Belle/Belle II的研究进展

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中国科学院粒子物理前沿卓越创新中心第六次全体会议
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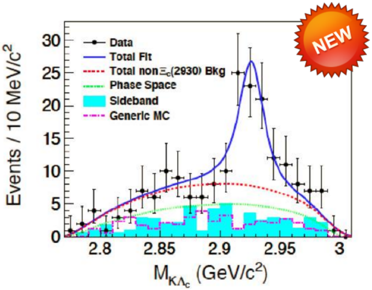
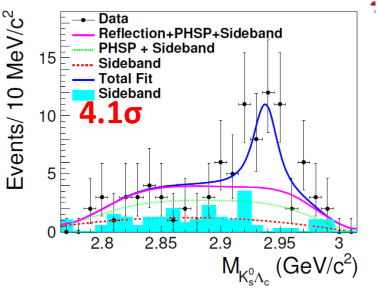
I. Belle 研究进展

- $\Xi_c(2930)^0$ in $B^+ \to K^+\Lambda_c^+\bar{\Lambda}_c^-$; evidence of charged $\Xi_c(2930)$ in $B^0 \to K^0\Lambda_c^+\bar{\Lambda}_c^-$.
- Measurements of absolute $\mathcal{B}$s of Ξ_c^0.
- $e^+e^- \to \gamma + \chi_{cJ}/\eta_c$, observation of χ_{c1}.

$\Xi_c(2930)$ in $B \to K + \Lambda_c^+ \bar{\Lambda}_c^-$ at Belle



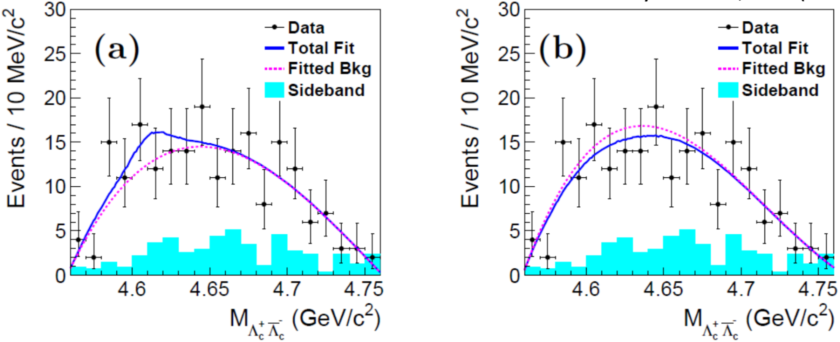


$\Xi_c(2930)^0$ in $B^+ \to K^+ \Lambda_c^+ \bar{\Lambda}_c^-$, $\Xi_c(2930)$ in $B^0 \to K^0 \Lambda_c^+ \bar{\Lambda}_c{}^-$

- $\Xi_c(2930)^0 = csd$: the first charmed-strange baryon established in B decays; clear confirmation (5.1σ) for BaBar claim.
  Y.B. Li, C.P. Shen, et al, EPJC78, 252(2018)
- First evidence of charged $\Xi_c(2930)$ (4.1σ): $M = 2942.3 \pm 4.4 \pm 1.6$ MeV$/c^2$, $\Gamma = 14.8 \pm 8.8 \pm 7.1$ MeV$/c^2$.
  Y.B. Li, C.P. Shen, et al, EPJC78, 928(2018)

Search for $Y(4660)$ and its spin part in $B^+ \to K^+\Lambda_c^+\bar{\Lambda}_c^-$ at Belle

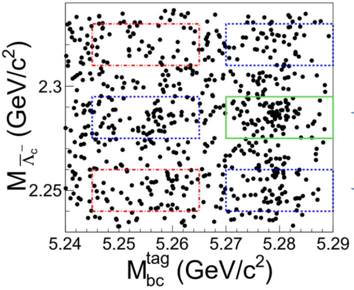
Eur. Phys. J. C78, 252 (2018)

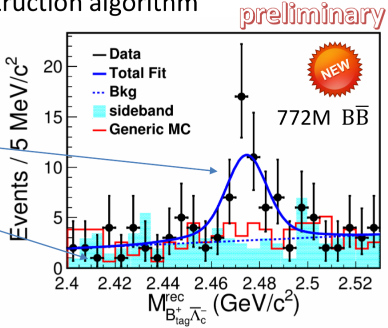


- No Y(4660) and its spin partner Y_η were observed. in the $\Lambda_c^+\bar{\Lambda}_c^-$ invariant mass distribution
- 90% C.L. upper limits of $B^+ \to K^+Y(4660) \to K^+\Lambda_c^+\bar{\Lambda}_c^-$ and $B^+ \to K^+Y_\eta \to K^+\Lambda_c^+\bar{\Lambda}_c^-$ are 1.2×10^{-4} and 2.0×10^{-4}.

Measurements of Br of $B^- \to \bar{\Lambda}_c^- \Xi_c^0$, $\Xi_c^0 \to$anything

- The $\bar{\Lambda}_c^-$ reconstructed via its $\bar{p}K^+\pi^-$ and $\bar{p}K_S^0$ decays
- A tagged B meson candidate, B_{tag}^+, is reconstructed using a neural network based on the full hadron-reconstruction algorithm





- An unbinned maximum likelihood fit: $N(\Xi_c^0)=40.9 \pm 9.0$, 5.5σ(stat.)
- $B(B^- \to \bar{\Lambda}_c^- \Xi_c^0, \Xi_c^0 \to$anything$)= (9.51 \pm 2.10 \pm 0.88) \times 10^{-4}$ for the first time

From Chengping's talk at HFCPV2018.

