

Subject: LARP Review letter and report.

Filed: BStrauss/vb/3/2/12 Q: Facilities Division/Reviews/LARP/LARP review 2011 letter.

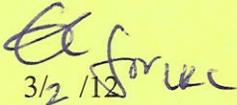
Concurrences

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Department of Energy

Washington, DC 20585

MAR 5 2012

Dr. Eric Prebys
LARP Program Leader
Fermi National Accelerator Laboratory
P.O. Box 500
Batavia, IL 60510-0500

Dear Dr. Prebys:

With this letter, I am transmitting the report from the DOE LARP Annual Program Review held at the Fermi National Accelerator Laboratory on June 1-2, 2011. The report is based on the peer review letters/reports written by our consultants who participated in the review as well as presentations made by the LARP management and associated discussions during the review. The report conveys the findings from the review and provides guidance to LARP management on the direction of its research program.

I want to thank the LARP management for all the efforts and preparation to make the review run smoothly and successfully. Overall it has been another productive year for LARP, but there were some specific recommendations from the consultants for the LARP Organization and Management. These comments and recommendations essentially duplicate those stated last year and are:

1. Accelerator Physics---perform simulations in the coming year to help guide CERN's choice of quadrupole aperture;
2. Crab Cavities---work with CERN to develop clear specifications and a realistic R&D plan with goals for the crab cavities;
3. Magnets---undertake, in close consultation and cooperation with CERN, a substantial role for modeling energy deposition and radiation damage from beam losses and other collider issues related to the IR quad aperture decision; and
4. LARP management---develop a strategic plan for LARP R&D that supports the LHC schedule, and meets out year budgets, and work with DOE and CERN to establish a formalism for the dialog and protocol which will provide the needed specifications in time to meet agreed upon milestones.



**Office of High Energy Physics
Report on the**

**U.S. LHC Accelerator Research Program
(LARP)**

**Fermi National Accelerator Laboratory
June 1-2, 2011**

Executive Summary

The review committee was generally pleased with the accomplishment and the coordination among the member laboratories on the research efforts within LARP. In particular are the results and the quality of work performed under the LARP program—the Accelerator Systems (AS) has delivered all instrumentation to the Large Hadron Collider (LHC) at CERN as promised; the Magnet Systems (MS) has successfully matured the conductor design for Nb₃Sn quadrupoles with the achievement of its technical objective for the long quadrupole (LQ); and the LARP Management has run a very successful program with all the collaborating laboratories working together effectively and efficiently.

LARP continues to make significant contributions, with respect to commissioning and operations, to the achieved successes of LHC. CERN has expressed their appreciation for these contributions, noting that the U.S. LARP team is an integral part of the LHC accelerator program. The Long Term Visitor and Toohig Fellows programs are viewed by CERN to be very attractive and successful, and to benefit both the U.S. and CERN programs. Many of the LARP activities have significant application to present and future accelerator R&D confronting U.S. accelerators. The Chamonix meetings in 2010 and 2011 have redirected the course of LHC accelerator upgrades and improvements for the next decade, resulting in a course for accelerator R&D that is now more strategic and is dependent on LARP activities.

The LARP accelerator science program has delivered both instrumentation and instrumentation to the LHC. Studies continue on radiation damage, beam-beam effects and electron cloud instabilities. The rotating collimator still has some engineering and construction challenges.

The LARP magnet science program is the world's leading effort in Nb₃Sn SC magnets for accelerators. The LQ fabrication and testing has demonstrated the robustness of the LARP design in the transition from short model magnets to long magnets and the >200 T/m achievement is a major milestone. The High-field Quadrupole (HQ) program is now in full swing, with two magnets built and each undergone two cycles of assembly, testing, and re-assembly. The insulation failure in HQ2 is now under investigation. The new luminosity upgrade strategy, in response to the Chamonix 2010 LHC meeting, projects a Technology Selection in 2013-2014, for which a Long HQ quadrupole must be built and tested. However, the specifications for that LHQ magnet and the criteria for the selection have yet to be articulated.

