Leptonic and semi-leptonic decays of charmed mesons at BESIII

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BESIII

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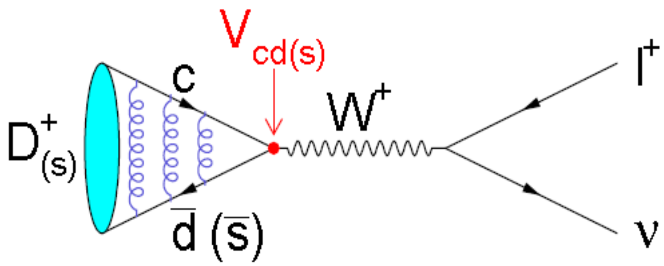
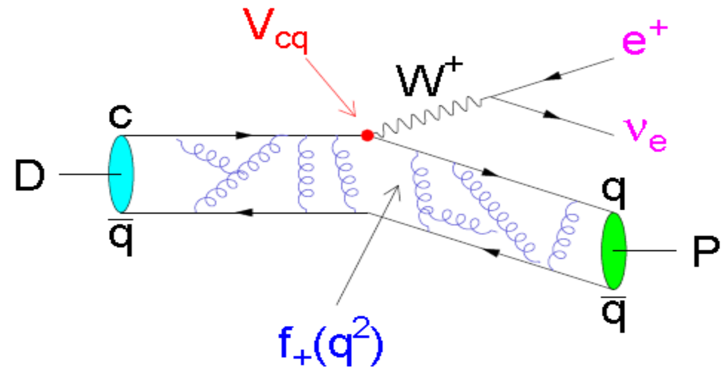
Motivation





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

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

The weak and strong effects in (semi-)leptonic decays of charmed mesons [D^0 ($c\bar{u}$), D^+($c\bar{d}$), D_s^+($c\bar{s}$)] can be well separated

- **The CKM matrix U describes the mixing between different quark flavors in weak reactions, and satisfies unitarity relation. The elements can only be measured in experiments**

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

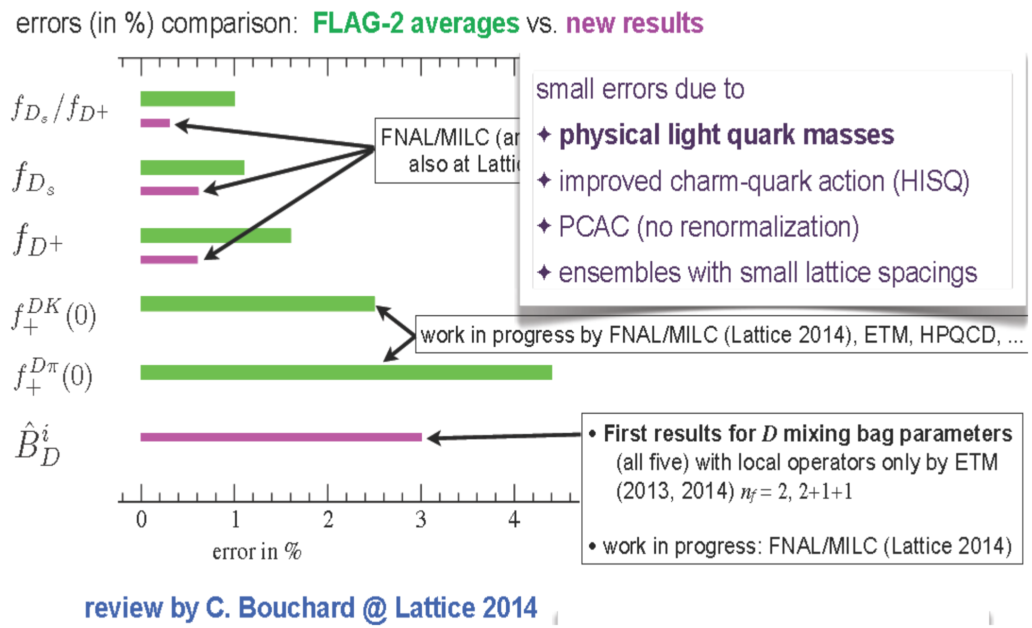
Measurements of $|V_{cs(d)}|$ are important to test the unitarity the CKM matrix, which is important to search for new physics beyond the SM

Motivation

- The strong effects between different quark flavors can be parameterized as the decay constants of $D_{(s)}$ [$f_{D(s)}$] or the hadronic form factor [$f_+(0)$], which can be calculated in the Lattice Quantum Chromodynamics (LQCD)

Determinations of $f_{D(s)}$] and $f_+(0)$ are important to test the LQCD calculations

The $f_{D(s)}$] and $f_+(0)$ that pass experimental tests will in return further benefit the test on the CKM matrix unitarity



- In the SM, the couplings of leptons to gauge bosons are independent of lepton flavors.

Improved measurements of the branching fractions of these decays are also help to test LFU in (semi-)leptonic D decays

BEPCII

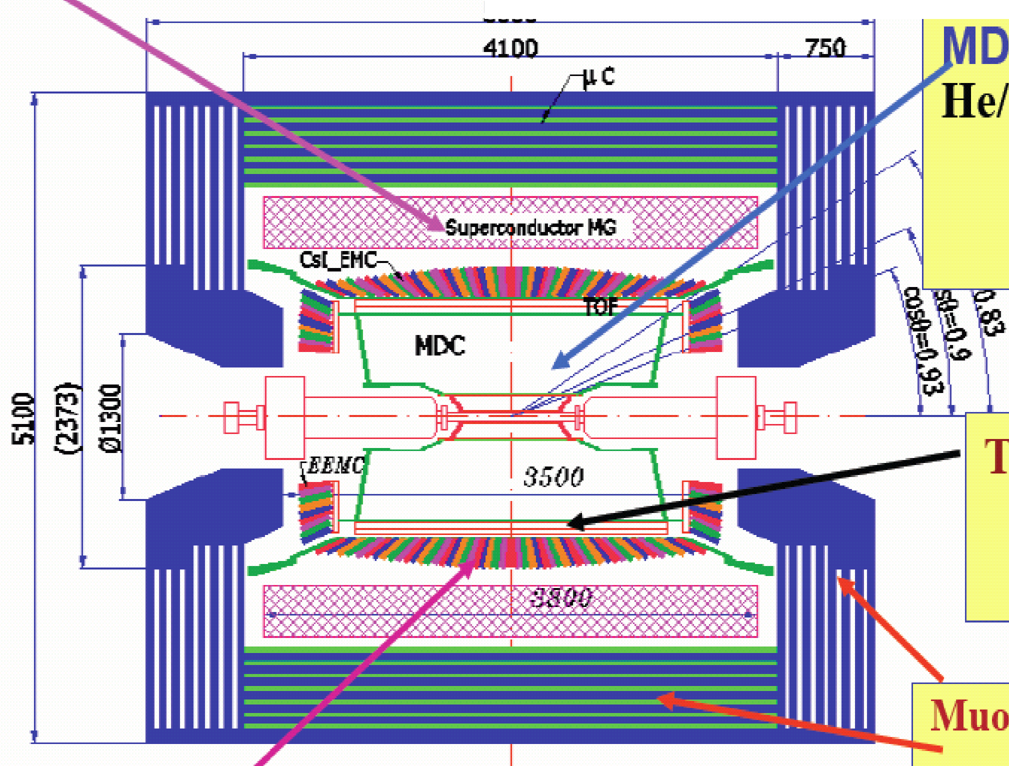
Beam energy: 1.0-2.3 GeV
Optimum energy: 1.89 GeV
Designed luminosity: 1.00×10^{33} $cm^{-2}s^{-1}$
Data taken from: 2009
Achieved luminosity: 1.00×10^{33} $cm^{-2}s^{-1}$

BESIII

Magnet: 1 T Super conducting

Nucl. Instr. Meth. A614, 345 (2010)

MDC: small cell & Gas:
He/C_3H_8 (60/40), 43 layers
σ_{xy}=130 μm
σ_p/p = 0.5% @1GeV
dE/dx=6%



TOF:
σ_T = 100 ps Barrel
110 ps Endcap

Muon ID: 9 layers RPC
8 layers for endcap

EMC: CsI crystal, 28 cm
ΔE/E = 2.5% @1 GeV
σz = 0.6 cm/√E

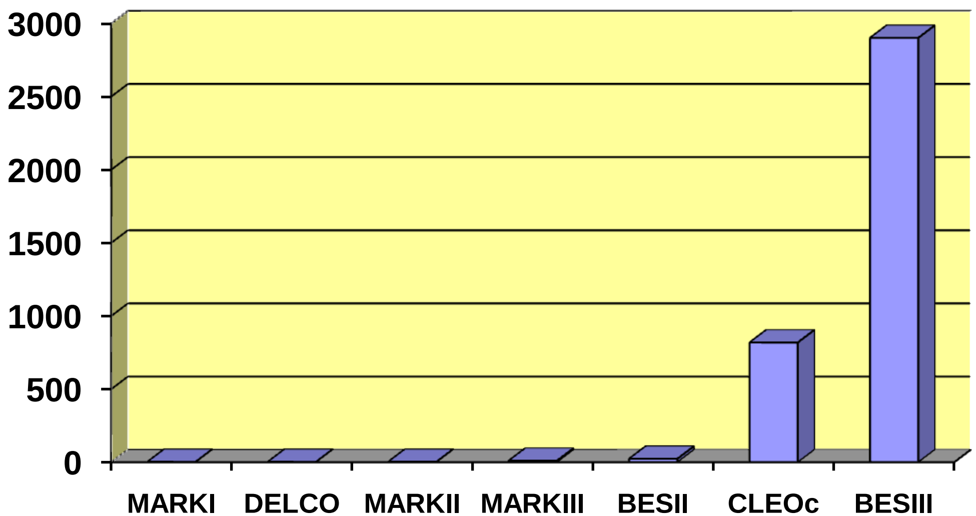
Data Acquisition:
Event rate = 4 kHz
Total data volume ~ 50 MB/s

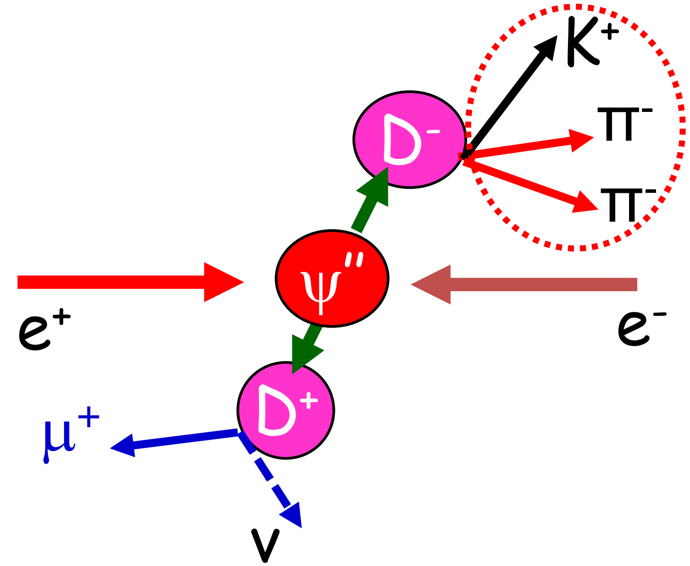
60 ps for ETOF after upgraded in 2015

Charmed meson samples

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

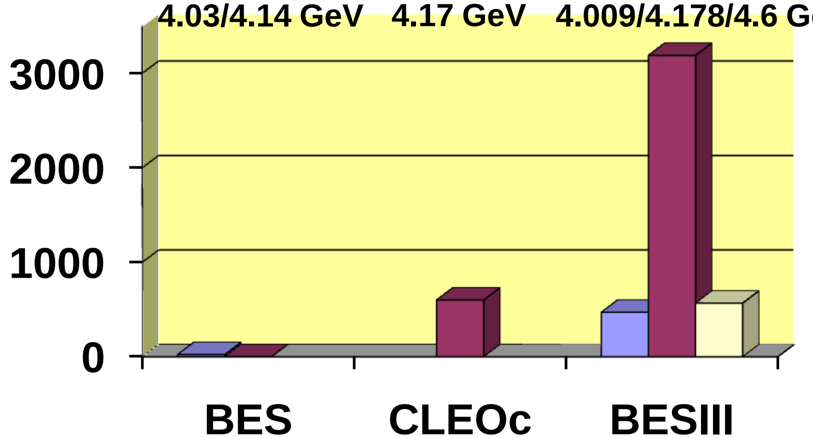
2010-2011
3.773 GeV





- $D_s^+/D_s^+/\Lambda_c^+$ samples

2011/2016/2014



$$N_{\rm ST}^i = 2\times N_{D\bar{D}} \times B_{\rm ST}^i \times \varepsilon_{\rm ST}^i$$

$$N_{\rm DT}^i = 2\times N_{D\bar{D}} \times B_{\rm ST}^i \times B_{\rm sig} \times \varepsilon_{\rm ST\,vs.sig}^i$$

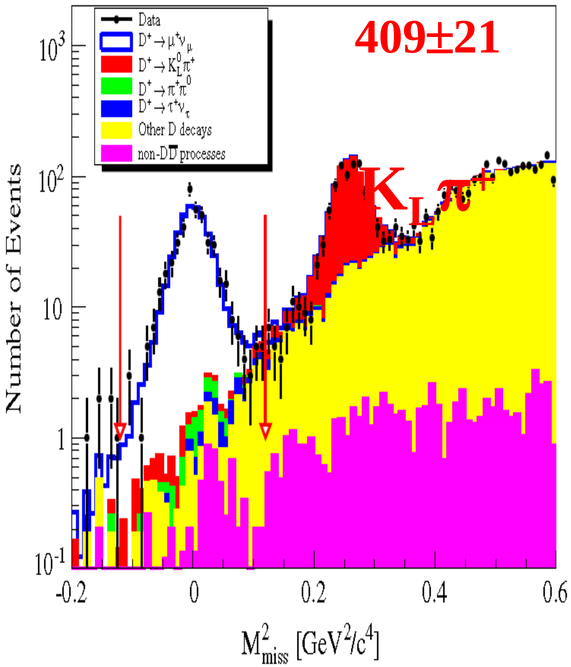
$$B_{\rm sig} = \frac{N_{\rm DT}^{\rm tot}}{N_{\rm ST}^{\rm tot} \times \bar{\varepsilon}_{\rm sig}}$$

