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Study Baryon Properties via Charmonium Decays @ BESIII

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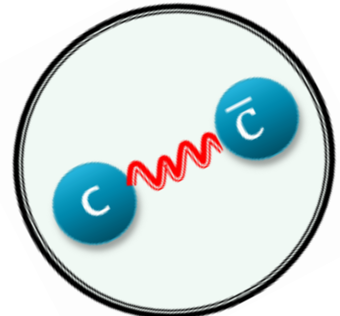
Outline

- **Introduction**
- **Recent results**
  - $J/\psi, \psi(3686) \rightarrow B\bar{B}$ (B: baryon)
    - $J/\psi, \psi(3686) \rightarrow \Xi^0\bar{\Xi}^0, \Sigma(1385)^0\bar{\Sigma}(1385)^0$
    - $J/\psi, \psi(3686) \rightarrow \Lambda\bar{\Lambda}, \Sigma^0\bar{\Sigma}^0$
    - $J/\psi, \psi(3686) \rightarrow N\bar{N}(p\bar{p}, n\bar{n})$
  - Measurement of cross section of $e^+e^- \rightarrow B\bar{B}$
    - $e^+e^- \rightarrow p\bar{p}$
    - $e^+e^- \rightarrow \Lambda\bar{\Lambda}$
    - $e^+e^- \rightarrow \Lambda_c\bar{\Lambda}_c$
- **Summary**

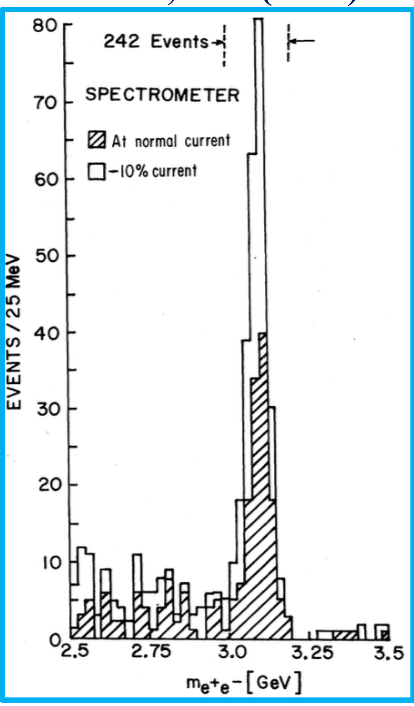
Charmonium states



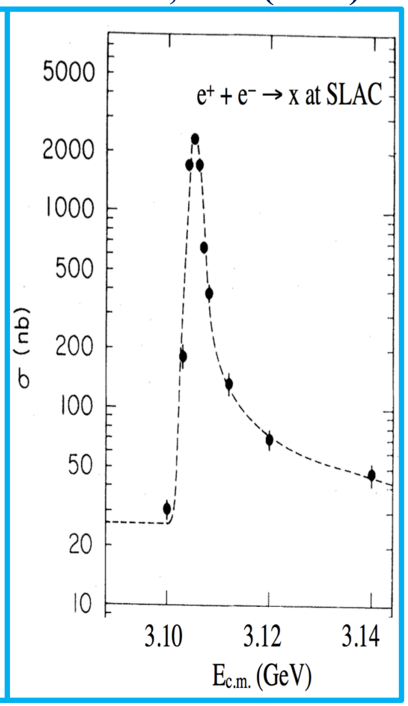
- **Nonrelativistic $c\bar{c}$ bound states**
  - J/ψ (1^3S_1) is the first member with $J^{PC}=1^{--}$, others shown in right plots like $\psi(2S), \psi(1D), etc.$.
- **Observations are consistent with predictions from Potential Models and L-QCD in describing spectra&onium properties!**

"November Revolution"

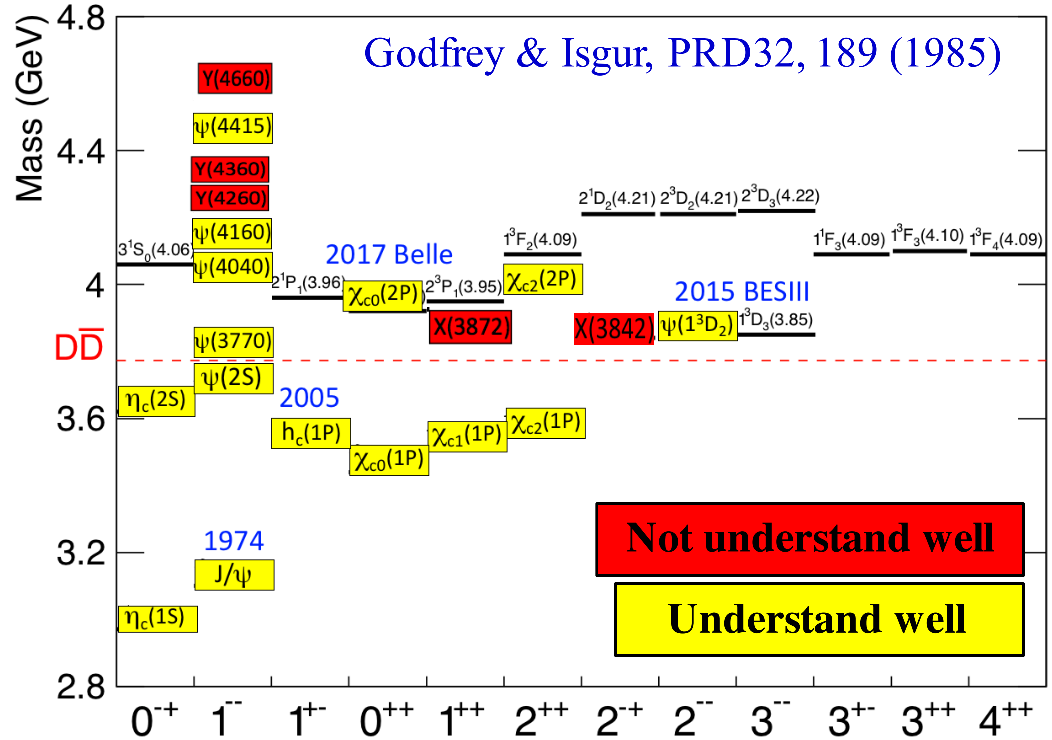
PRL33, 1404(1974)



PRL33, 1406(1974)

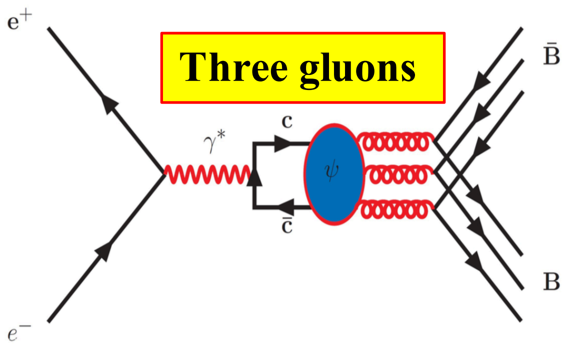


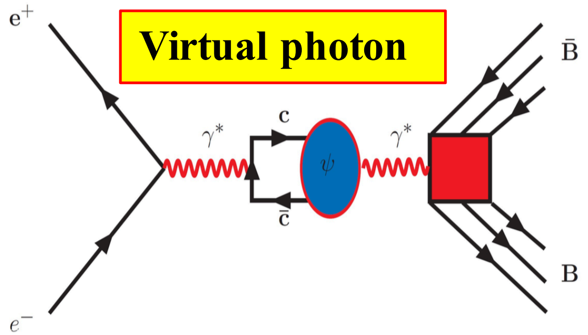
Charmonium(-like) spectroscopy

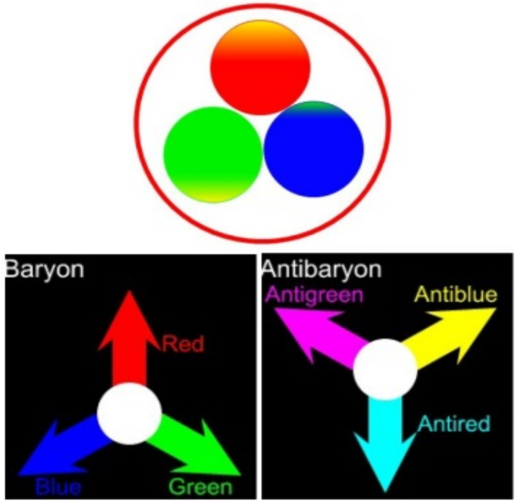


Baryon Properties

- Established baryons described by 3-quark configuration with the zero total color charge.
- $B\overline{B}$ production via Charmonium decay:







- Provide a favorable test of pQCD and baryonic properties
  - ✓ Quark mass effect, EM effect, et al.
    (C. Carimalo, Int. J. Mod. Phys. A 2(1987) 249; M. Claudson, PRD25, (1982) 1345)
  - ✓ Test of "12% rule"
  - ✓ $B\overline{B}$ threshold effect
  - ✓ Hyperon polarization
  - ✓ Baryon EMFFs
  - ✓ …

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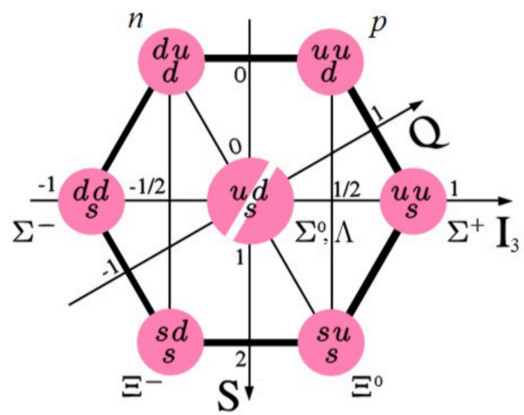
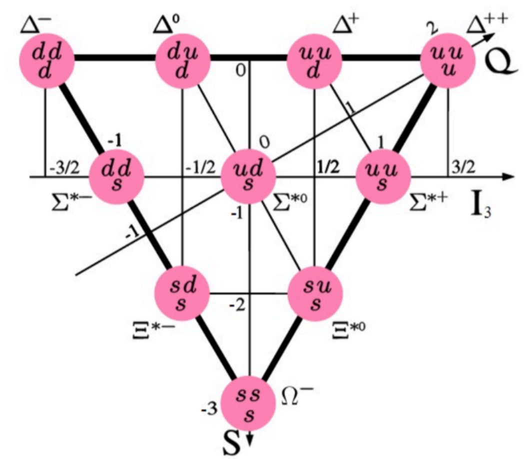
- **Recent results**
  - **$J/\psi, \psi(3686) \to B\bar{B}$ (B: baryon)**
    - $J/\psi, \psi(3686) \to \Xi^0\bar{\Xi}^0, \Sigma(1385)^0\bar{\Sigma}(1385)^0$
    - $J/\psi, \psi(3686) \to \Lambda\bar{\Lambda}, \Sigma^0\bar{\Sigma}^0$
    - $J/\psi, \psi(3686) \to N\bar{N}(p\bar{p}, n\bar{n})$
  - **Measurement of cross section of e^+**
    - $e^+e^- \to p\bar{p}$
    - $e^+e^- \to \Lambda\bar{\Lambda}$
    - $e^+e^- \to \Lambda_c\bar{\Lambda}_c$
- **Summary**



