball, etc..





Potential models:

Example from Barnes, Godfrey, Swanson:

$$V_0^{(c\bar{c})}(r) = -\frac{4}{3}\frac{\alpha_s}{r} + br + \frac{32\pi\alpha_s}{9m_c^2}\tilde{\delta}_\sigma(r)\vec{S}_c\cdot\vec{S}_{\bar{c}}$$

(Coulomb + Confinement + Contact)

$$V_{\text{spin-dep}} = \frac{1}{m_c^2}\left[\left(\frac{2\alpha_s}{r^3}-\frac{b}{2r}\right)\vec{L}\cdot\vec{S} + \frac{4\alpha_s}{r^3}T\right]$$

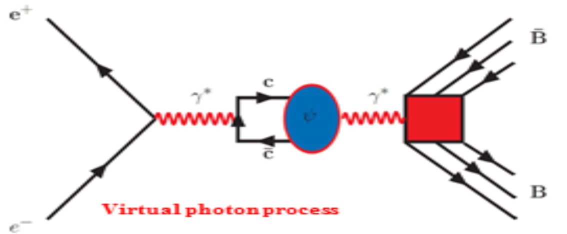
(Spin-Orbit + Tensor)

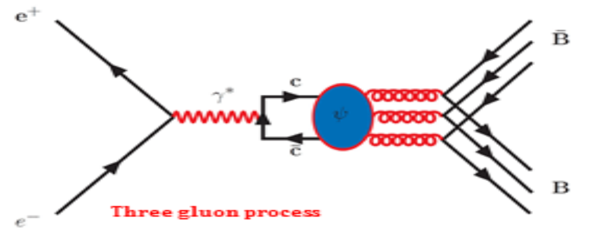
PRD72, 054026 (2005)

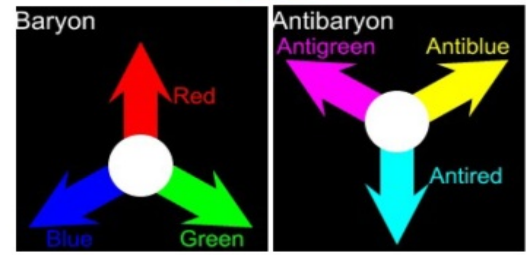
- **Potential models and L-QCD, very successful in describing spectra & onium properties!**

Baryon spectroscopy/production

- Established baryons described by 3-quark configuration with the zero total color charge.
- Production of $B\overline{B}$ in e^+e^- annihilation:

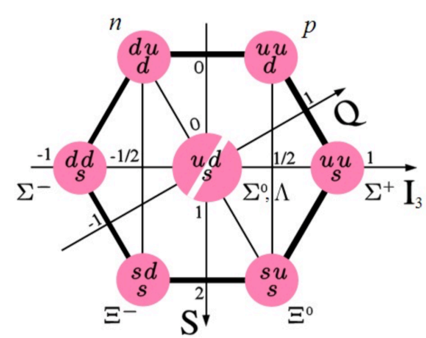


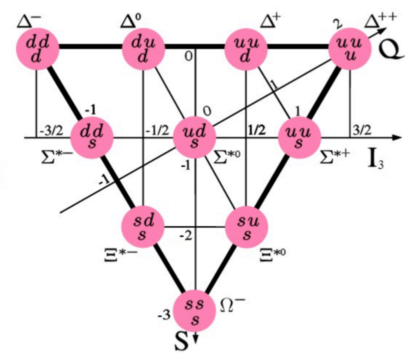




- Provide a favorable test of pQCD and baryonic properties
  - ✓ Test "12%" rule: $Q_h = \frac{Br(\psi(2S)\rightarrow X_h)}{Br(J/\psi\rightarrow X_h)} = 12\%$ (QCD prediction).
  - ✓ Test SU(3)-flavor symmetry
    - – Allowed for $\psi \rightarrow B_8\overline{B}_8, B_{10}\overline{B}_{10}$, forbidden for $\psi \rightarrow B_8\overline{B}_{10}$.
  - ✓ Angular distribution study ($\frac{dN}{d(cos\theta)} \propto 1 + \alpha cos^2\theta$):
    - -- Quark mass effect, electromagnetic effect, etc.: $0 < \alpha < 1$.
  - ✓ $B\overline{B}$ threshold effect
    - -- $B\overline{B}$ bound states or unobserved meson resonances
  - ✓ Electromagnetic form factor (EMFFs)
    - -- Further understand the strong interaction
    - -- Measure time-like EMFFs
  - ✓ Search for 1^{--} Y states in $B\overline{B}$ final states above open charm threshold.

Octet / decuplet





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- □ **Recent results**
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  - ➢ Measurement of cross section of e^+e^-
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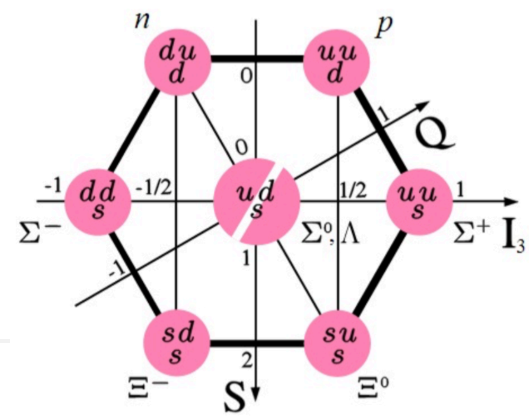
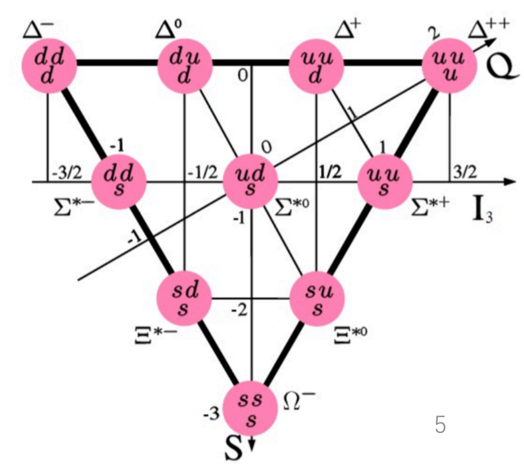




Physical Review D 93, 0732003 (2016)

Study of ψ decays to the $\Xi^-\bar{\Xi}^+$ and $\Sigma(1385)^{\mp}\bar{\Sigma}(1385)^{\pm}$ final states

DIRECTLY accepted for first one at BESIII!

Anything

$J/\psi(\psi(2S)) \rightarrow \Xi^-\bar{\Xi}^+, \Sigma(1385)^{\mp}\bar{\Sigma}(1385)^{\pm}$

