Report of the DOE Review of Laboratory Detector R&D Activities

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Executive Summary

A review of the laboratory generic detector research and development program (detector R&D) funded by the Department of Energy (DOE) High Energy Physics program was carried out in Bethesda, Maryland on July 8-10, 2009. There were eight U.S. university faculty and two European laboratory directors acting as reviewers who provided verbal feedback at the review and individual review letters afterward. Howard Nicholson, DOE program manager for detector R&D was in charge of the review, and there were a number of personnel from the DOE Office of Science including Associate Director, Dennis Kovar and Research Director Glen Crawford who attended many of the sessions.

Reviewers were especially impressed with the Micro Systems laboratory at LBNL which has developed CCD's widely used in cameras for Dark Energy studies along with the quality of the technical staff and management personnel. Reviewers were also impressed with the breadth of SLAC's detector program with particular strength in sensors, electronics, and data acquisition systems and with SLAC's technical staff and management personnel. Reviewers felt that the small amount of funding Brookhaven received was leveraged very effectively with the Instrumentation Division there which has had an outstanding reputation over the years in developing new detector systems for particle physics research. Reviewers thought that Argonne was working on several high payoff, high risk projects and that one project, the development of a resistive plate chamber digital hadron calorimeter which was primarily motivated as a detector subsystem for a future international linear collider, was taking up a large fraction of the base budget for an effort which was currently low priority for the DOE Office of High Energy Physics. Finally, although reviewers were impressed with the potential of the Fermilab 3D silicon program, they were quite critical of the liquid argon effort which they thought was not making appropriate use of worldwide research and development efforts in liquid argon detectors, and they were critical of the lack of central management of the detector R&D program at Fermilab.

Reviewers were asked to provide an overall rating for each lab evaluating their contributions to the national effort in detector R&D. On a scoring system where 5 was outstanding, 4 excellent, 3 very good, 2 good, 1 fair, and 0 poor, LBNL received an overall score of 4.8, SLAC received a score of 4.6, Brookhaven received a score of 4.1, Argonne received a score of 3.3, and Fermilab received a score of 2.5.

Many of the reviewers recommended that funding for the detector R&D program at Fermilab be reduced, funding for the Argonne program remain the same, and funding be increased for the Brookhaven, LBNL, and SLAC programs. Other major reviewer recommendations included establishing an annual detector workshop to promote communication between labs and universities, establish mechanisms and accounting standards to promote better coordination among the laboratory programs to minimize duplication of effort and facilitate better comparison among programs, establish incentives for attracting good people to the detector R&D program, and encourage new detector initiatives which have the potential for significant impact on high energy physics research.

Introduction

A review of the detector research and development (detector R&D) program of the five national laboratories Argonne National Laboratory (ANL), Brookhaven National Laboratory (BNL), Fermi National Accelerator Laboratory (Fermilab), Lawrence Berkeley National Laboratory (LBNL), and SLAC National Accelerator Laboratory (SLAC) was carried out during the three day period July 8-10, 2009 at the Bethesda North Marriott Hotel & Conference Center in Bethesda, Maryland.

The names, institutions, and email addresses of the ten external review panelists are given in Appendix A. The panel consisted of two European laboratory directors and eight university researchers supported by DOE's Office of High Energy Physics. Howard Nicholson of DOE chaired the review. Other DOE Office of High Energy Physics personnel, including Associate Director Dennis Kovar, Director of Research Glen Crawford, Director of Facilities Michael Procario, attended as much of the review as their schedules allowed.

The Agenda for the Review is given in Appendix B. Each laboratory had between two and three hours for an open presentations, and one half hour to speak privately with the review panel about their detector R&D program. Reviewers were each asked to give their initial impressions of the detector R&D program to DOE during the closeout, and to provide confidential review letters, including a numerical scoring of their overall evaluation of the labs' R&D programs on a scale of 0 (poor) to5 (outstanding).

The Charge Letter for the review is given in Appendix C and a template for the reviewer report letters is given in Appendix D. Graphs of the panelists' numerical grades for each of the laboratories and a graph of the comparison of average laboratory numerical grades are given in Appendix E. Laboratory budgets for detector R&D are given in Appendix F.

Overall, LBNL received the highest average score of 4.8. Panelists were very impressed by the Micro Systems lab CCD work, the management of the program, the scientific leadership and technical expertise, and the importance and impact of past and present detector R&D done there.

SLAC rated a close second with an average score of 4.6. Reviewers were impressed with the SLAC sensor, electronics, and data acquisition R&D, and with the management and the quality of the scientific and technical staff. A concern of the SLAC detector development program is that its future seems to depend substantially on projects which have not yet been approved or which have uncertain futures.

Brookhaven ranked third with an average score of 4.1. Reviewers felt that the Brookhaven HEP group did a good job leveraging the small amount of detector R&D funding provided by the DOE HEP program ($772k) with the Instrumentation Division to produce innovative devices. A concern of the Brookhaven program was the extent to which the Brookhaven HEP group could sustain this productive association in the future in competition with other, well-funded divisions of the laboratory.

Argonne ranked fourth with an average score of 3.3. Reviewers felt that Argonne had invested a considerable amount of its budget in a digital hadron calorimeter effort motivated by a lepton linear collider which was not currently a high HEP priority and that it was also involved in several risky but high reward projects.

Fermilab ranked lowest with an average score of 2.5. Reviewers were critical of Fermilab management oversight of its detector R&D program, and were not impressed with the liquid argon effort. As the only national laboratory involved solely with HEP, reviewers wanted to see more national and international leadership and a better return on an investment which is currently approximately half the total national laboratory budget for detector R&D.

In what follows, for the laboratory detector R&D program as a whole and for each of the laboratories are extracts from the panel reviewer letters in the format of: 1) factual findings with regard to the laboratory program, 2) relevant comments about the program, and 3) recommendations. Reviewers' findings and evaluations were, for the most part, remarkably uniform. In the few cases where there was a range of opinions, the relevant bullet indicates this range. In the Response to the Charge section, the reviewers' written comments are extracted to address the specific items in first part of the Review Charge.

Findings, Comments and Recommendations

Overall Lab Detector R&D Program

Findings:

DOE Laboratories are currently doing generic detector R&D in many research areas identified as high priority by P5. Some of these areas are: the LHC program, lepton collider detectors, the neutrino program, dark matter direct detection, dark energy measurements, measurements of rare processes, and particle astrophysics.

There is duplication of effort across laboratories in some generic R&D areas without the coordination needed for optimization of resources and overall efficiency of the activities.

Each laboratory has their own history, culture, and style of operation.

Comments:

The reviewers found that there was an impressive amount of generic detector R&D being carried out at the laboratories being reviewed. They felt it would be useful to have a knowledgeable single point of contact designated for each lab to facilitate exploring possible joint projects and user access to lab facilities. Reviewers also commented that there should be better mechanisms to encourage more collaboration between university groups and national lab, such as joint R&D programs between labs and universities to share resources and ideas

Reviewers noted that there appeared to be considerable leveraging of resources with generic detector R&D funding in many laboratories, either via Laboratory Directed R&D (LDRD) funding or other sources. Fermilab is the only laboratory which does not have a LDRD program to leverage HEP detector R&D funding, so some small experiments that would normally be funded out of LDRD are instead funded out of the generic detector R&D program at Fermilab.

There was general concern about ensuring coordination in several research areas to avoid unnecessary duplication. Examples cited of research overlaps at several labs are 3D silicon, edgeless silicon, silicon photomultiplier variants, transition edge sensors, and high speed data acquisition systems. Reviewers were also concerned that laboratory generic R&D programs will have natural institutional inertia so that labs will choose projects that they know how to do and cautiously move into new areas

Reviewers suggested several general principles to guide organization and prioritization of the national detector R&D program:

- Generic detector R&D should be guided by physics motivations rather than an interest in the intrinsic physics of particle detector technology.

- There should be a mechanism for determining when core facilities have outlived their usefulness or when new core facilities are needed.
- An organized set of R&D goals needs to be established in a way that allows better input from the community and against which progress can be measured. For example, what are the top ten R&D goals for the community and how are they being pursued?