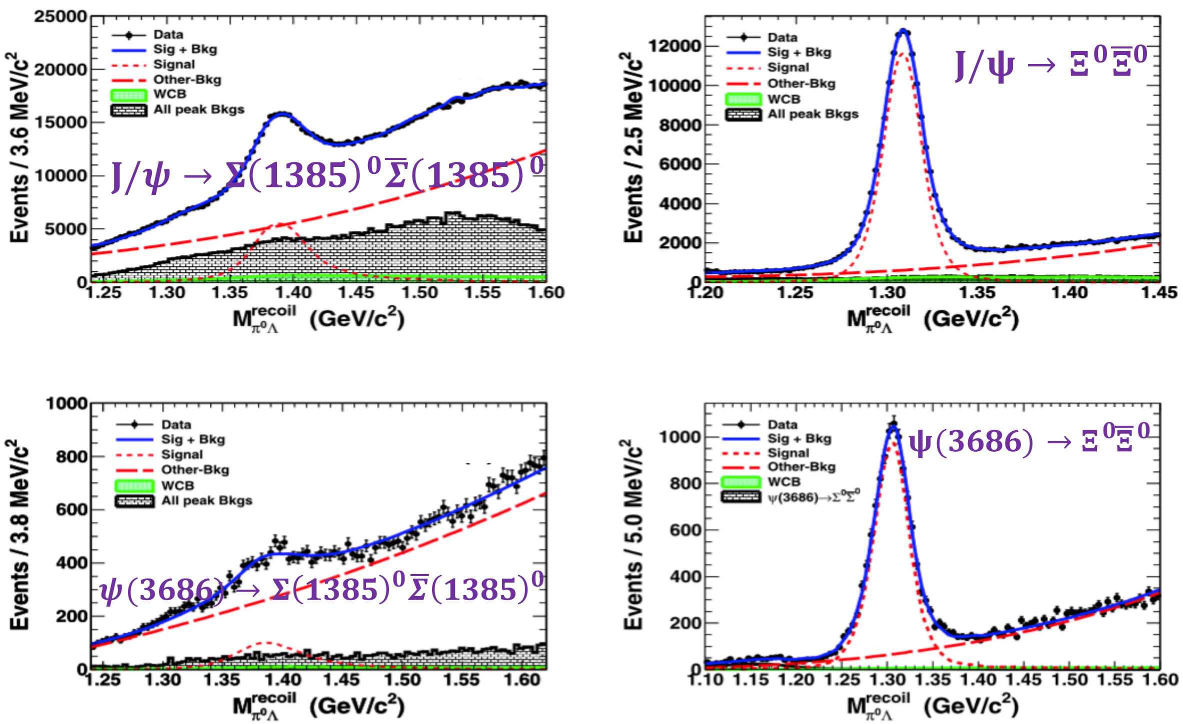


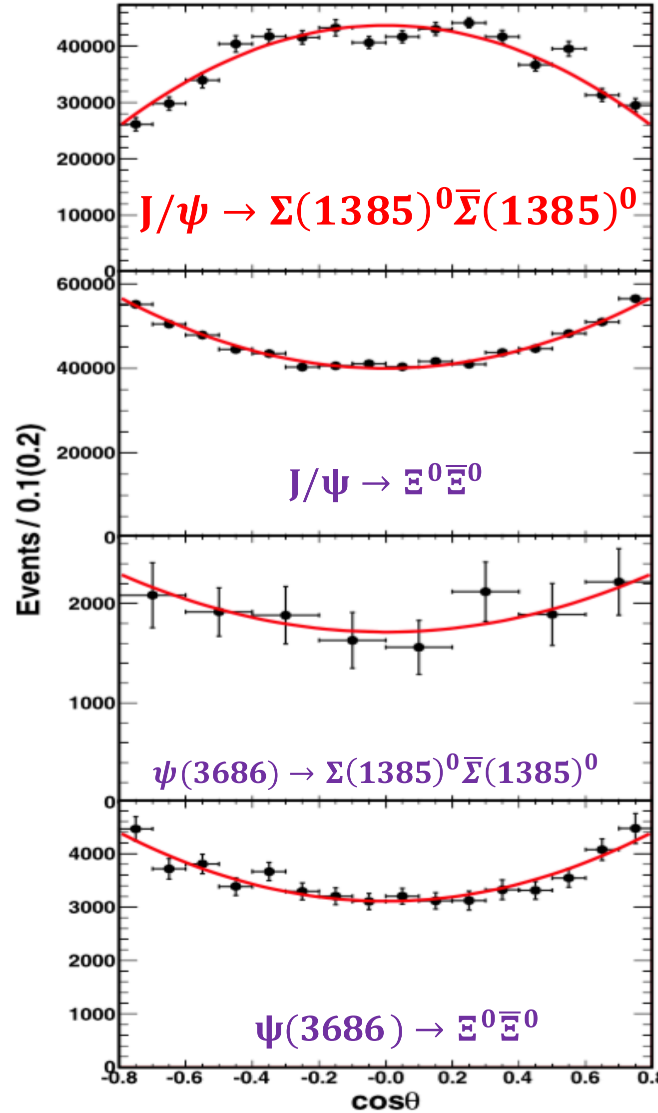
I. Study of J/ψ and $\psi(3686) \rightarrow \Sigma(1385)^0\bar{\Sigma}(1385)^0$ and $\Xi^0\bar{\Xi}^0$

Data Samples: 1310M J/ψ & 448M ψ(3686)

PLB 770 (2017) 217-225

- **Single baryon reconstruction strategy**
- **Angular distribution study (to test quark mass effect, EM effect, et al.)**
- **Test of "12% rule"**





- **Angular distribution for $J/\psi \rightarrow \Sigma(1385)^0\bar{\Sigma}(1385)^0$ is found to be different from other ones.**

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

PLB 770 (2017) 217-225

■ Numerical results

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

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,**
- **Negative α value is found and deviated from the predictions (quark mass effect, EM effect) without the consideration of the higher order correction) , …, or complicated structure/properties of baryon.**

■ Test of "12% rule"

Deviated from 12%

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

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

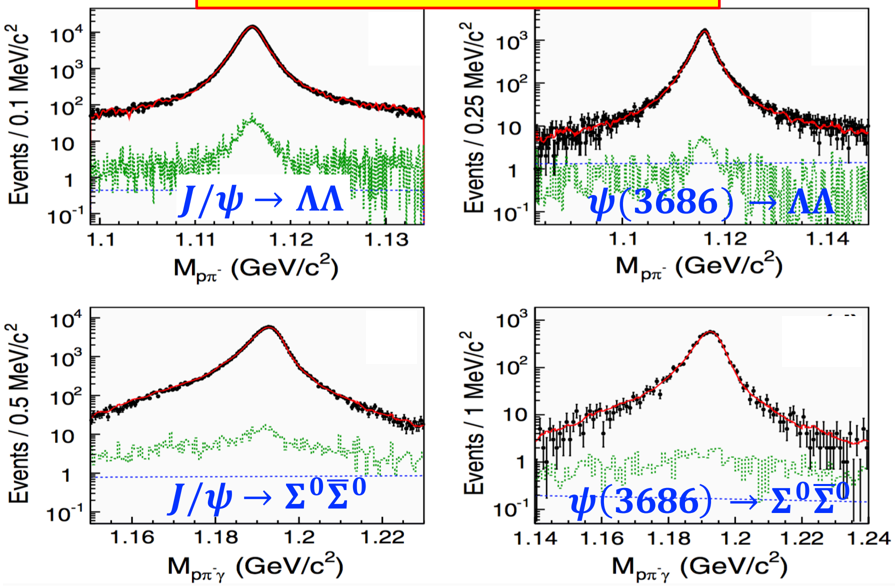
PRD 95, 052003 (2017)

■ Full reconstruction

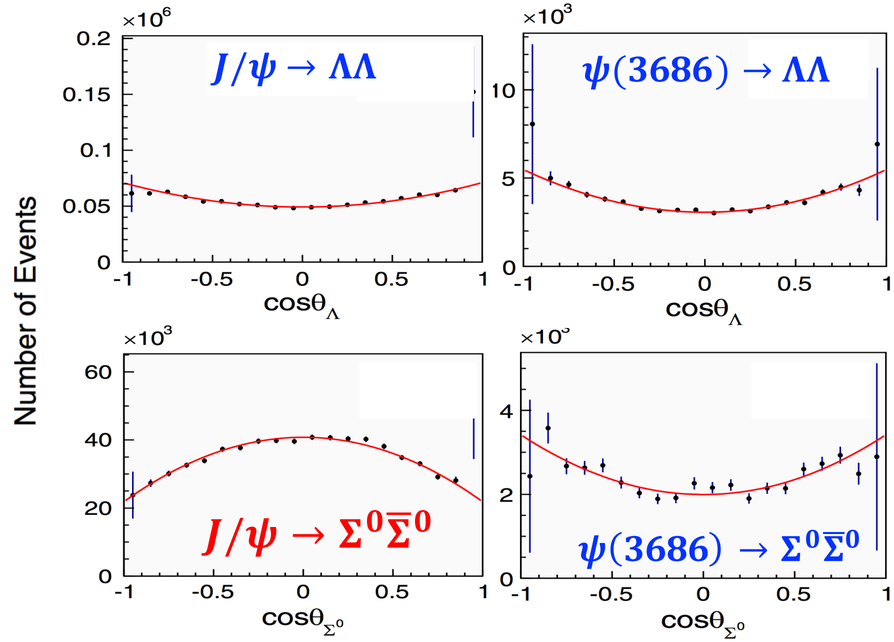
✓ $J/\psi, \psi(3686) \to \Lambda\Lambda, \Sigma^0\bar{\Sigma}^0$
$\to \Lambda\bar{\Lambda}, \gamma\gamma\Lambda\bar{\Lambda}$
$\to p\bar{p}\pi^+\pi^-, \gamma\gamma p\bar{p}\pi^+\pi^-$

Data Samples: 1310M J/ψ & 448M ψ(3686)

Invariant mass



Angular distribution



Numerical results

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

■ Negative α value for $J/\psi \to \Sigma^0\bar{\Sigma}^0$ is found and different from the expectation of pQCD.

