Semi-leptonic D decays

Hailong Ma (IHEP)
(For BESIII Collaboration)

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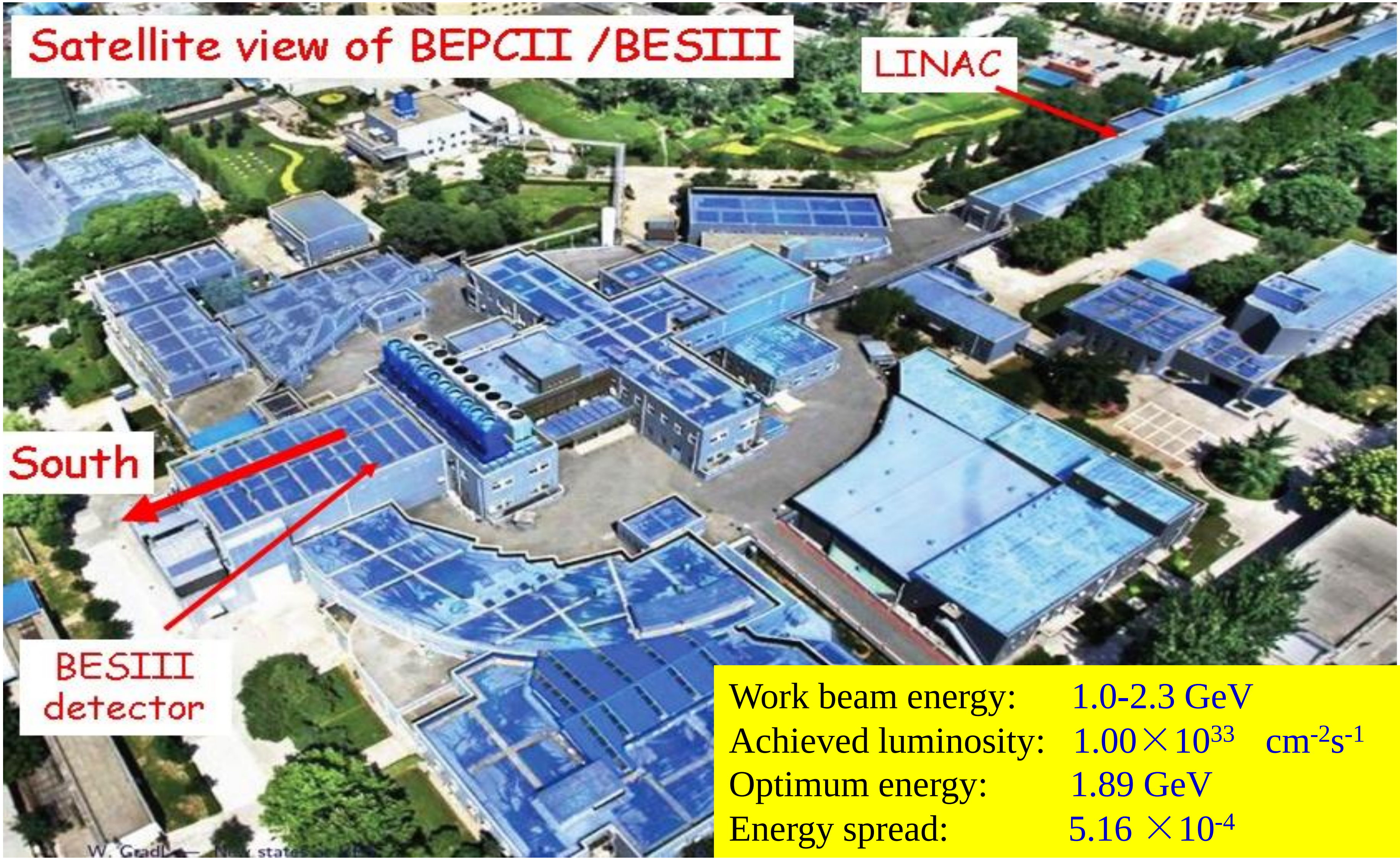
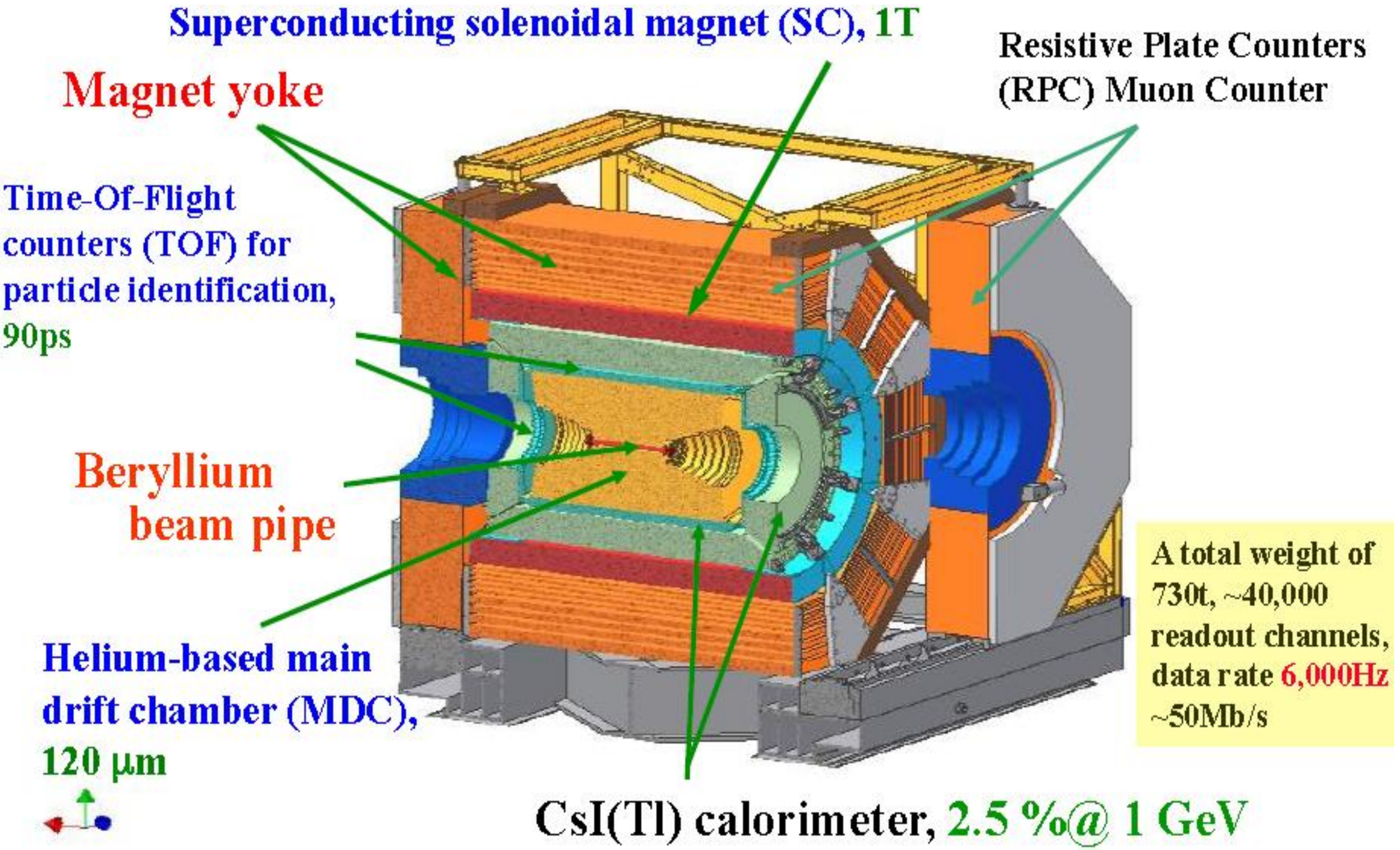
BEPCII collider



Work beam energy: 1.0-2.3 GeV
Achieved luminosity: 1.00×10^{33} $cm^{-2}s^{-1}$
Optimum energy: 1.89 GeV
Energy spread: 5.16×10^{-4}

BESIII detector

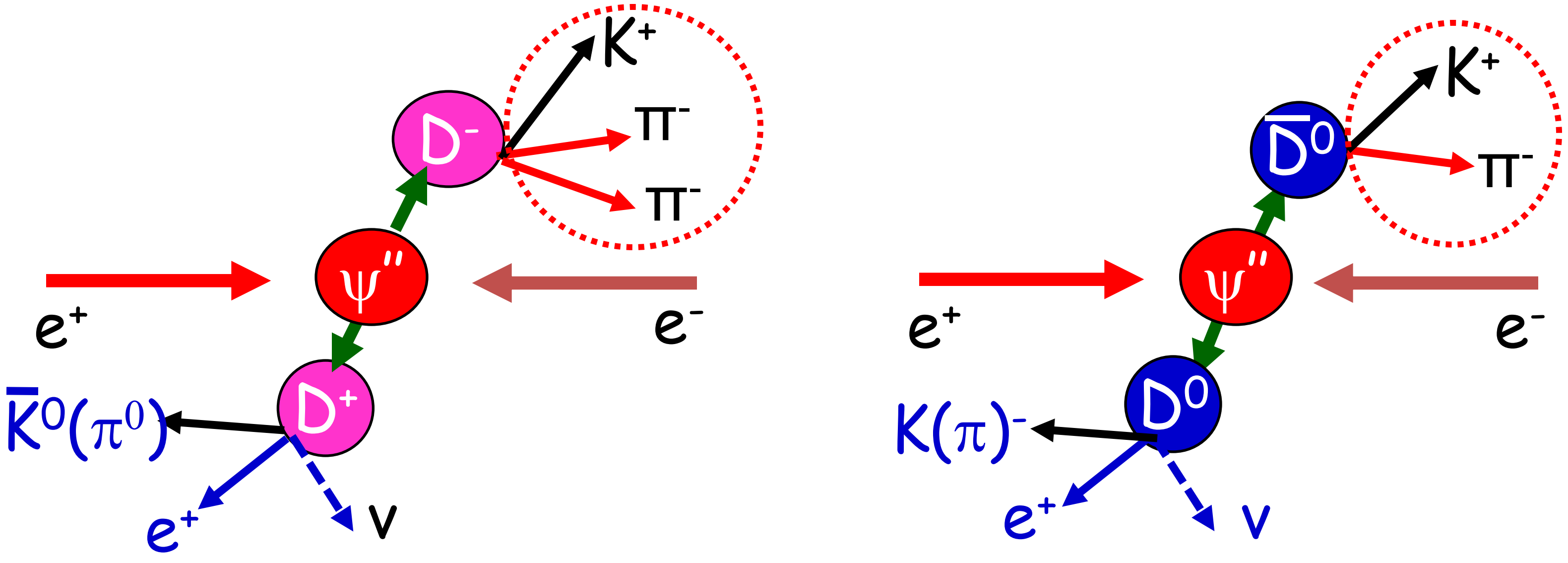


D^0 and D^+ samples used at BESIII

2.93 fb^{-1} data were taken around 3.773 GeV

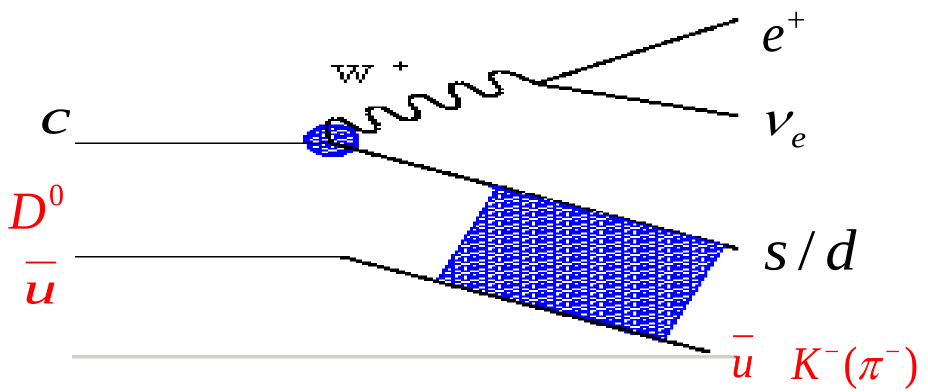
$D^0\bar{D}^0$ and D^+D^- are produced in pair at $\psi(3770)$