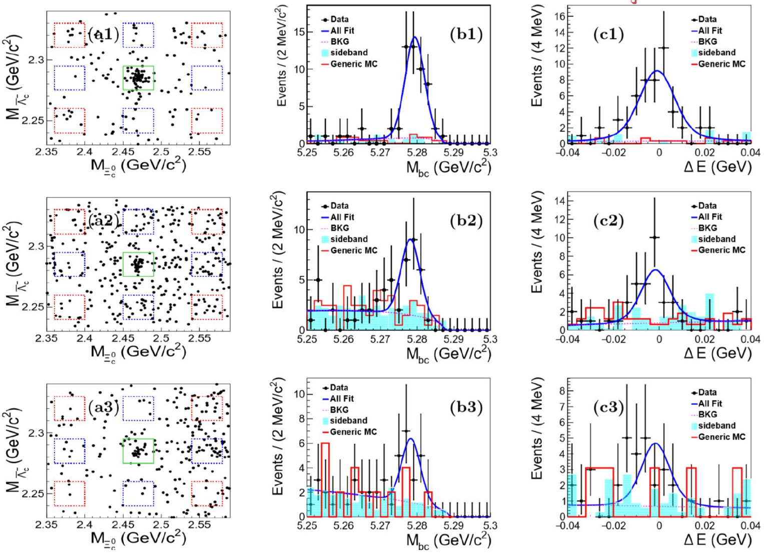
Measurements of Brs of $B^- \to \bar{\Lambda}_c^- \Xi_c^0$, with $\Xi_c^0 \to \Xi^-\pi^+; \Xi_c^0 \to \Lambda K^-\pi^+; \Xi_c^0 \to pK^-K^-\pi^+$

preliminary

$\Xi^-\pi^+$
44.8 ± 7.3
9.5σ

$\Lambda K^-\pi^+$
24.1 ± 5.5
6.8σ

$pK^-K^-\pi^+$
16.6 ± 5.4
4.6σ



Measurements of absolute Brs of Ξ_c^0

Summary of the measured branching fractions and the ratios of Ξ_c^0 decays

preliminary

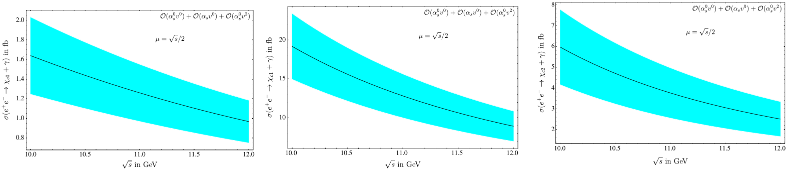
Channel	Br/Ratio	PDG
$B(\boldsymbol{B}^- \to \overline{\boldsymbol{\Lambda}}_c^- \Xi_c^0)$	$(9.51 \pm 2.10 \pm 0.88) \times 10^{-4}$	
$B(\boldsymbol{B}^- \to \overline{\boldsymbol{\Lambda}}_c^- \Xi_c^0)\, B(\Xi_c^0 \to \Xi^- \pi^+)$	$(1.71 \pm 0.28 \pm 0.15) \times 10^{-5}$	$(2.4 \pm 0.9) \times 10^{-5}$
$B(\boldsymbol{B}^- \to \overline{\boldsymbol{\Lambda}}_c^- \Xi_c^0)\, B(\Xi_c^0 \to \Lambda K^- \pi^+)$	$(1.11 \pm 0.26 \pm 0.10) \times 10^{-5}$	$(2.1 \pm 0.9) \times 10^{-5}$
$B(\boldsymbol{B}^- \to \overline{\boldsymbol{\Lambda}}_c^- \Xi_c^0)\, B(\Xi_c^0 \to pK^- K^- \pi^+)$	$(5.47 \pm 1.78 \pm 0.57) \times 10^{-6}$	
$B(\Xi_c^0 \to \Xi^- \pi^+)$	$(1.80 \pm 0.50 \pm 0.14)\%$	
$B(\Xi_c^0 \to \Lambda K^- \pi^+)$	$(1.17 \pm 0.37 \pm 0.09)\%$	
$B(\Xi_c^0 \to pK^- K^- \pi^+)$	$(0.58 \pm 0.23 \pm 0.05)\%$	
$B(\Xi_c^0 \to \Lambda K^- \pi^+)/B(\Xi_c^0 \to \Xi^- \pi^+)$	$0.65 \pm 0.18 \pm 0.04$	1.07 ± 0.14
$B(\Xi_c^0 \to pK^- K^- \pi^+)/B(\Xi_c^0 \to \Xi^- \pi^+)$	$0.32 \pm 0.12 \pm 0.07$	0.34 ± 0.04

- We have performed an analysis of $\boldsymbol{B}^- \to \overline{\boldsymbol{\Lambda}}_c^- \Xi_c^0$ inclusively and exclusively
- First model-independent measurement of absolute Brs of Ξ_c^0 decays
- The branching fraction $B(\boldsymbol{B}^- \to \overline{\boldsymbol{\Lambda}}_c^- \Xi_c^0)$ is measured for the first time
- The measured $B(\Xi_c^0 \to \Xi^- \pi^+)$ can be used to determine the BR of other Ξ_c^0 decays.

$e^+e^- \to \gamma + \chi_{cJ}/\eta_c$

Motivation

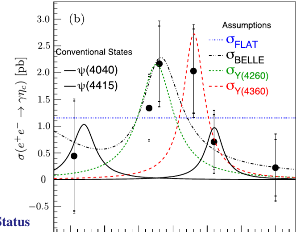
- Continuum production predictions by NRQCD (for Belle II):



N. Brambilla *et al.*, PRD**97**, 096001(2018)

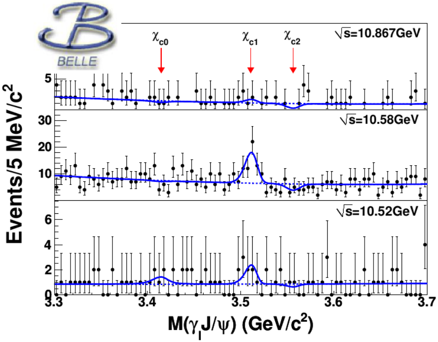
- We can study with Belle data at first:
  - $\sigma(e^+e^- \to \chi_{c0} + \gamma) = (1.4 \pm 0.3)$ fb;
  - $\sigma(e^+e^- \to \chi_{c1} + \gamma) = (15.0 \pm 3.3)$ fb;
  - $\sigma(e^+e^- \to \chi_{c2} + \gamma) = (4.5 \pm 1.4)$ fb.
- $e^+e^- \to \gamma + \chi_{cJ}/\eta_c$ measured by BESIII: PRD96,051101(2017) and Chin.Phys.C39, 041001(2015)

