Charm physics at BESIII

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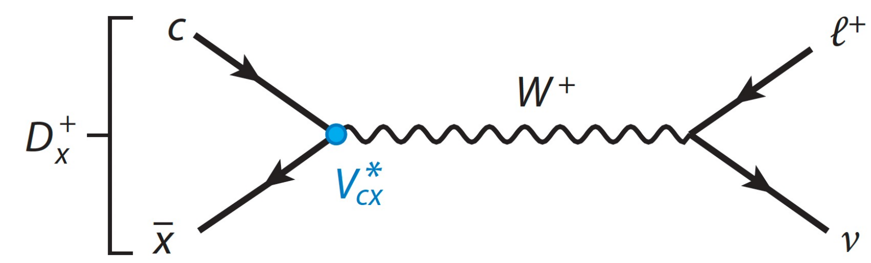
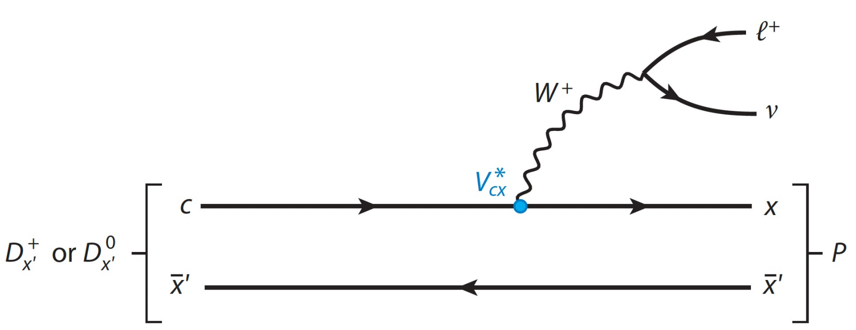
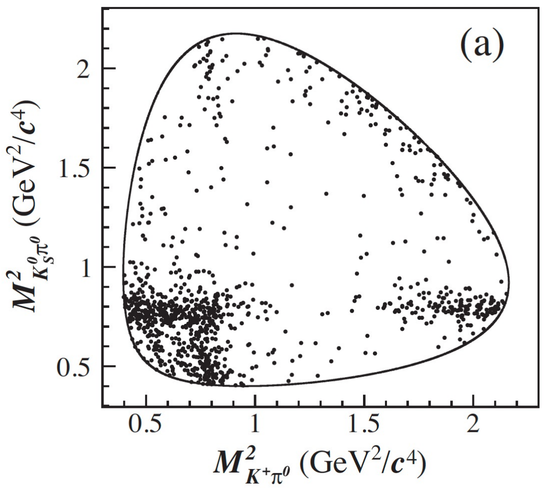
Outline

- 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







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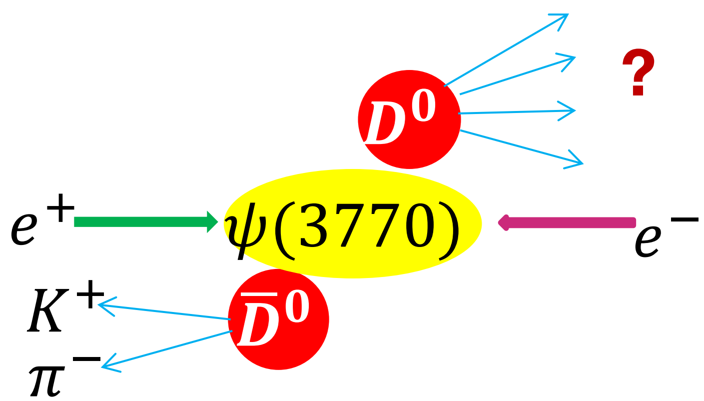
- Summary

BESIII Data Taken near Threshold

- 20.3 fb^{-1} at E$_{cm}$ 3.773 GeV: $e^+e^-\rightarrow$ ψ(3770)$\rightarrow D\bar{D}$
- 7.33 fb^{-1} at E$_{cm}$ 4.128 - 4.226 GeV: $e^+e^-\rightarrow D_sD_s^*$
- 4.5 fb^{-1} at Ecm = 4.600-4.699 GeV: $e^+e^- \rightarrow \Lambda_c^+\bar{\Lambda}_c^-$

Production of charm hadron pair



Tag one side to study another side

Fully reconstruction → **Clean sample** → **Hadronic decays**

Recoil four-momentum → **missing particle (neutrino)** → **(Semi)-leptonic decays**

Absolute branching fraction

Amplitude analysis

etc.

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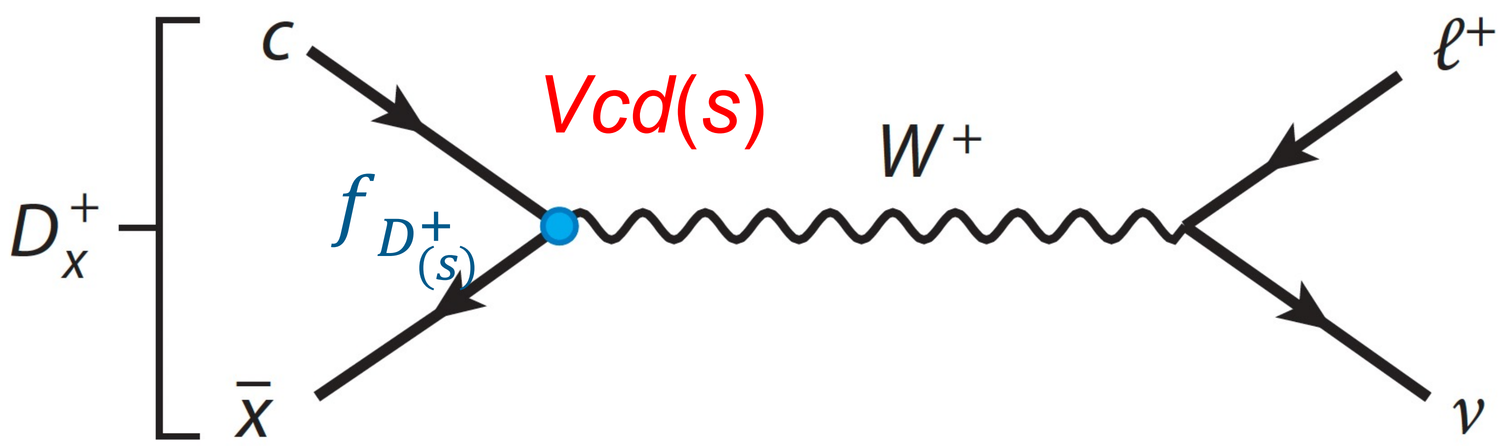
Pure leptonic D decay



$$J^p = 0^- \qquad \Gamma(D_{(s)}^+ \to l^+\nu) = \frac{G_F^2 f_{D_{(s)}^+}^2}{8\pi} |V_{cd(s)}|^2 m_l^2 m_{D_{(s)}^+} \left(1 - \frac{m_l^2}{m_{D_{(s)}^+}^2}\right)^2$$

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

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

Calibrate Lattice QCD

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

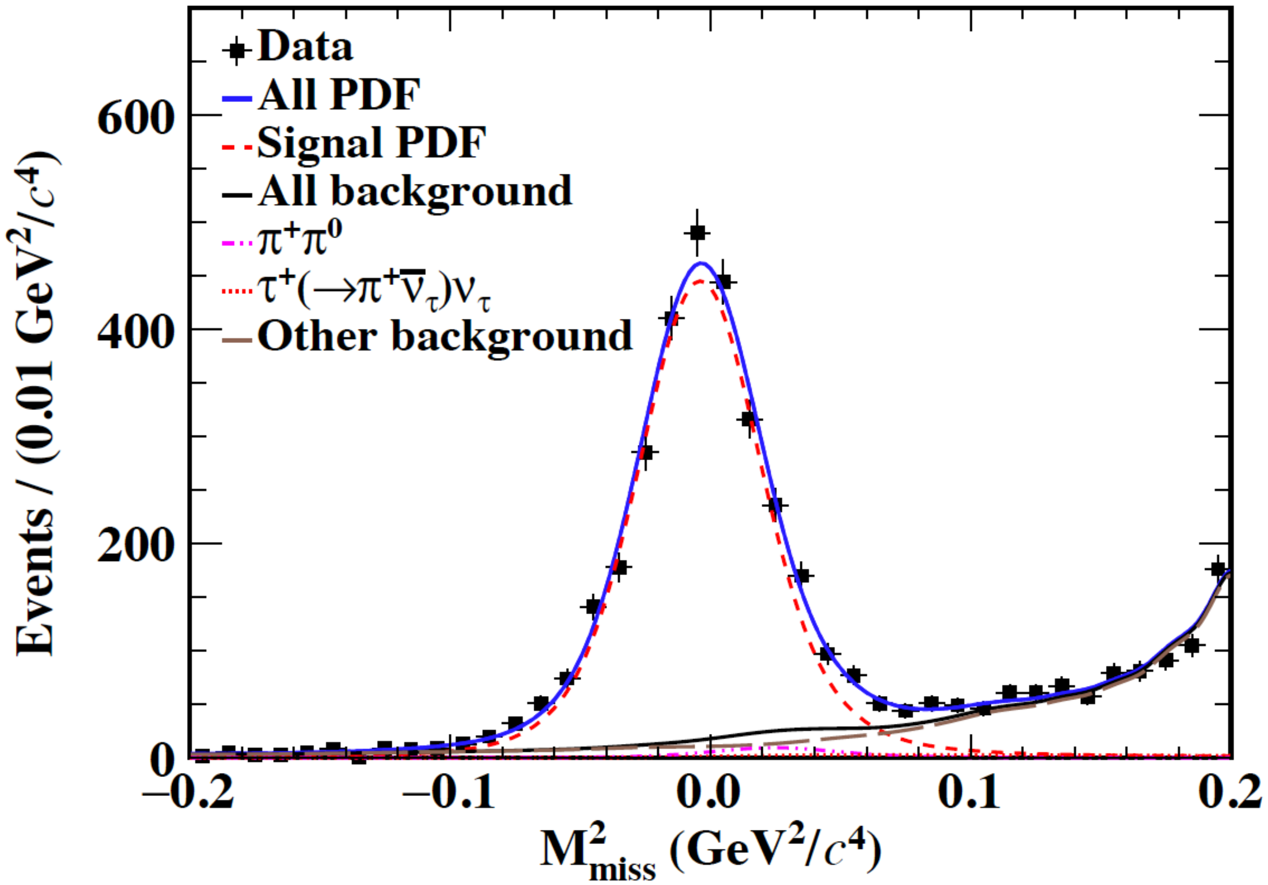
Test the unitarity of CKM matrix

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

$D^+ \to l^+\nu_l$

$D^+ \to \mu^+\nu_\mu$



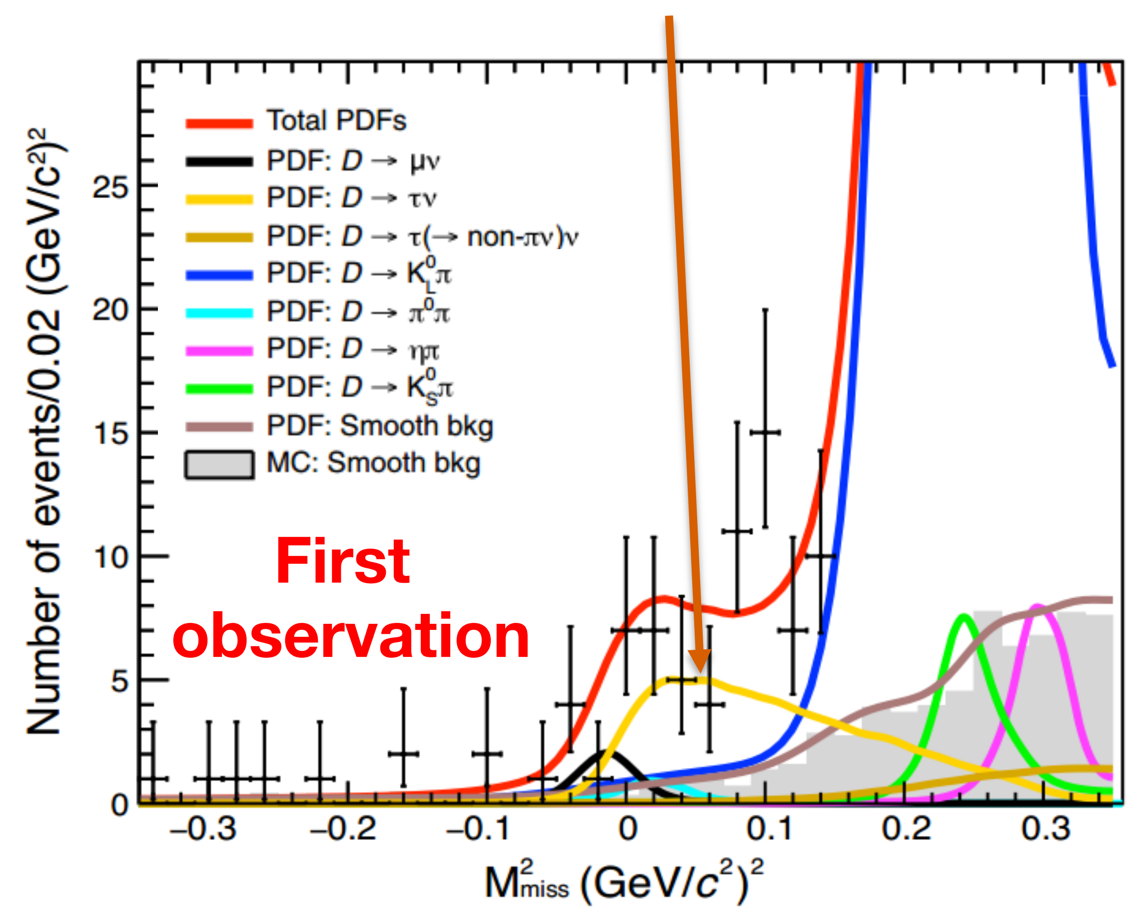
$\mathcal{B}(D^+ \to \mu^+\nu_\mu) = (3.981 \pm 0.079 \pm 0.040)\times 10^{-4}$

$f_{D^+}|V_{cd}| = (47.53 \pm 0.48_{\text{stat}} \pm 0.24_{\text{syst}} \pm 0.12_{\text{input}})$ MeV

arXiv:2410.07626

Updated results based on the 20 fb^{-1} full dataset

$D^+ \to \tau^+\nu_\tau$



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

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

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

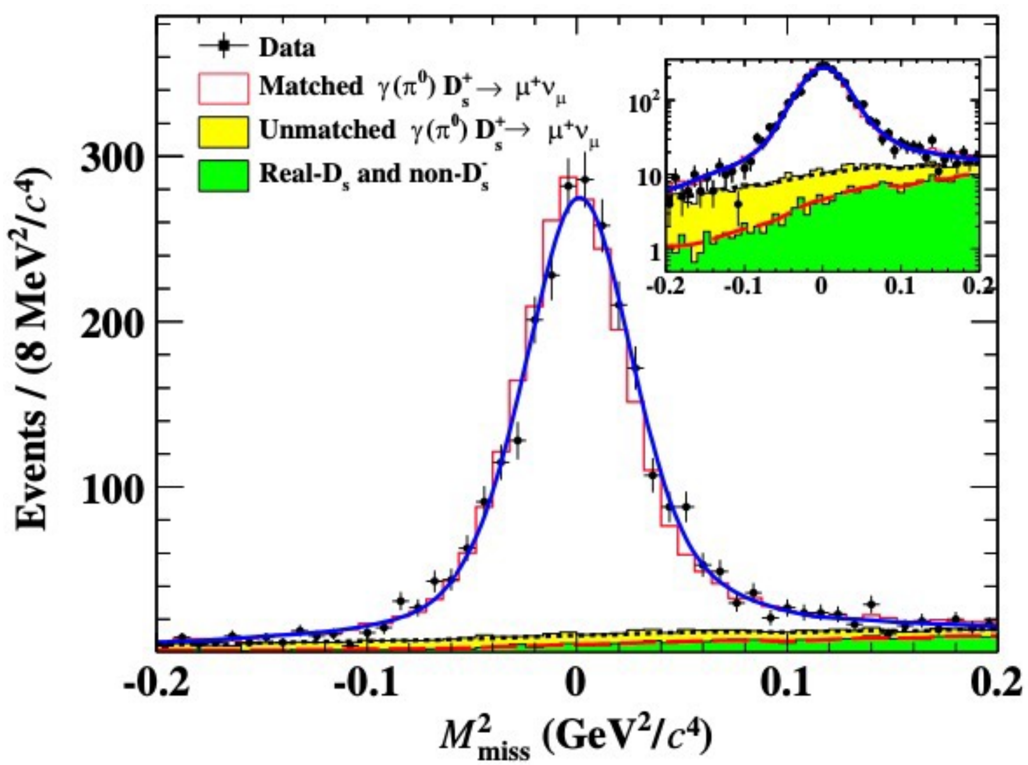
Phys. Rev. Lett. 123, 211802 (2019)

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

To be updated using the 20 fb^{-1} full dataset

$D_s^+ \to l^+\nu$

$D_s^+ \to \mu^+\nu$



$\mathcal{B}(D_s^+ \to \mu^+\nu_\mu) = (5.294 \pm 0.108 \pm 0.085)\times 10^{-3}$

$f_{D_s^+}|V_{cs}| = 241.8 \pm 2.5_{stat} \pm 2.2_{syst}$ MeV

Phys. Rev. D 108, 112001 (2023)

$D_s^+ \to \tau^+(\rho^+\nu)\nu$

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

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

Phys. Rev. D 104, 032001 (2021)

$D_s^+ \to \tau^+(e^+\nu\nu)\nu$ most precise

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

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

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

$D_s^+ \to \tau^+(\mu^+\nu\nu)\nu$

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

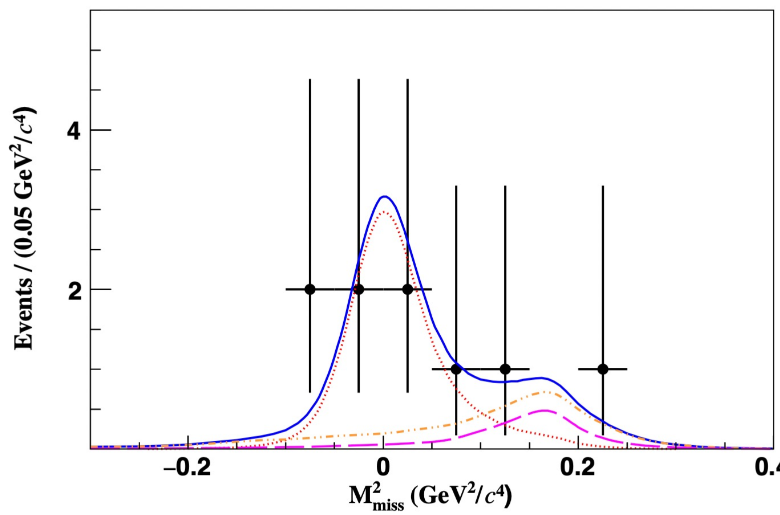
$f_{D_s^+}|V_{cs}| = (246.2 \pm 3.7_{stat} \pm 2.5_{syst})$ MeV.

