# HFLAV Charm Decays Group

## Status & Plans

## 15 January 2025, HFLAV meeting

Paras Naik & Hailong Ma (conveners)


# HFLAV

## Charm Decays

- Hailong Ma (IHEP, BES-III)
- Paras Naik (Liverpool, LHCb)
- Tara Nanut Petrič (CERN, LHCb)
- John Yelton (Florida, Belle / Belle II)
- Marco Gersabeck (Freiburg, LHCb)
- Alan Schwartz (Cincinnati, Belle / Belle II)

# HFLAV 2023 publication and prior sections

- As a reminder, the set of sections in the 2023 publication was as follows:
  - Semileptonic decays (Hailong)
  - Leptonic decays (Hailong)
  - Hadronic D decay branching fractions and final state radiation (Paras)
  - Excited $D_{(s)}$ mesons (Tara)
  - Excited charmed baryons (John)
  - Rare and forbidden decays (Marco)
- Details of changes with respect to previous publications discussed in the 2023 HFLAV CKM meeting

# Current Status

- Tara has left HFLAV (and LHCb), we wish her well in future endeavours
- Webpages all contain modern results
  - New results are continuing to be added in due course
- Code and instructions preserved in HFLAV GitLab
- Next few slides cover potential changes for 2025(+)

# Semileptonic Decays

- This section is the largest (by number of pages) within the Charm Decays chapter, and growing. Hailong works on both this section and the Leptonic Decays section.
- We plan to discuss with the HFLAV conveners the need for one extra person to work within these sections (mainly the Semileptonic section) in the coming weeks. [suggestion in backup]

**Publications of semi-leptonic D decays after HFLAV2023**

1. Semileptonic $D_s^+$ decays via $e^+e^- \to D_s^{*+}D_s^{*-}$, PRD110, 072017 (2024)
2. Observation of $D^+ \to \eta' \mu^+ \nu_\mu$ and First Experimental Study of $D^+ \to \eta' \ell^+ \nu_\ell$ Decay Dynamics, arXiv: 2410.08603
3. Analysis of $D^{0(+)} \to \bar{K} l^+ \nu_l$, PRD110, 112006 (2024)
4. Study of the decay $D^0 \to \pi^- \pi^0 e^+ \nu_e$, PRD110, 112018 (2024)
5. Analysis of $D^+ \to K_S^0 \pi^0 e^+ \nu_e$, JHEP10(2024)199
6. Observation of $D^{0(+)} \to b_1(1235)^{-(0)} e^+ \nu_e$, arXiv:2407.20551
7. Updated study of $D_s^+ \to K^0 e^+ \nu_e$, PRD110, 052012 (2024)
8. Study of $D^0 \to K^- \pi^0 \mu^+ \nu_\mu$, PRL134, 011803 (2025)
9. Search for $D^{0(+)} \to P\eta e^+ \nu_e$, PRD110, 112001 (2024)
10. Analysis of $D^0 \to a_0(980)^- e^+ \nu_e$, arXiv:2411.07730
11. Study of $D^0 \to K_S^0 \pi^- e^+ \nu_e$, arXiv:2412.10803

# Leptonic Decays

- Also a lot of recent activity in Leptonic Decays

**Publications of leptonic D decays after HFLAV2023**

1. Leptonic $D_s^+$ decays via $e^+e^- \to D_s^{*+}D_s^{*-}$, PRD110, 052002 (2024)
2. Search for $D^{*+} \to e^+\nu_e$ and $D^{*+} \to \mu^+\nu_\mu$, PRD110, 012003 (2024)
3. Precision measurment of $D^+ \to \mu^+\nu_\mu$, arXiv:2410.07626
4. Improved measurement of $D^+ \to \tau^+\nu_\tau$, accepted by JHEP, arXiv:2410.20063
5. Search for $D^+ \to e^+\nu_e$ , arXiv:2501.04760