The Committee listed a number of recommendations for the LARP program. The key recommendations are as follows:

- Accelerator Physics—perform simulations in the coming year to help guide CERN's choice of quadrupole aperture
- Crab Cavities—work with CERN to develop clear specifications and a realistic R&D plan with goals for the crab cavities and prepare a proposal to DOE to fabricate a “base” cavity;
- Magnets—undertake, in close consultation and cooperation with CERN, a substantial role for modeling energy deposition and radiation damage from beam losses and other collider

issues related to the IR quad aperture decision, formulate a plan for transition to a HL-LHC construction project; and

- LARP management—develop a strategic plan for LARP R&D that supports the LHC schedule, and meets the FY 2011 and succeeding budgets; and work with DOE and CERN to establish a formalism for the dialog and protocol which will provide the needed specifications in time to meet agreed upon milestones. This is the second successive year that this recommendation was stated.

Introduction

After the initial delay to repair some of its superconducting magnets, the 27 km Large Hadron Collider (LHC) at the European Laboratory for Particle Physics (CERN) near Geneva, Switzerland, is now operating at the world's highest collision energies. It is a unique facility for basic research in high energy physics to probe the structure of matter and the underlying symmetries in the universe through controlled proton-proton collisions. The United States has contributed to its construction with in-kind contributions for the magnetic focusing systems at the four major interaction regions of the LHC ring. In addition, the U.S. has and is providing substantive support for accelerator instrumentation, beam studies and diagnostics.

To maximize the science exploitation from its major investment in the technology and science of particle accelerators, the U.S. initiated the LHC Accelerator Research Program (LARP) to develop the tools and technology for improving the performance of the machine. This also serves to maintain U.S. core competency in accelerator technology in the areas of superconducting magnet design and engineering as well as accelerator physics, commissioning and instrumentation. The R&D projects undertaken by LARP are expected to be consistent with the plans envisioned by CERN for the program at the LHC.

The annual program review of LARP was held on June 1-2, 2011 at Fermi National Accelerator Laboratory (FNAL) by the Department of Energy (DOE). The charge for the review was given in a memorandum from Michael Procaro to LK Len, on May 29, 2011 (attached as Appendix A). The review covered issues pertaining to the management of the program, various accelerator R&D activities, operation of components of the LHC hardware and beam instrumentation delivered by LARP for the accelerator and development of Nb₃Sn superconducting magnets (see the agenda in Appendix B). The list of reviewers is included in Appendix C. The reviewers were asked to evaluate:

- The quality and significance of the LARP scientific and technical accomplishments, and the merit, feasibility and impact of its planned research program;
- The effectiveness of management in strategic planning, developing appropriate core competencies, implementing a prioritized and optimized program for potential participation in future accelerator upgrades at the LHC at CERN; specifically, are these LARP activities well aligned with present LHC schedule;
- The effectiveness and appropriateness of the laboratory interactions to maximize the leveraging of existing infrastructure and expertise available at those laboratories.

In addition, they were also asked to comment on the priority and levels of R&D effort for LARP to undertake in the superconducting magnet and accelerator systems that would be most effective and optimum in positioning the U.S. for participation in the planned LHC upgrades and also in the multi-year plan developed by the LARP management consistent with this goal, what is the timeline and the resources needed to mount this program, what are the scientific and technical risks associated with the proposed program, and are the available resources for LARP being optimally used to achieve the planned goals.

Presentations made by LARP participants can be found at the LARP review webpage: <https://indico.fnal.gov/contributionListDisplay.py?confId=4380>. At the review, the committee questioned the speakers during their presentations and discussed their observations in executive sessions in the presence of DOE representatives Michael Procario, LK Len and Bruce Strauss. Members of the panel provided both oral and written preliminary findings to LARP management at a close-out session at the end of the review. This report reflects the final conclusions of the consultants proffered in written evaluations sent subsequently to Dr. Procario.

The discussion in the rest of this document, based on the written reports of the consultants and presentations made by LARP management, provides additional information on the views and recommendations offered by the committee of experts.