Singly tagged $\bar{D}^0$ and D^- mesons are reconstructed by hadron decays with large branching fraction and less combinatorial backgrounds



At the recoil side of singly tagged $\bar{D}^0$ and D^- mesons, leptonic and semi-leptonic decays can be studied

$f^+_{K(\pi)}(q^2)$ and $|V_{cs(d)}|$ from $D^0 \to K(\pi)^- e^+ \nu$



D semileptonic decays provide bridge to extract the CKM matrix $|V_{cs(d)}|$, and measure the q^2 dependent form-factors $f^+_{K(\pi)}(q^2)$

$$\frac{\Delta\Gamma(D^0 \to K/\pi^- e^+ \upsilon_e)}{dq^2} = X \frac{G_F^2 |V_{cs(d)}|^2}{24\pi^3} p^3 \left|f_+^2(q^2)\right|^2$$

– **Single pole form**

$$f_+(q^2) = \frac{f_+(0)}{1 - \frac{q^2}{M^2_{\rm pole}}}$$

– **Modified pole model**

$$f_+(q^2) = \frac{f_+(0)}{(1 - \frac{q^2}{M^2_{\rm pole}})(1 - \alpha \frac{q^2}{M^2_{\rm pole}})}$$

– **ISGW2 model**

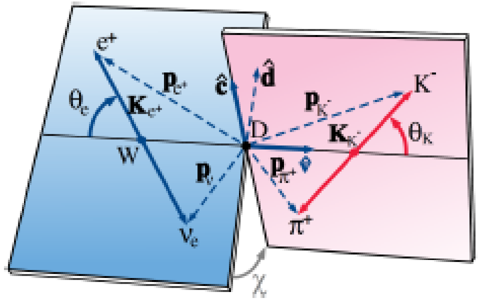
$$f_+(q^2) = f_+(q^2_{\rm max}) \left(1 + \frac{r^2_{\rm ISGW2}}{12}(q^2_{\rm max} - q^2)\right)^{-2}$$

– **Series expansion model**

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

Recently improved LQCD calculations on $f_+^{D\to K(\pi)}(0)$ [1.7(4.4)%] provide good chance to precisely measure the CKM matrix element $|V_{cs(d)}|$, which are important for the unitarity test of the CKM matrix and search for NP beyond the SM

Form factors from D→Ve⁺v



- $m^2 = (p_{\pi^+} + p_{K^-})^2$
- $\cos(\theta_K) = \frac{\not{D}\cdot\mathbf{K}_{K^-}}{|\mathbf{K}_{K^-}|}$
- $\cos(\chi) = \hat{c}\cdot\hat{d}$
- $q^2 = (p_{e^+} + p_{\nu_e})^2$
- $\cos(\theta_e) = -\frac{\not{D}\cdot\mathbf{K}_{e^+}}{|\mathbf{K}_{e^+}|}$
- $\sin(\chi) = (\hat{c}\times\not{D})\cdot\hat{d}$

Decay rate depend on 5 variables and 3 form factors

$$d^5\Gamma = \frac{G_F^2|V_{cs}|^2}{(4\pi)^6 m_D^2} X\beta\mathcal{I}(m^2, q^2, \theta_K, \theta_e, \chi) dm^2 dq^2 d\cos(\theta_K) d\cos(\theta_e) d\chi$$

- $X = p_{K\pi} m_D$, $p_{K\pi}$ is the momentum of the $K\pi$ system in the D rest frame
- $\beta = 2p^*/m$, p^* is the breakup momentum of the $K\pi$ system in its rest frame
- $\mathcal{I}$ can be expressed in terms of helicity amplitudes $H_{0,\pm}$:

$$H_0(q^2) = \frac{1}{2m q}\left[(m_D^2 - m^2 - q^2)(m_D + m)A_1(q^2) - 4\frac{m_D^2 p_{K\pi}^2}{m_D + m}A_2(q^2)\right]$$

$$H_\pm(q^2) = (m_D + m)A_1(q^2) \mp \frac{2m_D p_{K\pi}}{m_D + m}V(q^2)$$

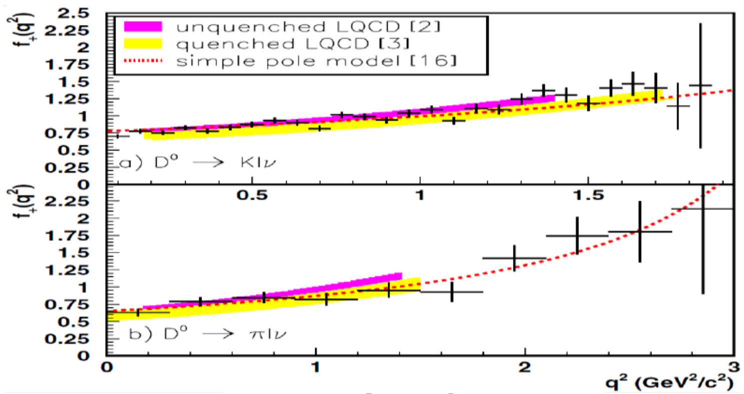
- Vector form factor: $V(q^2) = \frac{V(0)}{1 - q^2/m_V^2}$; or: FF ratio $r_V = V(0)/A_1(0)$
- Axial-vector form factor: $A_1(q^2) = \frac{A_1(0)}{1 - q^2/m_A^2}$, $A_2(q^2) = \frac{A_2(0)}{1 - q^2/m_A^2}$; or: FF ratio $r_2 = A_2(0)/A_1(0)$

Determine FFs in D→Ve⁺v and understand nature of resonance V

Previous measurements of $f_+^{D\to K(\pi)}(0)|V_{cs(d)}|$

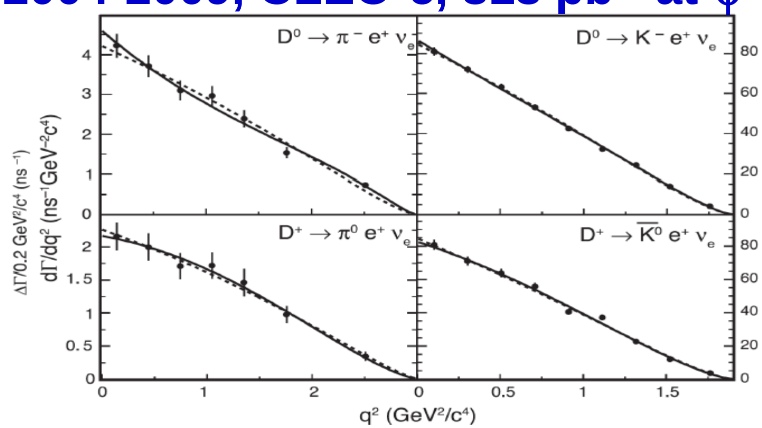
During the past 26 years, studies of $D\to K(\pi)l^+\nu$ are made by MARKIII, E691, CLEO, CLEOII, BESII, FOCUS, BELLE, Babar and CLEO-c

- **BELLE, 282 fb^{-1} at 10.58 GeV**



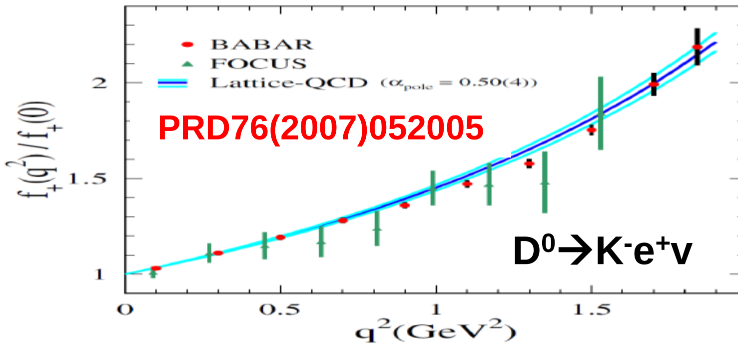
PRL97(2006)061804

- **2004-2009, CLEO-c, 818 pb^{-1} at ψ''**

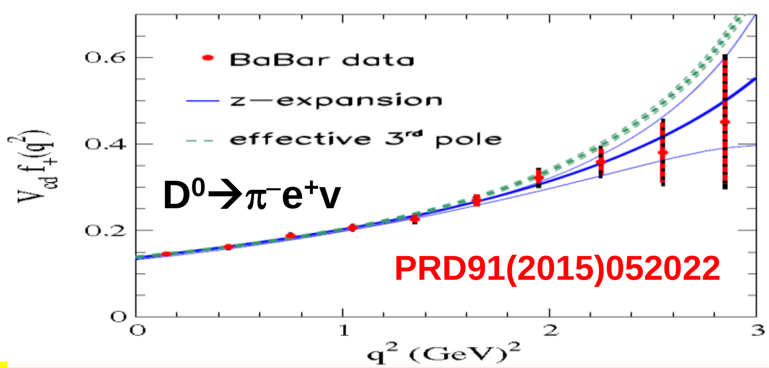


PRD80(2009)032005

- **Babar, 75 fb^{-1} at 10.58 GeV**



- **Babar, 347.2 fb^{-1} at 10.58 GeV**

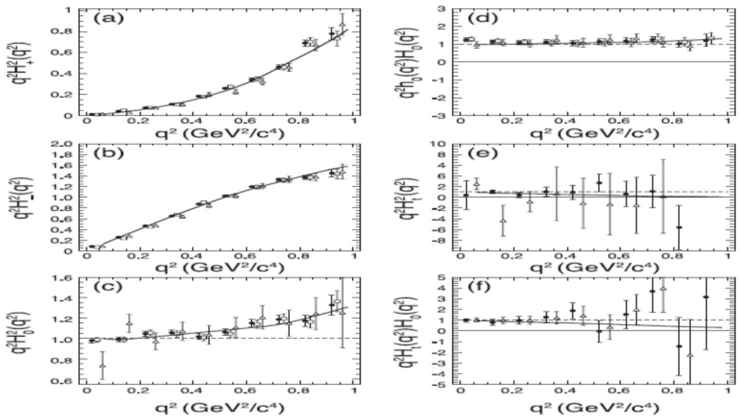


Before 2010, the LQCD calculated $f_+^{D\to K(\pi)}(0)$ precision is at 10% level, thus limiting $|V_{cs(d)}|$ measurement

Previous analyses of $D \rightarrow V l^+ \nu$

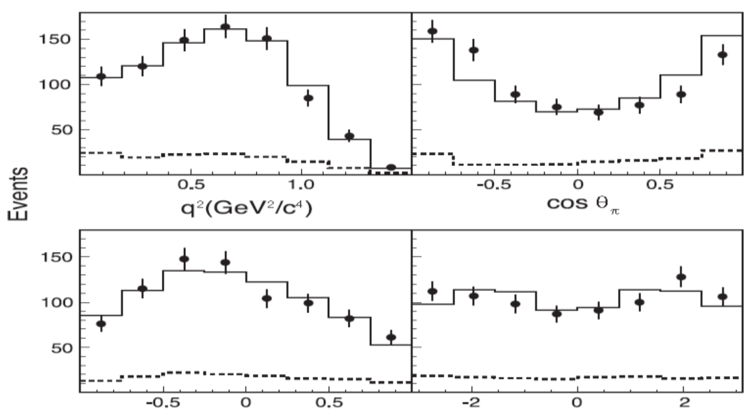
The most precise amplitude analyses of $D \rightarrow \bar{K}^{*0} l^+ \nu$ and $\rho e^+ \nu$ have been made by CLEOII, FOCUS, Babar and CLEO-c

- $D^+ \rightarrow K^- \pi^+ l^+ \nu$, CLEO-c, 818 pb^{-1} at ψ''



