Decays of charmed hadrons

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Joint Workshop of future tau-charm factory

Outline

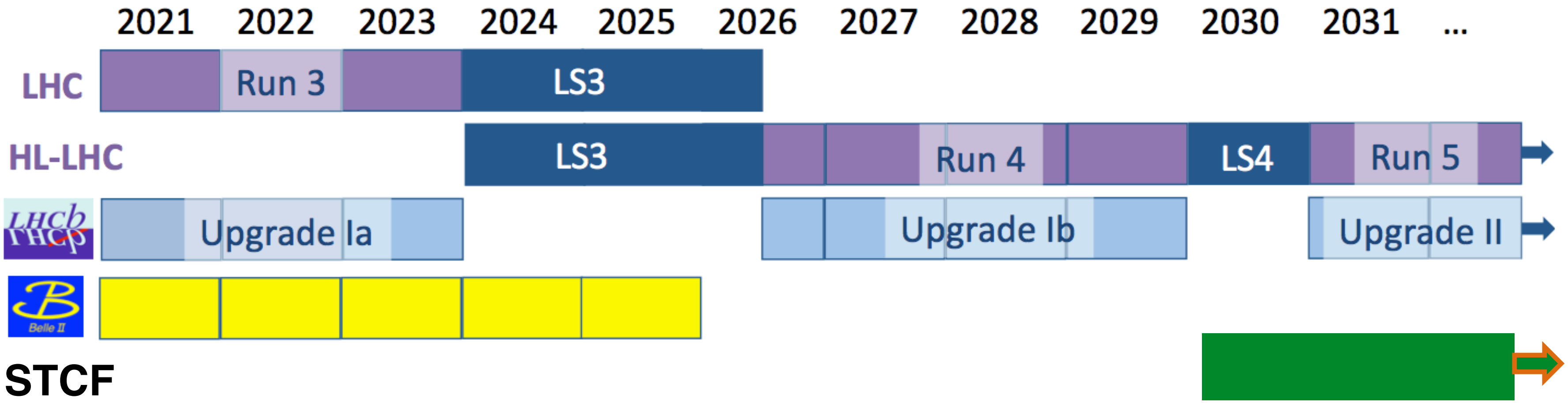
- Charmed meson decays
  - CKM matrix, Decay constants (f_D/f_{Ds}), form factors, LFU test
  - Neutral D mixing and strong phase
- Charmed baryon decays

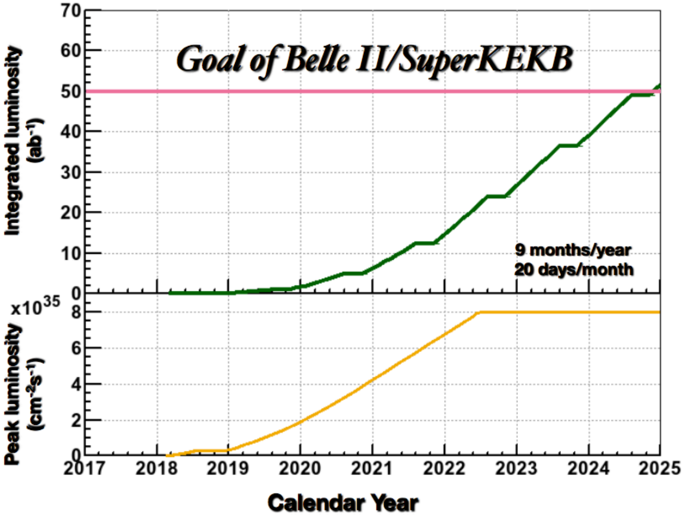
Disclaimer: only personal highlights, not comprehensive

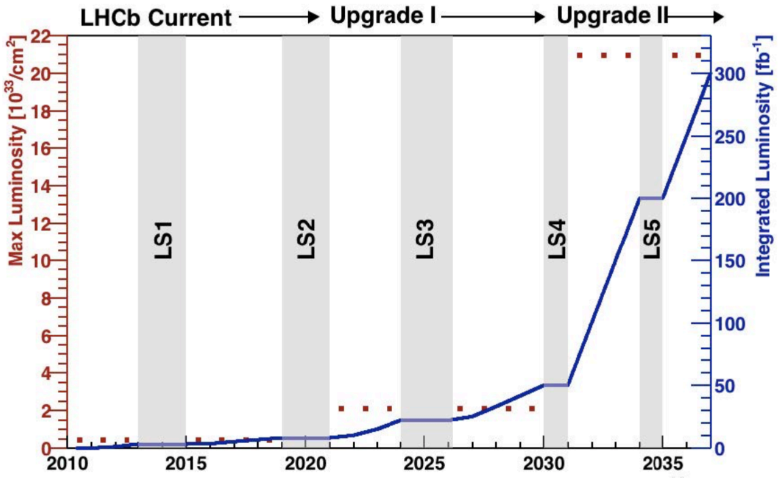
Current facilities for charm study

- Hadron colliders (huge cross-section, energy boost)
  - LHCb: 9fb^{-1} until now; world's largest sample of c-hadron decays in charged modes (x40 current B factories)
  - B-factories (Belle(-II), BaBar): ~e^+e^- Colliders (more kinematic constrains, clean environment, ~100% trigger efficiency)
  - Threshold production (BESIII)
    - Pair production and double tag technique
    - Low backgrounds and high efficiency
    - Quantum correlations and CP-tagging are unique

Future facilities for charm study

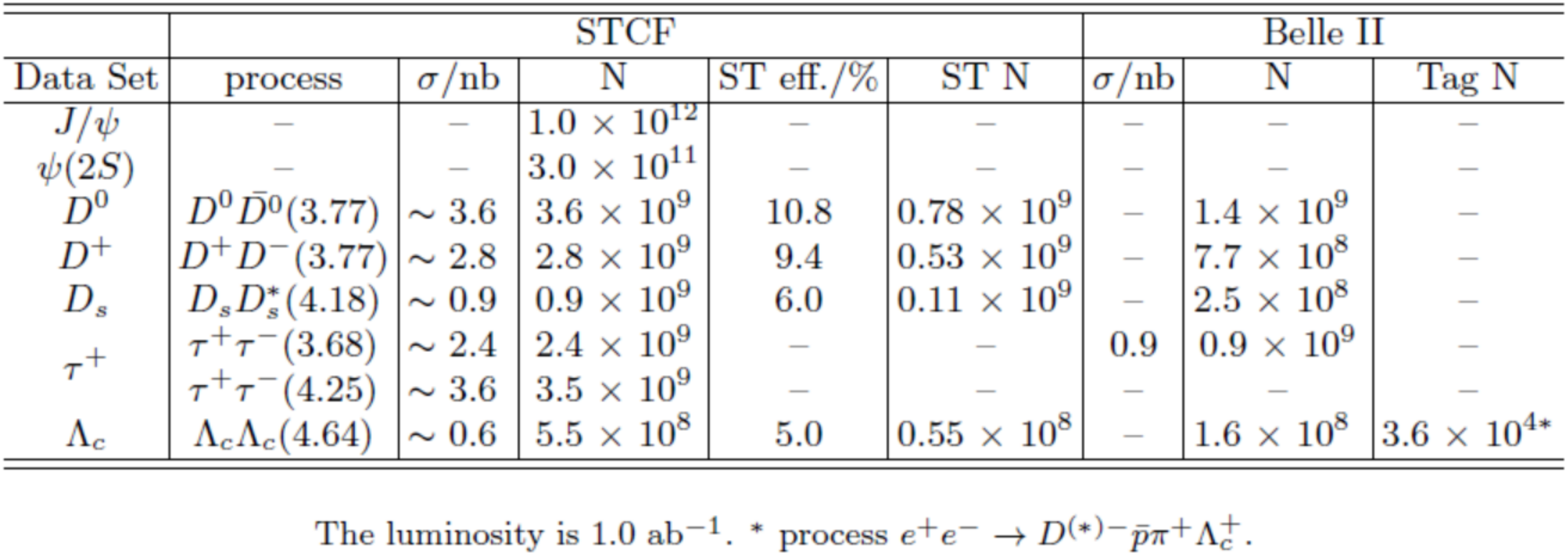






Data samples

Data samples with 1 ab^{-1} integral luminosity



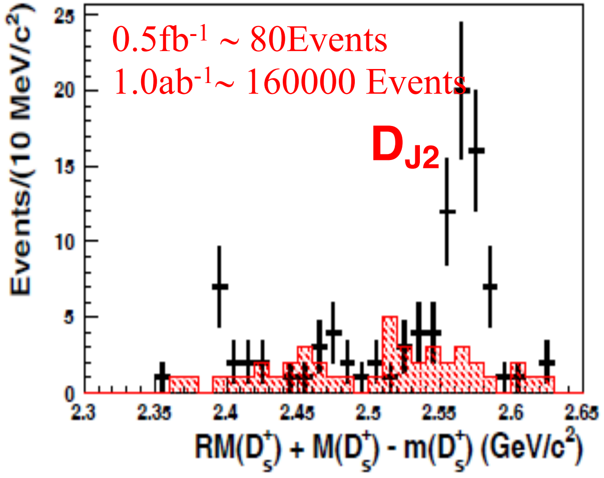
	STCF					Belle II		
Data Set	process	σ/nb	N	ST eff./%	ST N	σ/nb	N	Tag N
J/ψ	–	–	1.0×10^{12}	–	–	–	–	–
$\psi(2S)$	–	–	3.0×10^{11}	–	–	–	–	–
D^0	$D^0\bar{D}^0(3.77)$	~ 3.6	3.6×10^9	10.8	0.78×10^9	–	1.4×10^9	–
D^+	$D^+D^-(3.77)$	~ 2.8	2.8×10^9	9.4	0.53×10^9	–	7.7×10^8	–
D_s	$D_sD_s^*(4.18)$	~ 0.9	0.9×10^9	6.0	0.11×10^9	–	2.5×10^8	–
τ^+	$\tau^+\tau^-(3.68)$	~ 2.4	2.4×10^9	–	–	0.9	0.9×10^9	–
	$\tau^+\tau^-(4.25)$	~ 3.6	3.5×10^9	–	–	–	–	–
Λ_c	$\Lambda_c\Lambda_c(4.64)$	~ 0.6	5.5×10^8	5.0	0.55×10^8	–	1.6×10^8	$3.6 \times 10^{4*}$

The luminosity is 1.0 ab^{-1}. * process $e^+e^- \to D^{(*)-}\bar{p}\pi^+\Lambda_c^+$.