Findings

The review committee (see Appendix C) heard technical progress reports presented by the LARP participants in the development of accelerator and magnet systems during the past year. The presentations were of high quality and the overall responsiveness of the LARP team to questions and challenges was deemed satisfactory. The presentations showed a strong cohesiveness and smooth coordination of the different LARP research efforts across the laboratories. There were also two talks by CERN collaborators on the LHC schedule and upgrade plan.

The reviewers found that the LARP activities under the Accelerator Systems to be noteworthy and excellent. These include beam instrumentation, low-level radio-frequency (LLRF), crab cavities and accelerator physics. All accelerator instrumentation was delivered to CERN as promised and is working well. CERN representatives at the review stated that LARP contributions to LHC startup, commissioning, and operation have been extremely valuable.

As reported by Oliver Brüning and Lucio Rossi the Chamonix meetings in 2009 and in particular 2010 have resulted in a number of upgrade thrusts and task forces. These include a shutdown in the 2013 timeframe for repair and optimization of the magnet to magnet splices, long term consolidation for the injector complex, an SPS upgrade, the High Luminosity project (HL-LHC), as well as the launching of the study to double the beam energy of the LHC. Current plans include raising the machine energy to first 6.5 TeV per ring followed by operation at the nominal machine energy of 7 TeV per beam. At the time of this review peak luminosity was $2E07$ with the goal in 2011 for integrated luminosity of $1fb^{-1}$ to the major experiments.

Of major interest to U.S. planning are the HL-LHC and the potential contributions to the upgraded machine.

The rotatable collimator is considered to be a "Phase II" design that would replace or complement the present CERN design. Despite excellent results of the bent crystals as primary collimators, CERN believes that while additional R&D is good, complications with alignment of the crystal may limit its utility in the LHC. Present LARP analysis of the electron lens as beam-beam compensation device has evolved into support of HEBC hardware. LARP has scheduled a collimation review meeting for June 14-15, 2011 to determine next steps.

There are several studies underway by the members of U.S. LARP covering TMCI instability, non-linear simulation codes, dynamic modeling, etc. U.S. LARP is a vital partner in the High Lumi Design study.

With respect to Crab Cavities a workshop was held at CERN on December 15-17, 2010 where it was agreed that compact cavities could be realized and would improve LHC luminosity. There were many proposed designs but the workshop did not choose one over another.

In the area of beam dynamics simulations have been performed in support of LARP and beam studies also have been performed at RHIC, the Tevatron and the SPS. Work is scheduled to resolve discrepancies between simulation approaches and experimental results. LARP is accepting a joint coordinating role in energy deposition studies of the HL-LCH.

Within the LARP Magnet Systems, it was found that the Technology Quadrupole (TQ) magnet program has successfully matured the mechanical, electrical and conductor design for Nb₃Sn quadrupoles, and validated the LARP design philosophy for most of the important elements of magnet technology: the superconducting strand, the cabling, the insulation, the management of stress within the quadrupole structure, quench protection.

The Long Quadrupole (LQ) fabrication and testing has demonstrated the robustness of the LARP design in the transition from short model magnets to long magnets, which had remained until now a question mark. The quality control during coil fabrication has coupled well with repair of the few faults detected, and disassembly and reassembly has been accomplished with recovery of full performance. The LQ success has been a major milestone for Nb₃Sn magnet technology and is a signal achievement of LARP during the past year.

The new luminosity upgrade strategy, after the Chamonix 2011 meeting, projects a Technology Selection by 2014, for which a pre-prototype quadrupole must be built and tested. However, the specifications for that magnet and the criteria for the selection have not yet been articulated. The target for installing a full complement of Nb₃Sn quadrupoles by 2022 will require an ambitious transition to a manufacturing project very soon after the Technology Selection. The infrastructure may require lead times that reach almost back to the present.

LARP Management has been very successful in getting all the collaborating laboratories to work together effectively and efficiently. The Program Management activities, which include commissioning at the LHC, and the Long Term Visitor and Toohig Fellowship programs, were found to be valued highly by CERN. LARP has made significant contributions to help achieve the successes at the LHC. The CERN representatives at the review acknowledged and expressed their appreciation for these contributions, and notes that the LARP team is an integral part of the LHC accelerator program. The Chamonix meetings have redirected the course of LHC accelerator upgrades and improvements for the next decade, resulting in a course for accelerator R&D that is now more strategic (with five new task forces) and is dependent on LARP activities.