$E_{\rm CM}$ (GeV)		$N^{\rm obs}$	significance (σ)	$\sigma^{\rm UP}$ (pb)	$\sigma^{\rm B}$ (pb)
4.009	χ_{c0}	7.0 ± 6.6	1.6	182	$65.0 \pm 61.3 \pm 5.3$
	χ_{c1}	4.4 ± 2.6	2.2	5.3	$2.4 \pm 1.4 \pm 0.2$
	χ_{c2}	1.8 ± 1.7	1.5	18	$4.7 \pm 4.4 \pm 0.6$
4.230	χ_{c0}	0.2 ± 2.3	0.0	26	$0.7 \pm 8.0 \pm 0.1$
	χ_{c1}	6.7 ± 4.3	1.9	1.7	$0.7 \pm 0.5 \pm 0.1$
	χ_{c2}	13.3 ± 5.2	2.9	5.0	$2.7 \pm 1.1 \pm 0.3$
4.260	χ_{c0}	0.1 ± 1.9	0.0	26	$0.5 \pm 8.8 \pm 0.1$
	χ_{c1}	3.0 ± 3.0	1.1	1.1	$0.4 \pm 0.4 \pm 0.1$
	χ_{c2}	7.5 ± 3.9	2.3	4.2	$2.0 \pm 1.1 \pm 0.2$
	χ_{c0}	0.1 ± 0.7	0.0	23	$0.7 \pm 5.0 \pm 0.1$
4.360	χ_{c1}	5.2 ± 4.9	2.4	2.9	$1.4 \pm 1.3 \pm 0.1$



$e^+e^- \to \gamma + \chi_{cJ}$ from Belle

- $\chi_{cJ} \to \gamma J/\psi,\ J/\psi \to \mu^+\mu^-$ for reconstruction;
- 5C constraints: 4C to initial e^+e^- collision system &. 1C to J/ψ mass
- ISR events $e^+e^- \to \gamma_{\rm ISR}\psi(2S) \to \gamma_{\rm ISR}\gamma\chi_{cJ}$ removed by $M(\gamma_{\rm ext}\gamma\mu^+\mu^-) < 3.60$ GeV$/c^2$ or > 3.78 GeV$/c^2$:
  - $N^{\rm residual}(\chi_{c1}) = 0.84 \pm 0.15$ and $N^{\rm residual}(\chi_{c2}) = 0.43 \pm 0.05$.



A significant χ_{c1} signal in 10.58 GeV data sample:

- $N^{\rm obs}(\chi_{c1}) = 39.0^{+9.5}_{-8.8}$ with $\varepsilon = 19.9\%$;
- The significance: 5.1σ including systematic uncertainties;
- $\sigma^{\rm Born}(e^+e^- \to \gamma + \chi_{c1}) = (17.3^{+4.2}_{-3.9}(stat.) \pm 1.7(syst.))$ fb.

S. Jia, X.L. Wang et al.,

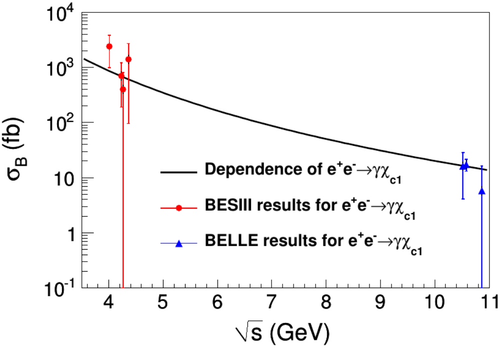
$\sigma(e^+e^- \to \gamma\chi_{c1})$ vs. $\sqrt{s}$

- Assuming $\sigma(e^+e^- \to \gamma\chi_{cJ}/\eta_c) \propto 1/s^n$, the prediction:

charmonium	χ_{c0}	χ_{c1}	χ_{c2}	η_c
n	1.4	2.1	2.4	1.3

L.B. Chen, Y. Liang and C.F. Qiao, JHEP1801,091(2018)

- Combining measurements from BESIII and Belle.
- Fitting yields $n = 2.1^{+0.3}_{-0.4}$.

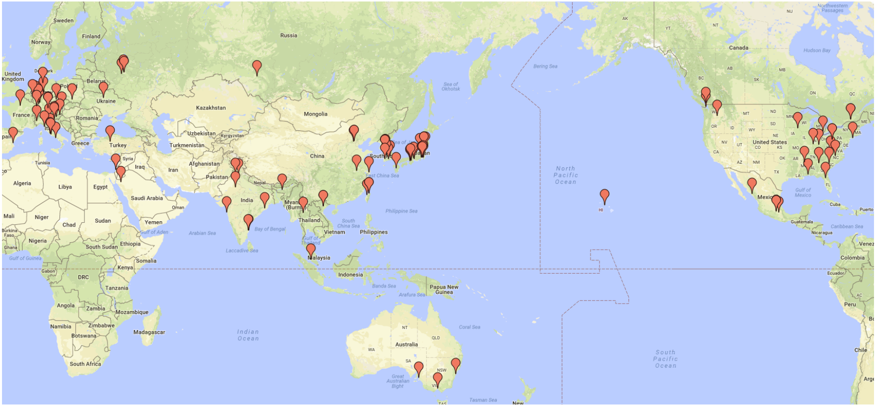


- ULs determined in $e^+e^- \to \gamma + \eta_c,\ \chi_{c0},\ \chi_{c2}$.
- Accepted by PRD.

II. Belle II进展

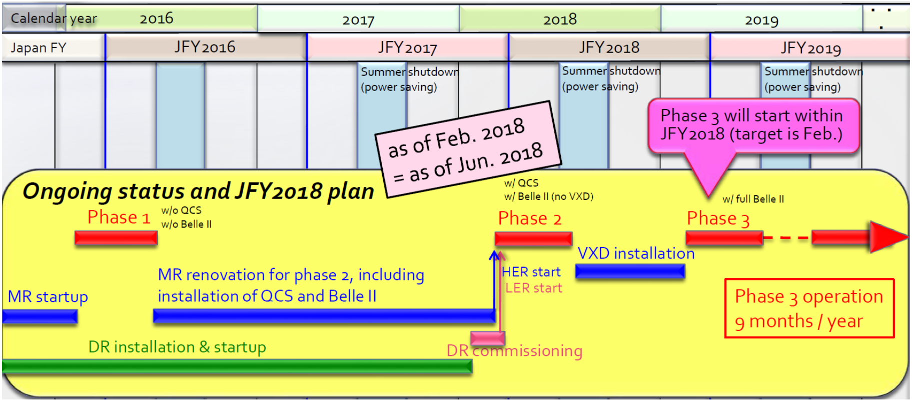
- Belle II合作组
- SuperKEKB进展
- Belle II探测器表现
- 中国组过去一年的工作

