LQCD-ext and LQCD-ARRA Projects
2011 Annual Review

Response to Questions

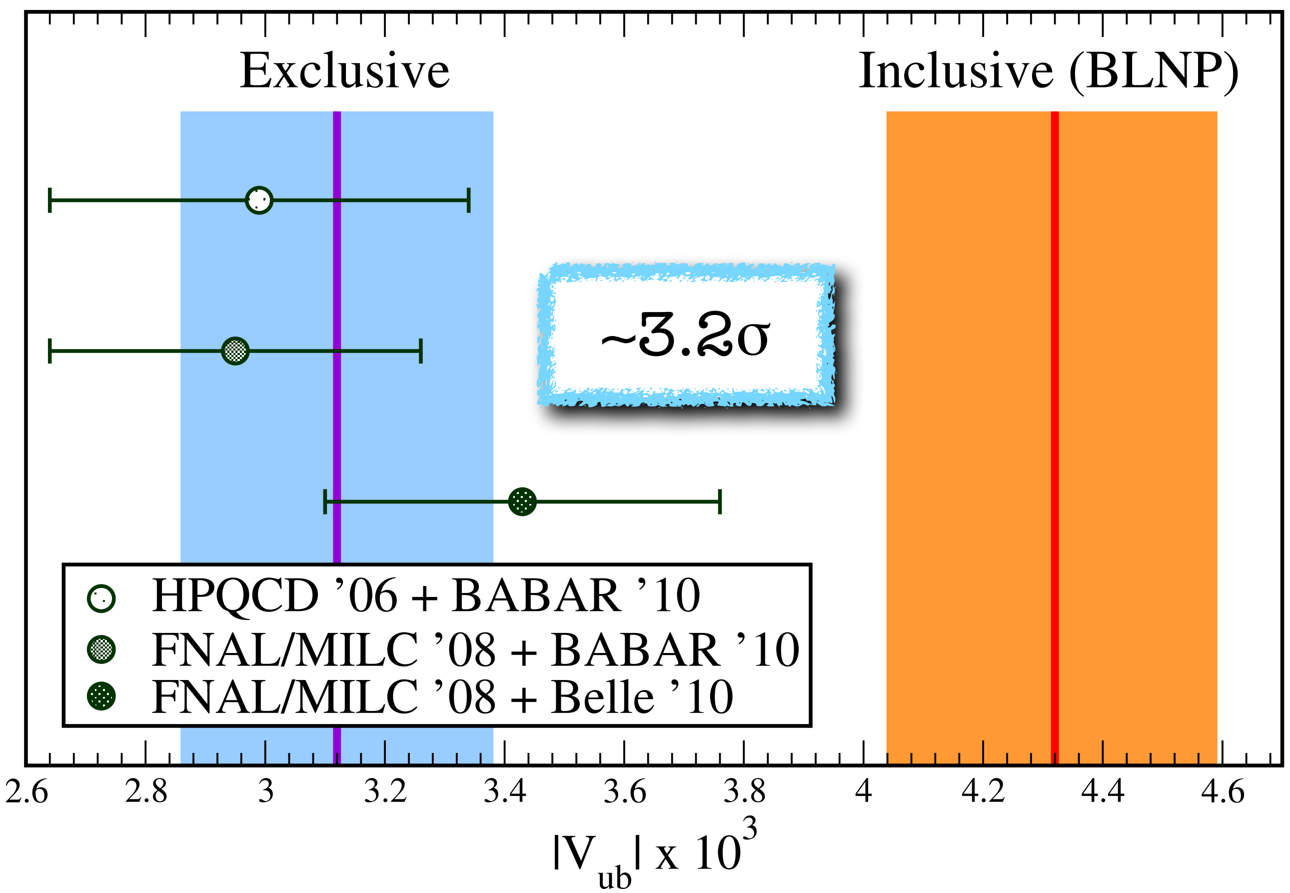
For the USQCD Collaboration
http://www.usqcd.org

LQCD-ext and LQCD-ARRA Projects
2012 Annual Review
Fermilab
May 16-17, 2012

1) What would be the top three physics priorities in each of the subject areas? What would be an example of a possible home run?

Each of the four physics speakers will give his own list of examples of top priorities from his area. We would get different answers from other physicists. It is the jobs of the SPC to balance among the many topics in forming each year's program.

