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

PUBLIC MEETING MINUTES

Hilton Washington DC North
620 Perry Parkway, Gaithersburg, MD

October 28, 2016

NUCLEAR SCIENCE ADVISORY COMMITTEE
SUMMARY OF MEETING

The U.S. Department of Energy (DOE) and National Science Foundation (NSF) Nuclear Science Advisory Committee (NSAC) meeting was convened at 8:00 a.m. EST on Friday, October 28, 2016, in the conference facility at the Hilton Washington DC North Hotel, in Gaithersburg, Maryland, by Committee Chair David Hertzog.

Committee members present:

David Hertzog (Chair)	John Hardy	Jeffrey Nico
Paul Benny	Karsten Heeger	Filomena Nunes
Helen Caines	Roy Holt	Daniel Phillips
Gordon Cates	Kate Grzywacz Jones	Krishna Rajagopal
Abhay Deshpande	Cynthia Keppel	Martin Savage
Frederic Fahey	Suzanne Lapi	
George Fuller	Michael Lisa	

Committee members not in attendance:
Mark Pitt and Michael Wiescher

NSAC Designated Federal Officer:
Timothy Hallman, U.S. Department of Energy (DOE), Office of Science (SC), Office of Nuclear Physics (ONP), Associate Director

Others present for all or part of the meeting:
Ethan Alpern, DOE/SC/ Office of Communications and Public Affairs
M. Arif, National Institute of Standards and Technology
Elizabeth Bartosz, DOE/SC/ONP
Joe Carlson, Los Alamos National Laboratory
Vincenzo Cirigliano, Los Alamos National Laboratory
Leland Cogliani, Lewis-Burke Associates
David Dean, Oak Ridge National Laboratory
James Dunlap, Brookhaven National Laboratory
George Fai, DOE/SC/ONP
Manouchehr Farkhondeh, DOE/SC/ONP
Brad Filippone, California Institute of Technology
Glenn Fox, Lawrence Livermore National Laboratory
Doon Gibbs, DOE Brookhaven National Laboratory
Jehanne Gillo, DOE/SC/ONP
Joseph Glaser, DOE/SC/ONP
Takeyasu Ito, Los Alamos National Laboratory
Brian Knesel, DOE/SC/ONP
L.K. Len, DOE/SC/OHEP
Bob McKeown, JLab, Thomas Jefferson National Accelerator Facility
Bogdan Mihaila, National Science Foundation
Berndt Mueller, Brookhaven National Laboratory
Hugh Montgomery, JLab, Thomas Jefferson National Accelerator Facility

William E. Ormand, Lawrence Livermore National Laboratory
Allena Opper, National Science Foundation
Dennis Phillips, DOE/SC/ONP
Robert Redwine, Massachusetts Institute of Technology
Susan Seestrom, Los Alamos National Laboratory
Bradley Sherrill, Michigan State University/National Superconducting Laboratory
Michelle Shinn, DOE/SC/ONP
Paul Sorensen, DOE/SC/ONP
James Sowinski, DOE/SC/ONP
Alan Stone, DOE/SC/OHEP
Mike Telson, General Atomics
Robert Tribble, DOE/Brookhaven National Laboratory
Sarah Wilk, DOE/National Nuclear Security Administration
Sherry Yennello, Texas A&M University

OPENING REMARKS

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 Friday, October 28, 2016, by NSAC 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.

DOE OFFICE OF NUCLEAR PHYSICS OVERVIEW

Timothy J. Hallman, Associate Director of the DOE Office of Science (SC) for Nuclear Physics (NP), said that the DOE NP office is pursuing two pieces of community guidance. The first is the 2015 Long Range Plan for Nuclear Science. The Fiscal Year (FY) 2017 President's Budget Request will contain support for the following priorities, discussed in the plan. Recommendations: (1) capitalizing on investments made under the guidance of the 2007 Long Range Plan; (2) developing a U.S.-led, ton-scale, neutrinoless double beta decay experiment; (3) developing a new facility containing a high-energy high-luminosity polarized electron ion collider (EIC) for the study of gluons, and (4) increasing investment in small-scale and mid-scale projects that enable research at universities and laboratories.

The second piece of guidance that NP had pursued was from the March 2016 report of the Committee of Visitors (COV). For both DOE laboratory and university programs and projects, the COV was asked to provide an assessment of NP processes used to solicit, review, recommend, and document proposal actions and monitor active projects and programs. Also, within the boundaries defined by DOE missions and available funding, it was recommended the COV should assess the quality of the resulting portfolio, including its breadth and depth, and its national and international standing. The COV was also asked to comment on strengths or deficiencies in any component or sub-component of the Office's portfolio and opportunities for improvements progress made towards addressing action items from the previous COV Review.

Of interest to the NSAC: NP is planning to revise the peer review process for grant renewals. Up to two award renewals will be handled using the current approach, via mail reviews. The third renewal proposal could be included as part of a competitive peer review process, with all new proposals from the annual "campaign" for that year. Hallman said this strategy would add flexibility for NP to support research in new fields. He shared other news items including: NP is seeking approval to re-open the position for the Research Division Director. There are two positions open for Fundamental Symmetries and Nuclear Structure and Nuclear Astrophysics: they will be re-advertised November 28, 2016, and NP is open to re-applications. The neutrino-less double beta decay (0νββ) Funding Opportunity Announcement (FOA) closed October 28th. Also, a National Academy committee is forming to discuss infrastructure needed for Space Radiation Effects Testing; its first meeting will be in February of 2017. There will be a new FOA for SciDAC.

Hallman commented on the status of appropriations for NP research. SC is operating under a short-term Continuing Resolution in terms of congressional appropriations and NP has mitigated potential issues with funding for the moment. The total funds enacted by Congress for Nuclear Physics for 2016 is $617,100.00; and FY17 totals would increase by $15.7M in the President's Request. Hallman's presentation contains more detailed funding breakouts and is available online.

The next formal step, which has been initiated in documenting the need for an Electron Ion Collider will be a National Academies Study of the science such a facility could accomplish. NP has also commissioned a community review of EIC status and R&D needs. Kevin Jones will chair this review, scheduled from November 29- December 2, 2016. Charge elements were briefed. This is not a selection committee, but a group to prioritize the research and development needed in the future.

