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BESIII

Leptonic and semileptonic charm decays at BESIII

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(on behalf of the BESIII collaboration)

Rencontres de Moriond 2026: Electroweak Interactions & Unified Theories



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Outline

1 Main goal

2 BESIII experiment

3 Leptonic decays

- $D^+ \rightarrow \mu^+ \nu_\mu$
- Other Measurement of $D_{(s)}^+ \rightarrow \ell^+ \nu_\ell$

4 Semileptonic decays

- $D \rightarrow P \ell^+ \nu_\ell$ $P = \text{pseudoscalar}$
- $D \rightarrow V \ell^+ \nu_\ell$ $V = \text{vector}$
- $D \rightarrow S e^+ \nu_e$ $S = \text{scalar}$
- $D \rightarrow A e^+ \nu_e$ $A = \text{axial-vector}$

5 Comparison of $|V_{cs}|$ and $|V_{cd}|$

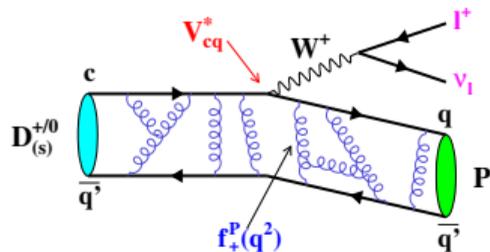
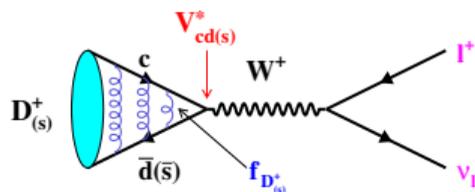
6 Comparison of decay constant $f_{D_{(s)}^+}$

7 Summary and prospect

8 Back up

Main goal

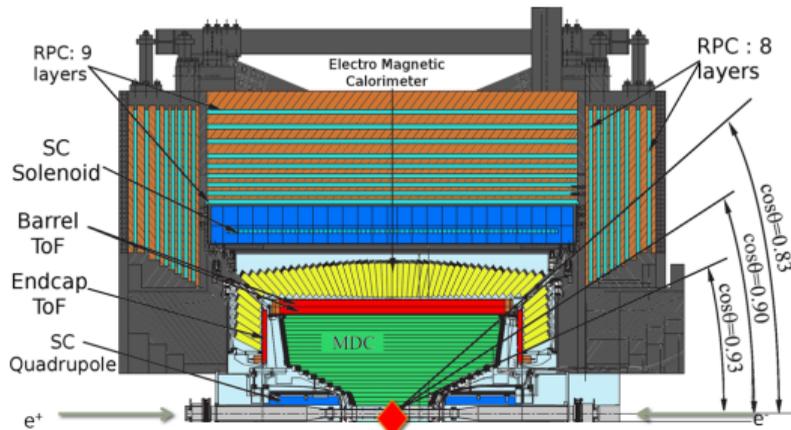
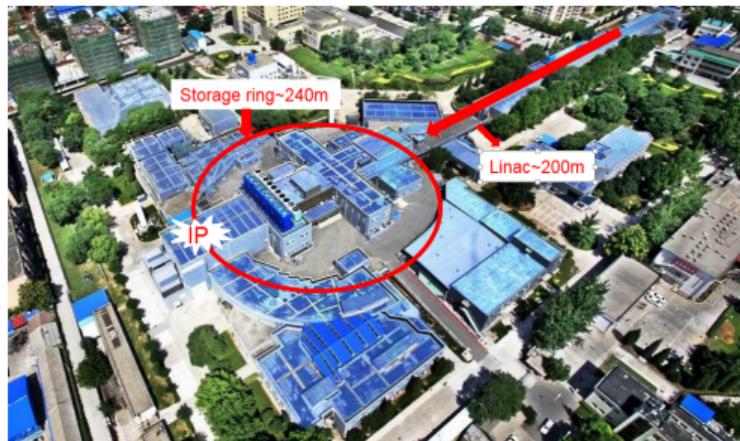
$$V_{\text{CKM}} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}$$



$$\Gamma = \frac{G_F^2}{8\pi} |V_{cq}|^2 |f_{D_s^+}|^2 m_\ell^2 m_{D_s^+} (1 - m_\ell^2/m_{D_s^+}^2)^2 \quad \frac{d\Gamma}{dq^2} = X \frac{G_F^2 |\vec{p}_P|^3}{24\pi^3} |V_{cq}|^2 |f_+(q^2)|^2$$

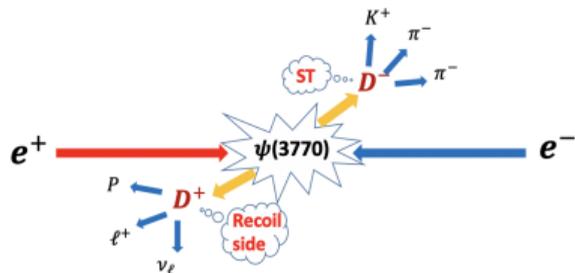
- In the charm meson, the precision of CKM elements is currently limited by $|V_{cs}|$ ($\sigma = 0.6\%$) and $|V_{cd}|$ ($\sigma = 1.8\%$)
- Latest LQCD: $f_{D_s^+} = 249.9(05)$ MeV ($\sigma = 0.2\%$); $f_{D^+} = 212.1(07)$ MeV ($\sigma = 0.3\%$);
 $f_+^{D \rightarrow \bar{K}}(0) = 0.7452(31)$ ($\sigma = 0.4\%$); $f_+^{D \rightarrow \pi}(0) = 0.6300(51)$ ($\sigma = 0.8\%$)
- Decay constant $f_{D_s^+}$ and FF $f_+(0)$ measurements \Rightarrow Calibrate LQCD calculations
- $|V_{cq}|$ measurement \Rightarrow Test CKM matrix unitarity
- Branching fraction ratios $\mathcal{R}_{\mu/e} = \frac{\mathcal{B}(D \rightarrow X \mu \nu_\mu)}{\mathcal{B}(D \rightarrow X e \nu_e)} \Rightarrow$ Test lepton flavor universality (LFU)

BESIII experiment



- $\sqrt{s} = (1.84 - 4.95) \text{ GeV}$
- Peak luminosity: $1.1 \times 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$ @ 3.773 GeV
- MDC: $\sigma_P/P = 0.5\%$ @ 1 GeV;
 $\sigma_{dE/dx} = 6\%$
- TOF: $\sigma_T = 68(110) \text{ ps}$ for barrel (endcap); endcap upgraded in 2015
 $\sigma_T = 60 \text{ ps}$
- EMC: $\sigma_E/E = 2.5\%(5\%)$ for barrel (endcap)
- BEPCII and BESIII Upgrade has been completed at 2025

BESIII dataset and double-tag method

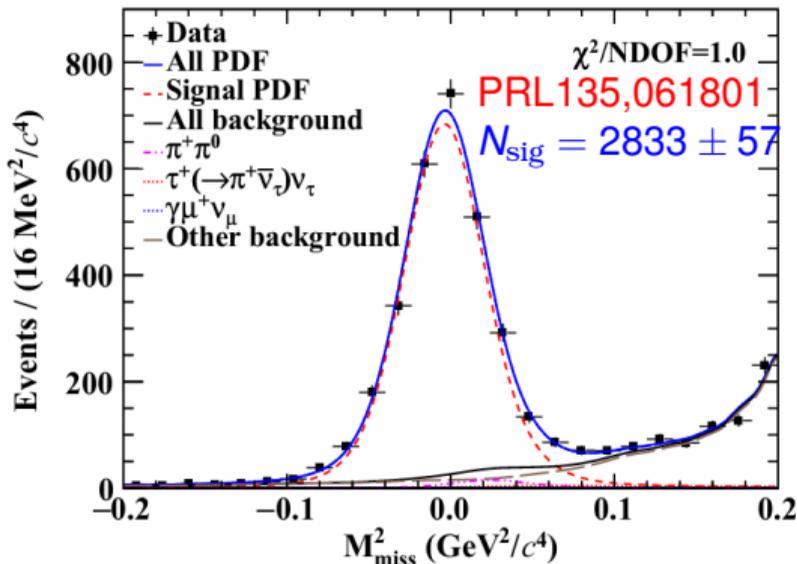


- e^+e^- annihilations data near threshold
 \Rightarrow Double-tag method & Clean environment
- Undetectable neutrinos \Rightarrow extract the (semi-)leptonic signals
 $U_{\text{miss}} = E_{\text{miss}} - |\vec{p}_{\text{miss}}|, M_{\text{miss}}^2 = E_{\text{miss}}^2 - |\vec{p}_{\text{miss}}|^2$
- Branching fraction with double-tag method: $\mathcal{B} = \frac{N_{\text{DT}}}{N_{\text{ST}}\epsilon_{\text{DT}}/\epsilon_{\text{ST}}}$
 \Rightarrow Systematic uncertainties on the ST mostly canceled