# Hadronic D decays and final state radiation

- Varying FSR modeling across experiments affects efficiency calculations
  - FSR treatment is needed for modes approaching 1% precision on branching fractions, thus we perform averages this way for $D^0 \to K\pi$, $D^0 \to KK$, $D^0 \to \pi\pi$.
  - Total errors on *best* branching fraction measurements are:
    $D^0 \to K\pi$ ~1.3%, $D^+ \to K\pi\pi$ ~1.8%, $D_s \to KK\pi$ ~2.8%
    - However, there is no work to do for $D^+ \to K\pi\pi$ yet; the PDG only includes one measurement in their average (CLEO-c, used PHOTOS 2.15 — modern & consistent with PHOTOS++). Have not seen a BES III paper on this yet.
    - The situation for $D_s$ more interesting (4 measurements), but less urgent due to large relative error.
    - Still, developing the framework could be helpful / publishable.
- Perhaps more of a priority: Averages are performed with a proprietary fitter (hflav/DHadBFs/CombineKpi). Should cross-check with (eventually move to) a common fitter i.e. hflav/averaging.

# Excited $D_{(s)}$ mesons

## Last updated in 2023 (Formerly Tara)

- HFLAV Charm Decays performs averages of excited $D_{(s)}$
  - masses/widths
  - mass differences
  - polarization amplitudes
- We also perform averages of the product of B and excited $D_{(s)}$ branching fractions
  - This duplicates some of the work done in the B to Charm group (!), perhaps for long-forgotten historical reasons.
  - Such branching fractions belong in B to Charm, but we should retain any useful discussion that we provide based on the results.
  - We should formulate a coherent plan between our groups before the next paper.
- We think this section remains useful and would like to retain it. Will discuss with HFLAV conveners.

# Hadronic $D_s$ decay branching fractions

## Last updated in 2014 (Formerly Alan)

- PDG world averages for Hadronic $D_s$ decays are sufficient.
  - HFLAV took into account correlations among some BESIII measurements that the PDG did not.
  - Also we provided a combined $D_s^+$ -> anti-$K^0$ $K^+$ average;
    the PDG lists $D_s^+$ -> $K_S$ $K^+$, $D_s^+$ -> $K_L$ $K^+$, and $D_s^+$ -> anti-$K^0$ $K^+$ separately
- The HFLAV results however, are “never” cited. Taking the BESIII correlations into account is better, but if not providing increased accuracy or precision then it may not draw much attention
- There have been recent measurements at BES III in $D_s$ decays
  - Perhaps an opportunity for someone from BES III to continue this work
    (see backup for suggestion)

# $\Lambda_c$ hadronic branching fractions

## Last updated in 2016 (Formerly Xiao-Rui Lyu & Anze Zupanc)

- $\Lambda_c$ branching fraction measurements are absolute, or relative to pKπ (incl. Λπ relative to pKπ), or relative to Λπ
- PDG made an average of 20 hadronic decay modes in 2016. HFLAV performed fit in 2016 with 12 hadronic modes + 1 semi-leptonic mode accounting for correlations. The justification was the following:

> The advantage of our fit is that it takes into account correlations among measurements from the same experiment, *i.e.*, systematic uncertainties related to normalization, track-finding efficiency, particle identification efficiency, and $\pi^0$, $K^0_S$, and $\Lambda$ reconstruction efficiencies. For the twelve hadronic branching fractions measured by BESIII, we use BESIII's published correlation matrix [517].

- Does the PDG continue to not take such correlations into account? If so, then there may be a role for us.
- Same question as before though — are people/experiments using our averages?
  In 2016 HFLAV's pKπ result was (6.46 ± 0.24)% / PDG was (6.35 ± 0.33)% - perhaps worth advertising
- $\Xi_c$ branching fractions could also be averaged — but this may not require the HFLAV treatment yet
- Most recent work performed at BES III, Belle, LHCb. Will proceed with usual procedure regarding requesting a new person to join HFLAV (see backup for suggestion).

