Department of Energy
Washington, DC 20585

AUG 17 2011

Dr. Harry Weerts
Argonne National Laboratory
9700 S. Cass Avenue
Argonne, IL 60439

Dear Dr ~~Weerts~~ Harry:

I have enclosed a copy of the final report resulting from the Office of High Energy Physics (HEP) comparative review of the non-accelerator research programs at Argonne National Lab, Brookhaven National Laboratory, Fermi National Accelerator Laboratory, Lawrence Berkeley National Laboratory, and SLAC National Accelerator Laboratory, which was held September 27 through October 1, 2010, in Bethesda, Maryland. The review panel was charged with assessing the quality of the recent research efforts and the merit and feasibility of the proposed research for achieving the scientific goals and milestones of the field, as well as the relevance to the overall HEP mission.

Reviews such as this will help to inform HEP when making funding decisions and optimizing the program. We hope that you will also find it useful when planning and optimizing your program. While you should carefully consider the comments and recommendations regarding your laboratory's program, it is also important for you to read the sections on the other laboratories since some of the efforts span several laboratories and may also relate to your program. It is also important for you to consider the section regarding comparisons between laboratories and scientific thrusts, since much of it is relevant for all the laboratories.

The non-accelerator program was found to be strong overall and world-leading in many areas. Some important overall recommendations were regarding the relative balance of the different scientific thrust areas and that care should be taken to ensure that efforts are focused on the HEP mission goals, since many experiments have a much broader science program. Following the criteria developed by the Particle Astrophysics Science Assessment Group (PASAG) in their October 2009 report, it was recommended that the laboratories concentrate on areas where they can effectively contribute unique elements that strongly relate to the HEP mission and require the strength of a national laboratory.

The panel recommended an increased level of coordination between the laboratories in moving some of the scientific thrusts forward and optimizing the program. They also recommended that the laboratories take the lead in providing management and coordination of an experiment or scientific thrust when possible.

We, and the review panel, greatly appreciated the work that the laboratories invested in preparation for and carrying out this review. I believe that you will find the review panel's comments and recommendations useful as you proceed with your research.

Sincerely,

Glen Crawford
Director, Research and Technology Division
Office of High Energy Physics
Office of Science

Enclosure

cc: Peter B. Littlewood
Mike Procario, w/o enclosure
Michael Salamon, w/o enclosure
Kathleen Turner, w/o enclosure

Department of Energy
Office of Science
Office of High Energy Physics
Report on the

Review of the Non-Accelerator Based Experimental Research Program at ANL, BNL, FNAL, LBNL and SLAC

September 27 – October 1, 2010

Executive Summary

The Department of Energy (DOE) Office of High Energy Physics (HEP) conducted a peer review of the non-accelerator based experimental research programs at the national labs. The review panel members individually evaluated the quality of each lab's program and their proposed plan for the next three years. The review results will allow HEP to compare the programs at the different labs and make funding decisions to optimize the program. The panel evaluated the program along the following thrust lines: dark matter, dark energy, high energy cosmic- and gamma-rays, cosmic microwave background, other cosmology efforts and neutrino studies. Each lab's program was evaluated and, in addition, the overall program was compared by thrust and each lab's program was compared to that of the other labs.

This Executive Summary includes the main recommendations across the non-accelerator lab programs that were made by a majority of the panel members. Detailed comments and recommendations are included in the body of the report.

The non-accelerator program was found to be strong overall and world-leading in many areas. The direct detection of dark matter, determining the nature of dark energy and neutrino studies are the top priorities in the non-accelerator program. Other areas have capabilities of scientific studies and discoveries of direct relevance to the HEP mission, though in some cases much of their program is less directly relevant, whereas others areas have typically been funded by other agencies. The panel members recommended continued support for current experiments through their planned data-taking phase.

The panel recommended that support for the direct detection of dark matter should be increased relative to the other thrusts, that it was important to investigate multiple technologies and that the labs should help steward the dark matter program. They recommended that dark energy should also be pursued using multiple methods and that the labs develop and monitor the efforts to ensure a focused and organized dark energy program. The panel members recommended continued support of current cosmic- and gamma-ray experiments at about the current level but any investments in future experiments are made at a proportionate level, since their goals may lean increasingly towards traditional astrophysics. They recommended that a high bar be set for participation by the labs in cosmic microwave background studies, to where they can make unique, targeted contributions, since this science is typically funded by other agencies.

The panel agreed that the non-accelerator neutrino program is very important and could lead to important discoveries over the next few years. In particular, the panel recommended strong support for Daya Bay, which will start taking data soon, and continued support for the EXO-200 experiment during its current phase, with follow-on efforts reviewed in context of all the proposed technologies.

In general, many of the experiments in particle astrophysics have broad scientific goals, and the panel members recommended that care be taken to ensure that efforts are focused on the HEP mission goals.

Many of the smaller R&D efforts in the non-accelerator program are now progressing to the next generation and will need to follow the DOE project management rules. It was noted by the panel that the national labs have the strengths and advantages to ensure best management practices. It was recommended that the labs take the lead in providing management and coordination of an experiment when possible.

The panel members noted that the labs and research groups have differences in the ways their programs are managed and executed. Some efforts include the management of the experiment and collaboration from the start. Others join existing efforts, sometimes bringing the advantages and strengths of a national lab and other times working more in the mode of a university or "user" group. The panel recommended that, following the criteria developed by PASAG for involvement in non-accelerator experiments, a lab should be able to show its unique contributions that require the participation of a national lab.

Many panel members commented that many labs seem to be trying to have the broadest program possible and were concerned that this may not be the most efficient use of resources and talent across the program. The panel recommended an increased level of coordination between the labs and that each lab concentrates where it can most effectively contribute unique elements that strongly relate to the HEP mission and require the strength of a national lab.

Introduction

The Office of High Energy Physics (HEP) is conducting triennial reviews of the non-accelerator based experimental research at its national laboratories. The goal of these reviews is to evaluate the quality of the non-accelerator based research programs, assess each lab's three year plan for future efforts and the quality of the support and infrastructure supplied by the laboratory for this program. These reviews will allow HEP to compare the programs at the different labs and make funding decisions to optimize the national program.

A review of the non-accelerator program was held on September 27 through October 1, 2010 at the Doubletree Inn in Bethesda, Maryland. The charge requested that the panel assess the quality of the recent research efforts and the merit and feasibility of their proposed research for achieving the scientific goals and milestones of the field, as well as the relevance of their research efforts to the overall HEP mission. When evaluating the laboratories programs, the panel members were asked to consider the recommendations made by recent High Energy Physics Advisory Panel (HEPAP) subpanels, Particle Physics Project Prioritization Panel (P5) and the Particle Astrophysics Science Assessment Group (PASAG), and the recent National Research Council (NRC) Astronomy and Astrophysics Decadal Survey (Astro2010), as well as the criteria for HEP participation in Cosmic Frontier activities developed by PASAG.

The reviews of the labs' research contributions were requested along the following programmatic thrust lines: dark matter, dark energy, high energy cosmic- and gamma-rays, cosmic microwave background (CMB), other cosmology efforts and neutrino studies. For each individual laboratory research group, we requested a specific evaluation of:

1. The quality and impact of the research by the group in the recent past;
2. The scientific significance, merit, and feasibility of the proposed research;
3. The competence and future promise of the group for carrying out the proposed research;
4. The adequacy of resources for carrying out the proposed research, and cost-effectiveness of the research investment;
5. The quality of the support and infrastructure provided by the laboratory; and
6. How well the group's activities relate to the overall HEP mission.

Each lab provided a progress report and proposal. This included spreadsheets of their budgets and Full Time Equivalent (FTE) personnel for the past 3 years and proposed funding for the next 3 years. At the review, each lab gave presentations which described their program.

Panel members individually gave HEP comments and recommendations during a closeout of the review and they also sent in confidential individual review letters. This report is a summary of the evaluations and commentary provided by the reviewers both in the review itself and the individual letters. The panel Chair has synthesized this material to reflect the general tenor of the review and the important issues raised but it is not intended to be a comprehensive record of all comments received by HEP. In particular, comments and recommendations that address issues outside the scope of the review charge have been redacted. Since each panel member wrote their

own independent review letter, in some cases the individual comments and recommendations are in conflict, and this is noted in this report as appropriate.

This report is organized as follows. In the first section, comments and recommendations on the overall program are described, including general comments, comments on each scientific thrust and comparisons between thrusts and between labs. Then there is a section for each lab, where their program, including funding and of FTE personnel is described along with a summary of the panel members' comments and recommendations in each of the thrusts. Appendices at the end include a list of panel members (A), the agenda (B), and the charge letter for the review (C).

Overall Program

General Comments

The panel members commented that there were "many excellent presentations" during the review and "it is clear that the non-accelerator research program in the five DOE laboratories we reviewed is strong, diverse and aligned with the scientific priorities outlined in several recent reports such as PASAG and Astro2010."

They noted that with the "exciting research opportunities" and "changes to the accelerator based program such as the end of data taking with BaBar", it "is not surprising that the non-accelerator activities of the labs increased over the past years." The panel members commented that the "labs had an absolute critical role in defining large dark energy projects", most of which would not be here today without these leadership efforts". "To a lesser extent, this is also true for dark matter experiments" and the other thrusts. Several panelists remarked that there has "somewhat less growth in the non-accelerator university program" but this "will change over the next years as some of these conceptual designs turn into real projects" and "while the expansion of the lab based program is slowing down."

Comparison of the Program – by Scientific Thrust

The panel members agreed that the detection of dark matter, understanding the nature of dark energy and neutrino studies are priorities in the field. They recommended continued support for operating experiments, as well as strong support for Daya Bay, the search for dark matter, and the pursuit of the nature of dark energy, though the balance of these efforts may need to be reconsidered.

The actual (FY10) costs and proposed funding (FY11 – FY13) by thrust, as reported by the labs in their proposals, is shown in the table below. The total funding actually provided by DOE HEP during FY10 is in the last row. The lab's costs may differ from the funding provided due to carry-over funds being applied or transfers from other budget codes.

Dark Matter

The panel members commented that "Direct Dark Matter detection is of such importance and difficulty that present planning should assume the need for eventual confirmation of any discovery with a second technology" and therefore a strong effort in multiple techniques should be pursued. In general, the panel was concerned that "the nation has underinvested in Dark Matter and needs to build up this area" relative to other thrusts at the cosmic frontier. There were individual comments such as the funds "spent last year on direct dark matter detection is woefully low, given the high priority of this activity assessed by PASAG, and given the high discovery potential and closeness to the historical mission of DOE High Energy physics". However, there were concerns that "productively increasing this support presents a thorny challenge" since many strong university groups are working at foreign labs, many in the field are concentrating on efforts for a future underground lab and the fact that many lab scientists are more interested in dark energy. The panel recommended that support for the direct detection of

dark matter should be increased, with care taken to ensure a balanced program of several techniques.

Table 1 – Funding by Thrust

		FY10 actual	FY11 proposed	FY12 proposed	FY13 proposed
Dark Matter	$K	4081.6	6847.3	8340.9	7708.8
	FTE	14.9	26.6	33.4	30.5
Dark Energy	$K	16800.1	19651.2	21115.2	21953.4
	FTE	64.6	71.7	77.1	79.7
High Energy Cosmic/Gamma	$K	14698.3	14294.8	14191.6	14374.1
	FTE	53.1	53.2	52.9	52.1
CMB	$K	506.6	1818.2	2210.6	2793.2
	FTE	1.5	7.5	8.6	10.5
Cosmic-other	$K	2296.6	4610.0	3049.0	4109.0
	FTE	7.8	10.8	7.1	8.2
Neutrinos	$K	5850.2	6356.2	6974.2	7346.6
	FTE	22.3	24.2	24.5	25.3
TOTAL	$K	**44233.4**	**53577.7**	**55881.5**	**58285.0**
	FTE	**164.3**	**194.0**	**203.6**	**206.3**
TOTAL DOE HEP provided	***$K***	***43990.0***			

The panel members recognized that the US has a history of leadership in the Cryogenic Dark Matter Search (CDMS), with smaller and newer efforts in other technologies. FNAL has played a leadership role in dark matter for a number of years and the panel was supportive of the newer efforts at SLAC and LBNL.

