Semi-leptonic and leptonic $D^{0(+)}$ and D_s decays at BESIII

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On behalf of BESIII Collaboration

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Beauty 2018 – La Biodola

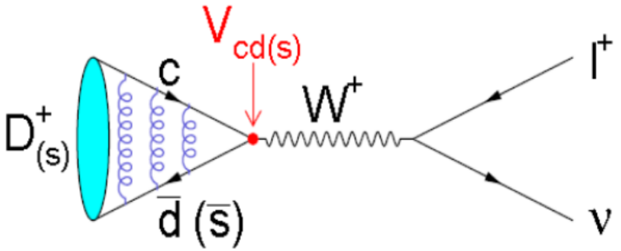
Outline

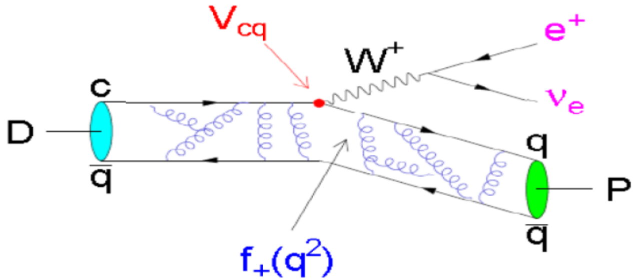
- Introduction
- BESIII @ BEPCII
  - Data samples

- D meson decays
- D_s meson decays

(Semi-)leptonic decays

Heavy meson (semi-)leptonic decays provide an ideal window to study the interplay between strong and EW interactions.





From precise determination of the branching ratio it is possible to access to

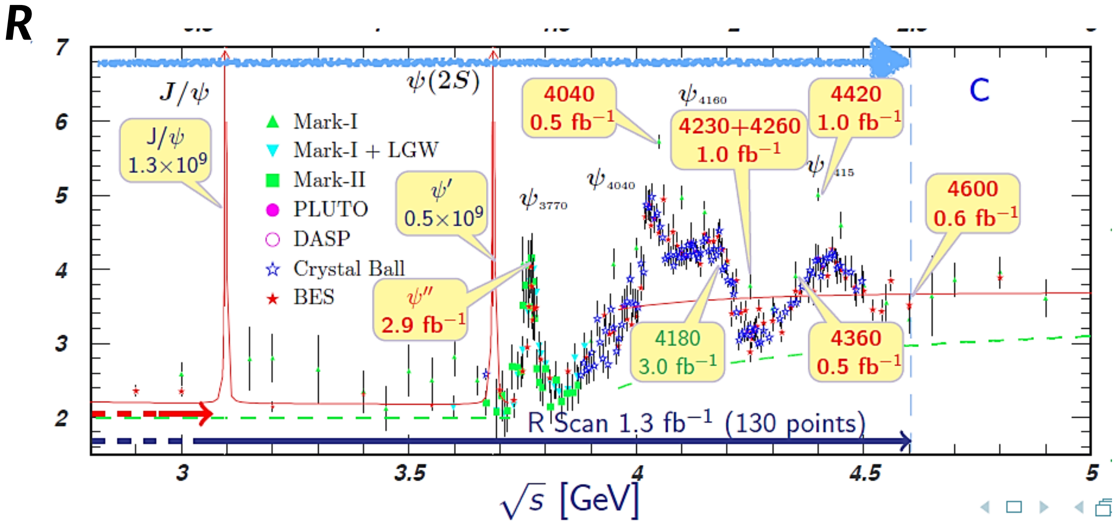
- $f_{D(s)}$ decay constant, $f_+(q^2)$ form factors,
- CKM matrix elements
- Lepton universality

Lattice QCD tuning
Unitarity test of CKM
New Physics?

BESIII Data samples

Center of mass energy can be **shifted** at *threshold openings*:

- Very low hadronic background
- Challenge for detector performance



Dedicated data samples:

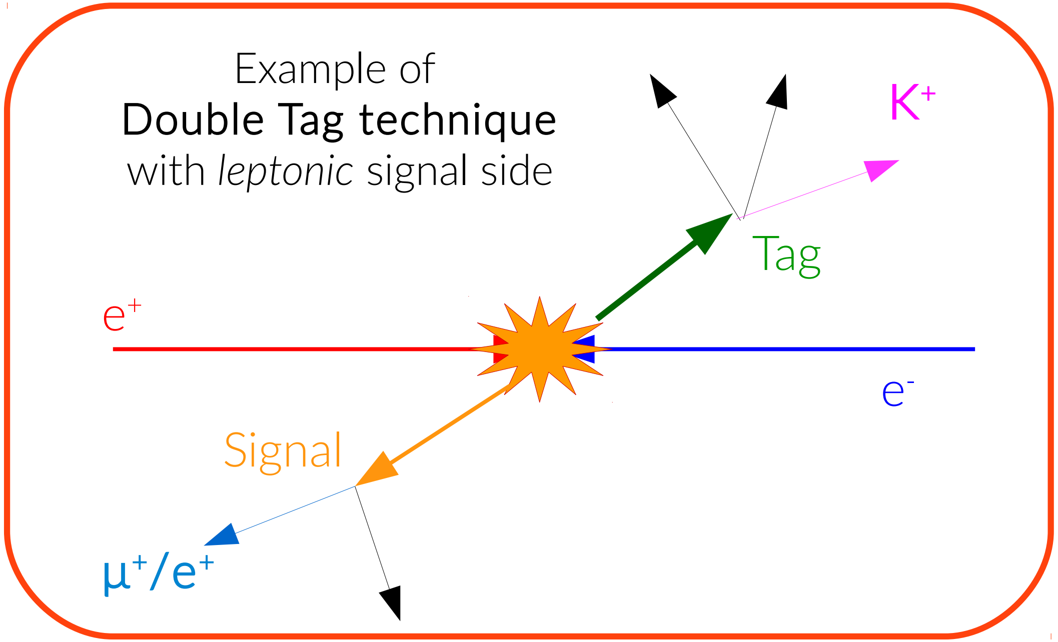
$D^{0(+)}$ data:

- E_{cm} = 3773 MeV
  - Integrated luminosity = 2.93 fb^{-1}

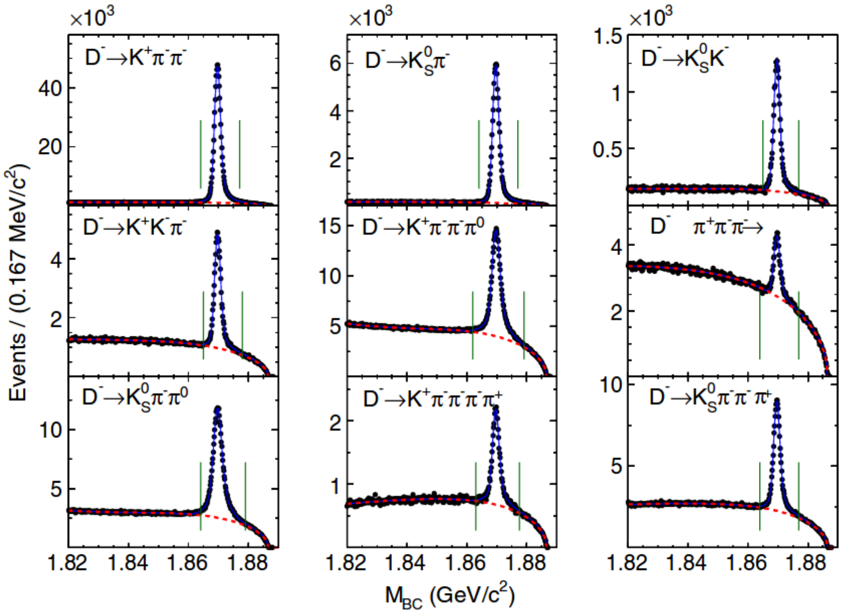
D_s^+ data:

- E_{cm} = 4009 MeV
  - Integrated luminosity = 0.482 fb^{-1}
- E_{cm} = 4178 MeV
  - Integrated luminosity = 3.19 fb^{-1}

Charmed meson decay at threshold at BESIII



Example D^- Tag mode



Variables of interest (calculated in e^+e^- reference frame)

Mass beam constrained

$$M_{bc} = \sqrt{E_{beam}^2 - p_{candidate}^2}$$

Energy difference

$$\mathrm{dE} = \mathrm{E}_{\mathrm{candidate}} - \mathrm{E}_{\mathrm{beam}}$$

Missing mass

$$\mathrm{U}_{\mathrm{miss}} = \mathrm{E}_{\mathrm{miss}} - |\vec{p}_{\mathrm{miss}}|$$

D decays

Selected topics *(based on 21 M D^0 and 16 M D^+)*:

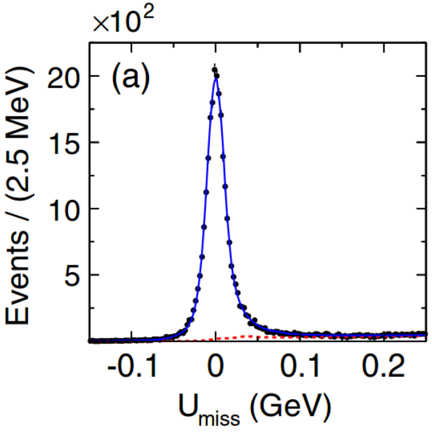
- Semileptonic $D^+ \to K^0/\pi^0\ e^+\ \nu_e$ (PRD 96, 012002 (2017))
- Semileptonic $D^0 \to K^-\ \mu^+\ \nu_\mu$ (preliminary)
- Semileptonic $D^{+(0)} \to \pi^{0(-)}\ \mu^+\ \nu_\mu$ (arXiv: 1802.05492 – submitted to PRL)
- Leptonic $D^+ \to \tau^+\ \nu_\tau$ (preliminary)

$D^+ \to K^0/\pi^0 e^+ \nu_e$

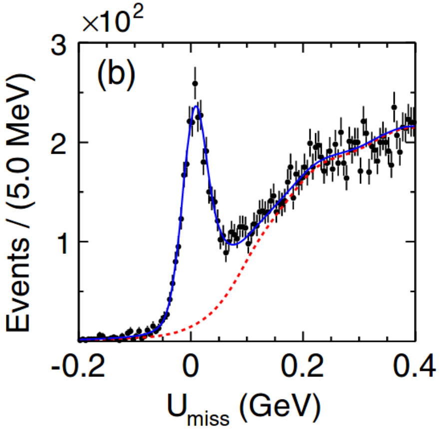
PRD 96, 012002 (2017)

Study to extract CKM parameters (V_{cs} and V_{cd}) and form factors $f^K_+(0)$ $f^\pi_+(0)$ to tune the LQCD calculation

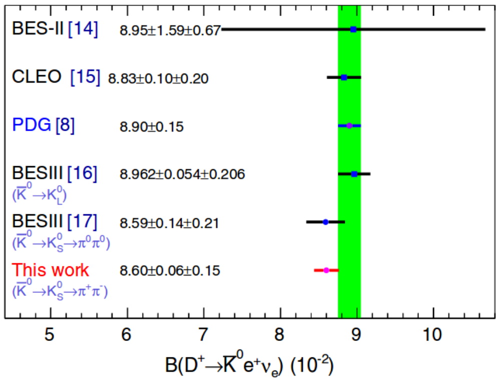
Differential decay rate $$\frac{d\Gamma}{dq^2} = X\frac{G_F^2}{24\pi^3}|V_{cs(d)}|^2 p^3 |f_+(q^2)|^2,$$

