



US LHC Accelerator Research Program

bnl - fnal- lbnl - slac

IRQ R&D - Introduction

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LARP collaboration meeting

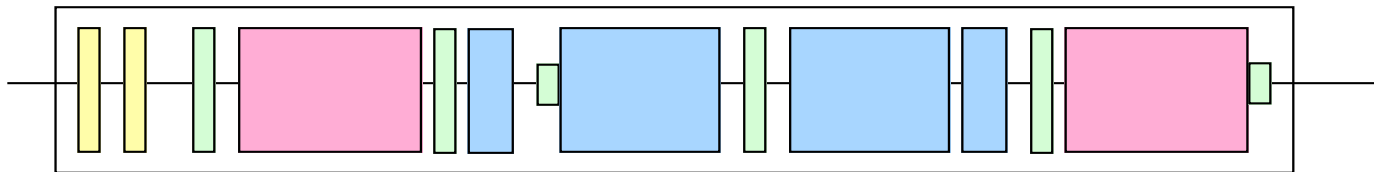
19-21 October, 2004

Napa, CA



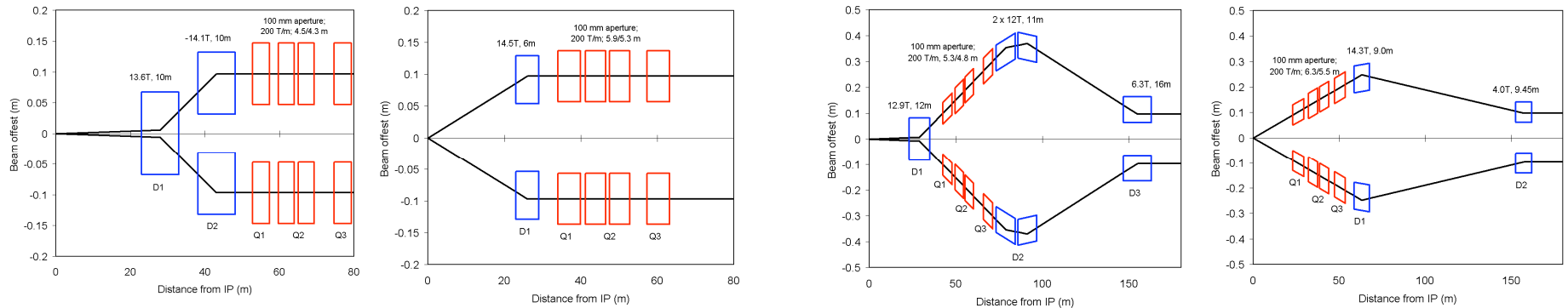
LHC Inner Triplet Designs

LHC IR optics based on single-bore inner triplet with large-aperture quads



The key elements of this approach are large-aperture high-gradient quads

LHC IR optics based on double-bore inner triplet with 100 mm quads



The key elements of these approaches are separation dipoles and then double bore IRQ



Approaches and Challenges

At present time the IRQ R&D program is focused on the large-aperture quadrupoles based on Nb₃Sn superconductor for the single-bore inner triplet and double-bore inner triplet with parallel apertures.

We will push magnet parameters above the present state-of-the-art:

- $J_c(12T, 4.2K) \sim 3 \text{ kA/mm}^2$ in the coil
- the B_{\max} in the coil at quench $\sim 15 \text{ T}$
 - B_{\max} exceeds the level reached in Nb₃Sn accelerator magnets to date
 - the maximum stress in the coil, induced by Lorentz forces, approaches to the level which may cause significant degradation or even damage of brittle Nb₃Sn conductor

Nb₃Sn is brittle => new technologies for accelerator magnets:

- W&R is the baseline technology



IRQ R&D Phases

Program starts with Conceptual Design Studies of IR and magnet designs.

A series of short models has to address the issues of magnet **technology**, **quench performance**, **field quality**, **mechanics**, **quench protection**, **reproducibility**, **long term performance**, etc.

Length dependent effects will be studied with 4-m long **quadrupole** coils, as soon as we achieve acceptable quench performance on short models.

