Leptonic and semi-leptonic charm decays at BESIII

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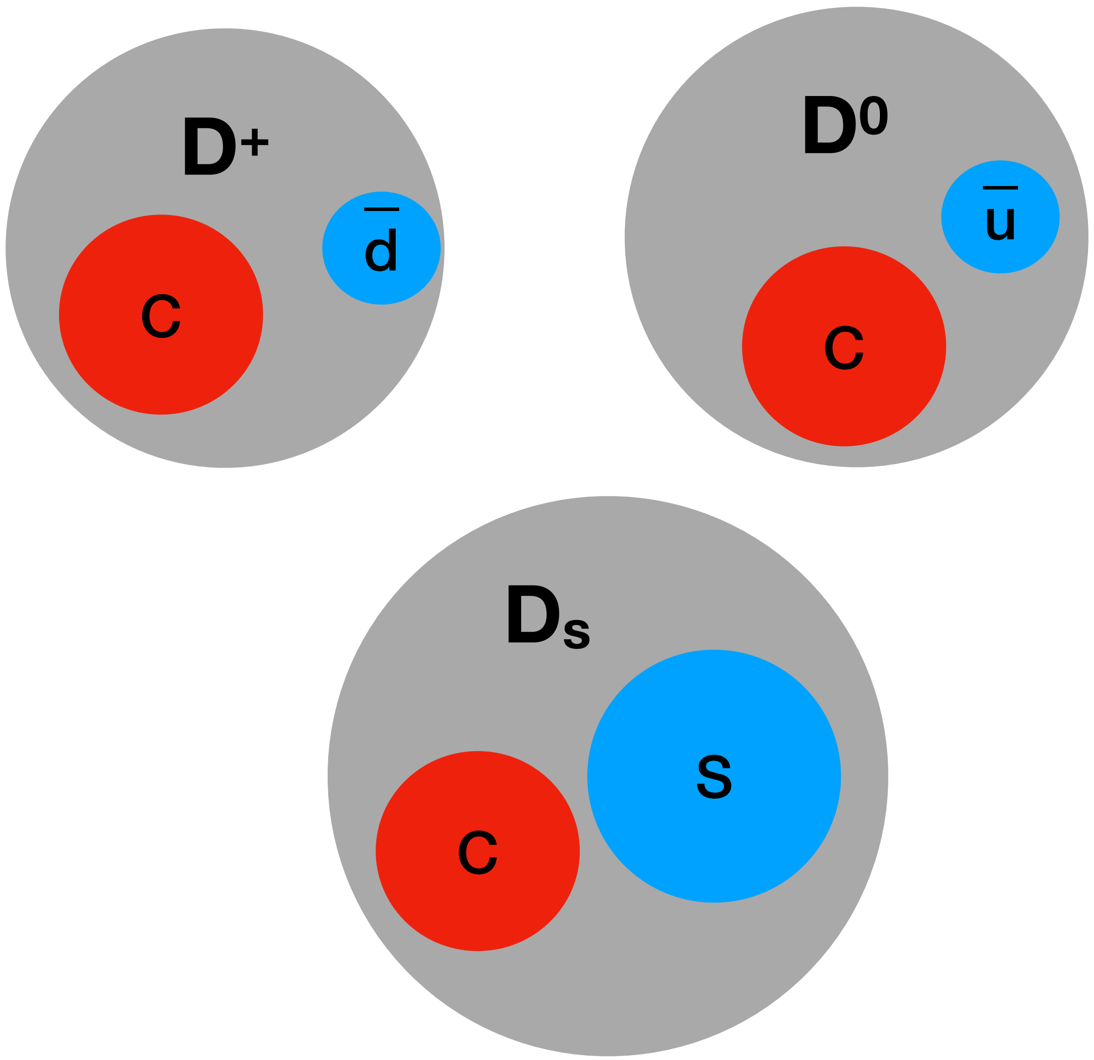
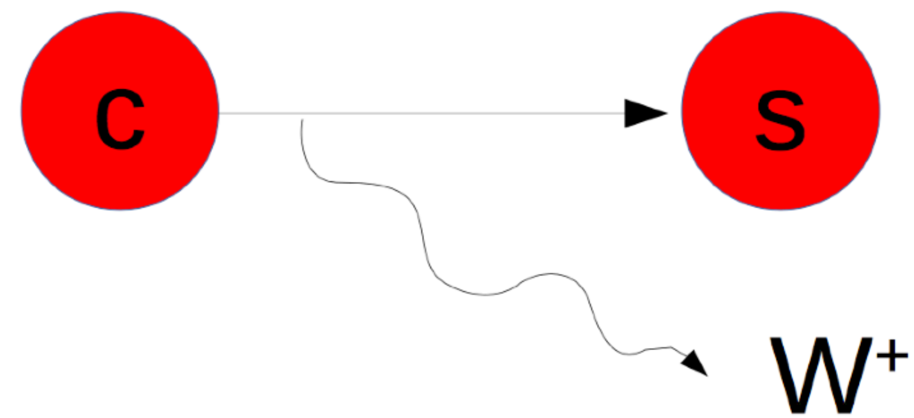
On behalf of the BESIII Collaboration

Outline

- Introduction
  - D^0, D^+,and D_s Dataset
  - DTag
- Pure leptonic decays of D^0
- Semi-leptonic decays of $D^{0(+)}$
- (Semi-) leptonic decays of D_s
- Summary

Physics of $D_{(s)}$ meson





Cabibbo-favored decay

- The lightest mesons containing a single charm quark
- Only decay through the weak interaction

BESIII Data Taken near DD^{bar} Threshold

- BEPCII e^+e^- collider
- 2.9 fb^{-1} dataset at $\psi(3770) \rightarrow DD^{bar}$ resonance

Not even enough energy for one additional pion

- 3.19 fb^{-1} dataset at E_{cm} 4.178GeV
  - D_s are produced mostly via $e^+e^- \rightarrow D_sD_s^*$
- XYZ dataset at E_{cm} 4.19 - 4.23 GeV (about .8x of 4180 data)
- Advantages:

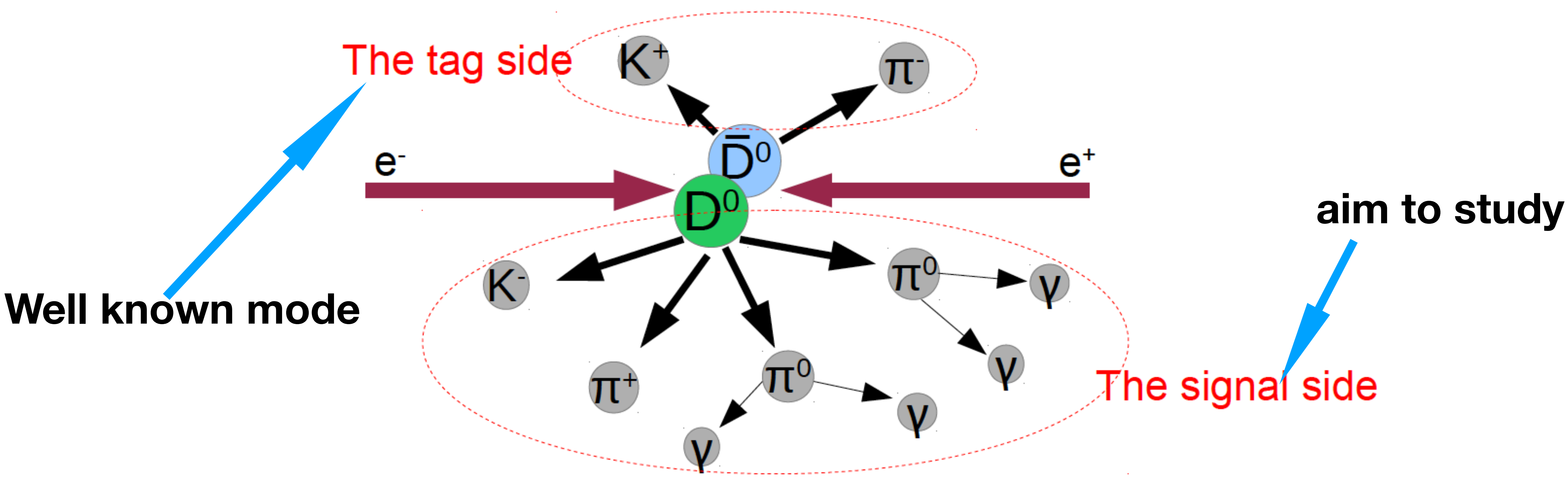
Clean **Tagging**

Access to absolute branching fraction

Many systematic uncertainties cancel

DTag Technique

- Two types of samples
- Single-tag (ST):
  - reconstruct only one D meson
- Double-tag (DT):
  - reconstruct both D mesons (fully reconstruct the event)



Branching Fraction and Tagging

- Single tag (ST)

$$N^{\rm ST}_{\rm tag} = 2N_{D^0\bar{D}^0}\mathcal{B}_{\rm tag}\varepsilon_{\rm tag}$$

- Double tag (DT)

$$N^{\rm DT}_{\rm tag,sig} = 2N_{D^0\bar{D}^0}\mathcal{B}_{\rm tag}\mathcal{B}_{\rm sig}\varepsilon_{\rm tag,sig}$$

$\varepsilon_{\rm tag,sig} \approx \varepsilon_{\rm tag}\varepsilon_{\rm sig}$ (factorization)

where $N_{D^0\bar{D}^0}$ is the total number of produced $D^0\bar{D}^0$ pairs, $\mathcal{B}_{\rm tag(sig)}$ is the branching fraction of the tag (signal) side, and the ε are the corresponding efficiencies.

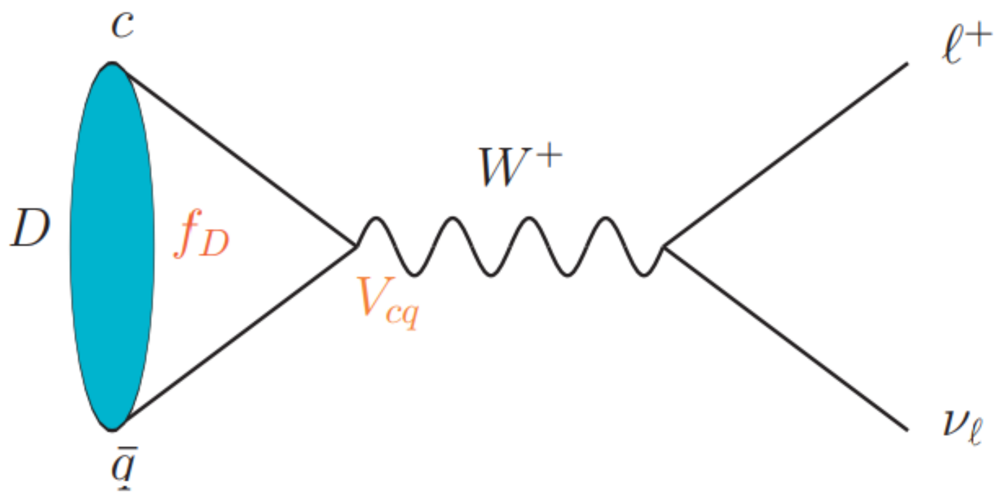
$$\mathcal{B}_{\rm sig} = \frac{N^{\rm DT}_{\rm tag,sig}}{N^{\rm ST}_{\rm tag}}\frac{\varepsilon_{\rm tag}}{\varepsilon_{\rm tag,sig}}$$

$N_{D^0\bar{D}^0}$, $\mathcal{B}_{\rm tag}$ are canceled.
$\varepsilon_{\rm tag}$ is approximately canceled due to factorization

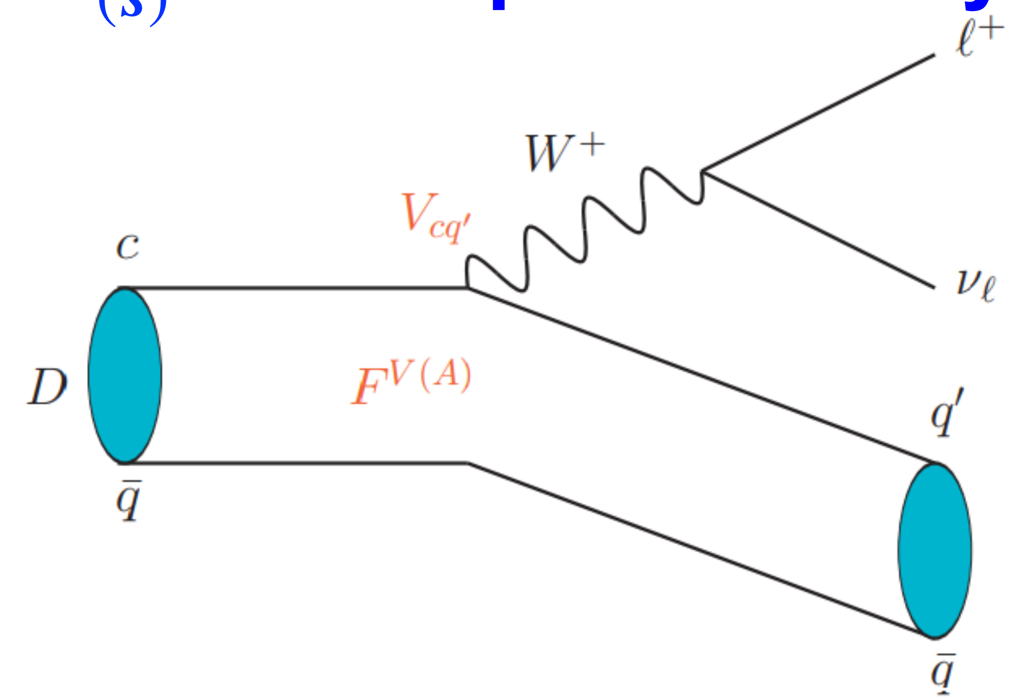
This is the basic idea for branching fraction.
Equations used in analysis vary case by case.

Introduction

$D_{(s)}$ pure leptonic decay



$D_{(s)}$ semi-leptonic decay



$$\mathcal{M} \propto |V_{cs(d)}| H^\mu L_\mu$$

$$\Gamma(D^+_{(s)} \to l^+ \nu_l) \propto \left| f_{D^+_{(s)}} \right|^2 \bullet \left| V_{cd(s)} \right|^2$$

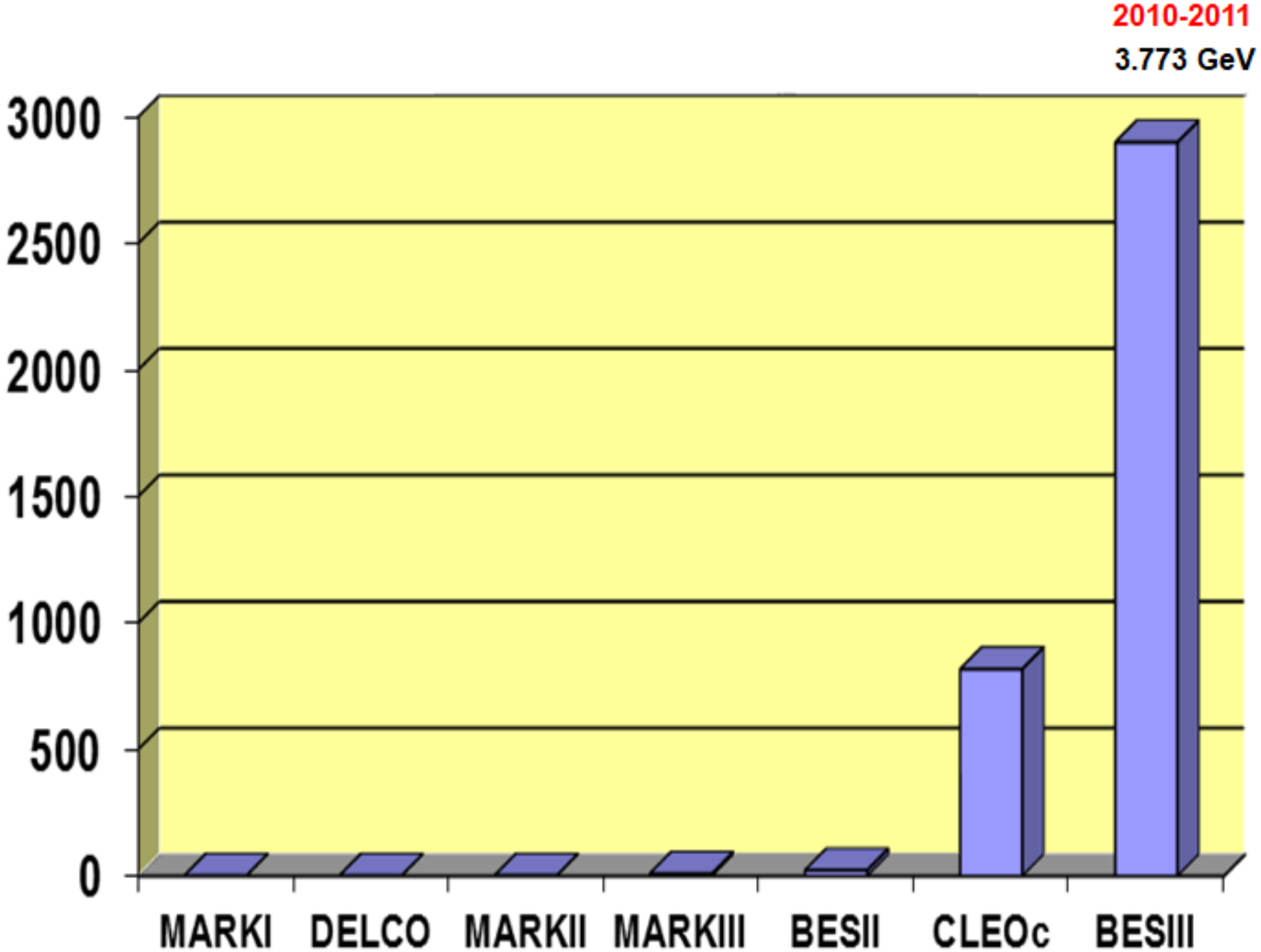
$$\Gamma\left(D_{(s)} \to P\, l^+ \nu_l \right) \propto \left| f_+(q^2) \right|^2 \bullet \left| V_{cd(s)} \right|^2$$