There was some concern about the balance of the dark matter program and panel members felt that care should be taken to investigate several different technologies in enough detail to know if they would be suitable for a future large detector.

The panelists found laboratory management of dark matter experiments to be very important, saying the "US Dark Matter effort is under-resourced relative to its ranking by PASAG. Solid management and coordination is one of the places where the US Dark Matter effort has been weak, largely because of the origination of much of the innovation in the university programs". "Project management is now complicated enough such that it requires the experience of a laboratory". It's "especially important for safety issues, but also for managing funds and keeping the project on schedule" and "positions the experiment well for the next generation."

The panel commented that "the next generation of dark matter detectors requires laboratory support for management, engineering etc", the "labs should lead two designs for the direct

detection of dark matter to be ready for a [generation-2] review" and the labs need to "help be a steward of the field and help coordinate the various experiments and studies." The panel recommended that the "labs have to take on leading roles, provide coordination and join facilities" to help the field progress and achieve discovery.

Dark Energy

It was felt that "understanding the accelerating expansion of the universe is also truly fundamental" and dark energy should be pursued using multiple methods. There were concerns that the relative support for dark energy was too large compared to dark matter searches. The panel recommended that close monitoring "to ensure a focused and organized dark energy program is essential" as well as being mindful that most of the experiments have much broader science goals than dark energy.

In the dark energy program, panel members had some concerns that "a coherent overall strategy, optimizing observations both from the ground and space" is lacking and the situation may not change soon due to different priorities and funding availabilities by the agencies. It may be that future experiments are broader than dark energy and "the DOE High Energy interests will represent a declining fraction of scientific inquiry" in future experiments. Several had comments such as the Astro2010 and PASAG reports "justifies pruning down" the program to a smaller number of experiments that have a "clear delineation of the DOE High Energy Dark Energy physics interests" and where our community can play leadership roles.

The panel recommended strong support of the priorities in the field, including "supporting operations for [the Dark Energy Survey] (DES)", "getting the [Large Synoptic Survey Telescope] (LSST) approved" and "supporting R&D for a spectroscopic survey [Big Baryon Acoustic Oscillation Survey or Dark Energy Spectrograph] (BigBOSS, DESpec…)". It was felt that HEP should "target support to those labs that make unique or critical contributions to these programs."

The panel commented that there are "leading contributions from SLAC, FNAL and LBNL" in dark energy and that "LBNL is the clear center of excellence in this area, and this should be treasured and protected." "Efforts at BNL and ANL seemed more modest and less critical." The panel felt that it is important to have a "world leading role on future experiments" and that "dark energy on the ground will certainly be the field where the US leadership will be undisputed in the years to come."

There was concern about going forward on a space mission, with several panel members having comments such as if "[Wide Field InfraRed Space Telescope] WFIRST is delayed beyond 2020, it is not clear whether the dark energy motivation" will continue and "WFIRST should be treated with caution".

High Energy Cosmic- and Gamma-rays

The panel members commented that continued support of current experiments in this thrust, including the Pierre Auger Observatory in Argentina, the Very Energetic Radiation Imaging

Telescope Array System (VERITAS) in Arizona, and the Fermi Gamma-ray Space Telescope (FGST), is reasonable and necessary. The US has a "world leading role" on these experiments and they are all operating well and producing excellent data and scientific results. Panel members commented that while high energy cosmic ray and gamma ray experiments have capabilities of scientific studies and discoveries of direct relevance to the HEP mission, much of their programs are less directly relevant. The panel recommended continued support for the labs' efforts in this thrust at approximately the current level and also recommended that care must be taken such that the size of the investment in future experiments, that may lean increasingly towards traditional astrophysics, is made at a proportionate level.

SLAC's world-leading effort on FGST is "clearly the strongest effort among the national labs in this area". They have "been doing a superb job, both on operations and on the science" which should "continue with good support". FNAL has a world-leading, "unique role with its involvement in Auger" and is "the only lab with a direct involvement in ultra high energy cosmic-rays". They have "been doing a very good job at constructing (a feat for which they should be congratulated) and operating this array." ANL's efforts on VERITAS "have been extremely impressive" and their role has provided "an excellent introduction to a field not used to national labs on how they can be collaborative and help."

Many panel members were concerned about the future direction of this thrust, including Auger upgrades or a northern site, or participation in the Cherenkov Telescope Array (CTA). It was noted that the VERITAS upgrade recommended by PASAG had already been approved and funded by the National Science Foundation (NSF). Some panel members had comments such as the "center of effort will be increasingly toward astrophysics and away from DOE High Energy physics interests" and the efforts were not as high priority as dark matter or dark energy in PASAG. However, it was noted that "the techniques employed may be closer to HEP techniques" than in some other thrusts.

In general, the panel members felt that "gamma ray astronomy is an area capable of major discoveries of direct relevance to HEP (most notably dark matter annihilation), but much of the physics is less relevant to HEP" and therefore "care must be taken that the financial burden is not shouldered disproportionately by HEP."

In the area of gamma-ray astrophysics, most panelists felt that US participation CTA is unclear since "Europe seems to be going ahead with this project and, given the US funding model, we will be too late to make a contribution". Many commented that the labs are in a good position to have strong roles in the project, with several proposed contributions that could go forward at different stages of the project. "Given the prospects for US funding in the short term, the lab needs to be realistic about where it can have the biggest impact." If they pick an area where the "lab has significant (if not unparalleled) capability", it might "give them influence beyond the funding which may be significantly delayed." The panel members agreed that to "make it worthwhile, there should be a definitive contribution to "to stake out an identifiable US component". Many also commented that the proposed ANL and SLAC roles should be "somehow melded into a recognizable DOE-supported US group" with a plan of coordinating

their possible contributions that are under consideration. It was recommended that the labs should be conservative in their efforts on CTA until a decision about US participation is made. The institutions involved could then adjust their planned contributions to fit within available funding, which may not open up until later in the decade.

Regarding cosmic-ray studies, most panel members felt that the "long term future is unclear" and the labs should "propose a more precise plan", including investigating other techniques, if they want to continue in this area, especially since "physics will not be very challenging in the short term because the progress in statistics will be very slow". The panel recommended that the Auger future science potential be reviewed in the context of the overall program.

Cosmic Microwave Background

The panel members agreed that the study of CMB to explore the era of inflation is "compelling science" and "perfectly aligned with the DOE High Energy Mission". However, this area is "traditionally supported by other agencies" and many felt that the "necessity of DOE support is unclear". The panel recommended that there be a high bar set for participation by the labs in areas where they can make unique, targeted contributions. Targeted support was recommended for the "excellent thrust at ANL", but the panel felt that the "small efforts in SLAC, LBNL and FNAL…did not really seem strongly motivating for DOE support".

Neutrinos

The panel agreed that the labs have a "world leading neutrino" program and that "US expertise is very important". The "Daya Bay effort over the next 3 years represents one of the best for a great discovery". A few had comments such as "Daya Bay looks to be the definitive experiment, while Double Chooz seems to fall short unless we are on the verge of discovery", though the effort on Double Chooz was acknowledged to be small but strong. The panel recommended "sufficient support to Daya Bay to ensure timely completion of both the experiment and data analysis".

Regarding the search for neutrino-less double beta decay with the Enriched Xenon Observatory (EXO), the panel recommended continued support for the current 200kg detector phase (EXO-200) phase, with follow-on efforts decided in context of all the neutrino-less double beta decays experiments. They noted that "showing the neutrino is its own anti-particle" is very important and therefore this argues for more than one approach. Since stewardship of neutrino-less double beta decay experiments is going to be done by the DOE Nuclear Physics program, it is assumed that efforts towards a full-scale experiment should be "transitioned to the [DOE] nuclear physics program" and a major future experiment should be decided via a competition. Many panel members also commented that they hoped expertise gained using Xenon for EXO could be applied towards dark matter experiments, since it is turning out to be a promising avenue.

Comparison of the Program – by Laboratory

The panel commented that that all the laboratories "are doing excellent research" and the "quality and impact of recent research as well as the competence and promise of the research groups are high with near uniformity." They noted that the "adequacy of resources is generally

marginal, and cost-effectiveness is generally high". The panel assumed that there will be "no dramatic changes are made in overall budgets of any lab" and therefore "if a given lab's program wants to grow", they should "first look to redirect from lower priority efforts within that lab". This "sort of introspection" should be the "prerequisite for any request to add to the overall effort at a given lab".

The actual (FY10) costs and proposed funding (FY11 – FY13) by thrust, as reported by the labs in their proposals, is shown in the table below. The total funding actually provided by DOE HEP during FY10 is in the last row. The lab's costs may differ from the funding provided due to carry-over funds being applied or transfers from other budget codes.

Table 2 – Funding by Lab

		FY10 Actual	**FY11 proposed**	**FY12 Proposed**	**FY13 proposed**
ANL	$K	1252.0	2505.0	2869.0	3326.0
	FTE	5.9	13.3	14.6	16.0
BNL	$K	1807.0	2287.2	2969.0	3548.0
	FTE	6.3	7.6	10.1	12.9
FNAL	$K	11540.5	17421.0	16041.0	15801.0
	FTE	43.1	59.1	55.6	52.0
LBNL	$K	7573.0	8615.0	8627.0	8850.0
	FTE	27.0	28.0	28.2	27.9
SLAC	$K	22060.9	22749.5	25375.5	26760.0
	FTE	82.0	86.1	95.1	97.4
TOTAL	$K	**44233.4**	**53577.7**	**55881.5**	**58285.0**
	FTE	**164.3**	**194.0**	**203.6**	**206.3**
TOTAL DOE HEP provided	***$K***	***43990.0***			

"While all five labs have non-accelerator programs there are clear differences" in the way their programs and thrusts within the program are executed. Some groups "take an idea, form collaboration and lead the effort through the long approval process", for example the [Large Synoptic Survey Telescope] LSST effort at SLAC, DES at FNAL and "even though not yet successful [SuperNova Acceleration Probe, Joint Dark Energy Mission] SNAP/JDEM/WFIRST at LBNL also falls into this category." It was recommended that "for each of the major projects there should be a lead laboratory."

Other labs have "joined existing efforts and operate much like a university group, often not taking advantage of the strengths of a national lab." The panel recommended that a lab join an experiment "if they can offer something unique to the project" but if "all they contribute is just a user group, supporting university researchers is much more cost effective" to the HEP program.

Many panel members felt that each lab is trying "to have the broadest possible portfolio in non-

accelerator physics, with most having groups working on dark energy, dark matter, neutrinos and CMB" and were concerned that this is not "the most efficient use of resources and talent". The panel recommended an "increased level of coordination" and concentration on where they can most effectively contribute the "unique and important elements that the labs bring to the picture" in areas that strongly "relate to the HEP mission."

Labs in the top tier in terms of the non-accelerator program were considered to be FNAL, LBNL and SLAC with ANL and BNL considered to be in the second tier. Several panel members had comments such as "LBNL has the most distinguished history and most talent per physicist, but programmatically is simply not as strong as FNAL and SLAC." Other comments included that "BNL has a superb neutrino group" and ANL "has striven hard to find its way into non-accelerator physics", but is still building a program.

ANL's program was felt to be the most limited, without any "leadership roles". The panel agreed that "because of Carlstrom's (U. Chicago)" joint appointment the newly proposed CMB effort may be the "most interesting part of non-accelerator program at ANL" and was recommended for funding. While useful, their contributions to VERITAS and DES did not "require the resources of a national lab." There were some concerns about the effort on CTA and the potential for US participation and that, through no fault of the lab, the "window of opportunity for Double Chooz is closing due to schedule delays."