■ **Test of "12% rule"**

$$Q_h = \begin{cases} \frac{\mathcal{B}(\psi(3686)\to\Lambda\bar{\Lambda})}{\mathcal{B}(J/\psi\to\Lambda\bar{\Lambda})} = (20.43 \pm 0.11 \pm 0.58)\% \\ \frac{\mathcal{B}(\psi(3686)\to\Sigma^0\bar{\Sigma}^0)}{\mathcal{B}(J/\psi\to\Sigma^0\bar{\Sigma}^0)} = (20.96 \pm 0.27 \pm 0.92)\% \end{cases}$$

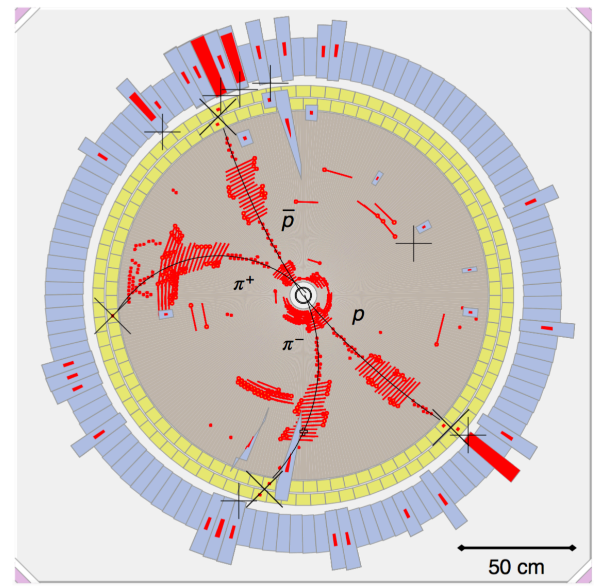
Highlights!

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

Published in Nature physics (2019)

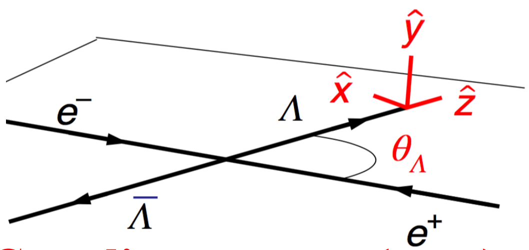
Data Sample: 1310M J/ψ

arXiv:1808.08917

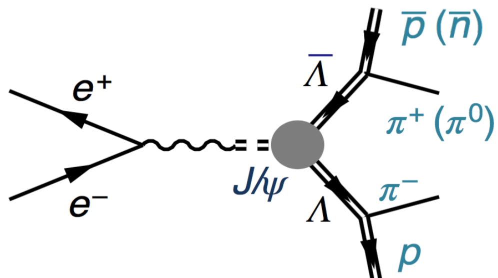


Event display

■ Joint angular distribution



Coordinate system(x,y,z)



Feynman diagram

$$
\begin{aligned}
&\mathcal{W}(\xi;\alpha_\psi,\Delta\Phi,\alpha_-,\alpha_+)\\
&=1+\alpha_\psi\cos^2\theta_\Lambda+\ \alpha_-\alpha_+[\sin^2\theta_\Lambda(n_{1,x}n_{2,x}-\alpha_\psi n_{1,y}n_{2,y})\\
&+(\cos^2\theta_\Lambda+\alpha_\psi)n_{1,z}n_{2,z}]\\
&+\ \alpha_-\alpha_+\sqrt{1-\alpha_\psi^2}\ \cos(\Delta\Phi)\sin\theta_\Lambda\cos\theta_\Lambda(n_{1,x}n_{2,z}+n_{1,z}n_{2,x})\\
&+\sqrt{1-\alpha_\psi^2}\ \sin(\Delta\Phi)\ \sin\theta_\Lambda\cos\theta_\Lambda(\alpha_- n_{1,y}+\alpha_+ n_{2,y})
\end{aligned}
$$

where $\hat{\mathbf{n}}1$ ($\hat{\mathbf{n}}2$) is the unit vector in the direction of the nucleon in the rest frame of Λ ($\bar{\Lambda}$).

■ A non-zero $\Delta\Phi$ has polarization

$$
P_y(\cos\theta_\Lambda)=\frac{\sqrt{1-\alpha_\psi^2}\ \sin(\Delta\Phi)\cos\theta_\Lambda\sin\theta_\Lambda}{1+\alpha_\psi\cos^2\theta_\Lambda}
$$

Highlights!

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

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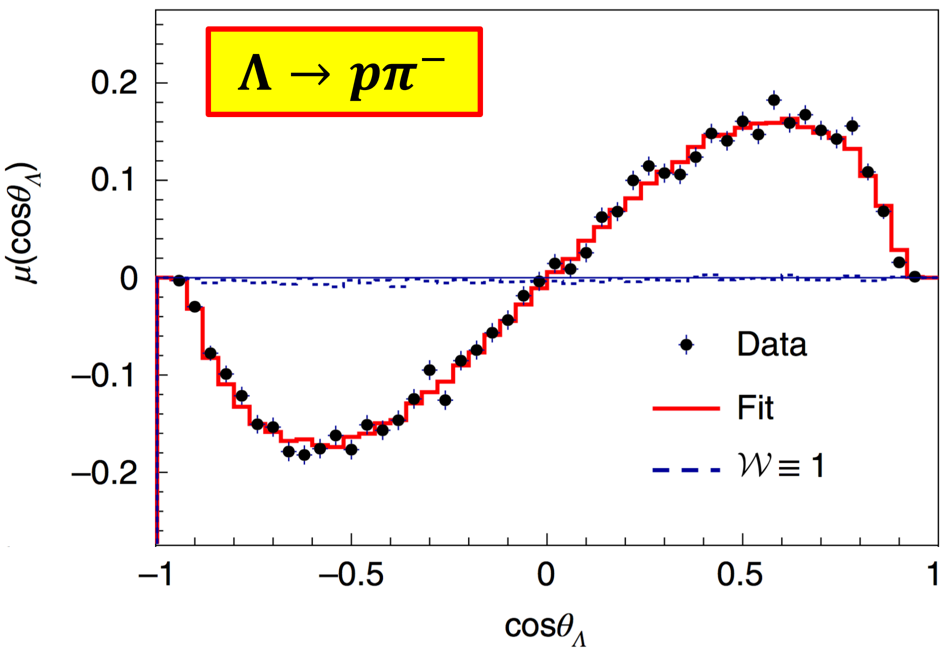
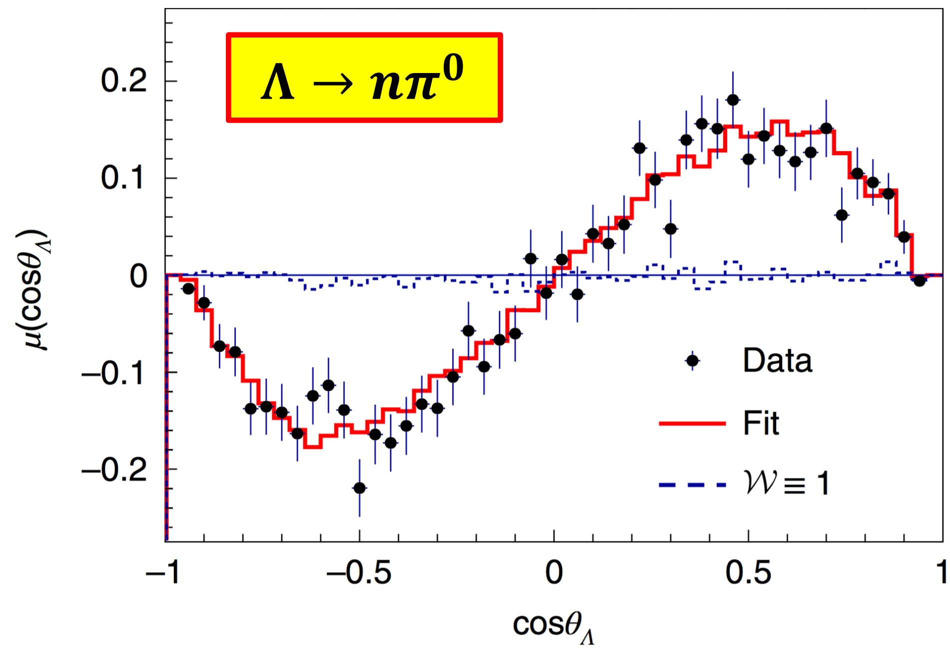
Moment: $\mu(\cos\theta_\Lambda) = \frac{1}{N}\sum_i^{N(\theta_\Lambda)}(\sin\theta_1^i \sin\phi_1^i - \sin\theta_2^i \sin\phi_2^i)$





- Moment corresponds to the polarization calculated for 50 bins in $cos\theta$.
- A clear polarization signal, strongly dependent on the Λ direction $cos\theta$ is observed for Λ and $\bar{\Lambda}$.

Highlights!