Reviewers also felt that more generic R&D applicable to DUSEL activities is needed.

Recommendations:

- Develop a mechanism to provide overall coordination of the R&D activities in the laboratories to increase efficiency and optimize the use of the $20 million spend on laboratory generic R&D.
- Establish an annual conference/workshop in generic detector R&D which would be useful to increase communication and encourage collaboration between laboratories and universities, both in the U.S. and abroad. It should also serve to identify future physics detector needs which are not currently being addressed and help to coordinate the lab R&D efforts.
- Have DOE provide the laboratories with specific accounting standards that allow a more direct comparison of detector R&D funding and accomplishments from KA15 funding alone.
- Periodically reassess the split between accelerator R&D and detector R&D funding.
- Support test beams in the U.S.
- Allocate funding for "Grand Challenges" to encourage the formation of multi-lab and multi-disciplinary approaches to new and important problems (such as the large-area photo-detector project).
- Create a National Instrumentation Advisory Board which meets on a yearly basis and advises DOE and Labs on their instrumentation program from a national and international perspective.
- Create a National Instrumentation Fellowship directed at Ph.D. students and postdocs to encourage them to pursue research in instrumentation.
- Reserve some of the generic detector R&D funding for competitive proposals from labs, multilab collaborations, and lab and/or multilab university collaborations.
- Have laboratories submit annual progress reports for generic detector R&D. (This may already be addressed by annual laboratory reviews.)

Argonne National Lab

Overall average score: 3.3

Findings:

Argonne (ANL) staff have experience and expertise in calorimetry for HEP experiments. For example, ANL played a key role in the design and construction of the hadron tile calorimeter for the LHC ATLAS experiment and the calorimeter for the ZEUS experiment.

They are building on this experience by developing and building well-functioning Resistive Plate Chambers (RPCs) for use in digital calorimetry. ANL has built a prototype digital calorimeter using RPCs with steel absorbers and custom electronics, and tested it with cosmic rays and with Fermilab particle beams. They have begun preparations for the construction and testing of a larger (cubic meter) prototype for a digital calorimeter as members of the CALICE collaboration.

Argonne is exploring detector R&D initiatives in a variety of other areas with possible applications to HEP:

- wireless/fiberless data acquisition systems;
- silicon photomultipliers and topological triggers for a ground based gamma ray detector;
- Large-area, microchannel plate based photodetectors; and
- transition edge sensors (TES).

Comments:

The reviewers found the Argonne presentations and the proposed budget were clearly linked and easy to understand. They noted that the ANL detector R&D strategy has been to start with LDRD-funded concepts, move to detector R&D funding, then move to actual experiments. They generally commended this staged approach. Further, they found that the ANL Advanced Photon Source (APS) and Center for Nanoscale Materials (CNM) provide unique infrastructure capabilities for developing and testing detector concepts.

However, the reviewers felt that the recent ANL detector R&D efforts have had only modest impact on the current HEP program. The current R&D efforts were mostly found to have a greater potential impact but also higher technical risk. Overall the reviewers liked the balance of risk and reward, and found the investments to be at an appropriate scale, though they encouraged the digital calorimetry effort to be completed expeditiously once the current demonstration prototype is completed and tested.

Specific reviewer comments about individual components of the ANL detector R&D program:

- The Argonne digital calorimetry is important but the fraction of the budget devoted to it is high.

- A digital hadron calorimeter for a future ILC and gamma ray astronomy trigger work are currently not well aligned with P5 report priorities for HEP although the HEP particle astrophysics program is in a state of flux.
- Silicon photomultiplier and CCD testing is useful but not cutting edge R&D and might be done at a university in a more cost effective way.
- Microchannel plate photodetector development is risky and Argonne personnel may not have the expertise to successfully carry out this effort, but there would be enormous payoff if the R&D is successful.
- Wireless/fiberless data acquisition systems are also risky but have very great payoff if the R&D is successful.
- TES show great promise for future experiments looking for rare decays such as direct searches for weakly interacting dark matter, neutrinoless double beta decay, and far-infrared and millimeter-wave astrophysics. Several research teams with reasonable funding have been carrying out R&D in this field in Europe for a couple of decades.

Recommendations:

- Keep funding constant at the current level.
- End the digital hadron calorimeter project after the test of the one meter prototype has been carried out.

Brookhaven National Lab

Overall average score: 4.1

Findings:

Brookhaven (BNL) is unique among DOE-HEP labs in that it leverages its detector R&D funding with a strong Instrumentation Division which is mostly supported through laboratory overhead. This has enabled the lab to develop infrastructure that is unavailable elsewhere and provides significant benefits to the HEP program with a very modest direct investment. For example, the Instrumentation Division's silicon fabrication laboratory is the only U.S. research facility capable of fabricating non-CCD silicon detectors.

BNL has used the resources assembled in the Instrumentation Division to carry out R&D in a number of important areas, including developing silicon detectors for high radiation environments, R&D on compact gaseous microstrip detectors ("microMegas"), development of long drift noble liquids for use in neutrino and proton decay experiments, and pioneering work on 3D electronics and SiGe circuits.

BNL has plans for future R&D initiatives, including exploring diamond as a dynode structure for a next generation photon detector. BNL management indicated that the process for indentifying and selecting new detector R&D efforts was under review.

Comments:

The reviewers were very positive about the technical achievements of the BNL program and the Instrumentation Division in particular. They noted that BNL has a earned a reputation for innovation in semiconductor detectors and electronics, maintains good facilities for sensor and electronics development, and has a history of outstanding work on radiation hard silicon detectors for HEP and other scientific applications. They also noted that BNL has the only experienced chemistry group supporting HEP experiments in the U.S. and the lab should ensure that this group continues to be viable.

The reviewers also found that the R&D on microMegas and liquid argon detectors, particularly with respect to front end electronics, to be very high quality. However, they were concerned that no cost-benefit analysis for the in-cryostat electronics for future large liquid argon detectors was presented, and that the microMegas R&D for future large detectors seemed to be directed toward a future ATLAS upgrade instead of a generic detector R&D effort.

Although they were very positive about the past achievements of the Instrumentation Division, many reviewers were concerned about how much influence the HEP division will have with the direction of the Instrumentation Division in the future, and how much influence the

Instrumentation Division has on the management and direction of the overall BNL detector R&D program.

Specific reviewer comments about individual components of the BNL detector R&D program:

- Brookhaven's work on diamond dynodes for photomultipliers is very innovative, but it is not clear how successful this project is likely to be.
- SLAC seems to have a better program on data acquisition systems.

Recommendations:

- Increase funding by the order of $500k.

Fermi National Accelerator Laboratory

Overall average score: 2.5

Findings:

The Fermilab detector R&D budget is the largest of any of the national laboratories and is approximately half the budget of the entire national laboratory detector R&D program. The lab invests these resources in many areas and many projects, including:

- 3D silicon pixel detector and silicon on insulator (SOI) R&D;
- triggerless data acquisition systems;
- high Z and lithium doped plastic scintillator;
- total absorption hadron calorimetry (TAHCAL);
- low noise (1/2 electron) CCD readout using double correlated sampling; and
- liquid argon as a dark matter and neutrino detector.

Fermilab also operates the only test beam facility in the U.S. for detector development studies and it is heavily subscribed.

In addition, Fermilab has developed and built detectors for specific physics applications partially supported by this program, including: the COUPP bubble chamber detector which has set competitive limits on the cross section for spin dependent weakly interacting massive dark matter; an axion dark matter search experiment (GammeV) using spare Tevatron magnets; and a small liquid argon tracking chamber (ArgoNeut) as a precursor to larger-scale liquid argon detectors.

Comments:

The reviewers noted that Fermilab has extensive infrastructure for sensor, electronics, and detector system development and has traditionally been strong in certain areas such as custom IC design and large-scale mechanical support system design. A few of the current detector R&D efforts (3D silicon pixel sensors, data acquisition, scintillator R&D) were found to be notable on a national scale.