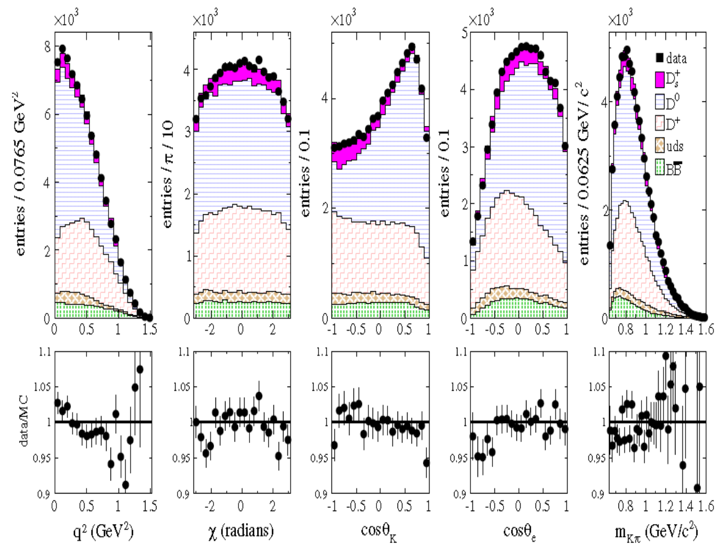
PRD81(2010)112001

- $D \rightarrow \rho e^+ \nu$, CLEO-c, 818 pb^{-1} at ψ''



PRL110(2013)131802

- $D^+ \rightarrow K^- \pi^+ e^+ \nu$, Babar, 347.5 fb^{-1}@Y(4S)



PRD83(2011)072001

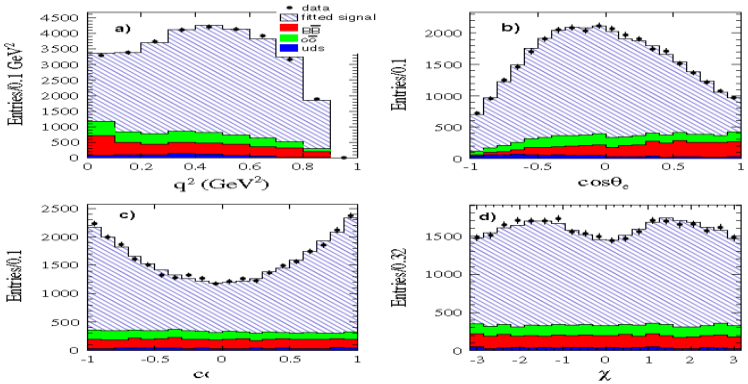
Previously, no amplitude analysis was performed for $D^+ \rightarrow \omega e^+ \nu$ and the one for $D^0 \rightarrow K^{*-} e^+ \nu$ is still limited due to low statistics

Previous studies of $D_s^+ \to (P,V) l^+ \nu$

Recent studies of $D_s^+ \to (P,V) l^+ \nu$ are made by Babar and CLEO-c

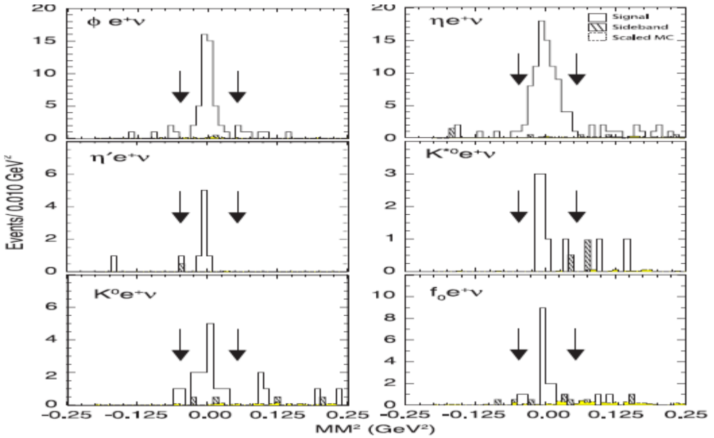
Compared to $D^{0(+)}$ decays, D_s^+ SL decay studies are limited

- **$D^+ \to K^+K^-e^+\nu$, Babar, 214 fb^{-1}@Y(4S)**



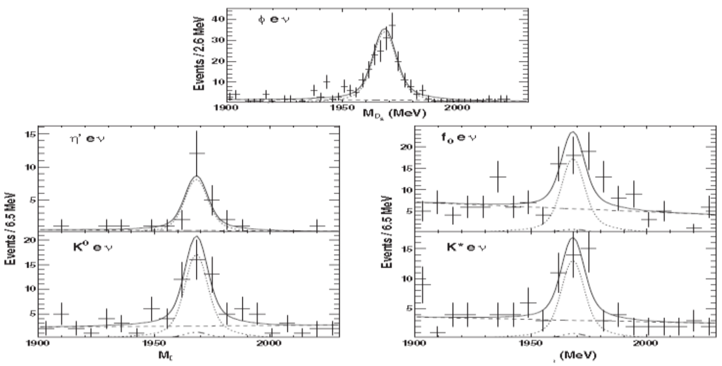
PRD78(2008)051101

- **CLEO-c[1], 310 fb^{-1} at 4.17 GeV**



PRD80(2009)052007

- **CLEO-c[2], 600 fb^{-1} at 4.17 GeV**

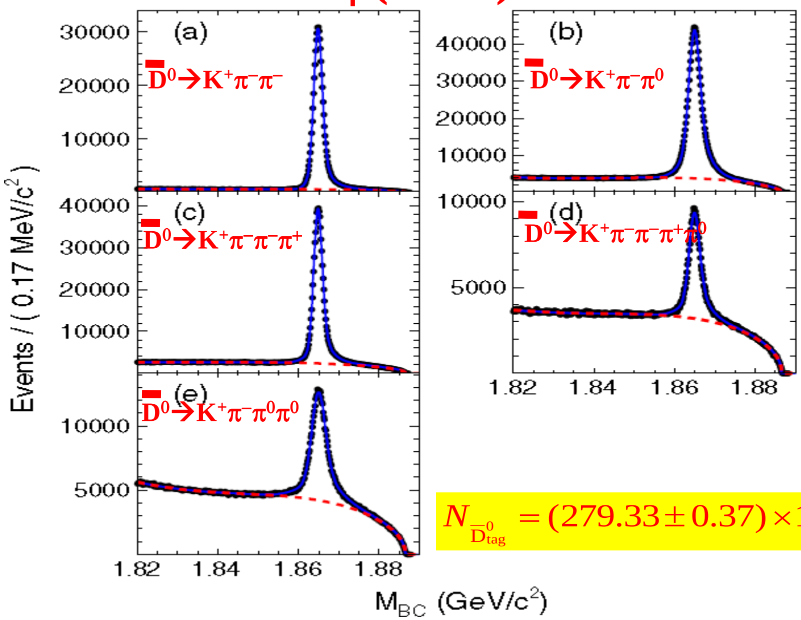


PRD91(2015)052022

Signal mode	BABAR (%)	CLEO-c[1] (%)	CLEO-c[2] (%)
$D_s \to \phi e \nu$	$2.61 \pm 0.03 \pm 0.08 \pm 0.15$	$2.36 \pm 0.23 \pm 0.13$	$2.14 \pm 0.17 \pm 0.08$
$D_s \to \eta e \nu$	...	$2.48 \pm 0.29 \pm 0.13$	$2.28 \pm 0.14 \pm 0.19$
$D_s \to \eta' e \nu$	...	$0.91 \pm 0.33 \pm 0.05$	$0.68 \pm 0.15 \pm 0.06$
$D_s \to f_0 e \nu, f_0 \to \pi\pi$	Seen	$0.20 \pm 0.03 \pm 0.01$	$0.13 \pm 0.03 \pm 0.01$
$D_s \to K_S e \nu$	...	$0.19 \pm 0.05 \pm 0.01$	$0.20 \pm 0.04 \pm 0.01$
$D_s \to K^* e \nu$	...	$0.18 \pm 0.07 \pm 0.01$	$0.18 \pm 0.04 \pm 0.01$

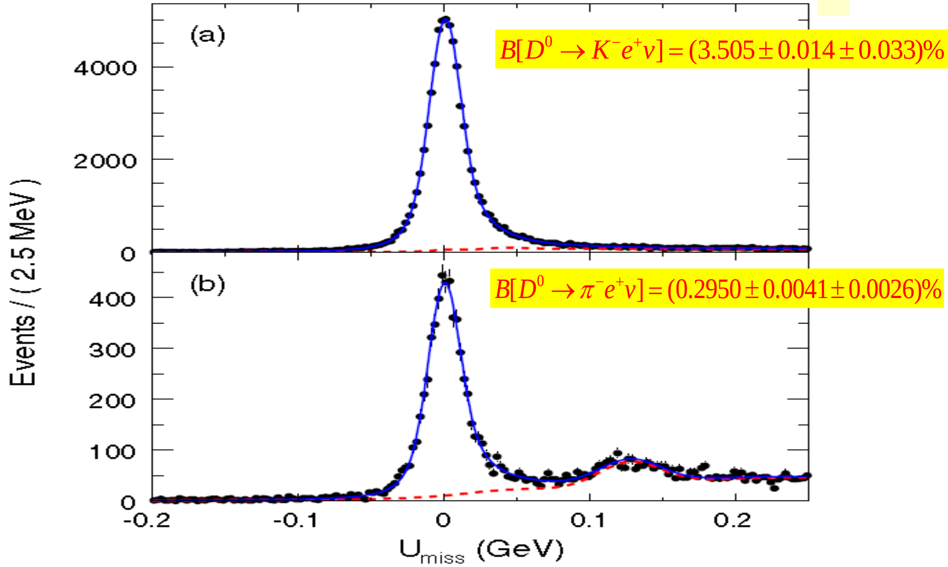
Absolute BFs of $B[D^0 \to K(\pi)^- e^+ \nu]$

$e^+e^- \to \psi(3770) \to D^0\bar{D}^0$



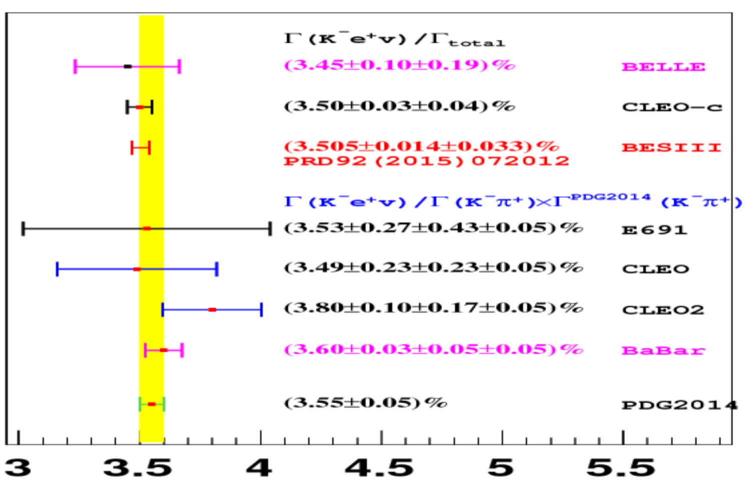
$N_{\bar{D}^0_{tag}} = (279.33 \pm 0.37) \times 10^4$