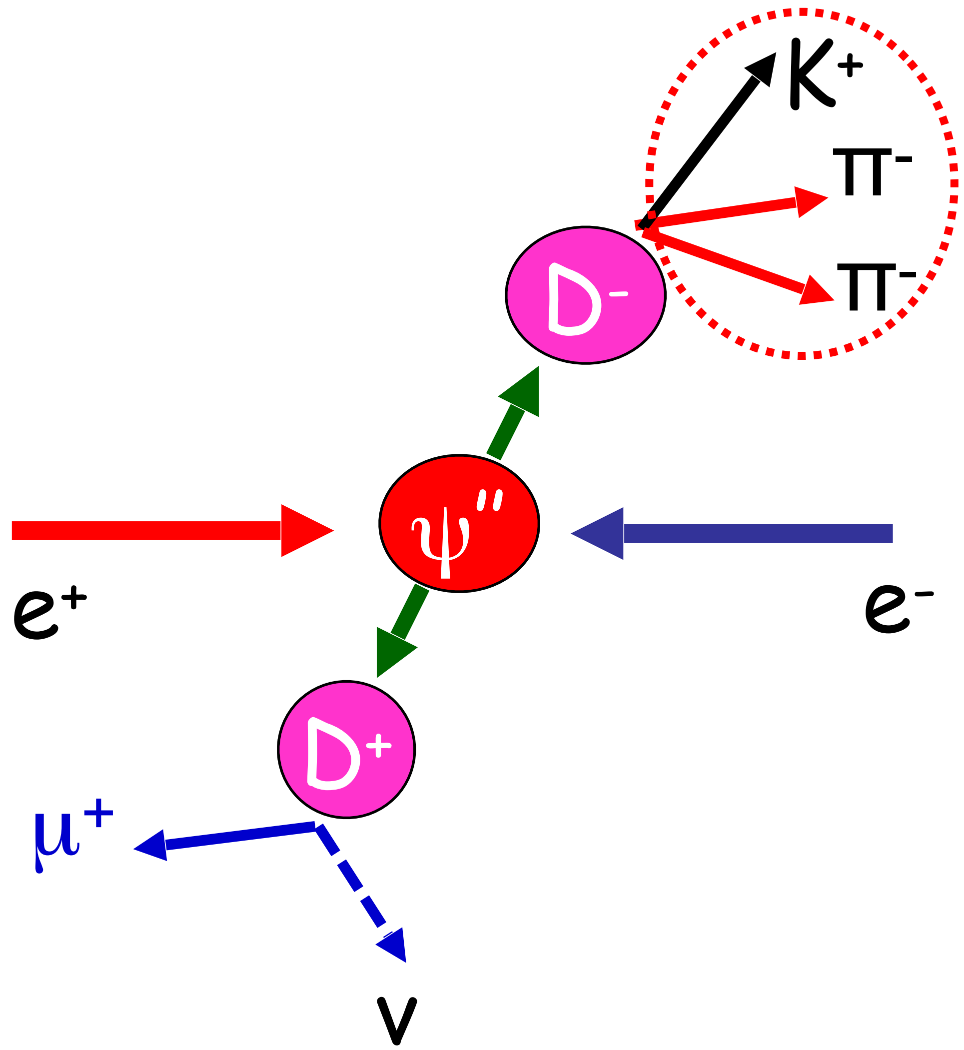
Decay constant $f_{D^+_{(s)}}$, form factor $f_+(q^2)$: Calibrate Lattice QCD

CKM matrix element |*Vcd(s)*|: Test the unitarity of CKM matrix

Lepton flavor universality test in charm sector

$D^{0(+)}$ samples at $\psi(3770)$



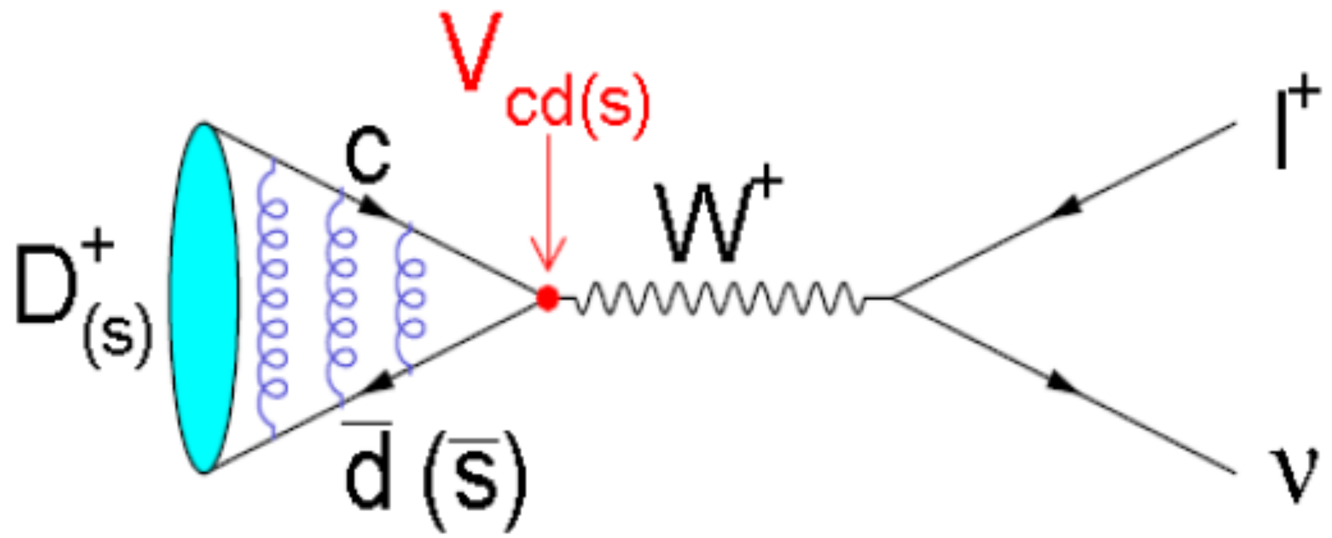


Neutrino is the only particle missing in an event

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

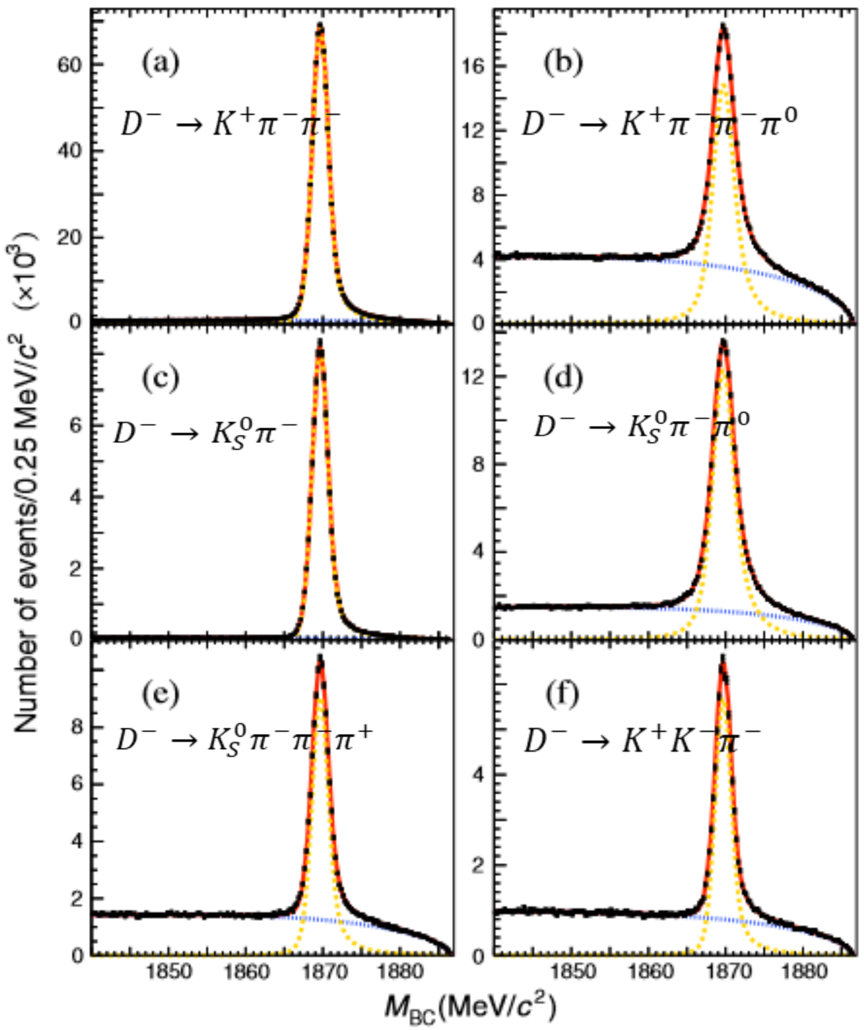
$$M^2_{\rm miss} = E^2_{\rm miss} - |\vec{p}^{\,2}_{\rm miss}|$$

Pure leptonic D decay

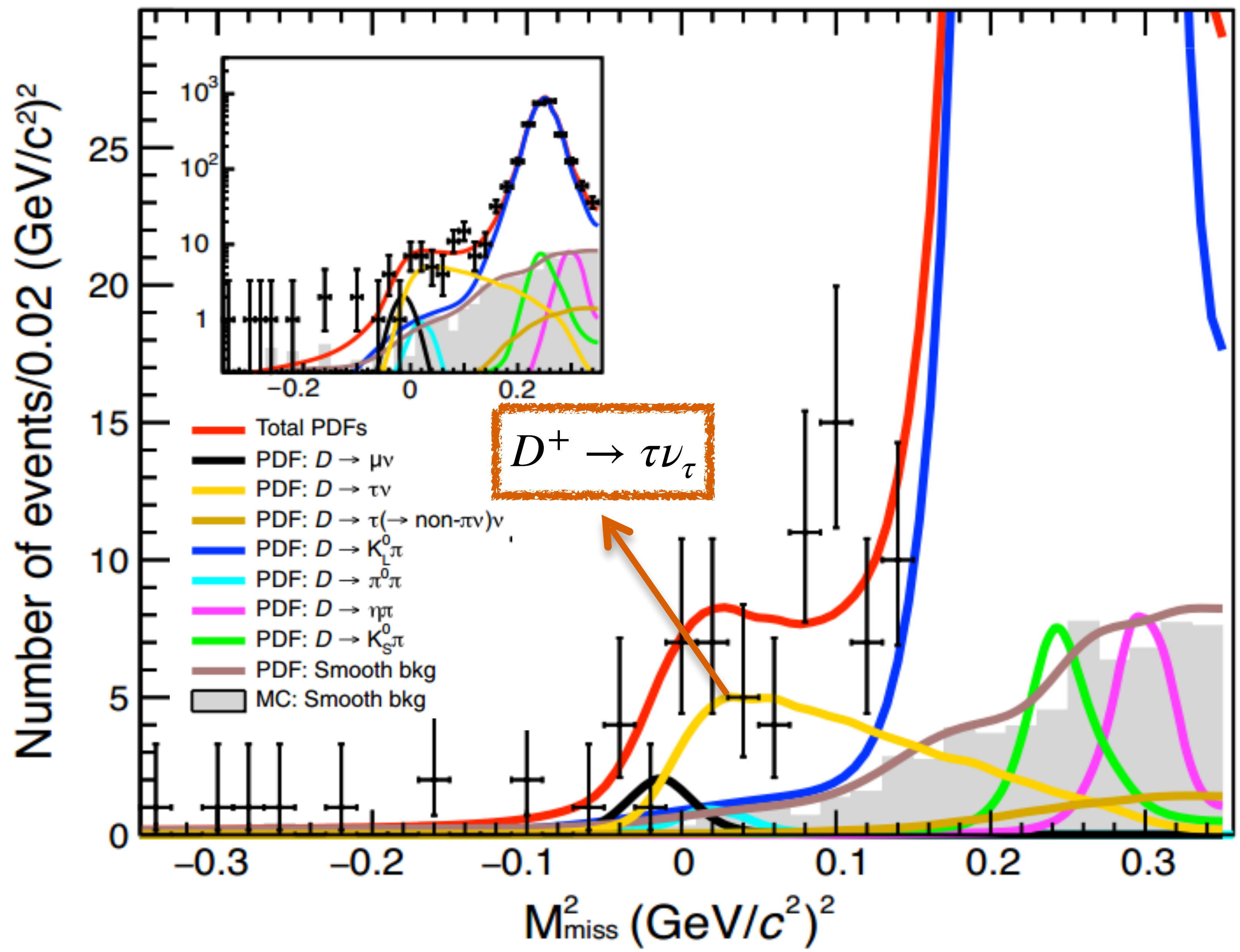


$$\Gamma\left(D^+_{(s)} \to l^+ \nu\right) = \frac{G_F^2 f^2_{D^+_{(s)}}}{8\pi} \left|V_{cd(s)}\right|^2 m_l^2 \, m_{D^+_{(s)}} \left(1 - \frac{m_l^2}{m^2_{D^+_{(s)}}}\right)^2$$

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



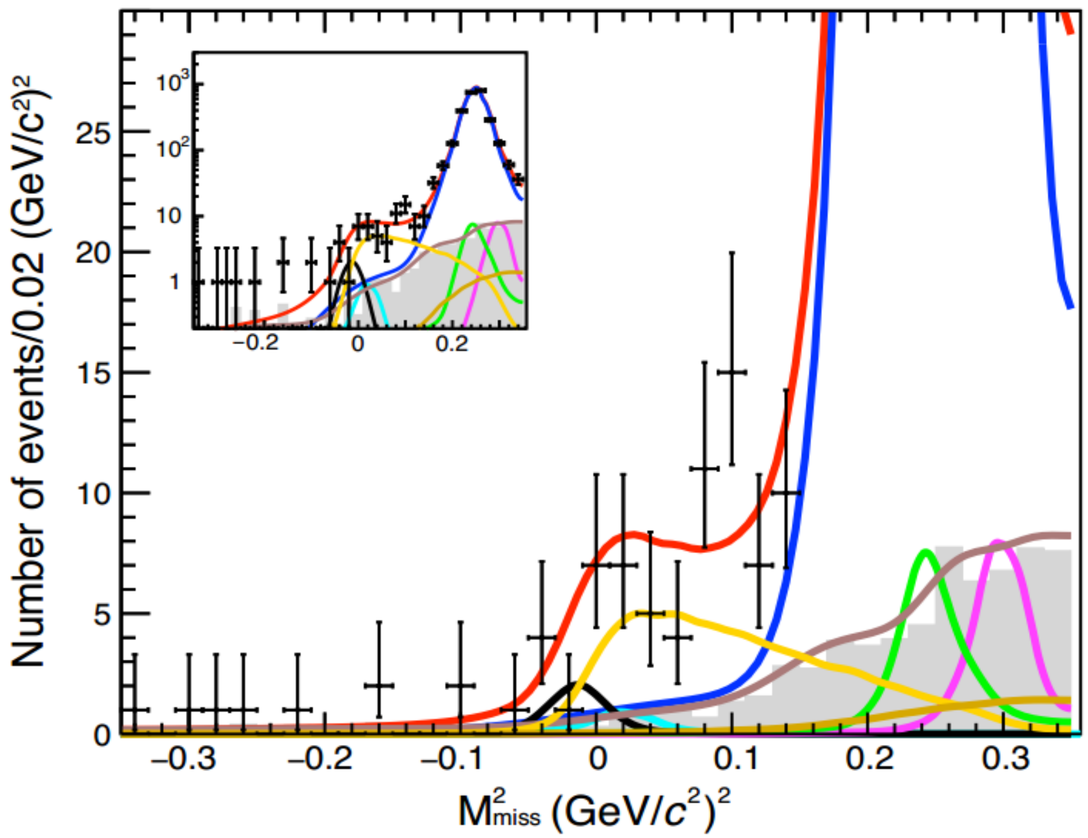
Tag modes, i	N^i_{tag} ($\times 10^3$)
$K^+\pi^-\pi^-$	797.6 ± 1.0
$K^+\pi^-\pi^-\pi^0$	245.1 ± 0.7
$K_S^0\pi^-$	92.6 ± 0.3
$K_S^0\pi^-\pi^0$	206.3 ± 0.6
$K_S^0\pi^-\pi^-\pi^+$	110.2 ± 0.4
$K^+K^-\pi^-$	68.1 ± 0.3



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

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

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



137±27 signal events

First observation with a significance of 5.1σ.

$$R_D \equiv \frac{\Gamma(D^+ \to \tau^+ \nu_\tau)}{\Gamma(D^+ \to \mu^+ \nu_\mu)} = 3.21 \pm 0.77$$

consistent

SM:

$$R_{\tau/\mu} = \frac{\Gamma(D^+ \to \tau^+ \nu_\tau)}{\Gamma(D^+ \to \mu^+ \nu_\mu)} = \frac{m_\tau^2 (1 - \frac{m_\tau^2}{M_{D^+}^2})^2}{m_\mu^2 (1 - \frac{m_\mu^2}{M_{D^+}^2})^2} = 2.7$$

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

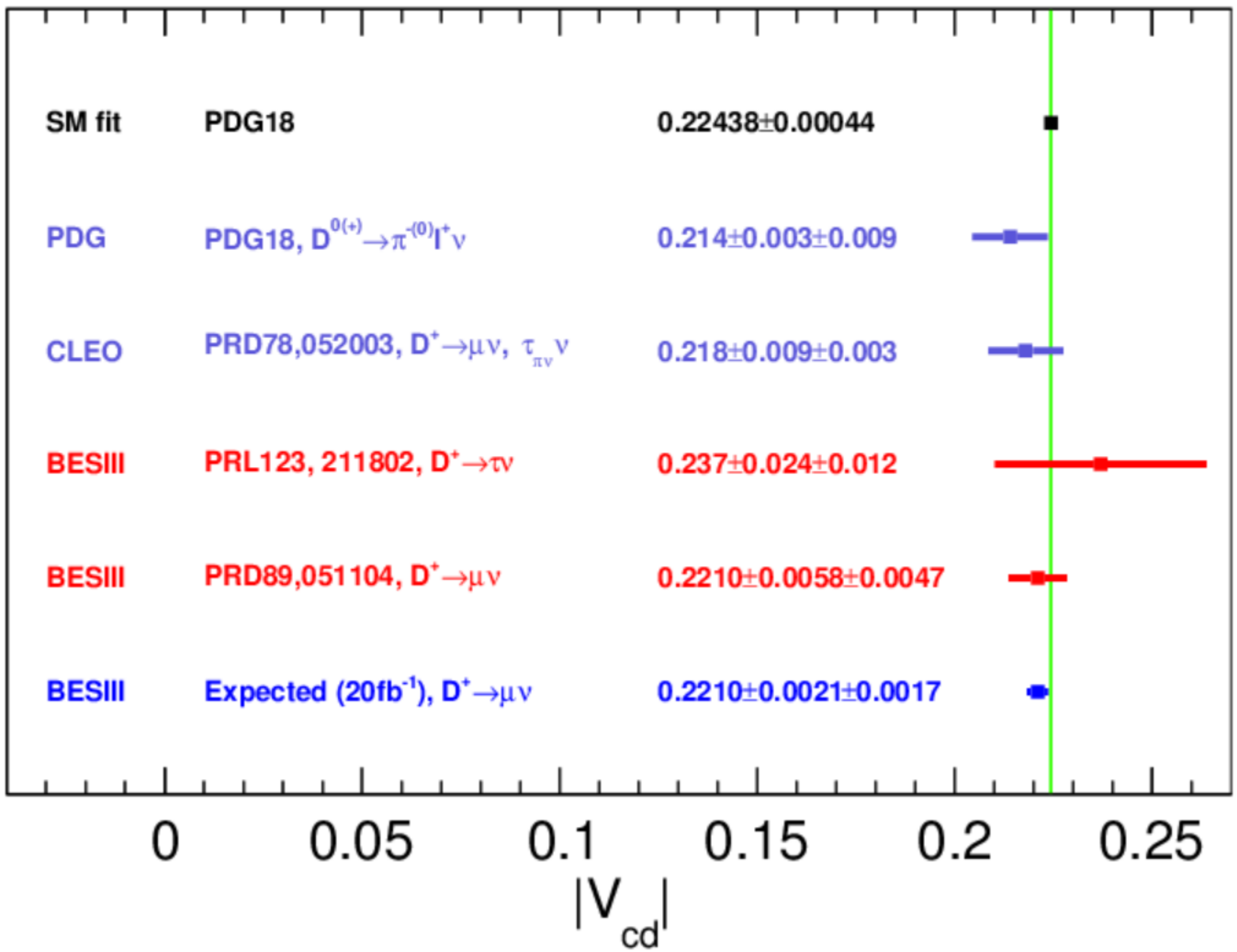
$$|V_{cd}| = 0.237 \pm 0.024_{\text{stat.}} \pm 0.012_{\text{syst.}} \pm 0.001_{\text{ex-syst}}$$

$$f_{D^+} = 224.5 \pm 22.8_{\text{stat.}} \pm 11.3_{\text{syst.}} \pm 0.9_{\text{ex-syst.}}\ \text{MeV}$$