JHEP 09(2023) 124

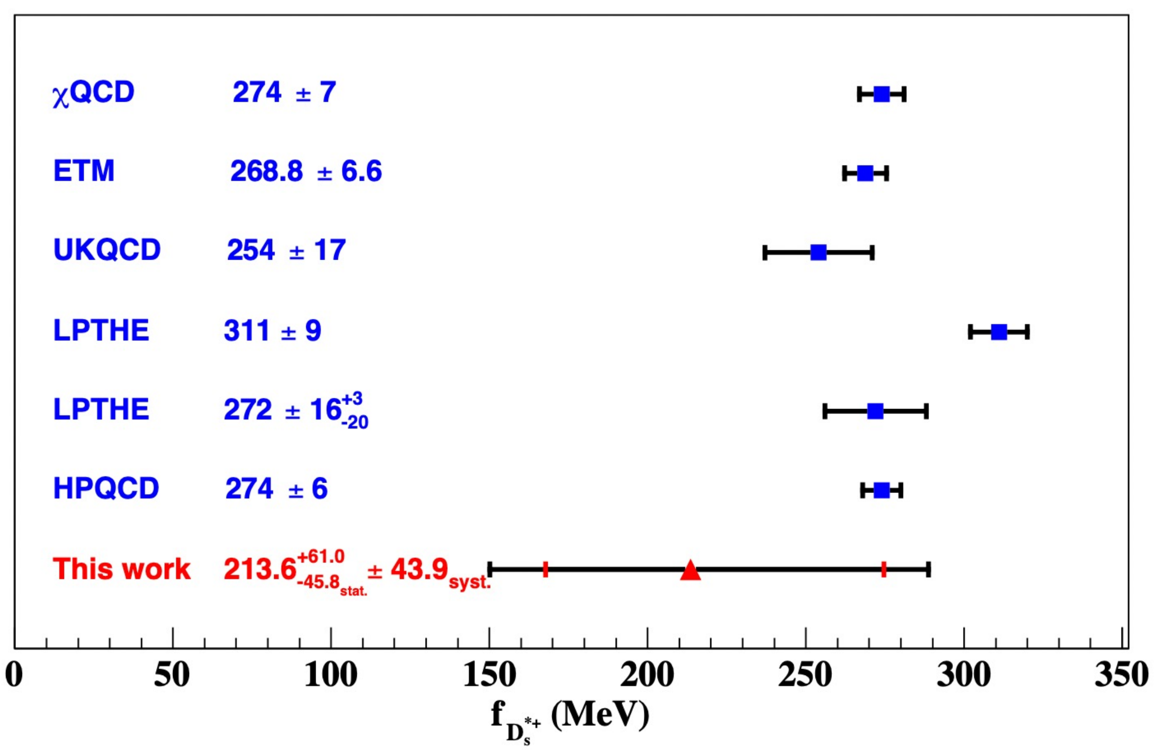
$\tau^+\nu_\tau$ can contribute comparable statistics to $\mu^+\nu$

First experimental study of $D_s^{*+} \to e^+\nu$

Phys. Rev. Lett. 131, 14180(2023)



First experimental result on $f_{D_s^{*+}}$

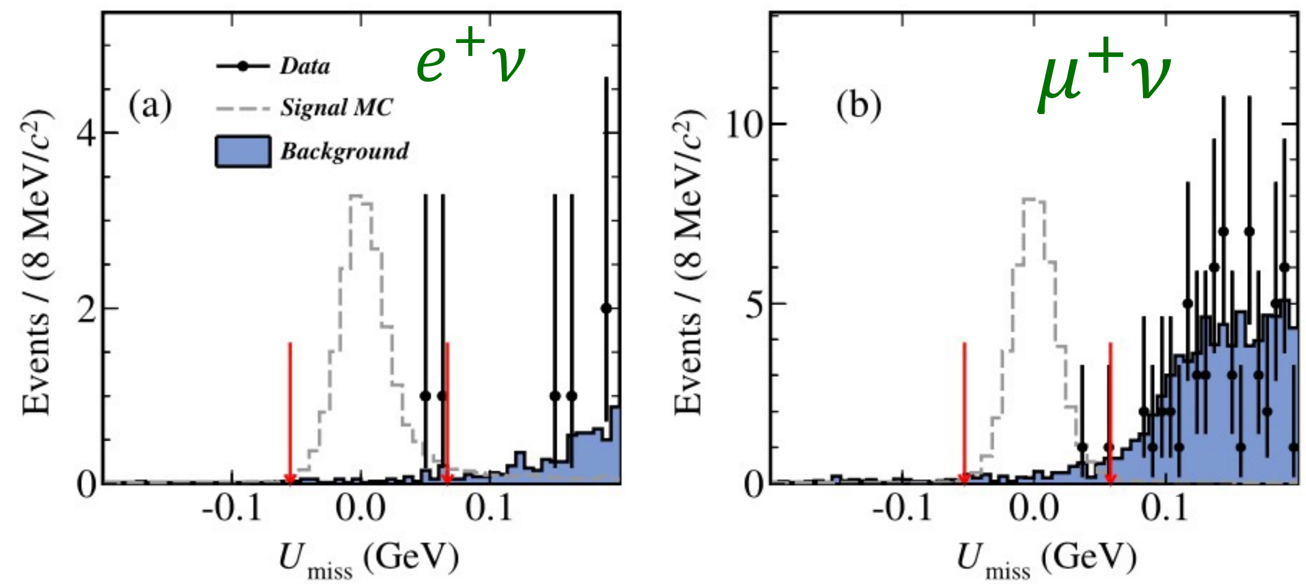


$$\mathcal{B}(D_s^{*+} \to e^+\nu_e) = (2.1^{+1.2}_{-0.9} \pm 0.2)\text{x}10^{-5}$$

with significance 2.9σ

Search for $D^{*+} \to l^+\nu$

Phys. Rev. D 110, 012003(2024)



No significant signal observed

$\mathcal{B}(D^{*+} \to e^+\nu_e) < 1.1\times10^{-5}$ @ 90% C.L.

$\mathcal{B}(D^{*+} \to \mu^+\nu_\mu) < 4.3\times10^{-6}$ @ 90% C.L.

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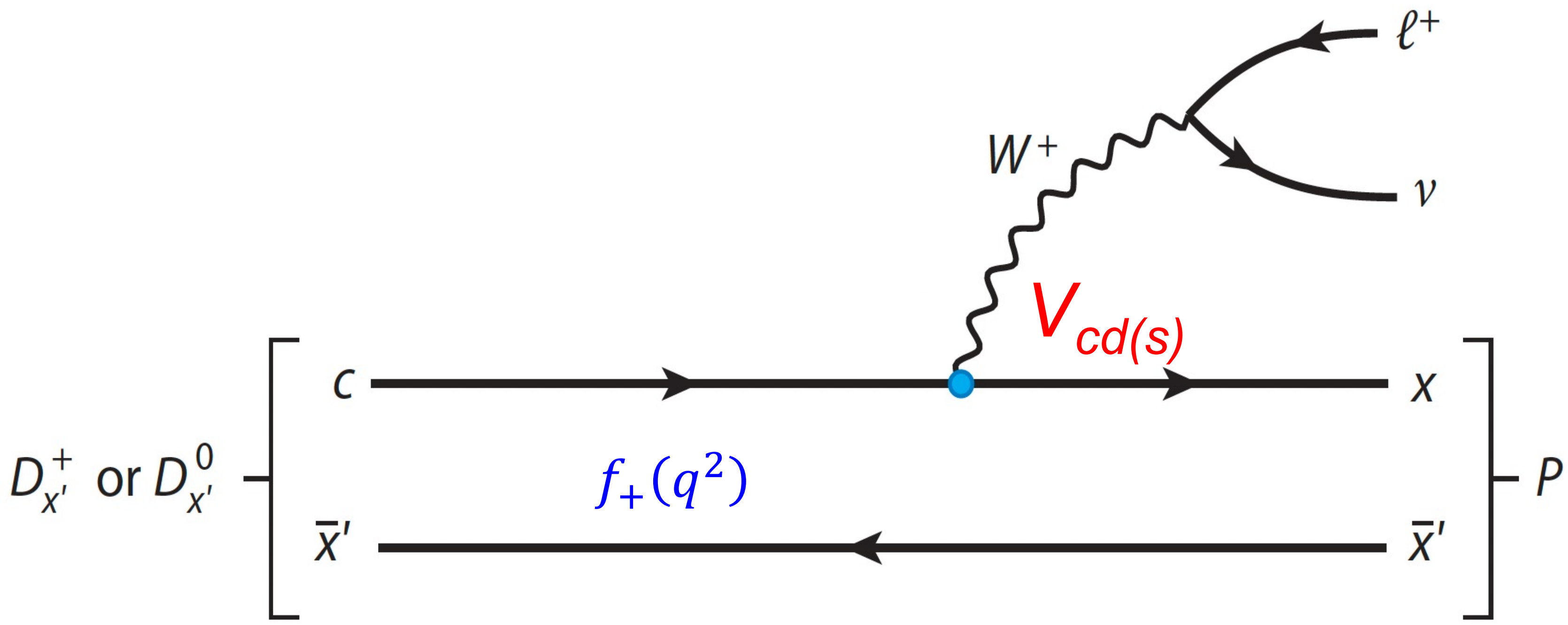
Semi-leptonic $D \to P e^+ \nu$



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

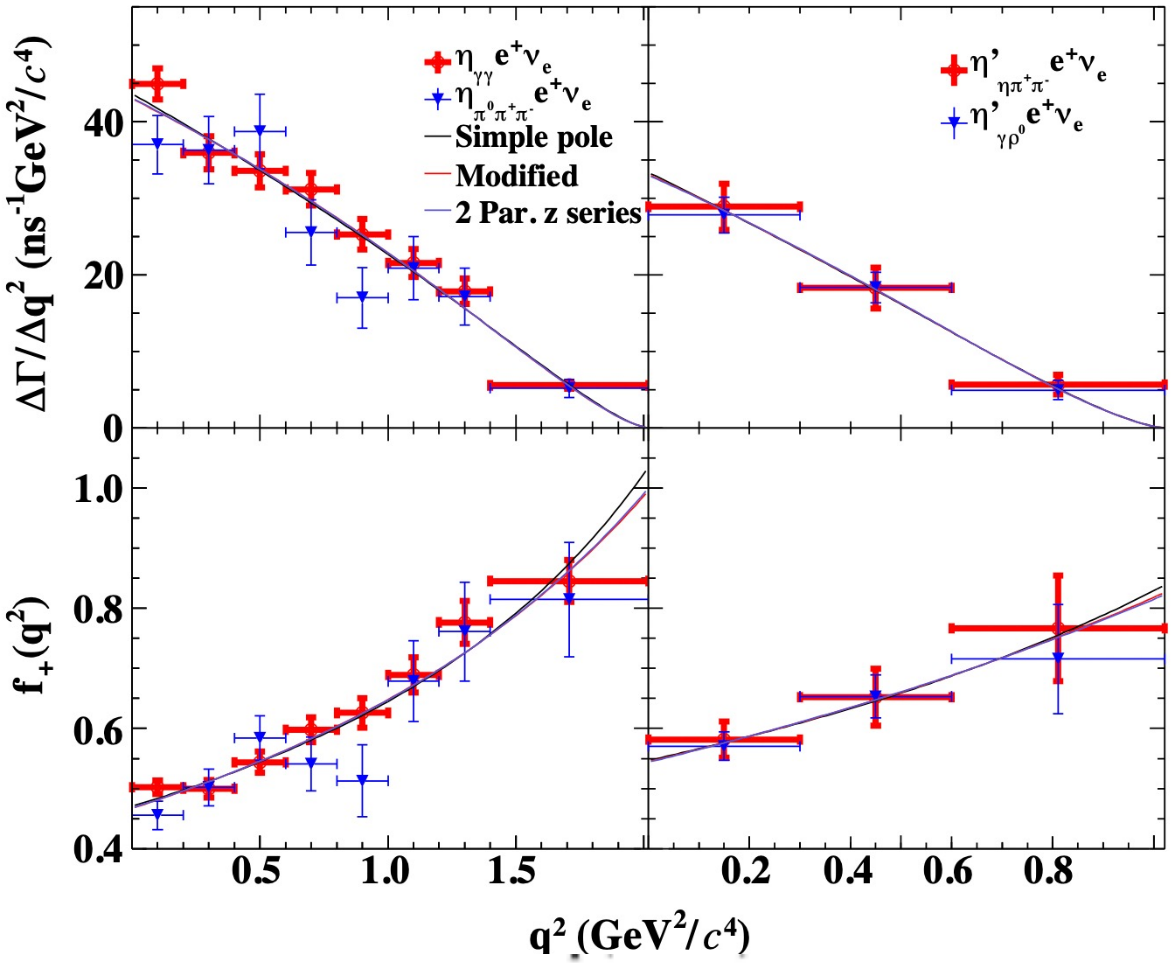
$$(X = 1 for K^-, \pi^-, \bar{K}^0, \eta^{(\prime)}; X = \frac{1}{2} for\ \pi^0)$$

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

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

Test $\mathrm{e} - \mu$ Lepton flavor universality

$D_s^+ \to \eta^{(\prime)} e^+ \nu$

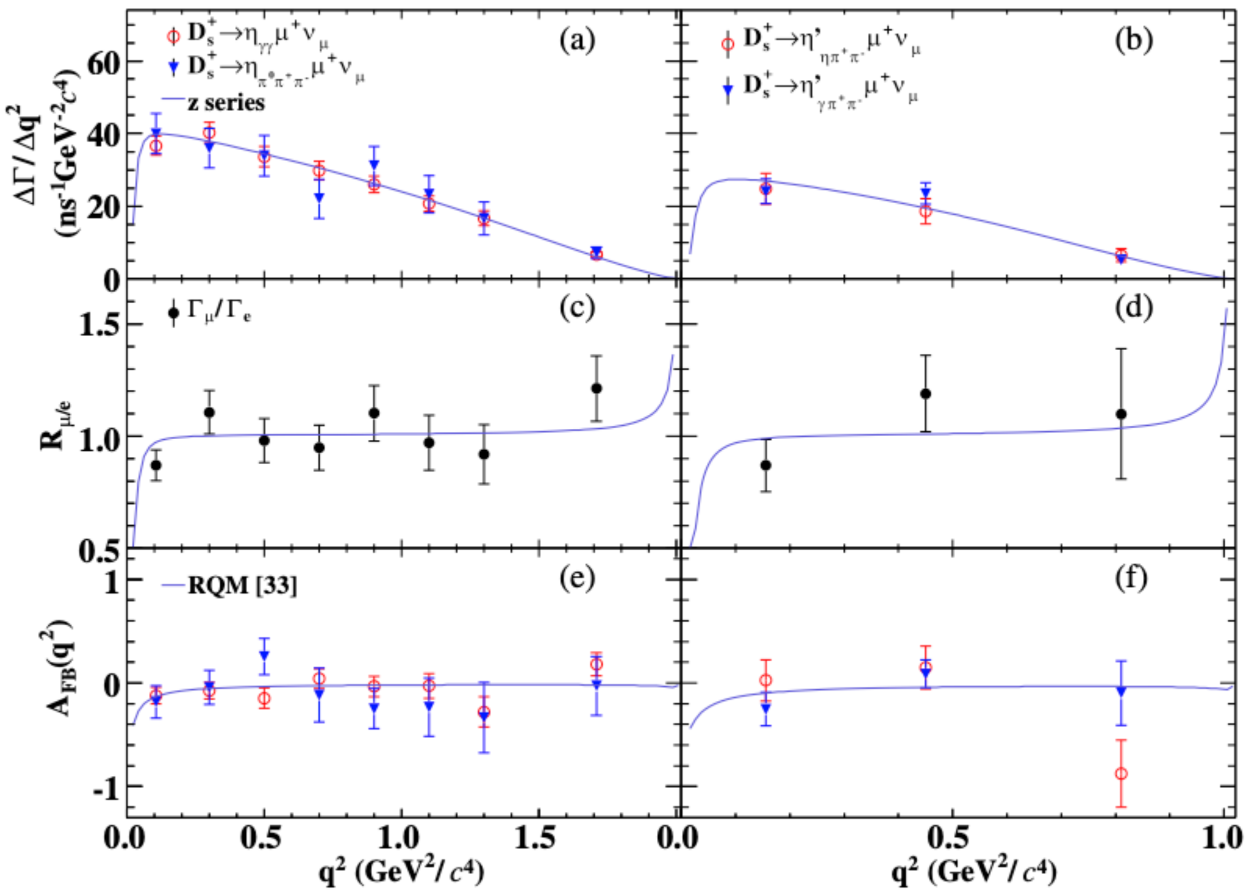


$$f_+^{D_s\to\eta}(0)|V_{cs}| = 0.452(07)(07)$$

$$f_+^{D_s\to\eta'}(0)|V_{cs}| = 0.525(24)(09)$$

Phys. Rev. Lett. 123, 121801 (2019)
Phys. Rev. D 108, 092003 (2023)

