北京谱仪III上粲介子四体半轻衰变的研究进展

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湖南大学

第四届强子与重味物理理论与实验联合研讨会

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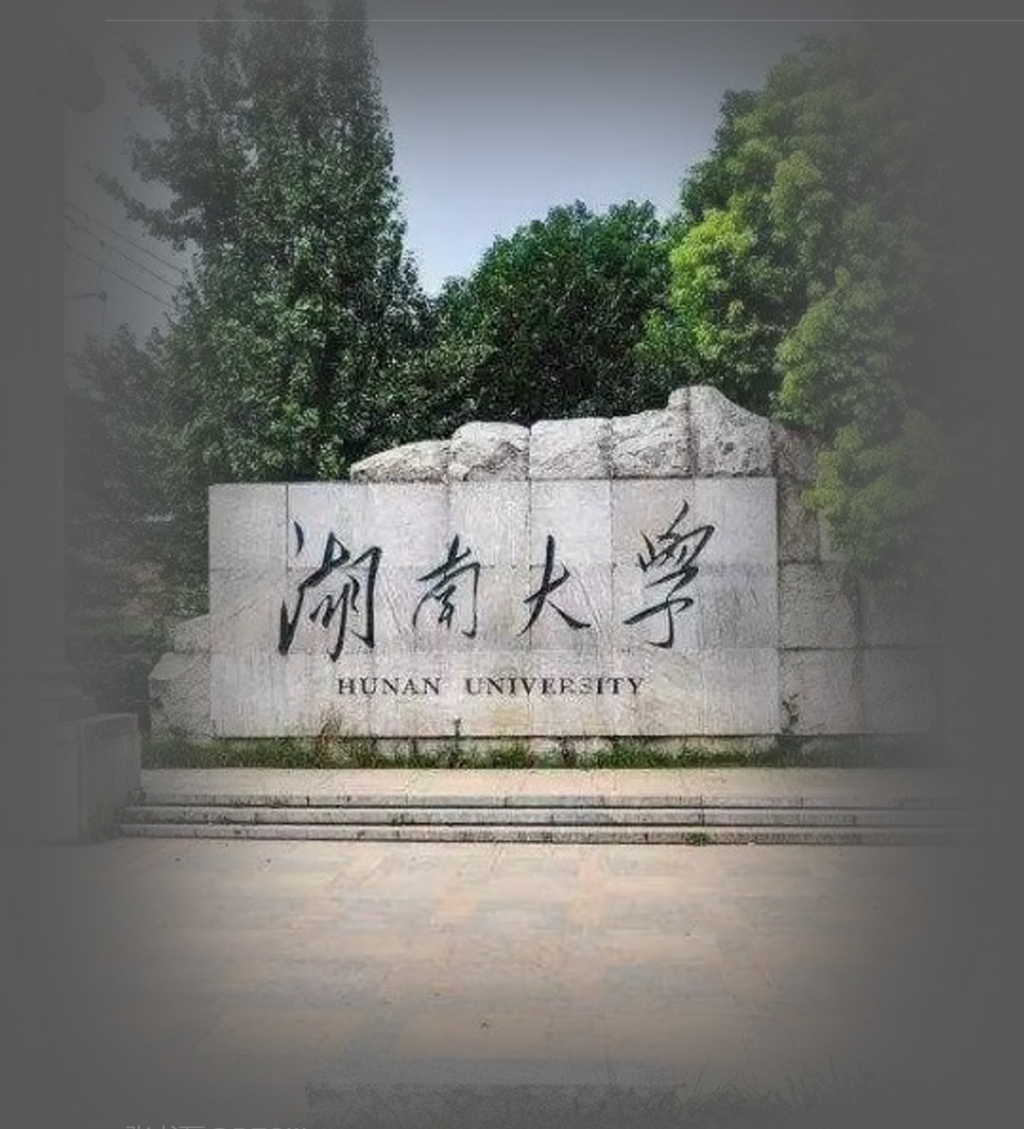
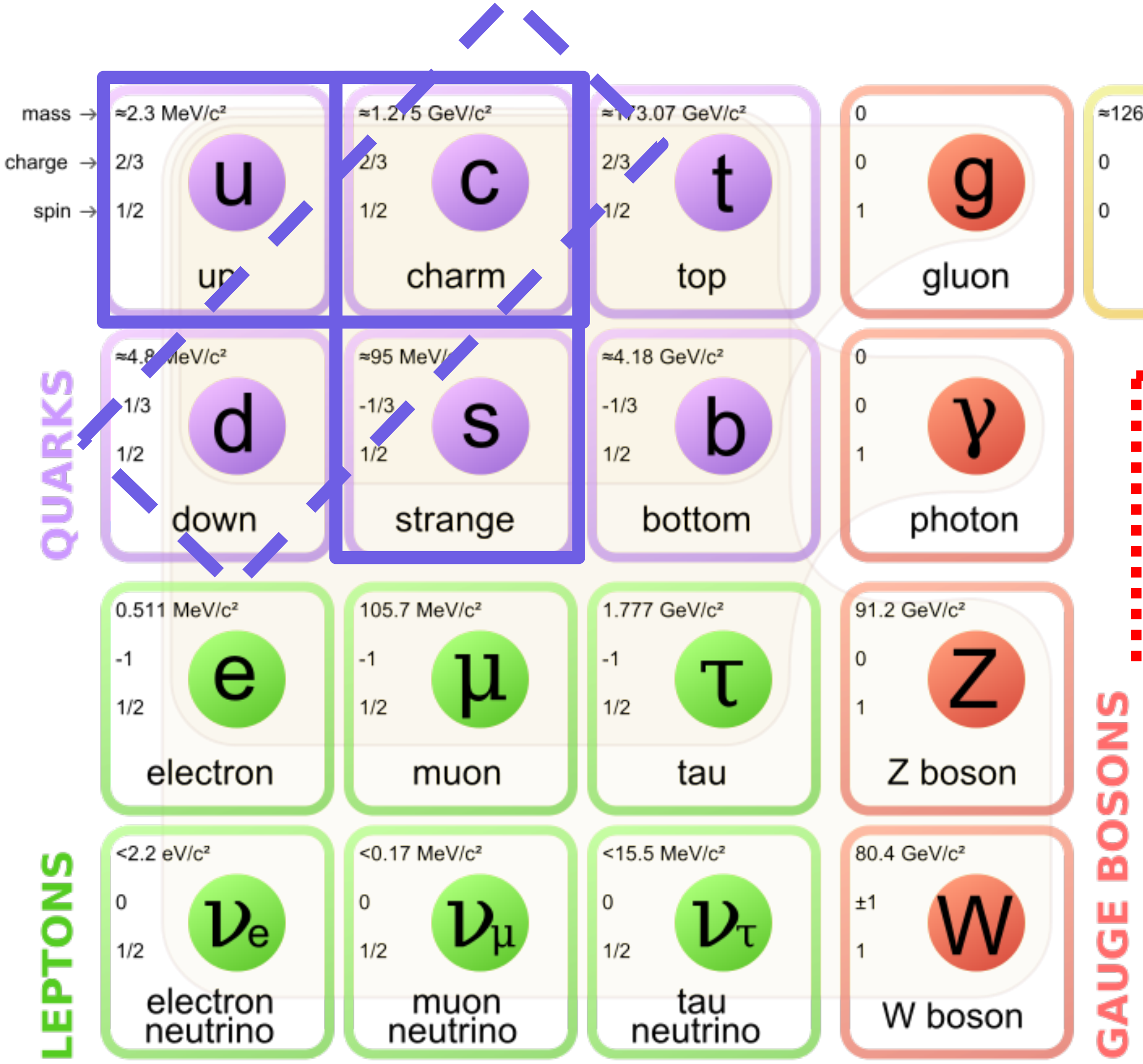
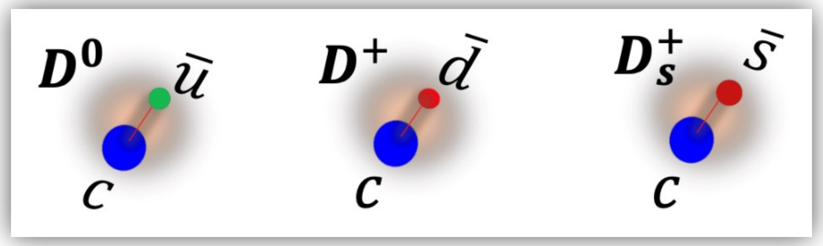
Content



Physics motivation





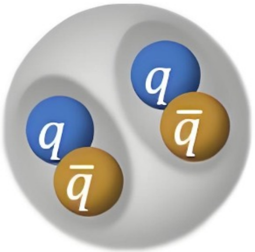
Charm physics

- **QCD**: Non-perturbative energy region ➔ **NPQCD**
- **Standard Model test**：High-precision ➔ **New Physics**

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

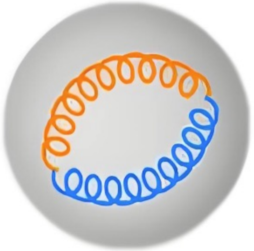
Physics motivation

Tetraquark

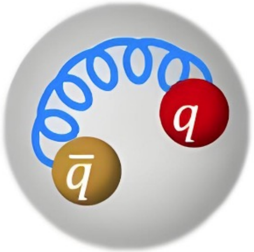


Hadronic molecules

Pentaquark



Glueball



hybrid

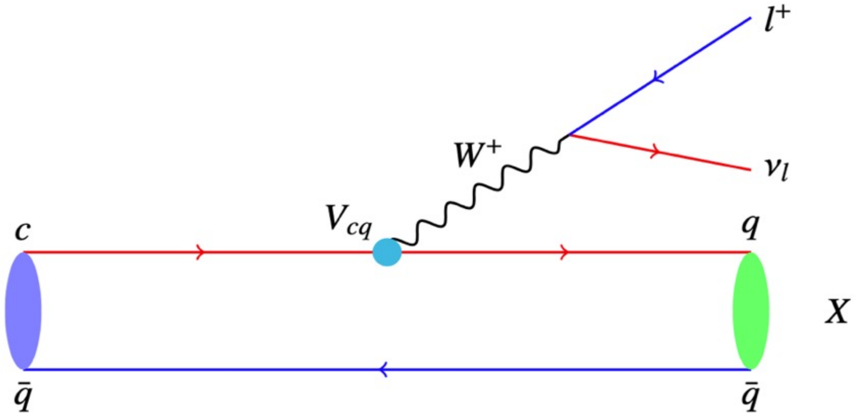
- **Quark model allows for them.**
- **How about scalar mesons:**

  $\boldsymbol{f_0(500), K^*(700), f_0(980)}$ **and** $\boldsymbol{a_0(980)}$**, etc**

➔ $q\bar{q}$ mixture, tetraquark, hadronic molecule or hybrid?

