NUCLEAR SCIENCE ADVISORY COMMITTEE
to the
U.S. DEPARTMENT OF ENERGY and NATIONAL SCIENCE FOUNDATION

PUBLIC MEETING MINUTES

Virtual Meeting
July 19, 2021

NUCLEAR SCIENCE ADVISORY COMMITTEE
SUMMARY OF MEETING

The U.S. Department of Energy (DOE) and National Science Foundation (NSF) Nuclear Science Advisory Committee (NSAC) virtual meeting was convened at 11:00 a.m. EDT on Monday, July 19, 2021, via Zoom®, by **Committee Chair Gail Dodge**. The meeting was open to the public and conducted in accordance with Federal Advisory Committee Act (FACA) requirements. Attendees can visit http://science.energy.gov for more information about NSAC.

NSAC Members Present

Thomas Albrecht-Schoenzart
Sonia Bacca
Lee Bernstein
Joseph Carlson
Gail Dodge (Chair)
Evangeline Downie
Renee Fatemi
Bonnie Fleming
Tanja Horn
Oliver Kester
Joshua Klein
Thomas Schaefer
Rebecca Surman
Fred Wietfeldt
Boleslaw Wyslouch
Sherry Yennello

NSAC Members Absent

None

NSAC Designated Federal Officer

Timothy Hallman, U.S. Department of Energy, Office of Science (SC), Office of Nuclear Physics (NP), Associate Director

Attending

There were approximately 90 participants present for all or part of the teleconference.

Monday, July 19, 2021

Welcome and Introduction, Gail Dodge, NSAC Chair.

Gail Dodge welcomed attendees and asked the NSAC members to introduce themselves. Timothy Hallman, the designated federal officer, introduced himself and the other NP members present. Allena Opper and others from the NSF introduced themselves. The primary purpose of this meeting is for NSAC to vote on the acceptance of a report from the Molybdenum-99 (^{99}Mo) Subcommittee.

DOE Office of Nuclear Physics Overview, Timothy Hallman, NP

The FY22 President's Budget Request allocates $720M for NP. Budget guidance allowed NP to prioritize items within the Operations, Projects, and Research categories but not between categories. Operations and Research are most robustly supported by the President's Request, while Projects are supported to a lesser degree. The FY22 House Mark for NP is $665M. If the FY22 appropriation is closer to the House Mark than the President's Request, then meeting field-

wide NP goals will be challenging. However, the Senate Subcommittee on Energy and Water Development or a potential Infrastructure Bill could alter FY22 appropriations. Though the FY22 budget remains uncertain, it is important that the NP community continue to deliver discoveries, knowledge, technological advances and workforce training.

Under the FY22 President's Budget Request, the Relativistic Heavy Ion Collider (RHIC), Continuous Electron Beam Accelerator Facility (CEBAF) and Argonne Tandem Linac Accelerator System (ATLAS) operate at 90%, 90% and 93% of optimal utilization, respectively. Facility for Rare Isotope Beams (FRIB) transitions from a construction project to a scientific user facility and operates at 100% of optimal utilization at $77M, falling slightly below the $82M planned level of support. Management and Operations (M&O) commitments for the Large Hadron Collider (LHC) are met. Project support for Major Items of Equipment (MIEs) includes 1) completion of the super Pioneering High Energy Nuclear Interaction eXperiment (sPHENIX) at the baseline level of $0.2M; 2) continuation of the Gamma-Ray Energy Tracking Array (GRETA) below planned levels at $6.6M; 3) continuation of the Measurement of Lepton-Lepton Electroweak Reaction (MOLLER) at $7M Total Estimated Cost (TEC); 4) continuation of the Ton-scale Neutrinoless Double Beta Decay (0vββ) at $1.44M TEC; and 5) continuation of the High Rigidity Spectrometer (HRS) research project at $3M TEC. The Electron-Ion Collider (EIC) will receive its third year of Other Project Costs (OPC) ($10M) and TEC ($20M) funds. Support continues for NP participation in two crosscutting scientific research initiatives: Artificial Intelligence (AI) and Machine Learning (ML) at $4M and Quantum Information Science (QIS) at $10.5M. NP will also participate in four new crosscutting initiatives: Accelerator Science and Technology at $2M; Integrated Computational Data & Infrastructure at $1M; Microelectronics at $500K; and Reaching a New Energy Sciences Workforce (RENEW) at $3M. RENEW aims to advance Diversity, Equity and Inclusion (DEI) in the NP research community. Funding for national laboratories and universities is strengthened relative to the FY21 Enacted Budget; support for core research in Medium Energy, Heavy Ions and Theory increases by 12% and support for the Fundamental Symmetries and Nuclear Structure and Nuclear Astrophysics portfolios increases by 15%. Notably, these budget items saw successive funding cuts in FY20 and FY21. While Neutron Electric Dipole Moment (nEDM) is supported significantly below the planned profile with possible scheduling impacts, support for Scientific Discovery through Advanced Computing (SciDAC) increases by $600K, Nuclear Data increases by $3.5M and Accelerator R&D increases by ~$1M over FY21 Enacted levels. Finally, the DOE Isotope Program, previously embedded in the FY21 NP Budget, is a separate item in the FY22 Request.