Data sample	E_{cm} (GeV)	\mathcal{L}_{int} (fb^{-1})	Single tag yields ($\times 10^6$)
$e^+e^- \rightarrow \psi(3770) \rightarrow D\bar{D}$	3.773	20.3	$\bar{D}^0 \sim 16.9; D^- \sim 11.0$
$e^+e^- \rightarrow D_s^\pm D_s^{*\mp}$	4.128-4.226	7.33	$D_s^- \sim 0.8$
$e^+e^- \rightarrow D_s^{*+} D_s^{*-}$	4.237-4.669	10.64	$D_s^- \sim 0.12$

Precision measurement of the branching fraction of $D^+ \rightarrow \mu^+ \nu_\mu$

Reference	\mathcal{L} (fb $^{-1}$)	BF($\times 10^{-4}$)	f_{D^+} (MeV)	$ V_{cd} $	Precision (%)
CLEO, PRD78,052003	0.818	3.82(32)(09)	207.1(87)(24)(08)	0.2195(92)(26)(09)	4.4
BESIII, PRD89,051104	2.93	3.71(19)(06)	204.1(52)(17)(08)	0.2164(55)(17)(09)	2.7
BESIII, PRL135,061801	20.3	4.034(80)(40)	213.5(21)(11)(08)	0.2265(23)(11)(09)	1.2 ★



$$\begin{aligned} \Gamma_{D^+ \rightarrow \ell^+ \nu_\ell} &= \Gamma_{D^+ \rightarrow \ell^+ \nu_\ell}^{(0)} \left[1 + \frac{\alpha}{\pi} C_p \right] \\ &= \frac{G_F^2 f_{D^+}^2 m_{D^+}^3}{8\pi} |V_{cd}|^2 \mu_\ell^2 (1 - \mu_\ell^2)^2 \left[1 + \frac{\alpha}{\pi} C_p \right] \end{aligned}$$

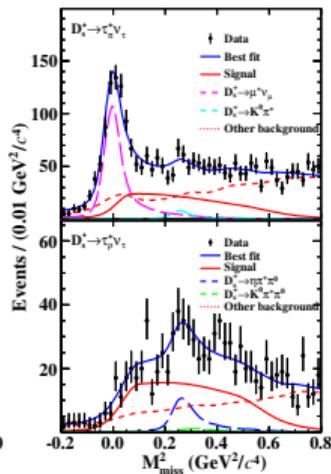
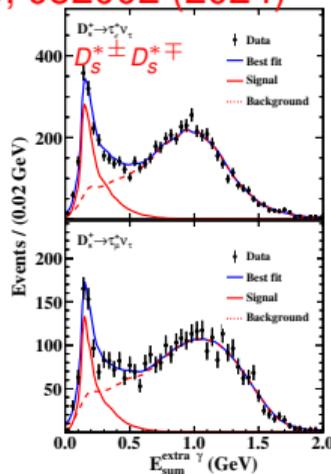
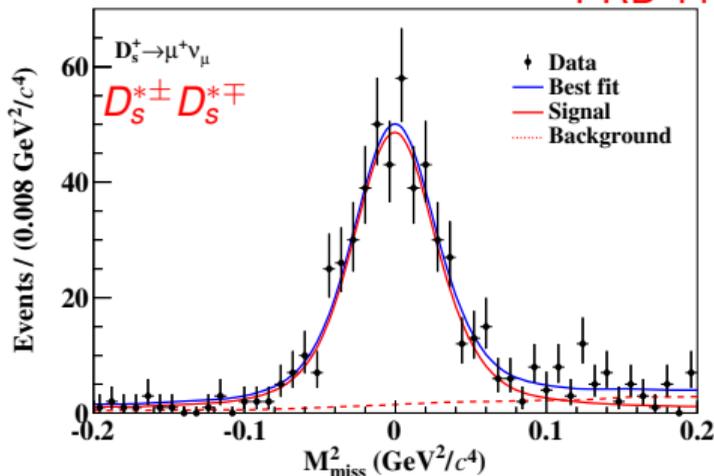
- the radiative correction term [1]: $\left[1 + \frac{\alpha}{\pi} C_p \right]$
- Structure-dependent bremsstrahlung [2,3] \implies Subtracted in the fit
- Short-distance (+1.8%) [4,5] and Long-distance (-2.5%) [6] electroweak correction

- 1 D. Silverman and H. Yao, *Phys. Rev. D* 38, 214 (1988).
- 2 G. Burdman, J.T. Goldman, and D. Wyler, *Phys. Rev. D* 51, 111 (1995).
- 3 A. Bazavov *et al.*, *Phys. Rev. D* 98, 074512 (2018).

- 4 J. C. Yang and M.Z. Yang, *Nucl. Phys. B* 914, 301 (2017).
- 5 A. Sirlin, *Nucl. Phys. B* 196, 83 (1982).
- 6 T. Kinoshita, *Phys. Rev. Lett.* 2, 477 (1959).

Other Measurement of $D_s^+ \rightarrow \ell^+ \nu_\ell$

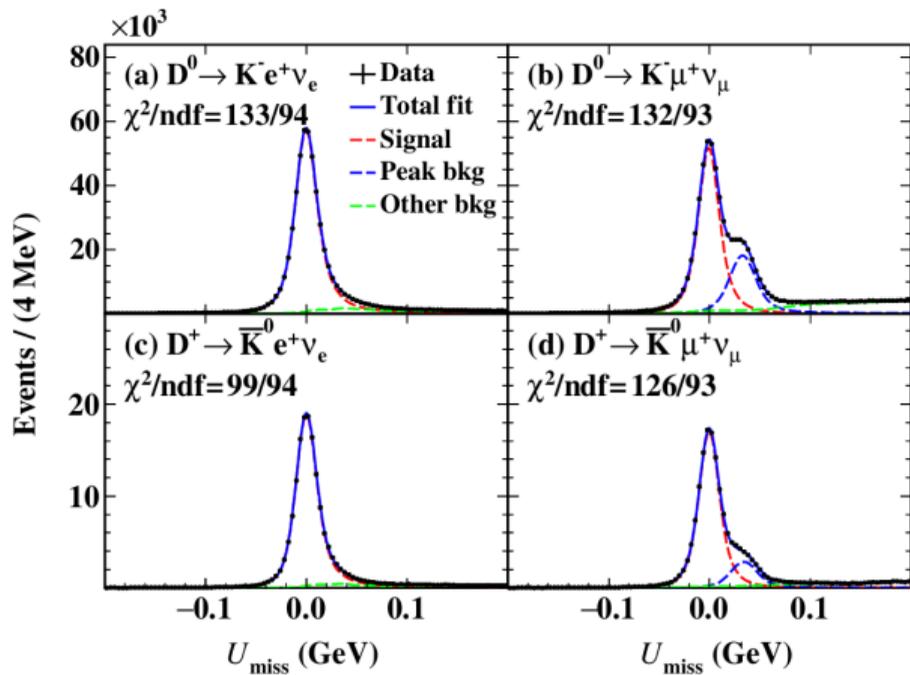
PRD 110, 052002 (2024)



