BESIII 上粲介子半轻衰变的研究

潘祥

苏州大学

第十届手征有效场论研讨会
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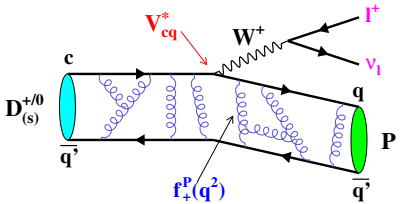
Outline

Motivation



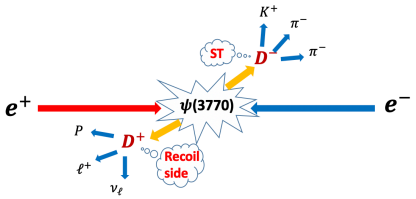
$$\frac{d\Gamma}{dq^2} \propto |V_{cq}|^2 |f_+(q^2)|^2$$

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

Uncertainties dominated by $|V_{cs}|$ and $|V_{cd}|$

- Semi-leptonic decays of charm mesons are important for determining CKM matrix elements $|V_{cs(d)}|$, calibrating LQCD, testing LFU, *et al.*
- **FF measurement⇒Calibrate LQCD calculations**
- **$|V_{cq}|$ measurement ⇒Test CKM matrix unitarity**
- **BF ratios⇒Test lepton flavor universality (LFU)**

BESIII dataset and double-tag method



- e^+e^- annihilations data near threshold
  ⇒Double-tag method& Clean environment
- Undetectable neutrinos⇒extract the semileptonic signals
  $U_{\rm miss} = E_{\rm miss} - |\vec{p}_{\rm miss}|$, $M^2_{\rm miss} = E^2_{\rm miss} - |\vec{p}_{\rm miss}|^2$
- BF with double-tag method: $\mathcal{B} = \frac{N_{\rm DT}}{N_{\rm ST}\epsilon_{\rm DT}/\epsilon_{\rm ST}}$
  ⇒Systematic uncertainties on the ST mostly canceled

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

$D_{(s)} \to P(S)\ell^+\nu_\ell$

Theoretical expression of differential decay rate:

- Point-like: $D_{(s)} \to P\ell^+\nu_\ell$ $(P = K, \pi, \eta, \eta')$ [PRD101(2020)013004]

$$\frac{d\Gamma}{dq^2} = \frac{G_F^2|V_{cq}|^2}{24\pi^3}\frac{(q^2-m_\ell^2)^2|\vec{p}_P|}{q^4 m_D^2}(1+\frac{m_\ell^2}{2q^2})m_D^2|\vec{p}_P|^2|f_+(q^2)|^2$$

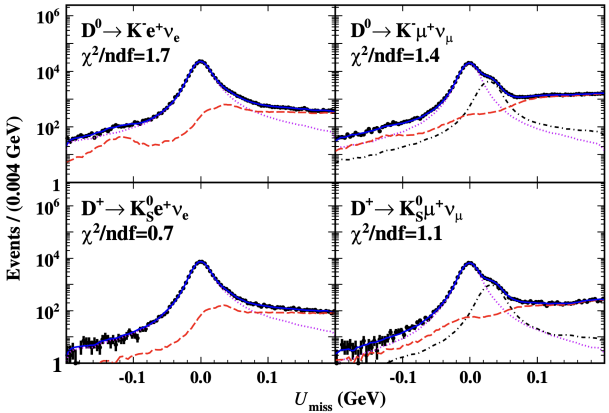
- Consider resonance's width: $D_{(s)} \to S\ell^+\nu_\ell$ $(S = a_0(980), f_0(980), f_0(500))$ [PRD102(2020)016022, PLB759(2016)501]

$$\frac{d^2\Gamma}{dq^2 ds} = \frac{G_F^2|V_{cq}|^2}{192\pi^4 m_D^3}\lambda^{1/2}(m_D^2, s, q^2)(1-\frac{m_\ell^2}{q^2})^2(1+\frac{m_\ell^2}{2q^2})\lambda(m_D^2, s, q^2)|f_+(q^2)|^2 P(s)$$

$$P(s) = \begin{cases} P(s) = \frac{g_1\rho_{\pi\pi}}{|m_0^2 - s - i(g_1\rho_{\pi\pi}+g_2\rho_{K\bar{K}})|^2}, \text{Flatte for } a_0(980)/f_0(980) \\ \frac{m_{f_0}\Gamma(s)}{(s-m_{f_0})^2+m_{f_0}^2\Gamma^2(s)}, \text{RBW for } f_0(500) \end{cases}$$

$D^0 \to K^-\ell^+\nu_\ell$ and $D^+ \to \bar{K}^0\ell^+\nu_\ell$

PRD110(2024)112006



- Data: 7.93 fb^{-1}@3.773 GeV
- **Improved measurement of BFs**

$$\mathcal{B}(D^0 \to K^- e^+ \nu_e) = (3.521 \pm 0.009 \pm 0.016)\%$$
$$\mathcal{B}(D^0 \to K^- \mu^+ \nu_\mu) = (3.419 \pm 0.011 \pm 0.016)\%$$
$$\mathcal{B}(D^+ \to \bar{K}^0 e^+ \nu_e) = (8.864 \pm 0.039 \pm 0.082)\%$$
$$\mathcal{B}(D^+ \to \bar{K}^0 \mu^+ \nu_\mu) = (8.665 \pm 0.046 \pm 0.084)\%$$