# Future Plans

- We await the next cut-off date for a 2025(+) publication
- Subgroup members are generally available to perform updates and write-ups.
- Align with wider HFLAV procedures:
  - Averaging code uniformity
    - e.g. Switch proprietary D+FSR BFs code to hflav/averaging
  - Paras representing us in WG for digital format (i.e. where sources can be traced)
- Will discuss with HFLAV conveners about the need for additional personnel

# Backup

# Semileptonic Decays

## Potential candidate (to be discussed with HFLAV conveners)

### Xiang Pan (Soochow University)

**Education:**

Sep. 2019-Jul. 2022 Ph. D Fudan University
Sep. 2016-Jul. 2019 Master degree Soochow University
Sep. 2012-Jul. 2016 Bachelor Soochow University

**Employment:**

Aug. 2022-Jun. 2025 Postdoc Soochow University

**Research interesting:**

Charm physics: (Semi)leptonic decays
Light hadron: Radiative decays of excited hyperon

**Service work:**

Study of single-tag yields of $\bar{D}^0$ and $D^-$ with 20 $\mathrm{fb}^{-1}$ data

**Publications (BESIII):**

1. Observation of $D^+ \to \eta' \mu^+ \nu_\mu$ and First Experimental Study of $D^+ \to \eta' \ell^+ \nu_\ell$ Decay Dynamics, arXiv: 2410.08603
2. Observation of $D_s^+ \to \eta' \mu^+ \nu_\mu$, Precision Test of Lepton Flavor Universality with $D_s^+ \to \eta^{(\prime)} \ell^+ \nu_\ell$, and First Measurements of $D_s^+ \to \eta^{(\prime)} \mu^+ \nu_\mu$ Decay Dynamics, Phys. Rev. Lett. **132**, 091802 (2024).
3. Precision Measurements of $D_s^+ \to \eta e^+ \nu_e$ and $D_s^+ \to \eta' e^+ \nu_e$, Phys. Rev. D **108**, 092003 (2023).
4. Measurement of the branching fraction of leptonic decay $D_s^+ \to \tau^+ \nu_\tau$ via $\tau^+ \to \pi^+ \pi^0 \bar{\nu}_\tau$, Phys. Rev. D **104**, 032001 (2021).
5. Observation of the Doubly Cabibbo-Suppressed Decay $D^+ \to K^+ \pi^+ \pi^- \pi^0$ and Evidence for $D^+ \to K^+ \omega$, Phys. Rev. Lett. **125**, 141802 (2020).
6. Observation of $D^+ \to \eta \eta \pi^+$ and improved measurement of $D^{0(+)} \to \eta \pi^+ \pi^{-(0)}$, Phys. Rev. D **101**, 052009 (2020).

# Hadronic $D_s$ decay branching fractions

## Potential candidate (to be discussed with HFLAV conveners)

### Bai-Cian Ke (Zhengzhou University)

**Education and Employment:**

Sep. 2011-Jul. 2017 Ph.D. Carnegie Mellon University
Sep. 2017-Jan. 2019 Post Doctor IHEP
Jan. 2019-Jul. 2021 Professor Shanxi normal University
Aug. 2021-Now Professor Zhengzhou University

**Research interesting:**

Charm physics and Charmonium

**Service work:**

2021-Now Co-convenor of BESIII charm physics group
2020-Now BESIII weekly run coordinator
2024-Now Member of the Editorial Board of CPC