Comments

The reviewers found the overall accomplishments in the LARP program to be very impressive. In the Accelerator Systems, they were especially impressed by the completion and delivery of all instrumentation to the LHC with all systems working well. The development of the fast kicker technology for e-cloud control is interesting and potentially useful in many other applications. The reviewers saw a need for developing detailed technical and safety requirements for installation of the rotatable collimator in the SPS and for evaluating performance of the device. These requirements should be clearly stated and formally agreed upon by LARP and CERN. Pass/fail criteria in the Hi-Rad-Mat test also need to be very clearly specified before proceeding with the test. The main goal of the crab cavity activities at this time appears to be studies to validate a chosen crab cavity design.

There is also an urgent need, in lights of the new CERN strategy after Chamonix 2010 and 2011, for a dialog between LARP and CERN to reach criteria for a Technology Selection. The longer-term effort towards a magnet construction project following a successful Technology Selection requires that infrastructure needs for manufacturing long magnets be addressed quickly. As the only group that has perfected Nb₃Sn magnet technology, it is essential that LARP magnet group recognize that it is now in a new phase, where a pre-project build-up of the infrastructure for winding, potting, reacting and assembly of the final magnets and design for reliability become a major part of their task. There appears to have been no action on the suggestion from previous year's reviews, where it was suggested that the Accelerator and Magnet teams cooperate to model the aspects of operation of the IR quadrupoles in the HL-LHC as required to inform the analysis of the aperture requirements. CERN's present view on this is that a decision on aperture should await LHC operation with 7 TeV beams. Given the projected schedules for 7 TeV beam operation (>2015) and installation of the IR upgrade (>2018) the two timings would likely be inconsistent. There are a number of technical issues remain to be addressed in the magnet program, and are embodied in LARP's agenda for the coming years.

The review panel commended the LARP Management for establishing a well run program which is impacting the LHC and bringing benefit to accelerator R&D in general. Its collaborating laboratories are working effectively and efficiently with each other. Recommendations from the last review were adequately addressed except the magnet aperture recommendation which is repeated this year. As stated in previous reviews LARP is an R&D program, and was not established to build and deliver hardware, so additional rigor is needed within LARP to clearly define the end of the R&D phase, to decide when to move into a prototype and production (or project) phase, and to delineate funding between the two activities. This is particularly relevant to infrastructure development. There is also a need for better articulated specifications and deliverables for each R&D item. These need to be determined by the LHC task forces in time to meet both LARP and LHC technology decisions. Given the constrained funding scenarios available in the future, it is important to prioritize tasks and fund those with specific and high visibility technology deliverables.

Recommendations

Several recommendations have been provided by the review panel in the three areas of the LARP program as discussed in the above sections.

LARP Accelerator Program

The Panel's recommendations for the overall LARP accelerator program include:

For crab cavity—

1. Work with the CERN-RF Group to develop clear specifications and a realistic R&D plan with goals for the crab cavities.
2. Prepare and submit a limited scope plan to DOE requesting potential funds to fabricate a prototype “bare” cavity conforming to specifications from the CERN crab cavity workshop.

For accelerator science—

1. Continue work on simulations of radiation damage to superconducting magnets in the LHC IR. See also recommendations below.
2. Continue work on beam physics especially beam-beam interactions.

LARP Magnet Program

For the magnet program, the panel provided the following recommendations:

1. The panel again **strongly** recommended that, during the coming year, in close consultation and cooperation with CERN, LARP undertake a substantial role for modeling energy deposition and radiation damage from beam losses and other collider issues related to the IR quad aperture decision.
2. LARP/APUL magnet program management should develop a detailed plan including budget and schedule to advise DOE on future transition to an HL-LHC construction project.
3. Begin integrating cryogenic and cryostat design into the magnets.
4. If possible seek qualified alternate strand vendors and improve piece length.