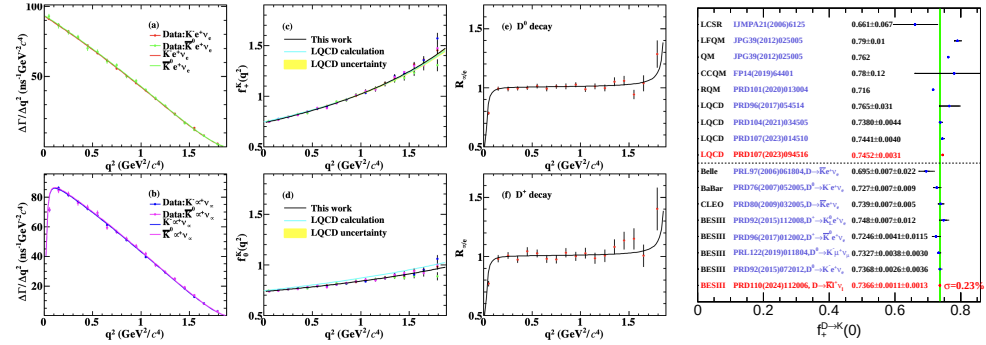
- **Most precision LFU test:** Consistent with $\mathcal{R}_{\rm SM} = 0.975 \pm 0.001$

$$\frac{\mathcal{B}(D^0 \to K^- \mu^+ \nu_\mu)}{\mathcal{B}(D^0 \to K^- e^+ \nu_e)} = 0.971 \pm 0.004 \pm 0.006$$
$$\frac{\mathcal{B}(D^+ \to \bar{K}^0 \mu^+ \nu_\mu)}{\mathcal{B}(D^+ \to \bar{K}^0 e^+ \nu_e)} = 0.978 \pm 0.007 \pm 0.013$$

- **Isospin test:** Consistent with 1

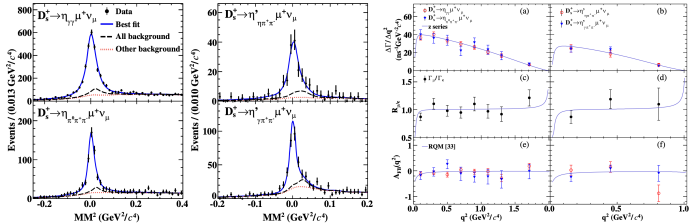
$$\frac{\Gamma(D^0 \to K^- e^+ \nu_e)}{\Gamma(D^+ \to \bar{K}^0 e^+ \nu_e)} = 1.000 \pm 0.007 \pm 0.012$$
$$\frac{\Gamma(D^0 \to K^- \mu^+ \nu_\mu)}{\Gamma(D^+ \to \bar{K}^0 \mu^+ \nu_\mu)} = 0.993 \pm 0.008 \pm 0.012$$

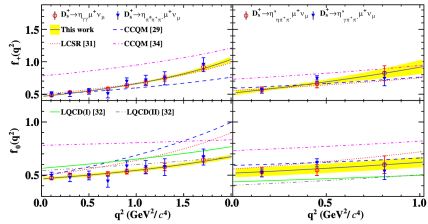
$D^0 \to K^-\ell^+\nu_\ell$ and $D^+ \to \bar{K}^0\ell^+\nu_\ell$



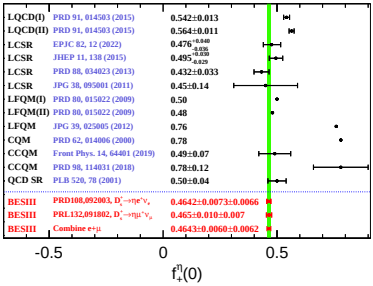
- Latest LQCD: $f_+^{D\to K}(0) = 0.7452(31)$ $(\sigma = 2.4\% \to 0.4\%)$
- **Most precisions of FF $f_+^K(0)$ $(\sigma = 0.23\%)$ and $|V_{cs}|$ $(\sigma = 0.48\%)$**
  $f_+^K(0) = 0.7366 \pm 0.0011_{\rm stat} \pm 0.0013_{\rm syst}$; $|V_{cs}| = 0.9623 \pm 0.0015_{\rm stat} \pm 0.0017_{\rm syst} \pm 0.0040_{\rm LQCD}$
- **Measured FF $f_+^K(0)$ is consistent with the LQCD calculations within 2.5σ**

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

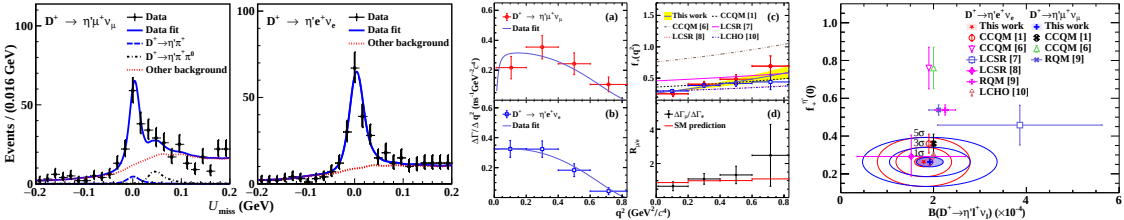




- Data: 7.33 fb^{-1}@4.128-4.226 GeV PRL132(2024)091802
- **Precision of BFs are improved by a factor of $\sim$6**
  $\mathcal{B}(D_s^+ \to \eta\mu^+\nu_\mu) = (2.235 \pm 0.051 \pm 0.052)\%$
  $\mathcal{B}(D_s^+ \to \eta'\mu^+\nu_\mu) = (0.801 \pm 0.055 \pm 0.028)\%$
- **First extraction of the FFs via semimuonic decays**
  $f_+^{\eta}(0) = 0.465 \pm 0.010 \pm 0.007$; $f_+^{\eta'}(0) = 0.518 \pm 0.038 \pm 0.012$
- **Most precision test of lepton flavor universality in D_s sector**
  $\mathcal{R}^{\eta}_{\mu/e} = 0.991 \pm 0.029 \pm 0.016$; $\mathcal{R}^{\eta'}_{\mu/e} = 0.988 \pm 0.082 \pm 0.031$
- **First extraction of the forward-backward asymmetry parameters**
  $\langle A_{\rm FB}^{\eta}\rangle = -0.059 \pm 0.031 \pm 0.005$; $\langle A_{\rm FB}^{\eta'}\rangle = -0.064 \pm 0.079 \pm 0.006$