- Belle II (50/ab) has ~20 times more statistics in production
- STCF is expected to have higher detection efficiency. It's double tag yields expected to be ~20 times more than Belle II
- In addition, STCF has low backgrounds for productions at threshold

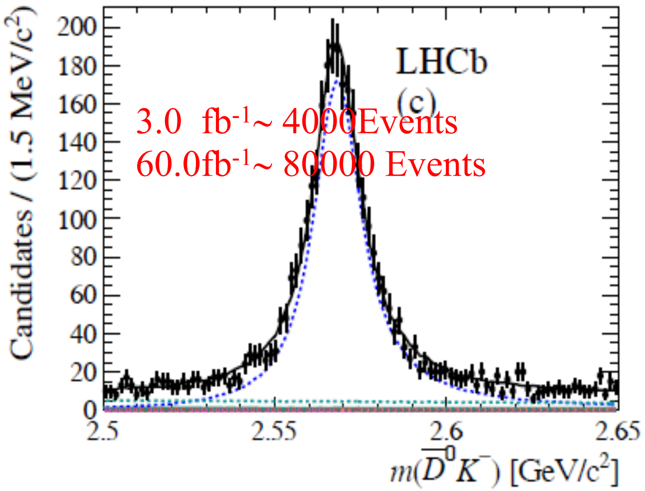
Charm Physics

- 4×10^9 pairs of $D^{\pm,0}$ and 10^7~$10^8 D_s$ pairs per year
  - 10^{10} charm from Belle II/year
- Competition to Belle II
  - The multiplicity of final state is lower by a factor of 2
  - Threshold effect, clear, double tagging
  - Produce in QM coherent state, $J^{PC}=1^{--}$ for DD, $J^{PC}=0^{++}$ for γDD
- Highlighted Physics programs
  - Precise measurement of leptonic, semi-leptonic decay (f_D, f_{Ds}, CKM matrix…)
  - $D^0-\bar{D}^0$ mixing, CPV
  - Rear decay (FCNC, LFV, LNV….)
  - Excite charm meson states D_J, D_{sJ} (mass, width, J^{PC}, decay modes)
  - Charmed baryons (J^{PC}, Decay modes, absolute BF)
  - Light meson and hyperon spectroscopy studied in charmed hadron decays



$0.5 fb^{-1}$ ~ 80Events

$1.0 ab^{-1}$~ 160000 Events

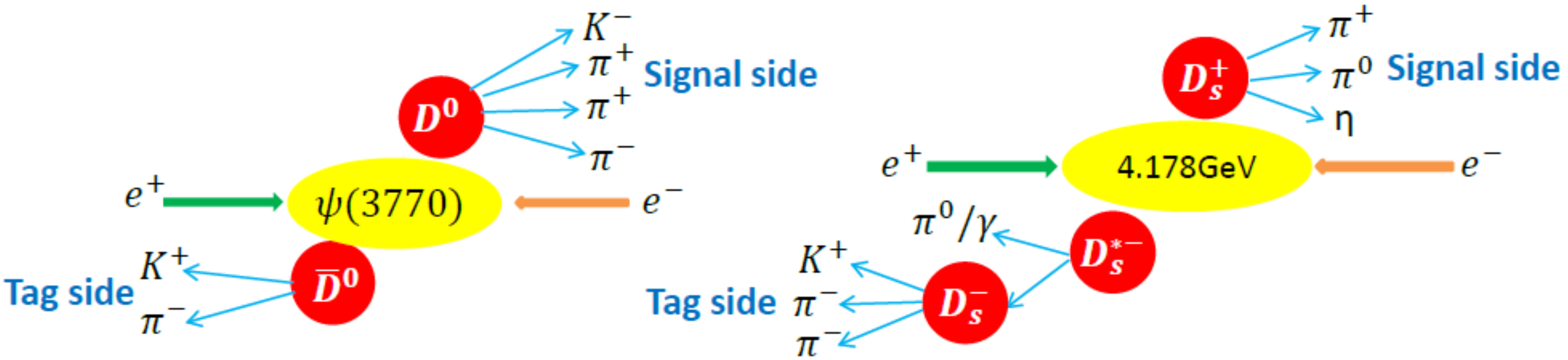


$3.0\ fb^{-1}$~ 4000Events

$60.0 fb^{-1}$~ 80000 Events

Double Tag (DT) techniques

- 100% of beam energy converted to *D* pair (Clean environment, kinematic constrains ν Recon.)
- $D_{(S)}$ generated in pair ⇒ absolute Branching fractions
- Fully reconstruct about 15% of $D_{(S)}$ decays



$$\Delta E = E_D - E_{\text{Beam}}$$

$$M_{\text{BC}} = \sqrt{E_{\text{Beam}}^2 - p_D^2}$$

◆ **Double tag techniques: Hadronic tag on one side, on the other side for missing-mass studies (Double tag efficiency is high.)**

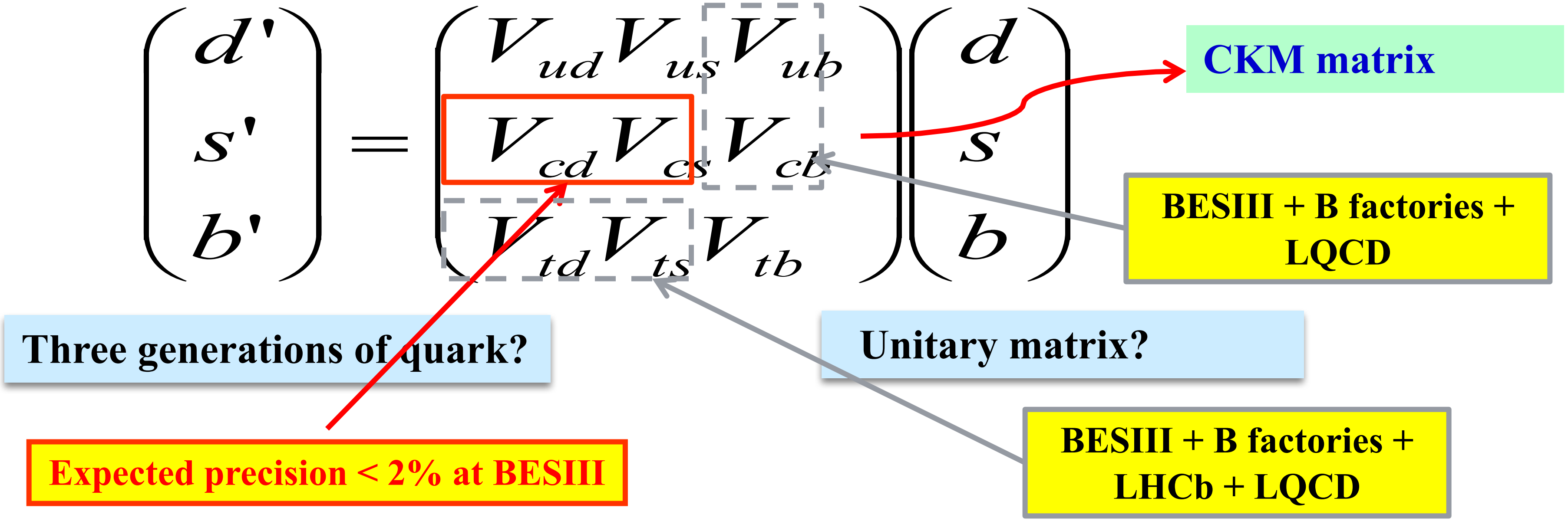
Features in studying charm hadron decays

	STCF	Belle(-II)	LHCb
Production yields	★★	★★★★	★★★★★
Background level	★★★★★	★★	★★
Systematic error	★★★★★	★★★	★★
Completeness	★★★★★	★★★	★
(Semi)-Leptonic mode	★★★★★	★★★	★
Neutron/K_L mode	★★★★★	★★	☆
Photon-involved	★★★★★	★★★★★	☆
Absolute measurement	★★★★★	★★★	☆

- Most are precision measurements, which are mostly dominant by the systematic uncertainty
- STCF has overall advantage

Precision measurement of CKM elements
-- Test EW theory

CKM matrix elements are fundamental SM parameters that describe the mixing of quark fields due to weak interaction.



$$\begin{pmatrix} d' \\ s' \\ b' \end{pmatrix} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \begin{pmatrix} d \\ s \\ b \end{pmatrix}$$

CKM matrix

BESIII + B factories + LQCD

Three generations of quark?

Unitary matrix?

