U.S. DEPARTMENT OF ENERGY

# OFFICE OF HIGH ENERGY PHYSICS REPORT ON THE LQCD-ext III 2021 Annual Progress Review

May 18-19, 2021

**United States Department of Energy**
**Washington, DC 20585**

# Executive Summary

The Annual Progress Review of the Lattice Quantum Chromodynamics extension III (LQCD-ext III) research program was held on May 18-19, 2021, via ZOOM. The purpose of the review was to assess LQCD-ext III's progress towards its overall scientific and technical goals, and to assess the role of the National Lattice Quantum Chromodynamics Collaboration (USQCD) in governing the usage of the program's hardware. In particular, the LQCD-ext III team was instructed to address five charges:

1. the continued significance and relevance of the LQCD-ext III program, with an emphasis on its impact on the experimental program supported by the Department of Energy (DOE) Office of High Energy Physics (HEP);
2. the progress toward scientific and technical milestones as presented in the LQCD-ext III's Execution Plan;
3. the status of the technical design and proposed technical scope for fiscal year (FY) 2021-2022 for the program;
4. the feasibility and completeness of the proposed budget and schedule for the program;
5. the effectiveness with which the LQCD-ext III program has addressed the recommendations from last year's review.

The USQCD collaboration addressed the charge:

6. The effectiveness of USQCD in allocating the LQCD-ext III resources to its community of lattice theorists, the scientific impact of this research on the entire HEP community, and the status, operational procedures, and related activities of the USQCD collaboration itself.

In general, the review panel was very impressed with the technical and scientific achievements of LQCD-ext III and USQCD but they presented several suggestions and recommendations to both efforts. They noted the impacts of LQCD-ext III simulations on experimental programs in precision measurements of the Standard Model (SM), Beyond the Standard Model (BSM) model building, hadronic matrix elements, and neutrino interactions. The USQCD's organization of the theory community to present a consensus for the muon g-2 measurement now being made by E896 at Fermilab was singled out and the challenges it faces were extensively discussed. The hadronic vacuum polarization contribution to the muon g-2 is still not sufficiently understood to compare the experimental results to the standard model. There are internal discrepancies between the results of various groups doing ab-initio calculations and comparisons to the data driven dispersive estimate are not completed and understood. A resolution of these problems rely on more capability computing and lie, for the most part, outside the scope of this review. However, the review panel emphasized that USQCD should prioritize these calculations and seek a resolution before the experiment presents additional results with higher precision. The review panel had several recommendations to improve the program's user survey. They recommended that USQCD conduct an anonymous survey to evaluate the diversity, equity and inclusion (DEI) climate within the LQCD-ext III research program. USQCD should also design and

implement a feedback mechanism enabling internal assessment of the overall effectiveness and membership selection procedures of the USQCD governance (both the executive committee (EB) and the scientific policy committee (SPC)) and the effectiveness of the award allocation process to proposals. In addition, questions should be added to the user survey that would allow users to comment on the SPC allocation process, fairness, and scientific impact. And, finally, the panel recommends that the LQCD program present a timeline for results in the context of the HEP and the Office of Nuclear Physics (NP) experimental timelines at each subsequent progress review.

# HEP Report on the LQCD-ext III 2021

# Annual Progress Review

## Table of Contents

# I. Introduction and Background

The DOE Offices of Advanced Scientific Computing Research (ASCR), High Energy Physics (HEP) and Nuclear Physics (NP) have been involved with the National Lattice Quantum Chromodynamics Collaboration (USQCD) in hardware acquisition and software development since 2001. The Lattice Quantum Chromodynamics IT hardware acquisition and operations project ("LQCD"), which started in 2006 and ran through 2009, operated a "Quantum Chromodynamics-on-a-chip" (QCDOC) machine at Brookhaven National Laboratory (BNL), and built and operated special-purpose commodity clusters at the Fermi National Accelerator Laboratory (FNAL) and the Thomas Jefferson National Accelerator Facility (TJNAF). The project's four-year budget was $9.2M. LQCD met its 2009 project goal of providing 17.2 Teraflops of sustained computer power for lattice calculations. The clusters designed, constructed and operated by LQCD complement the lattice community's access to supercomputers: supercomputers produce the gauge configurations and quark propagators of Quantum Chromodynamics and the clusters and other hardware platforms of LQCD run the programs that analyze those configurations and compute matrix elements and predict cross-section and rates of decay processes.