LARP Organization and Management

The review panel has two recommendations for the management and organization aspects of LARP:

1. Provide a detailed plan, including budget profile, to DOE on transitioning from LARP R&D into HL-LHC by February 1, 2012. A similar recommendation was stated last year.
2. Provide to DOE by February 1, 2012, a prioritized list of LARP R&D activities indicating which will be emphasized and which will be reduced.

Appendix A – Charge Letter



Department of Energy

Washington, DC 20585

MAR 29 2011

MEMORANDUM FOR LK LEN

LARP PROGRAM MANAGER
FACILITIES DIVISION
OFFICE OF HIGH ENERGY PHYSICS

FROM:

MICHAEL PROCARIO *Mike Procario*
ACTING ASSOCIATE DIRECTOR OF SCIENCE
FOR HIGH ENERGY PHYSICS

SUBJECT:

U.S. Large Hadron Collider Accelerator Research Program Annual
Technical and Management Review

This memorandum is to request that you organize and conduct a Technical and Management review of the U.S. Large Hadron Collider (LHC) Accelerator Research Program (LARP). This review should appropriately involve the input and participation of related programs in the Office of High Energy Physics (OHEP).

The LHC Accelerator Research Program, encompassing research and development activities in superconducting materials and magnets, accelerator systems, beam instrumentation, and LHC accelerator commissioning efforts, plays an important role in the nation's high energy physics program with its strong participation in the experiments at the LHC at CERN. It is important for OHEP to understand the progress and future plan of the research program, the effectiveness of its management and whether resources and planning are being directed optimally to support the scientific goals of the nation's high energy physics program.

It is requested that your review evaluate:

- The quality and significance of the LARP scientific and technical accomplishments, and the merit, feasibility and impact of its planned research program;
- The effectiveness of management in strategic planning, developing appropriate core competencies, implementing a prioritized and optimized program for potential participation in future accelerator upgrades at the LHC at CERN; specifically, are these LARP activities well aligned with present LHC schedule;
- The effectiveness and appropriateness of the laboratory interactions to maximize the leveraging of existing infrastructure and expertise available at those laboratories;
- The strength and relevance of any new proposed research activities, to enable OHEP to make more fully informed decision on this new scope of work.



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In the context of these general review criteria, there are special circumstances that the nation's high energy physics program is facing where additional information at this time would be helpful for this office in its planning. In particular, with respect to the most current LHC schedule, what should be the priority and levels of R&D effort for LARP to undertake in the superconducting magnet and accelerator systems that would be most effective and optimum in positioning the U.S. for participation in the LHC upgrades? Is the multi-year plan developed by the LARP management consistent with this goal? What is the timeline and the resources needed to mount this program? What are the scientific and technical risks associated with the proposed program, and are the available resources for LARP being optimally used to achieve the planned goals?

The review should also comment upon what progress has been made towards addressing action items, if any, from previous LARP Reviews.

I would appreciate receiving the review reports, suitable for transmission to the laboratories, within 45 days after the review.

cc: Eric Prebys, FNAL
Michael Procario, SC-25.2
Bruce Strauss, SC-25.2

Appendix B – Agenda for Review of LARP July 13-14, 2009

Wednesday 01 June 2011

- 08:30 - 09:00 Executive Session (closed)
Executive Orientation Session
Location: Comitium (Wilson Hall 2, SE)
- 09:00 - 10:15 Opening Plenary
Introductory Session
Location: Comitium (Wilson Hall 2, SE)
- 09:00 **Introduction** 25'
Speaker: Eric Prebys (Fermilab)
Material: [Slides](#)
- 09:25 **View from CERN/schedule** 25'
Speaker: Oliver Bruning (CERN)
Material: [Slides](#)
- 09:50 **LHC Upgrade Projects and Design Studies** 25'
Speaker: Lucio Rossi (CERN)
Material: [Slides](#)
- 10:15 - 10:30 Coffee
- 10:30 - 12:30 Magnet Systems A
First Magnet Systems parallel session
Location: Universe (Wilson Hall 1 North)
- 10:30 **Introduction** 30'
Speaker: Sabbi GianLuca (LBNL)
Material: [Slides](#)
- 11:00 **LQ Program** 30'
Speaker: Giorgio Ambrosio (FNAL TD/MSD)
Material: [Slides](#)
- 11:30 **HQ Program** 30'
Speaker: Shlomo Caspi (LBNL)
Material: [Slides](#)
- 12:00 **Discussion** 30'
- 10:30 - 12:30 Accelerator Systems A
First Accelerator Systems parallel session
Location: Comitium (Wilson Hall 2, SE)
- 10:30 **LLRF** 15'

