

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

PUBLIC MEETING MINUTES

**Hilton Washington DC/Rockville Hotel & Executive Meeting Center
1750 Rockville Pike, Rockville, MD 20852**

April 8, 2019

NUCLEAR SCIENCE ADVISORY COMMITTEE SUMMARY OF MEETING

The U.S. Department of Energy (DOE) and National Science Foundation (NSF) Nuclear Science Advisory Committee (NSAC) was convened at 8:30 a.m. EST on Monday, April 8, 2019, at the Hilton Washington DC/Rockville Hotel & Executive Meeting Center in Rockville, MD, by **Committee Chair David Hertzog**. 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.

Committee Members Present

David Hertzog (Chair)	George Fuller	Jeffrey Nico
Mei Bai	Kate Jones (online)	Sofia Quaglioni
Helen Caines	Cynthia Keppel	Krishna Rajagopal
David Dean	Yury Kolomensky	Jenifer Shafer
Jozef Dudek	Suzanne Lapi	Artemis Spyrou
Olga Evdokimov	Zein-Eddine Meziani	

Committee members unable to attend:

Geoffrey Greene
Silvia Jurisson
Daniel Phillips

NSAC Designated Federal Officer:

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

Others present for all or part of the meeting:

John Arrington, Argonne National Laboratory (ANL)	Manouchehr Farkhondeh, DOE
David Asner, Brookhaven National Laboratory (BNL)	Glenn Fox, Lawrence Livermore National Laboratory (LLNL)
Ethan Balkin, DOE	Jehanne Gillo, DOE
Elizabeth Bartosz, DOE	Thomas Glasmacher, Michigan State University (MSU)
Steve Binkley, DOE SC, Deputy Director	Roxanne Guenette, Harvard University
Denise Caldwell, National Science Foundation (NSF)	Mike Heffner, LLNL
Joseph Carlson, Los Alamos National Laboratory (LANL)	Stuart Henderson, Jefferson Lab (JLab)
Maria Chamizo, BNL	Tanja Horn, The Catholic University of America
Heather Crawford, Lawrence Berkeley National Laboratory (LBNL)	Ben Jones, University of Texas at Austin
T. Reneau Conner, Oak Ridge Institute for Science and Energy (ORISE)	Brian Knesel, DOE
Frederica Darema, NSF	Brenda May, DOE
James Decker, Yale University	Robert McKeown, JLab
	Curtis Meyer, Carnegie Mellon University
	Allison Mills, DOE
	Allena Opper, NSF

Erich Ormand, LLNL
 Graham Peaslee, University of Notre Dame
 David Radford, ORNL
 Martin Savage, University of Washington
 Bradley Sherrill, National Superconducting
 Cyclotron Laboratory (NSCL)
 Nigel Smith, SNOLAB
 Paul Sorensen, DOE
 Jim Sowinski, DOE
 Alan Stone, DOE

Rebecca Surman, University of Notre Dame
 James Symons, LBNL
 Jim Thomas, NSF
 Richard Witt, DOE
 Bolek Wyslouch, Massachusetts Institute of
 Technology (MIT)
 Ranu Yale, University of Kentucky
 Sherry Yennello, Texas A&M University

Others attending by webcast:

Mitch Ambrose, American Institute of
 Physics (AIP)
 Whitney Armstrong, ANL
 Linda Barker, TVWorldwide
 David Brown, BNL
 Matthew Carnavos, DOE
 Julie Carruthers, DOE
 Arthur Champagne, University of North
 Carolina
 Zhenyu Chen, Stonybrook University
 Zohreh Davoudi, University of Maryland
 Matthew Dietrich, ANL
 Sean Dobbs, Florida State University
 Karen Dow, MIT
 Alexandra Gade, MSU
 Dave Gardy, TVWorldwide
 Giorgio Gratta, Stanford University
 Fanqing Guo, Yale University
 Jeter Hall, SNOLAB
 James Hawkins, DOE
 Karsten Heeger, Yale University
 Jiangyong Jia, BNL
 Benjamin Kallen, Lewis Burke
 Joshua Klein, Pennsylvania State University
 Krishna Kumar, University of
 Massachusetts