The panel commented that BNL has an "excellent program in neutrinos" with "a narrowly focused but important program, especially on Daya Bay," for which they provide leadership in the community. It was felt that while there are "strong pieces to the dark energy program", especially in instrumentation, but they don't have a leadership or "coherent dark energy program" and there is minimal "coupling between instrumentation and science efforts."

The panel commented that FNAL has "excellent programs in dark energy and dark matter science", provides "leadership and support for a larger community", and provides "innovative ideas for small(er) scale experiments." They had some concerns about the future direction of Auger and cosmic ray studies.

The panel commented that LBNL has an "excellent program in dark energy and neutrino (Daya Bay) science" but its "focus is narrower and mostly on dark energy" compared to FNAL and SLAC. They also provide "leadership and support for a larger community". There were some concerns about the future of the dark energy program and it was commented that the lab needs to actively plan several scenarios for going forward.

The panel commented that SLAC has "excellent programs in dark energy and high energy gamma ray science", provides "leadership and support for a larger community", and their new effort in dark matter "appears to be critical for the success of CDMS." There were some concerns about the future directions and efforts on FGST, CTA and EXO, as well as smaller dark energy and CMB efforts.

Argonne National Laboratory (ANL)

Program Description

The Argonne non-accelerator research program consists of work in the cosmic and intensity frontiers. The table below is from the lab's report of their actual costs and FTEs in each category during the past 2 years and their proposed efforts and funding for the coming 3 years. The total funding actually provided by HEP during FY09 and FY10 is in the last row. The lab's costs may differ from the funding provided due to carry-over funds being applied or transfers from other budget codes.

Table 3 – ANL funding and personnel

		FY09 actual	FY10 actual	FY11 Proposed	FY12 proposed	FY13 proposed
Dark Energy	$K	475.0	534.0	642.0	794.0	959.0
	FTE	1.5	3.2	3.6	4.1	4.6
High Energy Cosmic/Gamma	$K	432.0	373.0	457.0	620.0	861.0
	FTE	2.4	1.2	2.3	3.1	4.1
CMB	$K	0.0	0.0	848.0	887.0	929.0
	FTE	0.0	0.0	4.6	4.6	4.5
Neutrinos	$K	250.0	345.0	558.0	568.0	577.0
	FTE	0.9	1.5	2.8	2.8	2.8
TOTAL	$K	**1157.0**	**1252.0**	**2505.0**	**2869.0**	**3326.0**
	FTE	**4.8**	**5.9**	**13.3**	**14.6**	**16.0**
TOTAL DOE HEP provided	***$K***	***994.0***	***1252.0***			

The ANL cosmic frontier effort was started in FY07 with participation in the VERITAS ground based gamma-ray experiment. In FY08, they began a 3-year astrophysics initiative, funded by Laboratory Directed R&D (LDRD) funds, with $1.5M going to the HEP division, $2.5M for development of transition edge sensors (TES) sensors in the materials science and $0.5M for nuclear astrophysics. Their LDRD support is ending and they are requesting a annual steady-state research funding level of ~ $2M in astrophysics. Other efforts at the lab in theory, computing and computational cosmology bring enhancements to the particle astrophysics research program.

In dark energy, the group had an active program in charge-coupled device (CCD) testing, calibration and engineering contributions to the Dark Energy Camera (DECam) for DES in the past 3 years and established a research group on DES, concentrating on supernovae studies. A postdoc that has a computational cosmology fellowship is part of the core group and they propose to hire a new junior staff member in supernova science when this fellowship ends. In order to fully take advantage of their position in DES science, they also request to fully fund a senior staff member who is currently funded partially in the nuclear physics program. Future

plans include participation in LSST.

The LDRD funding for the HEP group allowed them to establish a clear role in VERITAS and an initial involvement in a future ground-based gamma-ray CTA. On VERITAS, they are working on a trigger upgrade as well as data-analysis. On CTA, which is currently in a pre-conceptual design phase, they have a large role in R&D for innovative mechanical telescope structures. To maintain a leading role on VERITAS and position them for a leading role on CTA, ANL is requesting to increase their funding to support new postdocs on VERITAS and CTA and a new staff member on CTA. They will request funds for engineering efforts on CTA through a coordinated R&D proposal.

The majority of the LDRD funds were used to establish a sensor development capability at ANL to develop new, more sensitive TES sensors for the South Pole Telescope (SPT) experiment. This effort uses expertise in the Center for Nanoscale Materials and will enable the measurement of polarized CMB signals. ANL is responsible for the 90 GHz sensors for the SPT-polarization (SPTpol) experiment's focal plane which will take data next year. This effort was part of a strong collaboration with Professor John Carlstrom and his group at the University of Chicago. Carlstrom now has a joint appointment at ANL and they are requesting funds to ramp up their CMB group to take advantage of this opportunity.

Their intensity frontier involvement on the Double Chooz reactor neutrino experiment is part of the larger ANL neutrino program, with other efforts supported under the proton budget line. The HEP contributions to the Double Chooz common funds are being sent through ANL starting in FY 2010. In order to fully take advantage of the data coming out of Double Chooz, they are requesting additional funds for the next few years.

Panel Findings, Comments and Recommendations

Dark Energy

The reviews on the dark energy efforts were mixed. ANL's role seems "important but small", they are "clearly doing useful and relevant work", and they have "done a good job on the PreCam and are making significant contributions".

However many panel members felt that their contributions in hardware and analysis are not unique: "it is not obvious that this really requires DOE lab resources", the "instrument that they built did not require the technical expertise unique to the laboratory", they are "not making a high profile contribution to DES" and "SN [supernova] modeling is underway in many other places".

Some panel members remarked that "they shouldn't necessarily start a dark energy group because they did some instrumentation that could have been done as work for others" and "this is an example of a lab slipping into an experiment when others could do and probably should have done the job".

It was felt that this shouldn't be a high priority effort for their program since "dark energy research is very strongly supported elsewhere in the Laboratory system" and that "that this relatively small program needs to be weighed against other programs where the lab can have a bigger impact (like CMB)".

High Energy Cosmic- and Gamma-ray

The panel members were supportive of their work on VERITAS though some questioned whether "gamma ray observations were part of the DOE mission" but noted that "DOE has taken on VERITAS and FGST" and they are part of the program. ANL has a "small and energetic" group, they were the "first lab to get involved in ground based gamma ray observatories", and they have "made good use of the synergies with the Chicago cosmic-ray and gamma-ray groups".

It was also noted that "there is a good synergy between the photomultiplier (PMT) work for VERITAS and walls of cheap photodetectors for [Long Baseline Neutrino Experiment] LBNE water Cherenkov", and if this pans out, then VERITAS will contribute to a new enabling technology". "The development of new photo-detection methods would be very important for this and related fields".

Regarding the request for a postdoc to aid with the VERITAS trigger upgrade, several panel members felt that this should be supported with remarks such as "it should be their highest priority" and it is "reasonable that the overall cosmic-particles program increases a little at ANL as they are a unique resource", but others noted that "the experiment itself should be winding down, not getting bigger".

Panel members made comments relevant to the overall US CTA effort as well as comments specific to each lab. The comments in the SLAC section of the report should also be considered.

There were mixed comments on ANL's proposed effort on CTA with some panel members saying they "have excellent integration with both the VERITAS/AGIS [Advanced Gamma-ray Imaging Survey] and CTA collaborations and are effective in using the resources of a national lab wisely." If CTA does go forward, they are seen as being "well-positioned", "this is an example where specific lab-based infrastructure presents an opportunity" and "their experience and infrastructure "may place them to lead in the CTA project". However, they "will be a small group in a large European project" and "future prospects for DOE participation in CTA-US were not clear."

There were mixed comments about the specific items ANL proposed to work on in CTA. "I believe they could lead the US effort as they are already seriously working on the likely initial telescope design" but should "develop a prototype [telescope] before investing heavily in unproven technology". The "novel US-based design" of the telescope is "potentially a game-changer", though "only if risks inherent in any radical change can be shown soon to be understood and controlled". Others said ANL "might want to explore how the work on topological and array triggers could be morphed into a potential CTA contribution" instead of the

telescope, which was not seen to be clearly a DOE capability. There were also concerns about building infrastructure, such as telescope support structures, to be deployed in another country, and what this would entail in terms of commitments and responsibilities. It was recommended that they investigate possibilities for contributions at a low level of effort, until a decision about participation is made.

Cosmic Microwave Background

The panel was very enthusiastic about the CMB program that is starting up at ANL. "Carlstrom is world-class and they have a real opportunity here" for an "outstanding partnership" on "future Nobel-class" work. They should "build on it" since he is half-time at ANL. The SPT is "technically a much better experiment than QUIET [Q/U Imaging ExperimenT]" and there is an "easy way for ANL and DOE to make significant contribution". It was noted that DOE plays a minor role in the CMB field and that it is "strongly supported outside DOE". Many reviewers commented that only the ANL proposal is tempting" out of all the CMB proposals by the labs because this effort has the "potential to be strongest CMB partnership at a lab/university and it "could make big impact" and recommended that it go forward.

There were some concerns about where a role in SPTpol would lead in the future and recommendations that a longer-term partnership on SPTpol should be re-evaluated after 3 years to ensure it can achieve the science goals and that efforts won't take away from high priority HEP goals.

Neutrinos

Regarding Double Chooz, the panel felt it is a small, very good effort that needs to be completed in a relatively short time scale since it will be eventually be overtaken by Daya Bay. However, it is important and could make a discovery and should be supported to succeed. Panel members recommended that it should be supported at roughly constant level of effort in the short term and then the funding and personnel redirected to other activities.

Overall

Support for the overall ANL non-accelerator program was strong and the panel commented that the "move to astroparticle should be encouraged". The panel felt that a significant bump in funding is probably unreasonable and suggested that some of the funds come from redirection of efforts within the non-accelerator program or from other areas. Many panel members had concerns about the role of ANL's program within the entire HEP program and recommended that ANL revisit its non-accelerator program to identify its unique contributions that could not be done at a university.

The reviews on the dark energy and gamma-ray parts of the program were mixed, with comments that the work was good but that unique contributions or the case for a lab role had not been strongly made in the case of dark energy and that a future US role in CTA is unclear. Many panel members felt that ANL's CMB effort was the only one at all the labs that had a clear reason why it should go forward and that the HEP's minimal CMB program should be expanded to include the proposed work on SPT. The reviews on the neutrino program were very positive.

Brookhaven National Laboratory (BNL)

Program Description

The BNL non-accelerator research program funded by HEP consists of work in the cosmic and intensity frontiers. The table below is from the lab's report of their actual costs and FTEs in each category during the past 2 years and their proposed efforts and funding for the coming 3 years. The total funding actually provided by HEP during FY09 and FY10 is in the last row. The lab's costs may differ from the funding provided due to carry-over funds being applied or transfers from other budget codes.

Table 4 – BNL funding and personnel

		FY09 Actual	FY10 actual	FY11 proposed	FY12 proposed	FY13 proposed
Dark Energy	$K	641.0	437.0	754.8	1291.0	1760.0
	FTE	1.8	1.3	2.0	4.3	6.7
Neutrinos	$K	1049.1	1370.0	1532.4	1678.0	1788.0
	FTE	3.5	4.9	5.5	5.8	6.2
TOTAL	$K	**1690.1**	**1807.0**	**2287.2**	**2969.0**	**3548.0**
	FTE	**5.2**	**6.3**	**7.6**	**10.1**	**12.9**
TOTAL DOE HEP provided	***$K***	***1690.0***	***1807.0***			

BNL has a small, but growing cosmic frontier program in dark energy. They have participated in LSST R&D since 2003 and have a key role in the LSST camera focal plan development, led by the Instrumentation Division and supported by the laboratory and LSST R&D funds. To complement the laboratory's efforts on LSST, they developed a plan for a dark energy research group and hired two new, young astrophysicists in 2008 and 2009, to augment their small group already participating on the LSST computing and simulation efforts. In order to have a phased science program, the new hires currently have significant roles in the data-taking and analysis on the DES and Baryon Oscillation Spectroscopic Survey (BOSS) experiments. The group plans a significant role in LSST science in the future. The new hires have been funded on laboratory funds over the last few years and they are requesting phased-in support from HEP for the dark energy efforts over the next few years.