Exciting research developments were presented. The 12 GeV CEBAF upgrade at TJNAF is ~98.4% complete. This new capability will enable searches for exotic new quarks and anti-quark particles. **Hallman** shared some first results demonstrating the promise of GLUEX. At Argonne, proposed capabilities to enhance ATLAS include a multi-user upgrade. The Facility for Rare Isotope Beams (FRIB) is nearly 70% complete; FRIB will increase the number of isotopes with known properties from ~2,000 observed over the last century to ~5,000. On Friday, October 14, 2016, the first FRIB ion beam was produced from the Artemis electron-cyclotron-resonance (ECR) ion source. About 300 euA of oxygen 3+ beam was extracted from the ion source and struck the Faraday Cup downstream. FRIB promises a watershed in understanding astrophysical sciences. Fabrication of SECAR, a recoil separator for nuclear astrophysics, is underway. The initiation of the Gamma-Ray Energy Tracking Array (GRETA) MIE is included in the 2017 Budget Request. The Relativistic Heavy Ion Collider (RHIC) continues to excel in terms of luminosity and performance. Work on the low-energy electron cooling (LEReC) is progressing. The PHENIX detector is being de-commissioned and reconfigured for the upgrade, sPHENIX, which received CD-0 on September 27. For the study of fundamental symmetries, the first light at KATRIN has been observed. KATRIN is an international collaboration of over 150 scientists, technicians, and engineers. The NP community views a large scale neutrino-less double beta decay experiment as a "must do" experiment. Other items mentioned included the Majorana Demonstrator; and nEXO (liquid xenon) for which stewardship was transferred to NP in FY17. In the area of Nuclear Theory: Hallman described aspects for a strong Theory research effort and the view that the 2012 Topical Theory Collaborations effort has been highly successful. For the DOE Isotope Program: DOE is responsible for producing isotopes in short supply. The initiation of the Stable Isotope Production Facility (SIPF) is part of the FY2017 President's Request and it projected cost is approximately $9.5-10.5M. The United States is currently dependent on foreign supplies of stable isotopes. DOE does not compete with industry on isotope production. **Hallman** concluded his presentation and invited questions and comments.

Discussion

Frederic Fahey asked when NP planned to start the new process regarding grant renewals. **Hallman** said they have a concept but still need to work out the details. The thinking is that a lot of research NP supports is long-term, done in an accelerators and it therefore requires long-term and continuous support. Two award terms, or six years, should be enough time to get something accomplished.

Fahey then asked, for international collaborations planning: are there guidelines published somewhere for requirements?

Jehanne Gillo said she put out a survey to all NP-supported national labs and has detailed information on international activities ongoing and planned. She said she works on international documentation on a case-by-case basis. University collaborations are not as restricted as the national labs when it comes to the development of international documentation.

Karsten Heeger asked to clarify whether grant renewals would occur every six, or nine years. **Hallman** said nothing had been decided, but the current thinking is the award period runs for three years; the investigator proposes a renewal and gets support for another three years: so the thinking is a total of six years of support before re-competing with all proposals.

Krishna Rajagopal expressed concerns that, without a phase-in, the new policy may set up an artificial periodicity in which every six years, all the major investigators would compete against each other, with less competitive years in between. Why not set up some type of more regulated cycle?

Hallman commented that when a renewal proposal comes in, generally there is not dramatic change proposed.

Rajagopal used an example of a new scientist waiting to submit a new proposal so he or she might not have to compete with a major player up for re-competition. He warned NP staff to consider unintended effects.

Hallman said NP staff could consider periodically doing something similar to the comparative review they did in 2013, but something was needed since NP does not get as good a critical assessment of research proposals when each is reviewed by three reviewers, than when proposals go head-to-head.

Rajagopal said he thought the comparative review met that goal.

Hallman said NP staff had received comments that the comparative review process had been disruptive to investigators.

Filomena Nunes said the Committee of Visitors reviewed the whole process and had received feedback from the community and SC. It was a painful process; and SC desired a more continuous way of reviewing proposals. The changed had been approved by the NSAC.

Hertzog asked, why not rotate program reviews instead.

Hallman answered there is no thought of competing proposals between the NP sub-fields, but he understood Hertzog's suggestion of a staggered amount of time, per sub-field, that welcomed new proposals. The idea would be that one-third of the field would be compared against itself, every certain number of years. There is a need to do it, and NP wants the community to support the plan.

Rajagopal said his colleagues' experience in the High Energy Physics community had been that the new process had created perverse incentives. He recommended that NP staff's assessment include a look at that community.

Hallman said he appreciated the feedback and anticipated a long-lead kind of implementation.

Hertzog asked for other topics of discussion. At Jefferson Lab, why was the 12 GeV CEBAF upgrade cited as being 98.4 % complete?

Hallman answered that much of the machine had been re-constituted and commissioned. There is one hall that is still high risk.

From the audience, **Hugh Montgomery** of Jefferson Lab said it had a review by the DOE Office of Project Assessment (OPA) that week, and the machine was operating. He provided an update on the physics program in Hall A; he said that Hall D would conduct a commissioning period in the spring. In Hall C: three magnets and all detectors are done. The magnets are from a French vendor;

the first is on-site and beginning to cool. The second is in Baltimore, Maryland; and the third is due to leave France in weeks. Hall B contains a torus with a coil constructed by FermiLab, operating at 2,000 Amps. A solenoid magnet is being built in Pennsylvania; the vendor is expected to deliver at the end of January. JLab is sequencing the key performance parameters (KPPs) and expected to complete them by the end of September. They have also been able to operate the Heavy Photon Search experiment w/ High Energy Physics (HEP) in the spring. They have generated a low energy beam for the Proton Radius (PRad) experiment in Hall B, which was completed and enabled a measurement of the proton radius.

Michael Lisa asked for more details on the EIC science and National Academies study.

Hallman said he did not have additional details, but that the National Academies study would be a big step, and it would likely run 18 months.

Cynthia Keppel asked about Molybdenum 99 (Mo-99) experiments at Princeton.

Hallman said there needs to be progress; and that **Gillo** would be a good point of contact.

Rajagopal inquired about a fourth topical collaboration – what is topic?

George Fai, in the audience, said it would relate to general studies of fission at the intersection of nuclear data NNSA activities. Another aspect could be applied fission feeding into the process.

Hallman also discussed funding for Topical Theory studies and Exascale.

NSF NUCLEAR PHYSICS OVERVIEW

Allena Opper, Program Director for Experimental Nuclear Physics at NSF gave an overview of NP at NSF. She discussed major trends in funding for the community. In 2011, the nuclear astrophysics program was moved from the Particle Astrophysics Physics Program and added to the Nuclear Physics Program. The base NP funding in FY16 was slightly lower than that of FY15 but because of opportunities outside of base funding the total funds awarded for NP research in FY16 went up. The cooperative agreement for the National Superconducting Cyclotron Laboratory (NSCL) is almost finalized and NSF expects to fund the lab at $24.5M/Y. About 25 percent of the funds will go to research, and the remaining 75 percent of funds will go for maintenance and operations. The Major Research Instrumentation (MRI) program funds instrumentation in the range of $100K to $4M. $1.8M was awarded to nuclear physics research in MRI awards. Midscale funding is intended for final design and construction of mid-scale instrumentation: projects that cost $4M to $12M. Projects for the NP community in FY16 include Neutron EDM and MUSE (elastic scattering of electrons and muons to study the proton radius). Midscale has gone from 3-6 percent of funding.

In FY13, during the Sequester, congressional appropriations language stated that NSF funding for facilities had to be maintained, even though total appropriations were reduced by 10 percent. The Sequester basically flattened NSF NP funding for half a decade. In Experimental Nuclear Physics, FY15 saw a huge increase in proposals and funding requests. There were 64 proposals, including 8 for double beta decay. NSF awarded 22 proposals, so the funding rate is just below 40 percent in experimental NP. Available funding doesn't vary very much, although dollars requested increased significantly. Consequently, funding is more competitive than it used to be.