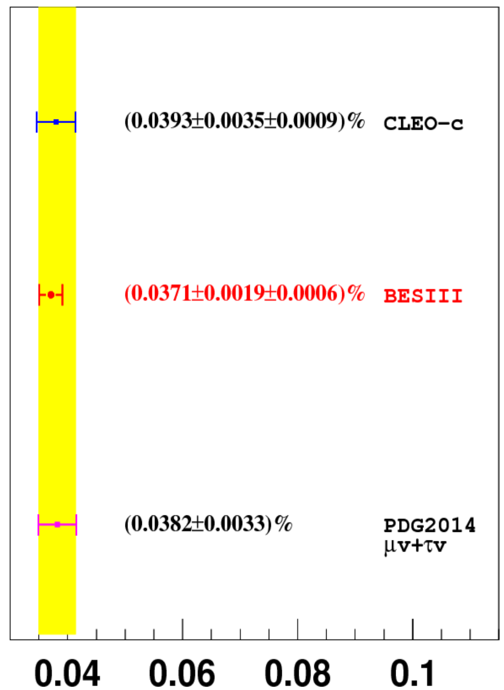
$$\bar{\varepsilon}_{\rm sig} = \sum_{i=1}^{N} (N_{\rm ST}^i \times \varepsilon_{\rm ST\,vs.sig}^i / \varepsilon_{\rm ST}^i) / \sum_{i=1}^{N} N_{\rm ST}^i$$

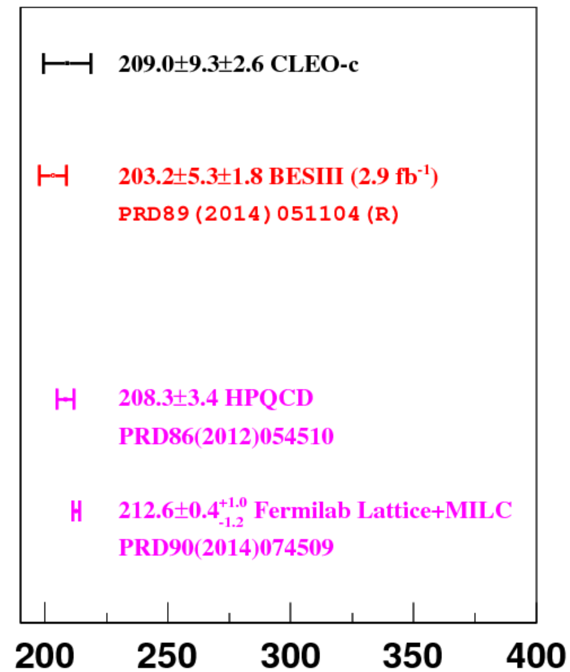
Measurement of D⁺ decay constant

2.93 fb^{-1} data@ 3.773 GeV

PRD89(2014)051104(RC)







$B_{D^+\to\mu^+\nu}=(3.71\pm0.19\pm0.06)\times10^{-4}$

$f_D|V_{cd}|$=45.75±1.20±0.39 MeV

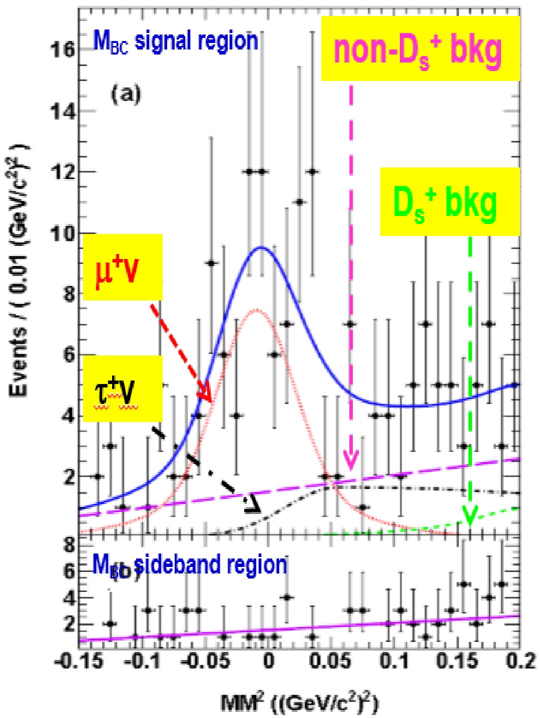
$B[D^+ \to \mu^+\nu]$

f_{D^+} [MeV]

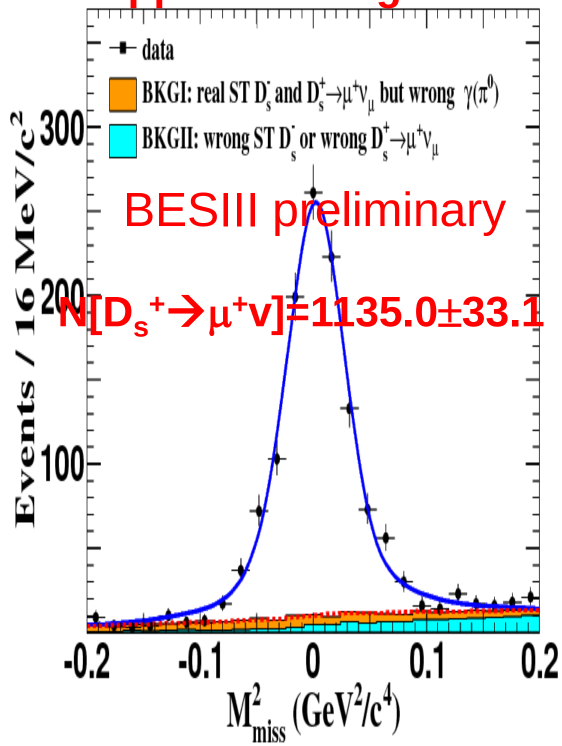
Measurements of D_s^+ decay constant

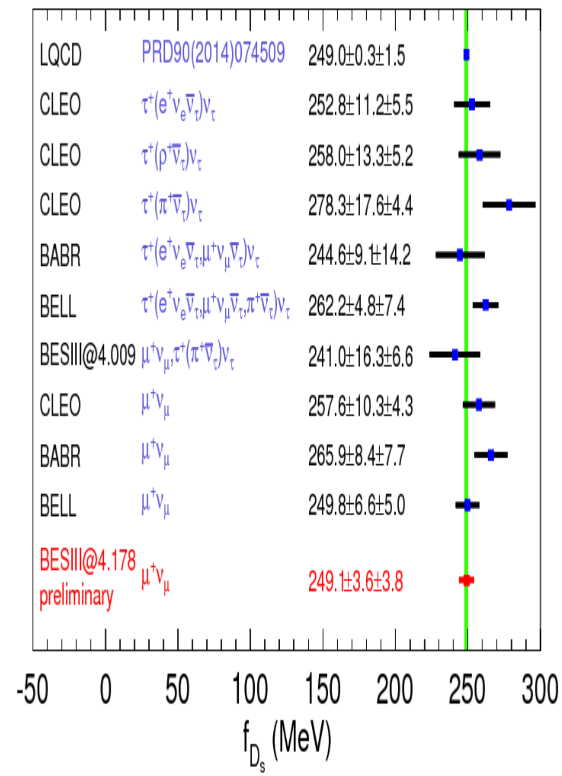
0.48 fb^{-1} data@4.01 GeV **3.19 fb^{-1} data@4.178 GeV**

PRD94(2016)072004



Use μ counter to suppress background



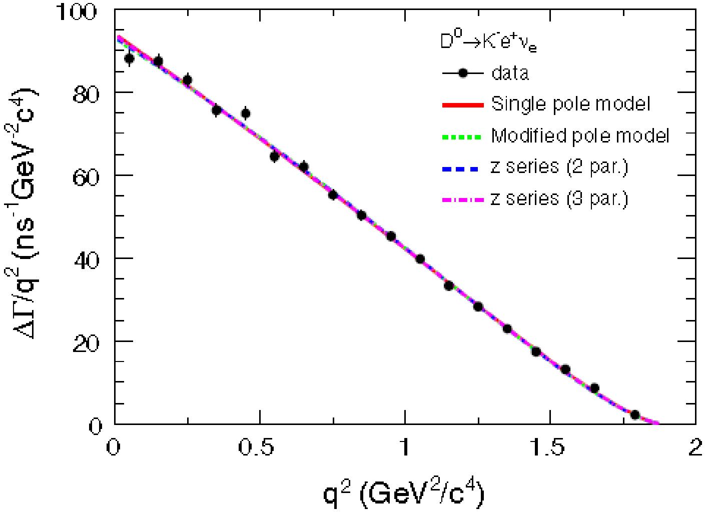


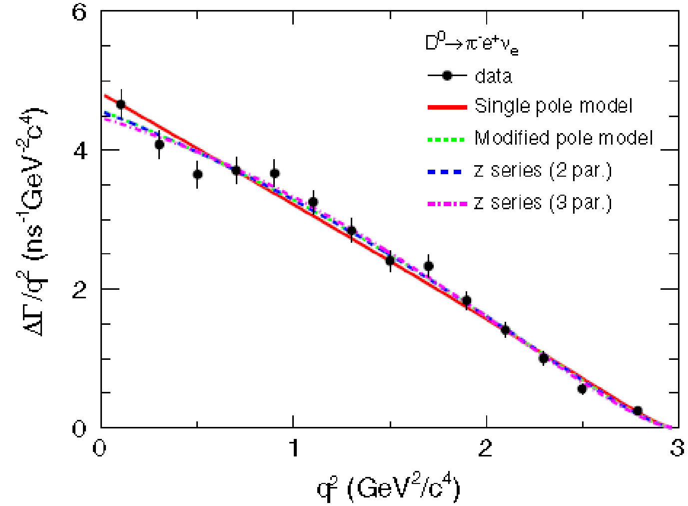
$f_{D_{s+}}$=(241.0±16.3±6.6) MeV

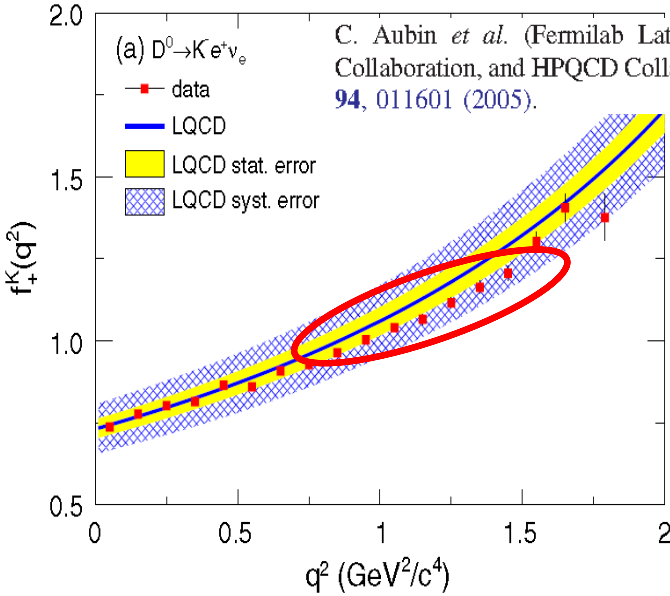
$f_{D_s}|V_{cs}|$=242.5±3.5±3.7 MeV

Form factors in $D^0 \to K(\pi)^- e^+ \nu$

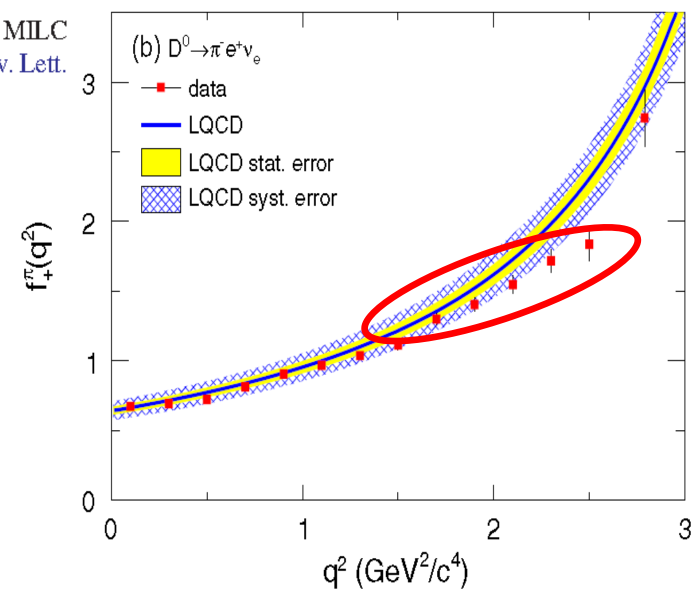
$D^0 \to K^- e^+ \nu$ PRD92(2015)072012 **$D^0 \to \pi^- e^+ \nu$**



