Charm Physics at Belle and Belle II

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on behalf of the Belle and Belle II collaborations

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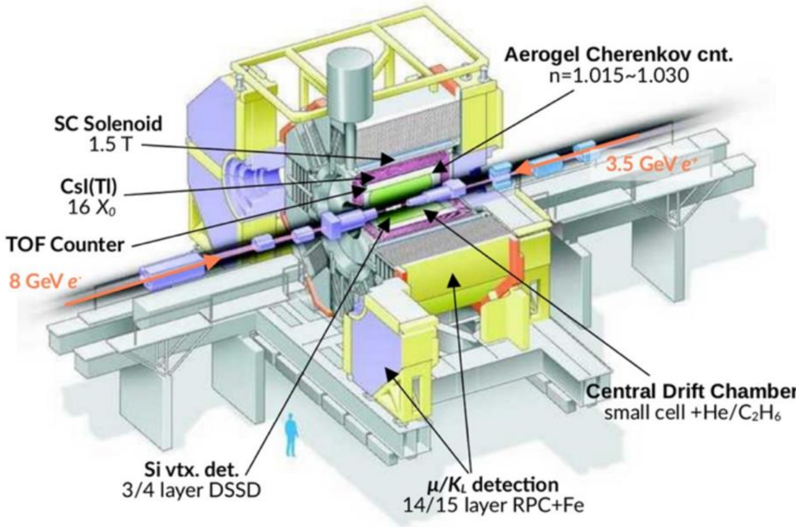
Outline

- Belle and Belle II experiments
- Charmed mesons
  - Search for *CP* violation in $D^+_{(s)} \to K^0_S K^- \pi^+ \pi^-$ decays
    Belle + Belle II [arXiv: 2409.15777]
  - Time-integrated *CP* asymmetry in $D^0 \to K^0_S K^0_S$ decays
    Belle + Belle II [PRD 111, 012015 (2025)]
  - D^0-$\overline{D}^0$ mixing parameters in $D^0 \to K^0_S \pi^+ \pi^-$ decays
    Belle + Belle II [arXiv: 2410.22961]
- Charmed baryons
  - Two-body decays of Ξ^0_c and Ξ^+_c
    Belle + Belle II [JHEP 10 045 (2024); arXiv: 2412.10677; PRELIMINARY]
- Summary

Belle and Belle II experiments

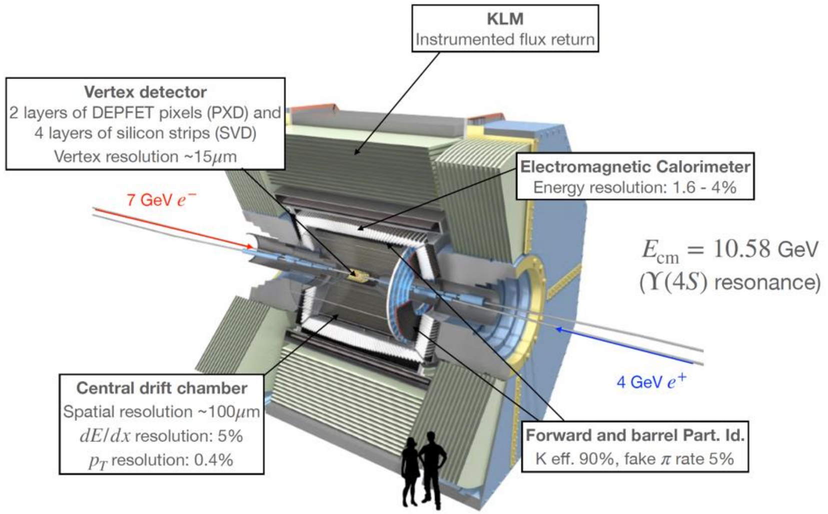
- Belle and Belle II collect(ed) data at asymmetric e^+e^- colliders at of near the $\Upsilon(4S)$ resonance.
  - ✓ KEKB (1999-2010), Peak luminosity $=2.1 \times 10^{34}\mathrm{cm}^{-2}\mathrm{s}^{-1}$, $\mathrm{L}_{\mathrm{int}} \sim 1\ \mathrm{ab}^{-1}$.
  - ✓ SuperKEKB (2019~), Peak luminosity $=5.1 \times 10^{34}\mathrm{cm}^{-2}\mathrm{s}^{-1}$, Run 1(2019-2022): $\mathrm{L}_{\mathrm{int}} \sim 427\ \mathrm{fb}^{-1}$; Run 2(2024~): $\mathrm{L}_{\mathrm{int}} \sim 150\ \mathrm{fb}^{-1}$.

BELLE@KEKB



- Belle and Belle II are now **synergic** experiments.
  - ✓ Belle data can be analyzed within the Belle II software framework.
  - ✓ Common review procedures since summer of 2023.
  - ✓ Especially important for charm analyses, where large statistics is crucial to improve the precision.

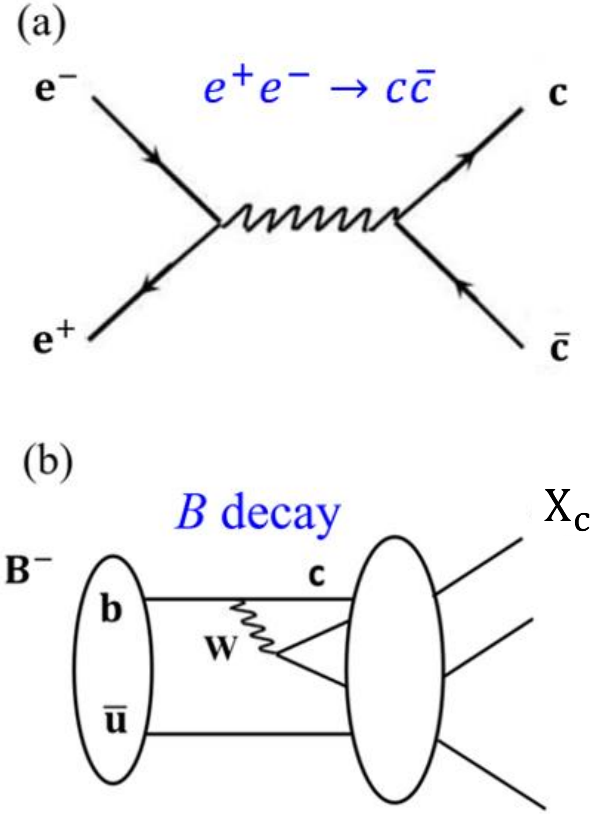
BELLE II @SuperKEKB



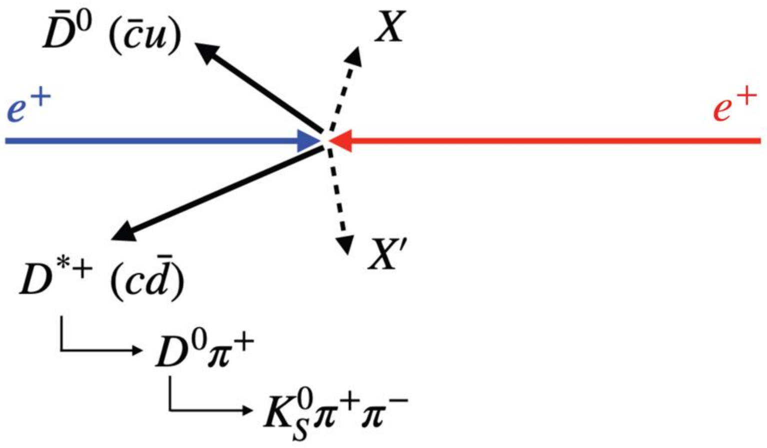
Streamlines combined analyses

Charm physics at Belle (II)

- Two ways to produce the charm hadrons at B-factories:
- Two charmed hadrons produced from continuum, along with fragmentation particles: $e^+e^- \to c\bar{c} \to X_c$, $\sigma(e^+e^- \to c\bar{c})$~1.3nb @ $\sqrt{s} = 10.58$ GeV.
- One or more charmed hadrons produced in B mesons decays: $e^+e^- \to \Upsilon(4S) \to B\bar{B} \to X_c$.



$$\mathbf{e^+e^- \to c\bar{c} \to D_{tag}X_{frag}D_{sig}}$$



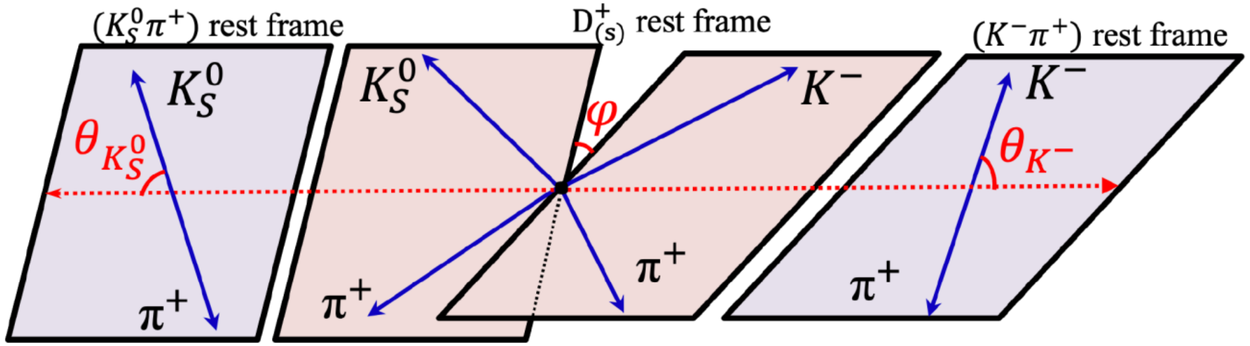
No entanglement between two charmed hadrons, inaccessible strong phase.