$\pi^{\pm}\Lambda$

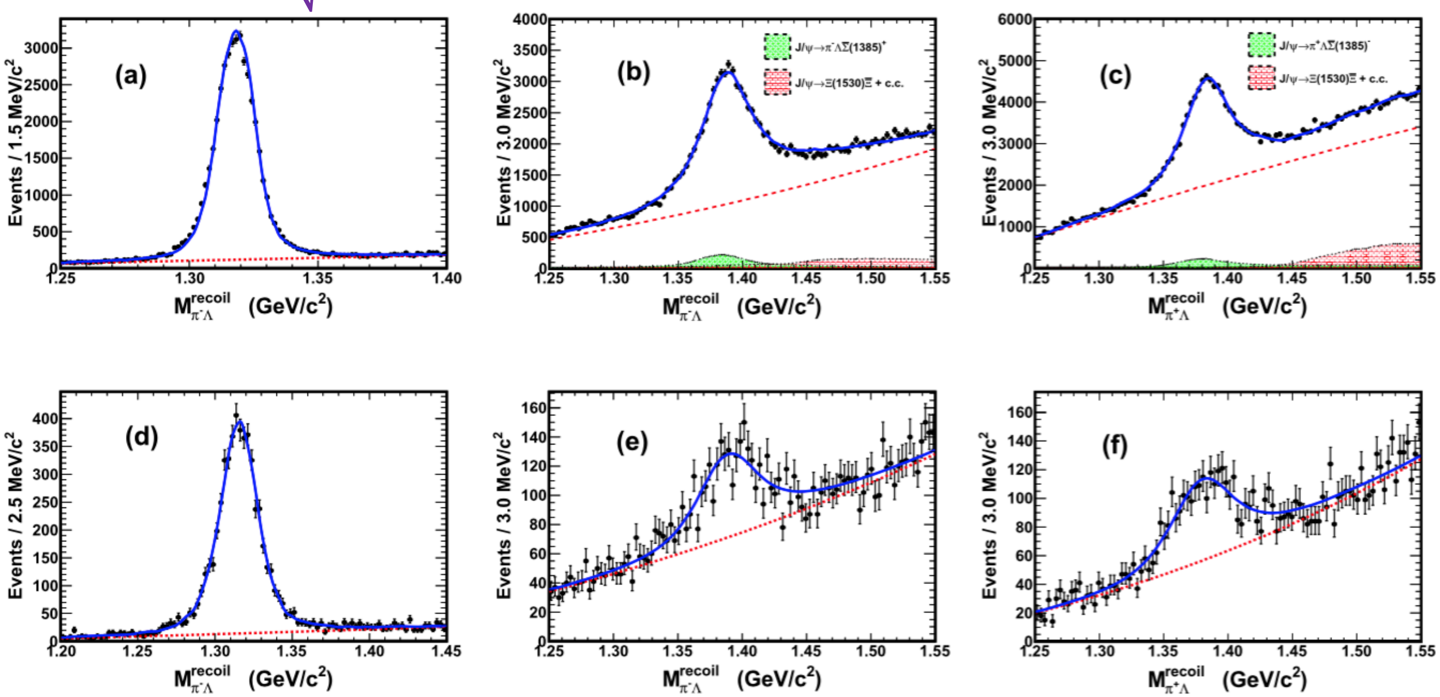
$p\pi^{\pm}$

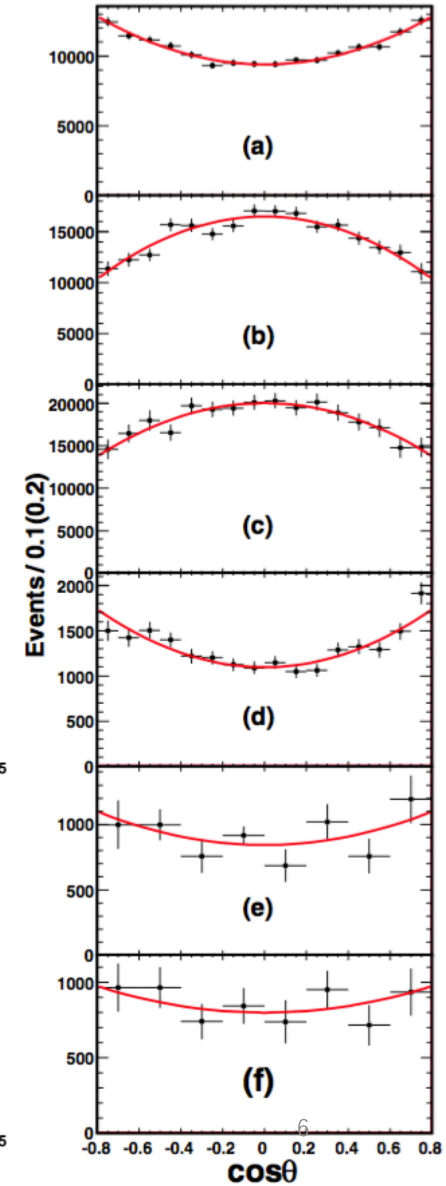
$$M_{\pi\Lambda}^{recoil} = \sqrt{(E_{c.m.} - E_{\pi\Lambda})^2 - \vec{p}^{\,2}}$$

Data samples:

$225\times10^6 J/\psi$ & $106\times10^6 \psi(3686)$

(a) $J/\psi \rightarrow \Xi^-\bar{\Xi}^+$
(b) $J/\psi \rightarrow \Sigma(1385)^-\bar{\Sigma}(1385)^+$
(c) $J/\psi \rightarrow \Sigma(1385)^+\bar{\Sigma}(1385)^-$
(d) $\psi(3686) \rightarrow \Xi^-\bar{\Xi}^+$
(e) $\psi(3686) \rightarrow \Sigma(1385)^-\bar{\Sigma}(1385)^+$
(f) $\psi(3686) \rightarrow \Sigma(1385)^+\bar{\Sigma}(1385)^-$





Physical Review D 93, 0732003 (2016)

Study of ψ decays to the $\Xi^-\bar{\Xi}^+$ and $\Sigma(1385)^{\mp}\bar{\Sigma}(1385)^{\pm}$ final states

■ Numerical results ($Br(N_{obs}/N_{\psi}\cdot\epsilon)$ and α values)

Br ($\times 10^{-4}$)

Mode	$J/\psi \to$			$\psi(3686) \to$		
	$\Xi^-\bar{\Xi}^+$	$\Sigma(1385)^-\bar{\Sigma}(1385)^+$	$\Sigma(1385)^+\bar{\Sigma}(1385)^-$	$\Xi^-\bar{\Xi}^+$	$\Sigma(1385)^-\bar{\Sigma}(1385)^+$	$\Sigma(1385)^+\bar{\Sigma}(1385)^-$
This work	10.40 ± 0.06 ± 0.74	10.96 ± 0.12 ± 0.71	12.58 ± 0.14 ± 0.78	2.78 ± 0.05 ± 0.14	0.85 ± 0.06 ± 0.06	0.84 ± 0.05 ± 0.05
MarkI [5]	14.00 ± 5.00	...	...	< 2.0	...	...
MarkII [6]	11.40 ± 0.80 ± 2.00	8.60 ± 1.80 ± 2.20	10.3 ± 2.4 ± 2.5	...	...	...
DM2 [7]	7.00 ± 0.60 ± 1.20	10.00 ± 0.40 ± 2.10	11.9 ± 0.4 ± 2.5	...	...	...
BESII [8,12]	9.00 ± 0.30 ± 1.80	12.30 ± 0.70 ± 3.00	15.0 ± 0.8 ± 3.8	3.03 ± 0.40 ± 0.32	...	...
CLEO [9]	...	...	...	2.40 ± 0.30 ± 0.20	...	...
BESI [26]	...	...	...	0.94 ± 0.27 ± 0.15	...	...
PDG [3]	8.50 ± 1.60	10.30 ± 1.30	10.30 ± 1.30	1.80 ± 0.60	...	...

α

Mode	$J/\psi \to$			$\psi(3686) \to$		
	$\Xi^-\bar{\Xi}^+$	$\Sigma(1385)^-\bar{\Sigma}(1385)^+$	$\Sigma(1385)^+\bar{\Sigma}(1385)^-$	$\Xi^-\bar{\Xi}^+$	$\Sigma(1385)^-\bar{\Sigma}(1385)^+$	$\Sigma(1385)^+\bar{\Sigma}(1385)^-$
This work	0.58 ± 0.04 ± 0.08	−0.58 ± 0.05 ± 0.09	−0.49 ± 0.06 ± 0.08	0.91 ± 0.13 ± 0.14	0.64 ± 0.40 ± 0.27	0.35 ± 0.37 ± 0.10
BESII [8]	0.35 ± 0.29 ± 0.06	−0.54 ± 0.22 ± 0.10	−0.35 ± 0.25 ± 0.06	...	...	...
MarkIII [6]	0.13 ± 0.55		...	...	...	...
Claudson *et al.* [10]	0.16	0.11	0.11	0.32	0.29	0.29
Carimalo [11]	0.27	0.20	0.20	0.52	0.50	0.50

Negative?

- ➢ Provide more new and precise measurements and experimental evidences, But for the predictions of α values without the consideration of the higher order correction , it is deviated from the measured values.