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

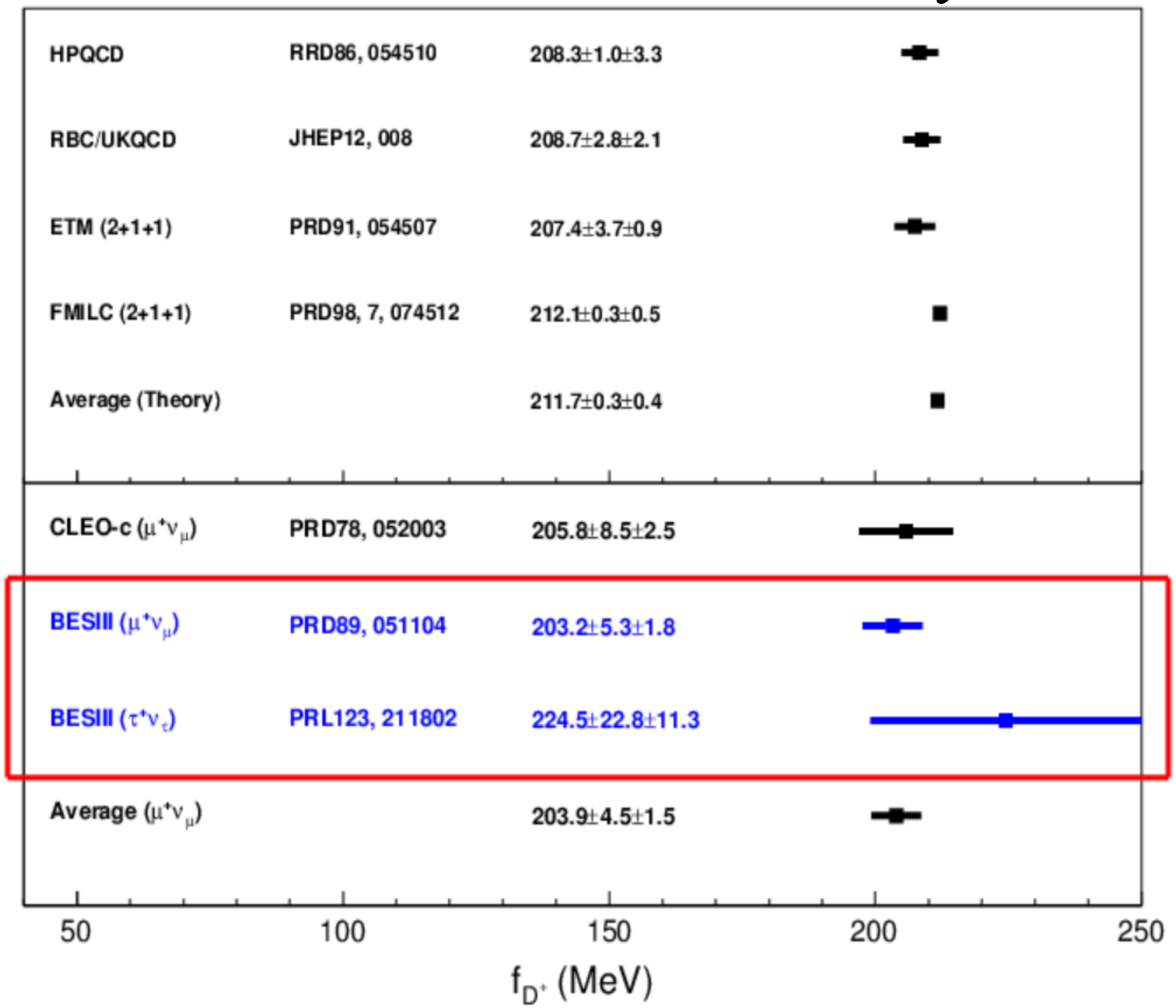
Comparison of $|V_{cd}|$

Input：$f_{D^+} = 212.3 \pm 0.6$ MeV LQCD average

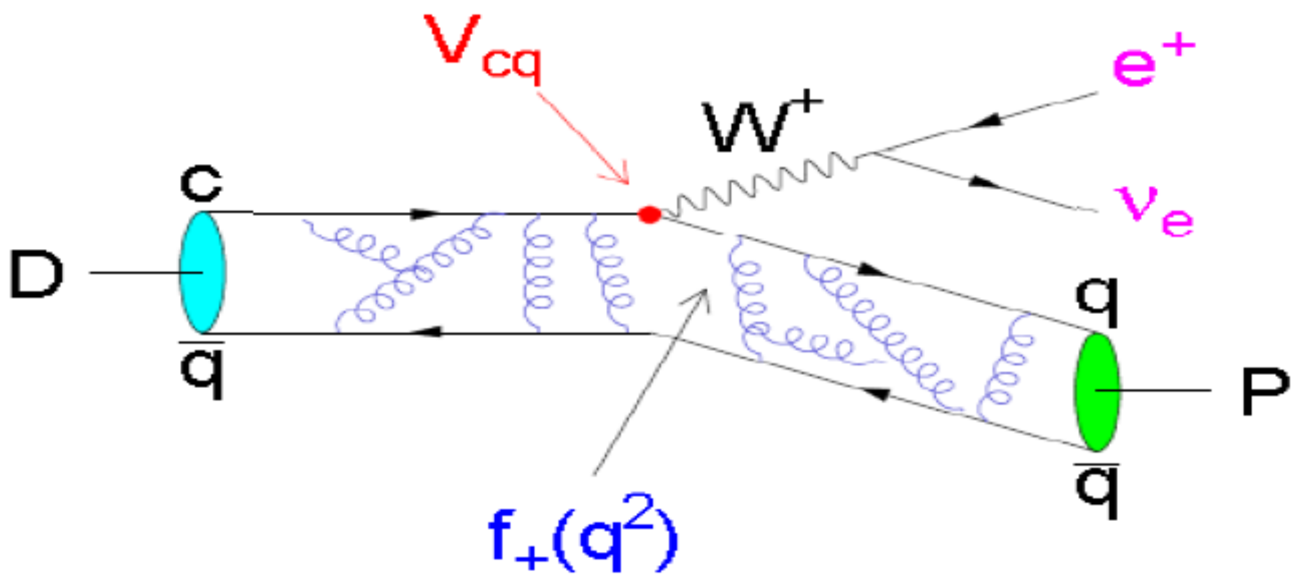


Comparison of f_{D^+}

Input：$|V_{cd}|$
=0.22438±0.00044
PDG2018 from CKM unitarity



Semi-leptonic D decay



$$D \to P e^{+} \nu \; (P = K,\ \pi, \eta^{(\prime)})$$

$$\frac{d\Gamma}{dq^2} = X \frac{G_F^2 p^3}{24\pi^3} \left| f_+(q^2) \right|^2 \left| V_{cd(s)} \right|^2 \left(X = 1\ for\ K^-,\ \pi^-,\ \bar{K}^0, \eta^{(\prime)};\ X = \frac{1}{2}\ for\ \pi^0\right)$$

– **Single pole form**

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

– **Modified pole model**

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

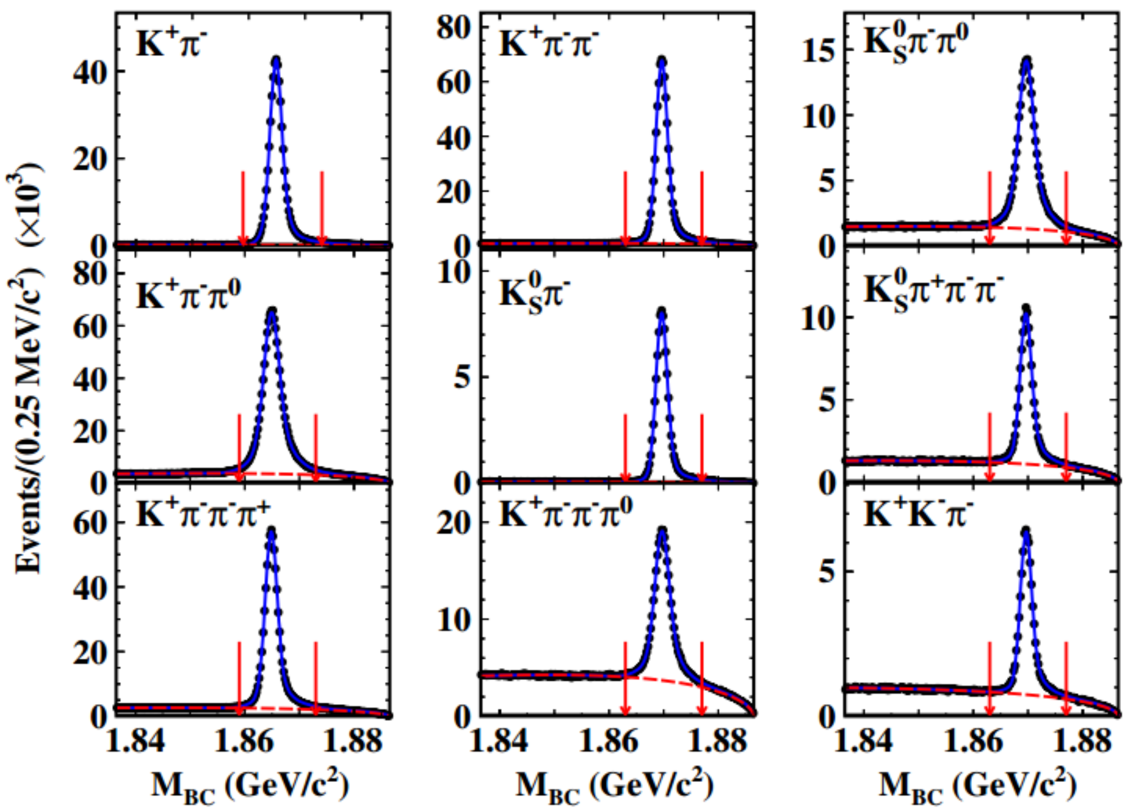
– **ISGW2 model**

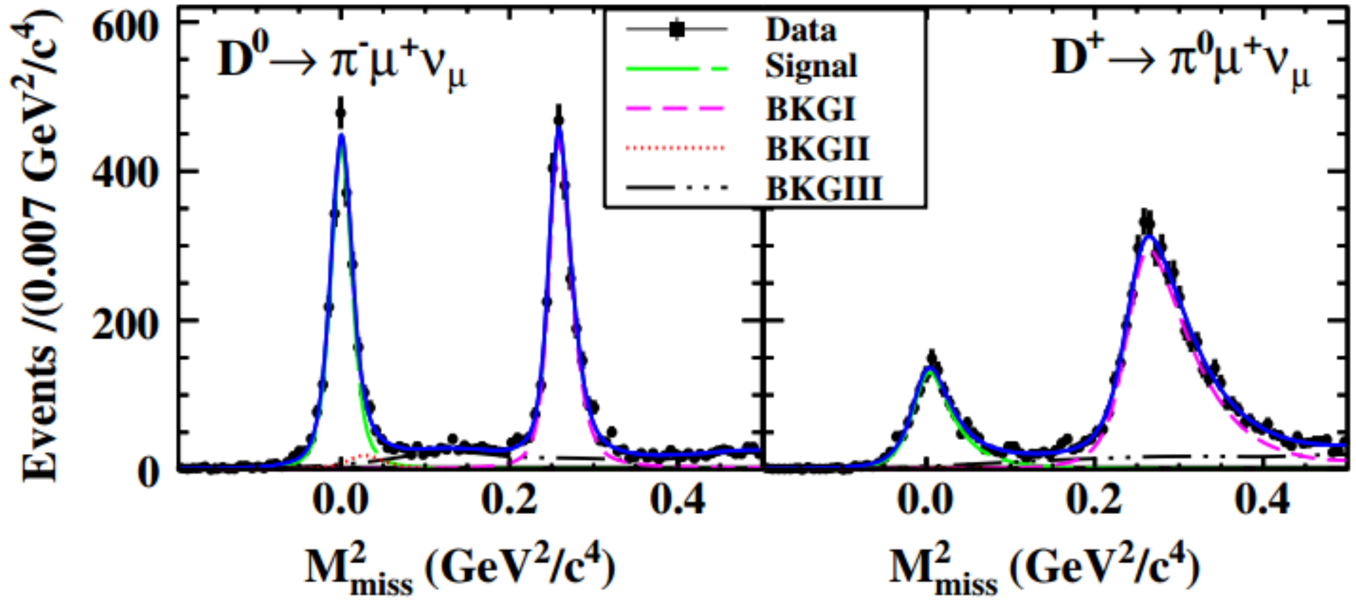
$$f_+(q^2) = f_+(q_{max}^2)\left(1 + \frac{r^2}{12}(q_{max}^2 - q^2)\right)^{-2}$$

– **Series expansion model**

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

$D^{0(+)} \to \pi^{-(0)}\mu^+\nu_\mu$





BKGI: $D^{0(+)} \to \pi^{-(0)}\pi^+\bar{K}^0$

BKGII: $D^0 \to K^-\pi^+,\ D^{0(+)} \to \pi^{-(0)}\pi^+,$
$D^{0(+)} \to \pi^{-(0)}\pi^+\pi^0$

BKGIII: other non-peaking backgrounds

$$\mathscr{B}(D^0 \to \pi^-\mu^+\nu_\mu) = (0.272 \pm 0.008 \pm 0.006)\,\%$$

$$\mathscr{B}(D^+ \to \pi^0\mu^+\nu_\mu) = (0.350 \pm 0.011 \pm 0.010)\,\%$$

Phys. Rev. Lett. 121, 171803 (2018)

$D^{0(+)} \to \pi^{-(0)}\mu^+\nu_\mu$

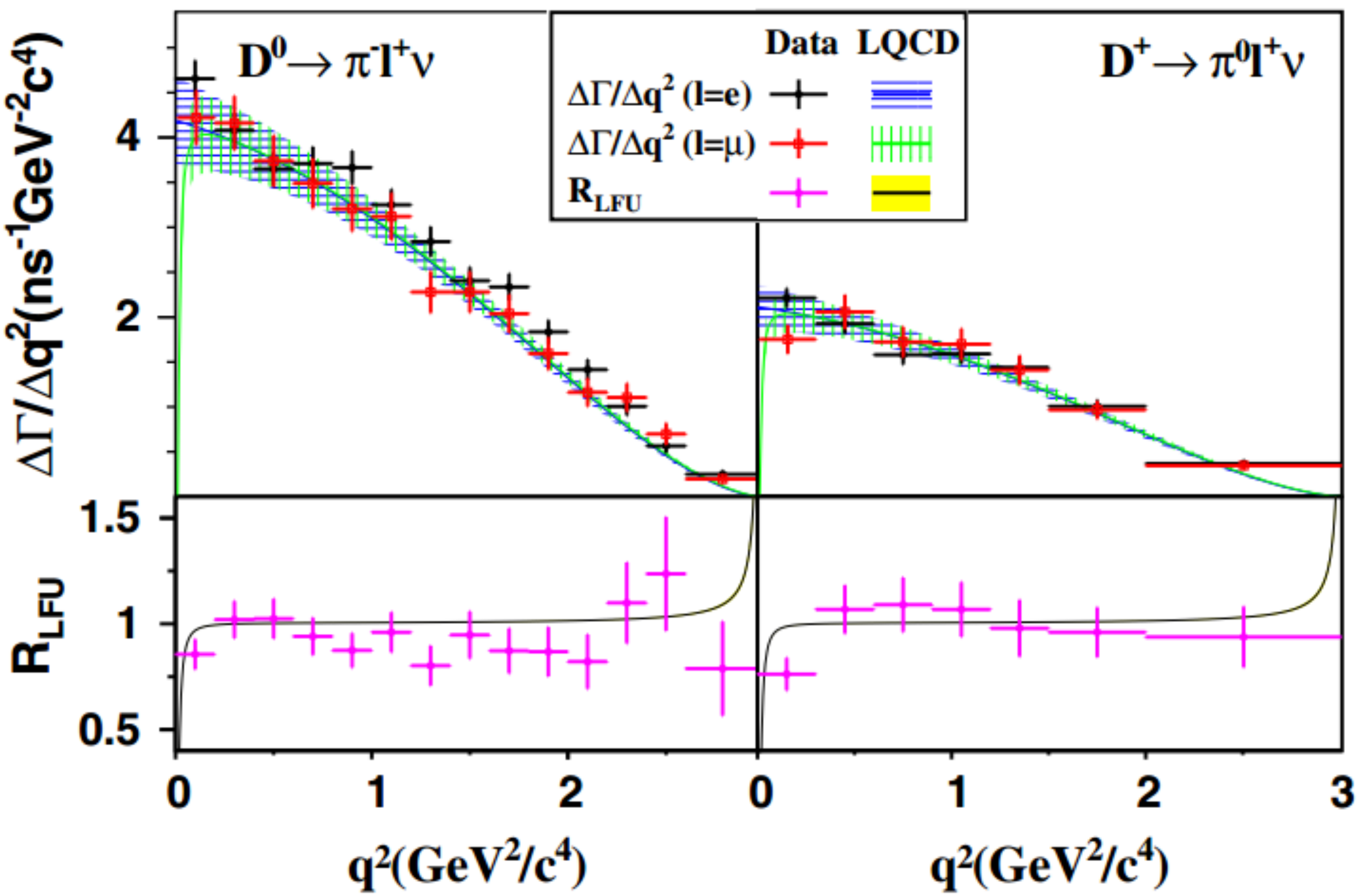
SM expectation: $\mathbf{0.985 \pm 0.002}$ $[Eur.Phys.J.C78, 501(2018)]$

$$R_{LFU}^{\pi^-} = \frac{\Gamma\left(D^0 \to \pi^-\mu^+\nu_\mu\right)}{\Gamma\left(D^0 \to \pi^- e^+\nu_e\right)} = 0.922 \pm 0.030 \pm 0.022$$