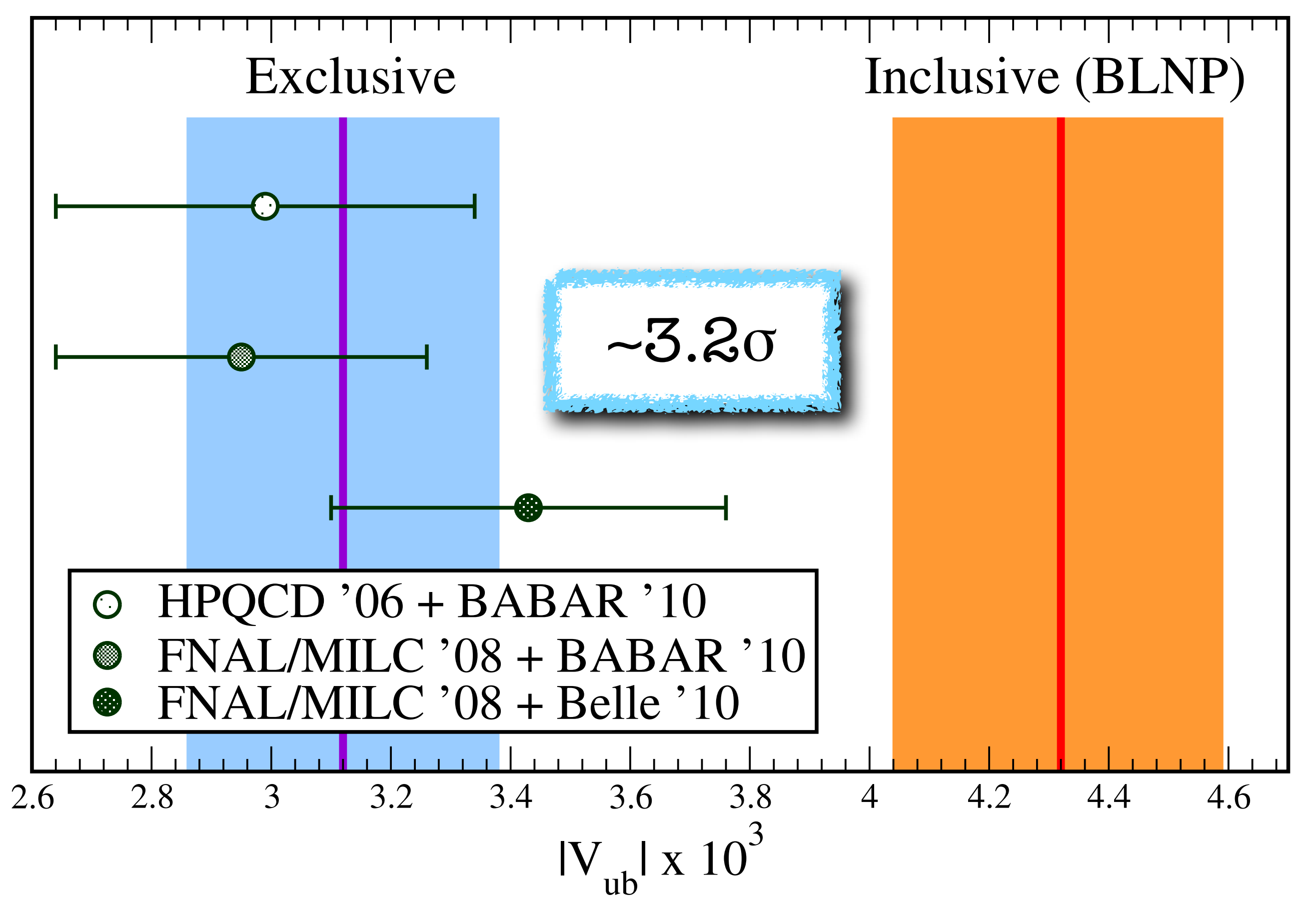
Top three priorities for lattice HEP



Top three priorities for lattice HEP

(1) $|V_{ub}|$

- Currently a >3σ tension between determinations of $|V_{ub}|$ from exclusive $B \to \pi l \nu$ decays and inclusive $B \to X_u l \nu$ decays
- Particularly worrisome because large deviations from Standard Model not expected in tree-level processes, so likely indicates underestimated uncertainties
- Lattice-QCD calculations of $B \to \pi l \nu$ & $B_s \to K l \nu$ can be used for independent determinations of $|V_{ub}|_{excl}$, while calculations of f_B are needed to interpret measurements of $B \to \tau \nu$ as determinations of $|V_{ub}|$



