Probing NP with rare charm decays @ Belle II

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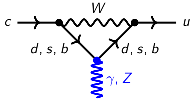
Rare charm decays are special!

1. **Window to test FCNCs in the up-sector!**
2. **Strong non-perturbative dynamics** → **"Null tests"** $\mathcal{O} \pm \delta\,\mathcal{O}$
   - Use SM symmetries: $\mathcal{O}_{\mathrm{SM}} = \mathbf{0}$,
   - Small uncertainties: $\mathcal{O}_{\mathrm{SM}} \gg \delta\,\mathcal{O}_{\mathrm{SM}}$,
   - Use large hadronic effects to enhance NP contributions,
   - Construct $\mathcal{O}$ sensitive to specific NP,
   - Use $SU(3)_F$-flavor symmetry, ...
3. **Very efficient GIM mechanism:** $\sum_i \lambda_i = 0$ with $\lambda_i \equiv V_{ci}^* V_{ui}$.



$$= \sum_{i=d,s,b} \lambda_i f_i = \lambda_s \left[(f_s - f_d) + \frac{\lambda_b}{\lambda_s} (f_b - f_d) \right]$$

$f_i \sim \frac{m_i^2}{(4\pi)^2 M_W^2}$, $\mathrm{Im}(\lambda_b/\lambda_s) \sim 10^{-3}$

BRs (A_{CP}) are loop-(CKM-) suppressed!

Excellent place to search for BSM physics!

Rare charm decays are well-suited for Belle II

- $N(c\bar{c})_{\text{Belle II}} = 65 \cdot 10^9$! (Abada:2019lih)
- **How many charm hadrons h_c?**

⋆ $N(h_c) = 2\, f(c \to h_c)\, N(c\bar{c})$

⋆ **Fragmentation fractions** (1509.01061)

$$N(h_c) \sim 10^{10}!$$

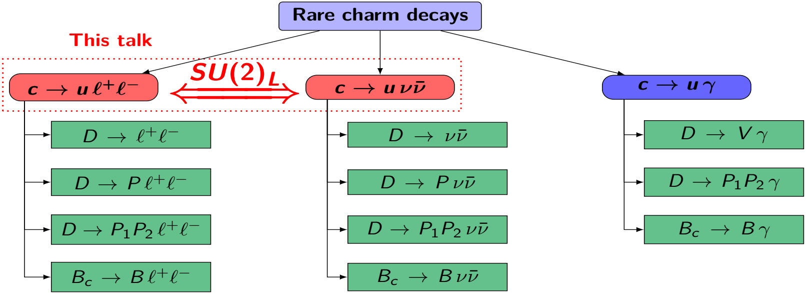
h_c	$f(c \to h_c)$	$N(h_c)_{\text{Belle II}}$
D^0	0.59	$8 \cdot 10^{10}$
D^+	0.24	$3 \cdot 10^{10}$
D_s^+	0.10	$1 \cdot 10^{10}$
Λ_c^+	0.06	$8 \cdot 10^{9}$

- **And translated to branching ratios?**

Relative statistical uncertainty: $\delta\mathcal{B}(h_c) = 1/\sqrt{N^{\text{exp}}}$ with $N^{\text{exp}} = \eta_{\text{eff}}\, N(h_c)\, \mathcal{B}(h_c)$

$$\eta_{\text{eff}}\, \mathcal{B}(h_c) \sim 10^{-9} \text{ for } \delta\mathcal{B}(h_c) = \frac{1}{5}$$

A sketch of the playground



Observables:

Branching ratios
Angular observable
LU ratios& LFV
CP asymmetries

⇑

Theory:

2011.12856, 2004.01206, 1909.11108, 1510.00311, 1606.05521, 1703.08799, 1705.02251, 1705.05891, 1707.00988, 1510.00311, 0810.4858 , 1409.0181, 1208.0759 , 2004.01206, 1805.08516, 2202.02331, 2107.13010, 1712.05783, 1805.02516, 2101.02421, ... ,

Experiment:

1305.5059 , 1512.00322, 1107.4465 , 2011.00217, 1802.09752, 1510.08367, 1310.2535 , 1707.08377, 2111.03327, 1712.07938, 1806.10793, ...