$\mathbf{1.7\sigma}$ **consistent**

$$R_{LFU}^{\pi^0} = \frac{\Gamma\left(D^+ \to \pi^0\mu^+\nu_\mu\right)}{\Gamma\left(D^+ \to \pi^0 e^+\nu_e\right)} = 0.964 \pm 0.037 \pm 0.026$$

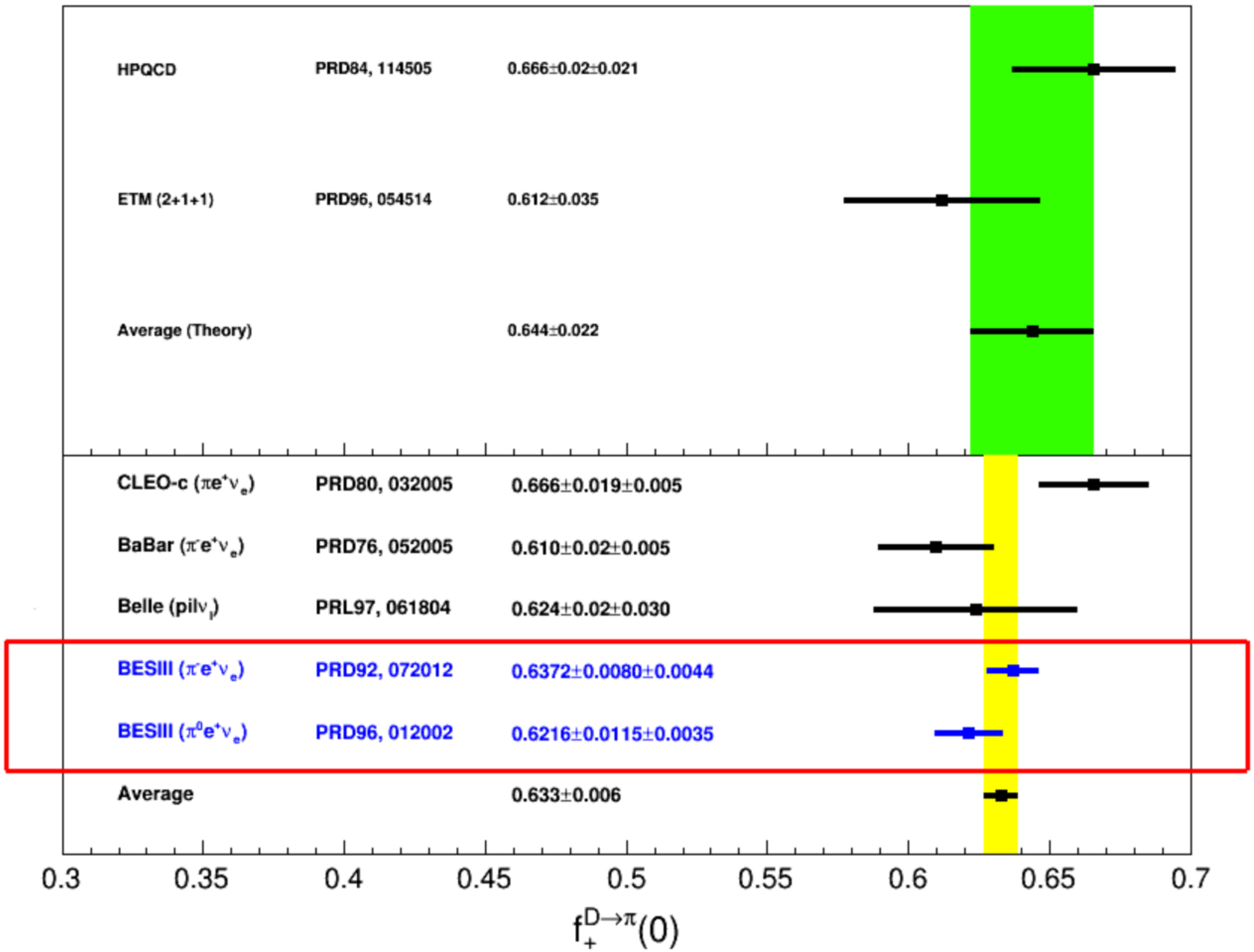
$\mathbf{0.5\sigma}$ **consistent**



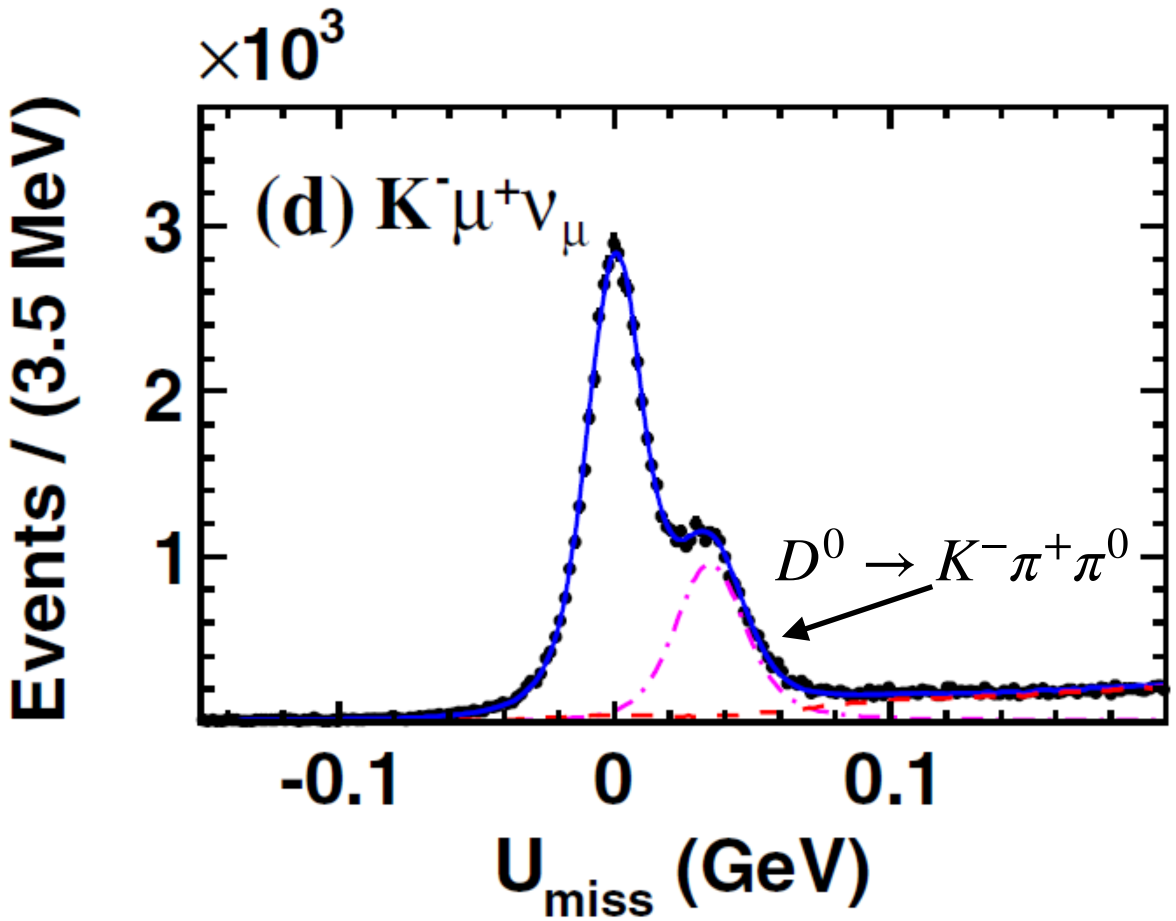
Comparison of $f_+^{D\to\pi}(0)$

Inputs from CKMFitter

$$|V_{cd}| = 0.22438 \pm 0.00044$$



$D^0 \to K^- \mu^+ \nu_\mu$



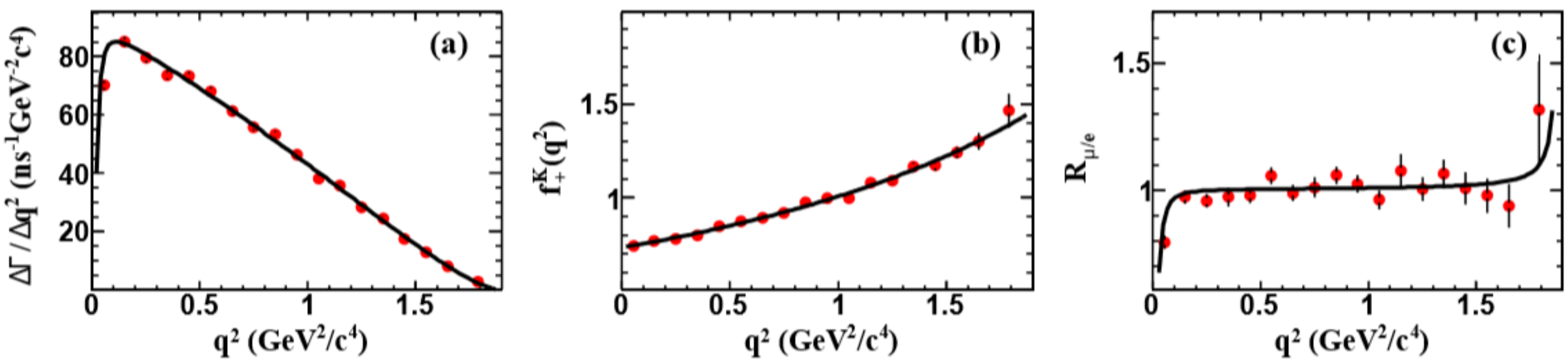
$\mathcal{B}(D^0 \to K^- \mu^+ \nu_\mu) = (3.413 \pm 0.0019 \pm 0.035)\%$

$f_+^K(0)|V_{cs}| = (0.7133 \pm 0.0038 \pm 0.0030)$

$f_+^K(0) = (0.7327 \pm 0.0039 \pm 0.0030)$

$|V_{cs}| = (0.955 \pm 0.005 \pm 0.004 \pm 0.024)$

$\frac{\mathcal{B}(D^0 \to K^- \mu^+ \nu_\mu)}{\mathcal{B}(D^0 \to K^- e^+ \nu_e)} = (0.974 \pm 0.007 \pm 0.012)$ (0.975)



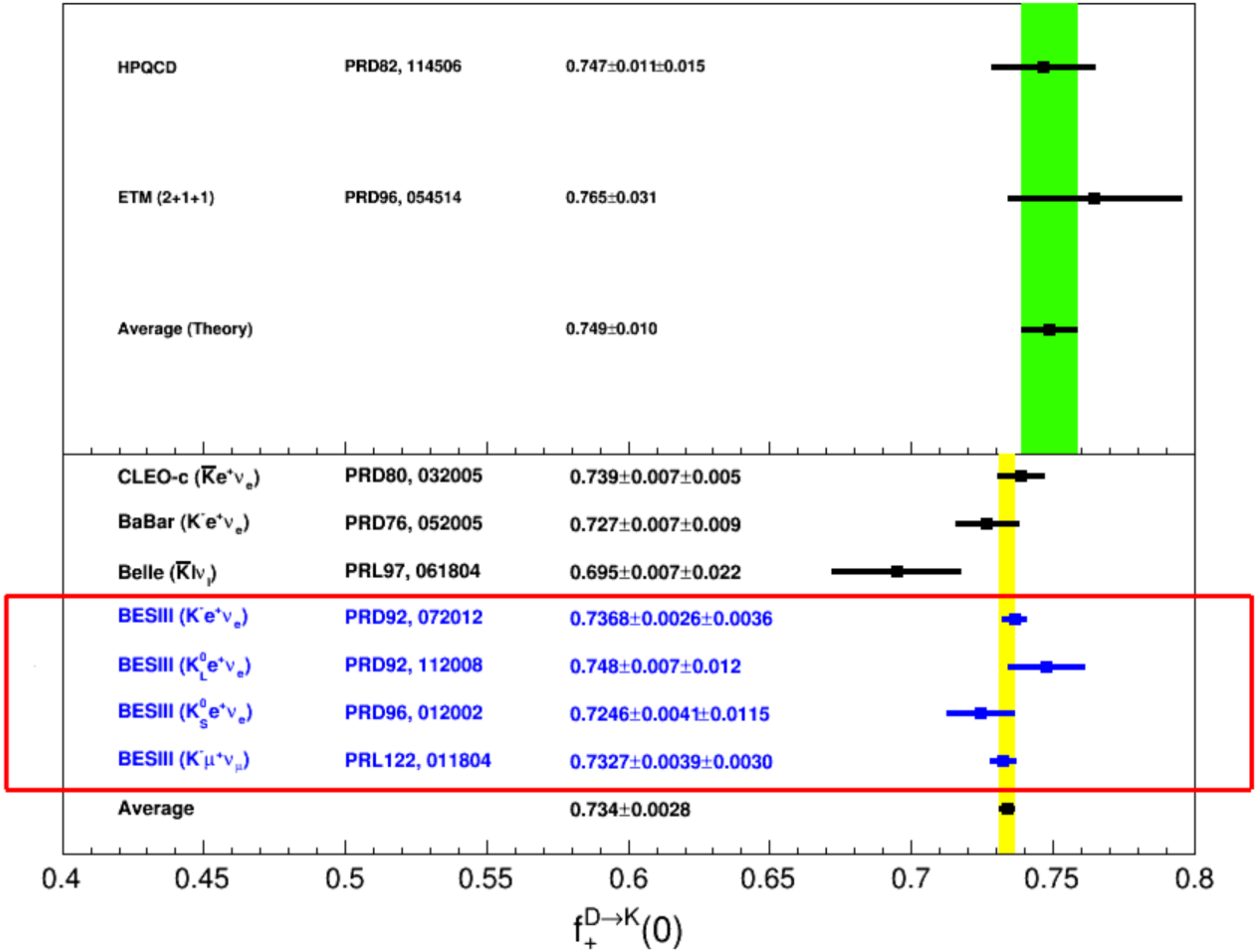
No significant evidence of LFU violation is found

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

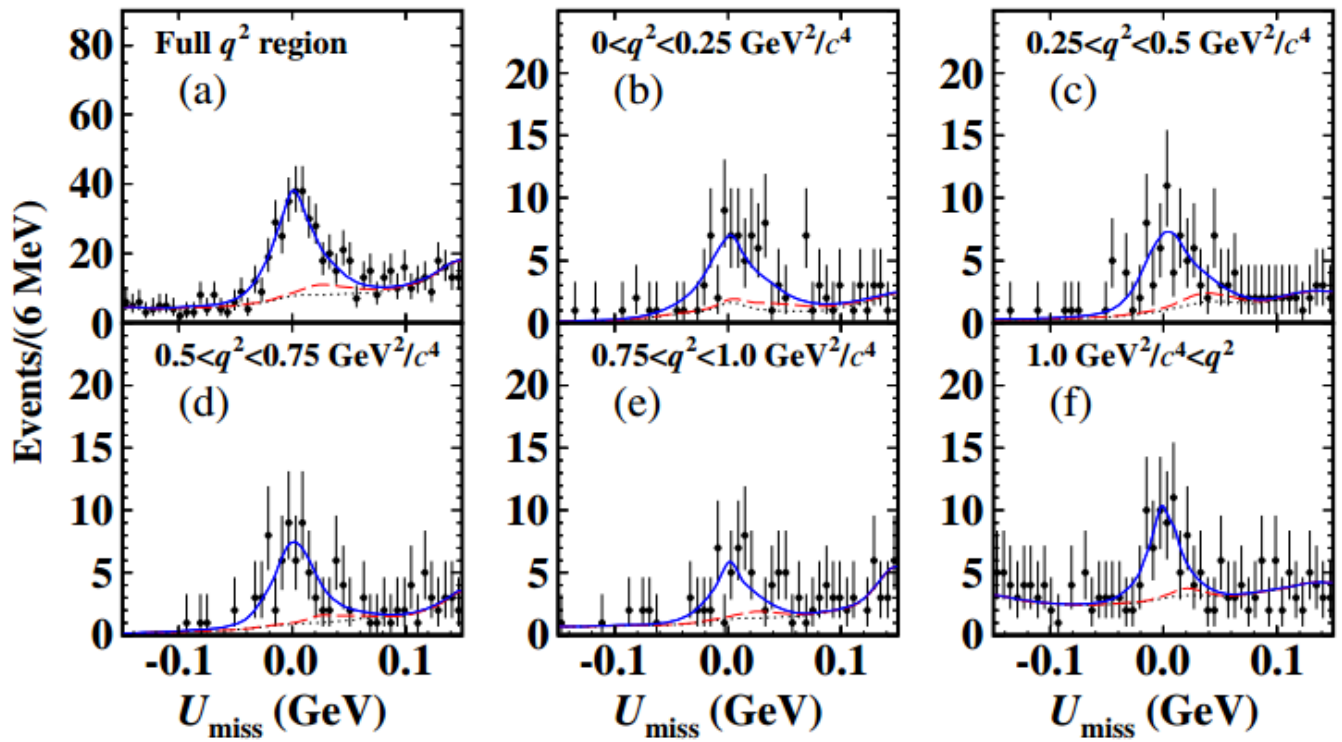
Comparison of $f_+^{D\to K}(0)$

Inputs from CKMFitter

$$|V_{cs}| = 0.97359^{+0.00010}_{-0.00011}$$



First observation of $D^+ \to \eta\mu^+\nu_\mu$



$$\mathcal{B}(D^+ \to \eta\mu^+\nu_\mu) = (10.4 \pm 1.0 \pm 0.5) \times 10^{-4}$$