$D_s^+ \to \eta^{(\prime)} \mu^+ \nu$



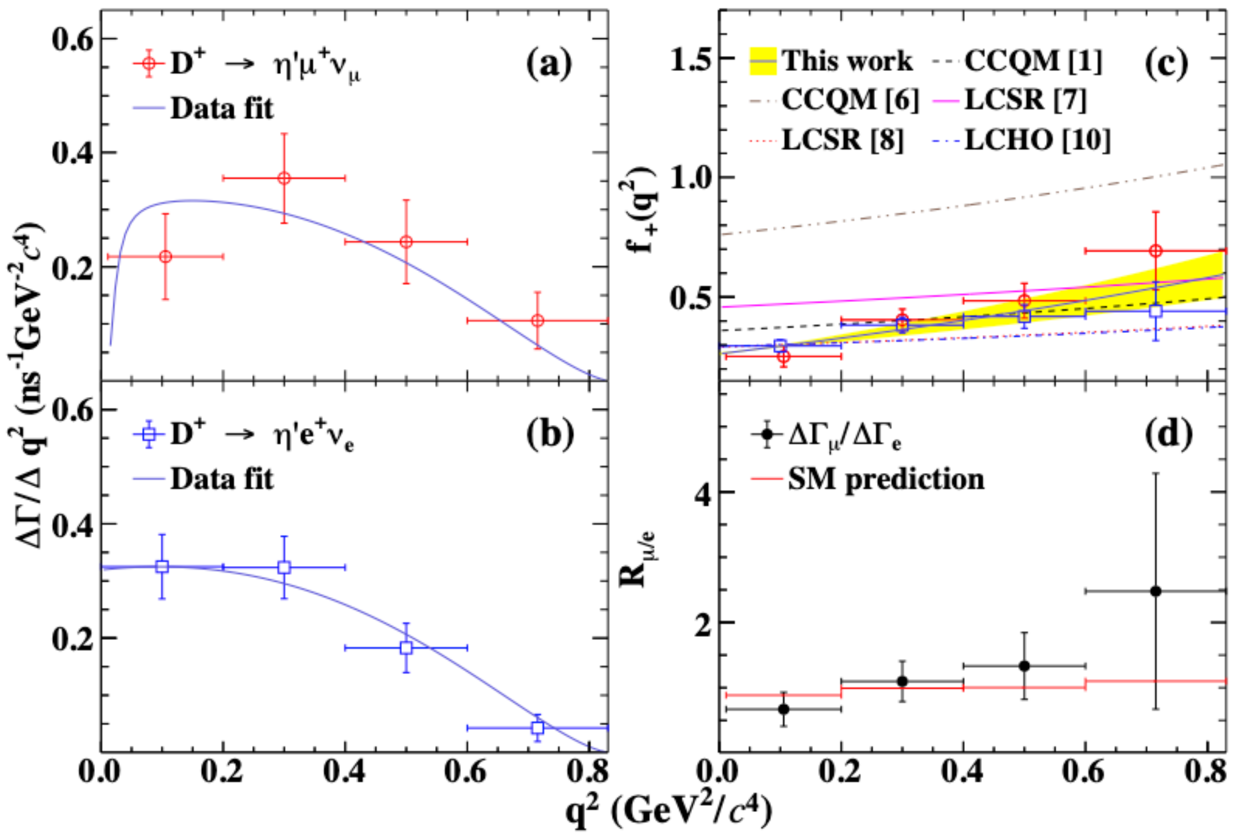
$$f_+^{D_s\to\eta}(0)|V_{cs}| = 0.451(10)(08)$$

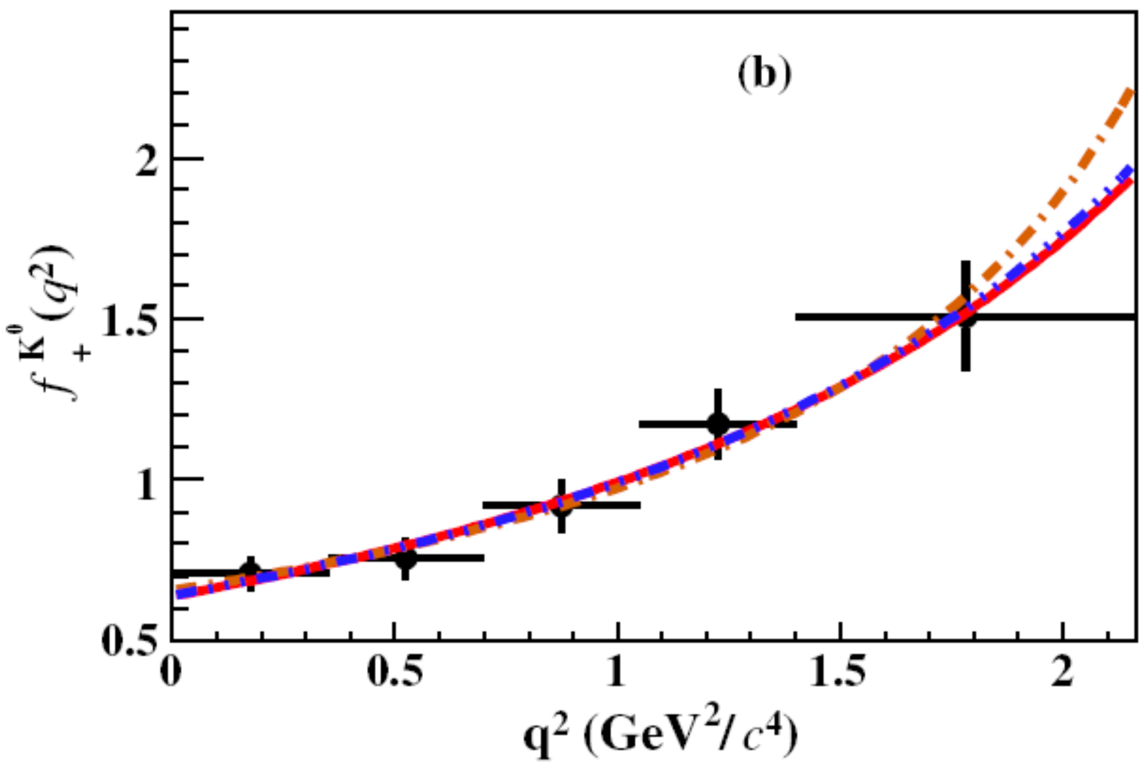
$$f_+^{D_s\to\eta'}(0)|V_{cs}| = 0.506(37)(11)$$

Phys. Rev. Lett. 132, 091802 (2024)

$D^+ \to \eta' l^+ \nu$

$D_s^+ \to K^0 e^+ \nu$





$$f_+^{\eta'}(0)|V_{cd}| = (5.92 \pm 0.56_{\text{stat}} \pm 0.13_{\text{syst}}) \times 10^{-2}$$

arXiv:2410.08603

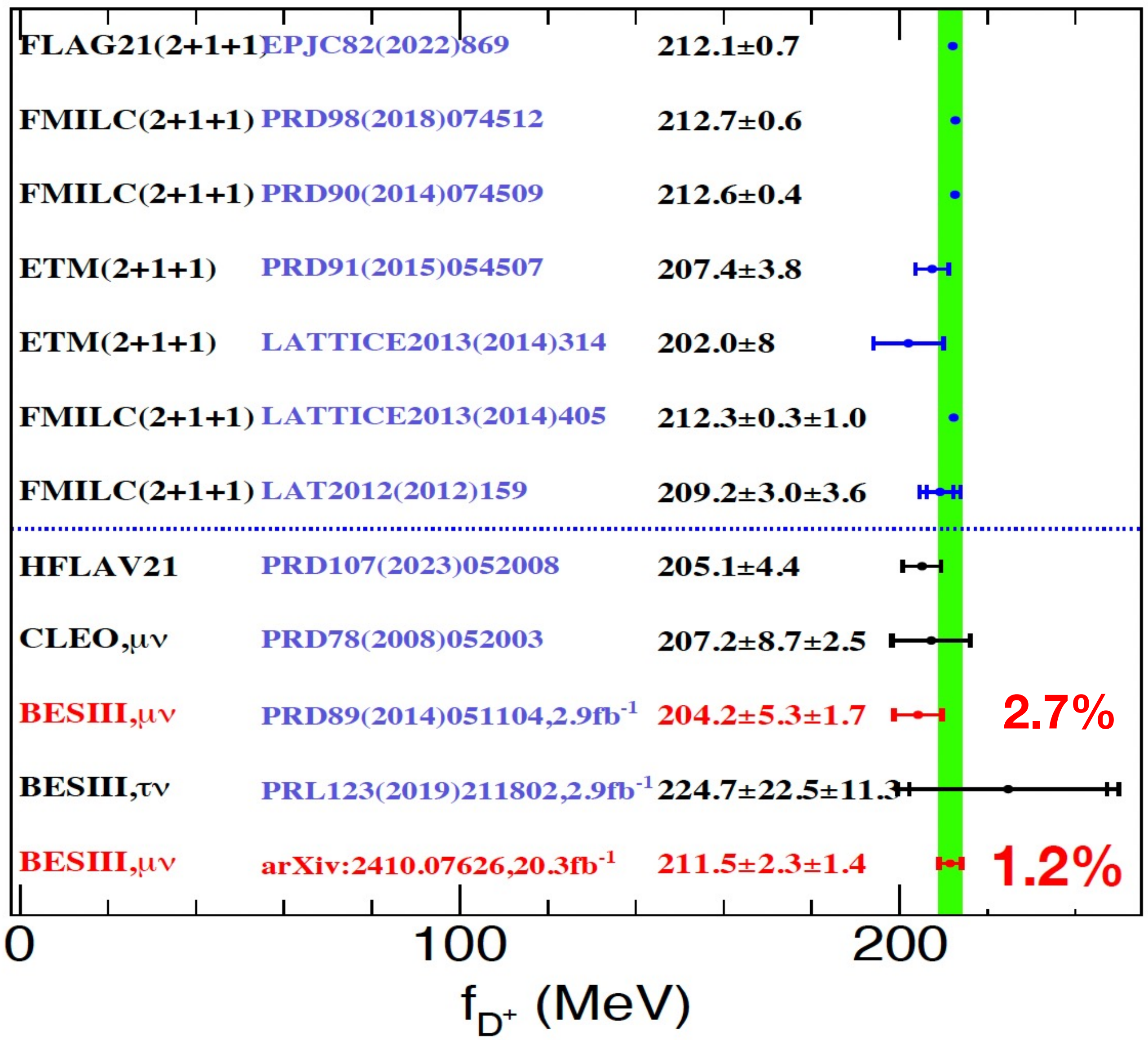
$$f_+^{K^0}(0) = 0.636 \pm 0.049 \pm 0.013$$