Model R&D will be followed by the construction of one or more **quadrupole prototypes** containing all of the **features required for use in the LHC**.



IRQ design studies summary and open issues

IRQ conceptual design studies and preparation to the short model R&D were started few years ago at Fermilab and LBNL.

They included:

- magnetic analysis on different IRQ designs
- mechanical analysis of different IRQ mechanical structures
- Nb₃Sn IRQ thermal analysis
- IRQ quench protection
- studies of structural material properties

The summary of recent results will be presented and discussed at this meeting:

- preliminary answers on some R&D questions



IRQ design studies in FY2005-2007

We will continue IRQ design studies in FY2005-2007 focusing on analysis and discussions of:

- IR design parameters, IRQ aperture/gradient/length issues, field quality tables (with AP group and CERN)
- quadrupole magnetic designs, mechanics, operation temperature and temperature margin, quench protection issues, etc.
- the experimental data from the model magnet R&D \Rightarrow feedback to magnet development and AP groups
- the LHC IR commissioning and operation performance (when available) \Rightarrow feedback to model magnet R&D

At this meeting we need to discuss the issues and questions to be addressed in FY2005.



First phase of IRQ short model R&D

The final answers on most of these questions can be provided only by model magnet R&D.

The first 3-year phase of the short model R&D program focuses on the 90 mm shell-type technological quadrupoles (TQ).

TQ models will serve as a tool for both quadrupole technology development and magnet performance studies:

- 2-, 3- and 4-layer coil designs and fabrication technologies
- different mechanical designs
- different assembly techniques

This choice, in addition to the technical considerations, reduces cost and risks of this important phase of the program.

In the future based on the results of this phase and program needs we could optimize the magnet aperture size and the nominal field gradient.



FY2005-FY2007 short model R&D goals

The main goals of the first 3-year IRQ R&D phase are:

- fabricate, test and evaluate **two shell-type coil designs**: 2(3)-layers and 4-layers
- fabricate, test and evaluate two alternative mechanical structures based on *bladder-key-Al shell* or *collar-yoke-skin*
- develop and study **narrow and wide cables** for both coil designs
- study and optimize **strand parameters** for quadrupole models
- develop and evaluate **coil fabrication technologies**
- develop and build tooling to perform short model (1-m long) R&D
- develop **infrastructure for fabrication and test of long (up to 4-m long) quadrupole coils**

By the end of this phase we are planning to choose the **optimal conductor**, **coil aperture and design** and **mechanical structure** for the next phase of the short model R&D which will have to address the *field quality* and *reproducibility* issues.



TQ design considerations

In order to provide internal consistency and compatibility of this phase of the program, optimize program cost and reduce the development time we decided to:

- unify as much as possible the coil fabrication tooling
- distribute responsibilities among the groups for
 - tooling development and procurement
 - coil and magnet component design and procurement
 - magnet fabrication and test



FY2005-FY2007 short model R&D milestones

The primary goal of FY2005 is fabrication and test of first simplified quadrupole technological model TQ4L1a by collaborative efforts of 3 Labs.

Starting from FY2006 **two coil designs** and **two mechanical structures** will be studied, one at Fermilab and another one at LBNL to compare technologies and magnet performance.

By the end of FY2007 we are planning to choose the **optimal conductor**, **coil aperture and design** and **mechanical structure** for the next phase of the short model R&D based on the model technologies and performances as well as to develop **infrastructure for fabrication and test of long (up to 4-m long) quadrupole coils**.

At this meeting we need to discuss the details of FY2005 short model R&D plan, milestones, coordination of efforts, etc.



Session agenda

01:30 Introduction, A. Zlobin

01:40 IR Quad Design Study Summary & Open Issues, V.Kashikhin

02:05 IR Quad Design Study Summary & Open Issues, G. Sabbi

02:30 IR Quad Model Magnet R&D, S. Caspi

03:15 *break - 1/2 hr*

03:45 IR Quad Model Magnet R&D, A. Zlobin

04:15 Sub-Scale Quad, P. Ferracin

05:00 General Discussion - open

06:00 Adjourn