Reference	Data set fb ⁻¹	$B(\%)$	$f_{D_s^+}$ $D_s^+ \rightarrow \mu^+ \nu_\mu$	$ V_{cs} $	Stat
PRD 108, 112001 (2023)	7.33 $D_s^\pm D_s^{*\mp}$	$0.5294 \pm 0.0108 \pm 0.0085$	$248.4 \pm 2.5 \pm 2.2 (\sigma = 1.4\%)$	$0.968 \pm 0.010 \pm 0.009 (\sigma = 1.4\%)$	
PRD 110, 052002 (2024)	10.64 $D_s^\pm D_s^{*\mp}$	$0.547 \pm 0.026 \pm 0.016$	$246.5 \pm 5.9 \pm 3.6 (\sigma = 2.8\%)$	$0.986 \pm 0.023 \pm 0.014 (\sigma = 2.8\%)$	
			$D_s^+ \rightarrow \tau^+ \nu_\tau$		
PRL 127, 171801 (2021)	6.32 $D_s^\pm D_s^{*\mp}$	$5.27 \pm 0.10 \pm 0.12$	$251.1 \pm 2.4 \pm 3.0 (\sigma = 1.5\%)$	$0.978 \pm 0.009 \pm 0.012 (\sigma = 1.5\%)$	$\tau^+ \rightarrow e^+ \nu_e \bar{\nu}_\tau$
PRD 104, 052009 (2021)	6.32 $D_s^\pm D_s^{*\mp}$	$5.21 \pm 0.25 \pm 0.17$	$249.7 \pm 6.0 \pm 4.2 (\sigma = 2.9\%)$	$0.972 \pm 0.023 \pm 0.016 (\sigma = 2.9\%)$	$\tau^+ \rightarrow \pi^+ \bar{\nu}_\tau$
PRD 104, 032001 (2021)	6.32 $D_s^\pm D_s^{*\mp}$	$5.29 \pm 0.25 \pm 0.20$	$251.6 \pm 5.9 \pm 4.9 (\sigma = 3.0\%)$	$0.980 \pm 0.023 \pm 0.019 (\sigma = 3.0\%)$	Simultaneous fit at various energy points
JHEP 09, 124 (2023)	7.33 $D_s^\pm D_s^{*\mp}$	$5.37 \pm 0.17 \pm 0.15$	$253.4 \pm 4.0 \pm 3.7 (\sigma = 2.2\%)$	$0.987 \pm 0.016 \pm 0.014 (\sigma = 2.2\%)$	$\tau^+ \rightarrow \pi^+ \pi^0 \bar{\nu}_\tau$
PRD 108, 092014 (2023)	7.33 $D_s^\pm D_s^{*\mp}$	$5.44 \pm 0.17 \pm 0.13$	$255.0 \pm 4.0 \pm 3.4 (\sigma = 2.1\%)$	$0.993 \pm 0.015 \pm 0.013 (\sigma = 2.1\%)$	$\tau^+ \rightarrow \mu^+ \nu_\mu \bar{\nu}_\tau$
PRD 110, 052002 (2024)	10.64 $D_s^{*+} D_s^{*\mp}$	$5.60 \pm 0.16 \pm 0.20$	$252.7 \pm 3.6 \pm 4.5 (\sigma = 2.3\%)$	$1.011 \pm 0.014 \pm 0.018 (\sigma = 2.3\%)$	$\tau^+ \rightarrow \pi^+ \bar{\nu}_\tau$ with BDT constrain the same BF $\tau^+ \rightarrow \mu^+ \nu_\mu \bar{\nu}_\tau, e^+ \nu_e \bar{\nu}_\tau, \pi^+ \bar{\nu}_\tau, \pi^+ \pi^0 \bar{\nu}_\tau$

Precise measurements of $D^0 \rightarrow K^- \ell^+ \nu_\ell$ and $D^+ \rightarrow \bar{K}^0 \ell^+ \nu_\ell$

- [arXiv:2601.21196](https://arxiv.org/abs/2601.21196) and [arXiv:2601.21185](https://arxiv.org/abs/2601.21185)
- 20.3 fb⁻¹ data sample @ 3.773 GeV



- $\mathcal{B}(D^0 \rightarrow K^- e^+ \nu_e) = (3.527 \pm 0.005 \pm 0.016)\%$
- $\mathcal{B}(D^0 \rightarrow K^- \mu^+ \nu_\mu) = (3.429 \pm 0.007 \pm 0.017)\%$
- $\mathcal{B}(D^+ \rightarrow \bar{K}^0 e^+ \nu_e) = (8.918 \pm 0.025 \pm 0.050)\%$
- $\mathcal{B}(D^+ \rightarrow \bar{K}^0 \mu^+ \nu_\mu) = (8.763 \pm 0.029 \pm 0.052)\%$

- LFU test (SM: 0.975 ± 0.001) \sim consistent

$$\frac{\mathcal{B}(D^0 \rightarrow K^- \mu^+ \nu_\mu)}{\mathcal{B}(D^0 \rightarrow K^- e^+ \nu_e)} = 0.972 \pm 0.003 \pm 0.004$$

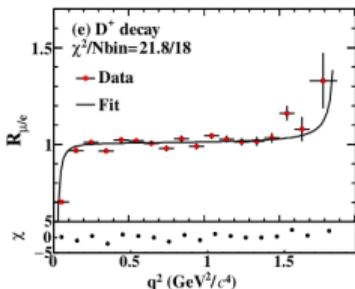
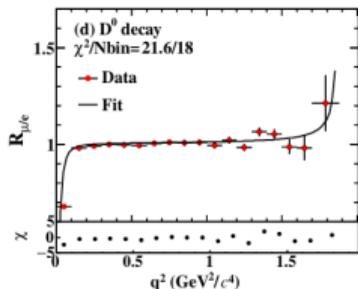
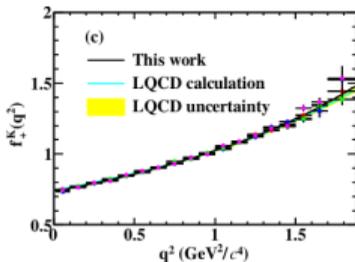
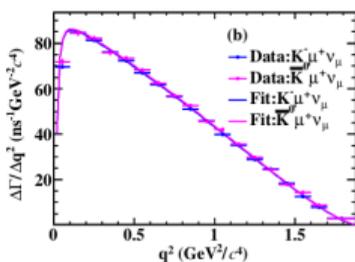
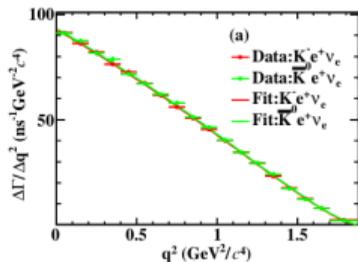
$$\frac{\mathcal{B}(D^+ \rightarrow \bar{K}^0 \mu^+ \nu_\mu)}{\mathcal{B}(D^+ \rightarrow \bar{K}^0 e^+ \nu_e)} = 0.982 \pm 0.004 \pm 0.002$$

Precise measurements of $D^0 \rightarrow K^- \ell^+ \nu_\ell$ and $D^+ \rightarrow \bar{K}^0 \ell^+ \nu_\ell$

$$h_0(q^2) = \frac{2m_D |q|}{\sqrt{q^2}} f_+(q^2)$$

$$h_t(q^2) = \frac{m_D^2 - m_K^2}{\sqrt{q^2}} f_0(q^2)$$

$$\frac{d\Gamma^\ell}{dq^2} = \frac{G_F^2 |V_{cs}|^2 |q| q^2}{96\pi^3 m_D^2} \left(1 - \frac{m_\ell^2}{q^2}\right)^2 \left[\left(1 + \frac{m_\ell^2}{2q^2}\right) |h_0(q^2)|^2 + \frac{3m_\ell^2}{2q^2} |h_t(q^2)|^2 \right]$$



LCSR	Int. J. Mod. Phys. A 21, 6125	0.661 ± 0.067	
LFQM	J. Phys. G 39, 025005	0.79 ± 0.01	
QM	J. Phys. G 39, 025005	0.762	
CCQM	Front. Phys. 14, 66401	0.78 ± 0.12	
RQM	Phys. Rev. D 101, 013004	0.716	
LQCD	Phys. Rev. D 96, 054514	0.7650 ± 0.0310	
LQCD	Phys. Rev. D 104, 034505	0.7380 ± 0.0044	
LQCD	Phys. Rev. D 107, 014510	0.7441 ± 0.0040	
LQCD	Phys. Rev. D 107, 094516	0.7452 ± 0.0031	
Belle	Phys. Rev. Lett 97, 061804	$D \rightarrow \bar{K} e^+ \nu_e$ $0.697 \pm 0.007 \pm 0.022$	
BaBar	Phys. Rev. D 76, 052005	$D^0 \rightarrow \bar{K}^- e^+ \nu_e$ $0.727 \pm 0.007 \pm 0.009$	
CLEO	Phys. Rev. D 80, 032005	$D \rightarrow \bar{K} e^+ \nu_e$ $0.739 \pm 0.007 \pm 0.009$	
BESIII 2.93fb ⁻¹	Phys. Rev. D 92, 112008	$D^+ \rightarrow \bar{K}_L^0 e^+ \nu_e$ $0.748 \pm 0.007 \pm 0.012$	
BESIII 2.93fb ⁻¹	Phys. Rev. D 96, 012002	$D^+ \rightarrow \bar{K}^0 e^+ \nu_e$ $0.7246 \pm 0.0041 \pm 0.0115$	
BESIII 2.93fb ⁻¹	Phys. Rev. Lett 122, 011804	$D^0 \rightarrow \bar{K}^- \mu^+ \nu_\mu$ $0.7327 \pm 0.0038 \pm 0.030$	
BESIII 2.93fb ⁻¹	Phys. Rev. D 92, 072012	$D^0 \rightarrow \bar{K}^- e^+ \nu_e$ $0.7368 \pm 0.0026 \pm 0.0036$	
BESIII 7.93fb ⁻¹	Phys. Rev. D 110, 112006	$D \rightarrow \bar{K} e^+ \nu_e$ $0.7366 \pm 0.0011 \pm 0.0013$	
BESIII 20.3fb ⁻¹	arXiv:2601.21196	$D \rightarrow \bar{K} e^+ \nu_e$ $0.7355 \pm 0.0007 \pm 0.0014$	