$$f_+^\eta(0)|V_{cd}| = 0.087 \pm 0.008 \pm 0.002$$

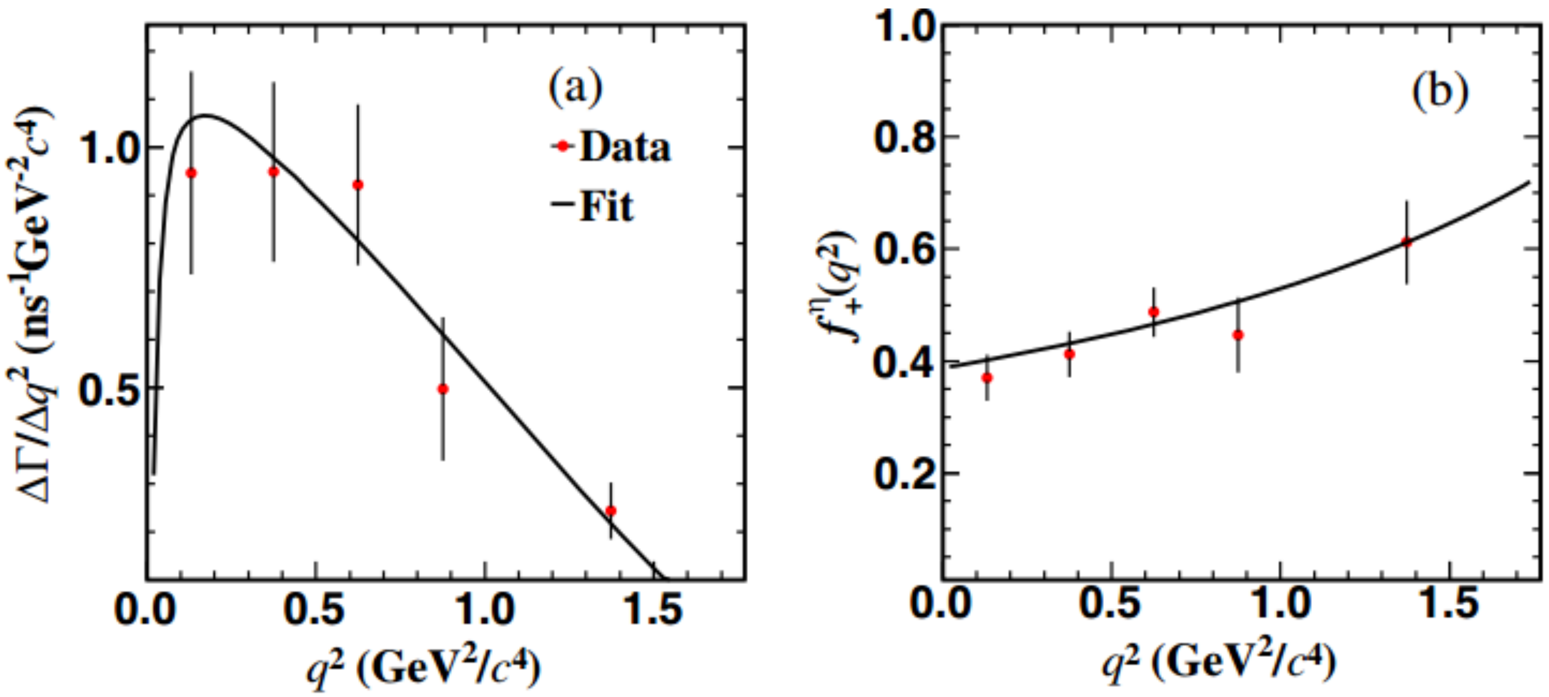
$$f_+^\eta(0) = 0.39 \pm 0.04 \pm 0.01$$

$$|V_{cd}| = 0.242 \pm 0.022 \pm 0.006 \pm 0.033$$

$$R = \frac{\mathcal{B}(D^+ \to \eta\mu^+\nu_\mu)}{\mathcal{B}(D^+ \to \eta e^+\nu_e)_{\rm PDG}} = 0.91 \pm 0.13$$

SM(0.97-1.00)

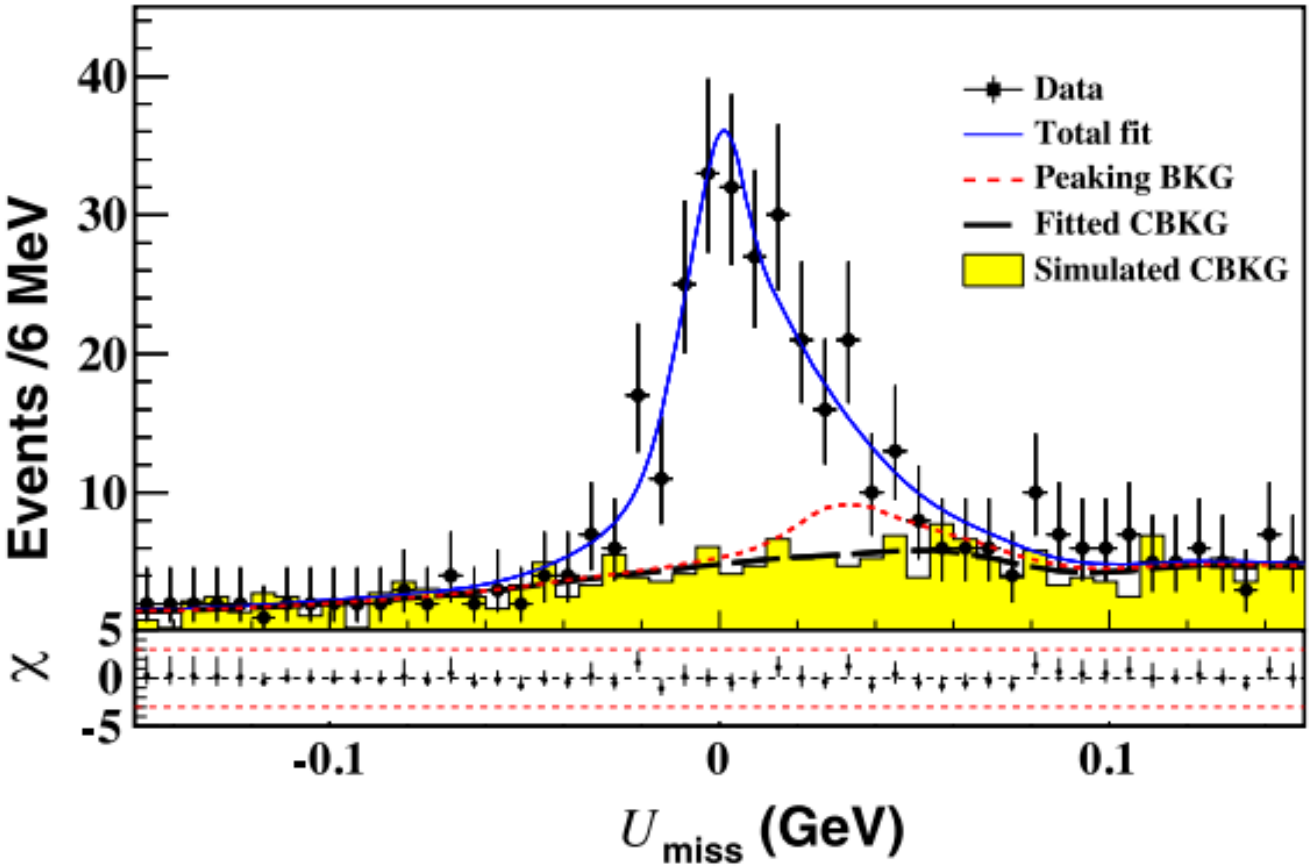
no LFU violation within current sensitivity



Experimental confirmation for the first time since it was predicted in 30 years ago. Phys. Rev. D 39, 799 (1989).

Phys. Rev. Lett. 124, 231801 (2020)

First observation of $D^+ \to \omega\mu^+\nu_\mu$



$\mathcal{B}(D^+ \to \omega\mu^+\nu_{\mu^+}) = (17.7 \pm 1.8 \pm 1.1) \times 10^{-4}$

Consistent with theoretical calculation (LFQM, CCQM, and LCSR methods).

$$R = \frac{\mathcal{B}(D^+ \to \omega\mu^+\nu_\mu)}{\mathcal{B}(D^+ \to \omega e^+\nu_e)_{\rm PDG}} = 1.05 \pm 0.14$$

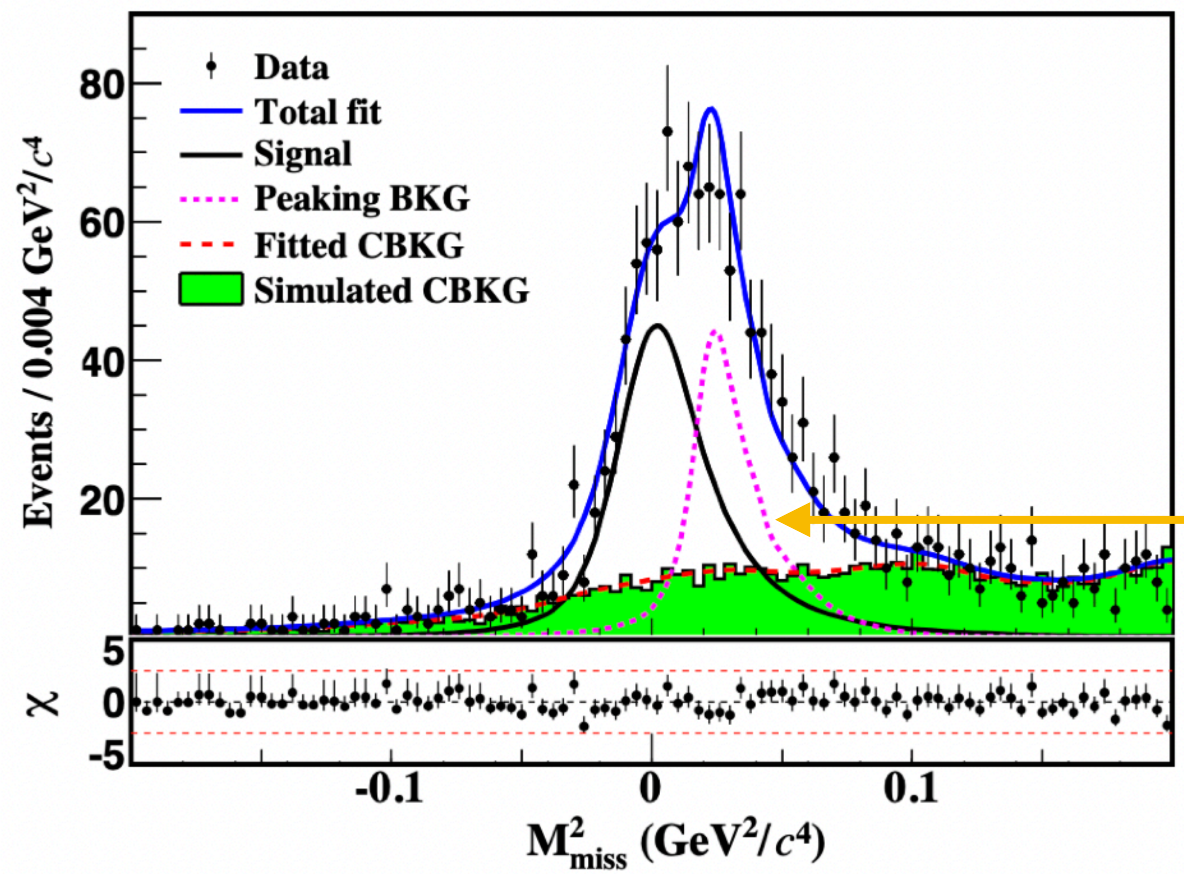
SM(0.93-0.99)

no LFU violation within current statistics

Experimental confirmation for the first time since it was predicted in 30 years ago.
Phys. Rev. D 39, 799 (1989).

Phys. Rev. D 101, 072005 (2020)

First observation of $D^0 \to \rho^- \mu^+ \nu_\mu$



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

$$\mathcal{B}_{D^0 \to \rho^- \mu^+ \nu_\mu} = (1.35 \pm 0.09_{\rm stat} \pm 0.09_{\rm syst}) \times 10^{-3}$$

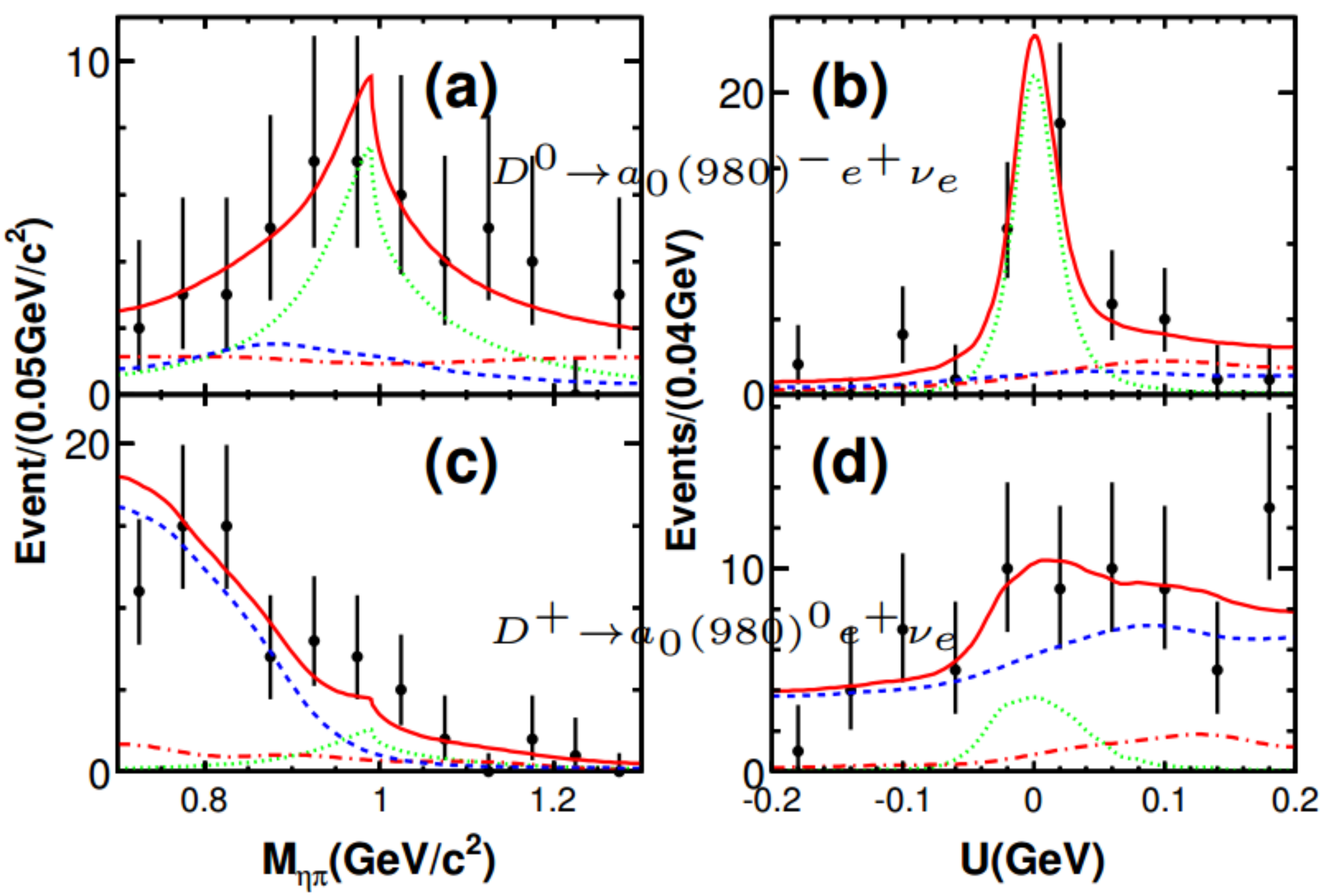
$$\mathcal{B}_{D^0 \to \rho^- \mu^+ \nu_e} / \mathcal{B}_{D^0 \to \rho^- e^+ \nu_e} = 0.90 \pm 0.11$$ SM(0.93-0.96)

$$\Gamma_{D^0 \to \rho^- \mu^+ \nu_\mu} / (2\Gamma_{D^+ \to \rho^0 \mu^+ \nu_\mu}) = 0.71 \pm 0.14$$

2.1σ from unity based on isospin symmetry

arXiv:2106.02292

$D^{0(+)} \rightarrow a_0(980)^{-(0)} e^+ \nu_e$

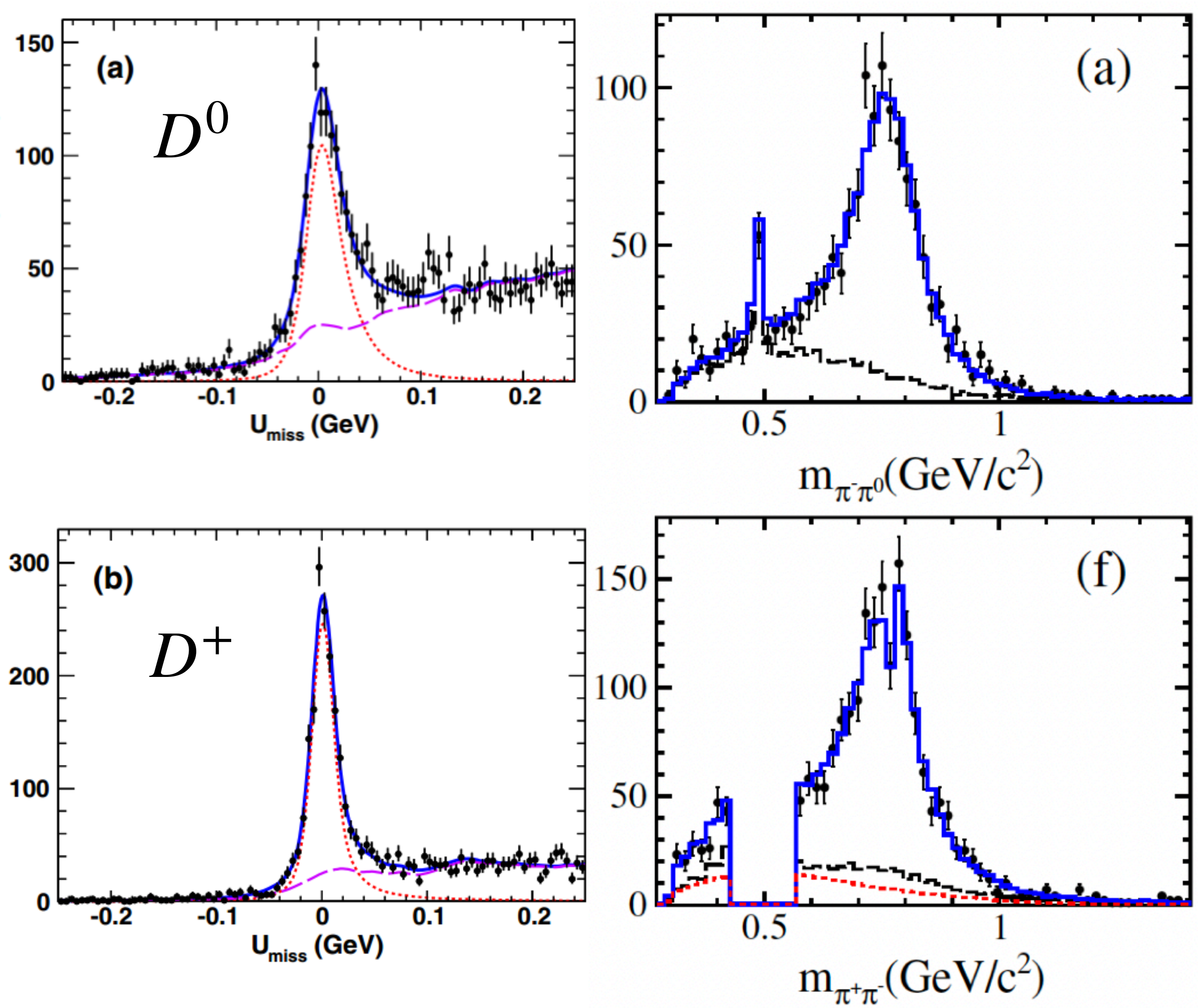


Semileptonic decay to scalar meson

Decay	BF ($\times 10^{-4}$)	Significance
$D^0 \to a_0(980)^- e^+ \nu_e,\ a_0(980)^- \to \eta\pi^-$	$1.33^{+0.33}_{-0.29} \pm 0.09$	6.4σ
$D^+ \to a_0(980)^0 e^+ \nu_e,\ a_0(980)^0 \to \eta\pi^0$	$1.66^{+0.81}_{-0.66} \pm 0.11$ < 3.0 (90% C.L.)	2.9σ