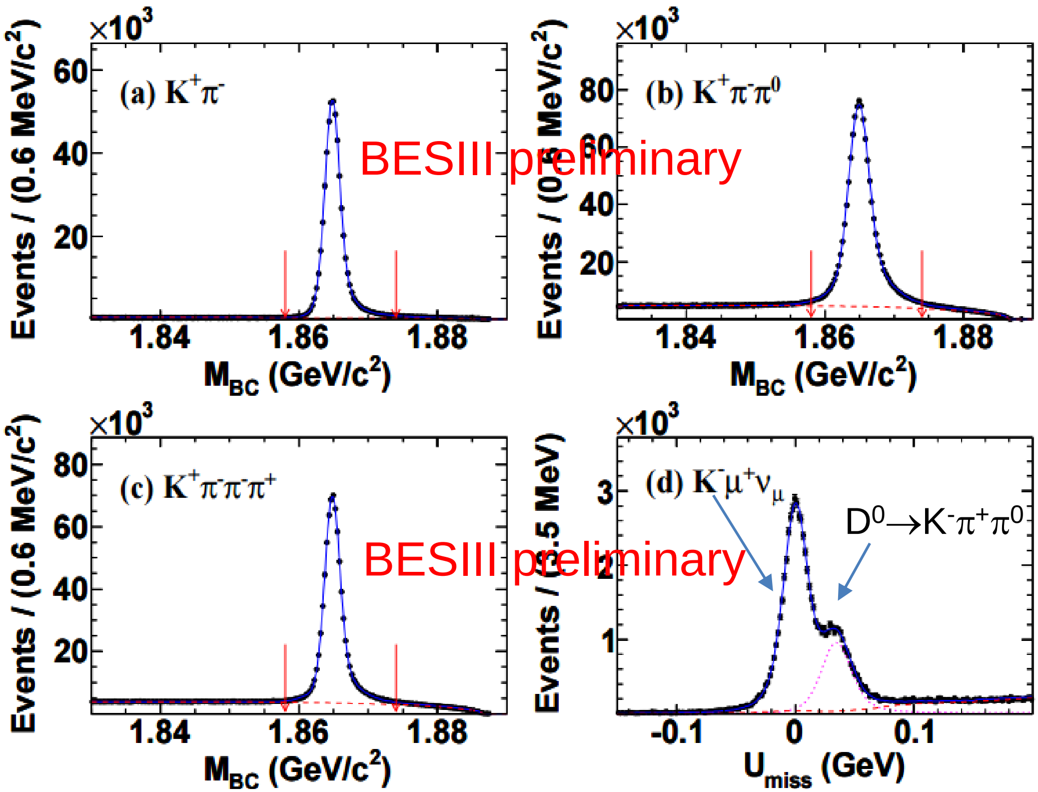


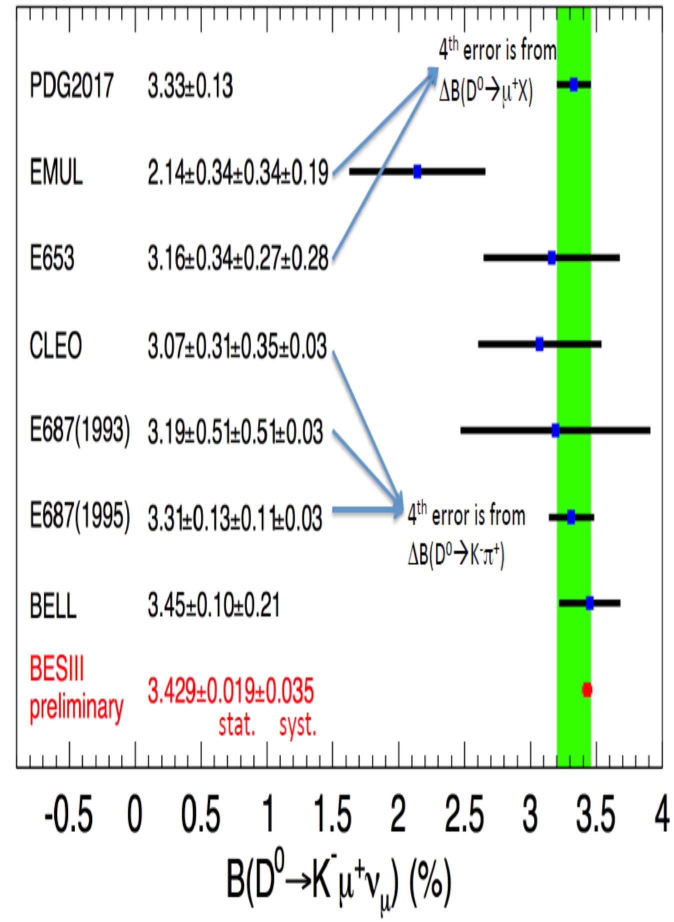


C. Aubin *et al.* (Fermilab Lattice Collaboration, MILC Collaboration, and HPQCD Collaboration), Phys. Rev. Lett. **94**, 011601 (2005).



Absolute branching fraction of $D^0 \to K^-\mu^+\nu$





Total ST yield: $(234 \pm 2) \times 10^4$

DT yield: 47100 ± 259

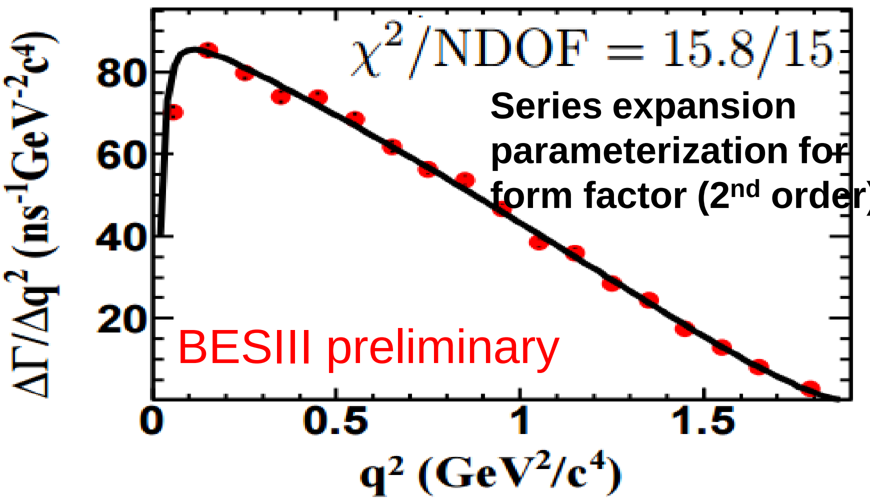
Improved analysis of $D^0 \to K^- \mu^+ \nu$ dynamics

Differential partial widths

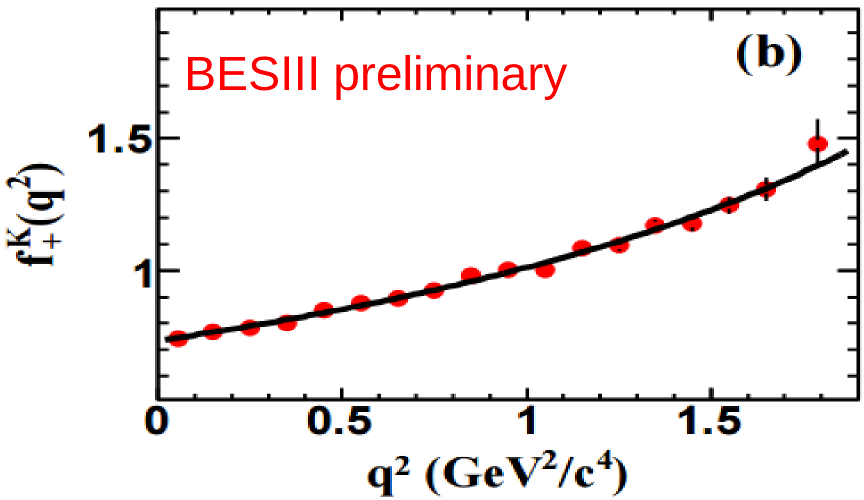
$$\frac{d\Gamma}{dq^2} = \frac{G_F^2|V_{cs}|^2}{8\pi^3 m_D}|\vec{p}_K||f_+^K(q^2)|^2\left(\frac{W_0 - E_K}{F_0}\right)^2$$
$$\times \left[\frac{1}{3}m_D|\vec{p}_K|^2 + \frac{m_\ell^2}{8m_D}(m_D^2 + m_K^2 + 2m_D E_K)\right.$$
$$+ \frac{1}{3}m_\ell^2\frac{|\vec{p}_K|^2}{F_0} + \frac{1}{4}m_\ell^2\frac{m_D^2 - m_K^2}{m_D}\mathrm{Re}\left(\frac{f_-^K(q^2)}{f_+^K(q^2)}\right)$$
$$\left. + \frac{1}{4}m_\ell^2 F_0\left|\frac{f_-^K(q^2)}{f_+^K(q^2)}\right|^2\right]$$

Assumed to be independent of q^2 following FOCUS's treatment (PLB607(2005)233)

$$q = p_\mu + p_\nu$$
$$W_0 = (m_D^2 + m_K^2 - m_\ell^2)/2m_D$$
$$F_0 = W_0 - E_K + m_\ell^2/2m_D$$



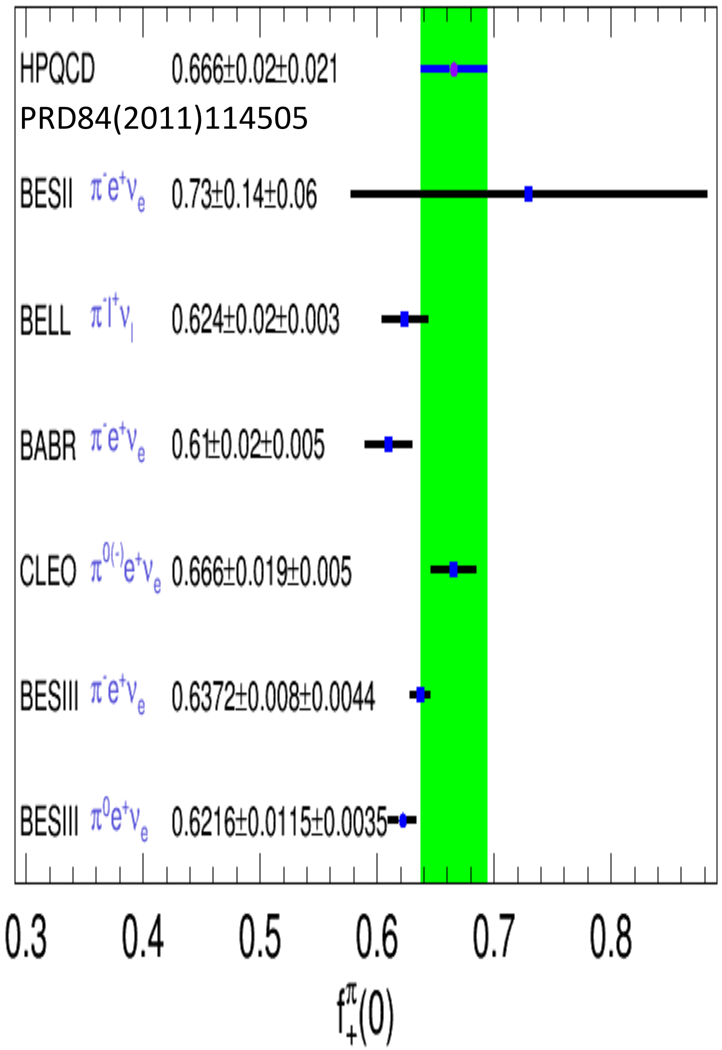
Series expansion parameterization for form factor (2nd order):

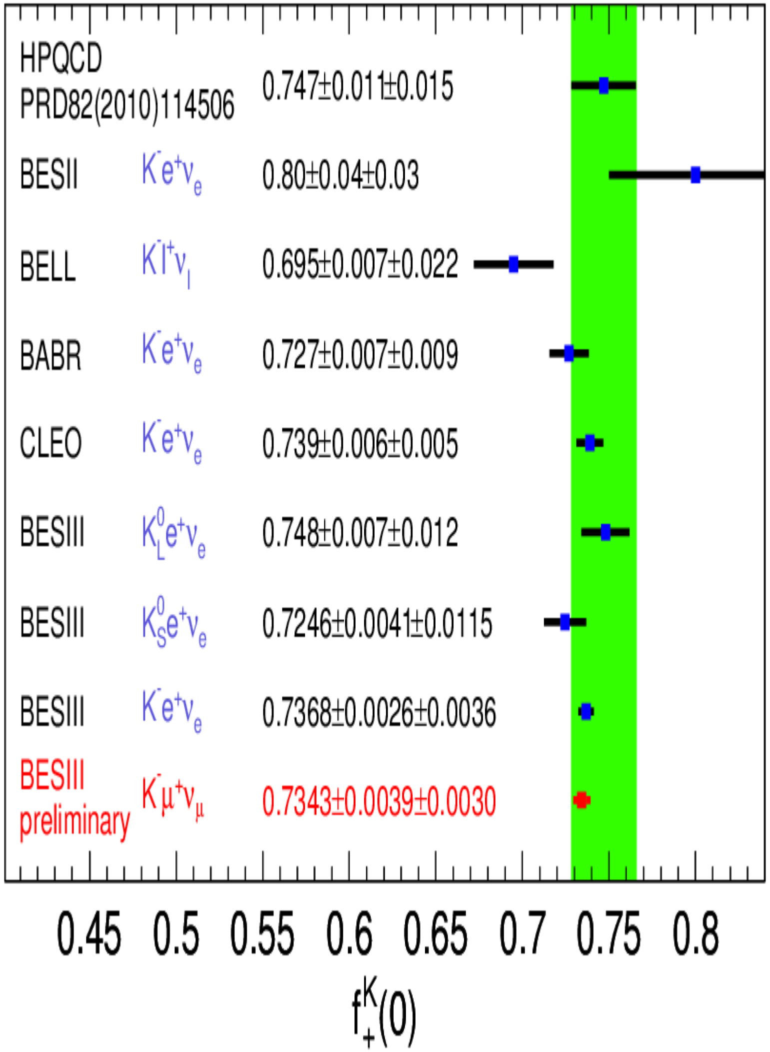


$$f_+^K(0)|V_{cs}| = 0.7148 \pm 0.0038_{\mathrm{stat.}} \pm 0.0029_{\mathrm{syst.}}$$
$$r_1 = -1.94 \pm 0.21_{\mathrm{stat.}} \pm 0.07_{\mathrm{syst.}}$$

$$f_-^K/f_+^K = -0.7 \pm 0.9_{\mathrm{stat.}} \pm 0.1_{\mathrm{syst.}}$$

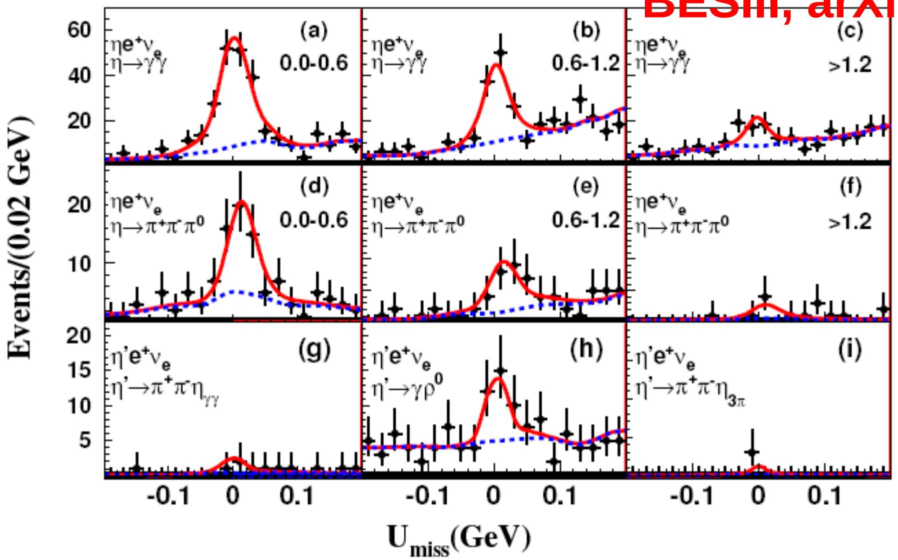
Comparisons of form factors $f_+^{K(\pi)}(0)$

