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

PUBLIC MEETING MINUTES

Virtual Meeting
March 18, 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 10:00 a.m. EDT on Thursday, March 18, 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

Gail Dodge (Chair)	Jozef Dudek	Suzanne Lapi
Thomas Albrecht-Schoenzart	Olga Evdokimov	Thomas Schaefer
Sonia Bacca	Renee Fatemi	Artemis Spyrou
Lee Bernstein	Bonnie Fleming	Rebecca Surman
Joseph Carlson	Tanja Horn	Fred Wietfeldt
Evangeline Downie	Joshua Klein	Boleslaw Wyslouch
	Krishna Kumar	Sherry Yennello

NSAC Designated Federal Officer

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

Thursday, March 18, 2021
Morning Session

Welcome and Introduction, Gail Dodge, NSAC Chair

NSAC Committee Chair, Gail Dodge welcomed everyone and asked the NSAC members to introduce themselves. Dodge reminded members and the public that questions should be submitted to the Q&A.

Perspectives from the Department of Energy, Steve Binkley, Deputy Director for Science Programs, Office of Science

Binkley shared details of political appointees. He is currently serving as the Acting Director of the Office of Science; no nominee has been named for the Director of the Office of Science to date. The confirmation of David Turk, the Deputy Secretary nominee, is progressing. The Acting Undersecretary for Science, Kathleen Hogan, served as the former Deputy Assistant Secretary in the Energy Efficiency Renewable Energy office. And the Applied Energy Program is again under the Undersecretary for Science. Two new political appointees in the Office of Science are Dr. Tanya Das, Chief of Staff, and Special Assistant Natalie Tham. One area of focus for the administration is expected to be in clean energy. The President's budget request is anticipated in the May timeframe.

Discussion

Klein inquired about the head of the Office of Science and Technology Policy (OSTP) being a cabinet-level position. **Binkley** confirmed that the President issued an Executive Order making the head of OSTP a cabinet member. Eric Lander is the nominee for that position and is in the confirmation process. Elevating the Director of OSTP to the cabinet level will provide direct access to the President.

A participant on Chat asked about diminished support for nuclear activities and thoughts on the future in general. **Binkley** responded that the Secretary of Energy has made very strong statements about the importance of basic science research and clearly understands the scope and scale of the Office of Science. The Chief of Staff in the Office of Science has also made statements at internal meetings recognizing the importance of science.

Perspectives from the National Science Foundation, Denise Caldwell, Division Director for Physics (PHY)

The vision of the new Director of the NSF, Dr. Sethuraman Panchanathan, is to advance the frontiers of research into the future, ensure accessibility and inclusivity, and secure global leadership. Staff changes at Mathematics and Physical Science (MPS) include Sean Jones, the new Assistant Director, and Tie Luo, who is the Deputy Assistant Director. Recent retirements mean the positions of Director of the Office of Multidisciplinary Activities and the Division Director for Astronomical Sciences positions, as well as the Deputy Division Director for Chemistry and for Materials Research Divisions, need to be filled.

The President's FY21 budget formulation has not been received. An appropriation through the omnibus bill was larger than the original. And NSF's plan is under review.

MPS facilities projects include the Daniel K. Inouye Solar Telescope (DKIST) and the Large Synoptic Survey Telescope (LSST) construction as well as the upgrade to the A Toroidal LHC ApparatuS (ATLAS) and the Compact Muon Solenoid (CMS) detectors at the High Luminosity-Large Hadron Collider (HL-LHC). Progress is being made despite delays due to COVID impacts. After adjustments, facilities operations continue as things come back online and safety measure are being taken. The NSF continues to address the Arecibo Observatory collapse and is planning a workshop (April-June) to identify ideas for the future of Arecibo.

Laser Interferometer Gravitational-Wave Observatory (LIGO) -Virgo highlights included a successful O3 observational run. A second Neutron Star Merger was discovered but not yet identified. It is not clear if the small object is a black hole or a neutron star. The massive black hole binary is the most massive one detected to date.

LIGO is now preparing for a fourth run ~June 2022 depending on how COVID impacts the schedule. Detector improvements are being implemented to improve the sensitivity by at least 25%. LIGO continues the development of the upgrade known as A+, funded by the NSF, UK Research and Innovation (UKRI) and the Australian Research Council (ARC). A+ is expected to be fully-operational by 2024 and will increase Advanced LIGO sensitivity by 70%. Kamioka Gravitational Wave Detector (KAGRA) in Japan, one of the partner interferometers to LIGO, is coming online, not at optimum sensitivity but ready to join the observing network.

Windows on the Universe and Multi Messenger Astrophysics is operated by a meta-program where a group of program directors look at proposals submitted to the regular programs in Astronomy, Physics, and the Polar Programs. If those proposals fill a set of criteria (coordination, observations, and interpretation criteria) then special funding is considered.

Mid-scale Research Infrastructure (MsRI) addresses the growing needs for infrastructure to advance research. The NSF-wide program supports projects in the gap between Major

Research Instrumentation (MRI) and Major Research Equipment and Facilities Construction (MREFC) in the $6M to $100M range. There are two levels of proposals, the MsRI-1is for projects between $6M to $20M; and MsRI-2 for projects between $20M to $100M. The MsRI-1 is ongoing through FY21 and MsRI-2 will be planned for FY22.