The hardware project, organized by the USQCD collaboration of ~120 lattice computational physics theorists, successfully completed its original four-year allocation. The collaboration then proposed and was granted an extension project, LQCD-ext, which ran from FY2010 - FY2014. LQCD-ext worked with a robust budget of $22.9M. The project pioneered the use of GPUs and this new "disruptive" technology helped the project exceed its original milestones by a wide margin.

The second extension of the project, LQCD-ext II, was described by the USQCD collaboration in a proposal entitled "LQCD-ext II Computational Resources for Lattice QCD: 2015-2019" dated October 23, 2013. This document presented the scientific objectives, the computational strategy, and the hardware requirements of the LQCD-ext II project. The scientific content of the proposal reviewed successfully on November 8, 2013, and the scientific vision and specific goals of the project were enthusiastically endorsed by a panel of scientific experts. The reviewers recommended full funding, $23.4M for the five year period. However, due to budget constraints, the HEP and NP provided budget guidance to the project team of between $14M and $18M for the five year period, well below the project's request. These plans became the basis for the project team's planning for LQCD-ext II. That project passed its CD-1 review on February 25, 2014 and was granted CD-1 approval on May 1, 2014. It held its CD-2/3 review on July 10, 2014 and was approved on Oct. 1, 2014.

The budget planning for the LQCD-ext II project was of some concern to the review panels of the 2014 and the 2015. The original five year budget of $23.4M ($4.68M per year) proposed by the collaboration and endorsed by the November 8, 2013, Science Review resulted in the following anticipated Teraflops profile from FY2015 to FY2019:

| Full Funding Scenario ($23.4M) | FY2015 | FY2016 | FY2017 | FY2018 | FY2019 |
|---|---|---|---|---|---|
| Planned computing capacity of new deployments, TeraFlops | 165 | 233 | 330 | 467 | 660 |

However, funding at the $14M level followed funding profile:

| | **FY2015** | **FY2016** | **FY2017** | **FY 2018** | **FY 2019** | **Total** |
|---|---|---|---|---|---|---|
| HEP | 1.0 | 2.0 | 2.0 | 2.0 | 2.0 | 9.0 |
| NP | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 5.0 |
| **Total** | **2.0** | **3.0** | **3.0** | **3.0** | **3.0** | **14.0** |

The estimated Teraflops profile was reduced to:

| Reduced Funding Scenario ($14.0M) | FY2015 | FY2016 | FY2017 | FY2018 | FY2019 |
|---|---|---|---|---|---|
| Planned computing capacity of new deployments, TeraFlops | 0 | 107 | 160 | 244 | 358 |

which was a 53 percent reduction in compute power compared to the full funding scenario. This reduction in computing capacity challenged USQCD to maintain its productivity, its balance with its Leadership Class computing allocations and its international standing. The 2014 review panel commented on these developments since they influenced the use and productivity of the FY2014 hardware acquisitions they endorsed. The 2015, 2016 and 2017 review panels also commented on the extra challenges that constrained funding placed on the project and they noted that any additional funding would directly increase the project's hardware acquisition plans. LQCD-ext II managed its computing resources wisely over this time period and the productivity of the project increased accordingly even with a less-than-optimal budget.

Over the course of the project, and its extension, 2006-present, the hardware acquisition strategy of LQCD had been essential to its success. Each year the project's technical personnel benchmark the kernels of the Quantum Chromodynamics (QCD) code on the newest cluster, GPU and supercomputer hardware, and the winner of the price-to-performance competition becomes next year's provider.