Physics motivation

??? ➠ Why is the semi-leptonic decay of charmed meson?



$$\Gamma(D_{(s)} \to S\,\ell^+\nu_\ell) \propto |V_{cd(s)}|^2 |f_+(q^2)|^2\, dq^2$$

$$\Gamma(D_{(s)} \to V\ell^+\nu_\ell) \propto \left|V_{cd(s)}\right|^2 \mathfrak{T}(A_1(q^2), A_2(q^2), V(q^2))dq^2$$

- **Clean environment:** hadrons ***X*** can be separated from leptons pair.
- **High statistics** of charmed meson at experiments.
  - CKM matrix elements $\left|V_{cd(s)}\right|$ meaurements ➔ **Test CKM matrix unitarity (New Physics).**
  - $\mathcal{R}_{\mu/e} = \mathcal{B}(D_{(s)} \to X\mu^+\nu_\mu)/\mathcal{B}(D_{(s)} \to Xe^+\nu_e)$ measurement ➔ **Test lepton flavor universality (LFU)**
  - Hadronic Form factor (FF) measurements ➔ **Test different QCD models (LQCD)**
  - Light scalar mesons study ➔ **Help to understand quark confinement**

Content

Data sample

- Symmetric e^+e^- collider @2 – 5GeV
- Pair-production near threshold
- $D\bar{D}$@3.773GeV: **~20.3 fb^{-1}**

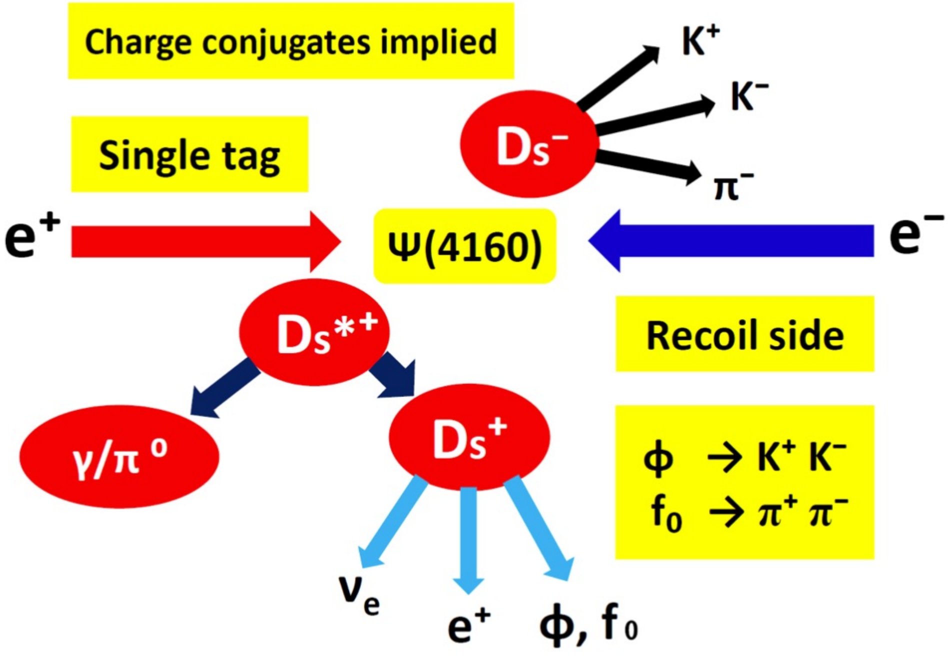
2.93 fb^{-1}@2010-2011; 4.99 fb^{-1}@2021-2022; 8.16 fb^{-1}@2021-2022; 4.19 fb^{-1}@2022-2024

- $D_s D_s^*$ @4.13-4.23GeV: 7.33 fb^{-1}

E_{cm}(GeV)	Data taking year	$\mathcal{L}(\mathrm{fb}^{-1})$	ST D^0	ST D^+	ST D_s^+
3.773	2010-11→2022-24	2.93→20.3	2.7 M →~17M	1.7 M →~11M	
4.13-4.23	2012,2016-17,2019	7.33			0.8 M

Analysis method: Double Tag

Take Ds decay as an example (complicated case)



$\mathcal{B}_\gamma(D_S^* \to \gamma D_S)$

$$N_{tag} = 2N_{D_S^+ D_S^-} \mathcal{B}_{tag}\,\epsilon_{tag}$$
$$N_{sig} = 2N_{D_S^+ D_S^-} \mathcal{B}_{tag}\mathcal{B}_{sig}\mathcal{B}_\gamma\epsilon_{sig}$$

$$\mathcal{B}_{sig} = \frac{N_{sig}}{\mathcal{B}_\gamma N_{tag}\epsilon_{sig}/\epsilon_{tag}}$$

$$\mathcal{B}_{sig} = \frac{N_{sig}}{\mathcal{B}_\gamma \sum_\alpha N_{tag}^\alpha \epsilon_{sig}^\alpha / \epsilon_{tag}^\alpha}$$

- Mature method
- Absolute BF measurement
- Low background
- Systematic cancellation (tag)

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

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Content

The differential decay rate of $D_{(s)} \to V \ell \nu_\ell$

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

V: $\rho(770), K^*(892), \phi(1020)$
S: $K^*(700), f_0(500), f_0(980)$

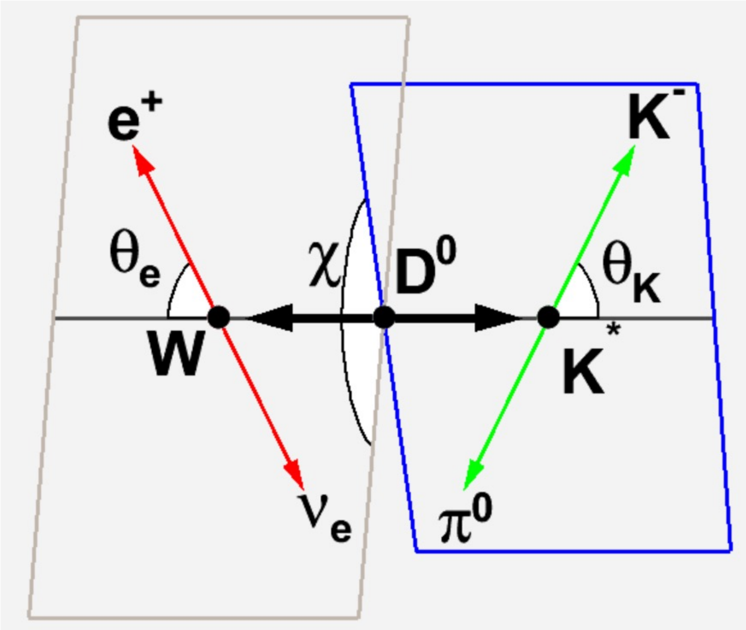
Theory: Phys. Rev. **137**, B438(1965)
Phys. Rev. D 46,5040(1992)

- The decay intensity $\mathfrak{I}$ can include components of S/P/D wave processes.
- Unbinned maximum likelihood method.

  (implemented based on the RooFit framework).
- Form factor (single pole parameterization, double pole ...)

$$A_i(q^2) = \frac{A_i(0)}{1 - q^2/M_A^2} \qquad V(q^2) = \frac{V(0)}{1 - q^2/M_V^2}$$

$$r_V = \frac{V(0)}{A_1(0)} \qquad r_2 = \frac{A_2(0)}{A_1(0)}$$



Analysis method : Maximum Likelihood Method

- Minimize the negative log-likelihood function:

$$NLL = -\sum_{i=1}^{N} \ln \frac{\omega(\xi_i,\eta)}{\sigma_s}$$

$\omega(\xi_i,\eta)$ is the decay intensity , σ_s is the normalization factor, using signal Monte Carlo samples：

$$\sigma_s = \int d\xi\, \omega(\xi,\eta)\, \epsilon(\xi) \propto \frac{1}{N_{selected}} \sum_{k=1}^{N_{selected}} \frac{\omega(\xi_k,\eta)}{\omega(\xi_k,\eta_0)}$$

- When the background is low:

$$NLL = (-lnL_{data}) - (-lnL_{bkg})$$

- When the background is high:

$$-\sum_{i=1}^{N} \ln\left((1-f_b)\frac{\omega(\xi_i,\eta)}{\int d\xi_i \omega(\xi_i,\eta)\epsilon(\xi_i)} + f_b \frac{B_\epsilon(\xi_i)}{\int d\xi_i B_\epsilon(\xi_i)\epsilon(\xi_i)}\right)$$

c -> s semi-leptonic decay: $D_s^+ \to K^+K^-\mu^+\nu_\mu$

JHEP12(2023)072

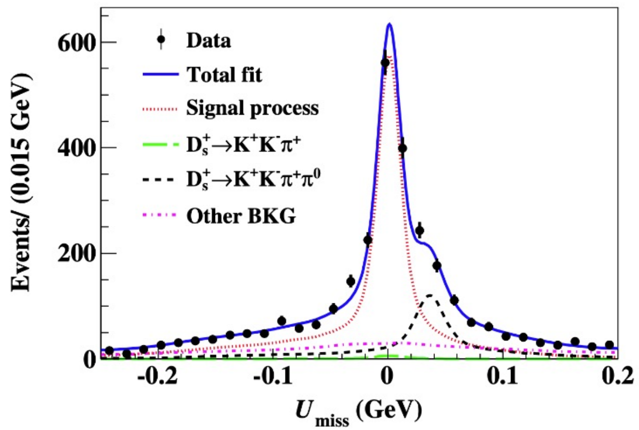
- $7.33\ \text{fb}^{-1}$ data @ 4.13-4.23 GeV
- $N_{\text{sig}} = 1725 \pm 68$ for BF measurement

$\mathcal{B}(D_s^+ \to \phi\mu^+\nu_\mu) = (2.25 \pm 0.09 \pm 0.07)\times 10^{-2}$

$\mathcal{R}_{\mu/e} = \mathcal{B}(D_s^+ \to \phi\mu^+\nu_\mu)/\mathcal{B}(D_s^+ \to \phi e^+\nu_e) = 0.94 \pm 0.08$ ➔ No **LFU** violation

$\mathcal{B}(D_s^+ \to f_0(980)\mu^+\nu_\mu)\cdot\mathcal{B}(f_0(980) \to K^+K^-) < 5.45\times 10^{-4}$@90% C.L. ($\sim 2.2\sigma$)

- **First FF measurement** based on single pole parameterization:
  - **Partial wave analysis** is performed ➔ ϕ dominate
  - $\boldsymbol{\mu}$ **mass** is considered in the formula



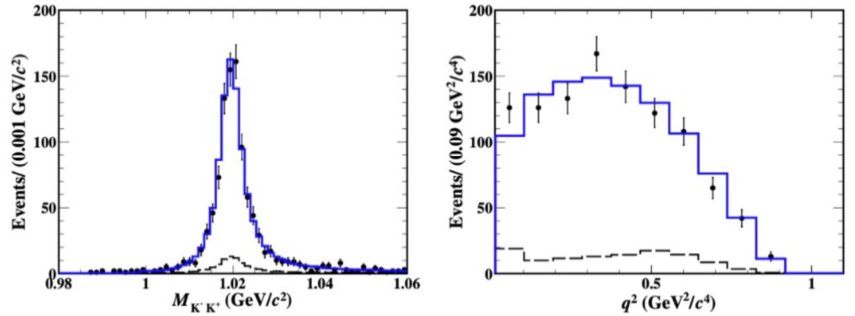
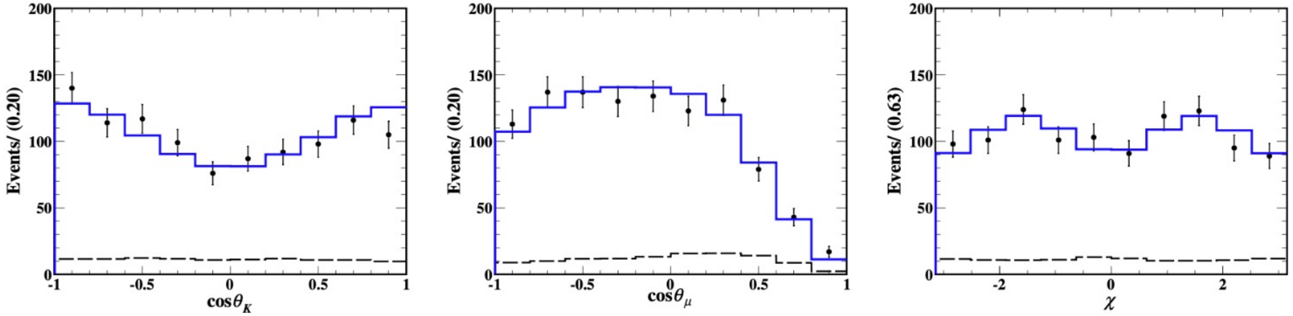


Table 5. Measured FF ratios and comparison with previous measurements.

