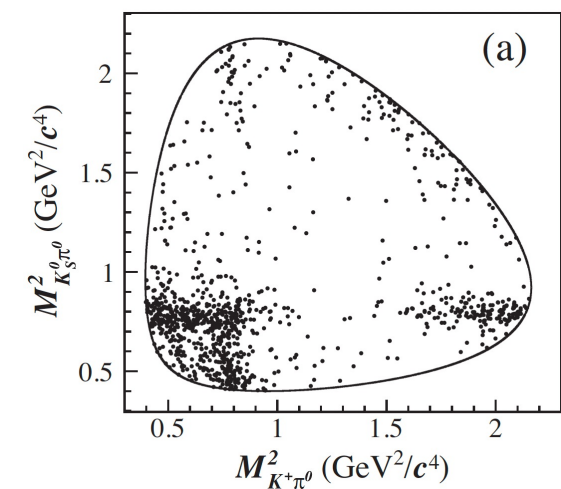
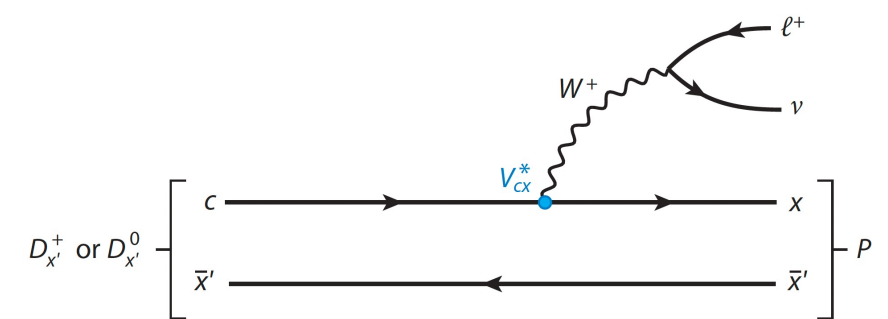
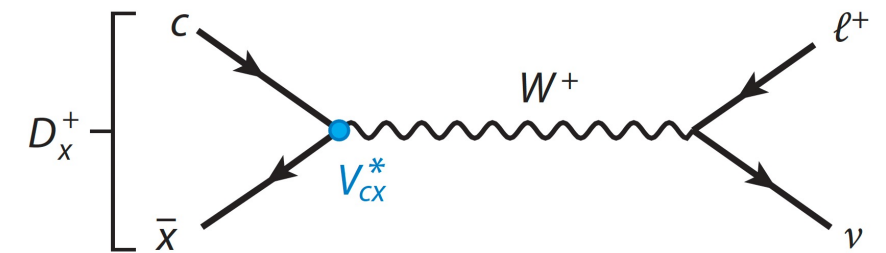


Charm physics measurement at BESIII

Bai-Cian Ke
Zhengzhou University

Outline

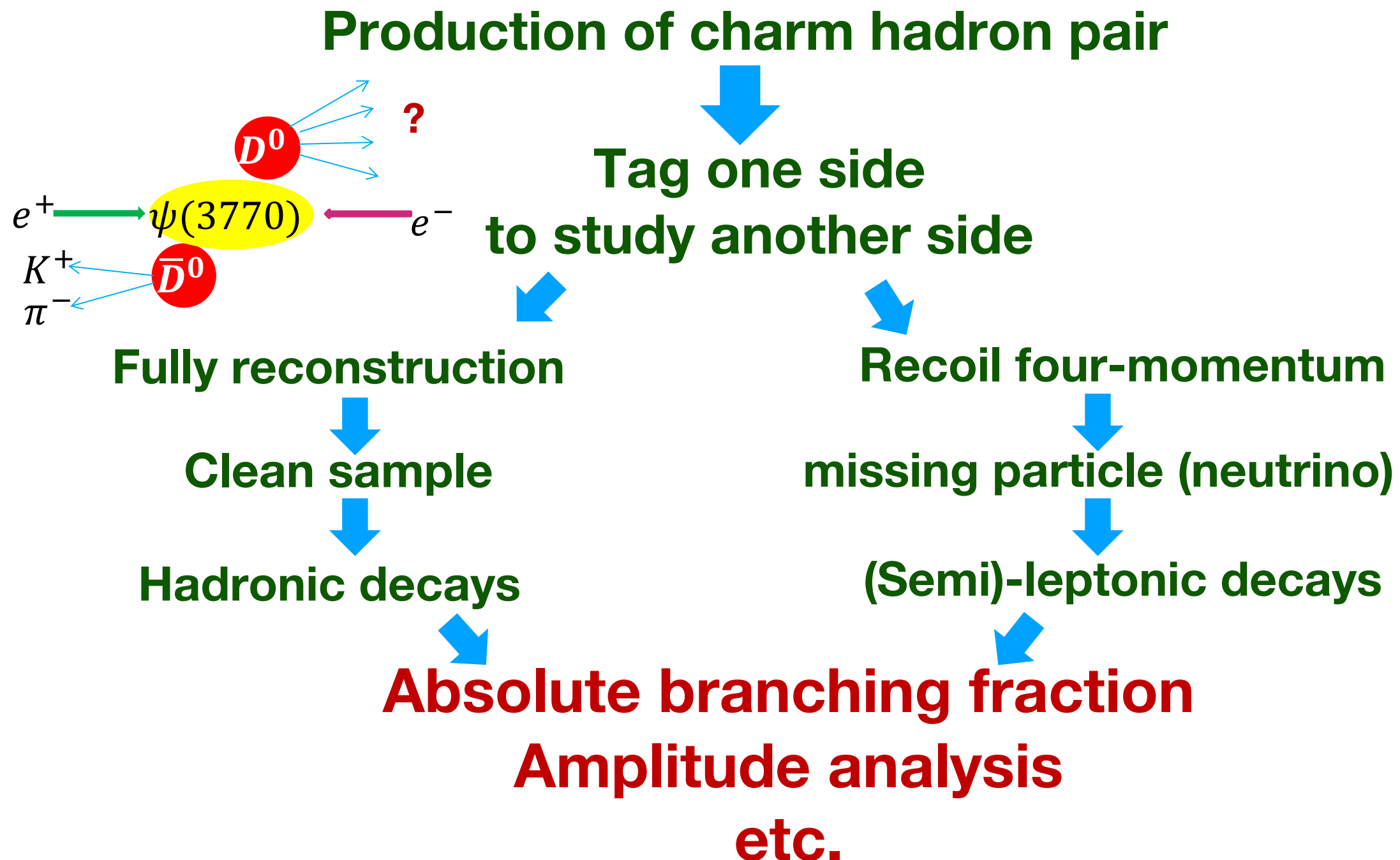
- BESIII dataset
- Charmed meson (D^0 , D^+ , D_s^+)
 - pure leptonic decays
 - semi-leptonic decays
 - hadronic decays
 - quantum correlation
- Charmed baryon (Λ_c^+)
 - semi-leptonic decays
 - hadronic decays
- Prospect



- **BESIII dataset**
- Charmed meson (D^0 , D^+ , D_s^+)
 - pure leptonic decays
 - semi-leptonic decays
 - hadronic decays
 - quantum correlation
- Charmed baryon (Λ_c^+)
 - semi-leptonic decays
 - hadronic decays
- Summary

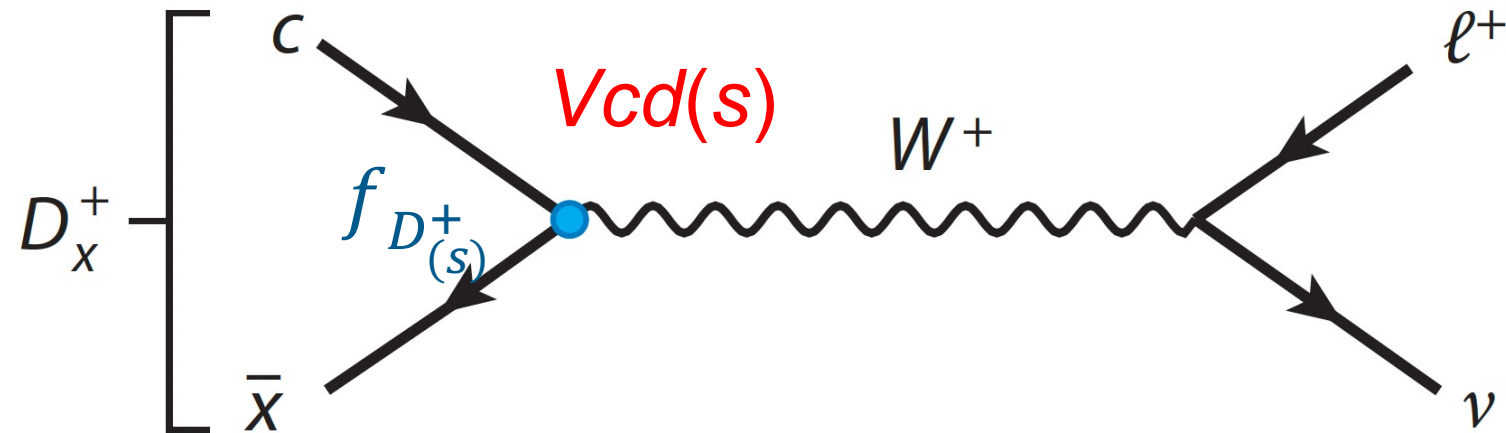
BESIII Data Taken near Threshold

- 7.9 fb^{-1} at $E_{\text{cm}} 3.773 \text{ GeV}$: $e^+ e^- \rightarrow \psi(3770) \rightarrow D \bar{D}$
- 7.3 fb^{-1} at $E_{\text{cm}} 4.128 - 4.226 \text{ GeV}$: $e^+ e^- \rightarrow D_s D_s^*$
- 4.5 fb^{-1} at $E_{\text{cm}} = 4.600 - 4.699 \text{ GeV}$: $e^+ e^- \rightarrow \Lambda_c^+ \bar{\Lambda}_c^-$



- BESIII dataset
- Charmed meson (D^0 , D^+ , D_s^+)
 - pure leptonic decays
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Pure leptonic D decay



$$\Gamma(D_{(s)}^+ \rightarrow l^+ \nu) = \frac{G_F^2 f_{D_{(s)}^+}^2}{8\pi} |V_{cd(s)}|^2 m_l^2 m_{D_{(s)}^+} \left(1 - \frac{m_l^2}{m_{D_{(s)}^+}^2}\right)^2$$

Decay constant $f_{D_{(s)}^+}$:

Calibrate Lattice QCD

CKM matrix element $|V_{cd(s)}|$:

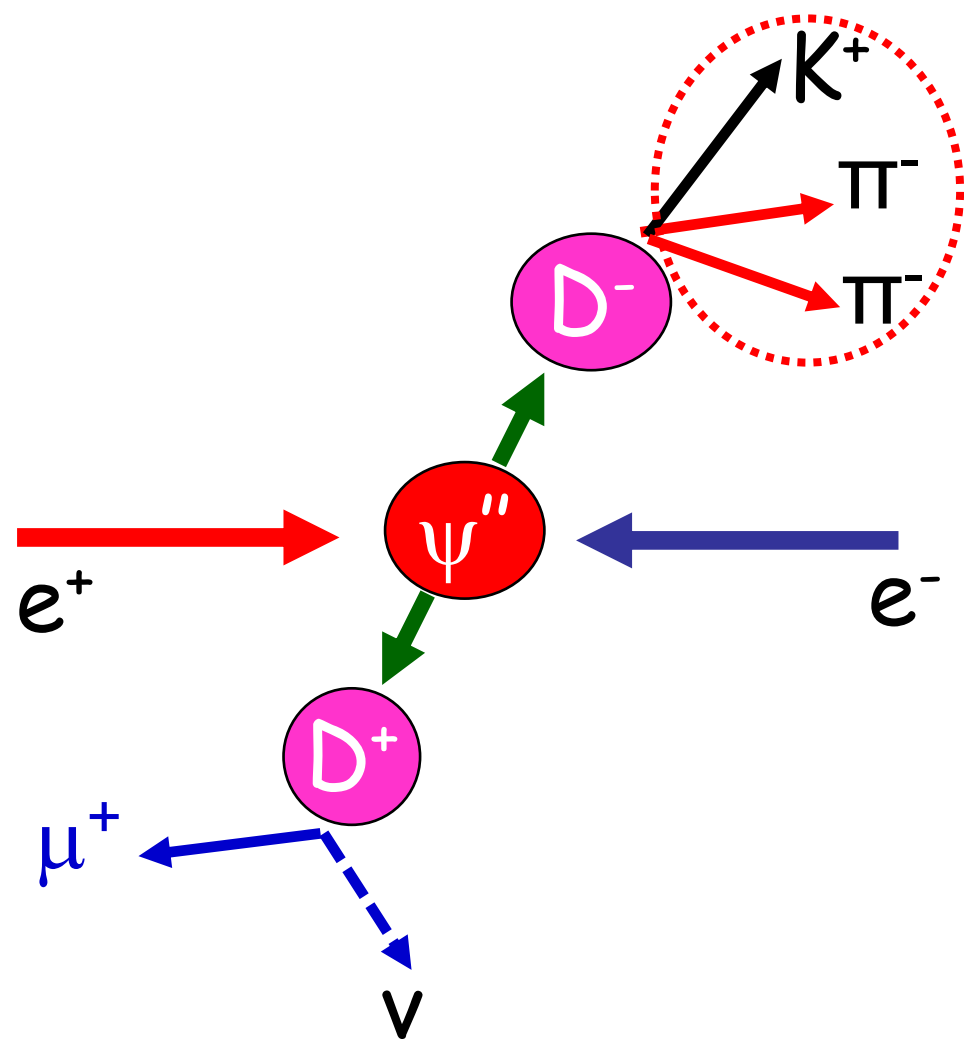
Test the unitarity of CKM matrix

Lepton flavor universality

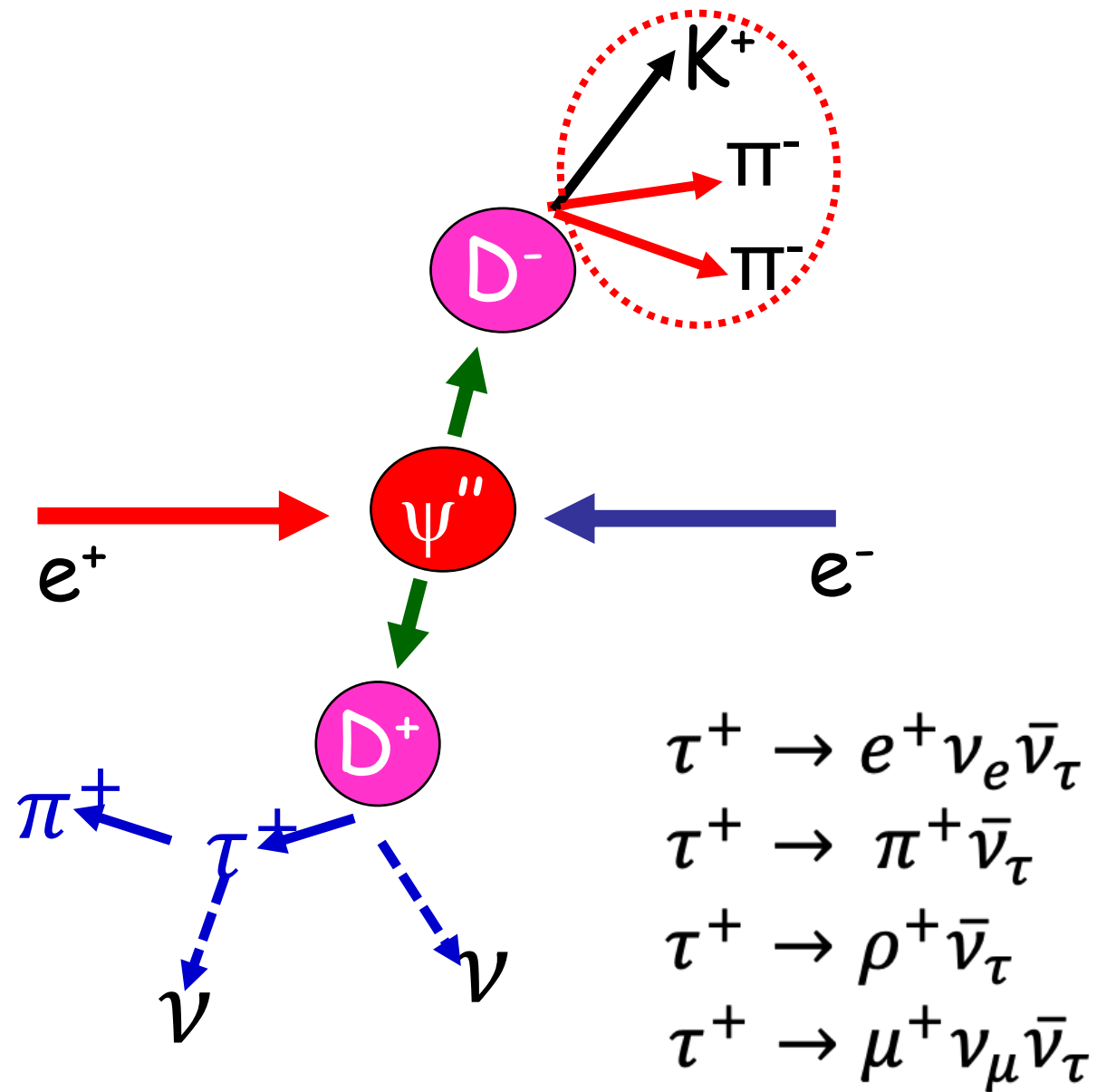
$e^+ \nu_e : \mu^+ \nu_\mu : \tau^+ \nu_\tau$