- Full topics for charm physics:
  - *CP* violation
  - D^0-$\bar{D}^0$ mixing
  - Lifetimes of charm hadrons
  - Rare decay
  - Charmed baryons
  - …

Search for *CP* violation in $D^+_{(s)} \to K^0_S K^- \pi^+ \pi^-$ decays

- First search for *CP* violation in $D^+_{(s)} \to K^0_S K^- \pi^+ \pi^+$ decays using six observables (X) based on the triple product and quadruple product of the momenta of final-state particles, and the particles' helicity angles.

1. Triple-product (TP) $C_{TP} = \vec{p}_{K^-} \cdot (\vec{p}_{K^0_S} \times \vec{p}_{\pi^+_l})$
2. Quadruple-product (QP) $C_{QP} = (\vec{p}_{K^-} \times \vec{p}_{\pi^+_h}) \cdot (\vec{p}_{K^0_S} \times \vec{p}_{\pi^+_l})$
3. $C_{TP} C_{QP}$
4. $\cos\theta_{K^0_S} \cos\theta_{K^-}$
5. $\cos\theta_{K^0_S} \cos\theta_{K^-} C_{TP}$
6. $\cos\theta_{K^0_S} \cos\theta_{K^-} C_{QP}$



Belle + Belle II~1.4/ab arXiv: 2409.15777

✓ The asymmetries about zero for both $D^+_{(s)}$ and $D^-_{(s)}$:

$$A_X(D^+_{(s)}) = \frac{N(X>0) - N(X<0)}{N(X>0) + N(X<0)}$$

$$\bar{A}_{\bar{X}}(D^-_{(s)}) = \frac{\bar{N}(\bar{X}>0) - \bar{N}(\bar{X}<0)}{\bar{N}(\bar{X}>0) + \bar{N}(\bar{X}<0)}$$

A_X and $\bar{A}_{\bar{X}}$ are *CP*-conjugate quantities.

✓ *CP*-violating parameter

$$A^X_{CP} = \frac{A_X(D^+_{(s)}) - \bar{A}_{\bar{X}}(D^-_{(s)})}{2}$$

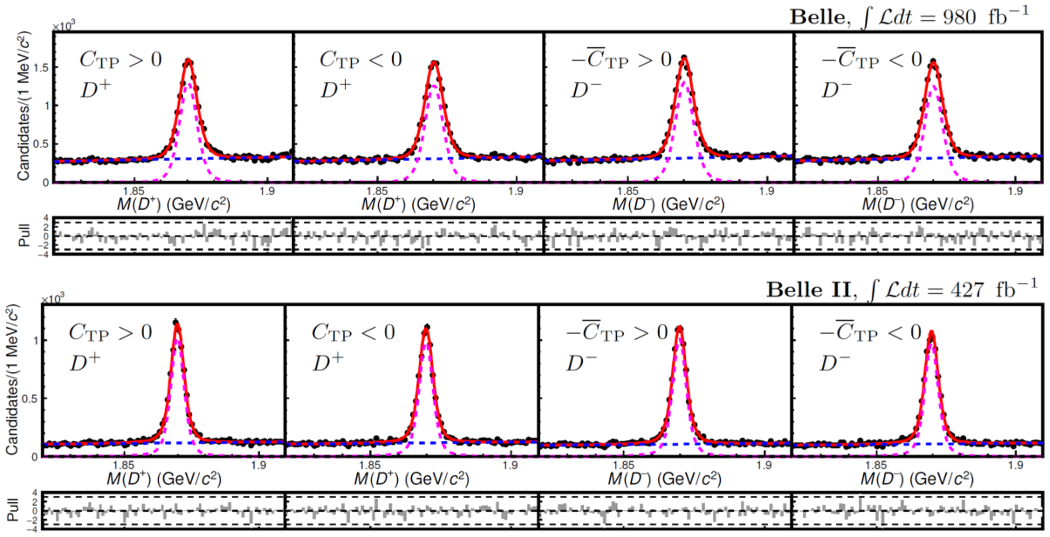
$A^X_{CP} \neq 0$ indicates *CP* violation

Search for *CP* violation in $D^+_{(s)} \to K^0_S K^- \pi^+ \pi^-$ decays

- The A^X_{CP} is extracted by performing a simultaneous fit to the $M(D_{(s)})$ distributions of four subsamples as determined by the charge of $D_{(s)}$ and the sign of X.

- $N(D^+_{(s)}, X > 0) = \frac{N_+}{2}(1 + A_X)$
- $N(D^+_{(s)}, X < 0) = \frac{N_+}{2}(1 - A_X)$
- $N(D^-_{(s)}, \overline{X} > 0) = \frac{N_-}{2}(1 + A_X - 2A^X_{CP})$
- $N(D^-_{(s)}, \overline{X} < 0) = \frac{N_-}{2}(1 - A_X + 2A^X_{CP})$

D decay, $X = C_{TP}$ for an example



Belle + Belle II~1.4/ab arXiv: 2409.15777

✓ No evidence for CPV is found (A^X_{CP} in units of 10^{-3}).

	X	A^X_{CP} Belle	A^X_{CP} Belle II	Combined A^X_{CP}	Significance
D^+	C_{TP}	$-4.0 \pm 5.9 \pm 3.0$	$-0.2 \pm 7.0 \pm 1.8$	$-2.3 \pm 4.5 \pm 1.5$	0.5σ
	C_{QP}	$-1.0 \pm 5.9 \pm 2.5$	$-0.4 \pm 7.0 \pm 2.4$	$-0.7 \pm 4.5 \pm 1.7$	0.2σ
	$C_{TP}\,C_{QP}$	$+6.4 \pm 5.9 \pm 2.2$	$+0.6 \pm 7.0 \pm 1.3$	$+3.9 \pm 4.5 \pm 1.1$	0.8σ
	$\cos\theta_{K^0_S}\cos\theta_{K^-}$	$-4.7 \pm 5.9 \pm 3.0$	$-0.6 \pm 6.9 \pm 3.0$	$-2.9 \pm 4.5 \pm 2.1$	0.6σ
	$C_{TP}\cos\theta_{K^0_S}\cos\theta_{K^-}$	$+1.9 \pm 5.9 \pm 2.0$	$-0.2 \pm 7.0 \pm 1.9$	$+1.0 \pm 4.5 \pm 1.4$	0.2σ
	$C_{QP}\cos\theta_{K^0_S}\cos\theta_{K^-}$	$+14.9 \pm 5.9 \pm 1.4$	$+7.0 \pm 7.0 \pm 1.6$	$+11.6 \pm 4.5 \pm 1.1$	2.5σ
D^+_s	C_{TP}	$-0.3 \pm 3.1 \pm 1.3$	$+1.0 \pm 3.9 \pm 1.1$	$+0.2 \pm 2.4 \pm 0.8$	0.1σ
	C_{QP}	$+0.6 \pm 3.1 \pm 1.2$	$+2.0 \pm 3.9 \pm 1.4$	$+1.1 \pm 2.4 \pm 0.9$	0.4σ
	$C_{TP}\,C_{QP}$	$+1.5 \pm 3.2 \pm 1.4$	$-2.7 \pm 3.9 \pm 1.7$	$-0.2 \pm 2.5 \pm 1.1$	0.1σ
	$\cos\theta_{K^0_S}\cos\theta_{K^-}$	$-3.7 \pm 3.1 \pm 1.1$	$-6.3 \pm 3.9 \pm 1.2$	$-4.7 \pm 2.4 \pm 0.8$	1.8σ
	$C_{TP}\cos\theta_{K^0_S}\cos\theta_{K^-}$	$-4.4 \pm 3.2 \pm 1.4$	$+0.8 \pm 3.9 \pm 1.4$	$-2.2 \pm 2.5 \pm 1.0$	0.8σ
	$C_{QP}\cos\theta_{K^0_S}\cos\theta_{K^-}$	$-1.6 \pm 3.1 \pm 1.3$	$-0.0 \pm 3.9 \pm 1.7$	$-1.0 \pm 2.4 \pm 1.0$	0.4σ

- Most precise measurements of triple-product asymmetry for D^+_s decays and for SCS D^+ decays.
- The first use of the other A^X_{CP} asymmetries to search for *CP* violation in the charm sector.