2.93 fb^{-1} data, PRD92(2015)072012

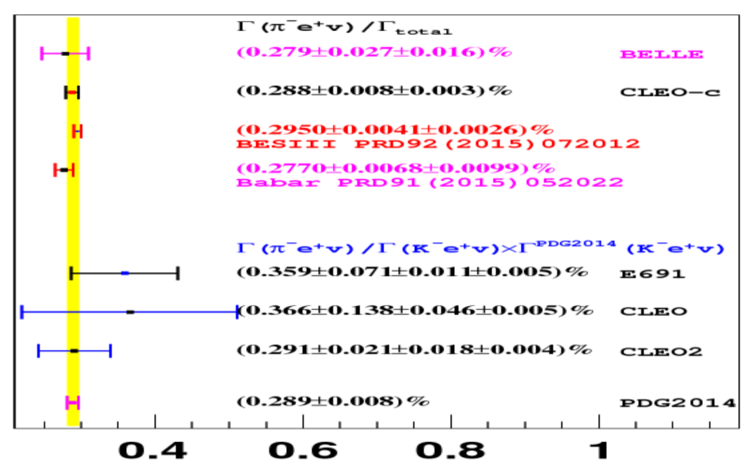


$B[D^0 \to K^- e^+ \nu] = (3.505 \pm 0.014 \pm 0.033)\%$

$B[D^0 \to \pi^- e^+ \nu] = (0.2950 \pm 0.0041 \pm 0.0026)\%$



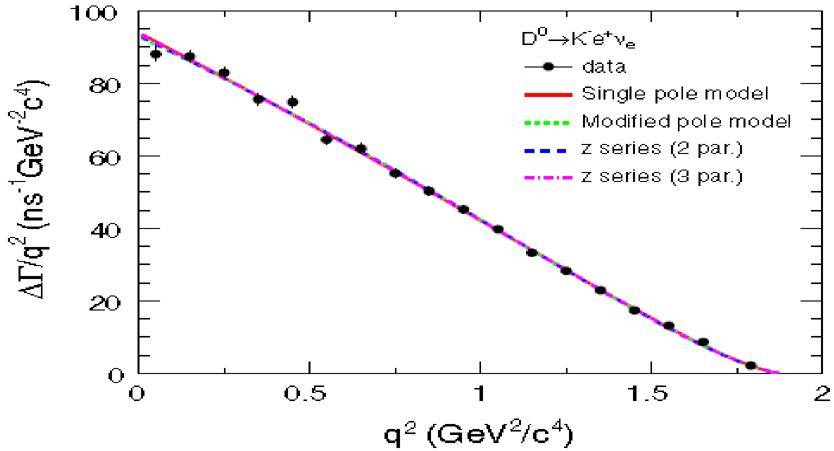
$B[D^0 \to K^- e^+ \nu]$

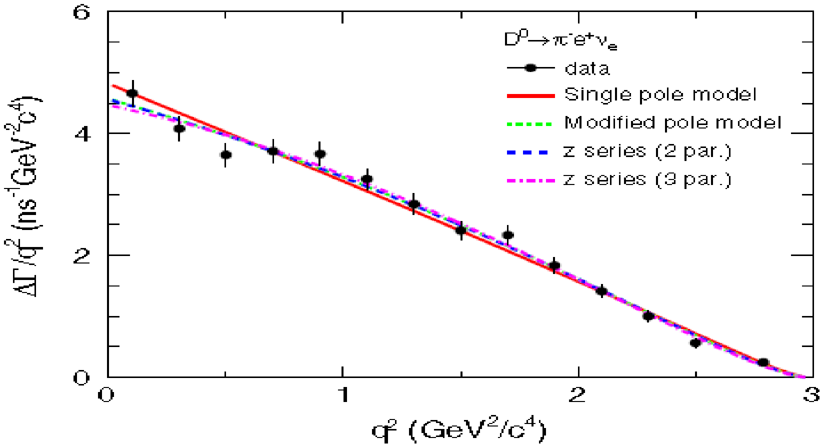


$B[D^0 \to \pi^- e^+ \nu]$

Extracted Parameters of Form Factors

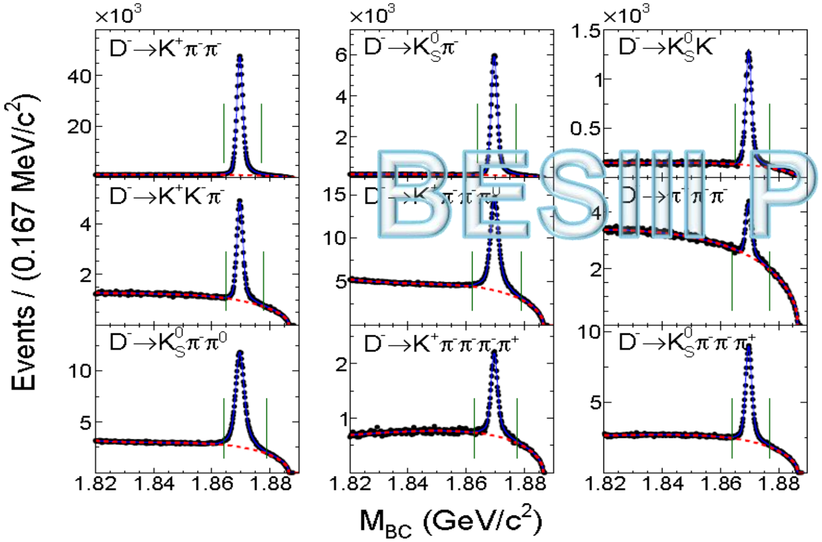
PRD92(2015)072012



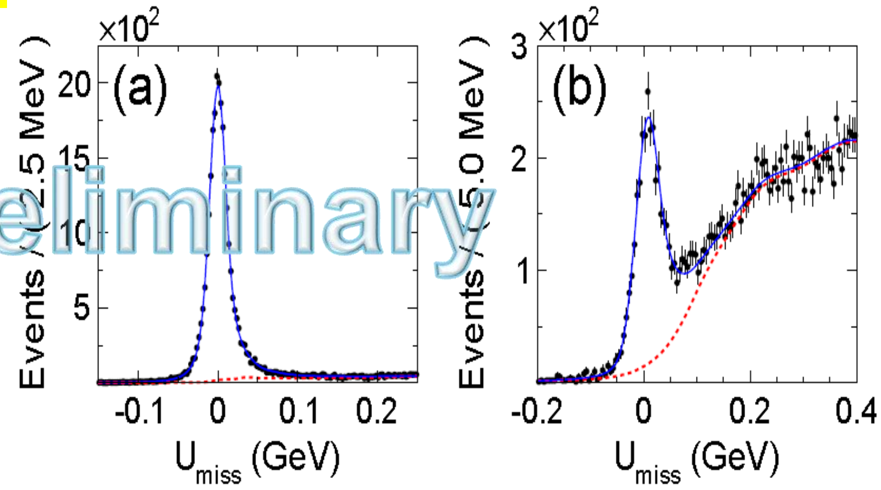


		$D^0 \to K^- e^+ v$		$D^0 \to \pi^- e^+ v$
Simple Pole	$f_K^+(0)\lvert V_{cs}\rvert$	0.7209±0.0022±0.0033	$f_\pi^+(0)\lvert V_{cd}\rvert$	0.1475±0.0014±0.0005
	M_{pole}	1.9207±0.0103±0.0069	M_{pole}	1.9114±0.0118±0.0038
Mod. Pole	$f_K^+(0)\lvert V_{cs}\rvert$	0.7163±0.0024±0.0034	$f_\pi^+(0)\lvert V_{cd}\rvert$	0.1437±0.0017±0.0008
	α	0.3088±0.0195±0.0129	α	0.2794±0.0345±0.0113
Series.2.Par	$f_K^+(0)\lvert V_{cs}\rvert$	0.7172±0.0025±0.0035	$f_\pi^+(0)\lvert V_{cd}\rvert$	0.1435±0.0018±0.0009
	r_1	-2.2278±0.0864±0.0575	r_1	-2.0365±0.0807±0.0260
Series.3.Par	$f_K^+(0)\lvert V_{cs}\rvert$	0.7196±0.0035±0.0041	$f_\pi^+(0)\lvert V_{cd}\rvert$	0.1420±0.0024±0.0010
	r_1	-2.3331±0.1587±0.0804	r_1	-1.8434±0.2212±0.0690
	r_2	3.4223±3.9090±2.4092	r_2	-1.3871±1.4615±0.4677

Analysis of $D^+ \to \bar{K}^0 e^+ \nu$ and $\pi^0 e^+ \nu$

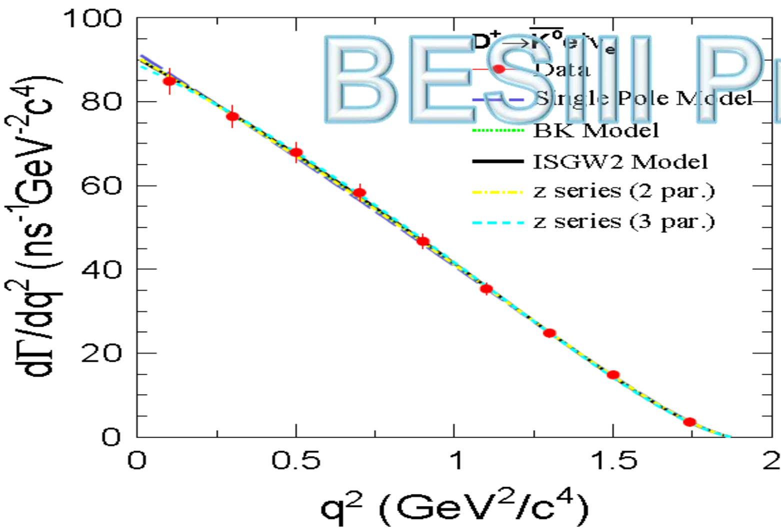


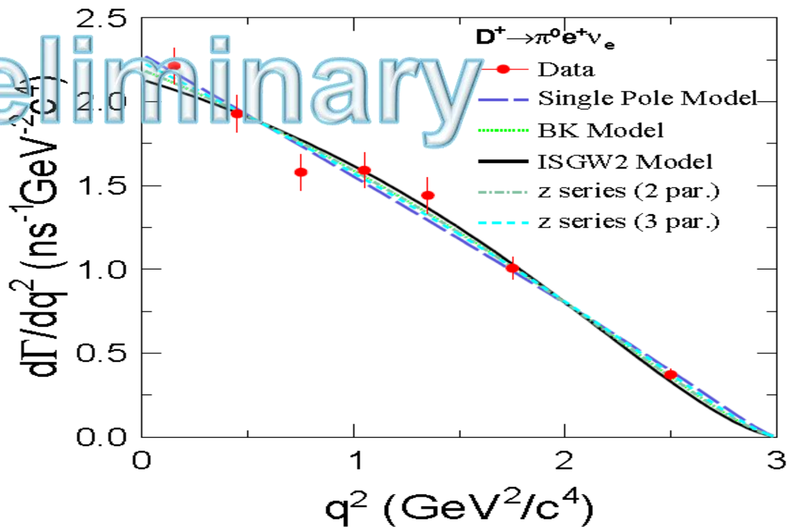
$N_{D^-_{tag}} = (170.31 \pm 0.34) \times 10^4$



$B[D^+ \to \overline{K}^0 e^+ \nu] = (8.604 \pm 0.056 \pm 0.151)\%$

$B[D^+ \to \pi^0 e^+ \nu] = (3.631 \pm 0.075 \pm 0.051) \times 10^{-3}$





Extracted Parameters of Form Factors

Single pole model		
Decay mode	$f_+(0)\|V_{cq}\|$	$m_{\rm pole}$ (GeV/c^2)
$D^+ \to \bar{K}^0 e^+ \nu_e$	$0.7094 \pm 0.0035 \pm 0.0111$	$1.935 \pm 0.017 \pm 0.006$
$D^+ \to \pi^0 e^+ \nu_e$	$0.1429 \pm 0.0020 \pm 0.0009$	$1.898 \pm 0.020 \pm 0.003$

Modified pole model		
Decay mode	$f_+(0)\|V_{cq}\|$	α
$D^+ \to \bar{K}^0 e^+ \nu_e$	$0.7052 \pm 0.0038 \pm 0.0112$	$0.294 \pm 0.031 \pm 0.010$
$D^+ \to \pi^0 e^+ \nu_e$	$0.1400 \pm 0.0024 \pm 0.0010$	$0.285 \pm 0.057 \pm 0.010$

