



# USQCD and Weak-Matrix Elements

Ruth Van de Water for the SPC  
USQCD All Hands' Meeting  
May 4, 2012

# Scientific Goals

- ◆ From the **USQCD HEP SciDAC-3 proposal**:
  - ❖ Obtain “precise calculations of the effects of the strong interactions on weak and electromagnetic transition amplitudes” needed to
    - ◆ obtain **elements of the CKM matrix**,
    - ◆ **test the Standard Model** in the quark-flavor sector, and
    - ◆ (ultimately) to determine the **underlying structure of whatever BSM theory is realized in nature**
  - ❖ **Support the US experimental high-energy physics program** at the energy and intensity frontiers by “improv[ing] the accuracy of QCD calculations to the point where they no longer limit what can be learned from high precision experiments that seek to test the Standard Model”

# SciDAC-3 Thrusts

- (1) “[I]mprove the errors on quantities for which results with fully-controlled errors exist, but for which the errors are still larger than or comparable to those from other sources”
- ◆ *E.g.*, Constraint on CKM unitarity triangle from  $\Delta M_s/\Delta M_d$  limited by uncertainty in  $B^0_{(d,s)}$ -mixing matrix elements
  - ◆ *E.g.*, Exclusive determination of  $|V_{ub}|$  limited by uncertainty in  $B \rightarrow \pi l \nu$  form factor (and disagrees with inclusive  $|V_{ub}|$  by  $>3\sigma$ )
- (2) “[E]xpand our program of calculations to meet the needs of upcoming intensity-frontier experiments, for example ... the Project X kaon program at Fermilab, LHCb, Belle II and SuperB.” *E.g.*,
- ◆ Long-distance contributions to neutral kaon mixing and  $K \rightarrow \pi \nu \bar{\nu}$  decays
  - ◆ Rare B decays such as  $B \rightarrow Kl^+l^-$
  - ◆ Long-distance contribution to  $D^0$ -meson mixing
  - ◆ Matrix elements for  $D \rightarrow \pi\pi$  and  $D \rightarrow KK$  decays

# 2012-2013 Project Requests

## ◆ **TYPE A:**

- ❖ Mackenzie: “B and D Meson Decays with Unquenched Improved Staggered Fermions”
- ❖ Mawhinney: “Pion and Kaon Physics from 2+1 flavor DWF Lattices with  $m_\pi = 140$  MeV and  $V=(5.5 \text{ fm})^3$ ”
- ❖ Shigemitsu: “High-Precision Heavy-Quark Physics”
- ❖ Sugar: “QCD with Four Flavors of Highly Improved Staggered Quarks”
- ❖ Witzel: “B-meson physics with domain-wall light quarks and relativistic heavy quarks”

## ◆ **TYPE B(-ISH):**

- ❖ Ishikawa: “Application of low-mode averaging to  $B^0 - \bar{B}^0$  mixing with static heavy quark and domain-wall light quarks”
- ❖ Sharpe: “Non-perturbative renormalization with improved staggered fermions”

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### Total Requests

- ❖ Shi ■ 27.9M Jpsi core-hours ANL BG/P (36% total ANL time)
  - ❖ Sug ■ 139.8M Jpsi core-hours clusters (49% total cluster time)
  - ❖ Wi ■ 786.8k GPU-hours (17% total GPU time)
- heavy quarks”

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# Topics Covered

## ◆ PION AND KAON PHYSICS

- ❖ Pseudoscalar decay constants and light-quark masses ([Mawhinney, Sharpe, Sugar](#))
- ❖  $B_K$  ([Mawhinney, Sharpe](#))
- ❖  $K \rightarrow \pi\pi$  matrix elements ([Mawhinney](#))
- ❖  $K \rightarrow \pi l \nu$  form factor ([Mackenzie](#))

## ◆ B AND D MESON PHYSICS

- ❖  $D_{(s)}$  meson leptonic decay constants and semileptonic form factors ([Mackenzie](#))
- ❖  $B_{(s)}$  meson decay constants and mixing matrix elements ([Ishikawa, Shigemitsu, Witzel](#))
- ❖  $B_{(s)}$  meson semileptonic form factors ([Mackenzie, Shigemitsu, Witzel](#))
- ❖  $D_{(s)}^*$  meson radiative and pionic decays ([Shigemitsu](#))

# Remarks from the SPC

- ◆ WME a large and successful component of the USQCD scientific program
  - ❖ Would be nice to see **more exploratory proposals** such as for long-distance contributions to  $K \rightarrow \pi \nu \bar{\nu}$  decays or  $D^0$ -meson mixing, or for  $D \rightarrow \pi\pi$  and  $D \rightarrow KK$  decay matrix elements
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Further comments?