NP has shown significant progress on three of the four top recommendations outlined in the 2015 Long Range Plan (LRP) for Nuclear Science: 1) Capitalizing on investments made to maintain U.S. leadership in nuclear science, 2) Constructing a high-energy high-luminosity polarized EIC as the highest priority for new construction following FRIB completion; and 3) Increasing investments in small-scale and midscale projects and initiatives. The development and deployment of a U.S.-led 0vββ experiment has also progressed. A portfolio review of the three front-runner technologies (Cryogenic Underground Observatory for Rare Events – CUORE Upgrade with Particle Identification/CUORE-CUPID; Large Enriched Germanium Experiment for Neutrino-less double beta Decay/LEGEND-1000; and next Enriched Xenon Observatory/nEXO) was held in July of 2021 to inform the U.S. investment strategy. Panel members were asked to finalize their independent review reports by the end of this week. A North American-European Summit is scheduled September 29 - October 1, 2021, to determine if

common ground exists for an international approach for 0νββ investment. Ideally, two 0νββ experiments using different technologies and systematics will be deployed to confirm signal detection.

FRIB is now a Scientific User Facility. The first call for proposals to the 1,500-member user group resulted in 82 proposal submissions from 130 institutions in 30 countries requesting 9,784 hours of beam time. The first experiments are scheduled for the spring of 2022.

ATLAS is working on two Accelerator Improvement Projects: a multi-user upgrade and a neutron generator upgrade to CARIBU (CAlifornium Rare Isotope Breeder Upgrade).

RHIC is unrivaled in scientific capabilities and maintains high availability (>85%). RHIC has completed runs searching for a critical point between the phases of nuclear matter. Results are forthcoming. Completion of the ongoing sPHENIX upgrade to RHIC is anticipated in FY23.

At the Large Hadron Collider (LHC), the Compact Muon Solenoid (CMS) Minimum ionizing particles Timing Detector (MTD) Science Review was conducted, and an A Large Ion Collider Experiment (ALICE) Forward Upgrade Review is anticipated.

The CEBAF science program is underway. Following the 12 GeV upgrade, recently published results from the Gluonic Excitation Project (GlueX) illuminate the mechanism of threshold J/Psi production and the upper limit on the pentaquark. The new lead (Pb) Radius EXperiment (P-REX) results provide an important benchmark to chiral effective field theory calculations and have direct relevance for bounding the radius of neutron stars in concert with neutron star merger data from Laser Interferometer Gravitational-Wave Observatory (LIGO).

MOLLER remains a bellwether experiment because of the potential to discover new physics. MOLLER achieved Critical Decision (CD)-1 in FY21. A science review was held for the proposed Solenoidal Large Intensity Device (SOLID) detector, and the report is in preparation. Additional funding is required for this project's progression.