Time-integrated *CP* asymmetry in $D^0 \to K_S^0 K_S^0$

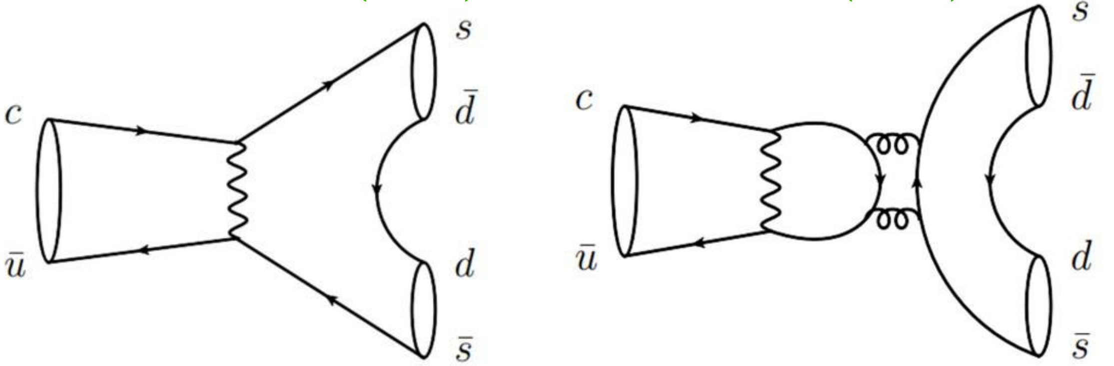
- The $D^0 \to K_S^0 K_S^0$ is a singly Cabibbo-suppressed decay, which involves the interference between $c \to us\bar{s}$ and $c \to ud\bar{d}$ amplitudes.

Belle + Belle II~1.4/ab PRD 111 012015 (2025)

- Such interference can generate *CP* asymmetries at the 1% level.

[PRD 99, 113001 (2019); PRD 92, 054036 (2015)]

- The world-average value of the *CP* asymmetry, $A_{CP}(D^0 \to K_S^0 K_S^0)$: $(-1.9 \pm 1.0)\%$, is limited by statistic



$$A_{CP} \equiv \frac{\Gamma(D^0 \to K_S^0 K_S^0) - \Gamma(\bar{D}^0 \to K_S^0 K_S^0)}{\Gamma(D^0 \to K_S^0 K_S^0) + \Gamma(\bar{D}^0 \to K_S^0 K_S^0)}$$

- Γ is the time-integrated decay rate.

- Experiment extraction on A_{CP}: taking $D^0 \to K^+K^-$ as a control mode to correct for production and detection asymmetries

$$A_{raw} = \frac{N_{D^0} - N_{\bar{D}^0}}{N_{D^0} + N_{\bar{D}^0}},$$ tagged with $D^{*+} \to D^0 \pi^+$ decays

$$A_{CP}^{K_S^0 K_S^0} = \left(A_{raw}^{K_S^0 K_S^0} - A_{raw}^{K^+K^-}\right) + A_{CP}^{K^+K^-}$$

$$A_{CP}^{K^+K^-} = A_{CP}^{dir}(D^0 \to K^+K^-) + \Delta Y = (6.7 \pm 5.4) \times 10^{-4}$$

[PRL 131, 091802 (2023); PRD 104, 072010 (2021)]

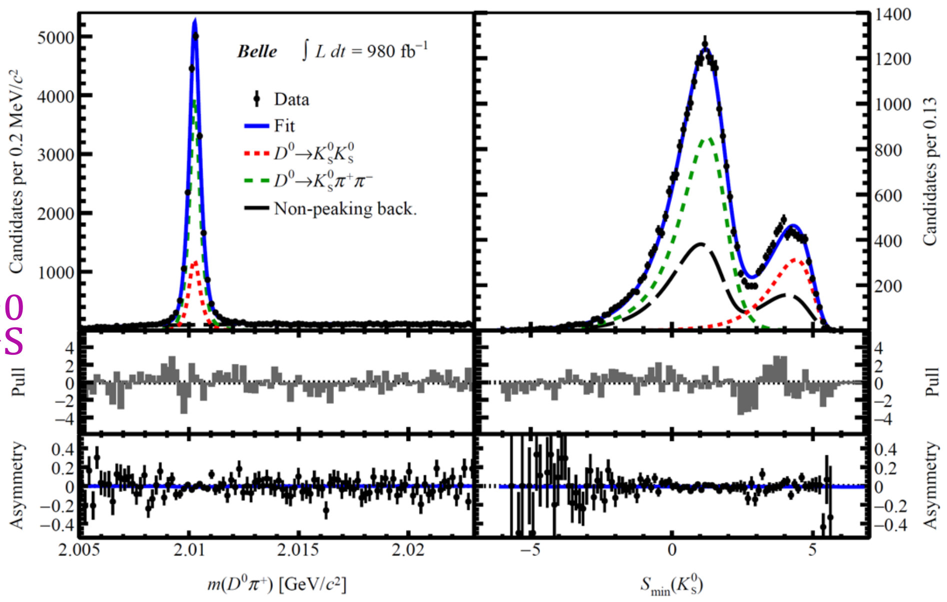
Time-integrated *CP* asymmetry in $D^0 \to K_S^0 K_S^0$

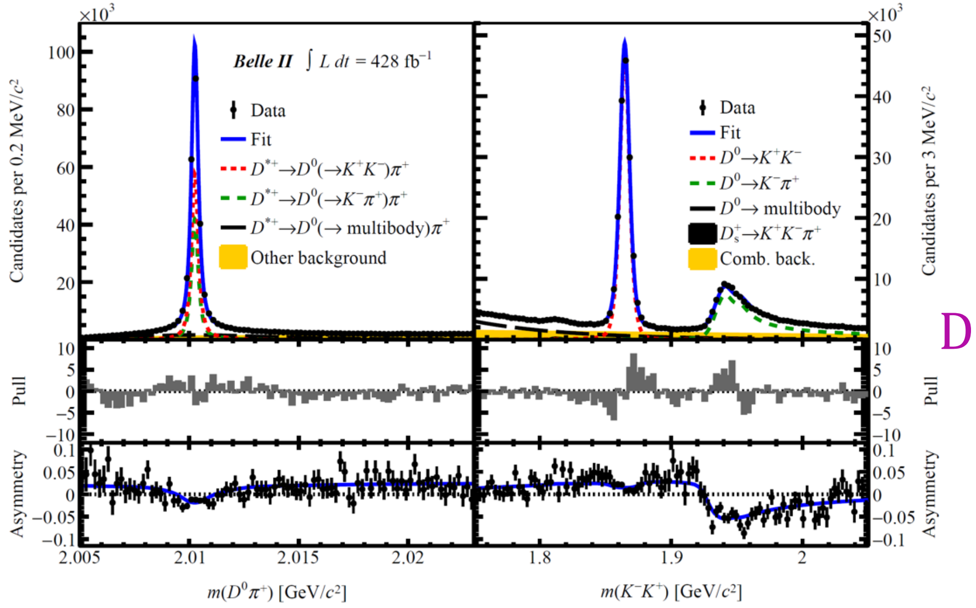
- We determine the signal yield and raw asymmetry by fitting to the $m(D^0\pi^+)$ and $S_{min}(K_S^0)$ distributions, simultaneously for D^{*+} and D^{*-} candidates.

Belle + Belle II~1.4/ab PRD 111 012015 (2025)

- $S_{min}(K_S) = \log[\min(L_1/\sigma_{L1},\ L_2/\sigma_{L2})]$from two K_S(sperate peaking background $D^0 \to K_S^0\pi^+\pi^-$;
- The raw asymmetry of control channel is extracted by fitting to the $m(D^0\pi^+)$ and $m(K^+K^-)$.

$D^0 \to K_S^0 K_S^0$





$D^0 \to K^+K^-$

Belle: $A_{CP}(D^0 \to K_S^0 K_S^0) = (-1.1 \pm 1.6 \pm 0.1)\%$,

Belle II: $A_{CP}(D^0 \to K_S^0 K_S^0) = (-2.2 \pm 2.3 \pm 0.1)\%$,

Belle + Belle II: $A_{CP}(D^0 \to K_S^0 K_S^0) = (-1.4 \pm 1.3 \pm 0.1)\%$

LHCb: $A_{CP}(D^0 \to K_S^0 K_S^0) = (-3.1 \pm 1.2 \pm 0.4 \pm 0.2)\%$

[PRD 104, L031102 (2021)]

D^0-$\bar{D}^0$ mixing parameters in $D^0 \to K_S^0\pi^+\pi^-$ decays

Belle + Belle II~1.3/ab arXiv: 2410.22961

- D^0-$\bar{D}^0$ mixing parameters:

$$x = \frac{m_1 - m_2}{\Gamma} \qquad y = \frac{\Gamma_1 - \Gamma_2}{2\Gamma}$$

Mass of the $D_{1/2}$ state — Width of the $D_{1/2}$ state

Mass eigenstates:

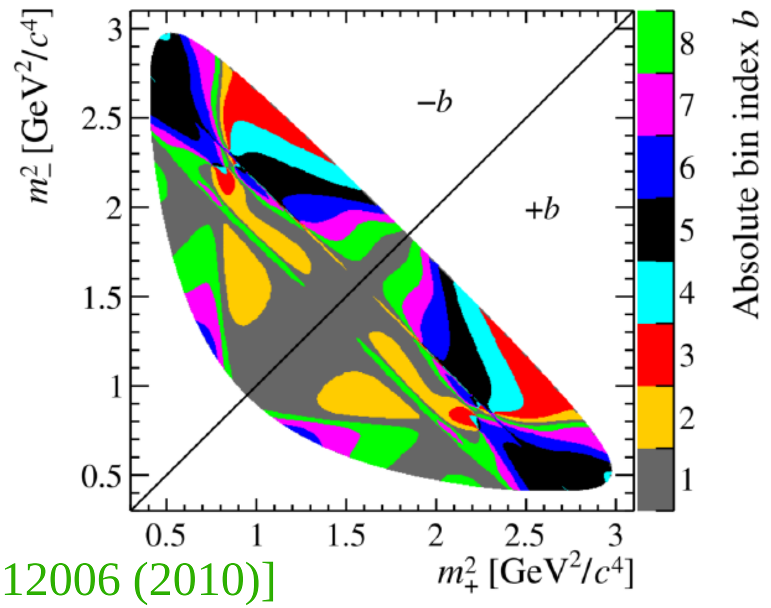
$$|D_{1,2}> = p|D^0> + q|\bar{D}^0>$$

$$|p|^2 + |q|^2 = 1$$

- World average values: $x = (4.07 \pm 0.44) \times 10^{-3}$ $\quad |q/p| = 0.994^{+0.016}_{-0.015}$ [PRD 107 052008 (2023)]

  $y = (6.45^{+0.24}_{-0.23}) \times 10^{-3}$ $\quad \arg(q/p) = (-2.6^{+1.1}_{-1.2})°$

- By splitting the Dalitz plot into bins, the need for an explicit amplitude model is avoided.
- Using combined Belle and Belle II datasets, we perform a model-independent measurement of the D^0 - $\bar{D}^0$ mixing parameters using D^{*+}-tagged $D^0 \to K_S^0\pi^+\pi^-$ decays.



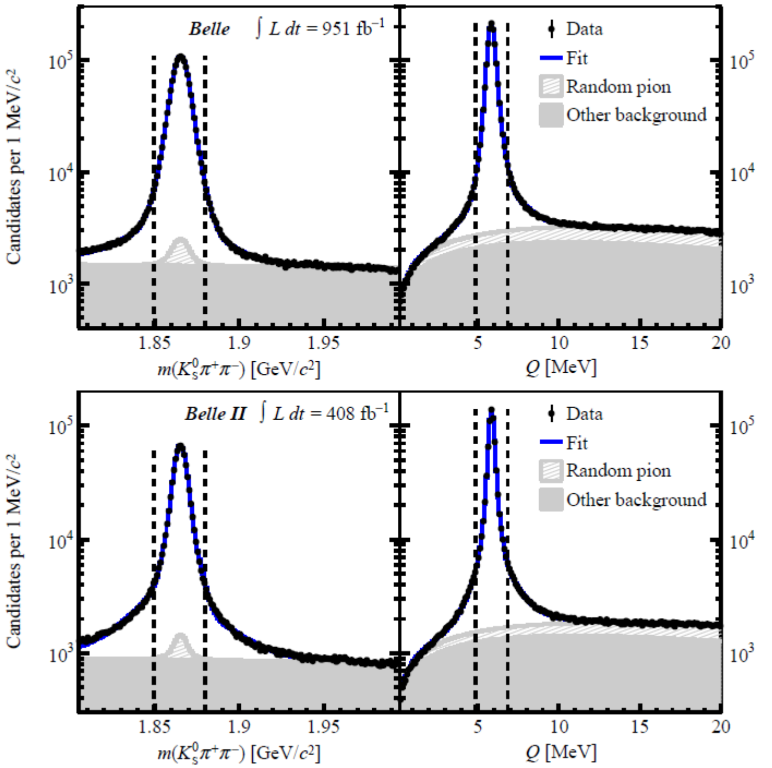
[PRD 82 112006 (2010)]

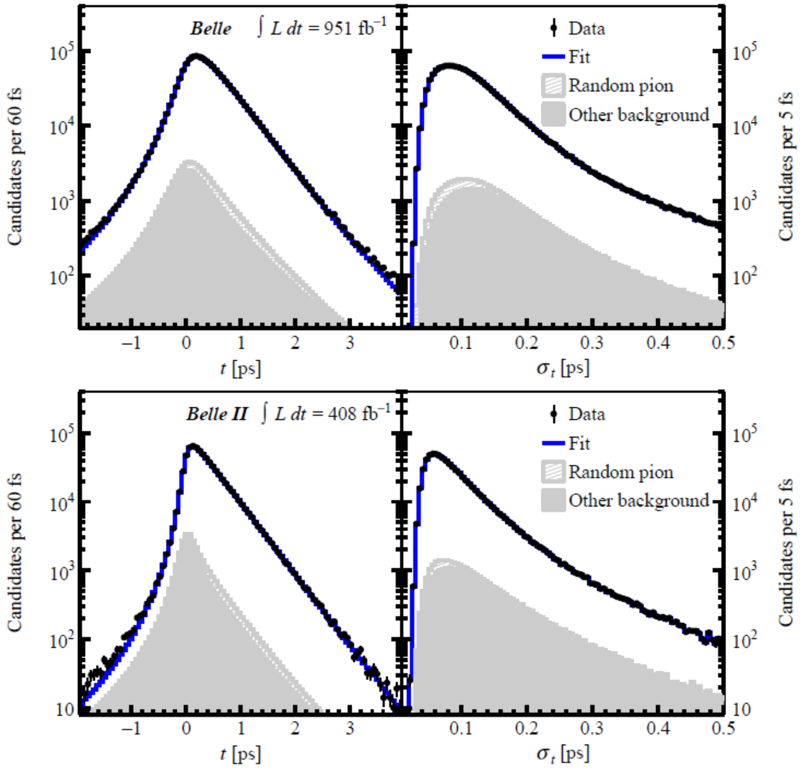
D^0-$\bar{D}^0$ mixing parameters in $D^0 \to K_S^0\pi^+\pi^-$ decays

- Signal and background are separated using fits to the two-dimensional distribution of D^0 mass and energy released Q in the D^{*+}.

Belle + Belle II~1.3/ab arXiv: 2410.22961

- The mixing parameters are determined using an unbinned maximum-likelihood fit to the (t, σ_t) distributions of the candidates populating the signal region and split into the 16 Dalitz plot bins.





Sample average purity 95.8%

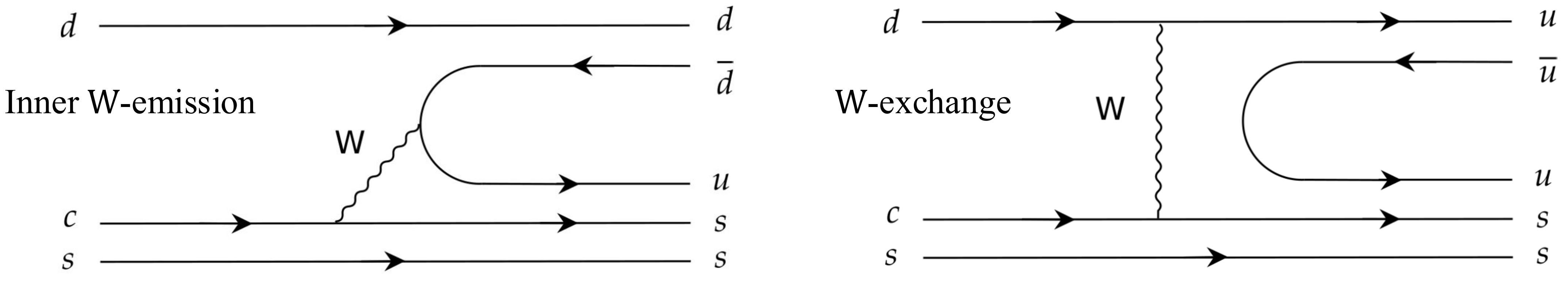
$$x = (4.0 \pm 1.7 \pm 0.4) \times 10^{-3}$$
$$y = (2.9 \pm 1.4 \pm 0.3) \times 10^{-3}$$

These results are about 20% and 14% more precise than the model-dependent Belle measurement!

[PRD 89 091103 (2014)]

Study of two-body decays of Ξ_c^0 and Ξ_c^+

- In hadronic weak decays of charmed baryons, nonfactorizable contributions play a crucial role and pose significant challenges for theoretical predictions.



- In 2019, Belle measured the absolute branching fractions of $\Xi_c^0 \to \Xi^-\pi^+$[1] and $\Xi_c^+ \to \Xi^-\pi^+\pi^+$[2], sparking renewed interest in the study of Ξ_c^0 and Ξ_c^+ decays.
- Theoretical calculations for the two-body hadronic weak decays of Ξ_c^0 and Ξ_c^+ have been performed based on dynamical model calculations and SU(3) flavor symmetry methods [3-9].
- Using the combined data from Belle and Belle II to search for new decay modes of Ξ_c^0 and Ξ_c^+, and to validate different theoretical models.