The usage of the hardware procured by LQCD has been governed by the USQCD collaboration through its Executive Committee (EC) and SPC. In addition, the collaboration organizes the community's access to the DOE Leadership Class Supercomputers available through the Innovative and Novel Computational Impact on Theory and Experiment program. Members of the USQCD collaboration submit proposals through the EC for computer time, some on the Leadership Class machines for large-scale capability computing, and some on the dedicated clusters of LQCD for large scale capacity computing. Allocations on the dedicated clusters of LQCD are awarded by the SPC based on a merit system. Three classes of applications for

computer time allocations on the dedicated LQCD hardware are distinguished, these being large-scale mature projects (allocation class A), mid-sized projects (allocation class B), and exploratory projects (allocation class C). Suitable computer platforms are assigned to the various projects upon approval. The clusters of the hardware project analyze and compute matrix elements from the gauge field configurations generated on Leadership Class machines. This strategy requires a balance between the compute power of the clusters and the Leadership Class machines.

Following recommendations from past reviews, a Scientific Advisory Board (SAB) was formed in 2013 and has participated in the USQCD allocation process. The SAB brings the perspective of the broader HEP and NP community into the high level decision making processes of USQCD and is meant to guarantee that the goals of the lattice effort reflect the diverse needs, challenges and interests of high energy and nuclear researchers. The SAB consists of seven members, four experimentalists and three theorists. They comment on the science goals of USQCD, the effectiveness and fairness of the allocation process and participate in the annual all-hands meeting.

In addition to the original hardware project LQCD, USQCD has also played a role in software development through the Scientific Discovery through Advanced Computing (SciDAC) program. USQCD was awarded a SciDAC-I grant (2001-2006) which was used to develop efficient portable codes for QCD simulations. USQCD was subsequently awarded a second "SciDAC-II" grant (2006-2011) to optimize its codes for multi-core processors and create a physics toolbox. These SciDAC grants supported efforts to provide a user interface to lattice QCD which permits the user to carry out lattice QCD simulations and measurements without the need to understand the underlying technicalities of the lattice formulation of relativistic quantum field theories and its implementation on massively parallel computers. In 2012, USQCD submitted two proposals to the SciDAC-III program, and both were funded, one through NP and ASCR, and the other through HEP and ASCR. In 2017 USQCD submitted two proposals to the SciDAC IV competition and the NP proposal was funded.

USQCD organized and submitted a proposal, the Exascale Computing Project, to ASCR's Exascale program. That effort was funded and USQCD is actively involved in preparing for the next era in computer power.

The precision and relevance of the lattice community's calculations have improved steadily over the years. Lattice calculations now come with detailed error analyses. The experimental community has taken note of this important development and looks to lattice calculations in their planning. In order to impact the experimental and theoretical programs of NP and HEP, the collaboration has been encouraged to organize workshops where it can interact with the other communities and actively disseminate its program. These workshops have been successful in engaging a wider audience for the lattice calculational program, and now USQCD's contributions to many annual workshops are wide-spread and generally significant and appreciated.

In 2018, HEP converted the lattice hardware project to a research program. The project was told to move away from dedicated hardware and begin supporting and using laboratory-based Institutional Clusters. The motivation for the policy change was HEP's intention of providing a more level playing field in computing across its entire program. NP had different priorities and decided to continue supporting dedicated hardware at TJNAF, outside of the HEP project.

However, in order to maintain the scientific productivity of the effort, the engagement of USQCD in the lattice effort was not changed and the allocation process for its members to use both HEP and NP facilities remained unchanged.

Brookhaven indicated strong interest in supporting lattice gauge theory in 2018. David Lissauer, the Deputy Associate Laboratory Director for Nuclear and Particle Physics, and Kerstin Kleese van Dam, the Director of the lab's Computation Science Initiative, participated actively in the 2018 annual progress review. BNL staff indicated their commitment to the Institutional Cluster funding model. The LQCD-ext II project team indicated that interactions with BNL had been productive and successful: the BNL staff endorsed the project team's commitment to discover and procure the most cost effective hardware chips for lattice gauge theory simulations each year. Several meetings between the project team and the Fermilab computing division were scheduled over the next few months to formulate a plan to work together to design, purchase hardware and use institutional clusters.