Sonia Letant, LLNL
 Kent Leung, North Carolina State University
 (NCSU)
 Xiaofeng Luo, Central China Normal
 University
 Bogdan Mihaila, NSF
 Paul Mantica, MSU
 T Marsh, TVWorldwide
 Robert McGrath, Stonybrook University
 Paul Mueller, ORNL
 Mark Pitt, Virginia Tech
 Robert Redwine, MIT
 Thomas Schaefer, NCSU
 Michelle Shinn, DOE
 Justin Stevens, William & Mary
 Jim Thomas, NSF
 Will Thomas, AIP
 Brent VanDevender, PNNL
 Robert Varner, ORNL
 John Weiland, DOE
 Andrew Weston-Dawkes, DOE
 Richard Witt, DOE
 Peter D. Wolf, Nuclear Energy Solutions
 Remco Zegers, MSU

Monday, April 8, 2019
Morning Session

WELCOME AND INTRODUCTIONS

NSAC Committee Chair **David Hertzog** welcomed everyone and asked the NSAC members to introduce themselves. Hertzog reviewed the agenda and mentioned two charges issued to NSAC.

PERSPECTIVES FROM THE DEPARTMENT OF ENERGY

Steve Binkley, Deputy Director for Science Programs, DOE SC, discussed interactions with other countries and two memoranda issued in December 2018 and January 2019 on sensitive technologies and foreign talent programs. There are currently 62 formal (government-to-government) International Agreements (IA) involving 16 countries. Several of the 17 IAs in progress involve NP facilities, research, and program activities. Development of IAs are governed by seven principles: Quid pro quo—mutual benefit; Mutual respect; Maintain openness, transparency, respect for individuals; Research for peaceful purposes; Community engagement and buy in; Use of rigorous project management, where appropriate; and Governed by formal, government-to-government agreements, when appropriate. In addition to formal IAs, there are many international collaborations with the national labs, including Memoranda of Agreement (MOA), Cooperative Research and Development Agreements (CRADA), and Strategic Partnership Programs (SPP).

The Deputy Secretary of Energy issued a memorandum in December 2018 concerning security issues related to sensitive technologies applied to four countries, China, Russia, Iran, and North Korea. A second memorandum, issued in January 2019, focused on foreign talent programs. SC is working with the national labs' Chief Research Officers (CRO) to identify technologies of concern and to develop controls and procedures. Implementation is anticipated in the next six months. As a matter of policy, DOE will not provide funding to anyone receiving financial support from a Foreign Talent program. This policy will be applied at the national labs and potentially at universities. DOE is working closely with NSF and the Department of Defense on this issue and expects the policy to be implemented by Fall 2018.

Discussion

Dudek requested a definition of a foreign talent program. **Binkley** pointed to the Thousand Talents program from China, explaining the issue is that the nature and identification of talent programs is not firm. Having a clear, concise list of such programs will be important. Principal investigators will need to disclose their sources of funding and identify foreign sources.

Rajagopal clarified the target issue in the foreign talent memorandum. **Binkley** explained the concern is for lab personnel who are receiving DOE funding at the same time as financial support from a foreign talent program. **Rajagopal** expressed concern about the perception of U.S. policies on international collaborations, suggesting the guiding principles be reaffirmed in a more public way.

Bai inquired about the extent of the foreign talent policy and reiterated that the consequences might be the U.S. losing their edge against other countries, especially European, who are actively recruiting via talent programs. **Binkley** explained the memorandum focuses on the four sensitive countries. He acknowledged that there have been instances where offers were made to U.S. talent at the senior level. **Rajagopal** echoed Bai's comments stating this policy change could have negative effects.

Shafer asked if there was discussion about better vetting the foreign talent funding sources. **Binkley** said it is in parallel with vetting individuals who come to U.S. labs. However, that same vetting process does not apply to universities.

Kolomensky asked if any current IAs will be amended by the new policies. **Binkley** explained the IAs in place and in process already address the foreign talent policy; there is no plan to revisit the IAs.

Caines mentioned that while there are IAs in place, collaborations have become more difficult in the past few years and asked if there are plans to change or end IAs that are in place. **Binkly** stated that the current administration has firm policies about engagements with Russian entities. At this time the current IAs will remain in place.

Spyrou inquired if there will be a reach-back aspect to the foreign talent policy. **Binkley** said the memorandum is not retroactive.

DOE OFFICE OF NUCLEAR PHYSICS

Timothy J. Hallman, Associate Director of the Office of Nuclear Physics, discussed the President's budget request for 2020. NP's budget request is ~\$625M and the fiscal year (FY) 19 enacted appropriation was \$690M. Research support is at 41%, facilities at 40%, and projects at 13% of the total budget.

