DESIGN STUDY FOR THE LHC UPGRADE WP3: MAGNETS

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TASK LIST

- HL-LHC working package on magnets
  - This is a design study (deliverable is paper)
  - Timeline 2011-2015
  - $ is available for EU partners only (for CERN, only the part for the management)

- HL-LHC will coordinate and rely on the results of previous EU initiatives
  - Eucard HFM (High Field Magnets) for the Nb_3Sn part
  - SLHC-preparatory phase (ex phase-I) which builds a short 120 mm aperture model in Nb-Ti (plan B for upgrade)

  - 11 T dipoles for collimation are not within HL-LHC (different timeline), but strong coordination is needed

TASK LIST

1. Communication and management
2. Nb_3Sn quadrupoles
3. Separation dipoles
4. Cooling
5. Miscellaneous

TASK 2 – Nb_3Sn QUADRUPOLES

- Task Objectives
  - Analyze the performance of existing Nb_3Sn models, in particular LARP HQ quadrupoles
  - Conceptual design studies of a very large aperture option (150 mm)
  - Finalize the requirements for the HL-LHC inner triplet Nb_3Sn quadrupole
- Task description

This task is intended to give a final assessment of the possibility of using Nb_3Sn quadrupoles for the LHC inner triplet and the performance parameters that can be achieved. A tentative layout with a 120 mm aperture quadrupole is given from WP2, and the necessary full list of requirements (field quality, radiation resistance, integration in the machine) should be worked out. A comparison with the present performance of the 120 mm aperture short model (HQ) magnets of LARP should be done, and iterations on the design if needed should be carried out. In particular we plan to analyze the following issues: (i) radiation resistance of all components (ii) magnet field quality and the possibility to apply corrections using magnetic shims (iii) option of splitting the magnet into two coils, with a related estimate of the loss in performance, possibly complemented by a hardware test, (iv) design of a helium containment vessel compatible with a magnet structure based on aluminum shrinking cylinder (v) magnet protection).

This task will be mainly driven by LARP collaboration (BNL, FNAL and LBL). LASA will lead the quench protection study.

Task 2 – Nb_3Sn Quadrupoles

- Deliverables

  M48 Report on design study of the Nb_3Sn inner triplet

- Milestones

  M12 Requirements for Nb_3Sn inner triplet and comparison with present status of the art

  M24 Study of magnetic shimming in HQ

  M36 Study of minimal distance between two coils in a cold mass

- Relation to other WP
  - Inputs from WP2. Moreover, this task feeds directly back to WP2 (e.g. required space for eventual absorber inserts at regions with higher losses etc which have an impact on the detailed IR layout).

- Task leader: G. Luca Sabbi

Task 3 – Separation dipoles

- Task Objectives
  - Conceptual design of separation dipoles according to the specifications given by WP2 using either Nb_3Al or Nb-Ti. If a model is built, specify and follow-up the tests needed for assessing the design.
  - Explore the possibility of using separation dipoles to create doglegs to increase the beam separation, thus allowing the installation of non-compact crab cavities.

Task 3 – Separation dipoles

- Task description

The input necessary from WP2 is the needed integrated strength, a tentative lay-out, and an aperture requirement for the separation dipoles D1 and D2 used in the ATLAS and CMS interaction regions. Then, the first step is the conceptual designs of a separation dipole. For the D1 we propose considering Nb_3Al or Nb-Ti conductor. For the D2 the Nb-Ti option only is considered. Main issues as (i) field quality, (ii) peak stresses at operational field, (iii) integration in the machine, (iv) radiation resistance (v) magnet protection will be analysed. If both options are viable, the second step would be the proposal of a short model to assess the Nb_3Al technology. The third step would then be the follow-up the construction of the model, contributing to the test definition and to the analysis of the test results.

A similar type of technology would allow to further separate the LHC beams from the nominal distance of 194 mm to a wider one (400 to 500 mm). This “dogleg” is the plan B if the option of compact crab cavities is not viable. The inputs from the WP4 (crab cavities) and WP2 (beam dynamics) are the integrated field and the aperture. The task outcome is the conceptual design of a dogleg, and should strongly rely on the results of the D1-D2 program.

This task is lead by KEK for the Nb_3Al part and by BNL for the Nb-Ti option. LASA will steer the studies on protection.

Task 3 – Separation dipoles

- Deliverables

  M48 Report on design study of the separation dipoles

- Milestones

  M12 Requirements for separation dipoles

  M24 Conceptual design of Nb_3Al and Nb-Ti separation dipoles

  M36 Conceptual design of a crab cavity dogleg

- Relation to other WP
  - Inputs from WP2 and WP4. The task results feed also back to WP: the final length for the dipole magnets will impact the space available for local Crab Cavity installations and potential installations for the compensation of long-range beam-beam interactions.