Experiments	r_V	r_2
PDG [42]	1.80±0.08	0.84±0.11
This analysis	1.58±0.17±0.02	0.71±0.14±0.02
BABAR [25]	1.807±0.046±0.065	0.816±0.036±0.030
FOCUS [58]	1.549±0.250±0.148	0.713±0.202±0.284
Theory	r_V	r_2
CCQM [5]	1.34±0.27	0.99±0.20
CQM [6]	1.72	0.73
LFQM [7]	1.42	0.86
LQCD [3]	1.72±0.21	0.74±0.12
HMχT [8]	1.80	0.52



$|U_{\text{miss}}| < 0.02$ **GeV**

$N_{\text{Event}}^{D_s^+} = 939$, Bkg: $(9.8 \pm 0.7)\%$

c -> s semi-leptonic decays: $D^0 \rightarrow K^{*-}\mu^+\nu_\mu$

Phys. Rev. Lett. 134, 011803 (2025)

- 7.93 fb^{-1} data @3.773GeV
- $N_{sig} = 6436 \pm 119$
- $\mathcal{B}(D^0 \rightarrow K^-\pi^0\mu^+\nu_\mu) = (0.729 \pm 0.014 \pm 0.011)\%$
- $\mathcal{B}(D^0 \rightarrow K^{*-}\mu^+\nu_\mu) = (2.062 \pm 0.039 \pm 0.032)\%$

  $f_{\text{S-wave}} = (5.76 \pm 0.35 \pm 0.29)\%$

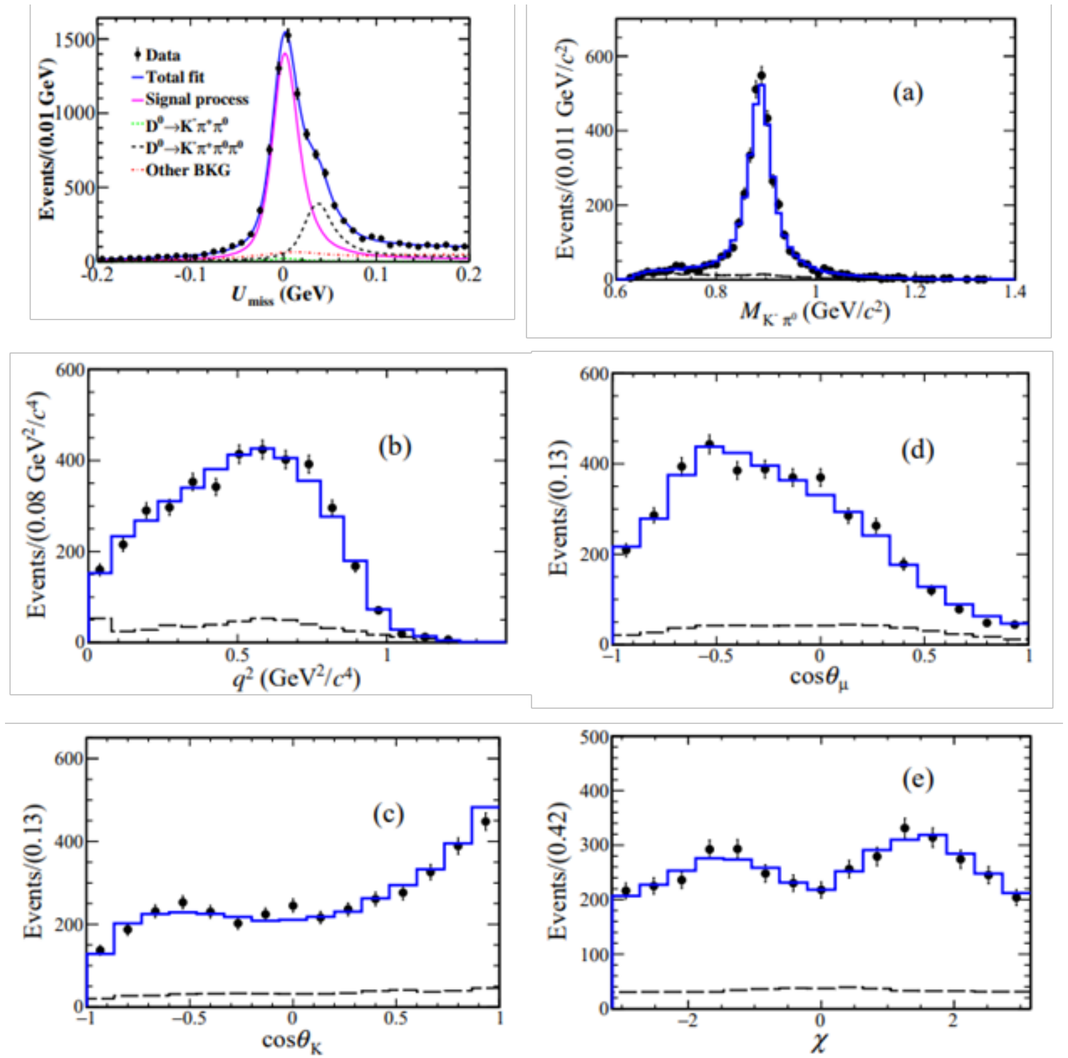
  $f_{P-wave} = (94.24 \pm 0.35 \pm 0.29)\%$

$\mathcal{R}_{\mu/e} = \mathcal{B}(D^0 \rightarrow K^{*-}\mu^+\nu_\mu)/\mathcal{B}(D^0 \rightarrow K^{*-}e^+\nu_e) = 0.96 \pm 0.08$

- First measurement of the form factor. ：

  $r_V = 1.37 \pm 0.09 \pm 0.03,$

  $r_2 = 0.76 \pm 0.06 \pm 0.02$



$|U_{\text{miss}}| < 0.015$ GeV

$N^{SL}_{\text{Event}} = 3375$, Bkg: $(12.6 \pm 0.7)\%$

c -> s semi-leptonic decays: $D^0 \rightarrow K^{*-}\mu^+\nu_\mu$

TABLE IV. Measured the BF and FF ratios of $D^0 \to K^*(892)^-\mu^+\nu_\mu$, and compared them with theoretical calculations and previous measurements.

Theory	$\mathcal{B}$ (%)	r_V	r_2
LCSR [7,16]	$2.01^{+0.09}_{-0.08}$	1.39	0.60
χUA [17]	1.98	...	...
CCQM [6]	2.80	1.22 ± 0.24	0.92 ± 0.18
CQM [8,18]	3.09	1.56	0.74
LFQM [9]	...	1.36	0.83
$\mathrm{HM}_\chi\mathrm{T}$ [10]	...	1.60	0.50
Experiments	$\mathcal{B}$ (%)	r_V	r_2
BESIII [39]	...	$1.46 \pm 0.07 \pm 0.02$	$0.67 \pm 0.06 \pm 0.01$
FOCUS [11]	1.89 ± 0.24	$1.71 \pm 0.68 \pm 0.34$	$0.91 \pm 0.37 \pm 0.10$
This Letter	$2.073 \pm 0.039 \pm 0.032$	$1.37 \pm 0.09 \pm 0.03$	$0.76 \pm 0.06 \pm 0.02$

$r_2 = 0.76 \pm 0.06 \pm 0.02$

$|U_{\mathrm{miss}}| < 0.015$ GeV
$N^{SL}_{\mathrm{Event}} = 3375$, Bkg: $(12.6 \pm 0.7)\%$

c -> s semi-leptonic decays: $D^+ \to \overline{K}^{*0} e^+ \nu_e$

J. High Energ. Phys. 10, 199 (2024)

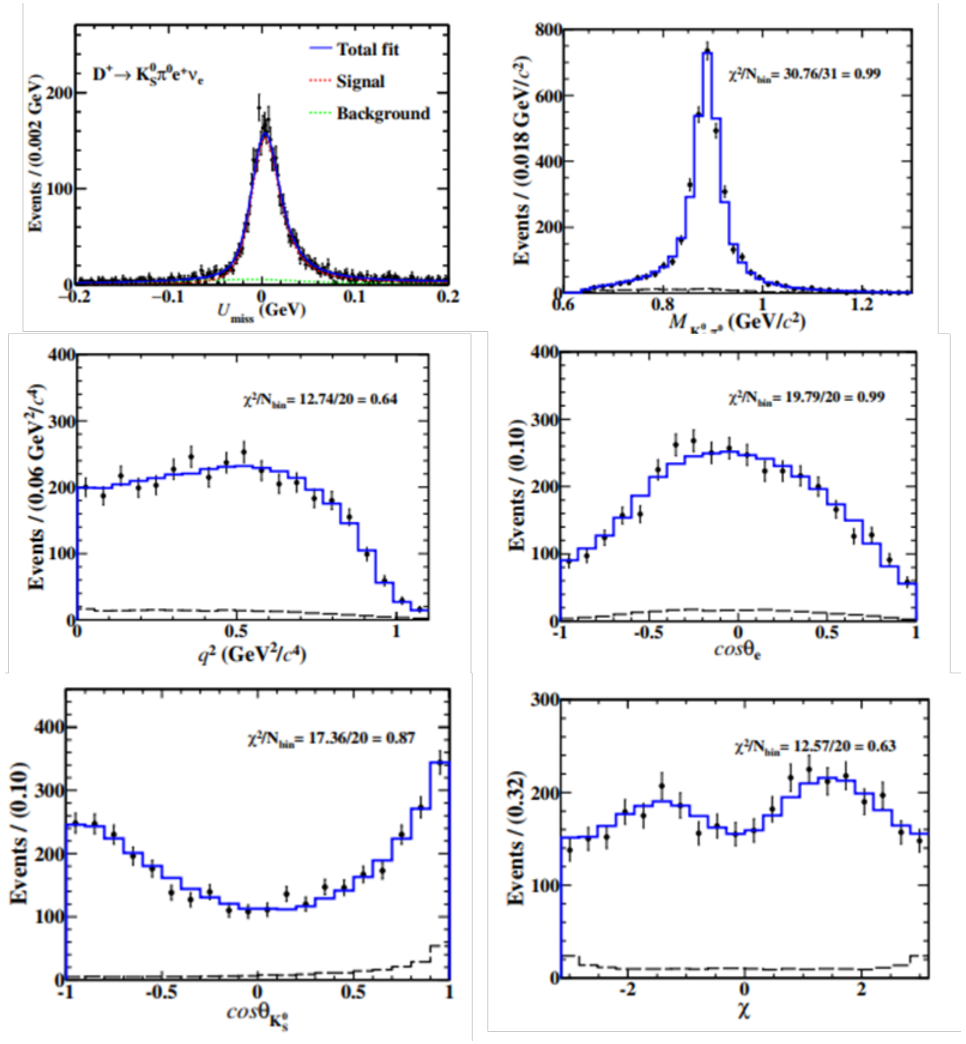
- 7.93 fb^{-1} data @3.773GeV
- $N_{sig} = 3852 \pm 75$
- $\mathcal{B}(D^+ \to K_S^0 \pi^0 e^+ \nu_e) = (0.881 \pm 0.017 \pm 0.016)\%$
- $\mathcal{B}(D^+ \to \overline{K}^{*0} e^+ \nu_e) = (4.97 \pm 0.011 \pm 0.012)\%$

