# Charm physics at BESIII

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**For BESIII Collaboration**

EPS-HEP2017, 5 -12 July 2017, Venice, Italy

# Main goals of charm physics at BESIII

**Leptonic and semileptonic decays of charmed mesons ($D^0$, $D^+$, $D_s^+$ ) provide an ideal window to explore weak and strong effects**

- **D(s) leptonic and semileptonic decays**

  **$f_{D(s)+}$, $f^{K(\pi)}_{+}(0)$: better calibrate LQCD**

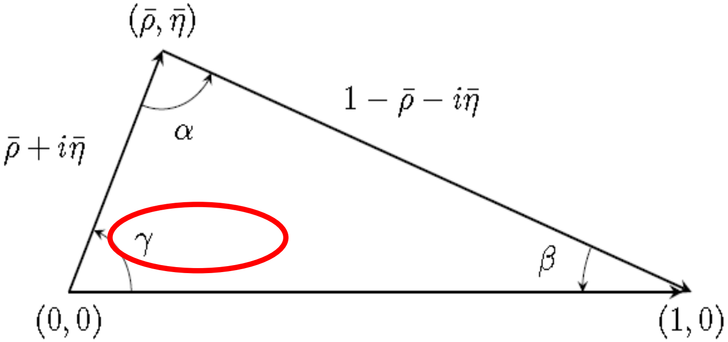
  **$|V_{cs(d)}|$: better test on CKM unitarity**

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

- **D hadronic decays**

  **$D^0\bar{D}^0$ mixing parameters and CP voilation**

  **Strong phase in $D^0$ decays: Constraint on $\gamma/\phi_3$ measurement in B decays**



- **Rare D decays → New physics**

- **Absolute BFs of $\Lambda_c^+$**

  **Before BESIII, no absolute BF measurements of $\Lambda_c^+$ using near threshold data, in the past 40 years**

# Contents

- Samples of $D_{(s)}^{+}$ and $\Lambda_c^{+}$
- $D_{(s)}^{+} \rightarrow l^{+}v$ ($l=\mu, \tau$)
- $D^{0(+)} \rightarrow Kl^{+}v$ and $\pi l^{+}v$ ($l=e, \mu$)
- Search for $D^{0(+)} \rightarrow a_0(980)^{-(0)}e^{+}v$ and $\gamma e^{+}v$
- Hadronic decays of D
- $\Lambda_c^{+} \rightarrow \Lambda l^{+}v$
- Hadronic decays of $\Lambda_c$
- Summary

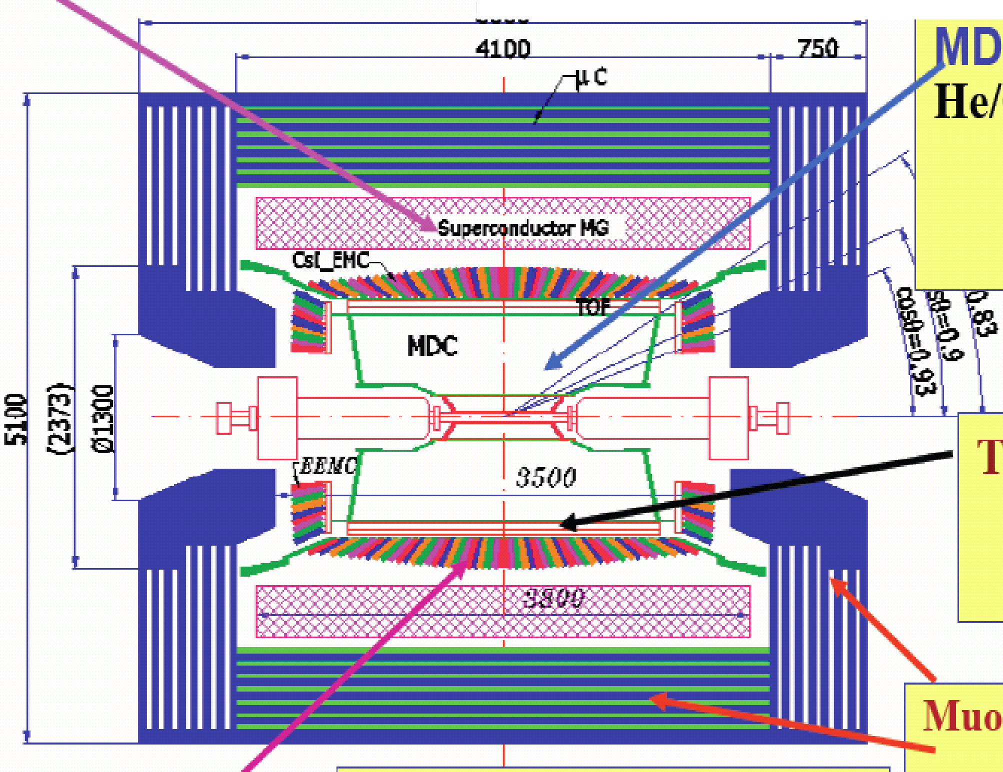
# BEPCII: high luminosity double–ring collider

| | |
|---|---|
| **Beam energy:** | 1.0-2.3 GeV |
| **Design Luminosity:** | $1.00\times10^{33}$ $cm^{-2}s^{-1}$ |
| **Optimum energy:** | 1.89 GeV |
| **Achieved Luminosity:** | $1.00\times10^{33}$ $cm^{-2}s^{-1}$ |
| **Data taken from:** | 2009 |

# BESIII detector

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

**Magnet: 1 T Super conducting**



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

**TOF:**
$\sigma_T$ = 100 ps Barrel
110 ps Endcap

**Muon ID: 9 layers RPC**
8 layers for endcap

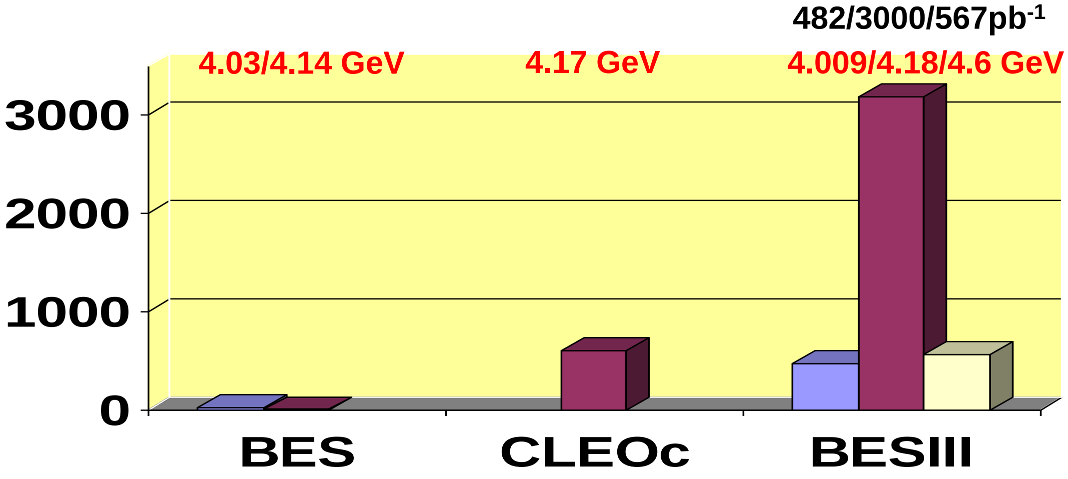
**EMC: CsI crystal, 28 cm**
ΔE/E = 2.5% @1 GeV
σz = 0.6 cm/√E

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

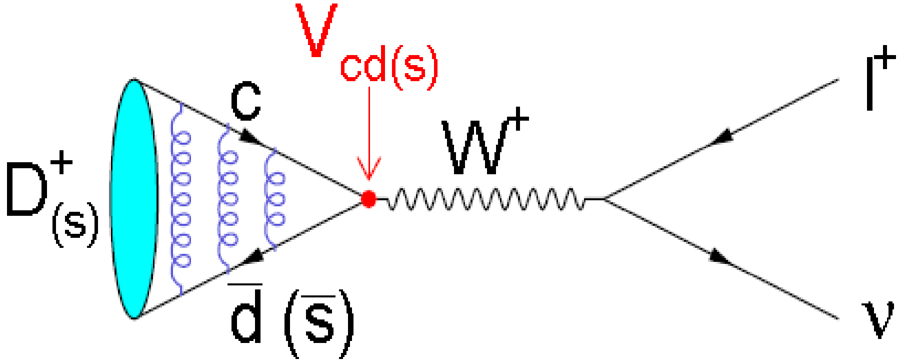
# $D^{0(+)}$, $D_s^+$ ,$\Lambda_c^+$samples at BESIII (in $pb^{-1}$)

- **$D^{0(+)}$ samples at 3.773 GeV**

- **$D_s^+/D_s^+/\Lambda_c^+$ samples at 4.009/4.18/4.6 GeV**



# $D_{(s)}^+$ leptonic decays



**In the SM:**

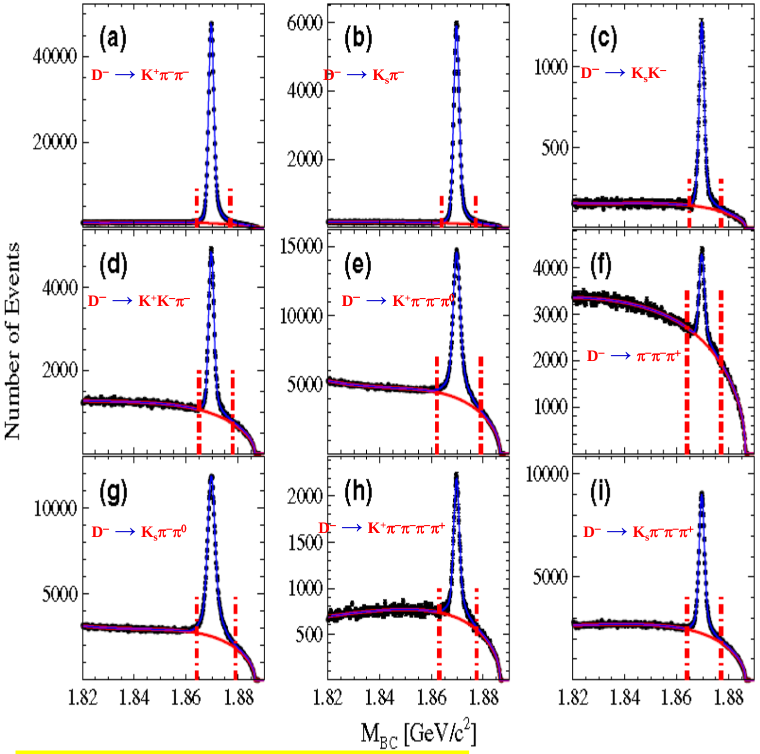
$$\Gamma(D^+_{(s)} \to \ell^+\nu_\ell) = \frac{G_F^2 f^2_{D^+_{(s)}}}{8\pi} |V_{cd(s)}|^2 m_\ell^2 m_{D^+_{(s)}} \left(1 - \frac{m_\ell^2}{m^2_{D^+_{(s)}}}\right)^2$$

**Bridge to precisely measure**

- **Decay constant $f_{D(s)+}$ with input $|V_{cd(s)}|^{\text{CKMfitter}}$**
- **CKM matrix element $|V_{cd(s)}|$ with input $f^{\text{LQCD}}_{D(s)+}$**

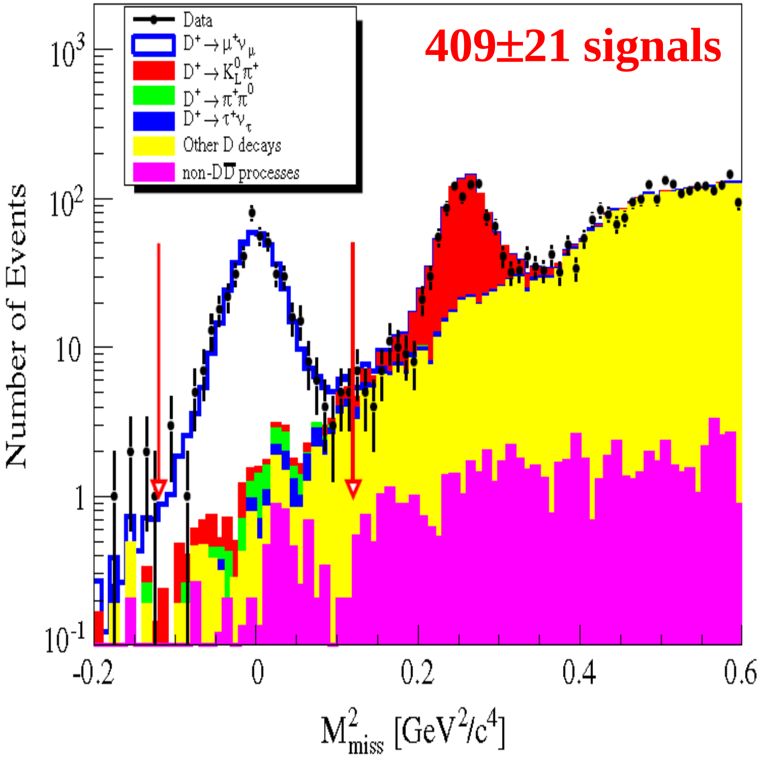
# Improved B[$D^+ \to \mu^+\nu$], $f_{D^+}$ and $|V_{cd}|$