■ $f_+^{D \rightarrow K}(0) = 0.7355 \pm 0.0007_{\text{stat}} \pm 0.0014_{\text{syst}}$;

■ $|V_{cs}| = 0.9608 \pm 0.0009_{\text{stat}} \pm 0.0019_{\text{syst}} \pm 0.0040_{\text{LQCD}}$

■ Experimental uncertainties of $f_+^{D \rightarrow K}(0)$ and $|V_{cs}|$: 0.21%

■ Additional uncertainty of the input $f_+^{D \rightarrow K}(0)$ calculated by LQCD: 0.42%

Precise measurements of $D^0 \rightarrow K^- \ell^+ \nu_\ell$ and $D^+ \rightarrow \bar{K}^0 \ell^+ \nu_\ell$

- θ_W is the angle between the lepton momentum and the direction opposite to the D -meson momentum in the $\ell \nu_\ell$ rest frame

- Forward-backward asymmetry: $A_{\text{FB}}(q^2) = \frac{d\Gamma^\ell(\cos\theta_W > 0) - d\Gamma^\ell(\cos\theta_W < 0)}{d\Gamma^\ell(\cos\theta_W > 0) + d\Gamma^\ell(\cos\theta_W < 0)}$

- Theoretical expression: $A_{\text{FB}}(q^2) = \frac{3\mathcal{N}(q^2)}{2} \frac{1}{d\Gamma^\ell/dq^2} \left(1 - \frac{m_\ell^2}{q^2}\right)^2 \frac{m_\ell^2}{q^2} \Re(h_0(q^2)h_t(q^2))$

- Overall forward-backward asymmetry

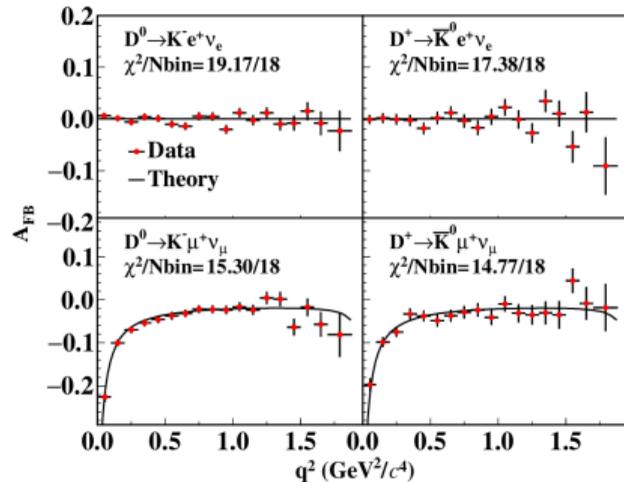
$$A_{\text{FB}}(D^0 \rightarrow K^- e^+ \nu_e) = (+0.3 \pm 1.7 \pm 1.7) \times 10^{-3}$$

$$A_{\text{FB}}(D^0 \rightarrow K^- \mu^+ \nu_\mu) = (-58.8 \pm 2.2 \pm 2.1) \times 10^{-3}$$

$$A_{\text{FB}}(D^+ \rightarrow \bar{K}^0 e^+ \nu_e) = (-0.9 \pm 2.9 \pm 1.8) \times 10^{-3}$$

$$A_{\text{FB}}(D^+ \rightarrow \bar{K}^0 \mu^+ \nu_\mu) = (-54.4 \pm 3.6 \pm 0.7) \times 10^{-3}$$

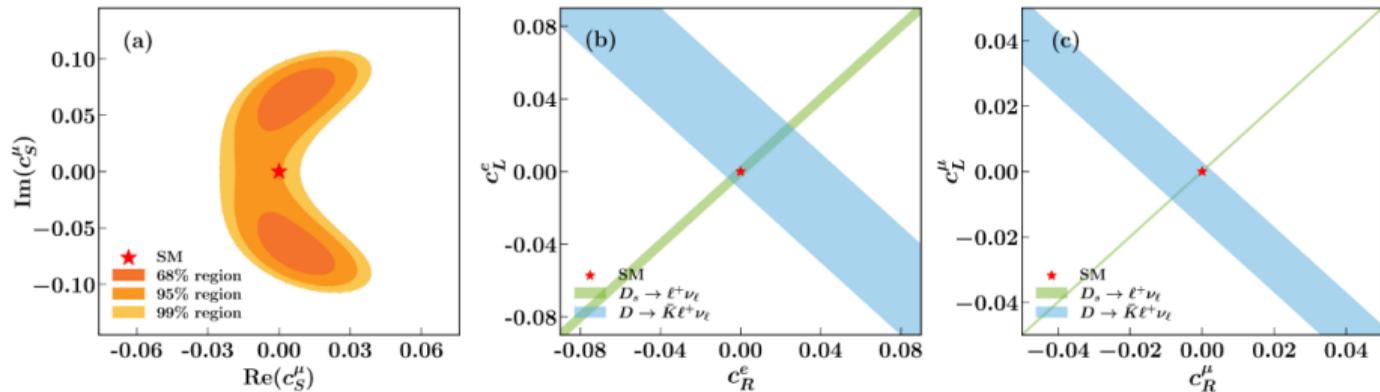
- q^2 -binned forward-backward asymmetries



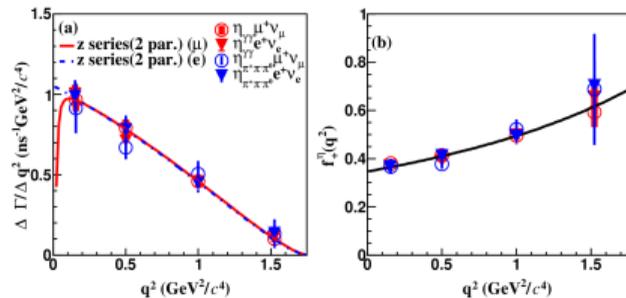
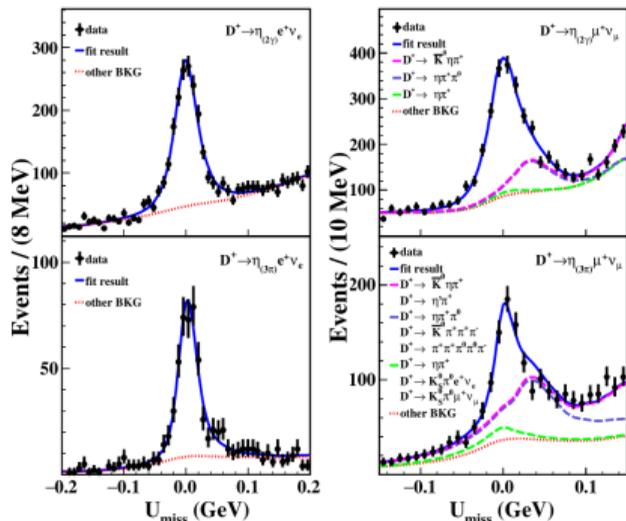
First Experimental Constraint on the Scalar Current in the $D^{0(+)} \rightarrow \bar{K} \ell^+ \nu_\ell$ Transition

- Corresponding effective Lagrangian: $\mathcal{L}_{\text{eff}} = -\frac{4G_F}{\sqrt{2}} V_{cs}^* \sum_{\ell=e,\mu,\tau} \sum_i c_i^\ell \mathcal{O}_i^\ell + \text{H.C.}$
 - SM: $\mathcal{O}_{\text{SM}}^\ell = (\bar{s} \gamma_\mu P_L c)(\bar{\nu}_\ell \gamma^\mu P_L \ell)$ with coefficient $c_{\text{SM}}^\ell = 1$
 - NP: Potential right(left)-handed scalar current $\mathcal{O}_{R(L)}^\ell = (\bar{s} P_{R(L)} c)(\bar{\nu}_\ell P_{R(L)} \ell)$ with complex Wilson coefficient $c_{R(L)}^\ell$
- Simultaneous fit to the measured partial decay rates and forward-backward asymmetries to constraints on the right- and left-handed components of the scalar current with input the BF of $D_s^+ \rightarrow \ell^+ \nu_\ell$
- $h_t(q^2) = \left(1 + c_S^\ell \frac{q^2}{m_\ell(m_s - m_c)}\right) \frac{m_D^2 - m_K^2}{\sqrt{q^2}} f_0(q^2)$ and

$$B(D_s^+ \rightarrow \ell^+ \nu_\ell) = \tau_{D_s} \frac{m_{D_s}}{8\pi} f_{D_s}^2 \left(1 - \frac{m_\ell^2}{m_{D_s}^2}\right)^2 G_F^2 \times |V_{cs}|^2 m_\ell^2 \left|1 - c_P^\ell \frac{m_{D_s}^2}{(m_c + m_s)m_\ell}\right|^2$$