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

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arXiv:1808.08917

Table 1 | Summary of the results

Parameters	This work	Previous results
α_ψ	$0.461 \pm 0.006 \pm 0.007$	0.469 ± 0.027 (ref. [14])
$\Delta\Phi$	$42.4 \pm 0.6 \pm 0.5°$	–
α_-	$0.750 \pm 0.009 \pm 0.004$	0.642 ± 0.013 (ref. [6])
α_+	$-0.758 \pm 0.010 \pm 0.007$	-0.71 ± 0.08 (ref. [6])
$\bar{\alpha}_0$	$-0.692 \pm 0.016 \pm 0.006$	–
A_{CP}	$-0.006 \pm 0.012 \pm 0.007$	0.006 ± 0.021 (ref. [6])
$\bar{\alpha}_0/\alpha_+$	$0.913 \pm 0.028 \pm 0.012$	–

- **First observation of a transverse polarization of the baryon.**

>5 s.d. difference (17% higher than) to PDG

Test of CP violation:

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

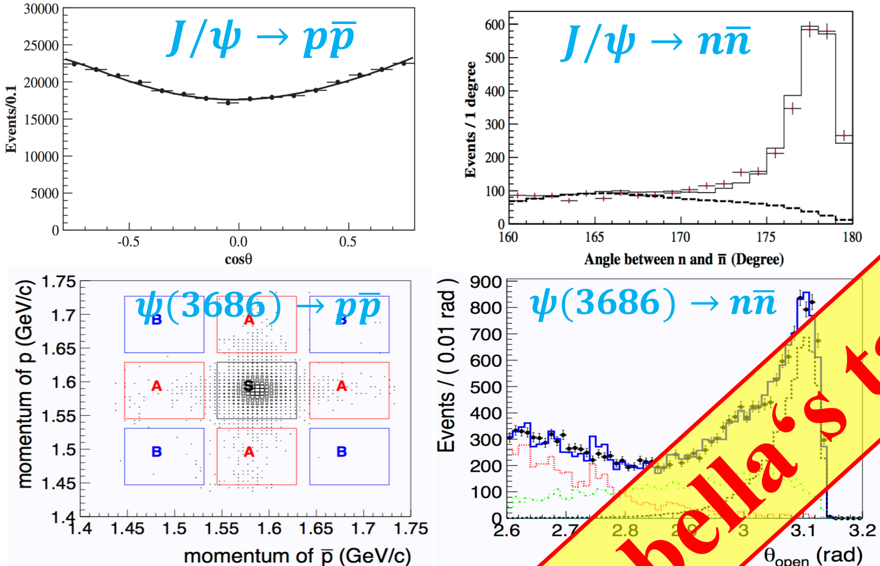
- **Most sensitive test of CP violation for Λ baryons with improved precision over previous measurements.**
- **BESIII has collected 10B J/ψ data sample, test of CP violation in baryon decays will reach sensitivities comparable to theoretical prediction ($A_{CP}^{SM} \approx 10^{-4}$).**

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

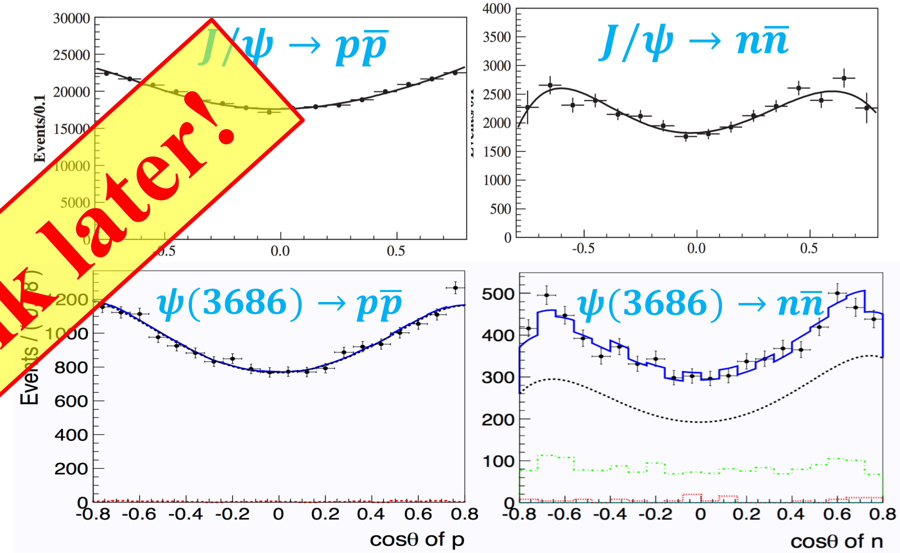
Data Samples: 225M J/ψ & 448M ψ(3686)

PRD 86, 032014 (2012) &
PRD 98, 032006 (2018)

Signal yields extraction



Angular distribution



See Isabella's talk later!

Numerical results

Channel	α	$Br\times10^{-4}$
$J/\psi\to p\bar{p}$	$0.60\pm0.01\pm0.02$	$21.12\pm0.04\pm0.31$
$J/\psi\to n\bar{n}$	$0.50\pm0.04\pm0.21$	$20.70\pm0.10\pm1.70$
$\psi(3686)\to p\bar{p}$	$1.03\pm0.06\pm0.03$	$3.05\pm0.02\pm0.12$
$\psi(3686)\to n\bar{n}$	$0.68\pm0.12\pm0.11$	$3.06\pm0.06\pm0.14$

- Results J/$\psi\to N\bar{N}$ is close to each other
- For $\psi(3686)\to N\bar{N}$, BF is close to each other, but α not.

■ Test of "12% rule"

$$Q_h=\begin{cases}\dfrac{\mathcal{B}(\psi(3686)\to p\bar{p})}{\mathcal{B}(J/\psi\to p\bar{p})}=(14.4\pm0.6)\% \\ \dfrac{\mathcal{B}(\psi(3686)\to n\bar{n})}{\mathcal{B}(J/\psi\to n\bar{n})}=(14.8\pm1.2)\%\end{cases}\sim12\%$$

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  - ➢ $J/\psi, \psi(3686) \rightarrow B\bar{B}$ (B: baryon)
    - ✓ $J/\psi, \psi(3686) \rightarrow \Xi^0\bar{\Xi}^0, \Sigma(1385)^0\bar{\Sigma}(1385)^0$
    - ✓ $J/\psi, \psi(3686) \rightarrow \Lambda\bar{\Lambda}, \Sigma^0\bar{\Sigma}^0$
    - ✓ $J/\psi, \psi(3686) \rightarrow N\bar{N}(p\bar{p}, n\bar{n})$
  - ➢ Measurement of cross section of $e^+e^- \rightarrow B\bar{B}$
    - ✓ $e^+e^- \rightarrow p\bar{p}$
    - ✓ $e^+e^- \rightarrow \Lambda\bar{\Lambda}$
    - ✓ $e^+e^- \rightarrow \Lambda_c\bar{\Lambda}_c$
- □ Summary

Born cross sections and FFs

- **Experimentally, Born cross sections of $e^+e^- \to B\bar{B}$ 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

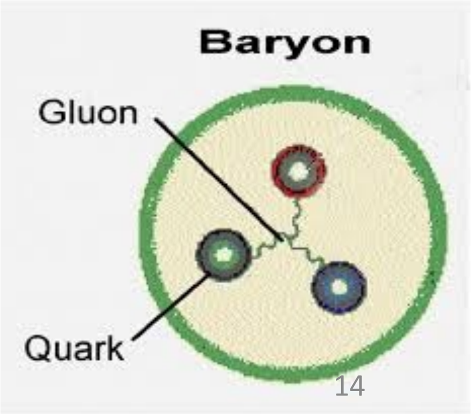
is proportional to the square root of the baryon pair born cross section

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

- **EMFFs G_E, G_M determination**

$$\frac{d\sigma^B(s)}{dcos\theta} \propto 1 + \alpha\cos^2\theta$$

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

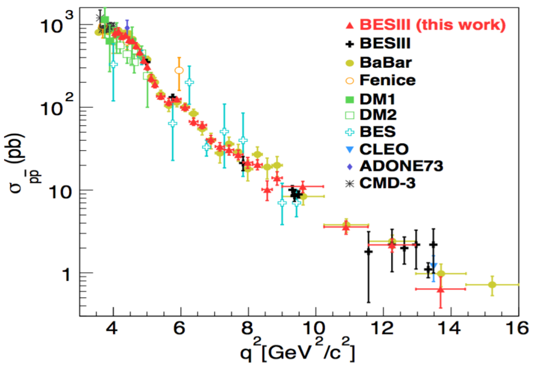


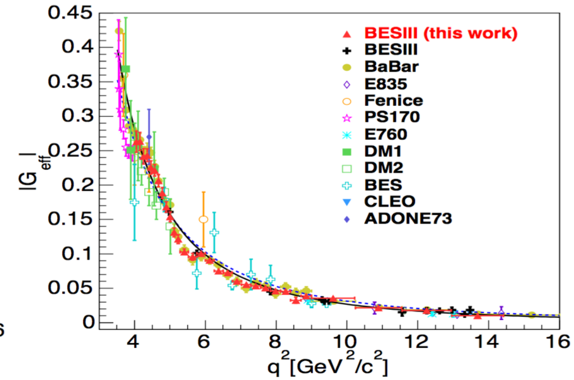
I. Measurement of $\sigma^B(e^+e^- \to p\bar{p})$ using ISR method

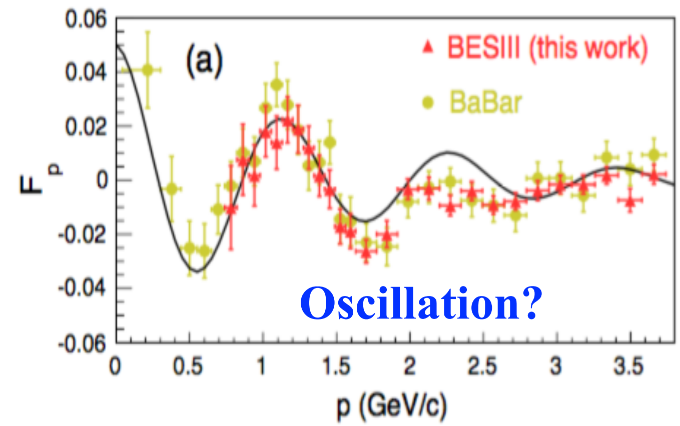
arXiv:1902.00665

Cross section and eff. FFs

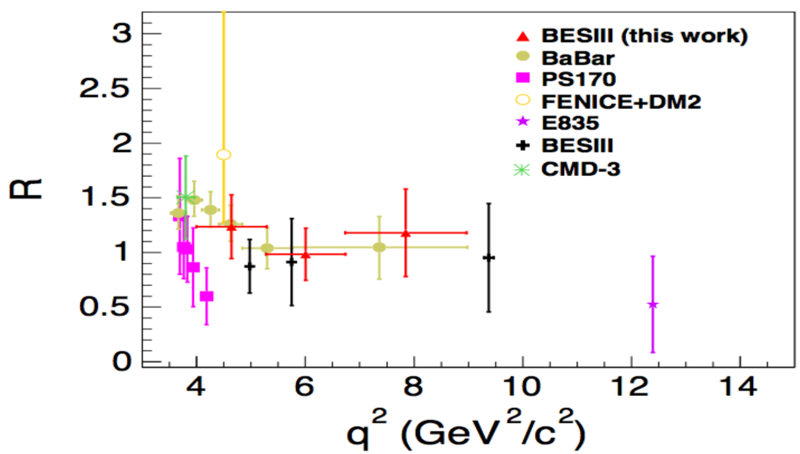
Data Samples: 7.4/pb @ $\sqrt{s} = 3.773$ to 4.6 GeV