Toward the end of LQCD-ext II project in 2018-2019, the project and USQCD put together a plan for the next five year period, 2020-2024. USQCD prepared seven whitepapers describing its five-year plans in all of its research subfields and the whitepapers were published in a special edition of a European research journal. That plan was reviewed in a special comprehensive HEP review which pitted the lattice effort against all the theory research efforts supported by HEP. This review occurred in Rockville, MD, on July 9-10, 2019. A review team of seven outstanding theorists, under the direction of Bill Kilgore, the program manager of HEP theory, evaluated the lattice program and recommended that it continue for another five years. They supported increasing its funding from the requested amount of $2.0M per year to $2.5M per year to address storage needs and new growth opportunities. The review team also endorsed the institutional cluster model for the program.

The May 18-19, 2021, review was the second review of the new five year cycle. This review took place via ZOOM. The review consisted of two days of presentations and a third half-day of questions and answers, report writing, and a closeout session. The Appendices to this report provide additional detailed material relating to the review: App. A contains the charge letter to the LQCD-ext III management team, App. B lists the reviewers and DOE participants, and App. C contains the agenda and links to the talks.
Six expert reviewers from high energy theory, phenomenology, and computer science participated in the review. The review began with a presentation by Andreas Kronfeld, spokesperson for USQCD, which gave an overview of the USQCD collaboration and the LQCD-ext III project. His deputy, Robert Edwards, followed with more details on the collaboration, its structure, governance and accomplishments in science and personnel. Then there were four presentations on the scientific topics which comprise lattice gauge theory. These are discussed in more detail below. Management talks followed and finally Andreas Kronfeld returned with a discussion of USQCD's plans for the future.

The remaining sections of this report present the findings, comments, and recommendations of the review committee for each of the six charge elements that the LQCD-ext III team was asked to address in their charge letter.

# II. Continued Significance and Relevance

## Findings

The USQCD community is performing broad and innovative research that applies to many ongoing experiments in the HEP and NP program. The Standard Model predictions continue to provide important checks and underpin the interpretation of the measurements made by the experiments. Some examples include results in flavor physics, muon to electron conversion, and nucleon characteristics. Most notably, LQCD and USCQD more generally have supported the experimental program by contributing to the theoretical prediction of muon g-2. LQCD resources are also brought to bear on the calculation of parton distribution functions, in support of experimental efforts at the LHC as well as in planning for the EIC. Other projects using LQCD resources are constraining neutrino scattering cross sections in support of neutrino oscillation experiments and computing matrix elements for the interpretation of neutrino-less double beta decay results, as well as the neutron electric dipole moment, muon to electron conversion and dark matter searches. Ten percent of the resources of LQCD-ext III are dedicated to exploring BSM scenarios to allow rapid response should anomalies be discovered at the LHC or elsewhere.

## Comments

The project is broadly well aligned with the needs of the experimental program and is confronting questions and problems that will be important to the interpretation or implementation of the major experimental efforts in the US HEP portfolio. The USQCD federation emphasizes workshops with experimentalists and is taking good advantage of the Snowmass community planning exercise to make sure there is exchange of ideas and understanding of needs.

We encourage the SPC to better enunciate quantitatively how their allocation of resources is guided by experimental needs or impact. We also encourage USQCD to continue to collect a cumulative record of the scientific output and its impact on the experimental program to improve the steering of the future program's priorities.

USQCD could improve the definition and role of the interactions with its SAB and implement a more regular timeline for formal exchanges with the advisory board.

USQCD should continue to engage with the large experimental efforts in focused discussion to coordinate goals and to establish priorities. Fine tuning of priorities might benefit from more focused engagement with experimental collaborations.

### Recommendations

None.

# III. Progress Towards Scientific and Technical Milestones

### Findings

There has been impressive and uniform progress in all scientific areas of the LQCD research program. Important and timely milestones were reached in the context of quark flavor physics, g-2 of the muon and the computations of nuclear matrix elements, parton distribution functions and a range of beyond-the-SM computations.

### Comments

The range of the results achieved over the past year is highly impressive and contains innovative, timely and world-leading, influential results. Noteworthy examples are the calculations of the muon g-2 light-by-light contributions, novel innovative results on parton distribution functions, the USQCD leadership of the muon g-2 Theory Initiative, computations of nuclear matrix elements, the computation of electroweak symmetry breaking and dark matter properties in strongly coupled non-QCD-like theories.