$D^+ 10^{-5} : 1 : 2.67$

$D_s^+ 10^{-5} : 1 : 9.75$



One neutrino missing in an muonic event



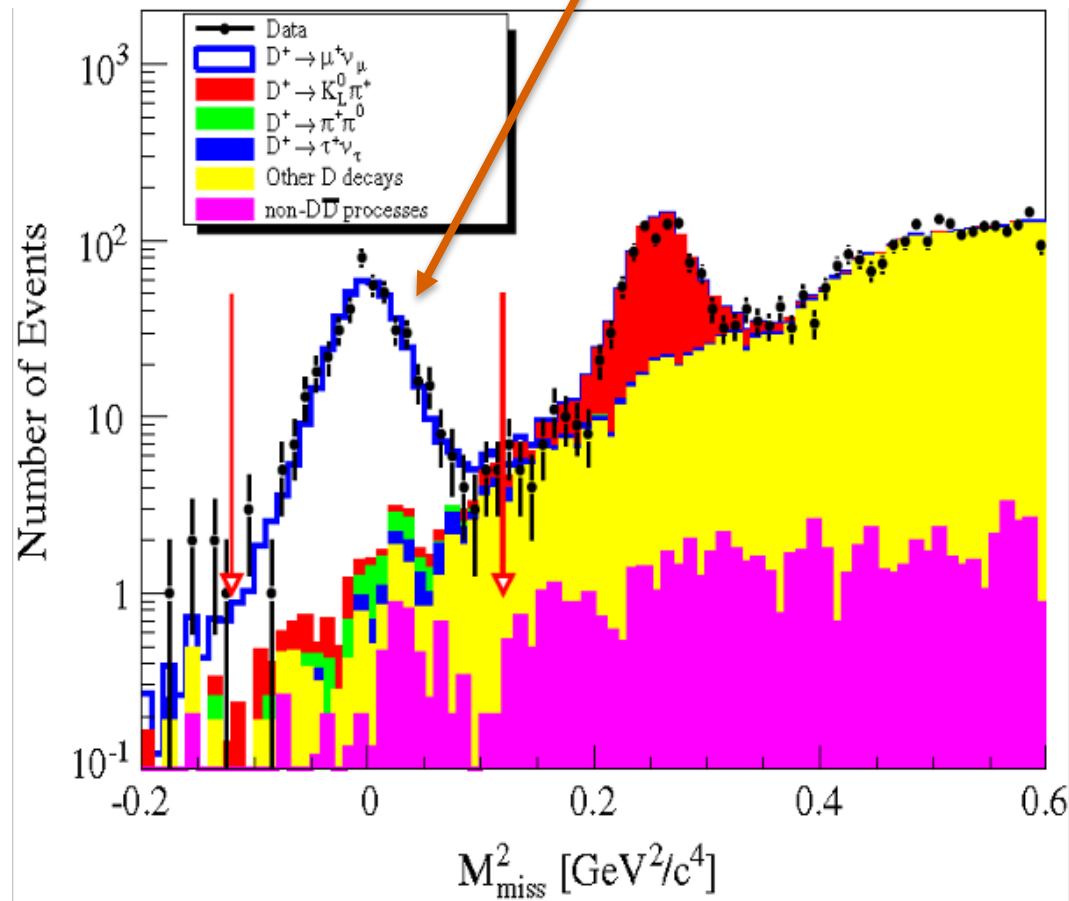
Two or three neutrinos missing in an tau event

$$U_{\text{miss}} = E_{\text{miss}} - |\vec{p}_{\text{miss}}|$$

$$M_{\text{miss}}^2 = E_{\text{miss}}^2 - |\vec{p}_{\text{miss}}|^2$$

$$D^+ \rightarrow l^+ \nu_l$$

$$D^+ \rightarrow \mu^+ \nu_\mu$$

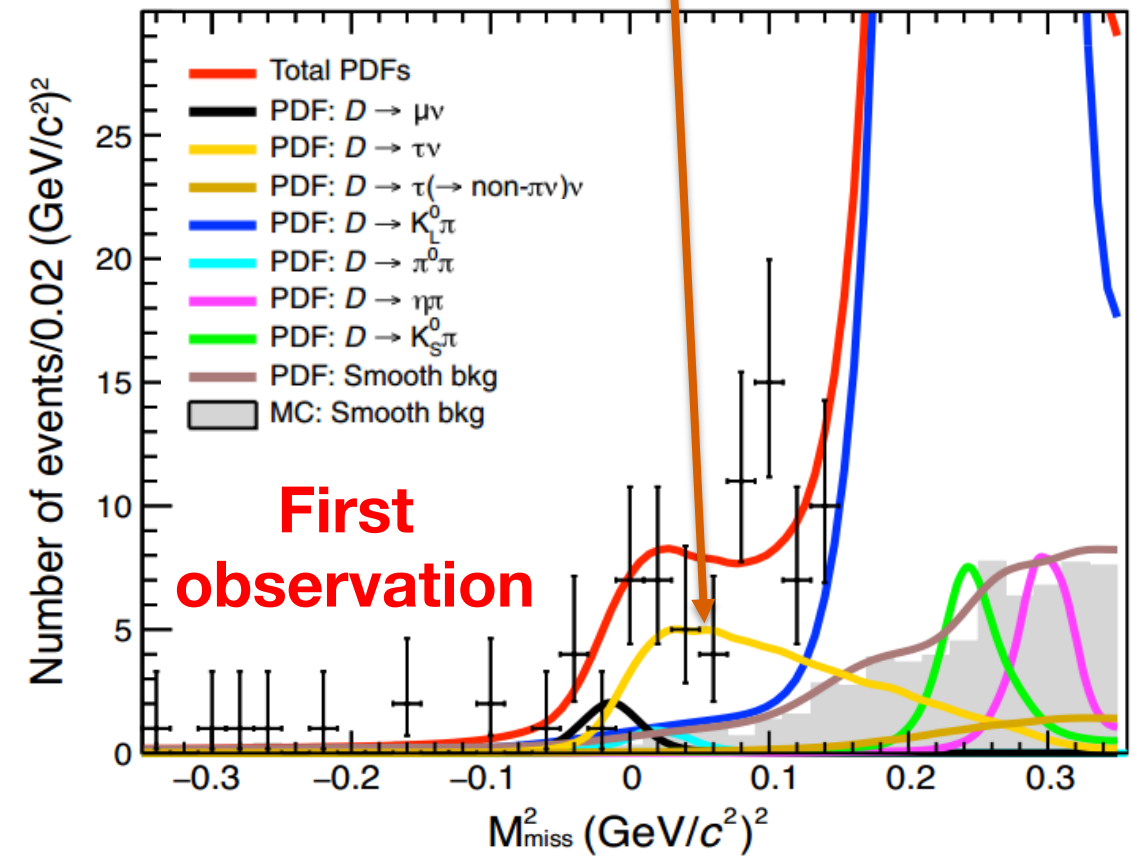


$$\mathcal{B}(D^+ \rightarrow \mu^+ \nu_\mu) = (3.71 \pm 0.19 \pm 0.06) \times 10^{-4}$$

$$f_{D^+} |V_{cd}| = 46.7 \pm 1.2 \pm 0.4 \text{ MeV}$$

Phys. Rev. D 89, 051104 (2014)

$$D^+ \rightarrow \tau^+ \nu_\tau$$



τ^+ is reconstructed via $\tau^+ \rightarrow \pi^+ \nu_\tau$

$$\mathcal{B}(D^+ \rightarrow \tau^+ \nu_\tau) = (1.20 \pm 0.24 \pm 0.12) \times 10^{-3}$$

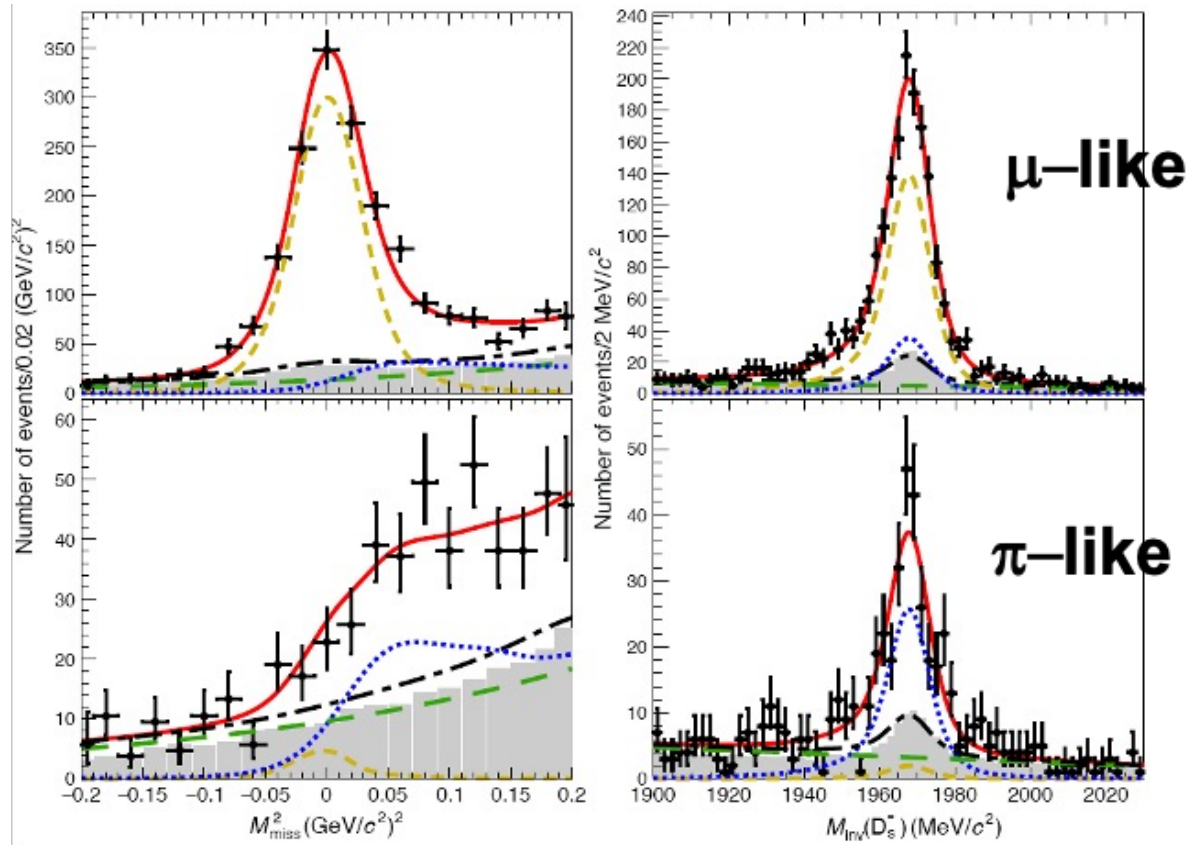
$$f_{D^+} |V_{cd}| = 50.4 \pm 5.0 \pm 2.5 \text{ MeV}$$

Phys. Rev. Lett. 123, 211802 (2019)

Unfortunately $D^+ \rightarrow \tau^+ \nu_\tau$ can't contribute to D^+ decay constant measurement

$D_S^+ \rightarrow l^+ \nu$

$D_S^+ \rightarrow \mu^+ \nu$ and $\tau^+(\pi^+ \nu) \nu$



$$\mathcal{B}(D_S^+ \rightarrow \mu^+ \nu_\mu) = (5.35 \pm 0.13 \pm 0.16) \times 10^{-3}$$

$$f_{D_S^+} |V_{cs}| = 243.1 \pm 3.0 \pm 3.7 \text{ MeV}[\mu]$$

$$\mathcal{B}(D_S^+ \rightarrow \tau^+ \nu_\tau) = (5.21 \pm 0.25 \pm 0.17)\%$$

$$f_{D_S^+} |V_{cs}| = 243.0 \pm 5.8 \pm 4.0 \text{ MeV}[\tau]$$

Phys. Rev. D 104, 052009 (2021)

$D_S^+ \rightarrow \tau^+(\rho^+ \nu) \nu$

$$\mathcal{B}(D_S^+ \rightarrow \tau^+ \nu_\tau) = (5.29 \pm 0.25 \pm 0.20)\%$$

$$f_{D_S^+} |V_{cs}| = 244.8 \pm 5.8 \pm 4.8 \text{ MeV}$$

Phys. Rev. D 104, 032001 (2021)

$D_S^+ \rightarrow \tau^+(e^+ \nu \nu) \nu$ **most precise**

$$\mathcal{B}(D_S^+ \rightarrow \tau^+ \nu_\tau) = (5.27 \pm 0.10 \pm 0.12)\%$$

$$f_{D_S^+} |V_{cs}| = 244.4 \pm 2.3 \pm 2.9 \text{ MeV}$$

Phys. Rev. Lett. 127, 171801 (2021)

$D_S^+ \rightarrow \tau^+(\mu^+ \nu \nu) \nu$

$$\mathcal{B}(D_S^+ \rightarrow \tau^+ \nu) = (5.34 \pm 0.16 \pm 0.10)\%$$

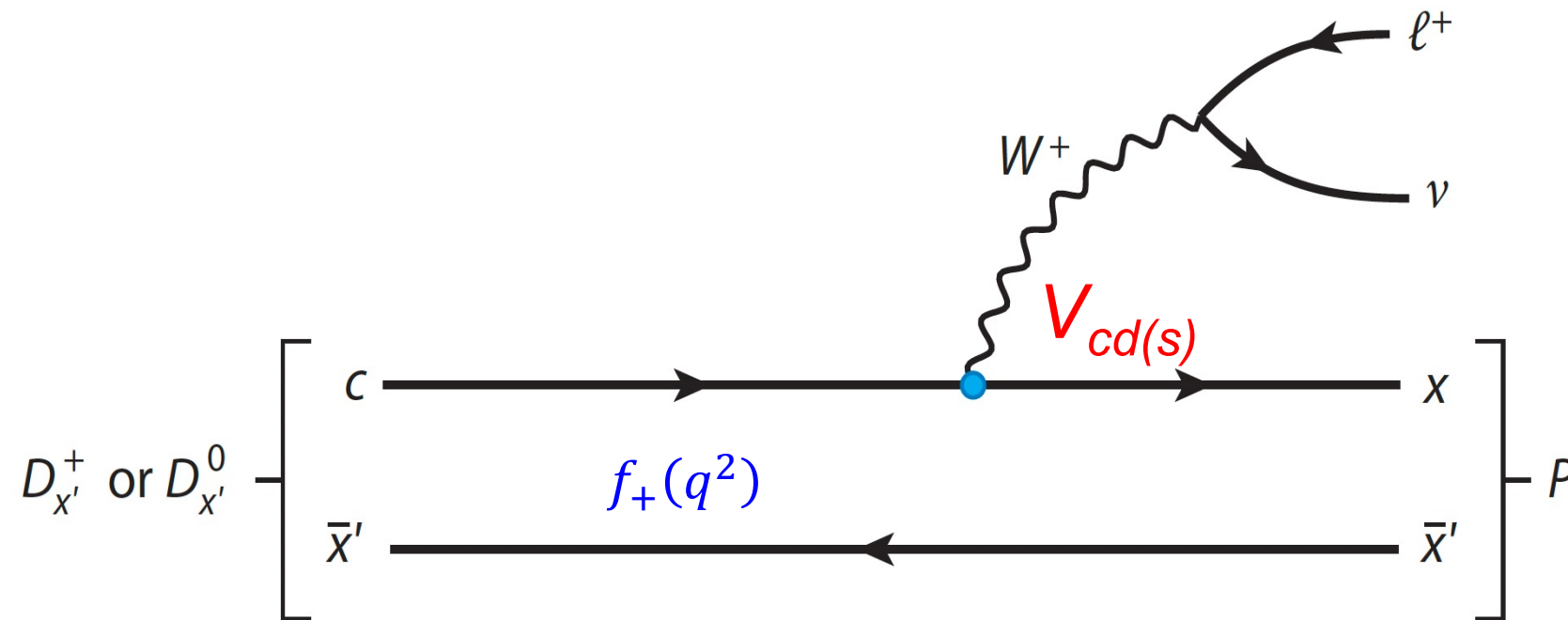
$$f_{D_S^+} |V_{cs}| = (246.2 \pm 3.7_{\text{stat}} \pm 2.5_{\text{syst}}) \text{ MeV.}$$

arXiv: 2303.12468

$D^+ \rightarrow \tau^+ \nu_\tau$ can contribute comparable statistics to $\mu^+ \nu$