At the intensity frontier, they have a major role in the Daya Bay reactor neutrino experiment. This is part of a larger BNL role in experimental neutrino physics, with the other efforts supported under the proton budget line. The Daya Bay experiment is currently in the installation and commissioning phase. BNL is one of the two US host labs for management of Daya Bay and their responsibilities include major efforts on the muon veto system, online software, oversight of the installation and integration for all the US scope, safety procedures and preparations for data-taking analysis. In the next few years, they plan to complete the installation and commissioning and then begin operations of the detectors and to play a strong

role in data taking and analysis. They are requesting funds to add an additional scientist to Daya Bay to enhance their efforts over the next few years and for increased travel support to fulfill their responsibilities.

Panel Findings, Comments and Recommendations

Dark Energy

Reviews on the dark energy program were mixed with the panel members commenting that individual efforts are strong, but that there is not a coherent program. "They have two strong pieces – the instrumentation group and the two young scientists working on [dark energy] DE science – but no real group".

The panel members were very positive about their hardware role with comments such as "the instrumentation effort is critical for the LSST CCD program and should most definitely be supported" and they have a "very strong role in instrumentation for LSST at BNL, which should definitely continue". It was noted that BNL "runs a spectacular instrumentation division which receives accolades for the engineering itself – such work will give glory to the lab whether or not there is a DE group consisting of two young researchers".

Most panel members understood the need for the lab to "develop a science program to complement the instrument effort" in order for the lab to continue supporting the instrumentation effort", but one thought they should consider work for others, urging "DOE to work with the lab [management] to remove this condition." Several had comments such as the "reason given for the hires was to create a science program linked to the LSST focal plane modules being built at BNL in their instrumentation division. Since the new DE scientists have no instrumentation experience, they do not represent a solution to this problem. Therefore BNL moved two established scientists with no expertise into a management role to bridge the gap". Since the engineering group "talks directly with the camera steering committee several times a week" and "is well-integrated into the group, these two managers are superfluous." Several panel members had comments such as "it seemed that they did not have anyone who was effective at bridging between a purely science and purely instrument focus" and "they have failed to organize this effort".

All panelists felt that the "two young scientists hired on special lab funds are very strong scientifically" and that their "work is excellent". Many had comments such as the new hires are "very isolated at BNL" and the "environment for them does not seem sufficiently rich and supportive to make this effort succeed; numerous universities provide far richer astrophysics environments".

Reviews on the proposed dark energy data center were not positive, with panel members commenting that they "seem sub-critical in the right science expertise and experience to host this center", "BNL would certainly not be my first choice as the host institution", and "since many universities have supercomputer complexes", the claim that BNL brings unique capabilities "is not compelling".

Most panel members felt that the "case for augmenting the science program" is not strong and the "best solution" would be to "redirect their current funds" and use the "current BNL DE base budget to support [the new hires]". "I can understand that the lab wants to hire the best people in a field and let them do what they want to because that is what is done at universities. However, it is not obvious that DOE can afford this as an add-on in tough budget times".

Neutrinos

The panel members were very positive about the BNL non-accelerator neutrino efforts on Daya Bay. "The Daya Bay project is among the very-best motivated projects in the portfolio we evaluated. The discovery potential is high, and both the physics and techniques are extremely well aligned with the DOE High Energy goals". "BNL is doing an outstanding job on both the hardware as well as software for simulation and analysis". "Steve Kettell and David Jaffe are doing outstanding work on leadership positions on Daya Bay" and the effort "appears to be well integrated with a larger neutrino program within the lab. While it was felt that "the Daya Bay program should be supported to make this measurement which is of critical importance for the entire neutrino program", the panel members were mixed on their request for additional support for BNL. "The overall US Daya Bay effort would benefit from additional scientific personnel like a new postdoc" but there "should be a competition among all collaborators" including labs and universities. Others noted that this should be the highest priority for additional funding for BNL "although I always will feel that redirection from the substantial other BNL non-accelerator efforts should be strongly advocated" and perhaps additional travel funds should be provided and not a new hire.

Overall

Support for the dark energy effort was mixed with many panel members commenting that the instrumentation group and new hires were each doing very good work but that it was not a coordinated program. Though the panel understood that it is difficult to find the right people that can bridge the gap between physics and instrumentation, they felt that the focus of the two efforts is not nearly as well-connected as similar efforts at other labs. There was not support for increasing the funding for this effort and instead panel members recommended using redirection to provide the funds needed for the new hires. About half of the panelists felt that BNL "appears to have the weakest plan for future astroparticle activities".

Support for the neutrino effort on Daya Bay was found to be strong and the panel recommended that it should continue at about the current level, with consideration of increased personnel on Daya Bay should be done in a national context.

Fermi National Accelerator Laboratory (FNAL)

Program Description

The FNAL non-accelerator research program consists of work at the cosmic frontier. The table below is from the lab's report of their actual costs and FTEs in each category during the past 2

years and their proposed efforts and funding for the coming 3 years. The total funding actually provided by HEP during FY09 and FY10 is in the last row. The lab's costs may differ from the funding provided due to carry-over funds being applied or transfers from other budget codes. The funding includes scientist support as well as R&D and operations support for the experiments. Project fabrication funding is provided in a different budget.

Table 5 – FNAL funding and personnel

		FY09 actual	FY10 actual	FY11 proposed	FY12 proposed	FY13 proposed
Dark Matter	$K	3510.9	2619.6	4791.0	5411.0	4543.0
	FTE	11.5	9.9	19.6	22.2	18.7
Dark Energy	$K	4954.4	4872.6	6558.0	6241.0	5864.0
	FTE	21.5	19.9	24.1	22.1	21.0
High Energy Cosmic/Gamma	$K	2832.8	2456.1	2339.0	2276.0	2335.0
	FTE	9.9	8.0	8.0	7.7	7.5
CMB	$K	135.3	307.6	300.0	243.0	169.0
	FTE	0.6	0.9	0.6	0.2	0.1
Cosmic-other	$K	539.2	1284.6	3433.0	1870.0	2890.0
	FTE	1.9	4.4	6.8	3.4	4.6
TOTAL	$K	**11972.6**	**11540.5**	**17421.0**	**16041.0**	**15801.0**
	FTE	**45.4**	**43.1**	**59.1**	**55.6**	**52.0**
TOTAL DOE HEP provided	***$K***	***10649.0***	***12404.0***			

FNAL started at the cosmic frontier in the 1980's with a theoretical astrophysics group, in collaboration with the University of Chicago, and then began an experimental effort in the 1990's with a leading role in the Sloan Digital Sky Survey (SDSS). The FNAL Center for Particle Astrophysics (FCPA) was established as part of the successful bid by the Fermi Research Alliance (FRA) bid for the DOE contract, and prioritizes and manages the program. Funds for the FCPA are included in "Cosmic-Other" in the table above. The program includes a range of efforts in dark matter, dark energy, cosmic-rays and searches for new particles and new physics up to the Planck scale.

In dark matter, the lab has major efforts and roles in the SuperCDMS at Soudan experiment which is currently operating, the next-generation SuperCDMS at Sudbury Neutrino Observatory Lab (SNOLab) experiment which is undergoing R&D, the Chicagoland Observatory for Underground Particle Physics (COUPP) which has a 4kg version currently at SNOLab and a 60kg version in the Fermilab Neutrinos in the Main Injector (NuMI) tunnel, as well as growing efforts in DarkSide and other new initiatives. In FY11 through FY13, increased funding is requested in response for proposals that have been submitted for R&D leading to a construction start for SuperCDMS-SNOLab, to move and operate COUPP-60 at SNOLab and to begin DarkSide, along with increased scientific support. Fabrication funds for SuperCDMS-SNOLab are not part of this budget request and therefore the funding request goes down as the effort

moves to fabrication.

Dark energy is a major effort at FNAL and they have experiments using several different analysis methods. The current program includes final processing and analysis on SDSS and fabrication, start of commissioning and scientific research on DES. The DECam is the responsibility of FNAL and will be delivered by the end of FY11, leading to operations starting in FY12. The group is investigating participation in LSST, WFIRST and developing concepts for a new spectrograph (DESpec) to follow the DES experiment in Chile and a 21 cm baryon acoustic oscillation experiment. In FY11 through FY13, increased funding is requested for the operations of the DES experiment in order to fully support their responsibilities for integration, commissioning, operations and maintenance of the DECam, as well as computing hardware support and additional scientist support to fully utilize the data.

FNAL hosts the project office for the Pierre Auger cosmic ray observatory in Argentina, which has been operating since 2008, and they also play a large role in the research efforts and R&D for future enhancements. They are planning to ramp their efforts down slowly over the next few years. A proposal for future R&D is being submitted separately.

In the CMB and Cosmic-Other categories, they have a small effort in developing new opportunities in on the QUIET-II CMB experiment, a small effort on a search for axion-like particles on GammeV, and a plan to study the fundamental nature of spacetime using laser interferometry techniques (Holometer experiment). A small effort is devoted to detector R&D that may be useful for future experiments at the cosmic frontier. Their funding request ramps up to fabricate the small experiments over the next year but then ramps down to a steady-state.

FNAL reported that inadequate funds were migrated in the last few years to the non-accelerator program to support the current efforts and this is why a large increase is shown in FY 2011. They also have concerns about uncertain schedules for project funding which causes delays in their program. If funding for constant level of effort is provided, they would be able to grow only part of their dark matter program, and DES commissioning would be delayed by a year. Future initiatives would continue at a low level. If only flat-flat funding is available, FNAL management reported that the DES operations may be further delayed due to lack of available personnel, the dark matter program may shrink to a single technology, further improvements to Auger South would not be supported, efforts on QUIET-II and future dark energy initiatives would be minimal and most of the R&D for future experiments would end.

Panel Findings, Comments, and Recommendations

Dark Matter

The panelists all found that FNAL has a very strong program in dark matter with comments such as "FNAL leads all national laboratories in dark matter research", they are "well positioned to play an important role in Dark Matter research, a top scientific priority in all reviews of particle astrophysics", "they are the only lab with a significant investment in dark matter… and supporting multiple technologies", and are "clearly doing an excellent job."

A few had comments that the "specific choices that FNAL has made [in which projects to participate in] are fairly serendipitous" due to proximity to University of Chicago and particular interests of their scientists and they "should take care to assess where the dark matter field is going to ensure a balanced portfolio" in future planning.

The panel found their work on the individual dark matter experiments to be very strong. "FNAL has taken a major leadership role in CDMS/SuperCDMS at Soudan and done it exceptionally well". Their "contribution to CDMS-II was first-rate, crucial, and aligned with the special strengths a Lab brings to the table: experience with infrastructure development" and the "in the data acquisition system, where the high data throughput enabled CDMS-II to have superior knowledge of detector response through radioactive source calibrations." Regarding the proposed next phase, there were a few concerns such as "going ahead with the SNOLab ramp-up is inappropriate until this milestone [confirming the uniformity and reliability of the iZip towers] is passed". However, most panel members felt that it go forward expeditiously, commenting that FNAL should be supported in the "plan (with help from SLAC) to move this [SuperCDMS] to SNOLab where the backgrounds will be much lower and build it up to 200kg".

The panelists noted that FNAL "has helped develop [COUPP]", the "COUPP detector concept is particularly innovative and might offer [Weakly Interacting Massive Particle] WIMP discovery at the lowest imaginable cost" and "so far the results have been encouraging". The effort "exploits FNAL strengths in a similar manner [as CDMS]. They were all supportive of continuing with the 4kg and 60kg versions at SNOLab, saying "I'd rank it very high in FNAL's portfolio". Regarding a next-generation after COUPP-60, several panelists had comments such as "they must demonstrate additional background rejection" and "they must be reviewed in the context of the contributions of other projects in the dark matter field."