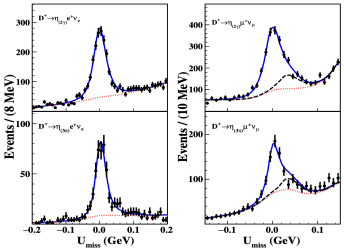


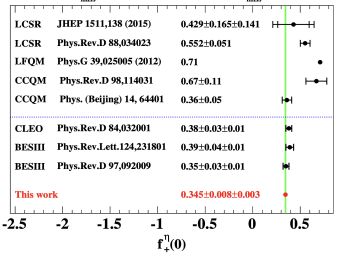
$D^+ \to \eta'\ell^+\nu_\ell$

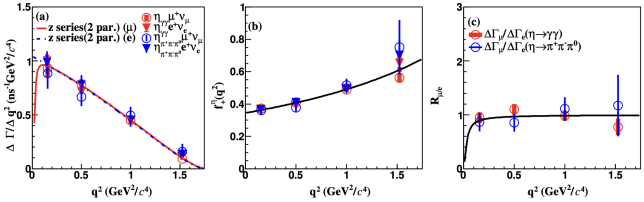


- Data: 20.3 fb^{-1}@3.773 GeV PRL134(2025)111801
- **First observation of $D^+ \to \eta'\mu^+\nu_\mu$ with significance of 8.6σ**
  $\mathcal{B}(D^+ \to \eta'\mu^+\nu_\mu) = (1.92 \pm 0.28 \pm 0.08) \times 10^{-4}$; $\mathcal{B}(D^+ \to \eta' e^+\nu_e) = (1.79 \pm 0.19 \pm 0.07) \times 10^{-4}$
- **First extraction of the FF of $D^+ \to \eta'\ell^+\nu_\ell$**: $f_+^{\eta'}(0) = 0.263 \pm 0.025 \pm 0.006$
- **LFU test**: $\mathcal{R}_{\mu/e}^{\eta'} = 1.07 \pm 0.19 \pm 0.03$
- **$\eta - \eta'$ mixing angle**: $\phi_P = (39.8 \pm 0.8 \pm 0.3)^\circ$ $\left(\cot^4\phi_P = \frac{\Gamma_{D_s^+ \to \eta'\ell^+\nu_\ell}/\Gamma_{D_s^+ \to \eta\ell^+\nu_\ell}}{\Gamma_{D^+ \to \eta'\ell^+\nu_\ell}/\Gamma_{D^+ \to \eta\ell^+\nu_\ell}}\right)$

$D^+ \to \eta\ell^+\nu_\ell$







- arXiv:2506.02521, submitted to JHEP
- Data: 20.3 fb^{-1}@3.773 GeV
- **Precisions of BFs and FF are improved by** $\sim 2\times$

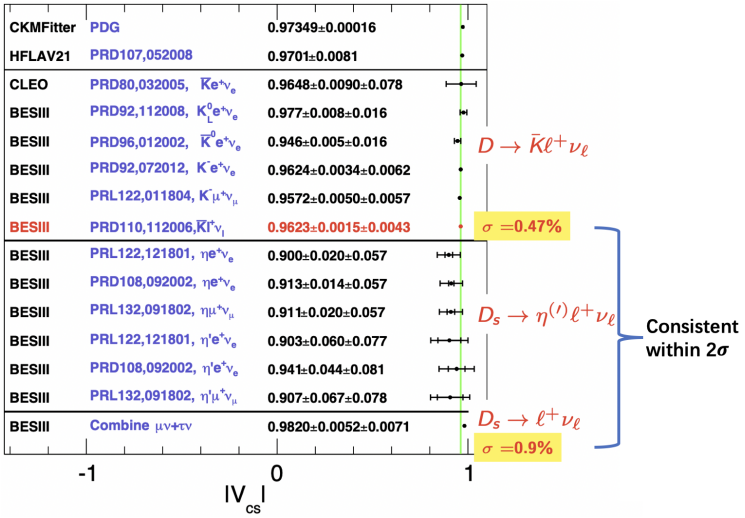
$$\mathcal{B}(D^+ \to \eta\mu^+\nu_\mu) = (9.08 \pm 0.35 \pm 0.23) \times 10^{-4}$$

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

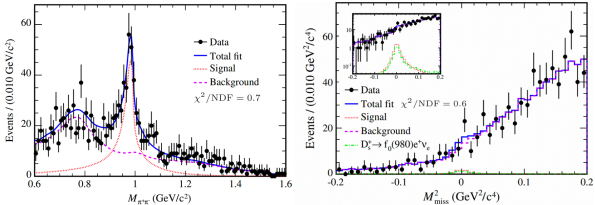
$$f_+^\eta(0) = 0.345 \pm 0.008 \pm 0.003$$

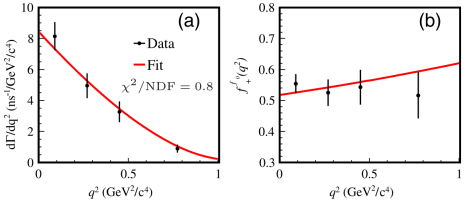
- **LFU test**: $\mathcal{R}^\eta_{\mu/e} = 0.93 \pm 0.05 \pm 0.02 \Longrightarrow$ Consistent with SM