Observables:

Branching ratios

⇑

Theory:

2007.05001, 2010.02225, 2012.15847, 2101.10712, 2107.07291, ...

Experiment:

2112.14236, 1611.09455.

Ideally:

Theory + Experiment

⇓

Optimized observables!

Observables:

Branching ratios
Angular observables
CP asymmetries

⇑

Theory:

2104.08287, 2009.14212, 1812.04679, 1905.00907, 1802.02769, 1702.05059, 1701.06392, 2203.14982, ...

Experiment:

1603.03257, 0808.1838, 0808.1838,

For a review:
Mod.Phys.Lett.A 36 (2021) 04, 2130002

EFT approach to charm physics (1)

1. **Dynamical fields ϕ_i at μ_{EW}: $\phi_i^{\text{SM}} = q_i, \ell_i, A_\mu, \ldots$**

2. **Symmetries to build all $O_j(\phi_i)$ up to desired dimension ($D = 6$):**

$$\mathcal{H}_{\text{eff}} \sim \frac{4\,G_F}{\sqrt{2}}\,\frac{\alpha_e}{4\pi}\sum_i C_i\,O_i$$

$$O_1^q = (\overline{u}_L\gamma_\mu T^a q_L)(\overline{q}_L\gamma^\mu T^a c_L)\,, \quad O_2^q = (\overline{u}_L\gamma_\mu q_L)(\overline{q}_L\gamma^\mu c_L)\,,\ q = d, s\,,$$

$$O_7^{(\prime)} = \frac{m_c}{e}(\overline{u}_{L\,(R)}\,\sigma_{\mu\nu}\,c_{R\,(L)})\,F^{\mu\nu}\,, \quad O_{9\,(10)}^{(\prime)} = (\overline{u}_{L\,(R)}\gamma_\mu c_{L\,(R)})(\bar{\ell}\,\gamma^\mu(\gamma_5)\,\ell)\,,$$

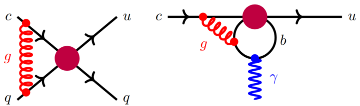
$$O_{S\,(P)}^{(\prime)} = (\overline{u}_{L\,(R)}c_{R\,(L)})(\bar{\ell}\,(\gamma_5)\,\ell)\,, \quad O_{T\,(T5)} = \frac{1}{2}(\overline{u}\,\sigma_{\mu\nu}\,c)(\bar{\ell}\,\sigma^{\mu\nu}\,(\gamma_5)\,\ell)\,.$$

3. **Compute $C_i(\mu_{\text{EW}})$ to avoid large $\alpha_s(\mu_{\text{low}})\log(\mu_{\text{low}}^2/\mu_{\text{EW}}^2)$.**

$m_{q_{\text{light}}} = 0$ + GIM mechanism $\Longrightarrow$ $C_{7,9,10}^{\text{SM}}(\mu_{\text{EW}}) = 0$!

EFT approach to charm physics (2)

4. RGEs to go down $\mu_{\text{low}} \approx m_c$ (2-step matching at μ_{EW} and m_b).
   - Penguins generated at $\mu = m_b$
   - $O_{7,9}$ mix with $O_{1,2}$:



$$|C_7^{\text{eff}}(\mu_c)| \lesssim 0.004 \,\&\, |C_9^{\text{eff}}(\mu_c)| \lesssim 0.01$$

   - **BUT NOT** all other SM WCs:

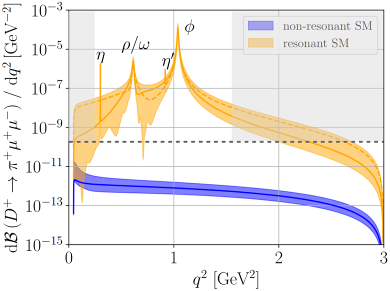
$$C_i'^{\,\text{SM}} = C_S^{\text{SM}} = C_T^{\text{SM}} = C_{T5}^{\text{SM}} = C_{10}^{\text{SM}} = 0$$

Rock stars of charm physics!
Any observable proportional to these WCs is a null test!