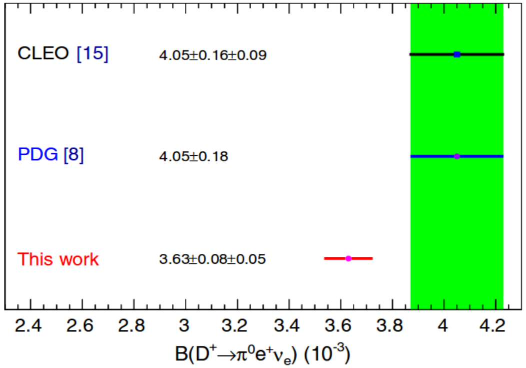


$D^+ \to K^0 e^+ \nu_e$



$D^+ \to \pi^0 e^+ \nu_e$

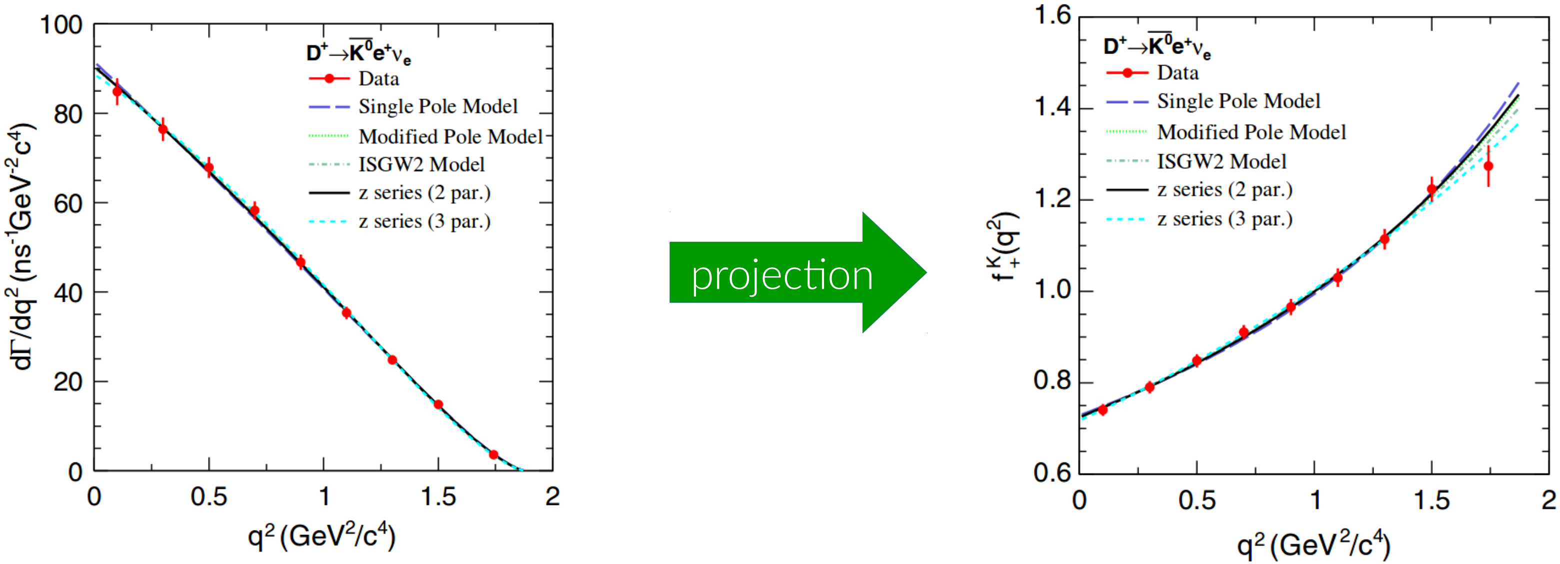




World **most precise** results – within *1σ agreement* with PDG

$|f_+(0)V_{cs(d)}|$ from $D^+ \to K^0/\pi^0 e^+ \nu_e$

It is also possible to extract the factors $|f_+(0)V_{cs(d)}|$ by fitting to the differential decay rates with different form factor parametrizations and then extract the projections



$$q^2 = (E_{e^+} + E_{\nu_e})^2/c^4 - (\vec{p}_{e^+} + \vec{p}_{\nu_e})^2/c^2$$

From 2 parameters z series expansion results

$$f_+(0)|V_{cs}| = 0.7053 \pm 0.0040 \pm 0.0112$$

$$f_+(0)|V_{cd}| = 0.1400 \pm 0.0026 \pm 0.0007$$

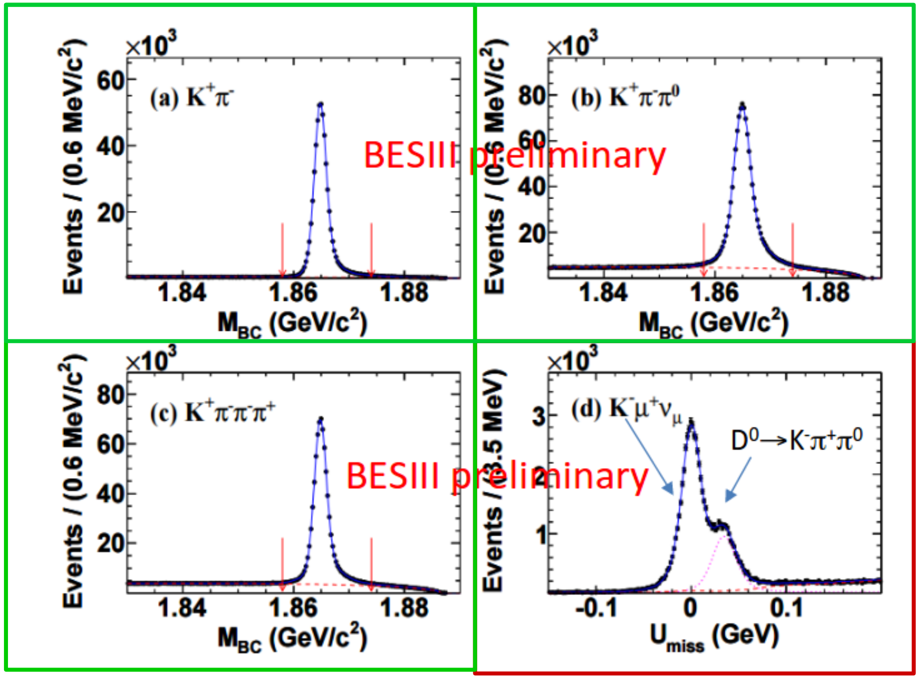
$D^0 \to K^- \mu^+ \nu_\mu$ (preliminary)

$$\frac{d\Gamma}{dq^2} = \frac{G_F^2|V_{cs}|^2}{8\pi^3 m_D}|\vec{p}_K||f_+^K(q^2)|^2\left(\frac{W_0-E_K}{F_0}\right)^2 \times\left[\frac{1}{3}m_D|\vec{p}_K|^2 + \frac{m_\mu^2}{8m_D}(m_D^2+m_K^2+2m_DE_K)+\frac{1}{3}m_\mu^2\frac{|\vec{p}_K|^2}{F_0}+\frac{1}{4}m_\mu^2\frac{m_D^2-m_K^2}{m_D}\mathrm{Re}\left(\frac{f_-(q^2)}{f_+(q^2)}\right)+\frac{1}{4}m_\mu^2F_0\left|\frac{f_-(q^2)}{f_+(q^2)}\right|^2\right] \quad (6)$$

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

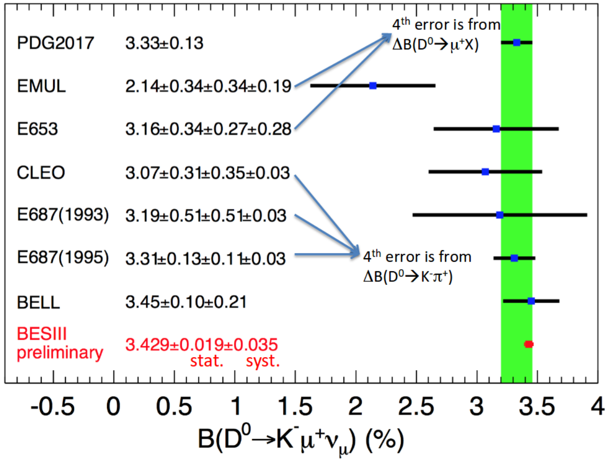
Assumed to be indipendent of q^2 following FOCUS (PLB607(2005)233)

Tag side/Signal events



No MUC, since p_μ to low

To reduce background, cut on $K\mu$ invariant mass

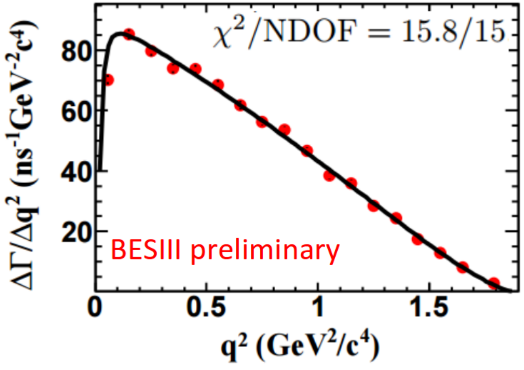


World most precise measurement

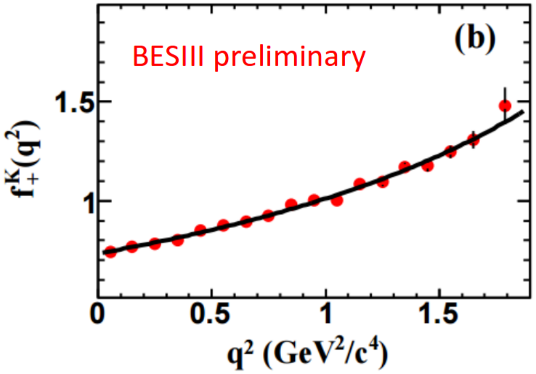
From ~4% to ~0.5% accuracy

$D^0 \to K^- \mu^+ \nu_\mu$ (preliminary)

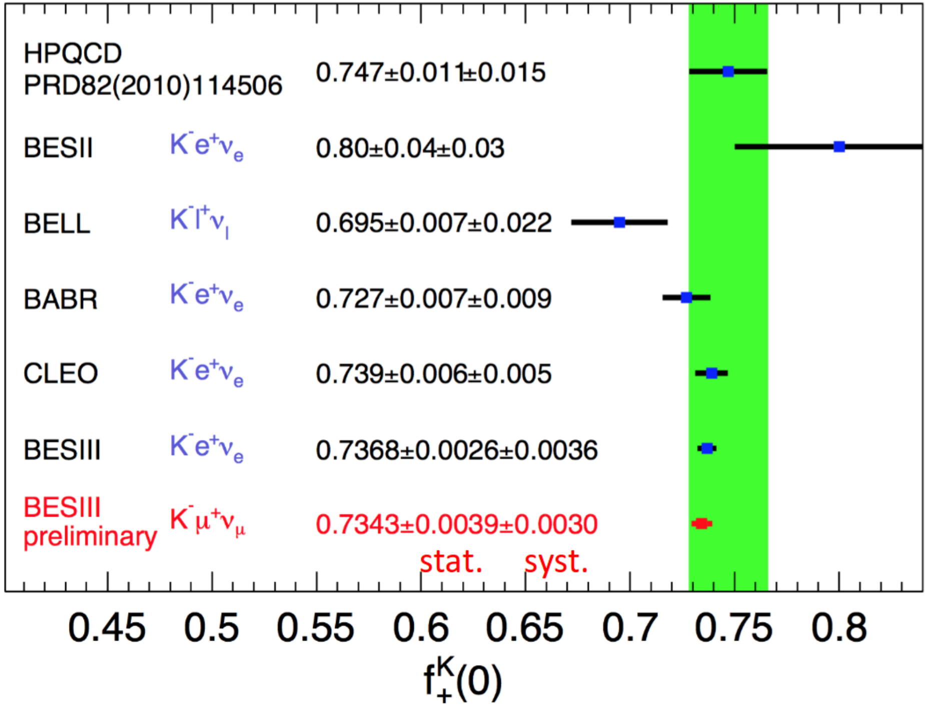
$$f_+^K(t) = \frac{1}{P(t)\Phi(t,t_0)} \frac{f_+^K(0)P(0)\Phi(0,t_0)}{1+r_1(t_0)z(0,t_0)}(1+r_1(t_0)[z(t,t_0)])$$



Projection on form factor



$$f_+^K(0)|V_{cs}| = 0.7148 \pm 0.0038_{\rm stat.} \pm 0.0029_{\rm syst.}$$



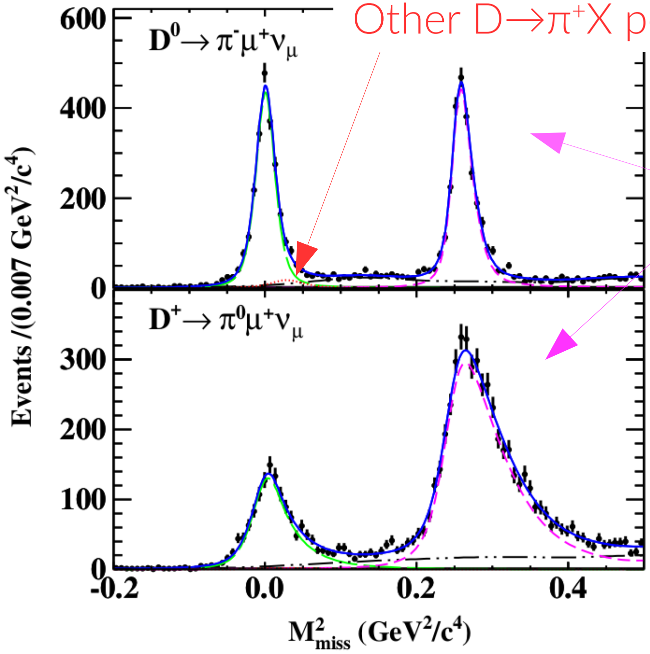
Precise determination of the f_+^K

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

Submitted to PRL
ArXiv: 1802.05492

Test of lepton flavor universality
Present data lower of about 15% with respect to SM prediction.
Error dominated by the *accurancy* of $D^0 \rightarrow \pi^- \mu^+ \nu$ (10% level)

$$R_{LU}^{0(+)} = \frac{D^{0(+)} \rightarrow \pi^{-(0)} \mu^+ \nu_\mu}{D^{0(+)} \rightarrow \pi^{-(0)} e^+ \nu_e}$$