Expected precision < 2% at BESIII

BESIII + B factories + LHCb + LQCD

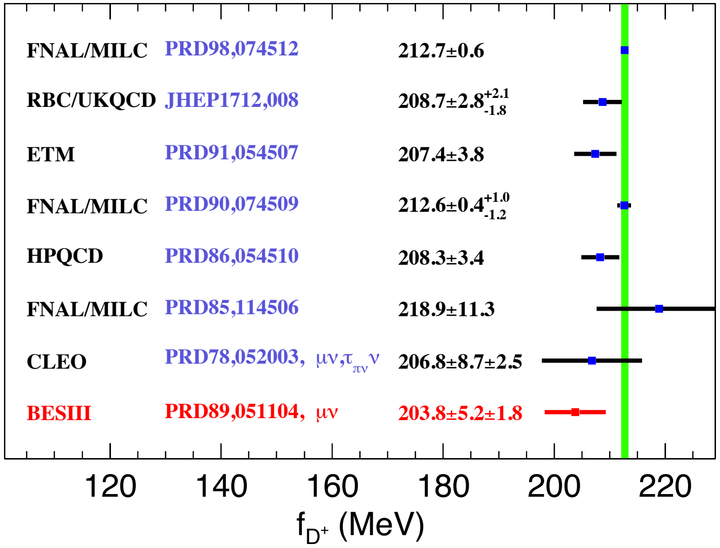
- **Precision measurement of CKM matrix elements**
- **A precise test of SM model**
- **New physics beyond SM?**

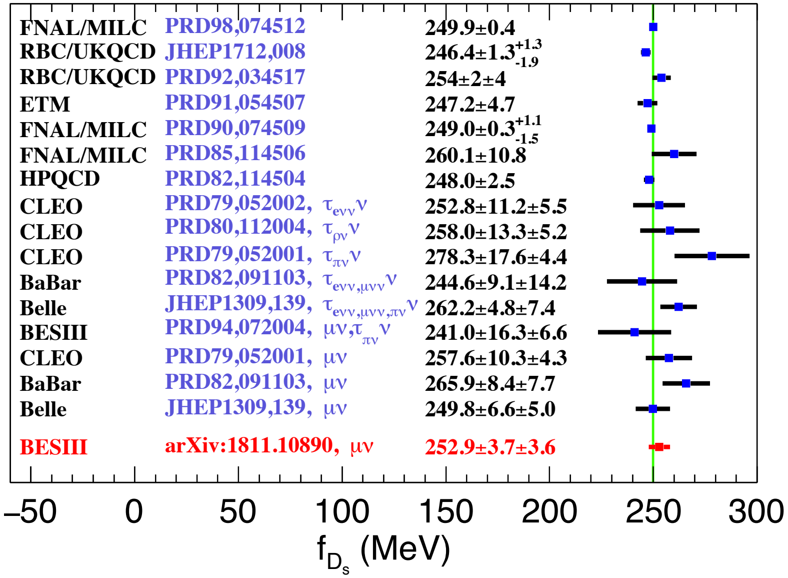
$D_{(S)}$ Leptonic decays

Purely Leptonic:

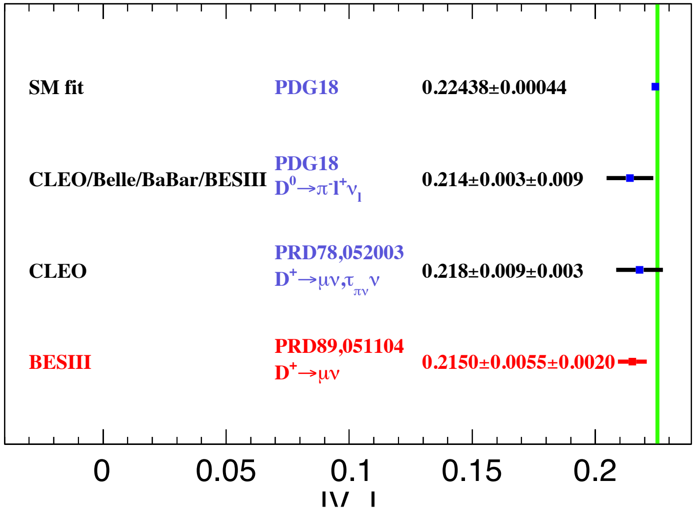
- Extract decay constant $f_{D(s)}$ incorporates the strong interaction effects (wave function at the origin)
- To validate Lattice QCD calculation of $f_{B(s)}$ and provide constrain of CKM-unitarity

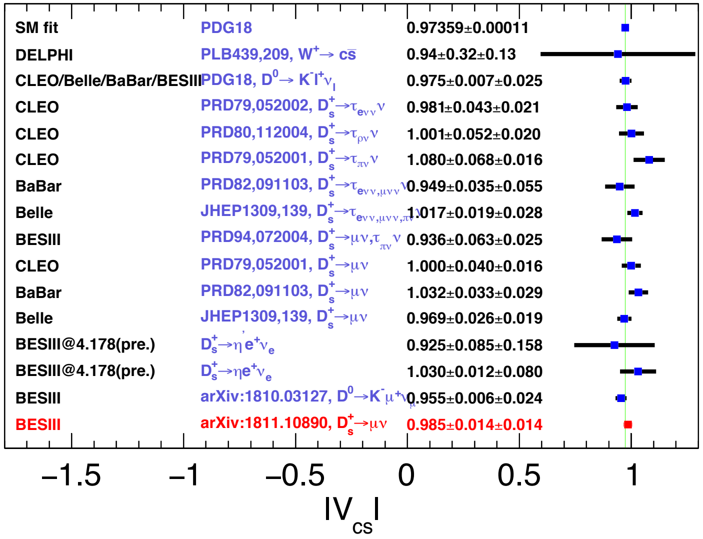
$$\Gamma(D^+_{(s)} \to \ell^+\nu_\ell) = \frac{G_F^2 f^2_{D^+_{(s)}}}{8\pi} \mid V_{cd(s)} \mid^2 m_\ell^2 m_{D^+_{(s)}} \left(1 - \frac{m_\ell^2}{m^2_{D^+_{(s)}}}\right)^2$$





Vcs and Vcd





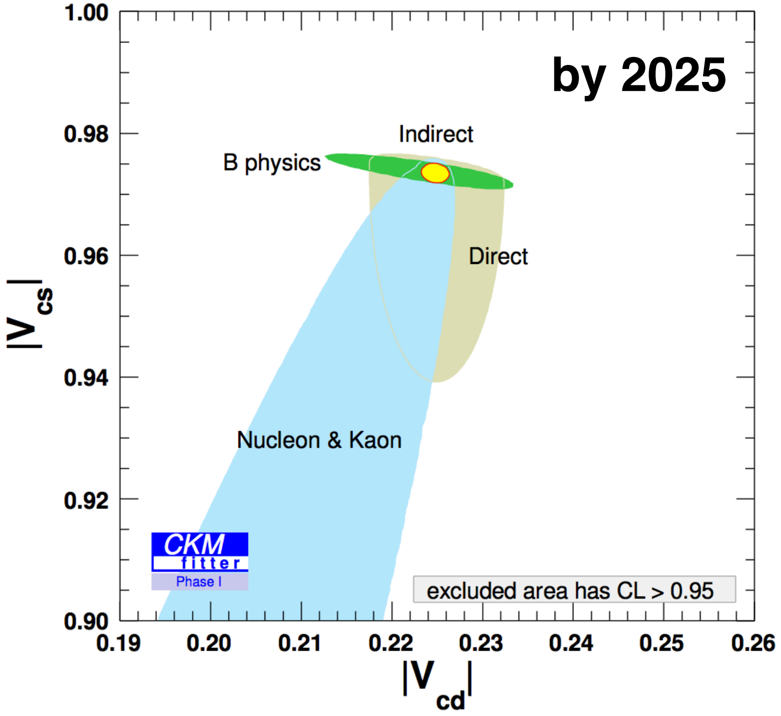
Future BESIII:

Vcd: ~1.5% (stat. dominant)

Vcs: ~1.5% (syst. dominant)

STCF: <0.2% (syst. dominant)

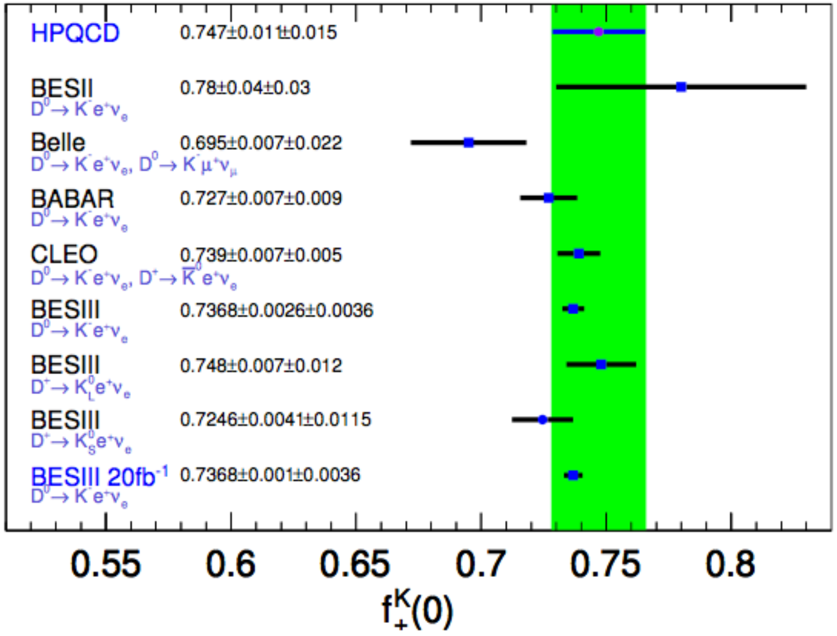
systematic control is challenging

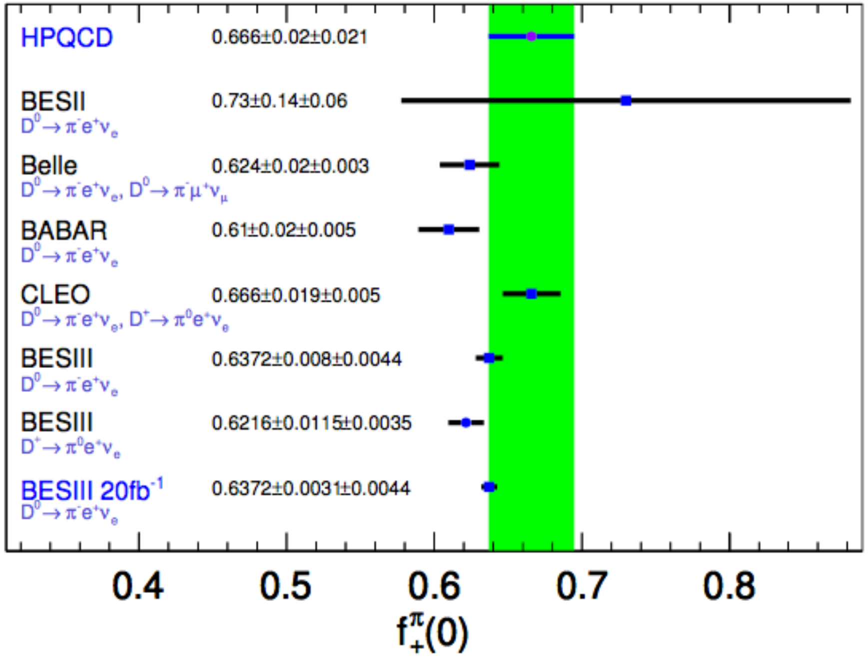


$D_{(S)}$ Semi-Leptonic decays

Semi-leptonic: form facotr (FF)