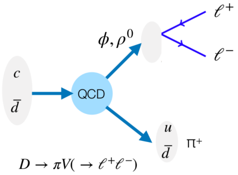
5. $\langle O_i(\mu_{\text{low}})\rangle$ from non-perturbative techniques (Lattice, LCSR, ...)

6. Include resonances: Breit–Wigner distributions + exp. data.

Rare semileptonic charm $c \to u\,\ell^+\ell^-$ decays



Dominated by resonances!



$$\mathcal{B}(D \to \pi\,\ell^+\ell^-)_{\mathrm{SM}} \approx \mathcal{B}(D \to \pi V(\to \ell^+\ell^-))$$

- **Current data still allows for large NP effects at large q^2**

$$\mathcal{B}(D^+ \to \pi^+\mu^+\mu^-) < 6.7 \cdot 10^{-8}\ (90\%\ \mathrm{C.L.})$$

- **Allowing to get bounds on WCs ($\mathcal{B}(D^+ \to \mu^+\mu^-) < 2.9 \cdot 10^{-9}\ (90\%\ \mathrm{C.L.})$)**

$$|C_7| \lesssim 0.3,\ |C_9^{(\prime)}| \lesssim 0.9,\ |C_{10}^{(\prime)}| \lesssim 0.6,\ |C_{S,P}^{(\prime)}| \lesssim 0.06,\ |C_{T,T5}| \lesssim 1.6$$

- **NP searches in BRs are difficult, and clearly are not the way to go!**
- **Can we extract something positive from BRs? YES, with more data model parameters (a_j, δ_j) can be constrained and the model can be improved!**

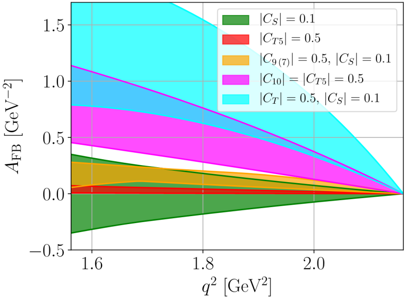
Null tests the way to go! Angular observables

- **Lepton forward-backward asymmetry (many more ...)**

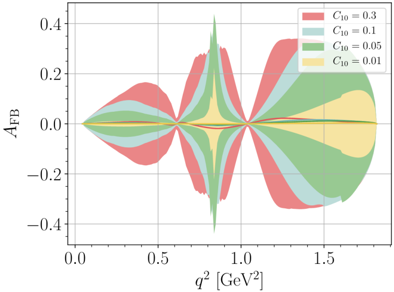
$$A_{FB}(q^2) \propto \left[\int_0^1 - \int_{-1}^0\right] \frac{d^2\Gamma}{dq^2 d\theta_{\ell P}}$$

- **Linear dependence with C_i', $C_{S,T,T5,10}$ $\rightarrow$ $A_{FB}^{SM}(q^2) \approx 0$**

$D_s^+ \rightarrow K^+ \mu^+ \mu^-$ (1909.11108)



$\Lambda_c \rightarrow p \mu^+ \mu^-$ (2107.13010)



Any signal is NP!