Improved precision on $D^0 \rightarrow \pi^- \mu^+ \nu$

$$\mathcal{B}^0_{\pi\mu\nu} = (0.267 \pm 0.007 \pm 0.007)\%$$

First measurement of $D^+ \rightarrow \pi^0 \mu^+ \nu$

$$\mathcal{B}^+_{\pi\mu\nu} = (0.342 \pm 0.011 \pm 0.010)\%$$

Combining with previous BESIII results

$$R^0_{LU} = 0.905 \pm 0.027 \pm 0.023 \qquad R^+_{LU} = 0.942 \pm 0.037 \pm 0.027$$

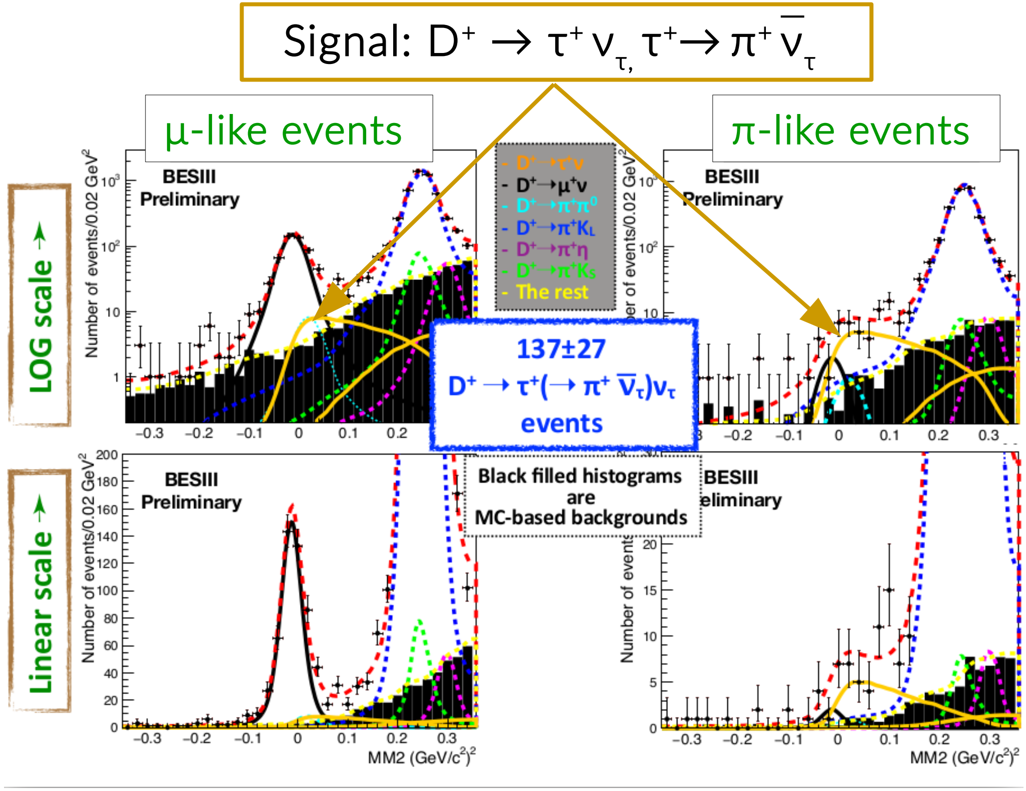
Theoretically: $R^{0(+)} = 0.97$

Agreement at 1.9σ and 0.6σ level

Leptonic $D^+ \to \tau^+ \nu_\tau$ (preliminary)

Search for pure leptonic decay of D meson (never observed before) and possible test of *lepton universality*.

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



Two signal regions:

- μ-like (E_{EMC} < 300 MeV);
- π-like (E_{EMC} > 300 MeV)

Simultaneous Fit to the missing-mass-squared

$$M_{\text{miss}}^2 = (E_{\text{beam}} - E_{\mu^+})^2 - (-\vec{p}_{D^-_{\text{tag}}} - \vec{p}_\mu)^2$$

Preliminary Results

$BF(D^+ \to \tau^+\nu_\tau) = (1.20 \pm 0.24)\ 10^{-4}$

$R = 3.21 \pm 0.64$, consistent with SM prediction ($R = 2.66 \pm 0.01$) at 0.9σ level

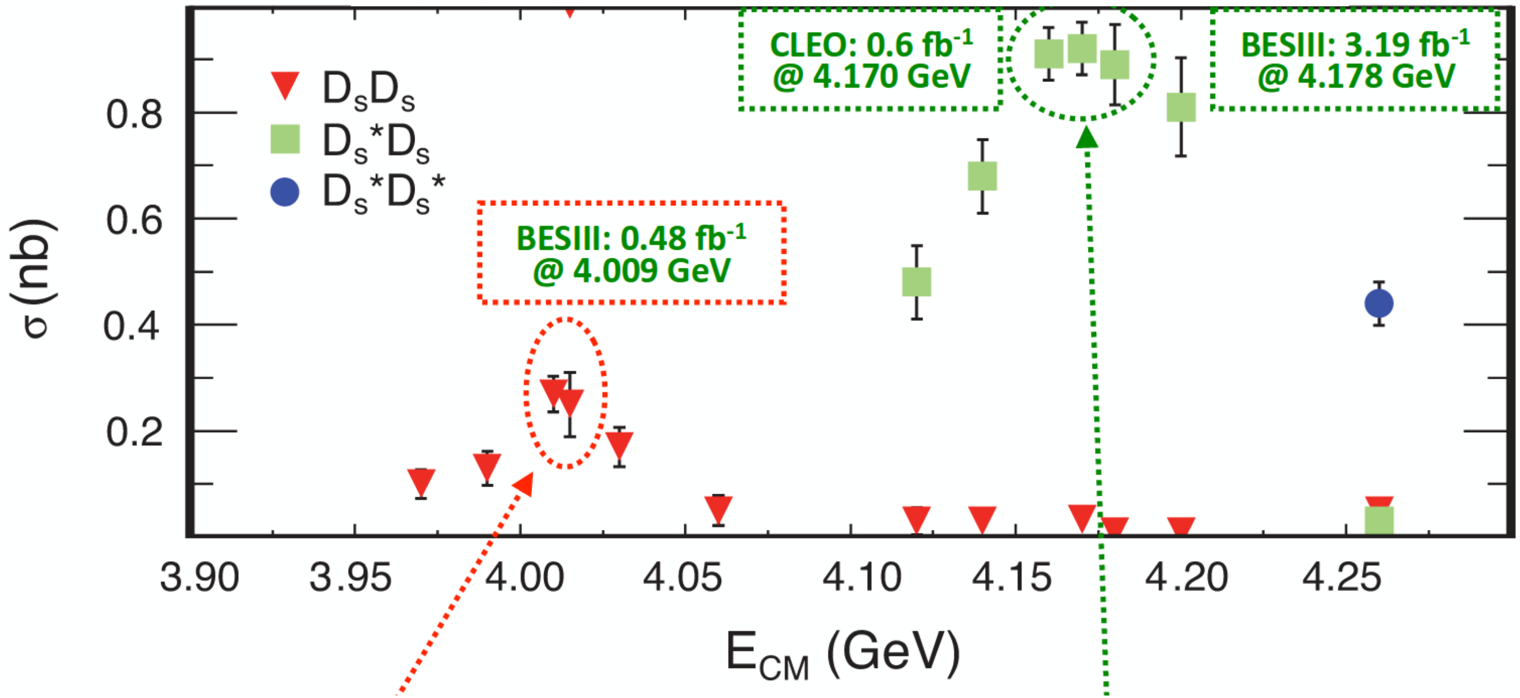
D_s decays

Selected topics

- Leptonic $D_s^+ \to \mu^+ \nu_\mu$ @ 4.178 GeV (Preliminary)
- Semileptonic $D_s^+ \to \eta^{(\prime)} e^+\nu_e$ @ 4.178 GeV (Preliminary)

D_s data samples

CLEO PRD80, 072001 (2009)



Clean sample, low production rate

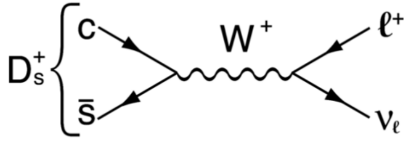
~0.4 M D_s produced

Higher production rate, BF($D^*_s \to \gamma D_s$)

~6 M D_s produced

Leptonic $D_s^+ \rightarrow l^+ \nu_l$

Leptonic D_s decays are helicity suppressed.
The expected ratios of $D_s \rightarrow e\nu_e : \mu\nu_\mu : \tau\nu_\tau$ = 2×10^{-5}:1:10

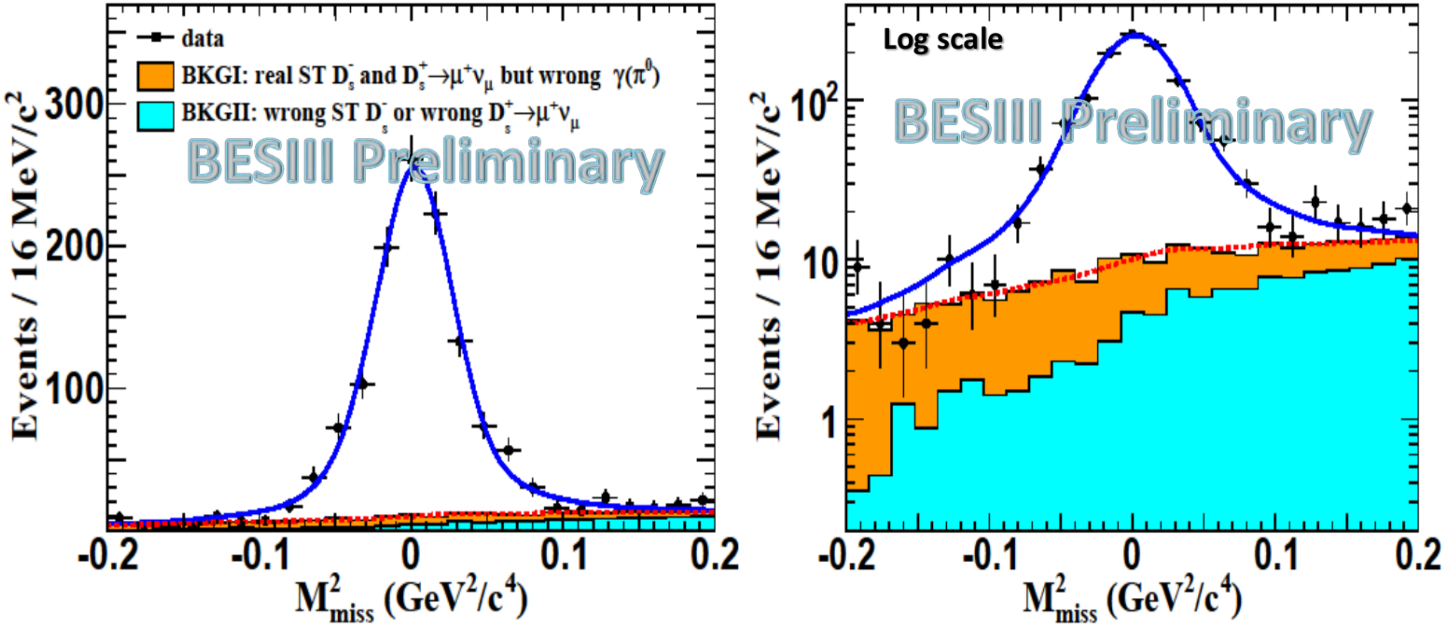


$$\Gamma(D_s^+ \to \ell^+\nu_\ell) = \frac{G_F^2}{8\pi} f_{D_s^+}^2 m_\ell^2 m_{D_s^+} \left(1 - \frac{m_\ell^2}{m_{D_s^+}^2}\right)^2 |V_{cs}|^2$$

By studying the partial decay rate is possible to access
- form factor f_{Ds}
- CKM matrix element V_{cs}

There is a *discrepancy* in f_{Ds} prediction
from **lattice** (f_{Ds} **= 249.0 ± 1.2 MeV)** and **experiments** (f_{Ds} **= 257.5 ± 4.6 MeV**)
that can be addressed by *New Physics* models (two Higgs-doublet, R-parity violation)

Leptonic $D_s^+ \to \mu^+\nu_\mu$ @ 4.178 GeV (preliminary)