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

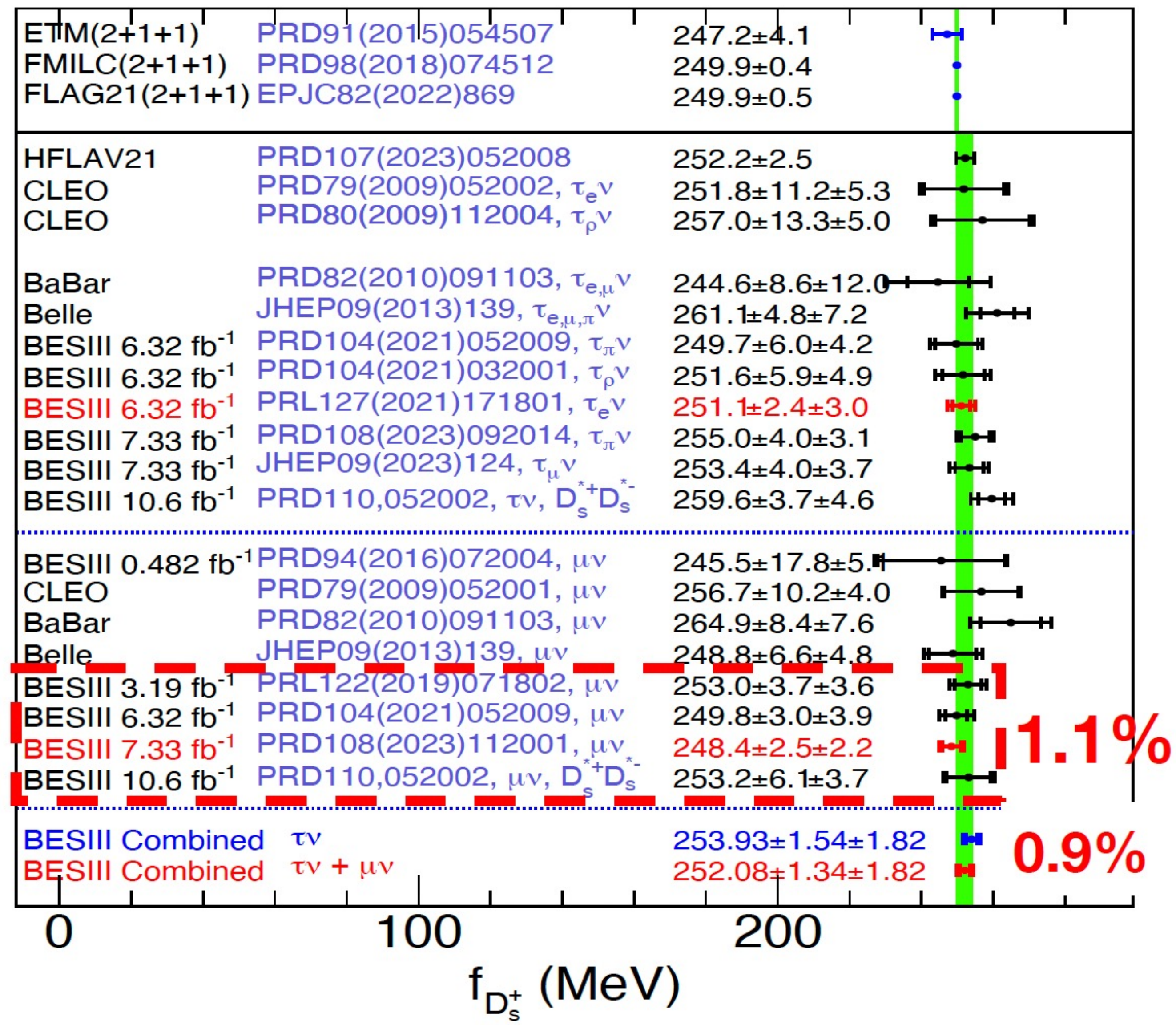
arXiv:2406.1910

Comparison of decay constant

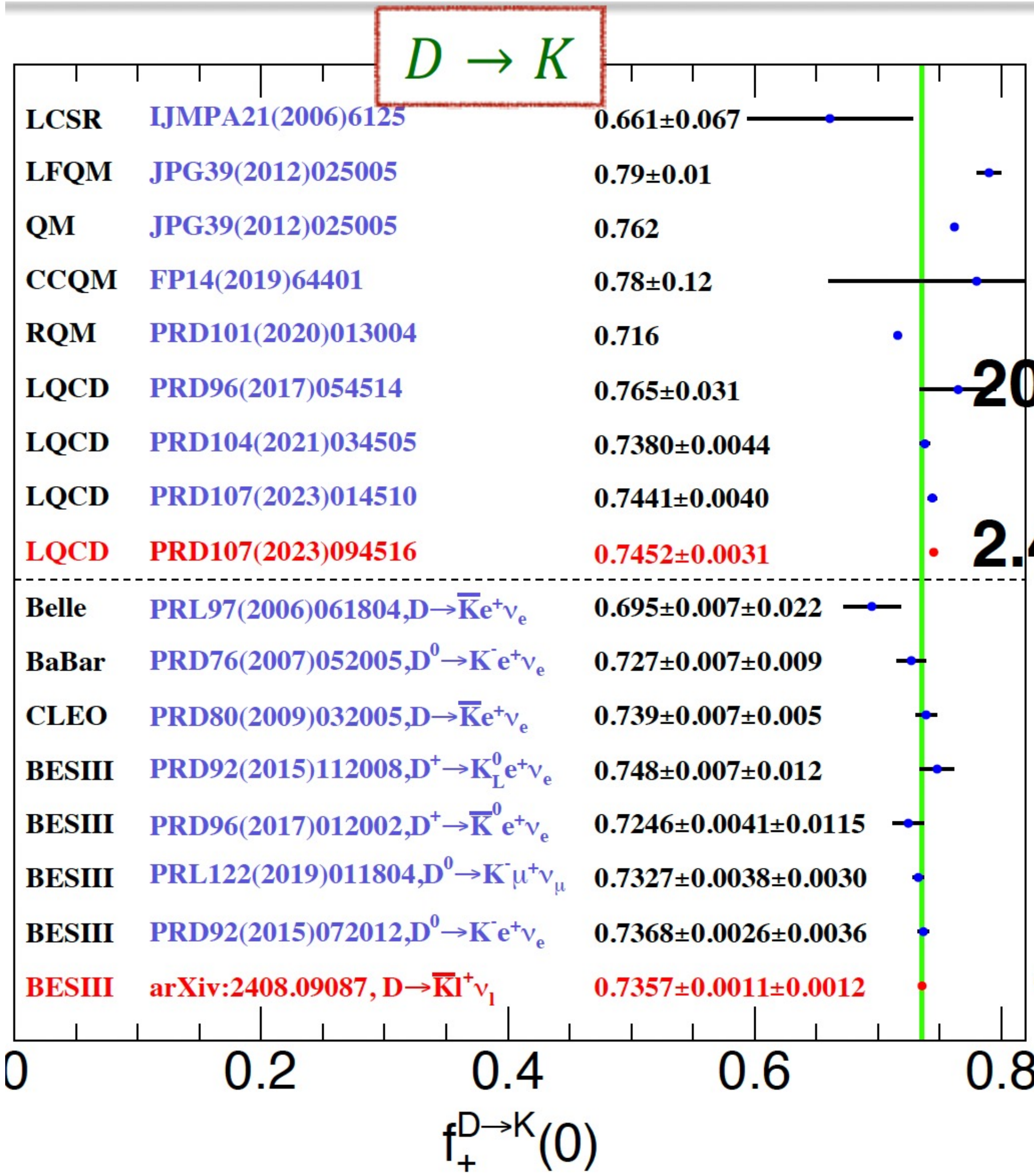
f_{D^+}



$f_{D_s^+}$



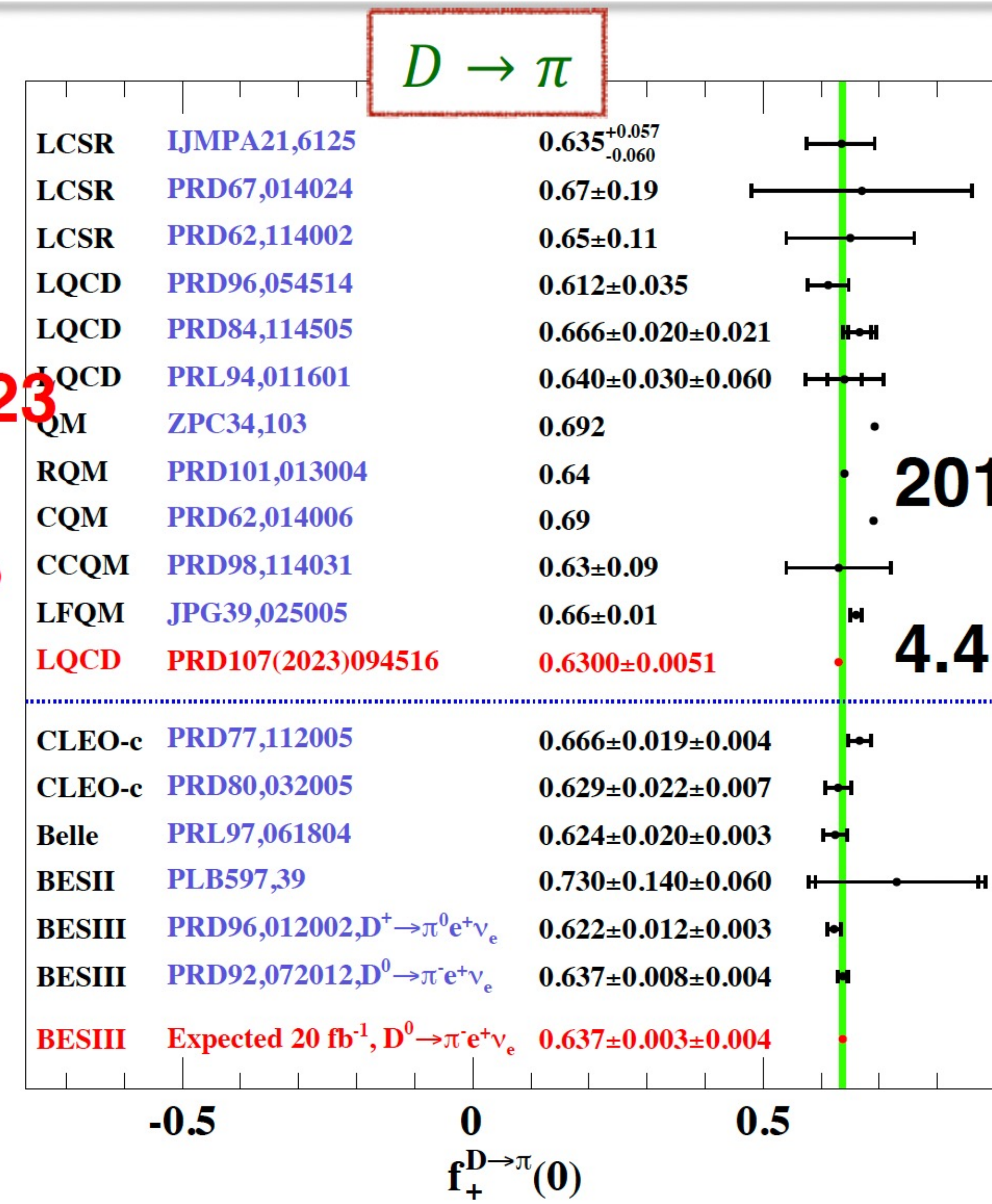
Comparison of form factor



2010→2023

2.4→0.4%

< 0.3%



2011→2023

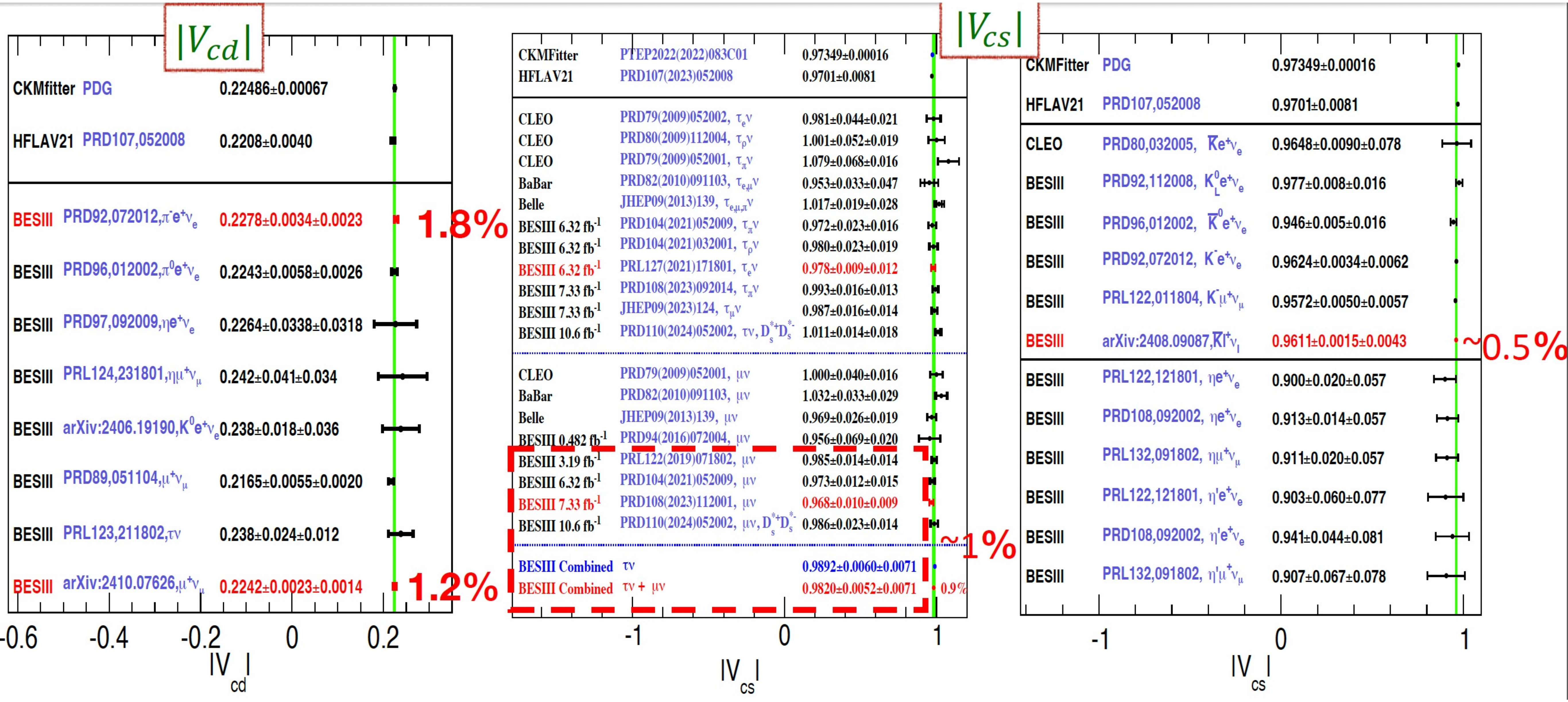
4.4→0.8%

1.4%

<1%

Experimental precision is comparable to the latest QCD result

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



Both pure- and semi-leptonic decays contribute

We have also study…

$D \to Sl\nu$

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

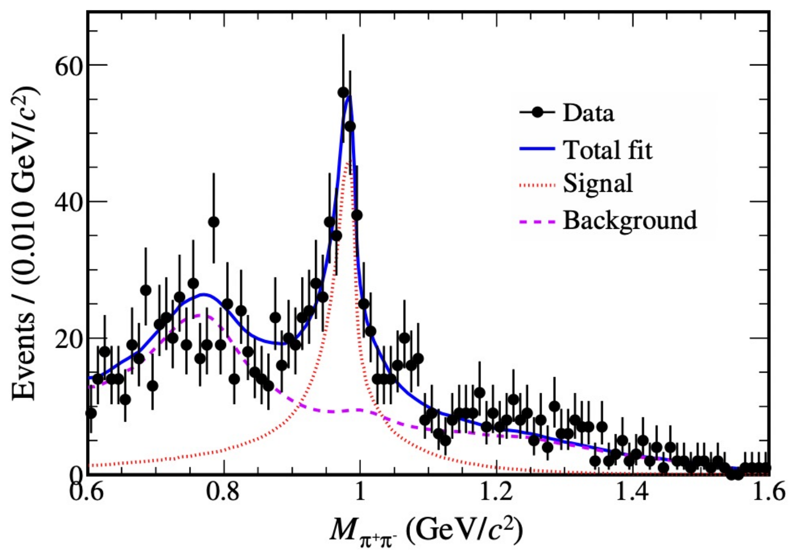
$\mathcal{B} = (7.9 \pm 1.4 \pm 0.4)\times 10^{-4}$

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

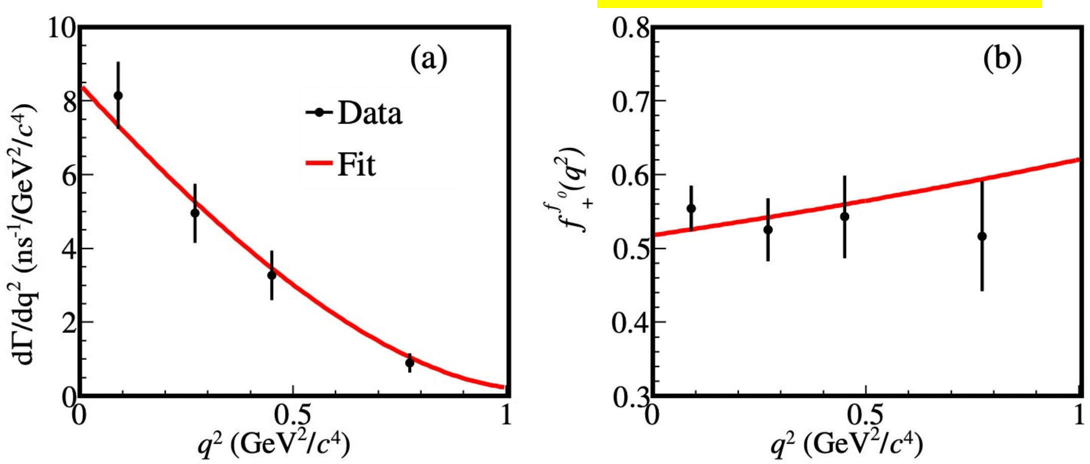
Study $f_0(980)$ in $D_s^+ \to \pi^+\pi^- e^+\nu_e$

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

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



First measurement

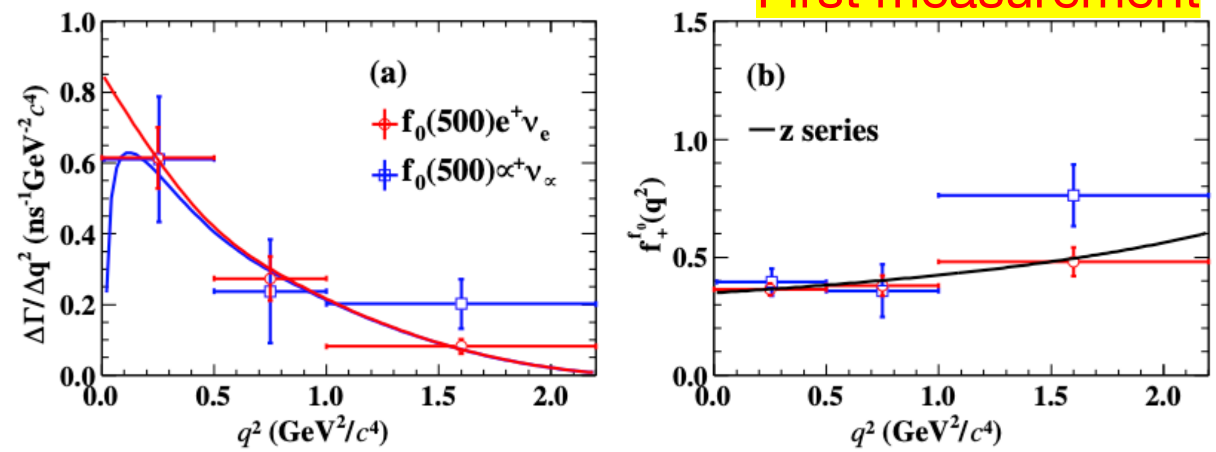


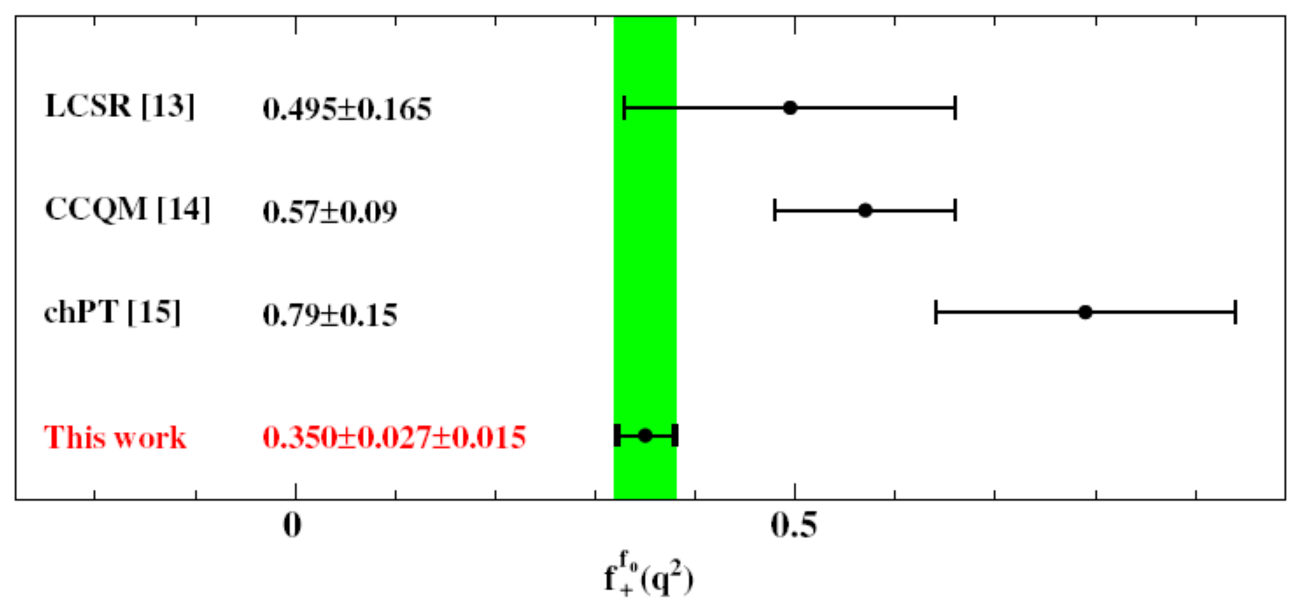
$$f_+^{f_0}(0)|V_{cs}| = 0.504 \pm 0.017 \pm 0.035$$

