HIGH ENERGY PHYSICS ADVISORY PANEL
to the
U.S. DEPARTMENT OF ENERGY and NATIONAL SCIENCE FOUNDATION

PUBLIC MEETING MINUTES

DoubleTree by Hilton Hotel Bethesda
8120 Wisconsin Avenue
Bethesda, MD 20814

December 8 - 9, 2014

HIGH ENERGY PHYSICS ADVISORY PANEL
SUMMARY OF MEETING

The U.S. Department of Energy (DOE) and National Science Foundation (NSF) High Energy Physics Advisory Panel (HEPAP) was convened at 9:00 a.m. EST on Monday, December 8, 2014, at the DoubleTree Hilton Hotel, Bethesda, MD, by Panel Chair Andrew Lankford.

Panel members present:

Andrew Lankford, Chair	Tao Han	Hitoshi Murayama
Ursula Bassler	Karsten Heeger	Gabriella Sciolla
Ilan Ben-Zvi	Georg Hoffstaetter	Ian Shipsey
James Buckley	A. Hassan Jawahery	Thomas Shutt
Bruce Carlsten	Zoltan Ligeti	Ian Shipsey
Mirjam Cvetic	Brad Keister	Robert Tschirhart
Robin Erbacher	Patricia McBride	

HEPAP members joining by conference call:
Mary Bishai Paul Steinhardt

HEPAP members unable to attend:
John Carlstrom Leslie Rosenberg

HEPAP Designated Federal Officer:
Glen Crawford, U.S. Department of Energy (DOE) , Office of Science (SC), Office of High Energy Physics (HEP), Research Technology, Detector R&D, Director

Others present for all or part of the meeting:
David Asner, Pacific Northwest National Laboratory (PNNL)
Michael Barnett, Lawrence Berkeley National Laboratory (LBNL)
Laura Biven, DOE SC
Greg Bock, Fermi National Accelerator Laboratory (Fermilab), Associate Laboratory Director for Particle Physics
David Boehnlein, DOE, SC, HEP, Energy Frontier, Physics Research
John Boger, DOE, SC, HEP, General Accelerator R&D
Marta Celuly, URA
Lali Chatterjee, DOE, SC, HEP, Computational High Energy Physics
Jim Cochran, Iowa State University
Eric Colby, DOE
Mark Coles, National Science Foundation
Michael Coske, DOE / American Association for Advancement of Science
Jean Cottam, NSF, PHY, Particle Astrophysics, Program Director
James Davenport, DOE Dmitri Denisov, Fermilab
Robert Diebold, Diebold Consulting
Keith Deines, DOE HEP
Aaron Dominquez, University of Nebraska
Saul Gonzalez, NSF, Division of Physics, Experimental Elementary Particle Physics
Harold Gordon, BNL

Paul Grannis, Stony Brook University Department of Physics
Don Hartsill, Cornell University
George Hoffstaetter, Cornell University
Tina Kaarsberg, DOE
Ben Kallen, FRA
Young Kee-Kim, University of Chicago
John Kogut, DOE, SC, HEP, Facilities Operations
Ted Lavine, DOE SC
Will Leemans, LBNL
Dan Lehman, DOE
L.K. Len, DOE
David Lissauer, BNL
Luhia Vyacheslav, NSF
Joe Lykken, Fermilab
Peter Kim, DOE
Andy Kinney, DOE
Ken Marken, DOE, SC, HEP, General Accelerator R&D
Helmut Marsiske, DOE, SC
David McFarlane, Stanford Linear Accelerator Center (SLAC)
Brian Mealers, NSF
Harvey Newman, CalTech
Scot Olivier, Lawrence Livermore National Laboratory (LLNL)
Ken Olsen, Superconducting Particle Accelerator Forum of the Americas
Ritchie Patterson, Cornell University, Director of CLASSE, Professor of Physics
Abid Patwa, DOE, SC, HEP, Energy Frontier, Physics Research
Michael Procario, DOE
Srini Raju Goapele, BNL
Doug Ray, PNNL
Steve Ritz, University of California, Santa Clara
Carly Robinson, DOE
Natalie Roe, LBNL
Eli Rosenberg, DOE
Michael Salamon, DOE
James Shank, National Science Foundation
Tom Shott, Stanford University
James Siegrist, DOE, SC, HEP, Associate Director
Gus Sinnes, LANL
Anthony Spadafora, LBNL, Physics Division, Deputy
Alan Stone, DOE
Bruce Strauss, DOE
David Sutter, University of Maryland
James Symons, LBNL
V.L. Teplitz, U.S. State Department
Kathleen Turner, DOE, SC, HEP, Cosmic Frontier
Michael Tuts, Columbia University, Experimental High-Energy Physics, Professor
Bruce Wafford, ORAU

Trent Wakenight, ORAU
Harry Weerts, ANL
Satoshi Yamashita, University of Tokyo
Rik Yoshida, ANL
Michael Zisman, DOE

DECEMBER 8, 2014

OPENING REMARKS

The U.S. Department of Energy (DOE) and National Science Foundation (NSF) High Energy Physics Advisory Panel (HEPAP) was convened at 9:00 a.m. EST on Monday, December 8, 2014, by **Panel Chair Andrew Lankford**. 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/hep/hepap for more information about HEPAP.

Lankford announced that the following HEPAP members will rotate off of the panel following completion of three year terms: Ursula Bassler, Mirjam Cvetic, Robin Erbacher, Gil Gilchriese, Patricia McBride, Ian Shipsey, and Robert Tschirhart.

DOE OFFICE OF SCIENCE REPORT

James Siegrist shared an update from the DOE SC Office of High Energy Physics (OHEP). OHEP has global recognition based on the overall acceptance of the P5 Report. Full implementation may take time. High priority projects are the Linear Hadron Collider (LHC) and LBNF upgrades.

There are five scientific drivers that map to the three SC research frontiers. In the Energy Frontier, more than 360 papers have been submitted by ATLAS and CMS during the first run of the LHC. Research has included ATLAS findings on the decay of Higgs to fermions and a joint CMS-LHCb paper. The LHC will resume operations in Spring 2015 at a higher energy and strengthen the U.S. role in overall LHC discoveries~~. By 2023, a high luminosity upgrade will achieve 10 times greater energy.~~ This will require a CERN-DOE-NSF cooperation agreement and will lead to investments in R&D for options that include lepton colliders and very high energy hadron colliders.

In the Intensity Frontier, NOvA is taking on data using the world's most powerful neutrino beam and longest baseline. One highlight is the Belle II Experiment Construction. It will achieve 100 times the luminosity of PEP-II. Belle II consists of significant international partnering. Since achieving CD-3 in April 2014, Belle II has made good progress on several research fronts.

Research in the Intensity Frontier includes work to precisely measure charged lepton properties and search for rare particle interactions using muon beams at Fermilab. There are precision studies of K mesons, c/b quarks and τ leptons. Research is also pursuing the neutrino mass hierarchy and measuring neutrino properties. Neutrino program planning is underway at several locations.

In the Cosmic Frontier, the High-Altitude Water Cherenkov Observatory (HAWC) in Mexico is taking data. HAWC is doing a high-sensitivity synoptic survey of the sky at wavelengths between 100 GeV and 100 TeV. An upgrade will be complete in February 2015.

Within dark energy, BOSS is operating until the end of 2014. In fabrication, the LSS-camera CD-3a was approved in June, and planning included CD-1 review in September for the Dark

Energy Spectroscopic Instrument (DESI). Direct detection work includes first generation (DM-G1) experiments.

Cosmic and gamma-ray laboratory work includes DOE operations completed by FY16 for VERITAS and Auger, and the HAWC gamma-ray observatory that started taking data in late November 2014. The South Pole Telescope polarization is in operation collecting cosmic wave background (CMB) data. DOE's role in the SPT-3G was successfully reviewed in September 2014, and the community is planning for a CMB Stage IV experiment.

Siegrist noted that several international agreements are occurring.

The OHEP budget for FY14 was $796M and the FY15 request is $744M. Based on the P5 Report, this request is below Scenario A. The House and Senate marks are higher. There is a significantly higher Senate mark for stewardship. The House also included MIEs for ATLAS and CMS Phase-1 upgrade and DM-g2. SC is awaiting final answers.

The House and Senate have been briefed on the P5 Plan implementation. The current Continuing Resolution (CR) ends on December 11. Plans for implementation depend on the final appropriation and a CR in FY15 that could present complications but allows for fulfilling Scenario A. A full appropriation of around $775M would allow for full implementation.

SC is working with laboratories to respect P5 priorities and avoid damage to programs under all possible funding scenarios. Labs are asked to defer costs in anticipation of shortfalls. University research may also be impacted by current funding profiles.

The Scientific Discovery through Advanced Computing (SciDAC) FOA funding opportunity is open until January 7, 2015. The OHEP research FY15 FOA closed and a comparative review is being conducted with decisions to come in January. The Accelerator Stewardship FOA is closed with final decisions coming after the FY15 funding appropriation is made known. The Early Career Research Program FOA is about to be reviewed and the DOE Office of Science Graduate Student Research (SCGSR) Program is now closed

Siegrist announced DOE staffing news. Abid Patwa will manage the U.S. LHC operations. Staffing changes include a request for anyone who would like to help with P5 implementation.