However, the chief concern expressed by all the reviewers was that the Fermilab detector R&D budget seems large relative to their past and projected future accomplishments, and their non-centrally organized detector R&D management structure does not appear to have strong leadership or clear scientific goals. They noted that the detector R&D program may be transforming from a program based on applying new but demonstrated technologies to specific experimental problems to a longer term, more fundamental detector R&D effort. Several reviewers encouraged Fermilab to develop a wider vision of their role in detector R&D in the national and international HEP communities.

Specific reviewer comments about individual elements of the Fermilab detector R&D program:

- The Fermilab liquid argon detector R&D is apparently not taking advantage of the R&D work in this area carried out in Europe, particularly on ICARUS, and it is not clear what Fermilab is contributing to new developments in this area. The cold readout effort needs to be evaluated on a cost/benefit basis and coordinated with BNL.
- Several Fermilab detector R&D projects (TAHCAL, solid Xenon detectors, Germanium Observatory for Dark Matter GEODM) are not as strong and well defined. Others (continued development of carbon fiber structures for low mass supports of silicon trackers in collider geometries and the Serial Power Interface (SPI) chip) seem better suited to LHC detector upgrade R&D rather than generic detector R&D.
- Fermilab's work on evaluation of silicon photomultipliers as readout sensors might be done as efficiently and more cheaply at universities.
- Some of Fermilab's R&D efforts are really stand alone projects (COUPP and GammeV). Some (COUPP, GEODM) are university-led efforts.
- Fermilab's single test beam is in high demand and has good instrumentation, but it is not a high quality beam and is not particularly well matched to the needs of a national program. CERN has a much more extensive test beam facility.
- Aside from the test beam and some technical and engineering support services for projects within the mission of the laboratory, the lack of support for widely used HEP community tools such as PAW and ROOT is striking for a lab at the center of the U.S. HEP effort.

Recommendations:

- Reduce funding by $1M.
- Develop a coherent detector R&D management plan with a clear vision of the Fermilab role in the national and international HEP community.
- Generic detector R&D projects should be internally reviewed on a regular basis.
- As the only U.S. purely HEP laboratory, Fermilab should be taking leadership in organizing workshops in new detector technology to attract expertise from the other DOE labs, the university community, and non-HEP sources.

Lawrence Berkeley National Laboratory

Overall average score: 4.8

Findings:

LBNL has extensive infrastructure (the MicroSystems Laboratory) which develops new CCDs for physics research. They have a long list of accomplishments in this area, including:

- Producing science grade CCDs (2k x 4k 15 micron pixels) for the Dark Energy Survey (DES).
- Developing CCDs which have been installed in the Sloan telescope for the BOSS spectrograph upgrade, at the Palomar Hale 200 inch telescope for the SWIFT integral field spectrograph, and in the LRIS spectrograph upgrade at the Keck 10 meter telescope.
- Three patents for development of fully back illuminated CCDs.

LBNL also carries out R&D in a variety of areas related to current and near-future HEP detector applications, including:

- CCD pixel control and readout electronic integrated circuits.
- DC-DC converters.
- "intelligent" silicon.
- mechanical and thermal structures for large future tracking detectors
- nanowire carpet hybrid pixel detectors using nanotechnology self assembly.
- high pressure xenon TPCs.

Comments:

The reviewers praised LBNL's strong scientific leadership and technical expertise in this area, In particular they felt that detector R&D at LBNL has a strong focus on particle astrophysics, and that LBNL has become a unique resource in this high priority HEP activity They noted that LBNL has good infrastructure for developing novel detectors and has sensor and process simulation tools, and excellent integrated circuit design capabilities. Thanks in part to this infrastructure, they found that LBNL has been a leader in developing front end electronics for silicon detectors and has a history of leadership in silicon and germanium detector design

The reviewers uniformly found that the LBNL MicroSystems Laboratory is a world leader in the development of state-of-the-art scientific grade CCDs which are crucial for current and next generation Dark Energy experiments as well as other science applications.

The only slightly negative comment was that LBNL's collaboration with university groups seems to be confined to University of California schools and could be expanded more broadly.

Specific reviewer comments on individual efforts within the LBNL detector R&D program:

- LBNL's R&D on exploring high radiation dose tolerant circuitry is well thought out and complementary to BNL's R&D on very high dose sensors.
- LBNL's R&D work on intelligent silicon, which has the goal of correlating information across separate detector planes to identify relevant physics objects for triggering and to reduce data readout volume, consists of architecture, packaging, processing, data transmission, and system issues. This is important R&D for future detector systems in high luminosity experiments.
- LBNL's plan and progress on R&D on the development of carpet nanowires is somewhat vague at this time and the R&D plan is not detailed enough to evaluate.
- LBNL's R&D on DC-DC converters may be more appropriately funded as an ATLAS upgrade project.

Recommendations:

- Encourage LBNL to share expertise with a wider spectrum of university groups.

SLAC National Accelerator Laboratory

Overall average score: 4.6

Findings:

The SLAC detector R&D program includes core engineering, generic detector R&D, electronics and data acquisition development, detector systems, machine-detector interface studies, detector simulation toolkit development, particle flow studies and related hardware. The lab is trying to restore the End Station A test beam line to enhance its capabilities for in-house detector development studies and to serve the broader community.

SLAC has developed a concept for a focusing ring imaging Cherenkov counter with improved timing resolution and demonstrated the ability to improve measurement of the Cherenkov angle by correcting for chromatic effects. SLAC is developing capabilities to use Stanford's nano-fabrication facilities for HEP detector R&D such as the development of a CMOS polychrome imager, fabrication of large germanium crystals, and the development of radioactive free readout electronics for the enriched xenon observatory (EXO) and other low background experiments.

SLAC is also working on a variety of other detector R&D projects including 3D silicon diodes with short charge collection distances and improved radiation hardness, spherical thick diodes, gray tone diffusion, diamond detectors, new forms of thermal neutron detectors, and low radioactivity silicon circuit boards.

Comments:

The reviewers found that SLAC has very strong capabilities in silicon detector development, electronics, and data acquisition systems, and it makes good use of the resources at Stanford University and in Silicon Valley. In particular they called out the efforts to design a high speed, high volume data acquisition system with modular building blocks and the development of the flexible KPiX readout chip as noteworthy.

The reviewers commented that the laboratory infrastructure developed to support these efforts was outstanding; and that the scientific staff involved in detector R&D was first-rate, including recognized world experts.

The reviewers' general assessment was that SLAC's management for its detector R&D program was good, but they felt that the dividing line between generic R&D and project based R&D at SLAC needs to be more carefully defined.

There was a related general concern that SLAC is basing a considerable amount of its future program on projects which have not yet been approved or have uncertain futures (ILC and lepton colliders, JDEM, LSST, AGIS, SuperB, and GEODM). Since not all of these are likely to succeed, the future direction of the detector R&D effort was somewhat unclear.

Specific reviewer comments on individual efforts within the SLAC detector R&D program:

- Work on the improving the Cherenkov angle measurement in the Detection of Internally Reflected Cherenkov light (DIRC) detector could be high priority for future experiments such as a SuperB factory. There is some question about its importance without an approved SuperB relative to other work.
- SLAC's R&D on low radioactivity readout electronics has the potential for being very useful for next generation dark matter and double beta decay experiments.
- Although the polychrome imager is an interesting idea, its overlapping color bands would lead to a degradation in photo-z resolution in JDEM and LSST and this would be a problem for cosmic shear measurements.

Recommendations:

- SLAC should take steps to make their many excellent creative developments more widely accessible and applicable (i.e., generic).
- The SLAC Reconstruction toolkit needs a Root interface.
- The SLAC End Station Test Beam should be supported.

Response to the Charge

In this section, reviewer comments are organized to address the specific laboratory evaluations in the first part of the review charge.

Sensor development:

Argonne is developing Transition Edge Sensors (TES) and large area photodetectors (LAPD) and is testing silicon photomultipliers and CCDs. Reviewers ranked the TES work as excellent, LAPD as potentially very high impact but very risky. Silicon photomultiplier work might be done as well and more cheaply at universities.

