

Discussion on (Heavy) Flavor Physics

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(Flavor-) Breaking News

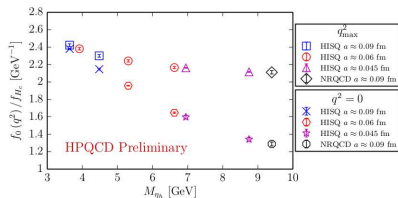
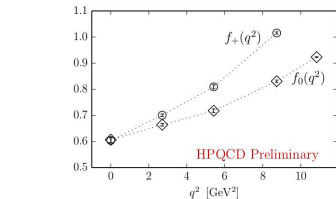
- CMS update on $h \rightarrow \tau\mu$ [CMS 2016]
 - $\text{Br}(h \rightarrow \tau\mu) < 1.51\%$ (CMS, Run I)
 - $\text{Br}(h \rightarrow \tau\mu) < 1.43\%$ (ATLAS, Run I)
 - $\text{Br}(h \rightarrow \tau\mu) < 1.20\%$ (CMS, Run II “first look”)
- Reduces global significance to $\approx 2\sigma$

SM Input and Future Facilities

- Measure SM input parameters from tree-level
 - $\gamma/\phi_3, |V_{ub}|, |V_{cb}|$ to 1%
 - Can there be NP in tree level?
- Measure $\text{Br}(B_d \rightarrow \mu^+ \mu^-)$; $b \rightarrow s\nu\bar{\nu}$; $h \rightarrow cc$; ...
- Timeline:
 - LHCb: 8/fb by 2018; 30/fb by 2023; 50/fb by 2030
 - Belle II: Start early / late 2018. 50/ab by 2024
 - ATLAS, CMS: 150/fb by 2018; 300/fb in 2023; 3000/fb by ...
 - BES: Physics program until beyond 2020
 - Future machines: FCC-ee (lepton flavor, $B \rightarrow K^* \tau\tau$, ...)
- Kaon (NA62, KOTO) and Lepton Physics

Theory / Lattice Progress

- Decay constants and form factors
 - Beauty; status, and progress?
 - Charm; status, and progress?
- Hadronic decays
 - Can we extend progress in K physics to charm?
 - $D \rightarrow \pi\pi, KK$ – Multi-channel extension of Lellouch-Lüscher
- What about QED?
 - Can soft photon emission be relevant (e.g. for “anomalies”)
 - Status of QED on the lattice?



Preliminary results for $B_c \rightarrow \eta_c$ form factors:

Upper Form factors $f_+(q^2)$ and $f_0(q^2)$;

Lower Extrapolation in heavy quark mass m_h for ratio of $f_0(q_{\text{max}})/f_{H_c}$ and $f_0(0)/f_{H_c}$.

Conclusions:

1. Encouraging agreement between NRQCD and heavy HISQ;
2. Promising $B \rightarrow J/\Psi$ results allow new determination of $|V_{cb}|$;
3. Improved renormalisation parameters for $B \rightarrow D^{(*)}$ decays.

A. Lytle (HPQCD Collaboration), Beauty 2016.

Anomalies / Puzzles

- $R_K \equiv \frac{\mathcal{B}(B^+ \rightarrow K^+ \mu^+ \mu^-)}{\mathcal{B}(B^+ \rightarrow K^+ e^+ e^-)} \Big|_{[1,6] \text{ GeV}} = 0.745_{-0.047}^{+0.090} + 0.036$ [LHCb 1406.6482]
 - Can QED effects be important?
- $R_{D^*} \equiv \frac{\mathcal{B}(\bar{B} \rightarrow D^* \tau^- \bar{\nu}_\tau)}{\mathcal{B}(\bar{B} \rightarrow D^* \ell^- \bar{\nu}_\ell)} = 0.316 \pm 0.016 \pm 0.010$ [HFAG '16]
 - Can we explain this?
- $|V_{ub}|$ & $|V_{cb}|$ inclusive vs. exclusive
 - RH currents?? Other explanations?
- Rare B decays ($B \rightarrow K^* \mu^+ \mu^- - P'_5, \dots$)
 - Will we ever agree on a theory prediction?
- Tensions in global UT fit?

Importance of Kaon Physics

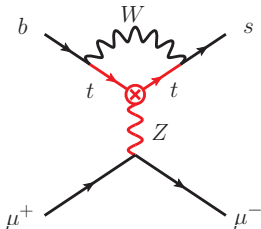
- Rare $K \rightarrow \pi\nu\bar{\nu}$ decays among the cleanest probes of NP
- CP violation
 - Huge theoretical progress in recent years, mainly lattice
 - Precise B_K is now standard
 - $\Delta M_K, \epsilon_K$: Inclusion of dynamical charm?
 - ϵ' : Hadronic matrix elements
- Prospects?
- An “Andrzej question”:
 - Let's say we don't find NP at LHC. Can we control the theory well enough to be sure there is some NP in K physics?

NP

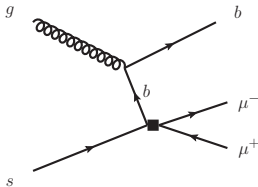
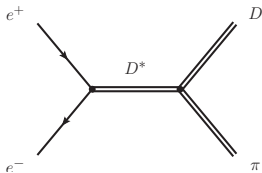
- NP – NonPerturbative or New Physics?
- $B \rightarrow K^* \ell \ell$
 - Power corrections, non-factorizable corrections, quark-hadron duality, charm resonances. . .
- Charm
 - $1/m_c$ expansion expected to fail
 - Use data – $SU(3)$ and subgroups: Sum rules
 - Does $1/N_c$ work for charm?

Connection to High p_T – SM-EFT

- What can EFT above e/w scale tell us about flavor?
 - Difference between $SU(2) \times U(1)$ SM-EFT and $EW\chi L$?
 - Additional relations among operators [\[1407.7044\]](#)
- Can flavor anomalies be related to flavor-diagonal new physics?



Connection to High p_T – Direct Searches



- Can we test flavor in high- p_T observables?
 - Flavor violation in Higgs decays; FCNC top decays
 - Search for (flavored) exotic states
 - Produce mesons via FCNC [1509.07123]
 - Other new ideas?

Why Flavor? – Physics Implications

- Is there a realistic chance to solve the “flavor puzzle”?
 - Flavor symmetries?
 - Test specific models?
- Relation to other fields?
- E.g., can we test electroweak baryogenesis?
 - Are the CP phases we test in flavor connected to the BAU?
 - Can we test CPV in Higgs sector using flavor observables?
 - Or do we need other probes (EDMs, ...)?
- E.g. dark matter
 - Bounds on light DM from rare decays
 - “Dark Υ ” [1510.05020]