The HEP S&T Connections Thrust was announced. The intent is to make stronger connections with other SC Programs and the broader national S&T enterprise. It follows up on an analysis done earlier and points out the value of discovery through synergistic collaborations. The thrust consists of near-term plans to explore research capabilities and specific topics. Current activities include connecting with DOE Basic Energy Sciences (BES), looking at Materials by Design and how the HEP community can use this technique for detector work, a study group with ASCR and a roundtable with BES.

Discussion

Gabriella Sciolla noted that the P5 Report has been impactful but that there is little difference in the Energy Frontier budget between FY14 and FY15. **Siegrist** noted that the LHC upgrades are yet to come. The P5 Report directs aggressive pursuit of the upgrades and continued U.S. involvement in LHC. These events are a few years down the road. The P5 Report forces a trade-off between research and projects, and balancing research reductions and rising construction demands.

Thomas Shutt noted a difference in the House and Senate marks in the Intensity Frontier. **Siegrist** explained that the difference is the investment in the LBNE. **Lankford** pointed out that differences in construction line account for the difference. **Glen Crawford** noted that the Senate put costs in the construction line and the House put it in the frontier.

Mirjam Cvetic noted cuts for theory. **Crawford** shared that House FY15 marks reflect a three to five percent cut to research across the board. It is anticipated that the budget will be flat. Differences between university and lab investments will depend on DOE's current review of proposals. Research continues to go down overall as OHEP tries to get funding into projects and is due to trying to get projects started in essentially flat budgets. **Siegrist** added that the House and Senate both do not like reducing funding for research.

Zoltan Ligeti noted that House and Senate cuts for theory in FY15 are more than three to five percent. **Crawford** noted that a better overall budget is one strategy. FY14 was a little anomalous and ended up as a good year compared to prior years. An overall increase would show up in all areas. DOE will not grow the budget based on simply increasing research. It will follow the P5 Plan which will hold steady on research funding by FY16. If the budget is flat, DOE will try to hold research funding as flat as possible.

Ian Shipsey shared that the community wonders if panelists in the 2014 Energy Frontier review were asked to support one issue over another. **Crawford** noted that this was not the case.

Shipsey asked if it would be better to support private investigators (PIs) and allow them to make decisions on how to use the funds they are given, based on the overall decline in university funding. **Siegrist** shared that Congress likes the budget line buckets which makes this difficult. **Crawford** added that DOE tries to let PIs be flexible and move funds from one line item to another. DOE will discuss moving funds to transition things or support new ideas and give advice on how to structure those adjustments. A researcher interested in doing something new should write a proposal that proves that they know the research area and have worked in that area. **Crawford** shared that PIs have the flexibility to decide on the percentages of funding spent on particular areas once they receive the grant.

Robin Erbacher commented that PIs feel pressure as research support for the Energy Frontier has declined in comparison to the Intensity Frontier and may cause some PIs to move into the Intensity Frontier. Getting a new start in a different area is hard and there seems to be no mechanism in the review process to get funding for the switch based just on showing excellence in a particular area. **Crawford** responded that OHEP is open to suggestions on managing this.

Siegrist shared with **Erbacher** noted that Congress does not like to reappropriate funding for projects and are nervous about research funding reductions as it is demoralizing to the community. Congress is aware of the P5 Report and he is hopeful that the out year budgets will look better.

Erbacher asked if the Scenario B budget will prevent a five percent research reduction and avoid continued reductions. **Siegrist** shared that the hope is the out years will be better and OHEP will be able to treat the research lines better if Scenario B can be met. In the exact P5 Plan, not every single aspect can be implemented immediately. Accelerator R&D is under pressure under the current budget scheme and some is redirection of the people in the project. OHEP must maneuver through a complicated matrix. If budgets are better in out year, then it could have big impact on research projects. **Siegrist** added that money for projects is allocated by Congress and the staff is very involved in the decisions.

Georg Hoffstaetter asked about the House mark. **Siegrist** noted that the House staff was unhappy with how the Administration formulated the budget and this is reflected in the decrease in Accelerator Stewardship. The Administration supports stewardship strongly and as the budget was developed in the Administration, stewardship was preserved. There were significant overall cuts in the physics budget. House marks suggest that the Administration should consider

stewardship relative to the overall physics budget. Large budget cuts with increases to stewardship is probably not a good strategy. OHEP will be more careful with this in the future.

Hoffstaetter asked about advanced technology R&D. **Siegrist** noted that part of the P5 Report was to get PIP-II built and do other things at Fermilab. There is a move from research to future project R&D. **Crawford** added that there is a complicated mix that involved technology R&D getting hit hard as projects are ramped up.

Harvey noted a difference of around $20M between the FY14 and FY15 requests. **Siegrist** pointed out that the Small Business Innovation Research funding is $0 and accounts for the difference as it is not shown in the current year. The exact value depends on the mix between ops, research and construction, and the funds are a levy from Congress on the budget. DOE will discuss the funding mix with user groups.

Siegrist agreed with **Sciolla** that the three to five percent cut to university programs will be difficult. **Sciolla** shared that university funding supports the physics analysis that helps get the physics out of experiments, and it supports training for future researchers.

NATIONAL SCIENCE FOUNDATION REPORT

Dr. Denise Caldwell, Division Director from the NFS Division of Physics (PHY), provided an update. PHY is awaiting word on the CR and hopes to have news by December 11. Funds for PHY are not known in the same way as they are in SC as funds go to the NSF Director where decisions are made. Caldwell hopes that information on the FY15 budget is available by at least June and perhaps even April.

In 2014, Phase 1 upgrade investments for ATLAS and CMS were made early. These and LHC investments will continue.

The FY15 funding competitions are underway. The only program with an open deadline is accelerator research and the deadline is April 4. The other programs have closed.

Proposal submissions for PHY are made using a solicitation rather than submission process. Complicated projects involving a large group with some members who may have additional funded activities in addition to that collaboration are asked to present that information to the NSF review panels. The only mechanism for doing this is a solicitation and it requires a deadline forcing people to submit proposals on time. It forces a more equitable review process.

PHY is within the Mathematics and Physical Sciences Division (MPS). MPS has a FACA committee (MPSAC) and a sub-committee led by Young-Kee Kim. It will examine the P5 report to see how it maps to NSF, where PHY will go in the next five years, and how to balance NSF investments in light of the report. NSF has accepted the P5 Report. The MPSAC subcommittee will submit a response to NSF by the end of January 2015. The NSF feels it is necessary to do this since it does not have a line item budget and the response can inform PHY's proposed use of NSF funding within funding constraints.

PHY will hold a Committee of Visitors (COV) on February 4 – 6, 2015, to look at PHY operations. The COV can look at any materials as long as there is no specific conflict of interest.

Discussion

Tao Han asked how the Director allocates funding for the division. **Caldwell** explained that the Director and Assistant Directors for each of the directorates discuss budget development. FY17 budget development is already underway. The Assistant Directors have meet with their respective Division Directors and formed proposals about active areas and areas for investment. Directorates can form their arguments that proposals that go to the Director. One current area of

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investment is a complement to the Materials Genome Project that has come out of the Engineering Directorate. A budget is formulated and sent to the Office of Management and Budget (OMB) for comment. Continued discussion leads to the development of a budget that is then subject of Congressional review.

Han asked at what level the budget is micro-managed. **Caldwell** shared that the impact of micro-managing is about 10 percent. The bulk of NSF funding still goes into core programs. As an example, there is a lot of cyber infrastructure investment that is part of the core.

Lankford asked if the NSF has pressure to support research and support for university grants working for experiments, data analysis, and future experiments in the Experimental Particle Physics Program and Astrophysics Program. **Caldwell** shared that NSF's top priority is funding university research programs and PIs. Funding for PIs will never drop below 50 percent of the total budget. The percentage has stayed at around 55 percent for the past eight years, and this is important to supporting students and post-doctoral candidates. PHY will selectively look at P5 recommendations as some things that arise may relate to having a balance between what NSF should maintain and the cost of supporting facilities versus PIs. NSF has felt it necessary and of benefit to invest in some things that drive fields in different ways. This was the thinking behind the Accelerator Science Program. NSF will continue to support mid-scale projects that most individual projects cannot support on their own.

Lankford cited cuts to DOE research funding, asked how NSF compares, and if groups that receive PHY funding can maintain the same level of funding. **Caldwell** shared that there are impacts on every aspect of PHY. The biggest impact was the FY13 sequester. The cut for programs within PHY was 10 percent. Due to this severity, priority has been given to areas of research in which NSF was interested and in which PHY did not strongly participate. NSF was given instructions that funding for facilities, construction, and existing cooperative agreements should not be changed. NSF has also decided not to revisit recurring grant agreements. The programs in PHY faced a 12.5 percent cut. It is believed that the Division lost about 150 students and post-doctoral candidates due to these cuts. It impacts Particle Physics but that area is not specifically singled-out.

~~**Discussion**~~

Hassan Jawahery asked how the MPSAC subcommittee will share its findings relative to DOE's response to the report. **Caldwell** clarified that this will inform the NSF MPS and the subcommittee will be made aware of how the DOE is responding. This will not drive NSF to work independently of DOE, but will guide NSF's decision to put itself in it best position.

Karsten Heeger asked if the subpanel will review all of the P5 report and recommendations. **Caldwell** shared that the review will not identify specific proposals to fund or those types of details, but will inform NSF on what things to consider when deciding how to go forward.