The panelists supported FNAL's efforts on DarkSide, saying "Synergies with other liquid argon detector projects make FNAL well suited to be involved in the DarkSide project". The "DarkSide effort is embryonic, but sensible" and the plan to install a 50kg version in Gran Sasso in 2012 "seems worthwhile". They were also supportive of the new DAMIC (Dark Matter In CCDs) effort which may also have other uses, saying "CCD camera technology may have useful applications to dark matter, especially to light WIMPS, currently a possibility for explaining CoGent [Coherent Germanium Neutrino Technology], DAMA [DArk MAtter], and CDMS data".

Many panel members commented that FNAL may be in a position to "take a leading role" in the coordination of the overall dark matter program: "they are in a good position to take a lead in managing the national dark matter effort, a need that was identified by the panel several times". Several noted that all efforts to determine one technology for a large future experiment "has been in the context of the Deep Underground Science and Engineering Laboratory (DUSEL), which skews the discussion somewhat" and were supportive of coordinated R&D efforts to help bring together the field sooner by developing "a combined facility which can screen materials and serve as a staging ground for new ideas on active neutron shielding and cosmogenic simulations"

and the "lack of facilities for measuring low levels of radioactivity has been a major problem in the US". "FNAL has also championed the idea of a test facility for DM [dark matter] at Soudan. I think this is an excellent idea". They also noted that "FNAL could play an important and expanded role in supporting dark matter research by...provide technical and management support for dark matter experiments, especially as the detectors get larger and more complicated, develop and manage facilities for material studies for low background detectors, especially for measuring radioactive impurities in materials, and organizing workshops on detector technologies".

Dark Energy

The panelists agreed that DES is "*the* dark energy project of the years 2013-2016 worldwide" and "FNAL provides excellent leadership" and noted that the "unique camera exploits silicon detector technology developed jointly by DOE national laboratories for elementary particle collider physics" and is "well aligned with the special infrastructure and strengths of FNAL". Their program has had a "strong start in DE by leading the DES-DECam, which provides good positioning for the LSST future, and [has benefitted from] the SDSS heritage as well". They all recommended continued support for DES, saying "now is not the time to squeeze overly on this effort".

Their work on SDSS is winding down and panelists had comments such as it "is a very successful research program that is mapping a large portion of the sky with a sophisticated digital telescope. It involves of a large number of collaborators and institutions that was nurtured and managed by FNAL. It is an example of what can happen when scientists and technical staff at DOE laboratories collaborate with university groups to exploit HEP expertise and facilities to develop sophisticated instruments".

It was noted that work on DES "will be important for LSST" though several had comments such as they view FNAL's role as "subsidiary to SLAC's leading role" and they may need to "participate with modest effort until DES ramps down".

Regarding their small role in JDEM, which has now been absorbed into WFIRST, panelists noted that a "delay could allow temporary strengthening of the DM projects, where FNAL could lead and coordinate the DOE-DM effort" and voiced concerns about FNAL's role, saying "whoever leads the WFIRST/Omega effort may or may not choose to coordinate help from FNAL" and noted that plans for the National Aeronautics and Space Administration (NASA) going forward on WFIRST are still unclear.

The panelists were mixed on support on future Baryon Acoustic Oscillation (BAO) experiments, saying "BigBoss with LBNL will be extremely important for a systematic BAO investigation", "I was interested to learn about DESpec as a cost effective way to extend the reach of DES...and is complementary to BigBOSS" but "I'd rank BigBOSS at the bottom of priorities, with QUIET-II and the 21 cm BAO".

Most panelists had comments on the 21 cm BAO effort such as it is "an example of very smart FNAL scientists exploring a terrific project, but, a project that doesn't really fit well into the

DOE High Energy mission" and is "better suited for the radio astronomy community". Most agreed that "after writing a few great papers this project really should be passed out of DOE stewardship" and the "price tag is the cost of senior colleagues, whose hobby may end up spawning a new research field at FNAL which is not the highest HEP priority".

High Energy Cosmic- and Gamma-ray

The panelists all agreed that "FNAL has done an excellent job of project management and operations" for the Pierre Auger Observatory, and the "Fermilab contribution is modest, but relevant for a national lab and has significant impact". "Auger has done fantastic work and really proven the existence of a cutoff (whatever the origin) in the highest energy cosmic rays". It was noted that "the FNAL scientists are also doing first-rate work analyzing the data and reconciling systematic issues with collider results" but it "is not clear...that FNAL brings special prowess that is not available in University program". A few felt that the FNAL effort should be reduced, saying "given the maturity of this program it might be possible to realize some efficiencies" which could "provide some financial support for other (FNAL) programs".

Most were concerned about the future role of FNAL and the HEP community in cosmic-ray experiments, with comments such as "Auger results are impressive, but the future thrust needs to be clarified", "since Auger north will not be built, should FNAL still be doing service work at the rate of $2.4 M per year and 8-9 people? Can they redirect some of this...work without losing physics ground?" They felt that due to "the reality that there will likely be no Auger North", FNAL and the collaboration "needs a realistic plan for the future. More statistics will help, but not solve the problems. They need to figure out how to reconcile with differences in similar data with the HIRES [HI RESolution Fly's Eye] experiment and they eventually need a sunset plan for operations."

It was noted that "the upcoming science goals are all refinements of things already published" and "simply continuing the experiment as it is...is unlikely to result in a major breakthrough". Several panel members were supportive of investigating future enhancements, saying "if the proposed R&D pans out it could be transformative because the rate of data collection would increase significantly if the microwave or radio efforts augment (or replace) the fluorescence detectors and allow 24/7 data taking" but "it may be advisable to check on the R&D progress as a gate for constant funding".

The panelists all recommended that the effort on Auger needs to "be evaluated in the future to determine if it is still within the main research goals of the DOE HEP program". FNAL may need to develop an exit strategy if hosting the project office is not a high priority for the future. They may also want to consider their continued level of scientific effort. A review could be done stand-alone or within the context of "a `senior review,' such as NASA conducts for operating facilities". If no compelling "justification can be made for continued participation that is within the DOE mission" then FNAL should "pull out at that time".

Cosmic Microwave Background

While the panelists found that the "CMB efforts were interesting", many commented that it was

not "so clear how good a fit it is and how relevant FNAL is to that effort". Though some effort funded by the "QUIET-II project office, should it ever be formed, might be appropriate" but they did not find "any strong reason for KA13 [the HEP non-accelerator program budget code] to support this effort".

Cosmic Frontier – other

The panelists commented that the "Holographic and Axion experiments were fascinating", "it is nice to see some smaller scale innovative work" and it is a good example "of how HEP technologies at Fermilab can be exploited for related science research". Several commented that these are "refreshing ideas adept for university connections" and "preserving these [types of] efforts is important since they represent the initiative of new young researchers (our most valuable resource) and they highly leverage FNAL uniqueness".

The panelists noted that the "Holometer effort is potentially of great importance, and I encourage further theoretical validation of the technique prior to ramping up spending on this project".

The panelists remarked that the "PI of the GammeV effort received an OJI [Outstanding Junior Investigator award], a rare occurrence in the Lab system, which validates the quality of this work". It was felt that "given the magnets and lasers present at FNAL, it is very natural to conduct this research at FNAL" and that "it is by nature broad-band in its sensitivity to the mass of the axion, and thus complementary to [Axion Dark Matter eXperiment] ADMX. Many panelists recommended that "this activity [be placed] at a very high level of support, just below the direct Dark Matter effort".

Their detector R&D effort on solid xenon was supported by the panel since it "could have interesting applications to double beta decay, dark matter, neutrino detection, axions".

Many panelists agreed that "while it is proper to experiment with relatively inexpensive projects that test new ideas, when these projects become expensive they have to compete with other initiatives on the national scene" and the "next steps in both of these programs need to be reviewed carefully in light of the national priorities".

Overall

The panelists noted that Fermilab has had a long history of being involved in the Cosmic Frontier, and they have "developed a diverse and excellent program in non-accelerator research" that "aligns well with the DOE program objectives".

The panel felt that Fermilab is in a special position as the sole remaining domestic lab with accelerators supporting accelerator-based high energy physics and that there should be a much higher threshold for redirection of effort to their non-accelerator physics program. Therefore they recommended that the non-accelerator program at Fermilab be maintained at approximately the current level of effort. "Merging a robust non-accelerator program with the future accelerator program has many intellectual and technical benefits, but may pose financial problems when funds are tight" but their "continued leadership in [non-accelerator research]

should be supported".

All the panelists agreed that FNAL has the strongest and broadest program in dark matter and a unique position among the labs. The panel members recommended that FNAL investigate ways to take the lead in coordinating the efforts for dark matter experiments for the HEP program. Though all the panelists agreed that dark energy is an important part of the program, with successful roles in SDSS and DES, most recommended that it be second in priority and that the lab consider a rebalance of dark matter and dark energy support. Many panelists felt that it may be time for "FNAL to capture the lead in dark matter by converting some of the DE personnel and effort over to DM". It was felt that they have done an outstanding job of managing and operating Auger and they now need to plan its future path in terms of the FNAL commitment and its place in the DOE HEP program.

The panel commented that "Fermilab has established a very nice program of innovative ideas led by excellent young scientists" and "encouraging the best young scientists to reach their full potential is also a high priority". However there was concern that these ideas "should not be an excuse for multiplying small projects" that will get big. The program should be organized in order to make sure that only the most interesting projects emerge and get bigger. It was recommended that redirection of effort and funding within the non-accelerator program, rather than increased support, be used if they want to continue the set of new small-scale initiatives, such as the holometer and axion searches, which are a small part of the overall Fermilab budget, but a larger fraction of the non-accelerator budget.

Overall the panel ranked the dark matter efforts as the highest priority, followed by new initiatives and their current dark energy experiments and the current efforts on Auger. Future efforts on Auger, CMB, and new dark energy initiatives were ranked lowest.

Lawrence Berkeley National Laboratory (LBNL)

Program Description

The LBNL non-accelerator research program funded by DOE-HEP consists of work in the cosmic and intensity frontiers. The table below is from the lab's report of their actual costs and FTEs in each category during the past 2 years and their proposed efforts and funding for the coming 3 years. The total funding actually provided by HEP during FY09 and FY10 is in the last row. The lab's costs may differ from the funding provided due to carry-over funds being applied or transfers from other budget codes. The funding includes scientist support as well as R&D and operations support for the experiments. Project fabrication funding, operations support for Daya Bay and R&D for dark energy experiments is provided in a different budget. The FTEs shown include scientists only.

LBNL has had a strong program in cosmology over the past twenty years. It has historically been funded at a low level by HEP but has had profound impact on the entire field, starting with George Smoot's work on the Cosmic Background Explorer (COBE) space mission in the early

1990's and followed by the co-discovery of dark energy via supernova measurements by Saul Perlmutter and his group. The cosmology/dark energy group has continued to grow and now accounts for about half of their program in HEP. Along with scientific leadership, they bring experience and expertise in instrumentation design and development, mission design, simulations, data pipelines, analysis and computation to the dark energy efforts.

Table 6 – LBNL funding and personnel

		FY09 actual	FY10 actual	FY11 proposed	FY12 proposed	FY13 proposed
Dark Matter	$K	0.0	33.0	353.0	532.0	550.0
	FTE	0.0	0.1	0.7	1.8	1.8
Dark Energy	$K	5411.0	5657.0	6117.0	5973.0	6105.0
	FTE	20.7	19.9	19.7	19.2	19.1
CMB	$K	202.0	199.0	208.0	208.0	223.0
	FTE	0.6	0.6	0.6	0.6	0.6
Cosmic-other	$K	1035.0	1012.0	1177.0	1179.0	1219.0
	FTE	3.5	3.4	4.0	3.6	3.6
Neutrinos	$K	496.0	672.0	760.0	735.0	753.0
	FTE	3.3	3.1	3.0	3.0	2.9
TOTAL	$K	**7144.0**	**7573.0**	**8615.0**	**8627.0**	**8850.0**
	FTE	**28.1**	**27.0**	**28.0**	**28.2**	**27.9**
TOTAL DOE HEP provided	***$K***	***7348.0***	***7732.0***			

LBNL has recently started participation in the Large Underground Xenon (LUX) dark matter search experiment. They plan to provide management support for the experiment, technical contributions and scientific effort and are requesting increased funding to support this.