The Relativistic Heavy Ion Collider (RHIC) will operate at 41% of optimal (12 weeks of running), JLab at 24% of optimal (8 weeks), and Argonne Tandem Linac Accelerator System (ATLAS) at 31% of optimal (14 weeks). The Facility for Rare Isotope Beams (FRIB) operations budget is lower than envisioned; FRIB construction budget is not impacted. The Gamma Ray Energy Tracking Array (GRETA) continues to be built (\$2.5M) and sPHENIX continues to be constructed within the RHIC base with \$3M. This is the last year of funding (\$1.5M) for Stable Isotope Production Facility (SIPF). The Measurement of a Lepton-Lepton Electroweak Reaction (MoLLER) Major Item of Equipment (MIE) is initiated with \$300K for ultra-precise measurements with the upgraded Continuous Electron Beam Accelerator Facility (CEBAF) machine. Tonne-scale $0\nu\beta\beta$ MIE receives \$1.44M and the high rigidity spectrometer at FRIB is initiated at \$1M. The Electron Ion Collider (EIC) will receive Other Project Costs (OPC) funding of \$1.5M. There is increased funding for the DOE Isotope Program in research and mission readiness funding. \$5M is requested for the construction start of the Stable Isotope Production and Research Center (SIPRC) at ORNL.

The FY20 request allows NP to pursue aspects of the 2015 Long Range Plan (LRP). Experience with FY18 and FY19 has required nimbleness for big swings in the budget. In FY20 NP needs to be ready for these swings and uncertainty. The community needs to stay focused and continue to deliver on important outcomes for the nation.

FRIB is 89% complete, ahead of schedule and on cost. ATLAS continues as a premier stable beam facility. The 12GeV CEBAF program operates for 32 weeks in FY19. RHIC continues to implement new capabilities for new discoveries.

Within SC there are a number of high priority research initiatives. Machine Learning (ML) and Artificial Intelligence (AI), biosecurity, quantum information science (QIS), exascale computing, microelectronics, and isotopes. Nuclear physics has overlaps in isotopes and some connection to exascale, QIS, and ML. NP started QIS in 2018 without a dedicated funding line; 5 awards were made in 2018 and are actively in progress. NSAC has a subpanel to articulate the unique role nuclear science research can and should play in QIS. NP will publish a funding opportunity announcement (FOA) called Quantum Horizons and will award \$6.8M before September 30, 2019. The SC FY20 request for ML and AI is \$71M. Nuclear Science at NSF and DOE may have an important role to play; NSAC may be asked to provide input on that role. An Interagency FOA on nuclear data is coming out and is open to universities and labs.

The DOE Isotope Program mission is central to the DOE and also NP. Responses to the NSAC recommendations concerning the isotope program include establishing enriched stable isotope capabilities, which DOE IP is pursuing with the completion of SIPF and construction of

SIPRC at ORNL. \$2M is requested in FY20 to create the capability, at FRIB, to harvest isotopes from the beam-dump.

The SC Graduate Student Research (SCGSR) Nuclear Physics program provides stipends for graduate students to have a research experience at a laboratory. An award has been made related to heavy ions.

A formal position statement by SC on diversity, equity, and inclusion, has been posted to the SC website. This states SC's commitment to fostering safe, diverse, equitable, and inclusive work, research, and funding environments and that DOE SC will not tolerate discrimination of any kind. Links are provided for channels to report bad behavior or harassment.

Discussion

Fuller asked about the thrust for AI and ML and connections to QIS.

Hallman said in NP the connection to QIS has yet to be determined and NP has gone to NSAC for input. QIS and ML are probably quite inextricably connected to each other.

Kolomensky asked about the effect of a continuing resolution (CR) on MIE starts.

Hallman explained that the usual rule in a CR is no new starts, but it can vary. **Kolomensky** noticed NP is not one of the offices participating in the ML and AI effort. He asked if proposals will be entertained at this point. **Hallman** said NP has not identified ML and AI as one of the topical areas in the annual solicitation. A discussion about entertaining some early proposals could take place; it is not ruled out.

Rajagopal asked how nuclear physicists should pursue the funds available under ML or exascale computing. **Hallman** explained in the case of exascale it is happening, ASCR has issued FOAs related to exascale, NP has one award and some funding for a second award. ML is a new request to Congress, there was no funding in FY19. Nuclear physicists should propose exciting ideas and try to attract support.

Rajagopal asked what is anticipated as the tonne-scale experiment moves forward.

Hallman said the tonne-scale experiment is a coordinated activity with NSF. Several technologies exist and are making great strides. There is research and development to continue to retire significant risk and show-stopping questions, then a down select to the technology that has the greatest value and greatest discovery potential will be conducted. The process has to be discussed and articulated. It will take a long time, no matter the technology, to have enough isotopes to carry out the tonne-scale experiment. The DOE IP is aware of that.