Robert Tschirhart noted that the subpanel will look at candidates for MRE upgrades, so there is some judgment as to who should receive funding. He asked if other candidates could be identified for upgrades. **Caldwell** shared that the subpanel will identify criteria for making these decisions. The charge specifically calls out LHC Phase 2 Upgrades as it is a short-term priority. The subpanel may provide direction on where else to invest.

Ben-Zvi noted that this will enable advances in accelerator science at universities.

PRESENTATION FROM THE HEPAP ACCELERATOR R&D SUBPANEL

Don Hartill shared an update on the R&D subpanel looking at accelerator R&D for a world-leading future program in accelerator-based particle physics. The subpanel will have a final report by the end of December 2014. Similar subpanels convened in 1980, 1996 and 2006.

The current subpanel is looking at short-term and long-term goals for a world-leading program. It is assessing how R&D efforts are training future accelerator scientists and technologists, and will suggest ways to maintain a balanced national program aligned with recommendations in the Scenario C of the P5 Report.

The P5 Report proposed science drivers for accelerator R&D and startup dates for existing projects starting with an upgrade to LHC around 2020 and stretching to the ILC startup around 2030. Future projects were also proposed that assume a 10 year window for increased understanding and discovery. This sets a timeframe of 10 years or less for new projects and a timeline of up to 10 years for new construction.

The subpanel has met around the U.S. in an effort to conduct its assessment and set up an online repository and website for input. The energy and intensity frontiers and novel particle acceleration have been the focus of respective meetings held by the subpanel.

The subpanel examined general accelerator thrust R&D areas in coordination with the General Accelerator Research and Development Program (GARD). The FY15 Presidential Request for GARD is $71.5M. In addition to GARD, NSF has started its own accelerator science program and has made 14 awards for a broad range of topics. Around $1.2M of its $9.8M budget is allotted for research and development.

GARD opportunities include combining beam stability at synchrotron injection energies with higher power targets. Optimization studies could lower construction costs and maximize operation efficiency.

The LHC Hi Lumi Upgrade Program in the U.S. encompasses the LARP program to construct high field quadrupoles and dipoles based on $NbSn_3$. The program includes crab SRF cavities. The upgrade will begin in 2023 and run for 2.5 years. It will then run until 2035 integrating ~3000 fb^{-1}.

Future collider options include an ILC in Japan, a 50 to 80 km ring in China, and a $150M Euro investment spread over 10 years in laser plasma acceleration. Discussions at the Future Circular Collider collaboration meeting at CERN in September also pointed out other collider work being proposed and undertaken globally. R&D is now part of CERN's medium term plan. Future collider possibilities include ILC construction in Japan. The P5 concluded that moderate muon colliders should not endorsed.

The subpanel considered a variety of challenges to the field in compiling its report. Funding for GARD is limited, construction timelines are long, and construction plans are in varying states of maturity.

Hartill reminded the HEPAP that the panel is not asked to do a review of projects but to recommend a balanced accelerator R&D program to OHEP. This task has been informed by the consideration of several initiatives that total around $25M to $30M per year.

The superconducting magnet program will need increased investment to make a contribution to future high energy particle physics colliders. The cost of Nb for the cavities in LCLS II cryomodules is only 10% of the cost so improved manufacturing techniques have the largest potential for significantly reducing the cost of the completed cryomodules for a high energy SRF based collider.

The subpanel has divided the GARD thrust areas into five R&D areas: accelerator physics and instrumentation, advanced acceleration, particle sources and targets, superconducting magnets and materials, and superconducting RF. At least two subpanel members are assigned to each area and are developing guidance and recommendations.

The subpanel was unable to deliver its report at this HEPAP meeting but has started on a process to prioritize the accelerator R&D programs to guide OHEP. It is evaluating the types of accelerators needed and how they can impact the five R&D areas, along with next steps needed and long-term impacts.

The subpanel is currently proposing five types of accelerator facilities. The subpanel is also the proposing the lowering of accelerating gradient for the plasma wakefield approach to ~1 GeV/m. It has requested information from groups that have these details and will need to go back to ask about the likely evolution of beam quality with further R&D.

Inputs from the advanced acceleration community are being reviewed and the subpanel will meet in January and finish the draft report in March 2015 for presentation to HEPAP at its meeting in April 2015. The report will include descriptions of the need to train the next generation of accelerator scientists and technologists.

After the report is submitted, the subpanel will need to continue its work. Hartill pointed out that efforts might also need protection to allow for the creation of needed infrastructure.

Discussion

Jawahery asked if the subpanel will contribute to the DOE BES' advancement of accelerator facility operations as they operate most of the facilities. **Hartill** shared that a prior panel recommended this but it did not happen. One of the prior panel's recommendations made to NSF did occur. There is R&D associated with other sections of SC that mostly are focused on their own problems and not on general accelerator things.

Erbacher noted U.S. involvement in accelerator R&D through LARP and asked if the panel would recommend participation in international efforts. **Hartill** shared that the subpanel is neutral on efforts in Europe. The next discussion of collaboration will be in Washington DC in March 2015. Relative to the laser program in Europe, the division of funding per country is much larger than what the U.S. is spending on accelerator R&D and accomplishments will surpass that of the U.S. The subpanel will include recommendations for things such as superconducting magnets being aligned with 100 TeV machines.

Han asked if the final report will address the technological feasibility of future facilities. **Hartill** shared that it will comment on the needed R&D to have a realistic chance to develop needed machines. The field and manufacturing capabilities are all questions and necessities.

Hartill responded to **Hitoshi Murayama's** interest in machines sharing that one option is to do more of the same. Another is to apply advanced acceleration techniques. Another is to use high-powered conducting cavities as an after-burner. For TeV, a paradigm shift of some sort is needed and it may be the advanced accelerator business or muon colliders.

PRESENTATION ON MATERIALS BY DESIGN AND CONDENSED MATTER CONNECTIONS TO HIGH ENERGY PHYSICS

Mike Norman of Argonne National Laboratory (ANL) shared background on the ANL Material Sciences Division and its work on low temperature detectors. These apply to HEP as they support beamline work, dark matter searches, and other things. Most detectors use transition edge sensors and use joule heating to tune to a transition region and stay there. As a pulse comes

in, the temperature increases and joule heating will cause the temperature to go back down. The material gives an accurate temperature reading. Microwave Kinetic Inductance Detectors (MKIDs) give a precise measure of the incident temperature that comes into the sample.

Thermal detectors allow for working all the way up to x-rays. A lot of materials engineering is involved. Depending on the detector, a low temperature or high temperature may be used. This range of temperatures, and a huge array of absorbers and thermal conductors are used. Progress in cosmic micro-wave background has evolved from 16 detectors in 2001 to the SPT-3G telescope funded by DOE with 15,324 detectors and scheduled to start in 2016.

The CUORE project is designed to detect neutrino-less double beta decay and aids understanding neutrino masses. Similar to CMB, it uses MKIDs and transition edge sensors and 750 gram crystals of natural TeO2 thermistors. Using TeO2 allows for a higher abundance rate. It costs about $17 per gram. There are other materials that can be used and research is looking at what to do beyond CUORE.

The CUORE-IHE project is one example of the use of things other than TeO2. Working in this area poses a question of what sensors to use, how to manage background effects, and deal with sensitivities. There is a lot material science involved in this work.

NSCL-II, Argonne and Brookhaven are using TES for x-ray scattering and looking at low-energy charge excitations. The TES allows for energy discrimination and shows differences between elastic and inelastic findings. This work will revolutionize detector technology.

There are efforts to go beyond current technology. Examples include work in transitioning to superinsulating states. This manages a huge rise in voltage levels. Research is being done in the transition to superconducting state (TiN).

Superconducting radio-frequency (SRF) cavities help manage operational and capital costs. Using niobium allows for high thermodynamic vertical fields. There are high temperature superconductors but that happens due to vortex penetration. That is bad for cavities. One issue is getting niobium up to its high theoretical levels. Surface resistance destroys the Q factor of the cavity. There is a possibility to lay down more pristine niobium and with control of the surface, high quality Qs can be reached. The main problem is that there are still hot spots on the surface.

Researchers are taking niobium and layering in insulators and superconducting layers. Once inside the niobium, the cavity in which it is used will be smaller and machines will be more affordable. Vortex penetration could be avoided and in principle, this device will work. One researcher is trying to make these types of cavities.

ANL's cavity program involves up to five divisions working in a multitude of areas. There is a lot of work taking place between materials science and HEP, and that could lead to the next machine.

Superconductors are mostly used for MRI magnets but can be used in motors and generators for off-shore wind, maglev movement, energy storage, fusion energy, and superconducting cavities. All of these applications have a sweet spot for application. Theoretically, current superconductors have the qualities that are desired but there is some level of superconduction going in one direction. At Argonne, researchers are working with proton irradiation to create pinning vortices. No company is going to run cable through these devices, so researchers have looked at low-energy oxygen irradiation to double critical current in the superconductor. There are easy ways to find vortex pinning and achieve critical currents to be used and make high-energy superconducting magnets for the next machines that people are thinking about.

Undulators are being developed that use zirconium under YBCO. Undulators are being developed that will reach the design needs for the next machines. After many years at Argonne,

Fermilab and other places, there is the feeling that 30 Tesla magnets will be viable. The advantage is working at areas like 30 kelvin to avoid using current cooling materials.

Another area of work is gamma-rays and the detection of people sneaking nuclear material into the U.S. Progress is being made as shown through the growth of crystals that are very dense indicating that these can be used for gamma-ray detection at room temperature.