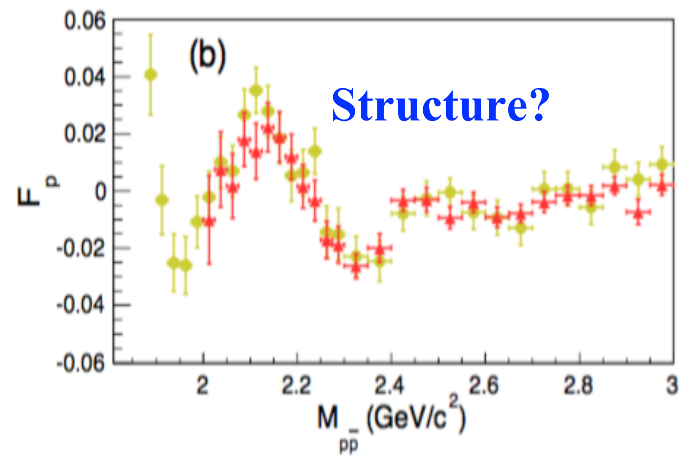






Electromagnetic G_E/G_M ratio

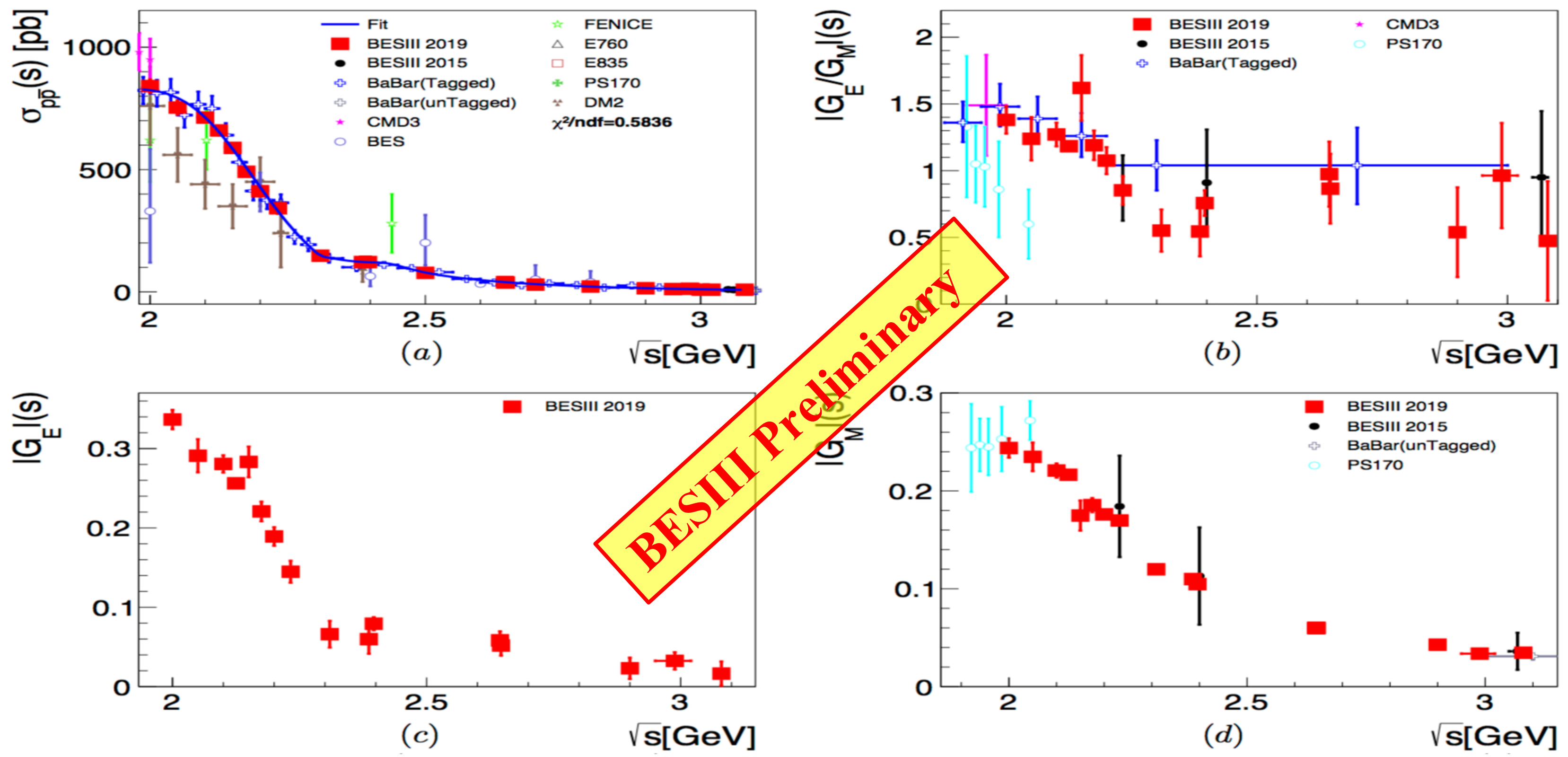




- More precise measurement at BESIII,
- Discrepancy between PS170 and others,
- More information for understanding nucleon internal structure and dynamics.

II. Measurement of Proton EMFF in $e^+e^- \to p\bar{p}$

Data samples: 688.5/pb, 22 center-of-mass energy points from 2.00 to 3.08 GeV.



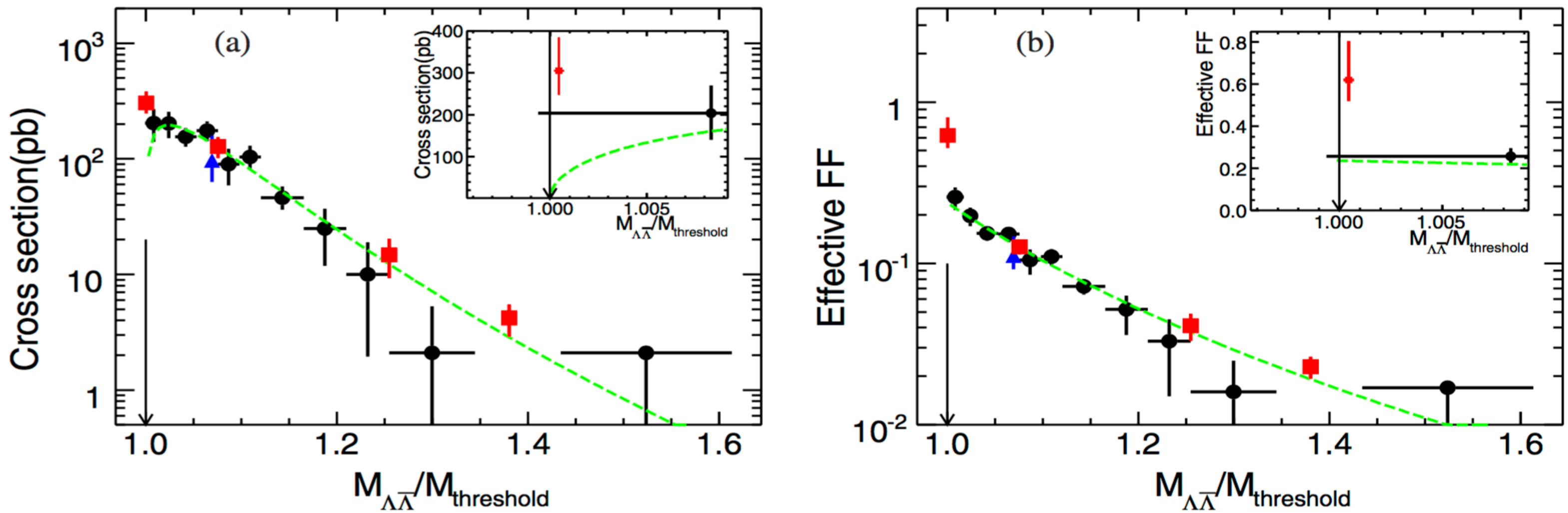
- Discrepancy between PS170 and others for |GE/GM|.
- In time-like region, this result achieves an unprecedented accuracy. Especially for |GE/GM|, providing an uncertainty comparable to the space-like region for the first time.

III. Measurement of $\sigma^B(e^+e^- \to \Lambda\bar{\Lambda})$ near threshold

PRD 97, 032013 (2018)

Data samples: ~40/pb, 4 energy points: 2.2324, 2.4,2.8 and 3.08 GeV.