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



**$2.93\ \text{fb}^{-1}$ data@ 3.773 GeV**

**PRD89(2014)051104R**



**409±21 signals**

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

**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**

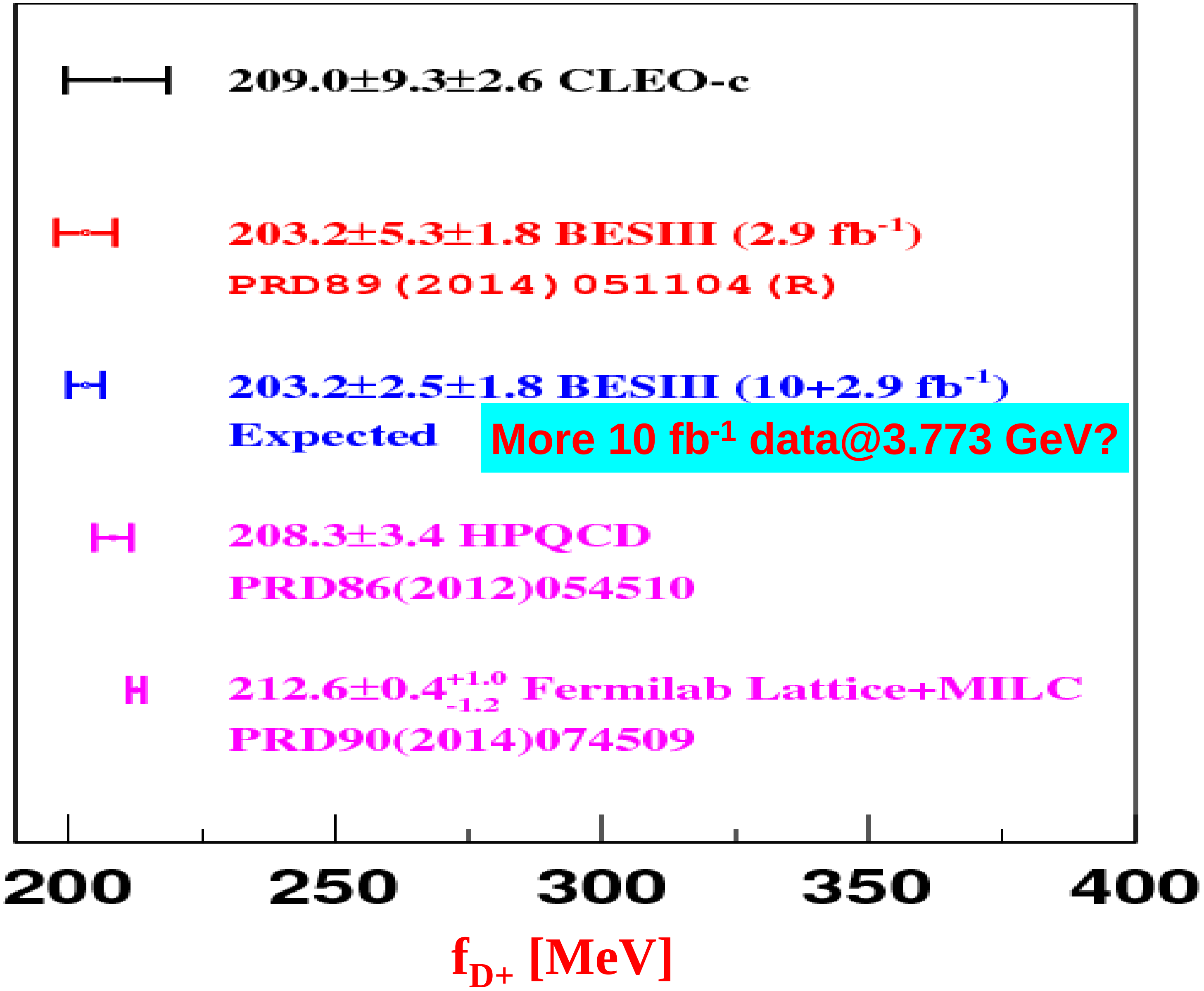
**$f_{D^+}$=(203.2±5.3±1.8) MeV**

BESIII

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

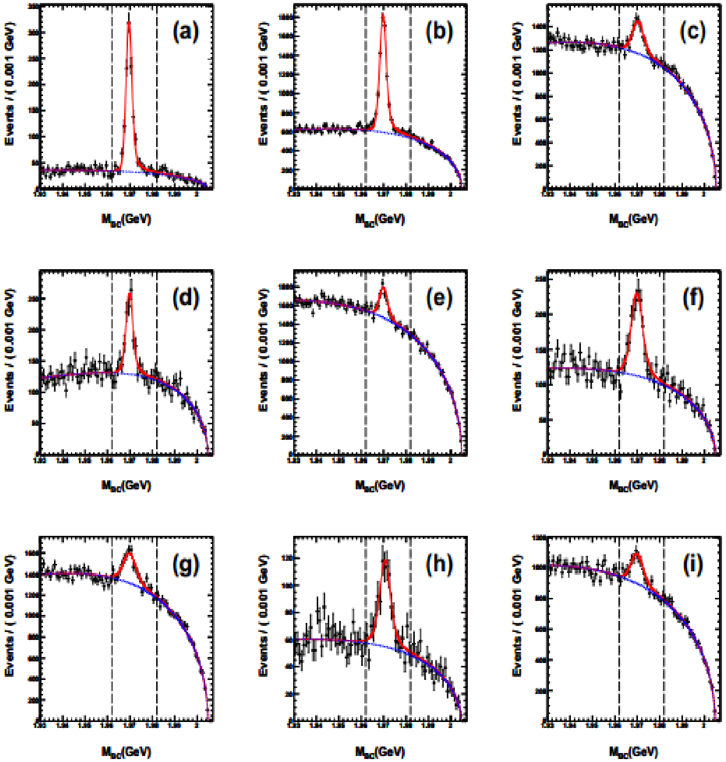
**$|V_{cd}|$=0.2210±0.0058±0.0047**

# Comparison of $f_{D+}$ and prospect at BESIII

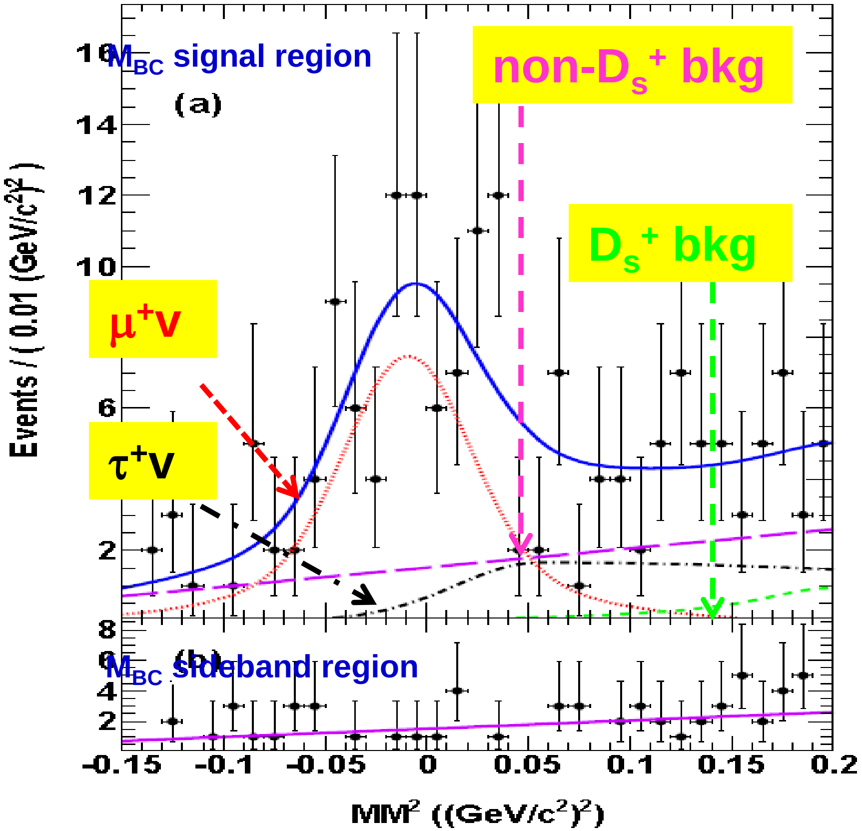


More 10 $fb^{-1}$ data@3.773 GeV?

# $f_{D_s^+}$ at 4.009 GeV



PRD94(2016)072004



non-$D_s^+$ bkg

$D_s^+$ bkg

$\mu^+\nu$

$\tau^+\nu$

$$N_{D_s^- tag} = 15127 \pm 312$$

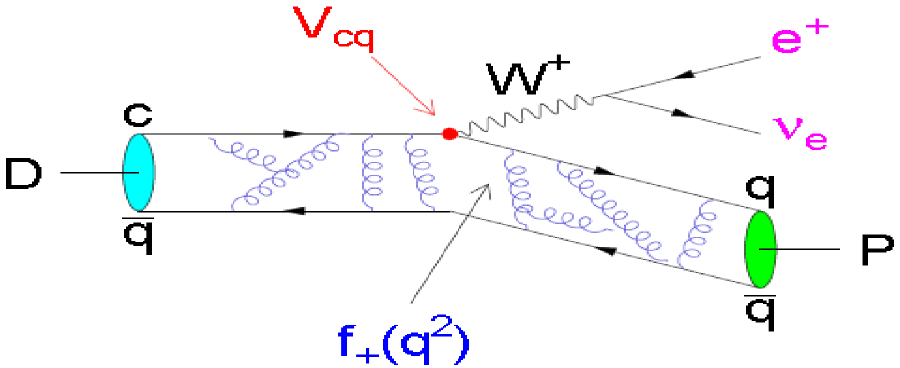
**$B[D_s^+ \to \mu^+\nu]=(0.495\pm0.067\pm0.026)\%$**

**$f_{Ds+}=(241.0\pm16.3\pm6.6)$ MeV**

**$B[D_s^+ \to \tau^+\nu]=(4.83\pm0.65\pm0.26)\%$**

**~3 $fb^{-1}$ data@ 4.18 GeV in hand，will further improve measurements**

# Semi-leptonic decay $D^0 \rightarrow K(\pi)^- e^+ \nu$

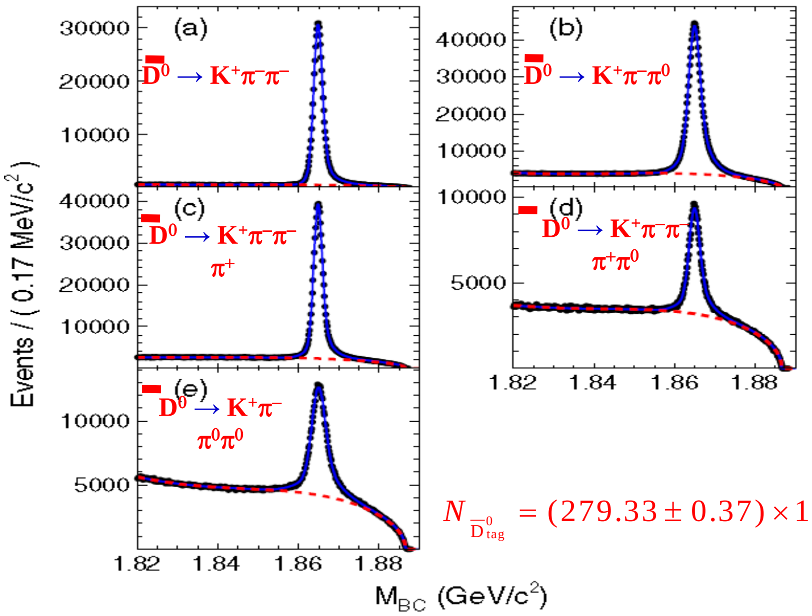


**Differential rates:** $$\frac{d\Gamma}{dq^2} = X \frac{G_F^2 |V_{cd(s)}|^2}{24\pi^3} p^3 |f_+(q^2)|^2$$

**Bridge to precisely measure:**

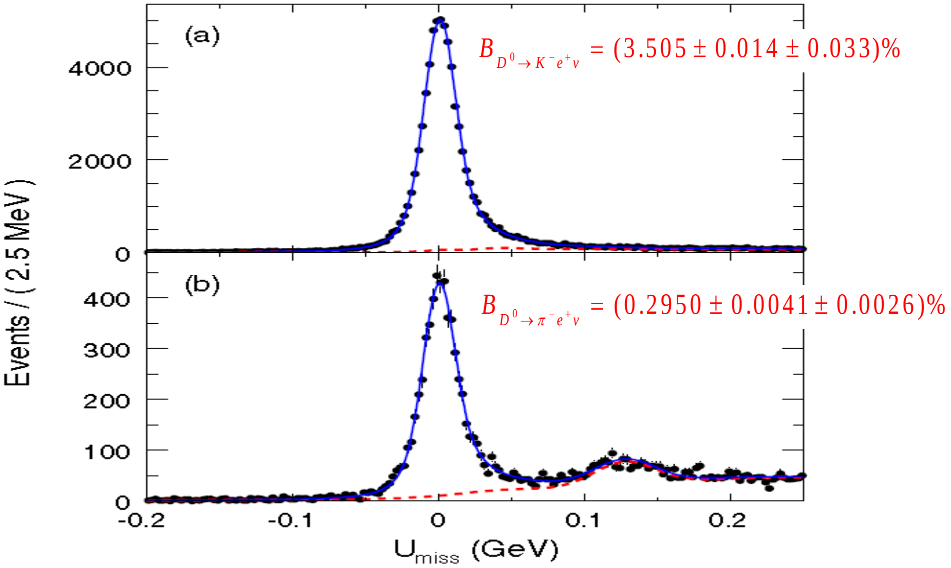
- **Form factors $f_+^{D \rightarrow K(\pi)}(0)$ with input $|V_{cd(s)}|^{\text{CKMfitter}}$**
  - **Single pole form**
    $$f_+(q^2) = \frac{f_+(0)}{1 - \frac{q^2}{M_{\text{pole}}^2}}$$
  - **Modified pole model**
    $$f_+(q^2) = \frac{f_+(0)}{(1 - \frac{q^2}{M_{\text{pole}}^2})(1 - \alpha \frac{q^2}{M_{\text{pole}}^2})}$$
  - **ISGW2 model**
    $$f_+(q^2) = f_+(q_{\text{max}}^2) \left(1 + \frac{r_{\text{ISGW2}}^2}{12} (q_{\text{max}}^2 - q^2)\right)^{-2}$$
  - **Series expansion model**
    $$f_+(t) = \frac{1}{P(t)\Phi(t, t_0)} a_0(t_0) \left(1 + \sum_{k=1}^{\infty} r_k(t_0)[z(t, t_0)]^k\right)$$
- **CKM matrix element $|V_{cs(d)}|$ with input $f_+^{\text{LQCD}, D \rightarrow K(\pi)}(0)$**

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



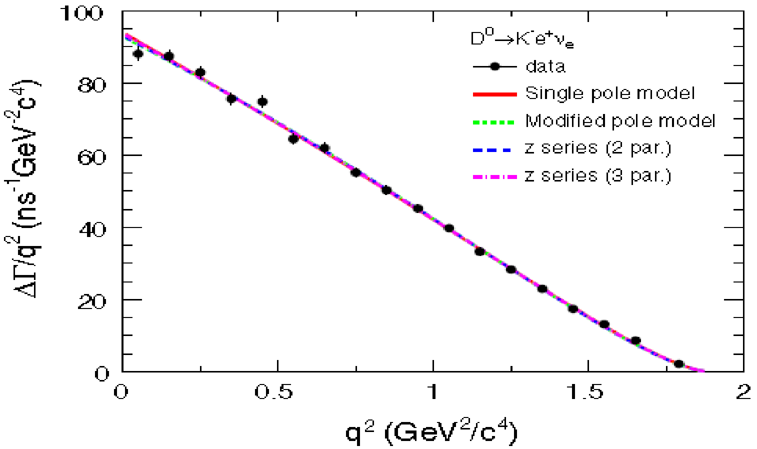
$N_{\bar{D}^0_{\rm tag}} = (279.33 \pm 0.37) \times 10^4$

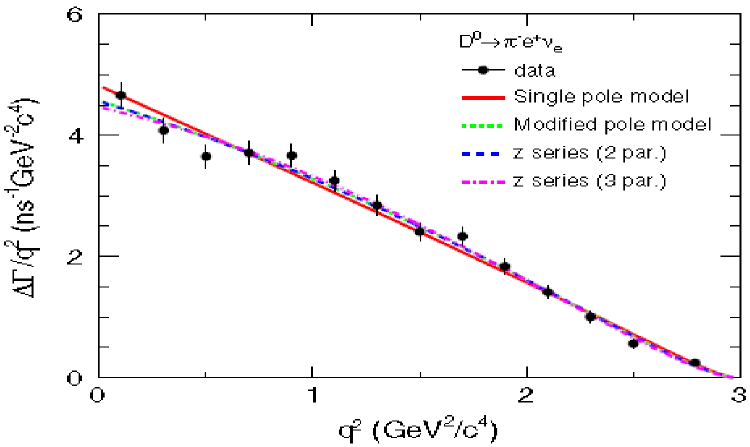
**PRD92(2015)072012**



$B_{D^0 \to K^- e^+ \nu} = (3.505 \pm 0.014 \pm 0.033)\%$

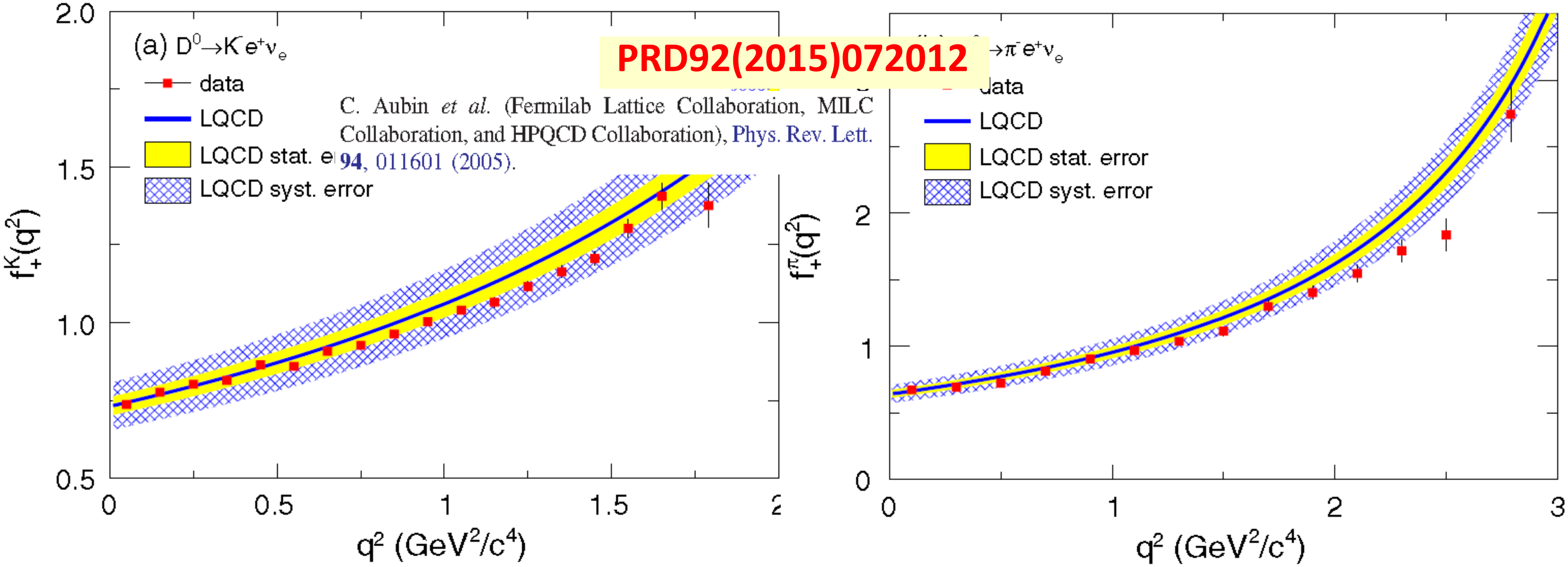
$B_{D^0 \to \pi^- e^+ \nu} = (0.2950 \pm 0.0041 \pm 0.0026)\%$