Materials genome work uses computation and materials synthesis to design new materials. Materials design for semiconductors is not difficult but more difficult for this area of work. Some materials have been found with low enough energies to form. Iron-boron compounds have been found that have low kelvin and for materials genome, this is the only point where a superconductor has been predicted and produced. Trying to predict superconductors and produce them will become more viable. The procedure for this is hard as there is no microscopic theory even after 30 years of study.

Search criteria for new superconductors includes super metals, space layers, and then tuning for the right combinations. The periodic table is big and most compounds are quaternary, and hopefully a design base for superconductors will be achieved.

Typically superconductors are layered, and just because they have a high level of Tc does not mean that they have great functionality. Increased Tc leads to a reduced phase stiffness.

An additional area of work at Argonne is in monopoles, anapoles and skyrmions.

Moving down in temperature and as Higgs mode turns on, these get excited. When hit with a terahertz frequency, one can watch the system ring. The results show Higgs modes and frequency. Vortices typically mess things up but are charged with Zissy weight. Looking at the electromagnetic field will show plus and minus domains as a function of time. They annihilate and Higgs modes go through the system.

Typically in condescend matter, one is only interested in dipole moments. However, the anapole moment will give a divergence of eight, but in a solid you can reach a non-zero divergence term. Anapoles have movements that circulate around the sphere and reach plus or minus regions. All of these have been reached through scattering and x-ray.

Torodial moments have been seen in lithium-ion batteries by optical second harmonic generation. A signal is seen at twice the frequency and show multiple types of dipole moments. All have been seen in the condensed moment context.

Magnetic monopoles are seen in magnets. The use of magnetic electrolight theory fits this well. Artificial lattices use magnetic particles over an array and show the direction of magnetization of the plane. These can be manipulated and show a meeting at the vortex.

Emergent E_8 Symmetry in an Ising Spin chain can be seen. The ratio of energies in this work is the golden ratio. Tuning can achieve ion-range order and excitation energy scale applies a golden ratio.

Skyrmions have non-zero topological properties. They are topological protected and used in low-energy electronics. The circulating magnetic field is visible.

There has been a prediction of Majorana modes. A juncture between superconductors can be formed. The existence of zero mode can be achieved and putting a chain of iron atoms can show that the Majorana modes mobilize on the end of the iron wires. These can be used for topological computing and inhibit decoherence.

Holographic approaches are being used at Argonne. AdS/CFT involves taking a small coupling field theory and placing it on the AdS4 space-time. Mapping the problem that cannot be solved to one that can be solved allows for working the condensed matter context. An extra coordinate allows for working from ultraviolet to the infrared on the interior. This experiment

gives a natural context for thinking about coupling QFT. Work using a "black brane" in the experimental setup can condense leading to a change to AdS4. Putting spinners in this set up gives quasiparticles. Coupling this to Majorana lead to a Bogoliubov gap. This is similar to what is seen in high temperature superconductors.

The goal of this is to help condensed matter gauge theories. Overcoming constraints associated with fields can help overcome things that have been around for 30 years without resolution (slide).

There is research applying tensor networks to lattice gauge theories. This enables designing the order of Hilbert space in which one is interested. Working in a low energy sector has a low area of entanglement. This space allows for more free energies and division of the system into two subsystems. People use this through the massive swinger model. It is an alternate to lattice gauge theories and avoids the lattice gauge problems associated with lattice gauge work.

Discussion

Tschirhart highlighted the use of high temperature superconductors applied to magnets for next generation colliers. He asked if the move from niobium 10 can move along faster. **Norman** shared that technology is driving this. Research is limited by the use of things like wires to carry current. Using liquid nitrogen as an example would allow for putting the cables anywhere. Lower costs will drive this, and the power industry must be interested, too. The problem is the layered nature of material. The ideal that low energy oxygen irradiation can help means that this can be pushed farther than niobium.

Tschirhart shared that HEP is interested in high critical fields. **Norman** talked about high industrial fields that had high Teslas. He commented that using NiCO at low kelvin can help to achieve a sweet spot for many applications. This work has been around since 2008 but the drive is that new materials will be easier to use.

Bruce Strauss noted that materials science can be helpful. He asked why one cannot buy a long conductor and buy it by the ton, and expressed that it was intellectual insulting to say that HTS conductors can be used in accelerators. **Norman** agreed that this is correct for the near-term yet recent breakthroughs such as building new wires provide new options.

Strauss asked when the materials science community will drive the development of long transmission lines. **Norman** believes that this is a question of investment, and American Superconducting is the only company doing this work. Many discoveries are made in China and Japan due to levels of investment.

Tschirhart highlighted the Materials Genome Project, and asked why a researcher like Dr. Strauss cannot request a high critical field conductor that can be made into a cable. **Norman** shared that one can do reengineering of defects and propose this. Congress has not provided new funding for the Materials Genome Initiative. The 46 original EFRC projects are now 32. There is not enough money on the experimental side. The U.S. has to look at making the investment that China and Japan have made.

Cvetic was pleased to see high energy theoretical ideas being quickly applied in other fields. **Norman** noted that skyrmions are a good example where spintronics can become a reality. Lower power spintronics are a way to avoid breaking down Moore's Law.

Harvey Newman addressed concerns about the time span between research and application. There are findings that require work in surface physics, nanotechnology and other areas. There is a need to build in enough speed and trackers. These are handled by areas of materials science not mentioned. **Norman** agreed and cited research on photonic meta-materials with LD RD funding.

Jawahery noted that at one time people considered ITC for cavities and asked if that is because people do not think other materials can match. **Norman** shared that researchers are thinking about other things as they have better properties and ITC allows vortex penetration.

PRESENTATION ON OHEP INTERNATIONAL INTERACTIONS

James Siegrist shared work being done by OHEP on international agreements.

In 2012, the DOE began to operate differently relative to lab-to-lab interactions to include memoranda of understanding and cooperative research and development agreements. Secretary Moniz has given additional direction that includes the idea the MOUs cannot be used for R&D collaborations and scientific exchanges. Activities must be cleared through the DOE site office and HQ before being signed. The result is better coordination between labs, DOE, the State Department, and greater U.S. government visibility for HEP international activities. The State Department makes other agencies including the OMB aware of pending arrangements.

There are three levels of international agreements that differ based on the levels of specificity. Nation-to-Nation S&T Agreements are the highest level of agreements that cover the exchange of personnel, intellectual property and other aspect of cooperation. There are implementation agreements that allow for a focus on particular S&T areas of cooperation. Project annexes and protocols are used for particular projects or classes of activities such as high intensity proton accelerators.

The agreement process starts with SC international advisors and DOE General Counsel. It moves to State Department and inter-agency review. The process can take several months.

The existing U.S.-CERN Agreement will expire in 2017. It was originally signed by DOE, NSF and CERN. The main roles was participation in LHC and construction of the accelerator. A new agreement is being negotiated. The P5 Report is a major influencer as it reaffirms the importance of U.S. involvement in LHC. Siegrist believes that the discussion of the new agreement is going well and that the P5 Report provides justification.

When the CERN agreement was signed in 1997 it was believed that enough science would emerge in 20 years. However, the P5 Report shows that there is future work that will be impactful and should continue to be conducted at CERN.

The LHC Accelerator Research Program (LARP) looks to leverage expertise from CERN and U.S. leadership. It is targeted to reduce risk for HL-LHC work. The State Department has provided C-175 approval for CERN negotiation. A bilateral cooperation agreement is being discussed.

The Long-baseline Neutrino Program (LBNE) has been discussed with international partners starting with a meeting in Paris in June 2014. Through subsequent meetings, Fermilab has developed the first draft of a governance document for working with the iIEB and it is ready for review. Potential PIs are invited to discuss the science goals and rationale for this. The LOI will be ready for the Fermilab Advisory Program Committee after meetings at Fermilab in December.

Progress continues in the DOE partnership with the Indian Department of Atomic Energy for cooperation in accelerators and particle detector R&D. A first annex 1 agreement has gone to Secretary Moniz for signature. Progress has been made towards finalizing the Annex II agreement on cooperation in scientific activities.

DOE is engaging in negotiations with the Italian Ministry of Education, Universities and Research to implement arrangements for cooperation in HEP, astroparticle and NP research, and related fields and technologies.

There is currently no agreement between the U.S. and U.K to serve as a vehicle for collaboration on LBNF and other areas. U.S. involvement on MICE has not required an S&T level agreement, and a RAL user agreement may be sufficient. There are no U.S.–U.K. level meetings but discussions with U.K. representatives take place at times at international meetings.

DOE and the Japan National Government signed an agreement in April 2013. The S&T efforts agreement was renewed in April 2014. DOE has been represented by lab representatives and the HEPAP Chair for meetings with Japanese representatives for more than 36 years. This has paved a way for ILC.

DOE has agreements with the Chinese Academy of Sciences and Ministry of Science and Technology of the People's Republic of China. There have been meetings with the Chinese government for 35 years. Joint projects that are large enough can justify HEP project annexes. Daya Bay was done through lab-to-lab arrangement rather than a formal arrangement.

Work with Canada on SNOLab for Super CDMS-SNOLAB will likely be a user agreement.

Brazil is looking to sign a user agreement with the neutrino program.

A group of the world's funding agencies called the Funding Agencies for Large colliders (FALC) is interested in global accelerator based programs and meets regularly as a funding agency complement to ICFA in considering the global accelerator based program.