**Selected Publications (BESIII):**

1. Study of $D_s^+ \to f_0(980)\rho^+$ and $D_s^+ \to \phi\pi^+$ Decays through $D_s^+ \to \pi^+\pi^+\pi^-\pi^0$, Phys. Rev. Lett. 134, 011904 (2025).
2. Observation of $D^+ \to K_S^0 a_0(980)^+$ in the Amplitude Analysis of $D^+ \to K_S^0\pi^+\,\eta$, Phys. Rev. Lett. 132, 131903 (2024).
3. Observation of $D \to a_0(980)\pi$ in the decays $D^0 \to \pi^+\pi^-\eta$ and $D^+ \to \pi^+\pi^0\eta$, Phys. Rev. D 110, L111102 (2024).
4. Study of $D^+ \to K_S^0 K^*(892)^+$ in $D^+ \to K_S^0 K_S^0\pi^+$, Phys. Rev. D 110, 092006 (2024).
5. Recent Progress in Leptonic and Semileptonic Decays of Charmed Hadrons, Annu. Rev. Nucl, Part. Sci. 2023. 73:285–314.
6. Amplitude analysis and branching fraction measurement of the decay $D^+ \to K_S^0\pi^+\pi^0\pi^0$, JHEP09(2023)077.
7. Observation of an $a_0$-like State with Mass of 1.817 GeV in the Study of $D_s^+ \to K_S^0 K^+\pi^0$, Phys. Rev. Lett. 129, 182001 (2022).
8. Study of the Decay $D_s^+ \to K_S^0 K_S^0\pi^+$ and Observation of an isovector partner of $f_0(1710)$, Phys. Rev. D 105, L051103 (2022).
9. Amplitude analysis and branching fraction measurement of the decay $D_s^+ \to \pi^+\pi^0\pi^0$, JHEP01(2022)052.
10. Amplitude analysis and branching fraction measurement of the decay $D_s^+ \to K^+\pi^+\pi^-\pi^0$, JHEP01(2022)052.

# $\Lambda_c$ hadronic branching fractions

## Potential candidate (to be discussed with HFLAV conveners)

# Pei-Rong Li (Lanzhou University)

**Education**

**University of Chinese Academy of Sciences (UCAS)**, Beijing, China
Doctor of Science. Conferred date: June, 2016
Thesis Title: Study on the Charmed Baryon decays and search for the exotic hadronic states at BESIII.
Advisor: Yangheng Zheng, Xiao-Rui Lyu

**School of Physics, Qufu Normal University**, Qufu, China
Bachelor of Science. Conferred date: June, 2011
Thesis Title: Research of Neutron Scattering and Spallation Neutron Source.
Advisor: Fenglan Shao

**Current Position**

**Full professor, School of Nuclear Science and Technology, Lanzhou University**, LanZhou, China.

**Grants and Honors**

**Outstanding Youth funding by the National Natural Science Foundation of China** (Aug. 2024)
**Most Influential Paper Award of Chinese Physics Society** (Dec. 2020)
**Excellent Doctoral Dissertation Award of Chinese Academy of Sciences** (Sep. 2017)
**"Chung-Yao Chao" Postdoctoral Research Fellowship** (Sep. 2017)
**"Chenguang Cup" excellent paper Award of Chinese Academy of Sciences** (Aug. 2016)
**National scholarship for doctoral students** (Dec. 2015)