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

# Calibration of LQCD

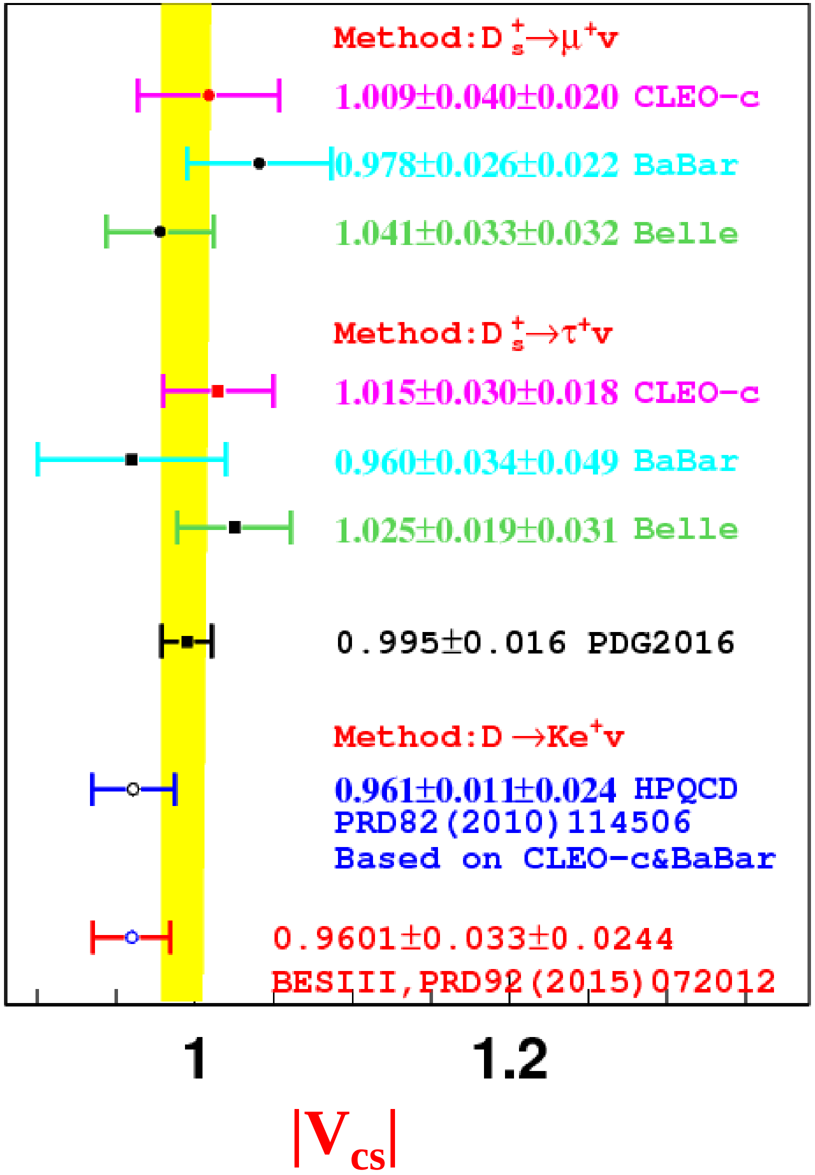


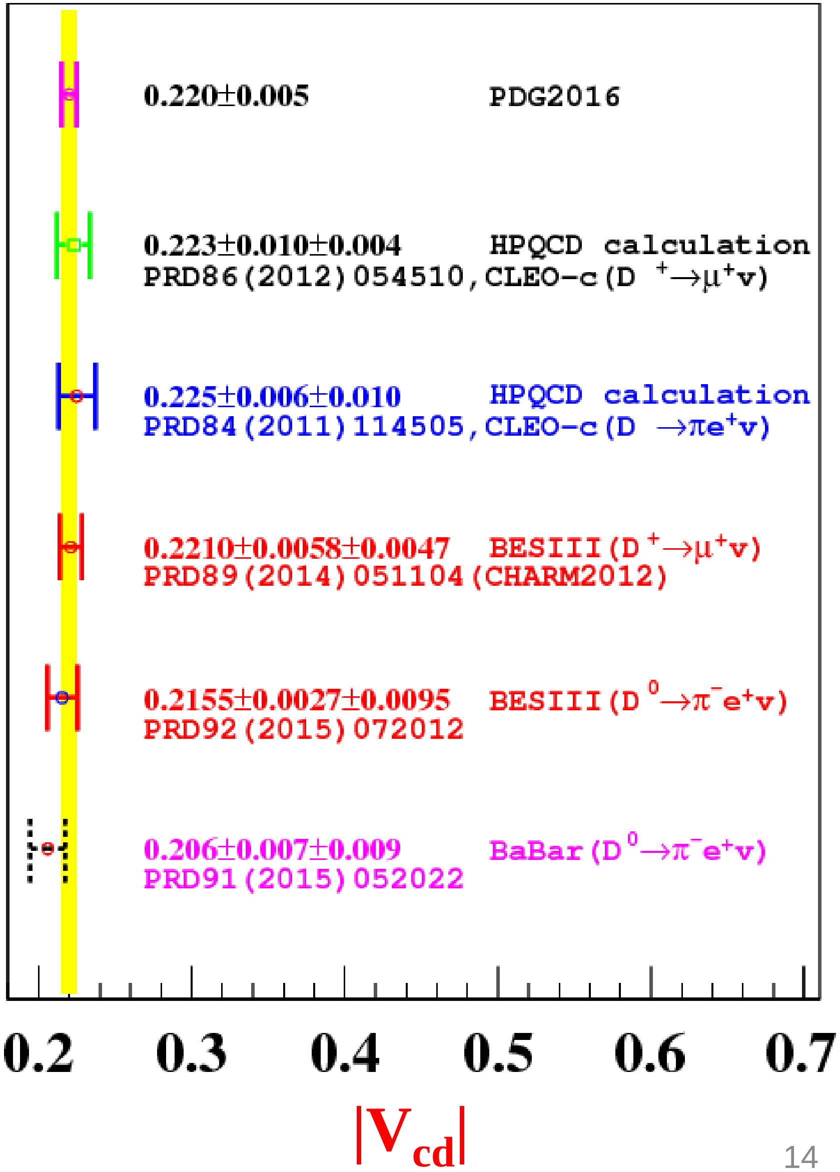
**PRD92(2015)072012**

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

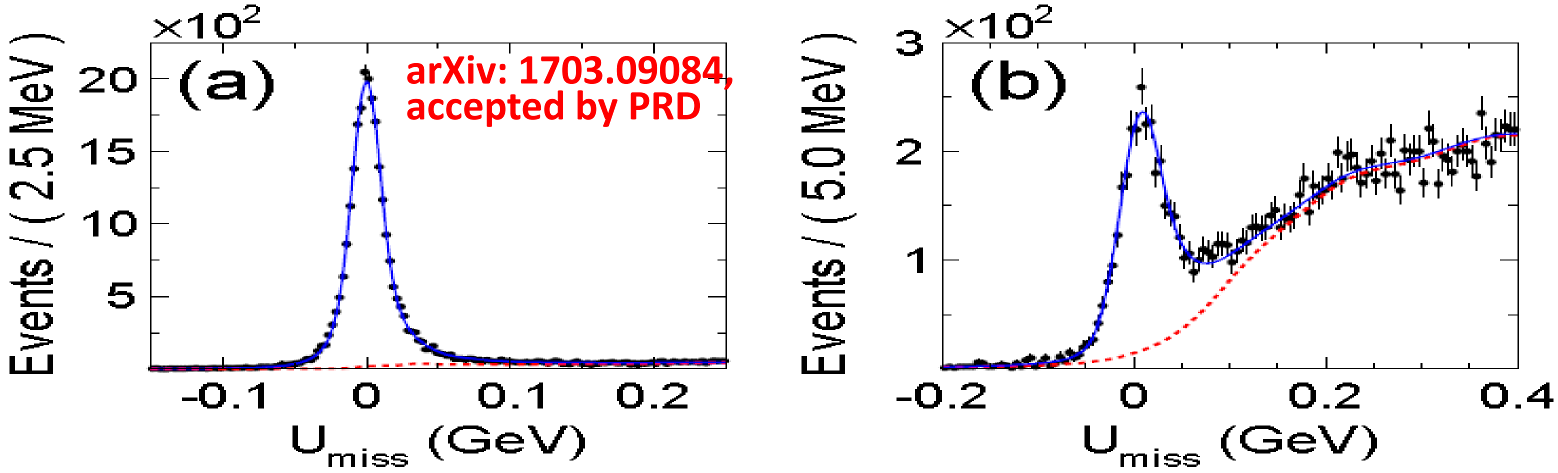
| | | $D^0 \to K^- e^+ v$ | | $D^0 \to \pi^- e^+ v$ |
|---|---|---|---|---|
| **Simple Pole** | $f_K^+(0)\|V_{cs}\|$ | 0.7209±0.0022±0.0033 | $f_\pi^+(0)\|V_{cd}\|$ | 0.1475±0.0014±0.0005 |
| | $M_{pole}$ | 1.9207±0.0103±0.0069 | $M_{pole}$ | 1.9114±0.0118±0.0038 |
| **Mod. Pole** | $f_K^+(0)\|V_{cs}\|$ | 0.7163±0.0024±0.0034 | $f_\pi^+(0)\|V_{cd}\|$ | 0.1437±0.0017±0.0008 |
| | $\alpha$ | 0.3088±0.0195±0.0129 | $\alpha$ | 0.2794±0.0345±0.0113 |
| **Series.2.Par** | $f_K^+(0)\|V_{cs}\|$ | 0.7172±0.0025±0.0035 | $f_\pi^+(0)\|V_{cd}\|$ | 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** | $f_K^+(0)\|V_{cs}\|$ | 0.7196±0.0035±0.0041 | $f_\pi^+(0)\|V_{cd}\|$ | 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 |

# Comparison of $|V_{cs(d)}|$





# Analysis of $D^+ \to \bar{K}^0(\pi^0)\, e^+\nu$



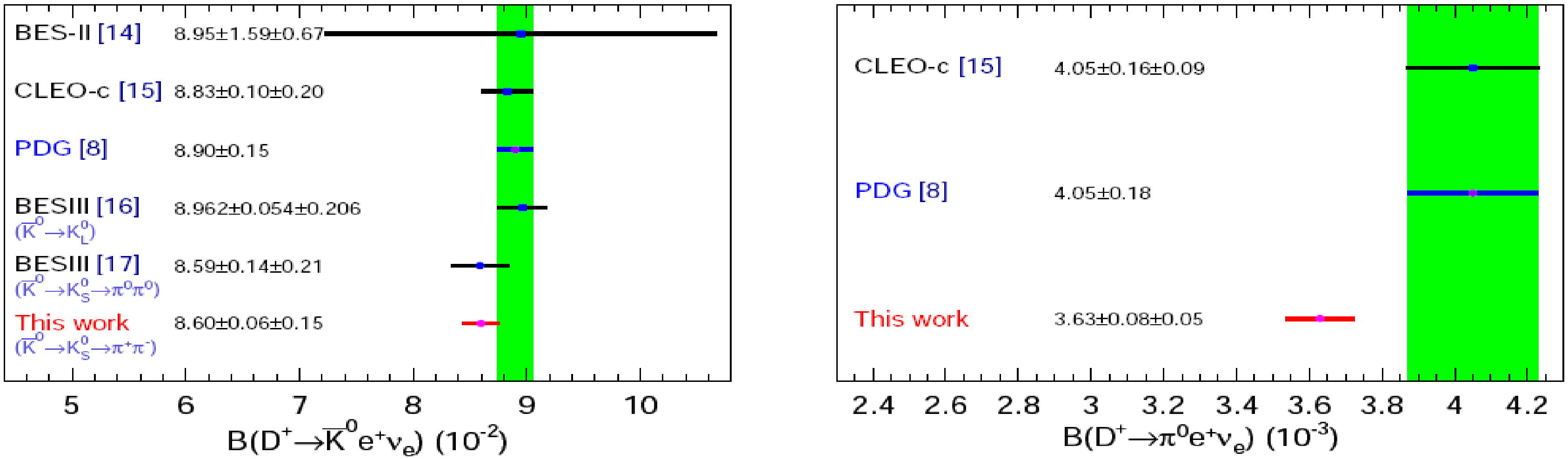
**arXiv: 1703.09084, accepted by PRD**

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

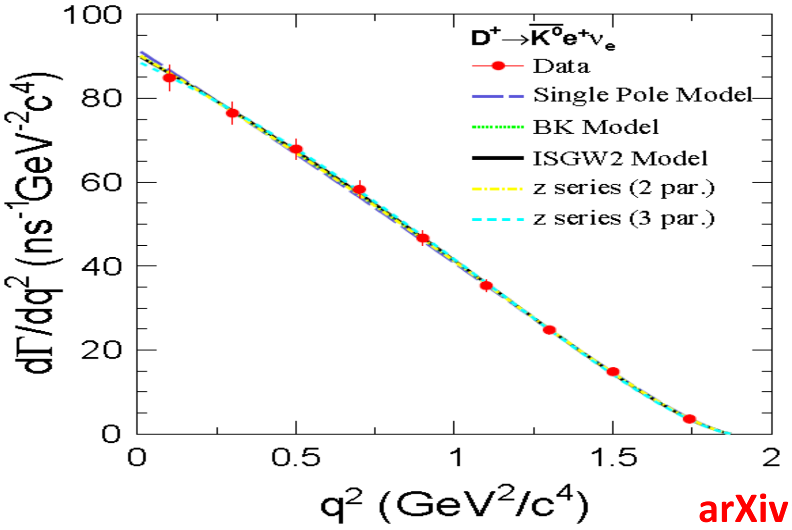
$$B[D^+ \to \pi^0 e^+ \nu] = (3.631 \pm 0.075 \pm 0.051) \times 10^{-3}$$

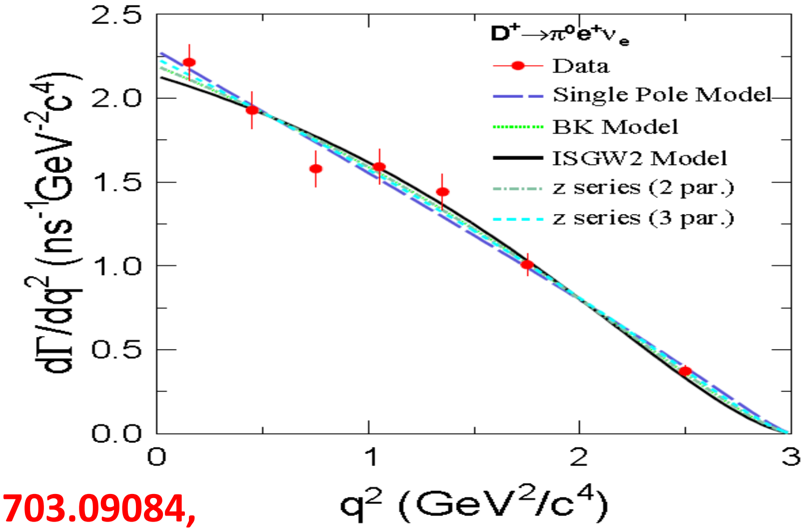
$$\frac{\Gamma[D^0 \to K^- e^+ \nu]}{\Gamma[D^+ \to \bar{K}^0 e^+ \nu]} = 1.03 \pm 0.01 \pm 0.02$$

$$\frac{\Gamma[D^0 \to \pi^- e^+ \nu]}{2\Gamma[D^+ \to \pi^0 e^+ \nu]} = 1.03 \pm 0.03 \pm 0.02$$

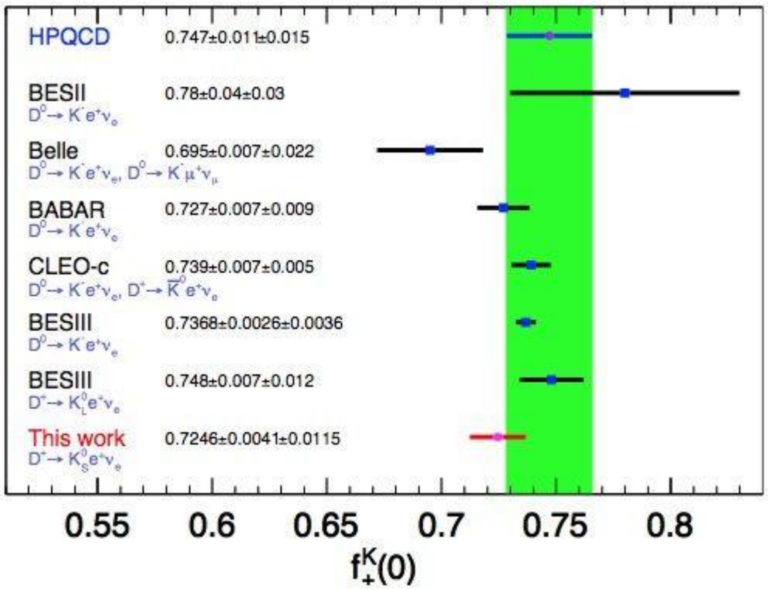


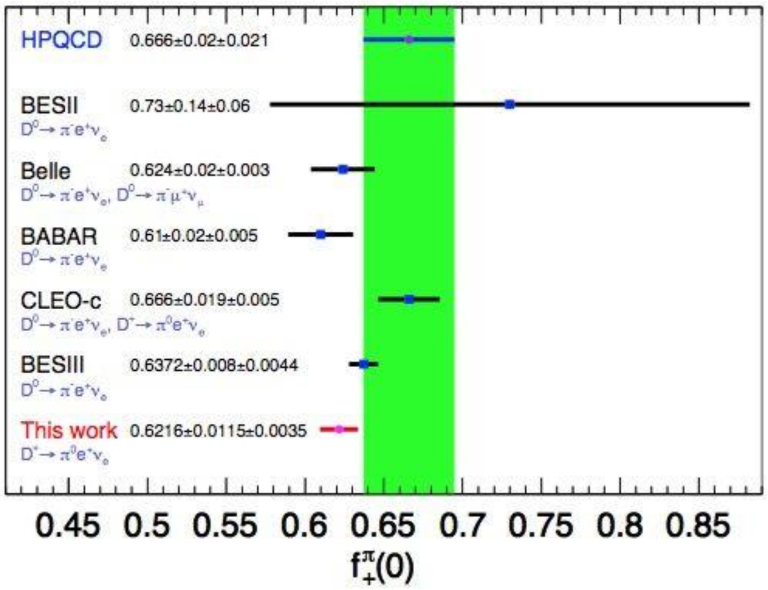
# Comparisons of FFs by $D^+ \to \bar{K}^0(\pi^0)e^+v$





**arXiv: 1703.09084, accepted by PRD**





# Lepton universality in $D^{0(+)} \longrightarrow \pi^{-(0)} l^+ v$

- **Lepton universality (LU)**

$$R_{\mathrm{LU}}^{0(+)} = \frac{B(D^{0(+)} \to \pi^{-(0)} \mu^+ v)}{B(D^{0(+)} \to \pi^{-(0)} e^+ v)} \sim 0.97$$