  $f_{\text{S-wave}} = (5.41 \pm 0.35 \pm 0.37)\%$

  $f_{\text{P-wave}} = (93.88 \pm 0.27 \pm 0.29)\%$
- Measurement of the form factor. ：

  $r_V = 1.43 \pm 0.07 \pm 0.03,$

  $r_2 = 0.72 \pm 0.06 \pm 0.02$



$|U_{\text{miss}}| < 0.015$ GeV

$N_{\text{Event}}^{SL} = 3566$, Bkg: $(6.54 \pm 0.64)\%$

c -> s semi-leptonic decays: $D^+ \to \bar{K}^{*0} e^+ \nu_e$

Reference		r_V	r_2
Experiment	Average [23]	1.49±0.05	0.802±0.021
Lattice QCD	LMMS [7]	1.6±0.2	0.4±0.4
	BKS [8]	1.99±0.22±0.33	0.7±0.16±0.17
	ELC [9]	1.3±0.2	0.6±0.3
	UKQCD [10]	$1.4^{+0.5}_{-0.2}$	0.9±0.2
	LANL [11]	1.83±0.09	0.74±0.19
	APE [12]	1.6±0.3	0.7±0.4
Quark model	WSB [13, 14]	1.4	1.3
	ISGW [2, 15]	1.4	1.0
	GS [16]	2.0	0.8
QCD sum rules	BBD [17, 18]	2.2±0.2	1.2±0.2
This work	–	$1.43 \pm 0.07_{\text{stat.}} \pm 0.03_{\text{syst.}}$	$0.72 \pm 0.06_{\text{stat.}} \pm 0.02_{\text{syst.}}$

Table 5. Hadronic form factors of $D \to \bar{K}^*$ at q^2=0 predicted by different theories.

$N^{SL}_{\text{Event}} = 3566$, Bkg: $(6.54 \pm 0.64)\%$

c -> s semi-leptonic decays: $D^0 \to K^{*-} e^+ \nu_e$

arXiv:2412.10803 (Accepted by JHEP)

- 7.93 fb^{-1} data @3.773GeV
- $N_{sig} = 8752 \pm 132$ (bkg level: 10.7%)
- $\mathcal{B}(D^0 \to \bar{K}^0 \pi^- e^+ \nu_e) = (1.444 \pm 0.022 \pm 0.024)\%$
- $\mathcal{B}(D^0 \to K^{*-} e^+ \nu_e) = (2.039 \pm 0.032 \pm 0.034)\%$

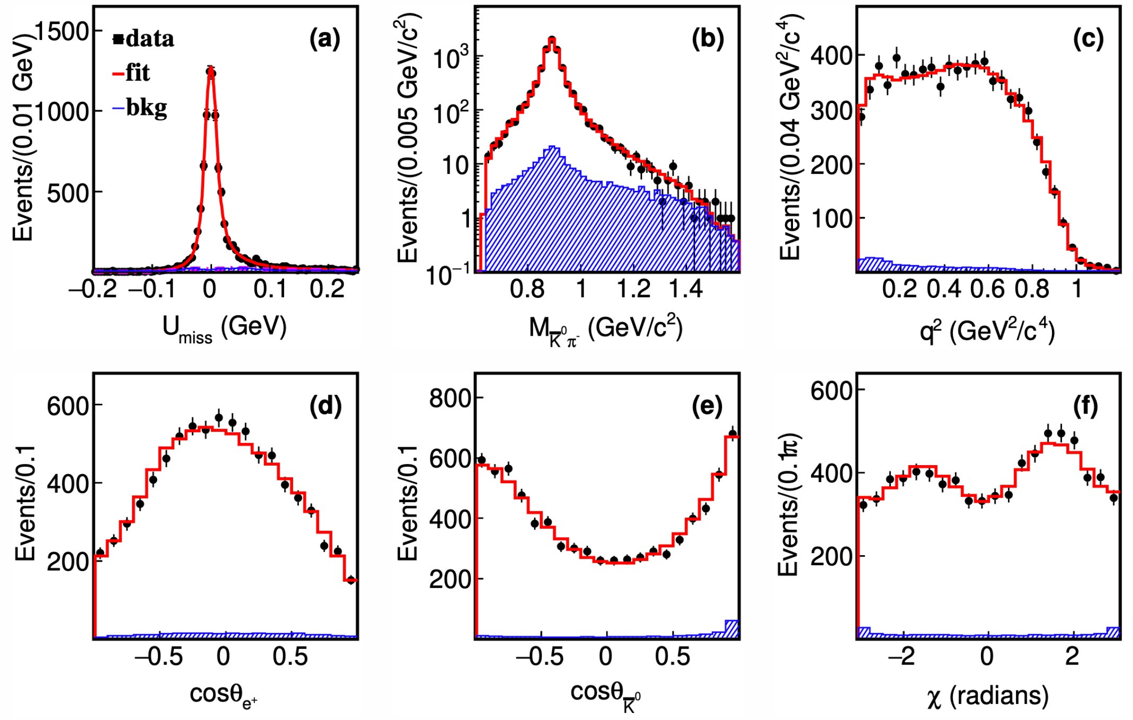
  $f_{\mathrm{S-wave}} = (5.87 \pm 0.32 \pm 0.16)\%$

  $f_{\mathrm{P-wave}} = (94.15 \pm 0.32 \pm 0.16)\%$
- Measurement of the form factor ：

  $r_V = 1.48 \pm 0.05 \pm 0.02,$

  $r_2 = 0.70 \pm 0.04 \pm 0.02$

  $A_1(0) = 0.610 \pm 0.007 \pm 0.004$ (First based on this decay)



$|U_{\mathrm{miss}}| < 0.05$ GeV
$N^{SL}_{\mathrm{Event}} \sim$ 8K, Bkg: ~4%

c -> s semi-leptonic decays: $D^0 \to K^{*-}e^+\nu_e$

arXiv:2412.10803 (Accepted by JHEP)

- 7.93 fb^{-1} data @3.773GeV
- $N_{sig} = 8752 \pm 132$ (bkg level: 10.7%)
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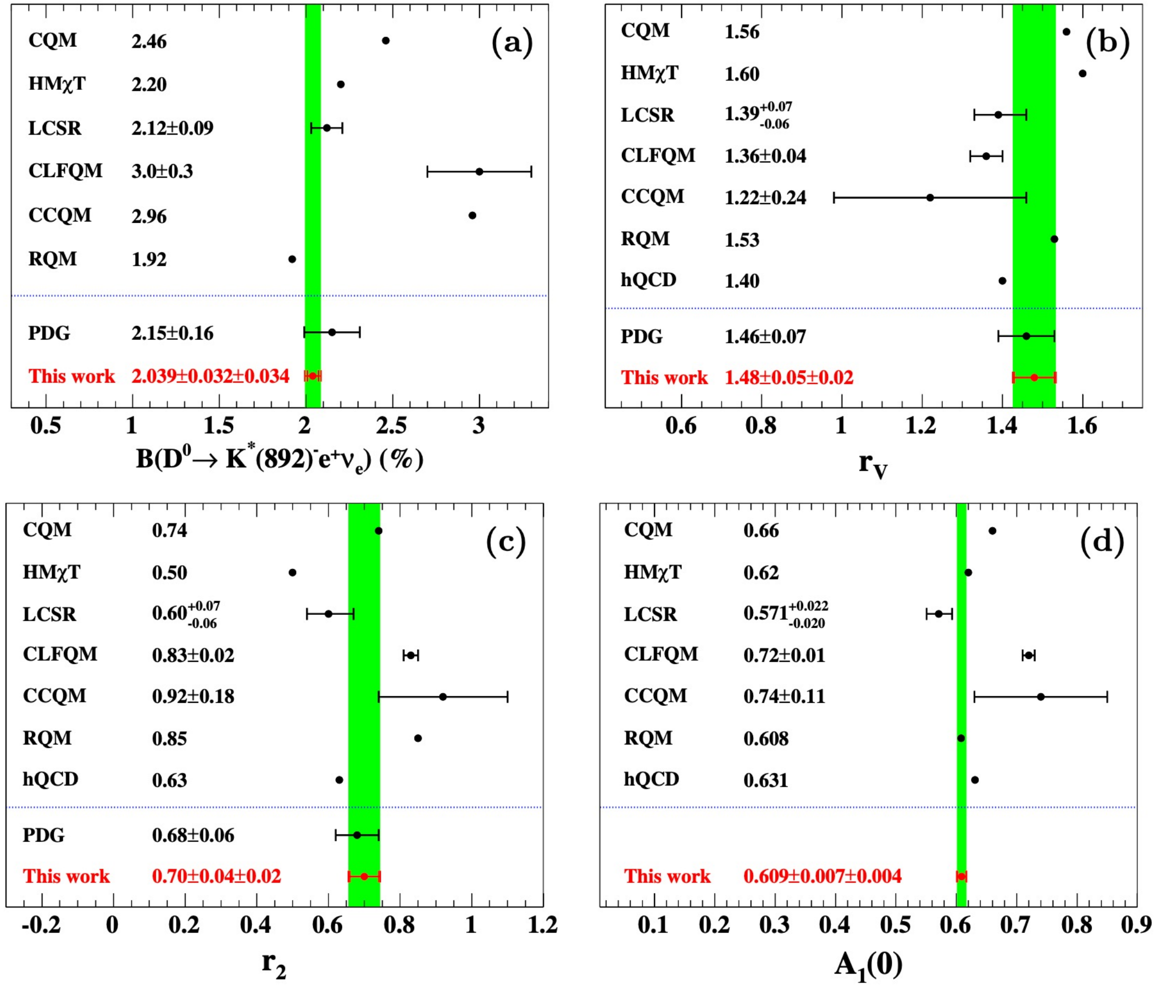


c -> d semi-leptonic decays : $D^0 \to \rho^- e^+ \nu_e$

Phys. Rev. D 110, 112018 (2024)