[1] PRL 122 (2019) 082001; [2] PRD 100 (2019) 031101; [3] PLB 794 (2019) 19; [4] PRD 101 (2020) 014011; [5] JHEP 02 (2020) 165; [6] JHEP 09 (2022) 35; [7] JHEP 03 (2022) 143; [8] PRD 108 (2023) 053004; [9] JHEP 02 (2023) 235…

Observations of $\Xi_c^0 \to \Xi^0 h^0, h^0 = \pi^0/\eta/\eta'$

- The Cabibbo-favored decays $\Xi_c^0 \to \Xi^0\pi^0$, $\Xi^0\eta$, and $\Xi^0\eta'$ are observed for the first time.
- Taking the $\Xi_c^0 \to \Xi^-\pi^+$ as the normalization mode, the ratios of branching fractions are measured to be:

$$\frac{\mathcal{B}(\Xi_c^0 \to \Xi^0\pi^0)}{\mathcal{B}(\Xi_c^0 \to \Xi^-\pi^+)} = (0.48 \pm 0.02 \pm 0.03)$$

$$\frac{\mathcal{B}(\Xi_c^0 \to \Xi^0\eta)}{\mathcal{B}(\Xi_c^0 \to \Xi^-\pi^+)} = (0.11 \pm 0.01 \pm 0.01)$$

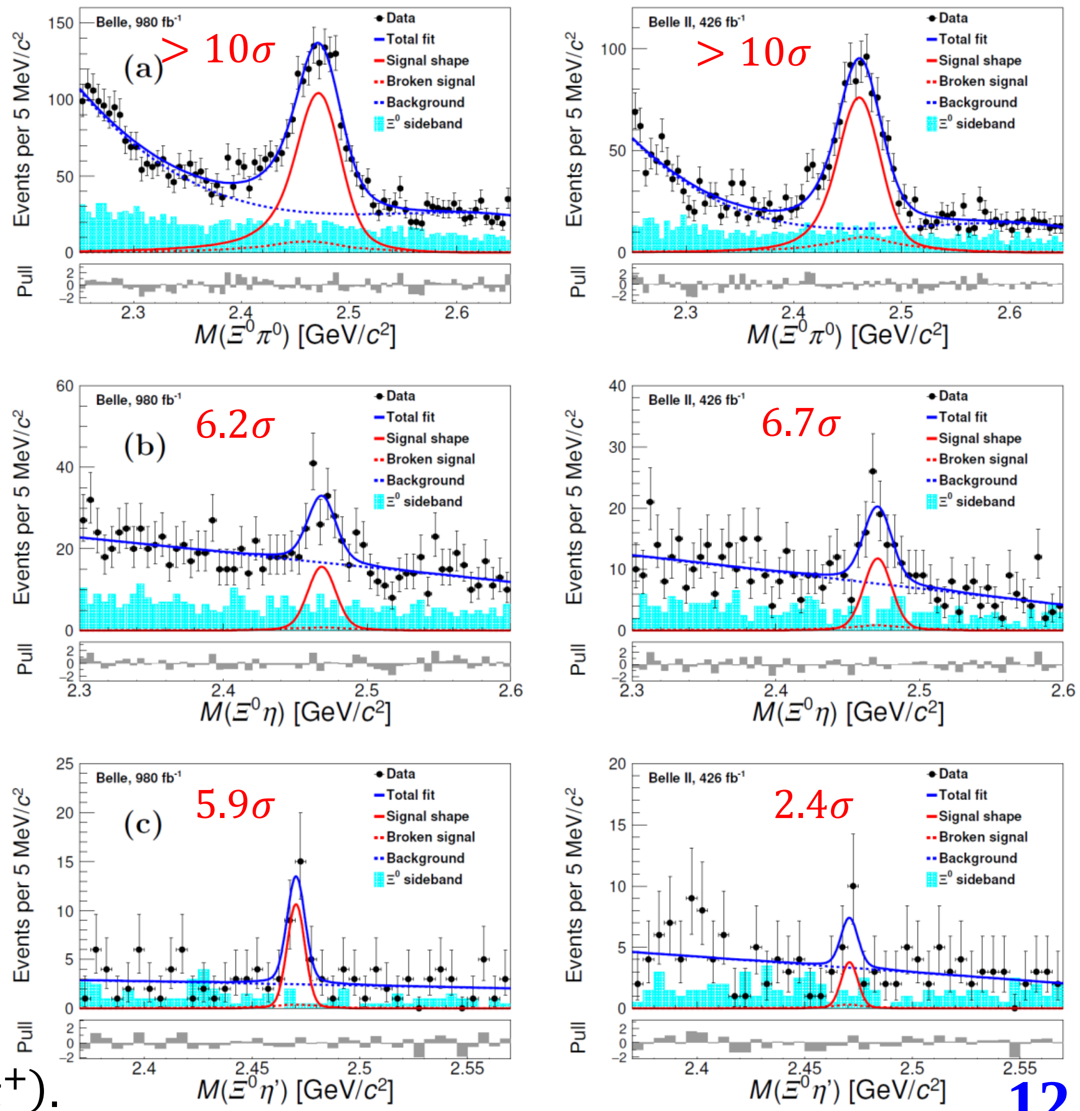
$$\frac{\mathcal{B}(\Xi_c^0 \to \Xi^0\eta')}{\mathcal{B}(\Xi_c^0 \to \Xi^-\pi^+)} = (0.08 \pm 0.02 \pm 0.01)$$

- Taking $\mathcal{B}(\Xi_c^0 \to \Xi^-\pi^+) = (1.43 \pm 0.32)\%$, we obtain

$$\mathcal{B}(\Xi_c^0 \to \Xi^0\pi^0) = (6.9 \pm 0.3 \pm 0.5 \pm 1.5) \times 10^{-3}$$
$$\mathcal{B}(\Xi_c^0 \to \Xi^0\eta) = (1.6 \pm 0.2 \pm 0.2 \pm 0.4) \times 10^{-3}$$
$$\mathcal{B}(\Xi_c^0 \to \Xi^0\eta') = (1.2 \pm 0.3 \pm 0.1 \pm 0.3) \times 10^{-3}$$

The first and second uncertainties above are statistical and systematic, respectively, while the third ones arise from the uncertainty in $\mathcal{B}(\Xi_c^0 \to \Xi^-\pi^+)$.

Belle + Belle II~1.4/ab JHEP 10 (2024) 045



Measurement of α asymmetry of $\Xi_c^0 \to \Xi^0\pi^0$

- The interference between the parity-violating and parity-conserving amplitudes leads to an asymmetry in the angular decay distribution, quantified by the parameter α:

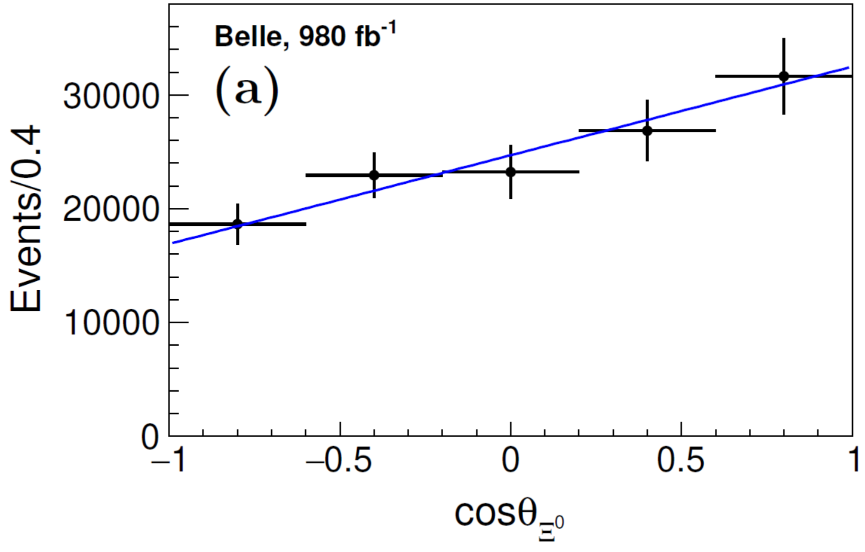
$$\frac{dN}{d\cos\theta_{\Xi^0}} \propto 1 + \alpha(\Xi_c^0 \to \Xi^0\pi^0)\alpha(\Xi^0 \to \Lambda\pi^0)\cos\theta_{\Xi^0}$$

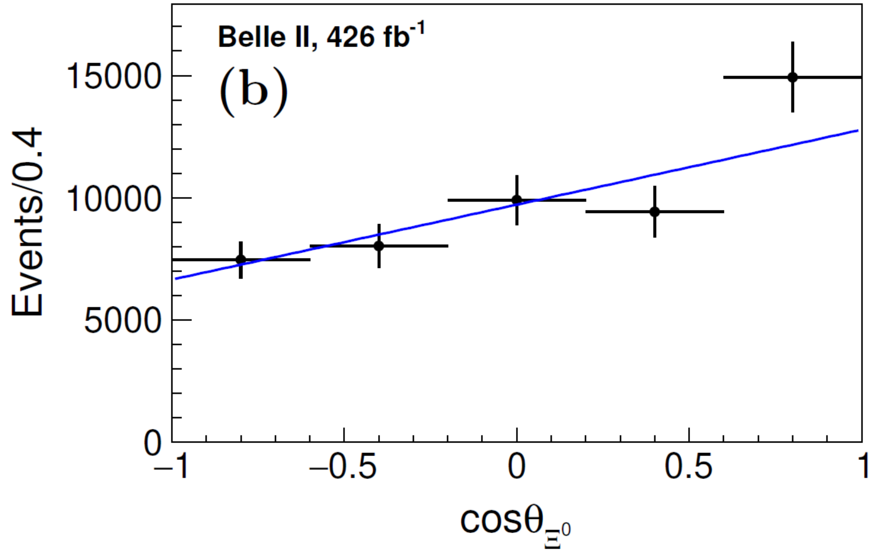
- $\alpha(\Xi^0 \to \Lambda\pi^0) = -0.349 \pm 0.009$
- θ_{Ξ^0} is the angle between the Λ momentum vector and the direction opposite to the Ξ_c^0 momentum vector in the Ξ^0 rest frame.