■ Ratio of branching fractions ($\frac{Br(\psi(3686)\to X_h)}{Br(J/\psi\to X_h)}$)

$\Xi^-\bar{\Xi}^+$	$\Sigma(1385)^-\bar{\Sigma}(1385)^+$	$\Sigma(1385)^+\bar{\Sigma}(1385)^-$
(26.73±0.50±2.30)%	(7.76±0.55±0.68)%	(6.68±0.40±0.50)%

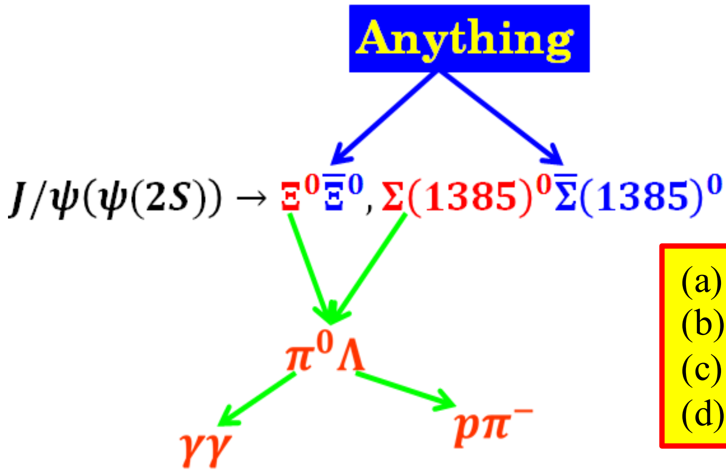
Deviated from 12% !

- ➢ Theoretical models are expected to be improved to understand the difference.

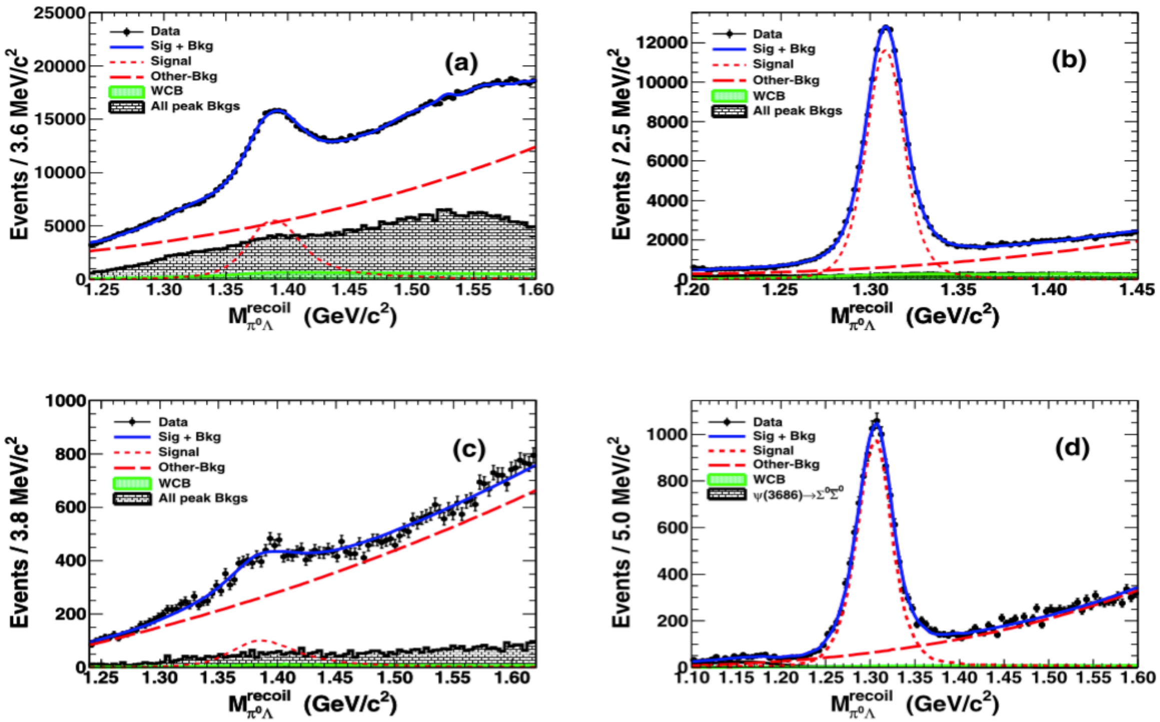
Physics Letters B 770 (2017) 217-225

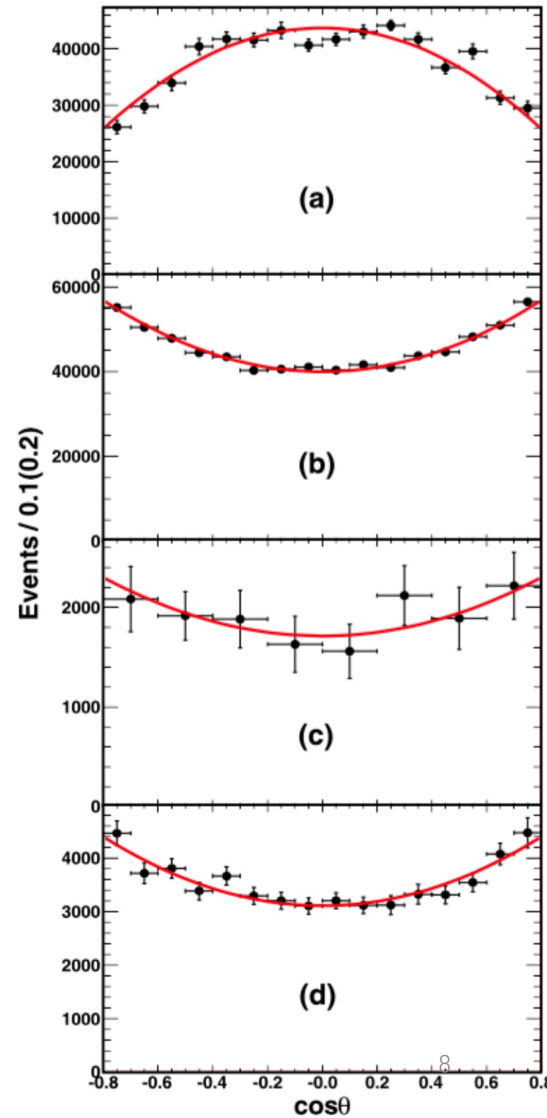
Study of J/ψ and $\psi(3686) \to \Sigma(1385)^0\bar{\Sigma}(1385)^0$ and $\Xi^0\bar{\Xi}^0$

Data samples: $1310\times10^6 J/\psi$ & $448\times10^6 \psi(3686)$



(a) $J/\psi \to \Sigma(1385)^0\bar{\Sigma}(1385)^0$
(b) $J/\psi \to \Xi^0\bar{\Xi}^0$
(c) $\psi(3686) \to \Sigma(1385)^0\bar{\Sigma}(1385)^0$
(d) $\psi(3686) \to \Xi^0\bar{\Xi}^0$





Physics Letters B 770 (2017) 217-225

Study of J/ψ and $\psi(3686) \to \Sigma(1385)^0\bar{\Sigma}(1385)^0$ and $\Xi^0\bar{\Xi}^0$

Numerical results (*Br* and α values)

Br ($\times10^{-4}$)

Mode	$J/\psi \to \Sigma(1385)^0\bar{\Sigma}(1385)^0$	$J/\psi \to \Xi^0\bar{\Xi}^0$	$\psi(3686) \to \Sigma(1385)^0\bar{\Sigma}(1385)^0$	$\psi(3686) \to \Xi^0\bar{\Xi}^0$
This work	$10.71 \pm 0.09 \pm 0.82$	$11.65 \pm 0.04 \pm 0.43$	$0.69 \pm 0.05 \pm 0.05$	$2.73 \pm 0.03 \pm 0.13$
BESII [23]	–	$12.0 \pm 1.2 \pm 2.1$	–	–
CLEO [24]	–	–	–	$2.75 \pm 0.64 \pm 0.61$
Dobbs et al. [25]	–	–	–	$2.02 \pm 0.19 \pm 0.15$
PDG [4]	–	12.0 ± 2.4	–	2.07 ± 0.23

α

Mode	$J/\psi \to \Sigma(1385)^0\bar{\Sigma}(1385)^0$	$J/\psi \to \Xi^0\bar{\Xi}^0$	$\psi(3686) \to \Sigma(1385)^0\bar{\Sigma}(1385)^0$	$\psi(3686) \to \Xi^0\bar{\Xi}^0$
This work	$-0.64 \pm 0.03 \pm 0.10$	$0.66 \pm 0.03 \pm 0.05$	$0.59 \pm 0.25 \pm 0.25$	$0.65 \pm 0.09 \pm 0.14$
Carimalo et al. [6]	0.11	0.16	0.28	0.33
Claudson [7]	0.19	0.28	0.46	0.53

Negative?