Born cross section and effective FFs



- Traditional theory predicts a vanishing cross section at threshold.
- This measurement is larger than the expectation for neutral baryon pairs.
- Born cross section at threshold (2.2324 GeV) is measured to be

$$\sigma^B = (305 \pm 45^{+66}_{-36})\text{pb}.$$

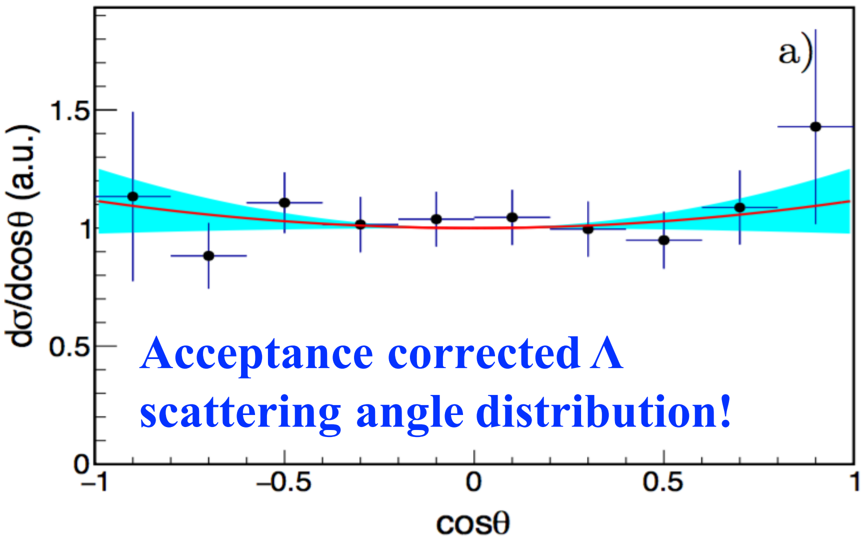
- Born cross section for other points are in good agreement with previous measurements (BABAR, DM2) with improved precision.

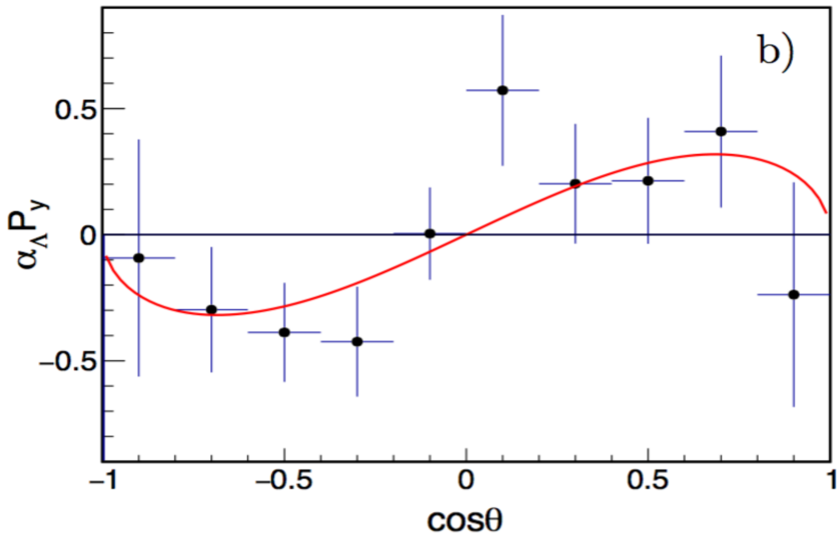
IV. Measurement of Λ EMFF in $e^+e^- \to \Lambda\bar{\Lambda}$ @ $\sqrt{s}$=2.396GeV

arXiv:1903.09421

- **Full reconstruction method**
  - ✓ $\Lambda \to p\pi^- \& \bar{\Lambda} \to \bar{p}\pi^+$

Data Sample: 66.9 pb^{-1}





Numerical Results

$$\sigma = 118.7 \pm 5.3 \pm 5.1$$
$$|G_{eff.}| = 0.123 \pm 0.003 \pm 0.003$$
$$R = \left|\frac{G_E}{G_M}\right| = 0.96 \pm 0.14 \pm 0.02$$
$$\Delta\Phi = \Phi_E - \Phi_M = 37^o \pm 12^o \pm 6^o$$

- **First complete determination of baryon time-like EMFFs**
- **Polarization observed**
- **More information for understanding $\Lambda\bar{\Lambda}$ near threshold**

V. Precision measurement of $\sigma^B(e^+e^- \to \Lambda_c\bar{\Lambda}_c)$ near threshold

PRL120, 132001 (2018)

■ Reconstruction modes

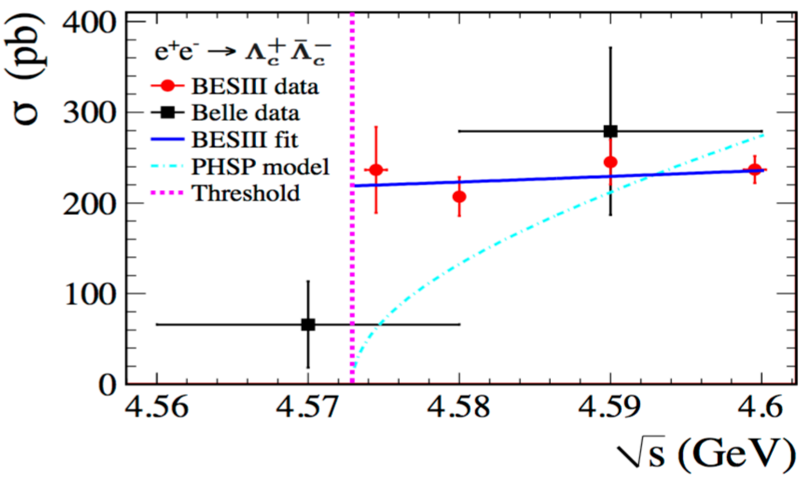
➢ **10 Cabibbo-favored hadronic modes:**
$pK^-\pi^+, pK_S^0, \Lambda\pi^+, pK^-\pi^+\pi^0, pK_S^0\pi^0,$
$\Lambda\pi^+\pi^0, pK_S^0\pi^+\pi^-, \Lambda\pi^+\pi^+\pi^-, \Sigma^0\pi^+, \Sigma^+\pi^+\pi^-$

➢ **c.c. mode is included by default**

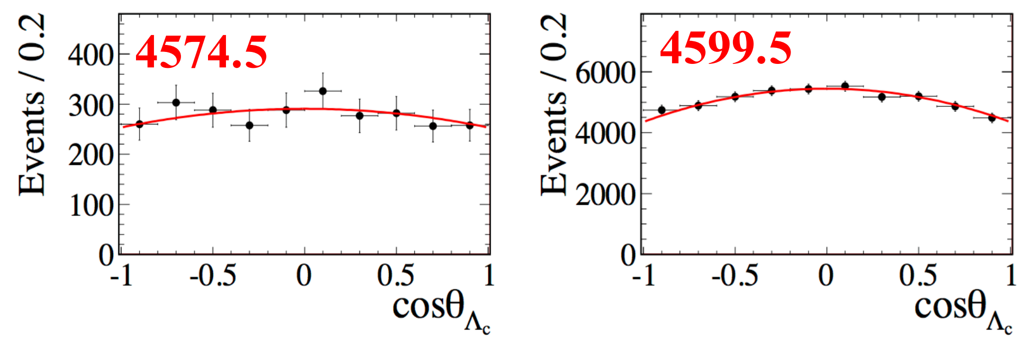
Data Samples

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

Born cross section



EMFFs (G_M/G_E) measurement



$$|G_E/G_M|^2(1-\beta^2) = (1-\alpha_{\Lambda_c})/(1+\alpha_{\Lambda_c})$$

$\sqrt{s}$ (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 studies for baryon properties in Charmonium decay achieved:
  - ✓ Negative α value for $J\psi \to \Sigma\bar{\Sigma}, \Sigma^*\bar{\Sigma}^*$(not for others)
  - ✓ "12% rule" broken still (while $\psi \to N\bar{N}$ not)
  - ✓ BCS/EMFFs of $e^+e^- \to B\bar{B}$ near threshold measured
  - ✓ $B\bar{B}$ threshold effect observed
  - ✓ Observation of Λ hyperon polarization
  - ✓ Still need more experimental/theoretical efforts
- More new results for studying baryon properties in Charmonium decay are on the way!


Thanks for your attention!