Phys. Rev. Lett. 121, 081802 (2018)

$D^{0(+)} \to \pi^-\pi^{0(+)}e^+\nu_e$



Signal mode	BF ($\times 10^{-3}$)
$D^0 \to \pi^-\pi^0 e^+\nu_e$	$1.445 \pm 0.058 \pm 0.039$
$D^0 \to \rho^- e^+\nu_e$	$1.445 \pm 0.048 \pm 0.039$
$D^+ \to \pi^-\pi^+ e^+\nu_e$	$2.449 \pm 0.074 \pm 0.073$
$D^+ \to \rho^0 e^+\nu_e$	$1.860 \pm 0.070 \pm 0.061$
$D^+ \to \omega e^+\nu_e$	$2.05 \pm 0.66 \pm 0.30$
$D^+ \to f_0(500) e^+\nu_e$, $f_0(500) \to \pi^+\pi^-$	$0.630 \pm 0.043 \pm 0.032$
$D^+ \to f_0(980) e^+\nu_e$, $f_0(980) \to \pi^+\pi^-$	<0.028

From Wang and Lu PRD82, 034016(2010)

$$R = \frac{\mathcal{B}(D^+ \to f_0(500)e^+\nu_e) + \mathcal{B}(D^+ \to f_0(980)e^+\nu_e)}{D^+ \to a_0(980)^0 e^+\nu_e}$$

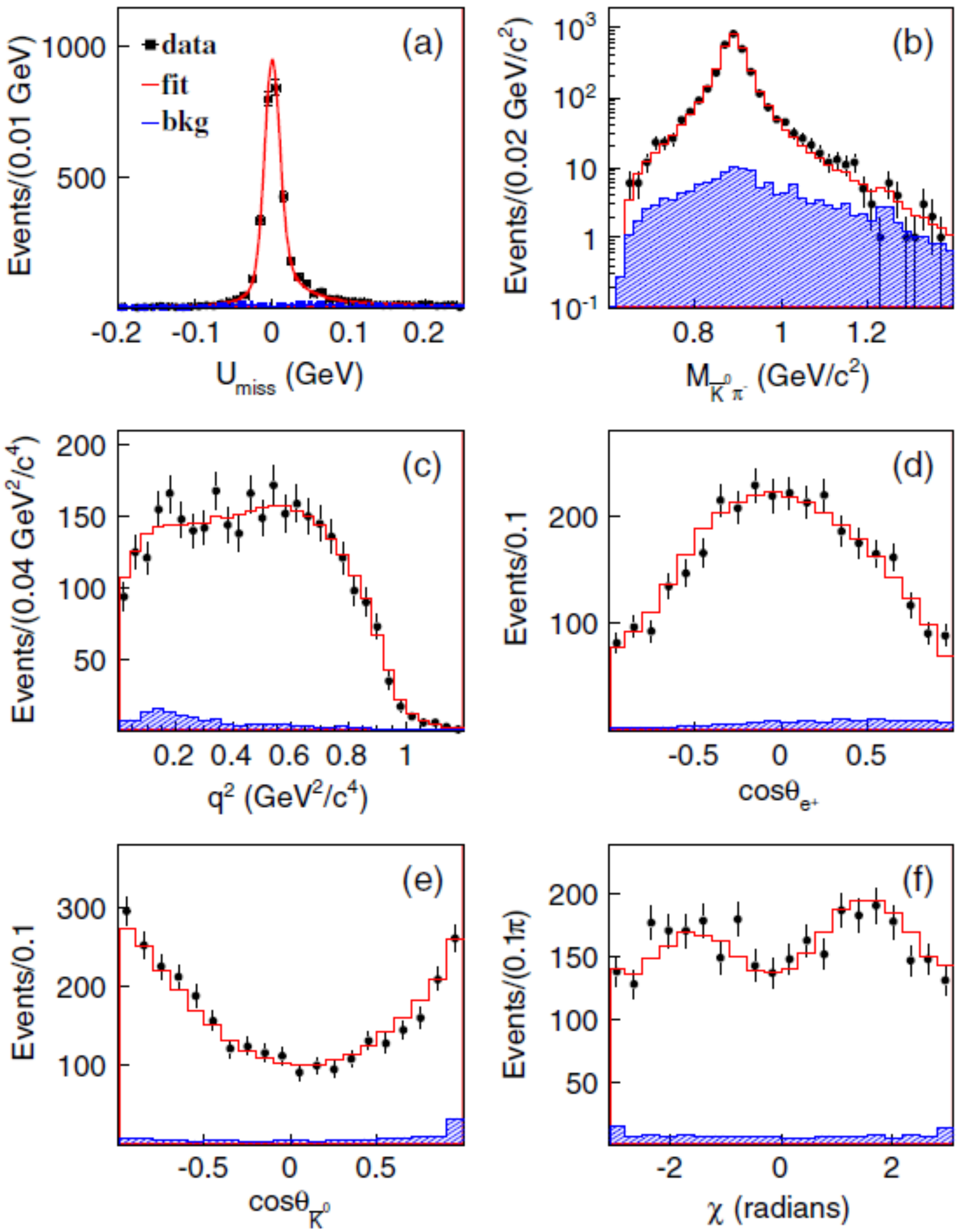
$$= \begin{cases} 1.0 \pm 0.3 & \text{two quark description} \\ 3.0 \pm 0.9 & \text{tetraquark description} \end{cases}$$

Use $\mathcal{B}(D^+ \to a_0(980)^0 e^+\nu_e) \times \mathcal{B}(a_0(980)^0 \to \eta\pi^0) < 3.0 \times 10^{-4}$ from BESIII PRL121,081802(2018) and other inputs from PDG.

$\Rightarrow R > 2.7$@90%CL $\Rightarrow$ Tetraquark favored for f_0 and a_0

Phys. Rev. Lett. 122, 062001 (2019)

$D^0 \to \bar{K}^0 \pi^- e^+ \nu_e$



$$B(D^0 \to \bar{K}^0 \pi^- e^+ \nu_e) = (1.434 \pm 0.029 \pm 0.032)\,\%$$

$$B(D^0 \to K^*(892)^- e^+ \nu_e) = (2.003 \pm 0.046 \pm 0.047)\,\%$$

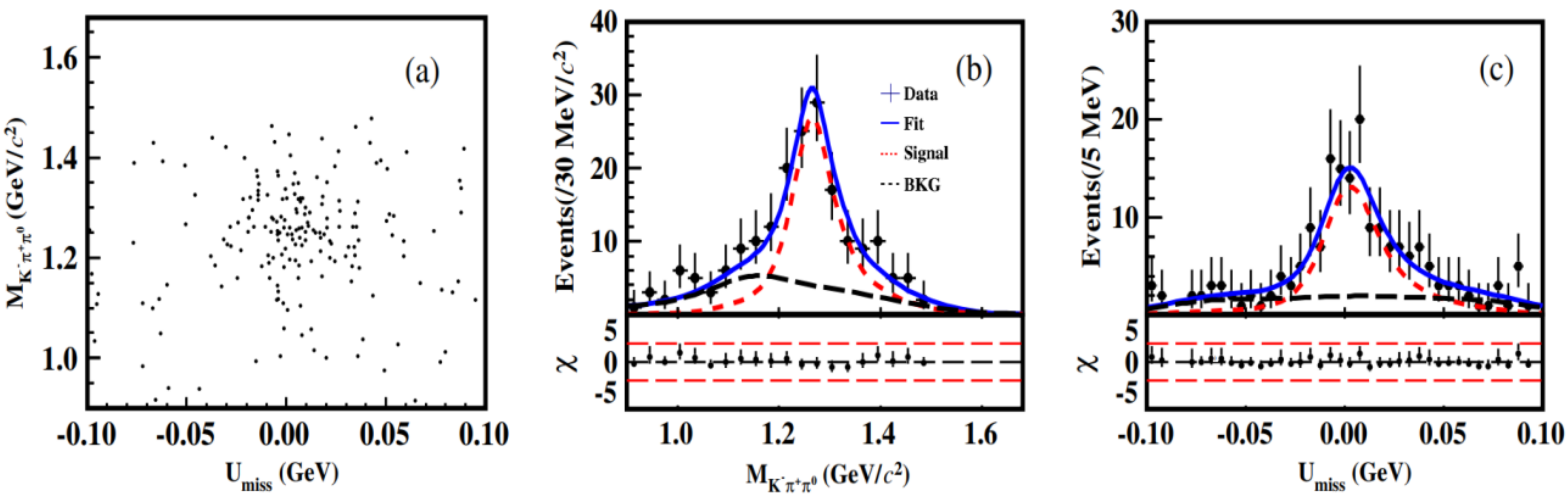
observed

$$B\left(D^0 \to \left(\bar{K}^0 \pi^-\right)_{S-\text{wave}} e^+ \nu_e\right) = (7.90 \pm 1.40 \pm 0.91) \times 10^{-4}$$

Phys. Rev. D 99, 011003(R) (2019)

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

First observation of D meson semi-leptonic decay into axial-vector mesons.



$$\mathcal{B}_{D^0\to K_1(1270)^- e^+\nu_e} = (1.09\pm0.13^{+0.09}_{-0.13}\pm0.12)\times10^{-3}$$

Test the theoretical calculations (agree with the CLFQM and LCSR prediction.)

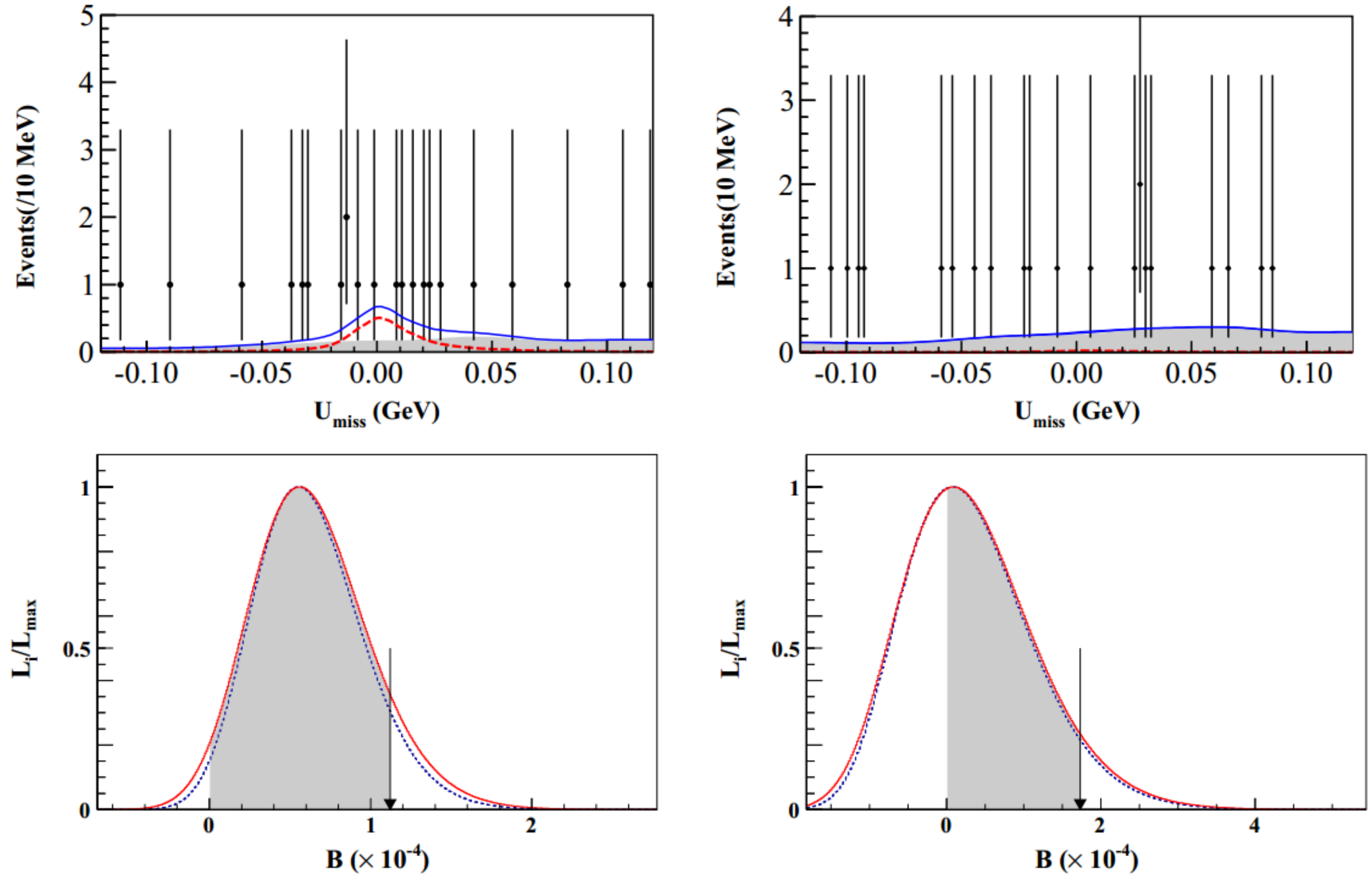
Provide important input to study the photon polarization in $B \to K_1\gamma$ by measuring the ration of up-down asymmetries.

$$\frac{\Gamma(D^+ \to \overline{K}_1(1270)^0\, e^+\, \nu_e)}{\Gamma(D^0 \to K_1(1270)^-\, e^+\, \nu_e)} = 1.2^{+0.7}_{-0.5}$$ (Isospin conservation test)

Phys. Rev. Lett. 122, 062001 (2019)

$D^{0(+)} \to b_1(1235)^{(-)0} e^+ \nu_e$

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



$$\mathcal{B}_{D^0 \to b_1(1235)^- e^+ \nu_e} \cdot \mathcal{B}_{b_1(1235)^- \to \omega \pi^-} < 1.12 \times 10^{-4}$$

$$\mathcal{B}_{D^+ \to b_1(1235)^0 e^+ \nu_e} \cdot \mathcal{B}_{b_1(1235)^0 \to \omega \pi^0} < 1.75 \times 10^{-4}$$

No significant signal is observed

Phys. Rev. D 102, 112005 (2020)

(Semi-)leptonic Ds decay

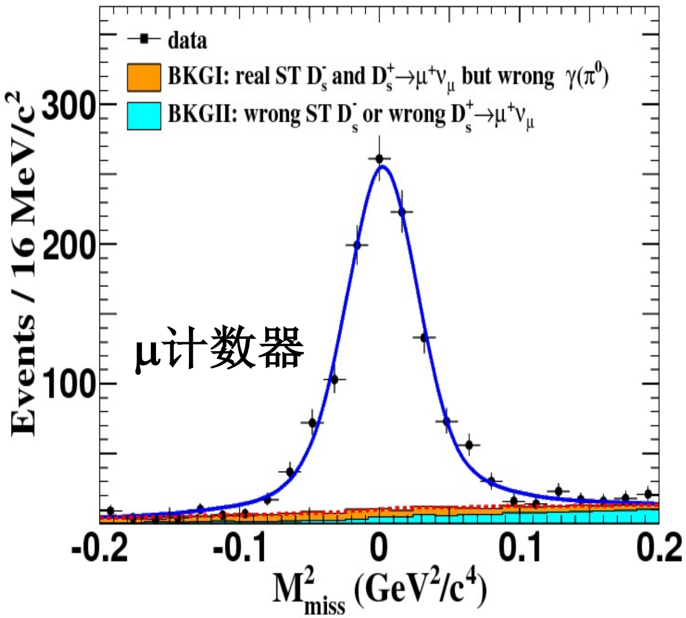
- **Pure leptonic decay**
  - $D_s^+ \to \mu^+ \nu_\mu$ — *Phys. Rev. Lett. 122, 071802 (2019)*
- **Semi-leptonic decay**
  - $D_s^+ \to K^0 e^+ \nu_e,\ K^{*0} e^+ \nu_e$ — *Phys. Rev. Lett. 122, 061801 (2019)*
  - $D_s^+ \to \eta e^+ \nu_e,\ \eta' e^+ \nu_e$ — *Phys. Rev. Lett. 122, 121801 (2019)*
  - $D_s^+ \to p\bar{p} e^+ \nu_e$ — *Phys. Rev. D 100, 112008 (2019)*
  - $D_s^+ \to \gamma e^+ \nu_e$ — *Phys. Rev. D 99, 072002 (2019)*
  - $D_s^+ \to X e^+ \nu_e$ — *arXiv:2104.0731*

The talk "Leptonic Ds decay at BESIII" in Parallel session, 08 June 12:00

Studies of $D_s^+ \to l^+\nu_l$

$D_s^+ \to \mu^+\nu$ 3.19 fb^{-1}@4.18 GeV

PRL122(2019)071802



$$B[D_s^+ \to \mu^+\nu] = (5.49 \pm 0.16 \pm 0.15)\times 10^{-3}$$

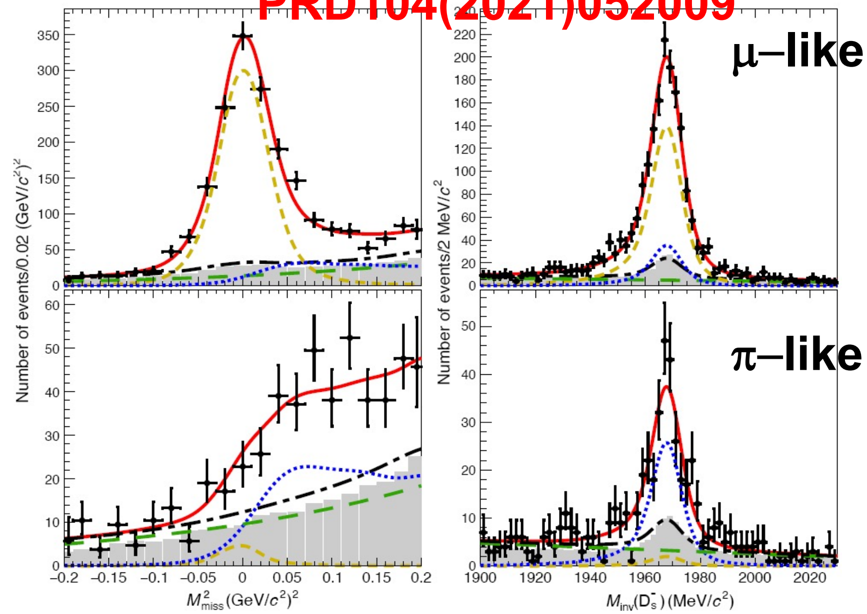
$$f_{D_s^+}|V_{cs}| = 246.2 \pm 3.6 \pm 3.5 \text{ MeV}$$

$$A_{CP}[\mu\nu] = \frac{B_{D_s^+\to\mu^+\nu} - B_{D_s^-\to\mu^-\nu}}{B_{D_s^+\to\mu^+\nu} + B_{D_s^-\to\mu^-\nu}} = (2.0 \pm 3.0 \pm 1.2)\%$$