Discussion

Tschirhart asked about other collaborations with CERN such as work on FCC. **Siegrist** noted that there are many activities at CERN. DOE is learning if the umbrella agreement would cover all of the general work being done or if there is a need for other annexes. That is being determined.

Shutt wondered how small an experiment this applies to. **Siegrist** commented that there is no definition as is~~t~~ done with MIE rules. DOE relies on agency judgment as to what is needed. If OMB and OSTP have a problem with something then DOE will pursue the agreements. As an example, U.S. investment in Daya Bay was $30M and if started today, there would be an interest in an agreement for this.

Murayama asked about the rationale for this approach and what the State Department notices. **Siegrist** shared that State is the broker for this. At times, other agencies are interested in what DOE does with international collaborators. The process allows for other agencies to know what DOE is doing abroad. **Murayama** what might prompt State to say no. **Siegrist** believes that it would likely be due to OMB or OSTP having a problem or slowing down the process. For example, the Russian invasion of Crimea slowed down scientific discussions.

Patricia McBride noted that the U.S. is currently an observer on the CERN Council and asked what had changed. **Siegrist** shared that the U.S. role is to make in-kind contributions rather than paying to be a member. The draft of the agreement is kind of silent on this. The earliest we could see a signed CERN agreement is after March 2015 Council meeting.

Coles – asked if the term international binding agreements is new and if these are legally binding. **Mike Solomon** explained that legally binding agreements do not say that they are legally binding. They can be gotten out of at any time. Agencies must observe words like "will" and "shall", and "intend" and "planned" become very important.

Lankford asked if there are NSF procedures similar to those used by DOE for the LHC.~~.~~ **Siegrist** noted that NSF has been an LHC partner at every step, and documentation goes through DOE and NSF legal counsel. **Caldwell** added that the agreement has been discussed by DOE and NSF, and the agreement has gone through the NSF legal process beginning with the C-175.

Siegrist clarified for **Jawahery** that the State Department is involved in part to ease the exchange of the technology. Exportation questions go to the Department of Commerce and they look at places like India that are not signatories to the Non-Proliferation Treaty. State contacts every agency as part of the process. Since DOE agreements have to do with research, there has been little noise from Commerce. **Jawahery** noted the shipment of instruments as an example. **Siegrist** shared that without the agreement with India, it is very difficult to ship materials. An agreement helps avoid tariffs, Bunker Adjustment Factors, and other things. **Solomon** added that an international agreement calls out the avoidance of tariffs. For example, if India imposes a tax on materials coming in, then the agreement is used to avoid the tax. This applies to universities and labs, but is different for universities. ~~Solomon can be a resource for universities.~~

PRESENTATION ON HEPAP ACTIVITIES

Andrew Lankford raised the discussion of a subcommittee on laboratory and university roles. Specifically, roles are tied to the P5 Report and recommendations therein. HEPAP has previously discussed forming a subcommittee to enable execution of the HEP program. A COV also recommended examining a balance between lab and university research programs.

Starting points are investigating the agencies' missions and goals, lab and university contributions to the missions, the mission of the labs and universities relative to the agencies, and what agencies can do to help labs and universities accomplish their missions. Agency missions and roles differ compared with one another and may differ from lab and university missions.

To date, discussions of a subcommittee have made only modest progress. Lankford contends that a subcommittee could make progress in addressing difficult topics.

Glen Crawford elaborated on DOE and HEP roles and responsibilities, to include the missions of both organizations. DOE addresses fundamental ideas at the heart of physics and all of the physical sciences. U.S. particle physics occurs via 150 universities and at 43 laboratories.

The DOE supported 4,300 FTEs working in HEP in 2013, and five national laboratories with 2,600 FTEs. The laboratory program workforce supported by DOE consists predominantly of PhD researchers and is 41 percent of the total PhD population. University support from DOE supports more than 100 institutions with 1,700 FTEs and more than 250 grants. Around one-third of HEP researchers funded by DOE are faculty and about one-third are graduate students.

Outcomes sought by the DOE OHEP are varied but rely on HEP stakeholders fulfilling diverse roles. DOE's roles are inherently governmental and result in determining Federal program priorities for budget requests; determining budget policy, guidance and strategy; and, approving, awarding and administering government prime contracts. Relative to laboratories, DOE labs are prime contractors and the laboratory employees are contractor employees.

DOE labs are judged based on specific annual metrics that include performance. Labs are also responsible for delivering on facilities, upgrades, planning for facilities, and how best to support users. Labs participate in research itself and are expected to nurture and support HEP research collaborations to enable discovery. Participation in all phases of R&D are expected.

Universities are expected to contribute HEP R&D to enable discovery science. Participation in all phases of R&D is expected, along with training students and post-doctoral researchers, and specific areas of research to be conducted.

The DOE budget formulation process is inherently governmental but is informed by HEPAP and P5 Report. OHEP and DOE's guidelines include following HEPAP and P5 recommendations, following planned profiles for projects, using operations plans for facility

operations, overseeing core research at the right level-of-effort, and using remaining funds for new activities.

Construction and facility support is central to DOE's science mission. The critical decision (CD) process and Lehman reviews are the gold standard in DOE. SC manages projects flexibly to deal with large-scale and unique projects. This requires paying attention to project execution, the use of Federal oversight, and coordination with contractor project managers. The size of projects supported by DOE raises the visibility of DOE's work. These factors drive a complex balance of project and budget requirements and timelines. This execution model is suitable for laboratories. It has a vital role in project management and construction. This does not exclude universities. The funding execution process does not always fit easily with university timelines.

The DOE budget execution process is also inherently governmental. Once a plan is laid out, execution is driven by proposals from labs, universities and the CD process. Financial plans are reviewed and budgets are appropriated. Within a framework for funding allocations, universities and laboratories are funded differently due to the differences between contracts and grants, along with differences between lab and university roles and responsibilities.

Discussion

Bassler asked about the role of university groups. The role includes detector construction. **Crawford** noted that particular emphasis is placed on this among other areas of emphasis.

Cvetic highlighted the difference between labs and university research, and the differences between fields. She noted that theory research is sometimes less complex than other fields, and asked if the issues of differences should be raised in theory due to its lesser complexity compared with other fields. **Crawford** noted earlier comments on the differences between the lab and university roles and differences between the people conducting the research. **Cvetic** noted that one should be able to compare the institutions regardless of the field.

Murayama reflected on the DOE mission and why it supports HEP at all. **Crawford** noted that DOE participates in scientific research broadly and in areas that provide economic value. Secretary Moniz may note the value of investing in fundamental scientific areas, yet some initiatives have been pushed forward that are not aligned with fundamental or basic science. The DOE strategic plan does elaborate on basic science.

Jawahery noted that the DOE mission is striking as it seems to under-emphasize training and developing the scientific workforce. He wondered if noting the value of DOE and OHEP program investments should be made clear to generate more interest from Congress and greater funding support. **Crawford** responded that the NSF and the Department of Education are strongly considered the lead agencies for education. DOE's mission does describe training the people needed and advanced training efforts are being improved. OHEP is trying to always improve this part of its program and welcomes input on ways to do so.

Lankford clarified for **Erbacher** that the HEPAP should discuss how to pursue forming a subcommittee. **Erbacher** shared that the need for this discussion grew from cuts to funding and dismissing university technical staff who maintained equipment, as well as reductions in student funding. There is still a role for universities to do this work and contribute to particle physics. **Lankford** noted that these issues motivated discussion of this task and need to be discussed.

Tschirhart asked about the extent to which other SC offices hold the same strategies as the OHEP and what makes the program unique. **Crawford** does not know the extent to which OHEP is unique in the SC. The merit program in OHEP is one distinct aspect. How offices in SC manage laboratories may differ. The merit program was also designed with OHEP's mode of

doing business and with respect to conducting international business. The way that the OHEP works was designed to fit how well it can perform within its own context.

Tschirhart thought that it might useful to know how other SC programs review proposals. **Crawford** suggested that the OHEP can get back to the HEPAP on that and invited other SC office representatives to offer input.

Mary Bishai asked about the specific things that the subcommittee would address and what OHEP is looking for, especially with regard to specific differences between labs and universities. **Crawford** noted that a prior COV suggested further study on this and discussions have been taking place for a while. If a group comes together, it could be useful to have a set of advice for OHEP on how to achieve balance and improve the overall program. The program is complex with diverse issues but could benefit from this effort. **Lankford** responded that issues raised were also likely at the root of the COV recommendation for a subcommittee. It is not always obvious if there is structural support to achieve the best possible science. There have also been past efforts to offer advice to improve the university community but that failed to address achieving a balance. **Bishai** shared that part of the problem is that efforts are project specific. It is hard to imagine an approach to effectively address general issues rather than specific projects. **Lankford** agreed that there may not be a specific solution but advice could be generated without regard for the dynamics of a field, frontier, or specific project. As an example, the impact of cutting of budgets on labs and universities. **Bishai** suggested that there are different takes on the problem but more so, people do not know the specific question.

Newman commented that the complexity may be due to the fact that the role of physics is put in an anomalous position in the DOE and regarded in the budget with defense and other areas yet is reflected differently in the mission statement.

Alan Stone noted that use of the words problem or fix suggest that there is a particular character by which one would charge the subcommittee and perhaps could be worded in a more neutral way to achieve an approach that is more optimal.