NSF strongly supports the Industries of the Future initiative mentioned in the FY21 Administration R&D Budget Priority Memo. MPS participates in five of the areas: quantum information science (QIS), artificial intelligence (AI), advanced wireless/5G, biotechnology, and advanced manufacturing. The Divisions of Chemistry, Materials Research, Mathematics and Physics are involved in biotechnology and life process and QIS; the Division of Materials Research is involved in materials research through the Biomaterials and other program; and the Chemistry and Materials Research Divisions are strongly involved in advanced manufacturing.

Under the National Quantum Initiative Act, passed by Congress in December 2018, NSF must carry out a basic research and education program in QIS and engineering, and establish a set of multidisciplinary centers devoted to the promotion of QIS. NSF has been carrying out the research and education program for a long time and will continue this.

MPS is considered the steward of the Quantum Leap activity with investments that contribute to the foundation of a new technology based on QIS. Over the last few years, the NSF has contributed to broadening the emphasis outside MPS to include more enhanced activities on the part of the Engineering Directorate and the Computer Science Directorate. NSF initiated the Quantum Leap Challenge Institutes (QLCI), which will support large-scale projects driven by a cross-disciplinary challenge research theme for advancing the frontiers of QIS and engineering. The focus is on revolutionary new approaches and research will span the areas of quantum computation, quantum communication, quantum simulation, and quantum sensing. NSF awarded the QLCI competition in two phases. In the first phase, three awards were given, one each in networking, computing, and sensing. The QLCI Phase Two competition is currently underway and proposals are being reviewed. Small interdisciplinary teams explore highly innovative, original, and potentially transformative ideas for developing and applying quantum science, quantum computing, and quantum engineering in the specific area of quantum interconnects. Supplemental resources continue to be provided for access to quantum computing platforms on the cloud from Amazon, IBM, and Microsoft.

The Convergence Accelerator Program is designed to bridge the gap between state-of-the-art fundamental research and industry partnerships. There can be up to two tracks in particular areas and currently there is a track in quantum technology.

In 2020, the NSF issued a call for proposals to create one National Artificial Intelligence (AI) Research Institute focused on the foundations of AI and its relationship to use-inspired research, to use domain science to inform AI and vice versa. In the first competition, MPS created two Institutes in Chemistry and Physics. The NSF AI Institute for Artificial Intelligence and Fundamental Interactions (IAIFI), a collaboration between MIT, Harvard, Northeastern, and Tufts, is putting together a multidisciplinary program on how AI can benefit Physics.

NSF advisory teams have been consulting with the community and program directors on the NSF COVID response and have identified areas of need. These include minority serving institutions (MSIs), women researchers, underrepresented groups, early-career faculty, and post-docs, trainees, and fellows. Caldwell pointed out that associated funding opportunities announcements (FOA) will be announced in the next few weeks.

NSF is working with MPS in the area of diversity, equity, and inclusion (DEI). The Launching Early-Career Academic Pathways in the Mathematical and Physical Sciences

(LEAPS) program solicitation has been released. It is designed to launch the careers of pre-tenured faculty in MPS fields at MSIs, predominantly undergraduate institutions, and Carnegie Research 2 universities, and has the goal of achieving excellence through diversity.

Discussion

Dodge clarified that the diversity is only for faculty at Minority Serving Institutions (MSI) or undergraduate institutions. **Caldwell** responded that the solicitation outlines proposal submission eligibility. **Dodge** asked if NSF is considering supplements for principal investigators hit hard by COVID. **Caldwell** indicated that a range of possibilities are under discussion at NSF. She reassured the community that NSF is trying to determine the best response for identified needs.

Horn asked about NSF's position and vision for the EIC detectors. **Caldwell** said that DOE has the construction expertise for a major facility like the Electron Ion Collider (EIC) and NSF will focus on the research. NSF continues to look for areas where Principal Investigators can provide a strong component and where NSF investment has an identifiable scope.

Spyrou asked about COVID's impact on grant support for early career faculty, graduate students, and postdocs when there are university budget problems, where new faculty positions are not opened, and where postdocs cannot move. **Caldwell** said there are possibilities being discussed regarding those critical transition points. A solution for postdocs may be to offer an additional year. For early faculty, it might be extending the tenure clock. Caldwell's view is to keep people in the field as much as possible, get them through the transition points, and not lose a generation of physicists.

Yennello asked whether bridging positions, covered by the university, are being considered for postdocs. **Caldwell** responded that while she had not heard, others may be discussing it. The current discussions are on identifying critical needs.

Dodge read a chat question asking for more specifics on the $600M COVID relief funds for the NSF. **Caldwell** responded that the budget office is waiting for the release of the President's FY22 budget as there is Congressional language that needs to be included in the planning. More specifics will not be available until after that. The solicitation will be coming out and the community will be fully informed when that happens.

Dodge relayed a chat question about plans to locate specific disenfranchised organizations and/or people and create a full list of acceptable situations. **Caldwell** explained that the planning is complicated and must be done in the fairest, most equitable way. **Dodge** read a comment from chat that running out of eligibility is a critical concern for postdocs. **Yennello** suggested making postdoc awards eligible to be taken into their new tenure track.

Horn asked about use-inspired research and if Caldwell expected to make choices about the basic science, since some transform easier than others into technology applications. **Caldwell** said it depends on what steps the Director takes to realize his vision. She noted that basic science is crucial and NSF's role in fostering it is absolutely critical.