Study $f_0(500)$ in $D^+ \to \pi^+\pi^- e^+\nu_e$

arXiv:2401.13225

First measurement



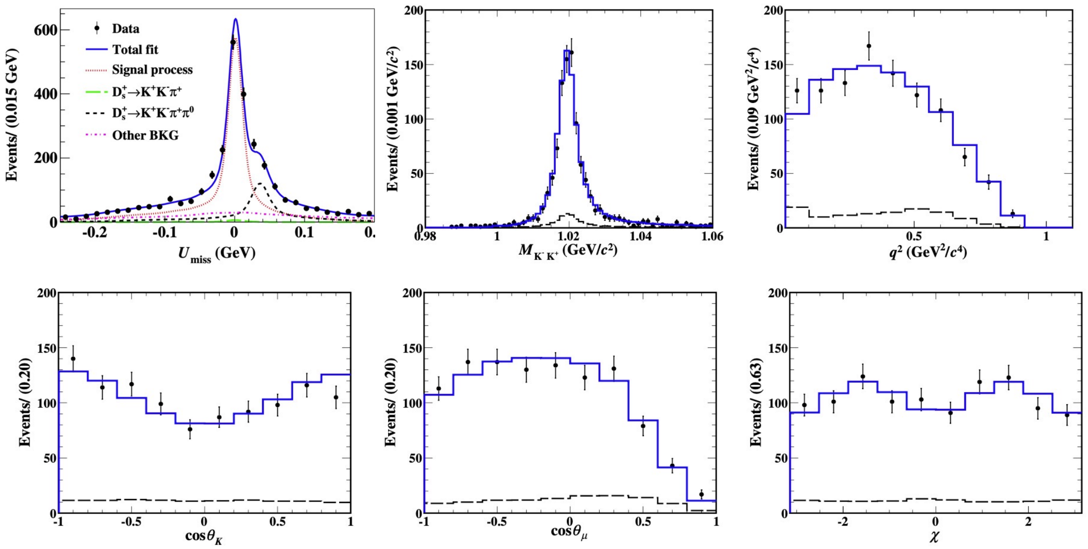


$$f_+^{f_0}(0)|V_{cd}| = 0.0787 \pm 0.0060_{\rm stat} \pm 0.0033_{\rm syst}$$

We have also study…

$D \to Vl\nu$

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



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

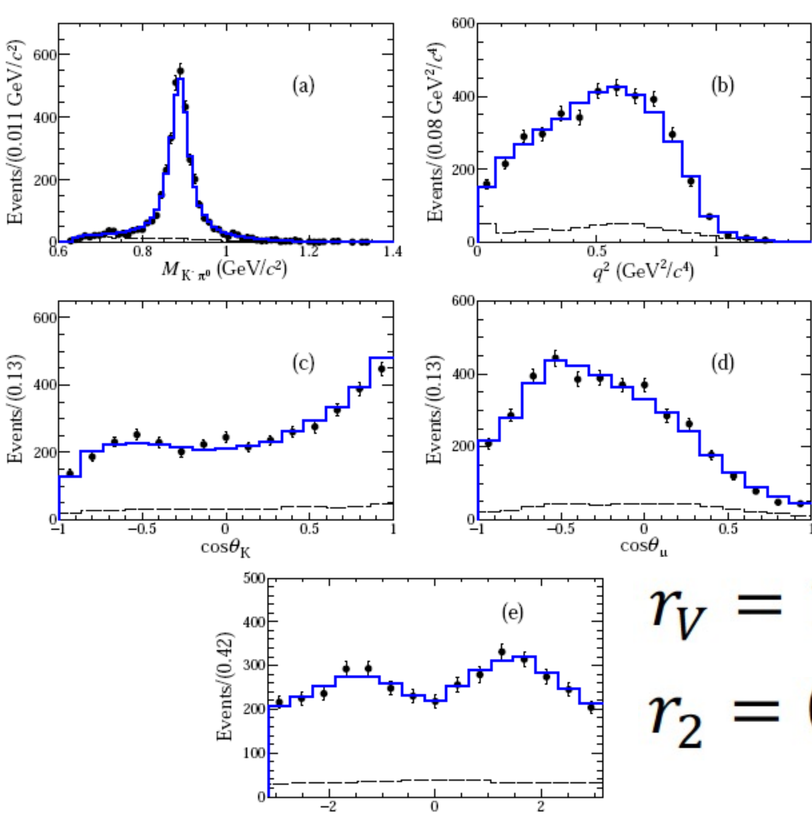
$r_V = 1.58 \pm 0.17 \pm 0.02$

$r_2 = 0.77 \pm 0.28 \pm 0.07$

JHEP 12(2023)072

$D^+ \to K^{*-}\mu^+\nu_e$

arXiv:2403.10877



$r_V = 1.37 \pm 0.09 \pm 0.03$

$r_2 = 0.76 \pm 0.06 \pm 0.02$

$D \to Al\nu$

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

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

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

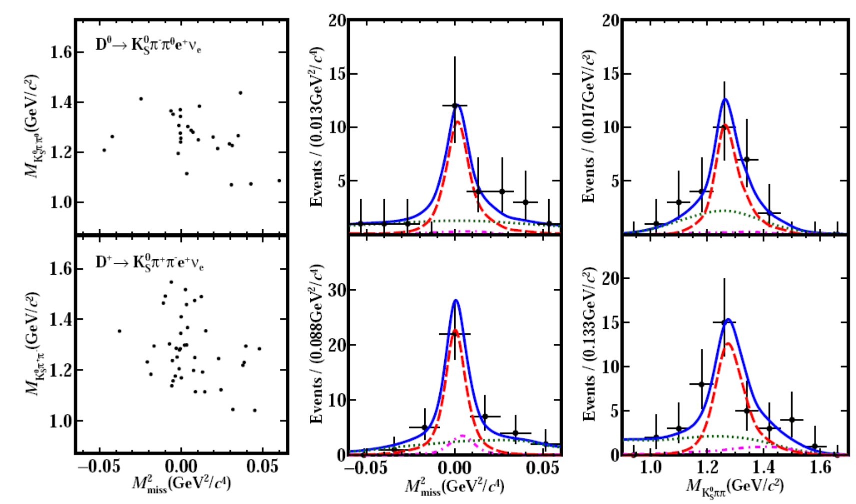
$D^+ \to K_1(1270)^0 e^+\nu$

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

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

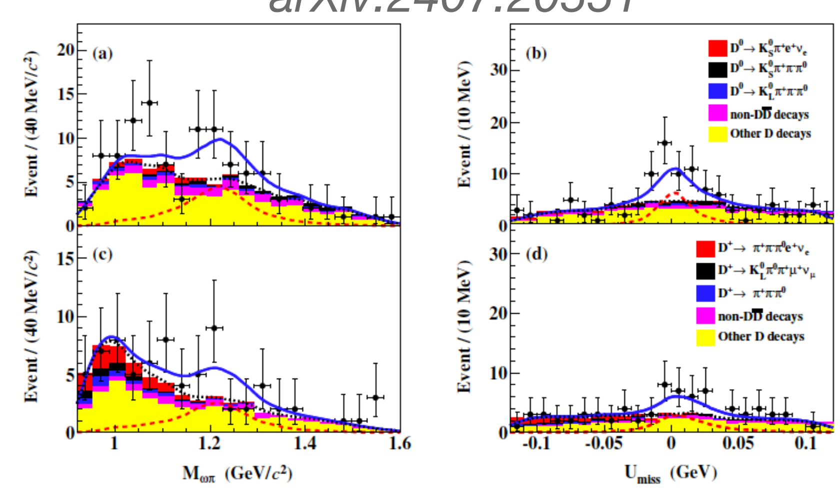
$D \to K_1(1270)(\to K_S\pi\pi)e^+\nu$

arXiv:2403.19091



$D^+ \to b_1(1235)^0 e^+\nu$

arXiv:2407.20551



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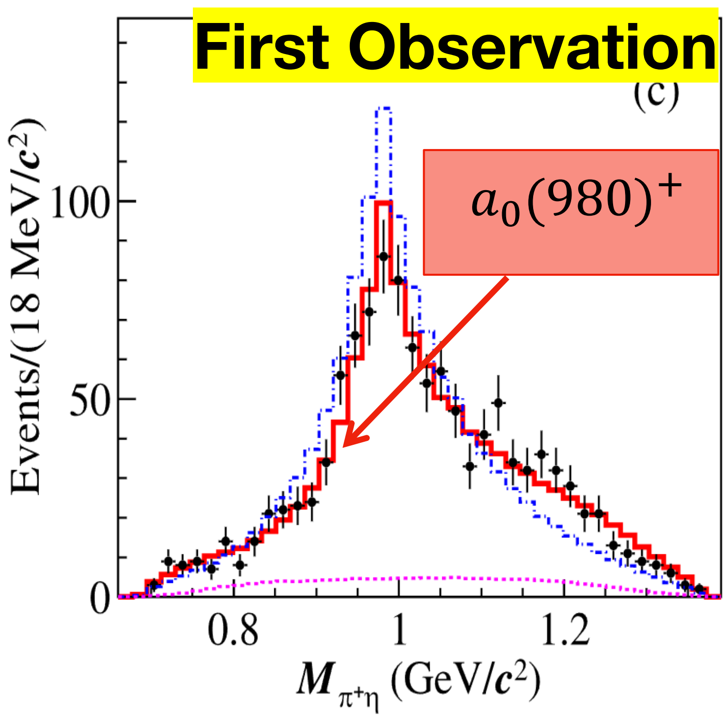
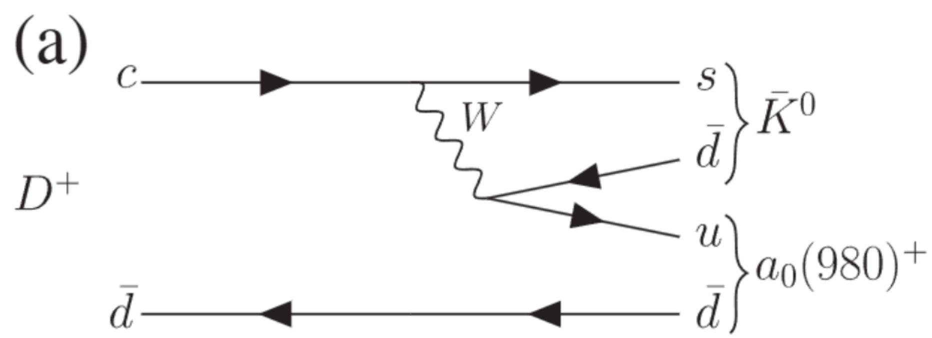
Study of $D^+ \to K_S^0 a_0(980)^+$

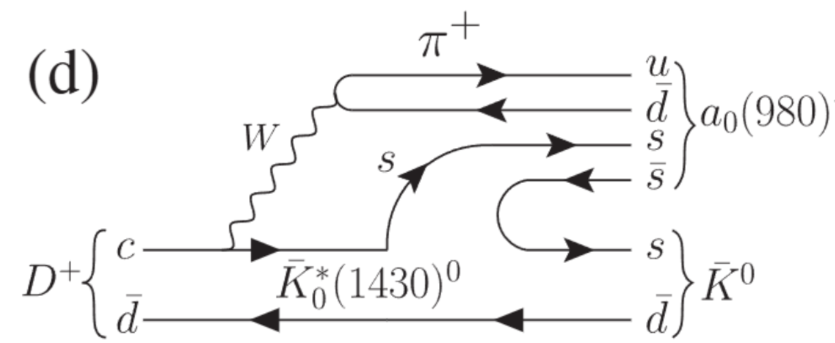
PRL 132, 131903 (2024)

Among $D \to$ SP, $D^+ \to K_S^0 a_0(980)^+$ is, except $\kappa\pi$, the only decay free of weak-annihilation contributions.

2.93fb^{-1}@E_{cm}=3.773 GeV
1113 candidates with 98.2% purity







$$\mathcal{B}(D^+ \to K_S^0 \pi^+ \eta) = (1.27 \pm 0.04_{stat} \pm 0.03_{syst})\%$$

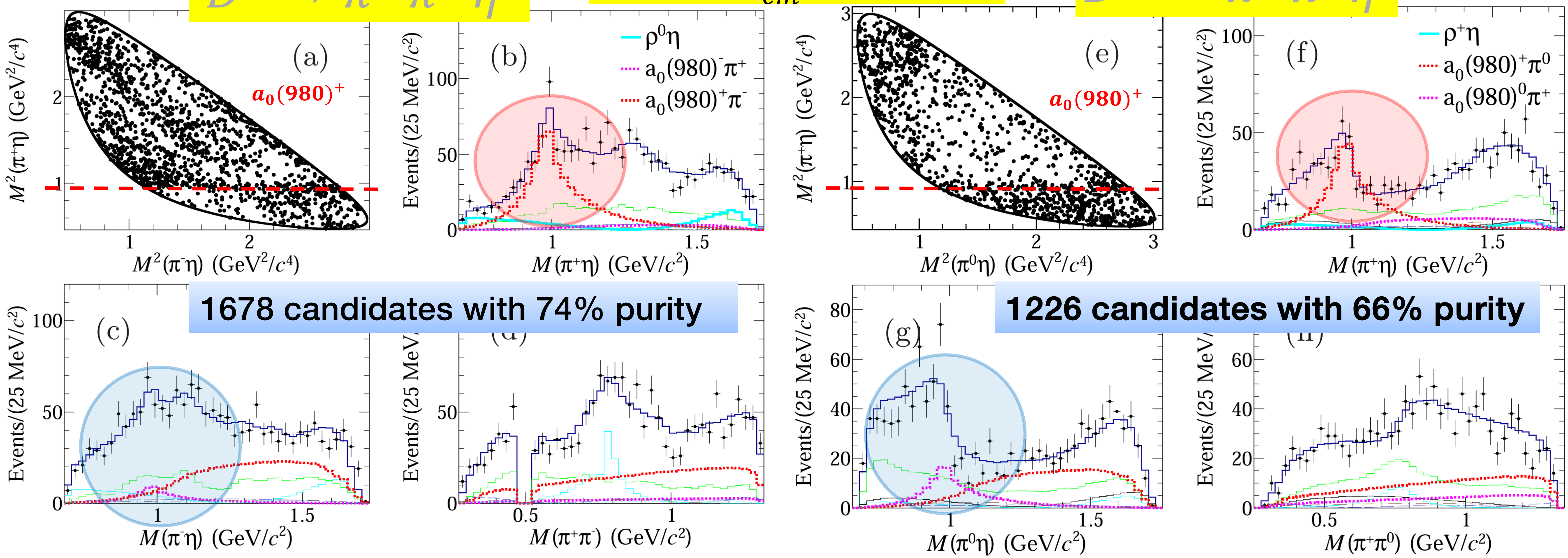
- $\mathcal{B}(D^+ \to K_S^0 a_0(980)^+, a_0(980)^+ \to \pi^+ \eta) = (1.33 \pm 0.05_{stat} \pm 0.04_{syst})\%$
- **Provide sensitive constraints in the extraction of contributions from external and internal W-emission diagrams of $D \to SP$**
- Understand the inconsistency between theory and experiment of the $D \to a_0(980)^+ P$[1-3].

[1]Phys. Rev. D 105, 033006 (2022).
[2]Phys. Rev. D 67, 034024 (2003).
[3] Phys. Rev. D 81, 074031 (2010)

Observation of $D \to a_0(980)\pi$

arXiv:2404.09219

$D^0 \to \pi^+\pi^-\eta$ | 7.9fb^{-1}@E_{cm}=3.773 GeV | $D^+ \to \pi^+\pi^0\eta$



Amplitude	Phase (in unit rad)	FF (%)	Significance (σ)	BF ($\times 10^{-3}$)
$D^0 \to \rho^0\eta$	0 (fixed)	$15.2 \pm 1.7 \pm 1.0$	> 10	$0.19 \pm 0.02 \pm 0.01$
$D^0 \to a_0(980)^-\pi^+$	$0.06 \pm 0.16 \pm 0.12$	$5.9 \pm 1.3 \pm 1.0$	8.9	$0.07 \pm 0.02 \pm 0.01$
$D^0 \to a_0(980)^+\pi^-$	$-1.06 \pm 0.12 \pm 0.10$	$44.0 \pm 4.0 \pm 5.3$	> 10	$0.55 \pm 0.05 \pm 0.07$
$D^0 \to a_2(1320)^+\pi^-$	$-1.16 \pm 0.25 \pm 0.23$	$2.1 \pm 0.9 \pm 0.8$	4.5	$0.03 \pm 0.01 \pm 0.01$
$D^0 \to a_2(1700)^+\pi^-$	$0.08 \pm 0.17 \pm 0.23$	$5.5 \pm 1.8 \pm 2.7$	6.1	$0.07 \pm 0.02 \pm 0.03$
$D^0 \to (\pi^+\pi^-)_{S-\text{wave}}\eta$	$-0.92 \pm 0.29 \pm 0.14$	$3.9 \pm 1.8 \pm 2.1$	5.3	$0.05 \pm 0.02 \pm 0.03$
$r_{+/-}$		$7.5^{+2.5}_{-0.8} \pm 1.7$	7.7^*	-
$D^+ \to \rho^+\eta$	$-4.03 \pm 0.19 \pm 0.13$	$9.3 \pm 3.0 \pm 2.1$	6.0	$0.20 \pm 0.07 \pm 0.05$
$D^+ \to (\pi^+\pi^0)_V\eta$	$-0.64 \pm 0.22 \pm 0.19$	$15.8 \pm 4.8 \pm 5.2$	4.7	$0.34 \pm 0.11 \pm 0.11$
$D^+ \to a_0(980)^+\pi^0$	0 (fixed)	$43.7 \pm 5.6 \pm 1.9$	9.1	$0.95 \pm 0.12 \pm 0.05$
$D^+ \to a_0(980)^0\pi^+$	$2.44 \pm 0.20 \pm 0.10$	$17.0 \pm 4.4 \pm 1.7$	7.9	$0.37 \pm 0.10 \pm 0.04$
$D^+ \to a_2(1700)^+\pi^0$	$0.92 \pm 0.20 \pm 0.14$	$4.2 \pm 2.1 \pm 0.7$	3.6	$0.09 \pm 0.05 \pm 0.02$
$D^+ \to a_0(1450)^+\pi^0$	$0.63 \pm 0.41 \pm 0.30$	$7.0 \pm 2.8 \pm 0.7$	4.7	$0.15 \pm 0.06 \pm 0.02$
$r_{+/0}$		$2.6 \pm 0.6 \pm 0.3$	4.0^*	-

The external W-emission dominates the $D \to a_0(980)\pi$ decays in the diquark scenario, contrary to expectations of its negligible contribution due to the very small $a_0(980)$ decay constant[1].