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

6.3 fb^{-1}@4.18-4.23GeV

PRD104(2021)052009



$$B[D_s^+ \to \mu^+\nu] = (5.35 \pm 0.13 \pm 0.16)\times 10^{-3}$$

$$B[D_s^+ \to \tau^+\nu] = (5.22 \pm 0.25 \pm 0.17)\%$$

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

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

$$A_{CP}[\mu\nu] = (-1.2 \pm 2.7)\%$$

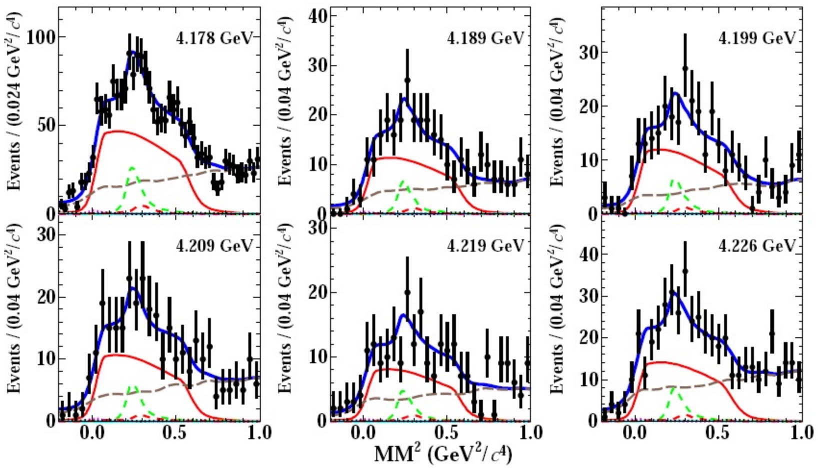
$$A_{CP}[\tau\nu] = (2.9 \pm 4.9)\%$$

Studies of $D_s^+ \to l^+\nu_l$

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

6.3 fb^{-1}@4.18-4.23GeV

PRD104(2021)032001



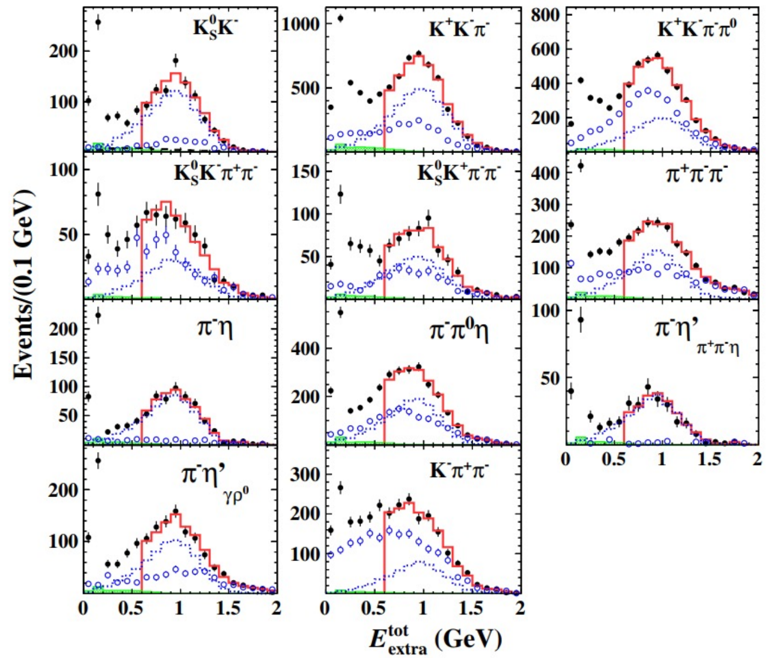
$B[D_s^+ \to \tau^+ v] = (5.29 \pm 0.25 \pm 0.20)\%$

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

$D_s^+ \to \tau^+(e^+ vv)v$

6.3 fb^{-1}@4.18-4.23GeV

PRL127(2021)171801



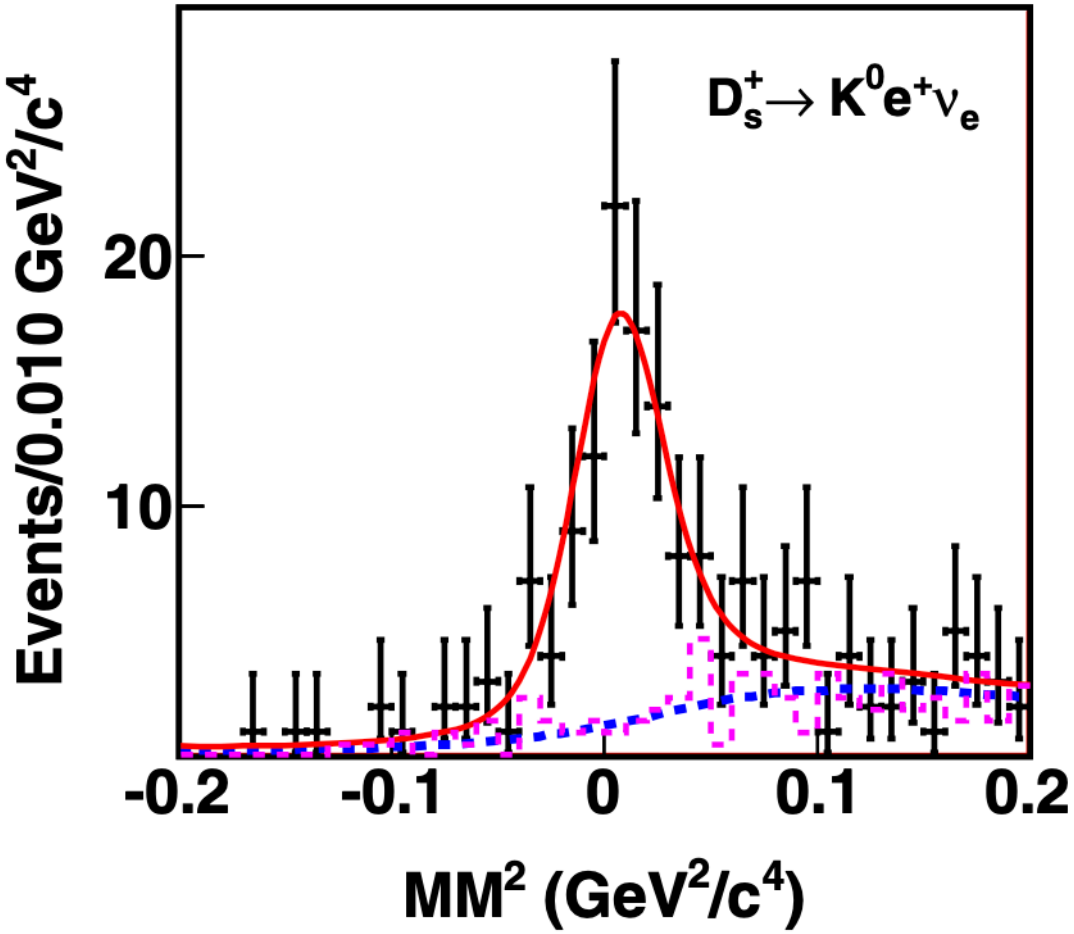
$B[D_s^+ \to \tau^+ v] = (5.27 \pm 0.10 \pm 0.12)\%$

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

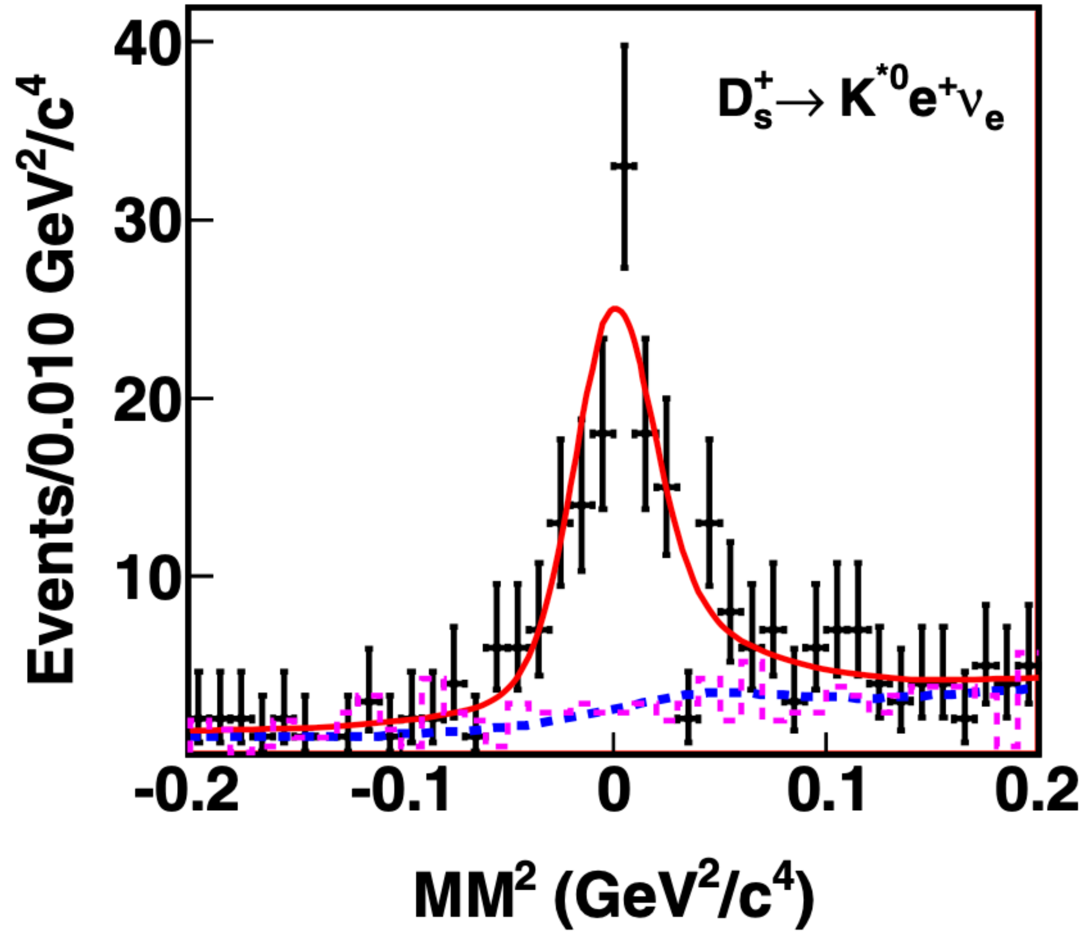
$D_s^+ \to K^{*(0)} e^+ \nu_e$

Cabibbo-suppressed channels

$N_{\mathrm{DT}}^{K^0} = 117.2 \pm 13.9$



$N_{\mathrm{DT}}^{K^{*0}} = 155.0 \pm 17.2$



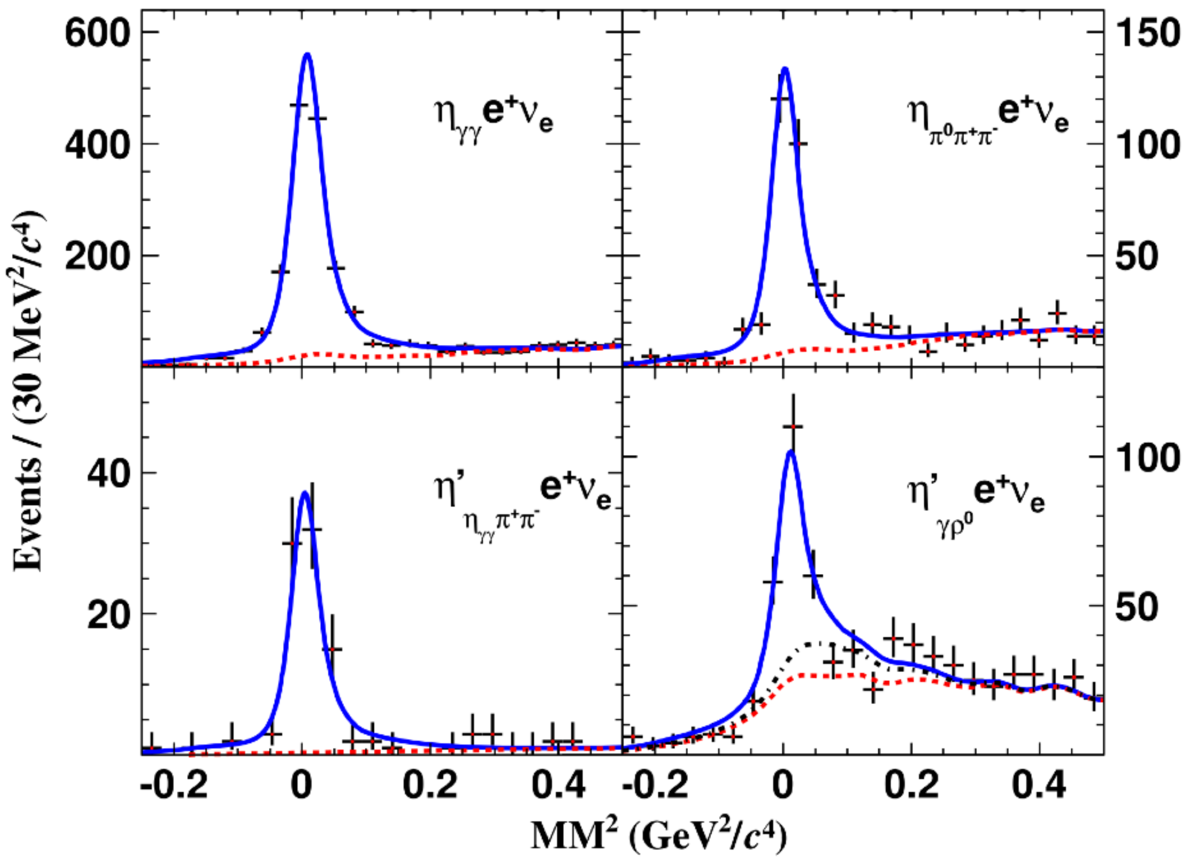
$$B\left(D_s^+ \to K^0 e^+ \nu_e\right) = (3.25 \pm 0.38 \pm 0.16) \times 10^{-3}$$

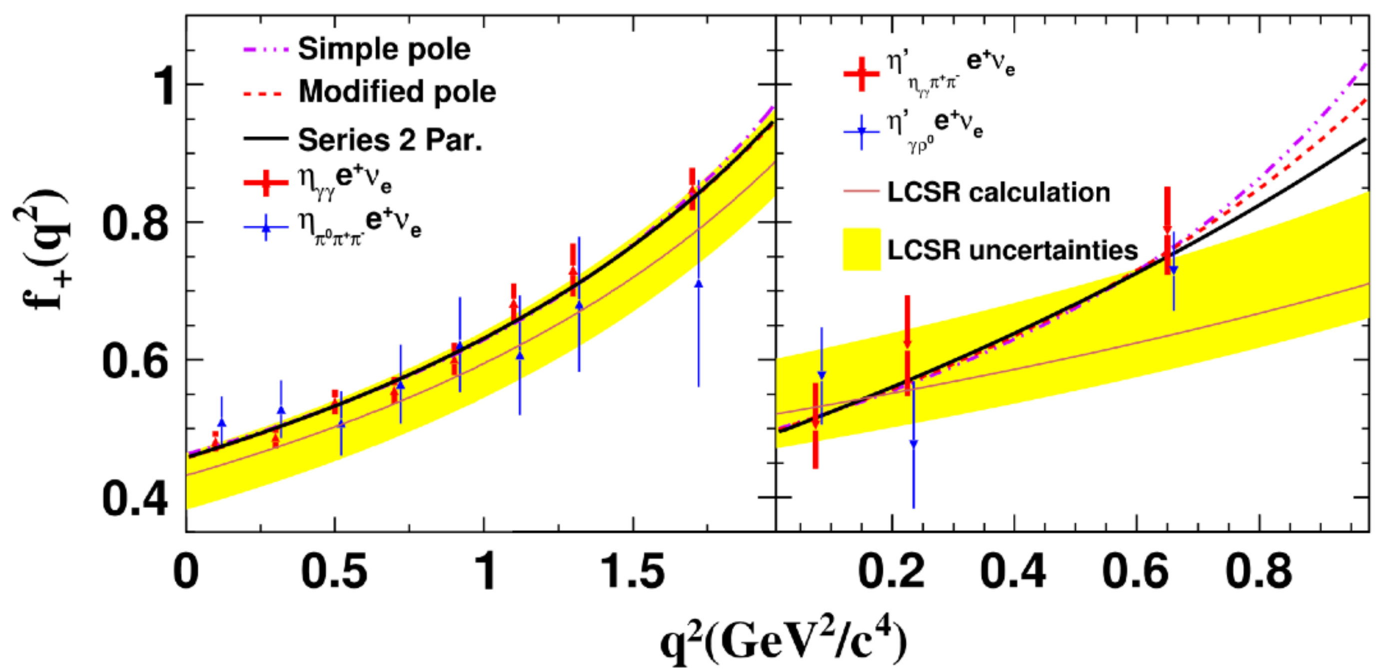
$$B\left(D_s^+ \to K^{*0} e^+ \nu_e\right) = (2.37 \pm 0.26 \pm 0.20) \times 10^{-3}$$

Precision improved 2 over PDG and First FF measurements

Phys. Rev. Lett. 122, 068801 (2019)

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





$$\mathscr{B}_{D_s^+ \to \eta e^+ \nu_e} = (2.323 \pm 0.063_{\rm stat} \pm 0.063_{\rm syst})\,\%$$

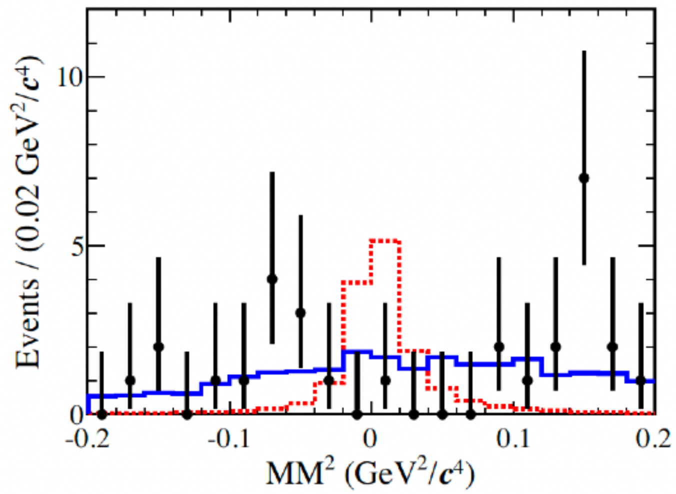
$$\mathscr{B}_{D_s^+ \to \eta' e^+ \nu_e} = (0.824 \pm 0.073_{\rm stat} \pm 0.027_{\rm syst})\,\%$$