Brookhaven is trying to develop radiation hard silicon sensors (MCZ, CID, 3D), high gain diamond amplifiers with multialkali photocathodes, and a fundamental understanding of micromegas gas amplifier. Virtually all of this work is being carried out in the Instrumentation Division, and reviewers were concerned that very little of the financial support for this work or control of the program comes directly out of HEP detector R&D funding. However the work is very high quality and the HEP funding has been well leveraged.

Fermilab is developing thinned 3D pixel detectors with bonded electronics, is testing silicon photomultipliers, packaging and testing CCDs, and developing plastic scintillators and scintillator fabrication technologies. Reviewers felt that the 3D pixel detector development work was excellent, the scintillator effort was good, and the other areas were not particularly outstanding.

LBNL is developing novel CCD detectors in its Micro Systems Lab and has some work on nanowire carpets to replace segmented wafers. The Micro Systems Lab work was considered truly exceptional both in quality and impact for the High Energy Physics community, while the nanowire R&D, which is an interesting idea, is too new to evaluate.

SLAC has a new hire for detector development work, and makes good use of the Stanford Nanofabrication and Nano-characterization facilities. The lab is developing a polychrome imager, working on large volume Ge detectors, grey tone diffusions to reduce breakdown, 3D structures and irradiation studies of these structures, pixel time-of-flight (TOF) detectors, double metal Si strip, dual readout prototypes, spherical thick diodes, and active edge radiation sensors and diamond sensors for high radiation environments. Although the polychrome imager may not be practical for astrophysics, the Ge detectors could also be done at some universities, and the pixel TOF detectors may have limited utility without an ILC, the breadth and quality of the SLAC sensor effort is impressive.

Detector Systems:

Argonne is developing a one cubic meter digital hadron calorimeter using glass resistive plate chambers (RPCs). Date from this project which was largely motivated by a lepton collider should be useful for future calorimeter projects, but the reviewers felt that the project should come to an end after the one cubic meter prototype has been built and test beam data has been taken and analyzed.

Brookhaven is working on long drift noble liquid detectors in an attempt to understand fundamental limits in terms of signal and noise, and on electronics for detector systems by making extensive use of its Instrumentation Division. There is also some effort to understand how photomultiplier tubes implode under pressure motivated by very large volume water Cerenkov detectors. Reviewers generally felt that this work outstanding, particularly since the actual HEP Detector R&D funding at Brookhaven has been so small.

Fermilab is working on liquid argon detectors and has a Silicon Detector Facility to support HEP silicon detector R&D efforts. It also has played a major role in constructing detector systems, and it has developed a dark matter bubble chamber (COUPP) and has interests in solid Xenon detectors and dual readout calorimetry. Reviewers were generally not impressed with the Fermilab liquid argon effort because it wasn't clear how innovative or generic it was, and felt the Fermilab detector system R&D program was not coherent or particularly well managed.

LBNL is working on a high pressure Xenon TPC because of the promise of better energy resolution than liquid xenon TPCs for neutrinoless double beta decay and there has been some development of new materials (carbon foam) for detector system structures. Reviewers were generally quite favorable of the high pressure Xenon TPC effort, although it was pointed out that there were a number of promising technologies for double beta decay and dark matter experiments. The carbon foam effort was acknowledged but not evaluated.

SLAC is working on a compact and chromatically corrected detection of internally reflected Cerenkov light detector (DIRC) for particle identification motivated by a future SuperB factory, a complete ILC detector system utilizing a tracking silicon detector (SiD) along with issues related to the accelerator-detector interface (MDI), and on parts of the design and construction of the enriched xenon observatory (EXO) and cryogenic dark matter search experiment (CDMS and GeoDM upgrade). Reviews had mixed reaction to wisdom of the DIRC and ILC work based on the uncertain future of these two programs. Some thought this was valuable generic R&D for future detectors and some thought it was low priority. In general the reviewers thought the SLAC R&D in this area was high quality.

Data acquisition systems, triggering, front end electronics and detector related computing:

Argonne is working on a topological trigger suitable for high energy gamma ray observatories such as VERITAS and AGIS, a high speed data acquisition system to replace VME, and has begun work on a wireless/fiberless data acquisition system. Some reviewers thought these activities could have a significant impact on future experiments, others thought the gamma ray trigger work was not high priority for HEP, and the data acquisition work was either not particularly advanced or aggressive or very risky.

Brookhaven's generic R&D consists of work on in cryostat readout electronics for liquid argon for future large volume liquid argon detectors, and development of SiGe ASIC integrated circuits. Reviewers felt that the Brookhaven efforts were very high quality although concern was expressed that the cryogenic liquid argon electronics, which reduces the need for cryogenic feedthroughs and long cables between the detector and amplification stages in large liquid argon detectors, may create heat and contamination problems for the liquid argon.

Fermilab is developing readout systems for pixel R&D and test beams, is developing a trigger-less data acquisition system, and is working on a cold electronics readout systems for liquid argon detectors, Reviewers acknowledged this work but had little to say about it either positive or negative.

LBNL is working on control and readout electronics for CCDs and intelligent silicon data acquisition systems for high rate, high multiplicity environments of future colliders. Reviewers generally thought that this was high quality and very significant work.

SLAC is working on low radioactivity electronic boards for low background experiments, a system-on-a-chip approach to high-rate low-mass front end boards, multi-layer ASIC assemblies, a multi-gigabit data transmission integrated with detector system, the development of generic high-speed, high-volume data acquisition systems composed of modular building blocks, and a simulation and reconstruction toolkit for particle flow algorithm development for jet energy resolution for a linear collider. Reviewers were impressed with both the quality of the SLAC personnel and the quality and significance of the work.

Core Detector R&D efforts at the Laboratories:

In a flat funding scenario, reviewers in general proposed to keep the Argonne funding constant, to increase the Brookhaven funding to sustain the high leveraging of this funding with the Instrumentation Division, to at least maintain or increase funding at LBNL and SLAC, and to decrease funding at Fermilab.

Reviewers found the core detector R&D program at Argonne about right in size and scope, although they wanted to reduce the digital hadron calorimeter effort as soon as the beam test and data analysis of the cubic meter detector was completed. Reviewers also commented on the risky nature of some of the efforts and that some of the Argonne effort was not on work which was identified as highest priority by P5. Argonne has good mechanical, electrical, and computing infrastructure.

Reviewers identified the Instrumentation Division as providing the bulk of the core detector R&D program at Brookhaven with the very small amount of HEP funding providing support for a few scientists. In general, reviewers felt that more Detector R&D funding to Brookhaven was appropriate. Brookhaven's Instrumentation Division provides excellent infrastructure for detector R&D from internal laboratory funding, and its nuclear chemistry division also contributes to the detector R&D effort.

Reviewers were generally not impressed with the Fermilab detector R&D effort. They felt it lacks coherence and should be centrally managed, that it was hard to identify a meaningful core program in the context of the budget presented, and that the liquid argon effort did not seem to be making new, significant, or innovative contributions to the development of liquid argon calorimetry. One reviewer pointed out that Fermilab was undergoing a transition as its accelerator user program winds down and the detector related activities effort there are changing. Reviewers generally found the test beam program useful, but it lacks many capabilities of the CERN test beams. Fermilab has a very good mechanical infrastructure for large detector design and construction and a very good ASIC capability.

Reviewers were very impressed with the LBNL detector R&D effort, particularly the Micro Systems Laboratory which was a unique facility for producing scientific grade CCDs. Several scientific staff members were identified as being particularly distinguished in the detector R&D area. LBNL has outstanding infrastructure for CCD development work and for electronics chip design.

Reviewers were also very impressed with the SLAC detector R&D effort and supported the broadening of the effort there from a past emphasis on ILC and SuperB related detector development work to ATLAS and DUSEL related efforts. A couple of the scientific staff were singled out as being widely recognized contributors to the current and future US detector R&D effort. SLAC has access to the outstanding infrastructure of Stanford University in Nano-fabrication and Nano-characterization capabilities, and to the nearby capabilities of Silicon Valley.

The Breadth of Support for Detector Development for the HEP Community

Argonne is involved in significant collaborative efforts with neighboring universities and laboratories as well as other U.S. universities involved in ILC R&D and astrophysics projects. The laboratory has also enabled national participation in ATLAS.

