1 Fermi National Accelerator Laboratory (FNAL) Report

1.1 Introduction and Summary

FNAL is the only dedicated HEP laboratory in the US and plays a unique role of providing a strong, well-balanced research program designed to address critical needs for future HEP programs.

FNAL maintains facilities for: silicon detector development, liquid argon-based detectors, NICADD scintillator extrusion, CCD characterization, thin-film deposition, high power laser applications and test beams. These facilities are extremely valuable to the scientific community and the test beam will be critical for developing detectors for the LHC upgrade, ILC and rare decay physics. The lab also maintains an experienced team of engineers for ASIC development, cryogenics and data acquisition.

The projects proposed for KA15 funding are the 3D vertically integrated pattern recognition associative memory (VIPRAM), low noise CCD readout, a microwave kinetic induction detector (MKID), rad hard optical data links, a next generation data acquisition standard using the Advanced Telecommunications Computing Architecture (ATCA), simulation of high resolution calorimetry, dual readout calorimetry, and software framework for DAQ. The scientists and engineers at Fermilab have a long and distinguished record of developing innovative ideas into working systems.

FNAL has become a leader in the development and use of LAr in Intensity Frontier and Cosmic Frontier experiments. The LAr TPC test facility at Fermilab is unique, extremely valuable and doing important work such as the characteristics of the low energy response of liquid argon.

FNAL also provides an important test beam facility to the entire US HEP community for detector development studies. It is in the unique position to provide test beams in which different species of particle interactions can be studied.

The Detector Systems Group has carried out high quality research with substantial impact in the field. The Panel felt that existing program is very productive, but could be more cost-effective.

It was generally agreed that the FNAL KA15 program's management and direction was much improved since the 2009 review. There is a good internal structure with a coherent plan that emphasizes on those areas that are a good match to FNAL resources. A series of internal reviews (under a Detector Advisory Group) of the R&D projects guides the management of Detector R&D program. The panel suggested external review of new ideas would be beneficial.

The Panel noted that collaboration with other laboratories and with universities has also grown since the 2009 review.

1.2 Findings

- The VIPRAM project is pushing the development of 3D IC technology in order to provide the needed interconnections. This particular 3D electronics connects the associate memories needed to do pattern recognition to find tracks in silicon pixel detectors.
- FNAL continues with developing silicon tracking sensors with integrated trigger functionality.
- The low-noise CCD readout has many potential applications, both for telescopes and for dark matter detectors.
- The MKID can be used as a detector that could collect spectroscopic data in the IR, visible and UV bands simultaneously, and produce a camera far superior to any currently in existence. FNAL has an ambitious goal of developing 100,000 pixel imager MKIDs with complex readout.
- A crystal growing system has been built and has produced a 1 kg solid Xenon crystal. FNAL proposes to continue R&D to measure scintillation yield, electron drift and to compare with liquid.
- FNAL has developed extensive LAr facilities including a materials test stand, clean chamber for purity tests, and cryogenic distillation column. Liquid Argon Purity Demonstrator (LAPD) showed that LAr purity can be maintained to keep the lifetime of the electrons longer than 3 ms without requiring evacuation of the vessel.
- FNAL built an argon distillation column to separate argon from nitrogen from well gas (which is depleted in Ar-39) for use in DarkSide and DEAP dark matter experiments
- The work on optical links includes making a radiation n hard array capable or 120 Gbps aggregate rate and electro optical modulators. Much of this work is in cooperation with Argonne.
- The ATCA data acquisition system could have immediate impact in many small test setups, similar to the role the mini-DAQ played in the construction, assembly and testing of the ATLAS detector.

1.3 Comments

- The design of systems based on silicon sensors with 3D IC technology seems still not mature. Development of new ideas that could possibly produce the breakthrough in the field should be, however, encouraged. Since the problems to be solved are particularly challenging, a better and wider national and international collaboration would be an important added value. The Fermilab management should develop a technology roadmap to evaluate the benefits and viability of this effort.
- MKID is an exciting project which seems to have the potential to contribute substantially to experiments in the Cosmic Frontier. FNAL has unique capabilities to contribute to the project.
- Solid Xenon crystal R&D is an interesting generic detector R&D project which should be continued.
- FNAL's development of the distillation column for processing of argon gas from deep wells is likely to have great value in this area. There is a concern that if Darkside is not chosen as a Generation-2 Dark Matter search experiment, the work could be orphaned. The highly successful long-drift purity demonstration was a crucial step in the development of kiloton LAr detectors.
- A future large scale LAr detector for neutrino and proton decay physics seems ideal for a major US-based program and Fermilab is well positioned to take the lead on this.
- The ATCA work should continue, and should be closer coordinated with similar work being done at SLAC.
- FNAL has made some effort in the past year to give more support to test beams, but even more is needed to address the community need. A particular need is low energy beams with excellent particle identification.
- Fermilab should seek to work cooperatively with other laboratories that are actively pursuing in similar technologies.
- As the only U.S. laboratory with purely HEP mission, Fermilab should take leading role in organizing workshops in new detector technology to attract expertise from the other DOE labs, the university community, and non-HEP sources.

1.4 Recommendations

- None.