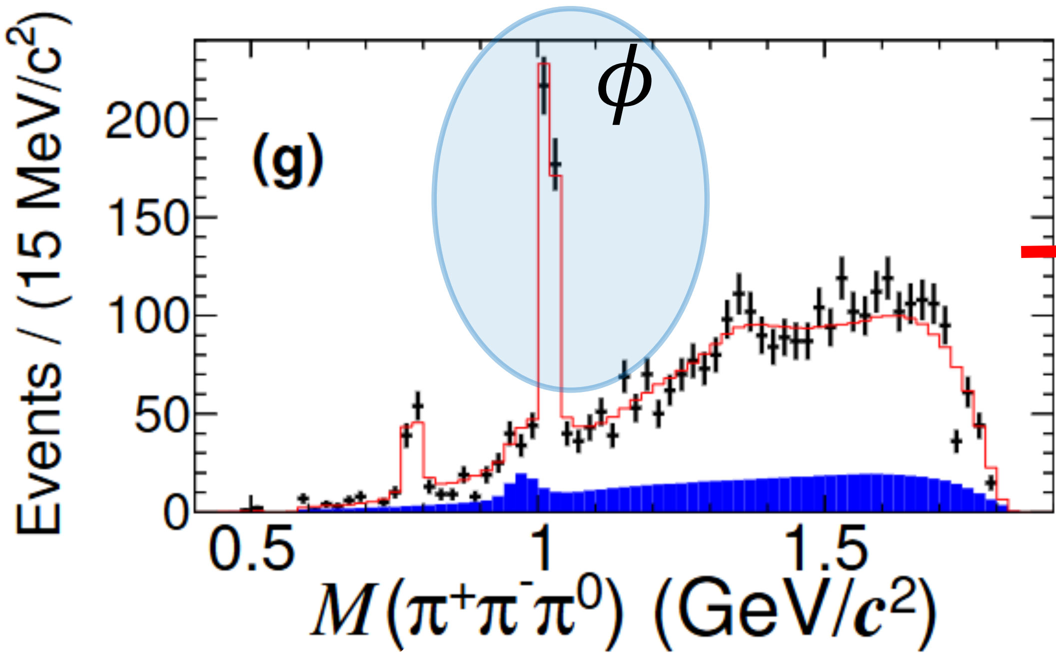
- $\mathcal{B}(D^0 \to \pi^+\pi^-\eta) = (1.24 \pm 0.04_{stat} \pm 0.03_{syst})\%$
- $\mathcal{B}(D^+ \to \pi^+\pi^0\eta) = (2.18 \pm 0.12_{stat} \pm 0.03_{syst})\%$
- $a_0(1817)$ is not observed in both channels

[1] Phys. Rev. D **105**, 033006(2022).

Study of $D_s^+ \to \phi(\pi^+\pi^-\pi^0, K^+K^-)\pi^-$

$D_s^+ \to \pi^+\pi^-\pi^0\pi^+$ arXiv:2406.17452

First Measurement

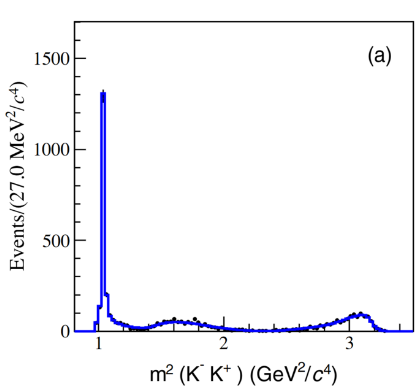


Component	Phase (rad)	FF (%)	BF (10^{-3})
$f_0(1370)\rho^+$	0.0(fixed)	$24.9 \pm 3.8 \pm 2.1$	$5.08 \pm 0.80 \pm 0.43$
$f_0(980)\rho^+$	$3.99 \pm 0.13 \pm 0.07$	$12.6 \pm 2.1 \pm 1.0$	$2.57 \pm 0.44 \pm 0.20$
$f_2(1270)\rho^+$	$1.11 \pm 0.10 \pm 0.10$	$9.5 \pm 1.7 \pm 0.6$	$1.94 \pm 0.36 \pm 0.12$
$(\rho^+\rho^0)_S$	$1.10 \pm 0.18 \pm 0.10$	$3.5 \pm 1.2 \pm 0.6$	$0.71 \pm 0.25 \pm 0.12$
$(\rho(1450)^+\rho^0)_S$	$0.43 \pm 0.18 \pm 0.17$	$4.6 \pm 1.3 \pm 0.8$	$0.94 \pm 0.27 \pm 0.16$
$(\rho^+\rho(1450)^0)_P$	$4.58 \pm 0.16 \pm 0.09$	$8.6 \pm 1.3 \pm 0.4$	$1.75 \pm 0.27 \pm 0.08$
$\phi((\rho\pi) \to \pi^+\pi^-\pi^0)\pi^+$	$2.90 \pm 0.15 \pm 0.18$	$24.9 \pm 1.2 \pm 0.4$	$5.08 \pm 0.32 \pm 0.10$
$\omega((\rho\pi) \to \pi^+\pi^-\pi^0)\pi^+$	$3.22 \pm 0.21 \pm 0.09$	$6.9 \pm 0.8 \pm 0.3$	$1.41 \pm 0.17 \pm 0.06$
$a_1^+(\rho^0\pi^+)_S\pi^0$	$3.78 \pm 0.16 \pm 0.12$	$12.5 \pm 1.6 \pm 1.0$	$2.55 \pm 0.34 \pm 0.20$
$a_1^0((\rho\pi)_S \to \pi^+\pi^-\pi^0)\pi^+$	$4.82 \pm 0.15 \pm 0.12$	$6.3 \pm 1.9 \pm 1.2$	$1.29 \pm 0.39 \pm 0.24$
$\pi(1300)^0((\rho\pi)_P \to \pi^+\pi^-\pi^0)\pi^+$	$2.22 \pm 0.14 \pm 0.08$	$11.7 \pm 2.3 \pm 2.2$	$2.39 \pm 0.48 \pm 0.45$

- $\mathcal{B}(D_s^+ \to \phi\pi^+, \phi \to \pi^+\pi^-\pi^0) = (5.08 \pm 0.32 \pm 0.10)\times10^{-3}$
- $\mathcal{B}(D_s^+ \to \phi\pi^+, \phi \to K^+K^-) = (2.21 \pm 0.05 \pm 0.07)\%$

$D_s^+ \to K^+K^-\pi^+$

PRD 104, 012016



- $\frac{\mathcal{B}(\phi\to\pi^+\pi^-\pi^0)}{\mathcal{B}(\phi\to K^+K^-)} = 0.230 \pm 0.014_{stat} \pm 0.010_{syst}$.
- **Deviates from PDG value** (0.313 ± 0.010) **% by > 4σ.**
- **First measurement of R_ϕ in charmed mesons, and the lower than expected value motivates further studies.**

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

Quantum Correlation

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

Best laboratory to measure strong-phase parameters

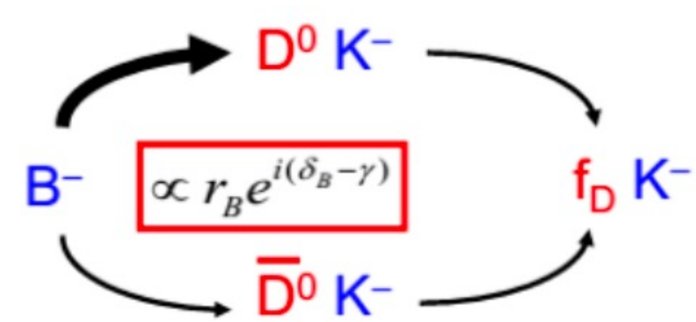
CP-odd: $\psi(3770) = \left(D^0\bar{D}^0 - D^0\,\bar{D}^0\right) = (D_+D_- - D_-D_+)$

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

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_+ → GLW/GGSZ method;

strong phase $ci(')$ and $si(')$ → GGSZ method

non-self-conjugated decay: the coherence factor R and averaged strong phase difference δ → ADS method

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

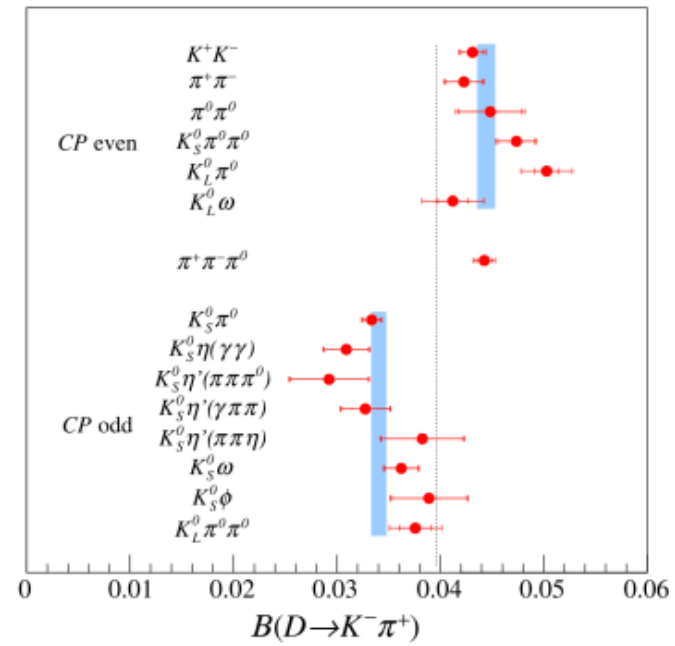
- **An update measurement of the asymmetry between CP-odd and CP-even eigenstate decays into $K^-\pi^+$**

30% more precise !

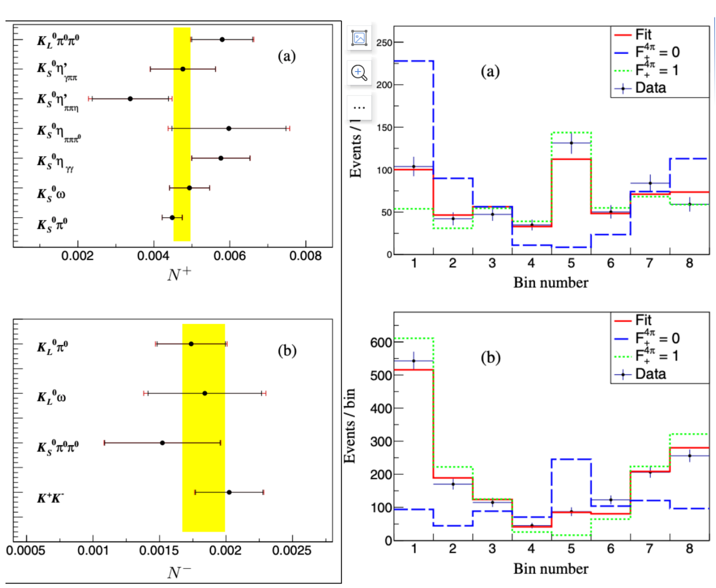
$$\mathcal{A}_{K\pi} \equiv \frac{\mathcal{B}(D_- \to K^-\pi^+) - \mathcal{B}(D_+ \to K^-\pi^+)}{\mathcal{B}(D_- \to K^-\pi^+) + \mathcal{B}(D_+ \to K^-\pi^+)} = \frac{-2r_D^{K\pi}\cos\delta_D^{K\pi} + y}{1 + \left(r_D^{K\pi}\right)^2} = 0.132 \pm 0.011 \pm 0.007$$

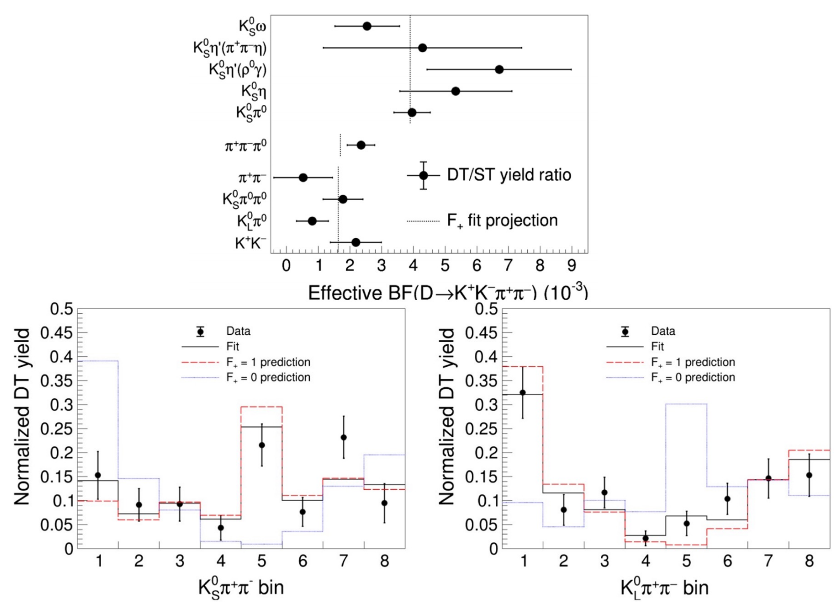
- **$\delta_D^{K\pi}$=($187.6^{+8.9+5.4}_{-9.7-6.4}$)**

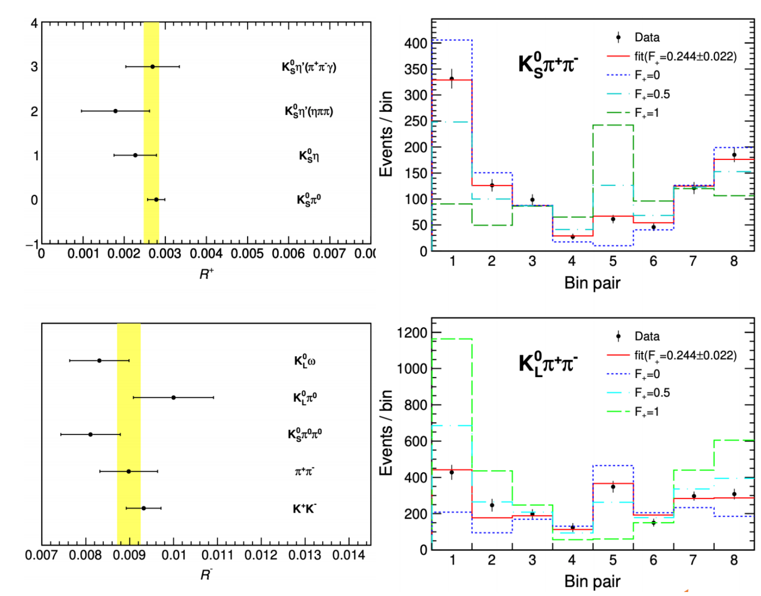
EPJC 82, 1009 (2022)



Determination of CP fraction







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

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

PRD 106, 092004(2022)

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

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

PRD 107, 032009(2023)

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

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

PRD 108, 032003 (2023)