- Task leader: T. Nakamoto

Task 4 – Cooling

- Task Objectives
  - Choose the operational temperature of the inner triplet quadrupoles and of the separation dipoles. Consider and compare both the superfuid and supercritical He options.
- Task description

The cooling system of the Nb_3Sn inner triplet can operate either in superfluid (i.e., below 2.17 K) or in supercritical helium (i.e., above 2.17 K). Contrary to Nb-Ti magnets, Nb_3Sn can operate in supercritical helium at around 4.5 K with a limited loss in field gradient w.r.t. the superfluid option (about 10%). This would also solve the Nb_3Sn conductor instability issues that have been found by the US colleagues during the last decade.

As the heat loads envisaged today are more than one and a half order of magnitude above what is prevalent in the previous accelerators magnets designed for operation at supercritical helium (RHIC, HERA, Tevatron), it is mandatory to address the problem of cooling from the very beginning of the design of future quadrupoles.

Both the supercritical and the superfluid options should be analysed and compared. The program can be divided into different phases: (i) analysis of heat loads and status of the different cooling scenarios (ii) principle of heat removal system, thermohydraulic simulations and first experiments (iii) validation of the system.

A similar study should be carried out for the separation dipoles.

This task is steered by CERN for the superfluid part and by CEA-Grenoble for the supercritical part.

Task 4 – Cooling

- Deliverables

  M48 Report on design study of the cooling
- Milestones

  M18 Study of the supercritical He cooling

  M36 Study of the superfluid He cooling
- Relation to other tasks and WP
  - Relation to tasks 3.2 and 3.3, and inputs from WP2.
- Task leader: R. Van Weelderen

TASK 5 – MISCELLANEOUS

- Task Objectives
  - Design a two-in-one quadrupole for the outer triplet (Q4-Q6) with nominal beam separation (192 mm) and aperture as large as possible (80-100 mm), satisfying the electromagnetic and mechanical requirements. Design of a two-in-one quadrupole for the inner triplet in the case of a dipole first option.
  - Review the Nb-Ti option for the inner triplet considering the new targets in luminosity, and follow-up the tests of the short model built within the SLHC-PP program.
  - Analysis of the expected lifetime of resistive quadrupoles in IR3 and IR7. Study of possible solutions for the time scale of 2030 with in integrated radiation of 3000 fb^{-1}, both resistive and superconductive.

Task 5 – Miscellaneous

- ## Task description

This task includes three different studies:

The conceptual design of a large aperture two-in-one quadrupole for the outer triplet. The present baseline of the LHC involves 70 mm aperture magnets (MQY) whose aperture could be a bottleneck. One should explore the possibility of having two-in-one quadrupoles with apertures in the range 80-100 mm, with the same constraint of the 194 mm beam separation. Electromagnetic and mechanical aspects should be analysed. This design also applies to the option of a two-in-one inner triplet in the option of a dipole first option. This subtask is steered by CEA-Saclay.

The analysis of the expected lifetime of the resistive quadrupoles used in the cleaning insertion (MQWA and MQWB). The first step is to have an estimate of the radiation load, together with the lifetime of the present hardware. Then solutions to extend the lifetime of present hardware up to 2030 or options to replace them will be analysed. This subtask is steered by CERN (TBC).

The Nb-Ti option for the inner triplet is the plan B in case that experience shows that the Nb_3Sn technology is not suitable. A considerable work has been done in the SLHC-PP framework, i.e. the so-called phase I, which aimed at a peak luminosity of 2.3×10^{34} cm^{-2} s^{-1}. A short model is being built. One has to check that the Phase I scenario and lay-out is compatible with the new targets of the HL-LHC. This subtask is steered by CERN (TBC).

Task 5 – Miscellaneous

- Deliverables

  M48 Miscellaneous issues in magnet design

- Milestones

  M18 Review of the Nb-Ti option for inner triplet for new peak and integrated luminosity targets

  M36 Analysis of options for quadrupoles in cleaning insertions

  M36 Study of two-in-one quadrupoles for outer triplet

- Task leader: J. M. Rifflet

Other requirements from WP2

- Feedback from Oliver: what is missing
  - Option of a magnetic TAS (either with dipole or quadrupole magnets).
  - Options of a D0 design integrated in the detectors.
  - Where do we study the design of SC corrector magnet packages (e.g. inside the triplet assembly)?

Partners

- EU:
  - CEA Saclay (Fr) – Magnet design
  - CEA Grenoble (Fr) – Supercritical cooling system
  - LASA INFN Milano (It) – Magnet protection

- World
  - LARP: FNAL, BNL, LBL (Us) – Nb_3Sn quadrupoles
  - BNL (Us) – Separation dipoles in Nb-Ti
  - KEK (Jp) – Separation dipoles in Nb_3Al