Opper shared highlights of research in the community. The University of Notre Dame is studying $^{12}C(\alpha, \gamma)^{16}O$ & Stellar Helium Burning. A new technique, gamma-ray calorimetry, was developed by Michigan State University and the University of Oslo with the SuN detector at NSCL and used to extract $^{69}Ni(n,\gamma)^{70}Ni$. This is important because constraints on neutron capture rates are key to modeling stellar explosions. NSCL has also generated other new results such as β-delayed neutron emission, which is important for r-process nucleosynthesis. Using the SuN detector at NSCL, A. Spryou and collaborators detected neutron emission weaker than previously thought, so this finding will shift final abundance distributions. Also Notre Dame, University of Wisconsin La Crosse, and the University of Kentucky studied the nature of 0+ states in deformed nuclei. B.P. Crider *et al* at the University of Kentucky studied fast-neutron-induced background near Q value for $0\nu\beta\beta$. In Hall D, an Arizona State University group used a triplet photoproduction process to measure photon beam polarization. The University of Illinois sPHENIX team is developing a Tungsten powder-scintillation fiber calorimeter. They are building their first 2D modules and testing at Fermilab will occur in January. The University of Kentucky looked at Di-jets and shared data. The PRad experiment has taken data that are intended to address the "proton radius puzzle"; PRad is occurring at JLab Hall B. After a two year hiatus due to the February 2014 fire and radiation leak at the WIPP site, EXO-200, the Enriched Xenon Observatory, successfully re-commissioned its major systems and started its Phase-II Operation.

A big challenge in studying neutrinoless double beta decay is background and one way to cleanly detect $0\nu\beta\beta$ is to detect the decay daughters. A subgroup of the EXO collaboration has been working on techniques to tag the $^{136}Ba^{++}$ daughters from $0\nu\beta\beta$ decay of ^{136}Xe. The Colorado State University collaborators from EXO have been funded through the INSPIRE program to develop those techniques using methods from atomic physics, nuclear physics and chemistry.

The due date for experimental NP and Theory proposal submissions, including those for workshops and conferences is November 11th, 5pm. The new solicitation contains details on the process for the Physics Division on midscale proposals. CAREER proposals are under review; there was $1.8M awarded to MRI grants in nuclear physics. In FY16, Physics received 34 MRI proposals, and of those NP received 10 proposals; 2 were funded. One grant was awarded for the development of a Separator for Capture Reactions (SECAR) Phase 2, at Michigan State University, to H Schatz ($1.5M). Another award for MRI was given to develop the Fast Interaction Trigger Detector for the ALICE Experiment at the Large Hadron Collider (LHC) at CERN. California Polytechnic State and Chicago State University principal investigators are J Klay and A Harton ($369K). There will likely be a new solicitation in FY17.

Regarding AGEP: the Alliance for Graduate Education and the Professoriate: the program is intended to increase participation of underrepresented groups at AGEP legacy institutions – check online – if PIs have a grad student in an underrepresented group and not currently funded, they can request support up to $60K for stipend and tuition.

Opper gave some final updates on NSF/ MPS/ Physics Personnel changes. Notably, Fleming Crim is departing, and she did not know who will be the new Associate Director for MPS. Her contact info is in the publicly-available presentation, chart 22.

Discussion

Nunes wanted more data on theory, proposals submitted versus awarded grants, noting that NSAC had seen data for the experimental program but not for Theory.

Opper said one of the challenges was that there were smaller numbers regarding theory than the experimental program proposals.

Bogdan Mihaila, NSF Program Manager for the Nuclear Theory program, said 28 theory proposals had been submitted; 12 were awarded per year.

Opper mentioned double beta decay being moved from the Particle Astrophysics Program to the Nuclear Physics Program and that the number of researchers supported is going up.

Mihaila said data is in backup slides and available.

Nunes said she was assuming the fraction of dollars awarded for theory had been reduced.

Mihaila responded with “Is theory underfunded?” Yes. Funding throughout NSF remains flat. All fields of physics are in the same situation. We are trying to make the best use of money we have available, being mindful of experienced versus inexperienced applicants. Theory had a $500K increase in its budget, but for a specific purpose.

Rajagopal said that for years, funding for NP Theory had been flat. Was the way to grow Theory’s portion of the “research pie” to have the next-best not-funded proposal be as strong as possible so it could best compete against proposals in other sub-fields for any remaining funds.

Mihaila said no. What usually happens is the division, just like any organization, has a reserve. When it becomes available, we make our case and sometimes may be able to make a small increase in proposals funded, but that small increase does not sustain the budget or grow the program.

Kate Jones referred to extra proposals in double beta decay.

Opper replied that $1.3M was added and went into Fundamental Symmetries.

PRESENTATIION OF THE ^{99}Mo SUBCOMMITTEE REPORT

Susan Seestrom, Subcommittee Chair from Los Alamos National Laboratory, displayed the Charge to NSAC – basically the same in 2015 from that in 2014. **Fahey** had been added to the committee because of relevant expertise, and stakeholders had given feedback on membership of the committee. She discussed the process which included updates on program status by NNSA, the Office of Environmental Management (EM), and the DOE Operating Experience Committee (OEC); Thomas Ruth of the National Academies Study Group also presented the recent results of the National Academy study on ^{99}Mo.

For background: there is widespread use of ^{99m}Tc for nuclear medicine diagnostic imaging. ^{99m}Tc is the daughter of ^{99}Mo. Today, ^{99}Mo is produced by fission of ^{235}U. There is U.S. government interest in reducing the use of Highly Enriched Uranium (HEU) in its commitment to nuclear nonproliferation; there was concern in the medical community that this could lead to shortages or a significant increase in price for medical isotopes. This issue was addressed in the 2009 National Academy study; however, supply chain disruptions have occurred during 2005-2014, and there is currently no U.S. producer of ^{99}Mo. More than half of ^{99m}Tc came from Canada, which is no longer producing it. The NNSA strategy to deal with this problem has been to form cooperative agreement partners and encourage new U.S. and/ or international partners to produce it.

The goal was to produce 3,000 6-day Curies, which is roughly half of the U.S. use. **Seestrom** said there are three active cooperative agreement partners: NorthStar Missouri that produces low specific activity products, SHINE, and General Atomics using selective gas extraction. Each cooperative agreement is awarded under a 50% - 50% cost-share arrangement, consistent with the American Medical Isotopes Production Act (AMIPA) and Section 988 of the Energy Policy Act of 2005. The cooperative agreements are currently limited to $25M each.

Since 2014, the international context has changed in important ways. OECD-NEA HLG-MR issued a new report “2016 Medical Isotope Supply Review: ^{99}Mo/^{99m}Tc Market Demand and Production Capacity Projection 2016-2021.” The report said that “the current irradiator and processor supply chain capacity should be sufficient and if well maintained, planned, and scheduled, be able to maintain an unplanned outage of a reactor or processor through 2021.” NAS also issued a report entitled “Molybdenum-99 for Medical Imaging,” stating, a “…substantial likelihood of severe ^{99}Mo/^{99m}Tc supply shortages after October 2016.” The Canadian government, which supplies 50 percent of the U.S. market of ^{99}Mo/^{99m}Tc, issued a contingency plan for emergency production of ^{99}Mo during the period 2016-2018, should a worldwide shortage develop. After 2018, capacity should be acceptable. The 35 percent outage reserve capacity is the key difference between NAS and OECD analyses. NAS was more skeptical about what would actually happen, versus what suppliers said would happen. Reasons are: there are four suppliers instead of five, a reliance on an aging reactor, and no backup reactors with breakages likely to occur over the years. The high risk for supply disruptions fed into the negative outlook taken by the NAS.