Comparison of $|V_{cs}|$

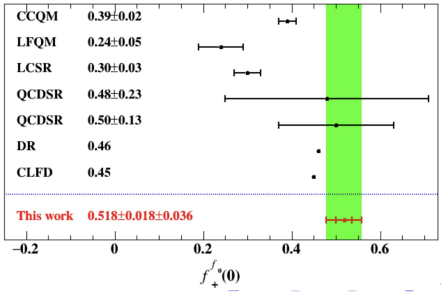


$D_s^+ \to f_0(980)e^+\nu_e$ via $f_0(980) \to \pi^+\pi^-$

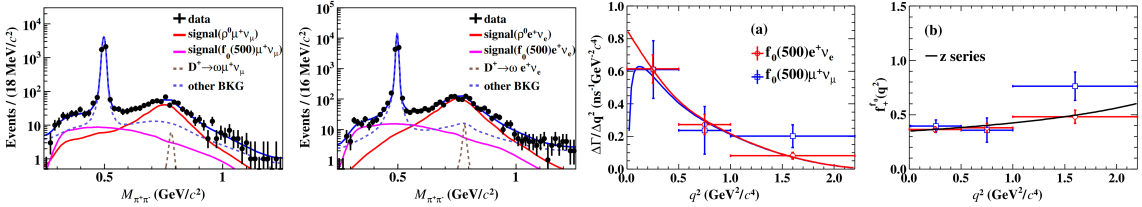




- 7.33 fb^{-1}@4.128-4.226 GeV PRL132(2024)141901
- **Updated BF measurement**
  $\mathcal{B}(D_s^+ \to f_0(980)_{\pi^+\pi^-} e^+\nu_e) = (1.72 \pm 0.13 \pm 0.10) \times 10^{-3}$
- **$q\bar{q}$ mixing angle**: $\sin\phi(1/\sqrt{2})(u\bar{u} + d\bar{d}) + \cos\phi s\bar{s}$
  $\phi = (19.7 \pm 12.8)^\circ \Rightarrow s\bar{s}$ component dominates
- **First FF measurement**: $f_+^{f_0(980)}(0) = 0.518 \pm 0.018 \pm 0.036$
- **First search of $D_s^+ \to f_0(500)e^+\nu_e$** ($M_{\pi^+\pi^-}$ <0.45 GeV/c^2)
  $\mathcal{B}(D_s^+ \to f_0(500)_{\pi^+\pi^-} e^+\nu_e) < 3.3 \times 10^{-4}$@90% C. L.



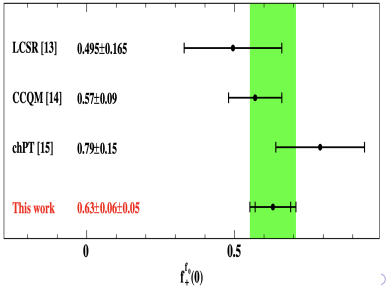
$D^+ \to f_0(500)\mu^+\nu_\mu$ and $D^+ \to \pi^+\pi^-\ell^+\nu_\ell$



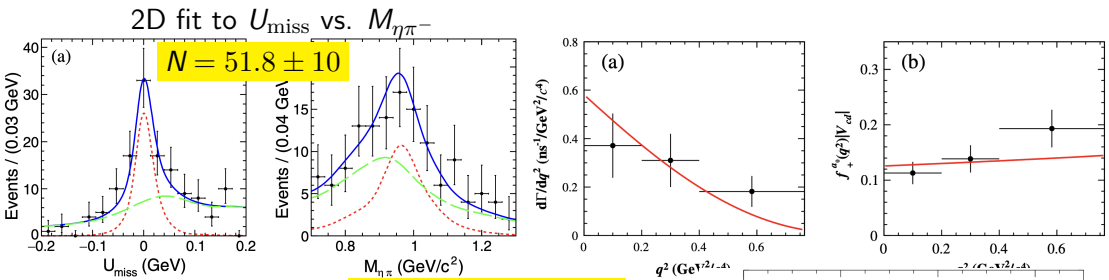
- 2.93 fb^{-1}@3.773 GeV PRD110(2024)092008
- **First observation of** $D^+ \to f_0(500)\mu^+\nu_\mu$

  $\mathcal{B}_{D^+\to f_0(500)_{\pi^+\pi^-}\mu^+\nu_\mu} = (0.72 \pm 0.13 \pm 0.10) \times 10^{-3}$

  $\mathcal{B}_{D^+\to \rho^0_{\pi^+\pi^-}\mu^+\nu_\mu} = (1.64 \pm 0.13 \pm 0.11) \times 10^{-3}$
- **First FF measurement**: $f_+^{f_0(500)}(0) = 0.63 \pm 0.06 \pm 0.05$
- $\mathcal{R}^{\rho^0}_{\mu/e} = 0.88 \pm 0.10$ (SM$\sim$0.96), $\mathcal{R}^{f_0(500)}_{\mu/e} = 1.14 \pm 0.28$ (SM$\sim$0.90)



$D^0 \to a_0(980)^- e^+ \nu_e$ via $a_0(980)^- \to \eta\pi^-$



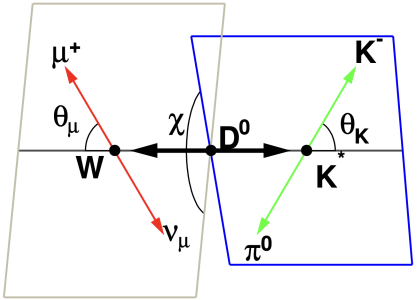
- Data: 7.93 fb^{-1}@3.773 GeV PRD111(2025)L091501
- **Improve measurement of BF**

  $\mathcal{B}(D^0 \to a_0(980)^- e^+ \nu_e, a_0(980)^- \to \eta\pi^-) = (0.86 \pm 0.17 \pm 0.05) \times 10^{-4}$
- **First extraction of the FF**
- $f_+^{a_0(980)}(0) = 0.559 \pm 0.056 \pm 0.013$

$D \to V\ell^+\nu_\ell$ ($V = K^*(892), \rho, \omega, \phi$)

$$\Gamma(D \to V\ell^+\nu_\ell) \propto |V_{cd(s)}|^2 \mathcal{I}(A_1(q^2), A_2(q^2), V(q^2)...) dm^2 dq^2 d\cos(\theta_h) \cos(\theta_\ell) d\chi$$