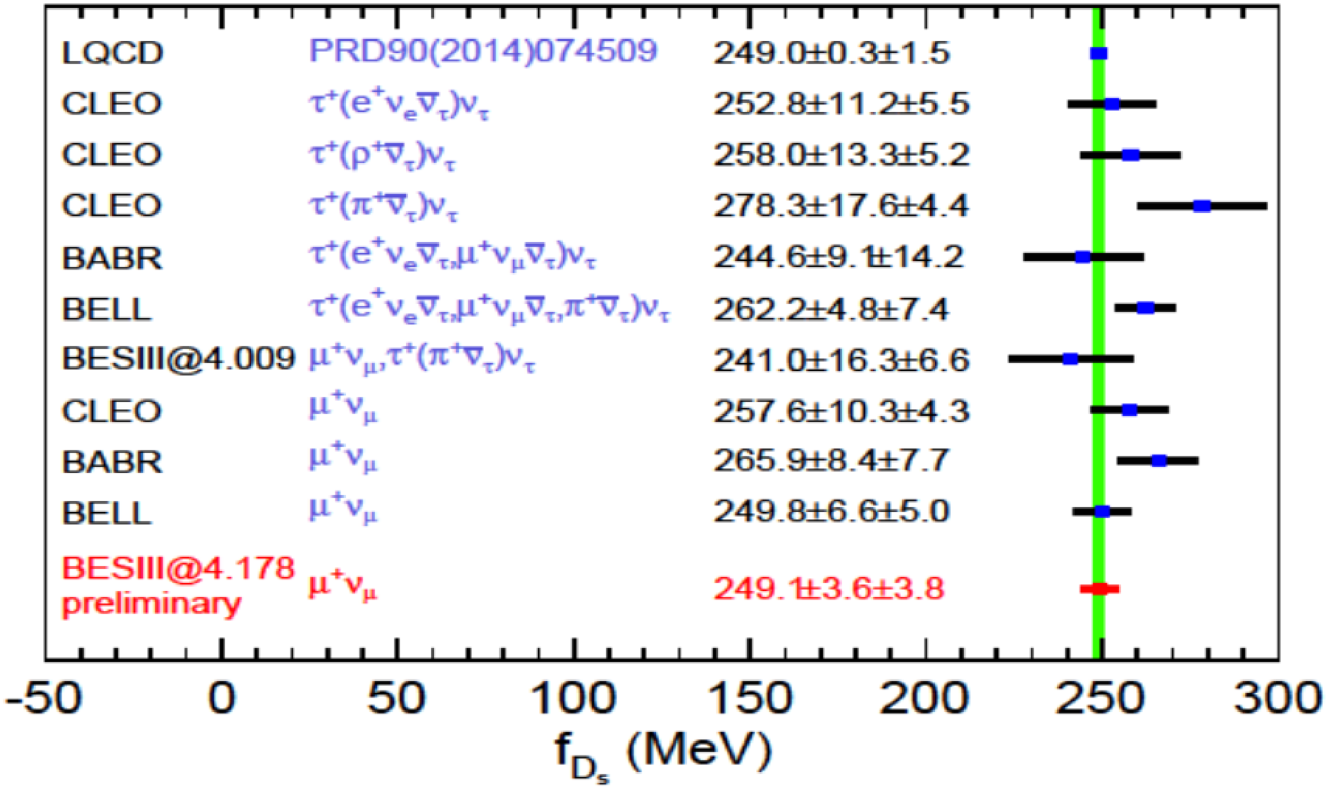


Fit to missing mass squared:
1) Signal/BKGI ratio constrained by signal MC
2) BKGII fixed via Inclusive MC

$$\mathcal{B}(D_s^+ \to \mu^+\nu_\mu) = (5.28 \pm 0.15 \pm 0.14) \cdot 10^{-3}$$

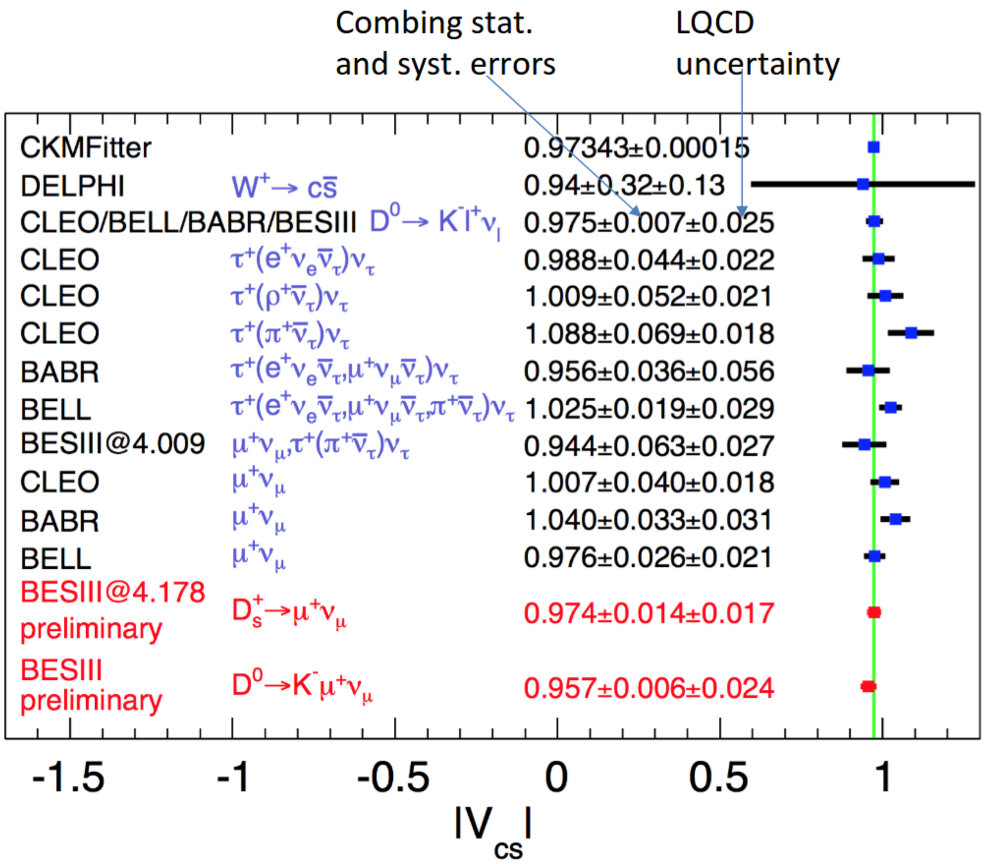
Accuracy from 13% to 2.8%

Leptonic $D_s^+ \to \mu^+\nu_\mu$ @ 4.178 GeV (preliminary)



Closing the gap with the theoretical calculation!

V_{cs} from $D_s^+ \to \mu^+\nu_\mu$ and $D^0 \to K^- \mu^+ \nu_\mu$



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To extract $|V_{cs}|$ for

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

Take f_K from PRD82(2010)114506

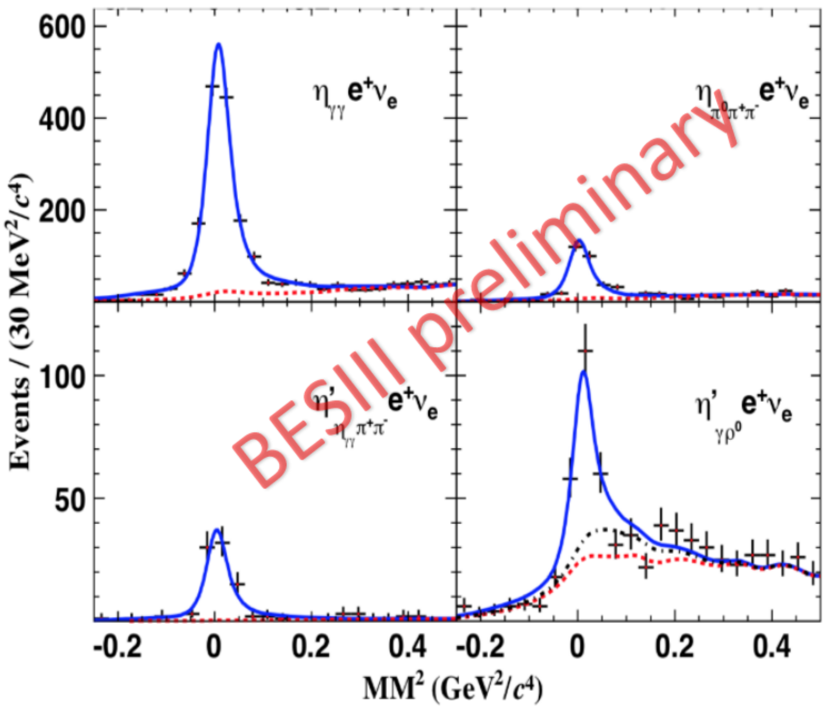
Comparable precision between $D^0 \to K^- \mu^+ \nu_\mu$ and $D_s^+ \to \mu^+\nu_\mu$

Semileptonic $D_s^+ \to \eta^{(\prime)} e^+\nu_e$ @ 4178 GeV (Preliminary)

At present time, no measurement of $f^{\eta^{(\prime)}}_+$ form factor.
Moreover, complementary test of the η-η' mixing

$$\begin{pmatrix} |\eta\rangle \\ |\eta'\rangle \end{pmatrix} = \begin{pmatrix} \cos\phi_P & -\sin\phi_P \\ \sin\phi_P & \cos\phi_P \end{pmatrix} \begin{pmatrix} |\eta_q\rangle \\ |\eta_s\rangle \end{pmatrix}$$

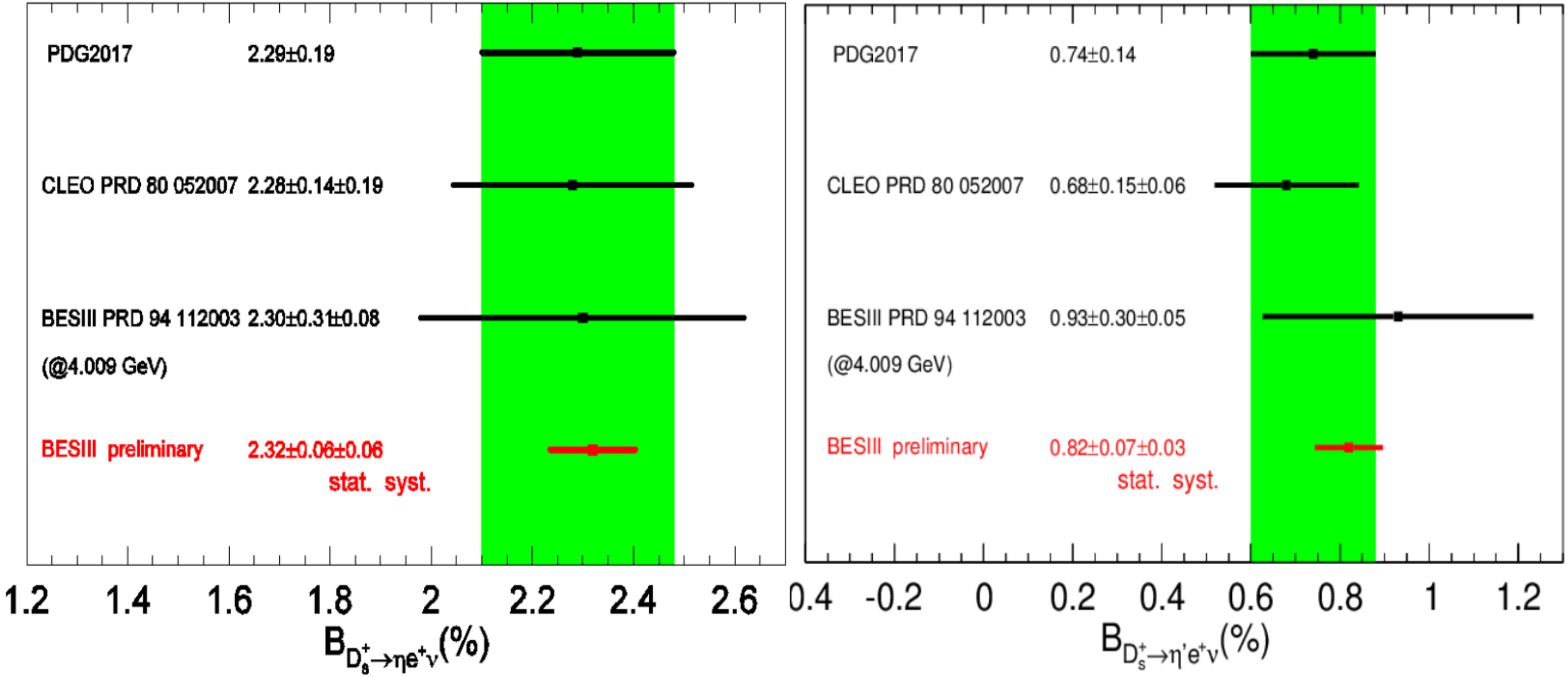
$$\frac{\Gamma(D_s^+ \to \eta' e^+\nu)/\Gamma(D_s^+ \to \eta e^+\nu)}{\Gamma(D^+ \to \eta' e^+\nu)/\Gamma(D^+ \to \eta e^+\nu)} \simeq \cot^4\phi_P$$



Result of the simultaneous fit

Decay	$\eta^{(\prime)}$ decay	$\epsilon_{\gamma(\pi^0)\mathrm{SL}}$ (%)	$N_{\mathrm{DT}}^{\mathrm{tot}}$	$\mathcal{B}_{\mathrm{SL}}$ (%)
$\eta e^+\nu_e$	$\gamma\gamma$	41.11±0.27	1834±47	2.32±0.06±0.06
	$\pi^0\pi^+\pi^-$	16.06±0.31		
$\eta' e^+\nu_e$	$\eta\pi^+\pi^-$	14.07±0.10	261±22	0.82±0.07±0.03
	$\gamma\rho^0$	18.98±0.10		