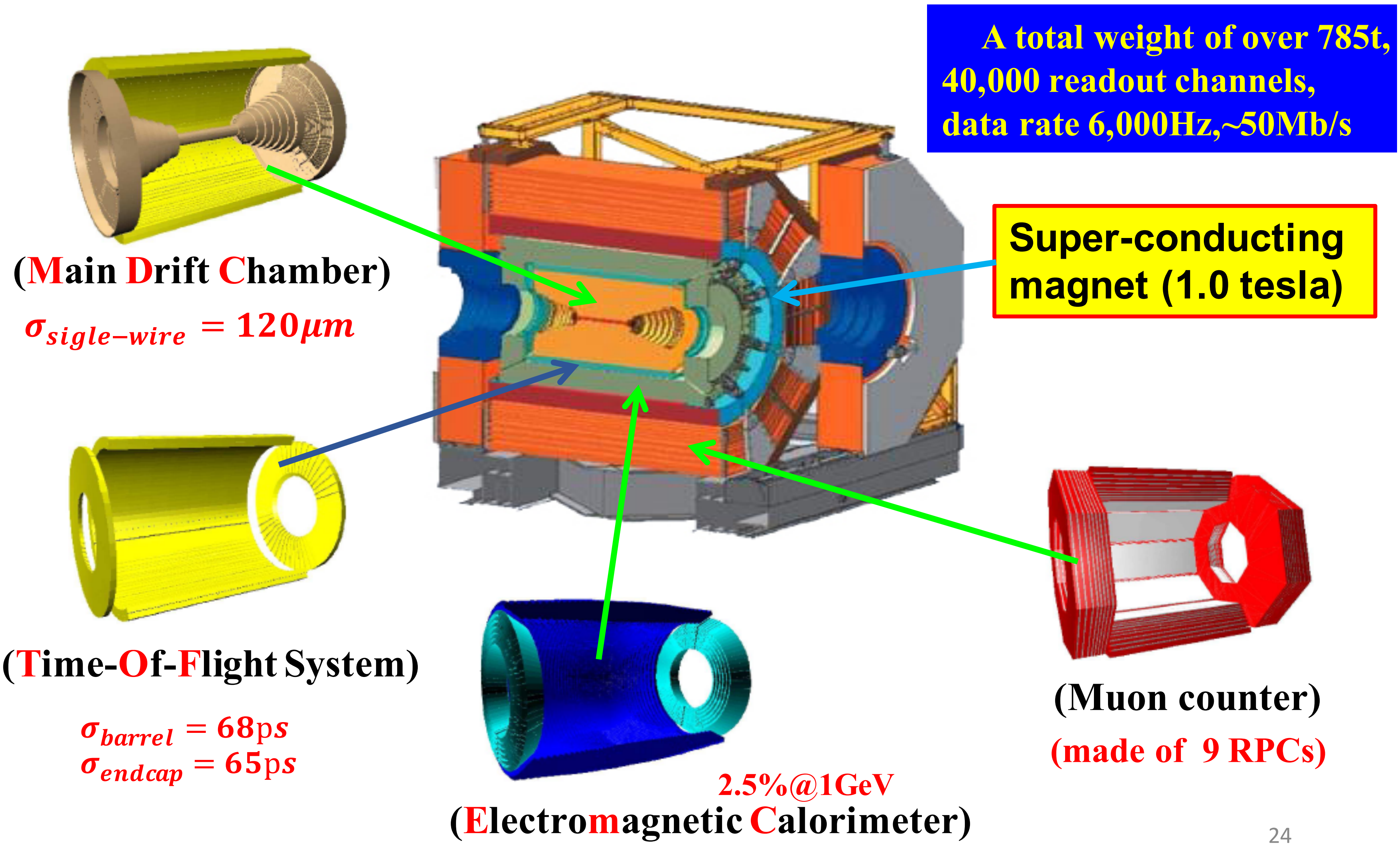
Backup

Beijing Electron Positron Collider-II

Beam energy: 1-2.3 GeV
Design Lum: 1×10^{33} $cm^{-2}s^{-1}$
Opt. energy: 1.89 GeV
Energy spread: 5.16×10^{-4}
Bunches No.: 93
Bunch length: 1.5 cm
Total current: 0.91 A
SR mode: 0.25A @ 2.5 GeV

Reached peaking luminosity: $1.0 \times 10^{33}\ cm^{-2}s^{-1}$

Beijing Spectrometer-III detector



BESIII Collaboration

Europe (16)

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

US (4)

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

Korea (1)

Seoul Nat. Univ.

Japan (1)

Tokyo Univ.

Mongolia (1)

Institute of Physics and Technology

India (1)

Indian Institute of Technology

Pakistan (2)

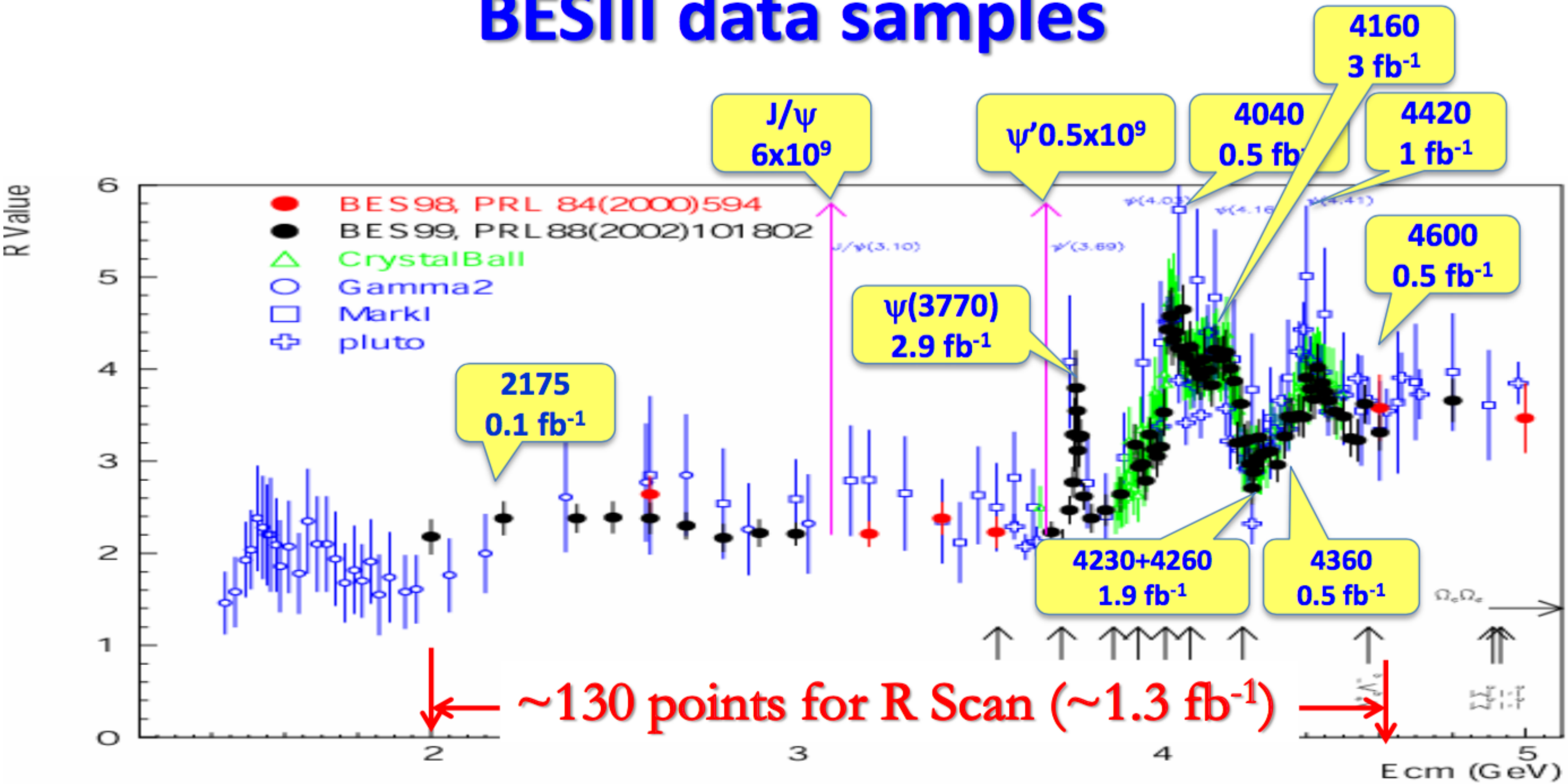
Univ. of Punjab
COMSAT CIIT

China(37)

IHEP, CCAST, UCAS, Shandong Univ., Univ. of Sci. and Tech. of China
Zhejiang Univ., Huangshan Coll., Shanghai Jiaotong Univ.
Huazhong Normal Univ., Wuhan Univ., Xingyang Normal Univ.
Zhengzhou Univ., Henan Normal Univ., Hunan Normal Univ.
Peking Univ., Tsinghua Univ. , *Beijing Inst. of Petro-chemical Tech.*
Zhongshan Univ.,Nankai Univ., Beihang Univ.
Shanxi Univ., Sichuan Univ., Univ. of South China
Hunan Univ., Liaoning Univ., Univ. of Sci. and Tech. Liaoning
Nanjing Univ., Nanjing Normal Univ., Southeast Univ.
Guangxi Normal Univ., Guangxi Univ.
Suzhou Univ., Hangzhou Normal Univ.
Lanzhou Univ., Henan Sci. and Tech. Univ.
Jinan Univ., Fudan Univ.

~500members
From 67 institutions in 14 counties

BESIII data samples



World largest J/ψ, ψ(2S), ψ(3770), ψ(4160), Y(4260), …

produced directly from e^+e^- collision

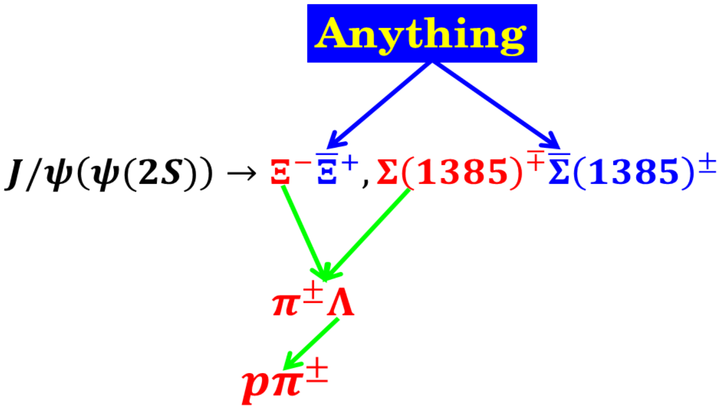
3.5/fb in 4.2-4.3 GeV, 500/pb at each energy

7

J/ψ data taking next run to reach 10 billion J/ψ events

Physical Review D 93, 0732003 (2016)

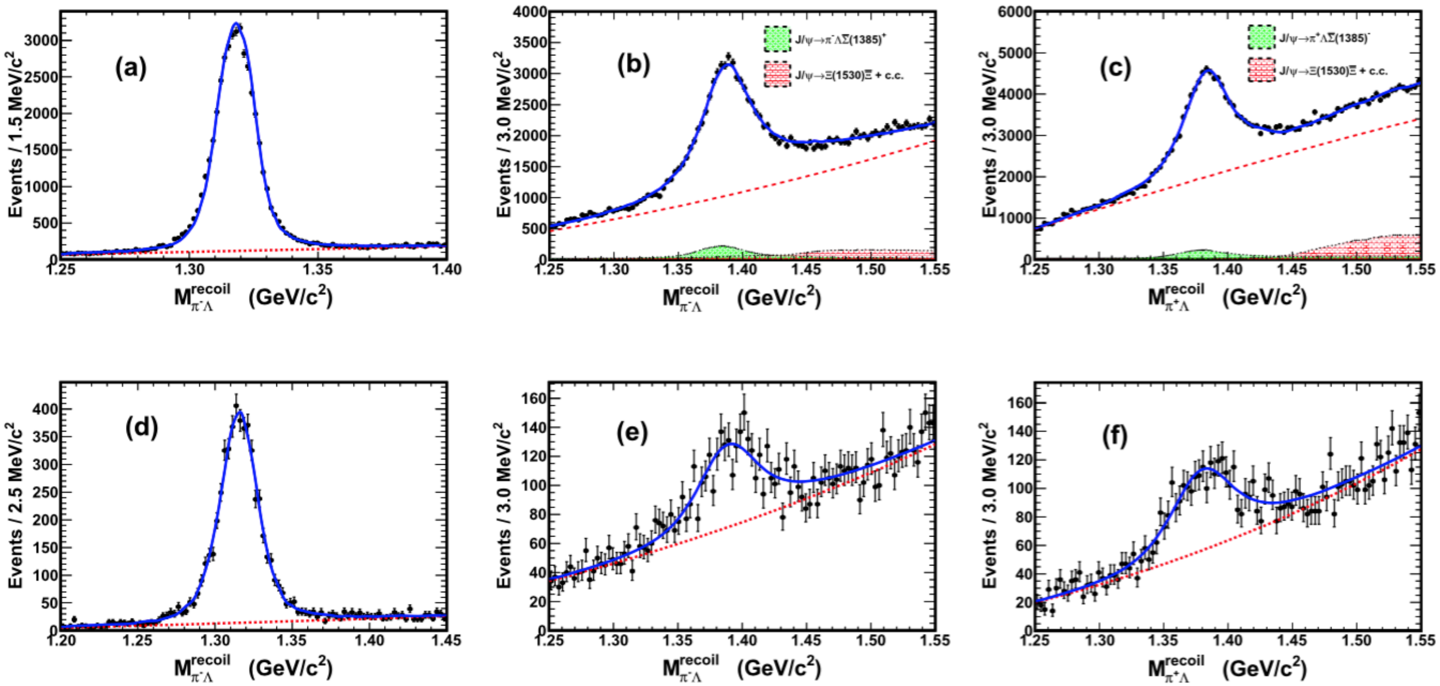
I. Study of J/ψ and $\psi(3686) \to \Xi^-\bar{\Xi}^+$ and $\Sigma(1385)^{\mp}\bar{\Sigma}(1385)^{\pm}$