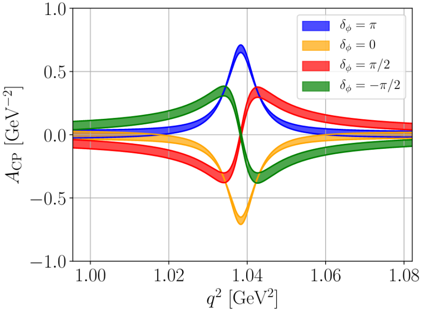
Next stop, CP-asymmetries!

$$A_{\mathrm{CP}}(q^2) \propto \frac{d\Gamma}{dq^2} - \frac{d\bar{\Gamma}}{dq^2}$$

Let's get benefit from resonances! (1208.0759)

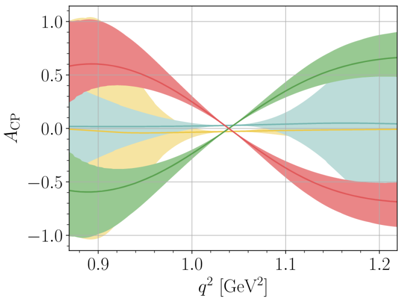
- **Linear dependence with $\mathrm{Im}[C_i^{\mathrm{NP}}] \times \mathrm{Im}[C_{9,P}^{\mathrm{R}}] \rightarrow$** $A_{\mathrm{CP}}^{\mathrm{SM}}(q^2) \approx 0$

$D_s^+ \rightarrow K^+ \mu^+ \mu^-$ (1909.11108)



$C_9 = 0.1 \exp(i\pi/4)$, $q^2 \in [(m_\phi - 5\,\Gamma_\phi)^2, (m_\phi + 5\,\Gamma_\phi)^2]$

$\Lambda_c \rightarrow p\, \mu^+ \mu^-$ (2107.13010)



$C_9 = 0.5 \exp(i\pi/4)$, $q^2 \in [(m_\phi - 5\,\Gamma_\phi)^2, (m_\phi + 5\,\Gamma_\phi)^2]$

Any signal is CP-violating NP!

LU ratios

- LU can be probed in $c \to u\,\ell^+\ell^-$ (same as B decays)

$$R_P^D = \frac{\int_{q^2_{\text{min}}}^{q^2_{\text{max}}} \frac{d\mathcal{B}(D \to P\mu^+\mu^-)}{dq^2} dq^2}{\int_{q^2_{\text{min}}}^{q^2_{\text{max}}} \frac{d\mathcal{B}(D \to Pe^+e^-)}{dq^2} dq^2}$$

- Same kinematical limits → Cancellation of had. uncertainties!
- Well control of SM prediction: $R_P^D|_{\text{SM}} \approx 1$
- e.g. $D^+ \to \pi^+\,\ell^+\ell^-$ 1909.11108, see 1805.08516 ($D \to P_1 P_2\,\ell^+\ell^-$)
  - full q^2: insensitive to NP.
  - low q^2: poor knowledge of resonances → sizable uncertainties.
  - high q^2: induce significant NP effects.

	SM	$\lvert C_9\rvert = 0.5$	$\lvert C_{10}\rvert = 0.5$	$\lvert C_9\rvert = \pm\lvert C_{10}\rvert = 0.5$	$\lvert C_{S(P)}\rvert = 0.1$	$\lvert C_T\rvert = 0.5$	$\lvert C_{T5}\rvert = 0.5$
full q^2	$1.00 \pm \mathcal{O}(10^{-2})$	SM-like	SM-like	SM-like	SM-like	SM-like	SM-like
low q^2	$0.95 \pm \mathcal{O}(10^{-2})$	$\mathcal{O}(100)$	$\mathcal{O}(100)$	$\mathcal{O}(100)$	$0.9 \ldots 1.4$	$\mathcal{O}(10)$	$1.0 \ldots 5.9$
high q^2	$1.00 \pm \mathcal{O}(10^{-2})$	$0.2 \ldots 11$	$3 \ldots 7$	$2 \ldots 17$	$1 \ldots 2$	$1 \ldots 5$	$2 \ldots 4$