- Measure $|V_{cx}|$ x FF
- Charm physics:
  - CKM-unitarity ⇒ $|V_{cx}|$, extract FF, test LQCD
  - Input LQCD FF to test CKM-unitarity





BESIII: systematic dominant
STCF: systematic control is challenging

Tests of lepton flavor universality (LFU)

Pure-leptonic modes

$$R_{D^+_{(s)}} = \frac{\Gamma(D^+_{(s)} \to \tau^+\nu_\tau)}{\Gamma(D^+_{(s)} \to \mu^+\nu_\mu)} = \frac{m^2_{\tau^+}\left(1-\frac{m^2_{\tau^+}}{m^2_{D^+_{(s)}}}\right)^2}{m^2_{\mu^+}\left(1-\frac{m^2_{\mu^+}}{m^2_{D^+_{(s)}}}\right)^2}.$$

SM prediction: R_D=2.66±0.01

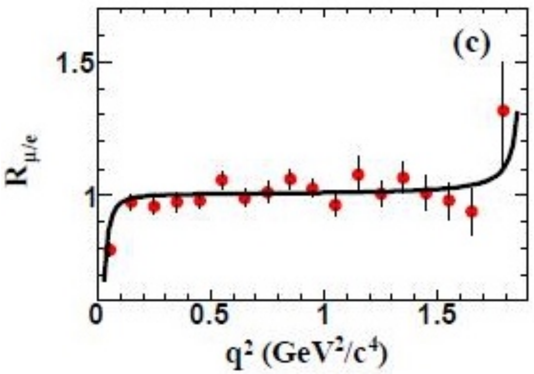
BESIII: R_D=3.21±0.64 (preliminary)

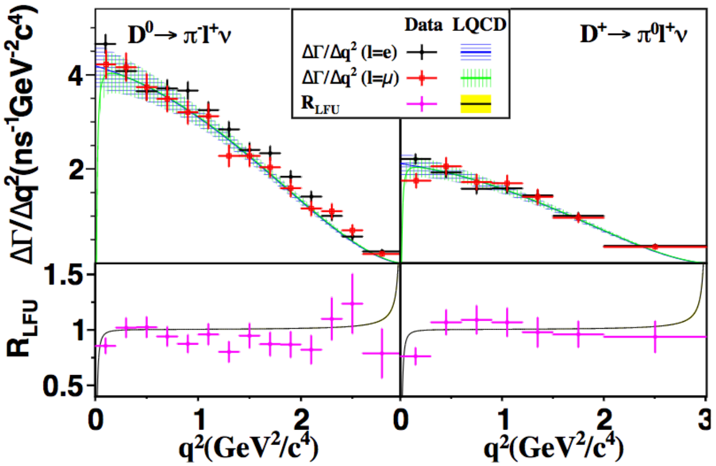
1σ difference?

1/ab at STCF: $\delta R_{D(s)}/R_{D(s)}$~0.5% (systematic dominant)

Semi-leptonic modes

$$R_{\mu/e} = \Gamma_{D^0\to K^-\mu^+\nu_\mu}/\Gamma_{D^0\to K^-e^+\nu_e}$$





2.93/fb@3773MeV;
3.19/fb@4178MeV

	$R(D_s^+)$	$R(D^+)$	$R(K^-)$	$R(\bar{K}^0)$	$R(\pi^-)$	$R(\pi^0)$
SM	9.74(1)	2.66(1)	0.975(1)	0.975(1)	0.985(2)	0.985(2)
BESIII	10.19(52)	3.21(64)	0.974(14)	1.013(29)	0.922(37)	0.964(45)

2σ difference?

Future STCF data will large constrain these tests.

$D^0 - \overline{D}^0$ mixing & CPV

- **$D^0 - \overline{D}^0$ mixing rate at threshold**

$$R_M = \frac{x^2 + y^2}{2} = \frac{N[(K^\pm \pi^\mp)(K^\pm \pi^\mp)]}{N[(K^\pm \pi^\mp)(K^\mp \pi^\pm)]}$$

with 1ab^{-1} data:

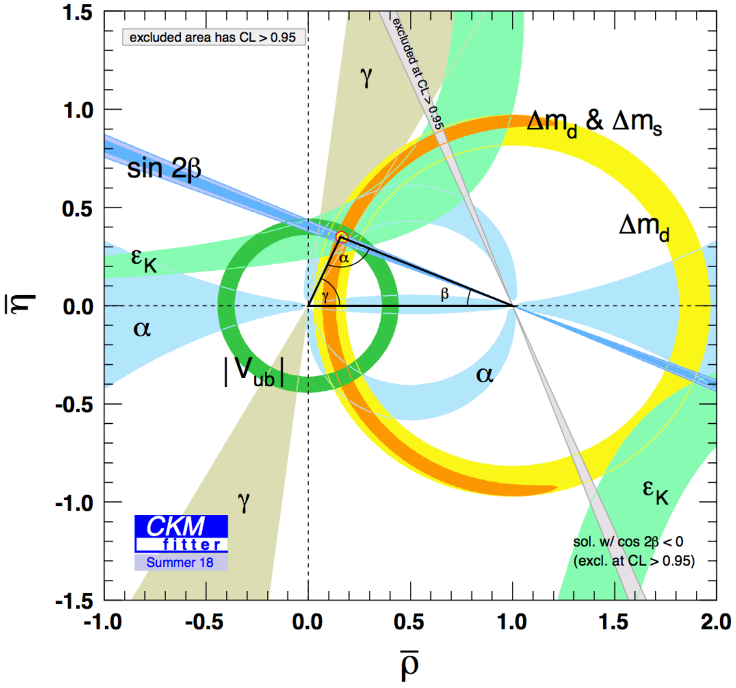
- $R_M = (x^2+y^2)/2 \sim 10^{-5}$ in Kπ and Keν channels
- probe y: $\Delta y_{CP} < 0.1\%$
- $\Delta A_{CP} \sim 10^{-3}$ in *KK* and *ππ* channels

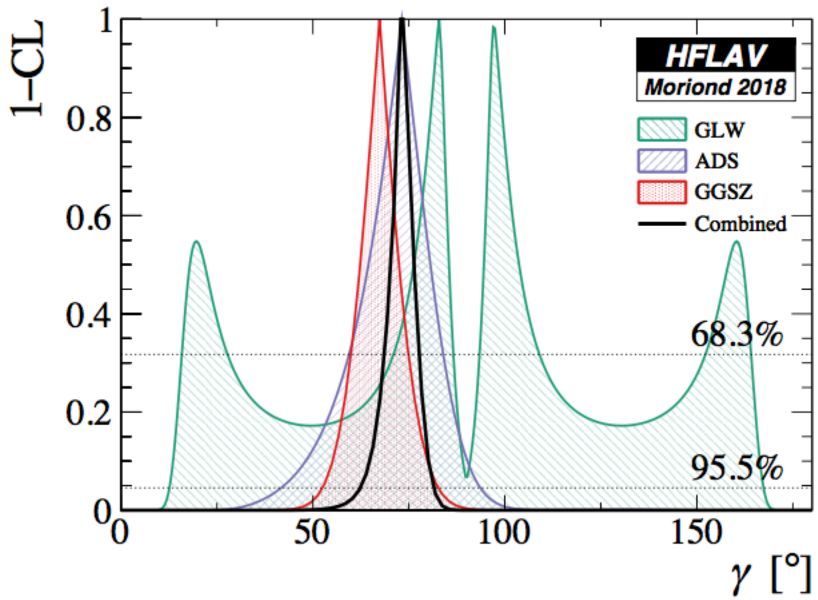
However, at LHCb after upgrade II by 2035: (estimated from arXiv: 1808.08865)

- (x'^2, y') ± $(0.2, 3.8)\times10^{-5}$ with WS $D^0 \rightarrow K\pi$
- $D^0 - \overline{D}^0$ WS rate asymmetry (like |q/p|) ±0.2%
- y_{CP}, A_Γ ± 0.0018% in $D^0 \rightarrow K^-K^+$ and $D^0 \rightarrow \pi^-\pi^+$ decays
- (x, y) ±$(6, 6)\times10^{-5}$ using $D^0 \rightarrow K_S\pi\pi$
- $\Delta A_{CP} \sim 5 \times 10^{-5}$ in *KK* and *ππ* channels
- strong phase $\sigma(\cos\delta_{K\pi}) < 10^{-4}$ from constrains of (x', y') and (x, y)