Rajagopal sought input assistance individual scientists can provide to help NP plan and prepare for budget shifts. **Hallman** advised to be conservative and to persevere in the face of a down turn outlook. It is important not to make big, irreversible decisions.

Lapi asked about efforts to communicate with different agencies to leverage funding for AI. **Hallman** has not personally seen anything like the National Quantum Initiative for AI.

Lapi said NIH has efforts with AI for image interpretation. **Binkley** added there is active interagency coordination with the National Science and Technology Council. DOE will engage the parts of NIH where there are significant opportunities to date. There is also draft legislation for a government-wide AI initiative.

Meziani asked how the 2015 Long Range Plan (LRP) will go forward given the science presented by the instruments of the time. **Hallman** explained it will continue to be a challenge. Looking at the FY19 appropriation for NP it matches well with the modest growth scenario in the 2015 LRP and it has allowed NP to get a start on the initial MIEs. With the exception of the EIC, the MIEs have all achieved CD-0. The 2015 LRP vision is being pursued. Hallman expressed optimism that the good science will carry through.

PERSPECTIVES FROM THE NATIONAL SCIENCE FOUNDATION

Denise Caldwell, Division Director for Physics (PHY) explained that Mathematics and Physical Sciences (MPS) consists of five Divisions; PHY is one of them. MPS funding in 2018 was \$1.5B, the bulk of which funded individual investigator awards (IIA). National Science Foundation (NSF) funds the progress of science. NSF uses the science it supports to provide the foundation for the preparation of an advanced high-tech workforce.

The FY20 NSF budget is not yet available. In FY18 the budget was ~\$8B; MPS' fraction was ~\$1.5B. Budget details for FY19 will be available once NSF has an approved operating plan. NSF's budget request for FY20 is a reduction in the total. NSF has chosen to make investment in the Big Ideas. All of the Big Ideas are implemented NSF-wide. MPS is the steward for Quantum Leap and Windows on the Universe, but also participates in Harnessing the Data Revolution, Mid-scale Research Infrastructure (Mid-scale RI) and Understanding the Rules of Life. PHY will maintain its own Mid-scale program, will continue external partnerships, and develop future partnerships.

MPS' Big Idea investments for Quantum Leap will be \$30M for quantum enabled science and technology including QIS, quantum materials for microelectronics, quantum computing, computer simulation, and other quantum technologies. MPS will invest in Windows on the Universe at \$30M for gravitational wave telescopes, IceCube, and Laser Interferometer Gravitational-Wave Observatory (LIGO).

Mid-scale RI is the Big Idea to fill the gap between \$4M, where Major Research Instrumentation (MRI) stops, and where Major Research Science and Engineering Centers (MRSEC) begins at \$70M. Mid-scale One is for projects between 6M-\$20M; Mid-scale Two is for projects between \$20M-\$70M. Pre-proposals for these activities are in and under review.

Caldwell closed with two science examples, the Advanced Cold Molecule Electron Dipole Moment (ACME) partnership between Yale and Harvard, and LIGO's release of its catalog of discoveries through 2018.

Discussion

Fuller asked if there was an increase in PHY funding for facilities, specifically the squeeze light upgrade. **Caldwell** indicated there has been a slight increase in facilities. The A+ budget line goes to the LIGO line and is a spike that will drop back down once LIGO-A+ is completed. The frequency dependent squeeze light upgrade must build another small interferometer beside one of the arms and bring it into the system; it is being worked on now.

Spyrou inquired about nuclear physics being a part of Windows of the Universe. **Caldwell** said absolutely nuclear physics is part of that Big Idea. She encouraged scientists to think broadly and ask if their idea fits in a solicitation. Co-funding for collaborations is widespread in NSF.

Kolomensky asked for details on the review process for Mid-scale RI proposals. **Caldwell** explained these will follow the NSF review process, but Mid-scale Two proposals will have a more detailed review.

Hertzog adjourned NSAC for a break at 10:40 a.m. The meeting was reconvened at 10:57 a.m.

NSF OFFICE OF NUCLEAR PHYSICS OVERVIEW

Allena Opper, Program Officer, Nuclear Physics, NSF, discussed new personnel and the PHY budget, and provided highlights and announcements. The Deputy Division Director in

PHY continues to be filled on an acting basis. Jim Thomas from LBNL and RHIC joined MPS in September 2018 as an Intergovernmental Personnel Act (IPA) rotator. The Mid-scale RI-1 solicitation (\$6M-\$20M) was released November 21, 2018 and Mid-scale RI-2 (\$20M-\$70M) was released December 11, 2018. The pre-proposals for Mid-scale RI-1 have been reviewed and invitations are being sent for full proposals. Mid-scale RI-2 pre-proposals are in and are being reviewed; invitations for full proposals are expected by the end of May, with full proposals due in August. Mid-scale RI-1 awards will be made in FY19, and Mid-scale RI-2 awards will be made in FY20. She expressed thanks to the review community who are helping with the review process on a compressed timeline.