- BESIII dataset
- Charmed meson (D^0 , D^+ , D_s^+)
 - pure leptonic decays
 - **semi-leptonic decays**
 - hadronic decays
 - quantum correlation
- Charmed baryon (Λ_c^+)
 - semi-leptonic decays
 - hadronic decays
- Prospect

Semi-leptonic $D \rightarrow P e^+ \nu$



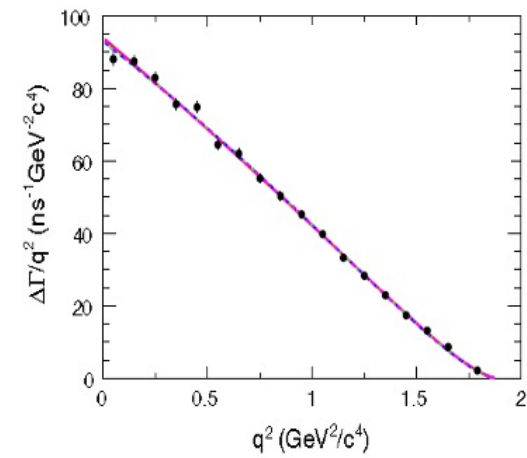
$$\frac{d\Gamma}{dq^2} = X \frac{G_F^2 p^3}{24\pi^3} |f_+(q^2)|^2 |V_{cd(s)}|^2$$

$$(X = 1 \text{ for } K^-, \pi^-, \bar{K}^0, \eta^{(\prime)}; X = \frac{1}{2} \text{ for } \pi^0)$$

Form factor $f_+(0)$: Calibrate Lattice QCD

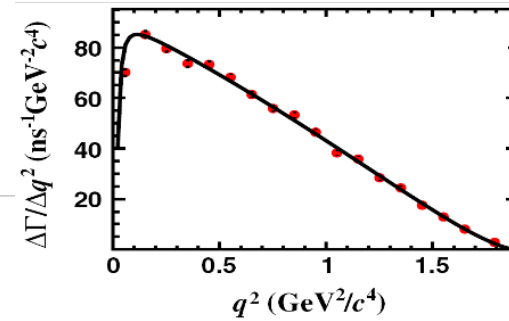
CKM matrix element $|V_{cd(s)}|$: Test the unitarity of CKM matrix

Test $e - \mu$ Lepton flavor universality



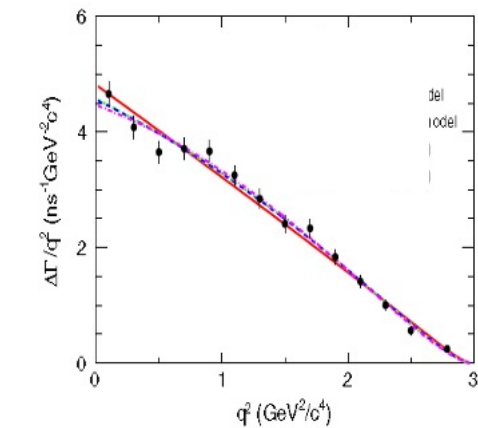
$$f_+^{D \rightarrow K}(0) |V_{cs}| = 0.717(03)(04)$$

Phys. Rev. D 92, 072012 (2015)



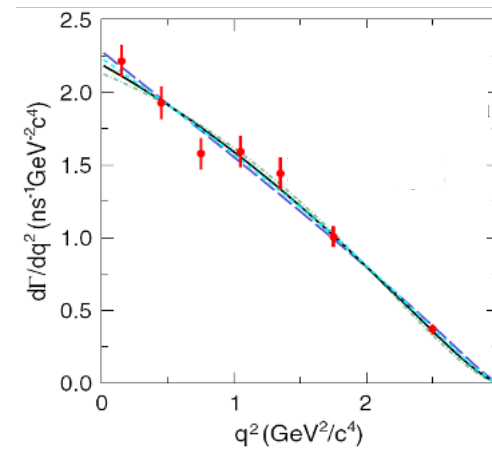
$$f_+^{D \rightarrow K}(0) |V_{cs}| = 0.7148(38)(29)$$

Phys. Rev. Lett. 122, 011804 (2019)



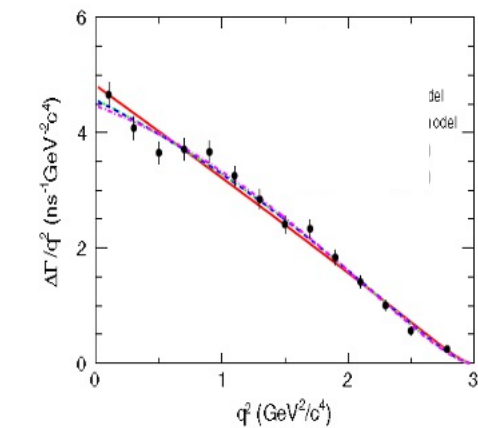
$$f_+^{D \rightarrow \pi}(0) |V_{cd}| = 0.144(02)(01)$$

Phys. Rev. D 92, 072012 (2015)



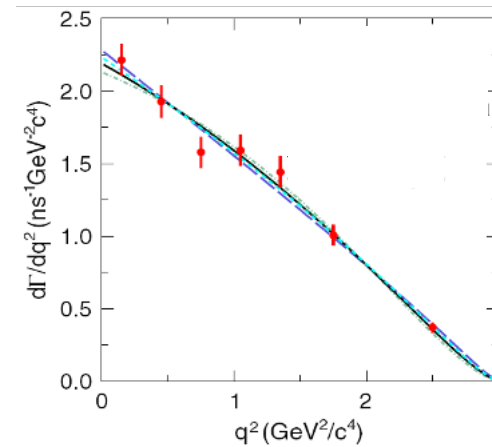
$$f_+^{D \rightarrow \pi}(0) |V_{cd}| = 0.140(03)(01)$$

Phys. Rev. D 96, 012002 (2017)



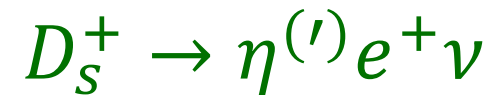
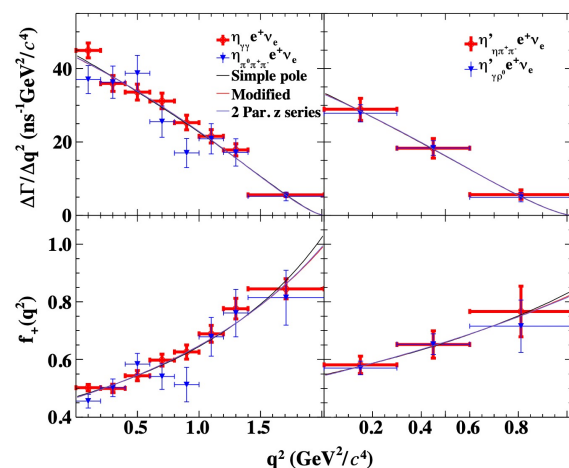
$$f_+^{D \rightarrow \pi}(0) |V_{cd}| = 0.144(02)(01)$$

Phys. Rev. D 92, 072012 (2015)



$$f_+^{D \rightarrow \pi}(0) |V_{cd}| = 0.140(03)(01)$$

Phys. Rev. D 96, 012002 (2017)



$$f_+^{\eta}(0) |V_{cs}| = 0.4553 \pm 0.0071_{\text{stat}} \pm 0.0061_{\text{syst}}$$

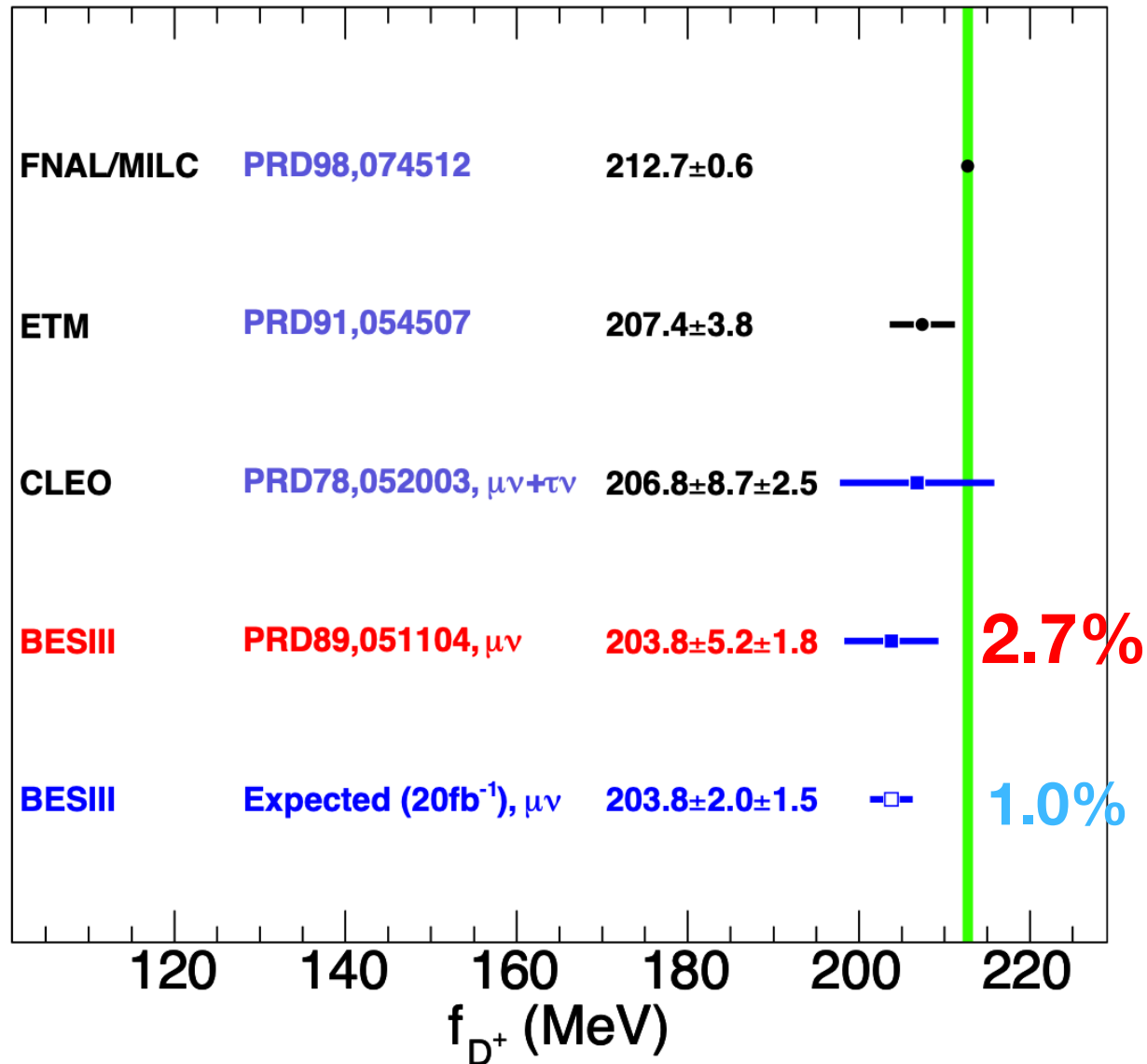
$$f_+^{\eta'}(0) |V_{cs}| = 0.529 \pm 0.024_{\text{stat}} \pm 0.008_{\text{syst}}$$

arXiv:2306.05194

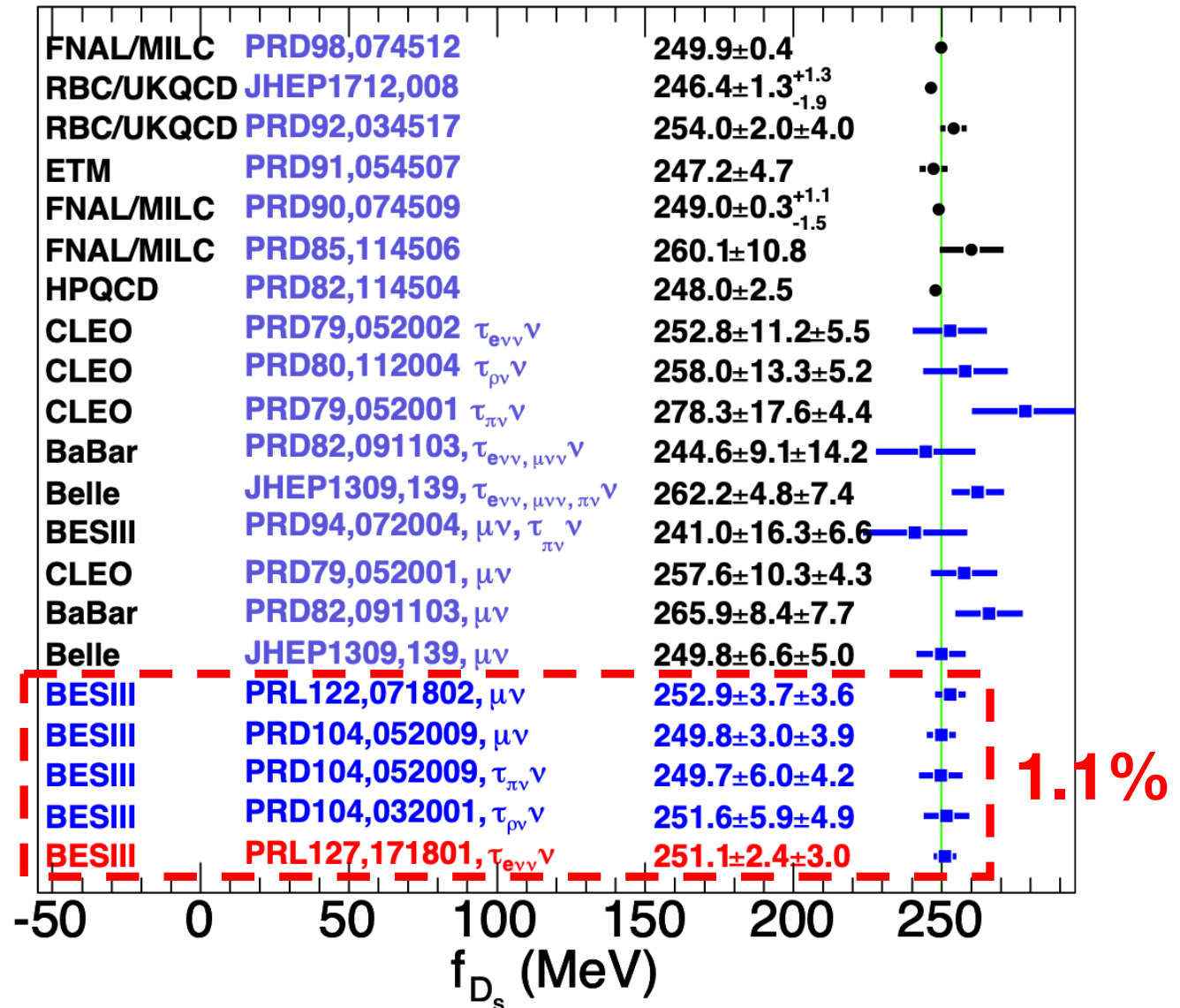
Phys. Rev. Lett. 123, 121801 (2019)