LBNL continues its leadership roles in dark energy with several efforts using different methods in a phased program of experiments. They are leading operating experiments studying nearby and distant supernova searches (Supernova Factory, Supernova Cosmology Project) and baryon acoustic oscillations (BOSS). The LBNL Microsystems Lab had key roles in developing the CCDs for DES, which will begin operations in 2012, though they have only a minor role in data analysis. They spearheaded the design of a space-based dark energy experiment with the SNAP and JDEM concepts. However the recent (August 2010) Astro2010 report, recommended as its top space-based priority a new mission, WFIRST, which would do dark energy as well as other science topics, instead of JDEM. LBNL is closing down their effort on JDEM in early 2011 and plan to keep their options open for participation in a future space mission, led by NASA or perhaps the European-led Euclid. Their major proposed future dark energy experiment is BigBOSS, a stage-IV dark energy experiment, which would fabricate new instrumentation to install on the Mayall telescope at Kitt Peak National Observatory in Arizona. The National Optical Astronomy Observatory (NOAO) reviewed and approved their BigBOSS proposal and they are now working together to respond to the review and develop a path towards funding.

They are also investigating participation in the SLAC-led DOE efforts on LSST. Operations funds for BOSS are included in their budget.

A small effort at LBNL has provided key contributions to CMB efforts on PolarBear, Planck data analysis and computational CMB. The experiments are primarily funded by NSF or NASA.

In the Cosmic-Other category, they have strong efforts theoretical studies, simulations and modeling which complement and enhance their experimental efforts. Some of these efforts that are directly related to the experiments are funded by the non-accelerator experimental program and were reviewed, whereas others are funded by the theory program at DOE.

At the intensity frontier, LBNL had a leading role in the KamLAND reactor neutrino experiment in Japan and are now providing the technical and scientific leadership for the US contributions to the Daya Bay reactor neutrino experiment in China. The US project manager is at LBNL, but is funded on project funds. The group supported on the non-accelerator research funds includes the US scientific spokesman and members working on technical and hardware contributions, scientific studies and simulations, and software and computing.

Their FY2011 funding request includes additional support for their management efforts on LUX, increased science effort on Daya Bay and increased support to fully fund their current scientists. Some funding has been provided through special fellowships, carry-over or project funds in previous years. The additional funding requested in future years maintains their current level of effort.

Panel Findings, Comments and Recommendations

Dark Matter

The panel members were almost unanimously supportive of LBNL's "self-described 'fledgling' role in LUX", saying it may be the "best thing that has happened to the experiment". "LBNL's contribution to LUX of an experienced scientist/manager aligns with LBNL's strengths, and I rank it a high priority."

While considering it a positive move for LUX, several panelists had concerns about the size of the effort, saying it is a "unique DM niche for a Lab but they have a tiny contribution", "the lab's role is minor and under less than optimal budget scenarios may be considered as not the highest priority" and if they have plans to expand their roles in dark matter in the future "I recommend coordinating this with the other laboratories to avoid duplication of effort". One panelist noted that "Berkeley could play a role as national lab to foster dark matter direct search using xenon".

Dark Energy

The panelists all had excellent views of the dark energy program, with comments such as "LBNL has provided world leadership in Dark Energy Science" and this is "a strong program with a long history in this research".

The panel members were all impressed with the supernova work, saying "Perlmutter's work on SN is excellent", his group is "highly distinguished", and they are "still driving the field of SN research". Several panelists remarked that the effort on the "most stringent controls of systematic uncertainties" that "definitely put on a firm basis the initial dark energy discovery" is a tradition in the high energy physics community and not likely to have been done by the astronomy community at this time. They recommended that the supernova effort "warrants solid support."

The panelists were positive regarding on the BAO efforts at LBNL, saying the "LBNL group plays an important role in BOSS", they are "leaders in the BAO experiments on the ground and are leading the BigBOSS proposal" and these efforts are "the result of their studies on how BAO on the ground can complement space-based work." Several commented positively that BigBOSS "would certainly provide a leading role for LBNL". However, they were mixed on the priority in the program, with some commenting that BigBOSS "would be one of the first Stage IV experiments (together with LSST)", the "great promise combined with the lead of BigBoss spectral BAO/DE research may warrant additional support" while others had comments such as Astro2010 "did not endorse BigBOSS, but suggested a competition among mid-sized experiments", and their "unique contributions distinct from the DES/LSST/WFIRST sequence were not clear at all" and "seem unlikely to bring about the type of transformative change in view that a large theta-13, discovery of the Dark Matter, or discovery of B-modes would bring."

The panel members commented that "LBNL has a unique world class group in dark energy which has worked hard to move forward the field towards a space mission" and "over the last 10 years the LBNL team has developed a great level of expertise for a satellite mission – both technically and scientifically." Though funded out of a different DOE program and not part of this review, several panelists commented on their Microsystems lab efforts, saying that they have "also been the drivers behind the instrumentation that have enabled these fields", the "lab is a center of excellence and has done a terrific job in supplying thick CCDs capable of infrared sensitivity to a number of telescopes, most recently DES" and it is important to note that "it takes a long time to build up that level of capability, and one should therefore make sure it does not erode" since "technology driven initially by one need may turn out to open up research in another area."

The panel members were mixed on how much effort LBNL should put in continuing to pursue a space option. The future of a space based mission "is less clear" and there was "some concern about the large group of excellent scientists devoted to this part of the program. Several panel members felt that the "DOE investment in the JDEM effort which should not be lost" and commented that their work has already provided "an extensive toolbox for the design of any space-based telescope, as well as spinoffs for ground based work." The sense was that LBNL "should continue with [investigating] space-based efforts for the time being as it is such a strong group, but remain aware of the need for a plan B in case a space option does not look realistic", and a few felt that if WFIRST doesn't go forward, LBNL should "be given the support and encouragement to seek another country or the EU [European Union] who can help put the mission in space." However, others said "I cannot muster much support for the space-based

Dark Energy activities", and the "strong science case that WFIRST will have a discovery potential for DOE High Energy topics beyond LSST or even DES did not seem to me to be made sufficiently to rank this activity high."

Since the "leadership of DES is at Fermilab, and LSST at SLAC", some panel members felt that what "LBNL can do [next] is not clear" and "this group must sort out over the next few years what they can do." Overall the panel recommended that they receive "a year or so of sustained support at current levels while the situation clarifies" and they redirect efforts if needed. Also, they recommended encouraging "the lab to carefully monitor the resources assigned to this effort to make sure that other programs don't suffer from this quest for a space mission."

Cosmic Microwave Background

The panel members were mixed on their support for the LBNL efforts in CMB. Regarding PolarBear, several had comments such this is "terrific science, and LBNL's facilities, history, and intellectual environment tend to indicate support for the CMB science" but one panel member remarked that "I can't give a useful judgment on whether this activity is better or worse than the other excellent work going on in this field". Several had concerns such as the effort's "integration with other funding sources including NSF was un-discussed" and perhaps NSF should "be purchasing effort from LBNL". Many were impressed with the computational work for Planck and other data analyses, saying "the work was, in contrast, well discussed and had clear glimmers of excellence and centrality"

A few panel members commented on advanced detector work for CMB experiments, saying that the "DOE should support detector activities around CMB, to prepare for the next CMBPol [CMB-polarization experiment], possibly with earlier developments on ground" with another saying that "the focus on radiation hard designs suitable for a future CMB space mission is somewhat premature."

Overall the panelists did not recommend strong support of this effort, saying that the "presentations did not really convince me that the LBNL contribution to CMB was crucial" and "it is not clear that there is a strong need for DOE support."

Cosmic Frontier – other

The panel members agreed that the theory, simulations and modeling is a "very strong effort and I especially liked how well it was integrated with the various experimental programs", they have "an excellent group at the frontier between theory and observation" and the "theoretical cosmology work presented by Seljak is excellent."

While it was agreed that "this is an excellent investment for the science return" and DOE "should definitely continue supporting them", several had questions about "where should the funding for this effort come from?" Several panelists had comments such as "while I believe their efforts fit better with the DOE's theory program, I have no problems maintaining the status quo and if necessary to argue that this group has been grand-fathered in".

Neutrinos

The panel members all found LBNL's role on Daya Bay to be strong, saying they are "leading the US effort on Daya Bay", it "brings into play the special resources of a lab, including the US Project Manager, the US onsite safety officer, and the finance-control officer" and the "Daya Bay groups at LBNL and BNL are doing well on this important neutrino experiment." LBNL provides "a very solid and broad contribution to a key experiment", and they have "an important role in Daya Bay, especially in the liquid scintillator quality control and in testing PMTs from MACRO [Monopole Astrophysics and Cosmic Ray Observatory] and Hamamatsu." Daya Bay was noted to be a "critical experiment to the field" and will do "a crucial measurement required for the planning of new long baseline experiments."

The panelists were impressed by the scientific aspects of the LBNL effort, with comments such as "the science group is strong", "Kam Biu Luk, who ten years ago was perhaps overshadowed by some of the other scientists at LBNL, has really come into his own as co-leader of the U.S. Daya Bay collaboration, and "Luk has done an excellent job of organizing multiple university groups to mobilize for a short term experiment, including active participation by Chinese groups, the largest of which is IHEP [Institute of High Energy Physics]." Though China provides two-thirds of the funding, the "US effort is very visible", therefore "this represents excellent leverage for an important result."

Most panelists recommended strong support for this effort, saying it "must rank among the very highest priority activities in KA13. One-shots for travel and construction concerns should be provided to ensure completion of the construction and readiness of the experiment and data processing" and "the LBNL effort should be strongly supported".

Overall

Regarding the overall program, the panel felt that LBNL is an extremely productive lab, with an impressive quality of research and excellent scientists and facilities. It has been the leading cosmology lab in the world with impressive contributions to the field, including the CMB work of COBE and the discovery of dark energy. Their detector development and capabilities are a unique center of competence. The multiple synergies and joint appointments with University of California (UC) at Berkeley make it one of the most attractive places in the world to the best scientists. They have been good stewards in the field by redirecting efforts and have struggled to maintain their group by using other funds and initiatives to fund their groups over the last few years.

The panel recommended that DOE provide the resources to maintain the high level of science and excellent instrumentation efforts that have been built up at LBNL. It was also recommended that the lab work on comprehensive planning of the dark energy program to ensure it stays strong and broad. Several panel members recommended that strong support for Daya Bay be the highest priority followed by support for current dark energy, dark matter, instrumentation and CMB experiments, while a space-based dark energy mission should be the lowest priority.

SLAC National Accelerator Laboratory

Program Description

The SLAC non-accelerator research program consists of work at the cosmic and intensity frontiers. The table below is from the lab's report of their actual costs and FTEs in each category during the past 2 years and their proposed efforts and funding for the coming 3 years. The total funding actually provided by HEP during FY09 and FY10 is in the last row. The lab's costs may differ from the funding provided due to carry-over funds being applied or transfers from other budget codes. The funding includes scientist support as well as R&D and operations support for the experiments. Project fabrication funding is provided in a different budget. Actual costs were not provided by SLAC for FY09.