Perspectives from DOE Nuclear Physics, Timothy J. Hallman, Associate Director, Office of Science for Nuclear Physics

The FY20 budget for Nuclear Physics research and operations was $650M. In FY21, the budget is $635M, a reduction of $16.5M. In Core Research, there has been a reduction of 3.75% from FY20. Those affected by this reduction include the Large Hadron Collider Management & Operating commitments and the Facility for Rare Isotope Beams (FRIB) research ramp-up. The

Neutron Electric Dipole Moment (nEDM) was supported below the planned profile. Experimental commitments were met, and limited funding is available for new awards. QIS funds increased and Accelerator R&D was reduced. This year a new AI/Machine Learning (ML) initiative is supported at the $4M level.

Facilities operations were also subject to a 3.75% cut. The Relativistic Heavy Ion Collider (RHIC) is estimated to run 28 weeks. The Continuous Electron Beam Accelerator Facility (CEBAF) is expected to operate for seven weeks, due to the installation of the Central Helium Liquefier (CHL). The Argonne Tandem Linac Accelerator System (ATLAS) is estimated to operate for 39 weeks, and operations at the Facility for Rare Isotope Beams (FRIB) are supported at $50M. FRIB construction was not impacted and is funded at a baseline of $5.3 M. For ongoing Major Items of Equipment (MIEs), the Gamma Ray Energy Tracking In-Beam Array (GRETA) is funded below its baseline level, Super Pioneering High Energy Nuclear Interaction eXperiment (sPHENIX) is at its baseline level of $5.5M, and the Measurement of a Lepton-Lepton Electroweak Reaction (MOLLER) MIE increased to $5M, but below the planned level. Ton-scale Neutrinoless Double Beta Decay ($0\nu\beta\beta$) is at $1.4M, and the High Rigidity Spectrometer is funded at $3M. The Long Range Plan for Nuclear Science (LRP) continues to be executed and there has been substantial progress made in realizing the plan.

Development and deployment of a U.S.-led ton-scale $0\nu\beta\beta$ experiment is nearing the next stage of advancement. Three technologies are ready for deployment: CUORE Upgrade with Particle Detection (CUPID) is based on scintillating bolometry using Mo-100 enriched Li2Mo4 crystals; the Large Enriched Germanium Experiment for Neutrinoless double beta Decay (LEGEND-1000) makes use of enriched Ge-76 crystals assembled into drifted charge, point contact detectors; and the next Enriched Xenon Observatory (nEXO), which is based on time projection chamber (TPC) using large amounts of liquid xenon isotopically-enriched in Xe-136. The background constraints for all technologies are exceptionally challenging and a choice must be made for a possible site. Options includes the Sanford Underground Research Facility (South Dakota), SnoLab (Canada), and Gran Sasso (Italy). Hallman shared recent successes from the CUPID, LEGEND-1000 and nEXO collaborations. There are monthly technical updates provided by each of the collaborations to DOE NP, as well as interactions with potential international collaborators regarding investment in $0\nu\beta\beta$ science. An NP $0\nu\beta\beta$ Portfolio Review is planned for July 13-16, 2021 and a North American-European Summit is planned for September 27-29, 2021 to discuss $0\nu\beta\beta$ investment.

FRIB is the newest SC User Facility, a high current, low energy microscope probing the atomic nucleus. FRIB will increase the number of known isotopes and enable world-leading research on nuclear structure. FRIB is ~96% complete. A recent call for proposals yielded 82 proposals requesting 9,784 hours of beam time.

ATLAS continues as the premier stable beam user facility. In addition to a multi-user upgrade, an upgrade to the CAlifornium Rare Isotope Breeder Upgrade (CARIBU) facility, dubbed nuCARIBU is also being completed, where, instead of a ^{252}Cf source, a neutron generator to induce the fission on actinide foils will be used. RHIC machine performance continues to set new records and the search for a critical point between the phases of nuclear matter is a focus. The sPHENIX upgrade is nearing completion. A timing detector for Compact Muon Solenoid (CMS) detector at the LHC is being considered, and a CMS timing detector Science Review is upcoming.

The CEBAF program is underway. New results from GlueX illuminate the mechanism of threshold J/Psi production and the upper limit on the pentaquark. The new Lead Radius

Experiment (PREX-II) results are unblinded and the weak radius can be combined with the charge density to obtain the baryon density of ^{208}Pb. This is the first clean determination of the central baryon density of a heavy nucleus, is accurate to 2%, and provides an important benchmark to chiral effective field theory calculations. The result has direct relevance for bounding the radius of neutron stars in concert with neutron star merger data from LIGO.

MOLLER has achieved Critical Decision (CD) -1.

In 2020, the Electron Ion Collider (EIC) CD-0, site selection, project start, and dedication were accomplished. The EIC will be located at Brookhaven National Lab and is a partnership with Jefferson Lab (JLab) in both construction and research. The EIC is a game-changing resource for the international nuclear physics community. The SC Office of Project Assessment reviewed the EIC's readiness for CD-1 and the DOE's Office of Project Management conducted an independent cost review. Both reviews were positive and recommended proceeding with CD-1. The EIC Users Group was formed in 2016 and has 1,259 collaborators as of February 2021; discussions with countries potentially interested in contributing to the project are ongoing. The convergence of the capabilities on the EIC and the prospect of error-corrected quantum computing is an exciting prospect of turning quantum chromodynamics (QCD) into precision science like quantum electrodynamics.

Many types of nuclear data are crosscutting to numerous applications. The Workshop for Applied Nuclear Data Activities (WANDA) continues to be a strong endeavor in which the nuclear data community and several U.S. government agencies participate.