Improved Measurements of $D^+ \rightarrow \eta \ell^+ \nu_\ell$ decays



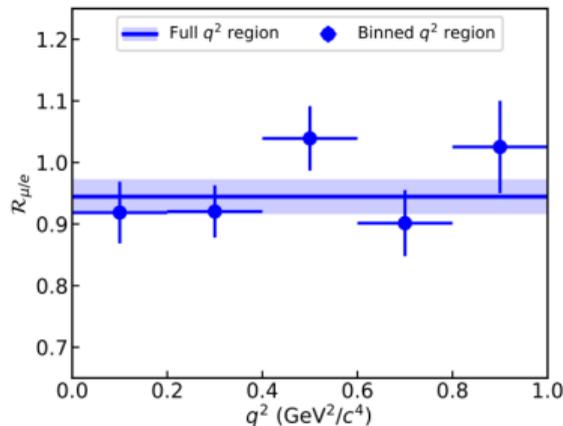
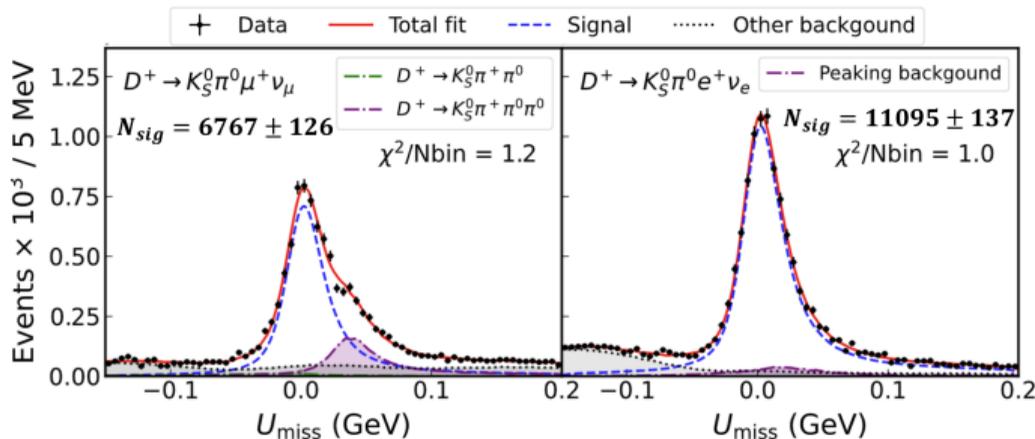
- Data: 20.3 fb^{-1} @ 3.773 GeV [[arXiv:2506.02521](https://arxiv.org/abs/2506.02521)]
- η reconstructed with $\eta \rightarrow \gamma\gamma$ and $\eta \rightarrow \pi^+\pi^-\pi^0$
- Perform a simultaneous fit with shared BF

$$\mathcal{B}(D^+ \rightarrow \eta e^+ \nu_e) = (9.75 \pm 0.29 \pm 0.28) \times 10^{-4}$$

$$\mathcal{B}(D^+ \rightarrow \eta \mu^+ \nu_\mu) = (9.12 \pm 0.47 \pm 0.28) \times 10^{-4}$$
- LFU test: $\mathcal{R}_{\mu/e}^\eta = 0.94 \pm 0.06 \pm 0.03$
- Perform a simultaneous fit to the partial decay rates of the $D^+ \rightarrow \eta \ell^+ \nu_\ell$
- FF of $D^+ \rightarrow \eta \ell^+ \nu_\ell$: $f_+^\eta(0) = 0.374 \pm 0.007 \pm 0.003$
- Precision improved **3.4 times** compared to the previous best results.

Combined measurement of $D^+ \rightarrow \bar{K}^{*0}(892)\ell^+\nu_\ell$ via $\bar{K}^{*0}(892) \rightarrow K_S^0\pi^0$

- 20.3 fb⁻¹ data sample @ 3.773 GeV
- PRL 135, 171801 (2025)

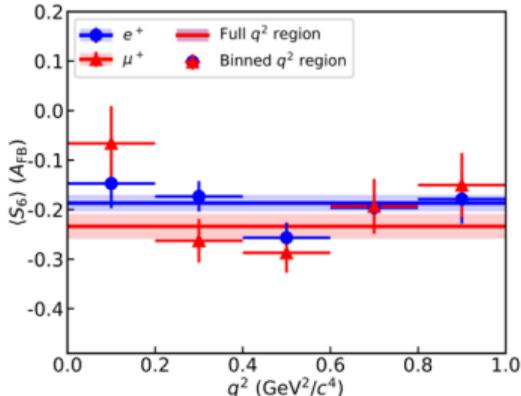
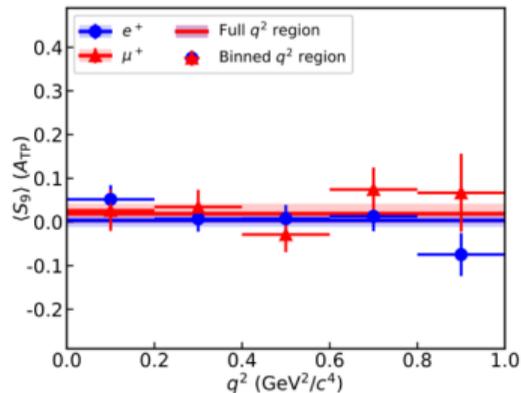
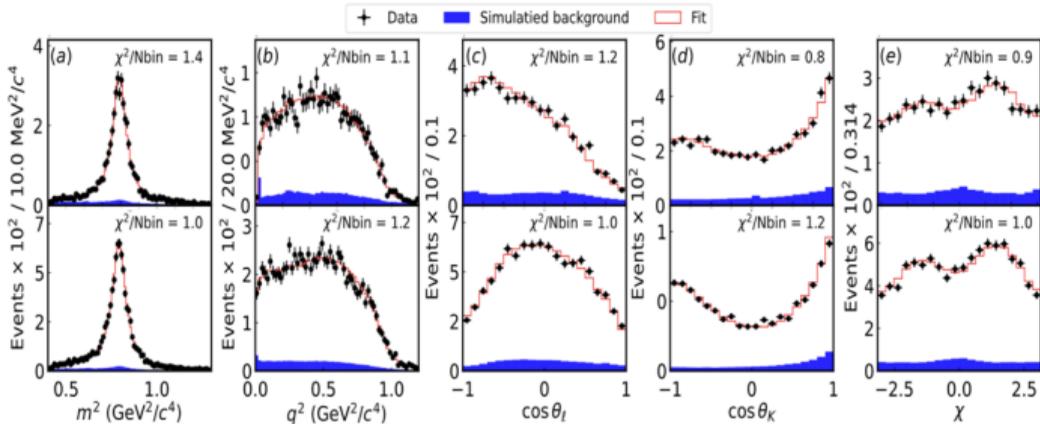


- $\mathcal{B}(D^+ \rightarrow K_S^0 \pi^0 e^+ \nu_e) = (0.943 \pm 0.012 \pm 0.010)\%$
 $\implies \mathcal{B}(D^+ \rightarrow K^{*0}(892) e^+ \nu_e) = (5.29 \pm 0.07 \pm 0.06)\%$
- $\mathcal{B}(D^+ \rightarrow K_S^0 \pi^0 \mu^+ \nu_\mu) = (0.896 \pm 0.017 \pm 0.008)\%$
 $\implies \mathcal{B}(D^+ \rightarrow K^{*0}(892) \mu^+ \nu_\mu) = (4.99 \pm 0.10 \pm 0.05)\%$ **First measurements**
- $\mathcal{R}_{\mu/e} = 0.94 \pm 0.02 \pm 0.01$

Combined measurement of $D^+ \rightarrow \bar{K}^{*0}(892)\ell^+\nu_\ell$ via $\bar{K}^{*0}(892) \rightarrow K_S^0\pi^0$