At both the Instrumentation Division and Physics Department level, Brookhaven has a multi-decade history of world-wide involvement in the HEP effort welcoming international and university collaborators to share facilities and join in projects. The laboratory has enabled national participation in ATLAS. There is concern that without increased funding from DOE for high energy physics the Instrumentation Division will not be able to support the high energy physics program as effectively in the future as it has in the past.

The Fermilab test beam is an international resource and the lab support for it has great value to the U.S. and international communities, but in other areas the laboratory only gets directly involved with other institutions in projects that are within the mission of the laboratory. Fermilab has historically had a significant role in constructing detector systems from sensors developed at universities or other laboratories. Fermilab has also involved many universities in its 3D silicon R&D.

LBNL has made many large contributions to past and planned experiments by taking on substantial responsibilities for detector design, development, and construction as well as supporting the potential needs of the community by undertaking innovative generic R&D. The laboratory has enabled national participation in ATLAS. One reviewer felt that LBNL was not significantly involved with university groups outside the University of California system.

SLAC has made many excellent contributions to both generic and project specific detector R&D over a long period to the benefit of the HEP community and should take steps to make these developments more widely accessible to the high energy physics community. The laboratory has enabled national participation in ATLAS and ILC.

Appendix A

The Review Panel

U.S. National Laboratory Detector R&D Review – July 8-10

International:

Name:	Institution	email:
Marcello Giorgi	Pisa	giorgi.superb@pi.infn.it
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Joe Incandela	UCSB	Joseph.Incandela@cern.ch
Roger Rusack	U. Minnesota	rusack@physics.umn.edu
Ian Shipsey	Purdue	shipsey@physics.purdue.edu
Bob Svoboda	UC Davis	svoboda@physics.ucdavis.edu
Rick Van Berg	Penn	rick@hep.upenn.edu
Andy White	Texas Arlington	awhite@uta.edu

Appendix B

Review Agenda

DOE Review of Laboratory Detector R&D
July 8-10, 2009
Marriott Hotel
North Bethesda, Maryland

July 8

8:30 am	Executive Session		
	Introductions & Welcome	5'	Dennis Kovar
	Introduction to DOE/OHEP	15'	Glen Crawford
	Charge and Logistics	40'	Howard Nicholson
9:30 am	Lawrence Berkeley National Laboratory	60'	
10:30 am	Break	15'	
10:45 am	Lawrence Berkeley National Laboratory (cont.)	90'	
12:15 pm	Closed LBNL session with panel	30'	
12:45 pm	Working Lunch	60'	
1:45 pm	Fermi National Accelerator Laboratory	90'	
3:15 pm	Break	15'	
3:30 pm	Fermi National Accelerator Laboratory (cont.)	90'	
5:00 pm	Closed Fermilab session with panel	30'	
5:30 pm	Executive session	60'	
6:30 pm	Adjourn		

July 9

8:30 am	SLAC National Accelerator Laboratory	90'
10:00 am	Break	15'
10:15 am	SLAC National Accelerator Laboratory	60'
11:15 am	Closed SLAC session with panel	30'
11:45 pm	Working Lunch	60'
12:45 pm	Argonne National Laboratory	120'
2:45 pm	Break	15'
3:00 pm	Closed ANL session with panel	30'
3:30 pm	Brookhaven National Laboratory	120'
5:30 pm	Closed BNL session with panel	30'
6:00 pm	Executive session	30'
6:30 pm	Adjourn	

July 10

9:00 am	Executive Session	210'
	Discussion	
	First Writing	
	Closeout with DOE	
12:30 pm	Adjourn – End of Review	

Appendix C

Review Charge

MEMORANDUM FOR: Dr. Howard Nicholson, SC-25.1

FROM: Dr. Glen Crawford, Director, Research & Technology Division, for High Energy Physics

SUBJECT: Lab Detector R&D Charge

The mission of the DOE High Energy Physics (HEP) program is to understand how our universe works at its most fundamental level, and the Detector R&D subprogram supports that mission by providing funding for the development of the tools which are essential for conducting research at the forefront of the field, thereby advancing our strategic goals for science.

This letter is to request that you conduct a review of HEP-supported laboratory efforts in the area of Detector R&D on July 8-10, 2009 in Bethesda, MD. The purpose of this review is to assess the quality of the recent scientific performance by these laboratory groups, the merit and feasibility of their proposed activities for achieving the scientific goals and milestones of the field, and the relevance of their detector R&D efforts to the overall HEP mission.

We are particularly interested in a review of the laboratories' contributions (as applicable) along the following programmatic thrust lines:

- Sensor development
- Detector system development
- Data acquisition system development including triggering and front end electronics and online computing

In addition, since this is a new program at DOE, we are also interested in an evaluation of the appropriateness of

- the size and scope of the current core detector R&D efforts at each of the laboratories, and
- the breadth of support for detector development that the laboratories provide to the entire HEP community.

The final report should outline the laboratory-based HEP research program in each of these thrusts as well as the appropriateness of the size and scale of each program, and discuss the unique and important elements that the laboratory programs bring to bear in addressing Detector R&D throughout the HEP community. In this context, we request a comparative assessment of each lab's overall performance in these areas relative to its peers, as well as an assessment of overall effectiveness relative to comparable university groups. The overall evaluation of the lab research groups will be an important input to the process of optimizing resource allocations within the various research thrusts.

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

1. The quality and impact of the Detector R&D by the group in the recent past;
2. The scientific significance, merit, and feasibility of the proposed program;
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 laboratories should provide relevant information which addresses these items in advance of the review.

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 lab contributions to the research thrusts noted above and the individual lab evaluations. The letters will be confidential within OHEP. Individual lab 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 OHEP. I would like to receive the individual laboratory evaluations and the summary report no later than September 15, 2009.

cc: D. Kovar, DOE, SC-25
M. Procario, DOE, SC-25.2
H. Weerts, ANL
T. Ludlam, BNL
Y. Kim, FNAL
G. Bock, FNAL
J. Siegrist, LBNL
S. Kahn, SLAC

Appendix D

Review Letter Template

Letter Outline

1. **Overall Introduction and Summary for the lab Detector R&D program as a whole.**

    a. What is/should be the overall vision for the laboratory Detector R&D program?
    b. Are the thrusts appropriate and comprehensive? If not, what should they be?
    c. How technically effective and cost effective is the overall program?
    d. How well does this program enable and support the mission of OHEP? (Specific examples are appropriate.)

2. **For *each* laboratory:**

    a. **Introduction and Summary**

        i. Technical and cost effectiveness of work in the thrust areas (high/med/low).
        ii. Quality, breadth, and accessibility of lab infrastructure.
        iii. Overall grade (Outstanding, Excellent, Very Good, Good, Fair, Poor) for the laboratory program.
        iv. To what extent is the current budget and future budget request appropriate?