The NNSA has exhibited leadership in developing the Uranium Lease and Take Back Program (ULTB), and this year the ULTB officially started. A new partnership has begun with General Atomics that includes Canada partnership. NorthStar neutron capture has been iterating with the US Food and Drug Administration (FDA) on the question of biologic purity in the context of the compounding pharmacy issue. FDA has increased stringency on purity, and NorthStar has dealt with greater stringency because of that. NorthStar predicts it can ship material to market once it has FDA approval and is optimistic for 2017 market delivery.

SHINE uses a DT source and must build a nuclear facility. Although SHINE reports that it has raised enough funds to complete design, the progress of this project has been hindered by the limited availability of investment funds. SHINE has been issued a Construction Permit by the U.S. Nuclear Regulatory Commission (NRC): first permit since 1985 for a non-power facility.

General Atomics predicts it will be ready to ship material soon but must resolve waste take-back costs first in the coming months. A low-enriched Uranium (LEU) lease agreement between MURR and NNSA was signed, and delivery of 20 kg LEU is imminent. Waste take-back costs are affecting General Atomics' schedule in pursuing new technology based on the fission of LEU.

NNSA has worked proactively over the course of the program based on the specific AMIPA requirements, especially considering the many complex factors outside its direct control. NNSA is working with the international community to achieve full cost recovery and thus a level playing field for new US producers. NNSA is trying to accelerate development of new domestic suppliers – funding seems to be an issue. The Subcommittee found that there is a significant chance that NNSA will meet its goal of achieving US production of ^{99}Mo, with FDA approval, for use in the US Market during 2017.

Seestrom discussed the current status of implementing NNSA ^{99}Mo Program and progress made since the second assessment. She reported that the Subcommittee had concluded the strategy for continuing to implement the NNSA goals is complete and feasible, based on specific actions reported in her talk. The Subcommittee also believed the NNSA is appropriately managing risks: it is doing the most important things the Subcommittee advised them to do, especially working out a better short-term contingency plan with the Canadian government as well as a global contingency plan. And finally, contingency should global community not move toward full cost recovery.

The Subcommittee made a final recommendation on take-back: they must have a business case on costs associated with take-back. Take-back costs must be better defined so potential customers have predictable costs. DOE will likely have to take risks on not getting all costs recovered. The Subcommittee considers it extremely urgent that DOE identify a way to cap the liability associated with spent nuclear fuel (SNF) and radioactive waste in the ULTB program for potential US ^{99}Mo producers.

Discussion

Hertzog thanked **Seestrom** and the Subcommittee for a compact and readable report and welcomed initial questions from the NSAC. He announced a break from 10:40 to 11:05am.

When the NSAC resumed the meeting, **Hertzog** briefly set ground-rules for the discussion.

Seestrom said she sensed she might have cut details too much in descriptions of the three projects; should she revise the report to make the details more meaningful?

Hertzog replied there was a lot of literature that readers could reference.

Fahey thanked **Seestrom** for presenting the material in an understandable and precise way. As someone who works in a U.S. radio-nuclear medicine clinic, the supply shortage is very important. If there was an unplanned shortage and the NRU had to come up with a way to make up the shortage, that it should consider that plan better. Last year, the committee recommended to NNSA that more funding would be helpful to get one of the projects in a position to provide domestically produced ^{99}Mo. From now till March of 2018 other groups around the world could be ramping up production; so an increasing domestic supply could change market prices. There is one partner with the ability to provide ^{99}Mo to the U.S. in 2017: a relief to those like him who work in clinics. He added that the committee was also concerned about the uncertainty about cooperative agreements pertaining to the take-back program, the cost risks, and incentives. He commended **Seestrom** on the report.

Lisa added thanks for a well-written report. He asked whether in 2018 when the Canadian reactor is shutting down, why wouldn't Canada just make ^{99}Mo during the gap period?

Seestrom replied that Canada is incurring costs to provide ^{99}Mo to the U.S. and it doesn't "want to be in that business anymore."

Lisa asked would NorthStar make a profit.

Seestrom said she had not seen any business cases by the companies, but she liked the strategy to use an existing reactor, and/ or to use low-specific activity to try and get a market share. She said in 2018 that market share would be more challenging to access, once other ^{99}Mo producers entered the market.

Lisa then asked about a drop in demand a few years ago.

Seestrom said she thought it was due to a reduced demand. She had engaged with a physician to ask why reduced demand, and the usage of cardiac catheters or riskier alternative medical procedures had increased when the ^{99}Mo supply had been constrained.

Lisa asked that since supply was inconsistent, could the demand drop.

Suzanne Lapi said demand will likely drop, due to clinicians choosing to use other procedures.

Fahey said half of the procedures are myocardial perfusion studies, and ^{99}Mo is important in assessing specific medical problems. The number of procedures done now is 20 percent less than the number of procedures in 2008.

Seestrom added that the developing world would also contribute to increasing demand.

Rajagopal thanked **Seestrom** and said he appreciated NSAC comments being included to inform the report. When will NSAC no longer need to provide these annual reviews?

Seestrom said Congress and AMIPA had mandated those reviews, and she didn't see anything changing the trajectory in the short term. Even an increase in funding would not make a difference for 2018. There is a good chance that market success will be achieved in 2017. Maybe then NSAC, could do one close-out review. **Seestrom** said if five years from now there is still no US producer, then Congress would need to redefine the program.

Hallman said since the annual review is a matter of statute, Congress would have to change it. But DOE could engage with Congress to request reporting relief, once events became clearer.

John Hardy commented on the contingency over the next two years and the Canadian government's assurances. He worked for 25 years at Chalk River. It will be shut down in 2018. The people there are applying for jobs elsewhere. What happens if the experts have all vacated the premises before the operation is scheduled to cease?

Seestrom conceded the plan was high-level, but that matter was considered in the NAS report. Tom Ruth, who co-chaired the committee that wrote the report, had repeatedly made those points. There are uncertainties inherent in those assessments. Nordion in Canada has signed up as a partner with General Atomics.

Keppel asked a question on anticipated demand of ^{99}Mo: is there development of other radiopharmaceuticals that might displace it?

Lapi said yes, people are moving to Rubidium and others. Most of those techniques use different scanners, so there is a longer timeframe needed to phase-in alternative radiopharmaceuticals. There would not likely be a complete replacement of ^{99}Mo.

Fahey shared that there were five gamma scanners and 1 PET scanner at his institution. Most are single photon conducted with Tc^{99m}. The gamma scanners are much more numerous around the country.

Phillips asked if having several suppliers would facilitate being able to meet the demand.

Seestrom said when the Funding Opportunity Announcement was issued in 2012, that if three suppliers succeeded, that they would have to supplant all others in the market.

Phillips how much that approach depended on the older Missouri reactor.

Seestrom replied there is complete reliance on the Missouri reactor by NorthStar and GA. SHINE, in contrast, will require a new facility for Deuterium. They are behind because they have to build a new facility. She had visited the University of Missouri Research Reactor Center (MURR) reactor during a meeting; UM had replaced and refurbished the facility. All other reactors around the world are old reactors. The Missouri reactor is using highly enriched reactor fuel. Any reactor that produces fuel must convert to low-enriched uranium. This is not a solution for MURR because it is such a small reactor.