Determination of γ/ϕ_3 angle in CKM

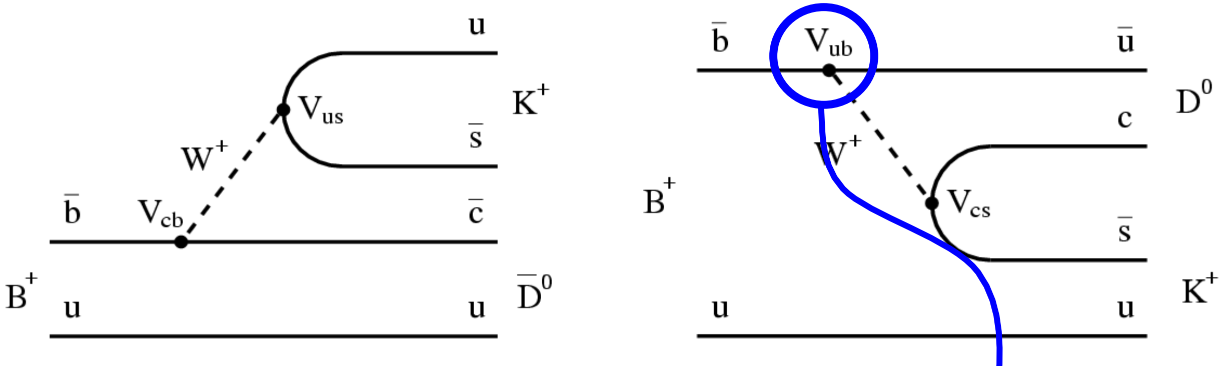
- The cleanest way to extract γ is from B→DK decays:
  - current uncertainty $\sigma(\gamma) \sim 5^0$
  - however, theoretical relative error $\sim 10^{-7}$ (very small!) ***[JHEP 1401 (2014) 051]***
  - use for “direct” vs “indirect” (“tree” vs “loop” disagreement)
  - over-constrain the Unitarity Triangle
- Information of *D decay strong phase* is needed
  - Best way is to employ quantum coherence of DD production at threshold





γ/ϕ_3 from $B^- \to D^0 K^-$

Interference between tree-level decays; theoretically clean

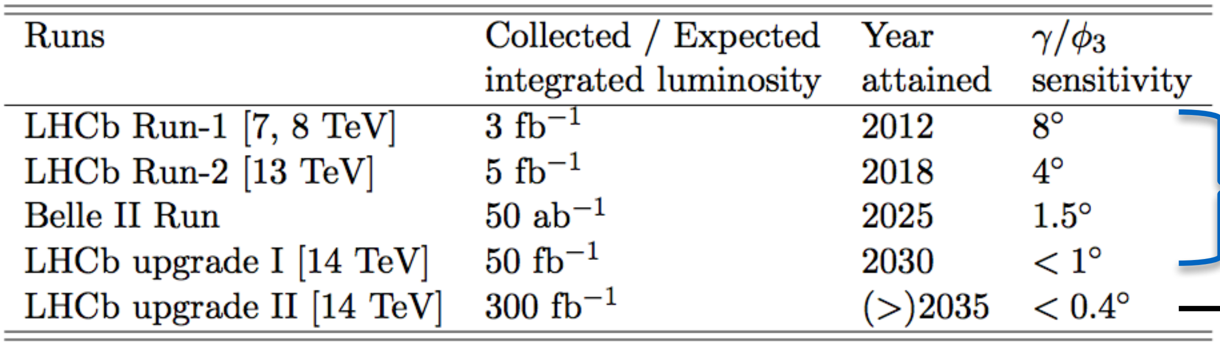


$$\frac{A(B^+ \to D^0 K^+)}{A(B^+ \to \overline{D^0} K^+)} \equiv r_B e^{i(\delta_B + \phi_3)}$$

Three methods for exploiting interference (choice of D^0 decay modes):

- Gronau, London, Wyler (GLW): Use CP eigenstates of $D^{(*)0}$ decay, e.g. $D^0 \to K_s\pi^0$, $D^0 \to \pi^+\pi^-$
- Atwood, Dunietz, Soni (ADS): Use doubly Cabibbo-suppressed decays, e.g. $D^0 \to K^+\pi^-$
- Giri, Grossman, Soffer, Zupan (GGSZ): Use Dalitz plot analysis of 3-body D^0 decays, e.g. $K_s\pi^+\pi^-$; high statistics; need precise Dalitz model

CKM unitarity triangle



Runs	Collected / Expected integrated luminosity	Year attained	γ/ϕ_3 sensitivity
LHCb Run-1 [7, 8 TeV]	3 fb^{-1}	2012	8°
LHCb Run-2 [13 TeV]	5 fb^{-1}	2018	4°
Belle II Run	50 ab^{-1}	2025	1.5°
LHCb upgrade I [14 TeV]	50 fb^{-1}	2030	$< 1^\circ$
LHCb upgrade II [14 TeV]	300 fb^{-1}	(>)2035	$< 0.4^\circ$

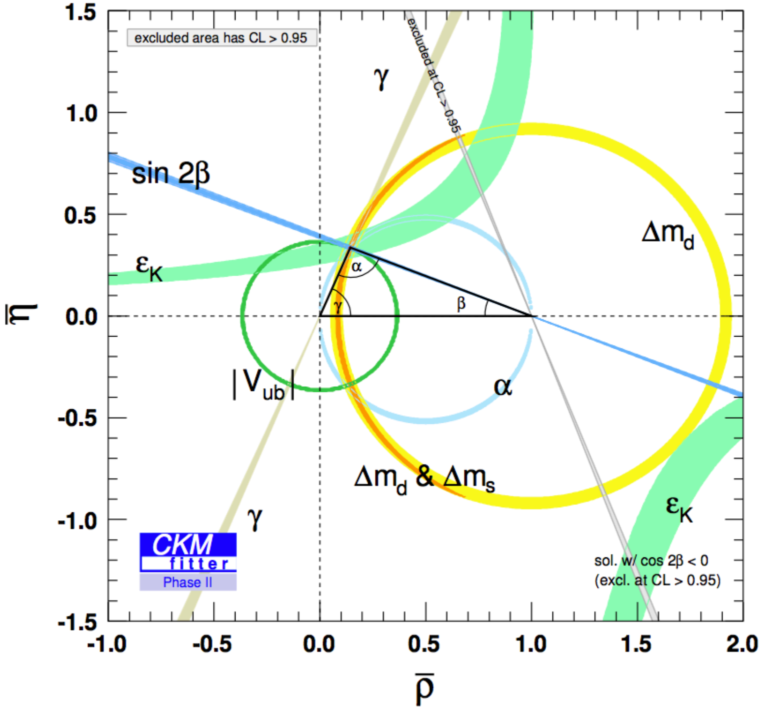
BESIII 20/fb:
$\sigma(\gamma) \sim 0.4^\circ$

→ STCF is needed!

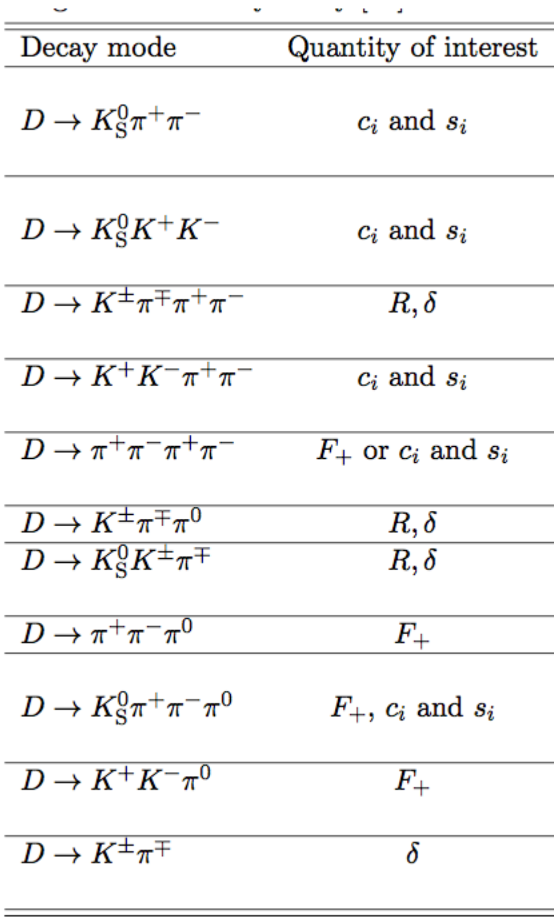
- ADS method: use *D* doubly Cabibbo-suppressed decays, e.g. $D^0 \rightarrow K^+\pi^-$
  - With 1 ab^{-1} @ STCF : $\sigma(\cos\delta_{K\pi}) \sim 0.007$; $\sigma(\delta_{K\pi}) \sim 2^\circ \Rightarrow \sigma(\gamma) < 0.5^\circ$
- GGSZ method: use Dalitz plot analysis of 3-body D^0 decays, e.g. $K_s\,\pi^+\pi^-$ high statistics; need precise Dalitz model
  - STCF reduces the contribution of *D* Dalitz model to a level of ~0.1°, since expected precision from future HL-LHCb projects would be <0.4°.