- Provide more new and precise measurements and experimental evidences, but for the predictions of α values **without the consideration of the higher order correction**, it is basically deviated from the measured values.

Test of isospin conservation

Mode	$\frac{\mathcal{B}(\psi\to\Xi^0\bar{\Xi}^0)}{\mathcal{B}(\psi\to\Xi^-\bar{\Xi}^+)}$	$\frac{\mathcal{B}(\psi\to\Sigma(1385)^0\bar{\Sigma}(1385)^0)}{\mathcal{B}(\psi\to\Sigma(1385)^-\bar{\Sigma}(1385)^+)}$	$\frac{\mathcal{B}(\psi\to\Sigma(1385)^0\bar{\Sigma}(1385)^0)}{\mathcal{B}(\psi\to\Sigma(1385)^+\bar{\Sigma}(1385)^-)}$
J/ψ	$1.12 \pm 0.01 \pm 0.07$	$0.98 \pm 0.01 \pm 0.08$	$0.85 \pm 0.02 \pm 0.09$
$\psi(3686)$	$0.98 \pm 0.02 \pm 0.07$	$0.81 \pm 0.12 \pm 0.12$	$0.82 \pm 0.11 \pm 0.11$

Within 1σ of expectation of isospin symmetry!

Ratio ($\frac{Br(\psi(3686)\to X_h)}{Br(J/\psi\to X_h)}$) for testing 12% rule

$$\frac{Br(\psi(2S)\to\Sigma(1385)^0\bar{\Sigma}(1385)^0)}{Br(J/\psi\to\Sigma(1385)^0\bar{\Sigma}(1385)^0)} = (7.28 \pm 0.56 \pm 0.75)\%,\quad \frac{Br(\psi(2S)\to\Xi^0\bar{\Xi}^0)}{Br(J/\psi\to\Xi^0\bar{\Xi}^0)} = (23.43 \pm 0.27 \pm 1.28)\%,$$

Deviated from 12%

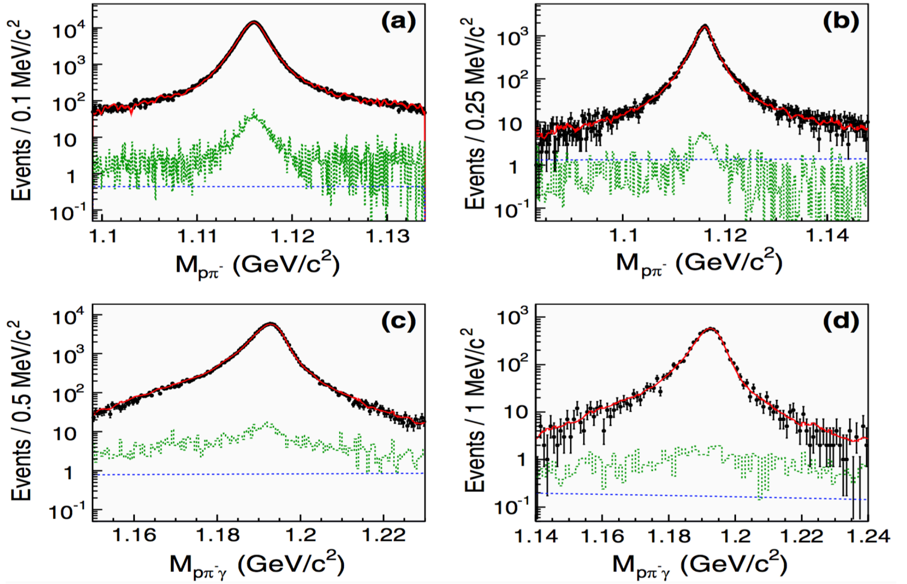
Physical Review D 95, 052003 (2017)

Study of J/ψ and ψ(3686) decay to $\Lambda\bar{\Lambda}$ and $\Sigma^0\bar{\Sigma}^0$ final states

Data samples: $1310\times10^6 J/\psi$ & $448\times10^6 \psi(3686)$

■ Full reconstruction

$$J/\psi, \psi(3686) \rightarrow \Lambda\bar{\Lambda}, \Sigma^0\bar{\Sigma}^0 \rightarrow \Lambda\bar{\Lambda}, \gamma\gamma\Lambda\bar{\Lambda} \rightarrow p\bar{p}\pi^+\pi^-, \gamma\gamma p\bar{p}\pi^+\pi^-$$



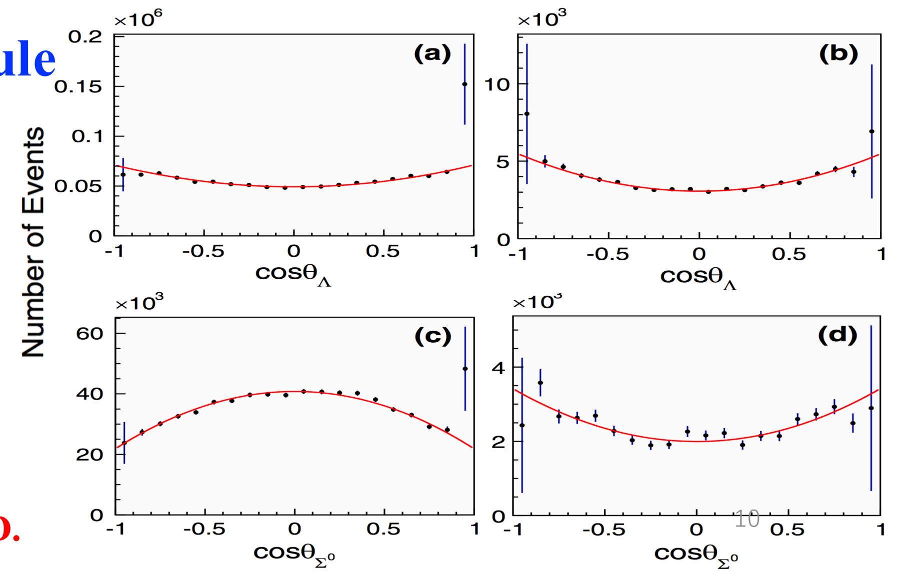
■ Numerical results (α values and Br)

	Channel	α	$\mathcal{B}$ $(\times10^{-4})$
(a)	$J/\psi \rightarrow \Lambda\bar{\Lambda}$	$0.469 \pm 0.026 \pm 0.008$	$19.43 \pm 0.03 \pm 0.33$
(c)	$J/\psi \rightarrow \Sigma^0\bar{\Sigma}^0$	$-0.449 \pm 0.020 \pm 0.008$	$11.64 \pm 0.04 \pm 0.23$
(b)	$\psi(3686) \rightarrow \Lambda\bar{\Lambda}$	$0.82 \pm 0.08 \pm 0.02$	$3.97 \pm 0.02 \pm 0.12$
(d)	$\psi(3686) \rightarrow \Sigma^0\bar{\Sigma}^0$	$0.71 \pm 0.11 \pm 0.04$	$2.44 \pm 0.03 \pm 0.11$

■ Ratio ($\frac{Br(\psi(3686)\rightarrow X_h)}{Br(J/\psi\rightarrow X_h)}$) for testing 12% rule

$$\frac{\mathcal{B}(\psi(3686)\rightarrow\Lambda\bar{\Lambda})}{\mathcal{B}(J/\psi\rightarrow\Lambda\bar{\Lambda})} = (20.43\pm0.11\pm0.58)\%$$

$$\frac{\mathcal{B}(\psi(3686)\rightarrow\Sigma^0\bar{\Sigma}^0)}{\mathcal{B}(J/\psi\rightarrow\Sigma^0\bar{\Sigma}^0)} = (20.96\pm0.27\pm0.92)\%$$