Semileptonic $D_s^+ \to \eta^{(\prime)} e^+\nu_e$ @ 4178 GeV (Preliminary)



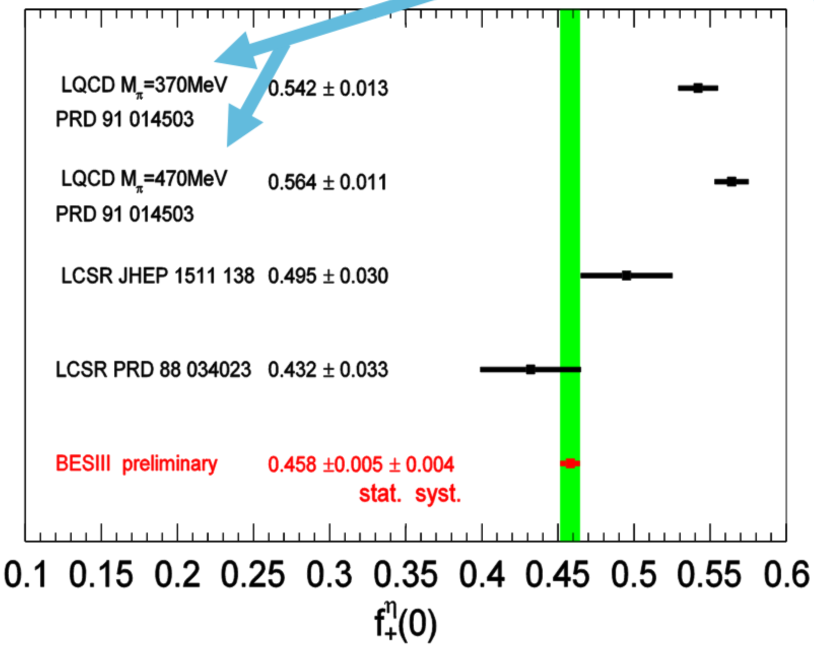
World’s most precise results! Accuracy down to ~3%(~10%)

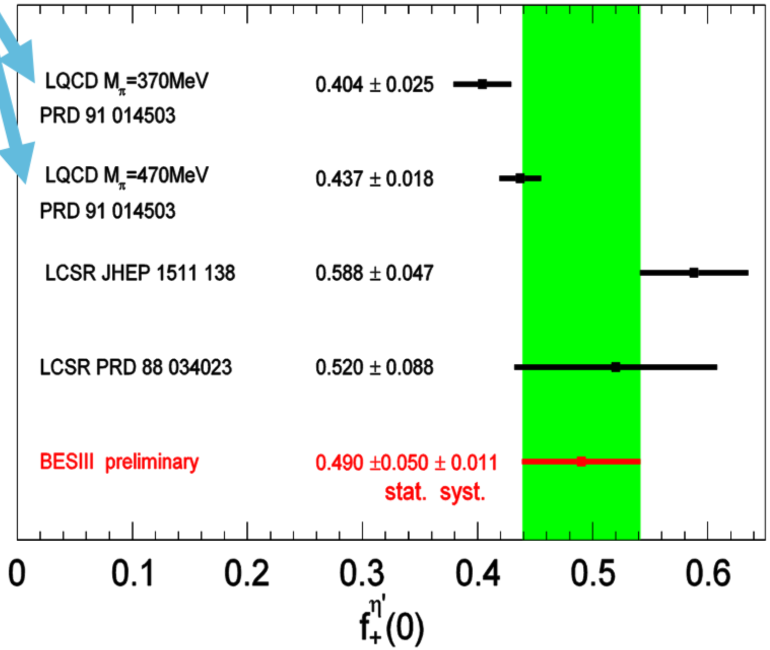
Semileptonic $D_s^+ \to \eta^{(')} e^+\nu_e$ @ 4178 GeV (Preliminary)

World first measurement of form factor

Case	Simple pole			Modified pole			Series 2 Par.		
	$f_+^{\eta^{(\prime)}}(0)\lvert V_{cs}\rvert$	$M_{\rm pole}$	$\chi^2/{\rm NDOF}$	$f_+^{\eta^{(\prime)}}(0)\lvert V_{cs}\rvert$	α	$\chi^2/{\rm NDOF}$	$f_+^{\eta^{(\prime)}}(0)\lvert V_{cs}\rvert$	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

No systematic uncertainty is considered





Summary and outlook

- With the **world largest** sample at 3.773 GeV, **BESIII** has a leading role in D meson leptonic and semileptonic decays searches, with the ability to measure with **high precision** *branching fraction*, f_D, f_+ *form factors* and *CKM matrix* elements.
  - Thanks to the production at threshold, the **environment** is very **clean** and it is possible to start testing lepton universality in several D decays

- The data at $D_s\bar{D}_s$ threshold can be used to search for studying complicated decay topologies, thanks to the almost **background-free** environment

- The newest data sample at 4.178 GeV will be used to **improve the statistical accuracy** of the processes and in a near future other semileptonic decay measurements are expected
  - First measurement of f^{η}_{+} form factor to tune the LQCD calculation
  - the CKM matrix elements and the form factor determination will follow

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Additional Material

List of D/D_s (semi-)leptonic publication

D Decay @ 3773 MeV

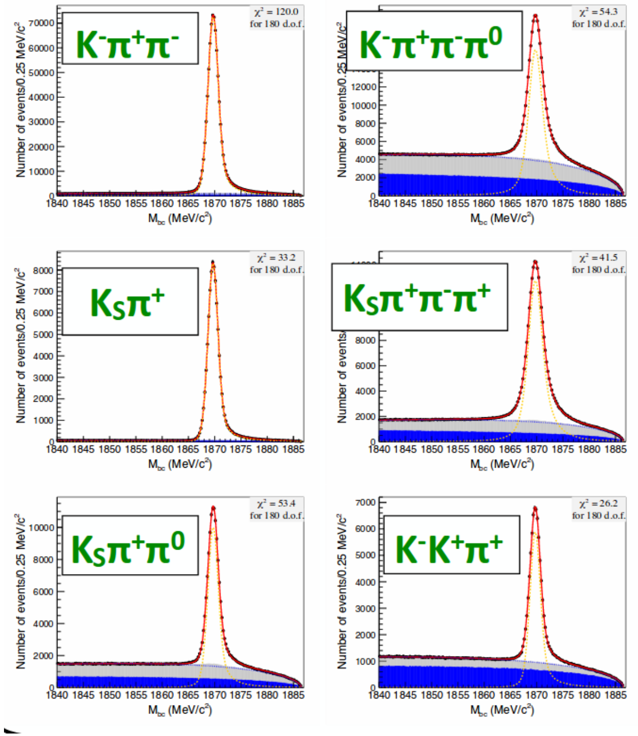
- $D^0 \to (K^-/\pi^-) e^+ \nu$ (PRD 92 (2015) 072012)
- $D^+ \to (\overline{K}^0/\pi^0) e^+ \nu$ (PRD 96 (2017) 012002)
- $D^+ \to K_L e^+ \nu$ (PRD 92 (2015) 112008)
- $D^+ \to \omega/\phi\ e^+ \nu$ (PRD 92 (2015) 071101)
- $D^+ \to K^- \pi^+ e^+ \nu$ (PRD 94 (2016) 032001)
- $D^+ \to \overline{K}^0 \mu^+ \nu$ (EPJC 76, (2016) 369)
- $D^+ \to \overline{K}^0 e^+ \nu$, $K_s \to \pi^0\pi^0$ (CPC 40 (2016) 113001)
- $D^+ \to \mu^+ \nu$ (PRD 89 (2014) 051104 (R))

D_s Decay @ 4008 MeV

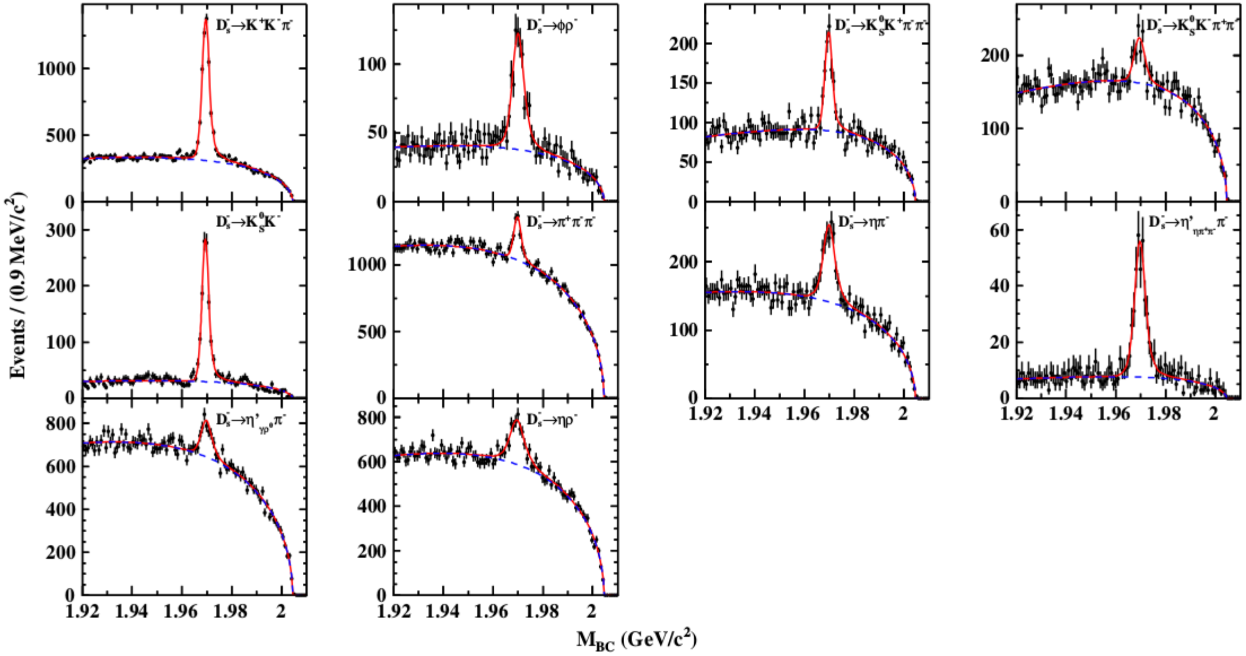
- $D_s^+ \to \tau^+/\mu^+ \nu$ (PRD 94 (2016) 072004)
- $D_s^+ \to \eta^{(')} e^+ \nu$ (PRD 04 (2016) 112003)
- $D_s^+ \to \phi/\eta^{(')} e^+/\mu^+ \nu$ (PRD 97 (2018) 012006)

Tag side reconstruction

D decays



D_s decays



Form factor parametrizations

Single pole

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

Modified pole

$$f_+(q^2) = \frac{f_+(0)}{(1 - q^2/m^2_{D^{*+}_{(s)}})(1 - \alpha q^2/m^2_{D^{*+}_{(s)}})}$$

D. Becirevcic and A. B. Kaidalov, Phys. Lett. B 478, 417 (2000)

ISGW2

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

D. Scora and N. Isgur, Phys. Rev. D 52, 2783 (1995)

Series expansion

$$z(q^2, t_0) = \frac{\sqrt{t_+ - q^2} - \sqrt{t_+ - t_0}}{\sqrt{t_+ - q^2} + \sqrt{t_+ - t_0}}$$

$$f_+(q^2) = \frac{1}{P(q^2)\phi(q^2, t_0)} \sum_{k=0}^{\infty} a_k(t_0)[z(q^2, t_0)]^k$$

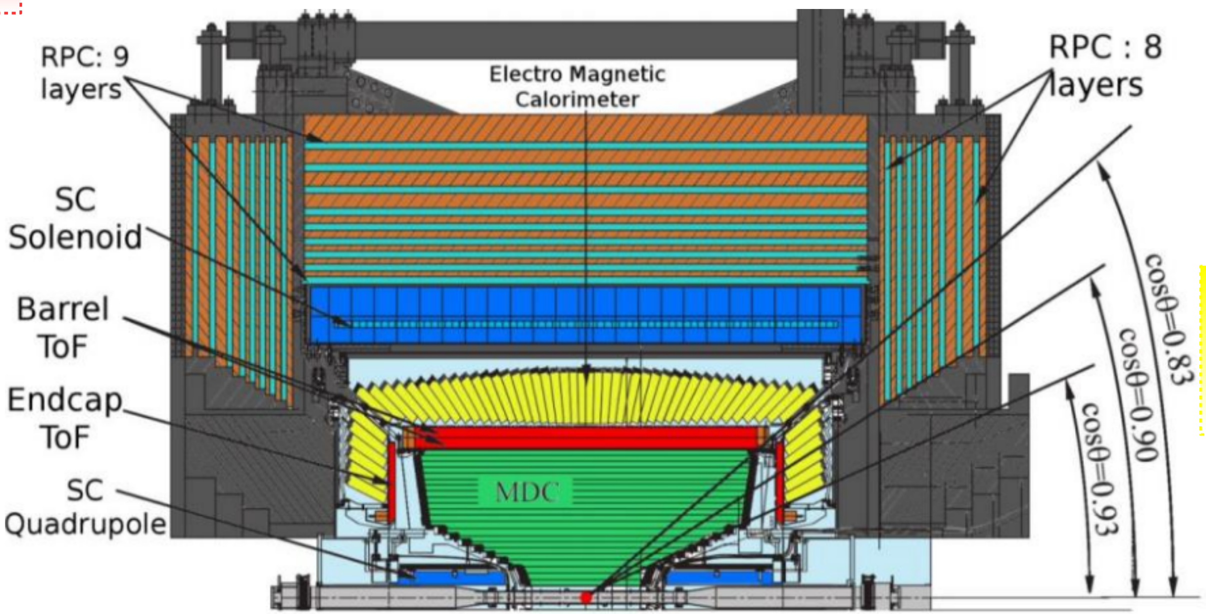
T. Becher and R. J. Hill, Phys. Lett. B 633, 61 (2006)