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(2) $|V_{cb}|$

- Limiting uncertainty in unitarity-triangle constraint from ϵ_K and in Standard-Model predictions for $K \to \pi\nu\nu$ is $A^4 \propto |V_{cb}|^4$
- Need lattice-QCD calculations of $B \to D l\nu$ & $B \to D^* l\nu$ form factors at nonzero recoil

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(3) Muon g-2

- Result of new Fermilab g-2 experiment can only be interpreted as constraint on or discovery of new physics if the Standard-Model prediction is reliable and with sufficiently small uncertainties
- Need lattice-QCD calculation of hadronic light-by-light & hadronic vacuum polarization contributions

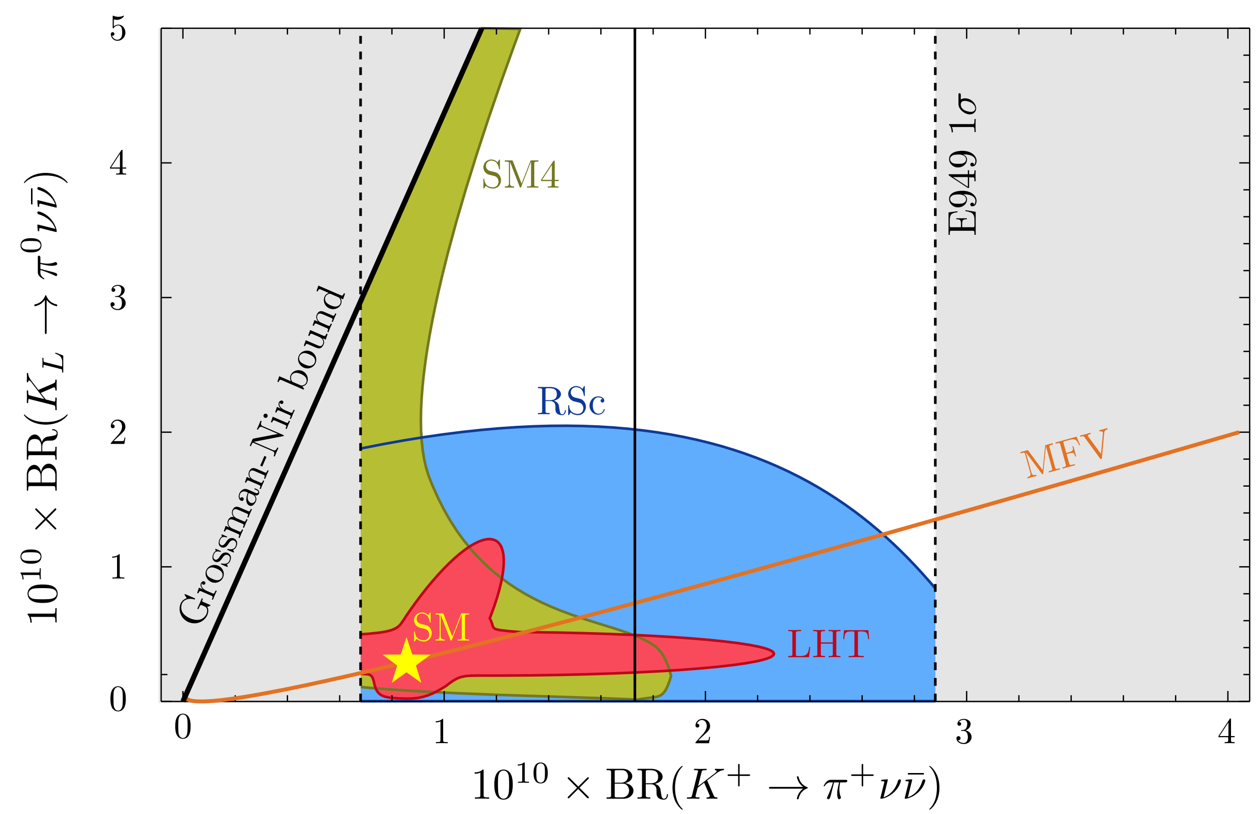
A possible "home-run" for lattice HEP?