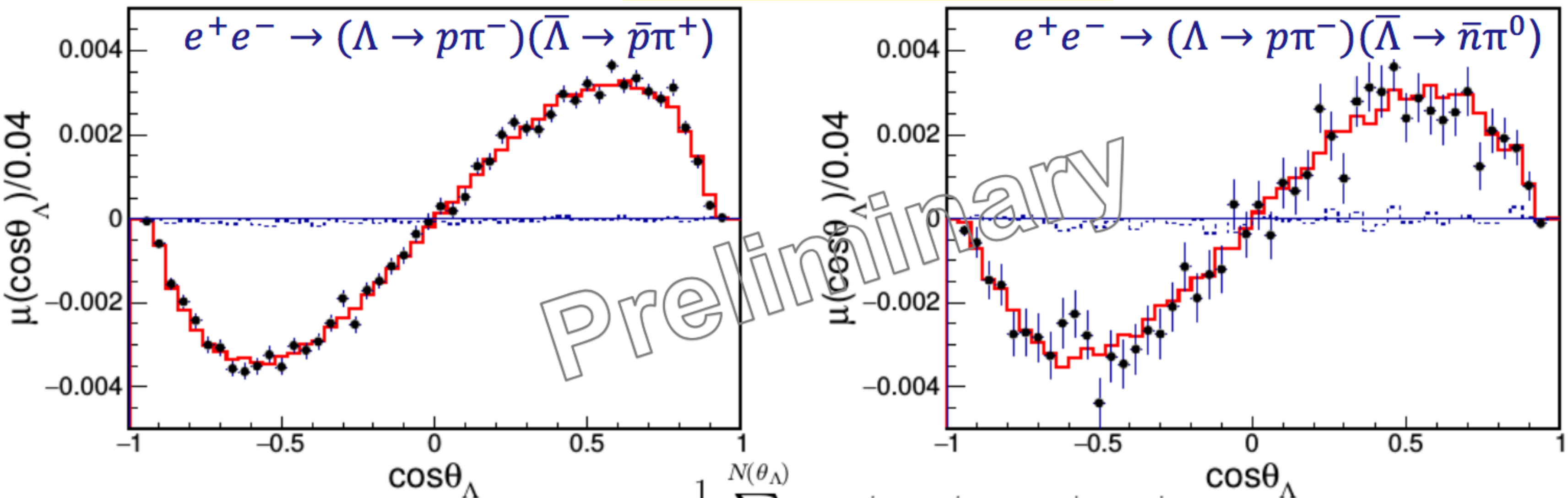


- ✓ The branching fractions are measured consistently and with high precision compared with the previous experiments .
- ✓ The α values are measured with high precision for J/ψ decay, and first measurement for $\psi(2S)$ decay.
- ✓ The Q value is still different with the expectation of pQCD.

Observation of Λ hyperon spin polarization in $J/\psi \rightarrow \Lambda\bar{\Lambda}$

$\Delta\Phi$=42.3°±0.6°±0.5°

Data: $1310 \times 10^6 J/\psi$



$$\mu(\cos\theta_\Lambda) = \frac{1}{N}\sum_{i}^{N(\theta_\Lambda)}(\sin\theta_1^i \sin\phi_1^i - \sin\theta_2^i \sin\phi_2^i)$$

Parameters	This work	Previous results
α_ψ	$\mathbf{0.461 \pm 0.006 \pm 0.007}$	0.469 ± 0.027 BESIII
$\Delta\Phi$ (rad)	$\mathbf{0.740 \pm 0.010 \pm 0.008}$	–
α_-	$\mathbf{0.750 \pm 0.009 \pm 0.004}$	0.642 ± 0.013 PDG
α_+	$\mathbf{-0.758 \pm 0.010 \pm 0.007}$	-0.71 ± 0.08 PDG
$\bar{\alpha}_0$	$\mathbf{-0.692 \pm 0.016 \pm 0.006}$	–
A_{CP}	$\mathbf{-0.006 \pm 0.012 \pm 0.007}$	0.006 ± 0.021 PDG
$\bar{\alpha}_0/\alpha_+$	$\mathbf{0.913 \pm 0.028 \pm 0.012}$	–

CP asymmetry:

$$A_{CP} = \frac{\alpha_- + \alpha_+}{\alpha_- - \alpha_+}$$

Physical Review D 86, 032014 (2012) & arXiv:1803.02039

Study of J/ψ and ψ(3686) → $N\bar{N}$ final states

Data samples: $225\times10^{6}\,J/\psi$ & $448\times10^{6}\,\psi(3686)$

Full reconstruction

$J/\psi, \psi(3686) \rightarrow N\bar{N}\ (p\bar{p}, n\bar{n})$

Numerical results (α values and Br)

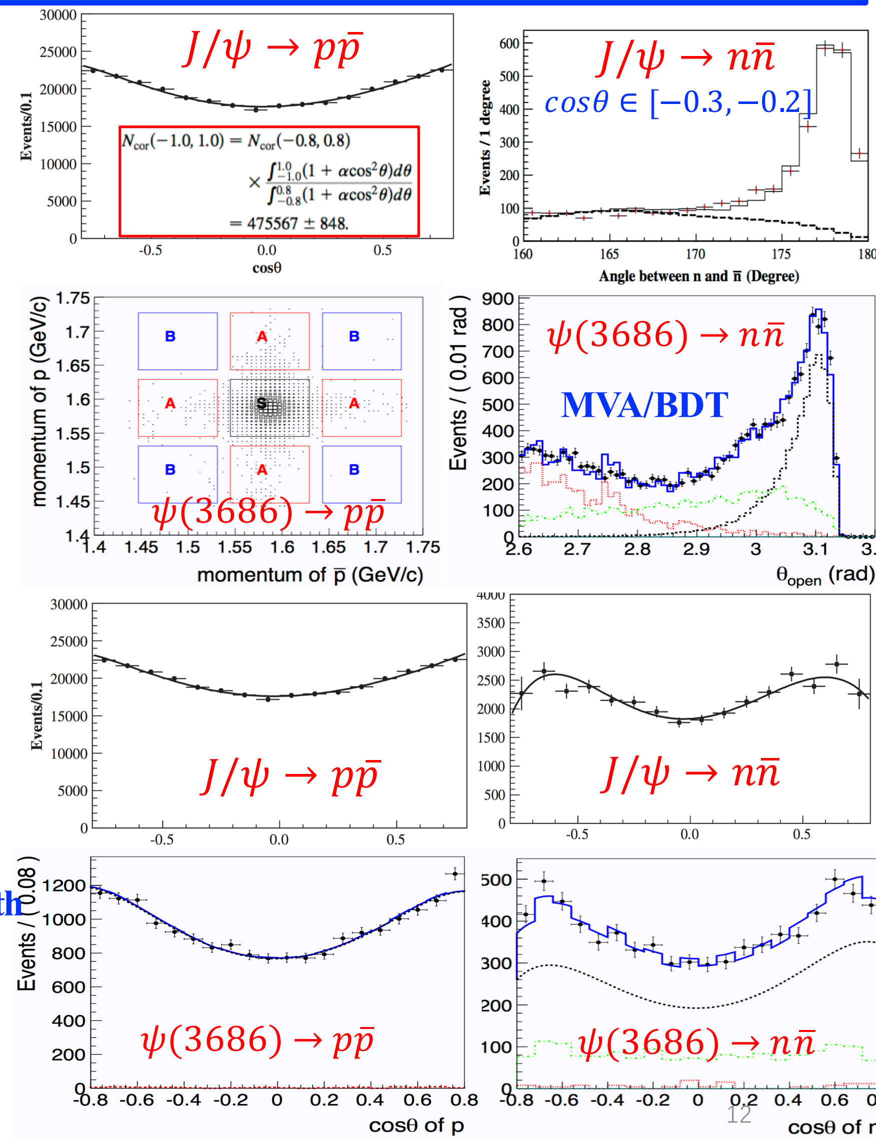
Channel	α	$Br\times10^{-4}$
$J/\psi \rightarrow p\bar{p}$	$0.60 \pm 0.01 \pm 0.02$	$21.12 \pm 0.04 \pm 0.31$
$J/\psi \rightarrow n\bar{n}$	$0.50 \pm 0.04 \pm 0.21$	$20.70 \pm 0.10 \pm 1.70$
$\psi(3686) \rightarrow p\bar{p}$	$1.03 \pm 0.06 \pm 0.03$	$3.05 \pm 0.02 \pm 0.12$
$\psi(3686) \rightarrow n\bar{n}$	$0.68 \pm 0.12 \pm 0.11$	$3.06 \pm 0.06 \pm 0.14$