In the area of clean energy, an understanding of neutronics in new nuclear reactor design is needed. Efforts in nuclear data are needed for space exploration, especially in electricity production and propulsion. NASA needs to understand the impact of ion fragmentation as it relates to astronaut and instrumentation during long haul flight exposure.

SC stood up five quantum centers with funding at $25M per year for each; NP contributes $4M per year. One recent outcome of NP-supported research in QIS was conducted by Pacific Northwest National Lab, MIT and collaborators, where they studied the impact of natural radiations on quantum computers. The results suggest there may be a need for deploying quantum computers underground to limit exposure to the natural radiation.

Diversity is a fundamental part of the SC business model. An SC committee representing all programs conducted a comprehensive look at business practices to understand how language might be a barrier to creating diverse communities by preventing access, participation, and retention. An NP pilot program was designed in partnership with MSIs and Historically Black Colleges and Universities (HBCUs) to form a direct pipeline for students in underrepresented groups. This was informed by the American Institute of Physics' TEAM-UP Report and resulted in a FOA yielding 36 proposals that create collaborations with 40 MSIs and HBCUs. Lessons learned will be incorporated into an SC initiative on diversity and traineeship. Other recent FOAs include the Nuclear Data Interagency Working Group FOA, the Quantum Horizons: QIS Research and Innovation for Nuclear Science FOA, and the Data Analytics for Autonomous Optimization and Control of Accelerators and Detectors FOA.

There have been DOE NP staff changes including the addition of six new people, one retirement, and one career change. SC has issued calls for nominations for the Distinguished Scientist Awards to recognize outstanding achievements in a scientific area. This award comes with $1M in funding and scientists at the National Laboratories are eligible. The NP community is fortunate to have received two awards: Barbara Jacak, Berkeley Lab and for Cynthia Keppel (JLab).

Discussion

Klein asked about the distribution of Total Estimated Cost (TEC) funds for ton-scale $0\nu\beta\beta$, the timing of the September International Summit, and its influence on the Portfolio Review. **Hallman** responded that the Portfolio Review and a choice of technology needed to occur before the TEC funds are distributed. Discussions at the Summit will focus on how funding agencies around the world could work together in a global investment strategy.

Bernstein inquired about the administration of the Isotope Program. **Hallman** explained that from a Congressional point of view, the Isotope and Nuclear Physics program appropriations are expected to be completely separate in the FY22 budget. Questions should go to Jehanne Gillo, Director of the DOE Isotope Program.

Fatemi asked about the impact of the COVID situation on young faculty in tenure-track positions, and the possibility of supporting bridge positions to mitigate financial strain and hire young faculty members. **Hallman** responded that going forward there is support for mitigating impacts. However, data collection and analysis are needed to understand the impacts of COVID before considering potential actions.

Schaefer requested information on the search for a new NP physics research division director. **Hallman** indicated that with the change in Administration there was hope that the department position quota on senior executive staff might be relaxed. This remains an ongoing discussion with the Acting Director of the Office of Science and an urgent priority.

Evdokimov asked about funding for the EIC User Group. **Hallman** explained that the working mode is one where a university group joins a collaboration. The direct funding contribution goes from the SC to the university group to participate in the program.

Break from 12:01 p.m. reconvened at 12:11 p.m.

NSF Nuclear Physics Overview, Allena K. Opper, Program Director, Nuclear Physics, NSF

NSF has no details on Appropriations from the $600M pandemic relief bill, however, the bill states that $600M be provided to NSF to fund or extend new and existing research grants, cooperative agreements, scholarships, fellowships, apprenticeships, and related administrative expenses to prevent, prepare for, and respond to COVID.

The COVID-19 impacts are being experienced in different ways. The American Physical Society (APS) has analyzed data from the March meetings for 2020 and 2021. There has been a 20% decrease in submitted abstracts from the experimental community and a slight uptick from the theoretical and computational communities. There has been a 13% abstract reduction for those who have earned their PhD in the last five years and a 10% reduction for those who got their Ph.D.'s between five and 10 years ago. In Experimental Nuclear Physics from 2015 to 2020 the number of proposals submitted each year has varied between 55 and 70 but in 2021 only 40 proposals were submitted. Researchers whose awards would normally be ending this summer but whose research was disrupted by COVID are continuing their work through no cost extensions.

Opper encouraged proposals addressing underrepresentation of various populations and annual review content. She reminded NSAC that annual reports must include goals and accomplishments of the award's intellectual merits and its broader impact. Proposals are in and under review for Experimental & Theoretical Nuclear Physics, MRI, and MsRI-1 and MsRI-2.

The NSF Cooperative Agreement for the National Superconducting Cyclotron Laboratory (NSCL) ends FY21; funding from NSF for NSCL will end September 30 and the lab will be incorporated officially into the broader FRIB laboratory. This transition is going smoothly in large part because of the excellent communications between DOE and NSF, as well as the excellent communication between FRIB and NSCL. Other areas in which there is good coordination between DOE and NSF are the MOLLER project, EIC preparations and neutrinoless double beta decay.

Opper shared several highlights about μ(g-2), SeaQuest D-Y, sPHENIX, EPD installation, heavy-flavor hadron observables, STAR Forward Upgrade detectors, γ-ray spectroscopy, and nuclear structure studies by Florida State University (FSU) groups working at MSU and at FSU, theoretical models with relativistic jets to explain a tidal disruption event that occurs when a star is torn apart by a supermassive black hole, and precision mass measurements at NSCL.