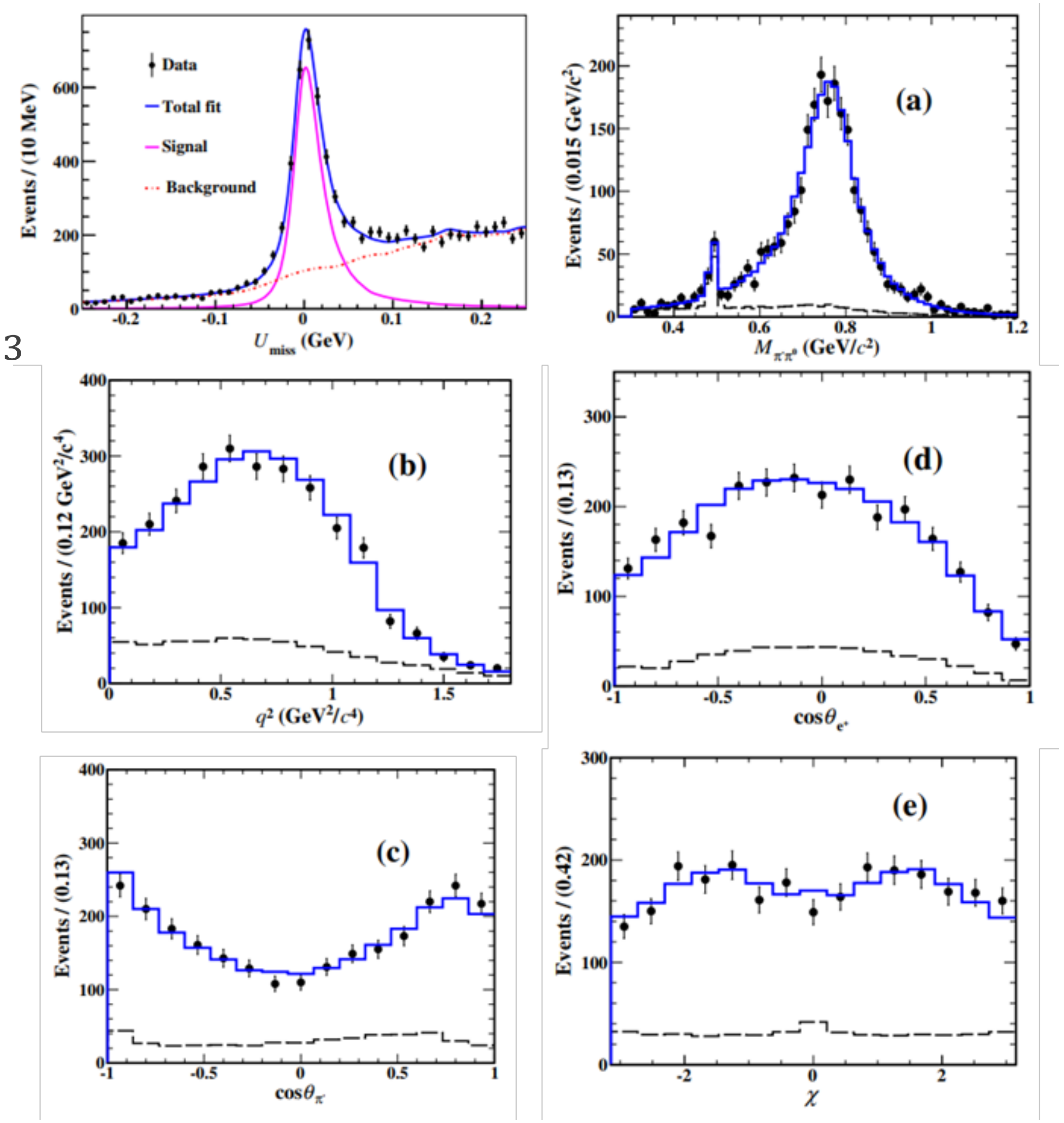
- 7.93fb^{-1} data @3.773GeV
- $N_{sig} = 3337 \pm 77$ (background level: 18.7%)
- $\mathcal{B}(D^0 \to \rho^- e^+ \nu_e)$= $(1.439 \pm 0.033 \pm 0.027)\times 10^{-3}$
- Form factor measurement:

$r_V = 1.548 \pm 0.079 \pm 0.041,$

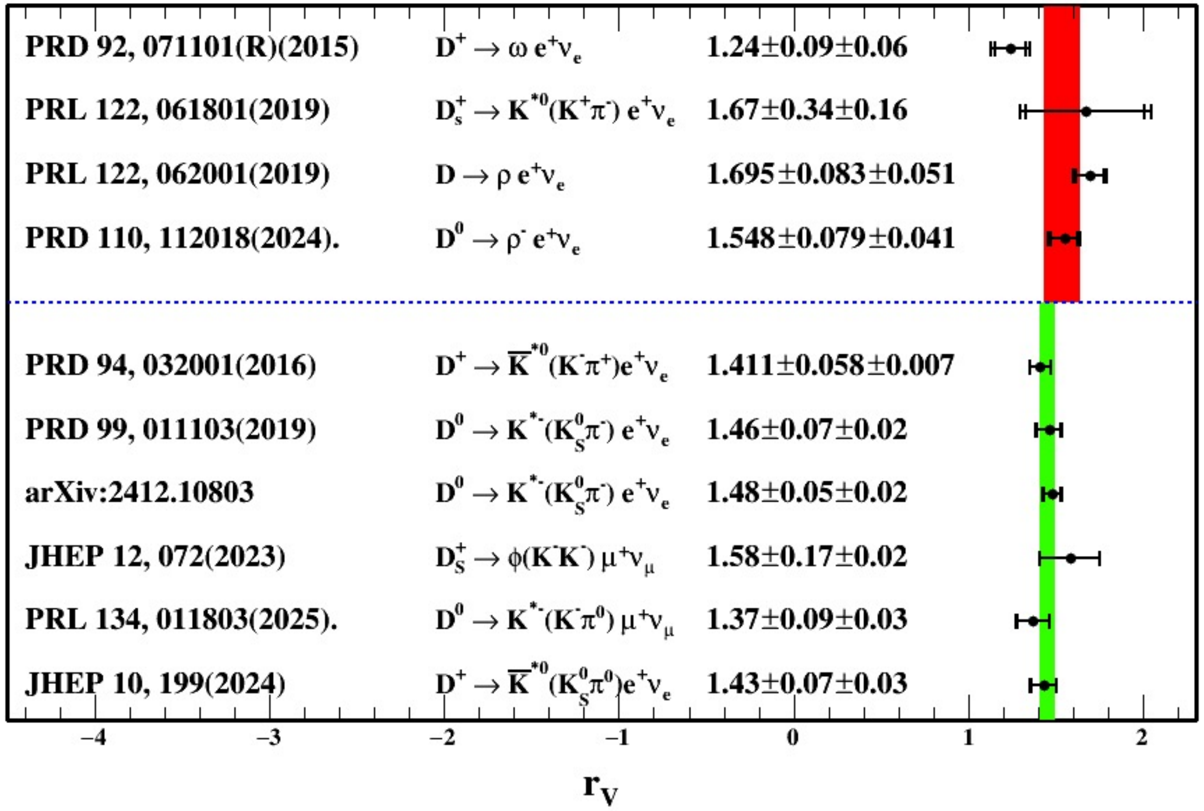
$r_2 = 0.823 \pm 0.056 \pm 0.026$

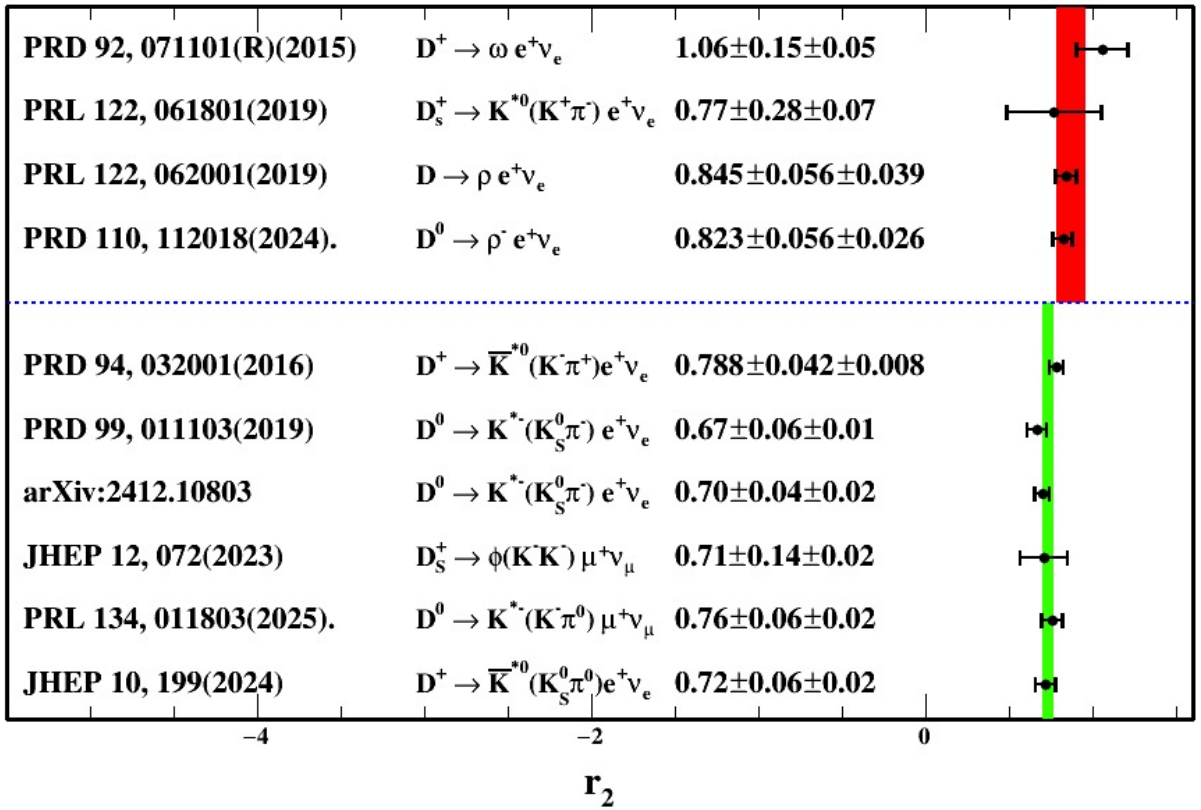
TABLE I. The theoretical calculation results of the hadronic form-factor ratios r_V and r_2 for $D^0 \to \rho(770)^- e^+ \nu_e$.

Theory	r_V	r_2
CQM [7]	1.53	0.83
CCQM [8]	1.26 ± 0.25	0.93 ± 0.19
LFQM [9]	1.47	0.78
LCSR [10]	1.34	0.62
HM_χT [11]	1.72	0.51



Comparisons of r_V and r_2





The differential decay rate of $D_{(s)} \to S\,\ell\,\nu_\ell$

$$\Gamma(D_{(s)} \to S\ell^+\nu_\ell)/dq^2 \propto |V_{cd(s)}|^2|f_+(q^2)|^2$$

$$S: a_0(980), f_0(500), f_0(980)$$

- Use least χ^2 method to fit the measured partial decay width in different q^2 bin.
- Taking the correlations among q^2 bins into account.
- FF in different form (The width needs to be considered ?)