A recent National Academy of Sciences report highlights EIC importance in maintaining U.S. leadership in accelerator science and collider technology. The EIC achieved CD-0 with site selection and project dedication and commencement in FY20. CD-1 approval was granted on June 25, 2021, and EIC will now begin the baselining process towards CD-2. The EIC User Community comprised 1,259 collaborators from 252 institutions and 34 countries in FY21 and has been actively formulating EIC detector design. A call for detector collaboration proposals was issued, and successful proposals will be selected in FY22.

Nuclear data is of increasing importance to several cross-cutting applications such as medicine, astrophysics, space exploration, materials, QIS, clean energy, and nonproliferation technologies. The NP-led Nuclear Data Interagency Working Group (NDIAWG) aims to close data gaps across fields and participating agencies.

NP has made strong gains in gender diversity but needs to further engage communities of color and other underserved and underrepresented groups. The FY21 NP and SC diversity, equity, and inclusion (DEI) Pilot Traineeship program funding opportunity announcement (FOA) garnered strong interest from participants and Congress. NP received 36 proposals to support over 200 traineeships across the country. Proposed collaborations involved 91 potential participating institutions, including nine national laboratories, 44 Minority Serving Institutions (MSIs) of which 18 are Historically Black Colleges and Universities (HBCUs) and two are Predominately Black Institutions (PBIs), nine community colleges, and two women's colleges. The first round of awards was issued, and a second cohort will receive funding in October 2021.

A review panel has been assembled for the Data Analytics for Autonomous Optimization and Control of Accelerators and Detectors FOA and will meet in August 2021. Deliberations for

the NDIAWG FOA have begun. NP plans to issue an FOA for QIS Research and Innovation for Nuclear Science soon.

NP positions are open for a Nuclear Theory Program Manager (PM) and a Heavy Ion PM. A solicitation for an International Cooperation and Outreach PM will be announced soon.

Discussion

Bernstein and **Kester** inquired about the FRIB operations budget. **Yennello** requested clarification on whether the FRIB operation at 100% of optimal utilization falls under the President's Request and is not necessarily within the House Mark. **Hallman** added that the FRIB FY21 operations budget is $50M. The FY22 planning operations budget is $82M and the President's Request is $77M. The latter is a robust number that will allow FRIB to start its science program. Initially, FRIB will need to balance hours for machine development and science. Within the $77M budget, 100% of the weeks needed for science can still be run.

Horn requested additional information about how a possible Infrastructure Bill could compensate for potential project budget contractions in FY22. **Hallman** noted that only the House Mark is currently available. NP awaits the Senate Energy and Water Subcommittee Mark and the resulting outcome of Senate and House negotiations. Funding of NP projects from the Infrastructure Bill would depend both on passage of the bill and specific language in the bill addressing SC activities.

Wyslouch asked about prospective plans for the next LRP. **Hallman** observed that DOE and NSF have not advanced planning activities at this time in part because 0νββ progress is required and the budget remains uncertain. If the FY22 appropriation is in line with the President's Request and 0νββ progress has been made, then LRP activities will likely commence at the end of 2021.

NSF Nuclear Physics Overview, Allena Opper, NSF, Division of Physics (PHY), Program Director

NSF is a mission-driven agency that supports all fields of fundamental science and engineering, excluding the medical sciences. The NSF Office of the Director is guided by the National Science Board (NSB), the White House and Congress. Seven research directorates fall under the Office of the Director including Mathematical and Physical Sciences (MPS). MPS comprises five divisions including the Division of Physics (PHY), which in turn contains the Experimental Nuclear Physics and Theory Nuclear Physics programs. PHY supports the National Superconducting Cyclotron Laboratory (NSCL). The Experimental and Theory Nuclear Physics programs support university laboratories and Theory Hubs, respectively.

Experimental Nuclear Physics awards are typically three years in length, and the annual number of submitted proposals consequently exhibits a three-year cyclic trend. Peak submission years are followed by two successive years of declining submissions. A record number of 68 proposals was submitted in 2018, with an even greater number anticipated in 2021. However, 2021 submissions were low (40 proposals), likely due to COVID-19. Many principal investigators (PIs) received no-cost extensions because they were unable to conduct experiments. Awards have not been issued for 2021.