**Publication**

- "First Measurement of the Decay Asymmetry in the Pure $W$-Boson-Exchange Decay $\Lambda_c^+ \to \Xi^0 K^+$ ", (BESIII Collaboration), Phys. Rev. Lett.**132**, 031801(2024).
- "Measurement of Energy-Dependent Pair-Production Cross Section and Electromagnetic Form Factors of a Charmed Baryon", (BESIII Collaboration), Phys. Rev. Lett.**131**, 191901(2023).
- "Measurement of the branching fractions of the singly Cabibbo-suppressed decay of $\Lambda_c^+ \to p\eta$ and $\Lambda_c^+ \to p\omega$", (BESIII Collaboration), JHEP**11**,137(2023).
- "Determination of spin and parity of $D_{(s)}^*$ mesons", (BESIII Collaboration), Phys. Lett. B**846**, 138245(2023).
- "Observation of Three Charmoniumlike States with $J^{PC} = 1^{--}$ in $e^+e^- \to D^{*0}D^{*-}\pi^+$", (BESIII Collaboration), Phys. Rev. Lett.**130**, 121901(2023).
- "Search for hidden-charm tetraquark with strangeness in $e^+e^- \to K^+D_s^{*-}D^{*0} + c.c.$", (BESIII Collaboration), Chin.Phys.**C47**, 033001(2023).
- "Observation of the Cabibbo-Suppressed decays $\Lambda_c^+ \to n\pi^+\pi^0$, $\Lambda_c^+ \to n\pi^+\pi^-\pi^+$ and the Cabibbo-Favored decay $\Lambda_c^+ \to nK^-\pi^+\pi^+$", (BESIII Collaboration), Chin. Phys. **C47**, 023001(2023).
- "Partial wave analysis of the charmed baryon hadronic decay $\Lambda_c^+ \to \Lambda\pi^+\pi^0$ ", (BESIII Collaboration), JHEP**12**,033(2022).
- "Luminosities and energy of $e^+e^-$ collision data taken between 4.61 GeV and 4.95 GeV at BESIII ", (BESIII Collaboration), Chin. Phys. **C46**,113003(2022).
- "Evidence for a neutral near-threshold structure in the $K_S^0$ recoil-mass spectra in $e^+e^- \to K_S^0 D_s^+ D^{*-}$ and $e^+e^- \to K_S^0 D_s^{*+} D^{-}$", (BESIII Collaboration), Phys. Rev. Lett.**129**, 112003(2022).
- "Observation of the Singly Cabibbo Suppressed Decay $\Lambda_c^+ \to n\pi^+$ ", (BESIII Collaboration), Phys. Rev. Lett.**128**, 142001(2022).
- "Observation of a Near-Threshold Structure in the $K^+$ Recoil-Mass Spectra in $e^+e^- \to K^+(D_s^- D^{*0} + D_s^{*-} D^0)$ ", (BESIII Collaboration), Phys. Rev. Lett.**126**, 102001(2021).
- "Measurements of the absolute branching fraction of $\Lambda_c^+ \to pK_S^0\eta$ decays ", (BESIII Collaboration), Phys. Lett. **B817**, 136327(2021).
- "Measurement of $\psi(2S)$ production cross-sections in proton-proton collisions at $\sqrt{s} = 13$ TeV", (LHCb Collaboration), Eur. Phys. J. **C80**.185(2020).
- "Erratum to: Measurement of $\psi(2S)$ meson production in pp collision at $\sqrt{s} = 7$ TeV ", (LHCb Collaboration), Eur. Phys. J. **C80**.40(2020).
- "Measurement of the absolute branching fractions of $\Lambda_c^+ \to \Lambda\eta\pi^+$ and $\Sigma(1385)\eta$ ", (BESIII Collaboration), Phys. Rev. D**99**,032010(2019).
- "Evidence for the decay of $\Lambda_c^+ \to \Sigma^+\eta$ and $\Sigma^+\eta'$ ", (BESIII Collaboration), Chin. Phys. **C43**,083002(2019).
- "Observation of $e^+e^- \to K^+D_s^{*-}D^{*0} + c.c.$ and study of the $P$-wave $D_s$ mesons ", (BESIII Collaboration), Chin. Phys. **C43**,031001(2019).
- "Measurements of branching fractions for D meson decaying into $\phi$ meson and a pseudoscalar meson ", (BESIII Collaboration), Phys. Lett. B**798**, 135017(2019).
- "Measurements of Absolute Branching Fractions for $\Lambda_c^+ \to \Xi^0 K^+$ and $\Xi(1530)^0 K^+$", (BESIII Collaboration), Phys. Lett. B**783**, 200(2018).
- "Precision measurement of the $e^+e^- \to \Lambda_c^+\bar{\Lambda}_c^-$ cross section near threshold ", (BESIII Collaboration), Phys. Rev. Lett. **120**,132001(2018).
- "Measurements of absolute hadronic branching fractions of $\Lambda_c^+$ baryon", (BESIII Collaboration), Phys. Rev. Lett. **116**, 052001 (2016).
- "Observation of a neutral charmoniumlike state $Z_c(4025)^0$ in $e^+e^- \to (D^*\bar{D}^*)^0\pi^0$", (BESIII Collaboration), Phys. Rev. Lett. **115**, 182002 (2015).
- "Observation of a charged charmoniumlike structure in $e^+e^- \to (D^*\bar{D}^*)^\pm\pi^\mp$ at $\sqrt{s} = 4.26$ GeV", (BESIII Collaboration), Phys. Rev. Lett. **112**, 132001 (2014).
- "Recent charmed baryon results at BESIII", Pei-Rong Li, Nuclear and Particle Physics Proceedings, Volumes 270-272, January-March 2016, Pages 123-126.