**Expectations based on ZPC46 (1990)93, PRD69 (2004)074025, PLB633(2006)61 and PDG16**

**BFs on PDG16:**

$$R_{\mathrm{LU}}^{0} = 0.82 \pm 0.08 \quad (\sim 2.0\sigma)$$

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

**Large error in B[$D^0 \to \pi^- \mu^+ v$] and no measure of B[$D^+ \to \pi^0 \mu^+ v$]. Precision measurements are desired**

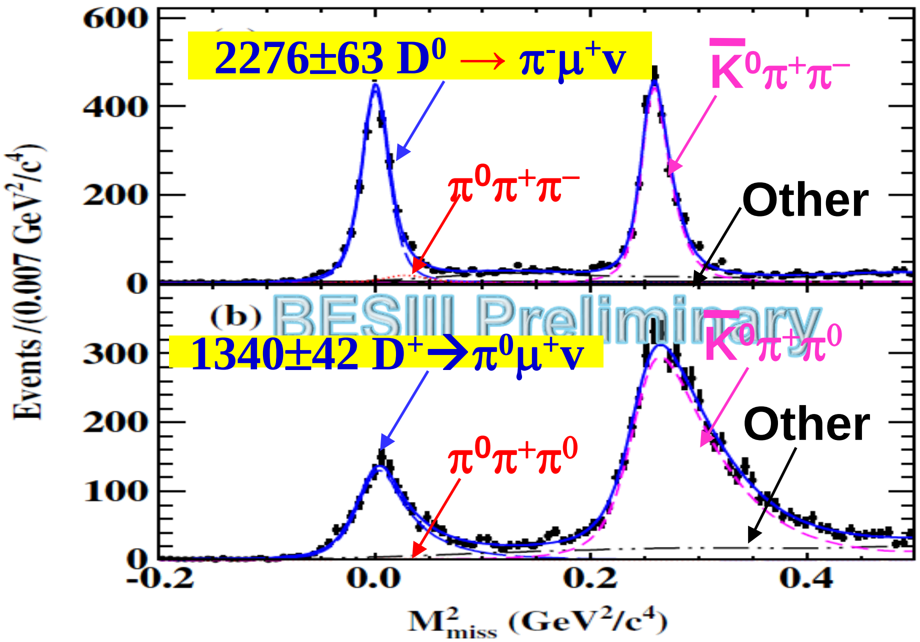
- **Isospin symmetry (IS)**

$$R_{\mathrm{IS}}^{\ell} = \frac{\Gamma(D^0 \to \pi^- \ell^+ v)}{2\Gamma(D^+ \to \pi^0 \ell^+ v)} \sim 1$$

**PDG16:** $R_{\mathrm{IS}}^{e} = 0.911 \pm 0.043 \quad (2.1\sigma)$

**BESIII:** $R_{\mathrm{IS}}^{e} = 1.03 \pm 0.03 \pm 0.02$

**With 3(6) dominant $D^{0(-)}$ single tag**



**BFs:** $B(D^0 \to \pi^- \mu^+ \nu) = (0.267 \pm 0.007 \pm 0.007)\%$

**agrees with PDG and with better precision**

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

**measured for the first time**

**LU:** $R_{\mathrm{LU}}^{0} = 0.918 \pm 0.036$ $R_{\mathrm{LU}}^{+} = 0.921 \pm 0.045$

**agree with expectation in 1.5(1.1) σ**

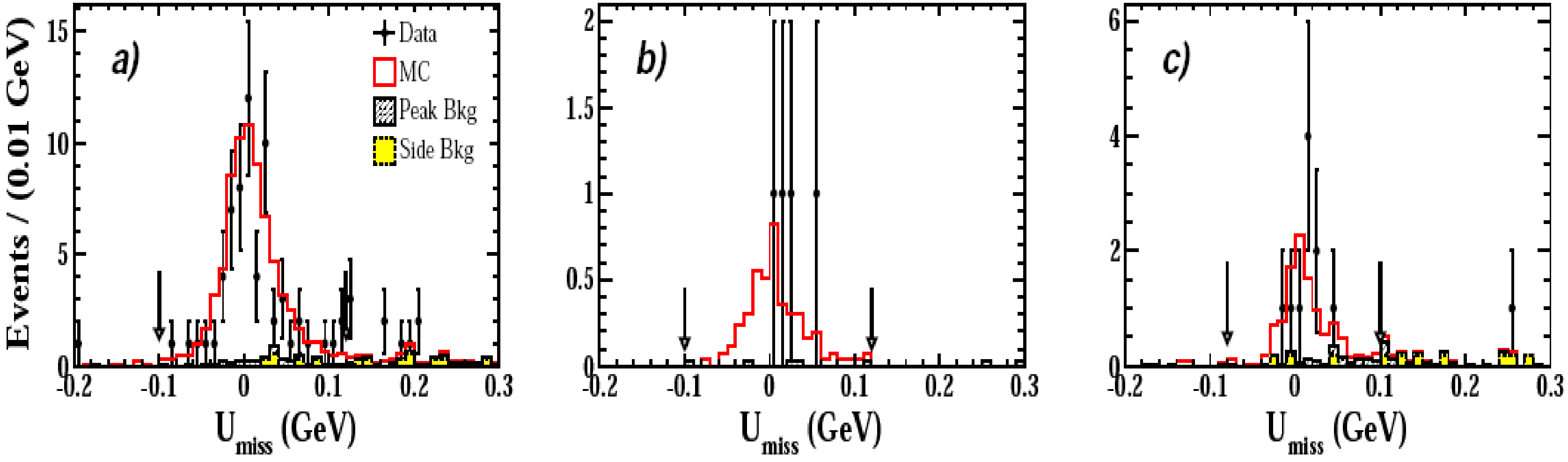
**IS:** $R_{\mathrm{IS}}^{\mu} = 0.990 \pm 0.054$

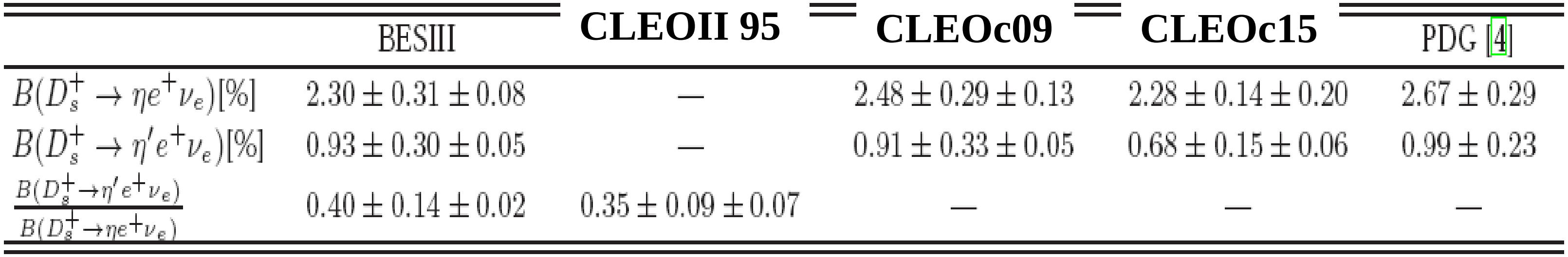
**agree with IS prediction within uncertainty**

# Measurements of BFs of $D_s^+ \to \eta^{(')} e^+ \nu$

- 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

**PRD94(2016)112003**





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

# Search for $D^{0(+)} \to a_0(980)^{-(0)} e^+ \nu$

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

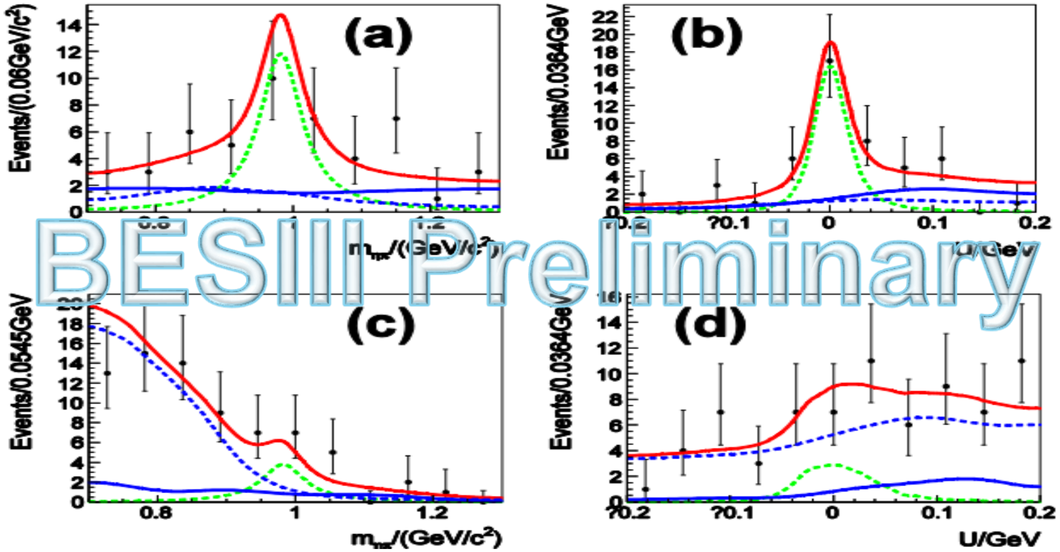
- With chiral unitarity approach in the coupled channels, BF is predicted to be order of $5(6)\times10^{-5}$ for $D^{0(+)}$ decays

- 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

**With 3(6) dominant $D^{0(-)}$ single tag**



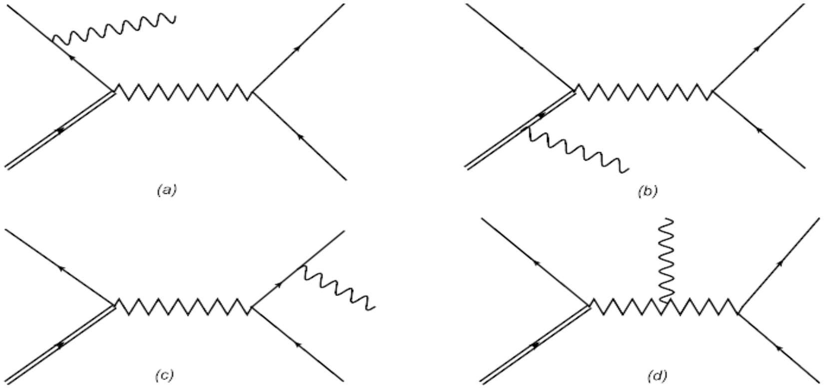
- $B(D^0 \to a_0(980)^- e^+ \nu_e) \times B(a_0(980)^- \to \eta\pi^-)$
  $= (1.12^{+0.31}_{-0.28}(stat) \pm 0.10(syst)) \times 10^{-4}$ $5.9\sigma$

- $B(D^+ \to a_0(980)^0 e^+ \nu_e) \times B(a_0(980)^0 \to \eta\pi^0)$
  $= (1.47^{+0.73}_{-0.59}(stat) \pm 0.14(syst)) \times 10^{-4}$ $3.0\sigma$

- $B(D^+ \to a_0(980)^0 e^+ \nu_e) \times B(a_0(980)^0 \to \eta\pi^0)$
  $< 2.7 \times 10^{-4}$ @ 90% C.L.

# Search for $D^+ \to \gamma e^+ \nu$

**J.C. Yang and M.Z. Yang, NPB889,778(2014)**



Tree level amplitudes

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

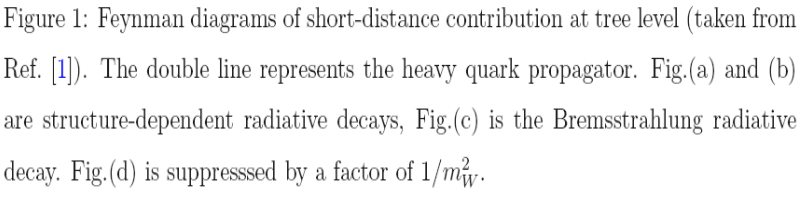


Figure 1: Feynman diagrams of short-distance contribution at tree level (taken from Ref. [1]). The double line represents the heavy quark propagator. Fig.(a) and (b) are structure-dependent radiative decays, Fig.(c) is the Bremsstrahlung radiative decay. Fig.(d) is suppresssed by a factor of $1/m_W^2$.

**With 6 dominant D⁻ single tag**

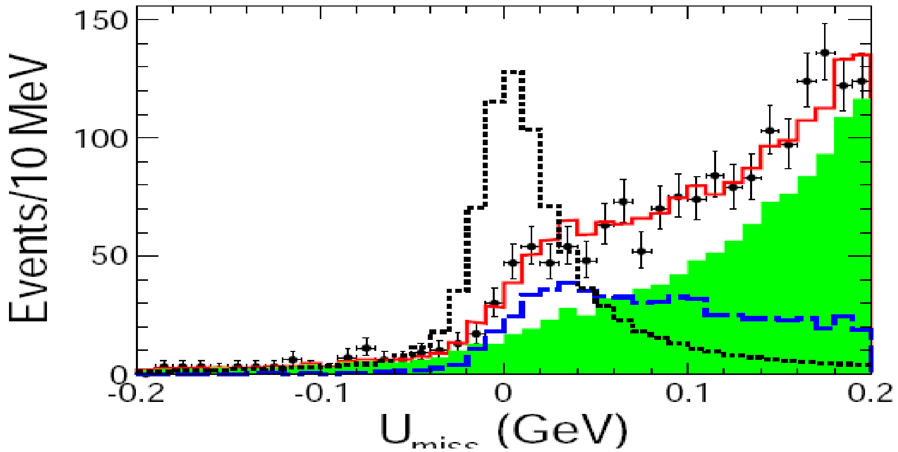
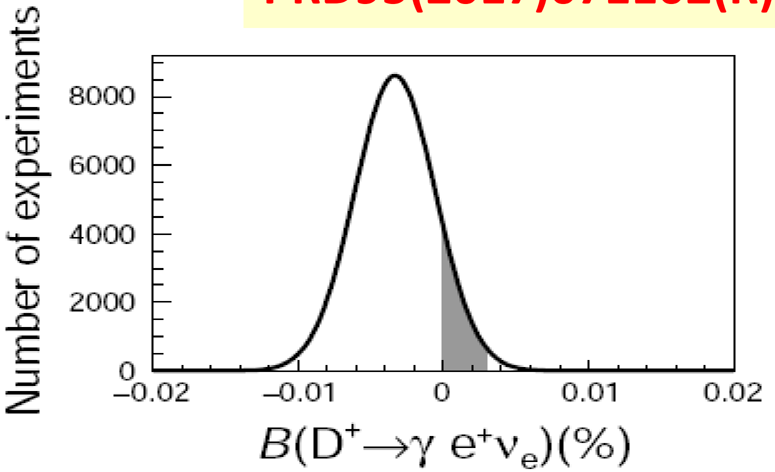


FIG. 2. (color online) The $U_{\rm miss}$ distribution. Dots with error bars are data, the red solid-line histogram shows the overall fit curve, the blue dash-line histogram shows the background $D^+ \to \pi^0 e^+ \nu_e$, and the green shaded histogram includes all other background. The black dotted line shows the signal MC simulation normalized to the branching fraction $\mathcal{B}(D^+ \to \gamma e^+ \nu_e) = 100 \times 10^{-5}$.