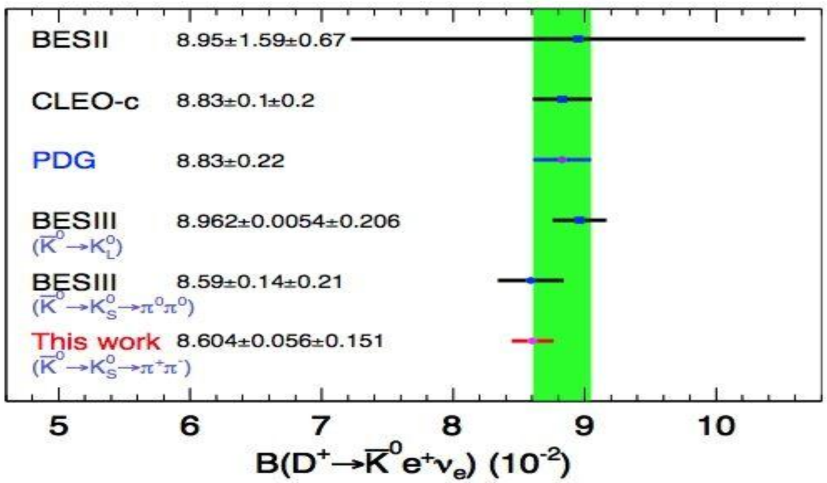
ISGW2 model		
Decay mode	$f_+(0)\|V_{cq}\|$	r (GeV^{-1})
$D^+ \to \bar{K}^0 e^+ \nu_e$	$0.7039 \pm 0.0037 \pm 0.0111$	$1.587 \pm 0.023 \pm 0.007$
$D^+ \to \pi^0 e^+ \nu_e$	$0.1381 \pm 0.0023 \pm 0.0007$	$2.078 \pm 0.067 \pm 0.011$

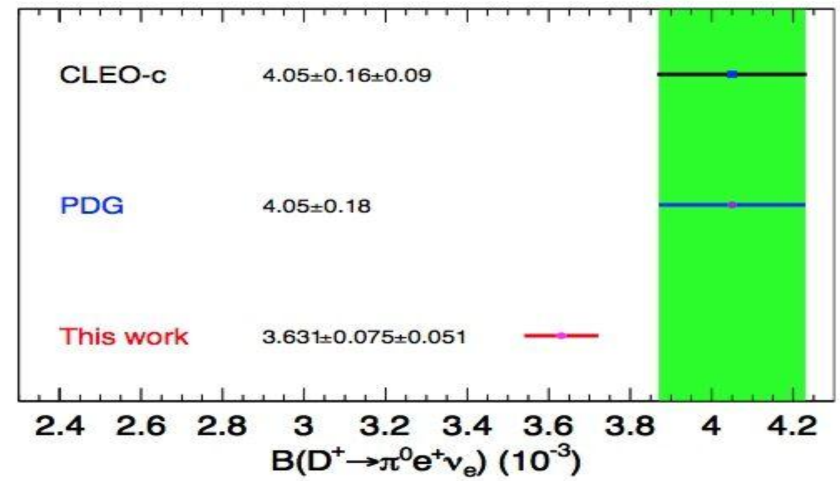
BESIII Preliminary

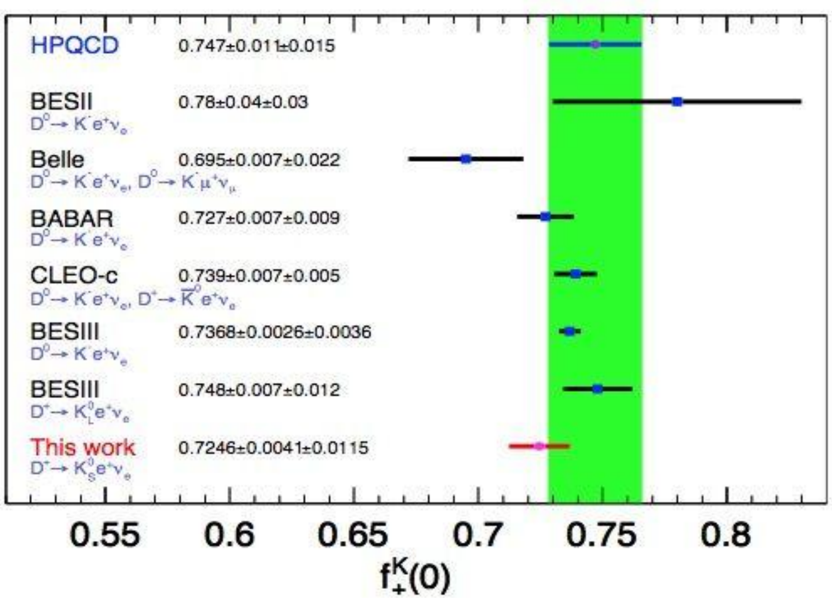
Two-parameter series expansion		
Decay mode	$f_+(0)\|V_{cq}\|$	r_1
$D^+ \to \bar{K}^0 e^+ \nu_e$	$0.7053 \pm 0.0040 \pm 0.0112$	$-2.18 \pm 0.14 \pm 0.05$
$D^+ \to \pi^0 e^+ \nu_e$	$0.1400 \pm 0.0026 \pm 0.0007$	$-2.01 \pm 0.13 \pm 0.02$

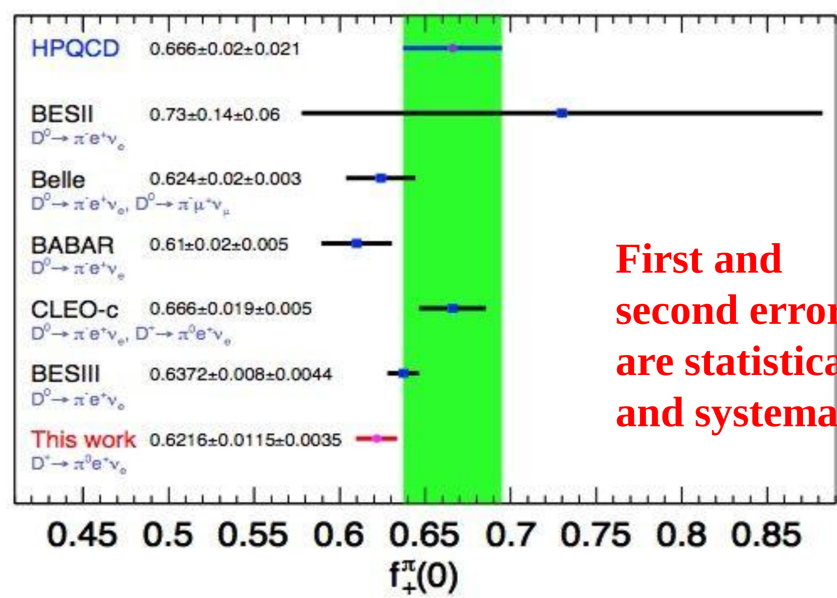
Three-parameter series expansion			
Decay mode	$f_+(0)\|V_{cq}\|$	r_1	r_2
$D^+ \to \bar{K}^0 e^+ \nu_e$	$0.6983 \pm 0.0056 \pm 0.0112$	$-1.76 \pm 0.25 \pm 0.06$	$-13.4 \pm 6.3 \pm 1.4$
$D^+ \to \pi^0 e^+ \nu_e$	$0.1413 \pm 0.0035 \pm 0.0012$	$-2.23 \pm 0.42 \pm 0.06$	$1.4 \pm 2.5 \pm 0.4$

Comparisons of BFs and FFs









First and second errors are statistical and systematic

Analysis of $D^+ \rightarrow K^0_L e^+ \nu$

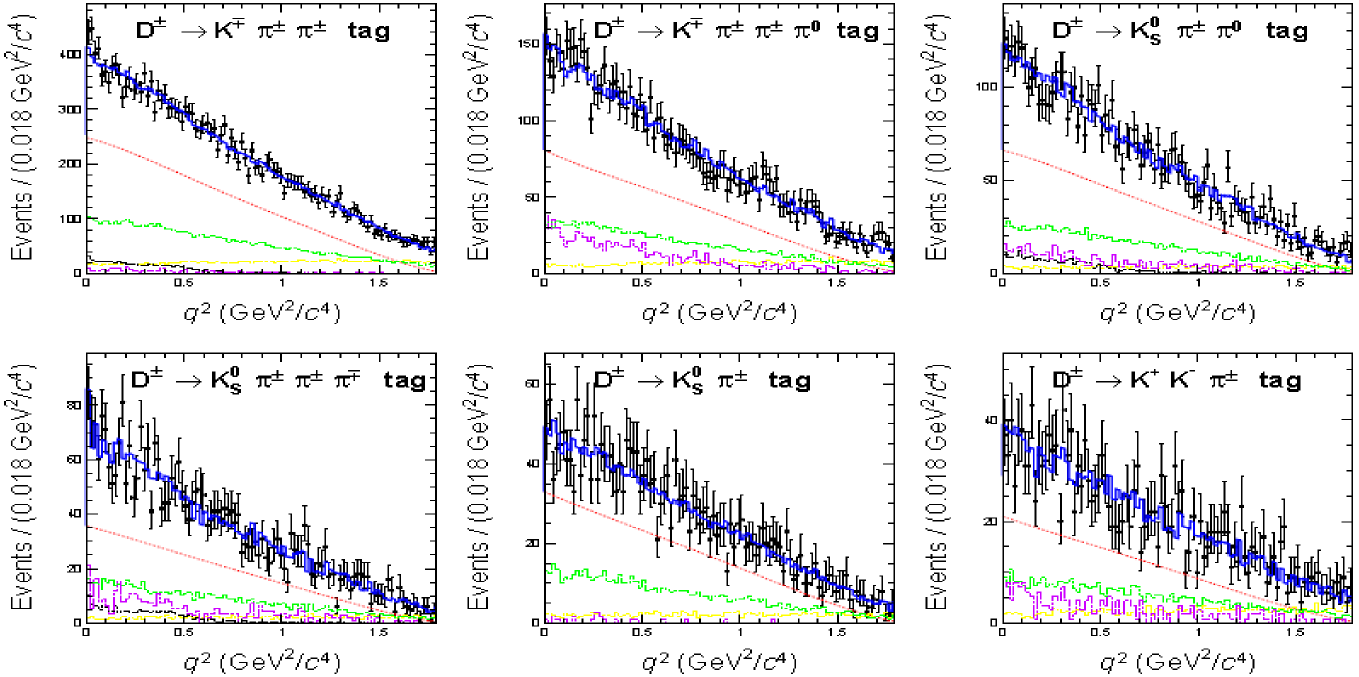
- Regardless of long flight distance, K^0_L interact with EMC and deposit part of energy, thus giving position information
- After reconstructing all other particles, K^0_L can be inferred with position information and constrain $U_{miss} \rightarrow 0$

$B(D^+ \rightarrow \overline{K}^0_L e^+ \nu) = (4.482 \pm 0.027 \pm 0.103)\%$

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

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

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



$D^+ \rightarrow K^0_L e^+ \nu$ is measured for the first time

PRD92(2015)112008

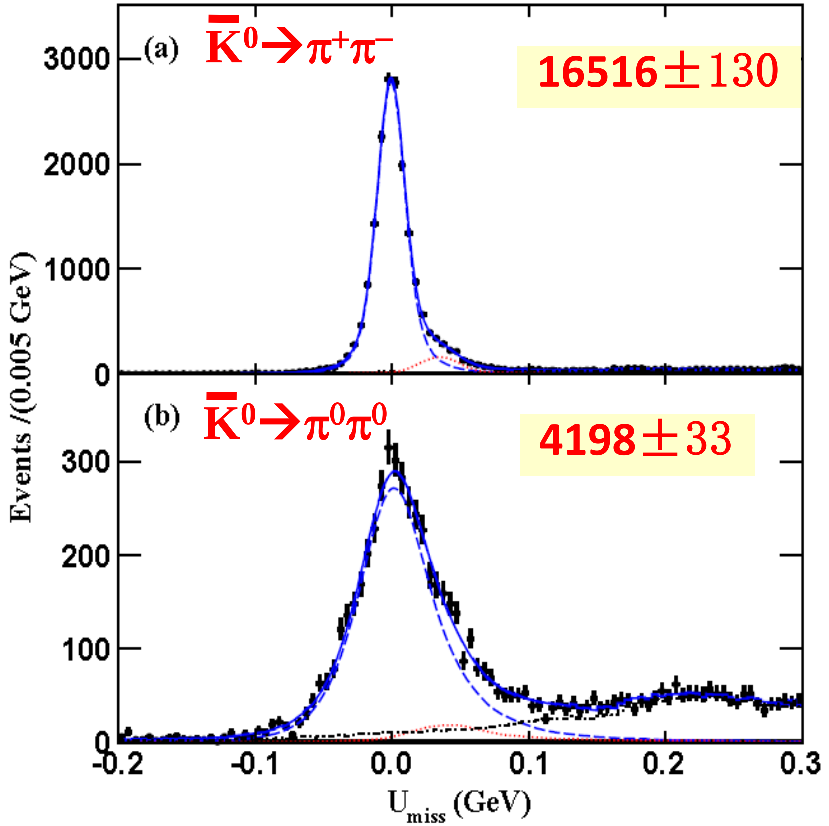
$f^K_+(0)|V_{cs}| = 0.728 \pm 0.006 \pm 0.011$