Scenario beyond 2035

STCF will provide complementary information on the strong phase and allow detailed comparisons in different models



- 300 /fb for LHCb
- 3000 /ab for CMS/ATLAS
- 50 /ab for Belle II
- 20 /fb @ 3773MeV for BESIII



Decay mode	Quantity of interest
$D \to K^0_S\pi^+\pi^-$	c_i and s_i
$D \to K^0_S K^+K^-$	c_i and s_i
$D \to K^\pm\pi^\mp\pi^+\pi^-$	R, δ
$D \to K^+K^-\pi^+\pi^-$	c_i and s_i
$D \to \pi^+\pi^-\pi^+\pi^-$	F_+ or c_i and s_i
$D \to K^\pm\pi^\mp\pi^0$	R, δ
$D \to K^0_S K^\pm\pi^\mp$	R, δ
$D \to \pi^+\pi^-\pi^0$	F_+
$D \to K^0_S\pi^+\pi^-\pi^0$	F_+, c_i and s_i
$D \to K^+K^-\pi^0$	F_+
$D \to K^\pm\pi^\mp$	δ

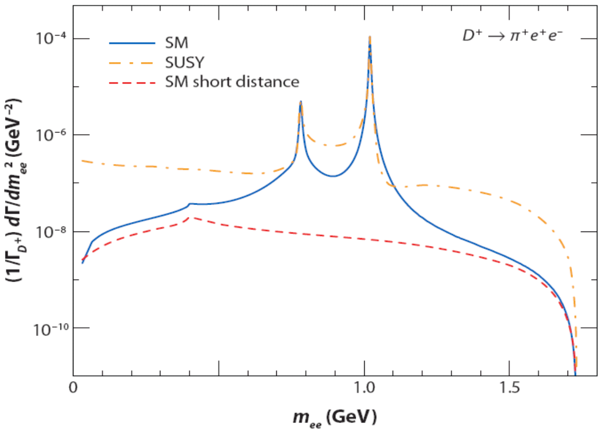
Charm rare decays

- FCNC suppressed by GIM mechanism in SM:
  - Short distance : interested, computable by pQCD, directly test SM

$$\mathcal{B}_{D^0\to X_u^0 e^+e^-} \simeq 8\cdot 10^{-9}$$

$$\mathcal{B}_{D^+\to X_u^+ e^+e^-} \simeq 2\cdot 10^{-8}$$

  - Long distance effect can enhance the rate to $10^{-6}\sim 10^{-7}$, dominantly.
  - Allow with sizeable decay rate in NP



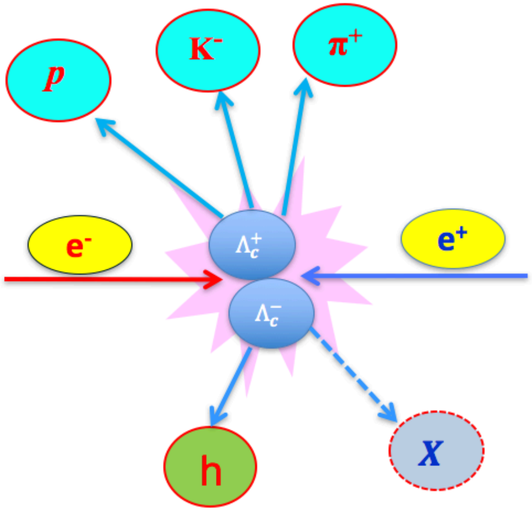
  - $1ab^{-1}$ @ STCF can achieve the sensitivity to $10^{-8}\sim 10^{-9}$, tested SM strictly
  - Can discriminate NP from SM by measuring :
    - $D\to Vl^+l^-$: AFB asymmetry
    - $D\to Pl^+l^-$: line shape of dilepton mass, to reveal the interference effect between long-distance and FCNC weak amplitude (NP amplitude);

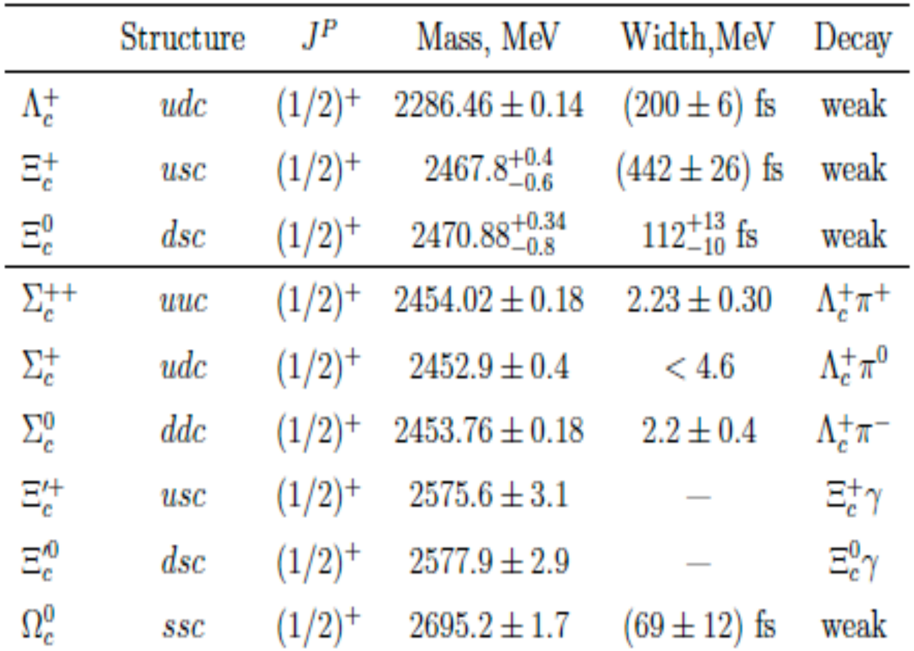
- LFV, LNV and BNV decays are forbidden in the SM. However, NP models can allow at sizable levels.
  - STCF: $10^{-8}\sim 10^{-9}$ ➔ stringent constrains to NP models

More detail MC simulation are necessary!

Charmed baryon (B_c)

Charmed baryons are produced via $e^+e^- \to B_{1c}B_{2c}$ with $B_{ic} = n_1n_2c$





	Structure	J^P	Mass, MeV	Width,MeV	Decay
Λ_c^+	udc	$(1/2)^+$	2286.46 ± 0.14	(200 ± 6) fs	weak
Ξ_c^+	usc	$(1/2)^+$	$2467.8^{+0.4}_{-0.6}$	(442 ± 26) fs	weak
Ξ_c^0	dsc	$(1/2)^+$	$2470.88^{+0.34}_{-0.8}$	112^{+13}_{-10} fs	weak
Σ_c^{++}	uuc	$(1/2)^+$	2454.02 ± 0.18	2.23 ± 0.30	$\Lambda_c^+\pi^+$
Σ_c^+	udc	$(1/2)^+$	2452.9 ± 0.4	< 4.6	$\Lambda_c^+\pi^0$
Σ_c^0	ddc	$(1/2)^+$	2453.76 ± 0.18	2.2 ± 0.4	$\Lambda_c^+\pi^-$
$\Xi_c'^+$	usc	$(1/2)^+$	2575.6 ± 3.1	—	$\Xi_c^+\gamma$
$\Xi_c'^0$	dsc	$(1/2)^+$	2577.9 ± 2.9	—	$\Xi_c^0\gamma$
Ω_c^0	ssc	$(1/2)^+$	2695.2 ± 1.7	(69 ± 12) fs	weak

- Systematic measurement of absolute decay BFs with well controlled systematics and low backgrounds

Many activities now on Λ_c^+ decays

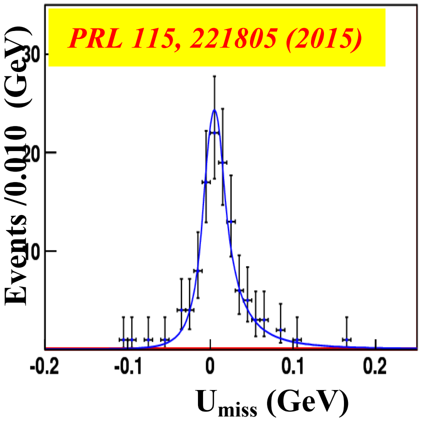
$\Lambda_c^\pm$

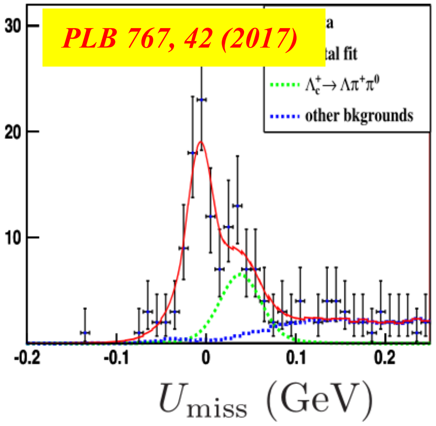
EPJC77, 895

PRL116, 052001

PRL113, 042002

Mode	HFLAV 2016 (%)	BESIII (%)	PDG 2014 (%)	BELLE (%)
pK_S^0	1.59 ± 0.07	$1.52 \pm 0.08 \pm 0.03$	1.15 ± 0.30	
$pK^-\pi^+$	6.46 ± 0.24	$5.84 \pm 0.27 \pm 0.23$	5.0 ± 1.3	$6.84 \pm 0.24^{+0.21}_{-0.27}$
$pK_S^0\pi^0$	2.03 ± 0.12	$1.87 \pm 0.13 \pm 0.05$	1.65 ± 0.50	
$pK_S^0\pi^+\pi^-$	1.69 ± 0.11	$1.53 \pm 0.11 \pm 0.09$	1.30 ± 0.35	
$pK^-\pi^+\pi^0$	5.05 ± 0.29	$4.53 \pm 0.23 \pm 0.30$	3.4 ± 1.0	
$\Lambda\pi^+$	1.28 ± 0.06	$1.24 \pm 0.07 \pm 0.03$	1.07 ± 0.28	
$\Lambda\pi^+\pi^0$	7.09 ± 0.36	$7.01 \pm 0.37 \pm 0.19$	3.6 ± 1.3	
$\Lambda\pi^+\pi^-\pi^+$	3.73 ± 0.21	$3.81 \pm 0.24 \pm 0.18$	2.6 ± 0.7	
$\Sigma^0\pi^+$	1.31 ± 0.07	$1.27 \pm 0.08 \pm 0.03$	1.05 ± 0.28	
$\Sigma^+\pi^0$	1.25 ± 0.09	$1.18 \pm 0.10 \pm 0.03$	1.00 ± 0.34	
$\Sigma^+\pi^+\pi^-$	4.64 ± 0.24	$4.25 \pm 0.24 \pm 0.20$	3.6 ± 1.0	
$\Sigma^+\omega$	1.77 ± 0.21	$1.56 \pm 0.20 \pm 0.07$	2.7 ± 1.0	
$\Lambda e^+\nu_e$	3.18 ± 0.32	$3.63 \pm 0.38 \pm 0.20$	2.1 ± 0.6	


PRL 115, 221805 (2015)