**PRD95(2017)071102(R)**

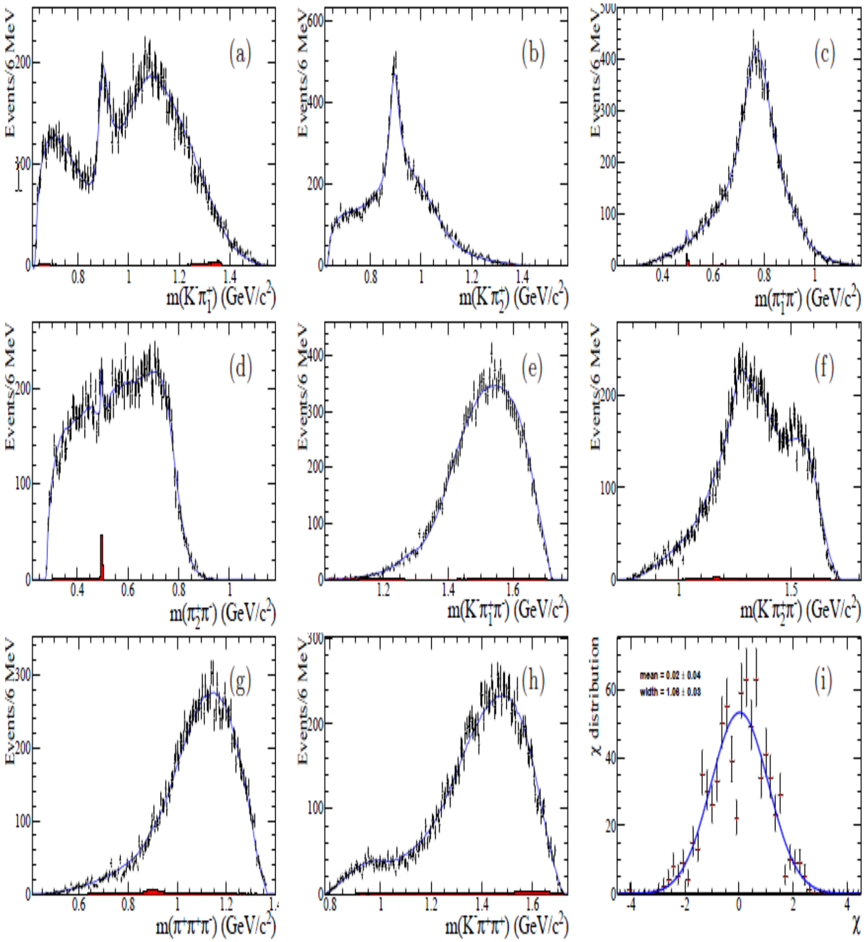


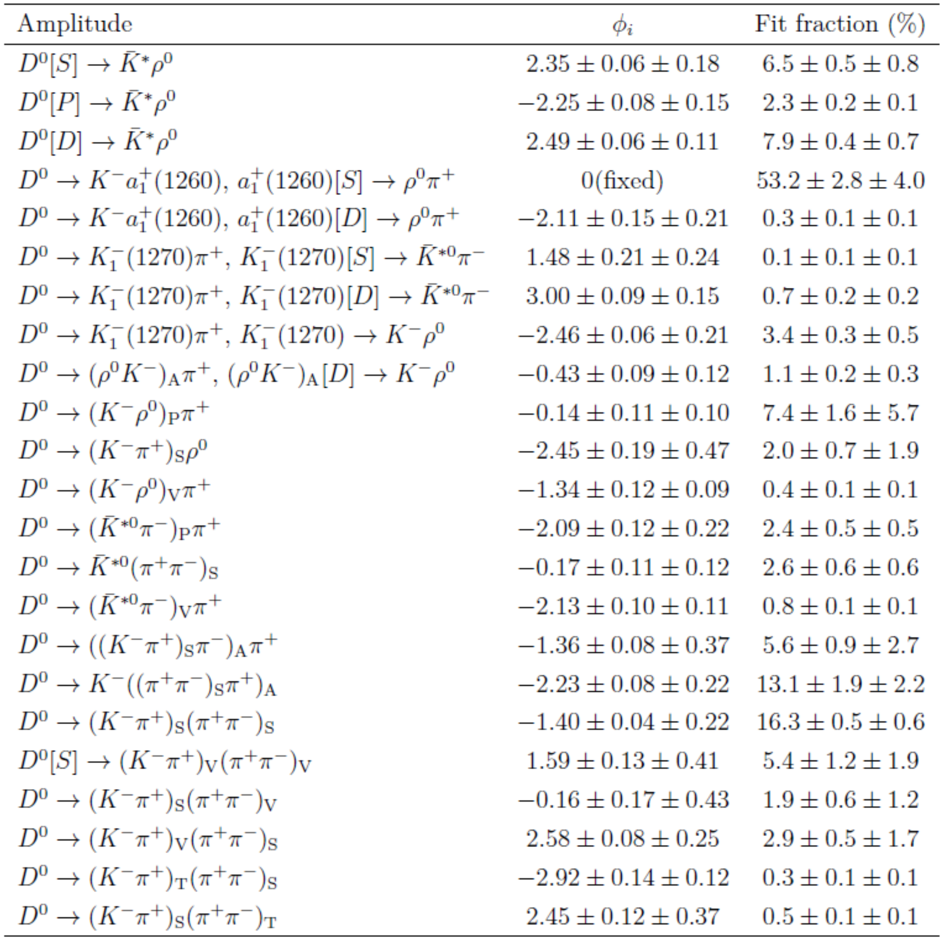
**$B[D^+ \to \gamma e^+ \nu]|_{E\gamma > 10\ \mathrm{MeV}} < 3.0 \times 10^{-4}$ @90%C.L.**

# Amplitude analysis of $D^0 \to K^-\pi^+\pi^+\pi^-$

## Help to determine the absolute BF, strong phase, benefit $\gamma/\phi_3$

## Previous analyses only from MarkIII and E691



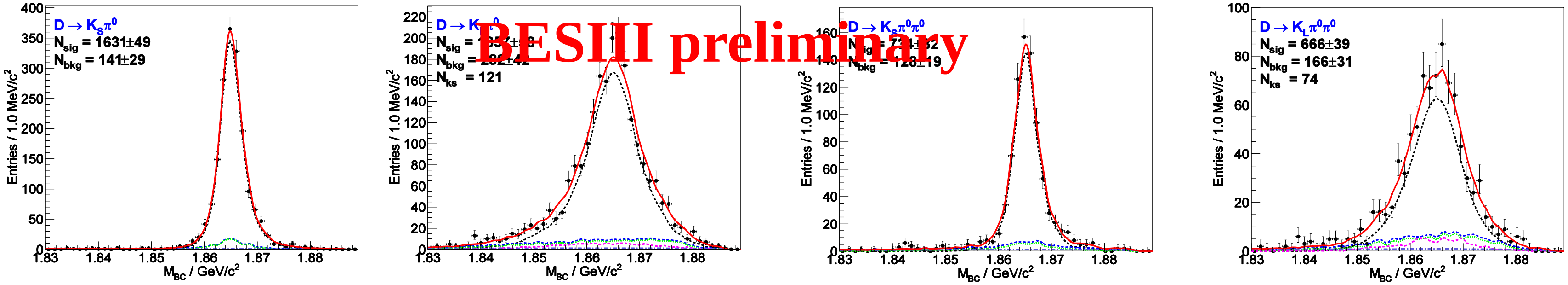


| Amplitude | $\phi_i$ | Fit fraction (%) |
|---|---|---|
| $D^0[S] \to \bar{K}^*\rho^0$ | $2.35 \pm 0.06 \pm 0.18$ | $6.5 \pm 0.5 \pm 0.8$ |
| $D^0[P] \to \bar{K}^*\rho^0$ | $-2.25 \pm 0.08 \pm 0.15$ | $2.3 \pm 0.2 \pm 0.1$ |
| $D^0[D] \to \bar{K}^*\rho^0$ | $2.49 \pm 0.06 \pm 0.11$ | $7.9 \pm 0.4 \pm 0.7$ |
| $D^0 \to K^-a_1^+(1260)$, $a_1^+(1260)[S] \to \rho^0\pi^+$ | 0(fixed) | $53.2 \pm 2.8 \pm 4.0$ |
| $D^0 \to K^-a_1^+(1260)$, $a_1^+(1260)[D] \to \rho^0\pi^+$ | $-2.11 \pm 0.15 \pm 0.21$ | $0.3 \pm 0.1 \pm 0.1$ |
| $D^0 \to K_1^-(1270)\pi^+$, $K_1^-(1270)[S] \to \bar{K}^{*0}\pi^-$ | $1.48 \pm 0.21 \pm 0.24$ | $0.1 \pm 0.1 \pm 0.1$ |
| $D^0 \to K_1^-(1270)\pi^+$, $K_1^-(1270)[D] \to \bar{K}^{*0}\pi^-$ | $3.00 \pm 0.09 \pm 0.15$ | $0.7 \pm 0.2 \pm 0.2$ |
| $D^0 \to K_1^-(1270)\pi^+$, $K_1^-(1270) \to K^-\rho^0$ | $-2.46 \pm 0.06 \pm 0.21$ | $3.4 \pm 0.3 \pm 0.5$ |
| $D^0 \to (\rho^0K^-)_A\pi^+$, $(\rho^0K^-)_A[D] \to K^-\rho^0$ | $-0.43 \pm 0.09 \pm 0.12$ | $1.1 \pm 0.2 \pm 0.3$ |
| $D^0 \to (K^-\rho^0)_P\pi^+$ | $-0.14 \pm 0.11 \pm 0.10$ | $7.4 \pm 1.6 \pm 5.7$ |
| $D^0 \to (K^-\pi^+)_S\rho^0$ | $-2.45 \pm 0.19 \pm 0.47$ | $2.0 \pm 0.7 \pm 1.9$ |
| $D^0 \to (K^-\rho^0)_V\pi^+$ | $-1.34 \pm 0.12 \pm 0.09$ | $0.4 \pm 0.1 \pm 0.1$ |
| $D^0 \to (\bar{K}^{*0}\pi^-)_P\pi^+$ | $-2.09 \pm 0.12 \pm 0.22$ | $2.4 \pm 0.5 \pm 0.5$ |
| $D^0 \to \bar{K}^{*0}(\pi^+\pi^-)_S$ | $-0.17 \pm 0.11 \pm 0.12$ | $2.6 \pm 0.6 \pm 0.6$ |
| $D^0 \to (\bar{K}^{*0}\pi^-)_V\pi^+$ | $-2.13 \pm 0.10 \pm 0.11$ | $0.8 \pm 0.1 \pm 0.1$ |
| $D^0 \to ((K^-\pi^+)_S\pi^-)_A\pi^+$ | $-1.36 \pm 0.08 \pm 0.37$ | $5.6 \pm 0.9 \pm 2.7$ |
| $D^0 \to K^-((\pi^+\pi^-)_S\pi^+)_A$ | $-2.23 \pm 0.08 \pm 0.22$ | $13.1 \pm 1.9 \pm 2.2$ |
| $D^0 \to (K^-\pi^+)_S(\pi^+\pi^-)_S$ | $-1.40 \pm 0.04 \pm 0.22$ | $16.3 \pm 0.5 \pm 0.6$ |
| $D^0[S] \to (K^-\pi^+)_V(\pi^+\pi^-)_V$ | $1.59 \pm 0.13 \pm 0.41$ | $5.4 \pm 1.2 \pm 1.9$ |
| $D^0 \to (K^-\pi^+)_S(\pi^+\pi^-)_V$ | $-0.16 \pm 0.17 \pm 0.43$ | $1.9 \pm 0.6 \pm 1.2$ |
| $D^0 \to (K^-\pi^+)_V(\pi^+\pi^-)_S$ | $2.58 \pm 0.08 \pm 0.25$ | $2.9 \pm 0.5 \pm 1.7$ |
| $D^0 \to (K^-\pi^+)_T(\pi^+\pi^-)_S$ | $-2.92 \pm 0.14 \pm 0.12$ | $0.3 \pm 0.1 \pm 0.1$ |
| $D^0 \to (K^-\pi^+)_S(\pi^+\pi^-)_T$ | $2.45 \pm 0.12 \pm 0.37$ | $0.5 \pm 0.1 \pm 0.1$ |

**PRD95(2017)072010**

# Absolute BFs and $y_{CP}$ of $D^0 \to K_{S/L}\pi^0(\pi^0)$

- Two dimensional fits to $M_{BC}$(tag) versus $M_{BC}$(signal)
- Projections of DT evens on the $M_{BC}$(sig) vs. $K\pi$ (for example)



BESIII preliminary

**Branching fractions and asymmetries**

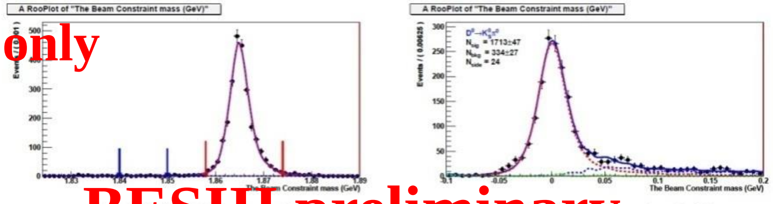
Statistical only

$$R(D \to K_{S,L} + \pi's) = \frac{Br(D \to K_S\pi's) - Br(D \to K_L\pi's)}{Br(D \to K_S\pi's) + Br(D \to K_L\pi's)}$$

Table 10: Decay rates and the asymmetries of $D \to K^0_{S,L}\pi^0$ and $D \to K^0_{S,L}\pi^0\pi^0$.

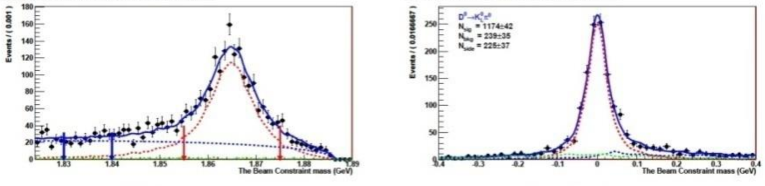
| $D \to K^0_{S,L}\pi^0$ | | | |
|---|---|---|---|
| | $Br_{K_S\pi^0}(\%)$ | $Br_{K_L\pi^0}(\%)$ | $R(D \to K_{S,L}\pi^0)$ |
| $K\pi$ | 1.208±0.041 | 1.061±0.038 | 0.0646±0.0245 |
| $K3\pi$ | 1.212±0.037 | 0.985±0.036 | 0.1035±0.0237 |
| $K\pi\pi^0$ | 1.251±0.028 | 0.953±0.029 | 0.1351±0.0186 |
| All | 1.230±0.020 | 0.991±0.019 | 0.1077±0.0125 |

| $D \to K^0_{S,L}\pi^0\pi^0$ | | | |
|---|---|---|---|
| | $Br_{K_S2\pi^0}(\%)$ | $Br_{K_L2\pi^0}(\%)$ | $R(D \to K_{S,L}2\pi^0)$ |
| $K\pi$ | 1.024±0.049 | 1.299±0.080 | -0.1183±0.0385 |
| $K3\pi$ | 0.887±0.043 | 1.097±0.073 | -0.1060±0.0409 |
| $K\pi\pi^0$ | 1.010±0.036 | 1.158±0.060 | -0.0681±0.0313 |
| All | 0.975±0.024 | 1.175±0.040 | -0.0929±0.0209 |



BESIII preliminary

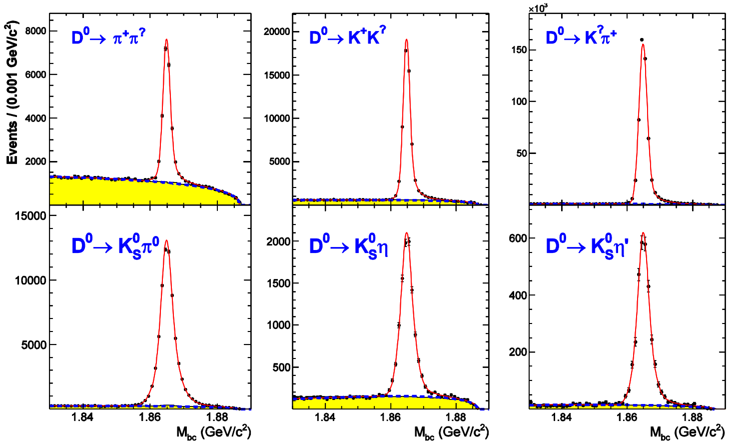
(a) $K_S^0\pi^0$ VS $Ke\nu$ tag-side (b) $K_S^0\pi^0$ VS $Ke\nu$ signal-side

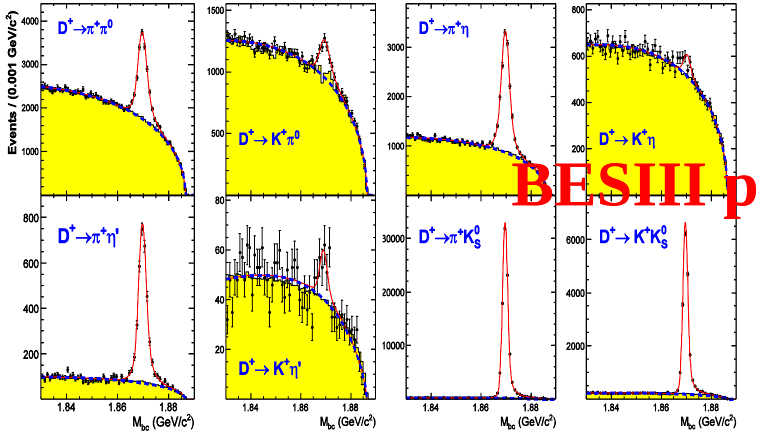


(c) $K_L^0\pi^0$ VS $Ke\nu$ tag-side (d) $K_L^0\pi^0$ VS $Ke\nu$ signal-side

- $y_{CP}$ (($K_S\pi^0$, $K_L\pi^0$) vs. $Ke\nu$) = (0.98±2.43)%

# BF measurements of some $D^{0(+)} \to PP$





BESIII preliminary

- The study of the hadronic decays of charmed *D* mesons is of great significance in the study of the strong and weak interactions in *D* decays.
- The analysis on $D \to PP$ modes will provide materials for the study of SU(3) breaking effect[1] . And the observation of CP violation in D decay is commonly believed to be indications of new physics.
- $D^0 \to K^-\pi^+$ is an important normalization mode.
- Most of the D decays have been studied by CLEO in 2010[2] , other measurements come from Belle[3] , BaBar[4] and CDF[5] , etc.
- Some of the branching fractions (BFs) are not well established. With the 2.93 fb$^{-1}$ data taken at 3.773 GeV within BESIII , the results will help to improve these measurements.