BESIII @ BEPCII

Time Of Flight:
σ_t (barrel) = 90 ps
σ_t (endcap) = 110 ps

1 Tesla Magnetic field

Muon counters:
$\delta_{r\varphi}$ = 1.4 cmv – 1.7 cm



Electromagnetic Calorimeter:
$dE/\sqrt{E}$ (1 GeV) = 2.5 %

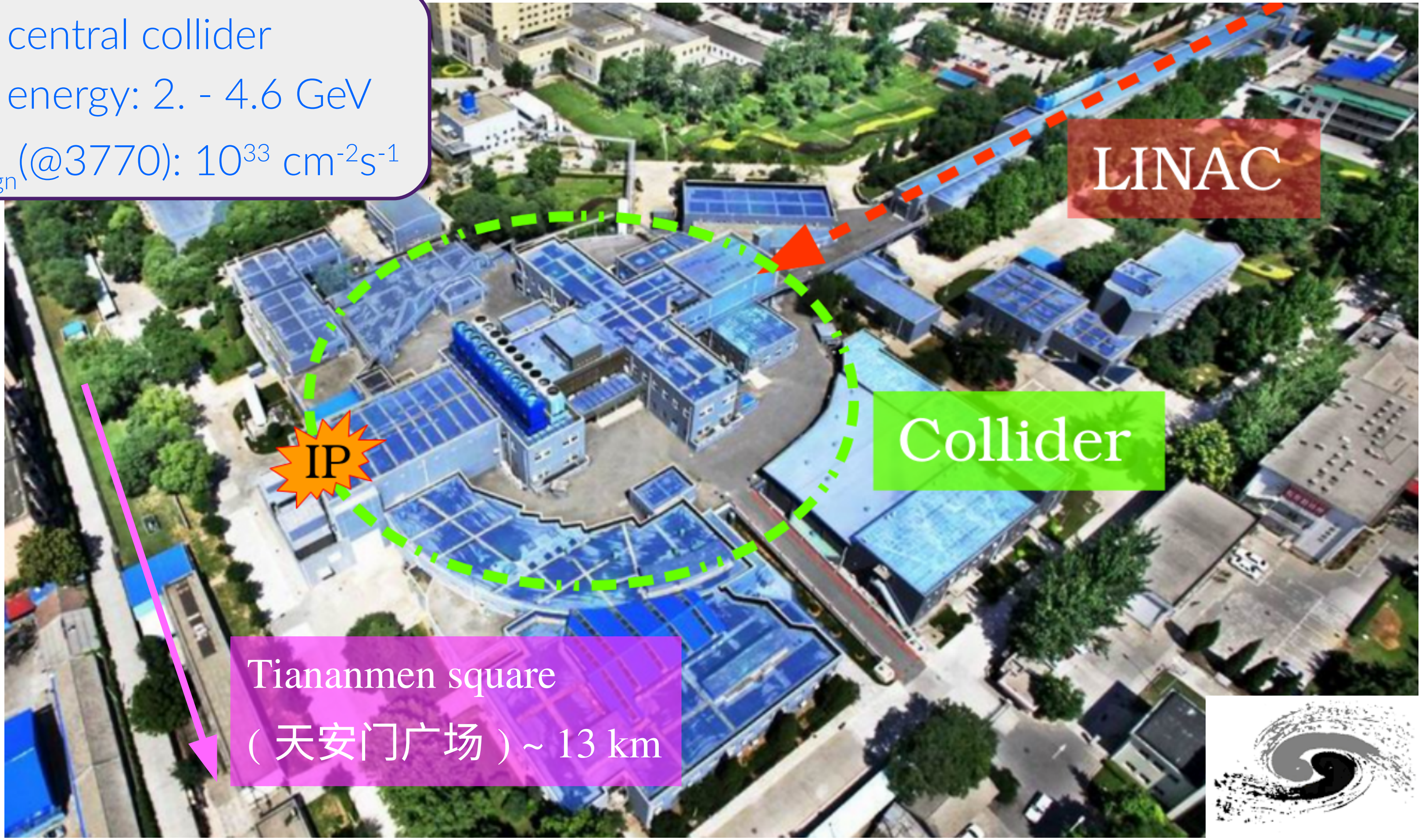
Main Drift Chamber:
σ_x (1 GeV/c) ~ 130 μm
dp/p (1 GeV/c) = 0.5 %

BEPCII @ IHEP (Beijing)

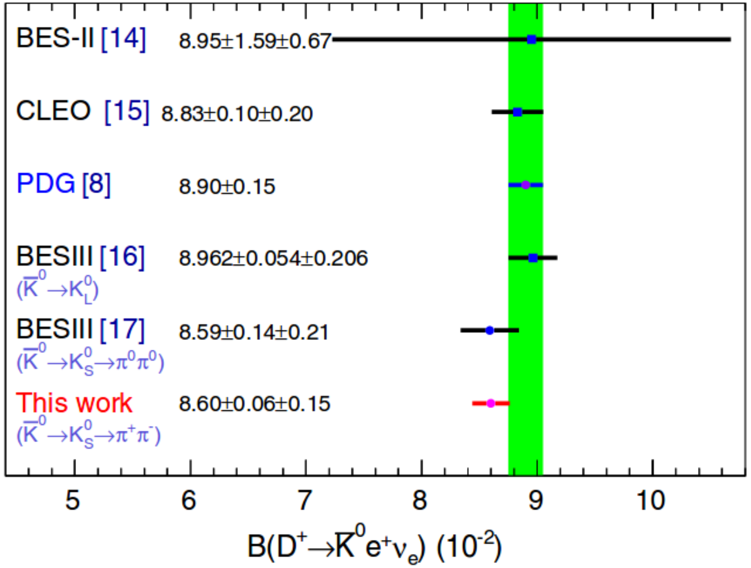
e^+e^- central collider

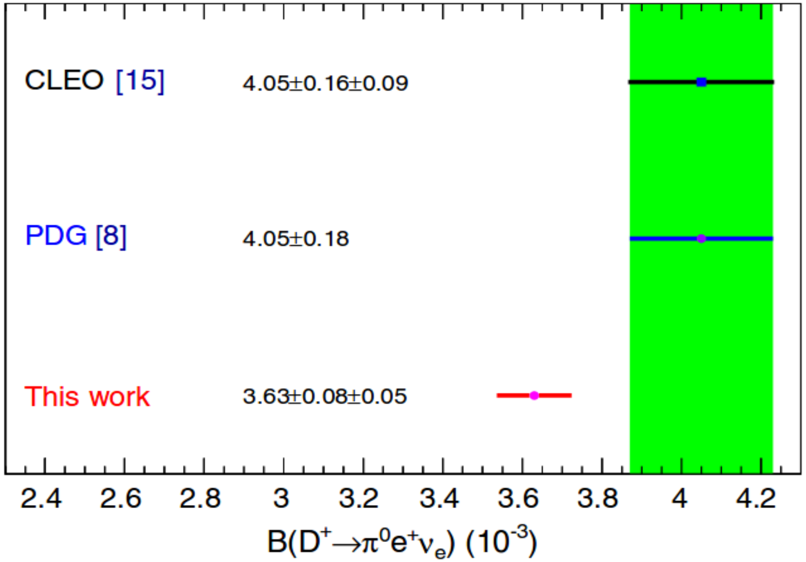
CM energy: 2. - 4.6 GeV

L_{design}(@3770): 10^{33} $cm^{-2}s^{-1}$



$D^+ \to K^0/\pi^0 e^+ \nu_e$





World **most precise** results – within *1σ agreement* with PDG

Test of isospin symmetry using previous BESIII results (Phys. Rev. D92,072012 (2015)):

$$I_K \equiv \frac{\Gamma(D^0 \to K^- e^+ \nu_e)}{\Gamma(D^+ \to \bar{K}^0 e^+ \nu_e)} = 1.03 \pm 0.01 \pm 0.02$$

$$I_\pi \equiv \frac{\Gamma(D^0 \to \pi^- e^+ \nu_e)}{2\Gamma(D^+ \to \pi^0 e^+ \nu_e)} = 1.03 \pm 0.03 \pm 0.02,$$

Isospin prediction confirmed

$|f_+(0)|$ and $|V_{cs(d)}|$ from $D^+ \to K^0/\pi^0 e^+ \nu_e$

Form factors

Using the value of V_{cs} and V_{cd}

$$|V_{cs}| = 0.97351 \pm 0.00013$$

$$|V_{cd}| = 0.22492 \pm 0.00050$$

from the Standard Model constraint fit

It is possible to extract

$$f_+^K(0) = 0.725 \pm 0.004 \pm 0.012$$

$$f_+^\pi(0) = 0.622 \pm 0.012 \pm 0.003$$

CKM matrix elements

By using

$$f_+^K(0) = 0.747 \pm 0.011 \pm 0.015$$

$$f_+^\pi(0) = 0.666 \pm 0.020 \pm 0.021$$

from LQCD calculation

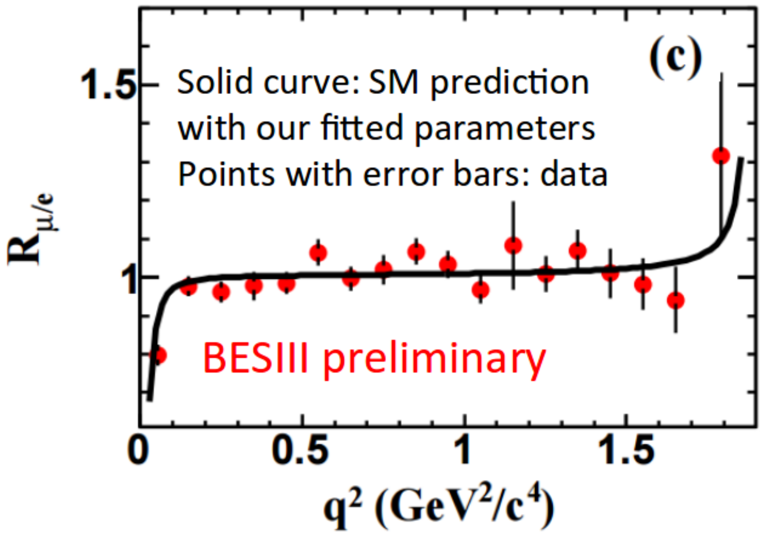
It is possible to measure

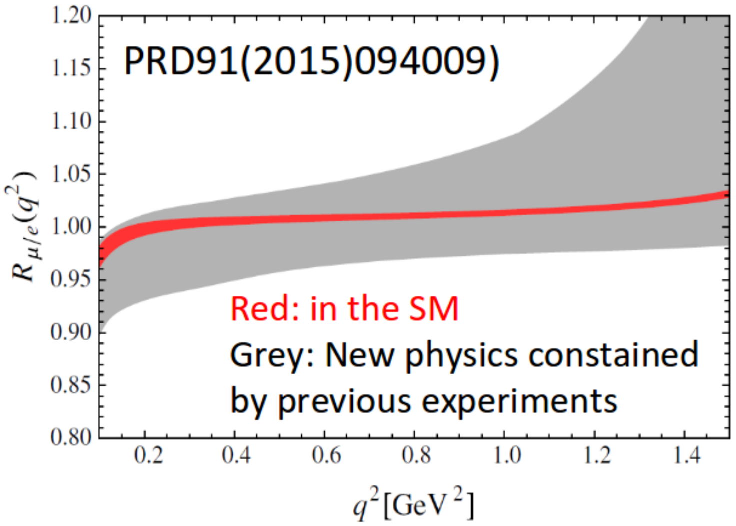
$$|V_{cs}| = 0.944 \pm 0.005 \pm 0.015 \pm 0.024$$

$$|V_{cd}| = 0.210 \pm 0.004 \pm 0.001 \pm 0.009$$

$D^0 \to K^- \mu^+ \nu_\mu$ (preliminary)

Combining with $D^0 \to K^- e^+ \nu_e$ at BESIII (PRD 92 (2015) 072012)





Integrating over all q^2 bins

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

Lepton universality confirmed

Leptonic $D^+ \to \tau^+ \nu_\tau$ (preliminary)

Search for pure leptonic decay of D meson and possible test of *lepton universality*.