Ratio ($\frac{Br(\psi(3686)\rightarrow X_h)}{Br(J/\psi\rightarrow X_h)}$) for testing 12% rule

$$\frac{\mathcal{B}(\psi(3686)\rightarrow p\bar{p})}{\mathcal{B}(J/\psi\rightarrow p\bar{p})} = (14.4 \pm 0.6)\%$$

$$\frac{\mathcal{B}(\psi(3686)\rightarrow n\bar{n})}{\mathcal{B}(J/\psi\rightarrow n\bar{n})} = (14.8 \pm 1.2)\%$$

- ✓ The branching fractions are measured consistently and with high precision compared with the previous experiments .
- ✓ The α values are measured with high precision for J/ψ decay, and first measurement for $\psi(2S)$ decay.
- ✓ The Q value is consistent with the expectation of pQCD 12%.

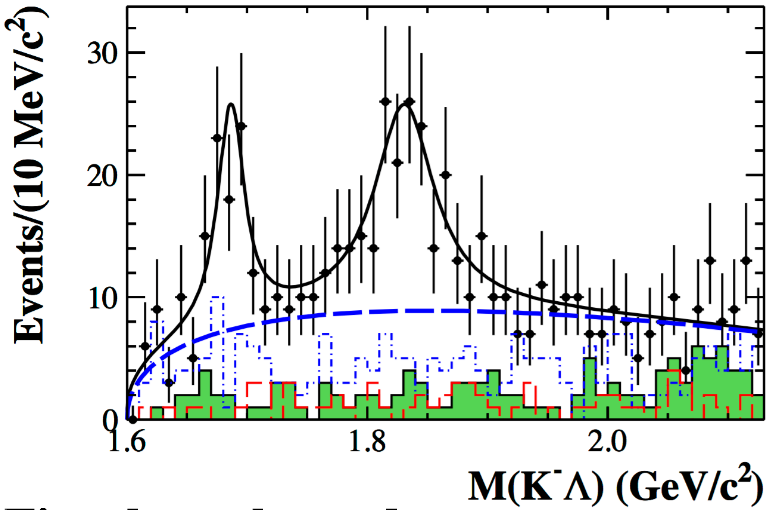


Physical Review D 86, 032014 (2012)

Observation of $\psi(3686) \to \Xi(1690/1820)\bar{\Xi}^+ + c.c.$

Data samples: $106\times10^6 \psi(3686)$

- **Two resonances are observed in $\psi(3686) \to K^-\Lambda\bar{\Xi}^+$ process**



- **PDF:** Breit-Wigner ⊗ Gaussian

$$A(m) = \frac{p_\Lambda(m)^{(L_{(K^-\Lambda)}+1/2)} p_{\bar{\Xi}^+}(m)^{(L_{(\Xi^*-\bar{\Xi}^+)}+1/2)}}{m - M + i\frac{\Gamma}{2}} \cdot \left(\frac{B_{L_{(K^-\Lambda)}}(p_\Lambda(m))}{B_{L_{(K^-\Lambda)}}(p'_\Lambda)}\right)\left(\frac{B_{L_{(\Xi^*-\bar{\Xi}^+)}}(p_{\bar{\Xi}^+}(m))}{B_{L_{(\Xi^*-\bar{\Xi}^+)}}(p'_{\bar{\Xi}^+})}\right)$$

Mass and width (M,Γ); $p_{\Lambda/\Xi}$ momentum; L is orbital angular distribution; $B_L(p)$ Blatt-Weisskopf form factor[1].

- **Fitted results and resonance parameters**

	$\Xi(1690)^-$	$\Xi(1820)^-$
M(MeV/c^2)	1687.7±3.8±1.0	1826.7±5.5±1.6
Γ(MeV)	27.1±10.0±2.7	54.4±15.7±4.2
Event yields	74.4±21.2	136.2±33.4
Significance(σ)	4.9	6.2
Efficiency(%)	32.8	26.1
$\mathcal{B}$ (10^{-6})	5.21±1.48±0.57	12.03±2.94±1.22
M_{PDG}(MeV/c^2)	1690±10	1823±5
Γ_{PDG}(MeV)	<30	24^{+15}_{-10}

The spin-parities for both resonances have not determined due to the limited statistics.

In the fit, the spin- parities for both resonances assumed to be JP = 1/2− ,3/2− with previous experimental results[2,3], the $\Xi^*\bar{\Xi}$ angular momenta L($\Xi^*\bar{\Xi}$) are set to be 0 for both resonances, while the $K^-\Lambda$ angular momenta L($K^-\Lambda$) are 0 and 2.

[1] B. S. Zou and D. V. Bugg, Eur. Phys. J. A16, 537 (2003).
[2] B. Aubert et al., (BABAR Collaboration), Phys. Rev. D604 78, 034008 (2008).
[3] J. B. Gay et al., Phys. Lett. B 62, 477 (1976).

Outline

☐Introduction

☐Recent results

Cross section

$$\sigma = \oint_{4\pi} \frac{d\sigma}{\mathrm{d}\Omega} d\Omega = \int_0^{2\pi} \int_0^{\pi} \frac{d\sigma}{\mathrm{d}\Omega} sin\theta d\theta d\varphi$$

$$\boldsymbol{\sigma^B} = \frac{\boldsymbol{N_{obs}}}{\mathcal{L}(1+\delta)(1+\Pi)\epsilon \mathcal{B}r(B \to \mathrm{hadrons})},$$

5. $\psi(3686) \to \Xi(1690/1820)\bar{\Xi}$

➢**Measurement of cross section of $e^+e^- \to B\bar{B}$**

1. $e^+e^- \to p\bar{p}$
2. $e^+e^- \to \Lambda\bar{\Lambda}$
3. $e^+e^- \to \Lambda_c\bar{\Lambda}_c$

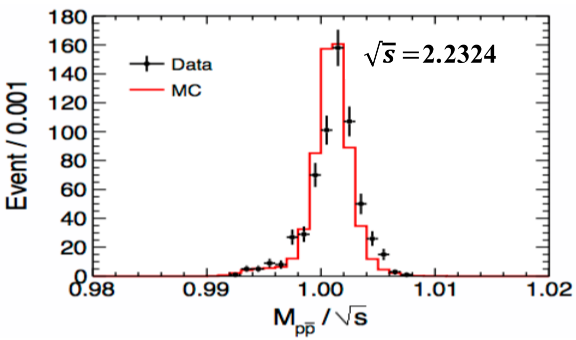
☐Summary

Physical Review D 91, 112004(2015)

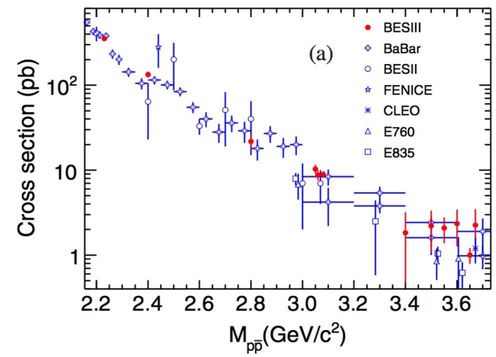
Measurement of the proton form factor in $e^+e^- \to p\bar{p}$