In FY19 NSF had an increase in funding of 4%. One of the big changes in the final funding, compared to the President's budget request, was the amount of funding for major research equipment and facilities construction. In the President's FY20 budget request PHY funding for research is reduced by 20% compared to the actual funding in FY18. Large Hadron Collider (LHC) and LIGO funding is increased. PHY Mid-scale funding will be cut 53% in FY20 compared to FY18, but PHY Mid-scale had a one-time bump up in FY18. NCSL is currently supported at \$24M per year which includes \$6M for the research programs of the nuclear science faculty at MSU.

Opper shared highlights including the Modular Neutron Array (MoNA) collaboration, ^{11}C half-life measurement at the Nuclear Science Laboratory (at Notre Dame University), proton capture reactions using the High-Efficiency Total Absorption Spectrometer (HECTOR), deformed nuclear halo evidence using GRETINA (Gamma-Ray Energy Tracking In-beam Nuclear Array) at NSCL, PrimEx final result, and the Solenoidal Tracker at RHIC (STAR) observation of semi-exclusive scattering of colliding polarized protons and unpolarized protons.

Discussion

Evdokimov asked how High-luminosity LHC and LIGO+ will go forward, given the President's budget request, considering U.S. participation is critical to those. **Caldwell** explained in FY18 NSF spent the \$16.6M. In FY19 the planning will be complete. If construction is started it will go into a construction budget line. Advanced LIGO+ completion is anticipated in FY19, with design-stage activities completed by 2020. **Opper** added the preliminary design of projects, to get them shovel ready and qualified for the construction funding line, is funded by the research programs.

Kolomensky noticed that one of the highest cut lines in the budget is the CAREER program and asked if NSF would articulate their focus on junior faculty to Congress. **Caldwell** explained that the FY18 actual number is an indication that more exceptional proposals were submitted and awarded. She impressed upon the community that both the CAREER program and the regular NSF awards support junior faculty. The CAREER program has additional requirements over and above the regular NSF proposal.

Fuller asked what NSAC can do to help NSF argue for better funding. **Opper** said proposing good science and having scientific discoveries that NSF can point to is the best way to argue the impact.

Hertzog expressed frustration over the limited operating time for nuclear physics accelerators. He applauded the agency Opper stated the budget appropriation is a two-step process for most agencies. Congress is hearing this community, good science cases are being taken to them, and they are presenting marks above the President's budget request. NSF has a third stage in the budget process making it a bit more diffuse.

UPDATES ON GRETA & HRS

Heather Crawford, Lawrence Berkeley National Laboratory, shared the progress and activities of GRETA and HRS. GRETA will be a 4π gamma ray tracking detector, a high purity germanium semi-conductor based detector with high intrinsic resolution. GRETA will have full solid angle coverage and therefore very high-efficiency as compared to predecessors. The GRETA project has a strong collaboration between LBNL, ANL, and ORNL. GRETA is a national instrument which is envisioned to sit at FRIB and the Fragment Mass Analyzer or the Argon Gas Field Analyzer at the ATLAS facility.

The GRETA Users Executive Committee (GUEC), with over 200 active and registered users, is closely coordinated with the FRIB users organization. GUEC has led the establishment of working groups to define the requirements for GRETA as well as planned workshops.

GRETA encompasses a total of 30 Quad modules which contain four crystals. The project includes a mechanical infrastructure, electronics to instrument the full 30 Quad modules, and a computing cluster to support the full array. GRETA received CD-3a in October 2018. CD-2/3 is anticipated in mid-2020, and has a preliminary Total Project Cost (TPC) of \$58.3M. The preliminary design stage is essentially complete. Final design activities are beginning and the project is staged to optimize the physics.

The HRS has achieved CD-0. The enabling capability of the HRS is the gain factor (up to 100) in intensity of beams usable for fast beam physics. The fast beam user community of 500+ people have been very involved in the process of defining the capabilities needed in the development of the conceptual design. The HRS currently has a TPC range of \$88.6M. The HRS project is not only the separator itself, but also a high transmission beamline. HRS accommodates ancillary devices to meet scientific objectives of FRIB. HRS sits in the middle of existing buildings; the construction of the experimental building has started and the anticipated building occupancy is the end of 2019.