    b. **Thrusts**

        i. **Factual Findings**

            1. Sensors
            2. Detector R&D
            3. DAQ, Trigger, Computing
            4. Size of core program

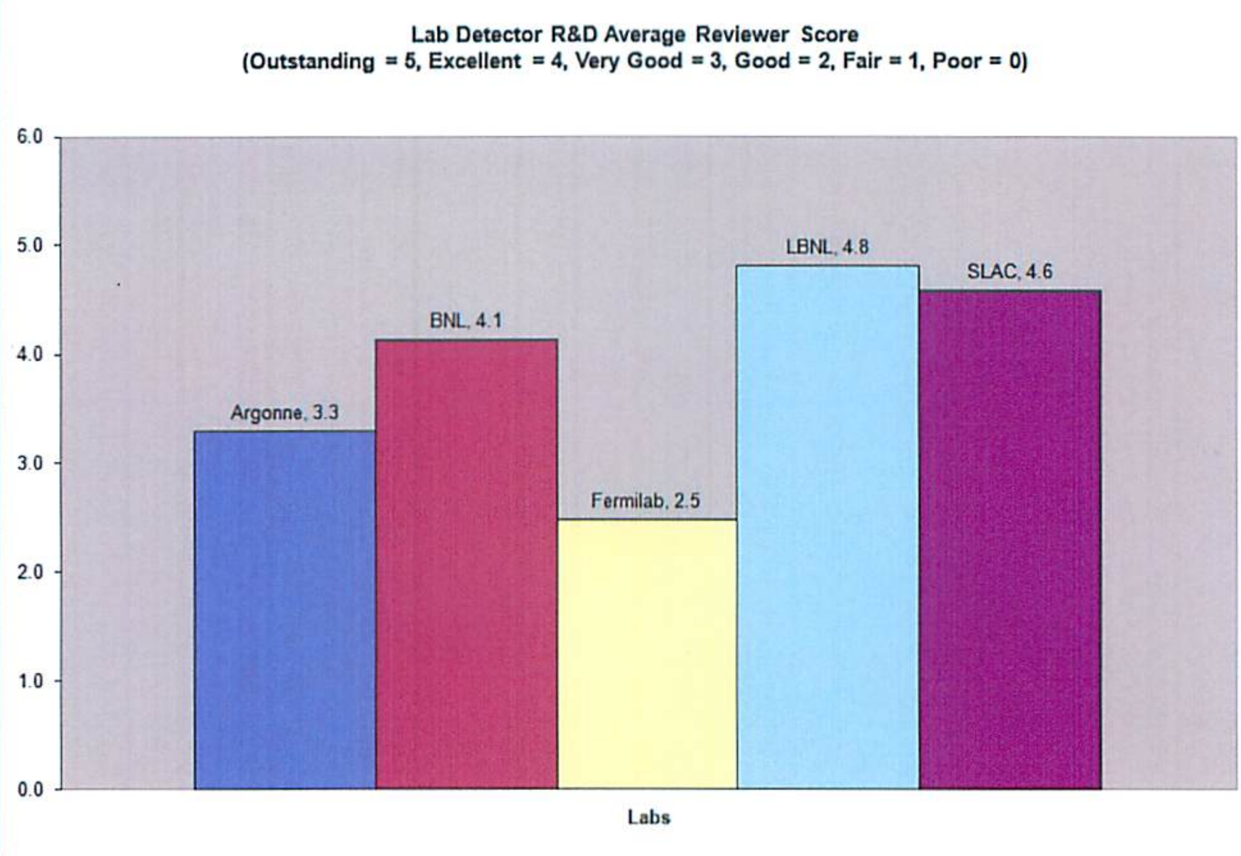
        ii. **Comments**
            1. Does the program fulfill the mission of OHEP?
            2. How unique are the facilities?
            3. What is the quality and impact of recent work? (Publications, patents, etc.)
            4. How effective is the laboratory program in enabling the mission of the overall program?

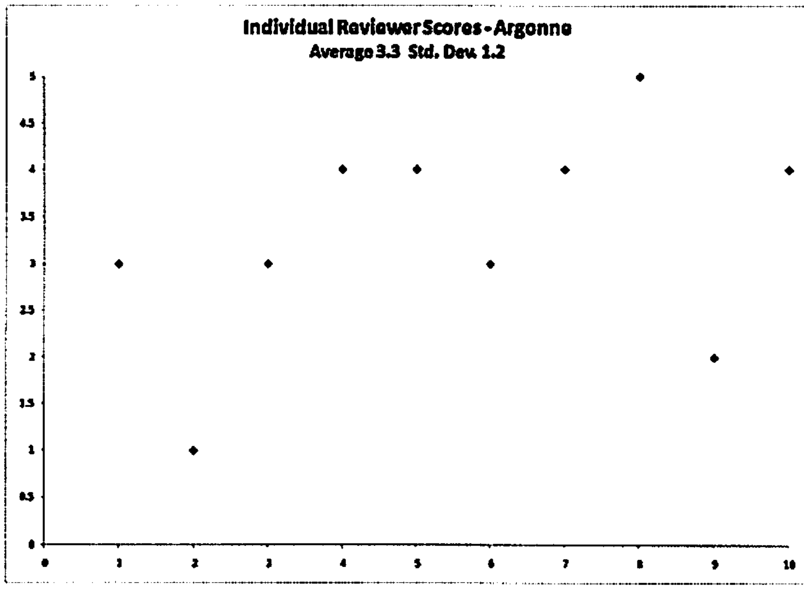
        iii. **Recommendations**

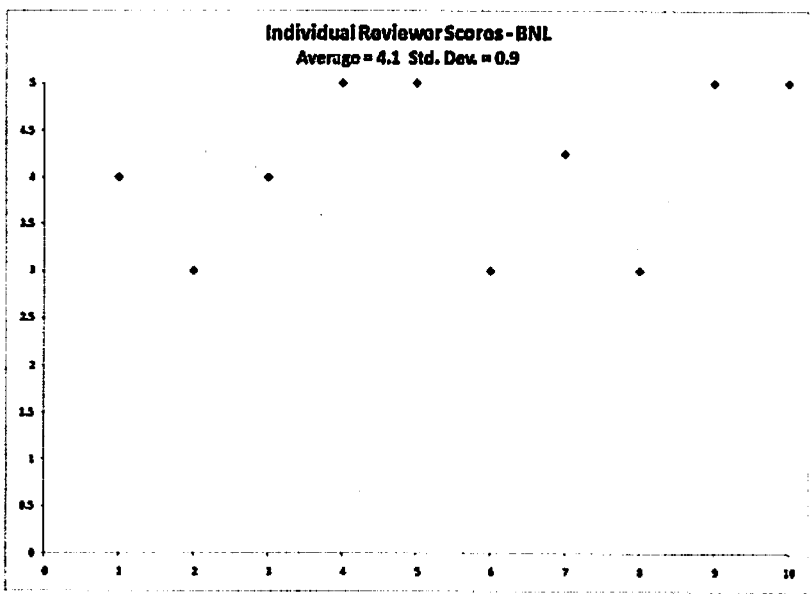
            Not required but include if a small number of action items needed