PLB 767, 42 (2017)

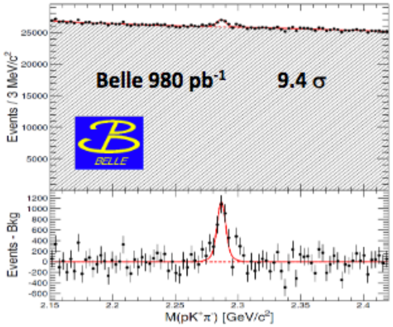
$\Gamma[\Lambda_c^+ \to \Lambda\mu^+\nu_\mu]/\Gamma[\Lambda_c^+ \to \Lambda e^+\nu_e] = 0.96 \pm 0.16 \pm 0.04$

STCF: *errors on the ratio reduced by two orders of magnitudes*

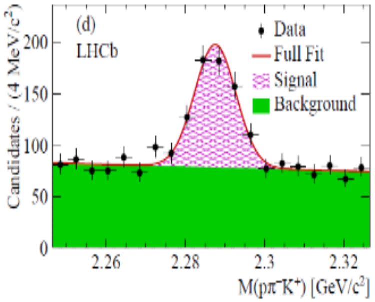
➔ provides stringent LFU test

Observation of DCS decay $\Lambda_c^+ \to p\pi^- K^+$

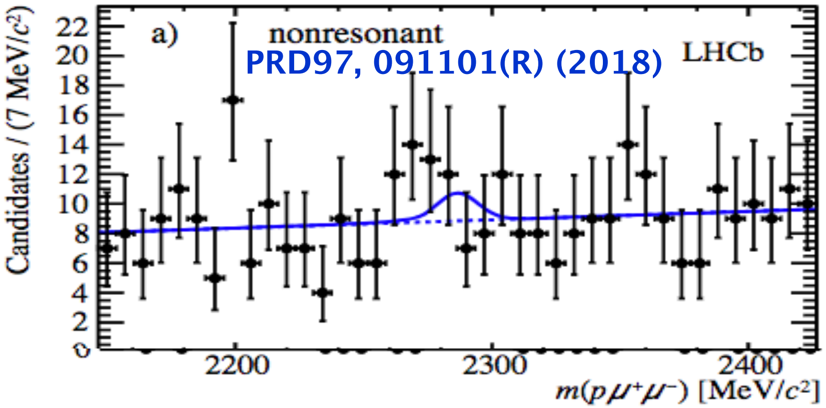
PRL 117, 011801(2016)



JHEP03, 043(2018)



$\mathcal{B}(\Lambda_c^+ \to p\mu^+\mu^-) < 7.7\ (9.6) \times 10^{-8}$


PRD97, 091101(R) (2018)

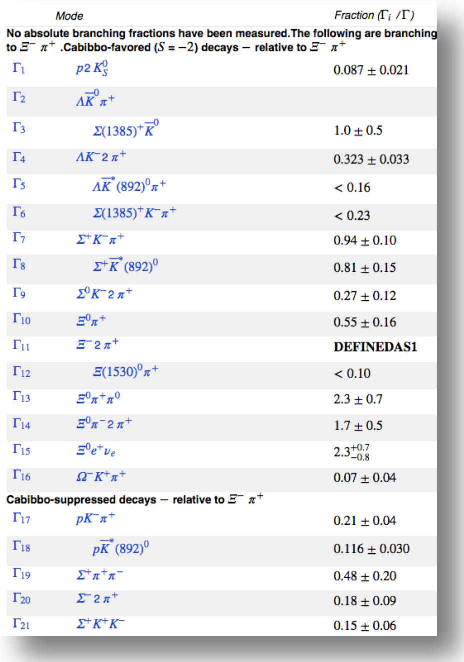
$$\Delta A_{CP}^{\rm wgt} = A_{CP}(pK^-K^+) - A_{CP}^{\rm wgt}(p\pi^-\pi^+)$$
$$= (0.30 \pm 0.91 \pm 0.61)\,\%,$$

LHCb, JHEP 03, 182 (2018)

Single charmed baryon in PDG

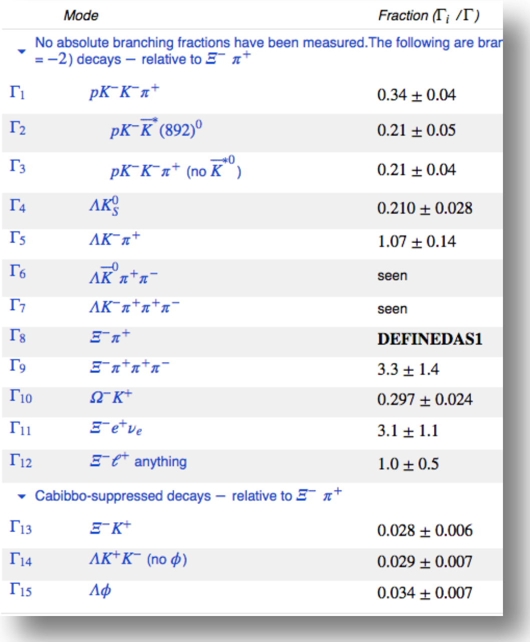
Absolute branching fractions measurement at threshold production will be important

Ξ_c^+: relative to $\Xi^-2\pi^+$



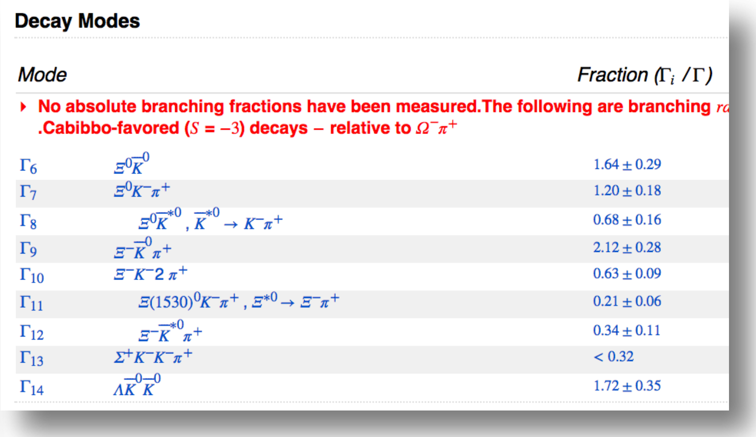
	Mode	Fraction (Γ_i /Γ)
No absolute branching fractions have been measured.The following are branching to $\Xi^-\ \pi^+$ .Cabibbo-favored ($S = -2$) decays − relative to $\Xi^-\ \pi^+$		
Γ_1	$p 2 K_S^0$	0.087 ± 0.021
Γ_2	$\Lambda \overline{K}^0 \pi^+$	
Γ_3	$\Sigma(1385)^+ \overline{K}^0$	1.0 ± 0.5
Γ_4	$\Lambda K^- 2\pi^+$	0.323 ± 0.033
Γ_5	$\Lambda \overline{K}^*(892)^0 \pi^+$	< 0.16
Γ_6	$\Sigma(1385)^+ K^- \pi^+$	< 0.23
Γ_7	$\Sigma^+ K^- \pi^+$	0.94 ± 0.10
Γ_8	$\Sigma^+ \overline{K}^*(892)^0$	0.81 ± 0.15
Γ_9	$\Sigma^0 K^- 2\pi^+$	0.27 ± 0.12
Γ_{10}	$\Xi^0 \pi^+$	0.55 ± 0.16
Γ_{11}	$\Xi^- 2\pi^+$	**DEFINEDAS1**
Γ_{12}	$\Xi(1530)^0 \pi^+$	< 0.10
Γ_{13}	$\Xi^0 \pi^+ \pi^0$	2.3 ± 0.7
Γ_{14}	$\Xi^0 \pi^- 2\pi^+$	1.7 ± 0.5
Γ_{15}	$\Xi^0 e^+ \nu_e$	$2.3^{+0.7}_{-0.8}$
Γ_{16}	$\Omega^- K^+ \pi^+$	0.07 ± 0.04
Cabibbo-suppressed decays − relative to $\Xi^-\ \pi^+$		
Γ_{17}	$p K^- \pi^+$	0.21 ± 0.04
Γ_{18}	$p \overline{K}^*(892)^0$	0.116 ± 0.030
Γ_{19}	$\Sigma^+ \pi^+ \pi^-$	0.48 ± 0.20
Γ_{20}	$\Sigma^- 2\pi^+$	0.18 ± 0.09
Γ_{21}	$\Sigma^+ K^+ K^-$	0.15 ± 0.06

Ξ_c^0: relative to $\Xi^-\pi^+$



	Mode	Fraction (Γ_i /Γ)
No absolute branching fractions have been measured.The following are bran = -2) decays − relative to $\Xi^-\ \pi^+$		
Γ_1	$p K^- K^- \pi^+$	0.34 ± 0.04
Γ_2	$p K^- \overline{K}^*(892)^0$	0.21 ± 0.05
Γ_3	$p K^- K^- \pi^+$ (no $\overline{K}^{*0}$)	0.21 ± 0.04
Γ_4	ΛK_S^0	0.210 ± 0.028
Γ_5	$\Lambda K^- \pi^+$	1.07 ± 0.14
Γ_6	$\Lambda \overline{K}^0 \pi^+ \pi^-$	seen
Γ_7	$\Lambda K^- \pi^+ \pi^+ \pi^-$	seen
Γ_8	$\Xi^- \pi^+$	**DEFINEDAS1**
Γ_9	$\Xi^- \pi^+ \pi^+ \pi^-$	3.3 ± 1.4
Γ_{10}	$\Omega^- K^+$	0.297 ± 0.024
Γ_{11}	$\Xi^- e^+ \nu_e$	3.1 ± 1.1
Γ_{12}	$\Xi^- \ell^+$ anything	1.0 ± 0.5
Cabibbo-suppressed decays − relative to $\Xi^-\ \pi^+$		
Γ_{13}	$\Xi^- K^+$	0.028 ± 0.006
Γ_{14}	$\Lambda K^+ K^-$ (no ϕ)	0.029 ± 0.007
Γ_{15}	$\Lambda \phi$	0.034 ± 0.007