Nunes said the last recommendation that was not addressed by NNSA, could it be re-phrased so it is actionable.

Seestrom If none of the producers emerged and got market share, what would you do? Full cost recovery is a risk for the NNSA. The Subcommittee purposefully did not say more because it could not identify a recommendation that would not cause more harm than good.

Phillips asked about the extent to which the international supply complicates U.S. production of ^{99}Mo.

Seestrom answered that in the NorthStar projects, they must have Mo^{98} targets, so NorthStar would be impacted. NorthStar has stated that it has a sufficient supply for some period of time – Seestrom was unsure on the period of time. It was unclear how much starting material they would actually need; so the Subcommittee felt it important to articulate the risk.

Phillips asked about cooperation with the DOE national labs.

Seestrom mentioned they played a role in developing technologies with the cooperative agreement partners.

Hallman added, work-for-others technologies.

Seestrom said the DOE labs had done physics or chemistry work that could be published in the open literature and that was also of interest to the cooperative agreement partners.

Hertzog said they had heard a few anecdotal stories.

Seestrom specified that Livermore, Argonne, Los Alamos, and Oak Ridge have partnered.

Heeger asked about SHINE and Argonne's partnership.

Seestrom said she didn't know about Argonne. How long they ran met some requirement for how long they'd need to run. SHINE would need to build a $200M facility. NNSA doesn't want to affect decisions about what companies or models will succeed in the market, but it is more complicated than that. But they still are moving forward and have funds on-hand for the design phase of the facility

Fuller said the disposal phase is not well defined yet. Is physical transport of the material part of the problem?

Seestrom said no; there was no technical path for disposal.

Hertzog asked about the final report status. NSAC has reviewed a draft.

Seestrom said other than minor edits, the only change was the paragraph on Mo^{98}/ Mo^{99} isotopes. Specific technologies being pursued could be added – or not – sought clarification.

Hertzog said there could be one or two sentences on each technology, but no need for more than that.

Hardy said he had read the phrase, "no low specific activity." Why does the report say there is low specific activity material? A small clarification should be made.

Hertzog summarized that the changes would include small typological changes, **Hardy's** small clarification, and a review to avoid disclosing industry proprietary information.

Seestrom said she had checked with the companies and NNSA on the proprietary information and had feedback on all current language in the report.

Fuller recommended adding a summary of production channels and risks either in an appendix or as a figure.

Seestrom replied she could add a paragraph summarizing early paragraph on cooperative agreements.

Hertzog recommended instead including that as an appendix with explanatory material.

Rajagopal asked if Seestrom was asking the NSAC for any further guidance.

Seestrom asked whether NNSA had addressed the NSAC Subcommittee recommendations reasonably. The Subcommittee mentioned the $25M, but it never explicitly said it believed the NNSA response to be reasonable and acceptable.

Hertzog said if the Subcommittee felt yes, to include it in the report. Or it could say NNSA "had been responsive" to the recommendations.

Hallman said they had heard from the NNSA that representatives there had thought "long and hard" and had taken care in responding to the Subcommittee.

Hertzog mentioned finishing the report was urgent.

Seestrom asked **Fahey** if he objected to anything in the report, and **Fahey** said he did not.

Hertzog requested comments from NSAC members on accepting the report including changes discussed.

Savage said he was surprised on the situation of the United States on the shortage. He agreed to the report as discussed.

Other individual NSAC members briefly commented and complimented the Subcommittee's work. The NSAC unanimously accepted the report, with changes as discussed.

Seestrom asked when the final draft was due.

Hertzog recommended in two business days, or as soon as possible.

Seestrom asked if the NSAC wanted a final draft. All members indicated they were comfortable with simply receiving the final report copy.

ROLE AND CONTRIBUTIONS TO THE NATIONAL NUCLEAR SCIENCE PROGRAM OF THE ASSOCIATION FOR RESEARCH AT UNIVERSITY NUCLEAR ACCELERATORS (ARUNA)

Calvin Howell, Professor of Physics at Duke University, thanked the NSAC members for inviting him to share work done at university accelerator facilities. The consortium was founded about five years ago and consists of 10 accelerator facilities. Research programs are in physics frontier areas, including nuclear structure, nuclear astrophysics, fundamental symmetries and low-energy QCD. The facilities are used both for applied and interdisciplinary research and help to educate about 16 percent of the nation's PhDs in experimental nuclear physics. These facilities offer hands-on and small group research experiences. He compared different accelerators in terms of complexity of the work and expense to maintain. Most research is done in the area of astrophysics; but Notre Dame and Texas A&M facilities can study fundamental symmetry like double beta decay. Nearly all are used for applications important to the nation. They operate at 1,500 to 3,000 hours per year. Accelerator laboratories in ARUNA enable subatomic experimental physics to be conducted in a table-top style, similar to atomic-optical-molecular and condensed-matter experimental research. Research groups are comprised of about 20 people. Experiment durations are about six years and develop concepts into proof of principle.

Reading the long-range plan afresh, **Howell** said he looked for portions that pertain to the university nuclear accelerator community. He then shared examples of ARUNA research that aligns with the long-range plan for nuclear science. The Ohio University Edwards Accelerator Lab has a fast neutron beam facility and a swinger magnet. Researchers there are interested in ^{76}Germanium nuclei in the mass range to study neutrinoless double beta decay. At Texas A&M, the K-100 cyclotron was brought back online and can be used with a K-150 and K-500 machine. The accelerator facilities, their beams, and target capabilities are evolving to meet the needs and curiosity of the scientific community. A&M is studying the structure of the super neutron rich Helium isotope – ^{9}He. Also at Texas A&M, the accelerator was used to demonstrate a theory on ternary fission fragment production. A&M is also working with ^{70}Zn to detect fragments and determine angles of rotation for fission fragments.

At TUNL, work is being done to support neutrino scattering and beta decay. The High Intensity Gamma Ray Source is being used to study the fine structure of the giant M1 resonance in ^{90}Zr. Also, nucleon forces and neutron beams can be studied at TUNL and Tandem Laboratory, employing neutron scattering off a deuterium target. He said that facility had discovered previous measurements of ^{9}He at Texas A&M and advocated for repeatable results within the community for specific experiments.

At the University of Kentucky, nuclear structure studies have been done on how to better minimize background when studying neutrino-less double beta decay. Investigators conducted a detailed study of the nuclear structure of ^{76}Ge via the ^{76}Ge(n,n′γ) reaction.

Nuclear structure studies overlap with Nuclear Astrophysics, especially when nuclear structure has a significant impact on reaction rates. At Notre Dame, four-alpha coincident events were measured by an array of four double-sided silicon strip detectors. Observation of the cluster states could shed new light on the possible existence of the four-α linear chain structure in ^{16}O and potentially enhance the helium burning rate in stars, an area of great interest within the astrophysics community.