The NSCL ReA6 upgrade is nearing completion with it connected to ReA3 and the ReA6 cryomodule cool down begun. The ReA6 beam commissioning is set to start April 12, 2021, and the first ReA6 experiment is schedule to start in early May.

Finally, Opper mentioned the "My Nuclear Life" podcast by Shelly Lesher, University of Wisconsin at Lacrosse, who interviews guests on various nuclear physics topics.

Discussion

A chat participant asked how many applications and funding amounts were expected for this round of MRI, MsRI-1 and MsRI-2 solicitations. **Opper** said that MsRI-1 is for projects between $6M-$20M and MsRI-2 projects are $20M-$100M. Competition is high since these two programs are NSF-wide.

Hallman and **Opper** presented service appreciation awards to Jozef Dudek, Olga Evdokimov, Tori Forbes, Krishna Kumar, Suzanne Lapi, and Artemis Spyrou for their years of service and contributions to the nuclear physics community.

Dodge adjourned the NSAC meeting at 12:30 p.m. for lunch and reconvened the meeting at 1:20 p.m.

Thursday, March 18, 2021
Afternoon Session

Medical Applications of Nuclear Physics Research, Cynthia Keppel, Group Leader Jefferson Lab's Experimental Halls A and C, Thomas Jefferson National Accelerator Facility or JLab

JLab nuclear scientists apply their core research capabilities to find commonalities between nuclear science and medicine. This synergistic development can be found in the instrumentation and detection systems, computing, software and data management, and particle accelerator technology.

The large JLab spectrometers are composed of radiation detection systems. Particle detector spin-offs have advanced patient care. JLab's "workhorse" tools include the photomultiplier tubes, silicon photomultipliers, scintillator and detector electronics, and more.

The gamma camera is a photodetector that has been adapted by JLab for breast cancer detection. On a standard mammogram, looking for a tumor is based on density variation. The tumor, being denser than the soft tissue around it, is usually easy to image, however, there may be micro calcifications rather than a clear solid density spot. To get a functional image, radiopharmaceuticals are introduced and are taken up by the tumor. Metabolically, a look at function relies on the fact that tumors either take up different substances or take up some substances in greater abundance than the healthy tissue. JLab built a photon detector that sits on an arm and has a portable data acquisition system which is currently imaging patients.

Surgeons removing breast cancers can use this functional imaging technique in the operating room during surgery. The hand-held gamma camera is used in the surgical suite to look for margins of tumors. The camera is remote and wireless so physicians do not have to look away during surgery. To help with this, JLab is working on an onboard display.

The APEX, or A Prime EXperiment, at JLab developed an "active catheter" for Brachytherapy applications. Using a stepper motor drive, radioactive sources are typically placed near the tumor, delivering a high radiation dose to the tumor while reducing exposure to surrounding healthy tissue. There is no real-time dose measurement, instead, simulations are used based on extrapolated stepper motor positions. The APEX uses a scintillating fiber array placed into a catheter to make in vivo dose measurements. As a result of the development of the real-time dosimetry technology, three patents were licensed to Radiadyne. Radiadyne had made a product called OARtrac which made this technology a bench to bedside application. In 2018, JLab won two awards for this work: the Medtech Breakthrough and R&D100 Award.

The detector group at JLab is working on advanced brain imaging technology using awake animal models to aid in Alzheimer's brain function research. In pharmaceutical development, people look at the brain function by taking an animal into an imaging device where the animal is anesthetized while the image is obtained. The goal of this project is to create a Positron Emission Tomography (PET) device that tracks Infrared Reflective Markers on an animal, in this case a mouse, and enable the AwakeSPECT system to obtain detailed, functional images of the brain of a conscious mouse as it moves around inside a clear burrow. The PET is using a radiopharmaceutical and the 3-D map of the function uses a marker for a particular disease of interest, attached with the radio label.

The Low Energy Recirculator Facility (LERF) at JLab is a free electron laser used to test cryomodules. It also has the potential to create copper isotopes for theranostic use via photo production using Bremsstrahlung photons on a gallium target. Theranostics is where the radioisotope is used as both a therapy and diagnostic marker. That is, in addition to the site-specific radio labeled markers, decay particles from the radioisotope kills the tumor. The isotope ^{67}Cu is exciting because it emits beta particles capable of tumor kill and has appropriate gamma emission for imaging via single photon emission computed tomography (CT).

Proton radiotherapy is another area for nuclear science and medicine. Radiotherapy with a proton accelerator allows oncologists to design fine-tuned 3-D cancer treatment plans. It enables higher-precision, localized treatment because the deposited dose in the tumor can be tuned and controlled with the beam energy, unlike X-ray treatments. Good control of beam delivery is needed to deliver these precise energies, scan the tumor shape, monitor beam simulation, and more. Proton facilities are looking more like accelerator facilities as accelerator technology is being applied more in this field. More than 250,000 patients were treated with particle therapy worldwide between 1954 and 2020. Annually, the proton therapy community averages ~15,000 patients. Tumor sites and patient treatments are increasing and more hospitals and clinics are adopting proton therapy, but the accelerators need to be more affordable, smaller, and more automated.

Nuclear science can help with proton beam simulation and radiation transport through the patient that is customized by treatment, anatomy, and tumor. Varian Medical Systems funded JLab to incorporate into simulations the relative biological effectiveness (RBE) factor, which allows comparison between killing power of a radiation of a given type to that of X-rays. A single RBE value is currently applied to all proton patient treatment plans. Using basic nuclear science, as the end of the path nears, the protons in the beam have decreasing energy. Near a Bragg peak, the dose distribution is increased and there is a higher RBE at the distal end of the Bragg peak. The RBE distribution needs to be weighted in the treatment planning. JLab is doing simulation and planning integration.