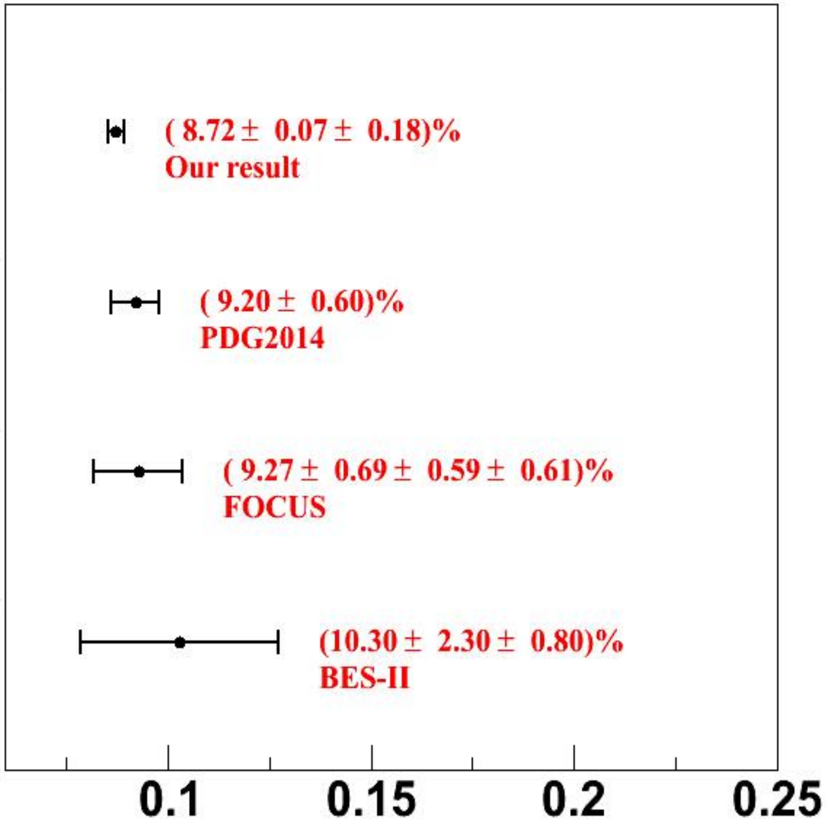
$r_1 = a_1/a_0 = -1.91 \pm 0.33 \pm 0.24$

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

Simultaneous fits

arxiV:1605.00068





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

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

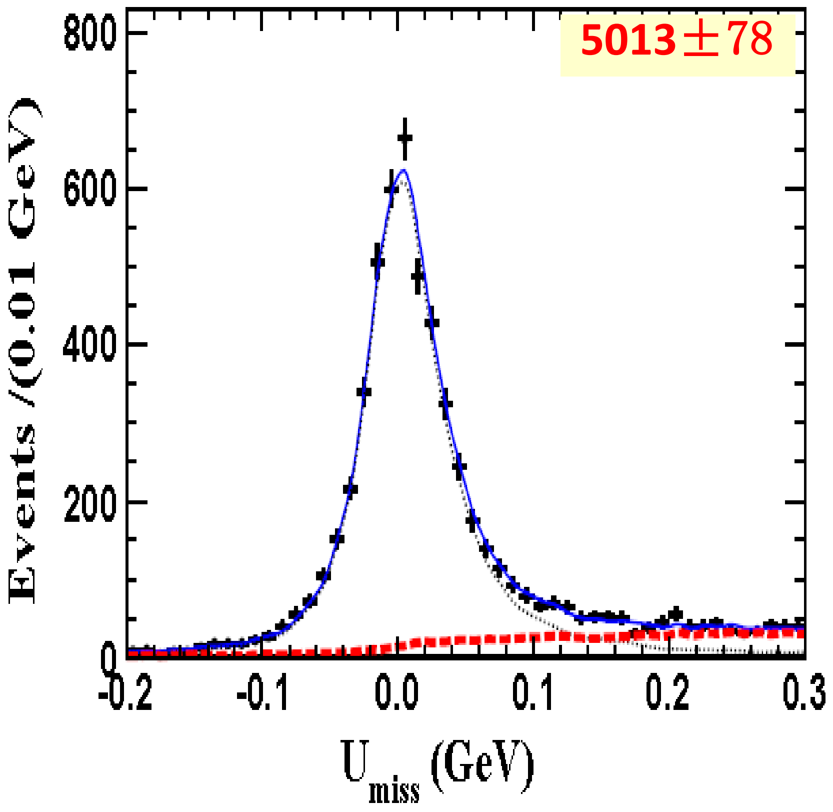
Support isospin conservation in these two decays within errors

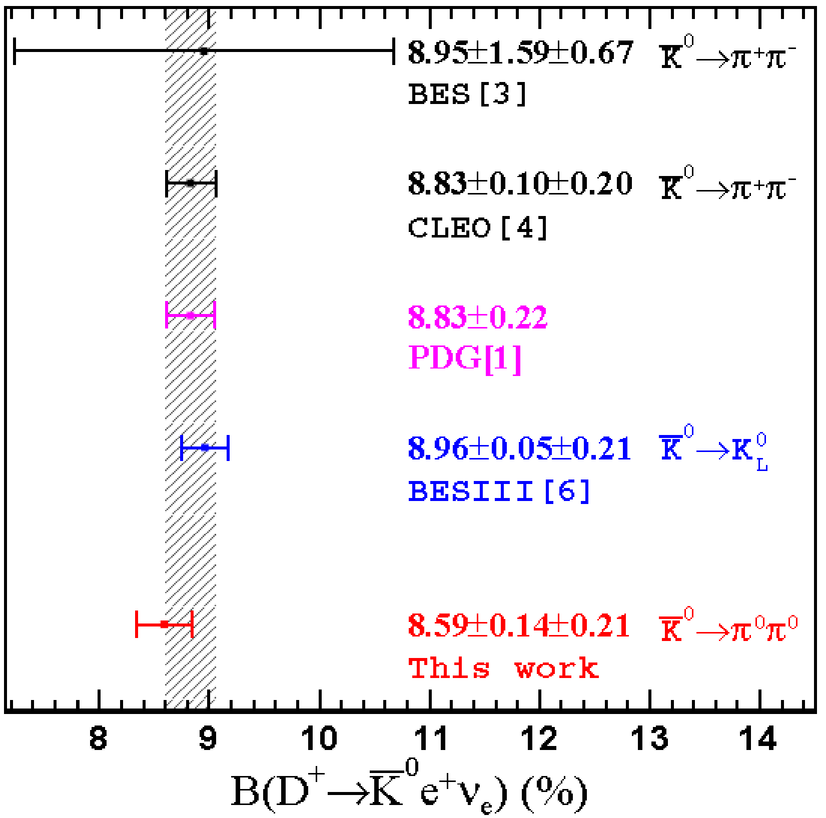
$$\frac{\Gamma[D^+ \to \bar{K}^0 \mu^+ \nu]}{\Gamma[D^+ \to \bar{K}^0 e^+ \nu]} = 0.988 \pm 0.033$$

Consistent with theory prediction 0.97 within error

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

arxiV:1605.00068





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

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

Supporting isospin conservation in these two decays within 1.2σ

PWA analysis of $D^+ \to K^-\pi^+e^+\nu$

arxiV:1512.08627

- **Fractions with >5σ significance**

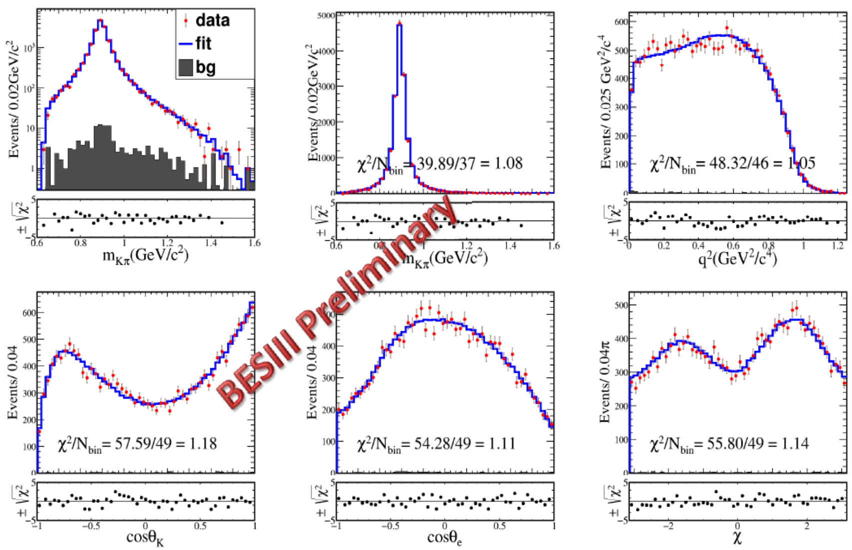
$$f(D^+ \to (K^-\pi^+)_{K^{*0}(892)}\, e^+\nu_e) = (93.93 \pm 0.22 \pm 0.18)\%$$

$$f(D^+ \to (K^-\pi^+)_{S-wave}\, e^+\nu_e) = (6.05 \pm 0.22 \pm 0.18)\%$$

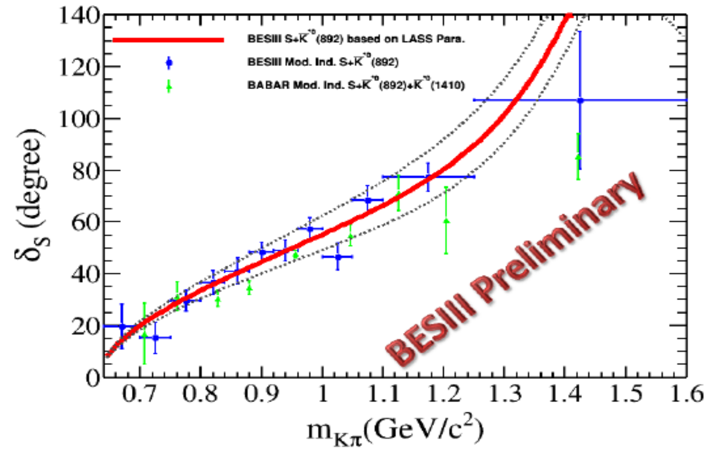
- **Properties of different Kπ (non-) resonant amplitudes**

$$m_{K^{*0}(892)} = (894.60 \pm 0.25 \pm 0.08)\ \mathrm{MeV}/c^2$$
$$\Gamma_{K^{*0}(892)} = (46.42 \pm 0.56 \pm 0.15)\ \mathrm{MeV}/c^2$$
$$r_{BW} = (3.07 \pm 0.26 \pm 0.11)\ (\mathrm{GeV}/c)^{-1}$$

- **q^2 dependent form factors in $D^+ \to \bar{K}^{*0}(892)e^+\nu$**



Model independent S-wave phase measurement



$$V(q^2) = \frac{V(0)}{1-q^2/m_V^2}, \quad A_{1,2}(q^2) = \frac{A_{1,2}(0)}{1-q^2/m_A^2}$$

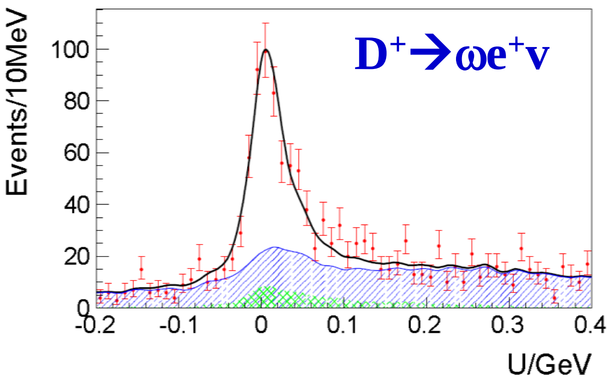
$M_{V/A}$ is expected to $M_{D^*(1-/+)}$