- By performing a simultaneous fit to Belle and Belle II data, we obtain

$$\alpha(\Xi_c^0 \to \Xi^0\pi^0) = -0.90 \pm 0.15(\text{stat.}) \pm 0.23(\text{syst.})$$

Belle + Belle II~1.4/ab JHEP 10 (2024) 045





Measurements of $\mathcal{B}(\Xi_c^+ \to pK_S^0/\Lambda\pi^+/\Sigma^0\pi^+)$

- The singly-suppressed decays $\Xi_c^+ \to pK_S^0$, $\Lambda\pi^+$, and $\Sigma^0\pi^+$ are observed for the first time.
- Taking the $\Xi_c^+ \to \Xi^-\pi^+\pi^+$ as the normalization mode, the ratios of branching fractions are measured to be:

$$\frac{\mathcal{B}(\Xi_c^+ \to pK_S^0)}{\mathcal{B}(\Xi_c^+ \to \Xi^-\pi^+\pi^+)} = (2.47 \pm 0.16 \pm 0.07)\%$$

$$\frac{\mathcal{B}(\Xi_c^+ \to \Lambda\pi^+)}{\mathcal{B}(\Xi_c^+ \to \Xi^-\pi^+\pi^+)} = (1.56 \pm 0.14 \pm 0.09)\%$$

$$\frac{\mathcal{B}(\Xi_c^0 \to \Sigma^0\pi^+)}{\mathcal{B}(\Xi_c^+ \to \Xi^-\pi^+\pi^+)} = (4.13 \pm 0.26 \pm 0.22)\%$$

- Taking $\mathcal{B}(\Xi_c^+ \to \Xi^-\pi^+\pi^+) = (2.9 \pm 1.3)\%$, we obtain

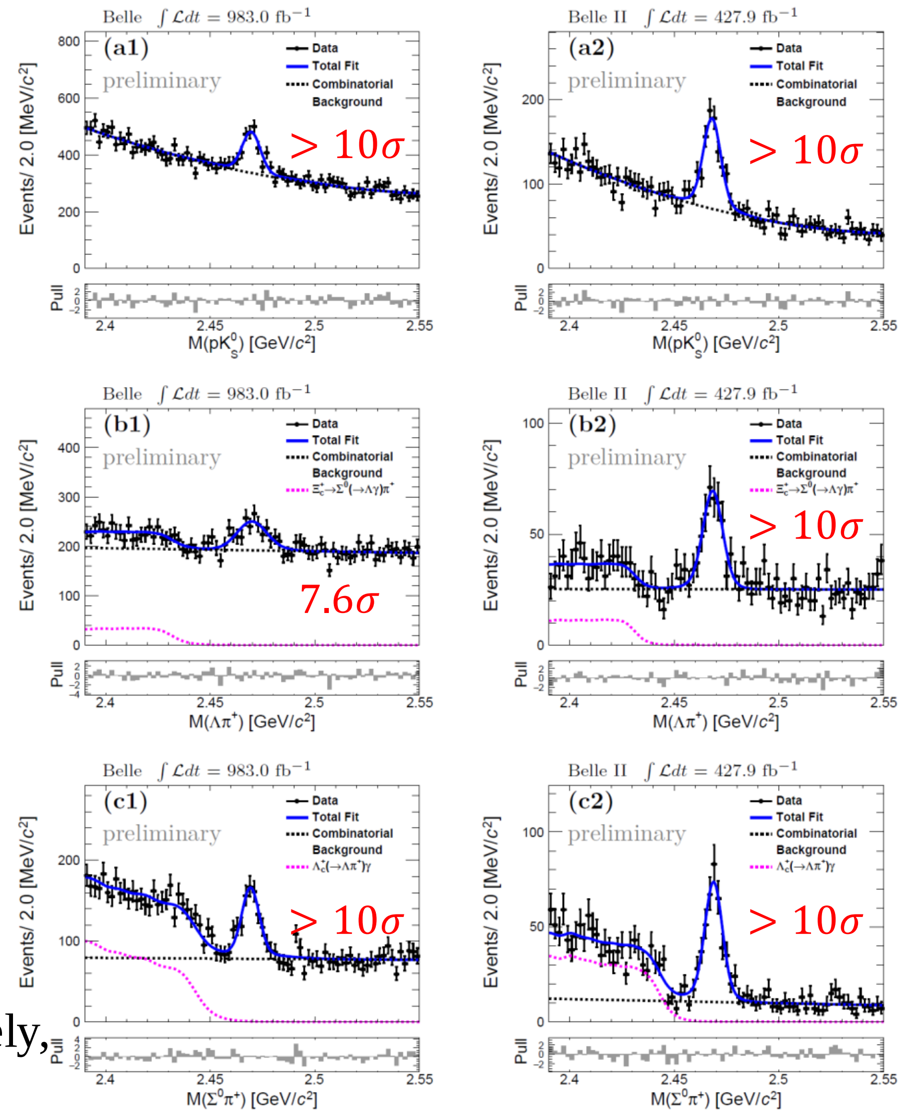
$$\mathcal{B}(\Xi_c^+ \to pK_S^0) = (7.16 \pm 0.46 \pm 0.20 \pm 3.21) \times 10^{-4}$$

$$\mathcal{B}(\Xi_c^+ \to \Lambda\pi^+) = (4.52 \pm 0.41 \pm 0.26 \pm 2.03) \times 10^{-4}$$

$$\mathcal{B}(\Xi_c^+ \to \Sigma^0\pi^+) = (1.20 \pm 0.08 \pm 0.07 \pm 0.54) \times 10^{-3}$$

The first and second uncertainties above are statistical and systematic, respectively, while the third ones arise from the uncertainty in $\mathcal{B}(\Xi_c^+ \to \Xi^-\pi^+\pi^+)$.

Belle + Belle II~1.4/ab arXiv: 2412.10677



Measurements of $\mathcal{B}(\Xi_c^+ \to \Sigma^+ K_S^0 / \Xi^0 K^+ / \Xi^0 \pi^+)$

- Taking the $\Xi_c^+ \to \Xi^-\pi^+\pi^+$ as the normalization mode, the ratios of branching fractions are measured to be

$$\frac{\mathcal{B}(\Xi_c^+ \to \Sigma^+ K_S^0)}{\mathcal{B}(\Xi_c^+ \to \Xi^-\pi^+\pi^+)} = (6.4 \pm 0.7 \pm 0.3)\% \text{ [for the first time]}$$

$$\frac{\mathcal{B}(\Xi_c^+ \to \Xi^0 K^+)}{\mathcal{B}(\Xi_c^+ \to \Xi^-\pi^+\pi^+)} = (1.6 \pm 0.2 \pm 0.1)\% \text{ [for the first time]}$$

$$\frac{\mathcal{B}(\Xi_c^+ \to \Xi^0 \pi^+)}{\mathcal{B}(\Xi_c^+ \to \Xi^-\pi^+\pi^+)} = (23.3 \pm 0.8 \pm 1.0)\%$$

- Taking $\mathcal{B}(\Xi_c^+ \to \Xi^-\pi^+\pi^+) = (2.9 \pm 1.3)\%$, we obtain

$$\mathcal{B}(\Xi_c^+ \to \Sigma^+ K_S^0) = (1.86 \pm 0.20 \pm 0.08 \pm 0.83) \times 10^{-3}$$

