Key measurements for future flavor physics

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Where are we?

The BIG question:

Can we see BSM?

What about QCD?

- Past: Problem. Need to overcome QCD in order to probe the weak interaction
- Future: Learn about QCD using the weak interaction
Are we seeing the tail?
The Zoltan plot

The diagram shows a plot of significance (-\sigma) on the x-axis against f (theoretical cleanliness) on the y-axis. The plot includes the following points:

- CPV in \( \tau \)
- \( B \rightarrow K^e e^- / B \rightarrow K \mu^\pm \mu^- \)
- D0 \( \mu \mu \) CP asym
- \( B \rightarrow D^{(*)}\tau\nu \)
- \( B \rightarrow K^* \mu^\pm \mu^- \) angular
- \( |V_{cb}| \) incl/excl
- \( |V_{ub}| \) incl/excl
- g-2
- \( \epsilon'/\epsilon \)

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What next?

My personal list. Please let me know the missing items

- Keep going
- CPV in Charm
- Strong phases
- Baryons
- Multi-body decays
Keep going
“Near” future

A lot of things that are “in the making” and we like to make sure we do the best:

- $B \rightarrow DK$. A lot to do (can unbinned do better?)
- Anomalies: $R_D, R_K, \ldots$
- “Standard” CPV. We need to think about isospin breaking
- Rare kaon decays, $K \rightarrow \pi \nu \bar{\nu}$
CPV in charm
CPV in charm

A big deal...

- Is it SM? Or, better to ask: Is it BSM?
- Assuming it is SM, we learn about QCD
- My best way to summarize the situation is: “It is hard to argue that it is BSM”

we learn

- Charm is not heavy
- Flavor SU(3) is good
How to further test CPV in charm?

We need to keep checking if it is BSM

- Get $a_{CP}$ for each mode
- In the SM it comes from $\Delta U = 0$. Look for CPV in $\Delta U = 1$, like in $D^+ \rightarrow \pi^+\pi^0$
- Get more information on strong phases
- Looking for related decays, for example, $D \rightarrow KK\pi$
Charm baryons?

Look at

\[ \Lambda_c \rightarrow pK^+K^- \quad \Lambda_c \rightarrow p\pi^+\pi^- \]

Same diagrams as \( D \rightarrow K^+K^- \) and \( D \rightarrow \pi^+\pi^- \)

In the SU(3) limit

\[ a_{CP}(D \rightarrow KK) = -a_{CP}(D \rightarrow \pi\pi) \]

The spectators are important. In the SU(3) limit

\[ a_{CP}(\Lambda_c \rightarrow pK^+K^-) \neq a_{CP}(\Lambda_c \rightarrow p\pi^+\pi^-) \]

Measuring the asymmetries in baryons can teach us about QCD
Strong phases
Strong phases

We like to get as many as we can

- Important in many cases: $B \to D K$, CPV in charm
- Getting them out of correlated decays where the decaying state is
  
  \[ a |D\rangle + b |\bar{D}\rangle. \]
- So far done at tau-charm factories $\psi(3770) \to D \bar{D}$
- Can we do it at LHCb and/or Belle-II?
  - From $\psi(3770)$
  - From $B \to D \bar{D}$ decays
  - From $B \to D \bar{D}X$ decays
Baryons
Baryons open a new set of probes to QCD

- We already have indications for CPV in $\Lambda_b$ decays
  - We know the weak phase, we can learn about QCD
  - We have more variables to play with

- Polarization: Can help us probe the Dirac structure of operators
  - At high energy, we can use it to get $b$ polarization
  - At Belle-II, get $c$ polarization
Multi-body decays
Multi-body decays

A lot already has been done, and much more to do

- We can use much more data
- CPV “without” strong phases
  - Take advantage of resonances (like in $B \to D^{**} \tau \nu$)
  - CP-odd angular correlations (triple products and more)
Conclusions
Conclusions

Win-win situation

- Hopefully, we will see BSM
- Even if not, we are learning about QCD