PET imaging is now being applied to verify proton beam delivery. The PET camera can see the trace of the beam going through the patient. This allows the dose to be delivered to the right spot, but advanced PET detection is needed with cameras on board to translate the image into a dose. This requires simulation and is an area for technology development.

Proton beam characterization and dosimetry is a potentially excellent tool for (new) pencil beam scanning delivery. Precise delivery of the proton beam requires daily calibration. Devices on a quality assurance (QA) bed measure the beam's distribution with seven millimeter resolution. At the Super BigBite Spectrometer (SBS) at JLab, there is a large area gas electron multiplier, which can handle a very high rate and can measure protons with 70 micron resolution. This project recently received an award from the APS Division of Licensing and Protection (DLP).

Proton CT is the next step in imaging where a low dose, high-energy delivery goes through the patient to a tomography device on one side and on the other it switches to the lower energy, higher dose patient treatment. To deal with the anatomy and setup variation, it would be useful to have a 3D image on board to do the adaptive planning for patients. However, the beam delivery space changes and needs better imaging technology.

JLab, like other national laboratories and universities, has a broad range of expertise and the facilities to support research activities. Nuclear facilities and their expertise can be leveraged for medical and other technology development. There is synergy that can be seized upon if needs and possibilities are understood. The National Cancer Institute is doing a series of virtual workshops on Accelerating Precision Radiation Oncology through Advanced Computing and Artificial Intelligence.

Discussion

Wietfeldt asked whether existing accelerators need to be repurposed for proton therapy. **Keppel** explained that there is no point in repurposing anything over 250 MeV protons as that would go through the patient. It has to be a low energy cyclotron. The ideal range is ~70 to 230 MeV. The key is a local hospital because the entire medical support structure and patient populations are needed as well. The costs for new facilities and new accelerators are also declining.

Spyrou inquired about the status of heavy ion therapy. **Keppel** explained that there are no heavy ion therapy centers in the U.S. From a nuclear scientist standpoint, the Bragg peak is much narrower in heavy ion therapy. Since the average size of a detected tumor is two centimeters, tumors are not caught early enough in the Bragg peak to make a difference. Also, the heavier beam fragments are at the back end of the Bragg peak. Carbon has a higher RBE, so there is more direct action on the DNA. A higher RBE is tumor killing, but the incoming proximal dose is larger and has more impact on healthy tissue. There are also radio-resistant tumors. Carbon ion beams have been successful when implemented in Europe, Japan, and Russia where the patients typically have gastrointestinal (GI) tumors. Problems arise when there is a lot of soft tissue around sensitive to radiation damage, like with the X-ray beam. In the U.S., private entities have largely funded these projects.

Lapi asked about funding strategies for basic and applied science. **Keppel** expressed that collaboration and interagency work has been effective. For instance, because JLab cannot get direct funding, a center off-campus was created to apply for NIH and private funds and then partner with the lab. NIH funds basic technology development. However, going to private industry has many new challenges and multiple strategies need to be included. Workshops are also a sign of a new era of interagency work.

Bernstein was curious about the possibility of using radioactive ion beams, the beam currents needed for effective therapy, gamma tracking for the carbon breakup reactions, and the dependency of gamma-ray production data for those reactions. **Keppel** said for proton therapy the beam current is hundreds of nano amps. People are trying to get the proton range, determining where the proton beam stops, and uncovering the distal end of the Bragg peak. If we can verify, in a patient treatment room, that the range is as planned, that is a big win because there is no in-vivo dosimetry. If we get past prompt photon imaging and treatment rooms the next thing is to determine the dose profile in the room and production mechanism.

Downie asked about ways to engage with undergraduate institutions and research partners to offer projects that demonstrate societal benefit and improve the image of physics amongst underrepresented groups. **Keppel** said that one advantage to building medical devices is it is nice to be able to walk into the lab, build something, and then use it within a year with a patient. That is an attractive timeframe for student involvement. Students can follow a project from beginning to end, and the societal implications are more readily understandable. Students gravitate towards these projects. The timeframe tends to be less extensive than core nuclear science. These are pluses for attracting underrepresented groups as well.

Presentation of New Charge Molybdenum-99, Timothy J. Hallman, Associate Director, Office of Science for Nuclear Physics

Hallman provided background information on the charge for Molybdenum-99 (Mo-99) explaining that past concerns in the medical community about shortages drove the implementation of these NSAC reviews. The American Medical Isotopes Production Act of 2012 states that the Secretary of Energy "shall…use the Nuclear Science Advisory Committee to conduct reviews of the progress made in achieving the [National Nuclear Security Administration-Material Management and Minimization (NNSA-MMM)] program goals and make recommendations to improve effectiveness." The Mo-99 charge letter calls for the seventh instance of NSAC conducting the assessment.

Questions asked include what is the current status of implementing the goals of the NNSA program? Is the strategy for continuing to implement the NNSA goals complete and feasible? Are the risks identified in implementing the goals being managed appropriately, and has the NNSA MMM program addressed concerns and recommendations articulated in the last assessment? And what steps should be taken to further improve the NNSA program effectiveness? This seventh assessment must be submitted to the agencies in the spring of 2021.