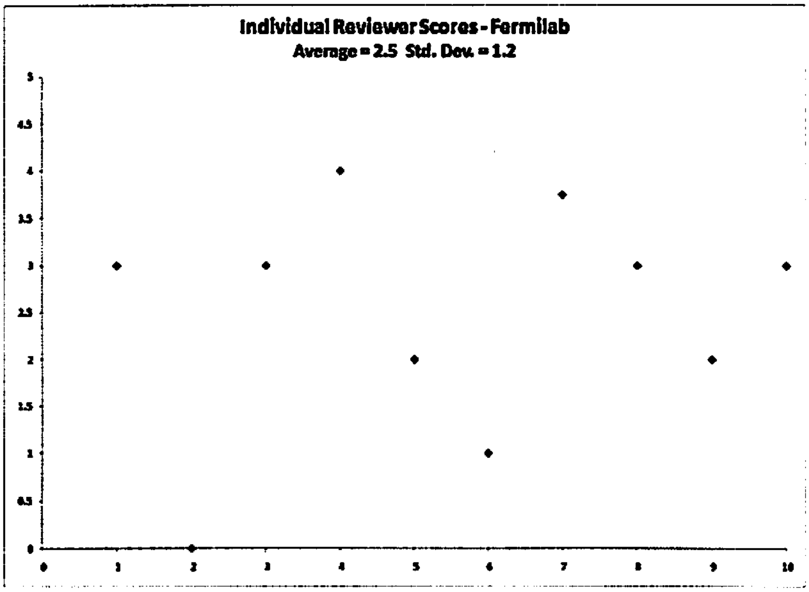
Appendix E

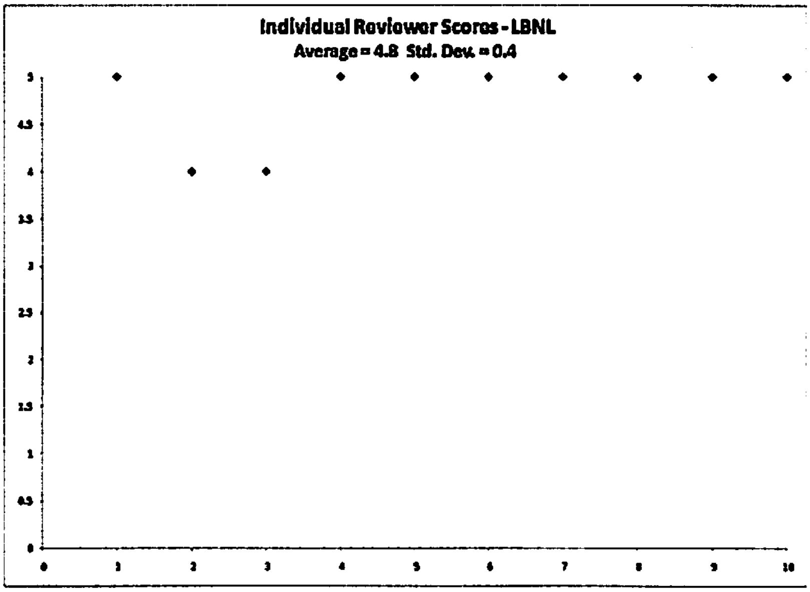
Panel Summary Scores

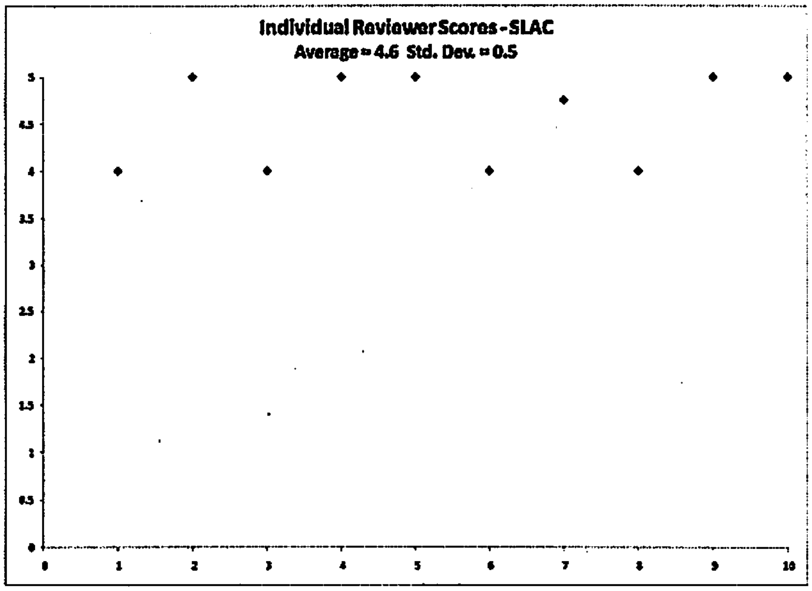



Individual Reviewer Scores - Argonne
Average 3.3 Std. Dev. 1.2


Individual Reviewer Scores - BNL
Average = 4.1 Std. Dev. = 0.9


Individual Reviewer Scores - Fermilab
Average = 2.5 Std. Dev. = 1.2


Individual Reviewer Scores - LBNL
Average = 4.8 Std. Dev. = 0.4


Individual Reviewer Scores - SLAC
Average = 4.6 Std. Dev. = 0.5

Appendix F

Laboratory Detector R&D Funding by Thrust

ANL

DOE Support FY 2009 (Actual)										
Personnel Support from DOE:	Core & Infrastructure		Sensors		Detector Systems		DAQ & Computing		TOTAL	
	No. heads	FTE	No. heads	FTE	No. heads	FTE	No. heads	FTE	No. heads	FTE
Permanent PhD	3	1.00	14	0.80	2	1.50	0	0.00	19	3.30
Temporary PhD	0	0.00	1	0.40	0	0.00	0	0.00	1	0.40
Graduate Students	0	0.00	1	0.50	2	0.40	0	0.00	3	0.90
Engineer	4	0.30	2	0.80	3	1.10	0	0.00	9	2.20
Computing Professional	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Technician	1	0.10	0	0.00	2	0.35	0	0.00	3	0.45
Administrative	1	0.15	0	0.00	0	0.00	0	0.00	1	0.15
TOTAL	9	1.55	18	2.50	9	3.35	0	0.00	36	7.40
DOE/HEP Funding (per activity):										
SWF (in $, include overhead)		$362,500		$461,000		$722,000		$0		$1,545,500
M&S (in $, include overhead)		$110,000		$50,000		$169,000		$0		$329,000
Travel (in $, include overhead)		$10,000		$5,000		$15,000		$0		$30,000
TOTAL		$482,500		$516,000		$906,000		$0		$1,904,500

DOE Support FY 2010 (Proposed)										
Personnel Support from DOE:	Core & Infrastructure		Sensors		Detector Systems		DAQ & Computing		TOTAL	
	No. heads	FTE	No. heads	FTE	No. heads	FTE	No. heads	FTE	No. heads	FTE
Permanent PhD	3	1.00	18	3.45	2	1.50	3	0.20	26	6.15
Temporary PhD	0	0.00	6	5.50	1	1.00	2	0.30	9	6.80
Graduate Students	0	0.00	1	0.50	2	1.00	0	0.00	3	1.50
Engineer	4	0.50	3	1.00	3	0.80	3	0.90	13	3.20
Computing Professional	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Technician	1	0.25	0	0.00	2	0.25	0	0.00	3	0.50
Administrative	1	0.25	0	0.00	0	0.00	0	0.00	1	0.25
TOTAL	9	2.00	28	10.45	10	4.55	8	1.40	55	18.40
DOE/HEP Funding (per activity):										
SWF (in $, include overhead)		$468,338		$1,793,138		$848,700		$309,465		$3,419,640
M&S (in $, include overhead)		$112,000		$2,090,274		$72,000		$94,575		$2,368,849
Travel (in $, include overhead)		$15,000		$26,779		$15,000		$0		$56,779
TOTAL		$595,338		$3,910,190		$935,700		$404,040		$5,845,268

BNL

DOE Support FY 2009 (Actual)										
Personnel Support from DOE:	Core & Infrastructure		Sensors		Detector Systems		DAQ & Computing		TOTAL	
	No. heads	FTE	No. heads	FTE	No. heads	FTE	No. heads	FTE	No. heads	FTE
Permanent PhD	4	1.68	0	0.00	1	0.32	0	0.00	**5**	**2.00**
Temporary PhD	0	0.00	0	0.00	0	0.00	0	0.00	**0**	**0.00**
Graduate Students	0	0.00	0	0.00	0	0.00	0	0.00	**0**	**0.00**
Engineer	1	1.00	0	0.00	0	0.00	0	0.00	**1**	**1.00**
Computing Professional	0	0.00	0	0.00	0	0.00	0	0.00	**0**	**0.00**
Technician	0	0.00	0	0.00	0	0.00	0	0.00	**0**	**0.00**
Administrative	0	0.00	0	0.00	0	0.00	0	0.00	**0**	**0.00**
TOTAL	5	2.68	0	0.00	1	0.32	0	0.00	**6**	**3.00**
DOE/HEP Funding (per activity):										
SWF (in $, include overhead)		$582,857		$0		$74,734		$0		**$657,591**
M&S (in $, include overhead)		$102,856		$0		$11,553		$0		**$114,409**
Travel (in $, include overhead)		$0		$0		$0		$0		**$0**
TOTAL		**$685,713**		**$0**		**$86,287**		**$0**		**$772,000**