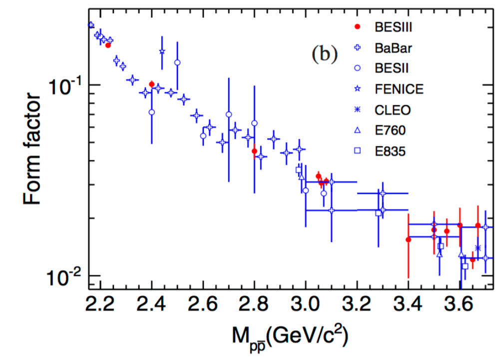
Data samples: $\sqrt{s} = 2.2324\ to\ 3.671\ GeV$

- Full reconstruction method
- Signal yields extraction by counting number of events

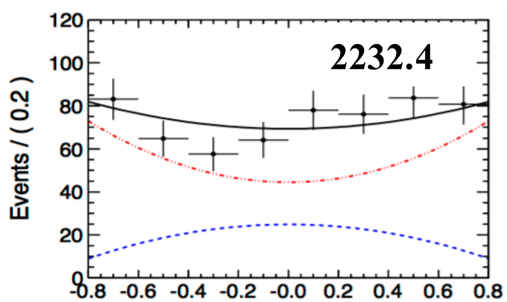


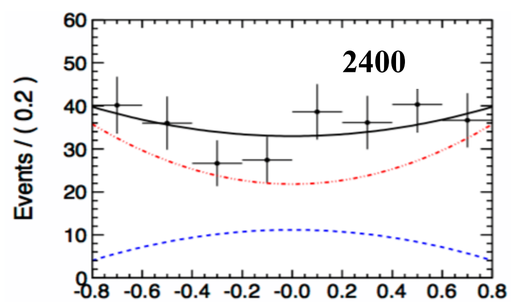
- Born cross section and effective FFs

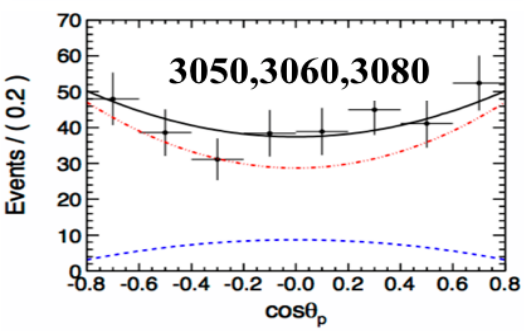




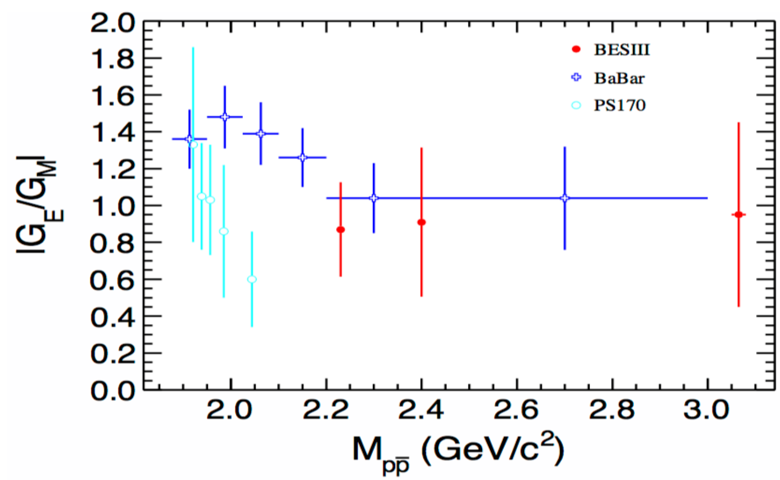
- Electromagnetic G_E/G_M ratio extraction







$$\begin{cases} \dfrac{d\sigma^B(s)}{d\cos\theta} \propto 1 + \eta\cos^2\theta \\ R = \sqrt{\dfrac{\tau(1-\eta)}{1+\eta}} \\ R = \left|\dfrac{G_E(s)}{G_M(s)}\right| \end{cases}$$



Provide more experimental evidences about nucleon internal structure and dynamics!

Physical Review D 97, 032013 (2018)

Measurement of cross section near mass threshold for $e^+e^- \to \Lambda\bar{\Lambda}$

Data samples

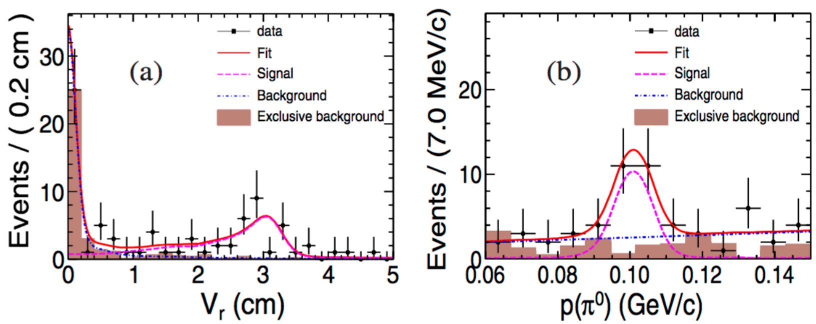
$\sqrt{s}$ GeV	Lumi. (pb^{-1})
2.2324	2.63
2.40	3.42
2.80	3.75
3.08	30.73

■ Reconstruction

1. $e^+e^- \to \Lambda\bar{\Lambda} \to \bar{p}\pi^+, \bar{n}\pi^0 X$ @2.2324
2. $e^+e^- \to \Lambda\bar{\Lambda} \to p\bar{p}\pi^+\pi^-$ @others

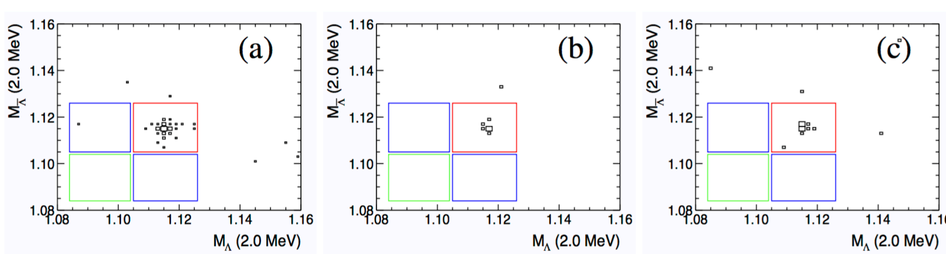
■ Signal yields extraction @2.2324

- ✓ Fit to the distance from IP to the beam pipe
- ✓ Fit to π^0 momentum for $\bar{n}\pi^0$X
- ✓ A boosted decision tree (BDT) technique are used to distinguish between $\bar{n}$ and γ

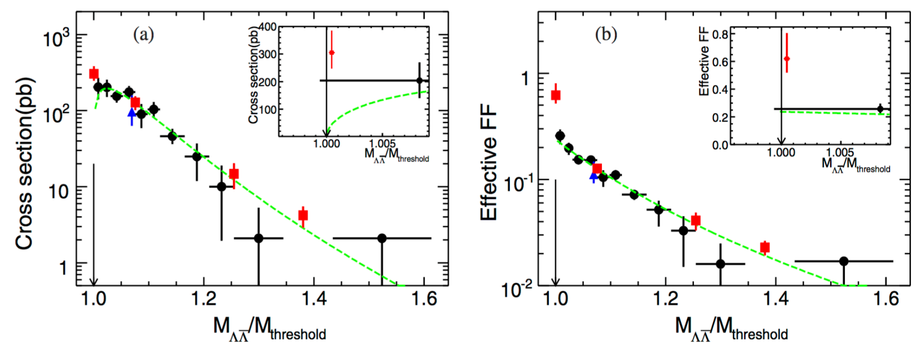


■ Signal yields extraction @others

- ✓ Counting



■ Born cross section and effective FFs



- ■ The result is larger than the traditional theory expectation for neutral baryon pairs, which predicts a vanishing cross section at threshold.
- ■ The results may help to understand the mechanism of baryon production and test the theory hypotheses based on the threshold enhancement effect.