| Mode | $N_{\text{signal}}^{\text{net}}$ | $\varepsilon$ (%) | $\mathcal{B}\pm$(stat)$\pm$(sys) | $\mathcal{B}_{\text{PDG}}$ |
|---|---|---|---|---|
| $\pi^+\pi^-$ | $21105 \pm 249$ | $66.03 \pm 0.25$ | $(1.505 \pm 0.018 \pm 0.031) \times 10^{-3}$ | $(1.421 \pm 0.025) \times 10^{-3}$ |
| $K^+K^-$ | $55433 \pm 273$ | $62.82 \pm 0.32$ | $(4.229 \pm 0.020 \pm 0.087) \times 10^{-3}$ | $(4.01 \pm 0.07) \times 10^{-3}$ |
| $K^-\pi^+$ | $537745 \pm 767$ | $64.98 \pm 0.09$ | $(3.896 \pm 0.006 \pm 0.073)$ % | $(3.93 \pm 0.04)$ % |
| $K_S^0\pi^0$ | $66539 \pm 302$ | $38.06 \pm 0.17$ | $(1.236 \pm 0.006 \pm 0.032)$ % | $(1.20 \pm 0.04)$ % |
| $K_S^0\eta$ | $9532 \pm 126$ | $31.96 \pm 0.14$ | $(5.149 \pm 0.068 \pm 0.134) \times 10^{-3}$ | $(4.85 \pm 0.30) \times 10^{-3}$ |
| $K_S^0\eta'$ | $3007 \pm 61$ | $12.66 \pm 0.08$ | $(9.562 \pm 0.197 \pm 0.379) \times 10^{-3}$ | $(9.5 \pm 0.5) \times 10^{-3}$ |
| $\pi^0\pi^+$ | $10108 \pm 267$ | $48.98 \pm 0.34$ | $(1.259 \pm 0.033 \pm 0.025) \times 10^{-3}$ | $(1.24 \pm 0.06) \times 10^{-3}$ |
| $\pi^0K^+$ | $1834 \pm 168$ | $51.52 \pm 0.42$ | $(2.171 \pm 0.198 \pm 0.060) \times 10^{-4}$ | $(1.89 \pm 0.25) \times 10^{-4}$ |
| $\eta\pi^+$ | $11636 \pm 215$ | $46.96 \pm 0.25$ | $(3.790 \pm 0.070 \pm 0.075) \times 10^{-3}$ | $(3.66 \pm 0.22) \times 10^{-3}$ |
| $\eta K^+$ | $439 \pm 72$ | $48.21 \pm 0.31$ | $(1.393 \pm 0.228 \pm 0.124) \times 10^{-4}$ | $(1.12 \pm 0.18) \times 10^{-4}$ |
| $\eta'\pi^+$ | $3088 \pm 83$ | $21.49 \pm 0.18$ | $(5.122 \pm 0.140 \pm 0.210) \times 10^{-3}$ | $(4.84 \pm 0.31) \times 10^{-3}$ |
| $\eta'K^+$ | $87 \pm 25$ | $22.39 \pm 0.22$ | $(1.377 \pm 0.428 \pm 0.202) \times 10^{-4}$ | $(1.83 \pm 0.23) \times 10^{-4}$ |
| $K_S^0\pi^+$ | $93884 \pm 352$ | $51.38 \pm 0.18$ | $(1.591 \pm 0.006 \pm 0.033) \times 10^{-2}$ | $(1.53 \pm 0.06) \times 10^{-2}$ |
| $K_S^0K^+$ | $17704 \pm 151$ | $48.45 \pm 0.14$ | $(3.183 \pm 0.028 \pm 0.065) \times 10^{-3}$ | $(2.95 \pm 0.15) \times 10^{-3}$ |

$$\mathcal{B} = \frac{N_{net}^{signal}}{2 \cdot N_{D^0\bar{D}^0(D^+D^-)} \cdot \varepsilon}, N_{D^0\bar{D}^0} = \left(10{,}621 \pm 29_{(stat)}\right) \times 10^3, N_{D^+D^-} = \left(8{,}296 \pm 31_{(stat)}\right) \times 10^3$$

quoted from Derrick's talk given at APS2014

The $\mathcal{B}(D^0 \to K^-\pi^+)$ has been corrected by the PDG value of $\mathcal{B}(D^0 \to K^+\pi^-)$ .

For $D^0 \to K_S^0\eta$, $D^+ \to \pi^0\pi^+$, $D^+ \to \eta\pi^+$, $D^+ \to \eta'\pi^+$, $D^+ \to K_S^0\pi^+$ and $D^+ \to K_S^0K^+$, it shows better precision than the present values.

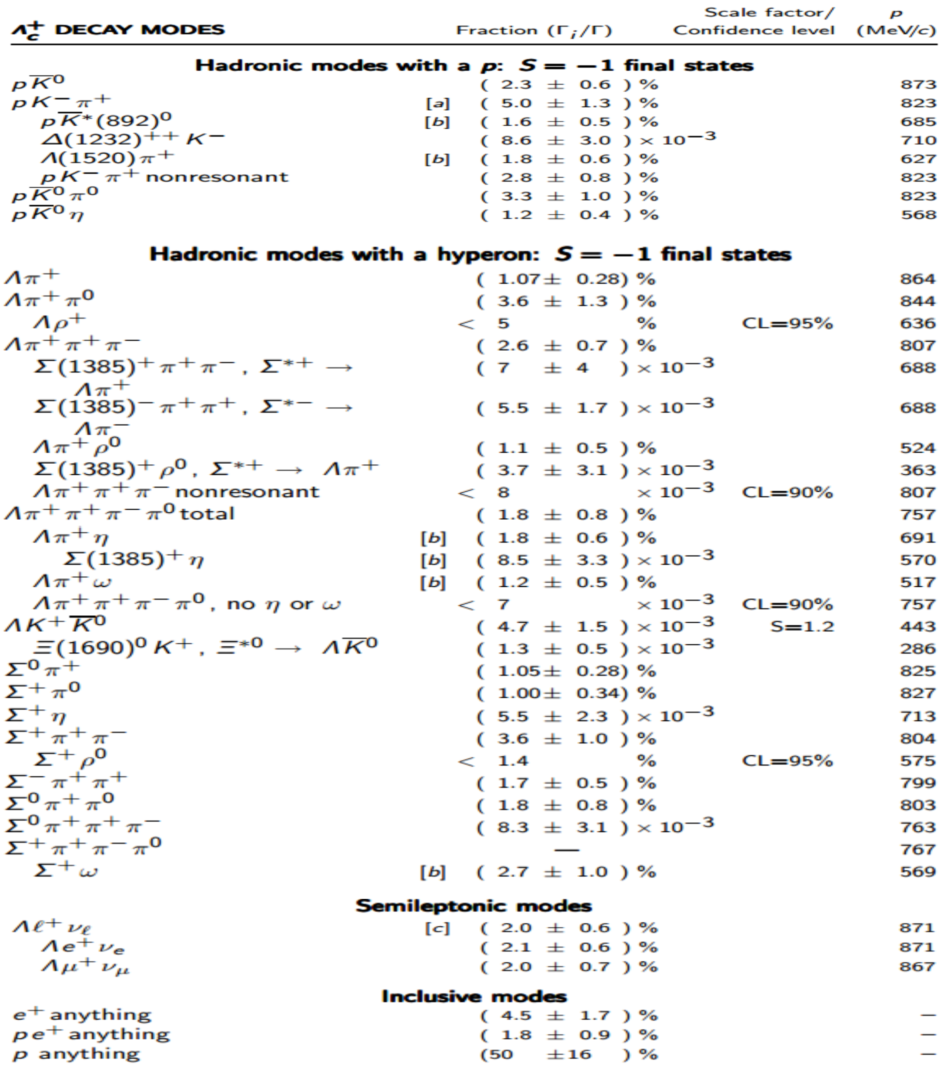
# $\Lambda_c^+$ decays

- $\Lambda_c^+$ was observed in 1979

- **Before 2014, all decays of $\Lambda_c^+$ are measured relative to $\Lambda_c^+ \to pK^-\pi^+$, which suffer large error of 25%, with high energy data. No absolute measurement using data produced at $\Lambda_c^+$ pair threshold**

- **Sum of BFs of known decays $\Lambda_c^+$ is only about 60%**

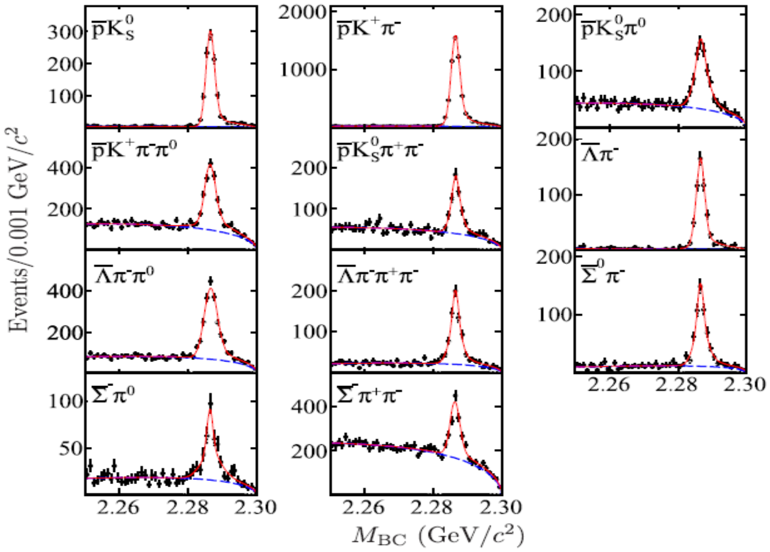
- **In 2014, Belle reported improved measurement of $B[\Lambda_c^+ \to pK^-\pi^+]$, with a precision of ~5%**



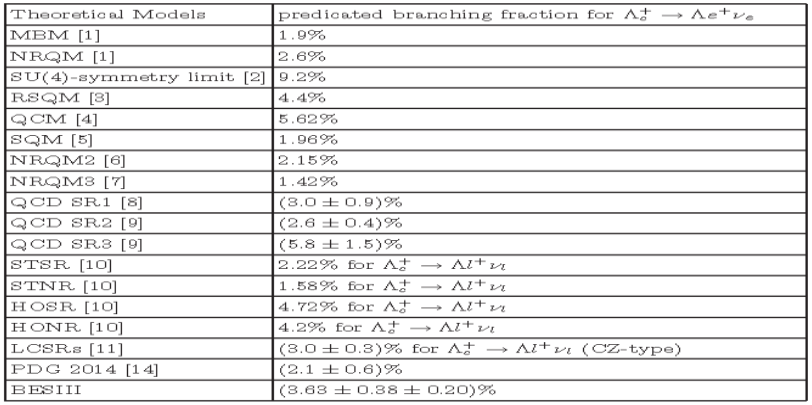
| $\Lambda_c^+$ DECAY MODES | | Fraction ($\Gamma_i/\Gamma$) | Scale factor/ Confidence level | $p$ (MeV/$c$) |
|---|---|---|---|---|
| **Hadronic modes with a $p$: $S = -1$ final states** | | | | |
| $p\overline{K}^0$ | | $(2.3 \pm 0.6)\ \%$ | | 873 |
| $pK^-\pi^+$ | [a] | $(5.0 \pm 1.3)\ \%$ | | 823 |
| $p\overline{K}^*(892)^0$ | [b] | $(1.6 \pm 0.5)\ \%$ | | 685 |
| $\Delta(1232)^{++}K^-$ | | $(8.6 \pm 3.0) \times 10^{-3}$ | | 710 |
| $\Lambda(1520)\pi^+$ | [b] | $(1.8 \pm 0.6)\ \%$ | | 627 |
| $pK^-\pi^+$ nonresonant | | $(2.8 \pm 0.8)\ \%$ | | 823 |
| $p\overline{K}^0\pi^0$ | | $(3.3 \pm 1.0)\ \%$ | | 823 |
| $p\overline{K}^0\eta$ | | $(1.2 \pm 0.4)\ \%$ | | 568 |
| **Hadronic modes with a hyperon: $S = -1$ final states** | | | | |
| $\Lambda\pi^+$ | | $(1.07 \pm 0.28)\ \%$ | | 864 |
| $\Lambda\pi^+\pi^0$ | | $(3.6 \pm 1.3)\ \%$ | | 844 |
| $\Lambda\rho^+$ | | $< 5\ \%$ | CL=95% | 636 |
| $\Lambda\pi^+\pi^+\pi^-$ | | $(2.6 \pm 0.7)\ \%$ | | 807 |
| $\Sigma(1385)^+\pi^+\pi^-$, $\Sigma^{*+} \to \Lambda\pi^+$ | | $(7 \pm 4) \times 10^{-3}$ | | 688 |
| $\Sigma(1385)^-\pi^+\pi^+$, $\Sigma^{*-} \to \Lambda\pi^-$ | | $(5.5 \pm 1.7) \times 10^{-3}$ | | 688 |
| $\Lambda\pi^+\rho^0$ | | $(1.1 \pm 0.5)\ \%$ | | 524 |
| $\Sigma(1385)^+\rho^0$, $\Sigma^{*+} \to \Lambda\pi^+$ | | $(3.7 \pm 3.1) \times 10^{-3}$ | | 363 |
| $\Lambda\pi^+\pi^+\pi^-$ nonresonant | | $< 8 \times 10^{-3}$ | CL=90% | 807 |
| $\Lambda\pi^+\pi^+\pi^-\pi^0$ total | | $(1.8 \pm 0.8)\ \%$ | | 757 |
| $\Lambda\pi^+\eta$ | [b] | $(1.8 \pm 0.6)\ \%$ | | 691 |
| $\Sigma(1385)^+\eta$ | [b] | $(8.5 \pm 3.3) \times 10^{-3}$ | | 570 |
| $\Lambda\pi^+\omega$ | [b] | $(1.2 \pm 0.5)\ \%$ | | 517 |
| $\Lambda\pi^+\pi^+\pi^-\pi^0$, no $\eta$ or $\omega$ | | $< 7 \times 10^{-3}$ | CL=90% | 757 |
| $\Lambda K^+\overline{K}^0$ | | $(4.7 \pm 1.5) \times 10^{-3}$ | S=1.2 | 443 |
| $\Xi(1690)^0K^+$, $\Xi^{*0} \to \Lambda\overline{K}^0$ | | $(1.3 \pm 0.5) \times 10^{-3}$ | | 286 |
| $\Sigma^0\pi^+$ | | $(1.05 \pm 0.28)\ \%$ | | 825 |
| $\Sigma^+\pi^0$ | | $(1.00 \pm 0.34)\ \%$ | | 827 |
| $\Sigma^+\eta$ | | $(5.5 \pm 2.3) \times 10^{-3}$ | | 713 |
| $\Sigma^+\pi^+\pi^-$ | | $(3.6 \pm 1.0)\ \%$ | | 804 |
| $\Sigma^+\rho^0$ | | $< 1.4\ \%$ | CL=95% | 575 |
| $\Sigma^-\pi^+\pi^+$ | | $(1.7 \pm 0.5)\ \%$ | | 799 |
| $\Sigma^0\pi^+\pi^0$ | | $(1.8 \pm 0.8)\ \%$ | | 803 |
| $\Sigma^0\pi^+\pi^+\pi^-$ | | $(8.3 \pm 3.1) \times 10^{-3}$ | | 763 |
| $\Sigma^+\pi^+\pi^-\pi^0$ | | — | | 767 |
| $\Sigma^+\omega$ | [b] | $(2.7 \pm 1.0)\ \%$ | | 569 |
| **Semileptonic modes** | | | | |
| $\Lambda\ell^+\nu_\ell$ | [c] | $(2.0 \pm 0.6)\ \%$ | | 871 |
| $\Lambda e^+\nu_e$ | | $(2.1 \pm 0.6)\ \%$ | | 871 |
| $\Lambda\mu^+\nu_\mu$ | | $(2.0 \pm 0.7)\ \%$ | | 867 |
| **Inclusive modes** | | | | |
| $e^+$ anything | | $(4.5 \pm 1.7)\ \%$ | | — |
| $pe^+$ anything | | $(1.8 \pm 0.9)\ \%$ | | — |
| $p$ anything | | $(50 \pm 16)\ \%$ | | — |

**Systematic studies of $\Lambda_c^+$, search for new decays, absolute BF measurements are important to fully explore the $\Lambda_c^+$ decay mechanisms**

# First absolute BFs of $\Lambda_c^+ \rightarrow \Lambda l^+ \nu$

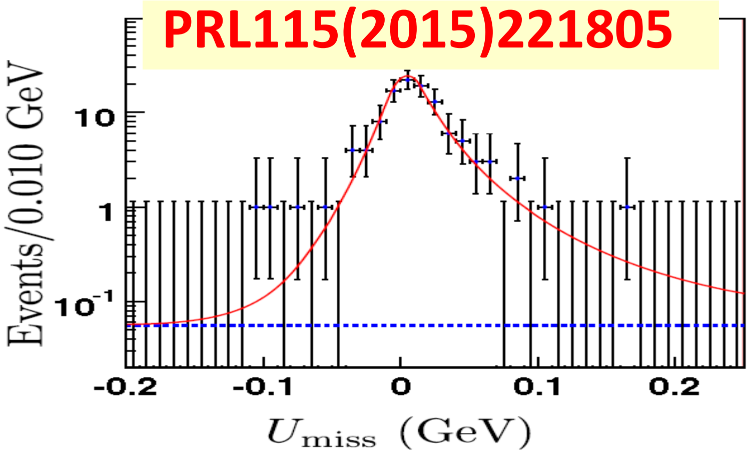


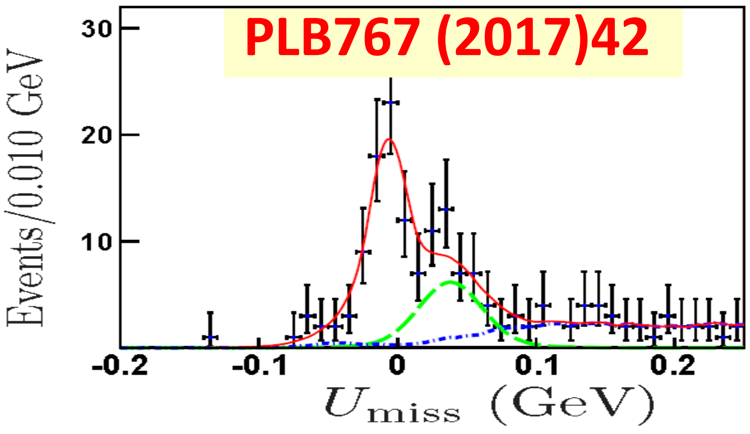
## Theory: (1.4-9.2)%



| Theoretical Models | predicated branching fraction for $\Lambda_c^+ \longrightarrow \Lambda e^+ \nu_e$ |
|---|---|
| MBM [1] | 1.9% |
| NRQM [1] | 2.6% |
| SU(4)-symmetry limit [2] | 9.2% |
| RSQM [3] | 4.4% |
| QCM [4] | 5.62% |
| SQM [5] | 1.96% |
| NRQM2 [6] | 2.15% |
| NRQM3 [7] | 1.42% |
| QCD SR1 [8] | $(3.0 \pm 0.9)\%$ |
| QCD SR2 [9] | $(2.6 \pm 0.4)\%$ |
| QCD SR3 [9] | $(5.8 \pm 1.5)\%$ |
| STSR [10] | 2.22% for $\Lambda_c^+ \longrightarrow \Lambda l^+ \nu_l$ |
| STNR [10] | 1.58% for $\Lambda_c^+ \longrightarrow \Lambda l^+ \nu_l$ |
| HOSR [10] | 4.72% for $\Lambda_c^+ \longrightarrow \Lambda l^+ \nu_l$ |
| HONR [10] | 4.2% for $\Lambda_c^+ \longrightarrow \Lambda l^+ \nu_l$ |
| LCSRs [11] | $(3.0 \pm 0.3)\%$ for $\Lambda_c^+ \longrightarrow \Lambda l^+ \nu_l$ (CZ-type) |
| PDG 2014 [14] | $(2.1 \pm 0.6)\%$ |
| BESIII | $(3.63 \pm 0.38 \pm 0.20)\%$ |

