USQCD intensity-frontier program: Perspective

Ruth Van de Water for the SPC

2013 USQCD All Hands' Meeting

Broad scientific goals

- Intensity-frontier program covers **quark-flavor physics and charged-lepton physics**
  (Also includes tests of fundamental physics with nucleons -- mostly funded by NP)

- **Role of USQCD is to support the US HEP experimental intensity-physics program** 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" — *USQCD HEP SciDAC-3 proposal*

- 2013 White Paper *"Lattice QCD at the Intensity Frontier"* outlines a program of calculations matched to experimental priorities

(5-year) physics program

(1) "Calculate ... new, more computationally demanding, matrix elements that are needed for the interpretation of planned (and in some cases old) experiments," *e.g.:*

- ϵ'/ϵ
- Muon g-2
- Long-distance contribution to D^0-meson mixing,
- Matrix elements for $D \to \pi\pi$ and $D \to KK$ decays

(2) "Improve the calculation of the matrix elements needed for the CKM unitarity fit," *e.g.:*

- $B^0_{(d,s)}$-mixing matrix elements
- $B \to \pi l \nu$ form factor
- $B \to D^* l \nu$ form factor

(3) Improve Standard-Model predictions for rare decays *(my addition), e.g.:*

- $K \to \pi \nu \bar{\nu}$
- $B \to K l^+ l^-$

2013-2014 project requests

- Aubin: “Hadronic contributions to the muon g-2 using staggered fermions”
- Christ: “Generating ensembles with 2+1 flavors of domain wall fermions”
- Izubuchi: “Hadronic vacuum polarization and hadronic light-by-light contributions to the muon anomalous magnetic moment using statistical error reduction techniques”
- Kelly: “Lattice Determination of the $\Delta I = 1/2$ $K \rightarrow \pi\pi$ Amplitude”
- Mackenzie: “CKM Physics from B, D, and K Mesons with HISQ Fermions”
- Mawhinney: “Pion and Kaon Physics from 2+1 Flavor DWF Lattices with m_pi = 140 MeV and V=(5.5 fm)^3, II”
- 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 at their physical mass and relativistic heavy quarks”

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- Total Requests (excludes zero-priority)
  - 374 M Jpsi core-hours ANL BG/Q (91% ANL full-priority time)
  - 146M Jpsi core-hours BNL BG/Q (126% BNL BG/Q time)
  - 150M Jpsi core-hours clusters (44% total cluster time)
  - 84M Jpsi core-hours GPUs (13% total GPU time)

  = 46% available USQCD resources
- i = 140
- Sugar: "QCD with Four Flavors of Highly Improved Staggered Quarks"
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Topics Covered

- **Pion and Kaon physics**
  - Pseudoscalar decay constants and light-quark masses (Mawhinney, Sugar)
  - K→πlν form factor (Mackenzie, Mawhinney)
  - K→ππ matrix elements (Kelly, Mawhinney)
- **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 (Mackenzie, Shigemitsu, Witzel)
  - $B_{(s)}$ meson semileptonic form factors (Mackenzie, Shigemitsu, Witzel)
- **MUON g-2**
  - Hadronic vacuum polarization (Aubin, Izubuchi)
  - Hadronic light-by-light (Izubuchi)

Strong points of 2013/14 IF proposals

- Precision of calculations will benefit greatly from **availability of physical pion masses** (both MILC HISQ and RBC/UKQCD DWF ensembles)

  ➡ Expect significant improvements in calculations needed to obtain CKM matrix elements and constrain the CKM unitarity triangle

- Given the aimed improvements in precision, effects of isospin-breaking, electromagnetism, and the dynamical charm quark cannot be neglected

  - Both MILC and RBC/UKQCD are **working on including EM effects**, either via quenched or dynamical simulations or QED reweighting

  - MILC **HISQ ensembles include dynamical charm**

- *Prospects for lattice-QCD calculation of ε'/ε with controlled errors very exciting!*

- Theoretical methods for hadronic vacuum-polarization contribution to muon g-2 in place, so calculation is ready for large-scale calculation with fine lattice spacings and physical pions!

Concerns about USQCD IF program

- Proposals largely focus on improving precision of existing quark-flavor calculations, and on simple "gold-plated" matrix elements
  - Only a single collaboration working on $K \to \pi\pi$ decays, despite their phenomenological importance
  - Only a single collaboration working on the hadronic light-by-light contribution to muon g-2, despite the critical need of the upcoming experiment
  - Would like to see **more exploratory proposals to develop new methods** such as dalternate approaches for the light-by-light contribution to muon g-2, long-distance contributions to rare kaon decays or D^0-meson mixing, or matrix elements of $D \to \pi\pi$ and $D \to KK$ decays (*please take advantage of new flexibility of class B proposals!!!*)
- The **US experimental HEP intensity-frontier program in the upcoming decade will be focused on charged leptons and neutrinos**
  - Perceived importance of quark-flavor physics will diminish in the eyes of the DOE
  - To stay relevant and maintain our funding, we *must think seriously about how we can aid experiments such as Mu2E, LBNE, …*

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Further comments?

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