Comparison of decay constant

$$f_{D^+}$$



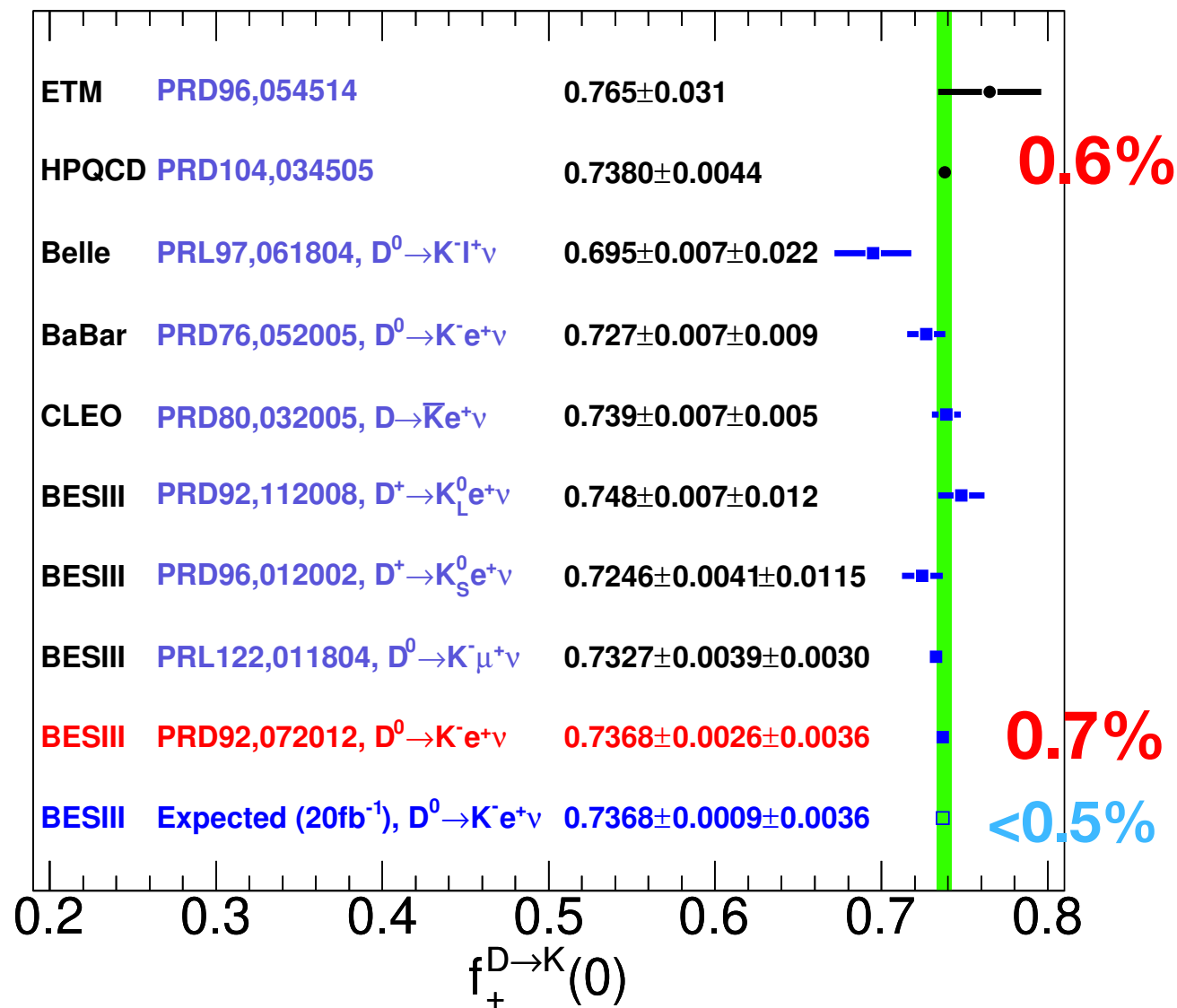
$$f_{D_s^+}$$



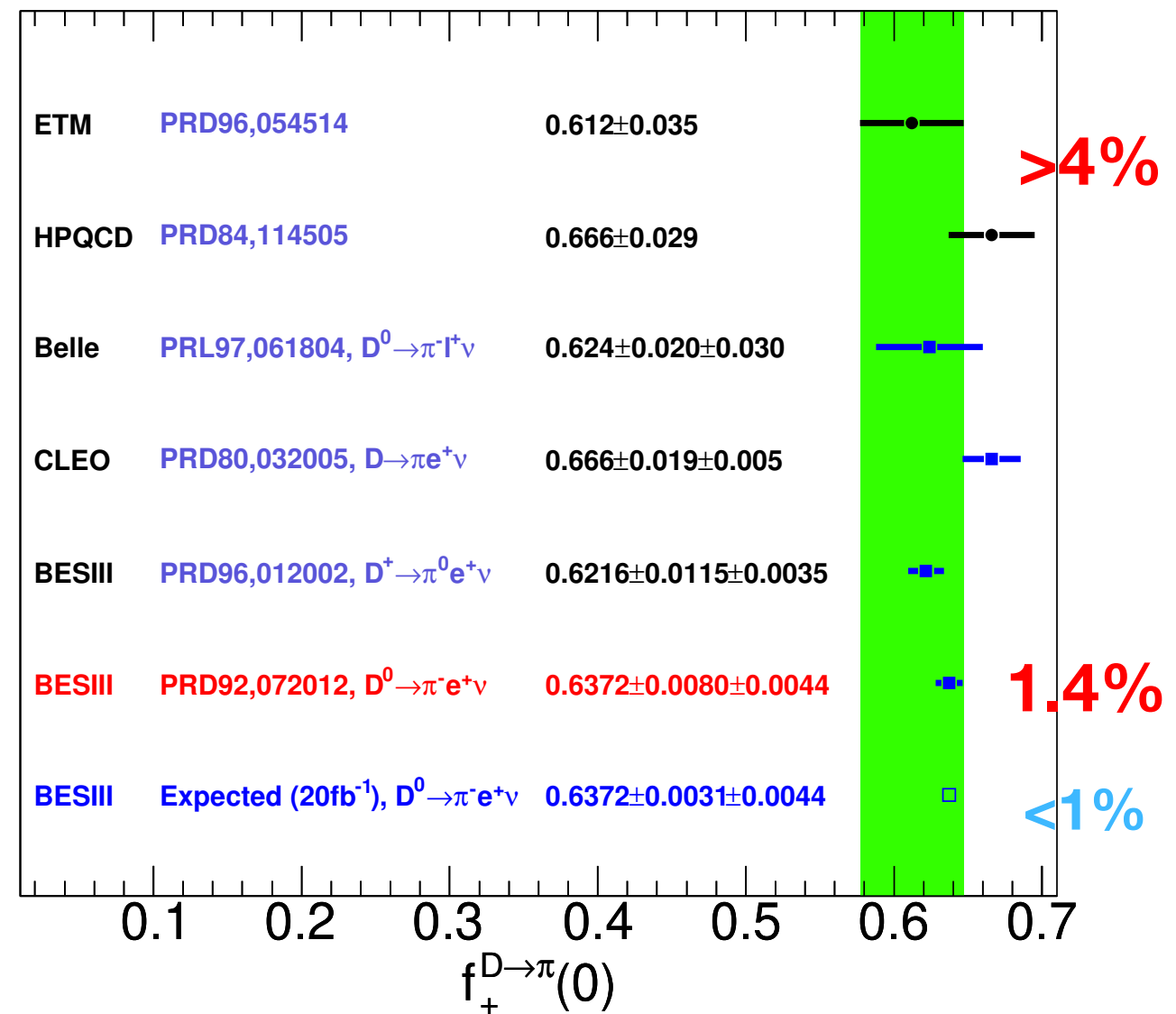
Dominated by statistical uncertainty

Comparison of form factor

$D \rightarrow K$



$D \rightarrow \pi$

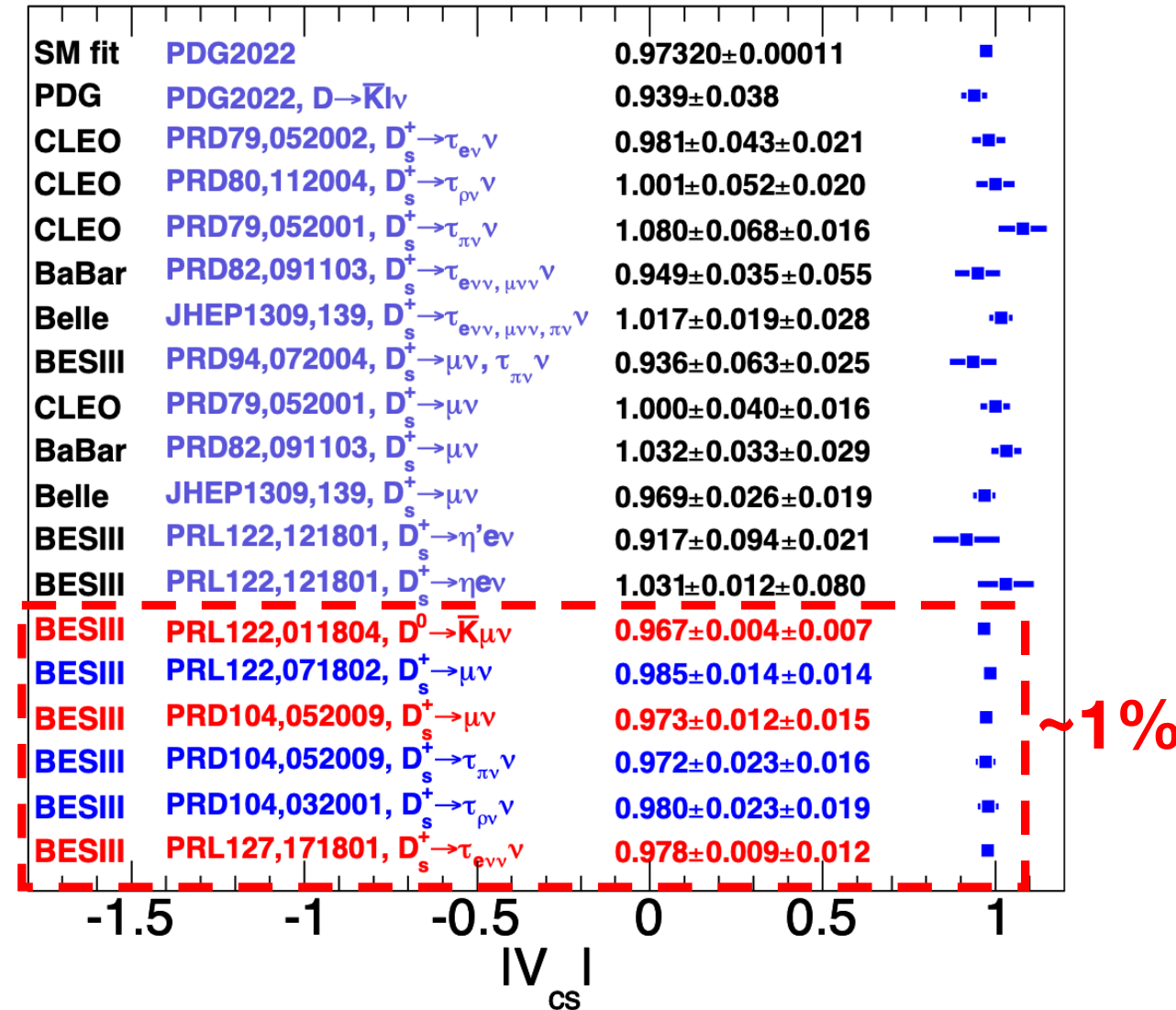
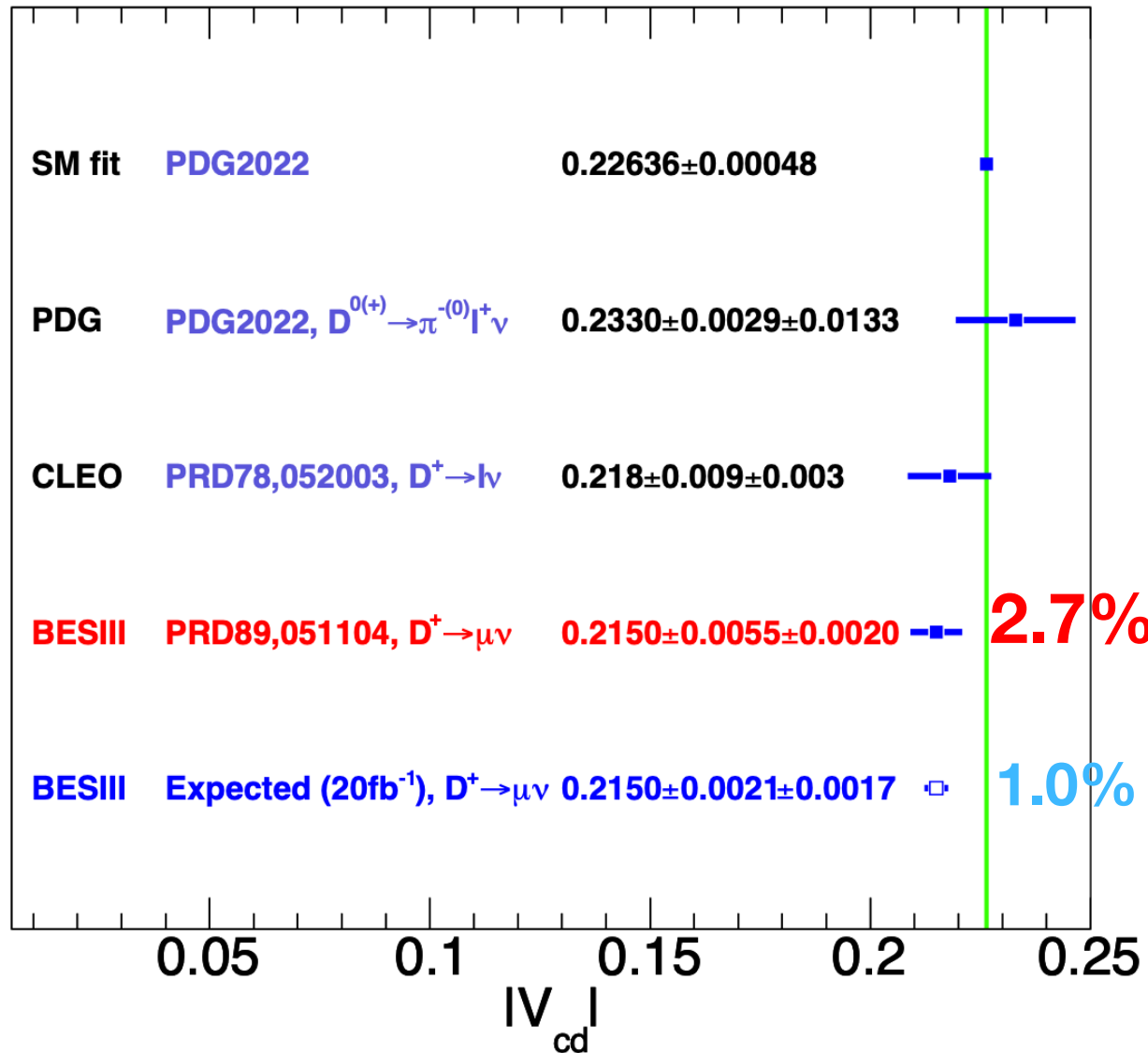


Experimental precision is comparable to the latest QCD result

Comparison of $|V_{cd(s)}|$

$|V_{cd}|$

$|V_{cs}|$



Both pure- and semi-leptonic decays contribute

We have also study...