Belle II Collaboration



- Belle II Collaboration: 26 counties/regions, 113 institutions, $>$ 800 collaborators.
- Belle II China Group: 高能所, 中科大, 北大, 北航, 复旦, 辽宁师大，以及苏州大学. 成员超过45名。
- 中国组网页: https://napp.fudan.edu.cn/belle2/

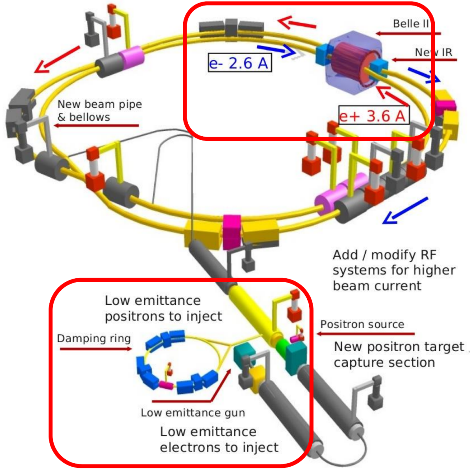
Current schedule

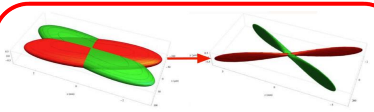


- First collisions on 4/26/2018, 8 years after KEKB and Belle being shut down.
- Phase 2 until July 17th.
- On the way to Phase III: Physics Run.

The SuperKEKB

A lot of new designs





"nano-beam" scheme

Beam squeezing: x20 smaller at IR

$$\text{Luminosity} = \frac{\gamma_{\pm}}{2er_e}\left(1+\frac{\sigma_y^*}{\sigma_x^*}\right)\frac{I_{\pm}\zeta_{\pm y}}{\beta_y^*}\frac{R_L}{R_y}$$

x2 ($I_{\pm}$)

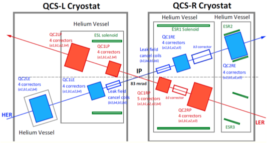
X1/20 (β_y^*)

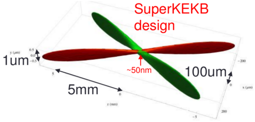
Target luminosity: $8\text{x}10^{35}\text{cm}^{-2}\text{s}^{-1}$

KEKB x 40!

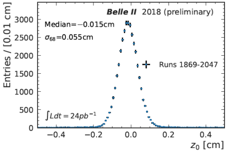
The final focus: Key of achieving the goal of $L = 0.8 \times 10^{36}\ \mathrm{cm^{-2}s^{-1}}$

The superconducting final focus system

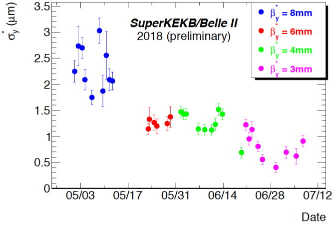




Large cross angle:
22 mrad (KEKB) → 83 mrad (SKB).



- Effective bunch length is reduced from $\sim$ 10 mm (KEKB) to 0.5 mm (SuperKEKB).



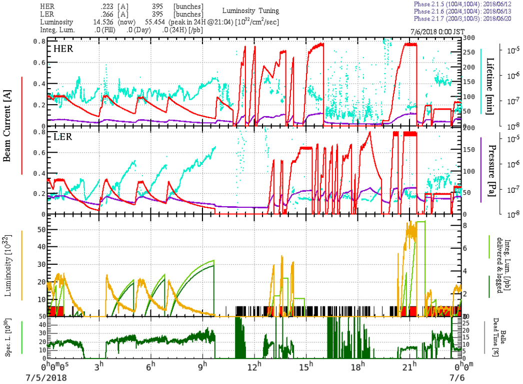
- The record the vertical spot size is 400nm with $I \sim 15$ mA, goal is $\mathcal{O}(50\ \mathrm{nm})$ with full capability of the QCS system.
- Early Phase 3 will continue with $\beta^* = 3$ mm, goal is $\beta^* \sim 0.3$ mm.
- Struggling with beam-beam blow-up, a major issue for Phase3.

SuperKEKB achievements at Phase II

Keep on squeezing the two beams with the superconducting final focus $\beta_y^* = 3$ mm.

$$L_{peak} = 5.5 \times 10^{33} / cm^2 / \sec$$

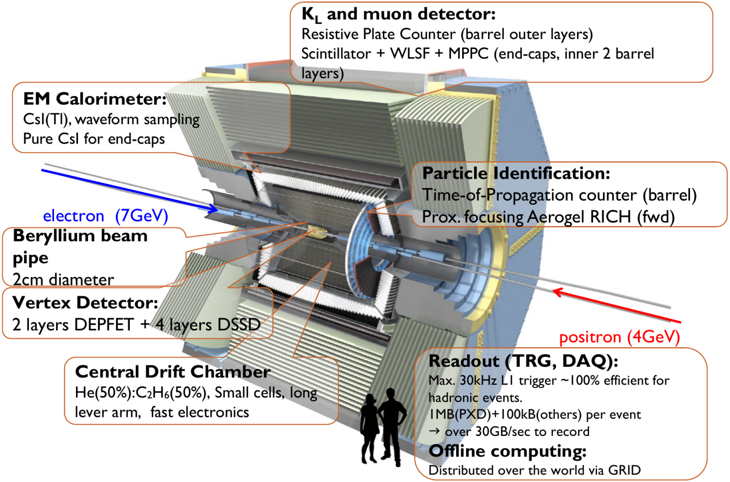
Phase 2,
July 2018



- Luminosity tuning had priority, so most of the time was assigned for accelerator physicists.
- Belle II only record 0.5 fb^{-1} data, usually owl shift.
- $L = 0.55 \times 10^{34}\ \text{cm}^{-2}\text{s}^{-1}$ achieved in Phase II, compared to $L_{max} = 2.1 \times 10^{34}$ by KEKB.