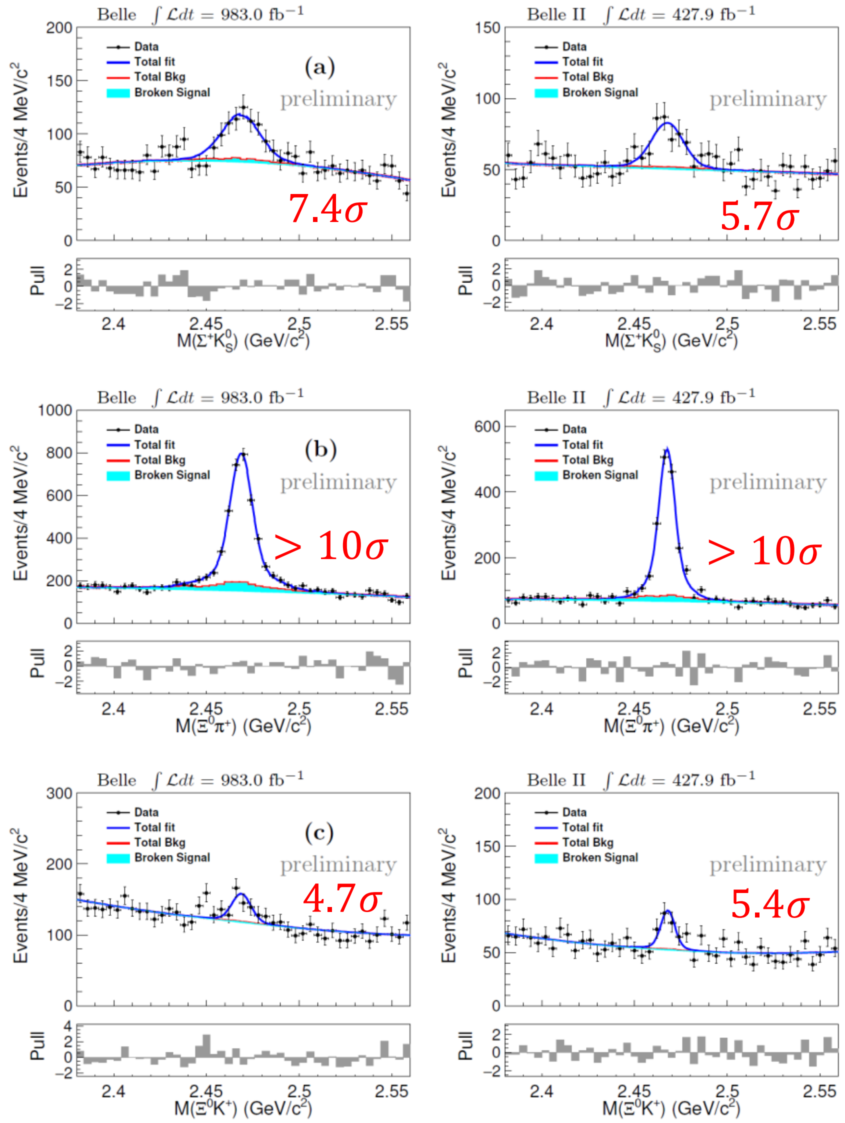
$$\mathcal{B}(\Xi_c^+ \to \Xi^0 K^+) = (0.46 \pm 0.07 \pm 0.02 \pm 0.21) \times 10^{-3}$$

$$\mathcal{B}(\Xi_c^+ \to \Xi^0 \pi^+) = (6.77 \pm 0.24 \pm 0.30 \pm 3.03) \times 10^{-3}$$

- The ratio of $\mathcal{B}(\Xi_c^+ \to \Xi^0 K^+)$ and $\mathcal{B}(\Xi_c^+ \to \Xi^0 \pi^+)$ are determined to be

$$\frac{\mathcal{B}(\Xi_c^+ \to \Xi^0 K^+)}{\mathcal{B}(\Xi_c^+ \to \Xi^0 \pi^+)} = (6.8 \pm 1.1 \pm 0.4)\%$$

Belle + Belle II~1.4/ab PRELIMINARY



Summary

- Belle and Belle II offer a unique environment and sensitivity for SM measurements, as well as for the search for *CP* violation in the charm sector.

- In the past year, some fascinating results have been achieved in the search for *CP* violation of D mesons, measurement of D^0-$\overline{D}^0$ mixing, and the $\Xi_c^{+/0}$ decays using the combined data from Belle and Belle II.

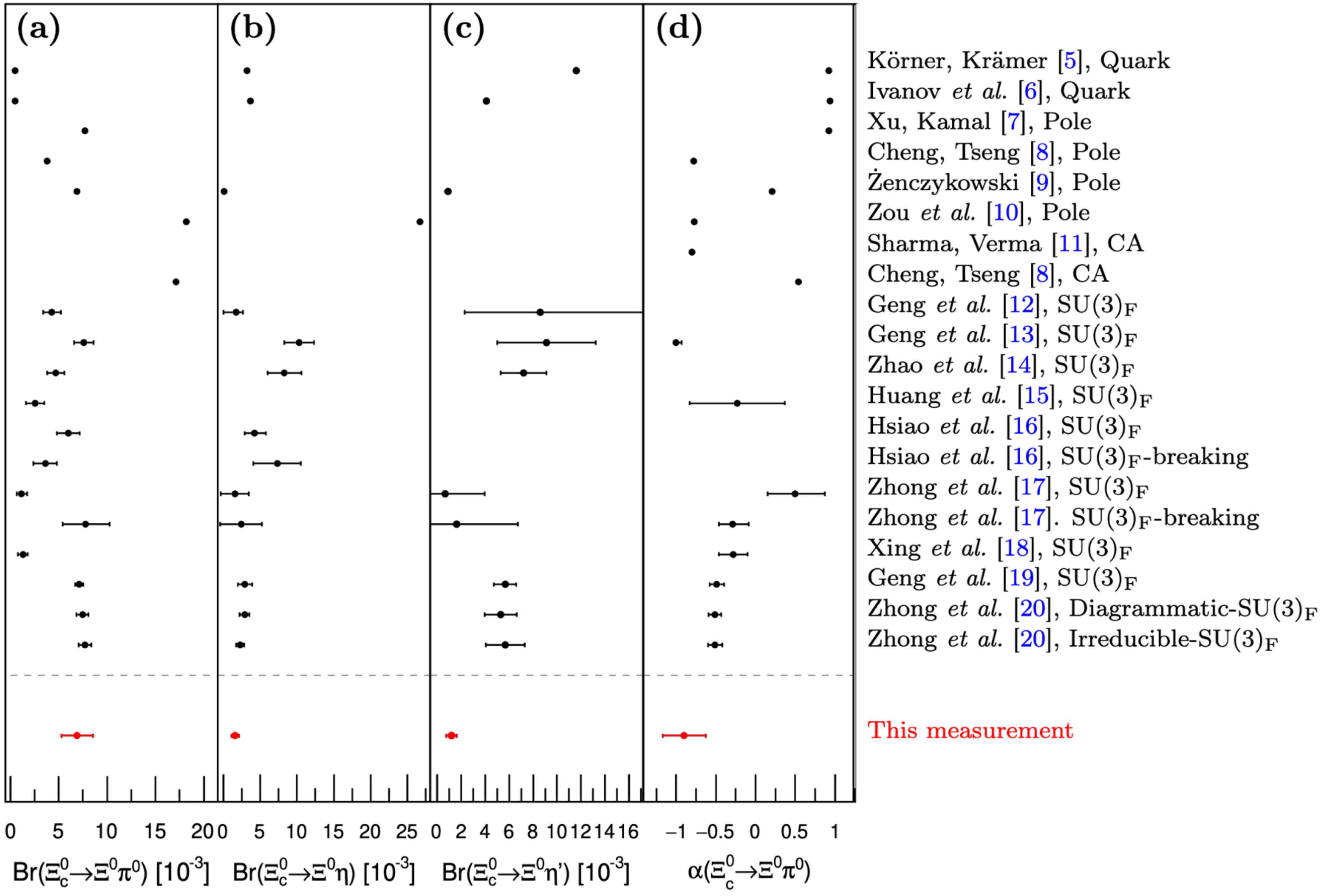
- Belle II has started data taking for Run 2, and more precise and improved results are on the way. Stay tuned!