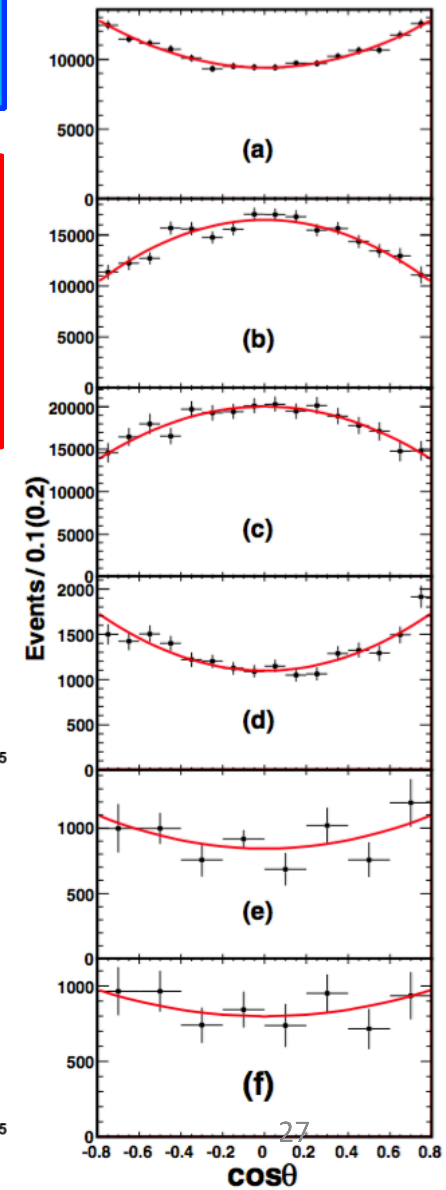


$$M_{\pi\Lambda}^{recoil} = \sqrt{(E_{c.m.} - E_{\pi\Lambda})^2 - \vec{p}^2}$$

Data Samples:
225M J/ψ & 106M ψ(3686)

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





Physical Review D 93, 0732003 (2016)

I. Study of J/ψ and $\psi(3686) \to \Xi^-\bar{\Xi}^+$ and $\Sigma(1385)^{\mp}\bar{\Sigma}(1385)^{\pm}$

■ Numerical Results

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	$10.40 \pm 0.06 \pm 0.74$	$10.96 \pm 0.12 \pm 0.71$	$12.58 \pm 0.14 \pm 0.78$	$2.78 \pm 0.05 \pm 0.14$	$0.85 \pm 0.06 \pm 0.06$	$0.84 \pm 0.05 \pm 0.05$
MarkI [5]	14.00 ± 5.00	...	...	< 2.0	...	...
MarkII [6]	$11.40 \pm 0.80 \pm 2.00$	$8.60 \pm 1.80 \pm 2.20$	$10.3 \pm 2.4 \pm 2.5$	...	...	...
DM2 [7]	$7.00 \pm 0.60 \pm 1.20$	$10.00 \pm 0.40 \pm 2.10$	$11.9 \pm 0.4 \pm 2.5$	...	...	...
BESII [8,12]	$9.00 \pm 0.30 \pm 1.80$	$12.30 \pm 0.70 \pm 3.00$	$15.0 \pm 0.8 \pm 3.8$	$3.03 \pm 0.40 \pm 0.32$	...	...
CLEO [9]	...	...	...	$2.40 \pm 0.30 \pm 0.20$	...	...
BESI [26]	...	...	...	$0.94 \pm 0.27 \pm 0.15$	...	...
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	$0.58 \pm 0.04 \pm 0.08$	$-0.58 \pm 0.05 \pm 0.09$	$-0.49 \pm 0.06 \pm 0.08$	$0.91 \pm 0.13 \pm 0.14$	$0.64 \pm 0.40 \pm 0.27$	$0.35 \pm 0.37 \pm 0.10$
BESII [8]	$0.35 \pm 0.29 \pm 0.06$	$-0.54 \pm 0.22 \pm 0.10$	$-0.35 \pm 0.25 \pm 0.06$	...	...	...
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**
- ➢ **Measured α values deviated from the predictions (without the consideration of the higher order correction) , negative α value, ….**

■ Test of "12% rule" $\left(\frac{Br(\psi(3686)\to X_h)}{Br(J/\psi\to X_h)}\right)$

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

Deviated from 12% !

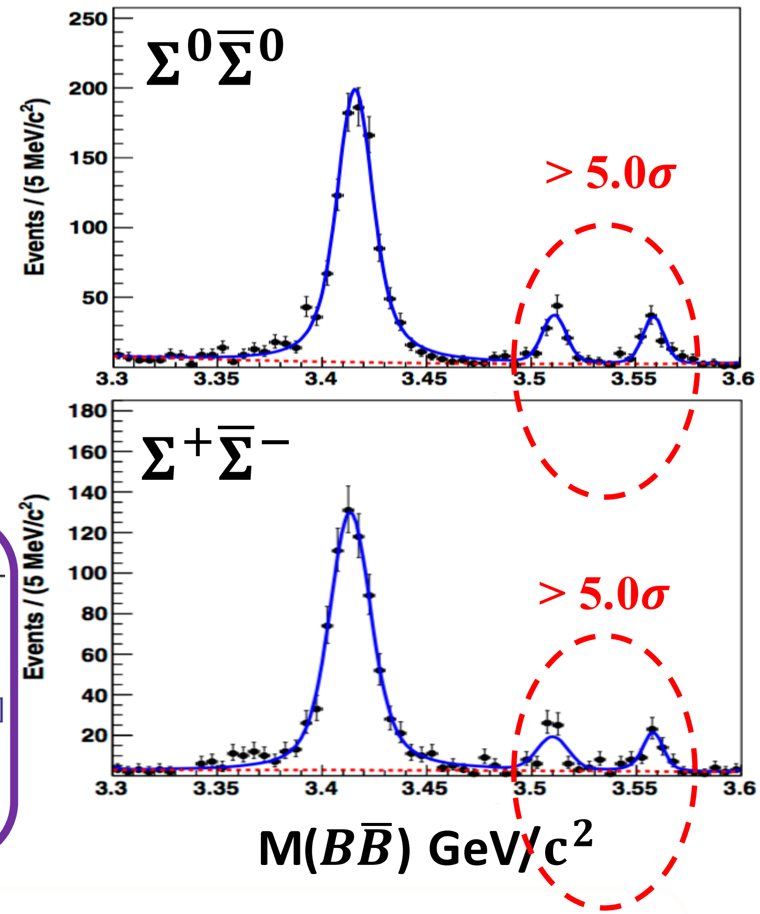
- ➢ **Theoretical models are expected to be improved to understand the difference.**

V. Improved measurement of $\chi_{cJ} \to \Sigma^0\bar{\Sigma}^0, \Sigma^+\bar{\Sigma}^-$ decays

Data Sample: 448M $\psi(3686)$

PRD 97, 052011 (2018)

- **Test QCD model based effective field theory**
  - ✓ Color octet mechanism(COM)
  - ✓ Isospin symmetry
  - ✓ Helicity selection rule



Numerical results

Channel	This work	PDG	Previous BESIII [6]	Theory
$\chi_{c0} \to \Sigma^+\bar{\Sigma}^-$	$50.4 \pm 2.5 \pm 2.7$	39 ± 7	$43.7 \pm 4.0 \pm 2.8$	5.5-6.9 [3]
$\chi_{c1} \to \Sigma^+\bar{\Sigma}^-$	$3.7 \pm 0.6 \pm 0.2$	<6	$5.2 \pm 1.3 \pm 0.5$ (<8.3)	3.3 [4]
$\chi_{c2} \to \Sigma^+\bar{\Sigma}^-$	$3.5 \pm 0.7 \pm 0.3$	<7	$4.7 \pm 1.8 \pm 0.7$ (<8.4)	5.0 [4]
$\chi_{c0} \to \Sigma^0\bar{\Sigma}^0$	$47.7 \pm 1.8 \pm 3.5$	44 ± 4	$46.0 \pm 3.3 \pm 3.7$	(25.1 ± 3.4, 18.7 ± 4.5) [2]
$\chi_{c1} \to \Sigma^0\bar{\Sigma}^0$	$4.3 \pm 0.5 \pm 0.3$	<4	$3.7 \pm 1.0 \pm 0.5$ (<6.0)	3.3 [4]
$\chi_{c2} \to \Sigma^0\bar{\Sigma}^0$	$3.9 \pm 0.5 \pm 0.3$	<6	$3.8 \pm 1.0 \pm 0.5$ (<6.2)	(38.9 ± 8.8, 4.2 ± 0.5) [2] 5.0 [4]

- **Provide more precise measurements.**
- **Consistent with previous experiments and COM model[2,4], inconsistent with Charm meson loop model[3].**