Cut view of Belle II detector

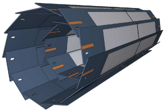
$H = 7.1\text{m}, L = 7.4\text{m}, W = 1400\text{t}$

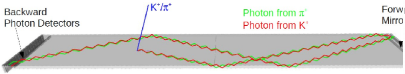


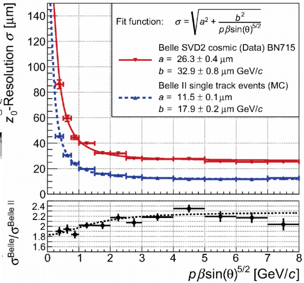
- Belle II subsystems: PXD， SVD， CDC， iTOP, ARICH, ECL, KLM, DAQ/TRG, GRID...
- 中国组（可）参与：PXD, SVD, CDC, iTOP, ARICH, KLM, DAQ/TRG, GRID

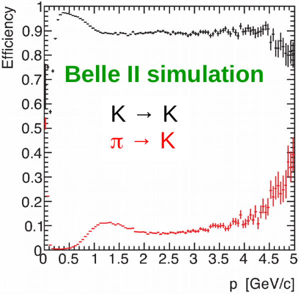
Detector highlights

PXD and iTOP









Vertex detectors:

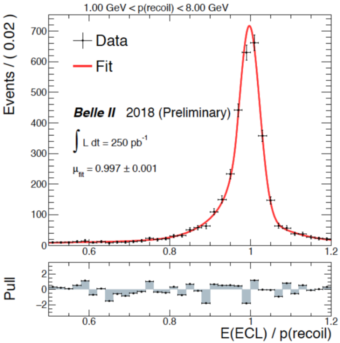
- spatial resolution has a factor $\sim$ 2 than Belle;
- despite lower Lorentz boost, $O(30\%)$ improvement in separating the B decay vertices!
- $\sim 30\%$ larger acceptance for K_s reconstruction

Particle Identification (PID):

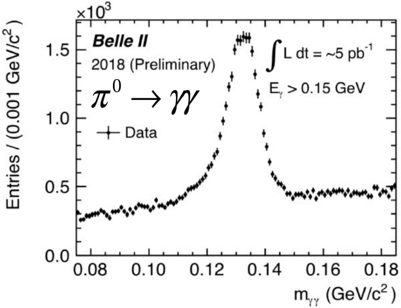
- $K - \pi$ separation is fundamental to distinguish among important final states and bkgs;
- crucial ingredient for B flavor tagger;
- expected performance: $K(\pi)$ efficiency $> 90\%$, with $\pi(K)$ fake rate $< 10\%$ for $p < 4$ GeV$/c$.

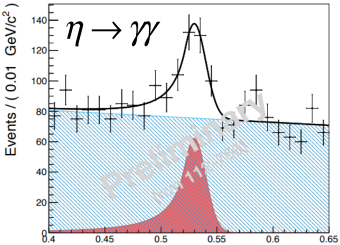
Signals involving photons (ECL)

$$e^+e^- \to \mu^+\mu^-\gamma$$



Single Photon Lines





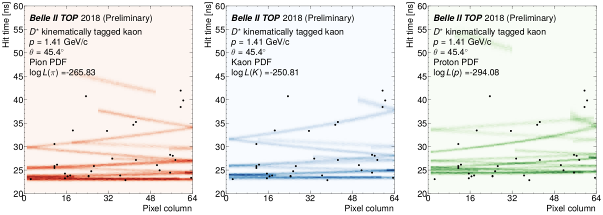
Ready for the dark sector !

$$e^+e^- \to \gamma X$$

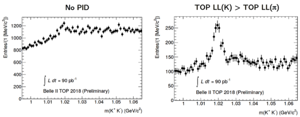
$$e^+e^- \to \gamma ALPS \to \gamma(\gamma\gamma)$$

TOP for Particle Identification: $K^{\pm}$, p and $\pi^{\pm}$

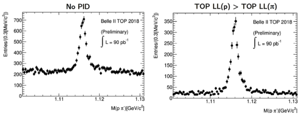
- The charged correlation with the slow pion determines which track is the kaon (or pion)
- Kinematically identified kaon from a D^{*+} in the TOP.
- Cherenkov x vs. t pattern (mapping of the Cherenkov ring):

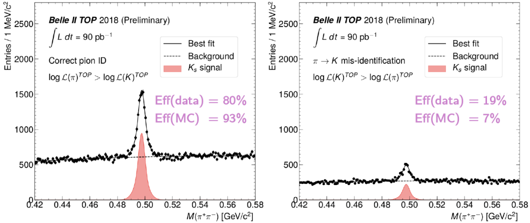


φ → K⁺K⁻ with both the tracks in the TOP acceptance



Λ → pπ with the **proton candidate** in the TOP acceptance

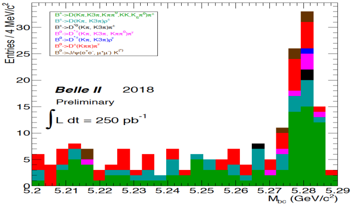




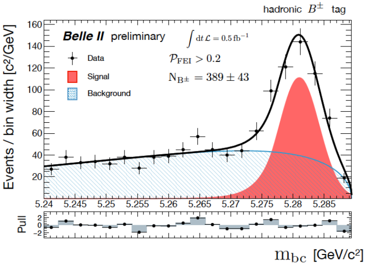
$K_S^0 \to \pi^+\pi^-$

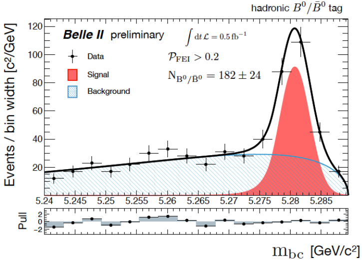
B mesons from Belle II

- Rediscovery of B mesons in June, shown at ICHEP2018.



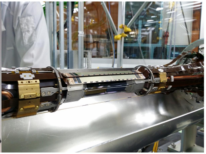
- Use the full Phase 2 dataset and apply the FEI (Full Event Interpretation) technique based on boosted decision trees (BDTs, a machine learning technique).





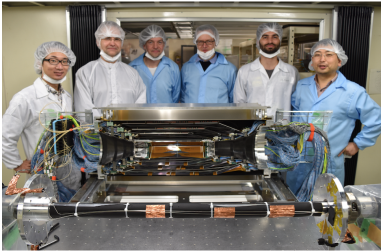
Onwards to Phase 3 and the Physics Run

- VXD = PXD+SVD
- PXD installation ongoing well at KEK.