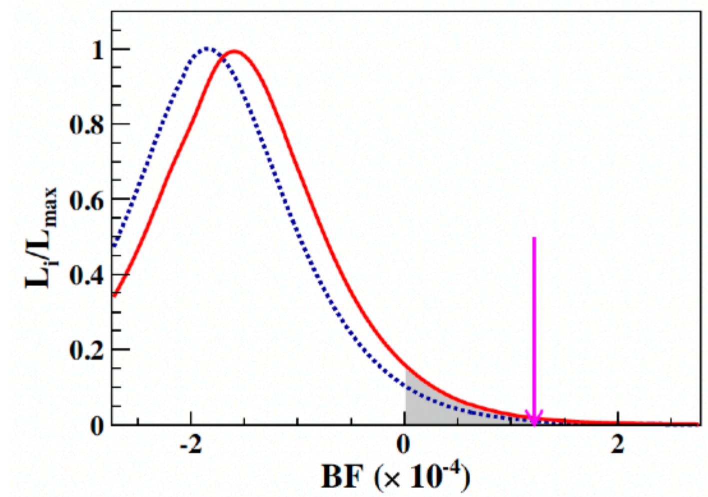
$$f_+^{\eta}(0)\,|V_{cs}| = 0.4455 \pm 0.0053_{\rm stat} \pm 0.0044_{\rm syst}\text{MeV}$$

$$f_+^{\eta'}(0)\,|V_{cs}| = 0.477 \pm 0.049_{\rm stat} \pm 0.011_{\rm syst}\text{MeV}$$

Phys. Rev. Lett. 122, 121801 (2019)

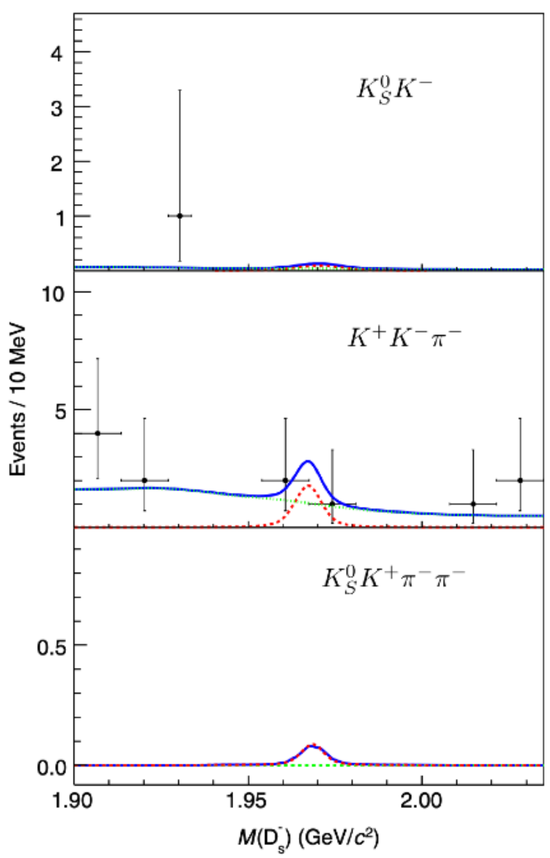
$D_s^+ \to a_0(980)^0 e^+ \nu_e$





$$\mathscr{B}(D_s^+ \to a_0(980)^0 e^+ \nu_e) \times \mathscr{B}(a_0(980)^0 \to \pi^0 \eta) < 1.2 \times 10^{-4}$$

Phys. Rev. D 103, 092004 (2021)



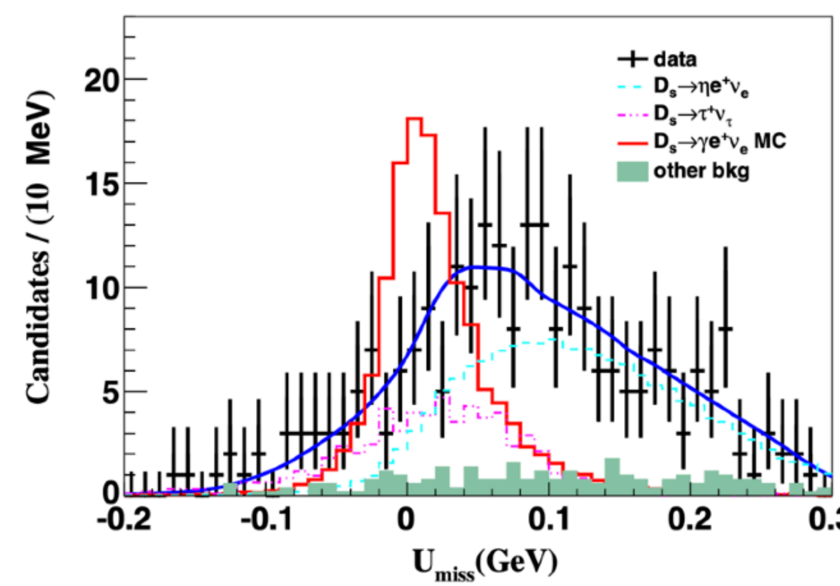
$D_s^+ \to p\bar{p} e^+ \nu_e$

Upper limit @ 90% CL.:

$$\mathcal{B}(D_s^+ \to p\bar{p} e^+ \nu_e) < 2.0 \times 10^{-4}$$

Phys. Rev. D 100, 112008 (2019)

$D_s^+ \to \gamma e^+ \nu_e$



$$\mathscr{B}_{D_s^+ \to \gamma e^+ \nu_e} < 1.3 \times 10^{-4}$$

Phys. Rev. D 99, 072002 (2019)

Summary

First evidence for:

$D^+ \to a_0(980)^0 e^+ \nu_e$

First observation for:

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

$D^+ \to \pi^0 \mu^+ \nu_\mu$

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

$D^+ \to f_0(500) e^+ \nu_e$

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

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

First measurements the dynamics on:

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

$D_s^+ \to K^{0(*)} e^+ \nu_e$

$D^0 \to \bar{K}^0 \pi^- e^+ \nu_e$

Precisely measured:

Decay constant f_{D_s}

Form factor $f_+^K(0), f_+^\pi(0), f_+^{\eta^{(\prime)}}(0)$

$|V_{cd(s)}|$

Test the lepton universality:

No evidence for LFUV in charm at 1.5% precision

Light hadron results:

$\eta - \eta'$ mixing angle

Test on θ_{K_1}

Tetraquark description favored for light scalar meson

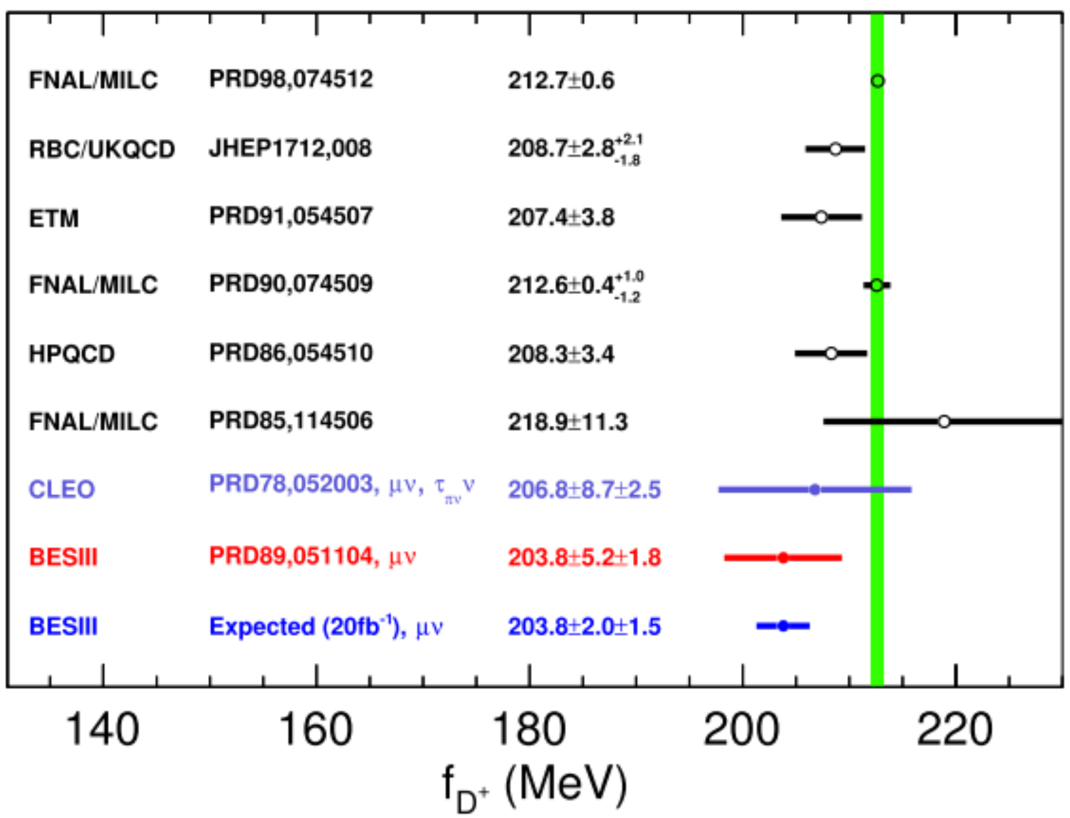
Prospect

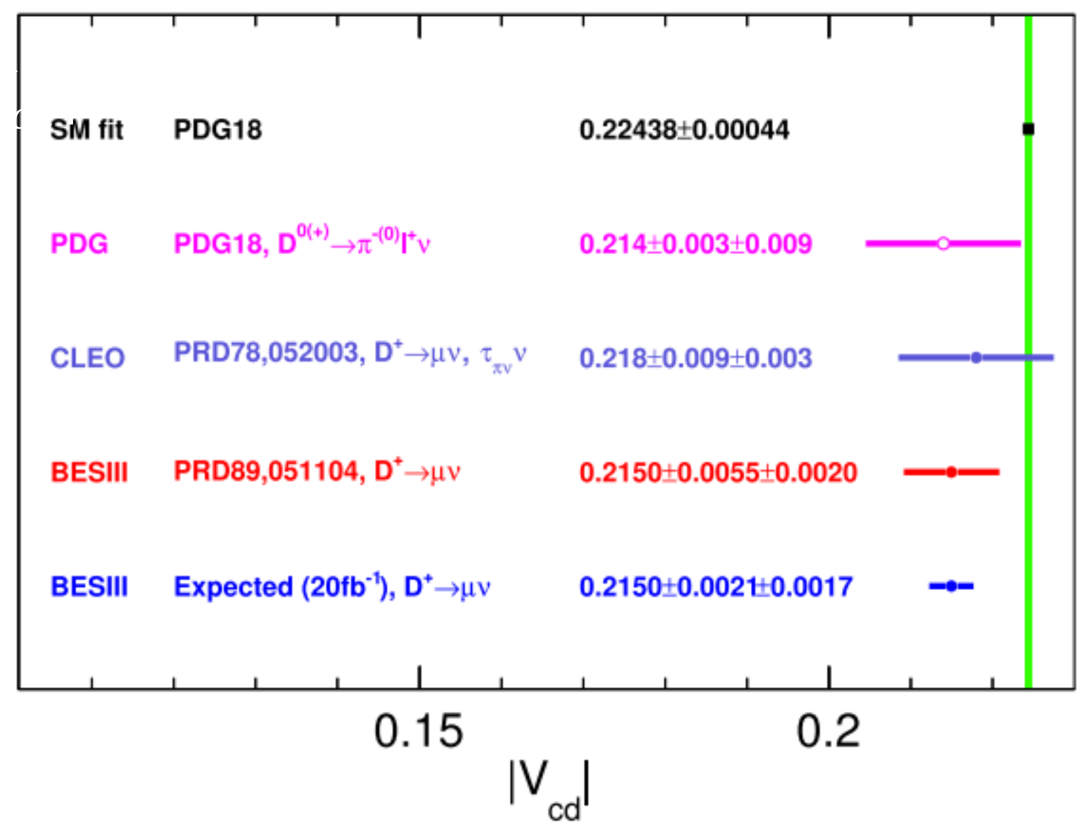
From White Paper (Chin. Phys. C 44, 040001 (2020))

With 20 fb^{-1} of data set at 3.773 GeV in the coming two years

Leptonic Decay

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





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

Prospect

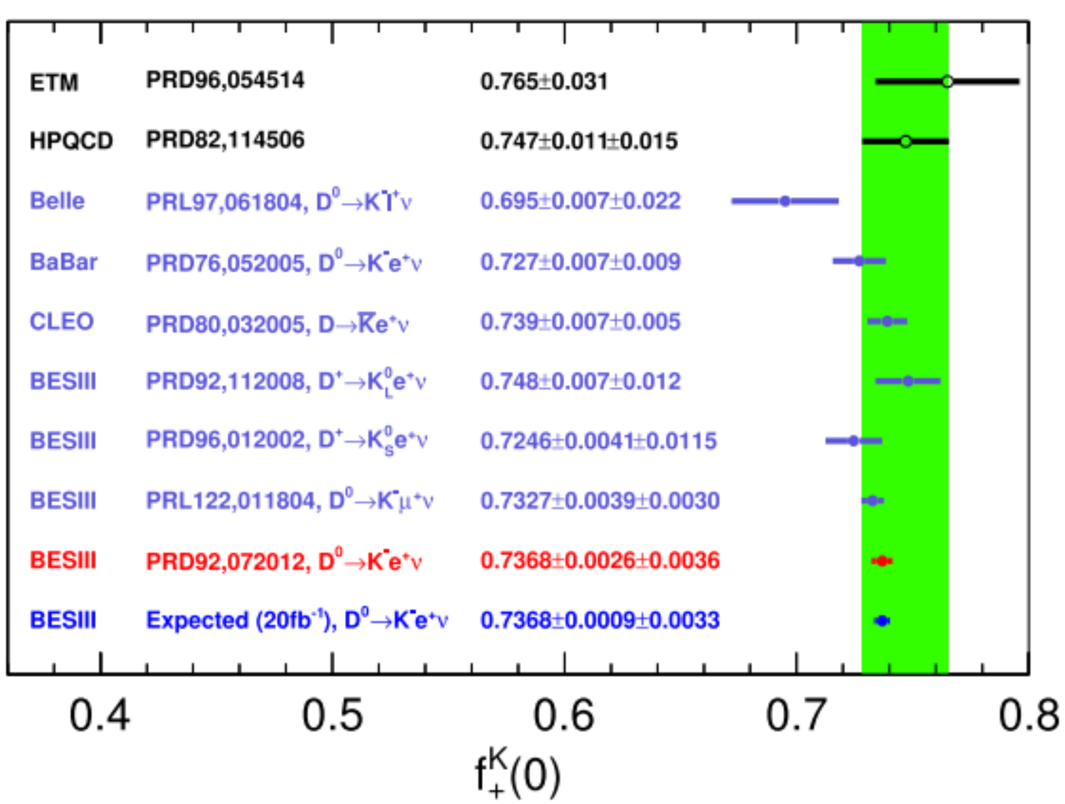
From White Paper (Chin. Phys. C 44, 040001 (2020))

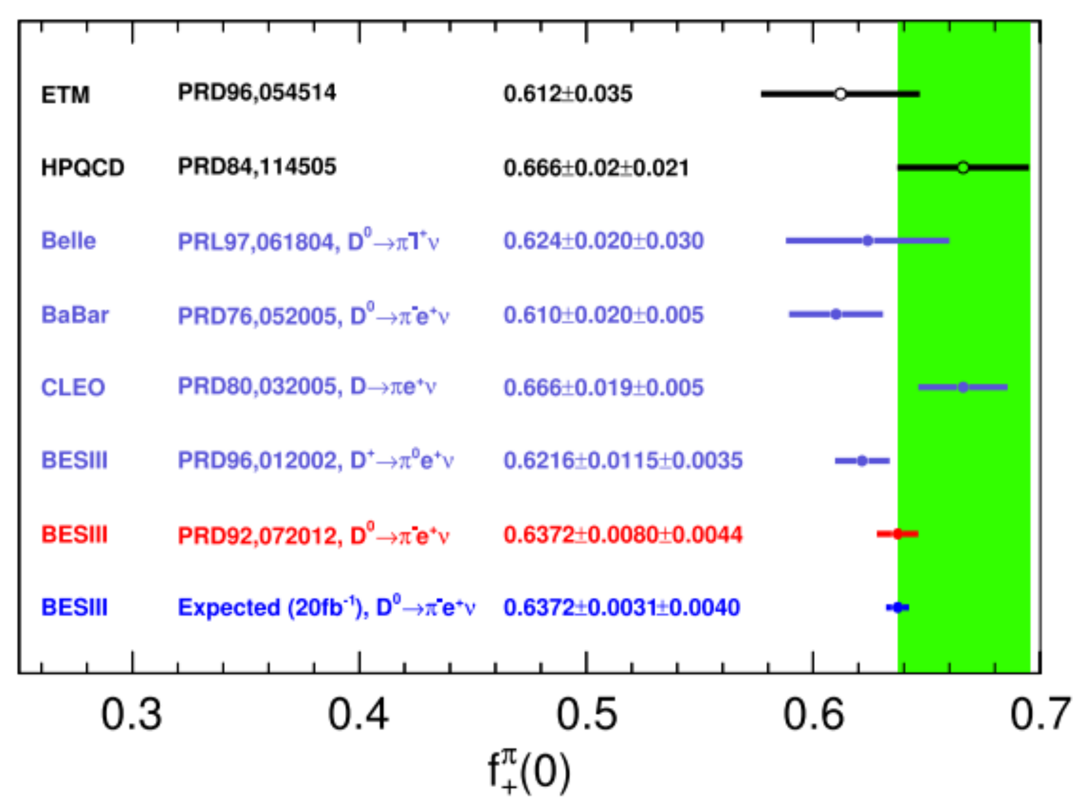
With 20 fb^{-1} of data set at 3.773 GeV in the coming two years

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: $D^0 \to K(1270)^- \nu_e$, $D^+ \to \overline{K}_1(1270)^0 e^+ \nu_e$, $D^+ \to \eta' \mu^+ \nu_\mu$, $D^0 \to a_0(980)^- e^+ \nu_e$, $D^+ \to a_0(980)^0 e^+ \nu_e$
- $|V_{cd(s)}|$ with SL $D^{0(+)}$ decays in electron channels are expected to reach to 0.5%.

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





Thanks for your attention