LARP JOINT IR STUDIES

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Abstract

LARP initiated Joint IR Studies (JIRS) in October 2007 (FY2008) to coordinate efforts related to the LHC Phase I and II upgrades previously situated either in Accelerator Systems or in Magnet Systems. This note outlines JIRS goals, main directions and milestones.

INTRODUCTION

After a number of years of operation at nominal parameters, the LHC will be upgraded for higher luminosity. The Interaction Region (IR) upgrade is currently planned at CERN in two phases with a target luminosity for Phase I of ~$2.5 \cdot 10^{34}$ $cm^{-2}s^{-1}$ and for Phase II of ~10^{35} $cm^{-2}s^{-1}$. In Phase I the baseline 70-mm NbTi low-beta quadrupoles will be replaced with larger aperture NbTi magnets and in Phase II with higher performance Nb_3Sn magnets.

US-LHC Accelerator Research Program (LARP) is working on the development of large-aperture high-performance Nb_3Sn magnets for the LHC Phase II luminosity upgrade. Significant progress in Nb_3Sn accelerator magnet R&D was made during recent years in the framework of LARP and core magnet programs. This included development and optimization of Nb_3Sn strands and cables, coil fabrication technologies based on the W&R approach, mechanical support structures and magnet assembly techniques for high-field magnets. Nb_3Sn magnet performance (quenches and field quality) was demonstrated by series of short dipole and quadrupole models [1-4]. A Nb_3Sn accelerator magnet technology scale up was also started with quite encouraging results [4-5].

Recent progress in the Nb_3Sn accelerator magnet technology suggests the possibility of using a limited number of Nb_3Sn quadrupoles in the Phase I upgrade to improve the IR performance at higher luminosity and provide an early demonstration of Nb_3Sn magnet technology in a real accelerator environment. To coordinate efforts related to the LHC Phase I and II upgrades, LARP has started Joint IR Studies (JIRS) in October 2007 (FY2008). These studies will extend and integrate connected tasks that were previously performed by LARP either within Accelerator Systems or in Magnet Systems and also help to improve efficiency in communication with CERN. This note outlines JIRS goals, main directions and milestones for the next two years.

JIRS MISSION AND TASKS

During the next two years (FY08-09) LARP Magnet R&D will focus on two major goals. The first goal is the continuation of the Nb_3Sn technology scale up using technological quadrupoles of the LQ series to demonstrate the viability of long (up to 4-m) Nb_3Sn quadrupoles [6]. The second goal is to study and extend the parameter space of Nb_3Sn IR quadrupoles to higher fields and apertures using 1-m long models of HQ series [7].

Next LARP will work on the development of Nb_3Sn *accelerator* magnets suitable for the LHC luminosity upgrades. The main goal of Joint IR Studies (JIRS) is to provide input parameters and guidance for this work. The general framework of JIRS is determined by the Mission Statement of LARP "Joint Interaction Region Studies". Based on this document JIRS are mostly concerned with the post-LQ and HQ magnet series:

- QA quadrupole – accelerator quality magnet.
- QB quadrupole – main Phase II upgrade magnet.
- "Slim" magnets in front of Inner Triplets.

The QA quadrupoles are defined above as the accelerator quality magnets designed to demonstrate the possibilities and limitations of Nb_3Sn accelerator magnet technology. Assuming the possibility of using a limited number of Nb_3Sn quadrupoles in the Phase I upgrade this magnet series could also be considered as a prototype of Nb_3Sn Phase I quadrupoles. Thus the work on QA quadrupole has highest priority. This effort will include definition and evaluation of a list of potential QA locations in LHC in communication with CERN including Q1-Q3 in a potential Phase I "hybrid" IR layouts. We will develop specifications for the accelerator-quality parameters of QA quadrupoles including magnet aperture and length, maximum and nominal gradients, alignment and field quality requirements, persistent current and snap-back effects, power supply and quench protection requirements, etc. We will examine the possibility of using LQ or HQ designs and tooling to build QA magnets. JIRS will also identify and propose bench tests on QA (or LQ or HQ) magnets that would help to explore and demonstrate Nb_3Sn accelerator magnet performance and operation lifetime (except radiation).

The QB quadrupoles are defined as prototypes for the Phase II upgrade. We will perform preliminary studies to generate a self-consistent set of target parameters for Phase II quadrupoles, including all the necessary accelerator quality parameters, consistent with possible upgrade scenarios. These studies will provide guidance for LARP magnet R&D, well before CERN defines the final design and operation parameters of Phase II IR quadrupoles. The preliminary QB design and accelerator-quality parameters will be also used to estimate and simulate correction system parameters and possible issues related to a QB implementation in the Phase II upgrade.