Testing LFV with $c \to u\,\ell^+\ell'^-$ decays

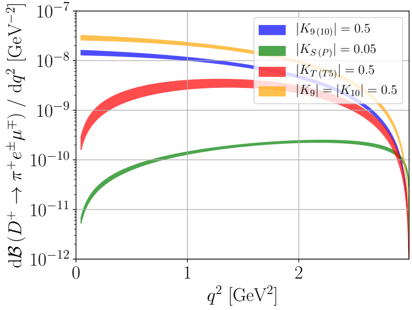
- **Forbidden in SM! Any signal is LFV NP!**

- **Experimental limits (90% C.L.)** (2011.00217, 1107.4465)

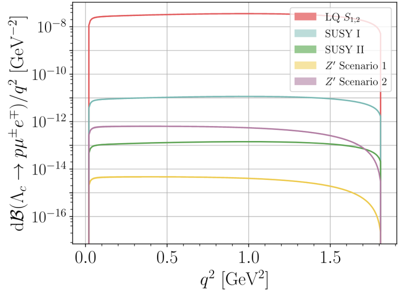
$$\mathcal{B}(D^+ \to \pi^+\, e^{+(-)}\mu^{-(+)})_{\text{LHCb}} < 2.1(2.2)\cdot 10^{-7}$$

$$\mathcal{B}(\Lambda_c \to p\, e^{+(-)}\mu^{-(+)})_{\text{Babar}} < 9.9\,(19)\cdot 10^{-6}$$

1909.11108



2107.13010



Dineutrino modes $c \to u\,\nu\bar{\nu}$

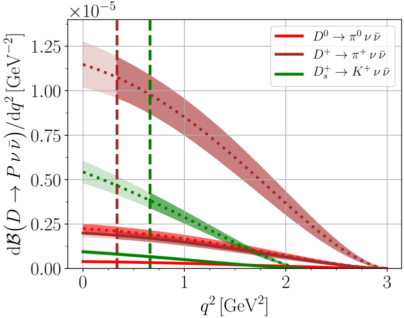
- **Extremely GIM-suppressed in the SM** (hep-ph/0112235, 0908.1174)

$$\mathcal{B}(D \to \pi\nu\bar{\nu})_{\mathrm{SM}} \sim 10^{-16}!$$

- **Only experimental information on (90% C.L.)** (1611.09455, 2112.14236)

$$\mathcal{B}(D^0 \to \nu\bar{\nu}) < 9.4 \cdot 10^{-5},\; \mathcal{B}(D^0 \to \pi^0\nu\bar{\nu}) < 2.1 \cdot 10^{-4}$$

2010.02225



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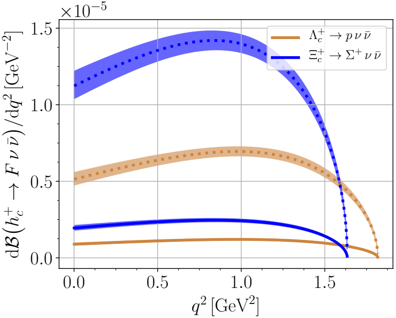
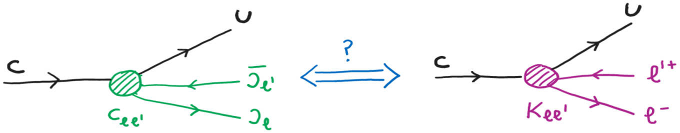


Can we get complementary information on LFV from dineutrino modes?