Observe $f_0(980)$ in $D_s^+ \rightarrow \pi^0 \pi^0 e^+ \nu$

$$\mathcal{B} = (7.9 \pm 1.4 \pm 0.4) \times 10^{-4}$$

Phys. Rev. D(L) 105, L031101 (2022)

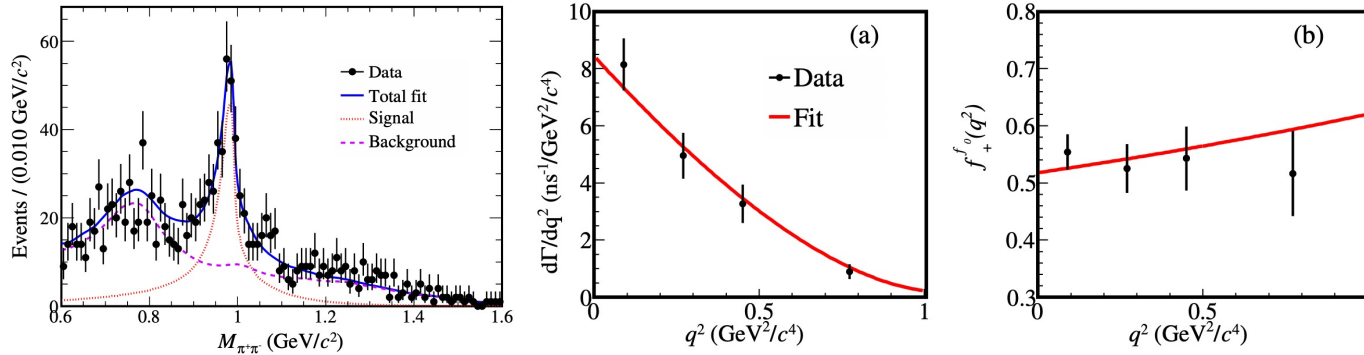
Study $f_0(980)$ in $D_s^+ \rightarrow \pi^+ \pi^- e^+ \nu_e$

$$\mathcal{B} = (1.72 \pm 0.13 \pm 0.10) \times 10^{-3}$$

$$f_+^{f_0}(0) |V_{cs}| = 0.504 \pm 0.017 \pm 0.035$$

arXiv:2303.12927

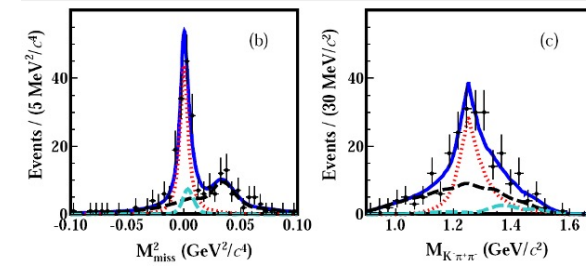
First measurement



$D^0 \rightarrow K_1(1270)^- e^+ \nu$

$$\mathcal{B} = (1.9 \pm 0.13 \pm 0.13 \pm 0.12) \times 10^{-4}$$

Phys. Rev. Lett. 127, 131801 (2021)

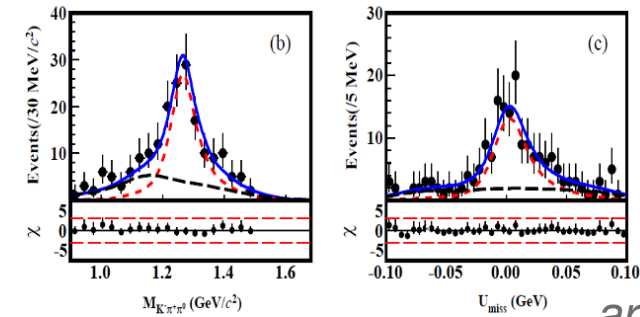


$D \rightarrow A l \nu$

$D^+ \rightarrow K_1(1270)^0 e^+ \nu$

$$\mathcal{B} = (2.30 \pm 0.26 \pm 0.18 \pm 0.25) \times 10^{-4}$$

Phys. Rev. Lett. 123, 231801 (2019)



arxiv: 2307.03024

$D \rightarrow V l \nu$

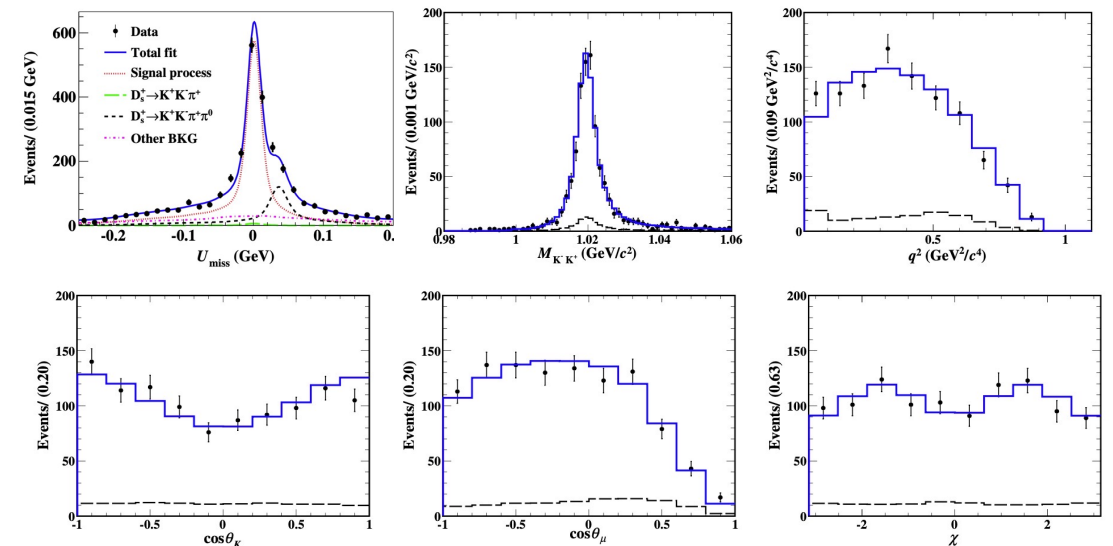
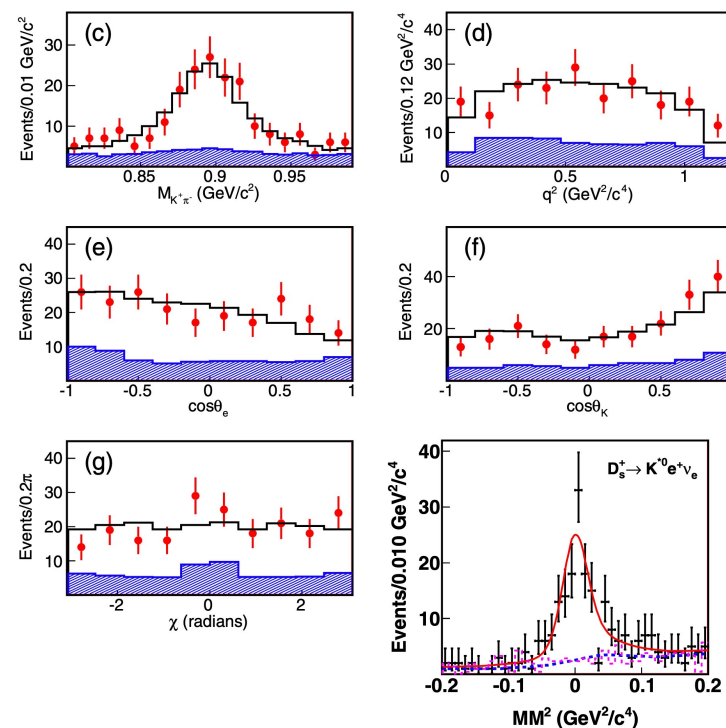
$D_s^+ \rightarrow K^{*0} e^+ \nu_e$

$$\mathcal{B} = (2.37 \pm 0.26 \pm 0.20) \times 10^{-3}$$

$$r_V = 1.67 \pm 0.34 \pm 0.16$$

$$r_2 = 0.77 \pm 0.28 \pm 0.07$$

Phys. Rev. Lett. 122, 061801 (2019)



$D_s^+ \rightarrow \phi \mu^+ \nu_e$

$$\mathcal{B} = (2.25 \pm 0.09 \pm 0.07) \times 10^{-2}$$

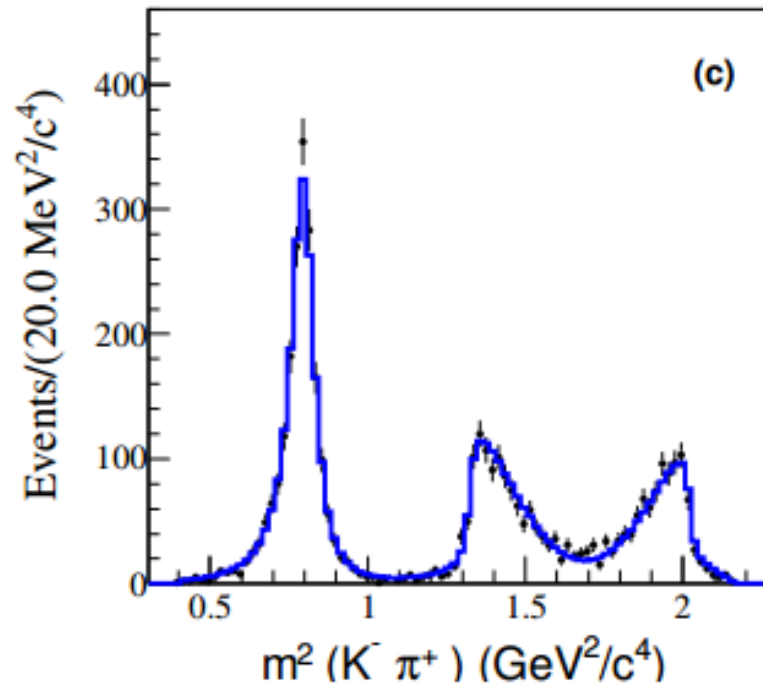
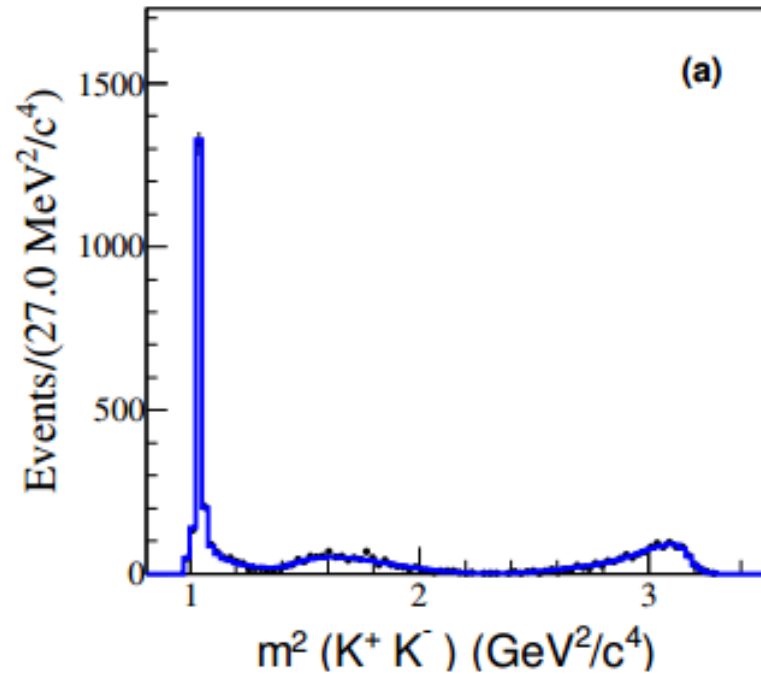
$$r_V = 1.58 \pm 0.17 \pm 0.02 \quad 16$$

$$r_2 = 0.77 \pm 0.28 \pm 0.07$$

- BESIII dataset
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 - hadronic decays
- Prospect

Amplitude analysis of $D_S^+ \rightarrow K^+ K^- \pi^+$

Dalitz plot projections:



Considering interference of $D_S \rightarrow \phi\pi$ and other processes, such as $D_S \rightarrow K^*K$

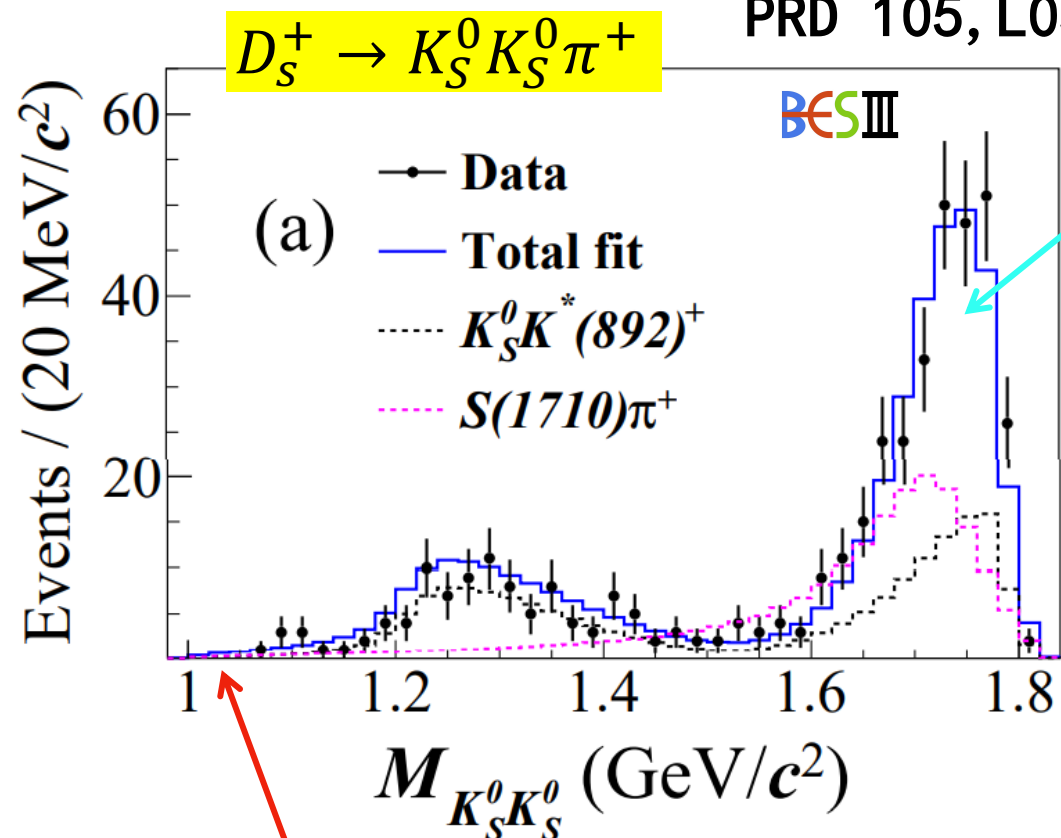
The best precision at present

$$B(D_S^+ \rightarrow K^+ K^- \pi^+) = (5.47 \pm 0.08_{stat.} \pm 0.13_{syst.})\%$$

Process	BF (%)	
	BESIII (this analysis)	PDG
$D_S^+ \rightarrow \bar{K}^*(892)^0 K^+, \bar{K}^*(892)^0 \rightarrow K^- \pi^+$	$2.64 \pm 0.06_{stat} \pm 0.07_{sys}$	2.58 ± 0.08
$D_S^+ \rightarrow \phi(1020)\pi^+, \phi(1020) \rightarrow K^+ K^-$	$2.21 \pm 0.05_{stat} \pm 0.07_{sys}$	2.24 ± 0.08
$D_S^+ \rightarrow S(980)\pi^+, S(980) \rightarrow K^+ K^-$	$1.05 \pm 0.04_{stat} \pm 0.06_{sys}$	1.14 ± 0.31
$D_S^+ \rightarrow \bar{K}_0^*(1430)^0 K^+, \bar{K}_0^*(1430)^0 \rightarrow K^- \pi^+$	$0.16 \pm 0.03_{stat} \pm 0.03_{sys}$	0.18 ± 0.04
$D_S^+ \rightarrow f_0(1710)\pi^+, f_0(1710) \rightarrow K^+ K^-$	$0.10 \pm 0.02_{stat} \pm 0.03_{sys}$	0.07 ± 0.03
$D_S^+ \rightarrow f_0(1370)\pi^+, f_0(1370) \rightarrow K^+ K^-$	$0.07 \pm 0.02_{stat} \pm 0.01_{sys}$	0.07 ± 0.05
$D_S^+ \rightarrow K^+ K^- \pi^+$ total BF	$5.47 \pm 0.08_{stat} \pm 0.13_{sys}$	5.39 ± 0.15

Observation of $a_0(1817)$ in D_s decays

PRD 105, L051103 (2022)