- K → πνν decays can receive large new-physics contributions in both SUSY and many non-SUSY scenarios

	LHT	RSc	4G	2HDM	RHMFV
$D^0 - \bar{D}^0$ (CPV)	★★★	★★★	★★	★★	
ϵ_K	★★	★★★	★★	★★	★★
$S_{\psi\phi}$	★★★	★★★	★★★	★★★	★★★
$S_{\phi K_S}$	★	★	★★		
$A_{CP}(B \to X_s\gamma)$	★		★		
$A_{7,8}(K^*\mu^+\mu^-)$	★★	★	★★		
$B_s \to \mu^+\mu^-$	★	★	★★★	★★★	★★
$K^+ \to \pi^+\nu\bar{\nu}$	★★★	★★★	★★★		★★
$K_L \to \pi^0\nu\bar{\nu}$	★★★	★★★	★★★		★★
$\mu \to e\gamma$	★★★	★★★	★★★		
$\tau \to \mu\gamma$	★★★	★★★	★★★		
$\mu + N \to e + N$	★★★	★★★	★★★		
d_n	★	★★★	★	★★★	
d_e	★	★★★	★	★★★	
$(g-2)_\mu$	★	★★	★		

Table 3. "DNA" of flavour physics effects for the most interesting observables in a selection of non-SUSY models. ★★★ signals large NP effects, ★★ moderate to small NP effects and ★ implies that the given model does not predict visible NP effects in that observable. Empty spaces reflect my present ignorance about the given entry.

[Buras, Acta Phys.Polon, B41:2487-2561,2010]



[D. Straub, arXiv:1012.3893 (CKM 2010)]

- Improved lattice-QCD calculations of $|V_{cb}|$ plus an observed experimental excess with respect to the Standard-Model prediction **could definitely establish the presence of new physics in the flavor sector at the >5σ level**

Other possible lattice-QCD "home-runs"

5σ new-physics discovery also possible and well-motivated in other quantities where the Standard-Model predictions depend critically on nonperturbative matrix elements from lattice QCD

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- Determining that the experimental value of $\varepsilon'_K/\varepsilon_K$ is inconsistent with the Standard Model

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(1) $\varepsilon'_K/\varepsilon_K$

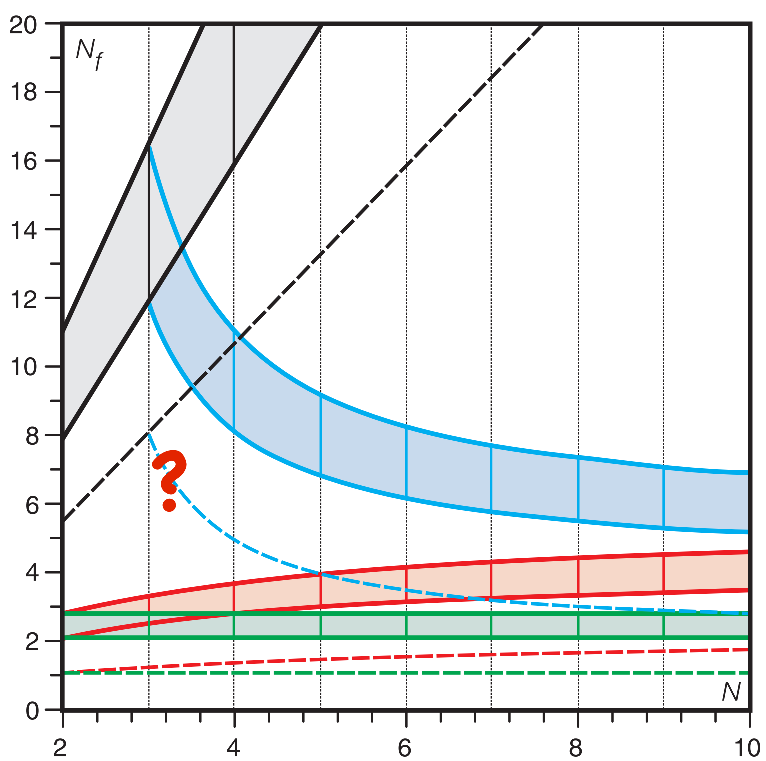
- Determining that the experimental value of $\varepsilon'_K/\varepsilon_K$ is inconsistent with the Standard Model