Proposals requesting support in either Nuclear Physics program for conferences, workshops and research projects must be submitted through the new PHY solicitation (NSF 21-593) by December 7, 2021. Submissions must conform to the new NSF Proposal & Award Policies & Procedures Guide (PAPPG) which contains a Proposal Preparation Checklist.

The PHY solicitation contains additional guidance for proposals seeking Midscale Instrumentation funding with a Total Project Cost (TPC) between $4M and $20M over multiple years. Projects at the Design and Construction or Acquisition of Instrumentation stages are eligible. Currently, PHY supports three Midscale projects (nEDM, LEGEND-200 and MOLLER).

NSF also supports Research at Undergraduate Institutions (RUI) and Research Opportunity Award (ROA) programs (NSF 14-579) to fund research by faculty members at Predominately Undergraduate Institutions (PUIs). Proposal deadlines are also December 7, 2021.

PHY published a Dear Colleague Letter (DCL) titled, "Growing a Strong, Diverse Workforce" (NSF 21-065) in April 2021 advertising the availability of Graduate Research and Research Experience for Undergraduate (REU) Supplements with an emphasis on underrepresented minorities in Science Technology Engineering and Mathematics (STEM) fields. To be eligible, PIs must already have PHY funding. Candidate graduate students cannot be currently receiving federal funds. Graduate and undergraduate students must be U.S. citizens, U.S. nationals, or permanent residents. Graduate awards are renewable up to two times. Typically, NSF undergraduate awards are limited to one per primary investigator, but PHY may increase award numbers if undergraduate candidates are from underrepresented groups. There is no submission deadline for these supplements.

MPS issued two new solicitations. Launching Early-Career Academic Pathways in MPS (LEAPS) offers up to $250K/24 months to launch careers of pre-tenured faculty in MPS fields at MSIs, PUIs and Carnegie Research 2 (R2) universities with the goal of achieving excellence through diversity. Ascending Post-doctoral Research Fellowships (ASCEND) supports post-doctoral fellows who will broaden the participation of underrepresented groups in MPS fields and will prepare participants to transition to an academic faculty position. Fellowships of $100K/year for up to three years are awarded and administered by Fellows, not institutions. MPS intends to renew these solicitations in FY22.

The NSCL ReAccelerator 6 (ReA6) upgrade was completed and the first ReA6 experiment began in May 2021.

The total NSF FY21 appropriation was $8.48B, with $6.19B of that allocated to Research and Related Activities. An additional $600M was appropriated to NSF in response to COVID-19. Of these funds, $6M were allocated to PHY. Nuclear Physics programs used $1.5M of these funds to support individuals at critical career points, including post-doctoral researchers and graduate students.

The NSF FY22 Budget Request highlights enhancing fundamental research and development; addressing racial equity in science and engineering; addressing climate science and sustainability research; strengthening U.S. leadership in emerging technologies; and constructing additional major facilities. The FY22 President's Budget Request for NSF is 20% greater than FY21 appropriations of $8.48B. FY22 funding for Research and Related Activities increased by 18% and Agency Operations and Award Management increased by 25% over the FY21 appropriations of $6.88B and $0.37B, respectively. Portions of these funding increases will be used to create and staff the new Technology, Innovation and Partnerships (TIP) directorate. MPS will see a 7% funding increase over FY21 levels and PHY will see a 4% increase. No House or Senate Marks are currently available.

NSAC is charged jointly by NSF and DOE to provide Nuclear Science guidance, and the agencies coordinate closely on nuclear physics projects and experiments including MOLLER,

EIC and 0νββ. NSF found its observations of the recent DOE portfolio review for the 0νββ experiment instructive.

NSF-wide priorities offer additional opportunities for nuclear physics, including Midscale programs (and within PHY), Windows on the Universe, Quantum Leap and AI Institutes. NSF Nuclear Physics continually works on programmatic balance addressing university labs, large groups and single PIs; research scope; and project risk.

There have been no changes in PHY personnel, though Jim Thomas, the Experimental Nuclear Physics Program Director will return to LBNL in September 2021.

Discussion

Bernstein asked for more information about the proposed TIP directorate. **Opper** replied that NSF cannot discuss anything that is still being deliberated by Congress.