ℓ and ν_ℓ (with $\ell = e, \mu, \tau$) belong to same **SU(2)$_L$ doublet** in the SM.



$$\begin{pmatrix} c_{ee} & c_{e\mu} & c_{e\tau} \\ c_{\mu e} & c_{\mu\mu} & c_{\mu\tau} \\ c_{\tau e} & c_{\tau\mu} & c_{\tau\tau} \end{pmatrix}$$

Neutrino flavor not tagged!

$$\mathcal{B}(c \to u\, \nu\bar{\nu}) = \sum_{\ell,\ell'} \mathcal{B}(c \to u\, \nu_\ell \bar{\nu}_{\ell'})$$

LU, cLFC or general:

$$\mathcal{B}(c \to u\, \nu\bar{\nu}) \sim \frac{1}{3} \sum_{\ell,\ell'} c_{\ell\ell'}$$

$$\begin{pmatrix} k_{ee} & k_{e\mu} & k_{e\tau} \\ k_{\mu e} & k_{\mu\mu} & k_{\mu\tau} \\ k_{\tau e} & k_{\tau\mu} & k_{\tau\tau} \end{pmatrix}$$

Charged leptons tagged!

LU: $R_H \sim \frac{\mathcal{B}(c \to u\, \mu^+ \mu^-)}{\mathcal{B}(c \to u\, e^+ e^-)} \sim 1 + k_{\mu\mu} - k_{ee}$

cLFC or general: $\mathcal{B}(c \to u\, \ell'^+ \ell^-) \sim k_{\ell\ell'}$

Is there a link between $c_{\ell\ell'}$ and $k_{\ell\ell'}$?

Low-energy $|\Delta c| = |\Delta u| = 1$ EFT description

$$c \to u\,\nu_\ell \bar{\nu}_{\ell'} \quad \overset{?}{\Longleftrightarrow} \quad c \to u\,\ell^- \ell'^+$$

$$\mathcal{H}_{\text{eff}}^{\nu_\ell \bar{\nu}_{\ell'}} = -\frac{4\,G_F}{\sqrt{2}} \frac{\alpha}{4\pi} \sum_k \mathcal{C}_k^{U\ell\ell'}\, Q_k^{U\ell\ell'} \qquad \mathcal{H}_{\text{eff}}^{\ell^- \ell'^+} = -\frac{4\,G_F}{\sqrt{2}} \frac{\alpha}{4\pi} \sum_k \mathcal{K}_k^{U\ell\ell'}\, O_k^{D\ell\ell'}$$

Only two operators (no RH neutrinos like SM) **Further operators non-connected**

$$Q_{\mathrm{L\,(R)}}^{U\ell\ell'} = (\bar{u}_{L\,(R)} \gamma_\mu c_{L\,(R)})\,(\bar{\nu}_{\ell'\,L} \gamma^\mu \nu_{\ell\,L}) \qquad O_{\mathrm{L\,(R)}}^{U\ell\ell'} = (\bar{u}_{L\,(R)} \gamma_\mu c_{L\,(R)})\,(\bar{\ell}'_L \gamma^\mu \ell_L)$$

...

Dineutrino BR is obtained via an incoherent neutrino flavor sum:

$$\mathcal{B}\,(c \to u\,\nu\bar{\nu}) = \sum_{\ell,\ell'} \mathcal{B}\,(c \to u\,\nu_\ell \bar{\nu}_{\ell'}) \sim \sum_{\ell,\ell'} \left| \mathcal{C}_L^{U\ell\ell'} \pm \mathcal{C}_R^{U\ell\ell'} \right|^2$$

$\mathcal{C}^P$ and $\mathcal{K}^P$ in the mass basis. $P = D$ $(P = U)$ $\to$ down-quark sector (up-quark sector).

Correlate neutrinos and charged leptons with $\mathrm{SU}(2)_L$

Lowest order $\mathrm{SU}(2)_L \times \mathrm{U}(1)_Y$–invariant effective theory 1008.4884

$$\mathcal{L}^{\mathrm{LO}}_{\mathrm{SMEFT}} \supset \frac{C^{(1)}_{\ell q}}{v^2}\bar{Q}\gamma_\mu Q\,\bar{L}\gamma^\mu L + \frac{C^{(3)}_{\ell q}}{v^2}\bar{Q}\gamma_\mu \tau^a Q\,\bar{L}\gamma^\mu \tau^a L + \frac{C_{\ell u}}{v^2}\bar{U}\gamma_\mu U\,\bar{L}\gamma^\mu L + \frac{C_{\ell d}}{v^2}\bar{D}\gamma_\mu D\,\bar{L}\gamma^\mu L$$