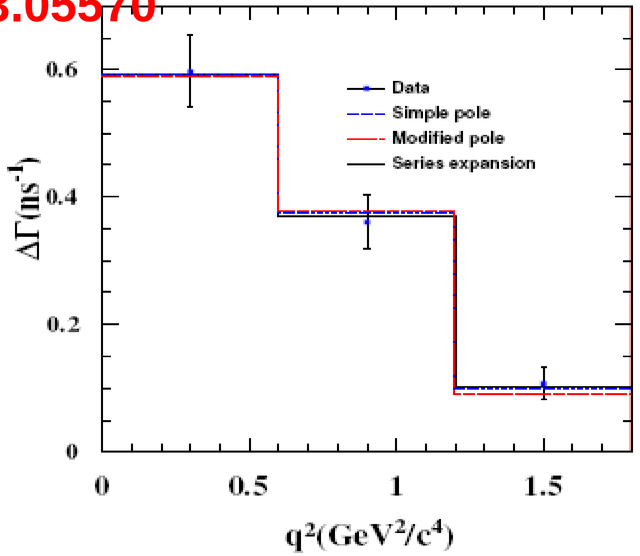




Measurements of D⁺→η(')e⁺ν

BESIII, arXiv:1803.05570





$$\mathcal{B}_{\eta e^+\nu_e} = (10.74 \pm 0.81 \pm 0.51) \times 10^{-4}$$

$$\mathcal{B}_{\eta' e^+\nu_e} = (1.91 \pm 0.51 \pm 0.13) \times 10^{-4}$$

$$\frac{\mathrm{d}\Gamma(D^+ \to \eta e^+\nu_e)}{\mathrm{d}q^2} = \frac{G_F^2|V_{cd}|^2}{24\pi^3}|\vec{p}_\eta|^3|f_+(q^2)|^2$$

Fit parameters	Simple pole	Modified pole	Series expansion
$f_+(0)\|V_{cd}\|$ $(\times 10^{-2})$	$8.15 \pm 0.45 \pm 0.18$	$8.24 \pm 0.51 \pm 0.22$	$7.86 \pm 0.64 \pm 0.21$
Shape parameter	$1.73 \pm 0.17 \pm 0.03$	$0.50 \pm 0.54 \pm 0.08$	$-7.33 \pm 1.69 \pm 0.40$
ρ	0.80	-0.85	0.90
χ^2/ndf	$0.1/(3-2)$	$0.3/(3-2)$	$0.5/(3-2)$

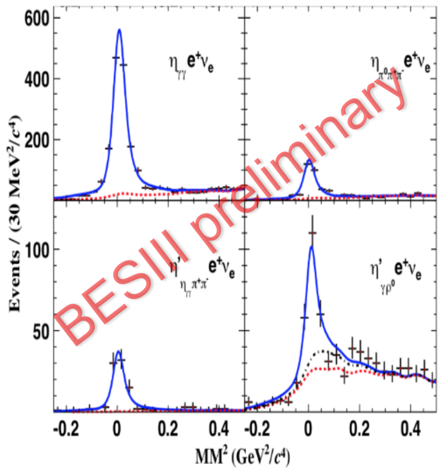
BFs help to constrain gluon component

$$\begin{pmatrix} \eta \\ \eta' \\ G \end{pmatrix} = \begin{pmatrix} \cos\phi' & -\sin\phi' & 0 \\ \sin\phi'\cos\phi_G & \cos\phi'\cos\phi_G & \sin\phi_G \\ -\sin\phi'\sin\phi_G & -\cos\phi'\sin\phi_G & \cos\phi_G \end{pmatrix} \begin{pmatrix} \eta_q \\ \eta_s \\ g \end{pmatrix}$$

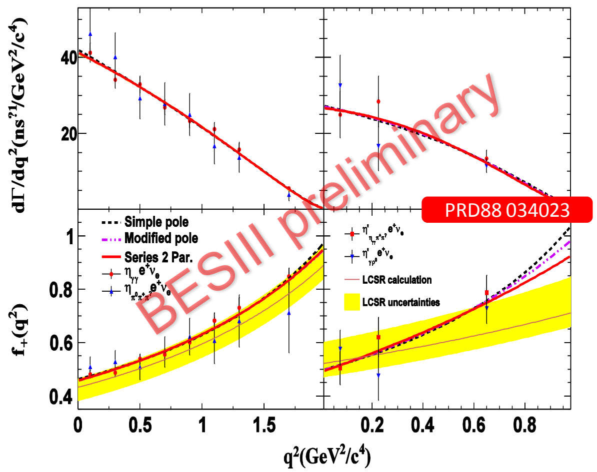
Combing CLEO's BFs and taking input value by EPJC69,133 and NPPS162, 312, the η–η' mixing angle is determined to be $\phi_P = (40 \pm 3_{\text{experiment}} \pm 3_{\text{theory}})^0$

First form factor measurement of $D_s \to \eta^{(\prime)} e^+ \nu$

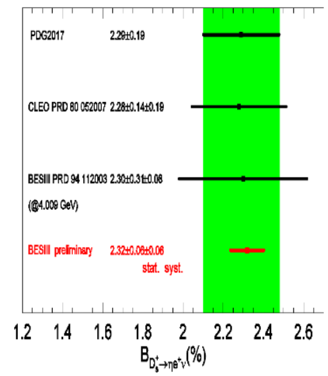
MM² fits

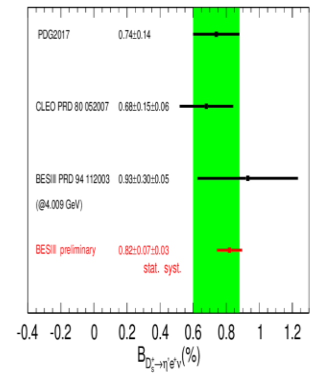


Fits to partial decay rates



Comparisons of branching fractions

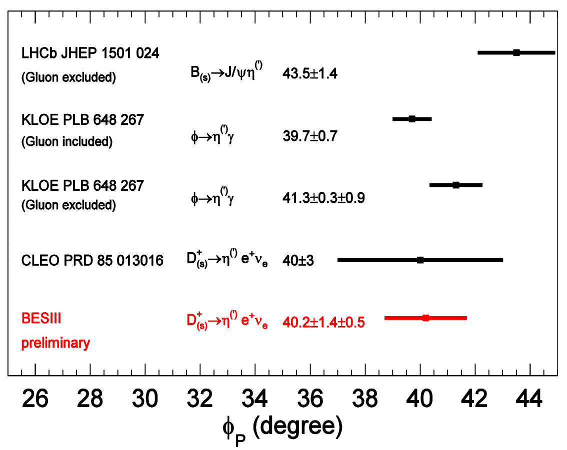




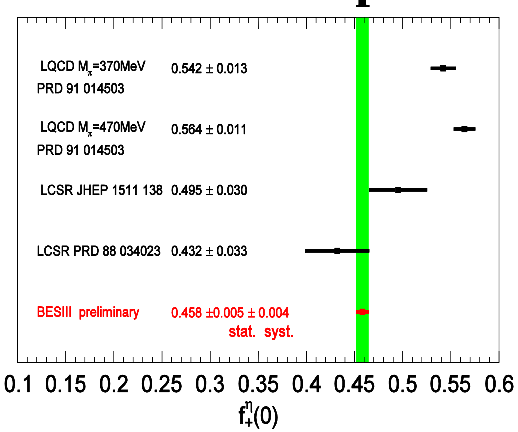
Case	Simple pole $f_+^{\eta^{(\prime)}}(0)\lvert V_{cs}\rvert$	$M_{\rm pole}$	$\chi^2/{\rm NDOF}$	Modified pole $f_+^{\eta^{(\prime)}}(0)\lvert V_{cs}\rvert$	α	$\chi^2/{\rm NDOF}$	Series 2 Par. $f_+^{\eta^{(\prime)}}(0)\lvert V_{cs}\rvert$	r_1	$\chi^2/{\rm NDOF}$
$\eta e^+\nu_e$	0.450(5)(3)	3.77(8)(5)	12.2/14	0.445(5)(3)	0.30(4)(3)	11.4/14	0.446(5)(4)	−2.2(2)(1)	11.5/14
$\eta' e^+\nu_e$	0.494(45)(10)	1.88(54)(5)	1.8/4	0.481(44)(10)	1.62(91)(11)	1.8/4	0.477(49)(11)	−13.1(76)(11)	1.9/4

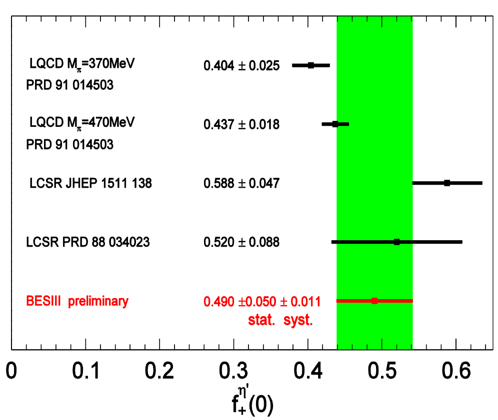
η-η' mixing angle

$$\frac{\Gamma(D_s^+ \to \eta' e^+ \nu)/\Gamma(D_s^+ \to \eta e^+ \nu)}{\Gamma(D^+ \to \eta' e^+ \nu)/\Gamma(D^+ \to \eta e^+ \nu)} \simeq \cot^4 \phi_P$$

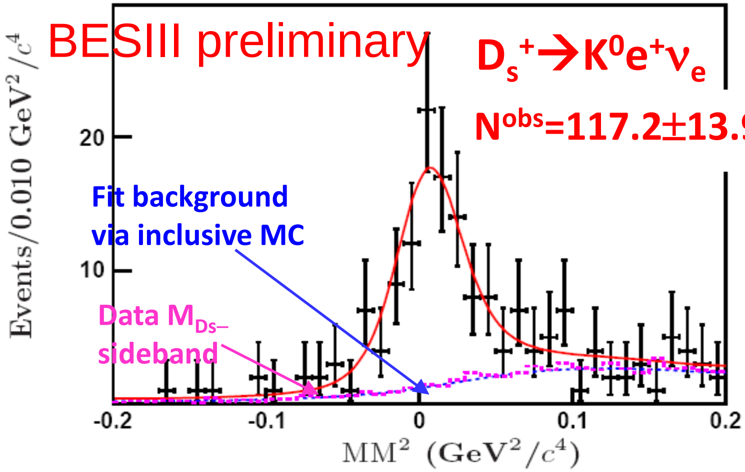


Comparisons of form factors



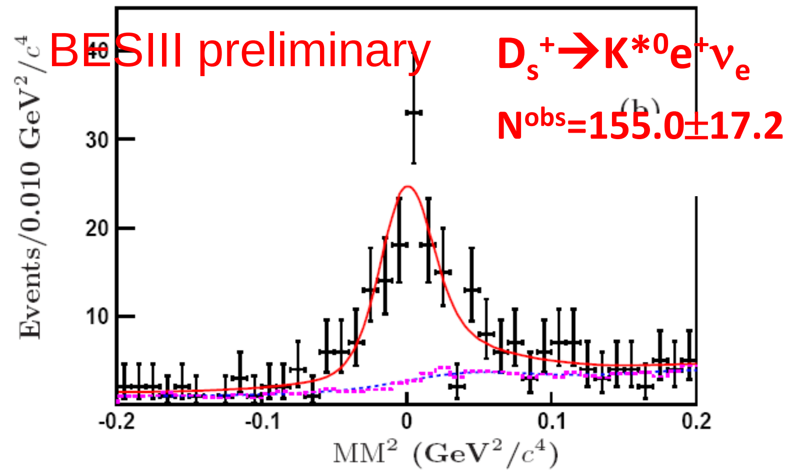


First form factor measurement of $D_s^+ \to K^{(*)0} e^+ \nu$



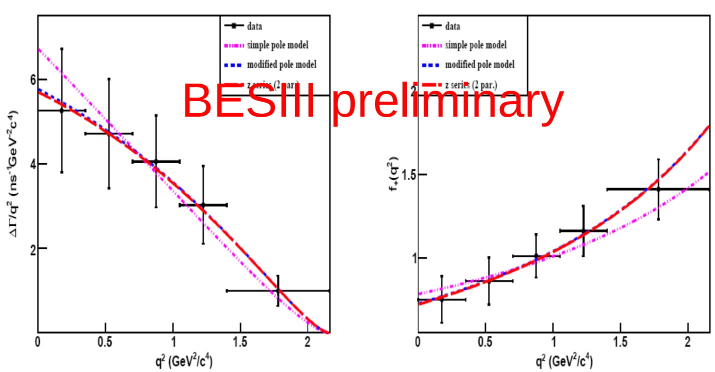
$B[D_s^+ \to K^0 e^+ \nu_e] = (3.25 \pm 0.38_{stat} \pm 0.14_{syst}) \times 10^{-3}$

$(3.9 \pm 0.9) \times 10^{-3}$ [PDG17]



$B[D_s^+ \to K^{*0} e^+ \nu_e] = (2.38 \pm 0.26_{stat} \pm 0.12_{syst}) \times 10^{-3}$

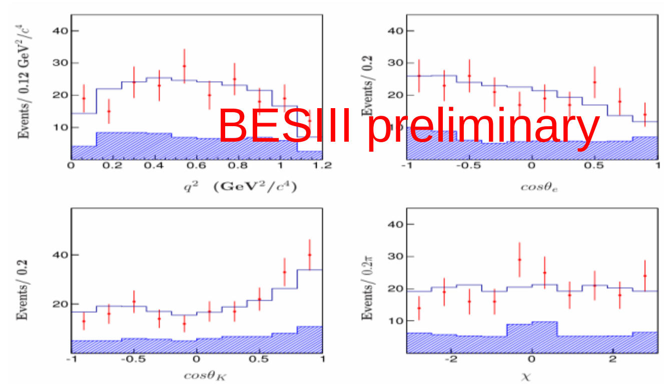
$(1.8 \pm 0.4) \times 10^{-3}$ [PDG17]