Discussion

There was no discussion regarding the new charge for Mo-99. **Dodge** asked if Hallman would answer questions about COVID and the Early Career Research program or speak on it. **Hallman** responded that he did not know of a discussion at this point about accommodations to address the impacts of COVID-19 in the program, such as allowing a longer time period for eligibility. He imagined that might be implemented to mitigate the effects of COVID-19, but at this moment the parameters of the program are unchanged, in terms of young scientists and Ph.D.'s.

U.S. Department of Energy, Office of Science, Graduate Student Research (SCGSR) Program Presentation, Sharon Stephenson, Program Manager, Nuclear Structure/Astrophysics, Office of Nuclear Physics

Stephenson explained that the SCGSR is managed by Dr. Ping Ge, a program manager in the Office of Workforce Development for Teachers and Scientists. The SCGSR program was officially started in 2014 and the award funds have almost doubled during that time. SCGSR supports graduate students working onsite up to one year at all 17 DOE-supported facilities and laboratories. To date, over 500 awards have been made across SC (60 to NP) and involve ~130 universities. NP awards have been distributed across NP programs with the majority in medium energy, theory, nuclear structure and nuclear astrophysics, and fundamental symmetries. The annual number of SCGSR awards in NP has increased from seven to the anticipated number of 14 in 2020.

Convergence research topical areas (microelectronics, data science, conservation law and symmetries, accelerator science) are efforts within SC to embrace research scope that includes multiple programs. An applicant can apply to a convergence area, but at least two offices or programs must agree that the research scope falls within their program. The benefit to applicants is that if the research scope does not apply to more than one program, the decision will rest with the program to find an appropriate fit.

NP is leveraging funds and supporting graduate students as much as possible. The percentage break down of NP Awards since 2014, by Lab, is JLab (21%), Los Alamos (21%), Oak Ridge (18%), Berkeley Lab (13%), Brookhaven (12%), Livermore (7%), Argonne (5%), and Fermilab (3%).

Discussion

Klein asked how the applications were reviewed and who has ownership. He expressed concern that interdisciplinary research tends to have difficulty being supported and it does not get the added value of being interdisciplinary. **Stephenson** responded that initially a student will choose a convergence area, whereafter the application will go to the appropriate programs. The programs address how useful the research might be for their portfolio. They do not see what other reviewers have said. If the minimum (2 programs) have indicated usefulness then reviewers, divided between the programs, evaluate the application. Those rankings are provided and a decision is made. She acknowledged that the culture of shared programs is an open question that needs to be resolved.

Carlson encouraged Stephenson to do everything possible to publicize SCGSR. He expressed caution about distributing students equally across programs as they are writing a proposal with a mentor.

Bernstein favored not enforcing any geographic distribution. He mentioned that the program required the student to be advanced to Ph.D. candidacy. He stated that students tend to be finishing their third year by the time they have satisfied this requirement, creating less opportunity for engagement. He suggested exploring that more fully and noted that the language might need to be changed to encourage more openness to things outside of the typical physics Ph.D. degree window. **Stephenson** appreciated the suggestion and remarked that the program is reviewed annually and stated she would bring it up. **Fleming** agreed with and echoed Bernstein's statements. She pointed out that students at her institution face the same challenges in that they do not reach Ph.D. candidacy until their third year, which can create a barrier to eligibility for the program. **Stephenson** appreciated the comments and indicated that she focused on things that can be done to ensure equal access for applicants. She indicated she is considering ways to make that easier.

Dodge asked if there are two different fellowship programs for graduate students, this one being focused on students that go into National Labs. **Stephenson** responded that there is now only one graduate fellowship program.

Fleming addressed the Ph.D. candidacy issue further and suggested that a letter from a Department Chair stating a student had finished their coursework and chosen an advisor would alleviate the marker of advancing to candidacy, which is different for each institution. **Yennello** added that perhaps students could be past a certain stage, such as their first year or their first three semesters, pointing out that courses at smaller schools might stretch out longer due to less frequent offerings. **Bernstein** added that a letter from the graduate advisor in the department or something similar might offer some flexibility.

Lapi asked about the isotope program and whether it will have its own funding or is still participating in the program. **Stephenson** shared that it is currently included under the umbrella, but this summer, it will become a standalone program, officially.

Downie noted that outreach can be increased through advertising earlier to make graduate students aware of it. She mentioned that the National Society of Hispanic Businesses had a graduate mailing list that could be used to increase awareness and diverse participation.

Dodge inquired if health insurance costs for students who are away from campus have been explored. **Stephenson** said she would bring it forward. Currently, SCGSR eligibility requirements are for lawful permanent residents and US citizens only.

Yennello suggested presenting information to the APS Division of Nuclear Physics as well as the MSI research internship program. **Downie** mentioned that there is a mailing list of people who have participated in the event. **Dodge** offered another possibility that the labs send out the information directly to users.

Artificial Intelligence for Nuclear Physics Presentation, Tanja Horn, Professor of Physics, The Catholic University of America

Horn provided an overview of the activities on AI and nuclear physics. She reviewed the Report of the Subcommittee on AI/ML, Data-intensive Science, and High-Performance Computing (AI for Science) that was led by the Office of Advanced Scientific Computing Research (ASCR) and the AI for NP Workshop (March 2020).

The National Artificial Intelligence Research and Development Strategic Plan, signed February 11, 2019, called for a concerted effort to promote and protect AI technology and innovation in the U.S. The AI for Science subcommittee, led by Dr. Tony Hey, was charged to assess the opportunities and challenges of AI/ML and to identify strategies to address the challenges and deliver on opportunities.