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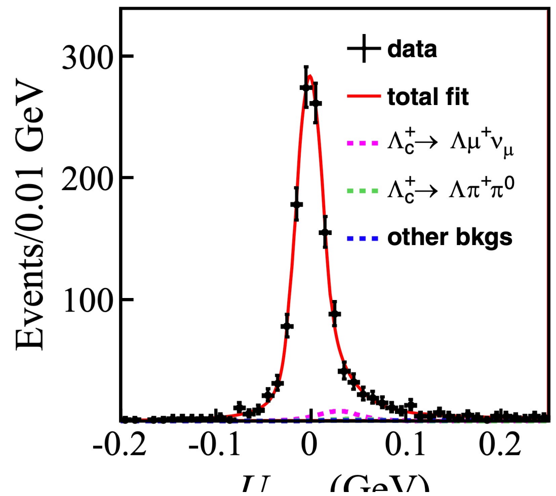
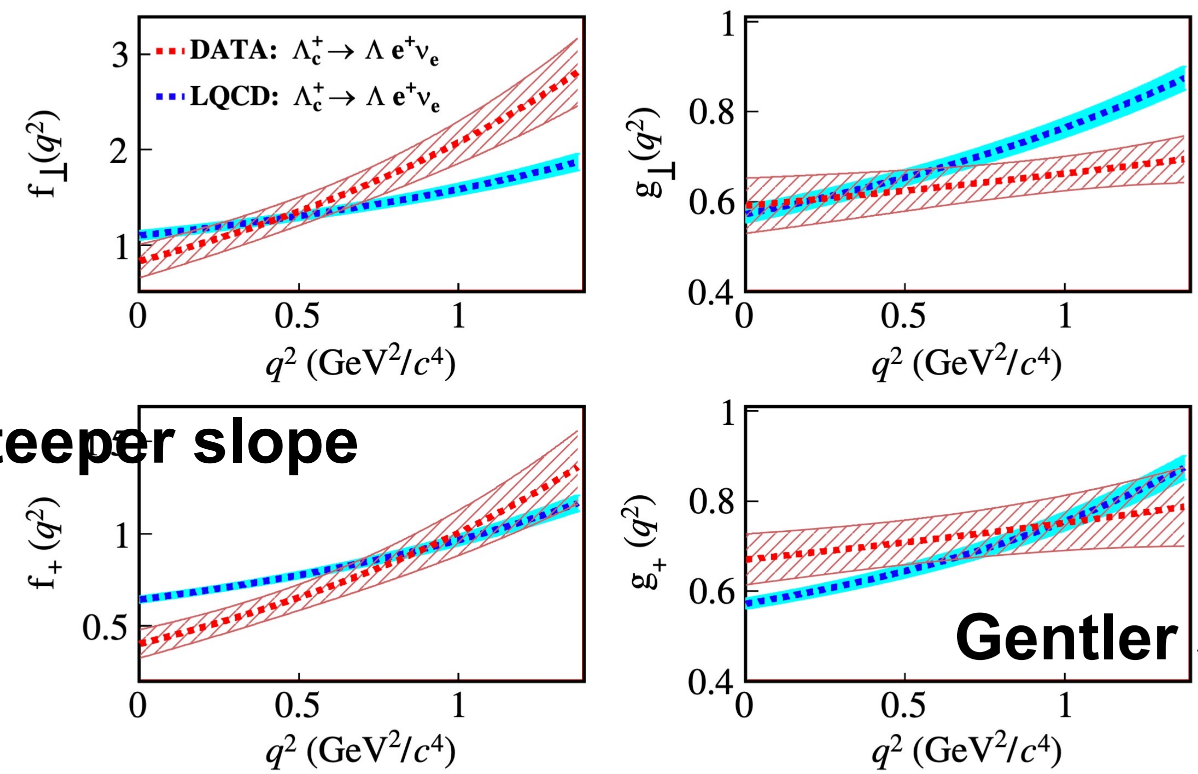
- Charmed baryon (Λ_c^+)
  - semi-leptonic decays
  - hadronic decays
- Prospect

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



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

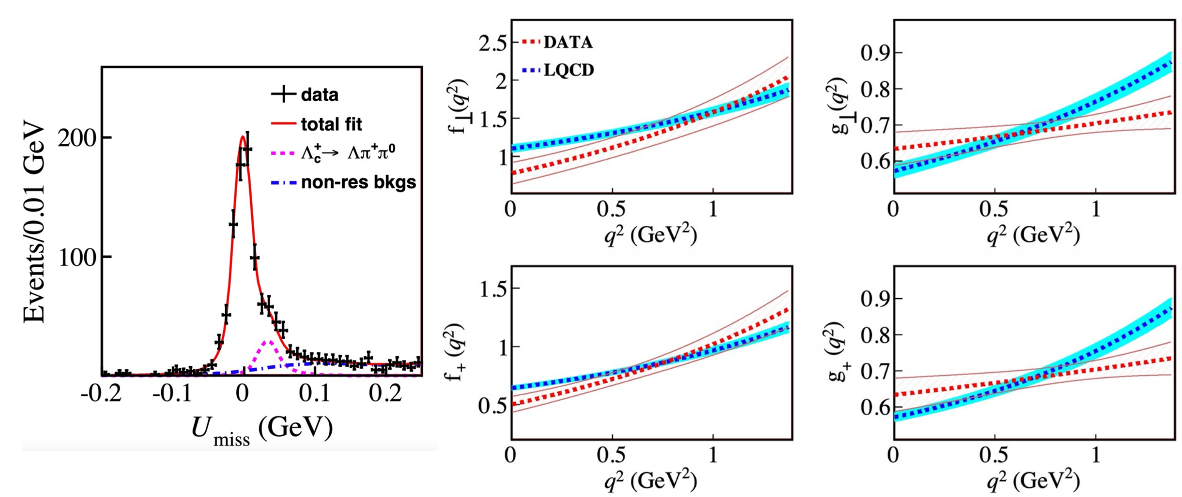
Different kinematic behavior compared to LQCD



Steeper slope

Gentler slope

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



Updated BF and first FF measurement:

~4% most precise

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

$$|V_{cs}| = (0.936 \pm 0.017_{\mathcal{B}} \pm 0.024_{LQCD} \pm 0.0240.024_{\tau_{\Lambda_c^+}})\times 10^{-3}$$

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

PRD 108, L031105(2023)

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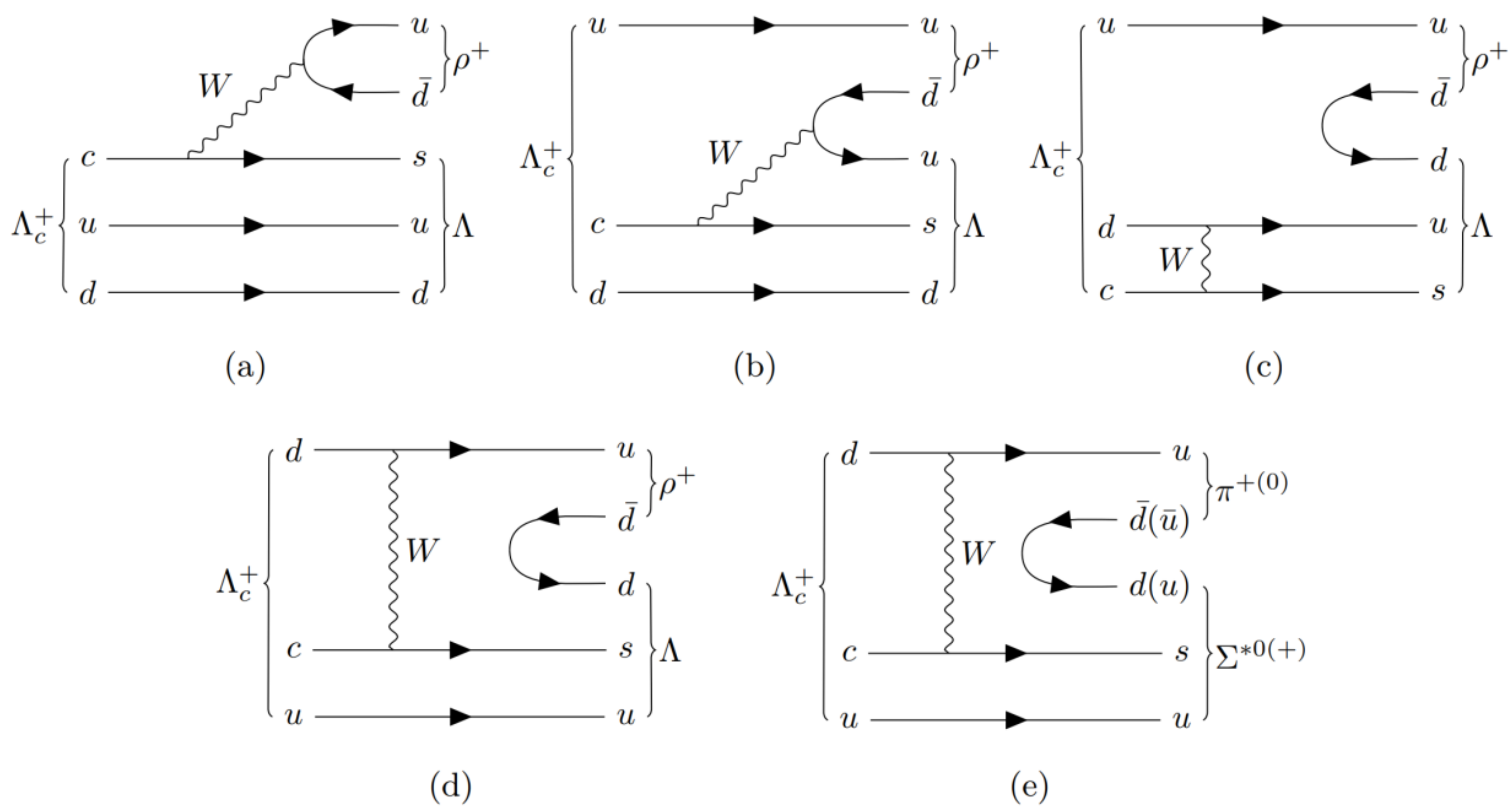
Partial wave analysis of the charmed baryon hadronic decay $\Lambda_c^+ \to \Lambda\pi^+\pi^0$



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

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

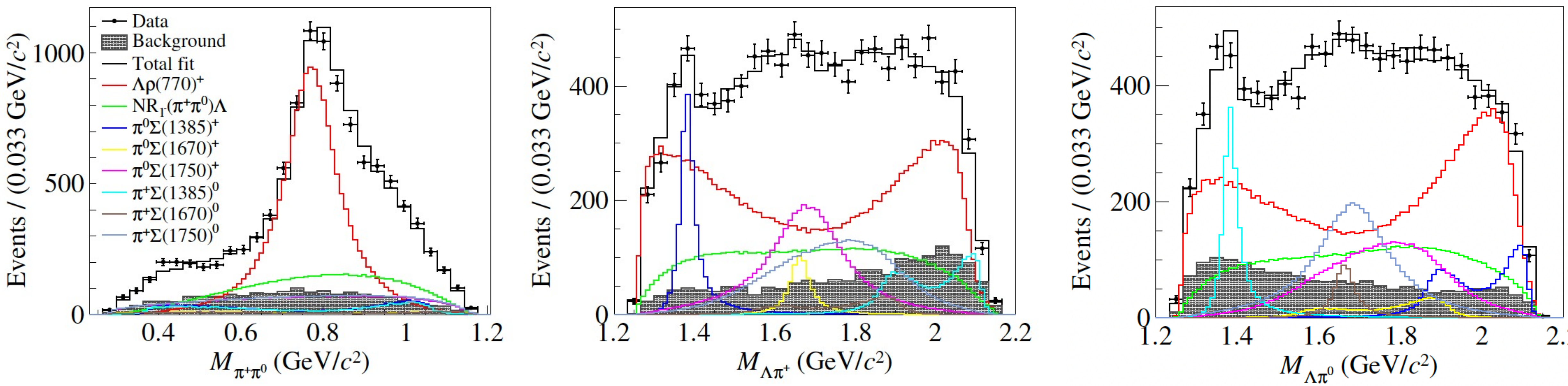
Provide important inputs to the theoretical calculations for non-factorizable

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 $\Lambda_c^+ \to \Lambda\pi^+\pi^0$

JHEP12 (2022) 033



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

	Theoretical calculation		This work	PDG
$10^2 \times \mathcal{B}(\Lambda_c^+ \to \Lambda\rho(770)^+)$	4.81 ± 0.58 [13]	4.0 [14, 15]	4.06 ± 0.52	< 6
$10^3 \times \mathcal{B}(\Lambda_c^+ \to \Sigma(1385)^+\pi^0)$	2.8 ± 0.4 [16]	2.2 ± 0.4 [17]	5.86 ± 0.80	—
$10^3 \times \mathcal{B}(\Lambda_c^+ \to \Sigma(1385)^0\pi^+)$	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	—

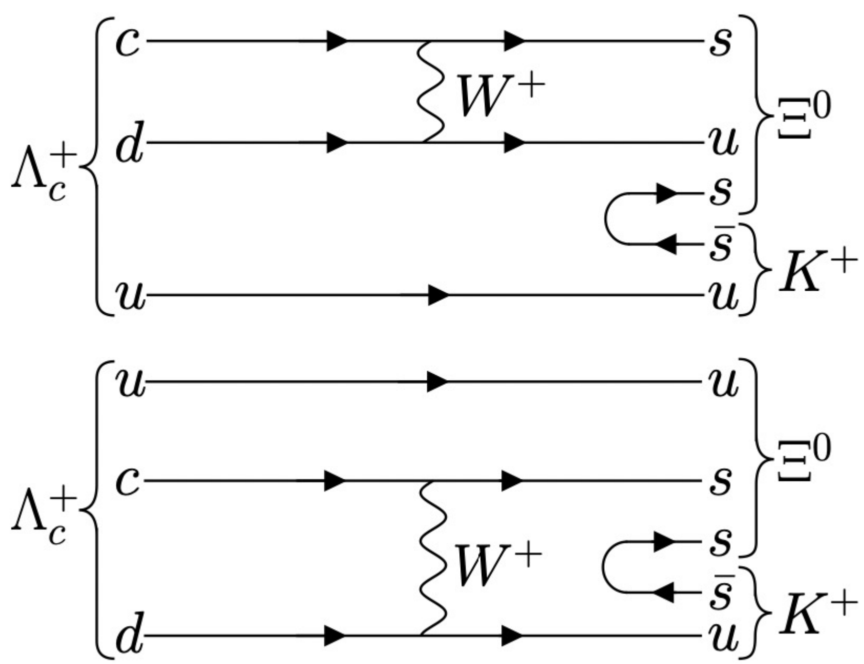
The first measurement of the decay asymmetry parameters for the relevant resonance

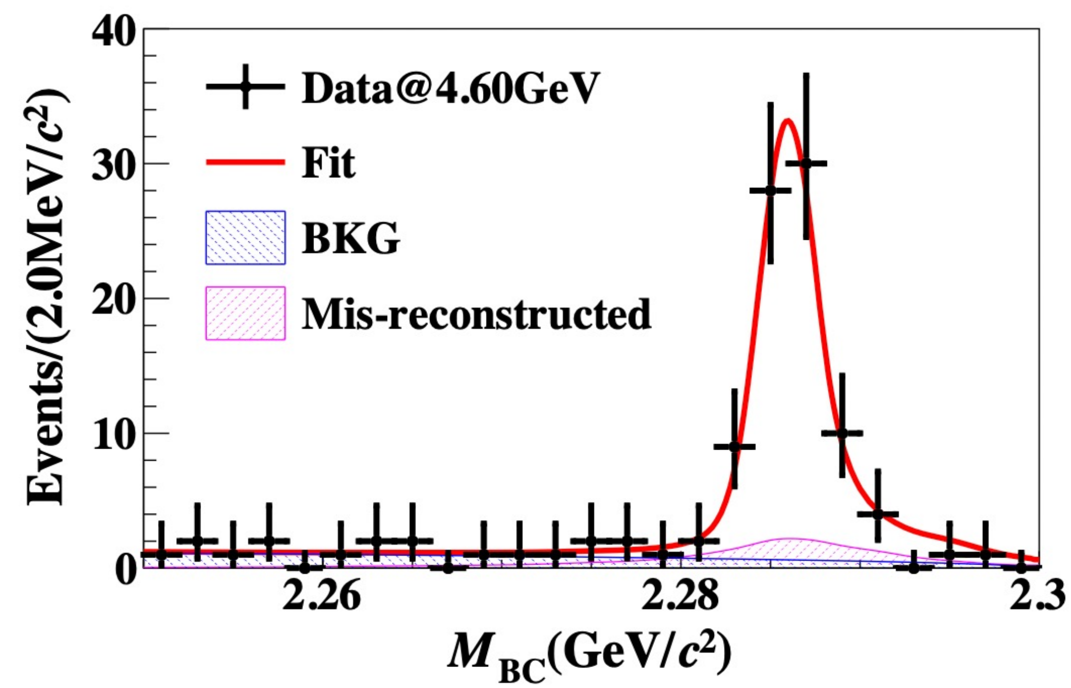
Ref. [13]: PRD 101 (2020) 053002.
Ref. [14,15]: PRD 46 (1992) 1042; PRD 55 (1997) 1697.
Ref. [16]: EPJC 80 (2020) 1067.
Ref. [17]: PRD 99 (2019) 114022

First Measurement of the Decay Asymmetry in the pure W-boson-exchange Decay $\Lambda_c^+ \to \Xi^0 K^+$

PRL 132, 031801 (2024)

Only receives the non-factorization contribution





$e^+e^- \to \Lambda_c^+ \bar{\Lambda}_c^-$

Two individual helicity $H_{\frac{1}{2},\frac{1}{2}}$ and $H_{\frac{1}{2},-\frac{1}{2}}$

$$\alpha_0 = \frac{\left|H_{\frac{1}{2},-\frac{1}{2}}\right|^2 - 2\left|H_{\frac{1}{2},\frac{1}{2}}\right|^2}{\left|H_{\frac{1}{2},-\frac{1}{2}}\right|^2 + 2\left|H_{\frac{1}{2},\frac{1}{2}}\right|^2}$$