Model	Parameter	Value	$f_+(0)$
Simple pole	$f_+(0)\lvert V_{cd}\rvert$	$0.175 \pm 0.010 \pm 0.001$	$0.778 \pm 0.044 \pm 0.004$
Modified pole model	$f_+(0)\lvert V_{cd}\rvert$	$0.163 \pm 0.017 \pm 0.003$	$0.725 \pm 0.076 \pm 0.013$
	α	$0.45 \pm 0.44 \pm 0.02$	
Series two parameters	$f_+(0)\lvert V_{cd}\rvert$	$0.162 \pm 0.019 \pm 0.003$	$0.720 \pm 0.084 \pm 0.013$
	r_1	$-2.94 \pm 2.32 \pm 0.14$	

Taking $|V^{CKMfitter}_{cd}|$ as input

Four dimensional un-binned likelihood fit is performed. K* parameter's are fixed

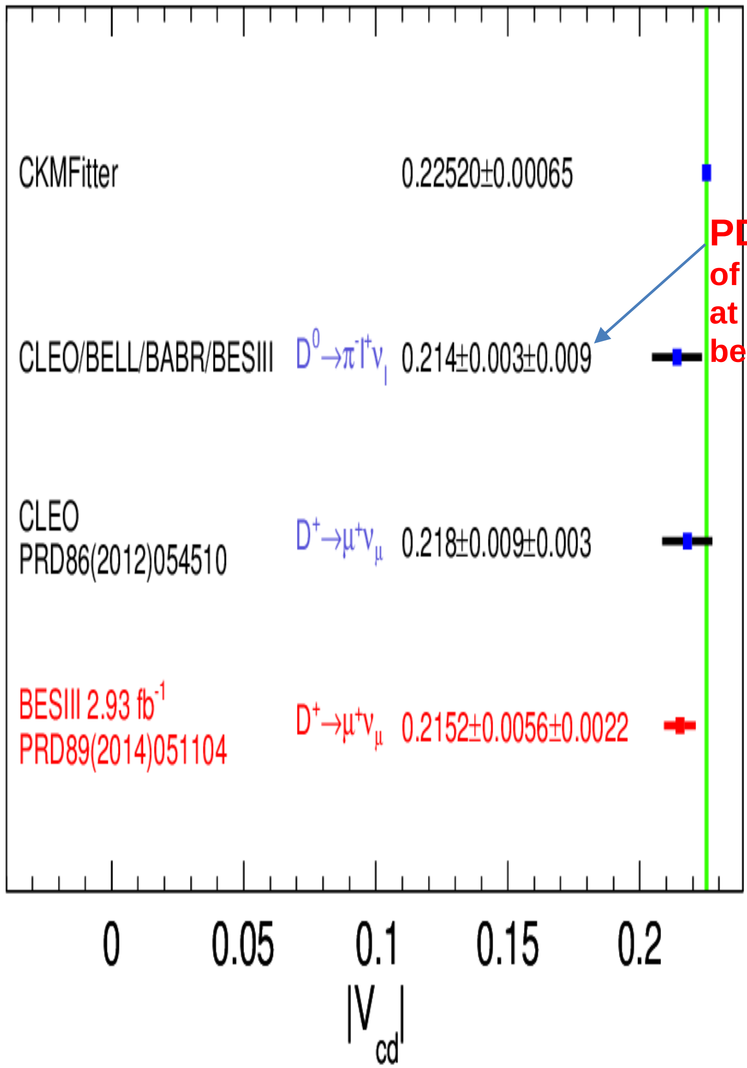


$r_V = 1.67 \pm 0.34 \pm 0.16$

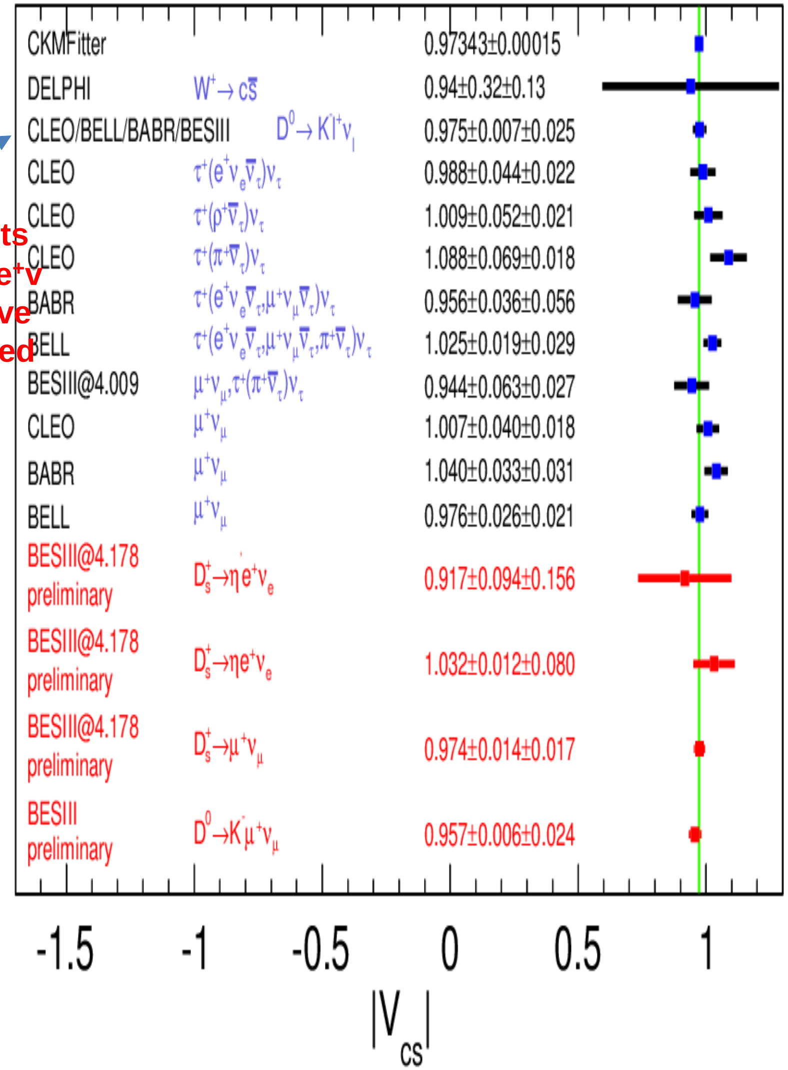
$r_2 = 0.77 \pm 0.28 \pm 0.07$

Comparisons of CKM matrix elements $|V_{cs(d)}|$

For measurements, the first error is the combined stat. and syst. errors, the second is LQCD uncertainty

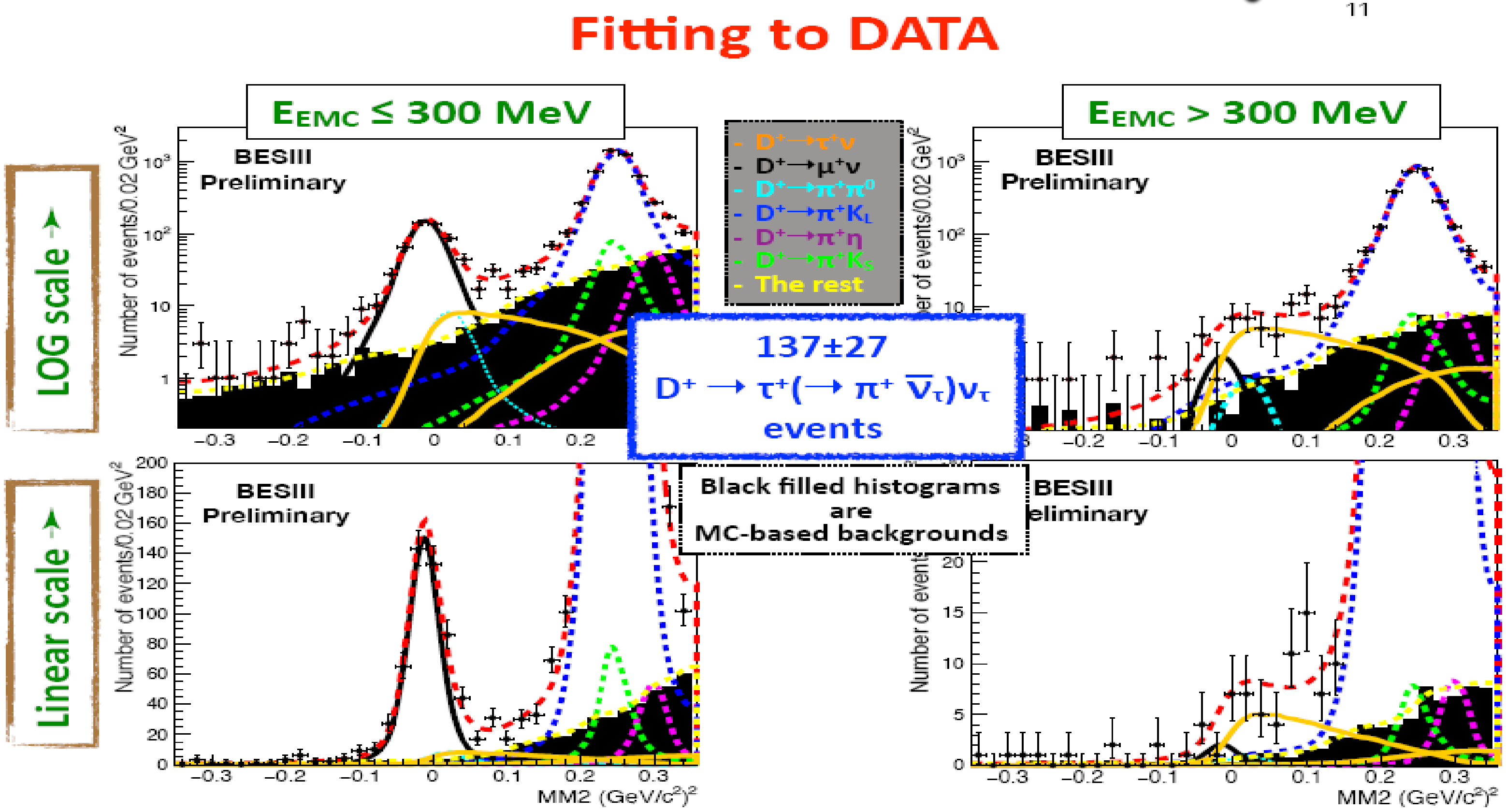


PDG: results of $D^0 \to K(\pi)^- e^+ \nu$ at BESIII have been included



LFU test in $D^+ \rightarrow l^+ \nu$ decays

Fitting to DATA



4σ

$B[D^+ \rightarrow \tau^+ \nu] = (1.20 \pm 0.24_{stat.}) \times 10^{-3}$

$$R \equiv \frac{\Gamma(D^+ \to \tau^+ \nu)}{\Gamma(D^+ \to \mu^+ \nu)} = \frac{m_{\tau^+}^2 \left(1 - \frac{m_{\tau^+}^2}{M_{D^+}^2}\right)^2}{m_{\mu^+}^2 \left(1 - \frac{m_{\mu^+}^2}{M_{D^+}^2}\right)^2}$$

SM prediction: 2.66

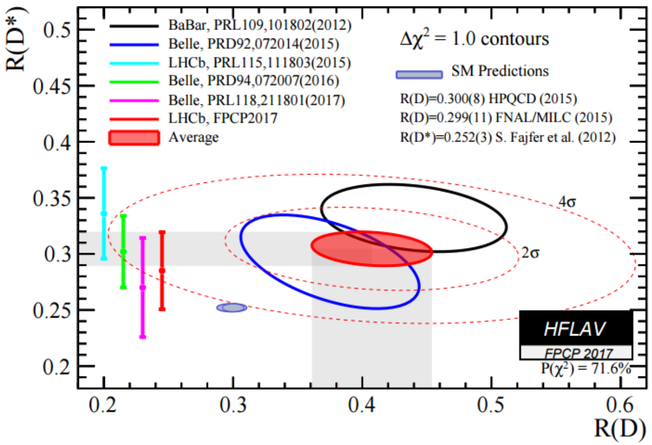
BESIII: 3.21±0.64

LFU test in $D^{0(+)} \to \pi l^+ \nu$ decays

$$R_{LU}^{0(+)} = \frac{B(D^{0(+)} \to \pi^{-(0)}\mu^+\nu)}{B(D^{0(+)} \to \pi^{-(0)}e^+\nu)} \sim 0.985(2)$$

Evidence of violation of LFU at 4σ in

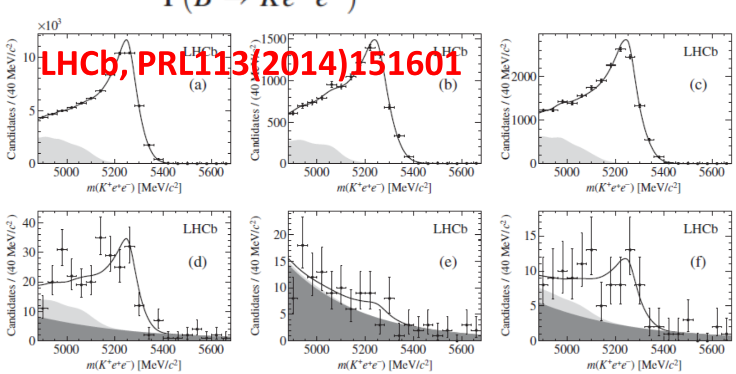
$$R(D^{(*)}) = \frac{B(B \to D^{(*)}\tau\nu)}{B(B \to D^{(*)}l\nu)}$$



Evidence at 2.6σ in FCNC decays $B^+ \to K^+\mu^+\mu^-/K^+e^+e^-$

$$R_K = \frac{\Gamma(\bar{B} \to \bar{K}\mu^+\mu^-)}{\Gamma(\bar{B} \to \bar{K}e^+e^-)} = 0.745^{+0.090}_{-0.074} \pm 0.036$$