Horn highlighted Section 6.2 and focused on the unique features of NP including the multi-scale, highly correlated, and high dimensionality nature of NP; diversity of datasets in NP; and availability of NP data on short timescales. Grand challenges for AI in NP are harnessing the physics program of the EIC, realizing the science potential of FRIB, reconstructing events in nuclear physics, improving tracking algorithms, and particle identification. The AI for Science report includes eight key findings and six recommendations. The findings focus on the once-in-a-generation opportunity, the lack of sufficient solutions and algorithms, new advances in the DOE scientific user facilities, a concerted and coordinated R&D effort, the DOE labs unique position, national implications beyond the Office of Science, the pivotal role of a trained workforce, and partnerships. The recommendations focus on the creation and structure of a 10-year AI for Science initiative, an instrument-to-edge initiative, workforce training and retention, and interagency and international collaboration.

Horn turned to the AI for Nuclear Physics workshop held in March 2020. The output of the workshop is in a white paper available from arXiv: 2006.05442v2 and in the European Physics Journal A. Horn shared examples to demonstrate AI/ML in nuclear theory and lattice QCD, AI to detect complex signatures in experimental methods – both near and long term, AI/ML for detector design and to extract physics, and control and optimization of complex accelerators – both in accelerator science and operations. The priority research directions that resulted from the workshop are a focus on game changers in nuclear theory, a holistic approach to experimentation with expert systems to increase scientific output, experimental design unconstrained by computation, improving simulations and analysis, and accelerator design and operations. There were also four community identified needs and commonalities: workforce development, problem-specific tools, enabling infrastructure, and uncertainty quantification.

At WANDA, held in March 2020, the large potential for AI/ML algorithms to address critical problems in the nuclear data pipeline was discussed. AI/ML use is expected to grow exponentially in nuclear data. That growth offers new approaches to long standing problems, speed ups in TensorFlow and Pytorch libraries, and allows new researchers to use AI/ML. New trends that were identified include transforming workflows, "physics-aware" AI/ML models, and using AI/ML to guide experiments, theory, and evaluations.

Horn closed with an outlook on AI in nuclear physics. These include ubiquitous areas where AI/ML can be beneficial; talent and tools among nuclear physics researchers; addressing challenges that existing technologies cannot; NP data sets that expose the limitations of cutting edge methods; beneficial collaborations between NP, AI/ML, data science, and industry; cross-disciplinary funding programs to facilitate connections to computer science; education to increase the level of AI/ML literacy; and research and curricula in AI/ML to attract students.

Discussion

Bernstein stated that there is excitement in nuclear data for the potential of AI/ML. In terms of what it can do for the physics as well as making data more accessible to people. AI/ML will help fill in gaps until either measurements can be performed or models can be improved.

Dodge asked about a summer school program to bring in students and postdocs. **Horn** noted that there is a global, DOE-funded, school for nuclear physics that rotates locations. The recent one held at the University of Maryland and JLab was established for people with experience ranging from absolute beginner to expert to discuss the AI basics, topics from neural networks to variations in Monte Carlo studies, detector design, optimizations, and data set feature extractions. **Dodge** wondered if the US Particle Accelerator School could also offer a class relevant to this topic.

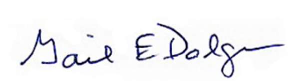
Public Comment

Horn asked Hallman about the vision and schedule for the next LRP as well as progress on the $0\nu\beta\beta$. **Hallman** was optimistic that enough progress can be made to maintain the envisioned time scale toward the end of this calendar year. Interactions with the Division of Nuclear Physics and planning for Town Hall meetings may only be partially complete by the end of the calendar year. Regarding $0\nu\beta\beta$, his goal is that NP will be far enough along on double beta decay to get started in earnest towards the end of this calendar year. **Opper** added that this is something that NSF has been discussing as well.

Dodge read a comment in the Q&A that NSF reviewers hesitate to fund DOE nuclear physics projects and posed the question of how to separate out projects that will be funded by DOE versus NSF. **Horn** responded that this was discussed in the AI for Science subcommittee about how such a learning project would be funded. It came up in a different context because of the exascale projects. Exascale typically has individuals who are conversant in the computation and technologies. But AI for Science envisions having users who are not conversant in the technologies or the computation. The subcommittee expressed that there should be some startup projects where everyone brings together the two parts to initiate these collaborations. The goal is that these would morph into something longer term, something like a SciDAC. **Hallman** considered this to be an issue that needs a better focus. This is seen particularly in fundamental symmetries with proposals that could reasonably be considered either NP or high energy physics (HEP) and where such a proposal should land, which program is most appropriate. For example, the high energy physicists imagine that some of these things are NP, but in NP they may be considered HEP. In Neutrino Physics there are some HEP groups interested in double beta decay, but NP is the steward. With construction of the ton scale experiment there may be groups from both cultural backgrounds that want to participate in that research. The question is if they have traditionally been a HEP group do they continue to get their funding from HEP or should it move to NP. There are other areas where this is also true.

Meeting adjourned at 3:39pm by Gail Dodge.

The minutes of the U.S. Department of Energy and the National Science Foundation/Nuclear Science Advisory Committee meeting, held on March 18, 2021, via virtual by zoom webinar are certified to be an accurate representation of what occurred.



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Gail Dodge
NSAC Chair
Date: August 8, 2021