[Phys. Rev. 137, B438 (1965), Phys. Rev. D 46,5040 (1992)]



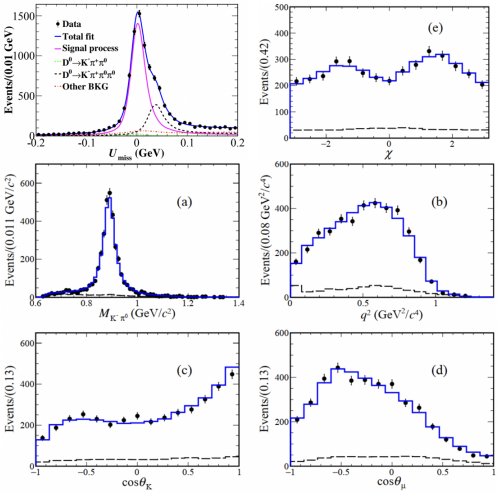
- Decay intensity $\mathcal{I}$ include S, P, D wave components
- Five kinematic variables: $m, q^2, \theta_K, \theta_\mu, \chi$
- Three FF parameterization (single pole)

  $A_{1,2}(q^2) = \frac{A_{1,2}(0)}{1-q^2/M_A^2}$; $V(q^2) = \frac{V(0)}{1-q^2/M_V^2}$

  $r_V = \frac{V(0)}{A_1(0)}$; $r_2 = \frac{A_2(0)}{A_1(0)}$
- Un-binned maximum likelihood

  $-\mathrm{In}\mathcal{L} = (-\mathrm{In}\mathcal{L}_{\mathrm{data}}) - (-\mathrm{In}\mathcal{L}_{\mathrm{bkg}})$

$D^0 \to K^*(892)^-\mu^+\nu_\mu$ via $K^*(892)^- \to K^-\pi^0$



PRL134(2025)011803

- Data: 7.9 fb^{-1}@3.773 GeV$\Longrightarrow N_{\rm DT} = 6436 \pm 119$
- **First measurement of BF**

  $\mathcal{B}(D^0 \to K^-\pi^0\mu^+\nu_\mu) = (0.729 \pm 0.014 \pm 0.011)\%$

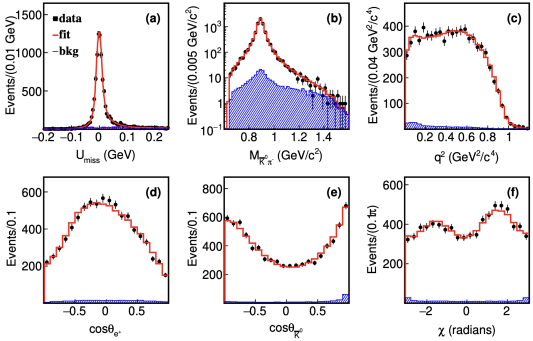
  $\mathcal{B}(D^0 \to K^*(892)^-\mu^+\nu_\mu) = (2.062 \pm 0.039 \pm 0.032)\%$
- **LFU test ($\mathcal{R}_{\rm SM} \sim 0.92 - 0.99$) Consistent**

  $\mathcal{R}_{\mu/e} = \frac{\mathcal{B}(D^0 \to K^*(892)^-\mu^+\nu_\mu)}{\mathcal{B}(D^0 \to K^*(892)^- e^+\nu_e)} = 1.020 \pm 0.030 \pm 0.028$
- **First FF measurement**

  $r_V = \frac{V(0)}{A_1(0)} = 1.37 \pm 0.09 \pm 0.03$

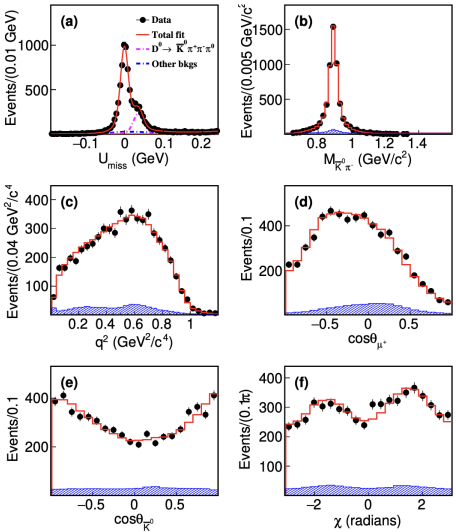
  $r_2 = \frac{A_2(0)}{A_1(0)} = 0.76 \pm 0.06 \pm 0.02$

$D^0 \to K^*(892)^- e^+ \nu_e$ via $K^*(892)^- \to \bar{K}^0\pi^-$



- Data: 7.9 fb^{-1}@3.773 GeV$\Longrightarrow$ $N_{\rm DT} = 8752 \pm 132$ JHEP03(2025)197
- **Updated measurement of BF**
  $\mathcal{B}(D^0 \to \bar{K}^0\pi^0 e^+\nu_e) = (1.444 \pm 0.022 \pm 0.024)\%$; $\mathcal{B}(D^0 \to K^*(892)^- e^+\nu_e) = (2.039 \pm 0.032 \pm 0.034)\%$
- **Updated FF measurement**
  $r_V = \frac{V(0)}{A_1(0)} = 1.48 \pm 0.05 \pm 0.02$; $r_2 = \frac{A_2(0)}{A_1(0)} = 0.70 \pm 0.04 \pm 0.02$; $A_1(0) = 0.610 \pm 0.007 \pm 0.004$

$D^0 \to K^*(892)^-\mu^+\nu_\mu$ via $K^*(892)^- \to \bar{K}^0\pi^-$



PRL135(2025)111803

- Data: 7.9 fb^{-1}@3.773 GeV$\Longrightarrow N_{\rm DT} = 6796 \pm 98$
- **First measurement of BF**

  $\mathcal{B}(D^0 \to \bar{K}^0\pi^0\mu^+\nu_\mu) = (1.373 \pm 0.020 \pm 0.023)\%$