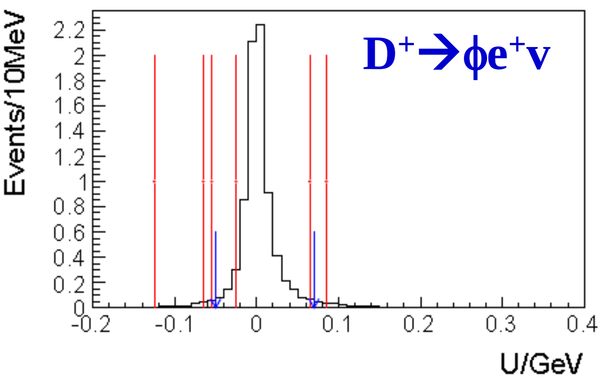
$$m_V = (1.81^{+0.25}_{-0.17} \pm 0.02)\ \mathrm{GeV}/c^2$$
$$m_A = (2.61^{+0.22}_{-0.17} \pm 0.03)\ \mathrm{GeV}/c^2$$
$$A_1(0) = 0.573 \pm 0.011 \pm 0.020$$
$$r_V = V(0)/A_1(0) = 1.411 \pm 0.058 \pm 0.007$$
$$r_2 = A_2(0)/A_1(0) = 0.788 \pm 0.042 \pm 0.008$$

Model independent form factors

Study of $D^+ \to \omega e^+ \nu$ and search for $D^+ \to \phi e^+ \nu$

PRD92(2015)071101R

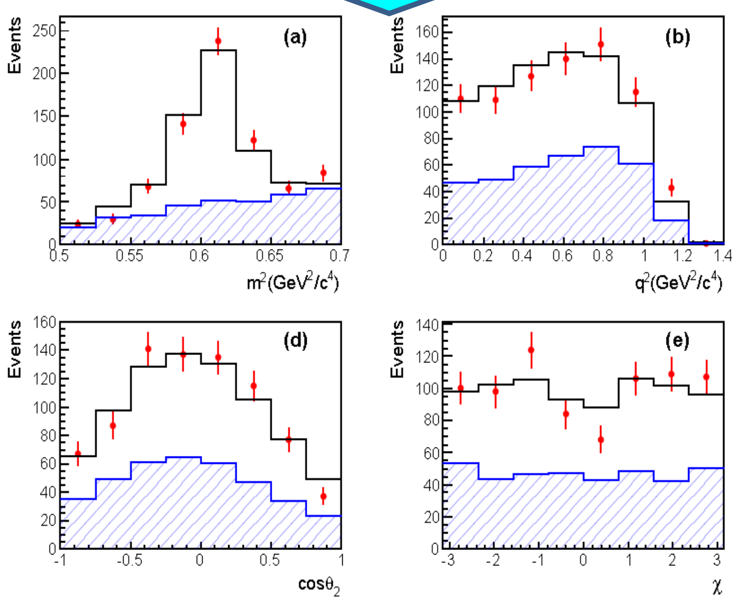




$B[D^+ \to \omega e^+ \nu] = (1.63 \pm 0.11 \pm 0.08) \times 10^{-3}$

$B[D^+ \to \phi e^+ \nu] < 1.3 \times 10^{-5}$ at 90% C.L.

Better precision or sensitivity



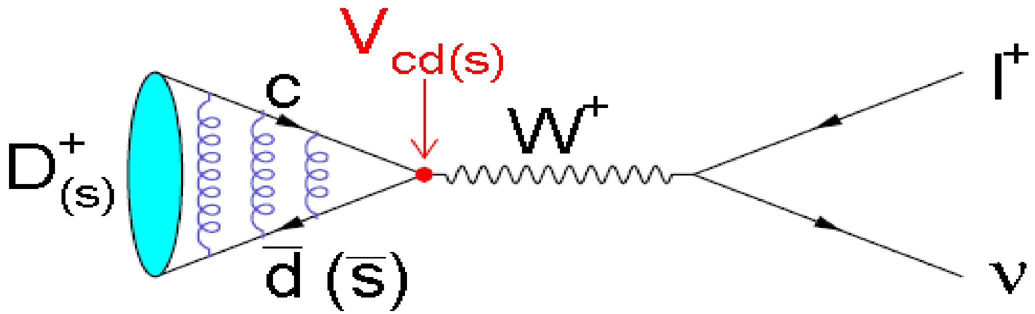
Amplitude analysis of $D^+ \to \omega e^+ \nu$ is performed for the first time

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

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

Status of $D_{(s)}^+ \to l^+ v$ studies

$D^+_{(s)}$ leptonic decays open a window to access the CKM matrix $|V_{cs(d)}|$, and the $D^+_{(s)}$ decay constants



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

	Experiments	Femilab Lattice+MILC (2014)		HPQCD (2012)	
	Averaged	Expected	Δ	Expected	Δ
f_{D+}(MeV)	203.9±4.7	$212.6 \pm 0.4^{+1.0}_{-1.2}$	1.8σ	208.3±3.4	0.8σ
f_{Ds+}(MeV)	256.9±4.4	$249.0 \pm 0.3^{+1.1}_{-1.5}$	1.7σ	246.0±3.6	1.4σ
$f_{D+}:f_{Ds+}$	1.260±0.036	$1.1712 \pm 0.0010^{+0.0029}_{-0.0032}$	2.5σ	1.187±0.013	1.9σ

- The experimentally measured and the theoretical expected f_{D+}, f_{Ds+}, $f_{D+}:f_{Ds+}$ differ by about 2σ

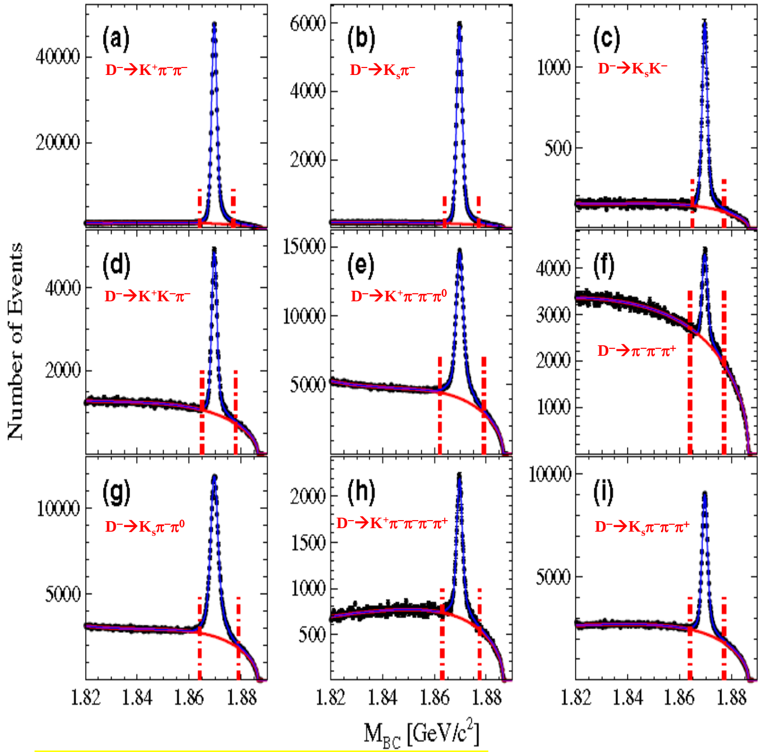
- Precisions of the LQCD calculations of f_{D+}, f_{Ds+}, $f_{D+}:f_{Ds}$ reach 0.5%, 0.5% and 0.3%, which are challenging the experiments

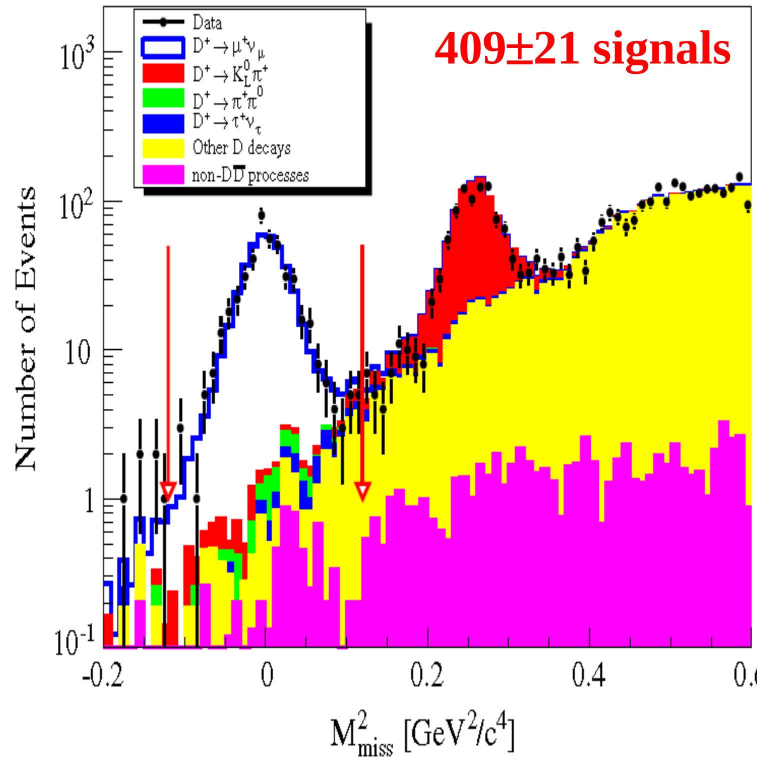
$B[D^+ \to \mu^+ \nu]$, f_{D+} and $|V_{cd}|$ at 3.773 GeV

$e^+e^- \to \psi(3770) \to D^+D^-$

2.93 fb^{-1} data

PRD89(2014)051104R





$N_{D^-_{tag}} = (170.31 \pm 0.34) \times 10^4$

$B[D^+ \to \mu^+\nu] = (3.71 \pm 0.19 \pm 0.06) \times 10^{-4}$

Input t_{D+}, m_{D+}, $m_{\mu+}$ on PDG and $|V_{cd}|$ of CKM-Fitter

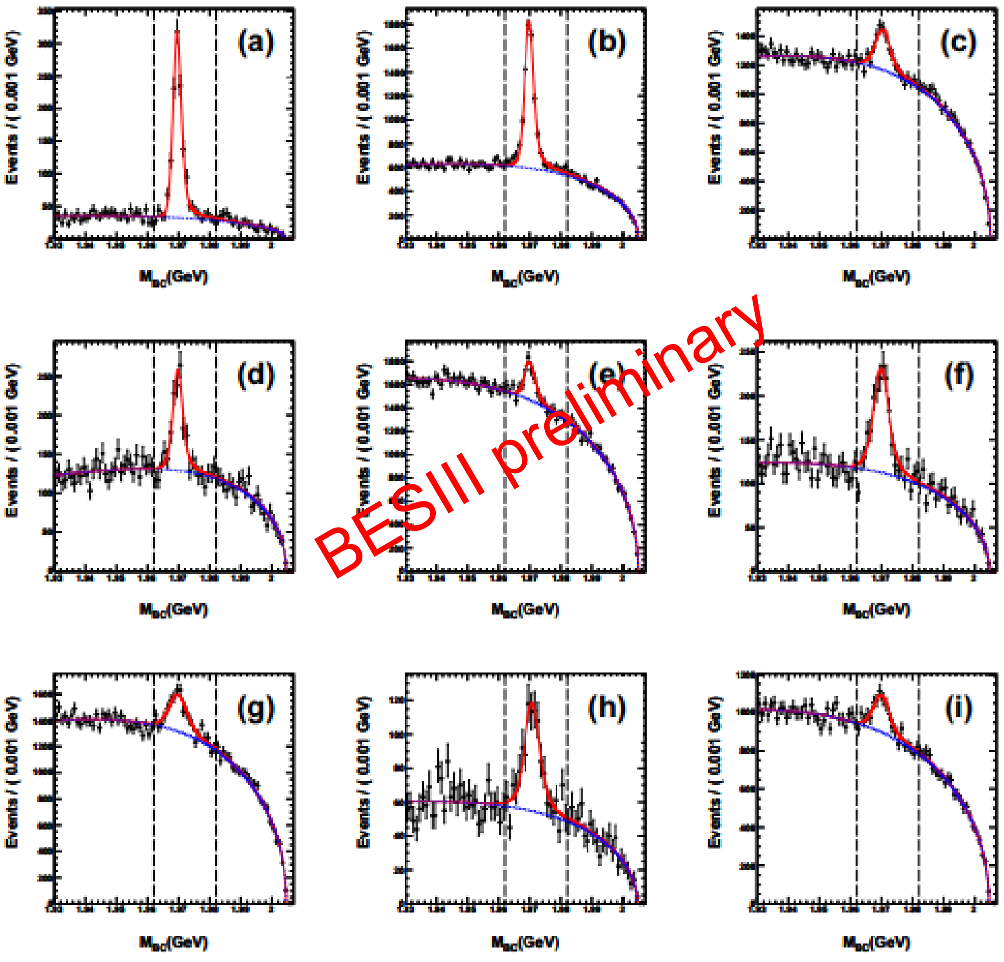
$f_{D+} = (203.2 \pm 5.3 \pm 1.8)$ MeV

Input t_{D+}, m_{D+}, $m_{\mu+}$ on PDG and LQCD calculated f_{D+}=207±4 MeV[PRL100(2008)062002]