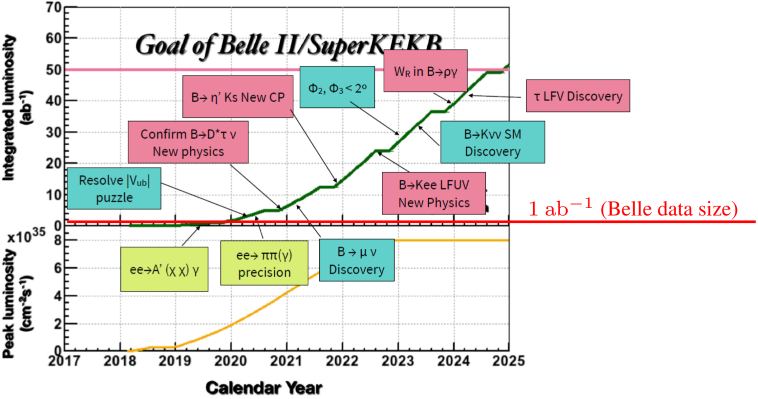
- 叶桦(DESY)正在KEK负责相关工作。
- 复旦博士后刘清源通过中联合项目，正在DESY参与PXD的工作。

- SVD installation, finished in July, 2018

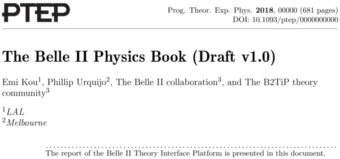


- Successful marriage of the PXD and SVD, current highlight of Belle II.

Luminosity and prospects



Book of Belle II Physics is available at arXiv:1808.10567



PTEP

Prog. Theor. Exp. Phys. **2018**, 00000 (681 pages)
DOI: 10.1093/ptep/0000000000

The Belle II Physics Book (Draft v1.0)

Emi Kou[1], Phillip Urquijo[2], The Belle II collaboration[3], and The B2TiP theory community[3]

[1] *LAL*
[2] *Melbourne*

The report of the Belle II Theory Interface Platform is presented in this document.

Belle II China Group in the past year

- New institutions: Fudan in June 2017, LNNU and SUDA in June 2018.
- Workshops:1st Workshop in March 2018, 1st Winter School in Nov. 2018.
- Hardware:
  - New lab at Fudan, working on KLM and DAQ upgrades; M&O of KLM.
  - IHEP's proposal for DAQ upgrade, based on xFP;
  - USTC has interest on DAQ;
  - IHEP joining the CDC maintenance and operation;
- M&O of Belle II: Fudan(+SUDA) in KLM, IHEP in CDC.
- Exchanges and cooperation: Agreement between Fudan and KEK.
- Computing resources: BUAA joining Belle II GRID, Fudan building a cluster, and IHEP is applying 修购计划.
- VIPs visiting KEK: 2018年7月中科院财务与保障局局长，8月发改委副主任。
- Web site: https://napp.fudan.edu.cn/belle2/
  - Databases, public and internal;
  - Wiki
  - Blog
  - Forum
  - HyperNews in the future?

Summary

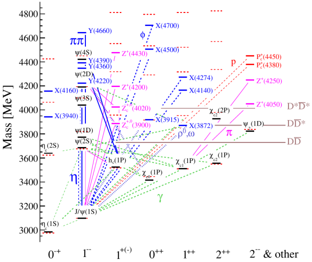
- Belle analyses:
  - $\Xi_c(2930)^0$ in $B^+ \to K^+\Lambda_c^+\bar{\Lambda}_c^-$; evidence of charged $\Xi_c(2930)$ in $B^0 \to K^0\Lambda_c^+\bar{\Lambda}_c^-$.
  - Measurements of absolute $\mathcal{B}$s of Ξ_c^0.
  - $e^+e^- \to \gamma + \chi_{cJ}/\eta_c$, observation of χ_{c1}.
- Belle II had the first collisions on April 26, 2018, and the Phase 2 was until July 17th.
- The Phase 2 got very impressive results from both the SuperKEKB accelerator and the Belle II detector.
- $L_{peak} = 0.55 \times 10^{34}$ cm^{-2}s^{-1} was achieved during Phase 2.
- The nano-beam scheme is working well and the Belle II detector has very good performance!
- Belle II is going to start physics running in 2019.
- Belle II China group did a lot of work in the past year.

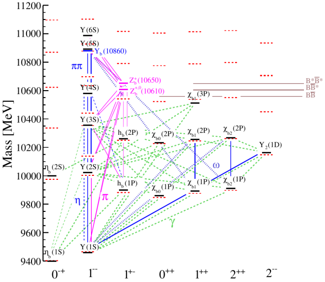
Thank you!

Back-up

A lot list of charged charmonium-like states

State	M (MeV)	Γ (MeV)	J^{PC}	Process (decay mode)	Experiment
$Z_c^{+,0}(3900)$	3886.6 ± 2.4	28.1 ± 2.6	1^{+-}	$e^+e^- \to \pi^{-,0}(J/\psi\pi^{+,0})$	BESIII (Ablikim *et al.*, 2013a, 2015f), Belle (Liu *et al.*, 2013)
				$e^+e^- \to \pi^{-,0}(D\bar{D}^*)^{+,0}$	BESIII (Ablikim *et al.*, 2014b, 2015e)
$Z_c^{+,0}(4020)$	4024.1 ± 1.9	13 ± 5	$1^{+-}(?)$	$e^+e- \to \pi^{-,0}(h_c\pi^{+,0})$	BESIII (Ablikim *et al.*, 2013b, 2014c)
				$e^+e^- \to \pi^{-,0}(D^*\bar{D}^*)^{+,0}$	BESIII (Ablikim *et al.*, 2014a, 2015d)
$Z^+(4050)$	4051^{+24}_{-43}	82^{+51}_{-55}	$?^{?+}$	$B \to K(\chi_{c1}\pi^+)$	Belle (Mizuk *et al.*, 2008), *BABAR* (Lees *et al.*, 2012a)
$Z^+(4200)$	4196^{+35}_{-32}	370^{+99}_{-149}	1^+	$B \to K(J/\psi\pi^+)$	Belle (Chilikin *et al.*, 2014)
				$B \to K(\psi'\pi^+)$	LHCb (Aaij *et al.*, 2014b)
$Z^+(4250)$	4248^{+185}_{-45}	177^{+321}_{-72}	$?^{?+}$	$B \to K(\chi_{c1}\pi^+)$	Belle (Mizuk *et al.*, 2008), *BABAR* (Lees *et al.*, 2012a)
$Z^+(4430)$	4477 ± 20	181 ± 31	1^+	$B \to K(\psi'\pi^+)$	Belle (Choi *et al.*, 2008; Mizuk *et al.*, 2009), Belle (Chilikin *et al.*, 2013), LHCb (Aaij *et al.*, 2014b, 2015b)
				$B \to K(J\psi\pi^+)$	Belle (Chilikin *et al.*, 2014)
$P_c^+(4380)$	4380 ± 30	205 ± 88	$(\frac{3}{2}/\frac{5}{2})^{\mp}$	$\Lambda_b^0 \to K(J/\psi p)$	LHCb (Aaij *et al.*, 2015c)
$P_c^+(4450)$	4450 ± 3	39 ± 20	$(\frac{5}{2}/\frac{3}{2})^{\pm}$	$\Lambda_b^0 \to K(J/\psi p)$	LHCb (Aaij *et al.*, 2015c)
$Y_b(10860)$	$10891.1^{+3.4}_{-3.8}$	$53.7^{+7.2}_{-7.8}$	1^{--}	$e^+e^- \to (\Upsilon(nS)\pi^+\pi^-)$	Belle (Chen *et al.*, 2008; Santel *et al.*, 2016)
$Z_b^{+,0}(10610)$	10607.2 ± 2.0	18.4 ± 2.4	1^{+-}	$Y_b(10860) \to \pi^{-,0}(\Upsilon(nS)\pi^{+,0})$	Belle (Bondar *et al.*, 2012; Garmash *et al.*, 2015), Belle (Krokovny *et al.*, 2013)
				$Y_b(10860) \to \pi^-(h_b(nP)\pi^+)$	Belle (Bondar *et al.*, 2012)
				$Y_b(10860) \to \pi^-(B\bar{B}^*)^+$	Belle (Garmash *et al.*, 2016)
$Z_b^+(10650)$	10652.2 ± 1.5	11.5 ± 2.2	1^{+-}	$Y_b(10860) \to \pi^-(\Upsilon(nS)\pi^+)$	Belle (Bondar *et al.*, 2012; Garmash *et al.*, 2015)
				$Y_b(10860) \to \pi^-(h_b(nP)\pi^+)$	Belle (Bondar *et al.*, 2012)
				$Y_b(10860) \to \pi^-(B^*\bar{B}^*)^+$	Belle (Garmash *et al.*, 2016)