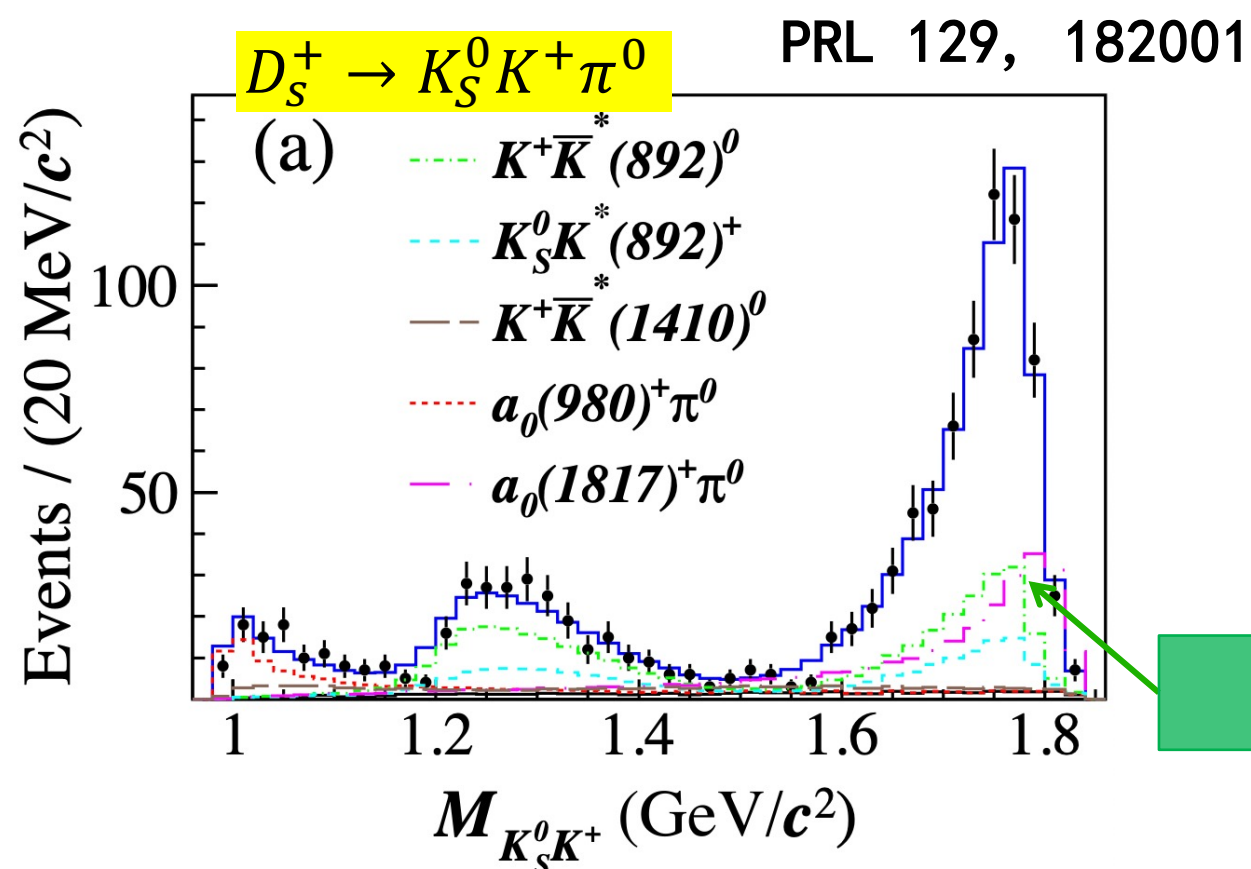


constructive interference: $a_0(1817)$ and $f_0(1710)$

- The isovector partner of $f_0(1710)$ or $X(1812)$?
- Same resonance observed in η_c to $\pi\pi\eta$ by BaBar?

PRD 104, 072002 (2021)

destructive interference: $a_0(980)$ and $f_0(980)$



$a_0(1817)^+$ in $K_S^0 K^+$ mass spectrum

- $M = 1.817 \pm 0.008 \pm 0.020$ GeV/c²
- $\Gamma = 0.097 \pm 0.022 \pm 0.015$ GeV/c²
 - $\mathcal{B}(D_s^+ \rightarrow a_0(1817)^+ \pi^0) = (3.44 \pm 0.52 \pm 0.32) \times 10^{-3}$
 - Significance $> 10\sigma$

Amplitudes analyses of D_s decays

$D_s^+ \rightarrow \pi^+ \pi^0 \eta$	Phys. Rev. Lett. 123, 112001 (2019)
$D_s^+ \rightarrow K^+ K^- \pi^+$	Phys. Rev. D 104, 112016 (2019)
$D_s^+ \rightarrow K^+ K^- \pi^+ \pi^0$	Phys. Rev. D 104, 032011 (2021)
$D_s^+ \rightarrow K_s^0 K^- \pi^+ \pi^+$	Phys. Rev. D 103 , 092006 (2021)
$D_s^+ \rightarrow \pi^+ \pi^- \pi^+ \eta$	Phys. Rev. D 104, L071101 (2021)
$D_s^+ \rightarrow K_s^0 \pi^+ \pi^0$	JHEP 06, 181 (2021)
$D_s^+ \rightarrow K_s^0 K^+ \pi^0$	Phys. Rev. Lett 129, 182001 (2022)
$D_s^+ \rightarrow K_s^0 K_s^0 \pi^+$,	Phys. Rev. D 105, L051103 (2022)
$D_s^+ \rightarrow \pi^+ \pi^0 \eta'$	JHEP 04, 058 (2022)
$D_s^+ \rightarrow \pi^+ \pi^- \pi^+$	Phys. Rev. D 106, 112006 (2022)
$D_s^+ \rightarrow \pi^+ \pi^0 \pi^0$	JHEP 01, 052 (2022)
$D_s^+ \rightarrow K^+ \pi^+ \pi^-$	JHEP 08, 196 (2022)
$D_s^+ \rightarrow K^+ K^- \pi^+ \pi^+ \pi^-$	JHEP 07, 051 (2022)
$D_s^+ \rightarrow K^+ \pi^+ \pi^- \pi^0$	JHEP 09(2022) 242
$D_s^+ \rightarrow K^+ \pi^+ \pi^-$	JHEP 08(2022) 196

We have finished amplitude analyses of most three and four body decays of D_s

- BESIII dataset
- Charmed meson (D^0 , D^+ , D_s^+)
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 - hadronic decays
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 - hadronic decays
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Quantum Correlation

Quantum correlated data: $e^+ e^- \rightarrow \psi(3770) \rightarrow D^0 \bar{D}^0$

Best laboratory to measure strong-phase parameters

CP-odd: $\psi(3770) = (D^0 \bar{D}^0 - D^+ D^-) = (D_+ D_- - D_- D_+)$

$J^{PC} = 1^{--}$

CP-even eigenstate

CP-odd eigenstate

• Inputs for CPV studies at B experiments

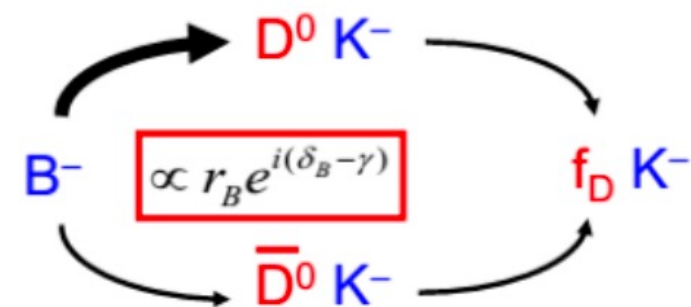
• The CKM angle γ/ϕ_3 :

self-conjugated decay: CP fraction F_+ \rightarrow GLW/GGSZ method;

strong phase $ci(')$ and $si(')$ \rightarrow GGSZ method

non-self-conjugated decay: the coherence factor R and averaged

strong phase difference $\delta \rightarrow$ ADS method



Determination of $\delta_D^{K\pi}$

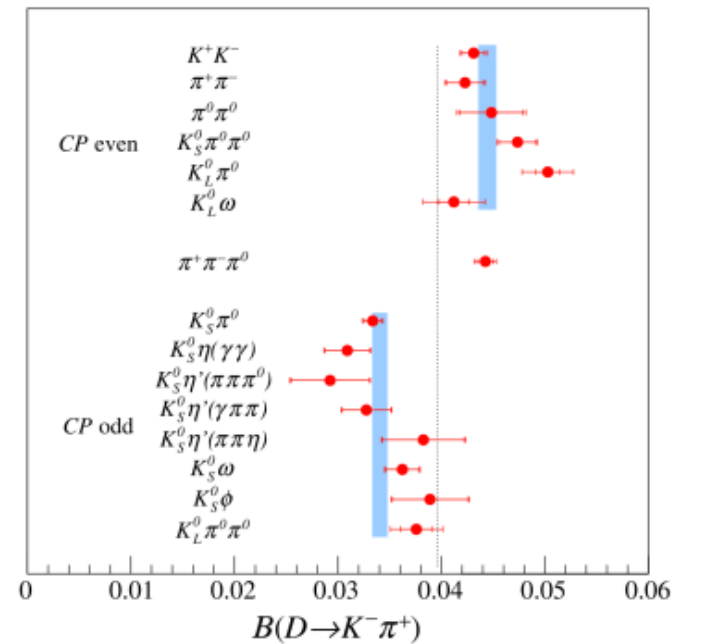
- An update measurement of the asymmetry between CP-odd and CP-even eigenstate decays into $K^-\pi^+$

$$A_{K\pi} \equiv \frac{\mathcal{B}(D_- \rightarrow K^-\pi^+) - \mathcal{B}(D_+ \rightarrow K^-\pi^+)}{\mathcal{B}(D_- \rightarrow K^-\pi^+) + \mathcal{B}(D_+ \rightarrow K^-\pi^+)} = \frac{-2r_D^{K\pi} \cos \delta_D^{K\pi} + y}{1 + (r_D^{K\pi})^2} = 0.132 \pm 0.011 \pm 0.007$$

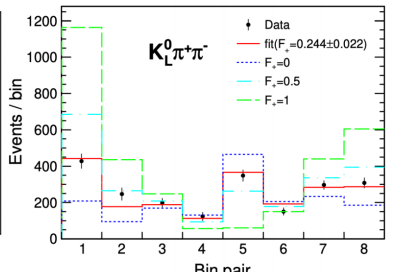
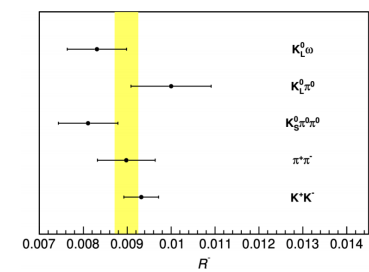
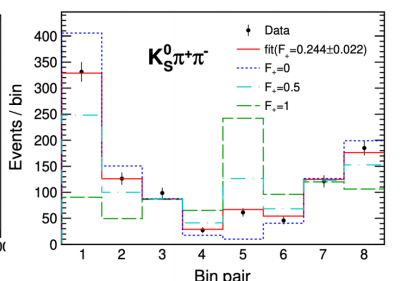
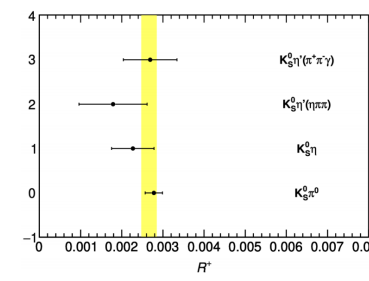
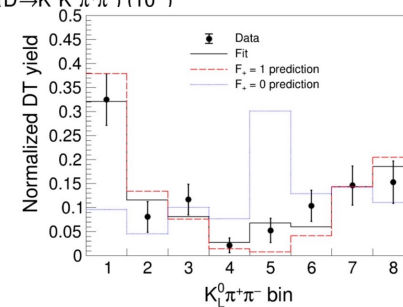
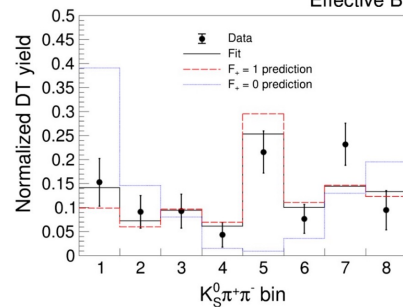
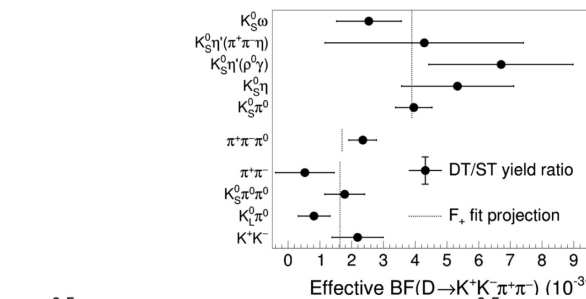
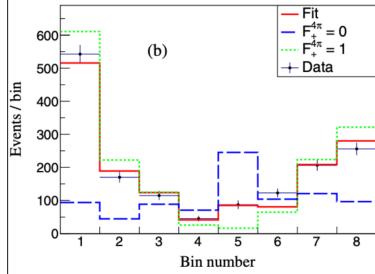
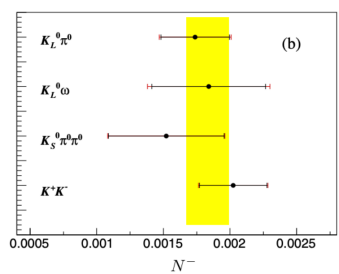
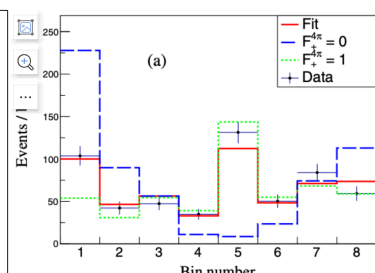
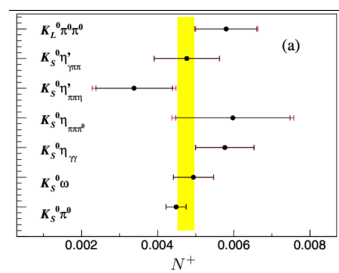
30% more precise !

- $\delta_D^{K\pi} = (187.6_{-9.7}^{+8.9+5.4})$

EPJC 82, 1009 (2022)



Determination of CP fraction



$$D^0 \rightarrow \pi^+ \pi^- \pi^+ \pi^-$$

$$F_+ = 0.735 \pm 0.015 \pm 0.005$$

PRD 106, 092004(2022)

$$D^0 \rightarrow K^+ K^- \pi^+ \pi^-$$

$$F_+ = 0.730 \pm 0.037 \pm 0.021$$

PRD 107, 032009(2023)