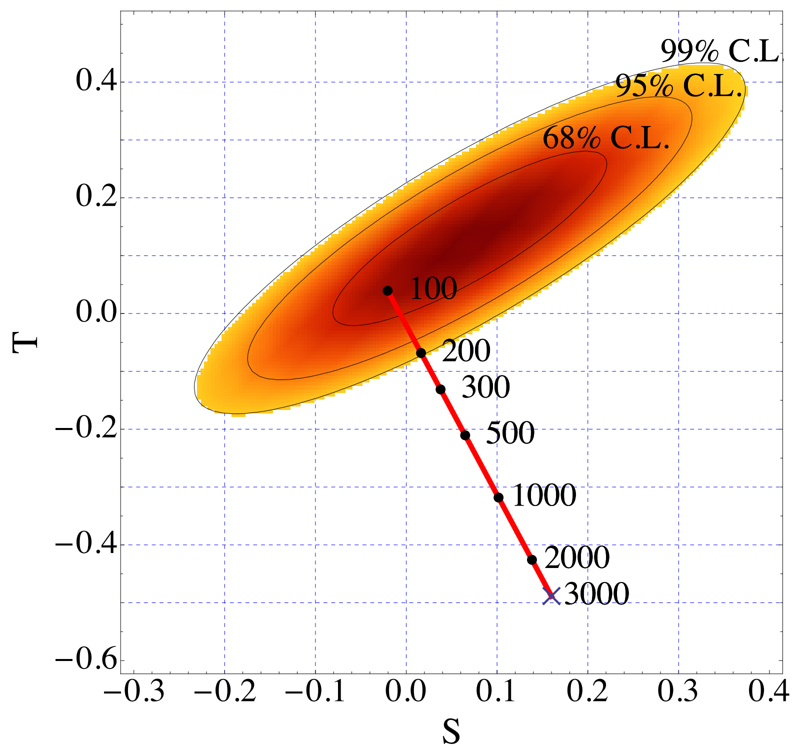
(2) Muon g-2

- Determining that the value of muon g-2 measured at BNL (and soon to be improved at Fermilab) is inconsistent with the Standard Model

High priority goals of the USQCD BSM program

1. To establish a viable strongly coupled gauge theory of the composite Higgs mechanism, consistent with the Electroweak precision constraints and exhibiting large anomalous mass dimension.





2. To develop precision methods for calculating low energy WW scattering in composite Higgs models from the equivalence theorem and chiral parametrization.

3. To develop precision methods for the mass spectrum of composite Higgs models in the TeV region, particularly signals for the mass and width of the Higgs particle and to develop robust methods to study the slowly changing gauge coupling over large scales.

HOME RUN: to discover a non-perturbative dynamical symmetry-breaking mechanism of Supersymmetry

Most important QCD thermodynamics project

1) Equation of state at zero net baryon density
   a) Broad scientific interest
   b) Validation of the numerical approach (two groups disagree)
   c) Important input for hydro models for heavy ion experiments
   d) Base of gauge configurations for subsequent thermo project

2) Fluctuations of conserved charges
   a) comparison with experimental results for even-by-event fluctuations @RHIC
   b) understanding the freeze-out conditions @ RHIC, test of Hadron Resonance Gas

3) Quarkonium spectral functions
   a) understanding the quarkonium nuclear suppression factor @ RHIC and LHC
      => onset of deconfinement in heavy ion collisions

Locate the critical end-point on the QCD phase diagram (T-mu plane) via LQCD ?

game changer for understanding the QCD phase diagram, extremely important
for beam energy scan @RHIC, CBM@FAIR and NICA

HIGH PRIORITY NUCLEAR PHYSICS TOPICS

- WHAT IS THE SPECTRUM OF QCD? — JLab @ 12GeV, GlueX
  - DETERMINATION OF LOCATIONS AND WIDTHS OF LOW-LYING RESONANCES INCLUDING EXOTIC STATES
- AID EXPERIMENT IN MEASURING GPDs — JLab @ 12 GeV
  - RELIABLE COMPUTATIONS OF LOW MOMENTS OF GPDs
- CONSTRAINTS TO PHYSICS BEYOND THE STANDARD MODEL
  - TENSOR AND SCALAR CHARGES OF THE NUCLEON TO 10% PRECISION
    - UNCb, UNCB: ULTRA COLD NEUTRON DECAY EXPERIMENTS SEARCHING FOR PHYSICS BEYOND THE STANDARD MODEL
- NUCLEAR MATTER IN ASTROPHYSICAL ENVIRONMENTS
  - COMPUTE THE ELASTIC SCATTERING PHASE SHIFTS IN HYPERON-NUCLEON INTERACTIONS, RESULTING CONSTRAINTS TO THE EQUATION OF STATE FOR NUCLEAR MATTER IN NEUTRON STARTS
- COMPUTE THE BINDING ENERGIES OF NUCLEI (INCLUDING HYPER-NUCLEI) FOR UP TO A=4

JLab, J-parc, FAIR, KEK

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2) What are the current allocations in the various physics areas? Have they evolved in time?