Discussion

Hertzog asked what the GRETA funding buys: crystals, electronics, etc. **Crawford** stated each crystal is ~\$1M; three have been ordered. The bulk of the project is the detectors.

The preliminary design is complete and is undergoing internal review; the team is moving on to the final design stage.

Meziani asked if there is a primary or targeted region in terms of measuring the gains being made at HRS. **Crawford** explained there is a strong connection to astrophysics theory to identify the key nuclei. The priority of measurements will be driven by sensitivity studies.

STATUS OF THE GLUEX EXPERIMENT

Curtis Meyer, Carnegie Mellon University, provided information on the GlueX experiment. GlueX is a discovery experiment for the photoproduction of hybrid mesons at the 12 GeV CEBAF machine. GlueX is utilizing a unique photon beam, hermetic detector, and sophisticated analyses. GlueX is looking at the bound states of quantum chromodynamics (QCD) and determining the role of gluons. The beamline was commissioned in Fall 2014 with 12 GeV beams delivered in December 2015. An engineering run occurred in 2016 with additional runs in 2017 and 2018 yielding five petabytes of data. The full phase I data set will be available September 2019. Large statistics in unexplored reactions are anticipated for the GlueX experiment.

Phase II will begin in Fall 2019. The GlueX Detection of Internally Reflected Cherenkov light (DIRC) provides enhanced kaon identification in the forward direction. The DIRC achieved BABAR specifications in one week; the expectation is to begin running in November 2019. DIRC enables a program involving strange quarks, opening the full program of GlueX. With the GlueX DIRC and higher rate capability the reach of GlueX will expand.

Discussion

Kolomensky asked how evaluation of potential discoveries will occur if exotic states are seen, in particular if there are detailed simulations. **Meyer** stated they are working closely with theorists and proceeding carefully to ensure there is the right theoretical input. GlueX is in the final stages of tuning the Monte Carlo to agree with the detector as much as possible.

Rajagopal inquired if the experiment was looking beyond standard models, for example dark photons or axion-like particles. **Meyer** explained researchers from MIT were looking for dark photons and are waiting for the full 2017 data. MIT has been spearheading the effort on the really exotic states but multiple groups are interested in mining the data.

Dudek requested information on the plans for archiving the datasets as well as the tools needed to make use of the GlueX datasets. **Meyer** said the data is available, the software is heavily version controlled enabling the immediate recovery of any version.

Hertzog asked if something stood out in modern lattice calculations compared to older calculations. **Meyer** explained the states are there but not the width predictions from the lattice; there are no decay predictions yet.

Meziani expressed confusion between two statements: “high states were rich in glue,” and “looks like constituent quark type of behavior of gluons.” He asked about the ability to separate contributions of gluons. **Meyer** explained exotic quantum numbers are the signature to focus on initially because that is not $q\bar{q}$. One state with exotic numbers does not explain anything, more than one state needs to be found and patterns need to be seen for coupling. The model that says it looks like a gluon is a model that can reproduce the Lattice QCD calculation. It does not come from Lattice QCD, but can describe what Lattice QCD is predicting.

Kolomensky asked how J/ψ was reconstructed. **Meyer** said e^+e^- is the only decay mode possible at the moment.

Hertzog adjourned NSAC for lunch at 12:45 p.m.

Monday, April 8, 2019 Afternoon Session

The NSAC meeting was reconvened at 1:54 p.m.

RECOGNITION OF SERVICE TO NSAC

Hallman recognized members of NSAC for their service over the past three years. Citations for these individuals were from DOE and NSF expressing their appreciation for significant contributions made while serving on NSAC during 2016-2019. Those recognized included Helen Caines, David Dean, Lynn Fransiconi, George Fuller, Cynthia Keppel, Jeffrey Nico, Krishna Rajagopal, Kate Jones, Daniel Phillips, and Kawtar Hafidi.

PRESENTATION OF THE MO-99 SUBCOMMITTEE REPORT

Suzanne Lapi, University of Alabama, Birmingham, reviewed the Mo-99 subcommittee charge, the process, background, and findings and recommendations. The charge focused on the current status of the Mo-99 program, the progress made, the strategy for continued implementation, risks and management, and NNSA's performance relative to previous recommendations. The subcommittee met in December of 2018 and were briefed by NNSA and representatives of the Organisation for Economic Co-operation and Development (OECD) on the international context of the Mo-99 program.