$|V_{cd}| = 0.2210 \pm 0.0058 \pm 0.0047$

$B[D_s^+ \rightarrow l^+ \nu]$ and $f_{D_s^+}$ at 4.009 GeV

$e^+e^- \rightarrow D_s^+ D_s^-$



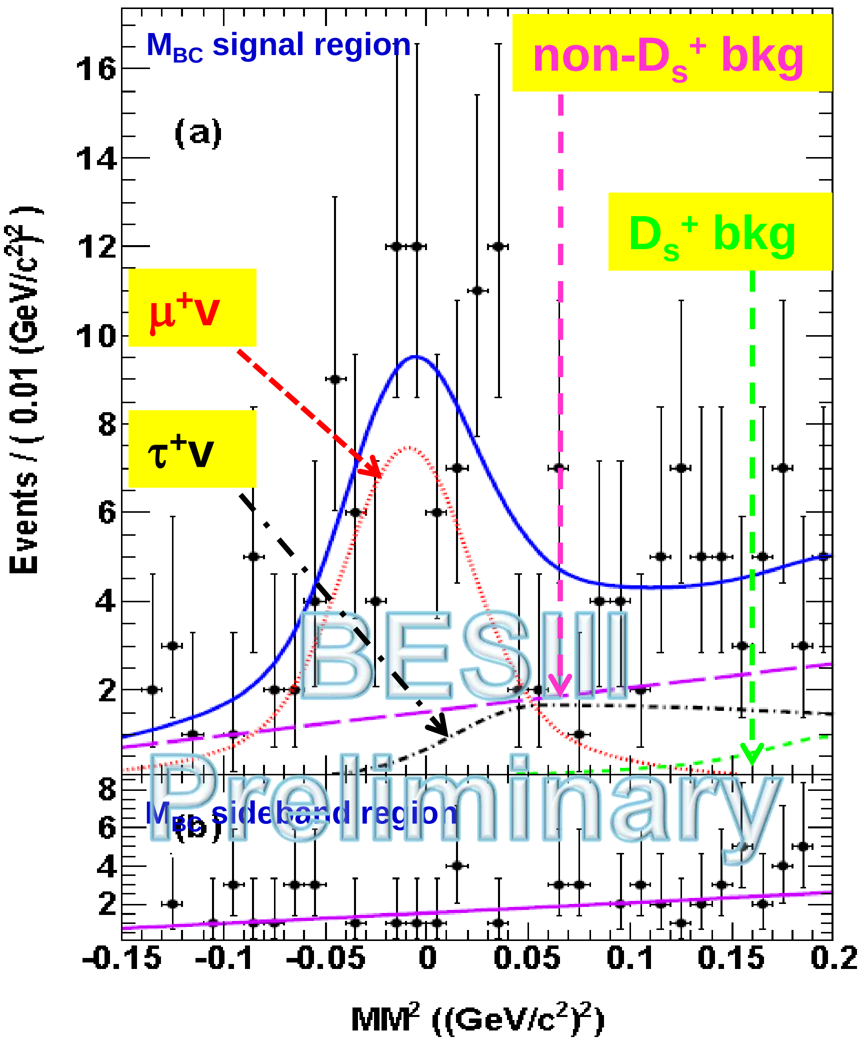
482 pb^{-1} data

15127 ± 312 D_s events in total

	Mode	N_{tag}
(a)	$K_S^0 K^-$	1065 ± 39
(b)	$K^+ K^- \pi^-$	5172 ± 114
(c)	$K^+ K^- \pi^- \pi^0$	1900 ± 140
(d)	$K_S^0 K^+ \pi^- \pi^-$	576 ± 48
(e)	$\pi^+ \pi^- \pi^-$	1606 ± 139
(f)	$\pi^- \eta$	814 ± 52
(g)	$\pi^- \pi^0 \eta$	2172 ± 150
(h)	$\pi^- \eta' (\eta' \rightarrow \pi^+ \pi^- \eta)$	440 ± 39
(i)	$\pi^- \eta' (\eta' \rightarrow \pi^+ \pi^- \gamma)$	1383 ± 143

M_{BC} signal: (1.962, 1.982) GeV
M_{BC} sideband: (1.946, 1.956) and (1.986, 2.000) GeV

f_{D_s+} based on SM-constrained fits



$$R \equiv \frac{\Gamma(D_s^+ \to \tau^+ \nu_\tau)}{\Gamma(D_s^+ \to \mu^+ \nu_\mu)} = \frac{m_{\tau^+}^2 \left(1 - \frac{m_{\tau^+}^2}{m_{D_s^+}^2}\right)^2}{m_{\mu^+}^2 \left(1 - \frac{m_{\mu^+}^2}{m_{D_s^+}^2}\right)^2} = 9.76$$

Constrained fits give 69.3±9.3 $D_s^+ \to \mu^+ v$ signals or 32.5±4.3 $D_s^+ \to \tau^+ v$ signals

$B[D_s^+ \to \mu^+ v] = (0.495 \pm 0.067 \pm 0.026)\%$

after considering 1% $\gamma\mu^+ v$ final state

$B[D_s^+ \to \tau^+ v] = (4.83 \pm 0.65 \pm 0.26)\%$

These are consistent with results without SM-constrained fit

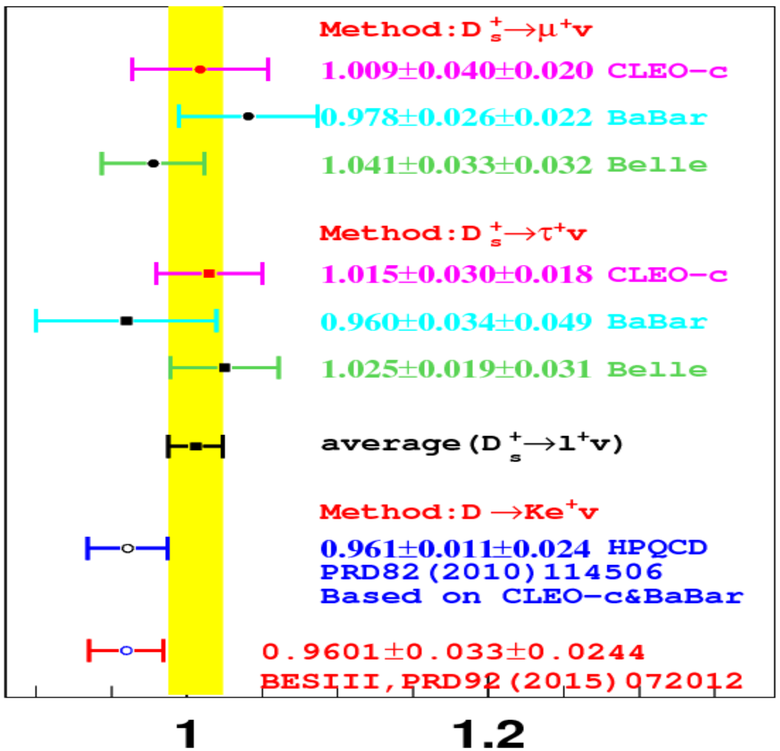
Taking G_F, m_μ, m_{D_s+} and $|V_{cs}|=|V_{ud}|$ and B as input, we determine decay constant

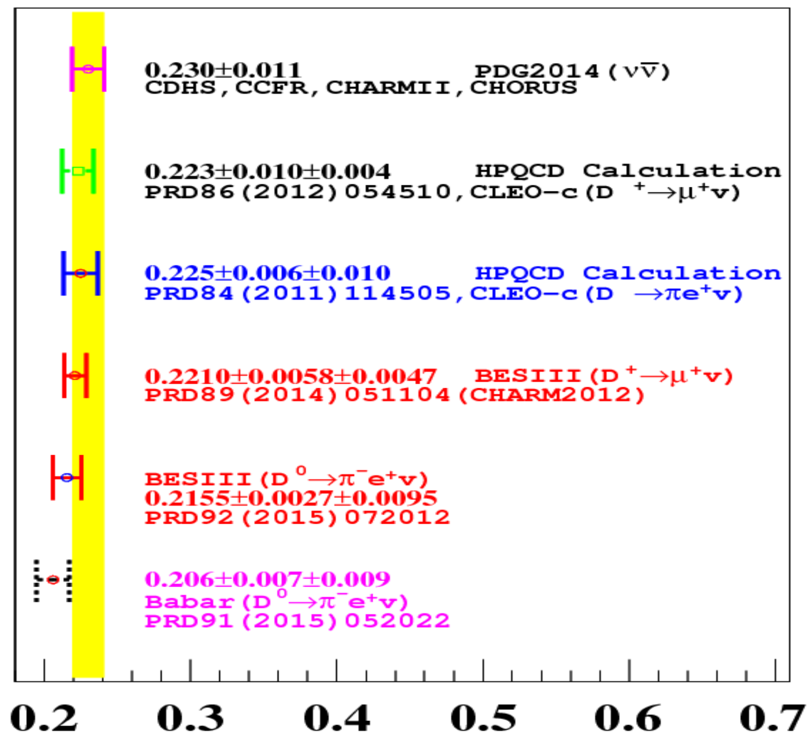
$f_{D_s+} = (241.0 \pm 16.3 \pm 6.6)$ MeV

Precise measurements of $|V_{cs}|$ and f_{D_s+} are hopefully to be done with 3 fb^{-1} data at 4.18 GeV in the near future.

Comparisons of $|V_{cs(d)}|$

- **Method 1** $B[D_{(s)}^+ \to l^+ \nu]$ → Input t_{D+}, m_{D+}, $m_{\mu+}$ on PDG and LQCD calculated $f_{D(s)+}$ → $|V_{cd(s)}|$
- **Method 2** $f_+^{D\to K(\pi)}(0)|V_{cs(d)}|$ → Input $f_+^{D\to K(\pi)}(0)$ of LQCD → $|V_{cs(d)}|$





Method 2 suffers larger theoretical uncertainty in $f_+^{D\to K(\pi)}(0)$ [1.7(4.4)%]

Summary

- **Precise measurements of D semi-leptonic decay branching fractions, form factors and $|V_{cs(d)}|$ have been extracted recently based on 2.93 fb^{-1} data at $\psi(3770)$ by BESIII**

- **3 fb^{-1} data at 4.18 GeV is almost in hand, more results on D_s^+ leptonic and semi-leptonic decays are expected in the near future**

- **Further improved calculations on FFs of $D \rightarrow K(\pi) l^+ v$ will helpful to improve $|V_{cs(d)}|$ measurements**

Thank you!