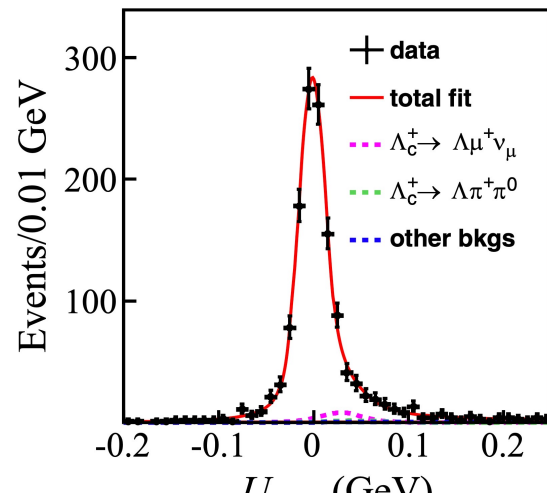
$$D^0 \rightarrow K_S^0 \pi^- \pi^+ \pi^0$$

$$F_+ = 0.235 \pm 0.010 \pm 0.002$$

arxiv:2305.03975

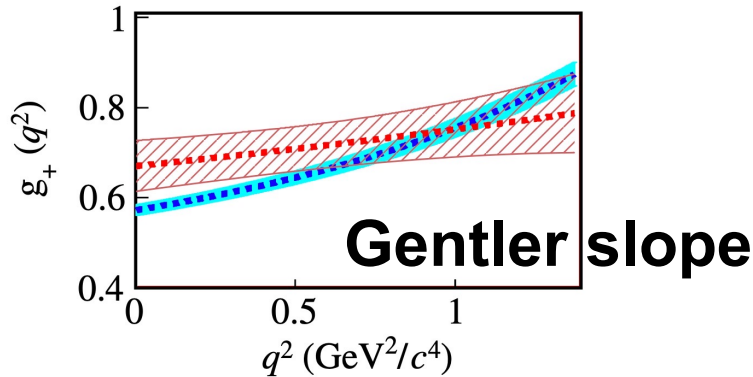
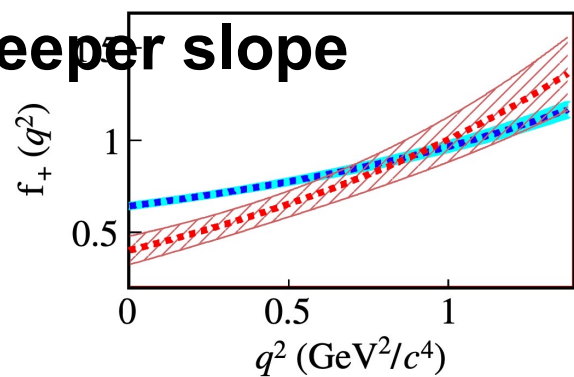
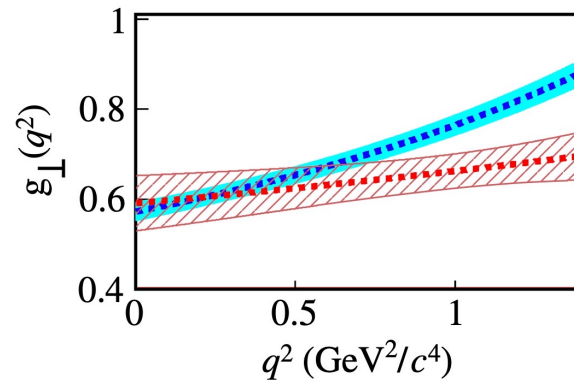
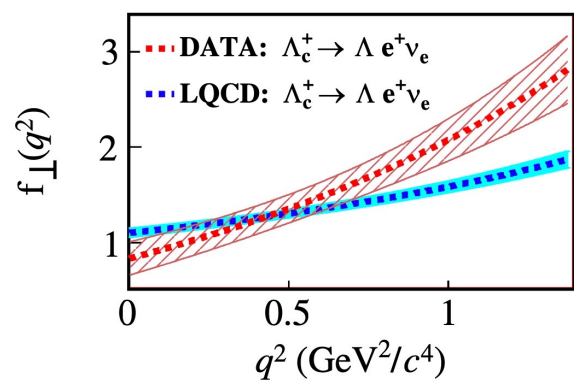
- BESIII dataset
- Charmed meson (D^0 , D^+ , D_s^+)
 - pure leptonic decays
 - semi-leptonic decays
 - hadronic decays
 - quantum correlation
- Charmed baryon (Λ_c^+)
 - semi-leptonic decays
 - hadronic decays
- Prospect

Study of $\Lambda_c^+ \rightarrow \Lambda e^+ \nu$

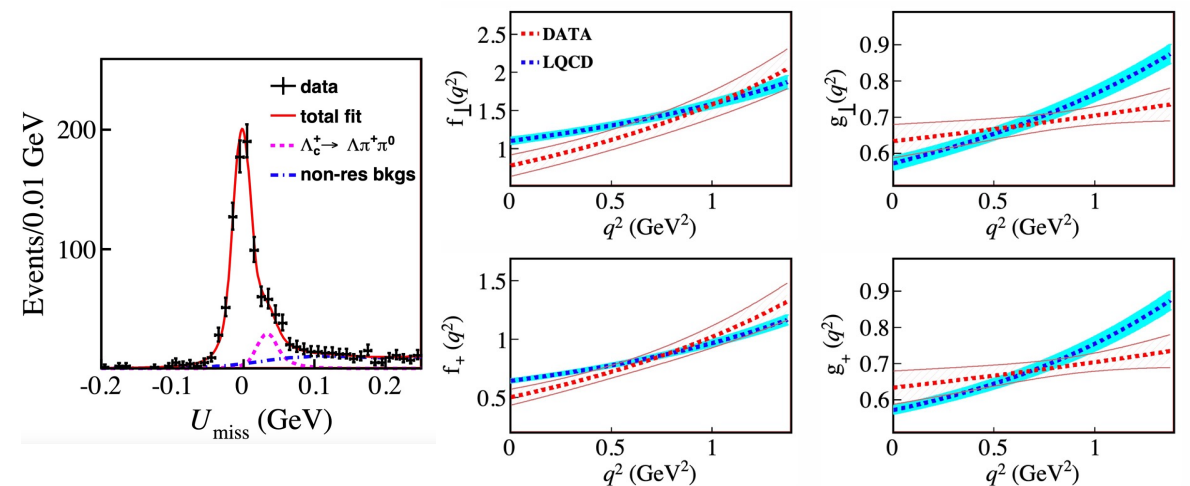


First direct comparisons to LQCD for $\Lambda_c^+ \rightarrow \Lambda$ decay form factor

Different kinematic behavior compared to LQCD



Study of $\Lambda_c^+ \rightarrow \Lambda \mu^+ \nu$



Steeper slope

Gentler slope

Updated BF and first FF measurement:

$$\mathcal{B}(\Lambda_c^+ \rightarrow \Lambda e^+ \nu) = (3.56 \pm 0.11 \pm 0.07) \times 10^{-3}$$

~4% most precise

$$|V_{cs}| = (0.936 \pm 0.017_B \pm 0.024_{LQCD} \pm 0.024_{\tau_{\Lambda_c^+}}) \times 10^{-3}$$

PRL 129, 231803 (2022)

Agree with PDG 2022

$$\mathcal{B} = (3.48 \pm 0.14 \pm 0.10) \times 10^{-3}$$

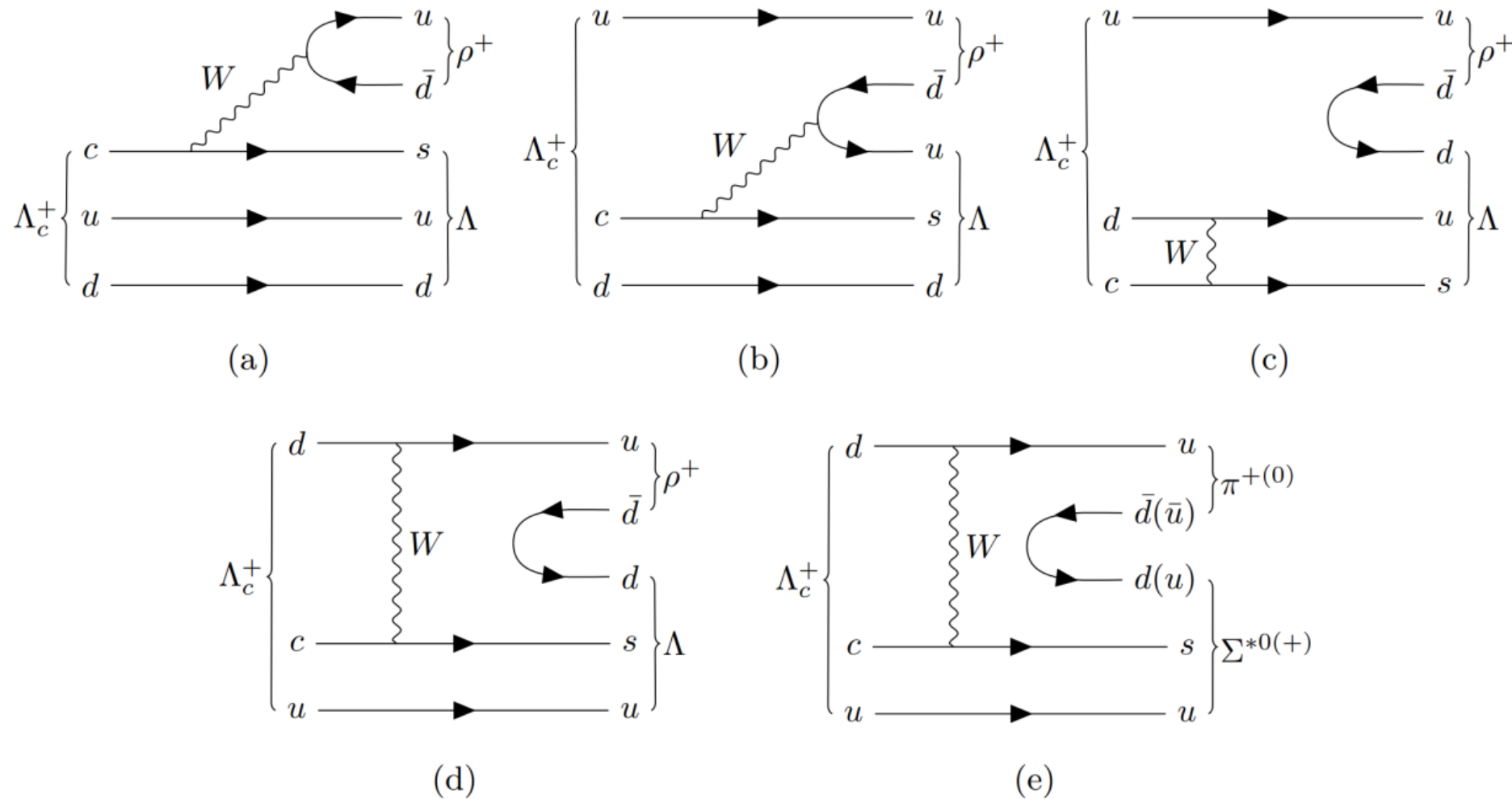
$$R_{e/\mu} = 0.98 \pm 0.05 \pm 0.03$$

vs SM: 0.97 --> No LFUV

Arxiv:2306.02624 (2023)

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Partial wave analysis of the charmed baryon hadronic decay $\Lambda_c^+ \rightarrow \Lambda \pi^+ \pi^0$



$\Lambda_c^+ \rightarrow \Lambda \rho^+$: both factorizable(a) and non-factorizable(b-d)

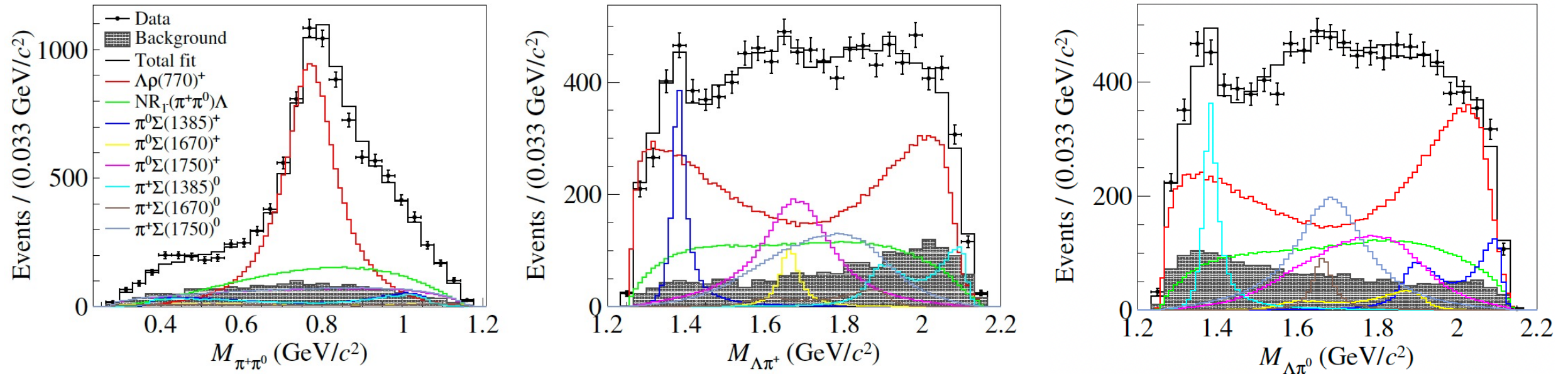
$\Lambda_c^+ \rightarrow \Sigma(1385) \pi$: **pure non-factorizable(e)**

Provide important inputs to the theoretical calculations for non-factorizable

Use new-developed Tensor Flow based package TF-PWA*.

(*BESIII Preliminary: <https://github.com/jiangyi15/tf-pwa>)

Partial wave analysis of the charmed baryon hadronic decay $\Lambda_c^+ \rightarrow \Lambda \pi^+ \pi^0$



The first PWA of $\Lambda_c^+ \rightarrow \Lambda \pi^+ \pi^0$

	Theoretical calculation	This work	PDG	
$10^2 \times \mathcal{B}(\Lambda_c^+ \rightarrow \Lambda \rho(770)^+)$	4.81 ± 0.58 [13]	4.0 [14, 15]	4.06 ± 0.52	< 6
$10^3 \times \mathcal{B}(\Lambda_c^+ \rightarrow \Sigma(1385)^+ \pi^0)$	2.8 ± 0.4 [16]	2.2 ± 0.4 [17]	5.86 ± 0.80	—
$10^3 \times \mathcal{B}(\Lambda_c^+ \rightarrow \Sigma(1385)^0 \pi^+)$	2.8 ± 0.4 [16]	2.2 ± 0.4 [17]	6.47 ± 0.96	—
$\alpha_{\Lambda \rho(770)^+}$	-0.27 ± 0.04 [13]	-0.32 [14, 15]	-0.763 ± 0.070	—
$\alpha_{\Sigma(1385)^+ \pi^0}$	$-0.91^{+0.45}_{-0.10}$ [17]		-0.917 ± 0.089	—
$\alpha_{\Sigma(1385)^0 \pi^+}$	$-0.91^{+0.45}_{-0.10}$ [17]		-0.79 ± 0.11	—

The first measurement of the decay
asymmetry parameters for the
relevant resonance

Ref. [13]: PRD 101 (2020) 053002.

Ref. [14, 15]: PRD 46 (1992) 1042;
PRD 55 (1997) 1697.

Ref. [16]: EPJC 80 (2020) 1067.

Ref. [17]: PRD 99 (2019) 114022

Measurement of the absolute branching fraction of the singly Cabibbo suppressed decays of $\Lambda_c^+ \rightarrow n\pi^+$

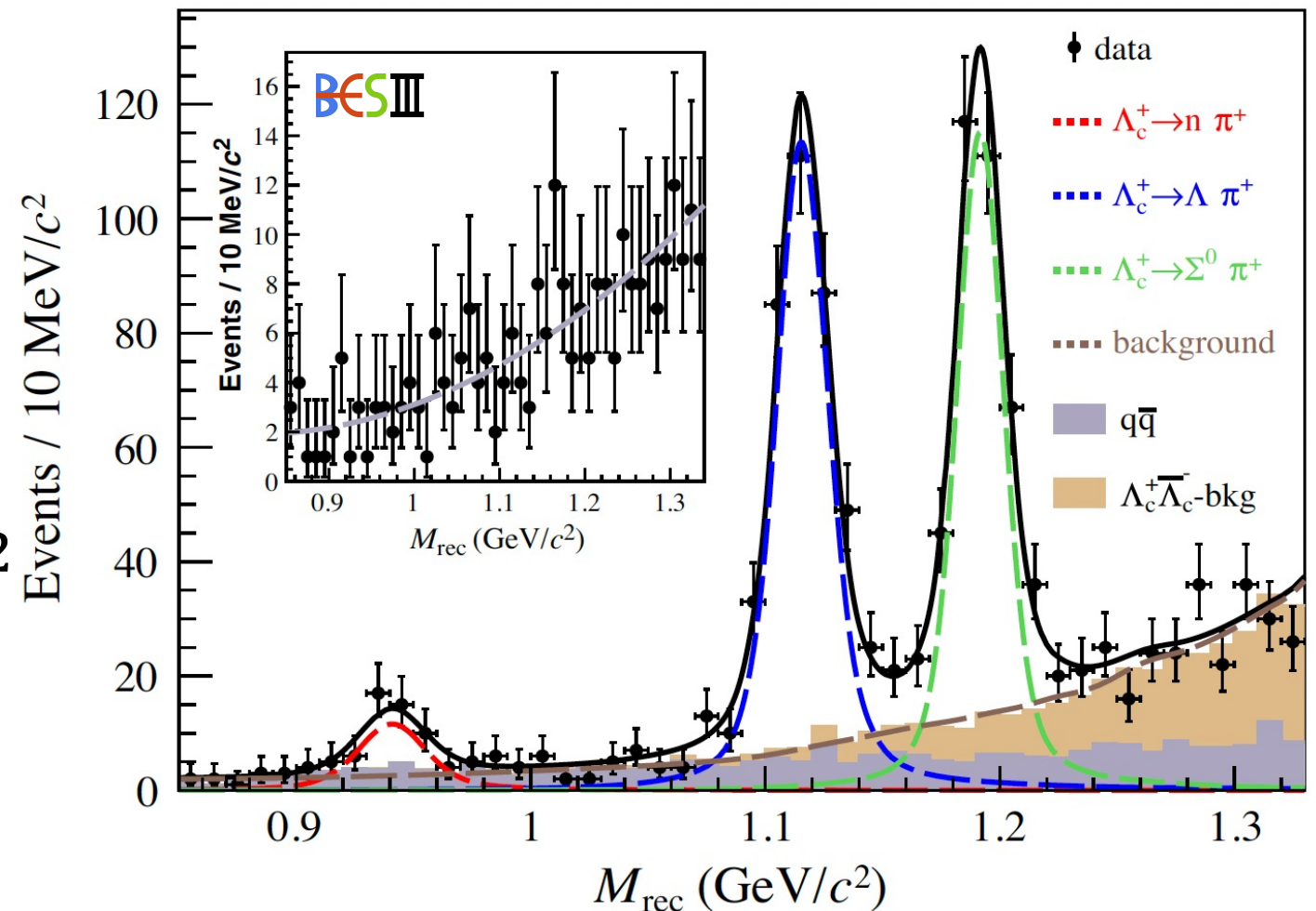
PRL 128, 142001 (2022)

$$\mathcal{B}(\Lambda_c^+ \rightarrow n\pi^+) \quad \text{First measurement} \\ = (6.6 \pm 1.2 \pm 0.4) \times 10^{-4}$$

$$\mathcal{B}(\Lambda_c^+ \rightarrow \Lambda\pi^+) \\ = (1.31 \pm 0.08 \pm 0.05) \times 10^{-2}$$

$$\mathcal{B}(\Lambda_c^+ \rightarrow \Sigma^0\pi^+) \\ = (1.22 \pm 0.08 \pm 0.07) \times 10^{-2}$$

$$\mathcal{B}(n\pi^+)/\mathcal{B}(p\pi^0) > 7.2 \text{ at } 90\% \text{ C.L.}$$



Use recoil mass to access neutron

- Disagrees with most predictions of phenomenological models
- **Non-factorization contributions may be overestimated.**