In the area of nuclear astrophysics, small research universities have especially excelled. With accelerators, reaction rates relevant to stars are the frontier of low energy physics. Florida State University has explored energy bottlenecks in stellar chain reactions. The John D. Fox Accelerator Laboratory uses a Tandem and LINAC to look for reaction rate using Neon using a surrogate reaction. At TUNL Laboratory for Experimental Nuclear Astrophysics, researchers have developed a post-beam capability and improved signal to background ratios. Experiments using ^{22}Ne(p,γ)^{23}Na and abundance anomalies are relevant to the study of globular clusters. Scientists at Texas A&M University have developed the Asymptotic Normalization Coefficients (ANC) method to determine many rates at stellar energies using conventional nuclear reactions. Notre Dame is conducting three separate projects in this field, including (1) the ^{22}Ne(α,n) neutron source in stellar helium burning; (2) measuring ^{12}C+^{16}O fusion cross section with the St. ANA accelerator; and (3) measuring the half-life of ^{60}Fe for increased understanding of stars and the early solar system.

Notre Dame has atomic mass spectroscopy capabilities and can study the lifetime of rare isotopes such as ^{60}Fe, important in the area of low energy quantum chiral dynamics (QCD); and standard properties of the nucleon are studied at these facilities. At HIGS ^{3}H nucleon forces are studied.

Fundamental symmetries and neutrinos are also studied at the university accelerators. Howell highlighted functional symmetry studies at Texas A&M, Notre Dame, and the University of Washington.

Regarding workforce development, Howell said 11 PhDs per year are generated from work using the university facilities. For every 80 physics PhDs, a small percentage is theorists. Howell mentioned several students and noted that ones who worked in small groups of less than 10 or 20, and on shorter-turn projects of three years, tended to be most attractive to be hired by the private sector.

Howell summarized by saying that ARUNA facilities enable frontier physics research to be carried out by small collaborations and are important places for tomorrow's nuclear physicists to learn. The unique capabilities and features of the ARUNA facilities add nimbleness to the national nuclear physics program.

Discussion

Heeger asked about how ARUNA was founded.

Howell answered to coordinate resources amongst common themes and share information. When the group started organizing itself, it hoped to increase efficiency in its contribution to national science matters.

Helen Caines asked about the PhDs and whether we are meeting demand for nuclear chemists.

Howell said no. For big neutrino detectors, they needed people to get contaminants out of the system, and there seemed to be a shortage of people with that expertise in this country. Texas A&M plays heavily in training people with such expertise.

Dr. Robert Tribble, Deputy Director of Science and Technology at Brookhaven National Laboratory, said if you look at availability and the DOE lab demand, there is a huge disparity. Specifically at LANL, Savannah, and Livermore: it is close to a crisis.

Hallman said they had requested special funds to establish a traineeship, and those were granted.

Hearing no further questions, **Hertzog** announced the lunch period from 12:55 until 1:45pm.

PROGRESS AND OUTLOOK IN NUCLEAR SCIENCE ON THE SEARCH FOR NEW PHYSICS USING ELECTRON DIPOLE MOMENTS (EDMs)

Roy Holt, in the Physics Division at Argonne National Laboratory, gave a talk on electron dipole moment experiments: the leptonic and hadronic electron dipole moments (EDMs). Their study could help answer big questions such as: Why do we exist? Why is there more matter than antimatter? And why only one part in 10^9 of matter is left from the Big Bang? There are new sources of charge parity (CP) violation out there, beyond the Standard Model. The Long Range Plan also contains focused language on EDMs: that they shed light on matter/ antimatter asymmetry in the universe. Also, "Improved sensitivities by a factor of 10–100 would imply reach on the scale of CPV interactions in the 10–50 TeV range, inaccessible at high-energy colliders today ..." There is no Standard Model background, as there is a question whether a non-zero EDM exists.

EDM searches may occur in three sectors: nucleons, nuclei, and leptons. In each sector, experimental limits are still 10 orders of magnitude away from a discovery regarding the Standard Model. Holt surveyed current, active EDM searches in the field; and he found leptonic EDMs at approximately seven research facilities; and 17 facilities involved in hadronic EDM searches. He explained that all EDM experiments have one common feature: that sensitivity depends on three factors: electric field, coherence time, and number of counts. In terms of systematics: a small magnetic field variance can have huge effects on outcomes. Therefore, shielding, field gradients, and magnetometry are important concepts.

Leptonic EDMs: we know molecules are highly polarizable. Yale and Harvard scientists produced a cryogenic molecular beam and observed large flux, good statistics. They have a large internal E-field (84 GV/cm) plus and internal co-magnetometer to control systematics. This eliminates dependence on the external field. Now they are running with a 600x increase of observed count rate, and we will observe results of at least an order of magnitude better than we have seen now. Competing institutions include Berkeley (2002) and Imperial College (2011). In fact, Imperial College is working with YbF (Ytterbium Monoflouride). Expected sensitivity is 2 x 10^{-29} ecm, 90% CL.

Eric Cornell at JILA is using HfF^+: in an ion trap, a very clever design. Cornell has produced a rotating e-field that traps the ion. Because it is a meta-stable state, the effective E-field is 23.3 GV/cm and a coherence time >0.5s. The count rate is all he has to work on.

Dave Hertzog and T. Gorringe wrote a review article on muon physics, including EDMs. You get an induced motional E-field generating ~13GV/m. Measure up and down the slopes of Muon decays using tracking detectors.

For hadronic EDMs: there are relevant neutron EDM experiments around the world: three in North America, four in Europe, and two in Japan. Neutron EDM was one of the beginning searches for EDMs. Holt said he couldn't cover all of the experiments but wanted to highlight five of them that have performed significantly beyond the present limits. PSI nEDM collaboration is centered mostly in Europe but does include one United States partner. Holt displayed the PSI nEDM spectrometer design that includes Mercury and Cesium magnetometers. Accumulated sensitivity of the ILL experiment is <1 x 10^{-26} ecm. Phase 1 operation will come to an end in months. The next phase will be installed and commissioned in 2018, with 10^{-27} sensitivity expected to be achieved by 2020.

The TUM EDM experiment contains contributors in the U.S. as well as Europe and is a Ramsey experiment with UCN trapped at room temperature, ultimately to be cryogenic. The room temperature option is already available. Using two chambers enables an E-field reversal. An interesting feature of the Super-SUN experiment is they collect ultra-cold neutrons in a sextapole electric field to magnetically trap the neutrons, so no interference from the walls occurs. The nEDM collaboration includes many players; its sensitivity is ~2x10^{-28} ecm, 100 times better than the existing limit. They have a polarized ^{3}He co-magnetometer and two cells with opposite E-fields. They can control the temperature of the environment. Years 2014-2017 will feature a critical component demonstration for nEDM at the SNS (the Spallation Neutron Source); the experiment will be commissioning the experiment in 2022. The TRIUMF experiment includes collaboration between Japan and Canada and is open to additional members. The first UCN is in place. The Phase 1 KEK apparatus will run in 2019; Phase 2 will run beginning in 2020.

At LANL, there is R&D for a nEDM experiment; collaborators are at several U.S. universities. Sensitivity is 10^{-27} ecm. It is relatively low in cost, compared to other experiments. The UCN density for the new source should be 5 to 10 times more sensitive at 10^{-27} ecm.