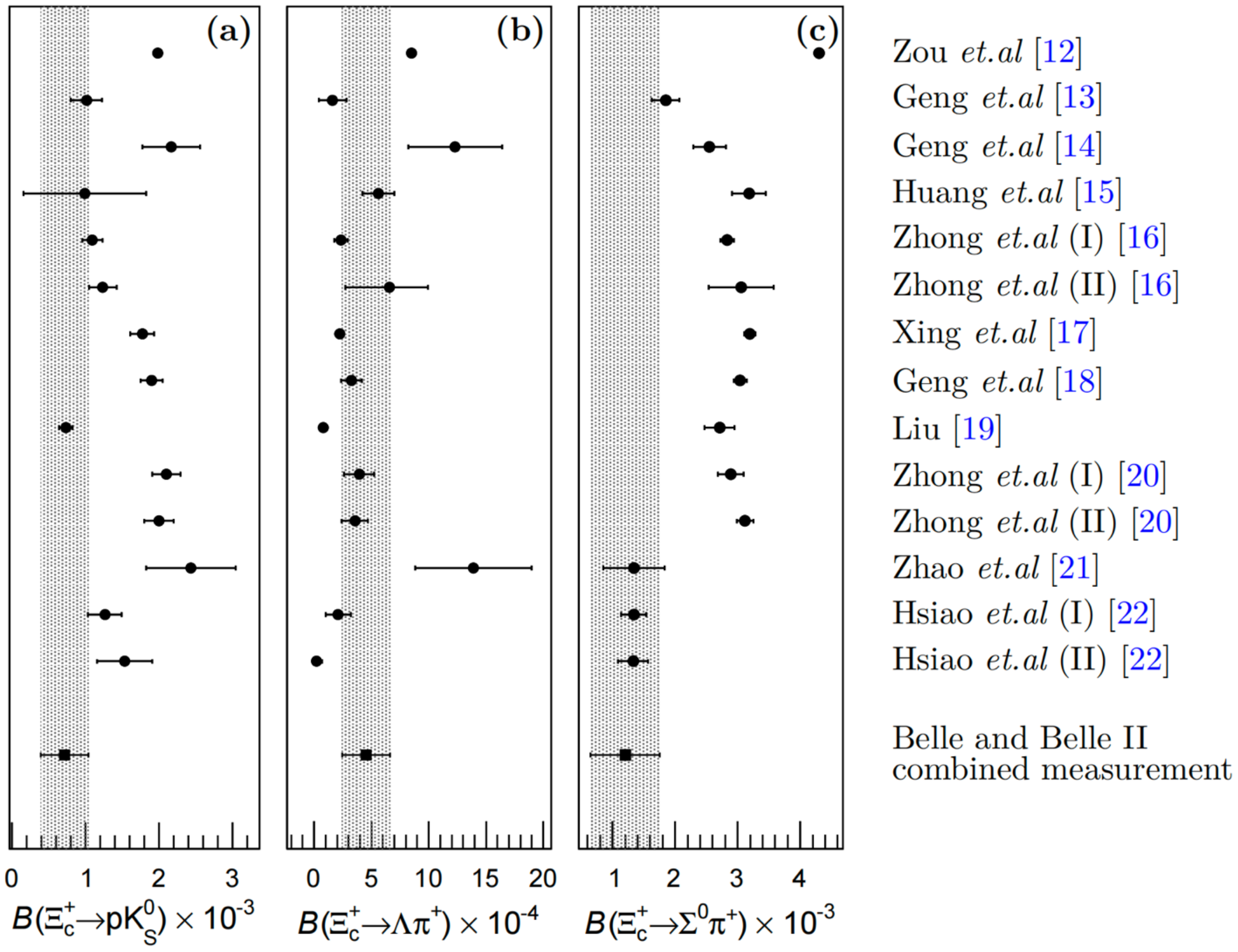
BELLE

Thanks for your attention !

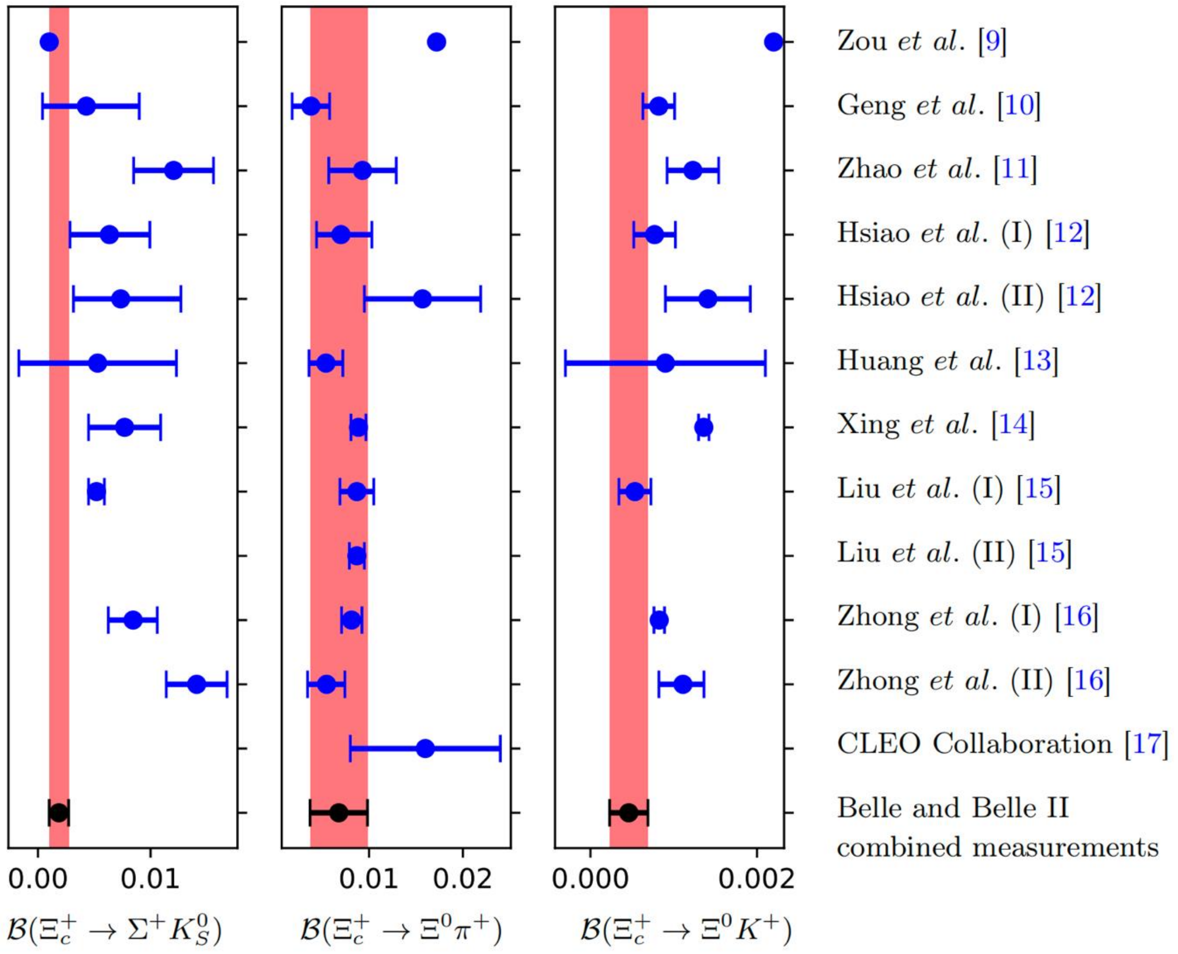
Belle II

Backup


(a)
(b)
(c)
(d)
Körner, Krämer [5], Quark
Ivanov et al. [6], Quark
Xu, Kamal [7], Pole
Cheng, Tseng [8], Pole
Żenczykowski [9], Pole
Zou et al. [10], Pole
Sharma, Verma [11], CA
Cheng, Tseng [8], CA
Geng et al. [12], $SU(3)_F$
Geng et al. [13], $SU(3)_F$
Zhao et al. [14], $SU(3)_F$
Huang et al. [15], $SU(3)_F$
Hsiao et al. [16], $SU(3)_F$
Hsiao et al. [16], $SU(3)_F$-breaking
Zhong et al. [17], $SU(3)_F$
Zhong et al. [17]. $SU(3)_F$-breaking
Xing et al. [18], $SU(3)_F$
Geng et al. [19], $SU(3)_F$
Zhong et al. [20], Diagrammatic-$SU(3)_F$
Zhong et al. [20], Irreducible-$SU(3)_F$
This measurement
0 5 10 15 20
0 5 10 15 20 25
0 2 4 6 8 10 12 14 16
−1 −0.5 0 0.5 1
$Br(\Xi_c^0 \to \Xi^0 \pi^0)$ $[10^{-3}]$
$Br(\Xi_c^0 \to \Xi^0 \eta)$ $[10^{-3}]$
$Br(\Xi_c^0 \to \Xi^0 \eta')$ $[10^{-3}]$
$\alpha(\Xi_c^0 \to \Xi^0 \pi^0)$



(a)
(b)
(c)
Zou et.al [12]
Geng et.al [13]
Geng et.al [14]
Huang et.al [15]
Zhong et.al (I) [16]
Zhong et.al (II) [16]
Xing et.al [17]
Geng et.al [18]
Liu [19]
Zhong et.al (I) [20]
Zhong et.al (II) [20]
Zhao et.al [21]
Hsiao et.al (I) [22]
Hsiao et.al (II) [22]
Belle and Belle II combined measurement
$B(\Xi_c^+ \to pK_S^0) \times 10^{-3}$
$B(\Xi_c^+ \to \Lambda\pi^+) \times 10^{-4}$
$B(\Xi_c^+ \to \Sigma^0\pi^+) \times 10^{-3}$



Zou et al. [9]
Geng et al. [10]
Zhao et al. [11]
Hsiao et al. (I) [12]
Hsiao et al. (II) [12]
Huang et al. [13]
Xing et al. [14]
Liu et al. (I) [15]
Liu et al. (II) [15]
Zhong et al. (I) [16]
Zhong et al. (II) [16]
CLEO Collaboration [17]
Belle and Belle II combined measurements
$\mathcal{B}(\Xi_c^+ \to \Sigma^+ K_S^0)$
$\mathcal{B}(\Xi_c^+ \to \Xi^0 \pi^+)$
$\mathcal{B}(\Xi_c^+ \to \Xi^0 K^+)$