■ First comprehensive angular and the decay-rate CP asymmetry analysis

■ $r_V = 1.42 \pm 0.3 \pm 0.2$ $r_2 = 0.75 \pm 0.3 \pm 0.1$



■ Triple-product asymmetry

■ $\mathcal{A}_{\text{TP}}^e = (-0.4 \pm 1.3 \pm 0.0)\%$

■ $\mathcal{A}_{\text{TP}}^\mu = (-1.9 \pm 2.0 \pm 0.3)\%$

■ Forward-backward asymmetry

■ $\mathcal{A}_{\text{FB}}^e = (-18.7 \pm 1.4 \pm 0.5)\%$

■ $\mathcal{A}_{\text{FB}}^\mu = (-23.4 \pm 2.3 \pm 0.3)\%$

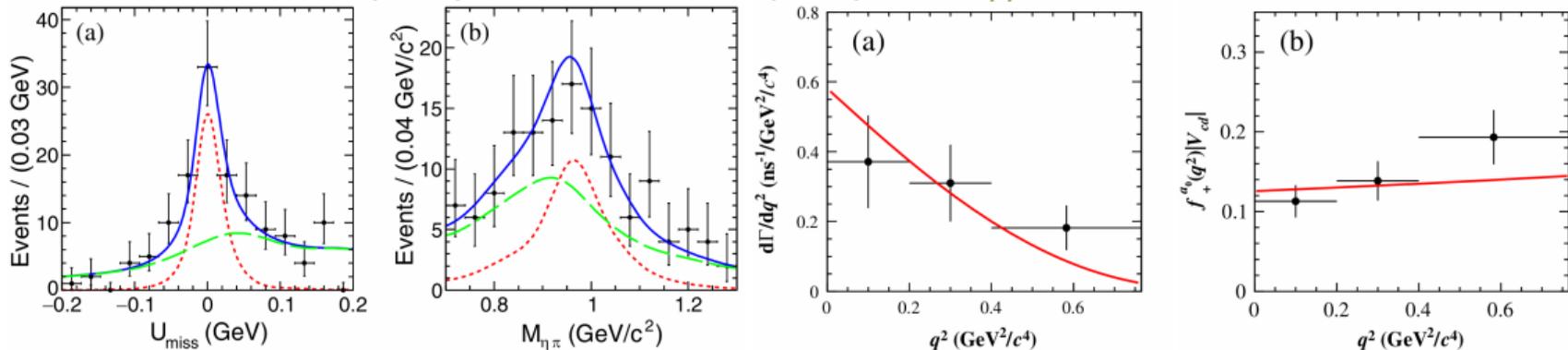
Other Measurement of $D \rightarrow \bar{K}\pi\ell^+\nu_\ell$

	$D^0 \rightarrow K_S^0\pi^-e^+\nu_e$	$D^0 \rightarrow K_S^0\pi^-\mu^+\nu_\mu$	$D^0 \rightarrow K^-\pi^0e^+\nu_e$
Reference	arXiv:2603.04136		arXiv:2603.00743
Data set fb ⁻¹	20.3		
$\mathcal{B}(D \rightarrow \bar{K}\pi\ell^+\nu_\ell)(\%)$	$1.447 \pm 0.012 \pm 0.009$	$1.391 \pm 0.013 \pm 0.008$	$0.7878 \pm 0.0063 \pm 0.0048$
$\mathcal{B}(D \rightarrow \bar{K}^*(892)\ell^+\nu_\ell)(\%)$	$2.043 \pm 0.018 \pm 0.012$	$1.964 \pm 0.018 \pm 0.012$	$2.221 \pm 0.018 \pm 0.014$
$\mathcal{B}(D \rightarrow \bar{K}_2^*(1430)\ell^+\nu_\ell)(\times 10^{-5})$	$4.00 \pm 1.22 \pm 0.78$	$3.85 \pm 1.17 \pm 0.75$	$7.603 \pm 2.457 \pm 0.194$
r_V	$1.444 \pm 0.026 \pm 0.010$		$1.41 \pm 0.05 \pm 0.01$
r_2	$0.752 \pm 0.020 \pm 0.004$		$0.77 \pm 0.04 \pm 0.02$
$A_1(0)$	$0.618 \pm 0.002 \pm 0.004$		-
$\mathcal{R}_{\bar{K}^*(892)}^{\mu/e}$	$0.961 \pm 0.012 \pm 0.005$		$0.928 \pm 0.020 \pm 0.012$

- Similar works of isospin channels are listed here.

	$D^0 \rightarrow K_S^0\pi^-e^+\nu_e$	$D^0 \rightarrow K_S^0\pi^-\mu^+\nu_\mu$	$D^0 \rightarrow K^-\pi^0\mu^+\nu_\mu$
Reference	JHEP 03 197(2025)	PRL 135, 111803 (2025)	PRL 134, 011803 (2025)
Data set fb ⁻¹	7.93		
$\mathcal{B}(D \rightarrow \bar{K}\pi\ell^+\nu_\ell)(\%)$	$1.444 \pm 0.022 \pm 0.024$	$1.373 \pm 0.020 \pm 0.023$	$0.773 \pm 0.014 \pm 0.012$
$\mathcal{B}(D \rightarrow \bar{K}^*\ell^+\nu_\ell)(\%)$	$2.039 \pm 0.032 \pm 0.034$	$1.948 \pm 0.033 \pm 0.036$	$2.073 \pm 0.039 \pm 0.032$
r_V	$1.48 \pm 0.05 \pm 0.02$	$1.46 \pm 0.11 \pm 0.04$	$1.37 \pm 0.09 \pm 0.03$
r_2	$0.70 \pm 0.04 \pm 0.02$	$0.71 \pm 0.08 \pm 0.03$	$0.76 \pm 0.06 \pm 0.02$
$N_{\text{obs}}(K)$	8.7	6.8	6.4
$\mathcal{R}_{\mu/e}$	$0.96 \pm 0.02 \pm 0.02$		$1.02 \pm 0.03 \pm 0.03$

Study of $D^0 \rightarrow a_0(980)^- e^+ \nu_e$ with $a_0(980)^- \rightarrow \eta_{\gamma\gamma} \pi^-$



■ Data: 7.93 fb^{-1} @ 3.773 GeV [[PRD 111, L091501 \(2025\)](#)]

■ Improve BF's measurement of $D^0 \rightarrow a_0(980)^- e^+ \nu_e$ decay with $a_0(980)^- \rightarrow \eta_{\gamma\gamma} \pi^-$

The $M_{\eta\pi^-}$ is modeled with a standard Flatté formula for the $a_0(980)$ signal

$$\mathcal{B}(D^0 \rightarrow a_0(980)^- e^+ \nu_e) = (0.86 \pm 0.17 \pm 0.05) \times 10^{-4}$$

■ First determined the FFs with the simple pole model

$$f_+^{a_0}(0) = 0.559 \pm 0.056 \pm 0.013$$

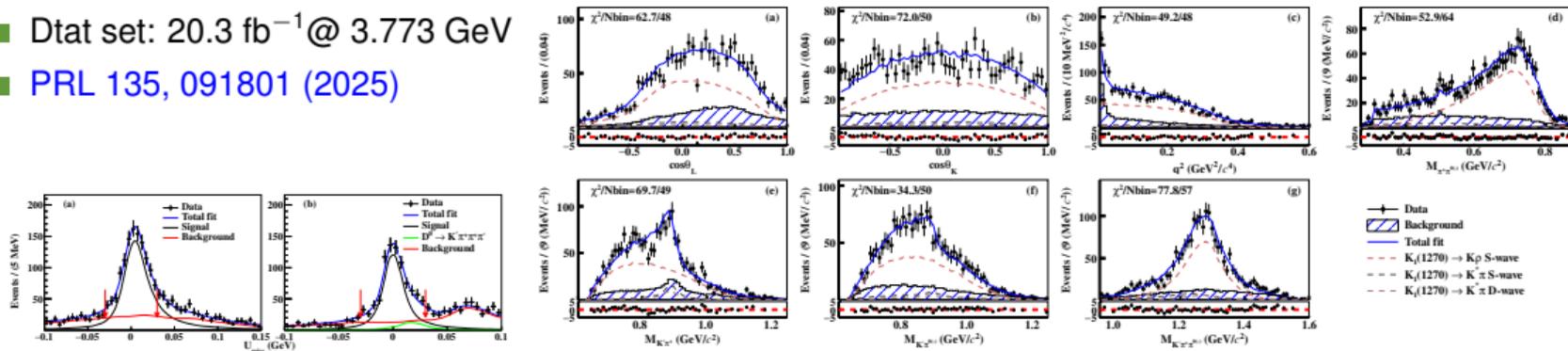
$$\frac{d^2\Gamma(D^0 \rightarrow a_0(980)^- e^+ \nu_e)}{ds dq^2} = \frac{G_F^2 |V_{cd}|^2}{192\pi^4 m_{D^0}^3} \lambda^{3/2}(m_{D^0}^2, s, q^2) |f_+^{a_0}(q^2)|^2 P(s)$$

$$\lambda(x, y, z) = x^2 + y^2 + z^2 - 2xy - 2xz - 2yz$$

$$\text{Relativistic Flatté formula } P(s) = \frac{g_{\eta\pi\pi}^2 \rho_{\eta\pi\pi}}{|m_0^2 - s - i(g_{\eta\pi\pi}^2 \rho_{\eta\pi\pi} + g_{KK}^2 \rho_{KK})|^2}$$