Fatemi noted that some potential undergraduate researchers are temporary residents or Dreamers under the Deferred Action for Childhood Arrivals, DACA, program and asked about REU Supplements for minorities. **Opper** stated that NSF REU supplements follow a particular structure and specific rules. Text in the REU supplements, the DCL, LEAPS, and ASCEND, state that by submitting, the PI attests that all eligibility requirements have been met.

Auguste inquired if there is a central NSF mentoring program for underrepresented students. **Opper** replied that a number of programs outside of MPS aim to increase student mentoring opportunities. The NSF Alliances for Graduate Education and the Professoriate (AGEP) program offers PIs the chance to establish mentoring programs at their university. AGEP requires an institutional-level commitment. The AGEP - Graduate Research Supplements (GRS) program supported by MPS is only open to PIs at AGEP institutions. PHY GRS do not require PIs to be faculty at AGEP institutions.

Presentation of the NSAC ^{99}Mo Subcommittee Report, Suzanne Lapi, ^{99}Mo Subcommittee Chair and Professor, University of Alabama at Birmingham

^{99m}Tc is a daughter product of ^{99}Mo and is widely used for nuclear medicine diagnostic imaging. The NNSA-Material Management and Minimization (M3) ^{99}Mo Program assists global ^{99}Mo production facilities in converting from use of Highly Enriched Uranium (HEU) to use of Low-Enriched Uranium (LEU) and accelerates the establishment of U.S. commercial non-HEU-based ^{99}Mo production.

Following the NSF and DOE charge to NSAC to provide the 7th annual assessment of the NNSA-M3 ^{99}Mo program, the ^{99}Mo Subcommittee was formed, comprising eight members with diverse expertise. The Subcommittee was briefed virtually by NNSA and the DOE Office of Environmental Management on May 10, 2021. All active cooperative agreement (CA) partners submitted written reports before the meeting. The Subcommittee met virtually on June 21, 2021 to discuss the report.

The Subcommittee reported that all major global ^{99}Mo producers will be using LEU targets by the end of 2022. COVID-19 minimally disrupted international ^{99}Mo production but affected international transportation of processed ^{99}Mo. This disruption was resolved quickly with only a modest impact to ^{99}Mo U.S. availability. As found in previous reports, the global demand growth of ^{99}Mo has been maintained, and the supply is adequate excepting conditions under adverse events. Longer-term projections indicate a possible significant international ^{99}Mo overcapacity as additional facilities come online.

Currently, three companies have active CAs with NNSA. ^{99}Mo from NorthStar's neutron capture technology entered the market in 2018. Northstar received Food and Drug Administration (FDA) approval to implement enriched ^{98}Mo targets at Missouri University Research Reactor (MURR) for enhanced production. Additionally, ^{99}Mo produced via the ^{100}Mo(γ, n) reaction from NorthStar's accelerator technology is anticipated to enter the market in 2023. ^{99}Mo from Subcritical Hybrid Intense Neutron Emitter (SHINE) Medical Technologies' accelerator with LEU fission will enter the market in 2022 and ^{99}Mo from Niowave's photonuclear LEU fission technology is anticipated to enter the market in 2024 or 2025. All CA partners acknowledged the importance of assistance from national laboratories. A fourth partner, Northwest Medical Isotopes, had management and planning changes and is currently working with NNSA to determine the best path forward for their CA. While U.S.-produced ^{99}Mo is now on the market, the target large-scale domestic supply has not yet been reached.

The Subcommittee found that the NNSA-M3 program is on track to realize a significant domestic ^{99}Mo supply and a global conversion to LEU sources. NorthStar's entrance into the market verifies that the NNSA program strategy can work. No new program risks were identified, and all risks within the program's scope are well managed. NNSA has partially addressed a prior recommendation regarding uranium waste disposal. The Uranium Lease and Take Back (ULTB) program has made progress in resolving the outstanding disposal issue but lacks a path for disposal of greater than Class-C waste. While all current CA partners have a path forward, only one CA partner is pursuing this approach at this time. To improve program effectiveness, the Subcommittee suggests that the NNSA continue to investigate disposal pathways and further refine the disposal cost model. The other prior recommendation that the NNSA release an FOA prioritizing time-to-market has been met through release of DE-FOA-0002303 in July 2020. This FOA's merit criteria includes the evaluation of commercial deployment, technology maturity, and business strategy and management capacity to help U.S. industries achieve commercial-scale production of ^{99}Mo by 2023. Award announcements were expected in the fall of 2021. NorthStar and SHINE are projected to be capable of meeting ^{99}Mo production goals of 3000 6-day Ci/week by 2023. The report recommends that NNSA define metrics for a program exit strategy and present the approach to the next NSAC ^{99}Mo Subcommittee at the next program assessment.