Table 7 – SLAC funding and personnel

		FY09 Actual	FY10 actual	FY11 proposed	FY12 proposed	FY13 proposed
Dark Matter	$K	0.0	1429.0	1703.3	2397.9	2615.8
	FTE	0.0	4.9	6.3	9.4	10.0
Dark Energy	$K	0.0	5299.6	5579.4	6816.2	7265.4
	FTE	0.0	20.3	22.3	27.4	28.2
High Energy Cosmic/Gamma	$K	0.0	11869.2	11498.8	11295.6	11178.1
	FTE	0.0	43.9	42.9	42.1	40.5
CMB	$K	0.0	0.0	462.2	872.6	1472.2
	FTE	0.0	0.0	1.7	3.2	5.3
Neutrinos	$K	0.0	3463.2	3505.8	3993.2	4228.6
	FTE	0.0	12.9	12.9	12.9	13.4
TOTAL	$K	**0.0**	**22060.9**	**22749.5**	**25375.5**	**26760.0**
	FTE	**0.0**	**82.0**	**86.1**	**95.1**	**97.4**
TOTAL DOE HEP provided	***$K***	***18945.0***	***20795.0***			

SLAC has been involved in non-accelerator research at a relatively low level for many years. This grew with the R&D effort towards a next-generation gamma-ray space mission in the early 1990's and then the selection of the proposal by the Stanford/SLAC-led team by NASA in 2000. SLAC's involvement in non-accelerator research has grown significantly since the Kavli Institute for Particle Astrophysics and Cosmology (KIPAC) was created at SLAC in 2003.

SLAC started a dark matter effort in 2009 with the joining of the SuperCDMS collaboration. An LDRD award in FY10 and FY11 provided funds for development of large diameter detectors and simulations that are needed for the next phase of SuperCDMS, proposed for SNOLab. From FY11 to FY13, SLAC physicists will be involved with SuperCDMS-Soudan operations and analysis. They will also continue R&D and design for the proposed SuperCDMS-SNOLab,

which they plan to co-manage with FNAL. They are requesting funds to approximately double their scientific effort in dark matter over the next 3 years. R&D funds are being proposed separately and not shown above.

The major part of their dark energy program is focused on leading the camera design and development for the LSST, the top priority ground-based experiment recommended by Astro2010. In addition, they also have a major role in the scientific planning and leadership for LSST. SLAC is also collaborating on the FNAL-led DES experiment, which will start taking data in 2012, and is investigating participation in the proposed LBNL-led BigBOSS, and a possible future space mission. In addition, they have scientific efforts on setting limits on dark energy through studies of clusters of galaxies using data from existing x-ray, optical, and millimeter-wave facilities. To carry out their responsibilities on the experiments, they are requesting significant increases in scientific funding for their dark energy efforts over the next 3 years. Funds for LSST R&D and fabrication, if it goes forward, would be provided separately.

SLAC has a leadership role on the NASA-DOE-International FGST, including the management of the fabrication and integration of the Large Area Telescope (LAT), the primary instrument on FGST and development and operations of the Instrument Science Operations Center (ISOC). The observatory was launched in June 2008 and started taking physics data right away. Along with their operational and computational responsibilities, they also have a large role in data analysis. They expect that the mission lifetime will be extended from the original 5 to 10 years and plan to continue leading the ISOC and continuing strong participation in data analysis, with a concentration on dark matter and other astrophysical measurements. They are also doing R&D for proposed participation on a next-generation ground-based gamma-ray observatory, the CTA. Their funding request over the next 3 years includes increased scientific participation in CTA R&D and design but a slow ramp-down of the FGST effort as operations become standardized. A separate proposal for R&D for CTA will be considered by DOE and is not part of the current funding request, which goes down approximately 3% per year.

SLAC support for CMB experiments has provided support for several scientists to participate in the BICEP (Background Imaging of Cosmic Extragalactic Polarization) series of experiments over the last few years, which search for B-mode polarization generated by gravitational waves and would provide a direct measure of the energy scale of inflation. BICEP results were published in 2009, BICEP2 is current taking data and the Keck Array is being integrated and will deploy in late 2010. A 2-year LDRD award was used for future technology development, and they plan to continue R&D on HEMT (High Electron Mobility Transistor) and bolometer technologies over the next 3 years, eventually leading to the optimal strategy for large-scale experiments. In the next 3 years they will also work on the development and the production of Ka and Q-band modules for QUIET-II, if it is approved by NSF, and R&D activities in support of the Polar Array experiment. They are requesting additional scientific support for these activities.

SLAC is the lead laboratory on the design and fabrication of the EXO neutrinoless double beta decay experiment. The EXO-200 phase is starting operations at the Waste Isolation Pilot Project

(WIPP) lab in New Mexico and SLAC is managing the operations of the experiment. They also are doing R&D for barium tagging and concept design for a next-generation experiment, EXO-1ton, which would be installed in a deep underground lab. They are requesting increased funding to fully support this R&D effort and exploit the EXO-200 science over the next 3 years.

With flat funding over the next 3 years, SLAC reported that they would be able to support current efforts on SuperCDMS, DES, LSST, FGST, and EXO-200, but R&D for a ton-scale EXO and for CMB experiments would be delayed. However, if the "SuperB" b-physics experiment doesn't go forward, additional migration to the non-accelerator program would allow R&D for EXO-1ton.

Panel Findings, Comments and Recommendations

Dark Matter

The panel members were all supportive of SLAC new effort on SuperCDMS and "found their contribution targeted on exactly what SuperCDMS needs and what SLAC does best: Management, Ge Tower Production, and Computing." The panel members all felt they "should concentrate on these tasks" and "a bigger involvement of SLAC could play an important role in helping to improve the production process, by shortening the fabrication time, while reducing cost" since "the greatest challenge that SuperCDMS faces is the reliable and economical fabrication of its detectors". It was felt that SLAC has "found a nice niche that meshes well with the FNAL effort", "adding Paul Brink to the SLAC staff makes a lot of sense" and that "moving computing to the lab is also a good idea and long overdue." Several panelists recommended that the SLAC effort be "strongly focused on yield, efficiency, and reliability of the detector production" since the "failure on these issues would render all the other work, for example, on the Monte Carlo, etc, inessential."

Many panel members pointed out that "there is no activity at SLAC on liquid xenon dark matter detectors" and that "with the EXO liquid xenon project it would seem to be natural that SLAC could play an important role in xenon for dark matter."

Dark Energy

LSST is "an excellent program, strongly supported by Astro2010", and it will be the "leading program of its kind in the world". The panel members were all supportive of SLAC's efforts on LSST, saying "they are clearly doing an excellent job on LSST", "LSST is the highest priority ground-based program and SLAC plays a leadership role", the "collaboration with other national labs is good" and the "overlap with SLAC strengths in all areas, from collaboration management through computing to infrastructure is overwhelming and positive, and a good use of Lab strengths". SLAC has a "major role in LSST as the lead for the camera with additional significant responsibilities in data management and simulations" and this "positions them to operate the LSST [dark energy] science center". One panelist commented on the overall LSST science program, saying "I place LSST as SLAC's highest priority, although it does seem to me that only a minority of this project really meets the DOE High Energy goals."

Most panel members supported their other dark energy roles in DES and "to a lesser extent, new initiatives in BigBOSS" and other experiments, commenting that it is "healthy to keep parallel analysis and development efforts at multiple labs" and that the "relative timescales" of the experiments, "helps avoid disjoint efforts across the labs".

Other panel members felt that "focusing the SLAC effort to seize the moment and focus on LSST is the most productive avenue" and didn't rank the work on "BOSS, BigBOSS, or even DES highly". Several panel members had comments such as the "SLAC group on DES is more like a university user group and while the effort on observational cosmology using x-ray observations to extract DE constraints produces interesting results one could argue that this would be a more natural fit for receiving support from NSF Astronomy Division or KIPAC." They recommended that in "a flat budget scenario, additional DE research SLAC is performing besides LSST might be an area to look for some cost savings."

High Energy Cosmic- and Gamma-ray

The panel members all agreed that "the Fermi project is excellent and SLAC plays a leading role" and "has had a critical role in both building and operating the LAT." "This is a good example of DOE and NASA working together harmoniously." They remarked that "the Fermi science program at SLAC is extraordinarily strong and they are "collaboration leaders in dark matter studies with Fermi" and "are leading or involved with all the dark matter search strategies/analysis." Their responsibilities on operations, including "instrument calibrations and configuration, is very proactively maintained." They're doing an "excellent job on the operation support center (ISOC)", "their efforts in making computing resources available to the collaboration have been extraordinarily valuable" and one of "the greatest SLAC contributions have been their role in software development and computing." Overall, the panelists agreed that "SLAC has been fundamental in the proposing and execution of the Fermi LAT and it is gratifying to see the successful science that has flowed from SLAC's vision."

Many panel members remarked on the size of the ISOC and analysis efforts going forward. "The science budget is the 2nd largest item in the SLAC non-accelerator budget, next to the funding for the ISOC." The "collaboration has produced a prolific number of papers but only a fraction of them is directly related to the HEP mission." However, several were concerned that the scientist effort "might even increase over time for preparation for a senior review around 2013". Regarding their effort on the ISOC, several panelists had comments such as "given my own experiences, I conclude that the ISOC group will become more efficient over time" and even though the request shows a decline in FTEs, "my own experience is consistent with a slightly higher reduction." "As the program continues, it does provide a possible place to ramp down faster and contribute to new initiatives" and they should "explore a faster ramp down on "community service" that could be done elsewhere".

Panel members made comments relevant to the overall US CTA effort as well as comments specific to each lab. The comments in the ANL section of the report and should also be considered.

Regarding the SLAC effort on CTA, the panel members were mixed. The experiment was seen as important with comments such as "the imaging atmospheric Cherenkov technique for gamma-ray astrophysics was born and came of age in the US" and therefore "it is important to maintain sufficient support for the US to remain prominent in this field" and "it is an obvious next direction to go given the strong effort on Fermi." However, others remarked that since it "was 4th choice out of 4 for Astro2010 and is a European endeavor, there is a higher bar to joining this effort", "relatively little telescope time is spent searching for dark matter" and there was concern that "funding is very tight, and the true targets of this activity are really not aligned with the DOE High Energy goals". Panel members were also concerned that the "schedule for the European led CTA project is quite accelerated – almost completely incompatible with US funding realities".

If CTA does go forward, they supported SLAC's role, saying "the SLAC team devoted to the CTA is very strong", and is "positioned to exploit SLAC's capabilities and infrastructure well. This is a case where the lab environment is stronger than the University environment" and "there is a clear role for a national lab given the sharp increase in scale relative to previous experiments in this field".

For SLAC, several felt they should consider "contributions that can fit with both the baseline (single mirror) or US telescope" which "would allow them to play a key role in CTA even if the funding for US design telescopes was not yet in place." Panelists commented that "camera development", "electronics development" or "computational and data handling resources" would be strong contributions for SLAC. However, there was concern that these might all come too late. The panel recommended that SLAC keep support for CTA at a low level of effort until a decision about participation is made.

Cosmic Microwave Background

Regarding their CMB activities, the panel members noted that "their work is of high quality" and the "SLAC group is working on a number of important experiments in the field but not leading the effort". Most of the reviewers had comments such as the "CMB activities are very relevant to the KIPAC" portfolio but it is "not clear that it requires DOE Lab resources" and should instead "continue to be supported through KIPAC funds", perhaps letting SLAC "provide work for others". The case for the CMB effort at SLAC was the "weakest that we reviewed" and the panel ranked the "potential impact as lower" than the efforts of the other labs "as most of this work could be done at a university."

Neutrinos

The panel was positive on their work on EXO-200, but concerned about where it fit in with all neutrino-less double beta decay experiments and the prospects for and level of involvement SLAC should have in a next-generation experiment. While the panel felt that "the personnel are excellent, among the very best at SLAC and in the field", several felt that it "is nearly tragic that such talented people have done such fine work, to be most likely surpassed by other techniques" used in the other experiments.

The panelists were all in agreement of continuing EXO-200, saying "SLAC is the major lab working on the EXO-200 [Time Projection Chamber] TPC detector at WIPP… [T]hey have an essential role and this work should be supported", it is "in a critical phase and support should continue for the 200 kg detector" and "it is important to finish this round of this double beta-decay experiment".