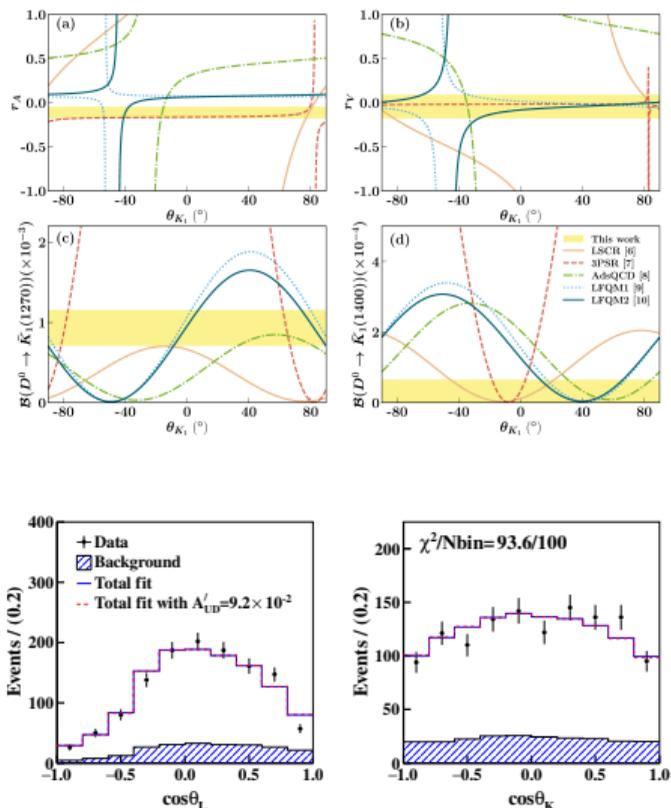
First study of $D^{0(+)} \rightarrow K^- \pi^+ \pi^{0(-)} e^+ \nu_e$ decay dynamics

- Dstat set: 20.3 fb^{-1} @ 3.773 GeV
- PRL 135, 091801 (2025)



- Improve BF's measurement of $D \rightarrow K_1(1270)e^+\nu_e$ & **First upper limit on $D \rightarrow K_1(1400)e^+\nu_e$**
 - $\mathcal{B}(D^+ \rightarrow \bar{K}_1^0(1270)e^+\nu_e) = (2.27 \pm 0.11 \pm 0.07 \pm 0.07) \times 10^{-3}$
 - $\mathcal{B}(D^+ \rightarrow \bar{K}_1^0(1400)e^+\nu_e) < 1.4 \times 10^{-4}$
 - $\mathcal{B}(D^0 \rightarrow K_1^-(1270)e^+\nu_e) = (1.02 \pm 0.06 \pm 0.06 \pm 0.03) \times 10^{-3}$
 - $\mathcal{B}(D^0 \rightarrow K_1^-(1400)e^+\nu_e) < 0.7 \times 10^{-4}$
- **First FFs measurement:** $r_A = (-11.2 \pm 1.0 \pm 0.9) \times 10^{-2}$ & $r_V = (-4.3 \pm 1.0 \pm 2.5) \times 10^{-2}$
- Component: $K\rho(770) & K^*(892)\pi \rightarrow \mathcal{B}(K_1(1270) \rightarrow K^*\pi) / \mathcal{B}(K_1(1270) \rightarrow K\rho) = (20.3 \pm 2.1 \pm 8.7)\%$

First study of $D^{0(+)} \rightarrow K^- \pi^+ \pi^{0(-)} e^+ \nu_e$ decay dynamics



- The eigenstates of momentum (K_{1A} (1P_1) & K_{1B} (3P_1)) mix into $K_1(1270)$ & $K_1(1400)$
- FFs are sensitive to the mixing angle θ_{K_1} :
 - $f_{K_1(1270)} = f_{K_{1A}} \sin \theta_{K_1} + f_{K_{1B}} \cos \theta_{K_1}$
 - $f_{K_1(1400)} = f_{K_{1A}} \cos \theta_{K_1} - f_{K_{1B}} \sin \theta_{K_1}$
- Three unknown pars. ($f_{K_{1A}}, f_{K_{1B}}, \theta_{K_1}$) & Two equations
 \Rightarrow Determine θ_{K_1} requires one parameter input!
- However, for all theoretical predictions, we have **four observables to give stringent test** on them without assuming the value of θ_{K_1} .
- Theoretical calculation suggests up-down asymmetry in $D \rightarrow K_1(1270) e^+ \nu_e$: $A'_{ud} = \frac{4}{3} f_h$ [PRL 125 051802 (2020)]
- 2D Angular fit
 - $A'_{ud} = 0.01 \pm 0.11$, consistent with SM prediction
 - $\frac{4}{3} A_{ud} = (0.092 \pm 0.022)$
 - Deviation would indicate New Physics effects

Other Measurements

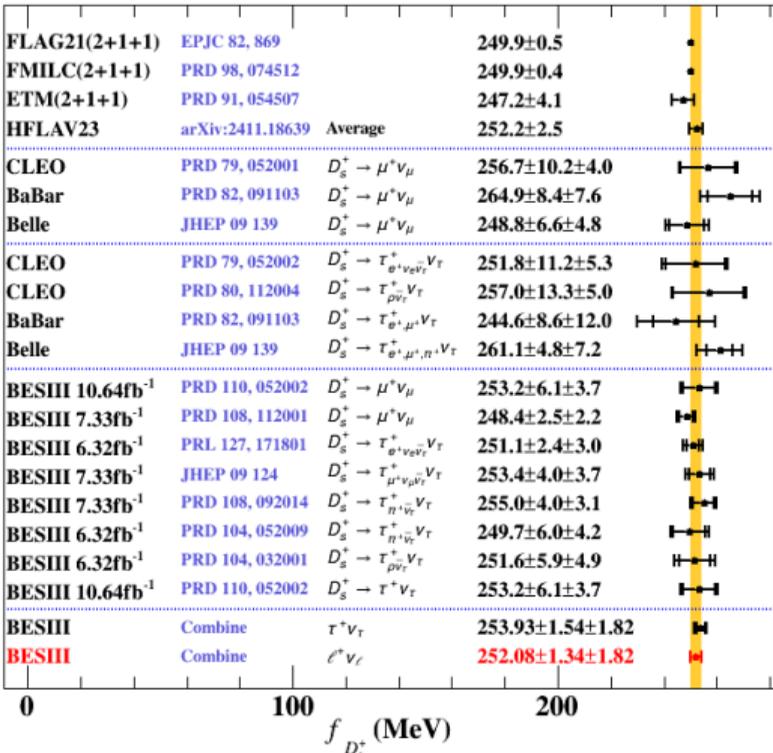
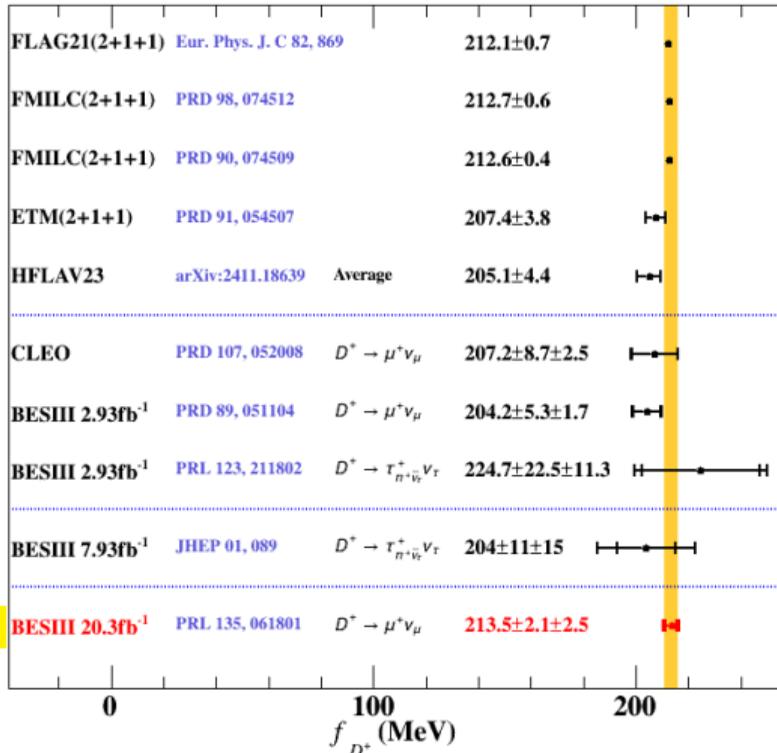
- First observation of $D^{0(+)} \rightarrow \bar{K}_1(1270)\mu^+\nu_\mu$ decay with $\bar{K}_1(1270) \rightarrow K^-\pi^+\pi^0(-)$