1. **Writing in $SU(2)_L$-components:** ($C \to$ dineutrinos and $K \to$ dileptons in the gauge basis)

$$C_L^U = K_L^D = \frac{2\pi}{\alpha}\left(C^{(1)}_{\ell q} + C^{(3)}_{\ell q}\right), \quad C_R^U = K_R^U = \frac{2\pi}{\alpha}C_{\ell U}.$$

2. **Mass basis:** $\boxed{\mathcal{C}_L^U = W^\dagger\,\mathcal{K}_L^D\,W + \mathcal{O}(\lambda), \qquad \mathcal{C}_R^U = W^\dagger\,\mathcal{K}_R^U\,W}$

3. **BR is independent of PMNS matrix!**

$$\mathcal{B}(c \to u\,\nu\bar{\nu}) \sim \sum_{\ell,\ell'}\left|\mathcal{C}_L^{U\ell\ell'} \pm \mathcal{C}_R^{U\ell\ell'}\right|^2 = \mathrm{Tr}\left[(\mathcal{C}_L^U \pm \mathcal{C}_R^U)(\mathcal{C}_L^U \pm \mathcal{C}_R^U)^\dagger\right]$$

$$= \mathrm{Tr}\left[W^\dagger(\mathcal{K}_L^D \pm \mathcal{K}_R^U)W\,W^\dagger(\mathcal{K}_L^D \pm \mathcal{K}_R^U)^\dagger W\right] = \sum_{\ell,\ell'}\left|\mathcal{K}_L^{D\ell\ell'} \pm \mathcal{K}_R^{U\ell\ell'}\right|^2 + \mathcal{O}(\lambda)$$

Prediction of dineutrino rates for different leptonic flavor structures $\mathcal{K}^{\ell\ell'}_{L,R}$ can be probed with lepton-specific measurements!

Possible leptonic flavor structures for $\mathcal{K}_{L,R}^{\ell\ell'}$

$$\mathcal{B}(c \to u\,\nu\bar{\nu}) \sim \sum_{\ell,\ell'} |\mathcal{K}_L^{D\ell\ell'} \pm \mathcal{K}_R^{U\ell\ell'}|^2$$

i) ***Lepton-universality* (LU).**

$$\begin{pmatrix} k & 0 & 0 \\ 0 & k & 0 \\ 0 & 0 & k \end{pmatrix}$$

ii) ***Charged lepton flavor conservation* (cLFC).**

$$\begin{pmatrix} k_{ee} & 0 & 0 \\ 0 & k_{\mu\mu} & 0 \\ 0 & 0 & k_{\tau\tau} \end{pmatrix}$$

iii) $\mathcal{K}_{L,R}^{\ell\ell'}$ **arbitrary.**

$$\begin{pmatrix} k_{ee} & k_{e\mu} & k_{e\tau} \\ k_{\mu e} & k_{\mu\mu} & k_{\mu\tau} \\ k_{\tau e} & k_{\tau\mu} & k_{\tau\tau} \end{pmatrix}$$

Dineutrino branching ratios

$$\mathcal{B} = A_+ \, x^+ + A_- \, x^- , \qquad x^{\pm} = \sum_{\ell,\ell'} \left| \mathcal{C}_L^{U\ell\ell'} \pm \mathcal{C}_R^{U\ell\ell'} \right|^2$$

→ Long-distance dyn. & kinematics $A_\pm$: **LCSR (low q^2) + Lattice (high q^2)**

→ Short-distance dynamics $x^\pm$: **WCs (BSM)**

→ Excellent complementarity $\mathcal{B}$:

- $A_- = 0$ in $D \to P \nu\bar{\nu}$ decays.
- $A_- > A_+$ in $D \to P_1 P_2 \nu\bar{\nu}$ decays.
- $A_- = A_+$ in inclusive D decays.