Speaker: John Fox (SLAC)

Material: [Slides](#) 

- 10:45 **SPS Feedback** 15'
Speaker: John Fox (SLAC)
Material: [Slides](#) 
- 11:00 **Instrumentation** 20'
Speaker: Alessandro Ratti (LBNL)
Material: [Slides](#) 
- 11:20 **Collimation** 40'
Speaker: Thomas Markiewicz (SLAC)
Material: [Slides](#) 
- 12:00 **Discussion** 30'
- 12:30 - 13:30 **Lunch**
- 13:30 - 15:45 **Accelerator Systems B**
Second Accelerator Systems parallel
Location: Comitium (Wilson Hall 2, SE)
- 13:30 **Crystal Collimation** 15'
Speaker: Nikolai Mokhov (Fermilab)
Material: [Slides](#) 
- 13:45 **Energy Deposition Studies** 10'
Speaker: Nikolai Mokhov (Fermilab)
Material: [Slides](#) 
- 13:55 **Beam-beam and Electron Lens** 20'
Speaker: Alexander Valishev (Fermilab)
Material: [Slides](#) 
- 14:15 **Crab Cavities** 30'
Speaker: Rama Calaga (BNL)
Material: [Slides](#) 
- 14:45 **Discussion** 30'
- 13:30 - 15:45 **Magnet Systems B**
Second Magnet Systems parallel
Location: Universe (Wilson Hall, 1 North)
- 13:30 **Tour/Discussion: LARP magnets** 1h00'
- 14:30 **LHQ Program** 15'
Speaker: Giorgio Ambrosio (FNAL TD/MSD)
Material: [Slides](#) 
- 14:45 **Conductor and Cable** 30'

Speaker: Arup Ghosh (Brookhaven National Laboratory)

Material: [Slides](#)

▪ 15:15 **Summary and HL-LHC Plan** 30'

Speaker: Sabbi GianLuca (LBNL)

Material: [Slides](#)

○ 15:45 - 16:00 Coffee

○ 16:00 - 17:00 Plenary Session

Afternoon Plenary

Location: Comitium (Wilson Hall 2, SE)

▪ 16:00 **Toohig Fellows and Long Term Visitors** 15'

Speaker: Eric Prebys (Fermilab)

Material: [Slides](#)

▪ 16:15 **Budget Overview and Meeting our Commitments** 15'

Speaker: Eric Prebys (Fermilab)

Material: [Slides](#)

▪ 16:30 **Discussion** 30'

○ 17:00 - 18:00 Executive Session (closed)

First day closing executive session

Location: Comitium (Wilson Hall 2, SE)

○ 18:00 - 19:30 Users' Meeting Reception (Wilson Hall Atrium)

• **Thursday 02 June 2011**

○ 08:30 - 10:00 Question and Answer Session

Plenary with answers to questions and discussion from previous day

Location: Comitium (Wilson Hall 2, SE)

Material: [Q1-4 \(slides\)](#) [Q7 \(slides\)](#) [Question 5 \(slides\)](#) [Radiation issues](#)

○ 10:00 - 10:15 Coffee

○ 10:15 - 12:00 Writing Session (closed)

Executive writing session

Location: Universe (Comitium (Wilson Hall 2, SE))

○ 12:00 - 13:00 Lunch

○ 13:00 - 14:00 Writing Session (closed)

Executive writing session

Location: Comitium (Wilson Hall 2, SE)

○ 14:00 - 15:00 Closeout

Closeout presentations

Location: Comitium (Wilson Hall 2, SE)

Material:

Appendix C – List of Consultants

- Joseph Minervini, MIT
 - 617-253-5503
 - minervini@psfc.mit.edu
- Joe Bisognano, UWISC
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