Previous measurements

At present, only Upper limit ($BF < 1.2\ 10^{-3}$ @ 90% C.L.) with an integrated luminosity of $L = 0.878\ fb^{-1}$ (PRD 78, 052003 (2008))

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

Expected sensitivity

- Based on the theoretical ratio $R = 2.67 \pm 0.01$
  and previous measurement of $BF(D^+ \to \mu^+\nu_\mu) = (3.74 \pm 0.17)\ 10^{-4}$
  expected branching ratio is $BF(D^+ \to \tau^+\nu_\tau) = (9.99 \pm 0.45)\ 10^{-4}$
- BESIII has slightly more than three times the integrated luminosity of CLEO, so we expect to see some signals.

BESIII Analysis strategy

Signal: $D^+ \to \tau^+ \nu_\tau,\ \tau^+ \to \pi^+ \nu_\tau$

Main background: $D^+ \to \mu^+\nu_\mu$, but treated as part of the signal.

Other background: single charged tracks events

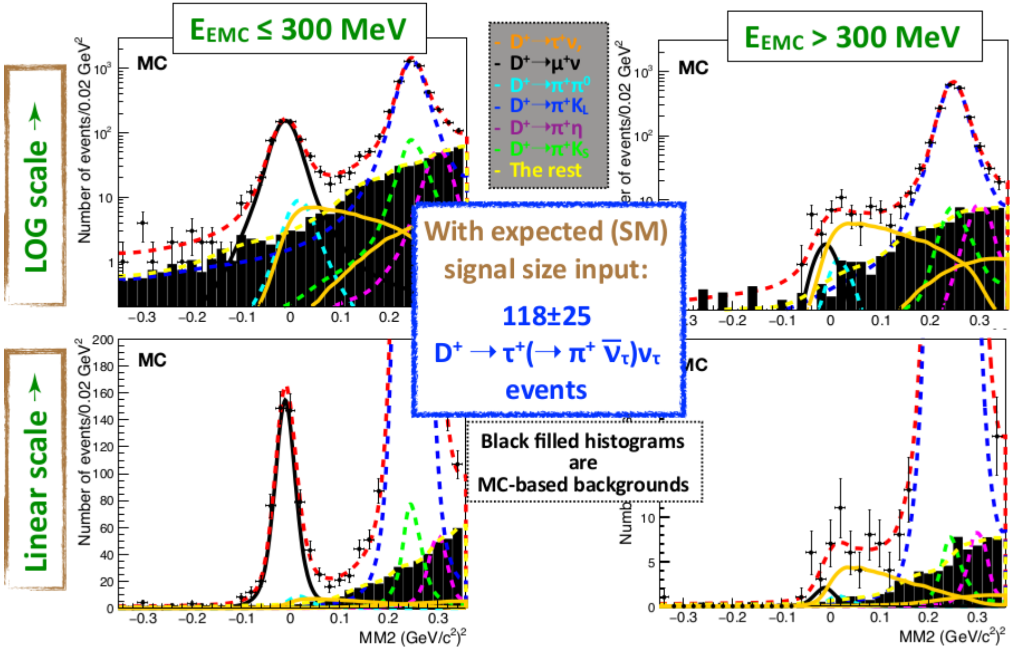
Leptonic $D^+ \to \tau^+ \nu_\tau$ (preliminary)

Simultaneous Fit to the missing-mass-squared $M^2_{\text{miss}} = (E_{\text{beam}} - E_{\mu^+})^2 - (-\vec{p}_{D^-_{\text{tag}}} - \vec{p}_\mu)^2$

divided in two sample region, based on the energy deposited in the EMC

- μ-like: E_{EMC} < 300 MeV (signal + μ contamination)
- π-like: E_{EMC} > 300 MeV (mostly signal)

MC simulations



Unbinned maximum likelihood fit components:

- Fixed $D^+ \to \mu^+\nu_\mu$ to PDG value
- Floating $D^+ \to \tau^+\nu_\tau$
- Floating $D^+ \to K_L\pi^+$
- Fixed $D^+ \to K_S\,\pi^+$ to PDG value
- Fixed $D^+ \to \pi^+\pi^0$ to PDG value
- Fixed $D^+ \to \eta\pi^0$ to PDG value

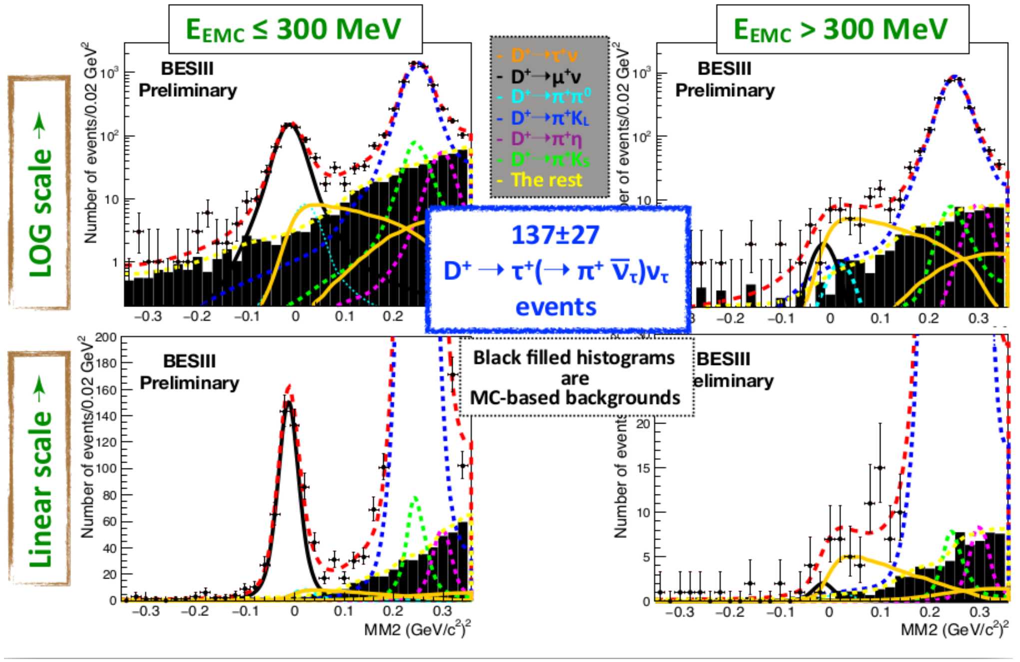
Leptonic $D^+ \to \tau^+ \nu_\tau$ (preliminary)

Simultaneous Fit to the missing-mass-squared $M^2_{\text{miss}} = (E_{\text{beam}} - E_{\mu^+})^2 - (-\vec{p}_{D^-_{\text{tag}}} - \vec{p}_\mu)^2$

divided in two sample region, based on the energy deposited in the EMC

- μ-like: E_{EMC} < 300 MeV (signal + μ contamination)
- π-like: E_{EMC} > 300 MeV (mostly signal)

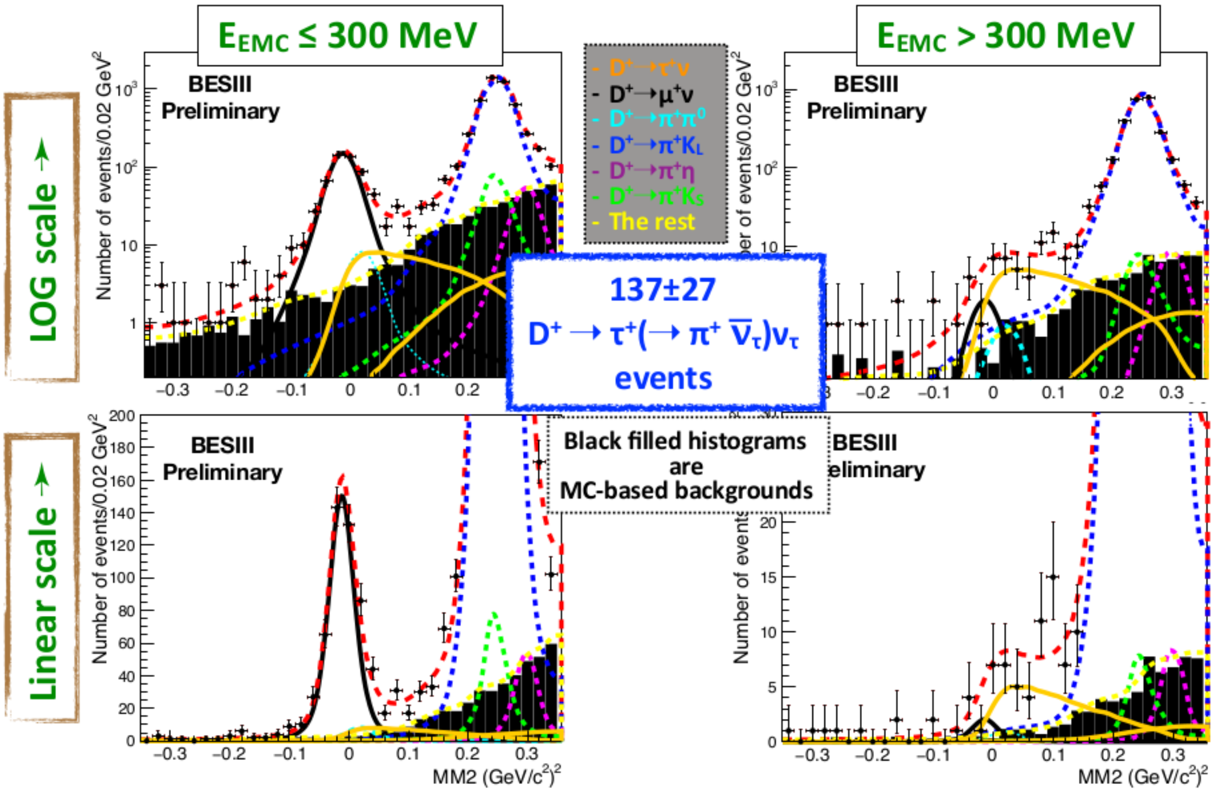
Real data



Unbinned maximum likelihood fit components:

- Fixed $D^+ \to \mu^+\nu_\mu$ to PDG value
- Floating $D^+ \to \tau^+\nu_\tau$
- Floating $D^+ \to K_L\pi^+$
- Fixed $D^+ \to K_S\, \pi^+$ to PDG value
- Fixed $D^+ \to \pi^+\pi^0$ to PDG value
- Fixed $D^+ \to \eta\pi^0$ to PDG value

Leptonic $D^+ \to \tau^+ \nu_\tau$ (preliminary)



137 ± 27 events

Significance > 4σ

EVIDENCE

$BF(D^+ \to \tau^+\nu_\tau) = (1.20 \pm 0.24)\ 10^{-4}$

R = 3.21 ± 0.64,
consistent with SM prediction
(*R = 2.66 ± 0.01*) at 0.9σ level

Leptonic $D_s^+ \to l^+ \nu_l$ @ 4.009 GeV

PRD 94 072004 (2018)

Measurements of $D_s^+ \to \tau^+\nu_\tau$ and $D_s^+ \to \mu^+\nu_\mu$

τ is reconstructed in $\pi\bar{\nu}_\tau$ and fit to the missing mass squared distributions

Two branching ratios are extracted

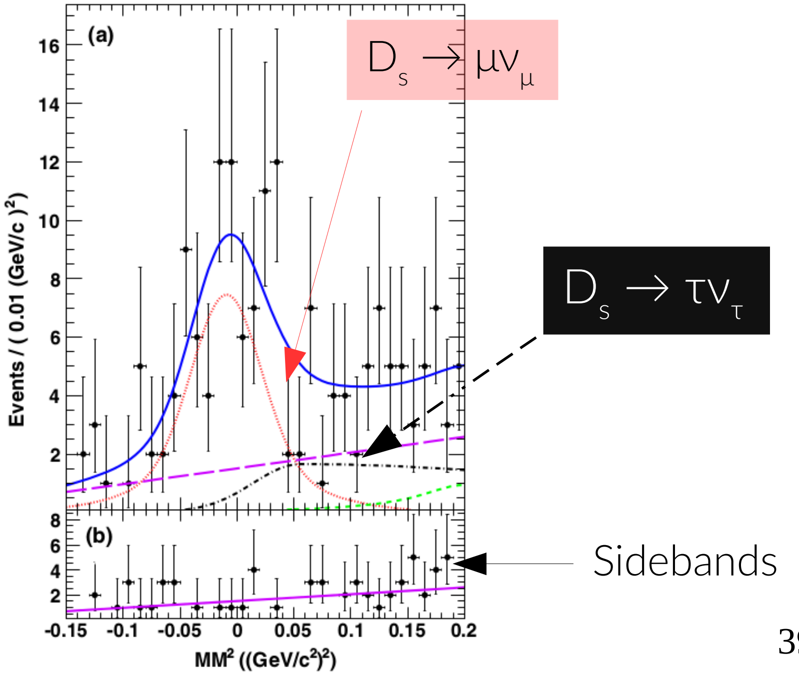
1) Standard Model constrained

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

<u>Results:</u>

$$\mathcal{B}(D_s^+ \to \tau^+\nu_\tau) = (4.83 \pm 0.65 \pm 0.26)\%$$

$$\mathcal{B}(D_s^+ \to \mu^+\nu_\mu) = (0.495 \pm 0.067 \pm 0.026)\%$$



Leptonic $D_s^+ \to l^+ \nu_l$ @ 4.009 GeV

PRD 94 072004 (2018)