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 - hadronic decays
- **Prospect**

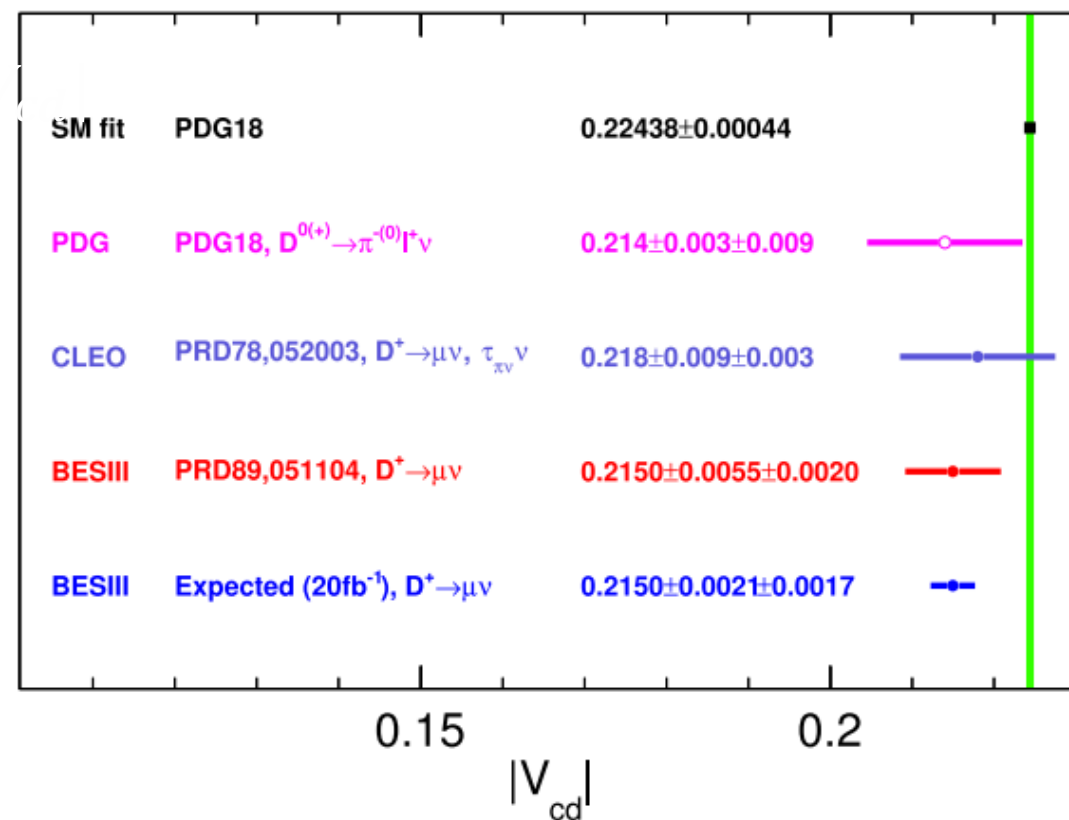
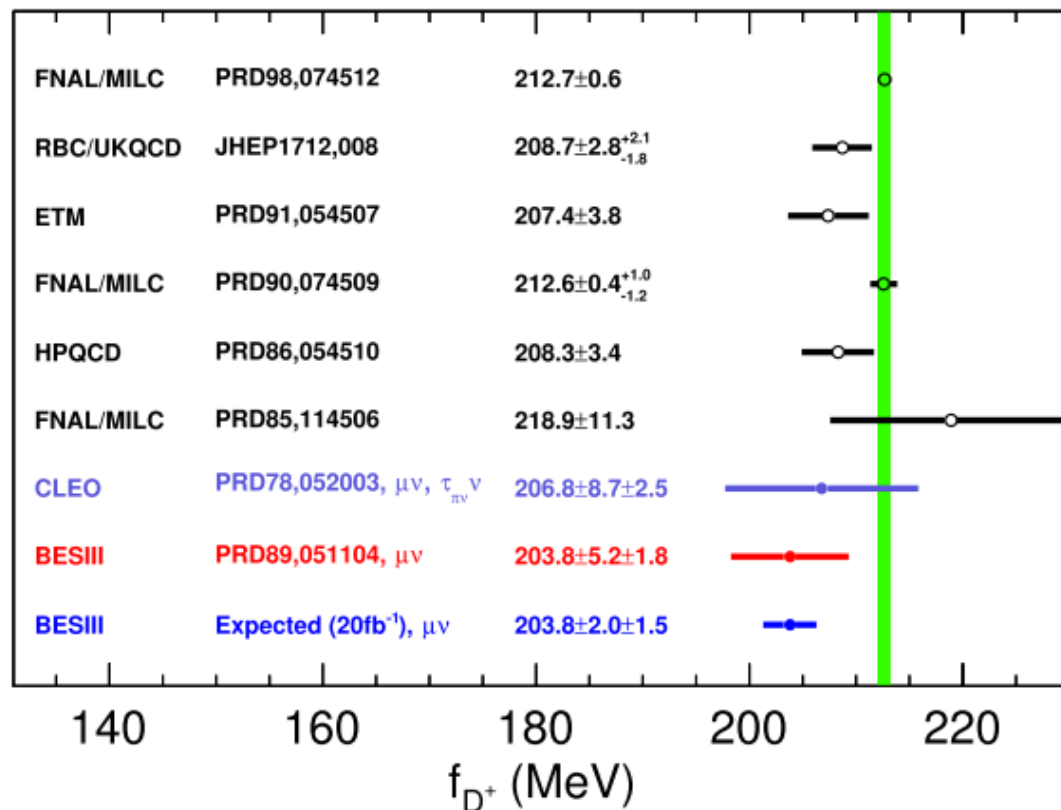
Prospect

From White Paper (Chin. Phys. C 44, 040001 (2020))

20 fb⁻¹ of data set at 3.773 GeV is on the way

Leptonic Decay

	2.93 fb ⁻¹	20 fb ⁻¹
f_{D^+}	2.6%	1.0%
$ V_{cd} $	2.5%	1.0%
LFU	19%	8%



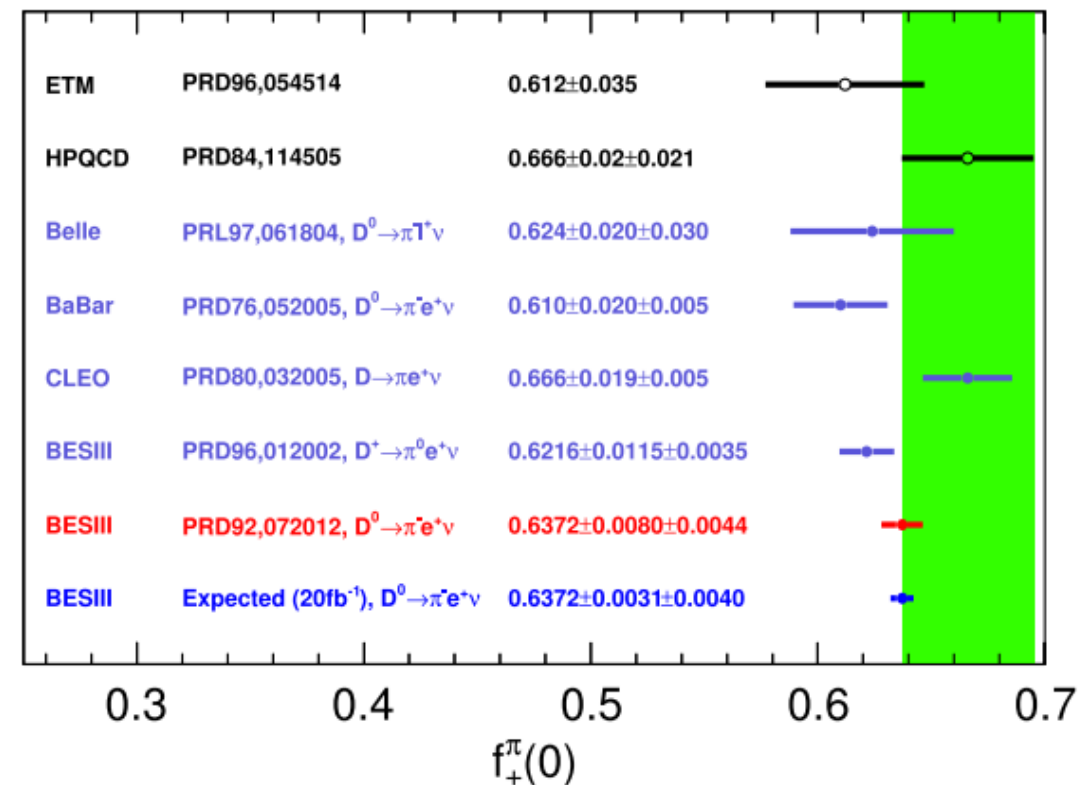
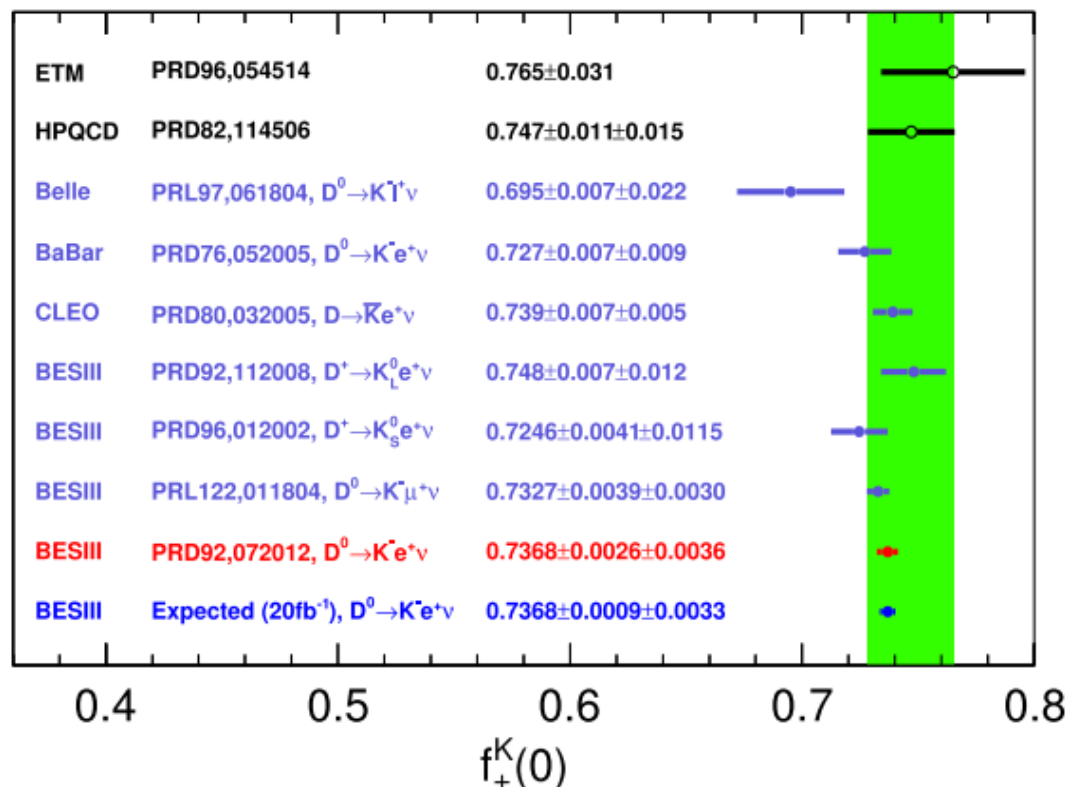
BESIII is expected to provide unique data to improve the knowledge of f_{D^+} and $|V_{cd}|$ and test LFU in $D^+ \rightarrow l^+ \nu_l$ decays.

20 fb⁻¹ of data set at 3.773 GeV is on the way

Semi-leptonic Decay

- All form-factor measurements which are currently statistically limited will be improved by a factor of up to 2.6.
- Determine FF for the first time: $D^0 \rightarrow K(1270)^- \nu_e$, $D^+ \rightarrow \bar{K}_1(1270)^0 e^+ \nu_e$, $D^+ \rightarrow \eta' \mu^+ \nu_\mu$, $D^0 \rightarrow a_0(980)^- e^+ \nu_e$, $D^+ \rightarrow a_0(980)^0 e^+ \nu_e$
- $|V_{cd(s)}|$ with SL $D^{0(+)}$ decays in electron channels are expected to reach to 0.5%.

	LQCD	Expected
$f_+^K(0)$	2.4%	1.0%
$f_+^\pi(0)$	4.4%	0.5%



Quantum correlation of neutral charmed meson pairs

Decay mode	Quantities	Status (2.93 fb ⁻¹)
$K_S^0 \pi^+ \pi^-$	c_i, s_i	Finished(2020)
$K_S^0 K^+ K^-$	c_i, s_i	Finished(2021)
$K^- \pi^+ \pi^+ \pi^-$	R, δ	Finished(2020)
$K^+ K^- \pi^+ \pi^-$	F_+ or c_i, s_i	F_+ Finished(2022), c_i, s_i on going
$\pi^+ \pi^- \pi^+ \pi^-$	F_+ or c_i, s_i	F_+ Finished(2022), c_i, s_i on going
$K^- \pi^+ \pi^0$	R, δ	Finished(2021)
$K_S^0 K^\pm \pi^\mp$	R, δ	On going
$\pi^+ \pi^- \pi^0$	F_+	On going
$K_S^0 \pi^+ \pi^- \pi^0$	F_+ or c_i, s_i	F_+ Finished(2023), c_i, s_i on going
$K^+ K^- \pi^0$	F_+	On going
$K^- \pi^+$	δ	Updated Finished (2022)

- Making progress in past few years.
- Many ongoing projects, eventually 20 fb⁻¹ $\psi(3770)$ data samples.

Amplitude analyses and branching fraction measurement of charmed meson hadronic decays

Precisely measuring the structure of golden modes, for example $D^+ \rightarrow K^- \pi^+ \pi^+$

First amplitude analysis of Cabibbo-suppressed decays.

Measuring the polarization of $D \rightarrow VV$ in $D \rightarrow K3\pi$ or $D \rightarrow KK\pi\pi$

Searching for new physics and rare decays

Flavor changing neutral currents (FCNC) $e^+e^-, \mu^+\mu^-$ etc.

Quantum number violation processes $e^+e^+, \mu^-\mu^-$ etc.

Radiative decays $\gamma\omega, \gamma K_1$ etc.

Thanks for your attention