Δ_0 is phase shift between them

$\Lambda_c^+ \to \Xi^0 K^+$

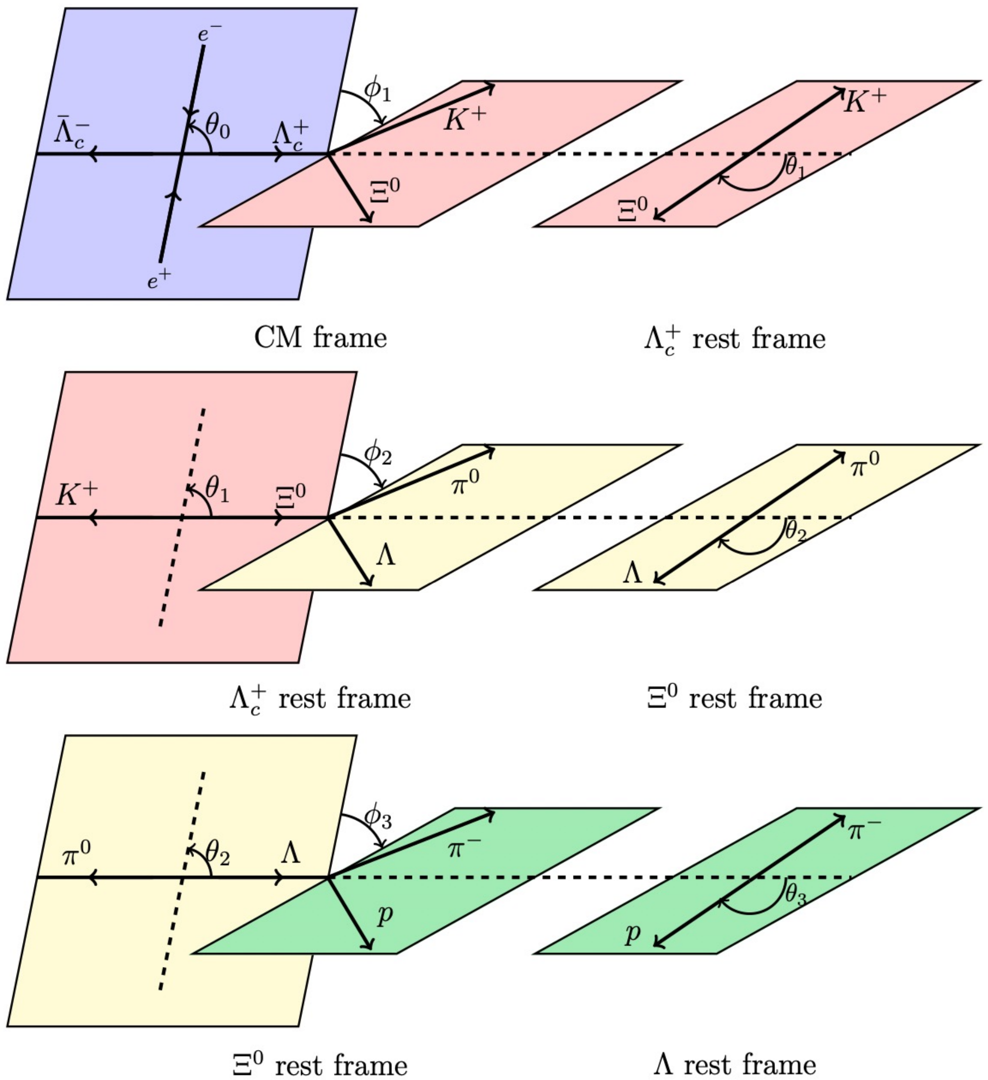
$$\alpha^2 + \beta^2 + \gamma^2 = 1$$

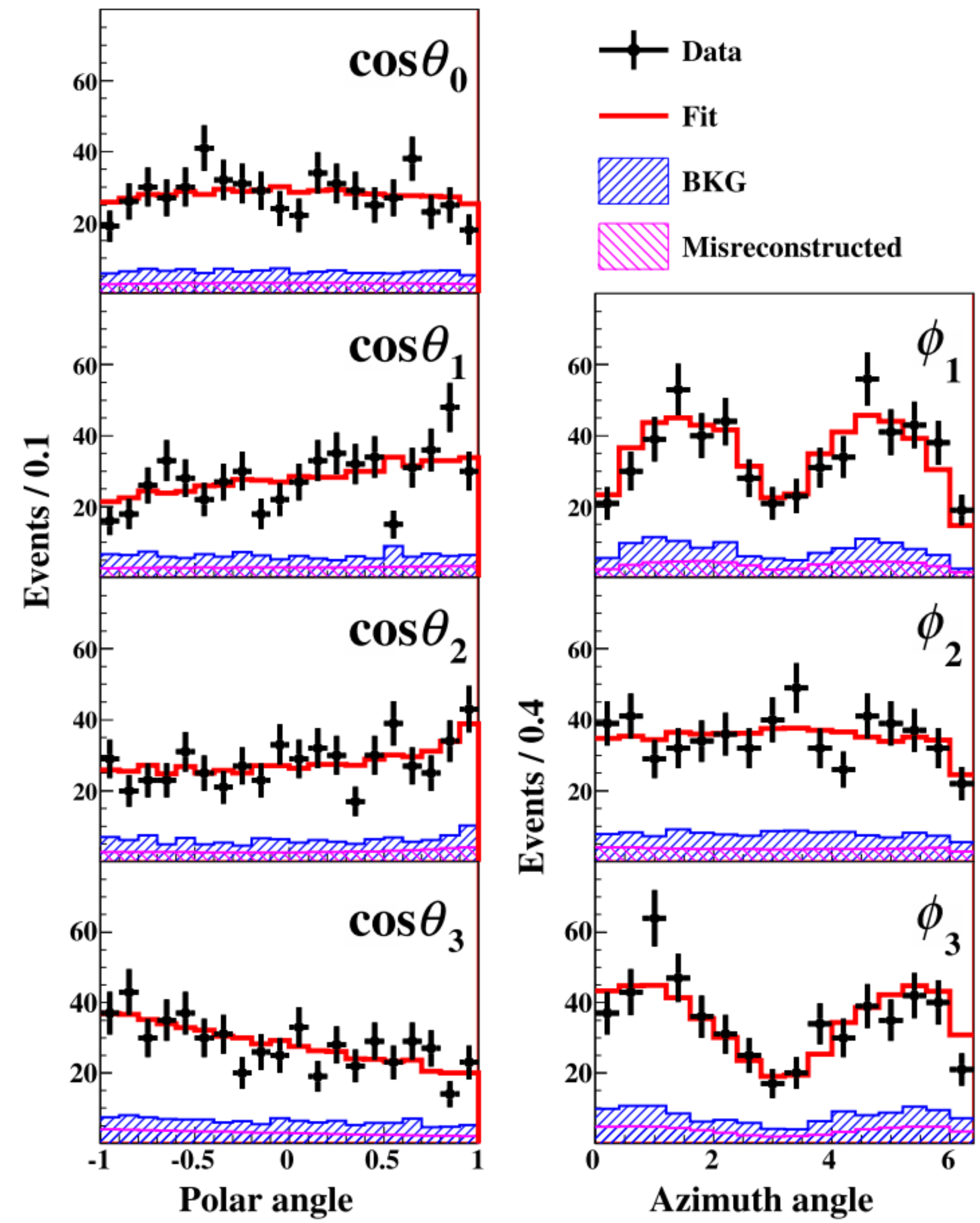
$$\alpha = \frac{2Re(S^*P)}{|S|^2 + |P|^2}$$

$$\beta = \sqrt{1-\alpha^2}\sin\Delta$$

$$\gamma = \sqrt{1-\alpha^2}\cos\Delta$$

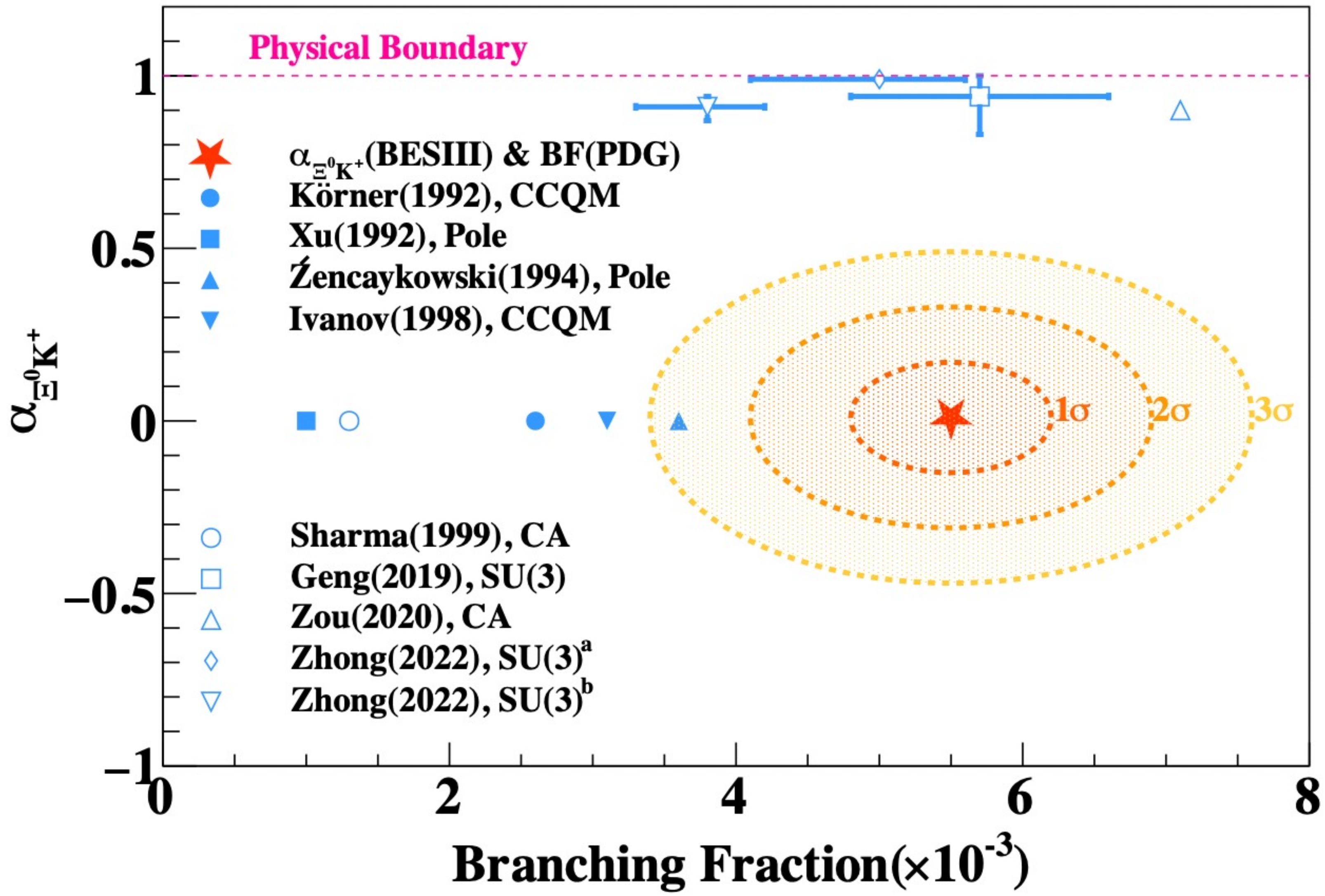
First Measurement of the Decay Asymmetry in the pure W-boson-exchange Decay $\Lambda_c^+ \to \Xi^0 K^+$





- ❖ Fixed the parameters in $e^+e^- \to \Lambda_c^+\bar{\Lambda}_c^-$ and Ξ^0 and Λ decays
- ❖ Free parameters of $\alpha_{\Xi^0 K^+}$ and $\Delta_{\Xi^0 K^+}$
- ❖ Six data sets between 4.6 and 4.7 GeV

First Measurement of the Decay Asymmetry in the pure W-boson-exchange Decay $\Lambda_c^+ \to \Xi^0 K^+$



$$\alpha_{\Xi^0 K^+} = 0.01 \pm 0.16 \pm 0.03 \qquad \delta_p - \delta_s = -1.55 \pm 0.25 \pm 0.05$$

$$\Delta_{\Xi^0 K^+} = 3.84 \pm 0.90 \pm 0.17 \text{ rad} \qquad \text{or} \quad 1.59 \pm 0.25 \pm 0.05$$

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Prospect

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

20 fb^{-1} of data set at 3.773 GeV is ready

Leptonic Decay

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

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: $D^0 \to K(1270)^- \nu_e$, $D^+ \to \bar{K}_1(1270)^0 e^+ \nu_e$, $D^+ \to \eta' \mu^+ \nu_\mu$, $D^0 \to a_0(980)^- e^+ \nu_e$, $D^+ \to a_0(980)^0 e^+ \nu_e$
- $\lvert V_{cd(s)}\rvert$ 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%

Prospect

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

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)
$K_S^0K^+K^-$	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)
$K_S^0K^\pm\pi^\mp$	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.

Prospect

Amplitude analyses and branching fraction measurement of charmed meson hadronic decays

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

First amplitude analysis of Cabbibo-suppressed decays.

Measuring the polarization of $\mathrm{D} \to \mathrm{VV}$ in $\mathrm{D} \to \mathrm{K3\pi}$ or $\mathrm{D} \to \mathrm{KK\pi\pi}$

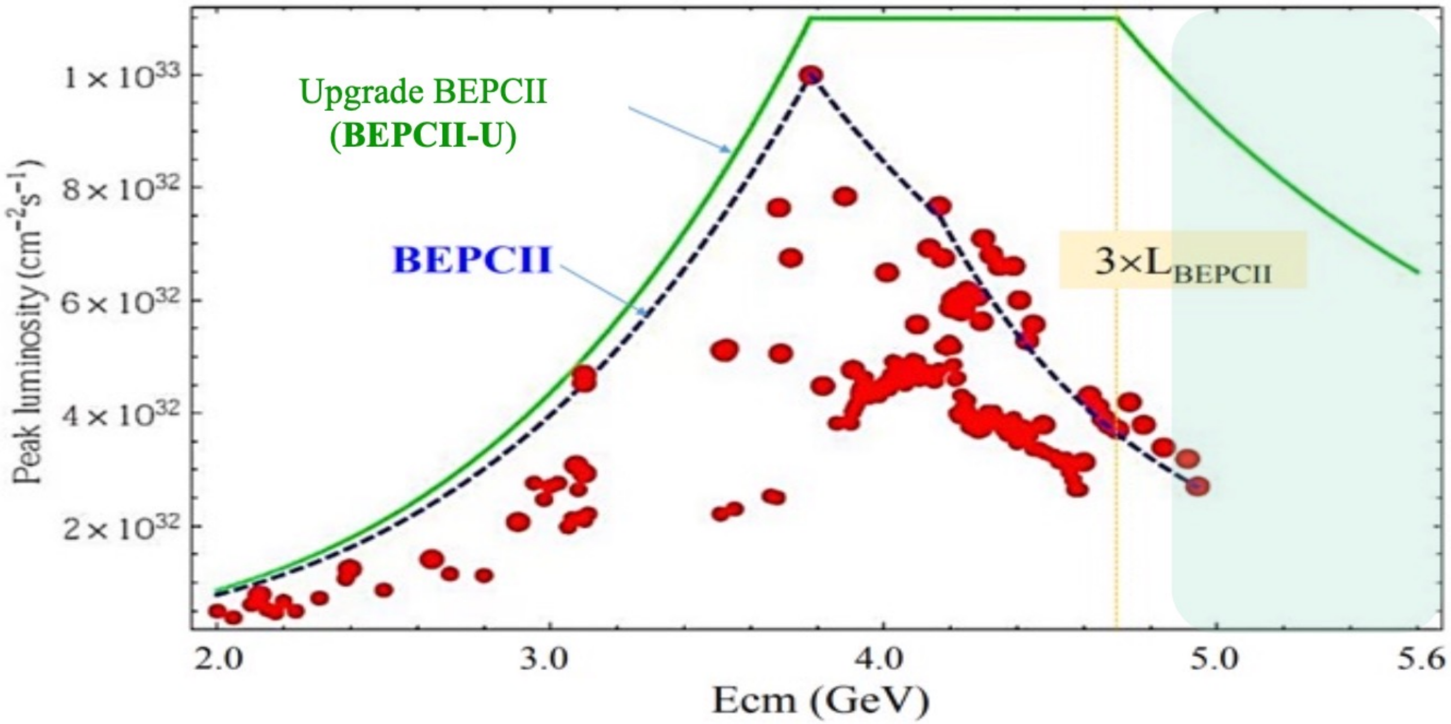
Searching for new physics and rare decays

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.

Prospect at BESIII



Energy thresholds

$e^+e^- \to \Lambda_c^+\bar{\Sigma}_c^-$	4.74 GeV
$e^+e^- \to \Lambda_c^+\bar{\Sigma}_c\ \pi$	4.88GeV
$e^+e^- \to \Sigma_c\ \bar{\Sigma}_c$	4.91 GeV
$e^+e^- \to \Xi_c\bar{\Xi}_c$	4.94 GeV
$e^+e^- \to \Omega_c\bar{\Omega}_c$	5.40GeV

- **Unique data samples at the thresholds for charmed baryons.**
  - **Hadron physics: spectroscopy, (transition-)form-factors, fragmentation …**
    - **Precise test of SM: weak decays, CKM, CP violation, rare/forbidden decays …**

Thanks for your attention