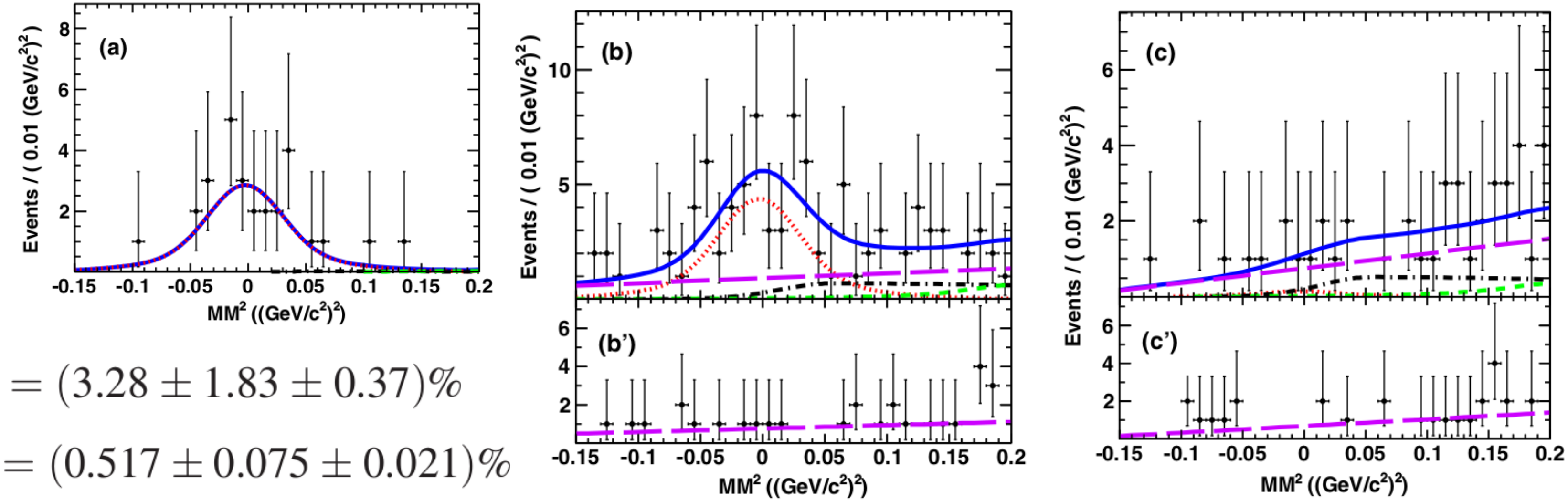
Measurements of $D_s^+ \to \tau^+\nu_\tau$ and $D_s^+ \to \mu^+\nu_\mu$

τ is reconstructed in $\pi\bar{\nu}_\tau$ and fit to the missing mass squared distributions

Two branching ratios are extracted

2) Non Standard Model constrained

Identified three region and constrained ratio between the three using real data from other processes



Results:

$$\mathcal{B}(D_s^+ \to \tau^+\nu_\tau) = (3.28 \pm 1.83 \pm 0.37)\%$$

$$\mathcal{B}(D_s^+ \to \mu^+\nu_\mu) = (0.517 \pm 0.075 \pm 0.021)\%$$

Leptonic $D_s^+ \to l^+ \nu_l$ @ 4.009 GeV

PRD 94 072004 (2018)

Measurements of $D_s^+ \to \tau^+\nu_\tau$ and $D_s^+ \to \mu^+\nu_\mu$

τ is reconstructed in $\pi\bar{\nu}_\tau$ and fit to the missing mass squared distributions

Two branching ratios are extracted

f_{Ds} decay constant

$$f_{D_s^+} = \frac{1}{G_F m_\ell (1 - \frac{m_\ell^2}{m_{D_s^+}^2})|V_{cs}|}\sqrt{\frac{8\pi\mathcal{B}(D_s^+ \to \ell^+\nu_\ell)}{m_{D_s^+}\tau_{D_s^+}}}$$

$D_s^+ \to \mu^+\nu_\mu$ from SM constrained fit

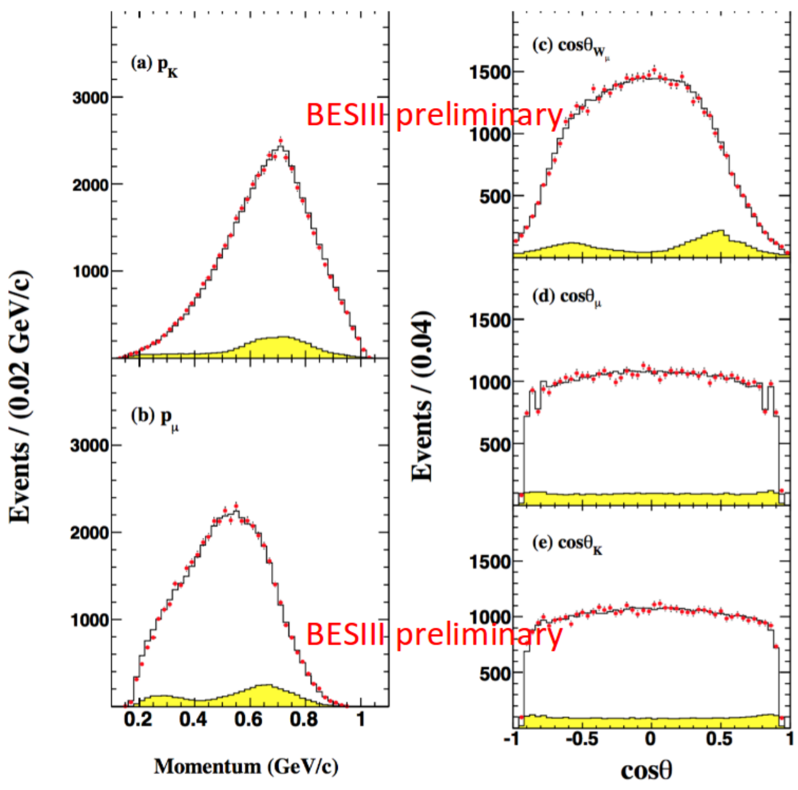
$|V_{cs}| = 0.97425$

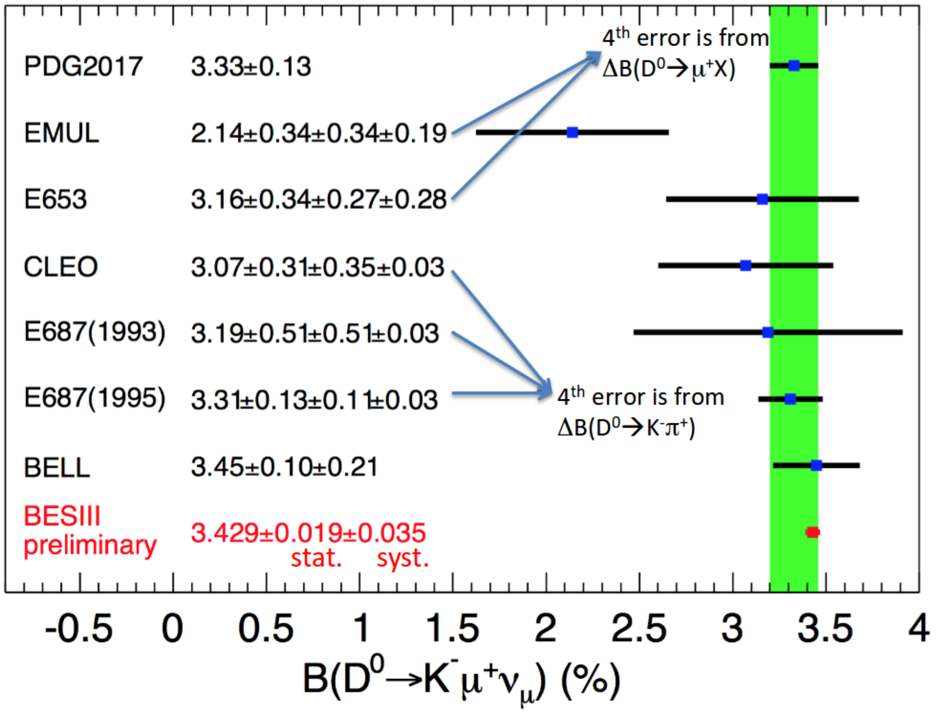
Results:

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

$D^0 \to K^- \mu^+ \nu_\mu$ (preliminary)

Data – **MC** simulation in very good agreement.



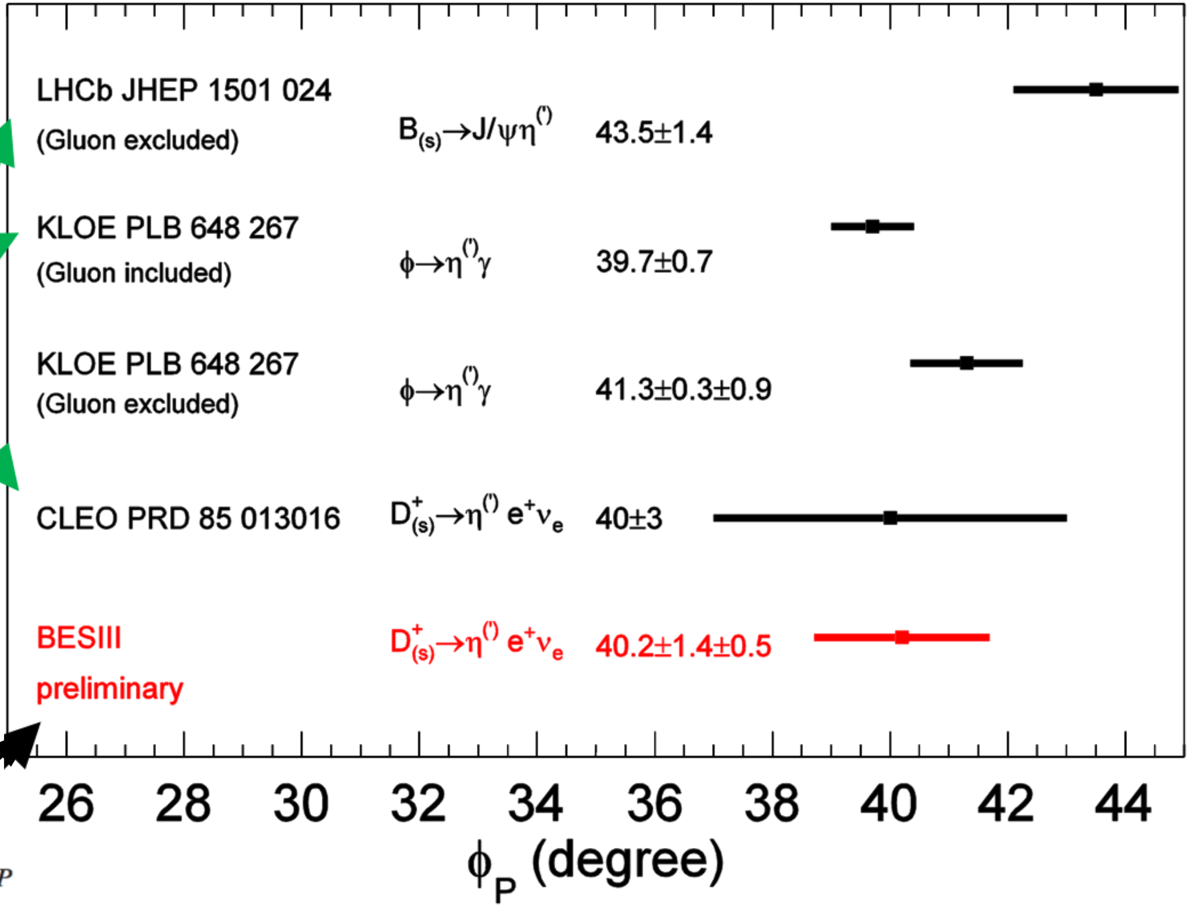


World most precise measurement

From ~4% to ~0.5% accuracy

Semileptonic $D_s^+ \to \eta^{(\prime)} e^+ \nu_e$ @ 4178 GeV (Preliminary)

Paper only reported one uncertainty, but include both statistical and systematic



Combining this work results and the ones of ArXiv: 1803.0557 $D^+ \to \eta^{(\prime)} e^+ \nu_e$ in

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