**3 $fb^{-1}$ help to explore FF studies**


**PRL115(2015)221805**


**PLB767 (2017)42**

$B[\Lambda_c^+ \rightarrow \Lambda e^+ \nu] = (3.63 \pm 0.38 \pm 0.20)\%$

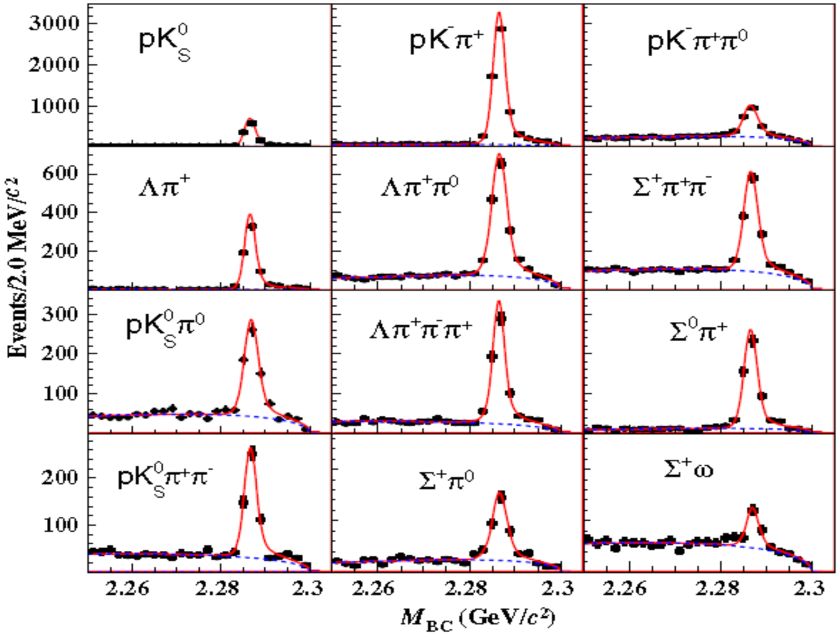
$B[\Lambda_c^+ \rightarrow \Lambda \mu^+ \nu_\mu] = (3.49 \pm 0.46 \pm 0.26)\%$

$\Gamma[\Lambda_c^+ \rightarrow \Lambda \mu^+ \nu_\mu] / \Gamma[\Lambda_c^+ \rightarrow \Lambda e^+ \nu_e] = 0.96 \pm 0.16 \pm 0.04$

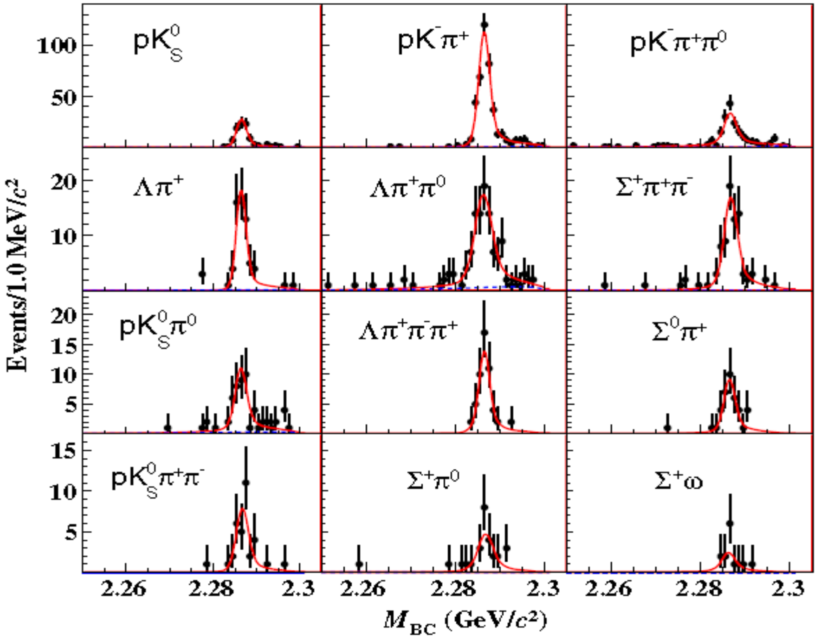
# Significantly improved BFs of $\Lambda_c^+ \rightarrow$ decays

**PRL116(2016)052001**

**ST: ~15000**



**DT: ~1000**



$$N_j^{\rm ST} = N_{\Lambda_c^+\bar{\Lambda}_c^-}\mathcal{B}_j\varepsilon_j$$

$$N_{ij}^{\rm DT} = N_{\Lambda_c^+\bar{\Lambda}_c^-}\mathcal{B}_i\mathcal{B}_j\varepsilon_{ij}$$

$$\mathcal{B}_i = \frac{N_{ij}^{\rm DT}}{N_j^{\rm ST}}\frac{\varepsilon_j}{\varepsilon_{ij}}$$

$$N_{i-}^{\rm DT} = N_{\Lambda_c^+\bar{\Lambda}_c^-}\sum_j \mathcal{B}_i\mathcal{B}_j\varepsilon_{i-}^{\rm DT}$$

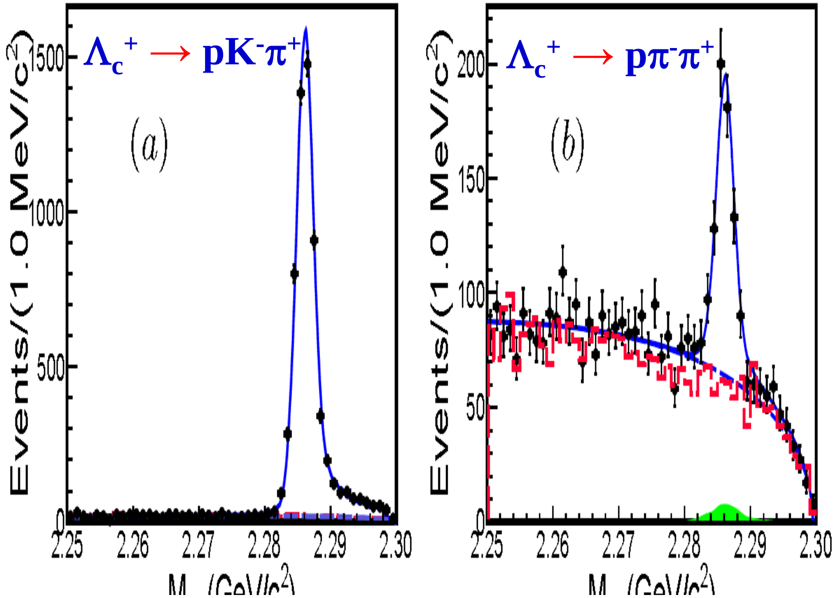
$$\varepsilon_{i-}^{\rm DT} = [\sum_j(\mathcal{B}_j\varepsilon_{ij})/\sum_j\mathcal{B}_j$$

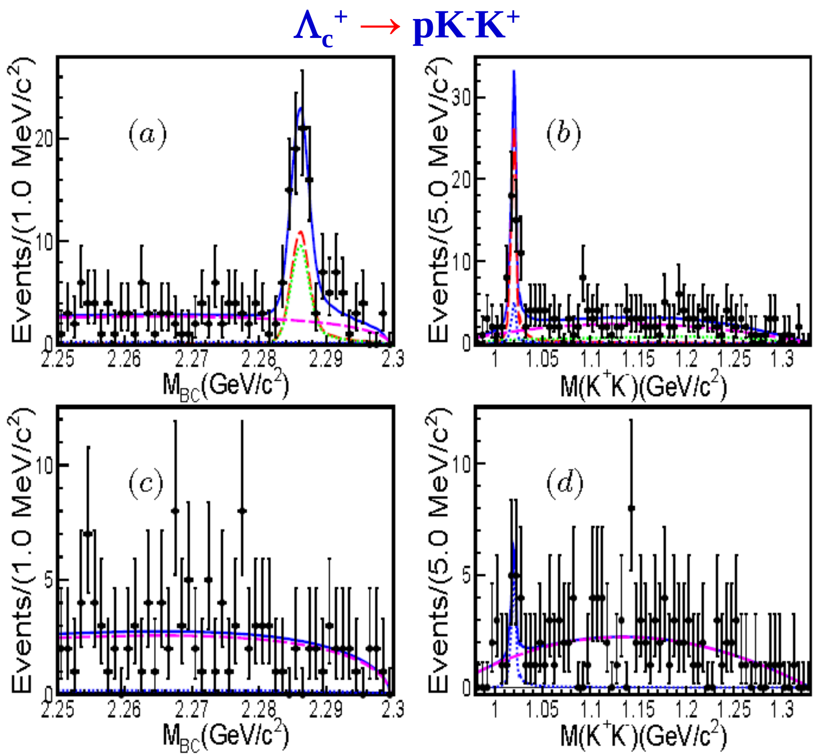
| Mode | This work (%) | PDG (%) |
|---|---|---|
| $pK_S^0$ | $1.52 \pm 0.08 \pm 0.03$ | $1.15 \pm 0.30$ |
| $pK^-\pi^+$ | $5.84 \pm 0.27 \pm 0.23$ | $5.0 \pm 1.3$ |
| $pK_S^0\pi^0$ | $1.87 \pm 0.13 \pm 0.05$ | $1.65 \pm 0.50$ |
| $pK_S^0\pi^+\pi^-$ | $1.53 \pm 0.11 \pm 0.09$ | $1.30 \pm 0.35$ |
| $pK^-\pi^+\pi^0$ | $4.53 \pm 0.23 \pm 0.30$ | $3.4 \pm 1.0$ |
| $\Lambda\pi^+$ | $1.24 \pm 0.07 \pm 0.03$ | $1.07 \pm 0.28$ |
| $\Lambda\pi^+\pi^0$ | $7.01 \pm 0.37 \pm 0.19$ | $3.6 \pm 1.3$ |
| $\Lambda\pi^+\pi^-\pi^+$ | $3.81 \pm 0.24 \pm 0.18$ | $2.6 \pm 0.7$ |
| $\Sigma^0\pi^+$ | $1.27 \pm 0.08 \pm 0.03$ | $1.05 \pm 0.28$ |
| $\Sigma^+\pi^0$ | $1.18 \pm 0.10 \pm 0.03$ | $1.00 \pm 0.34$ |
| $\Sigma^+\pi^+\pi^-$ | $4.25 \pm 0.24 \pm 0.20$ | $3.6 \pm 1.0$ |
| $\Sigma^+\omega$ | $1.56 \pm 0.20 \pm 0.07$ | $2.7 \pm 1.0$ |

**Much better precision**

# SCS decays $\Lambda_c^+ \to pK^+K^-$ and $p\pi^+\pi^-$

**PRL117(2016)232002**



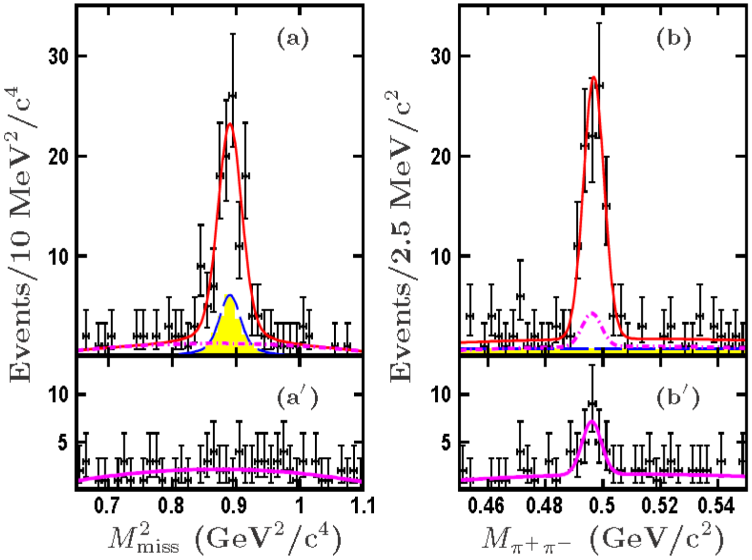


**These help to distinguish predictions from different theoretical models and understand contributions from factorizable effects**

| Decay modes | $\mathcal{B}_{\rm mode}/\mathcal{B}_{\rm ref.}$ | $\mathcal{B}_{\rm mode}$ | $\mathcal{B}$(PDG) |
|---|---|---|---|
| $\Lambda_c^+ \to p\pi^+\pi^-$ | $(6.70 \pm 0.48 \pm 0.25) \times 10^{-2}$ | $(3.91 \pm 0.28 \pm 0.15 \pm 0.24) \times 10^{-3}$ | $(3.5 \pm 2.0) \times 10^{-3}$ |
| $\Lambda_c^+ \to p\phi$ | $(1.81 \pm 0.33 \pm 0.13) \times 10^{-2}$ | $(1.06 \pm 0.19 \pm 0.08 \pm 0.06) \times 10^{-3}$ | $(8.2 \pm 2.7) \times 10^{-4}$ |
| $\Lambda_c^+ \to pK^+K^-$ (non-$\phi$) | $(9.36 \pm 2.22 \pm 0.71) \times 10^{-3}$ | $(5.47 \pm 1.30 \pm 0.41 \pm 0.33) \times 10^{-4}$ | $(3.5 \pm 1.7) \times 10^{-4}$ |

# Observation of $\Lambda_c^+ \rightarrow nK_S\pi^+$

**PRL118(2017)112001**



**$B[\Lambda_c^+ \rightarrow nK_S\pi^+]=(1.82\pm0.23\pm0.11)\%$**

**$\Gamma[\Lambda_c^+ \rightarrow n\bar{K}^0\pi^+]/\Gamma[\Lambda_c^+ \rightarrow pK^-\pi^+]=0.62\pm0.09$**

**$\Gamma[\Lambda_c^+ \rightarrow n\bar{K}^0\pi^+]/\Gamma[\Lambda_c^+ \rightarrow p\bar{K}^0\pi^+]=0.97\pm0.16$**

**First measurement of BF of $\Lambda_c^+$ decay containing neutron**

$$\cos\delta = -0.24 \pm 0.08$$

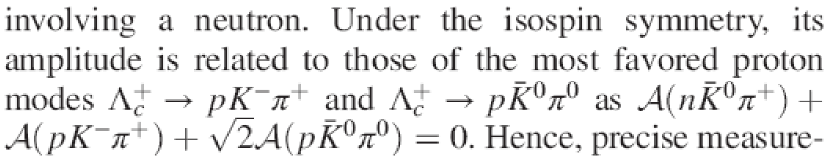
$$|I^{(1)}|/|I^{(0)}| \qquad 1.14 \pm 0.11$$

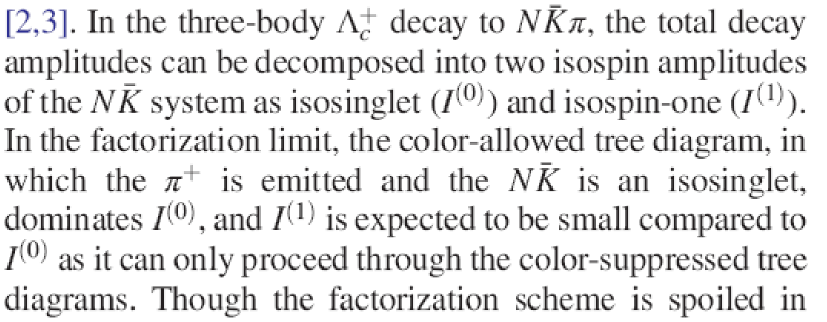
**Help to understand SU(3) and isospin symmetry and determine strong phase**