Paul Steinhardt emphasized that the differences between labs and universities is complex. Theory is different as lab and university theorists are very similar. This is also a time at which theory funding is being reduced and people are leaving the field. A separate consideration may be made for theory versus experimental as the story for theory may be easier to resolve and put into action. **Crawford** agreed that there are similarities and similarities for experimentalists, too. DOE sees the role of universities and labs differently and hence there are differences in how they are treated. **Steinhardt** suggested that the differences should be heard. HEPAP should look at whether or not the differences really exist, if there can be some improvement to the balance between labs and universities, and at ways to improve things for theory overall.

Zoltan Ligeti noted that on the operations side there are big differences between university and and labs conducting work in theory, but that differences in theory research is not that strong. **Cvetic** added that the charge could reflect the necessity to explore this.

James Shank suggested that the COV is the right forum for this and relies on the COV to suggest things and the subcommittee may not be the best resource. **Crawford** agreed but also noted that the last COV raised this point and that it should be raised with the HEPAP.

Paul Grannis noted that the last COV raised concerns and noted that the complexity meant that it should go to the HEPAP. The discussion also raised more concerns on the theory side rather than the experimental side.

Lankford pointed out distinctions between the two agencies, and that the NSF mission is fairly simple. He noted that the particle physics community in the U.S. is fortunate to derive

support from two agencies. Even looking at the funding from one agency such as DOE should also appreciate the big picture and that funding is originating from other sources.

OTHER HEPAP BUSINESS

Lankford offered HEPAP members opportunity to raise other questions or comments.

Erbacher raised prior discussion about the repercussions due to differences in university versus laboratory management. PIs were told that it is not sustainable to send students overseas to places like CERN to do research and funds would be threatened. Some of conversations that occurred at that time were due in part to doing less hardware and detection work at universities that is important to sustaining training of young researchers. For the energy frontier, many students have to go to CERN or Fermilab for this experience. The subcommittee may consider how labs are supported in creating learning experiences for students, and how a balance can be achieved. If universities should have a role in contributing to detector development, then the role should be defined. An option is for students to visit labs. There are many possible trade-offs.

Lankford offered public comment.

Newman commented on synergies between new technologies and techniques. Universities seem like the place for this, especially to make connections where theory and experiment have mutual interests. **Shutt** asked if this is a question of looking at lab and university funding, or identifying efficiencies by understanding processes at both places. The charge can be broader than just funding. **Lankford** noted that consideration may be given to effective resource use based on the unique strengths of universities and labs, but agreed that it is about more than funding.

Murayama suggested that there needs to be sufficient academic freedom and that the slides presented by Lankford do not reflect it well. **Lankford** shared that people from labs and universities share that they are not able to explore their academic curiosity. This is an issue that should be addressed, albeit with better language that is shown in the slides.

HEPAP Chair Lankford adjourned the meeting for day one at 5:43 p.m. EST.

DECEMBER 9, 2014

The High Energy Physics Advisory Panel (HEPAP) was convened at 8:42 a.m. EST on Tuesday, December 9, 2014, by Panel Chair Andrew Lankford.

PRESENTATION ON THE PARTICLE DATA GROUP

Michael Barnett shared an update on the Particle Data Group (PDG), and described the wide range and number of collaborators involved in the PDG. Strong central coordination at Lawrence Berkeley National Laboratory (LBNL) provides quality control.

PDG underwent a successful computing upgrade in 2011 that has enabled the complex operation to run smoothly. There are many in the PDG who help manage the work of 207 authors and keep track of publications in the field, among other things.

The DOE S&T review of LBNL in 2013 lauded the PDG and its accomplishments.

One product that comes out of PDG is a 1,700 page review of particle physics available in print and online, and as a PDF summary. Online publication allows for tracking readers' interests. The number who look at data listings is similar to the number of reviewers.

Coverage of astrophysics and cosmology has expanded in recent years and downloads of that content topped 50,000 in 2014, equal to 10 percent of all downloads.

Higgs coverage is a highlight of the publication and the most downloaded topic from among the diverse range of topics covered. The topics covered are the same as those reflected in the DOE HEP homepage. The number of citations and hits on the PDG website has grown.

PDG also organizes workshops and emphasizes research efforts. LBNL PDG members ensure ongoing quality as they are qualified physics scientists. The standards upheld by PDG were recognized by the DOE S&T review in 2013.

PDG is addressing the shift to greater use of information on smart phones and laptops. Studies have been done by PDG to recognize user needs and interests, and PDG reflects on reader responses to surveys. Only 18 percent desire the full-size 1,700 page book and 82 percent want the smaller booklet in some form. Two-thirds of readers want a smart phone app.

Issues with the book include economically producing the full-size book. The PDG will keep the full-size book but at a reduced size and without data listings, and at a cost to LBNL of $80,000. The cost of the smaller booklet is borne by CERN. Research on the production of the booklet showed that it can be kept as is.

Demand for electronic publishing is growing, and LBNL is addressing long-term possibilities such as placing emphasis on searching and indexing over navigation. Options presented are intended to balance service and quality with an increasing amount of publications and searching. PDG is also managing changing funding streams to include reductions in NSF funding and reduced DOE funding due to the CR. Support also comes from Japan and CERN. Some of the options that readers desire and that would make the publication content even more accessible are not currently figured into the PDG budget.

Discussion

Sciolla thanked Barnett for PDG's work and asked about requesting a small fee for printing the large book. **Barnett** shared that the administrative costs would be high and the mechanism for collecting money at LBNL is not doable. Providing the book for free is a good model. Staff salaries and shipping costs far exceed the printing cost.

Tschirhart noted that the number of downloads for dark matter and dark energy seem much lower than other topics, at about 6,000 per year for each. **Barnett** pointed out that these topics are still in the top 10 percent of downloaded topics.

Tschirhart asked if PDG has considered a Wikipedia type of model for researcher interests and inputs. **Barnett** shared that a reader survey pointed to the value of contributed content as a long-term possibility.

Bassler asked about contact with other communities that are addressing topics outside of particle physics. **Barnett** shared that PDG is most aware of nuclear physics but does not know of similar efforts in other fields such as medicine.

Erbacher expressed concern about the use of a Wikipedia type model. PDG articles are peer-reviewed and recognize contributions from experts in the field. She asked about outreach and PDG's publication of the Particle Adventure. **Barnett** shared that it is still maintained and is now an app available on Android.

Barnett confirmed for **Erbacher** that PDG is seeking a part-time FTE to develop long-term capabilities and support maintenance requirements.

Ligeti asked about placing the book on Amazon.com. **Barnett** wants to continue keeping the book available as a free publication.

Murayama proposed that an app rather than a book could be done by working with a programmer. **Barnett** shared that past efforts to work this way with CERN have been difficult.

PRESENTATION ON THE APS DIVISION OF PARTICLE AND FIELDS REPORTS

Ian Shipsey described the American Physical Society (APS) Division of Particle and Fields (DPF). It manages a diverse and extensive range of outstanding scientific questions that have been in existence for a long time. The P5 Report has provided a basis for advancing the DPF and responding to scientific questions.

The APS is the second largest physics society in the world with more than 50,000 members. ~~ASP~~ APS has 14 divisions of which DPF is one. It has 11 topical groups. It is active in governmental and public outreach. DPF has 3,500 members and works to understand the structure, interactions and interrelationships of particles and fields, the design and development of high energy accelerators, and instrumentation technique design and development for high energy physics.

The DPF interacts with many other committees and award-granting entities. Other organizations can inform DPF direction and ability to address scientific questions.

DPF has developed a new logo and communication strategy, reflected in the DPF newsletter. It is a living newsletter that is consistently updated.

Involvement in Snowmass was a major activity for DPF in 2013 and results were used to develop the DPF vision. The Snowmass proceedings have conveyed the diversity of topics relative to particles and fields, and set up the P5 planning process. DPF held a session for those who could not attend Snowmass to confer and discuss DPF direction.

Following Snowmass, APS and DPF arranged a Congressional visit in 2013 at a time that coincided with the Noble Prize ceremony and award for the Higgs discovery. Posters and materials were used to draw in attendees, and several Congressional leaders spoke at the event. The event was well-received and accolades were shared from Congressional offices.

The P5 process drew in additional community and DPF input. DPF and P5 organized town halls and similar events to gather input. The P5 Report was accepted in May 2014 and more than 2,300 community members signed a letter of support for the DOE and DPF.

The P5 rollout campaign is continuing. DPF is planning a return to Capitol Hill on April 14, 2015. The visit is entitled, "U.S. Particle Physics in a Global Age of Science and Discovery."

DPS has been working with APS and CERN to drive open access to CERN-authored articles.

On December 9, 2014, DPF~~S~~ is sending a letter to OMB recognizing the challenge of restrictions placed on travel to conferences by OMB. It urges that OMB's restrictions on travel damages U.S. scientific productivity, among other things.

DPF~~S~~ is involved in the APS Physics Annual Meeting, to be held on April 11 – 14, 2015, in Baltimore.

The University of Michigan will host the DPF Annual Meeting in August 2015.

DPS is launching a mentoring award effort. Nominations for the award are due on January 15, 2015, and the award will be given at the DPS Annual Meeting.

Instrumentation R&D is one thing that can advance particle physics. The Coordinating Panel for Advanced Detectors (CPAD) was created by DPF~~S~~ to address a shortage of instrumentation R&D in the U.S. There are 10 working groups in CPAD. CPAD met at Snowmass 2013 and is continuing to request community input to give direction on instrumentation development. In December 2014, CPAD and DPF will announce an award for exceptional contributions to instrumentation.