Some proposed IR concepts consider using the so called "slim" magnets (dipoles or quadrupoles) inside ATLAS and/or CMS detectors. In support of these studies JIRS will produce a list of preliminary parameters (aperture, length, outer diameter, nominal field/gradient, field quality, alignment, etc.) and operation conditions (radiation deposition, forces and fields from detector magnet, dynamic and static heat load, etc.) for these magnets. The possibility of conventional NbTi technology or alternative magnet technologies (Nb_3Sn, Nb_3Al or HTS) needs to be evaluated and compared in terms of operational margin, magnet life-time, etc.

In FY08-09 JIRS are organized in two directions (Simulations and Studies) and include four tasks. The present JIRS structure is shown in Table I. The working plan for each task includes associated aspects related to QA, QB and "Slim" magnets. The highest priority (~80-90% of resources) will be given to QA general magnet studies and use of QA quadrupoles in the Phase I upgrade. Internal task interaction, exchange of information, discussions and feedback, and coordination with CERN will lead to the integrated results expected from JIRS.

Table I. JIRS structure.

WBS	Task	Coordinator
3.3	Joint IR Studies	A. Zlobin (Fermilab)
3.3.1	*Simulation*	
3.3.1.1	Operating Margins	N. Mokhov (Fermilab)
3.3.1.2	Accelerator Quality & Tracking	G. Robert-Demolaize (BNL)
3.3.2	*Studies*	
3.3.2.1.	Optics & Layout	J. Johnstone (Fermilab)
3.3.2.2.	Magnet Feasibility Studies	P. Wanderer (BNL)

PHASE I LUMINOSITY UPGRADE

CERN has adopted a staged LHC IR upgrade plan. Phase I upgrade, scheduled nominally for 2012, will increase the luminosity in two IRs used by ATLAS and CMS experiments to the level of ~$2.5*10^{34}$ $cm^{-2}s^{-1}$. It will be achieved mainly by reducing the beta-star in the interaction points by a factor of two from 50 to 25 cm and using larger-aperture NbTi quadrupoles. Phase II upgrade will increase the luminosity up to 10^{35} $cm^{-2}s^{-1}$ using higher performance Nb_3Sn magnets.

It is likely that the Phase II upgrade will be delayed with respect to the originally planned date (2015) providing more time for the development of Nb_3Sn quadrupoles with ultimate parameters. The progress in Nb_3Sn accelerator magnets achieved in the U.S., the magnet parameters and operation conditions as well as the upgrade schedule allows seriously considering the possibilities of U.S. participation in the Phase I IR upgrade. The U.S. could provide a limited number (4 or 8 out of the 16 required) of Nb_3Sn quadrupoles with more relaxed parameters for the new Inner Triplets.

The idea of hybrid triplets was originally proposed by CERN [8] to share the cost of the Phase I upgrade. The primary goals from the LARP standpoint are the improvement of the IR performance at higher luminosity (due to the higher nominal gradient and temperature margin of Nb_3Sn quadrupoles) and an earlier demonstration of Nb_3Sn accelerator magnet technology in the LHC before using it in the Phase II.

The hybrid proposal is an exciting challenge for LARP. Besides resolving various technical issues, the development and production of Nb_3Sn magnets for the Phase I upgrade would require launching a construction project similar to that produced the present baseline NbTi LHC IR quadrupoles. It will also involve some LARP R&D re-programming and a modest funding increase beyond current LARP budget.

The JIRS working group started technical analysis and evaluation of the Phase I hybrid concept and Nb_3Sn magnet requirements. This involves analysis of compatibility of Nb_3Sn quadrupoles with the Phase I IR optics, cryogenics, power and quench protection systems, etc. JIRS will establish and maintain broad and unrestricted communications with the LHC Insertions Upgrade Working Group (LIUWG) at CERN, but will work independently.

The cost and schedule analyses of the hybrid proposal will be also performed and presented to the DOE review in June 2008, at the same time as the LIUWG technical report on the Phase I upgrade conceptual design. A final commitment to U.S. deliverables in a hybrid Phase I upgrade will occur after a technical review including the magnet cost and schedule.

CONCLUSIONS

LARP Joint IR Studies will guide LARP magnet R&D towards its ultimate goal – LHC Phase II upgrade based on high-performance Nb_3Sn accelerator magnets. In FY08 JIRS primary focus is on evaluation of the possibilities of LARP contribution to the LHC Phase I upgrade. The goal is to pursue Nb_3Sn magnet R&D and suggest consistent IR optics and magnet parameters, without favoring any upgrade proposal. JIRS work will proceed in close communication with the AB and AT divisions at CERN.

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