Four approaches to Mo-99 production include neutron capture, accelerators, accelerators with low-enriched uranium (LEU) fission, and LEU target technologies. Global demand remains constant and reserve capacity of Mo-99 will require bringing these new technologies online. Cooperative agreement (CA) partners include NorthStar Medical Radioisotopes, SHINE Medical Technologies, and General Atomics. All projects for each CA partner received \$25M. NorthStar has two projects on neutron capture and accelerator technologies; the first entered the market in 2018 and the second will enter in 2020. SHINE's project considers accelerator LEU fission technology and they plan to enter the market in 2020. General Atomics' project focused on LEU technology, but they have withdrawn their CA and no longer plan to enter the market.

The NorthStar neutron capture project had three FDA approvals and initiated direct customer and commercial shipments for patient use in late 2018. The NorthStar accelerator project received approval from their Board and began contract negotiations to purchase up to the eight electronic accelerators. SHINE's accelerator project has completed construction on Building One and the first production unit accelerator was delivered. SHINE received \$150M financial commitment from Deerfield Management Company as well as \$30M in private funding. NNSA issued a new FOA, open to new and existing CA partners, in July of 2018. The NNSA announced it would begin negotiations for potential CA awards with four U.S. companies, NorthStar, SHINE, Northwest Medical Isotopes, and Niowave, Inc.

Since the 2017 review, NNSA has moved the program forward, consistent with the American Medical Isotope Production Act (AMIPA) requirements. Issues related to the long-term financial reliability of any producers entering the market remain, some are related to the uranium lease and take back (ULTB) or full cost recovery (FCR) issues. In terms of strategy for continuing to implement the NNSA goals, the subcommittee held that establishing an economically viable and lasting domestic production of Mo-99 was relatively incomplete and that feasibility still needed to be demonstrated. The major risk is the finalization of the ULTB program. The subcommittee found that previous recommendations and concerns had been partially addressed by the NNSA. Two new recommendations, on FCR and ULTB, were made.

DISCUSSION OF THE MO-99 SUBCOMMITTEE REPORT

Dean inquired about the differences between this report and last year's report. **Lapi** explained three new developments were included, NorthStar's entry into the market, the loss of General Atomics, and the release of a new FOA. The ULTB recommendation was made again.

Fuller asked about plans to address the potential oversupply of Mo-99. **Lapi** stated the subcommittee thought market forces would handle any oversupply, but noted oversupply could mean a lack of economic viability for producers of Mo-99.

Meziani sought clarification on the ULTB program implementation. **Lapi** explained there are different aspects to the ULTB program, not all of which have to do with NNSA. Coordination between DOE Environmental Management (EM) and NNSA must focus on the

ULTB program. A clear understanding of the waste make up is required. NNSA and some of the partners explained they may not know what is in the waste until beginning production of Mo-99.

Shafer asked if something broad-scoping, like an NAS push, would help pressure movement to resolve the ULTB issue. **Lapi** explained the subcommittee cannot recommend what other groups do. However, with the new company in the marketplace availability of Mo-99 will change. There are a number of other companies making Mo-99 with LEU, just making normal reactors. Shortages have been seen, but have not been as dramatic as before.

Nico requested more information on the four prospective new suppliers relative to the program and timeline. **Lapi** indicated there will still be cost matching. Since the new suppliers were recently awarded there is not enough information to share.

Lapi added that there are companies coming on board with the expectation that the ULTB service will help them. For the last three years the committee's recommendations and language has been escalating. The committee feels strongly that the ULTB program should be put in place.

Hertzog explained to NSAC that ULTB applies only to a fraction of the overall companies. The ULTB allows companies to lease uranium, but they do not have to have NNSA take back the waste. If the company can dispose of it themselves they are welcome to do so. The Full Cost Recovery operations is a mandate that the companies execute this procedure. World business competitors do not have the same mandate.

Meziani stated the situation is complicated when each country has to decide how to address FCR. **Lapi** explained that all OECD countries have signed on to the concept of FCR.

Kolomensky sought the genesis of FCR. **Lapi** said the OECD countries agreed to FCR to encourage new technologies and discourage the use of highly-enriched uranium (HEU). Calculating FCR is complicated because taking existing facilities, for example, into account makes a difference. The general idea is everybody should adhere to FCR, but how that is implemented is tricky.

Hertzog called for a vote to accept the Mo-99 report. Panelists stated their vote individually and the report was accepted unanimously.