  $\mathcal{B}(D^0 \to K^*(892)^-\mu^+\nu_\mu) = (1.948 \pm 0.033 \pm 0.036)\%$
- **LFU test ($\mathcal{R}_{\rm SM} \sim 0.92 - 0.99$) Consistent**

  $\mathcal{R}_{\mu/e} = \frac{\mathcal{B}(D^0 \to K^*(892)^-\mu^+\nu_\mu)}{\mathcal{B}(D^0 \to K^*(892)^-e^+\nu_e)} = 0.955 \pm 0.020 \pm 0.017$

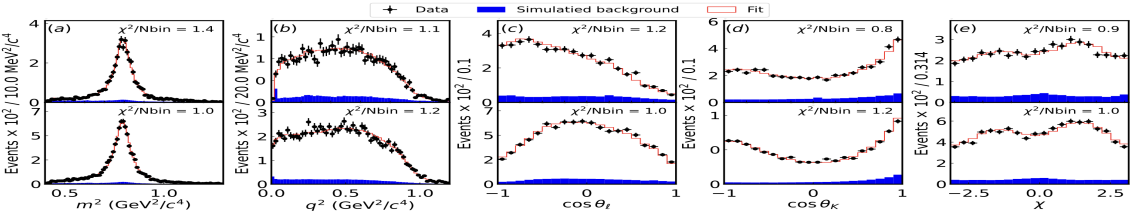
  $\mathcal{R}_{\mu/e} = \frac{\mathcal{B}(D^0 \to \bar{K}^0\pi^-\mu^+\nu_\mu)}{\mathcal{B}(D^0 \to \bar{K}^0\pi^-e^+\nu_e)} = 0.951 \pm 0.020 \pm 0.016$
- **First FF measurement**

  $r_V = \frac{V(0)}{A_1(0)} = 1.46 \pm 0.11 \pm 0.04$

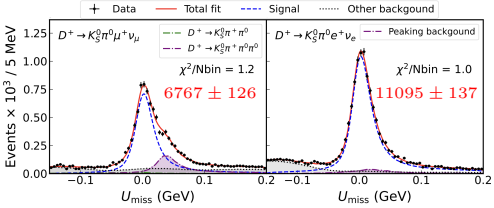
  $r_2 = \frac{A_2(0)}{A_1(0)} = 0.71 \pm 0.08 \pm 0.03$

  $A_1(0) = 0.623 \pm 0.008 \pm 0.008$

$D^+ \to \bar{K}^*(892)^0\ell^+\nu_\ell$ via $\bar{K}^*(892)^0 \to K^0_S\pi^0$



arXiv:2506.05761, Accepted by PRL



Data: 20.3 fb^{-1}@3.773 GeV

- **First observation of $D^+ \to K^0_S\pi^0\mu^+\nu_\mu$**

  $\mathcal{B}(D^+ \to K^0_S\pi^0\mu^+\nu_\mu) = (0.896 \pm 0.017 \pm 0.008)\%$

  $\mathcal{B}(D^+ \to K^0_S\pi^0 e^+\nu_e) = (0.943 \pm 0.012 \pm 0.010)\%$

  $\mathcal{B}(D^+ \to \bar{K}^*(892)^0\mu^+\nu_\mu) = (5.00 \pm 0.10 \pm 0.06)\%$

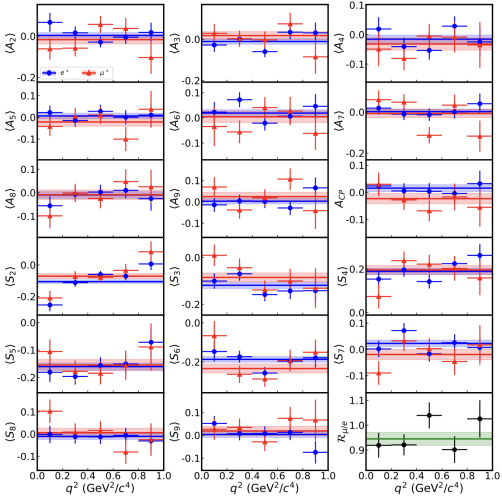
  $\mathcal{B}(D^+ \to \bar{K}^*(892)^0 e^+\nu_e) = (5.29 \pm 0.07 \pm 0.06)\%$
- **LFU test ($\mathcal{R}_{\rm SM} \sim 0.92 - 0.95$) Consistent**

  $\mathcal{R}_{\mu/e} = \frac{\mathcal{B}(D^+ \to \bar{K}^*(892)^0\mu^+\nu_\mu)}{\mathcal{B}(D^+ \to \bar{K}^*(892)^0 e^+\nu_e)} = 0.94 \pm 0.02 \pm 0.01$
- **Improved FF measurement**

  $r_V = \frac{V(0)}{A_1(0)} = 1.42 \pm 0.03 \pm 0.02$

  $r_2 = \frac{A_2(0)}{A_1(0)} = 0.75 \pm 0.03 \pm 0.01$

$D^+ \to \bar{K}^*(892)^0\ell^+\nu_\ell$ via $\bar{K}^*(892)^0 \to K^0_S\pi^0$



- NP contributions may result CPV or LFV in $D \to K^0_S\pi^0\ell^+\nu_\ell$
- LFV can be test via: integrated and q^2-binned $\mathcal{R}_{\mu/e}$
- CPV can be test via: A_{CP} and a full set of angular observables $\langle A_i \rangle$ and $\langle S_i \rangle$
- In SM model, all $\langle A_i \rangle$, A_{CP} and $\langle S_{7,8,9} \rangle$ are zero.
- No deviation from SM is seen.