Further progress on the muon g-2 hadron vacuum polarization (HVP) calculation is of particular importance. This will require mainly computing resources from leadership capability machines, but continued and possibly prioritized allocation of LQCD resources for HVP calculations remains essential for achieving the desired accuracy and for international competitiveness.

### Recommendations

The panel recommends that the LQCD program present a timeline for results in the context of the HEP and NP experimental timelines in each subsequent progress review. This should include a review of the past one to three years with the relevant results achieved and the fractional distribution of computing resources dedicated to each goal over that time period. The next one to three years should also be presented with the goals for QCD results to be published, including challenges needed to overcome and the computing resources required to meet these goals. These should also be made available to the wider USQCD community to increase transparency.

# IV. Technical Design and Scope for FY2021/22

## Findings

LQCD has been managing roughly 1PFlops of computing resources over the past year split between BNL and FNAL. This is represented by different computing architectures including CPU-only (multi-core & many-core), and hybrid CPU+GPU. The current operational model is a pay-for-use model where DOE labs are contracted to manage the purchase, installation, operation, and maintenance of the computing resources. Roughly five percent of the budget is allowed for storage purposes, the remaining is used largely for computations with a small portion for operational support. In addition, the community relies on DOE HPC allocations for some of the more complex, "industrial" calculations that cannot reasonably be performed on the dedicated compute resources. These capability resources, however, are governed by external competitive review processes that cannot be relied on in the long term. Though, the community has been quite successful at receiving allocations through these programs in the past due to their exceptional ability to utilize these platforms effectively.

In the coming one to two years, capacity computing resources are expected to remain flat in line with the program demands which are also expected to remain flat.

## Comments

The LQCD computing model appears to be optimally tuned to meet the USQCD community's needs for capacity computing. Through the survey, the user community indicates that their needs are being met.

## Recommendations

None.

# V. Feasibility and Completeness of Budget and Schedule

## Findings

Progress is limited, to a large extent, by the available funding envelope.

## Comments

Within the current limitations the proposed budget and schedule are realistic and are aimed at continuing to provide support to the broad program.

An increased budget would allow additional, accelerated progress on selected timely projects. We would encourage a more aggressive approach to ensure the best possible outcome for funding.

### Recommendations

None.

# VI. Effectiveness of Management Structure and Responsiveness to past Recommendations

### Findings

Responsiveness to last year's recommendation has led to two actions: 1) USQCD has strengthened their collaboration with neutrino experiments by participation in conferences and engaging with the Snowmass project, and 2) USQCD has established a committee to oversee DEI issues.

### Comments

The response #1 seems adequate, and has led to several Letters of Intent being submitted for Snowmass.

The response #2 seems a bit vague. The review panel welcomes the creation of a Code of Conduct, but would like to see a faster reaction on other issues, like the organization of the dedicated workshop, work in collaboration with the DEI Officer at Fermilab, and a set of concrete practices to improve inclusivity in USQCD activities. It is not enough to simply blame the overall bad DEI situation in HEP.

### Recommendations

An anonymous survey to evaluate the DEI climate within USQCD should be conducted.

# VII. Effectiveness of USQCD, Scientific Impact, Procedures and Related Activities

## Findings

USQCD allocates the LQCD-ext III resources in an equitable manner. Allocations are proposal driven; there is not a strong, top-down influence on the work. Proposals overrun resources by a factor of 1.6 to 1.8. As a result, all allocations are below the requested levels. Proposals are not often rejected outright.

There have been numerous scientific publications in all areas in the last 12 months.

## Comments

The review panel appreciates the constraints under which the allocations are being made - in particular, related to non-capacity resources. The review panel is also positively impressed by the breadth of the scientific program that is sustained by USQCD. However, a robust and more detailed assessment of the effectiveness of the allocation process is difficult to establish based on the proposed material at this review.

Consider potential deficiencies of the prioritization mechanism of proposals according to their scientific merit and potential impact.

The publication rate seems healthy and does have a positive influence on the HEP community in many different areas.