Rajagopal asked about the process by which NSAC's role comes to an end. **Hertzog** said that NSAC asked NNSA when the program is done. **Lapi** shared there are differences of opinion when NSAC's role ends. **Hallman** added the exit strategy for NSAC is not well-defined. When all parties concerned agree that the process has stopped adding value an informal discussion will take place about ending the program. The statement that all parties should agree is key. NNSA has indicated this practice continues to be valuable to them in terms of communicating the status to Congress. If NSAC recommendations are having an impact the work will continue.

UPDATE ON THE QIS SUBCOMMITTEE

Martin Savage, University of Washington, gave an interim report on the QIS subcommittee formed in 2019. Savage stated there are essentially two eras of impact of quantum mechanics on nuclear physics research. The first era, from last century, was defined by the uncertainty principle, and the second is an era where entanglement and non-locality are exploited. The charge to NSAC requests a report that identifies unique opportunities for nuclear

physics to contribute to QIS and quantum computing and vice versa. The report will be delivered early summer 2019. There are two planned meetings, the first happened March 28-30, 2019, in Washington, and a second meeting will happen April 30th to May 1st in Seattle.

Some of the information provided at the first meeting indicated the U.S. anticipates long-term and sustained support for developing a quantum ecosystem and economy and for broad applications of quantum information and quantum computing. There is nationwide interest and engagement. The field is inherently multidisciplinary. There is significant and impressive international efforts in quantum information and quantum computing. International collaboration has proved beneficial; the countries have gone through substantial planning, are growing, and each has a long-term vision for QIS.

The first meeting was a high level meeting. The second meeting will be a deep dive focusing on quantum sensors and quantum detection, quantum encryption and communication, quantum simulations, and quantum centers and high sensitivity experiments as well as a Technology company panel. Deliberations and consensus will occur on the afternoon of the second day. The report will include recommendations and conclusions.

Discussion

Hertzog asked Hallman when the next NSAC meeting is scheduled. **Hallman** indicated that had not yet been decided.

APPLIED NUCLEAR PHYSICS PROGRAM

Graham Peaslee, University of Notre Dame, shared accomplishments and directions at The University of Notre Dame's Applied Nuclear Physics program. Peaslee explained 11 projects coming out of his lab. Nuclear reactions for Department of Homeland Security enabled a peak behind sealed walls. Ion beams for archaeology confirmed the Roman Empire used copper in their coins. Ion beams for public health enabled the identification of lead sources and helped create test kits that can be rapidly processed using Extended Frequency Range (XFR) technology. They confirmed that heavy metals were used in tattoo inks, and helped change a law enforcing flame retardants be removed from residential furniture manufactured after 2014. Per- and polyfluoroalkyl substances (PFAS) were found in Mardi Gras beads that were made from recycled e-waste plastics. PFAS were discovered in food wrappers. The lab's findings helped change practice and policy for firefighting foam. In partnership with Starfire Industries, the lab is developing a field deployable accelerator on a truck that will drastically decrease the time and financial costs associated with site characterization where firefighting foam was used. Lapi's lab conducted a study to radiolabel fluorine-18 and found that it goes to different organs and different disease vectors. The lab is also producing proton-rich isotopes, which has led to an industrial partnership exploring creating a small radioisotope production facility for medical use.

Peaslee explained that there are many labs doing similar activities. He encouraged the community to participate in like opportunities to demonstrate impact and attract students. He also discussed the role of funding agencies and sources of funding. He suggested that agencies include a small mix of nuclear applications funding in and amongst their various packages.

Discussion

Peaslee indicated this activity is not for everyone. It is not designed to turn all of the labs into applied factories. Thinking about an occasional student or an occasional funding pot that would do this could go a long way.

Bai asked if the accelerators were all tandem or not. **Peaslee** explained they are all tandems; 3 NEC machines (10M, 5M, and 3M volts), and one 1M volt machine in South Dakota.

Opper inquired if Peaslee was open to jointly directing a student from another university who may not have access to an accelerator. **Peaslee** assured NSAC he was open to that and thought it would be a good model. Collaborators have come to his lab wanting to do similar activities. They have reached transition points and want to engage in the research. These activities are possible to do with their own students; they are perfectly capable of running an accelerator but at a slower place.

PUBLIC COMMENT

None

Hertzog adjourned the April 2019 NSAC meeting at 3:32 p.m.

The minutes of the U.S. Department of Energy and the National Science Foundation/Nuclear Science Advisory Committee meeting, held on April 8, 2019, at the Hilton Rockville, Rockville, Maryland, are certified to be an accurate representation of what occurred.

David Hertzog, Chair of the Nuclear Science Advisory Committee on June 7, 2019

A handwritten signature in black ink, appearing to read 'D. Hertzog', with a long horizontal flourish extending to the right.