$D \to F$	A_+ $[10^{-8}]$	A_- $[10^{-8}]$
$D^0 \to \pi^0$	0.9	0
$D^+ \to \pi^+$	3.6	0
$D^0 \to \pi^0\pi^0$	0	0.2
$D^0 \to \pi^+\pi^-$	0	0.4
$D^0 \to X$	2.2	2.2
$D^+ \to X$	5.6	5.6

Upper limits on dineutrino modes can probe LU!

- **Limits from high-p_T & charged dilepton D and K-decays (†):**[1]

	$\lvert\mathcal{K}_A^{P\ell\ell'}\rvert$	ee	$\mu\mu$	$\tau\tau$	$e\mu$	$e\tau$	$\mu\tau$
$s\,d$	$\lvert\mathcal{K}_L^{D\ell\ell'}\rvert$	$5 \cdot 10^{-2\dagger}$	$1.6 \cdot 10^{-2\dagger}$	6.7	$6.6 \cdot 10^{-4\dagger}$	6.1	6.6
$c\,u$	$\lvert\mathcal{K}_R^{U\ell\ell'}\rvert$	2.9	$0.9^{\dagger}$	5.6	1.6	4.7	5.1

- $x^{\pm} < 2\,x \,,\; x = \sum_{\ell,\ell'} \left(\lvert\mathcal{K}_L^{D\ell\ell'}\rvert^2 + \lvert\mathcal{K}_R^{U\ell\ell'}\rvert^2\right) + \mathcal{O}(\lambda) = \sum_{\ell,\ell'} R^{\ell\ell'} + \mathcal{O}(\lambda)$

$\boldsymbol{x = 3\,R^{\mu\mu} \lesssim 2.6\,,}$ **(Lepton Universality)** **LU is fixed by muons.**

$\boldsymbol{x = R^{ee} + R^{\mu\mu} + R^{\tau\tau} \lesssim 156\,,}$ **(charged Lepton Flavor Conservation)**

$\boldsymbol{x = R^{ee} + R^{\mu\mu} + R^{\tau\tau} + 2\,(R^{e\mu} + R^{e\tau} + R^{\mu\tau}) \lesssim 655.}$

[1] 2002.05684, 2003.12421 & 2007.05001 (†)

Dineutrino branching ratios upper limits

$h_c \to F$	$\mathcal{B}^{\text{max}}_{\text{LU}}$ $[10^{-7}]$	$\mathcal{B}^{\text{max}}_{\text{cLFC}}$ $[10^{-6}]$	$\mathcal{B}^{\text{max}}$ $[10^{-6}]$
$D^0 \to \pi^0$	**0.5**	**2.8**	**12**
$D^+ \to \pi^+$	1.9	11	47
$D^0 \to \pi^0\pi^0$	0.1	0.7	2.8
$D^0 \to \pi^+\pi^-$	0.2	1.3	5.4
$\Lambda_c^+ \to p^+$	1.4	8.4	35
$\Xi_c^+ \to \Sigma^+$	2.7	17	70

$\mathcal{B}(D^0 \to \pi^0 \nu\bar{\nu}) < 2.1 \cdot 10^{-4}$ from BES III is about one order of magnitude away from our predictions 2112.14236

Outlook

- ⋆ Window to explore FCNCs in the up-sector.
- ⋆ Unique phenomenology (strong GIM suppression).
- ⋆ Clean null test observables can probe NP.
- ⋆ Plenty of opportunities:
  - Angular observables
  - CP-asymmetries
  - LU ratios
  - LFV
  - Dineutrino modes
- ⋆ Well-suited for Belle II.

Thank you for your attention!

$\delta\mathcal{B}$ vs $\mathcal{B}$: exp. projections and theo. predictions

2010.02225