Turning to the subject of nuclei, the ^{199}Hg collaboration contains only a small number of collaborators. Holt explained the current EDM experiment. 300-600 seconds is a long spin relaxation time. Over the last three decades, the sensitivity has increased from 10^{-26} to 10^{-30} ecm. There is a HeXe experiment that includes Jülich, MSU, PTB, TU Munich, and the University of Michigan. There is another HeXe collaboration called MIXED that achieved a sensitivity of 10^{-28} ecm in four hours and 10^{-29} ecm in one day, which is the present limit for Xenon.

Holt discussed progression of a search for the EDM of Radium-225, from 2006 to the present. Multiple universities are collaborating on the Radium-225 experiments. They only capture a half percent of the Radium atoms coming out of the oven and want to improve that using techniques such as a new Radium source with FRIB.

CeNTREX is a cold molecule nuclear time-reversal experiment that is complementary to ^{199}Hg and n EDMs. The goal is to produce a 30x better improvement over ^{199}HG by 2022. Another new idea is the storage ring proton EDM experiment, with 10^{-29} ecm projected sensitivity and including Korea and COSY/Germany. CERN is a candidate host lab. Also, he mentioned the Deuteron EDM experiments by the JEDI collaboration at COSY.

EDM measurements for multiple systems are necessary. In field theory, six parameters are important, necessitating six measurements. Holt summarized by saying many new technologies are being developed, with improved sensitivities for some elements even within a year or two.

Discussion

Benny asked at what point do you run into trouble if you don't see an EDM when trying to research matter/ antimatter?

Holt answered if the EDM becomes a bump in the road that he expected clever physicists would find ways to get around it.

Fuller said there are other ways to generate or other models – such as in the neutrino sector.

Rajagopal made a comment in the context of neutrinoless double beta decay. The theorists have already wriggled.

Hertzog said it is amazing how many neutron EDM experiments there are – some are real and some are virtual, correct?

Holt said he tried to only speak on the ones that he thinks are real, and these are the hardest experiments on earth to do. It is helpful to have several different experimental methods.

Fuller said recently he had heard Doyle of Harvard say all this progress is without modern AMO techniques.

Holt said basically Doyle meant one needs AMO techniques (atomic, molecular, and optical physics) for these experiments.

Fuller said, "Coherence time…"

Holt added: "He has been working on beam experiments. The JILA idea of the ion trap is good for both high fields and long coherence time. You're right, it's an AMO experiment."

Hallman came to the front of the room and shared his longtime appreciation of **Holt's** expertise and service in the area of nuclear science. On behalf of DOE and NSF, he presented **Holt** with a certificate of appreciation.

THE BIG PICTURE ON THE SEARCH FOR NEW PHYSICS AND WHAT NUCLEAR SCIENCE FUNDAMENTAL SYMMETRIES EXPERIMENTS CAN CONTRIBUTE TO IT

Vincenzo Cirigliano, of the Theoretical Division at Los Alamos National Laboratory, said the search for physics beyond the Standard Model is motivated by observation that it cannot represent the whole story. Phenomenology-driven questions include: What is the nature of dark matter? What is the origin of the baryon asymmetry in the universe? How do neutrinos acquire mass? What is dark energy? Theory-driven arguments include: What stabilizes G_{Fermi}/G_{Newton} against large radiative corrections? Do the gauge forces unify at high E? What about gravity? What is the origin of fermion generations and pattern of masses & mixings? Since there is no guaranteed path to discovery in this area, the community is searching broadly.

Where is the new physics? Is it Heavy? Is it Light and weakly coupled? These questions drive two experimental approaches, both of which are needed to understand structure and new physics.

At the Energy Frontier, high energy research is done by the Large Hadron Collider. It has enabled a major discovery, the Higgs boson with m_h=125GeV. The community now is focusing on aspects relating to the Higgs, as a probe of new physics. Higgs couplings to heavy particles are consistent with Standard Model prediction (~10 percent level). This also provides an opportunity for the Precision Frontier, explored at both at the collider and in low-energy experiments.

Supersymmetry models are appealing and have received much attention because they can lead to stability of G_{Fermi}/G_{Newton}, dark matter, and other areas of physics. Direct searches plus light Higgs represent the simplest SUSY scenarios under pressure. Di-lepton new resonances are a new area of exploration, as are di-jets, and di-photons. There are many non-SUSY searches occurring as well. For the search for dark matter at LHC, you can record in the presence of a mono-jet. The presence of dark matter would alter the distribution. Summarizing the Energy Frontier: Higgs at 125 GeV is a major discovery; and the simplest scenarios are being pushed to TeV scale and beyond.

On the Precision Frontier, there are three classes of new physics probes: searches for rare or forbidden process that probe symmetries of the SM: proton decay, double beta decay, and EDMs. A second class involves precision measurements of SM-allowed processes: β-decays (neutron, nuclei), PVES, muon properties (lifetime and g-2). They are sensitive to very high-scale new physics. A third class is direct measurements of properties of light and weakly coupled particles: active versus sterile neutrinos, dark photons, dark Higgs, and axion. These probes contribute to the overall endeavor: discovery potential, diagnosing power, and access to physics needed to address big questions. A rough indication of discovery potential is given by reach in Λ and may include rare and forbidden processes. Λ is the maximal scale probed by a given measurement, assuming O(1) couplings (for all probes) and loop factor for g-2, EDMs, LFV.

Precision measurements may match or exceed LHC existing bounds and future reach; they can play an important role in reconstructing TeV dynamics. For diagnosing power, combining several low-E measurements may lead to model-discriminating power, like putting together double beta decay, mass scale, and oscillations can inform the neutrino mass model. Nuclear Science Fundamental Symmetries experiments cluster around big questions, often probing dynamics otherwise inaccessible.

In the areas of double beta decay and lepton number violation, **Cirigliano** explained that B-L is conserved in the Standard Model, leading to new physics, with far-reaching implications. Double beta decay probes a breadth of models. Ton-scale 0νββ searches ($T_{1/2} > 10^{27\text{-}28}$ yr) probe at unprecedented levels LNV from a variety of mechanisms. Another "high scale seesaw" indicates a correlation of 0νββ with neutrino phenomenology. Other mass probes will contribute to the interpretation of a positive or null result. This has interplay with the Cosmic Frontier which may expose potential new physics in cosmology.

Cirigliano covered additional topics relating to general see-saw, baryogenesis, and 0νββ. TeV sources of LNV may lead to significant contributions toNLDBD not directly related to the exchange of light neutrinos. And a low scale seesaw is intriguing example with one light sterile νR with mass (~eV) and mixing (~0.1) to fit short baseline anomalies.

He discussed EDMs and CPV Higgs couplings as well as EDMs in high-scale SUSY models. EDMs are among a handful of observables capable of probing such high scales. In the (N)MSSM, CPV phases appearing in the gaugino- higgsino mixing contribute to both baryogenesis and EDM.

In Precision Measurements, beta decays and parity-violating electron scattering have played a central role in establishing the Standard Model. Today, with precision approaching the 0.1 percent level, together with the muon g-2 they probe quantum effects in the Standard Model at unprecedented levels. In the area of beta decays and charged carbon interactions, beta decay fares quite well. The strongest probe of beta decay comes with CKM unitarity. We need higher precision. In 1978 the first PVS was observed, which later generated a Nobel Prize. **Cirigliano** discussed MOLLER work at Jefferson Laboratory, with its sensitivity to doubly charged scalars. On the impact of PVES on new physics, there is room for discovery. The sensitivity to heavy new physics is parameterized by local operators.