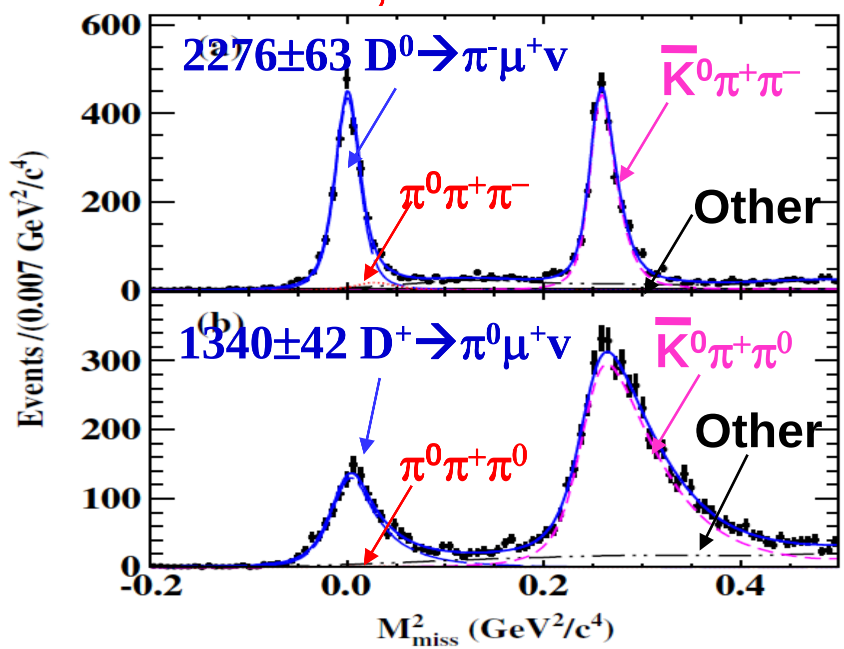
LHCb, PRL113(2014)151601



B^{PDG16}: $R_{LU}^0 = 0.82 \pm 0.08 \quad (\sim 2.1\sigma)$

$B(D^0 \to \pi^-\mu^+\nu) = (0.237 \pm 0.024)\%$

BESIII, arXiv:1802.05492



$B[D^0 \to \pi^-\mu^+\nu] = (0.267 \pm 0.007 \pm 0.007)\%$

$B[D^+ \to \pi^0\mu^+\nu] = (0.342 \pm 0.011 \pm 0.010)\%$

$$\mathcal{R}_{LU}^0 = 0.905 \pm 0.027_{stat.} \pm 0.023_{syst.}$$

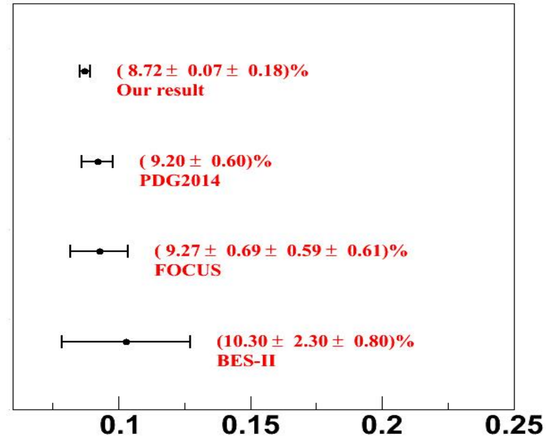
$$\mathcal{R}_{LU}^+ = 0.942 \pm 0.037_{stat.} \pm 0.027_{syst.}$$

LFU test in D→Kl⁺v decays

BESIII, EPJC76(2016)369

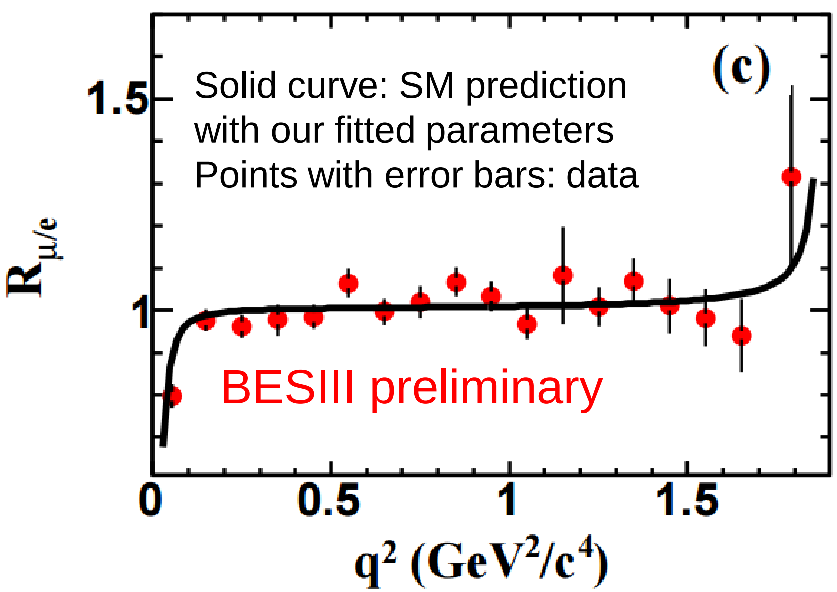
$$\frac{\Gamma[D^+ \to \overline{K}^0 \mu^+ v]}{\Gamma[D^+ \to \overline{K}^0 e^+ v]} = 0.988 \pm 0.033$$

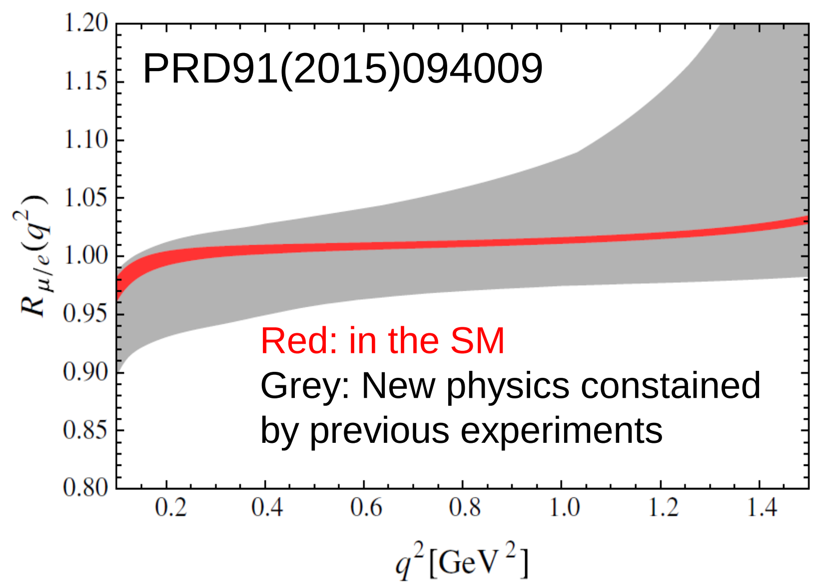
Consistent with theory prediction 0.97 within error



BESIII preliminary

$$R_{\mu/e} = \frac{\Gamma(D^0 \to K^- \mu^+ \nu_\mu)}{\Gamma(D^0 \to K^- e^+ \nu_e)} = 0.978 \pm 0.007_{stat.} \pm 0.012_{syst.}$$





First observation of D→Se⁺ν

- Explore the nontrivial internal structure of light hadron mesons, traditional $q\bar{q}$ states, tetra quark system.

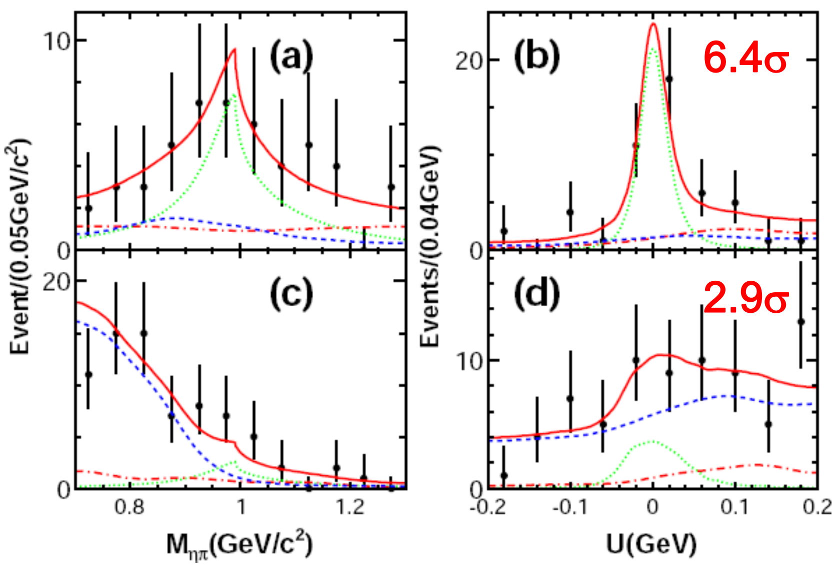
- With chiral unitarity approach in the coupled channels, BF is predicted to be order of $5(6)\times10^{-5}$ for $D^{0(+)}$ decays

- Improve understanding of classification of light scalar mesons

$$R \equiv \frac{B(D^+\to f_0 l^+\nu)+B(D^+\to\sigma l^+\nu)}{B(D^+\to a_0 l^+\nu)}$$

R=1(3) if traditional $q\bar{q}$ (tetra quark) system

BESIII, arXiv:1803.02166



$$\mathcal{B}(D^+ \to a_0(980)^0 e^+\nu_e) \times \mathcal{B}(a_0(980)^0 \to \eta\pi^0) = (1.66^{+0.81}_{-0.66} \pm 0.11) \times 10^{-4}, \quad < 3.0 \times 10^{-4} \text{ at the } 90\% \text{ C.L.}$$

$$\mathcal{B}(D^0 \to a_0(980)^- e^+\nu_e) \times \mathcal{B}(a_0(980)^- \to \eta\pi^-) = (1.33^{+0.33}_{-0.29} \pm 0.09) \times 10^{-4}$$

$$\frac{\Gamma(D^0 \to a_0(980)^- e^+\nu_e)}{\Gamma(D^+ \to a_0(980)^0 e^+\nu_e)} = 2.03 \pm 0.95 \pm 0.06$$

Summary

- Using 2.93 and 3.2 fb^{-1} e^+e^- collision data taken at 3.773 and 4.178 GeV with the BESIII detector, experimental studies of (semi)leptonic $D_{(s)}$ decays have been performed

1. Measurements of decay constants $f_{D(s)+}$, form factors in semileptonic D decays $f_+^{K(\pi)}(0)$: better calibrate LQCD

2. Determinations of $|V_{cs(d)}|$: better test on CKM matrix unitarity

3. Search for LFU violation in $D_{(s)} \to l^+ v$, $D \to K(\pi) l^+ v$ decays

4. Observation of $D \to S e^+ v$ decays

- More results will be coming in the near future

Thank you!

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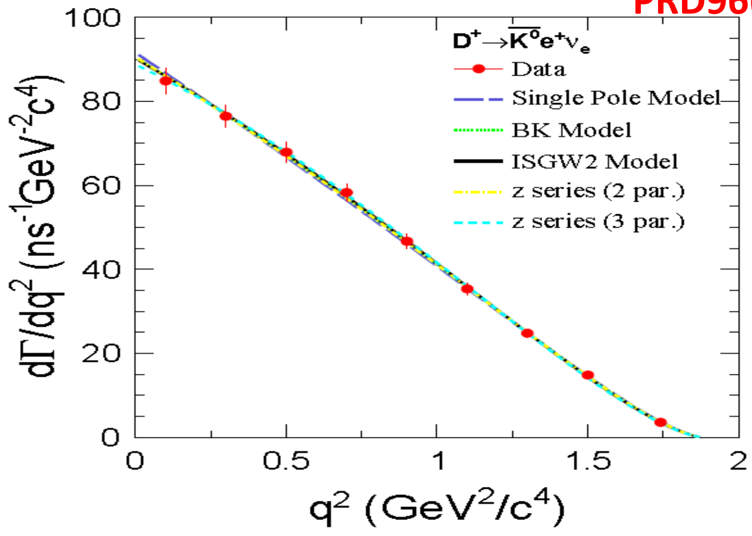
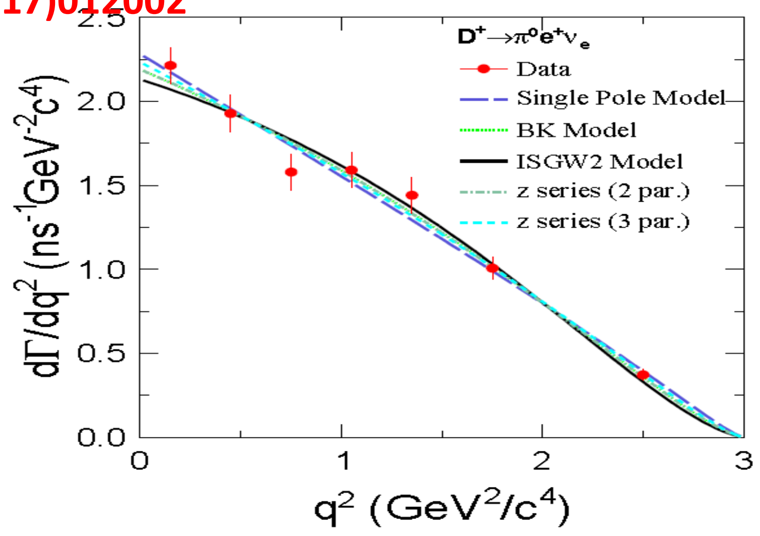
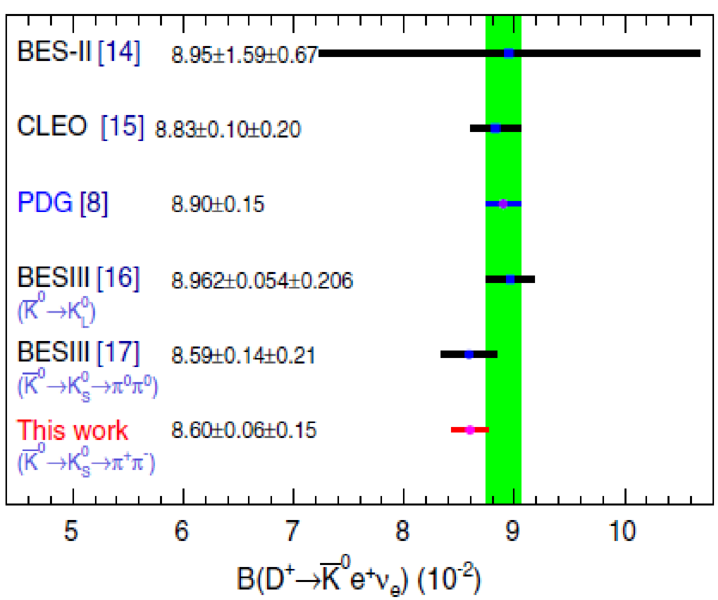
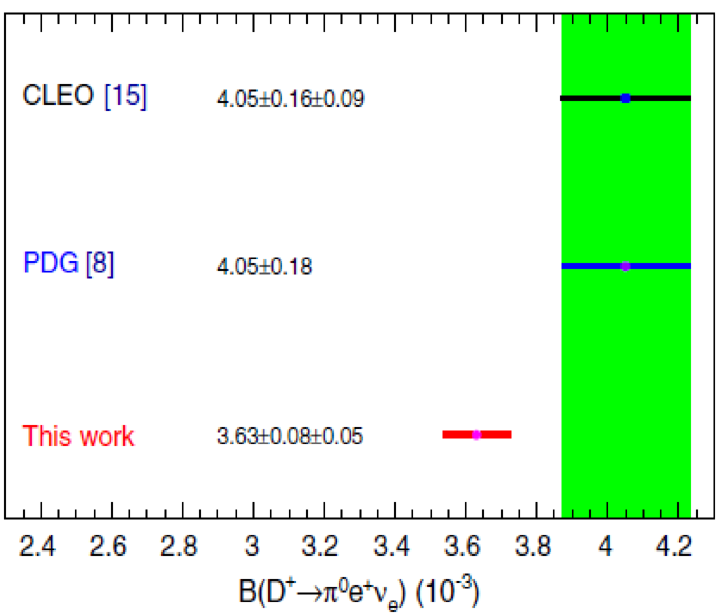
Dynamics in $D^+ \to \bar{K}(\pi)^0 e^+ \nu$