Discussion

Kester inquired how an NNSA exit strategy would take a CA company's proximity to market into account. **Lapi** replied that NNSA's metrics define success as having two U.S. companies capable of producing significant target volumes of ^{99}Mo. If these criteria are met, then an exit strategy should be created.

Mausolf inquired about NorthStar neutron capture technology and whether it used government-supplied HEU. **Lapi** stated that MURR uses HEU and supplies the neutrons for this project. NorthStar is using this technology as a jumping-off point for accelerator assembly to produce ^{99}Mo via the ^{100}Mo(γ, n) reaction that will be independent of the reactor. **Harvey** confirmed that MURR is fueled by HEU. NorthStar has a direct contract allowing reactor use and pays a fee for full cost recovery. NorthStar does not consider neutron source a challenge. **Dix** added that the NNSA is working with MURR to convert its fuel to LEU.

Dodge adjourned the NSAC meeting at 12:45 p.m. for a break and reconvened the meeting at 1:15 p.m.

Continued discussion of the NSAC Mo-99 Subcommittee Report

Mattmuller appreciated Lapi's effective leadership of the ^{99}Mo Subcommittee.

Dix thanked Lapi and the NSAC Subcommittee for their work and agreed with the report's recommendation. Steps will be taken to ensure a successful strategy for government exit.

Kester asked if the handling and disposal of Class-C waste was part of the report's evaluation. **Lapi** clarified that while disposal was beyond the program's purview, the Subcommittee still felt that it was important to address through report comments.

NSAC Committee Vote

Of the 16 NSAC Members, 12 were eligible to vote. These 12 NSAC members unanimously voted to approve the report and its recommendation. Members thanked the Subcommittee for producing an instructive and thorough report.

The NSAC Chair will transmit the report to the DOE and NSF.

Continued general discussion

On behalf of a participant, Dodge asked for more information about the hiring process for the DOE Physics Research Division Director. **Hallman** explained that this Senior Executive Service (SES) position is part of the SC Staffing Plan. To date, the position has received approval at the level of the Secretary's Office and additional DOE processes are in motion. Though a solicitation has not yet been issued, significant progress has been made. **Dodge** reminded participants that two DOE solicitations are currently open for PM positions in Nuclear Theory and Heavy Ions until July 26, 2021.

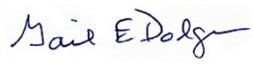
Horn inquired about possible budget impacts on EIC progress. **Hallman** reiterated that specific impacts cannot be determined at this time. However, the EIC is a very important initiative that is central to supporting quantum chromodynamics (QCD) research. Ultimately, if NP were forced to reconsider priorities due to budget constraints, DOE would consult the community as done previously in the so-called Tribble (LRP implementation) exercises.

Horn asked if there is a long-term vision for NSF Midscale Infrastructure projects. **Opper** remarked that PHY typically supports six Midscale projects at any given time. Three are currently in Nuclear Physics. At the end of this fiscal year, operating funds will no longer be provided to NSCL because of FRIB activities. PHY may redirect some of these funds to other programs, but the bulk are expected to support Midscale Infrastructure and other instrumentation needs.

Public Comment: None.

Meeting adjourned at 1:35 pm by Gail Dodge.

The minutes of the U.S. Department of Energy and the National Science Foundation/Nuclear Science Advisory Committee meeting, held on July 19, 2021, via virtual by zoom webinar are certified to be an accurate representation of what occurred.



Gail E. Dodge
NSAC Chair
Date: Sept. 11, 2021