DOE Support FY 2010 (Proposed)										
Personnel Support from DOE:	Core & Infrastructure		Sensors		Detector Systems		DAQ & Computing		TOTAL	
	No. heads	FTE	No. heads	FTE	No. heads	FTE	No. heads	FTE	No. heads	FTE
Permanent PhD	4	1.93	0	0.00	1	0.07	0	0.00	**5**	**2.00**
Temporary PhD	0	0.00	0	0.00	0	0.00	0	0.00	**0**	**0.00**
Graduate Students	0	0.00	0	0.00	0	0.00	0	0.00	**0**	**0.00**
Engineer	2	1.50	1	1.00	0	0.00	0	0.00	**3**	**2.50**
Computing Professional	0	0.00	0	0.00	0	0.00	0	0.00	**0**	**0.00**
Technician	1	0.50	0	0.00	0	0.00	0	0.00	**1**	**0.50**
Administrative	0	0.00	0	0.00	0	0.00	0	0.00	**0**	**0.00**
TOTAL	7	3.93	1	1.00	1	0.07	0	0.00	**9**	**5.00**
DOE/HEP Funding (per activity):										
SWF (in $, include overhead)		$844,346		$195,229		$17,830		$0		**$1,057,405**
M&S (in $, include overhead)		$449,001		$109,451		$28,146		$0		**$586,598**
Travel (in $, include overhead)		$10,000		$3,000		$2,000		$0		**$15,000**
TOTAL		**$1,303,347**		**$307,680**		**$47,976**		**$0**		**$1,659,003**

Fermilab

DOE Support FY 2009 (Actual)										
Personnel Support from DOE:	Core &		Sensors		Detector Systems		DAQ & Computing		TOTAL	
	No. heads	FTE	No. heads	FTE	No. heads	FTE	No. heads	FTE	No. heads	FTE
Permanent PhD	1	0.12	2	0.45	0	0.00	1	0.10	4	0.67
Temporary PhD	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Graduate Students	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Engineer	14	4.79	12	6.35	27	6.52	4	0.96	57	18.62
Computing Professional	2	0.41	1	0.35	1	0.35	1	0.16	5	1.27
Technician	12	4.61	18	4.11	49	10.89	2	0.25	81	19.86
Administrative	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
TOTAL	29	9.93	33	11.26	77	17.76	8	1.47	147	40.42
DOE/HEP Funding (per activity):										
SWF (in $, include overhead)	$1,810,476		$2,147,194		$3,315,082		$305,900		$7,578,652	
M&S (in $, include overhead)	$1,081,383		$586,266		$1,656,108		$81,553		$3,405,310	
Travel (in $, include overhead)	$48,117		$21,034		$28,592		$9,647		$107,390	
TOTAL	$2,939,976		$2,754,494		$4,999,782		$397,100		$11,091,352	

DOE Support FY 2010 (Proposed										
Personnel Support from DOE:	Core &		Sensors		Detector Systems		DAQ & Computing		TOTAL	
	No. heads	FTE	No. heads	FTE	No. heads	FTE	No. heads	FTE	No. heads	FTE
Permanent PhD	1	0.30	0	0.00	0	0.00	0	0.00	1	0.30
Temporary PhD	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Graduate Students	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Engineer	7	2.45	17	8.85	27	7.58	3	0.65	54	19.53
Computing Professional	0	0.00	1	0.25	1	0.10	1	0.25	3	0.60
Technician	10	3.94	17	5.19	36	7.76	2	0.25	65	17.14
Administrative	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
TOTAL	18	6.69	35	14.29	64	15.44	6	1.15	123	37.57
DOE/HEP Funding (per activity):										
SWF (in $, include overhead)	$1,313,300		$2,610,600		$2,651,400		$218,200		$6,793,500	
M&S (in $, include overhead)	$998,839		$856,135		$1,341,862		$118,164		$3,315,000	
Travel (in $, include overhead)	$49,561		$21,665		$25,438		$9,936		$106,600	
TOTAL	$2,361,700		$3,488,400		$4,018,700		$346,300		$10,215,100	

LBNL

DOE Support FY 2009 (Actual)										
Personnel Support from DOE:	Core & Infrastructure		Sensors		Detector Systems		DAQ & Computing		TOTAL	
	No. heads	FTE	No. heads	FTE	No. heads	FTE	No. heads	FTE	No. heads	FTE
Permanent PhD	0	0.00	0	0.00	2	2.00	0	0.00	2	2.00
Temporary PhD	0	0.00	0	0.00	1	0.33	0	0.00	1	0.33
Graduate Students	0	0.00	0	0.00	1	0.47	0	0.00	1	0.47
Engineer	4	1.50	1	1.00	2	0.46	0	0.00	7	2.96
Computing Professional	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Technician	8	5.85	3	1.37	0	0.00	0	0.00	11	7.22
Administrative	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
TOTAL	12	7.35	4	2.37	6	3.26	0	0.00	22	12.98
DOE/HEP Funding (per activity):										
SWF (in $, include overhead)		$1,808		$683		$768		$0		$3,259
M&S (in $, include overhead)		$904		$25		$25		$0		$954
Travel (in $, include overhead)		$26		$10		$10		$0		$46
TOTAL		$2,738		$718		$803		$0		$4,259

DOE Support FY 2010 (Proposed										
Personnel Support from DOE:	Core & Infrastructure		Sensors		Detector Systems		DAQ & Computing		TOTAL	
	No. heads	FTE	No. heads	FTE	No. heads	FTE	No. heads	FTE	No. heads	FTE
Permanent PhD	0	0.00	0	0.00	1	1.00	0	0.00	1	1.00
Temporary PhD	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Graduate Students	0	0.00	0	0.00	1	0.47	0	0.00	1	0.47
Engineer	5	3.05	2	1.50	1	0.62	0	0.00	8	5.17
Computing Professional	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Technician	8	5.90	3	1.47	0	0.00	0	0.00	11	7.37
Administrative	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
TOTAL	13	8.95	5	2.97	3	2.09	0	0.00	21	14.01
DOE/HEP Funding (per activity):										
SWF (in $, include overhead)		$2,137		$852		$657		$0		$3,646
M&S (in $, include overhead)		$531		$75		$75		$0		$681
Travel (in $, include overhead)		$40		$10		$10		$0		$60
TOTAL		$2,708		$937		$742		$0		$4,387

SLAC

DOE Support FY 2009 (Actual)										
Personnel Support from DOE:	Core & Infrastructure		Sensors		Detector Systems		DAQ & Computing		TOTAL	
	No. heads	FTE	No. heads	FTE	No. heads	FTE	No. heads	FTE	No. heads	FTE
Permanent PhD	0	-	2	1.0	0	-	0	-	2	1.0
Temporary PhD	0	-	0	-	0	-	0	-	0	-
Graduate Students	0	-	0	-	0	-	0	-	0	-
Engineer	9	3.0	0	-	1	0.8	2	1.6	12	5.4
Computing Professional	1	0.5	0	-	1	1.0	4	1.6	6	3.1
Technician	3	1.1	0	-	1	0.3	0	0.2	4	1.5
Administrative	0	-	0	-	0	-	0	-	0	-
TOTAL	13	4.6	2	1.0	3	2.1	6	3.3	24	11.0
DOE/HEP Funding (per activity):										
SWF (in $, include overhead)		$1,228		$310		$470		$944		$2,953
M&S (in $, include overhead)		$50		$100		$25		$50		$225
Travel (in $, include overhead)		$0		$0		$0		$0		$0
TOTAL		$1,278		$410		$495		$994		$3,178

DOE Support FY 2010 (Proposed)										
Personnel Support from DOE:	Core & Infrastructure		Sensors		Detector Systems		DAQ & Computing		TOTAL	
	No. heads	FTE	No. heads	FTE	No. heads	FTE	No. heads	FTE	No. heads	FTE
Permanent PhD	0	-	3	1.5	0	-	0	-	3	1.5
Temporary PhD	0	-	0	-	0	-	0	-	0	-
Graduate Students	0	-	0	-	0	-	0	-	0	-
Engineer	9	3.0	1	0.5	1	0.6	2	1.1	13	5.1
Computing Professional	1	0.5	0	-	1	1.0	4	1.6	6	3.0
Technician	2	1.1	0	-	1	0.3	0	-	3	1.4
Administrative	0	-	0	-	0	-	0	-	0	-
TOTAL	12	4.5	4	2.0	3	1.9	6	2.6	25	11.0
DOE/HEP Funding (per activity):										
SWF (in $, include overhead)		$1,257		$607		$414		$775		$3,053
M&S (in $, include overhead)		$50		$120		$25		$25		$220
Travel (in $, include overhead)		$0		$0		$0		$0		$0
TOTAL		$1,307		$727		$439		$800		$3,273