## Recommendations

Implement a feedback mechanism enabling internal assessment of the overall effectiveness and membership selection procedures of the USQCD governance (both EB and SPC) and effectiveness in the award allocation process in response to proposals.

The review panel recommends adding questions to the User Survey that allows users to comment on the SPC allocation process, fairness, and scientific impact.

# APPENDIX A

**Charge Letter to the LQCD-ext III Project Team**

**Department of Energy**
Office of Science
Washington, DC 20585

02/25/2021

Dr. W. Boroski
LQCD-ext III Contract Project Manager
Fermi National Laboratory
Mail Station: 370 (FCC 1W)
P.O. Box 500
Batavia, IL 60510-0500

Dear Dr. Boroski:

The Department of Energy (DOE) Office of High Energy Physics (HEP) plans to conduct an Annual Progress Review of the Lattice Quantum Chromodynamics (LQCD-ext III) Computing Program on May 18-19, 2021, virtually, using ZOOM. A review panel of experts in high energy physics, project management and computer science is being convened for this task.

John Kogut of the HEP is responsible for this review; he will be assisted by Bill Kilgore, the Theory Program Manager of the HEP.

Each panel member will evaluate background material on the LQCD-ext III research program and attend all the presentations at the May 18-19 review. The focus of the 2021 LQCD-ext III Annual Progress Review will be on understanding:

- The continued significance and relevance of the LQCD-ext project, with an emphasis on its impact on the experimental program of the DOE HEP;
- The progress toward scientific and technical milestones;
- The status of the technical design and proposed technical scope for FY 2021- 2022;
- The feasibility and completeness of the proposed budget and schedule;
- The effectiveness of the proposed management structure, and

responsiveness to any recommendations from last year's review.

Since LQCD-ext III provides computer cycles that are distributed by the United States Quantum Chromodynamics Collaboration (USQCD) collaboration, the panel members will also consider:

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- The effectiveness of USQCD in allocating the LQCD-ext III resources to its community of lattice theorists, the scientific impact of this research on the entire HEP community and the status, operational procedures and related activities of the USQCD collaboration itself.

The two days of the review will consist of presentations and executive sessions. The second day will include an executive session and preliminary report writing; a brief close-out will conclude the review. Preliminary findings, comments, and recommendations will be presented at the close-out. You should work with John Kogut to generate an agenda which addresses the goals of the review.

Each panel member will be asked to review those aspects of the LQCD-ext III project listed above which are within their scope of expertise and write an individual report on his/her findings. These reports will be due at the DOE two weeks after completion of the review. John Kogut, the Federal Project Manager, will accumulate the reports and compose a final summary report based on the information in the letters. That report will have recommendations for your consideration that you and USQCD should respond to in a timely fashion.

Please designate a contact person for the review panel members to contact regarding any logistics questions. You should set up a web site for the review with relevant background information on LQCD-ext III, links to the various LQCD-ext III sites the collaboration has developed, and distribute relevant background and research materials to the panel at least two weeks prior to the review. Please coordinate these efforts with John Kogut so that the needs of the review panel are met.

We greatly appreciate your willingness to assist us in this review. We look forward to a very informative and stimulating review.

Sincerely,

James Siegrist

Digitally signed by James Siegrist
Date: 2021.02.25 13:54:41 -05'00'

James Siegrist
Associate Director of Science
for High Energy Physics

# APPENDIX B

## Reviewers for LQCD-ext III Annual Progress Reviewers 2021

1. Mateusz Ploskon (mploskon@lbl.gov ;LBNL, computation specialist and CMS physicist)
2. Taylor Childers (jchilders@anl.gov; ANL, HEP computational physicist, formerly ATLAS)
3. Luigi Del Debbio (luigi.del.debbio@ed.ac.uk; Edinburgh, lattice BSM, PDFs from pheno and from lattice)
4. Dominick Stöckinger (dominik.stoeckinger@tu-dresden.de; TU Dresden ; muon g–2 beyond the SM theorist)
5. Thomas Teubner (thomas.teubner@liverpool.ac.uk; Liverpool, muon g–2, dispersive and lattice approaches, SM theorist)
6. Patricia Vahle (plvahle@wm.edu; William & Mary, neutrino experimenter)