PRD96(2017)012002









Analysis of $D^+ \to K_L e^+ v$

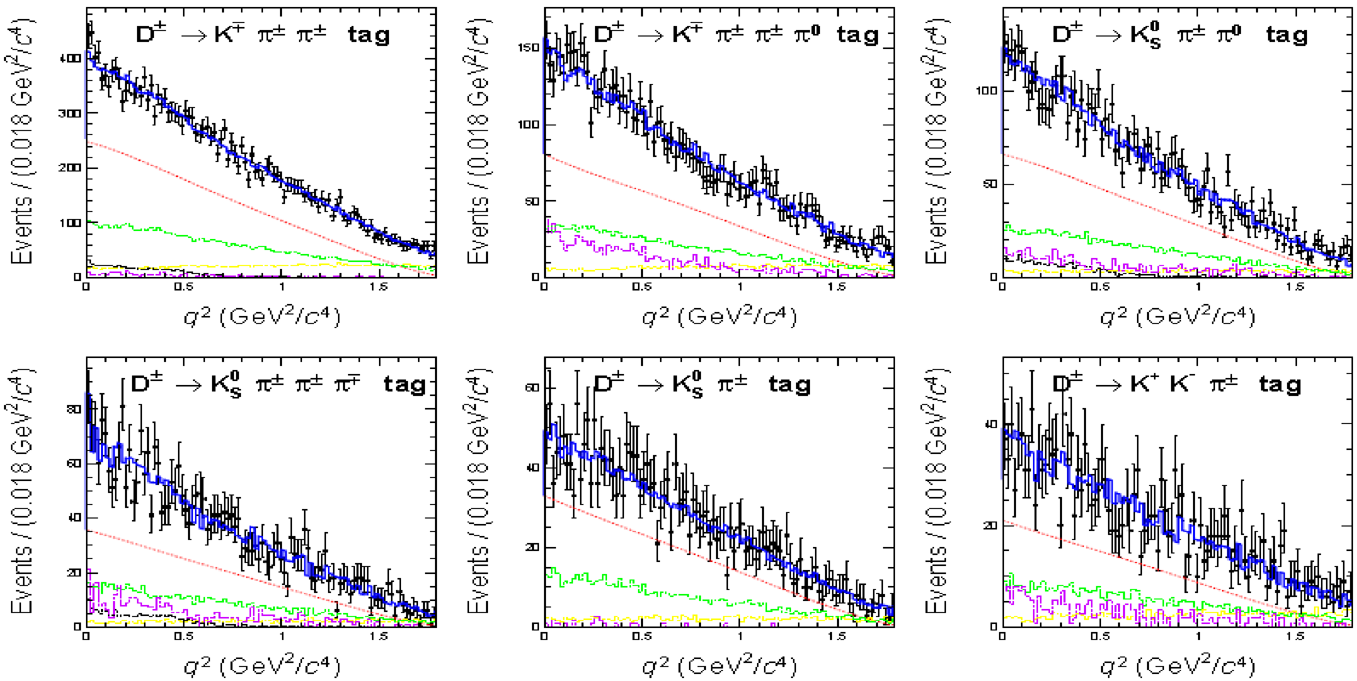
- Regardless of long flight distance, K_L interact with EMC and deposit part of energy, thus giving position information
- After reconstructing all other particles, K_L can be inferred with position information and constraint $U_{miss} \to 0$

$\bar{B}(D^+ \to K_L e^+ v) = (4.482 \pm 0.027 \pm 0.103)\%$

$$A_{CP} \equiv \frac{\mathcal{B}(D^+ \to K_L^0 e^+ \nu_e) - \mathcal{B}(D^- \to K_L^0 e^- \bar{\nu}_e)}{\mathcal{B}(D^+ \to K_L^0 e^+ \nu_e) + \mathcal{B}(D^- \to K_L^0 e^- \bar{\nu}_e)}$$

$A_{CP}^{D^+ \to K_L e^+ v} = (-0.59 \pm 0.60 \pm 1.50)\%$

Simultaneous fit to event density $I(q^2)$ with 2-par. series Form Factor



$D^+ \to K_L e^+ v$ is measured for the first time

PRD92(2015)112008

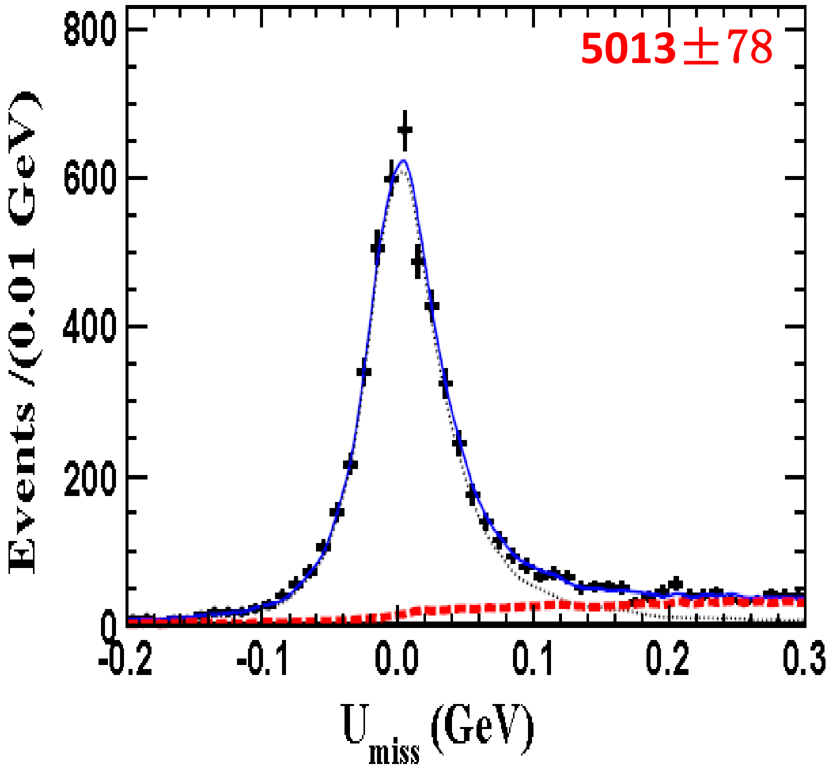
With 6 dominant D^- single tag

$f^K_+(0)|V_{cs}| = 0.728 \pm 0.006 \pm 0.011$

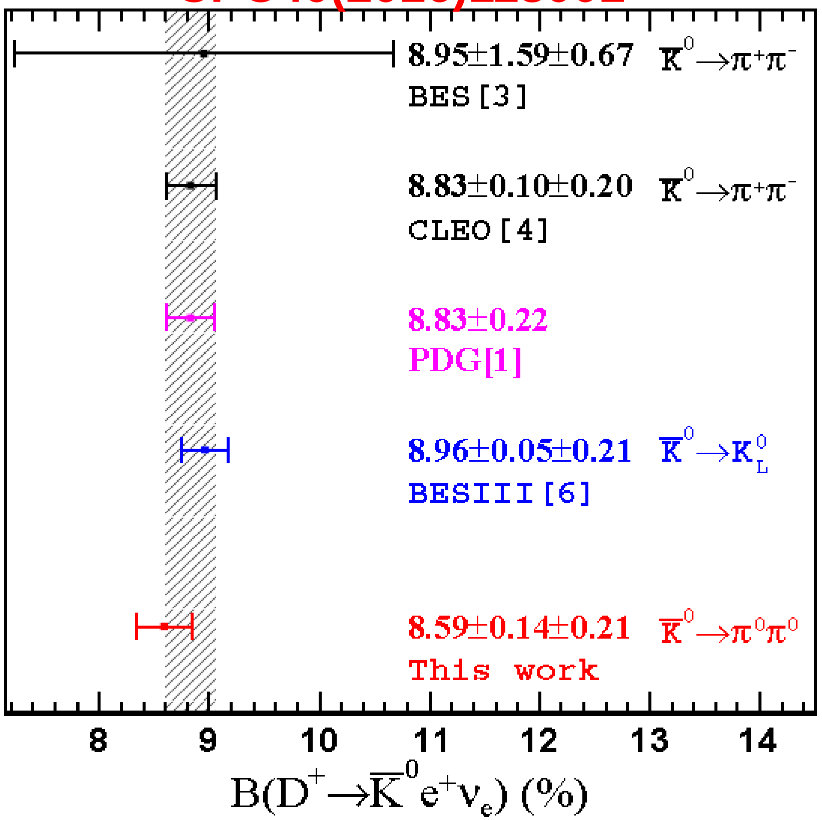
$r_1 = a_1/a_0 = -1.91 \pm 0.33 \pm 0.24$

Absolute BF for $D^+ \to \bar{K}^0 e^+ \nu$ via $\bar{K}^0 \to \pi^0\pi^0$

With 6 dominant D^- single tag



CPC40(2016)113001



Taking τ_{D+}, τ_{D0}, $B[D^0 \to K^- e^+ \nu]$ and $B[D^+ \to \bar{K}^0 e^+ \nu]$ from the PDG as input

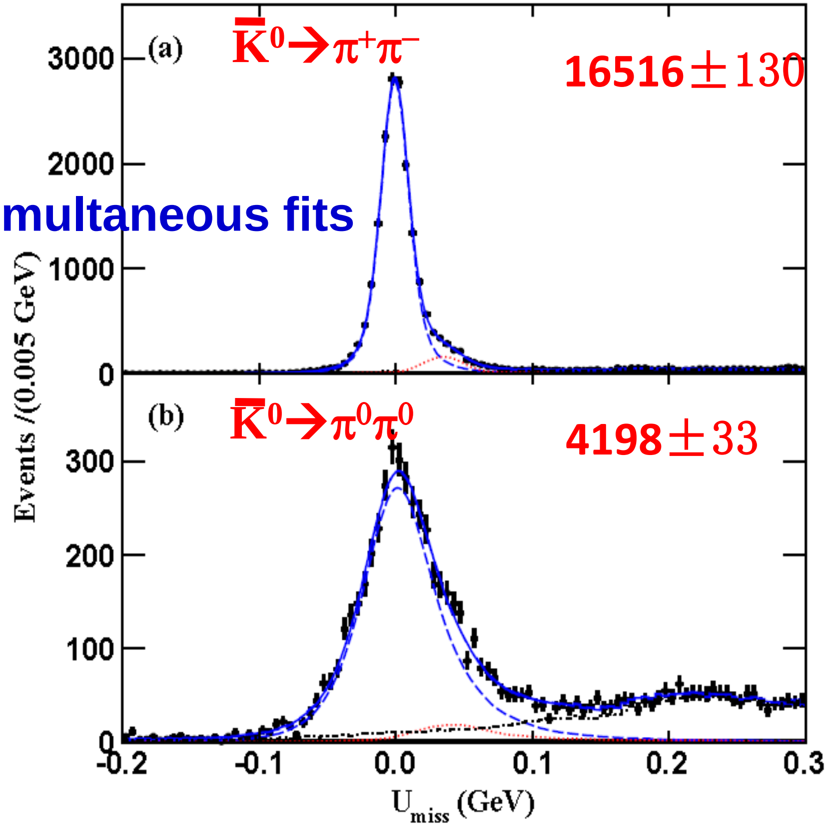
$$\frac{\Gamma[D^0 \to K^- e^+ \nu]}{\Gamma[D^+ \to \bar{K}^0 e^+ \nu]} = 0.969 \pm 0.025$$

Agrees with isospin conservation within 1.2σ

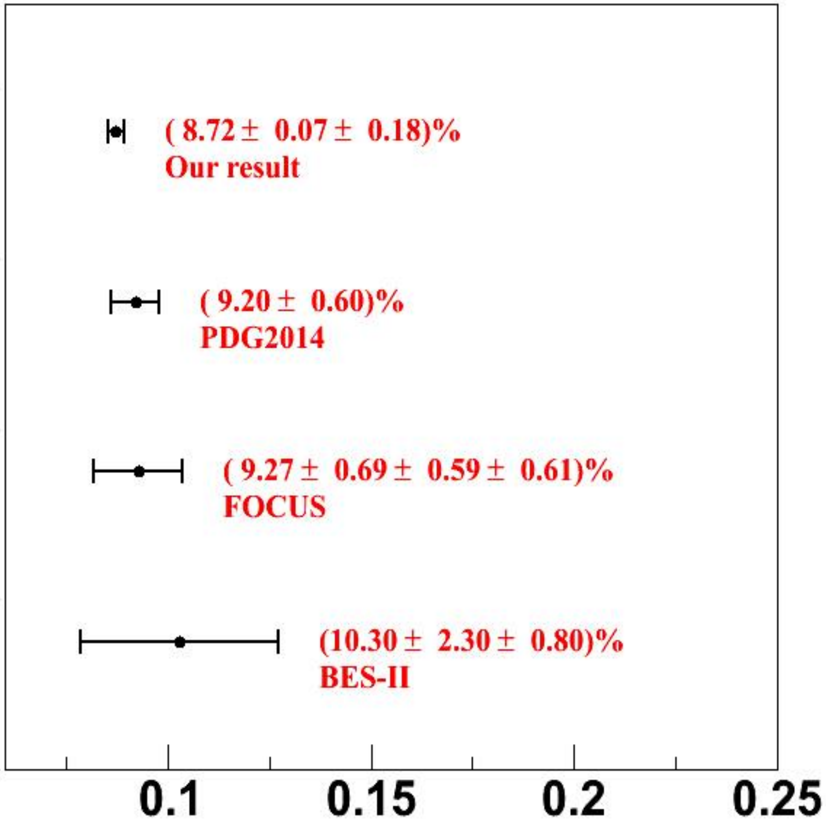
Improved BF for $D^+ \to \bar{K}^0 \mu^+ \nu$