Ω_c^0: relative to $\Omega^-\pi^+$

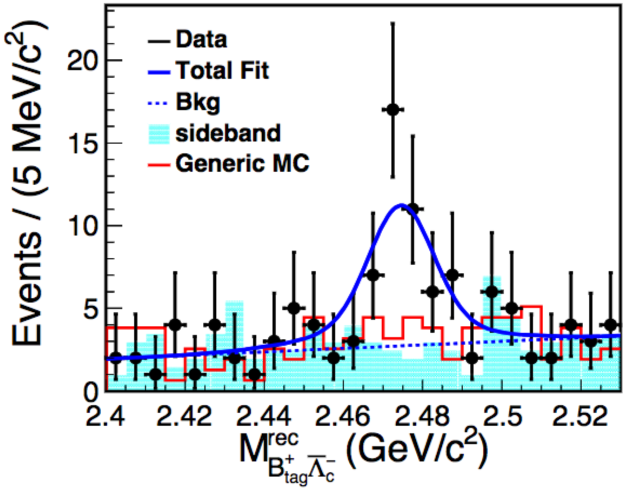


Decay Modes

	Mode	Fraction (Γ_i /Γ)
No absolute branching fractions have been measured.The following are branching ra .Cabibbo-favored ($S = -3$) decays – relative to $\Omega^-\pi^+$		
Γ_6	$\Xi^0 \overline{K}^0$	1.64 ± 0.29
Γ_7	$\Xi^0 K^- \pi^+$	1.20 ± 0.18
Γ_8	$\Xi^0 \overline{K}^{*0}$, $\overline{K}^{*0} \to K^- \pi^+$	0.68 ± 0.16
Γ_9	$\Xi^- \overline{K}^0 \pi^+$	2.12 ± 0.28
Γ_{10}	$\Xi^- K^- 2\pi^+$	0.63 ± 0.09
Γ_{11}	$\Xi(1530)^0 K^- \pi^+$, $\Xi^{*0} \to \Xi^- \pi^+$	0.21 ± 0.06
Γ_{12}	$\Xi^- \overline{K}^{*0} \pi^+$	0.34 ± 0.11
Γ_{13}	$\Sigma^+ K^- K^- \pi^+$	< 0.32
Γ_{14}	$\Lambda \overline{K}^0 \overline{K}^0$	1.72 ± 0.35

- First measurement of absolute BF of Ξ_c^0 at Belle **[arxiv:1811.09738]**

$$\mathcal{B}(\Xi_c^0 \to \Xi^-\pi^+) = (1.80 \pm 0.50 \pm 0.14)\%,$$



Precision study of the B_c weak decays

- Era of precision study of the charmed baryon (Λ_c, Ξ_c and Ω_c) decays at STCF
  to help developing more reliable QCD-derived models in charm sector
  - Hadronic decays:
    to explore as-yet-unmeasured channels and understand full picture of intermediate structures in B_c decays, esp., those with neutron/Σ/Ξ particles
  - Semi-leptonic decays:
    to test LQCD calculations and LFU
  - CPV in charmed baryon: BP and BV two-body decay asymmetry, charge-dependent rate of SCS
  - Rare decays: LFV, BNV, FCNC

STCF will provide very precise measurements of their overall decays, up to the unprecedented level of $10^{-6} \sim 10^{-7}$

Summary

- **STCF** is **one of the crucial precision frontier :** threshold production data is unique to carry out the measurements of the charmed hadron decays
- **Important playground for studying non-perturbtive QCD and search for new physics**
  - ✓ CKM matrix, Decay constants (f_D/f_{Ds}), form factors
  - ✓ Neutral D mixing and strong phase
  - ✓ Charmed baryon decays
- Complementary to Belle II and LHCb in understanding the QCD/EW models and searching for new physics

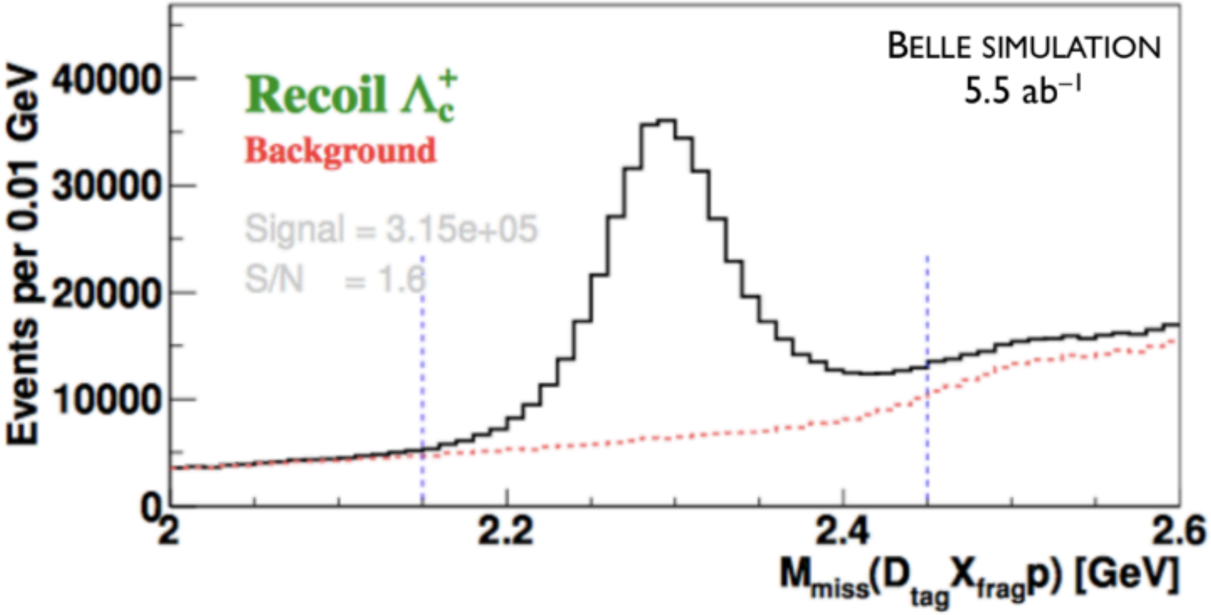
Thank you!

谢谢！

Extension of the Full Charm Event Reconstruction with:

$$e^+e^- \to D_{\text{tag}} X_{\text{frag}} p \boxed{\Lambda_c^+}$$

- in this case $M_{miss} = \Lambda_c^+$ mass



➡ *BelleII* simulation scaled to 50 ab^{-1} yields **2.8×10^6 inclusive Λ_c^+**

➡ **Unique** sample that allows to:

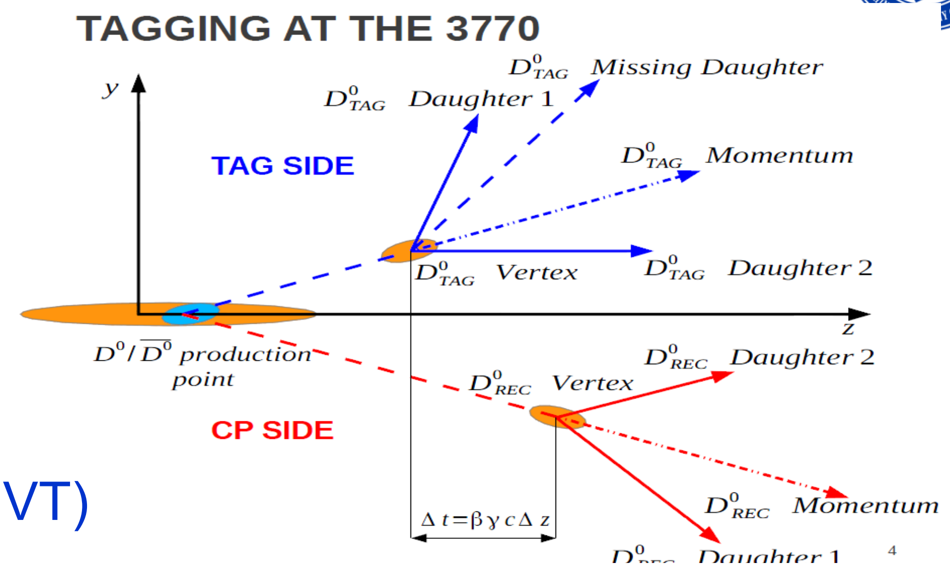
- measure absolute branching fractions
- measure semileptonic decays
- search for rare decays with missing energy

Asymmetric beam? charm mixing at Ψ(4040)?

- Flavor tagging($D^0 \rightarrow K^- l^+ \nu$)
- Time-dependent measurement available

$$\mathcal{A}(\Delta t) = \frac{\bar{\Gamma}(\Delta t) - \Gamma(\Delta t)}{\bar{\Gamma}(\Delta t) + \Gamma(\Delta t)}$$

- Require good Δz/Δt resolution (SVT)



Considering *Ψ(4040)*→*DD**→*DDγ*, *DD* pairs are in *C*-even states and charm mixing contribution is doubled compared with time-dependent (un-correlated) case.

CPV and D mixing reach

courtesy by Neri&Rama

3 ab^{-1} data @Ψ(3770):
asymmetric γβ=0.2~0.6
3 ab^{-1} data @Ψ(4040)
50 fb^{-1} data at upgrade LHCb
50 ab^{-1} at BELLE-II

Parameter	Ψ(3770)	Ψ(4040)	LHCb	Belle-II
$x(\%)$	0.02-0.05	0.03	0.015	0.08
$y(\%)$	0.02-0.03	0.03	0.010	0.04
$\lvert q/p \rvert(\%)$	2-5	0.9	1	5
$\arg(q/p)(^\circ)$	2-3	0.8	3	2.6