Cirigliano discussed Theory versus the experiment on the muon anomalous magnetic moment. The measurement is very important to discover all sorts of models, but especially the dark sector. The Dark sector with $U(1)_d$ is motivated by dark matter phenomenology. Dark gauge boson A' can mix with y; two parameters are (mA', ε). J-Lab is exploring this area. Many different probes are employed to study the dark sector. JLab is also studying Dark Z and precision measurements. .

Summarizing, he said that should new physics appear at the LHC, NS probes will be essential in understanding the BSM symmetries and disentangling models. Should new physics not appear at the LHC, the precision frontier will be for a while the only tool to explore new physics. Current/ planned nuclear science experiments provide competitive probes of dark sectors and new physics up to Λ >10 TeV.

Discussion

Benny asked are there reasons the force carrier of the dark sector can mix with photon or Z.

Cirigliano said the leadings ones are dark photon, dark Higgs, and standard neutrino. Their interaction is unsuppressed. With the study of dark sector, you are always limited by the scale.

Benny asked should one expect kinematic mixing, if you have a force carrier in the dark sector?

Cirigliano said super-heavy particles can help study in a phenomenological manner.

Deshpande said by the time the LHC came along, physics has also come along independently. What is the update by LHC to produce improvement in physics beyond the Standard Model?

Hertzog said he was at a workshop on parton distribution functions, and knowledge was beyond what it was even a short time ago.

Hertzog said **Cirigliano** had given a remarkably comprehensive overview, and he appreciated it very much. He called a break to resume at 3:55pm.

PRESENTATION OF THE NUCLEAR PHYSICS SMALL BUSINESS INNOVATION RESEARCH/ SMALL BUSINESS TECHNOLOGY TRANSFER (SBIR/STTR) PROGRAMS

Michelle Shinn, Program Manager for Industrial Concepts in the Office of Nuclear Physics, talked about SBIR/ STTR. These programs were established in 1982 as Bell labs and other large industrial labs were closing. By 1992, the National Laboratories were producing a lot of innovation, but STTR were established in 1992 to stimulate innovation through R&D between small business and research institutions. Both were re-authorized in 2011 through the end of FY17. There are three SBIR general phases: 1: $150K for feasibility study; 2: $1-1.5M for prototypes or processes; and 3: no dollar limits for the commercialization phase. DOE does not use Phase 3, but instead leverages sequential funding mechanisms for Phase 1 and 2 grants.

At DOE specifically, there is a triad of organizations that operates the SBIR/ STTR programs. The DOE SBIR/STTR Office handles the FOA and funds administration management, while the DOE program office selects the topics but does not manage the grants/ contracts. For the last 10 years, **Manouchehr Farkhondeh, Ph.D.,** Program Manager of Advanced Technology R&D within DOE SC/ NP has ably managed this program. DOE SC also has "Topic Associates," or TAs, with specific areas of expertise. Due to the complexity, the FOAs are grouped into two separate releases or phases.

In FY15, all federal agencies with an extramural research budget greater than $100M contributed 2.9 percent of that budget to the SBIR portion of the program. If greater than $1B in extramural R&D, then 0.4 percent must go to the STTR program. The values have risen steadily since 2011. Shinn explained exactly how funding levels are determined for Nuclear Physics at DOE. The Budget Office separately confirms the base amount that NP does. The SBIR/ STTR office uses 1-2 percent of funds for administration and capital assistance funds. Phase 1 awards are $150K for 9 months; Phase 2 awards are much higher and longer in duration. In NP, $16M is expected to go to SBIR/ STTR, with $17M in FY17, rising steadily by $1M per year into the future.

Shinn briefed the topic development process; it is not done in a vacuum. They review awards in Basic Energy Sciences and High Energy Physics. They also try to communicate with the Defense Threat Reduction Agency (DTRA) to minimize topical overlaps. Topics for FY17 include (chart); and subtopics are revised each year to advance NP core technologies. There is no fixed set-aside for each topic, and proposals from all five topics compete with each other. She gave some details on each of the topics and explained reasons the topics were chosen and prioritized.

NP has tracked numbers of letters of intent, a.k.a. the proposals. DOE NP engages with the principal investigator to determine whether the proposal aligns with DOE's intent for the future direction of physics. In 2016, NP received 277 letters of intent and 169 Phase 1 proposals. One-third were accepted, or 28. Tracking since FY07, the number of Phase 2 proposals jumped greatly in FY15 due to the movement of High Energy Physics over into NP.

The SBIR/ STTR Exchange Meeting is an effort by DOE NP to bring together the program managers, principal investigators, and STTR businesses in the community to enhance the possibilities for commercialization. Typically, 60-80 participants attend the two-day meeting. NP discovered that most of the products brought to market are sold overseas, in Asia or Europe. One example is radiation monitoring devices developed with CLYC. Another example is the growth of high purity Germanium crystals, creating a self-contained imaging system called the Germanium Gamma Ray Imager (GeGI) that is now used commercially for nuclear materials identification. In 2016, Faraday Technology has been looking to develop hydrofluoric acid-free electropolishing. Multiple labs, including JLAB, Fermi, Oak Ridge, and industry (AES) participated and are R&D 100 Finalists. It is being deployed at ORNL for processing of SNS SRF cavities. In FY14, Akonia Holographics received a Fast Track Award for their proposal, "Low-Latency Ultra-High Capacity Holographic Data Storage Archive Library." Holographic storage wins in terms of cost, footprint, speed, and reliability. In December 2015, they reached 2.2 Terabytes per square inch: world-record aerial storage.

Several changes to the programs will occur in FY17. Awardee contact information and the abstract will be publicly available, online, and the community can join an email list that include announcement of the SBIR/ STTR calendar and grants. The Exchange Meeting will be held in June for Phase 1.

Discussion

Jones asked about Intellectual Property (IP). If someone at a university is partnering with a private company, who owns the IP?

Shinn said the small business owns the IP. Or if the business has a Memorandum of Agreement, then the IP is owned by-contract, and the legal teams work it out. In that case it is usually a joint ownership. A recent review of the National Labs indicated the CREDA process takes too long. Applying for Phase 1 support partnering with a National Lab is disincentivizing because it takes the Lab too long to commence work. There are fast-track mechanisms being explored.

Cates asked if NP funds homeland-security related, fissile material detection technologies.

Shinn said is must be NP-specific at the outset. When it is dual-use and benefits NP, then yes. She said NP are working with PHDS Company on the GeGI Imager that could detect fissile material.

Hertzog then invited public comment.

Farkhondeh said this is good news, that the EIC and SBIR programs connected the company to JLab. Great use for ES.

PUBLIC COMMENTS

None

CLOSING REMARKS AND ADJOURNMENT

Hertzog adjourned the meeting at 4:40 p.m. EST.

The minutes of the U.S. Department of Energy and the National Science Foundation/ Nuclear Science Advisory Committee meeting, held on October 28, 2016, at the Hilton Hotel, Gaithersburg, Maryland, are certified to be an accurate representation of what occurred.

David Hertzog, Chair of the Nuclear Science Advisory Committee on February 6, 2017