Decay	$D^+ \rightarrow \bar{K}_1^0(1270)\mu^+\nu_\mu$	$D^0 \rightarrow K_1^-(1270)\mu^+\nu_\mu$
Reference	PRD 111, L071101 (2025)	
Data set (fb^{-1})	7.93	
Significance	12.5 σ	6.0 σ
\mathcal{B}	$(2.36 \pm 0.20_{-0.27}^{+0.18} \pm 0.48) \times 10^{-3}$	$(0.78 \pm 0.11_{-0.09}^{+0.05} \pm 0.15) \times 10^{-3}$
$\mathcal{R}_{\mu/e}$	$0.74 \pm 0.13_{-0.13}^{+0.08}$	$1.03 \pm 0.14_{-0.15}^{+0.11}$
$\Gamma_{D^+}/\Gamma_{D^0}$	$1.22 \pm 0.10_{-0.09}^{+0.06}$	

- First observation of $D^0 \rightarrow b_1(1235)^- e^+\nu_e$ and Evidence $D^+ \rightarrow b_1(1235)^0 e^+\nu_e$ with $b_1(1235) \rightarrow \omega_{\pi^+\pi^-\pi^0}\pi$

Decay	$D^0 \rightarrow b_1(1235)^- e^+\nu_e$	$D^+ \rightarrow b_1(1235)^0 e^+\nu_e$
Reference	PRL 136, 021801 (2026)	
Data set (fb^{-1})	7.93	
Significance	5.2 σ	3.1 σ
$\mathcal{B}(\text{SL}) \times \mathcal{B}(b_1(1235) \rightarrow \omega\pi)$	$(0.72 \pm 0.18_{-0.08}^{+0.06}) \times 10^{-4}$	$(1.16 \pm 0.44 \pm 0.16) \times 10^{-4}$
$\Gamma_{D^0}/\Gamma_{D^+}$	$0.78 \pm 0.19_{-0.05}^{+0.04}$	

Comparison of decay constant $f_{D(s)^+}$



■ Precisions of measured f_{D^+} and $f_{D_s^+}$ from BESIII: 1.2%, 0.9%

Summary and Prospect

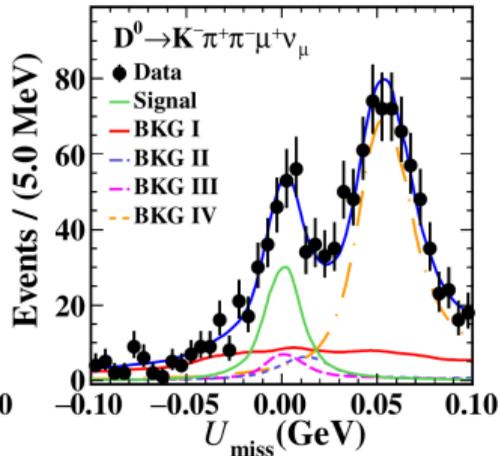
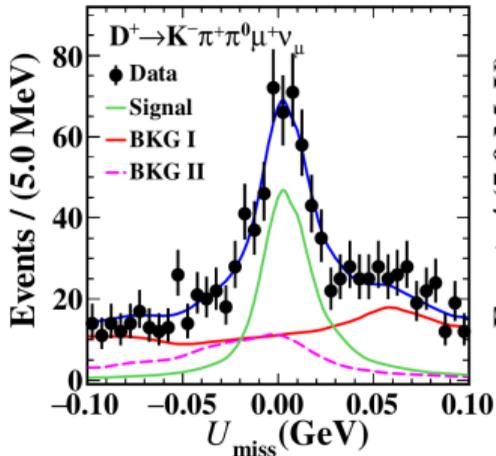
- Leptonic and semileptonic decays of charm mesons are important for determining the CKM matrix elements, calibrating LQCD, testing LFU, *et al.*;
- Precisions of $|V_{cd}|$ and $|V_{cs}|$ have been reduced to 1.2% and 0.5%, respectively;
- Precisions of f_{D^+} , $f_{D_s^+}$ and $f_+^{D \rightarrow \bar{K}}(0)$ have been reduced to 1.2%, 0.9%, and 0.21%, respectively;
- Machine learning has demonstrated the power in experimental particle physics, offering the possible in searching for the rare decays of charm hadrons in future.
- 20.3 fb⁻¹ data @3.773 GeV is ready at Jul. 2024, more precision measurements and searching for rare semileptonic decays will be presented;
- Additional 3 fb⁻¹ data @4.178 GeV in future [CPC44(2020)040001] will further improve the precisions in D_s decay.
- Since BEPCII and BESIII have been upgraded, much higher instantaneous luminosity at higher energies and access to $\sqrt{s} = 5.6$ GeV, which allows the production of Σ_c , Ξ_c , Ω_c pair

Thanks!

Back up

Observation of $D^{0(+)} \rightarrow \bar{K}_1(1270)\mu^+\nu_\mu$ decay with $\bar{K}_1(1270) \rightarrow K^-\pi^+\pi^0(-)$

- Data: 7.93 fb^{-1} @ 3.773 GeV [PRD 111, L071101 (2025)]
- First observation of $D^+ \rightarrow \bar{K}_1^0(1270)\mu^+\nu_\mu$ and $D^0 \rightarrow K_1^-(1270)\mu^+\nu_\mu$ with significance of 12.5σ and 6.0σ
 - $\mathcal{B}(D^+ \rightarrow \bar{K}_1^0(1270)\mu^+\nu_\mu) = (2.36 \pm 0.20_{-0.27}^{+0.18} \pm 0.48) \times 10^{-3}$
 - $\mathcal{B}(D^0 \rightarrow K_1^-(1270)\mu^+\nu_\mu) = (0.78 \pm 0.11_{-0.09}^{+0.05} \pm 0.15) \times 10^{-3}$
- LFU test: $\mathcal{R}_{\mu/e}^{D^+} = 1.03 \pm 0.14_{-0.15}^{+0.11}$ $\mathcal{R}_{\mu/e}^{D^0} = 0.74 \pm 0.13_{-0.13}^{+0.08}$
- Partial decay width ratio: $\frac{\Gamma[D^+ \rightarrow \bar{K}_1^0(1270)\mu^+\nu_\mu]}{\Gamma[D^0 \rightarrow K_1^-(1270)\mu^+\nu_\mu]} = 1.22 \pm 0.10_{-0.09}^{+0.06}$



Observation of $D^0 \rightarrow b_1(1235)^- e^+ \nu_e$ and Evidence $D^+ \rightarrow b_1(1235)^0 e^+ \nu_e$

- Data: 7.93 fb^{-1} @ 3.773 GeV [PRL 136, 021801 (2026)]

- $b_1(1235)$ reconstructed by $\omega\pi$

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

- $b_1(1235)$ is parametrized by a relativistic Breit-Wigner function with mass and width fixed to the world-average values

- Perform two-dimensional unbinned maximum likelihood fits to the $M_{\omega\pi\pi}$ versus U_{miss}

- First observation of $D^0 \rightarrow b_1(1235)^- e^+ \nu_e$ with significance of 5.2σ and find evidence for $D^+ \rightarrow b_1(1235)^0 e^+ \nu_e$ with 3.1σ

$$\mathcal{B}(D^0 \rightarrow b_1(1235)^- e^+ \nu_e) \times \mathcal{B}(b_1^- \rightarrow \omega\pi^-) = (0.72 \pm 0.18_{-0.08}^{+0.06}) \times 10^{-4}$$

$$\mathcal{B}(D^+ \rightarrow b_1(1235)^0 e^+ \nu_e) \times \mathcal{B}(b_1^0 \rightarrow \omega\pi^0) = (1.16 \pm 0.44 \pm 0.16) \times 10^{-4}$$

- Partial decay width ratio with $\mathcal{B}(b_1^- \rightarrow \omega\pi^-) = \mathcal{B}(b_1^0 \rightarrow \omega\pi^0)$:

$$\frac{\Gamma[D^0 \rightarrow b_1(1235)^- e^+ \nu_e]}{\Gamma[D^+ \rightarrow b_1(1235)^0 e^+ \nu_e]} = 0.78 \pm 0.19_{-0.05}^{+0.04}$$