## Attending DOE program managers

J. Kogut LQCD-ext III HEP Federal Program Director

Bill Kilgore, Theory Program Manager

# APPENDIX C

## Review Agenda

**Day One – May 18th - Tuesday**

| PDT | CDT | EDT | BST | CEST | |
|---|---|---|---|---|---|
| 07:00 | 09:00 | 10:00 | 15:00 | 16:00 | Executive Session (45 min) – *John Kogut & Committee* |
| 07:45 | 09:45 | 10:45 | 15:45 | 16:45 | Welcome and Logistics (5 min) – *Bill Boroski* |
| 07:50 | 09:50 | 10:50 | 15:50 | 16:50 | Scientific Goals of USQCD (30 min) – *Andreas Kronfeld* |
| 08:20 | 10:20 | 11:20 | 16:20 | 17:20 | USQCD Governance (30 min) – *Robert Edwards* |
| 08:50 | 10:50 | 11:50 | 16:50 | 17:50 | Break (10 min) |
| 09:00 | 11:00 | 12:00 | 17:00 | 18:00 | LQCD-ext III Management and Performance (60 min) – *Bill Boroski* |
| 10 :00 | 12:00 | 13:00 | 18:00 | 19:00 | Science 1: Quark & Lepton Flavor Physics (30 min) – *Luchang Jin* |
| 10:30 | 12:30 | 13:30 | 18:30 | 19:30 | Science 2: Beyond the Standard Model (30 min) – *George Fleming* |
| 11:00 | 13:00 | 14:00 | 19:00 | 20:00 | Executive Session (30 min) – *John Kogut & Committee* |
| 11:30 | 13:30 | 14:30 | 19:30 | 20:30 | Adjourn |

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**Day Two – May 19th - Wednesday**

| PDT | CDT | EDT | BST | CEST | |
|---|---|---|---|---|---|
| 07:00 | 09:00 | 10:00 | 15:00 | 16:00 | Executive Session (30 min) – *John Kogut & Committee* |
| 07:30 | 09:30 | 10:30 | 15:30 | 16:30 | Science 3: Parton Distribution Functions (30 min) – *Chris Monahan* |
| 08:00 | 10:00 | 11:00 | 16:00 | 17:00 | Science 4: NME for Neutrino & Other HEP Experiments (30 min) – *Phiala Shanahan* |
| 08:30 | 10:30 | 11:30 | 16:30 | 17:30 | Break (10 min) |
| 08:40 | 10:40 | 11:40 | 16:40 | 17:40 | 2019–2020 User Survey Results (20 min)– *Jo Fazio* |
| 09:00 | 11:00 | 12:00 | 17:00 | 18:00 | BNL IC Performance and Plans (30 min) – *Tony Wong* |
| 09:30 | 11:30 | 12:30 | 17:30 | 18:30 | Executive Session (60 min) – *John Kogut & Committee* |
| 10:30 | 12:30 | 13:30 | 18:30 | 19:30 | Committee Adjourns, *but* … |
| | | | | | Committee Request for Information (60 min) – *John Kogut & Project Leadership* |
| 11:30 | 13:30 | 14:30 | 19:30 | 20:30 | Project Team Meeting (30 min) – *Entire Project Team* |

**Day Three – May 20th - Thursday**

| PDT | CDT | EDT | BST | CEST |
|---|---|---|---|---|

| | | | | | |
|---|---|---|---|---|---|
| 06:30 | 08:30 | 09:30 | 14:30 | 15:30 | Response to Committee Questions & Discussion (90 min) |
| 08:00 | 10:00 | 11:00 | 16:00 | 17:00 | Break (10 min) |
| 08:10 | 10:10 | 11:10 | 16:10 | 17:10 | Executive Session & Preliminary Report Writing (120 min) |
| 10:10 | 12:10 | 13:10 | 18:10 | 19:10 | Closeout (60 min) |
| 11:10 | 13:10 | 14:10 | 19:10 | 20:10 | Adjourn |

The URL for the LQCCD Review 2021 is:.

Lattice QCD Extension III 2020 Annual Progress Review (usqcd.org)

Presentation and background materials are posted there.