The panel members were concerned about pursuing this effort after EXO-200, saying the "long range future of EXO depends on barium tagging to reduce background" which is "still unproven after several years of R&D and progress seems very slow". Several commented that the "R&D has proven it is even more difficult than expected, and the R&D dollars would be better spent elsewhere." It was generally recommended that SLAC's effort in "Ba grabbing should be kept at a constant level of effort through the end of EXO-200. At that point, SLAC's efforts should be reviewed both in light of its successes and the plans for a future experiment". Several panel members recommended that "in a flat budget scenario this might be an area to look for some cost savings."

The panelists agreed that "before the DOE commits to fund a larger detector a careful review of all neutrino-less double beta decay experiments and technologies is advisable" and a future "Xenon experiment should compete with similar experiments" being funded by, and under the stewardship of DOE nuclear physics".

Many panel members hoped that the "EXO effort and expertise could gradually turn toward direct dark matter detection, where a great discovery with potential ownership by the DOE Lab program is more likely." They commented on the best use of the EXO scientists' expertise, saying they "could have used their noble gas experience to initiate support to a dark matter experiment using xenon", since "it has turned out that liquid Xenon is now a very attractive if not the most attractive medium for direct dark matter searches" "and the "strong assets of SLAC could have brought the US program into a clear lead in the direct detection of dark matter with liquid Xenon".

It was seen as important to continue their effort on EXO-200 operations, but the effort on the next-generation of EXO and CTA was felt to be in the middle of the list of priorities. Future EXO efforts should be reviewed in the context of all neutrino-less double beta decay experiments.

Overall

The panel members commented favorably on the SLAC non-accelerator program, and felt that the lab has done an excellent job of transitioning from a major HEP accelerator program and broadening the lab's scientific scope. Their broad, impressive program is now the largest DOE non-accelerator research program of all the labs. "Synergies with Stanford and KIPAC…makes the SLAC scientific environment very stimulating" and "it also gives SLAC tremendous flexibility to absorb personnel and reprogram" and to attract world class scientists.

In comparison of the efforts in their program, the reviewers commented that "SLAC has made

major contributions to Fermi, LSST and SuperCDMS" and these should remain the highest priority, though they may consider ramping down parts of FGST in the coming years. It was felt that their emphasis on DE and DM in the future is well placed and aligned with the HEP program.

It was seen as important to continue their effort on EXO-200 operations, but the effort on the next-generation of EXO and CTA was felt to be in the middle of the list of priorities. Future EXO efforts should be reviewed in the context of all neutrino-less double beta decay experiments. It was also felt that CMB activities, though good, should be lowest priority for being supported at the lab level. Other dark energy activities, that aren't in direct support of LSST, were also felt to be not high priority and could be a place to look for cost savings.

Concerning funding availability and priorities, the panel members commented that their funding is nearly half the KA-13 total and recommended that the main source of increased effort should be from redirection from the accelerator-based program. They also recommended that SLAC review its program to identify unique efforts that need the support of a lab and aren't something that could be done at a university.

APPENDIX A – Review Panel

Panel Member	Institution	Email
Kathleen Turner, Chair	DOE-HEP	kathy.turner@science.doe.gov
Bob Cousins	UCLA	cousins@physics.ucla.edu
Jordan Goodman	Maryland	goodman@umdgrb.umd.edu
Frank Calaprice	Princeton	calaprice@princeton.edu
Julie McEnery	GSFC	julie.e.mcenery@nasa.gov
Pierre Binetruy	France	binetruy@apc.univ-paris7.fr
Harry Nelson	UCSB	hnn@hep.ucsb.edu
Ulrich Becker	MIT	becker@mit.edu
Gary Hinshaw	GSFC	gary.f.hinshaw@nasa.gov
Randy Johnson	Cincinnati	randy.johnson@uc.edu
Klaus Honscheid	Ohio State	kh@mps.ohio-state.edu
Prisca Cushman	U. Minnesota	prisca@physics.umn.edu
Nick Suntzeff	Texas A&M	nsuntzeff@tamu.edu

APPENDIX B – Review Agenda

DOE Review of Laboratory Non-Accelerator-based Research
September 27 – October 1, 2010
Doubletree Inn, 8120 Wisconsin Ave., Bethesda, Maryland 20814

Sept. 27

3 – 6pm Executive Session

Sept. 28

8:30am-12pm **SLAC**

Introduction	David McFarlane (15+10)
Non-accelerator program overview	Roger Blandford (30+10)
High Energy Cosmic Particles program: Fermi GST	Seth Digel (35+10)
Fermi ISOC and computing	Rob Cameron (20+5)
Break (15)	
High Energy Cosmic Particles program: CTA	Stefan Funk (20+5)
Dark Energy Program (LSST, DES, JDEM)	Steve Kahn (45+10)

12:20 – 1:20pm **Executive Session** (working lunch)

1:20 – 3:30pm **SLAC**

Neutrino masses and mixing: EXO-200 and EXO R&D	Marty Briedenbach (35+10)
Dark Matter program: SuperCDMC	Eduardo Do Couto E Silva (35+10)
CMB science and R&D	Sarah Church (20+5)
Budget planning and conclusions	David MacFarlane (10+5)

3:30–4:30 pm **Executive Session**

4:30 – 6pm **FNAL**

Overview of FNAL program	Craig Hogan

Sept. 29

8-8:30am **SLAC**

Answers to questions from previous session (if needed)

8:30am – 12 noon **FNAL**

Dark Energy	Josh Frieman (60')
Dark Matter	Dan Bauer (60')
Cosmic Particles	Sein Ahn (30')
New Inititiatives	Aaron Chou (30')

noon – 1:30pm **Executive Session** (working lunch)

1:30pm – 4:30pm **BNL**

Introduction	Steve Vigdor (15')
Daya Bay research program	Steve Kettell (30')
Daya Bay from Commissioning to Physics	David Jaffe (30')
Dark Energy Science Program	Erin Sheldon (30')
Focal Plane Modules for the LSST camera	Paul O'Connor (30')

4:30–6pm **Executive Session**

Sept. 30

8-8:30am **FNAL**

Answers to questions from previous session (if needed)

8:30-9am **BNL**

Answers to questions from previous session (if needed)

9am-1pm **LBNL**

Overview	(Bob Cahn , 20+10)
Daya Bay	(Kam-Biu Luk, 15 + 10)
SN program	(Saul Perlmutter, 25 + 10)
BAO: BOSS and BigBOSS	(David Schlegel, 25 + 10)
Break	
JDEM/WFIRST Science	(Michael Levi, 20 + 10)
Theory	(Uros Seljak, 15 + 5)
DES and Instrumentation	(Natalie Roe , 15 + 5)

1-2:30pm **Executive Session** (working lunch)

2:30–5:30pm **ANL**

Introduction & Overview	Harry Weerts (10 min)
Neutrino	Maury Goodman (20 + 10 min)
High Energy Cosmic Particles	Karen Byrum (30 + 15 min)
Dark Energy & Cosmology	Steve Kuhlmann (30 + 15 min)
CMB	John Carlstrom (30 + 15 min)
Summary	Harry Weerts (5 min)

5-6pm **Executive Session**

Oct 1

8-8:30am **LBNL**

Answers to questions from previous session (if needed)

8:30-9am **ANL**

Answers to questions from previous

9-11am **Report writing**

11am-noon **Review Closeout (Executive Session)**

12 noon **Review Ends**

APPENDIX C – Review Charge

Department of Energy
Washington, DC 20585

SEP 7 2010

MEMORANDUM FOR KATHLEEN TURNER

FROM: GLEN CRAWFORD, DIRECTOR
RESEARCH AND TECHNOLOGY DIVISION
OFFICE OF HIGH ENERGY PHYSICS

SUBJECT: Laboratory Non-Accelerator-Based Research Review

The mission of the High Energy Physics (HEP) program is to understand how our universe works at its most fundamental level. This is achieved by our program goal of exploring the fundamental interactions of energy, matter, time, and space in order to understand the unification of fundamental particles and forces, seek the identities of the mysterious forms of unseen energy and matter that dominate the universe; search for possible new dimensions of space; and investigate the nature of time itself.

This letter is to request that you conduct a review of HEP-supported laboratory research efforts in the area of Non-Accelerator-based Physics on September 27 – October 1, 2010, at the Doubletree Inn in Bethesda, Maryland.

The non-accelerator research area has efforts in two of the three frontiers (Cosmic, Energy, and Intensity) in the HEP program. The Cosmic Frontier investigates fundamental properties of matter, energy, space, and time using data from astrophysical sources. Such investigations complement particle accelerator-based research and reveal new phenomena and insights and a deeper understanding of fundamental physics and the makeup of the universe. The Intensity Frontier uses intense particle beams and highly sensitive detectors to investigate fundamental forces and particle interactions by studying events that occur rarely in nature. Experiments using data from nuclear reactors and astrophysical sources to study properties of neutrinos are part of the Non-Accelerator-based research program.

Recent National Research Council (NRC) and Federal Advisory Committee reports provided guidance for the Cosmic and Intensity Frontier programs. In June 2008, the Particle Physics Project Prioritization Panel (P5) recommended a 10-year plan for the three frontiers within several funding scenarios. In October 2009, the Particle Astrophysics Science Assessment Panel (PASAG) recommended an optimum program that addresses the highest priority science in particle astrophysics within different funding envelopes, as well as providing prioritization criteria for HEP involvement. The NRC's Decadal Survey of Astronomy and Astrophysics (Astro2010) August 2010 report recommended priorities for the Department of Energy (DOE), the National Aeronautics and Space Administration, and the National Science Foundation for the next decade which influence the opportunities for DOE participation. The three agencies will coordinate efforts to develop an optimized program in response to the recommendations.

The purpose of this review is to assess the quality of the recent scientific performance by these research groups, the merit and feasibility of their proposed research for achieving the scientific goals and milestones of the field, and the relevance of their research efforts to the overall HEP mission. When evaluating the laboratories programs, the recommendations made by P5, the PASAG, and Astro2010 should be considered, as well as the criteria for DOE HEP participation in Cosmic Frontier activities developed by PASAG. We are particularly interested in a review of the labs' research contributions along the following programmatic thrust lines:

- Dark Matter
- Dark Energy
- High-energy Cosmic Particles (cosmic rays, gamma rays, neutrinos)
- Neutrino masses and mixing
- Other efforts (e.g., Cosmic Microwave Background, theoretical studies, computational studies, other scientific thrusts, management, etc.)

For each individual laboratory research group, we request a specific evaluation of:

1. The quality and impact of the research by the group in the recent past;
2. The scientific significance, merit, and feasibility of the proposed research;
3. The competence and future promise of the group for carrying out the proposed research;
4. The adequacy of resources for carrying out the proposed research, and cost-effectiveness of the research investment;
5. The quality of the support and infrastructure provided by the laboratory; and
6. How well the group's activities relate to the overall HEP mission.

The final report should outline the laboratory-based HEP research program in each of these thrusts and discuss any unique and important elements that the laboratory programs bring to bear in addressing these research topics. In this context, we also request a comparative assessment of each laboratories overall effectiveness when compared with its peers, as well as an assessment of overall effectiveness when compared with university groups. The overall evaluation of the laboratory research groups will be an important input to the process of optimizing resource allocations with the various research thrusts.

The laboratories should provide relevant information which addresses these items in advance of the review. Their proposed program should be described for a variety of funding scenarios that you provide to them.

I encourage you to interact with the laboratory groups at the review and provide them with whatever immediate feedback you find appropriate. Upon the completion of the review, reviewers should send a letter summarizing their findings and evaluations, which address both the overall assessment of laboratory contributions to the research thrusts noted above and the individual laboratory evaluations. The letters will be confidential

within HEP. Individual laboratory evaluations will be summarized and conveyed to the laboratories. The overall assessment of laboratory contributions to the research thrusts will be incorporated into a summary report from HEP. I would like to receive the individual laboratory evaluations and the summary report no later than November 15, 2010.

cc: D. Kovar, DOE
M. Procario, DOE
M. Salamon, DOE
H. Weerts, ANL
T. Ludlam, BNL
S. Vigdor, BNL
Y. Kim, FNAL
G. Bock, FNAL
J. Siegrist, LBNL
D. MacFarlane, SLAC