Physical Review Letters 120, 132001 (2018)

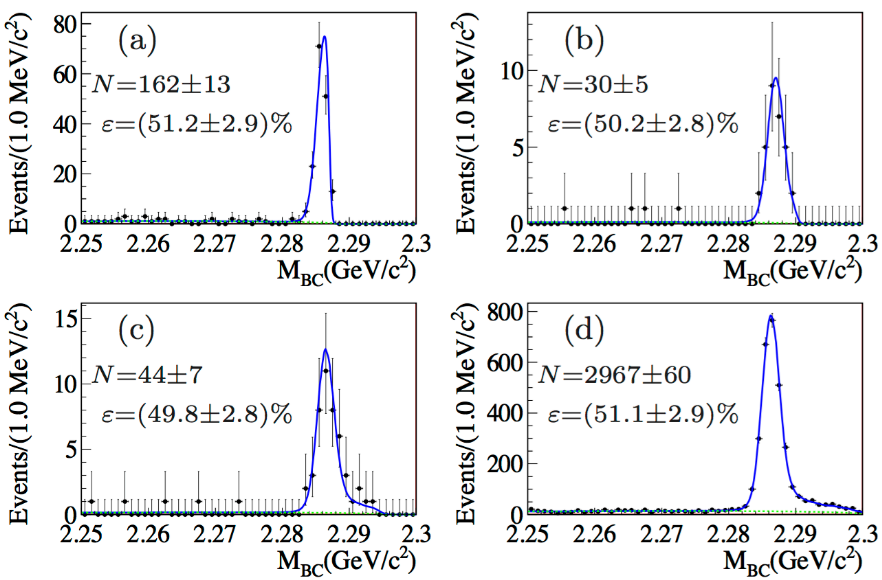
Precision measurement of the $e^+e^- \to \Lambda_c\bar{\Lambda}_c$ cross section near threshold

Data samples

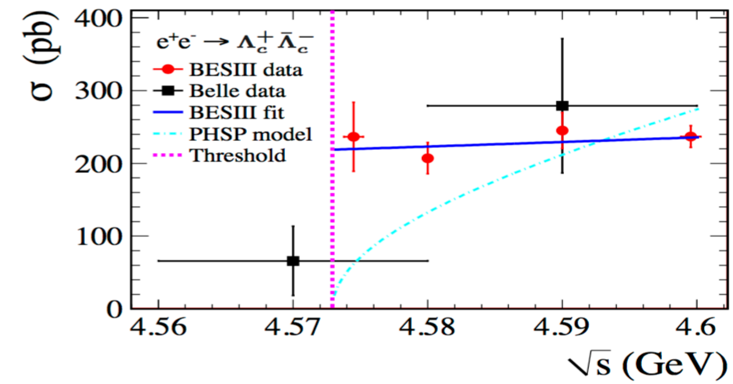
$\sqrt{s}$ (GeV)	$\mathcal{L}_{int}$ (pb^{-1})
4.5745	47.67
4.580	8.545
4.590	8.162
4.5995	566.9

■ Reconstruction method $M_{\rm BC}c^2 \equiv \sqrt{E_{\rm beam}^2 - p^2c^2}$

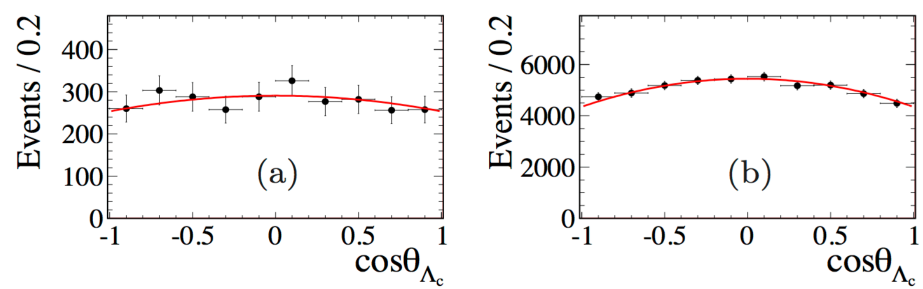
- ➢ **10 Cabibbo-favored hadronic modes:**
  $pK^-\pi^+, pK_S^0, \Lambda\pi^+, pK^-\pi^+\pi^0, pK_S^0\pi^0, \Lambda\pi^+\pi^0, pK_S^0\pi^+\pi^-, \Lambda\pi^+\pi^+\pi^-, \Sigma^0\pi^+, \Sigma^+\pi^+\pi^-$
- ➢ **c.c. mode is included by default**



■ Comparison of Born cross section



■ Measurements of α and G_M/G_E ratio



$\sqrt{s}$ (MeV)	α_{Λ_c}	$\lvert G_E/G_M\rvert$
4574.5	$-0.13 \pm 0.12 \pm 0.08$	$1.14 \pm 0.14 \pm 0.07$
4599.5	$-0.20 \pm 0.04 \pm 0.02$	$1.23 \pm 0.05 \pm 0.03$

These results provide important insights into the production mechanism and structure of the Λ_c baryons.

Summary

■**BESIII is successfully operating since 2008.**

- ✓Collected large data samples in the τ-charm threshold region
- ✓Continues to take data until 2022 at least

■**Many results for $B\overline{B}$ in 1^{--} state decay have been obtained:**

- ✓ Precise measurement of Br/α for $J/\psi,\psi(2S) \to B\overline{B}$
- ✓ New observation/measurement of $J/\psi,\psi(2S) \to B\overline{B}$
- ✓ "12% rule" is violated compared with the expectation of pQCD **with exception of $\psi \to N\overline{N}$.**
- ✓ Born cross section of $e^+e^- \to B\overline{B}$ near threshold measured.
- ✓ The threshold effect of production cross section observed.
- ✓ Need theoretical model further explain above difference

■**More new results for $B\overline{B}$ in 1^{--} state decay are on the way!**

Thanks for your attention !

Backup

Born cross sections and FFs

■ Experimentally, Born cross sections of $e^+e^- \to B\overline{B}$ are calculated by:

$$\sigma^B = \frac{N_{obs}}{\mathcal{L}(1+\delta)(1+\Pi)\epsilon \mathcal{B}r(B\to \text{hadrons})},$$

where N_{obs} number of observed events, $\mathcal{L}$ luminosity, $1+\sigma$ ISR factor, $1+\Pi$ vacuum polarization factor, $\mathcal{B}r$ the branching fraction.

■ Theoretically, Born cross section can be expressed as:

$$\sigma^B = \frac{4\pi\alpha^2 C\beta}{3s}\left[|G_M|^2 + \frac{2m_B^2}{s}|G_E|^2\right].$$

- $G_{M/E}$: electric/magnetic FF
- $\beta = \sqrt{1-\frac{4m_B^2}{s}}$: velosity
- $\alpha = \frac{1}{137}$: fine structure constant
- s: the square of CM energy

The effective form factor defined by

$$|G_{eff}(s)| = \sqrt{\frac{|G_M|^2 + \left(\frac{2m_B^2}{s}\right)|G_E|^2}{1+2m_B^2/s}}$$

Coulomb factor C
- For neutral B: C =1,
- For charged B: C $=\varepsilon F$ with $\varepsilon = \frac{\pi\alpha}{\beta}$ and F$=\frac{\sqrt{1-\beta^2}}{1-e^{-\varepsilon}}$

for a non-zero cross section at threshold

is proportional to the square root of the baryon pair born cross section

$$|G_{eff}(s)| = \sqrt{\frac{3s\sigma^B}{4\pi\alpha^2 C\beta(1+\frac{2m_B^2}{s})}}.$$

■ The electric and magnetic form factor G_E, G_M can be expressed by the following

- $G_{M/E}$: electric/magnetic FF
- $\beta = \sqrt{1-\frac{4m_B^2}{s}}$: velosity
- $\alpha = \frac{1}{137}$: fine structure constant
- s: the square of CM energy

$$R = \sqrt{\frac{\tau(1-\eta)}{1+\eta}} \qquad R = \left|\frac{G_E(s)}{G_M(s)}\right|$$