– **Single pole form**

$$f_+(q^2) = \frac{f_+(0)}{1 - q^2/M_{pole}^2}$$

– **Modified pole model**

$$f_+(q^2) = \frac{f_+(0)}{\left(1 - \frac{q^2}{M_{pole}^2}\right)\left(1 - \alpha\frac{q^2}{M_{pole}^2}\right)}$$

– **ISGW2 model**

$$f_+(q^2) = f_+(q_{max}^2)\left(1 + \frac{r^2}{12}(q_{max}^2 - q^2)\right)^{-2}$$

– **Series expansion model**

$$f_+(t) = \frac{1}{P(t)\Phi(t,\ t_0)}a_0(t_0)(1 + \sum_{k=1}^{\infty} r_k(t_0)\left[z(t,t_0)\right]^k)$$

The differential decay rate of $D_{(s)} \to S \ell \nu_\ell$

- Point-like differential decay rate:

$$\frac{d\Gamma(D_{(s)}\to S\ell^+\nu_\ell)}{dq^2} = \frac{G_F^2|V_{cd(s)}|^2}{24\pi^3} p_S^3(m_\ell)|f_+(q^2)|^2$$

- Double differential decay rate:

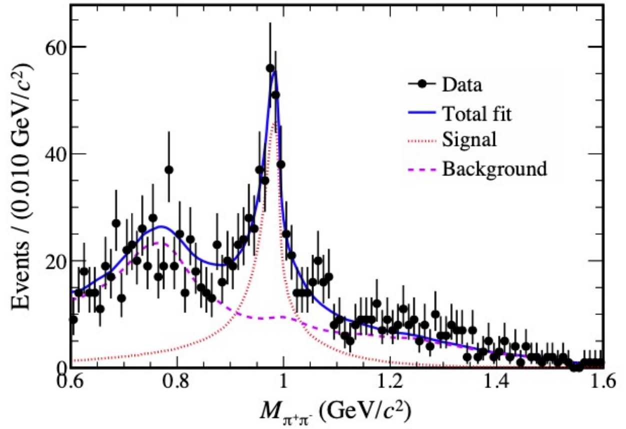
(N.N.Achasov *et al*., PRD102,016022(2020); W. Wang, PLB759,501(2016))

$$\frac{d^2\Gamma(D_{(s)}\to S\ell^+\nu_\ell)}{ds\,dq^2} = \frac{G_F^2|V_{cd(s)}|^2}{192\pi^4 m_{D_{(s)}}^3} \lambda^{\frac{3}{2}}\left(m_{D_{(s)}}^2, s, q^2\right)|f_+(q^2)|^2 P(s)$$

$$P(s) = \begin{cases} \dfrac{g_1\rho_{\pi\pi/\pi\eta}}{|m_0^2 - s - i(g_1\rho_{\pi\pi/\pi\eta} + g_1\rho_{KK})|^2}, & \text{Flatte: } f_0(980)/a_0(980) \\[2ex] \dfrac{m_{f_0}\Gamma(s)}{(s-m_{f_0}^2)^2 + m_{f_0}^2\Gamma^2(s)}, & \text{RBW: } f_0(500) \\[2ex] \dfrac{m_r\Gamma_{tot}(s)}{(m_r^2 - s - g_1^2\frac{s-s_A}{m_r^2-s_A}z(s))^2 + m_r^2\Gamma_{tot}^2(s)}, & \text{Bugg: } f_0(500) \end{cases}$$

Study of the $f_0(980)$ and $f_0(500)$ through the decay $D_s^+ \to \pi^+\pi^- e^+\nu_e$

Phys. Rev. Lett. 132, 141901 (2024)



- 7.33 fb^{-1} data @ 4.128-4.226 GeV ➔ $N_{\text{sig}} = 439 \pm 33$
- $\mathcal{B}(D_s^+ \to f_0(980)e^+\nu_e, f_0(980) \to \pi^+\pi^-) = (1.72 \pm 0.13 \pm 0.10)\times 10^{-3}$
  - ➔ **$s\bar{s}$ is dominant** based on $|f_0(980)\rangle = \sin\phi|\frac{1}{\sqrt{2}}(u\bar{u} + d\bar{d})\rangle + \cos\phi\,|s\bar{s}\rangle$
    $\phi = (19.7 \pm 12.8)^\circ$
- **First form factor measurement** with simple pole form:
  - ➔ $f_+^{f_0}(0)|V_{cs}| = 0.504 \pm 0.017 \pm 0.035$
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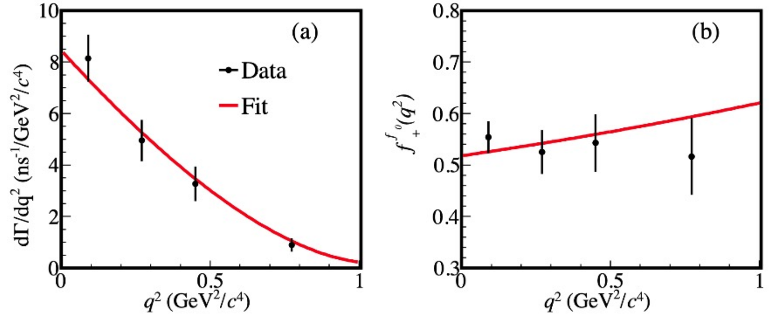
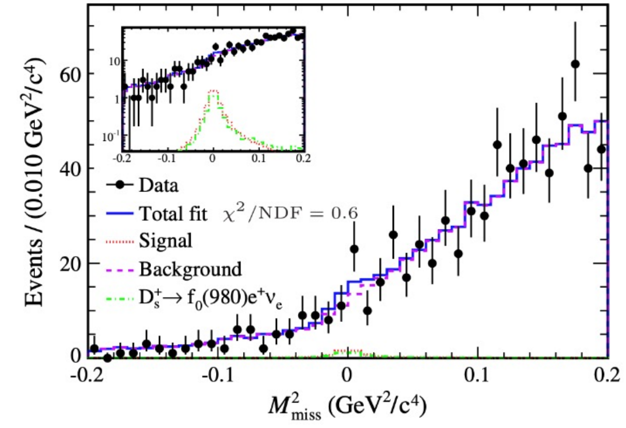


	This work	CLFD [6]	DR [6]	QCDSR [7]	QCDSR [8]	LCSR [9]	LFQM [11]	CCQM [12]
$f_+^{f_0}(0)$	$0.518 \pm 0.018_{\text{stat}} \pm 0.036_{\text{syst}}$	0.45	0.46	0.50 ± 0.13	0.48 ± 0.23	0.30 ± 0.03	0.24 ± 0.05	0.36 ± 0.02
Difference (σ)	—	1.7	1.4	0.1	0.2	4.3	4.3	2.8
ϕ	$\phi = (19.7 \pm 12.8)^\circ$	$(32 \pm 4.8)^\circ$	$(41.3 \pm 5.5)^\circ$	35°	$(8^{+21}_{-8})^\circ$	—	$(56 \pm 7)^\circ$	31°

- **First search** of $D_s^+ \to f_0(500)e^+\nu_e, f_0(500) \to \pi^+\pi^-$ ($M_{\pi^+\pi^-} < 0.45$ GeV/c²)
- $\mathcal{B}(D_s^+ \to f_0(500)e^+\nu_e, f_0(500) \to \pi^+\pi^-) < 3.3\times 10^{-4}$



Study of the $f_0(980)$ and $f_0(500)$ through the decay $D_s^+ \to \pi^+\pi^- e^+\nu_e$

Phys. Rev. Lett. 132, 141901 (2024)

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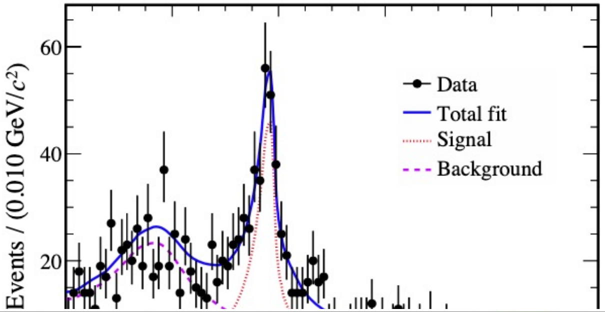

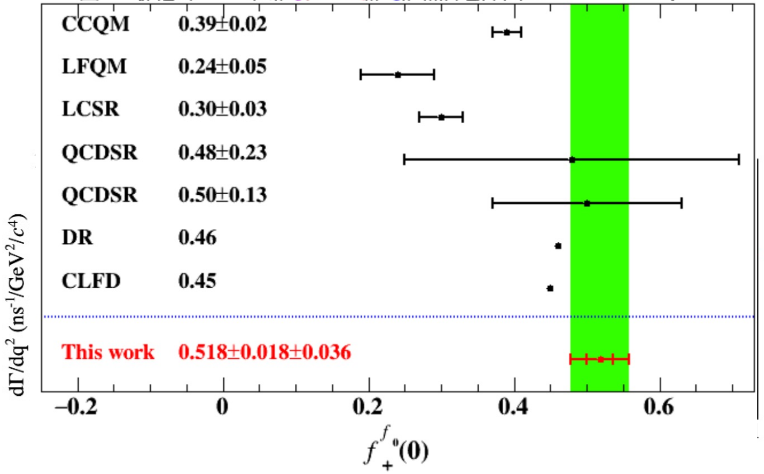

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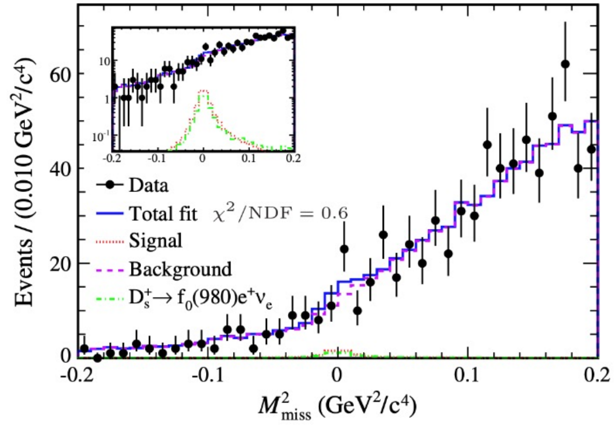
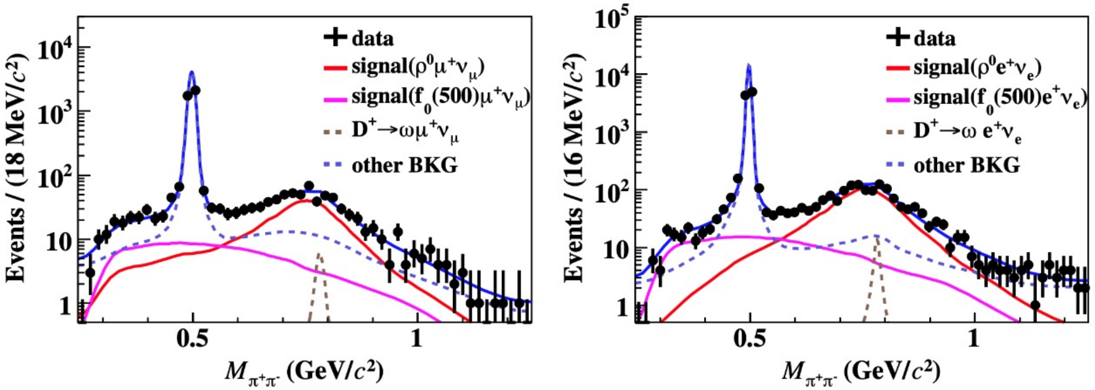


Study of the decay $D^+ \to f_0(500)\ell^+\nu_\ell$

Phys. Rev. D 110, 092008 (2024)

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

Signal mode	$N_{\rm obs}$	$\mathcal{S}$ (σ)	$\epsilon_{\rm sig}$ (%)	$\mathcal{B}_{\rm sig}(\times 10^{-3})$
$f_0(500)\mu^+\nu_\mu$	209 ± 38	5.9	18.93 ± 0.13	0.72 ± 0.13
$\rho^0\mu^+\nu_\mu$	496 ± 38	> 10	19.86 ± 0.13	1.64 ± 0.13
$f_0(500)e^+\nu_e$	412 ± 43	> 10	44.76 ± 0.25	0.60 ± 0.06
$\rho^0 e^+\nu_e$	1237 ± 47	> 10	44.12 ± 0.25	1.84 ± 0.07