Shipsey announced individuals who have received awards for contributions to the particle physics field and have become APS Fellows in the DPF. Outgoing members of the DPF were also acknowledged to include DPF Chair Jon Rosner.

Particle physics is local and global, and works across the five fields of physics. Critical is enacting the P5 plan and driving toward the achievement of the P5 Scenario C. This is an exciting time for particle physics with an existing story to tell.

Discussion

Siegrist commented that DPF's role in the P5 rollout was critical and the report has been well-received by Congress. The community should recognize that DPF can play a role again, and is an entity trusted by lawmakers and decision makers. He recommended that the community should get its best leaders involved in DPF, and it has been underutilized in the past.

Bassler thanked **Shipsey** for the DPF's work.

Lankford noted that value of DPF updates to the HEPAP on an annual basis.

PRESENTATION OF THE LINEAR HADRON COLLIDER ENERGY FRONTIER REPORT

Aaron Dominguez told the HEPAP that the LHC has been a success for ATLAS and CMS. LHC's first run has been successful and the U.S. is a critical player in the field due to LHC. Discoveries made highlight important areas but provoke additional questions. ATLAS and CMS can address these questions, and will work beyond the discovery of Higgs to advance the field.

CMS involves 49 universities and one national lab. ATLAS involves 31 universities and three national labs.

The first run of LHC produced 8 TeV and 23.3fb in 2012~~ and about 20 proton collisions.~~ Experiments in run one led to 370 publications. One hundred more public results or peer-reviewed journal articles are anticipated before the start of run two.

The Higgs Boson discovery occurred between summer 2011 and December 2012, and was undertaken rapidly due to the combination of the EPS and lepton-photon experiments. The mass of the Higgs and couplings can be measured. Different channels are being combined to understand the mass. The signal strength of the Higgs can be measured at about 12 percent in CMS and ATLAS. Dominguez shared the coupling parameters possible through ATLAS.

An entire Higgs program has been developed at LHC. Higgs itself can be a portal into dark matter and hidden sectors, among other things. There is an entire Higgs landscape to explore.

Along with Higgs, ttbar cross-measurement combines ATLAS and CMS.

CMS and LHCB have observed Bs to μμ, and the two decay modes are visible in CMS. From that, the branching ratio can be extracted.

LHC is also looking for super-symmetry and exotica where mass limits are being placed up to 1.5 TeV. There is no direct evidence of super-symmetry to date.

The accelerator has been upgraded and experiments have been repaired over the past two years. The first beam will occur on March 9, 2015, and 25 ns bunch spacing will occur by June 26. This will replace 50 ns bunching achieved on May 21, 2015. Intensity will be ramped up over the rest of the year, and the ion will be run in December.

Run two will occur in 2015 through 2021. There will be one long shut down during run two. The LHC is currently in the middle of shut down one. Shut down three will take place around the start of 2021. Upgrades over the next two years are important for the phase two upgrade in 2023.

There have been various studies of what CMS and ATLAS can accomplish in Run two. LHC will ultimately become something of a Higgs factory and will produce up to 6 million Higgs by the end of Run two. This will allow for greater measurements of precision. The first chunk of Run two will achieve a 100 fb-1 which is a factor 1.5 larger. Sensitivity will increase as will improvements in analysis, leading to the discovery of supersymmetric tops particles (stops).

Experiments in Run one are rapidly ramping up. CMS is being closed up and end caps are being placed over the beam pipe. Repairs have been made to the tracker bulkhead to seal humidity leaks. Condensation entered the CMS barrel pixel detector during shutdown but this has been repaired and is ready for installation.

The inner barrel layer has been installed in ATLAS.

ATLAS and CMS are starting the commissioning phase of the experiments and preparing for Run two. The phase one upgrades of experiments is also underway. There is a pile-up of interactions and upgrades must be upgraded. There will 50 and up to 100 simultaneous interactions from crossings, and sensors have to be upgraded to handle this and enable reconstruction of these particles at these same luminosities.

The upgrades for CMS are evolutionary. The Hadron Calorimeter will have new frontend photosensors and accompanying backend electronics. The Pixel Tracker will have a new three-layer endcap detector and four-layer barrel detector as of 2016 or 2017. Layouts are being developed to support the tracker development. The Level 1 Trigger will undergo a conversion to a modern electronics system (µTCA) with high bandwidth optical links and large FPGAs.

Predicted results from the new four-layer pixel detector show promise. Dominguez showed the ratio of the number of events for each sequential cut for the upgraded detector relative to the current detector. Gains in efficiency will be around 60 percent.

ATLAS phase-one upgrades are similar to those for CMS and include a fast track trigger and different trigger scheme. The muon detector will handle a higher flux of particles during higher-luminosity runs in the LHC. The calorimeter trigger will be upgraded to enable better particle flow. Upgrades will include the enhancement of the front-end region.

Planning is also being done for the high luminosity running of LHC. The higher luminosity will present some challenges but can be managed by the tracker, among other things. Planning is leading to technical proposals that will inform the phase two upgrade.

LHC will produce more Higgs and study Higgs coupling, and use Higgs as a portal into other sectors to measure the branching ratio of Higgs into visible modes.

SUSY work continues at LHC, and there is a robust heavy-ion component to LHC's work.

Discussion

Han asked about extensions at large N. **Dominguez** shared that the upgrades will lead to greater segmentation and not go beyond 4.9.

Han asked when results from run two will be available. **Dominguez** shared that in phase one, the first publication was produced in January 2010 just months after a start in 2009. There will results right away after run two and more after an upgrade in luminosity and a doubling of beam energy. ATLAS and CMS are able to quickly produce high quality analysis. **Dominguez** confirmed for **Sciolla** that there will be results rapidly and in time for summer conferences.

Tschirhart asked about phase two upgrades and responsiveness to things discovered in phase two, and if plans will change. **Dominguez** believes that there must be some broad parameters such as reconstructing protons, and these will not change even though responsiveness

is important. One thing that has changed is a desire to measure every particle, and the way that detectors are put together is changing.

Murayama pointed out a special physics run that will occur in May 2015. **Bassler** answered that these are runs with high detectors.

PRESENTATION OF THE FERMILAB REPORT

Joe Lykken, the Deputy Director and Chief Research Officer of Fermi National Accelerator Laboratory (Fermilab / FNAL), shared an update on the facility, projects and new initiatives, and progress on the neutrino program.

The P5 Plan includes major components that reinforce one another, and FNAL is fully-aligned with the plan and its execution. The lab is managing challenges associated with delivering on the plan as well as operational challenges in its maintenance and service to users.

Highlights among projects at FNAL include the NOvA CD-4 completed in September 2014. NOvA has a broad science scope and has produced nearly 1 million neutrino events in its lifetime. NOvA has a large collaborative community.

CMS phase 1 upgrades and CD-2/3 ESAB in November 2014 involve multiple institutions.

MicroBooNE is hooked up and CD-4 is anticipated in December 2014. The tank will be filled with argon and experimentation can begin.

Mu2e has generated a lot of interest from U.S. and international groups, especially since the P5 report.

Lab infrastructure includes the Science Laboratories Infrastructure (SLI) program that allows for upgrades through the DOE. Laboratories need to get on a list at the DOE. Additional infrastructure changes include making space for the Neutrino Division and other changes to Wilson Hall. There is also a new remote operation center.

The test beam facility was used by more than 350 users and users in 20 countries in 2014.

The staff has been reshaped to support top P5 priorities. One priority is the HL-LHC upgrade that includes doing project upgrades to meet a production schedule that beings in 2018.

The P5 Plan also endorsed several projects underway at FNAL. These include the G2 Dark Matter experiment, DESI, LSST, and CMB. Appropriate expertise and resources at FNAL are being mapped to support community led initiatives.

FNAL works with other national labs, as urged by Secretary Moniz. One key example is a partnership between FNAL, Argonne, TJNAF and LBNL on the next generation LCLS-II light source at SLAC. Another is collaboration domestically and internationally on HL-LHC.

Neutrinos is one P5 priority addressed through the formation of a new international collaboration to build large liquid argon detectors deep underground. The intention is that the effort is coherent with both LBNL and non-FNAL efforts. Lykken reflected HEPAP's belief that particle physics is global and this is shown through FNAL's work. CERN efforts reflect a U.S. – European partnership and connections between CERN and FNAL.

The timeline for international collaboration on neutrinos shows agreements between multiple countries and emphasizes work that can be done in the U.S. and not just at CERN. In October, iIEB collaborators visited Sanford and drafted an agreement to use that site. Two open PI meetings were held in December to help form this collaboration. More than 90 institutions are interested in joining the collaboration. The interim board for the group is Sergio Bertolucci.

An important milestone is launching a working group on international governance for the LBNF. A white paper will be produced that specifies a governance approach. It will describe specific governance of the LBNF. The collaboration does not yet have a name, but will design,

build and operate a system of neutrino detectors. It will be responsible for the scientific strategy and the construction project embedded in the collaboration.

The collaboration group will work from a bottom-up approach in designing its science strategy and then will iterate with funding agencies to design an effective path forward. The group could adapt the LHC model with an international detector collaboration, a host lab providing infrastructure, and appropriate international oversight bodies. International oversight is provided by the International Joint Oversight Group (IJOG) and additional groups.