S. Olsen, T. Skwarnicki and D. Zieminska: Rev. Mod. Phys. 90, 015003(2018)

- Rough summary of XYZ discoveries:
  - Belle: $X(3872)$, $X(3915)$, $X(3940)$, $Y(4160)$, $Y(4350)$, $Y(4660)$, $Y(4630)$, $Z_c(3900)$, $Z(4050)$, $Z(4200)$, $Z(4250)$, $Z(4430)$, $Z_b(10610)$, $Z_b(10650)$, $X(3860)^*$
  - BaBar: $Y(4260)$, $Y(4360)$ ($Y(4324)$).
  - BESIII: $Z_c(3900)$, $Y(4220)$.
  - LHCb: $P_c(4380)$, $P_c(4450)$, $X(4700)$.
- China group contributions: $Y(4008)$, $Y(4260)$, $X(4350)$, $Y(4360)$, $Y(4660)$, $Z_c(3900)$, ...

Some golden observables (I)

Pure-leptonic and semi-leptonic B decays

Process	Observable	Theory	Sys. limit (Discovery) [ab^{-1}]	vs LHCb	vs Belle	Anomaly	NP
$B \to \pi \ell \nu_l$	$\|V_{ub}\|$	⋆⋆⋆	10-20	⋆⋆⋆	⋆⋆⋆	⋆⋆	⋆
$B \to X_u \ell \nu_\ell$	$\|V_{ub}\|$	⋆⋆	2-10	⋆⋆⋆	⋆⋆	⋆⋆⋆	⋆
$B \to \tau \nu$	$Br.$	⋆⋆⋆	>50 (2)	⋆⋆⋆	⋆⋆⋆	⋆	⋆⋆⋆
$B \to \mu \nu$	$Br.$	⋆⋆⋆	>50 (5)	⋆⋆⋆	⋆⋆⋆	⋆	⋆⋆⋆
$B \to D^{(*)} \ell \nu_\ell$	$\|V_{cb}\|$	⋆⋆⋆	1-10	⋆⋆⋆	⋆⋆	⋆⋆	⋆
$B \to X_c \ell \nu_\ell$	$\|V_{cb}\|$	⋆⋆⋆	1-5	⋆⋆⋆	⋆⋆	⋆⋆	⋆⋆
$B \to D^{(*)} \tau \nu_\tau$	$R(D^{(*)})$	⋆⋆⋆	5-10	⋆⋆	⋆⋆⋆	⋆⋆⋆	⋆⋆⋆
$B \to D^{(*)} \tau \nu_\tau$	P_τ	⋆⋆⋆	15-20	⋆⋆⋆	⋆⋆⋆	⋆⋆	⋆⋆⋆
$B \to D^{**} \ell \nu_\ell$	$Br.$	⋆	-	⋆⋆	⋆⋆⋆	⋆⋆	-

Time dependent CPV

$B \to J/\psi K_S$	ϕ_1	⋆⋆⋆	5-10	⋆⋆	⋆⋆	⋆	⋆
$B \to \phi K_S$	ϕ_1	⋆⋆	>50	⋆⋆	⋆⋆⋆	⋆	⋆⋆⋆
$B \to \eta' K_S$	ϕ_1	⋆⋆	>50	⋆⋆	⋆⋆⋆	⋆	⋆⋆⋆
$B \to J/\psi \pi^0$	ϕ_1	⋆⋆⋆	>50	⋆	⋆⋆⋆	–	–
$B \to \rho^\pm \rho^0$	ϕ_2	⋆⋆⋆	–	⋆	⋆⋆⋆	⋆	⋆
$B \to \pi^0 \pi^0$	ϕ_2	⋆⋆	>50	⋆⋆⋆	⋆⋆⋆	⋆⋆	⋆⋆
$B \to \pi^0 K_S$	S_{CP}	⋆⋆	>50	⋆⋆⋆	⋆⋆⋆	⋆⋆	⋆⋆

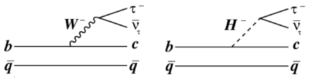
Some golden observables (II)