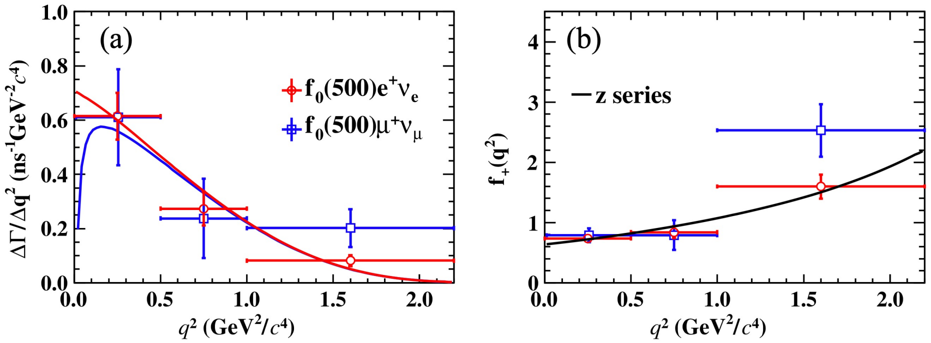
➔ The measured BF of $D^+ \to f_0(500)\ell^+\nu_\ell$ are closer to **tetraquark assumption**.
R.M. Wang et al, PRD107,056022 (2023)
Y.K. Hsiao et al, arXiv:2306.06091

- **First FF measurement** of $D^+ \to f_0(500)(\pi^+\pi^-)\ell^+\nu_\ell$.

Based Z series expansion for FF and Bugg form for $f_0(500)$

➔ $f_+^{f_0}(0)|V_{cd}| = 0.143 \pm 0.014 \pm 0.011$

➔ $f_+^{f_0}(0) = 0.63 \pm 0.06 \pm 0.05$



ps: $|V_{cd}| = 0.22486 \pm 0.00067$ from SM global fit (PDG2022)

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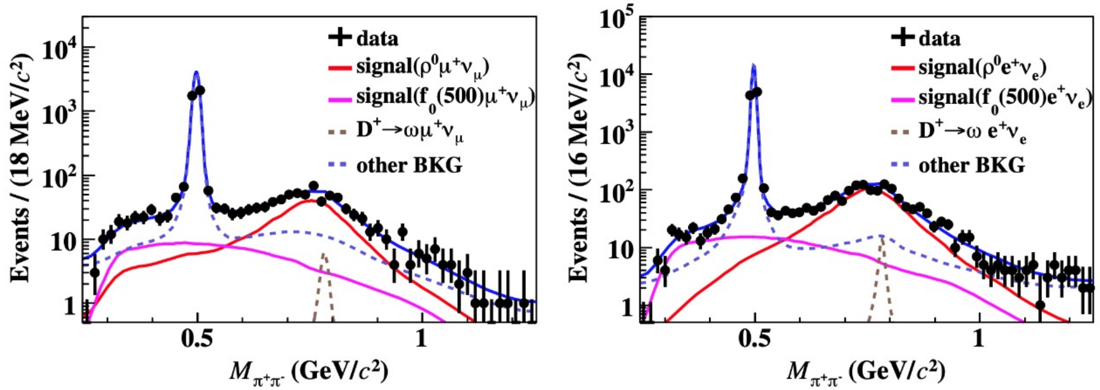

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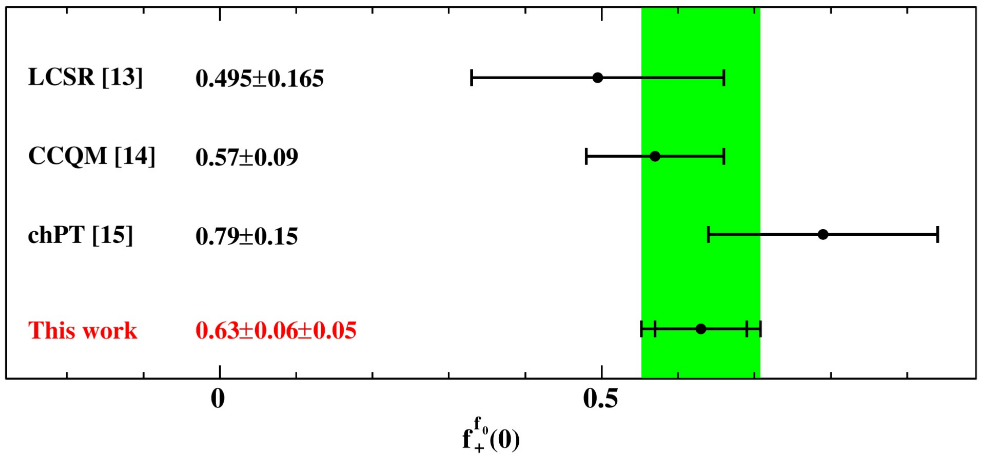


Study of the decay $D^0 \to a_0(980)^-(\eta\pi^-)e^+\nu_e$

arXiv: 2411.07730 (Submitted to PRL)

- 7.93 fb^{-1} data @ 3.773 GeV ➔ $N_{sig} = 51.8 \pm 10.0$
- **Updated BF measurement** of $D^0 \to a_0(980)^- e^+\nu_e$.

$\mathcal{B}(D^0 \to a_0(980)^- e^+\nu_e, a_0(980)^- \to (\eta\pi^-))$

$= (0.86 \pm 0.17 \pm 0.05)\times 10^{-4}$

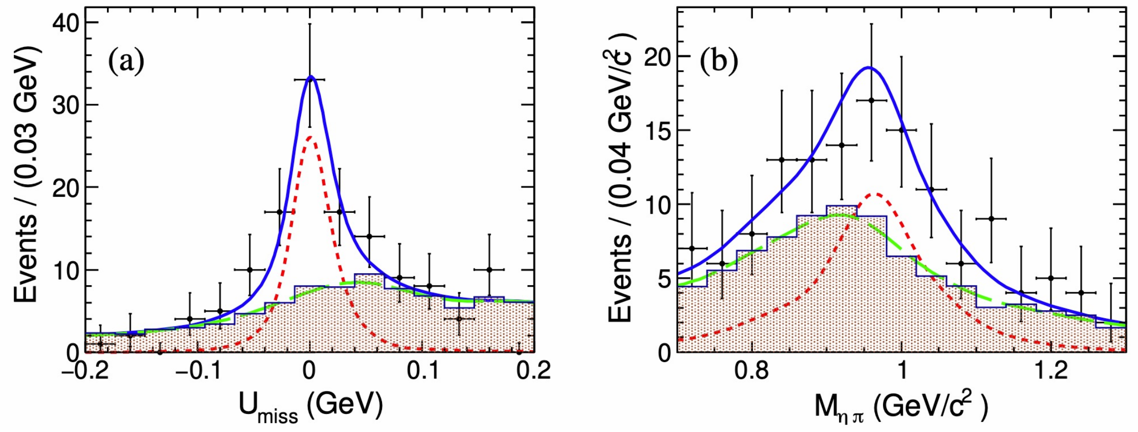
- **First FF measurement:**

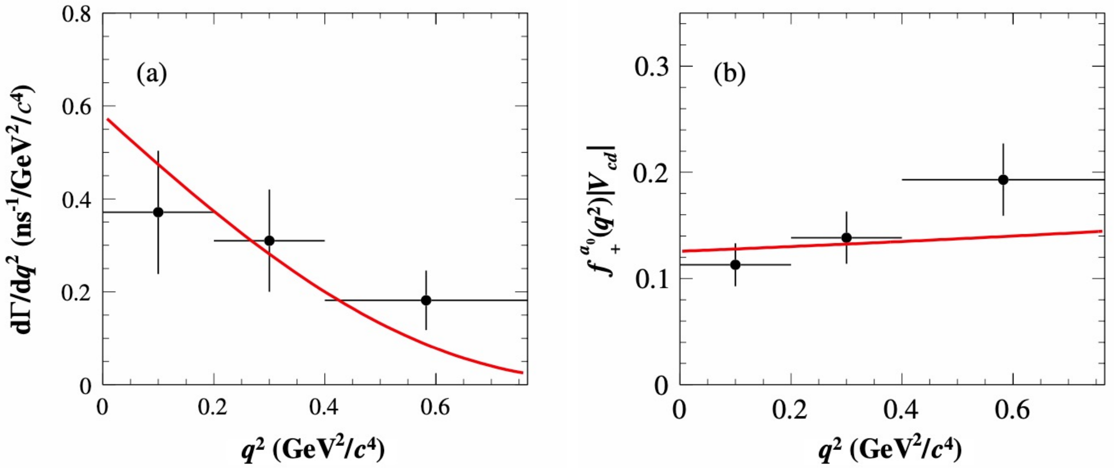
Single-pole form for FF and Bugg form for $a_0(980)^-$

➔ $f_+^{a_0}(0)|V_{cd}| = 0.126 \pm 0.013 \pm 0.003$

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

ps: $|V_{cd}| = 0.22487 \pm 0.00068$ from SM global fit (PDG2024)





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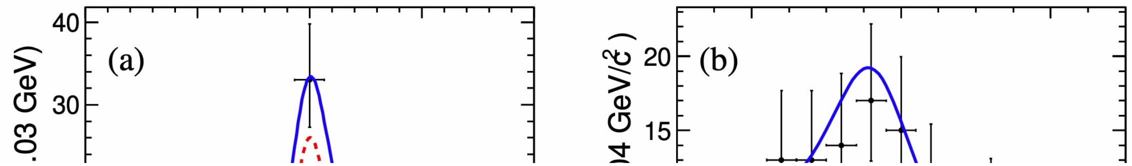