IJOG can occur soon and start work on the bilateral agreements that will be needed. FNAL will be responsible for infrastructure and oversight for facility and detector construction projects. There will be a resource review board and an experiment-facility interface group. The plan will be written up and go to the iIED. IJOG will own the plan and implement it accordingly.

FNAL is executing short baseline neutrino work, echoing the P5 Plan. MicroBooNE is supporting this, as will a new near detector test and the ICARUS collaboration that is coming to FNAL in 2017 after refurbishment at CERN. The collaborations are writing a joint proposal that will go to the FNAL PAC in January. There are several international partners, and additional non-DOE resources are expected to include CERN contributions to infrastructure for Lar1-ND.

Lykken shared that the biggest challenge at this point is project management, and evolving from an operations lab to a project lab.

Discussion

Murayama asked about collaboration. **Lykken** shared that the focus should be on liquid argon. As the facility evolves, other detectors such as water shrink-off should be considered. The collaboration may need to consider other options or let other groups form to consider these options.

Sciolla noted that 2015 is about to start and asked about a facility for the new detector. **Lykken** shared that the building can be used through a mechanism called DDP that does not require a three-year process, and a new building will be constructed pending proposal approval to house ICARUS.

Erbacher asked if FNAL has successfully received funds for infrastructure. **Lykken** has received infrastructure upgrades and is trying to get CD-0 to get on the list at DOE to get on the timeline for potential funding support.

Erbacher asked about the international collaboration and if this will become a user facility. She noted that issues have arisen in the past with DHS and other offices when DOE tries to secure appropriate visas and other permissions for people to work at the lab. **Lykken** does not anticipate any new issues. There are already problems with visas and FNAL is aware of the mechanisms required based on the number of non-U.S. citizens who already work with FNAL.

PRESENTATION OF DOE PLAN FOR SHORT BASELINE NEUTRINO EXPERIMENTS

Glen Crawford shared information on DOE's plans for neutrino research at FNAL and outside of the lab. The P5 Report proposed small-scale short baseline experiments in neutrino with a goal of recognizing the U.S. as the global lead for neutrino research.

DOE's process for an intermediate neutrino program include working with LBNF and achieving a coherent program that may occur at other facilities, using other accelerators or not using accelerators, using reactors, and with researchers who are at various stages in the development of their experiments.

Brookhaven National Laboratory will host a DOE meeting on February 4 – 6, 2015, to gather community input through working groups on various neutrino topics. The agencies will share their viewpoints. The workshop will provide ideas for near-term small-scale projects that are scientifically compelling, competitive from a global standpoint, and technically ready to begin. Based on workshop input and available funds, a new funding opportunity may be announced for these types of projects. Specific requirements may be called out in full if those are needed.

DOE is aware of many things that do not fit in this scope but recognizes the need to be aware of these. Some examples include technology R&D for future experiments and theory support of the broad neutrino program. These things will be discussed at the workshop and help DOE address many issues. Funding for these efforts is best addressed through the standard solicitation process. There could also be additional opportunities for funding and partnerships.

Discussion

Tschirhart asked about interactions with other offices and asked if other offices will be invited. **Crawford** shared that Brookhaven is organizing the workshop but he hopes that they will invite other groups. DOE is in contact with NES and other entities such as high-energy, nuclear physics groups and others supported by HEP at NSF would attend.

Shipsey asked about collaboration with NP and partnerships for funding. **Crawford** shared that this is currently speculative. He believes that there is interest in partnering. It will be driven by what is heard at the workshop. The community can guide what needs to be addressed in the next five years. Shipsey asked if international groups should be invited to participate. Crawford is already working on neutrino and hopes to have a focused effort with others.

Crawford responded to a question from the public sharing that the program scope could include one experiment and some smaller experiments. This is based on OHEP's knowledge of currently available budgets.

DISCUSSION OF HEPAP ACTIVITIES

Lankford provided status reports on several activities being undertaken by HEPAP.

Conference travel support has been discussed at several meetings. It was proposed that community input on conference travel support be gathered through a survey executed by APS-DPF and Shipsey agreed to discuss this concept with the DPF~~FP~~ Chairline and Executive Committee (EC). The EC chose not to execute the survey. DOE OHEP still needs input. Comments can be shared via Lankford and Shipsey. **Siegrist** urged that DOE still needs data on conference travel support to guide decision-making.

Erbacher reminded the HEPAP of concerns about a survey that were voiced at the HEPAP meeting in September 2014. She suggested that HEPAP discussed that people could vote with their feet, but that does not support DOE's information needs and could limit the emergence of new meetings that are useful. The product that DOE is seeking is not clear.

Siegrist and **Crawford** clarified that concern is most frequently heard about participation in larger conferences and the cost of attendance at international conferences. HEPAP might agree on what information it gives to agencies rather than agencies offering those questions.

Erbacher and **Shipsey** have brainstormed about a survey and it could be informed by a list of criticisms that agencies hear. **Crawford** agreed that the agencies could generate a list of concerns to support survey development.

Shipsey added that initial discussions pointed out the need for a set of questions from the agencies and that this meeting might serve as a time for identifying the details to be discussed.

Siegrist shared that a response from HEPAP about the necessity for surveys might be useful, but more helpful would be a survey that responds to the concerns that agencies are hearing.

McBride shared that researchers could contribute to identify the value of having conferences and why attendance is valuable. DPF~~V~~ needs to be involved as they can be hit harder by budget constraints than DOE SC.

Siegrist added that an argument should be made to show the value of participating in experiments at places like CERN and how conferences are used to promote the field. There is also a specific set of values that surround large conferences. There is also a threshold of $100k for large conferences. He asked if there is a need for analysis to understand the threshold. He believes that OMB is micro-managing how the field does its science, whether OMB realizes it or not.

Hoffstaetter agreed that the accelerator community should be involved. He asked what the survey means. A solicitation of problems that have occurred could be very good.

There is no telling how OMB would respond to this, but **Erbacher** pointed out that issues around Snowmass illuminated these challenges and may have ended up generating more costs due to smaller sub-meetings.

Murayama noted that BES may have bigger conferences and similar concerns. **Siegrist** is not aware of challenges that they face but suggested that OHEP can engage BES, and that Lankford can engage the BES Advisory Committee Chair.

Lankford noted OHEP's desire for a clear explanation of the value that conferences have in the field. He suggested that a group could self-generate the roles that conferences play and in doing so, generate insight on additional input that might be needed. HEPAP agreed that this approach makes sense and that DPF , ~~DPV~~ and HEPAP might collaborate on this analysis.

On December 8, the HEPAP discussed the value of a future subcommittee to discuss laboratory and university roles. **Lankford** asked how the HEPAP might best approach coming up with the roles and responsibilities of all in the HEP community, that it might best start with a view of how the agencies interact, and how agency strategic plans fit with this. The problem is multi-dimensional and goes beyond universities versus laboratories. Not all universities and not all labs are the same.

Lankford reminded HEPAP of the concept of a National Scientific Programs Advisory Sub-Panel (NSPAsP) to advise DOE on the selection of particle physics projects for the national HEP portfolio. In particular, the national short-baseline neutrino program needs initial definition and could be explored through a workshop on the intermediate neutrino program on February 4 -6, 2015, at Brookhaven. White papers from this could give direction. If a sub-panel does emerge, this pilot project could give better understanding of the interplay of the NSPAsP and F-PAC.

Erbacher asked if the first panel would address the neutrino program and could illustrate what works for dealing with proposals that are below a certain funding threshold. **Lankford** shared that the decision about forming a sub-panel is not complete and depends on whether or not there is output from the neutrino workshop in February and if that motivates DOE to urge formation of this group.

Siegrist shared that a complication may be if the NSF finds things that are interesting. The concept of this type of activity might not be complementary to the processes that NSF uses to review and fund proposals.

Erbacher pointed out that the panel assembled by DOE and NSF for dark matter might be similar to this in that it recommended specific things for funding. **Siegrist** noted that it still depends on NSF's perspective and DOE does have value in collaborating with NSF, and a lot

depends on whether or not this is a HEPAP sub-panel or something else. **Crawford** added that NSF does not want to be in a position where a proposal review recommends one set of things and HEPAP recommends another set of things.

Lankford shared that the next HEPAP meeting is tentatively scheduled for April 6 – 7, 2015, in Washington D.C. The timing is good considering the FY16 budget rollout and the Accelerator R&D Subpanel report. Topics that can be addressed in April 2015 are the FY16 budget, the NSF MPSAC subcommittee on implementing the P5 Report, Accelerator R&D Subpanel final report, HEP connections with DOE Advanced Scientific Computing Research (ASCR), other selected computing and software topics, and public engagement and communication.

The HEPAP should regularly follow-up on the development of the implementation of the P5 Plan and hear a number of reports.

Tschirhart asked if upcoming FCC discussions with Japan would be covered. **Lankford** suggested that these could be heard during reports on other regions or could be part of an energy frontier talk. **Tschirhart** urged that a talk on the energy frontier could be interesting and include the FCC and Japan topic. **Hoffstaetter** noted that the first FCC meeting will be held in March 2015. **Lankford** believes that just a general report that emphasizes particle physics would be appropriate, and the future of the energy frontier presentation could occur at the next HEPAP meeting. **Siegrist** added that just a summary of the FCC meeting could be sufficient rather than an overview of the energy frontier field.