Radiative and electroweak penguin B decays

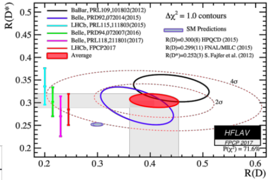
Process	Observable	Theory	Sys. limit (Discovery) [ab^{-1}]	vs LHCb	vs Belle	Anomaly	NP
$B \to K^{(*)}\nu\nu$	$Br., F_L$	⋆⋆⋆	>50	⋆⋆⋆	⋆⋆⋆	⋆	⋆⋆
$B \to X_{s+d}\gamma$	$A_{\rm CP}$	⋆⋆⋆	>50	⋆⋆⋆	⋆⋆⋆	⋆	⋆⋆
$B \to X_d\gamma$	$A_{\rm CP}$	⋆⋆	>50	⋆⋆⋆	⋆⋆⋆	-	⋆⋆
$B \to K_S\pi^0\gamma$	$S_{K_S\pi^0\gamma}$	⋆⋆	>50	⋆⋆	⋆⋆⋆	⋆	⋆⋆⋆
$B \to \rho\gamma$	$S_{\rho\gamma}$	⋆⋆	>50	⋆⋆⋆	⋆⋆⋆	-	⋆⋆⋆
$B \to X_s l^+l^-$	$Br.$	⋆⋆⋆	>50	⋆⋆⋆	⋆⋆	⋆⋆	⋆⋆⋆
$B \to X_s l^+l^-$	R_{X_s}	⋆⋆⋆	>50	⋆⋆⋆	⋆⋆⋆	⋆⋆	⋆⋆⋆
$B \to K^{(*)}e^+e^-$	$R(K^{(*)})$	⋆⋆⋆	>50	⋆⋆	⋆⋆⋆	⋆⋆⋆	⋆⋆⋆
$B \to X_s\gamma$	$Br.$	⋆⋆	1-5	⋆⋆⋆	⋆	⋆	⋆⋆
$B_{d,(s)} \to \gamma\gamma$	$Br., A_{\rm CP}$	⋆⋆	> 50(5)	⋆⋆	⋆⋆	-	⋆⋆
$B \to K^*e^+e^-$	P_5'	⋆⋆	>50	⋆⋆⋆	⋆⋆	⋆⋆⋆	⋆⋆⋆
$B \to K\tau l$	$Br.$	⋆⋆⋆	>50	⋆⋆	⋆⋆⋆	⋆⋆	⋆⋆⋆

$B \to D^{(*)} l\nu$: challenge to lepton universality

- Theoretically clean channel in SM
- Charged Higgs can contribute to the decay
- $R(D^{(*)})$ is sensitive parameter to BSM!

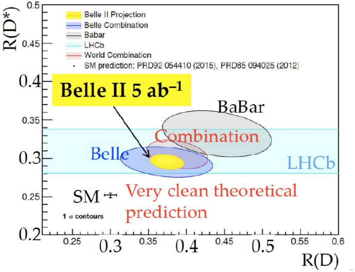


$$R(D^{(*)}) = \frac{Br(B \to D^{(*)}\tau\nu)}{Br(B \to D^{(*)}\mu\nu)}$$



	Exp	SM
$R(D^*)$	0.304±0.013±0.007	0.252±0.003
$R(D)$	0.407±0.039±0.024	0.300±0.008

4.1σ away from the SM

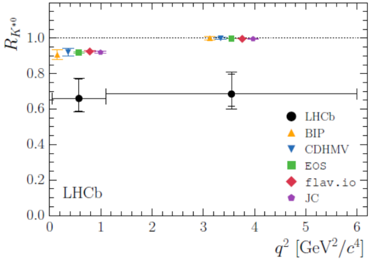


Belle II should be able to confirm the excess with ~5ab⁻¹ data

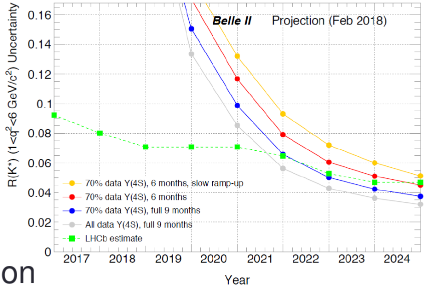
$B \to K^* \ell^+ \ell^-$: yet another smoking gun

- Interesting discrepancy as well as measured in P5'

JHEP 08 (2017) 055



$$R(K^*) = \frac{BR(K^* \mu\mu)}{BR(K^* ee)}$$



Note: LHCb value is extrapolated from run-1 result

- Belle II: good electron identification

  K*ee: ~200 events/ab^{-1}
  K*μμ: ~280 events/ab^{-1}

Data samples and expected signals based on NRQCD

TABLE I: The numbers of expected events in $e^+e^- \to \gamma\chi_{cJ}$ and $e^+e^- \to \gamma\eta_c$ at $\sqrt{s} = 10.52$, 10.58 and 10.867 GeV.

Channel	$\sqrt{s}$ GeV	σ_B (fb) predicted in Ref. [12] by NRQCD with all leading relativistic corrections included	$\mathcal{L}$ (fb^{-1})	$\mathcal{B}_{decay}$ ($\times 10^{-4}$)	ε(%)	$N_{expected}$
$e^+e^- \to \gamma\chi_{c0}$		1.4		7.6	19.0	0.1
$e^+e^- \to \gamma\chi_{c1}$	10.52	15.5	89.5	202.1	20.8	5.8
$e^+e^- \to \gamma\chi_{c2}$		4.7		114.4	19.9	1.0
$e^+e^- \to \gamma\chi_{c0}$		1.4		7.6	18.9	0.1
$e^+e^- \to \gamma\chi_{c1}$	10.58	15.1	711.0	202.1	19.9	43.2
$e^+e^- \to \gamma\chi_{c2}$		4.5		114.4	19.8	7.2
$e^+e^- \to \gamma\chi_{c0}$		1.3		7.6	17.7	0.1
$e^+e^- \to \gamma\chi_{c1}$	10.867	13.5	121.4	202.1	16.8	5.6
$e^+e^- \to \gamma\chi_{c2}$		4.0		114.4	16.3	0.9

Channel	$\sqrt{s}$ GeV	σ_B (fb) by LO QCD/σ_B (fb) by NLO QCD in Ref. [14]	$\mathcal{L}$ (fb^{-1})	$\Sigma_i \mathcal{B}_i \varepsilon_i$(%)	$N_{expected}$
$e^+e^- \to \gamma\eta_c$	10.52	0.38/0.13	89.5	0.79	0.3/0.1
$e^+e^- \to \gamma\eta_c$	10.58	0.37/0.12	711.0	0.78	2.1/0.7
$e^+e^- \to \gamma\eta_c$	10.867	0.32/0.10	121.4	0.76	0.3/0.1