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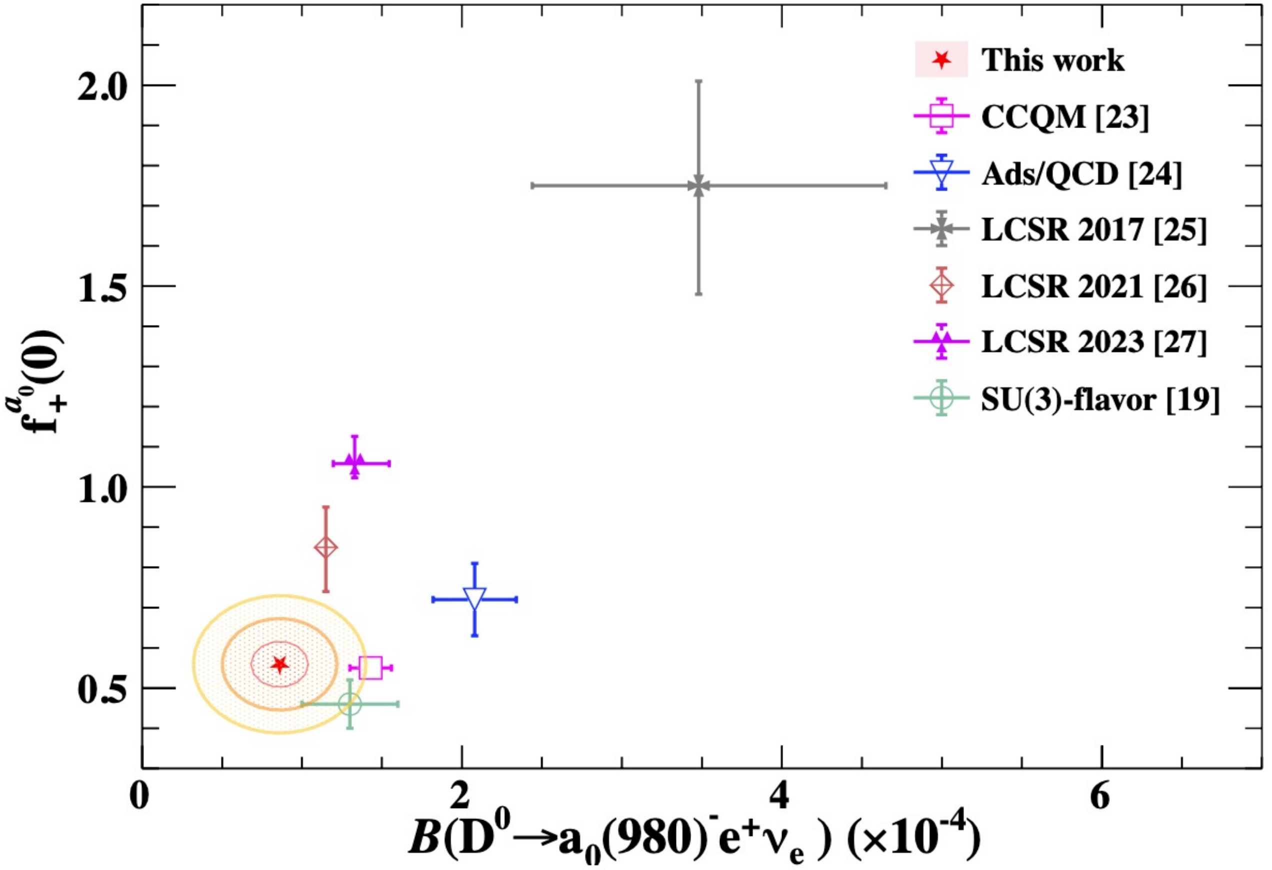


Content

01 **Physics motivation ✓**

02 **Data and analysis method ✓**

03 **Some recent results ✓**

04 **Summary and prospect ✓**

Summary and prospect

- Summary

BESIII have performed high-precision measurements on charm meson semi-leptonic decays to vector mesons ($\rho(770), K^*(892), \phi(1020)$) and scalar mesons ($f_0(500), f_0(980)$, $a_0(980)$) using the unique advantage of charm meson pair produced at threshold .

  - Absolute branching fraction measurements using double-tagging method
  - Hadronic form factors measurements through amplitude analysis.
  - Can help to measure CKM matrix elements $|V_{cs}|/|V_{cd}|$
  - Help to understand the nature of light scalar mesons

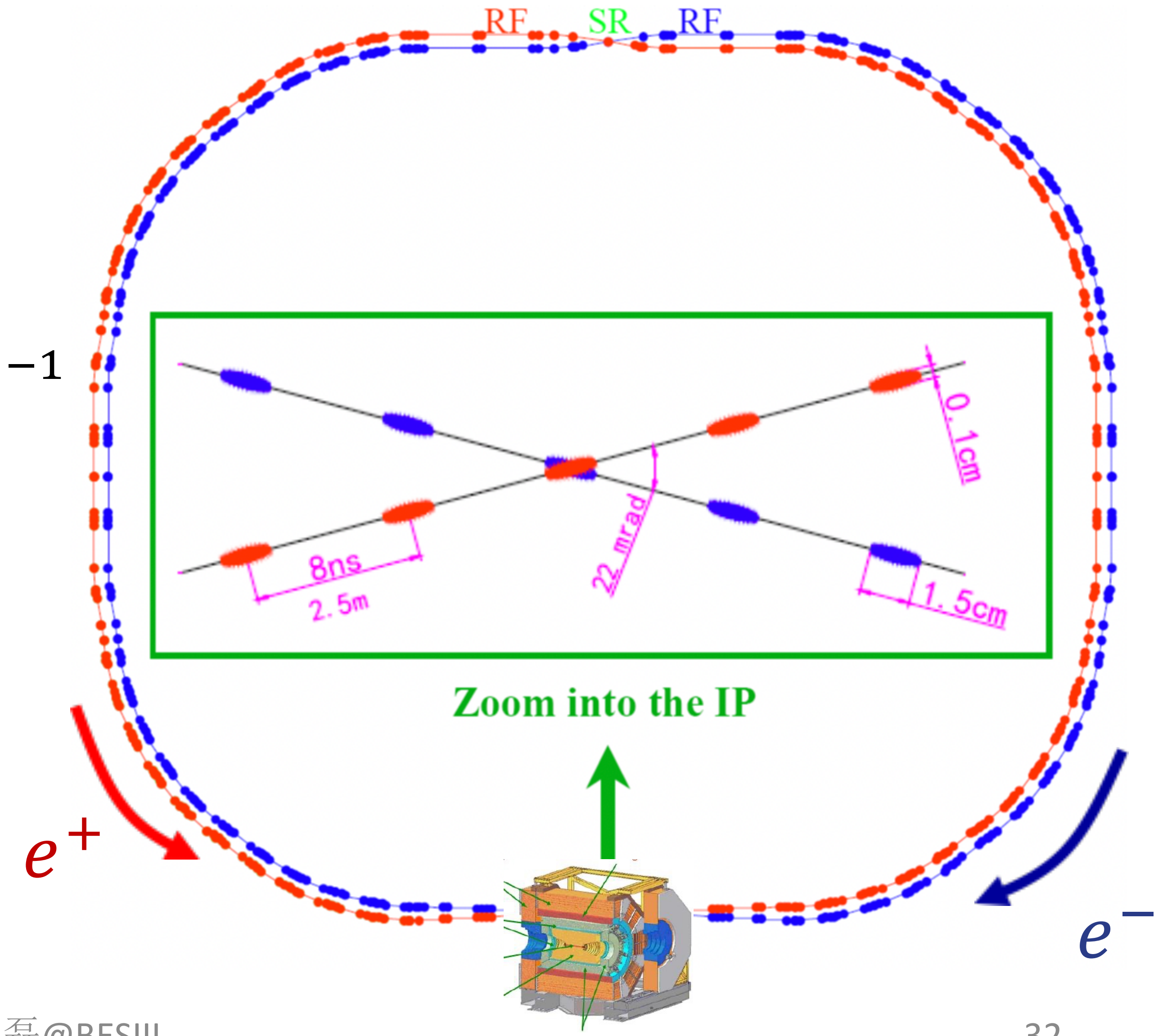
- prospect
  - BESIII has ~**20 fb^{-1}** @3.773 GeV in total now.
  - More studies are on the way, especially the muon channels.
  - More jointed measurements of multiple channels

BESIII experiment

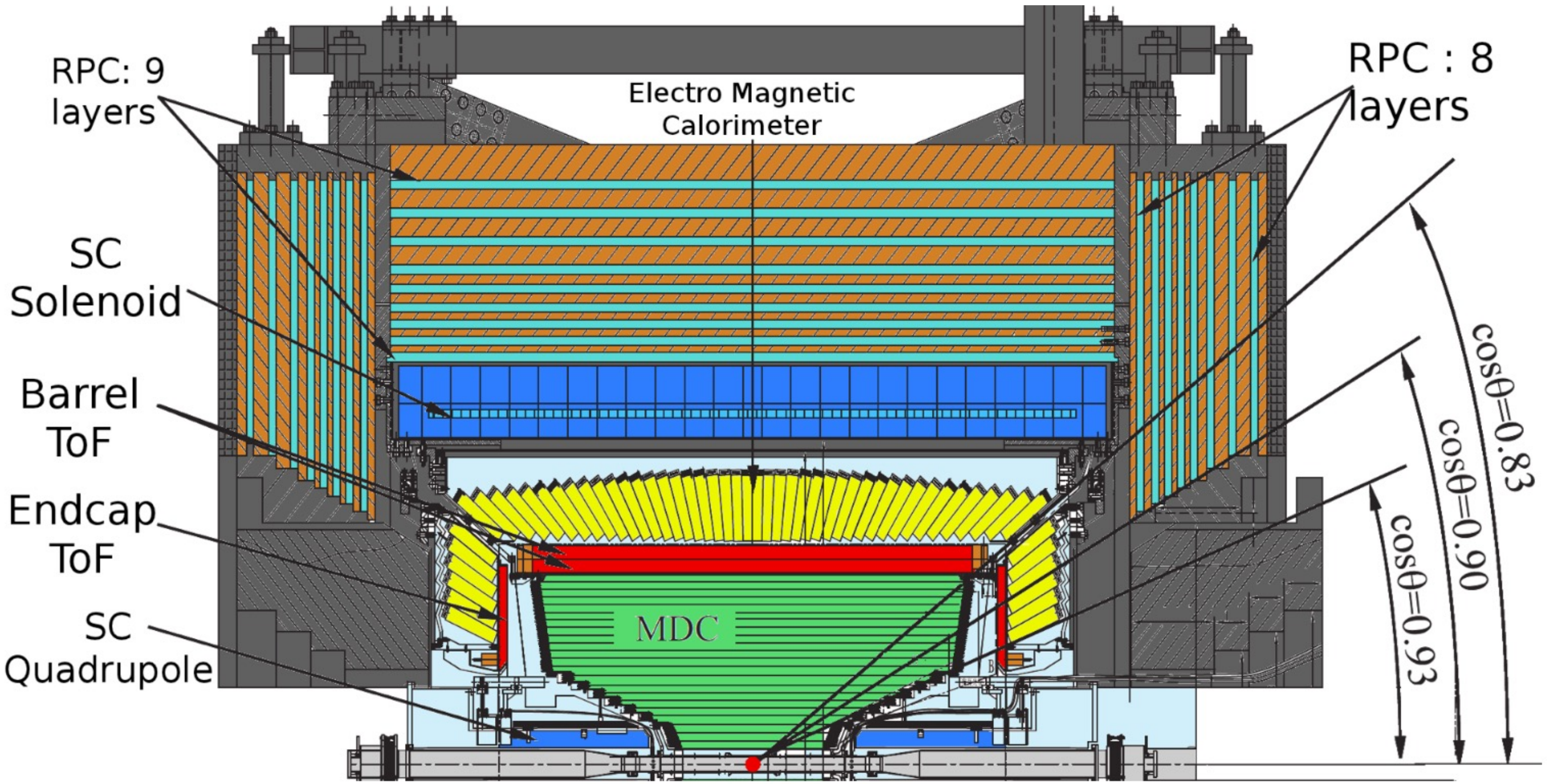
BEPCII collider

- Two ring symmetric e^+e^- collider
- Circumference: 240 m
- Design luminosity: $1\times10^{33}cm^{-2}s^{-1}$

  Achieved time: 5 April, 2016
- E_{cm}: 2 – 5 GeV
- Beam crossing angle: 22 mrad



BESIII detector



MDC

$\frac{\delta p}{p} < 0.5\%$ @1 GeV

$\frac{\delta(dE/dx)}{dE/dx} < 6\%$

TOF

δt 80 ps Barrel

δt 110 ps Endcap

EMC

$\frac{\delta E}{E} < 2.5\%$ @1 GeV

$\delta z = 0.6/\sqrt{E}$

MUC

$\delta(xy) <$2 cm