**Cai-Dian Lv et al, PRD93(2016)056008**

$$\cos\delta = \frac{\mathcal{B}(n\bar{K}^0\pi^+) - \mathcal{B}(pK^-\pi^+)}{2\sqrt{\mathcal{B}(p\bar{K}^0\pi^0)(\mathcal{B}(pK^-\pi^+) + \mathcal{B}(n\bar{K}^0\pi^+) - \mathcal{B}(p\bar{K}^0\pi^0))}}$$

$$R_p = \frac{\mathcal{B}(\Lambda_c \rightarrow p\bar{K}^0\pi^0)}{\mathcal{B}(\Lambda_c \rightarrow pK^-\pi^+)}, \qquad R_n = \frac{\mathcal{B}(\Lambda_c \rightarrow n\bar{K}^0\pi^+)}{\mathcal{B}(\Lambda_c \rightarrow pK^-\pi^+)}$$

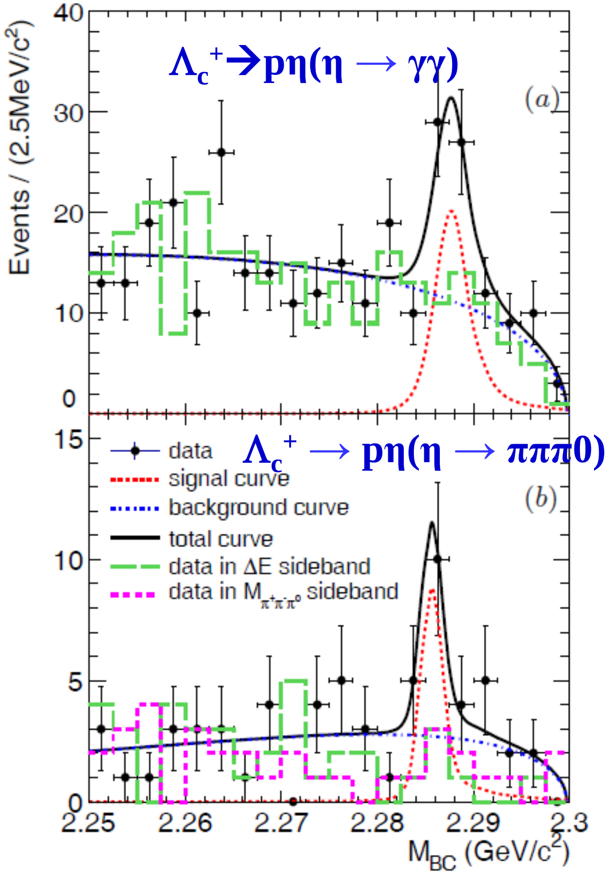

involving a neutron. Under the isospin symmetry, its amplitude is related to those of the most favored proton modes $\Lambda_c^+ \rightarrow pK^-\pi^+$ and $\Lambda_c^+ \rightarrow p\bar{K}^0\pi^0$ as $\mathcal{A}(n\bar{K}^0\pi^+) + \mathcal{A}(pK^-\pi^+) + \sqrt{2}\mathcal{A}(p\bar{K}^0\pi^0) = 0$. Hence, precise measure-

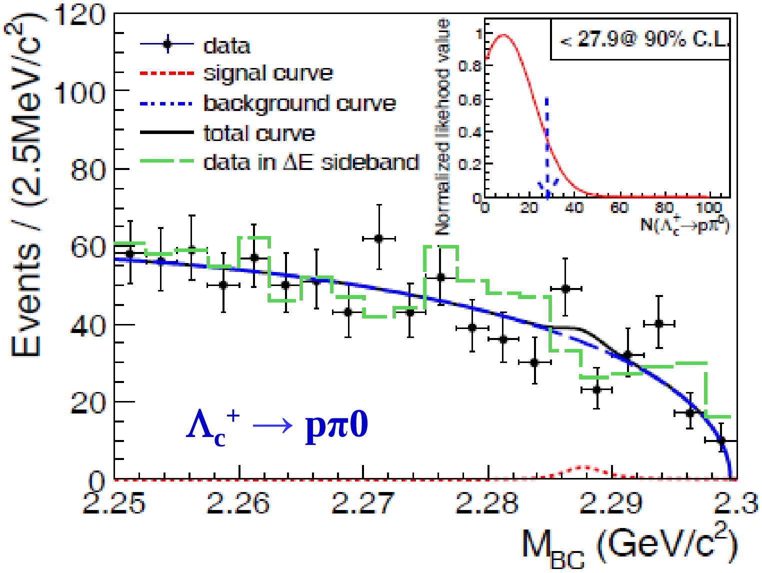

[2,3]. In the three-body $\Lambda_c^+$ decay to $N\bar{K}\pi$, the total decay amplitudes can be decomposed into two isospin amplitudes of the $N\bar{K}$ system as isosinglet ($I^{(0)}$) and isospin-one ($I^{(1)}$). In the factorization limit, the color-allowed tree diagram, in which the $\pi^+$ is emitted and the $N\bar{K}$ is an isosinglet, dominates $I^{(0)}$, and $I^{(1)}$ is expected to be small compared to $I^{(0)}$ as it can only proceed through the color-suppressed tree diagrams. Though the factorization scheme is spoiled in

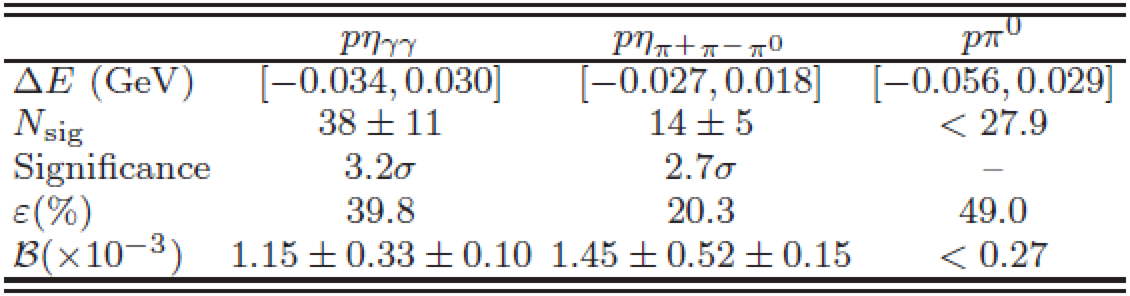
# Evidence of $\Lambda_c^+ \to p\eta$ and search of $\Lambda_c^+ \to p\pi^0$

**PRD95 (2017) 111102**

Single-Cabibbo-suppressed decay







| | $p\eta_{\gamma\gamma}$ | $p\eta_{\pi^+\pi^-\pi^0}$ | $p\pi^0$ |
|---|---|---|---|
| $\Delta E$ (GeV) | $[-0.034, 0.030]$ | $[-0.027, 0.018]$ | $[-0.056, 0.029]$ |
| $N_{\mathrm{sig}}$ | $38 \pm 11$ | $14 \pm 5$ | $< 27.9$ |
| Significance | $3.2\sigma$ | $2.7\sigma$ | – |
| $\varepsilon(\%)$ | 39.8 | 20.3 | 49.0 |
| $\mathcal{B}(\times 10^{-3})$ | $1.15 \pm 0.33 \pm 0.10$ | $1.45 \pm 0.52 \pm 0.15$ | $< 0.27$ |

**$B(\Lambda_c^+ \to p\eta)=(0.124\pm0.028\pm0.010)\%$ (First evidence)** **$B(\Lambda_c^+ \to p\pi^0) < 0.027\%$**

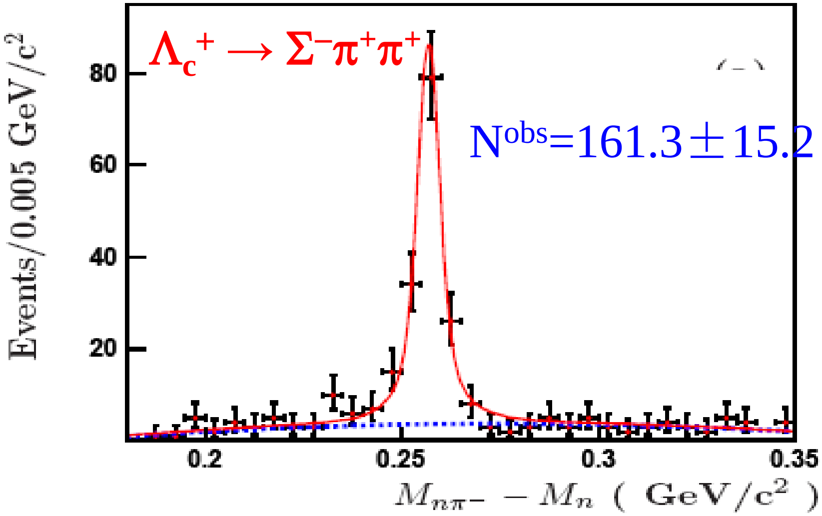
It is expected that BF of **$\Lambda_c^+ \to p\eta$ will be much larger than that of $\Lambda_c^+ \to p\pi^0$ due to SU(3) flavor symmetry.**

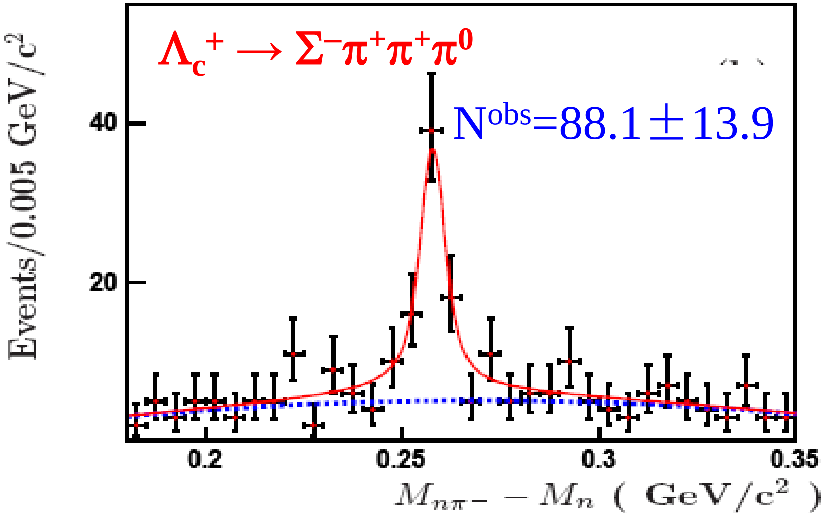
# Observation of $\Lambda_c^+ \to \Sigma^-\pi^+\pi^+\pi^0$

**arXiv:1705.11109**

**Accepted by PLB**

**More studies of decays containing neutron**





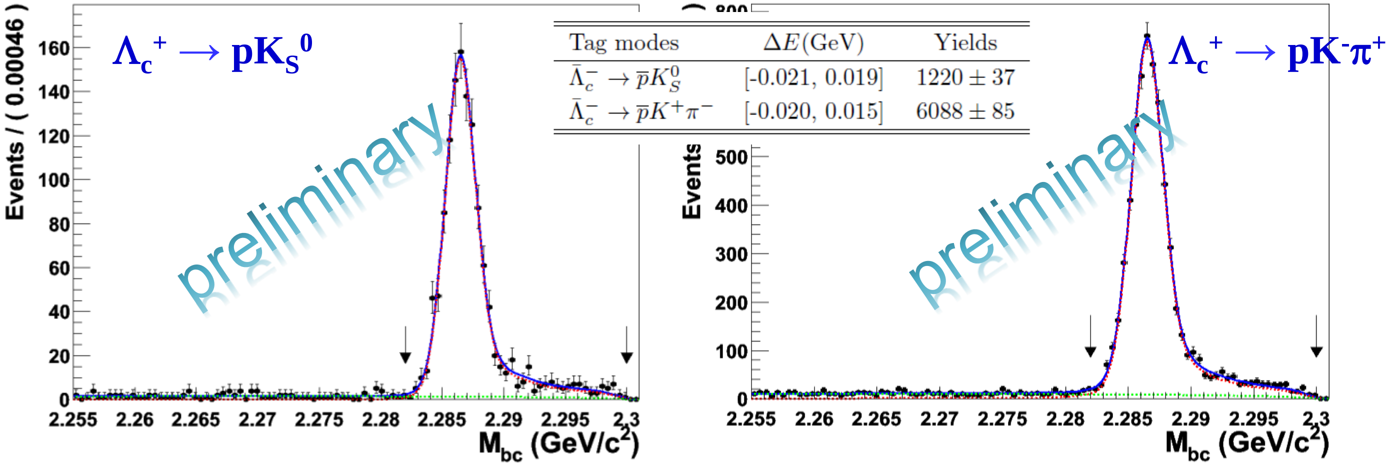
**$B[\Lambda_c^+ \to \Sigma^-\pi^+\pi^+]$ =(1.81±0.17)%**

**$B[\Lambda_c^+ \to \Sigma^-\pi^+\pi^+\pi^0]$=(2.11 ±0.33)%** **[First observation]**

where the errors are statistical only. The sources of the systematic errors arise mainly from the systematic uncertainties in PID, tracking, $\pi^0$ efficiency, fitting, MC statistics and number of $\bar{\Lambda}_c^-$ tags. The total systematic errors are estimated to be about 5%.

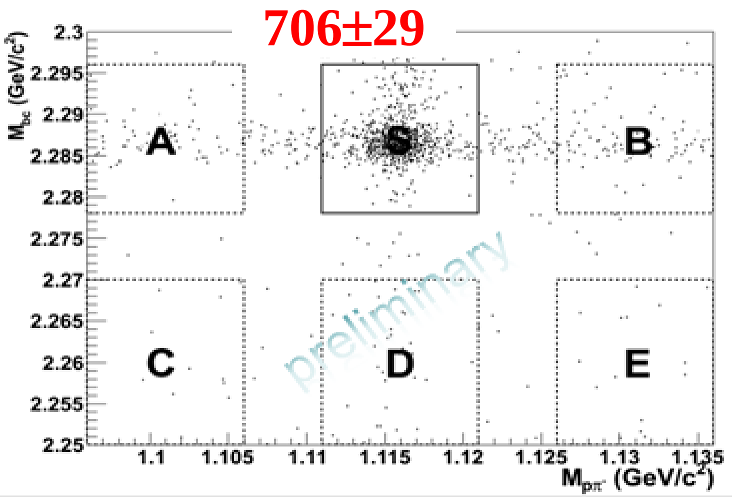
**The measured branching fraction for $\Lambda_c^+ \to \Sigma^-\pi^+\pi^+$ is consistent with and more precise than $B[\Lambda_c^+ \to \Sigma^-\pi^+\pi^+]=(2.3\pm0.4)\%$ in PDG2015.**

# Inclusive decay $\Lambda_c^+ \to \Lambda X$



| Tag modes | $\Delta E$(GeV) | Yields |
|---|---|---|
| $\bar{\Lambda}_c^- \to \bar{p}K_S^0$ | [-0.021, 0.019] | $1220 \pm 37$ |
| $\bar{\Lambda}_c^- \to \bar{p}K^+\pi^-$ | [-0.020, 0.015] | $6088 \pm 85$ |

**706±29**



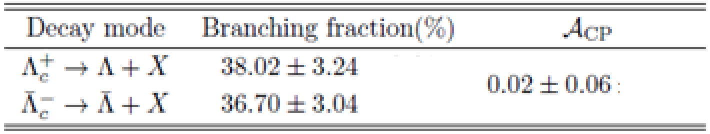
$$\mathcal{A}_{CP} = \frac{\mathcal{B}(\Lambda_c^+ \to \Lambda + X) - \mathcal{B}(\bar{\Lambda}_c^- \to \bar{\Lambda} + X)}{\mathcal{B}(\Lambda_c^+ \to \Lambda + X) + \mathcal{B}(\bar{\Lambda}_c^- \to \bar{\Lambda} + X)}.$$

**Help to explore the source of missing decays and search for new decay. Better input for charm baryon and B physics**

$$N_{sig} = N_S - (N_A + N_B)/2 - r \cdot N_D + r \cdot (N_C + N_E)/2$$

$\mathcal{B}(\Lambda_c^+ \to \Lambda + X) = (36.98 \pm 2.18)\%$ **stat. only**

**Agrees with PDG2015 value (35±11)%,**



| Decay mode | Branching fraction(%) | $\mathcal{A}_{CP}$ |
|---|---|---|
| $\Lambda_c^+ \to \Lambda + X$ | $38.02 \pm 3.24$ | $0.02 \pm 0.06$ |
| $\bar{\Lambda}_c^- \to \bar{\Lambda} + X$ | $36.70 \pm 3.04$ | |

# Summary

- With 2.93, 0.482, 0.567 fb$^{-1}$ data taken at 3.773, 4.009 and 4.6 GeV, BESIII have studied $D_{(s)}^{+} \rightarrow l^{+}v$ and $D^{0} \rightarrow K(\pi)^{-}l^{+}v$, searched for $D^{+(0)} \rightarrow a_{0}(980)^{0(-)}e^{+}v$, hee, $\gamma e^{+}v$ and $D^{0}e^{+}v$, measurements of D hadronic decays, absolute $\Lambda_{c}^{+}$ BFs using near threshold data
- Improved measurements of decay constant $f_{D+}$ and form factor $f_{+}^{D \rightarrow K(\pi)}(q^{2})$, which are important to test and calibrate LQCD calculations
- Improved measurements of CKM matrix element $|V_{cs(d)}|$, which are important to test the CKM matrix unitarity

- About 3 fb$^{-1}$ data at 4.18 GeV was accumulated in 2016, the measurements of $f_{Ds+}$ and $|V_{cs}|$ by $D_{s}^{+} \rightarrow l^{+}v$, the first FF studies of $D_{s}^{+} \rightarrow \eta^{(\prime)}e^{+}v$… can be expected in the near future

# Thank you!