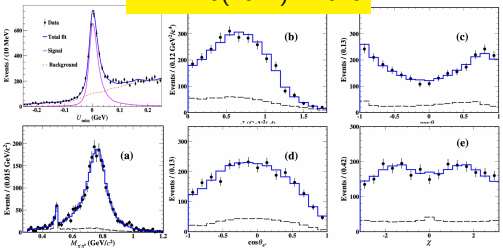
Summary of $D \to \bar{K}\pi\ell^+\nu_\ell$

	$D^0 \to \bar{K}^0\pi^- e^+\nu_e$	$D^0 \to \bar{K}^0\pi^-\mu^+\nu_\mu$	$D^0 \to K^-\pi^0\mu^+\nu_\mu$	$D^+ \to \bar{K}^0\pi^0\ell^+\nu_\ell$
Reference	JHEP03(2025)197	PRL135(2025)111803	PRL134(2025)011803	arXiv:2506.05761 Accepted by PRL
Data Set (fb^{-1})	7.93	7.93	7.93	20.3
Signal yields	8752±132	6796±98	6436±119	e : 11095 ± 137 μ : 6767 ± 126
$\mathcal{B}(D \to \bar{K}\pi\ell^+\nu_\ell)(\%)$	$1.444 \pm 0.022 \pm 0.024$	$1.373 \pm 0.020 \pm 0.023$	$0.729 \pm 0.014 \pm 0.011$	e : $0.943 \pm 0.012 \pm 0.010$ μ : $0.896 \pm 0.017 \pm 0.008$
$\mathcal{B}(D \to \bar{K}^*\ell^+\nu_\ell)(\%)$	$2.039 \pm 0.032 \pm 0.034$	$1.948 \pm 0.033 \pm 0.036$	$2.062 \pm 0.039 \pm 0.032$	e : $5.29 \pm 0.07 \pm 0.06$ μ : $5.00 \pm 0.10 \pm 0.06$
r_V	$1.48 \pm 0.05 \pm 0.02$	$1.46 \pm 0.11 \pm 0.04$	$1.37 \pm 0.09 \pm 0.03$	$1.42 \pm 0.03 \pm 0.02$
r_2	$0.70 \pm 0.04 \pm 0.02$	$0.71 \pm 0.08 \pm 0.03$	$0.76 \pm 0.06 \pm 0.02$	$0.75 \pm 0.03 \pm 0.01$
$\mathcal{R}^{K^*}_{\mu/e}$	$0.955 \pm 0.020 \pm 0.017$		$1.020 \pm 0.030 \pm 0.028$	$0.94 \pm 0.02 \pm 0.01$

Studies of $D^+ \to K^-\pi^+\ell^+\nu_\ell$ are ongoing

$D^0 \to \rho(770)^- e^+ \nu_e$ and $D_s^+ \to \phi\mu^+\nu_\mu$

PRD110(2024)112018

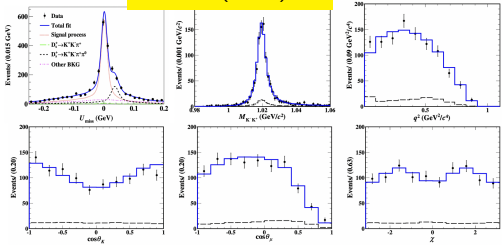


- Data: 7.9 fb^{-1}@3.773 GeV$\Rightarrow$ $N = 3337 \pm 77$
- **Precision of BF is improved by 1.6×**

  $\mathcal{B}(D^0 \to \rho^- e^+ \nu_e) = (1.439 \pm 0.033 \pm 0.027) \times 10^{-3}$
- **Updated FF measurement**

  $r_V = 1.548 \pm 0.079 \pm 0.041$; $r_2 = 0.823 \pm 0.056 \pm 0.026$

JHEP12(2023)072

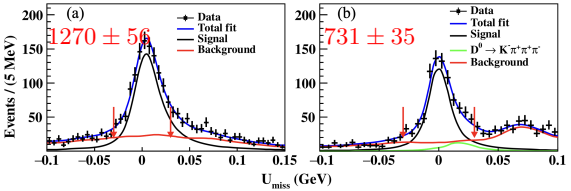


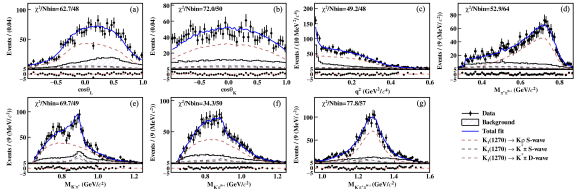
- Data: 7.33 fb^{-1}@4.128-4.226 GeV$\Rightarrow$ $N = 1725 \pm 68$
- **Precision of BF is improved by 4.3×**

  $\mathcal{B}(D_s^+ \to \phi\mu^+\nu_\mu) = (2.25 \pm 0.09 \pm 0.07)\%$
- **Updated FF measurement**

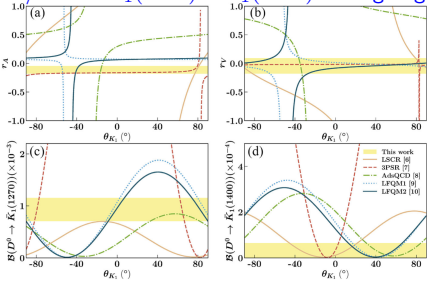
  $r_V = 1.58 \pm 0.17 \pm 0.02$; $r_2 = 0.71 \pm 0.14 \pm 0.02$
- **LFU test**: $\mathcal{R}^{\phi}_{\mu/e} = 0.94 \pm 0.08$

$D^{0(+)} \to \bar{K}_1(1270)e^+\nu_e$ via $\bar{K}_1(1270) \to K^-\pi^+\pi^{0(-)}$





FF/BF vs. $K_1(1270) - K_1(1400)$ mixing angle θ_{K_1}



- Data: 20.3 fb^{-1}@3.773 GeV PRL135(2025)091801
- **Improved measurement of BF**

  $\mathcal{B}(D^+ \to \bar{K}_1(1270)^0 e^+\nu_e) = (2.27 \pm 0.11 \pm 0.10) \times 10^{-3}$