With 6 dominant D^- single tag

Simultaneous fits



EPJC76(2016)369



Taking $B[D^0 \to K^- \mu^+ \nu]$ and $B[D^+ \to \bar{K}^0 e^+ \nu]$ from the PDG as input

$$\frac{\Gamma[D^0 \to K^- \mu^+ \nu]}{\Gamma[D^+ \to \bar{K}^0 \mu^+ \nu]} = 0.963 \pm 0.044$$

Support isospin conservation in these two decays within errors

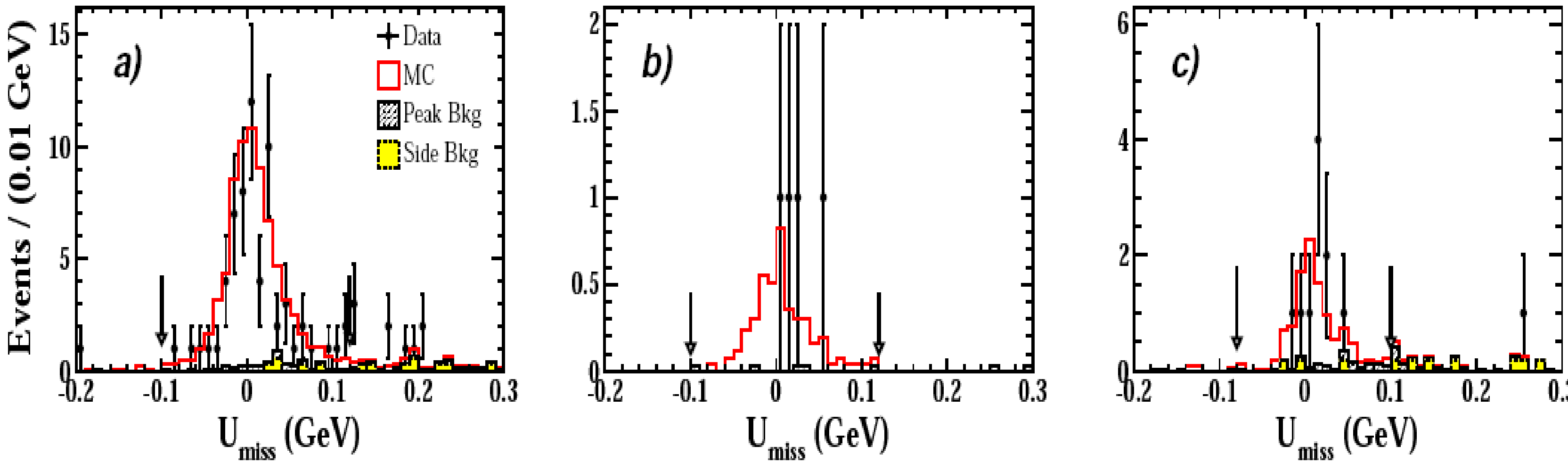
$$\frac{\Gamma[D^+ \to \bar{K}^0 \mu^+ \nu]}{\Gamma[D^+ \to \bar{K}^0 e^+ \nu]} = 0.988 \pm 0.033$$

Consistent with theory prediction 0.97 within error

Measurements of BFs of $D_s^+ \rightarrow \eta^{(\prime)} e^+ \nu$

- Benefit the understanding of the source of difference of inclusive decay rates of $D^{0(+)}$ and D_s^+
- Complementary information to understand η–η' mixing

482 pb^{-1} data@4.009 GeV, PRD94(2016)112003

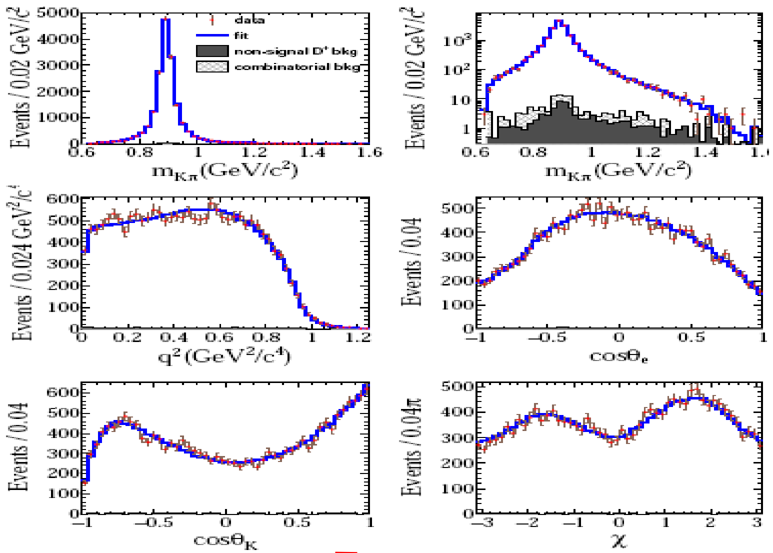


	BESIII	CLEOII 95	CLEOc09	CLEOc15	PDG [4]
$B(D_s^+ \to \eta e^+ \nu_e)[\%]$	$2.30 \pm 0.31 \pm 0.08$	—	$2.48 \pm 0.29 \pm 0.13$	$2.28 \pm 0.14 \pm 0.20$	2.67 ± 0.29
$B(D_s^+ \to \eta' e^+ \nu_e)[\%]$	$0.93 \pm 0.30 \pm 0.05$	—	$0.91 \pm 0.33 \pm 0.05$	$0.68 \pm 0.15 \pm 0.06$	0.99 ± 0.23
$\frac{B(D_s^+ \to \eta' e^+ \nu_e)}{B(D_s^+ \to \eta e^+ \nu_e)}$	$0.40 \pm 0.14 \pm 0.02$	$0.35 \pm 0.09 \pm 0.07$	—	—	—

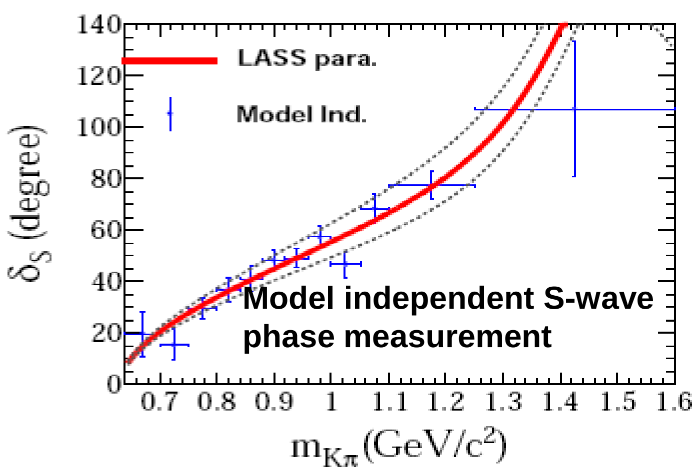
$D^+ \to V e^+ \nu$

PRD94(2016)032001

$D^+ \to K^- \pi^+ e^+ \nu$

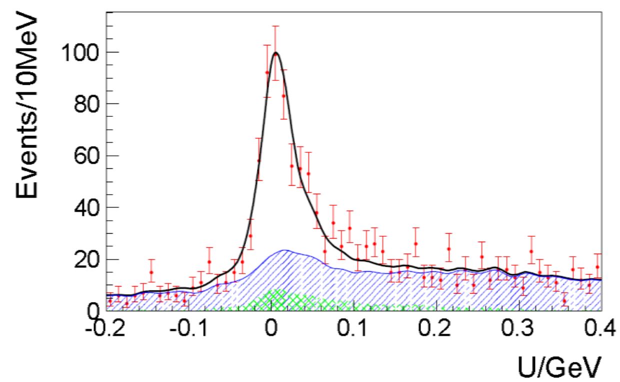


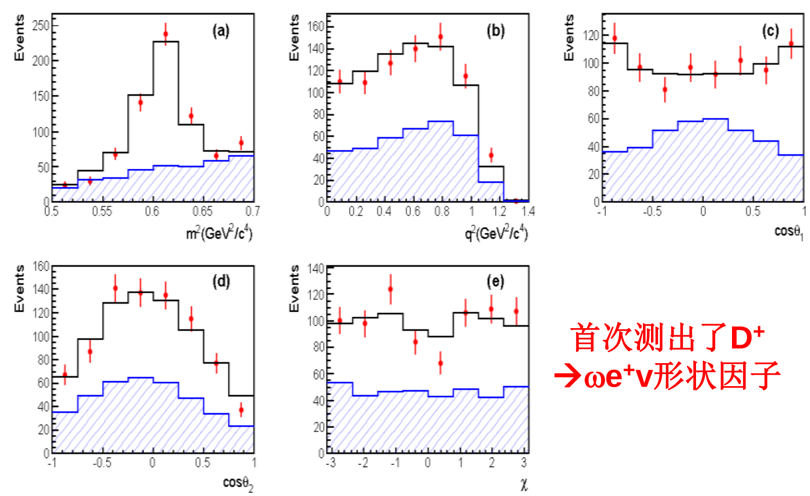
改进了$D^+ \to \bar{K}^{*0} e^+ \nu$形状因子测量



PRD92(2015)071101(RC)

$D^+ \to \omega e^+ \nu$





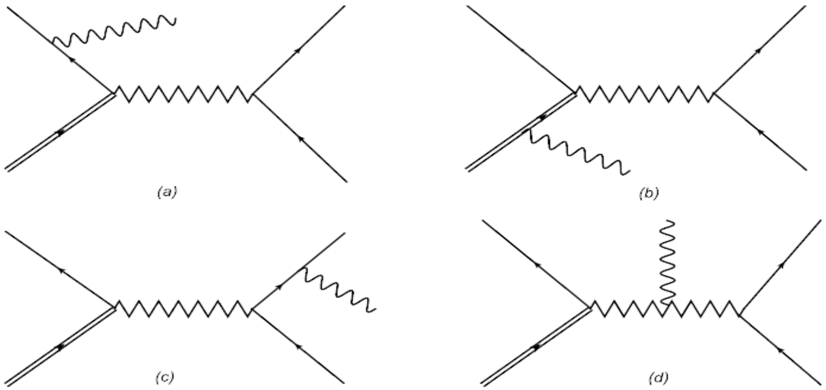
首次测出了$D^+ \to \omega e^+ \nu$形状因子

$r_V = V(0)/A_1(0) = 1.24 \pm 0.09 \pm 0.06$

$r_2 = A_2(0)/A_1(0) = 1.06 \pm 0.15 \pm 0.05$

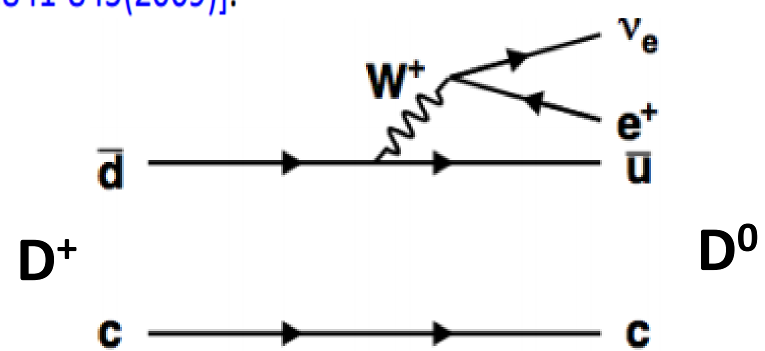
Rare D semileptonic decays

Various theory models predict BFs in 10^{-6}–10^{-4}

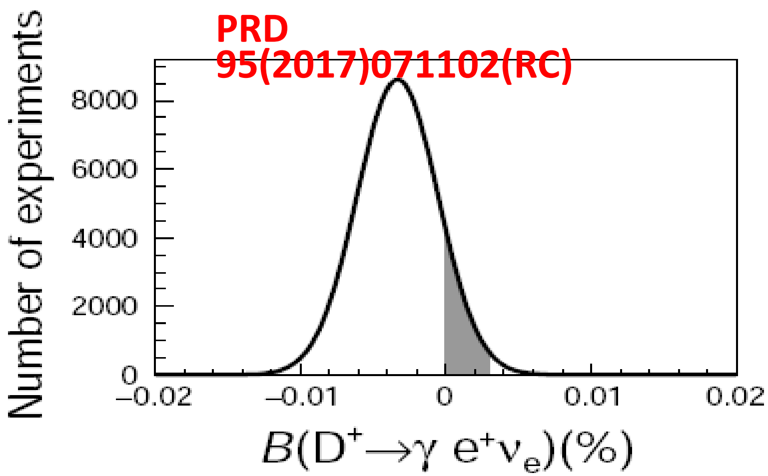


Tree level amplitudes

Applying the SU(3) symmetry for the light quarks, this rare decay branching fraction can be predicted by theoretical calculation and its theoretical value is 2.78×10^{-13} [EPJC, 59:841-845(2009)].

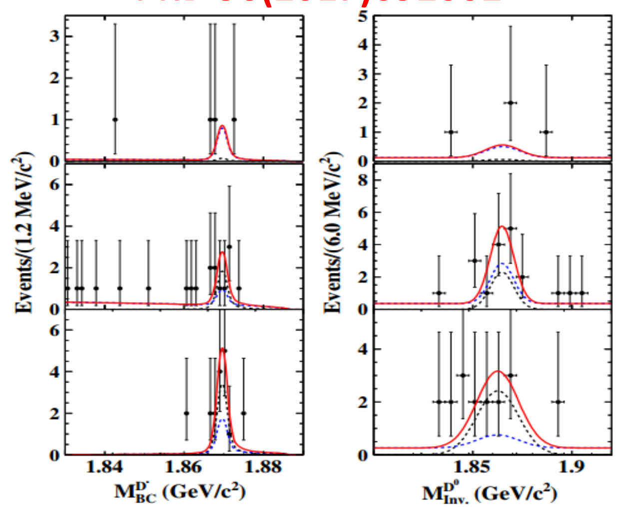


PRD 95(2017)071102(RC)



$B[D^+\to\gamma e^+\nu]|_{E\gamma>10\ MeV}<3.0\times10^{-4}$ @90%C.L.

PRD 96(2017)092002



$B[D^+\to D^0 e^+\nu]<1\times10^{-4}$ @90%C.L.