Resource distribution by field

2011-2012 allocation breakdown:

Weak matrix elements:	**INCITE 53%**	**Cluster: 37%**	**GPU: 9%**
Beyond Standard Model:	**INCITE 9%**	**Cluster: 20%**	**GPU: 12%**
Nuclear Physics:	**INCITE 22%**	**Cluster: 23%**	**GPU: 56%**
Thermodynamics:	**INCITE 16%**	**Cluster: 11%**	**GPU: 15%**

2012-13 requests:

- Similar distribution: except GPU request rising in HEP

3) How does the US lattice gauge theory effort compare with efforts oversees? For example in computing power, in publications, or in citations?

The size of the large machines that will be used by lattice theorists is (in equivalent BG/Q racks):

	Total racks	% for LGT	date operational
US			
LLNL	96	10	8/12
ANL	48	3	3/13?
Titan	~50	3	1/13
World			
Kobe	24	5	10/12 <- derated 50% from BG/Q
Cineca(Italy)	10	5	8/12
Julich	6+6	3	6/12 + ?
UKQCD	6	4	4/12
KEK	3+3	6	10/12 + ?
RBC	2	1	4/12
BNL	1	0.5	2/12

In publications, we have information in high temperature QCD and in BSM physics. We can assemble more information on weak matrix elements and nuclear physics over the next week.

In high temperature QCD, there are three main world collaborations. Their publication record in the last year are:
Budapest-Wuppertal: 6 publications and 27 citations,
WHOT-QCD (Japan) : 3 publications and 17 citations,
USQCD (BNL and HotQCD) : 4 publications, 42 citations.
Comparison of recent USQCD BSM activities with Europe and Japan in lattice simulations on the energy frontier

In BSM,
- USQCD published on spires 32 papers in 2011 + 2012 with 32 authors and approximately 230 citations.
- Europe and Japan published on spires approximately 20 papers in the same time period with 34 people and
  approximately 80 citations.

4) Don Holmgren.

5) What fraction of projects are now actively working with GPUs. How do you expect this to change over the years? Will the payoff saturate as use is expanded through the projects.

- Analysis on clusters:
  - Current usage of GPU-s approximately 11/37, or ~30%. of analysis projects: inverters only for Wilson-like & Staggered-like solvers
  - Anticipate growth with addition of domain-wall solvers – possibly half of all analysis??
  - GPU-s not necessarily suitable for all applications, e.g., staging large I/O into GPU
- Gauge generation on capability resources:
  - Titan and Blue Water machines → driving development of HMC on GPU-s
  - Strong scaling imposes limits on job sizes (20% of resource?)
- All cases:
  - Rewriting all codes for GPU-s not practical. New technologies - QCD enabled JIT (Just-In-Time), compiler based pragmas, etc. – enable greater acceptance.
- Speculative whether GPU-enabled clusters suitable for largest-lattice gauge generation.
  - need leadership resources.
- USQCD forecasts anticipated computational needs: GPU accelerated systems deployed according to scientific demands.

6. How does the BG/Q price/performance estimate scale to large numbers of racks? Are there overheads in scaling to large systems?

One rack of BG/Q is 16,000 cores. It is already a large system and is all that we could afford. (In any case, the BG/Q scales very well to large numbers of racks.)

7) Should we consider an experimenter on the SPC?

- This is an important question we have considered before. We agree that experimental input to our program is very important.
- We believe that there are two difficulties with this particular suggestion:
  * Expertise in the experimental (or phenomenology) community is diffuse. A single experimenter would be expert on a small fraction of the important areas in which decisions are made. It would take many people to cover the important areas in nuclear and high energy experiment.
  * The SPC is a small committee of seven members who work very hard, collectively to allocate USQCD resources. This is a large job which requires expertise on both what is important and what is possible. We believe it would be unreasonable to ask a non-lattice physicist to acquire the expertise to contribute to these deliberations at an appropriate level.
- The USQCD-organized “lattice meets experiment” workshops have been very successful in promoting productive interaction with a large number of experimental physicists and phenomenologists. With this arrangement many lattice theorists, including those actually making the proposals, benefit from serious outside input.

8) To encourage hiring in lattice gauge theory, has USQCD considered having a speakers bureau which could, for example, suggest plenary talks for APS conferences, DNP conferences, etc., and which could have talks and speakers available for university colloquia?

This is a very good idea. We will find an effective mechanism to identify and promote good lattice plenary talks at the major US conferences and lattice talks at university colloquia. This is important to increase the broader visibility of both lattice physics and the talented young people working in the field.