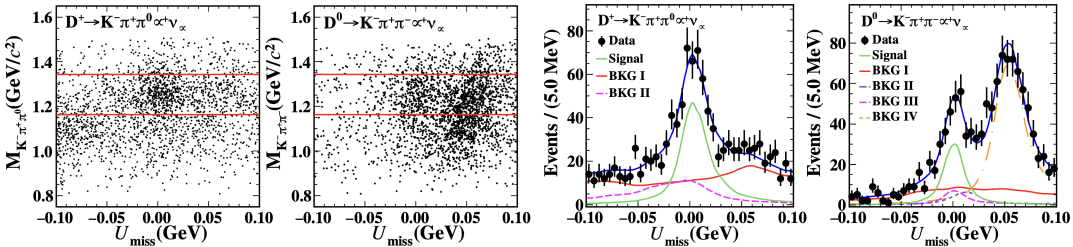
  $\mathcal{B}(D^0 \to K_1(1270)^- e^+\nu_e) = (1.02 \pm 0.06 \pm 0.07) \times 10^{-3}$
- **First extraction of FF** [cited from PRD104(2021)053003]

  $r_A = (-11.2 \pm 1.0 \pm 0.9) \times 10^{-2}$

  $r_V = (-4.3 \pm 0.10 \pm 2.5) \times 10^{-2}$
- **No evidence of $D \to \bar{K}_1(1400)e^+\nu_e$**; UL is set at 90% C.L.

  $\mathcal{B}(D^{0(+)} \to \bar{K}_1(1400)e^+\nu + e) < 1.4 \times 10^{-4} (0.7 \times 10^{-4})$

$D^{0(+)} \to \bar{K}_1(1270)\mu^+\nu_\mu$ via $\bar{K}_1(1270) \to K^-\pi^+\pi^{0(-)}$

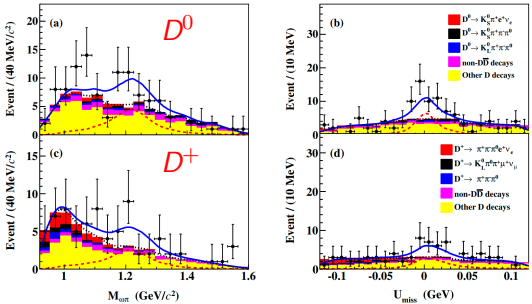


- Data: 7.9 fb^{-1}@ 3.773 GeV PRD111(2025)L071101
- **Observation of** $D^+ \to \bar{K}_1(1270)^0\mu^+\nu_\mu$ (12.5σ) **and** $D^0 \to K_1(1270)^-\mu^+\nu_\mu$ (6.0σ)

  $\mathcal{B}(D^+ \to \bar{K}_1(1270)^0\mu^+\nu_\mu) = (2.36 \pm 0.20^{+0.18}_{-0.27} \pm 0.48) \times 10^{-3}$

  $\mathcal{B}(D^0 \to K_1(1270)^-\mu^+\nu_\mu) = (0.78 \pm 0.11^{+0.05}_{-0.09} \pm 0.15) \times 10^{-3}$
- **LFU test**: $\mathcal{R}^{D^+}_{\mu/e} = 1.03 \pm 0.14^{+0.11}_{-0.15}$; $\mathcal{R}^{D^0}_{\mu/e} = 0.74 \pm 0.13^{+0.08}_{-0.13}$
- **Isospin conservation**: $\frac{\Gamma(D^+ \to \bar{K}_1(1270)^0\mu^+\nu_\mu)}{\Gamma(D^0 \to K_1(1270)^-\mu^+\nu_\mu)} = 1.22 \pm 0.10^{+0.06}_{-0.09}$

$D^{0(+)} \to b_1(1235)e^+\nu_e$ via $b_1(1235) \to \omega\pi$



- Data: 7.9 fb^{-1}@ 3.773 GeV arXiv:2407.20551, submitted to PRL
- **First observation of** $D^0 \to b_1(1235)e^+\nu_e$ (5.2σ)**; Evidence of** $D^+ \to b_1(1235)^0 e^+\nu_e$ (3.1σ)
  $\mathcal{B}(D^0 \to b_1(1235)^- e^+\nu_e, b_1(1235)^- \to \omega\pi^-) = (0.72 \pm 0.18^{+0.06}_{-0.08}) \times 10^{-4}$
  $\mathcal{B}(D^+ \to b_1(1235)^0 e^+\nu_e, b_1(1235)^0 \to \omega\pi^0) = (1.16 \pm 0.44 \pm 0.16) \times 10^{-4}$
- **Isospin test**: $\frac{\Gamma(D^0 \to b_1^- e^+\nu_e)}{2\Gamma(D^+ \to b_1^0 e^+\nu_e)} = 0.78 \pm 0.19 \pm 0.05$, consistent with 1

Summary and Prospect

Summary:

- Recent results of semileptonic decays of charm meson at BESIII are reported:
  - Precisions of $|V_{cs}|$ and $f_+^{D\to\bar{K}}(0)$ have been reduced to 0.5% and 0.25%, respectively!
  - No evidence of $\mu - e$ LFU violation is found (especially for $D^{0(+)} \to \bar{K}\ell^+\nu_\ell$ $\sigma = 0.7\%(1.5\%)$)
  - Precision measurements of BF and FF for $D_{(s)} \to \eta^{(\prime)}\ell^+\nu_\ell$ and $D \to \bar{K}^*\ell^+\nu_\ell$
  - Study the nature of light hadrons in semi-leptonic decay (a_0, f_0, b_1 and K_1)

Prospect:

- 20.3 fb^{-1}data @3.773 GeV is ready at Jul. 2024, more precision measurements, searching for rare semileptonic decays, and jointed measurements of multiple channels will be presented;
- Additional 3 fb^{-1}data @4.178 GeV in future [CPC44(2020)040001] will further improve the precisions in D_s sector.

Thank you